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TECHNICAL REPORT

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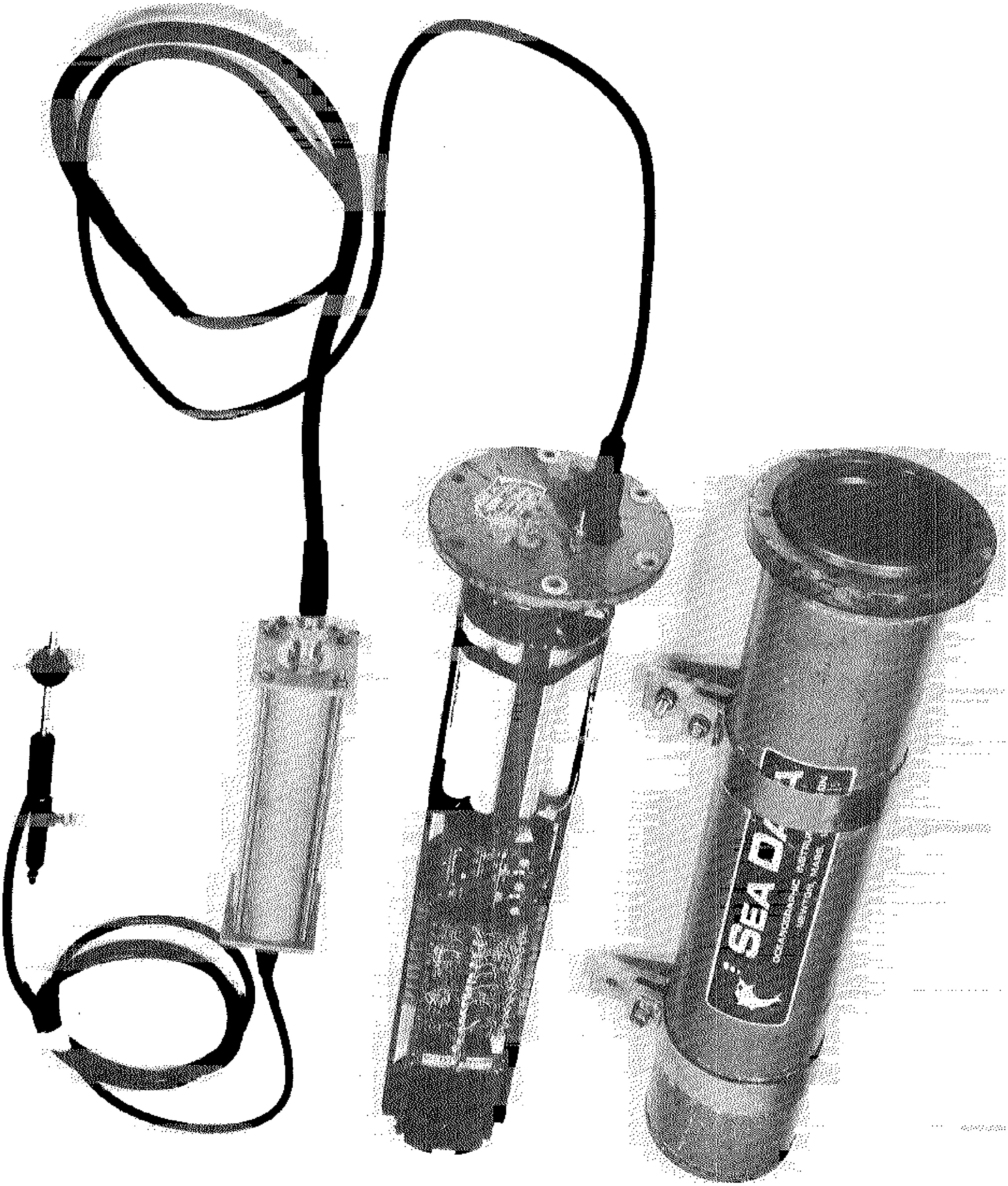
Approved for Distribution: John I. Ewing, Chairman
Department of Geology and Geophysics



Field Evaluation of Sea Data Directional Wave Gage (Model 635-9)

by D. G. Aubrey

Abstract

A directional wave gage consisting of a two-axis electromagnetic current meter and a pressure sensor, developed by Sea Data Corporation, with modifications specified by the author, was successfully deployed during the joint NOAA/U.S. Army Corps of Engineers Coastal Engineering Research Center's Atlantic Remote Sensing Land/Ocean Experiment (ARSLOE) during November, 1980. Data recovery rate was 100%, and instrument function was verified through comparison with a four-element pressure sensor array at the same location, an X-band imaging radar, and with surface meteorological observations charting developing local wave fields. The instrument was proven to be a viable alternative for point measurements of directional wave fields and for estimating the first five fourier coefficients in a directional wave model.

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Introduction

A field evaluation of a compact, internally-recording directional wave gage was performed at Duck, N.C. (figure 1), in November, 1980, at the U.S. Army Corps of Engineer's Field Research Facility (FRF), as part of the Atlantic Remote Sensing Land/Ocean Experiment (ARSLOE). The directional wave gage was built by Sea Data Corporation, of Newton, MA, with modifications specified by the author, for use in a Woods Hole Oceanographic Institution Sea Grant project evaluating tidal inlet dynamics at Nauset Inlet, Cape Cod, MA (Aubrey, 1979). Participation in ARSLOE was designed to evaluate the performance of the Sea Data system against that of other directional wave gages sampling simultaneously.

ARSLOE, jointly sponsored by the NOAA Ocean Waves Program and the U.S. Army's Coastal Engineering Research Center (CERC), was a field experiment designed to intercompare remote and *in situ* observations of the ocean surface wave field. Added to this was an effort to acquire synoptic observations of the physics of ocean wave generation, growth, and dissipation. Table 1 presents the various types of instrumentation deployed, responsible agencies, and dates of operation. The Sea Data system is listed as ARSLOE number 91.

A post-experiment workshop was held by ARSLOE at Virginia Beach, VA., from February 18-20, 1980, with the intent of coordinating comparisons between the various instrument platforms, and to develop working groups for investigating different elements of surface wave generation, propagation, and dissipation.

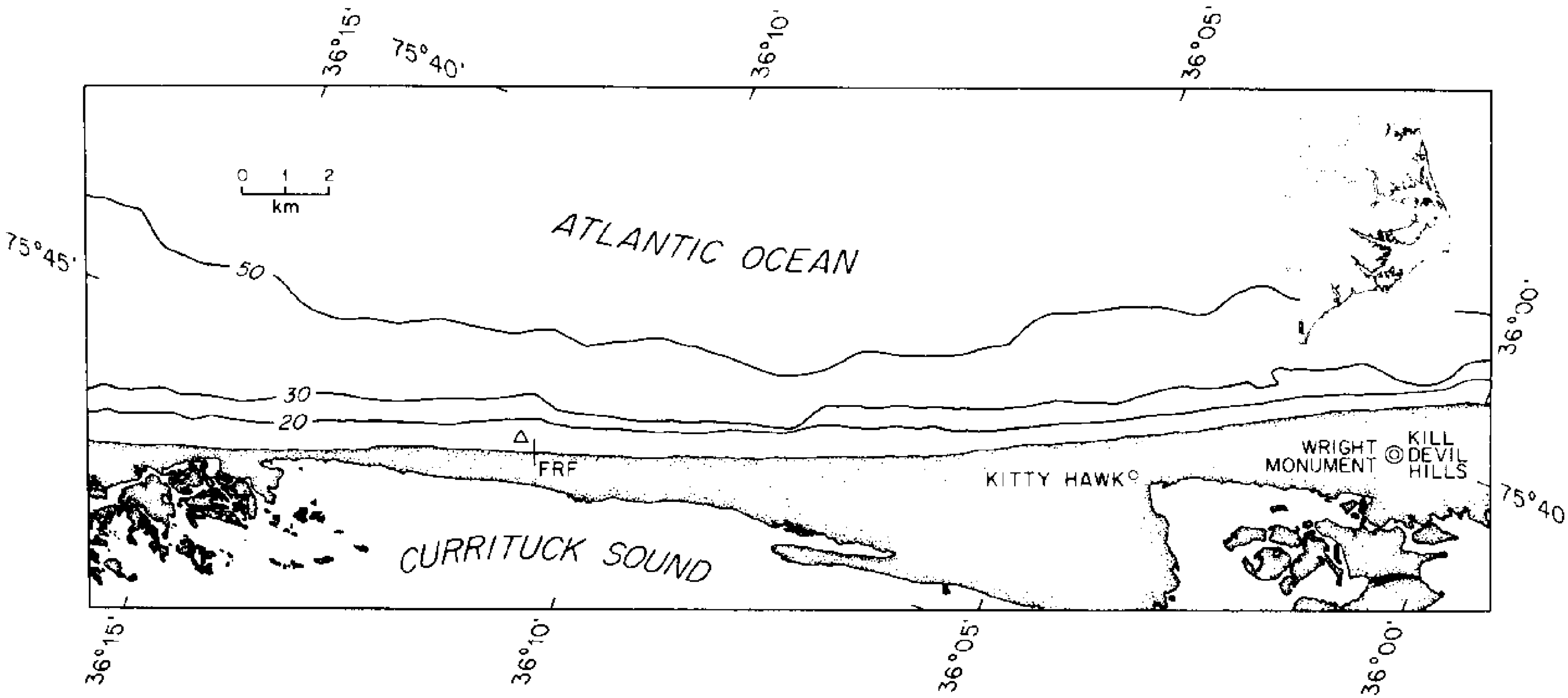

Figure 1: Location map for U.S. Army Corps of Engineers Coastal Engineering Research Center's Field Research Facility (FRF), site of 1980 ARSLOE experiment.

TABLE I

List of ARSLOE participants, sensor types, and location of sensors relative to the Field Research Facility (FRF).

ARSLOE NO.	SENSOR	LOCATION	ORGANIZATION
2	Air Temperature	FRF Bldg	CERC/NWS
61	Microbarograph	FRF Bldg	CERC/NWS
74	Rain Gauge	FRF Bldg	CERC/NWS
75	Relative Humidity	FRF Bldg	CERC/NWS
4	Anemometer	FRF Bldg	CERC/NWS
5	Anemometer	Pier - 1400'	CERC/NWS
6	Anamometer	Pier - 1900'	CERC/NRL
90	ION Anemometer	Pier - 1900'	TSI
93	Anemometer	Pier - 1900'	CERC/NRL
99	Anemometer	Pier - 1850'	Johns Hopkins/APL
7	Baylor Gauge	Pier - 1900'	CERC/FRF
8	Baylor Gauge	Pier - 1420	CERC/FRF
9	Baylor Gauge	Pier - 1060'	CERC/FRF
10	Baylor Gauge	Pier - 900'	CERC/FRF
11	Baylor Gauge	Pier - 780'	CERC/FRF
12	Baylor Gauge	Pier - 700'	CERC/FRF
13	Baylor Gauge	Pier - 620'	CERC/FRF
89	Pressure Transducer	Pier - 1420'	WES
71	CW Doppler Radar (X-band)	Pier - 1900'	NRL
80	SONAR (Sx-70)	Pier - 1850'	Johns Hopkins/APL
81	Stillwell Camera	Pier - 1850'	Johns Hopkins/APL
58	LEO	Pier - 1900'	CERC
3	Air Temperature	Pier - 1900'	CERC/NRL
85	Water Temp Probe	Pier - 1900'	CERC/NRL
86	Water Temp Probe	Pier - 6 MSL	CERC

87	Water Temp Probe	Pier -20 MSL	CERC
84	Tide Gauge	Pier - 1900'	CERC/NOAA
83	Tide Gauge	Pier - 720'	CERC/NOAA
66	Pressure Dransducer	Pier - 1420'	WES
77	Salinity Probe	Pier -22 MSL	CERC
78	Salinity Probe	Pier -6 MSL	CERC
57	Lead Line Sounding	Pier	CERC
52	Current Meter	Pier	CERC
55	Dye	1000' N to 1000' of Pier	CERC
49	Current Meter	1000' N of Pier	CERC
51	Current Meter	500' N of Pier	CERC
67	CERC Radar	Pier - 1900'	CERC
62	Pressure Transducer	Pier - 1900'	CERC/FRF
63	Pressure Transducer	N of Pier	CERC/FRF
33	Waverider	1 km E	CERC
54	Current Meter	800' N of Pier	Norway
64	Pressure Transducer SXY Gauge	800' N of Pier	CERC/Scripps
65	Pressure Transducer (3 pt. array)	800' N of Pier	Univ. of Florida
91	Current Meter	800' N of Pier top of SXY Gauge	Woods Hole
47	Concrete Blocks	Beyond of Pier	CERC
56	Hydrographic Survey	Vicinity of Pier	CERC
76	Rods	A - Nearshore B - Offshore - 1900'	CERC
145	Current Meter	Pier - 1900'	NRL
31	WADI Buoy	3 km	NEREIDES

34	Waverider	3 km E	CERC
35	Waverider	6 km	CERC
36	Waverider	12 km E	CERC/NOAA
17	Discus Buoy	12 km E	N.C. State
23	ENDECO Buoy	12 km E	NOAA/NOS
24	Met Buoy	12 km E	Canada
16	Current Meter	12 km E	Norway
37	Waverider	12 km E x 15 km S	NOAA/NOS
38	Waverider	12 km E x 15 km N	NOAA/NOS
32	Waverider	20 km E	Canada
26	Met Buoy	20 km E	NOAA/PMEL
42	XERB	36 km E	NOAA/NOS
18	Discus Buoy 41001	322 km E	NOAA
15	Cloverleaf	12, 20, 40, 60 km	Japan
14	Bottom Sampler	Shore - 36 km	CERC
79	Side Scan Sonar	Shore - 36 km	CERC
144	Geophysical Measurements	Shore - 36 km	CERC/WES
69	H.F. Radar - Array	Shore - 40 km	NOAA/ERL
73	H.F. Radar - Loop	Shore - 40 km	NOAA/ERL
92	Baylor Gauge	Nags Head	CERC
98	Hydrographic Soundings		NOAA/NOS
82	Tide Gauge	Sound	CERC/NOAA
113	UH-1	End of Pier	NRL
114	OV-1	Shore - 40 km	Ft. Hood/CERC
119	RF-4B	Shore - 40 km	KANG/CERC

121	P-3	Shore - 40 km	NASA/NRL
127	P-3	Shore - 40 km	NOAA/SAIL
139	RF-4B	Shore - 40 km	U.S. Marine Corps
131	P-3	Shore - 40 km	NRL
134	Queen Air	Shore - 40 km	Photo Science/ETL
101	NOAA-6	Area	NOAA/NESS
103	LANDSAT	Area	NOAA/NESS
102	GOES	Area	NOAA/NESS
106	NIMBUS-7	Area	NOAA/NESS
100	TIROS-N	Area	NOAA/NESS

Hardware

The 635-9 directional wave gage consists of a Sea Data Corporation, cassette tape drive, with electronics for powering and sampling a pressure sensor and two-axis electromagnetic current meter. Power is supplied by a battery pack contained within an aluminum pressure case (coated with polyurethene paint). The pressure sensor is a Paroscientific, Inc., Digiquartz pressure transducer Model 245-A (0 to 45 psia), with a nominal precision of better than 0.01%. The current meter is a Marsh McBirney, Inc., Model 512/OEM, two-axis electromagnetic sensor, with a sphere diameter of 3.81 cm. In the configuration deployed at Duck, N.C., the pressure sensor was mounted in the cap of the pressure case, and the current meter was contained external to the pressure case, with a cable supplying power and transmitting data between the two. Sea Data has another configuration of the 635-9 in which the current meter probe is mounted directly on the end cap of the pressure case.

The Sea Data electronics provide a wide range of switch-selectable burst intervals, burst rates, and burst duration. In the ARSLOE experiment, burst rate was 1.0 seconds, burst interval was 6 hours, and burst duration was 2048 seconds. During each burst, samples of pressure and the two horizontal velocity components were taken. The time constant on the current meter was 0.25 seconds. Data was stored on a standard digital certified 450 foot (137 m) cassette tape, with a capacity of approximately 15 megabits of information, recorded on a four-track Sea Data cassette transport. This tape capacity corresponds to approximately forty-five days of data with the sampling parameters specified above. An internal clock provides elapsed time, which is also recorded on the digital cassette.

No compass was mounted in the pressure case during the ARSLOE experiment, although a Digicourse Model 225 gimbaled compass has been added since, to monitor any unexpected rotation of the rigid moorings to which the directional wave gage is attached.

A flooding problem with the electronics package of the Marsh-McBirney current meter, combined with a time constraint imposed by the ARSLOE experiment, precluded precalibration of the current meter by our lab before field installation. Immediately upon recovery from the field, however, a steady flow current meter calibration was run at WHOI in a tow tank (Figures 2 and 3). Over the range of velocities examined, the calibration curve is approximately linear. As demonstrated by Aubrey (1981), the 512 current meters must be calibrated in steady, oscillatory, and combined steady/oscillatory flows to obtain a true indication of their hydrodynamic performance. However, since even a careful laboratory flume test is not a complete description of the sphere's behavior in the field, we are using steady flow laboratory calibration as a standard for comparing current meter performance.

Installation and Retrieval

The 635-9 was deployed in Duck, N.C., on 31 October, 1980 (Figure 1). The internal clock was zeroed at 1900 hours eastern daylight time (EDT) on 29 October, 1980, and cassette tape ARSLOE 10/80/2 was begun. Deployment was delayed two days (until approximately 1315 EDT on 31 October, 1980) due to inclement weather

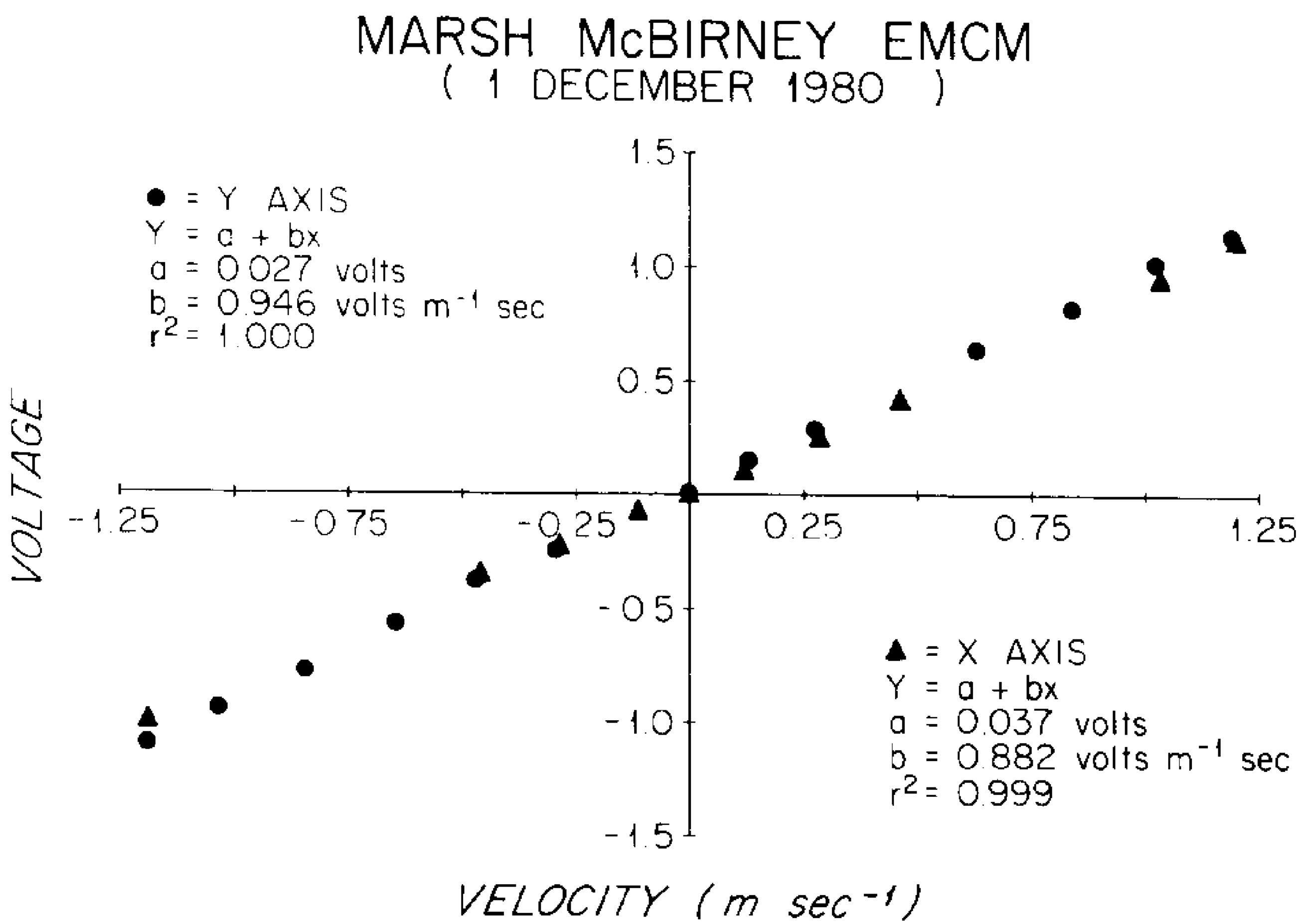

Figure 2: Steady flow calibration of Marsh McBirney 512/OEM current meter used in ARSLOE experiment as a component of the Sea Data 635-9 directional wave system.

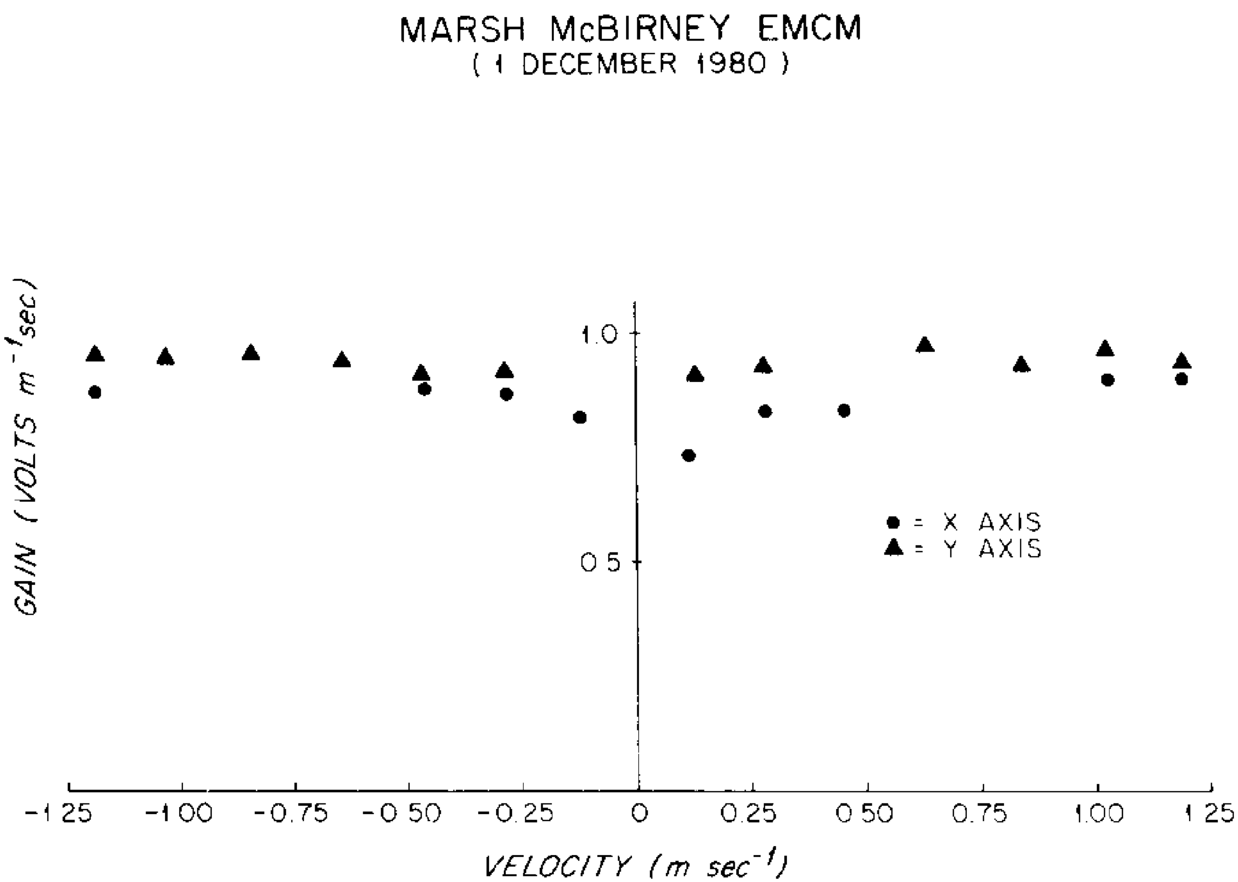

Figure 3: Gain plotted against velocity for the same current meter as in figure 2.

(an unforecasted local storm). Internal settings on the recorder were:

burst interval	6 hours
burst duration	2048 samples
burst rate	1 sample/second

Consequently, sampling times were 0100, 0700, 1300, and 1900 hours EDT.

The 635-9 was mounted on a leg of a wave slope array owned by CERC and operated by Dr. R.J. Seymour of the California Division of Boating and Waterways (also of Scripps Institution of Oceanography, La Jolla, CA). The slope array consists of four steel legs radiating from a central core to pressure sensor cases at each end. The 635-9 was deployed on the southeast leg of the slope array (figure 4), with the pressure port at an elevation of 0.114 meters from the bed, and the center of the current meter probe 1.00 meters off the bed. The current meter orientation mark was directed $41^{o}20'$ east of true north (where a magnetic declination of $8^{o}40'$ west of north was assumed). The orientation of the current meter was determined by use of a compass which is easily read to within $\pm 2^{o}$, and which was mounted far enough away from the instrument platform to eliminate magnetic interference with the compass reading. The current meter probe was mounted with the two axes horizontal, using a mounting device developed and marketed by Deep Ocean Work Systems, Inc., of San Pedro, California. This mounting device has sufficient freedom to orient the meters horizontally as best determined by a level bubble mounted on the compass/orienting device.

The current meter was mounted sufficiently far from the pressure housing and the slope array components to minimize flow interference,

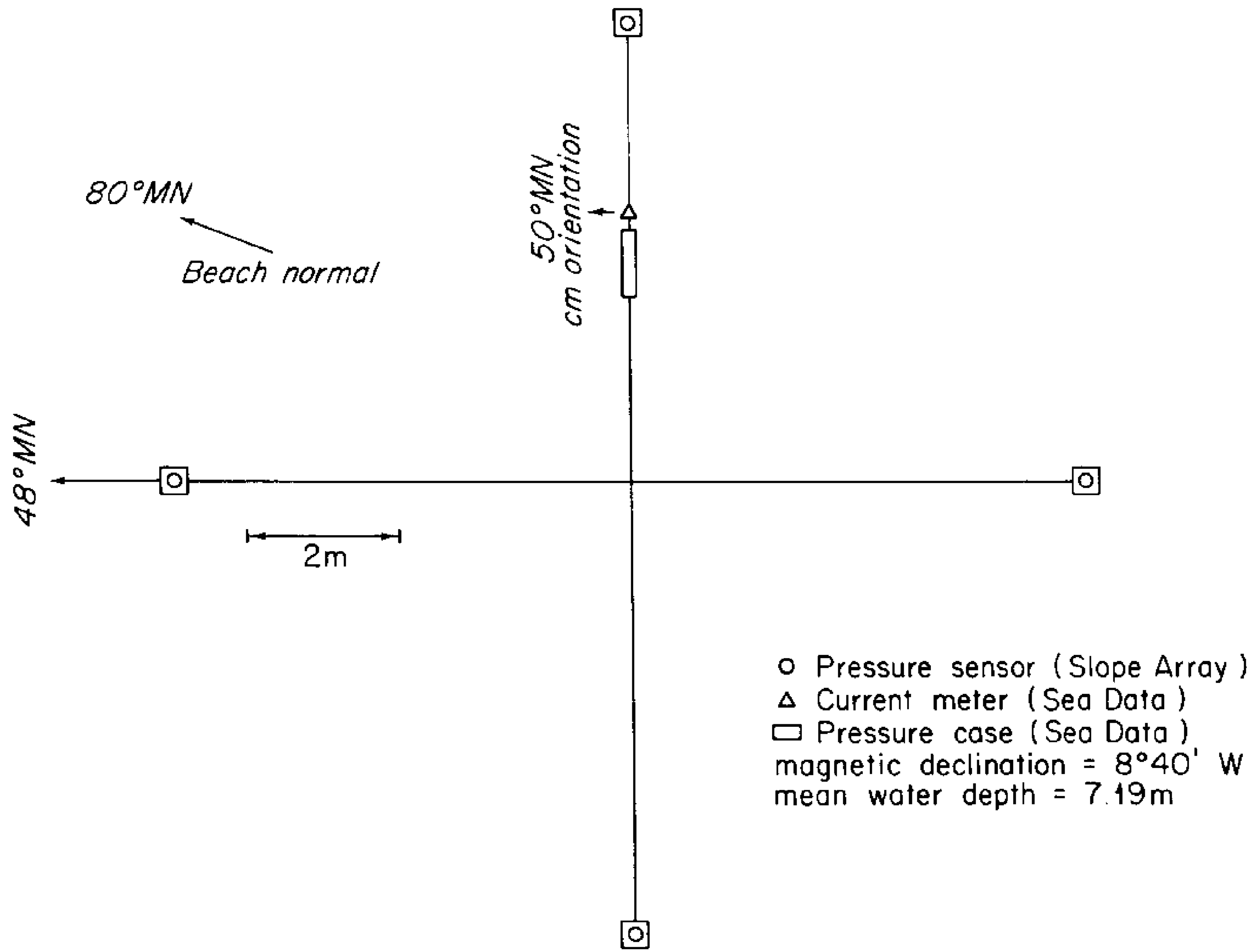

Figure 4: Schematic of slope array and 635-9 as deployed during ARSLOE.

(and thus contaminated directional estimates). The two sensors were sufficiently close in the horizontal (approximately 0.5 m) to eliminate phase differences between measured velocity and pressures, except for very short period waves which are effectively filtered by the water column.

The 635-9 directional wave gage was retrieved on 24 November 1980, during the period of largest waves encountered over the entire deployment. The orientation and tilt of the meter were verified during the retrieval, as best as possible considering the extreme wave conditions during the dive. No change in orientation of the gage appeared to have occurred during the deployment, and the current meter was free of biological contamination (algae, barnacles, mussels, etc.). The gage was out of the water by 1300 hours, EDT, on 24 November 1980. Retrieval of the gage coincided with the end of the ARSLOE experiment. At retrieval approximately half of the tape storage capacity remained, and the instrument was still functioning as designed. The instrument was removed under large wave conditions because of diver scheduling constraints.

In the following analyses, for comparison of wave direction to shore normal orientation, the shore normal is taken to be 72^{o} (252^{o})TN (figure 1). Mean water depth averaged over all burst intervals is 7.22 meters. All spectra are depth corrected.

Software

The use of a two-axis electromagnetic current meter and a pressure sensor for determining wave direction is patterned after work performed by Longuet-Higgins, Cartwright, and Smith (1963), Cartwright

(1963), and Nagata (1964). The directional wave spectrum is modeled as a fourier series truncated at five coefficients, with different coefficients for each frequency band:

$$S(f,\phi) = S(f)\left[a_0 + {}^2/_3(a_1 \cos\phi + b_1 \sin\phi) + \frac{1}{6}(a_2 \cos 2\phi + b_2 \sin 2\phi)\right]$$

$\hat{S}(f,\phi)$ is an estimate of the non-negative frequency-directional spectrum, S(f) is the one-dimensional frequency spectrum, and the a_n and b_n terms are frequency-dependent fourier coefficients of the directional spectrum. Cross-spectra of the u,v, and p terms yield:

$$C_{pp}(\omega) = (\rho g)^2 R^2(\omega)\int_0^{2\pi} S(\omega, \phi)d\phi$$

$$C_{uu}(\omega) = \left(\frac{gk}{\omega^2}\right)^2 R^2(\omega)\int_0^{2\pi} S(\omega, \phi)\cos^2\phi \, d\phi$$

$$C_{vv}(\omega) = \left(\frac{gk}{\omega^2}\right)^2 R^2(\omega)\int_0^{2\pi} S(\omega, \phi)\sin^2\phi \, d\phi$$

$$C_{pu}(\omega) = (\rho g)\left(\frac{gk}{\omega}\right) R^2(\omega)\int_0^{2\pi} S(\omega, \phi)\cos\phi \, d\phi$$

$$C_{pv}(\omega) = (\rho g)\left(\frac{gk}{\omega}\right) R^2(\omega)\int_0^{2\pi} S(\omega, \phi)\sin\phi \, d\phi$$

$$C_{uv}(\omega) = \left(\frac{gk}{\omega^2}\right)^2 R^2(\omega)\int_0^{2\pi} S(\omega, \phi)\sin\phi\cos\phi \, d\phi$$

where

$$R(\omega) = \frac{\cosh k\,(z+h)}{\cosh kh}$$

The relationships between the pressure and two horizontal velocity signals, and their auto- and cross-spectra, directly yield estimates of the fourier coefficients:

$$a_0 = \frac{1}{\pi} \frac{C_{pp}(\omega)}{(\rho g)^2 R^2(\omega)} = \frac{1}{\pi} \frac{C_{uu}(\omega) + C_{vv}(\omega)}{G^2(\omega) \quad R^2(\omega)}$$

$$a_1 = \frac{1}{\pi} \frac{C_{pu}(\omega)}{(\rho g)\, G(\omega)\, R^2(\omega)}$$

$$b_1 = \frac{1}{\pi} \frac{C_{pv}(\omega)}{(\rho g)\, G(\omega)\, R^2(\omega)}$$

$$a_2 = \frac{1}{\pi} \frac{C_{uu}(\omega) - C_{vv}(\omega)}{G^2(\omega)\, R^2(\omega)}$$

$$b_2 = \frac{2}{\pi} \frac{C_{uv}(\omega)}{R^2(\omega)\, G^2(\omega)}$$

$$G(\omega) = \frac{gk}{\omega}$$

where C_{st} represents the cross-spectrum between quantities s and t (auto-spectrum if s = t), p is the pressure, u and v are the horizontal velocities, h is the water depth, d is the distance above the bed (with a subscript indicating either pressure or velocity), z is the vertical coordinate positive upwards from the bed, g is the acceleration of gravity, ω is the wave frequency (equal to 2 times π divided by the wave period, T), k is the wave number (equal to 2 times π divided by the wave length, L). The cross spectra have zero quad spectra.

ω and k are related by the formula:

$$\omega^2 = gk \tanh(kh)$$

As demonstrated above, the pressure signal is necessary only to indicate local mean depth during the sample interval, since the sea surface fluctuations can be deduced alternatively by the two horizontal velocity components (generally at the expense of an increased noise level). The directional spectrum determined by this method is necessarily broad, given its representation by a truncated fourier series. It is convenient to define several measures of the directional spectrum:

$$\text{Mean direction:} \quad \overline{\phi} = \tan^{-1} (b_1/a_1)$$

$$\text{directional spread:} \quad \overline{(\phi-\overline{\phi})^2} = 2 - 2\,(a_1^2 + b_1^2)^{1/2}/a_0$$

Other estimates of directional spread are possible (see Longuet-Higgins et al., 1963; Mardia, 1972).

Analysis of the directional properties of the observed waves was performed using the above equations. Spectral estimates were formed with record lengths of 2048 seconds (34.1 min), with 16 ensemble averages, yielding a record length of 128 seconds, and frequency resolution of 0.0078125 hertz. The resultant spectral estimates have 32 degrees of freedom. All spectra are depth corrected.

Results

A modified form of the results of the analysis of the Duck, N.C., field data is presented in Appendix I. The compilation consists of date and run number (1 = 0100, 2 = 0700, 3 = 1300, and 4 = 1900 EDT), peak frequency, peak period, a qualitative estimate of bandwidth, total energy of the wave field in cm^2 (defined as the variance of the sea surface elevation, $< \eta^2 >$), the energy in the peak period (qualitatively defined to indicate relative importance of different peaks in frequency), mean direction at modal frequency (in degrees, TN, direction towards which waves were propagating), and directional spread (in degrees), where a low spread indicates a narrower directional band. The data for the entire experiment were processed, with a 100% data recovery. Signal quality was uniformly good, with few outliers (glitches) or high frequency contamination. Before processing, all signals were demeaned and detrended (using a linear fit), so low frequency energy contamination is minimal, as expected in this nearshore situation. Tabulated value of $< \eta^2 >$ were calculated both from the velocity data and pressure signal. The close fit between the two calculations of $< \eta^2 >$ gives us more confidence in the use of the current meter for month-long deployments.

Appendix II presents frequency spectra derived from the slope array, in which the 635-9 was embedded. Data were provided by the Coastal Waves Network under the direction of Dr. R.J. Seymour. The latter data is band-averaged in a non-linear fashion (number of bands merged varies with frequency), so it is not possible to give a single equivalent number of degrees of freedom. Record length for these data is 1024 seconds (half the length of the 635-9 records discussed here). An intercomparison of the energy levels between the two wave sensing platforms has been performed (figure 5), showing remarkable correspondence between energy levels, considering the comparison was performed by calculating energies from the horizontal velocities for the 635-9. Since a current meter is often noisier than a pressure sensor (based on previous experience), velocity agreement indicates the current meter worked well. As expected, comparison between the

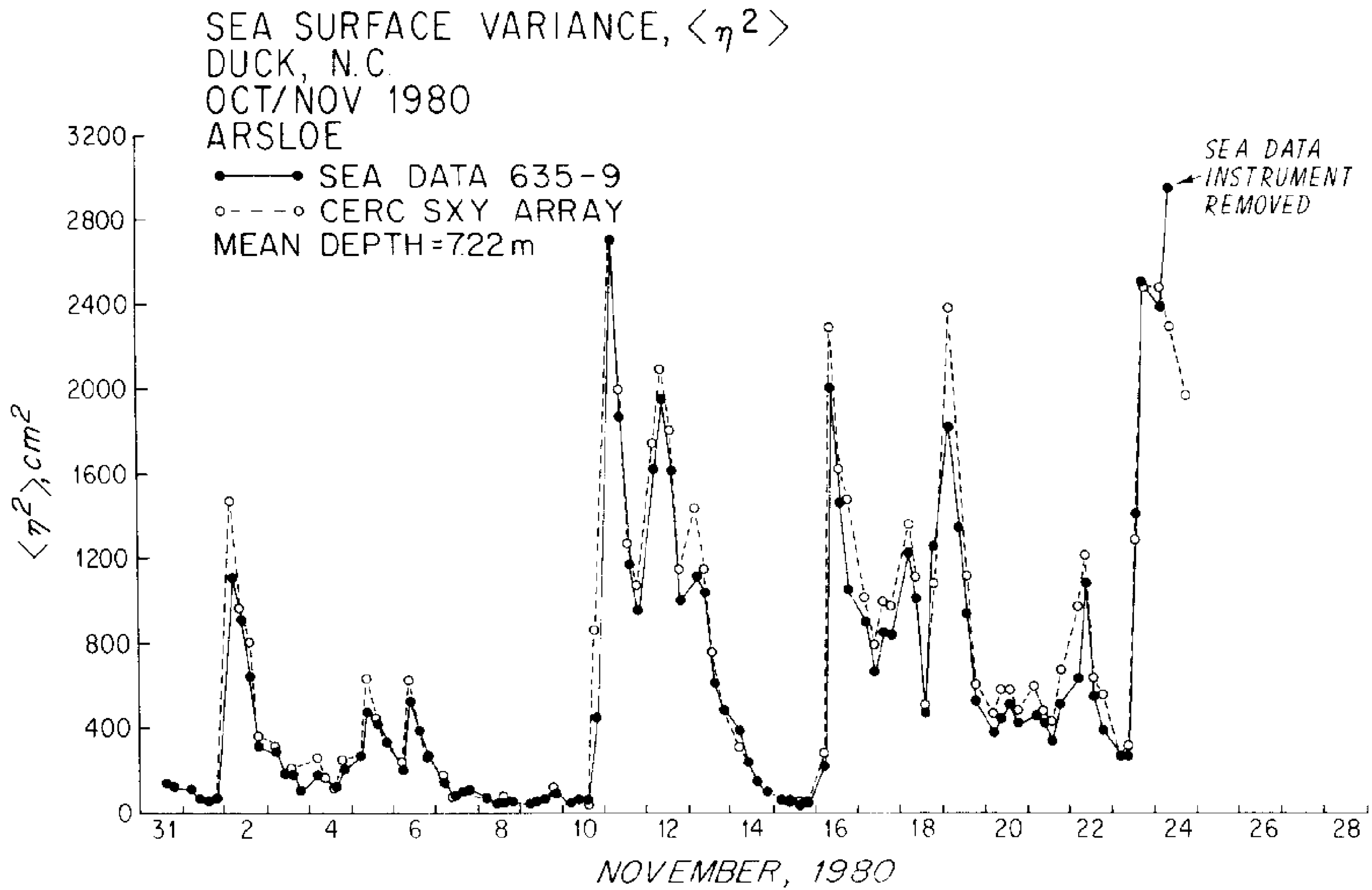

Figure 5: A comparison of sea surface variance $< \eta^2 >$ measured with a bottom-mounted current meter (635-9) and with a four-element pressure sensor array (slope array).

635-9 pressure sensor and slope array results was even better than that with the current meter. In order to intercompare results from Appendices I and II, the following relationships must be applied:

$$< \eta^2 > = \frac{1}{8} H_{rms}^2 = \frac{1}{2} A_{rms}^2 = \frac{1}{16} H_{1/3}^2$$

Directional wave estimates from the slope array were recently provided to us (Appendix 3). Comparison between directions at modal frequencies can be made using Appendices 1 and 3. The two directional estimates agree well (no r.m.s. errors have been calculated yet), but comprehensive comparison is not yet possible because of differences in analysis. The slope array mean directions may not correspond exactly with the 635-9 directions, and the nonlinear (in frequency) band averaging of the slope array may yield different results than our ensemble averages. A more quantitative comparison should be possible at a later date.

In addition, X-band surface imaging radar provided by CERC (see Mattie and Harris, 1979) was examined at the ARSLOE workshop in February, 1981, to intercompare with the results of the 635-9 measurements. A comparison of radar imagery surrounding the 635-9, over a variety of different wave conditions, qualitatively verified the directional estimates derived using the 635-9. Primary and secondary wave trains during several large and small wave events were jointly identified on the two types of observations (both of which have their particular weaknesses, without doubt). This qualitative agreement lends credence to the results of the *in situ* point-array measurement with the 635-9.

Wind data from the area (provided by the National Water Research Institute, Canada) lends further support to the 635-9 directional estimates (figure 6). By following the direction and magnitude of local winds, the development of local surface wind waves can be inferred. The growth and development of local wind waves, and their mean direction, agree well with directional estimates from the 635-9.

Examples of frequency spectra from several different periods are presented in figures 7 through 13, corresponding to periods with varying wave conditions. The frequency spectra, which have been band-limited to frequencies less than 0.25 Hz (due to the asymptotic nature of the frequency dependent depth correction to bottom pressure), clearly illustrate differences between unimodal swell and locally-generated wind wave fields.

Conclusions

The Sea Data Corporation model 635-9 directional wave gage performed well in a field intercomparison experiment at CERC's Field Research Facility at Duck, N.C. Over the period of its deployment from 31 October 1980 through 24 November, 1980, the gage sampled four times daily for 2048 seconds per burst, with a 100% data recovery. Frequency spectral estimates agree closely with those taken using a pressure sensor array within which the 635-9 was embedded. Directional estimates derived from the 635-9 qualitatively agree with slope array measurements, surface imaging radar and wind stress records taken at a nearby station. No quantitative directional comparisons are available with the radar and wind information (they have not yet been quantitatively analyzed) or with the slope array (because of differences in bandwidth and differences in analysis).

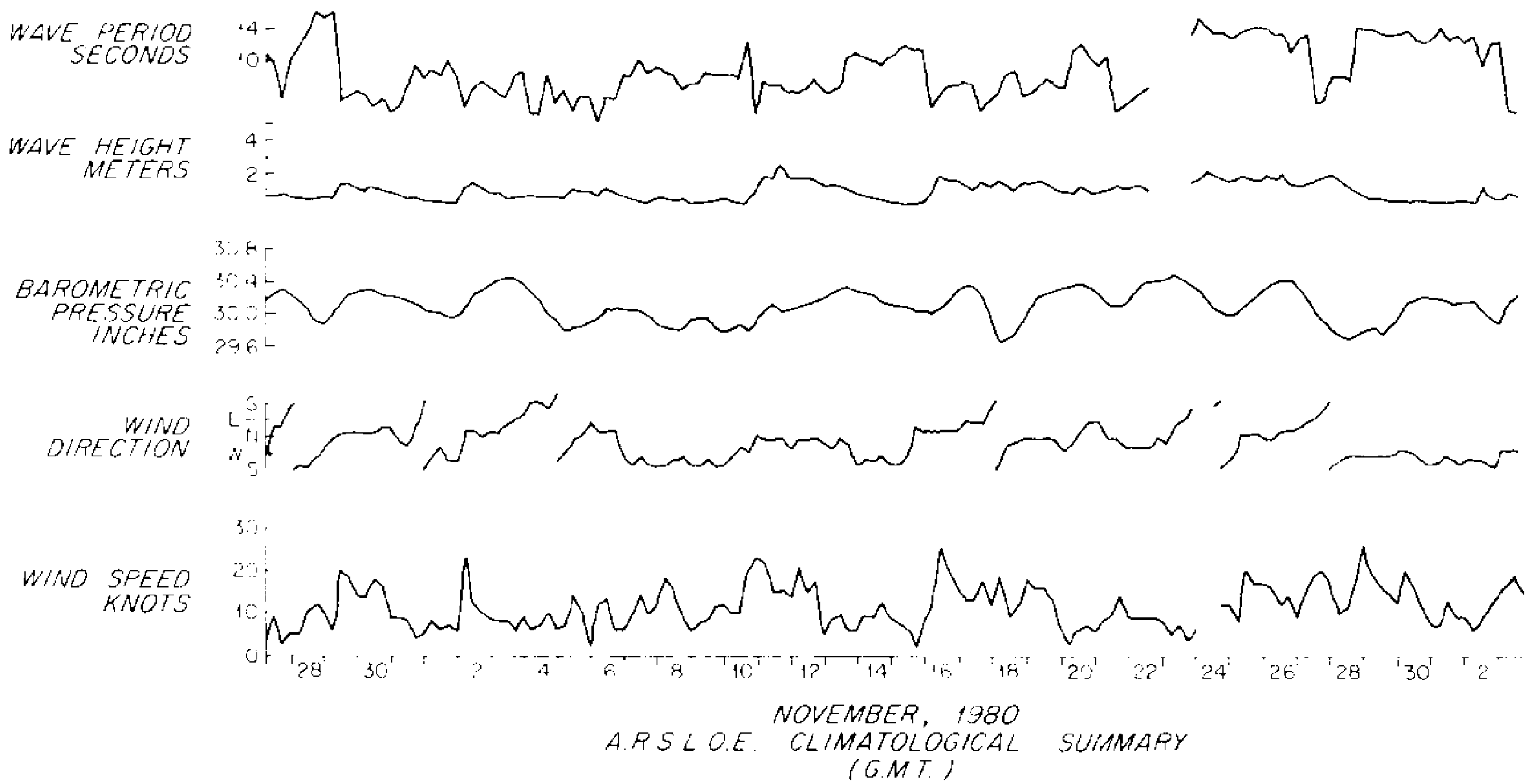

Figure 6: Wind, atmospheric pressure, and offshore wave characteristics measured 12 km offshore FRF by the Canada Centre for Inland Waters, NWRI, for November, 1980.

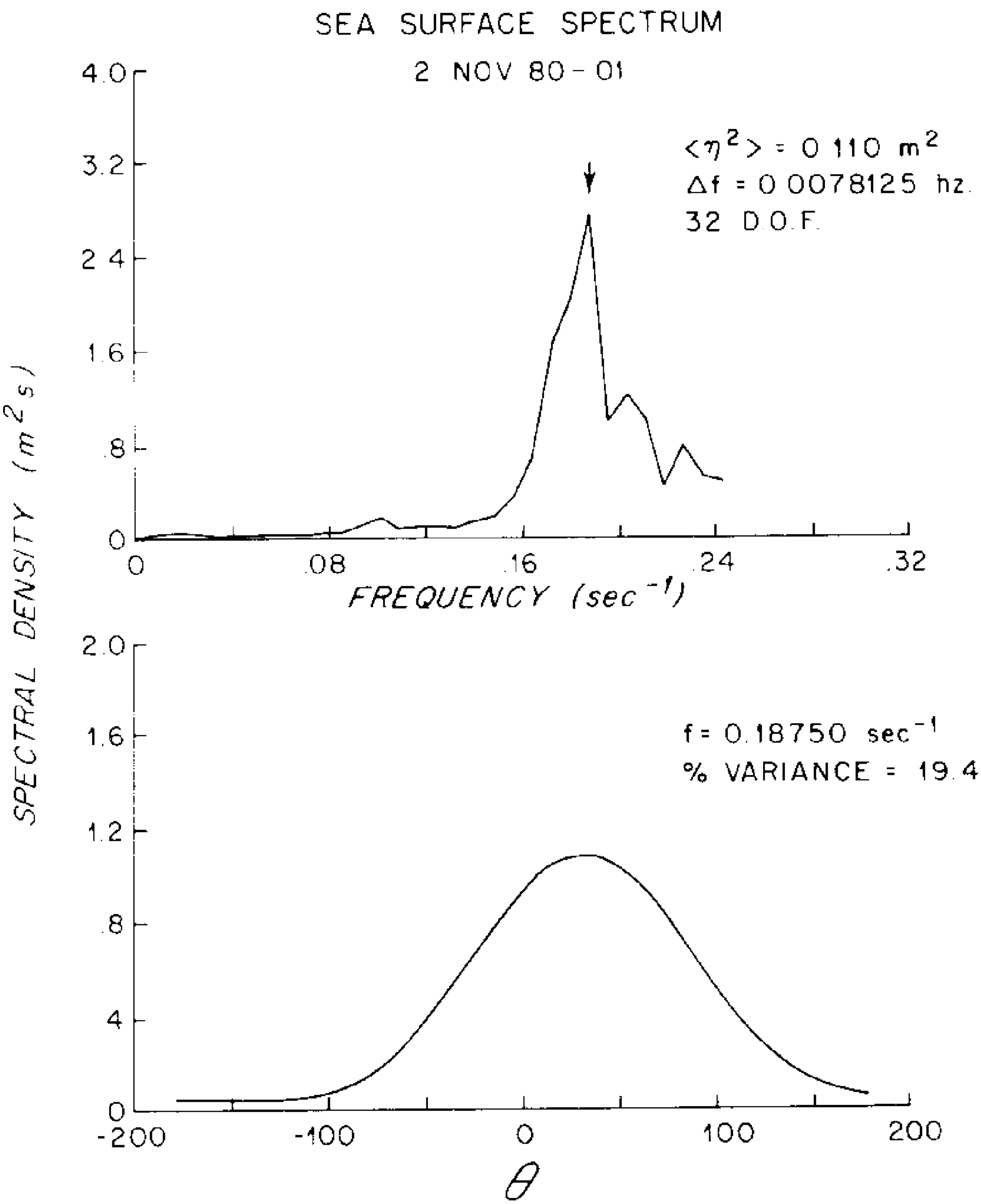

Figure 7: (a) Depth-corrected frequency spectrum for 2 November 1980 (0100 hrs), calculated from u, v. Peak is near 5 seconds. (b) Directional specrum at frequency = 0.1875 hz ϕ = 32° TN (direction waves are coming from), and angular spread is 17°. Units of energy are relative.

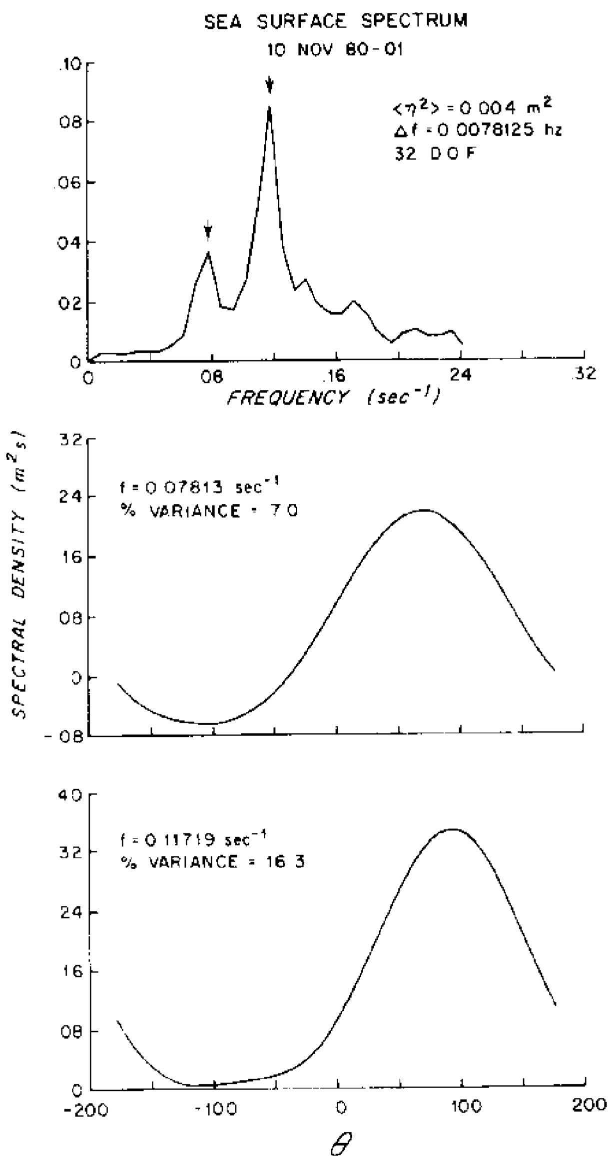

Figure 8: (a) Depth-corrected frequency spectrum for 10 November 1980 (0100 hrs), calculated from u, v. Peaks are near 13 seconds and 8.5 seconds.
(b) Directional spectrum at frequency = 0.07813 hz. ϕ = 94° (direction waves are coming from) and directional spread is 52°. Units of energy are relative.
(c) Directional spectrum at frequency = 0.11719 hz. ϕ = 96° (direction waves are coming from) and directional spread is 39°. Units of energy are relative.

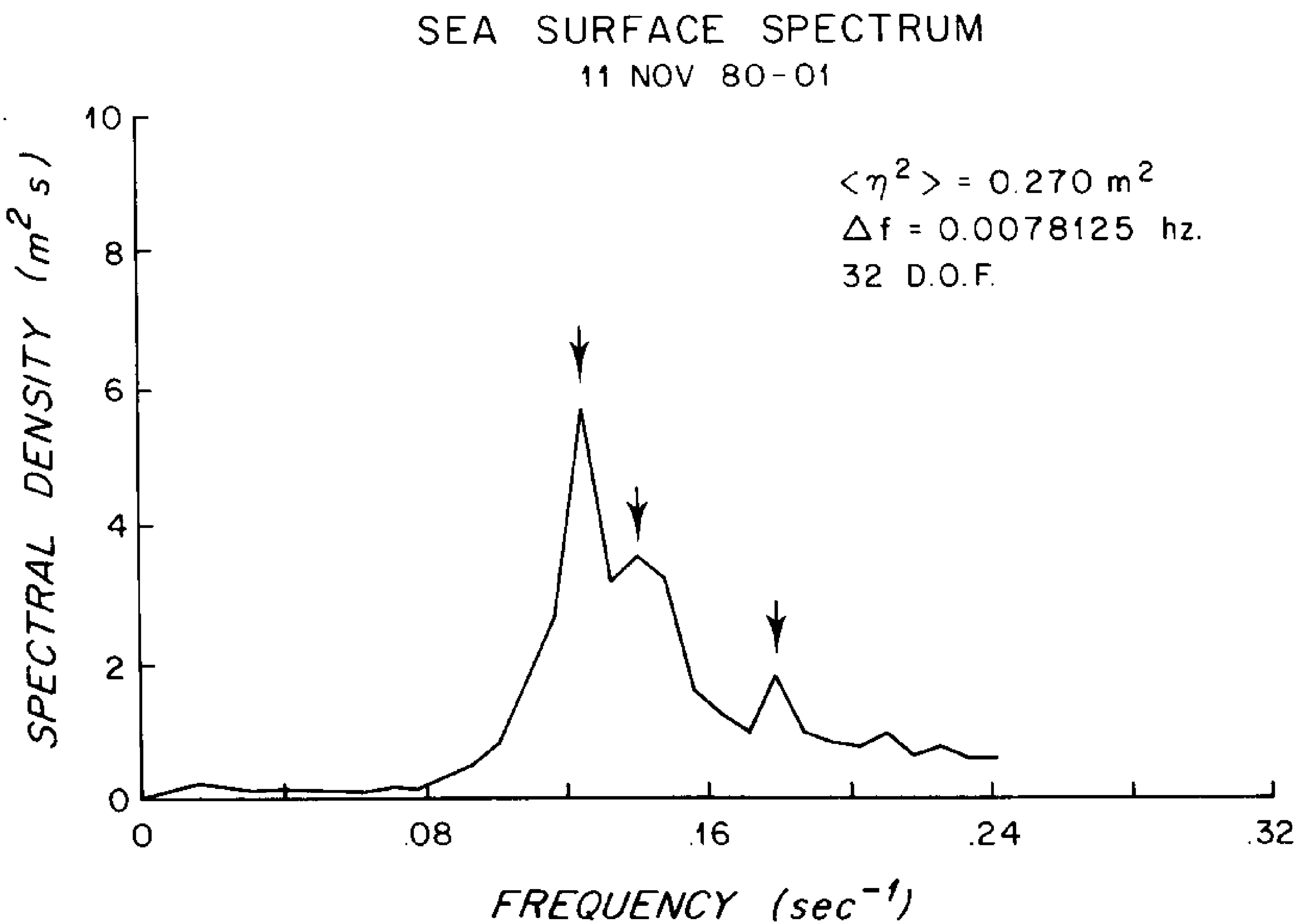

Figure 9: Depth-corrected frequency spectrum for 11 November 1980 (0100 hrs), calculated from u, v. Peaks are near 8, 7, and 5.5 seconds.

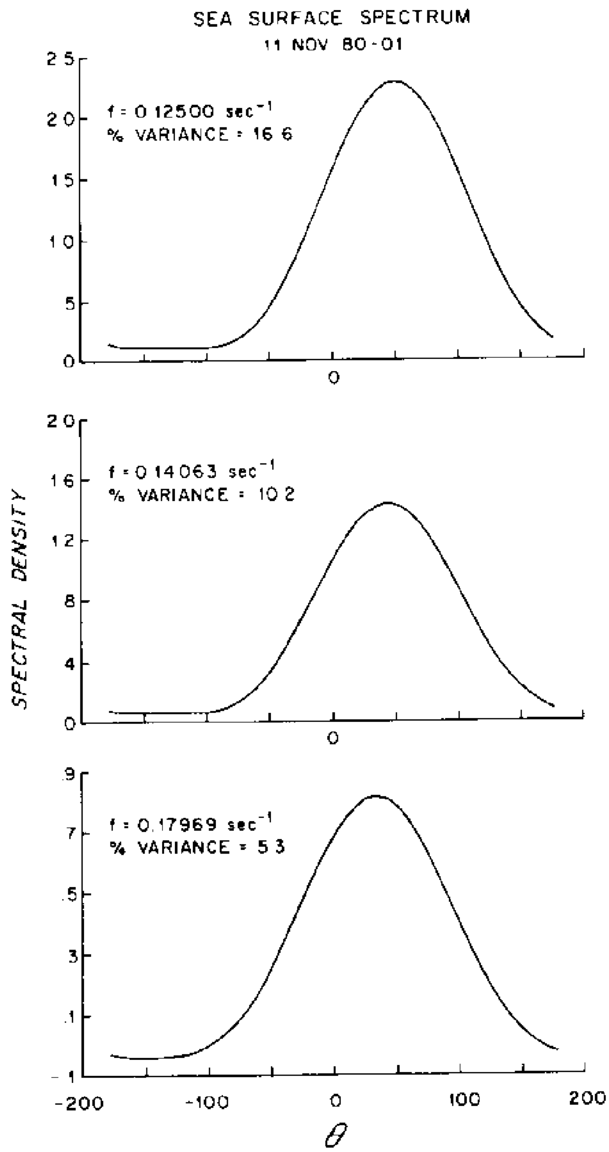

Figure 10: (a) Directional spectrum for 11 November 1980 (0100 hrs), for frequency = 0.125 hz. ϕ = 52° (direction waves are coming from) and directional spread is 22°. All directional energy densities are relative.
(b) Directional spectrum for frequency = 0.14063 hz. ϕ = 42° and directional spread is 24°.
(c) Directional spectrum for frequency = 0.17969 hz. ϕ = 36° (direction waves are coming from) and directional spread is 17°.

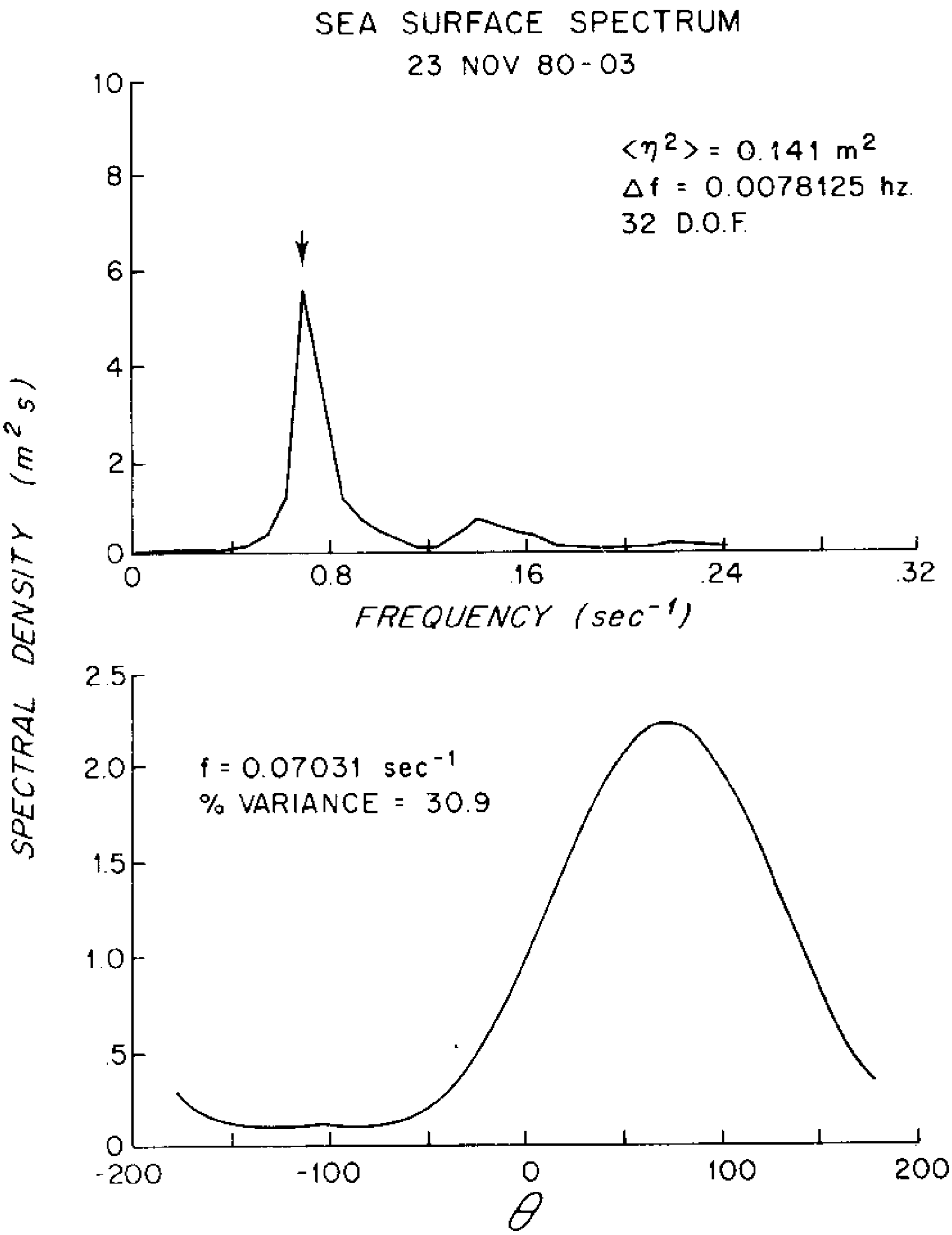

Figure 11: (a) Depth-corrected frequency spectrum for 23 November 1980 (1300 hrs), calculated from u, v. Peak is narrow-band, centered near 14 seconds.
(b) Directional spectrum at frequency = 0.07031 hz. $\phi = 70^{\circ}$ (direction waves are coming from) and directional spread is 20°. Energy units are relative.

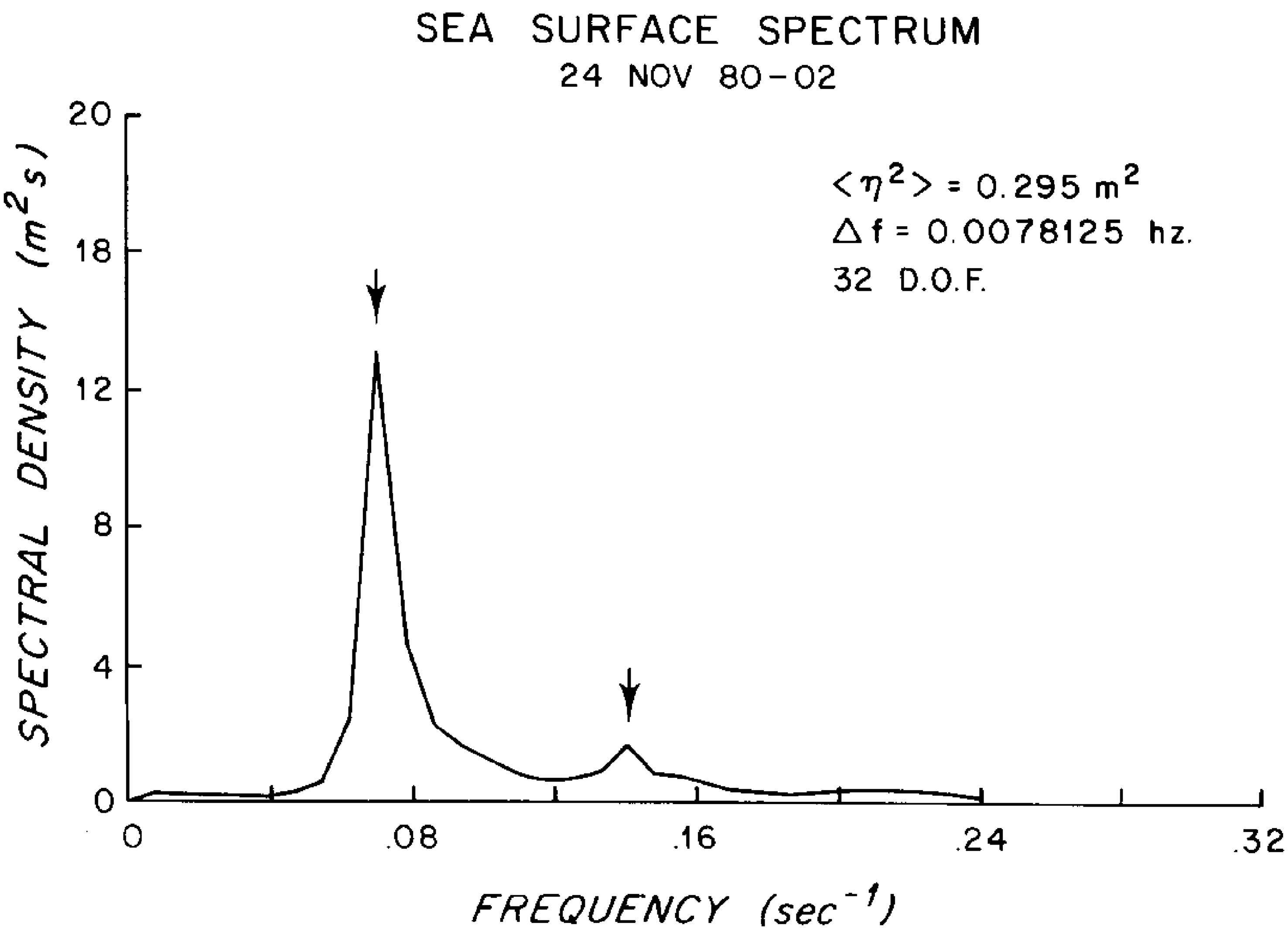

Figure 12: Depth-corrected frequency spectrum for 24 November 1980 (0700 hrs), calculated from u, v. Peaks in spectrum are near 14 seconds and 7 seconds.

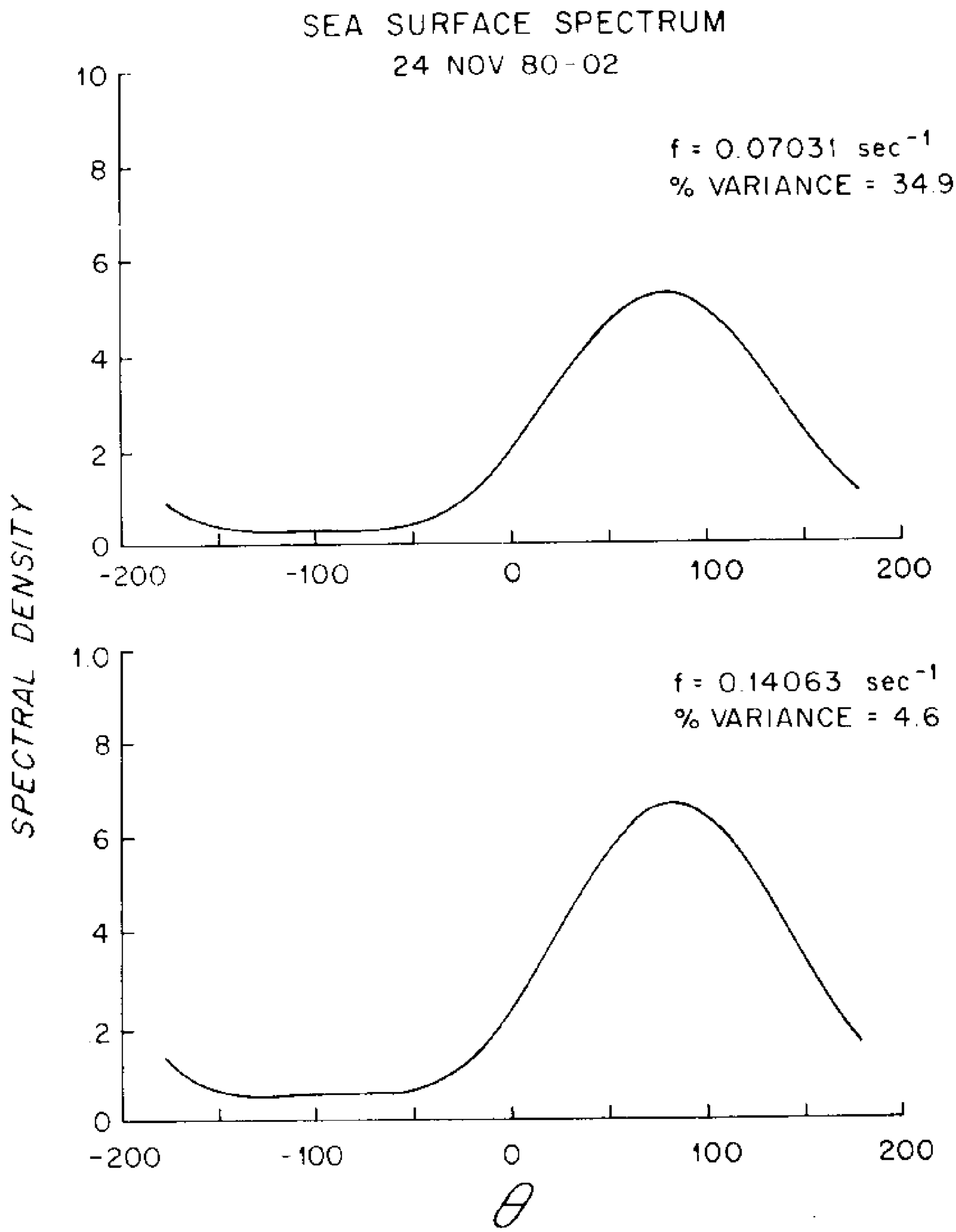

Figure 13: Directional spectra for 24 November 1980 (0700 hrs).
(a) Frequency = 0.07031 hz, ϕ = 79° (direction waves are coming from) and directional spread is 24°. Energy units are relative.
(b) Frequency = 0.14063 hz, ϕ = 78° (direction waves are coming from) and directional spread is 27°.

Future work with the data from this study will include quantitative comparisons of the directional estimates with the results from the slope array (CERC), a Marsh McBirney model 585 directional wave gage operated by CERC, surface imaging radar obtained by CERC, a three-axis acoustic current meter deployed by the Norwegian Hydrodynamic Laboratory (Trondheim, Norway), several CERC current meters and Baylor wave gages mounted on the FRF, and a University of Florida three element pressure sensor array. In addition to directional wave measurements, mean flow time histories will also be intercompared, with a microwave radar technique developed by the Naval Research Laboratory included in this intercomparison.

In addition, data adaptive techniques are being applied to increase the resolution of the directional estimates. In order to test the applicability of linear wave theory to shoaling waves in 7 meters water depth, phase differences between p, u, and v will be routinely computed. The question of wave field stationarity will be preliminarily evaluated by examining how wave statistics change between a 2048 second wave record, and a 1024 second record embedded within it.

Acknowledgements

The instrument was constructed by Sea Data Corporation of Newton, Massachusetts, under the guidance of Mr. Winfield Hill. Funds for performing the field study were provided by Exxon Research Production Research Company under Technical Services Agreement PR-6520 to Sea Data, Inc. The purchase of the instrument, program development, and data analysis were supported by the Department of Commerce, NOAA Office of Sea Grant under Grant numbers NA79AA-D-00102 and NA80AA-D-00077, and by the U.S. Army Research Office.

The diligence of Wayne Spencer in testing, calibrating, deploying and retrieving the instrument under highly adverse conditions is gratefully acknowledged. Dr. Robert Guza and Mr. Paul Cunningham of the Shore Processes Laboratory, Scripps Institution of Oceanography, loaned us a Marsh McBirney current meter for ARSLOE when our current meter malfunctioned. Pam Barrows typed the several drafts of this report. Dr. R.J. Seymour and his associates kindly provided us with wave estimates calculated from the pressure sensor slope array. Special thanks are given to the staff of the CERC Field Research Facility (under the direction of Curt Mason), for their energetic and cooperative support of field operations associated with this data acquisition effort.

This work benefitted from the cooperation of the many participants in ARSLOE, which was hosted jointly by the U.S. Army Corps of Engineers and the National Oceanic and Atmospheric Administration.

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APPENDIX I

Summary of results of Sea Data 635-9 data acquired during ARSLOE in October/November, 1980. Listed are run number (1 = 0100 EDT, 2 = 0700 EDT, 3 = 1300 EDT, 4 = 1900 EDT); peak frequency; corresponding peak period; subjective indication of peak width in frequency (narrow or broad); total energy variance, $< \eta^2 >$, in spectrum (numbers in parentheses are variance calculated from current meter, other numbers indicate variance calculated from pressure sensor); approximate variance in peak frequency; direction of propagation of waves in peak frequency (in degrees true north); and angular spread, in degrees, of wave field at peak frequency (low value indicates low directional spread, hence more directed wave train). All data are surface corrected.

DUCK, N.C.

RUN	PEAK	PERIOD (sec)	BW (Hz)	E_T (cm^2)	E_p (cm^2)	a_0	$P(a_0)$%
1 OCT 80-03	.09375	10.7	Narrow	127 (141)	12	304	39
-04	.08594	11.6	BROAD	115 (130)	15	275	44
	.125	8.0	"		12	269	31
Nov 80-01	.08594	11.6	"	98 (106)	8	262	39
	.1172	8.5	"		10	269	29
-02	.09375	10.7	"	54 (62)	8	285	40
-03	.1094	9.1	"	52 (59)	7	272	40
-04	.1094	9.1	"	60 (69)	9	275	37
Nov 80-01	.1016	9.8	"	1040 (1113)	13	280	27
	.1875	5.3	BROAD		755	212	17
-02	.1523	6.6	BR[illegible]	849 (917)	266	219	20
-03	.14063	7.1	"	604 (640)	213	241	26
-04	.1641	6.1	"	290 (312)	45	233	29
	.2109	4.7	"		30	220	28
3 Nov 80-01	.1563	6.4		254 (285)	32	250	29
-02	.1016	9.8		151 (182)	11	273	28
	.1641	6.1			15	233	33
-03	.125	8.0		155 (191)	16	267	28
	.18[illegible]	5.3			.4	257	29
-04	.1055	9.5		118 (100)	18	275	40
4 Nov 80-01	.1094	9.1		142 (180)	16	272	27
-02	.1016	9.8		140 (171)	16	262	32

DUCK, N.C.

RUN	PEAK	PERIOD (sec)	BW (Hz)	$E_T(cm^2)$	$E_p(cm^2)$	a_0	$P(a_0)$%
Nov80-03	.1172	8.5		112 (125)	18	269	30
-04	.1094	9.1		175 (204)	13	269	33
	.1875	5.3	BROAD		20	292	23
Nov80-01	.1172	8.5		235 (261)	29	272	29
	.1484	6.7			66	291	30
-02	.1953	5.1		388 (471)	240	215	25
-03	.1758	5.7		306 (417)	136	227	23
-04	.1719	5.8		(330)	80	234	34
Nov80-01	.1953	5.1		177 (200)	22	222	26
-02	.1875	5.3		505 (527)	142	218	23
-03	.1094	9.1		368 (401)	60	271	32
-04	.1328	7.5		250 (265)	33	258	31
7Nov 80-01	.1172	8.5		135 (143)	25	266	20
-02	.08594	11.6		85 (84)	12	266	41
-03	.1133	8.8		122 (105)	26	278	39
-04	.1172	8.5		100 (109)	15	260	29
3Nov 80-01	.1211	8.3		68 (73)	14	270	29
-02	.1094	9.1		43 (46)	4	272	32
-03	.1484	6.7		57 (44)	6	294	47
-04	.1445	6.9		44 (43)	8	288	43

DUCK, N.C.

RUN	PEAK	PERIOD (sec)	BW (Hz)	$E_T(cm^2)$	$E_p(cm^2)$	a_0	$P(a_0)$%
9Nov80-01	.1211	8.3		43 (42)	8	292	35
-02	.0859	11.6		52 (47)	4	281	50
-03	.1016	9.8		56 (68)	14	263	41
-04	.1094	9.1		94 (81)	11	270	44
10Nov80-01	.1172	8.5		60 (42)	7	276	39
-02	.07813	12.8		57 (54)	7	278	47.
-03	.07813	12.8		41 (57)	7	253	45
-04	.1953	5.1		452 (445)	118	201	26
	~~.2[illegible]~~	4.7			218	201	29
1Nov80-01	.125	8.0	BROAD	2400 (2706)	1799	232	22
	.1797	5.6			300	216	17
-02	.1484	6.7	"	1746 (1870)	1057	220	21
-03	.1328	7.5	"	1102 (1183)	300	230	24
-04	.1484	6.7		941 (973)	228	228	23
12Nov80-01	.1094	9.1		1447 (1628)	364	242	32
	.1406	7.1	BROAD		340	230	23
-02	.1172	8.5		1832 (1959)	492	239	23
	.1406	7.1			495	223	22
-03	.1328	7.5		1526 (1629)	331	230	22
	.1484	6.7			347	225	21
-04	.1484	6.7		965 (994)	251	230	20

DUCK, N.C.

RUN	PEAK	PERIOD (sec)	BW (Hz)	$E_T (cm^2)$	$E_p (cm^2)$	a_0	$P(a_0)$%
3 Nov 80-01	.1484	6.7	NARROW	1128(1138)	252	227	19
-02	.1172	8.5	" "	1003 (1034)	75	250	30
	.1563	6.4	BROAD		311	227	21
-03	.1172	8.5	BROAD	597(608)	75	251	30
	.1328	7.5	"		75	236	27
-04	.1016	9.8	Narrow	482(486)	184	246	36
4 Nov 80-01	.0938	10.7	"	386(391)	227	270	33
-02	.0977	10.2	"	239(232)	103	262	22
-03	.1016	9.8	"	182(164)	53	264	30
-04	.0977	10.2	Broad	99(104)	33	260	30
5 Nov 80-01	.10156	9.8	"	71 (64)	11	263	35
-02	.08594	11.6	"	50(57)	19	274	46
-03	.08594	11.6	"	41 (41)	14	259	53
-04	.0938	10.7	"	41 (46)	14	254	40
6 Nov 80-01	.1875	5.3	"	184(215)	52	217	33
-02	.1641	6.1	"	1862(2014)	1255	227	19
-03	.1406	7.1	"	1480(1475)	380	250	28
	.1563	6.4	"		374	241	25
-04	.1406	7.1	"	1142(1145)	349	240	20
7 Nov 80-01	.1367	7.3		911(903)	226	243	28

DUCK, N.C.

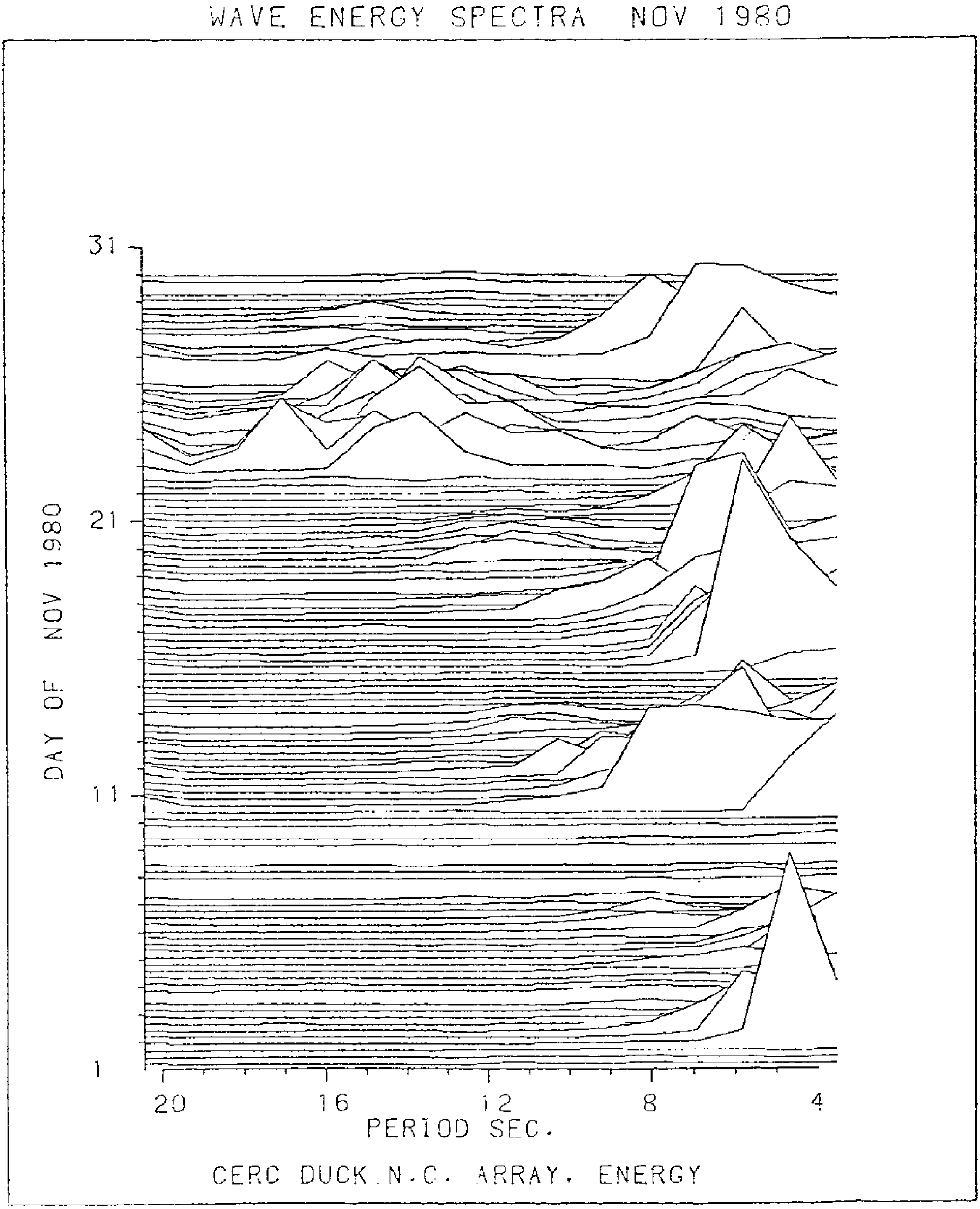
RUN	PEAK	PERIOD (sec)	BW (Hz)	$E_T (cm^2)$	$E_p (cm^2)$	a_0	$P(a_0)$%
7NOV80-02	.1406	7.1	BROAD	662(662)	215	240	20
-03	.1328	7.5	VERY BROAD high f	856(855)	176	250	24
-04	.17188	5.8		843(842)	175	252	21
8NOV80-01	.1484	6.7	BROAD	1293(1246)	735	272	21
-02	.1172	8.5	"	1038(1013)	517	276	26
-03	.1016	9.8	"	480(460)	96	278	28
	.1172	8.5	"		111	275	24
-04	.1641	6.1	"	1259(1263)	446	218	21
9NOV80-01	.1406	7.1	"	1802(1830)	971	230	21
-02	.1328	7.5	"	1337(1386)	505	231	26
-03	.125	8.0	"	943(944)	163	235	27
	.1406	7.1	"		159	244	25
-04	.1094	9.1	"	543(530)	112	239	34
	.1328	7.5	"		103	237	25
20NOV80-01	.10156	9.8	"	(385)	60	241	35
	.122[illegible]	[illegible]	"		58	243	55
-02	.0859	11.6		(452)	182	243	40
-03	.0859	11.6	"	(513)	175	252	36
-04	.0859	11.6	"	(413)	165	260	37
21NOV80-01	.0938	10.7	"	(560)	208	266	38
-02	.0859	11.6	"	(522)	244	263	54

DUCK, N.C.

RUN	PEAK	PERIOD (sec)	BW (Hz)	$E_T (cm^2)$	$E_p (cm^2)$	a_0	$P(a_0)$%
21Nov80-03	.0859	11.6	Narrow	(341)	102	254	32
-04	.0781	12.8	BROAD	(523)	74	270	47
	.1797	5.6	"		83	232	66
22Nov80-01	.1875	5.3	"	(637)	163	249	110
-02	.1484	6.7	"	994(1096)	510	229	26
-03	.1719	5.8	"	468(567)	148	228	19
-04	.1719	5.8	"	312(396)	108	220	32
23Nov80-01	.0625	16.0	NARROW	196(270)	38	247	42
	.1719	5.8	BROAD		44	247	34
-02	.0625	16.0	"	195(267)	51	251	42
-03	.0703	14.2	NARROW	1232(1411)	792	250	26
-04	.0703	14.2	"	2437(2509)	1381	255	28
	.1406	7.1	BROAD		219	256	25
24Nov80-01	.0625	16	NARROW	2255(2496)	1187	254	26
	.1328	7.5	BROAD		285	247	30
-02	.0703	14.2	NARROW	2633(2965)	1779	259	24
	.1406	7.1	BROAD		279	258	27

APPENDIX II

Summary of frequency spectra (band-averaged to yield equal period bands) calculated from slope array to which the Sea Data 635-9 was attached. Local time is PDT, so three hours must be added to obtain EDT, for comparison with Appendix I. Data provided by Dr. R.J. Seymour.



WAVE ENERGY SPECTRA NOV 1980
DAY OF NOV 1980
31
21
11
1
20
16
12
8
4
PERIOD SEC.
CERC DUCK N.C. ARRAY, ENERGY

CERC DUCK N.C. ARRAY, ENERGY
NOV 1980

LOCAL		SIG. HT	TOT. EN	PERCENT ENERGY IN BAND (TOTAL ENERGY INCLUDES RANGE 2048-4 SECS) BAND PERIOD LIMITS (SECS)								
AY/TIME		(CM.)	(CM.SQ)	22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
1	0437	33.6	70.5	7.5	0.7	1.2	1.7	4.9	25.6	30.1	21.3	7.5
1	1037	30.6	58.7	4.5	0.9	1.1	0.9	5.8	18.6	30.8	21.1	16.7
1	1637	33.3	69.5	4.1	2.1	1.3	1.7	7.3	18.4	32.8	18.5	14.2
1	2236	153.7	1476.8	0.8	0.2	0.2	0.1	0.2	1.0	2.0	6.0	90.0
2	0436	124.8	973.0	1.0	0.3	0.2	0.2	0.2	1.1	2.7	39.6	55.1
2	1036	113.5	805.5	0.8	0.1	0.2	0.2	0.2	1.1	7.6	50.8	39.5
2	1639	77.3	373.0	0.9	0.2	0.8	0.7	0.5	2.0	7.3	36.7	51.3
2	2243	71.6	320.8	2.1	0.3	1.5	0.6	0.6	3.4	6.3	29.5	56.2
3	0436	56.7	200.8	3.2	0.5	1.0	1.6	0.9	3.6	10.8	27.2	51.5
3	1038	58.1	211.0	3.9	0.4	0.8	0.7	0.3	2.7	20.1	24.1	47.4
3	2238	64.4	259.2	1.4	0.3	1.1	0.8	0.4	5.0	23.2	14.2	53.9
4	0436	53.0	175.4	4.0	0.5	0.7	1.9	1.0	4.8	26.1	17.1	44.2
4	1038	44.8	125.2	6.2	0.9	2.5	1.9	2.5	3.6	24.7	32.5	25.7
4	1637	62.9	247.6	1.2	0.3	0.3	2.0	0.7	2.5	19.6	11.4	62.5
4	2237	66.5	276.3	1.5	0.3	0.3	1.2	1.5	1.4	16.7	50.9	26.7
5	0436	99.5	618.7	0.8	0.2	0.2	0.5	0.6	0.5	3.7	7.1	86.8
5	1037	84.2	443.5	1.8	0.2	0.5	0.5	1.1	1.0	4.5	23.9	66.9
5	1638	73.3	335.7	1.7	0.2	0.2	1.0	1.2	1.2	4.6	29.0	61.3
5	2236	63.2	250.0	1.6	0.3	0.5	0.7	1.6	1.5	7.9	10.8	75.6
6	0437	99.8	622.7	0.4	0.2	0.2	0.5	0.5	1.6	5.8	22.1	69.2
6	1039	80.3	402.6	1.1	0.3	0.3	0.4	1.6	5.4	27.6	22.3	41.3
6	1041	80.3	402.6	1.1	0.3	0.3	0.4	1.6	5.4	27.6	22.3	41.3
6	1636	66.0	272.4	1.6	0.3	0.4	0.6	1.7	6.2	26.1	29.3	34.2
6	2237	54.7	187.3	2.9	0.3	0.4	1.1	5.7	11.7	45.8	20.6	11.9
7	0437	38.3	91.8	4.2	0.5	1.8	3.5	10.2	33.6	27.8	12.7	6.1
7	1035	41.6	107.9	2.3	0.6	1.5	2.7	13.3	13.3	52.0	10.2	4.6
8	0436	29.9	55.8	2.4	0.6	1.0	2.3	5.1	6.7	25.0	17.9	39.4
8	1044	37.2	86.6	1.8	0.7	1.6	2.8	4.7	5.8	10.4	45.2	27.5
8	1639	30.1	56.7	2.4	0.6	2.1	3.2	3.8	8.7	20.1	34.0	25.5
9	1039	34.4	74.2	3.5	1.2	1.3	7.6	6.3	14.2	27.6	15.3	23.5
9	1637	45.3	128.5	0.8	0.5	0.7	4.7	7.0	5.0	17.0	17.0	47.6
.0	0438	35.7	79.4	5.9	0.5	0.6	2.6	25.4	9.2	22.6	20.7	13.0

CERC DUCK N.C. ARRAY, ENERGY
NOV 1980

LOCAL DAY/TIME		SIG. HT (CM.)	TOT. EN (CM.SQ)	PERCENT ENERGY IN BAND (TOTAL ENERGY INCLUDES RANGE 2048-4 SECS) BAND PERIOD LIMITS (SECS) 22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
10	1039	29.7	55.0	2.9	1.0	1.4	8.3	19.3	12.2	19.8	20.4	15.1
10	1635	117.9	868.2	0.8	0.2	0.1	0.9	2.1	0.4	1.5	1.6	92.8
10	2238	208.1	2705.7	1.9	0.3	0.2	0.3	0.6	3.0	22.8	38.1	33.4
11	0435	178.9	1999.5	1.4	0.2	0.2	0.3	0.4	1.5	9.3	59.9	27.2
11	1037	142.9	1277.0	1.7	0.2	0.4	0.8	0.7	4.3	21.8	40.3	30.2
11	1637	131.4	1079.0	2.1	0.3	0.3	2.4	1.1	6.5	17.4	30.4	40.0
11	2237	168.0	1764.2	1.7	0.3	0.2	0.6	1.2	2.6	25.5	32.2	36.1
12	0437	183.4	2101.6	2.0	0.4	0.2	0.8	2.0	10.2	17.9	36.4	30.5
12	1039	170.1	1807.8	1.3	0.2	0.2	0.5	2.9	3.7	18.6	31.2	42.0
12	1640	136.1	1157.7	1.3	0.2	0.1	0.3	3.1	5.8	22.5	30.5	36.7
12	2237	151.0	1425.3	1.4	0.2	0.2	0.4	2.0	2.3	12.6	47.0	34.4
13	0436	136.1	1157.9	1.9	0.3	0.3	0.3	2.0	9.3	12.6	39.1	34.8
13	1042	110.5	762.5	1.3	0.2	0.3	1.1	3.6	12.4	20.2	21.6	39.8
13	1639	89.9	504.7	1.8	0.4	0.4	1.0	5.1	31.0	18.3	21.4	21.0
13	2238	72.0	324.0	3.6	0.2	0.4	2.3	11.7	42.1	20.1	12.3	7.6
14	1037	52.7	173.5	4.3	0.3	0.7	3.4	4.0	53.7	24.6	6.0	3.5
14	1643	43.9	120.4	3.7	0.6	2.6	6.3	11.4	37.8	23.8	9.4	4.9
14	2242	35.0	76.7	5.2	0.3	1.4	3.0	19.1	32.3	29.1	6.4	3.7
15	0442	29.1	52.9	4.5	0.7	2.4	7.2	20.9	26.0	21.9	9.5	7.4
15	1042	29.4	54.0	3.8	0.7	1.1	9.0	26.3	25.7	12.9	9.5	11.4
15	1642	29.8	55.6	6.0	0.5	1.4	9.0	25.4	24.3	11.9	7.4	14.5
15	2242	68.4	292.6	1.1	0.3	0.5	1.6	2.6	3.8	1.5	8.2	80.7
16	0442	191.8	2299.2	0.9	0.2	0.2	0.2	0.4	0.8	0.5	49.7	47.6
16	1042	161.7	1633.3	0.7	0.2	0.2	0.2	0.4	0.8	1.8	47.5	48.7
16	1640	154.0	1482.4	0.9	0.2	0.3	0.4	0.3	0.5	2.7	45.6	49.5
16	2239	127.8	1020.7	0.6	0.2	0.4	0.5	0.8	0.7	4.8	43.4	49.0
17	0436	113.2	801.3	1.3	0.2	0.4	0.5	0.8	2.1	13.8	40.2	41.1
17	1037	126.5	1000.9	1.2	0.2	0.2	0.8	1.0	1.4	12.4	30.0	53.2
17	1643	125.4	982.7	1.8	0.2	0.2	1.6	0.7	1.0	16.4	34.5	43.9
17	2248	148.0	1369.3	1.7	0.3	0.3	0.5	0.7	1.2	15.7	52.8	27.3
18	0428	133.5	1114.7	2.8	0.3	0.2	0.9	2.4	14.1	41.3	20.7	17.8
18	1049	90.5	511.9	2.3	0.3	0.2	0.6	3.5	13.5	23.7	19.1	37.3
18	1726	131.8	1085.9	1.3	0.2	0.7	0.4	2.4	5.8	7.9	26.2	55.6
18	2251	195.6	2392.3	1.4	0.2	0.3	0.6	0.4	1.9	5.9	59.2	30.5

CERC DUCK N.C. ARRAY, ENERGY
NOV 1980

PERCENT ENERGY IN BAND
(TOTAL ENERGY INCLUDES RANGE 2048-4 SECS)

LOCAL DAY/TIME		SIG. HT (CM.)	TOT. EN (CM. SQ)	BAND PERIOD LIMITS (SECS) 22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
19	1043	134.5	1130.6	1.9	0.2	0.3	1.0	1.6	3.3	14.2	36.3	41.5
19	1707	98.8	609.7	3.1	0.3	0.4	0.7	3.5	4.7	20.1	36.7	31.0
19	2304	86.4	466.9	3.2	0.6	0.6	1.0	5.8	15.6	13.6	24.8	35.2
20	0504	97.0	588.2	3.5	0.4	0.7	1.8	16.3	31.5	16.2	10.6	19.4
20	1040	96.3	579.2	3.0	0.5	1.8	2.8	12.2	38.9	11.2	9.6	20.4
20	1640	88.0	484.5	3.8	0.6	0.8	3.3	21.4	28.3	13.3	12.1	16.8
20	2240	98.3	604.0	5.1	0.3	0.8	6.4	13.1	26.8	21.6	11.9	14.4
21	0439	87.9	483.1	2.8	0.6	1.3	3.9	18.4	31.9	14.8	11.9	14.8
21	1047	83.0	430.2	2.0	0.7	1.4	4.3	15.2	28.8	17.2	13.9	17.0
21	1646	104.4	680.9	1.5	0.5	0.6	2.9	6.7	9.0	10.3	13.8	55.3
21	2239	125.1	978.7	0.8	0.4	0.3	0.9	1.5	5.2	7.7	13.4	70.2
22	0440	140.3	1230.7	0.7	0.3	0.6	0.6	1.3	2.1	6.5	50.8	37.5
22	1040	100.8	635.6	1.1	0.7	1.1	2.2	2.0	2.0	7.6	37.1	46.6
22	1640	94.5	557.9	1.1	0.5	1.9	2.0	2.9	4.1	5.4	27.9	54.6
22	2240	67.8	286.9	2.0	0.9	5.6	8.2	3.7	7.3	9.2	17.0	46.6
23	0440	72.1	324.9	2.0	0.8	6.5	10.2	6.8	6.0	8.1	24.8	35.2
23	1039	144.1	1297.6	2.8	1.0	3.4	21.2	34.9	7.9	6.5	13.6	9.2
23	1640	199.4	2486.0	3.4	1.5	18.6	16.0	17.9	15.2	7.6	11.0	9.3
23	2236	196.3	2408.7	6.4	1.9	16.7	18.2	9.3	14.6	7.5	16.1	9.7
24	0440	191.6	2293.8	4.4	0.8	1.6	14.6	31.7	17.7	10.0	11.6	8.0
24	1042	177.6	1971.6	4.7	1.2	3.2	24.0	25.6	10.5	6.5	14.9	9.7
24	2242	174.1	1893.4	3.3	0.7	2.6	11.5	35.7	12.3	8.7	16.6	9.0
25	1043	171.5	1839.2	2.8	0.9	6.9	22.2	16.0	4.6	8.0	14.5	24.6
25	1641	174.9	1912.6	2.7	0.8	3.3	20.8	15.2	7.9	4.8	14.8	30.2
25	2241	173.3	1877.6	2.1	0.4	3.2	9.1	20.6	6.3	4.3	22.0	32.3
26	0441	171.8	1845.6	2.4	0.2	2.0	16.8	12.1	9.7	6.1	22.3	28.8
26	1048	156.6	1532.5	1.6	0.8	1.5	4.3	16.2	6.5	5.4	38.3	25.8
26	1709	122.1	932.1	2.4	0.6	2.4	14.3	17.4	11.9	8.3	16.8	26.2
27	1714	186.7	2177.9	1.4	0.4	0.3	3.9	3.8	2.9	7.2	46.5	33.9
27	2249	178.2	1984.8	2.7	0.5	1.4	3.1	8.1	6.6	32.3	24.7	21.1
28	0446	138.7	1202.8	2.4	0.6	1.2	6.6	3.9	8.7	27.7	28.5	20.9
28	1646	76.3	364.2	3.1	0.7	6.2	19.3	17.3	8.4	18.7	21.2	5.5

CERC DUCK N. C. ARRAY, ENERGY
NOV 1980

PERCENT ENERGY IN BAND
(TOTAL ENERGY INCLUDES RANGE 2048-4 SECS)

LOCAL		SIG. HT	TOT. EN	BAND PERIOD LIMITS (SECS)								
AY/TIME		(CM.)	(CM. SQ)	22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
8	2243	53.6	179.7	2.5	1.1	6.9	22.4	14.0	14.3	22.1	14.1	3.1
9	0444	53.2	176.7	4.2	0.9	10.2	32.4	14.6	10.8	13.5	10.9	2.9
9	1042	55.3	191.4	3.4	0.8	3.3	51.9	16.6	5.8	7.3	6.4	4.9
9	1641	46.3	134.2	2.7	1.0	2.2	35.7	30.0	10.6	6.4	6.7	5.2
9	2307	35.1	76.9	3.4	0.9	2.4	13.7	34.7	11.1	5.8	10.5	18.0
0	0444	39.9	99.3	3.6	2.3	1.3	7.4	42.2	12.4	7.6	8.0	15.7
0	1640	39.1	95.7	3.5	2.8	2.9	7.5	40.7	11.7	7.4	13.2	10.7
0	2243	38.5	92.6	2.5	2.2	5.3	8.1	43.0	15.0	7.2	9.3	7.8

CERC DUCK N.C. ARRAY, ENERGY
NOV 1980

PERSISTENCE
CONSECUTIVE DAYS (1 OR MORE) SIGNIFICANT
WAVE HEIGHT IS -N- FEET OR LESS

FEET	DAYS				
1	3,	1,			
2	2,	3,	2,	2,	
3	7,	2,	1,	2,	
4	8,	3,	3,	2,	
5	9,	3,	1,	4,	3,
6	9,	12,	7,		
7	30,				
8	30,				
9	30,				
10	30,				
11	30,				
12	30,				

MAXIMUM DAILY SIGNIFICANT WAVE HEIGHT FOR NOV 1980

DATE (NOV)	1	2	3	4	5	6	7
SIG. HT (FT.)	5.0	4.1	2.1	2.2	3.3	3.3	1.4

DATE (NOV)	8	9	10	11	12	13	14
SIG. HT (FT.)	1.2	1.5	6.8	5.9	6.0	4.5	1.7

DATE (NOV)	15	16	17	18	19	20	21
SIG. HT (FT.)	2.2	6.3	4.9	6.4	4.4	3.2	4.1

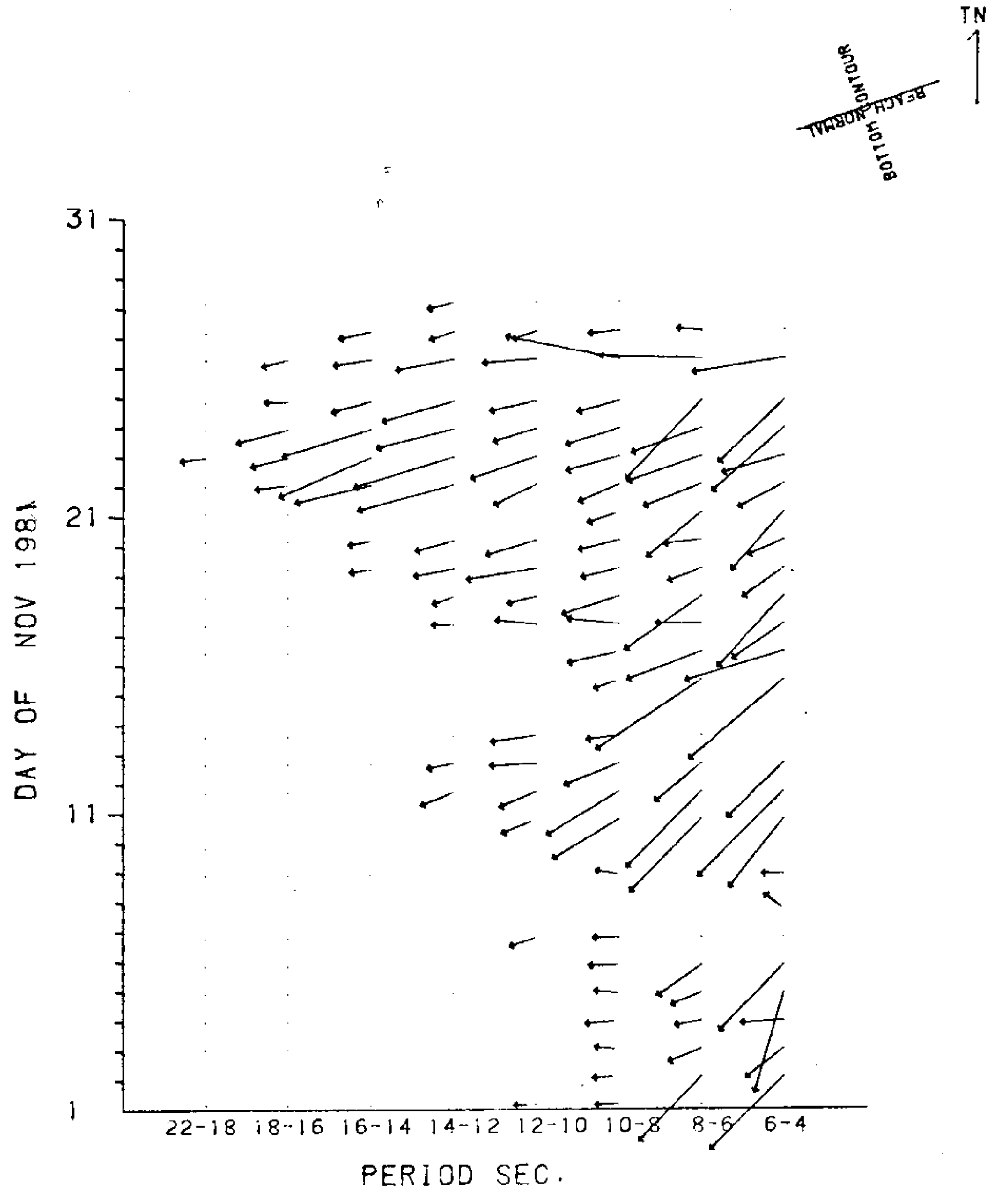
DATE (NOV)	22	23	24	25	26	27	28
SIG. HT (FT.)	4.6	6.5	6.3	5.7	5.6	6.1	4.6

DATE (NOV)	29	30	31
SIG. HT (FT.)	1.8	1.3	0.0

APPENDIX III

Summary of directional information calculated from slope array of four pressure sensors, in which the Sea Data 635-9 was embedded. Times are PDT; three hours must be added to convert to EDT for comparison with data from Appendix I. Angles, relative to true north, indicate direction of propagation of waves within each period band. No estimates of directional spread are given. Data provided by Dr. R.J. Seymour.

WAVE DIRECTION IN PERIOD BANDS



CERC DUCK N.C. ARRAY, DIRECTION

CERC DUCK N.C. ARRAY, DIRECTION
NOV 1980

ANGULAR DISTRIBUTION IN PERIOD BANDS
(ANGLES IN DEGREES)

LOCAL DAY/TIME		SIG. ANG (DEG)	TOT. SXY (CM. SQ)	BAND PERIOD LIMITS (SECS) 22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
1	0437	266.8	14.0		255.2	252.7	268.9	271.8	267.8	268.5	267.2	253.7
1	1037	265.1	11.5		244.6	261.5	270.5	270.6	275.7	274.0	268.8	235.3
1	1637	271.5	17.9		254.5	268.0	262.3	277.7	270.9	275.1	280.9	256.2
1	2236	224.7	-369.0		247.1	296.5	242.1	253.7	269.6	273.0	241.4	220.3
2	0436	227.2	-250.5		247.0	258.0	252.6	231.1	269.6	267.9	224.2	225.2
2	1036	235.6	-147.5		337.4	257.0	261.9	272.4	277.6	252.5	236.1	229.0
2	1639	235.4	-65.3		272.1	272.9	257.8	296.5	271.7	264.0	231.8	229.7
2	2243	238.9	-41.8		264.1	258.2	262.8	270.1	278.5	272.8	236.6	232.0
3	0436	245.0	-11.1		262.6	290.0	266.8	272.4	281.9	274.5	248.3	232.3
3	1038	250.7	2.8		253.8	270.5	284.2	263.0	276.9	274.4	255.7	235.9
3	1630	252.5	6.1		252.3	271.4	260.9	264.5	273.5	273.5	256.2	237.6
3	2238	264.6	41.5		258.4	273.6	252.9	273.4	272.8	271.9	265.4	260.7
4	0436	265.9	30.4		278.5	255.9	269.4	265.2	271.9	266.0	261.0	267.1
4	1038	264.9	21.2		259.6	256.6	276.9	261.0	265.9	268.9	263.6	262.7
4	1637	278.1	65.1		242.1	296.5	253.1	255.4	265.2	276.0	266.2	284.5
4	2237	280.7	87.5		254.2	251.5	259.5	258.3	268.3	274.8	285.0	282.7
5	0436	225.6	-146.5		163.5	252.3	271.8	265.7	268.5	275.7	248.7	196.3
5	1037	231.0	-93.8		250.1	265.9	271.5	254.1	269.2	266.6	237.5	222.3
5	1638	233.8	-61.1		265.7	260.9	250.9	259.2	271.0	266.7	236.0	227.6
5	2236	234.1	-42.4		260.5	269.5	252.9	264.1	258.4	268.3	259.6	220.9
6	0437	231.9	-118.9		234.6	179.8	260.0	257.1	265.1	269.7	235.2	224.5
6	1636	249.4	-1.2		251.5	250.7	257.6	262.0	260.2	270.4	247.3	231.3
6	2237	262.3	28.8		254.8	261.0	264.6	253.1	256.7	270.5	263.3	243.0
7	0437	259.4	9.8		238.3	255.5	257.4	251.2	252.0	268.8	270.1	255.6
7	1035	264.7	20.1		253.2	266.1	259.6	249.4	258.1	268.4	277.0	273.9
8	0436	275.1	14.7		254.2	259.1	263.9	258.2	267.3	270.8	277.2	308.5
8	1044	282.9	29.4		273.3	263.8	261.1	256.7	264.4	274.0	296.5	286.5
8	1639	273.6	14.8		233.5	258.0	259.4	274.8	261.1	273.5	277.4	315.9
9	1039	268.3	16.2		262.2	251.5	255.9	257.2	253.3	280.4	276.9	270.3
9	1637	268.9	25.8		268.9	271.2	251.4	247.3	259.5	269.7	266.5	315.3
10	0438	261.3	9.7		278.6	250.0	249.7	250.9	259.3	268.8	272.8	258.7
10	1039	261.5	7.4		330.8	251.5	255.2	252.3	258.1	264.5	282.2	255.6

CERC DUCK N.C. ARRAY, DIRECTION
NOV 1980

ANGULAR DISTRIBUTION IN PERIOD BANDS
(ANGLES IN DEGREES)
BAND PERIOD LIMITS (SECS)

LOCAL DAY/TIME		SIG. ANG (DEG)	TOT. SXY (CM. SQ)	22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
10	1635	222.3	-218.7		265.4	269.5	257.9	255.5	253.5	260.4	237.5	194.9
10	2238	227.8	-726.9		206.5	212.6	246.3	258.8	244.3	235.0	222.7	224.7
11	0435	224.3	-580.1		236.9	219.2	258.8	240.0	237.7	239.2	221.8	220.9
11	1037	229.0	-325.8		252.9	248.3	245.8	249.2	247.8	239.0	224.5	218.4
11	1637	229.2	-264.7		231.1	206.5	251.2	246.4	243.1	238.8	227.1	218.9
11	2237	230.9	-410.8		241.1	245.7	250.1	247.0	248.3	242.1	224.8	190.8
12	0437	232.0	-470.9		240.7	227.9	251.5	251.6	245.6	239.8	225.0	226.3
12	1039	230.2	-424.8		243.3	261.7	244.7	247.2	246.9	238.9	224.8	225.3
12	1640	233.6	-235.2		170.6	238.0	248.6	251.4	249.4	244.5	228.1	224.0
12	2237	229.6	-346.3		206.5	224.4	243.2	249.8	249.9	243.0	227.4	222.4
13	0436	236.2	-199.2		241.2	250.7	261.4	259.7	256.3	249.1	232.1	226.3
13	1042	240.0	-93.5		250.3	254.2	264.2	260.9	267.5	248.5	230.7	226.1
13	1639	248.3	-15.2		259.5	267.6	244.8	249.3	257.6	257.0	238.5	234.9
13	2238	256.8	28.5		244.0	267.7	258.9	259.1	264.8	253.8	243.9	236.6
14	1037	263.0	28.0		256.8	259.4	259.3	265.6	262.7	263.1	266.1	265.1
14	1643	262.4	19.4		247.5	259.5	270.2	261.4	261.5	264.3	260.6	258.0
14	2242	259.8	8.6		251.5	271.7	260.9	246.4	261.1	264.3	264.6	269.9
15	0442	260.5	7.0		249.1	242.0	258.1	263.0	258.7	265.1	262.2	252.5
15	1042	258.6	5.0		242.5	257.1	271.9	251.7	250.9	267.0	268.6	267.3
15	1642	258.0	4.9		239.9	252.7	260.1	252.4	255.1	268.4	265.6	260.9
15	2242	230.2	-59.5		223.2	265.4	271.1	252.1	255.7	259.9	234.9	224.4
16	0442	229.5	-555.7		227.8	242.6	264.0	253.8	256.5	250.1	228.4	229.4
16	1042	234.3	-305.2		242.5	226.0	255.1	253.4	257.9	250.3	236.7	230.2
16	1640	238.0	-225.2		242.8	273.7	244.5	258.7	255.9	249.1	241.5	233.0
16	2239	238.3	-154.6		256.6	275.1	251.1	270.8	255.4	248.8	237.7	236.6
17	0436	244.0	-68.5		249.9	248.7	251.5	262.7	265.1	258.0	243.6	237.6
17	1037	253.4	23.6		254.0	273.3	261.5	266.0	261.3	258.2	249.7	253.8
17	1643	255.5	54.7		257.0	227.6	260.6	254.6	262.4	268.3	253.9	251.8
17	2248	271.2	329.0		179.1	267.7	246.5	261.7	255.0	270.0	274.5	267.6
18	1049	259.0	63.1		243.6	261.1	276.5	270.6	276.6	276.4	271.6	235.7
18	1726	235.2	-181.7		206.5	253.4	282.0	287.3	296.5	274.9	228.6	219.4
18	2251	228.7	-599.8		230.4	252.9	264.1	251.7	274.0	251.5	226.0	222.3
19	1043	235.2	-203.5		273.3	245.5	256.3	251.4	256.1	252.7	235.1	223.1

CERC DUCK N. C. ARRAY, DIRECTION
NOV 1980

ANGULAR DISTRIBUTION IN PERIOD BANDS
(ANGLES IN DEGREES)
BAND PERIOD LIMITS (SECS)

LOCAL DAY/TIME		SIG. ANG (DEG)	TOT. SXY (CM. SQ)	22+	22-18	18-16	16-14	14-12	12-10	10-8	8-6	6-4
19	1707	236.3	-106.3		229.2	259.3	261.2	253.5	253.1	244.3	233.4	226.7
19	2304	239.4	-60.9		253.1	257.7	258.4	256.5	251.6	249.2	238.7	222.8
20	0504	248.7	-13.7		260.7	255.1	249.1	258.9	252.3	255.6	241.4	229.5
20	1040	253.8	28.5		262.1	249.7	261.7	259.8	261.6	256.5	248.9	234.6
20	1640	250.1	-4.6		273.0	259.8	252.2	249.1	257.9	251.7	248.6	236.5
20	2240	252.6	13.0		296.5	254.1	260.9	250.3	252.8	257.0	257.3	239.8
21	0439	253.6	13.8		255.7	254.2	258.7	253.3	252.3	253.2	256.0	254.0
21	1047	255.6	26.3		259.5	264.2	261.0	255.3	254.2	256.8	264.3	246.7
21	1646	241.8	-58.4		258.6	251.8	258.2	257.7	256.9	267.3	261.6	221.4
21	2239	232.7	-191.1		249.5	253.2	252.6	252.2	255.5	253.7	248.0	221.6
22	0440	227.4	-312.9		245.4	248.9	252.5	247.3	252.9	244.5	226.4	219.6
22	1040	231.8	-137.8		247.4	252.4	261.2	260.0	255.1	251.6	231.0	222.1
22	1640	231.9	-111.2		248.7	262.9	260.0	258.7	260.9	252.9	228.7	222.3
22	2240	242.0	-27.3		266.3	260.1	264.2	254.1	263.0	257.4	241.9	225.2
23	0440	244.6	-22.7		245.4	263.5	253.8	246.6	256.8	253.8	245.9	231.7
23	1039	252.8	34.4		261.4	264.4	257.6	255.5	244.7	247.2	249.2	243.1
23	1640	254.9	139.0		264.4	262.2	254.2	260.1	248.1	248.1	256.2	246.6
23	2236	256.1	158.6		247.2	255.3	258.4	261.0	252.9	252.8	257.3	253.9
24	0440	258.4	230.4		267.8	268.9	262.8	259.3	257.5	256.7	254.0	255.9
24	1042	251.7	3.3		263.6	256.4	247.1	253.5	251.8	254.9	251.5	254.7
24	1634	256.9	184.5		263.0	265.7	252.3	251.2	254.1	252.9	265.1	267.9
24	2242	255.6	102.0		265.1	260.2	253.4	249.2	251.8	267.2	262.9	266.0
25	1043	248.2	-49.8		258.8	256.2	253.6	256.6	253.4	253.2	250.9	228.7
25	1641	245.9	-99.8		257.6	268.0	254.8	252.2	256.2	261.8	243.2	227.0
25	2241	241.8	-189.1		237.6	261.6	265.2	255.4	248.7	256.9	232.1	222.4
26	0441	244.1	-139.8		271.5	265.7	258.8	255.6	252.0	253.6	237.7	226.4
26	1048	237.8	-242.6		257.1	271.5	255.3	254.6	257.9	254.7	224.2	226.4
26	1709	245.4	-57.9		257.2	254.8	250.9	253.9	260.2	256.4	237.4	229.2
27	2249	270.1	478.4		266.6	257.6	261.8	260.1	266.4	281.7	272.0	261.7
28	0446	268.7	272.1		329.9	256.2	253.6	251.3	263.1	278.0	274.8	262.4
28	1646	258.6	35.6		238.0	258.3	249.8	249.8	261.9	267.7	265.2	262.1
28	2243	259.3	20.1		254.2	249.3	258.7	251.4	251.8	265.1	275.4	258.0
29	0444	256.1	11.3		250.0	253.6	246.7	254.0	259.2	271.3	270.7	260.8

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29	1042	255.7	11.2		243.7	254.9	256.1	245.6	248.5	262.4	269.8	268.7
29	2307	251.0	0.6		257.0	250.0	251.7	256.7	245.5	265.4	268.7	189.6
30	0444	250.5	-0.6		258.5	248.0	250.3	249.2	254.3	268.1	271.0	229.2
30	1640	252.3	1.5		265.5	243.5	260.0	254.1	251.9	255.1	247.0	248.7
30	2243	257.5	8.6		250.2	256.4	259.1	262.7	249.4	254.6	253.5	252.3

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A directional wave gage consisting of a two-axis electromagnetic current meter and pressure sensor, developed by Sea Data Corporation, with modifications specified by the author, was successfully deployed during the joint NOAA/U.S. Army Corps of Engineers Coastal Engineering Research Center's Atlantic Remote Sensing Land/Ocean Experiment (ARSLOE) during November, 1980. Data recovery rate was 100%, and instrument function was verified through comparison with a four-element presuure sensor array at the same location, and x-band imaging radar, and with surface meteorological observations charting developing local wave fields. The instrument was proven to be a viable alternative for point measurements of directional wave fields and for estimating the first five fourier coefficients in a directional wave model.

17. Document Analysis a. Descriptors

1. Directional wave spectra
2. Wave measurement instrumentation
3. ARSLOE

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages 52
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