US Army Corps of Engineers
Waterways Experiment Station

Technical Report CERC-96-6
September 1996

Annual Data Summary for 1994 CERC Field Research Facility

Volume I: Main Text and Appendixes A and B

by *Michael W. Leffler, Clifford F. Baron, Brian L. Scarborough, Kent K. Hathaway, Paul R. Hodges, C. Ray Townsend*

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

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Waterways Experiment Station
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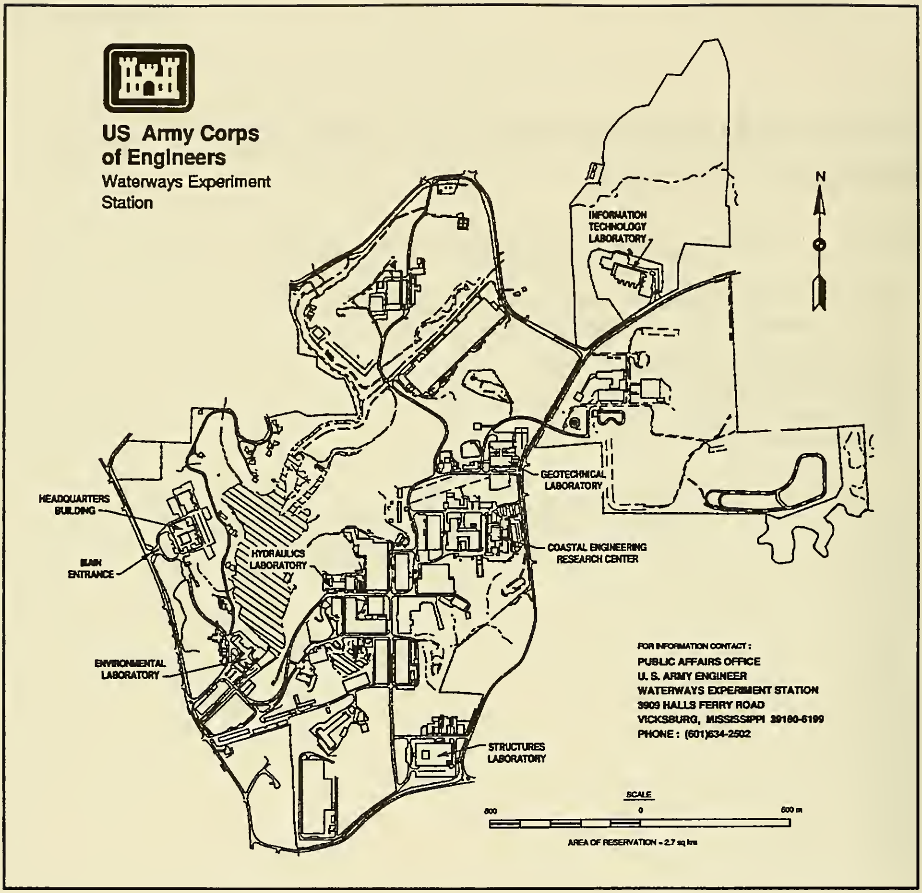

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[1] A limited number of copies of Appendixes C-E (Volume II) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Preface

This report is the 16th in a series of annual data summaries authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32525, "Field Research Facility Analysis," Coastal Flooding Program. Funds were provided through the U.S. Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC), under the program management of Ms. Carolyn M. Holmes, CERC. The HQUSACE Technical Monitors were Messrs. John H. Lockhart, Jr., Barry W. Holliday, and Charles Chesnutt.

Data for the report were collected and analyzed at the WES/CERC Field Research Facility (FRF) in Duck, NC. The report was prepared by Mr. Michael W. Leffler, FRF, under the direct supervision of Mr. William A. Birkemeier, Chief, FRF Group, Engineering Development Division (EDD), and Mr. Thomas W. Richardson, Chief, EDD; and under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, CERC, respectively. Mr. Kent K. Hathaway, FRF, assisted with instrumentation. Mr. Brian L. Scarborough, FRF, and Messrs. William T. Lease, Mason O. Cox, Mark A. Lampe, Douglas A. Dorman, and Paul S. Magness assisted with data collection. Messrs. Clifford F. Baron and Guan-hong Lee, and Ms. Judy H. Roughton assisted with data analysis at the FRF. Additional assistance was provided by Ms. Dawn S. Miller, FRF. The National Oceanic and Atmospheric Administration/National Ocean Service maintained the tide gauge and provided statistics for summarization.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

1 Introduction

Background

The U.S. 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.

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.

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.

This report, which summarizes data for 1994, continues a series of reports begun in 1977.

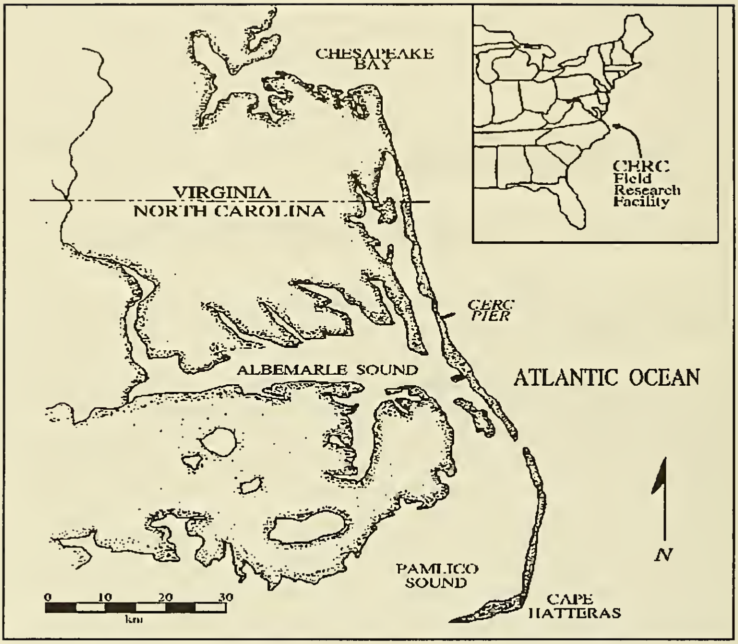

Figure 1. FRF location map

Organization of Report

This report is organized into nine chapters and five appendixes. Chapter 1 is an introduction; Chapters 2 through 8 discuss the various data collected during the year; and Chapter 9 describes the storms that occurred. Appendix A presents the bathymetric surveys, Appendix B summarizes deepwater wave statistics, and Appendixes C through E (published under separate cover as Volume II) contain summary statistics for other gauges.

In each chapter 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 until June when it was replaced with a Digital Equipment Corporation VAXstation 4000 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

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 gauges are provided in Appendixes B through E.

Table 1
1994 Data Availability

	Gauge ID	Jan 1 2 3 4 5	Feb 1 2 3 4	Mar 1 2 3 4	Apr 1 2 3 4 5	May 1 2 3 4	Jun 1 2 3 4	Jul 1 2 3 4 5	Aug 1 2 3 4	Sep 1 2 3 4	Oct 1 2 3 4 5	Nov 1 2 3 4	Dec 1 2 3 4
Weather													
Anemometer	932	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Atmospheric Pres.	616	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Air Temperature	624	* * * / *	/ * * /	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * /	* * * * *	* * * *	* * * *
Precipitation	604	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Waves													
Offshore Waverider	630	* * * * *	/ * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * / /	* * * *
Pressure Gauge	111	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Pier End	625	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * / *	* * * *
Pier Nearshore	641	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	/ * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Currents													
Pier End		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Pier Nearshore		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Beach		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * / * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Pier End Tide Gauge		* * * * /	/ * * *	* * * *	* * * * *	* * * *	* * * /	/ * / * *	* * * *	* * * *	* * * * *	* * / *	* * * *
Water Characteristics													
Temperature		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Visibility		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Density		* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Bathymetric Surveys		week 4: *			week 1: *			week 5: *		week 3: *		weeks 2, 3: * *	
Photography													
Beach		* * * * *	* * * *	* * * *	* * * * *	/ - / *	* * * *	* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *
Aerial		week 3: *											

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

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 (FRF 1994). 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
1261 Duck Rd.
Kitty Hawk, NC 27949-4472

Although the data collected at the FRF are designed primarily to support ongoing CERC research, use of the data by others is encouraged. 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 CERC or the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) determine whether other relevant data are available. For information regarding the availability of data for all years, contact the FRF at (919) 261-3511. Costs for collecting, copying, and mailing will be borne by the requester.

2 Meteorology

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

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 hr 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. Meteorological data are summarized in Table 2.

Table 2
Meteorological Statistics

	Mean Air Temperature deg C		Mean Atmospheric Pres. mb		Precipitation, mm				Wind Resultants			
					1994	1978-1994			1994		1980-1994	
Month	1994	1983-1994	1994	1983-1994	Total	Mean	Maxima	Minima	Speed m/sec	Direction deg	Speed m/sec	Direction deg
Jan	3.4	6.2	1021.3	1017.9	182	112	210	44	2.8	322	2.3	332
Feb	5.3	6.7	1021.7	1017.4	85	71	113	20	1.5	326	1.9	344
Mar	10.2	9.5	1013.8	1015.9	231	110	231	35	0.9	249	1.2	350
Apr	16.9	13.9	1018.7	1014.4	98	93	182	0	1.7	198	0.2	308
May	17.7	18.6	1014.6	1015.7	159	76	239	20	1.7	0	0.2	153
Jun	24.7	23.7	1014.8	1015.1	90	88	136	27	2.7	183	1.1	189
Jul	27.0	26.5	1017.1	1015.9	75	97	275	19	4.0	203	2.1	208
Aug	24.2	25.5	1017.6	1016.3	191	110	253	30	0.5	208	0.5	106
Sep	21.9	22.8	1016.1	1017.6	136	81	226	5	1.1	8	1.8	39
Oct	17.3	17.9	1016.1	1018.6	102	75	143	17	4.2	23	2.4	26
Nov	14.8	13.6	1017.9	1018.4	129	90	145	26	2.1	346	1.7	347
Dec	10.7	8.2	1019.8	1019.2	109	68	131	4	4.9	359	2.4	331
Average	16.2	16.1	1017.5	1016.8	132	89			0.8	331	0.8	351
Total					1587	1071						

Air Temperature

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

Measurement instruments

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,

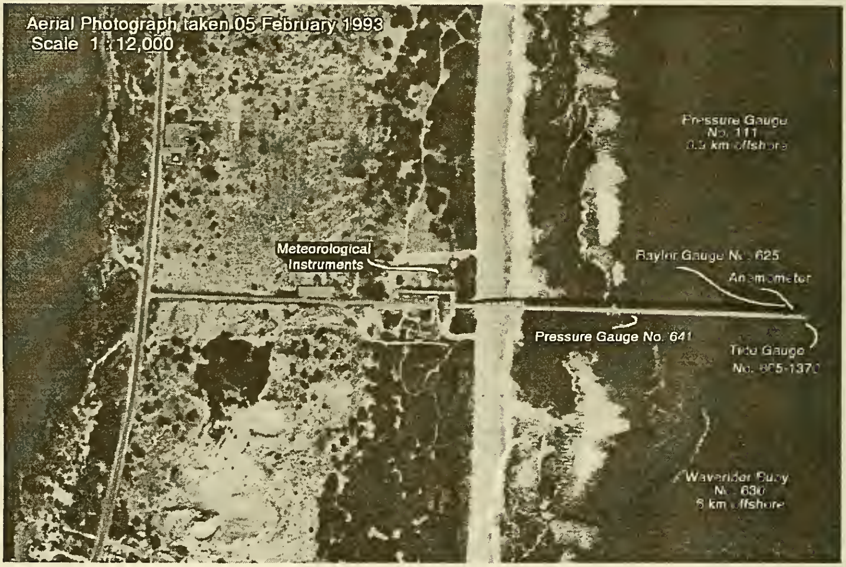

Figure 2. FRF gauge locations

the probe was installed 3 m above ground inside a "coolie hat" to shade it from direct sun, yet provide proper ventilation.

Results

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

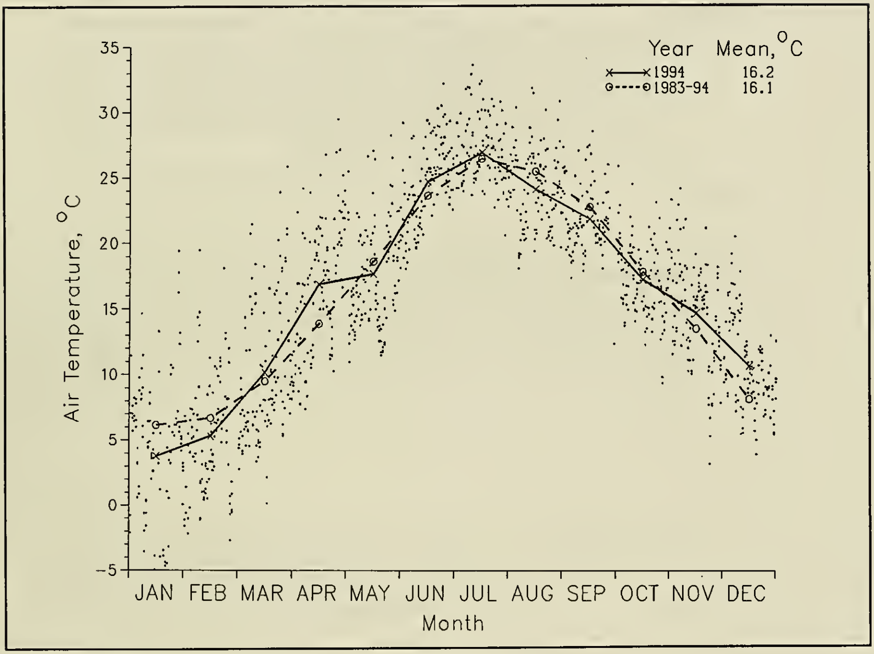

Figure 3. Daily air temperature values with monthly means

Atmospheric Pressure

Measurement instruments

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 gauge were compared with those from an NWS aneroid barometer to ensure proper operation.

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

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.

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. The 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.

Results

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

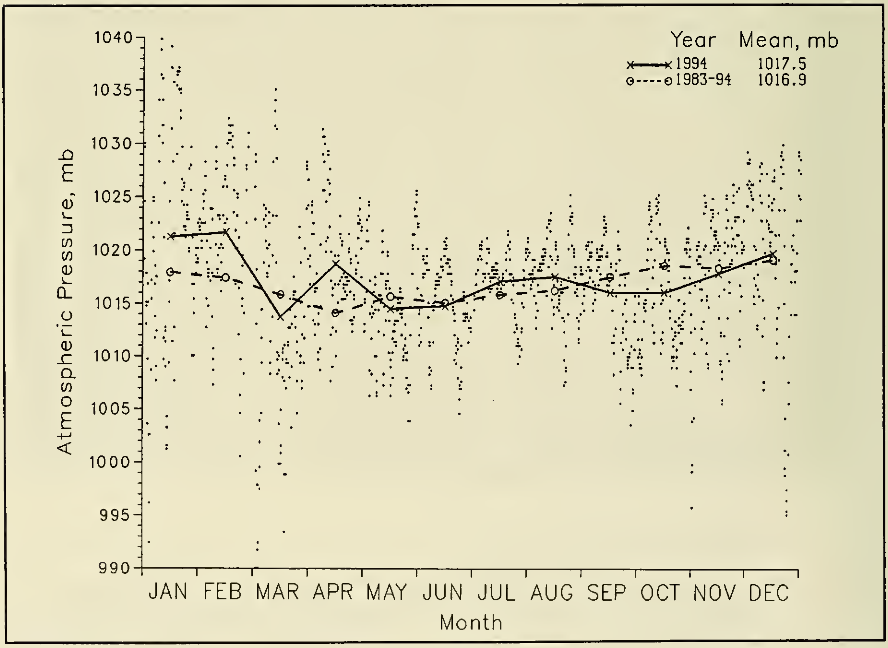

Figure 4. Daily barometric pressure values with monthly means

Precipitation

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

Measurement instruments

Electronic rain gauge. A Belfort Instrument Company (Baltimore, MD) 30-cm weighing rain gauge, located near the instrument shelter 47 m behind the dune, measured daily precipitation. According to the manufacturer, the instrument's accuracy was 0.5 percent for precipitation amounts less than 15 cm and 1.0 percent for amounts greater than 15 cm.

The rain gauge was inspected daily; however, the analog chart recorder was inoperable the entire year.

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

Results

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.

Wind Speed and Direction

Winds at the FRF are dominated by tropical maritime air masses that create low to moderate, warm southern breezes; arctic and polar air masses that 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 dominant wind direction changes with the season, being generally from northern directions in the fall and winter and from southern directions in the spring and

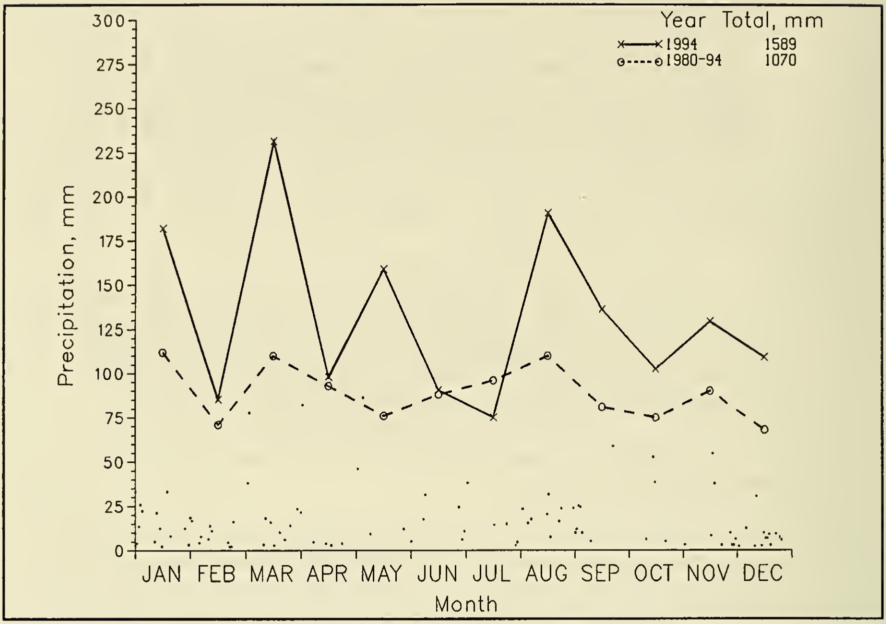

Figure 5. Daily precipitation values with monthly totals

summer. It is common for fall and winter storms (northeasters) to produce winds with average speeds in excess of 15 m/sec.

Measurement instrument

Winds were measured at the seaward end of the pier 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. 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

Annual and monthly joint probability distributions of wind speed versus direction were computed. Wind 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 6-8.

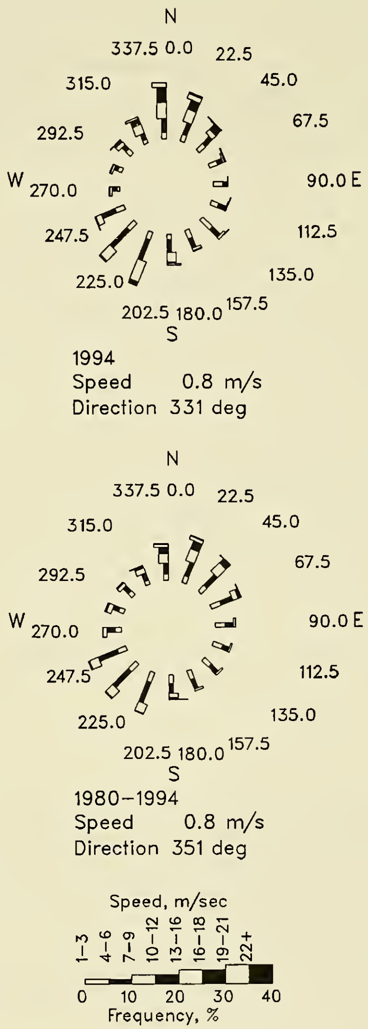

Figure 6. Annual wind roses

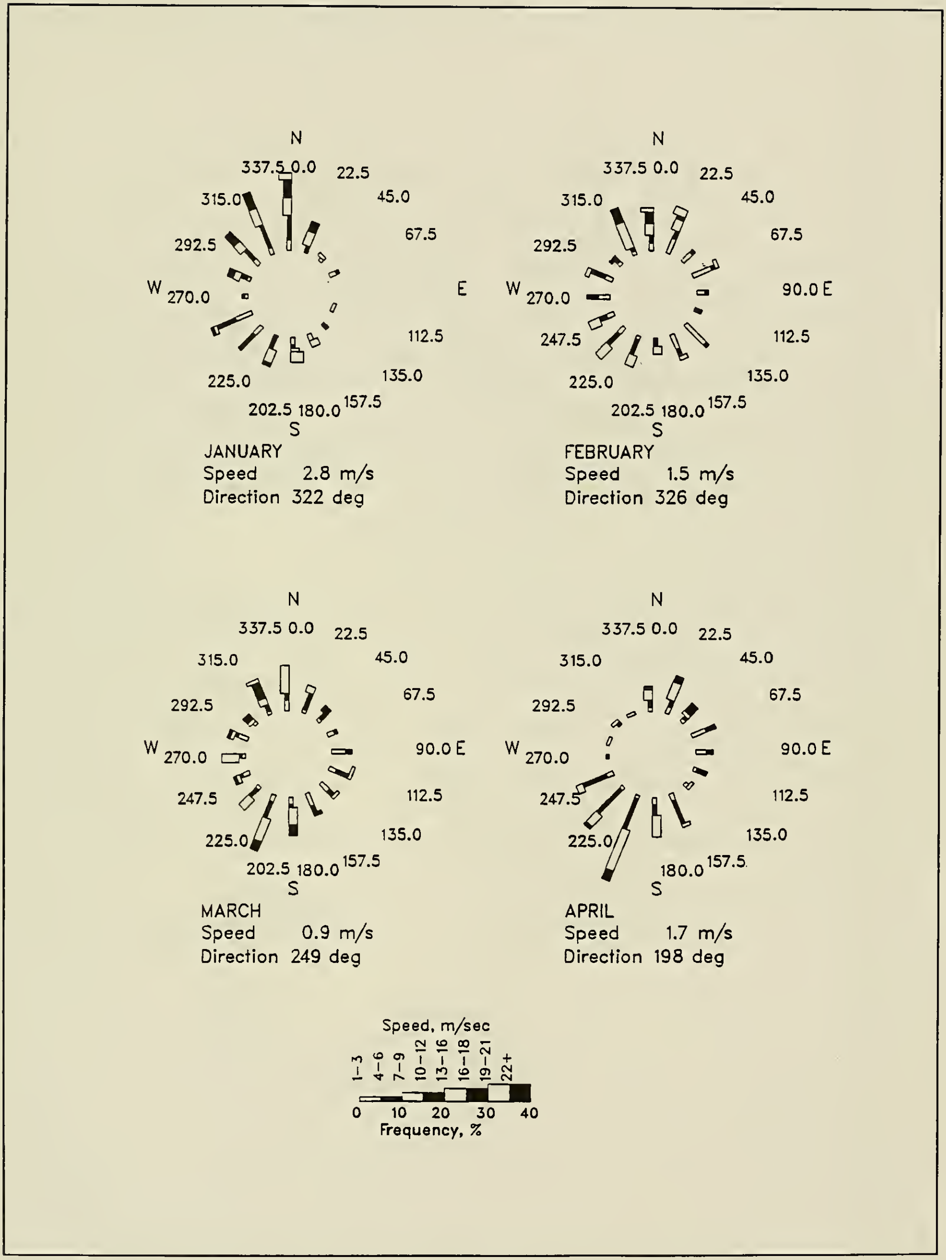

Figure 7. Monthly wind roses for 1994 (Continued)

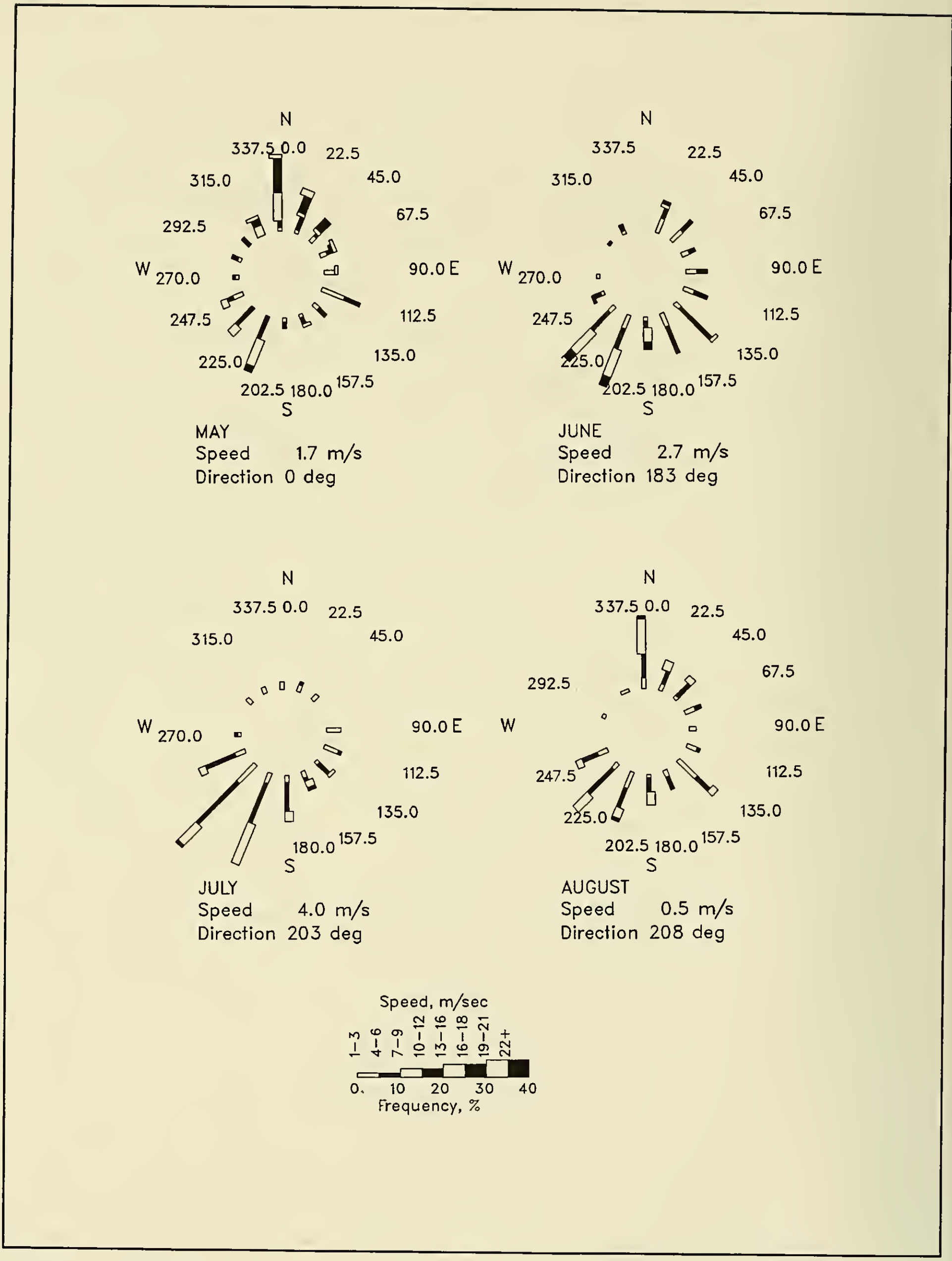

Figure 7. (Continued)

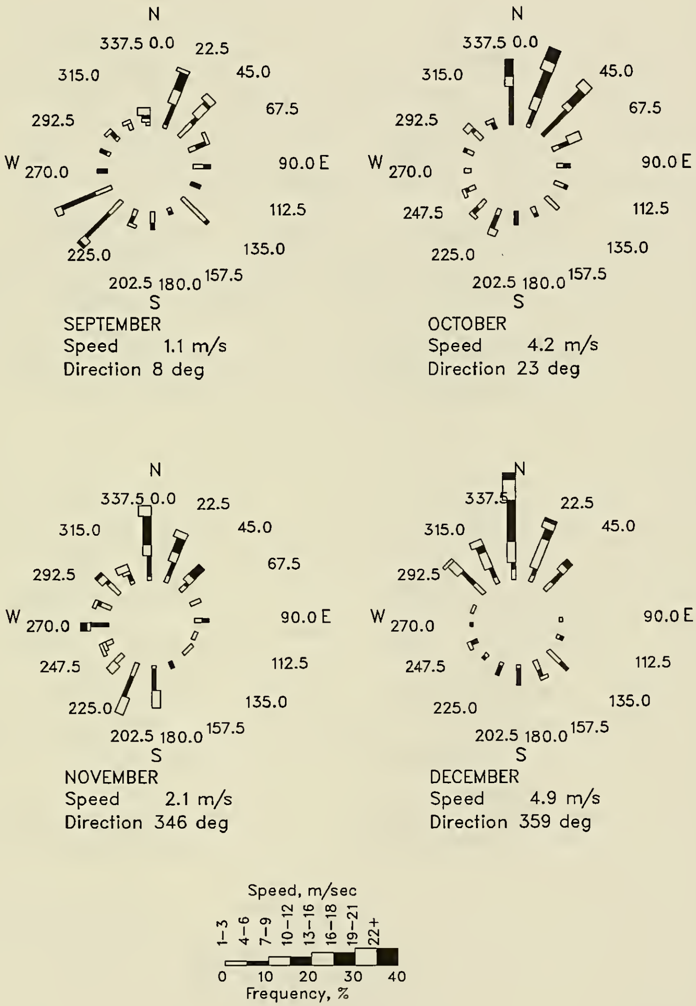

Figure 7. (Concluded)

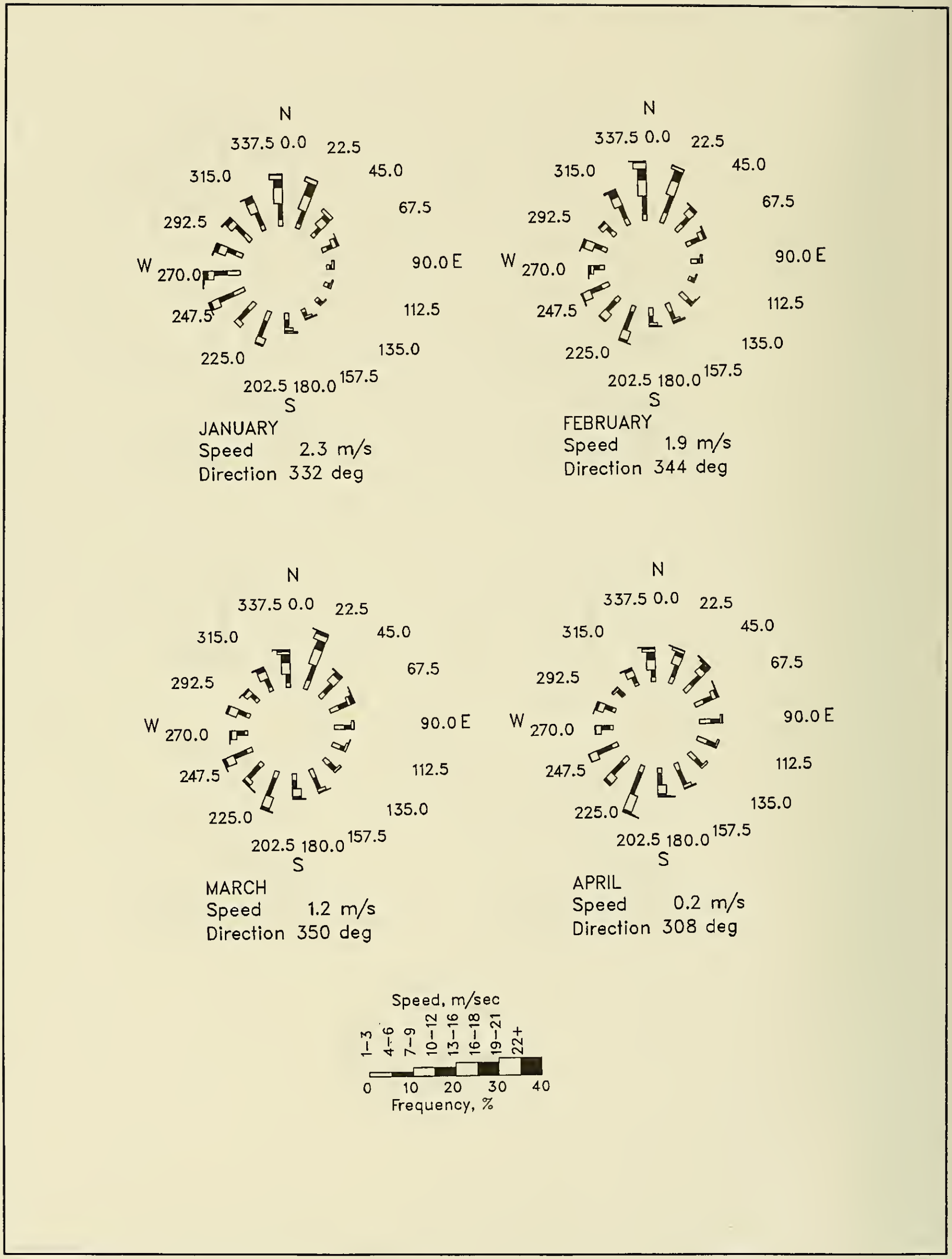

Figure 8. Monthly wind roses for 1980 through 1994 (Continued)

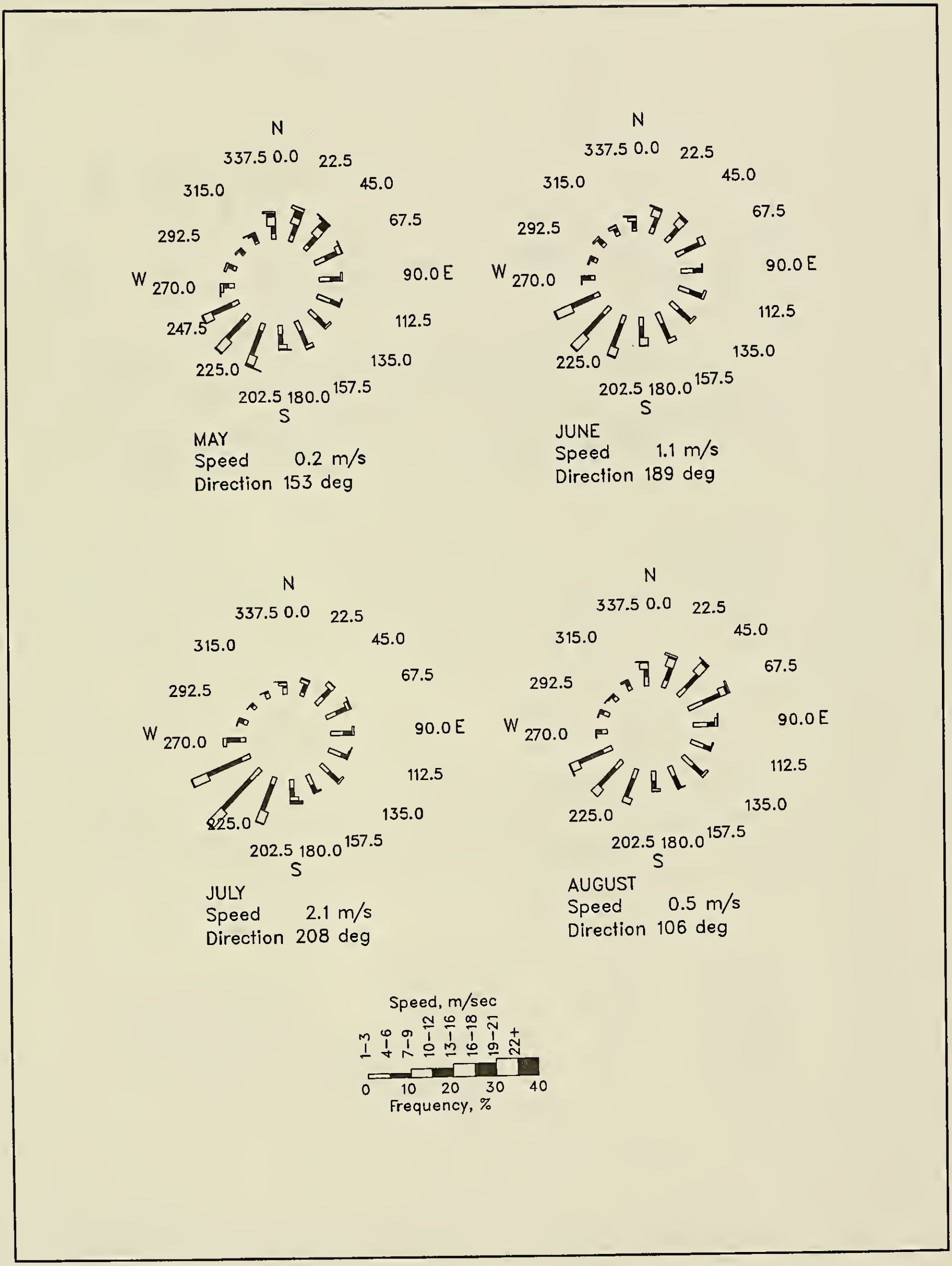

Figure 8. (Continued)

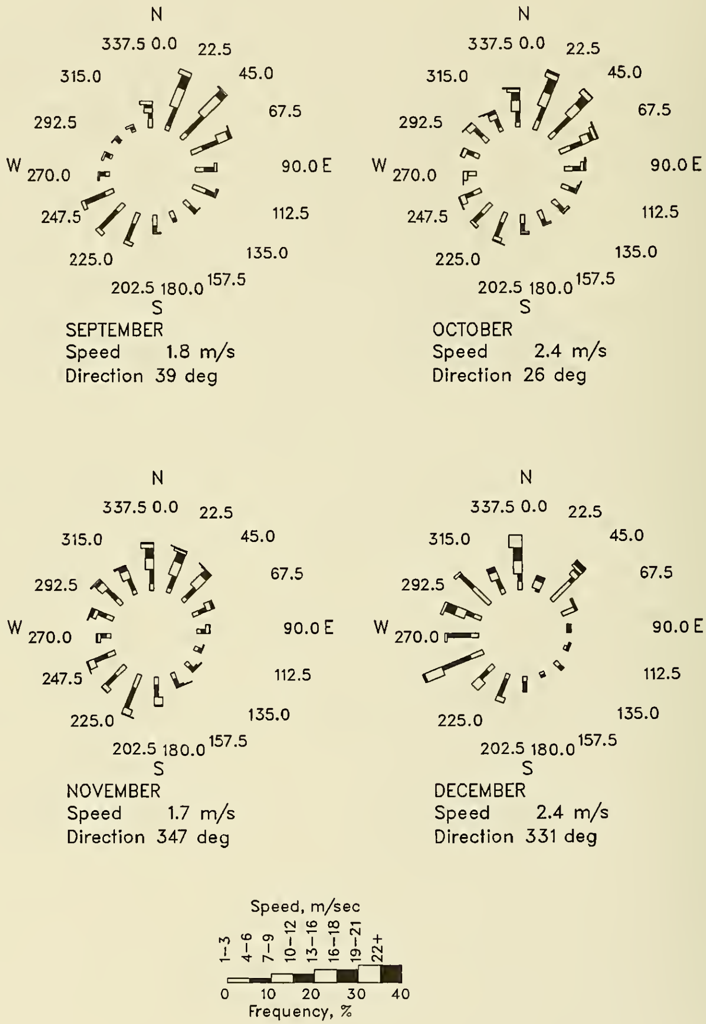

Figure 8. (Concluded)

3 Waves

This chapter presents summaries of the wave data. A discussion of individual major storms is given in Chapter 9 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 gauge, including height and period distributions, wave direction distributions, persistence tables, and spectra during storms.

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 that 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

The wave gauges included one wave staff gauge (Gauge 625), one buoy gauge (Gauge 630), and two pressure gauges (Gauges 111 and 641) as shown in Figure 2. Staff gauge 645 failed in May 1992 and was replaced by pressure gauge 641 at the same location. The gauges were located as follows:

Gauge Type/Number	Distance Offshore from Baseline	Water Depth m	Operational Period
Continuous wire (645)	238 m	3.5	11/84-05/92
Pressure Gauge (641)	238 m	3.5	11/92-12/94
Continuous wire (625)	567 m	8	11/78-12/94
Accelerometer buoy (630)	6 km	18	11/78-12/94
Pressure gauge (111)	1 km	8	09/86-12/94

Staff gauges

One Baylor Company (Houston, TX) parallel cable inductance wave gauge (Gauge 625 at sta 18+60 (Figure 2)) was mounted on the FRF pier. Rugged and reliable, this gauge requires little maintenance except to keep tension on the cables and to remove any material that may cause an electrical short between them. It was 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 gauge are within a 0- to 5-V range. Manufacturer-stated gauge accuracy is about 1.0 percent, with a 0.1-percent full-scale resolution; full scale is 14 m for Gauge 625. This gauge is susceptible to lightning damage, but protective measures have been taken to minimize such occurrences. A more complete description of the gauges' operational characteristics is given by Grogg (1986).

Buoy gauge

One Datawell Laboratory for Instrumentation (Haarlem, The Netherlands), Waverider buoy gauge (Gauge 630) measures the vertical acceleration produced by the passage of a wave. The acceleration signal is double-integrated to produce a displacement signal 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 to 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 gauges

One Senso-Metrics, Incorporated (Simi Valley, CA), pressure transduction gauge (Gauge 111) installed near the ocean bottom measures the pressure changes produced by the passage of waves creating an output signal that is linear and proportional to pressure when operated within its design limits. Predeployment and postdeployment 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 of 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.

One Paroscientific, Incorporated (Redmond, WA), pressure transduction gauge (Gauge 641) was installed near the ocean bottom on an instrument pile under the pier at station 7+80. Calibration is similar to that performed on Gauge 111. The sensor's range is 0 to 45 psia (equivalent to 0 to 30 m of seawater) with a manufacturer-stated accuracy of $\pm$0.01 percent. A perforated copper/nickel plate protects the sensor's diaphragm from biological fouling, and the system is periodically cleaned by divers.

Digital Data Analysis and Summarization

The data were collected, analyzed, and then archived on optical disk using the FRF's VAX computer. Data sets were normally collected every 3 hr. For each gauge, a data set consisted of five contiguous records of 4,096 points recorded at 0.5 Hz (approximately 34-min long), for a total of 2 hr and 50 minutes, resulting in only a 10-min gap between data sets. Analysis was performed on individual 34-min records.

The analysis program computes the first moment (mean) and the second moment about the mean (variance) and then edits the data by checking for "jumps," "spikes," and points exceeding the voltage limit of the gauge. 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.

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) which has been shown to produce better statistical properties than nonoverlapped segments. The mean and linear trends are removed from each segment prior to spectral analysis. To reduce side-lobe leakage in the spectral estimates, a data window was applied. The first and last 10 percent of data points were multiplied by a cosine bell (Bingham, Godfrey, and Tukey 1967). Spectra were computed from each segment with a discrete Fast Fourier Transform and then ensemble-averaged. Sea surface spectra from subsurface pressure gauges were obtained by applying the linear wave theory transfer function.

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 gauges and between 0.05 Hz and a high-frequency cutoff for subsurface gauges. 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 (three components are averaged per band, producing a frequency band width of 0.0117 Hz).

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 is presented in Andrews (1987).[2]

Results

The wave conditions for the year are shown in Figure 9. For all four gauges, 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.

Multiple-year comparisons of data for Gauge 111 actually incorporate data for 1985 and 1986 from Gauge 640 (a discontinued Waverider buoy previously located at the approximate depth and distance offshore of Gauge 111) and data for 1987 from Gauge 141, located 30 m south of Gauge 111. In addition Gauge 511 was used from January through October 1993. Multiple-year data for Gauge 641 also include data from Gauge 645 (a Baylor staff gauge) which was mounted at the same location as Gauge 641 from November 1984 until May 1992, when it failed.

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 Gauge 630 and the inshore gauges. The wave height statistics for the pressure gauge (Gauge 641), located at the landward end of the pier, were considerably lower than those for the other gauges. In all but the calmest conditions, this gauge is within the breaker zone. Consequently, these statistics represent a lower energy wave climate.

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[2] M. E. Andrews. 1987. "Standard wave data analysis procedures for coastal engineering applications," unpublished report prepared for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

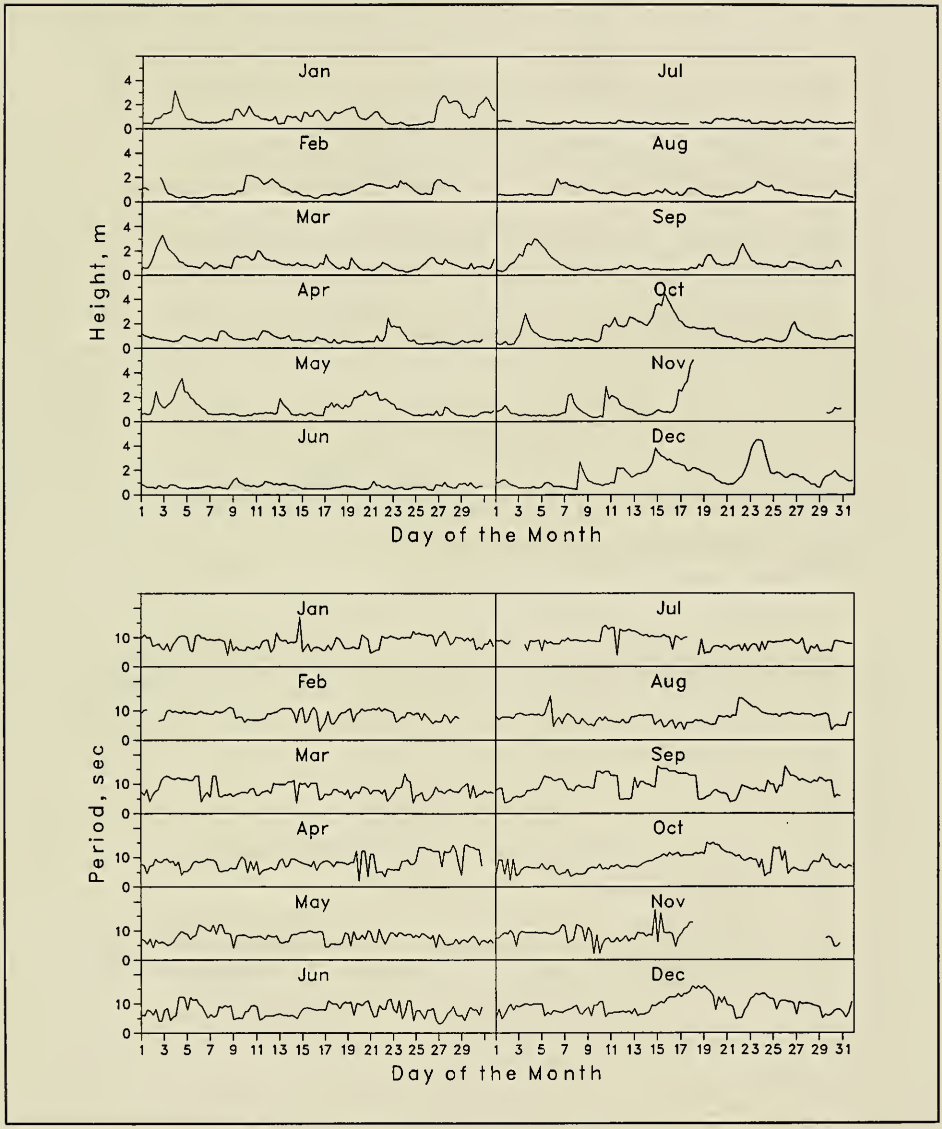


Figure 9. 1994 Time-histories of wave height and period for Gauge 630

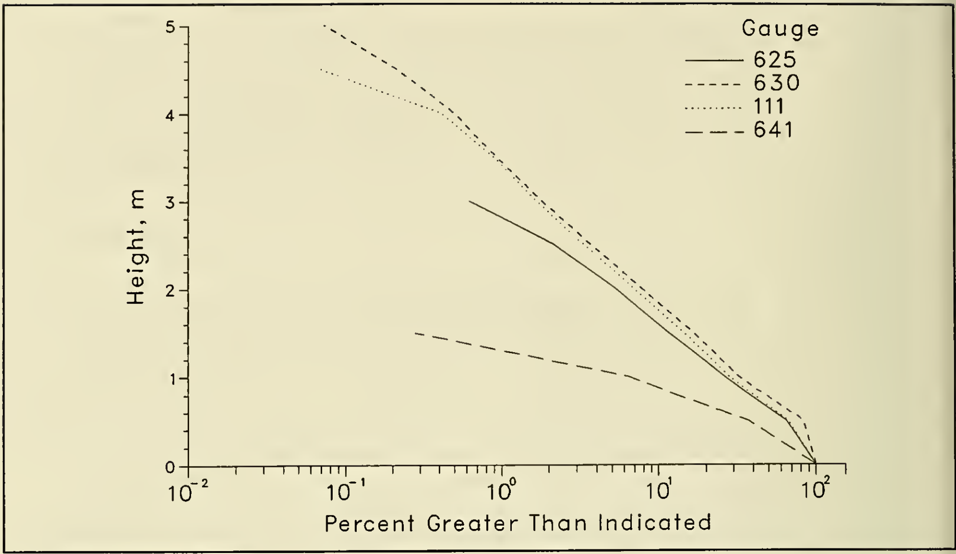


Figure 10. 1994 annual wave height distributions

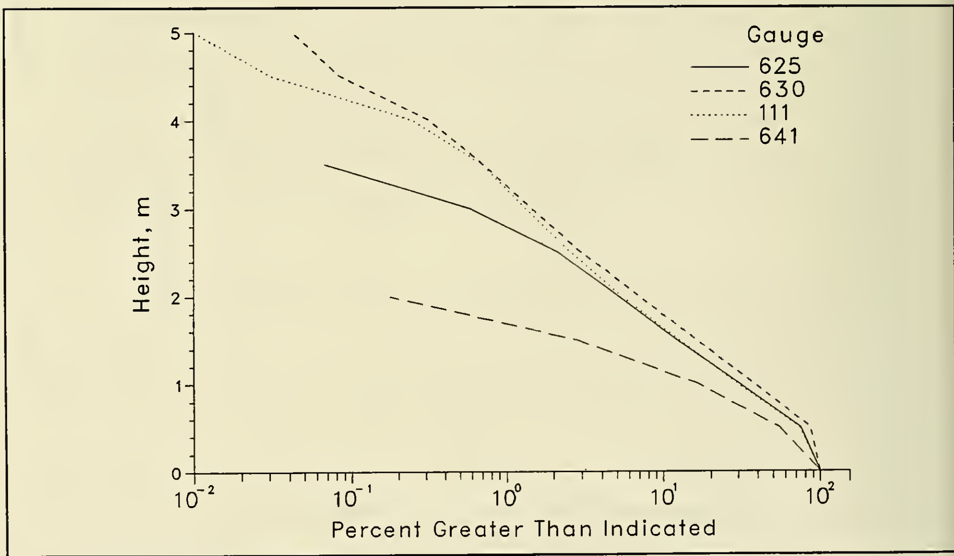


Figure 11. Annual distribution of wave heights for 1980 through 1994

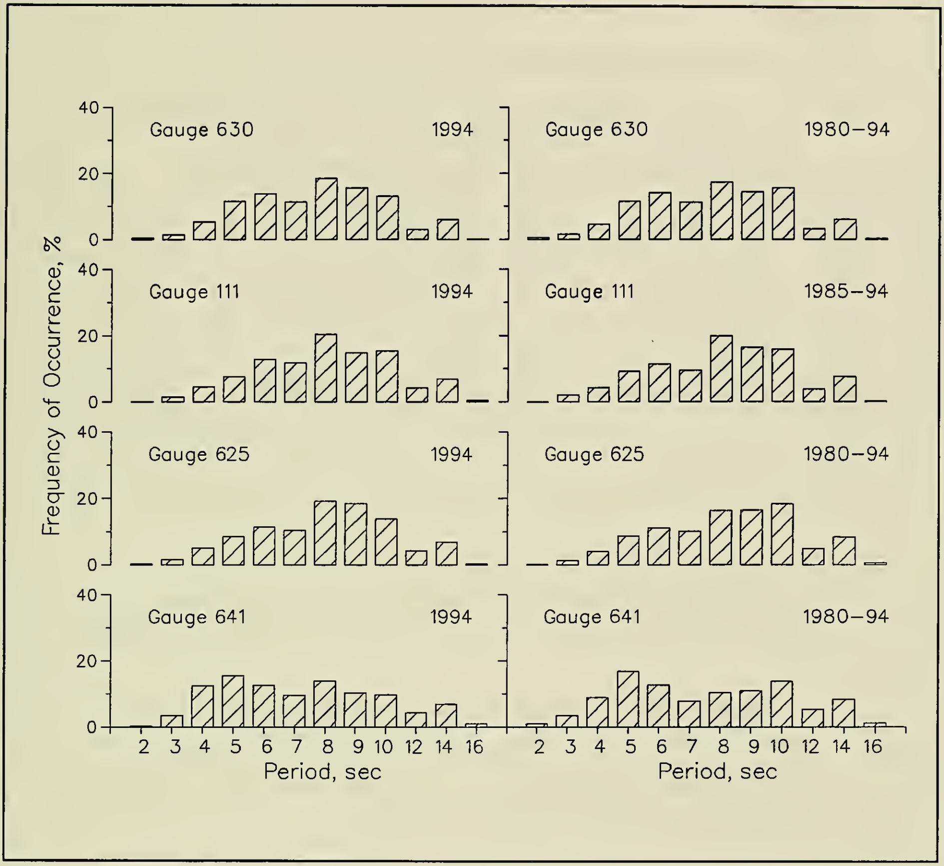


Figure 12. Annual wave period distributions for all gauges

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

Table 3

Wave Statistics for Gauge 630

	1994							1980-1994						
	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	1.1	0.7	3.2	3	8.4	2.2	122	1.2	0.7	4.5	1983	8.1	2.6	1496
Feb	1.0	0.6	2.2	10	8.6	1.8	109	1.2	0.7	5.1	1987	8.4	2.5	1352
Mar	1.0	0.6	3.3	2	8.0	2.4	123	1.2	0.7	4.7	1983	8.6	2.6	1691
Apr	0.8	0.4	2.5	22	8.4	2.7	118	1.0	0.6	5.0	1988	8.6	2.7	1670
May	1.1	0.7	3.6	4	7.8	1.9	124	0.9	0.5	3.6	1992	8.2	2.4	1713
Jun	0.7	0.2	1.4	9	7.7	2.3	119	0.8	0.4	2.7	1991	7.9	2.2	1597
Jul	0.6	0.2	0.8	20	8.5	2.3	116	0.7	0.3	2.1	1985	8.0	2.4	1629
Aug	0.8	0.4	1.9	6	7.6	2.1	121	0.8	0.4	3.6	1981	8.1	2.4	1655
Sep	1.0	0.7	3.0	4	9.5	3.2	120	1.0	0.6	6.1	1985	8.6	2.6	1654
Oct	1.3	0.9	4.5	15	8.1	2.9	124	1.3	0.8	5.4	1991	8.7	2.8	1729
Nov	1.1	1.0	5.1	18	8.6	2.6	75	1.2	0.7	5.1	1994	8.0	2.7	1470
Dec	1.6	1.0	4.5	23	9.3	2.8	123	1.3	0.8	5.6	1980	8.4	2.9	1475
Annual	1.0	0.7	5.1	Nov	8.4	2.5	1394	1.0	0.7	6.1	Sep 1985	8.3	2.6	19131

Annual joint distributions of wave height versus wave period for Gauge 630 are presented for 1994 in Table 4, and for all years combined in Table 5. Similar distributions for the other gauges are included in Appendixes B-E.

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 Gauge 625 (or Gauge 111 when data for Gauge 625 were unavailable) are shown in Figure 13. Monthly wave roses for 1994 and all years combined are presented in Figures 14 and 15, respectively.

Table 4

Annual (1994) Joint Distribution of H_{mo} versus T_p for Gauge 630[1]

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	29	14	22	65	43	115	459	416	244	158	108	.	1673
0.50 - 0.99	7	108	359	502	667	617	1055	861	581	57	273	14	5101
1.00 - 1.49	.	22	151	395	237	151	187	158	194	22	57	.	1574
1.50 - 1.99	.	.	.	172	273	115	57	36	136	29	57	.	875
2.00 - 2.49	.	.	.	14	143	86	36	29	50	7	50	.	415
2.50 - 2.99	.	.	.	.	14	50	36	22	22	7	36	.	187
3.00 - 3.49	.	.	.	.	.	7	7	14	50	7	.	.	85
3.50 - 3.99	.	.	.	.	.	.	.	22	22	.	.	.	44
4.00 - 4.49	.	.	.	.	.	.	.	.	7	14	7	.	28
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	14	.	14
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	7	.	7
Total	36	144	532	1148	1377	1141	1837	1558	1306	301	609	14	

[1] Percent occurrence (x100) of height and period.

Table 5

Annual (1980-1994) Joint Distribution of H_{mo} versus T_p for Gauge 630 (All Years)[1]

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	25	15	28	63	80	123	356	293	194	68	119	4	1368
0.50 - 0.99	32	135	271	490	570	536	915	773	764	125	225	14	4850
1.00 - 1.49	.	10	147	405	404	237	274	216	318	39	112	3	2165
1.50 - 1.99	.	.	11	166	244	106	82	76	137	32	66	3	923
2.00 - 2.49	.	.	1	25	93	68	52	33	62	26	34	1	395
2.50 - 2.99	.	.	.	1	14	34	20	15	34	9	25	1	153
3.00 - 3.49	.	.	.	.	1	11	13	13	21	6	8	1	74
3.50 - 3.99	.	.	.	.	.	1	6	9	13	5	5	.	39
4.00 - 4.49	.	.	.	.	.	.	3	5	8	3	4	1	24
4.50 - 4.99	.	.	.	.	.	.	.	1	2	.	1	1	5
5.00 - Greater	.	.	.	.	.	.	1	.	1	1	1	1	5
Total	57	160	458	1150	1406	1116	1722	1434	1554	314	600	30	

[1] Percent occurrence (x100) of height and period.

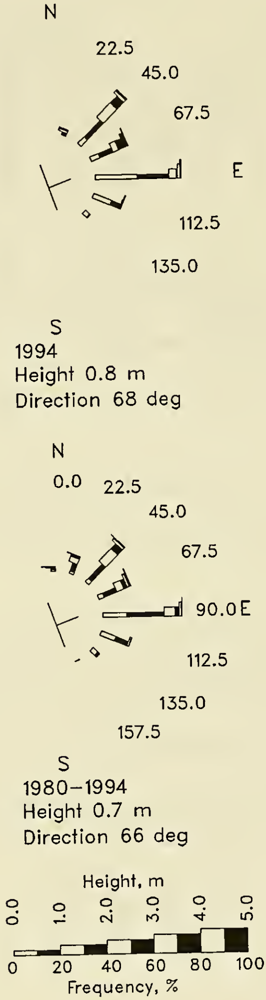


Figure 13. Annual wave roses

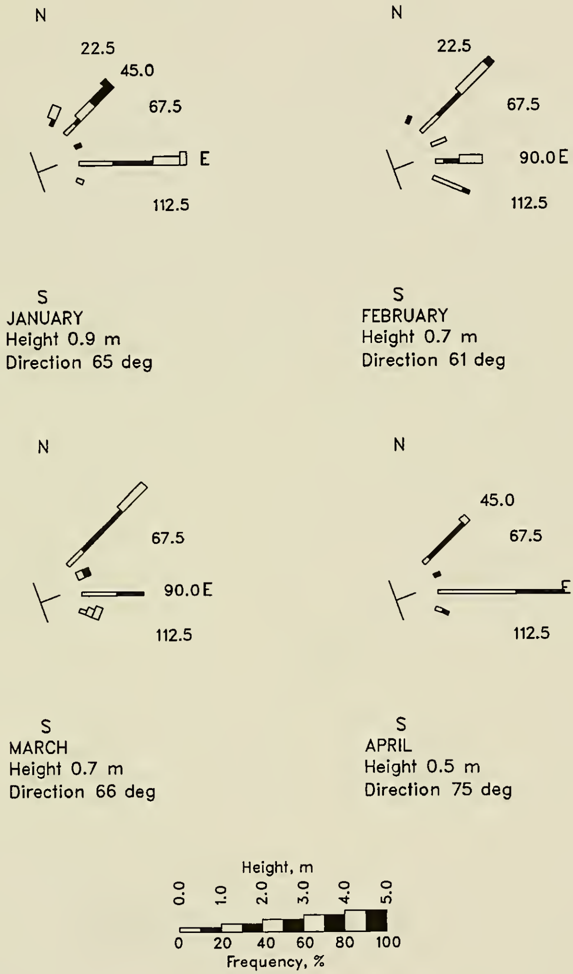


Figure 14. Monthly wave roses for 1994 (Continued)

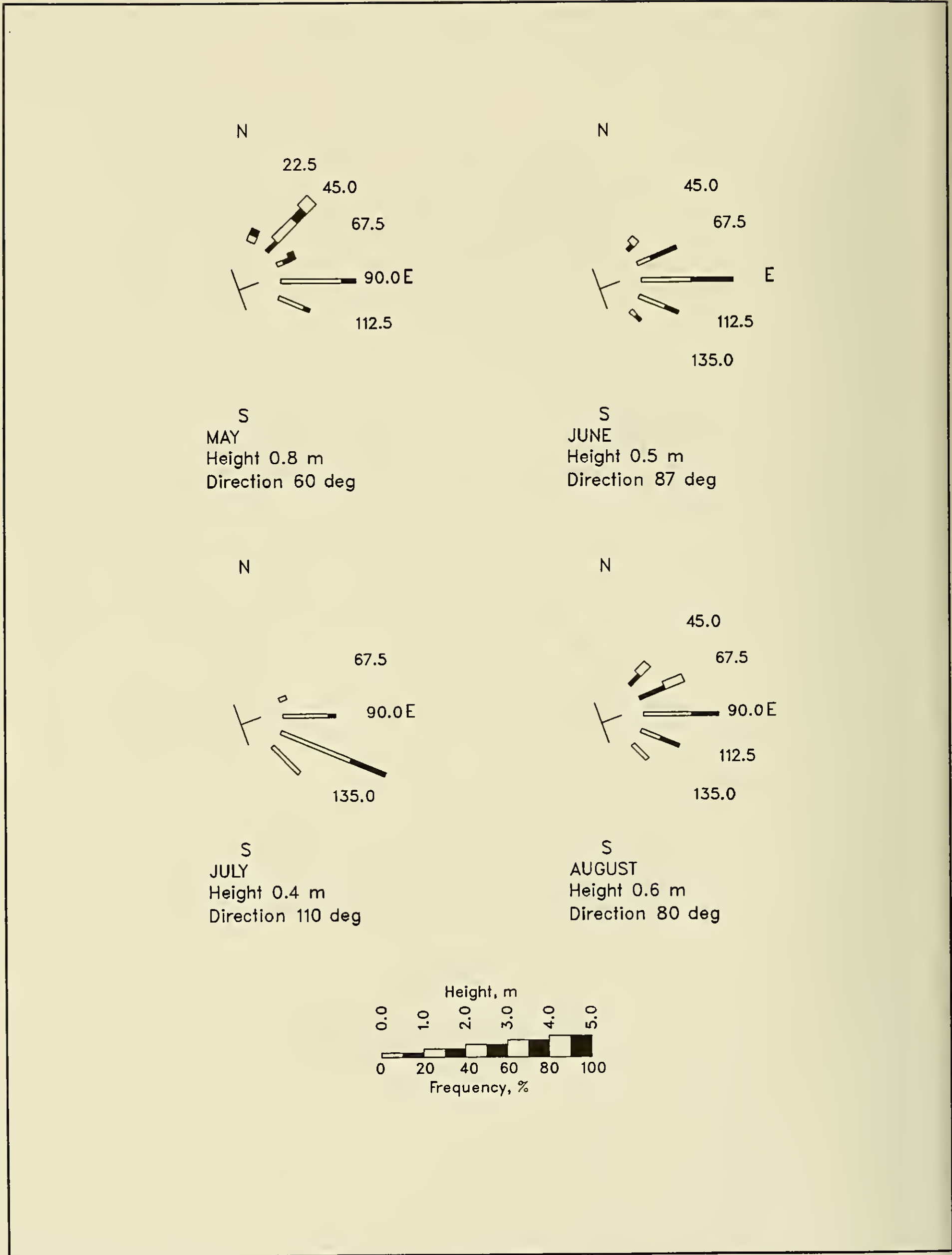


Figure 14. (Continued)

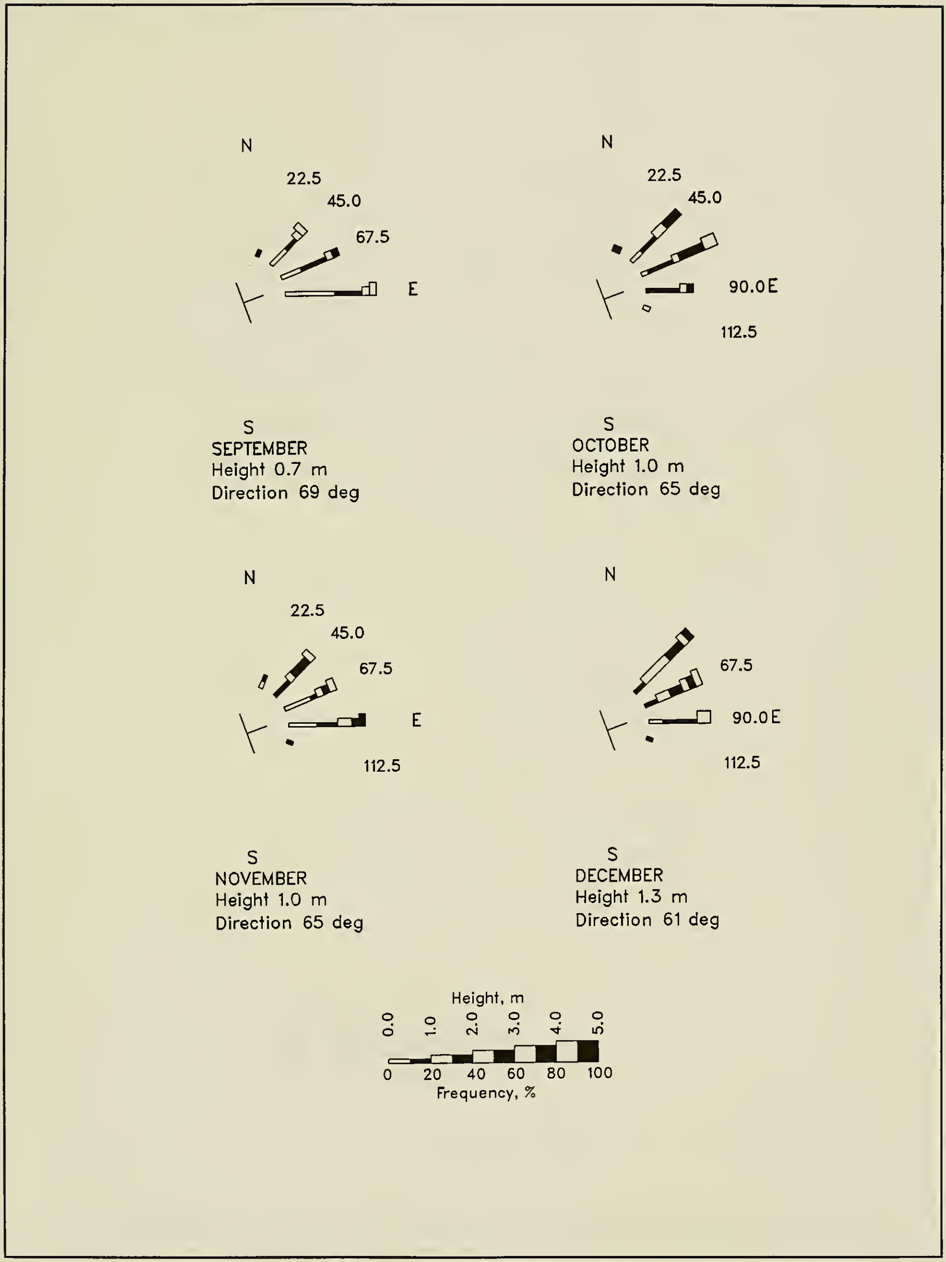


Figure 14. (Concluded)

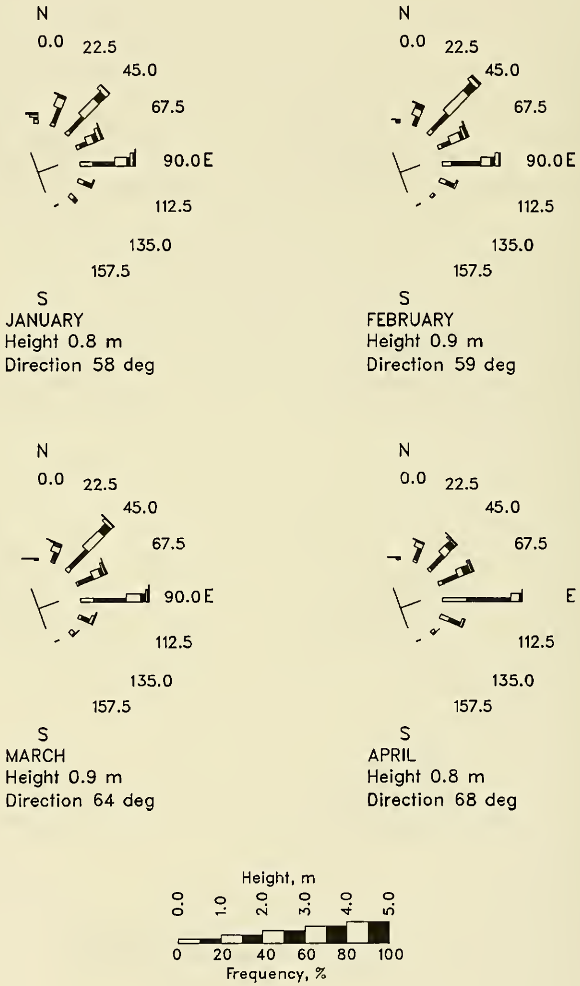


Figure 15. Monthly wave roses for 1980 through 1994 (Continued)

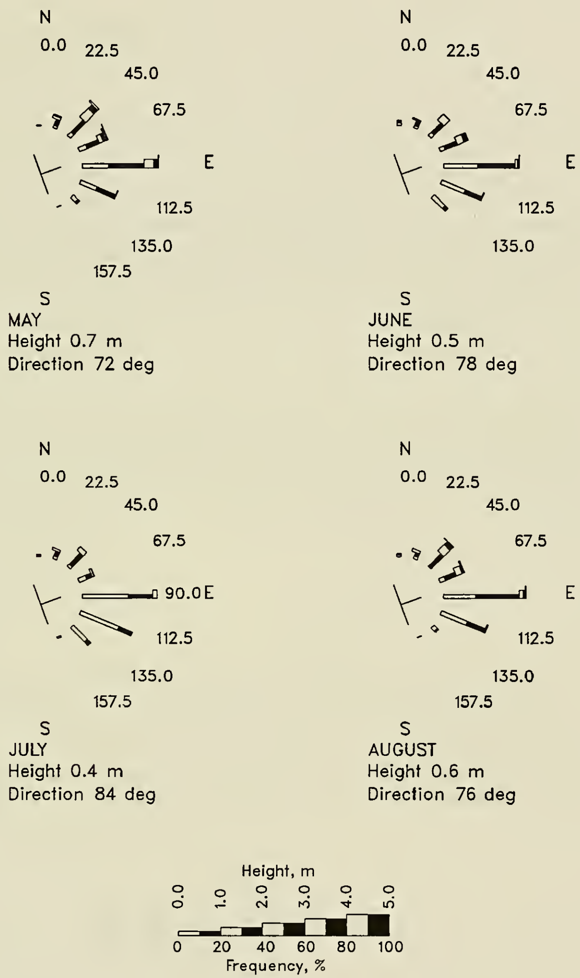


Figure 15. (Continued)

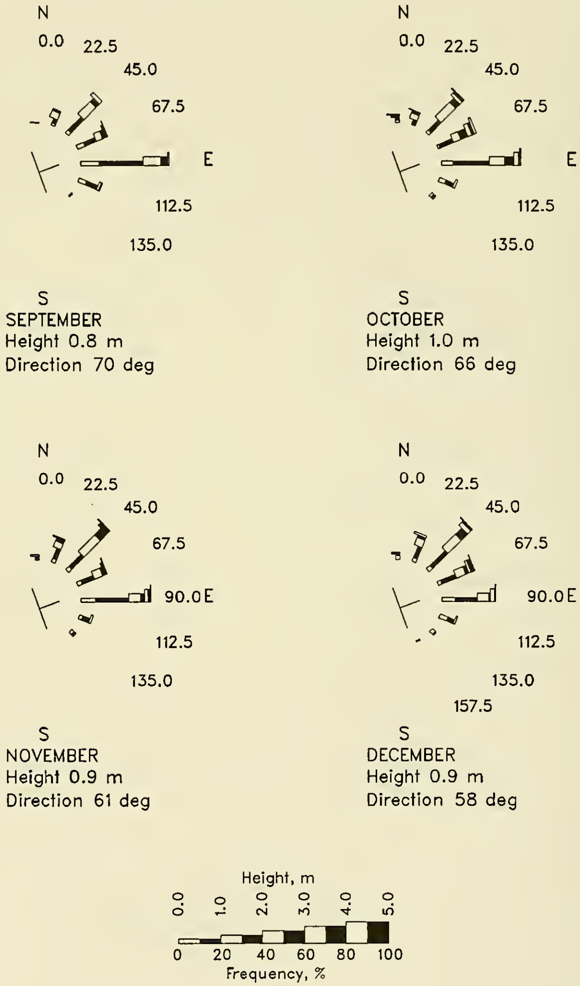


Figure 15. (Concluded)

4 Currents

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

Observations

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

Annual mean and mean currents for 1980 through 1994 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[1]

Month	Pier End, cm/sec 1994	Pier End, cm/sec 1980-1994	Pier Midsurf, cm/sec 1994	Pier Midsurf, cm/sec 1980-1994	Beach, cm/sec 1994	Beach, cm/sec 1980-1994
Jan	17	21	18	17	11	9
Feb	17	18	15	19	9	10
Mar	8	12	4	5	2	6
Apr	6	15	-5	3	4	2
May	14	16	16	1	14	4
Jun	-7	5	-19	-12	-5	-5
Jul	5	4	-7	-8	-4	-7
Aug	12	12	10	-2	5	-1
Sep	17	11	16	5	11	3
Oct	20	10	21	8	13	5
Nov	15	9	21	7	6	3
Dec	28	18	38	20	-5	4
Annual	13	13	11	5	5	3

[1] + = southward; - = northward.

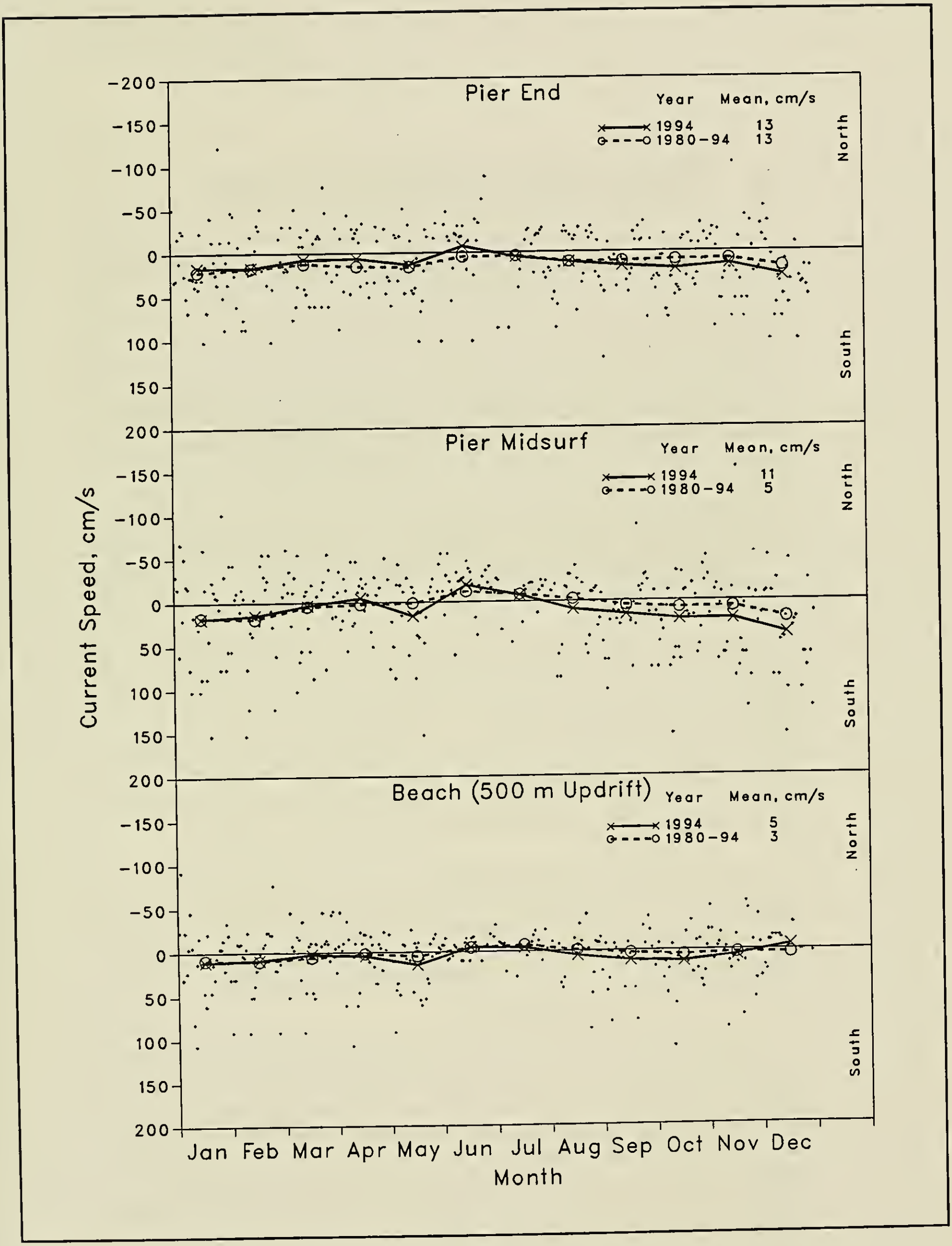


Figure 16. Daily current speeds and directions with monthly means for 1994

5 Tides and Water Levels

Measurement Instrument

Water level data were obtained from an 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 gauge. 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.

Operation and tending of the tide gauge conformed to NOS standards. The gauge 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 gauge level reading with a level read from a reference electric tape gauge. 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.

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

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

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.

NOTE: Due to a mistake in converting feet to centimeters the tide height statistics from 1987 through 1993 (As published in the 1987 through 1993 Annual Data Summaries) found in Table 7 and Figure 17 were in error. These have been corrected for this report.

Table 7

Tide Height Statistics[1]

Month or Year	Mean High Water	Mean Tide Level	Mean Sea Level	Mean Low Water	Mean Range	Extreme High	Date	Extreme Low	Date
					1994				
Jan	51	0	0	-52	103	106	27	-95	11
Feb	59	9	9	-41	100	111	24	-78	26
Mar	64	12	12	-41	105	107	4	-78	28
Apr	51	0	1	-51	102	107	27	-81	25
May	70	20	21	-30	100	116	24	-55	26
Jun	56	6	7	-44	100	98	22	-73	27
Jul	52	4	5	-45	97	80	19	-80	23
Aug	59	10	11	-38	97	96	6	-68	15
Sep	71	22	23	-27	98	119	4	-56	7
Oct	76	26	27	-23	99	106	3	-53	7
Nov	63	12	12	-39	102	122	18	-92	4
Dec	70	19	20	-32	102	103	15	-87	3
1994	62	12	12	-39	101	122	Nov	-95	Jan
					Prior Years				
1993	67	18	19	-31	98	150	Dec	-84	Nov
1992	66	17	17	-32	98	150	Dec	-84	Nov
1991	66	18	18	-31	97	150	Oct	-100	Dec
1990	59	11	11	-38	97	131	May	-94	Feb
1989	59	11	11	-37	96	239	Mar	-92	Apr
1988	55	7	7	-40	95	155	Apr	-86	Dec
1987	66	18	19	-29	95	136	Jan	-76	Nov
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
1979-1993	62	13	13	-36	98	239	Mar 1989	-119	Mar 1980

[1] Measurements are in centimeters.

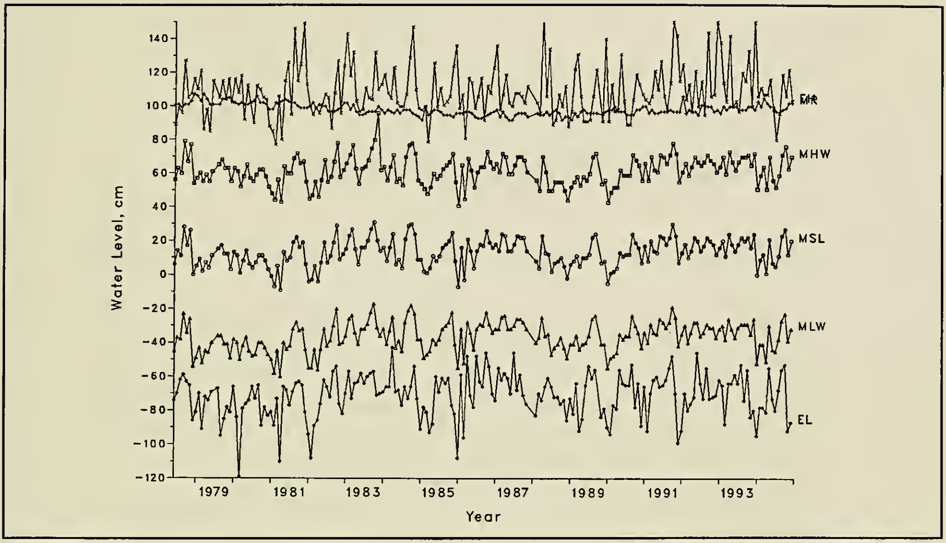


Figure 17. Monthly tide and water level statistics relative to NGVD

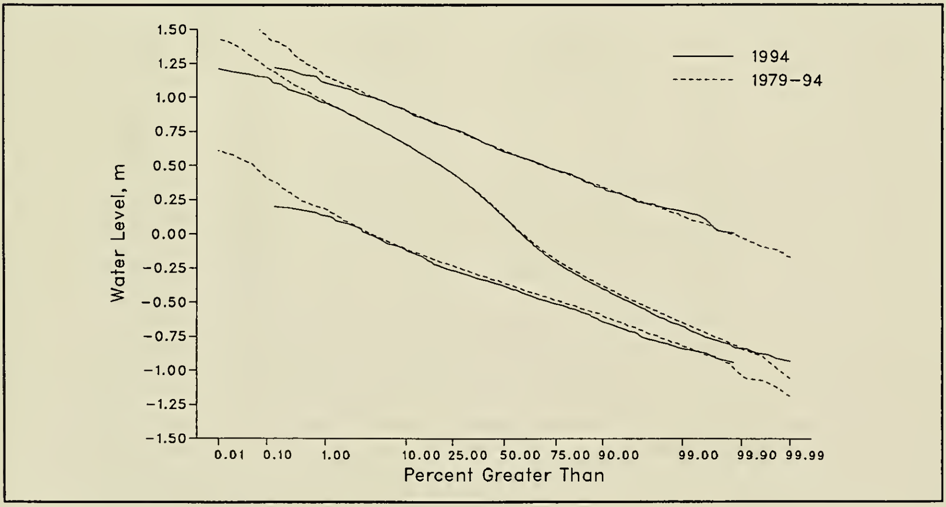


Figure 18. Distributions of hourly tide heights and high- and low-water levels

6 Water Characteristics

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 1994	Temperature deg C 1980-1994	Visibility m 1994	Visibility m 1980-1994	Density g/cm^3 1994	Density g/cm^3 1980-1994
Jan	5.3	6.3	1.4	1.3	1.0239	1.0233
Feb	4.4	5.6	1.9	1.8	1.0215	1.0230
Mar	6.7	7.1	1.5	1.5	1.0218	1.0227
Apr	11.3	11.0	1.8	1.9	1.0213	1.0222
May	15.7	15.3	1.8	2.3	1.0205	1.0217
Jun	21.0	19.5	3.3	3.3	1.0207	1.0212
Jul	21.6	21.8	3.1	3.7	1.0232	1.0215
Aug	21.1	23.4	2.9	3.2	1.0222	1.0206
Sep	22.2	23.0	2.3	2.2	1.0216	1.0209
Oct	18.1	19.3	1.1	1.5	1.0219	1.0218
Nov	15.7	14.9	0.8	1.1	1.0236	1.0229
Dec	11.2	10.1	0.6	1.1	1.0229	1.0234
Annual	14.5	14.8	1.9	2.1	1.0221	1.0221

Temperature

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).

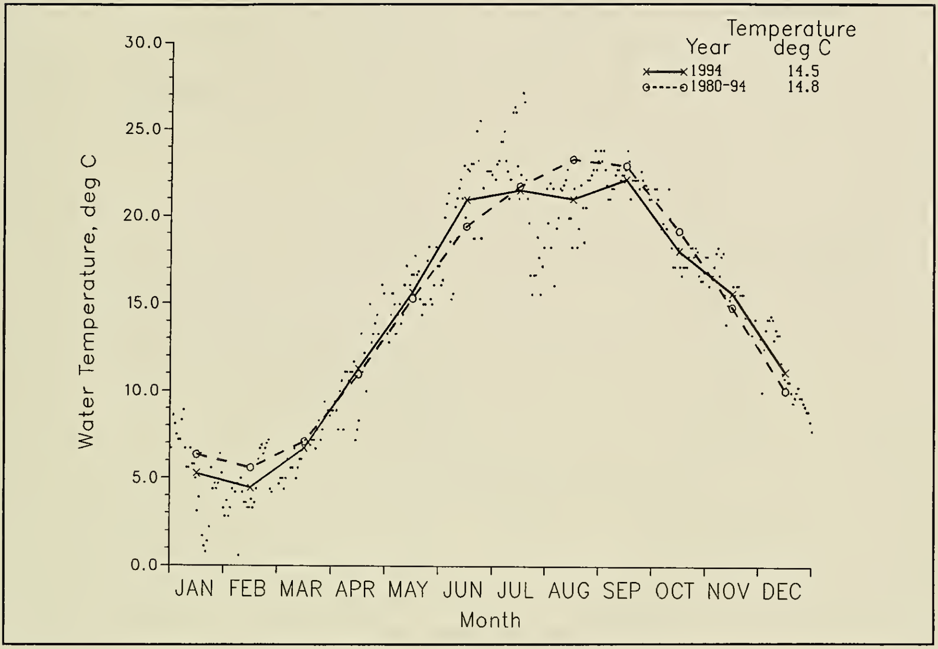


Figure 19. Daily water temperature values with monthly means

Visibility

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 that vary daily and yearly.

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.

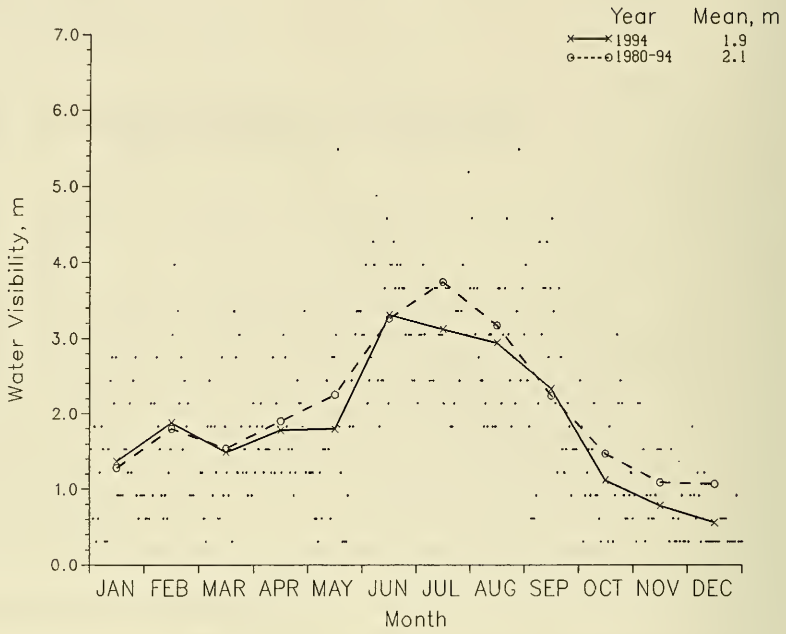


Figure 20. Daily water visibility values with monthly means

Density

Daily and monthly mean surface density values, plotted in Figure 21, were measured with a hydrometer. Monthly means are also given in Table 8. These values are direct readings from the hydrometer. Corrections for differences between ocean water temperature and jar water temperature, as well as use of uncalibrated hydrometers and other factors, could produce an error amounting to a couple of percent in the direct hydrometer readings.

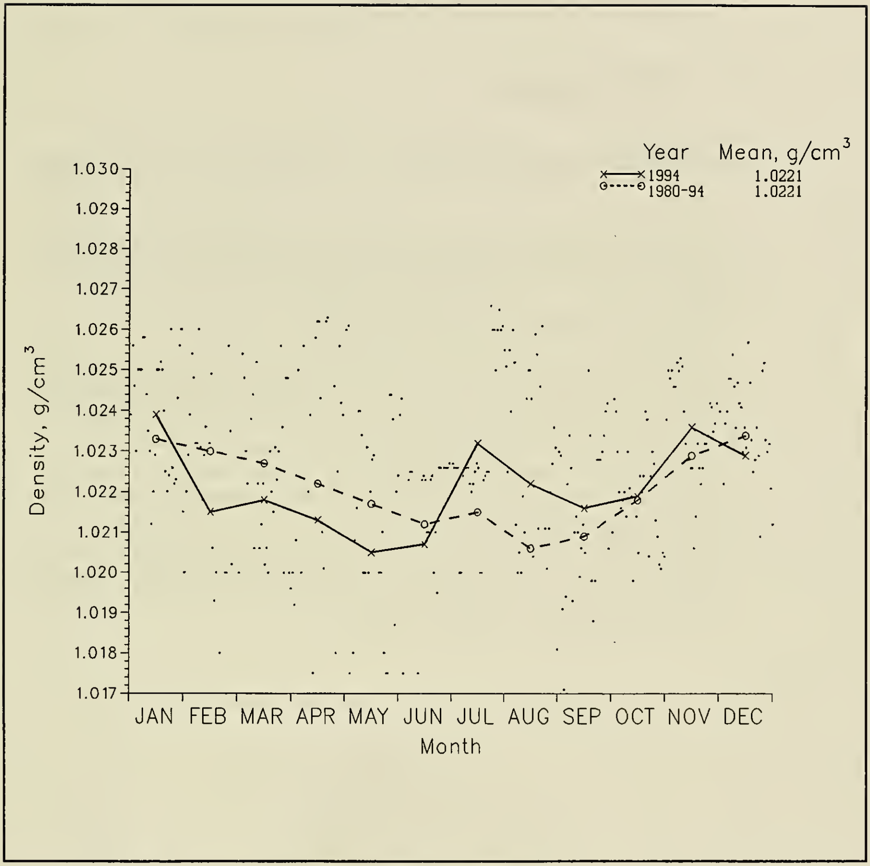


Figure 21. Daily water density values with monthly means

7 Surveys

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.

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 effect of the pier 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).

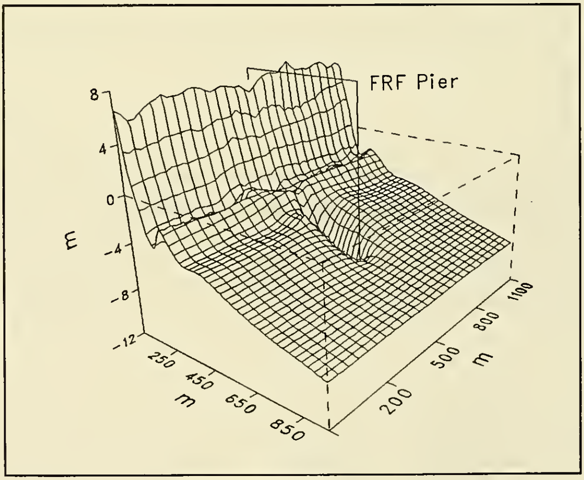


Figure 22. Permanent trough under the FRF pier, 24 January 1994

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

All surveys used the Coastal Research Amphibious Buggy (CRAB), a 10.7-m-tall amphibious tripod described by Birkemeier and Mason (1984), in combination with a Geodimeter 140-T self-tracking, electronic theodolite, distance meter. Profile locations are shown in each figure in Appendix A. 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.

A history of bottom elevations below Gauges 645 and 625 is presented in Figure 23 for pier stations 7+80 (238 m) and 18+60 (567 m), along with intermediate locations, 323 and 433 m.

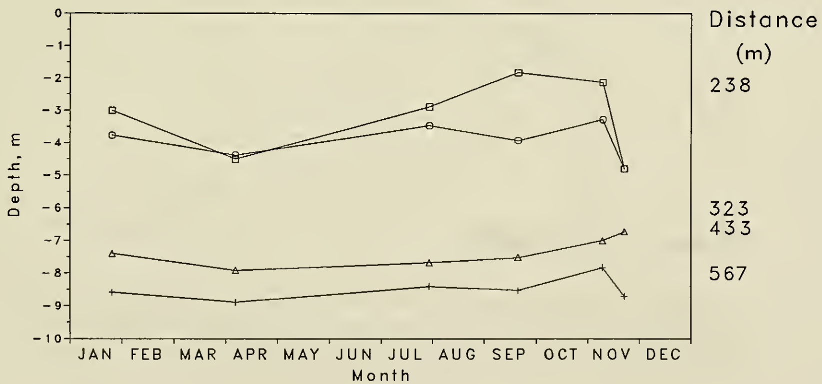


Figure 23. Time-history of bottom elevations at selected locations under the FRF pier

8 Photography

Aerial Photographs

Aerial photographs were taken biannually 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 14 January 1991; the available aerial photographs for the year are:

Date	Flight Lines	Format
22 January	1	Black/White
	2	Color

Beach Photographs

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, were marked on each of the slides.

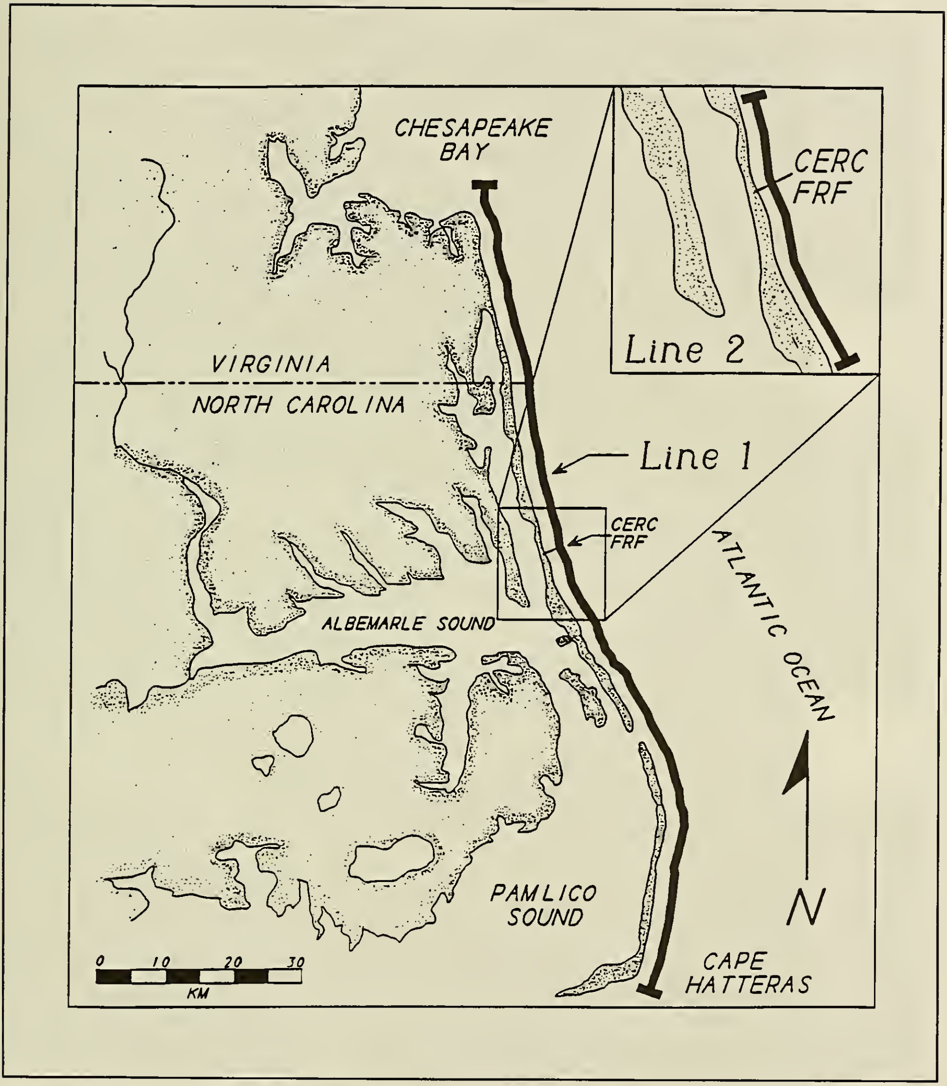
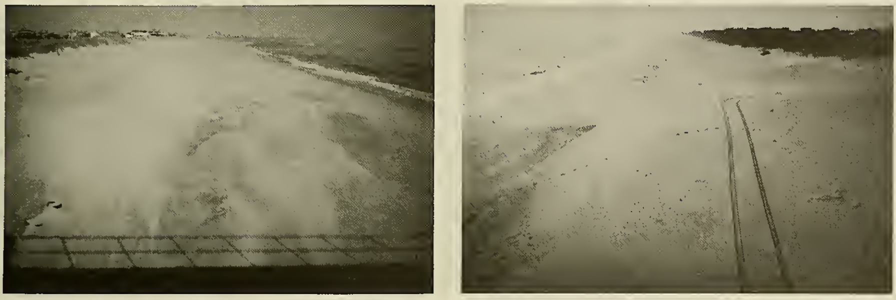


Figure 24. Aerial photography flight lines

Figure 25. Sample aerial photograph, 14 January 1991 (Scale = 1:12,000)

North View South View



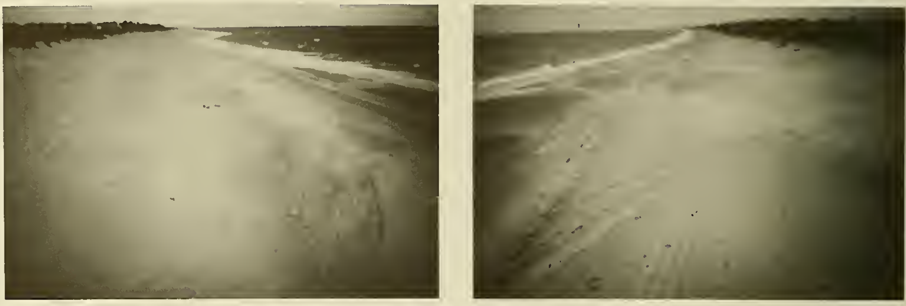
a. 22 January 1994

b. 22 February 1994

c. 22 March 1994

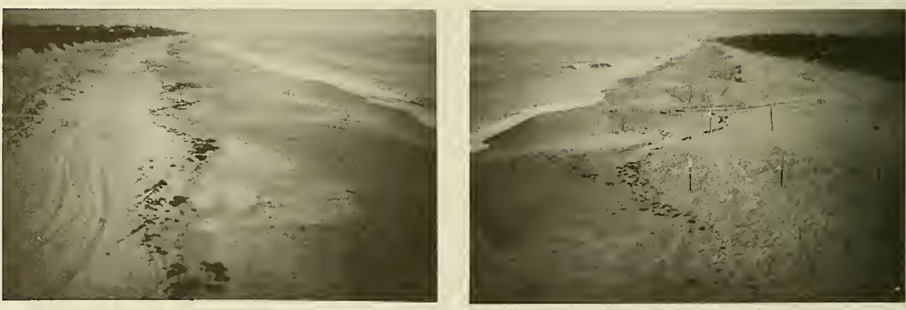
Figure 26. Beach photos looking north and south from the FRF pier (Sheet 1 of 4)

North View | South View



d. 22 April 1994

e. 23 May 1994

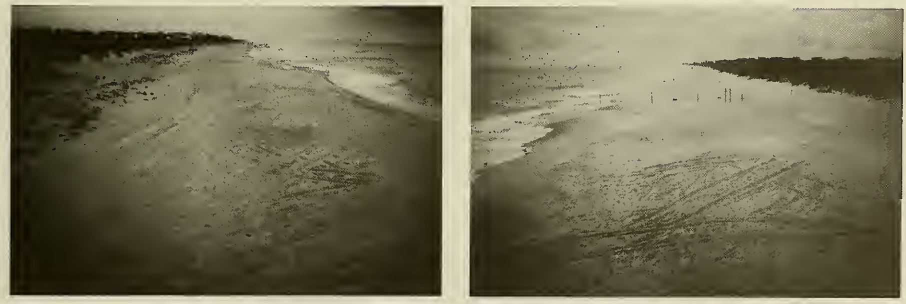


f. 22 June 1994

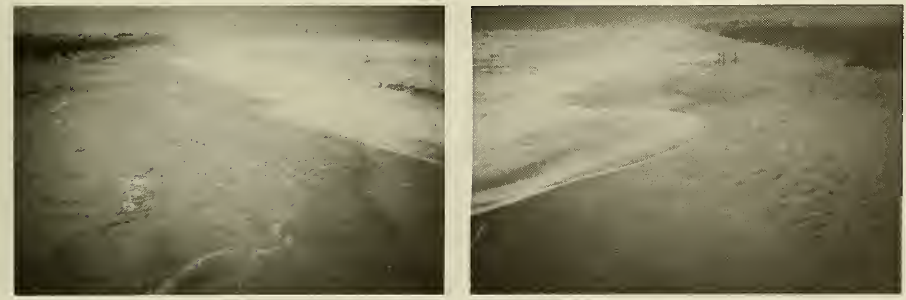
Figure 26. (Sheet 2 of 4)

North View | South View

g. 22 July 1994



h. 22 August 1994



i. 22 September 1994

Figure 26. (Sheet 3 of 4)

North View | South View

j. 22 October 1994

k. 22 November 1994

l. 22 December 1994

Figure 26. (Sheet 4 of 4)

9 Storms

This chapter 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 Gauge 630 are given in Appendix B. Prestorm and/or poststorm bathymetry diagrams are given in Appendix A. Tracking information was provided by NOAA Daily Weather Maps (U.S. Department of Commerce 1994).

3-4 January 1994 (Figure 27)

Forming off the Georgia/South Carolina border this storm quickly moved up the North Carolina coast. Maximum onshore winds (from northeast) reached 13 m/sec at 2042 EST on 3 January. The minimum atmospheric pressure was 991 mb while the maximum H_{mo} (at Gauge 630) was 3.14 m (T_p = 7.76 sec) at 1934 EST also on 3 January. There was 48 mm of precipitation.

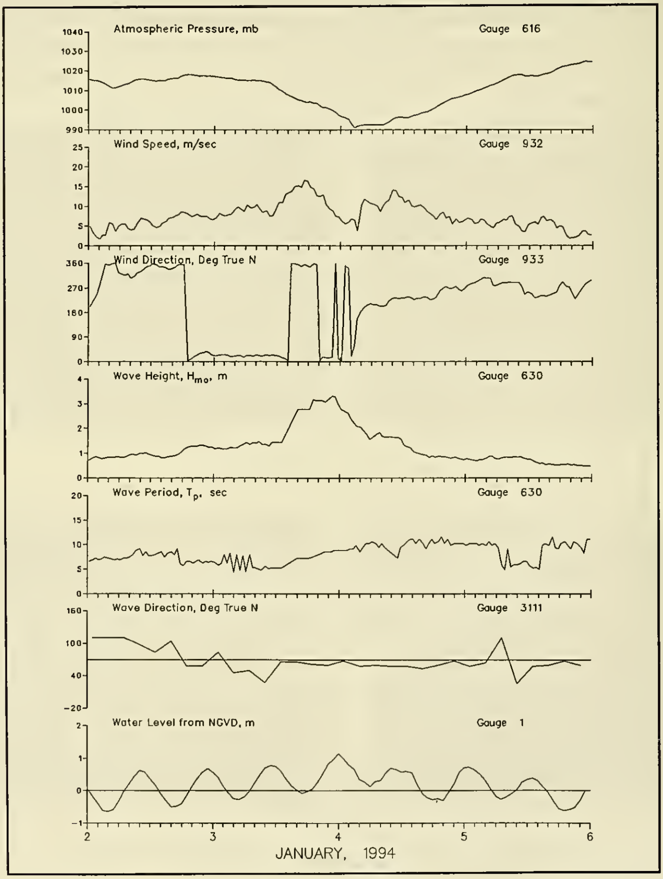


Figure 27. Data for 3-4 January 1994 storm

26-28 January 1994 (Figure 28)

A strong Canadian high pressure system produced maximum onshore winds (from northeast) of 11 m/sec at 0508 EST on 27 January. Waves at Gauge 630 reached a maximum H_{mo} of 2.97 m (T_p = 12.19 sec) at 0916 EST on 27 January. There was 12 mm of precipitation.

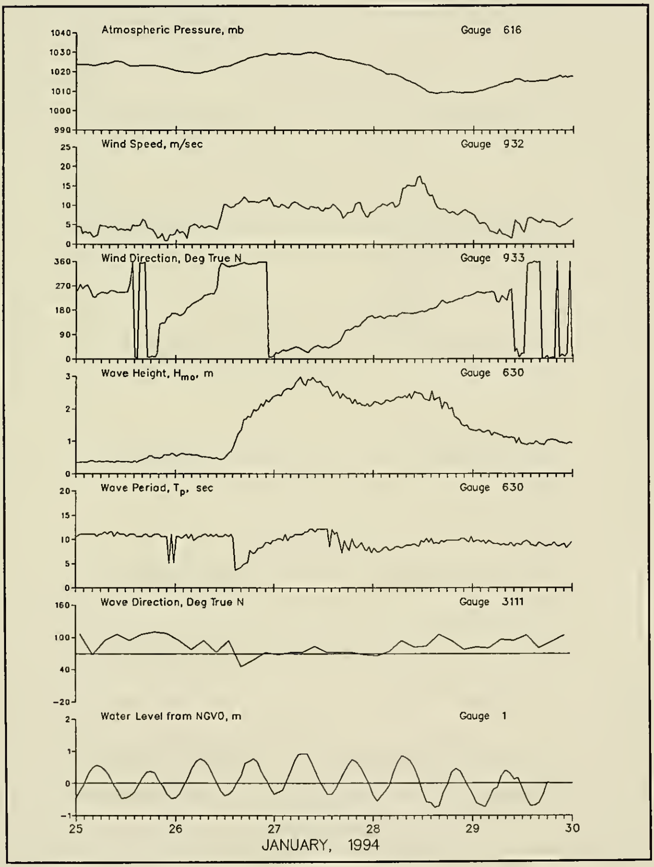


Figure 28. Data for 26-28 January 1994 storm

30-31 January 1994 (Figure 29)

Northeasterly winds funneled between a Canadian high pressure system and a small low pressure system located offshore of Cape Hatteras, NC, generated storm waves at the FRF. Waves at Gauge 630 reached a maximum H_{mo} of 2.78 m (T_p = 7.53 sec) at 2200 EST on 30 January. Onshore winds (from northeast) peaked at 13.4 m/sec at 1516 EST on 30 January. The FRF received 20 mm of precipitation from this storm.

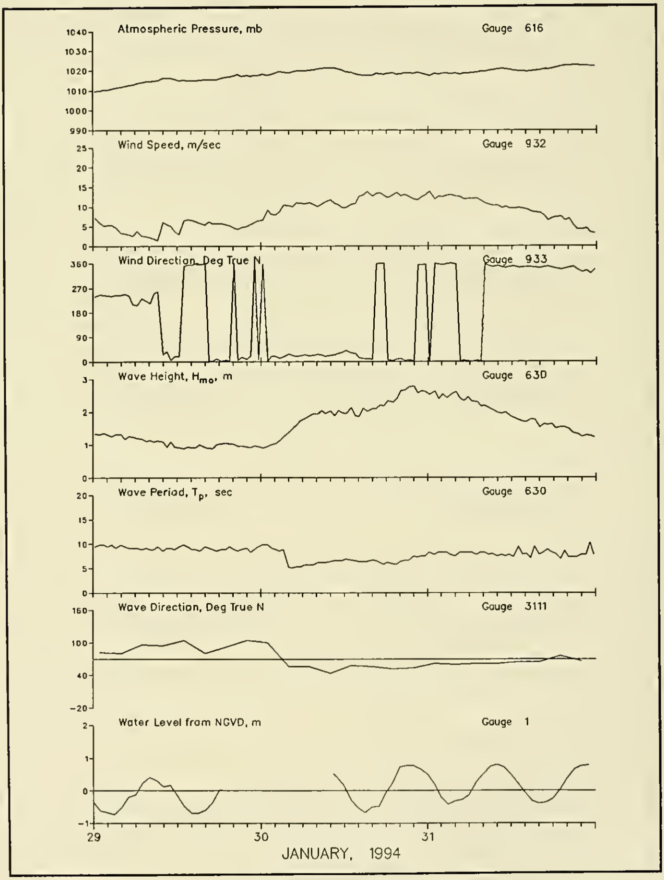


Figure 29. Data for 30-31 January 1994 storm

2-3 March 1994 (Figure 30)

Forming over Georgia early on 2 March this storm quickly moved up the eastern coast. Southeasterly winds approaching 17 m/sec peaked at 1300 EST on 2 March, followed by the maximum H_{mo} (at Gauge 630) of 3.4 m (T_p = 11.6 sec) which was recorded later that afternoon at 2116 EST. The minimum atmospheric pressure at the FRF was 989 mb. There was 77 mm of precipitation.

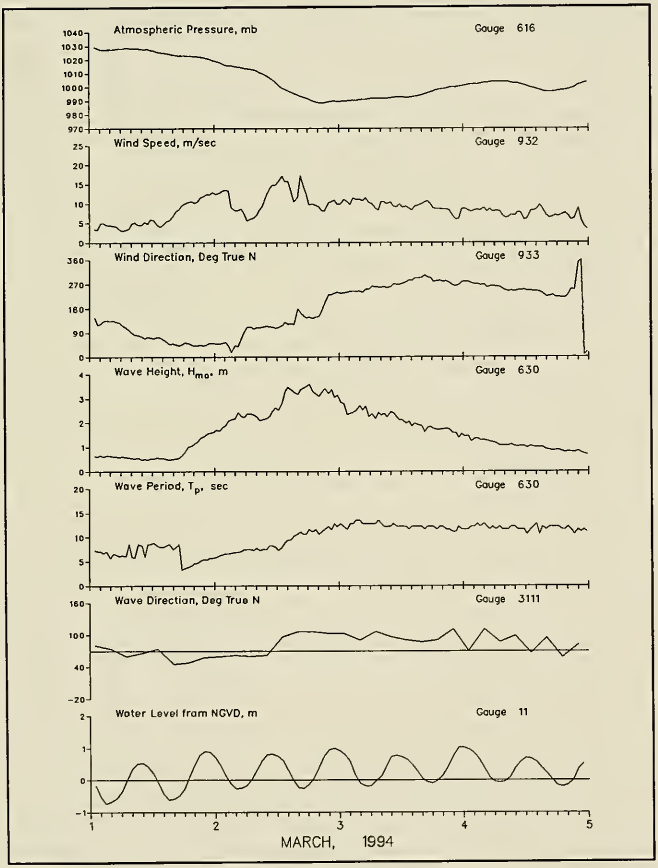


Figure 30. Data for 2-3 March 1994 storm

4 May 1994 (Figure 31)

Forming off the North Carolina coast early on 4 May and then rapidly moving offshore, this intense storm produced maximum onshore winds (from northeast) at the FRF approaching 19 m/sec at 1000 EST on 4 May. The maximum H_{mo} (at Gauge 630) of 4.11 m (T_p = 9.1 sec) was measured soon after at 1034 EST. The minimum atmospheric pressure recorded at the FRF was 1006 mb. There was 84 mm of precipitation.

Figure 31. Data for 4 May 1994 storm

20-21 May 1994 (Figure 32)

Strong winds associated with a high pressure system reached 15 m/sec (from northeast) at 0808 EST on 21 May. The maximum H_{mo} (at Gauge 625) reached 2.19 m (T_p = 6.00 sec) at 1000 EST on 21 May.

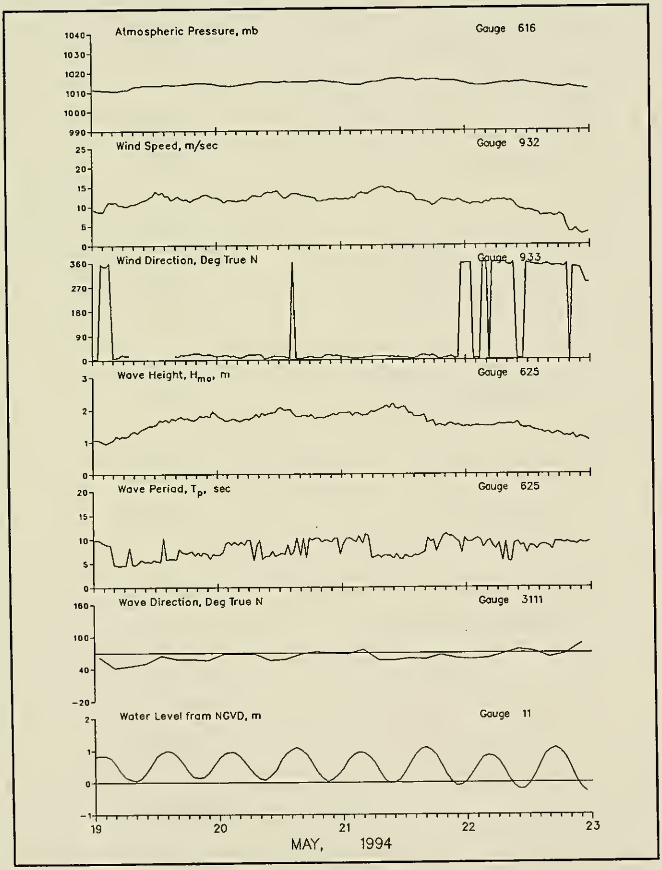


Figure 32. Data for 20-21 May 1994 storm

3-5 September 1994 (Figure 33)

A combination of a Canadian high pressure system and a low off the North Carolina coast produced onshore winds (from northeast) of 16 m/sec at 1000 EST on 4 September. The maximum H_{mo} (at Gauge 630) reached 2.9 m (T_p = 8.0 sec) at 1300 EST also on 4 September. There was 10 mm of precipitation.

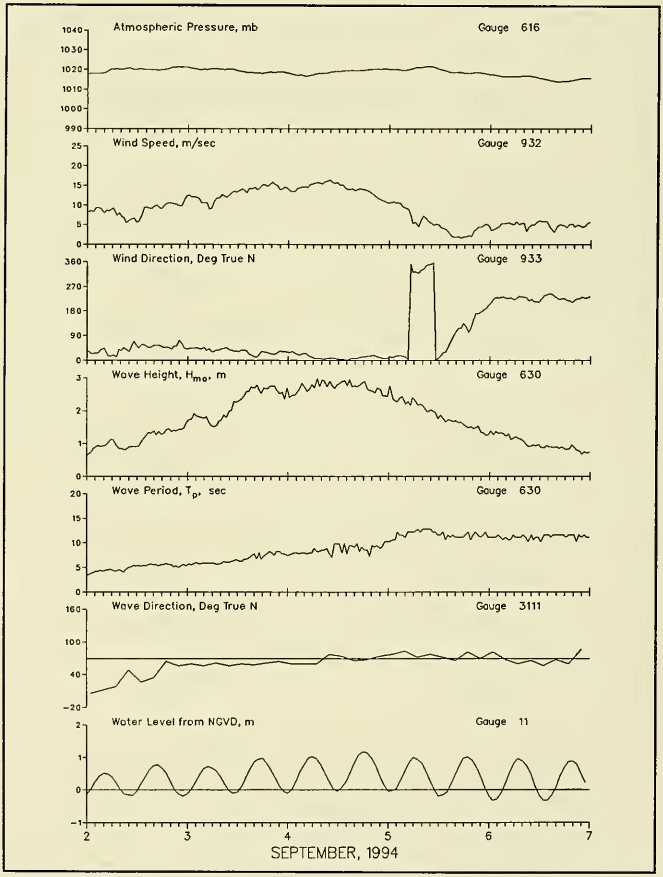


Figure 33. Data for 3-5 September 1994 storm

22 September 1994 (Figure 34)

Northeasterly winds associated with a western high pressure system and a low pressure system northeast of the FRF reached 17 m/sec at 0316 EST on 22 September. Also measured at the same time was the maximum H_{mo} (at Gauge 625) of 2.4 m (T_p = 8.26 sec). There was 64 mm of precipitation.

Figure 34. Data for 22 September 1994 storm

3 October 1994 (Figure 35)

A combination of a Canadian high pressure system and a storm located southest of Cape Hatteras, NC generated strong onshore winds. The maximum H_{mo} (at Gauge 625) of 2.3 m (T_p = 6.7 sec) was attained at 1334 EST on 3 October. Maximum winds (from northeast) reached 15 m/sec several hours earlier at 1100 EST. There was no precipitaion.

Figure 35. Data for 3 October 1994 storm

12-13 October 1994 (Figure 36)

Northeasterly winds associated with a high pressure system over New England and and a developing low in the Gulf of Mexico began to increase at the FRF on 11 October. Crossing Florida, the storm continued to intensify as it stalled south of Cape Hatteras, NC. Blocked by a northern high pressure system the storm slowly weakened. Maximum onshore winds (from northeast) reached 15 m/sec at 2116 EST on 12 October. The maximum H_{mo} (at Gauge 625) was 2.3 m (T_p = 6.9 sec) at 1742 also on 12 October. There was no precipitation.

Figure 36. Data for 12-13 October 1994 storm

14-17 October 1994 (Figure 37)

The weak storm located southeast of Cape Hatteras, NC, on 13 October re-intensified as it approached the North Carolina coast. Maximum onshore winds (from northeast) reached 20 m/sec at 1816 EST on 14 October. The maximum H_{mo} (at Gauge 630) reached 4.5 m (T_p = 11.1 sec) at 1300 EST on 15 October. There was 92 mm of precipitation.

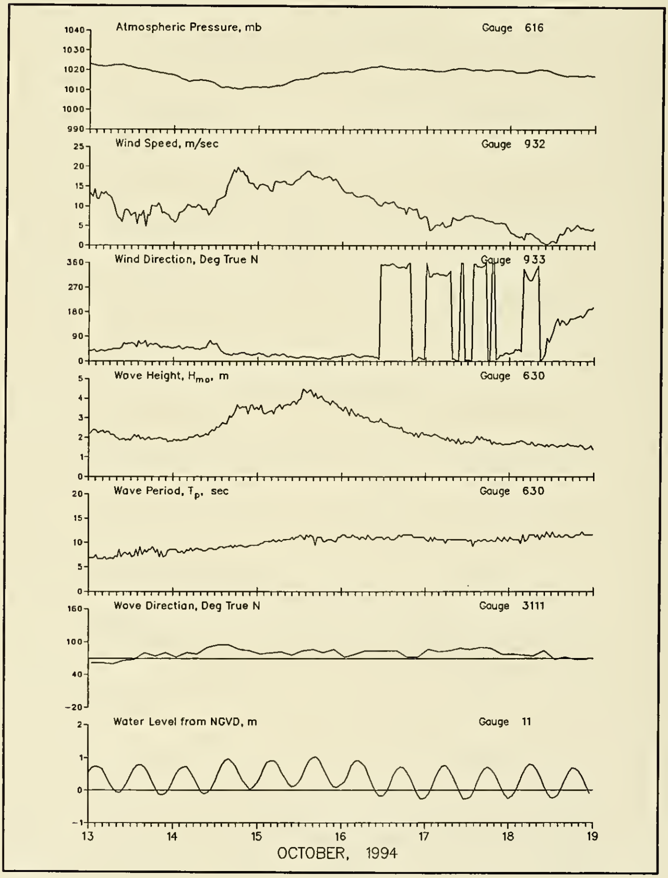


Figure 37. Data for 14-17 October 1994 storm

7 November 1994 (Figure 38)

Northeasterly winds produced by a Canadian high pressure system generated storm waves at the FRF. The maximum H_{mo} (at Gauge 625) was 2.00 m (T_p = 7.1 sec) at 0916 EST on 7 November. Onshore winds reached 17 m/sec at 0616 EST. There was no precipitation.

Figure 38. Data for 7 November 1994 storm

10 November 1994 (Figure 39)

Following the passage of a cold front strong northeasterly winds (16 m/sec) generated a maximum H_{mo} (at Gauge 625) of 2.3 m (T_p = 7.5 sec) at 1334 EST on 10 November. There was 41 mm of precipitation.

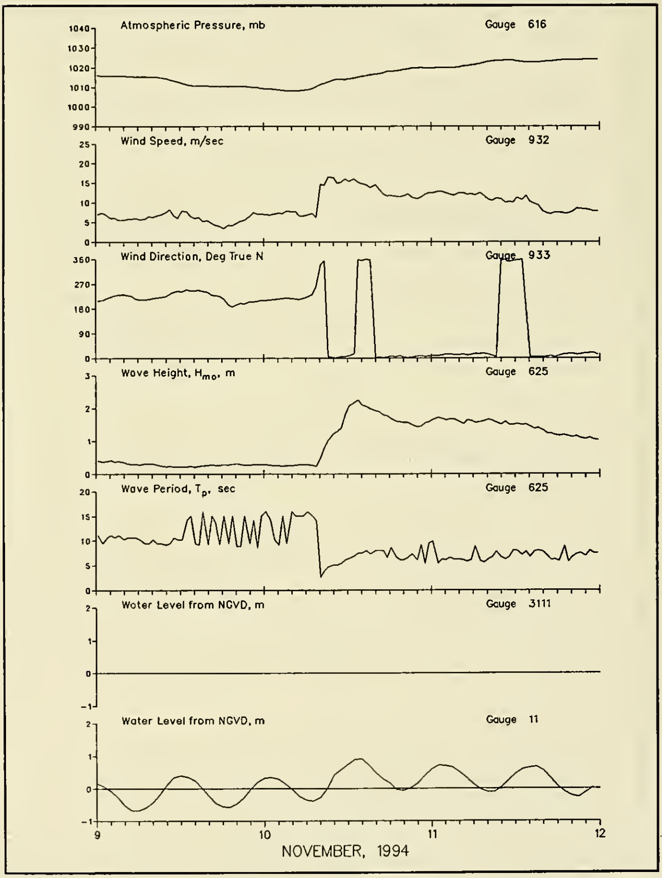


Figure 39. Data for 10 November 1994 storm

16-19 November 1994 (Figure 40)

While still located over southern Florida, Tropical Storm "Gordon's" interaction with a strong Canadian high pressure system produced northeasterly winds of 15 m/sec at 1816 EST on 16 November. Crossing Florida into the Atlantic, "Gordon" was located approximately 560 km south of Cape Hatteras, NC, on the morning of 17 November. Continuing to intensify, "Gordon" had, by early 18 November, been upgraded to a hurricane, before turning south to rapidly weaken and finally dissipate. The maximum H_{mo} (at Gauge 630) reached 5.0 m (T_p = 12.8 sec) at 2342 EST on 17 November before the gauge broke free from its mooring. Minimum atmospheric pressure at the FRF was 1005 mb. There was 192 mm precipitation.

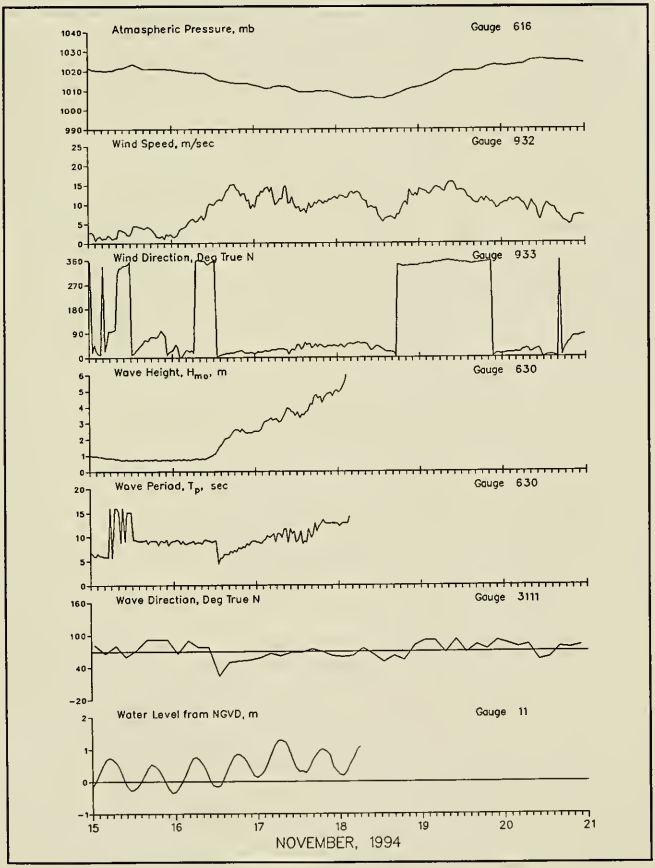


Figure 40. Data for 16-19 November 1994 Hurricane "Gordon"

8 December 1994 (Figure 41)

A Canadian high pressure system produced onshore winds (from the northeast) which peaked at 0700 EST on 8 December at 18 m/sec. The maximum H_{mo} (at Gauge 625) was 2.2 m (T_p = 6.9 sec) at 0808 EST. There was no precipitation.

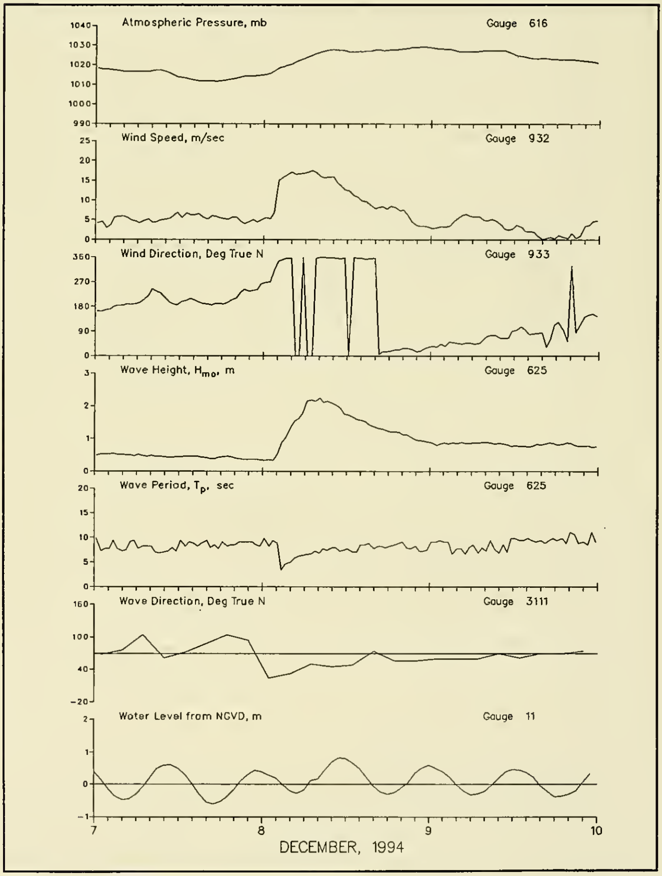


Figure 41. Data for 8 December 1994 storm

14-19 December 1994 (Figure 42)

A Canadian high pressure system produced onshore winds (from the northeast) which peaked at 1742 EST on 14 December at 17 m/sec. The developement of a low pressure system off Cape Hatteras, NC, early on 18 December sustained the winds for another day. The maximum H_{mo} (at Gauge 630) was 3.8 m (T_p = 9.1 sec) at 2116 EST on 14 December. There was 34 mm of precipitation.

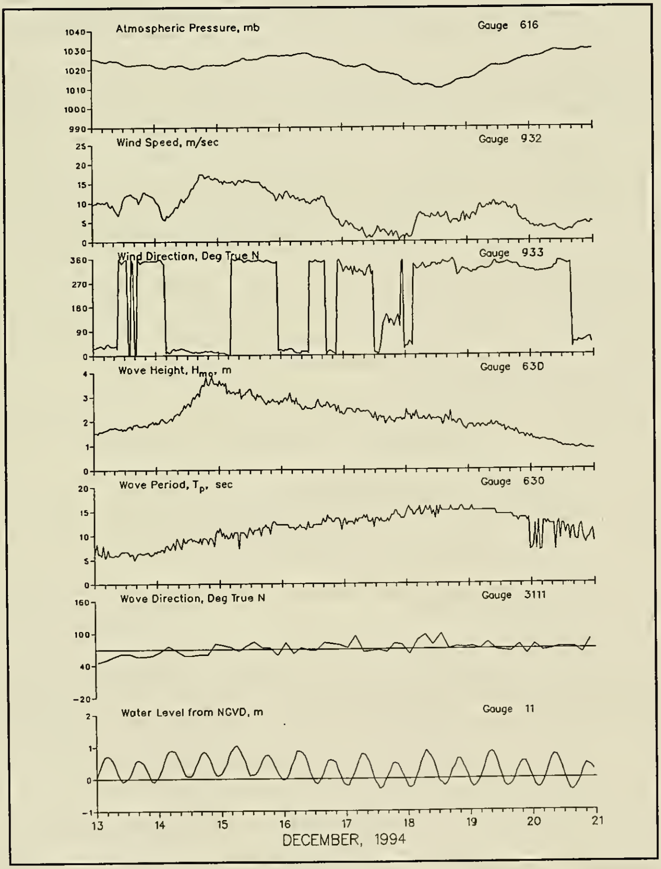


Figure 42. Data for 14-19 December 1994 storm

22-24 December 1994 (Figure 43)

Developing as the dominant storm from a pair of low pressure systems well off the North Carolina coast, this storm rapidly intensified as it passed Cape Hatteras, NC. The maximum H_{mo} (at Gauge 630) was 4.6 m (T_p = 12.8 sec) at 2308 EST on 23 December. Maximum onshore winds (from northeast) reached 21 m/sec at 2308 EST also on 23 December. The minimum atmospheric pressure at the FRF was 995 mb. There was 17 mm of precipitation.

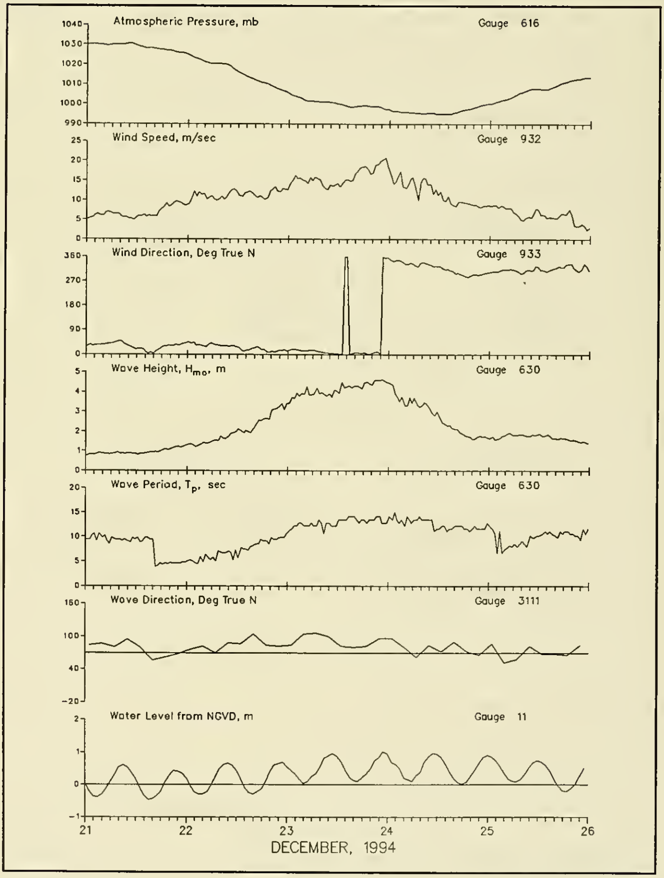


Figure 43. Data for 22-24 December 1994 storm

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Appendix A
Survey Data

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-meter increments referenced to the National Geodetic Vertical Datum (NGVD). The distance offshore is referenced to the Field Research Facility (FRF) monumentation baseline behind the dune.

Changes 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.

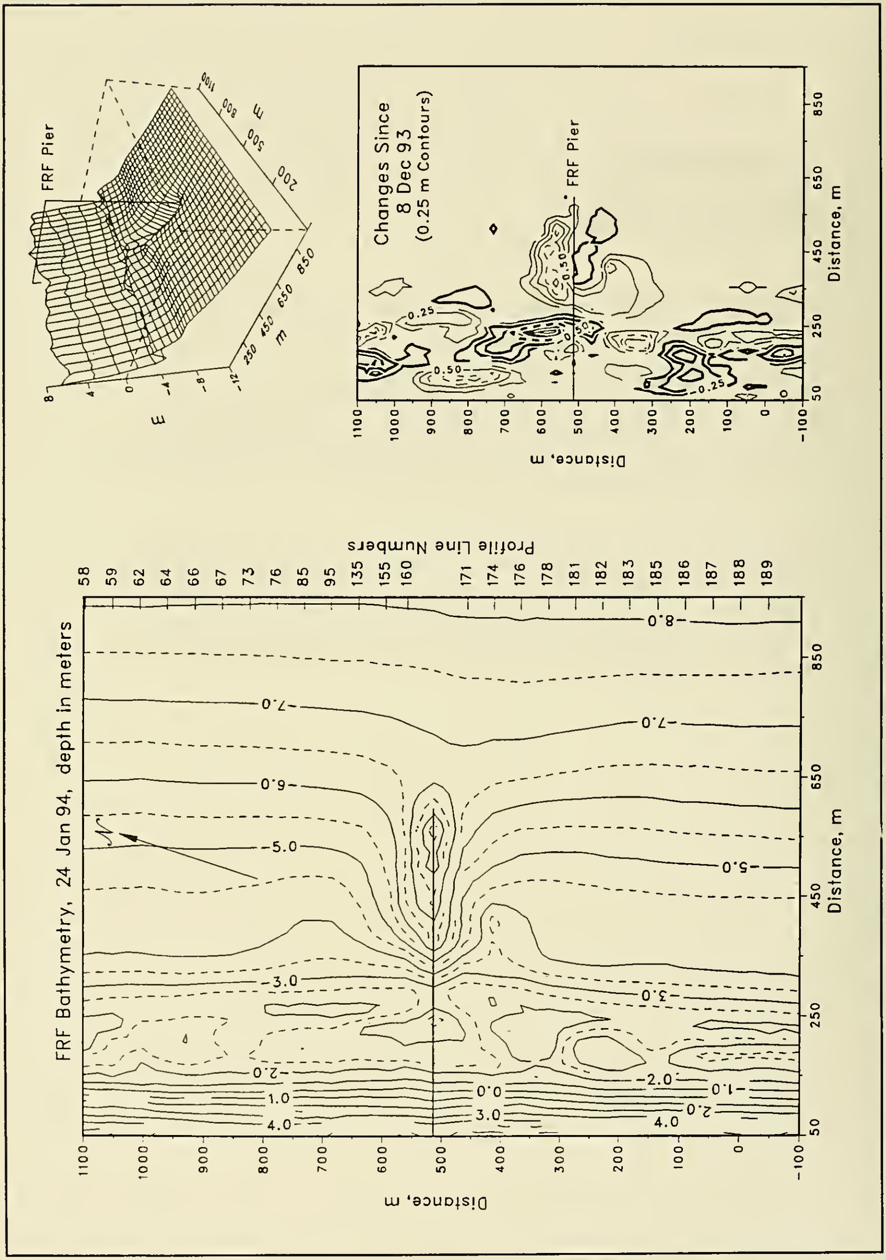


Figure A1. FRF bathymetry, 24 January 94 (depths relative to NGVD)

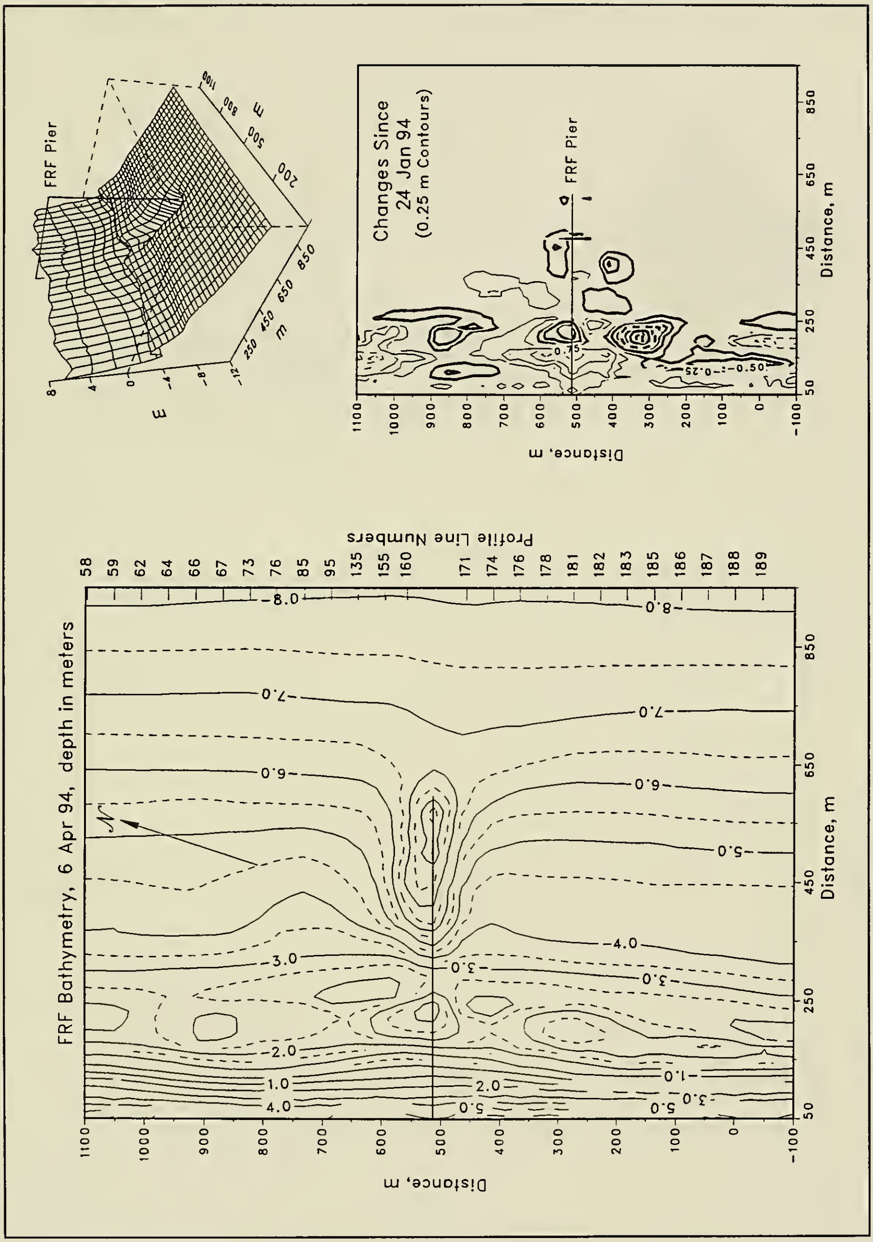


Figure A2. FRF bathymetry, 6 April 94 (depths relative to NGVD)

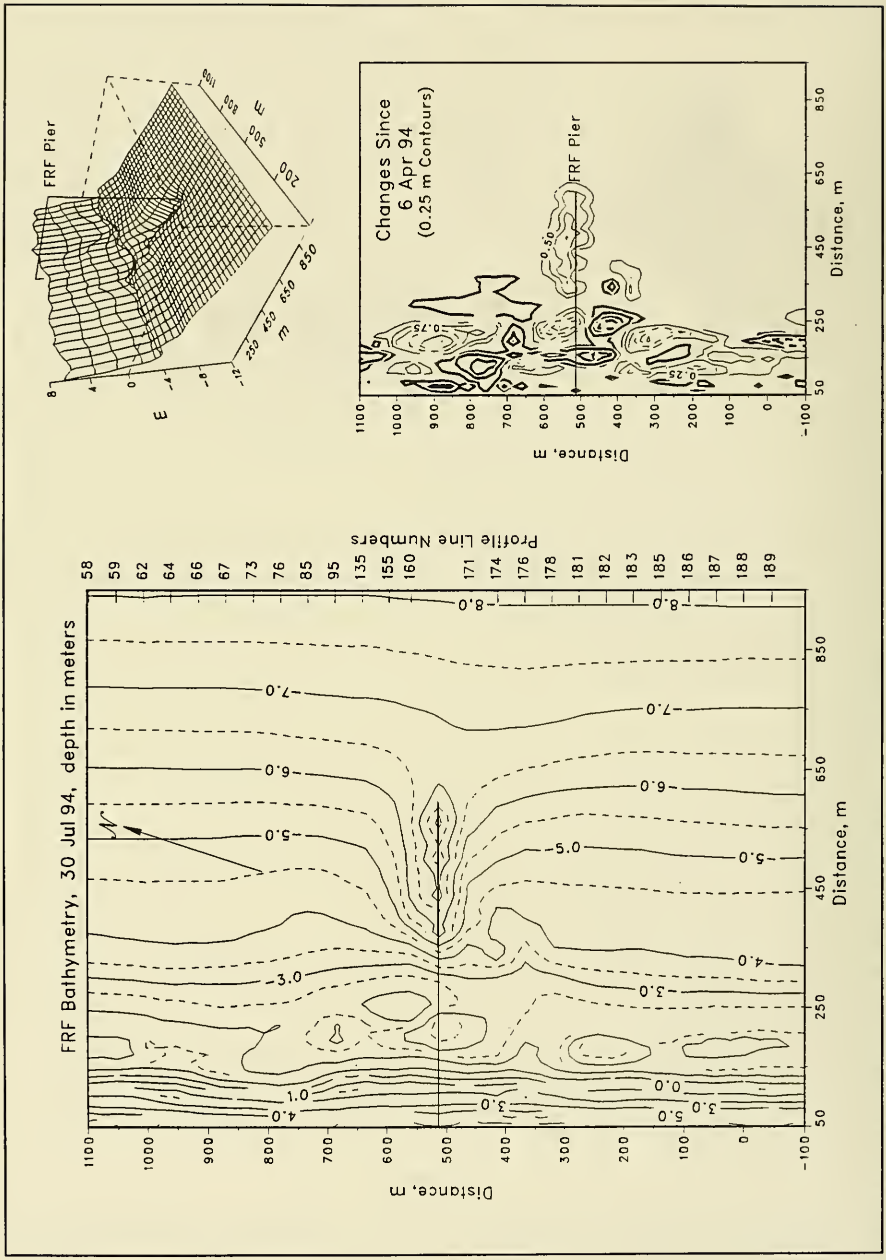


Figure A3. FRF bathymetry, 30 July 94 (depths relative to NGVD)

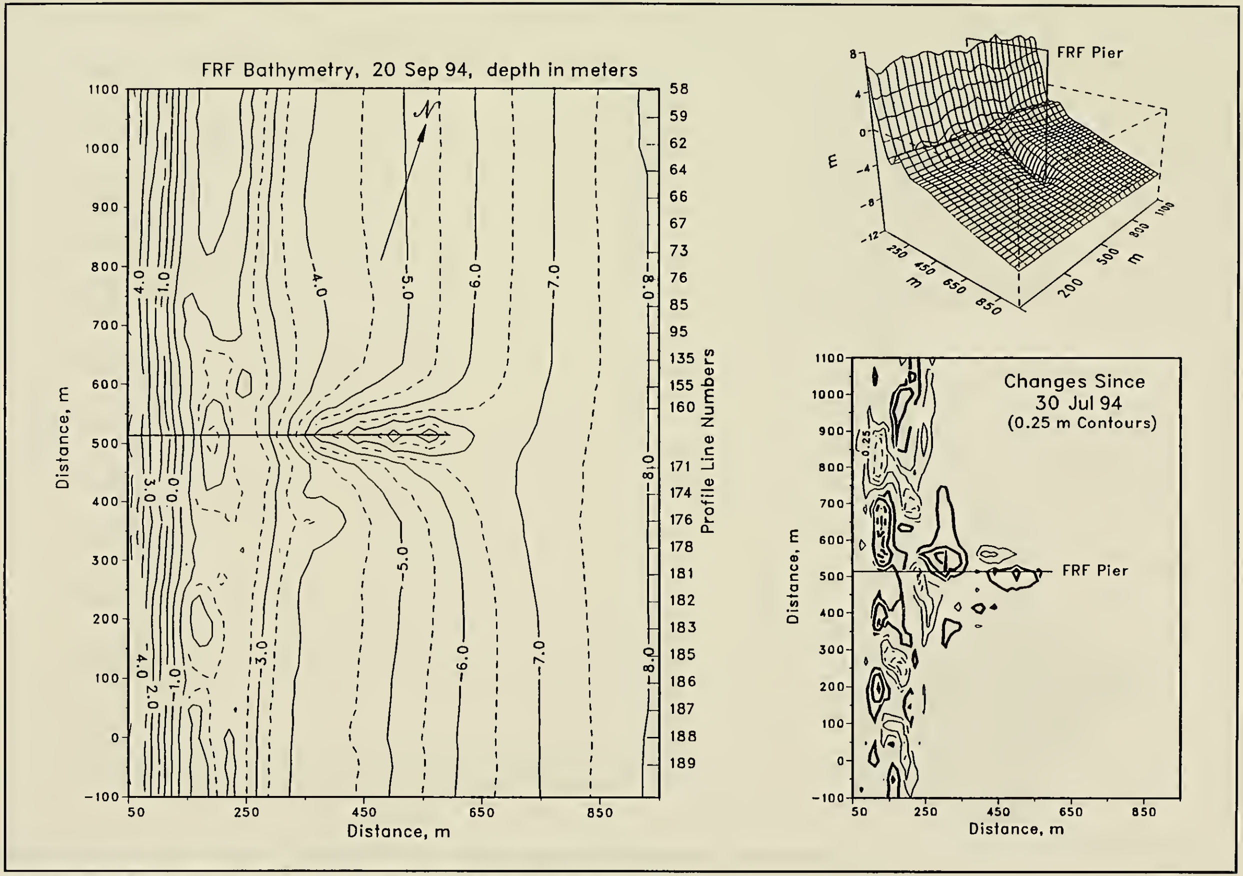


Figure A4. FRF bathymetry, 20 September 94 (depths relative to NGVD)

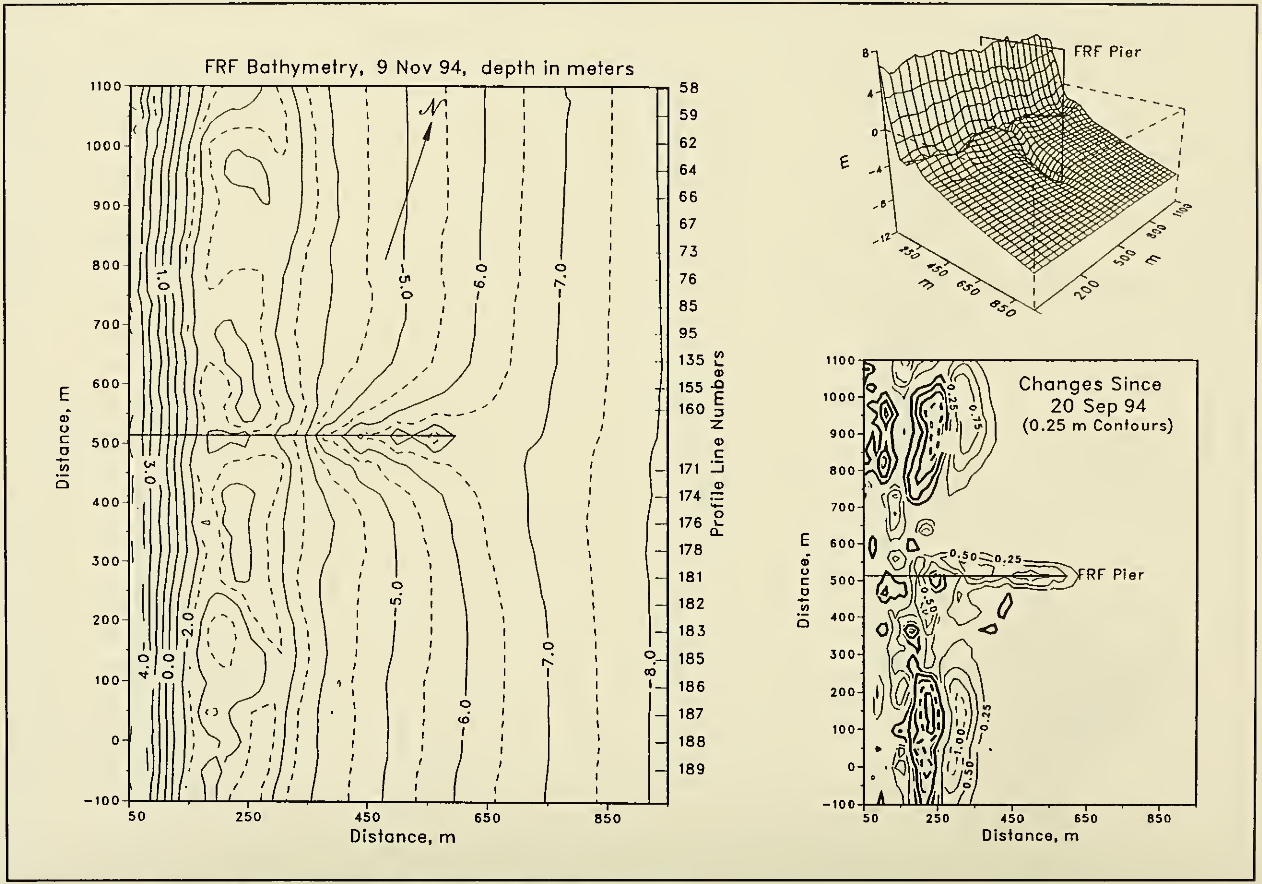


Figure A5. FRF bathymetry, 9 November 94 (depths relative to NGVD)

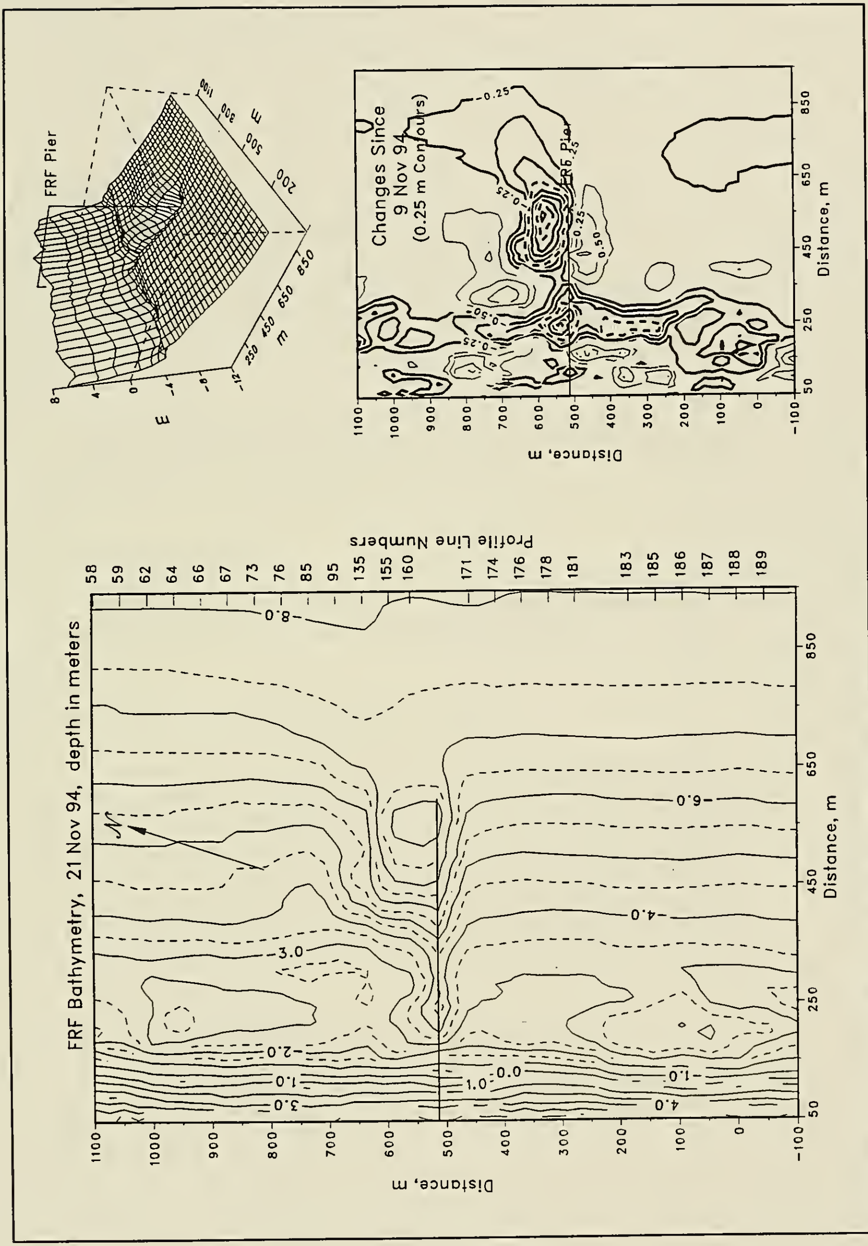


Figure A6. FRF bathymetry, 21 November 94 (depths relative to NGVD)

Appendix B
Wave Data for Gauge 630

Wave data summaries for Gauge 630 for 1994 and for 1980 through 1994 are presented in the following pages.

Daily H_{mo} and T_p

Figure B1 displays the individual wave height H_{mo} and peak spectral wave period T_p values, along with the monthly mean values.

Joint Distributions of H_{mo} and T_p

Annual and monthly joint distribution tables are presented in Tables B1 and B2, and data for 1980 through 1994 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 percentages by dividing by 100. Marginal totals are also included. The row total gives the number of observations out of 10,000 that fell within each specified peak period interval. The column total gives the number of observations out of 10,000 that fell within each specified wave height interval.

Cumulative Distributions of Wave Height

Annual and monthly wave height distributions for 1994 are plotted in cumulative form in Figures B2 and B3. Data for 1980 through 1994 are plotted in Figure B4.

Peak Spectral Wave Period Distributions

Annual and monthly peak wave period T_p distribution histograms for 1994 are presented in Figures B5 and B6. Data for 1980 through 1994 are presented in Figure B7.

Persistence of Wave Heights

Table B5 shows the number of times in 1994 when the specified wave height was equaled or exceeded at least once during each day for the duration (consecutive days). Data for 1980 through 1994 are averaged and 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 three times the height exceeded 1 m for shorter durations.

Spectra

Monthly spectra for the offshore Waverider buoy (Gauge 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 three-dimensional 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.

Monthly and annual wave statistics for Gauge 630 for 1994 and for 1980 through 1994 are presented in Table B7.

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

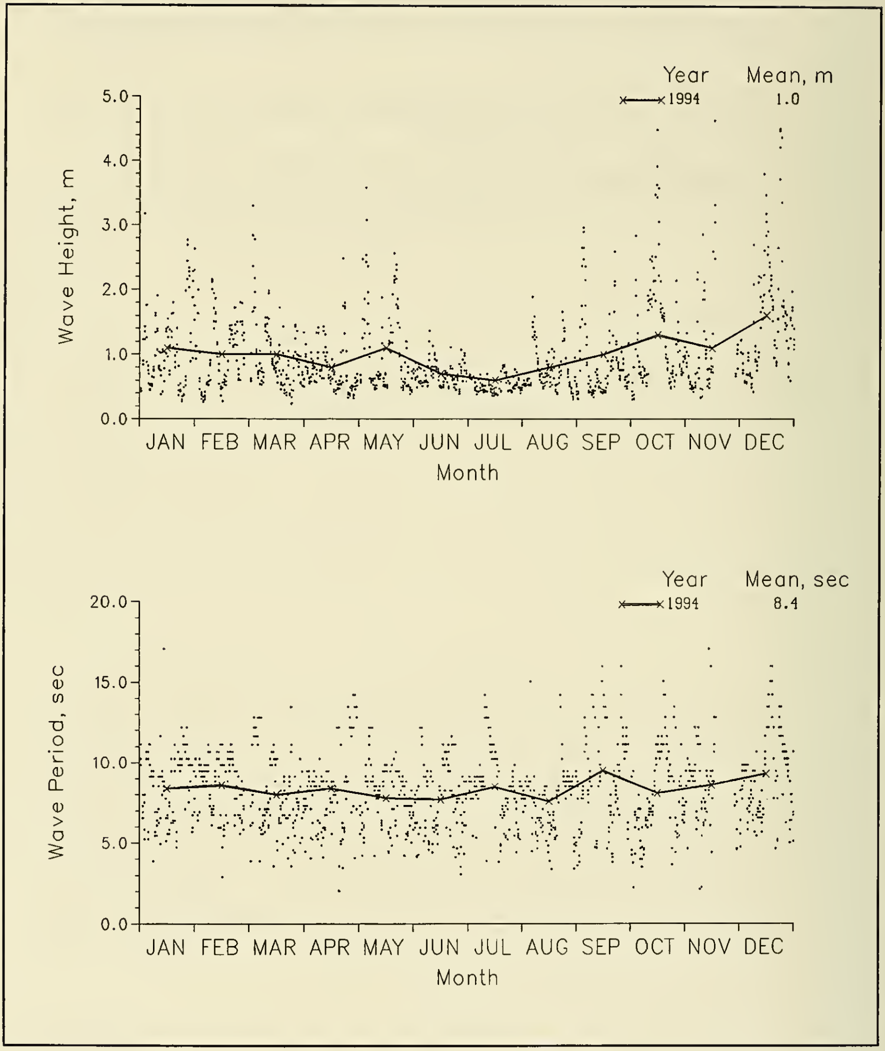


Figure B1. 1994 daily wave height and period values with monthly means for Gauge 630

Table B1
Annual Joint Distribution of H_{mo} versus T_p

Annual 1994, Gauge 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	29	14	22	65	43	115	459	416	244	158	108	.	1673
0.50 - 0.99	7	108	359	502	667	617	1055	861	581	57	273	14	5101
1.00 - 1.49	.	22	151	395	237	151	187	158	194	22	57	.	1574
1.50 - 1.99	.	.	.	172	273	115	57	36	136	29	57	.	875
2.00 - 2.49	.	.	.	14	143	86	36	29	50	7	50	.	415
2.50 - 2.99	.	.	.	.	14	50	36	22	22	7	36	.	187
3.00 - 3.49	.	.	.	.	.	7	7	14	50	7	.	.	85
3.50 - 3.99	.	.	.	.	.	.	.	22	22	.	.	.	44
4.00 - 4.49	.	.	.	.	.	.	.	.	7	14	7	.	28
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	14	.	14
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	7	.	7
Total	36	144	532	1148	1377	1141	1837	1558	1306	301	609	14	

Table B2
Monthly Joint Distribution of H_{mo} versus T_p

January 1994, Gauge 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	.	.	.	.	.	.	82	738	902	.	82	.	1804
0.50 - 0.99	.	82	82	410	246	164	410	1148	820	.	.	82	3444
1.00 - 1.49	.	.	82	820	656	246	410	246	164	.	.	.	2624
1.50 - 1.99	.	.	.	164	656	82	.	82	82	.	.	.	1066
2.00 - 2.49	.	.	.	82	82	164	82	82	246	.	.	.	738
2.50 - 2.99	.	.	.	.	.	82	.	.	82	.	82	.	246
3.00 - 3.49	.	.	.	.	.	82	.	.	.	.	.	.	82
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	82	164	1476	1640	820	984	2296	2296	0	164	82	

February 1994, Gauge 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	.	92	1284	183	.	.	.	1743
0.50 - 0.99	.	.	92	367	459	275	642	1101	917	.	.	.	3853
1.00 - 1.49	.	.	.	92	183	275	275	734	1101	.	.	.	2660
1.50 - 1.99	.	.	.	92	734	183	92	275	.	.	.	.	1376
2.00 - 2.49	.	.	.	.	275	92	.	.	.	.	.	.	367
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	92	0	92	551	1743	825	1101	3394	2201	0	0	0	

March 1994, Gauge 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	163	81	325	163	163	81	.	.	1138
0.50 - 0.99	.	81	244	569	894	1220	650	407	1057	.	325	.	5447
1.00 - 1.49	.	163	163	244	732	325	163	163	244	.	81	.	2278
1.50 - 1.99	.	.	.	81	325	163	.	.	81	.	81	.	731
2.00 - 2.49	.	.	.	.	.	81	.	.	.	.	81	.	162
2.50 - 2.99	.	.	.	.	.	.	81	.	.	.	81	.	162
3.00 - 3.49	.	.	.	.	.	.	.	.	81	.	.	.	81
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	325	407	975	2114	1870	1219	733	1626	81	649	0	

(Continued)

(Sheet 1 of 4)

Table B2 (Continued)

April 1994, Gauge 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	.	.	.	.	.	.	593	.	85	424	678	.	1780
0.50 - 0.99	85	85	339	593	678	932	1780	932	254	254	424	.	6356
1.00 - 1.49	.	85	169	678	85	254	169	.	.	.	.	.	1440
1.50 - 1.99	.	.	.	339	.	.	.	.	.	.	.	.	339
2.00 - 2.49	.	.	.	.	85	.	.	.	.	.	.	.	85
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	170	508	1610	848	1186	2542	932	339	678	1102	0	

May 1994, Gauge 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	.	.	.	.	242	323	403	161	.	.	.	.	1129
0.50 - 0.99	.	.	161	565	484	565	1774	968	161	.	242	.	4920
1.00 - 1.49	.	.	323	726	161	.	161	323	81	.	81	.	1856
1.50 - 1.99	.	.	.	323	161	323	81	81	81	.	.	.	1050
2.00 - 2.49	.	.	.	.	242	81	161	161	81	.	.	.	726
2.50 - 2.99	.	.	.	.	.	161	.	.	.	.	.	.	161
3.00 - 3.49	.	.	.	.	.	.	81	.	.	.	.	.	81
3.50 - 3.99	.	.	.	.	.	.	.	81	.	.	.	.	81
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	0	484	1614	1290	1453	2661	1775	404	0	323	0	

June 1994, Gauge 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	.	.	.	.	.	252	504	84	252	.	.	.	1092
0.50 - 0.99	.	168	1008	1092	1345	840	1345	1092	1008	.	336	.	8234
1.00 - 1.49	.	.	168	420	.	.	84	.	.	.	.	.	672
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	0	168	1176	1512	1345	1092	1933	1176	1260	0	336	0	

(Continued)

(Sheet 2 of 4)

Table B2 (Continued)

July 1994, Gauge 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	.	.	172	259	.	517	1638	776	1121	345	86	.	4914
0.50 - 0.99	.	172	172	948	517	862	1121	603	172	.	517	.	5084
1.00 - 1.49	.	.	.	.	.	.	.	.	.	.	.	.	0
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	0	172	344	1207	517	1379	2759	1379	1293	345	603	0	

August 1994, Gauge 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	.	.	.	331	.	.	744	248	.	.	.	.	1323
0.50 - 0.99	.	248	413	744	1322	661	2645	413	.	248	83	.	6777
1.00 - 1.49	.	.	165	413	83	248	248	248	83	.	.	.	1488
1.50 - 1.99	.	.	.	83	83	83	.	.	165	.	.	.	414
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	0	248	578	1571	1488	992	3637	909	248	248	83	0	

September 1994, Gauge 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	.	.	.	167	583	417	83	1000	417	.	2750
0.50 - 0.99	.	167	667	167	333	333	417	417	1333	.	750	.	4584
1.00 - 1.49	.	.	83	333	83	83	167	.	167	83	250	.	1249
1.50 - 1.99	.	.	.	333	.	.	83	.	.	.	83	.	499
2.00 - 2.49	.	.	.	.	167	83	.	83	83	.	83	.	499
2.50 - 2.99	.	.	.	.	.	83	250	83	.	.	.	.	416
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	250	750	833	583	749	1500	1000	1666	1083	1583	0	

(Continued)

(Sheet 3 of 4)

Table B2 (Concluded)

October 1994, Gauge 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	.	.	.	.	403	.	.	.	.	565
0.50 - 0.99	.	242	887	242	968	484	484	565	484	161	242	.	4759
1.00 - 1.49	.	.	161	323	161	81	.	.	.	161	81	.	968
1.50 - 1.99	.	.	.	323	484	81	161	.	645	81	161	.	1936
2.00 - 2.49	.	.	.	.	484	161	81	.	161	.	.	.	887
2.50 - 2.99	.	.	.	.	81	81	81	.	81	.	.	.	324
3.00 - 3.49	.	.	.	.	.	.	.	81	161	.	.	.	242
3.50 - 3.99	.	.	.	.	.	.	.	81	161	.	.	.	242
4.00 - 4.49	.	.	.	.	.	.	.	.	81	.	.	.	81
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	81	242	1129	888	2178	888	807	1130	1774	403	484	0	

November 1994, Gauge 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	267	.	.	133	.	.	533	933	133	.	.	.	1999
0.50 - 0.99	.	.	133	.	400	667	933	1600	533	.	267	133	4666
1.00 - 1.49	.	.	400	133	267	133	267	133	.	.	133	.	1466
1.50 - 1.99	.	.	.	.	267	267	.	.	.	.	.	.	534
2.00 - 2.49	.	.	.	133	267	.	133	.	.	.	.	.	533
2.50 - 2.99	.	.	.	.	.	267	.	.	.	.	.	.	267
3.00 - 3.49	.	.	.	.	.	.	.	.	267	.	.	.	267
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	133	.	133
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	133	.	133
Total	267	0	533	399	1201	1334	1866	2666	933	0	666	133	

December 1994, Gauge 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	.	.	.	.	162
0.50 - 0.99	.	.	.	163	244	407	407	1382	244	.	81	.	2928
1.00 - 1.49	.	.	163	407	407	163	325	81	488	.	81	.	2115
1.50 - 1.99	.	.	.	244	569	244	244	.	488	244	325	.	2358
2.00 - 2.49	.	.	.	.	163	325	.	.	.	81	407	.	976
2.50 - 2.99	.	.	.	.	81	.	.	163	81	81	244	.	650
3.00 - 3.49	.	.	.	.	.	.	.	81	163	81	.	.	325
3.50 - 3.99	.	.	.	.	.	.	.	81	81	.	.	.	162
4.00 - 4.49	.	.	.	.	.	.	.	.	.	163	81	.	244
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	81	.	81
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	0	163	814	1464	1139	1057	1869	1545	650	1300	0	

(Sheet 4 of 4)

Table B3
Annual Joint Distribution of H_{mo} versus T_p (All Years)

Annual 1980-1994, Gauge 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	25	15	28	63	80	123	356	293	194	68	119	4	1368
0.50 - 0.99	32	135	271	490	570	536	915	773	764	125	225	14	4850
1.00 - 1.49	.	10	147	405	404	237	274	216	318	39	112	3	2165
1.50 - 1.99	.	.	11	166	244	106	82	76	137	32	66	3	923
2.00 - 2.49	.	.	1	25	93	68	52	33	62	26	34	1	395
2.50 - 2.99	.	.	.	1	14	34	20	15	34	9	25	1	153
3.00 - 3.49	.	.	.	.	1	11	13	13	21	6	8	1	74
3.50 - 3.99	.	.	.	.	.	1	6	9	13	5	5	.	39
4.00 - 4.49	.	.	.	.	.	.	3	5	8	3	4	1	24
4.50 - 4.99	.	.	.	.	.	.	.	1	2	.	1	1	5
5.00 - Greater	.	.	.	.	.	.	1	.	1	1	1	1	5
Total	57	160	458	1150	1406	1116	1722	1434	1554	314	600	30	

Table B4
Monthly Joint Distribution of H_{mo} versus T_p (All Years)

January 1980-1994, Gauge 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	80	7	7	67	60	33	134	294	254	40	94	.	1070
0.50 - 0.99	60	180	201	388	368	321	408	749	809	87	187	7	3765
1.00 - 1.49	.	13	167	635	535	254	261	214	461	20	47	7	2614
1.50 - 1.99	.	.	27	328	434	160	87	107	214	33	47	.	1437
2.00 - 2.49	.	.	.	40	154	180	94	33	120	33	20	7	681
2.50 - 2.99	.	.	.	.	20	74	53	27	67	13	53	.	307
3.00 - 3.49	.	.	.	.	.	27	27	7	33	.	.	.	94
3.50 - 3.99	.	.	.	.	.	.	.	7	13	.	.	.	20
4.00 - 4.49	.	.	.	.	.	.	.	.	7	.	.	.	7
4.50 - 4.99	.	.	.	.	.	.	.	.	7	.	.	.	7
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	140	200	402	1458	1571	1049	1064	1438	1985	226	448	21	

February 1980-1994, Gauge 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	15	.	7	44	59	44	81	170	96	22	89	.	627
0.50 - 0.99	44	81	163	385	459	318	503	703	1050	15	148	7	3876
1.00 - 1.49	.	7	141	599	570	259	311	362	547	67	185	.	3048
1.50 - 1.99	.	.	7	214	362	178	118	141	170	67	89	.	1346
2.00 - 2.49	.	.	.	74	163	59	37	67	81	52	89	.	622
2.50 - 2.99	.	.	.	7	22	59	37	7	89	15	52	7	295
3.00 - 3.49	.	.	.	.	.	22	7	22	30	15	15	.	111
3.50 - 3.99	.	.	.	.	.	.	.	7	7	.	7	.	21
4.00 - 4.49	.	.	.	.	.	.	.	7	30	.	7	.	44
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	7	.	.	.	.	.	7
Total	59	88	318	1323	1635	939	1101	1486	2100	253	681	14	

March 1980-1994, Gauge 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	6	12	6	18	41	47	136	53	171	59	101	.	650
0.50 - 0.99	12	71	195	402	497	479	603	627	887	95	231	.	4099
1.00 - 1.49	.	18	213	420	514	308	319	278	651	53	278	.	3052
1.50 - 1.99	.	.	12	219	260	112	95	130	266	59	112	.	1265
2.00 - 2.49	.	.	.	30	59	47	83	59	118	24	83	.	503
2.50 - 2.99	.	.	.	.	30	18	30	6	53	12	35	6	190
3.00 - 3.49	.	.	.	.	6	12	6	12	47	6	6	.	95
3.50 - 3.99	.	.	.	.	.	.	.	18	47	.	18	.	83
4.00 - 4.49	.	.	.	.	.	.	6	12	18	.	18	.	54
4.50 - 4.99	.	.	.	.	.	.	.	.	12	.	.	.	12
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	18	101	426	1089	1407	1023	1278	1195	2270	308	882	6	

(Continued)

(Sheet 1 of 4)

Table B4 (Continued)

April 1980-1994, Gauge 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	6	12	18	36	30	24	257	162	126	96	138	.	905
0.50 - 0.99	72	174	228	479	599	509	904	814	1006	234	383	.	5402
1.00 - 1.49	.	12	108	293	353	311	341	311	329	66	120	.	2244
1.50 - 1.99	.	.	6	168	132	72	84	84	186	18	66	.	816
2.00 - 2.49	.	.	.	30	66	24	42	48	84	24	6	.	324
2.50 - 2.99	.	.	.	6	18	18	30	18	42	24	12	.	168
3.00 - 3.49	.	.	.	.	.	24	12	24	24	6	.	.	90
3.50 - 3.99	.	.	.	.	.	6	24	.	6	.	.	.	36
4.00 - 4.49	.	.	.	.	.	.	6	.	6	.	.	.	12
4.50 - 4.99	.	.	.	.	.	.	.	6	.	.	.	.	6
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	78	198	360	1012	1198	988	1700	1467	1809	468	725	0	

May 1980-1994, Gauge 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	6	18	41	88	140	146	356	298	198	64	128	.	1483
0.50 - 0.99	18	187	362	560	531	788	1255	1010	677	88	204	6	5686
1.00 - 1.49	.	6	169	251	292	169	356	263	269	12	76	.	1863
1.50 - 1.99	.	.	6	88	88	64	105	76	111	18	47	.	603
2.00 - 2.49	.	.	.	12	64	53	23	41	12	18	18	.	241
2.50 - 2.99	.	.	.	.	23	18	6	6	6	12	6	.	77
3.00 - 3.49	.	.	.	.	.	.	18	6	6	6	6	.	42
3.50 - 3.99	.	.	.	.	.	.	.	6	6	.	.	.	12
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	24	211	578	999	1138	1238	2119	1706	1285	218	485	6	

June 1980-1994, Gauge 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	19	25	38	100	163	301	639	482	276	31	25	.	2099
0.50 - 0.99	38	188	394	651	808	783	1653	1033	564	125	131	.	6368
1.00 - 1.49	.	6	113	257	207	163	182	81	81	.	31	.	1121
1.50 - 1.99	.	.	13	44	81	44	25	13	75	.	38	.	333
2.00 - 2.49	.	.	.	.	19	13	38	6	.	.	.	.	76
2.50 - 2.99	.	.	.	.	.	6	.	.	.	.	.	.	6
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	57	219	558	1052	1278	1310	2537	1615	996	156	225	0	

(Continued)

(Sheet 2 of 4)

Table B4 (Continued)

July 1980-1994, Gauge 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	18	74	147	196	424	1197	755	325	98	172	12	3430
0.50 - 0.99	31	184	374	700	798	737	1320	915	356	166	135	49	5765
1.00 - 1.49	.	12	49	166	203	74	104	31	31	.	.	.	670
1.50 - 1.99	.	.	.	37	6	12	18	12	31	.	.	.	116
2.00 - 2.49	.	.	.	6	.	.	6	.	.	.	.	.	12
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	43	214	497	1056	1203	1247	2645	1713	743	264	307	61	

August 1980-1994, Gauge 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	18	24	60	115	139	193	616	465	284	60	79	.	2053
0.50 - 0.99	30	121	284	550	822	798	1456	840	719	145	254	30	6049
1.00 - 1.49	.	6	127	302	260	193	236	139	91	12	30	.	1396
1.50 - 1.99	.	.	.	66	115	48	24	12	42	.	30	.	337
2.00 - 2.49	.	.	.	12	24	12	12	.	24	6	6	.	96
2.50 - 2.99	.	.	.	.	6	.	12	.	12	.	6	.	36
3.00 - 3.49	.	.	.	.	6	6	6	.	6	.	.	.	24
3.50 - 3.99	.	.	.	.	.	.	.	6	.	.	.	.	6
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	48	151	471	1045	1372	1250	2362	1462	1178	223	405	30	

September 1980-1994, Gauge 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	6	12	18	30	30	67	230	248	181	157	103	6	1088
0.50 - 0.99	.	121	242	387	484	568	955	786	979	121	290	.	4933
1.00 - 1.49	.	12	79	459	453	284	435	224	302	79	145	6	2478
1.50 - 1.99	.	.	12	151	254	115	79	97	60	18	91	6	883
2.00 - 2.49	.	.	.	30	85	48	60	24	54	48	54	.	403
2.50 - 2.99	.	.	.	.	.	54	36	12	6	6	6	.	120
3.00 - 3.49	.	.	.	.	.	6	12	6	6	6	6	.	42
3.50 - 3.99	.	.	.	.	.	.	6	6	6	6	6	.	30
4.00 - 4.49	.	.	.	.	.	.	6	.	6	.	.	.	12
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	6	.	.	6
Total	6	145	351	1057	1306	1142	1819	1403	1600	447	701	18	

(Continued)

(Sheet 3 of 4)

Table B4 (Concluded)

October 1980-1994, Gauge 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	29	.	6	6	35	64	185	139	191	23	121	.	799
0.50 - 0.99	23	69	220	341	393	341	746	526	827	174	330	6	3996
1.00 - 1.49	.	17	174	607	359	168	208	254	393	87	191	.	2458
1.50 - 1.99	.	.	23	237	393	127	98	87	202	87	174	23	1451
2.00 - 2.49	.	.	.	29	139	156	87	64	139	35	52	6	707
2.50 - 2.99	.	.	.	.	35	87	35	52	52	17	52	.	330
3.00 - 3.49	.	.	.	.	.	23	6	12	29	12	29	6	117
3.50 - 3.99	.	.	.	.	.	.	12	29	17	17	6	.	81
4.00 - 4.49	.	.	.	.	.	.	12	17	17	.	.	6	52
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	6	6
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	6	6
Total	52	86	423	1220	1354	966	1389	1180	1867	452	955	59	

November 1980-1994, Gauge 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	48	27	20	34	41	82	272	231	82	61	177	20	1095
0.50 - 0.99	34	95	327	565	510	463	578	612	544	102	122	41	3993
1.00 - 1.49	.	14	259	476	633	395	306	293	313	41	116	20	2866
1.50 - 1.99	.	.	14	224	361	197	143	95	136	41	7	7	1225
2.00 - 2.49	.	.	.	34	150	109	102	27	34	14	7	.	477
2.50 - 2.99	.	.	.	.	7	41	7	14	34	.	14	.	117
3.00 - 3.49	.	.	.	.	.	7	14	48	41	7	7	.	124
3.50 - 3.99	.	.	.	.	.	.	7	14	27	14	7	.	69
4.00 - 4.49	.	.	.	.	.	.	.	7	7	7	.	.	21
4.50 - 4.99	.	.	.	.	.	.	.	7	.	.	7	.	14
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	7	.	7
Total	82	136	620	1333	1702	1294	1429	1348	1218	287	471	88	

December 1980-1994, Gauge 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	61	20	34	68	20	34	95	203	115	102	210	7	969
0.50 - 0.99	34	149	244	468	542	244	414	631	766	129	251	27	3899
1.00 - 1.49	.	.	183	454	549	292	231	163	386	34	129	.	2421
1.50 - 1.99	.	.	20	244	508	176	122	68	156	47	88	.	1429
2.00 - 2.49	.	.	14	7	224	129	41	34	75	68	88	.	680
2.50 - 2.99	.	.	.	.	7	41	.	34	68	7	68	.	225
3.00 - 3.49	.	.	.	.	.	7	54	20	34	20	27	.	162
3.50 - 3.99	.	.	.	.	.	.	20	20	27	20	20	.	107
4.00 - 4.49	.	.	.	.	.	.	.	14	7	34	27	.	82
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	7	.	7
5.00 - Greater	.	.	.	.	.	.	.	.	7	7	7	.	21
Total	95	169	495	1241	1850	923	977	1187	1641	468	922	34	

(Sheet 4 of 4)

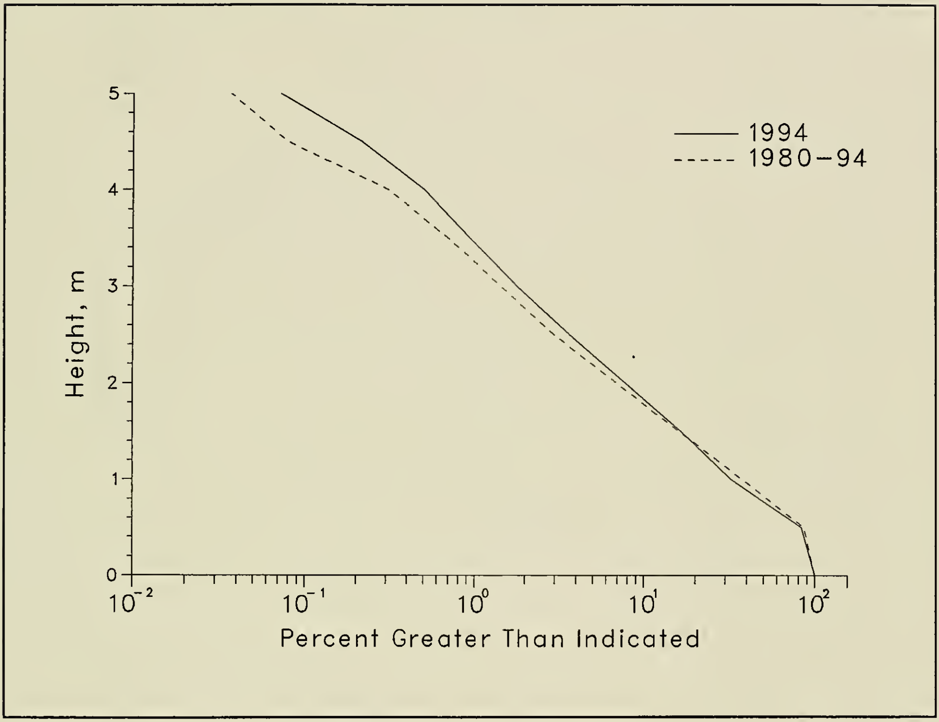


Figure B2. Annual cumulative wave height distributions for Gauge 630

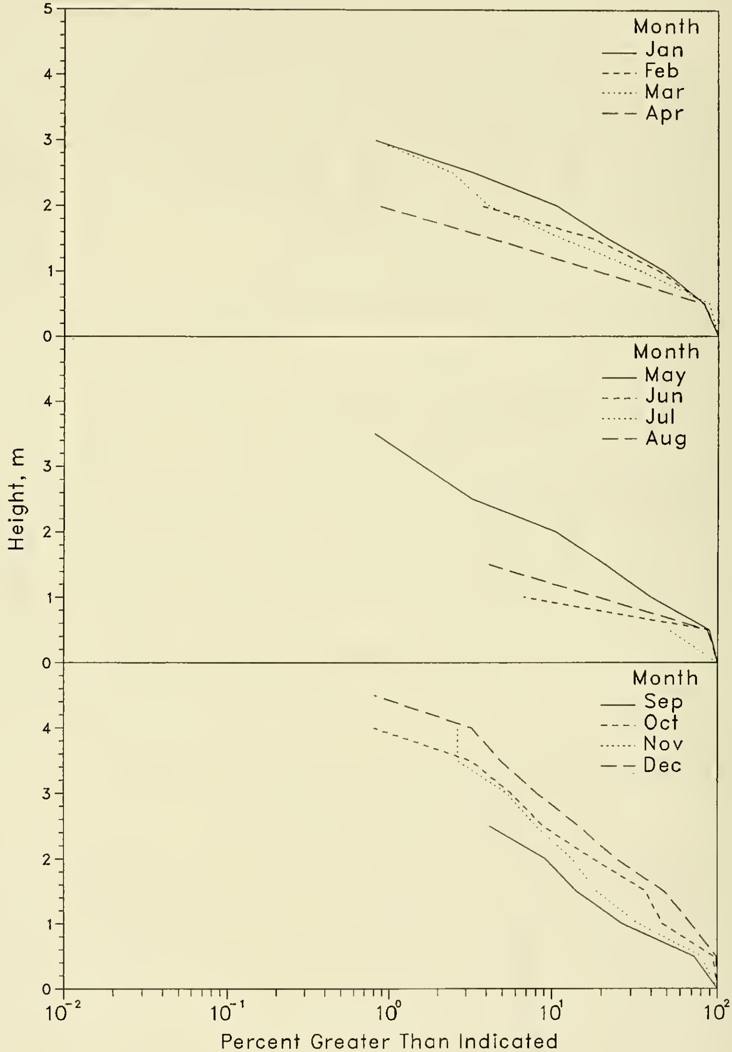


Figure B3. 1994 monthly wave height distributions for Gauge 630

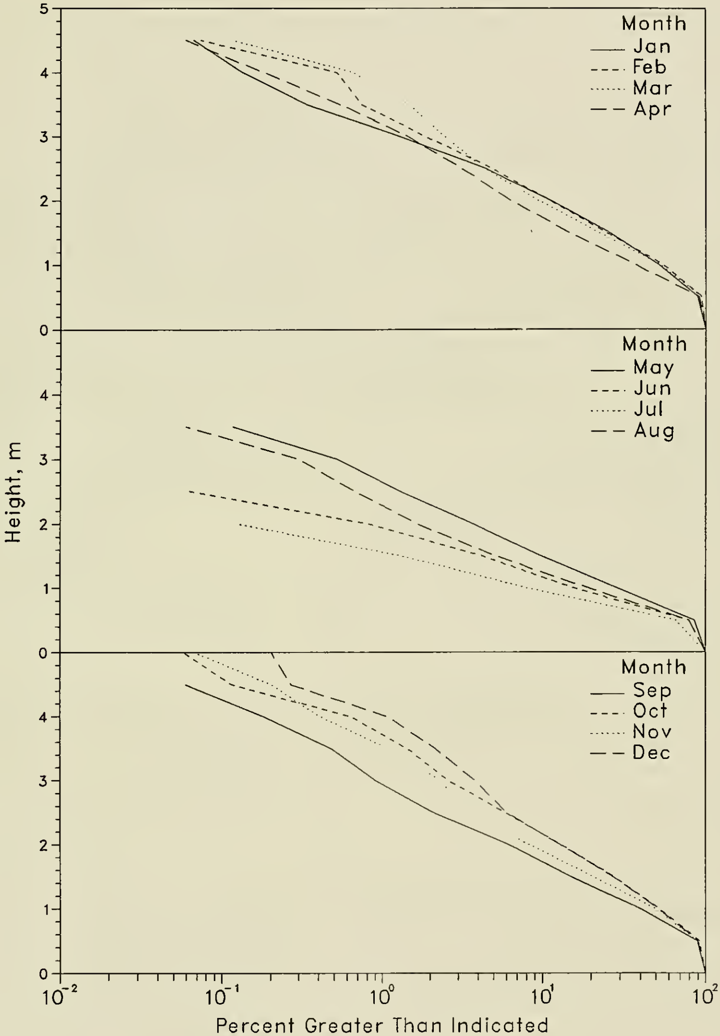


Figure B4. 1980-1994 monthly wave height distributions for Gauge 630

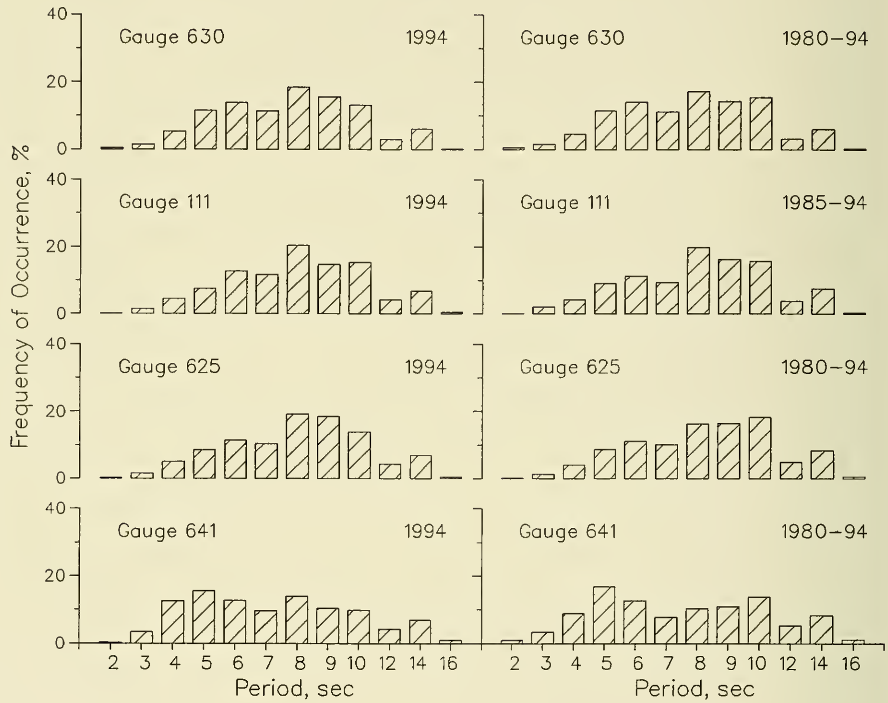


Figure B5. Annual wave period distributions for all gauges

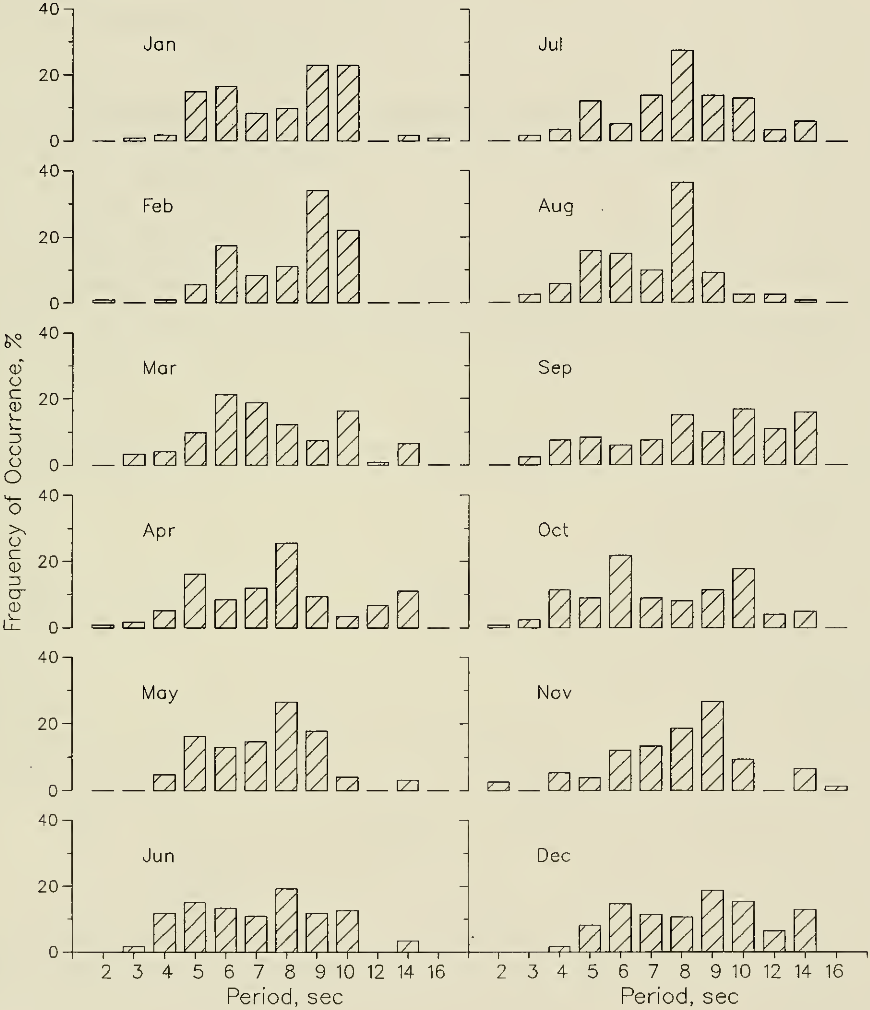


Figure B6. 1994 monthly wave period distributions for Gauge 630

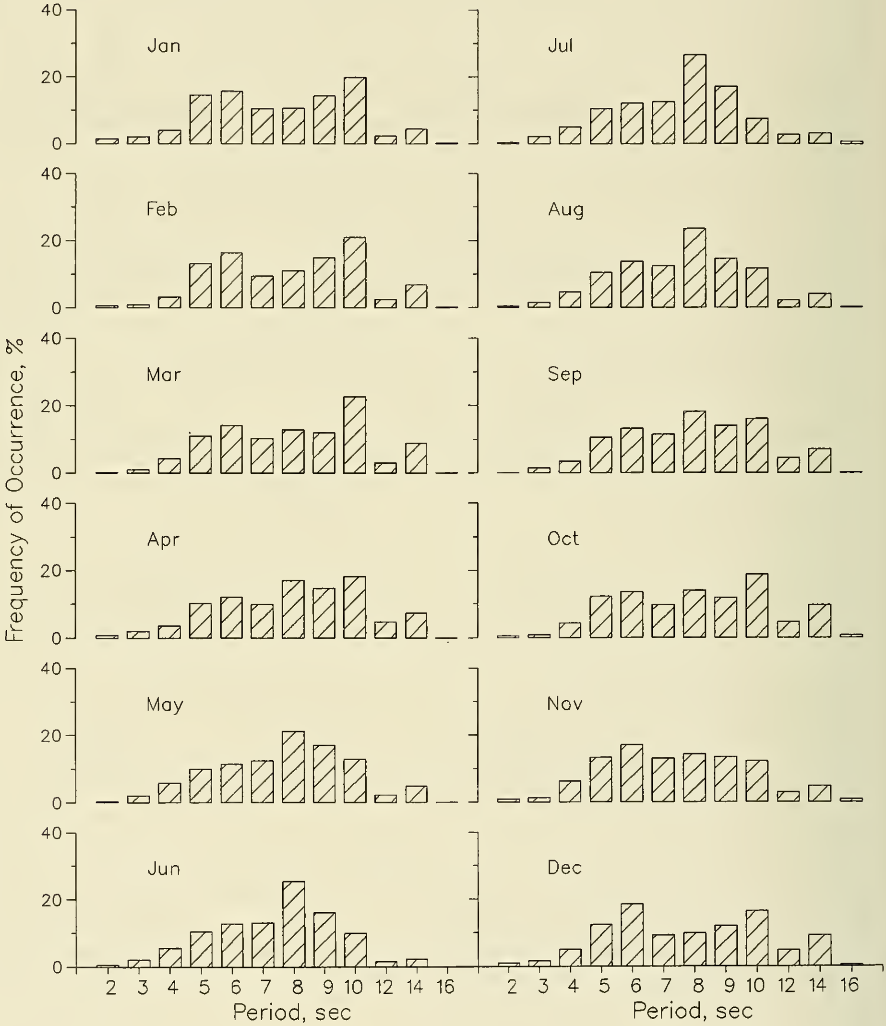


Figure B7. 1980-1994 monthly wave period distributions for Gauge 630

Table B5
1994 persistence of H_{mo} for Gauge 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		16	15	14			13		12			11			10				9
1.0	50	32	21	13	9	7	6		5		3								1
1.5	35	24	10	6		4			2	1									
2.0	21	13	5	3	2	1													
2.5	16	6	4	1															
3.0	7	4	1																
3.5	5	3																	
4.0	3	2																	

Table B6
1980 through 1994 persistence of H_{mo} for Gauge 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	19	18	16	14	13	12	11		10			9	8	7		6			5
1.0	50	34	24	17	14	10	8	6	5		3		2				1		
1.5	37	22	12	6	4		2		1										
2.0	22	11	5	2		1													
2.5	11	5	2																
3.0	6	3	1																
3.5	3	1																	
4.0	2	1																	

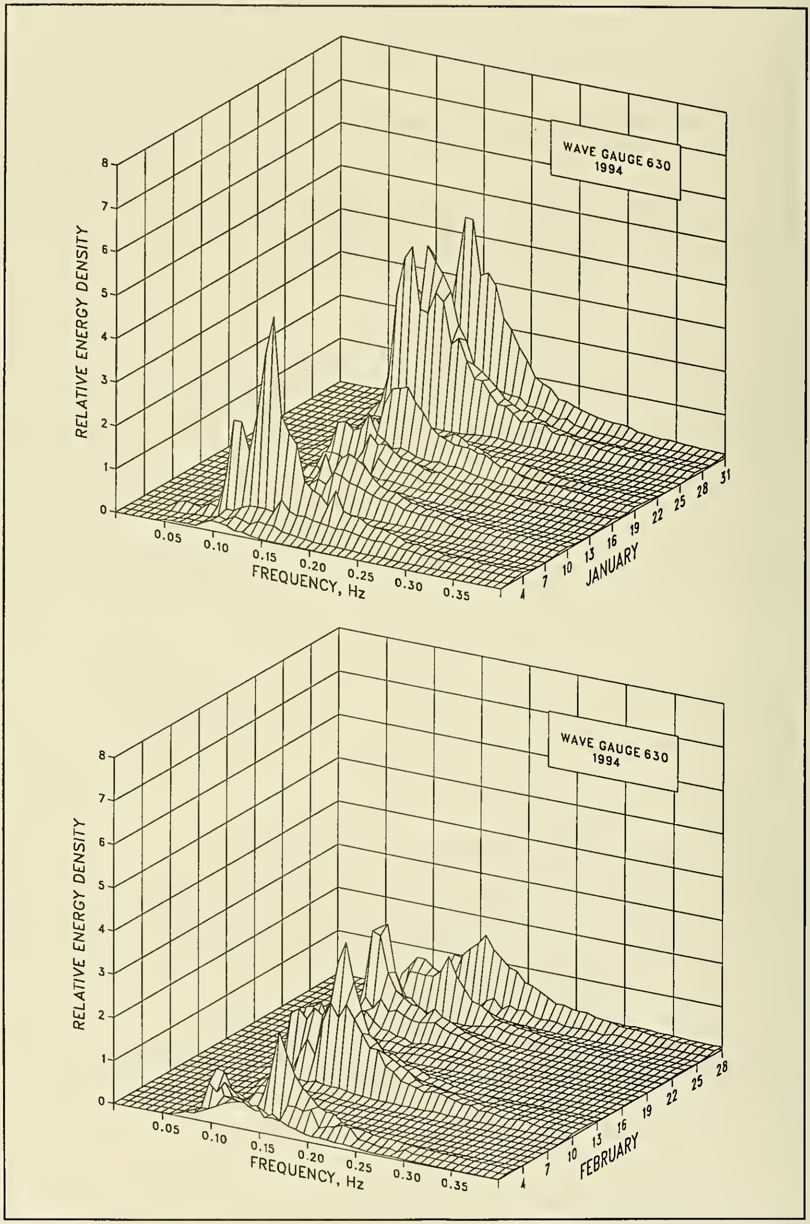


Figure B8. 1994 monthly spectra for Gauge 630 (Sheet 1 of 6)

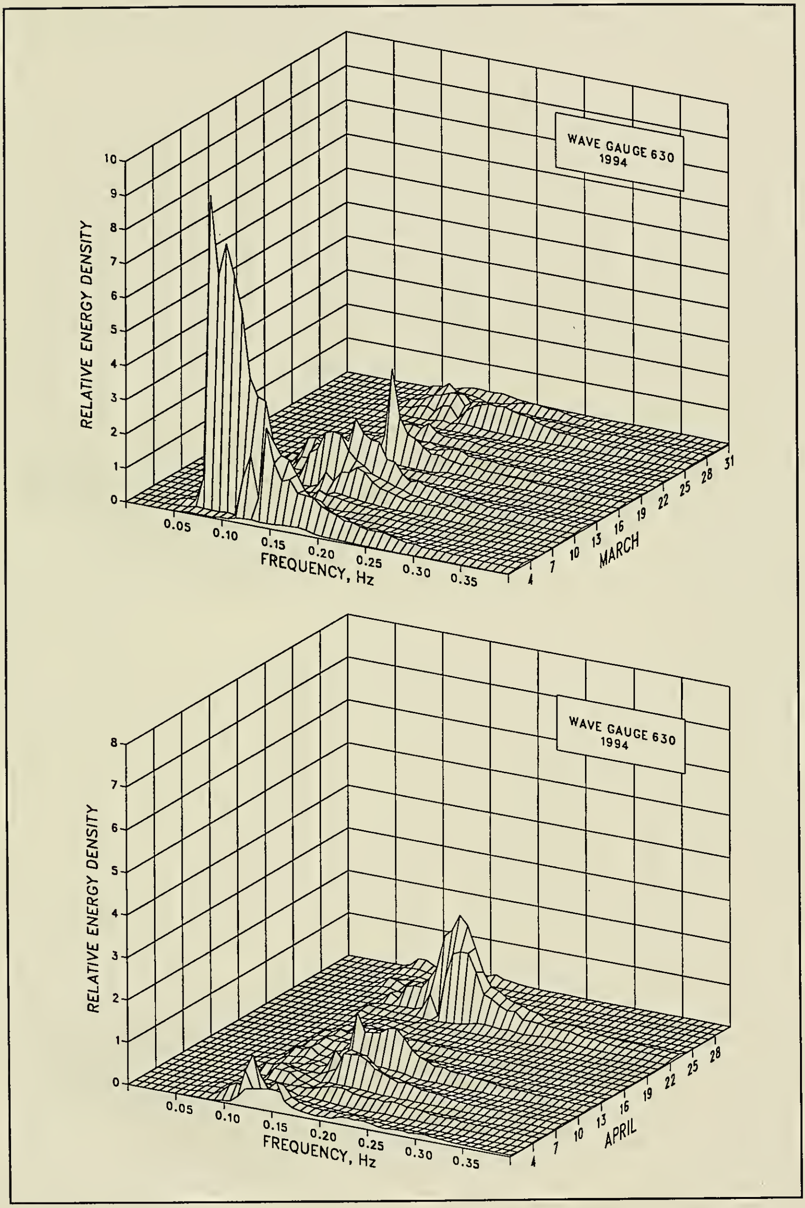


Figure B8. (Sheet 2 of 6)

Figure B8. (Sheet 3 of 6)

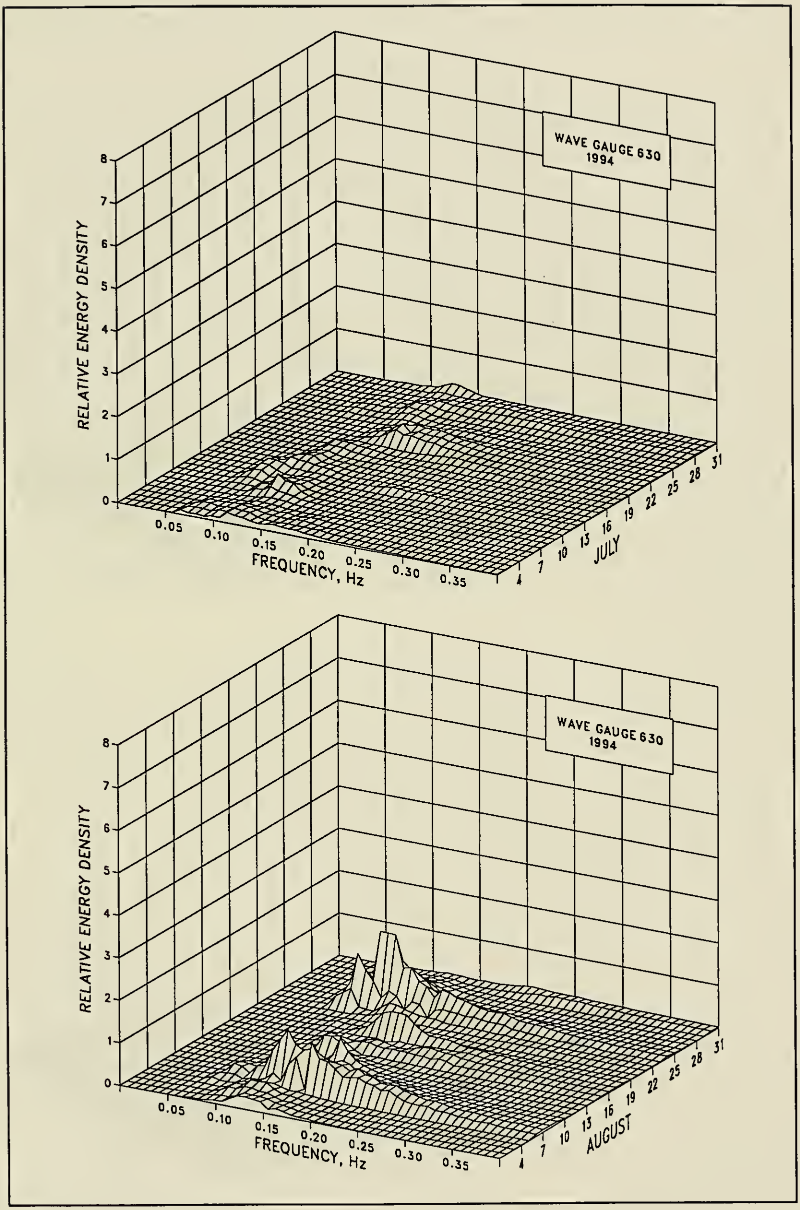


Figure B8. (Sheet 4 of 6)

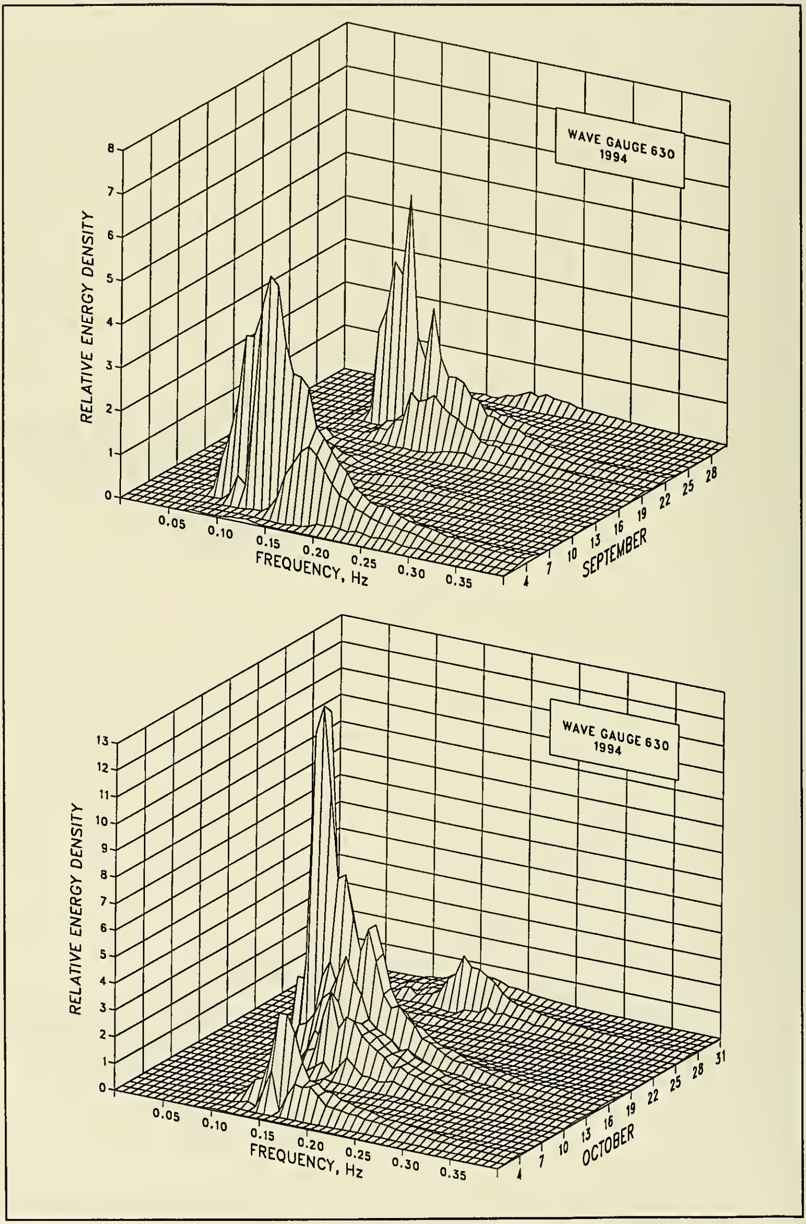


Figure B8. (Sheet 5 of 6)

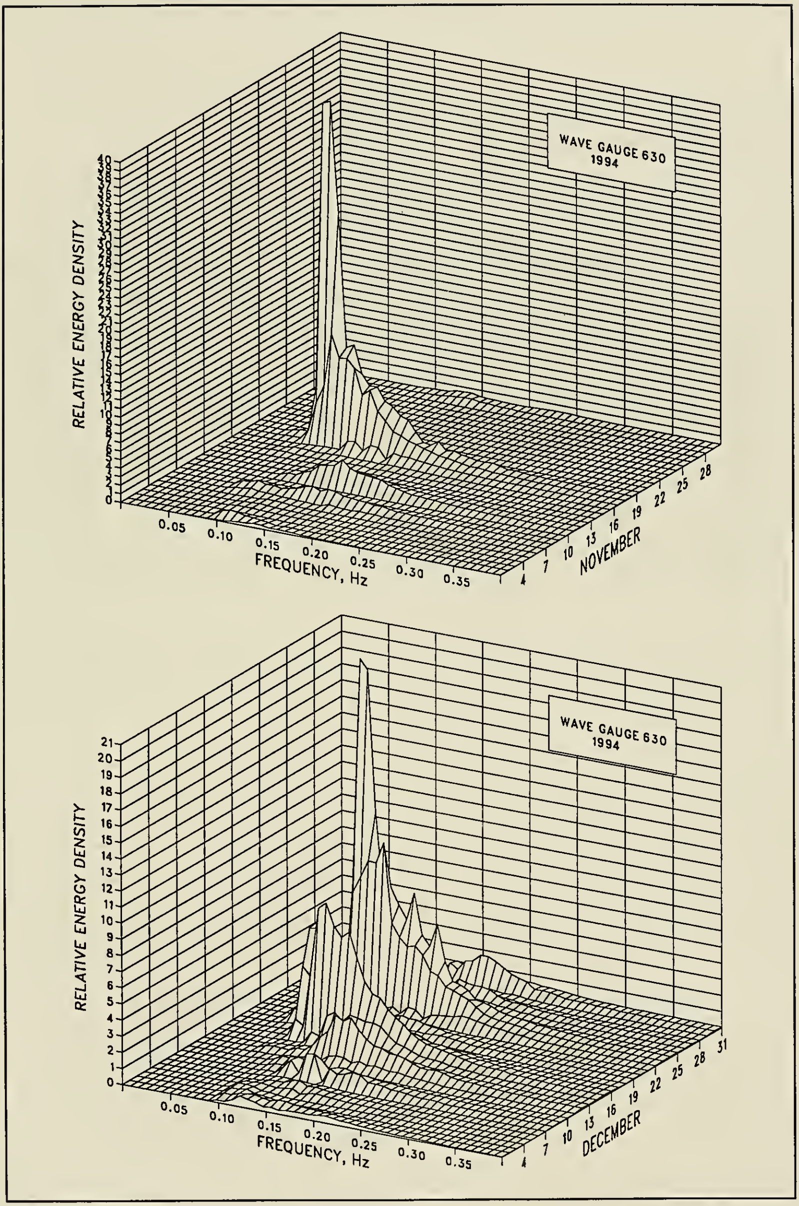
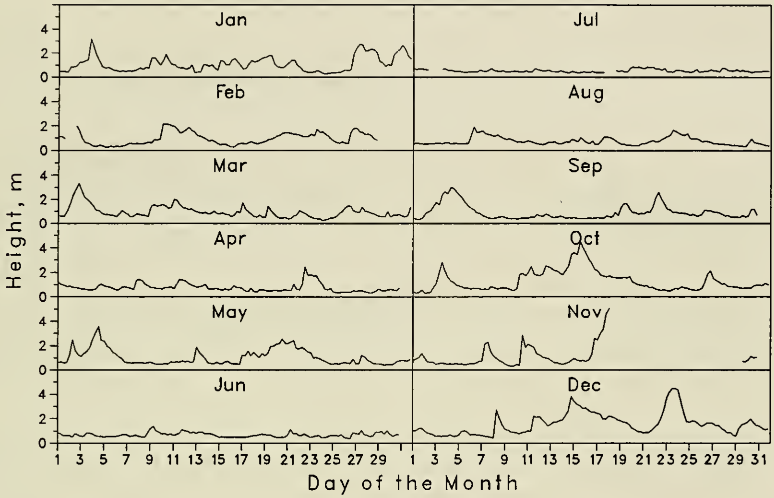


Figure B8. (Sheet 6 of 6)

Table B7
Wave statistics for Gauge 630

	1994							1980-1994						
	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	1.1	0.7	3.2	3	8.4	2.2	122	1.2	0.7	4.5	1983	8.1	2.6	1496
Feb	1.0	0.6	2.2	10	8.6	1.8	109	1.2	0.7	5.1	1987	8.4	2.5	1352
Mar	1.0	0.6	3.3	2	8.0	2.4	123	1.2	0.7	4.7	1983	8.6	2.6	1691
Apr	0.8	0.4	2.5	22	8.4	2.7	118	1.0	0.6	5.0	1988	8.6	2.7	1670
May	1.1	0.7	3.6	4	7.8	1.9	124	0.9	0.5	3.6	1994	8.2	2.4	1713
Jun	0.7	0.2	1.4	9	7.7	2.3	119	0.8	0.4	2.7	1991	7.9	2.2	1597
Jul	0.6	0.2	0.8	20	8.5	2.3	116	0.7	0.3	2.1	1985	8.0	2.4	1629
Aug	0.8	0.4	1.9	6	7.6	2.1	121	0.8	0.4	3.6	1981	8.1	2.4	1655
Sep	1.0	0.7	3.0	4	9.5	3.2	120	1.0	0.6	6.1	1985	8.6	2.6	1654
Oct	1.3	0.9	4.5	15	8.1	2.9	124	1.3	0.8	5.4	1991	8.7	2.8	1729
Nov	1.1	1.0	5.1	18	8.6	2.6	75	1.2	0.7	5.1	1994	8.0	2.7	1470
Dec	1.6	1.0	4.5	23	9.3	2.8	123	1.3	0.8	5.6	1980	8.4	2.9	1475
Annual	1.0	0.7	5.1	Nov	8.4	2.5	1394	1.0	0.7	6.1	Sep 1985	8.3	2.6	19131



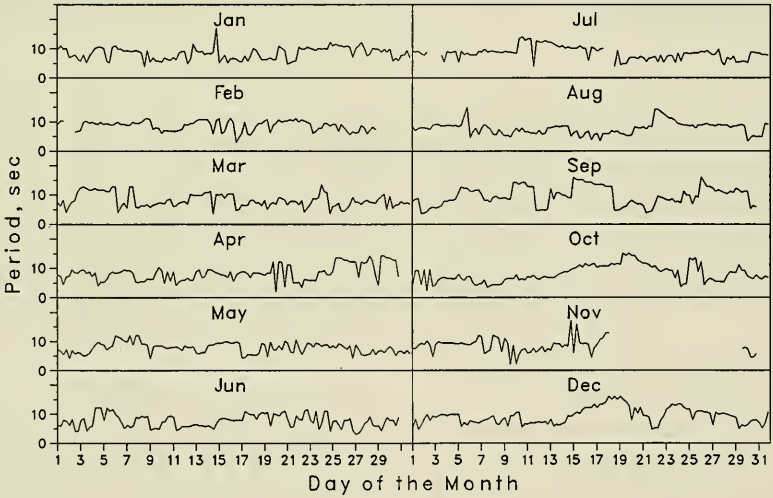


Figure B9. Time-histories of wave height and period for Gauge 630

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13. ABSTRACT *(Maximum 200 words)*

This report provides basic data and summaries for the measurements made during 1994 at the U.S. Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF) in Duck, NC. The report includes comparisons 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 biannual aerial photography, and descriptions of 15 storms that occurred during the year. The year was highlighted by a major storm in mid-March which caused extensive flooding and damage on the western (soundside) side of the Outer Banks.

This report is the 16th in a series of annual summaries of data collected at the FRF that began with Miscellaneous Report-CERC-82-16, which summarizes data collected during 1977-1979. These reports are available from the WES Technical Report Distribution Section of the Information Technology Laboratory, Vicksburg, MS.

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