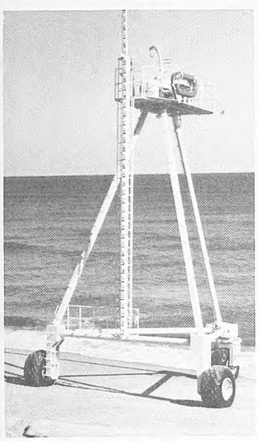
US Army Corps of Engineers



TECHNICAL REPORT CERC-89-10

ANNUAL DATA SUMMARY FOR 1987 CERC FIELD RESEARCH FACILITY

Volume I

MAIN TEXT AND APPENDIXES A AND B

by

Michael W. Leffler, Kent K. Hathaway, Brian L. Scarborough
Clifford F. Baron, Herman C. Miller

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This report provides basic data and summaries for the measurements made during 1987 at the US Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF) in Duck, NC. This report includes comparison of the present year's data with cumulative statistics from 1980 to the present.

Summarized in this report are meteorological and oceanographic data, monthly bathymetric survey results, samples of quarterly aerial photography, and descriptions of sixteen storms that occurred during the year. The year was highlighted by an intense Northeaster in March lasting 7 days. Waves with 4.9-m significant height were measured at a gage located 6 km offshore.

This report is ninth in a series of annual summaries of data collected at the FRF which began with Miscellaneous Report CERC-82-16, which summarizes data collected during

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18. SUBJECT TERMS (Continued).

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Oceanographic research--statistics (LC)
Oceanographic research stations--North Carolina--Duck (LC)
Water waves--statistics (LC)

19. ABSTRACT (Continued).

1977-1979. These reports are available from the WES Technical Report Distribution Section of the Information Technology Laboratory, Vicksburg, MS.

PREFACE

This report is the ninth in a series of annual data summaries authorized by the US Army Corps of Engineers (USACE), under Civil Works Research Work Unit 321-6, Field Research Facility Analysis, Coastal Flooding Program. Funds were provided through the US Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC), under the program management of Dr. C. L. Vincent, CERC. Mr. John H. Lockhart, Jr. was USACE Technical Monitor.

The data for the report were collected and analyzed at CERC's Field Research Facility (FRF) in Duck, NC. The report was prepared by Mr. Michael W. Leffler, Computer Programmer Analyst, FRF, under direct supervision of Mr. William A. Birkemeier, Chief, FRF Group, Engineering Development Division (EDD), and Mr. Thomas W. Richardson, Chief, EDD; and under general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief, CERC, respectively. Mr. Kent K. Hathaway, Oceanographer, FRF, assisted with instrumentation; and Brian L. Scarborough, Amphibious Vehicle Operator, FRF, assisted with data collection. Messrs. Herman C. Miller, Clifford F. Baron, John B. Strider, Jr., Daniel B. Hogan and Ms. Deborah R. Heibel and Ms. Wendy L. Smith assisted with data analysis at the FRF. The National Oceanic and Atmospheric Administration/National Ocean Service maintained the tide gage and provided statistics for summarization.

This report was edited by Mrs. Joyce H. Walker, Information Products Division, Information Technology Laboratory, WES.

Commander and Director of WES during the publication of this report was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

CONTENTS

* A limited number of copies of Appendixes C-E (Volume II) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

ANNUAL DATA SUMMARY FOR 1987
CERC FIELD RESEARCH FACILITY

PART I: INTRODUCTION

Background

1. The US Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF), located on 0.7 km^2 at Duck, NC (Figure 1), consists of a 561-m-long research pier and accompanying office and field support buildings. The FRF is located near the middle of Currituck Spit along a 100-km unbroken stretch of shoreline extending south of Rudee Inlet, VA, to Oregon Inlet, NC. The FRF is bordered by the Atlantic Ocean to the east and Currituck Sound to the west. The Facility is designed to (a) provide a rigid platform from which waves, currents, water levels, and bottom elevations can be measured, especially during severe storms; (b) provide CERC with field experience and data to complement laboratory and analytical studies and numerical models; (c) provide a manned field facility for testing new instrumentation; and (d) serve as a permanent field base of operations for physical and biological studies of the site and adjacent region.

2. The research pier is a reinforced concrete structure supported on 0.9-m-diam steel piles spaced 12.2 m apart along the pier's length and 4.6 m apart across the width. The piles are embedded approximately 20 m below the ocean bottom. The pier deck is 6.1 m wide and extends from behind the duneline to about the 6-m water depth contour at a height of 7.8 m above the National Geodetic Vertical Datum (NGVD). The pilings are protected against sand abrasion by concrete erosion collars and against corrosion by a cathodic system.

3. An FRF Measurements and Analysis program has been established to collect basic oceanographic and meteorological data at the site, reduce and analyze these data, and publish the results.

4. This report, which summarizes data for 1987, continues a series of reports begun in 1977.

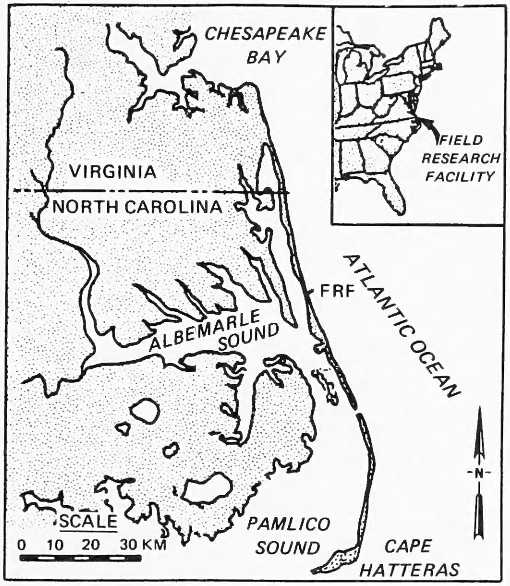


Figure 1. FRF location map

Organization of Report

5. This report is organized into nine parts and five appendixes. Part I is an introduction; Parts II through VIII discuss the various data collected during the year; and Part IX describes the storms that occurred. Appendix A presents the bathymetric surveys, and Appendixes C through E (published under separate cover as Volume II) contain wave data statistics.

6. In each part of this report, the respective instruments used for monitoring the meteorological or oceanographic conditions are briefly described along with data collection and analysis procedures and data results. The instruments were interfaced with the primary data acquisition system, a Digital Equipment Corporation (Maynard, MA) VAX-11/750 minicomputer located in the FRF laboratory building. More detailed explanations of the design and the

operation of the instruments may be found in Miller (1980). Readers' comments on the format and usefulness of the data presented are encouraged.

Availability of Data

7. Table 1 summarizes the available data. In addition to the wave data summaries in the main text, more extensive summaries for each of the wave gages are provided in Appendixes B through E.

Table 1

1987 Data Availability

	Gage	Jan					Feb				Mar				Apr					May				Jun				Jul					Aug				Sep				Oct					Nov				Dec			
	ID	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4
Weather																																																					
Anenometer	632	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Atmospheric Pres.	616	/	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Air Temperature	624	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Precipitation	604	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Waves																																																					
Offshore Waverider	630	*	*	*	/	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	/	*	/	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	/	*	*	*	*	*	*	*	*	*	*
Pressure Gage	141	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	/	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Pier End	625	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	/	*	/	*	*	*	*	*	*	*	*	*	/	/	-	-	-	/	*	*	/	*	*	*	*	*	*	*	*	*	*
Pier Nearshore	645	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	/	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*
Currents																																																					
Pier End		*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pier Nearshore		*	*	*	/	*	*	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Beach		*	*	/	/	*	*	/	*	/	/	/	/	/	/	*	/	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	/	/	*	*	*	*	/	/	*	*	*	*
Pier End Tide Gage		*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	-	-	-
Water Characteristics																																																					
Temperature		*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Visibility		*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Density		*	*	*	*	*	*	*	*	*	*	/	*	*	-	/	/	/	*	*	/	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Bathymetric Surveys												*			*											*				*							*														*		
Photography																																																					
Beach		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Aerial			*															*										*													*												

Notes: * Full week of data obtained.
/ Less than 7 days of data obtained.
- No data obtained.

8. The annual data summary herein summarizes daily observations by month and year to provide basic data for analysis by users. Daily measurements and observations have already been reported in a series of monthly Preliminary Data Summaries (Field Research Facility 1987). If individual data

for the present year are needed, the user can obtain detailed information (as well as the monthly and previous annual reports) from the following address:

USAE Waterways Experiment Station
Coastal Engineering Research Center
Field Research Facility
SR Box 271
Kitty Hawk, NC 27949-9440

Although the data collected at the FRF are designed primarily to support ongoing CERC research, use of the data by others is encouraged. The WES/CERC Coastal Engineering Information and Analysis Center (CEIAC) is responsible for storing and disseminating most of the data collected at the FRF. All data requests should be in writing and addressed to:

Commander and Director
US Army Engineer Waterways Experiment Station
ATTN: Coastal Engineering Information Analysis Center
PO Box 631
Vicksburg, MS 39181-0631

Tidal data other than the summaries in this report can be obtained directly from the following address:

National Oceanic and Atmospheric Administration
National Ocean Service
ATTN: Tide Analysis Branch
Rockville, MD 20852

A complete explanation of the exact data desired for specific dates and times will expedite filling any request; an explanation of how the data will be used will help CEIAC or the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) determine if other relevant data are available. For information regarding the availability of data for all years contact CEIAC at (601) 634-2012. Costs for collecting, copying, and mailing will be borne by the requester.

9. This section summarizes the meteorological measurements made during the current year and in combination with all previous years. Meteorological measurements during storms are given in Part IX.

10. Mean air temperature, atmospheric pressure, and wind speed and direction were computed for each data file which consisted of data sampled two times per second for 34 min every 6 hr beginning at or about 0100, 0700, 1300, and 1900 eastern standard time (EST); these hours correspond to the time that the National Weather Service (NWS) creates daily synoptic weather maps. During storms, data recordings were made more frequently. The data are summarized in Table 2.

Table 2

Meteorological Statistics

Month	Mean Air Temperature deg C		Mean Atmospheric Pres. mb		Precipitation, mm				Wind Resultants			
					1987	1978-1987			1987		1980-1987	
	1987	1983-1987	1987	1983-1987	Total	Mean	Maxima	Minima	Speed m/sec	Direction deg	Speed m/sec	Direction deg
Jan	5.6	5.2	1014.5	1017.1	140	97	180	44	3.6	322	2.6	338
Feb	4.2	5.9	1018.2	1017.1	44	70	84	20	3.6	5	1.9	353
Mar	7.5	9.0	1016.8	1015.9	110	85	168	35	2.8	9	1.6	357
Apr	11.6	13.4	1011.4	1013.4	131	94	182	0	2.4	3	0.3	298
May	18.7	19.0	1018.6	1016.3	31	66	239	20	0.2	295	0.5	194
Jun	23.8	23.4	1015.9	1015.6	61	75	130	27	1.8	211	1.1	196
Jul	26.3	26.0	1016.9	1016.3	54	83	200	19	0.9	200	1.6	217
Aug	26.1	26.1	1016.3	1016.7	55	103	221	30	0.9	76	0.6	72
Sep	23.8	22.4	1016.0	1018.1	35	77	160	5	1.5	86	1.8	38
Oct	15.4	17.9	1019.6	1020.1	74	64	143	17	3.0	3	2.6	31
Nov	12.8	13.2	1020.6	1018.9	127	90	145	26	1.0	353	2.0	358
Dec	8.1	8.6	1017.5	1019.8	47	67	131	4	1.6	269	2.1	335
Average	15.3	15.8	1016.9	1017.1	76	80			1.1	352	1.0	359
Total					908	971						

Air Temperature

11. The FRF enjoys a typical marine climate which moderates the temperature extremes of both summer and winter.

Measurement instruments

12. A Yellow Springs Instrument Company, Inc. (YSI) (Yellow Springs, OH) electronic temperature probe with analog output interfaced to the FRF's computer was operated beside the NWS's meteorological instrument shelter located 43 m behind the dune (Figure 2). To ensure proper temperature readings, the probe was installed 3 m above ground inside a "coolie hat" to shade it from direct sun yet provide proper ventilation.

Results

13. Daily and average air temperature values are tabulated in Table 2 and shown in Figure 3.

Atmospheric Pressure

Measurement instruments

14. Electronic atmospheric pressure sensor. Atmospheric pressure was measured with a YSI electronic sensor with analog output located in the laboratory building at 9 m above NGVD. Data were recorded on the FRF computer. Data from this gage were compared with those from an NWS aneroid barometer to ensure proper operation.

15. Microbarograph. A Weathertronics, Incorporated (Sacramento, CA) recording aneroid sensor (microbarograph) located in the laboratory building also was used to continuously record atmospheric pressure variation.

16. The microbarograph was compared daily with the NWS aneroid barometer, and adjustments were made as necessary. Maintenance of the microbarograph consisted of inking the pen, changing the chart paper, and winding the clock every 7 days. During the summer, a meteorologist from the NWS checked and verified the operation of the barometer.

17. The microbarograph was read and inspected daily using the following procedure:

a. The pen was zeroed (where applicable).

b. The chart time was checked and corrected, if necessary.

c. Daily reading was marked on the chart for reference.

d. The starting and ending chart times were recorded, as necessary.

e. New charts were installed when needed.

Figure 2. FRF gage locations

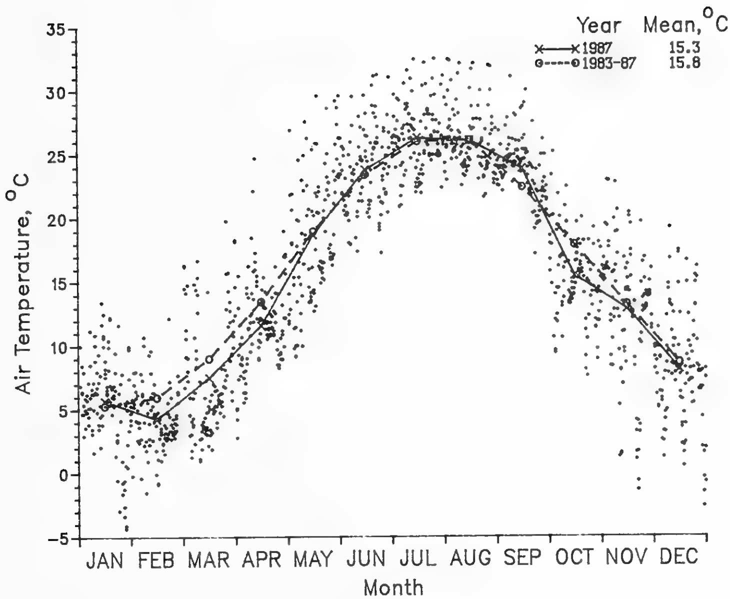


Figure 3. Daily air temperature values with monthly means

Results

18. Daily and average atmospheric pressure values are presented in Figure 4, and summary statistics are presented in Table 2.

Precipitation

19. Precipitation is generally well distributed throughout the year. Precipitation from midlatitude cyclones (northeasters) predominates in the winter; whereas, local convection (thunderstorms) accounts for most of the summer rainfall.

Measurement instruments

20. Electronic rain gage. A Belfort Instrument Company (Baltimore, MD) 30-cm weighing rain gage, located near the instrument shelter 47 m behind the dune, measured daily precipitation. According to the manufacturer, the

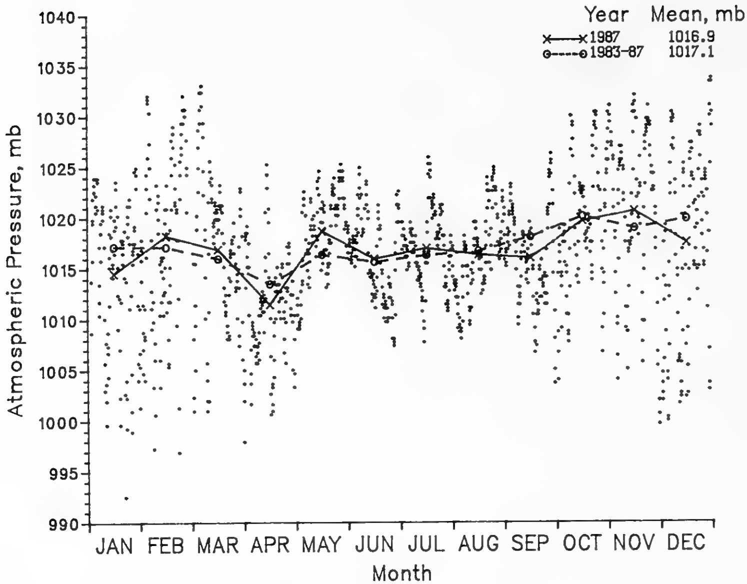


Figure 4. Daily barometric pressure values with monthly means

instrument's accuracy was 0.5 percent for precipitation amounts less than 15 cm and 1.0 percent for amounts greater than 15 cm.

21. The rain gage was inspected daily, and the analog chart recorder was maintained by procedures similar to those for the microbarograph.

22. Plastic rain gage. An Edwards Manufacturing Company (Alberta Lea, MN) True Check 15-cm-capacity clear plastic rain gage with a 0.025-cm resolution was used to monitor the performance of the weighing rain gage. This gage, located near the weighing gage, was compared daily; and very few discrepancies were identified during the year.

Results

23. Daily and monthly average precipitation values are shown in Figure 5. Statistics of total precipitation for each month during this year and average totals for all years combined are presented in Table 2.

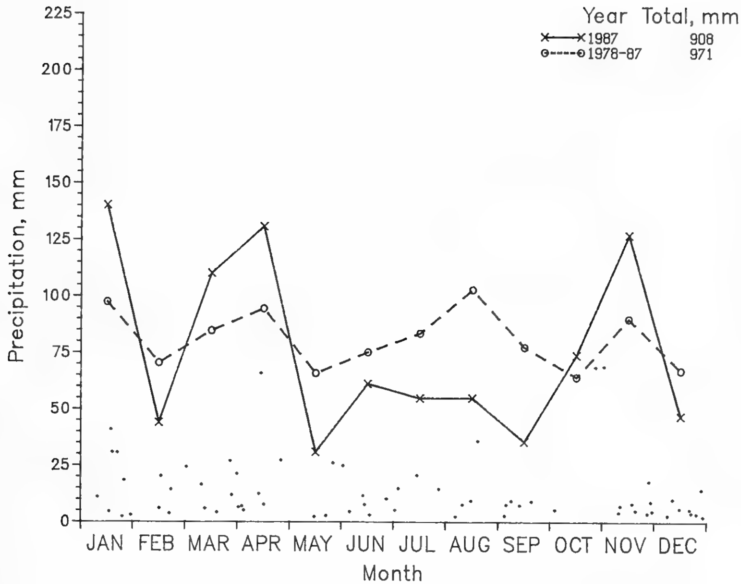


Figure 5. Daily precipitation values with monthly totals

Wind Speed and Direction

24. Winds at the FRF are dominated by tropical maritime air masses which create low to moderate, warm southern breezes; arctic and polar air masses which produce cold winds from northerly directions; and smaller scale cyclonic, low pressure systems, which originate either in the tropics (and move north along the coast) or on land (and move eastward offshore). The dominate wind direction changes with season, being generally from northern directions in the fall and winter and from southern directions in the spring and summer. It is common for fall and winter storms (northeasters) to produce winds with average speeds in excess of 15 m/sec.

Measurement instrument

25. Winds were measured on top of the laboratory building at an elevation of 19.1 m (Figure 2) using a Weather Measure Corporation (Sacramento, CA) Skyvane Model W102P anemometer. Wind speed and direction data were

collected on the FRF computer as well as on a strip-chart recorder. The anemometer manufacturer specifies an accuracy of ±0.45 m/sec below 13 m/sec and 3 percent at speeds above 13 m/sec, with a threshold of 0.9 m/sec. Wind direction accuracy is ±2 deg with a resolution of less than 1 deg. The anemometer is calibrated annually at the National Bureau of Standards in Gaithersburg, MD, and is within the manufacturer's specifications.

Results

26. Annual and monthly joint probability distributions of wind speed versus direction were computed. Winds speeds were resolved into 3-m/sec intervals; whereas, the directions were at 22.5-deg intervals (i.e. 16-point compass direction specifications). These distributions are presented as wind "roses," such that the length of the petal represents the frequency of occurrence of wind blowing from the specified direction, and the width of the petal is indicative of the speed. Resultant directions and speeds were also determined by vector averaging the data (see Table 2). Wind statistics are presented in Figures 6, 7 and 8.

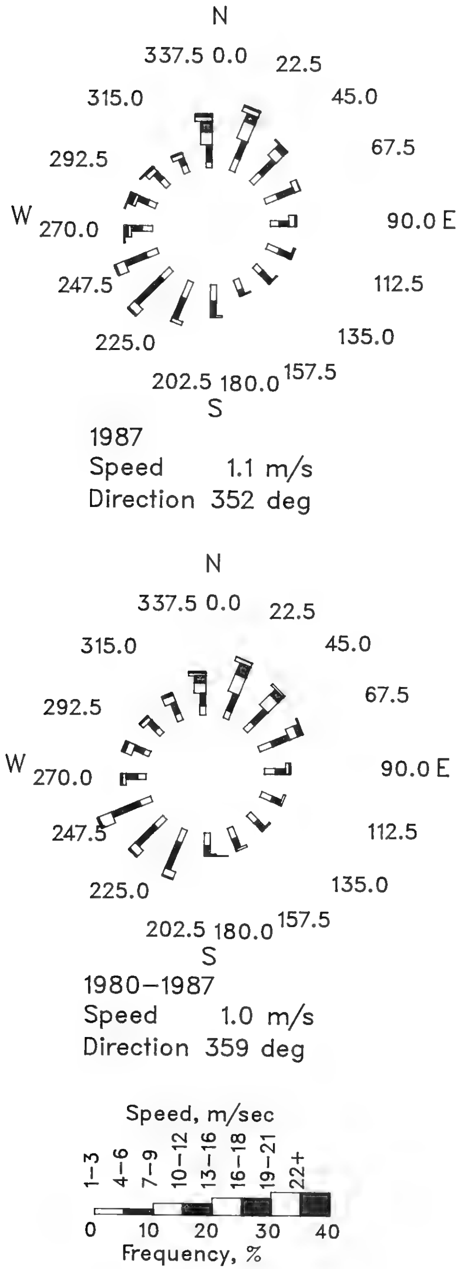


Figure 6. Annual wind roses

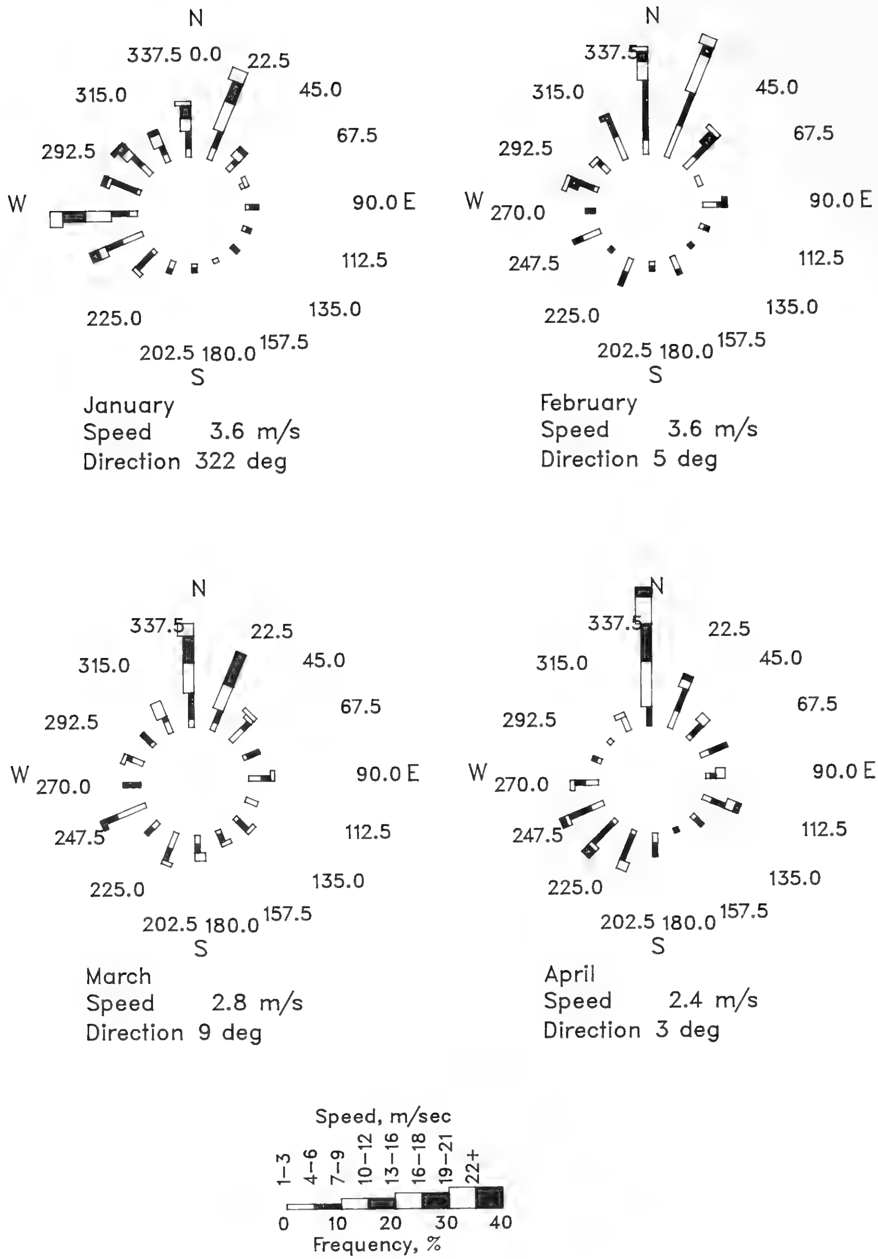


Figure 7. Monthly wind roses for 1987
(Sheet 1 of 3)

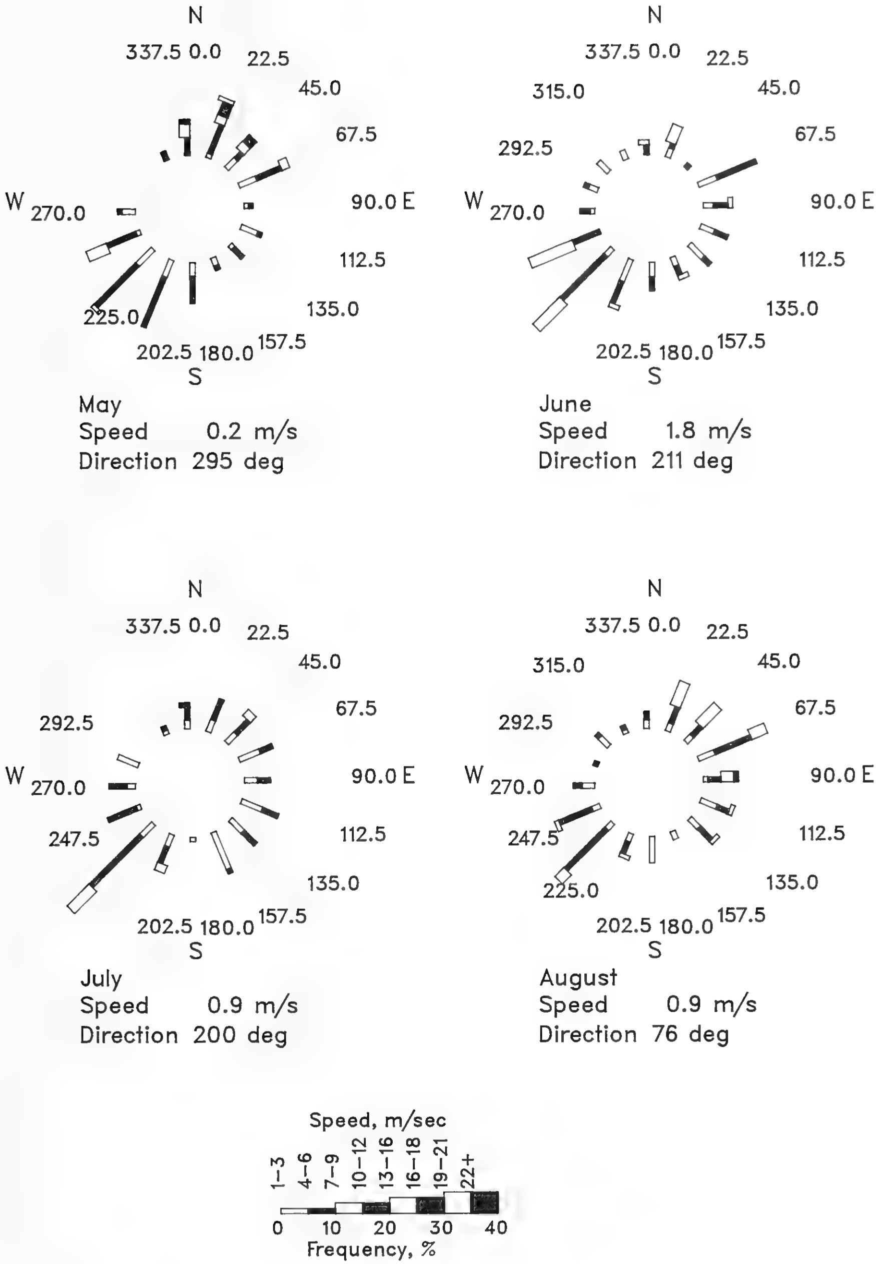


Figure 7. (Sheet 2 of 3)

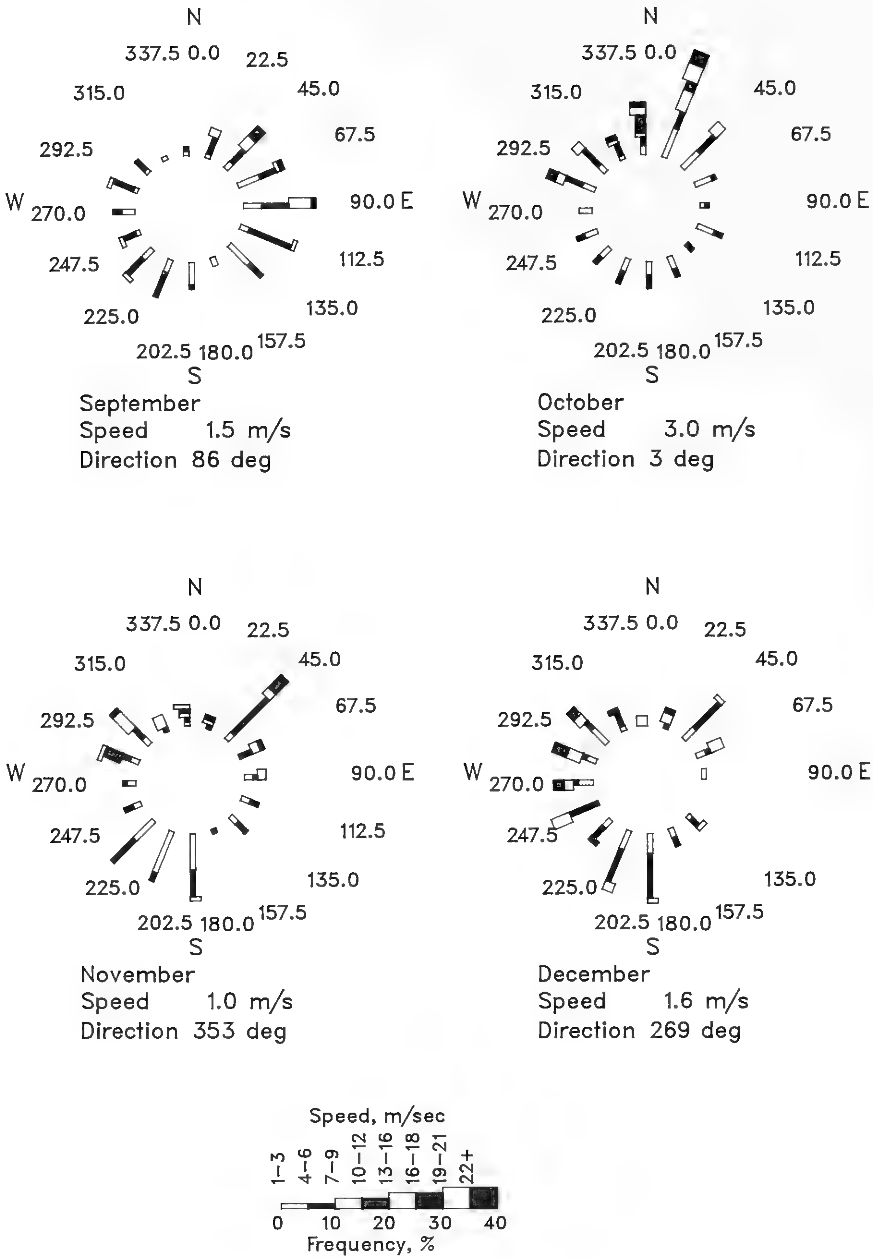


Figure 7. (Sheet 3 of 3)

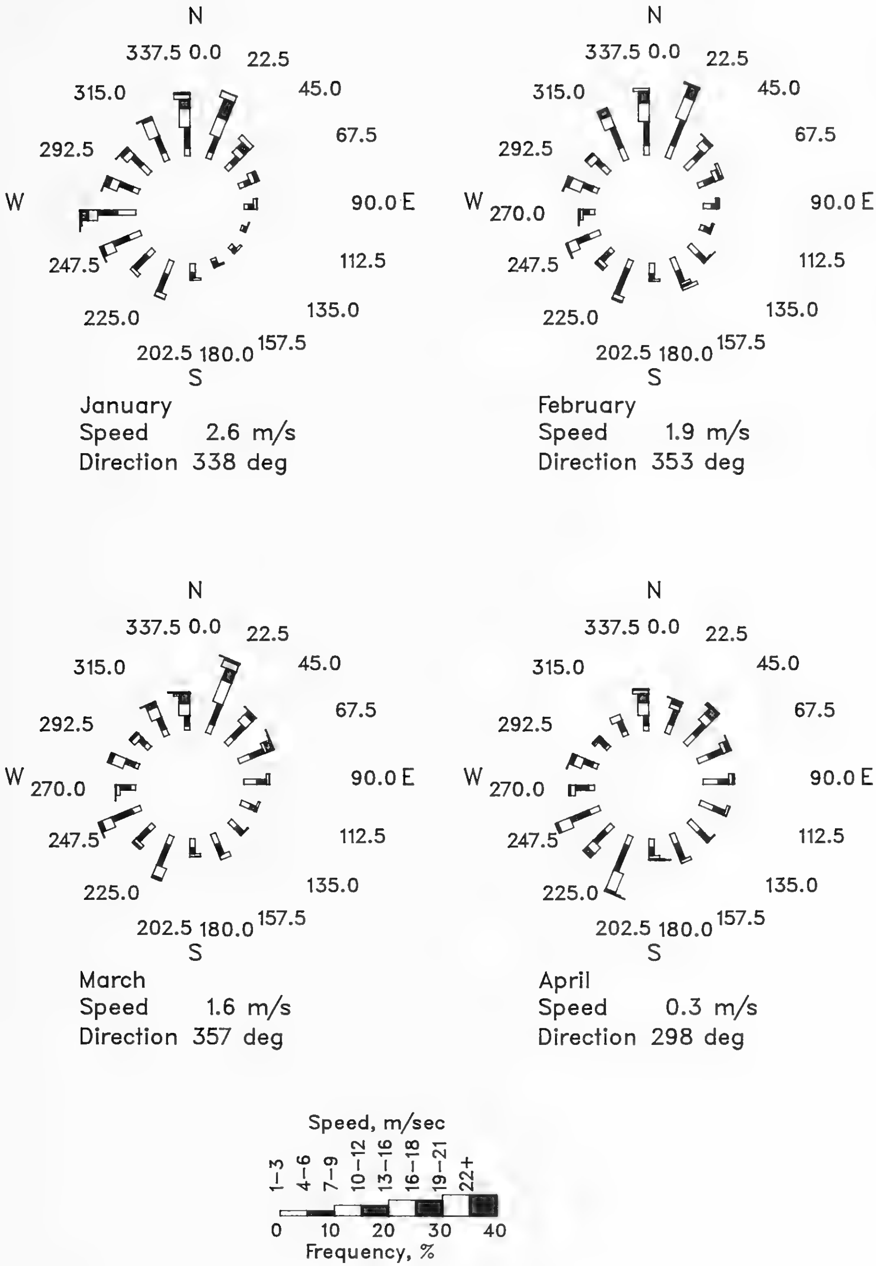


Figure 8. Monthly wind roses for 1980 through 1987 (Sheet 1 of 3)

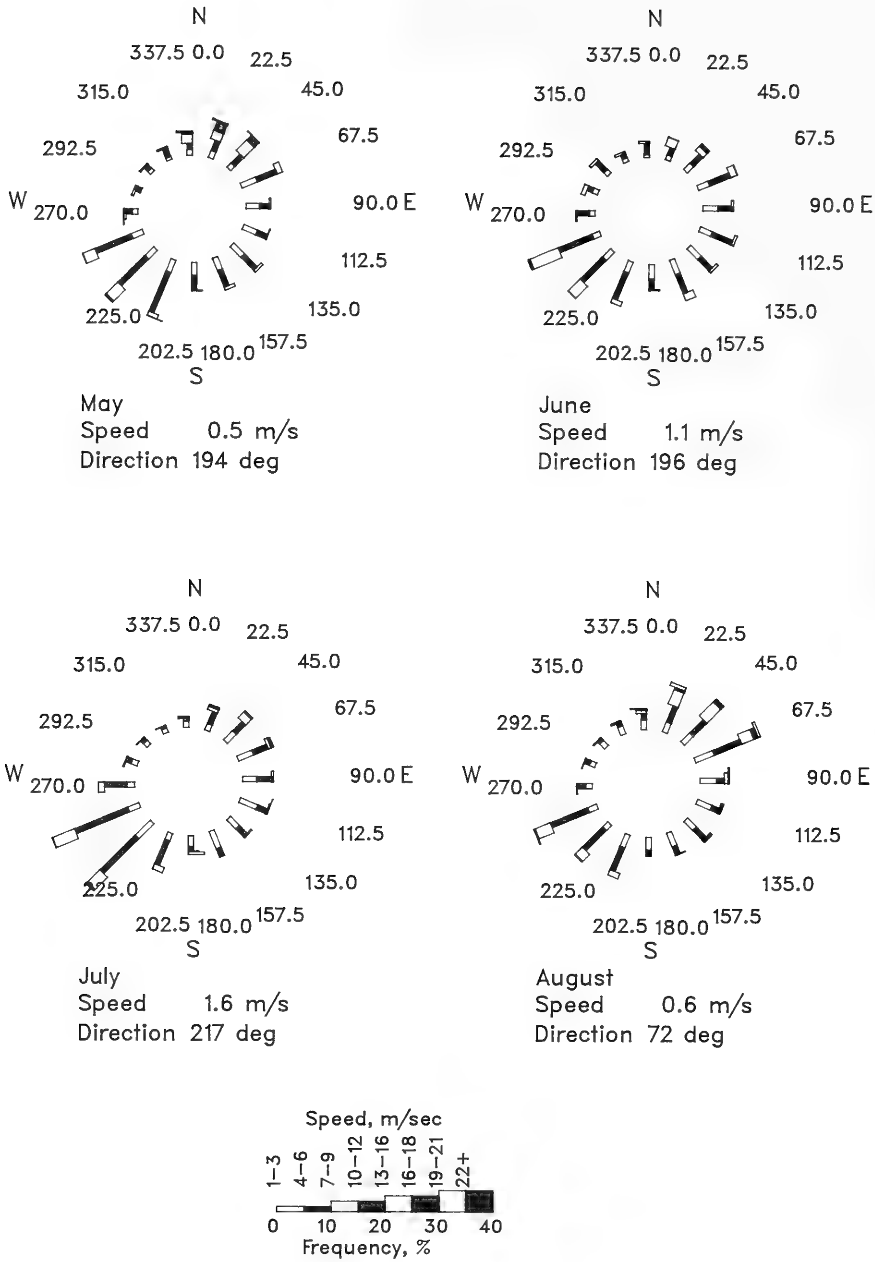


Figure 8. (Sheet 2 of 3)

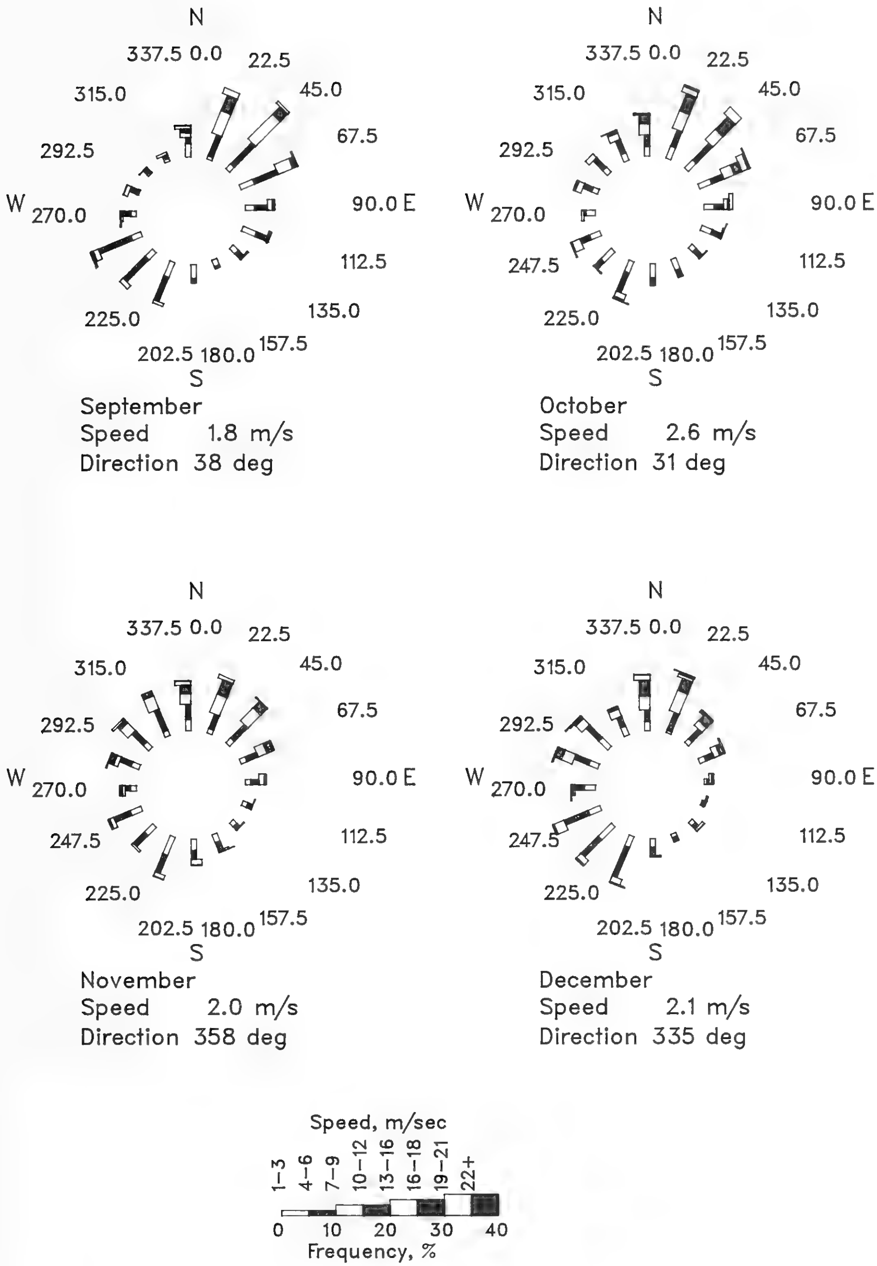


Figure 8. (Sheet 3 of 3)

PART III: WAVES

27. This section presents summaries of the wave data. A discussion of individual major storms is given in Part IX and contains additional wave data for times when wave heights exceeded 2 m at the seaward end of the FRF pier. Appendixes B through E provide more extensive data summaries for each gage, including height and period distributions, wave direction distributions, persistence tables, and spectra during storms.

28. Wave directions (similar to wind directions) at the FRF are seasonally distributed. Waves approach most frequently from north of the pier in the fall and winter and south of the pier in the summer, with the exception of storm waves which approach twice as frequently from north of the pier. Annually, waves are approximately evenly distributed between north and south (resultant wave direction being almost shore-normal).

Measurement Instruments

29. The wave gages included one buoy (Gage 630), one pressure (Gage 141) and two wave staff gages (Gages 625 and 645), as shown in Figure 2 and located as follows:

Gage Type/Number	Distance Offshore from Baseline	Water Depth m	Operational Period
Accelerometer buoy (630)	6 km	18	11/78-12/87
Pressure gage (141)	1 km	9	09/86-12/87
Continuous wire (625)	579 m	8	11/78-12/87
Continuous wire (645)	238 m	3.5	11/84-12/87

Staff gages

30. Two Baylor Company (Houston, TX) parallel cable inductance wave gages (Gage 645 at sta 7+80 and Gage 625 at sta 19+00 (Figure 2)) were mounted on the FRF pier. Rugged and reliable, these gages require little maintenance except to keep tension on the cables and to remove any material which may cause an electrical short between them. They were calibrated prior to installation by creating an electrical short between the two cables at known distances along the cable and recording the voltage output. Electronic signal conditioning amplifiers are used to ensure that the output signals from the gages are within a 0- to 5-V range. Manufacturer-stated gage accuracy is about 1.0 percent, with a 0.1 percent full-scale resolution; full scale is

14 m for Gage 625 and 8.2 m for Gage 645. These gages are susceptible to lightning damage, but protective measures have been taken to minimize such occurrences. A more complete description of the gages' operational characteristics was given by Grogg (1986).

Buoy gage

31. One Datawell Laboratory for Instrumentation (Haarlem, The Netherlands) Waverider buoy gage (Gage 630) measures the vertical acceleration produced by the passage of a wave. The acceleration signal is double-integrated to produce a displacement signal which is transmitted by radio to an onshore receiver. The manufacturer stated that wave amplitudes are correct to within 3 percent of their actual value for wave frequencies between 0.065 and 0.500 Hz (corresponding 15- to 2-sec wave periods). The manufacturer also specified that the error gradually increased to 10 percent for wave periods in excess of 20 sec. The results in this report were not corrected for the manufacturer's specified amplitude errors. However, the buoy was calibrated semiannually to ensure that it was within the manufacturer's specification.

Pressure Gage

32. One Senso-Metrics, Incorporated (Simi Valley, CA) pressure transduction gage (Gage 141) installed near the ocean bottom measures the pressure changes produced by the passage of waves creating an output signal which is linear and proportional to pressure when operated within its design limits. Pre- and post-deployment precision calibrations are performed at the FRF using a static deadweight tester. The sensor's range is 0 to 25 psi (equivalent to 0- to 17-m seawater) above atmospheric pressure with a manufacturer-stated accuracy of $\pm$0.25 percent. Copper scouring pads are installed at the sensor's diaphragm to reduce biological fouling, and the system is periodically cleaned by divers.

Digital Data Analysis and Summarization

33. The data were collected, analyzed, and stored on magnetic tape using the FRF's VAX computer. Data sets were normally collected every 6 hr. During storms, the collection was at 3-hr intervals. For each gage a data set consisted of 4 contiguous records of 4,096 points recorded at 0.5 Hz

(approximately 34-min long), for a total of 2 hr and 16 min. Analysis was performed on individual 34-min records.

34. The analysis program computes the first moment (mean) and the second moment about the mean (variance) then edits the data by checking for "jumps," "spikes," and points exceeding the voltage limit of the gage. A jump is defined as a data value greater than five standard deviations from the previous data value; whereas, a spike is a data value more than five standard deviations from the mean. If less than five consecutive jumps or spikes are found, the program linearly interpolates between acceptable data and replaces the erroneous data values. The editing stops if the program finds more than five consecutive jumps or spikes or more than a total of 100 bad points or the variance of the voltage is below 1×10^{-5} squared volts. The statistics and diagnostics from the analysis are saved.

35. Sea surface energy spectra are computed from the edited time series. Spectral estimates are computed from smaller data segments obtained by dividing the 4,096-point record into several 512-point segments. The estimates are then ensemble-averaged to produce a more accurate spectrum. These data segments are overlapped by 50 percent (known as the Welch (1967) method) and have been shown to produce improved statistical properties than from nonoverlapped segments. The mean and linear trends are removed from each segment prior to spectral analysis. To reduce sidelobe leakage in the spectral estimates, a data window was applied. The first and last 10 percent of data points was multiplied by a cosine bell (Bingham, Godfrey, and Tukey 1967). Spectra were computed from each segment with a discreet Fast Fourier Transform then ensemble-averaged. Sea surface spectra from subsurface pressure gages were obtained by applying the linear wave theory transfer function.

36. Unless otherwise stated, wave height in this report refers to the energy-based parameter H_{mo} defined as four times the zeroth moment wave height of the estimated sea surface spectrum (i.e., four times the square root of the variance) computed from the spectrum passband. Energy computations from the spectra are limited to a passband between 0.05 and 0.50 Hz for surface gages and between 0.05 Hz and a high frequency cutoff for subsurface gages. This high frequency limit is imposed to eliminate aliased energy and noise measurements from biasing the computation of H_{mo} and is defined as the frequency where the linear theory transfer function is less than 0.1 (spectral values are multiplied by 100 or more). Smoother and more statistically

significant spectral estimates are obtained by band-averaging contiguous spectral components (3 components are averaged per band producing a frequency band width of 0.0117 Hz).

37. Wave period T_p is defined as the period associated with the maximum energy band in the spectrum which is computed using a 3-point running average band on the spectrum. The peak period is reported as the reciprocal of the center frequency (i.e., T_p = 1/frequency) of the spectral band with the highest energy. A detailed description of the analysis techniques are presented in a report by Andrew (1987).

Results

38. The wave conditions for the year are shown in Figure 9. For all four gages, the distributions of wave height for the current year and all years combined are presented in Figures 10 and 11, respectively. Distributions of wave period are presented in Figure 12.

39. Multiple year comparisons of data for Gage 141 actually incorporate data for 1985 and 1986 from Gage 640, a discontinued Waverider buoy previously located at the approximate depth and distance offshore as Gage 141.

40. Refraction, bottom friction, and wave breaking contribute to the observed differences in height and period. During the most severe storms when the wave heights exceed 3 m at the seaward end of the pier, the surf zone (wave breaking) has been observed to extend past the end of the pier and occasionally 1 km offshore. This occurrence is a major reason for the differences in the distributions between Gage 630 and the inshore gages. The wave height statistics for the staff gage (Gage 645), located at the landward end of the pier, were considerably lower than those for the other gages. In all but the calmest conditions, this gage is within the breaker zone. Consequently, these statistics represent a lower energy wave climate.

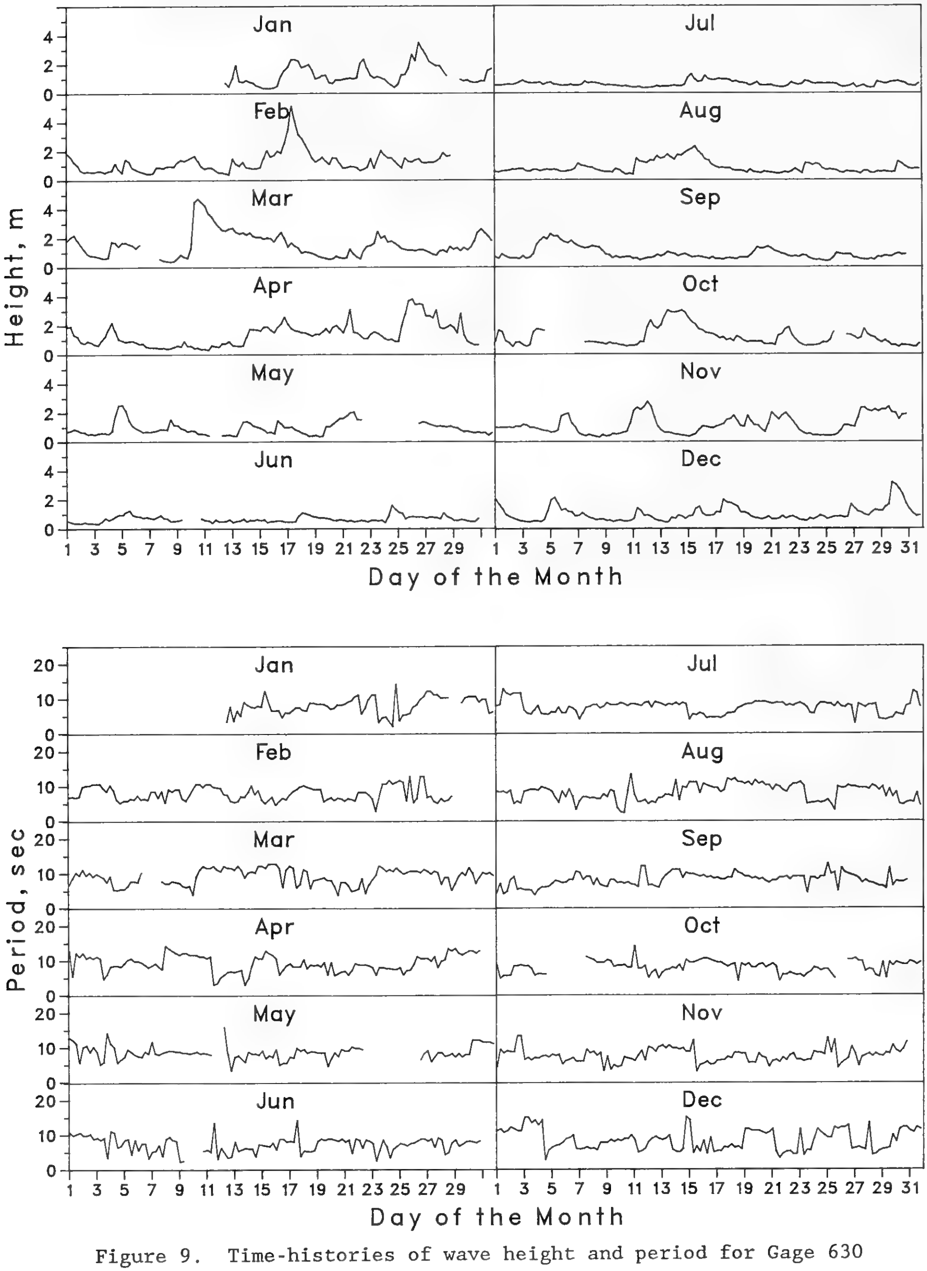


Figure 9. Time-histories of wave height and period for Gage 630

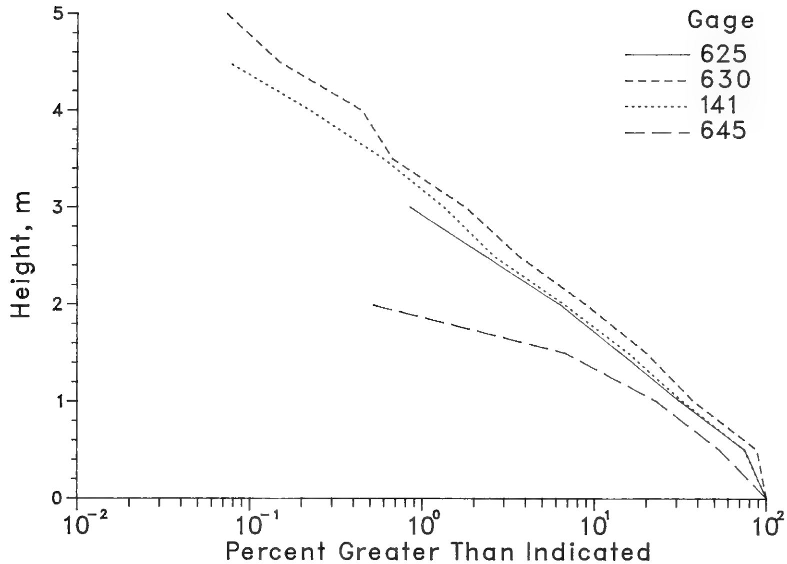


Figure 10. 1987 annual wave height distributions

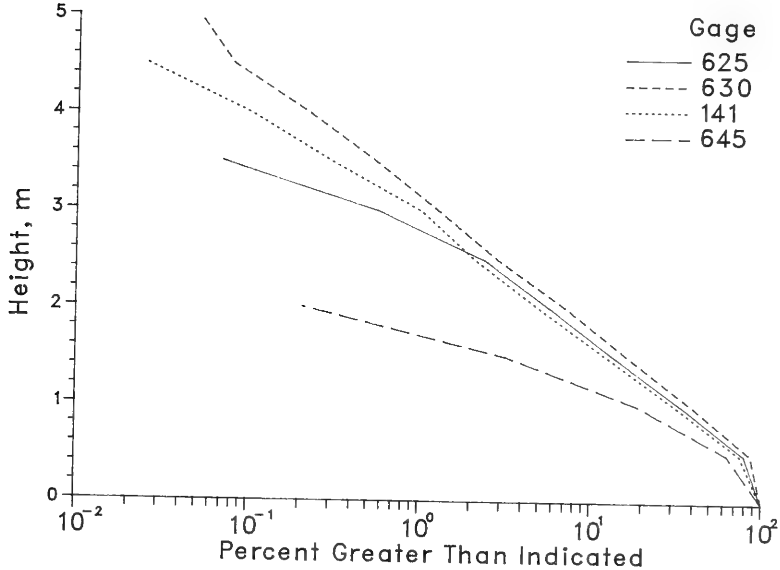


Figure 11. Annual distribution of wave heights for 1980 through 1987

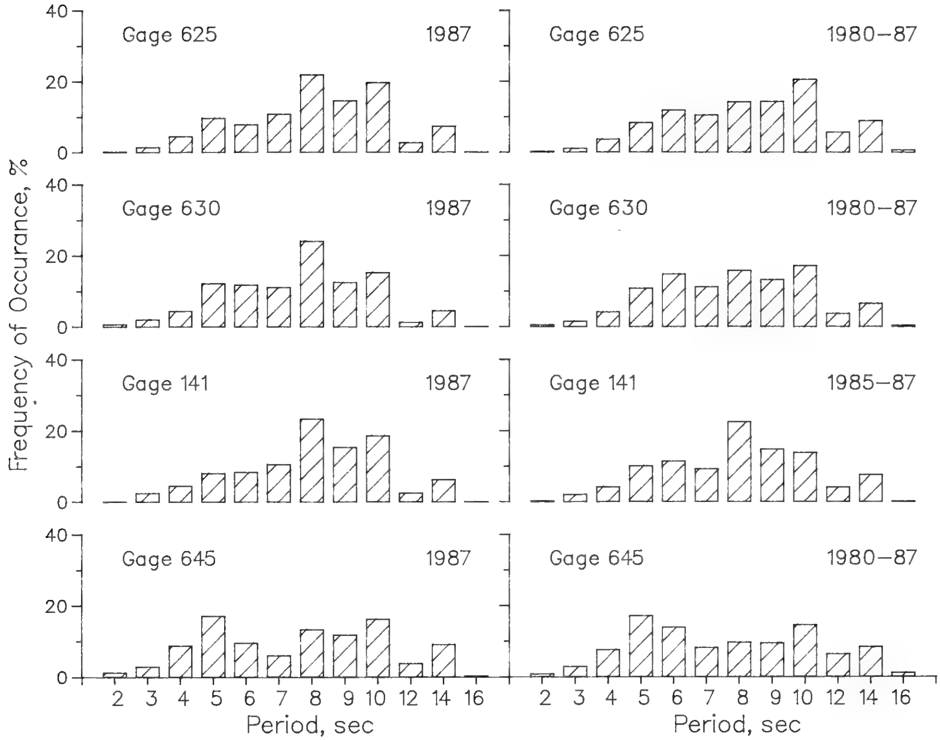


Figure 12. Annual wave period distributions for all gages

41. Summary wave statistics for the current year and all years combined are presented for Gage 630 in Table 3.

Table 3

Wave Statistics for Gage 630

1987 and 1980-1987 Mean, Standard Deviation and Extreme Hmo and Tp for Gage 630

	1987							1980-1987						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	1.3	0.7	3.5	26	8.1	2.5	72	1.2	0.7	4.5	1983	7.9	2.7	826
Feb	1.3	0.8	5.1	17	7.9	2.1	108	1.3	0.7	5.1	1987	8.6	2.6	789
Mar	1.6	0.9	4.7	10	9.1	2.3	117	1.2	0.7	4.7	1983	8.8	2.7	877
Apr	1.4	0.8	3.8	26	9.3	2.5	118	1.0	0.6	3.8	1985	8.7	2.7	859
May	1.0	0.5	2.5	5	8.7	2.0	103	0.9	0.5	3.3	1986	8.0	2.3	872
Jun	0.7	0.3	1.6	24	7.3	2.2	114	0.7	0.4	2.1	1981	7.7	2.2	826
Jul	0.6	0.2	1.3	15	7.6	1.9	121	0.6	0.3	2.1	1985	8.1	2.5	827
Aug	0.9	0.5	2.3	15	8.1	2.4	124	0.8	0.5	3.6	1981	8.0	2.5	830
Sep	0.9	0.5	2.3	5	8.1	1.9	119	1.0	0.6	6.1	1985	8.6	2.6	849
Oct	1.2	0.7	3.0	13	8.1	1.8	109	1.2	0.7	4.3	1982	8.7	2.7	931
Nov	1.2	0.7	2.7	12	7.7	2.1	119	1.2	0.7	4.1	1981	8.1	2.8	767
Dec	1.0	0.6	3.2	29	8.5	3.1	124	1.2	0.8	5.6	1980	8.4	2.9	769
Annual	1.1	0.7	5.1	Feb	8.2	2.3	1348	1.0	0.6	6.1	Sep 1985	8.3	2.6	10022

42. Annual joint distributions of wave height versus wave period for Gage 630 are presented for 1987 in Table 4, and for all years combined in Table 5. Similar distributions for the other gages are included in Appendixes B through E.

43. Annual distributions of wave directions (relative to True North) based on daily observations of direction at the seaward end of the pier and height from Gage 625 (or Gage 141 when data for Gage 625 were unavailable) are shown in Figure 13. Monthly wave "roses" for 1987 and all years combined are presented in Figures 14 and 15, respectively.

Table 4

Annual Joint Distribution of H_{mo} versus T_p for Gage 630

Annual 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	7	22	22	22	74	141	512	171	119	59	74	.	1223
0.50 - 0.99	59	163	237	593	504	571	1320	653	675	45	193	.	5013
1.00 - 1.49	.	22	148	364	267	134	341	163	267	7	52	.	1765
1.50 - 1.99	.	.	37	208	252	104	111	141	193	15	45	.	1106
2.00 - 2.49	.	.	.	30	67	89	74	82	126	.	59	.	527
2.50 - 2.99	.	.	.	.	15	37	22	7	89	.	15	.	185
3.00 - 3.49	.	.	.	.	.	30	15	22	37	.	7	.	111
3.50 - 3.99	.	.	.	.	.	7	7	.	7	.	.	.	21
4.00 - 4.49	.	.	.	.	.	.	.	15	7	.	7	.	29
4.50 - 4.99	.	.	.	.	.	.	.	.	7	.	.	.	7
5.00 - Greater	.	.	.	.	.	.	7	.	.	.	.	.	7
Total	66	207	444	1217	1179	1113	2409	1254	1527	126	452	0	

Table 5

Annual Joint Distribution of H_{mo} versus T_p for Gage 630 (All Years)

Annual 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	20	17	29	56	104	118	331	278	214	80	138	4	1389
0.50 - 0.99	35	126	247	477	575	502	834	691	832	156	217	17	4709
1.00 - 1.49	.	11	128	386	450	270	251	201	372	40	134	5	2248
1.50 - 1.99	.	.	12	141	263	114	75	70	137	37	83	5	937
2.00 - 2.49	.	.	2	26	78	78	49	45	77	33	46	2	436
2.50 - 2.99	.	.	.	.	7	35	19	16	43	12	25	.	157
3.00 - 3.49	.	.	.	.	1	7	16	15	19	5	10	.	73
3.50 - 3.99	.	.	.	.	.	1	4	8	11	5	4	.	33
4.00 - 4.49	.	.	.	.	.	.	1	2	8	1	2	.	14
4.50 - 4.99	.	.	.	.	.	.	.	.	3	.	.	.	3
5.00 - Greater	.	.	.	.	.	.	1	.	.	2	1	.	4
Total	55	154	418	1086	1478	1125	1581	1326	1716	371	660	33	

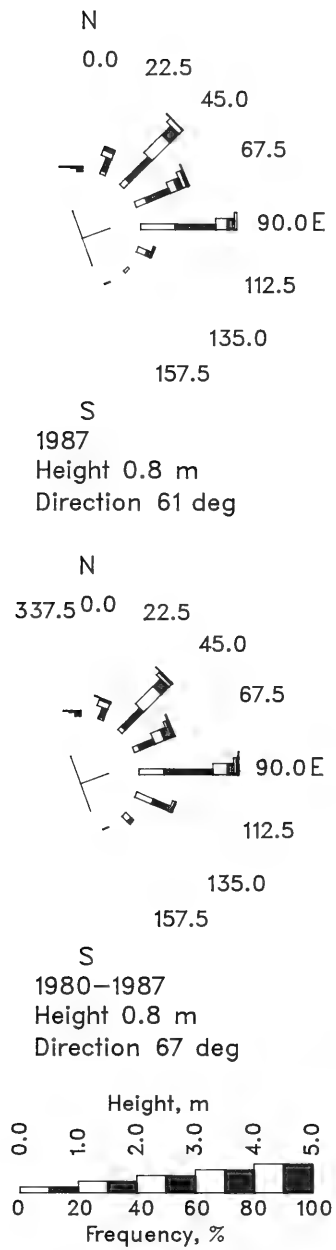


Figure 13. Annual wave roses

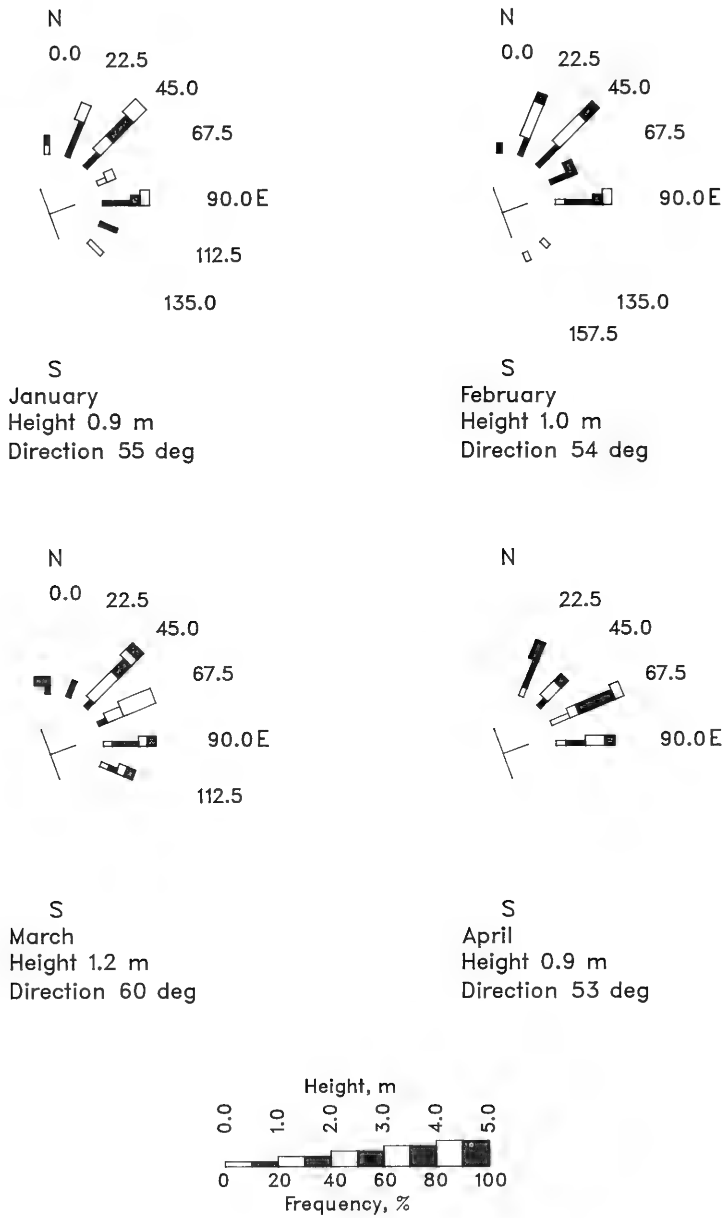


Figure 14. Monthly wave roses for 1987 (Sheet 1 of 3)

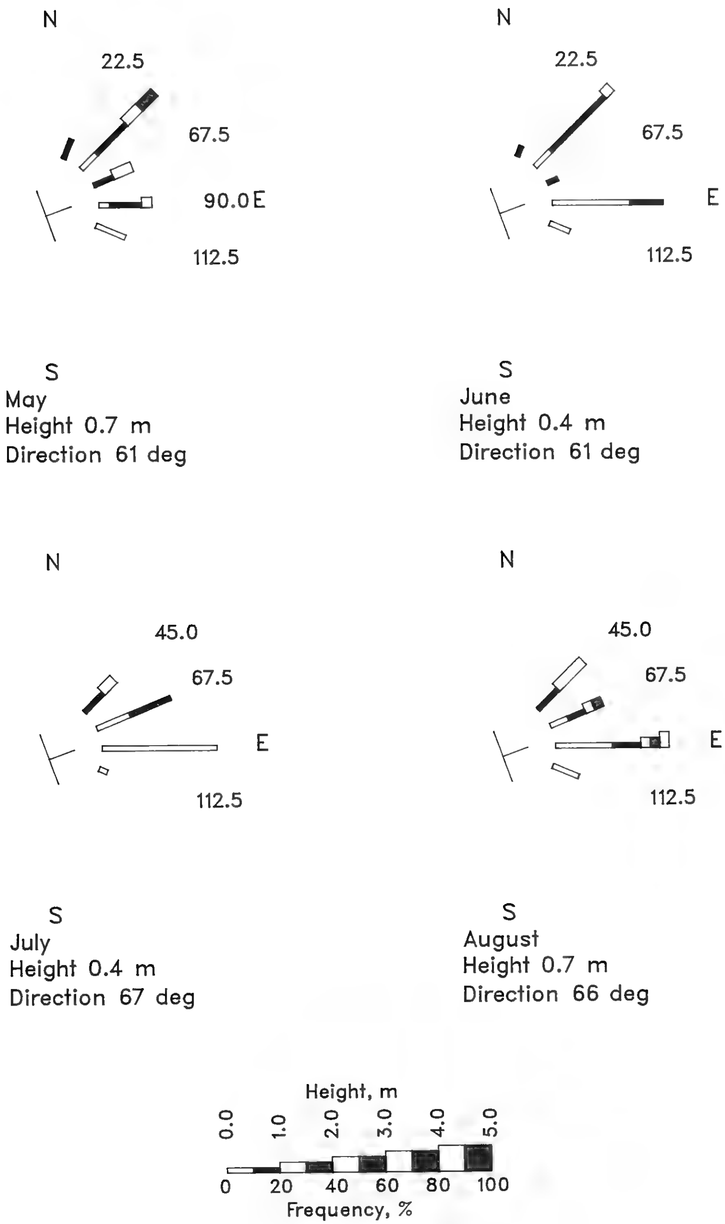


Figure 14. (Sheet 2 of 3)

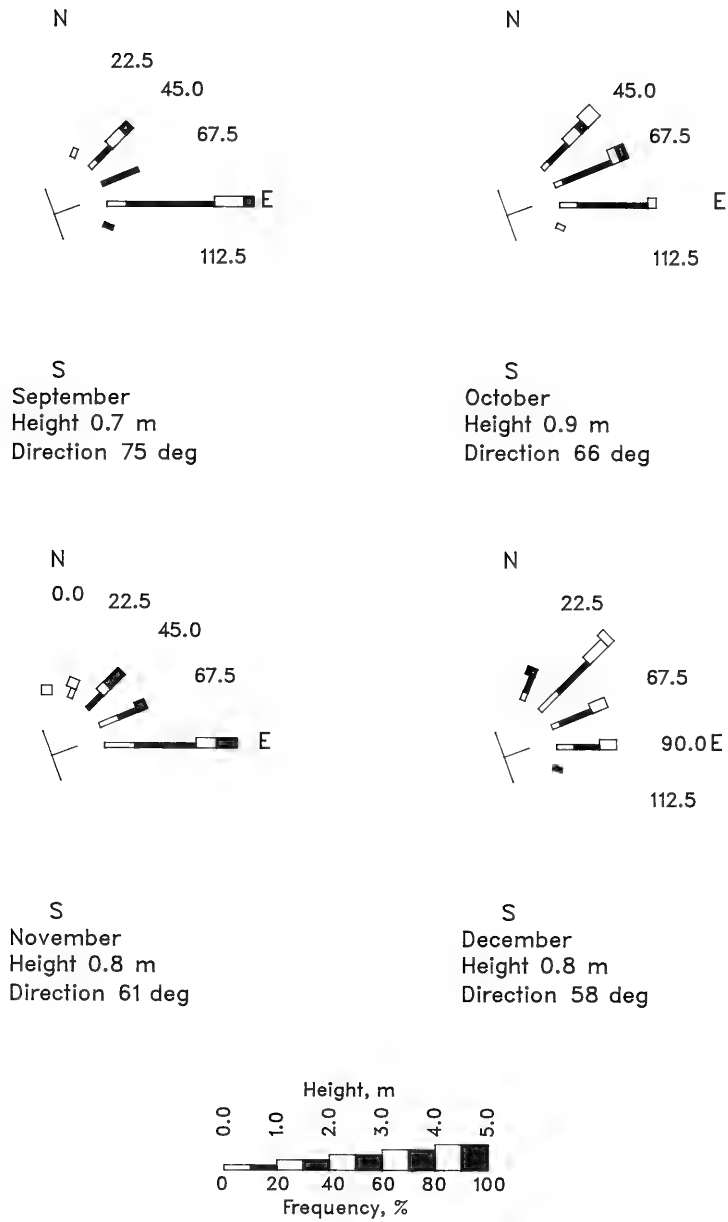


Figure 14. (Sheet 3 of 3)

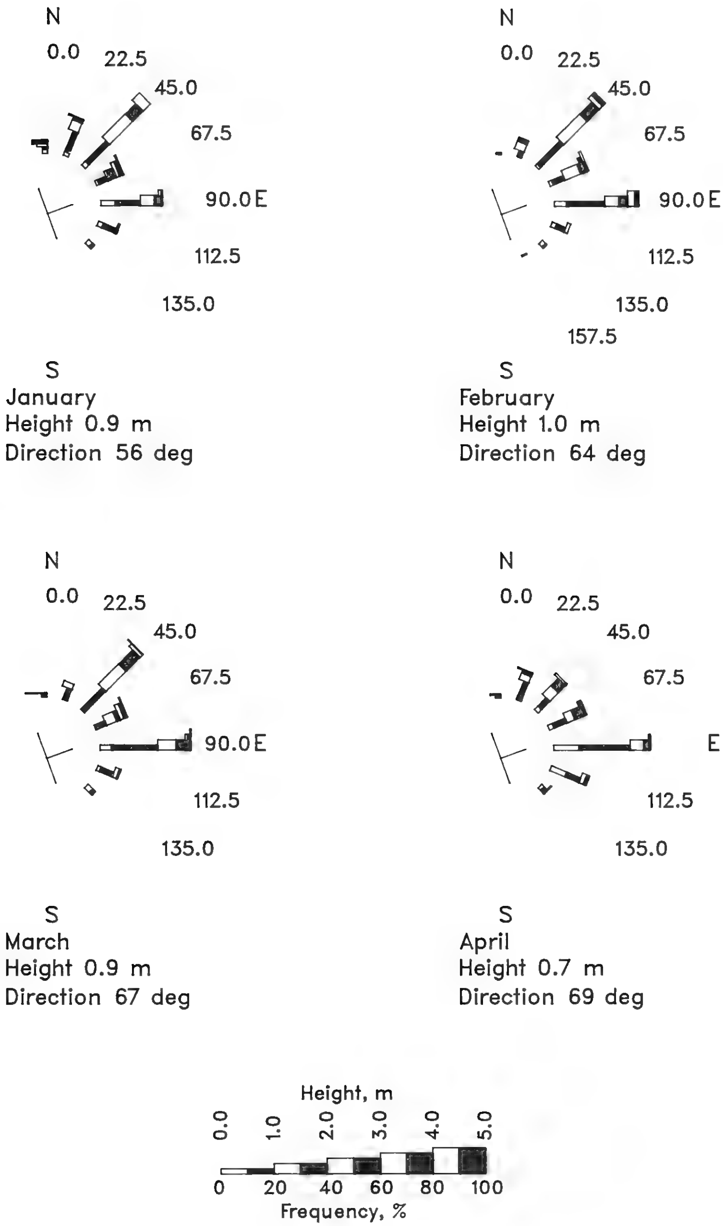


Figure 15. Monthly wave roses for 1980 through 1987 (Sheet 1 of 3)

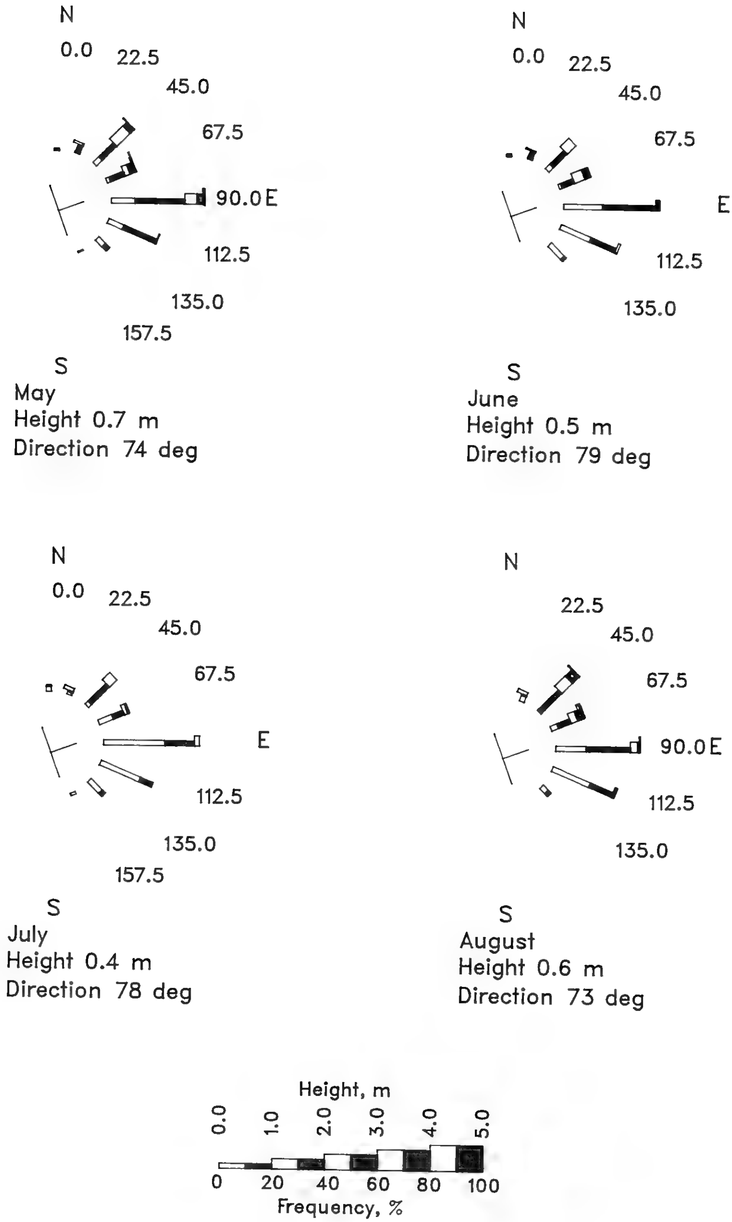


Figure 15. (Sheet 2 of 3)

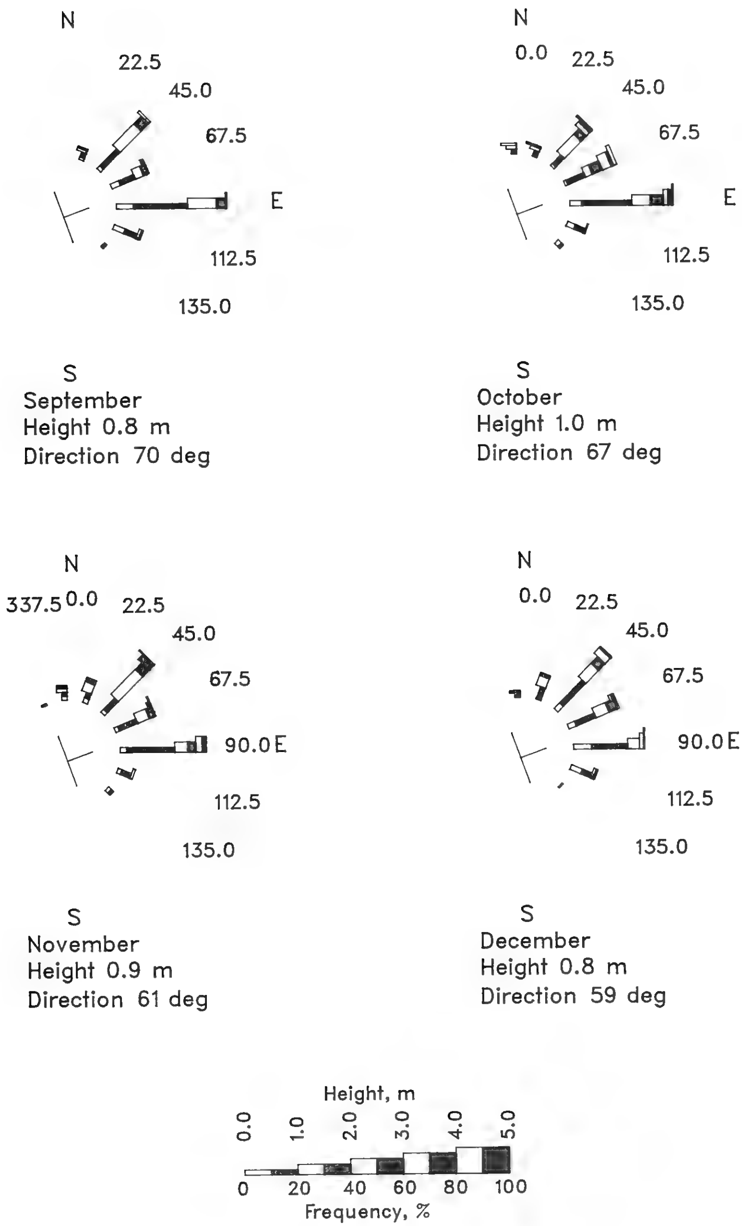


Figure 15 (Sheet 3 of 3)

PART IV: CURRENTS

44. Surface current speed and direction at the FRF are influenced by winds, waves, and, indirectly, by the bottom topography. The extent of the respective influence varies daily. However, winds tend to dominate the currents at the seaward end of the pier; whereas, waves dominate within the surf zone.

Observations

45. Near 0700 EST, daily observations of surface current speed and direction were made at (a) the seaward end of the pier, (b) the midsurf position on the pier, and (c) 10 to 15 m from the beach 500 m updrift of the pier. Surface currents were determined by observing the movement of dye on the water surface.

Results

46. Annual mean and mean currents for 1980 through 1987 are presented in Table 6 and in Figure 16. Figure 16 shows the daily and average annual measurements at the beach, pier midsurf, and pier end locations. Since the relative influences of the winds and waves vary with position from shore, the current speeds and, to some extent, direction vary at the beach, midsurf, and pier end locations. Magnitudes generally are largest at the midsurf location and lowest at the end of the pier.

Table 6

Mean Longshore Surface Currents*

Month	Pier End, cm/sec 1987	Pier End, cm/sec 1980-1987	Pier Midsurf, cm/sec 1987	Pier Midsurf, cm/sec 1980-1987	Beach, cm/sec 1987	Beach, cm/sec 1980-1987
Jan	23	18	19	21	11	15
Feb	30	19	35	11	27	13
Mar	17	16	-3	16	-1	14
Apr	35	11	13	1	4	5
May	20	12	2	-3	6	-2
Jun	12	3	5	-11	6	-5
Jul	14	3	-9	-16	-4	-9
Aug	5	8	-16	-15	4	-6
Sep	-1	10	-15	-3	-4	2
Oct	18	9	17	3	15	6
Nov	10	13	-4	9	1	11
Dec	12	14	6	14	16	8
Annual	16	11	4	2	7	6

* + = southward; − = northward.

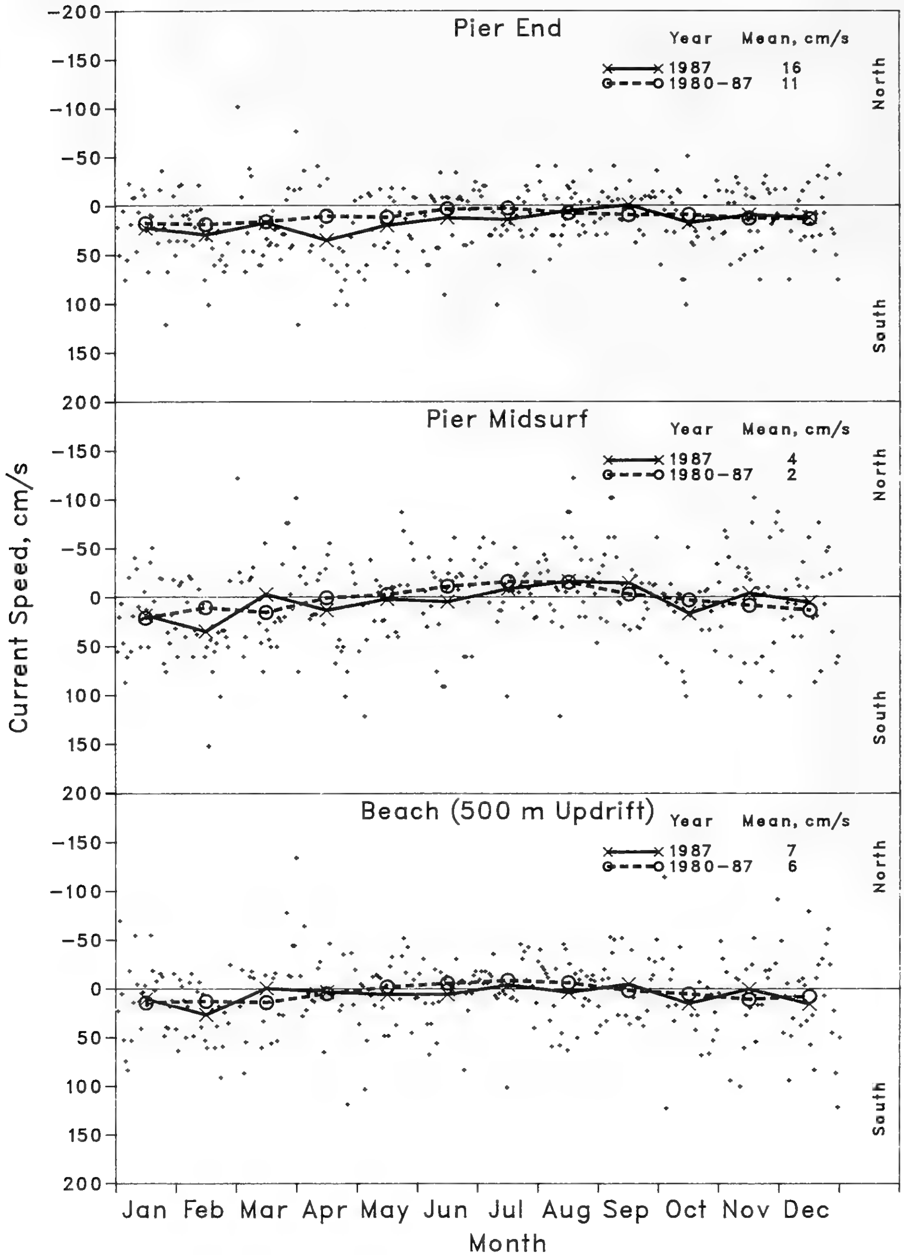


Figure 16. Daily current speeds and directions with monthly means for 1987

PART V: TIDES AND WATER LEVELS

Measurement Instrument

47. Water level data were obtained from a NOAA/NOS control tide station (sta 865-1370) located at the seaward end of the research pier (Figure 2) by using a Leupold and Stevens, Inc. (Beaverton, OR) digital tide gage. This analog-to-digital recorder is a float-activated, negator-spring, counterpoised instrument that mechanically converts the vertical motion of a float into a coded, punched paper tape record. The below-deck installation at pier sta 19+60 consisted of a 30.5-cm-diam stilling well with a 2.5-cm orifice and a 21.6-cm-diam float.

48. Operation and tending of the tide gage conformed to NOS standards. The gage was checked daily for proper operation of the punch mechanism and for accuracy of the time and water level information. The accuracy was determined by comparing the gage level reading with a level read from a reference electric tape gage. Once a week, a heavy metal rod was lowered down the stilling well and through the orifice to ensure free flow of water into the well. During the summer months, when biological growth was most severe, divers inspected and cleaned the orifice opening as required.

49. The tide station was inspected quarterly by a NOAA/NOS tide field group. Tide gage elevation was checked using existing NOS control positions, and the equipment was checked and adjusted as needed. NOS and FRF personnel also reviewed procedures for tending the gage and handling the data. Any specific comments on the previous months of data were discussed to ensure data accuracy.

50. Digital paper tape records of tide heights taken every 6 min were analyzed by the Tides Analysis Branch of NOS. An interpreter created a digital magnetic computer tape from the punch paper tape which was then processed on a large computer. First, a listing of the instantaneous tidal height values was created for visual inspection. If errors were encountered, a computer program was used to fill in or recreate bad or missing data using correct values from the nearest NOS tide station and accounting for known time lags and elevation anomalies. The data were plotted, and a new listing was generated and rechecked. When the validity of the data had been confirmed, monthly tabulations of daily highs and lows, hourly heights (instantaneous

height selected on the hour), and various extreme and/or mean water level statistics were computed.

Results

51. Tides at the FRF are semidiurnal with both daily high and low tides approximately equal. Tide height statistics are presented in Table 7. Figure 17 plots the monthly tide statistics for all available data, and Figure 18 compares the distribution of daily high and low water levels and hourly tide heights. The monthly or annual mean sea level (MSL) reported is the average of the hourly heights; whereas, the mean tide level is midway between mean high water (MHW) and mean low water (MLW) which are the averages of the daily high and low water levels, respectively, relative to NGVD. Mean range (MR) is the difference between MHW and MLW levels, and the lowest water level for the month is the extreme low (EL) water while the highest water level is the extreme high (EH) water level.

Table 7

Tide Height Statistics*

Month or Year	Mean High Water	Mean Tide Level	Mean Sea Level	Mean Low Water	Mean Range	Extreme High	Date	Extreme Low	Date
1987									
Jan	55	14	15	-27	82	113	2	-62	24
Feb	51	12	12	-27	78	82	17	-46	24
Mar	60	20	20	-21	81	89	10	-52	1
Apr	58	19	19	-20	78	99	26	-48	2
May	50	11	12	-27	77	85	13	-51	13
Jun	50	12	12	-27	77	83	24	-58	13
Jul	54	15	15	-25	79	90	12	-38	1
Aug	58	18	19	-22	80	90	11	-57	10
Sep	58	18	18	-22	80	88	20	-49	8
Oct	57	17	18	-23	80	85	8	-59	5
Nov	51	12	12	-27	78	93	11	-63	8
Dec	-	-	-	Gage Inoperative		-	-	-	-
1987	55	15	16	-24	79	113	Jan	-63	Nov
Prior Years									
1986	60	13	13	-35	95	123	Dec	-108	Jan
1985	59	10	11	-37	96	136	Dec	-93	Apr
1984	64	16	16	-32	97	147	Oct	-77	Jul
1983	68	19	19	-30	98	143	Jan	-73	Mar
1982	58	8	9	-42	99	127	Oct	-108	Feb
1981	59	8	9	-42	101	149	Nov	-110	Apr
1980	59	8	8	-43	102	118	Mar	-119	Mar
1979	60	9	9	-43	103	121	Feb	-95	Sep
1979-1987	60	12	12	-36	97	149	Nov 1981	-119	Mar 1980

* Measurements are in centimeters.

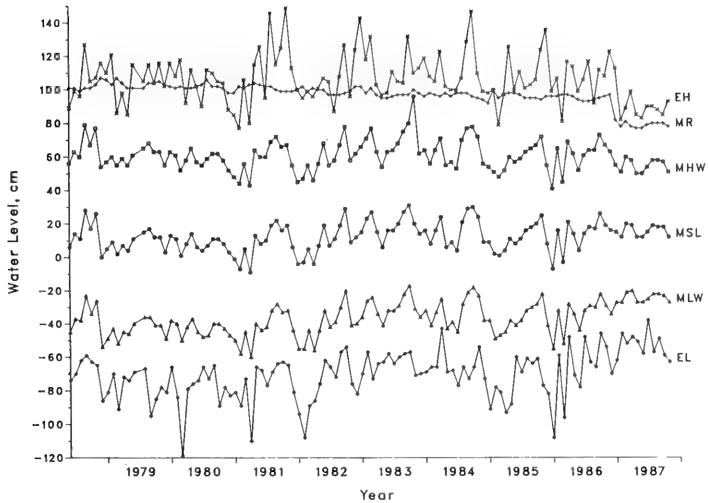


Figure 17. Monthly tide and water level statistics relative to NGVD

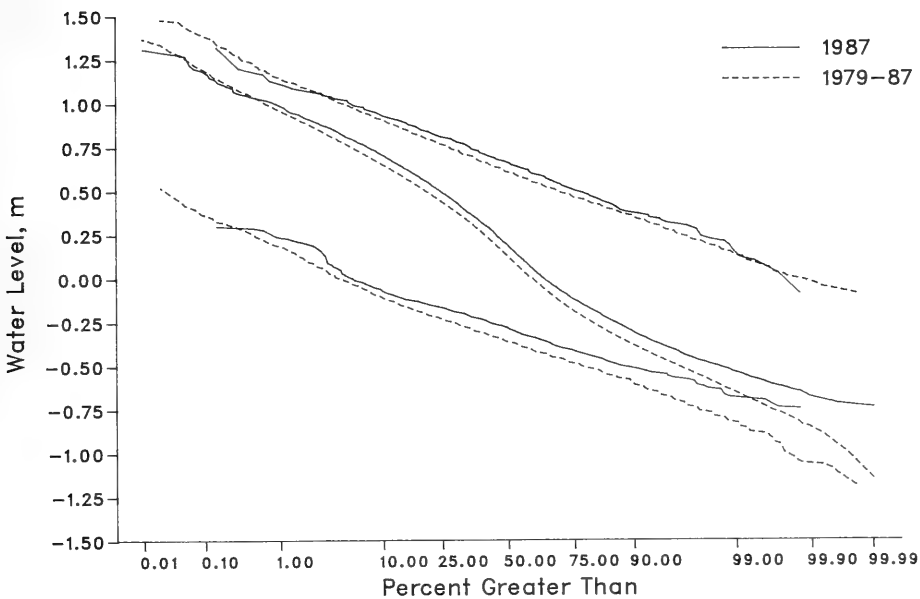


Figure 18. Distributions of hourly tide heights and high and low water levels

PART VI: WATER CHARACTERISTICS

52. Monthly averages of daily measurements of surface water temperature, visibility, and density at the seaward end of the FRF pier are given in Table 8. The summaries represent single observations made near 0700 EST and, therefore, may not reflect daily average conditions since such characteristics can change within a 24-hr period. Large temperature variations were common when there were large differences between the air and water temperatures and variations in wind direction. From past experience, persistent onshore winds move warmer surface water toward the shoreline, although offshore winds cause colder bottom water to circulate shoreward resulting in lower temperatures.

Table 8

Mean Surface Water Characteristics

Month	Temperature deg C 1987	Temperature deg C 1980-1987	Visibility m 1987	Visibility m 1980-1987	Density g/cm^3 1987	Density g/cm^3 1980-1987
Jan	6.4	5.8	0.8	1.1	1.0228	1.0236
Feb	3.8	4.5	1.4	1.6	1.0221	1.0231
Mar	5.7	6.5	1.3	1.4	1.0217	1.0228
Apr	10.2	10.9	1.6	2.0	1.0193 *	1.0224
May	15.5	15.2	2.0	2.3	1.0207	1.0223
Jun	19.1	19.3	3.2	3.5	1.0215	1.0215
Jul	22.7	21.8	4.3	3.9	1.0209	1.0215
Aug	24.4	23.3	3.4	3.0	1.0208	1.0205
Sep	24.2	22.8	3.8	2.2	1.0207	1.0209
Oct	18.0	19.1	2.4	1.5	1.0218	1.0216
Nov	14.0	14.7	1.3	0.9	1.0232	1.0227
Dec	9.8	10.1	1.1	1.0	1.0237	1.0232
Annual	14.6	14.5	2.2	2.1	1.0217	1.0222

* Only 11 density measurements in April.

Temperature

53. Daily sea surface water temperatures (Figure 19) were measured with an NOS water sampler and thermometer. Monthly mean water temperatures (Table 8) varied with the air temperatures (see Table 2).

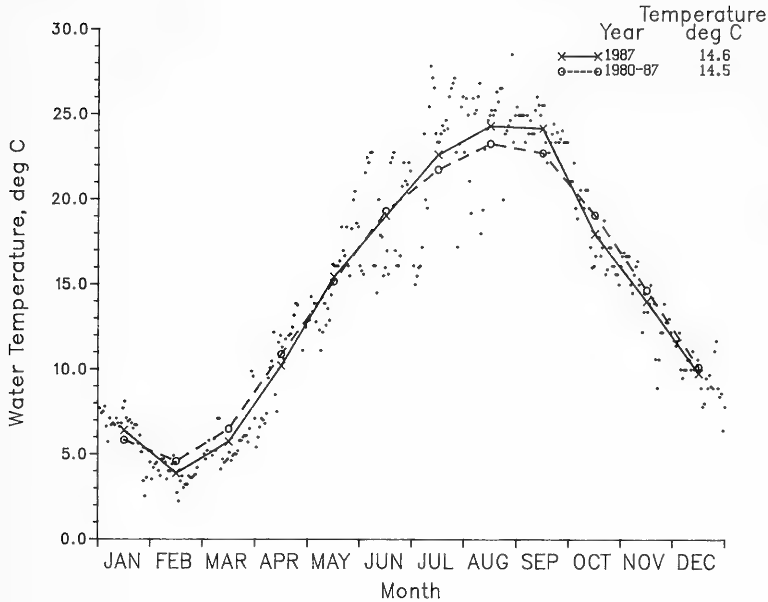


Figure 19. Daily water temperature values with monthly means

Visibility

54. Visibility in coastal nearshore waters depends on the amount of salts, soluble organic material, detritus, living organisms, and inorganic particles in the water. These dissolved and suspended materials change the absorption and attenuation characteristics of the water which vary daily and yearly.

55. Visibility was measured with a 0.3-m-diam Secchi disk and, similar to water temperature, variation was related to onshore and offshore winds. Onshore winds moved warm clear surface water toward shore; whereas, offshore winds brought up colder bottom water with large concentrations of suspended matter. Figure 20 presents the daily and monthly mean surface visibility values for the year. Large variations were common, and visibility less than 1 m was expected in any month. Monthly means are given in Table 8.

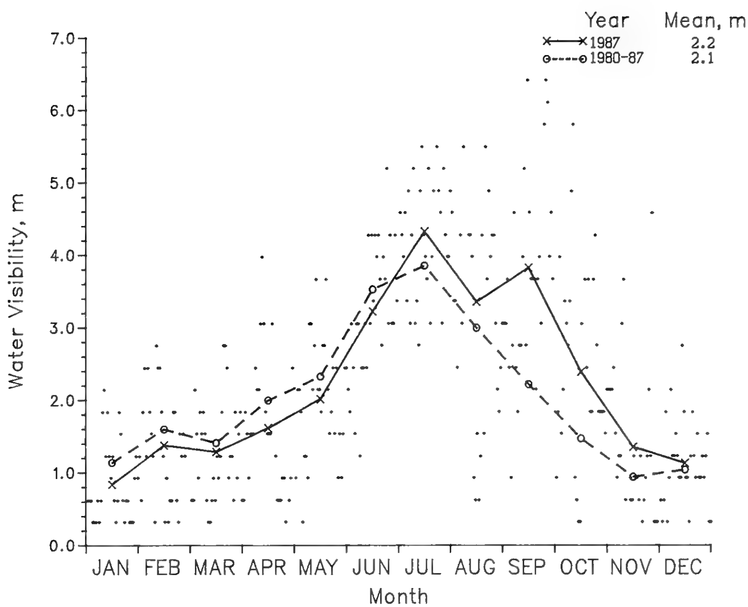


Figure 20. Daily water visibility values with monthly means

Density

56. Daily and monthly mean surface density values, plotted in Figure 21, were measured with a hydrometer. Monthly means are also given in Table 8.

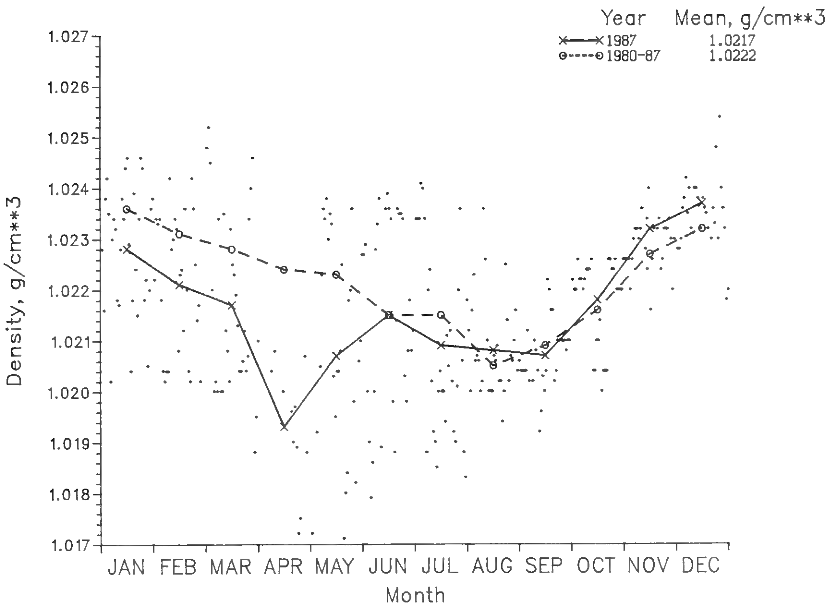


Figure 21. Daily water density values with monthly means

57. Waves and currents interacting with bottom sediments produce changes in the beach and nearshore bathymetry. These changes can occur very rapidly in response to storms or slowly as a result of persistent but less forceful seasonal variations in wave and current conditions.

58. Nearshore bathymetry at the FRF is characterized by regular shore-parallel contours, a moderate slope, and a barred surf zone (usually an outer storm bar in water depths of about 4.5 m and an inner bar in water depths between 1.0 and 2.0 m). This pattern is interrupted in the immediate vicinity of the pier where a permanent trough runs under much of the pier, ending in a scour hole where depths can be up to 3.0 m greater than the adjacent bottom (Figure 22). This trough, which apparently is the result of the interaction of waves and currents with the pilings, varies in shape and depth with changing wave and current conditions. The pier's effect on shore-parallel contours occurs as far as 300 m away, and the shoreline may be affected up to 350 m from the pier (Miller, Birkemeier, and DeWall 1983).

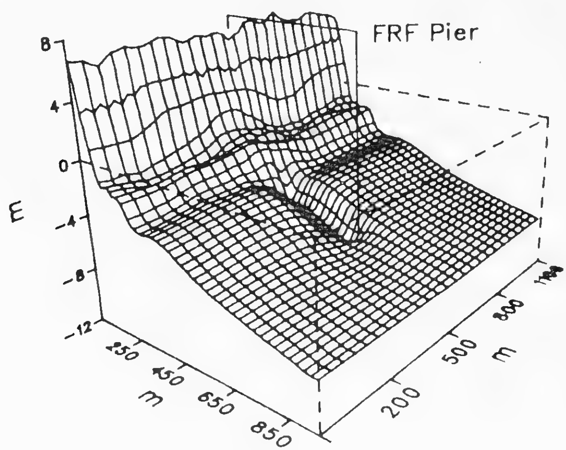


Figure 22. Permanent trough under the FRF pier, 9 December 1987

59. To document the temporal and spatial variability in bathymetry, surveys were conducted approximately monthly of an area extending 600 m north and south of the pier and approximately 950 m offshore. Contour maps resulting from these surveys along with plots of change in elevation between surveys are given in Appendix A.

60. All surveys utilized the Coastal Research Amphibious Buggy (CRAB), a 10.7-m-tall amphibious tripod, and a Zeiss electronic surveying system described by Birkemeier and Mason (1984). The profile locations are shown in each figure in Appendix A. Survey accuracy was about ±3 cm horizontally and vertically. Monthly soundings along both sides of the FRF pier were collected by lowering a weighted measuring tape to the bottom and recording the distance below the pier deck. Soundings were taken midway between the pier pilings to minimize errors caused by scour near the pilings.

61. A history of bottom elevations below Gages 645 and 625 is presented in Figure 23 for their respective pier stations of sta 7+80 (238 m) and sta 19+00 (579 m) along with intermediate locations, 323 and 433 m.

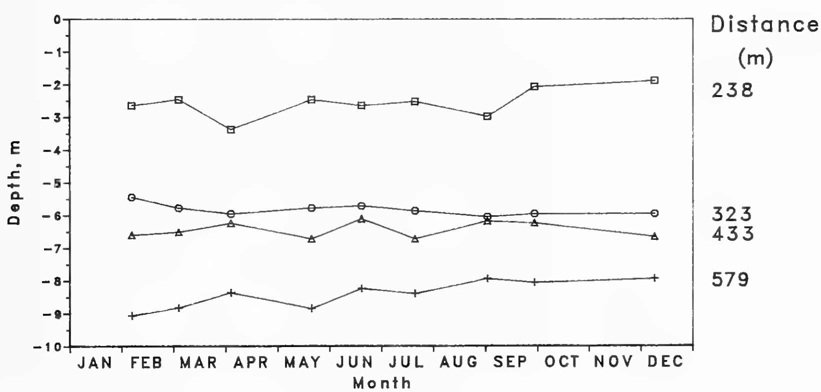


Figure 23. Time-history of bottom elevations at selected locations under the FRF pier

PART VIII: PHOTOGRAPHY

Aerial Photographs

62. Aerial photography was taken quarterly using a 23-cm aerial mapping camera at a scale of 1:12,000. All coverage was at least 60 percent overlap, with flights flown as closely as possible to low tide between 1000 and 1400 EST with less than 10 percent cloud cover. The flight lines covered are shown in Figure 24. Figure 25 is a sample of the imagery obtained on 10 July 1987; the available aerial photographs for the year are:

Date	Flight Lines	Format
9 Jan	2	Color
	3	B/W
27 Apr	2	Color
	3	B/W
	1	B/W
10 Jul	2	Color
	3	B/W
3 Oct	2	Color
	3	B/W

Beach Photographs

63. Daily color slides of the beach were taken using a 35-mm camera from the same location on the pier looking north and south (Figure 26). The location from which each picture was taken, as well as the date, time, and a brief description of the picture, was marked on the slides.

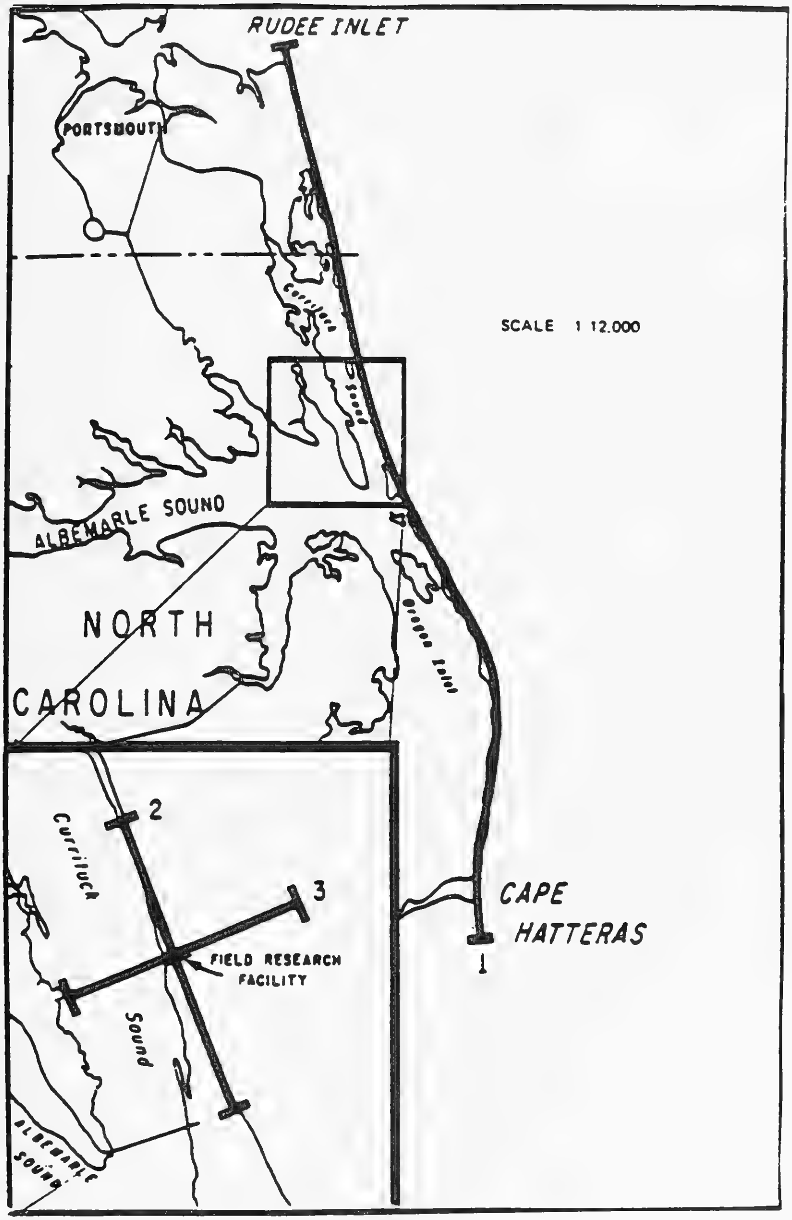


Figure 24. Aerial photography flight lines

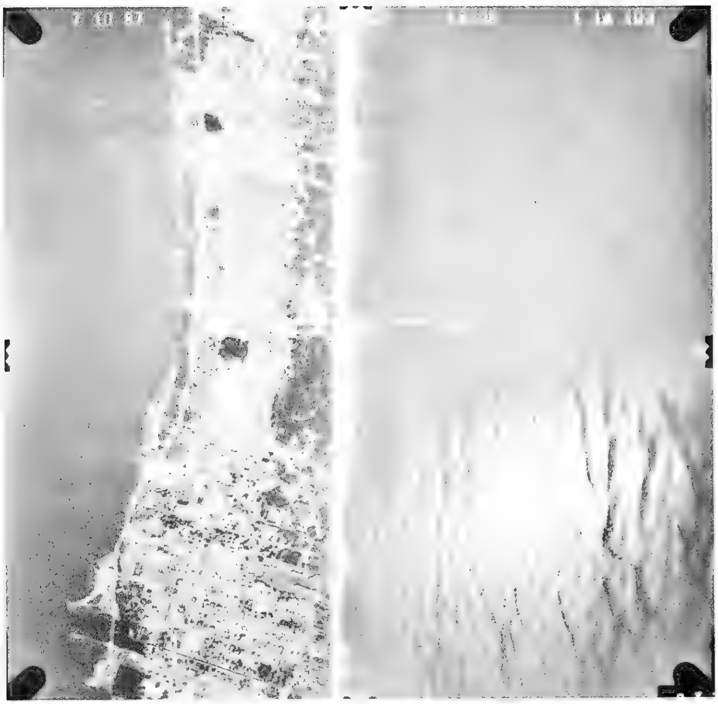


Figure 25. Sample aerial photograph, 10 July 1987

North View South View

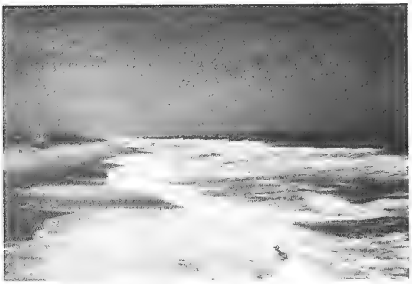
14 January 1987

15 February 1987

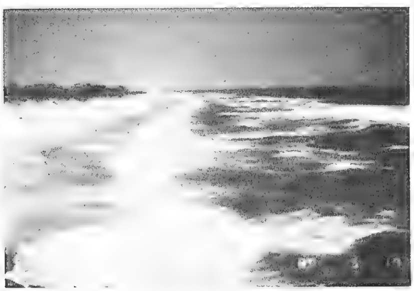
18 March 1987

Figure 26. Beach photos looking north and south from the FRF pier (Sheet 1 of 4)

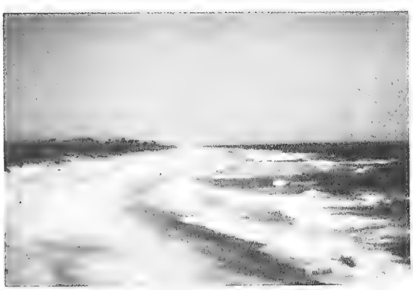
North View | South View




14 April 1987



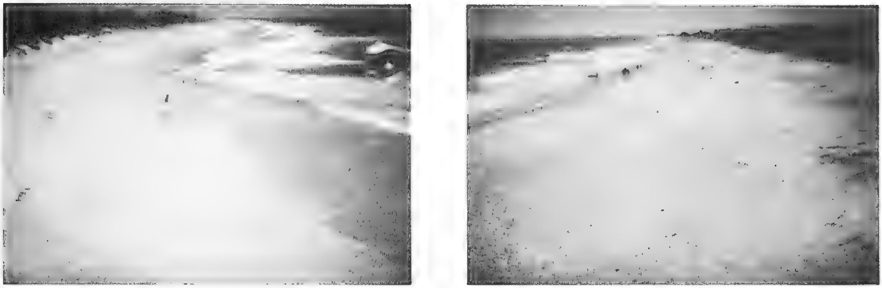

17 May 1987



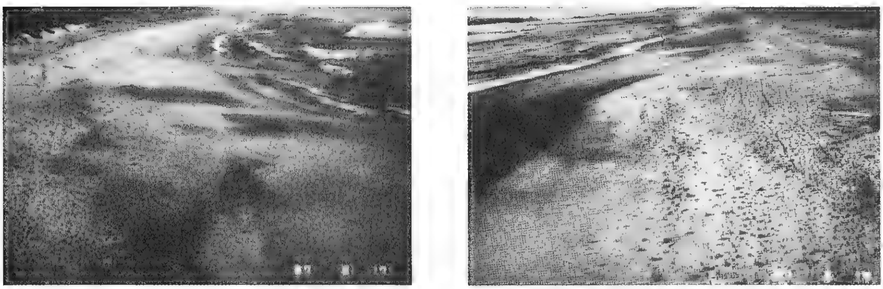

18 June 1987

Figure 26. (Sheet 2 of 4)

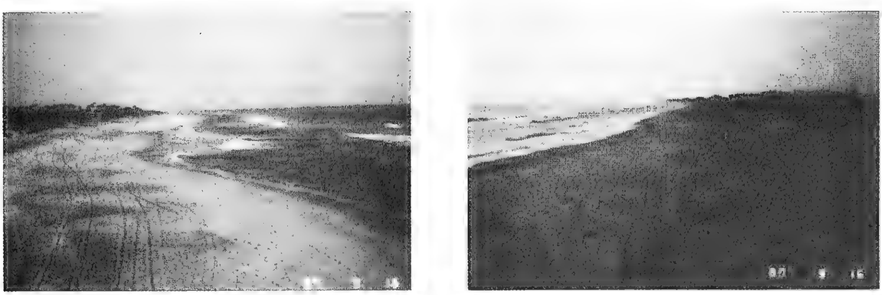
North View South View



18 July 1987



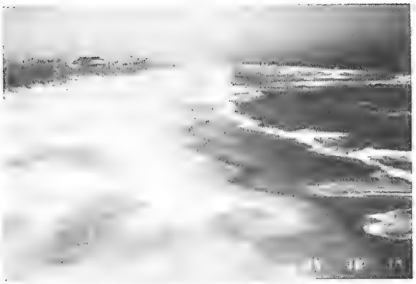
17 August 1987

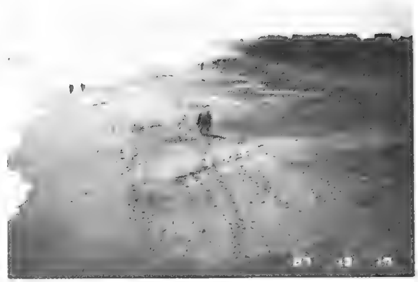


16 September 1987

Figure 26. (Sheet 3 of 4)

North View | South View





17 October 1987

6 November 1987

19 December 1987

Figure 26. (Sheet 4 of 4)

PART IX: STORMS

64. This section discusses storms (defined here as times when the wave height parameter, H_{mo}, equaled or exceeded 2 m at the seaward end of the FRF pier). Sample spectra from Gage 630 are given in Appendix B. Prestorm and/or poststorm bathymetry diagrams are given in Appendix A. NOAA Daily Weather Maps (US Department of Commerce 1987) provided tracking information.

1-2 January 1987 (Figure 27)

65. This storm formed over the Gulf of Mexico and early on 1 January was located off the Georgia coast. It increased in intensity and speed, rapidly moved up the coast, and by 2 January was located off New England. On 1 January at 2000 EST, the atmospheric pressure dropped to 993 mb. Maximum onshore winds exceeded 12 m/sec (ENE), and maximum H_{mo} (Gage 141) of 3.81 m (period = 10.24 sec) was recorded at 1900 EST also on 1 January.

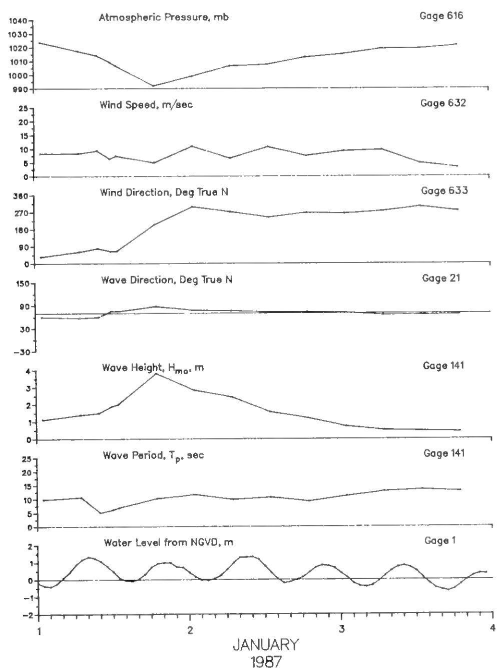


Figure 27. Data for 1-2 January 1987 storm

17 January 1987 (Figure 28)

66. Following the passage of a cold front, strong onshore winds generated by a large Canadian high-pressure system began to affect the FRF on the afternoon of 16 January. Maximum wind speeds exceeded 14 m/sec (NNE), and the largest H_{mo} (Gage 141) of 2.32 m (period = 7.76 sec) was recorded at 1500 EST on 17 January. Total precipitation was 4 mm.

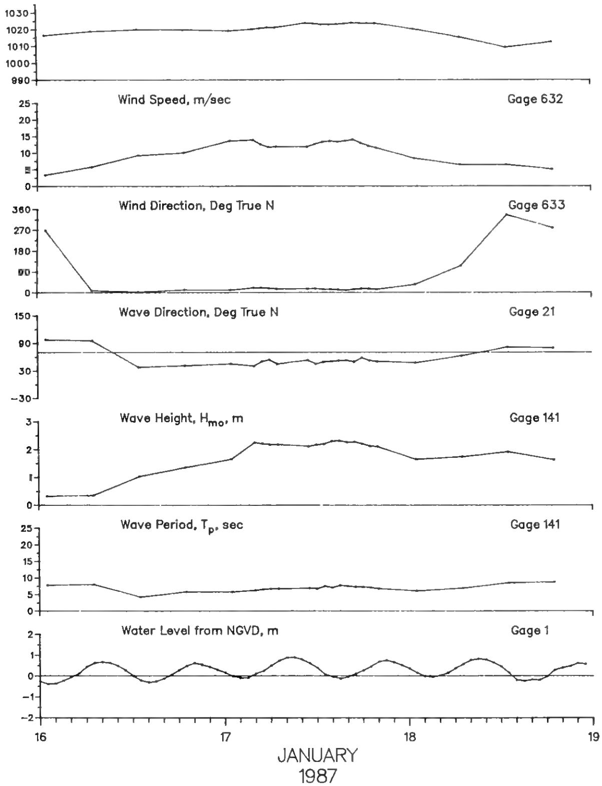


Figure 28. Data for 17 January 1987 storm

25-27 January 1987 (Figure 29)

67. This low-pressure system formed on 23 January over the western United States, later tracked over the southern United States, and early on 26 January moved offshore at Cape Hatteras, NC. On 25 January, onshore winds peaked at 17 m/sec (NE) at 2200 EST. The minimum atmospheric pressure of 977.7 mb occurred on 26 January at 0300 EST. The maximum H_{mo} (Gage 141) of 3.26 m (period = 9.85 sec) was recorded at 1400 EST on 26 January and remained above 2 m for 33 hr. Total precipitation was 22 mm.

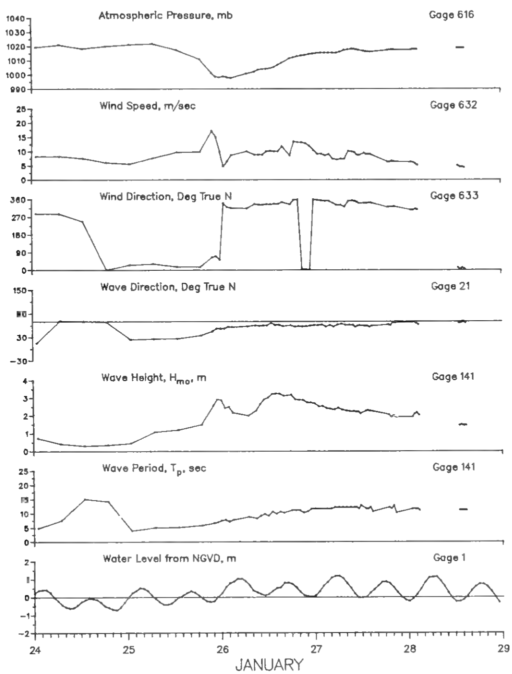


Figure 29. Data for 25-27 January 1987 storm

16-18 February 1987 (Figure 30)

68. Northeast winds generated by a strong Canadian high-pressure system first affected the FRF early on 16 February following the passage of a cold front. Maximum onshore winds approached 18 m/sec (NNE) at 0508 EST on 17 February, and the maximum H_{mo} (Gage 141) of 4.30 m (period = 8.53 sec) was recorded at 0808 EST on the same day. Total precipitation was 27 mm.

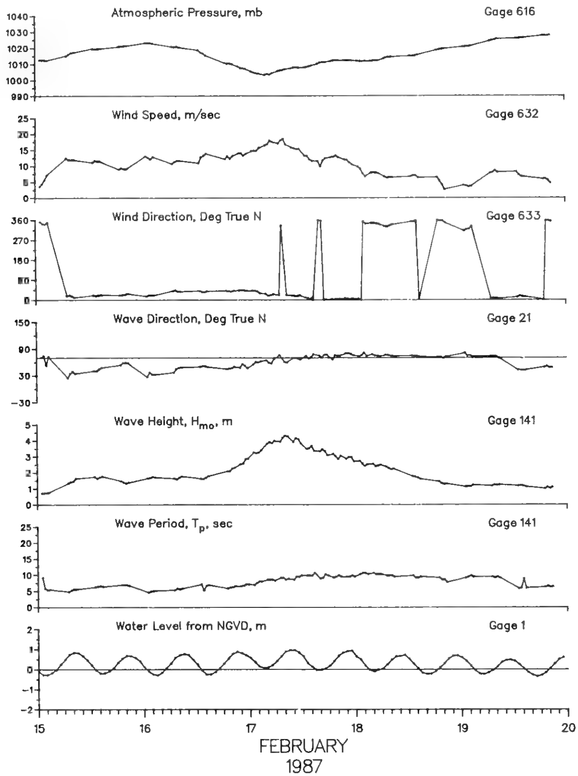


Figure 30. Data for 16-18 February 1987 storm

10-16 March 1987 (Figure 31)

69. Forming off Cape Hatteras, NC, on 10 March, this intense storm was spawned from another low-pressure system which had developed over the Gulf of Mexico and tracked northeast along the Appalachian Mountains. This storm quickly moved well offshore and was replaced by a smaller storm which formed off Virginia on 13 March and moved to the northeast. The minimum atmospheric pressure of 1001 mb was recorded on 9 March at 2042 EST. Maximum onshore winds exceeded 20 m/sec (NNE) at 0734 EST on 10 March with the maximum H_{mo} (Gage 141) of 4.52 m (period = 11.64 sec) recorded at 1300 EST on the same day. The H_{mo} remained above 3 m for 28 consecutive hr and above 2 m for 159 hr. Total precipitation was 22 mm.

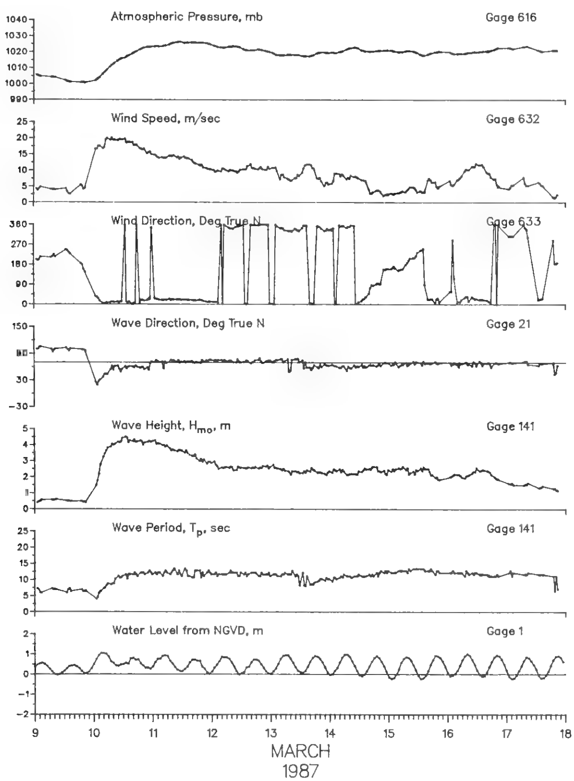


Figure 31. Data for 10-16 March 1987 storm

23-24 March 1987 (Figure 32)

70. Onshore winds generated by a Canadian high-pressure system produced storm waves at the FRF early on 23 March. Maximum winds exceeded 10 m/sec (N), and maximum H_{mo} (Gage 141) was 3.15 m (period = 11.64 sec); both values were recorded at 1300 EST on 22 March.

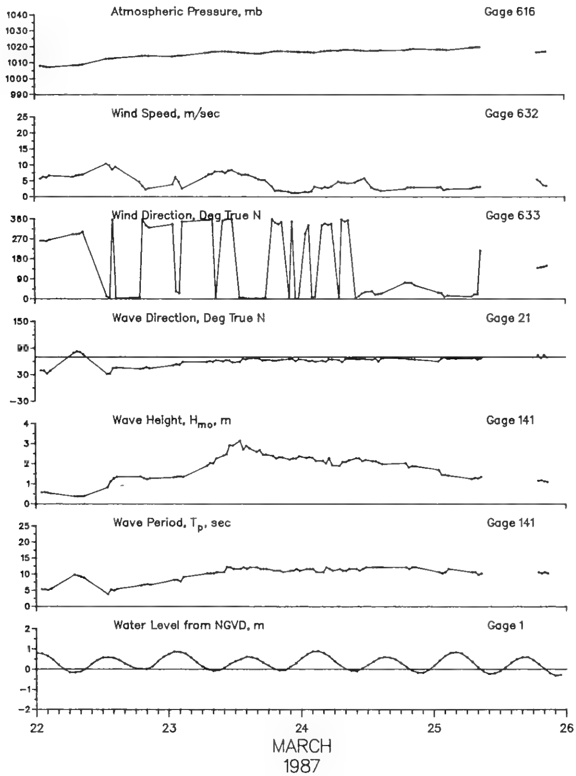


Figure 32. Data for 23-24 March 1987 storm

30-31 March 1987 (Figure 33)

71. Onshore winds produced by a combination of a Canadian high-pressure system and a storm traveling along a cold front over the Appalachian Mountains briefly produced storm waves at the FRF. Maximum onshore winds in excess of 11 m/sec (SSE) were recorded at 0842 EST on 31 March. The minimum atmospheric pressure of 997 mb occurred at 0842 EST, and the maximum H_{mo} (Gage 141) of 2.35 m (period = 9.48 sec) was recorded at 1000 EST the same day. Total precipitation was 21 mm.

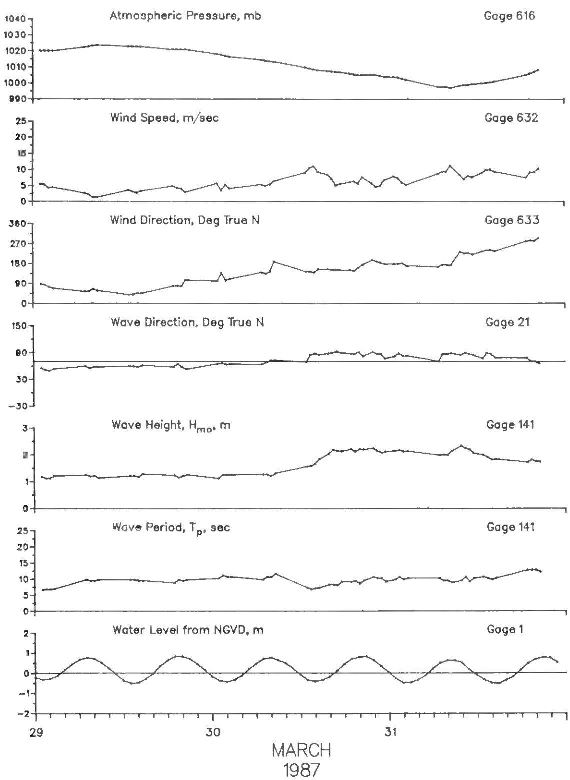


Figure 33. Data for 30-31 March 1987 storm

16 April 1987 (Figure 34)

72. This storm originated over the central United States and was located over western South Carolina by 16 April. It rapidly weakened and moved offshore on 18 April. On the 16th, maximum wind speeds exceeded 12 m/sec (ESE), peaking at 1108 EST. The maximum H_{mo} (Gage 141) of 2.35 m (period = 8 sec) was recorded at 1600 EST, and the lowest atmospheric pressure of 1000 mb occurred at 1416 EST. Total precipitation was 7 mm.

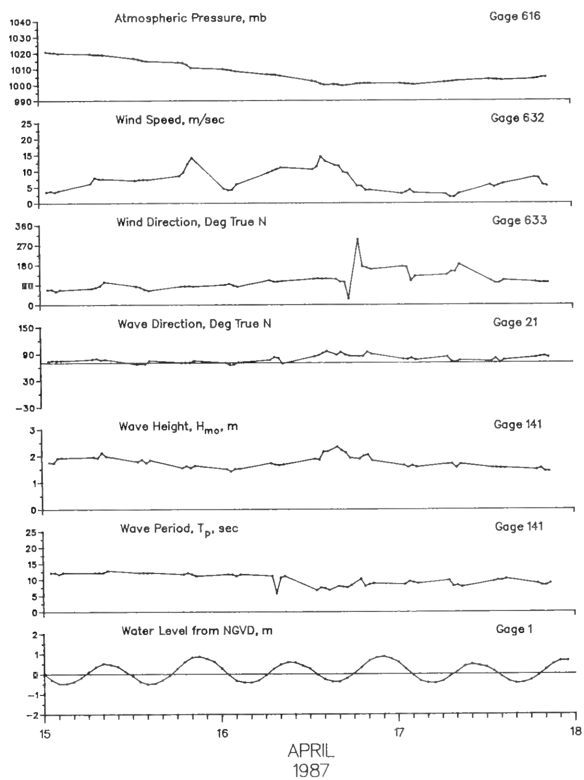


Figure 34. Data for 16 April 1987 storm

25-28 April 1987 (Figure 35)

73. This storm developed over Georgia on 23 April, slowly traveled to the northeast, and became almost stationary off Cape Hatteras, NC. By 25 April the low developed into a major storm and moved well offshore on 27 April. On the 26th, maximum onshore winds exceeded 18 m/sec (N to NNE) at 1442 EST. The maximum H_{mo} (Gage 625) of 3.14 m (period = 11.14 sec) occurred 5 hr later, and the lowest atmospheric pressure of 1012 mb was recorded at 1408 EST. Total precipitation was 27 mm.

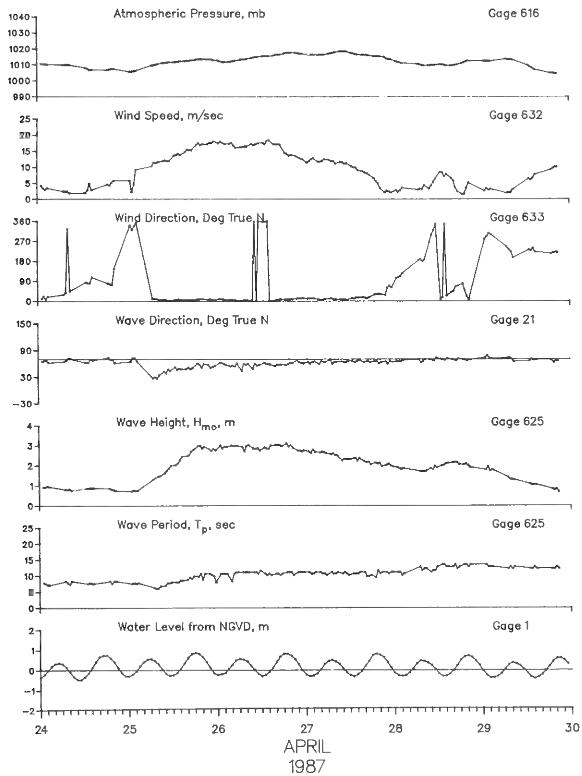


Figure 35. Data for 25-28 April 1987 storm

4-5 May 1987 (Figure 36)

74. Strong onshore winds generated by a large Canadian high-pressure system along with a weak low-pressure system developed on 4 May. That day, maximum onshore winds exceeded 16 m/sec (NNE) at 1742 EST, and maximum H_{mo} (Gage 141) of 2.69 m (period = 7.31 sec) was recorded at 2008 EST. The atmospheric pressure did not drop, and there was no precipitation.

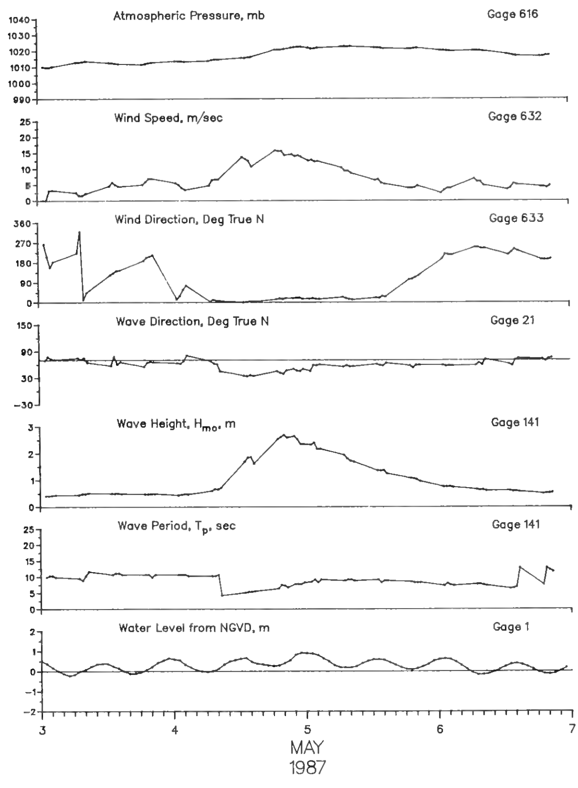


Figure 36. Data for 4-5 May 1987 storm

14-16 August 1987 (Figure 37)

75. A Canadian high-pressure system affected onshore winds at the FRF on 11 August. Augmented by a weak storm that developed off Florida's east coast on 14 August, onshore winds continued through 16 August. Maximum wind speeds exceeding 10 m/sec (NE) and H_{mo} (Gage 141) of 2.46 m (period = 11.13 sec) were recorded at 0734 EST on 15 August. Because the winds were produced by a high-pressure system atmospheric pressure never declined, and there was no precipitation.

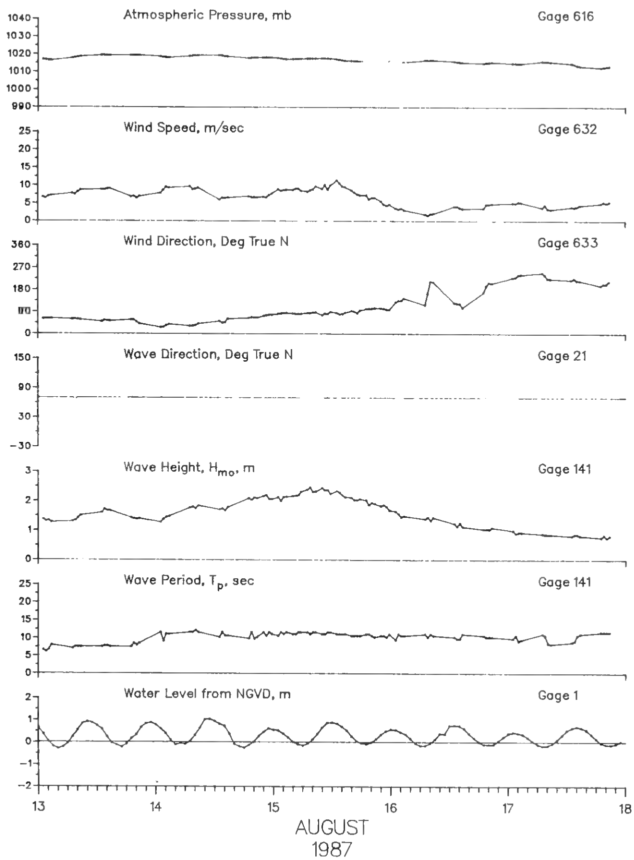


Figure 37. Data for 14-16 August 1987 storm

4-5 September 1987 (Figure 38)

76. Strong onshore winds generated by a strong Canadian high-pressure system briefly produced storm waves at the FRF. The maximum wind speed of 13 m/sec (NE) was recorded at 2200 EST on 4 September. That same day, the maximum H_{mo} (Gage 141) of 2.38 m (period = 7.11 sec) occurred at 2042 EST.

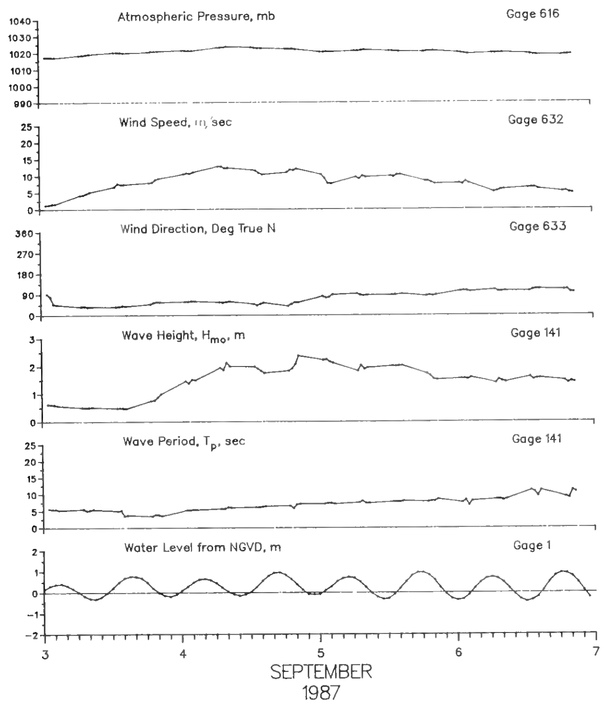


Figure 38. Data for 4-5 September 1987 storm

12-15 October 1987 (Figure 39)

77. Following the passage of a cold front late on 11 October, strong onshore winds generated by a huge high-pressure system located in the central US rapidly produced storm waves at the FRF. Onshore winds exceeded 10 m/sec (N to NNE) for 86 consecutive hr with the peak wind speed of 17 m/sec (NNE) occurring at 1934 EST on 13 October. Waves above 2 m were recorded for 80 consecutive hr with the maximum H_{mo} (Gage 141) of 3.28 m (period = 9.14 sec) occurring on 14 October at 0542 EST.

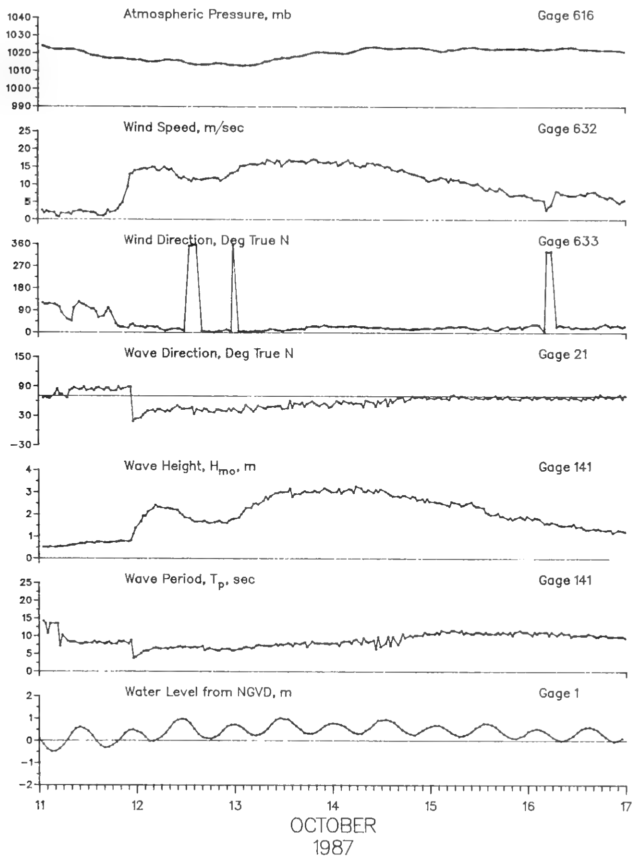


Figure 39. Data for 12-15 October 1987 storm

11-12 November 1987 (Figure 40)

78. On 9 November, this storm developed off the Texas coast, moved rapidly to the northeast, and by 11 November was located off the Virginia coast. The storm intensified and continued its rapid movement up the east coast, reaching New England on 12 November. Maximum onshore winds exceeded 13 m/sec (E) at 2200 EST on 11 November; maximum H_{mo} (Gage 141) of 2.63 m (period = 10.24 sec) occurred at 0400 EST on 12 November. The lowest atmospheric pressure, 1007.2 mb, was recorded on 10 November at 1634 EST. Total precipitation was 11 mm.

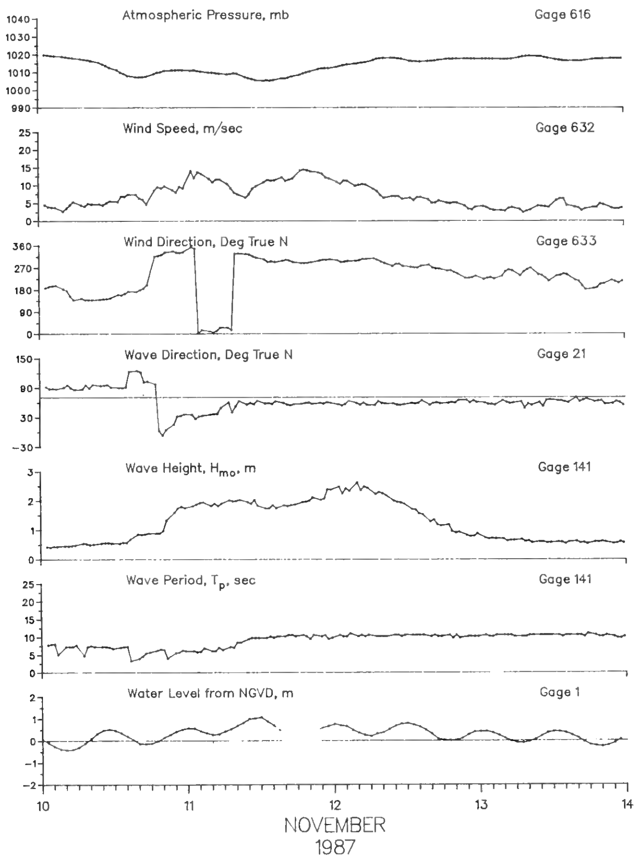


Figure 40. Data for 11-12 November 1987 storm

27-29 November 1987 (Figure 41)

79. Winds caused by a strong Canadian high-pressure system began to generate storm waves at the FRF on 27 November. The additional development of a storm over Tennessee that moved to the North Carolina coast on 29 November prolonged the onshore winds through 30 November. The maximum H_{mo} (Gage 141) of 2.44 m (period = 7.53 sec) occurred on 27 November at 1300 EST. Maximum onshore winds approaching 12 m/sec (NE) were recorded at 1900 EST on the 27th. The lowest atmospheric pressure was 998.9 mb on 30 November at 1442 EST. Total precipitation was 34 mm.

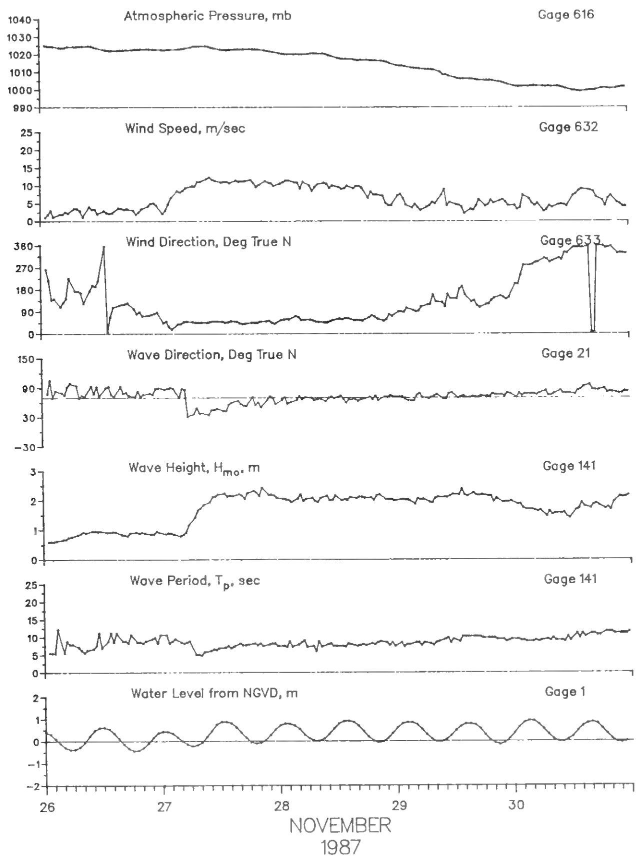


Figure 41. Data for 27-29 November 1987 storm

29-30 December 1987 (Figure 42)

80. This storm formed off Cape Hatteras, NC, early on 29 December and rapidly strengthened as it quickly moved up the east coast. It was located off Nova Scotia, Canada, by 30 December. Maximum onshore winds approached 14 m/sec (NNE) at 2042 EST on the 29th; 5 hr later the maximum H_{mo} (Gage 625) of 2.79 m (period = 11.13 sec) was recorded; and the minimum atmospheric pressure of 1001.8 mb occurred on the 29th at 0434 EST. Precipitation totalled 16 mm.

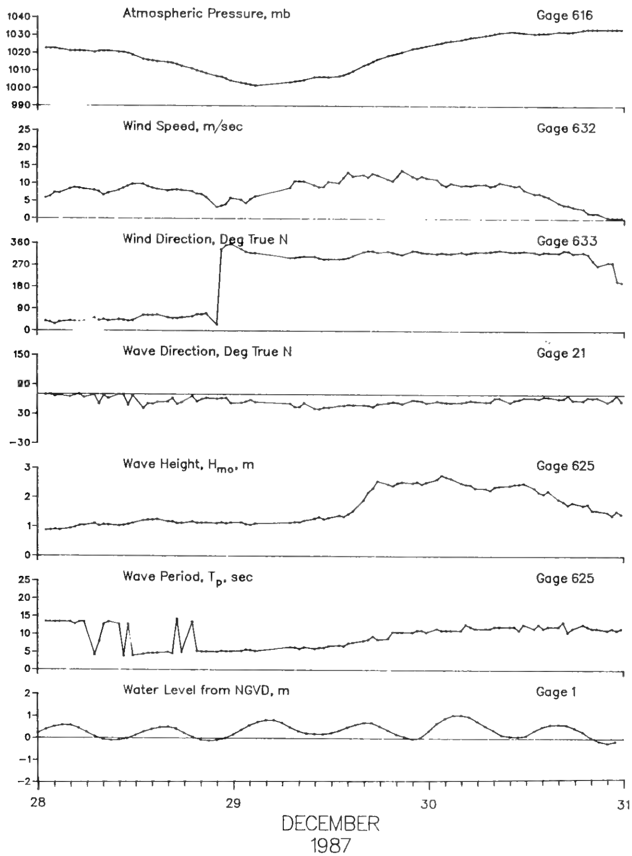


Figure 42. Data for 29-30 December 1987 storm

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APPENDIX A: SURVEY DATA

1. Contour diagrams constructed from the bathymetric survey data are presented in this appendix. The profile lines surveyed are identified on each diagram. Contours are in half meters referenced to National Geodetic Vertical Datum (NGVD). The distance offshore is referenced to the Field Research Facility (FRF) monumentation baseline behind the dune.

2. Change in FRF bathymetry diagrams constructed by contouring the difference between two contour diagrams are also presented with contour intervals of 0.25 m. Wide contour lines show areas of erosion. Other areas correspond to areas of accretion. Although these change diagrams are based on considerable interpolation of the original survey data, they do facilitate comparison of the contour diagrams.

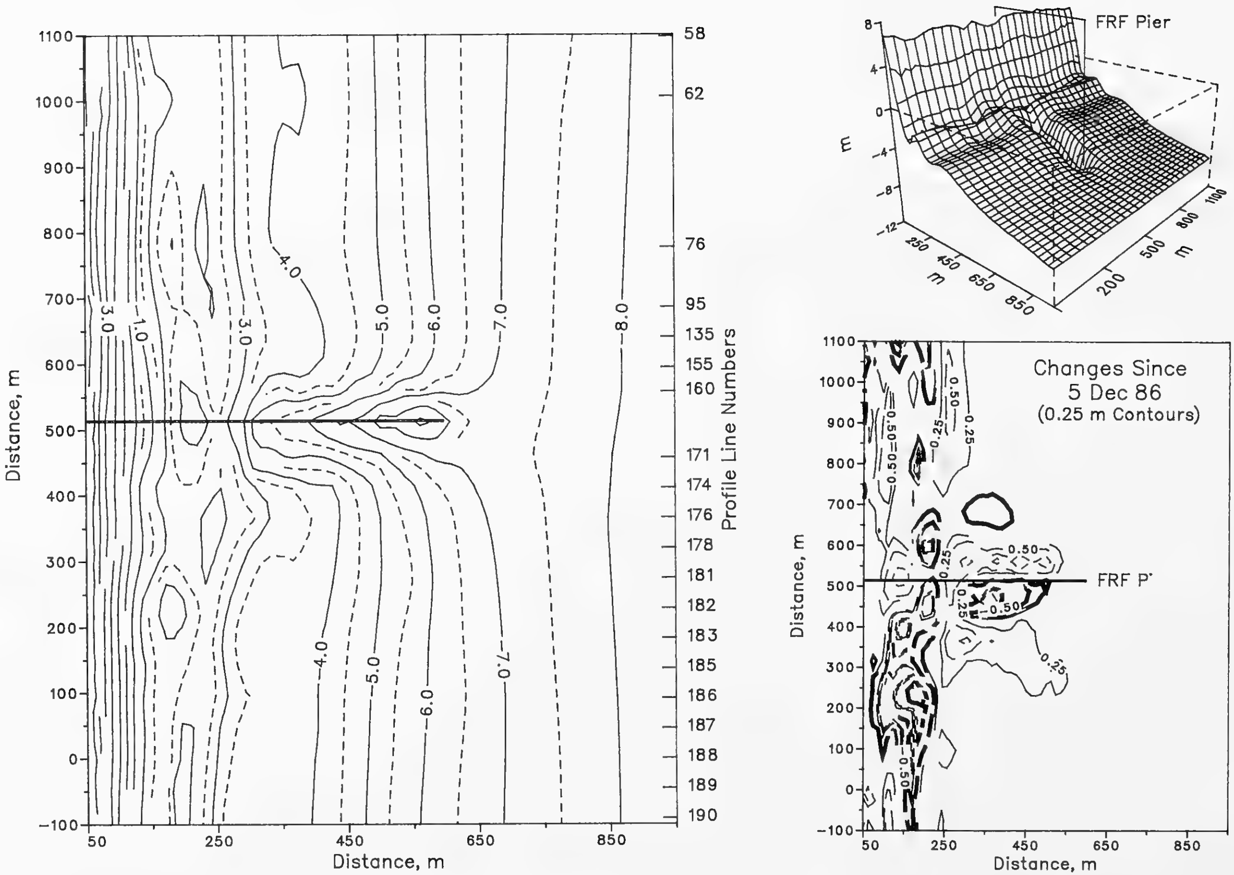


Figure A1. FRF bathymetry, 4 February 1987
(depths relative to NGVD)

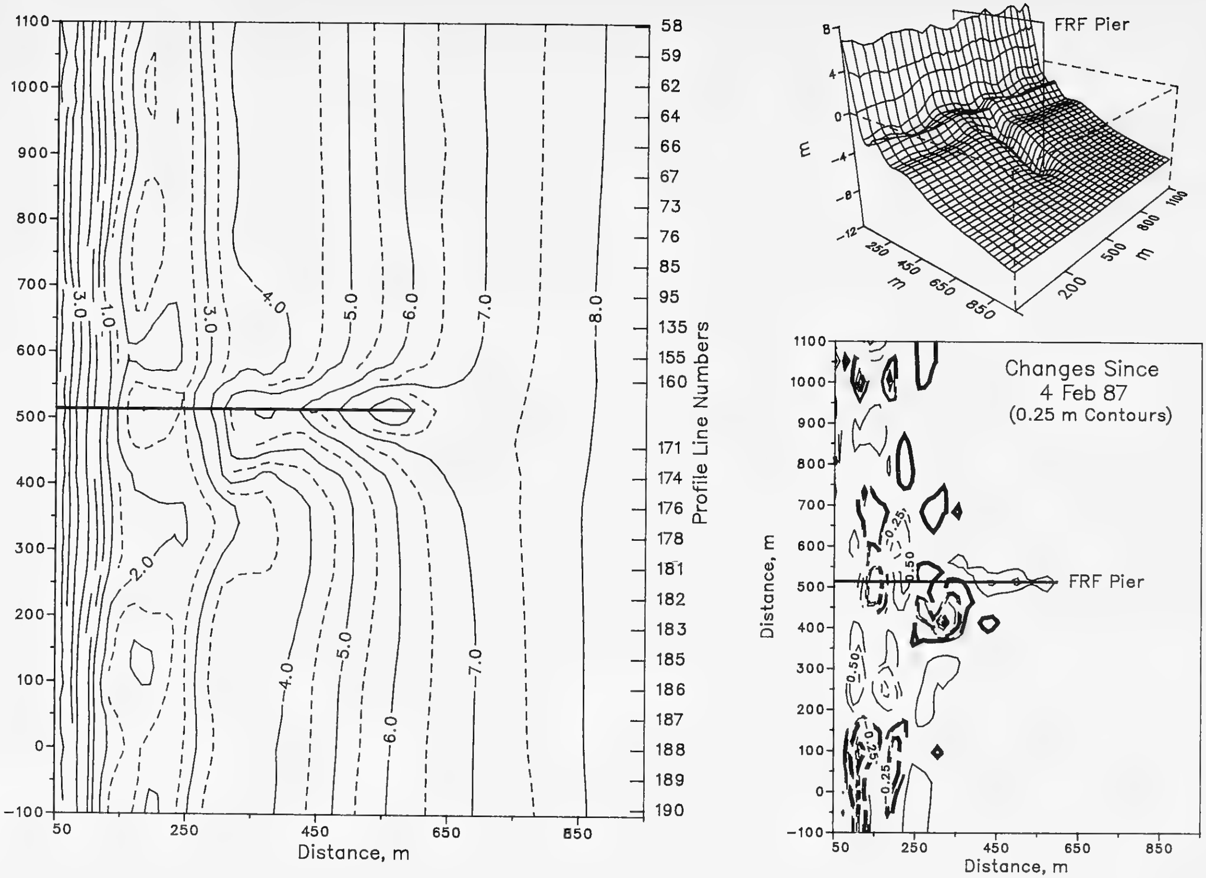


Figure A2. FRF bathymetry, 3 March 1987
(depths relative to NGVD)

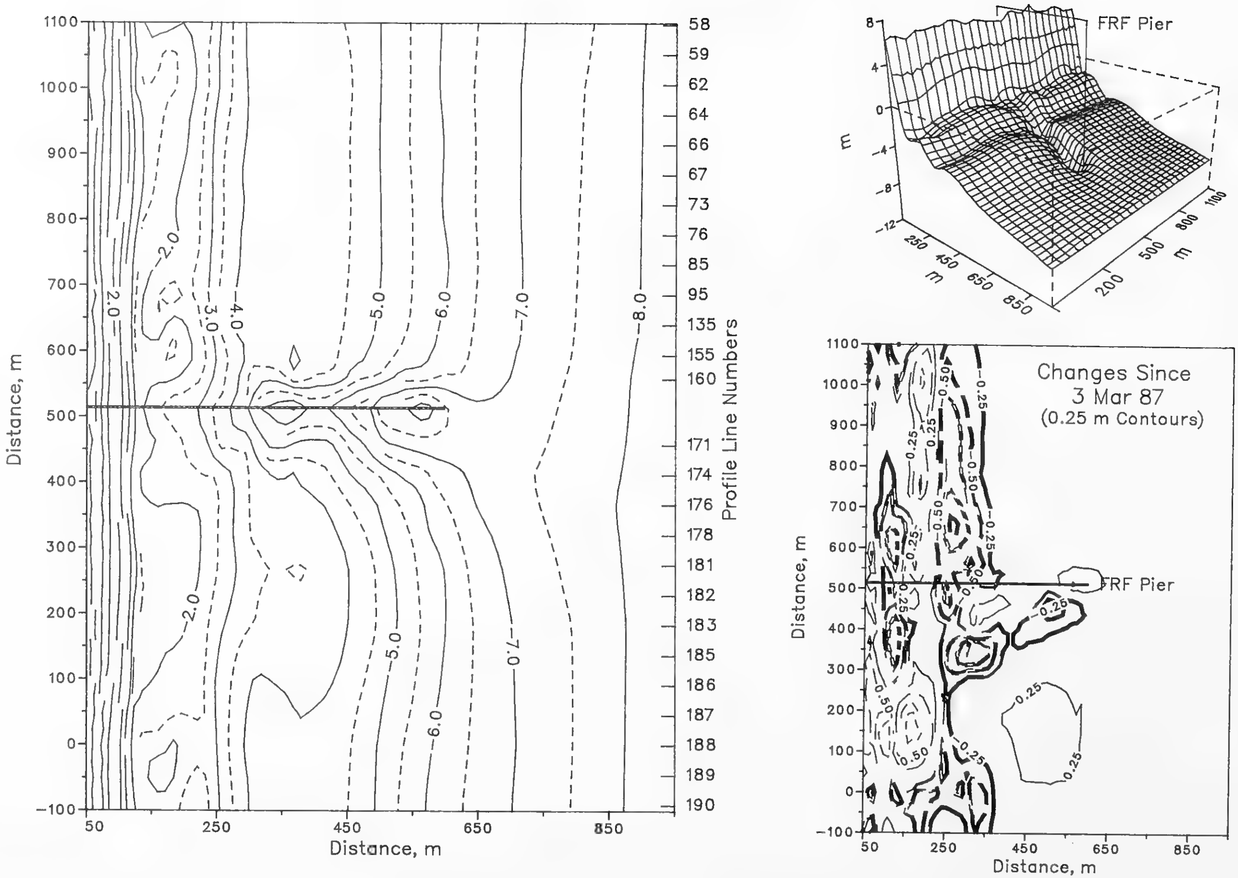


Figure A3. FRF bathymetry, 2 April 1987
(depths relative to NGVD)

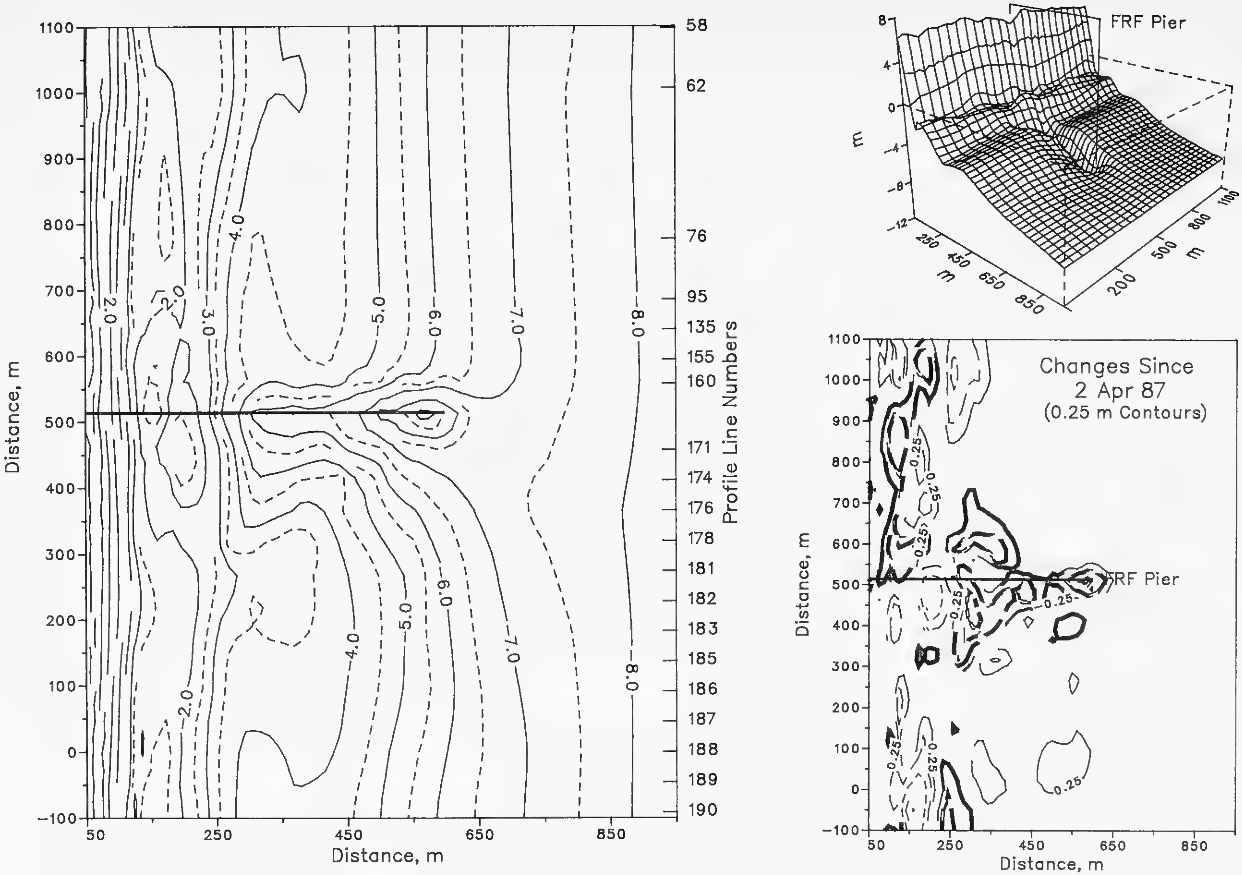


Figure A4. FRF bathymetry, 19 May 1987
(depths relative to NGVD)

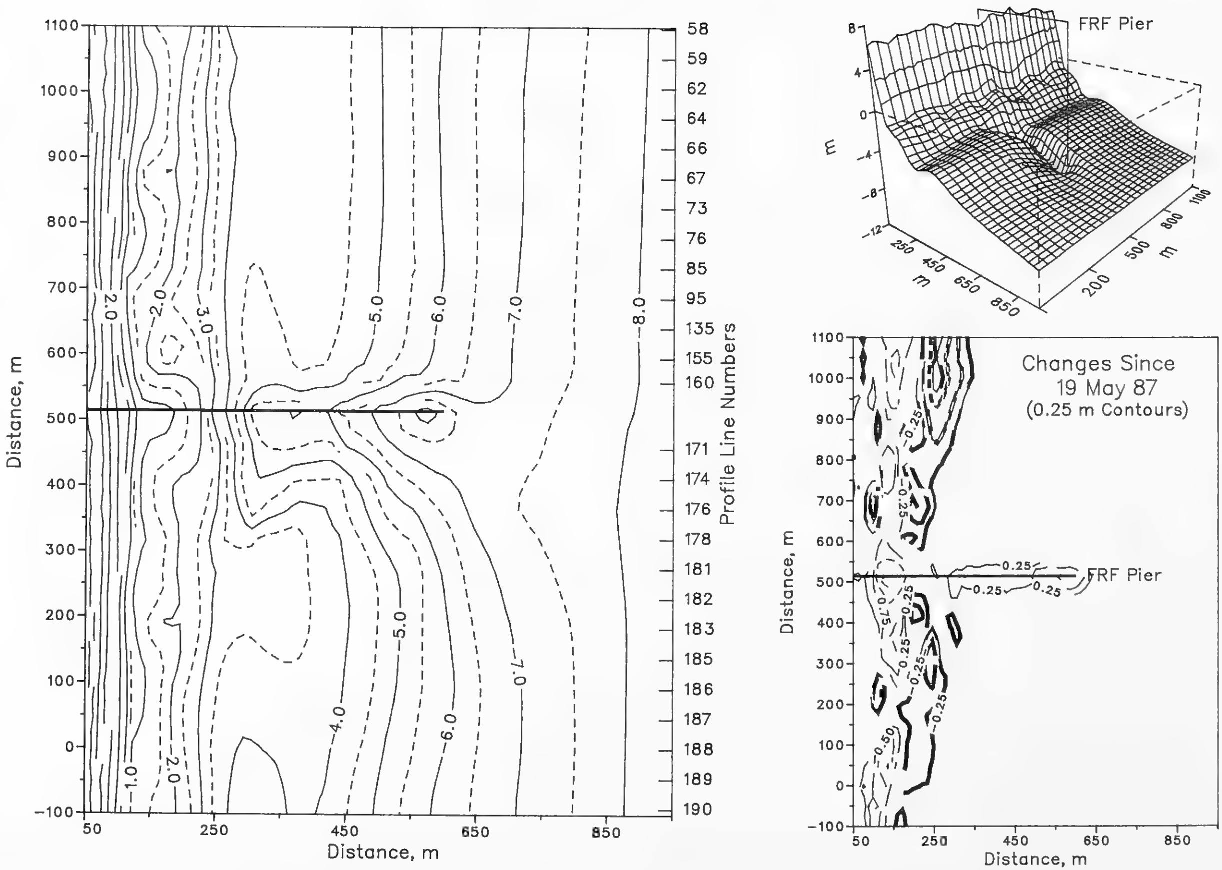


Figure A5. FRF bathymetry, 17 June 1987
(depths relative to NGVD)

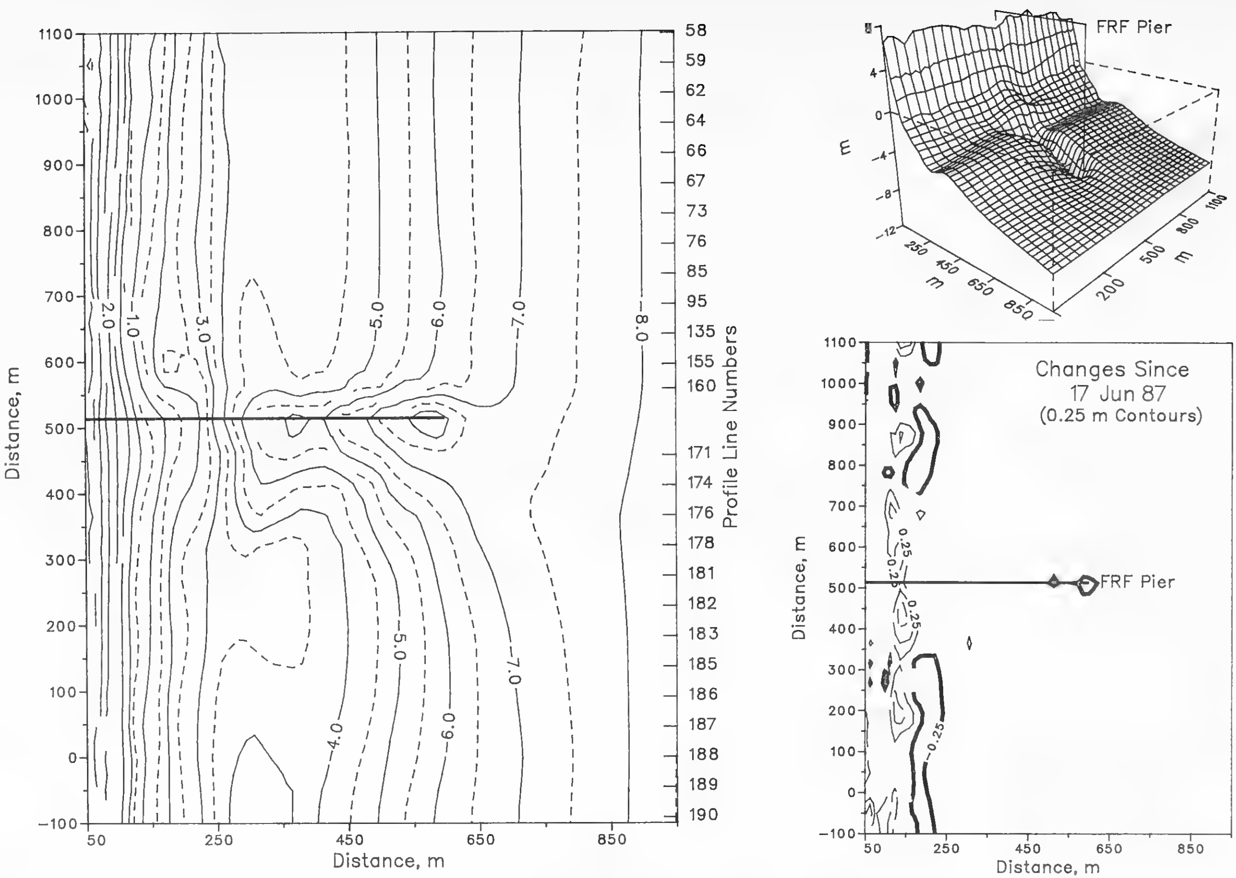


Figure A6. FRF bathymetry, 22 July 1987
(depths relative to NGVD)

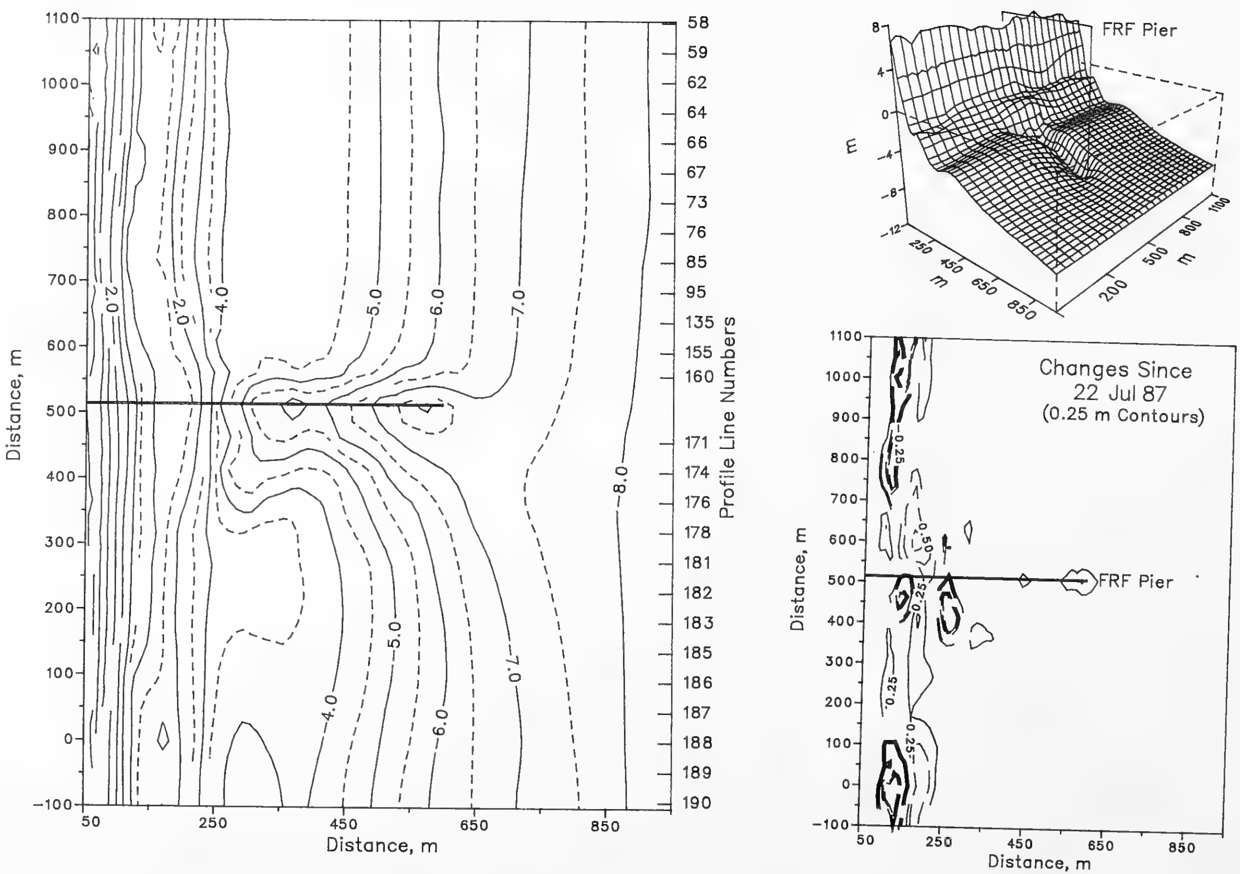


Figure A7. FRF bathymetry, 1 September 1987
(depths relative to NGVD)

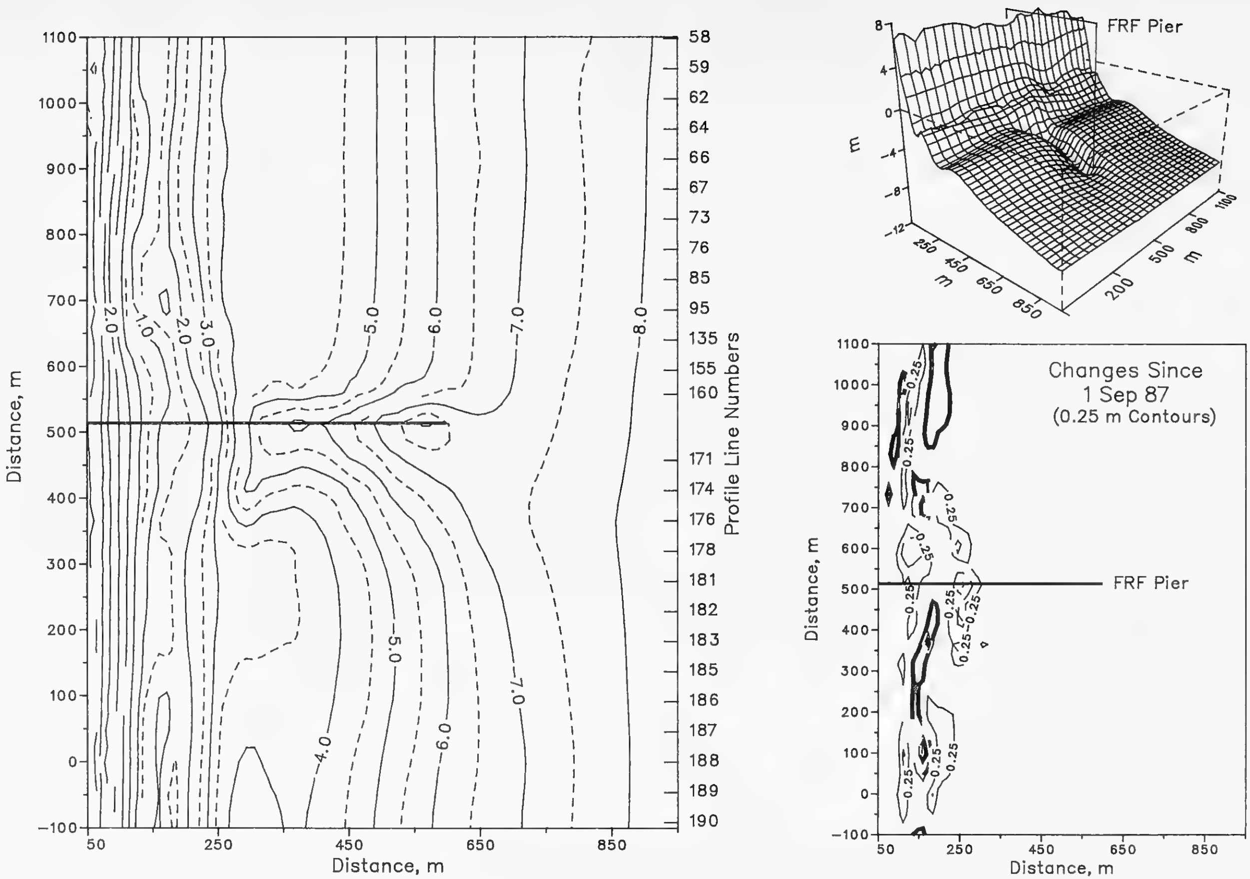


Figure A8. FRF bathymetry, 29 September 1987
(depths relative to NGVD)

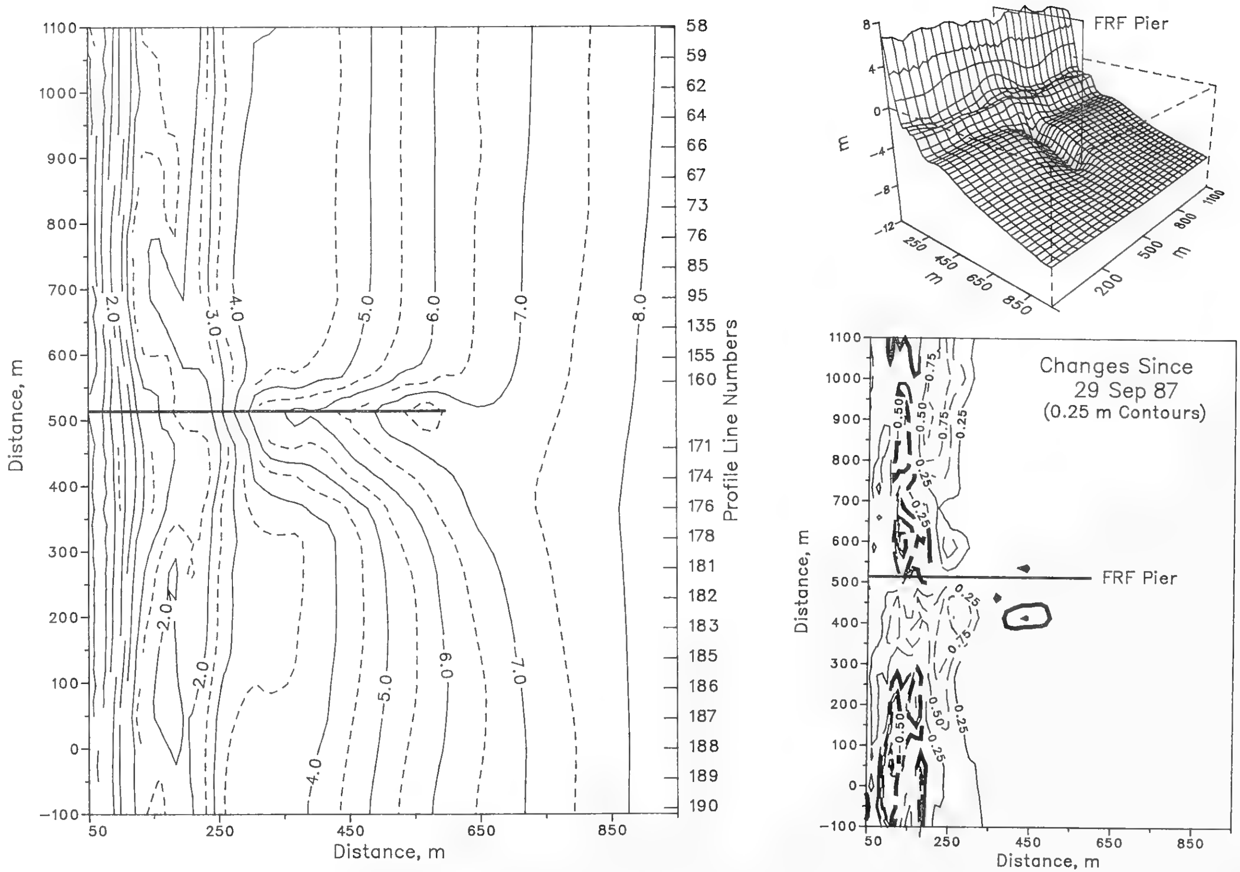


Figure A9. FRF bathymetry, 9 December 1987
(depths relative to NGVD)

APPENDIX B: WAVE DATA FOR GAGE 630

1. Wave data summaries for Gage 630 are presented for 1987 and for 1980 through 1987 in the following forms:

Daily H_{mo} and T_p

2. Figure B1 displays the individual wave height and peak spectral wave period values along with the monthly mean values.

Joint Distributions of H_{mo} and T_p

3. Annual and monthly joint distributions tables are presented in Tables B1 and B2, and data for 1980 through 1987 are in Tables B3 and B4. Each table gives the frequency (in parts per 10,000) for which the wave height and peak period were within the specified intervals; these values can be converted to percent by dividing by 100. Marginal totals are also included. The row total gives the total number of observations out of 10,000 which fell within each specified peak period interval. The column total gives the number of observations out of 10,000 which fell within each specified wave height interval.

Cumulative Distributions of Wave Height

4. Annual and monthly wave height distributions for 1987 are plotted in cumulative form in Figures B2 and B3. Data for 1980 through 1987 are in Figure B4.

Peak Spectral Wave Period Distributions

5. Annual and monthly peak wave period, T_p, distribution histograms for 1987 are presented in Figures B5 and B6. Data for 1980 through 1987 are in Figure B7.

Persistence of Wave Heights

6. Table B5 shows the number of times in 1987 when the specified wave height was equaled or exceeded at least once during each day for the duration (consecutive days). Data for 1980 through 1987 are given in Table B6. An example is shown below:

Height	Consecutive Day(s) or Longer																		
m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	18	15		14	13	12		11	10	9				8		7			
1.0	50	34	24	21	18	14	12	8	7	3			2						
1.5	41	19	8	6	2	1													
2.0	22	9	5	1															
2.5	10	5	2																
3.0	6	1																	
3.5		1																	
4.0	1																		

This example indicates that wave heights equaled or exceeded 1.0 m 50 times for at least 1 day; 34 times for at least 2 days; 24 times for at least 3 days, etc. Therefore, on 16 occasions the height equaled or exceeded 1.0 m for 1 day exactly (50 - 34 = 16); on 10 occasions for 2 days; on 3 occasions for 3 days, etc. Note that the height exceeded 1 m 50 times for 1 day or longer, while heights exceeded 0.5 m only 18 times for this same duration. This change in durations occurred because the longer durations of lower waves may be interspersed with shorter, but more frequent, intervals of higher waves. For example, one of the times that the wave heights exceeded 0.5 m for 16 days may have represented 3 times the height exceeded 1 m for shorter durations.

Spectra

7. Monthly spectra for the offshore Waverider buoy (Gage 630) are presented in Figure B8. The plots show "relative" energy density as a function of wave frequency. These figures summarize the large number of spectra for each month. The figures emphasize the higher energy density associated with storms as well as the general shifts in energy density to different frequencies. As used here, "relative" indicates the spectra have been smoothed by the 3-D surface drawing routine. Consequently, extremely high- and low-energy density values are modified to produce a smooth surface.

The figures are not intended for quantitative measurements; however, they do provide the energy density as a function of frequency relative to the other spectra for the month.

8. Monthly and annual wave statistics for Gage 630 for 1987 and for 1980 through 1987 are presented in Table B7.

9. Figure B9 plots monthly time histories of wave height and period.

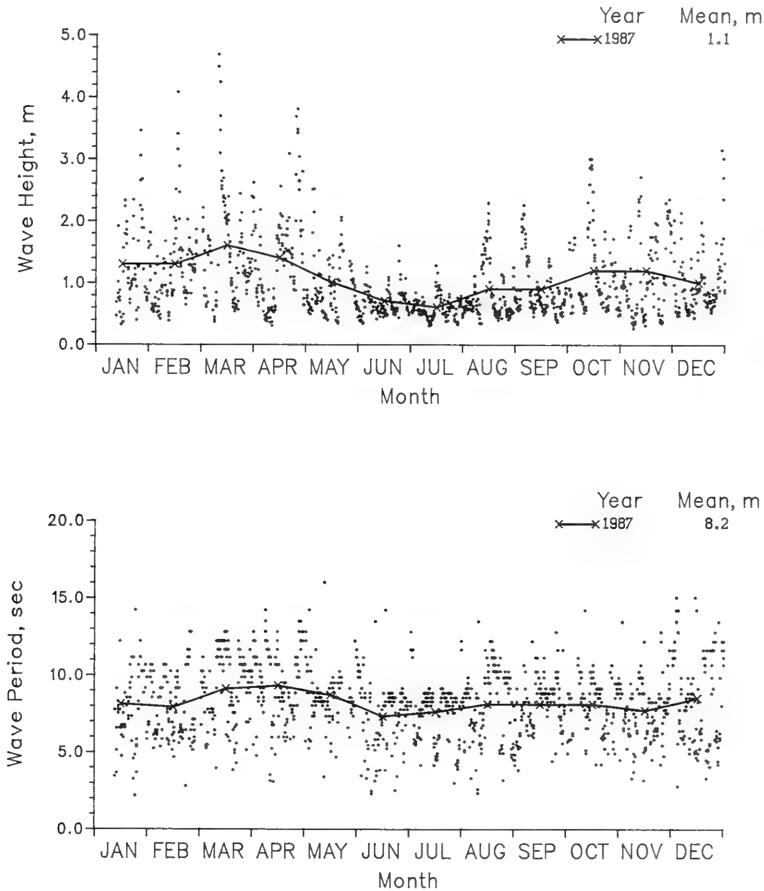


Figure B1. 1987 daily wave period values with monthly means for Gage 630

Table B1

Annual Joint Distribution of H_{mo} versus T_p

Annual 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	7	22	22	22	74	141	512	171	119	59	74	.	1223
0.50 - 0.99	59	163	237	593	504	571	1320	653	675	45	193	.	5013
1.00 - 1.49	.	22	148	364	267	134	341	163	267	7	52	.	1765
1.50 - 1.99	.	.	37	208	252	104	111	141	193	15	45	.	1106
2.00 - 2.49	.	.	.	30	67	89	74	82	126	.	59	.	527
2.50 - 2.99	.	.	.	.	15	37	22	7	89	.	15	.	185
3.00 - 3.49	.	.	.	.	.	30	15	22	37	.	7	.	111
3.50 - 3.99	.	.	.	.	.	7	7	.	7	.	.	.	21
4.00 - 4.49	.	.	.	.	.	.	.	15	7	.	7	.	29
4.50 - 4.99	.	.	.	.	.	.	.	.	7	.	.	.	7
5.00 - Greater	.	.	.	.	.	.	7	.	.	.	.	.	7
Total	66	207	444	1217	1179	1113	2409	1254	1527	126	452	0	

Table B2

Monthly Joint Distribution of H_{mo} versus T_p

January 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	417	278	.	.	.	139	139	.	973
0.50 - 0.99	139	278	139	139	.	556	972	694	694	.	.	.	3611
1.00 - 1.49	.	278	278	278	.	.	417	139	556	.	.	.	1946
1.50 - 1.99	.	.	.	417	694	.	278	139	278	.	.	.	1806
2.00 - 2.49	.	.	.	139	139	417	139	.	139	.	139	.	1112
2.50 - 2.99	.	.	.	.	.	139	.	.	.	.	139	.	278
3.00 - 3.49	.	.	.	.	.	.	.	139	139	.	.	.	278
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	139	556	417	973	1250	1390	1806	1111	1806	139	417	0	

February 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	93	93	93	185	.	.	.	.	.	464
0.50 - 0.99	93	.	.	463	648	463	833	648	926	.	.	.	4074
1.00 - 1.49	.	.	.	833	1204	93	.	278	278	.	278	.	2964
1.50 - 1.99	.	.	93	370	463	93	.	93	370	.	.	.	1482
2.00 - 2.49	.	.	.	93	93	.	.	185	93	.	.	.	464
2.50 - 2.99	.	.	.	.	93	.	.	.	93	.	.	.	186
3.00 - 3.49	.	.	.	.	.	93	.	93	.	.	.	.	186
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	93	.	.	.	.	93
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	93	.	.	.	.	.	93
Total	93	0	93	1852	2594	835	1111	1390	1760	0	278	0	

March 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	342	.	.	.	.	.	.	342
0.50 - 0.99	.	85	.	171	427	427	684	256	342	.	.	.	2392
1.00 - 1.49	.	85	171	342	342	85	171	427	940	.	85	.	2648
1.50 - 1.99	.	.	.	256	171	256	85	256	598	.	171	.	1793
2.00 - 2.49	.	.	.	.	85	.	256	85	855	.	427	.	1708
2.50 - 2.99	.	.	.	.	.	.	.	.	427	.	85	.	512
3.00 - 3.49	.	.	.	.	.	.	.	.	85	.	85	.	170
3.50 - 3.99	.	.	.	.	.	.	.	.	85	.	.	.	85
4.00 - 4.49	.	.	.	.	.	.	.	85	85	.	85	.	255
4.50 - 4.99	.	.	.	.	.	.	.	.	85	.	.	.	85
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	170	171	769	1025	1110	1196	1109	3502	0	938	0	

(Continued)

(Sheet 1 of 4)

Table B2 (Continued)

April 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	.	.	.	.	.	85	169	85	424	169	85	.	1017
0.50 - 0.99	.	254	85	169	254	254	254	339	847	.	678	.	3134
1.00 - 1.49	.	.	85	85	.	254	932	.	169	.	254	.	1779
1.50 - 1.99	.	.	.	424	169	.	508	339	508	169	254	.	2371
2.00 - 2.49	.	.	.	169	85	85	85	85	.	.	85	.	594
2.50 - 2.99	.	.	.	.	.	85	85	85	254	.	.	.	509
3.00 - 3.49	.	.	.	.	.	85	85	.	254	.	.	.	424
3.50 - 3.99	.	.	.	.	.	85	85	.	.	.	.	.	170
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	254	170	847	508	933	2203	933	2456	338	1356	0	

May 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	.	97	.	.	.	194	777	.	97	.	97	.	1262
0.50 - 0.99	.	.	.	388	97	777	1845	583	971	97	485	.	5243
1.00 - 1.49	.	.	97	388	194	291	1262	97	.	.	.	.	2329
1.50 - 1.99	.	.	.	97	.	.	.	583	.	.	.	.	680
2.00 - 2.49	.	.	.	.	.	.	.	194	97	.	.	.	291
2.50 - 2.99	.	.	.	.	97	97	.	.	.	.	.	.	194
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	97	97	873	388	1359	3884	1457	1165	97	582	0	

June 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	.	.	.	.	175	88	789	351	263	175	.	.	1841
0.50 - 0.99	263	789	175	1053	965	965	2632	263	263	.	.	.	7368
1.00 - 1.49	.	.	175	175	88	175	88	.	.	.	.	.	701
1.50 - 1.99	.	.	.	88	.	.	.	.	.	.	.	.	88
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	263	789	350	1316	1228	1228	3509	614	526	175	0	0	

(Continued)

July 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	83	165	83	331	2314	248	83	.	83	.	3390
0.50 - 0.99	83	83	744	1322	413	992	1983	248	413	.	83	.	6364
1.00 - 1.49	.	.	165	83	.	.	.	.	.	.	.	.	248
1.50 - 1.99	.	.	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	83	83	992	1570	496	1323	4297	496	496	0	166	0	

August 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	81	.	.	.	.	81	242	484	484	81	.	.	1453
0.50 - 0.99	81	242	161	645	968	161	1452	1210	968	.	161	.	6049
1.00 - 1.49	.	.	323	726	161	.	.	161	161	.	.	.	1532
1.50 - 1.99	.	.	.	81	81	242	81	161	81	.	.	.	727
2.00 - 2.49	.	.	.	.	.	.	.	.	242	.	.	.	242
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	162	242	484	1452	1210	484	1775	2016	1936	81	161	0	

September 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	84	84	252	252	.	.	168	.	840
0.50 - 0.99	.	84	420	588	840	840	1513	1513	840	.	84	.	6722
1.00 - 1.49	.	.	.	.	252	168	672	168	168	.	.	.	1428
1.50 - 1.99	.	.	.	84	168	168	168	.	84	.	.	.	672
2.00 - 2.49	.	.	.	.	84	168	84	.	.	.	.	.	336
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	84	420	672	1428	1428	2689	1933	1092	0	252	0	

(Continued)

Table B2 (Concluded)

October 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	.	92	92	.	.	.	.	184
0.50 - 0.99	.	.	92	459	275	642	2294	1284	367	92	.	.	5505
1.00 - 1.49	.	.	183	275	92	183	183	550	459	.	.	.	1925
1.50 - 1.99	.	.	275	367	459	92	.	.	183	.	.	.	1376
2.00 - 2.49	.	.	.	.	92	.	.	275	.	.	.	.	367
2.50 - 2.99	.	.	.	.	.	183	183	.	92	.	.	.	458
3.00 - 3.49	.	.	.	.	.	183	.	.	.	.	.	.	183
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	0	550	1101	918	1283	2752	2201	1101	92	0	0	

November 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	168	168	.	168	168	840	336	.	.	252	.	2100
0.50 - 0.99	.	84	252	336	756	588	588	336	168	84	.	.	3192
1.00 - 1.49	.	.	84	336	588	252	336	.	168	84	.	.	1848
1.50 - 1.99	.	.	84	252	504	168	252	168	168	.	.	.	1596
2.00 - 2.49	.	.	.	.	168	504	336	168	.	.	.	.	1176
2.50 - 2.99	.	.	.	.	.	.	.	.	84	.	.	.	84
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	252	588	924	2184	1680	2352	1008	588	168	252	0	

December 1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	.	242	81	.	161	81	.	565
0.50 - 0.99	81	81	645	1129	161	242	806	484	1290	242	726	.	5887
1.00 - 1.49	.	.	242	806	242	81	161	161	403	.	.	.	2096
1.50 - 1.99	.	.	.	161	484	161	.	.	81	.	81	.	968
2.00 - 2.49	.	.	.	.	81	.	.	.	81	.	81	.	243
2.50 - 2.99	.	.	.	.	.	.	.	.	81	.	.	.	81
3.00 - 3.49	.	.	.	.	.	.	81	81	.	.	.	.	162
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	81	81	887	2096	968	484	1290	807	1936	403	969	0	

(Sheet 4 of 4)

Table B3

Annual Joint Distribution of H_{mo} versus T_p (All Years)

Annual 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec)												Total
	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	
0.00 - 0.49	20	17	29	56	104	118	331	278	214	80	138	4	1389
0.50 - 0.99	35	126	247	477	575	502	834	691	832	156	217	17	4709
1.00 - 1.49	.	11	128	386	450	270	251	201	372	40	134	5	2248
1.50 - 1.99	.	.	12	141	263	114	75	70	137	37	83	5	937
2.00 - 2.49	.	.	2	26	78	78	49	45	77	33	46	2	436
2.50 - 2.99	.	.	.	.	7	35	19	16	43	12	25	.	157
3.00 - 3.49	.	.	.	.	1	7	16	15	19	5	10	.	73
3.50 - 3.99	.	.	.	.	.	1	4	8	11	5	4	.	33
4.00 - 4.49	.	.	.	.	.	.	1	2	8	1	2	.	14
4.50 - 4.99	.	.	.	.	.	.	.	.	3	.	.	.	3
5.00 - Greater	.	.	.	.	.	.	1	.	.	2	1	.	4
Total	55	154	418	1086	1478	1125	1581	1326	1716	371	660	33	

Table B4

Monthly Joint Distribution of H_{mo} versus T_p (All Years)

January 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	121	12	.	109	97	36	182	97	230	36	85	.	1005
0.50 - 0.99	73	242	254	363	387	375	327	533	872	97	254	.	3777
1.00 - 1.49	.	24	157	508	557	242	145	121	557	.	73	12	2396
1.50 - 1.99	.	.	24	278	508	242	97	97	254	12	48	.	1560
2.00 - 2.49	.	.	.	36	194	230	109	24	145	48	36	12	834
2.50 - 2.99	.	.	.	.	12	97	61	24	48	24	61	.	327
3.00 - 3.49	.	.	.	.	.	.	24	12	36	.	.	.	72
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	12	.	.	.	12
4.50 - 4.99	.	.	.	.	.	.	.	.	12	.	.	.	12
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	194	278	435	1294	1755	1222	945	908	2166	217	557	24	

February 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	13	38	25	101	.	38	25	127	.	367
0.50 - 0.99	25	63	89	380	494	266	520	621	1166	25	165	13	3827
1.00 - 1.49	.	13	89	634	710	228	317	368	596	101	253	.	3309
1.50 - 1.99	.	.	13	190	342	203	89	101	215	76	127	.	1356
2.00 - 2.49	.	.	.	89	114	25	38	89	114	63	114	.	646
2.50 - 2.99	.	.	.	.	13	38	.	.	139	25	76	.	291
3.00 - 3.49	.	.	.	.	.	13	.	25	38	13	25	.	114
3.50 - 3.99	.	.	.	.	.	.	.	13	13	.	.	.	26
4.00 - 4.49	.	.	.	.	.	.	.	13	38	.	.	.	51
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	13	.	.	.	.	.	13
Total	25	76	191	1306	1711	798	1078	1230	2357	328	887	13	

March 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	11	.	.	11	57	57	80	46	137	68	68	.	535
0.50 - 0.99	11	91	205	365	433	422	513	639	787	171	205	.	3842
1.00 - 1.49	.	11	194	376	525	331	274	319	764	68	376	.	3238
1.50 - 1.99	.	.	.	228	239	103	91	114	285	103	160	.	1323
2.00 - 2.49	.	.	.	11	57	34	80	57	182	46	125	.	592
2.50 - 2.99	.	.	.	.	23	11	11	11	68	23	57	.	204
3.00 - 3.49	.	.	.	.	11	.	11	23	57	11	11	.	124
3.50 - 3.99	.	.	.	.	.	.	.	23	23	.	11	.	57
4.00 - 4.49	.	.	.	.	.	.	11	11	11	.	23	.	56
4.50 - 4.99	.	.	.	.	.	.	.	.	23	.	.	.	23
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	22	102	399	991	1345	958	1071	1243	2337	490	1036	0	

(Continued)

(Sheet 1 of 4)

April 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	12	23	23	35	23	349	233	210	105	116	.	1129
0.50 - 0.99	93	175	221	396	477	501	757	617	1141	279	373	.	5030
1.00 - 1.49	.	12	116	233	384	326	361	256	396	70	175	.	2329
1.50 - 1.99	.	.	.	140	140	93	105	105	198	35	128	.	944
2.00 - 2.49	.	.	.	47	35	12	35	70	35	35	12	.	281
2.50 - 2.99	.	.	.	.	.	23	35	12	47	35	12	.	164
3.00 - 3.49	.	.	.	.	.	12	23	23	35	.	.	.	93
3.50 - 3.99	.	.	.	.	.	12	23	.	.	.	.	.	35
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	93	199	360	839	1071	1002	1688	1316	2062	559	816	0	

May 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	11	23	34	92	149	183	447	252	172	23	69	.	1455
0.50 - 0.99	23	172	367	665	585	722	1250	1078	711	34	172	.	5779
1.00 - 1.49	.	.	103	229	344	195	413	195	310	11	103	.	1903
1.50 - 1.99	.	.	11	57	80	23	103	69	69	34	80	.	526
2.00 - 2.49	.	.	.	23	11	57	.	46	11	34	34	.	216
2.50 - 2.99	.	.	.	.	11	11	11	11	11	23	11	.	89
3.00 - 3.49	.	.	.	.	.	.	.	.	.	11	11	.	22
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	34	195	515	1066	1180	1191	2224	1651	1284	170	480	0	

June 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	24	36	61	97	242	339	605	557	230	48	12	.	2251
0.50 - 0.99	61	242	363	738	738	702	1610	884	605	194	36	.	6173
1.00 - 1.49	.	.	73	230	206	206	218	121	109	.	61	.	1224
1.50 - 1.99	.	.	12	48	73	73	24	12	61	.	.	.	303
2.00 - 2.49	.	.	.	.	12	12	12	12	.	.	.	.	48
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	85	278	509	1113	1271	1332	2469	1586	1005	242	109	0	

(Continued)

July 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	12	24	60	109	278	302	1137	798	339	145	290	24	3518
0.50 - 0.99	36	121	351	617	762	689	1330	907	447	254	73	73	5660
1.00 - 1.49	.	24	60	181	181	97	60	48	.	.	.	.	651
1.50 - 1.99	.	.	.	60	12	24	36	.	.	.	.	.	132
2.00 - 2.49	.	.	.	12	.	.	12	.	.	.	.	.	24
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	48	169	471	979	1233	1112	2575	1753	786	399	363	97	

August 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	24	36	72	108	193	241	494	554	422	84	120	.	2348
0.50 - 0.99	36	108	241	578	795	699	1313	795	614	169	301	.	5649
1.00 - 1.49	.	12	157	301	241	265	157	108	72	12	.	.	1325
1.50 - 1.99	.	.	.	60	157	84	36	24	24	.	36	.	421
2.00 - 2.49	.	.	.	24	24	12	24	.	48	.	12	.	144
2.50 - 2.99	.	.	.	.	12	.	24	.	12	.	12	.	60
3.00 - 3.49	.	.	.	.	.	12	12	.	12	.	.	.	36
3.50 - 3.99	.	.	.	.	.	.	.	12	.	.	.	.	12
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	60	156	470	1071	1422	1313	2060	1493	1204	265	481	0	

September 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	12	12	35	24	24	94	330	294	141	118	12	1096
0.50 - 0.99	.	59	177	318	601	459	824	766	1143	165	236	.	4748
1.00 - 1.49	.	12	82	412	589	353	471	247	389	59	153	12	2779
1.50 - 1.99	.	.	12	71	283	130	71	130	59	12	82	.	850
2.00 - 2.49	.	.	.	35	82	47	24	35	82	35	24	.	364
2.50 - 2.99	.	.	.	.	.	35	24	12	.	.	.	.	71
3.00 - 3.49	.	.	.	.	.	.	.	12	12	12	12	.	48
3.50 - 3.99	.	.	.	.	.	.	.	.	12	12	12	.	36
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	12	.	.	12
Total	0	83	283	871	1579	1048	1508	1532	1991	448	637	24	

(Continued)

(Sheet 3 of 4)

Table B4 (Concluded)

October 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	21	.	.	.	54	64	193	150	226	43	129	.	880
0.50 - 0.99	.	43	150	333	430	419	677	462	902	161	322	11	3910
1.00 - 1.49	.	.	150	591	365	236	140	236	473	97	161	.	2449
1.50 - 1.99	.	.	32	193	451	86	54	64	183	97	236	43	1439
2.00 - 2.49	.	.	.	11	118	204	54	86	161	54	97	11	796
2.50 - 2.99	.	.	.	.	11	140	43	64	54	11	43	.	366
3.00 - 3.49	.	.	.	.	.	43	11	.	11	.	32	.	97
3.50 - 3.99	.	.	.	.	.	.	.	21	.	21	.	.	42
4.00 - 4.49	.	.	.	.	.	.	.	.	21	.	.	.	21
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	21	43	332	1128	1429	1192	1172	1083	2031	484	1020	65	

November 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	13	39	39	26	65	91	169	169	104	65	183	.	963
0.50 - 0.99	26	52	352	508	587	508	456	495	639	169	156	65	4013
1.00 - 1.49	.	26	196	469	743	443	235	248	352	26	91	39	2868
1.50 - 1.99	.	.	26	222	365	209	130	65	143	65	13	13	1251
2.00 - 2.49	.	.	.	26	78	143	169	52	26	26	13	.	533
2.50 - 2.99	.	.	.	.	.	26	13	26	65	.	13	.	143
3.00 - 3.49	.	.	.	.	.	.	26	65	.	13	13	.	117
3.50 - 3.99	.	.	.	.	.	.	.	.	52	26	13	.	91
4.00 - 4.49	.	.	.	.	.	.	.	.	.	13	.	.	13
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	39	117	613	1251	1838	1420	1198	1120	1381	403	495	117	

December 1980-1987, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period(sec)												
0.00 - 0.49	.	13	52	52	13	26	117	156	143	182	364	13	1131
0.50 - 0.99	39	143	208	481	637	234	377	481	949	143	286	52	4030
1.00 - 1.49	.	.	156	481	611	338	221	130	429	26	143	.	2535
1.50 - 1.99	.	.	13	143	533	117	65	52	143	.	52	.	1118
2.00 - 2.49	.	.	26	.	221	156	39	65	104	52	78	.	741
2.50 - 2.99	.	.	.	.	.	26	.	26	78	.	13	.	143
3.00 - 3.49	.	.	.	.	.	.	91	26	26	.	13	.	156
3.50 - 3.99	.	.	.	.	.	.	26	26	39	.	13	.	104
4.00 - 4.49	.	.	.	.	.	.	.	.	13	.	.	.	13
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	13	13	.	26
Total	39	156	455	1157	2015	897	936	962	1924	416	975	65	

(Sheet 4 of 4)

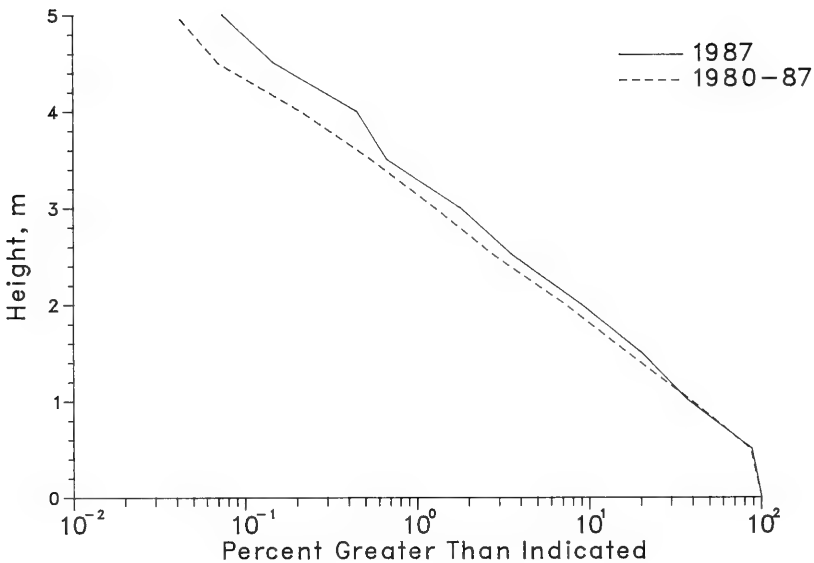


Figure B2. Annual cumulative wave height distributions for Gage 630

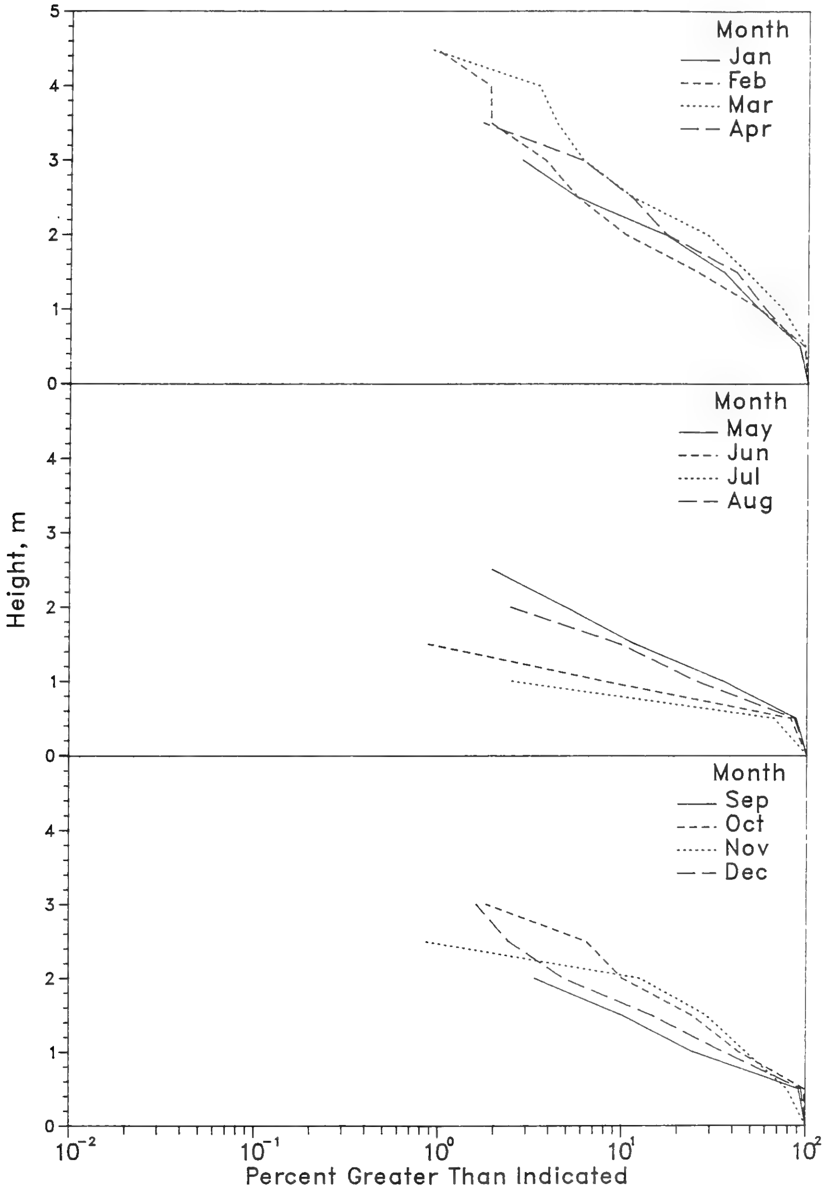


Figure B3. 1987 monthly wave height distributions for Gage 630

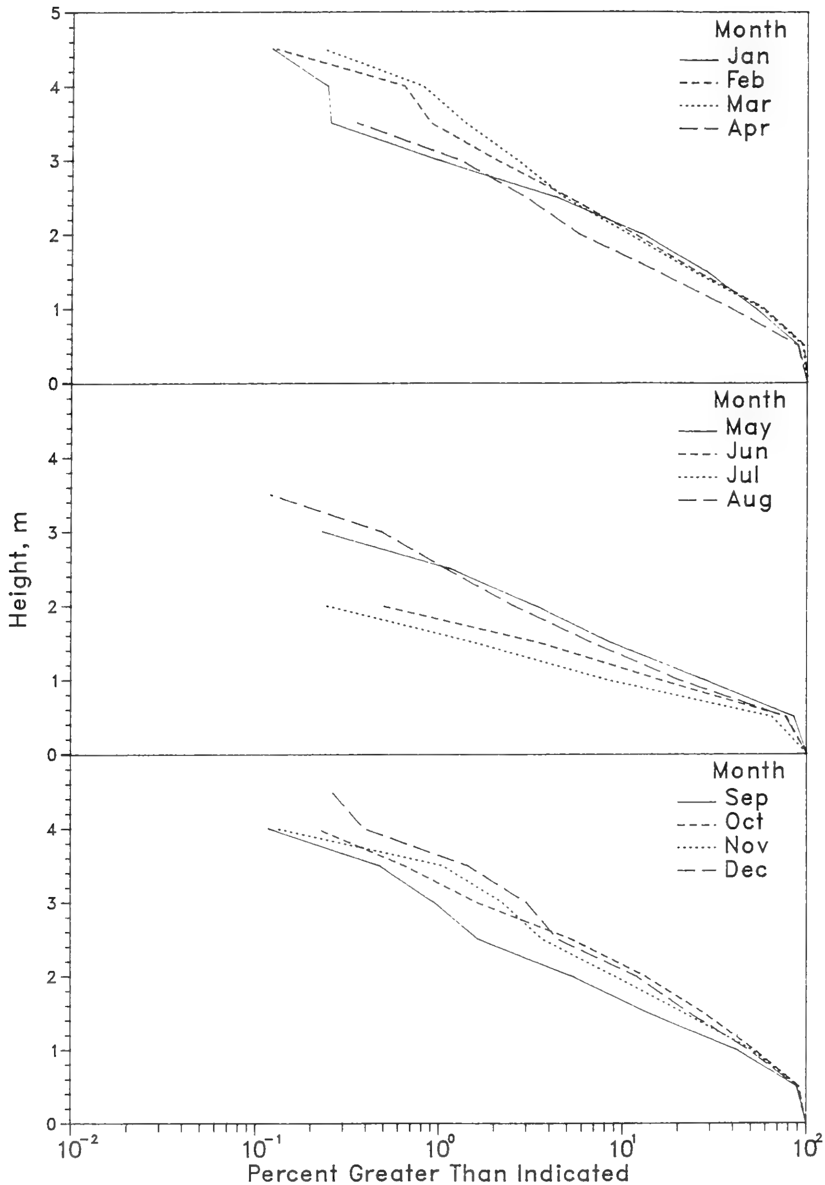


Figure B4. 1980-1987 monthly wave height distributions for Gage 630

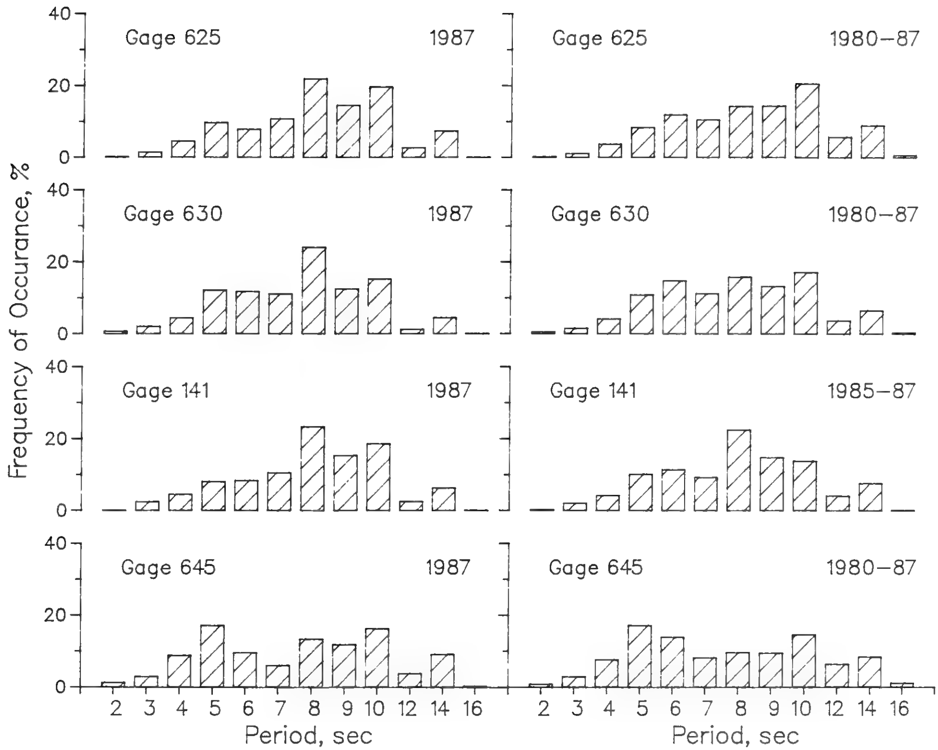


Figure B5. Annual wave period distributions for all gages

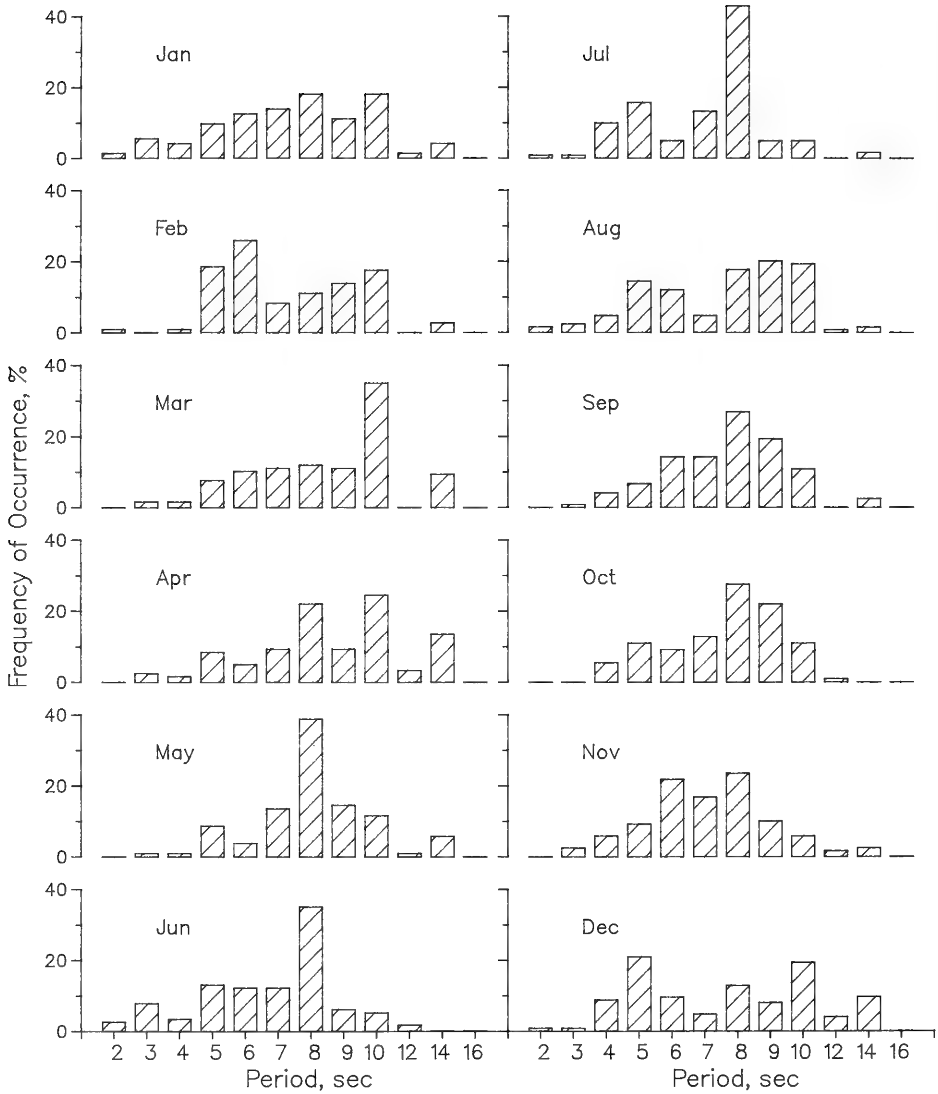


Figure B6. 1987 monthly wave period distributions for Gage 630

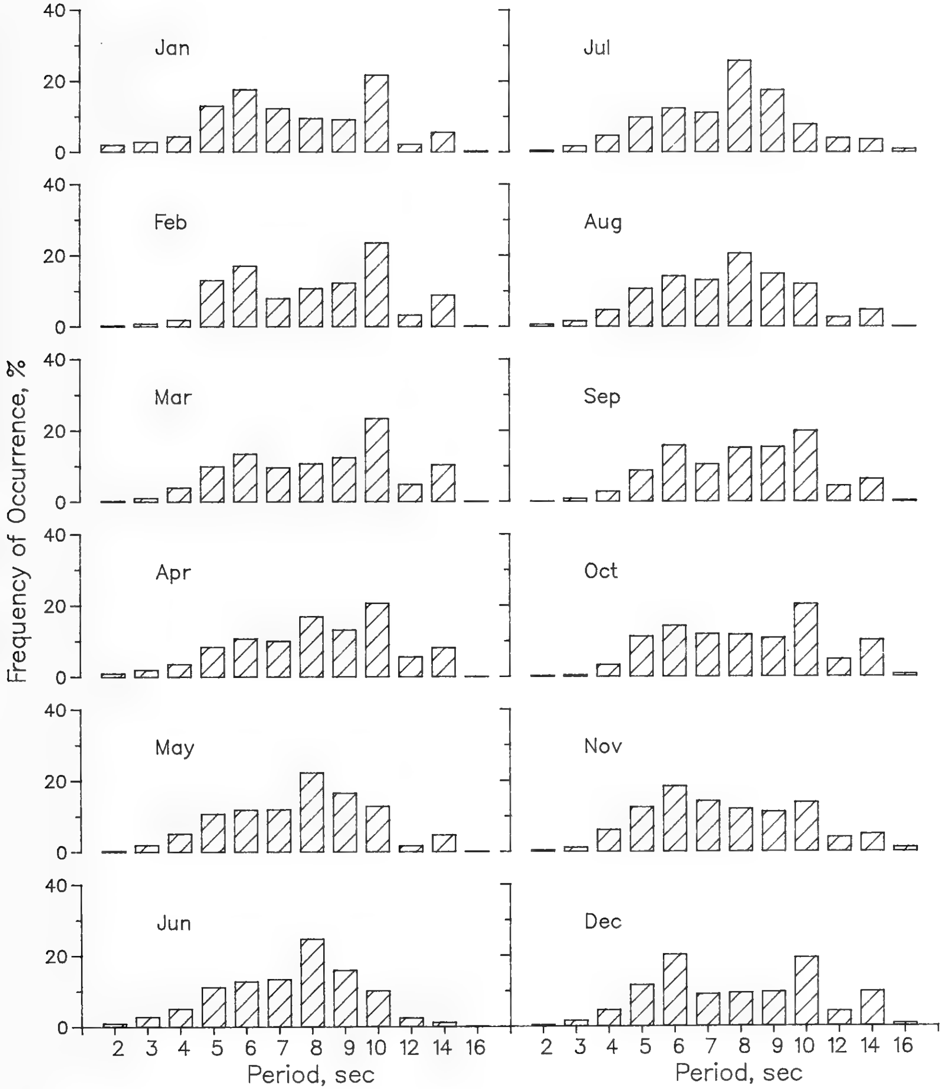


Figure B7. 1980-1987 monthly wave period distributions for Gage 630

Table B5

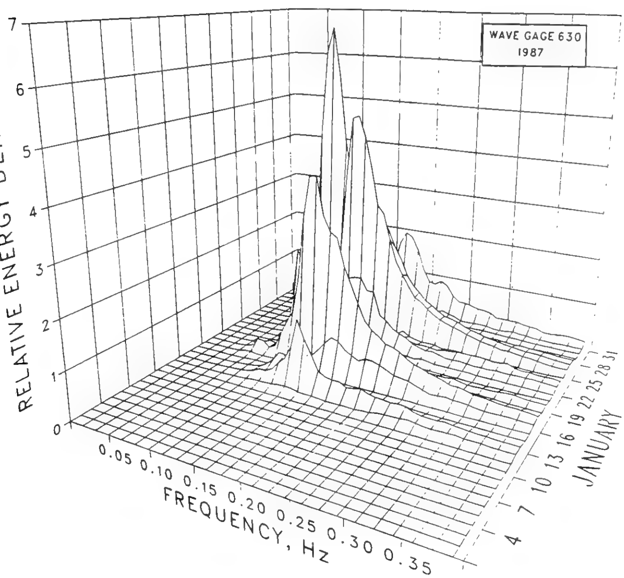
1987 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5		15			14		13		11	10		9			8				
1.0	53	41	24	17	12	10	5		3	2						1			
1.5	45	28	14	8	6	2		1											
2.0	25	15	5	4	2		1												
2.5	14	8	3	1															
3.0	9	4	1																
3.5	4	1																	
4.0	2	1																	

Table B6

1980 through 1987 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	22	19	17	15	14	13	12	11	10			9	8	7	6	5			3
1.0	50	35	25	18	14	10	7	5	4	3	2						1		
1.5	38	22	11	6	4	2		1											
2.0	22	12	5	2	1														
2.5	11	5	2																
3.0	6	2																	
3.5	3	1																	
4.0	2																		



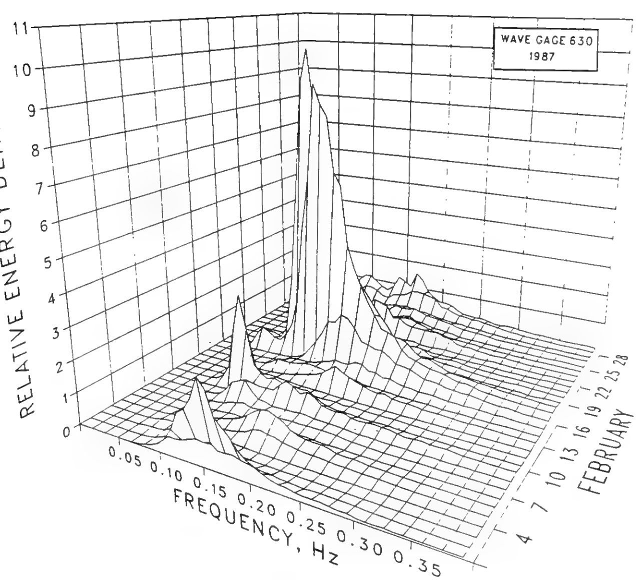
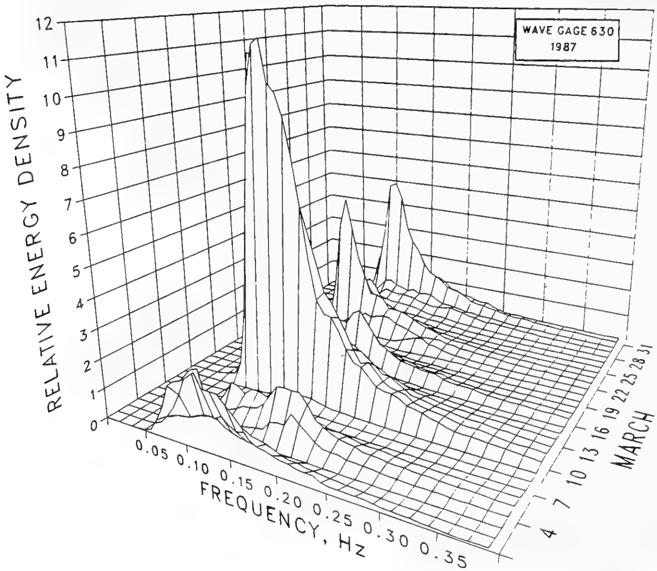


Figure B8. 1987 monthly spectra for Gage 630
(Sheet 1 of 6)



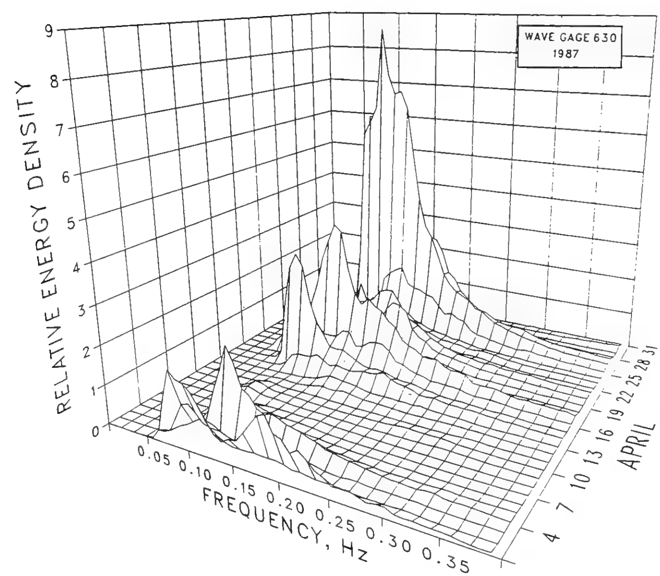
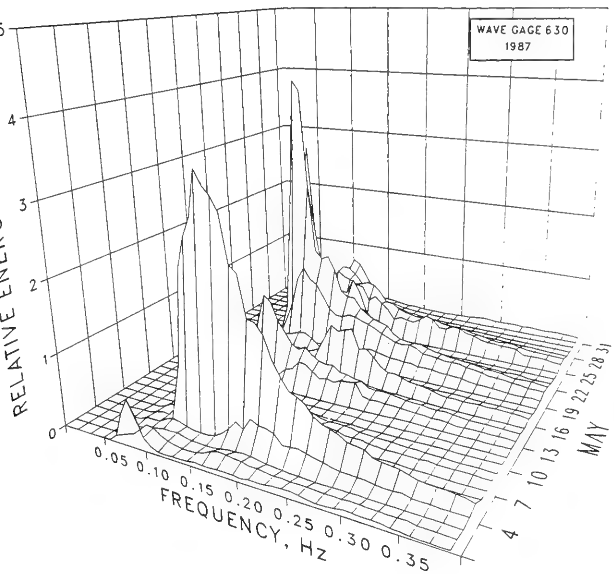


Figure B8. (Sheet 2 of 6)



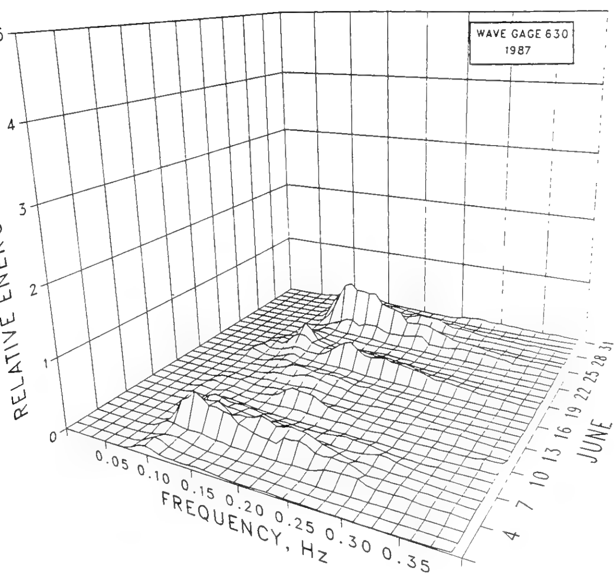
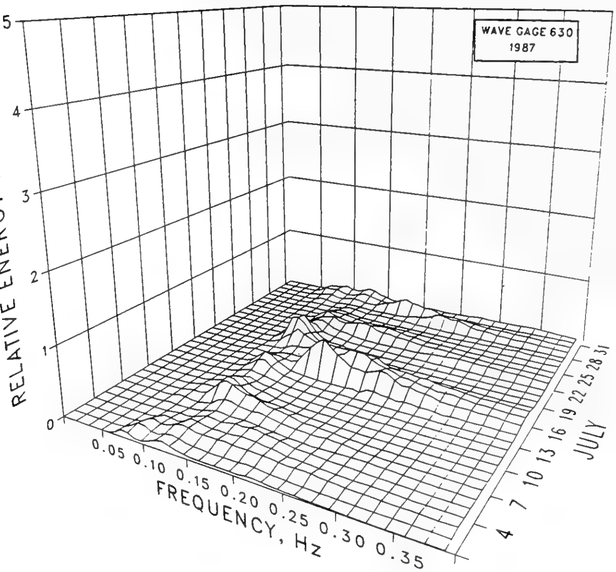


Figure B8. (Sheet 3 of 6)



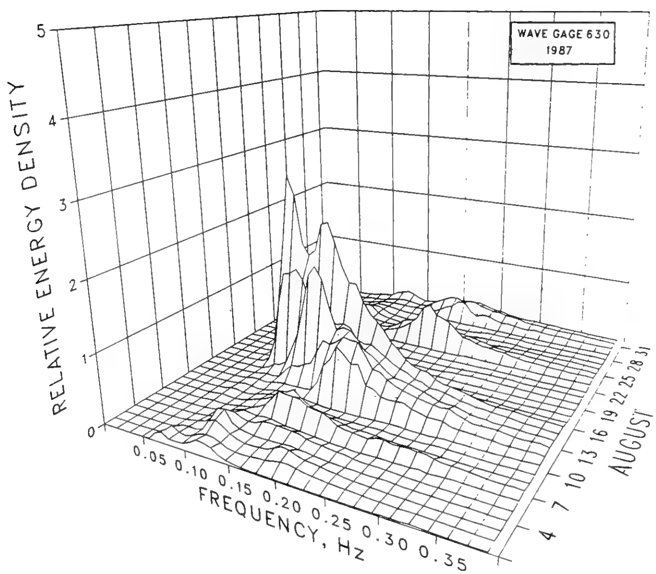
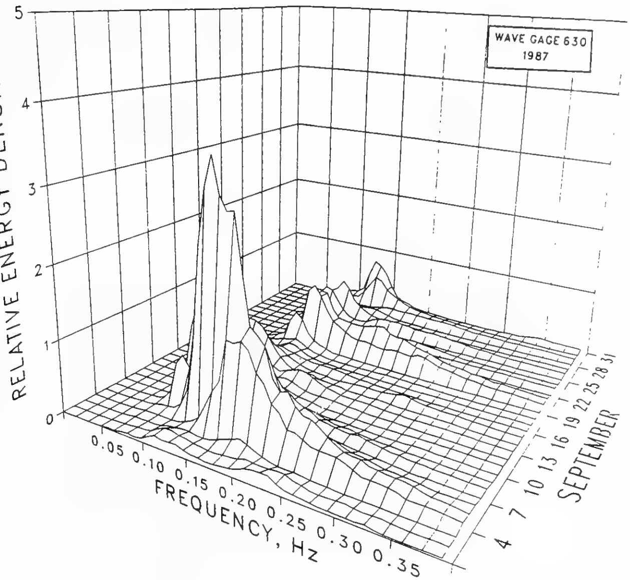


Figure B8. (Sheet 4 of 6)



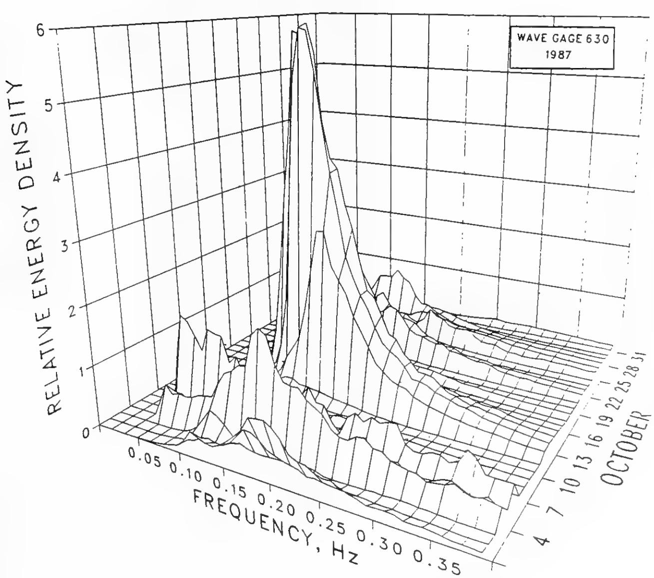
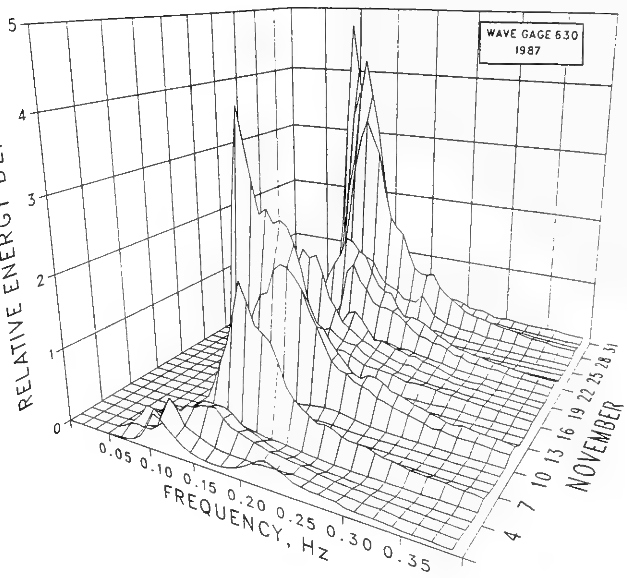


Figure B8. (Sheet 5 of 6)



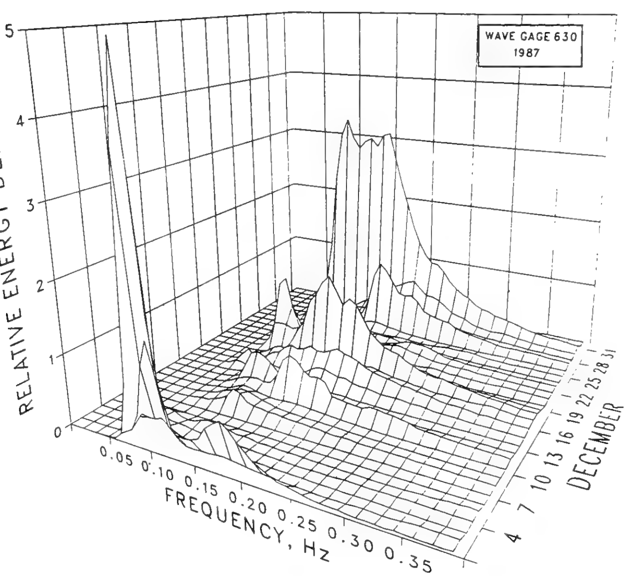


Figure B8. (Sheet 6 of 6)

Table B7

Wave Statistics for Gage 630

	1987							1980-1987						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	1.3	0.7	3.5	26	8.1	2.5	72	1.2	0.7	4.5	1983	7.9	2.7	826
Feb	1.3	0.8	5.1	17	7.9	2.1	108	1.3	0.7	5.1	1987	8.6	2.6	789
Mar	1.6	0.9	4.7	10	9.1	2.3	117	1.2	0.7	4.7	1983	8.8	2.7	877
Apr	1.4	0.8	3.8	26	9.3	2.5	118	1.0	0.6	3.8	1985	8.7	2.7	859
May	1.0	0.5	2.5	5	8.7	2.0	103	0.9	0.5	3.3	1986	8.0	2.3	872
Jun	0.7	0.3	1.6	24	7.3	2.2	114	0.7	0.4	2.1	1981	7.7	2.2	826
Jul	0.6	0.2	1.3	15	7.6	1.9	121	0.6	0.3	2.1	1985	8.1	2.5	827
Aug	0.9	0.5	2.3	15	8.1	2.4	124	0.8	0.5	3.6	1981	8.0	2.5	830
Sep	0.9	0.5	2.3	5	8.1	1.9	119	1.0	0.6	6.1	1985	8.6	2.6	849
Oct	1.2	0.7	3.0	13	8.1	1.8	109	1.2	0.7	4.3	1982	8.7	2.7	931
Nov	1.2	0.7	2.7	12	7.7	2.1	119	1.2	0.7	4.1	1981	8.1	2.8	767
Dec	1.0	0.6	3.2	29	8.5	3.1	124	1.2	0.8	5.6	1980	8.4	2.9	769
Annual	1.1	0.7	5.1	Feb	8.2	2.3	1348	1.0	0.6	6.1	Sep 1985	8.3	2.6	10022

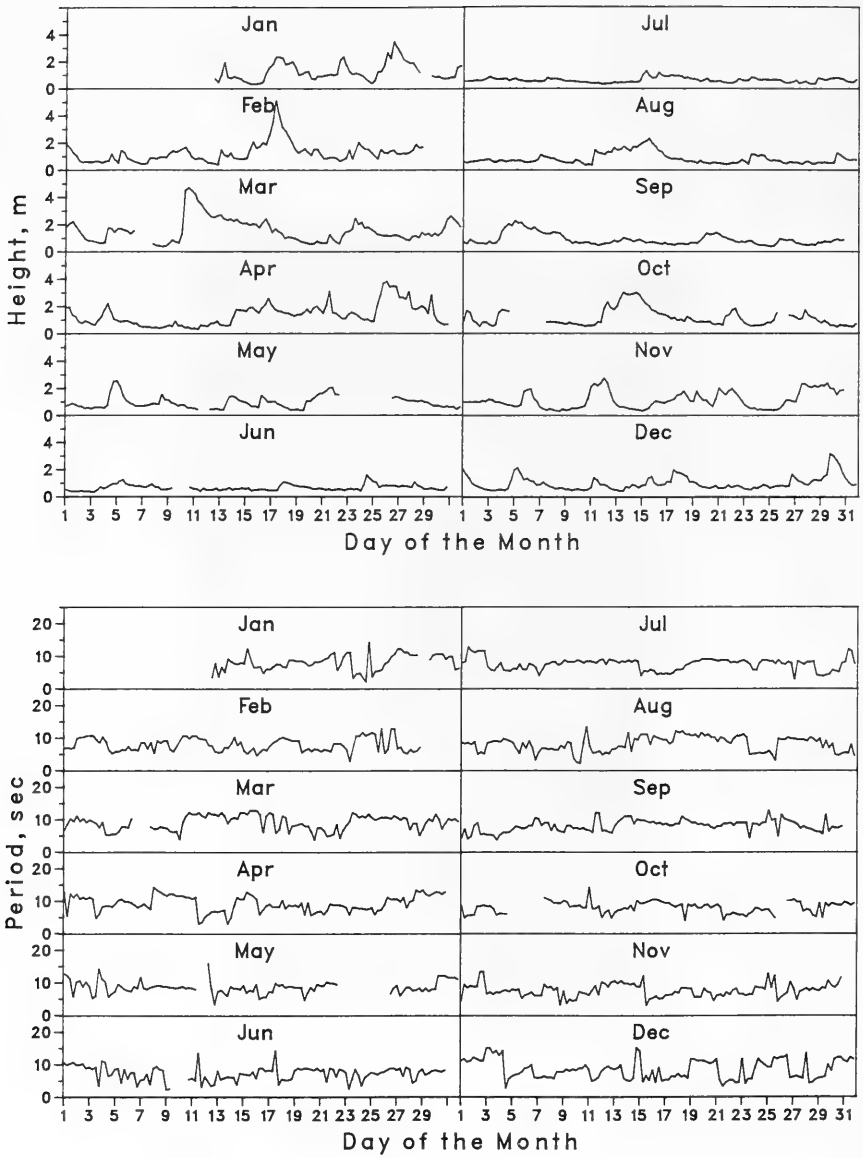


Figure B9. Time-histories of wave height and period for Gage 630

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