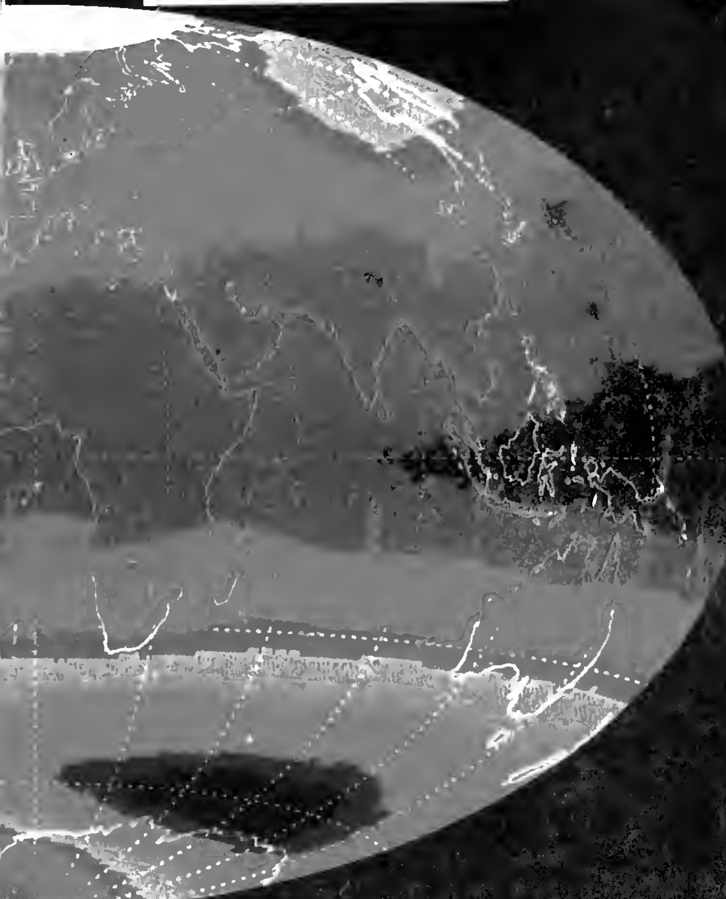
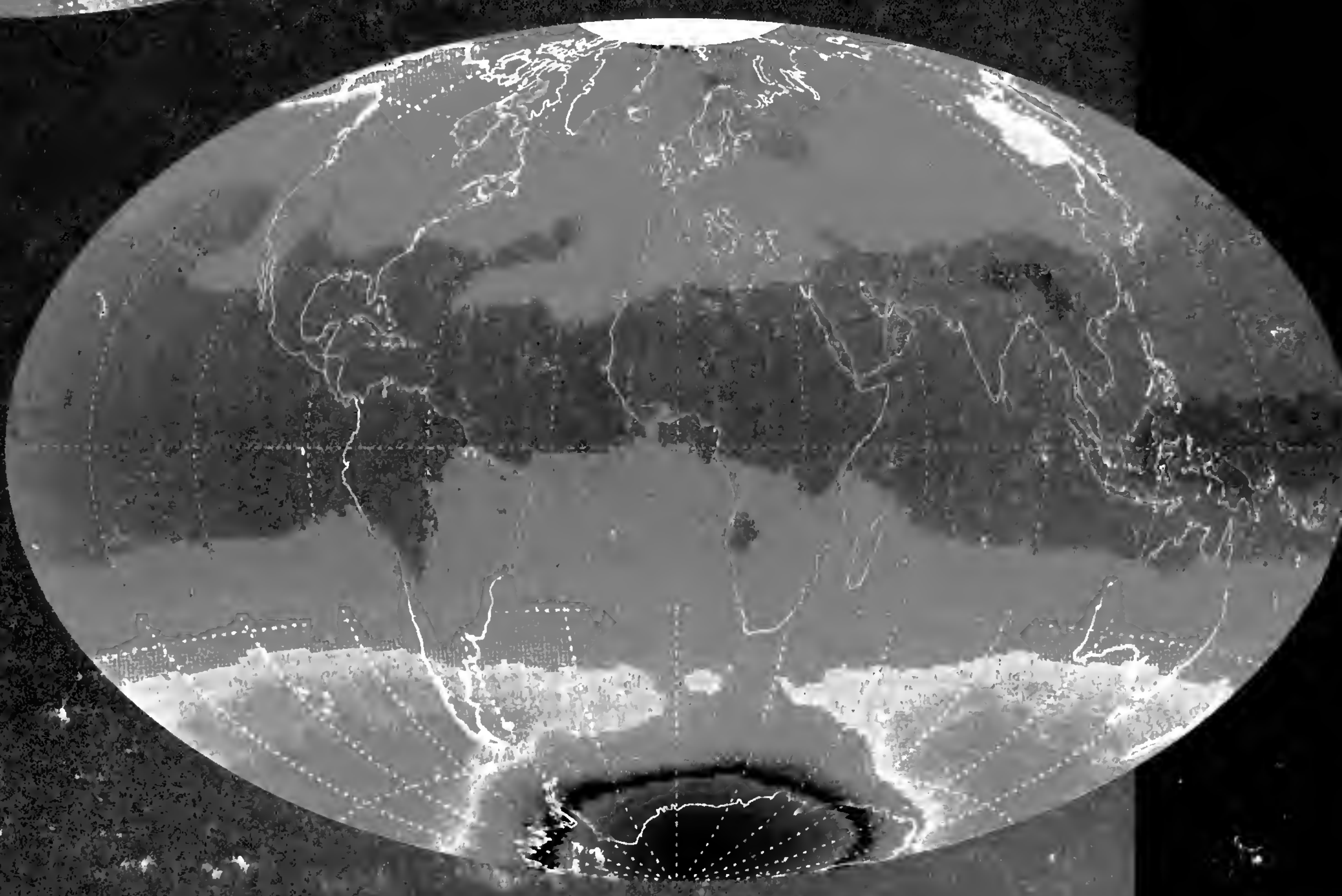
Atmospheric Chemistry & Dynamics Branch





Top cover image: Nimbus-7 TOMS *data showing the ozone hole over* Antarctica *for the month of* October 1979.

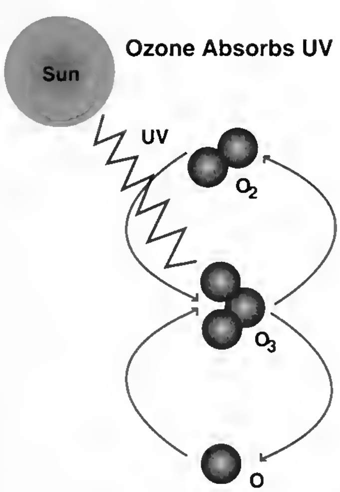
Atmospheric Chemistry and Dynamics Branch

Mission

The principal mission of the Atmospheric Chemistry and Dynamics Branch is to understand the behavior of tropospheric and stratospheric ozone and trace gases that influence ozone. Ozone and trace gases such as methane, nitrous oxide, and the chlorofluorocarbons profoundly influence the habitability of the Earth even though together they comprise less than one percent of the Earth's atmosphere. Ozone itself absorbs nearly all the biologically damaging solar ultraviolet radiation before it reaches the Earth's surface. The Clean Air Act of 1977 assigns the responsibility for studying the ozone layer to NASA. The Atmospheric Chemistry and Dynamics Branch is the center for ozone and related atmospheric research at the Goddard Space Flight Center.

Branch Research Overview

Ozone is found throughout the atmosphere, but its highest concentration is in the stratosphere, the region between approximately 12 and 50 km in altitude. Stratospheric ozone varies on different spatial scales and over many time scales. Atmospheric motions cause it to fluctuate on a daily basis. Circulation changes over the year drive seasonal variations. Year-to-year changes occur because of changes in atmospheric circulation, volcanic eruptions, and solar activity. Superimposed on those variations are decade-scale negative trends which have been shown to be driven by the increase of stratospheric chlorine generated when industrially produced chloroflourocarbons (CFCs) are photochemically destroyed. International agreements (the Montreal Protocol and its subsequent amendments) have been signed to reduce production of CFCs. As the provisions of these treaties take effect, the chlorine content of the stratosphere should decline and stratospheric ozone should begin to recover. It becomes important, therefore, for scientists not only to to distinguish



Ozone absorption heats the stratosphere

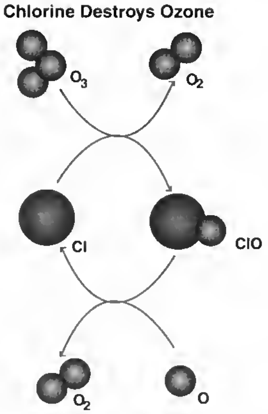
between natural and anthropogenically caused variations in stratospheric ozone, but to monitor and interpret the ozone recovery process as it takes place during the next half-century.

While most atmospheric ozone is found in the stratosphere, ozone in the troposphere—the lowest layer of the atmosphere—is also important. High values of ozone in the troposphere can result from polluted urban areas in summer, from biomass burning, and from stratospheric air transported into the upper troposphere.

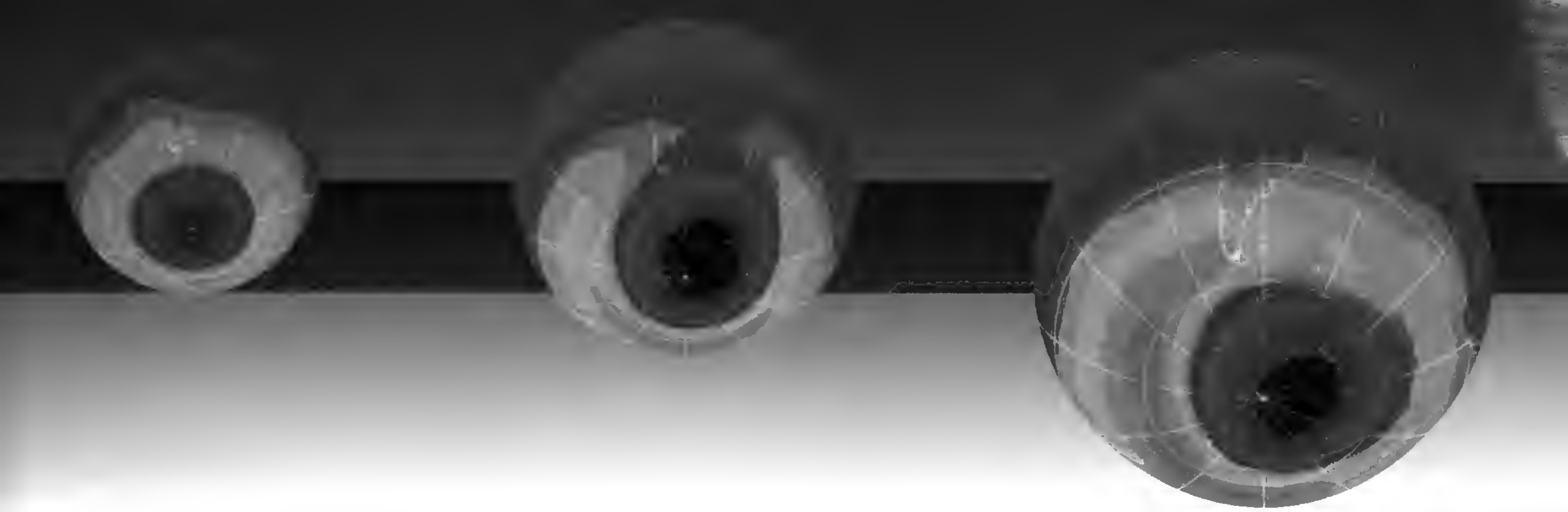
To investigate the chemistry and dynamics of ozone and other trace gas requires a comprehensive research and measurement program focused on the chemical properties of ozone and ozone-depleting gases, the meteorological characteristics of the stratosphere, and the mechanisms by which pollutants released in the troposhere reach the stratosphere. Because of the interdisciplinary nature of this research, the Atmospheric Chemistry and Dynamics Branch carries out joint research projects with other scientific groups in Goddard's Laboratory for Atmospheres as well as other NASA and National Oceanic and Atmospheric Adminstration (NOAA) research centers.

In-house-designed ozone-measuring satellite instruments have been flown since 1970 with future launches scheduled for coming years. All of these instruments, which measure ozone by looking at the amount of ultraviolet absorption, have provided high-quality data sets which span the globe. The Branch is also involved in the planning and implementation of aircraft campaigns designed to investigate ozone loss in the lower stratosphere.

Chlorine Destroys Ozone



Another important Branch activity is the design and development of comprehensive models of the atmospheric chemical system. These models are used to test our understanding of Earth's atmosphere and to predict the impact of trace gas emissions on ozone. The models are currently being used to assess the impact of the current fleet of subsonic aircraft, and of a new generation of proposed supersonic transport aircraft on the ozone layer.



Instruments

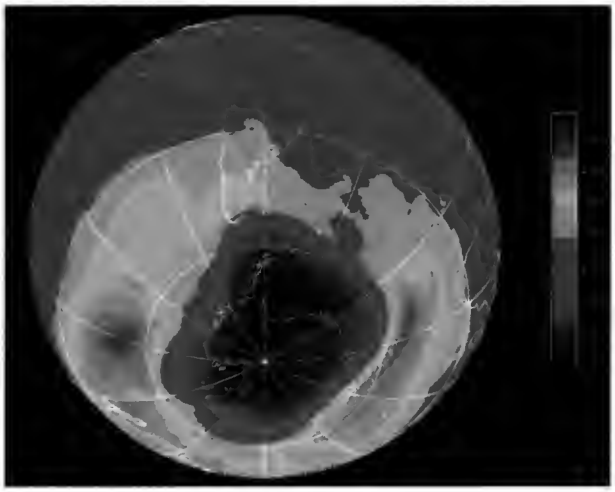
The Atmospheric Chemistry and Dynamics Branch is active in developing and deploying instruments to make atmospheric measurements. These include devices flying on earth-orbiting satellites, ground-based monitoring systems, and instruments carried aloft by balloons or aircraft.

Satellite Instruments

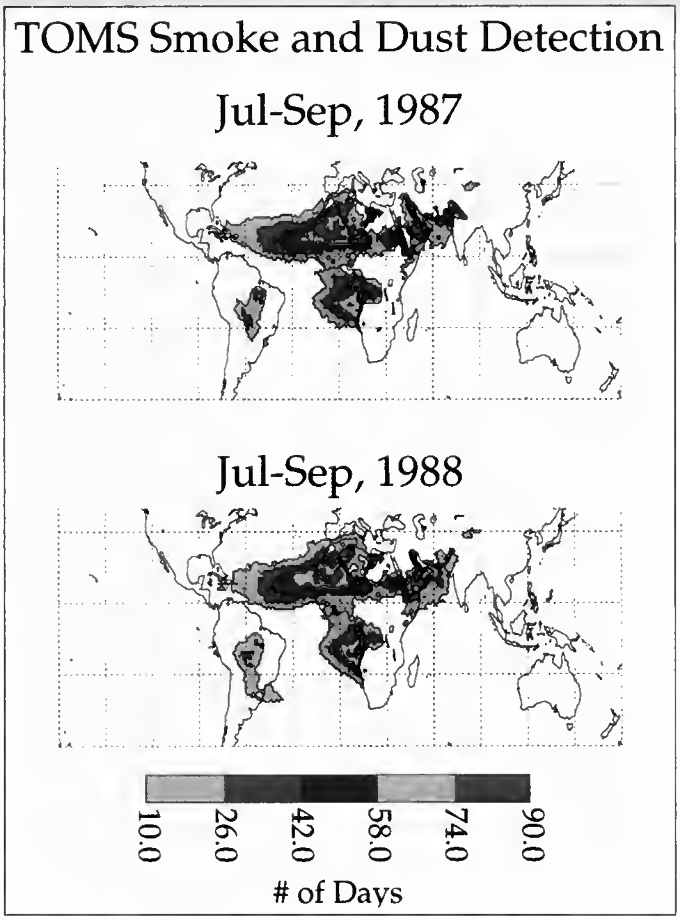
TOMS

The Total Ozone Mapping Spectrometer (TOMS) provides total column ozone by measuring ultraviolet light scattered back into space from the earth's atmosphere. By scanning over the earth's surface, TOMS creates daily global maps of total ozone amounts. TOMS has been critically important in making detailed maps of the Antarctic "ozone hole" which appears each austral spring, as well as in performing statistical studies of global ozone depletion.

Four TOMS instruments have flown: the first, on board the Nimbus 7 satellite, operated from October 1978 through May 1993. Nimbus TOMS's longevity has enabled studies of subtle trends outside the ozone hole region. A second instrument was launched on board the Russian Meteor-3 satellite in August 1991; it provided data until December 1994. Two updated versions of the instrument were launched in 1996 as parts of the U. S. Earth Probes and Japanese Advanced Earth Observing Satellite (ADEOS) programs. Both instruments are currently producing data.



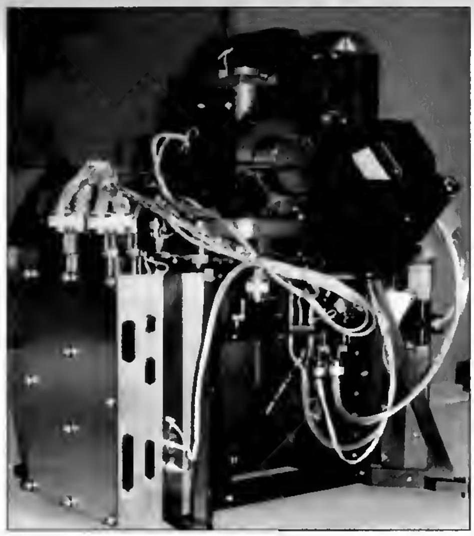
False-color image of total ozone data measured by the Meteor-3 TOMS instrument on October 2, 1994. Very low values of ozone can be seen over Antarctica—the "ozone hole"—surrounded by a ring of higher values.



The number of days of occurrence and distribution of absorbing aerosols during the most active months.

In addition to ozone, TOMS also measures sulfur dioxide injected into the stratosphere by volcanic eruptions, thus providing a means of tracing volcanic emissions as they are transported and dispersed by the winds. TOMS data have been used to track the eruptions of El Chichon, Mount Pinatubo, and Cerro Hudson.

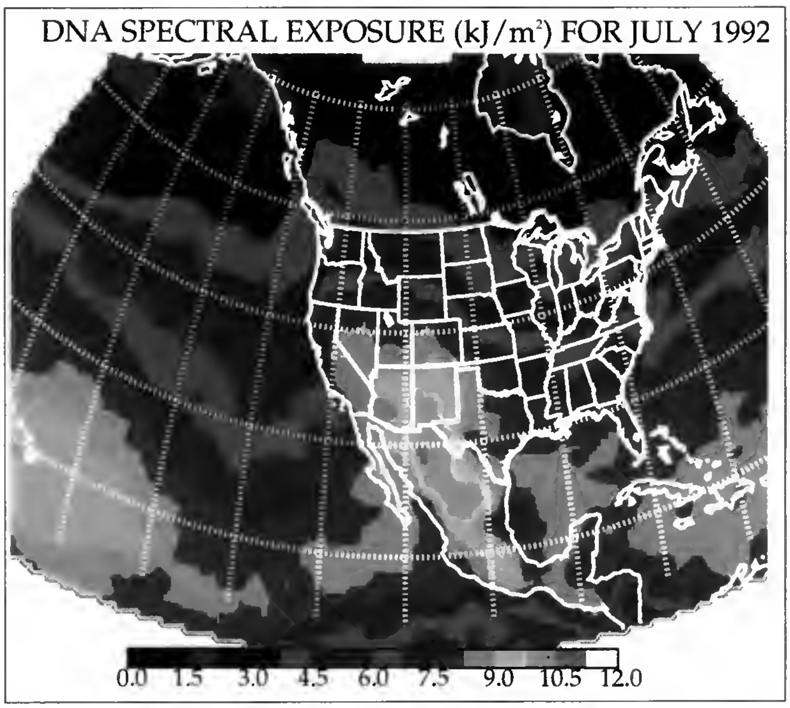
Recently TOMS has acquired a new capability to detect atmospheric aerosols (dust, smoke, volcanic ash, and sulfate particulates) from the improved accuracy of the Version 7 algorithm. The entire TOMS data set has been processed so that researchers can investigate the global and seasonal distribution of aerosols, and determine whether there have been changes in the amount of aerosols in the atmosphere since 1979. The TOMS data is the first and only aerosol data set to provide complete global coverage over both land and water. For the first time, the ground sources of most of the aerosols can be seen as well as the redistribution of the aerosols by prevailing winds. TOMS data shows that 10% of Earth's surface is covered with significant amounts of absorbing aerosols for most of each year. The largest contributor to the absorbing aerosol content is from desert dust blowing off of the Sahara and Sahel regions of Africa. Other significant contributions to Earth's atmospheric aerosol content come from agricultural biomass burning in southern and equatorial Africa, forest clearing in South America, and boreal fires in Canada and Siberia. Earth-Probe TOMS was placed in a low orbit (500 km instead of 950 km) to improve our ability to view the sources of aerosols and to possibly detect contributions from



TOMS *instrument on the* ADvanced *Earth Observing Satellite* (ADEOS).

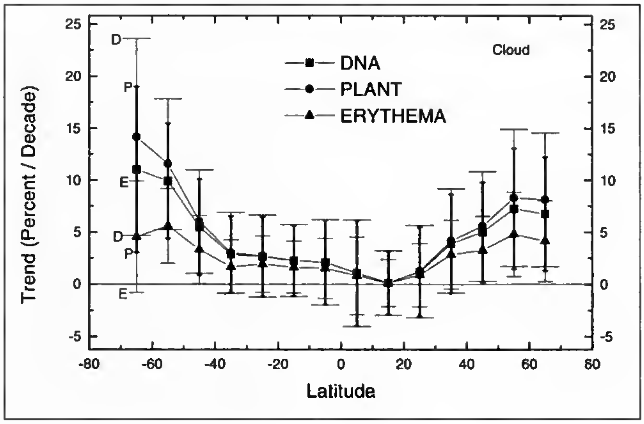
urban and industrial pollution. The distribution and amount of aerosols (both absorbing and non- absorbing) affect the radiation balance of the Earth. The TOMS aerosol data are now being incorporated into global climate models (GCMs) in cooperation with university and other NASA groups.

In addition to ozone monitoring and aerosol detection, TOMS data have been used to determine the daily amount of ultraviolet radiation striking the Earth's surface. This problem owes its importance to the direct effect of UV radiation on human health through changes in skin cancer incidence, immune system deficiencies, eye cataracts, and food production. The results have permitted us to determine that UV-B radiation (280 nm - 320 nm), which is absorbed by ozone, has increased by a few percent per decade in response to decreases in the amount of ozone at latitudes poleward of 35° while nonabsorbed UV-A radiation (320 nm - 400 nm), which is not absorbed by ozone has remained constant. The constancy of UV-A shows that the global cloud amounts have not changed significantly since 1979. This unique global



The varying intensity of UV radiation (300 nm to 310 nm) as a function of latitude and altitude in the vicinity of the United States.

The changes in UV radiation since 1979 for wavelength ranges important for 3 biological processes. 1. The damage of DNA molecules, 2. The damage to plants, and 3. The damage to human skin (erythema).



UV data set is being used to monitor UV changes and used to better understand the results from a large network of ground based instrumentation.

SSBUV

The purpose of the Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument is to perform calibration checks of the backscattered ultraviolet (BUV) ozone-sounding instruments on the NASA and NOAA satellites in order to remove calibration drift, so that ozone trends in the middle stratosphere can accurately be derived. Calibration checks are performed by comparing coincident observations between SSBUV and the satellite instruments. Comparison of the observed quantities does not require a retrieval algorithm and therefore provides a calibration check of the satellite instrument. The SSBUV experiment has flown on the Space Shuttle eight times since October 1989, with its last flight completed in January 1996. Regular flights of about once every eight months and maintenance of the SSBUV calibration to 1% from flight to flight were major challenges for SSBUV.

SSBUV has provided calibration checks or has been used in the verification of ozone data from SBUV/2 instruments on the NOAA-9, NOAA-11, and NOAA-14 satellites; the Nimbus-7 TOMS instrument, and the European Space Agency's recently launched Global Ozone Monitoring Experiment (GOME). SSBUV has also participated in several intercomparison campaigns to validate solar spectral irradiance and ozone data from instruments flying on the Upper

Atmospheric Research Satellite (UARS) and the Space Shuttle. In addition to the in-orbit calibration efforts, SSBUV has provided data on other atmospheric phenomena such as nitric oxide amounts in the upper stratosphere and mesosphere, and Raman Scattering in the troposphere. The SSBUV series of flights has resulted in 23 refereed publications dealing with calibration science, satellite validation, and atmospheric and solar science. Although the SSBUV instrument has now ended its flights, the laboratory will continue to provide calibrations for future U.S. and European environmental satellite sensors. The SSBUV instrument is proposed to provide a reference calibration instrument for the network of deployed UV-B monitors. Work in the laboratory will continue to explore new technology for remote sensing for Earth System Science Pathfinder missions and the future National Polar Orbiting Environmental Satellite System.

UARS

The Upper Atmosphere Research Satellite (UARS) is intended to investigate the chemistry, dynamics, and energetics of the middle atmosphere (from the upper troposphere to the thermosphere). It was launched from the Space Shuttle on September 12, 1991. The UARS mission was originally conceived within the Branch, the UARS Project Science Office is located in the Branch, and a number of our scientists are UARS principal investigators or co-investigators. The UARS measurements include solar and particle input to the atmosphere, the atmospheric winds and temperatures, and many atmospheric constituents. The UARS data contain the most complete set of global middle atmosphere observations ever attempted and are being used to address many outstanding issues concerning the middle atmosphere.

This is an artist's conception of the UARS *satellite in flight.* UARS *was deployed from the* Space Shuttle *on* 12 September, 1991.

UARS Guest Investigator Program Activity

A program has been developed to study the chemical and dynamical processes controlling ozone in the middle atmosphere by analyzing UARS constituent data in conjunction with multidimensional models. The overall objective of the research is to gain a better understanding of the processes which produce observed ozone loss so that more reliable predictions can be made of future anthropogenic changes. The approach is to use models to develop temporal and spatial continuity of the observations in order to apply them to specific atmospheric situations. This approach will enable us to exploit the full power of the combined UARS data set and to tightly constrain the variables of complex systems. The approach will also help to establish consistency among the measurements and develop confidence in using them to address outstanding issues. The models to be used include a three-dimensional (3-D) chemistry/transport model which uses winds and temperatures from data assimilation, a 3-D model with transport winds from a global spectral mechanistic model, two-dimensional models with full chemistry, a trajectory model (with chemistry if needed), and box and steady state models. The primary topics to be addressed are the chemistry of the midlatitude stratosphere, stratospheric winter polar chemistry and its effect on midlatitudes, stratospheric and mesospheric transport, and the effect of external influences (e.g., solar UV, energetic particle input) on middle atmosphere chemistry. In addressing a broad range of topics with a central focus on ozone, and by using a variety of modeling and analysis tools, we expect the separate components to strengthen each other and to make effective use of the data.

Ground-based measurements

Stratospheric Ozone Lidar Trailer Experiment (STROZ-LITE)

The STROZ-LITE system has been actively acquiring data since 1988. It is a mobile lidar instrument housed in a forty-five foot trailer. This system is capable of making vertical profile measurements of ozone, atmospheric temperature, and aerosols. Several lidar techniques are used

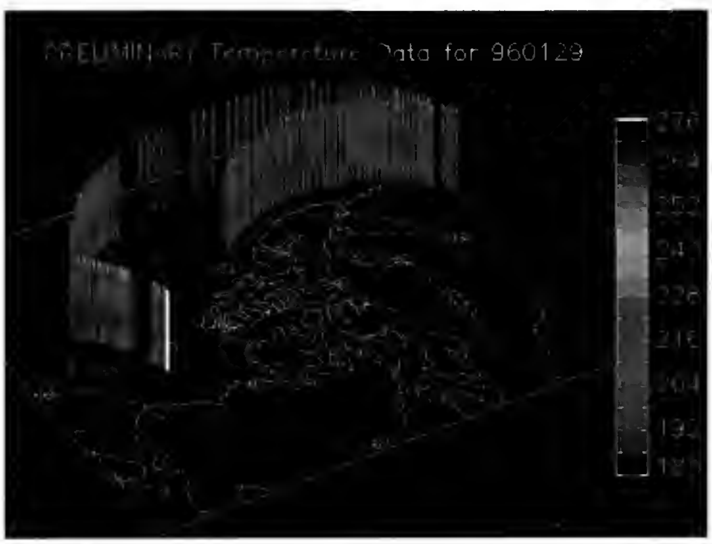
to make these measurements. This instrument is a primary instrument within the International Network for the Detection of Stratospheric Change (NDSC), and is part of the UARS Correlative Measurements Program. As part of these two programs, the Stratospheric Ozone Lidar has been deployed at various sites within the United States, France and New Zealand. STROZ-LITE is also used for validation by the science team for the NASA SAGE II instrument

Aerosol and Temperature Lidar (AT Lidar)

A second mobile lidar system has been developed within the Branch. This system has enhanced aerosol and temperature capabilities over the STROZ-LITE system. The lidar instrument uses two separate lasers to transmit three different wavelengths and retrieves lidar returns from four wavelengths. Wavelengths transmitted are: 1060 nm, 532 nm and 351 nm. In addition to the three elastically scattered wavelengths, the Raman scattered wavelength from the 351 nm laser is collected. This combination of wavelengths yields additional information relating to aerosol properties. In addition, a new technique for the measurement of temperature in regions of high aerosol concentration is being developed in collaboration with Colorado State University. This lidar instrument is to be part of the NDSC and was recently deployed to the NDSC Station at Mauna Loa Observatory, Hawaii.

Methane Lidar

Researchers within the Branch have developed an airborne lidar to measure profiles of methane and temperature. This instrument uses the



Temperature profiles (in Kelvin) from the Goddard methane lidar instrument on the NASA DC-8 *during the* TOTE/VOTE *experiment. The flight from Fairbanks, Alaska, to Greenland and back took place on* 29 *January,* 1996.

Raman scattering technique, and flies aboard the NASA DC-8 "flying laboratory." Methane is measured because it is a long-lived trace gas in the lower stratosphere and thus tends to be conserved in an air parcel. Temperature is measured in order to calculate a quasi-conserved quantity called potential temperature. One can use these two quantities to track the motions of streamers or parcels of air. This information, in conjunction with ozone measurements, should enable one to separate dynamical effects from chemical destruction of ozone.

A new instrument, the methane lidar is now operational and has flown successfully in the TOTE/VOTE field experiment.

Solar Sextant

The Solar Disk Sextant instrument is a balloon-borne device whose primary aim is to make highly precise measurements of the the diameter of the Sun. These measurements are to be used along with simultaneous solar luminosity measurements to determine the relationship between radius and luminosity changes in the sun. One can then use historical solar radius change data (obtained from solar eclipse data) to determine the amplitude of solar luminosity changes in the past. This will be of help in validating climate models. In addition, as a by-product of this research, we obtain a value for the solar oblateness, which is of great interest to those working in relativity and fluid dynamics, and several areas of solar physics. The Solar Disk Sextant has flown every September since 1992.

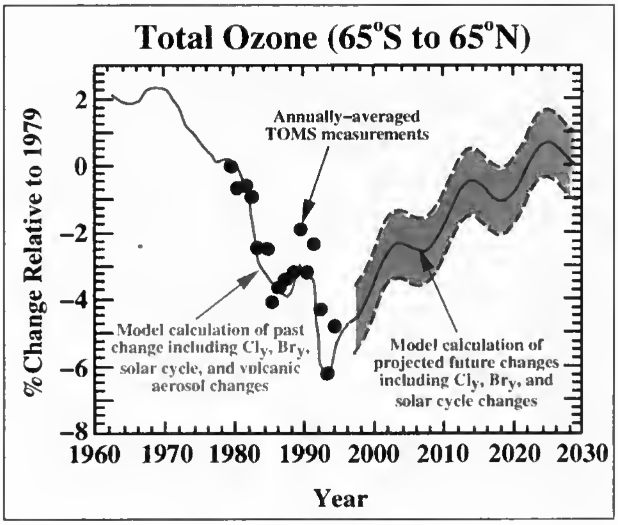
In this photo, the powerful laser beam from the STROZ-LITE *lidar is pointed into the night sky above Goddard Space Flight Center. Laser light scattered back to the instrument from stratospheric molecules is analyzed to obtain ozone concentrations at various altitudes.*

Modeling

Scientists in the Atmospheric Chemistry and Dynamics Branch write computer programs to simulate chemical and dynamical processes in the atmosphere; these are called "computer models." The simulations incorporate not only the physical laws governing atmospheric motions, but hundreds of chemical reactions as well. These models are used to predict changes in atmospheric ozone and to test our understanding of basic atmospheric processes. However, even with the fastest computers, these models can provide only a partial picture of the evolving chemical state of the atmosphere. A significant part of our research is focused on the development and improvement of chemical models.

Two-dimensional Chemical Modeling

Two-dimensional (2D) chemical models of the atmosphere have been developed to simulate natural and manmade influences on ozone. These models, whose two dimensions are latitude and height, can reasonably represent the transport and chemistry of the stratosphere and mesosphere on seasonal time scales. The neglect of longitude (east-west directions) is an important simplification that greatly reduces the computer time required and allows the chemistry to be calculated in great detail. The 2D model is fast enough to allow us to make hundred-year estimates of ozone layer evolution while still providing a good simulation of the seasonal changes in ozone.



Model calculation of past global ozone changes and future projections for ozone change assuming that the provisions of the Montreal Protocol are followed. The calculation of past changes included the effects of increasing chlorine and bromine, solar-cycle UV variations and volcanic aerosol changes. The annually-averaged TOMS data are shown for comparison. The projected future changes include the effect of decreasing chlorine and bromine as well as solar-cycle uv changes.

Halocarbon Assessments

A major application of the two-dimensional models of the atmosphere is the assessment of the effects of halocarbons on stratospheric ozone. Man-made (or synthetic) halocarbons are being regulated under international protocol agreements. If these agreements are followed, then ozone-depleting chemical constituents comprised of chlorine and bromine will maximize in the late 1990s and slowly decrease after that. A 2D model prediction of the change in total ozone between 65S and 65N between the years 1975 to 2030 shows that stratospheric ozone levels inversely follow the chlorine and bromine changes; ozone is predicted to reach its minimum levels in the late 1990s and slowly recover after that. The early part of this simulation can be compared to data from the Branch's TOMS satellite instruments, and the scatter can be used to indicate uncertainties in the longer-term predictions.

Three-dimensional Chemical Modeling

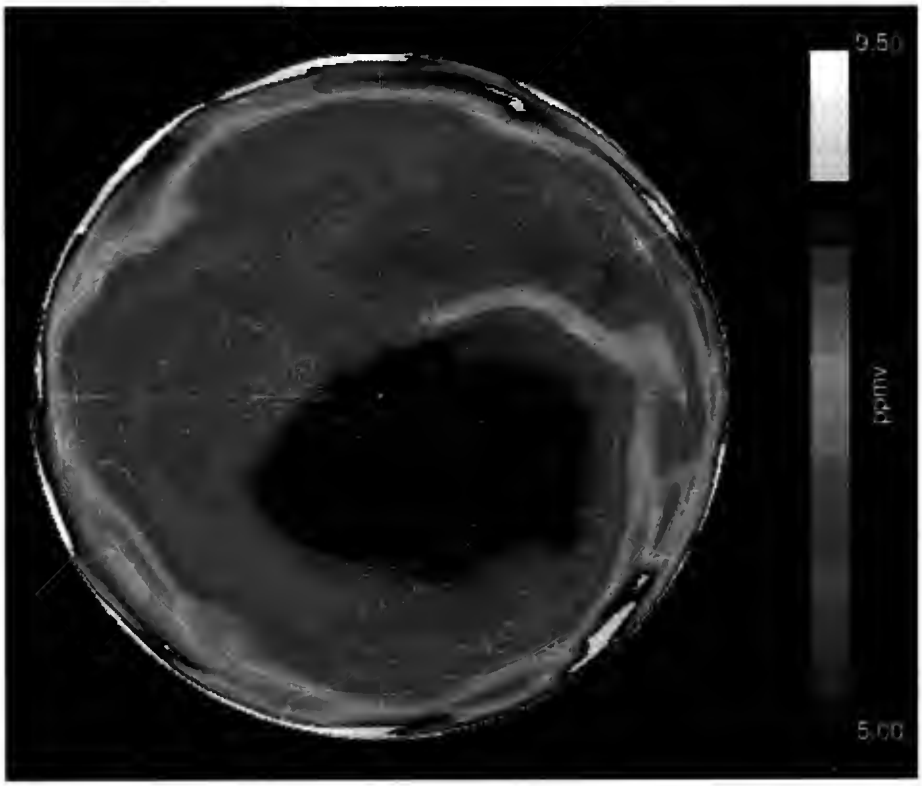
Three-dimensional Chemistry and Transport Model

Chemical and dynamical processes in the stratosphere are studied using a global three-dimensional (3-D) chemistry and transport model (CTM). The model produces constituent simulations by solving the 3-D continuity equation using meteorological fields from the Goddard Data Assimilation System. The research is focussed on comparison to observations from the ER-2 aircraft, from balloons, and especially from the UARS to develop a more complete understanding of the processes which control stratospheric ozone.

Depending on the nature of the simulation and the observational data available for comparison, such simulations provide information about the quality of the meteorological analysis, transport mechanisms, or photochemical processes. The simulations are used to provide a global context for limited observations and to estimate global effects of processes such as polar ozone loss. The model is also being used to address the transport and build-up of exhaust

from subsonic and supersonic aircraft flying in the lower stratosphere as part of the Atmospheric Effects of Aircraft Project.

A simulation including all the photochemical reactions thought to be important to the stratosphere has been completed for November 15, 1991 to May 31, 1992. Comparison with the UARS Cryogenic Limb Array Etalon Spectrometer (CLAES) observations of HNO_3 shows that the model underestimates the HNO_3 in the upper stratosphere during polar night. Further comparisons with the first global measurements of N_2O_5 made by CLAES and by the Improved Stratospheric and Mesospheric Sounder (ISAMS) (also on UARS) show that the discrepancy could be remedied by including a previously unidentified chemical process which converts N_2O_5 to HNO_3 during the polar night.



The model ozone field on the 800 K potential temperature surface (about 30 km altitude) for February 1, 1992, 75 days from the start of a simulation, shows low values in the polar vortex. A tongue of high ozone air is pulled from the tropics, across high latitudes, and mixes in the middle latitudes. The model ozone transport is evaluated by comparisons with satellite measurements. This modeling effort will lead to an improved capability to predict constituent behavior on seasonal and decadal timescales.

Trajectory model

A trajectory model traces the movement of air parcels as the winds blow them along. The model written and used within the Atmospheric Chemistry and Dynamics Branch traces parcels along "isentropic" surfaces (i.e., surfaces along which no heat energy is added to or removed from a parcel), although non-isentropic effects can be accounted for using radiative heating fields calculated within the Branch. Isentropic trajectories can be computed using winds from any of several sets of meteorological analyses and forecasts. The output of the model is used in dynamical statistical studies of air motions, as well as investigations of chemical histories of the air parcels.

Equatorial Oscillations and Small Scale Gravity Waves

Small scale gravity waves are increasingly recognized for the role they play in our understanding of the dynamics of the middle atmosphere. A realistic parameterization of such waves has been incorporated into a numerical model which produces relatively large equatorial oscillations in the zonal circulation on semi-annual and quasi-biennial time scales with amplitudes approaching 20 and 10 m/s, respectively. In the model, the quasi-biennial oscillation is not confined to the stratosphere as had been thought earlier, but extends into the upper mesosphere as seen from UARS observations. These findings are significant in the light of recent results which have shown planetary waves, for many years believed to be the primary cause of the equatorial oscillations, to be grossly inadequate.

Data Analysis

In addition to the measurements by satellite instruments and ground-based instruments, and the output of models, the Atmospheric Chemistry and Dynamics Branch uses various other collections of data in its scientific research.

Meteorological Analyses

The Branch data analysis group uses 17 years of National Centers for Environmental Prediction (NCEP) data, GSFC Data Assimilation Office (DAO) assimilation data, and United Kingdom Meteorological Office (UKMO) assimilation data in conjunction with the GSFC 2-D, 3-D, and trajectory models to enhance our understanding of the dynamics, chemistry, and radiative properties of the middle atmosphere. In particular, we have: 1) characterized the positioning of cold air events (i.e. polar stratospheric clouds) with respect to the polar vortex in both hemispheres at multiple levels, 2) characterized the average behavior of an air parcel inside the vortex, 3) determined the relative differences between NCEP and the GSFC GEOS-1 data assimilation, 4) estimated from previous years the amounts of material exchanged between the vortex and the mid-latitudes, and 5) analyzed and modeled the cold air events that occur on the edge of the vortex in both hemispheres.

NCEP *temperature and wind speed analyses for July 15, 1995, averaged along circles of constant latitude. Note the extremely cold temperatures over the Southern winter pole, south of the strong winds of the polar night jet. These temperatures give rise to polar stratospheric clouds, upon whose surfaces chemical reactions take place which trigger release of chlorine and consequent massive ozone depletion when the sun reappears over the South polar region in the spring.*

NCEP Data

The Branch currently maintains an entire set of National Center for Environmental Prediction (NCEP) tropospheric and stratospheric analyses from November 1978 to the present, including supplemental high-resolution analyses with consistent winds, beginning in August 1995. The NCEP stratospheric data are obtained from the Climate Prediction Center and follow a long-term, consistent analysis scheme based on a successive corrections method. These analyses also include IR total ozone, tropopause pressure, and tropopause temperature. In addition, the geopotential heights are used to calculate winds, relative vorticity, and potential vorticity. These data are automatically archived to a mass storage facility and are available to a variety of users.

Aircraft Field Experiments

The Atmospheric Chemistry and Dynamics Branch provides stratospheric meteorological support for certain high-altitude aircraft missions, and Branch scientists analyze the data taken during these missions.

Aircraft missions dealing with the ozone layer are staged by NASA, using the resources of several NASA centers in conjunction with the National Oceanic and Atmospheric Administration (NOAA) and various universities. They are run as field experiments using NASA Ames Research Center aircraft, such as the ER-2 high-altitude research aircraft and the DC-8 "flying laboratory" equipped with special instruments to look into the troposphere and stratosphere.

The Atmospheric Chemistry and Dynamics Branch at GSFC has participated in these missions:

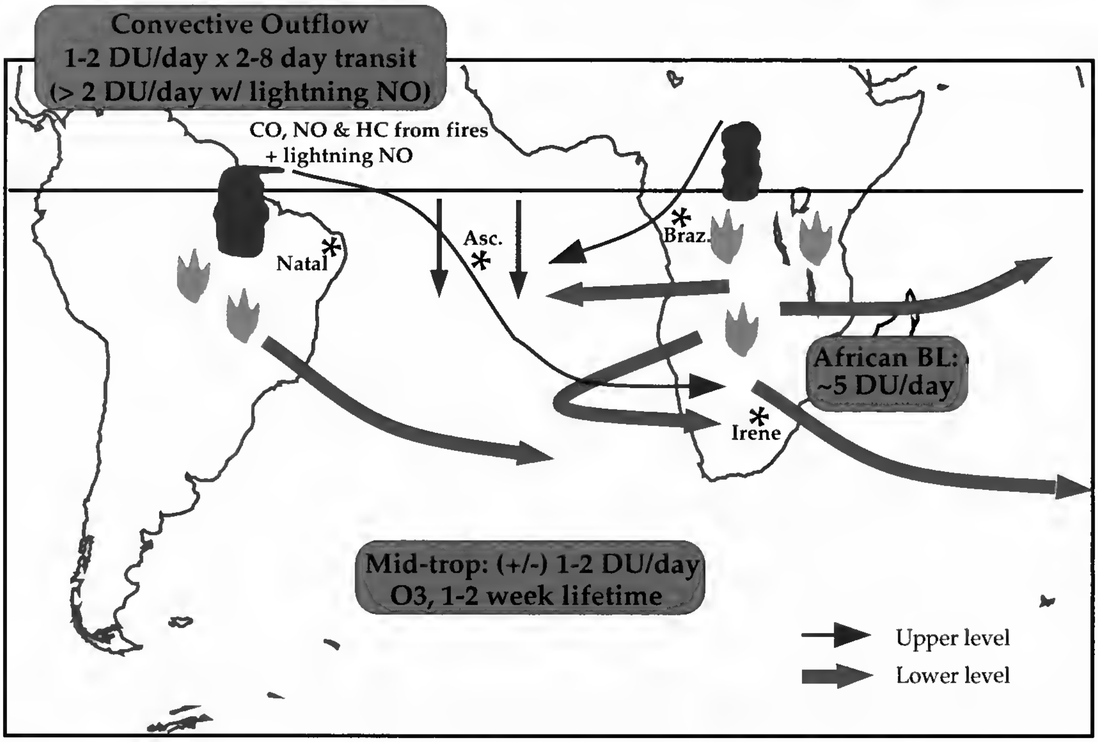
- Airborne Antarctic Ozone Experiment (AAOE)
- Airborne Arctic Stratospheric Expedition (AASE)
- Airborne Arctic Stratospheric Expedition II (AASE II)

The NASA *high-altitude* ER-2 *research aircraft (foreground) and the* DC-8 *flying laboratory (background) are shown here on the ramp at* NASA *Ames Research Center in California. Personnel from* Goddard's *Atmospheric Chemistry and Dynamics* Branch *provide meteorological support for field experiments involving these two aircraft, and* Branch *scientists analyze the data acquired in these experiments.*

- Stratospheric measurements of Photochemistry, Aerosols, and Dynamics Experiment (SPADE)
- Airborne Southern Hemisphere Ozone Experiment/Measurements for Assessing the Effects of Stratospheric Aircraft (ASHOE/MAESA)
- Transport and Atmospheric Chemistry near the Equator - Atlantic (TRACE-A)
- Tropical Ozone Transport Experiment/Vortex Ozone Transport Experiment (TOTE/VOTE)
- Stratospheric Tracers of Atmospheric Transport (STRAT)
- Photochemistry of Ozone Loss in the Arctic Region in Summer (POLARIS)

Tropospheric Studies

Weather systems in the troposphere are constantly moving and mixing air on the same time scales as chemical reactions change the chemical composition of the air. The Branch Tropospheric Studies Group uses chemical and meteorological models to analyze all aspects of



Schematic of the mechanism deduced by trajectory and photochemical modeling of DC-8 aircraft data from the October 1992 NASA TRACE-A (TRansport and Atmospheric Chemistry near the Equator - Atlantic) experiment. The south Atlantic Basin each September-October is characterized by a maximum in tropospheric ozone. Biomass fires supply most of the ozone precursors that recirculate over southern Africa, allowing the ozone to build up and move out over the Atlantic Ocean. Deep convection from the incipient wet season over South America takes fire products from burning savannas to the upper troposphere. Over the Atlantic, ozone is formed following convection, with subsidence causing a buildup over areas like Ascension Island. Lightning also plays a role in ozone formation in the tropics. Photochemical models can account for the magnitude of the October ozone that is observed. Trajectories showed this ozone over the south Atlantic in Oct. 1992 originated 75-80% from Africa, 20-25% from South America.

tropospheric problems. They perform computer simulation of trace gas chemistry and transport to assess effects on global chemistry and climate change, and are active in planning, conducting and analyzing field data from NASA aircraft experiments, particularly those involving the link between chemistry, convection and biomass burning on ozone. They maintain close ties with the Mesoscale Atmospheric Processes Branch (Code 912), the Climate and Radiation Branch

(Code 913) and the Biospheric Sciences Branch (Code 923) at GSFC, as well as the University of Maryland Joint Center for Earth System Science (JCESS).

Ozone in the troposphere is a greenhouse gas, a health hazard and harmful to plants and materials. In contrast to stratospheric ozone, which is necessary for life on earth, increases in tropospheric ozone are a cause for concern. The study of tropospheric ozone and photochemically active trace gases is the major activity related to the Branch's tropospheric research.

Tropospheric ozone is highly variable. Highest mixing ratios are typically found in the upper troposphere, where air mixes with ozone-rich stratospheric air, and in polluted urban regions in summer. The TOMS satellite instruments have been used to estimate tropospheric ozone in the tropics, where the stratospheric column is relatively uniform and can be subtracted or corrected for in the total. These satellite advances and aircraft field missions have highlighted a new region of surprisingly high ozone extending from South America across the South Atlantic to southern Africa. High ozone over the warm tropics can alter our assumptions about climate change. This ozone, resulting to a large extent from biomass burning on both continents, is a dramatic example of how local phenomena can have global consequences.

EOS

The Earth Observing System (EOS) is a major component of NASA's Mission to Planet Earth (MTPE). The Atmospheric Chemistry and Dynamics Branch has an interdisciplinary proposal funded under EOS, "An Investigation of the Chemical and Dynamical Changes in the Stratosphere Up to and During the EOS Observing Period." The Principal Investigator is Dr. Mark Schoeberl.

The purpose of this investigation is to characterize both anthropogenic and natural stratospheric changes in ozone. One part of this effort consists of generating high-quality long-term data sets

for stratospheric ozone, temperature, and trace gases starting with the Nimbus-7 measurements, continuing with UARS, and on through the EOS periods using forecast/assimilation techniques. The assimilation analyses will provide dynamically and chemically balanced global representations of satellite and ground-based data. The assimilated data will significantly improve the evaluation of trace constituent budgets and meteorological diagnostics and will help characterize the dynamical/chemical/radiative interactions in the stratosphere.

The other part of the investigation is to use models to characterize the data sets and estimate anthropogenic change. To this end, the Multiyear Ozone Depletion Experiment (MODE) is underway to simulate long-term change in ozone within the polar vortex, including the simulation of the growth of the Antarctic ozone hole.

This effort overlaps and is strongly linked with many of the other research activities in Goddard's Atmospheric Chemistry and Dynamics Branch and the Data Assimilation Office.

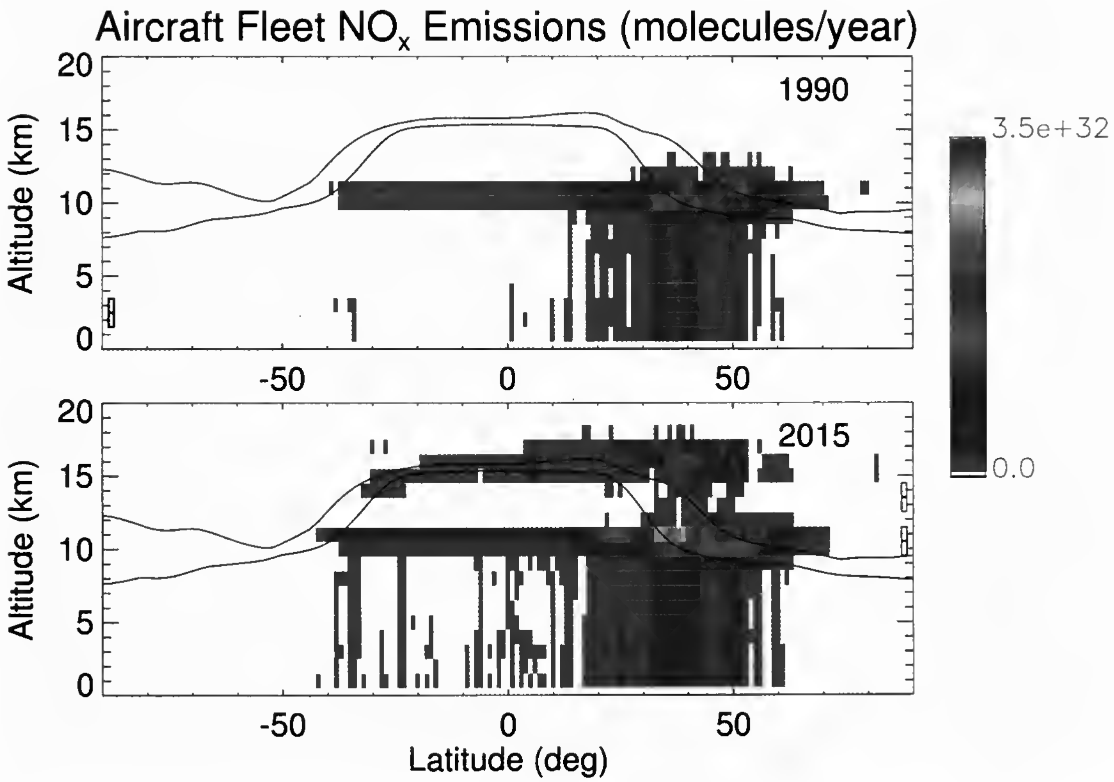
AEAP

ATMOSPHERIC EFFECTS OF AVIATION PROJECT

The Atmospheric Effects of Aviation Project (AEAP) office resides within the Atmospheric Chemistry and Dynamics Branch. AEAP is an aeronautics project which consists of two major subprojects. The Atmospheric Effects of Stratospheric Aircraft (AESA) is a study of the potential effects of the operation of a projected future fleet of high speed civil transport aircraft. The Subsonic Assessment program (SASS) is a study of the effects of the present subsonic aircraft fleet and of projected future subsonic fleets. Branch scientists are also involved as investigators in AEAP-sponsored activities.

The objective of this research is to develop a scientific basis for assessment of the atmospheric impact of aviation, particularly commercial aircraft cruise emissions. The project office manages atmospheric observation, global modeling, near-field interaction, emission characteriza-

tion, laboratory studies, and operational scenario elements which combine to produce an assessment. The assessment considers potential impacts on ozone, climatically-important gases, clouds, and particulates. This work cooperates closely with Mission to Planet Earth (MTPE) activities.



Calculated distribution of emissions of nitrogen oxides from aircraft for the current fleet (1990) and that projected in 2015. Emission rates are greatest at northern mid-latitudes in flight corridor regions. Emissions for 2015 show growth in subsonic commercial aviation along with stratospheric emissions from proposed fleet of supersonic transport aircraft. Solid black lines depict seasonal maximum and minimum altitude positions of division between troposphere and stratosphere.

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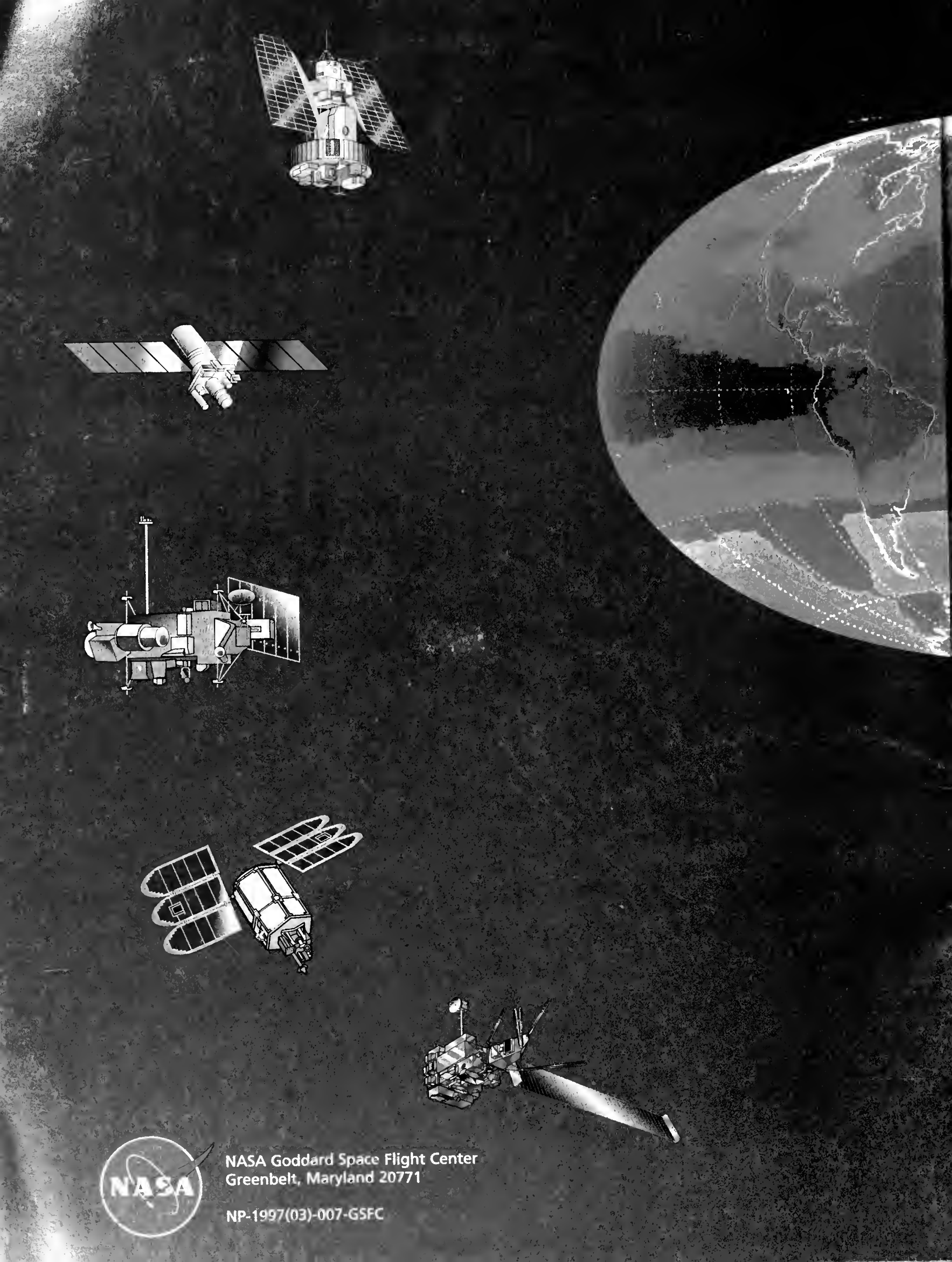
Acronyms

AAOE	Airborne Antarctic Ozone Experiment
AASE	Airborne Arctic Stratospheric Expedition
AASE II	Airborne Arctic Stratospheric Expedition II
ADEOS	ADvanced Earth Observing Satellite
AEAP	Atmospheric Effects of Aviation Project
ASHOE/MAESA	Airborne Southern Hemisphere Ozone Experiment/ Measurements for Assessing Effects of Stratospheric Aircraft
BUV	Backscatter Ultraviolet
CFCs	ChloroFlouroCarbons
CLAES	Cryogenic Limb Array Etalon Spectrometer
CTM	Chemistry and Transport Model
DAO	Data Assimilation Office
EOS	Earth Observing System
GCMs	Global Climate Models
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
ISAMS	Improved Stratospheric and Mesospheric Sounder
JCESS	Joint Center for Earth System Science
MODE	Multiyear Ozone Depletion Experiment
MTPE	Mission To Planet Earth
NCEP	National Centers for Environmental Prediction
NDSC	Network for the Detection of Stratospheric Change
NOAA	National Oceanic and Atmospheric Adminstration
POLARIS	Photochemistry of Ozone Loss in the Arctic Region in Summer
SAGE II	Stratospheric Aerosols and Gas Experiment II
SBUV	Solar Backscatter Ultraviolet
SPADE	Stratospheric measurements of Photochemistry, Aerosols, and Dynamics Experiment
SSBUV	Shuttle Solar Backscatter Ultraviolet
STRAT	Stratospheric Tracers of Atmospheric Transport
STROZ-LITE	Stratospheric Ozone Lidar Trailer Experiment
TOMS	Total Ozone Mapping Spectrometer
TOTE/VOTE	Tropical Ozone Transport Experiment/Vortex Ozone Transport Experiment
TRACE-A	TRansport and Atmospheric Chemistry near the Equator - Atlantic
UARS	Upper Atmospheric Research Satellite
UKMO	United Kingdom Meteorological Office



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