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National Oceanic and Atmospheric Administration
Environmental Research Laboratories

Environmental Research Laboratories

Publication Abstracts

FY 1989

U.S. DEPARTMENT OF COMMERCE
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Environmental Research Laboratories

Publication Abstracts

FY 1989

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FOREWORD

As the research arm of the National Oceanic and Atmospheric Administration (NOAA), the Environmental Research Laboratories (ERL) support the present responsibilities and the development of future services of NOAA. Programs include investigation of ocean processes and their interactions with the atmosphere; studies of the ocean environment as it is affected by waste disposal and development of energy and food resources; fundamental studies of the upper atmosphere and space environments; atmosphere and ocean research on weather and climate change; research on severe local storms, hurricanes, and tsunamis; studies of cloud processes; research on the environmental effects of regional and global pollution; and development of equipment, instruments, systems, and facilities for these programs.

A principal measure of the success of a research laboratory is its output of scientific and technical papers and reports. The listings (including abstracts when available) in the following pages are an index of such ERL output for the period October 1, 1988, through September 30, 1989. This document includes all known articles published in journals for FY 1988 and those reports published within the official series of the Laboratories, as well as conference proceedings and other reports. It also includes publications by ERL-University cooperative institutes and by contractors funded by ERL.

Joseph O. Fletcher, Director
Environmental Research Laboratories
Boulder, Colorado

A GUIDE FOR USERS

Abstracts for this volume were submitted print ready by each Laboratory. If no abstract accompanied the original publication, the words "No abstract" follow the bibliographic entry.

Sections are arranged alphabetically by Laboratory. Some Laboratories have included an addendum listing publications inadvertently omitted from the FY 1988 volume.

Entries within the Laboratory sections are arranged alphabetically by author. ERL authors' names are typed in all capital letters.

An author index starts on p. 197. A guide for using the index is on p. 195.

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ERL Publication Abstracts
FY 1989

AERONOMY LABORATORY

AL-001

Anthes, Richard A., Ying-Hwa Kuo, Eirh-Yu Hsie, Simon Low-Nam, and T.W. Bettge. Estimation of skill and uncertainty in regional numerical models. Q.J.R. Meteorological Society 115:763-806 (1989).

The results from 72-hour simulations and forecasts from the Penn State/NCAR limited-area model, in which a number of numerical and physical factors are varied, are analyzed to understand the contribution to model error or uncertainty introduced by these factors. The factors include the initial conditions, horizontal resolution (80 km and 160 km) and domain size, lateral boundary conditions, and physical parametrizations. The results are compared with those of a global forecast model (the NCAR Community Climate Model). The simulations and forecasts are verified both for 12 individual cases and for the ensemble average of the 12 cases, using several objective measures of skill. The differences in these skill scores between models are tested for their significance. The use of observed lateral boundary conditions (LBC) exerts a strong control on the growth of errors over a domain size 3600×4800 km^2. Objective measures of error show little growth beyond about 36 hours, so that 72-hour errors are nearly as low as the 36-hour errors. On these time and space scales, the quality of the LBC is more important than any other factor tested in the temporal evolution of the model errors. The results show that the large-scale atmospheric motions have a major effect on the evolution of small-scale features in the model. Small variations in initial conditions have little effect on the model skill beyond 12-24 hours. Of all the factors examined, small uncertainties or errors in the initial conditions have the least effect on model skill beyond 12 hours. Latent heating effects associated with condensation and precipitation, and sensible and latent heat fluxes from the surface have a statistically significant effect on model skill. However, relatively simple parametrizations of these effects produce nearly the same skill as do more complex schemes for the cases studied here. There is a large variation in model skill from case to case; some cases are easier to forecast than others. Also, there is much greater variation in different model performances for a single case than when averaged over all 12 cases. The concept of climatological use and verification of regional models is introduced. The climatological skill of the control model version which includes all physical processes appears to be quite good. The skill scores of the ensemble average simulation are considerably better than the average scores for individual cases, the model has small bias errors, and the horizontal structure of the model-simulated atmosphere is similar to the observed structure for scales of motion resolved by the upper-air observational network over the United States.

AL-002

BALSLEY, B.B., and D.A. CARTER. Mountain waves in the tropical Pacific atmosphere: A comparison of vertical wind fluctuations over Pohnpei and Christmas Island using VHF wind profilers. Journal of the Atmospheric Sciences 46:2698-2715 (1989).

We compare vertical wind fluctuations observed by VHF radar wind profilers in the tropical troposphere over a large, mountainous island (Pohnpei, at 7°N, 157°E) and a large, low-profile atoll (Christmas Island, at 2°N, 158°W). The major differences in the two data sets appears to be due to the frequent occurrence of mountain waves over Pohnpei and to their absence over Christmas Island. These waves are generated continuously at low levels over Pohnpei by the steady ENE trade winds acting on the 800m high terrain, and can extend at least in the lower stratosphere. We find the occurrence of mountain waves at middle- and upper-tropospheric levels over Pohnpei to be governed primarily by a "critical-layer" relationship between the winds aloft and the near-surface winds: a reversal in the direction of the upper level winds relative to the lower-level trade winds precludes the upward propagation of mountain waves, whereas a non-reversed wind profile allows the waves to propagate freely in the lower stratosphere, and possibly to much higher heights, depending on the phase of the QBO.

AL-003

BALSLEY, B.B., W.L. ECKLUND, D.A. CARTER, K.S. GAGE, R. Mugica, A. Mabres, R. Rodriguez, S.K. Avery, E.J. Violette, and R.F. Woodman. The ST radar under construction at Piura, Peru (5°S, 81°W). Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:510 (1989).

No abstract.

AL-004

Burkholder, J.B., P.D. Hammer , C.J. HOWARD, and A. Goldman. Infrared line intensity measurements in the ν = 0-1 band of the ClO radical. Journal of Geophysical Research 94(D2):225-2234 (1989).

Line intensities of the ClO radical in the fundamental vibrational band, ν = 0-1, have been measured using a high-resolution Fourier transform spectrometer coupled to a long path length absorption cell. The ClO infrared absorption spectra were recorded at 0.0004 cm^{-1} unapodized resolution in 50 coadded scans at total pressures less than or equal to 0.4 Torr, He buffer gas. Spectra were recorded at calibrated [ClO] over the range 4 x 10^{12} to 1.4 x 10^{13} molecule cm^{-3}, using two different chemical sources of ClO: Cl + O_3 and NO + OClO. The band intensity was measured as S = 9.68 ± 1.45 cm^{-2} atm^{-1} (95% confidence level) at 296 K, which is in agreement with a recent ClO band intensity determination using the concentration independent Herman-Wallis method of band intensity analysis (Burkholder et al., 1987a). This value of the ClO band intensity is a factor of 2 greater than the value recently reported by Kostiuk et al. (1986). A N_2 collisional broadening coefficient of γ^o = 0.093±0.018 cm^{-1} atm^{-1} (95% confidence level) was determined from spectra recorded with 10 Torr N_2 added. A source of systematic error in the use of the Cl + O_3 reaction as a quantitative source of ClO radicals is discussed.

AL-005

CARROLL, M.A., E.P. Condon, D.D. DUNLAP, G.L. Gregory, B.A. Ridley, G.W. Sachse, and M. Trainer. Measurements of NO_x over the eastern Pacific Ocean and southwestern United States during the spring 1984 NASA GTE aircraft program. Journal of Geophysical Research 94:5043-5067 (1989).

Measurements of NO, NO_x (NO + NO_2), O_3 and CO are presented from seven aircraft flights made over the eastern Pacific Ocean and the southwestern United States in spring of 1984. The sampling region was characterized by large- and small-scale variability for all of the measurements, likely as a result of vigorous synoptic-scale meteorology and the influence of tropopause folds. Median values for NO, NO_x, O_3, and CO from the flights made over the ocean in the region of 5.8-7.6 km were 10 parts per trillion by volume (pptv), 32 pptv, 46 parts per billion by volume (ppbv) and 120 ppbv, respectively. Corresponding values from two flights made over the continent at similar altitudes were 66 pptv, 38 pptv, 42 pptv, and 111 ppbv. There was a strong tendency for NO or NO_x to be correlated positively with O_3 and to be anticorrelated with dew-point/frost-point measurements. No significant overall correlation occurred between NO_x and CO for the ocean data. The variability of NO_x was such that regions of net destruction and regions of net production of O_3 were sampled both over the ocean and over the continent. However, in the middle free troposphere over the ocean, net O_3 destruction was predominant.

AL-006

CARROLL, M.A., E.P. Condon, G.L. Gregory, G.F. Hill, B.A. Ridley, G.W. Sachse, and A.L. Torres. An intercomparison of results from ferrous sulphate and photolytic converter techniques for measurements of NO_x made during the NASA GTE/CITE 1 aircraft program. Journal of Geophysical Research 93:15,803-15,811 (1988).

Two techniques designed for measurements of NO_x (NO + NO_2) were intercompared during aircraft flights made in the spring of 1984 in the middle free troposphere over the eastern Pacific Ocean and southwestern United States. One NO chemiluminescence instrument was equipped with a ferrous sulphate converter, another with a photolytic converter. The ferrous sulphate-equipped instrument was apparently much less specific for NO_2. It registered levels about 3 times larger than the photolytic converter and gave NO_2/NO ratios that were much larger than photochemical calculations would indicate as reasonable. Additionally, the results imply that active NO_x was only 10-20% of total odd nitrogen in the middle free troposphere.

AL-007

CARROLL, M.A., G.L. Gregory, B.A. Ridley, and G.W. Sachse. NO and NO_2 in the troposphere: Technique and measurements in regions of a folded tropopause. Journal of Geophysical Research 93:15,813-15,830 (1988).

During the 1984 spring program of the NASA Global Tropospheric Experiment, measurements of NO, NO_2, O_3, and CO were made during two aircraft flights that encountered tropopause fold events. The technique used to measure NO_x (NO + NO_2) is described. In the neighborhood of both tropopause fold events, CO and O_3 were strongly anticorrelated. In one fold, encountered over the eastern Pacific Ocean at night, NO_x was positively correlated with the stratospheric origin of the air mass. In this fold at altitudes between 5.5 and 6.0 km, NO_x reached mixing ratios near 150 parts per trillion by volume (pptv) considerably larger than the levels of 10-50 pptv in the air external to the fold. In contrast, in a daytime encounter with a fold over the southwestern United States at altitudes of 6.7-8.8 km, NO_x did not correlate well with CO,

O_3, or dew point, but remained roughly constant at levels of 100-200 ppbv. Outside of the fold, in a region of strong convection activity, NO_x peaked to just over 500 pptv. It appears that mixing of tropospheric air containing elevated NO_x weakened the expected trends for the fold over the continent compared to the fold over the ocean, and therefore NO_x may not always be a good tracer of air of recent stratospheric origin. However, the observations emphasize that the stratospheric source of NO_x acts to introduce NO_x over a short period and through a large vertical region of the troposphere, not just near the tropopause, as is assumed in many tropospheric models.

AL-008

CARTER, D.A., B.B. BALSLEY, W.L. ECKLUND, K.S. GAGE, A.C. Riddle, R. Garello, and M. Crochet. Investigations of internal gravity waves using three vertically directed closely-spaced wind profilers. Journal of Geophysical Research 94(D6):8633-8642 (1989).

A network of three wind profilers spaced about 5 km apart was operated in southern France during the Alpine Experiment (ALPEX) program. The wind profilers measured vertical motions, and the experiment was designed to study traveling internal waves by comparing the vertical velocity fluctuations observed at each station. The measured phase velocities, together with the observed periods, were used to deduce the horizontal wavelength of the waves. Only a relatively few cases of monochromatic waves could be identified using this array. Most of the waves that were detected had phase velocities opposite to the prevailing wind and had the speeds required to cause trapping as the intrinsic frequency was Doppler shifted upward to the Brunt-Väisälä frequency.

AL-009

CARTER, D.A., P.E. Currier, and W.L. ECKLUND. A PC-based radar controller/signal processor. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:609-610 (1989).

No abstract.

AL-010

CLARK, W.L., and J.L. GREEN. Flatland data analysis system. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:665-668 (1989).

No abstract.

AL-011

CLARK, W.L., J.L. GREEN, and J.M. WARNOCK. Monitoring VHF radar system performance using cosmic noise. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:593-596 (1989).

No abstract.

AL-012

Currier, P.E., and W.L. ECKLUND. Ground clutter suppression at UHF by the use of surface wind measurements. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:641-642 (1989).

No abstract.

AL-013

Currier, P.E., W.L. ECKLUND, D.A. CARTER, J.M. WARNOCK, and B.B. BALSLEY. Temperature profiling within an acoustic source and a UHF wind profiler. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:528 (1989).

No abstract.

AL-014

Dabberdt, W.F., H. Cole, K.S. GAGE, W.L. ECKLUND, and W.L. Smith. Determination of boundary-layer fluxes with an integrated sounding system. Proceedings, Western Pacific International Meeting and Workshop on TOGA COARE, Noumea, New Caledonia, May 24-30, (1989).

An important atmospheric goal of TOGA COARE is to determine the exchange of momentum, and sensible and latent heat in the western Pacific over the time scales of convective storms, westerly bursts and lower frequency events. TOGA COARE will also require detailed moisture budget studies in support of improved understanding of sub-gridscale processes and the evaluation of model parameterization schemes. Present field-deployable measurement systems do not provide observations on the temporal and spatial scales necessary to properly address these and other issues. We present the concept of the so-called Boundary-Layer Integrated Sounding System (BLISS) as a means to provide these measurements. The BLISS consists of a suite of demonstrated in situ and remote sensing subsystems which together provide the measurements to sense directly or retrieve high-resolution profiles of winds, temperature and moisture and associated fluxes. Individual subsystems under consideration include: surface meteorological station; UHF Doppler wind profiling radar; radio acoustic sounder; infrared interferometer-spectrometer; microwave radiometer; and an Omega-VLF radiosonde system for in situ but low frequency profiles to -20mb. Other features of the integral system include a central data acquisition and processing counter, real-time satellite telemetry link, and rugged, easily transported base station. We estimate the cost to be sufficiently modest to enable deployment of a network of order 10-15 systems in support of TOGA COARE.

AL-015

Dlugokencky, E.J., and C.J. HOWARD. Studies of NO_3 radical reactions with some atmospheric organic compounds at low pressures. The Journal of Physical Chemistry 93:1091-1096 (1989).

Rate constants for the reactions of NO_3 with trans-2-butene (1), isoprene (2),α-pinene (3), and acetaldehyde (4) have been measured as a function of temperature at low pressures in a fast flow system with LIF detection of the NO_3 reactant and NO_2 product. Rate constants for reaction 1 were found to be independent of pressure from 0.44 to 4.5 Torr, and the Arrhenius plot was curved. The data were fit by the four-parameter equation, $k_1(T = 204\text{-}378\ K) = (1.78 \pm 0.36) \times 10^{-12} \exp[-(530 \pm 100)/T] + (1.28 \pm 0.26) \times 10^{-14} \exp[(570 \pm 110)/T]$ (where all the error limits are the 95% confidence levels including a factor for systematic error, and the units are cm^3 molecule^{-1} s^{-1}). The data for isoprene were fit by a normal Arrhenius equation, $k_2(T = 251\text{-}381\ K) = (3.30 \pm 0.45) \times 10^{-12} \exp[-(450 \pm 70)/T]$. The Arrhenius plots for α-pinene and acetaldehyde were linear, and the fits gave $k_3(T = 261\text{-}384\ K) = (1.19 \pm 0.31) \times 10^{-12} \exp[(490 \pm 70)/T]$ and $k_4(T = 264\text{-}374\ K) = (1.44 \pm 0.18) \times 10^{-12} \exp[(-1860 \pm 300)/T]$. The efficiencies for the conversion of NO_3 to NO_2 were determined for reactions of trans-2-butene and isoprene at low pressures and room temperature in He, N_2, and O_2 carrier gases, and at 360 K in 1 Torr of He. The measured yields of NO_2 decreased with increasing size of the organic reactant, with increasing pressure, with decreasing temperature, and with increasing deactivation efficiency of the carrier gas. These observations and the temperature dependencies of the rate constants indicate that reactions 1-3 proceed by way of an addition mechanism. From the analysis used to determine the NO_2 yields, NO_2 fluorescence quenching rate constants were determined for isoprene, $k = (3.5 \pm 1.1) \times 10^{-10}$, and trans-2-butene, $k = (3.0 \pm 0.9) \times 10^{-10}$.

AL-016

Eaton, F., J. Brown, W.L. CLARK, D. Favier, K.S. GAGE, J.L. GREEN, W. Hatch, J. Hines, E. Murphy, G. Nastrom, W. Peterson, T.E. VANZANDT, and J.M. WARNOCK. Comparisons of the transverse coherence length and isoplanatic angle from measurements taken with the Flatlands very high frequency radar, optical techniques, and thermosondes. Preprints, Conference on Optics, Electro-Optics, and Laser applications in Science and Engineering, Los Angeles, CA, January 15-20, 1989. The International Society for Optical Engineering, Bellingham, WA (1980).

Comparisons are made of the transverse coherence length (r_o) and isoplanatic angle (θ_o) derived from measurements taken with the Flatlands very high frequency (VHF) radar, an r_o system, an isoplanometer, and temperature fluctuation sensors mounted on a thermosonde. The measurements were conducted at the Flatlands location near Urbana, Illinois, from 7-13 June 1988. The site was selected because of the lack of orographic effects on airflow and the refractive index structure parameter ($C_{n_o}^2$). The radar was operated with alternating beams in the north and east directions at 20° zenith angle in order to avoid contamination by specular reflections. Contributions of the refractive index structure parameter (C_n^2) from different altitudes above ground to the integrated-path r_o and θ_o values are presented and discussed. Diurnal variations of r_o and θ_o obtained from the suite of instruments are shown with particular emphasis on the "neutral" events. Measured results are compared to results from the Aeronomy Laboratory's theoretical model of C_n^2.

AL-017

ECKLUND, W.L. Hardware design for MST, ST and lower troposphere/boundary layer radars. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:518-521 (1989).

No abstract.

AL-018

ECKLUND, W.L. A microstrip antenna array for UHF wind profiling. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:529 (1989).

No abstract.

AL-019

ECKLUND, W.L., D.A. CARTER, B.B. BALSLEY, and P.E. Currier. A 915 MHz boundary layer wind profiler. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:556-561 (1989).

No abstract.

AL-020

ECKLUND, W.L., D.A. CARTER, B.B. BALSLEY, K.S. GAGE, and P.E. Currier. Recent developments in lower tropospheric wind profiling. Preprint volume, First European Wind Profiler Workshop, Trappes, France, March 6-8, 1989, C33-C44 (1989).

A small UHF wind-profiling radar has been developed at NOAA's Aeronomy Laboratory. This radar provides high-resolution wind profiles from near the surface upward to 2-3 km in clear air. Since the radar is very sensitive to heavy clouds and rain, it can be used to monitor the height of the melting layer and the vertical extent of hydrometeors. The small radar also provides temperature profiles up to 1 km when operated with an acoustic source in the RASS mode.

AL-021

ECKLUND, W.L., K.S. GAGE, D.A. CARTER, and B.B. BALSLEY. Status and plans for the Pohnpei, F.S.M. (7°N, 157°E) ST radar. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:493 (1989).

No abstract.

AL-022

ECKLUND, W.L., J.L. GREEN, D.A. CARTER, W.L. CLARK, P.E. Currier, J.M. WARNOCK, and K.S. GAGE. Summertime observations in Illinois using two wind profilers. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 701-704 (1989).

No abstract.

AL-023

ECKLUND, W.L., K. Moran, P.E. Currier, B. Weber, D.A. CARTER, and D. Wuertz. A comparison of wind profilers operating at 915, 405, and 50 MHz. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:413-415 (1989).

No abstract.

AL-024

FAHEY, D.W., J. Austin, J.G. Anderson, C.B. Farmer, L.E. Heidt, R.L. Jones, K.K. KELLY, D.M. MURPHY, M.H. Proffitt, A.F. TUCK, and J.F. Vedder. Lagrangian photochemical modeling studies of the 1987 Antarctic spring vortex. 1. Comparison with AAOE observations. Journal of Geophysical Research 94:11,529-11,558 (1989).

In this paper, results from a photochemical model integrated along ensembles of 8-day air parcel trajectories are used to simulate the latitude and vertical composition gradients observed from the ER-2 aircraft during the 1987 Airborne Arctic Ozone Experiment (AAOE). The photochemical model used includes heterogeneous chemical reactions when polar stratospheric clouds are inferred, from local temperature and pressure to be present. The model results were found to be very sensitive to NO_y mixing ratios and the frequency of polar stratospheric clouds (PSCs). Trajectories often showed instantaneous (adiabatic) cooling rates of up to 30 K d^{-1} with air parcels even at high latitudes spending substantial periods outside modeled clouds. This leads to a photochemical "balance" in the model calculations between the perturbations to the composition caused by the heterogeneous reactions and the restoring effects of HNO_3

destruction. For the period of interest (early September 1987), the model was able to simulate well both the latitude gradient of ClO on the 428 K potential temperature surface and the ClO vertical gradient at 72°S. The model simulated well the NO and NO_y concentrations at high latitudes inside the dehydrated, denitrified region, although NO values outside were significantly overestimated. There is evidence from the chlorine and the nitrogen species partitioning in the model that even outside the denitrified, dehydrated region the chemical composition is perturbed. It is argued that heterogeneous processing on type I PSCs has occurred in this outer region, but without denitrification or dehydration. Model results imply that the BrO observations made from the ER-2 within the dehydrated, denitrified region are consistent with there being approximately 5 parts per trillion by volume of BrO_y at 428 K in spring. Within the high ClO region, ozone destruction rates are calculated to exceed 2% d^{-1} with approximately 80% due to the ClO dimer mechanism.

AL-025

FAHEY, D.W., K.R. Chan, G.V. Ferry, K.K. KELLY, M. Loewenstein, D.M. MURPHY, L.R. Poole, and J.C. Wilson. In situ measurements of total reactive nitrogen, total water, and aerosol in a polar stratospheric cloud in the Antarctic. Journal of Geophysical Research 94:11,299-11,315 (1989).

Measurements of total reactive nitrogen (NO_y), total water, and aerosol were made as part of the Airborne Antarctic Ozone Experiment during August and September 1987. The measurements were made using instruments located on board the NASA ER-2 aircraft, which conducted 12 flights over the Antarctic continent, reaching pressure altitudes of 20 km at 72°S latitude. The data presented here focus on a flight during which a polar stratospheric cloud (PSC) was encountered, containing concentrations of 0.8- to 2.6-μm diameter aerosol particles greater than 1 cm^{-3}. The temperatures in the cloud ranged as low as 184 K near 65-mbar pressure, but they remained above the frost point of water ice, except for short intervals. From knowledge of the vapor pressures over nitric acid condensates, the appearance of aerosol above the background level is consistent with the formation of the trihydrate phase, $HNO_3 \cdot 3H_2O$. The anisokinetic feature of the NO_y sample probe enhances the concentration of large aerosol particles in the inlet by a factor of ~9. NO_y levels above 20 parts per billion by volume (ppbv) observed in the PSC indicate that aerosol NO_y species contribute substantially to the NO_y signal. The amount of aerosol $HNO_3 \cdot 3H_2O$ necessary to enhance the NO_y signal to observed levels is calculated from aerosol impaction theory and is found to be in satisfactory agreement with the observed aerosol volume. In addition, using the saturation vapor pressures and an estimate of available HNO_3 in the cloud, the predicted volume of $HNO_3 \cdot 3H_2O$ also shows satisfactory agreement with the directly measured aerosol volume. These results indicate that substantial aerosol volume containing HNO_3 and H_2O is formed at temperatures above the frost point in the Antarctic stratosphere in the winter and spring months. Such aerosol formation is thought to be the prerequisite for the production of active chlorine in heterogeneous reactions and for the large-scale removal of NO_y through aerosol sedimentation.

AL-026

Fritts, D.C., T. Tsuda, T.E. VANZANDT, S.A. Smith, T. Sato, S. Fukao, and S. Kato. Momentum flux in the troposphere and lower stratosphere using the MU radar. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:353-354 (1989).

No abstract.

AL-027

GAGE, K.S., B.B. BALSLEY, D.A. CARTER, W.L. ECKLUND, and J.R. MCAFEE. The Christmas Island ST radar (2°N, 157°W), Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:498-499 (1989).

No abstract.

AL-028

GAGE, K.S., B.B. BALSLEY, W.L. ECKLUND, D.A. CARTER, and J.R. MCAFEE. Wind profiler related research in the tropical Pacific. Proceedings, Western Pacific International Meeting and Workshop on TOGA/COARE, Noumea, New Caledonia, May 24-30, 1989.

This paper is broadly concerned with the application of wind profiling Doppler radar technology to tropical atmospheric research. Examples of the use of wind profilers in the tropics are drawn from the Aeronomy Laboratory's wind profilers located on Pohnpei (7°N, 158°E) and Christmas Island (2°N, 157°W). The Pohnpei wind profiler was constructed in 1984 and has been used exclusively to observe vertical motions. The Christmas Island wind profiler has observed horizontal and vertical velocities routinely

since 1986. These two wind profilers form part of a planned trans-Pacific network of wind-profiling radars that will eventually span the tropical Pacific.

AL-029
GAGE, K.S., B.B. BALSLEY, W.L. ECKLUND, R.F. Woodman, and S.K. Avery. A trans-Pacific network of wind-profiling Doppler radars for tropical atmospheric research. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:44-55 (1989).

No abstract.

AL-030
GAGE, K.S., W.L. ECKLUND, B.B. BALSLEY, J. Soegijo, M. Pardede, and S.M. Notosuyidno. A proposed ST radar for Biak, Indonesia (1°S, 136°E). Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:516 (1989).

No abstract.

AL-031
GAGE, K.S., W.L. ECKLUND, and D.A. CARTER. Convection waves observed using a VHF wind-profiling Doppler radar during the pre-STORM experiment. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 705-708 (1989).

No abstract.

AL-032
GAGE, K.S., W.L. ECKLUND, and D.A. CARTER. A first look at convection waves observed by an ST radar. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:384-393 (1989).

No abstract.

AL-033
GAGE, K.S., and G.D. Nastrom. A simple model for the enhanced frequency spectrum of vertical velocity based on tilting of atmospheric layers by lee waves. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:292-298 (1989).

No abstract.

AL-034
GOLDAN, P.G., R. Fall, W.C. KUSTER, and F.C. FEHSENFELD. Uptake of COS by Growing Vegetation: A Major tropospheric sink. Journal of Geophysical Research 93:14,186-14,192 (1988).

Laboratory measurements of the uptake of COS by soybeans, corn, wheat, and alfalfa under conditions of controlled illumination, temperature, and CO_2 concentration, and at COS concentrations spanning those typically found in the troposphere (~500 parts per trillion by volume), indicate that the major uptake pathway is through open stomata. Similarities between the uptake resistances observed for COS and CO_2 provide a means of estimating global COS uptake from estimates of global terrestrial primary plant productivity. With an estimated annual plant uptake of 0.2-0.6 Tg COS (Tg = 10^{12} g), this appears to be the largest global sink for this major tropospheric sulfur reservoir species. With this vegetative sink included, estimated known sources and sinks appear to be in approximate balance.

AL-035
Goldman, A., J.B. Burkholder, C.J. HOWARD, R. Escribano, and A.G. Maki. Spectroscopic constants for the ν_9 infrared band of HNO_3. Journal of Molecular Spectroscopy 131:195-200 (1988).

High-resolution infrared measurements have been made on the ν_9 band of HNO_3 from 414 to 500 cm^{-1}. Over 2300 transitions have been measured, assigned, and fit to obtain 15 rovibrational constants for the $\nu_9 = 1$ state that reproduce the observed spectrum with a RMS deviation of 0.0004 cm^{-1}. The band center for ν_9 is at 458.2287 ± 0.0005 cm^{-1}.

AL-036

GREEN, J.L., R.R. Beland, J.H. Brown, W.L. CLARK, F.D. Eaton, L.D. Favier, K.S. GAGE, W.H. Hatch, J.R. Hines, E.A. Murphy, G.D. Nastrom, W.A. Peterson, T.E. VANZANDT, and J.M. WARNOCK. Comparisons of refractivity turbulence estimates from the Flatland VHF radar with other measurement techniques. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 709-712 (1989).

No abstract.

AL-037

GREEN, J.L., and W.L. CLARK. The Flatland radar antenna steering implementation. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:522 (1989).

No abstract.

AL-038

GREEN, J.L., and W.L. CLARK. Flatland radar on-line signal processing and radar control system. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:604-608 (1989).

No abstract.

AL-039

GREEN, J.L., T.E. VANZANDT, K.S. GAGE, J.M. WARNOCK, W.L. CLARK, and G.D. Nastrom. The status of the Flatland radar and recent studies. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:500-502 (1989).

No abstract.

AL-040

Greenblatt, G.D. and C.J. HOWARD. Oxygen atom exchange in the interaction of ^{18}OH with several small molecules. The Journal of Physical Chemistry 93:1035-1042 (1989).

Oxygen atom exchange between ^{18}OH and several oxygen-containing molecules was studied in a flow tube by using laser magnetic resonance detection of the reagent ^{18}OH and product ^{16}OH. No significant exchange was observed for O_2, H_2O, CO, CO_2, N_2O, OCS, and SO_2 at 298 and 400 K, and upper limits to the exchange rate coefficients are reported. The rate coefficients for the reactions of ^{18}OH and ^{16}OH with CO were found to be $(1.49 \pm 0.15) \times 10^{-13}$ and $(1.44 \pm 0.15) \times 10^{-13}$ cm^3 molecule^{-1} s^{-1}, respectively, at 298 K. NO and NO_2 were found to exchange rapidly with $k_{ex} = (1.8 \pm 0.6) \times 10^{-11}$ and $(1.0 \pm 0.4) \times 10^{-11}$ cm^3 molecule^{-1} s^{-1}, respectively at 298 K. On the basis of a simple model of adduct formation k_∞ values for the OH + NO and NO_2 association reactions were estimated to be $\leq(3.6 \pm 1.2) \times 10^{-11}$ and $\leq(1.5 \pm 0.6) \times 10^{-11}$ cm^3 molecule^{-1} s^{-1}, respectively. Error limits are 95% confidence limits.

AL-041

Hofmann, D.J., J.M. Rosen, J.W. Harder, and J.V. Hereford. Balloon-borne measurements of aerosol, condensation nuclei, and cloud particles in the stratosphere at McMurdo Station, Antarctica, during the spring of 1987. Journal of Geophysical Research 94:11,253-11,269 (1989).

Measurements of the vertical profile of particles with condensation nuclei counters and eight channel aerosol detectors at McMurdo Station, Antarctica, in 1987 verified observations made in 1986 concerning the absence of upwelling in the polar vortex and the presence of a condensation nuclei layer in conjunction with the ozone hole region. New observations of a bimodal aerosol size distribution, consisting of a large-particle (≈1 μm) mode mixed in with the small-particle sulfate mode, at temperatures below -79°C are consistent with the presence of nitric acid-water particles at low concentrations. Higher concentrations of large particles were observed in association with nacreous clouds. An unusual particle layer which contained enhanced concentrations of both the small-particle (sulfate) mode and the large-particle (nitric acid) mode was detected at temperatures below -85°C, suggesting simultaneous nucleation and growth phenomena. The vortex condensation nuclei layer was observed to form at the same time as the ozone hole, indicating that formation of the layer is triggered by photochemical processes and may be important in controlling ozone depletion above 22 km.

AL-042

Hofmann, D.J., S. SOLOMON. Ozone destruction through heterogeneous chemistry following the eruption of El Chichón. Journal of Geophysical Research 94:5029-5041 (1989).

It is now well established that heterogeneous reactions provide an important mechanism for Antarctic ozone depletion. Recent laboratory studies suggest that the same reactions that occur on HNO_3/H_2O ice clouds in the cold Antarctic stratosphere can also take place on sulfuric acid particles (e.g., volcanic and background aerosols) typical of lower latitudes, albeit at slower rates. The reduction in stratospheric ozone observed at northern mid-latitudes in late 1982 through 1983 following the volcanic eruption of El Chichón is investigated in terms of ozone loss through heterogeneous chemistry on the aerosol which formed in the stratosphere. The rates of the relevant heterogenous reactions are believed to be critically dependent on (1) the aerosol surface area density and (2) the percent by weight sulfuric acid in the liquid particles. Direct measurements of both of these important quantities for El Chichón aerosol are described and used as a basis for model calculations of their possible effects on ozone and other trace species. The observed volcanic particle surface area reached a maximum at mid-latitudes of about 50 $\mu m^2 cm^{-3}$ (above a typical background value of about 0.75) at an altitude of 18-20 km in early 1983. This enhancement of surface area is about the same as that encountered in stratospheric clouds in the Antarctic, suggesting a possible basis for ozone depletion through heterogeneous chemistry. Observations of NO_2 and HNO_3 also suggest that heterogenous reactions on both background and volcanic aerosol play a significant role in partitioning reactive nitrogen species in middle an high latitudes in winter. It is shown that heterogenous reactions similar to those occurring in Antarctica may have been responsible for at least a portion of the anomalous ozone reduction observed at mid-latitudes in early 1983.

AL-043

Judasz, T.J., and B.B. BALSLEY. Improved theoretical and experimental models for the coaxial colinear antenna. IEEE Transactions on Antennas and Propagation 37:289-296 (1989).

An improved theoretical model of the coaxial colinear (COCO) antenna is presented. Uniform and tapered current distributions have been obtained experimentally and theoretically on end-fed coaxial colinear antennas. There is reasonable agreement between theory and measurements. The linear systems of equations of the theoretical model are solved using a preconditioned conjugate gradient method. The gains of a few COCO antennas relative to equivalent lengths of half-wave dipoles are given.

AL-044

Keene, W.C., R.W. Talbot, M.O. Andreae, K. Beecher, H. Berresheim, M. Castro, J.C. Farmer, J.N. Galloway, M.R. Hoffmann, S-M. Li, J.R. Maben, J.W. Munger, R.B. NORTON, A.A.P. Pszenny, H. Puxbaum, H. Westberg, and W. Winiwarter. An intercomparison of measurement systems for vapor and particulate phase concentrations of formic and acetic acids. Journal of Geophysical Research 94:6457-6471 (1989).

During June 1986, eight systems for measuring vapor phase and four for measuring particulate phase concentrations of formic acid (HCOOH) and acetic acid (CH_3COOH) were intercompared in central Virginia. HCOOH and CH_3COOH vapors were sampled by condensate, mist, Chromosorb 103 GC resin, NaOH-coated annular denuders, NaOH impregnated quartz filters, K_2CO_3 and Na_2CO_3 impregnated cellulose filters, and Nylasorb membranes. Atmospheric aerosol was collected on Teflon and Nuclepore filters using both hi-vol and lo-vol systems to measure particulate phase concentrations. Samples were collected during 31 discrete day and night intervals of 0.5-2 hour duration over a 4-day period. Performance of the mist chamber and K_2CO_3 impregnated filter techniques were also evaluated using zero air and ambient air spiked with $HCOOH_g$, CH_3COOH_g, and formaldehyde (CH_2O_g) from permeation sources. Results of this intercomparison show significant systematic and episodic artifacts among many currently deployed measurement systems for $HCOOH_g$ and CH_3COOH_g. The spiking experiments revealed no significant interferences for the mist chamber technique and results generated by the mist chamber and denuder techniques were statistically indistinguishable. The condensate technique showed general agreement with the mist chamber and denuder methods, but episodic bias between these systems was inferred from large and significant differences observed during the first day of sampling. Nylasorb membranes are unacceptable for collecting carboxylic acid vapors as they did not retain $HCOOH_g$ and CH_3COOH_g quantitatively. Strong base impregnated filter and GC resin sampling techniques are prone to large positive interferences apparently resulting, in part, from reactions involving CH_2O_g to generate HCOOH and CH_3COOH subsequent to collection. Significant bias presumably associated with differences in postcollection handling was observed for particulate phase measurements by participating groups. Analytical bias did not contribute significantly to differences in vapor and particulate phase measurements.

AL-045

KELLY, K.K., E.V. Browell, K.R. Chan, D.W. FAHEY, G.V. Ferry, G.L. Gregory, L.E. Heidt, R.L. Jones, M. Loewenstein, M.P. McCormick, D.M. MURPHY, J.R. Podolske, M.H. Proffitt, S.E. Strahan, and J.F. Vedder. Dehydration in the lower Antarctic stratosphere during late winter and early spring, 1987. Journal of Geophysical Research 94:11,317-11,357 (1989).

Measurements of total water were made with Lyman α resonance fluorescence hygrometers mounted on the ER-2 and DC-8 aircraft. Direct evidence was obtained for dehydration of the lower stratosphere over Antarctica; minimum values were about 1.5 parts per million by volume (ppmv), compared with values of 3.0 4.5 ppmv immediately outside the region high potential vorticity gradient in the potential temperature range $420 < \theta < 460$ K. On one flight, ice crystals large enough to have appreciable sedimentation velocities were observed. The DC-8 data at $300 < \theta < 320$ K frequently showed extensive belts of dry, ozone-rich air between 60°and 75°S latitude, with the equatorward "edge" in water well correlated with that observed by the ER-2 some 8-9 km higher. Data from near Punta Arenas and from the ferry flights are used to argue that the effects of dehydration over Antarctica were visible at mid-latitudes.

AL-046

Langford, A.O., P.D. GOLDAN, and F. C. FEHSENFELD. A molybdenum oxide annular denuder system for gas phase ambient ammonia measurements. Journal of Atmospheric Chemistry 8:359-376 (1989).

An automated molybdenum oxide annular denuder system (MOADS) has been developed for gas phase ambient ammonia measurements. This system combines high sensitivity (detection limit <50 pptv) with continuous sampling, moderate collection times (30 min) and automated operation. The present denuder design confers two important advantages over the tungsten oxide coated quartz denuder tubes used previously for nitric acid and ammonia measurements. First, the present denuders use oxidized metal substrates and are easier to fabricate and more durable than denuders made from metal oxide coated glass or quartz tubes. Second, molybdenum (VI) oxide surfaces are used which oxidize a reproducible fraction of the adsorbed NH_3 directly to NO upon desorption eliminating the need for a secondary catalytic converter. Laboratory tests of the collection/recovery characteristics of annular denuders made from both the (IV) and (VI) oxides of tungsten and molybdenum are described and preliminary results from field tests are presented.

AL-047

Lin, X., M. Trainer, and S.C. LIU. On the nonlinearity of the tropospheric ozone production. Journal of Geophysical Research 93:15,879-15,888 (1988).

The relationship of photochemical ozone production versus photochemical loss of ozone precursor, that is, either NO_x or nonmethane hydrocarbons (NMHCs), is studied by using a box model with particular emphasis on the nonlinearity problem of the relationship with respect to the concentration of the precursor. Model calculations indicate that the composition of NMHCs, the ratio of NMHCs to NO_x, and the background concentrations of natural hydrocarbons, CO, and CH_4 all play important roles in determining the nonlinearity of O_3 production with respect to the loss of NO_x loss processes are also investigated. Mechanisms that contribute to the nonlinearity are discussed. The nonlinear property of O_3 production versus loss of hydrocarbons and CO is different from that of NO_x. When the sum of CO and all hydrocarbons, including CH_4, natural NMHCs, and anthropogenic NMHCs, is used as the reference O_3 precursor, the nonlinearity is much less pronounced for ambient conditions usually found in rural air.

AL-048

LIU, S.C., R.A. Cox, P.J. Crutzen, D.H. Ehhalt, R. Guicherit, A. Hofzumahaus, D. Kley, S.A. Penkett, L.F. Phillips, D. Poppe, F.S. Rowland. Oxidizing capacity of the atmosphere. In The Changing Atmosphere, F.S. Rowland and I.S.A. Isaksen (eds.). John Wiley & Sons Ltd. 219-232 (1988).

No abstract.

AL-049

MCAFEE, J.R., B.B. BALSLEY, and K.S. GAGE. Momentum flux measurements over mountains: problems associated with the symmetrical two-beam radar technique. Journal of Atmospheric and Oceanic Technology 6:500-508 (1989).

An experiment to measure the vertical transport of horizontal momentum was carried out using the Poker Flat, Alaska, MST radar operating in a symmetrical two-beam mode. We show that the difficulties inherent in this measurement are magnified by problems associated with the effects of orographic flow over the local mountainous terrain. These difficulties show up most clearly when comparing the average vertical velocities measured using antenna beam position in two orthogonal vertical planes. The measured fluxes

are dominated by large values of the long-period (>6h) fluctuations. Although this observation is consistent with previous measurements at other locations, we show that the accuracy of the symmetric two-beam method under these geographic conditions is questionable.

AL-050

McKellar, A.R.W., J.B. Burkholder, J.J. Orlando, and C.J. HOWARD. Fourier transform infrared spectrum of the ν_3 band of HCO. Journal of Molecular Spectroscopy 130:445-453 (1988).

The ν_3 fundamental band of the formyl radical, HCO, in the 5.3-μm region has been observed at high resolution (0.0025 cm^{-1}, unapodized) using a Fourier transform spectrometer. The HCO radicals were formed by the reaction of F atoms with H_2CO in a fast-flow multiple-traversal absorption cell. A total of 298 lines were measured with an accuracy of about 0.0004 cm^{-1} and assigned to transitions with values of the rotational quantum numbers N and K_a up to 20 and 5, respectively. These data greatly improve the knowledge of the HCO ν_3 line positions and $(\nu_1\nu_2\nu_3) = (001)$ vibrational state molecular parameters as compared to earlier laser magnetic resonance studies of this band, especially for higher values of N. The ν_1 fundamental band of HCO was also observed and an analysis of these data agrees well with the recent study of Dane et al. [Journal of Chemical Physics 88:2121-2128 (1988)].

AL-051

MOUNT, G.H., S. SOLOMON, R.W. SANDERS, R.O. JAKOUBEK, A.L. SCHMELTEKOPF. Observations of stratospheric NO_2 and O_3 at Thule, Greenland. Science 242:555-559 (1988).

Scattered sunlight and direct light from the moon was used in two wavelength ranges to measure the total column abundances of stratospheric ozone (O_3) and nitrogen dioxide (NO_2) at Thule, Greenland (76.5°N), during the period from 29 January to 16 February 1988. The observed O_3 column varied between about 325 and 400 Dobson units, and the lower values were observed when the center of the Arctic polar vortex was closer to Thule. This gradient probably indicates that O_3 levels decrease due to dynamical processes near the center of the Arctic vortex and should be considered in attempts to derive trends in O_3 levels. The observed NO_2 levels were also lowest in the center of the Arctic vortex and were sometimes as low as 5×10^{14} molecules per square centimeter, which is even less than comparable values measured during Antarctic spring, suggesting that significant heterogenous photochemistry takes place during the Arctic winter as it does in the Antarctic.

AL-052

MURPHY, D.M. Wall collisions, angular flux and pumping requirements in molecular flow through tubes and microchannel arrays. Journal of Vacuum Science and Technology A. 7:3075-3091 (1989).

Microchannel arrays can be used to produce intense molecular beams with free molecular flow. Arrays can attain much higher intensities than a single orifice small enough to be in free molecular flow. Pumping requirements are greatly reduced compared to supersonic jets producing similar beam intensities. Theoretical descriptions of the angular flux and wall collisions in single tubes and microchannel arrays are developed. These results are extended to the situation of a finite mean free path and the consideration of wall collisions which occur before transmission through a tube. Despite the large average number of wall collisions experienced by molecules passing through a long tube, molecules along the axis of the beam experience zero or few wall collisions. The near absence of wall collisions on the beam axis allows reactive species to be sampled with microchannel arrays. Tubes with a length to radius ratio of up to about 40 are useful for reactive species. Most wall collisions for molecules transmitted along the beam axis through microchannel arrays are collisions in which a molecule enters the array, collides with the wall, goes back to the source region, and then is transmitted through the array. The nearly effusive beam allows the selection of species based on their thermal velocities. A long single tube used as a skimmer will provide a greater pressure drop than an orifice.

AL-053

MURPHY, D.M., K.R. Chan, K.K. KELLY, M. Loewenstein, J.R. Podolske, M. H. Proffitt, S.E. Strahan, and A.F. TUCK. Indicators of transport and vertical motion from correlations between in situ measurements in the airborne Antarctic ozone experiment. Journal of Geophysical Research 94:11,669-11,685 (1989).

Analysis of small-scale structure in the in situ measurements made from the ER-2 during the Airborne Antarctic Ozone Experiment shows the existence of a region at the boundary of the chemically perturbed region where the mixing ratios and small-scale structure of trace gases are influenced by transport across the boundary. This transition region is characterized by horizontal interchange and vertical layering of air parcels from within and outside of the chemically perturbed region and negative small-scale correlations between ClO and ozone. The horizontal transport in this region creates large surface areas

between dissimilar air masses, providing the potential for substantial mixing. This paper does not attempt to quantify the amount of mixing. Correlations between ClO and O_3 show that the transition region extends to 2°-4° of latitude to either side of the boundary of the chemically perturbed region. A +4-wide transition region would contain nearly as much air as the chemically perturbed region proper. Analysis of water vapor and nitrous oxide data suggests that diabatic descent is associated with dehydration. This could be caused by strong radiative cooling of those polar stratospheric clouds in which enough water condenses for the particles to fall and dehydrate the air.

AL-054

Nastrom, G.D., J.L. GREEN, T.E. VANZANDT, K.S. GAGE, and W.L. CLARK. Measurement of large-scale vertical velocity using clear-air Doppler radar. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:367-376 (1989).

No abstract.

AL-055

Nastrom, G.D., M.R. Peterson, J.L. GREEN, K.S. GAGE, and T.E. VANZANDT. Sources of gravity waves as seen in vertical velocities measured by the Flatland VHF radar. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 713-716 (1989).

No abstract.

AL-056

PARRISH, D.D., and F.C. FEHSENFELD. Rural ozone production: Field study measuring many of the photochemically important trace species. Preprints, 198th Meeting of the American Chemical Society, Miami Beach, FL, September 10-15, 1989. Division of Environmental Chemistry, American Chemistry Society, 472-476 (1989).

Extended abstract.

AL-057

Proffitt, M.H., J.G. Anderson, and W.H. Brune. Ozone destruction by chlorine radicals within the Antarctic vortex: The spatial and temporal evolution of ClO-O_3 anticorrelation based on in situ ER-2 data. Journal of Geophysical Research 94:11,465-11,479 (1989).

In situ O_3 and ClO data obtained from the ER-2 aircraft are used to define the chemical evolution of the Antarctic vortex region from August 23 to September 22, 1987. Initial conditions are characterized at aircraft flight altitude (18 km) by highly amplified ClO mixing ratios (800 parts per trillion by volume (pptv) within a well-defined "chemically perturbed region" (CPR) poleward of the circumpolar jet, within which ozone exhibits limited erosion (~15%) in middle to late August. Within this CPR, ozone decays consistently throughout the course of a 10-flight series, such that by late September, 75% of the O_3 has disappeared within the region of highly amplified ClO concentrations (which reached 500 times normal levels at ER-2 cruise altitude). As this ozone depletion develops, O_3 and ClO exhibit dramatic negative correlation on isentropic surfaces, obtained as the aircraft passed through the edge of the CPR. Taken in conjunction with an analysis of the mechanisms defining the rate of catalytic O_3 destruction, it is concluded that ClO is an essential constituent in the catalytic destruction of ozone with the vortex. Therefore it is concluded that the observed disappearance of ozone with the Antarctic vortex would not have occurred in the absence of global chlorofluorocarbon release.

AL-058

Proffitt, M.H., K.R. Chan, D.W. FAHEY, B.L. Gary, K.K. KELLY, A.J. Krueger, M. Loewenstein, J.J. Margitan, J.R. Podolske, J.A. Powell, M.R. Schoeberl, and A.F. TUCK. A chemical definition of the boundary of the Antarctic ozone hole. Journal of Geophysical Research 94:11,437-11,488 (1989).

A campaign utilizing an ER-2 high-altitude and a DC-8 aircraft, both fitted with state-of-the-art instrumentation to study the Antarctic ozone hole, was conducted out of Punta Arenas, Chile, from August 17 through September 22, 1987. Data indicated a chemically perturbed region roughly coincident with the Antarctic polar vortex and with the region of large temporal decrease of ozone that is usually referred to as the Antarctic ozone hole. A rapid rise in ClO was observed as the ER-2 proceeded into the ozone hole at about 18 km altitude, and it is this feature that is used to define the boundary of the chemically perturbed region as that latitude along the flight track where ClO reaches 130 parts per trillion by

volume (pptv). In situ data taken simultaneously aboard the ER-2 as well as Total Ozone Mapping Spectrometer (TOMS) satellite ozone data along the flight tracks, are analyzed at fixed positions relative to this boundary and are presented as averages over the duration of the mission. These analyses indicate a narrow transition zone for the chemical species N_2O and H_2O and for the meteorological parameters of temperature, wind speed, and potential vorticity is also seen, indicating the dynamical character of the chemically defined boundary. TOMS column values of about 260 Dobson units (DU) generally persisted at the boundary during this period. One-month temporal trends of the in situ data both inside and outside this boundary are also presented. Interpretations of these analyses are offered that are consistent with ongoing diabatic cooling, accompanying advective poleward transport across the boundary. These data strongly implicate man's release of chlorine into the atmosphere as a necessary ingredient in the formation of the Antarctic ozone hole.

AL-059

REID, G.C., K.S. GAGE, and J.R. MCAFEE. The response of the tropical tropospheric and lower stratosphere to variations in pacific sea-surface temperature. Proc. of the 13th Annual Climate Diagnostics Workshop, Cambridge, MA, 61-65 (1988).

No abstract.

AL-060

Riddle, A.C., K.S. GAGE, and B.B. BALSLEY, Preparation of an archival data base for the Poker Flat, Alaska, MST radar. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:669-671 (1989).

No abstract.

AL-061

SANDERS, R.W., S. SOLOMON, M.A. CARROLL, and A.L. SCHMELTEKOPF. Visible and near-ultraviolet spectroscopy at McMurdo Station, Antarctica 4. Overview and daily measurements of NO_2, O_3, and OClO during 1987. Journal of Geophysical Research 94:11,381-11,391 (1989).

Near-ultraviolet absorption spectroscopy in the wavelength range from 330 to 370 nm was used to measure O_3, NO_2, and BrO at McMurdo Station (78°S) during 1987. Visible absorption measurements of O_3, NO_2, and OClO were also obtained using the wavelength range from about 403 to 453 nm. These data are described and compared to observations obtained in 1986. It is shown that comparisons of observations in the two wavelength ranges provide a sensitive measure of the altitude where the bulk of atmospheric absorption takes place. The measurements indicate that the bulk of the NO_2 column abundance is located near 30 km, while those of OClO and O_3 are near 20 km. The measurements of NO_2 display a systematic increase during the month of September, probably reflecting the release of odd nitrogen from reservoirs formed earlier in the winter season. The measurements of OClO display a strong diurnal variation, with considerably higher values being obtained in the evening than those measured in the morning. The evening twilight OClO column abundances obtained in 1987 were notably larger than those in 1986, perhaps because stratospheric temperatures were colder, and associated heterogeneous chemistry may have been more intense. This in turn implies a faster rate of ozone destruction in 1987 than in 1986 by halogen chemistry. These observations provide important constraints on the coupled nitrogen-halogen chemistry of Antarctic spring and its influence on the springtime Antarctica ozone depletion.

AL-062

Sengupta, N., J.M. WARNOCK, E.E. Gossard, and R.G. Strauch. Remote sensing of meteorological parameters using a wind-profiling radar. Preprints, First European Wind Profiler Workshop, Trappes, France, March 6-8, 1989, D9-D20 (1989).

The described experiment tested the feasibility of (a) using a surface-based radar to measure gradients of temperature and humidity aloft and (b) using standard radiosonde data to calculate height profiles of the radio refractive index structure parameter, C_n^2. The statistical model developed by NOAA's Aeronomy Laboratory was used to calculate values of C_n^2 and ε for comparison with the radar-measured values. The radar-calculated and observed quantities were found to be in reasonably good agreement.

AL-063

SOLOMON, S., H.L. Miller, J.P. Smith, R.W. SANDERS, G.H. MOUNT, A.L. SCHMELTEKOPF, and J.F. Noxon. Atmospheric NO_3 1. Measurement technique and the annual cycle at 40°N. Journal of Geophysical Research 94:11,041-11,048 (1989).

The nitrate radical abundance is often measured by making use of its strong absorption of visible radiation in a band near 662 nm. We show that this NO_3 absorption feature has strong negative correlation with water vapor, which requires that water vapor absorption be explicitly considered in attempts to measure NO_3 from the ground. Concurrent observation of a second, weaker NO_3 feature near 623 nm provides an independent means of confirming and quantifying the accuracy of the measurement. The considerations are included in the analysis of a full year of nighttime stratospheric NO_3 data at 40°N. The observations are in good general agreement with theoretical predictions and do not support the existence of a stratospheric scavenger for NO_3.

AL-064

SOLOMON, S., G.H. MOUNT, R.W. SANDERS, R.O. JAKOUBEK, and A.L. SCHMELTEKOPF. Observations of the nighttime abundance of OC1O in the winter stratosphere above Thule, Greenland. Reprint Series, Science 242:550-555 (1988).

Observations at Thule, Greenland, that made use of direct light from the moon on 2, 3, 4, 5, and 7 February 1988 revealed nighttime chlorine dioxide (OC1O) abundances that were less than those obtained in Antarctica by about a factor of 5, but that exceeded model predictions based on homogeneous (gas-phase) photochemistry by about a factor of 10. The observed time scale for the information of OC1O after sunset strongly supports the current understanding of the diurnal chemistry of OC1O. These data suggest that heterogeneous (surface) reactions due to polar stratospheric clouds can occur in the Arctic, providing a mechanism for possible Arctic ozone depletion.

AL-065

SOLOMON, S., R.W. SANDERS, M.A. CARROLL, and A.L. SCHMELTEKOPF. Visible and near-ultraviolet spectroscopy at McMurdo Station, Antarctica 5. Observations of the diurnal variations of BrO and OC1O. Journal of Geophysical Research 94:11,393-11,403 (1989).

Observations of the diurnal variations of OC1O and BrO during austral spring, 1987 using long-path visible and near-ultraviolet absorption spectroscopy are presented and compared to simplified model calculations. It is shown that care must be taken to compare model calculations and measurements along the line of sight of the instrument. Evening twilight observations of C01O are found to be broadly consistent with current photochemical schemes, assuming C1O and BrO levels near 50 mbar of about 0.5 parts per billion by volume (ppbv) and 7 parts per trillion by volume (pptv), respectively, throughout the observing period from late August to mid-October. Nighttime observations of OC1O obtained using the Moon as a light source display evidence for growth after sunset in late August, but not in late September. Further, the observed morning twilight OC1O abundances are in agreement with model calculations in late August, but they generally fall below calculations in late September and October. Observations of BrO in mid-September show far greater evening than morning twilight abundances. It is shown that the diurnal variations of BrO and OC1O in mid-September and October can be explained by formation of the $BrONO_2$ reservoir species at night, although other reservoir species with comparably long lifetimes could also explain the observations. If formation of $BrONO_2$ is the correct explanation for these data, the observations suggest that NO_2 levels in the Antarctic lower stratosphere are of the order of a few pptv or less in late August, a few tens of pptv in mid-September, and a few hundred pptv in October.

AL-066

Strauch, R.G., K.P. Moran, P.T. May, A.J. Bedard, and W.L. ECKLUND. RASS temperature soundings with wind profiler radars. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 741-745 (1989).

No abstract.

AL-067

Tsuda, T., T. Inoue, D.C. Fritts, T.E. VANZANDT, S. Kato, T. Sato, and S. Fukao. MST radar observations of a saturated gravity wave spectrum. Journal of the Atmospheric Sciences 46:2440-2447 (1989).

We present vertical wavenumber spectra of mesoscale wind fluctuations using data observed in the troposphere, lower stratosphere and mesosphere by the MU radar at 35°N in Japan in October 1986 and June 1987, as well as lower stratospheric spectra obtained by the Arecibo UHF radar at 18°N in Puerto Rico in June 1983. These spectra are much more homogeneous than previously available spectra since all of the data were observed by the same radar technique, the data in the different atmospheric regions were taken essentially simultaneously, and all of the spectra were analyzed using very similar methods. In the large-wavenumber ranges of the observed spectra, the asymptotic slopes and amplitudes agree well with the saturated gravity wave spectral model developed by Dewan and Good (1986) and Smith et al. (1987), which

has a slope of -3 and a spectral amplitude proportional to the buoyancy frequency squared. The good agreement between the model spectrum and the observed spectra from different altitudes, different seasons, and two different stations located at 35° and 18°N suggests that the model is essentially correct, in spite of the heuristic nature of some of its assumptions. The spectral densities of the zonal and meridional components are similar at large wavenumbers, while the meridional spectrum has larger energy density at small wavenumbers where the spectrum is not saturated. The dominant vertical scales of the gravity wave field in the mesosphere, lower stratosphere, and troposphere are estimated to be >10 km, 2.2 to 3.3 km, and $\geq$3.3 km in October and $\geq$4.5 km in June, respectively, consistent with determinations from previous studies.

AL-068

Tsuda, T., T.E. VANZANDT, S. Kato, S. Fukao, and T. Sato. Spectral analysis of temperature and Brunt-Väisälä frequency fluctuations observed by radiosondes. Conference Proceedings, Symposium 6, The Middle Atmosphere After MAP, COSPAR 88, Espoo, Finland, July 18-23, 1988. Handbook for MAP 27:461-468 (1989).

We have observed temperature profiles over the MU observatory, Japan, by using a radiosonde with 30m height resolution in summer from 30 June to 4 September 1987, and in winter from 22 December 1986 to 25 February 1987 [Figs. 1-4]. In summer, the tropopause is located at around 16 km. There is a sharp increase in the N^2 (N: Brunt-Väisälä frequency) profile, which clearly separates the troposphere and stratosphere. On the other hand, in winter the increase of N^2 is gradual and somewhat irregular, so that the transition region from the troposphere to the stratosphere is fairly broad, although the tropopause is usually found at 10-12 km. We present in this paper vertical wavenumber spectra of normalized temperature perturbation and N^2 determined in the 2-8.5 km (troposphere) and 18.5-25 km (lower stratosphere) altitude ranges [Figs. 5 and 6]. The observed spectra are compared with saturated gravity wave theory, which predicts a spectrum of normalized temperature as $1/10 \times N^4/(g^2 m^3)$ and N^2 as $1/10 \times N^4/m$, where g and m are acceleration of gravity and vertical wavenumber, respectively.

AL-069

TUCK, A.F. Synoptic and chemical evolution of the Antarctic vortex in late winter and early spring, 1987. Journal of Geophysical Research 94:11,687-11,737 (1989).

Evidence from the ER-2 and DC-8 aircraft flights is considered, together with analysis of temperature, winds, potential vorticity and trajectories, satellite data, and ozonesonde observations, to come to a view of whether the air in the lower stratosphere over Antarctica during winter and early spring of 1987 was a fixed slug of air, or if there was significant mass flow through the system. It is concluded that synoptic-scale forcing, via "sudden coolings", produced polar stratospheric clouds, which intervened to alter the homogeneous gas phase chemical balance. As a result, there was a source of the ClO molecule and sinks for H_2O, NO_y (equal to the sum of reactive gas phase nitrogen compounds), and O_3 operating within the region of high potential vorticity gradients on isentropic surfaces, that is, inside the vortex. It is further concluded that as a result of horizontal mixing, downward diabatic motion, and, at potential temperatures below 400 K, advective transfer, that the effects of these polar sinks and chemical reactions can be transmitted to middle latitudes.

AL-070

TUCK, A.F., J. Austin, E.V. Browell, R.L. Jones, A.J. Krueger, M.P. McCormick, and D.S. McKenna. Diagnostic studies of the Antarctic vortex during the 1987 airborne Antarctic ozone experiment: Ozone miniholes. Journal of Geophysical Research 94:11,641-11,668 (1989).

During the Airborne Antarctic Ozone Experiment (AAOE) localized rapid reductions in total ozone, called "miniholes", were observed by the Total Ozone Mapping Spectrometer (TOMS) within the main ozone hole. Evolving too rapidly to be the result of chemical destruction, miniholes must be the result of atmospheric transport. An important question then is "Do miniholes represent large-scale transport of ozone poor air into the vortex?" In this paper we examine the genesis and evolution of miniholes, and we demonstrate by the calculation of air parcel trajectories that miniholes are not the result of irreversible transport of ozone-poor air into the polar vortex. We show instead that minihole genesis can be attributed, in large part, to synoptic-scale tropospherically forced reversible advection (both horizontal and vertical) of low-ozone air below the level of the main ozone depletion, resulting from the poleward penetration of an anticyclone below the main vortex. We then examine the implications of the disturbed flows associated with minihole formation. Employing differential infrared absorption laser (DIAL) data, Stratospheric Measurement (SAM) II retrievals, and United Kingdom Meteorological Office (UKMO) global analysis fields and trajectories, we highlight two aspects of minihole formation, which have important implications for both theories of photochemical ozone destruction and vortex isolation. We conclude that tropospheric forcing which reduces the ozone column through advection also forces the formation of Polar Stratospheric Clouds (PSCs) (type I and II), throughout a substantial depth of atmosphere, resulting in a large portion

of the air in the vortex being exposed to heterogeneous chemistry as it passes through individual quasi-stationary PSC regions. Finally we conclude that synoptic-scale transport associated with these events can lead to the exchange of vortex air with air from lower latitudes. The lower limit on the mass exchange over the period of ozone depletion is estimated to be 4% of the total depleted mass, with large uncertainties.

AL-071

TUCK, A.F., E.P. Condon, J.J. Margitan, O.B. Toon, and R.T. Watson. The planning and execution of ER-2 and DC-8 aircraft flights over Antarctica, August and September 1987. Journal of Geophysical Research 94:11,181-11,222 (1989).

During August and September 1987, instrumented ER-2 and DC-8 aircraft flew 12 to 13 flights over Antarctica, respectively, to investigate the dramatic loss of ozone that has occurred there in the lower stratosphere during recent austral springs. The flights, which are documented in some detail, provided a wealth of data on homogeneous gas phase composition, upon polar stratospheric clouds, and upon tracers for dynamic motion. An important aspect of the ER-2 data is that periods of high surface winds at Punta Arenas, Chile, which generally prevented a flight, frequently coincided with equatorward extension of the vortex toward the flight track region (52° -72°S, 60° -80°W). The ER-2 flights are thus biased toward days when the vortex was being pushed away from the tip of South America and the Antarctic Peninsula. Any attempt to use the ER-2 data as a time series must take into account the variable position of the vortex edge along the flight track. At DC-8 flight levels, numerical weather prediction models had a tendency to underestimate the wind speeds by up to 50% in situations of strong meridional flow. Since such events had detectable effects on the lower stratospheric vortex, this too could be an important limitation.

AL-072

Tyndall, G.S., and C.J. HOWARD. Kinetics of the reaction of CH_3S with O_3 at 298 K. The Journal of Physical Chemistry 93:4707-4710 (1989).

Laser-induced fluorescence was used to detect CH_3S radicals in the laser flash photolysis of CH_3SH-O_3-H_2O-He (SF_6) mixtures. Evidence was found for a reaction between CH_3S and O_3, with a rate coefficient $(4.1 \pm 2.0) \times 10^{-12}$ cm^3 molecule^{-1} s^{-1}. The yield of CH_3S from the reaction OH + CH_3SH was determined to be 1.1 ± 0.2. Our results suggest that the $CH_3S + O_3$ reaction could be the major sink for CH_3S in the atmosphere.

AL-073

Tyndall, G.S., and A.R. RAVISHANKARA. Kinetics and mechanism of the reactions of CH_3S with O_2 and NO_2 at 298 K. The Journal of Physical Chemistry 93:2426-2435 (1989).

Rate coefficients for the reactions $CH_3S + O_2 \rightarrow$ products (1) and $CH_3S + NO_2 \rightarrow$ products (2) have been measured at 298 K by laser induced fluorescence detection of CH_3S which was generated by pulsed 248-nm laser photolysis of CH_3SSCH_3. k_1 was found to be less than 2.5×10^{-18} cm^3 s^{-1}. k_2 was measured to be $(6.10 \pm 0.90) \times 10^{-11}$ cm^3 s^{-1}. The mechanism of reactions 1 and 2 was investigated. The major product in reaction 2 is NO, with a yield of 0.80 ± 0.20. Secondary production of NO was observed, indicating that CH_3SO formed in reaction 2 also reacts with NO_2, with a rate coefficient of $(8 \pm 5) \times 10^{-12}$ cm^3 s^{-1}. At long reaction times laser excited fluorescence was detected from a product, possibly CH_3SO.

AL-074

Vaghjiani, G.L., and A.R. RAVISHANKARA. Absorption cross sections of CH_3OOH, H_2O_2, and D_2O_2 vapors between 210 and 365 nm at 297 K. Journal of Geophysical Research 94(D3):3487-3492 (1989).

The gas phase absolute UV absorption cross sections at 213.9 nm for CH_3OOH, H_2O_2, and D_2O_2 have been determined to be $(22.51 \pm 0.78) \times 10^{-20}$, $(33.04 \pm 2.17) \times 10^{-20}$, and $(35.57 \pm 4.25) \times 10^{-20}$ cm^2 molecule^{-1}, respectively, at 297 ± 1 K. The corresponding values at 253.7 nm for H_2O_2 and D_2O_2 were $(7.37 \pm 0.31) \times 10^{-20}$ and $(7.86 \pm 1.04) \times 10^{-20}$ cm^2 molecule^{-1}. The UV absorbance of a slowly flowing mixture of peroxide and helium carrier gas in a Pyrex absorption cell was measured, followed by collection and titration of the eluting peroxide with Fe^{2+} or I^- solutions. The relative cross sections for CH_3OOH and H_2O_2 at 298.1, 326.1, 340.4, and 361.1 nm were also determined, using the absolute values at 213.9 nm. The absorption spectra of these peroxides were recorded in the wavelength region between 210 and 365 nm, using a diode array spectrometer, and normalized to the above cross sections to obtain absolute values for the UV absorption cross sections over this entire wavelength region. The obtained results are compared to those from previous investigations. The atmospheric relevance of our measured cross sections is discussed.

AL-075

Vaghjiani, G.L., and A.R. RAVISHANKARA. Kinetics and mechanism of OH reaction with CH_3OOH. The Journal of Physical Chemistry 93:1948-1959 (1989).

The reaction of hydroxyl radical with methyl hydroperoxide, CH_3OOH, was investigated in the temperature range 203-423 K by pulsed photolytic generation of OH and detection by laser-induce fluorescence. The rate coefficient for the overall reaction, OH + CH_3OOH → products (k_1) was measured by using ^{18}OH and OD in place of OH. The rate coefficient for the CH_3O_2 production channel OH + CH_3OOH → CH_3O_2 + H_2O (k_{1a}) was obtained by using OH. The channel that yields CH_2OOH, OH + CH_3OOH → CH_2OOH + H_2O (k_{1b}), is not observed when monitoring OH since CH_2OOH rapidly falls apart to give back OH (and CH_2O) but is observed when studying the ^{18}OH or OD reaction with CH_3OOH. By monitoring OH production in OD + CH_3OOH reaction at 249 K, the two-channel mechanism was confirmed, and the values for k_1 and k_{1a} were also determined. Both reaction 1 and channel 1a show negative activation energies, with $k_1 = (2.93 \pm 0.30) \times 10^{-12} \exp[(190 \pm 14)/T]$ cm^3 $molecule^{-1}$ s^{-1} (average of ^{18}OH and OD studies) and $k_{1a} = (1.78 \pm 0.25) \times 10^{-12} \exp[(220 \pm 21)/T]$ cm^3 $molecule^{-1}$ s^{-1}, where the indicated error is 1σ, including estimated systematic errors and $\sigma_A = A\sigma_{\ln A}$. The rate coefficient for the reaction of OD with CH_3OOD is at least a factor of 2 smaller than that for reaction 1a. The thermal decomposition lifetime for CH_2OOH to give OH + CH_2O is deducted to be shorter than 20 μs at 205 K. The mechanism of reaction 1 and the implications of our kinetic and mechanistic results to Earth's atmospheric chemistry are discussed. The measured value of k_1 and the branching ratio, k_{1a}/k_{1b}, at 298 K are compared with previous indirect measurements of Niki et al. [Journal of Physical Chemistry 87:2190 (1983)].

AL-076

VANZANDT, T.E. Advances in understanding the gravity wave spectrum during MAP. Conference Proceedings, Symposium 6, The Middle Atmosphere After MAP, COSPAR 88, Espoo, Finland, July 18-23, 1988. Handbook for MAP 27:123-131 (1989).

No abstract.

AL-077

VANZANDT, T.E. Progress in existing and planned MST and ST radars. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:450 (1989).

No abstract.

AL-078

VANZANDT, T.E., and D.C. Fritts. A theory of enhanced saturation of the gravity wave spectrum due to increases in atmospheric stability. Pure and Applied Geophysics 130:399-420 (1989).

In this paper we consider a vertical wavenumber spectrum of vertically propagating gravity waves impinging on a rapid increase in atmospheric stability. If the high-wavenumber range is saturated below the increase, as is usually observed, then the compression of vertical scales as the waves enter a region of higher stability results in that range becoming supersaturated, that is, the spectral amplitude becomes larger than the saturation limit. The supersaturated wave energy must then dissipate in a vertical distance of the order of a wavelength, resulting in an enhanced turbulent energy dissipation rate. If the wave spectrum is azimuthally anisotropic, the dissipation also results in an enhanced vertical divergence of the vertical flux of horizontal momentum and enhanced wave drag in the same region. Estimates of the enhanced dissipation rates and radar reflectivities appear to be consistent with the enhancements observed near the high-latitude summer mesopause. Estimates of the enhanced mean flow acceleration appear to be consistent with the wave drag that is needed near the tropopause and the high-latitude summer mesopause in large-scale models of the atmosphere. Thus, this process may play a significant role in determining the global effects of gravity waves on the large-scale circulation.

AL-079

VANZANDT, T.E., J.L. GREEN, G.D. Nastrom, K.S. GAGE, W.L. CLARK, and J.M. WARNOCK. Measurement of vertical velocity using clear-air Doppler radars. Conference Proceedings, Symposium 6, The Middle Atmosphere After MAP, COSPAR 88, Espoo, Finland, July 18-23, 1988. Handbook for MAP 27:477-481 (1989).

No abstract.

AL-080

VANZANDT, T.E., G.D. Nastrom, J.L. GREEN, and K.S. GAGE. The spectrum of vertical velocity from Flatland radar observations. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:377-383 (1989). Also Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 717-720 (1989).

No abstract.

AL-081

VANZANDT, T.E., S.A. Smith, T. Tsuda, D.C. Fritts, T. Sato, S. Fukao, and S. Kato. Anisotropy of the velocity fluctuation field in the lower stratosphere. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:350-352 (1989).

No abstract.

AL-082

Wahner, A., R.O. JAKOUBEK, G.H. MOUNT, A.R. RAVISHANKARA, and A.L. SCHMELTEKOPF. Remote sensing observations of nighttime OC1O column during the Airborne Antarctic Ozone Experiment, September 8, 1987. Journal of Geophysical Research 94:11,405-11,411 (1989).

The daytime and nighttime slant column abundances of OC1O were measured by near-UV absorption spectroscopy between 64° and 76°S latitude and 62° and 84°W longitude during the DC-8 flight on days 251 and 252 (UT) 1987 as a part of the Airborne Antarctic Ozone Experiment (AAOE). Daytime and nighttime measurements used the scattered sunlight and the Moon as the light sources, respectively. The measured OC1O column abundance during the nighttime was found to be 10 times larger than that measured during the day.

AL-083

Wahner, A., A.R. RAVISHANKARA, S.P. Sander, and R.R. Friedl. Absorption cross section of BrO between 312 and 385 nm at 298 and 223 K. Chemical Physics Letters 152(6):507-512 (1988).

The absolute UV cross section of BrO at 338.1 ± 0.1 nm, the peak of the $(7,0)$ band of the $A(^2\Pi) \leftarrow X(^2\Pi)$ transition, was measured at 298 ± 2 and 223 ± 4 K to be (1.71 ± 0.14) x 10^{-17} and (221 ± 0.16) x 10^{-17} cm^2, respectively, using the technique of flash photolysis-ultraviolet absorption. The spectral resolution for these measurements was 0.18 nm. The absorption spectra of BrO in the wavelength range 312-385 nm were measured at 298 ± 2 and 223 ± 4 K using a flow tube reactor coupled to a diode array spectrometer. Using the (7,0) band cross sections, the absorption cross sections in the above wavelength range were calculated.

AL-084

WARNOCK, J.M., R.R. Beland, J.H. Brown, W.L. CLARK, F.D. Eaton, L.D. Favier, K.S. GAGE, J.L. GREEN, W.H. Hatch, J.R. Hines, E.A. Murphy, G.D. Nastrom, W.A. Peterson, and T.E. VANZANDT. Comparison among clear-air radar, thermosonde and optical measurements and model estimates of C_n^2 made in very flat terrain over Illinois. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:432-438 (1989).

No abstract.

AL-085

WARNOCK, J.M., K.S. GAGE, and J.L. GREEN. Flatland radar measurements of tropopause heights and comparison of specular echo strength with model estimates. Conference Proceedings, 4th MST Radar Workshop, Kyoto, Japan, November 29-December 2, 1988. Handbook for MAP 28:39-42 (1989).

No abstract.

AL-086

WARNOCK, J.M., K.S. GAGE, and J.L. GREEN. Studies of the radar reflectivity of vertical echoes measured by the Flatland VHF clear-air Doppler radar. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, MA, 721-724 (1989).

No abstract.

AL-087
WEINSTOCK, J. A theory of turbulent transport. Journal of Fluid Mechanics 202:319-338 (1989).

A calculation is made of the turbulent transport terms (third moments) that occur in the Reynolds stress equation for buoyant and/or sheared fluids. This calculation is based on neglect of a two-time fourth-order cumulant - a weaker approximation than neglect of the usual single-time fourth-order cumulant. The previously used eddy-damping assumption for single point moments is avoided. This assumption is then examined critically. Comparison is afterward made between the turbulent transport terms derived here and those derived previously by the eddy-damping method, and between the respective derivations. Also the dissipation of third moments is calculated. The calculation is formally limited to mean quantities which very but slowly in space and time, and to small anisotropy.

AL-088
WEINSTOCK, J. Comparison of a pressure-strain rate theory with simulations. Journal of Fluid Mechanics 205:195-214 (1989).

A theoretical expression for the slow part (the nonlinear fluctuation part) of the pressure-strain rate is compared with simulations of anisotropic homogeneous flows. The purpose is to determine the quantitative accuracy of the theory and to test its qualitative predictions that the generalized Rotta coefficient, a non-dimensionalized ratio of slow term to kinetic energy anisotropy, varies with direction and can be negative (this is counter to isotropy return). Comparisons are made between theoretical and simulated values of the slow term and of the generalized Rotta coefficients. Also compared to simulations is an extension of the theory to account for non-stationary turbulence fields. The implication of the comparison for two-point closure theories and for Reynolds stress modelling is pointed out.

AL-089
WEINSTOCK, J. Superadiabatic excess and gravity wave saturation. Journal of the Atmospheric Sciences 45:22 (1988).

Attention is called to a recent calculation of the superadiabatic excess - the ratio of wave amplitude at saturation to wave amplitude at convective instability threshold - caused by a saturated gravity wave. (This excess is also referred to as the degree of supersaturation). The implications of this excess for linear saturation by convective instability are pointed out. Errors and misprints in the recent calculation are also pointed out and corrected.

AL-090
WEINSTOCK, J. Time averaged transport coefficients in photo-chemical modeling: A conjecture. Journal of Geophysical Research 94:14,703-14,704 (1988).

It has been pointed out by several authors that constituent diffusivities associated with breaking gravity waves vary dramatically with the wave saturation amplitude. This variation introduces an uncertainty for the value to be used for diffusivity. In principle, this particular uncertainty may be avoided if an appropriate time average is used, and the corresponding wave statistics are known. A simple hypothesis is put forward regarding what average is appropriate.

AL-091
Wormhoudt, J., K.E. McCurdy, and J.B. Burkholder. Measurements of the strengths of infrared bands of CF_2. Chemical Physics Letters 158(6):480-485 (1989).

The ν_P infrared band strength of the CF_2 radical has been measured using tunable diode laser absorption by the $^PR_1(20)$ line at 1240.50 cm^{-1}. Experiments were performed in a flow apparatus in which CF_2 was generated by thermal dissociation of CF_2HCl. Simultaneous single pass absorption of UV light from a KrF excimer laser was used with a literature value of the UV absorption cross section to quantify CF_2 concentrations. The measured line strength at 360 K is $(1.4\pm0.4) \times 10^{-20}$ cm^{-1} $(molecule/cm^2)^{-1}$. This results in a band strength of $(1.1\pm0.4) \times 10^{-17}$ cm^{-1} $(molecule/cm^2)^{-1}$, in good agreement with a measurement using a different technique. Analysis of FTIR spectra of the ν_1 and ν_3 bands indicates that the ν_3 band strength is larger by a factor of 2.4.

Addendum

AL-092

BALSLEY, B.B. The MST radar technique: Historical background and potential for atmospheric research. In Future Directions in Electrical Engineering: Atmospheric and Space Sciences, (Proceedings of the Cornell Electrical Engineering Centennial Symposium, St. Louis, MO, April 17, 1985), S. Linke (ed.). Promethean Press, Ithaca, NY, 473-496 (1988).

No abstract.

AL-093

BALSLEY, B.B., W.L. ECKLUND, D.A. CARTER, and A.C. Riddle. A note on reducing the horizontal sidelobes of near-vertically directed COCO arrays. IEEE Transactions on Antennas and Propagation 36:139-141 (1988).

A method of modifying quasi-broadside arrays of coaxial collinear (COCO) antennas in order to significantly reduce horizontal sidelobe levels is discussed. Tests made prior to and after these modifications show a sidelobe reduction of more than three orders of magnitude.

AL-094

GAGE, K.S., B.B. BALSLEY, W.L. ECKLUND, D.A. CARTER, A.C. Riddle, and J.R. MCAFEE. Zonal wind observations at Christmas Island (2°N, 157°W) during the 1986-87 El Niño. Proceedings, Twelfth Annual Climate Diagnostics Workshop, Salt Lake City, UT, October 12-16, 1987. NOAA/NWS/NMC Climate Analysis Center, 37-49 (1987).

No abstract.

AL-095

GREEN, J.L., G.D. Nastrom, K.S. GAGE, T.E. VANZANDT, W.L. CLARK, and J.M. WARNOCK. Observations of vertical velocity over Illinois by the Flatland radar. Geophysical Research Letters 15:269-272 (1988).

A new VHF clear-air Doppler radar has been constructed in very flat terrain near Urbana, Illinois. This radar, called the Flatland radar, as presently configured measures a profile of the vertical component of the wind velocity every 2.5 minutes. It is found that typical time variances of vertical velocity over this very flat terrain are similar to the small variances observed during "quiet" periods near mountains. The observed absence of extended periods of large variance supports the hypothesis that the "active" periods observed near mountains are mainly due to orographic effects. The absence of such effects at Flatland should facilitate the study of other meteorological processes. For example, in the case study presented here it is suggested that the vertical motions associated with large-scale baroclinic storms are measurable by the Flatland radar.

AIR RESOURCES LABORATORY

AR-001

ANGELL, J.K. Relation of Antarctic 100 mb temperature and total ozone to equatorial QBO, Equatorial SST, and sunspot number, 1958-87. Geophysical Research Letters 15(8):915-918 (1988).

Year-to-year changes in springtime (September-October-November or SON) values of Antarctic 100 mb temperature and total ozone have been compared with each other and with year-to-year changes in SON values of equatorial 50 mb temperature (reflecting the quasi-biennial oscillation or QBO) and sea-surface temperature (SST) in eastern equatorial Pacific (reflecting El Niño). During the 30-year period 1958-87, there has been a significant (at the 5% level) correlation of 0.73 between year-to-year changes in SON values of Antarctic 100 mb temperature and total ozone, as well as a significant correlation of -0.64 between year-to-year changes in SON values of Antarctic 100 mb temperature and equatorial 50 mb temperature. There has been little correlation (-0.18) between year-to-year changes in Antarctic 100 mb temperature and SST in eastern equatorial Pacific. However, year-to-year changes in Antarctic total ozone have been almost equally related to year-to-year changes in equatorial 50 mb temperature and equatorial SST (respective correlations of -0.44 and -0.42), with a significant correlation of -0.60 if the latter two quantities are considered jointly (multiple correlation). Unlike the Arctic in winter, there is no evidence of an increase in springtime values of Antarctic 100 mb temperature (and total ozone) with increase in sunspot number when the equatorial QBO is in the west-wind phase, but there is provisional evidence of such an increase in the east-wind phase.

AR-002

ANGELL, J.K. Variations and trends in tropospheric and stratospheric global temperatures, 1958-87. Journal of Climate 1(12):1296-1313 (1988).

Examined in this paper are the variations and trends in tropospheric and low-stratospheric temperature for seven climatic zones, hemispheres, and world for intervals 1958-87 and 1973-87, based on 63 well-distributed radiosonde stations. For the 30-yr interval 1958-87, these data indicate an increase in year-average global temperature at the surface and in the tropospheric 850-300 mb layer of 0.08°C $(10\ yr)^{-1}$ and 0.09°C $(10\ yr)^{-1}$, respectively, just significant at the 5% level. Nevertheless, during this interval there is evidence for a slight decrease in year-average temperature at the surface and in the troposphere of north polar and north temperate zones. The global 300-100 mb temperature is indicated as having decreased by 0.18°C $(10\ yr)^{-1}$ during this 30-yr interval (significant at the 1% level), with a temperature decrease in all seven climatic zones, though largest in the south polar zone (associated with the Antarctic "ozone hole" phenomenon). For the 15-year interval 1973-87, the global temperature in the low-stratospheric 100-50 mb layer is indicated as having decreased by a significant 0.62°C $(10\ yr)^{-1}$, the decrease again largest in the south polar zone 2.04°C $(10\ yr)^{-1}$ but observed in all zones except the north temperate zone. During 1958-87, there is evidence for an increase in the meridional temperature gradient between equatorial zone and north polar zone both at the surface and in the troposphere, but in the Southern Hemisphere there has been a decrease in this gradient at the surface and essentially no change in the troposphere. In the hemispheric and global average, warming has been greater (though not significantly so) in MAM (March-April-May) and JJA than in DJF and SON, both at the surface and in the troposphere, though in both polar zones the surface warming has been greatest in winter. The close relation between sea-surface temperature in eastern equatorial Pacific and tropospheric temperature in the tropics is discussed in some detail. Finally, temperature variations and trends in the western hemisphere tropics are examined up to heights of 55 km using high-level radiosonde data and rocketsonde data.

AR-003

ARTZ, R.S., and G.D. ROLPH. Evaluation of precipitation chemistry siting criteria using paired stations from northern Maine and southeastern Texas. Atmospheric Environment 23(5):1033-1050 (1989).

Two-year precipitation chemistry data records from each of two paired stations are compared to determine whether the precipitation chemistry is different. In each pair, one of the stations (Caribou, Maine, and Victoria, Texas) violates National Atmospheric Deposition Program (NADP) siting requirements, while the other station (Presque Isle, Maine, and Beeville, Texas) is in compliance. Methods employed to carry out this study include the calculation of precipitation weighted statistics, the study of logarithmic distributions, the study of regression line residuals, the study of relative sample differences, and the use of the non-parametric Wilcoxon test for two matched samples. Results indicate no clear differences occurred between paired stations over a seasonal or longer period of time; however, considerable variation was observed on a weekly basis. Maine stations were in

excellent agreement for all ions; Texas stations showed small differences between ions typically associated with soil dust and between ions typically associated with anthropogenic activity.

AR-004

ARTZ, R.S., G.D. ROLPH, and J. HARRIS. Meteorological summary of four WATOX 1985 research intensives. Atmospheric Environment 22(11):2361-2369 (1988).

A detailed review of four intensive events in the Western Atlantic Ocean Experiment (WATOX) in 1985 is given. Three air parcel trajectory models are used to assess the general flow characteristics associated with these events, and results show that all three models produce trajectories with similar source regions. Not surprisingly, isentropic trajectories tended to show faster transport because of vertical movement from higher altitudes. The goal of sampling during periods of strong northwesterly flow was generally met.

AR-005

BALDOCCHI, D.D. Canopy-atmosphere water vapour exchange: Can we scale from a left to a canopy? Estimation of Areal Evapotranspiration (Proceedings of a Workshop held at Vancouver, B.C., Canada, August 1987). IAHS Publ. No. 177, 21-41 (1989).

A goal of canopy micrometeorology is to understand mass and energy exchanges at the leaf and canopy levels and to scale these exchanges from one level to another. This paper discusses the processes governing evaporation that are amenable to scaling and the environmental and physiological conditions under which such scaling may be applicable. Factors affecting the scaling of evaporation from a leaf to a canopy include: the degree of canopy development, the relationship between the aerodynamic and surface resistance, the degree of coupling between the leaf, plant and canopy and their environment, and whether or not certain processes are operational or significant at one scale, but are not on another scale.

AR-006

BALDOCCHI, D.D. Turbulent transfer in a deciduous forest. Tree Physiology 5:357-377 (1989).

Carbon dioxide, water vapor and other passive scalars are physically transferred between a plant canopy and the atmosphere by turbulence. Intense and intermittent sweep and ejection events transfer most of the mass. Although the capacity for turbulence to transfer material is high, mass transfer is coupled to the diffusive source or sink strength of the foliage and soil and is ultimately limited to a minimum level set up the supply of material, or the demand for it. The diffusive source/sink strength of material leaving or entering leaves and the soil is a function of many physical, biological and chemical attributes and processes. These attributes and processes include the amount and distribution of foliage, the leaf boundary layer and surface resistances, the turbulence and radiative regimes in the canopy, biochemical and photochemical reactions and the scalar concentration field within and above the canopy and inside leaves and the soil. Here we discuss how these factors contribute to turbulent transfer in a deciduous forest.

AR-007

BALDOCCHI, D.D. Turbulence transfer of sensible heat and momentum in an almond orchard. Preprint Volume, 19th Conference on Agriculture and Forest Meteorology and the Ninth Conference on Biometeorology and Aerobiology, Charleston, SC, March 7-10, 1989. American Meteorology Society, Boston, 186-187 (1989).

No abstract.

AR-008

BALDOCCHI, D.D. Turbulent transfer in a broadleaf forest. Proceedings, Fourth Australasian Conference on Heat and Mass Transfer, Christchurch, New Zealand, May 9-12, 1989. University of Canterbury, Christchurch, New Zealand, 9-23 (1989).

Turbulent transfer in a plant canopy is regulated by many structural, physical, physiological and chemical processes. The processes that contribute to turbulence transfer in a canopy are best described using a multi-layer framework since turbulence, radiation, thermal and structural properties vary appreciably with depth inside the canopy. The theory that describes turbulent transfer in a deciduous forest canopy is discussed and is examined in light of models and measurements.

AR-009

BALDOCCHI, D.D., B.B. HICKS, and T.P. MEYERS. Measuring biosphere-atmosphere exchanges of biologically related gases with micrometeorological methods. Ecology 69(5):1331-1340 (1988).

Ecologists are expected to play an important role in future studies of the biosphere/atmosphere exchange of materials associated with the major biogeochemical cycles and climate. Most studies of material exchange reported in the ecological literature have relied on chamber techniques. Micrometeorological techniques provide an alternative means of measuring these exchange rates and are expected to be used more often in future ecological studies, since they have many advantages over the chamber techniques. In this article we will provide an overview of micrometeorological theory and the different micrometeorological techniques available to make flux measurements.

AR-010

BALDOCCHI, D.D., and T.P. MEYERS. A spectral and lag-correlation analysis of turbulence in a deciduous forest canopy. Boundary-Layer Meteorology 45:32-58 (1988).

The processes influencing turbulence in a deciduous forest and the relevant length and time scales are investigated with spectral and cross-correlation analysis. Wind velocity power spectra were computed from three-dimensional wind velocity measurements made at six levels inside the plant canopy and at one level above the canopy. Velocity spectra measured within the plant canopy differ from those measured in the surface boundary layer. Noted features associated with the within-canopy turbulence spectra are: (a) power spectra measured in the canopy crown peak at higher wavenumbers than do those measured in the sub-canopy trunkspace and above the canopy; (b) peak spectral values collapse to a relatively universal value when scaled according to a non-dimensional frequency comprised of the product of the natural frequency and the Eulerian time scale for vertical velocity; (c) at wavenumbers exceeding the spectral peak, the slopes of the power spectra are more negative than those observed in the surface boundary layer; (d) Eulerian length scales decrease with depth into the canopy crown, then increase with further depth into the canopy; (e) turbulent events below crown closure are more correlated with turbulent events above the canopy than are those occurring in the canopy crown; and (f) Taylor's frozen eddy hypothesis is not valid in a plant canopy. Interactions between plant elements and the mean wind and turbulence alter the processes that produce, transport and remove turbulent kinetic energy and account for the noted observations.

AR-011

BALDOCCHI, D.D., and T.P. MEYERS. Turbulence spectra in a deciduous forest. Preprint Volume, 19th Conference on Agriculture and Forest Meteorology and the Ninth Conference on Biometeorology and Aerobiology, Charleston, SC, March 7-10, 1989. American Meteorological Society, Boston, 89-90 (1989).

No abstract.

AR-012

BATES, J.J., and C. Gautier. Interaction between net shortwave flux and sea surface temperature. Journal of Applied Meteorology 28:43-51 (1989).

Ocean surface shortwave irradiance estimate, from GOES satellite data computed using the model of Gautier and Frouin (1985), are compared to in situ measurements from research vessels and buoys during the frontal air-sea interaction experiment (FASINEX). They reveal that the satellite method overestimates percentage cloudiness during fractional cloud cover and large satellite viewing angles. An empirical relationship, based on physical constraints, is developed to correct for the overestimation of percentage cloud cover under these conditions. Subsequent comparison of the corrected satellite estimates with in situ measurements show a root-mean-square difference of 10% of the daily mean values, with a mean difference between satellite and in situ data of 1-10 W m^{-2}. From fields of corrected satellite estimates a cloudiness parameter, called the equivalent cloud amount is used to examine the influences and feedbacks between the clouds and the sea surface temperatures (SST's). Correlations between cloud and SST fields show a high day-to-day variability attributed to the passage of several large-scale frontal cloud bands. The monthly mean correlation, however, shows large, positive values. This indicates that in the mean there are more clouds and/or clouds with higher liquid water content over the colder northern waters versus the warmer southern waters. Thus, the longer-term mean cloudiness field may act in a positive feedback sense, keeping the cold water from gaining as much heat as the already warmer water.

AR-013

BOATMAN, J.F. The role of atmospheric aerosols in modifying the earth's climate. In Environmental Quality and Ecosystem Stability: Vol VI-A, Environmental Quality, M. Luria, Y. Steinberger, and E. Spanier (eds.). ISEEQS, Jerusalem, Israel, 331-334 (1989).

The Earth is a planet in radiative equilibrium. Of course, the temperature at which radiative balance is achieved on Earth may change in response to a change in the sun's energy, the planetary albedo, the atmospheric transmissivity, or the atmospheric absorption. The concentration of so-called "greenhouse" gases (CO_2, CO, CH_4, N_2O, chlorofluorocarbons, and others) is increasing. In the absence of other changes, this must inevitably lead to a rise in the Earth's radiative equilibrium temperature. This paper discusses the role of atmospheric aerosols in modifying the Earth's climate. It describes possible climatic feedback mechanisms between clouds, aerosols, and the sea. A conceptual mode, based on these feedback mechanisms, is developed. Model predictions of possible changes in the Earth's climate are discussed with an eye toward new confirmatory research.

AR-014

BOATMAN, J.F., M. Luria, C.C. VAN VALIN, and D.L. WELLMAN. Continuous atmospheric sulfur gas measurements aboard an aircraft: A comparison between the flame photometric and fluorescence methods. Atmospheric Environment 22(9):1949-1955 (1988).

Analyzers that use the flame photometric and pulsed fluorescence techniques measured trace concentrations of S gas aboard an instrumented aircraft. Concentrations in the range of 1-20 ppbv were found at various locations over the U.S. East Coast and near Bermuda at altitudes up to 4000 m (650 mb). The response of both instruments changes significantly with ambient air pressure. In the case of the fluorescence method, a simple correction is applied to both the zero and span values. For the flame photometric instrument, the correction is more complicated, less accurate and valid only for ambient air pressures above 750 mb. A comparison between the two methods, based on several thousand 1-min averages, shows that the flame photometer produced consistently larger concentrations (27%) than the fluorescence device. Additional comparisons between the continuous monitors aboard the OAA King Air and similar instruments aboard other aircraft sampling in parallel produced reasonable agreement. The use of two different techniques for measuring S gas establishes a range in the S gas concentration. This range is meaningful, since it delineates the contributions of the various interferences.

AR-015

BOATMAN, J.F., C. VAN VALIN, and L. GUNTER. The relationship between sulfur dioxide and hydrogen peroxide in the northeastern United States during summer: 3 case studies. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 48-51 (1989).

Extended abstract.

AR-016

BOATMAN, J.F., D.L. WELLMAN, C.C. VAN VALIN, R.L. GUNTER, J.D. Ray, H. Sievering, Y. Kim, S.W. WILKISON, and M. Luria. Airborne sampling of selected trace chemicals above the central United States. Journal of Geophysical Research 94(D4):5081-5093 (1989).

Field observations during a series of 24 atmospheric sampling flights in winter, spring, summer, and fall of 1987 provided a preliminary climatology of selected trace chemicals above the central United States. Flights were along the 91.5°W meridian between 29° and 41°N latitude. The data set includes continuous measurements of trace gases (O_3, SO_2, H_2O_2, and NO/NO_y), aerosol number and size distributions, meteorological variables, and position. Filter samples produced SO_4^{2-}, NO_3^-, and SO_2, and trace metal data. Flask air samples yielded methane, hydrocarbon (C_2-C_5), and CO concentrations. Mean concentrations of the measured species at 2450 $\pm$ 150 m and 1450 $\pm$ 150 m represent each season. These data are discussed as functions of season, location, and air mass origin. Solar energy (821-991 w m^{-2}), temperature (18°-11.6°C) and water vapor mixing ratio (13.5-10.1 g kg^{-1}) peaked during summer at low and high altitude. Carbon monoxide levels 88-160 parts per billion by volume (ppbv) peaked in spring and were characteristic of the planetary boundary layer during both spring and summer. Methane concentrations were maximized during spring (1770-1744 ppbv) and fall (1774-1733 ppbv) and minimized during winter (1747-1730 ppbv) and summer (1736-1705 ppbv) at low and high altitude. Spring had the highest (21.3-21.4 ppbv) and summer the lowest (7.1-5.3 ppbv) hydrocarbon concentrations at low and high altitude. Sulfur dioxide concentrations were highest in summer (1.0-23 ppbv) and winter (0.9-1.6 ppbv) at low altitude. SO_2 concentrations at high altitude had no seasonal trend and averaged less than 0.9 ppbv. Sulfate concentrations were highest in summer (3.2-1.7 μg m^{-3}) at low and high altitude. The average hydrogen peroxide concentration varied by a factor of 16 (0.3-4.8 ppbv) between winter and summer. Ozone concentrations were between 49 and 70 ppbv and were highest in spring and

summer. The ratio of sulfate to sulfur dioxide increased sightly with altitude during winter, spring and summer. This is probably due to SO_2 oxidation in clouds. The ratio of H_2O_2 to SO_2 is >1 during spring and summer and <1 during winter. This indicates that the conversion of sulfur dioxide to sulfate by reaction with hydrogen peroxide is not oxidant-limited during spring and summer.

AR-017

BODHAINE, B.A., and ROSSON, R.M. (eds.) Geophysical Monitoring for Climatic Change No. 16 Summary Report 1987. Environmental Research Laboratories, Boulder, CO, 110 pp. (1988).

No abstract.

AR-018

Bowne, N.E., J.E. Howes, Jr, F. POOLER, JR., and J.K.S. CHING. Acid model operational diagnostic evaluation study surface measurements program. Preprints, Sixth Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 29 - February 3, 1989. American Meteorological Society, Boston, 1-4 (1989).

Extended abstract.

AR-019

BRIGGS, G.A. Field measurements of vertical diffusion in convective conditions. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 167-170 (1989).

Extended abstract.

AR-020

BRIGGS, G.A. Surface inhomogeneity effects on convective diffusion. Boundary-Layer Meteorology 45:117-135 (1988).

It is suggested that convective scaling, with appropriate extensions, provides the most useful framework for estimating the effects of urban-scale surface inhomogeneities on diffusion in convective conditions. Strong contrasts in surface heat flux exist between cropland, forest, urban areas, and water or marshland surfaces. It is argued that a typical fetch for convective turbulence to readjust to changed heat (or buoyancy) input from the surface below is $2(U/w^*)h$, where U is the mean wind speed in the mixing layer, w^* is the convective scaling velocity, and h is the mixing depth. In contrast, the fetch required for wind speed to readjust to new underlying surface roughness is of the order $(U/u^*)^2h/2$, where u^* is the friction velocity. The ratio w^*/U is the best index of diffusion rates in moderately to very unstable conditions. General urban effects on heat flux, h, and U are discussed separately, then their combined effects on w^*/U are estimated. While this ratio can double over a large city during light winds, its increase is much less for small cities, or during moderate winds. Finally, some examples of heat flux inhomogeneities causing stationary convective features are presented. Steady downdrafts associated with these features are of the order of $0.4w^*$, and could significantly increase surface concentrations from elevated sources.

AR-021

BRODE, R.W. Screening procedures for estimating the air quality impact of stationary sources. EPA-450/4-88-010, Office of Air Quality Planning, and Standards, Research Triangle Park, NC, 145 pp. (1988).

No abstract.

AR-022

BRODE, R.W., and T.E. PIERCE. SCREEN: A PC-based regulatory screening model for diffusion estimates. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 179-182 (1989).

Extended abstract.

AR-023

Brown, M.J., S.P.S. Arya, and W.H. SNYDER. Vertical dispersion from surface and elevated releases. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, California, January 29 - February 3, 1989. American Meteorological Society, Boston, 1:163-166 (1989).

No abstract.

AR-024

Butler, J.H., J.W. ELKINS, C.M. Brunson, K.B. Egan, T.M. THOMPSON, T.J. CONWAY, and B.D. Hall. Trace gases in and over the West Pacific and East Indien Oceans during the El Niño-Southern Oscillation event of 1987. NOAA DR ERL ARL-16 (PB89-159685), 104 pp. (1988).

Five trace gases in the surface water and atmosphere of the West Pacific and East Indian Oceans were measured by automated gas chromatography from May through July 1987. The data included more than 1000 measurements each of N_2O, F11 and F12 in the surface water and in the atmosphere, and about 2000 measurements each of CH_4 end CH_2 in the surface water and atmospheric boundary layer of the West Pacific. In addition, over 600 measurements of dissolved N_2O were obtained from hydrocasts made elong the entire 45,000 km cruise track. Data from this cruise are presented here in graphic and tabular form, along with detailed discussions of the methods used in analyzing the samples end reducing the data, and a brief summary of the results and their significance. Also included are results from laboratory tests of a new, automated headspace technique for dissolved N_2O and laboretory tests of the Weiss equilibretor. Deta from the equilibretor tests were used to develop a mathematical model of its performance.

AR-025

Butler, J.H., J.E. Pequegnat, L.I. Gordon, end R.D. Jones. Cycling of methane, carbon monoxide, nitrous oxide, and hydroxylamine in a meromictic, coastel lagoon. Estuarine, Coastal and Shelf Science 27:181-203 (1988).

The vertical distributions of methane, carbon monoxide, nitrous oxide, and hydroxylamine were measured in a seasonally stratified, coastal lagoon in northern California. The production of gases was estimated from mass-balance calculations whers possible, including considerations of diffusion and microbial oxidation. From late spring through most of the summer the lagoon remained oligotrophic, with biological activity concentrated near the pycnocline and the sediments. Methane, attaining high levels of super-saturetion, wes produced mainly in the sediments and in the metalimnion. Its subsequent fate was governed primarily by transport, but also by microbial activity. Carbon monoxide also reached high concentrations, but, having a turnover time of e few hours, was reguleted almost entirely by micro-organisms. Nitrous oxide production was evident neer the halocline throughout most of the study, but was epparent near the sediments only in the spring. Throughout the summer, N_2O in the hypolimnion was consumed in the sediments, presumably by denitrificetion. Hydroxylemine was present in the spring when nitrous oxide was produced, but absent during the summer when nitrous oxide was being consumed. Nitrous oxide distribution, like that of methane, wes governed by diffusion end microbial processes, but hydroxylamine, with estimated turnover times of only a few hours, was probebly regulated by microbes and in situ chemicel oxidation.

AR-026

Castro, I.P., W.H. SNYDER, end R.E. LAWSON, Jr. Wind direction effects on dispersion from sources downwind of steep hills. Atmospheric Environment 22(10):2229-2238 (1988).

A previous experimental study of the nature of dispersion from point sources downwind of three-dimensional hills of various crosswind espect retio (spanwise breadth/height) has been extended to the case when the approaching wind is not normel to the spanwise axis of the hill. Surface concentration patterns resulting from sources placed et various heights heve been exemined, with ettention limited to cases which led to the greetest concentration for the normel wind direction (θ=0). Sufficient date have been obteined to determine the terrein emplification fector (i.e., the ratio of the maximum ground-level concentration in the presence of the hill to thet in its absence) for various wind directions, hills and source heights, and elso to find how the ground-level concentration at the position of its maximum velue for θ=0 varies with wind direction. This ellows one to use wind tunnel data to estimate the effects of long-time-scale wind meender, essuming that wind-tunnel averages are equivalent to full-scale averages of, say, 15 minutes. It is demonstrated that in some circumstances the amplification factor (A) for e particular source position ectually increases with small changes in wind direction. In general, however, there is a monotonic decrease in A as θ from zero, which is most rapid for hills of small aspect ratio. In the case of wider hills, it is possible for the amplification factor to be reduced below unity for large θ.

AR-027

Chimonas, G., and C.J. NAPPO. Wave drag in the planetary boundary-layer over complex terrain. Boundary-Layer Meteorology 47:217-232 (1989).

The concepts of mountain-induced wave drag are applied to the smaller scale problem of the boundary layer over complex terrain. It is found that the Reynolds stress and surface drag caused by surface-generated waves can be at least as large as those conventionally associated with turbulence. Conditions in which wave effects are important are identified.

AR-028

CHING, J.K.S. Simulating vertical transport and transformation of mixed layer pollutants by non-precipitating convective cumulus clouds. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 19-22 (1989).

Extended abstract.

AR-029

CLARK, T.L., R.L. DENNIS, and S.K. Seilkop. Re-examination of interim estimates of annual sulfur dry deposition across the eastern United States. EPA/600/4-89/026, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 34 pp. (1989).

During the summer of 1987 annual amounts of sulfur dry deposition were first estimates, heretofore termed interim estimates since they were expected to be superceded in the near future, were derived from predictions of the Regional Acid Deposition Model (RADM) adjusted using the empirical data from two monitoring networks. Since that time, additional years of empirical data have become available and a portion of the previously available empirical data have been superseded. Consequently, the process of estimating annual amounts of sulfur dry deposition was repeated to determine whether these interim estimates should be revised, and if so by how much. This study concludes that the interim estimates appeared to be too low by 13% and recommends that the interim estimates be systematically increased by the same amount. A comparison of the revised estimates to empirically-derived sulfur dry deposition amounts suggests that there is one systematic error in the revised estimates. Adjusted RADM predictions of dry deposition tend to be biased low in the most significant source regions (where at least 2300 ktonnes SO_2/yr are emitted within 80 km of the site). Conversely, in locations farther removed from significant sources (81-160 km) there is evidence that the estimates are biased high. However, in general, sulfur dry deposition estimates from adjusted model predictions are within +60% of the empirical data.

AR-030

CLARK, T.L., S. Seilkop, and R.D. Cohn. Protocol for the evaluation of long-range transport and diffusion models using 1987 ANATEX data. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 86-89 (1989).

Extended abstract.

AR-031

CLAWSON, K.L. Irrigation scheduling by remote sensing. Proceedings, 31st Annual Symposium, Idaho Academy of Science, Idaho Falls, ID, April 13-15, 1989, pp. 27 (1989).

No abstract.

AR-032

CLAWSON, K.L., C.R. DICKSON, and G.E. START. High-tech application of balloons in pollution meteorology: A transport and diffusion measurement tool. Proceedings, 31st Annual Symposium, Idaho Academy of Science, Idaho Falls, ID, April 13-15, 1989, pp. 32 (1989).

No abstract.

AR-033

CLAWSON, K.L., R.D. Jackson, and P.J. Pinter, Jr. Evaluating plant water stress with canopy temperature differences. Proceedings, 1988 Annual Meetings, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Anaheim, CA, November 27-December 2, 1988, pp. 15 (1988).

No abstract.

AR-034

DELUISI, J.J., D.U. Longenecker, C.L. Mateer, and D.J. Wuebbles. An analysis of northern middle-latitude Umkehr measurements corrected for stratospheric aerosols for 1979-1986. Journal of Geophysical Research 94(D7):9837-9846 (1989).

Umkehr observations of ozone profile for five northern middle-latitude Dobson spectrophotometer stations are objectively corrected for stratospheric aerosol during the period 1979-1986. The corrections are done by means of theoretical calculations, using observations of stratospheric ozone and aerosols. Stratospheric ozone and aerosol profile data to correct the Umkehr measurements are derived from ozonesonde observations and observations provided by five lidar stations in the northern hemisphere middle latitudes. Optical properties of the stratospheric aerosol existing during and after the major injection by El Chichón are derived from surface and aircraft photometric observations and in situ aircraft observations of aerosol size distribution. The corrected Umkehr data display some noteworthy ozone reductions in the upper stratosphere. The magnitude of these reductions does not seem to be extraordinary when considering features seen in long-term Umkehr data. However, the rates may be extraordinary, for example, in layers 8 and 9, in which decreases in ozone concentration during 1979-1986 were 9% and 15% respectively, using corrected data.

AR-035

DENNIS, R.L., J.N. McHenry, and S.K. Seilkop. A sulfur dioxide emissions sensitivity study conducted with the RADM engineering model. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 30-33 (1989).

Extended abstract.

AR-036

DENNIS, R.L., J.N. McHenry, R.E. Stogner, and J.S. Chang. A source-receptor analysis comparing estimates from the RADM engineering model with estimates from the Lagrangian RELMAP model. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 36-39 (1989).

Extended abstract.

AR-037

DIAZ, H.F., J.T. Andrews, and S.K. Short. Climate variations in northern North America (6000 BP to present) reconstructed from pollen and tree-ring data. Arctic and Alpine Research 21(1):45-59 (1989).

The characteristic anomaly patterns of modern surface temperature and precipitation are compared to tree-ring indices (0-300 yr) and fossil pollen (0-6000 yr) variations in northern North America. The data base consists of 245 climate stations, 55 tree-ring chronologies, 153 modern pollen collections, and 39 fossil pollen sites. A few areas exhibit relatively high climatic sensitivity, displaying generally consistent patterns during alternate warm and cold periods, regardless of time scales. The surface changes are related to the redistribution (i.e., changes in the mean position and strength) of the planetary-scale waves and to north-south shifts in the mean boundary of the Arctic Front. The zone where the largest changes occur is typically located along the mean present-day boundary between Arctic and Pacific airstreams. Establishing plausible relationships between vegetation responses and concomitant changes in atmospheric circulation patterns increases our confidence that the paleoclimatic signals are indeed related to large-scale circulation changes.

AR-038

DIAZ, H.F., R.S. Bradley, and J.K. Eischeid. Precipitation fluctuations over global land areas since the late 1800's. Journal of Geophysical Research 94(D1):1195-1210 (1989).

An analysis of southern hemisphere land precipitation records for the last 100 years indicates an increase in mean annual precipitation since the 1940's, with positive anomalies, compared to the 1921-1960 reference period, occurring during approximately the last 15 years in all seasons except southern summer (December-February). There is little or no temporal correlation with corresponding precipitation indices for the northern hemisphere (Bradley et al., 1987a). Furthermore, while trends in the northern hemisphere temperate regions were opposite those in the northern tropical areas, in the southern hemisphere both zones exhibit similar trends. The change toward higher precipitation in middle latitudes begins about 10 years earlier in the northern than in the southern hemisphere (in the 1940's versus the 1950's, respectively). For the northern hemisphere, the overall linear trend from 1890 to 1986 is not significantly different from zero. However, a decline is evident since the 1950's, primarily due to lower rainfall amounts south of about 30°N. Globally, the trend is toward higher values in annual and seasonal precipitation, except for the boreal summer season (June-August). Most of the observed increase, however, took place from about 1940 to the mid- 1950's, after which time the record has displayed little overall trend, instead exhibiting decade-long fluctuations. The observations are only broadly consistent with zonally averaged profiles of precipitation changes derived from general circulation model (GCM) simulations of climate using doubled atmospheric CO_2 concentrations, although we note that there is considerable variability in precipitation response from one model to another. One possible discrepancy occurs in the northern hemisphere tropics, where most GCMs indicate relatively little change in precipitation in response to CO_2 doubling (Gutowski et al., 1988), whereas in the past couple of decades there has been a major decline in rainfall in this region. The overall increase in southern hemisphere precipitation is consistent with marine observations for the tropics and extratropical southern latitudes, which show an increase in sea surface temperature of about 0.3°C since the mid-1970's and an increase in surface wind speed of between 0.4 and 0.8 m/s since 1950. The potential increase in evaporation could have contributed to the observed rainfall trends. We note, however, that precipitation in tropical land areas is strongly influenced by the phases of the El Niño/Southern Oscillation (ENSO), being generally lower during warm events and higher during the opposite cold phase. The effects of the strong ENSO warm events of 1982-1983 and around 1940 are clearly evident in the global record, as are precipitation peaks during cold years, such as 1974-1975 and 1954-1956.

AR-039

Dobosy, R.J., K.S. Rao, J.W. Przybylowicz, R.M. ECKMAN, and R.P. HOSKER. Mass and momentum balance in the Brush Creek drainage flow determined from single-profile data. Journal of Applied Meteorology 28(6):467-476 (1989).

Fluxes and flux-divergences of mass and momentum in Brush Creek Valley, computed from measurements taken by Tethersondes and Doppler sodars in the 1984 ASCOT experiment, are presented. Estimates of mass influx from open sidewalls in Brush Creek, derived from concurrent tower measurements, are also given. Mass and momentum fluxes calculated from single-profile data were within a factor of 1.5 of those obtained by integrating Doppler lidar data. Flux-divergences for budget calculations should be derived from a Doppler lidar or equivalent remote sensor data, because single-profile measurements were found to have sampling errors which are too large for reliable flux divergence estimates. The mass influx from the sidewalls was insufficient to account for the mass flux-divergence in the main valley. This imbalance in the drainage flow mass budget is speculated to be due to inflow from the small box-canyon tributaries, rather than from subsidence of air above the main valley.

AR-040

DOLL, D.C., T.E. PIERCE, and N.C. POSSIEL. Regional ozone modeling in the northeastern United States: Selection of meteorological episodes. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 40-43 (1989).

Extended abstract.

AR-041

DONNELLY, R.F. The solar electromagnetic radiation flux study (SERFS). STP Newsletter 88-1, World Data Center A for Solar Terrestrial Physics, Boulder, CO, 34-36 (1988).

No abstract.

AR-042

DONNELLY, R.F. The solar UV Mg II core-to-wing ratio from the NOAA9 satellite during the rise of solar cycle 22. Advances in Space Research 8(7):77-80 (1988).

The Solar Backscatter Ultraviolet (SBUV/2) instrument on the NOAA9 satellite monitors daily the solar UV spectral irradiance in the Mg II h and k lines. The core-to-wing ratio R(MgIIc/w) is presented for 27 May 1986 through 31 May 1988. R(MgIIc/w) has a minimum in both 27-day and 81-day running averages in early Jan. 1987 with a secondary minimum in late Aug. 1986. Strong 27-day solar-rotational variations peaked in Oct. 1986, April and July 1987, and April 1988. The solar-cycle 22 rise in rotational minima started in Feb. 1987 and increased to a more rapid rise in Nov. 1987 through May 1988. The rotational peak of April 1988 was 4.4% higher than the solar cycle minimum 27-day average, which is a little less than half the decline in R(MgIIc/w) from NIMBUS7 from solar maximum to minimum during solar cycle 21.

AR-043

DONNELLY, R.F. Solar UV variability. MAP Handbook, Vol 29, Proceedings, IAGA Symposium on Solar Activity Forcing of the Middle Atmosphere, Czechoslovakia, April 4-7, 1989, J. Lastoricka (ed.). SCOSTEP Secretariat, University of Illinois, Urbana, 1-8 (1989).

No abstract.

AR-044

DRAXLER, R.R. HYBRID single-particle Lagrangian integrated trajectories (HY-SPLIT): Model description. NOAA TM ERL ARL-166 (PB89-127591), 23 pp. (1988).

The algorithms and equations used in the development of a long-range transport and dispersion model are presented. The model calculation methods are a hybrid between Eulerian and Lagrangian approaches. A single pollutant particle represents the initial source. Advection and diffusion calculations are made in a Lagrangian framework. However, meteorological input data can either be gridded from rawinsonde observations or archived from the output of an Eulerian primitive equation forecast model. As the dimensions of the initial particle diffuse into regions of different wind direction or speed, the single particle is divided into multiple particles to provide a better representation of the more complex flow field. Air concentrations are calculated on a fixed three-dimensional grid by integrating all particle masses over the sampling time.

AR-045

DRAXLER, R.R. Overview and preliminary results from the Across North America Tracer Experiment (ANATEX). Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 82-85 (1989).

Extended abstract.

AR-046

DRAXLER, R.R., and J.L. HEFFTER (eds.). Across North America Tracer Experiment (ANATEX) Volume I: Description, ground-level sampling at primary sites, and meteorology. NOAA TM ERL ARL-167 (PB89-156137), 83 pp. (1989).

ANATEX was conducted during the first 3 months of 1987 with routine emissions of tracers, regardless of the synoptic conditions, from two sources separated by about 1000 km. Ground-level tracer measurements were made at "primary" sites up to 3000 km from the sources and at "remote" sites for hemispheric coverage. Tracer measurements were also made from aircraft flying within about 500 km of the sources and on towers located along a ground-level sampling arc (Volumes II and III). Three months of sampling data provide a comprehensive data base for evaluating the accuracy and reliability of the transport and dispersion aspects of long-range models. Since a different and unique tracer was released from each source site, the sampling data can be used to demonstrate the ability of models to separate the effects of local and distant sources. Further, because these data are on the regional scale, covering the entire eastern United States and Canada, it is possible to characterize the meteorological influences on regional transport. ANATEX was conducted between January 5, 1987, and March 29, 1987. Three different tracers totaling about 7500 kg were released during this period. There were 33 releases of the different tracers from each of two sites: Glasgow, Montana (GGW) and St. Cloud, Minnesota (STC). Tracer was routinely released every 2.5 days, alternating between 0500-0800 GMT and 1700-2000 GMT. Thus, a unique feature of ANATEX is that it was conducted during a wide variety of meteorological conditions with both daytime and nighttime tracer releases. Supplemental rawinsondes were taken at 0600 and 1800 GMT during the entire ANATEX period, near both tracer sources and at four additional sites within about 500 km. Ground-level air samples of 24-h duration were taken at 77 sites for 84 days starting January 5. Most of the sites were located near rawinsonde stations east of 105°W and between 26°N and 55°N and along two arcs at 1000 and 1600 km from GGW. Additional long-term weekly samples were taken at 12 remote sites between San Diego, California and Pt. Barrow, Alaska and between Norway and the Canary Islands. Short-term 6-h samples

were collected at ground-level and 200 m along an arc of five towers between Tulsa, Oklahoma and Green Bay, Wisconsin. Aircraft sampling near GGW and STC was used to establish the initial tracer path, as the ground-level sampling network was non-existent or too widely spaced near the source locations.

AR-047

DUTTON, E.G., R.S. Stone, and J.J. DELUISI. South Pole surface radiation balance measurements April 1986 to February 1988. NOAA DR ERL ARL-17 (PB89-224018), 49 pp. (1989).

Measured radiation budget (or balance) components with daily time resolution are presented for the U.S. South Pole Station. The measurement project and the data reduction and summary procedures are described. Useful plots and tables are used to present the data in final form. Additionally, meteorological data, which could be useful in interpretation of the radiation measurements, are included. It is seen that, during the three peak solar months, there is a radiative gain of about 20 W m^{-2} by the surface (except for December 1987 where a small loss was recorded) whereas during the dark months there is an average loss of about 15 to 20 W m^{-2}. Many transitory events of one to several days duration are also seen in the record. Radiation budget measurements are continuing at the site on an ongoing basis in an effort to establish a climatological record.

AR-048

ECKMAN, R.M. The suitability of different wind-field techniques for an emergency-response dispersion model. Proceedings, ANS Topical Meeting on Emergency Response - Planning, Technologies, and Implementation, Charleston, SC, September 26-28, 1988. CONF-880913, UC-610, Paper 4-4 (1988).

A dispersion model in an emergency-response system must use some technique to generate an accurate wind field from limited measurements. Most wind-field techniques fall into four categories: interpolation, mass-conservative, diagnostic, and dynamic techniques. In this extended summary, the suitability of these categories for emergency response is discussed. For a dispersion model that must provide real-time dispersion estimates during an accident, spatial interpolation will be the most appropriate technique. For more complex models that are used in emergency-response planning and post-accident assessments, either a mass-conservative or diagnostic technique should be suitable.

AR-049

ECKMAN, R.M., and R.J. Dobosy. The suitability of diffusion and wind-field techniques for an emergency-response dispersion model. NOAA TM ERL ARL-171, 28 pp. (1989).

Most atmospheric dispersion models have two separate components: a diffusion component that simulates the dilution of a contaminant by turbulence, and a wind-field component that transports the contaminant away from the source. Many modeling techniques have been developed for each of these components. This report examines the suitability of these modeling techniques for a near-field emergency response model that must simulate the dispersion of a hazardous contaminant out to several kilometers from a source. For an emergency response model that must provide real-time dispersion estimates (a Class A model), a puff model is the most appropriate diffusion technique, and simple interpolation is the most appropriate wind-field technique. For more-complex models that are used for emergency planning and post-accident assessments (Class B models), a puff model is still suitable, but the wind-field techniques should be able to remove spurious velocity divergence and channel the wind flow in complex terrain.

AR-050

EDER, B.K. An examination of $SO_4^=$ precipitation patterns over the eastern United States: 1981-1986. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorology Society, Boston, 25-29 (1989).

Extended abstract.

AR-051

EDER, B.K., L.E. TRUPPI, and P.L. FINKELSTEIN. A climatology of temperature and precipitation variability in the United States. EPA/600/3-89/025, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 43 pp. (1989).

This paper examines the seasonal and annual variance and standardized range from temperature and the seasonal and annual coefficient for variation and normalized standardized range for precipitation, on a climatic division level for the contiguous United States for the period 1895 to 1985. Examination of the temperature variance reveals a continentality phenomenon in which the largest variances occur in the upper midwest section of the country, while the smallest variances are

generally found in coastal regions along the West Coast, the Gulf Coast and southeastern states. The winter season displays roughly twice the amount of seasonal variance as does spring, and roughly four times that of summer or autumn. Analysis of the standardized temperature range supports the continentality phenomenon; however, the transitional seasons, spring and autumn, display the largest amount of within season variability with winter and summer displaying the least amount. Examination of the coefficient of variation for precipitation depicts a propensity for the largest seasonal and annual variation to occur over the southwestern states from Texas to California. Conversely, the smallest coefficient of variations are found over the northeastern sections of the country from New England into the mid-Atlantic and Great Lakes states. Analysis of the seasonal and annual standardized precipitation range reveals that the pattern mimics the coefficient of variation patterns, but does however, exhibit less of a gradient, resulting in a smoother pattern. Areas of greater than normal seasonal and annual precipitation ranges include the southwestern states from Texas to California, while areas of less than normal ranges include the northeastern and Ohio River Valley states.

AR-052

Eischeid, J.K., S.J.S. Khalsa, and K.M. WEICKMANN. Comparisons between the 30-60 day oscillations in the tropics and the varying frequency of atmospheric angular momentum oscillations. Preprints, 18th AMS Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 129-130 (1989).

Extended abstract.

AR-053

ELLIOTT, W.P. (ed). The statistical treatment of CO_2 data records. NOAA TM ERL ARL-173, 131 pp. (1989).

This collection of papers is an outgrowth of a meeting concerned with the treatment of carbon dioxide data held in Hilo, Hawaii, 24-26 March, 1988. A small group of scientists gathered to discuss various methods of extracting from raw CO_2 data information on the background concentration in the atmosphere. The meeting was sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the World Meteorological Organization (WMO). While the subject of the meeting was the treatment of CO_2 data, some of the considerations should be applicable to any trace gas measurement program. These programs will encounter many of the same problems, as well as others of their own.

AR-054

ESKRIDGE, R.E., B. Lamb, and E. Allwine. Analysis of the wind and plume dispersion in a residential neighborhood. Preprints, Sixth Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 29 - February 3, 1989. American Meteorological Society, Boston, 146-149 (1989).

No abstract.

AR-055

Fryrear, D.W., J.E. Stout, and D.A. GILLETTE. Instrumentation for wind erosion. Proceedings, 1988 Wind Erosion Conference, Lubbock, TX, April 11-13, 1988. Sponsored by Texas Tech University, Lubbock, 118-132 (1988).

Reliable field measurement of soil losses due to wind erosion have not been possible because of the lack of satisfactory equipment. Many wind erosion samplers have been developed; but some require accessory equipment to operate, some are difficult to construct and maintain, and some lack the capacity or efficiency to be suitable for field use. Within the last five years new equipment has been designed and extensively tested that will permit the measurement of soil movement across and above eroding soil surfaces. These new samplers are efficient, will operate under extremely adverse conditions, and can provide total soil movement information both horizontally and vertically over eroding surfaces. Another new wind erosion instrument will measure momentum of eroding material at specified levels as well as at the instant threshold conditions that are exceeded in the field. Laboratory and portable wind tunnels have been used to study the wind erosion process and to test wind erosion control practices. Laboratory tunnels permit complete control of many factors, but some tillage and natural weathering conditions cannot be duplicated under laboratory conditions. Portable wind tunnels will permit the testing of various practices under natural weathering conditions, but there is a limit in the height of plant material that can be tested. Scientists must recognize the limitations of any wind tunnel when trying to duplicate field boundary conditions.

AR-056

Galloway, J.N., R.S. ARTZ, U. Dayan, and J.F. BOATMAN. WATOX-85: An aircraft and ground sampling program to determine the transport of trace gases and aerosols across the western Atlantic Ocean. Atmospheric Environment 22(11):2345-2360 (1988).

This paper presents an overview of the design and results of WATOX-85, an intensive measurement program of a variety of trace chemicals in the atmosphere of the western North Atlantic Ocean. WATOX-85 is a component of the Western Atlantic Ocean Experiment (WATOX), which is designed to determine the fate and flux of several types of chemical compounds that are advected eastward from North America to the Atlantic Ocean atmosphere. WATOX-85 occurred during the period February-April 1985. Measurements of the composition of gases, aerosols, and precipitation were performed at ground level at Lewes, Delaware and High Point, Bermuda and in the boundary layer and free troposphere off the east coast of Virginia and around the island of Bermuda. The above ground measurements were performed with a Beechcraft King Air aircraft. Atmospheric sampling was focused on times when the flow was westerly, generally just after cold front passages. In the gas phase SO_2, HNO_3, NO, NO_x, HCHO, O_3, CO, C_2-C_4 HCs and Rn were measured. SO_4^{2-}, NO_3^-, NH_4^+, trace metals, HCOOH, CA^{2+}, Mg^{2+}, NA^+ and chlorinated HCs were analyzed in the precipitation and aerosols samples that were collected.

AR-057

GILLETTE, D.A. Estimation of dust production by wind erosion, for use by the National Acid Precipitation Assessment Program. Proceedings, 1988 Wind Erosion Conference, Lubbock, TX, April 11-13, 1988. Sponsored by Texas Tech University, Lubbock, 188-197 (1988).

No abstract.

AR-058

GILLETTE, D.A. Threshold friction velocities for dust production for agricultural soils. Journal of Geophysical Research 93(D10):12,645-12,662 (1988).

Threshold velocities for agricultural soils were measured for a wide variety of conditions in order to quantify a model of dust emissions for the United States. These measurements supplement threshold velocities for arid and semiarid soils (Gillette, et al., 1980, Gillette, et al., 1982). The model will be used in precipitation acid/base balance studies. The soils were organized according to surface texture, organic matter content, and calcium carbonate composition. They were further organized by the physical surface states; smooth-loose, cloddy, and crusted. Sandy soils were found to have the lowest threshold velocities and were the least affected by wetting (precipitation). Loamy soils were found to have the highest threshold velocities and were the most affected by precipitation wetting.

AR-059

GILLETTE, D.A., and K.J. HANSON. Spatial and temporal variability of dust production caused by wind erosion in the United States. Journal of Geophysical Research 94(D2):2197-2206 (1989).

Variability of model dust emissions by wind erosion was tested for sensitivity to variations of wind speed in the United States for a 31-year period (1948-1978) and for a wide range of threshold velocities that arise from differing precipitation scenarios, from drought to abundant rainfall. Results showed that dust production increased about an order of magnitude when threshold velocities were changed from those appropriate for abundant rainfall to those appropriate for drought. About the same range of variability for dust production was seen in the model results when soil conditions and land use were held constant and U.S. wind data for 1948-1978 were used. Maximum dust production for the United States occurs in the spring, and minimum dust production occurs in the summer. Maximum model dust production for a 1-year period occurred in the early 1950's and early 1970's, when a U.S. wind record for 1948-1978 was used. The location of maximum dust production is the area including the panhandles of Texas and Oklahoma and some surrounding areas.

AR-060

GILLETTE, D.A., and R. Passi. Modeling dust emission caused by wind erosion. Journal of Geophysical Research 93(D1):14,233-14,242 (1988).

A model for the estimation of total dust production for the United States is discussed. Its primary use will be in the inventory of alkaline elements for use in acid/base balance studies of atmospheric precipitation by the National Acid Precipitation Assessment Program (NAPAP). The model is a summation of the expected dust production caused by wind erosion for individual sampling units of the detailed soil and land use inventory of the National Resources Inventory compiled by the U.S. Department of Agriculture. the model is based on a dust emission function derived theoretically and

verified by experiment. An extremely important parameter is the threshold velocity for dust production; this parameter is dependent on effects of vegetative residue, roughness of the soil, live standing plants, soil texture and the effect of atmospheric precipitation. Experimentation has supplied values of this parameter for the calculation. Wind data used in the model were obtained from the Wind Energy Resource Information System (WERIS). The model was calibrated with dust emission data for the area, including the panhandles of Texas and Oklahoma.

AR-061

GODOWITCH, J.M. Evaluation and sensitivity analyses results of the MESOPUFF II model with CAPTEX measurements. EPA/600/3-89/056, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 99 pp. (1989).

The MESOPUFF II regional Lagrangian puff model has been evaluated and tested with the Cross-Appalachian Tracer Experiment (CAPTEX) data base. The model was applied to the sic full-scale CAPTEX episodes in order to simulate the tracer plume formed from the 3-hour release of an inert, non-depositing perfluorocarbon tracer gas from either one of two selected sites. Surface tracer measurements were made at 3 hour or 6 hour intervals over an extensive sampling network of arcs downwind to 1100 km in the northeastern U.S. and southeastern Canada. An operational evaluation was conducted by exercising the model transport and dispersion components with all default features set according to the user's guide. Transport in the model is simulated by a mixed-layer averaged wind field and an upper level wind field averaged from the mixing height to 700 mb level. Puff growth within 100 km downwind is governed by horizontal and vertical dispersion parameters derived from expressions fitted to the standard PGT curves, while time dependent formulas are applied at greater distances. Model performance was quantitatively determined from standard statistical measures of difference and correlation between modeled and observed tracer concentrations paired in time and location. The model over-predicted peak and mean concentrations, whether paired in time and/or location. Modeled mean concentrations were within a factor of two of observed mean values in four of the experiments. The over-predictions are primarily attributed to an underestimation of vertical dispersion during neutral stability conditions which were specified during the afternoon hours after releases. Graphical maps and comparative tests between observed and modeled concentration pairs revealed that spatial displacements between the observed and modeled plumes contributed to the large scatter and low correlations found in the evaluation statistics. Analysis of plume centroid positions revealed that the greatest changes in the separation of the observed and modeled plumes occurred during the nocturnal periods. Revisions are suggested to better treat this source type in the model. Diagnostic model test results with optional wind fields in the model (e.g. surface, 850 mb single level wind fields) and various dispersion options are compared to those from the operational model and the observed data. A surface wind field transported the modeled plume considerable slower and generally to the left of the observed plume while the single level 850 mb wind field consistently shifted the modeled plume to the right (clockwise) of the actual plume location. Model results with the mixed-layer averaged wind field displayed the best overall performance in comparisons of the position and time of impact of the peak concentration with the observed plume values at the 300 km arc. The 24-h peak and plume average concentration results from model test runs, which focused on different options and variations in key parameters of the dry deposition and chemical transformation modules, are compared to base case values. All model runs were performed with SO_x emissions from a realistic elevated point source. Peak SO_2 concentrations showed negligible variations when deposition or chemical transformation were omitted, however, mean SO_2 concentrations were more sensitive than SO_2 by variations in the surface resistance and by changes in parameters controlling the chemical transformation rate.

AR-062

GODOWITCH, J.M. Evaluation and testing of the MESOPUFF II model system with CAPTEX measurements. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 56-59 (1989).

Extended abstract.

AR-063

HALTER, B.C., J.M. HARRIS, and T.J. CONWAY. Component signals in the record of atmospheric carbon dioxide concentration at American Samoa. Journal of Geophysical Research 93(D12):15,914-15,918 (1988).

Variability in atmospheric CO_2 concentration over periods of 1-5 days at Cape Matatula, American Samoa, was studied. The variability was found to be the result of the alternating influences of three air mass source regions. Partitioning of Samoa CO_2 data according to these air mass source regions revealed annual cycles in the partitioned data sets corresponding to those of the tropical South Pacific, the mid-latitude southern hemisphere, and the tropical North Pacific regions.

AR-064

Hansen, A.D.A., B. A. BODHAINE, E.G. DUTTON, and R.C. Schnell. Aerosol black carbon measurements at the South Pole: Initial results, 1986-1987. Geophysical Research Letters 15(11):1193-1196 (1988).

In December 1986 an aethelometer was installed at the NOAA/GMCC South Pole Observatory to measure concentrations of the combustion effluent trace species aerosol black carbon (BC) with a time resolution of one hour. We present data covering a 1-yr period from December 1986 through November 1987. The hourly data show infrequent events in which the concentrations increased greatly for periods of a few hours. We attribute these events to local contamination and identified them as such in the database. The remaining background data then yield daily average BC concentrations generally ranging from 50 pg m^{-3} to 5 ng m^{-3}, with a minimum in the early austral winter. The results imply long-range transport of this aerosol species, and suggest a minimum value of the order of 10 pg m^{-3} for its global background concentration.

AR-065

HANSON, K., G.A. Maul, and T.R. Karl. Are atmospheric "Greenhouse" effects apparent in the climatic record of the contiguous U.S. (1895-1987)? Geophysical Research Letters 16(1):49-52 (1989).

The temperature and precipitation climate records for the United States have been examined. These records consist of area-averages across the contiguous United States and northern plains. They are based on as many as 6,000 stations. Time series of these data were tested for constancy of the mean using the Spearman rank test and two-phase regression. Test results indicate that overall trends are near zero. The only evidence for a long-term trend is in Fall precipitation for the contiguous United States. This trend appears to result from higher fall precipitation during the period 1970-1987 compared to the remainder of the period (1895-1969).

AR-066

HEFFTER, J.L. ANATEX measured concentration uncertainty considerations in model evaluation. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 90-96 (1989).

Extended abstract.

AR-067

HICKS, B.B. Assessment of atmosphere/ocean flux measurement techniques and capabilities. The Ocean as a Source and Sink for Atmospheric Trace Constituents, Final Report of SCOR Working Group 72, Unesco, pp. 9-20 (1989).

No abstract.

AR-068

HICKS, B.B., C.E. Kolb, and D.H. Lenschow. Chapter 5 - New opportunities for flux measurement. Global Tropospheric Chemistry - Chemical Fluxes in the Global Atmosphere, D.H. Lenschow and B.B. Hicks (eds.). Report of Workshop on Measurements of Surface Exchange and Flux Divergence of Chemical Species in the Global Atmosphere, 83-85 (1989).

No abstract.

AR-069

HICKS, B.B., D.R. MATT, and R.T. McMILLEN. A micrometeorological investigation of surface exchange of O_3, SO_2 and NO_2: A case study. Boundary-Layer Meteorology 47:321-336 (1989).

Data obtained in an intensive field study of the dry deposition of sulfur dioxide, ozone, and nitrogen dioxide, conducted in 1985 in central Pennsylvania, are used to illustrate the factors that must be considered to assure that high quality results are derived. In particular, the quality of the site must be such that flux measurements made above the surface are representative of surface values. For this purpose, tests involving momentum transfer and the surface energy budget are especially useful. In addition, conditions must not be changing rapidly, and the statistical uncertainty associated with flux measurement must be low. For the set of data presented here, conservative quality-assurance guidelines are used to reject potentially erroneous flux data. For ozone, most of the measured fluxes are of use in deriving surface resistances. For SO_2, far fewer data points are available. For NO_2, fluxes appear to lack the order of the O_3 and SO_2 fluxes, and do not enable

surface resistances to be computed. The highest-quality SO_2 and O_3 data yield surface resistances in fair average agreement with model predictions for SO_2, but substantially higher than predictions for O_3.

AR-070

HICKS, B.B., D.R. MATT, and R.T. McMILLEN. A micrometeorological investigation of surface exchange of trace gases: A case study. NOAA TM ERL ARL-172, 71 pp. (1989).

Data obtained in an intensive field study of the dry deposition of sulfur dioxide, ozone, and nitrogen dioxide, conducted in 1985 in central Pennsylvania, are used to illustrate the factors that must be considered to assure that high quality results are derived. In particular, the quality of the site must be such that flux measurements made above the surface are representative of surface values. For this purpose, tests involving momentum transfer and the surface energy budget are especially useful. In addition, conditions must not be changing rapidly, and the statistical uncertainty associated with flux measurement must be low. For the set of data presented here, conservative quality-assurance guidelines are used to reject potentially erroneous flux data. For ozone, most of the measured fluxes are of use in deriving surface resistances. For SO_2, far fewer data points are available. For NO_2, fluxes appear to lack the order of the O_3 and SO_2 fluxes, and do not enable surface resistances to be computed. The highest-quality SO_2 and O_3 data yield surface resistances in fair average agreement with model predictions for SO_2, but substantially higher than predictions for O_3.

AR-071

HICKS, B.B., and T.P. MEYERS. Measuring and modelling dry deposition in mountainous areas. In Acid Deposition at High Elevation Sites, M.H. Unsworth and D. Fowler (eds.). Kluwer Academic Publishers, 541-552 (1988).

A trial programme has been initiated to test methods for estimating dry deposition rates from measurements of air concentration, using selected surface and atmospheric data to specify the appropriate deposition velocities. Results obtained in the testing programme are used here to compare a site on the slopes of Whiteface Mountain, New York, and a similarly forested site distant from mountains. Data are presented on atmospheric resistances to turbulent exchange, and on the surface resistance associated with the dry deposition of sulphur dioxide. All considerations involving the concept of a deposition velocity combining surface and vertical-diffusion components are limited in generality, because of the overriding assumption that the aerodynamic transfer is dominated by vertical diffusion, therefore neglecting advective effects such as blowthrough. For the case of sulphur dioxide, the increase in computed dry deposition resulting when such advective effects are taken into account is found to be small. This results from the fact that SO_2 exchange is largely controlled by surface rather than atmospheric resistance; hence a similar result is expected for other trace gases most strongly influenced by surface resistance, such as ozone, and could be expected to extend to particle deposition in some size ranges. However, for nitric acid vapour (and presumably for all other trace gases having surface resistance small in comparison to atmospheric resistance) the consequences of surface heterogeneity and topographic complexity on deposition velocities could be very large.

AR-072

HICKS, B.B., T.P. MEYERS, C.W. Fairall, V.A. Mohnen, and D.A. Dolske. Ratios of dry and wet deposition of sulfur as derived from preliminary field data. Global Biogeochemical Cycles 3(2):155-162 (1989).

Preliminary data obtained in the operation of a nested-network dry deposition measurement program in the eastern United States are used in conjunction with wet deposition data obtained at (or near) the same sites to investigate the variability of ratios of dry to wet deposition of sulfur (as sulfur dioxide and submicron sulfate for dry deposition, and as sulfate for wet deposition). On a monthly basis, the ratio is extremely variable at every location; however, a more coherent picture arises when the average annual cycle is considered. The sites studied here (Oak Ridge, Tennessee; State College, Pennsylvania; Whiteface Mountain, New York; and Bondville, Illinois) yield dry/wet ratios for sulfur deposition that minimize in the summer, with values of about 0.3. At other times of the year, values sometimes exceeding 2.0 are obtained. A summer peak at Oak Ridge is tentatively attributed to the effects of a local drought. The variability is such that use of dry/wet ratios to estimate dry deposition rates when only wet deposition data are available cannot be recommended.

AR-073

HICKS, B.B., K.S. Rao, R.J. Dobosy, R.P. HOSKER, JR., J.A. Herwehe, and W.R. PENDERGRASS. TRIAD: a puff-trajectory model for reactive gas dispersion with application to UF_6 released into the atmosphere. NOAA TM ERL ARL-168 (PB89-182703), 136 pp. (1989).

Chemical reactions between released pollutants and atmospheric constituents can influence atmospheric dispersion if the heats of reaction are such that buoyancy can be affected or mechanical turbulence damped. If the reaction is sufficiently exothermic, plume rise can be increased; if sufficiently endothermic, then plume rise can be suppressed. The model described here focuses on uranium hexafluoride, a common chemical in the nuclear industry, which reacts exothermically with atmospheric water vapor. The reaction can generate heat at a sufficient rate that turbulent mixing is enhanced considerably. The model is constructed to take the consequences of such chemical reactions into account by modifying the initial puff specification. A puff dispersion code is operated in conjunction with a wind field routine that accepts data from an array of towers (or a single tower, if that is all that is available), and interpolates wind field information as required. The puff module is based on the INPUFF-2 model developed by the Environmental Protection Agency. The three components (initial puff specification, wind field, and puff dispersion) of the model have been combined into a single code named TRIAD. This report outlines the theoretical basis for the chemical parameterizations, summarizes the results of tests conducted using a more sophisticated air chemistry model, discusses the capabilities and limitations of the TRIAD, and includes a detailed User's Guide to the current version of the TRIAD model.

AR-074

HUBER, A.H. Video images of smoke dispersion in the near wake of a model building. Part I. Temporal and spatial scales of vortex shedding. Journal of Wind Engineering and Industrial Aerodynamics 31:189-224 (1988).

No abstract.

AR-075

HUBER, A.H., and W.B. PETERSEN. Simulating concentration fluctuations in the wake of a building using a Gaussian integrated puff model. Preprints, Sixth Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 29 - February 3, 1989. American Meteorological Society, Boston, 154-157 (1989).

No abstract.

AR-076

Hutchison, B.A., and D.D. BALDOCCHI. Forest meteorology. Chapter 3, Analysis of Biogeochemical Cycling Processes in Walker Branch Watershed, D.W. Johnson and R.I. Van Hook (eds.). Springer-Verlag, 21-95 (1989).

No abstract.

AR-077

Kahl, J.D. Confidence limits on source-receptor relationships determined by ensemble trajectory analysis. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 93-96 (1989).

No abstract.

AR-078

Kahl, J.D., and A.D.A. Hansen. Determination of regional sources of aerosol black carbon in the Arctic. Geophysical Research Letters 16(4):327-330 (1989).

Black carbon aerosol (BC), a strong absorber of visible light, constitutes a small but significant fraction of the effluent arising from carbonaceous fuel combustion processes. Estimates of the source strengths and geographical distribution of BC emissions, needed to model their effects on radiative transfer, are currently unavailable. In this letter we present a methodology for estimating regional emissions of BC in Arctic latitudes based on the synthesis of three independent pieces of information: time-resolved measurements of BC and CO_2 at Pt. Barrow, Alaska; long-range atmospheric trajectory analyses; and tabulated values of regional fuel consumption. From a limited data base we obtain an example result indicating annual BC emissions in the Novaya Zemlya/Taymyr Peninsula regions of the northern U.S.S.R. on the order of 108 g yr^{-1}.

AR-079

Karl, T.R., H.F. DIAZ, and G. Kukla. Urbanization: Its detection and effect in the United States climate record. Journal of Climate 1(11):1099-1123 (1988).

Several equations were developed that related the effect of urban growth, measured by increasing population, to the mean seasonal and annual temperature: the diurnal maximum, minimum, average and range. These equations were derived from a network of 1219 stations across the United States, which were analyzed for the years 1901-84. The results indicate that urban effects on temperature are detectable even for small towns with populations under 10,000. Stations with populations near 10,000 are shown to average 0.1°C warmer for the mean annual temperature than nearby stations located in rural areas with populations less than 2000. Urbanization decreases the daily maxima in all seasons except winter and the temperature range in all seasons. It increases the diurnal minima and the daily means in all seasons. The equations indicate that, for the annual mean temperature, urbanization during the twentieth century accounts for a warm bias of about 0.06°C in the U.S. Historical Climatology Network (HCN). Due to the large number of stations located in sparsely populated areas [(over 85% (70%) of all stations had a 1980 population of less than 25,000 (10,000)], the impact of urbanization is not large in relation to decadal changes of temperature in the United States. The average heat island impact during the period 1901-84 for the HCN is largest for the daily minima (0.13°C) and the temperature range (-0.14°C), while the impact on the daily maxima (-0.01°C) is an order of magnitude smaller.

AR-080

Khalsa, S.J.S., and K.M. WEICKMANN. A composite study of intraseasonal oscillations in atmospheric angular momentum and outgoing long-wave radiation during Northern Hemisphere winter. Proceedings, Thirteenth Annual Climate Diagnostics Workshop, Cambridge, MA, October 31-November 4, 1988, 66-72 (1988).

No abstract.

AR-081

Kiladis, F.N., and H.F. DIAZ. Global climatic anomalies associated with extremes in the Southern Oscillation. Journal of Climate 2:1069-1090 (1989).

Composite temperature and precipitation anomalies during various stages of an event in the Southern Oscillation (SO) have been computed for several hundred stations across the globe. Large regions of coherent, significant signals are shown to exist for both extremes of the SO, with warm event signals generally opposite to those during cold events. In addition, during the year preceding the development of an event in the SO (year -1), climatic anomalies tend to be opposite to those during the following year (year 0). This confirms that the biennial tendency of the SO over the Pacific/Indian ocean sectors is also present in more remote regions with climatic signals related to the SO. Many of the signals are consistent enough from event to event to be useful for extended range forecasting purposes.

AR-082

Kim, Y.J., H. Sievering, and J.F. BOATMAN. Airborne measurement of atmospheric aerosol particles in the lower troposphere over the central United States. Journal of Geophysical Research 93(D10):12,631-12,644 (1988).

A series of airborne measurements of atmospheric aerosols were made in four seasonal field periods over the central United States as part of Central U.S. RADM Test and Assessment Intensives (CURTAIN). The primary objective of the CURTAIN aerosol measurements was to provide a data base for evaluation of the Regional Acid Deposition Model (RADM). Aerosol size distributions were measured at two altitudes of about 1450 and 2450 m above sea level (asl) over the size range 0.1-16 μm, using two Particle Measuring Systems, Inc., probes, an active scattering aerosol spectrometer probe and a forward scattering spectrometer probe, mounted on the National Oceanic and Atmospheric Administration King Air research aircraft. Aerosol samples were also collected by a 2.5-cm filter pack system for subsequent elemental analysis by X ray fluorescence (XRF). The average aerosol number concentration reached a maximum in summer at both low and high altitudes. The average aerosol number concentration was minimized during fall at low altitude and during winter at high altitude. The coarse particle mode of the aerosol volume distributions displayed a drastic seasonal change, with a winter volume geometric median diameter (VGMD) of 4.34 μm and a summer VGMD of 9.21 μm. The summer peak in the coarse-mode VGMD and volume concentration is attributed to increased windblown dust particles and the presence of liquid water as part of the aerosol volume under high relative humidity conditions. No significant latitudinal dependence was found in the CURTAIN aerosol data at low and high altitude, during the day or night, or from season to season. The CURTAIN aerosol data are influenced differently by the mixed layer from season to season. In winter, high-altitude aerosol data were collected above the top of

the mixed layer. Therefore the vertical profile of aerosol concentration shows a general decrease above the base of the mixed layer temperature inversion. In summer, high-altitude aerosol data were collected within the mixed layer. The vertical distribution of aerosol number concentration was rather constant during summer. XRF elemental analysis performed on the collected aerosol samples shows that fine-fraction Fe and K are fairly strongly correlated with accumulation mode mass during summer. This indicates that soil and agricultural fertilizer aerosol sources are important contributors. Correlations for fine and coarse masses with various atmospheric parameters are calculated. Positive correlations with temperature and relative humidity are found. Low wind speed and east winds are correlated with higher fine mass.

AR-083

KOMHYR, W.D., R.D. GRASS, and R.K. Leonard. Dobson spectrophotometer 83: A standard for total ozone measurements, 1962-1987. Journal of Geophysical Research 94(D7):9847-9861 (1989).

Dobson spectrophotometer 83 was established in 1962 as a standard for total ozone measurements in the United States. In 1980 the instrument was designated by the World Meteorological Organization (WMO) as the primary standard Dobson spectrophotometer for the world. Since the early 1960s, virtually all (~90) Dobson instruments in the global Dobson instrument network have been calibrated several times, either directly or indirectly, relative to instrument 83. Calibrations of instrument 83 by the Langley method were performed in 1962 at Sterling, Virginia, and during 1972-1987 at Mauna Loa Observatory (MLO), Hawaii. A detailed analysis of these calibration data, as well as calibration data based on standard lamp measurements made since 1962, indicates that the long-term (25-year) ozone measurement precision for the instrument is known to within an uncertainty of $\pm$0.5%. On an absolute scale, the ozone measurements made at MLO with instrument 83 are estimated to be too low by about 2.4%, as a result of errors in the A and D wavelength ozone absorption coefficients used with the instrument and their temperature dependence. Cumulative other biases most likely do not exceed $\pm$1%. This documentation of the calibration history of instrument 83 lends credence to the accuracy with which other Dobson instruments have been calibrated in the past and to dobson and satellite instrument ozone measurement comparisons, thereby increasing confidence in ozone trends determined by these ozone measurement systems in recent years.

AR-084

KOMHYR, W.D., R.D. GRASS, P.J. REITELBACH, S.E. KUESTER, P.R. Franchois, and M.L. FANNING. Total ozone, ozone vertical distributions, and stratospheric temperature at South Pole, Antarctica in 1986 and 1987. Journal of Geophysical Research 94(D9):11,429-11,436 (1989).

Ozone and temperatures measured in 1986 and 1987 at South Pole, Antarctica, are compared, with emphasis on observations made at the time of formation of the Antarctica ozone hole. In early October 1987, total ozone decreased at South Pole to a record low of 127 Dobson units (DU), compared with the early October 1986 value of 158 DU. Electrochemical concentration cell (ECC) ozonesonde soundings made during both years showed the ozone depletion at 11-23 km in 1987 to be greater in vertical extent and magnitude and to proceed more rapidly. As in 1986, two exponential ozone decrease rates occurred in 1987 at 17 $\pm$ 1 km, with half-lives of 19.5 and 4.5 days (compared with half-lives of 35 and 12 days observed in 1986). By early October 1987, nearly all ozone was depleted from a 4-km-thick atmospheric layer centered at 17 km. At the time of ozone hole formation, stratospheric temperatures were colder, but tropospheric temperatures were warmer, in 1987 compared to 1986. Because polar vortex breakdown occurred 3 weeks later in 1987 than it did in 1986, stratospheric temperatures in the heart of the ozone depletion region were 10°-40°C colder in mid-to-late November 1987.

AR-085

KOMHYR, W.D., T.B. HARRIS, L.S. WATERMAN, J.F.S. CHIN, and K.W. Thoning. Atmospheric carbon dioxide at Mauna Loa Observatory 1. NOAA global monitoring for climatic change measurements with a nondispersive infrared analyzer, 1974-1985. Journal of Geophysical Research 94(D6):8533-8547 (1989).

Atmospheric CO_2 measurements made with a nondispersive infrared analyzer during 1974-1985 at Mauna Loa Observatory, Hawaii, are described, with emphasis on the measurement methodology, calibrations, and data accuracy. Monthly mean CO_2 data, representative of global background conditions, are presented for the period of record. The monthly means were derived from an all-data base of CO_2 hourly averages archived at the National Oceanic and Atmospheric Administration (NOAA) Geophysical Monitoring for Climatic Change (GMCC) facility in Boulder, Colorado; at the Carbon Dioxide Information Analysis Center (CDIAC) in Oak Ridge, Tennessee; and in the microfiche version of this paper. Flags in the all-data base identify CO_2 hourly averages that have been deemed unreliable because of sampling and analysis problems or that are unrepresentative of clean background air because of influences of the local environment, for example, CO_2 uptake by nearby vegetation or contamination and pollution effects. The select NOAA GMCC monthly mean data are compared with similar data obtained independently

at Mauna Loa Observatory by the Scripps Institution of Oceanography. The average difference of corresponding monthly mean CO_2 values for the two data sets is 0.15 $\pm$ 0.18 ppm, where the indicated variability is the standard deviation. Careful scrutiny of the NOAA GMCC measurement, calibration, and data processing procedures that might have caused the small bias in the data has revealed no unusual errors.

AR-086

KOMHYR, W.D., J.A. LATHROP, V.N. Arbuzova, V.U. Khattatov, P.G. Nureyev, V.V. Radokov, and I.V. Zamyshlayev. ECC ozonesonde observations at Mirny, Antarctica, during 1988. NOAA DR ERL ARL-19, 125 pp. (1989).

Atmospheric ozone vertical distributions, air temperatures, and wind speed and direction data are presented for 40 balloon electrochemical concentration cell (ECC) ozone soundings made at Mirny, Antarctica, in 1988.

AR-087

KOMHYR, W.D., J.A. LATHROP, R.W. POSTON, and T.O. MULLEN. ECC ozonesondes at South Pole, Antarctica, during 1988. NOAA DR ERL ARL-18, 277 pp. (1989).

Atmospheric ozone vertical distributions, air temperatures, and wind speed and wind direction data are presented for 67 balloon electrochemical concentration cell (ECC) ozonesonde soundings made at South Pole, Antarctica, in 1988.

AR-088

LAMB, R.G. Simulated effects of hydrocarbon emissions controls on seasonal ozone levels in the Northeastern United States: A preliminary study. EPA/600/3-88/017, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 86 pp. (1988).

The second generation Regional Oxidant Model (ROM2) is used to simulate ozone concentrations in the Northeastern United States over two week periods in each of three months: April, July and August 1980. In each period three separate model simulations are performed. The first of these, referred to as the base case, used the 1980 NAPAP 5.3 emissions inventory to specify anthropogenic hydrocarbon and NO_x emissions. The second simulation, referred to as Control Strategy #1, assumed reductions of 5% to 50% in hydrocarbon emissions depending on the county in which sources are located. The third simulation, Control Strategy #2, used the same emissions as Control Strategy #1 but with hydrocarbon emission rates reduced an additional 22% across the board. In all three simulations the NO_x emissions are the same and the hydrocarbon emissions from natural sources are identical. The predicted ozone changes that result from the emissions changes are extrapolated from the three, 2-week periods to the "ozone season", which begins on 1 April and runs through 31 October. The extrapolation is performed using a technique developed in this paper. Three general conclusions are drawn: (1) reducing hydrocarbon emission rates generally reduces ozone levels; (2) the emissions changes proposed in control strategies 1 and 2 reduce peak O_3 concentrations most -- they have virtually no effect on concentrations below about the 95-percentile level; (3) the impact of controls on ozone levels is sensitive to meteorological conditions. These and other results of the model simulations are discussed.

AR-089

LAWSON, R.E., JR., W.H. SNYDER, and R.S. Thompson. Estimation of maximum surface concentrations from sources near complex terrain in neutral flow. Atmospheric Environment 23(2):321-331 (1989).

A wind tunnel study was conducted to determine maximum ground-level concentrations for a variety of source positions (locations and heights) both upstream and downstream of two model hills, an axisymmetric hill (maximum slope 24°) and a two-dimensional ridge (maximum slope 16°), immersed in a simulated neutral atmospheric boundary layer. Terrain amplification factors derived from these measurements were used to construct contour plots showing regions or "windows" of enhanced ground-level concentration. These windows of enhanced ground-level concentration are shown to be a useful guide for estimating the effects of complex terrain on pollutant dispersion or, conversely, for determining source locations near complex terrain which minimize the enhancement of ground-level concentration.

AR-090

Lean, J. Chapter 7, Solar EUV irradiances and indices. Advances in Space Research 8(5):263-292 (1988).

Information about the solar EUV spectrum and its temporal variability is essential for studies of the earth's upper atmosphere. Despite a data base which spans two solar cycles, neither the EUV irradiance variations associated with the eleven-year solar activity cycle, nor the EUV spectral irradiance of the inactive ("quiet") sun have yet been accurately determined. Because ground-based solar observations have been made more frequently, and with a long-term accuracy superior to that of EUV irradiance measurements, they have assumed an important role as indicators of solar activity in studies of the earth's thermosphere. In this paper, the solar EUV irradiance data base acquired over the past 25 years is briefly described. The extent to which emissions at different EUV wavelengths and ground-based solar indices are similar, is examined statistically over time scales of the 27-day solar rotation, and less rigorously over the eleven-year solar cycle. It is shown that the detailed temporal structure of the EUV irradiance variations is a complicated function of wavelength and cannot be exactly reproduced by any of the traditional ground-based indices over either short- or long-time scales.

AR-091

Lean, J.L., H.J. Kostkowski, R.D. Saunders, and L.R. Hughey. Comparison of the NIST SURF and argon miniarc irradiance standards at 214 nm. Applied Optics 28(15):3246-3253 (1989).

Comparison of NIST's SURF-II primary irradiance standard and argon miniarc irradiance standard at 214 nm with an uncertainty of ~3% shows that at this wavelength these irradiance standards agree to within the uncertainties of 1.3 and 7%, respectively, assigned to them by NIST.

AR-092

Lee, R.N., K.M. Busness, and B. STUNDER. Aircraft operations and airborne measurement of perfluorotrimethylcyclohexane (PTCH) during ANATEX. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 113-116 (1989).

Extended abstract.

AR-093

Luria, M., C.C. VAN VALIN, and J.F. BOATMAN. Sulfur budget for the south-central United States. Man and His Ecosystem, Proceedings, 8th World Clean Air Congress 1989, The Hague, The Netherlands, September 11-15, 1989, L.J. Brasser and W.C. Mulder (eds). Elsevier Science, Amsterdam, 355-362 (1989).

The concentrations of sulfur dioxide (SO_2), particulate sulfate SO_4^{2-} and other trace gases, as well as meteorological and position parameters were measured from an instrumented aircraft over the south-central United States. Research flights were performed from Little Rock, Arkansas, along a north-south track near the 91.5°W meridian between 29° and 41°N latitude, at constant altitudes of 1700 and 2600 m above sea level. The measurements were carried out during 1987 and totaled about 24 h of air-sampling flight time during each of the four seasons. The average concentrations of SO_2 ranged from 1.6 to 6.8 $\mu g\ m^{-3}$ at the lower elevation and from 0.5 to 2.4 $\mu g\ m^{-3}$ at the higher elevation. Particulate sulfate ranged from 1.3 to 3.2 $\mu g\ m^{-3}$ at the lower elevation and 0.5 to 1.7 $\mu g\ m^{-3}$ at the higher elevation. Both SO_2 and particulate SO_4^{2-} concentrations peaked during the summer measurements. However, the increase of SO_4^{2-} from winter to summer was the more notable, probably as a result of enhanced photochemical activity. Sulfur fluxes were calculated using the concentrations and wind data observed during this study and following a procedure previously suggested by the authors. The calculations revealed that the net sulfur fluxes during the winter and summer are directed westward. Spring and fall fluxes are directed eastward.

AR-094

Luria, M., C.C. VAN VALIN, J.N. Galloway, W.C. Keene, D.L. WELLMAN, H. Sievering, and J.F. BOATMAN. The relationship between dimethyl sulfide and particulate sulfate in the mid-Atlantic Ocean atmosphere. Atmospheric Environment 23(1)139-147 (1989).

Dimethyl sulfide (DMS) and atmospheric aerosols were sampled simultaneously over the Atlantic Ocean in the vicinity of Bermuda using the NOAA King Air research aircraft. Total and fine (50% cut off at 2 μm diameter) aerosol fractions were sampled using two independent systems. The average non-sea-salt (nss) SO_4^{2-} concentrations were 1.9 and 1.0 $\mu g\ m^{-3}$ (as SO_4^{2-}) for the total and the fine fractions in the boundary layer (BL) and 0.53 and 0.27 $\mu g\ m^{-3}$ in the free troposphere (FT). Non-sea-salt SO_4^{2-} in the two aerosol fractions were highly correlated ($r = 0.90$), however a smaller percentage (55%) was found in the fine aerosol near Bermuda relative to that (90%) near the North American continent. The BL SO_4^{2-} concentrations measured in this study were higher than those measured by others at remote marine locations despite the fact that the 7-day air mass back trajectories indicated little or no

continental contact at altitudes of 700 mb and below; trajectories were over subtropical oceanic areas that are expected to be rich in DMS. DMS concentrations were higher near the ocean surface and decreased with increasing altitude within the BL; the average DMS concentration was 0.13 $\mu g\ m^{-3}$. Trace levels of DMS were also measured in the FT (0.01 $\mu g\ m^{-3}$). Computer simulation of the oxidation and removal of DMS in the marine atmosphere suggests that <50% of the SO_4^{2-} observed could be related to the natural S cycle.

AR-095

Luria, M., C.C. VAN VALIN, W.C. Keene, D.L. WELLMAN, J.N. Galloway, and J.F. BOATMAN. Eastward sulfur flux from the northeastern United States. Atmospheric Environment 22(9):1847-1854 (1988).

During January and February 1986 the concentrations of sulfur dioxide (SO_2) and particulate sulfate (SO_4^{2-}) were measured from an instrumented aircraft 80-120 km east of the New England coast. The average concentration of SO_2 in the boundary layer (BL) was 10 $\mu g\ m^{-3}$, the maximum 30-min average was 26 $\mu g\ m^{-3}$. The average and maximum values in the free troposphere (FT) were 3.9 and 31 $\mu g\ m^{-3}$, respectively. The concentrations of non-sea-salt SO_4^{2-} averaged 2.0 and 0.7 $\mu g\ m^{-3}$ in the BL and FT, and the maximum concentrations were 7.7 and 3.2 $\mu g\ m^{-3}$. Continuous wind speed records from the aircraft LORAN system were used to estimate altitude profiles of the offshore fluxes of SO_2 and SO_4^{2-} for the duration of the study. The estimated advection flux is $(3.5 \pm 0.4) \times 10^{-3}$ Tg(S)day^{-1} from the coastal segment between 41 and 43°N latitudes. Most (89%) of the S flux was found to be in the form of SO_2; the remainder corresponded to particulate SO_4^{2-}. The ratio of aerosol to gas-phase S in the BL was found to be similar to that in the FT, despite the fact that removal of SO_2 from the BL is expected to be much faster than that from the FT.

AR-096

Malanchuk, J.L., C.N. Herrick, and R.L. DENNIS. Comparative evaluations of NAPAP's illustrative future scenarios. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, Paper 89-113.10 (1989).

The objective of the NAPAP Integrated Assessment is to provide users with objective, broadly reviewed data and analyses for several realistic examples of control scenarios. These results are compared to a reference case that projects estimates of future conditions without the assumption of additional initiatives directed at acidic deposition control. The comparative evaluations will help to distinguish strategies over a broad range of policy questions that are more effective than others, and perhaps just as important, will help identify situations in which different strategies produce similar results. This paper will discuss issues of model adequacy and model linkage, suggest methods to approach these issues, and provide an illustrative comparison of two control strategies.

AR-097

MEYERS, T.P., and D.D. BALDOCCHI. A comparison of models for deriving dry deposition fluxes of O_3 and SO_2 to a forest canopy. Tellus 40B:270-284 (1988).

Four canopy models, representing the various classes of models that are currently used to estimate gaseous deposition to plant canopies are presented. The predictive capabilities of the models are evaluated with direct eddy correlation measurements of SO_2 and O_3 fluxes to a deciduous forest for both well-watered and water-stressed conditions. By increasing the degree of detail of the exchange-governing physical processes from the more simple single layer model to the more detailed multi-layer models, the predictions of the deposition rates improved by 40-50% as determined from the root mean square error (rmse). We also found by including the effect of water stress in the stomatal resistance formulations, the rmse of the predictions were decreased by generally 50% for the models that were examined.

AR-098

NAPPO, C.J., K.S. Rao, and J.A. Herwehe. Pollutant transport and diffusion in katabatic flows. Journal of Applied Meteorology 28(7):618-625 (1989).

The characteristics of pollutant transport and diffusion of a passive contaminant in a two-dimensional katabatic flow over a simple slope are examined using a primitive equation hydrodynamic model. It is shown that pollutants released above the drainage layer can be entrained into the layer and diffused to the ground surface. For elevated releases within the drainage layer, subsidence in the flow leads to relatively high surface concentrations of pollutants close to the stack. Pollutants released at ground level can spread through the entire depth of the drainage layer. This vertical diffusion is more effective for a shallow slope, resulting in higher concentrations at all heights, than for a stepper slope. These dispersion characteristics are quite different from those for stable

flows over flat terrain. The differences result from increases of boundary-layer depth, wind speed, and turbulence as the katabatic flow develops downslope. The katabatic flow and dispersion model is tested by simulating the perfluorocarbon and heavy methane tracer releases for Night 4 of the 1980 ASCOT field study in Anderson Creek Valley, California. These tests show that the observed concentrations and the depth of the drainage layer in the lower region of the slope are underpredicted because the model could not simulate the convergence of drainage air (pooling) in the valley basin. The nightly average values of the observed concentrations, however, are predicted well. It is concluded that the model is applicable to nearly two-dimensional open slopes.

AR-099

NOVAK, J. Verification procedures applied to the U.S. EPA Regional Oxidant Model. In Air Pollution Modeling and Its Application VI, H. van Dop (ed.). Plenum Publishing Corp., New York, 345-356 (1988).

Regional air quality simulation models have been developed as research tools to gain a greater understanding of long range transport and transformation of air pollutants and to evaluate regional control strategy alternatives. To ensure credibility of these complex model predictions, the performance of model codes must be verified for their adherence to theoretical formulations, accuracy of numerical algorithms, ability to reproduce observed data and sensitivity to uncertainties in input data. This paper describes the procedures used for verification of the U.S. EPA Regional Oxidant Model. Comparisons with observed data are presented together with a brief summary of the results from two ozone control strategy applications. The sensitivity of the model to known uncertainties in input data is discussed in relation to its effect on air pollution control strategy evaluation.

AR-100

NOVAK, J.N., and T. Birth. Development of a Geographic Information System for assessment of air pollution problems. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-105P.2 (1989).

Geographic Information Systems (GIS) are powerful tools for the spatial analysis of related information. Recognizing common needs and the requirement to share data, several EPA offices in the Research Triangle Park, North Carolina, cooperated in the design and implementation of a pilot GIS system for analysis of Regional Oxidant Model (ROM) pollutant concentration predictions in conjunction with other associated data sets of interest, such as emissions, air quality, and population, etc. The primary goal of the pilot project is to provide to analysts and researchers 1) a graphical analysis tool they can use directly with little GIS experience, and 2) direct access to a variety of large data sets required for assessment of air pollution issues. One of the main advantages of the GIS is the ability to overlay multiple data sets and highlight relationships of interest. The demonstration illustrates the typical use of GIS for analysis of the effectiveness of a particular VOC and NO_x emissions control strategy for reducing ozone concentrations in the Northeastern U.S.

AR-101

PARUNGO, F., C. NAGAMOTO, and B. KOPCEWICZ. Front range acidic clouds and precipitation. Preprints, 82nd Annual Meeting and Exhibition, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, 89-112.4 (1989).

No abstract.

AR-102

Patrinos, A.A.N., M.J. Leach, R.M. Brown, R.L. Tanner, and F.S. BINKOWSKI. An acid rain study in the Washington, D.C. area. Journal of Applied Meteorology 28:948-968 (1989).

A field study in the Washington, D.C. area explored the impact of urban emissions and mesoscale meteorology on precipitation chemistry. The study was a follow-up to an earlier, considerably more industrialized, study in the Philadelphia area; emissions along the Delaware Valley were found to affect the deposition of nitrate and sulfate on the urban mesoscale. The Washington studies were designed to complement and enhance the earlier study with an expanded sampling domain, sequential precipitation sampling and airborne measurements. Four storms were sampled successfully between October 1986 and April 1987. Results appear to confirm the conclusions of the Philadelphia study, although the upwind-downwind contrast in nitrate and sulfate deposition is not as pronounced. This difference is attributed to the area's widely distributed emission patterns and to the prevailing theories regarding the production of nitric acid and sulfuric acid on the relevant time and space scales. The importance of mesoscale meteorology and hydrogen peroxide availability is highlighted in at least two of the sampled storms.

AR-103

PERRY, S.G., D.J. Burns, L.H. Adams, R.J. Paine, M.G. Dennis, M.T. Mills, D.G. Strimaitis, R.J. Yamartino, and E.M. Insley. User's guide to the Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS). Volume I: Model description and user instructions. EPA/600/8-89/041, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 206 pp. (1989).

The Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS) is a refined air quality model for use in all stability conditions for complex terrain applications. It contains the technology of the original Complex Terrain Dispersion Model (CTDM) for stable and neutral conditions, but also models daytime, unstable conditions. The model makes use of considerable detail in the terrain and meteorological data (as compared to current EPA regulatory models) and requires the parameterization of individual terrain features, thus considering the three-dimensional nature of the interaction of the plume and terrain. This user's manual describes, in detail, the technical basis of the model and instructions for its use.

AR-104

PERRY, S.G., and W.H. SNYDER. Laboratory simulations of daytime mixed layer heights in complex terrain. Preprints, Sixth Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 29 - February 3, 1989. American Meteorological Society, Boston, 256-259 (1989).

No abstract.

AR-105

PETERSEN, W.B., W.H. SNYDER, J.Y. Ku, and S.T. Rao. Dispersion of dense gas releases in a wind tunnel. Preprints, 17th International Technical Meeting of NATO-CCMS on Air Pollution Modeling and its Application, Volume II, September 19-22, 1988, Cambridge, England. NATO/CCMS, Brussels, Belgium, II.5 (1988).

In view of numerous accidental releases of toxic gases into the atmosphere in recent years, there is increasing concern regarding the atmospheric dispersion of toxic and hazardous materials. Given that exposures to the toxic substances could be life threatening or severely incapacitating, there is an urgent need to develop and validate modeling approaches relevant to the atmospheric dispersion of airborne toxic material. The main point of this work is to illustrate the transport and dispersion of dense gas plumes using data collected in a wind tunnel, and to test the performance of two available dispersion models with the CO and SF concentration data from the wind tunnel experiments. It is not the intent to provide an exhaustive evaluation of atmospheric dispersion models appropriate to heavier-than-air releases. Rather we choose to compare one state-of-the-art dense gas model with a Gaussian puff model which is appropriate for neutrally buoyant releases. Although the simple Gaussian models do not incorporate the relevant physics for dense gas spread and diffusion, they may be useful in estimating ground level centerline concentrations.

AR-106

PIERCE, T.E. An air pollution climatology around an isolated point source using convective scaling parameters. Atmospheric Environment 22:2463-2475 (1988).

An air pollution climatology, which incorporated convective scaling parameters, is used to investigate the conditions associated with hour SO_2 concentrations from a coal-fired power plant. One year of data from the Paradise power plant in central Kentucky (U.S.A.) were analyzed. Variables which were examined included emission rate, plume rise, wind speed, wind direction, stability class, convective scaling velocity and similarity categories. The results show the meteorological conditions leading to high surface concentrations are the daytime hours having neutral/unstable atmospheric stability, light winds and effective plume height to mixing height ratios typically >0.85. In more than half of the 30 h of highest observed concentrations, the atmospheric conditions satisfy the criteria for mixed-layer scaling.

AR-107

PIERCE, T.E. An evaluation of a convective scaling parameterization for estimating the diffusion of a buoyant plume. In Air Pollution Modeling and Its Application VI, H. van Dop (ed.). Plenum Publishing Corp., New York, 203-215 (1988).

During limited-mixed convective conditions, high concentrations of air pollutants have been observed at ground-level from buoyant plumes. Routinely-applied Gaussian plume dispersion models have difficulty simulating diffusion for these conditions. However, advances in convective scaling offer some hope for improved model formulations. This paper evaluates the usefulness of a diffusion formula

proposed by Briggs. Thirty-nine hours of extensive meteorological, source, and tracer data were analyzed from the Kincaid field study. The evaluation of the Briggs formula compared to a Gaussian plume dispersion model showed better model performance. Because of the sensitivity of the Briggs formula to values of w* (convective scaling velocity), additional research is recommended to improve estimates of the sensible heat flux. Also, further study of the horizontal diffusion of buoyant plumes in the convective boundary layer is recommended.

AR-108

PIOTROWICZ, S.R., R.A. Rasmussen, K.J. HANSON, and C.J. FISCHER. Ozone in the boundary layer of the equatorial Atlantic Ocean. Tellus 41B:314-322 (1989).

Shipboard (~7 m) ozone and carbon monoxide measurements made in the equatorial Atlantic Ocean, south of the intertropical convergence zone, between 5°N and 10°S and 10°-30°W in August and September of 1986 exhibited variability in excess of a factor of 2. Ozone mixing ratios ranged from <25 to over 50 ppbv while carbon monoxide mixing ratios ranged from <50 to over 120 ppbv along the western edge of the equatorial Atlantic in spite of the fact that the prevailing, surface winds were from the east to southeast at between 5 and 15 m/s. Ozone and carbon monoxide mixing ratios were generally lower and exhibited less variability in the eastern tropical Atlantic where a lighter, south to southeasterly wind regime predominated. Isobaric trajectory analyses indicated that the high ozone and carbon monoxide mixing ratios appear to be related to long-range transport off of the African continent. Time-series analysis of the ozone data indicated a diel cycle in ozone mixing ratios with a morning maximum and afternoon minimum.

AR-109

POSSIEL, N.C., J.A. Tikvart, J.H. NOVAK, K.L. SCHERE, and E.L. Meyer. Evaluation of ozone control strategies in the northeastern region of the United States. In Atmospheric Ozone Research and its Policy Implications, T. Schneider et al. (eds.). Elsevier Science Publishers B.V., Amsterdam, 623-632 (1989).

The transport of ozone and precursor pollutants over hundreds of kilometers has an important impact on air quality in the Northeastern U.S. Of particular concern is the relatively close proximity of several major urban areas, joined with the influence of large rural fuel combustion sources. This paper reviews initial applications of a regional scale model to assess the effect of selected control strategies for reducing ozone concentrations in the Northeast region, and especially in the urban corridor. Generally it is found that reducing emissions of volatile organic compounds is an effective control measure. The need for further joint controls of volatile organic compounds and nitrogen oxides is addressed.

AR-110

Rao, K.S., R.M. ECKMAN, and R.P. HOSKER, JR. Simulation of tracer concentration data in the Brush Creek drainage flow using an integrated puff model. Journal of Applied Meteorology 28(7):609-616 (1989).

During the 1984 ASCOT field study in Brush Creek Valley, two perfluorocarbon tracers were released into the nocturnal drainage flow at two different heights. The resulting surface concentrations were sampled at 90 sites, and vertical concentration profiles at 11 sites. These detailed tracer measurements provide a valuable dataset for developing and testing models of pollutant transport and dispersion in valleys. In this paper, we present the results of Gaussian puff model simulations of the tracer releases in Brush Creek Valley. The model was modified to account for the restricted lateral dispersion in the valley, and for the gross elevation differences between the release site and the receptors. The variable wind fields needed to transport the puffs were obtained by interpolation between wind profiles measured using tethered balloons at five along-valley sites. Direct turbulence measurements were used to estimate diffusion. Subsidence in the valley flow was included for elevated releases. Two test simulations -- covering different nights, tracers, and release heights -- were performed. The predicted hourly concentrations were compared with observations at 51 ground-level locations. At most sites, the predicted and observed concentrations agree within a factor of 2 to 6. For the elevated release simulation, the observed mean concentration is 40 pL/L, the predicted mean is 21 pL/L, the correlation coefficient between the observed and predicted concentrations is 0.24, and the index of agreement is 0.46. For the surface release simulation, the observed mean is 85 pL/L, and the predicted mean is 73 pL/L. The correlation coefficient is 0.23, and the index of agreement if 0.42. The results suggest that this modified puff model can be used as a practical tool for simulating pollutant transport and dispersion in deep valleys.

AR-111

Rao, K.S., J.-Y Ku, and S.T. Rao. A comparison study of three urban air pollution models. Atmospheric Environment 23:793-801 (1989).

The predictions of three urban air pollution models with varying degrees of mathematical and computational complexities are compared against the hourly SO_2 ground-level concentrations observed on 10 winter nights of the RAPS experiment in St. Louis. The emphasis in this study is on the prediction of urban area source concentrations. Statistics for the paired comparison of predictions of each model with the observations are presented. The RAM and the ATDL model with stable diffusion coefficients overestimated the observed night-time concentrations. The results show that the performance of the ATDL model with near-neutral diffusion coefficients is comparable to the more sophisticated 3-D grid numerical model.

AR-112

Rao, S.T., G. Sistla, J.-Y. Ku, K.L. SCHERE, R.D. Scheffe, and J.M. GODOWITCH. Nested grid modeling approach for assessing urban ozone air quality. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-42A.2 (1989).

This paper describes an effort to interface the modeled concentrations and other outputs of the Regional Oxidant Model (ROM) as an alternative set of input files to apply in Urban Airshed Model (UAM) simulations. Five different days exhibiting high ozone concentrations during the 1980 ozone season were simulated by the UAM for the New York metropolitan area for a base scenario and for different sets of initial and boundary conditions and winds from the ROM. The methodology of integrating the ROM results into the UAM processor system is discussed. The modeled UAM ozone concentrations are compared with measured values for the various model input data scenarios in assessing the performance of the nested grid modeling approach. The results indicate relatively good agreement over the New Jersey/New York portion of the UAM domain, and an underprediction of ozone levels over Connecticut.

AR-113

Roberts, P.J.W., W.H. SNYDER, and D.J. Baumgartner. Ocean outfalls I: Submerged wastefield formation. Journal of Hydraulic Engineering 115(1):1-25 (1989).

Experiments to study the dilution and formation of wastefields resulting from discharge into a linearly density-stratified steady current of arbitrary speed and direction are reported in three papers. The experiments were conducted using a model multi-port diffuser for a range of parameters typical of ocean wastewater outfalls. In this paper, results are given from which the established wastefield characteristics for the "line plume" source conditions can be predicted. In general, the wastefield rise height and thickness decrease as the current speed increases. Dilution increases with current speed for all current directions, with diffusers perpendicular to the current resulting in higher dilutions than when parallel. Concentration profiles for perpendicular currents show little horizontal structure as the individual plumes rapidly merge. The results for dilution show no dependency on port spacing or source momentum flux over the parameter range tested, and the dominant source parameter is the buoyancy flux per unit length. The results confirm the value of the "line plume" approximation for predicting dilutions for deepwater ocean outfalls over a fairly wide parameter range.

AR-114

Roberts, P.J.W., W.H. SNYDER, and D.J. Baumgartner. Ocean outfalls II: Spatial evolution of submerged wastefields. Journal of Hydraulic Engineering 115(1):26-48 (1989).

Some of the basic features of submerged wastefield formation in stratified currents are reported in this paper. Dilution increased with distance from the diffuser in the initial mixing region until it attained a maximum value, which is the initial dilution, after which it remained constant. By assuming a model of buoyancy-induced turbulence collapse, expressions for the observed dependency on current speed in the forced entrainment regime of initial dilution, rise height, and mixing region length were obtained. An expression for lateral spreading in parallel currents was derived which was found to be of the same form as for unstratified currents, except that the rate of spreading in stratified currents is much slower. An expression for the rate of spreading in perpendicular currents was derived by applying results from mixed-region collapse. An applications example shows that the mixing region can extend for several hundred meters downstream from the discharge. Because of the gravitational spreading, a line diffuser will produce a wastefield width comparable to the diffuser length for most oceanic conditions, suggesting that Y or similarly complex diffuser configurations are not necessary to produce a widely dispersed wastefield.

AR-115

Roberts, P.J.W., W.H. SNYDER, and D.J. Baumgartner. Ocean outfalls III: Effect of defuser design on submerged wastefield. Journal of Hydraulic Engineering 115(1):49-70 (1989).

The effects of port spacing and jet momentum flux on the characteristics of submerged wastefields produced by multi-port ocean outfalls in linearly stratified currents were investigated experimentally. Within the parameter range studied the primary effect of these variables is on the rise height and thickness of the wastefield, and dilution is closely approximated by line plume results. Increased momentum flux causes a reduction in rise height at low current speeds while leaving the total entrainment path length of the jets, and hence dilution, fairly constant. The effects of increased momentum flux decrease as the current speed increases. Increased port spacing still resulted in merging of individual plumes even when fairly widely spaced, particularly in flowing currents, so point plume results were of limited applicability in predicting wastefield properties. Results are presented in graphical and tabular form from which rise heights and thicknesses can be estimated for discharges which do not approximate line plumes. An example of the procedure is given, and some implications for diffuser design are discussed.

AR-116

ROBINSON, E. Book Review. Tropospheric Ozone, Regional and Global Scale Interactions. (NATO ASI Series, Kluwer Academic Publishers, D. Reidel Publishing Co., Dordrecht, Holland, 1988, 425 pp.) Water, Air and Soil Pollution 44:415-417 (1989).

No abstract.

AR-117

ROBINSON, E., and T.E. DE FOOR. Stratospheric aerosol conditions over Mauna Loa during recent quiescent volcanic periods. In Aerosols and Climate, P.V. Hobbs and M.P. McCormick (eds.). Deepak, Hampton, Virginia, 325-334 (1988).

Lidar observations of stratospheric aerosol conditions have been made at the Mauna Loa Observatory for more than 10 years. Plumes from large-scale volcanic eruptions, the usual causes of enhanced aerosol backscattering in the stratosphere, and the impacts of major volcanic events such as Fuego in 1974 and El Chichón in 1982 are readily evident in the lidar record. However, in the intervals between major eruptions over the past 10 years the apparent residual or "background" stratospheric aerosol optical depth, as calculated from the Mauna Loa ruby lidar at 694 nm, has gradually increased at an annual rate of about 4.5×10^{-4}, or about 10% per year. The most likely explanation for this long-term increase in residual aerosol backscattering is the gradual accumulation of volcanic eruption materials in the stratosphere both from the large, well-publicized eruptions and from the more numerous, less intense events. These features of the residual stratospheric aerosol conditions and the impact of the more frequent moderate-scale eruptions are examined in this discussion with particular reference to recent Mauna Loa lidar observations.

AR-118

ROLPH, G.D., and B.J.B. STUNDER. Meteorological support: Descriptions of application programs for accessing and displaying data. NOAA TM ERL ARL-169 (PB89-194625), 68 pp. (1989).

Programs for accessing and displaying meteorological data are described. Surface and upper-air observations and model-generated forecast data may be accessed. Step-by-step procedures and examples are provided for each application program. Brief descriptions of air-parcel trajectory models are also included. Most of the programs require access to the NAS 9000 computer in Suitland, MD. Meteorological data for these programs are provided by NOAA's National Meteorological Center in Camp Springs, MD.

AR-119

Rosen, J.M., S.J. OLTMANS, and W.F. Evans. Balloon borne observations of PSCS, frost point, ozone and nitric acid in the north polar vortex. Geophysical Research Letters 16(8):791-794 (1989).

A new balloon borne instrument called a backscattersonde has been used to study Polar Stratospheric Clouds (PSCs) at Alert, NWT (82°N, 61.5°W) during January and February of 1989. These measurements were supplemented with frost point, ozone and nitric acid vapor soundings. Type I PSCs were observed at temperatures and pressures generally consistent with present vapor pressure models of HNO_3/H_2O condensate, but some noticeable inconsistencies exist. It is suggested that these apparent problems, as well as some characteristic peculiarities in the PSC profiles, could be explained by the presence of two phases of the HNO_3/H_2O condensate.

AR-120

Rosinski, J., P.L. Haagenson, C.T. NAGAMOTO, B. QUINTANA, F. PARUNGO, and S.D. Hoyt. Ice-forming nuclei in air masses over the Gulf of Mexico. Journal of Aerosol Science 19(5):539-551 (1988).

Aerosol particles collected over the Gulf of Mexico during the period from 20 July to 30 August 1986 were examined for their ability to nucleate ice by condensation-followed-by freezing. Ice-forming nuclei (IFN) in the 0.1-0.4 μm-diameter size range nucleated ice at a temperature of -4°C; their concentrations were between 2 and 10 m^{-3}. Fractions of aerosol particles in that size range nucleating ice at the initial (the highest) temperatures were between 10^{-8} and 10^{-7}. Peaks in the concentration of dimethyl sulfide (DMS) (0800 h) preceded peaks in ice-nucleating temperatures (1300 h) by 5 h; this is sufficient time for DMS molecules to be oxidized to sulfates and to produce mixed aerosol particles through coagulation of different-sized aerosol particle and absorption of sulfur-bearing gas molecules. Fractions of aerosol particles larger than 0.2 μm in diameter containing SO_4^{2-} ions were larger than 0.90; most of the time they were 0.99-1.00. All IFN displayed characteristic features of mixed IFN, that is of marine origin (part of IFN concentration independent of temperature) and of continental origin (part of IFN concentration dependent on temperature).

AR-121

SCHERE, K.L., and R.A. Wayland. Development and evaluation of the regional oxidant model for the northeastern United States. In Atmospheric Ozone Research and its Policy Implications, T. Schneider et al. (eds.). Elsevier Science Publishers B.V., Amsterdam, 613-622 (1989).

The second generation U.S. EPA Regional Oxidant Model (ROM2) has been developed over the last 10 years and is not operational. The 3-D grid model has been applied to the Northeast U.S. for a 50-day period in 1980. Model evaluation results show the ROM2 is performing well with respect to predicting the frequency distributions and spatial pattern of observed O_3 concentrations.

AR-122

SCHERE, K.L., and R.A. Wayland. EPA Regional Oxidant Model (ROM2.0): Evaluation on 1980 NEROS data bases. EPA/600/3-89/057, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 351 pp. (1989).

The second generation U.S. EPA Regional Oxidant Model (ROM2.0) has been evaluated for the northeastern United States using the 1980 NEROS data bases. The theoretical basis of the model and its structure and organization are described. The data bases available from the summer 1980 period include the routine monitoring data of meteorological and air quality parameters from the National Weather Service and the SAROAD network. In addition, several extensive field measurement projects were sponsored during the summer of 1980 in the northeastern U.S. on regional and urban scales. Supplementary meteorological and air quality measurements were made at the surface as part of these field projects. In addition, an extensive measurement campaign was conducted aloft using several aircraft also on regional and urban scales. Also, a complete emissions inventory was assembled for the 1980 base year for use in air quality modeling. The emissions inventory was composed of anthropogenic and biogenic components. The ROM2.0 evaluation was conducted using quasi-deterministic and diagnostic techniques. Strict temporal and spatial pairing between observations and predictions was not used in the analysis. Model simulation was conducted during the period of July 12 to August 31, 1980. The simulation was begun under relatively clean tropospheric conditions to circumvent the difficult problem of initialization. Model performance over the simulation period showed an overall 2% overprediction of the daily surface maximum O_3 concentrations. ROM-predicted concentrations, however, had a narrower range for ambient O_3 with underestimation of highest values and overestimation of lowest values. The ROM underpredicted daily maximum O_3 values at the 75th percentile for group 1 sites by 30-50 ppb during major episodes. Ratios of observed to predicted NO_x and NMHC concentrations during the 06-09 h, LDT period were 2.5 and -5, respectively, for surface observations. The spatial extent and concentrations of urban O_3 plumes were generally simulated well, although a bias in the transport direction along the East Coast caused frequent misalignment of the plumes. Model performance analyses using aircraft data showed the model to underpredict the regional O_3 tropospheric burden under episodic conditions, although individual plumes were modeled well.

AR-123

SCHIERMEIER, F.A. Sources and evaluation of uncertainty in long-range transport models. In Air Pollution Modeling and Its Application VI, H. van Dop (ed.). Plenum Press Corp., 11:357-366 (1988).

The American Meteorological Society, under joint sponsorship from the U.S. Environmental Protection Agency, the Atmospheric Environment Service, Canada and the Ontario Ministry of the Environment, Canada, convened a workshop in September 1984 to address an aspect of long-range transport modeling that has become a topic of considerable concern, that is, the quantification of uncertainty in

long-range transport model predictions and the implications of these uncertainties on formulations of control policy. A series of draft chapters provided a focus for discussion by 38 invited national and international experts in the areas of policy perspectives, methods for sensitivity and uncertainty analysis, and sources of errors and uncertainty in Eulerian, Lagrangian, and stochastic long-range transport models. Composite uncertainty in model outputs consists of the meteorological, chemical, and emissions input data uncertainty combined with model formulation uncertainty, the latter due to representation of the physical-chemical processes and partly attributable to the mathematical integrations. Therefore, insight into a model's response to arbitrary varying inputs for a particular formulation is required in order to evaluate quantitative estimates of the expected change in air quality or deposition as a result of specific changes in emissions. This insight can then be put to use in determining the most effective strategies to mitigate air-pollutant-related environmental problems.

AR-124

Sievering, H., J. BOATMAN, M. Luria, and C.C. VAN VALIN. Sulfur dry deposition over the western North Atlantic: The role of coarse aerosol particles. Tellus 41(B):338-343 (1989).

A number of investigators have observed substantial amounts of coarse fraction (D> 1 μm) non-sea-salt or excess sulfate (XSO_4) to prevail in marine boundary layer (MBL) aerosol. Its dry deposition velocity may be 1 cm s^{-1} or more with low uncertainty relative to the dry deposition velocity of fine-fraction XSO_4. Estimates of total sulfur dry deposition using MBL ambient air data over the western North Atlantic Ocean are presented. It is shown, at distances of hundreds to 1000 km downwind from sulfur source regions, that sulfur dry removal from the western North Atlantic MBL is dominated by the dry deposition of XSO_4 rather than that of SO_2.

AR-125

SNYDER, W.H. Fluid Modeling applied to atmospheric diffusion in complex terrain. Abstracts, Second International Conference on Atmospheric Sciences and Applications to Air Quality, Tokyo, Japan, October 3-7, 1988. Science Council of Japan, pp. 53 (1988).

Wind-tunnel and towing-tank studies conducted over the past 10 years at the U.S. Environmental Protection Agency's Fluid Modeling Facility (FMF) of flow and diffusion in complex terrain are reviewed. A primary impetus for this work was EPA's Complex Terrain Model Development Program (CTMDP) -- designed to develop reliable atmospheric dispersion models applicable to large pollutant sources in complex terrain, with primary emphasis on plume impaction during nighttime stable conditions. The FMF interacted closely with the model developers participating in the CTMDP and provided support in various ways through the conduct of a wide range of laboratory studies. Work at the FMF prior to the inception of the program provided the basic framework for the model -- the dividing-streamline concept -- and the focal point around which the field program was designed. At the beginning of the program, the FMF provided direct support as an aid to planning the details and strategies of the field experiments and testing the limits of applicability of the dividing-streamline concept. Later work included exercises of "filling in the gaps" in the field data, furthering the understanding of the physical mechanisms important to plume impaction in complex terrain and in stably stratified flows in general, testing various modeling assumptions, providing data for "calibration" of various modeling parameters, and testing the ability of the laboratory models to simulate full-scale conditions. Simultaneously, the FMF responded to the needs of the regulatory arm of EPA, the Office of Air Quality Planning and Standards (OAQPS), by providing guidance concerning expected terrain effects and by conducting demonstration studies. These latter studies were concerned primarily with simulation of diffusion in the neutral atmospheric boundary layer. Finally, several supplemental studies were conducted, broadening and expanding upon the specific requests of the model developers and the OAQPS. The highlights of the FMF complex-terrain research work are described herein.

AR-126

Spicer, C.W., C.L. Lindsey, W. Seiler, G. Schufmann, J. BOATMAN, G. Isaac, R. Leaitch, and J.K.S. CHING. Aircraft measurements for diagnostic evaluation of acid deposition models. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 1-6 (1989).

Extended abstract.

AR-127

START, G.E., C.R. DICKSON, J.F. SAGENDORF, G.R. ACKERMANN, K.L. CLAWSON, R.C. JOHNSON, and N.R. HUKARI. Atmospheric diffusion for airflows in the vicinity of the James Forrestal Campus, Princeton, University, Special Report to the U.S. Department of Energy, Princeton Area Office, Princeton, NJ, Vols. I and II, 469 pp. (1989)

During July, August, and September of 1988, a field measurement program was conducted to directly evaluate atmospheric diffusion conditions in the vicinity of the Princeton Plasma Physics Laboratory. Three conservative gaseous tracers were released simultaneously during 14 separate test windows. Each test was of six hours duration and 12 samples of 30 minutes length were collected at each of 98 sampling sites within 1000 m of the TFTR facility. The results of those direct tracer measurements were evaluated and compared with model estimates of expected atmospheric diffusion. The findings of those comparisons revealed greater dilutions of airborne effluents within the first kilometer downwind than estimated by the regulatory models. There were substantial differences between the site specific diffusion climatology and estimates from the generic diffusion (e.g., Pasquill-Gifford) family of diffusion curves. The CIT calculations performed using the generic diffusion curves provided overestimates of C/Q values expected in the PPPL setting. Use of the PPPL diffusion climatology permits reduction of the amount of overestimation in C/Q values and leads to well-founded calculations.

AR-128

Stewart, R.W., A.M. Thompson, M.A. Owens, and J.A. Herwehe. Comparison of parameterized nitric acid rainout rates using a coupled stochastic-photochemical tropospheric model. Journal of Geophysical Research 94:5219-5226 (1989).

A major tropospheric loss of soluble species such as nitric acid (HNO_3) results from scavenging by water droplets. Several theoretical formulations have been advanced which relate an effective time independent loss rate for soluble species to statistical properties of precipitation such as the wet fraction and length of a precipitation cycle. There is not enough data available on trace species concentrations to test the computational results of alternative loss rate models against observations. Therefore in this paper, various "effective" loss rates that have been proposed are compared with the results of detailed time dependent model calculations carried out over a seasonal time scale. The model which we have developed for this purpose is a stochastic precipitation model coupled to a tropospheric photochemical model. The results of numerous time dependent seasonal model runs are used to derive numerical values for the nitric acid residence time for several assumed sets of precipitation statistics. These values are then compared with the results obtained by utilizing theoretical "effective" loss rates in time independent models.

AR-129

STUNDER, B.J.B. Initial transport and diffusion based on ANATEX aircraft tracer measurements. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 97-100 (1989).

Extended abstract.

AR-130

Tans, P.P., T.J. CONWAY, and T. Nakazawa. Latitudinal distribution of the sources and sinks of atmospheric carbon dioxide derived from surface observations and an atmospheric transport model. Journal of Geophysical Research 94(D4):5151-5172 (1989).

Determination of the present global budget of atmospheric carbon dioxide (CO_2) from the small and persistent concentration gradients that exist in the atmosphere is discussed. The CO_2 concentration at any site results from a combination of two factors: local sources or sinks and long-range transport. To separate these two effects, an atmospheric transport model is needed. The extensive sets of global CO_2 measurements of the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Monitoring for Climatic Change (GMCC) division and of the Upper Atmosphere and Space Research Laboratory of Tohoku University are combined with a two-dimensional transport model to derive, in an "inverse" calculation, the latitudinal and seasonal distributions of sources and sinks of CO_2 necessary to reproduce the observed concentrations. The model transport parameters were previously derived from a three-dimensional general circulation model. It is found that the southern oceans are a sink of carbon of 0.8-1.5 Gt yr^{-1} (1 Gt equals 10^{15}g) and that the equatorial areas are a source to the atmosphere of 1.4-2.8 Gt yr^{-1}. Tropical deforestation as a major source of CO_2 must be smaller than that because the oceans account for a significant part of the equatorial flux. There seems to be significant seasonality in the sources and sinks of CO_2, both in the tropics and in the southern oceans. The seasonal net ecosystem production north of 25°N is found to be 6.2-8.2 Gt of carbon, but these estimates are probably somewhat too low. The source deduction problem is difficult to solve, especially for the middle and high latitudes in the northern hemisphere. This is due to a lack of observations over the continents, which occupy more than half of the global area at these latitudes and are the regions where the sources and sinks are most intense. Evidence is found in the results obtained for the GMCC and Tohoku data that the longitudinal variability of the data is large enough, even in equatorial and southern latitudes, to prevent a two-dimensional model from calculating

a fully credible source/sink field. The longitudinal variations in the observations have to be accounted for with a three-dimensional transport model.

AR-131

Taylor, G.E., Jr., P.J. Hanson, and D.D. BALDOCCHI. Pollutant deposition to individual leaves and plant canopies: Sites of regulation and relationship to injury. Chapter 10, Assessment of Crop Loss From Air Pollutants, W.W. Heck, O.C. Taylor, and D.T. Tingey (eds.). Elsevier, New York, 227-257 (1988).

No abstract.

AR-132

Thompson, A.M., R.W. Stewart, M.A. Owens, and J.A. Herwehe. Sensitivity of tropospheric oxidants to global chemical and climate change. Atmospheric Environment 23:519-532 (1989).

A photochemical model has been used to quantify the sensitivity of the tropospheric oxidants O_3 and OH to changes in CH_4, CO and NO emissions and to perturbations in climate and stratospheric chemistry. Coefficients of the form $\partial \ln[O_3]/\partial \ln[X]$ and $\partial \ln[OH]/\partial \ln[X]$, where [X]=flux of CH_4, CO, NO; stratospheric O_3 and H_2O have been calculated for a number of "chemically coherent" regions (e.g. nonpolluted continental, nonpolluted marine, urban) at low and middle latitudes. Sensitivities in O_3 and OH vary with regional emissions patterns and are nonlinear within a given region as [X] changes. In most cases increasing CH_4 and CO emissions will suppress OH (negative coefficients) and increase O_3 (positive coefficients) except in areas where NO and O_3 influenced by pollution are sufficient to increase OH. Stratospheric O_3 depletion will tend to decrease O_3 (except in high NO_x areas) and increase OH through enhanced u.v. photolysis. Increased levels of water vapor (one possible outcome of a global warming) will also decrease O_3 and increase OH. We conclude that in most regions, NO, CO and CH_4 emission increases will suppress OH and increase O_3, but these trends may be opposed by stratospheric O_3 depletion and climate change. A regional survey of OH and O_3 levels suggests that the tropics have a pivotal role in determining the earth's future oxidizing capacity.

AR-133

Thoning, K.W., P.P. Tans, and W.D. KOMHYR. Atmospheric carbon dioxide at Mauna Loa Observatory 2. Analysis of the NOAA GMCC data, 1974-1985. Journal of Geophysical Research 94(D6):8549-8565 (1989).

The first 12 years (1974-1985) of continuous atmospheric CO_2 measurements from the NOAA GMCC program at the Mauna Loa Observatory in Hawaii are analyzed. Hourly and daily variations in the concentration of CO_2 due to local sources and sinks are described, with subsequent selection of data representing background concentrations. A digital filtering technique using the fast Fourier transform and low-pass filters was used to smooth the selected data and to separate the seasonal cycle from the long-term increase in CO_2. The amplitude of the seasonal cycle was found to be increasing at a rate of 0.05 ± 0.02 ppm yr^{-1}. The average growth rate of CO_2 was 1.42 ± 0.02 ppm yr^{-1}, and the fraction of CO_2 remaining in the atmosphere from fossil fuel combustion was 59%. A comparison between the Mauna Loa continuous CO_2 data and the CO_2 flask sample data from the sea level site at Cape Kumukahi, Hawaii, showed that the amplitude of the seasonal cycle at Cape Kumukahi was 23% larger than at Mauna Loa, with the phase of the cycle at Mauna Loa lagging the cycle at Cape Kumukahi by about 1-2 weeks.

AR-134

Tikvart, J.A., J.L. DICKE, and J.S. TOUMA. Recent air quality modeling: Review of new techniques. Proceedings, 1989 TAPPI Environmental Conference, Charleston, SC, April 1989. Technical Association of the Pulp and Paper Industry, Atlanta, GA, Paper 14.1 (1989).

New and improved air quality modeling techniques regularly become available. Thus, it is necessary to periodically update and expand EPA's, guidance on such technique for regulatory applications to insure that the most accurate air quality impact assessments are always available. Since, the last revisions to this guidance were made in 1988, new techniques have been released for complex terrain, valley stagnation, and other, applications. Through a public hearing process, EPA has sought comment on the validity, accuracy, merits, limitations, and potential for regulatory, use of these techniques. Based on an analysis of the comments, EPA will make a formal proposal at a later time on the techniques considered to have, merit.

AR-135

Tobiska, W.K., and S.D. Bouwer. Intermediate-term variations of chromospheric and coronal solar flux during high solar cycle 21 activity. Geophysical Research Letters 16(8):779-782 (1989).

The solar Lyman-α emission, the MgII core-to-wing ratio, $R(MgII_{c/w})$, the 10.7-cm radio flux, $F_{10.7}$, and the 1-8 A X rays are compared during high solar cycle 21 activity from 1981-83. Daily variations of the Mg II and Lyman-α ultraviolet (UV) lines are highly correlated. There is moderate linear correlation between these lines and $F_{10.7}$ and poor linear correlation with 1-8 A X rays. Power spectral analysis indicates that all four fluxes have 27-day periodicities due to solar rotation while the $R(MgII_{c/w})$ and Lyman-α have noticeable 13-day periods in the datasets. $F_{10.7}$ moderately represents the 27-day solar UV variations and represents to a lesser degree variations shorter than or longer than rotation variations. X rays are not represented by $F_{10.7}$ on intermediate-term or shorter time-scales.

AR-136

TOUMA, J.S., C.F. Cole, K.D. Winges, and J.L. DICKE. Pit retention of particulate matter at surface coal mines. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-114.5 (1989).

Five alternative analytical techniques were developed to predict the mass of particulate matter that escapes from surface coal mine pits. The escape fraction techniques were evaluated by comparing values of escape fraction computed from the analytical techniques to values of escape fraction, inferred from smoke release studies performed at western surface coal mines. The simplest of the predictive techniques appears to perform best, although none of the techniques predicts escape fraction reliably over the range of wind speeds or stability classes measured at the surface coal mines.

AR-137

TOUMA, J.S., D.B. Joseph, J.L. DICKE, and R.G. Ireson. Improved techniques for assessing plume visual impact. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-14B.2 (1989).

No abstract.

AR-138

TOUMA, J.S., D.J. McNaughton, and P.M. Bodner. Development of a workbook for assessing impacts of toxic air pollutants. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-30.1 (1989).

No abstract.

AR-139

TOUMA, J.S., G.J. Schewe, and S.M. Templeman. Development of a shoreline dispersion model. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989. Air and Waste Management Association, Pittsburgh, AWMA 89-43.3 (1989).

No abstract.

AR-140

TURNER, D.B., L.W. Bender, T.E. PIERCE, and W.B. PETERSEN. Air Quality Simulation Models from EPA. Environmental Software 4:52-61 (1989).

Air Quality Simulation Models have been made available using the UNAMAP system. UNAMAP consists of FORTRAN source codes, test data and resulting print files on 9-track magnetic tape plus user's guides from NTIS. It is also available on EPA's IBM 3090 as executable codes and source codes. An assessment has been made of UNAMAP with recommendations to bring the system up-to-date regarding the state-of-the-art of technology transfer. An electronic Bulletin Board Service has been supporting UNAMAP since July 1987. FORTRAN mainframe source codes will soon be available on floppy diskettes from NTIS.

AR-141

VAN VALIN, C.C., and M. Luria. O_3, CO, hydrocarbons and dimethyl sulfide over the western Atlantic Ocean. Atmospheric Environment 22(11):2401-2409 (1988).

The concentrations of O_3 CO, dimethyl sulfide (DMS) and light hydrocarbons (C_2-C_4) were measured from an instrumented aircraft during February-April 1985, near the U.S. East Coast and in the vicinity of Bermuda as part of the Western Atlantic Ocean Experiment (WATOX). Sampling flights were performed within the boundary layer (BL) and in the free troposphere (FT) at both locations. Photochemical generation of O_3 in polluted air parcels transported from the continent within the BL was identified as the probable source of excess O_3 (up to 50 ppbv above background). Convective lifting of boundary layer air carried pollutants into the free troposphere. The concentrations of HC compounds in air sampled near Bermuda had a significant inverse relation to air mass transport time from the continent. The BL concentrations of the more reactive HCs (ethylene, propane, propylene, normal, and isobutane) declined faster than the less reactive HCs (acetylene and ethane), and were found to be proportional to air mass transport time over the ocean. DMS was detected, with few exceptions, only with the BL at both sampling locations. The average concentrations in the BL samples collected near the U.S. East Coast and in the vicinity of Bermuda were 27 and 54 pptv. In all samples taken in the BL the DMS concentration decreased sharply as a function of altitude.

AR-142

Vet, R.J., A. Sirois, D. Lamb, and R. ARTZ. Intercomparison of precipitation chemistry data obtained using CAPMoN and NADP/NTN protocols. NOAA TM ERL ARL-174, 39 pages + appendix (1989).

Results of a comparison of precipitation chemistry data, acquired under the CAPMoN and NADP/NTN protocols at the two colocated sites, are presented. For this intercomparison study precipitation was collected daily (CAPMoN) and weekly (NADP/NTN) for slightly more than one year. The data were analyzed qualitatively through scattergrams and statistically by testing the difference data against a simple constant-bias model. Although measurable and statistically significant biases exist in some variables (ammonium, nitrate, free acidity, and precipitation depth), the data from each network track each other and can be considered representative of the precipitation at the respective sampling sites, at least on a weekly time scale. It should be possible to combine the data from the NADP/NTN and CAPMoN networks in a meaningful way to analyze the spatial distribution of wet deposition across North America, as long as due concern is given to the comparability of the measurements.

AR-143

VIEBROCK, H.J., and E.M. Poole-Kober. Fiscal year 1987 summary report of NOAA Meteorology Division support to the Environmental Protection Agency. NOAA TM ERL ARL-170 (PB89-194294), 50 pp. (1989).

The Meteorology Division provided meteorological research and operational support to the U.S. Environmental Protection Agency. Basic meteorological operational support consisted of the application of dispersion models, and the conduct of dispersion studies and model evaluations. The primary research effort was the development and evaluation of air quality simulation models using numerical and physical techniques supported by field studies. Modeling emphasis was on the dispersion of photochemical oxidants and particulate matter on urban and regional scales, dispersion in complex terrain, and the transport, transformation and deposition of acidic materials. Highlights during FY-1989 included completion of the Complex Terrain Dispersion Model (CTDM), establishment of an electronic bulletin board for use under the User's Network for Applied Modeling of Air Pollution (UNAMAP), application of the Regional Oxidant Model (ROM) to assess the impact of proposed NO_x control strategies on ozone concentrations in the northeastern United States, completion of a sulfur-only version of the Regional Acid Deposition Model (RADM), and initiation of a major field study to evaluate the RADM and other regional dispersion models.

AR-144

Voldner, E.C., M.P. Olson, T.L. CLARK, R.L. DENNIS, M. Alvo, and S. Seilkop. International Sulfur Deposition Model Evaluation (ISDME): A Summary. In Air Pollution Modeling and Its Application VI, H. van Dop (ed.). Plenum Publishing Corp., New York, 305-320 (1988).

Eleven linear-chemistry atmospheric models of sulfur deposition were evaluated for each season of 1980. The evaluation data set consisted of sulfur wet deposition amounts calculated from screened precipitation chemistry measurements at 46 sites across eastern North America. The focus of this study differed substantially from those of preceding model evaluation studies in that the ISDME emphasized the ability of the models to replicate, within the uncertainties of the observations, the spatial patterns of observed seasonal amounts. Patterns of the predictions and observations were constructed via an interpolation technique known as simple kriging, which minimizes interpolation errors and estimates uncertainties resulting from the interpolation errors as well as measurement errors. The evaluation results indicated that for all seasons but spring, the models generally did

not mimic the observed location of the seasonal maximum amounts of sulfur wet deposition within the uncertainty limits. However, the interpolated predictions of eight models were within the uncertainly limits of the interpolated observations across at least 80% of the evaluation regional for at least three seasons.

AR-145

Vukovich, F.M., and J.K.S. CHING. Table look-up model to estimate cloud vertical transport for acid deposition models. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, January 30 - February 3, 1989. American Meteorological Society, Boston, 43-47 (1989).

Extended abstract.

AR-146

Wakamatsu, S., I. Uno, and K.L. SCHERE. Application of a three-dimensional photochemical smog formation model to the Tokyo Metropolitan Area. In Air Pollution Modeling and Its Application VI, H. van Dop, (ed.). Plenum Press, New York, 259-270 (1988).

No abstract.

AR-147

Wang, H., and D.D. BALDOCCHI. A numerical model for simulating the radiation regime within a deciduous forest canopy. Agricultural and Forest Meteorology 46:313-337 (1989).

A numerical model that simulates the radiation regime inside a fully leafed and leafless deciduous forest canopy is discussed and tested. The model incorporates features which account for the vertical variation on leaf inclination angles and penumbral effects; these features have been experimentally shown to significantly influence the radiation regime in a deciduous forest. This version of the model mimics measured values quite well and improves upon estimates of the canopy radiation regime that are based upon the general assumption that the leaf inclination angle distribution is spherical and that the Poisson probability distribution describes the probability of beam penetration. On the other hand, the numerical model assumes first-order scattering, which is inferior to multiple scattering routines.

AR-148

WEICKMANN, K.M. Convection and circulation anomalies over the oceanic warm pool during 1981-82. Proceedings, Western Pacific International Meeting and Workshop on TOGA-COARE, J. Picaut, R. Lukas and T. Delcroix, (eds.). Centre ORSTOM de Noumea, 214-224 (1989).

An important issue in understanding the low frequency evolution of the atmospheric circulation and the ocean-atmosphere system is the role of transients during individual events. We examine this question from an observational point-of-view for two different time scales and speculate on the importance of transients from these two different perspectives. Our analysis period covers September 1981-April 1982 which includes the development phase of the 1982-83 El Niño Southern Oscillation (ENSO) as well as six Madden-Julian (30-60 day) Oscillations (MJO). The latter include a strong event during December 1981 that is studied in detail. The self-similarity of these two time scales (Webster, 1989) is also highlighted.

AR-149

WEICKMANN, K.M., and S.J. Khalsa. Observations of coupling between oscillations in northern hemispheric angular momentum and the 30-60 day oscillation in the tropics. Preprints, 18th AMS Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 161-162 (1989).

Extended abstract.

AR-150

WELLMAN, D.L., M. Luria, C.C. VAN VALIN, and J.F. BOATMAN. The use of an airborne air sampling platform for regional air quality studies. NOAA TR ERL 437-ARL 10, 15 pp. (1989).

A Beechcraft King Air, owned and operated by the Office of Aircraft Operations, National Oceanic and Atmospheric Administration (NOAA), was converted from a passenger airplane into an atmospheric air quality sampling platform. It has been used in several regional air quality studies including the

Gulf Coast Experiment, the Western Atlantic Ocean Experiment (WATOX), and the Processing of Emissions by Clouds and Precipitation (PRECP) experiment. The aircraft is equipped to measure atmospheric trace gases (SO_2, O_3, and NO_x), aerosols, and meteorological parameters (temperature, humidity, wind speed, wind direction, atmospheric pressure, and solar radiation). It has grab sampling equipment (for aerosol chemistry and organic compounds) and instruments for continuously recording position and heading. Most of the scientific equipment aboard was provided by the Air Quality Group, Air Resources Laboratory, NOAA, with additional support from several universities and other institutions. The WATOX project is used as an example to demonstrate the capabilities of the aircraft as a regional air quality sampling platform. During this experiment, air samples were taken in the winter and spring seasons of 1985 and 1986 at two locations off the U.S. East Coast (Newport News, VA, and Boston, MA) and in the vicinity of Bermuda. These locations were selected to provide samples representative of contaminated air masses exiting from the continent and being transported over the Atlantic Ocean. Flight tracks were designed to assess the flux of atmospheric pollutants above and within the planetary boundary layer. Through the successful use of the aircraft, it was revealed that most of the pollutant transport within this region was being accomplished inside the boundary layer. Additionally, in several cases, contaminated air masses were observed in the free troposphere.

AR-151

Young, J.O., M. Aissa, T.L. Boehm, C.J. Coats, Jr., J.R. Eichinger, D.J. Grimes, S.W. Hallyburton, W.E. Heilman, D.T. Olerud, Jr., S.J. Roselle, A.R. Van Meter, R.A. Wayland, and T.E. PIERCE. Development of the Regional Oxidant Model Version 2.1. EPA/600/3-89/044, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 55 pp. (1989).

This report describes improvements that were made to version 2.0 of the Regional Oxidant Model (ROM) in order to create version 2.1. The ROM is an Eulerian grid model that calculates hourly concentrations of ozone and other chemical species for episodes up to about a month long. The ROM's modeling domain, composed of grid cells that are approximately 19 km on a side, encompasses an area on the order of 1000 km by 1000 km. The physical processes that the ROM simulates include photochemistry, nocturnal jets and temperature inversion, spatially- and temporally-varying wind fields, terrain effects, dry deposition, and emissions of biogenic and anthropogenic ozone precursors. Major technical improvements include upgrading the Carbon Bond Mechanism to version 4.2, improving the biogenic emissions processing system (which now includes a canopy model), updating the wind fields processor, and expanding the use of buoy data for determining meteorological data fields over water. Also, ROM 2.1 can be adapted more easily than version 2.0 to various modeling domains in eastern North America. In addition, the computer software has been redesigned to facilitate ROM's eventual application by outside users.

Addendum

AR-152

DIAZ, H.F., C.S. RAMAGE, S.D. WOODRUFF, and T.S. Parker. Climatic Summaries of Ocean Weather Stations. NOAA - Environmental Research Laboratories, Boulder, CO, 48 pp. + summary (1987).

Surface and upper air climatological summaries for 16 Ocean Weather Stations (OWS) are presented. Periods of record for surface data vary from 7 years for OWS X to more than 30 years for OWS C, M, and P. OWS T operated primarily during the summer typhoon season (May to November). Valid upper air records are generally of equal or lesser duration than those taken at the surface. The interval of time covered extends from 1945 for the earliest starting OWS to 1982 for a few OWS, some of which are still operating. The purpose of this special report is to make available to the scientific community high-quality climatological data over generally fixed ocean areas for comparison with data from traveling merchant ships and for comparison with profiles derived from satellite observations. The basic data used for preparation of the summaries are available through either the National Center for Atmospheric Research in Boulder, Colorado or the National Climatic Data Center in Asheville, North Carolina.

AR-153

Gillani, N,, V., W.H. White, and J.S. CHING. A semi-empirical mass balance approach for estimating primary emissions of reactive species from an urban-industrial complex. Proceedings, 80th Annual Meeting of the Air Pollution Control Association, New York, NY, June 21-26, 1987. Air Pollution Control Association, Pittsburgh, 087-58.5 (1987).

No abstract.

AR-154
LAMB, R.G. Design and applications of the Regional Oxidant Model (ROM). Proceedings, North American Oxidant Symposium, Quebec, Canada, February 25-27, 1987. Ministere de l' environment, Quebec, Canada, 154-189 (1987).

The basic design of the EPA's Regional Oxidant Model (ROM) is described and preliminary results are presented of a study of the impact of biogenic hydrocarbon emissions on ozone concentrations in the Northeastern United States. It is shown that the predicted maximum ozone levels during a six day period in July 1980 agree better with observed concentrations when the biogenic component is included in the hydrocarbon emissions then when it is omitted. The largest effects of the biogenic hydrocarbons occur in the Appalachians, downwind of large NO_x sources in the Ohio River, Where peak 1-hour averaged concentrations over the six-day period drop by as much as 50 ppb when the biogenic emissions are shut off.

AR-155
OLTMANS, S.J., W.D. KOMHYR, and R.D. GRASS. Atmospheric ozone at the South Pole during 1986. Antarctic Journal of the United States, 1987 Review, XXII(5):257-259 (1987).

No abstract.

AR-156
Tikvart, J.A., J.L. DICKE, and J.S. TOUMA. Including new modeling techniques in regulatory programs. Proceedings, 80th Annual Meeting of the Air Pollution Control Association, New York, NY, June 21-26, 1987. Air Pollution Control Association, Pittsburgh, Paper 87-73.1 (1987).

No abstract.

AR-157
VAN VALIN, C.C., M. Luria, D.L. WELLMAN, R.L. GUNTER, and R.F. Pueschel. Natural sulfur flux from the Gulf of Mexico: Dimethyl sulfide, carbonyl sulfide, and sulfur dioxide. NOAA TR ERL 432-ARL 9 (PB88-137484), 14 pp. (1987).

Atmospheric measurements of natural sulfur compounds were performed over the northern Gulf of Mexico during the late summer months of 1984. Air samples were collected with an instrumented aircraft at elevations of 30-3500 m, during both day and night. Most air samples were representative of the clean maritime atmosphere, although some were from continental contaminated air during periods of offshore flow at the coastline. In all samples, carbonyl sulfide concentrations were within the range of 400-500 pptv. Conversely, the dimethyl sulfide concentrations showed significant variability: during clean atmospheric conditions the average of all measurements was 27 pptv, whereas under polluted conditions the average was 7 pptv. Measurable quantities of dimethyl sulfide (>5 pptv) were not observed above the boundary layer. The average sulfur dioxide concentration measured in the marine (clean) atmosphere was 215 pptv, which is consistent with the oxidation of dimethyl sulfide being its major source.

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AO-001

Barnes, G.M., E.J. Zipser, and B. Ryan. Rainband structure in developing Tropical Cyclone Irma (1987). Research supported by NOAA Grant 45-WCNR-5-00388. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 151-152 (1989).

Extended abstract.

AO-002

BITTERMAN, D.S., and D.V. HANSEN. Direct measurements of current shear in the tropical Pacific Ocean and its effect on drift buoy performance. Journal of Atmospheric and Oceanic Technology 6(2):274-279 (1989).

Measurements of ocean surface currents derived from drift buoy trajectories are subject to errors caused by slippage of the buoy relative to the surrounding water. This slippage error is caused by a number of forces acting on the buoy and drogue element, one of which is the current shear in the water. Idealized model calculations are used to exemplify some effects of vertical current shear on drogues, and on the performance of drogued buoy systems in current shear. It is shown that shear enhances the performance of drogues, and that long drogues should perform better than short drogues in shear, but shear also can induce slippage by adding drag force to the buoy hull. To establish environmental design parameters, average and rms current shear values between 9.7 m and 22.5 m depth were computed from Doppler acoustic current profiler measurements from the tropical Pacific Ocean. Largest values of shear ($\sim$0.25 s^{-1} rms) were found near the equator in the eastern Pacific as expected. Elsewhere the shear was generally less than 0.02 s^{-1}, mostly less than 0.01 s^{-1}. Average values of shear were generally less than 0.007 s^{-1}.

AO-003

BLACK, M.L. Signal loss of WSR-57 radars as a function of range in tropical cyclones. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 514-517 (1989).

No abstract.

AO-004

BLACK, M.L., and F.D. MARKS, JR. Concentric eyewalls in Hurricane Gilbert (1988). Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 224-225 (1989).

Extended abstract.

AO-005

BLACK, P.G., R.L. Elsberry, L.K. Shay, R.M. Partridge, and J.D. Hawkins. Atmospheric boundary-layer and oceanic mixed-layer observations in Hurricane Josephine obtained from air-deployed drifting buoys and research aircraft. Journal of Atmospheric and Oceanic Technology 5(6):683-698 (1988).

Three drifting buoys were successfully air-dropped ahead of Hurricane Josephine. This deployment resulted in detailed simultaneous measurements of surface wind speed, surface pressure and subsurface ocean temperature during and subsequent to storm passage. This represents the first time that such a self-consistent data set of surface conditions within a tropical cyclone has been collected. Subsequent NOAA research aircraft overflights of the buoys, as part of a hurricane planetary boundary-layer experiment, showed that aircraft wind speeds, extrapolated to the 20 m level, agreed to within $\pm$ 2 m s^{-1}, pressures agreed to within $\pm$ 1 mb, and sea-surface temperatures agreed to within $\pm$ 0.8°C of the buoy values. Ratios of buoy peak 1 min wind (sustained wind) to 1/2 h mean wind > 1.3 were found to coincide with eyewall and principal rainband features. Buoy trajectories and subsurface temperature measurements revealed the existence of a series of mesoscale eddies in the subtropical front. Buoy data revealed storm-generated, inertia-gravity-wave motions superposed upon mean current fields, which reached a maximum surface speed > 1.2 m s^{-1} immediately following storm passage. A maximum mixed-layer temperature decrease of 1.8°C was observed to the right of the storm path. A temperature increase of 3.5°C at 100 m and subsequent decrease of 4.8°C following storm passage indicated a combination of turbulent mixing, upwelling and horizontal advection processes.

AO-006

BLACK, P.G., L.K. Shay, R.L. Elsberry, and J.D. Hawkins. Response of the Gulf of Mexico to Hurricane Gilbert. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 226-227 (1989).

Extended abstract.

AO-007

BURPEE, R.W. A summer day without significant rainfall in south Florida. Monthly Weather Review 117(3): 680-687 (1989).

Precipitating cumulus clouds occur regularly in the afternoon over the south Florida peninsula during summer months. A day without significant rainfall or radar echoes is rare. This paper discusses one such day, 23 July 1987, during which a dry, stable airmass covered the Florida peninsula. Nonprecipitating shallow cumulus formed in a few areas, but there were not any deep, precipitating cumulus clouds over land. The thermodynamic characteristics of the airmass are described and the synoptic-scale patterns that produced the airmass are presented.

AO-008

BURPEE, R.W., and M.L. BLACK. Temporal and spatial variations near the centers of two tropical cyclones. Monthly Weather Review 117(10):2204-2218 (1989).

The Hurricane Research Division collected radar reflectivity data with a portable recorder that was attached to the WSR-57 radar at National Weather Service offices as Hurricane Alicia of 1983 and Elena of 1985 approached the U.S. coastline. The reflectivity data were used to compute rain rates for the eyewall region, including the rain-free eye and the rainbands in the annular area outside the eyewall, but within 75 km of the center of the eye. Area- and time-averaged rain rates (R) in the eyewall region were 5.2 and 6.0 mm h^{-1}, respectively, for Alicia and Elena. The corresponding averages in the rainband region were 2.8 and 3.4 mm h^{-1}. The rain rates include reflectivity corrections that were based upon the variation of average returned power with range in four hurricanes. Precipitation was convective in the eyewall region and largely stratiform in the rainband region. Comparison with published results from other tropical cyclones suggests that the corrected R's in the eyewall region are underestimated, but are within a factor of 1.6 of the actual amount. The R's in the rainband region, however, are similar to those from other studies. Alicia's eyewall region represented ~15% of the computational area and contributed ~25% of the total rain rate within 75 km of the center of the eye. Elena's eyewall region comprised ~22% of the area and contributed ~33% of the area-averaged rain rate. The area-averaged rain rate (R) in the eyewall region of both hurricanes varied by up to 4 mm in 1-2 h. In Alicia, the variations of R were caused by the growth and decay of mesoscale convective areas with reflectivity > 38 dBZ that achieved maximum areas of 500-800 km^2. In Elena, life cycles of individual convective cells with maximum reflectivities > 48 dBZ also accounted for large changes in the eyewall R. In both hurricanes, the time series of R in the rainband regions were less variable than the eyewall R because the rainband regions included larger areas than the eyewall and had a smaller percentage of area with convective activity. For several hours, the maximum rain rates in the eyewall and rainband regions of Alicia occurred in the left-front quadrant relative to the storm motion. Then the maximum rain rate in the eyewall region shifted to the right-front quadrant and the maximum in the rainband region moved to the right of the storm track. In Elena, the maximum rain rates in the eyewall and rainband regions were in the right-front quadrant throughout the computational period. About 55% of the precipitation in Elena's eyewall region occurred in the right-front quadrant. In both hurricanes, the maximum rain rate in the rainband region was generally oriented to the right of that in the eyewall region.

AO-009

BURPEE, R.W., M.L. BLACK, and F.D. MARKS, JR. Vertical motions measured by airborne Doppler radar in the core of Hurricane Elena. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 69-70 (1989).

Extended abstract.

AO-010

Carbone, R.E., and F.D. MARKS, JR. Velocity track display (VTD): A real-time application for airborne Doppler radar data in hurricanes. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 11-12 (1989).

Extended abstract.

AO-011

Carder, K.L., R.G. Steward, G.R. HARVEY, and P.B. ORTNER. Marine humic and fulvic acids: Their effects on remote sensing of ocean chlorophyll. Limnology and Oceanography 34(1):68-81 (1989).

Marine humic and fulvic acids were concentrated from about 1,400 liters of seawater from the Gulf of Mexico, and specific absorption coefficients were measured for each from 240 to 675 nmi. Spectral absorption coefficients were then calculated for Gulf of Mexico stations where earlier data on humic and fulvic acid concentrations were available. Marine humic and fulvic acid values have low molecular weights consistent with extrapolations from soil-derived curves of their specific absorption coefficients vs. molecular weight. Marine fulvic and humic acids appear to account for most, if not all, water color or Gelbstoff in the offshore regions of the Gulf of Mexico. Based on a remote-sensing reflectance model, it appears that the increase in the Gelbstoff: chlorophyll ratio for waters adjacent to and downstream from regions of high primary productivity accounts for much of the deviation found for such waters from the global chlorophyll algorithm of the Coastal Zone Color Scanner.

AO-012

CLARKE, T.L., J.R. PRONI, and L.C. Huff. Joint CGS-AOML acoustical bottom echo-formation research II: Field experiment results and recommendations for echo-sounder design. NOAA TM ERL AOML-67 (NTIS number not yet available), 71 pp. (1989).

Field experiments were conducted to test and verify a mathematical model that has been developed to assess the effects of bottom roughness and material properties on bottom echo shape. The physical basis of the model is reviewed and model output is presented. The experiments were conducted in lower Chesapeake Bay and involved taking high resolution acoustic data at a number of frequencies and taking supporting sediment samples. A unique, high-resolution bottom profiler was used to measure bottom roughness profiles for input to the model. While model predictions were in general agreement with the data, fine structure was observed in the echoes that could not be explained by the existing model. An extension to the model has been developed that is able to account for this structure. The essential ingredient of this extension is to consider bottom surface scattering as arising from a number of statistically independent patches within the transducer beam. This revised model should lead to improved predictions of bottom echo waveforms for echo-sounder design. The algorithm developed for removing ship motion from the observations suggests a design for a new type of echo-sounder detector circuit based on an energy threshold. This circuit could be easily implemented with modern digital signal processing (DSP) circuits, and it might be suitable for retro-fitting to existing echo-sounders.

AO-013

DEMARIA, M. A nested spectral model for hurricane track forecasting. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 206-207 (1989).

Extended abstract.

AO-014

DEMARIA, M., J.M. Davis, and D.M. Wojtak. Observations of mesoscale wave disturbances during the Genesis of Atlantic Lows Experiment. Monthly Weather Review 117(4):826-842 (1989).

The Portable Automated Mesonet (PAM) data obtained during the Genesis of Atlantic Lows Experiment (GALE) are used to document mesoscale wave activity during the three-day period from 4-6 February 1986. From the surface pressure analyses, four cases of wave activity are identified with wavelengths of 200-400 km, phase speeds of 20-40 m s^{-1}, and trough-to-crest pressure amplitudes of 0.5-3.5 mb. Precipitation was associated with the waves in two of the four cases. Detailed analyses of the horizontal structure show that the waves do not have the pressure-wind relationship expected from linear gravity wave theory. The wind vectors are oriented from high to low pressure, with a maximum amplitude between the high- and low-pressure areas. Low-level inversions were present in three of the four cases. In the case without a low-level inversion, the amplitude rapidly decreased as the wave moved towards the east. In the case that lasted for the longest time period (at least 8 h) and had the largest pressure amplitude, the sounding had a critical level (where the wind speed equaled the wave speed) and a level where the Richardson number was < 0.25. Vertical velocities as large as 30 cm s^{-1} were observed and there was some evidence that the wave was vertically tilted towards its direction of motion. Complex principal component analysis (CPCA) is applied to the surface pressure data to determine the applicability of this technique to the study of mesoscale waves. It is shown that CPCA could be used to generalize the results of this study to the entire 60-day period of GALE.

AO-015

DODGE, P.P. The precipitation structure of Hurricane Elena. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 522-524 (1989).

No abstract.

AO-016

Eberhart, G.L., P.A. RONA, and J. Honnorez. Geologic controls of hydrothermal activity in the Mid-Atlantic Ridge rift valley: Tectonics and volcanics. Marine Geophysical Research 10:233-259 (1988).

The rift valley at three widely separated sites along the Mid-Atlantic Ridge is characterized using geological and geophysical data. An analysis of bottom photographs and fine-scale bathymetry indicates that each study area has a unique detailed geology and structure. Spreading rates are apparently asymmetric at each site. Relationships between tectonic and volcanic structure and hydrothermal activity show that various stages in the evolution of the rift valley are most favorable for seafloor expression of hydrothermal activity. In a stage found at 26°08′N, site 1 (TAG), the rift valley is narrow, consisting of both a narrow volcanically active valley floor and inner walls with small overall slopes. High-temperature hydrothermal venting occurs along the faster spreading eastern inner wall of this U-shaped rift valley. Site 2 (16°46′N) has a narrow valley floor and wide block faulted walls and is at a stage where the rift valley is characterized by a V-shape. No neovolcanic zone is observed within the marginally faulted, predominantly sedimented floor and hydrothermal activity is not observed. The rift valley at site 3 (14°54′N), with postulated extrusive volcanic activity and a stage in valley evolution tending toward a U-shape, shows evidence of hydrothermal activity

within the slightly faster spreading eastern inner wall. Evidence for tectonic activity (inward- and outward-facing faults and pervasive fissuring) exists throughout the wide inner wall. Hydrothermal activity appears to be favored within a U-shaped rift valley characterized by a narrow neovolcanic zone and secondarily faulted inner walls.

AO-017
ENFIELD, D.B. El Niño, past and present. Reviews of Geophysics 27(1):159-187 (1989).

El Niño events - anomalous warmings of the tropical Pacific with associated climatic and economic impacts around the globe - have occurred at several-year intervals since before written records began with the logs of Francisco Pizarro in 1525. In this review, the history of El Niño research is traced from its beginnings through the key innovations of Bjerknes and Wyrtki to the unusual 1982-1983 event. Recent research is then reviewed, with detailed discussions of the key processes: instability growth and vacillation between climate states. Throughout the paper there are adjunct discussions of extraregional teleconnections, ecological impacts, and research on El Niño in the ancient record. The final section discusses the present paradigm for vacillations between El Niño and non-El Niño states and speculates on the possible chaotic nature of El Niño. El Niño and its atmospheric counterpart, the Southern Oscillation, appear to occur as an internal cycle of positive and negative feedbacks within the coupled ocean-atmosphere climate system of the tropical Pacific, although hypotheses based on external forcing also exist. All events are preceded by westerly wind anomalies on the equator near the date line. Baroclinic equatorial Kelvin waves are generated, propagating eastward toward South America where they depress the thermocline and raise sea level, while the deep, upper ocean reservoir of warm water in the western Pacific is depleted. Sea surface temperature (SST) anomalies in the cool eastern Pacific occur primarily because the normal source of cold water is depressed below the reach of mixing and upwelling processes. In the central equatorial Pacific, eastward advection by anomalous zonal flows is the principal mechanism. Nonlinear heat transfer to the lower atmosphere creates a positive ocean-atmosphere feedback resulting in the unstable growth of anomalies along the equator. Much of the present research aims at determining how the ocean-atmosphere system vacillates between the El Niño and non-El Niño states. Coupled models suggest that a longer time scale, negative-feedback process produces the transitions: at the apex of an El Niño development an anomalous atmospheric convection above the areas of reduced upper layer thickness in the off-equatorial ocean, which slowly propagate westward to the western boundary as Rossby waves and back to the central equatorial Pacific as upwelling Kelvin waves, re-establishing the normal cooling process. A similar negative feedback of opposite sign completes the second half of an oscillation, returning again to the El Niño state. However, the notion that El Niño/Southern Oscillation variability results only from an internal feedback process is still highly contentious and a number of external forcing mechanisms have been proposed.

AO-018
ENFIELD, D.B. Is El Niño becoming more common? Oceanography 1(2):23-27 (1988).

No abstract.

AO-019
FRANKLIN, J.L. Objective analyses of Omega dropwindsonde data from Hurricane Josephine (1984). Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorology Society, Boston, 204-205 (1989).

Extended abstract.

AO-020
FRANKLIN, J.L., C.S. Velden, C.M. Hayden, and J. KAPLAN. A comparison of VAS and ODW data around a subtropical cold low. Extended Abstracts, 4th Conference on Satellite Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 141-144 (1989).

Extended abstract.

AO-021
GAMACHE, J.F. Retrieval of thermodynamic and microphysical variables from airborne Doppler observations in Hurricane Norbert (1984). Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 525-528 (1989).

No abstract.

AO-022
GAMACHE, J.F. The eyewall water budget of Hurricane Norbert (1984) as determined from airborne Doppler radar. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 73-74 (1989).

Extended abstract.

AO-023

Georges, T.M., D.R. PALMER, R.M. Jones, and J.P. Riley. A survey of acoustic techniques for monitoring El Niño. Journal of the Acoustical Society of America 84:S91 (1988).

The challenge of understanding the El Niño-Southern Oscillation (ENSO) cycle in the equatorial Pacific Ocean is a test of one's abilities to observe, model, and forecast the processes of global climate change. Monitoring the structure, dynamics, and energetics of the ocean interior on the space-time scales of the ENSO signal appears to be a task for acoustic remote sensing. Therefore, the following acoustic strategies for monitoring ENSO-induced changes in the upper ocean are examined: (1) ocean acoustic tomography; (2) a long-range acoustic thermometer; (3) passive monitoring of ambient acoustic noise level; (4) an occultation technique that depends on bottom absorption; and (5) space-time scintillation analysis. Models of the ocean's acoustic properties are formulated from measurements made during the 1982-1983 ENSO event and we simulate acoustic amplitude and travel-time measurements to find out how sensitive they are to the temperature changes that accompany a strong El Niño.

AO-024

HANSEN, D.V. Physical aspects of the El Niño event of 1982-1983. In Global Ecological Consequences of the 1982-83 El Niño-Southern Oscillation, P.W. Glynn (ed.). Elsevier Oceanography Series (preprint) (1989).

El Niño events are marked by the appearance of anomalously warm ocean waters and unusual rainfall in normally arid coastal regions of Ecuador and Peru. During the past century such events have occurred at about four-year intervals on average, and nine of the events have been described as strong or very strong. In the spring of 1982 the heavy rainfall that normally characterizes the Indo-Pacific archipelago began to shift eastward toward the central Pacific. During the following year the region of anomalous rainfall traversed the ocean to the coast of South America, in phase with anomalous winds, currents, and sea surface temperatures. At the peak of the event in the eastern tropical Pacific, Peru and Ecuador experienced record-setting rainfall leading to flooding and avalanches, near surface ocean currents reversed from their normal direction, sea surface temperature rose to 5°C or more above normal, the thermocline plunged to 100 m or more below normal, and sea level rose to nearly half a meter above normal. Upon reaching the coast, many of the oceanic perturbations propagated poleward along the continental margins in both hemispheres, carrying the signs and effects of El Niño to middle and high latitudes in the Pacific. The magnitude of this event made it the "event of the century" in most variables, and the event of several centuries in some. The magnitude of perturbation of the atmosphere in the tropical Pacific sector certainly carried anomalies also in distant regions of the atmosphere, and thereby secondarily in other parts of the ocean. At greater distance, however, it becomes increasingly difficult to distinguish between anomalies resulting from El Niño and those arising from other kinds of variations of the atmospheric circulation.

AO-025

HANSEN, D.V., and A. HERMAN. A seasonal isotherm depth climatology for the eastern tropical Pacific. NOAA TR ERL 434 AOML-33 (Revised) (NTIS number not yet available), 35 pp. (1989).

A seasonal climatology of the depths of the 10°C, 15°C, and 20°C isotherms in the eastern tropical Pacific is presented. The analyses used Kriging, which is a method for optimal interpolation of data fields. The data set consisted of 10,505 expendable bathythermograph (XBT) and conductivity-temperature-depth (CTD) stations collected during non-El Niño years. Results are presented on shaded contour maps with values overprinted at 2° intervals. The method of analysis also yields an estimate of the uncertainty of each interpolated point.

AO-026

HANSEN, D.V., and A. HERMAN. Temporal sampling requirements for surface drifting buoys in the tropical Pacific. Journal of Atmospheric and Oceanic Technology 6(4):599-607 (1989).

Drifting buoy data from the eastern tropical Pacific Ocean are used to evaluate the degradation of sea surface temperature and current information incurred by reducing the number of transmissions from drifting buoys using the ARGOS system for position finding. Buoy locations are interpolated at uniform time intervals using an optimum interpolation method known as Kriging, which provides also an estimate of the rms position error. It is found that the published standard for surface current measurement for the TOGA Program (5 cm s^{-1}) can be met with transmissions on one day of three in the Southern Hemisphere. Due to stronger mesoscale variability in the Northern Hemisphere the standard would be jeopardized by reducing transmissions even to one day of two. The standard for observation of sea surface temperature (0.1°C) can be met in either hemisphere with transmissions on one day of four. The Lagrangian decorrelation times for the Northern Hemisphere region of the eastern tropical Pacific are estimated as four days in the meridional direction, and 14 days in the zonal direction. It is recommended that transmissions be made on one day of three, and the time scale for the TOGA standard be revised accordingly.

AO-027

HANSON, K., and G.A. MAUL. Analysis of the historical meteorological record at Key West, Florida (1851-1986) for evidence of trace-gas induced climate change. In Chapter 2.1, Implications of Climatic Changes in the Wider Caribbean Region. United Nations Environment Programme, UNEP (OCA)/CAR WG.1/INF.3, 27-35 (1989).

Meteorological data for Key West, Florida have been examined for evidence of changes during recent decades that may be attributed to increasing trace gases in the atmosphere. The 136-year temperature record (1851–1986) gives evidence that a warming has occurred. However, there are questions of the reality of the warming, because of the mix of temperature observing conditions over the period of record. The 101-year precipitation record (1886–1986) gives evidence that no significant change in precipitation has occurred during the period of record. Future work on the reality of the apparent warming at Key West is suggested.

AO-028

HANSON, K., G.A. MAUL, and T.R. Karl. Are atmospheric "greenhouse" effects apparent in the climatic record for the contiguous U.S. (1895–1987)? Geophysical Research Letters 16(1):49–52 (1989).

The temperature and precipitation climate records for the United States have been examined. These records consist of area-averages across the contiguous United States and northern plains. They are based on as many as 6,000 stations. Time series of these data were tested for constancy of the mean using the Spearman rank test and two-phase regression. Test results indicate that overall trends are near zero. The only evidence for a long-term trend is in fall precipitation for the contiguous United States. This trend appears to result from higher fall precipitation during the period 1970–1987 compared to the remainder of the period (1895–1969).

AO-029

HARVEY, G.R., and M.S. YOUNG. Ozone in seawater and lake water: A reversible reservoir. Geophysical Research Letters 15(11):1199–1201 (1988).

Observations made at sea and examination of global ozone monitoring data from oceanic sites indicate that ozone mixing ratios often increase with increasing wind speed. However, the slope of the increase approaches zero at wind speeds above about 6 m/sec (13 kts). Subsequent laboratory experiments confirmed that ozone can be purged from any seawater sample whether freshly collected, stored, or from depths of 3,500 m. Samples of Lake Michigan water are purged of ozone in less time than seawater and its capacity is less than that of seawater. The rate of evolution of ozone is increased by altering the pH, changing the ionic strength by the addition of salts or by evaporation. These results suggest that a significant portion of tropospheric boundary layer ozone mixing ratios could be maintained by a reversible equilibrium with the ocean and lake surfaces.

AO-030

HIRSH, M.A., and H.A. FRIEDMAN. Creating an awareness of the hurricane problem in at-risk coastal communities of south Florida. Proceedings, 2nd Conference on School and Popular Meteorological Education, Crystal City, VA, July 12–16, 1989. American Meteorological Society, Boston, 160–162 (1989).

Extended abstract.

AO-031

Houze, R.A., Jr. Observed structure of mesoscale convective systems and implications for large-scale heating. Research partially supported by NOAA Grant 40-WCNR-6-02428. Quarterly Journal of the Royal Meteorological Society 115(487):425–461 (1989).

Mesoscale convective cloud systems that produce large amounts of rain in midlatitudes and most of the rain in the tropics consist of convective and stratiform clouds. The convective regions contain numerous deep cells that are often, but not always, arranged in lines. The stratiform region is an outgrowth of the convective ensemble; it lies adjacent to the convective region and is seeded by ice particles detrained from convective towers. Sometimes it lies to the rear of a propagating convective line, while on other occasions it surrounds the convection. The heating of the large-scale environment by a mesoscale convective system is affected by both the convective and stratiform regions. Although processes such as melting and radiation are important, the net heating system is dominated by condensation and evaporation associated with vertical air motions. This paper reviews recent observational evidence regarding the mean vertical motion profiles in the convective and stratiform regions of mesoscale convective systems and the implications of these mean motions for the vertical distribution of heating of the large-scale environment. In both the convective and the stratiform regions, vertical motions have been determined by various techniques, including composites of rawinsonde and aircraft wind data, single- and dual-Doppler precipitation radar analyses, and wind-profiler observations. In stratiform regions, these data consistently show vertical velocity that is upward in the upper troposphere and downward in the lower troposphere. The level separating upward from downward motion is located from 0 to 2 km above the 0°C level, depending on location within the stratiform region. Diagnostic calculations show that these vertical motion profiles imply heating of the upper troposphere and cooling of lower levels by stratiform-region processes. Data on vertical motions in the convective regions are less consistent from case to case. These data sometimes indicate that the mean vertical velocity in convective regions is maximum in the lower troposphere. In other cases, the data indicate a maximum in the high troposphere. Diagnostic calculations show that heating profiles diagnosed from these two types of profile are quite different, the first having a maximum of heating in the lower troposphere, while the second has a maximum in the middle troposphere. Although it is difficult to determine whether or not the differences in estimates arise from different types of observations, analysis methods or sampling strategies, it seems likely that they stem from differences in the

large-scale environment of the different mesoscale systems. The ubiquitous occurrence of stratiform regions in mesoscale convective systems and hurricanes, together with their consistent heating profiles which systematically concentrate heating in upper levels while cooling lower levels, are a major consideration in evaluating the interaction of mesoscale systems with the large-scale environment. However, the consistency of the stratiform profiles from case to case lies primarily in the variation of the convective-region profiles from one case to another. It is suggested that future work should focus on the convective-region vertical profiles of vertical motion and heating and on the large-scale environmental factors that may control the variation of these profiles from case to case.

AO-032

JOHNS, E., D.R. Watts, and H.T. Rossby. A test of geostrophy in the Gulf Stream. Journal of Geophysical Research 94(C3):3211-3222 (1989).

In July 1982 two detailed sections of density and absolute velocity were taken across the Gulf Stream northeast of Cape Hatteras to conduct an accurate test of geostrophy in a strong current. The sections, which were taken about four days apart, were each completed within 48 hours, using one ship to make closely spaced (12 km) conductivity-temperature-depth measurements to 2,000 m, and a second ship to simultaneously take Pegasus absolute velocity profiles to the ocean bottom. The Gulf Stream path and curvature were also surveyed. The dynamically inferred velocity profiles were made absolute by matching their velocities to the Pegasus profiles at 2,000 m. The geostrophic method (properly referenced) underestimated the observed velocities by 10-25 cm s^{-1} in the core of the current above 500 m where speeds exceeded 150 cm s^{-1}. The difference is a factor of 2 larger than the sampling and measurement errors in corresponding parts of the current, estimated to be 5-10 cm s^{-1} in the strong current and 2-5 cm s^{-1} elsewhere. We can account for the supergeostrophic currents quite effectively by including the centripetal acceleration (from the path curvature) in the momentum equation. In this case the differences in the current core decrease to less than 5-10 cm s^{-1}, well within the uncertainties of the method. The transport above 2,000 m is less sensitive to curvature effects; it agrees to within 3 Sv before and 1 Sv after correcting for curvature, or approximately 2% of the total 93 Sv transport. The deep velocity field below 1,000 m had significant changes (10-20 cm s^{-1}) in structure, and even reversals, in the four days between the sections, with cross-stream scales of 50-100 km. This deep variability, attributed to topographic Rossby waves, introduces more than 10 Sv uncertainty in defining the total volume transport of the Gulf Stream.

AO-033

Landsea, C.W., H.E. WILLOUGHBY, and J.M. Masters. Analysis of Hurricane Gilbert at its maximum intensity. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 222-223 (1989).

Extended abstract.

AO-034

Leaman, K.D., E. JOHNS, and T. Rossby. The average distribution of volume transport and potential vorticity with temperature at three sections across the Gulf Stream. Journal of Physical Oceanography 19(1):36-51 (1989).

Average cross sections of downstream velocity and temperature, obtained using PECASUS current profilers at three locations along the Gulf Stream, have been portioned into 2.5°C temperature intervals to examine the distribution of transport increase versus temperature between the two southern sections (27° and 29°N) and off Cape Hatteras (73°W). Between 27°N and 29°N the total transport of the Florida Current over the sections increased only by about 3 x 10^6 m^3 s^{-1} (3 Sv) but the current broadens by about 50%. By Cape Hatteras, the transport has increased nearly three-fold to 93.7 Sv, of which two-thirds of the increase is contained in the 19.5°-17.0°C ("18°") layer and in water colder than the 7°C "sill" temperature found at 27°N. Cross-stream distributions of layer transport, potential vorticity, and thickness are estimated. At each section, the 10 x 10^{-7} m^{-1} s^{-1} contour tends to be a boundary (independent of temperature) between the region of relatively uniform layer potential vorticity on the anticyclonic (offshore) side of the current and an area with high lateral potential vorticity gradients on the cyclonic (onshore) side. In the colder (< 7°C) waters off Cape Hatteras, layer potential vorticity also tends to be uniform at ~5 x 10^{-7} m^{-1} s^{-1}. Layer potential vorticity in the 18° layer is quite uniform with minimum values ~3.5 x 10^{-7} m^{-1} s^{-1} at 27° and 29°N and somewhat less off Cape Hatteras, which is close to where 18°C water is formed in the wintertime. At Cape Hatteras this same layer shows a peak in transport/unit width at the point where the layer begins to thin as one moves into the Gulf Stream core from the southeast. A simple model based on conservation of layer potential vorticity is proposed to describe this transport structure.

AO-035

Liao, Q., and M.C. PAZOS. Drifting buoy data from western tropical Pacific for the period February 1, 1986 through February 28, 1989. NOAA DR ERL AOML-14 (NTIS number not yet available), 125 pp. (1989).

No abstract.

AO-036

LONG, R.B., and W.C. THACKER. Data assimilation into a numerical equatorial ocean model. Part I: The model and the assimilation algorithm. Dynamics of Atmospheres and Oceans 13:379-412 (1989).

Numerical modeling provides a powerful tool for the study of the dynamics of oceans and atmospheres. However, the relevance of modeling results can only be established by reference to observations of the system being modeled. Typical oceanic observation sets are sparse, asynoptic, of mixed type and limited reliability, generally inadequate in some respects, and redundant and inconsistent in others. An optimal procedure for interfacing such data sets with a numerical model is the so-called adjoint method. This procedure effectively assimilates the observations into a run of the numerical model by finding that solution to the model equations that best fits all observations made within some specified space-time interval. The method requires the construction of the adjoint of the numerical model, a process made practical for models of realistic complexity by the work of Thacker and Long (1988). In the present paper, the first of two parts, we illustrate the application of Thacker and Long's approach by constructing a data-assimilating version of an equatorial ocean model incorporating the adjoint method. The model is subsequently run for five years to near-steady state, and exhibits many of the features known to be characteristic of equatorial oceanic flows. Using the last 54 days of the run as a control, a set of simulated sea level and subsurface density observations are collected, then successfully assimilated to demonstrate that the procedure can recover the control run, given a generous amount of data. In part II (Long and Thacker, 1989), we conduct a sequence of numerical experiments to explore the ability of more limited sets of observations to fix the state of the modeled ocean; in the process, we examine the potential value of sea level data obtained via satellite altimetry.

AO-037

LONG, R.B., and W.C. THACKER. Data assimilation into a numerical equatorial ocean model. Part II: Assimilation experiments. Dynamics of Atmospheres and Oceans 13:413-439 (1989).

A sequence of numerical experiments is conducted using a linear, semi-spectral equatorial ocean model and an advanced data assimilation scheme. The numerical model is based on decomposition of the oceanic fields into Kelvin and Rossby waves belonging to the baroclinic modes of a stratified equatorial ocean. The assimilation procedure finds that solution to the model equations that best fits, in the generalized least-squares sense, all observations made within some specified space-time interval. All experiments are of the "identical twin" type; synthetic data are generated by sampling the observable fields produced by a control run of the model, then the data are assimilated using the same model. The sequence of numerical experiments serves two purposes: to demonstrate the performance of the assimilation procedure in the context of a fully three-dimensional, time-varying equatorial ocean model; and to examine the utility of specified data sets, and in particular, observations of sea level, in estimating the state of the equatorial ocean. The results indicate that the assimilation procedure works very well when sufficient data are provided. However, sea level data alone are not sufficient and must be supplemented with subsurface observations if more than a few baroclinic modes are allowed in the model ocean. The required amount of supplementary subsurface data (in the form of density profiles in these experiments) can be reduced by imposing smoothness constraints on the recovered model solution.

AO-038

LORD, S.J. Vorticity advection from nested analyses of the hurricane environment. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 202-203 (1989).

Extended abstract.

AO-039

Lyons, W.A., M.G. Venne, P.G. BLACK, and R.C. Gentry. Hurricane lightning: A new diagnostic tool for tropical storm forecasting? Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 113-114 (1989).

Extended abstract.

AO-040

MARKS, F.D., JR. Kinematic structure of the inner core of hurricanes as viewed by airborne Doppler radar. Proceedings, 3rd Interagency Airborne Geosciences Workshop, La Jolla, CA, February 21-24, 1989. American Meteorological Society, Boston, IV-79-IV-81 (1989).

Extended abstract.

AO-041

MARKS, F.D., JR. Radar observations of tropical weather systems. In Radar in Meteorology, D. Atlas (ed.). American Meteorological Society, Boston, 1024 pp. (1989).

No abstract.

AO-042
MARKS, F.D., JR. Three-dimensional structure of the eyewall of Hurricane Emily (1987) as determined from an airborne Doppler radar. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 71-72 (1989).

Extended abstract.

AO-043
MARKS, F.D., JR., and S.J. LORD. Kinematic structure of Hurricane Gloria as viewed by airborne Doppler radar and Omega dropwindsondes. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 529-532 (1989).

No abstract.

AO-044
MAUL, G.A. Climate change and sea level rise in the Caribbean region. The Siren 39:15-17 (1989).

No abstract.

AO-045
MAUL, G.A., Editor, Implications of climatic changes in the wider Caribbean region. Draft Report, United Nations Environment Programme, UNEP(OCA)/CAR WG.1/INF.3, 183 pp. (1989).

No abstract.

AO-046
MAUL, G.A. Implications of climatic changes in the wider Caribbean region: An overview. In Coping with Climate Change, J.C. Topping (ed.). Climate Institute, Washington, D.C., 432-458 (1989).

No abstract.

AO-047
MAUL, G.A., and N.J. BRAVO. Fate of satellite-tracked buoys and drift cards off southeastern Atlantic coast of the United States. Florida Scientist 52(3):154-170 (1989).

Twelve satellite-tracked drifting buoys were released, one each month between April 1984 and March 1985, at the 75 m isobath, 70 km southeast of Cape Canaveral, Florida. Starting in May 1984, 500 drift cards were also released at each buoy deployment from the same site (28°N, 80°W). In addition, satellite-tracked buoys from May 1979, September 1983, and February 1985, which drifted into or through the area, were studied for information about surface currents and particle trajectories. All 12 buoys from the 28°N/80°W launch site drifted north past Cape Canaveral (28.5°N); only the May 1984 buoy drifted into the coastal zone off Mayport, FL (30.4°N), although several others showed a tendency to do so in that area. Every buoy deployed within 5 km of the western edge of the Gulf Stream was entrained into the current, and some as far as 25 km were also entrained. The September 1983 buoy, which was deployed slightly west of 28°N/80°W, and the February 1985 buoy, which was deployed in the Gulf of Mexico, both came ashore near St. Lucie Inlet, FL (27.2°N), 140 km south of Cape Canaveral. Drift cards from May, September, October, and November 1984, and February 1985 were recovered west and north of 28°N/80°W. Forty percent of the cards recovered were from south of Cape Canaveral; Cocoa Beach, FL (28.3°N), and Pontevedra Beach, FL (30.2°N), reported most of the returns. For those months when drift cards were returned, buoy trajectories showed little correlation with drift card vectors. Drift cards established the possibility of materials coming ashore along the Florida Atlantic coast, both north and south of Cape Canaveral, particularly in the autumn.

AO-048
MAUL, G.A., and K. HANSON. Sea level variability in the IntraAmerican Sea with concentration on Key West as a regional example. In Chapter 2.7, Implications of Climatic Changes in the Caribbean Region. United Nations Environment Programme, UNEP (OCA)/CAR WG.1/INF.3, 89-101 (1989).

No abstract.

AO-049
MAUL, G.A., and N.M. KAVANAGH. English-Spanish bibliography in physical oceanography and climate for the Caribbean Sea and adjacent regions. Intergovernmental Oceanographic Commission of UNESCO, IOC/INF-783, 49 pp. (1989).

No abstract.

AO-050

MAUL, G.A., D.A. MAYER, M. BUSHNELL, and K. HANSON. Volume transport fluctuations in the Gulf Stream system modeled from Florida sea level records, 1931-1988. Proceedings, Chapman Conference on the Physics of the Gulf of Mexico. American Geophysical Union, 12 (1989).

No abstract.

AO-051

McCreary, J.P., Jr., H.S. Lee, and D.B. ENFIELD. The response of the coastal ocean to strong offshore winds: With application to circulation in the Gulfs of Tehuantepec and Papagayo. Journal of Marine Research 47:81-109 (1989).

Two ocean models are used to investigate the response of the coastal ocean to strong offshore winds: a linear 1 1/2-layer model, and a non-linear 1 1/2-layer model that allows entrainment of cool water into the surface layer. The models are forced by wind stress fields similar in structure to the intense winter-time, mountain-pass jets ($\sim$20 dyne/cm^2) that appear in the Gulfs of Tehuantepec and Papagayo for periods of three to ten days. Solutions are arranged in a hierarchy of increasing dynamical complexity, in order to illustrate the important physical processes. They compare favorably with observations in several ways. Some properties of solutions are the following. While the wind strengthens there is an ageostrophic current (not Ekman drift) that is directed offshore. This offshore drift forces coastal upwelling, thereby lowering the local sea level and sea surface temperature (SST). Although the drop in sea level at the coast can be large and rapid (of the order of 20 cm at the peak of a wind event), none of this signal propagates poleward as a coastally-trapped wave. While the wind weakens the ageostrophic current is directed onshore, and consequently the coastal ocean readjusts toward its initial state. Throughout the wind event, cyclonic and anticyclonic gyres spin up offshore on either side of the jet axis due to Ekman pumping. Entrainment cools SST offshore on and to the right (looking onshore) of the jet axis, and virtually eliminates the cyclonic gyre. The advection terms intensify the anticyclonic gyre and give it a more circular shape. After a wind event, the anticyclonic gyre propagates westward due to β. Its propagation speed is enhanced over that of a linear Rossby wave due to the non-linear terms associated with the increased layer thickness at the center of the gyre and with the divergence of momentum flux.

AO-052

Metz, S., J.H. Trefry, and T.A. NELSEN. History and geochemistry of a metalliferous sediment core from the Mid-Atlantic Ridge at 26°N. Geochimica et Cosmochimica Acta 52:2369-2378 (1988).

Fourteen thousand years of hydrothermal deposition are recorded in a metalliferous sediment core recovered from the Trans-Atlantic Geotraverse (TAG) Hydrothermal Field on the Mid-Atlantic Ridge at 26°N. An estimated 26 to > 96% of the sediment at this core site is hydrothermally derived as determined from the $CaCO_3$, Al and Fe data. Layers of essentially pure vent precipitates contain < 3% $CaCO_3$ and < 0.5% Al, with high concentrations of Fe (43%), Cu (4.1%), Zn (1.2%), Mn (1.1%), V (480 ppm), Pb (175 ppm), Cd (32 ppm) and Hg (3.8 ppm). Sediment accumulation rates vary from $\sim$1 to > 30 g/cm^2/1,000 y throughout the core, a function of the intensity of hydrothermal inputs. Distinct hydrothermal events are recorded at 6,000 and 8,500 y B.P. in layers containing > 90% vent-derived material. Vertical metal profiles and interelement relationships in the core result from variable deposition of oxides and sulfides, oxidation and dissolution of sulfide phases and scavenging of metals from seawater.

AO-053

Molinari, J., and D. Vollaro. External influences on hurricane intensity. Part I: Outflow layer eddy angular momentum fluxes. Research supported by NOAA Grants 50-WCNR-6-06096 and 50-WCNR-8-06055. Journal of the Atmospheric Sciences 46(8):1093-1105 (1989).

Outflow layer winds were objectively analyzed every 12 h for six days during the life cycle of Hurricane Elena (1985). A high correlation was found between angular momentum fluxes by azimuthal eddies at large radii and central pressure changes in the storm 27-33 h later. Momentum flux by eddies exceeded that by the azimuthal mean outside the 800 km radius, while vortex spin-up by the eddies reached instantaneous magnitudes as large as 25 m s^{-1}/day. Outflow maxima and minima repeatedly appeared > 1,000 km from the hurricane center and tracked inward with time. The results provide evidence of significant environmental control on the behavior of the storm. After reaching hurricane strength, Elena experienced a major secondary intensification associated with a large inward cyclonic eddy momentum flux produced by the passage of a middle latitude trough north of the hurricane. An outflow maximum appeared radially inside of the eddy momentum source, consistent with balanced vortex theory, and tracked inward with the eddy momentum source during the following 24 h. When the outflow maximum reached the storm core, an extended period of rapid pressure falls followed. It is speculated that these pressure falls represented a response to midlevel spin-up forced by the outflow layer momentum sources. Although environmental forcing dominated the later stages of Elena, the rapid initial intensification of the storm as it moved from land to water appeared to be a precursor to subsequent environmental interactions. The enhanced anticyclonic outflow from this initial deepening reduced the outflow-layer inertial stability, allowing a more radially extended region for external forcing. The secondary intensification of Elena is thus viewed as a cooperative interaction between mesoscale events at the hurricane core and synoptic-scale features in the upper tropospheric environment.

AO-054

Molinari, J., and D. Vollaro. Interaction of a hurricane with a baroclinic wave. Research supported by NOAA Grant 50-WCNR-8-06055. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 50-51 (1989).

Extended abstract.

AO-055

MOLINARI, R.L., and J. Morrison. The separation of the Yucatan Current from the Campeche Bank and the intrusion of the Loop Current into the Gulf of Mexico. Journal of Geophysical Research 93(C9):10,645-10,654 (1988).

Data collected in the eastern Gulf of Mexico during 1974, 1975, and 1976 show that the penetration of the Loop Current into the Gulf is strongly correlated with the location of the Yucatan Current on the Campeche Bank. The Loop does not penetrate far into the Gulf when the Yucatan Current separates from the bank in the vicinity of the Catoche Tongue (i.e., the eastern Campeche Bank). Deep Loop penetrations are correlated with separations farther west on the bank. The angle of the Yucatan Current at separation is also correlated with the location of separation (i.e., smaller angles relative to due east are correlated with separations from farther east on the bank). Thus, small angles at separation are correlated with shallow intrusions of the Loop. Historical temperature data collected in the eastern Gulf are reviewed and support these correlations. Simple conservation of potential vorticity considerations can explain the correlation between the angle at separation and the penetration of the Loop.

AO-056

ORTNER, P.B., L.C. HILL, and S.R. CUMMINGS. Zooplankton community structure and copepod species composition in the northern Gulf of Mexico. Continental Shelf Research 9(4):387-402 (1989).

Zooplankton community structure and copepod species composition are analyzed in samples obtained during spring and winter from three areas of the northern Gulf of Mexico: near the Mississippi River outflow, off Cape San Blas, and in the central Gulf of Mexico. Samples from different regions were distinguishable in correspondence analysis of dominant species and/or functional groups. The near-surface communities of the Mississippi and central Gulf were particularly distinct while Cape San Blas was intermediate in both structure and specific character. Saltier waters directly beneath the Mississippi Plume yielded samples similar to those from near-surface waters well offshore. At the same time near-surface waters off the Mississippi and off Cape San Blas to the west were distinguishable even during spring when the outflow from the Mississippi was at its annual peak. These differences are consistent with the discharge and flow patterns of the Mississippi River plume and the northern Gulf and with systematic differences in such parameters as temperature, salinity and chlorophyll concentration. The implications of these observations upon the feeding environments of the larvae of commercially significant fish species are addressed since both zooplankton prey and larval predators appear to be particularly abundant in the Mississippi River plume environs.

AO-057

OOYAMA, K.V. Thermodynamics in the primitive form for modeling the moist atmosphere. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 157-158 (1989).

Extended abstract.

AO-058

PALMER, D.R., T.M. Georges, and R.M. Jones. New techniques for investigating the properties of chaotic ray paths. Journal of the Acoustical Society of America 84:S91 (1988).

It has been established that acoustic ray paths in a range-dependent ocean environment can exhibit chaotic behavior [Palmer et al., Geophys. Res. Lett. 15, 569-572 (1988)]. The usual techniques for identifying chaotic rays are the examination of Poincaré sections and power spectra of path depth, as well as the observation of exponential sensitivity to initial conditions. These techniques are not always useful, however, and are not directly related to observable signal characteristics. Travel times, ray elevation angle at axis crossings, and upper and lower turning point depths have practical relevance and provide new insights into the character of chaotic rays. Since this effort involved the numerical calculation of ray paths for both the Helmholtz and parabolic equations, procedures were developed for comparing results obtained for the two equations.

AO-059

PALMER, D.R., M.G. Brown, F.D. Tappert, and H.F. BEZDEK. Classical chaos in nonseparable wave propagation problems. Geophysical Research Letters 15(6):569-572 (1988).

Numerical calculations show that acoustic ray paths in a weakly range-dependent, deterministic ocean model exhibit chaotic behavior, that is, have an exponentially sensitive dependence on initial conditions. Since the

ray equations define a nonautonomous Hamiltonian system with one degree of freedom, these results may be understood in terms of recent advances in classical chaos. The Hamiltonian structure of ray equations in general suggests that chaotic ray trajectories will be present in all types of linear wave motion in geophysics when variables do not separate, as in laterally inhomogeneous media.

AO-060

PIOTROWICZ, S.R., R.A. Rasmussen, K.J. HANSON, and C.J. FISCHER. Ozone in the boundary layer of the equatorial Atlantic Ocean. Tellus 41B:314-322 (1989).

Shipboard (~7) ozone and carbon monoxide measurements made in the equatorial Atlantic Ocean south of the inter-tropical convergence zone between 5°N and 10°S and 10°-30°W in August and September of 1986 exhibited variability in excess of a factor of 2. Ozone mixing ratios ranged from < 25 to over 50 ppbv while carbon monoxide mixing ratios ranged from < 50 to over 120 ppbv along the western edge of the equatorial Atlantic in spite of the fact that the prevailing surface winds were from the east to southeast at between 5 and 15 m/sec. Ozone and carbon monoxide mixing ratios were generally lower and exhibited less variability in the eastern tropical Atlantic where a lighter, south to southeasterly wind regime predominated. Isobaric trajectory analyses indicated that the high ozone and carbon monoxide mixing ratios appear to be related to long-range transport off of the African continent. Time series analysis of the ozone data indicates a diel cycle in ozone mixing ratios with a morning maximum and afternoon minimum.

AO-061

POWELL, M.D. Boundary-layer kinematic structure in outer hurricane rainbands. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorology Society, Boston, 67-68 (1989).

Extended abstract.

AO-062

POWELL, M.D. Boundary-layer structure and dynamics in outer hurricane rainbands. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 533-536 (1989).

No abstract.

AO-063

PRONI, J.R., and W.P. DAMMANN. Observations of acoustic backscatter from oceanic wastewater outfalls. Journal of the Acoustical Society of America 85:S42 (1989).

Narrow beam echo sounders were used to characterize the spatial distribution of wastewater plume material from six ocean outfalls in the south Florida area. Volume scattering strengths were computed and plotted as a function of depth and horizontal distance for 200 kHz echoes. Reduction in peak scattering strength with increased range from the outfall locations correlated well with reduction in concentration of Rhodamine-WT dye introduced into the undiluted wastewater at a concentration of 1 ppm. Sound power reflection coefficients ranging from 10^{-5} to 10^{-9} were observed for these wastewater plumes. The data presented demonstrates the degree to which the sound power reflection coefficient for a distribution of scatterers is dependent upon the concentration of those scatterers, and shows the utility of the acoustical method in watermass characterization.

AO-064

PSZENNY, A.A.P., A.J. Castelle, and J.N. Galloway. A Study of the sulfur cycle in the Antarctic marine boundary layer. Journal of Geophysical Research 94(D7):9818-9830 (1989).

Atmospheric sampling was conducted aboard R/V POLAR DUKE from March 21 to April 27, 1986, in the southern Drake Passage and in the coastal waters west of the Antarctic Peninsula. Average atmospheric concentrations (n=6) of sulfur dioxide (SO_2) vapor, aerosol methane-sulfonate ($CH_3SO_3^-$) and aerosol non-sea-salt sulfate (nss-$SO_4^=$) were 0.36, 0.22, and 0.34 nmol m^{-3}, respectively. Cascade impactor data indicated that more than 85% of the masses of both $CH_3SO_3^-$ and nss-$SO_4^=$ were on particles of < 0.25-μm mean aerodynamic radius. Average concentrations (n=8) of $CH_3SO_3^-$ and nss-$SO_4^=$ in precipitation were 0.09 and 0.57 μM, respectively. Box model calculations based of this limited data suggest a total sulfur removal rate from the local marine boundary layer of 0.3-7.2 μmol m^{-2} day^{-1}. This removal approximately balances the oceanic source of dimethylsulfide (DMS) sulfur of 1.2-4.4 μmol m^{-2} day^{-1} (± 100%) estimated by Berresheim (1987) from data obtained during the same cruise. The box model calculations also suggest that heterogeneous SO_2 oxidation may be the major pathway for DMS to sulfate conversion (~75%) and/or that other sources of sulfate may not be negligible. Observed mineral aerosol and ^{222}Rn concentrations were low but slightly elevated above "pure" remote marine background levels, suggesting a weak but discernible continental character in sampled air. Uncertainties are large owing to the limited sampling time, study area, and numbers of samples obtained, but overall, the sulfur cycle in the coastal Antarctic marine boundary layer appears not to differ remarkably from that in other remote marine regions.

AO-065

RAMOS, P.A., and D.R. PALMER. Comments on the Deep Six Sound Channel. Journal of the Acoustical Society of America 85:1767 (1989).

Some features of the Deep Six Sound Channel [J. C. Miller, J. Acoust. Soc. Am., 71, 859-862 (1982)], which may be important to those who wish to use the model in various applications, are noted and discussed.

AO-066

Rao, R.R., R.L. MOLINARI, and J.F. FESTA. Evolution of the climatological near-surface structure of the tropical Indian Ocean. Part I: Description of mean monthly mixed layer depth and sea-surface temperature, surface current, and surface meteorological fields. Journal of Geophysical Research 94(C8):10,801-10,815 (1989).

Mean monthly mixed layer depth (MLD), sea-surface temperature (SST), and surface current climatologies are generated for the tropical Indian Ocean. In addition, surface meteorological climatologies are produced for those variables which could influence the evolution of the MLD and SST fields. Only the MLD climatology is described in detail as climatologies for the other variables have appeared previously in the literature. The sum of the annual and semi-annual harmonics account for greater than 75% of the energy in the MLD time series over most of the basin. The amplitude of the annual signal is greater than 20 m between 10°S and 25°S, with deepest MLD's observed during the southern hemisphere winter. The south-central Arabian Sea, between the equator and 10°N, and the northern Arabian Sea are also regions of larger annual harmonic amplitude (> 15 m). The amplitude of the semi-annual harmonic is largest in the central Arabian Sea (> 25 m). Deepest MLD's are observed there during the height of the two monsoon seasons. Correlation coefficients are computed between MLD and SST and several other oceanographic and meteorological variables to explore possible causal relationships. Net energy flux through the sea surface can account for 75% of the variance in the SST and MLD time series over most of the region south of the equator. Large coefficients are also observed in the northwestern Arabian Sea. Correlations between SST and MLD and surface currents are, in general, small throughout the region with maxima observed in the central Arabian Sea, in the vicinity of the South Equatorial Current and in the extreme eastern equatorial Indian Ocean. These correlations are examined in more detail in Part II of this study in which simple models of mixed layer dynamics are employed.

AO-067

Rappaport, E.N., and P.G. BLACK. The utility of special sensor microwave/imager data in the operational analysis of tropical cyclones. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, J21-J24 (1989).

Extended abstract.

AO-068

RONA, P.A. Hydrothermal mineralization at oceanic ridges. Canadian Mineralogist 26:431-465 (1988).

A compilation of over 100 mineral occurrences at oceanic ridges and rifts comprising the global seafloor spreading center system has been made in terms of host-rock lithology (volcanic- or sediment-hosted) and of stage (early, advanced) and rate (slow-, intermediate- to fast-spreading) of opening of an ocean basin. At this early phase of exploration when less than 1 percent of the ~55,000 km global length of spreading centers has been systematically explored, examples of almost all major varieties of volcanic- and sediment-hosted hydrothermal deposits associated with basaltic rocks in the geologic record have been found at present spreading centers. Review of this global data base indicates that a range of hydrothermal mineral deposit sizes from small to large (> 1 x 10^6 tonnes) occurs at all seafloor spreading rates. However, larger deposits but fewer per unit length of spreading axis appear to form at slow- than at intermediate- to fast-spreading centers based on available data. Larger deposits are more common in sediment-hosted than in volcanic-hosted settings regardless of spreading rate. A spectrum of hydrothermal deposit varieties (stratiform, stockwork and disseminated sulfides; various forms of sulfate, carbonate, silicate, oxide and hydroxide deposits) occurs in almost all of the tectonic settings. High-intensity, ore-forming, subseafloor hydrothermal convection systems that conserve heat and mass and concentrate hydrothermal precipitates are extremely localized by anomalous physical and chemical conditions relative to nearly ubiquitous low-intensity hydrothermal activity at and flanking seafloor spreading axes at all spreading rates. Two distinct shapes of volcanic-hosted hydrothermal deposits at seafloor spreading centers and in the geologic record may be explained by differences in fluid dynamic behavior controlled by temperature-salinity properties of solutions. Massive sulfide deposits that are mound-shaped in profile are constructed by hydrothermal solutions that discharge as buoyant plumes; examples are the TAG massive sulfide mound forming on the Mid-Atlantic Ridge and the Archean Noranda-area deposits. Massive sulfide deposits that are saucer- or bowl-shaped in profile are formed by ponded solutions denser than surrounding seawater; examples are the Atlantis II Deep deposits of the Red Sea and Cretaceous Troodos deposits of Cyprus. Review of an existing data set on 508 massive sulfide deposits in the geologic record indicates that fewer volcanic- and sediment-hosted massive sulfide deposits are associated with basaltic rocks than with rhyolitic rocks (< 26% versus 56%, respectively). This observation suggests that seafloor spreading centers have been significant as tectonic settings for massive sulfide formation through geologic time, although subsidiary to continental rifts and volcanic island arcs.

AO-069

Rosenfeld, L.K., R.L. MOLINARI, and K.D. Leaman. Observed and modeled annual cycle of transport in the Straits of Florida and east of Abaco Island, the Bahamas (26.5°N). Journal of Geophysical Research 94(C4):4867-4878 (1989).

Direct velocity observations were collected with a free-fall acoustic velocity profiler along an east-west section extending 65 km offshore of Abaco Island, the Bahamas (26.5°N). The section, which includes five stations, was occupied 14 times between September 1984 and September 1987. The two inshore stations were located on the continental slope, and the three offshore stations were located over the abyssal plain (at depths approaching 4,700 m). The average total section transport between the surface and 2,500 m (the portion of the water column best sampled) was 10 Sv (1 Sv = 10^6 m^3/s) to the south. The range of transports is 40 Sv with maximum northward transport observed during April 1985 (5.3 Sv) and maximum southward transport observed during April 1986 (34.8 Sv). The average flow above 800-900 m is to the north at the four westernmost stations and is to the south below 800-900 m and over most of the easternmost station. The southward flow includes the Deep Western Boundary Current. Strong vertical shears extend to 1,100 m. An approximation for the upper layer (above 1,100 m) baroclinic transport has a mean of 12.2 Sv to the north and a range of 15 Sv. Results from a two-layer and a one-and-a-half-layer wind-driven model are compared with the annual cycles of total and upper layer transport, as determined from the observations. The barotropic transport from the two-layer model has a range of the order of $\pm$ 10 Sv, with a winter maximum and fall minimum. The range of the baroclinic transport from the one-and-a-half-layer model is an order of magnitude smaller and of opposite sign. Although there are similarities between the observations and the results of both models, the small signal-to-noise ratio precludes definitive confirmation of the annual cycle. The situation east of the Bahamas, where the two models give very different predictions, is compared with the Straits of Florida, where both models predict an annual cycle similar to that observed for the total transport. The roles played by topography and local and remote wind forcing in producing these results are discussed.

AO-070

SHAPIRO, L.J. The relationship of the quasi-biennial oscillation to Atlantic tropical storm activity. Monthly Weather Review 117(7):1545-1552 (1989).

Monthly averaged 30 and 50 mb zonal winds at Balboa are used to determine objectively the relationship of the quasi-biennial oscillation (QBO) to seasonal (August through October) Atlantic tropical storm activity during the years 1952-1986. The largest correlations between storm activity and the 30 mb wind are found in June, which is three months before the center of the season. Extrapolation and direct calculation confirm a near in-phase relationship between tropical storm activity and the zonal wind at about 50 mb. Zonal winds filtered to remove periods of about < 1 year are used to establish correlations between the QBO and tropical storm activity for 1955-1983 that are essentially independent of the month considered. A correlation at 30 mb is established with a conservative estimate of true skill, from both in-phase and out-of-phase information, that explains 30% of the variance in storm activity. The skill is much greater than that estimated from seasonal classification of the QBO. The statistics are resilient to removal of the effects of the El Niño cycle. When El Niño years are explicitly excluded, the true skill explains an estimated 32% of the variance. Low-latitude storms are even more strongly related to the QBO. Physical mechanisms possibly responsible for the observed associations are discussed in light of these results. A mechanism for the observed correlations is suggested that emphasizes the difference between lower tropospheric steering and the lower stratospheric zonal wind. The relationships of the results, and suggested physical mechanism, to those of Gray are considered.

AO-071

SHAPIRO, L.J. Vortex evolution on a beta plane. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 98-99 (1989).

Extended abstract.

AO-072

Shay, L.K., R.L. Elsberry, and P.G. BLACK. Vertical structure of the ocean current response to a hurricane. Journal of Physical Oceanography 19(5):649-669 (1989).

During the passage of Hurricane Norbert in 1984, the Hurricane Research Division of NOAA conducted a planetary boundary-layer experiment that included the deployment of airborne expendable current profilers (AXCP). A total of 16 AXCP's provided, for the first time, high-resolution vertical profiles of currents and temperatures in hurricane wind conditions. This study focuses on the vertical structure of the near-inertial baroclinic currents excited by the passage of this hurricane. The transient, hurricane-induced currents are isolated from the AXCP profiles in Norbert by subtracting a spatially-averaged current. Near the center of Hurricane Norbert, the WKBJ-scaled vertical wavenumber spectra are a decade greater than the Garrett-Munk spectra (GM75). The first ten linear, baroclinic-free modes are calculated from the spatially-averaged, Brunt-Väisälä frequency. To allow a more direct comparison with the AXCP observations in the high-wind regime, the near-inertial response for the three-dimensional velocities is simulated by superposing a hurricane-like wind stress field onto the first ten baroclinic modes. About 70% of the current variance in Hurricane Norbert can be explained by a sum of only the first four near-inertial modes. Most of the ocean current variability can be

accounted for by the wind stress curl, although the direct effect of the wind stress and the stress divergence do contribute to the observed current variance within 30-60 km from the storm. However, these last two effects rapidly diminish after one inertial period. Although the energy input by the hurricane forcing is spread over all of the vertical wavelengths, most of the energy is contained in the gravest four vertical modes which then govern the dynamics in the wake region.

AO-073

Speer, K., and P.A. RONA. A model of an Atlantic and Pacific hydrothermal plume. Journal of Geophysical Research 94(C5):6213-6220 (1989).

A turbulent entrainment model of a hydrothermal plume was modified to include the effects of vertical structure in the background temperature and salinity fields. Owing to the stably-stratified salinity field in the Pacific, relatively warm, salty water spreads at an equilibrium level, where the plume density equals the ambient density. In contrast, the unstable salinity profile in the Atlantic gives the plume added buoyancy, and it continues to rise to an equilibrium level where it is relatively cool and fresh. These attributes result from the mixing between the plume and the surrounding seawater at each level below the spreading layer. The equilibrium temperature anomaly is not directly proportional to the source strength but depends on the mixing and background salinity gradient. The net entrainment of surrounding seawater is greater in the Atlantic plume model than in the Pacific plume model for the same buoyancy flux. Recent data from the TAG hydrothermal field at 26°N on the Mid-Atlantic Ridge and data from a vent field on the Endeavor segment of the Juan de Fuca Ridge are compared to model results. The model predicts the penetration height and θ-S characteristics of the Atlantic plume, and explains some of the differences between the observed Atlantic and Pacific hydrothermal plumes.

AO-074

Stossmeister, G.J., and G.M. Barnes. Low-level structure of a nondeveloping tropical storm: Isabel (1985). Research supported by NOAA Grant 45-WCNR-5-00388. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 83-84 (1989).

Extended abstract.

AO-075

THACKER, W.C. Fitting models to inadequate data by enforcing spatial and temporal smoothness. Journal of Geophysical Research 93(C9):10,655-10,665 (1989).

When observations are too sparse to determine the state of a dynamical model, it is necessary to make use of prior knowledge or prejudice. The approach discussed here is to require that the model state be the best smooth fit to the sparse data. The requirement of smoothness is enforced by introducing bogus data, which correspond to hypothetical observations that properties such as slope, curvature, or temporal tendency of model fields have zero values within some specified accuracy. The bogus data serve to increase the effective ratio of data to model degrees of freedom. The concept of bogus data allows a bias toward smoothness to be incorporated easily into the adjoint method for fitting time-dependent models to asynoptic data. Computational examples using a simple three-wave model show that reasonable fits can be obtained even when the number of real data is considerably less than the number of model degrees of freedom.

AO-076

THACKER, W.C. The role of the Hessian matrix in fitting models to measurements. Journal of Geophysical Research 94(C5):6177-6196 (1989).

A numerical model can be fit to data by minimizing a positive quadratic function of the differences between the data and their model counterparts. The rate at which algorithms for computing the best fit to data converge depends on the size of the condition number and the distribution of eigenvalues of the Hessian matrix, which contains the second derivative of this quadratic function. The inverse of the Hessian can be identified as the covariance matrix that establishes the accuracy to which the model state is determined by the data; the reciprocals of the Hessian's eigenvalues represent the variances of linear combinations of variables determined by its eigenvectors. The aspects of the model state that are most difficult to compute are those about which the data provide the least information. A unified formalism is presented in which the model may be treated as providing either strong or weak constraints, and methods for computing and inverting the Hessian matrix are discussed. Examples are given of the uncertainties resulting from fitting an oceanographic model to several different sets of hypothetical data.

AO-077

Thompson, G., S.E. Humphris, B. Schroeder, M. Sulanowska, and P.A. RONA. Active vents and massive sulfides at 26°N (TAG) and 23°N (Snakepit) on the Mid-Atlantic Ridge. Canadian Mineralogist 26:697-711 (1988).

Two active hydrothermal vent sites on the Mid-Atlantic Ridge at 26°N (TAG) and 23°N (Snakepit) have recently been discovered at depths of 3,700 and 3,500 m, respectively. Although black smokers are present at both

sites, their geological settings differ. The TAG area is located on older sedimented crust a few kilometers from the spreading axis, at the junction of the rift-valley floor and the east wall; the Snakepit site is atop a large volcanic ridge (40 km long, up to 600 m high) in the axial zone of the rift valley. The TAG site is the larger of the two and is probably older. Hydrothermal discharge from vents at both sites ranges from shimmering water, through white smokers (226°C) to black smokers (335°C and 350°C). Hydrothermal solutions are similar in major-element composition to those from the East Pacific Rise. Mineralization is similar to that occurring on faster-spreading ridges, e.g., the dominant polymetallic sulfides are pyrite, pyrrhotite, chalcopyrite and sphalerite; anhydrite is the main sulfate phase. The deposits differ from some of those on the East Pacific and Juan de Fuca ridges in having little or no barite, very little amorphous silica, and in having abundant aragonite as a late-stage precipitate. Diagenesis and weathering, particularly at the TAG site, have produced abundant amorphous iron oxides and hydroxyoxides, goethite, hematite, atacamite, jarosite and sulfur. At the Snakepit site the black smokers consist mainly of pyrrhotite, but this sulfide phase is absent from the active chimneys at TAG. Zinc sulfide occurs as the predominant phase in the lower-temperature white smokers at both sites.

AO-078

Venne, M.G., W.A. Lyons, C.S. Keen, P.G. BLACK, and R.C. Gentry. Explosive supercell growth: A possible indicator of tropical storm intensification? Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 545-548 (1989).

No abstract.

AO-079

WILBURN, A.M., E. JOHNS, and M. BUSHNELL. Current velocity and hydrographic observations in the southwestern North Atlantic Ocean: Subtropical Atlantic Climate Studies (STACS), 1988. NOAA DR ERL AOML-13 (NTIS number not yet available), 83 pp. (1989).

No abstract.

AO-080

WILLIS, P.T., and A.J. Heymsfield. Hurricane microphysical trajectories. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorology Society, Boston, 75-76 (1989).

Extended abstract.

AO-081

WILLIS, P.T., and A.J. Heymsfield. Structure of the melting layer in mesoscale convective system stratiform precipitation. Journal of the Atmospheric Sciences 46(13):2008-2025 (1989).

This study examines the aircraft observations and theoretical evolution of particles above, through, and below the melting layer in the stratiform region associated with a mesoscale convective system (MCS). The aircraft data were obtained from an advecting spiral descent where the descent rate approximately corresponded to the typical hydrometeor fall speeds. The microphysical and thermodynamic measurements not only allowed us to characterize the particle evolution, but also enabled us to compare them with the theoretical evolution of the particles in the melting layer and to quantify the associated heating and cooling rates. Even though complete melting requires a fairly deep layer, most of the mass melts, and thus most of the cooling occurs, in a thin layer above the location of the radar bright band. Based upon the magnitude of vertical velocity fluctuations, the layers below the melting layer appear to be decoupled from those above. The ice water content above the melting layer is 2-3 times the liquid water content below the melting layer. The production of a few, very large, aggregates is dramatic after the onset of melting, due in part to a melting-induced increase in the terminal velocity difference between similar-sized hydrometeors. The radar reflectivity maximum (bright band) is due to these relatively few, very large, aggregates that survive to warmer temperatures. The reflectivity maximum is depressed well below the isothermal layer and the level where most of the ice mass is melted. Above the melting layer, small crystals are replenished by a fragmentation or breakup process.

AO-082

WILLIS, P.T., and P. Tattleman. Drop-size distributions associated with intense rainfall. Journal of Applied Meteorology 28(1):3-15 (1989).

The probability of occurrence of extreme rainfall rates is reviewed. The drop-size distributions associated with a range of high rainfall rates are examined using data from tropical storms and hurricanes. Mean drop-size distributions are presented for a range of high rainfall rates, as well as a Γ-distribution fit to the entire set of normalized drop-size distributions. This fit forms the basis for a model drop-size distribution for intense rain. The goodness of fit of the model is examined by comparing it with independent drop-camera measurements of high-rain-rate distributions from several geographic locations. The slope of exponential fits to the distributions are examined for constancy with rainfall rate and are generally found to decrease with increasing rainfall rate.

AO-083

WILLOUGHBY, H.E., W.P. BARRY, and M.E. RAHN. Real-time monitoring of Hurricane Gilbert. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 220-221 (1989).

Extended abstract.

AO-084

WILSON, D., and A. Leetmaa. Acoustic Doppler current profiling in the equatorial Pacific in 1984. Journal of Geophysical Research 93(C11):13,947-13,966 (1989).

Hydrographic data and acoustic Doppler current profiles collected from 150°W to 85°W in the equatorial Pacific during 1984 showed significant seasonal changes in the temperature and velocity fields. On the equator, the surface current was eastward in April up to 80 cm s^{-1}, reversing to westward at 100 cm s^{-1} by November. Over the same period, the Equatorial Undercurrent (EUC) transport decreased, the equatorial zonal pressure gradient (ZPG) increased, and the depth of the mixed layer and EUC core deepened. Off the equator at 150°W, the North Equatorial Countercurrent (NECC) was absent in April/May but pronounced in October/November. Superimposed on this seasonal variability were smaller-scale (roughly 1,000 km wavelength) correlated fluctuations in the upper ocean temperature and velocity fields. We identify these structures with the 20- to 30-day instability waves [Legeckis, 1977]. The coincident high-resolution velocity and temperature data allowed the calculation of Reynolds' stresses due to the waves and resultant heat and momentum flux estimates as well as details of the vertical phase structure. Barotropic instability at the northern edge of the EUC is a likely source of energy for these waves. Estimated EUC transport decreased from 50 in April to 25 x 10^6 m^3 s^{-1} in November while the westward wind stress doubled and the 0-/400-dbar ZPG quadrupled. The data were used to estimate terms in the momentum balance in the upper 150 m, and it was found that nonlinear terms were often at least as important as the integrated ZPG in balancing the surface wind stress. East of 120°W, the eastward advection of eastward momentum, UU_x, was particularly important. These momentum equation terms were used to estimate a profile of the coefficient of vertical eddy viscosity; it was similar to profiles estimated by bulk methods and by parameterization by Richardson number.

AO-085

Wood, V.T., and F.D. MARKS, JR. Hurricane Gloria: Simulated land-based Doppler velocities reconstructed from airborne Doppler radar measurements. Extended Abstracts, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 115-116 (1989).

Extended abstract.

Addendum

AO-086

Houze, R.A., Jr., S.J. Bograd, and B. Mapes. An atlas of horizontal patterns of radar reflectivity observed during EMEX aircraft missions. Research supported by NOAA Grant 40-WCNR-6-02428. Department of Atmospheric Science, University of Washington, Seattle (1988).

No abstract.

AO-087

WILLOUGHBY, H.E. The dynamics of the tropical cyclone core. Australian Meteorological Magazine 36(3): 183-191 (1988).

The core of a tropical cyclone occupies the inner 100-200 km of the vortex. It is dominated by a cyclonic primary circulation in balance with a nearly axisymmetric, warm core low-pressure anomaly. Superimposed on the primary circulation are weaker asymmetric motions and an axisymmetric secondary circulation. The asymmetries, which may be either internal gravity waves or Rossby waves, modulate precipitation and cloud into trailing spirals. The axisymmetric secondary circulation, driven by latent heat release and surface friction, comprises the following parts: surface inflow that extracts latent heat from the sea and replaces the frictional loss of angular momentum (M) to the sea; diabatically forced deep inflow that supplies an excess of M above frictional loss; the eyewall, an outward sloping locus of convective ascent; diabatically forced descent inside the eye; and upper tropospheric outflow. The eyewall usually moves inward as a result of differential adiabatic heating across the wind maximum. Eyewall succession occurs in intense cyclones when two concentric eyewalls are present and the outer replaces the inner. Because of their semibalanced dynamics, the primary and secondary circulations are relatively simple and well understood. These dynamics are not valid in the upper troposphere where the outflow is comparable to the swirling flow, nor do they apply to the asymmetric motions. Since the synoptic-scale environment appears to interact with the vortex core in the upper troposphere by means of the asymmetric motions, future research should emphasize this aspect of the tropical-cyclone dynamics.

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FS-001
Albers, S.C. Two-dimensional velocity de-aliasing in highly sheared environments. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 411-414 (1989).

No abstract.

FS-002
AUGUSTINE, J.A., E.I. TOLLERUD, and B.D. JAMISON. Distributions and Other General Characteristics of Mesoscale Convective Systems During 1986 as Determined from GOES Infrared Imagery. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 437-442, (1989).

No abstract.

FS-003
BARNES, S.L., and B.R. COLMAN. Quasi-Geostrophic Diagnosis of Tropopause Folding Associated with Extratropical Cyclone Development. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 247-252, (1989).

No abstract.

FS-004
Benjamin, S.G. An operational isentropic mesoscale data assimilation system. Abstracts Volume One, IAMAP 89, 5th Scientific Assembly, Reading, England, July 31-August 12, 1989. Commission Symposium on Mesoscale Phenomena: Analysis and Forecasting, August 2-4, 1989, MF33 (1989).

A Mesoscale Analysis and Prediction System (MAPS) has been developed to provide short-range guidance and detailed analyses over the U.S. at 3-h frequency. The asynoptic data sources for MAPS are commercial aircraft, notably those producing automated reports, satellites, wind profilers and surface stations. *All components of MAPS, including observation quality control, objective analysis, and primitive equation model, are configured in isentropic coordinates, providing extra resolution near fronts. The assimilation cycle is self-contained (three-hour MAPS forecasts serve as the background for subsequent analyses) except for specification of model lateral boundary conditions from the U.S. Nested Grid Model (NGM).

The 3-h isentropic cycle has been run in real-time since August 1988. Twelve-hour forecasts from MAPS compare favorably with those of the NGM model, especially at upper levels. Aircraft data clearly improve short-range forecasts not just of upper-level winds (observed most frequently), but also of wind and mass fields at most tropospheric levels. This result is due in part to model adjustment processes, and in part to analysis procedures, in particular, those concerning the 3-dimensional influence of single-level observations in isentropic coordinates.

FS-005
Benjamin, S.G. An isentropic meso-alpha scale analysis system and its sensitivity to aircraft and surface observations. Monthly Weather Review 117:1586-1603 (1989).

An objective analysis scheme for meteorological variables on constant potential temperature surfaces is presented. The analysis uses a form of multivariate statistical interpolation and is designed to retain mesoscale detail in disparate observations including rawinsonde, surface, aircraft, satellite, and wind profiler data while combing them with a forecast background (first guess) field. The wind and mass field analyses are interdependent. The horizontal correlation of forecast error on isentropic surfaces is modeled with an analytical function from statistics collected for this study; the vertical correlation of forecast error is modeled as a function of potential temperature separation. These correlations determine the weights applied to observed-minus-forecast increments in the analysis. The analysis is two dimensional except with respect to single-level data where it is three-dimensional. Comparisons of isentropic and isobaric analyses are shown, and examples of the effects of single-level (aircraft and surface) observations on isentropic analyses are presented. Although variable in space and time, these datasets are often of higher density than the rawinsonde network, and they support increased resolution of

mesoscale features in the analysis. More importantly, the examples reveal that three-dimensional analysis increment structures, especially in the vicinity of fronts, appear to be more physically reasonable in an isentropic analysis than in an isobaric analysis.

FS-006

Benjamin, S.G., K.A. Brewster, R. Brummer, B.F. Jewett, T.W. SCHLATTER, T.L. Smith, and P.A. Stamus. A 3-hour mesoscale assimilation system using ACARS aircraft data combined with other observations. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 117-122, (1989).

No abstract.

FS-007

BERAN, D.B., and J.T. Hastings. The SWORD Project: pointing new direction in environmental science data management. Proceedings of "Earth Observations and Global Change Decision Making: A National Partnership," September 18-19, 1989, Washington, DC, ERIM (Environmental Research Institute of Michigan), Ann Arbor, MI (1989).

The NOAA/Environmental Research Laboratories have an on-going program to "develop, deploy, operate, and assess" a demonstration network of atmospheric wind profilers during the period 1985-1992. As part of this program, wind profiler and related data will be made available to researchers across the country through a subsidiary project known as SWORD, for Synoptic-Scale Weather On-line Research Database. This document presents a summary of the technological concepts and implementation progress of SWORD, and suggests directions for future research and development in support of environmental science data management generally.

FS-008

BERAN, D.W., and L.M. Kaimal. Test range weather support. Preprints, Third International Conference on the Aviation Weather System, 30 January-3 February 1989, Anaheim, CA, American Meteorological Society, Boston, 87-88 (1989).

No abstract.

FS-009

Birkenheuer, D. Use of GOES data for local forecasting. Preprints, GOES I-M Operational Satellite Conference, Arlington, VA, April 3-6, 1989. American Meteorological Society, Boston, 70-75 (1989).

No abstract.

FS-010

Brady, R.H., and E.J. Szoke. A case study of nonmesocyclone tornado development in Northeast Colorado: similarities to waterspout formation. Monthly Weather Review, 117(4):843-856 (1989).

The evolution of the 26 July 1985 Erie, Colorado, tornado is described using data from NCAR's CP-2 Doppler radar. This tornado develops within 20 km of the radar site under weakly forced synoptic conditions and weak tropospheric flow, and is not accompanied by a mesocyclone. The initial circulation forms near the surface at the intersection of two mesoscale boundaries and develops vertically, intensifying into an F1 tornado when it becomes collocated with the intense updrafts of a rapidly developing cumulonimbus. This tornado appears to be the land equivalent of a waterspout, and comparisons between the two vortices are made. It is speculated that Florida and portions of the western High Plains may be prone to nonmesocyclone tornado development, and that vortex-intensification processes associated with nonmesocyclone tornadoes may be important in mesocyclone tornadogenesis. Suggestions on how to better forecast these tornadoes are also presented.

FS-011

Brewster, K.A., S.G. Benjamin, and R. Crawford. Quality control of ACARS meteorological observations -- a preliminary survey. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 124-129 (1989).

No abstract.

FS-012
CHAPPELL, C.F., and D.M. RODGERS. Meteorological Aspects of the Cheyenne, Wyoming, Flash Flood and Hailstorm of August 1, 1985. NOAA Technical Report ERL 435-FSL 1, 51 pp. (1988).

Analysis of a devastating storm that struck Cheyenne, Wyoming, on 1 August 1985 shows that the storm began as an east-west multicellular system just south of the city near the summit of the Cheyenne Ridge. This system developed in a conditionally unstable air mass that formed over southeast Wyoming as a southeasterly flow of very moist air at low levels became juxtaposed with an area of steepening lapse rates to the west. Early cells drifted slowly northward in agreement with the pressure-weighted vector mean wind of the environment. New onvective growth on the southwest flank of this multicellular system eventually produced a wave-shaped convective system, which rapidly developed supercell structure. As the supercell began to rotate, the storm became stationary over the city for nearly 2 hours. This lack of motion is believed to have been due to helicity, which promoted the transverse propagation of the supercell's updraft at a rate that counteracted the effects of the vector mean wind of the environment. The storm began to move southeastward with the arrival of a short-wave trough and soon dissipated as it encountered increasingly stable conditions. The results of the study suggest that the eastern foothills of the Rocky Mountains and the adjacent high plains may be particularly vulnerable to this type of storm. Deep convection frequently occurs over this area when moist air arrives from the Great Plains, driven by a low-level easterly jet. The combination of strong low-level easterly flow topped by weak middle-level southerly flow can apparently produce sufficient wind shear for supercell formation, while producing a vector mean wind for the environment that gives little or no eastward motion relative to the ground.

FS-013
Chen, S.J., L.S. Bai, and S.L. BARNES. Omega Diagnosis of a Cold Vortex with Severe Convection, Weather and Forecasting 3(4):296-304, (December 1988).

A real-time quasi-geostrophic omega diagnostic scheme, based on Hoskins' Q-vector analysis and developed by Barnes, was applied to a cold mesoscale vortex with severe convection over northeast China in summer. The limited area model used at the Beijing Weather Center did not predict this event because the baroclinic forcing was rather weak, but the Q-vector analysis clearly indicated the forcing 12 h before. In addition to Barnes' diagnostics, we estimate divergence tendency in low levels through computation of the rotational component of the Q-vector. Combined with the diagnosed stability tendency, moisture analysis, and low-level wind convergence zone, the convective area can be identified. This microcomputer diagnostic-graphics scheme, when coupled with intelligent use of conventional data, has potential as an aid for local short-range weather forecasting.

FS-014
COLMAN, B.R. Mesoscale Analysis of an Upslope Snowstorm in Colorado. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 372-377 (1989).

No abstract.

FS-015
COLQUHOUN, J.R., and D.J. Shepherd. An Objective Basis for Forecasting Tornado Intensity. Weather and Forecasting 4(1):35-50 (March 1989).

Although violent tornadoes comprise only 2.3 percent of tornado occurrences in the United States they cause 68 percent of the fatalities attributed to tornadoes and severe thunderstorms. Despite these statistics, no attempt is made to forecast or warn of tornado intensity. A basis for this is provided in a study of more than two hundred tornado events. Tornado intensity is best related to the magnitude of the vertical wind "shear" in the layer between the ground and 600 hPa. The result for this and other shear parameters are statistically highly significant when the data are grouped into two or three intensity classifications. Stability, as indicated by the "lifted index" and mid-tropospheric relative humidity, correlated poorly with tornado intensity. The relationships established have application to tornado forecasting and nowcasting.

FS-016
Dunn, L.B. Vertical motion evaluation of a Colorado snowstorm from a synoptician's perspective. Weather and Forecasting, 3(4):261-272 (December 1988).

The causes of vertical motions associated with a September snowstorm which resulted in a heavy snowband in northeastern Colorado have been examined from a synoptician's perspective. The aim of the examination is to look at the various causes of vertical motion as a forecaster might in a real-time situation. The three ways in which the vertical motions were estimated were by 1) a "conventional" approach, including 500 mb positive vorticity advection (PVA) and pattern recognition techniques; 2) a strictly quasi-geostropic approach, including advection of vorticity by the thermal wind a Q-vector analysis; and 3) a look at possible ageostrophic forcing in excess of, or operating on smaller scales than those expected from a purely quasi-geostrophic (QC) framework. Additionally, an examination of the atmosphere's potential response to forcing was attempted via a conditional symmetric instability analysis. The results show a failure of both the conventional approach and the purely QG forcing analysis in explaining the heavy snowband, although Q-vectors did much better than 500 mb PVA on the general area and timing of precipitation. Ageostrophic forcings operating on smaller scales than those resolved by QG analyses seem a likely reason for the vertical motions associated with the heavy snowband. The atmosphere was conditionally symmetrically unstable and thus likely to produce banded precipitation in response to forcing.

FS-017

GREENHUT, G.K., G. Mastrantonio. Turbulence Kinetic Energy Budget Profiles Derived from Doppler Sodar Measurements. Journal of Applied Meteorology 28(2):99-106 (1989).

Doppler sodar wind measurements made in light wind conditions in September 1979 near a power plant in Turbigo, Italy, are used to derive terms in the turbulence kinetic energy (TKE) budget. Measurements on five days are grouped into two classes: fair-weather conditions and boundary layer interaction with subsiding air. Profiles of σ_w^3/z are used to obtain the surface heat flux and the vertical velocity scaling parameter, as well as the buoyancy production term in the TKE budget. The vertical transport of TKE is derived from the profiles of $(W')^3$. The horizontal components are approximated using a parameterization based on the data of Lenschow et al. Dissipation in the TKE budget is obtained from a spectral analysis of the Doppler sodar data in the inertial subrange. The resulting TKE budget profiles for the two classes are compared with budgets obtained previously, using a number of different methods.

FS-018

GRIFFITH, C.G. Skill Scores of Satellite-Estimated Summertime Rainfall. Preprints, 11th Conference on Probability and Statistics, Monterey, California, October 1-5, 1989. American Meteorological Society, Boston, 144-149 (1989).

No abstract.

FS-019

Heideman, K.F., D.C. WALKER, and J.A. Flueck. DAR^{3}E-1 Evaluation: An Overview. NOAA Technical Report ERL 436-FSL 2, 29 pp. (1989).

The unique DAR^{3}E-I (Denver AWIPS-90 Risk Reduction and Requirements Evaluation, Part I) system combines an advanced, interactive workstation with special meteorological data sets and provides the capability to demonstrate and test many of the concepts central to the AWIPS-90 (Advanced Weather Interactive Processing System for the 1990's) component of the planned modernization of the National Weather Service (NWS). This overview of six evaluation reports focuses on the following areas: (1) forecaster assessment of the system, (2) forecaster product usage, and (3) forecaster performance as measured by forecasts and warnings. Forecasters agreed that the integration of standard data sets with new (primarily mesoscale) data sets into a single workstation, and the capability to manipulate the data in ways not previously possible, make DAR^{3}E-I a substantial improvement over the current AFOS (Automation of Field Operations and Services) system. Forecasters also identified some problem areas and they are being addressed in DARE^{3}E-II. Product usage analysis shows that DAR^{3}E-I provides sufficient flexibility in the daily product inventory to allow forecasters to focus on the contrasting forecasting problems presented on the synoptic and subsynoptic scales in both the cool and warm seasons. Doppler radar imagery is a key component of the mesoscale product set available on the DAR^{3}E-I system. On the basis of the data available, assessment of tornado warnings revealed a number of substantial improvements following installation of DAR^{3}E-I, including increased lead time, and decreased size of area warned and false alarm ratio (FAR). Similar, though smaller, improvements were observed with regard to severe thunderstorm warnings. In contrast, the probability-of-detection (POD) scores declined for both types of warnings over the same period. There is a suggestion of improvement in cool and warm season 0-12 hour temperature forecasts whereas precipitation forecasts after the installation of DARE^{3}E-I do not show any notable changes in skill or reliability.

FS-020
Hinkelman, J.W. An overview of the national program to improve aircraft icing forecasts. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 443-445 (1989).

No abstract.

FS-021
JESUROGA, R.T. Detailed snowstorm observations during the 15 November 1987 Continental aircraft accident at Stapleton International Airport. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 135-139 (1989).

No abstract.

FS-022
Kelsch, M. An evaluation of the NEXRAD hydrology sequence for different types of convective storms in northeastern Colorado. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 207-210 (1989).

No abstract.

FS-023
Khalsa, S.J.S. and G.K. Greenhut. Atmospheric Turbulence Structure in the Vicinity of an Oceanic Front. Journal of Geophysical Research 94(CA):4913-4922 (1989).

Fast response data taken aboard the National Oceanic and Atmospheric Administration WP-3D aircraft are used to determine the structure of atmospheric boundary layer turbulence on either side of a well-developed sea surface temperature front southwest of Bermuda. The data were taken on February 17, 1986, as part of the Frontal Air-Sea Interaction Experiment (FASINEX). A broad region of low-humidity air extending from 15 km to 35 km south of the front is probably due to the presence of a frontally induced secondary circulation. Evidence for a secondary flow is found in both the time series of atmospheric variables and the statistics obtained from conditionally sampled updrafts and downdrafts in the transect across the SST front. Larger sea-air temperature and humidity differences on the warm (south) side of the front give rise to surface layer sensible and latent heat and buoyancy fluxes that are larger than those on the cold side. Turbulence structure appears to be influenced as much by the presence of strong wind shear at the top of the boundary layer as by differing conditions at the surface on either side of the front. A larger rate of entrainment on the warm side of the front is indicated by the greater influence of low-momentum air from the overlying shear layer on updrafts in the upper part of the mixed layer, as well as the more frequent overturning of cool/moist updrafts and warm/dry downdrafts. It is conjectured that the larger entrainment rate is due to the interactions between the inversion layer and more energetic updrafts produced by greater surface forcing on the warm side of the front.

FS-024
Lipschutz, R.C., E.N. Rasmussen, J.K. Smith, J.F. PRATTE, and C.R. Windsor. PROFS' 1988 real-time Doppler products subsystem. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 211-215 (1989).

No abstract.

FS-025
MARROQUIN, A., and J.M. BROWN. Diagnosis of NGM Performance for Spring Storms Over the Western United States. Preprints, Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 617-622 (1989).

No abstract.

FS-026
McGEHAN, B.J. What's next in weather forecasting? Preprints, 2nd International Conference on School and Popular Meteorological and Oceanographic Education, Crystal City, VA, July 12-16, 1989. American Meteorological Society, Boston, 163-165 (1989).

No abstract.

FS-027
McGINLEY, J.A. and S.G. Benjamin. Mesoscale data assimilation for national, regional and local scales. Preprints, Department of Defense Environmental Technical Exchange Conference on Mesoscale Phenomena, Washington, D.C., January 23-27, 1989. Department of Defense, 287-298 (1989).

No abstract.

FS-028
MILLER, P.A., and M.J. Falls. A pilot study of methods to decrease measurement errors of tropospheric inversions by ground-based microwave radiometry. Journal of Atmospheric and Oceanic Technology 6(2):225-234 (1989).

Results of radiometer temperature profile simulations are analyzed in order to examine the hypothesis that knowledge of temperature inversion parameters obtained from other instruments would substantially improve the accuracy of radiometric temperature profiles. Five variations of a statistical retrieval method are used to produce radiometric temperature profiles. These profiles are then compared with radiosonde data under both inversion and non-inversion conditions. The best algorithm yields consistently better results than the traditional (pure radiometric) technique, but still fails to correctly reproduce the radiosonde inversions.

FS-029
MILLER, P.A., and M.J. Falls. The incorporation of inversion characteristics into ground-based microwave temperature soundings: A simulation study. Microwave Remote Sensing of the Earth System, A. Chedin (ed.). Hampton, Virginia, 51-73 (1989).

No abstract.

FS-030
MONINGER, W.R. Artificial Intelligence for Data Management. AI Applications in Natural Resource Management 3:47-48 (1989).

No abstract.

FS-031
MONINGER, W.R. Artificial Intelligence and Environmental Data. Proceedings, Conference on Earth Observations and Global Change. September 18-19, 1989, Washington D.C. (1989)

Artificial intelligence techniques can be used to increase the productivity of environmental researchers in at least three ways. (1) AI can be used to develop computer systems that encourage the recording of, and manage, critical ancillary information (metadata) necessary to the proper understanding of environmental data. (2) AI systems can serve as automated curators, also called intelligent front ends, to environmental databases. (3) Intelligent database rovers can be developed that search unattended through large environmental databases to identify possible flaws and possible important trends. We discuss current efforts by the AI community that address these needs, and suggest that environmental researchers take advantage of what AI has to offer.

FS-032
MONINGER, W.R. (Ed.). Meeting Report: Third Workshop on Artificial Intelligence Research in Environmental Science (AIRIES). AI Applications in Natural Resource Management 3:56-63 (1989).

No abstract.

FS-033

MONINGER, W.R., A. Ignatowski. METALOG: An interactive system to manage knowledge about data. Preprint Volume, Fifth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, CA, February, 1989. American Meteorological Society, Boston, 321-326 (1989).

No Abstract.

FS-034

MONINGER, W.R., C. BULLOCK, T. Breyfogle, D. Furtney. FIDES: An expert system to provide methodological forecast guidance. Preprints, Fifth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, CA, February 1989. American Meteorological Society, Boston, 397-401 (1989).

No abstract.

FS-035

MONINGER, W.R., J.A. Flueck, C. Lusk, W.F. Roberts. SHOOTOUT-89: A Comparative Evaluation of Knowledge-based Systems that Forecast Severe Weather. Preprint Volume, Uncertainty and AI Workshop 1989. Windsor, Canada, 265-271. Windsor Canada (Invited presentation. Substantially the same as Roberts, et al. (1989)

During the summer of 1989, the Forecast Systems Laboratory of the National Oceanic and Atmospheric Administration sponsored an evaluation of AI systems that forecast severe convective storms. The evaluation experiment, called SHOOTOUT-89, took place in Boulder, CO, and focussed on storms over the northeastern Colorado plains. Several systems participated in SHOOTOUT-89. These systems include traditional expert systems, an analogy-based system, and a system developed using methods from the cognitive science/judgment analysis tradition. Each day of the exercise, the systems forecasted for each of four specified forecast regions in northeastern Colorado, the probabilities of occurrence of: nonsignificant weather, significant weather, and severe weather. A verification coordinator working at the Denver Weather Service Forecast Office gathered ground-truth data from a network of observers. Systems were evaluated on forecast skill, and also on other metrics such as timeliness,ease of learning, ease of use, degree of portability to other locations. We report here initial results of the SHOOTOUT-89 experiment.

FS-036

NICKERSON, E.C., C. Ramis, E. Richard, P. Mascart, and J.P. Pinty. On the numerical simulation of downslope windstorms. Programme on Short- and Medium-Range Weather Prediction Research (PSMP) Report Series No. 31, 3rd Session of the Steering Group on Mediterranean Cyclones Study Project, Barcelona, Spain, 107-112 (1989).

No abstract.

FS-037

Rasmussen, E.N., J.K. Smith, J.F. PRATTE, and R.C. Lipschutz. Real time precipitation accumulation estimation using the NCAR CP-2 Doppler Radar. Preprints, 24th Conference on Radar Meteorology, March 27-31, 1989, Tallahassee, FL. American Meteorological Society, Boston, 236-239 (1989).

No abstract.

FS-038

Richard, E., P. Mascart, and E.C. NICKERSON. The role of surface friction in downslope windstorms. Journal of Applied Meteorology, 28:241-251 (1989).

Numerical simulations of the 11 January 1972 windstorm in Boulder, Colorado, were carried out using a hydrostatic model with a turbulent kinetic energy parameterization to investigate the role of frictional effects in the development of nonlinear mountain waves. Sensitivity tests to the roughness length specification and to the turbulent mixing and dissipation length formulations show that surface friction delays the onset of the strong surface winds and also prevents the downstream propagation of the zone of maximum windspeed. Shear production within convectively stable regions is the dominant mechanism for the

production of the turbulent kinetic energy. Moreover, these results are consistent with the hypothesis that a hydrostatic amplification mechanism is capable of accounting for the development of strong downslope winds.

FS-039

Richard, E., P. Mascart, and E.C. NICKERSON. Surface friction effects in downslope windstorm. Abstracts Volume One, IAMAP 89, 5th Scientific Assembly, Reading, England, July 31-August 12, 1989. Commission Symposium on Mesoscale Phenomena: Analysis and Forecasting, August 2-4, 1989, MF31.

Numerical simulations of the 11 January 1972 windstorm in Boulder, Colorado, were carried out using a hydrostatic model with a turbulent kinetic energy parameterization to investigate the role of frictional effects in the development of nonlinear mountain waves. Sensitivity tests to the roughness length specification and to the turbulent mixing and dissipation length formulations show that surface friction delays the onset of the strong surface winds and also prevents the downstream propagation of the zone of maximum wind speed. Shear production within convectively stable regions is the dominant mechanism for the production of the turbulent kinetic energy. Moreover, these results are consistent with the hypothesis that a hydrostatic amplification mechanism is capable of accounting for the development of strong downslope winds.

FS-040

Roberts, W.F., W.R. MONINGER, B. deLorenzis, E. Ellison, J. Flueck, J.C. Mcleod, C. Lusk, P.D. Lampru, R. Shaw, T.R. Stewart, J. Weaver, K.C. Young, S. Zubrick. A field test of artificial intelligence systems applied to the problem of severe weather forecasting: SHOOTOUT-89. Preprints, 11th Conference on Probability and Statistics, and 12th Conference on Weather Analysis and Forecasting, American Meteorological Society, Boston, and Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, October 1989. American Meteorological Society, Boston, J59-J64 (1989).

No abstract.

FS-041

RODGERS, D.M., and C.G. GRIFFITH. Interpretation of GOES Water Vapor Imagery and Its Application to Forecasting Thunderstorms. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, California, January 23 - February 3, 1989. American Meteorological Society, Boston, 351-355 (1989).

No abstract.

FS-042

SCHLATTER, T.W. An integrated approach to the display of Doppler radar and other meteorological data. Proceedings, International Seminar on Weather Radar Networking, Brussels, Belgium, 5-8 September, 1989. Commission of the European Communities, Cooperation in Science and Technology (COST 73) Project, 317-330 (1989).

No abstract.

FS-043

SCHLATTER, T.W. Real-time analysis of mesoscale data. Abstracts Volume One, IAMAP 89, 5th Scientific Assembly, Reading, England, July 31-August 12, 1989. Commission Symposium on Mesoscale Phenomena: Analysis and Forecasting, August 2-4, 1989, MF17-21.

No abstract.

FS-044

SCHULTZ, P. Relationships of several stability indices to convective weather events in Northeast Colorado. Weather and Forecasting 4:73-80 (1989).

Seven familiar stability indices were computed from sounding data for each 83 days of a convection forecasting experiment conducted during the summer 1985 in Northeast Colorado. Observations of convectively driven weather events were collected; the values of the indices were compared against this dataset to examine their performance as predictors of severe weather (large hail, tornadoes, high wind)

and significant weather (nonsevere but important from an economic or public safety standpoint). The results of the analysis are: (1) Benchmark values of the indices that give their typical magnitudes on active days versus quiescent days. These values, compared with those computed in other regions, illustrate the potential fallacy of interpreting the indices in the absence of analogous region-specific reference statistics. (2) Rankings that determine which indices worked best in this experiment. The highest ranked indices were the SWEAT index for severe weather and buoyancy for significant weather. Interestingly, SWEAT was the worst of those tested for significant weather. (3) Quantitative convection forecasting guidance. The observed relative frequencies of severe and significant convection as functions of the seven indices are presented in graphical form. When used in a forecasting context, these observed relative frequencies can be interpreted as probabilities of severe and/or significant weather. Some of the graphs are clearly bimodal; no explanation for this behavior is offered. (4) Some of the benefits that would be realized by collecting more data, in this and other regions, are suggested. For example, there is a good possibility that some indices show particular skill for certain types of events (e.g., hail vs high wind, etc.), but the present dataset is too small to clearly establish any such connections.

FS-045
SCHWARTZ, B.E. Rawinsonde Data: Operational and Archival Concerns. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 52-57 (1989).

No abstract.

FS-046
SMART, J. The profiler-observed wind structure of a continental type polar cyclone. Transactions, American Geophysical Union 1988 Fall Meeting, San Francisco, CA, December 5-9, 1988, 69 (44):1074 (1988).

No abstract.

FS-047
Stewart, T.R., W.R. MONINGER, J. Grassia, R.H. Brady, F.H. MERREM. Analysis of Expert Judgment in a Hail Forecasting Experiment. Weather and Forecasting 4:24-34 (1989).

This study compared meteorologists, an expert system, and simple weighted sum models in a limited-information hail forecasting experiment. It was found that forecasts made by meteorologists were closely approximated by an additive model, and that the model captured most of their forecasting skill. Furthermore, the additive model approximated the meteorologists' forecasts better than the expert system did. Results of this study are consistent with the results of extensive psychological research on judgment and decision making processes. Potential implications are discussed.

FS-048
TOLLERUD, E. I., X.P. Zhong, and B.G. Brown. Evaluating a Composite Climatology of Mesoscale Rainfall. Preprints, 4th International Meeting on Statistical Climatology, Rotorua, New Zealand, March 27-31, 1989, 216-221.

No Abstract

FS-049
TOLLERUD, E.I., J.M. BROWN, and D.L. Bartels. Structure of an MCS Induced Mesoscale Vortex as Revealed by the VHF Profiler, Doppler Radar and Satellite Observations. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 81-86 (1989).

No abstract.

FS-050
Wade, C.G., and S.L. BARNES. Geopotential Height Errors in NWS Rawinsonde Date at Denver. Bulletin of the American Meteorological Society 69(12):1455-1459 (1989).

A recent examination of Denver National Weather Service radiosonde data has revealed an error in the procedure used to establish the surface baseline pressure for Denver soundings obtained between 14 April 1983 and 2 March 1988. As a result of this error the baroswitch was improperly set on each sounding, resulting in geopotential heights that average from 16 to 30 m too low. This article alerts users of the Denver data to the existence and nature of this problem and shows the effect that such subtle bias errors in radiosonde height data can have on derived quantities such as geostrophic vorticity.

FS-051

Wilczak, J.M., D.E. Wolfe and S.C. ALbers. The 2 July 1987 tornado observed during CINDE: implications for NEXRAD. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorology Society, Boston, 251-254 (1989).

No abstract.

FS-052

Winston, H.A., and E.N. Rasmussen. A study of various implementations of the NEXRAD VIL algorithm. Preprints, 24th Conference on Radar Meteorology, March 27-31, 1989, Tallahassee, FL. American Meteorological Society, Boston, 236-239 (1989).

No abstract.

FS-053

Zhong, X.P., and E.I. TOLLERUD. Rainfall in Mesoscale Convective Complexes: Spatial Distribution and Seasonal Variation. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 111-116 (1989).

No abstract.

FS-054

Zupanski, M. and J. McGINLEY. Numerical analysis of the influence of jets, fronts, and mountains on alpine lee cyclogenesis. Monthly Weather Review 117:154-176 (1989).

Recent diagnostic and numerical studies have shown that lee cyclogenesis events in the lee of the Alps occur when: (1) an upper level trough is upstream; (2) a low level frontal system impinges on the Alps and, (3) an upper level jet streak on the west side of the trough moves into the northern Mediterranean. Three case studies focusing on the rapid development state of Alpine lee cyclogenesis are investigated by performing a set of numerical experiments, with emphasis on the above mentioned factors. In order to create slightly different initial fields, we have used a two layer smoothing technique, alternatively reducing low-level available potential energy [testing (2)], or reducing an upper level wind maxima [testing (3)]. Once this is done we readjust the mass and momentum fields using a variational initialization scheme with weak geostrophic constraints. Based on the results of these cases of lee cyclogenesis, the weaker lee developments were significantly reduced by decreasing the low-level frontal intensity (2), which implied a greater influence of the low level dynamical processes (frontal impingement) relative to jet streak processes (geostrophic adjustment). In the case of relatively strong cyclogenesis, dynamical processes associated with the upper-level jet streak become a more important factor than low level forcing. An overall inhibitory effect of the Alps was obvious in all three cases, particularly in the case of strong cyclogenesis. However, these experiments did show localization of development as manifested by a high-low dipole structure of the mountain induced pressure perturbations.

Addendum

FS-055

VAN DE KAMP, D.W. Profiler Training Manual No. 1: Principles of Wind Profiler Operation. National Weather Service Office of Meteorology, Washington, DC, 49 pp. (1988).

No abstract.

GEOPHYSICAL FLUID DYNAMICS LABORATORY

GF-001

Brasseur, G.P., J. C. Farman, I.S.A. Isaksen, B.C. Kruger, K. Labitzke, J.D. MAHLMAN, M.P. McCormick, P. Solomon, R.S. Stolarski, A. Turco, R.T. Watson. Changes in Antarctic ozone. In The Changing Atmosphere, F.S. Rowland and I.S.A. Isaksen (eds). Wiley-Interscience, New York, 235-256 (1988).

No abstract.

GF-002

Carissimo, B.C., R.T. PIERREHUMBERT, and H.L. Pham. An estimate of mountain drag during ALPEX for comparison with numerical models. Journal of the Atmospheric Sciences 45(13):1949-1960 (1988).

The pressure drag vector for a limited domain including the Alps is estimated for the ALPEX period of March and April 1982. All of the reported, three hourly, surface pressure data in the domain are used and maps of analyzed deviation surface pressure are obtained for the mountainous area. The very important drag values previously reported are confirmed and shown to occur when tight pressure gradients are localized above the steep orography. The peak values are found to be sensitive to the resolution of the analysis. A composite of the large drag variations occurring in relation to frontal passage and cyclogenesis is constructed. The diurnal cycle observed during periods of quiet synoptic activity is discussed. The observed drag compares favorably with the drag in the simulation of a case of cyclogenesis using a numerical model with comparable horizontal resolution.

GF-003

Cnang, P., and S.G.H. PHILANDER. Rossby wave packets in baroclinic mean currents. Deep-Sea Research 36(1):17-37 (1989).

A WKB description of the propagation of Rossby wave packets in a shallow water model of the tropical oceans indicates that the presence of the baroclinic mean currents can modify the characteristics of wave propagation significantly. For currents with weak latitudinal shear the effect of the current itself is less important than the effect of the associated variations in the depth of the thermocline, except near critical layers where waves are absorbed. For example, a westward current, and the associated shoaling of the thermocline towards the equator, can cause the speed of the long Rossby waves to decrease with decreasing latitude. (The speed increases towards the equator in the absence of mean currents.) Westward currents inhibit meridional propagation, but eastward currents enhance it. The amplification and decay of a wave packet as it propagates through a mean current are described in terms of the conservation of wave action. Implications of these results for the propagation of Rossby waves in the real ocean are discussed.

GF-004

COOK, K.H., and I.M. HELD. Stationary waves of the ice age climate. Journal of Climate. 1(8):807-819 (1988).

A linearized, steady state, primitive equation model is used to simulate the climatological zonal asymmetries (stationary eddies) in the wind and temperature fields of the 18000 YBP climate during winter. We compare these results with the eddies simulated in the ice age experiments of Broccoli and Manabe, who used CLIMAP boundary conditions and reduced atmospheric CO_2 in an atmospheric general circulation model (GCM) coupled with a static mixed layer ocean model. The agreement between the models is good, indicating that the linear model can be used to evaluate the relative influences of orography, diabatic heating, and transient eddy heat and momentum transports in generating stationary waves. We find that orographic forcing dominates in the ice age climate. The mechanical influence of the continental ice sheets on the atmosphere is responsible for most of the changes between the present day and ice age stationary eddies. This concept of the ice age climate is complicated by the sensitivity of the stationary eddies to the large increase in the magnitude of the zonal mean meridional temperature gradient simulated in the ice age GCM.

GF-005

DELWORTH, T.L., and S. MANABE. The influence of potential evaporation on the variabilities of simulated soil wetness and climate. Journal of Climate 1(5):523-547 (1988).

An atmospheric general circulation model with prescribed sea surface temperature and cloudiness was integrated for 50 years in order to study atmosphere-land surface interactions. The temporal variability of model soil moisture and precipitation have been studied in an effort to understand the interactions of these variables with other components of the climate system. Temporal variability analysis has shown that the spectra of monthly mean precipitation over land are close to white at all latitudes, with total variance decreasing poleward. In contrast, the spectra of soil moisture are red, and become more red with increasing latitude. As a measure of this redness, half of the total variance of a composite tropical soil moisture spectrum occurs at periods longer than nine months, while at high latitudes, half of the total variance of a composite soil moisture spectrum occurs at periods longer than 22 months. The spectra of soil moisture also exhibit marked longitudinal variations. These spectral results may be viewed in the light of stochastic theory. The formulation of the GFDL soil moisture parameterization is mathematically similar to a stochastic process. According to this model, forcing of a system by an input white noise variable (precipitation) will yield an output variable (soil moisture) with a red spectrum, the redness of which is controlled by a damping term (potential evaporation). Thus, the increasingly red nature of the soil moisture spectra at higher latitudes is a result of declining potential evaporation values at higher latitudes. Physically, soil moisture excesses are dissipated more slowly at high latitudes where the energy available for evaporation is small. Some of the longitudinal variations in soil moisture spectra result from longitudinal variations in potential evaporation, while others are explicable in terms of the value of the ratio of potential evaporation to precipitation. Regions where this value is less than one are characterized by frequent runoff and short time scales of soil moisture variability. By preventing excessive positive anomalies of soil moisture, the runoff process hastens the return of soil moisture values to their mean state, thereby shortening soil moisture time scales. Through the use of a second GCM integration with prescribed soil moisture, it was shown that interactive soil moisture may substantially increase summer surface air temperature variability. Soil moisture interacts with the atmosphere primarily through the surface energy balance. The degree of soil saturation strongly influences the partitioning of outgoing energy from the surface between the latent and sensible heat fluxes. Interactive soil moisture allows larger variations of these fluxes, thereby increasing the variance of surface air temperature. Because the flux of latent heat is directly proportional to potential evaporation under conditions of sufficient moisture, the influence of soil moisture on the atmosphere is greatest when the potential evaporation value is large. This occurs most frequently in the tropics and summer hemisphere extratropics.

GF-006

Hamilton, K., and J.D. MAHLMAN. General circulation model simulation of the semiannual oscillation of the tropical middle atmosphere. Journal of the Atmospheric Sciences 45(21):3212-3235 (1988).

A study has been made of the evolution of the zonal-mean zonal wind and temperature in a multiyear integration of the 40-level, 3° X 3.6° resolution "SKYHI" general circulation model (GCM) that has been developed at GFDL. In the tropical upper stratosphere the mean wind variation is dominated by a strong semiannual oscillation (SAO). The peak SAO amplitude in the model is almost 25 m s^{-1} and occurs near the 1 mb level. The phase of the SAO near the stratosphere is such that maximum westerlies occur shortly after the equinoxes. These features are in good agreement with the available observations. In addition the meridional width of the stratopause SAO in the GCM compares well with observations. A diagnostic analysis of the zonal-mean momentum balance near the tropical stratopause was performed using the detailed fields archived during the GCM integration. It appears that the easterly accelerations in the model SAO are provided by a combination of (i) divergence of the meridional component of the Eliassen-Palm flux associated with quasi-stationary planetary waves and (ii) mean angular momentum advection by the residual meridional circulation. The effects of the residual circulation dominate in the summer hemisphere, while the eddy contributions are more important in the winter hemisphere. The westerly accelerations in the model SAO result from the convergence of the vertical momentum transport associated with gravity waves that have a broad distribution of space and time scales. Thus, in contrast to some simple theoretical models, large-scale equatorial Kelvin waves appear to play only a very minor role in the dynamics of the SAO in the SKYHI GCM. A second equatorial SAO amplitude maximum was found in the tropical upper mesosphere of the GCM. This apparently corresponds to the mesopause SAO that has been identified in earlier observational studies. While the observed phase of this oscillation is reproduced in the model, the simulated amplitude is unrealistically small. The model integration included the computation of the concentration of N_2O. The results show a fairly realistic simulation of the semiannual variation of tropical stratospheric N_2O mixing ratio seen in satellite observations.

GF-007

HAMILTON, K. Interhemispheric asymmetry and annual synchronization of the ozone quasi-biennial oscillation. Journal of the Atmospheric Sciences 46(7):1019-1025 (1989).

The quasi-biennial oscillation (QBO) in total column ozone has been examined at several tropical stations. The ozone QBO at Mauna Loa (19.5°N) was found to have a remarkable annual synchronization. Both positive and negative extremes in the deseasonalized ozone time series almost always occur between December and March. The annual cycle-QBO phase locking is much more pronounced in this ozone record than it is for the familiar QBO in the prevailing tropical stratospheric winds. This result is taken as evidence that the dynamical QBO acts to modulate a strong seasonal ozone transport from midlatitudes to the tropics. If this transport is connected with quasi-stationary planetary waves, then this interpretation offers an obvious explanation for the interhemispheric asymmetry in the ozone QBO that has been noted in many earlier studies.

GF-008

HAYASHI, Y., and D.G. GOLDER. Tropical intraseasonal oscillations appearing in a GFDL general circulation model and FGGE data, Part II: Structure. Journal of the Atmospheric Sciences 45(21):3017-3033 (1988).

Space-time spectral and filter analyses are made of the structure of the tropical intraseasonal oscillations appearing in a GFDL 30-wavenumber spectral general circulation model and the FGGE IIIb data set. The model's tropical zonal velocity exhibits spectral peaks with periods of 40-50 and 25-30 days at wavenumber 1 for six individual years, although the 40-50 day peak is not as pronounced as that found in the FGGE dataset. Both the eastward moving 40-50 and 25-30 day oscillations take the form of a Kelvin-Rossby wave pattern in the upper troposphere and a Rossby mode in the lower troposphere. They also take the form of a latitudinally tilted Walker cell which is modified by a meridional convergence in the boundary layer.

GF-009

HAYASHI, Y., D.G. GOLDER, J.D. MAHLMAN, and S. Miyahara. The effect of horizontal resolution on gravity waves simulated by the GFDL "SKYHI" General Circulation Model. Pageoph 130(2/3):421-443 (1989).

To examine the effects of horizontal resolution on internal gravity waves simulated by the 40-level GFDL "SKYHI" general circulation model, a comparison is made between the 3° and 1° resolution models during late December. The stratospheric and mesospheric zonal flows in the winter and summer extratropical regions of the 1° model are much weaker and more realistic than the corresponding zonal flows of the 3° model. The weaker flows are consistent with the stronger Eliassen-Palm flux divergence (EPFD). The increase in the magnitude of the EPFD in the winter and summer extratropical mesospheres is due mostly to the increase in the gravity wave vertical momentum flux convergence (VMFC). In the summer extratropical mesosphere, the increase in the resolvable horizontal wavenumbers accounts for most of the increase in the gravity wave VMFC. In the winter extratropical mesosphere, the increase of VMFC associated with large-scale eastward moving components also accounts for part of the increase in the gravity wave VMFC. The gravity waves in the summer and winter mesosphere of the 1° model are associated with a broader frequency-spectral distribution, resulting in a more sporadic time-distribution of their VMFC. This broadening is due not only to the increase in resolvable horizontal wavenumbers but also occurs in the large-scale components owing to wave-wave interactions. It was found that the phase velocity and frequency of resolvable small-scale gravity waves are severely underestimated by finite difference approximations.

GF-010

HELD, I.M., S.W. Lyons, and S. Nigam. Transients and the extratropical response to El Niño. Journal of Atmospheric Sciences 46(1):163-174 (1989).

A baroclinic stationary wave model linearized about a zonally symmetric flow is used to interpret the extratropical atmospheric response to El Niño produced by a general circulation model. When forced by the anomalous diabatic heating and tendency due to transients, the linear model provides a useful simulation of this response. The direct response to anomalous diabatic heating is found to be small in the extratropics; the dominant term is the response to the anomalous transients, particularly the anomalous upper tropospheric transients in the vorticity equation. These results are complementary to those obtained with a nonlinear barotropic model by Held and Kang, and indicate that the anomalous subtropical convergence which plays a key role in that study is itself primarily forced by the anomalous transients. One can distinguish between two distinct parts of the response of the transients to the tropical heating: the movement of the Pacific storm track associated with the anomalous extratropical wave train, and changes in the penetration of Rossby waves into the tropics resulting from the modified tropical winds.

GF-011

Kantha, L.H., A. ROSATI, and B. Galperin. Effect of rotation on vertical mixing and associated turbulence in stratified fluids. Journal of Geophysical Research 94:4843-4854 (1989).

Combined effects of stratification and rotation on vertical mixing and the characteristics of associated small-scale turbulence are explored using second-moment closure methodology; the rotational terms in the equations for Reynolds stresses and turbulent heat fluxes are retained, not ignored as in earlier works. Semianalytical results valid for arbitrary values of rotation and stratification are derived by further invoking the local equilibrium limit of closure. Two cases are considered: nonzero vertical rotation and nonzero meridional rotation; the latter case is of more general interest in geophysics because of its potential application to equatorial mixed layers. In both cases the influence of rotation on mixing coefficients and Monin-Obukhov constant flux layer similarity relations is investigated for arbitrary values of rotation and stratification. In both cases, turbulent mixing coefficients assume tensorial properties. However, meridional rotation appears to have a stronger influence on vertical mixing and turbulence characteristics than does vertical rotation. These results, along with perturbation expansions for weak rotation, suggest that for geophysical flows, in most cases, the direct effect of rotation on vertical turbulent mixing itself is but a small correction, a few tens of percent at best. It is seldom large, although it might not be negligible in some particular cases. Nevertheless, the study of rotational effects on small-scale turbulence provides a fascinating insight into the direct impact of rotation on the characteristics of small-scale turbulence and mixing in stratified fluids; the results are also of interest in other fields such as engineering.

GF-012

LAU, N.-C. Variability of the observed midlatitude storm tracks in relation to low-frequency changes in the circulation pattern. Journal of the Atmospheric Sciences 45(1):2718-2743 (1988).

The principal modes of month-to-month variability of the wintertime storm tracks over the North Pacific and North Atlantic are identified by empirical orthogonal function analysis of the root-mean-square statistics of bandpass (2.5-6 day) filtered geopotential height data for 19 yr. One of the two leading modes depicts fluctuations in the level of synoptic-scale activity without any noticeable spatial displacement of the storm track axes, whereas the other mode is associated with meridional shifts of the storm tracks from their time-averaged positions. Higher order modes are indicative of diversion or truncation of cyclone tracks in particular geographical regions. It is demonstrated that the leading storm track modes are linked to some of the best-known monthly averaged teleconnection patterns. The dipolar western Pacific and western Atlantic patterns for the monthly mean flow are seen to be accompanied by marked changes in the intensity of the storm tracks over the western oceans, whereas the more wave-like Pacific/North American and eastern Atlantic teleconnection patterns are coincident with north-south displacements of the storm track axes over the eastern oceans. The representative synoptic scenarios for various storm track modes are portrayed using composite charts. These patterns illustrate the strong modulation of the trajectory of weather systems by the intensity and steering action of the monthly averaged flow field, so that the storm tracks are preferentially located at and slightly downstream of the quasi-stationary troughs. The shape and propagation of the synoptic scale eddies along the changing storm tracks, as well as the barotropic interactions between these disturbances and the monthly mean flow, are diagnosed using composite patterns of extended Eliassen-Palm vectors and eddy-induced geopotential tendencies at 300 mb. It is seen that the synoptic-scale fluctuations are typically crescent-shaped, and sometimes undergo noticeable deformation when they encounter quasi-stationary ridges. In the upper troposphere, enhanced eddy activity is accompanied locally by eastward acceleration, as well as by positive geopotential tendency immediately to the south, and negative geopotential tendency to the north, and vice versa. The distributions of eddy-induced geopotential tendency for individual storm track modes indicate a near inphase relationship between the synoptic scale barotropic forcing and the quasi-stationary flow pattern at 300 mb. The characteristic time scale for this forcing is approximately 7-10 days. The characteristic circulations at sea level associated with various storm track modes are examined using composite charts of the sea level pressure field. Some of these composites resemble the patterns associated with the North Pacific and North Atlantic Oscillations.

GF-013

LAU, N.-C., I.M. HELD, and J.D. Neelin. The Madden-Julian oscillation in an idealized general circulation model. Journal of the Atmospheric Sciences 45(24):3810-3832 (1988).

The structure of the intraseasonal oscillations in the tropics of an idealized general circulation model with a zonally symmetric climate is described. Space-time spectra show a peak in zonal winds and velocity potential at the equator in zonal wavenumbers 1 and 2, corresponding to eastward-propagating power at phase speeds of ≈ 18 m s^{-1}. This speed is significantly greater than that of the observed oscillation but comparable to that obtained in similar models by Hayashi and Sumi and Swinbank et al. The

corresponding eastward-propagating power in the precipitation spectrum is concentrated in wavenumbers 2-5. A composite procedure is used to describe the three-dimensional structure of the model's oscillation. The oscillation is characterized by circulation cells oriented along the equatorial zonal plane, with enhanced precipitation in the region of rising motion. Zonal wind changes tend to be positively correlated with geopotential height changes at the same level. Positive perturbations in the water vapor mixing ratio, evaporation, and lower tropospheric horizontal moisture convergence all exhibit distinct eastward displacements from the center of convection. Two different linear models are used to interpret the GCM results. The response to the GCM's composited diabatic heating field is first computed using a linear primitive equation model on the sphere. This linear model requires strong damping above the heated region, as well as near the surface, to produce a pattern in rough agreement with the GCM. A simple Kelvin wave-CISK model, in which the vertical structure of the heating is taken from the composite, is then shown to be capable of reproducing the phase speed simulated in the GCM.

GF-014

LEVITUS, S., Decadal and pentadal distribution of hydrographic stations at 1000m depth for the world ocean, Progress in Oceanography 20(2):83-101 (1989).

Global distributions of hydrographic stations at 1000m depth in the world ocean are presented by decades for the period 1900-1949 and pentads for the period 1950-1974. Distributions for individual years 1965-1967 are also presented. The distributions indicate regions that may contain enough data to be suitable for studies of interpentadal and interdecadal variability.

GF-015

LEVITUS, S. Interpentadal variability of temperature and salinity at intermediate depths of the North Atlantic Ocean, 1970-1974 versus 1955-1959. Journal of Geophysical Research 94(C5):6091-6131 (1989).

We have composited historical hydrographic observations for the world ocean for two pentads, 1955-1959 and 1970-1974, and have objectively analyzed these data for the purpose of studying the temporal variability of temperature and salinity in the North Atlantic Ocean. The subtropical gyre (500-1300 m) of the North Atlantic was colder and fresher during 1970-1974 compared to 1955-1959. The relatively large changes in temperature and salinity on constant-depth surfaces in the subtropical gyre were due to upward displacements of isopycnal surfaces. At intermediate depths the eastern portion of the subarctic gyre was also colder and fresher during the 1970-1974 pentad. In contrast, the western portion of the subarctic gyre exhibited higher temperatures and salinities during 1970-1974 compared to 1955-1959. Characteristic differences in temperature and salinity for both gyres were 0.5°C and 0.025°/$_{oo}$, respectively. Analysis of changes in potential vorticity indicates that in the subtropical gyre potential vorticity increased in all density layers above the 26.5 surface, suggesting that convection in this region may have been shallower in 1970-1974 compared to 1955-1959. Below the 26.5 surface, potential vorticity decreased through the 27.3 surface, indicating that deeper than normal convection may have formed the water masses in these layers. At 250 m depth, relatively large changes in temperature and salinity occurred along the line of maximum climatological mixed layer depth that extends northeast to southwest across the North Atlantic Ocean.

GF-016

LEVY, H., II. Simulated global deposition of reactive nitrogen emitted by fossil fuel combustion. Proceedings of the IAHS Third Scientific Assembly, Symposium I, Atmospheric Deposition, Baltimore, MD. May 1989, 3-9 (1989).

We use the medium resolution (265 km horizontal grid) Geophysical Fluid Dynamics Laboratory (GFDL) general circulation transport model to simulate the global deposition of reactive nitrogen emitted by fossil fuel combustion. The nitrogen species are transported as a single tracer, the global parameter for wet deposition is based on the observed wet deposition of nitrogen over North America, and constant bulk coefficients for dry deposition over land and sea are pre-calculated from measured concentrations and deposition velocities. The simulated yearly wet depositions in Europe, as well as nearby and distant export sites, are in reasonable agreement with observations. The agreement is generally quite good and almost always within a factor of 2. No more than 1.4 Tg of the 21.3 of nitrogen emitted by fossil fuel combustion are deposited in the Southern Hemisphere, yet this source accounts for less than 10% of the apparent background deposition. The 4 Tg of nitrogen exported by the three major source regions (US/Canada, Europe, and Asia) accounts for most of the deposition over the remote Northern Hemisphere. The simulated deposition over the North Pacific, which is in good agreement with estimates based on recent observations, is dominated by emissions from Asia, while US/Canadian emissions dominate deposition over the North Atlantic.

GF-017

LEVY II, H., and W.J. MOXIM. Simulated global distribution and deposition of reactive nitrogen emitted emitted by fossil fuel combustion. Tellus 41B, 256-271 (1989).

We use the medium resolution (~265 km horizontal grid) GFDL general circulation transport model to simulate the global spread and deposition of reactive nitrogen emitted by fossil fuel combustion. The nitrogen species are transported as a single tracer with no explicit chemistry. Chemical reactions are only present implicitly in the bulk coefficients for dry and wet removal. The observed wet deposition of nitrogen over North America is used to determine the global parameter for wet deposition, and constant bulk coefficients for dry deposition over land and sea are pre-calculated from measured concentrations and deposition velocities. The simulated yearly depositions in Western Europe and at regional export sites, as well as simulated yearly concentrations and their seasonal variation over the North Pacific, are compared with available observations. The agreement is generally quite good and almost always within a factor of 2. This model is then used to identify a number of important source regions and long-range transport mechanisms: (1) Asian emissions supply two-thirds of the soluble nitrogen compounds over the North Pacific. In the summer, North American emissions are important over the subtropical North Pacific. (2) Nitrogen emissions from Europe dominate the nitrogen component of Arctic haze in the lower troposphere, while North American and Asian emissions are only important locally. The model predicts a large gradient in the Arctic with average winter mixing ratios ranging from less than 0.1 ppbv over Alaska to more than 1 ppbv over eastern Russia. (3) Throughout the Southern Hemisphere, the emissions from fossil fuel combustion account for 10% or less of the observed soluble nitrogen at remote sites, an amount less than a previously simulated contribution from stratospheric injection. The long-range transport of PAN, NO_x production by lightning and biomass burning, and some, as yet, unknown marine biogenic source may all supply part of this background soluble nitrogen. However, the similarity between the seasonal cycles observed at Samoa for soluble nitrogen and for O_3, a species known to be supplied from the stratosphere, suggests a major role for either stratospheric injection or an upper tropospheric source.

GF-018

Lin, S.-J., and R.T. PIERREHUMBERT. Does Ekman friction suppress baroclinic instability? Journal of the Atmospheric Sciences 45(20):2920-2933 (1988).

The effect of Ekman friction on baroclinic instability is reexamined in order to address questions raised by Farrell concerning the existence of normal mode instability in the atmosphere. As the degree of meridional confinement is central to the result, a linearized two-dimensional (latitude-height) quasi-geostrophic model is used to obviate the arbitrariness inherent in choosing a channel width in one-dimensional (vertical shear only) models. The two-dimensional eigenvalue problem was solved by pseudospectral method using rational Chebyshev expansions in both vertical and meridional directions. It is concluded that the instability can be eliminated only by the combination of strong Ekman friction with weak large-scale wind shear. Estimates of Ekman friction based on a realistic boundary-layer model indicate that such conditions can prevail over land when the boundary layer is neutrally stratified. For values of Ekman friction appropriate to the open ocean, friction can reduce the growth rate of the most unstable mode by at most a factor of two but cannot eliminate the instability. By reducing the growth rate and shifting the most unstable mode to lower zonal wavenumbers, viscous effects make the heat and momentum fluxes of the most unstable mode deeper and less meridionally confined than in the inviscid case. Nevertheless, linear theory still underestimates the penetration depth of the momentum fluxes, as compared to observations and nonlinear numerical models.

GF-019

LIPPS, F.B., and R.S. HEMLER. Numerical modeling of a line of towering cumulus on day 226 of GATE. Journal of the Atmospheric Sciences 45(17):2428-2444 (1988).

A three-dimensional numerical model with warm rain bulk cloud physics is used to investigate the shallow convection observed on Day 226 of GATE. This convection had cloud tops at 3.0 km, cloud bases at 0.4 km and approximately 0.1 cm of rain at the surface. The simulated convection shows a strong sensitivity to the criterion for the onset of autoconversion of cloud water into rain water. The strongest convection occurs for the case in which no rain water forms. This case, however, does not conform to the observed convection, lacking the downdraft below cloud base and the observed strong surface outflow. The primary simulation produces a "finger" of convection propagating to the northeast, perpendicular to the northwest-southeast orientation of the larger-scale line of convection. The orientation and propagation speed of the calculated convection are in excellent agreement with observed radar data. This simulation also has a well-defined leading edge and strong surface outflow as observed. In poorer agreement, the cloud base was too high and the rainfall at the surface was less than observed.

Present calculations indicate that below cloud base the boundary layer air is flowing through the line from southwest to northeast. The primary moisture source for the cloud is the upper half of the subcloud layer, with nearly horizontal flow entering the cloud.

GF-020

MANABE, S., and R.J. STOUFFER. Two stable equilibria of a coupled ocean-atmosphere model. Journal of Climate 1:841-866 (1988).

Two stable equilibria have been obtained from a global model of the coupled ocean-atmosphere system developed at the Geophysical Fluid Dynamics Laboratory of NOAA. The model used for this study consists of general circulation models of the atmosphere and the world oceans and a simple model of land surface. Starting from two different initial conditions, "asynchronous" time integrations of the coupled model, under identical boundary conditions, lead to two stable equilibria. In one equilibrium, the North Atlantic Ocean has a vigorous thermohaline circulation and relatively saline and warm surface water. In the other equilibrium, there is no thermohaline circulation, and an intense halocline exists in the surface layer at high latitudes. In both integrations, the air-sea exchange of water is adjusted to remove a systematic bias of the model that suppresses the thermohaline circulation in the North Atlantic. Nevertheless, these results raise the intriguing possibility that the coupled system may have at least two equilibria. They also suggest that the thermohaline overturning in the North Atlantic is mainly responsible for making the surface salinity of the northern North Atlantic higher than that of the northern North Pacific. Finally, a discussion is made on the paleoclimatic implications of these results for the large and abrupt transition between the Allerod and Younger Dryas events which occurred about 11,000 years ago.

GF-021

MIYAKODA, K., A. ROSATI, R. GUDGEL, and Y. Chao. Study of ENSO with an ocean GCM. Pontificia Academia Scientiarvm 69:97-119 (1988).

A time series of surface atmospheric data is applied to an ocean GCM as a surface boundary condition. The GCM has 1° X 1° grid in the global domain except 1° X 1/3° high resolution in the equatorial zone, and has 12 vertical levels. The turbulence closure scheme is used for the vertical mixing. The atmospheric forcings are twice daily, based on the NMC analysis. The period simulated is the four years from 1980-1983, which include the 1982/83 El Niño. The simulation of the warm event is satisfactory. A diagnostic study on the ENSO process is performed. The time evolution of SO pressure patterns and of the surface wind fields for the 1982/83 case compare fairly well with the canonical case presented by Rasmusson and Carpenter (1982) and van Loon (1986). Based on this analysis, a hypothetical view is presented on the significance of the SO pattern and wind stress to the El Niño process.

GF-022

MIYAKODA, K., and J. SIRUTIS. A proposal of moist turbulence closure scheme, and the rationalization of Arakawa-Schubert cumulus parameterization. Meteorology and Atmospheric Physics 40:110-122 (1989).

Subgrid-scale parameterizations related to moist process are discussed. In the first half of the paper, a turbulence closure scheme, including the effect of condensation, is proposed. In this parameterization, the subgrid-scale transfer is limited within a single vertical layer of a model per each time step, and the specification of condensation is of yes-or-no type. Therefore, the scheme is suited for a mesoscale circulation model. In the second half of this paper, the bounded derivative method of Kreiss (1980) is applied to the formulation of parameterizations. One example is the derivation of various hierarchial versions of turbulence closure schemes, such as Mellor and Yamada (1974). Another example is an interpretation of the key assumption in Arakawa-Schubert (1974) theory of cumulus convection, i.e., the equilibrium of "cloud-work function".

GF-023

MIYAKODA, K. Atmospheric forecast model data assimilation and air-sea flux computations. Workshop Report on Atmospheric Forcing of Ocean Circulation, January 4-7, 1988. Tulane University, New Orleans, LA. Sponsored by (INO), (WOCE), and (TOGA), 55-94 (1989).

The estimate of air-sea fluxes in data assimilation is discussed. Air-sea fluxes consist of the transport of sensible and latent heat, radiation, and momentum at the air-sea interface. In order to gain a clear perspective on the problem of air-sea exchange, the current state of the seasonal forecast experiment, using an air-sea coupled model, is overviewed. An important feature of the current coupled model forecasts is that the estimated sea surface temperature is considerably lower than the observed. The deficient heat flux is as large as 100 W m^{-2} in the Equatorial Pacific and Kuroshio regions. The main

cause is the model's systematic error ("climate drift"). In the particular case, the atmospheric model's insufficient horizontal space resolution is responsible for the deficiency. It is pointed out that the accuracy of calculated fluxes in the GCM framework is determined not only by the specification of the flux algorithm in the interface boundary layers, but also by the formulations of other physics as well as the model's resolution. The second half of the paper is devoted to the discussion of estimating air-sea fluxes within the atmospheric data assimilation process. Data assimilation schemes in general are divided into two categories, i.e., the intermittent and the continuous versions. The characteristics of these versions are described, and some samples of the resultant flux estimates are shown. Finally, an inter-comparision is presented on the state-of-the-art flux estimates at two operational centers.

GF-024

OORT, A.H. Climate observations and diagnostics. In Physically-Based Modelling and Simulation of Climate and Climatic Change, Part II. M. E. Schlesinger (ed.). Kluwer Academic Publishers, 813-840 (1988).

An observational-statistical approach to the study of the Earth's climate is described. The approach is based mainly on in situ atmospheric and oceanic observations which are analyzed using the conservation equations of total mass, angular momentum, energy and water. Through such analyses one can diagnose the role of the various components in the climatic system. The different observational networks and some frequently used methods of objective analysis are also presented. Finally, some examples are given to show the possibilities of the approach to the case of global and regional budgets of energy and water.

GF-025

OORT, A.H. The search for unity in the climatic system. Summary of a lecture series presented at the Universite Catholique de Louvain, Institut D'Astronomie et de Geophysique, Georges Lemaitre, Belgium, October 1987, 1-28 (1988).

Studies of the earth's climate system clearly show that the atmosphere, oceans, land surfaces, cryosphere and biosphere are intimately connected with each other. Some of the complexities of the climate system are due to the very different time scales found in the subsystems and due to the operation of a variety of interactions and feedback processes between them. The role of the oceans and atmosphere in storing heat seasonally and in transporting energy poleward to maintain the climatic balance is discussed in detail.

GF-026

OORT, A.H., S.C. Ascher, S. LEVITUS, and J.P. Peixóto. New estimates of the available potential energy in the world ocean. Journal of Geophysical Research 94(C3):3187-3200 (1989).

On the basis of extensive global data sets the total amounts of internal, potential, latent, and kinetic energy in the world oceans and atmosphere are estimated and compared for annual mean and seasonal conditions. Next, an expression for the available gravitational potential energy in the oceans is derived. The computed amounts of zonal mean and transient eddy available potential energy and the amount of kinetic energy present in the oceans are found to be much smaller (at least 1 order of magnitude) than those in the atmosphere. Because of the sparseness of directly measured subsurface values, the estimates of the kinetic energy and the transient eddy available potential energy were obtained by extrapolation from the corresponding values measured at the ocean surface. The fact that relatively large density variations are found only in the upper few hundred meters of the oceans and the greater stability of the oceans are the basic reasons for the generally small values of the potential and kinetic energy in the oceans compared with those in the atmosphere.

GF-027

PHILANDER, S.G.H., and W.J. HURLIN. The heat budget of the Tropical Pacific Ocean in a simulation of the 1982-83 El Niño. Journal of Physical Oceanography 18(6):926-931 (1988).

The heat budget of a model that realistically simulates El Niño of 1982-1983 indicates that the enormous changes in the winds during that event failed to disrupt the usual seasonal variations in meridional heat transport. Cross-equatorial transport towards the winter hemisphere continued as in a regular seasonal cycle. The key factor was the continued seasonal migrations of the ITCZ during the El Niño. In early 1983 the ITCZ strayed further south than usual and remained near the equator longer than usual thus causing an increase in the northward heat transport. This, together with an increase in the evaporative heat loss because of higher sea surface temperatures, resulted in a large loss of heat from the band of latitudes 12°N-12°S approximately, during the El Niño.

GF-028

Ramaswamy, V., and V. Ramanathan. Solar absorption by cirrus clouds and the maintenance of the tropical upper troposphere thermal structure. Journal of the Atmospheric Sciences 46(14):2293-2310 (1989).

Radiative transfer calculations employing observed values of the ice crystal size distribution demonstrate that the absorption of solar radiation by cirrus clouds can make a significant contribution to the diabatic heating of the upper troposphere. The effects due to this absorption on the upper tropospheric (100-300 mb) thermal profile are investigated in a general circulation model (GCM) with interactive clouds; guided by observations, two experiments are performed assuming vastly different vertical profiles of the ice water density. Solar heating rates within the extensive cirrus decks associated with monsoon and other convective clouds reach values of 1.5 K day^{-1}. Thus, cirrus solar heating can be an important source for east-west asymmetries in the tropical diabatic heating. Furthermore, because of the latitudinal gradients in the solar insolation, cirrus solar absorption can also influence the meridional heating gradients within the upper troposphere. In spite of the significant east-west asymmetries in the imposed cirrus solar heating, the change in the GCM tropical temperatures is nearly zonally uniform. The magnitude of the zonal mean tropical temperature changes in the GCM (up to 5°K at P = 165 mb) indicate that lack of cirrus solar heating may be one reason for the cold bias of the GCMs. Furthermore, the shortwave heating can also account for the observed lapse rate stabilization in the upper troposphere. In addition to the solar effect, the longwave radiative effects of cirrus can also be important but their sign and magnitude are very sensitive to the vertical distribution of clouds. Cirrus longwave heating rates can range from large negative values (cooling) when overlying optically thick clouds (for example, in "deep" extended systems with base below the upper troposphere) to large positive values (heating) for "anvil" type cirrus located in the upper troposphere and with no other clouds below. For the overcast portions of the tropics, if "anvil" type cirri are the only clouds of significance in the upper troposphere, the longwave heating would be the dominant radiative component and this effect becomes more pronounced with increasing altitude of cloud location. Hence, for the tropical zone as a whole, the sign and magnitude of the longwave effect depends on the relative composition of the "deep" and "anvil" clouds. Radiation model calculations that employ climatological values of the vertical distribution of clouds yield a longwave heating effect for the cirrus with the magnitude being comparable to the solar effect. Thus, our results suggest a significant role of the cirrus radiative effects in maintaining the zonal mean thermal structure of the upper troposphere. This inference should be contrasted with the notion that the steep positive gradient in the tropical upper-troposphere potential temperatures is maintained by the latent heat released in penetrating cumulus towers.

GF-029

Sarmiento, J.L., T.D. Herbert, and J.R. Toggweiler. Causes of anoxia in the World Ocean. Global Biogeochemical Cycles 2(2):115-128 (1988).

We examine the hypothesis that global scale episodes of anoxia such as occurred in the Cretaceous are due to high productivity and/or stagnation of the circulation. Two modes of ocean circulation are considered: a thermohaline overturning cell, essentially vertical, which involves global scale upwelling into the surface followed by sinking in deep water formation regions; and an approximately horizontal cell which connects the abyss directly with deeply convecting waters in deep water formation regions. Modern analogs for these processes are formation of North Atlantic Deep Water and Antarctic Bottom Water, respectively. Over most of the oceans the surface new production is nutrient limited and thus directly proportional to the supply of nutrients by the vertical overturning cell. A reduction in oxygen can only be brought about by increased vertical overturning associated with increased production. In addition, the model shows that as the deep ocean becomes lower in oxygen, the sensitivity of the oxygen levels to the meridional circulation decreases such that it becomes difficult or impossible to achieve complete anoxia. This relative insensitivity of deep ocean oxygen levels to the magnitude of the vertical overturning cell and associated surface production may explain why it has been difficult to establish a clear connection between high surface productivities in low and mid-latitudes and anoxia. In deep water formation regions, on the other hand, new production is not nutrient limited. A reduction in abyssal oxygen can be brought about by high productivity in such regions and/or by stagnation of the horizontal circulation cell, in accordance with the stagnation hypothesis. Furthermore, the sensitivity of the deep ocean oxygen to the processes occurring in deep water formation regions increases as oxygen levels decrease. We therefore suggest that processes occurring in deep water formation regions may be the critical ones in determining deep ocean oxygen.

GF- 030

Sarmiento, J.L., T.D. Herbert, and J.R. Toggweiler. Mediterranean nutrient balance and episodes of anoxia. Global Biogeochemical Cycles 2(4):427-444 (1988).

We examine the causes of anoxia in regions such as the Eastern Mediterranean, which have exchange over sills with adjacent basins. Box models show that the concentration of the limiting nutrient is the major determinant of deep oxygen levels. The most effective way of increasing nutrient concentrations to the point where anoxia occurs is to change the flow pattern across the sills ventilating the basins. With a sill exchange pattern such as that in the present Strait of Sicily, it is difficult to obtain anoxia in the Eastern Mediterranean without also driving the Western Mediterranean to low oxygen and high nutrient levels. Episodes of anoxia in the Eastern Mediterranean are associated with a freshening of surface waters. A reversal in flow directions, presumably resulting from the observed freshening, will inevitably lead to anoxia associated with increased sediment burial rates of the limiting nutrient and will leave the Western Mediterranean largely unaffected, in keeping with the observational evidence.

GF-031

Snieder, R.K., and S.B. FELS. The flywheel effect in the middle atmosphere. Journal of the Atmospheric Sciences 45(24):3996-4004 (1988).

Because of the requirement of geostrophic balance, mechanical inertia can affect the thermal response of the atmosphere to transient heating. We examine some very simple linear models of this "flywheel effect," and discuss their possible reference to the Antarctic ozone hold.

GF-032

TOGGWEILER, J.R., K. DIXON, and K. BRYAN. Simulations of radiocarbon in a coarse-resolution world ocean model. 1. Steady state prebomb distributions. Journal of Geophysical Research 94(C6):8217-8242 (1989).

This paper presents the results of five numerical simulations of the radiocarbon distribution in the ocean using the Geophysical Fluid Dynamics Laboratory primitive equation world ocean general circulation model. The model has a 4.5° latitude by 3.75° longitude grid, 12 vertical levels, and realistic continental boundaries and bottom topography. The model is forced at the surface by observed, annually averaged temperatures, salinities, and wind stresses. There are no chemical transformations or transport of ^{14}C by biological processes in the model. Each simulation in this paper has been run out the equivalent of several thousand years to simulate the natural, steady state distribution of ^{14}C in the ocean. In a companion paper the final state of these simulations is used as the starting point for simulations of the ocean's transient uptake of bomb-produced ^{14}C. The model reproduces the mid-depth ^{14}C minimum observed in the North Pacific and the strong front near 45°S between old, deep Pacific waters and younger circumpolar waters. In the Atlantic, the model's deep ^{14}C distribution is much too strongly layered with relatively old water from the Antarctic penetrating into the northern reaches of the North Atlantic basin. Two thirds of the decay of ^{14}C between 35°S and 35°N is balanced by local ^{14}C input from the atmosphere and downward transport by vertical mixing (both diffusion and advective stirring). Only one third is balanced by transport of ^{14}C from high latitudes. A moderately small mixing coefficient of 0.3 $cm^2 s^{-1}$ adequately parameterizes vertical diffusion in the upper kilometer. Spatial variation in gas exchange rates is found to have a negligible effect on deepwater radiocarbon values. Ventilation of the circumpolar region is organized in the model as a deep overturning cell which penetrates as much as 3500 m below the surface. While allowing the circumpolar deep water to be relatively well ventilated, the overturning cell restricts the ventilation of the deep Pacific and Indian basins to the north. This study utilizes three different realizations of the ocean circulation. One is generated by a purely prognostic model, in which only surface temperatures and salinities are restored to observed values. Two are generated by a semidiagnostic model, in which interior temperatures and salinities are restored toward observed values with a 1/50 $year^{-1}$ time constant. The prognostic version is found to produce a clearly superior deep circulation in spite of producing interior temperatures and salinities which deviate very noticeably from observed values. The weak restoring terms in the diagnostic model suppress convection and other vertical motions, causing major disruptions in the diagnostic model's deep sea ventilation.

GF-033

TOGGWEILER, J.R., K. DIXON, and K. BRYAN. Simulations of radiocarbon in a coarse-resolution world ocean model. 2. Distributions of bomb-produced carbon 14. Journal of Geophysical Research 94(C6):8243-8264 (1989).

Part 1 of this study examined the ability of the Geophysical Fluid Dynamics Laboratory (GFDL) primitive equation ocean general circulation model to simulate the steady state distribution of naturally produced ^{14}C in the ocean prior to the nuclear bomb tests of the 1950's and early 1960's. In Part 2 we begin with the steady state distributions of Part 1 and subject the model to the pulse of elevated atmospheric ^{14}C concentrations observed since the 1950's. This study focuses on the processes and time scales which govern the transient distributions of bomb ^{14}C in the upper kilometer of the ocean. Model projections

through 1990 are compared with observations compiled by the Geochemical Ocean Sections Study (GEOSECS) in 1972, 1974, and 1978; the Transient Tracers in the Ocean (TTO) expedition in 1981, and the French INDIGO expeditions in 1985-1987. In their analysis of the GEOSECS ^{14}C observations, Broecker et al. (1985) noted that much of the bomb ^{14}C which entered the ocean's equatorial belts prior to GEOSECS accumulated in the adjacent subtropical zones. Broecker et al. argued that this displacement of bomb ^{14}C inventories was caused by the wind-driven upwelling and surface divergence in the tropics combined with convergent flow and downwelling in the subtropics. Similar displacements were invoked to shift bomb ^{14}C from the Antarctic circumpolar region into the southern temperate zone. The GFDL model successfully reproduces the observed GEOSECS inventories, but then predicts a significantly different pattern of bomb ^{14}C uptake in the decade following GEOSECS. The post-GEOSECS buildup of bomb ^{14}C inventories is largely confined to the subthermocline layers of the North Atlantic, the lower thermocline of the southern hemisphere, and down to 2000 m in the circumpolar region. A great deal of attention is devoted to detailed comparisons between the model and the available radiocarbon data. A number of flaws in the model are highlighted by the analysis. The Subantarctic Mode Waters forming along the northern edge of the circumpolar current are identified as a very important process for carrying bomb ^{14}C into the thermoclines of the southern hemisphere. The model concentrates its mode water formation in a single sector of the circumpolar region and consequently fails to form its mode waters with the correct T-S properties. The model also moves bomb ^{14}C into the deep North Atlantic and deep circumpolar region much too slowly.

GF-034

TOGGWEILER, J.R. Is the downward dissolved organic matter (DOM) flux important in carbon transport? Productivity of the Ocean: Present and Past, Dahlem Konferenzen, 1988. John Wiley & Sons, (Publ.) pp.65-83, (1989).

A new method for measuring the concentration of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in seawater has recently been applied to the study of the material balance in the oceanic water column. These measurements suggest that the downward transport of organic carbon and nitrogen in the dissolved organic phase is every bit as important as the downward transport in sinking particles. It appears that DOC and DON are the most important organic substrates supporting the consumption of oxygen and the remineralization of nitrate below the thermocline. Although still controversial, these findings are supported by a model study which shows that the vertical transport of organic matter cannot be attributed solely to the fast-sinking particles caught in sediment traps. A characterization of the vertical flux as such produces a model nutrient distribution which bears little resemblance to observed distributions.

GF-035

WILLIAMS, G.P. The dynamical range of global circulations - II. In Climate Dynamics 3:45-84, Springer-Verlag (1988).

The dynamical range of global atmospheric circulations is extended to specialized parameter regions by models. In Part I, we derived the basic range of circulations by altering Ω for moist and dry atmospheres with regular and modified surfaces. Again we find the circulations to be composed of only a few elementary forms. In axisymmetric atmospheres, the circulations consist of a single jet in the rotational midrange ($\Omega^*=\frac{1}{2}$-1) and of double jets in the high range (Ω^*=2-4), together with one or two pairs of Hadley and Ferrel cells; where $\Omega^*=\Omega/\Omega_E$ is the rotation rate normalized by the terrestrial value. These circulations differ from those predicted by first-order symmetric-Hadley (SH_1) theory because the moist inviscid atmosphere allows a greater nonlinearity and prefers a higher-order meridional mode. The axisymmetric circulations do, however, resemble the mean flows of the natural system - but only in low latitudes, where they underly the quasi-Hadley (QH) element of the MOIST flows. In midlatitudes, the axisymmetric jets are stronger than the natural jets but can be reduced to them by barotropic and baroclinic instabilities. Oblique atmospheres with moderate to high tilts (Θ_p=25°-90°) have the equator-straddling Hadley cell and the four basic zonal winds predicted by the geometric theory for the solstitial-symmetric-Hadley (SSH) state: an easterly jet and a westerly tradewind in the summer hemisphere, and a westerly jet and an easterly tradewind in the winter hemisphere. The nonlinear baroclinic instability of the winter westerly produces a Ferrel cell and the same eddy fluxes as the quasi-geostrophic QG element, while the instability of the summer easterly jet produces a QG-Hadley (QGH) element with a unique, vertically-bimodal eddy momentum flux. At high Θ_p and low Ω^*, the oblique atmospheres reach a limiting state having global easterlies, a pole-to-pole Hadley cell, and a warm winter pole. At low tilts (Θ_p < 10°), the oblique circulations have a mix of solstitial and equinoctial features. Diurnal heating variations exert a fundamental influence on the natural-Hadley (NH) circulations of slowly-rotating systems, especially in the singular range where the zonal winds approach extinction. The diurnality just modifies the NH element in the upper singular range ($1/45 < \Omega^* < 1/16$), but completely transforms it into a subsolar-antisolar Halley circulation in the lower range ($0 < \Omega^* < 1/45$). In the modified NH flows, the diurnality acts through the convection to enhance the generation of

the momentum-transferring planetary waves and, thereby, changes the narrow polar jets of the non-diurnal states into broad, super-rotating currents. Circulation theory for these specialized flows remains rudimentary. It does not explain fully how the double jets and the multiple cells arise in the axisymmetric atmospheres, how the QGH element forms in the oblique atmospheres, or how waves propagate in the slowly rotating diurnal atmospheres. but eventually all theories could, in principle, be compared against planetary observation: with Mars testing the QGH elements; Jupiter, the high-range elements; Titan, the equinoctial and solstitial axisymmetric states; and Venus, the diurnally modified NH flows.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

GL-001
ASSEL, R.A. Impact of global warming on Great Lakes ice cycles. The Potential Effects of Global Climate Change on the United States: Appendix A - Water Resources, EPA DW13932631-01-0. U.S. EPA Office of Policy, Planning and Evaluation, Washington, DC, 5.1-5.30 (1989).

No Abstract.

GL-002
BOLSENGA, S.J. Certain properties of spectrally integrated and spectral transmittances of freshwater ice from 400-700 NM. Proceedings, POAC '89: 10th International Conference on Port and Ocean Engineering under Arctic Conditions, Lulea, Sweden, June 12-16, 1989. Lulea University of Technology, 188-198 (1989).

Considerable information is available on the transmittance of photosynthetically active radiation (PAR: 400-700 nm) through sea ice, whereas relatively little is known about PAR transmittance through freshwater ice. Transmittances of PAR through some common freshwater ice types (including clear ice, refrozen slush, and snow ice) are reported from studies using instruments which measure both spectral (2-10 nm increments) and spectrally integrated transmittances over this range. Snow causes the greatest attenuation of radiation, often reducing transmittances to 10% or less over the spectrum as a result of even light covers (2-8 cm). Clear ice showed transmittances of 80-95% for the spectrally integrated data and from 65 to nearly 95% for the spectral data. Transmittances of other ice types were bounded by the clear ice/snow-covered-ice transmittance range. Comparisons between the spectral and spectrally integrated data sets show specific applications for each type of measurement.

GL-003
BOLSENGA, S.J., J.E. Gannon, G. Kennedy, D.C. NORTON, and C.E. Herdendorf. ROV dives under Great Lakes ice. Cold Regions Science and Technology 16:89-93 (1989).

No abstract.

GL-004
BOLSENGA, S.J., H.A. VANDERPLOEG, M.A. QUIGLEY, and G.L. FAHNENSTIEL. Note. Operations for an under-ice ecology program. Journal of Great Lakes Research 14(3):372-376 (1988).

A pilot program tested the feasibility of conducting a study on the under-ice ecology of the Great Lakes. The east arm of Grand Traverse Bay, in the lower peninsula of Michigan, was chosen as the test area. The project was conducted in three phases; (1) a pre-ice cruise (open water), (2) an under-ice phase, and (3) a post-ice cruise (open water). Overall, an under-ice ecology program that could produce sound scientific results was found to be feasible. However, to be successful, detailed planning is essential and careful attention must be given to operational safety, proper winter clothing, and scientific coordination.

GL-005
CARRICK, H.J., and R.L. Lowe. Benthic algal response to N and P enrichment along a pH gradient. Hydrobiologia 179:119-127 (1989).

Nutrient enrichment and its effect on benthic algal growth, community composition, and average cell size was assessed across two sites of differing pH within a single habitat. Nutrients were added using in situ substrata, which released either N, P, or no additional nutrients (controls) at each site for 21 days. Upon collection, chlorophyll and biovolume standing stocks of the attached algal microflora were measured. Chlorophyll concentration was different among all treatments, accumulating greatest on P, followed by N, and the least on C substrata ($P < 0.001$) and was highest at site-2 ($P < 0.001$), while total algal biovolume was highest on P compared to both N and C substrata ($P < 0.05$) and did not vary between sites. Increased growth on P substrata was due to the enhanced biovolume of filamentous green algae, although the affected taxa varied between sites. Biovolume to cell density ratios (as a measure of average cell size) were highest on P substrata over both N-enriched and control substrata ($P < 0.05$) and this pattern was similar between sites. Progression towards a community composed of larger cells following P enrichment observed along this pH gradient, seems to be related to the dominance of larger

celled filamentous green algae. Thus, nutrients exhibited greater control on benthic algal growth than did changes in hydrogen ion concentration.

GL-006

CARRICK, H.J., R.L. Lowe, and J.T. Rotenberry. Guilds of benthic algae along nutrient gradients: relationships to algal community diversity. Journal of North American Benthological Society 7(2):117-128 (1988).

We attempt to define groups of functionally related benthic algal species or guilds to assess if the species richness of such guilds varies across experimentally manipulated nutrient gradients, and to determine the relative contribution of these guilds to total community diversity. Nutrient gradients were established using nutrient-releasing substrata; treatments consisted of Si, N+P, Si+N+P, and controls. Nutrient enrichment significantly altered the biovolume of 27 species (out of a total of 141). Results from one-way ANOVA tests coupled with multiple means range tests categorized these species into four major guilds: three guilds of species which achieved their highest abundance on either Si, N+P, or Si+N+P treatments, and a guild that grew best on controls. This pattern of structuring was corroborated by cluster analysis and principal components analysis. Total community diversity and the relative contribution of guilds to total community diversity was less on N+P and Si+N+P substrata compared with that on Si and the control substrata. This suggests that nutrient enrichment may narrow the conditions amenable to many algal species (nutrient generalists), creating a niche occupied by those taxa sufficiently equipped to benefit under such conditions (nutrient specialists).

GL-007

CAVALETTO, J.F., H.A. VANDERPLOEG, and W.S. GARDNER. Wax esters in two species of freshwater zooplankton. Limnology and Oceanography 34(4):785-789 (1989).

Lipid classes were determined in three Lake Michigan hypolimnetic calanoid copepods, Limnocalanus macrurus, Diaptomus sicilis, and Senecella calanoides. Limnocalanus macrurus and S. calanoides contained large stores of wax esters (57-80% of total lipid). Wax esters in this amount have not previously been reported for freshwater zooplankton. Diaptomus sicilis exhibits a typical freshwater lipid profile and contains triacylglycerols as its lipid reserves. Lipid storage sites are morphologically different in the copepods. Limnocalanus macrurus and S. calanoides store their wax esters in a large sac that surrounds the intestine, whereas D. sicilis maintains lipid droplet morphology typical of freshwater "triacylglycerol-storing" zooplankton. Limnocalanus macrurus and S. calanoides are "glacial relicts" which may explain the origin of their typically marine wax ester lipid class.

GL-008

CLITES, A.H. Observations of concurrent drifting buoy and current meter measurements in Lake Michigan. Journal of Great Lakes Research 15(2):197-204 (1989).

Data generated by satellite-tracked drifting buoys released in the Great Lakes are being used to study lake circulation and test trajectory prediction models. Before data from drifters can be used with confidence, the water-tracking accuracy of the drifters must be known. During the winter of 1983, drogued drifters were released in Lake Michigan in the vicinity of an array of vector-averaging current meters. Several times during the next 3 months, the drifters moved within a few kilometers of one of the current meters and remained in the vicinity for up to 30 hours. The average wind effect that best aligns the currents measured by the moored current meters and the currents from drifter paths is 0.76% of the wind speed. This value is the weighted average of the wind effects calculated for seven separate cases, which ranged from 0.06% to 2.09% of the wind speed. The average value is in good agreement with theoretical estimates and field test results. The horizontal coherence of the currents within 5 km was fairly high as revealed by comparisons between drifter trajectories and current meter progressive vectors. The separation distance between the vectors was generally under 1 km while drifter path length ranged from 4 to 9 km. Results indicate that during these encounters, about 25% of the variability between current trajectories estimated by drifting buoys and current meter measurements is explained by a simple wind correction. The remaining discrepancy is attributed to wave action (Stokes drift) and data limitations such as a lack of overlake wind conditions.

GL-009

CROLEY, T.E., II. Lumped modeling of Laurentian Great Lakes evaporation, heat storage, and energy fluxes for forecasting and simulation. NOAA TM ERL GLERL-70 (PB89-185540/XAB) 48 pp. (1989).

Lake evaporation for the Laurentian Great Lakes is of the same order of magnitude as precipitation and runoff to the lakes and its estimation is important for simulations and forecasts of lake levels. Water or energy balance estimates of Great Lakes evaporation require storage-change data, not available in simulations or forecasts, and errors in the components of the balances are summed in the residual, giving large estimation errors for evaporation. Evaporation models, which use the aerodynamic equation with mass transfer coefficients developed originally in the Lake Hefner studies, were further developed for Lake Ontario during the International Field Year for the Great Lakes and adapted for other Great Lakes. Neither these models nor the balance models can be verified since independent estimates of evaporation are not available with sufficient accuracy. However, surface temperatures are available and can be used as verification data. The mass transfer coefficient research (where water surface temperatures must be known) is combined here with lumped model concepts of classical energy conservation and superposition heat storage to provide continuous simulation capability of both water surface temperatures and lake evaporation for use in outlooks and forecasts of lake levels. A new function is presented that uses a simple relation between surface temperature and heat stored in a lake based on current understandings of the thermal structure of large lakes. Calibration of the resulting model matches the water surface temperatures for those Great Lakes and small Lake St. Clair with satellite observations of water surface temperatures over the past 20 years. Evaporation and heat budgets over the annual cycle are presented for four of the Great Lakes and Lake St. Clair, and comparison with long-term water balances are made.

GL-010

CROLEY, T.E., II. Verifiable evaporation modeling on the Laurentian Great Lakes. Water Resources Research 25(5):781-792 (1989).

Water or energy balance estimates of Great Lakes evaporation require storage change data, not available in simulations or forecasts, and errors in the components of the balances are summed in the residual, giving large estimation errors. Neither these balance estimates nor evaporation models, which use the aerodynamic equation with mass transfer coefficients developed originally in the Lake Hefner studies, can be verified, since independent estimates of evaporation are not available with sufficient accuracy. However, water surface temperatures can be used to verify energy budgets. The mass transfer coefficient research is combined here with lumped concepts of classical energy conservation and a new superposition heat storage model to provide continuous simulation capability of both water surface temperatures and lake evaporation for use in outlooks and forecasts of lake levels. Calibration matches remotely sensed water surface temperatures for those Great Lakes with observations over the past 20 years. Model sensitivities are analyzed and heat and water budgets are compared.

GL-011

CROLEY, T.E., II, and H.C. HARTMANN. Climate change effects on Great Lakes levels. Reprinted from Hydraulic Engineering Proceedings '89, National Conference, Hydraulic Division/American Society of Civil Engineers, New Orleans, LA, August 14-18, 1989. 653-658 (1989).

The Great Lakes Environmental Research Laboratory has developed conceptual models for simulating moisture storages in and runoff from the 121 watersheds draining into the Laurentian Great Lakes, overlake precipitation into each lake, the heat storages in and evaporation from each lake, connecting channel flows and lake levels, and regulation of flows at control points. We determine net water supplies and levels for each lake to consider climate change scenarios developed from atmospheric general circulation models through linkages on air temperature, precipitation, humidity, wind speed, and cloud cover. Scenarios of a doubling of atmospheric CO_2 are considered by abstracting changes in linkages, making these changes in historical data, observing the impact of the changed data in model outputs, and comparing it to model results obtained from unchanged data. The implications of the climate change effects modeled herein suggest that new paradigms in water management will be required.

GL-012

CROLEY, T.E., II, and H.C. HARTMANN. Effects of climate changes on the Laurentian Great Lakes levels. The Potential Effects of Global Climate Change on the United States: Appendix A - Water Resources, EPA DW13932631-01-0. U.S. EPA, Office of Policy, Planning and Evaluation, Washington, DC, 4.1-4.34 (1989).

No abstract.

GL-013

Eisenreich, S.J., P.D. Capel, J.A. ROBBINS, and R. Bourbonniere. Accumulation and diagenesis of chlorinated hydrocarbons in lacustrine sediments. Environmental Science and Technology 23(9):1116-1126 (1989).

Two sediment cores were taken from the Rochester Basin of eastern Lake Ontario and analyzed for the radionuclides ^{210}Pb and ^{137}Cs and several high molecular weight chlorinated hydrocarbons (CHs). The two sites are geographically proximate but differ in sedimentation rate, permitting sedimentation-dependent processes to be factored out. The ^{210}Pb chronology showed a mixed depth of 3-5 cm and an intrinsic time resolution of 11-14 years. Vertically integrated numbers of deposit-feeding oligochaete worms and burrowing organisms are insufficient to homogenize the sediment on the time scale of CH inputs, which are non steady state. U.S. production and sales of polychlorinated biphenyls (PCBs), DDT, Mirex, and hexachlorobenzene (HCB), as determinants of the shape of the input function, adequately predict the overall shape and, in many cases, details in the sedimentary profile. Sediment focusing factors (FF) inferred from ^{137}Cs and ^{210}Pb inventories averaged 1.17 and 1.74 for cores E-30 and G-32, respectively. This permitted CH accumulation rates to be corrected for focusing. Apparent molecular diffusion coefficients modeled for many of the CHs were about (1-3) x 10^{-9} cm^2/s.

GL-014

FAHNENSTIEL, G.L., and H.J. CARRICK. Primary production in lakes Huron and Michigan: in vitro and in situ comparisons. Journal of Plankton Research 10(6):1273-1283 (1988).

Oxygen- and carbon-14-based primary production estimates from 9-16 h in vitro incubations were compared in lakes Huron and Michigan. For surface mixing layer comparisons, gross $O_2/^{14}C$ photosynthetic quotients (gross PQ) averaged 2.2, and net $O_2/^{14}C$ photosynthetic quotients (net PQ) averaged 1.4. The mean gross PQ is consistent with a theoretical PQ based on the CO_2 and NO_3 assimilation ratio. However, within the deep chlorophyll layer, gross PQ and net PQ averaged 4.9 and 2.8 respectively. These higher values were likely due to excess NO_3 reduction at the expense of CO_2 uptake. Thus, during short experiments under low light conditions, oxygen evolution and CO_2 uptake may not be tightly coupled. In vitro and in situ O_2-based production estimates were compared in four diurnal (dawn to dusk) experiments in Lake Huron. In situ production estimates were determined by measuring water-mass oxygen changes and oxygen transfer across the air-water interface. In situ production estimates were approximately twice in vitro production estimates for both surface mixing layer and deep chlorophyll layer comparisons. The difference between estimates was attributable to containment effects manifest in 13-16 h bottle incubations. Short-term (1-2 h) in vitro production was also compared to diurnal in vitro production. Rates of short-term production were ~1.6 times higher than rates of diurnal production, suggesting that short-term in vitro production experiments may provide reasonable estimates of in situ primary production.

GL-015

Fox, M.G., and A.M. BEETON. Phosphorus concentration trends in the Saline River watershed, USA. Verhandlungen-Internationale Vereinigung Fuer Theoretische und Angewandte Limnologie 23:1119-1124 (1988).

No abstract.

GL-016

GARDNER, W.S., J.F. CHANDLER, and G.A. LAIRD. Organic nitrogen mineralization and substrate limitation of bacteria in Lake Michigan. Limnology and Oceanography 34(2):478-485 (1989).

Labile organic nitrogen mineralization and the apparent degree of bacterial substrate limitation were examined to consider seasonal relationships between substrate availability and bacterial activity in Lake Michigan. Accumulation rates of ammonium nitrogen in amino acid fortified and unfortified samples of epilimnetic Lake Michigan water, incubated in the dark, provided reasonable estimates of potential and actual rates of organic nitrogen mineralization. The labile organic nitrogen demand (LOND), defined as the difference between these respective rates, provided an index of heterotrophic potential. LOND ranged from ~1-3 ng-atoms N liter h^{-1} (during May-June and November) to 3-9 ng-atoms N liter h^{-1} (during July-October) as compared to actual organic nitrogen mineralization rates of < 1 ng-atom N liter h^{-1} in some unfortified samples. The high LOND, relative to actual turnover, observed in late summer is consistent with the hypothesis that growth rates of epilimnetic Lake Michigan bacteria are strongly limited by organic substrate during late stratification.

GL-017

GARDNER, W.S., B.J. EADIE, J.F. CHANDLER, C.C. PARRISH, and J.M. MALCZYK. Mass flux and "nutritional composition" of settling epilimnetic particles in Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences 46(7):1118-1124 (1989).

A series of sediment-trap samples, collected at a 30-m depth in southeastern Lake Michigan, was analyzed to evaluate the seasonal flux and nutritional value of settling epilimnetic particles as potential food for benthic organisms. Flux was highest in the spring (due in part to resuspension), lowest in the summer during stratification, and intermediate during autumn months. Organic content of the particles ranged from 10% ash free dry weight (AFDW) in March through May samples to 17-19% in July-August samples. During the summer, microbial degradation of organic materials occurred in the trap bottles without added preservative, as evidenced by less AFDW in nonpreserved trap bottles than in similar chloroform-preserved bottles. The percentage of AFDW occurring as lipid ranged from 3.5% in April-May up to 14% during May through August. Dominant lipid classes were hydrocarbons, polar lipids including phospholipids and chlorophyll a, and free fatty acids. The ratio of n-alkane C-17 (algal indicator) to n-alkane C-29 (terrestrial or resuspension indicator) and the ratio of biogenic silica to AFDW in preserved samples both reached a maximum in May, shortly before lipid content peaked in the benthic amphipod Pontoporeia hoyi. This observation agrees with the hypothesis that P. hoyi receives much of its nutrition from the spring algal bloom.

GL-018

GAUVIN, J.M., W.S. GARDNER, and M.A. QUIGLEY. Effects of food removal on nutrient release rates and lipid content of Lake Michigan Pontoporeia hoyi. Canadian Journal of Fisheries and Aquatic Sciences 46(7):1125-1130 (1989).

Pontoporeia hoyi, the dominant benthic invertebrate in the upper Great Lakes, appears to be well adapted to environments with seasonal inputs of high-quality food such as those supplied by the spring diatom bloom. Ammonium and phosphate excretion rates and lipid content were examined in P. hoyi under the following conditions: (1) field animals sampled seasonally, (2) food-deprived animals in filtered lake water, and (3) control animals held in native sediments without new food inputs. Nutrient excretion rates for P. hoyi (0.5 to 2 nmole NH_4 (milligrams dry weight)$^{-1}\cdot h^{-1}$ and 0 to 0.15 nmole PO_4 (milligrams dry weight)$^{-1}\cdot h^{-1}$) were low relative to rates previously reported for other benthic and pelagic invertebrates and varied little among the three treatment groups. In contrast to the animals held in the laboratory without new food inputs, field-collected P. hoyi accumulated increased levels of lipids following the spring diatom bloom. However, after lipid levels in field animals peaked in May, they decreased during the rest of the season at rates similar to those of starved and control animals. P. hoyi's low nutrient-excretion rates, and its ability to accumulate and store energy as lipids, for periods when food is not abundant, appear to be important factors allowing this animal to thrive in temperate lakes with spring diatom blooms.

GL-019

HARTMANN, H.C. Historical basis for limits on Lake Superior water level regulations. Journal of Great Lakes Research 14(3):316-324 (1988).

The 1979 International Joint Commission (IJC) Supplementary Orders of Approval for the regulation of Lake Superior outflows call for maintaining Lake Superior water levels below an elevation of 183.49 m above the International Great Lakes datum of 1955 (IGLD55). When Lake Superior rose above 183.49 m (IGLD55) in 1985, the IJC ordered discharges in excess of the operational regulation plan outflows. Continued pressure to reduce high water levels on the lower Great Lakes by storing water in Lake Superior calls into question the sanctity of the 183.49 m (IGLD55) limit. Based on IJC hearings and historical water level records, the present limit appears to be equivalent to the upper limit specified in the original 1914 Orders of Approval, when the latter is adjusted for differential isostatic rebound. However, testimony reveals that the IJC of 1914 expected levels to exceed the limit by about 0.15 m during water supply conditions similar to those of 1869 and 1876, which were matched in 1985. Although the expected exceedance of the 1914 limit appears to be based on an inaccurate maximum water level record, other historical records substantiate that Lake Superior should be expected to rise above 183.49 m (IGLD55) during times of high water supplies, such as 1985.

GL-020

KEILTY, T.J. Note. A new biological marker layer in the sediments of the Great Lakes: Bythotrephes Cederstroemi (Schodler) Spines. Journal of Great Lakes Research 14(3):369-371 (1988).

The European cladoceran, Bythotrephes cederstroemi (Schodler), recently invaded the Laurentian Great Lakes. Based on recent zooplankton records, it most likely appeared first in 1984 in Lakes Ontario, Erie, and Huron, and in 1985 in Lake Michigan. It has yet to be reported from Lake Superior. This species is a relatively large-bodied predatory form that possesses a long, caudal, latterally barbed spine. B. cederstroemi spines and spine fragments were found in the upper fractions (predominantly 0-4 cm) of 35 sediment cores collected from seven areas of deposition in the eastern basin of Lake Erie. All remains were well preserved and easy to identify. Very few to 0 spines were found in core depths greater

than 4 cm suggesting that the invasion of this species has resulted in a new, readily distinguishable time horizon marker.

GL-021

KEILTY, T.J., and G.R. STEHLY. Preliminary investigation of protein utilization by an aquatic earthworm in response to sublethal stress. Bulletin of Environmental Contamination and Toxicology 43:350-354 (1989).

Previous studies have illustrated the potential usefulness of monitoring biomolecule levels (total protein, DNA, and RNA) in juvenile fish and invertebrates exposed to sublethal doses of environmental toxicants. Ninety-six hr exposures of five contaminants (benzophenone, ethyl acetate, hexavalent chromium, hydrogen cyanide, and p-cresol) to larval fathead minnows yielded measurable alterations in total protein, DNA, and RNA that closely paralleled results from concomitant 28-32 d growth assays (Barron and Adelman 1984). Daphnia magna exposed to toxicants in various assays also exhibited changes in protein, RNA, and DNA levels, with the most sensitive responses usually occurring during the rapid growth life stage (McKee and Knowles 1986a, b; Knowles and McKee 1987). These results suggest that the use of biomolecule analyses as indicators of reduced growth in chemically stressed aquatic organisms holds promise.

GL-022

KEILTY, T.J., D.S. White, and P.F. LANDRUM. Sublethal responses to endrin in sediment by Limnodrilus hoffmeisteri (Tubificidae), and in mixed-culture with Stylodrilus heringianus (Lumbriculidae). Aquatic Toxicology 13:227-250 (1988).

Sediment reworking by Limnodrilus hoffmeisteri (Tubificidae) alone, and with Stylodrilus heringianus (Lumbriculidae) were measured in sediments dosed with endrin by monitoring the burial of a ^{137}cesium marker layer. Endrin concentrations ranged from 16.1 to 81 400 ng/g dry sediment weight. Alterations in reworking rates were observed at sediment concentrations two to five orders of magnitude below LC_{50} values. In single species experiments with L. hoffmeisteri at low endrin concentrations, marker layer burial rate data did not suggest stimulation of reworking, as had previously been found for S. heringianus. At higher concentrations, reworking rates were equal to or slower than control rates early in experiments, followed by dramatic decreases thereafter. Reworking rates with mixed species (1:1 species ratio) suggested that the presence of S. heringianus enhanced the reworking response of L. hoffmeisteri. Post experimental worm dry weights were inversely related to high sediment concentrations for both species. Reductions in post-experimental L. hoffmeisteri mortalities and increases in L. hoffmeisteri dry weights in mixed species tests at high endrin concentrations implied that L. hoffmeisteri benefits from the presence of S. heringianus, although the reverse was not observed. High final sediment endrin concentrations in the upper three cm implied worm mediated upward contaminant transport. Bioaccumulation factors for S. heringianus ranged from 9.7 to 43.8 and were consistently three to four times greater than bioaccumulation factors for L. hoffmeisteri (1.7 to 13.6).

GL-023

KEILTY, T.J., D.S. White, and P.F. LANDRUM. Sublethal responses to endrin in sediment by Stylodrilus heringianus (Lumbriculidae) as measured by a ^{137}cesium marker layer technique. Aquatic Toxicology 13:251-270 (1988).

Sediment reworking rates of Stylodrilus heringianus (Oligochaeta: Lumbriculidae) were measured in microcosms containing sediments dosed with the chlorinated pesticide, endrin. Reworking rates were measured at 10°C by monitoring a ^{137}cesium marker layer burial in contaminated and uncontaminated microcosms. Endrin concentrations ranged from 3.1 to 42 000 ng/g dry sediment. Alterations in reworking rates were observed at sediment concentrations five and one half orders of magnitude below the LC_{50} (1 650 mg/g). For the lower concentrations, marker layer burial rate data suggested possible stimulatory effects in the first 300 to 600 h, followed by significant rate decreases relative to controls. For higher concentrations, rates were equal to or slower than control rates in the first 600 h, followed by dramatic decreases in the last 600 h. High final surficial sediment endrin concentrations at the end of experiments implied worm mediated upward transport. Worm mortalities were 9.3 to 28% for the two highest concentrations (42 000 and 11 500 ng/g) and 0 to 6.7% for all other concentrations including controls. Post experimental worm dry weights were inversely related to high concentrations. Bioaccumulation factors ranged from 34 to 67 on a g dry organism to g dry sediment basis.

GL-024

LANDRUM, P.F. Bioavailability and toxicokinetics of polycyclic aromatic hydrocarbons sorbed to sediments for the amphipod Pontoporeia hoyi. Environmental Science & Technology 23(5):588-595 (1989).

The accumulation kinetics, by the benthic amphipod, Pontoporeia hoyi, were measured for sediment-associated, selected polycyclic aromatic hydrocarbons (PAHs) and 2,4,5,2',4',5'-hexachlorobiphenyl (HCB). The kinetics data suggest that uptake occurs largely via the sediment interstitial water and is kinetically controlled by desorption from sediment particles and dissolved organic matter. Assimilation from ingested material may be significant for the more strongly sorbed compounds such as benzo[a]pyrene and HCB. The desorption rate of contaminants from the sediment matrix appears to determine whether the major sediment contaminant source is interstitial water or ingested particles. The log of the contaminant uptake clearance is inversely proportional to the log octanol-water partition coefficient for PAHs. Bioavailability of sediment-sorbed contaminants declined as the contact time between the sediment and contaminant increased. Chemical extractability remained high even though bioavailability was reduced. A conceptual model to describe accumulation of organic contaminants from sediments is described.

GL-025

LANDRUM, P.F., W.R. FAUST, and B.J. EADIE. Bioavailability and toxicity of a mixture of sediment-associated chlorinated hydrocarbons to the amphipod Pontoporeia hoyi. In Aquatic Toxicology and Hazard Assessment: 12th Volume, ASTM STP 1027, U.M. Cowgill, and L.R. Williams (eds.). American Society for Testing and Materials, Philadelphia, 315-329 (1989).

The toxicity and bioavailability of a mixture of 13 sediment-associated chlorinated hydrocarbons were determined for the amphipod, Pontoporeia hoyi. The processes were traced with two radiolabeled compounds ^{14}C-2,2',4,4'-tetrachlorobiphenyl (2244TCB) and ^{3}H-benzo(a)pyrene (BaP). The toxicity of the chlorinated hydrocarbon mixture resulted primarily from the lindane and dieldrin components. The 72 h LC_{50} was 14.5 nmol g^{-1} as the sum of the added chlorinated hydrocarbons and 4.7 nmol g^{-1} as the sum of the lindane and dieldrin. At 144 h the LC_{50}s had dropped to 1.51 and 0.53 nmol g^{-1} respectively. At the lowest dose, 2.4 nmol g^{-1} sediment, the time to yield 50% mortality (LT_{50}) was 119 h. The toxicokinetics for the radiolabeled compounds yielded sediment uptake clearance constants of 0.0018 and 0.018 g dry sediment g^{-1} animal h^{-1} for BaP and 2244TCB in the absence of added chlorinated hydrocarbons. At the lowest chlorinated hydrocarbons dose, the clearance constants of both BaP and 2244TCB were approximately doubled. The clearance constants were not proportional to the freely dissolved concentration of the radiolabeled compounds in the interstitial water but were presumed to be proportional to the compound desorption rates. For the chlorinated hydrocarbons, the uptake clearances were inversely proportional to the log of the octanol-water partition coefficient. The bioaccumulation factor (BAF, concentration in the organism divided by the concentration in the sediment) appeared to peak at about a log octanol-water partition coefficient of 6. However, the BAF ranged from less than 1 to greater than 30 for compounds with a log K_{ow} near 6.

GL-026

LANDRUM, P.F., and R. POORE. Toxicokinetics of selected xenobiotics in Hexagenia limbata. Journal of Great Lakes Research 14(4):427-437 (1988).

Understanding the role of benthos in the fate and transport of contaminants requires understanding the toxicokinetics of those organisms for both waterborne and sediment-associated compounds. This effort focused on the toxicokinetics of Hexagenia limbata as an important component of the benthic community of the upper Great Lakes connecting channels. The accumulation and elimination of two polycyclic aromatic hydrocarbon congeners and a hexachlorobiphenyl isomer were followed over the course of a season in H. limbata collected from Lake St. Clair. Both the water uptake clearance and elimination rate constants increased with increasing temperature through the spring and summer. The elimination constants were relatively large. The uptake constant for sediment-associated compounds was essentially constant the two times it was measured and was large compared to sediment accumulation by Pontoporeia hoyi. Steady state model calculations indicate that the amount of compound in H. limbata should decline as temperature increases. The BCF values on a lipid content normalized basis remain relatively constant for both PAHs and show some change with season for hexachlorobiphenyl. Based on the best estimates of environmental concentration of the contaminants studied in both sediment and water, the model suggests that H. limbata should obtain greater than 90% of its contaminant body burden from the sediment-associated pollutants.

GL-027

LANG, G.A., J.A. MORTON, and T.D. FONTAINE, III. Total phosphorus budget for Lake St. Clair: 1975-80. Journal of Great Lakes Research 14(3):257-266 (1988).

As part of the U.S.-Canadian Upper Great Lakes Connecting Channels Study a total phosphorus budget was developed for Lake St. Clair. An unbiased ratio estimator technique was used to estimate annual loads and variances from monitored hydrologic areas. During the 1975-80 period, Lake Huron was the major source of phosphorus to Lake St. Clair, accounting for approximately 52% of the total annual load.

Hydrologic area loads, which include diffuse and indirect point sources, contributed approximately 43% of the total annual load. The remaining 5% came from the atmosphere, shoreline erosion, and direct point sources. Of the hydrologic area loads, 85% could be attributed to diffuse sources. The Thames area contributed 58% of the total hydrologic area load, followed by the Sydenham (17%), the Clinton (9%), the Ruscom (7%), the Black (6%), the St. Clair (3%), and the Rouge (0.4%). Over the entire 6-year period examined, the lake's total input and output of phosphorus were nearly equal. It was concluded that there was no significant net source or sink of phosphorus in Lake St. Clair during the 1975-80 period.

GL-028

Lindner, G., W. Pfeiffer, J.A. ROBBINS, and E. Recknagel. Long-lived Chernobyl radionuclides in Lake Constance: speciation, sedimentation and biological transfer. Proceedings, XV Conference of the International Radiation Protection Association, Visby, Sweden, September, 1989. The Radio Ecology of Natural and Artificial Radionuclides. Progress in Radiation Protection Series, FS-89048T, W. Feld (ed.). Verlag Tuv Rheinland GMBH, Koln, 295-300 (1989).

No abstract.

GL-029

Lindner, G., W. Pfeiffer, U. Wahl, J. Kleiner, H.H. Stabel, P. Frenzel, J.A. ROBBINS, F. Giovanoli, A. Lenhard, and E. Recknagel. Sedimentation of longlived radionuclides in Lake Constance. Proceedings, Heavy Metals in the Environment, Vol. 1, Geneva, Switzerland, September 14, 1989. CEP Consultants Ltd, J-P. Vernet (ed.), Edinburgh, UK, 449-452 (1989).

The sedimentation of the longlived radionuclides ^{137}Cs, ^{106}Ru, ^{125}Sb, ^{110m}Ag and ^{144}CE from Chernobyl fallout was followed in Lake Constance by gamma spectroscopic analysis of trapped settling particles and sediment cores. The vertical transport was controlled by the speciation of the radionuclides in the water. Scavenging from solution occured both for cationic ^{137}Cs species and, with higher efficiency, for anionic ^{106}Ru and ^{125}Sb species. Autochthonous calcite precipitation appeared to be the main removal process. Stokesian sinking was suggested for the removal of ^{144}Ce, which was assumed to be included in nuclear fuel particles. In the sediments a new, sharp radiotracer marker was established.

GL-030

LIU, P.C. On the slope of equilibrium range in the frequency spectrum of wind waves. Journal of Geophysical Research 94(C4):5017-5023 (1989).

An effort to empirically assess the slope of the equilibrium range in a wind wave frequency spectrum with a large number of data recorded in the Great Lakes did not serve to clarify the uncertainty between a -4 or a -5 frequency exponent representation. The uncertainty is further compounded by indications that the slope is not necessarily unique, but tends to vary with wave momentum. For sufficiently well developed wind waves the exponent appears to cluster between -3 and -4. For practical applications the f^{-4} equilibrium range is perhaps an effective approximation. What the correct slope is for the equilibrium range, or even whether or not a unique slope exists, remains elusive and has yet to be satisfactorily substantiated.

GL-031

LIU, P.C. What is the slope of equilibrium range in the frequency spectrum of wind waves? Proceedings, 21st Coastal Engineering Conference CERC/ASCE, Costa del Sol-Malaga, Spain, June 21, 1988. 1045-1057 (1988).

An effort to empirically assess the slope of the equilibrium range in a wind-wave frequency spectrum with a large number of data recorded in the Great Lakes did not serve to clarify the uncertainty between a -4 or a -5 frequency exponent representation. The uncertainty is further compounded by indications that the slope is not necessarily unique, it tends to vary with wave momentum. For sufficiently well-developed wind waves the exponent appears to cluster between -3 and -4. For practical applications the f^{-4} equilibrium range is perhaps an effective approximation. What the correct slope is for the equilibrium range, or even whether or not a unique slope exists, remains elusive and has yet to be satisfactorily substantiated.

GL-032

McCORMICK, M.J. Potential climate changes to the Lake Michigan thermal structure. The Potential Effects of Global Climate Change on the United States: Appendix A - Water Resources, EPA DW13932957-01-0. U.S. EPA Office of Policy, Planning and Evaluation, Washington, DC, 6.1-6.26 (1989).

No abstract.

GL-033

MUZZI, R.W., and G.S. MILLER. Improving satellite tracked drifter buoy resolution by using LORAN-C. Proceedings, Oceans '89, Seattle, WA, September 18-21, 1989. Marine Technology Society and the Oceanic Engineering Society of the Institute of Electrical and Electronics Engineers, 856-859 (1989).

Free drifting satellite-tracked drifter buoys have provided a wealth of in situ data to examine global scale spatial variations in surface circulation over vast ocean areas. But in the Great Lakes, their position inaccuracies and limited number of positions makes them unsuitable for measuring the lake's smaller scale processes. To overcome this problem, a low-cost system was designed by adding a LORAN-C receiver to a satellite-tracked buoy. LORAN gives improved spatial and temporal resolution. A modified Si-Tex EZ97 LORAN-C receiver, Campbell Scientific SM192 solid-state storage module, and an 80C31 CMOS microprocessor control interface were added to a Polar Research Lab mini-TOD drifter. The LORAN antenna was positioned next to the ARGOS antenna on the top of the buoy. The microprocessor controlled cycling of the LORAN receiver and recording of the data. The ARGOS platform was not modified, and provided position comparison and near real-time positions for aid in retrieval. LORAN position data was recovered from the buoy after retrieval. Two prototype tests were fully successful, revealing evidence of smaller scale processes that could not be determined by satellite position tracking.

GL-034

NALEPA, T.F., and J.M. GAUVIN. Distribution, abundance, and biomass of freshwater mussels (Bivalvia:Unionidae) in Lake St. Clair. Journal of Great Lakes Research 14(4):411-419 (1988).

A mussel population survey was conducted in Lake St. Clair with divers using SCUBA to sample 29 stations throughout the lake. Mean abundance was 2 m^{-2} and mean biomass was 4.4 g dry wt m^{-2}. Of the 18 species collected, Lampsilis radiata siliquoidea was by far the most abundant, accounting for 45% of all individuals. The age-frequency distribution of L. r. siliquoidea was dominated by individuals between 9 and 12 years old. In contrast, the second most abundant species, Leptodea fragilis, showed yearly variation in recruitment with no apparent trends in year class strength. Annual production of L. r. siliquoidea was 0.20 g m^{-2} y^{-1} and the turnover ratio was 0.13. The diversity and composition of mussels in Lake St. Clair appear little changed since the turn of the century, but there are indications that population numbers may be declining in the future.

GL-035

QUIGLEY, M.A., and G.A. LANG. Measurement of amphipod body length using a digitizer. Hydrobiologia 171:255-258 (1989).

A digitizer/camera lucida method was developed to measure total body length and gut contents of an amphipod Pontoporeia hoyi. The method was more accurate and precise than two conventional methods (the forceps/ocular micrometer method, and the map wheel/camera lucida method). The digitizer/camera lucida method also provided rapid and direct transfer of body and gut length values to a computer file for subsequent analysis.

GL-036

QUINN, F.H. Detroit River flow reversals. Journal of Great Lakes Research 14(4):383-387 (1988).

Detroit River flow reversals were investigated using a water surface gradient analysis in conjunction with Detroit River unsteady flow models. Three cases and five highly probable cases were simulated to occur between 1900 and 1986; the most recent episode occurred in April 1984. Flow reversals are likely only during St. Clair River ice jams, when the water supply to Lake St. Clair is severely restricted. The reversals appear to be of limited duration, less than 12 hours, with maximum flows less than 4,200 m^3s^{-1}. Flow reversals were most common during the first 40 years of this century and 46 years separate the last two occurrences. The decreased frequency probably results from the 7.6 m and 8.2 m navigation dredging projects on the St. Clair River. The use of the Gibraltar water level gage to represent the mouth of the river was found to be critical for the analysis.

GL-037

QUINN, F.H. Great Lakes water levels, past, present, and future. Proceedings, The Great Lakes: Living with North America's Inland Waters, Milwaukee, WI, November 6, 1988. American Water Resources Association, 83-92 (1988).

The Great Lakes are one of our nation's greatest water resources containing 95 percent of the nation's and 20 percent of the world's fresh surface water. At the present time, all of the Great Lakes except for Lake Ontario, are receding from record high lake levels for this century. The high lake levels have had a severe impact upon the riparian interests around the lakes. Storms superimposed on the high lake levels have resulted in extensive flooding, houses destroyed, extreme erosion and bluff damage, marina problems, and a loss of habitat for various forms of wildlife. This presentation examines Great Lakes water level fluctuations, past, present, and future. Special emphasis is given to the conditions resulting in the recent lake level decline. The types of natural lake level fluctuations and their causes are examined and compared with anthropogenic lake level changes resulting from diversions, connecting channel dredging, regulation, and consumptive use. A longer term climatic perspective and possible future scenarios are discussed.

GL-038

QUINN, F.H., and S.A. Changnon. Climate scenarios for the Great Lakes Basin. Preprints, Sixth Conference on Applied Climatology, Charleston, SC, March 7-10, 1989. American Meteorological Society, Boston, 27-30 (1989).

No abstract.

GL-039

ROBBINS, J.A. The role of radiotracers in studies of aquatic contamination. Proceedings, Heavy Metals in the Environment, Vol. 1, Geneva, Switzerland, September 14, 1989. CEP Consultants Ltd, J-P. Vernet (ed.), Edinburgh, UK, 449-452 (1989).

Natural and man-made radionuclides, particularly ^{210}Pb and ^{137}Cs, have been widely used to chronicle the history of heavy metal contamination of lakes and reservoirs as recorded in sediments. Although this application is perhaps best known, these and other tracers have also been used in the Laurentian Great Lakes and other systems to calibrate lake contamination response models, determine epilimnetic residence times, establish sediment mixing scale lengths and rates, tag resuspended sediment components, and estimate the extent and rate of sediment focusing. Some of these applications are illustrated by the case of ^{137}Cs in Lake Erie.

GL-040

ROBBINS, J.A., T.J. KEILTY, D.S. White, and D.N. Edgington. Relationships between tubificid abundances, sediment composition, and accumulation rates in Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 46(2):223-231 (1989).

Sediment cores taken at 15 sites within the three main depositional basins of Lake Erie from 1976 to 1982 were sectioned in 1-cm intervals and analyzed for the abundance and vertical distribution of benthic organisms, ^{137}Cs, and ^{210}Pb (in some cores) and for surficial (upper 2 cm) organic and inorganic carbon. Zoobenthos populations were dominated (>85%) by tubificids (Limnodrilus hoffmeisteri, Quistadrilus multisetosus, and Tubifex tubifex) and varied in abundance from 6600 to 55 300 individuals$\cdot m^{-2}$. The depth above which 90% of the individuals occurred correlated significantly with their abundance and with radiometrically determined mixed depths. Rates of sediment reworking by tubificids exceeded sedimentation rates by 5-80 times, indicating that worms alone can produce the observed zone of constant tracer activity at the sediment-water interface. Tubificid abundance was not significantly related to organic carbon but instead correlated strongly with the sediment accumulation rate and organic carbon flux. In Lake Erie the abundance of tubificids may be limited by the rate of supply of nutrients as measured roughly in terms of the organic carbon flux.

GL-041

SCAVIA, D. On the role of bacteria in secondary production. Limnology and Oceanography 33(5):1220-1224 (1988).

No abstract

GL-042

Schelske, C.L., J.A. ROBBINS, W.S. GARDNER, D.J. Conley, and R.A. Bourbonniere. Sediment record of biogeochemical responses to anthropogenic perturbations of nutrient cycles in Lake Ontario. Canadian Journal of Fisheries and Aquatic Sciences 45:1291-1303 (1989).

Two sediment cores collected from the Rochester basin of Lake Ontario were dated with ^{210}Pb and stratigraphic correlation and analyzed to determine whether nutrient accumulation with time was consistent with previous computer-simulated total phosphorus (TP) loadings. Relative increases in TP and nonapatite inorganic phosphorus (NAIP) accumulation were less than the fivefold increase in TP loading from 1800 to 1950 predicted independently from Chapra's simulation model. In addition, increases in TP accumulation occurred mainly after 1940 and the proportion of NAIP relative to TP increased in one core and decreased in the other. Of the nutrients studied, only increases in organic carbon (OC) paralleled the increases in modelled TP loadings. The relative increase in inorganic carbon (IC) was greatest, with accumulation increasing an order of magnitude after 1940 in one core. This large increase in IC, amounting to 20% calcite in recent sediments, was attributed to biologically induced calcite precipitation, a secondary consequence of increased planktonic photosynthetic removal of carbon dioxide that resulted from accelerated eutrophication after 1940 when modelled TP concentrations increased rapidly. Biogenic silica (BSi) accumulation, an indicator of increased diatom production, peaked between 1850 and 1870 when increases in TP and NAIP fluxes were minimal. Results provide evidence that historic biogeochemical responses inferred from OC, IC, and BSi accumulation in the sediment record provide stronger signals of phosphorus enrichment effects than can be inferred directly from changes in accumulation of different forms of phosphorus in the sediment record.

GL-043

SCHWAB, D.J. A numerical wave prediction model for personal computers. Proceedings, 21st Coastal Engineering Conference CERC/ASCE, Costa del Sol-Malaga, Spain, June 21, 1988. 2991-2997 (1988).

A two-dimensional wave prediction model suitable for use on personal computers is described. The model requires the two-dimensional time-dependent wind field as input. Output consists of wave height, wave period, and wave direction estimates at all grid points on a computational grid representing an enclosed or semi-closed basin. Model predictions compare favorably with observations from a wave research tower in Lake Erie. A formula is provided to estimate how long a model simulation would take on a personal computer given the surface area of the computational domain, the grid size, and the computer clock speed.

GL-044

SCHWAB, D.J. The use of analyzed wind fields from the Great Lakes Marine Observation Network in wave and storm surge forecast models. Preprints, 2nd International Workshop on Wave Hindcasting and Forecasting, Vancouver, BC, April 25-29, 1989. Environment Canada, Atmospheric Environment Service, Downsview, Ontario, 257-266 (1989).

No abstract.

GL-045

SCHWAB, D.J., A.H. CLITES, C.R. Murthy, J.E. SANDALL, L.A. Meadows, and G.A. Meadows. The effect of wind on transport and circulation in Lake St. Clair. Journal of Geophysical Research 94(C4):4947-4958 (1989).

A numerical circulation and transport model is used to simulate currents and trajectories in Lake St. Clair. Results from the model are compared to three different types of measurements, namely, (1) mean currents from an array of fixed current meters, (2) currents measured from a ship during seven synoptic surveys of the lake, and (3) trajectories of satellite-tracked drifting buoys during four different experiments. The model is then used to predict the effects of storms on the residence time of water entering the lake from eight tributaries and the probable horizontal distribution in the lake of water from a particular tributary. Results show that although the average residence time of the lake is about 9 days, actual residence times range from less than 2 days to over 30 days depending on wind conditions. The calculated distribution patterns of water from various tributaries coincide closely with observed distributions of some water quality parameters and biota.

GL-046

STEHLY, G.R., and W.L. Hayton. Disposition of pentachlorophenol in rainbow trout (Salmo gairdneri): effect of inhibition of metabolism. Aquatic Toxicology 14:131-148 (1989).

The accumulation kinetics of pentachlorophenol (PCP) were investigated in rainbow trout (Salmo gairdneri) in the absence and presence of 25 mg/l salicylamide, an inhibitor of PCP metabolism. After exposure to 5mg/l PCP over 1-96 h, the amount of PCP in the whole fish, its concentration in water and the total amount of metabolites (water, whole fish and bile) were measured. Equations for these variables, based on a two compartment pharmacokinetic model, were fitted simultaneously to the data using the computer program NONLIN, which uses an iterative nonlinear least squares technique. Salicylamide

decreased the metabolic clearance of PCP, which resulted in an increase in the bioconcentration factor (BCF); this increase was partially offset by a salicylamide-induced decrease in the apparent volume of distribution of PCP. A clearance-volume compartment model permitted partitioning of the BCF in terms of the underlying physiologic and biochemical processes (uptake clearance, metabolic clearance and apparent volume of distribution). With this approach the BCF can be categorized as either dependent (e.g., PCP) or independent of uptake and metabolism (elimination) based on the relative sizes of the clearances for uptake and metabolism. Inhibition of PCP metabolism resulted in a loss of its dependence on uptake and metabolism. The BCF estimated as the apparent volume of distribution may be useful for assessment of the risk associated with exposure and bioaccumulation potential, as elimination is generally quite variable among aquatic species.

GL-047

STEHLY, G.R., and W.L. Hayton. Metabolism of pentachlorophenol by fish. Xenobiotica 19(1):75-81 (1989).

1. Interspecies variability in the metabolism of pentachlorophenol (PCP) was investigated by exposing rainbow trout, fathead minnows, sheepshead minnow, firemouth, and goldfish to water-borne ^{14}C-PCP for 64 h.
2. The amounts of metabolites in bile and exposure water were species-dependent; all of the metabolites excreted into the water were sulphate conjugates while bile was enriched in glucuronide conjugates.
3. Biliary excretion accounted for less than 30% of the total PCP metabolites.
4. Biliary metabolites alone were a poor indication of the metabolites produced and of the major routes of elimination.

GL-048

TARAPCHAK, S.J., and L.R. HERCHE. Orthophosphate concentrations in lake water: analysis of Rigler's radiobioassay method. Canadian Journal of Fisheries and Aquatic Sciences 45(12):2230-2237 (1988).

Rigler's radiobioassay method is frequently used to estimate maximum possible orthophosphate (P) concentrations in natural waters. An evaluation of the method, based on simulated P uptake by hypothetical phytoplankton communities, reveals that the Rigler value is not a consistent estimator of true maximum possible P concentration. Analyses show that all members of that family of curves for which the difference between true and assumed (or estimated) values of P is below the minimum half-saturation constant of a component species will pass through the plot's origin. A new upper bound, termed R (Rigler), which is the sum of the true ambient P concentration and the lowest half-saturation constant of a component species, is identified as a consistently distinguishable bound on maximum possible P concentrations in lake water. The R curve cannot be distinguished in a lake water experiment because of the complex behavior of uptake curves in the unobservable substrate region. A theoretical procedure, based on comparing uptake parameters for lake water samples and multispecific hypothetical communities, offers potential for calculating upper and lower limits on R in P-limited lake water samples.

GL-049

TARAPCHAK, S.J., and L.R. HERCHE. Phosphate uptake by microbial assemblages: Model requirements and evaluation of experimental methods. Journal of Environmental Quality 18(1):17-25 (1989).

A "compound" Michaelis-Menten model provides a conceptual framework for analyzing substrate-dependent phosphate (P) uptake by natural microbial assemblages. Phosphate uptake can be separated into three substrate domains: a region near ambient P concentrations, an intermediate region, and a high-substrate region representing substrate saturation of microbial uptake sites. Simulated P uptake for hypothetical microbial communities, ranging from non-phosphorus-limited to multiple-nutrient-limited communities, shows that (i) commonly used "high-level" P addition schemes will underestimate community uptake rates near natural ambient P concentrations in phosphorus-stressed systems by at least an order of magnitude, and (ii) deviations from the simple Michaelis-Menten model may be widespread in nature, particularly in highly phosphorus-stressed or multiple-nutrient-limited systems. A P uptake experiment on a natural microbial assemblage from a phosphorus-limited oligotrophic lake illustrates application of the compound model and statistical procedures for analyzing data. An empirical procedure, based on the concept of substrate-dependent continuity in P uptake, is proposed to determine if P addition schemes are adequate to estimate uptake constants near ambient lakewater P concentrations.

GL-050

VANDERPLOEG, H.A., G-A. Paffenhofer, and J.R. LIEBIG. Diaptomus vs. net phytoplankton: Effects of algal size and morphology on selectivity of a behaviorally flexible, omnivorous copepod. Bulletin of Marine Science 43(3):377-394 (1988).

Effects of algal size, colony form, and morphology on selection by Diaptomus sicilis and D. ashlandi were determined for certain net diatoms commonly found in the pelagic regions in lakes. Mechanisms of capture, observed by high-speed microcinematography, were correlated with selectivity results from traditional feeding experiments with mixtures of algae. The attribute of elongation (up to 365 mm) in one dimension possessed by Synedra spp. was not useful for avoiding grazing. In fact, at low concentrations, selectivities for Synedra were much higher than for Chlamydomonas of equal cell volume. This suggests a perceptual bias for capture of elongated algae. Films showed that D. sicilis could even bite off sections of 700-mm-long Melosira colonies. However, long fragments of Synedra and Melosira were often left behind after attacks by Diaptomus. Elongation in two dimensions, an attribute possessed by the stellate colonies of Asterionella formosa was extremely effective for avoiding grazing once more than six to eight cells per colony was reached. This result may explain the abundance of the eight-cell form in nature. Selectivity of Diaptomus changed with concentration in mixtures of a 12-mm-diameter spherical green alga and a 240-mm-long Synedra. In these same experiments, the proportion of attacked Synedra that were only partially ingested - i.e., the proportion rejected after partial ingestion - increased linearly with attack rate on Synedra, and was not correlated with attack rate on Chlamydomonas or on the sum of both algal species. These and other data demonstrate that this concentration-variable selectivity is not an optimal-foraging strategy. We assert these observations can be properly viewed within the classical ethological framework of motivation and excitability of different motor patterns used to capture, handle, and ingest different kinds of algae.

GL-051

VANDERPLOEG, H.A. [among 56 others]. Future marine zooplankton research--A perspective: Marine Zooplankton Colloquium 1, Lake Arrowhead Conference Center, Lake Arrowhead, California, USA, April 18-22, 1988. Marine Ecology Progress Series 55:197-206 (1989).

Zooplankton research over the past 100 yr has been focused largely on temporal scales of hours to weeks and spatial scales of decameters to kilometers. Research at both greater and lesser scales has been limited mainly by technical intractability. Recent advances in technology are expanding the horizons of enquiry to those scales which have long been difficult to observe. Discussions on future advances in marine zooplankton research and technology from an open meeting of marine zooplanktologists, held at Lake Arrowhead, California, USA in April 1988, led to specific recommendations for future research. Principal issues and areas of future research include: (1) characterization of individual small-scale behaviors leading to a better understanding of the dynamics of aggregation and dispersal; (2) determination of how environmental variability, rather than mean conditions, affects physiology and behavior; (3) relation of birth, death and growth rates to environmental conditions, both concurrent and past; (4) determination of nutritional requirements; (5) long-term observations of population and community dynamics which would permit analysis of interannual variability and its causes; (6) a critical need to maintain expertise in taxonomy; and (7) continued development of mathematical models encompassing biological, chemical, and physical parameters. Concrete steps that could be taken to facilitate these research goals include: (1) further development of in situ instrumentation that provides (a) measurements at high frequencies and resolutions, (b) the capability for long-term unattended measurements, and (c) the ability to monitor birth, growth, and physiology; (2) establishment of a Center of Marine Plankton Studies with the full spectrum of facilities required for sophisticated culture, maintenance and experimentation with single or multiple species; and (3) establishment of an Ocean Observatory from which continuous measurements could be made at multiple scales. Significant advances in many areas can be accelerated through multidisciplinary activities.

GL-052

Williamson, C.E., and H.A. VANDERPLOEG. Predatory suspension-feeding in Diaptomus: prey defenses and the avoidance of cannibalism. Bulletin of Marine Science 43(3):561-572 (1988).

High-speed (500 frames $\cdot s^{-1}$) 16-mm film analysis was used to examine the predatory suspension-feeding behavior of Diaptomus pallidus. Prior high-speed film analysis of Diaptomus feeding on algae revealed a transition from passive to active captures as cell size increased, where the transition from passive to active captures was distinguished by the additional use of the swimming legs and maxillipeds to aid in capture. In the current study we found that when feeding on microzooplankton, Diaptomus may also employ its first antennae and a more vigorous flap of its swimming legs in an actual attack or orientation response to facilitate prey capture. Diaptomus responded to different prey species at distances that varied with prey type. Many of the microzooplankton which are potentially vulnerable to predation by suspension-feeding diaptomids have rheotactic capabilities which permit them to detect the feeding

currents of Diaptomus before body contact and avoid predation through a rapid escape response. The most effective rheotactic escape response is exhibited by the nauplii of Diaptomus. Some experiments with CO_2-anesthetized nauplii demonstrate that nauplii are highly palatable to the omnivorous adults and that the rheotactic capabilities of the nauplii aid in reducing cannibalism.

Addendum

GL-053

BENNETT, J.R., and J.E. CAMPBELL. Accuracy of a finite-difference method for computing lake currents. Journal of Computational Physics 68(2):262-271 (1987).

A semi-analytic model is used to assess the accuracy of a finite-difference model for computing lake currents. Both models solve the vorticity equation for two-dimensional, time-dependent flow to compute currents in a circular lake with a parabolic depth profile. The semi-analytic solution is obtained by using separation of variables to remove the azimuthal dependence and reduce the equations in cylindrical coordinates to a single equation in two variables, time and radius. This equation is then solved by a finite-difference technique for grid sizes small enough that the solution appears to converge. Comparison with the rectangular finite-difference solution shows a strong improvement in accuracy with decreasing grid size. It is found that about 20 grid points across a lake basin are required to adequately resolve wind-driven flow.

GL-054

CROLEY, T.E., II. Water level fluctuations on the Great Lakes. In The Great Lake Erie, A Reference Text for Educators and Communicators, R.W. Fortner and V.J. Mayer (eds.). The Ohio State University Research Foundation, Columbus. 93-102 (1987).

No abstract.

NATIONAL SEVERE STORMS LABORATORY

NS-001

Balakrishnan, N., and D.S. ZRNIĆ. Correction of propagation effects at attenuating wavelengths in polarimetric radars. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 287-291 (1989).

No abstract.

NS-002

Balakrishnan, N., and D.S. ZRNIC. Suggested use of cross-correlation between orthogonally polarized echoes to infer hail size. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 292-296 (1989).

No abstract.

NS-003

Balakrishnan N., D.S. ZRNIĆ, J. Goldhirsh, and J. Rowland. Comparison of simulated rain rates from disdrometer data employing polarimetric radar algorithms. Journal of Atmospheric and Oceanic Technology 6:476-486 (1989).

Disdrometer data collected during three spring days, with moderate to heavy rain in the Norman, Oklahoma, region are used with various polarimetric radar algorithms to simulate rain rates. It is assumed that available measurables are 1) reflectivity at horizontal polarization, Z_H, 2) differential reflectivity, Z_{DR} (ratio of horizontal to vertical reflectivity factors in dB), and 3) differential propagation constant, K_{DP}. The accuracies of the simulated rain rates from Z_H, Z_{DR} and K_{DP} are evaluated and compared. A new algorithm that utilizes both reflectivity factor and differential propagation constant is also examined. In comparing the relative accuracies, the disdrometer-derived rain rates are assumed to be the "truth" measurements.

NS-004

BARTELS, D.L. Mid-level cyclonic vortices generated by mesoscale convective systems. M. S. thesis, University of Oklahoma, Norman, 131 pp. (1989).

The advent of satellites provided the perspective to view entire lifecycles of convective systems and to identify the wide variety of modes that exist. Since then, Mesoscale Convective Systems (MCSs [Maddox, 1980; Menard and Fritsch, 1988]) have been the subject of many studies aiming toward the goal of developing a conceptual model. Three distinct mesoscale circulations are consistently associated with mature MCS. A large, cold, divergent anticyclone develops in the vicinity of the tropopause owing to sustained convection overshooting the equilibrium level (Brown, 1979; Fritsch et al., 1981; Fritsch and Brown, 1982); this anticyclone apparently is shallow and short-lived (Menard and Fritsch, 1988). The boundary layer typically is characterized by a divergent meso-high, generated by downdraft cooling and significant rainfall under the MCC, which often persists for many hours. The mid-levels of the troposphere are characterized by latent heating and convergence (Maddox, 1981). The resultant mesoscale upward circulation helps sustain the characteristic cold cloud shield by perturbing the height of the tropopause. Warm-core cyclonic vortices (Menard and Fritsch, 1988; Johnson et al., 1988) have been associated with this mesoscale updraft. The mid-level vortex has been hypothesized to be the principal dynamical feature that characterizes an MCC (Zhang and Fritsch, 1987; Cotton et al., 1988). The first direct observational evidence of residual, mid-level cyclonic circulations was provided by Johnston (1981), who identified meso-beta scale circulations in film loops of visible satellite imagery. This study documents, via satellite data, 24 Mesoscale Convectively-generated Vortices (MCVs) over the central United States between 1981-1988, and examines environmental conditions within which these circulations become apparent after the demise of the MCS cold cloud shield. Most MCVs emerge from MCC-type (i.e., circular) systems, but of the cases noted, only half originated in systems which met the stringent MCC size and duration criteria (Maddox, 1980). The majority of MCVs (i. e. 80%) were first observed at latitudes south of 40°N. Since many convective systems occur at latitudes north of 40°N (Bartels et al., 1984), the paucity of MCVs in northern latitudes is not the result of a lack of convective systems. While it is difficult to assess the impact of satellite viewing angle (and other factors, such as diurnal cycle) on vortex identification, it is believed that the combination of conditions which lead to long-lived MCVs may well occur most frequently south of 40°N. Furthermore, since several MCVs evolved from small and relatively short-lived convective systems, the magnitude of latent heating, in some cases,

may not be as important as the background synoptic environment in determining which MCSs will exhibit visually documentable MCVs. Satellite data were used to identify 4 MCV lifecycle stages: (1) before MCV, (2) during MCV, (3) long-lived MCV, and (4) after MCV. Standard upper-air data were then used to diagnose the evolution of the kinematic and thermodynamic setting of MCVs. Features of the large-scale environment that appear conducive to the formation and longevity of MCVs include weak flow, weak vertical shear and weak background relative vorticity. Furthermore, the rapid meso-vortex generation observed can be explained with the quasi-geostrophic vorticity equation, i. e., convergence acting on the Coriolis parameter. Zhang and Fritsch (1988) have shown how convective activity can result in moistening and, thus a virtual warming of the environment The virtual warming effect is important in generating a meso-low because density perturbations caused by moisture are not easily dispersed by inertia-gravity waves. Thus the geographical distribution of MCVs may be partly explained by physiography since the virtual warming effect would be most pronounced in a region with initially dry mid-levels such as the west Central Plains. Special data taken within two MCV events are contrasted. Profiler data obtained in a quasi steady-state MCV revealed the MCV structure is consistent with a arm-core low in geostrophic balance. Maximum relative vorticity (and tangential winds) on the vortexcale was three to four times the Coriolis parameter and is located at the base (between 5-6 km) of the circulation. Shear vectors are consistent with a warm core above the circulation base and a cold core below. Finally, in-situ aircraft data obtained in a developing MCV verified that cloud features observed on satellite images are associated with mid-level, warm-core closed circulations.

NS-005

BRANDES, E.A., and R.M. RABIN. Cold front structure as seen by Doppler radar and tall instrumented tower. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 459-462 (1989).

No abstract.

NS-006

BROWN, R.A. Initiation and propagation of thunderstorm mesocyclones. Ph.D. dissertation, University of Oklahoma, Norman, 321 pp. (1989).

Dual Doppler radar measurements were used to investigate the kinematic and radar reflectivity features of a developing supercell storm that occurred in south-central Oklahoma on 6 June 1979 during Project SESAME. Although the Agawam storm exhibited reflectivity characteristics typical of a supercell storm propagating continuously to the right of the mean wind, Doppler velocity measurements revealed discrete propagation through the formation of a series of right-flank updrafts. The appearance of continuous rightward propagation evidently was in response to the temporal and spatial integration of decreasing precipitation being produced by the dying updraft and increasing precipitation being produced by the new right-flank updraft. The commencement of rightward propagation was associated with the development of middle-altitude updraft rotation (organizing stage of mesocyclone). Customarily, updraft rotation is thought to arise from the vertical tilting and stretching of streamwise horizontal vorticity. Though streamwise horizontal vorticity was present at low altitudes within the environment of the Agawam storm, this study indicates that updraft rotation resulted from an entirely different process--one that was initiated by the formation of middle-altitude vorticity couplet on the left and right forward flanks of the updraft. The couplet apparently developed when a nonrotating updraft became strong enough to act as an obstacle to the middle-altitude environmental flow. Middle-altitude updraft rotation commenced when the first new right-flank updraft grew upward through the cyclonic member of the vorticity couplet, entraining and stretching the ambient vertical vorticity. Each new rotating updraft produced its own vorticity couplet, which in turn was the source of vertical vorticity for the next updraft.

NS-007

BROWN, R.A., 1989. On the initiation of updraft rotation within the Agawam, Oklahoma, supercell storm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 66-69 (1989).

No abstract.

NS-008

BROWN, R.A., and V.T. Wood. A guide for interpreting Doppler velocity patterns. Report No. R400-DV-101, October 1987. The NEXRAD Joint System Program Office, Silver Spring, MD, 51 pp. (printed 1989).

The Next Generation Weather Radar (NEXRAD) System incorporates major technological advances that are designed to aid forecasters in preparing more accurate and timely warnings and short-term forecasts. Though computer algorithms are available to objectively interpret Doppler velocity data, there remains a

necessity for subjectively interpreting the patterns on Doppler velocity displays. This guide has been prepared--through the use of simulated flow fields--to help forecasters become proficient in pattern interpretation. The simulated patterns represent flow fields within clear air widespread precipitations as well as within convective storms.

NS-009

BURGESS, D.W., and J. Marwitz. The observed inflow structure of a thunderstorm with a mesocyclone. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 70-72 (1989).

No abstract.

NS-010

CARACENA, F., R.L. HOLLE, and C.A. DOSWELL III. Microbursts: A handbook for visual identification. NOAA/ERL, National Severe Storms Laboratory, Norman, Oklahoma (Available from U.S. Superintendent of Documents, Washington D.C. 20402, Req. No. 9.01701), 35 pp. (1989).

Aid is provided for spotters who are visually identifying microbursts and for forecasters who identify the environments in which microbursts are likely to happen. Following a discussion of physical models of a microburst environment, on which forecasts are based, two environmental extremes (wet/dry) for microbursts are described and typified by corresponding soundings, and illustrated through photographs that portray the type of sky associated with these environments. A vortex ring model of the flow within a microburst is shown, to aid in identification through its integration of subtle visual clues, which are liberally illustrated in the color photographs. The model accounts for the following characteristics that warn of microbursts: (1) precipitation (or dust) curl that is carried by the wind back up toward cloud base; (2) horizontal bulging near the surface in a precipitation shaft, forming a foot-shaped prominence; (3) an increase rather than a decrease in wind speed as the microburst expands out over the ground; and (4) abrupt surface wind gusts followed by a rapid dissipation of some types of microbursts.

NS-011

Christian, H.J., V. MAZUR, B.D. Fisher, L.H. Ruhnke, K. Crouch, and R.P. Perala. The Atlas/Centaur Lightning Strike Incident. Journal of Geophysical Research 94:D11 13,169-13,177 (1989).

On March 26, 1987, an Atlas/Centaur 67 vehicle carrying a naval communication satellite was launched at 1622:00.768 EST from pad 36B of the Cape Canaveral Air Force Station, Florida. The meteorological conditions at the time were typical of wintertime storms with heavy overcast, moderate rain, and occasional scattered lightning activity. The NASA Investigation Board determined that, at approximately 48 s into the flight, the vehicle was struck by a triggered, cloud-to-ground lightning flash, comprised of at least four return strokes. The resulting lightning current apparently coupled a transient signal into the wiring of the Centaur digital computer unit (DCU), which caused a change in one memory location. The altered memory was associated with the computation of the Atlas engine yaw commands and caused the DCU to issue a hardover engine gimbal command. This resulted in an excessive angle of attack, large dynamic loads, and the breakup of the Atlas/Centaur 67 vehicle. The paper represents a case study of meteorological conditions at the time of launch and of the lightning flash triggered by the Atlas/Centaur 67 vehicle. This is based on comprehensive analyses of the cause of the incident by the NASA Investigation Board.

NS-012

DAVIES-JONES, R.P. A generalized Q vector and its interpretation. IAMAP 89 Brief Review Papers and Abstracts, Vol. 1, Fifth Scientific Assembly of the International Association of Meteorology and Atmospheric Physics, University of Reading, UK, July 31 - August 12, 1989. 1:MF33 (1989).

No abstract.

NS-013

DOSWELL, C.A. III. On the use of holographs--vertical wind profile information in severe storms forecasting. NOAA/NWS/SRH, Scientific Services Division, Fort Worth, Texas, and NOAA/ERL, National Severe Storms Laboratory, Norman, Oklahoma, 19 pp. (1988).

No abstract.

NS-014
DOSWELL, C.A. III. Fundamental concepts of operational mesoscale analysis and forecasting for severe convective storms (Part I). WMO Programme on Short-and Medium Range Weather Prediction Research, PSMP Report Series No. 30, 81-99 (1989).

No abstract.

NS-015
DOSWELL, C.A. III. Fundamental concepts of operational mesoscale analysis and forecasting for severe convective storms (Part II). WMO Programme on Short-and Medium Range Weather Prediction Research, PSMP Report Series No. 30, 101-117 (1989).
No abstract.

NS-016
DOSWELL, C.A. III. Recent research findings on the role of vertical wind shear: Applications to forecasting. WMO Programme on Short and Medium Range Weather Prediction Research, PSMP Report Series No. 30, 141-155 (1989).

No abstract.

NS-017
DOSWELL, C.A. III, and J.A. Flueck. Forecasting and verifying in a field research project: DOPLIGHT '87. Weather and Forecasting 4:97-109 (1989).

Verification of forecasts during research field experiments is discussed and exemplified using the DOPLIGHT '87 experiment. We stress the importance of forecast verification if forecasting is to be a serious component of the research. A direct comparison and contrast is done between forecasting for field research and forecasting in the operational sense, highlighting the differences between them. The verification of field research program forecasting is also different from that done in operations, as a result of those forecasting differences. DOPLIGHT '87 was a field project conducted jointly by the National Severe Storms Laboratory and the Oklahoma City National Weather Service Forecast Office, and is described in detail. This a priori design of the forecasts to consider proper objective verification is, we believe, unique among research field programs. The forecast evaluation focuses on the contingency table and summary statistics derived from it, as treated in a companion paper by Flueck (1989; hereafter referred to as Flu89). Results are interpreted in terms of their implications for future field research experiments and for operational forecasting. For example, it is noted that DOPLIGHT '87 forecasts of convective potential were nearly constant from the evening before an anticipated operational day to about local noon on that day. This suggests that convective storm field research operational decisions could be made as early as the evening before an anticipated operational day with negligible loss of skill. Summary measure of the forecast verification suggest that the DOPLIGHT '87 forecasters demonstrated skill roughly comparable to the forecasters at the National Severe Storms Forecast Center in issuing outlooks of convective potential. The requirement for time to assimilate the most recent data is noted both for field experiments and for operations, and some discussion of the potential impact of new data acquisition and processing systems is offered.

NS-018
DOVIAK, R.J., and D.R. Christie. Thunderstorm-generated solitary waves: A wind shear hazard. Journal of Aircraft 26:423-431 (1989).

Observations of a boundary-layer solitary wave sensed with the National Severe Storms Laboratory's Doppler weather radar and a 444-m-tall instrumented tower suggest that solitary and other nonlinear waves are a source of significant wind shear hazard to safe flight and thus should be studied both experimentally theoretically. Wave transport of the horizontal momentum of the vertically sheared ambient air contributed much to the observed wind perturbations and horizontal wind shear. Observations are compared with, and shown to agree fairly closely with, the waveform predicted by steady state, weakly nonlinear, internal wave theory.

NS-019
DOVIAK, R.J., and K.W. Thomas. The wavefront shape and position of a great solitary wave of translation. Proceedings of International Geoscience and Remote Sensing Symposium, September 13-16, 1988, Edinburgh, Scotland, 1833-1837 (1988).

Doppler radar mapped the evolution of atmospheric solitary gravity waves emanating from a thunderstorm complex. The 100 km long curved wavefront and position of these few kilometer wide waves is hypothesized to be a result of an amplitude dependent wave speed.

NS-020

EILTS, M.D. Estimation of microburst asymmetry with a single Doppler radar. Third International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 57-61 (1989).

No abstract.

NS-021

EILTS, M.D., and S.K. Oakland. Convergence aloft as a precursor to microbursts. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 190-193 (1989).

No abstract.

NS-022

EILTS, M.D., and S.D. Smith. Efficient dealiasing of Doppler velocities using local environment constraints. Final Report DOT/FAA/SA-89/1, Federal Aviation Administration, Washington, DC, 37 pp. (1989).

A Doppler velocity dealiasing algorithm is described that processes one radial at a time by comparing that radial with a previous radial. This technique has worked reliable on numerous Doppler radar data sets for clear air, thunderstorm, and severe thunderstorm situations. It was also tested on four volume scans from severe weather environments with difficult aliasing problems to determine statistically how well the algorithm performs in a worst case environment. Of some 1.2 million velocities in these severe storms, 0.2% were improperly dealiased, and 93% of those were above 13 km height in the storm-top divergent region where shears were extreme. Every tornado, mesocyclone, gust front, microburst, and storm-top divergent signature was preserved, and could be identified by automated algorithms. This algorithm is adaptive and therefore efficient because simple checks are made initially, and progressively more sophisticated and time-consuming checks are used only if they are needed.

NS-023

EILTS, M.D., and S.D. Smith. Real-time Doppler velocity dealiasing. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 194-197 (1989).

No abstract.

NS-024

FORSYTH, D.E., D.W. BURGESS, M.H. JAIN, and L.E. Mooney. DOPLIGHT '87: Application of Doppler radar technology in a National Weather Service Office. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 198-202 (1989).

No abstract.

NS-025

Goodman, S.J., H.J. Christian, and W.D. RUST. A comparison of the optical pulse characteristics of intracloud and cloud-to-ground lightning as observed above clouds. Journal of Applied Meteorology 27, (12):1369-1381 (1989).

The time-resolved optical waveforms at 777.4 nm and electric-field changes produced by intracloud and cloud-to-ground lightning flashes were measured above clouds from a U2 airplane (flying at a height of 20 km) at the same time that ground-based measurements of lightning were obtained from a mobile laboratory and a regional lightning location network. The U2 optical pulse trains are examined for variability both within and between flashes. The optical pulse characteristics of cloud-to-ground flashes are further subdivided into first strokes, subsequent strokes, and intracloud components (*k*-changes). Descriptive statistics on these pulse categories have been compiled for 25 visually confirmed cloud-to-ground flashes (229 optical pulses) and 232 intracloud flashes (3126 optical pulses). The pulse shapes and intensities

of intracloud and cloud-to-ground flashes as viewed from above cloud are shown to exhibit remarkably similar waveshapes, radiances, and radiant energy densities. The median radiance at cloud top is approximately 7 x 10^{-3} W m^{-2} sr^{-1}, and the median energy density is 3 x 10^{-6} J m^{-2} sr^{-1}. A simple physical model is used to estimate, for comparative purposes, the radiance and energy density of the original light source within the cloud. First stroke optical pulses are seldom the most radiant or energetic pulses produced by ground discharges as seen from above the clouds. The intracloud components of cloud-to-ground flashes typically produce the optical pulses with the largest peak radiance within a cloud-to-ground flash; however, subsequent strokes are more likely to have the largest energy densities and most complex pulse shapes. On average, intracloud flashes have almost twice as many optical pulses as ground discharges. There is often significant pulse structure variation within and between individual flashes. Because of this variation, multiple stroke cloud-to-ground flashes are difficult to distinguish uniquely from intracloud flashes solely on the basis of their optical signature above cloud. Single stroke cloud-to-ground flashes, however, appear to have a unique single pulse optical signature. The relevance and implications of these pulse characteristics for lightning mapping from satellite-based optical sensors is addressed.

NS-026

Goodman, S.J., D.E. Buechler, P.D. Wright and W.D. RUST. Lightning and precipitation history of a microburst-producing storm. Geophysical Research Letter 15:1185-1188 (1988).

Quantitative measurements of the lightning and precipitation life-cycle of a micro-burst producing storm are described. The storm produced 116 total flashes of which only 6 were discharges to ground. The initial discharge occurred during a period of vigorous vertical development, approximately 4-6 min after small hail was first indicated by radar. The peak flash rate of 23 flashes min^{-1} occurred only 7-8 min later, 4 min prior to microburst onset, in conjunction with the peak in 2 storm mass, vertically integrated liquid water content, echo volume, and cloud height. An abrupt decrease in the total flash rates is associated with storm collapse and serves as a precursor to the arrival of the maximum microburst outflows at the surface. Ice-phase precipitation is shown to be an important factor in both the formation of the strong downdraft and the electrification of the storm.

NS-027

Goodman, S.J., D.E. Buechler, P.D. Wright, W.D. RUST, and K.E. Nielsen. Polarization radar and electrical observations of two microburst producing storms, Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March, 1989. American Meteorological Society, Boston, 109-116, (1989).

Quantitative measurements of the lightning and precipitation life-cycle of a microburst-producing storm are described. The storm produced 109 total flashes of which only 6 were discharges to ground. The initial discharge occurred as the storm reached its maximum height, approximately 6 min after small hail was first indicated by radar. The first flash was observed during a period of rapid vertical development when the cloud grew at a nearly constant rate of 12 m s-1. At this time, the maximum radar reflectivity in the cloud was 66 dBZ at a height of 4.5 km. The peak flash rate of 22 flashes min-1 occurred only 4 min later.

NS-028

Grice, G.K., K.W. HOWARD, S.L. BARNES, and C.A. DOSWELL (editors). A guide for operational meteorological research. National Weather Service, Fort Worth, TX, 81 pp. (1988).

No abstract.

NS-029

HANE, C.E., and M.A. LeMone. Retrieval of pressure and buoyancy from Doppler-derived winds in a High Plains hailstorm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 38-41 (1989).

No abstract.

NS-030

Houze, R.A., S.A. Rutledge, M.I. Biggerstaff, and B.F. SMULL. Interpretation of Doppler weather radar displays of midlatitude mesoscale convective systems. Bulletin of the American Meteorological Society 70: 608-619 (1989).

The utility of color displays of Doppler-radar data in revealing real-time kinematic information has been demonstrated in past studies, especially for extratropical cyclones and severe thunderstorms. Such displays can also indicate aspects of the circulation within a certain type of mesoscale convective system-the squall line with trailing "stratiform" rain. Displays from a single Doppler radar collected in two squall-line storms observed during the Oklahoma-Kansas PRE-STORM project conducted in May and June 1985 reveal mesoscale-flow patterns in the stratiform rain region of the squall line, such as front-to-rear storm-relative flow at upper levels, a subsiding storm-relative rear inflow at middle and low levels, and low-level divergent flow associated with strong mesoscale subsidence. "Dual-Doppler" analysis further illustrates these mesoscale-flow features and, in addition, shows the structure of the convective region within the squall line and a mesoscale vortex in the "stratiform" region trailing the line. A refined conceptual model of this type of mesoscale convective system is presented based on previous studies and observations reported here. Recognition of "single-Doppler-radar" patterns of the type described in this paper, together with awareness of the conceptual model, should aid in the identification and interpretation of this type of mesoscale system at future NEXRAD sites. The dual-Doppler results presented here further indicate the utility of multiple Doppler observations of mesoscale convective systems in the STORM program.

NS-031

HOWARD, K.W., and R.A. MADDOX. A satellite-based climatology of warm season thunderstorms over Mexico. Preprints, III InterAmerican Congress of Meteorology, III Mexican Congress on Meteorology November 14-18, 1988, Mexico City, 414-417 (1988).

Infrared (IR) geosynchronous operational environmental satellite (GOES) hard copy and digital imagery is used to document thunderstorm frequency over northern Mexico. Satellite imagery is used to define a "thunder day" and thus capture thunderstorm activity more accurately than classical climatological depictions based on surface observation. A pronounced shift in daily thunderstorm activity from eastern to western states occurs by middle summer as the subtropical, mid-tropospheric ridge intensifies westward across the Gulf of Mexico. This characteristic is clearly shown in monthly "thunder day" tabulations. Thunderstorm frequency charts also illustrate that orographic circulations along the Sierras strongly modulate the development of storms and resultant climatologies.

NS-032

HOWARD, K.W., and R.A. MADDOX. Mexican mesoscale convective systems--A satellite perspective. Preprints, III InterAmerican Congress on Meteorology, III Mexican Congress on Meteorology November 14-18, 1988, Mexico City, 404-408 (1988).

Satellite imagery is used to illustrate the types of organization that typify Mexican Mesoscale Convective Systems (MCS) and to depict typical life cycles. Perusal of imagery for the months of May through September, 1980-1987, allows development of an initial climatology of these systems. Favored geographical regions and characteristics of warm season MCSs over Mexico are illustrated, along with typical tracks, durations, and life cycles. It is hypothesized that these systems play a substantial role in determining the local climate of several regions of Mexico and that they are important components of the summertime circulation over much of North America, i.e., the southwestern U.S. monsoon.

NS-033

JORGENSEN, D.P., and M.A. LeMone. Characteristics of convective vertical velocity events observed by P-3 aircraft during TAMEX. Proceedings, Workshop on TAMEX Preliminary Scientific Results, Taipei, Republic of China, June 22-30, 1989. National Science Council, Taipei, and National Science Foundation,Washington, DC, 203-213 (1989).

No abstract.

NS-034

JORGENSEN, D.P., and M.A. LeMone. Precipitation and kinematic structure of the TAMEX 16 June mesoscale convective system. Part II: Pressure and buoyancy perturbations derived from airborne Doppler radar data. Proceedings, Workshop on TAMEX Preliminary Scientific Results, Taipei, Republic of China, June 22-30, 1989. National Science Council, Taipei, and National Science Foundation, Washington, DC, 103-109 (1989).

No abstract.

NS-035

JORGENSEN, D.P., and M.A. LeMone. Vertical velocity characteristics of oceanic convection. Journal of the Atmospheric Sciences 46: 621-644 (1989).

Oceanic cumulonimbus updraft and downdraft events observed in the Western Pacific during the TAMEX program by NOAA P-3 research aircraft are analyzed and discussed. The basic data set consists of flight-level data from 10 missions in the Taiwan region during May and June 1987. The 1 Hz time series of vertical velocity is used to define convective updrafts using the criteria that the velocity must be continuously positive for at least 0.5 km and exceed 0.5 m s^{-1} for 1 s. A subset of the strongest drafts, termed cores, are defined as events that exceed 1 m s^{-1} for 0.5 km. Downdrafts and downdraft cores are defined analogously. The statistics are from a total of 12,841 km of flight legs and consist of 359 updrafts and 466 downdrafts at altitudes from 150 m to 6.8 km MSL. The populations of average vertical velocity, maximum vertical velocity, diameter, and mass transport for both drafts and cores are approximately log-normally distributed, consistent with the results of previous studies of convective characteristics in other locations. TAMEX drafts and cores are comparable in size and strength with those measured in GATE and hurricanes but much weaker than those measured in continental thunderstorms. The median core updraft was less than 3 m s^{-1}, implying a time scale for ascent from cloud base to the freezing level of about 35 minutes. The microphysical implications of the low updraft rates are illustrated by comparing vertical profiles of radar reflectivity for TAMEX with those in other regions. The data are consistent with the hypothesis that the oceanic convection that was studied in GATE, hurricanes, and TAMEX is dominated by warm rain coalescence processes and that a large fractional rainout occurs below the freezing level. The rapid reduction of cloud water and radar reflectivity above the freezing level, as well as observations of abundant ice particles in all but the strongest updraft cores at temperatures just below 0°C, implies a rapid conversion of cloud water and rain to ice and graupel as the air ascends through the freezing level. The lack of reports of hail and other forms of severe weather in these oceanic regions is consistent with the aircraft and radar observations. The data from the "best" organized weather system investigated by the P-3 during TAMEX are used to examine the relationship of cloud buoyancy and vertical motion. Water loading and entrainment have a significant role in reducing both the core virtual temperature excess over the environment and the updraft velocity from what would be expected from the convective available potential energy of the environmental air. The majority of the strongest downdrafts possesses positive temperature perturbations (probably as a result of mixing with nearby updraft air) with the negative buoyancy being sustained by large amounts of rainwater.

NS-036

JORGENSEN, D.P., M.A. LeMone, and B. Jou. Precipitation and kinematic structure of an oceanic mesoscale convective system. Part I: Airborne Doppler radar analysis. Proceedings, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 232-233 (1989).

No abstract.

NS-037

Jou, B., D.P. JORGENSEN, and B.F. SMULL. Precipitation and kinematic structure of the TAMEX 16 June mesoscale convective system. Part I: Airborne Doppler radar analysis. Proceedings, Workshop on TAMEX Preliminary Scientific Results, Taipei, Republic of China, June 22-30, 1989. National Science Council, Taipei, and National Science Foundation, Washington, DC, 77-81 (1989).

No abstract.

NS-038

Klingle-Wilson, D., S.H. Olson, W. Wilson, W.P. Mahoney III, S.D. Smith, A. WITT, and M.D. EILTS. Gust front detection algorithm for the terminal Doppler weather radar. Part II: Performance Assessment. Preprints, Third International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 398-402 (1989).

No abstract.

NS-039

Lang, S.L., P.S. Ray, and C.L. ZIEGLER. Retrieval and evolution of microphysical fields in a small mountain thunderstorm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 93-96 (1989).

No abstract.

NS-040

LeMone, M.A., and D.P. JORGENSEN. Precipitation and kinematic structure of an oceanic mesoscale convective system. Part II: Results from analysis of in-situ data. Proceedings, 18th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, May 16-19, 1989. American Meteorological Society, Boston, 234-235 (1989).

No abstract.

NS-041

LeMone, M.A., and D.P. JORGENSEN. Precipitation and kinematic structure of the TAMEX 16 June mesoscale convective system. Part III: Analysis of in-situ data. Proceedings, Workshop on TAMEX Preliminary Scientific Results, Taipei, Republic of China, June 22-30, 1989. National Science Council, Taipei, and National Science Foundation, Washington, DC, 110-117 (1989).

No abstract.

NS-042

LEWIS, J.M. GUFMEX: A study of return flow in the Gulf of Mexico. Bulletin of the American Meteorological Society 70:24-29 (1989).

During February and March 1988, a limited field experiment was conducted over the Gulf of Mexico to gather data on two phenomena: air mass modification over the Loop Current, and return flow characteristics of modified polar air returning to the southern shores of the United States. Six-hourly radiosondes, special Cross-Chain LORAN (Long-Range Aid to Navigation) Atmospheric Sounding System (CLASS) soundings, and three P-3 flights including dropwindsondes and Airborne Expendable Bathythermograph (AXBT) measurements were taken. The experiment objectives and the data are described.

NS-043

LEWIS, J.M., C. Hayden, and J. Derber. A method for combining radiances and wind shear to define the temperature structure of the atmosphere. Monthly Weather Review 117:1193-1207 (1989).

The retrieval of temperature from satellite-observed radiances has traditionally been addressed as a one-dimensional or columnar problem which uses a guess profile of temperature. In this study, the traditional approach is augmented by incorporating observed wind shear as a general thermal wind constraint in the inversion of radiances to make a three-dimensional temperature analysis. The problem is case as a classical variational problem that minimizes a weighted sum of squares subject to constraint. The constraints are the general thermal wind equation and a set of regression equations expressing the radiances in terms of the temperature profile. The solution is found by the method of conjugate gradients. Experiments using observed winds with both simulated and observed radiances for the GOES VISSR Atmospheric Sounder (VAS) are described. In both cases, a first guess from a numerical forecast is used. Simulated radiances are used to establish the optimal relative weighting of the wind versus radiance observations and to determine the limits of accuracy on the retrieved temperature under idealized conditions. These relative weights are used in the real data experiments. Experiments are included where weights are varied horizontally and vertically to simulate uneven distribution or confidence in the data. Results indicate that (i) the inclusion of wind shear with simulated radiances reduces the cumulative error variance in the temperature estimate and reduces guess dependence; (ii) horizontal and vertical variations in parameter weighting is viable and well-behaved; and (iii) the algorithm's rate of convergence makes it suitable for small computer applications. Experiments with observed radiances are not as successful. The measured radiances do not improve the forecast. The principal deficiency appears to be that the regression model for expressing the radiances is inadequate to account for the influence of water vapor which affect the VAS measurements or the nonlinearity of radiance with respect to temperature. Extensions to the model as well as application to microwave measurements, which do not suffer these deficiencies, are discussed.

NS-044

LEWIS, J.M., and L.C. SHOWELL. GUFMEX: Preprints, III Interamerican Mexican Congress of Meteorology, III Mexican Congress on Meteorology, November 14-18, 1988, Mexico City, Mexico, 106-109 (1989).

During February and March 1988, a limited field experiment was conducted over the Gulf of Mexico to gather data on two phenomena: air mass modification over the Loop Current, and return flow characteristics of modified polar air returning to the southern shores of the United States. Six-hourly radiosondes, special Cross-Chain LORAN Atmospheric Sounding System (CLASS) soundings, and three P-3 flights including dropwindsondes and Airborne Expendable Bathythermograph (AXBT) measurements were accomplished. The experiment objectives and the data are described.

NS-045

LOPEZ, R.E., D. Atlas, D. Rosenfeld, J.L. Thomas, D.O. BLANCHARD, and R.L. HOLLE. Estimation of areal rainfall using the radar echo area time integral. Journal of Applied Meteorology 28:1162-1175 (1989).

This work extends the Area Time Integral (ATI) method of Doneaud et al., developed for the lifetime rainfall from an individual storm, and the instantaneous areawide rainfall method of Atlas et al., to the measurement of the cumulative areawide rainfall for periods up to 12 h. The database is the radar and raingage network data for the three summers of the Florida Area Cumulus Experiment (FACE) II. For 12-h accumulations, V, over the area of 3.6 X 104 km2, we find correlations of 0.92 between radar deduced rainfall and ATI where the latter is computed at intervals from 5 min up to 1 h. The slope of the regression line V/(ATI) is 3.4 mm h-1. Using a gage network with density of 1/11 km2 over an area 1.5 X 104 km2 the correlation coefficient drops to 0.84, still sufficiently high to confirm the validity of the ATI approach. Also, with the gages the V/(ATI) slope decreases to 2.6 mm h-1. The decrease in the correlation is due largely to anomalous propagation which falsely increases storm areas, and partly to the poorer sampling by the gages. The decrease in the rain volume from radar to gage-determined values is probably due to: 1) underestimation of the rain cores by the spaced gages; 2) the use of the wide beam WSR-57 and low threshold for echo area measurements, which detects weak anvil and other precipitation debris to increase the effective echo area without a proportional increase in surface rainfall; and 3) an inappropriate Z-R relation. A comparison of the V/(ATI) ratios using either radar or gage rainfall to the value expected theoretically on the basis of the probability distribution of rain rate at Miami shows that one should expect about twice the volume per unit echo area as those observed. This too is believed to be due to the wide beam and the low threshold which tends to enlarge the echo areas excessively. Improved correlations and better agreement with theory are expected at higher radar/rain rate thresholds and with narrower beams.

NS-046

LOPEZ, R.E., R.L. HOLLE, W.D. OTTO, and R. ORTIZ. Cloud-to-ground lightning in Colorado: Flashes of both polarities related to meteorological conditions, radar echoes, and severe weather. Proceedings, 1989 International Conference on Lightning and Static Electricity, Bath, United Kingdom, September 26-28, 1989. Royal Aerospace Establishment, Farnborough, Hampshire, United Kingdom, 1A.2.1-7 (1989).

Cloud-to ground lightning location data have been collected by a three direction-finder network in northeastern Colorado, USA. The data have been used to study the relationships of flashes to three types of meteorological parameters. The number of flashes of both polarities, as well as the relative occurrence of positives, shows a large seasonal variability. These fluctuations have been compared to the thermodymanic and dynamic parameters related to convective cloud growth potential based on the afternoon sounding at Denver, Colorado. The seasonal fluctuation of environmental parameters that favor deep, vigorous, and long-lasting convection coincides with the seasonal fluctuation of absolute lightning activity (both positive and negative flashes). For the ratio of positive to all flashes, however, the opposite is true: high ratios are related to a shallow convective layer and a low water-vapor content in the atmospheric column. High vertical wind shears are associated with low ratios during the summer, but in the spring and fall they are related to a high relative occurrence of positives. When composited with radar information, negative flashes were found slightly outside the echoes or in the region of low values but of the highest gradients of radar reflectivity. Positives occurred in areas of weak and uniform radar reflectivity away from the intense convective centers, or in the dissipating stages of the storms. Clouds with a moderate radar-detected precipitation rate near the ground were found to produce a large

number of negative flashes but not many positives. Clouds with a high precipitation rate produced a small number of negative flashes, but a considerable number of positive flashes. Flashes were also related to severe weather in the region. In the summer of 1985 the frequency of flashes with one or more severe storm occurrences is 350% greater than the frequency on days with no severe weather events. When individual severe weather phenomena were identified, such as tornadoes, heavy rain, flash floods, hail, or high winds, nearly all categories had more than twice as many flashes on days with a specific type of severe weather than on days without such a weather type.

NS-047

LOPEZ, R.E., R.L. HOLLE, and A.I. WATSON. Meteorological studies with cloud-to-ground lightning data: Samples of recent analyses. Proceedings, 4th WMO Technical Conference on Instruments and Methods of Observation (TECIMO-IV), Brussels, Belgium, September 4-8, 1989. WMO/TD No. 303, Geneva, 275-280 (1989).

No abstract.

NS-048

LOPEZ, R.E., W.D. OTTO, J.R. DAUGHERTY, and R.L. HOLLE. The relationship between radar and lightning characteristics of northeastern Colorado storm systems. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 85-88 (1989).

No abstract.

NS-049

MACGORMAN, D.R., D.W. BURGESS, V. MAZUR, W.D. RUST, W.L. Taylor, and B.C. Johnson. Lightning rates relative to tornadic storm evolution on 22 May 1981. Journal of Atmospheric Sciences 46:221-250 (1989).

On 22 May 1981, we acquired lightning and Doppler radar data on two tornadic storms in Oklahoma. Cloud-to-ground lightning flash rates were measured with a magnetic direction-finder system, and total flash rates in the vicinity of the mesocyclone were measured with an L-band radar. In both storms, there was no clear relationship between tornado occurrence and ground flash rates of the storm as a whole, but the stroke rate of each storm was highest after it stopped producing tornadoes. For the second storm, we examined both intracloud and cloud-to-ground lightning rates relative to mesocyclone evolution, analyzing the region within 10 km of the mesocyclone core. Our analysis began during initial stages of the mesocyclone core associated with the fourth and strongest of five tornadoes in the storm and continued until all mesocyclone cores in the storm dissipated. During this period, intracloud lightning flash rates reached a peak of almost 14 min^{-1} approximately 10 min after the peak in cyclonic shear at the 6 km level and at the same time as the peak in cyclonic shear at the 1.5 km level. The peak in intracloud rates also occurred 5-10 min after the peak in the area within 40 and 45 dBZ contours at the 8 km level and at about the same time as the peak in the area within 50 dBZ contours at 8 km and within 40 dBZ at 6 km. However, ground flash rates in the mesocyclone region were usually less than 1 min -1 during periods when intracloud rates were high and were negatively correlated with cyclonic shear at both 1.5 and 6 km. The ground flash rate was the last parameter to peak, approximately 15 min after intracloud lightning and a few minutes after the latest reflectivity area (the area having >dBZ at the 1 km level). We suggest that intracloud rates were governed in part by particle interactions during the growth in reflectivity at 7-9 km and in part by some process associated with the evolution of cyclonic shear at low altitudes. Earlier studies of tornadic storms indicate that the evolution of updrafts and downdrafts affects the evolution of both reflectivity and low-altitude cyclonic shear and so, as in previous storm studies, updraft evolution will affect intracloud rates. We suggest that the peaks in ground flash rates resulted from increasing the distance between the main positive and negative charge centers, from the sedimentation of negative charge to lower altitudes, or from the generation or advection of positive charge below the main negative charge. Although these data are from only a single day, consideration of sferics data from previous studies suggests that (1) most tornadic storms (80% or more) have an increase in total flash rates near the time of the tornado, and (2) the increase in total flash rates is often dominated by intracloud flashes.

NS-050

MACGORMAN, D.R., and W.D. RUST. An evaluation of the LLP and LPATS lightning ground strike mapping systems. Preprints, 5th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 249-254 (1989).

No abstract.

NS-051

MACGORMAN, D.R. and W.L. Taylor. Positive cloud-to-ground lightning detection by an LLP direction-finder network. Journal of Geophysical Research 94:D11,13,313-13,318 (1989).

We have investigated how reliably an automatic direction-finder network manufactured by Lightning Location and Protection, Inc. (LLP), identifies cloud-to-ground (CG) flashes that effectively lower positive charge to ground (+CG flashes). To provide independent verification of the occurrence of +CG flashes, we examined records from an extremely low frequency (ELF) system to determine whether 340 +CG flashes detected by the LLP system had coincident ELF waveforms characteristic of +CG flashes. The fraction of +CG flashes that had coincident ELF waveforms increased from 0.67 for flashes with range-normalized amplitudes of 0-25 LLP units to an average of 0.93 for flashes with range-normalized amplitudes of at least 75 LLP units. We also analyzed ELF coincidence for -CG flashes recorded by video systems and by the LLP system. A comparison of the results for +CG flashes and -CG flashes suggests (1) that false detection is negligible in the LLP system for +CG flashes with range-normalized amplitudes of at least 50 LLP units and (2) that no more than about 15% of the +CG flashes detected by the LLP system at smaller amplitudes are false detections. The true percentage of +CG flashes that are false detections is probably even lower, because at least some of the decrease in ELF coincidence at low amplitudes appears to have been caused by an increase in the fraction of coincident ELF signals that occurred below the ELF system's noise level.

NS-052

Mach, D.M., and W.D. RUST. A photoelectric technique for measuring lightning-channel propagation velocities from a mobile laboratory. Journal of Atmospheric and Oceanic Technology 6 (3):439-445 (1989).

We have developed a device to measure lightning-channel propagation velocities. It consists of eight solid state silicon detectors mounted behind precision horizontal slits in the focal plane of a 50-mm lens on a 35-mm camera body. Each detector has a 0.1° vertical field of view that is separated from adjacent detector slits by 2.8°. The horizontal field-of-view for each detector is 41° and the total vertical field of view for the device is 21°. The signal from each detector is amplified by a circuit with a 10-90% rise time of 0.6 μs and an equivalent decay time of 400 μs. The eight photodetector pulses, IRIG-B time, and slow and fast electric field change waveforms are recorded on a 14 track analog tape recorder with an upper frequency response of 1.0 MHz and a maximum dynamic interchannel timing error of 0.6 μs. To provide images of lightning geometry and permit time-to-thunder measurements, color video and sound are recorded with a standard VHS video cassette recorder. The return stroke velocity (RSV) device, video camera, and microphone are installed and coaxially aimed in an environmental enclosure on a remotely controlled pan-tilt unit atop our mobile laboratory permitting the recording of lightning signals at remote sites and while mobile. To evaluate the performance of the RSV device, we have analyzed 12 natural return strokes from Alabama, Florida, and Oklahoma and 4 return strokes triggered at the Kennedy Space Center, Florida. The velocities we determined vary from 1.2 to 2.5 x 10^8 ms^{-1}, with an average of 1.7 x 10^8 ms^{-1} ± 0.8 x 10^8 ms^{-1}. From comparisons of our results to those of a streaking camera, we find no significant differences between the velocities obtained from the same strokes with the two systems. We also find no differences between the characteristics of the pulses or the velocities calculated from them while the RSV device is moving or stationary.

NS-053

Mach, D. and W.D. RUST. A solid state lighting propagation speed sensor. Preprints, 27th Aerospace Sciences Meeting, Reno, NV, January 9-12, 1989. American Institute of Aeronautics and Astronautics, AIAA-89-0785 (1989).

We have developed a device to measure lightning channel propagation speeds. It consists of eight solid state silicon photodetectors mounted behind precision horizontal slits in the focal plane of a 50 mm lens on a 35 mm camera body. Each detector has a 0.1° vertical field of view that is separated from adjacent detector slits by 2.8°. With the device, we have analyzed propagation speeds from 140 strokes that consist of 98 natural and 43 triggered return strokes. For shorter channel lengths, less than 500m, natural lightning has a statistically higher average return stroke propagation speed of 1.9 ± 0.7 x 1^8 m s^{-1} than triggered lightning with an average return stroke propagation speed of 1.4 ± 0.4 x 10^8 m s^{-1}. Return stroke propagation speeds of 1.0 and 1.7 x 10^8 m s^{-1} were determined for two distant single stroke natural positive cloud-to-ground flashes. Dart leaders are detected for only 18% of the natural subsequent strokes while over 49% of the triggered strokes have detectable dart leaders. The average natural dart leader propagation speed of 1.8 ± 0.8 x 10^7 m s^{-1} is statistically greater than the average triggered dart leader propagation speed of 1.3 ± 0.8 x 10^7 m s^{-1}. We find no significant propagation speed change with height for either natural or triggered dart leaders.

NS-054

Mach, D.M., and W.D. RUST. Photoelectric return-stroke velocity and peak current estimates in natural and triggered lightning. Journal of Geophysical Research 94:D11,13,327-13,247 (1989).

Using data from a mobile, we present two-dimensional return-stroke velocities from 130 strokes that consist of 86 negative natural, 41 negative triggered, one positive triggered, and two positive natural return-strokes. The velocity measurements are divided into two groups: "short-channel" values with channel segments starting near the ground and less than 500m in length and "long-channel" values that start near the ground and exceed 500m in length. The average long-channel velocity is $1.3\pm0.3 \times 10^8$ m s^{-1} for natural return-strokes and $1.2\pm0.3 \times 10^8$ m s^{-1} for triggered return-strokes. For the short channels, natural return-strokes have a statistically higher (at the 98% confidence level) average velocity of $9.1\pm0.7 \times 10^8$ m s^{-1} than triggered strokes with an average velocity of $1.4\pm0.4 \times 10^8$ m s^{-1}. We compare our results with previous measurements of the return-stroke velocity for comparable channel segment lengths and find that there is no statistical difference between our results and the previous ones. A qualitative analysis indicates that the optical waveform from a return-stroke generally increases in risetime and decreases in amplitude at greater altitudes. Using the transmission line model (TLM), the shortest segment one-dimensional return-stroke velocity, and either the maximum or plateau electric field, we find natural strokes have a peak current distribution that is lognormal with a median value of 16 kA (maximum E) or 12 kA (plateau E) while triggered lightning has a median peak current value of 21 kA (maximum E) or 15 kA (plateau E). We find substantial differences between TLM and the shunt-measured peak currents and find no significant correlation between shunt peak currents and triggered return-stroke velocities. We do find correlations between TLM peak currents and velocities for triggered and natural subsequent return-strokes but not between TLM peak currents and natural first return=stroke velocities. In both cases where a correlation is found the trend is for greater peak currents to be associated with lower return-stroke velocities. Our peak current calculations are approximately half as large as previously reported. This difference is attributed to the greater return-stroke velocity measured by our photoelectric device and used in the transmission line model. Hence previous estimates of the return-stroke peak current seem too high. Two natural single-stroke positive cloud-to-ground flashes had velocities of 1.0 and 1.7×10^8 m s^{-1} and peak currents of 120-150 kA.

NS-055

MADDOX, R.A., and K.W. HOWARD. Mexican mesoscale convective systems - Two case examples. Preprints, III InterAmerican Congress on Meteorology, III Mexican Congress on Meteorology November 14-18, 1988, Mexico City, Mexico, 89-93 (1988).

Two Mexican Mesoscale Convective Systems (MSCs) are examined in a case study mode to explore both the environmental seetings that lead to these events and the possibility that they effect interactions between the subtropics and the middle latitude westerlies. A spring event along the east coast and a summer event over northwestern Mexico are considered. These systems exhibit many similarities with MCSs that occur frequently over the central United States. It is shown that large-scale forcing for vertical motion is very weak but that convective instability is surprisingly great. Substantial vertical displacement of moist boundary layer parcels is required to release the instability, and it is inferred that mesoscale lifting is essential to initiate and maintain these convective systems.

NS-056

MADDOX, R.A., and K.W. HOWARD. Mexican mesoscale convective systems--Large scale environmental conditions. Preprints, III InterAmerican Congress on Meteorology, III Mexican Congress on Meteorology November 14-18, 1988, Mexico City, Mexico, 395-399 (1988).

Mean atmospheric conditions associated with the occurrence of mesoscale convective systems over both the eastern and western coasts of Mexico are examined. The typical large-scale environment of these events appears quite benign with no obvious strong forcing for upward motion. Average soundings, however, show convective instability of a degree often associated with severe thunderstorms at more northerly latitudes. Substantial interactions between the large-scale circulation and mesoscale processes are apparently required to release the available buoyant energy. Candidate mesoscale features that could lead to the generation of Mexican MCSs include land-sea breezes, mountain-valley winds, organized mesoscale cold outflows from thunder storms initiated by elevated heating over the mountains or, in the case of eastcoast MCSs, from storms occurring further to the north over Texas.

NS-057

Marshall, T.C., W.D. RUST, W.P. Winn and K.E. Gilbert. The electrical structure in two thunderstorm anvil cloud. Journal of Geophysical Research 94:D2, 2717-2181 (1989).

Two electric field soundings through thunderstorm anvil clouds show similar charge structures: negatively charged screening layers on the top and bottom surfaces, a layer of positive charge in the interior, and one or two layers of zero charge. Both anvil clouds were strongly electrified: the peak magnitudes of the electric field in the two storms were 70 and 90 kV/m (and so, aircraft penetrating anvil clouds run the risk of triggering lightning flashes). The non-zero layers had charge densities comparable to those found in storm cores, ranging in magnitude from 0.4 to 2.7 nC/m^3. The layers ranged in thickness from 300 to 2000 m. The positive charge probably originated in the main positive charge region normally found at high altitudes in the core of thunderclouds. The removal of positive charge from the storm's core to the anvil may influence the ratio of intra-cloud to cloud-to-ground lightning flashes and the rate of generation of charge in the core. The negatively charged layers probably were screening layers resulting from the discontinuity in the electrical conductivity at the cloud boundaries. The lower negative screening layer appeared to be carried toward the storm's core by winds below and at the lower anvil boundary.

NS-058

MATEJKA, T. Pressure and buoyancy forces and tendencies in a squall line and their relation to its evolution. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 478-481 (1989).

No abstract.

NS-059

MAZUR, V. A physical model of lightning initiation on aircraft in thunderstorms. Journal of Geophysical Research, 94:3326-3340 (1989).

A physical model of initiation of lightning flashes by aircraft in thunderstorms, based on the 'bi-directional, uncharged leader' concept of Kasemir, is verified with airborne data from lightning strikes to instrumented airplanes (NASA F-106B and FAA CV-580). Characteristics of electromagnetic processes during lightning attachment to aircraft are identified with those in negative stepped leaders, positive leaders and continuous current in natural lightning, in flashes triggered by wire trailing rockets, and in laboratory discharges. It is shown that: (1) a triggered flash starts on aircraft with either negative corona or positive leader that depends on the ambient electric field vector and the vehicle form factors, (2) the positive leader with continuous current that increases with time is followed in a few milliseconds by the negative stepped leader with current pulses of a few kiloamperes, and (3) the two leaders develop in space simultaneously and bi-directionally from the oppositely charged extremities of the airplane.

NS-060

MAZUR, V. Triggered lightning strikes to aircraft and natural intracloud discharges, Journal of Geophysical Research 94:3311-3325 (1989).

A physical model of triggered lightning strikes to aircraft is applied to interpret the initiation of intracloud flashes depicted with the French UHF-VHF interferometric system. It is shown that both intracloud discharges and triggered strikes are initiated in a qualitatively similar way: the simultaneous bi-directional development of the negative stepped leader and the positive leader-continuous current process. The airborne visual observations and electromagnetic waveform records during the junction stage of intracloud flashes reveal (1) presence of continuous current during the entire period, and (2) a "multistroke" feature observed as variations of the low-frequency (continuous) current with current pulses superimposed and occurred only during periods of rising continuous current. It is shown that airborne measurements of lightning strikes to aircraft provide an opportunity to recognize recoil streamers in time domain data and to determine their characteristics (duration and amplitude), which are not obtainable with other techniques. Small-scale tortuosity (from tens of centimeters to several meters long) has been observed in visual images of lightning channels at close range with video cameras aboard the NASA F-106B airplane. The hypothesis is advanced that high-rate pulse bursts in VHF-and UHF-bands associated with recoil streamers are radiation pulses attributable to reflection processes at kinks of the highly tortuous channel traversed by a current pulse.

NS-061

MAZUR, V., B.D. Fisher and P.W. Brown. Cloud-to-ground strikes to the NASA F-106 airplane. Preprints, 1989 International Conference on Lightning and Static Electricity, University of Bath, UK 26-28 September 1989 8A.4.1-8A.4.3 (1989).

Data on cloud-to-ground (CG) strikes to the NASA F-106B instrumented airplane obtained during the 1984-86 seasons in storm penetrations at altitudes below 6 km are summarized. Determination that a strike to the F-106B was a CG flash was based on the time difference between moment of lightning attachments to the airplane and the ground as well as the range difference between points of attachments. In only one CG strike, out of a total of 20, was a first return stroke current flow through the F-106B indicated, since the time difference between attachment of the lightning channel to the airplane and to the ground, 10 ms, was within the time accuracy of the CG strike by the locating system (10 ms). In the remaining 19 cases, strikes were associated with processes in the flash either preceding or following the first return stroke. The peak current of CG strikes to the F-106B were less than 26 kA, which is in the range of average values of negative first return strokes measured at the ground. Also presented is the analysis of electromagnetic waveform records and video images obtained aboard the F-106B during a lightning strike which was part of a multistroke CG flash. There is strong indication that the CG flash began as a triggered strike and later produced nine return strokes, four of which were attached to the airplane. The analysis illustrates the possibility to investigate dart leaders, recoil streamers, and continuous current using direct measurements aboard the airplane.

NS-062

MEITIN, J.G., and A.I. WATSON. Comparison of the kinematic structure and precipitation characteristics of squall and non-squall mesoscale convective systems. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 486-489 (1989).

No abstract.

NS-063

Nielsen, K., and D.R. MacGORMAN. Lightning Ground Flash Rates Relative to Mesocyclone Evolution on 8 May 1986. Preprints, 24th Radar Conference on Radar Meteorology, Tallahassee, FL, 27-31 March, 1989. American Meteorological Society, Boston, 117-120 (1989).

Relationships between lightning ground flashes and other storm parameters are examined for the storm that produced a damaging tornado in Edmond, Oklahoma on 8 May 1986. Lightning ground strike rates and location are compared with single-Doppler radar data for a period of approximately 1 hr 20 min, extending from ten minutes prior to the first tornado until the mesocyclone could no longer be detected in single-Doppler data. Lightning ground flash rates increased rapidly as cyclonic shear in the mesocyclone increased, then decreased as the mesocyclone weakened and dissipated. When the mesocyclone was strong and well-organized, negative cloud-to-ground lightning strikes were most concentrated near the mesocyclone; there was a substantially higher density within 5 km of the mesocyclone than between 5 and 10 km. Positive CG lightning strikes did not concentrate in any particular area, but tended to avoid reflectivity cores north of the mesocyclone. The behavior of negative ground flashes in the Edmond storm is opposite to their behavior in the Binger storm studied by MacGorman et al. (1988). In the Binger storm, ground strikes were infrequent during the tornado and reached a peak as the mesocyclone dissipated. The behavior for the Edmond storm is similar, however, to the behavior of intracloud flash rates and total flash rates in the Binger storm. There were substantial differences in the structure and evolution of the two storms: During tornadic activity, the environment of the Edmond storm was uncapped while it was strongly capped during the Binger tornado; the Edmond storm interacted with and was overtaken by an approaching thunderstorm complex while the Binger storm was isolated throughout its lifetime. Also, negative cloud-to-ground lightning flash rates were well-correlated with cyclonic shear in the mesocyclone of the Edmond storm, but lagged cyclonic shear in the Binger storm, peaking as the mesocyclone dissipated. Rates and correlation for negative ground flashes in the Edmond storm were similar to those for intracloud flashes in the Binger storm. The observed differences between the Edmond and Binger storms suggest that it is not sufficient to treat relationships between lightning and tornadic activity as being uniform for all tornadoes if the predictive value of these relationships is to be acceptable. Instead, it is important to include information on storm environment, structure, and evolution when analyzing lightning or sferics in tornadic storms.

NS-064

Passarelli, R.E., Jr., and D.S. ZRNIC. An expression for phase noise. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 433-435 (1989).

No abstract.

NS-065

PASSI, R.M., and R.E. LOPEZ. A parametric estimation of systematic errors in networks of magnetic direction finders. Journal of Geophysical Research-Atmospheres 94:13,319-13,328 (1989).

We consider the problem of estimating the systematic errors in a network of magnetic direction finders using bearing data from a historical record containing a large number of lightning flash observations. It is clear that this problem is linked with the flash location estimation problem and that the two are statistically confounded in the sense that the effect of the one can not be separated from the other. We formalize mathematically a connection between the two problems to arrive at a self-consistent system. In this paper we parameterize the site errors as two-cycle sinusoidal functions and show that the estimation equations can be described by a model which separates into linear and nonlinear parameters. We take advantage of this separation to decouple large-dimensional equations into smaller-dimensional equations. Through these equation we show the link between the site error and flash location estimation problems. Validation of our modeling procedures is done by heuristic arguments and analysis of residuals. The latter reveals that not all of the residuals have been explained by sinusoidal site errors but that some residuals might result from the geometry of the network. This appears to be an important problem and is presently under study. Also, there is need to test the site error estimation algorithm developed in this paper against some ground truth.

NS-066

Pitts, F., B. Fisher, V. MAZUR, and T. Brown. Researching lightning strikes to aircraft. IEEE Spectrum, 7:34-38 (1988).

No abstract.

NS-067

RABIN, R.M. Diagnosing short-term changes in temperature profiles from single Doppler radar data. Monthly Weather Review 117:1501-1516 (1989).

A method is outlined to diagnose temperature changes aloft from single Doppler radar data and an initial radiosonde observation. One aim is to deduce changes in inversion strength and stability between synoptic soundings, which is particularly important in forecasting thunderstorm initiation. Results of two test studies are given with recommendations for future work.

NS-068

Reap, R.M., and D.R. MACGORMAN. Cloud-to-ground lightning: Climatological characteristics and relationship to model fields, radar observations & severe local storms. Monthly Weather Review, 117: 518-535 (1989).

Data for nearly 2 million lightning flashes recorded during the 1986-86 warm seasons by the National Severe Storm Laboratory's (NSSL's) lightning strike locating network were evaluated to determine some of the climatological characteristics of cloud-to-ground lightning. Among the characteristics studied were the seasonal, diurnal, and spatial variations of positive and negative lightning strike activity, including flash rates, signal strength, and flash multiplicity. The lightning data were also compared to manually digitized radar data, reports of tornadoes, large hail, and damaging winds, and to analyzed 0000 UTC fields obtained from operational numerical models. An examination of the diurnal distribution of lightning revealed that peak rates occurred later than in other sections of the country, reflecting the prevalence of nocturnal convection within much of the NSSL network. An analysis of the spatial variations in lightning activity also confirmed the existence of distinct climatological regimes within the network. A study of the diurnal variations in signal strength revealed that first return strokes lowering negative charge have higher signal strengths at night and in the early morning hours, when flash rates are normally decreasing. In addition, positive flashes were found to exhibit three distinct peaks in signal strength, two of which are associated with late afternoon and nocturnal maxima in flash activity. A good correspondence between lightning frequency and radar echo intensity was found for the region within strongly correlated with the low-level moisture flux and circulation, as characterized by favorable moisture convergence, cyclonic relative vorticity, and strong upward vertical motions in the boundary layer. Contrary to expectations, freezing level height and wind shear were not nearly as important as the boundary layer fields in determining thunderstorm formation and subsequent positive lightning activity. A significant correlation was also found between the occurrence of severe local storms and elevated rates of 30 or more positive flashes per hour within 48 km grid blocks.

NS-069

RUST, W.D. Lightning. Science 242:1713-1714 (1989).

No abstract.

NS-070

RUST, W.D. Utilization of a Mobile Laboratory for Storm Electricity Measurements. Journal of Geophysical Research 94:D11,13,305-13,311 (1989).

Since 1978, we have been developing and using a mobile laboratory to make observations of storms. With our mobile lab, we record electric field, slow and fast electric field changes from lightning, optical transients, return stroke velocity, temperature, pressure, dew point, wind speed and direction, lab position, and video images of clouds and lightning. The mobile lab idea has been key in obtaining new information on several phenomena, e.g., field changes to compare with high-altitude airplane measurements, electrical aspects of tornadic storms, and positive ground flashes. Mobile lab data were critical in an evaluation of the two ground strike location networks that provide scientific and operational data in the United States. We have documented that storms often are more dominated by intracloud (IC) lightning than previously reported. Observations on two tornadic storms show the IC flashes averaged ≥ 80% and 95% of the total lightning, respectively. Mobile lab and polarization radar data of storms producing wet microbursts in Alabama suggest that high percentages of IC flashes (95%) occur when a larger percentage of the total storm mass is convected above the freezing level. With the recent addition of mobile balloon launch and tracking, we also make soundings of the electric field and meteorological parameters within storms.

NS-071

RUST, W.D. and T.C. Marshall. Mobile, high-wind, balloon-launching apparatus. Journal of Atmospheric and Oceanic Technology 6:215-217 (1989).

In order to place instruments for measuring meteorological and electrical parameters into thunderstorms, we developed the capability of mobile ballooning. A key component is an inexpensive apparatus that allows us to inflate, transport, and launch balloons in high winds, rain, and hail. The launching apparatus is a cylinder of 'bubble' plastic that is made by joining the sides of the cylinder together with VELCRO 'rip strip.' We launch a balloon by pulling the rip strip rapidly. This allows the balloon to pop upward into the ambient low-level wind and carry its instrumentation aloft. We construct different-sized launch tubes to accommodate particular sizes of balloons.

NS-072

Rutledge, S.A., and D.R. MACGORMAN. Observations of positive cloud-to-ground lightning flashes from mesoscale convective systems. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 122-125 (1989).

No abstract.

NS-073

Sachidananda, M., and D.S. ZRNIC. Efficient processing of alternately polarized radar signals. Journal of Atmospheric and Oceanic Technology 6:173-181 (1989).

Processing of simultaneous measurements of differential polarization parameters (differential reflectivity, Z_{DR} and differential phase shift ϕ_{DP}) and Doppler spectral moments is discussed. It is shown how Z_{DR} and ϕ_{DP} modulate the Doppler signal and what effects they have on the autocovariance at lag 1 if a sequence of alternately polarized fields (linear horizontal, H, and Vertical, V) is transmitted. A scheme to overcome these effects is proposed and demonstrated on recorded time series data from a radar with polarization diversity.

NS-074

Smith, S.D., and R.M. RABIN. Considerations in estimating horizontal wind gradients from an individual Doppler radar or a network of wind profilers. Journal of Atmospheric and Oceanic Technology 6:446-458 (1989).

Applications of Doppler weather radar data to the analysis of wind fields are reviewed. Radial velocity measurements from a single radar are used to estimate horizontal wind vectors within small azimuthal sectors using two different models. One assumes a uniform wind, the other a linear wind within the sector. Errors in wind estimates owing to gradients of wind are derived using harmonic analysis. The radar data analysis techniques are tested on complex wind patterns which were reconstructed from dual-Doppler radar measurements.

NS-075

Smith, S.D., and R.M. RABIN. Estimation of divergence in the Prestorm boundary layer. Journal of Atmospheric and Oceanic Technology 6:459-475 (1989).

An analysis technique to derive wind field parameters from single-Doppler velocity measurements, known as Modified Velocity-Volume Processing (MVVP) is examined from both theoretical and operational perspectives. For this technique, radar data within limited spatial volumes are fit to a model which usually assumes linearity of the Cartesian wind components. The accuracies and limitations of this technique are illustrated with examples from a case study of a severe storm outbreak in central Oklahoma on 17 May 1981. Implications for use of the MVVP in convective storm forecasting are considered.

NS-076

Smith, S.D., A. WITT, M. EILTS, L. Hermes, D. Klingle-Wilson, S. Olson, and J. Sanford. Gust front detection algorithm for the terminal doppler weather radar, Part I: Current Status Preprints, 3rd International Conference on Aviation Weather Systems (#1.6). January 30 - February 3, 1989, Anaheim, CA. American Meteorological Society, Boston, 31-34 (1989).

No abstract.

NS-077

SMULL, B.F., and J.A. AUGUSTINE. Structure and environment of a non-squall mesoscale convective complex observed during PRE-STORM. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 502-505 (1989).

No abstract.

NS-078

Steinhorn, I., and D.S. ZRNIC. Differential propagation constant and differential reflectivity characterize rain and hail in high reflectivity regions. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 367-370 (1989).

No abstract.

NS-079

STENSRUD, D.J. and R.A. MADDOX. Opposing mesoscale circulations: A case study. Weather and Forecasting 3:189-204 (1988).

Two mesoscale convective systems developed over the central plains in and near the OK PRE-STORM observing network on 23-24 June 1985. Mesoscale outflows from these two systems collided in central Kansas at 0430 UTC 24 June. Special soundings taken behind the outflow boundaries indicated a stable atmosphere. However, a sounding taken south of the area of outflow collision sampled a conditionally unstable atmosphere in which lifting of 90 mb was needed to release the instability. The OK PRE-STORM forecast team monitored this situation using convectional data and special surface mesonetwork and sounding data. They issued a forecast update at 0500 UTC 24 June that anticipated new convective development in the conditionally unstable atmosphere near the area of outflow collision. As the outflows moved southward, surface convergence increased near the area of outflow collision, yet no new development of deep convection occurred. Special OK PRE-STORM upper-air soundings are utilized to compute divergence and vertical velocity via the line integral method at various times and locations during the development and decay of the two mesoscale convective systems. Strong rising motion is found in the lower troposphere near the zone of outflow collision at 0430 UTC 24 June, suggesting that the outflows were significantly impacting storm development and system propagation. However, at 0900 UTC 24 June, while strong rising motion is found below 800 mb, there also is strong sinking motion between 800 and 400 mb. It is hypothesized that this mesoscale downdraft occurred between the two mesoscale convective systems as their upper-level outflows converged. This layer of sinking air may have helped maintain a capping inversion at the top of a deepening moist layer and apparently was sufficient to inhibit development of new convection even in the face of strong low level forcing. The case illustrates the simultaneous development of mesoscale circulations that appear to be acting in opposition to each other, relative to the initiation of new storms. It further illustrates the complexity of the mesoscale and why it is often hard to anticipate the evolution of convective storm systems.

NS-080

Stump, G.S., and W.A. Gallus. An examination of new convective development with a PRE-STORM squall line case. Preprints 24th Conference on Radar Meteorology, Tallahasse, FL, March 27-31, 1989. American Meteorological Society, Boston, 506-509 (1989).

No abstract

NS-081

Trier, S.B., D.B. Parsons, and T.J. MATEJKA. An observational and numerical study of a subtropical cold front during TAMEX. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 561-564. (1989)

No abstract.

NS-082

Trier, S.B., D.B. Parsons, and T.J. MATEJKA. Observations of a cold front during TAMEX. Proceedings, Workshop on TAMEX Preliminary Scientific Results, Taipei, Republic of China, June 22-30, 1989. National Science Council, Taipei, and National Science Foundation, Washington, DC, 186-195 (1989).

No abstract.

NS-083

Uyeda, H., and D.S. ZRNIC. Fine structure of gust fronts obtained from the analysis of single Doppler radar data. Journal of the Meteorological Society of Japan 66:869-881 (1988).

Doppler velocity data obtained from a single Doppler radar are used to examine fine structures of gust fronts associated with severe thunderstorms. Fields of inflection points of velocities (on surfaces scanned by a radar) are analyzed and are compared with the fields of spectrum width of Doppler velocity and horizontal shear. The analysis is performed on the cases of May 9, 1981, and April 13, 1981, in Oklahoma. In the first case, a gust front consisted of an evolving undulate bore with three separate waves or discontinuities. Two of these waves are detected as a 60 km stretch of inflection points of Doppler velocity, whereas the third is marginally evident. For both cases, the length representing secondary features behind the main discontinuities are short (less than 20 km) and transient. Careful examinations of the structures at low altitude show that large spectrum width and large shear areas exist slightly behind the main line of inflection points. However, there is a multitude of areas with large shear and spectrum width that have no corresponding inflection point lines. Thus, these two parameters, spectrum width and horizontal shear, alone are not suitable for detection of gust fronts. Besides showing the presence of gust fronts, inflection points can also be good indicators of atmospheric waves. We discuss a pattern of such waves that are embedded in the environmental flow ahead of a gust front.

NS-084

VASILOFF, S. Vorticity dynamics of a squall line: A Doppler radar analysis of the 10-11 June 1985 squall line. Masters thesis, University of Oklahoma, Norman, 100 pp. (1989).

This study describes characteristics of the Oklahoma segment of the 10-11 June 1985 squall line as it began to dissipate. A surging outflow ahead of the squall line appeared responsible for the decline in the strength of the convective cells along the leading edge. Thermodynamic properties retrieved from wind and reflectivity fields derived from both single- and dual-Doppler radar analyses are used to evaluate the terms in the inviscid 2-dimensional Boussinesq horizontal vorticity equation. Evaluated an hour after the outflow surge, the sum of the terms was relatively small, indicating that a balance existed, primarily between the generation of negative vorticity by buoyancy gradients and the advection of positive vorticity into the squall line from the environment.

NS-085

WATSON, A.I., R.L. HOLLE, R.E. LOPEZ, R. ORTIZ, and J.R. DAUGHERTY. Use of the surface wind field as a predictor of thunderstorms and cloud-to-ground lightning at Kennedy Space Center. Preprints, 1989 International Conference on Lightning and Static Electricity, Bath, United Kingdom, September 26-28, 1989. Royal Aerospace Establishment, Farnborough, Hampshire, United Kingdom, 9B.2.1-7 (1989).

The classic Thunderstorm Project was the first to consider surface convergence as a potential predictor of thunderstorm activity in Florida. Several studies, one at the Kennedy Space Center, have shown that surface convergence can, in some cases, be used as a short-term predictor of thunderstorm

development. The prerequisites for surface convergence to be useful are first, a dense surface-wind observing network, and second, the seeds of convective development must occur in the boundary layer so that the wind sensors can detect the convective life cycle. In 1986, a convergence-lightning nowcasting technique was delivered to U. S. Air Force forecasters at KSC for operational test and evaluation. The procedure uses surface convergence, particularly the average over the area, to identify the potential for new thunderstorm growth. Under some weather situations, the area average technique fails to work. Normalized cell convergence is offered as a complementary technique to be used in association with the areal technique. Normalized cell convergence is defined as the integral of cellular convergence with respect to its area. One day is examined in detail and the relationship of normalized cell convergence to lightning flash counts, at 5-min intervals, is examined in a 68-day ensemble. Normalized cell convergence appears to be a viable alternative to the areal technique. With the implementation of this tool, the monitoring of the horizontal analyses of divergence, and the continued monitoring of areal divergence, the likely locations and timing of new convective growth can be ascertained.

NS-086

WATSON, A.I., R.E. LOPEZ, J.R. DAUGHERTY, R. ORTIZ, and R.L. HOLLE. A composite study of Florida thunderstorms, using radar, cloud-to-ground lightning, and surface winds. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 126-129 (1989).

No abstract.

NS-087

WATSON, A.I., R.E. LOPEZ, R.L. HOLLE, J.R. DAUGHERTY, and R. ORTIZ. Short-term forecasting of thunderstorms at Kennedy Space Center, based on the surface wind field. Preprints, 3rd International Conference on the Aviation Weather System, January 30-February 3, 1989, Anaheim, CA. American Meteorological Society, Boston, 222-227 (1989).

No abstract.

NS-088

WATSON, A.I., J.G. MEITIN, and J.B. CUNNING. Evolution of the kinematic structure and precipitation characteristics of a mesoscale convective system on 20 May 1979. Monthly Weather Review 116: 1555-1567 (1988).

The relationship of vertical motion to the occurrence of precipitation from the convective and stratiform regions of a mesoscale convective system (MCS) is presented. On 20-21 May 1979, an MCS developed over portions of Oklahoma, Texas, and Arkansas. The uniqueness of this system was its lack of squall-line characteristics and development of a large stratiform precipitation region. The evolution of the system is detailed by rawinsonde observations, radar cross sections, 15-min composite analyses of six NWS WSR-57 radars, and by raingages. The genesis stage of the MCS was described by strong convection along an east-west cold front that was reinforced by outflow generated by two mesoscale convective complexes (MCCs) that formed the night before in Kansas and Missouri. The mature stage of the MCS was characterized by the development of a large stratiform precipitation region while convection was limited to the southern and eastern flanks of the system. Finally, in the dissipative stage, a moderate north-south squall line that developed over west Texas in the afternoon moved rapidly to the east apparently associated with a short-wave aloft and appeared to sweep the entire system out of Oklahoma. A modified Cheng and Houze technique is applied to the radar composites to determine stratiform and convective regions utilizing temporal as well as areal considerations. For the system as a whole, the stratiform region generated 30-50% of the total precipitation. The vertical-motion profiles hold the key to the precipitation characteristics over the storm-scale network. The genesis period was characterized by a strongly convective profile. As the system matured, low-level upward motion ceased, while middle-level upward motion was sustained. A large area of stratiform rain developed as the deep convection weakened. Water-budget considerations suggest that the stratiform region was maintained by a combination of mesoscale middle-level updraft and by horizontal transfer of convective debris.

NS-089

Williams, E.R., A.I. WATSON, L.M. Maier, W. Jafferis, and J. Weems. A case study of a low lightning rate storm during the Florida winter. Preprints, 3rd International Conference on the Aviation Weather System, Anaheim, CA, January 30-February 3, 1989. American Meteorological Society, Boston, 393-397 (1989).

No abstract.

NS-090
ZACHARIAS, D. A case study of the May 10, 1985 tornado outbreak in northern Kansas. M.S. Thesis, School of Meteorology, University of Oklahoma, Norman, 135 pp. (1989).

No abstract

NS-091
ZIEGLER, C.L., and P.S. Ray. Doppler radar retrieval of the microphysical and electrical structure of a mountain thunderstorm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 97-99 (1989).

No abstract.

NS-092
ZRNIC, D.S., N. Balakrishnan, and M. Sachidananda. Polarimetric measurements determine the amounts of rain and hail in a mixture. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, March 27-31, 1989. American Meteorological Society, Boston, 396-400 (1989).

No abstract.

NS-093
ZRNIC, D.S., AND R.J. DOVIAK. Effect of drop oscillations on spectral moments and differential reflectivity measurements. Journal of Atmospheric and Oceanic Technology 6:532-536 (1989).

A perturbation method is applied to spheroidal oscillating drops to determine the effect of fundamental axisymmetric oscillations on the power spectra and polarimetric measurements. It is shown that vibration magnitudes that produce less than 10% change in equilibrium axial ratios are insufficient to produce measurable changes in the differential reflectivity or differential phase constant, yet they can lead to a detectable increase in sidebands of the power spectra. Larger oscillations do produce measurable effects on the polarimetric variables.

Addendum

NS-094
WATSON, A.I., R.E. LOPEZ, and R.L. HOLLE. Surface convergence techniques and the prediction of lightning at Kennedy Space Center. 1988 International Aerospace and Ground Conference on Lightning and Static Electricity, Oklahoma City, OK, April 19-22, 1988. NOAA/ERL/National Severe Storms Laboratory, Boulder, CO, 32-39 (1988).

Because the Kennedy Space Center (KSC) has a significant number of thunderstorms, especially during the summer, lightning is a real threat to operations. Therefore, advance warning when lightning is imminent is highly desirable. This study compares two convergence techniques leading to the prediction of convective development and lightning: the area-averaged technique, and a convergence cell approach. The area-averaged technique uses total area divergence across the network to identify the potential for new local thunderstorm growth. A threshold of 75 x 10^{-6} change in divergence is used to define a convergence event, and a separation of 30 minutes between flashes defines a lightning event. Convergence-lightning life cycles are found to be on the order of 1 hour from beginning convergence to first flash, and more than 2 hours from beginning convergence to the end of lightning. The convergence cell technique measures the strength of the convergence cell, which in turn leads to vertical development. Therefore, the likely lightning location and intensity can be ascertained in the larger network. Several cells can be monitored in the recently expanded KSC forecast network at the same time. These techniques cannot be used in isolation since the daily possibility of thunderstorms must be determined on the basis of the larger-scale synoptic situation. The monitoring of the local divergence will aid the forecaster to determine the timing, location, longevity, and possibly the intensity of specific lightning events.

PACIFIC MARINE ENVIRONMENTAL LABORATORY

PM-001
AAGAARD, K. A synthesis of the Arctic Ocean circulation. Rapports et Procès-verbaux des Réunions, Conseil international pour l'Exploration de la Mer 188:11-22 (1989).

Moored current measurements in four different areas of the Arctic Ocean suggest that the principal large-scale advection occurs in narrow boundary currents along the margins of the major basins. These boundary flows are in a cyclonic sense in each basin and are therefore counter to much of the upper ocean drift suggested by the ice motion. In the interior of the Arctic Ocean (or at least in its Canadian Basin) the kinetic energy appears concentrated in the mesoscale eddy field, and there is evidence that this field is primarily generated along the Arctic Ocean margins. In addition, the Arctic Ocean has recently been found to sustain a large-scale thermohaline circulation driven by freezing along its periphery; this circulation appears to be at least comparable in magnitude to that of the Greenland Sea. If one also considers the major peripheral exchanges through the Fram Strait, the Barents Sea, the Canadian Archipelago, and the Bering Strait, then the image which emerges is of an Arctic Ocean which overwhelmingly is forced at its lateral boundaries, and in which much of the organized transport is trapped along these boundaries.

PM-002
AAGAARD, K. Circulation: Beaufort Sea update. Proceedings, Alaska OCS Region 1987 Arctic Information Transfer Meeting Conference, OCS Study MMS 88-0040, Minerals Management Service, Anchorage, AK, 151-156 (1988).

No abstract.

PM-003
BAKER, E.T., J.W. LAVELLE, R.A. FEELY, G.J. MASSOTH, S.L. WALKER, and J.E. Lupton. Episodic venting of hydrothermal fluids from the Juan de Fuca Ridge. Journal of Geophysical Research 94(B7):9237-9250 (1989).

Evidence of large-scale episodic venting of hydrothermal fluids was initially discovered in August 1986 in the form of a 130-km^3 radially symmetric "megaplume" over the southern Juan de Fuca Ridge. We report here on the discovery in September 1987 of a second, smaller megaplume about 45 km north of the location of the first megaplume. The ^{3}He/heat, ^{3}He/dissolved Mn, and ^{3}He/dissolved silica ratios in both megaplumes were typical of high-temperature vent fluids. Evidence from long-term records of current flow over the southern Juan de Fuca Ridge, and from the mineralogy and Mn chemistry of megaplume particles, makes it unlikely that the second megaplume was a reencounter of the first. A plume model that relates the heat flux to the observed plume rise height of ~1000 m finds that the total heat content of the fluids that formed the megaplumes was 10^{16}-10^{17} J, or equivalently a fluid volume of 3-8 × 10^7 m^3 at 350°C. The geometry and suspended particle population of the first megaplume imply that such features are formed within a few days time. The extraordinary heat and volume fluxes associated with megaplumes (10^2-10^3 , greater than ordinary vent fields), as well as their typical hydrothermal chemistry, suggest that they resulted from tectonic or hydraulic fracturing that suddenly increased the permeability of the hydrothermal fluid reservoir in the axial crust. The flux of hydrothermal heat from continuous venting and episodic megaplumes on the southern Juan de Fuca Ridge is presently 4-10 × 10^9 W, a factor of 5-10 greater than various geophysical model calculations for this ridge segment. This imbalance may be symptomatic of a recent surge in the local cycle of magmatic activity.

PM-004
BATES, T.S. Evidence for the climatic role of marine biogenic sulfur. Ph.D. dissertation, University of Washington, Seattle, 99 pp. (1989).

The surface ocean plays an important role in the global biogeochemical sulfur cycle. Gaseous sulfur compounds emitted from the ocean are thought to be a major source of sulfate aerosol in the marine troposphere. Establishing the relationship between gaseous sulfur emissions, atmospheric sulfate concentrations, and aerosol particle populations is not only important in defining the ocean/atmosphere flux of sulfur, but also for the effects these particles may have on local cloud reflectivity, aerosol optical depth, and global climate. During 1982-1985, dimethylsulfide (DMS) concentrations were measured in over 1000 Pacific Ocean surface seawater samples. The data have been tabulated to take into account both regional and seasonal variations in concentration. These concentration data, combined with area-weighted summer and winter exchange coefficients, yield a net ocean to atmosphere DMS flux in the North

Pacific Ocean of 0.12 ± 0.06 Tmol/a. Extrapolating this calculation by regional areas to the global ocean yields a net DMS flux of 0.50 ± 0.25 Tmol/a, less than earlier estimates of 1.2 Tmol/a, but still consistent with estimates of non-sea-salt sulfate deposition and model studies of the marine atmospheric sulfur budget. Using these regional and seasonal DMS concentration data, it appears that oceanic DMS emissions are positively correlated with atmospheric aerosol particle populations. The major components of the atmospheric biogeochemical sulfur cycle were measured along the coast of Washington State during May of 1987. Combining simultaneous measurements of the key oceanic and atmospheric sulfur species, it is possible to show the importance of DMS emissions on the cycling of sulfur in the marine boundary layer. Simultaneous measurements of oceanic DMS, atmospheric aerosol sulfate and the size-resolved physical properties of the aerosol were made in the equatorial Pacific during July 1987. Under light and variable winds, in an area free of continental and anthropogenic air masses, an observed increase in oceanic DMS concentrations preceded simultaneous increases in non-sea salt sulfate aerosol, the fraction of volatile sub-micrometer (sub-μm) aerosol, the aerosol particle population, and the mean particle diameter of the sub-μm aerosol. These data support the hypothesis that oceanic DMS is the source of background marine sulfate aerosols formed from gas-to-particle conversions in the atmosphere.

PM-005

Betzer, P.R., K.L. Carder, R.A. Duce, J.T. Merrill, N.W. Tindale, M. Uematsu, D.K. Costello, R.W. Young, R.A. FEELY, J.A. Breland, R.E. Bernstein, and A.M. Greco. Long-range transport of giant mineral aerosol particles. Nature 336(6199):568-571 (1988).

Several recent studies have shown that large quantities of mineral dust from eastern Asia are transported through the atmosphere to the North Pacific each spring. The paucity of information on mineral fluxes during individual dust events prompted a coordinated effort, Asian Dust Input to the Oceanic System (ADIOS), which simultaneously measured mineral fluxes in the atmosphere and upper water column during such an event. In March 1986 a major dust outbreak in China moved over the North Pacific Ocean and was detected downstream using changes in particle number, size and composition. Most striking was the presence of "giant" (>75-μm) silica minerals found in atmospheric as well as water-column samples at the ADIOS sampling site (26°N, 155°W). Their appearance more than 10,000 km from their source cannot be explained using currently acknowledged atmospheric transport mechanisms. Furthermore, the large wind-blown minerals that dominated our samples are extremely rare in the long-term sedimentary record in the North Pacific.

PM-006

Calhoun, J.A., and T.S. BATES. Sulfur isotope ratios: tracers of non-sea salt sulfate in the remote atmosphere. In Biogenic Sulfur in the Environment, E.S. Saltzman and W.J. Cooper (eds.), American Chemical Society, 367-379 (1989).

The atmospheric biogeochemical sulfur cycle is being significantly impacted by increasing anthropogenic sulfur emissions. The effect of these emissions on the concentration of sulfate aerosol particles in the remote marine atmosphere is difficult to assess due to uncertainties surrounding the relative contributions of natural and anthropogenic sources. Sulfur isotope ratios can be used to determine the relative magnitude of these sources in the remote atmosphere provided 1) the isotopic ratios of the potential sulfur sources are known, 2) the isotopic compositions of the various sources are different from one another, and 3) the isotopic changes that occur during transformations are thoroughly documented. In the text which follows, these aspects of sulfur isotope chemistry are addressed. Isotopic interpretation of sulfur sources to the remote atmosphere is severely limited by the absence of critical isotopic measurements, yet it appears that continental sulfur sources are isotopically distinguishable from seasalt or marine biogenic sulfur sources. Improved analytical techniques will soon provide the means to obtain the necessary data.

PM-007

CANNON, G.A. Time variations of bottom-water inflow at the mouth of an estuary. Understanding the Estuary: Advances in Chesapeake Bay Research. Proceedings of a Conference, 29-31 March 1988, Baltimore, MD, Chesapeake Research Consortium Publication 129, CBP/TRS 24/88, 424-427 (1988).

Puget Sound is a fjord-like estuary, but its 30-km long entrance sill, Admiralty Inlet, has characteristics very similar to coastal plain estuaries. The replacement of bottom water in Puget Sound has been studied for many years, because it is a dominant process responsible for flushing some contaminants. Previous studies showed bottom-water inflow increased during neap tides when mixing was minimal over the entrance sill. Recent observations show the increased inflow starts before minimum neap tides, and simple model calculations with these data demonstrate this is an effect of variations in the horizontal density gradient at the mouth of the estuary caused by salinity variations outside the mouth.

This time-dependent process may be responsible for changing inflow characteristics at time scales between wind effects and seasonal effects, and it may be important in other estuaries such as Chesapeake Bay.

PM-008

Charlson, R.J., and T.S. BATES. The role of the sulfur cycle in cloud microphysics, cloud albedo, and climate. Preprints, Symposium on the Role of Clouds in Atmospheric Chemistry and Global Climate, Jan. 30-Feb. 2, 1989, Anaheim, CA, American Meteorological Society, Boston, MA, 1-3 (1989).

No abstract.

PM-009

Chen, C.T.A., R.A. FEELY, and J.F. GENDRON. Lysocline, calcium carbonate compensation depth, and calcareous sediments in the North Pacific Ocean. Pacific Science 42(3-4):237-252 (1988).

An extensive oceanographic investigation has been carried out in the North Pacific Ocean. The purpose of this report is to present the results of two cruises in which we participated and to report additional carbonate data from samples collected for us in the North Pacific. These data are combined with data from the literature to provide an overall picture of the carbonate system in the North Pacific. The degree of saturation of seawater with respect to calcite and aragonite was calculated from all available data sets. Four selected cross sections, three longitudinal and one latitudinal, and two three-dimensional graphs show that a large volume of the North Pacific is undersaturated with respect to $CaCO_3$. The saturation horizon generally shows a shoaling from west to east and from south to north in the North Pacific Ocean. It was found that the lysocline is at a depth much deeper (about 2500 m deeper) than the saturation horizon of calcite, and several hundred meters shallower than the calcium carbonate compensation depth. Our results appear to support the kinetic point of view of the $CaCO_3$ dissolution mechanisms. Differences in the abundance of the calcareous sediments are explained by differences in the calcium carbonate compensation depth.

PM-010

Coachman, L.K., and K. AAGAARD. Transports through Bering Strait: annual and interannual variability. Journal of Geophysical Research 93(C12):15535-15539 (1988).

Reanalysis of the 1976-1977 mean monthly transport estimates for Bering Strait of Coachman and Aagaard (1981) shows a considerably stronger wind dependence than was calculated by Aagaard et al. (1985). We find (1) a long-term mean transport of 0.8 Sv, (2) an annual transport cycle of amplitude 0.6 Sv, with the maximum in June, the minimum in February, and a secondary maximum in January probably associated with North Pacific blocking-ridge activity, and (3) an interannual variability marked by a number of low-flow years in the past two decades, including three of the four lowest-transport winter periods during this century. In a new current time series from 1984 to 1985 we find anomalously strong and persistent northerly flow during a 2-month period in which the current/wind correlation breaks down. This occurred during a prolonged period with southerly winds, and we believe the data point to an asymmetry in the dynamical response of the Bering Strait flow to major changes in wind direction.

PM-011

CURL, H.C., JR. Marine ecology: the water column. Proceedings of a Conference/Workshop on Recommendations for Studies in Washington and Oregon: Offshore Oil and Gas Development. Minerals Management Service, Dept. of Interior, May 23-25, 1988, Portland, OR, 65-72 (1989).

No abstract.

PM-012

EBLE, M.C., F.I. GONZALEZ, D.M. MATTENS, and H.B. MILBURN. Instrumentation, field operations, and data processing for PMEL deep ocean bottom pressure measurements. NOAA TM ERL PMEL-89 (NTIS not yet available), 71 pp. (1989).

The focus of this report is on the collection and processing of deep-ocean bottom pressure measurements made using the Paroscientific Model 410K-017 digiquartz pressure transducer. The observational program was initiated in 1986 for the purpose of collecting high quality data during the generation, propagation, and coastal runup stages of a tsunamigenic event. Because of its diversity and flexibility, the bottom pressure recorder (BPR) is also an important tool in many other areas of oceanic research, particularly when coupled with other instrumentation.

PM-013

EMBLEY, R.W., S.R. HAMMOND, and K. MURPHY. The caldera of Axial Volcano--remote sensing and submersible studies of a hydrothermally active submarine volcano. Global Venting, Midwater, and Benthic Ecological Processes, M.P. De Luca and I. Babb (eds.), National Undersea Research Program Report 88-4, 61-70 (1988).

No abstract.

PM-014

FEELY, R.A., R.H. Byrne, J.G. Acker, P.R. Betzer, C.T.A. Chen, J.F. GENDRON, and M.F. LAMB. Winter-summer variations of calcite and aragonite saturation in the northeast Pacific. Marine Chemistry 25:227-241 (1988).

New carbonate data obtained on February-March and June-July cruises in the northeast Pacific during 1985 were utilized to describe processes affecting seasonal variations of calcite and aragonite saturation. Large gradients in saturation state occur in the region between the Subtropical and the Subarctic Fronts in the north-south direction. These gradients are a function of large-scale mixing and biological processes in the North Pacific. The saturation values in the upper kilometer of the water column were observed to be significantly lower in winter than in summer. These decreases were due to a number of processes including: (i) the seasonal decrease in the temperature of the water column; (ii) the seasonal increase in vertical mixing causing CO_2-enriched deep waters to be upwelled; and (iii) the seasonal enhancement of respiration over photosynthesis. Seasonal changes in total CO_2 (TCO_2) concentrations appeared to have the greatest overall effect on the saturation state. Aragonite dissolution rate experiments were conducted during the June-July cruise to provide an independent verification of the saturation calculations. In all cases, significant increases in aragonite dissolution were observed below the 100% saturation depth. In the northeast Pacific, shallow undersaturation horizons provide for significant dissolution rates at depths below 400 m.

PM-015

FOX, C.G. Empirically derived relationships between fractal dimension and power law form frequency spectra. PAGEOPH 131(1/2):211-239 (1989).

Fractal analysis and Fourier analysis are independent techniques for quantitatively describing the variability of natural figures. Both methods have been applied to a variety of natural phenomena. Previous analytical work has formulated relationships between the fractal dimension and power law form frequency spectrum. Mandelbrot (1985) has shown that difficulties arise when the ruler method for measuring dimensionality is applied to other than self-similar figures. Since an investigator presumably does not know in advance the dimensionality of a natural profile, it is essential to quantify the nature of the discrepancy for self-affine cases. In this study, a series of experiments are conducted in which discrete random series of specified spectral forms are analyzed using the fractal ruler method. The various parameters of the fractal measurement are related to the parameters of the spectral model. In this way, empirical relationships between the techniques can be derived for discrete, finite series which simulate the results of applying the fractal method to observational data. The results of the study indicate that there are considerable discrepancies between the results predicted by theory and those derived empirically. The fundamental power law form of length versus resolution pairs does not hold over the entire region of analysis. The predicted linear relationship between fractal dimension and exponent of the frequency spectrum does not hold, and the spectral signals can be extended beyond the limits of dimension inferred by theory. Root-mean-square variability is also shown to be linearly related to the fractal intercept term. An investigation of the effect of nonstationary sampling is conducted by generating signals composed of segments of differing spectral characteristics. Fractal analyses of these signals appear identical to those conducted on stationary series. The discrepancies between theoretical prediction and empirical results described in this study reflect the difficulties of applying analytically derived techniques to measurement data. Both Fourier and fractal techniques are formulated through rigorous mathematics, assuming various conditions for the underlying signal. When these techniques are applied to discrete, finite length, nonstationary series, certain statistical transformations must be applied to the data. Methods such as windowing, prewhitening, and anti-aliasing filters have been developed over many years for use with Fourier analysis. At present, no such statistical theory exists for use with fractal analysis. It is apparent from the results of this study that such a statistical foundation is required before the fractal ruler method can be routinely applied to observation data.

PM-016

FOX, C.G., and M. VAN HEESWIJK. Sea Beam backscatter analysis applied to the classification of deep-sea volcanic terrains. Global Venting, Midwater, and Benthic Ecological Processes, M.P. De Luca and I. Babb (eds.), National Undersea Research Program Report 88-4, 71-79 (1988).

Hull-mounted sonar systems, such as Sea Beam, are typically used for mapping the bathymetry of the deep-sea floor. The same digital information that is used for the measurement of depth can be evaluated for the backscattering properties of the seafloor. The unique morphologies and petrologies of volcanic and hydrothermal terrains may produce identifiable backscatter signatures. The Alvin support vessel Atlantis II is equipped for digitally acquiring Sea Beam backscatter energy traces, allowing sonar remote sensing and submersible exploration to be performed in tandem. An experiment funded by the National Undersea Research Program, at Axial Seamount, Juan de Fuca Ridge, has produced the most extensive data set to date from a known hydrothermal area, and these data are being calibrated using the large groundtruth data base collected by NOAA's VENTS research program.

PM-017

FREITAG, H.P., M.J. MCPHADEN, and A.J. SHEPHERD. Comparison of equatorial winds as measured by cup and propeller anemometers. Journal of Atmospheric and Oceanic Technology 6(2):327-332 (1989).

This study compares the performance of cup vs. propeller anemometers from surface-following taut-line moorings in the equatorial Pacific. Vector wind components at 4 m above the sea surface were measured from a mooring instrumented with a cup anemometer and concurrently from a nearby mooring instrumented with a propeller anemometer. Mean wind conditions over the 115-day comparison period were typical of the southeast trade winds with a mean speed of 6.7 m s^{-1} and a steadiness factor of 0.96. Differences between the time series measured by the two wind sensors were small. Mean speed differed by 0.02 m s^{-1} and mean direction by 1.4°. Correlation coefficients for 2-hour vector-averaged zonal component, meridional component, speed and direction were 0.97 or above. The small differences in measurements imply that the two systems are equally suited for near-surface wind observations under typical tradewind conditions.

PM-018

GIESE, B.S. Equatorial oceanic response to forcing on time scales from days to months. NOAA TM ERL PMEL-87 (PB89-206775), 99 pp. (1989).

Episodes of westerly wind in the western Pacific may be an important source of sea surface temperature variability in the eastern Pacific on monthly, seasonal and interannual time scales. In this report we use a combination of data, linear theory and an ocean general circulation model to examine remote response to western Pacific wind forcing. Characteristics of the wind anomaly are determined using daily averaged observations of wind from equatorial islands near the date line. In the model, wind anomalies generate a train of eastward propagating Kelvin pulses. When the wind anomaly is weak the Kelvin response agrees with predictions of linear theory. For more realistic strong forcing there are three important deviations from linear theory; the amplitude of low baroclinic modes increases, the amplitude of higher baroclinic modes decreases, and the phase speed increases. In the presence of realistic oceanic background conditions, response in the equatorial waveguide is complicated by the equatorial undercurrent, a sloping thermocline and instability waves. As Kelvin pulses propagate from western to eastern Pacific surface zonal velocity associated with the first mode decreases, whereas velocity associated with the second mode increases. These changes can be deduced by the principle of conservation of energy flux. In the central and eastern Pacific Kelvin pulses act to amplify and change the phase of existing instability waves. Thermal changes brought about by enlarged instability waves can be comparable in magnitude to changes brought about by zonal advection of the zonal temperature gradient by Kelvin pulses. At the coast of South America, model Kelvin pulses cause a warming of 2°C for 45 days. Current observations made at 140°W and 110°W subsequent to a strong westerly wind event in May 1986 indicate passage of Kelvin-like pulses which agree in magnitude and timing with those modeled. At the coast of South America observations of sea surface temperature show a warm anomaly that lasts for almost two months, comparable in duration and magnitude to changes found in the model.

PM-019

HARRISON, D.E. Local and remote forcing of ENSO ocean waveguide response. Journal of Physical Oceanography 19(5):691-695 (1989).

Several experiments using an ocean general circulation model have been carried out in order to explore the degree to which the oceanic waveguide response during the 1982-83 ENSO event was locally and remotely forced. Experiments in which the chosen monthly mean surface stress field was imposed only within three degrees of the equator (3°N/S) and within seven degrees of the equator (7°N/S) reveal that the 7°N/S winds reproduce the equatorial results of the full winds case to within differences small compared to the variability of interest. The 3°N/S winds case reproduces equatorial dynamic height acceptably, but introduces errors in SST and upper-ocean currents that approach the ENSO signal. A 7°N-S experiment in which the meridional stress is set to zero (NOYST) shows that meridional stress plays a nontrivial, but not dominant role, in the 1982-83 model behavior; errors generally are comparable to those of the 3°N/S

case. A final experiment, in which the 1982-83 winds were imposed west of the dateline and climatological winds were imposed east of 170°W (WPAC), illustrates the extent to which the central and eastern Pacific were forced by winds in the western Pacific. While there is nontrivial remote forcing, the locally forced variability is roughly twice as great. Implications for coupled ocean-atmosphere modeling and for design of future surface wind stress monitoring arrays for ENSO prediction are considered.

PM-020

HARRISON, D.E. On climatological monthly mean wind stress and wind stress curl fields over the world ocean. Journal of Climate 2(1):57-70 (1989).

Using a version of the global surface marine observation historical data set, a new 1° spatial resolution global ocean surface wind stress climatology has been evaluated using the Large and Pond surface drag coefficient formulation. These new results are compared, after spatial smoothing, with those of Hellerman and Rosenstein, who used a different drag coefficient form. It is found that the new stresses are almost everywhere smaller than those of Hellerman and Rosenstein, often by 20%-30%, which is greater than the formal error estimates from their calculations. The stress differences show large-scale spatial structure, as would be expected given the spatial variation of the surface stability parameter and the known different wind variability regions. Basin zonally averaged Ekman transports are computed to provide perspective on the significance of the stress differences; annual mean differences can exceed 10 Sv (Sv = 10^6 m^3 s^{-1}) equatorward of 20° lat, but are smaller poleward. Wind stress curl and Sverdrup transport calculations provide a different perspective on the differences; particularly noticeable differences are found in the regions of the Gulf Stream and Kuroshio separation. Large annual variations in midlatitude wind stress curl suggest that study of the forced response at annual periods should be of interest.

PM-021

HARRISON, D.E., and B.S. Giese. Comment on "The response of the equatorial Pacific Ocean to a westerly wind burst in May 1986" by M.J. McPhaden et al. Journal of Geophysical Research 94(C4):5024-5026 (1989).

No abstract.

PM-022

HARRISON, D.E., W.S. Kessler, and B.S. Giese. Ocean circulation model hindcasts of the 1982-83 El Niño: thermal variability along the ship-of-opportunity tracks. Journal of Physical Oceanography 19(4):397-418 (1989).

Five different analyses of 1982-83 monthly average surface wind stress fields have been used to force an ocean general circulation model of the tropical Pacific, in a series of El Niño hindcast experiments, like the one reported by Philander and Seigel. Although there were prominent common departures from climatology in the surface wind stress field during 1982-83 according to each wind analysis, there are also very substantial differences between analyses. This study was done to investigate the sensitivity of such hindcasts to our uncertain knowledge of the surface wind stress field. We concentrate here on the behavior along the Pacific ship-of-opportunity tracks. According to the ship-of-opportunity XBT data, the ocean underwent major changes during this period. The vertical temperature gradients and mixed layer temperatures, as well as the depth of the thermocline, underwent substantial changes. There were also major changes in the geostrophic flow of the major current systems, as revealed by upper ocean dynamic height differences. Comparing the hindcasts with observations, we find that the gross large-scale changes of the ENSO event--surface warming in the second half of 1982, continued warmth into 1983 and cooling in mid-1983, together with major thermocline depth changes--are found in each hindcast. However, major quantitative differences exist between each hindcast and the observations in at least some region for some time and some variable. Within the waveguide, dynamic height changes generally are hindcast with quantitative skill using each wind stress field and the best hindcasts differ from the observations by only a few dyn-cm more than the estimated uncertainty in the observations. Such hindcast skill is unlikely to be fortuitous: evidently the major elements of the waveguide variability are forced by the 1982-83 surface wind stress field rather than evolving out of some aspect of the state of the ocean during late 1981. Sea surface temperature changes are generally hindcast with qualitative skill, but rms errors of 2-3°C are frequent. Subsurface temperature variability skill varies with hindcast, location and depth; skill is greatest in the thermocline. Outside the waveguide, hindcast skill tends to be reduced, and varies greatly with location and hindcast. Quantitative hindcast skill is found near 10°S and 10°N in some hindcasts in the WP, and near 10°S in most hindcasts in the CP, but there is never quantitative skill in the NECC region. The most striking inconsistency found involves the behavior of the NMC hindcast in the region of the North Equatorial Counter Current. Wind stress curl-forced Ekman pumping appears to be a significant factor in the variations in the more successful hindcasts. In almost every comparison, the

range of hindcast results brackets the observations, suggesting that the model physics is plausible. Overall, the special research effort wind fields produced better dynamic height results than did the operational wind product fields, but the operational fields produced generally better waveguide SST results. Improved knowledge of the surface wind stress field (and its curl) is a minimum requirement if we are to assess more critically model performance, and to identify needed model improvements.

PM-023

HAYES, S.P., M.J. MCPHADEN, and A. Leetmaa. Observational verification of a quasi real time simulation of the tropical Pacific Ocean. Journal of Geophysical Research 94(C2):2147-2157 (1989).

Time series of upper ocean temperature and currents in the equatorial Pacific simulated by a numerical general circulation model run in nearly real time are compared to observations for the period August 1985 through May 1987. The model was forced by monthly mean wind stress and climatological air-sea heat flux. Comparisons with observations near the equator in the western (165°E), central (140°W), and eastern (110°W) Pacific are discussed. Simulated sea surface temperature (SST) was too cool in the eastern Pacific and too warm in the western Pacific. Largest rms deviations were in the east and exceeded 2°C. On and north of the equator in the eastern Pacific, SST and thermocline depth fluctuations on seasonal and monthly time scales were prominent. South of the equator, seasonal variability dominated. The model simulations often reproduced the amplitude and phase of the seasonal changes but not the higher-frequency variability. Model runs which included monthly assimilation of upper ocean temperature observations were included in the study. None of the comparison time series were incorporated in the assimilation. Inclusion of thermal observations generally improved agreement of simulated and observed time series. This improvement was largely due to reduction in the mean offsets of SST and thermocline depths. Data assimilation did little to improve the month-to-month differences in thermocline depth. In addition, south of the equator in the eastern Pacific, relatively large, systematic intra-month SST deviations occurred. These deviations corresponded to an erroneous heat flux of about 80 W m^{-2} and indicated problems in the simulated upper ocean circulation. Although no velocity data were included in the assimilation, the improved model thermal structure led to improved velocity simulation at some locations. No comparisons indicated large-amplitude spurious velocity variations which could be associated with data assimilation transients.

PM-024

Hinckley, S., K. BAILEY, J. SCHUMACHER, S. Picquelle, and P. STABENO. Preliminary results of a survey for late-stage larval walleye pollock and observations of larval drift in the western Gulf of Alaska, 1987. Proceedings of the International Symposium on the Biology and Management of Walleye Pollock, Nov. 1988, Anchorage, AK, Alaska Sea Grant Report 89-1, 297-306 (1989).

In June and July of 1987, an exploratory survey for the nursery area of the late-larval and early-juvenile stages of walleye pollock (Theragra chalcogramma) was conducted in the western Gulf of Alaska. The goals of the survey were to define the geographical distribution of these life stages, estimate abundance, examine drift to their nursery area, and examine the feasibility of using these life stages in a pre-recruit survey. This paper represents a preliminary report on results of the survey. The center of distribution of late-larval and early-juvenile walleye pollock was between the Shumagin and the Semidi Islands. This corresponded to concurrent locations of satellite-tracked drifters released in the center of the egg distribution in Shelikof Strait in April. Larval numbers were low to the southwest and northeast of the center of distribution and offshore of the 200-m depth contour. Estimated total abundance of late-larval and early-juvenile walleye pollock in the survey area was 9.0 x 10^{10} individuals.

PM-025

Huyer, A., R.L. Smith, P.J. STABENO, J.A. Church, and N.J. White. Currents off southeastern Australia: results from the Australian Coastal Experiment. Australian Journal of Marine and Freshwater Research 39:245-288 (1989).

The Australian Coastal Experiment was conducted off the east coast of New South Wales between September 1983 and March 1984. The experiment was conducted with arrays of current meters spanning the continental margin at three latitudes (37.5°, 34.5°, and 33.0°S), additional shelf moorings at 29° and 42°S, coastal wind and sea-level measurements, monthly conductivity-temperature-depth probe/expendable bathythermograph (CTD/XBT) surveys, and two satellite-tracked buoys. Over the continental shelf and slope, the alongshore component of the current generally exceeded the onshore component, and the subtidal (<0.6 cpd, cycles per day) current variability greatly exceeded the mean flow. Part of the current variability was associated with two separate warm-core eddies that approached the coast, causing strong (>50 cm sec^{-1}), persistent (>8 days), southward currents over the continental slope and outer shelf. Temperature and geostrophic velocity sections through the eddies, maps of ship's drift vectors and temperature contours at 250 m, and the satellite-tracked drifter trajectories showed that these eddies were similar in structure to those

observed previously in the East Australian Current region. Both eddies migrated generally southward. Eddy currents over the shelf and slope were rare at Cape Howe (37.5°S), more common near Sydney (34.5°S), and frequent at Newcastle (33.0°S), where strong northward currents were also observed. Near Sydney, the eddy currents over the slope turned clockwise with depth between 280 and 740 m, suggesting net downwelling there. Repeated CTD sections also indicated onshore transport and downwelling at shallower levels; presumably, upwelling occurred farther south where the eddy currents turned offshore. Periodic rotary currents over the continental slope near Sydney and Newcastle indicated the presence of small cyclonic eddies on the flank of a much larger anticyclonic eddy. Between early October and late January, no strong southward currents were observed over the continental margin near Sydney. Data from this "eddy-free" period were analyzed further to examine the structure and variability of the coastal currents. Much of this variability was correlated with fluctuations in coastal sea-level (at zero lag) and with the wind stress (at various lags). The coherence and phase relationships among current, wind-stress, and sea-level records at different latitudes (determined from spectral analysis and frequency-domain empirical orthogonal functions) were consistent with the equatorward propagation of coastal-trapped waves generated by winds in phase with those near Cape Howe. Time-domain empirical orthogonal functions show that the current fluctuations decayed with distance from shore and with depth, as expected of coastal-trapped waves.

PM-026

Incze, L.S., A.W. Kendall, Jr., J.D. SCHUMACHER, and R.K. REED. Interactions of a mesoscale patch of larval fish (Theragra chalcogramma) with the Alaska Coastal Current. Continental Shelf Research 9(3):269-284 (1989).

Walleye pollock, Theragra chalcogramma, form dense aggregations during a brief spawning period from late March to mid-April in Shelikof Strait, Alaska. Spawning produces a large (order 20 × 50 km or more) "patch" of eggs at depth (generally >150 m), and hatching larvae often produce a "patch" in the upper 50 m. Patches can be defined as coherent features using graded concentration isopleths, and the mean concentration within patches has been observed to be as much as 68 times (for eggs) and nearly 6 times (for larvae) the background concentration. Larval patches drift southwestward and have been identified for about 30 days after hatching in some years. Data are presented for spawner biomass and for early life stages, as available, for 1981, 1983 and 1985. When comparing 1985 with 1981 (2 years with the best coverage), spawner biomass and mean egg concentration within the patch declined concordantly. Larval concentrations about 10 days after hatching differed widely, however: concentrations in early May 1985 were more than an order of magnitude lower than expected. Unlike either 1981 or 1983, no larval patch could be identified in late May 1985; this appears to be attributable to changes detected earlier in the month. The "apparent" mortality rate for a 10-day period after hatching in 1985 was about 0.50 d^{-1} greater than in 1981. Larval feeding conditions can be excluded as a likely cause of this interannual difference, but predation and advection cannot be. Our findings emphasize the short time period over which significant changes can occur, as well as additional sampling which must be done in future studies. We show that part of the emerging 1985 larval year class could have been removed by cross-channel disturbances in the flow field through Shelikof Strait.

PM-027

KESSLER, W.S. Observations of long Rossby waves in the northern tropical Pacific. NOAA TM ERL PMEL-86 (PB89-196331), 169 pp. (1989).

Long baroclinic Rossby waves are potentially important in the adjustment of the tropical Pacific pycnocline to both annual and interannual wind stress curl fluctuations. Evidence for such waves is found in variations of the depth of the 20°C isotherm in the northern tropical Pacific during 1970 through 1987. 190,000 bathythermograph profiles have been compiled from the archives of several countries; the data coverage is dense enough that westward-propagating events may be observed with a minimum of zonal interpolation. After extensive quality control, 20°C depths were gridded with a resolution of 2° latitude, 5° longitude and bimonths; statistical parameters of the data were estimated. A simple model of low-frequency pycnocline variability allows the physical processes of Ekman pumping, the radiation of long (non-dispersive) Rossby waves due to such pumping in mid-basin, and the radiation of long Rossby waves from the observed eastern boundary pycnocline depth fluctuations. Although the wind stress curl has very little zonal variability at the annual period in the northern tropical Pacific, an annual fluctuation of 20°C depth propagates westward as a long Rossby wave near 4°-6°N and 14°-18°N in agreement with the model hindcast. Near the thermocline ridge at 10°N, however, the annual cycle is dominated by Ekman pumping. The wave-dominated variability at 4°-6°N weakens the annual cycle of Countercurrent transport in the western Pacific. El Niño events are associated with westerly wind anomalies concentrated in the central equatorial Pacific; an upwelling wind stress curl pattern is generated in the extra-equatorial tropics by these westerlies. Long upwelling Rossby waves were observed to raise the western Pacific thermocline well outside the equatorial waveguide in the later stages of El Niños, consistent with the simple long-wave model. It has been suggested that El Niño events are initiated by downwelling long Rossby waves in the

extra-equatorial region reflecting off the western boundary as equatorial Kelvin waves. The bathythermograph observations show that although such downwelling waves commonly arrive at the western boundary (the Philippines coast), there is a low correlation between these occurrences and the subsequent initiation of El Niño events.

PM-028

LACKMANN, G.M., and J.E. OVERLAND. Atmospheric structure and momentum balance during a gap-wind event in Shelikof Strait, Alaska. Monthly Weather Review 117:1817-1833 (1989).

Gap winds occur in topographically restricted channels when a component of the pressure gradient is parallel to the channel axis. Aircraft flight-level data are used to examine atmospheric structure and momentum balance during an early spring gap-wind event in Shelikof Strait, Alaska. Alongshore sea level pressure ridging was observed. Vertical cross sections show that across-strait gradients of boundary-layer temperature and depth accounted for the pressure distribution. Geostrophic adjustment of the mass field to the along-strait wind component contributed to development of the observed pressure pattern. Boundary-layer structure and force balance during this event was similar to that often observed along isolated barriers. However, the Rossby radius was larger than the strait width, and atmospheric structure in the strait exit region indicates transition of the flow to open coastline conditions. Two across-strait momentum budgets show that the Coriolis force and across-strait pressure gradient were an order of magnitude larger than other terms. Largest terms in the along-strait balance were the pressure gradient force, acceleration, entrainment, and friction. Boundary-layer acceleration in the along-strait direction was 55% of the potential limit determined by the along-strait pressure gradient. Entrainment of air into the boundary layer was the largest retarding force and contributed to the along-strait profile of boundary-layer depth. Large horizontal divergence was observed within the strait, yet boundary-layer depth increased slightly following the flow. Entrainment at the inversion and sea surface fluxes accounted for along-strait variation of boundary-layer equivalent potential temperature.

PM-029

LAVELLE, J.W., H.O. MOFJELD, E. LEMPRIERE-DOGGETT, G.A. CANNON, D.J. PASHINSKI, E.D. COKELET, L. LYTLE, and S. Gill. A multiply-connected channel model of tides and tidal currents in Puget Sound, Washington and a comparison with updated observations. NOAA TM ERL PMEL-84 (PB89-139786), 103 pp. (1989).

Tides and tidal transports within Puget Sound have been calculated using a model in which the Sound is represented by 79 channels connected at 43 junctions. Linearized equations of motion were used to determine channel cross-sectionally averaged quantities for the principal tidal constituents (M_2, K_1, S_2, N_2, O_1, P_1, M_4). For the M_2 tide the amplitudes and phases at the entrances to the Sound and the friction coefficients in the channels were adjusted to bring observed and modeled tidal distributions into best agreement; for other constituents, only the tidal amplitudes and phases at the entrances were adjusted. Data from 47 tide stations in Puget Sound were used for fitting model parameters. Tidal amplitudes and phases match observations with an average difference of less than 1 cm and 2° respectively for each of the constituents indicated. Transport values from the model were subsequently compared to transports calculated from currents measured on four sections across the Sound at both M_2 and K_1 frequencies. Tidal transports at the M_2 frequency match the transports calculated from the data with average difference of less than 3% for amplitude and 4.3° for phase. The model was also used to calculate cross-sectionally averaged tidal currents, tidal prisms, and tidal dissipation rates for the composite tide and for constituents. As an example of those results, the composite tide and the M_2 and K_1 constituents have tidal prisms of 7.69, 4.74 and 3.73 km^3 and dissipation rates of 733,528 and 78 MW, respectively.

PM-030

Lupton, J.E., E.T. BAKER, and G.J. MASSOTH. Variable ^{3}He/heat ratios in submarine hydrothermal systems: evidence from two plumes over the Juan de Fuca ridge. Nature 337(6203):161-164 (1989).

The first vent fluid samples recovered from submarine hydrothermal systems on the Galápagos Rift and at 21°N on the East Pacific Rise (EPR) had a nearly identical ratio of ^{3}He/heat of ~0.5 × 10^{-12} cm^3 STP cal^{-1}, even though the two hydrothermal systems were separated geographically and had widely differing fluid exit temperatures (~20 and ~350°C, respectively). Jenkins et al. combined this ratio with independent estimates of the flux of mantle ^{3}He through the oceans, to calculate a global oceanic hydrothermal heat flux of 4.9 × 10^{19} cal yr^{-1}, which is in excellent agreement with geophysical estimates for this flux. Other investigators then combined this ^{3}He flux with measured ratios of various chemicals in vent fluids to ^{3}He (such as Mn/^{3}He and Si/^{3}He) to estimate global hydrothermal fluxes for these species. Here we show that ^{3}He/heat ratios vary by over an order of magnitude between submarine hydrothermal systems, suggesting that early measurements of the ^{3}He/heat relation are not representative of all hydrothermal systems, and that flux calculations based on the oceanic ^{3}He flux must be undertaken with caution.

PM-031

MASSOTH, G.J., D.A. Butterfield, J.E. Lupton, R.E. McDuff, M.D. Lilley, and I.R. Jonasson. Submarine venting of phase-separated hydrothermal fluids at Axial Volcano, Juan de Fuca Ridge. Nature 340:702-705 (1989).

Since the discovery of high-temperature venting on the East Pacific Rise in 1979, it has been expected, because of the physical properties of sea water at pressures and temperatures encountered during submarine hydrothermal circulation, that phase-separated fluids would discharge from ridgecrest vents. Although this notion is supported by the reported large deviations in vent-fluid chlorinity relative to that of sea water (-40% - +200%), by observations of venting at P-T conditions clearly within the two-phase region (220 bar and 420°C) and by fluid-inclusion data, unequivocal identification of phase-separated venting fluids has remained elusive. Here we report observations of chloride- and metal-depleted, gas-enriched fluids from a shallow vent field on the Juan de Fuca Ridge which confirm the expectation that phase-separated effluents are delivered to the deep ocean from some sea-floor venting systems.

PM-032

MASSOTH, G.J., H.B. MILBURN, S.R. HAMMOND, D.A. Butterfield, R.E. McDuff, and J.E. Lupton. The geochemistry of submarine venting fluids at Axial Volcano, Juan de Fuca Ridge: new sampling methods and a VENTS Program rationale. Global Venting, Midwater and Benthic Ecological Processes, M.P. De Luca and I. Babb (eds.), National Undersea Research Program Report 88-4, 29-59 (1988).

Observations of vent fluids collected in 1986 with the submersible Pisces IV from the ASHES vent field at Axial Volcano, Juan de Fuca Ridge suggest that hydrothermal fluids similar to those vented at other sediment-starved ridgecrest sites are being discharged along with unprecedented Cl-poor, gas-enriched fluids that are likely the result of phase separation. Anomalously low concentrations of silica, calcium, manganese and iron were also observed in the Cl-poor vent fluids. New sampling tools and protocols conceived to overcome the interpretive limitations inherent to conventional vent fluid data were tested during 1987 using the Deep Submersible Alvin. A Submersible-coupled In situ Sensing and Sampling System (SIS^3) enabled a more efficient collection of high quality vent fluid samples coincident with the sensing of temperature. An In Situ Chemical Analyzer (ISCA), based on the technology of flow injection analysis and configured to monitor the chemical output of a warm spring vent for H_2S, Fe^{2+}, pH, and temperature, was deployed with partial success for 3 days at the ASHES vent field. The integral role of vent fluid studies in testing the hypothesis that hydrothermal venting along the Juan de Fuca/Explorer/Gorda Ridge system plays a major role in controlling the chemistry of the northeastern Pacific Ocean is identified and supported.

PM-033

MCPHADEN, M.J., and R.A. Fine. A dynamical interpretation of the tritium maximum in the central equatorial Pacific. Journal of Physical Oceanography 18(10):1454-1457 (1988).

The tropical tritium distribution between 1974 and 1981 is characterized by a maximum along the equator centered between 125° and 145°W. It signifies that this region has received the maximum input of high northern latitude water. A dynamical interpretation of the maximum shows that it can be explained by the strength of the Sverdrup circulation in the central equatorial Pacific where there is a strong zonal convergence in the North Equatorial Countercurrent (NECC) and a strong meridional geostrophic flow towards the equator.

PM-034

MCPHADEN, M.J., H.P. FREITAG, S.P. HAYES, B.A. TAFT, Z. Chen, and K. Wyrtki. Reply to Comment by Harrison and Giese. Journal of Geophysical Research 94(C4):5027-5028 (1989).

No abstract.

PM-035

MCPHADEN, M.J., and B.A. TAFT. Dynamics of seasonal and intraseasonal variability in the eastern equatorial Pacific. Journal of Physical Oceanography 18(11):1713-1732 (1988).

Time series measurements from surface moored buoys in the eastern equatorial Pacific are analyzed for the period 1983-86. The data, collected as part of the EPOCS and TROPIC HEAT programs, consist of currents, temperatures, and winds on the equator at 110°, 124.5° and 140°W. The purpose is to examine the dynamics of seasonal and intraseasonal variability in the upper 250 m from a diagnosis of the depth integrated zonal momentum (i.e., transport) equation. The principal conclusions of this paper are that 1) there is an approximate balance between mean zonal wind stress and depth integrated pressure gradient;

nonlinear advection is significantly nonzero however and leads to an enhancement of eastward transport along the equator; 2) there is an interannual change in zonal wind stress and pressure gradient in which both approximately double over the record length; 3) at the annual cycle, zonal wind stress and depth integrated pressure gradient tend to balance, though the uncertainties are large and other physical processes (e.g., lateral diffusion) are likely to be important; and 4) there exists a very energetic intraseasonal eastward propagating Kelvin-like wave in zonal current, temperature, and dynamic height at periods of 60-90 days which is poorly correlated with the local winds. These waves have amplitudes that are large enough at times to obscure the annual cycle.

PM-036

MOFJELD, H.O. Depth dependence of bottom stress and quadratic drag coefficient for barotropic pressure-driven currents. Journal of Physical Oceanography 18(11), 1658-1669 (1988).

A level 2½ turbulence closure model is used to investigate the dependence on water depth H of bottom stress τ_b and quadratic drag coefficient C_d for a steady barotropic pressure-driven current in unstratified water when the current is the primary source of turbulence. For spatially uniform pressure gradient and bottom roughness z_o the magnitude $|\tau_b|$ increases from small values in shallow water to a maximum (at a depth ~0.004 U_o/f where U_o is the geostrophic current speed derived from the pressure gradient and f is the Coriolis parameter) at which the dynamics changes from being depth-limited to being controlled by similarity scales. As the depth increases further, $|\tau_b|$ decreases to its deep-water value, that is, 15% to 19% less than the maximum. The angle θ of the bottom stress relative to the geostrophic direction decreases rapidly from 90° in very shallow water, reaching its deep-water value (~11°-21°) at a somewhat shallower depth than does $|\tau_b|$. At the maximum stress θ is 8° larger than the deep-water angle. A set of computationally efficient formulas matched to the model results gives $|\tau_b|$ and θ for all combinations of U_o, H, f and bottom roughness z_o. Comparison with a variety of other models satisfying Rossby similarity over oceanographic ranges of parameters shows agreement of ~10% for $|\tau_b|$ and ~5° for θ. The coefficient C_d of the quadratic drag law relating $|\tau_b|$ to the vertically averaged velocity is found to be approximated reasonably well by a formula from nonrotating channel theory in which the coefficient depends only on the ratio H/z_o. The direction of the bottom stress relative to the vertically averaged velocity is equal to the geostrophic veering angle (~11°-21°) in deep water and decreases to ~5° for a range of intermediate depths (~0.004-0.01 U_o/f) where it is relatively independent of external Rossby number U_o/fz_o; the angle becomes less in shallower water.

PM-037

Muench, R.D. The sea ice margins: a summary of physical phenomena. NOAA TM ERL PMEL-88 (PB89-212328), 51 pp. (1989).

No abstract.

PM-038

MURPHY, P.P., T.S. BATES, H.C. CURL, JR., R.A. FEELY, and R.S. BURGER. The transport and fate of particulate hydrocarbons in an urban fjord-like estuary. Estuarine, Coastal and Shelf Science 27:461-482 (1988).

Hydrocarbon concentrations were measured on suspended particulates and on surficial marine sediments in the urban fjord-like estuary of Puget Sound, Washington. These data were combined with sediment deposition rates, suspended particulate concentrations and circulation data to assess hydrocarbon distributions and fates. Evaluation of major sinks for petroleum hydrocarbons (UCM) and polycyclic aromatic hydrocarbons (PAH) in an urban estuary indicates that >90% of the hydrocarbons which are associated with suspended particulates in the main basin of Puget Sound are deposited in the estuarine sediments. Approximately 63% of the PAH and 100% of the UCM associated with particles in the main basin settle directly to the sediments. The remainder is carried to the main basin sediments via horizontal transport from other areas. Trends in PAH ratios are used to identify major sources of PAH. Estimated sources of PAH are balanced by the estimated sinks.

PM-039

Nakata, K., K. Tsurusaki, Y. Okayama, and J.W. LAVELLE. An attempt to evaluate the effects of an anti-turbidity system on sediment dispersion from a Hopper dredge. NOAA TM ERL PMEL-85 (PB89-162515), 30 pp. (1989).

Measurements were made during six hopper dredge operations to investigate the differences in plumes of overspilled particulates when the dredger was and was not using an anti-turbidity system. Observations for discharge rates of suspended solids were taken aboard the dredge ship while concentration samples of

suspended solids were taken by survey boats in the plume and currents were metered by instruments on moorings. Measurements were given a common framework by the use of a dispersion model for the plume. Modeled and observational profiles match well when the rate of discharge is reserved as a fitting parameter. However, differences in results of the use and non-use of the anti-turbidity system are not discernible with the field data. Consequently, the model was used under identical advection and diffusion conditions to study the differences theoretically. Those numerical experiments suggest that there is an increase of about 25% in the amount of deposition in the immediate area of dredging with the anti-turbidity system, though the fractional amount of redeposition in both cases is small. The differences in results for the two systems calculated with the model depend on the assigned initial vertical distributions. Because these are poorly known at present, better definition of the differences with and without the anti-turbidity system await better measurements of the vertical distributions of suspended solids in the ocean immediately following discharge.

PM-040

OVERLAND, J.E., and C.H. PEASE. Modeling ice dynamics of coastal seas. Journal of Geophysical Research 93(C12):15619-15637 (1988).

A coupled sea ice, barotropic ocean model with a 1-km resolution and a seaward domain of 200 km quantifies three coastal processes: coupling of ice motion to wind-driven coastal currents, ice thickness redistribution under compaction at the coast, and formation of coastal shear zones. The model consists of an ice momentum balance, mass concentration and two-parameter ice thickness distribution, and equations for horizontal water motion and continuity using vertical structure functions. An appropriate constitutive law appears to be a hardening plastic based on qualitative observations from Alaskan continental shelves. For first-year sea ice, strength is taken to be proportional to the square of ice thickness. A north wind example of 10 m/s with the coastline to the west shows the depth dependence of rotational shear in the sea ice/ocean boundary layer and sea surface tilt which contributes an alongshore slope current. There is slight convergence of sea ice over the shelf, a coastal shear zone of 4 km, and an alongshore ice speed seaward of the shear zone of 6% of the wind speed caused by the combination of an under-ice shear layer and an alongshore slope current. For an onshore wind, ice is near free drift at 3% of the wind seaward of a ridging front, which propagates seaward. A square dependence of ice strength on thickness is required for the rubble field to approach a limiting thickness, consistent with observations. The hardening plastic interpretation of the rubble field has the stress state at the yield limit in contrast with a rigid plastic of high constant strength that yields only at the coast. We conclude that (1) ice thickness/motion feedback is important on scales less than 10 km, (2) the observational base to discriminate between mesoscale constitutive laws is not yet available, and (3) the relation of ice velocity to wind stress is variable because the ocean slope current responds only to the alongshore component of the wind.

PM-041

OVERLAND, J.E., and C.H. PEASE. Prediction of vessel icing: a 1989 update. Proceedings, 10th International Conference on Port and Ocean Engineering Under Arctic Conditions, June 12-16, 1989, Luleå, Sweden, K.B.E. Axelsson and L.A. Fransson (eds.), Luleå University of Technology, Research Report TULEA 1989:08, Vol. 2, 712-723 (1989).

The NOAA vessel icing algorithm is evaluated against theoretical advances. The most difficult factor is influence of sea temperature. Modeling demonstrates the importance of supercooling of spray during its trajectory to extreme ice accretion. This occurs when sea temperatures are less than 2-3°C above the saltwater freezing point. The sea surface temperature term in the NOAA algorithm is consistent with the supercooling hypothesis and a further category of "extreme" icing is added, which can explain anecdotal cases greater than 5 cm h^{-1}. A wave height/wind speed threshold is 5 m s^{-1} for a 15-m vessel, 10 m s^{-1} for a 50-m large trawler and 15 m s^{-1} for a 100-m vessel, developed from seakeeping theory. These wind speeds are exceeded 83%, 47% and 15% during February in the Bering Sea.

PM-042

PAULSON, A.J., R.A. FEELY, H.C. CURL, JR., E.A. Crecelius, and G.P. Romberg. Separate dissolved and particulate trace metal budgets for an estuarine system: an aid for management decisions. Environmental Pollution 57:317-339 (1989).

The sources and sinks of dissolved and particulate Pb, Cu and Zn were determined for the main basin of Puget Sound to understand the effect man has had on metal concentrations in both the water column and in the sediments. Municipal, industrial and atmospheric sources contributed about 66% of the total Pb added to the main basin of Puget Sound during the early 1980s. Advective inputs were the major sources of total Cu and Zn (~40%) while riverine and erosional sources contributed about 30%. The discharge of the particle-bound trace metals from rivers minimized the influence of particulate anthropogenic sources,

which constituted 50%, 23% and 18% of the total particulate Pb, Cu and Zn inputs, respectively. While advective transport was the major source of dissolved Cu and Zn (~60% of all dissolved inputs), industrial, municipal and atmospheric inputs contributed about 85%, 30% and 38% of the dissolved Pb, Cu and Zn inputs, respectively. The sources of dissolved and particulate Cu and Zn were comparable with the sinks within the errors of the analyses indicating their quasi-conservative nature. Advection removed about 60% of the total Cu and Zn added to the main basin while 40% was deposited in the sediments of Puget Sound. Because of this quasi-conservative nature of Cu and Zn, anthropogenic inputs of Cu and Zn were dispersed from the system more than they were contained within main basin sediments. About 75% of the dissolved Pb discharged into the main basin of Puget Sound was lost from the dissolved phase and was balanced by a similar gain in the particulate phase. Because of this extensive scavenging and the effective retention of particles within the main basin, about 70% of the total Pb added to the main basin was retained within its sediments. These separate mass balances have utility in management decisions because they show the relative contributions from different sources and demonstrate whether the influences of dissolved and particulate inputs are reflected solely in the water column or the sediments, respectively.

PM-043

PAULSON, A.J., R.A. FEELY, H.C. CURL, JR., and D.A. TENNANT. Estuarine transport of trace metals in a buoyant riverine plume. Estuarine, Coastal and Shelf Science 28:231-248 (1989).

The distributions of dissolved and particulate trace metals in Elliott Bay, Washington were determined in April, 1985 during the period of maximum discharge of freshwater for the year. The high freshwater discharge generated a thin buoyant plume (<2 m) which carried a high suspended load. Calculations made from high resolution sampling of salinity and total suspended matter in the plume suggest that their residence times in the upper 2 m of the water column ranged between 15 and 24 h. Total suspended matter, dissolved and particulate Fe, Mn and Pb, and particulate Cu and Zn in the plume were found to be conservative during their transit through Elliott Bay. Dissolved Cu and Zn exhibited a linear relationship with salinity downstream of a significant anthropogenic source. The particulate phase dominated the horizontal transport of Fe and Pb originating from freshwater sources. In contrast, the dissolved phase contributed 66%, 75% and 35% of the respective total horizontal fluxes of Mn, Zn and Cu that originated from riverine and anthropogenic sources. The trace metal concentrations of the suspended matter were uniform in Elliott Bay except for Mn concentrations. Mn concentrations of suspended matter increased with salinity due to mixing of lower concentration, riverine particulates with Puget Sound particulates of higher Mn concentrations. The lack of trace metal enrichments of Elliott Bay surface suspended matter during this period of high discharge was the result of the small vertical loss of suspended matter (<2% of the horizontal transport) and the rapid transit of suspended matter through the Bay.

PM-044

PAULSON, A.J., T.P. Hubbard, H.C. CURL, JR., R.A. FEELY, T.E. Sample, and R.G. Swartz. Decreased fluxes of Pb, Cu and Zn from Elliott Bay. Proceedings of Sixth Symposium on Coastal and Ocean Management/ASCE, July 11-14, 1989, Charleston, SC, 3916-3930 (1989).

Fluxes of dissolved Pb, Cu and Zn to Elliott Bay, Washington from industrial sources were calculated from metal-salinity plots and freshwater discharge rates. The changes in these calculated fluxes were used to evaluate the effectiveness of pollution abatement programs. Between 1981 and 1985, initial pollution abatement actions were directed at many commercial and industrial dischargers along the Duwamish Waterway and on Harbor Island including a secondary lead smelter site and shipbuilding facilities. Subsequently, the dissolved Pb flux to Elliott Bay from industrial flux of dissolved Cu decreased by a factor of 5, and the industrial flux of dissolved Zn remained unchanged. The closure of one shipyard, reduced activity at another and better management practices decreased the industrial fluxes of dissolved Cu and Zn to Elliott Bay in 1986 by 75% and 90%, respectively.

PM-045

PEASE, C.H. Beaufort/Chukchi ice motion and meteorology update. Proceedings, Alaska OCS Region 1987 Arctic Information Transfer Meeting Conference, OCS Study MMS 88-0040, Minerals Management Service, Anchorage, AK, 145-150 (1988).

No abstract.

PM-046

Picaut, J., S.P. HAYES, and M.J. MCPHADEN. Use of the geostrophic approximation to estimate time varying zonal currents at the equator. Journal of Geophysical Research 94(C3):3228-3236 (1989).

Moored thermistor chains at 2°N and 2°S and current-temperature moorings at 0° are used to examine the accuracy of geostrophically estimated zonal velocity on the equator in the eastern (110°W) and western (165°E) Pacific. The meridionally differentiated form of the geostrophic balance is used to eliminate large errors due to wind-balanced cross-equatorial pressure gradients. Statistical analyses indicate that for time scales longer than 30-50 days, the observed and geostrophically estimated zonal velocities are similar (correlation coefficients of 0.6-0.9 and comparable amplitudes). Thus low-frequency equatorial current oscillations are reasonably well represented by the geostrophic approximation. However, the mean currents are poorly resolved with the available array. In the eastern Pacific the mean zonal speed difference over the 10-month comparison period is 25 cm s^{-1} at 25 m and increases to 60 cm s^{-1} at 125 m. At 165°E mean differences in the upper 250 m are typically 50 cm s^{-1} over a 4-month record. The principal reason for these large mean differences is that the meridional scale of the mean currents is smaller than the spacing of the moorings. Comparison of observed and geostrophic velocity profiles obtained from shipboard sampling indicates that meridional spacing of about 1° latitude would be optimum for estimating the zonal velocity.

PM-047

QUINN, P.K., and T.S. BATES. Collection efficiencies of a tandem sampling system for atmospheric aerosol particles and gaseous ammonia and sulfur dioxide. Environmental Science and Technology 23(6):736-739 (1989).

The collection efficiencies of aerosol particles and gaseous NH_3 and SO_2 were tested for a tandem sampling system consisting of a cyclone separator followed by a 1.0 µm pore size 47-mm Millipore Teflon particle filter and four 47-mm Whatman 41 filters coated with oxalic acid and either K_2CO_3 or LiOH. The collection efficiency of the cyclone was compared with an 8.0 µm pore size Nuclepore filter using NaCl particles. Both the cyclone and the filter had a 50% collection efficiency at 0.9 µm (50 standard L/min, 55 cm s^{-1} filter face velocity). Known amounts of NH_3 and SO_2 were generated and collected on the coated filters. The collection efficiency of the system for NH_3 was found to be 103 ± 30%. The SO_2 collection efficiency on K_2CO_3_ and LiOH-coated filters was 100 ± 21 and 88 ± 9%, respectively, and was not affected by the presence of reduced sulfur gases or ozone in the sampled air stream.

PM-048

REED, R.K. and J.D. SCHUMACHER. Some mesoscale features of flow in Shelikof Strait, Alaska. Journal of Geophysical Research 94(C9):12603-12606 (1989).

Moored current observations were obtained from a small region of Shelikof Strait during 1986-1987. Results from two sites <4 km apart revealed very similar energy spectra and highly correlated alongstream component flow. At separations >11 km, however, correlations were quite weak. A new feature, intense 13-day spectral peaks of narrow horizontal and vertical scale, was also revealed. The feature appears to be a baroclinic, residual flow linked to tidal currents.

PM-049

REED, R.K., and J.D. SCHUMACHER. Transport and physical properties in central Shelikof Strait, Alaska. Continental Shelf Research 9(3):261-268 (1989).

Data from a repeated CTD section in central Shelikof Strait during 1985-1987 are used to derive volume transport and the distribution of near-bottom physical properties. Mean transport was 0.6 × 10^6 m^3 s^{-1} to the southwest, similar to that measured by a 5-month current-meter array. Computed transport values varied from 0.2 to 1.2 × 10^6 m^3 s^{-1}; differential Ekman pumping appeared to be important in creating large changes in transport over short time intervals. Near-bottom temperature and salinity varied as a result of changes in source waters to the south; during 1986 cold, low-salinity conditions prevailed. The seasonal cycles of surface and near-bottom temperature and salinity are compared to those found off the Kenai Peninsula.

PM-050

REED, R.K., J.D. SCHUMACHER, and A.W. Kendall, Jr. NOAA's Fisheries Oceanography Coordinated Investigations in the Western Gulf of Alaska. Eos, Transactions American Geophysical Union: The Oceanography Report 69(40):890-894 (1989).

No abstract.

PM-051

Reynolds, R.W., K. Arpe, C. Gordon, S.P. HAYES, A. Leetmaa, and M.J. MCPHADEN. A comparison of tropical Pacific surface wind analyses. Journal of Climate 2(1):105-111 (1989).

Surface wind analyses from three data assimilation systems are compared with independent wind observations from six buoys located in the Pacific within 8 deg of the equator. The period of comparison is 6 months (February to July 1987), with daily sampling. The agreement between the assimilation systems and the independent buoy data is disappointing. The long-term mean differences between the buoy and the assimilated zonal and meridional winds are as large as 3.1 m s^{-1}, which is comparable to the size of the means themselves. The zonal and meridional daily wind correlations range between 0.66 and 0.17. The wind field agreement was actually better among the different systems than between any system and the buoys. However, the agreement among the analysis products was usually better for the zonal winds than for the meridional winds. For the time period and locations presented, the comparisons with the independent data show that no assimilation system is clearly superior to any of the others.

PM-052

Rothstein, L.M., M.J. MCPHADEN, and J.A. Proehl. Wind forced wave-mean flow interactions in the equatorial waveguide. Part I: The Kelvin wave. Journal of Physical Oceanography 18(10):1435-1447 (1988).

A numerical model is designed to study the effects of the strong, near-surface shears associated with the equatorial current system on energy transmission of time-periodic equatorial waves into the deep ocean. The present paper is confined to long wavelength, low-frequency Kelvin waves forced by a longitudinally confined patch of zonal wind. Energy transmission into the deep ocean is investigated as a function of mean current shear amplitude and geometry and the forcing frequency. Solutions form well-defined beams of energy that radiate energy eastward and vertically toward the deep ocean in the absence of mean flow. However, the presence of critical surfaces associated with mean currents inhibits low-frequency energy from reaching the deep ocean. For a given zonal wavenumber, longitudinal propagation through mean currents will be less inhibited as the frequency increases (phase speed increases). When the mean current amplitude is large enough, the beam encounters multiple critical surfaces (i.e., critical surfaces for different wavenumber components of the beam) where significant exchanges of energy and momentum can take place with the mean currents via Reynolds stress transfers. Work against the mean vertical shear is the dominant wave energy loss for the case of a mean South Equatorial Current-Equatorial Undercurrent system, illustrating the need for high vertical resolution in equatorial ocean models. The model also describes the possible induction of a mean zonal acceleration as well as a mean meridional circulation. Eliassen-Palm fluxes are used to diagnose these dynamics. The presence of critical surfaces result in mean field accelerations on the equator above the core of the Equatorial Undercurrent. Implications of these results with regard to observations in the equatorial waveguide are discussed.

Addendum

PM-053

EMBLEY, R.W., I.R. Jonasson, M.R. Perfit, J.M. Franklin, M.A. Tivey, A. Malahoff, M.F. Smith, and T.J.G. Francis. Submersible investigation of an extinct hydrothermal system on the Galápagos Ridge: Sulfide mounds, stockwork zone, and differentiated lavas. Canadian Mineralogist 26:517-539 (1988).

Fifteen dives along the Galápagos Ridge in the region between 85°49'W and 85°55'W were made to examine the detailed relationships among tectonics, hydrothermal activity and lava compositions. Extensive tectonic activity and physical weathering have exposed the inner parts of large Cu-Zn sulfide mounds and the uppermost part of the underlying stockwork zone. The mineralization occurs at the top and southern base of a horst block, 40 to 80 m high, that separates the present Neovolcanic Zone to the north from an older rift valley to the south. The lavas in the Neovolcanic Zone are homogeneous MORB pillows; those on the horst block and within the southern valley are evolved MORB to andesite pillow and sheet flows. The alteration zone exposed beneath the sulfide mounds comprises a network of fracture-controlled pipe and sheet-like bodies of highly altered material which changes outward into relatively fresh but similarly closely fractured rocks. The hydrothermal upflow zone is extensively brecciated on a centimeter scale and encloses a stockwork of veinlets now filled largely by silica, clays and sulfides. The most highly altered rocks are strongly depleted in Ca, Na, K and Mn, and are enriched in S, Fe, Cu and Zn relative to their fresh analogs. Si and Mg are variable, the latter showing local depletions and enrichments according to the proportion and distribution of chlorite. Depletions in ^{18}O with increasing $^{87}Sr/^{86}Sr$ suggest extensive seawater-rock interaction (W/R up to 100:1) at T up to 350°C. Deep-tow and ALVIN-based magnetic profiles have a relative magnetization low centered over the southern valley and the horst block that could reflect more extensive hydrothermal alteration zones associated with the older seafloor. The

Galápagos stockwork is most analogous to the alteration zones associated with massive sulfide deposits in the ophiolites of Cyprus and Oman.

PM-054

MOFJELD, H.O. Review of "Tides, Surges and Mean Sea-Level, A Handbook for Engineers and Scientists," by D.T. Pugh. Eos, Transactions of the American Geophysical Union 69(37):850 (1988).

No abstract.

SPACE ENVIRONMENT LABORATORY

SE-001

Barrow, C.H., J. Watermann, D.S. EVANS, and K. Wilhelm. Antarctic Auroral Electron Precipitation Observed by the Electron Spectrometer (1ESO19) on Spacelab 1. MPAE-W-100-89-25, Max-Planck-Institut für Aeronomie, 38 p. (1989).

Electron flux measurements were made in the energy range 0.1-12.5 keV, by the electron spectrometer 1ESO19 on board Spacelab 1, during the period November 29 to December 7, 1983. The spacecraft was in a 57° inclination circular orbit at an altitude of about 250 km with orbital period 90 min. Although the experiment was originally designed for artificial beam response observations, several periods of natural keV electron precipitation were also recorded, and these have been surveyed and catalogued. New and improved data presentation has also been introduced. The data are interesting because of the high resolution of the electron spectrometer, the relatively low altitude of the observations, and the path of Spacelab 1, almost along the auroral oval. One observation, made in the southern hemisphere on November 30, 1983, is of particular interest as the NOAA-7 satellite, which measured electron flux in the energy range 0.3-20 keV, was then quite close in space and time. As correlative riometer and magnetometer observations suggest that auroral conditions remained stable during the 25 min period during the two sets of observations, the observations are used to infer the gross spatial structure of the auroral precipitation over the midnight sector. Comparison of the electron energy spectra observed by Spacelab 1 and NOAA-7 at different local times suggests a high degree of longitudinal homogeneity in the precipitation.

SE-002

Bornmann, P.L., and K.T. Strong. Two-component analysis of the decay of soft X-ray line emission during solar flares. The Astrophysical Journal, 333:1014-1025 (1988).

The light curve analysis technique of Bornmann has been extended to two components and is used to model the soft X-ray line fluxes observed during solar flares with the Flat Crystal Spectrometer on board the Solar Maximum Mission satellite. This technique uses the rate of change in flux of soft X-ray lines to derive the temperature and emission measure. The modified version of this technique solves for two components, rather than the previous single component. This modification was introduced to compare the results with the two components found in differential emission measure calculations. With this modification, the light curves of all observed lines are reproduced, in contrast to the single-component applications, which could not reproduce the lines formed at the highest temperatures. This modified light curve analysis technique has been applied to six of the flares modeled by the previous single-component technique. Five of these flares show significantly better fits to the observed fluxes when the two-component technique is applied. The two components exhibit different rates of decay. The temperature and emission measure of the hotter component always decay more rapidly than those of the cool component. This behavior is in agreement with differential emission measure calculations we have performed using the same soft X-ray data. Additional evidence from the two-component light curve model indicates that the isothermal assumption is not strictly valid. The presence of plasma at temperatures intermediate to the derived isothermal components is suggested.

SE-003

DRYER, M. MHD modeling of solar and interplanetary processes. Final Report, AFGL Contracts GLH7-2017 and GLH8-6004, 25 p. (1989).

Our objective has been to use magnetohydrodynamic (MHD) numerical modeling and simulations as tools to understand the physics of energy and momentum transport from the solar surface through the corona to interplanetary space. To achieve this goal, we have first identified possible physical mechanisms and, second, have performed synthesis calculations using self-consistent MHD theory via numerical and analytical methods. Solar and interplanetary (remote-sensing and in situ) observations play important roles in our synthesis strategy. Our models, unique in the field of solar/interplanetary physics, include both 2 1/2-D and 3-D time-dependent codes that, we believe, will lead to future operational status in geomagnetic storm forecasting procedures. Our strategy is oriented toward assuring that real-time observations would be used to drive physically based models, the outputs of which would be considered by space environment forecast-

ers. Following a short Introduction, this Final Report consists of a Summary providing highlights of this research project. A Bibliography of papers, tabulated by first author for easy reference, follows the Summary. The various papers are categorized with a description of their main points and conclusions. A set of representative figures, with extensive descriptive captions, is included for the reader interested in additional details. This work was prepared with partial support from several AFGL project orders to NOAA's Space Environment Laboratory during Fiscal Years 1987 and 1988. This support is acknowledged in each of the Bibliography's 28 papers that are now published, in press, or under consideration in scientific refereed journals and conference proceedings.

SE-004

DRYER, M., T.R. DETMAN, S.T. Wu, and S.M. Han. Three-dimensional, time-dependent MHD simulations of interplanetary plasmoids. Advances in Space Research, 9(4):(4)75-(4)80 (1989).

Plasmoids in the interplanetary medium have been hypothesized for nearly 2 decades by many observers. These suggestions can be classified into two categories: (1) solar-ejected diamagnetic plasmoids that retain their closed, albeit expanding, topology to and beyond Earth; and (2) plasmoids that are formed in the corona near the Sun or in the interplanetary medium as a consequence of reconnection of opposite-directed IMF lines.We present a 3-D MHD, time-dependent simulation of a plasmoid in the first category under the assumption that, before entering the computational domain, the plasmoid already exists at or near the Sun. Also, we present a simulation of a plasmoid in the second category, where a dipolar solar IMF with an initially flat heliospheric current sheet and a representative solar wind is disturbed by a simulated shock wave. Of particular interest is the draping of the IMF about the plasmoid in both examples. Although the shock in the second example propagates across the current sheet with negligible large-scale distortion, the strong transverse pressure gradients behind it apparently cause reconnection and formation of a plasmoid. The code, which has a grid too coarse for examination of kinetic reconnection studies, has both inherent and explicit numerical diffusion that allows reconnection. A fast forward MHD shock precedes the plasmoid as it expands into heliospheric space. We will describe the plasma and magnetic properties of the expanding plasmoid as it moves toward an observer at 1 AU.

SE-005

Dusenbery, P.B., and L.R. Lyons. Ion diffusion coefficients from resonant interactions with broadband turbulence in the magnetotail. Journal of Geophysical Research, 94(A3):2484-2496 (1988).

A potentially important source of hot ions within the central plasma sheet (CPS) is warm plasma sheet boundary layer (PSBL) ions which interact with broadband electrostatic waves and electric field drift toward the CPS. In the PSBL, the local interaction between the waves and particles can be assumed to be unmagnetized. The effect of the magnetic field is to organize wave and particle distributions in velocity space. Under these conditions, particle diffusion is, in general, two-dimensional and is similar to magnetized diffusion. The general quasi-linear equations describing such diffusion are presented assuming that a spectrum of waves is excited similar to the waves observed in the boundary layer. In order to apply the general quasi-linear diffusion coefficients, two particle distribution models are assumed based on PSBL observations. One is for the outer edge and one is for the inner edge of the boundary. An expression for the unmagnetized dielectric function is given and evaluated for wave frequency and growth rate for the assumed particle distribution models. It is found that slow and fast mode ion-sound waves can be unstable for the range of plasma parameters considered. The diffusion coefficients are then evaluated for resonant warm PSBL ion interactions with ion-sound waves. The results illustrate how resonant ion diffusion rates vary with pitch angle and speed, and how the diffusion rates depend upon the distribution of wave energy in k space. For the model of the outer edge of the PSBL, pitch angle diffusion is found to dominate energy diffusion, whereas both types of diffusion can be important for the model of the inner edge of the PSBL. It is found that the characteristic time for resonant warm boundary layer ions to diffuse in velocity space is ~10 min (for a wave electric field of 1 mV/M), which is approximately an ion bounce period. In addition, significant pitch angle and energy diffusion should occur resulting in isotropization of the warm PSBL ion beams to form the hot isotropic ion component in the CPS.

SE-006

Foster, J.C., T. Fuller-Rowell, and D.S. EVANS. Quantitative patterns of large-scale field-aligned currents in the auroral atmosphere. Journal of Geophysical Research, 94(3):2555-2564 (1989).

Quantitative patterns of the distribution of field-aligned current (FAC) density have been derived from gradients of the average patterns of the Hall and Pedersen currents at high latitudes under the assumption that the total current is divergence-free. The horizontal currents were calculated from empirical convection electric field models, derived from Millstone Hill radar observations, and the ionospheric Hall and Pedersen conductances, based on satellite observations of the precipitating particle energy flux and spectrum and including an average (equinox) solar contribution. These independent empirical models, and the resultant patterns of the field-aligned currents, are keyed to an auroral precipitation index which quantifies the intensity and spatial extent of high-latitude particle precipitation and which is determined from a single satellite crossing of the auroral precipitation pattern. The patterns detail the spatial distribution of the currents as a function of increasing disturbance level. The magnitudes of the total single-hemisphere currents into or out of the ionosphere are closely balanced at each activity level and increase exponentially between 0.1 and 6 MA with increasing values of the precipitation index. The interplanetary magnetic field (IMF) sector dependence of the FAC patterns is investigated for disturbed conditions. A large portion of the FAC pattern is closed by local Pedersen currents (current into the ionosphere is balanced by an equal current out of the ionosphere at that local time). This locally balanced portion of the FAC system is enhanced in the prenoon (postnoon) sector for IMF $B_y > +1$ nT ($B_y < -1$ nT). In addition, there are net currents into the ionosphere postnoon and out of the ionosphere in the premidnight sector. Whereas the magnitude of these nighttime net FACs increases with increasing negative IMF B_z, the magnitude and distribution of the net currents appear to be independent of the IMF B_y orientation.

SE-007

Foster, J.C., H.-C. Yeh, J.M. Holt, and D.S. Evans. Two-dimensional mapping of dayside convection. In Electromagnetic Coupling in the Polar Clefts and Caps, P.E. Sandholt and A. Egeland (eds.), Kluwer Academic Publishers, pp. 115-125 (1989).

Millstone Hill radar azimuth scans have been used to map the large-scale features of the ionospheric convection pattern in the vicinity of the cusp and cleft. Each scan covers 5 hours of MLT and 20° of invariant latitude, Λ, with 30 minute temporal resolution. Individual "snapshots" of the convection pattern for disturbed conditions on 31 January 1982 span the entire region of convection convergence near noon and compare favorably with average model representations of the dayside region. The characteristic features of ion and electron precipitation observed during satellite overflights of the radar field of view are used to identify the cusp and cleft and to relate the location of these magnetospheric features to the pattern of ionospheric convection electric field. Cusp precipitation is seen at 70°Λ and 09 MLT and the sunward/anti-sunward convection reversal immediately after a sudden turning of interplanetary magnetic field (IMF) B_y from -5 nT to +5 nT while IMF B_y was -10 nT.

SE-008

Freeman, J.W., Jr., R.A. Wolf, G.-H. Voigt, R.W.Spiro, R.V. Hilmer, J. Shade, and T. Tascione. Project for the development of a magnetospheric specification model. Partial funding provided by NOAA Space Environment Laboratory. In The Effect of the Ionosphere on Communication, Navigation, and Surveillance Systems, J.M. Goodman (ed.), based on Ionospheric Effects Symposium, 5-7 May 1987, National Technical Information Service, Springfield, VA., pp. 331-336 (1988).

We are developing a comprehensive model of the Earth's magnetosphere for operational use by the Air Weather Service and NOAA. The model is designed to specify magnetospheric conditions using real-time data and may also provide very limited forecast capability. The computational system will include models of global magnetic and electric fields, inner-magnetospheric particles, precipitating auroral particles, and upper-atmospheric Joule heating. It will be operated in conjunction with radiation belt and cosmic ray models to be developed by the Los Alamos Scientific Laboratory. A particle-moving algorithm will trace plasma motions in time. The system combines limited theoretical calculations with quantitative rules based on distilled observational and theoretical results to provide a comprehensive description of the magnetosphere that has a

significant degree of self-consistency. It is designed to accept input data from a variety of ground- and space-based sources that are available to the Air Weather Service and NOAA.

SE-009

GARCIA, H.A. The empirical relationship of peak emission measure and temperature to peak flare x-ray flux during Solar Cycle 21. Advances in Space Research, 8(11):(11)157-(11)160 (1988).

Approximately 180 major x-ray flares that occurred between September 1977 and May 1984 have been examined to determine some of the outstanding trends and collective properties that characterize this set of large events. This study concentrates only on the distribution of the maximum emission measure and the distribution of maximum electron temperature with respect to the maximum radiative flux in soft x-rays generated by the flare. Two unusual, but apparently related, phenomena appear to be revealed by these empirical relationships. The first of these is a linear dependence of the lower limit of the log emission measure with respect to the maximum flare x-ray flux. The second is the presence of two events arising from the same active region that prove the exception to the rule. One of these special events produced a thermal temperature of 60 MK.

SE-010

HILDNER, E. Space Environment Laboratory Annual Report, FY 1988. NOAA Special Report (PB89-159602), 41 pp. (1989).

No abstract.

SE-011

HIRMAN, J.W., G.R. HECKMAN, and M.S. GREER. Solar Cycle 22 continues strong climb. EOS, pp. 674 (1989).

No abstract.

SE-012

HIRMAN, J.W., G.R. HECKMAN, M.S.GREER, and J.B. SMITH. Solar and geomagnetic activity during Cycle 21 and implications for Cycle 22. EOS, pp. 962, 792, and 973 (1988).

Old Cycle 21 ended and new Cycle 22 began in September 1986. As measured by its sunspots, the new cycle of solar activity is rising more rapidly than any previous cycle in the records dating back to 1755 A.D. Progress of the new cycle--expected to last about 11 years--is of interest because terrestrial satellite missions and other technical systems are affected by various forms of solar activity; all forms of activity rise more or less in concert with the sunspots of the new cycle. In consequence, the solar output also varies. For example, the slowly varying background ultraviolet flux varies, affecting the density of the terrestrial thermosphere. In turn, satellite drag and radio propagation effects vary. Flares, energetic solar proton events, and geomagnetic storms occur in cycles that begin and end about the same time as the sunspot cycle but do not track it as well as the slowly varying radiation. The exceptionally rapid rise of the new cycle is the basis for prediction of a cycle of record amplitude with smoothed sunspot numbers ~200 and smoothed 10.7-cm solar radio flux ~250, which would equal or exceed the largest cycles of the past. Cycle 19, the largest recorded, peaked in 1958 with a smoothed sunspot number of 201. Methods based on observation of antecedent phenomena in Cycle 21 predict that Cycle 22 will have a large maximum sunspot number well above average but not record equaling. At the present time, there is no consensus regarding which group of predictions is likely to be more valid. Nonetheless, it appears increasingly likely that Cycle 22 will reach a peak sunspot number well above the average of all previous cycles. In another 6-12 months we expect to have a better idea of the maximum yet to come.

SE-013

Hones, E.W., Jr., J.D. Craven, L.A. Frank, D.S. EVANS, and P.T. Newell. The horse-collar aurora: A frequent pattern of the aurora in quiet times. Geophysical Research Letters, 16(1):37-40 (1989).

Reported here are DE 1 auroral imager observations of an auroral configuration which is given the name "horse-collar aurora." The horse-collar pattern comprises the total area of auroral

emissions from a single hemisphere and derives its name from the shape of the emitting area. The pattern is found in images recorded during quiet geomagnetic conditions and is possibly related to the theta aurora, another quiet time configuration of the auroras. This initial report of the DE 1 observations illustrates the horse-collar aurora with a 2-hour image sequence that displays its basic features and shows an example of its evolution into a theta-like auroral pattern. The interplanetary magnetic field was northward during this image sequence and there is some evidence for IMF B_y influence on the temporal development of the horse-collar pattern. A preliminary statistical analysis found the horse-collar pattern appearing in one-third or more of image sequences recorded during quiet conditions; it did not appear during disturbed conditions. Further study is required to establish more fully the characteristics of the horse-collar aurora and to determine its implications concerning solar wind-magnetosphere coupling when the IMF B_z is northward.

SE-014

JOSELYN, J.A. Geomagnetic quiet day selection. In Pure and Applied Geophysics (PAGEOPH), Vol. 31, No. 3, pp. 333-341, Birkhauser Verlag, Basel (1989).

Based on published literature and the response to a questionnaire sent to geomagnetic field, ionospheric, and magnetospheric researchers, several methods of choosing periods of quiet conditions based on geomagnetic records, as well as other observed parameters, have been identified. Caveats with respect to using geomagnetic indices to select quiet periods include the following: 1. Geomagnetic disturbances are strongly local. Even if the data from all available observatories indicate quiet behavior, there is the distinct possibility that some other location, not sampled, may be disturbed. 2. Geomagnetic indices are convenient but imperfect indicators of geomagnetic activity. Indices based on a quiet-day reference level have uncertainties comparable to the threshold value for quiet conditions. Indices representing average conditions during a 24-hr UT day may not be appropriate. 3. Geomagnetic activity does not fully reflect the range of possible factors that influence the ionosphere or magnetosphere.

SE-015

JOSELYN, J.A., J.A. Flueck, and T. Brown. Geomagnetic climatology. Annales Geophysicae 6(6):595-600 (1988).

The categorization of typical behavior in tropospheric weather, sometimes termed climatology, provides useful information for predicting the typical future. At the Space Environment Services Center (SESC), the geomagnetic 3-hourly K and daily A indices are forecast for Fredericksburg, Virginia, and College, Alaska. The K-index histories (or climatologies) for both of these locations were recently tabulated for a 29-year period (1957-1985). The results show that at Fredericksburg, a middle-latitude station, the prevailing geomagnetic condition is quiet with little diurnal variation. But at College, a high-geomagnetic-latitude station, a strong diurnal variation is seen with K-index values of 5 or more present 30% of the time between 0900 and 1500 UT (approximately 0000-0300 local time). Furthermore, a seasonal variation is evident when the monthly data are filtered. The high K-index values show the expected semiannual variation peaking at the equinoxes, but the low K-index values show, at best, only an annual variation. Finally, plots of the percent of occurrence of each K-index value over the 29 years do not correlate well with the sunspot cycle; phase shifts and variations of about 8 years in length are evident.

SE-016

Li, X.-Q., and S.T. Wu, Resistive and eruptive instability by pondermotive force with high-frequency plasma oscillations. In Laboratory and Space Plasmas, Proceedings of the Second International Workshop on the Relation Between Laboratory and Space Plasmas, Tokyo, Japan, November 25-26, 1986, H. Kikuchi (ed.), NOAA Contract 50RANR700099, Springer-Verlag, New York, pp. 239-265 (1989).

In this paper we investigated the subtle interaction between the magnetohydrodynamic (MHD) and high-frequency plasma waves and we derived the coupling equations for these phenomena. On the basis of this formalism, we examined the modulation instabilities by an electromagnetic soliton in a current sheet and showed that there is a resistive instability for constant-f approximation

(i.e., uniform magnetic field configuration),which eventually turns into an eruptive instability at the onset of the magnetic field reconnection.

SE-017

Martin, R.F., Jr., and T.W. SPEISER. A predicted energetic ion signature of a neutral line in the geomagnetic tail. Journal of Geophysical Research, 93(A10):11,521-11,526 (1988).

Under certain assumptions one can predict the formation of a magnetic neutral line on theoretical grounds, generally as a result of an unstable current sheet. Neutral points also seem to form spontaneously in a wide variety of plasma simulations, from MHD to fully kinetic. Hence such magnetic null regions are central to some models of magnetotail energization and magnetic substorms. Yet the observational evidence for such regions remains controversial. In this paper we present a new signature of a neutral line: the field-aligned ion beam characteristic of current sheet acceleration becomes dispersed into a "ridge" in the velocity space distribution function as a neutral line is approached. The results were obtained using single-particle simulations in a fixed magnetic field model. The origin of the ridge is shown to be due to initially earthward going ions which pass through the neutral line region. These ions come from a smaller part of the initially antiearthward flowing distribution, generating the depletion of the distribution function below the ridge.

SE-018

Marquette, W.H., and S.F. Martin. Long-term evolution of a high-latitude active region, NOAA Contract 50RANR600012, Solar Physics, 117:227-241, (1988).

We describe the decay phase of one of the largest active regions of solar cycle 22 that developed by the end of June 1987. The center of both polarities of the magnetic fields of the region systematically shifted north and poleward throughout the decay phase. In addition, a substantial fraction of the trailing magnetic fields migrated equatorward and south of the leading, negative fields. The result of this migration was the apparent rotation of the magnetic axis of the region such that a majority of the leading polarity advanced poleward at a faster rate than the trailing polarity. As a consequence, this region could not contribute to the anticipated reversal of the polar field. The relative motions of the sunspots in this active region were also noteworthy. The largest, leading, negative polarity sunspot at N 24 exhibited a slightly slower-than-average solar rotation rate equivalent to the mean differential rotation rate at N 25. In contrast, the westernmost, leading, negative polarity sunspot at N21 consistently advanced further westward at a mean rate of o.13 km s^{-1} with respect to the mean differential rotation rate at its latitude. These sunspot motions and the pattern of evolution of the magnetic fields of the whole region constitute evidence of the existence of a large-scale velocity field within the active region.

SE-019

McINTOSH, P.S., and H. LEINBACH. Watching the premier star. Sky and Telescope, November, 468-471 (1988).

No abstract.

SE-020

Michels, D.J., R. Schwenn, R.A. Howard, J.-D.F. Bartoe, S.K. Antiochos, G.E. Brueckner, C.-C. Cheng, K.P. Dere, G.A. Doschek, J.T. Mariska, N.R. Sheeley, Jr., D.G. Socker, P.W. Daly, B. Inhester, H.U. Keller, J.R. Kramm, H. Rosenbauer, P. Lamy, A. Llebaria, A. Maucherat, E.N. Parker, S.W. Kahler, S.L. Koutchmy, R.N. Smartt, W.J. WAGNER, J.-L. Bougeret, M. Pick, J.-C. Noens, R.H. Giese, M.J. Koomen, F. Giovane, N.Y. Misconi, G.M. Simnett, C. Eyles, D. Bedford, E. Priest, R. Lallement. `LASCO'-- A Wide-Field White-Light and Spectrometric Coronagraph for SOHO. In The SOHO Mission: Scientific and Technical Aspects of the Instruments (ESA SP-1004), pp. 55-61 (1989).

Panoramic images from the LASCO coronagraph will provide electron column densities from just above the limb, at 1.1 $R_{\odot}$, out into deep heliospheric space, at 30$_{\odot}$. In the inner portion, the corona will be analyzed spectroscopically by a high-resolution scanning, imaging interferometer. The spectral profiles of three emission lines and one Fraunhofer line will be measured for each picture point, giving temperatures, velocities, turbulent motions, and volume densities. Polar-

ization analysis will yield the direction of coronal magnetic fields. Scientific objectives include investigation of mechanisms for heating of the corona and acceleration of the solar wind, causes of coronal transients, and their role in development of large scale coronal patterns and interplanetary disturbances. The distribution and properties of dust particles, including those released from sun-grazing comments, will also be investigated, and interactions of coronal plasma with the dust.

SE-021

Osherovich, V.A. The equilibrium of the solar prominence in the external magnetic field. In Proceedings of Workshop on Dynamics and Structure of Solar Prominences, 18-20 November 1987, Palma de Mallorca, Spain, pp. 117-124 (1988).

The equilibrium of a solar prominence is treated analytically. For the internal structure, we require the magnetic field to be continuous and to have finite magnetic energy per unit length of the filament. This requirement leads to a solar prominence model based on eigenvalue solutions. The set of exact magnetohydrostatic solutions describes topologically different magnetic configurations. The external field can re-distribute plasma density excess or depletion.

SE-022

Osherovich, V.A. The physical nature of the upper subsidiary diffuse resonances. Journal of Geophysical Research, 94(A5):5530-5532 (1989).

The upper subsidiary diffuse resonances were first observed in the ionosphere in the Alouette 2 topside sounder experiment, later by the ISIS 1 satellite, and then by the JIKIKEN (EXOS B) satellite during its electron injection experiment. The frequencies of the subsidiary resonances are just higher than those of the diffuse resonances D_n (n = 1, 2, 3, 4). In our work we identify the upper subsidiary diffuse resonance as a hybrid resonance of the diffuse and cyclotron resonances. The corresponding frequencies are $f_{T,D_n} = (f^2_{D_n} + f^2_H)^{1/2}$, n = 1, 2, 3, 4 ..., where f_{T,D_n} is the observed frequency of the upper subsidiary diffuse resonance, f_{D_n} is the frequency of the nth diffuse resonance, and f_H is the electron gyrofrequency.

SE-023

Osherovich, V.A. Solar prominence model based on eigenvalue solutions. II. Filaments in the vertical magnetic fields. The Astrophysical Journal, 336:1041-1049 (1989).

An eigenvalue approach is employed to study the equilibrium of a solar filament in a stratified atmosphere with a vertical magnetic field. It is shown that the external vertical magnetic field can redistribute plasma density and create the positive density excess or negative density excess (cavity) above the prominence, depending on the relative width and the relative strength of the filament's magnetic field.

SE-024

Osherovich, V.A., and H.A. GARCIA. The relationship of sunspot magnetic fields to umbral sizes in return flux theory. The Astrophysical Journal, 336:468-474 (1989).

We study the relationship between the relative size of a sunspot umbra and the relative magnitude of the magnetic field at the outer edge of the penumbra. This analysis is based on the theory of return flux of round, unipolar sunspots. The essential result is that small umbrae or, equivalently, large penumbrae (relative to the total sunspot area) are associated with large relative magnetic return flux and with large total magnetic fields at the outer penumbral boundary. Observationally, we present data from 12 unipolar and approximately round sunspots containing two-component magnetic field measurements as well as umbral/penumbral size ratios. These data were compiled from the published papers of several authors, employing various methods for the magnetic field measurements. One of the main characteristics of all these sunspots is that the magnetic field at the outer penumbral boundary is close to horizontal. These observations compare well with our theoretical predictions. We suggest, therefore, that the size ratio of um-

bra to penumbra or, equivalently, the ratio of return magnetic flux to total magnetic flux, should be used as the main parameter in the classification of unipolar sunspots.

SE-025

Osherovich, V.A., and E.B. Gliner. Force-free electromagnetic waves. Solar Physics 117:391-397 (1988).

The time-dependent Force-Free Electromagnetic Field (FFEMF) is studied. In contrast to the case of Force-Free Magnetic Field (FFMF), it is shown that the FFEMF can occur in the form of waves. The FFEMF wave equation is solved in the case of one spatial dimension. Besides a periodical linear FFEMF wave solution, the existence of solitary wave solutions is demonstrated. The possible application of FFEMF solutions to solar flares is discussed.

SE-026

Rosenthal, D.A., and J.W. HIRMAN. A user's guide to the Space Environment Services Center geophysical alert broadcasts. NOAA Technical Memorandum ERL SEL-79 (PB89-194617), 15 pp. (1989).

Intended for users with little or no scientific background as well as highly technical readers, the User's Guide provides an overview of the National Oceanic & Atmospheric Administration's hourly short-wave radio bulletins that provide continually updated information on solar-activity-induced effects on the near-Earth space environment. It also provides a step-by-step explanation of the standardized format and terminology of the bulletins. Specific terms are highlighted and defined in a glossary. Bulletins are 45 seconds or less in duration and contain a large amount of useful data. Until now, no attempt has been made to provide a systematic method of their use by other than highly technically trained listeners.

SE-027

RUSH, C., M. Fox, D. Bilitza, K. DAVIES, L. McNamara, F. STEWART, and M. POKEMPNER. Ionospheric mapping: an update of foF2 coefficients. Telecommunication Journal 56(III):179-182 (1989).

No abstract.

SE-028

SAUER, H. H., SEL monitoring of the Earth's energetic particle radiation environment. In AIP Conference Proceedings 186: High-Energy Radiation Background in Space, Sanibel Island, Florida, 1987, R. G. Lerner (ed.), American Institute of Physics, New York, pp. 216-221 (1989).

The Space Environment Laboratory (SEL) of the National Oceanic and Atmospheric Administration (NOAA) maintains instruments on board the GOES series of geostationary satellites, and aboard the NOAA/TIROS series of low-altitude, polar-orbiting satellites, which provide monitoring of the energetic particle radiation environment as well as monitoring the geostationary magnetic field and the solar x-ray flux. The data are used by the SEL Space Environment Services Center (SESC) to help provide real-time monitoring and forecasting of the state of the near earth environment and its disturbances, and to maintain a source of reliable information to research and operational activities of a variety of users. The data, data sources, and products relevant to the characterization of the near-earth radiation environment and its response to solar cosmic ray events are briefly described, as are the laboratory's archives and uses of these data.

SE-029

SHAW, D. THEOPHRASTUS. In Fourth Annual Rocky Mountain Conference on Artificial Intelligence: Augmenting Human Intellect by Computer, June 8-9, 1989, Denver, Colorado, J.H. Alexander (ed.), pp. 7-17 (1989).

The design of a system to perform a given complex task may proceed along many paths. This paper describes the task of solar flare forecasting, and the "traditional" expert system designed to accomplish this task. Emphasis is placed on describing the complexity and limitations of cur-

rent knowledge in the domain, and the associated strengths and weaknesses of the expert system approach.

SE-030

SHAW, D, and R. GRUBB. The scientist's workbench. In proceedings of Fourth Annual Rocky Mountain Conference on Artificial Intelligence: Augmenting Human Intellect by Computer, June 8-9, 1989, Denver, Colorado, J.H. Alexander (ed.), pp.241-247 (1989).

A heterogeneous scientific computing environment, containing many types of computing devices, interfaces, data structures, and languages, presents formidable problems to the casual user. This paper describes an attempt to ease the user's burden by fostering the concept of "generic" computing resources. The method revolves around the notion of a local "standard" interface.

SE-031

Song, M.T., S.T. Wu, and M. DRYER. Soliton and strong Langmuir turbulence in solar flare processes. Astrophysics and Space Science, 152:287-311 (1989).

The occurrence of modulational instablity in the current sheet is investigated. Particular attention is drawn to the plasma micro-instability in this current sheet (i.e., the diffusion region) and its relation to the flare process. It is found that the solitons or strong Langmuir turbulence is likely to occur in the diffusion region under solar flare conditions in which the electric resistivity could be greatly enhanced by several orders of magnitude in this diffusion region. The result is a significant heating and stochastic acceleration of particles. Physically, the occurrence of soliton and strong Langmuir turbulence can be identified with a sudden eruption of an electric current leading to a local vacuum in which an electric potential is formed and results in the release of a huge amount of free energy. A numerical example is used to demonstrate the transition of the magnetic field, velocity, and plasma density from the outer MHD region into the diffusive (resistive) region and, then, back out again with the completion of the energy conversion process. This is all made possible by an increase of resistivity by 4-5 orders of magnitude over the classical value.

SE-032

Tappin, S.J., M. DRYER, S.M. Han, and S.T. Wu. Expected IPS variations due to a disturbance described by a 3-D MHD model. Planetary and Space Science, 36(11):1155-1163 (1988).

The variations of interplanetary scintillation due to a disturbance described by a three-dimensional, time-dependent, magnetohydrodynamical (MHD) model of the interplanetary medium are calculated. The resulting simulated IPS maps are compared with observations of real disturbances and it is found that there is some qualitative agreement. We are able to conclude that the MHD model with a more realistic choice of input conditions would probably provide a useful description of many interplanetary disturbances.

SE-033

Thomas, V.L., and R.D. ZWICKL. Network communities to merge. Information Systems Newsletter, April, p. 20 (1989).

No abstract.

SE-034

WAGNER, W.J. EUV monitoring and geomagnetic storm forecasts using the USAF-NOAA Solar X-Ray Imagers (SXI). In Proceedings of the Atmospheric Neutral Density Specialist Conference, Colorado Springs, CO, March 22-23, 1988, pp. 241-249 (1989).

Neutral atmosphere density models will require continuous real-time information. The histories and prognoses from data on radiant extreme ultraviolet (EUV) solar flux and geomagnetic storm heating are needed for advancing these operational models beyond mere climatology. The USAF-NOAA Solar X-Ray Imagers (SXI) will be providing these data in the 1990s.

SE-035

WAGNER, W.J. Observations of 1-8 $\mathring{A}$ solar X-ray variability during Solar Cycle 21. Advances in Space Research 8(7):(7)67-(7)76 (1988).

One of the goals of the Solar Electromagnetic Radiation Flux Study (SERFS) for the World Ionospheric-Thermospheric Study (WITS) is to provide a more complete record of the variation of

the daily 1-8 $\mathring{A}$ solar soft X-ray flux. As part of this study, I will calculate the daily mean and the daily background X-ray fluxes. The background fluxes, which I present in this paper, should be indicators of the quiescent X-ray flux principally from active regions. In contrast to this daily background flux, the daily mean flux includes the variable emissions from flares and coronal mass ejections. Although the present study uses 15 years of data from the NOAA Geostationary Operational Satellites (GOES) for 1974 to 1988, the inclusion of Solar Radiation (SOLRAD) data could extend this type of analysis back to 1964. In this paper, daily background X-ray fluxes in the form of monthly averages and annually smoothed (13-month) values are presented for Solar Cycle 21. Intermediate term variations (on the scale of months) of the 1-8 $\mathring{A}$ background flux roughly mimic those of other chromospheric and coronal indices such as Ca K, Helium 10830 $\mathring{A}$, and 10-cm radio flux. The annually smoothed daily background X-ray flux was unique in peaking the latest and in showing no broad maximum. This annually smoothed behavior is best matched by photospheric white-light facular areas. I also discuss anticipated future developments in soft X-ray monitoring. These include a new series of full-Sun soft X-ray photometers on the non-spinning GOES I-M. Also on GOES will be the operational USAF-NOAA Solar X-ray Imagers measuring the 8-20 $\mathring{A}$, the 20-60 $\mathring{A}$, and the thermospherically crucial 255-300 $\mathring{A}$ bands. Nevertheless, this report and that of /1/ both note the continuing existence of an "XUV flux measurement gap," with no long-term monitoring being planned between the soft X-ray region and the Lyman-alpha wavelengths.

SE-036

Wu, S.T., M. DRYER, S.M. Han. Three-dimensional, time-dependent MHD simulation of travelling interplanetary phenomena with solar origin. In Proceedings of the Third International School for Space Simulation, ISSS-3, Part 2, Beaulieu, France, June 22-27, 1987, pp. 235-238 (1988).

A three-dimensional, time-dependent magnetohydrodynamic (MHD) numerical model was developed for the study of travelling solar-interplanetary disturbances. This simulation model is based on the Lax-Wendroff finite difference scheme. the initial steady-state solar wind is assumed to be super-sonic and super-alfvenic. The background two-dimensional steady-state solar wind is obtained by dropping the time-dependent terms in the unsteady MHD equations. Transient MHD disturbances corresponding to the solar flare-generated shocks are generated at the lower radial boundary surface. The resulting development and propagation of three-dimensional solar disturbances interacting with the background solar wind are numerically simulated. A brief description of the mathematical formulation and numerical methodology is presented. Simulation results are shown to demonstrate the validity of the formulation and the capabilities of the model.

SE-037

Wu, S.T., M. DRYER, R.S. Steinolfson, and E.Tandberg-Hanssen. The effect of the solenoidal condition on the numerical magnetohydrodynamic simulation of coronal dynamics. The Astrophysical Journal, 333:386-394 (1988).

Several magnetohydrodynamic (MHD) simulations of coronal dynamics performed by our group more than 10 years ago violated the solenoidality condition ($\nabla \cdot B = 0$) for an "open" magnetic field topology. Using an improved code, we examine the effect on the physical validity of the numerical simulation (for a representative pulse disturbance) for the case when solenoidality is deliberately violated as compared to the case when it is preserved. We find that the error incurred in this specific case ("open" topology) in the energy density and in the plasma density profiles is rather small and, hence, does not invalidate the earlier conclusions concerning mass and wave motion.

SE-038

Wu, S.T., S. Wang, A.H. Wang, and M. DRYER. Application of similitude principle to the numerical simulation of solar atmospheric dynamics. Advances in Space Research, 8(11):221-226 (1988).

Numerical simulation has become a tool for the investigation of detailed physical structures of solar atmospheric dynamics. This tool has become an essential part of solar physics because the complexity of nonlinear characteristics of much solar phenomena renders the achievement of analytical solutions to be difficult to obtain. Although computer technology and numerical methods have made significant progress in recent years, realistic simulation for some prototype physical systems (for example: the birth and decay of an active region) still is not possible

because of the wide range of spatial and time scales that must be considered. Therefore, proper scaling rules must be recognized for the development of appropriate models. In this paper, we shall apply the similitude principle to develop these scaling rules for problems of solar atmospheric dynamics. It is found that these rules are highly dependent on the physical nature of the specific problem under consideration. A set of "similitude critiques" is presented for some specific physical conditions. Numerical examples of coronal dynamic response and active region dynamics are used to demonstrate these new ideas.

SE-039

Yeh, T. Flux rope dynamics for loop prominences, coronal mass ejections, and interplanetary magnetic clouds. In Solar System Plasma Physics, J.H. Waite, Jr., J.L. Burch, and R.L. Moore (eds.), American Geophysical Union, pp. 299-301 (1989).

No abstract.

SE-040

ZWICKL, R.D., and V.L.Thomas. SPAN: Riding the winds of change. EOS, 70, p. 194 (1989).

No abstract.

WAVE PROPAGATION LABORATORY

WP-001

Boe, B.A., P.L. Smith, H.D. Orville, N.C. Knight, M. Hjelmfelt, D.S. Griffith, J.L. Stith, and R.F. REINKING. North Dakota Thunderstorm Project Field Operations Plan, May, 1989. 75 pp.

No abstract.

WP-002

BEDARD, A.J. A review of the evidence for strong, small-scale vertical flows during down slope wind storms. Proceedings, 6th U.S. National Conference on Wind Engineering, Houston, TX, 8-10 March 1989, National Science Foundation, Washington, D.C., A1, 11-19 (1989).

During downslope windstorms, damage can occur on quite small scales. In the foothills near Boulder, Colorado, individual trees or lines of trees may be uprooted or snapped off with little or no damage to surrounding vegetation. Also, considerable damage can occur to individual structures with no primary damage occurring nearby. Often debris will be scattered in directions different from that of the mean flow. This paper reviews evidence for the existence of vertical motions and other small-scale features associated with downslope windstorms. Possible mechanisms for producing such organized regions of small-scale vorticity are suggested.

WP-003

BEDARD, A.J. Acoustic propagation in the atmosphere at low frequencies: measurement techniques and observations. Proceedings, 12th Aeroacoustic Conference, San Antonio, TX, 10-12 April 1989, American Institute of Aeronautics and Astronautics, Washington, D.C., 1108-1115 (1989).

We have measured low-frequency sounds related to aircraft, meteors, and other sources at long distances. At infrasonic frequencies (below about 20 Hz) atmospheric attenuation is low, permitting long distance propagation. The acoustic energy detected from meteors may be valuable not only for characterizing meteor details, but also for improving our knowledge of propagation. As an example we have detected a signal associated with a meteor about 1,000 km distant from the measurement site. This paper reviews measurement techniques and provides examples of atmospheric waves detected from distant sources. There is a need to develop methods for the measurement of low-frequency sounds over well-defined propagation paths. The possibilities for doing this are discussed. These include the use of Radar Acoustic Sounding Systems (RASS) for propagation studies. The design goal of RASS is to retrieve atmospheric temperature profiles. One by-product is information on the attenuation of acoustic waves in a well-defined atmosphere.

WP-004

BEDARD, A.J., J.C. KAIMAL, and H. Zimmerman. Environmental monitoring techniques: An overview. Proceedings, Sensors Expo West, Anaheim, CA, 23-25 May 1989, Sensors Mag., Peterborough, NH, 301A, 1-7 (1989).

No abstract.

WP-005

Chelton, D., E.J. WALSH, and J.L. MacArthur. Pulse compression and sea level tracking in satellite altimetry. Journal of Applied Meteorology, 14:407-438 (1989).

With the presently operational altimeter on the U.S. Navy satellite GEOSAT, and three new altimeters soon to be launched by the European, French and U.S. space agencies, satellite altimetry promises to become a standard technique for studying oceanographic variability. Little has been written about the instrumental technique used to determine sea surface height from altimetric measurements. In this paper, we summarize the pulse-compression technique by which a radar altimeter transmits a relatively long pulse and processes the returned signal in a way that is equivalent to transmitting a very short pulse and measuring the time history of the returned power in a sequence of range gates. The effective short pulse enhances the range resolution that would be obtained from the actual long pulse. The method used onboard the satellite to track the point on the returned signal corresponding to the range to mean sea level (spatially averaged over the altimeter footprint) is also summarized. Pulse compression and sea level tracking are important to the overall error budget for altimetric estimates of sea level. The dominant sources of sea level tracking errors are discussed.

WP-006

CHRISTIAN, T., and R.M. Wakimoto. The relationship between radar reflectivities and clouds associated with horizontal roll convection on 8 August 1982. Monthly Weather Review, 117:1529-1544 (1989).

Horizontal convective rolls (HCRs) and cloudstreets that occurred in northeastern Colorado are studied using Doppler radar data, cloud photography, and vertical soundings. Examination of the environment in which the HCRs form indicates a boundary layer wind speed that is much lower than those measured in previous studies. Evidence shows that the HCRs form in a well-defined boundary layer, yet the cloudstreets that develop seem to exist within a stable layer above. A relationship between the radar reflectivity echoes and the cloudstreets is firmly established. The echoes are aligned directly under the cloudstreets. The echoes at lower-levels are shown to be caused by convergence of particulate matter into updraft portions of the HCR circulation, yet evidence indicates the cloud-level echoes are due to backscatter from refractive index inhomogeneities at the surfaces of rising thermals. Examination of the echoes show that the strongest and tallest echoes are associated with cloud formation, and that echo maxima, spaced 3.0 to 8.0 km apart, exist along the HCR.

WP-007

CHRISTIAN, T., and R.M. Wakimoto. The relationship between radar reflectivities and clouds associated with horizontal convective rolls. Preprints, 24th Conference on Radar Meteorology, 27-31 March 1989, Tallahassee, FL, American Meteorological Society, Boston, MA, 42-45 (1989).

No abstract.

WP-008

CHURNSIDE, J.H. Angle-of-arrival fluctuations of retroreflected light in the turbulent atmosphere. Journal of the Optical Society of America, 3:275-279 (1989).

A geometrical-optics formulation is used to derive expressions for the angle-of-arrival variance produced when a retroreflector is illuminated and observed through the turbulent atmosphere. No fluctuations are observed when the retroreflector is illuminated by collimated or focused light. Light focused at a distance near twice the reflector range can produce large fluctuations, whereas diverging illumination tends to produce a variance that is less than that which would be observed on the transmitted beam at the reflector.

WP-009

CHURNSIDE, J.H., and S.F. CLIFFORD. Optical scintillometer/Doppler radar instrument for profiling turbulence. Proceedings, SPIE 1989 Technical Symposia on Aerospace Sensing, Orlando, FL, 28-30 March 1989, SPIE, Bellingham, WA, 159-166 (1989).

The scintillation of starlight contains information about the refractive turbulence strength C_n^2 in the atmosphere. The fluctuations to each two-dimensional spatial wavenumber in the scintillation pattern are caused by turbulent features that have the same two-dimensional wavenumber. Therefore, a receiver that spatially filters the scintillations in starlight can measure the amount of turbulence in the atmosphewre in a narrow band of wavenumbers. If the entire atmosphere were moving with constant velocity, the dominant wavenumber would produce a constant frequency as the turbulence moved across the filer. However, wind velocity typically varies with altitude and turbuelnce at different altitudes will produce different frequencies. If the wind velocity profile is known, the vertical profile of C_n^2 can be inferred from the frequency distribution of scintillations at a particular wavenumber.

WP-010

CHURNSIDE, J.H., AND S.F. CLIFFORD. Refractive turbulence profiling using stellar scintillation and radar wind profiles. Applied Optics, 27:4884-4890 (1988).

The fluctuations of spatially filtered starlight contain information about refractive turbulence strength C_n^2 at the spatial filter wavenumber. If the turbulence at different heights in the atmosphere is moving at different speeds, the contribution to the fluctuations from those heights will occur at different frequencies. Therefore, the C_n^2 profile can be inferred from the power spectrum of the fluctuations and the wind velocity profile. Vertical resolution is expected to be in the range of several hundred meters to about a kilometer. Turbulence strength measurements to better than 50% should be easily obtainable.

WP-011

CHURNSIDE, J.H., R.J. LATAITIS, and L.C. Huff. A theoretical and experimental investigation into turbulence effects on the rapid precision leveling system (RPLS) dispersion subsystem. NOAA TM ERL WPL-168, 65 pp. (1989).

We have calculated and measured the effects of refractive turbulence on a two-color dispersion technique for compensating for refraction in the Rapid Precision Leveling System. We found that turbulence introduced a large amount of scatter in plots of optical angle-of-arrival vs. a point measurement of temperature gradient, especially under stable atmospheric conditions. We found that low-frequency fluctuations could be largely corrected using dispersion. This implies averaging times longer than the inverse of this ratio must be used to obtain accurate measurements.

WP-012

CHURNSIDE, J.H., and R.J. LATAITIS. Probability density function of optical scintillations (scintillation distribution). NOAA TM ERL WPL-169, 40 pp. (1989).

The probability density function of optical scintillation in the turbulent atmosphere is investigated theoretically and experimentally. The log-normally modulated Rician (LR) is the best available model for these fluctuations. For large apertures, this model reduces to a simple log-normal density function, which can be used under most practical situations.

WP-013

CHURNSIDE, J.H., and R.J. LATAITIS. Statistics of a reflected laser beam in the turbulent atmosphere (path correlation). NOAA TM ERL WPL-172, 86 pp. (1989).

The statistics of the angle of arrival and of the irradiance of a reflected laser beam in the turbulent atmosphere are calculated. The angle-of-arrival fluctuations of a reflected beam depend strongly on the reflector characteristics; convex surfaces produce smaller fluctuations than concave surfaces do. The irradiance fluctuations on a path folded by a "large" reflector are generally larger than those that would be observed on a single path of the same total length.

WP-014

CHURNSIDE, J.H , and K. Shaik. Atmospheric propagation issues relevant to optical communications. NOAA TM ERL WPL-159, 51 pp. (1989).

Atmospheric propagation issues relevant to space-to-ground optical communications for near-Earth applications are studied. Propagation effects, current optical communication activities, potential applications, and communication techniques are surveyed. It is concluded that a direct-detection space-to-ground link using redundant receiver sites and temporal encoding is likely to be employed to transmit Earth-sensing satellite data to the ground some time in the future. Low-level, long-term studies of link availability, fading statistics, and turbulence climatology are recommended to support this type of application.

WP-015

Ciotti, P., G. Schiavon, D. Solimini, P. Tognolatti, and E.R. WESTWATER. Preliminary observations of atmospheric brightness temperature fluctuations at two microwave frequencies. Chapter in Microwave Radiometry and Remote Sensing Applications, P. Pampaloni, ed., VSP, Utrecht, Netherlands, 207-214 (1989).

No abstract.

WP-016

Ciotti, P., G. Schiavon, D. Solimini, P. Tognolatti, and E.R. WESTWATER. The Microwave Radiometric Profiler in Integrated Atmospheric Remote Sensing Systems. Chapter in Microwave Radiometry and Remote Sensing Applications, P. Pampaloni, ed., VSP, Utrecht, Netherlands, 179-194 (1989).

No abstract.

WP-017

Coakley, J.A., and J.B. SNIDER. Observed cloud reflectivities and liquid water paths--An update. Extended Abstracts, FIRE Science Meeting, Monterey, CA, 10-14 July 1989, NASA Langley, 63-66 (1989).

No abstract.

WP-018

Coakley, J.A., and J.B. SNIDER. Observed reflectivities and liquid water content for marine stratocumulus. Extended Abstracts, Symposium on the Role of Clouds in Atmospheric Chemistry and Global Climate, Anaheim, CA, 30 January-03 February 1989, American Meteorological Society, Boston, MA, 175-177 (1989).

No abstract.

WP-019

DERR, V.E., R.S. Stone, and L.S. FEDOR. Sensitivity of solar attenuation by continental stratus clouds to water and ice content, and cloud albedo. Proceedings, International Radiation Symposium, Lille, France, 18-24 August 1988, A. Deepak Publishing Co., Hampton, VA, 26-29 (1989).

An evaluation of the effects clouds have on climate depends on determining their radiative properties that are sensitive to variations in their physical and microphysical characteristics. Cloud cover, thickness, dropsize distributions and ice or water content vary spatially and temporally making it difficult to calculate theoretically cloud radiative effects. Thus, there is a need for simple empirical parameterizations to simulate cloud radiative interactions in global climate models. In this paper we present a simple parameterization of cloud transmissivity as a function of integrated liquid water content and solar zenith angle for continental stratus water clouds.

WP-020

Doran, J.C., M.L. Wesely, R.T. McMillen, and W.D. NEFF. Measurements of turbulent heat and momentum fluxes in a mountain valley. Journal of Applied Meteorology, 28:438 (1989).

Measurements of heat and momentum fluxes along the valley floor of Brush Creek in Colorado are described. The measurements were taken in the fall of 1984 as part of the Department of Energy's Atmospheric Studies in Complex Terrain field program. The sensible heat flux to the ground decreased from approximately 40-60 Wm^{-2} prior to midnight to about 10-25 Wm^{-2} in the morning hours. Surface friction velocities μ_* ranged from approximately 20-15 cms^{-1} during the corresponding time periods. Considerable site-to-site variability in flux values was found, and disturbances of the upwind flow appear to be a significant contributing cause.

WP-021

EBERHARD, W.L. Doppler lidar measurement of profiles of turbulence and momentum flux. Journal of Atmospheric and Oceanic Technology, 6:809-819 (1989).

A short-pulse C_n^2 Doppler lidar with 150-m range resolution measured vertical profiles of turbulence and momentum flux. Example measurements are reported of a daytime mixed layer with strong mechanical mixing caused by a wind speed of 15 ms^{-1}, which exceeded the speed above the capping inversion. The lidar adapted an azimuth scanning technique previously demonstrated by radar. Scans alternating between two elevation angles allow determination of $<u^2>$, $>v^2>$, and $<w^2>$. Expressions were derived to estimate the uncertainty in the turbulence parameters. A new processing method, partial Fourier decomposition, has less uncertainty than the filtering used earlier. Substantial improvements could be had with higher pulse rate, shorter pulses and wavelengths (to improve spatial resolution and minimum range by up to an order of magnitude), and operation from an aircraft.

WP-022

EBERHARD, W.L. Doppler lidar observations of urban particulate pollution and meteorology. Proceedings, 5th Conference on Coherent Laser Radar: Technology and Application, Munich, Federal Republic of Germany, 5-9 June 1989, German Aerospace Research Establishment, Wessling, Federal Republic of Germany, 15-18 (1989).

No abstract.

WP-023

EBERHARD, W.L. Lidar detection and discrimination of multiple fluorescent tracers possessing distinctive spectral characteristics. Preprint, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 29 January-3 February 1989, American Meteorological Society, Boston, MA, 128-131 (1989).

No abstract.

WP-024

EBERHARD, W.L., R.E. CUPP, and W.D. NEFF. Wind fields and aerosol distributions in the Denver Brown Cloud observed by CO_2 Doppler lidar. Preprints, Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 117-119 (1989).

No abstract.

WP-025

EBERHARD, W.L. and Z.Z. Chen. Lidar discrimination of multiple fluorescent tracers of atmospheric motions. Applied Optics, 28:2996-3007 (1989).

An analytical study demonstrates the feasibility of simultaneous lidar measurement and discrimination of multiple fluorescent particle tracers of air motions. Equations are presented for evaluating signal-to-noise ratio and interfering signals. Matrix methods can solve for the concentrations of several tracers from simultaneous measurements in at least as many spectral receiver channels, even when fluorescence spectra overlap. Two example systems, one with crosstalk and another without, are evaluated for accuracy in the presence of shot noise and calibration errors. Potential applications include observing the structure of complex flows and measuring the effect of release location on atmospheric transport and dispersion.

WP-026

EBERHARD, W.L., and Z.Z. Chen. Lidar technique for measuring multiple fluorescent tracers of atmospheric motions. NOAA TM ERL WPL-171, 60 pp. (1989).

An analytical study demonstrates the feasibility of simultaneous lidar measurement and discrimination of multiple fluorescent tracers of air motions. Past work on single tracers is reviewed, and laboratory measurements of some candidates' fluorescence spectra are reported. The characteristics of fluorescent materials, lidar components, and potential interfering signals are summarized. Matrix methods are presented that can solve for the concentrations of several tracers from simultaneous measurements in at least as many spectral receiver channels, even when fluorescence spectra overlap. Two example systems, one with strong crosstalk and another without, are evaluated for accuracy in the presence of shot noise and calibration errors. Schemes for calibration are suggested. Objectives for a field demonstration of the concept are outlined. Potential applications include measuring the effect of release location on atmospheric transport and dispersion and observing the structure of complex flows.

WP-027

Einaudi, F., BEDARD, A.J., and J.J. Finnigan. A climatology of gravity waves and other coherent disturbances at the Boulder Atmospheric Observatory during March-April 1984. Journal of the Atmospheric Sciences, 46:303-329 (1989).

We present a climatological study of gravity waves and other coherent disturbances at the Boulder Atmospheric Observatory, during the period mid-March to mid-April 1984. The data were collected by a network of micro-barographs and by sensors on the 300 m tower. The total observational period was divided into 522 time segments of 5120 s each. Coherent and incoherent motions were identified on the basis of a cross-correlation coefficient calculated from the microbarograph network for each time segment and frequency band analyzed, on the assumption that the atmospheric state can be described by an equivalent plane wave. Five passbands were considered in the period range 1-20 min. The analysis indicates that the atmospheric state at these passbands displays highly coherent structure most of the time. During the interval from 0800 to 1800 local time, coherent motions with cross-correlation coefficient larger than 0.5 are present about 25% of the time for periods between 1 and 5 min and more than 80% of the time for periods between 10 and 20 min. In the remaining hours of the day, the percentages rise to more than 40%

and 95% of the time, respectively. A relationship is illustrated between the turbulent kinetic energy measured on the tower and the amplitude of the pressure field at the ground for disturbances up to 5 min period. For longer periods, such a relationship appears to be absent, indicating that at longer scales the pressure field is dominated by processes generated higher up in the troposphere.

WP-028

FAIRALL, C.W., J.E. Hare, and J.B. SNIDER. An eight-month climatology of marine stratocumulus cloud fraction, albedo and integrated liquid water. Extended Abstracts, FIRE Science Meeting, Monterey, CA, 10-14 July 1989, NASA Langley, 39-43 (1989).

No abstract.

WP-029

FEDOR, L.S., G.S. Hayne, and E.J. WALSH. Airborne pulse-limited radar altimeter return waveform characteristics over ice in the Beaufort Sea. Conference Record, Oceans '88, Baltimore, MD, 31 October-1 November 1988, American Meteorological Society, Boston, MA, 1704-1710 (1988).

Pulse-limited radar data taken in March 1978 with the 13.9 GHz AAFE altimeter from 1500 m altitude over ice in the Beaufort Sea are registered to high quality photography. The variations of the radar return waveform shape and signal level are correlated with the variation of the ice type determined from photography.

WP-030

FEDOR, L.S., G.S. Hayne, and E.J. WALSH. Ice-type classification from airborne pulse-limited radar altimeter return waveform characteristics. Proceedings, International Geoscience and Remote Sensing Symposium, IGARSS '89 Digest, Vancouver, Canada, 3:1949-1952 (1989).

During mid-March 1978, the NASA C-130 aircraft was deployed to Eielson Air Force Base in Fairbanks, Alaska, to make a series of flights over ice in the Beaufort Sea. The radar altimeter data analyzed here were obtained northeast of Mackenzie Bay on March 14 in the vicinity of 69.9°N, 134.2°W. The data were taken with a 13.9 GHz radar altimeter developed under the NASA Advanced Applications Flight Experiments (AAFE) Program. This airborne radar was built as a forerunner of the SEASAT radar altimeter and utilized the same pulse compression technique. It has the same pulse compression ratio (1000:1) as the SEASAT altimeter and approximately the same range resolution (0.417 m versus 0.469 m for SEASAT). One significant difference was that the AAFE altimeter has only 24 range gates instead of the 60 that SEASAT had. Pulse-limited radar data taken with the altimeter from 1500 m altitude over sea ice are registered to high quality photography. The backscattered power is a function of the surface conductivity and is statistically related to the number of facets whose surface normal is directed towards the radar. The variations of the radar return waveform shape and signal level are correlated with the variation of the ice type determined from photography. The AAFE altimeter has demonstrated that the return waveform shapee and signal level of an airborne pulse-limited altimeter at 13.9 GHz respond to sea ice type. The signal level responded dramatically to even a very small fracture in the ice as long as it occurred directly at the altimeter nadir point. Shear zones and regions of significant compression ridging consistently produced low signal levels. The return waveforms frequently evidenced the characteristics of both specular and diffuse scattering, and there was an indication that the power backscattered at 3° off-nadir in a shear zone was actually somewhat higher than that from nadir.

WP-031

FEDOR, L.S., M.D. JACOBSON, A.J. BEDARD, E.R. WESTWATER, D.C. HOGG, and R.T. NISHIYAMA. Dual-channel microwave radiometer for airborne meteorological applications. NOAA TM ERL WPL-157, 29 pp. (1988)

Cloud liquid and water vapor are important parameters in meteorological processes. This memorandum presents the design of a dual-channel microwave radiometer to be installed on a NOAA research aircraft in order to measure these parameters. The discussion includes the utility of the instrument in variety of research programs including cloud physics, severe storms, cloud climatology, and satellite sensor validation.

WP-032

FEDOR, L.S., and E.J. WALSH. Interpretation of SEASAT radar altimeter returns from an overflight of ice in the Beaufort Sea. Proceedings, Oceans '88, Baltimore, MD, 31 October-2 November 1988, IEEE and Marine Technology Society, Washington, DC, 1697-1703 (1988).

SEASAT radar altimeter data are examined for the effects of sea ice on the returns during an overflight of the Beaufort Sea. Waveform parameters and their statistics are combined to form a parameter sensitive to the presence of sea ice. Variations in the value of this ice parameter are compared with ice charts obtained from the Canadian Atmospheric Environment Service. Particular attention is paid to the sensitivity of the radar altimeter to the open-ocean sea ice boundary.

WP-033

FRELICH, R.G., and G.R. OCHS. Extending the range of validity of optical scintillometer measurements. Proceedings, SPIE 1989 Technical Symposia on Aerospace Sensing, Orlando, Fl, 28-30 March 1989, PSIE, Bellingham, WA, 152-158 (1989).

Measurements of the level of turbulence C_n^2 have been successfully performed with the optical scintillometer. The successof this instrument is based on the observed fact that the variance of aperture-averaged scintillation is described by weak scattering theory even for conditions under which strong scintillation is observed for small apertures. However, for sufficiently long propagation paths the aperture-averaged variance is affected by strong scattering. The effects of strong scattering are calculated theoretically and compared to experiment. The physics of this regime are discussed and the important parameters investigated in order to extend the range of validity of optical scintillometer measurements.

WP-034

FRISCH, A.S., B.L. WEBER, D.B. WUERTZ, R.G. STRAUCH, and D.A. MERRITT. The variations of C_n^2 between 4 and 14 km above sea level. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 725-727 (1989).

No abstract.

WP-035

FRITZ, R.B., and W.D. NEFF. The use of an optical crosswind sensor to study urban airflows. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 120-121 (1989).

No abstract.

WP-036

GAYNOR, J. A preliminary study of Boulder Valley's air quality meteorology. Preprints, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January 3-February 1989, American Meteorological Society, Boston, MA, 253-255 (1989).

No abstract.

WP-037

GAYNOR, J., and C.A. Biltoft. A comparison of two sonic anemometers and fast-response thermometers. Journal of Atmospheric and Oceanic Technology, 6:208-214 (1989).

In an experiment conducted at the Boulder Atmospheric Observatory (BAO), comparisons were made between two types of sonic anemometer and thermometer systems. One sonic anemometer was a single-axis system manufactured by Campbell Scientific, Inc. (SCI), and the other the type routinely used on the BAO tower. It is similar to the sensors manufactured by Applied Technologies, Inc., and AIR, Inc. Two identical Campbell Scientific systems were mounted on each side of the BAO system and comparisons made over a range of atmospheric surface layer conditions. The means and standard deviations of the vertical wind component and temperature, along with the temperature fluctuation data due to the thermocouple filtering are noted. The effect of these differences on the measured heat fluxes and temperature variances is significant and discussed in some detail. It appears that the response of the CSI thermal mass to solar radiation was the major reason for the discrepancies.

WP-038

GAYNOR, J.E., and L.K. WITTENMEIER. Short-term climatology of Boulder Valley's high-pollution meteorology. Preprints, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorology Society, Boston, MA, 250-252 (1989).

No abstract.

WP-039

GIBSON, J.S. Simulated and measured spectral width estimates from a meteorological radar. Master's thesis, University of Colorado, Boulder, CO, 77 pp. (1988).

Spectral moment estimation is of importance to radar meteorologists for several reasons. Zero moment estimates measure average power received by the radar. This can be related to total liquid water content within the pulse volume by an assumed drop size distribution. First moments are estimates of the Doppler mean velocity and thus can give the meteorologist information on particle speed, and direction from which the wind field is inferred. Second moment estimates lead to information on turbulent dissipation rates and wind shear. This paper describes and compares the results of two signal processing techniques used to compute spectral moments in a meteorological pulsed Doppler radar system operated by the Wave Propagation Laboratory, Environmental Research Laboratories, National Oceanic and Atmospheric Administration (NOAA), in Boulder, Colorado. Different methods of calculating noise estimates and their effects upon the corresponding spectral moment estimates are studied. Signal transmission, data acquisition, real-time processing of the returned echo from the analog-to-digital converter through a pulse pair processor, and the current post spectral analysis techniques used are reviewed briefly. Post spectral analysis techniques included are a pulse pair algorithm and a discrete fast Fourier transform method. These two methods are used to estimate average power received, mean Doppler velocity, and spectral width. The results of processing simulated and real data by the two methods are compared for various ranges of spectral widths, signal-to-noise ratios, and noise suppression algorithms. The resulting biases and errors in the estimates are examined.

WP-040

GOSSARD, E.E. Measuring drop-size distributions in clouds with a clear-air-sensing Doppler radar. Journal of Atmospheric and Oceanic Technology, 5:640-649 (1988).

The advent of Doppler clear-air radars for wind-height profiling opens the way for their use in a variety of other applications. This paper uses knowledge of the clear-air Doppler spectrum for a zenith-pointing radar together with the measured water droplet Doppler vertical velocity spectrum to calculate spectra of drop number density through clouds of droplets having substantial fall velocity. The method has been applied by Japanese scientists to measure drop-size distributions of precipitation particles from data acquired at the VHF MU radar facility. Here the method is applied to records obtained with a 915 MHz wind profiler located at Denver, Colorado, and the resulting spectra are presented and compared with the spectra that would have been obtained if the clear-air information were ignored. From the number density drop-size distribution, the corresponding liquid water distribution can be calculated. It is concluded that failure to take into account turbulence in the medium can result in order-of-magnitude errors in number density and liquid water. The requirements and limitations of a radar remote sensing drop spectrometer are discussed.

WP-041

GOSSARD, E.E., and R.G. STRAUCH. Further guide for the retrieval of dropsize distributions in water clouds with a ground-based clear-air-sensing Doppler radar. NOAA Technical Document. 48 pp. (1989).

The advent of Doppler clear-air radars for wind-height profiling opens the way for their use in a variety of other applications. This paper uses knowledge of the clear-air Doppler spectrum from a zenith-pointing radar together with the measured water droplet Doppler vertical velocity spectrum to calculate spectra of drop number density through clouds of droplets having substantial fall velocity. The method has been applied by Japanese scientists to measure dropsize distributions of large precipitation particles from data acquired at the VHF, 7-m wavelength, MU radar facility and by Gossard to data from the 32-cm wavelength, WPL wind profiler at Denver. This report extends the methodology described in an earlier report. Specifically, methods for unfolding and using extended spectra are discussed, and deconvolution of spectra by Fourier transformation is compared with the iterative technique. Spectra measured with a 915-MHz, wind-profiling radar are used as examples and compared with the spectra that would have been obtained if the clear-air information were ignored. From the number density vs. dropsize distribution, the corresponding liquid water distribution can be calculated. Failure to take into account turbulence in the medium can result in large errors in number density and liquid water especially in the neighborhood of spectral lines and large gradients. The advantages and limitations of a ra-

dar remote sensing drop spectrometer are described, and radar wavelength-dropsize trade-offs are discussed.

WP-042

GOSSARD, E.E., and R.G. STRAUCH. Procedural guide for the retrieval of dropsize distributions in water clouds from ground-based clear-air-sensing Doppler radar observations . NOAA-TM-ERL, 48 pp. (1989).

The advent of Doppler clear-air radars for wind-height profiling opens the way for their use in a variety of other applications. This paper uses knowledge of the clear-air Doppler spectrum from a zenith-pointing radar together with the measured water droplet Doppler vertical velocity spectrum to calculate spectra of drop number density through clouds of droplets having substantial fall velocity. The method has been applied by Japanese scientists to measure dropsize distributions of large precipitation particles from data acquired at the VHF, 7-m wavelength, MU radar facility and by Gossard to data from the 32 cm wavelength, WPL wind profiler at Denver. This report extends the method and describes procedures that allow spectral lines and details to be extracted from the radar data. Spectra measured with a 915 MHz, wind-profiling radar are used as examples and compared with the spectra that would have been obtained if the clear-air information were ignored. From the number density vs. dropsize distribution, the corresponding liquid water distribution can be calculated. Failure to take into account turbulence in the medium can result in large errors in number density and liquid water especially in the neighborhood of spectral lines and large gradients. The advantages and limitations of a radar remote sensing drop spectrometer are described. A BASIC program for the retrieval is given in Appendix C.

WP-043

GOSSARD, E.E., and R.G. STRAUCH. The retrieval of dropsize distributions in water clouds from ground-based clear-air sensing Doppler radar observations . Proceedings, 1st European Wind Profiler Workshop, Trappes, France, 6-8 March 1989, European Community COST Program, Brussels, (1989).

The advent of Doppler clear-air radars for wind-height profiling opens the way for their use in a variety of other applications. This paper uses knowledge of the clear-air Doppler spectrum from a zenith-pointing radar together with the measured water droplet Doppler vertical velocity spectrum to calculate spectra of drop number density through clouds of droplets having substantial fall velocity. This report describes procedures that allow spectral lines and other details to be extracted from the radar data. Spectra measured with a 915 MHz, wind-profiling radar are used as examples and compared with the spectra that would have been obtained if the clear-air information were ignored. From the number density vs. dropsize distribution, the corresponding liquid water distribution can be calculated. Failure to take into account turbulence in the medium can result in large errors in number density and liquid water especially in the neighborhood of spectral lines and large gradients. The advantages and limitations of a radar remote sensing drop spectrometer are described.

WP-044

HALL, F.F. Wind variability measured by Doppler lidar. Short Note to Journal of Applied Meteorology, 28:155-158 (1989).

Wind power spectral density measured in the lower and middle troposphere under zonal flow conditions is consistent with a -5/3 slope to frequencies as high as 10^{-2} Hz. By conversion of frequency to a spatial coordinate it is found that a satellite-borne lidar when averaging such winds over a 300 km grid scale would measure the synoptic-scale wind with a 98% representativeness index.

WP-045

HARDESTY, R.M. Processing of low signal-to-noise ratio Doppler lidar returns. Proceedings, 5th Conference on Coherent Laser Radar, Munich, Federal Republic of Germany, 5-9 June 1989, German Aerospace Research Establishment, Wessling, FRG, 169-172 (1989).

No abstract.

WP-046

HARDESTY, R.M., R. BANTA, R.E. CUPP, W.L. EBERHARD, J. INTRIERI, and M.J. POST. Examples of wind phenomena measured by a pulsed CO_2 Doppler lidar. Proceedings, 5th Conference on Coherent Laser Radar, Munich, Federal Republic of Germany, 5-9 June 1989, German Aerospace Research Establishment, Wessling, FRG, 3-6 (1989).

No abstract.

WP-047

HILL, R.J. Implications of Monin-Obukhov similarity theory for scalar quantities. Journal of the Atmospheric Sciences, 46:2236-2244 (1989).

Monin-Obukhov similarity theory of surface-layer turbulence has been extended to include all scalar quantities. The tenets of this theory, as it is presently practiced, are followed to their logical conclusions, which produces some novel results. First, the similarity theory is applied to the variance of a scalar quantity and its correslation with another scalar quantity. For this similarity to apply to all scalar quantities, it is shown that the dimensionless functions of stability are all equal, that the correlation coefficient of any two scalars is +1 or -1, and that the correlation of two scalars has the same sign as the product of their fluxes. These results also apply to structure parameters and cross-structure parameters as well as to the dissipation rates of the scalar's variances and correlations. It is shown that the fluctuations of all the scalar quantities are proportional to one another. On the basis of Monin-Obukhov similarity, the Obukhov-Corrsin constants (i.e., Kolmogorov constants) fo scalar spectra and cospectra are shown to be equal, and are expressed as a function of stability. The dimensionless fluxes of scalar variance and correlation are shown to be the same for all scalars. Likewise the dimensionless functions for gradient production of scalar variance and covariance are the same for all scalars. All the above functions for gradient production of scalar variance and covariance are the same for all scalars. All the above demonstrate that internal consistency of the similarity theory of the horizontally homogeneous surface layer. The the same for all scalars. All the above demonstrate that internal consistency of the similarity theory of the horizontally homogeneous surface layer. The above results, however, show in what manner the similarity theory becomes an overidealization when it is extended to all scalar quantities. In particular, the internal dynamics of the surface itself is not considered in the similarity theory; yet it is reasonable that such internal dynamics causes violations of the similarity theory.

WP-048

HILL, R.J. Structure functions and spectra of advected scalar quantities in the inertial-convective and viscous-convective ranges of turbulence. Journal of the Atmospheric Sciences, 46:2245-2251 (1989).

The Obukhov-Corrsin constants (often referred to as Kolmogorov constants) are the constants of proportionality in formulas pertaining to the inertial-convective range of structure functions (or spectra) of scalar quantities and the cross-structure functions (or cospectra) of pairs of scalar quantities. These Obukhov-Corrsin constants are shown to be equal for all scalar quantities and pairs of scalar quantities. Ther inertial-convective and viscous-convective range formulas for cross-structure functions (or cospectra) can be deduced from those of the structure functions (or spectra). Special attention is given to the case of dimensionless scalar quantities like refractive index for which the inertial-convective range and for the spectra and cospectra in the viscous-convective range. The structure and cross-structure functions do not possess viscous-convective ranges distinct from their viscous-diffusive ranges, however, and dimensional analysis gives incorrect results in this case.

WP-049

HILL, R.J., R.A. Bohlander, S.F. CLIFFORD, and R.J. LATAITIS. Fluctuations in millimeter-wave signals caused by clear-air turbulence and inclement weather. Proceedings, SPIE 1989 Technical Symposia on Aerospace Sensing, Orlando, FL, 28-30 March 1989, SPIE, Bellingham, WA, 234-242 (1989).

Observations and theory for millimeter-wave propagation through clear-air turbulence, rain, fog, and snow are reviewed. Measurements have shown the effects of refractive and absorptive fluctuation in air. Measured quantities include the intensity, the phase difference between spaced antennas for a singl electromagnetic frequency as well as phase difference at a single

antenna for waves having differing frequencies. Typical statistics of these quantities are their variances, structure functions, temporal spectra, and probability distributions.

WP-050

Hocking, W.K., P.T. MAY, and J. Rottger. Interpretation, reliability and accuracies of parameters deduced by the spaced antenna method in middle atmosphere applications. Pure and Applied Geophysics, 130:571-604 (1989).

The spaced antenna method has proved to be an important and relatively inexpensive radar technique for making measurements of atmospheric wind velocities and other parameters. This discussion examines the reliability and accuracies of various parameters which can be measured with the technique.

WP-051

HOGG, D.C. An historical perspective of microwave propagation and antenna research. IEEE Antennas and Propagation Society Newsletter, 31:23-26 (1989).

No abstract.

WP-052

HOGG, D.C. and J.B. SNIDER. Microwave radiometry in measurement of radio pathlength through the troposphere. In Brunner, F.K. (Ed.), 1988, "Atmospheric Effects on Geodetic Space Measurements," Monograph 12, School of Surveying, Univ. of New South Wales, 63-70.

The design of millimeter-wave radiometers for accurate measurement of integrated water vapor on earth-space paths to provide radiowave excess pathlength for satellite based surveying systems is given. Effects of fluctuations in the integrated vapor are discussed. The utility of radiometric measurements in improving attainable accuracy of baseline estimation using the GPS system is illustrated by an example.

WP-053

INTRIERI, J. Density currents in the atmosphere as observed by the NOAA Doppler lidar. Proceedings, LASE '89, Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 1062: 249-256 (1989).

Three different examples of atmospheric density currents are observed by the NOAA Doppler lidar. The lidar has proved to be an extremely useful sensor to study the mesoscale dynamics of these clear-air phenomena.

WP-054

KAIMAL, J.C., S.F. CLIFFORD, and R.J. LATAITIS. Effect of finite sampling on atmospheric spectra. Boundary-Layer Meteorology, 47:337-347 (1989).

The effect of a finite averaging time on variances is well known, but its effect on power spectra is less clearly understood. We present numerical solutions for the spectral distortion arising from sampling over a finite time interval T and show that the commonly used filter function $(1-sinc^2\pi fT)$, valid for variances, is a reasonable approximation for power spectra only when $T \geq 10\tau_m$, where f is the cyclic frequency, and τ_m is the dominant time scale of the process. Our results exhibit an increasingly steeper low-frequency roll-off as T decreases relative to τ_m, indicating that the measured spectrum is subject to a greater suppression of the lower frequencies $(f < 1/T)$ than predicted by $(1-sinc^2\pi fT)$. This suppression is, in a sense, compensated by an overestimation of spectral estimates in the frequency range $f \geq 1/T$.

WP-055

KING, C.W., W.D. NEFF, and V.A. LEFEBVRE. Radiometric profiler measurements of water vapor for use in visibility analysis. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 122-124 (1989).

No abstract.

WP-056

KING, C.W., and C.A. RUSSELL. Temperature structure effects on pollutant distribution in the Denver metropolitan area. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 243-245 (1989).

No abstract.

WP-057

KROPFLI, R.A. Hazard index calculation for May 31, 1984 microburst at Erie, Colorado. NOAA TM ERL WPL-155, 50 pp. (1988).

The two X-band Doppler radars, operated by the NOAA Wave Propagation Laboratory, were used to collect high resolution data within a small, benign-looking microburst during the PHOENIX II boundary layer experiment. The lowest 2.5 km of the microburst was observed throughout its development and dissipation over a 15 minute period. These observations presented an excellent opportunity to compute a quantitative threat to a hypothetical aircraft whose flight track would carry it through the microburst. This hazard index is based on the kinetic energy loss to the aircraft that would be produced by the microburst; it is a function of the vertical air motion, horizontal spatial derivatives of the wind field, and the assumed aircraft air speed and direction. Indices were computed and plotted for all eight volume scans and peak values were observed to be sufficiently high to present a significant hazard to an aircraft even though the virga-produced microburst was visually unimpressive.

WP-058

Kusters, J., B.J. RYE, and A. Walker. Spatial weighting in laboratory incoherent light scattering experiments. Applied Optics, 28:657-664 (1989).

Diffraction-based calculations of the relative spatial weighting of the observed volume in incoherent scattering experiments, applicable to both direct detection and heterodyne systems and arbitrary transmitter and receiver profiles, have been largely confirmed in laboratory measurements using a CO_2 laser. The results indicate that heterodyne systems have superior spatial resolution at small scattering angles for a given detector geometry and permit quantitative assessment of this and the greater sensitivity of coherent systems to misalignment.

WP-059

LATAITIS, R.J., and J.H. CHURNSIDE. Propagation of an elliptical laser beam through the turbulent atmosphere (vertical beams). NOAA TM ERL WPL-165, 13 pp. (1989).

We calculate the effect of a turbulence gradient on the mean irradiance profile of an elliptical beam. We conclude that in a turbulent atmosphere the peak irradiance can be shifted to a point farther from the ground. Also, the vertical symmetry of the beam can be perturbed because of greater horizontal beam spreading at lower heights where turbulence is stronger. However, this effect is significant only for highly elliptical beams, and only when the horizontal beam divergence is determined by turbulence.

WP-060

LATAITIS, R.J., and J.H. CHURNSIDE. Statistics of two-color laser beam propagation in the turbulent atmosphere (spectral correlation). NOAA TM ERL WPL-167, 17 pp. (1989).

We develop expressions for the statistics of the angle-of-arrival fluctuations and of the irradiance fluctuations for a two-color laser beam after propagation through refractive turbulence in the atmosphere. The correlation, the cospectrum, and the coherence are included. We find the fluctuations in the angle-of-arrival and irradiance at two wavelengths to be highly correlated for most conditions of interest.

WP-061

LATAITIS, R.J., and J.H. CHURNSIDE. Turbulence effects on reflected optical patterns. NOAA TM ERL WPL-166, 10 pp. (1989).

The vacuum irradiance pattern produced by an optical beam illuminating a distant receiving plane is distorted by atmospheric turbulence. The distortion manifests itself as a wander and "breathing" of the beam spot. Reflected optical patterns exhibit the same type of distortion but

to a degree that depends on the type of reflector. We describe the reflected irradiance pattern in terms of several length scales of interest. Numerically derived optical patterns for a spherical wave reflected from a plane retroreflector are also presented. Various reflector diameters and turbulence strengths are considered. These results indicate that the small-scale structure in the reflected optical pattern is no longer discernible when $\varrho_0 \leq D_r$, where ϱ_0 is the spherical wave coherence length and D_r is the reflector diameter.

WP-062

Li, F., W. Large, W. Shaw, WALSH, E.J., and K. Davidson. Ocean radar backscatter relationship with near surface winds: A case study during FASINEX. Journal of Physical Oceanography, 19:342-353 (1989).

A case study of the ocean radar backscatter dependence on near-surface wind and wind stress is presented using the data obtained on 18 February 1986 during the Frontal Air-Sea Interaction Experiment. Our interest in this case stems from the particular wind-wave conditions and their variations across a sharp sea surface temperature front. These are described. Most importantly, the small change in wind speed across the front cannot account for the large change in wind stress implying significant changes in the drag coefficient and surface roughness length. When compared with previous results, the corresponding changes in radar backscatter cross section at 50 deg and 20 deg angles of incidence were consistent with the observed variations in wind stress, but inconsistent with both the mean wind and the equivalent neutral wind. Although not definitive, the results strengthen the hypothesis that radar backscatter is closely correlated to wind stress, and, therefore, could be used for remote sensing of the wind stress itself over the global oceans.

WP-063

MA, K., F.F. HALL, R.M. HARDESTY, T.R. LAWRENCE, and R.E. CUPP. Heterodyne quantum efficiency of a HgCdTe infrared Doppler detector. Applied Optics, 28:1750-1751 (1989).

Quantum efficiency of a HgCdTe photodiode was measured for both direct and heterodyne detection. Both measurements employed a blackbody radiation source; the receiver bandwidth for the heterodyne measurements was 50 MHz to approximate a Doppler lidar receiver. The quantum efficiency of the detector in the heterodyne mode was ~0.3, nearly 40% lower than the direct detection efficiency.

WP-064

MARTNER, B.E. Photogrammetric/radar analysis of the 2 July tornado during CINDE. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 58-61 (1989).

No abstract.

WP-065

MARTNER, B.E., A.S. FRISCH, and R.A. KROPFLI. NOAA X-band radar measurements in 3CPO. NOAA TM ERL WPL-153, 58 pp. (1988).

The NOAA Wave Propagation Laboratory participated in the Cloud Chemistry Cloud Physics Organization (3CPO) field project in east-central Illinois in the summer of 1988. The laboratory planned to use its circular polarization diversity Doppler X-band radar to study venting of polluted boundary layer air by convective clouds using a new technique known as TRACIR. The technique and the experimental plan are described and a summary of the radar operations is given. Unfortunately, a severe drought prevented the necessary clouds from forming during the project. Numerous measurements were made with the radar in clear air conditions using vertical scans and the velocity azimuth display (VAD) method to obtain data on turbulence characteristics of the planetary boundary layer. The VAD measurements and analysis procedures are described as well as a test of the efficiency of the NOAA airborne chaff cutters. The complete radar tape log for the project is included.

WP-066

MARTNER, B.E., and R.A. KROPFLI. A new radar technique for observing the exchange of air between clouds and their environment. Proceedings, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January - 3 February 1989, American Meteorological Society, Boston, MA, 133-136 (1989).

A remote sensing technique which uses circular dual-polarization radar to track chaff-filled parcels of air has been developed and tested. The chaff which acts as a as an air motion tracer can be detected by the radar's circular depolarization ratio measurement inside clouds even when the chaff's reflectivity signal is undetectable. A plan to employ the technique in a study of how effectively convective clouds vent pollutants out of the boundary layer is outlined.

WP-067

MARTNER, B.E., and R.A. KROPFLI. Tracking chaff-filled air through clouds with circular polarization diversity radar. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 332-335 (1989).

No abstract.

WP-068

MAY, P.T., B.L. WEBER, R.G. STRAUCH, R.J. LATAITIS, K.P. MORAN, and D.A. MERRITT. Single-station ocean current vector measurement: application of the spaced antenna (SA) technique. Geophysical Research Letters, 16:999-1002 (1989).

The Spaced Antenna (SA) technique is applied to measuring ocean surface currents for the first time. This allows the measurement of the ocean surface current transverse to the radar beam as well as the radial current and thus eliminates the requirement of two separate radars to measure the full current vector as with present ocean surface current radar systems. Therefore, this technique offers considerable advantages for ocean current mapping in terms of simplicity for real-time operational systems and could have wide applications, for example at sites where it is not practical to have two separate radars.

WP-069

MAY, P.T., K.P. MORAN, and R.G. STRAUCH. The accuracy of RASS temperature measurements. Journal of Applied Meteorology, (1989).

Temperature measurements obtained using radiosondes and Radio Acoustic Sounding Systems (RASS) are compared to assess the utility of the RASS technique for meteorological studies. The agreement is generally excellent: rms temperature differences are about 1.0 degrees C for comparisons during a variety of meteorological conditions. Observations taken under ideal circumstances indicate that a precision of about 0.2°C is achievable with the RASS technique. A processor being designed for RASS should allow routine temperature measurements approaching this precision.

WP-070

MAY, P.T., T. Sato, M. Yamamoto, T. Tsuda, and S. Fukao. Errors in the determination of wind speeds with Doppler radars. Journal of Atmospheric and Oceanic Technology, 116:235-242 (1989).

A numerical model to simulate radar data is used for testing various estimators of the Doppler-shift in Doppler radar echoes. Five estimators for the Doppler shift are considered: the pulse pair and poly-pulse pair algorithms in the correlation domain, least squares fitting to the power spectra in linear and logarithmic coordinates, and a matched filter in the spectral domain. An experiment with real data, to test the algorithms further and to assess the importance of small-scale wind fluctuations on radar performance, shows that geophysical limitations on the accuracy of the wind estimates are the dominant factor for observations with good signal-to-noise.

WP-071

MAY, P.T., AND R.G. STRAUCH. An examination of some algorithms for spectral moment estimation. Preprint, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 429-432 (1989).

It is desirable to find algorithms for the calculation of spectral moments, especially the first moment or mean radial velocity measured by a Doppler radar, which offer good accuracy at both high and low signal-to-noise ratio (SNR). When the SNR is very low, some moment estimates will have very large errors caused by noise. A method to average data which includes outliers is also examines. Artificially generated data are used to test various algorithms. First, we test algorithms which simply estimate the first moment of the signal spectrum. Then, procedures where groups of such estimates are combined to give an average value are tested. A problem that occurs with data with poor SNR is that completely erroneous mean velocity values (outliers) are sometimes obtained. Scatter from other targets such as aircraft can also cause these outliers. An

averaging algorithm is desired whereby the outliers do not enter into the average value. One such algorithm is the consensus averaging technique (Fischler and Bolles, 1981.

WP-072

MAY, P.T., and R.G. STRAUCH. An examination of wind profiler data processing algorithms. Journal of Atmospheric and Oceanic Technology, 6:731-735 (1989).

No abstract.

WP-073

MAY, P.T., R.G. STRAUCH, and K.P. MORAN. Altitude coverage of temperature measurements using RASS with wind profiler radars. Geophysical Research Letters, 15:1381-1384 (1989).

The Radio Acoustic Sounding System (RASS) technique for measuring temperature profiles with good time and height resolution has been applied using wind profiling radars operating at three frequencies (49.8, 404.37, and 915 MHz). The performance of the three systems is discussed in terms of the altitude coverage of the temperature measurements and physical processes limiting the coverage. The lower frequencies can probe greater altitudes, but the 49.8 MHz wind profilers have a minimum range of about 2.1 km limiting their usefulness for some studies. These preliminary results indicate that the use of RASS in concert with wind profilers has promise for operational meteorology.

WP-074

MAY, P.T., R.G. STRAUCH, and K.P. MORAN. RASS applied to wind profiler radars. Preprints, IGARSS '89, 12th Canadian Symposium on Remote Sensing, Vancouver, B.C., 10-14 July 1989, IEEE, New York, (1989).

Radio Acoustic Sounding (RASS) has been applied with wind profiler radars. Temperature profiles have been obtained up to several kilometers in altitude with RMS differences between the RASS measurements and conventional radiosonde observations of 1 degree C have been obtained. The technique shows great promise for a number of meteorological applications.

A numerical model to simulate radar data is used for testing various estimators of the Doppler shift in Doppler radar echoes. The estimators are the pulse pair and poly-pulse pair algorithms in the correlation domain, a least-squares fitting to the spectral peak of the power spectra, and direct calculations of the moments from periodograms in the spectral domain. Two averaging schemes (a consensus average and a median filter) are also examined for data with poor signal-to-noise ratios. The data processing method used in Doppler radar wind profilers, which operate over a very wide range of signal to noise ratios, is examined in detail. It is shown that the direct moment calculation combined with a consensus averaging technique has the best overall performance for accuracy and the ability to use data with a very low signal-to-noise ratio.

WP-075

MAY, P.T., R.G. STRAUCH, K.P. MORAN, and W.D. NEFF. High resolution weather observations with combined RASS and wind profiler. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 746-749 (1989).

It has recently been shown that the Radio Acoustic Sounding System (RASS) for remotely measuring atmospheric (virtual) temperature can be applied to wind profiler radars in a straightforward manner with excellent results (May et al., 1988). The technical requirements and the application of RASS to the wind profilers in the Colorado network was discussed in the companion paper (Strauch et al., 1989). The purpose of this paper is two-fold: the first part of the paper focuses on some reasonably extensive comparisons of the temperature profiles obtained with RASS using the Platteville 49.8 MHz profiler and the Denver 915 MHz profiler against profiles obtained with radiosonde observations (RAOB). These comparisons were made to verify that accurate temperature profiles can be obtained using the RASS/profiler combination; they generally show excellent agreement, e.g., Figure 1. This example was taken under light wind conditions so a large height coverage was obtained. Results from four consecutive RASS soundings are given on this figure, but they overlap at most altitudes, showing the high precision that can be obtained. The second part of the paper focuses on preliminary analysis of an interesting event to illustrate the utility of the high time resolution observations.

WP-076

MEITIN, R.J., and R.F. REINKING. A Doppler radar analysis of a winter mountain storm. Preprints, 5th WMO Conference on Weather Modification and Applied Cloud Physics, Beijing, People s Republic of China, 8-12 May 1989, WMO, Geneva, 93-96 (1989).

No abstract.

WP-077

MEITIN, R.J., and R.F. REINKING. A preliminary radar analysis of a winter mountain storm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 490-493 (1989).

No abstract.

WP-078

Menzies, R.T., and R.M. HARDESTY. Coherent Doppler lidar for measurements of wind fields. Proceedings IEEE, 77:449-462 (1989).

The use of coherent Doppler lidar for remote measurements of atmospheric wind fields is receiving increasing consideration as a valuable tool for studies of atmospheric dynamics, both on a local scale using ground-based systems and on a global scale from an earth-orbiting satellite platform. The signal processing techniques for obtaining the velocity estimates, and the fundamental factors that influence coherent lidar performance in this context, are reviewed. The similarities and distinctions between Doppler lidar and Doppler radar are discussed. Coherent Doppler lidars now have the capability to map wind fields over selected regions in the lower atmosphere and greatly enhance the capability to visualize flow patterns in real time. Examples of this capability are presented. The concluding discussion concerns several of the salient features of the NASA concept for an earth-orbiting Doppler lidar to be launched in the late 1990s.

WP-079

MILLER, P.A., and M.J. FALLS. Pilot study of methods to decrease measurement errors of trod sea level tracking in satellite altimetry. Journal of Atmospheric and Oceanic Technology, 6:225-234 (1989).

Results of radiometer temperature profile simulations are analyzed in order to examine the hypothesis that knowledge of temperature inversion parameters obtained from other instruments would substantially improve the accuracy of radiometric temperature profiles. Five variations of a statistical retrieval method are used to produce radiometric temperature profiles. These profiles are then compared with radiosonde data under both inversion and noninversion conditions. The best algorithm yields consistently better results than the traditional (pure radiometric) technique, but still fails to correctly reproduce the radiosonde inversions.

WP-080

MILLER, P.A., and M.J. FALLS. The incorporation of inversion characteristics into ground-based microwave temperature soundings: a simulation study. Chapter in Microwave Remote Sensing of the Earth System. A. Chedin, ed., A. Deepak Publishing, Hampton, VA, 51-73 (1989).

Results of radiometer temperature profile simulations are analyzed in order to examine the hypothesis that knowledge of temperature inversion parameters obtained from other instruments would substantially improve the accuracy of radiometric temperature profiles. Five different temperature retrieval algorithms are presented and compared with radiosonde data under both inversion and non-inversion conditions. The best algorithm yields consistently better results than the traditional (pure radiometric) technique, but still fails to perfectly reproduce the radiosonde inversions.

WP-081

MORAN, K.P., R.G. STRAUCH, K.B. EARNSHAW, D.A. MERRITT, B.L. WEBER, and D.B. WUERTZ. Lower tropospheric wind profiler. Preprint, 24th Radar Meteorology Conference, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 728-731 (1989).

No abstract.

WP-082
NEFF, W.D. An overview of 1986-1988 Denver pollution studies. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 228-229 (1989).

No abstract.

WP-083
NEFF, W.D. Meteorological classifications used in the 1987-1988 Denver Brown Cloud study. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 74-77 (1989).

No abstract.

WP-084
NEFF, W.D. The ontogeny of Denver pollution episodes. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 230-234 (1989).

No abstract.

WP-085
NEFF, W.D., and W.L. EBERHARD. Doppler lidar studies of the South Platte River Valley. Preprints, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 29 January-3 February 1989, American Meteorological Society, Boston, MA, 132-132 (1989).

No abstract.

WP-086
NEFF, W.D., and C.W. KING. Minisodar observations of inversion formation in the Denver urban core. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 78-78 (1989).

No abstract.

WP-087
NEFF, W.D., and C.W. KING. The accumulation and pooling of drainage flows in a large basin. Journal of Applied Meteorology, 27:518- (1989).

We describe a sequence of tethersonde and sodar measurements showing the effects of the pooling of cold air drainages in a basin located along the Colorado River below the Brush Creek drainage. Results obtained during periods of weak ambient winds show that the basin fills over a period of several hours,then eventually overflows. The depth of the pool is such as to affect tributary drainages, such as that of Brush Creek, and to cause the accumulating drainage jets to become elevated as they flow down the larger drainage channels into the basin.

WP-088
NEIMAN, P.J. The Boulder, Colorado, concentric halo display of 21 July 1986. Bulletin of the American Meteorological Society, 70:258-264 (1989).

No abstract.

WP-089
NEIMAN, P.J., R.M. HARDESTY, M.A. SHAPIRO, and R.E. CUPP. Doppler lidar observations of a downslope windstorm. Bulletin of the American Meteorological Society, 45:2265-2275 (1988).

During January and February 1987, the NOAA/WPL pulsed Doppler lidar was deployed in the foothills west of Boulder, Colorado, to study orographically induced flows over the Continental Divide. On 29 January 1987, the lidar, with its unique spatial and temporal data-gathering capabilities, documented a downslope windstorm affecting the Boulder area and the rest of the Front Range. The lidar recorded in detail 1) a low-level leeside wind maximum, 2) propagating wind gusts exhibiting two distinct periodicities, and 3) the eastern edge of a mountain wave feature where a jumplike flow reversal occurred. Such structures have not previously been observed with

comparable detail by conventional in situ and remote sensing instruments. The observed phenomena were similar to results obtained from mountain-wave numerical models. The most notable of the structural similariaties was between the observed and modeled wind gusts.

WP-090

OCHS, G.R. Measurement of the refractive-index structure parameter by incoherent aperture scintillation techniques. Proceedings, SPIE 1989 Technical Symposia on Aerospace Engineering, Orlando, FL, 28-30 March 1989, SPIE, Bellingham, WA, 107-115 (1989).

The current status of large aperture scintillation techniques for refractive index structure parameter measurement is reviewed, instrument design considerations and limitations are discussed, and a new incoherent aperture profiling system is described.

WP-091

OCHS, G.R., J.J. WILSON, and S.W. ABBOTT. A refractive-index structure parameter profiling system. NOAA TM ERL WPL-161, 47 pp. (1989).

We describe an instrument that measures the refractive-index structure parameter over three segments of optical paths from 300 to 600 meters long.

WP-092

OCHS, G.R., and R.B. FRITZ. Observations of spherical-wave scintillation in strong refractive-index turbulence. NOAA TM ERL WPL-154, (1988).

We present some observations of the fine structure of spherical-wave intensity scintillation, with concurrent independent measurements of refractive-index turbulence and inner scale, made over a 1 km path. Quantitative measurements of the spatial covariance were made by continuously cycling the spacing of two 1-mm diameter detectors, by operating continuously at fixed spacings, and by converting the temporal frequency observed by a small-diameter detector, moving at high speed in a circular pattern, to spatial wavelength. Qualitative information was also obtained through high-speed photographs. Details much smaller than the inner scale, which did not arise from the last few meters of the path, were observed by all techniques.

WP-093

Parsons, C.L., and E.J. WALSH. Off-Nadir radar altimetry. IEEE Transactions on Geoscience and Remote Sensing, 27:215-224 (1989).

Radical changes are likely in the design of satellite radar altimeters in the post-TOPEX/POSEIDON era. The implementation of the multiple-beam altimeter to provide off-nadir altimetry over a wide swath would provide much better information on oceanographic features whose time variability is more rapid than data grids that can be obtained from nadir altimetry by satellite orbital-precession. The paper briefly reviews and contrasts the characteristics of nadir versus off-nadir altimetry and points out a potentially serious problem that has been overlooked by earlier investigators, who focused on the nongeophysical error sources in off-nadir altimetry. Spatial gradients of radar cross section on the sea surface, caused by wind or current gradients or the variation of radar cross section with incidence angle, could introduce significant range errors in off-nadir altimetry. This potentially crippling effect can be overcome by leaving the traditional 13 GHz frequency and implementing the multibeam altimeter at 36 GHz. A multibeam altimeter proposed for the Eos is described as well as a Multimode Airborne Radar Altimeter being developed to study problems inherent in off-nadir altimetry.

WP-094

Porch, W.M., R.B. FRITZ, R.L. Coulter, and P.H. Gudiksen. Tributary, valley and sidewall airflow interactions in a deep valley. Journal of Applied Meteorology, 28:579-589 (1989).

Field experiments measuring nocturnal tributary flows have shown complex internal structure. Variations in the flow range from short-term (8-16 min) oscillations (related to tributary/valley flow interactions) to long-term flow changes throughout the night (related to upper ridge slope and tributary sidewall cooling rate changes). The mean vertical structure in the tributary flow shows a three layer structure. Outflow winds are observed near the surface and in an elevated jet up to several hundred meters height. A flow minimum or counterflow exists at about the height of the drainage flow maximum in the main valley. Comparisons of flow volumes and variations from a single large tributary show that 5%-15% of the nocturnal flow in the main valley

may be contributed through one tributary. This implies that tributaries may dominate main valley sidewall and midvalley subsidence contributions to valley drainage flows.

WP-095

POST, M.J. Aerosol backscatter profiles at 10.59 and 9.25 micrometers near Mauna Loa, Hawaii, 1988. Proceedings, 5th Conference on Coherent Laser Radar: Technology and Applications, Munich, Federal Republic of Germany, 5-9 June 1989, Optical Society of America, Washington, D.C., 239-241 (1989).

No abstract.

WP-096

POST, M.J. Remote sensing of winds and particulates using a CO_2 Doppler lidar. Proceedings, LASERS '88, South Lake Tahoe, NV, 4-9 December 1988, Society for Optical and Quantum Electronics,535-537 (1989).

No abstract.

WP-097

PRIESTLEY, J.T. Data acquisition and analysis for the 1988 micrometeorological scintillation experiment. NOAA TM ERL WPL-170, 74 pp. (1989).

The purpose of the 1988 Micrometeorological Scintillation Experiment was to assess the ability of several scintillation techniques to measure the heat and momentum fluxes and the stability of the atmospheric surface layer. This report documents the data acquisition and analysis software used for the experiment. An overview of the software modules is given, including their purposes and relationships to one another. A more detailed description of each module is also given. Selected portions of the software source code are provided in the appendices, and the complete source code is provided on an enclosed diskette.

WP-098

REINKING, R.F., and R.J. MEITIN. Recent progress and needs in obtaining physical evidence for weather modification potentials and effects. Journal of Weather Modification, 21:85-93 (1989).

Statistical and numerical modeling approaches to assess the effects of cloud seeding require the interactive input of, and understanding derived from, measurements that provide direct evidence of natural and altered development of precipitation. A brief review of recent progress in obtaining physical evidence to evaluate and verify potentials for and effects of precipitation enhancement and hail suppression is presented. Recent findings form the National Oceanic and Atmospheric Administration's Federal/State Cooperative Program in Weather Modification Research are emphasized, but other related results are included. In the context of many significant new advances toward proving hypotheses by direct measurement, a number of remaining needs for measurements and corresponding technologies are identified.

WP-099

REINKING, R.F., and REBECCA J. MEITIN. Advances and challenges in obtaining physical evidence for weather modification potentials and effects. Proceedings, WMO 5th Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, WMO, Geneva, WMO/TD-No. 269, I: 7-10 (1989).

No abstract.

WP-100

Rodriguez, E., F. Li, C.L. Parsons, and E.J. WALSH. Wide swath ocean topography mapping with interferometric altimeters. Proceedings, 12th Canadian Symposium on Remote Sensing (IGARSS 89),Vancouver, B.C., Canada, 10-14 July 1989, IEEE, NY, 2265-2267 (1989).

An interferometric radar altimeter is proposed to provide wide swath, high resolution ocean topography. Several system design issues of such an interferometric altimeter are presented. We show the tradeoffs between processing of the interferometric signal using the so-called amplitude approach and the so-called phase approach. We also discuss the systematic errors associated with uncertainties in the interferometer baseline and the attitude of interferometer orientation. An approach using the measurements at orbit cross over regions, together with the topography meas-

urements from a traditional nadir looking altimeter which are not contaminated by the baseline and attitude noises, is described. Preliminary simulation results show that such an approach can generate an acceptable error level is the ocean surface does not change appreciably between the observations.

WP-101

RUFFIEUX, D. Simulation of solar radiation of downtown Denver: the effect of building shadows on the city's energy budget. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 246-249 (1989).

No abstract.

WP-102

RYE, B.J. Power ratio estimation in incoherent backscatter lidar; direct detection with Gaussian noise. Applied Optics, 28:3639-3646 (1989).

Properties of small sample estimators for the return signal power ratio or log ratio in direct detection incoherent backscatter lidar systems are analyzed. As for heterodyne receivers it is usually preferable to form an estimator from the logarithmic difference of the sample averages rather than their ratio. Calculated values of bias and noise figures are confirmed using simulated data based on constant signal models and comparedwith the estimates obtained from nonlinear Kalman filters. The latter generally provide the least bias at high noise levels at the cost of greater computational complexity.

WP-103

RYE, B.J. A wavelength switching algorithm for single laser differential absorption lidar systems, Proceedings, SPIE, 1062:267-273 (1989).

An algorithm is presented for estimation of the logpower difference needed in DIAL observations for a system assumed to use only a single laser that is tuned to different wavelengths sequentially. Account is taken of the nonlinear measurement equation, missing observations, and signal fluctuations by use of adaptive Kalman filter techniques, and filter performance is demonstrated with simulated data.

WP-104

RYE, B.J., and R.M. HARDESTY. Nonlinear Kalman filtering techniques for incoherent backscatter lidar: Return power and log power estimation. Applied Optics, 28:3908-3917 (1989).

Recursive estimation of nonlinear functions of the return power in a lidar system entails use of a nonlinear filter. This also permits processing of returns in the presence of multiplicative noise (speckle). The use of the extended Kalman filter is assessed here for estimation of return power, log, power, and speckle noise (which is regarded as a system rather than a measurement component), using coherent lidar returns and tested with simulated data. Reiterative processing data samples using system models comprising a random walk signal together with an uncorrelated speckle term leads to self-consistent estimation of the parameters.

WP-105

RYE, B.J., and R.M. HARDESTY. Time series identification and Kalman filtering techniques for Doppler lidar velocity estimation. Applied Optics, 28:879-891 (1989).

The use of recursive techniques based on Kalman filter algorithms for identification of time series system models for Doppler lidar returns and the subsequent filtering and smoothing of measured data is explored. The form of possible stochastic system models is reviewed, and reiterative maximum likelihood and innovation spectral tests are used for identification. It is found that a random walk model is adequate for the returns here and possible explanations for this are considered. Examples are given to illustrate extension of our method to real-time applications and on-line outlier rejection.

WP-106

Sassen, K., D.O. Starr, and T. UTTAL. Mesoscale and microscale structure of cirrus clouds: three case studies. Journal of the Atmospheric Sciences, 46:371-396 (1989).

The structure and composition of three basic cirrus cloud types are examined through coordinated aircraft and ground-based polarization lidar and radar measurements. The cloud systems consist of a multilayered orographic cirrus, a 6-km deep cirrostratus, and a group of fibrous cirrus bands at the tropopause. The data reveal the presence of mesoscale generating regions with horizontal dimensions ranging from ~15 km in narrow cloud bands up to ~100 km in cirrostratus. These generating regions appear to be composed of complexes of much smaller convective structures, presumably on the ~1-km scale of cirrus uncinus cells, and so are termed Mesoscale Uncinus Complexes (MUC). Accumulations of ice particles within cirrus, commonly referred to as precipitation trails, are associated with generating regions at or near cloud tops, but are also created by the local production of ice crystals within embedded convective impulses. Supercooled cloud droplets large enough to be detected by aircraft probes ($\geq 5\mu m$ diameter) were sampled in embedded convective cells near cloud base at temperatures ranging from -21° to -36°C. Ice particle nucleation at colder temperatures is assumed to involve the homogeneous freezing of haze particles too small to be detected by the aircraft probes employed, although they appear to have been detected by the polarization lidar technique under some conditions. Average ice mass contents are temperature dependent in a manner consistent with the conversion of a relatively small amount of excess water vapor (corresponding to ice supersaturations of a few percent) to ice mass.

WP-107

SCHROEDER, J.A. A comparison of the individual and combined performance of ground-based, radio-acoustic, and radiometric temperature sounding systems. M.A. thesis, Colorado School of Mines, Golden, CO, 74 pp. (1989).

An experiment was conducted to compare the accuracy of atmospheric temperature soundings obtained simultaneously with a ground-based radio-acoustic sounding system (RASS), a ground-based microwave radiometric system and a combined RASS/radiometric system at Denver, Colorado, during July and August of 1988. Applying a linear statistical retrieval technique to measurements from all three systems permitted 3-way comparisons throughout the troposphere. Accuracy was evaluated by comparison with simultaneous in situ rawinsonde temperature measurements.

WP-108

SCHROEDER, J.A. A comparison of the individual and combined performance of ground-based, radio-acoustic and radiometric temperature sounding systems. Proceedings, 12th Canadian Symposium on Remote Sensing (IGARSS '89), Vancouver, B.C., Canada, 10-14 July 1989, IEEE, NY, 2300-2302 (1989).

No abstract.

WP-109

SCHROEDER, J.A. A preliminary comparison of temperature soundings obtained from simultaneous radiometric, radio-acoustic, and rawinsonde measurements. NOAA TM ERL WPL-173, 21 pp. (1989).

An experiment was conducted to compare the accuracy of atmospheric temperature soundings obtained simultaneously with a ground-based radio-acoustic sounding system (RASS), a ground-based microwave radiometric system, and a combined RASS/radiometric system at Denver, Colorado, during July and August of 1988. Applying a linear statistical retrieval technique to measurements from all three systems permitted three-way comparisons throughout the troposphere. Accuracy was evaluated by comparison with simultaneous in situ rawinsonde temperature measurements. Rms errors for the 22 sets of soundings compared ranged from 0.5 to 2.0 C, depending on altitude. Temperatures retrieved from the radiometer measurements were more accurate than those retrieved from RASS above 5 km and below 0.5 km AGL, where a bias in the low-altitude RASS measurements degraded the retrieved temperatures. Between 0.5 and 5 km the RASS temperature errors were less than 1°C. At the 750- and 700-mb pressure levels, the RASS errors matched the reported precision of rawinsonde measurements. Although the combined system errors were smaller than individual system errors, at all altitudes, above 0.5 km, the differences among the three systems were too small to conclude that the combined system performance was significantly better than that of either system alone.

WP-110

SENGUPTA, N., J.M. Warnock, E.E. GOSSARD, and R.G. STRAUCH. Remote sensing of meteorological parameters using a wind profiling radar . Proceedings, 1st European Wind Profiler Workshop, Trappes, France, 21 March 1989 (1989).

The described experiment tested the feasibility of (a) using a surface-based radar to measure gradients of temperature and humidity aloft and (b) using standard radiosonde data to calculate height profiles of the radio refractive index structure parameter, C_n^2. The statistical model developed by NOAA's Aeronomy Laboratory was used to calculate values of C_n^2 and ϵ for comparison with the radar-measured values. The radar-calculated and observed quantities was found to be in reasonably good agreement.

WP-111

SHANG, E.C. Ocean acoustic tomography based on adiabatic mode theory. Journal of the Acoustical Society of America, 85:1531-1537 (1989).

A new method of ocean acoustic tomography is developed on the basis of adiabatic normal-mode theory. It is a full-wave method suitable for low frequency in a slowly varying range-dependent waveguide. The modal phase difference perturbations are proposed as data for inverting the sound-speed profile perturbation for a continuous-wave (cw) source. The modal travel time perturbations are proposed as data for a pulse source. It is shown that the "normalized depth structure," as well as the "range-averaged strength parameter" (defined as the product of the effective horizontal scale and the maximum sound-speed perturbation), can be retrieved from the vertical slice modal tomography. A simulation example of inversion is presented to verify the basic ideas.

WP-112

Smith, P.L., H.D. Orville, J.L. Stith, B.A. Boe, D.A. Griffith, M.K. POLITOVICH and R.F. REINKING. Evaluation studies of the North Dakota Cloud Modification Project. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, WMO, Geneva, WMO/TD-No. 269, I:371-376 (1989).

No abstract.

WP-113

SNIDER, J.B., M.D. JACOBSON, and R.H. BEELER. Observations of attenuation at 20.6, 31.65, and 90.0 GHz--preliminary results from Wallops Island. Proceedings, NAPEX XIII, San Jose, CA, 29-30 June 1989, NASA and Jet Propulsion Laboratory, Pasadena, CA, 138-144 (1989).

Ground-based radiometric observations of atmospheric attenuation at 20.6, 31.65 and 90.0 GHz were made at Wallops Island, VA during April and May 1989. Early results from the analysis of the data set are compared with previous observations from California and Colorado. The relative attenuation ratios observed at each frequency during clear, cloudy and rainy conditions are shown. Plans for complete analysis of the data are described.

WP-114

Stith, J.L., M.K. POLITOVICH. Observations of the effects of entrainment and mixing on the droplet size spectra in a small cumulus. Journal of the Atmospheric Sciences, 46, 908-919 (1989).

Sulfur hexafluoride was released at the base of a small nonprecipitating, warm cumulus to study cloud mixing and entrainment processes. The tracer gas traveled to the top of the cloud where, during a 2.5 min period, it had mixed to produce a dilute mixture containing 30%, 19% and 51% of air from the original tracer region, an adjacent region of the dame cloud, and the environment surrounding the cloud, respectively. The droplet size distributions measured at the top of the cloud represented a mixture of larger droplets that had been growing from the base and smaller, recently activated droplets. The observations suggest that the source region for the small droplets was near cloud top. The large droplet concentration was conserved during the mixing process. These observations are compared with predictions from some recent models for cloud entrainment and droplet evolution.

WP-115

STRAUCH, R.G., D.A. MERRITT, K.P. MORAN, P.T. MAY, B.L. WEBER, and D.B. WUERTZ. Doppler radar wind profilers for support of flight operations. Journal of Aircraft and Aerospace Sciences, 15 (1989).

Wind profilers are becoming an accepted component of meteorological observing systems. This paper discusses various types of wind profilers, illustrates their capabilities and the data they

can provide to support flight operations, and discusses their limitations. In addition, the wind profiler has revived the Radio Acoustic Sounding System (RASS) technique for measuring temperatures. Preliminary RASS results are presented.

WP-116
STRAUCH, R.G., K.P. MORAN, P.T. MAY, A.J. BEDARD, and W.L. ECKLUND. RASS temperature sounding techniques. NOAA TM ERL WPL-158, 12 pp. (1989).

No abstract.

WP-117
STRAUCH, R.G., K.P. MORAN, P.T. MAY, A.J. BEDARD, and W.L. ECKLUND. RASS temperature soundings with wind profiler radars. Preprint, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 741-745 (1989).

No abstract.

WP-118
SUMMERS, S., W.D. NEFF, and C.W. KING. Forecasting air pollution episodes over Denver. Preprints, 6th Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 235-239 (1989).

No abstract.

WP-119
UTTAL, T., B.E. MARTNER, B. ORR, and R.M. Wakimoto. High resolution dual-Doppler radar measurements of a tornado. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 62-65 (1989).

No abstract.

WP-120
WALSH, E.J., D.W. Hancock, D.E. Hines, R.N. Swift, and J.F. Scott. An observation of the directional wave spectrum evolution from shoreline to fully developed. Journal of Physical Oceanography, 19:670-690 (1989).

The Surface Contour Radar (SCR) is a 36-GHz computer-controlled airborne system, which produces ocean directional wave spectra with much higher angular resolution than pitch-and-roll buoys. SCR observations of the evolution of the fetch-limited directional wave spectrum are presented which indicate the existence of a fully-developed sea state. The JONSWAP wave growth model for wave energy and frequency was in best agreement with the SCR measurements. The model of Conelan et al. correctly predicted the propagation direction of waves in the asymmetrical fetch situation nearshore. The Donelan et al. parameterization is generalized to permit other growth algorithms to predict the correct direction of propagation in asymmetrical fetch situations.

WP-121
WEICKMANN, A.M., J.P. RILEY, T.M. GEORGES, and R.M. JONES. EIGEN--A program to compute eigenrays from HARPA/HARPO rayset. NOAA TM ERL WPL-160, 91 pp. (1989).

EIGEN is a FORTRAN computer program that processes the rayset (machine-readable) output of the HARPA and HARPO acoustic ray-tracing programs. It interpolates in elevation angle to find the eigenrays that connect the source and a specified receiver. It also creates plots of range vs. elevation angle and range vs. travel time.

WP-122
WESTWATER, E.R., M.J. FALLS, E. Fionda, and J.B. SNIDER. Radiometric observations at 20.6, 31.65, and 90.0 GHz: continuing observations. Proceedings, NAPEX XIII, San Jose, CA, 30 June 1989, Jet Propulsion Laboratory, Pasadena, CA, 145-151 (1989).

Ground-based radiometer measurements at 20.6, 31.65 and 90.0 GHz have been analyzed to provide attenuation statistics, thus extending the data base of the previous NAPEX studies. Using data from colocated radiosondes, comparisons of the measurements and calculations of brightness temperatures are presented. The oxygen absorption model of Rosenkranz (1988) and the water vapor

absorption models of Liebe (1989) and of Waters (1976) are used in the study. Data from the July 1987 at San Nicolas Island, California, and from December 1987, August, 1988 and November 1988 at Denver, Colorado are included in the study. Joint-attenuation statistics at 20.6 and 31.65 GHz are presented for two locations of the Colorado Research Network (Denver and Platteville) for December 1987 and August 1988.

WP-123

WESTWATER, E.R., M.J. FALLS, and I.A. POPA FOTINO. Ground-based microwave radiometric observations of precipitable water vapor: a comparison with ground truth from radiosonde observing systems. Journal of Atmospheric and Oceanic Technology, 6:724-730 (1989).

Dual-channel microwave radiometric measurements of precipitable water vapor are compared with values determined from two types of radiosondes. The first type is used in conventional soundings taken by the National Weather Service. The second is used by the CLASS system, as operated by the National Center for Atmospheric Research. The standard deviations of the two comparisons are nearly equal, being about 0.1 cm, but statistically significant biases occur between the radiometer and the radiosondes. A bias of 0.162 cm is present between radiometer and NWS values during the day and 0.075 cm during the night. The comparison shows that significant differences exist between the radiometer and the NWS moisture soundings when the relative humidity drops below 20 percent for pressures greater than 500 hPa. When this situation occurs, the NWS soundings contain a default dewpoint depression value of 30°C. After such data are removed from the comparisons, agreement between radiometer and NWS radiosonde data is excellent.

WP-124

WESTWATER, E.R., M.J. FALLS, J.A. SCHROEDER, D. BIRKENHEUER, J.S. SNOOK, and M.T. DECKER. Combined ground- and Satellite-based radiometric remote sensing. Proceedings, International Workshop on Remote Sensing Retrieval Methods, 1988, A. Deepak Publishing Co., Norfolk, VA, 215-228 (1989).

The Wave Propagation Laboratory is currently operating a ground-based 5-channel microwave radiometer at Stapleton International Airport, Denver, Colorado. Combined soundings from the NOAA TOVS and the ground-based radiometer are shown to determine temperature profiles with rms errors less than 2.0 k from the surface to 300 mb. Operational VAS data acquisition and real-time sounding processing are now being performed by PROFS. Observations are represented from the ground-based radiometer. VAS soundings within 100 km of Denver, and ground truth provided by radiosondes. Combined thermal retrievals from the VAS and ground-based system are also presented. The Wave Propagation Laboratory also operates a limited network of four ground-based dual-frequency radiometers that measure precipitable water vapor and cloud liquid. An example illustrates how data from this system can be used to constrain the precipitable water analysis obtained from VAS.

WP-125

WESTWATER, E.R., and KROPFLI, R.A. Remote sensing techniques of the Wave Propagation Laboratory for the measurement of supercooled liquid water: applications to aircraft icing. NOAA TM ERL WPL-163, 28 pp. (1989).

No abstract.

WP-126

WESTWATER, E.R., and J.B. SNIDER. Ground-based radiometric observations of atmospheric emission at 20.6, 31.65 and 90.0 GHz. Proceedings, 6th International Conference on Antennas and Propagation ICAP-89, IEE, Hartfordshire, England, 229-233 (1989).

Over the past decade, the Wave Propagation Laboratory (WPL) has designed, constructed, and field tested several ground-based microwave radiometers to observe the atmosphere [Hogg et al. (1); Westwater and Snider (2)]. In particular, extensive experience has been gained by using both zenith-viewing and steerable dual-frequency instruments operating at 20.6 and 31.65 GHz. These instruments provide unique and meteorologically useful observations of precipitable water vapor V and integrated cloud liquid L. Perhaps equally as useful, but certainly not as well studied are the microwave attenuation characteristics that these devices can easily provide. Within the last year, WPL extended its radiometric capabilities by adding a channel at 90.0 GHz to the steerable and transportable radiometer. All three channels on this radiometer have equal beamwidths of 2.5°, and point in the same direction from the same location; hence, they are capa-

ble of simultaneously measuring emission and deriving attenuation for the same volume of air. We present here examples of some of the data taken with the new system at San Nicolas Island, California, USA, and at Denver, Colorado, USA. From these data, several statistical and physical quantities, relative to radio propagation studies, are derived and compared with theory.

WP-127

WESTWATER, E.R., J.B. SNIDER, and M.J. FALLS. Observations of atmospheric emission and attenuation at 20.6, 31.65, and 90.0 GHz by a ground-based radiometer. NOAA TM ERL WPL-156, 16 pp. (1988).

During 1987 and 1988, ground-based zenith-viewing observations of atmospheric thermal emission were made at frequencies of 20.6, 31.65, and 90.9 GHz. At the locations of the experiments--San Nicolas Island, California, and Denver, Colorado--radiosonde observations of temperature and humidity were also available. The data, after conversion to attenuation by use of the mean radiating temperature approximation, were processed to derive attenuation statistics. Both clear and cloudy attenuation characteristics are examined and compared with results from most recent theories. The predictability and interdependence of the three separate channels are also examined. It is found that attenuation for any two channels can predict that of the third to within 25%.

WP-128

WICKERS, M.T., W.P. SCHOENFELD, M.K. PAGOAGA, and R.J. HILL. How to extract data from the answer file of the millimeter-wave experiment. NOAA TM ERL WPL-164, 66 pp. (1989).

The method of retrieving data from the millimeter-wave experiment conducted at Flatville, Illinois, is described. It is assumed that the reader has a basic understanding of FORTRAN and is able to read and understand short FORTRAN programs. A few commands of the job control language for the Cyber Network Operation System (NOS) are also discussed.

WP-129

WILCZAK, J.M. Case study of an orographically induced, mesoscale vortex (Denver Cyclone) during CINDE. Preprint, International Conference on Mountain Meteorology and ALPEX, Garmisch-Partenkirchen, Federal Republic of Germany, 5-9 June 1989, German Aerospace Research Establishment (DFVLR), Oberpfaffenhofen, 114-115 (1989).

Observations taken during the Convection Initiation and Downburst Experiment (CINDE) are used to describe the formation and structure of an orographically induced mesoscale vortex that frequently occurs in northeastern Colorado. This vortex, locally known as the Denver Cyclone due to its proximity to the Denver metropolitan area, occurs in the lee of the Palmer Divide, an 800 m amplitude ridge of elevated terrain. We present a case study of the Denver Cyclone of 25 June 1987, that formed in a nighttime, stably stratified environment, approximately 4-6 hours after a synoptic southeast wind began to flow over the Palmer Divide. The 100 km diameter lee vortex remained stationary for over 24 hours.

WP-130

WILCZAK, J.M., and J. Glendening. Observations and mixed-layer modeling of a terrain-induced mesoscale gyre: the Denver Cyclone. Monthly Weather Review, 16:2689-2711 (1988).

In northeastern Colorado a frequently observed feature of the surface wind field is a stationary, terrain-induced mesoscale gyre, which is often associated with the formation of severe weather. Because of the gyre's proximity to the Denver metropolitan area, local weather forecasters frequently refer to it as the "Denver Cyclone." The development of one such cyclone, which occurred on 1 August 1985, is documented with mesonet,, radiosonde, wind-profiler, radiometer and tower data. Mixed-layer model simulations of this event closely agree with the observed gyre structure and indicate that the gyre is associated with a plume of warmer potential temperature air, which originates from a ridge of higher terrain to the south of Denver, and advects northward into the area of gyre formation. A mixed-layer vorticity budget demonstrates that the formation of the gyre results from the baroclinic and slope effects on the turbulent stress divergence profile.

WP-131

WILCZAK, J.M., D.E. WOLFE, and S.C. Albers. The 2 July 1987 tornado observed during CINDE: implications for NEXRAD. Preprints, 24th Conf. on Radar Meteorology, 27-31 March 1989, Tallahassee, FL, American Meteorological Society, Boston, MA, 251-254 (1989).

No abstract.

WP-132

WILSON, J.W., J.A. Moore, G.B. Foote, B. MARTNER, A.R. Rodi, T. UTTAL, and J.M. WILCZAK. Convection initiation and downburst experiment (CINDE). Bulletin of the American Meteorological Society, 69:1328-1348 (1988).

The Convection Initiation and Downburst Experiment (CINDE) was conducted in the Denver, Colorado area from 22 June to 2 August 1987 to study processes leading to the formation of deep convection and the physics of downbursts. A total of 6 Doppler radars, 87 mesonet stations, 3 research aircraft, 8 sounding systems and numerous photographic facilities were deployed within an 85 km x 85 km area. A comprehensive data set was obtained including measurements of convergence lines, downbursts, and tornadoes that occurred on 35, 22, and 11 days, respectively.

WP-133

WOLFE, D.E. A case study of a high pollution episode during the Denver Brown Cloud study. Preprints, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 240-242 (1989).

No abstract.

WP-134

WOLFE, D.E., and L.K. WITTENMEIER. An analysis of sonic anemometer vertical diffusion measurements in a complex urban environment. Preprints, 6th Joint Conference on Applications of Air Pollution Meteorology, Anaheim, CA, 30 January-3 February 1989, American Meteorological Society, Boston, MA, 139-141 (1989).

No abstract.

WP-135

WUERTZ, D.B. and B.L. WEBER. Editing wind profiler measurements. NOAA TR-ERL WPL-438, 78 pp. (1989).

An algorithm is described for editing profiler measurements of wind components over height and/or over time. The algorithm identifies and edits those measurements that do not fall within a continuously connected pattern. The algorithm is based on the premise that a fundamental component of any editor is a model that defines continuity. A simple continuity model is used to provide many examples to demonstrate that wind profiler measurements can be edited automatically and objectively with confidence.

WP-136

Young, J.W., F.D. Lane, and A.J. BEDARD. The effect of a ground-based inversion layer on an impacting microburst. Proceedings, 27th Aerospace Sciences Meeting, Reno, NV, 9-12 January 1989, American Institute of Aeronautics and Astronautics, Washington, D.C., (1989).

Present knowledge of hazardous microbursts is limited, and physical scale modeling can help improve our understanding. Dimensional analysis indicates that it is possible to model a microburst in a water tank using saline solutions of various densities. Furthermore, complicating factors such as a ground-based inversion layer can prevent microbursts from reaching the ground, greatly reducing the effectiveness of ground-based wind sensors. Bedard reviews evidence that even larger-scale gust fronts are influenced by ground-based inversions. Ground-based inversions can be created by introducing a layer of denser fluid along the bottom of the tank and microbursts created by dropping a negatively buoyant dyed fluid into the tank, using a release mechanism designed to create a puff of fluid with minimum initial vortex rollup. Tests show that the presence of an inversion layer will cause one of three events to occur: a mid-air microburst, a nondiverging microburst, or a diverging microburst. The Froude number provides an index predicting which of the three conditions is likely to occur. Added complexity such as an inversion layer can increase the danger of microbursts preventing warnings if surface wind speed sensors are used, and reemphasizes the need for improved warning methods so that aircraft may avoid dangerous wind shears under a variety of conditions.

WP-137

ZHAO, Y., M.J. POST, and R.M. HARDESTY. Receiving efficiency of pulsed coherent lidars. Conference on Lasers and Electro-Optics, 24-28 April 1989, Baltimore, MD, IEEE, NY, 362 (1989).

No abstract.

WP-138

ZHAO, Y., and M.J. POST. Receiving efficiency for pulsed coherent lidars. Proceedings, 5th Conference on Coherent Laser Radar: Technology and Applications, Munich, Federal Republic of Germany, 5-9 June 1989, Optical Society of America, Washington, DC, 147-150 (1989).

No abstract.

WP-139

ZHOU, J., G.T. MCNICE, and W.L. EBERHARD. Lidar observations on the stratospheric aerosol: Boulder, CO, 1985 to 1987. NOAA TM ERL WPL-162, 50 pp. (1989).

The lidar observations presented consist of 86 vertical profiles of backscatter measured by a ruby lidar (694.3-nm wavelength). Also presented are plots of scattering ratio profiles and tables containing values of the scattering ratio, aerosol backscattering coefficient, Rayleigh backscattering coefficient, and estimated aerosol optical depth versus altitude. Data acquisition and processing are briefly described. Some simple analyses of the lidar data are also discussed, including mean and peak aerosol backscatter characteristics, temperature versus aerosol structure, and trends in stratospheric aerosol optical depth.

Addendum

WP-140

Augustinus, A., J. Kusters, B.J. RYE, J. Dijk, and W. Wolters. Computer control of frequency tunable CO_2 lasers. Infrared Phys., 28:397-403 (1988).

Application of active frequency stabilization and cavity scanning techniques, under computer control, to C_n^2 lasers has been demonstrated. The methods avoid the need for passive stabilization and are appropriate for automated medium resolution spectroscopic systems including lidars. Procedures for self-adjustment of low pressure lasers and securing double mode laser outputs from high pressure lasers are described.

WP-141

BEDARD, A.J., G.E. GREEN, J. INTRIERI, and R. RODRIGUEZ. On the feasibility and value of detecting and characterizing avalanches remotely by monitoring radiated sub-audible atmospheric sound at long distances. Proceedings, A Multidisciplinary Approach to Snow Engineering, 11-14 July 1988, Santa Barbara, CA, National Science Foundation, Washington, DC, 267-275 (1988).

Because avalanches frequently occur in remote areas, it is often difficult to establish the timing or extent of snow movement. Such information is valuable for verifying avalanche prediction models, as well as establishing regional statistics. We summarize techniques developed for measuring low-frequency, small-amplitude sound waves in the atmosphere. Infrasonic observations made along the front range near Boulder, Colorado, suggest that it may be possible to detect low-frequency sound waves related to avalanches at distances of hundreds of kilometers. Several acoustic radiation mechanisms are possible. Source region acoustic measurements should be made of controlled avalanches in an effort to understand the acoustic radiation sources, and optimize measurement techniques.

WP-142

Coakley, J.A., and J.B. SNIDER. Dependence of marine stratocumulus reflectivities on path-integrated liquid water. Proceedings, FIRE Science Experiment Team Meeting, July 1988, Vail, CO, NASA Langley, 355-359 (1988).

Simple parameterizations that relate cloud liquid water content to cloud reflectivity are often used in general circulation climate models to calculate the effect of clouds on the earth's energy budget. Such parameterizations have been developed by Stephens (1978) and by Slingo and Schrecker (1982) and others. Here we week to verify the parametric relationship through the use of simultaneous observations of cloud liquid water content and cloud reflectivity. The column amount of cloud liquid water was measured using a microwave radiometer on San Nicolas Island fol-

lowing techniques described by Hogg et al. (1983). Cloud reflectivity was obtained through spatial coherence analysis of AVHRR imagery data (Coakley and Beckner, (1988). We present the dependence of the observed reflectivity on the observed liquid water path. We also compare this empirical relationship with that proposed by Stephens (1978).

WP-143

Conforti, G., A. Consortini, J.H. CHURNSIDE, and R.J. HILL. Effects of the receiving aperture size on atmospheric laser scintillation measurements. Proceedings, Scattering and Diffraction (vol. 1029), Hamburg, Federal Republic of Germany, 22-23 September 1988, SPIE, Billingham, WA, 119-122 (1988).

No abstract.

WP-144

INTRIERI, J.M., A.J. BEDARD, and R.M. HARDESTY. Doppler lidar observations of colliding outflow boundaries. 15th Conference on Severe Local Storms, 22-26 February 1988, Baltimore, MD, American Meteorological Society, Boston, MA, 249-252 (1988).

No abstract.

WP-145

Lenschow, D.H., Xing Sheng Li, Cui Juan Zhu, and B.B. STANKOV. The stably stratified boundary layer over the Great Plains. Part I: Mean and turbulence structure. Boundary-Layer Meteorology, 42:95-121 (1988).

We present airplane measurements of the stably stratified nocturnal boundary layer obtained during the Severe Environmental Storms and Mesoscale Experiment (SESAME) in 1979. The cases presented here were obtained over rolling terrain in central Oklahoma, with a mean slope of about 0.003. The results are in general agreement with previous modeling and observational studies for the mean and turbulence structure of the nocturnal boundary layer, with the exception that the eddy diffusivity of heat, and consequently the flux Richardson number are less than expected.

WP-146

Lenschow, D.H., S.F. Zhang, and B. STANKOV. The stably stratified boundary layer over the Great Plains. Part II: Horizontal variations and spectra. Boundary-Layer Meteorology, 42:123-135 (1988).

Airplane measurements of the stably stratified boundary layer obtained during the Severe Environmental Storms and Mesoscale Experiment (SESAME) over rolling terrain in south-central Oklahoma indicate that considerable horizontal variability exists in the flow on scales of several kilometers. Much of this wave-like structure appears to be tied to the terrain. The criteria for existence of stationary gravity waves indicate that these waves can exist under the observed conditions. The spectrum of terrain variations also supports the existence of these waves. Observed spectra of the vertical velocity have two peaks: one at wavelengths of several kilometers, which is due to waves and the other at wavelengths of about 100 m, which is due to turbulence. The variance at several kilometers wavelength increases somewhat with height at least up to about 800 m, but the variance contributed by turbulence decreases rapidly with height.

WP-147

Lenschow, D.H., M. Zhou, and B. STANKOV. The scalar gradient near the top of the convective boundary layer. Acta Oceanologica Sinica, 7:132-139 (1988).

The flux-gradient relationship for temperature in the unstably stratified atmospheric surface layer is well established, and seems to apply also to other scalars, such as humidity. Throughout the rest of the boundary layer, however, a flux-gradient relationship based on a flux at the surface is not well defined if a significant entrainment flux exists at the boundary-layer top. Wyngaard (see Wyngaard and Brost, 1983; Moeng and Wyngaard, 1984) has developed a model which assumes that a flux-gradient relationship can be defined separately for bottom-up transport due to a flux at the surface, and for top-down transport due to a flux through the boundary-layer top. He has shown, by means of large-eddy numerical simulations, that the model can successfully predict the flux-gradient relationship for scalars throughout most of the boundary layer. We have used aircraft profile measurements of temperature, humidity, and ozone concentration near the top of the boundary layer, and aircraft vertical flux measurements at several levels in the boundary

layer, as well as temperature profiler measurements from an elevator on the Boulder Atmospheric Observatory tower, flux measurements at several levels on the tower, to test the top-down flux-gradient relationship obtained from the numerical simulations. The shape of the observed scalar profiles agrees well with the shape obtained from numerical simulation, but the observed constant of proportionality predicts a somewhat larger gradient than that obtained from numerical simulation.

WP-148

STRAUCH, R.G. A modulation waveform for short-dwell-time meteorological Doppler radars. Journal of Atmospheric and Oceanic Technology, 5:512-520 (1988).

A modulation waveform for meteorological Doppler radars that obtain estimates of radar reflectivity, mean velocity, and Doppler width with dwell time much shorter than that used with conventional meteorological Doppler radars is described. The transmitted signal is a sequence of three identical chirp pulses; signal parameters can be estimated from the radar echoes of a single sequence with standard deviation similar to that of conventional meteorological radars that use dwell times more than an order of magnitude longer. This waveform would be particularly useful for radars with electronically steered antennas where the antenna scan rate is not limited by mechanical constraints and there is no spectral boadening caused by antenna motion.

WP-149

WEBER, B.F., F.F. HALL, and R.M. HARDESTY. A positively buoyant downburst investigated in two dimensions with Doppler lidar. 15th Conference on Severe Local Storms, 22-26 February 1988, Baltimore, MD, American Meteorological Society, Boston, MA, 403-406 (1988).

No abstract.

APPENDIX: FEDERAL-STATE COOPERATIVE PROGRAM IN WEATHER MODIFICATION RESEARCH

AP-001

Boe, B.A., P.L. Smith, H.D. Orville, N.C. Knight, M. Hjelmfelt, D.S. Griffith, J.L. Stith, and R.F. REINKING. North Dakota Thunderstorm Project Field Operations Plan, May, 1989. 75 pp.

No abstract.

AP-002

Chai, Steven., William G. Finnegan, Richard L. Pitter and Joseph A. Waterburton. A mechanistic interpretation of a winter orographic cloud seeding program. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva, WMO/TD-No. 269, I: 179-183 (1989).

No abstract.

AP-003

Changnon, S.A. Climate-based representations of summer rainfall in Illinois. J. Clim., 1, 1041-1046 (1988).

Historical (1901-85) summer rainfall data in central Illinois were used to construct three typical rain conditions: one representing the typical dry summer, another a typical wet, and a third the near-average summer rainfall conditions. Monthly rain totals were established, then daily rain frequencies were used to define all individual rain day amounts, and historical rain-day amounts by date were used to assign rain days and amounts to individual dates throughout the types of summers. In-day conditions relating to rainfall rate, time of rainfall and duration were constructed for each day of rain. The resulting 3 types of summer rainfall conditions were used to guide applications of water onto agricultural test plots (protected from natural rains) to measure crop yields effects from simulated rainfall modification.

AP-004

Changnon, S.A., and S.E. Hollinger. Use of unique field facilities to simulate effects of enhanced rainfall in crop production. J. Wea. Mod., 18, 108-112 (1988).

The simulation of various levels of rainfall increase on types of summer rainfall controlled through the use of covered agricultural plots was conducted during 1987 in central Illinois. Effects on corn and soybeans were tested in this experimentation, and plots received rainfall conditions representing dry, wet, and normal summers with additional rainfall applied at levels ranging from 10 to 40%, and varied based on the magnitude of individual daily rain amounts. These unique field experiments produced unusual results. The dry summer with added rainfall above 25% indicated major yield increases in both soybeans and corn. Corn yields were decreased by added rainfall in the typical wet summers of Illinois.

AP-005

Changnon, S.A., Hollinger, S., and Garcia P. Analyzing the effects of additional rainfall on corn and soybeans yields. Preprints 6th Conference on Applied Climatology, AMS, Boston, MA, 6 pp. (1989).

No abstract.

AP-006

Changnon, S.A., F.A. Huff, and C.-F. Hsu. Relations between precipitation and shallow ground water in Illinois. J. of Climate, 1, 1239-1250 (1988).

The statistical relationships between monthly precipitation (P) and shallow ground water levels (GW) in 20 sampling wells scattered across Illinois (with data for 1960-84) were defined using autoregressive integrated moving average modeling. A lag of one month between P and GW was the strongest temporal relationship found across Illinois, followed by no lag in the northern two-

thirds of Illinois where mollisols predominate. A lag of 2 months was found in the alfisols of southern Illinois. Spatial comparisons of the 20 P-GW correlations with several physical conditions revealed that the parent soil materials including outwash alluvium, glacial till, thick loess, and thin loess best defined regional relationships. These relationships allow studies of how altered precipitation, particularly in the summer season, affect the shallow ground water levels in Illinois under any precipitation conditions. The techniques of this equation should be transferrable to regions of comparable soil and climate.

AP-007

Changnon, S.A., Czys, R., Garcia, P., Hollinger, S., Huff, F., Nespor, J., Scott, R., and N. Westcott. The Precipitation Augmentation for Crops Experiment: Phase II. Final Report to ERL/NOAA under Cooperative Agreement NA87-RAH07077, 82 pp, Illinois State Water Survey (1988).

No abstract.

AP-008

Czys, R.R. The visualization of cloud droplet spectra. J. Atmos. and Oceanic Technol., 16, 1, 182-185 (1989).

This paper draws attention to the use of readily available, wire cage graphics for inspecting cloud droplet spectra measured using a Forward Light-Scattering Spectrometer Probe. The high resolution cloud droplet spectra from two different clouds are presented to illustrate the clarity with which microphysical processes can be visualized.

AP-009

Czys, R.R. Physical models used in the Precipitation Augmentation for Crops Experiment. Preprints 5th WMO Conference on Weather Modification and Applied Cloud Physics, Beijing, China, 221-224 (1989).

No abstract.

AP-010

Czys, R.R.Ice initiation by collision-freezing in warm-based cumuli. J. Appl. Meteor., 28, 1098-1104 (1988).

The mechanical shock of collision between supercooled water drops is explored as a mechanism for the origin of ice in the warm-based cumuli of the central United States. The results of laboratory experiments using groups of 3-mm diameter hemispherical drops supported on a petroleum substrate and cooled to either -10° or -15°C, are presented to demonstrate that supercooled drops can be caused to freeze mechanically. Cavitation is examined as a mechanism closely associated with ice nucleation in supercooled water. Pressure differences extrapolated from the Weber number for collisions between precipitation-size collector drops and a wide size range of smaller drops were found to exceed the criteria for cavitation and hence, freezing. This finding suggests that collision-freezing may occur in clouds and is worthy of further attention.

AP-011

Doneaud, A.A., A. Makarau, and L.R. Johnson. A modified ATI technique for nowcasting convective rain volumes over areas. J. Appl. Meteor., 27, 491-502 (1988).

Digital radar data from the North Dakota Cloud Modification Project (NDCMP)-the 1981 and 1982 summer experiments- are used to further investigate the relationship between convective rain volumes and are-time-integral (ATI). The ATI technique provides a means of estimating total rain volumes using area covered by rain events (for relectivities >25 dBZ) integrated over the cluster duration (Doneaud et al., 1984a).The purpose of this investigation is twofold: (a) to estimate ATIs only for the growth portion of a convective storm (while the rain volume is computed using the entire life history of the convective event); and (b) to nowcast the total rain volume of a convective system at the stage of its maximum development. For the aforementioned purpose, the ATIs were computed using the maximum echo area >25 dBX (ATIA), the maximum reflectivity (ATIR), and the maximum echo height (ARIH) as the end of the growth portion of the convective event.A simple linear regression analysis demonstrated that correlations between total rain volume (TVR) or the maximum rain volume (MVR) versus the ATIA were the strongest. In a log-log plot, the correlation coefficient and the standard error of estimates of total rain volume versus ATIA were 0.98 and 0.23 for the summer 1982 data, and 0.96 and 0.24 for the summer 1981 data, respectively. In percentage terms, the corresponding range

of variation of the rain volume for a given ATIA lies between 70% and -41% (1982 data) and between 74% and -44% (1981 data). That is comparable to the uncertainties which typically occur in rain volume estimates obtained from radar data employing Z-R conversion followed by space and time integration. This demonstrates that the total rain volume of a storm can be nowcast at is maximum stage of development (max ATIA).The scatter in the rain volume and in the maximum volumetric rain rate estimates are somewhat smaller if a multiple linear regression instead of a simple linear regression is considered, but the improvement is of little significance. The tests with independent data confirmed the consistency of the results for the regions considered.

AP-012

Feng, D. and W.G. Finnegan. An efficient, fast-functioning nucleating agent -- AgI AgCl 4NaCl. J. Weather Mod., 21:41-45, (1989).

A composite ice nucleus aerosol, AgIcl-4NaCl, has been generated and characterized for nucleation efficiencies, rates of ice crystal formation, and mechanisms of nucleation, under water saturation and transient supersaturation conditions. The addition of NaCl to the highly efficient contact nucleus, AgI0.8Cl0.2, changed the nucleation mechanism to condensation-freezing at water saturation and increased the rates of ice crystal formation dramatically, while retaining the high efficiency of the AgIcl nucleus aerosol. Under transient supersaturation conditions, this new aerosol demonstrated improved ice nucleation efficiencies at T 12°C, and even faster ice crystal formation rates, suggesting a change of nucleation aerosol should be advantageous for use in weather modification field programs under conditions where low cloud droplet concentrations suggest the use of a condensation-freezing nucleant.

AP-013

Finnegan, W.G. and R.L. Pitter, A postulate of electric multipoles in growing ice crystals: Their role in formation of ice crystal aggregates. Atmos. Res., 22:235-250 (1988).

This paper describes the basis of the postulate of electric multipoles in growing ice crystals. The postulate was initially developed to describe the orientation of aggregated ice crystals, for the purpose of learning about rate-determining forces involved in the initiation of ice crystal aggregation. A series of laboratory experiments were undertaken to test the postulate. A 6.7 -m3 controlled-temperature chamber was used to investigate the aggregation of growing ice crystals. The results show that small changes in dissolved salts are important in the orientation of initial ice crystal aggregates. We interpret these results to strongly support our hypothesis of electric multipoles in growing ice crystals.

AP-014

Finnegan, W.G. and R.L. Pitter. Ice crystal morphology: what makes snowflakes different, or alike? AMS, Symposium on the Role of Clouds in Atmospheric Chemistry and Global Climate, Anaheim, California. Amer. Meteorol. Soc., Boston, MA, 108-109 (1989).

No abstract.

AP-015

Finnegan, W.G., R.L. Pitter and L.G. Young. Reduction-oxidation (REDOX) reactions in growing ice crystals. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva, WMO/TD- no. 269, II: 655- 658 (1989).

No abstract.

AP-016

Huggins, A.W., A.B. Long, and B.A. Campistron. The impact of mesoscale precipitation bands on liquid water and precipitation efficiency in a winter storm in Utah. Proceedings. 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, 55-58 (1989).

No abstract.

AP-017

Johnson, J.E., R.C. Coon, and J.W. Enz. Economic Benefits of Crop Hail Reduction Efforts in North Dakota. North Dakota State University Agricultural Economics Report No. 247, April, 1989. 26 pp.(1989).

No abstract.

AP-018

Knapp, H.V., Durgunoglu, A., and S.A., Changnon. Effects of added summer rainfall on the hydrologic cycle of Midwestern watersheds. J. Wea. Mod., 18, 112-118 (1988).

The effects of added summer rainfall on agricultural areas in Illinois were investigated using a quasi-distributed-parameter watershed model. Increases in summer rainfall during July and August were simulated and used in the model to describe the changes in soil moisture, crop water use, shallow ground water, and streamflow conditions which could potentially occur from precipitation augmentation. Two historical periods, representing 4 dry years and 4 wet years of the past, were used in the simulations with 10% and 25% increases in precipitation applied. The greatest portion of the additional summer rainfall eventually percolated into ground water, and that less than 25% of the precipitation increase was used by crops.

AP-019

Long, A.B. On the precipitation efficiency of a winter mountain storm in Utah. Preprints, 11th Conference on Weather Modification, Edmonton, Alberta, Canada, American Meteorological Society, Boston, MA, 64-67 (1988).

No abstract.

AP-020

MEITIN, R.J., and R.F. REINKING. A Doppler radar analysis of a winter mountain storm. Preprints, 5th WMO Conference on Weather Modification and Applied Cloud Physics, Beijing, People's Republic of China, 8-12 May 1989, WMO, Geneva, 93-96 (1989).

No abstract.

AP-021

MEITIN, R.J., and R.F. REINKING. A preliminary radar analysis of a winter mountain storm. Preprints, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989, American Meteorological Society, Boston, MA, 490-493 (1989).

No abstract.

AP-022

Mitchell, D.L. and R.D. Borys. The effect of cloud and seeding on snow-size spectra and cloud droplet removal. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD-No. 269, I:217-220 (1989).

No abstract.

AP-023

Ochs, H.T., and S.Q. Kidder. A forecasting/nowcasting system for remote field locations. J. Atmos. Oceanic Technol., 6:218-221 (1989).

Vast quantities of frequently updated weather data for both forecasting and nowcasting are generally required in meteorological field programs. The continuing synthesis of this data to suit specific operations is best accomplished using computers. Recent advances in telecommunications and computer hardware have allowed improved assimilation and presentation of weather data to remote field sites at significantly reduced costs. This paper describes a forecasting/nowcasting system designed and assembled to support a weather modification field project in Illinois. With minor modifications, this system can be located anywhere that has access to electrical power and standard telephone lines. The use of new technology with on-site computer capabilities allow rapid generation of products specifically tailored to meet the requirements of individual field projects, both for forecasting the operations and nowcasting during operations.

AP-024

Pitter, R.L. and W.G. Finnegan. Another role for CCN in clouds. Symposium on the Role of Clouds in Atmospheric Chemistry and Global Climate, Anaheim, California. Amer. Meteorol. Soc., Boston, pp. 108-109 (1989).

No abstract.

AP-025
Pitter, R.L. and W.G. Finnegan. Development of heterogeneous nucleation theory for application in weather modification. 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD-No. 269, I:131- 132 (1989).

No abstract.

AP-026
Pitter, R.L. and W.G. Finnegan. Influence of chemical impurities on atmospheric ice crystal processes. Annual Meeting of the Pacific Northwest Division of AAAS, Chico, CA, June (1989).

No abstract.

AP-027
Pitter, R.L., W.G. Finnegan and L.G. Young. Electrochemical oxidation-reduction reactions in growing ice crystals: Freezing induced chemical reactions. International Conference on Global and Regional Environmental Atmospheric Chemistry, Beijing, China, p. 70, May (1989).

No abstract.

AP-028
Pitter, R.L. and R. Zhang. Effect of internal charge distribution in ice crystals on scavenging of aerosol particles. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD-No. 269, II:643-646 (1989).

No abstract.

AP-029
REINKING, R.F., and R.J. MEITIN. Recent progress and needs in obtaining physical evidence for weather modification potentials and effects. Journal of Weather Modification, 21:85-93 (1989).

Statistical and numerical modeling approaches to assess the effects of cloud seeding require the interactive input of, and understanding derived from, measurements that provide direct evidence of natural and altered development of precipitation. A brief review of recent progress in obtaining physical evidence to evaluate and verify potentials for and effects of precipitation enhancement and hail suppression is presented. Recent findings form the National Oceanic and Atmospheric Administration's Federal/State Cooperative Program in Weather Modification Research are emphasized, but other related results are included. In the context of many significant new advances toward proving hypotheses by direct measurement, a number of remaining needs for measurements and corresponding technologies are identified.

AP-030
REINKING, R.F., and REBECCA J. MEITIN. Advances and challenges in obtaining physical evidence for weather modification potentials and effects. Proceedings, WMO 5th Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, WMO, Geneva, WMO/TD-No. 269, I: 7-10 (1989).

No abstract.

AP-031
Sassen, K. Supercooled liquid cloud distribution over complex mountainous terrain. Proceedings, Fifth WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, WMO, Geneva. WMO/TD No. 269, I:51-54 (1989).

No abstract.

AP-032
Sassen, K., M.T. Davies and L. Liao. Remote Sensing observations of seeded winter storms from the 1989 Utah/NOAA Cooperative Weather Modification Program. Final Report to the Utah Division of Water Resources, University of Utah, Salt Lake City, UT, 35 pp. (1989).

No abstract.

AP-033

Scott, R.W. Forecasting convection intensities in Illinois from rawinsonde signatures. Preprints, 5th WMO Conference on Weather Modification and Applied Cloud Physics, Beijing, China, 221-224 (1989).

No abstract.

AP-034

Shang, R. A numerical study of aerosol scavenging by ice crystals. M.S. Thesis, Atmospheric Physics, University of Nevada, Reno, NV, 93 pp., (1989).

Two theoretical models are presented which allow computing the efficiency with which aerosol particles are collected by simple ice crystal plates. The present models incorporate gravitational, inertial, diffusive and electrostatic effects. The effect of an internal charge distribution, due to differential incorporation of ionic substances into ice crystal lattice, on aerosol scavenging is also investigated. Some calculations were performed using a low density for ice particles, to simulate scavenging efficiency is considerably affected by such an internal charge distribution for aerosol particles $0.1 \leq r \leq 1.0$ m. The present results imply that growing ice crystals containing dilute concentrations of ionizable salts may exhibit higher collision efficiencies. The present theoretical results reconcile the previously widely diverging results of snow crystal scavenging reported by many researchers. This study suggests that as aggregates form and grow, the internal charge distribution effect diminishes, while the net charge effect increases.

AP-035

Smith, P.L., M.W. Huston, and L.R. Johnson. Development of Evaluation Techniques for Operational Convective Cloud Modification Projects: 1987-88 Studies. Report SDSMT/IAS/R-89/03, South Dakota School of Mines and Technology, Rapid City. March 1989, 43 pp. (1989).

No abstract.

AP-036

Smith, P.L., L.R. Johnson, and F.J. Kopp. Development of Evaluation Techniques for Operational Convective Cloud Modification projects: 1986-87 sTudies. Report SDSMT/IAS/R-89/02, South Dakota School of Mines and Technology, Rapid City. March, 1989, 33 pp. (1989).

No abstract.

AP-037

Smith, P.L., H.D. Orville, J.L. Stith, B.A. Boe, D.A. Griffith, M.K. POLITOVICH and R.F. REINKING. Evaluation studies of the North Dakota Cloud Modification Project. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, WMO, Geneva, WMO/TD-No. 269, I:371-376 (1989).

No abstract.

AP-038

Stith, J.L., M.K. POLITOVICH. Observations of the effects of entrainment and mixing on the droplet size spectra in a small cumulus. Journal of the Atmospheric Sciences, 46, 908-919 (1989).

Sulfur hexafluoride was released at the base of a small nonprecipitating, warm cumulus to study cloud mixing and entrainment processes. The tracer gas traveled to the top of the cloud where, during a 2.5 min period, it had mixed to produce a dilute mixture containing 30%, 19% and 51% of air from the original tracer region, an adjacent region of the dame cloud, and the environment surrounding the cloud, respectively. The droplet size distributions measured at the top of the cloud represented a mixture of larger droplets that had been growing from the base and smaller, recently activated droplets. The observations suggest that the source region for the small droplets was near cloud top. The large droplet concentration was conserved during the mixing process. These observations are compared with predictions from some recent models for cloud entrainment and droplet evolution.

AP-039

Stone, R. and J. Warburton. The dispersion of silver iodide in mountainous target areas of the western United States. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TC- No. 269, I: 167-169, (1989).

No abstract.

AP-040

Warburton, J., R. Stone and L. Young. A new scientific method employing ice-nucleating and non ice-nucleating aerosols simultaneously for assessing the effects of cloud seeding on precipitation. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD-No. 269, I:191-194 (1989).

No abstract.

AP-041

Warburton, J., R. Stone and B. Demoz. A conceptual model for determining seeded/not-seeded ratios in weather modification experiments based on stable oxygen isotopic ratios and snow chemistry. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD-No. 269, I:187-190 (1989).

No abstract.

AP-042

Westcott, N. Influence of mesoscale winds on the turbulent structure of the urban boundary layer over St. Louis. Boundary Layer Meteor., 48:283-292 (1989).

Two fair weather afternoons have been examined, where the urban boundary layer over St. Louis, though exhibiting similar thermal characteristics, had a markedly different kinematic structure. The turbulent nature of the boundary layer was examined through analysis of double theodolite wind profiles at an urban and at a rural site on each day. On 14 July 1975, the winds increased with height above the inversion at both sites and on the following day, the winds decreased above the boundary layer in the same region. While the mean wind speed in the lowest 0.8 km AgI was similar on both days, the turbulence characteristics of the urban boundary- layer winds were distinctly different on these two afternoons. This was evidenced by the variance of the wind and is in agreement with simultaneous aircraft measurements reported by Hildebrand and Ackerman (1984). A similar difference in turbulence was not found over the rural site. It is suggested that the enhanced turbulence at the urban site on 14 July is likely associated with the wind profile immediately above the boundary layer, where the downwind flux of high momentum air from above the inversion may have resulted in stronger mechanical mixing within the boundary layer.

AP-043

Westcott, N.E. Differential reflectivity (ZDR) measurements. Preprint, 24th AMS Conf. on Radar Meteorology, Tallahassee, 388-390 (1988).

No abstract.

AP-044

Westcott, N.E. Growth habits of seeded and non-seeded radar echoes from the 1986 Precipitation Augmentation for Crops (PACE) field program. Preprint, 5th WMO Sci. Conf. on Weather Modification, Beijing, China. (1988)

No abstract.

AP-045

Westcott, N.E., and S.A. Changnon, Jr. Properties of echoes at first detection resulting in multicelled storms. Preprint, International Symposium on Hydrological Applications of Weather Radar. Univ. of Salford, Salford, England, 8 pp. (1989).

No abstract.

AP-046

Westcott, N., and P. Kennedy. Cell development and merger in an Illinois thunderstorm observed by Doppler radar. J. Atmos. Sci., 46:117-131 (1989).

A reflectivity and triple-Doppler radar study of the development of several cells and their successive union within a nonsevere thunderstorm is presented. Two characteristic separations were found in response to the collapse of an active cell and the more distant cells forming in a previously existing storm-modified area characterized by mesoscale convergence and rain cooled air. The manner in which these cells evolved appeared to be partially related to differences in the environment in which they formed. As suggested by peterson, the cells that formed closer to the main storm resembled the "weakly evolving" cells of Foote and Franks. The updraft of the "weakly evolving" cell analyzed here merged with the updraft in a cell in the main storm as one cell was decreasing in intensity and the other was increasing.

Later in the life cycle of the storm, two cells which initially formed further away from the main storm appeared more like classical "strongly evolving" cells. While the vertical air velocity analyses of these cells were incomplete, a trend towards the maintenance of a discrete cell updraft was noted. The ways in which the reflectivity cores of these two cells became merged with the main storm differed. In one case the development of a new cell between two existing cells produced the merger, in the second case differential cell motion played an important role. Additionally, periods of significant intercell flow at 4 km coincided with the times when the midlevel reflectivity bond linking the cell cores showed a rapid intensification. It is proposed that the intercell flow is a result of radial outflow observed at heights above the maximum updraft level in the actively growing echoes. The strengthening of the reflectivity bridge may have been the result of both particle transfer and environmental modification brought about by this radial outflow.

AP-047

Zhang, P., R.L. Pitter and D.L. Mitchell. Ground-based snowflake observations for analysis of orographic winter storms. Proceedings, 5th WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China. WMO, Geneva. WMO/TD- No. 269, I:47-49 (1989).

No abstract.

ABOUT THE AUTHOR INDEX

All authors of all publications are listed.

An asterisk indicates a first author.

ERL authors' names are typed in all capital letters.

The words "et al." indicate that a publication had more than one author.

The alphanumeric code following an author's name gives the location of the bibliographic entry. Example: WP-061 is the sixty-first entry in the Wave Propagation Laboratory section.

Following are the codes used, their meanings, and inclusive pages.

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AL	Aeronomy Laboratory	1-20
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