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CURRENT AND DIRECTIONAL WAVE MEASUREMENTS, IN THE BEAUFORT SEA COASTAL ZONE, AUGUST - SEPTEMBER, 1987

by

D.B. Fissel and O.J. Byrne
Arctic Sciences Ltd.
100 Ilsley Avenue, Unit AA
Dartmouth, N.S.
B3B 1L3

for

Dept. of Energy, Mines and Resources
Atlantic Geoscience Centre
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, N.S.
B2Y 4A2
(Scientific Authority: Dr. P. Hill)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES, cont...

ABSTRACT

An extensive set of current and directional wave data were collected within 700 m of the Beaufort Sea coastline over a 21 day period. During this period, a combination of five significant wind events and comparatively large open water fetch resulted in substantial wave activity within the coastal zone. The wave events had a significant wave height of 0.6 to 1.3 m and peak periods of 6.5 to 9.8 seconds.

Large wave orbital velocities were measured during wind events, with typical amplitudes of 0.2 to 0.4 m/s and peak values of up to 1.3 m/s. The wind-driven alongshore currents were generally low amplitude (up to 0.35 m/s) and not correlated to wind and wave activity. Peak current fluctuation amplitudes greatly exceeded the alongshore current by a factor ranging from 3 to 10.

ACKNOWLEDGMENTS

We thank the project's Scientific Authority, Dr. P. Hill, Atlantic Geoscience Centre, Bedford Institute of Oceanography, for his support and guidance through all phases of the study. We also appreciate the assistance rendered by the officers and crews of the vessels involved in this study: M.V. *Nahidik*, USGS *Karluk*, CSS *Tully* and the small vessel *Doppler*. Special thanks are due to Peter Barnes and Eric Reimnitz of the U.S. Geological Survey, and to Dr. Rob McDonald, Institute of Ocean Sciences, Sidney, British Columbia, for providing ship-time on the *Karluk* and *Tully*, respectively. The provision of accommodation by the Polar Continental Shelf Project, Tuktoyaktuk is also gratefully acknowledged.

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1. STUDY OBJECTIVES

Sediment transport processes in the shallow inshore waters of the southeastern Beaufort Sea are of considerable importance for scientific and engineering reasons. The scientific interest relates to the large influx of suspended sediments from the Mackenzie River, and the ultimate fate of these sediments (Fissel and Birch, 1984). Related engineering applications concern improved knowledge of sediment dynamics required for the effective design of offshore facilities, such as pipeline delivery systems for transport of oil and gas produced offshore.

Waves and currents represent the dominant mechanisms driving sediment transport through resuspension (and deposition) and advection. At present, the number of available directional wave and current data sets is extremely limited for the inshore shelf of the Canadian Beaufort Sea. Only three directional wave data sets of extended duration have been obtained to date: measurements at one site in 2.7 m water depth off King Point in 1985 (Gillie, 1985); and measurements in 1986 at two sites (5.9 and 10.5 m) offshore of North Head, Richards Is. (Hodgins et al., 1986). The number of current meter data sets is limited to approximately six (Birch et al., 1987).

Given the paucity of existing directional wave and current data sets and the importance of such data to improving on the present understanding of sediment transport processes, the primary project objective is to obtain additional directional wave and current data sets.

The specific study objectives were:

(1) To collect directional wave and current data in the breaker zone at three coastal sites, of differing sea-bottom characteristics and proximity to Mackenzie River discharge channels. These data must be of extended duration (30 days or more) and be sampled in such a manner as to permit computation of directional wave over a suitable range of time scales, to resolve wave and current dynamics.

(2) To monitor changes in beach and inshore oceanographic conditions (eg. wave patterns and water colour) through the use of time lapse camera systems. This information will be useful as an ancillary data set to (1) above, in documenting the conditions at the coast, concurrent with the period of wave and current measurements. The records should be valuable to other coastal studies being conducted concurrently by the Atlantic Geoscience Centre.

(3) To process, quality control, and archive the collected data in a form suitable for subsequent analysis and modelling.

(4) To provide data sets which are applicable in verification studies of wave hincast models (Pinchin et al. 1985).

2. DATA COLLECTION

2.1 SAMPLING LOCATIONS AND TIMES

The measurement program was conducted in two stages. In the first, a Sea Data model 635-9 Directional Wave/Current Meter (DRCM) was deployed at a site in West Mackenzie Bay (see Figure 1 and Table 1) on July 15. The equipment was deployed from a small aluminum jet boat, the Doppler, working from a shore camp on Ellice Island in the Mackenzie Delta. Site positioning was carried out with a Global Positional System (GPS) unit, which provides an accuracy of 30 m or better. The DWCM was supported by an aluminum frame resting in the seabed (Figure 2A).

Unfortunately, the instrument was not recovered, in spite of four intensive searches in the vicinity of the deployment location. The vessels involved in the search were the CSS Tully (August 16, 1987), the small vessel Doppler (August 22), the USGS Karluk (August 23-24) and the M.V. Nahidik (September 12). In addition to an acoustic release interrogation conducted on all searches, dragging operations were carried out during the last three searches. On the search of September 12, a side-scan sonar unit was also used to search the seabed for the equipment.

The second measurement program was conducted from mid-August to mid-September in the nearshore zone in Kugmallit Bay. A pair of DWCM and continuous recording current meters were deployed within 700 m of the shoreline in water depths of 3.5 and 5.0 m (see Table 1 and Figure 1). The mooring techniques used to support the instruments are illustrated in Figure 2B.

The instruments were deployed from the M.V. Karluk on August 27, and recovered from the M.V. Nahidik on September 17. On recovery, all but one of the instruments were in good operating condition. The Sea Data model 635-9 was found to have leaked, with sea water inside the pressure case. The data tape was advanced only one-half of that expected on the basis of operational time. Subsequent processing of the data revealed that no sensible data were recorded after the first three hours of instrument operation on the seabed.

Two video cameras were operated on the coastline near the oceanographic measurement sites of the second program. The cameras were mounted on an aluminum platform of 4 m height, which was supported by four guy wires to improve platform stability. One camera was directed offshore, while the second camera was aimed along the beach, at the foreshore. Camera operation was controlled by a timer/controller system, manufactured by Lobsiger Associates, Halifax, Nova Scotia. The cameras were activated for one minute at intervals of three hours, provided an operational duration of 30 days.

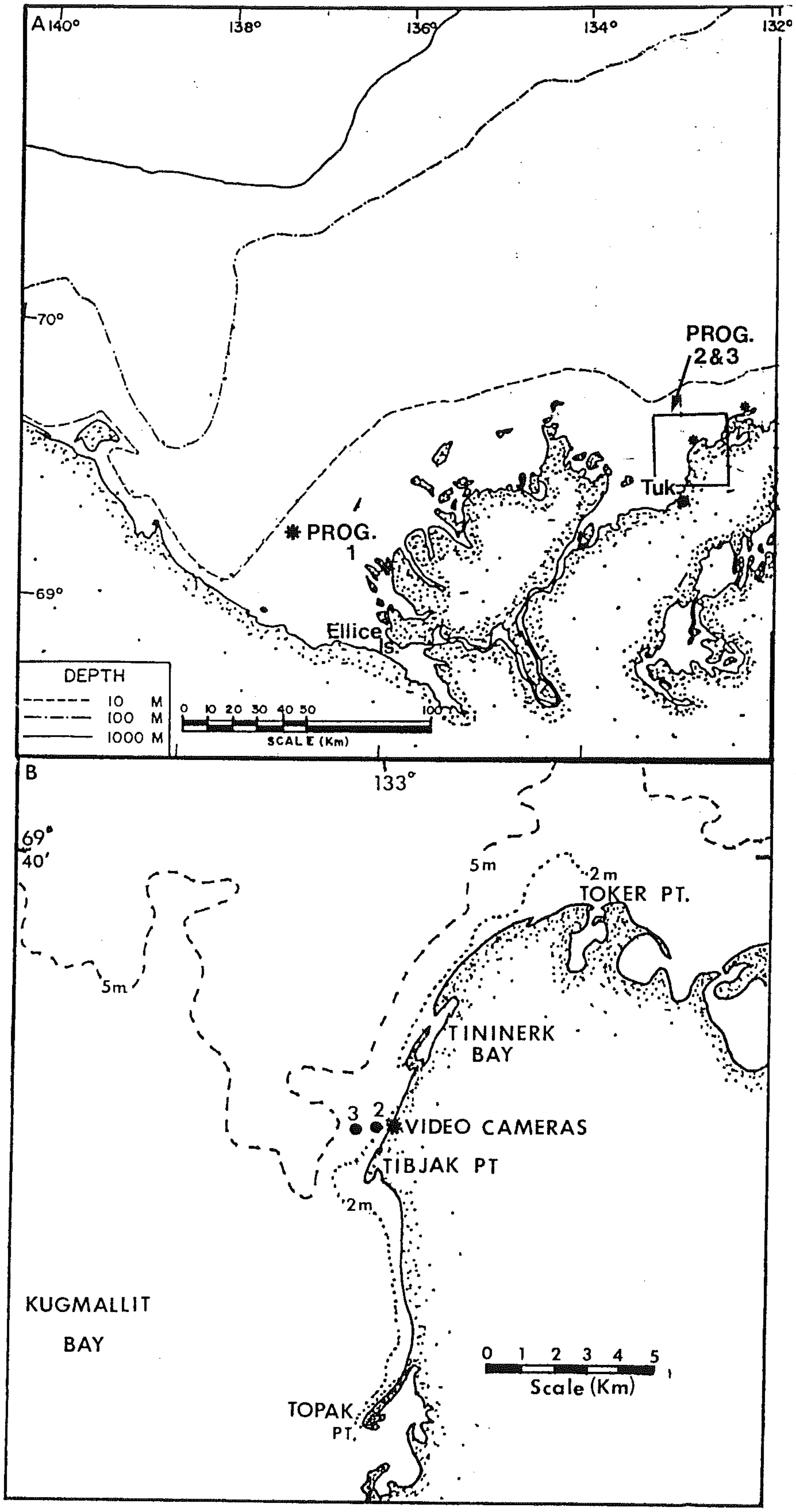

Figure 1: Sites of current and wave measurements: (A) site 1 in Mackenzie Bay and (B) sites 2 and 3 in Kugmallit Bay just north of Tibjak Point.

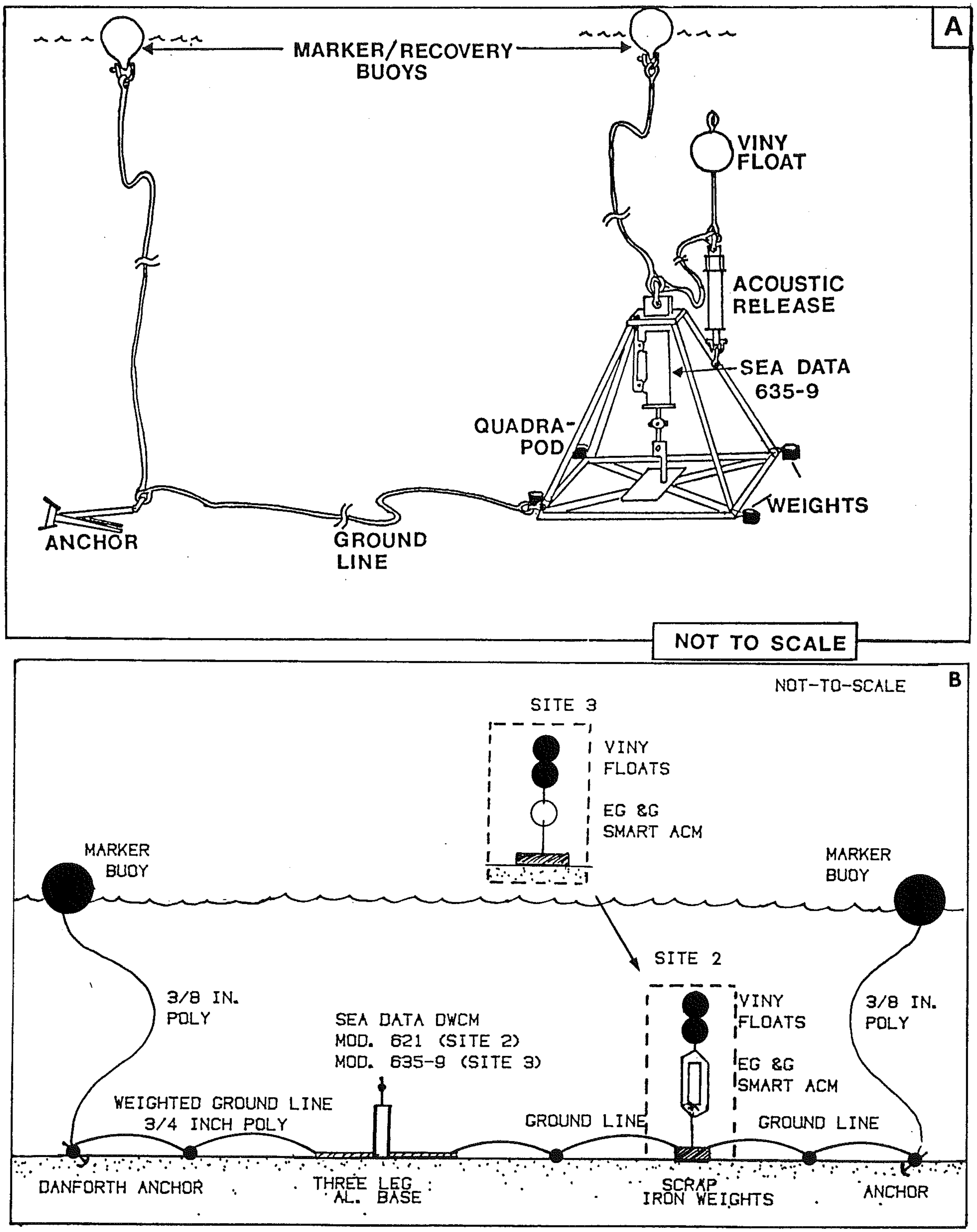

Figure 2: Illustration of the mooring techniques used to support the instruments at (A) site 1 and (B) sites 2 and 3.

TABLE 1

Times and locations of current meter and directional wave instrumentation

SITE	INSTRUMENT	LATITUDE	LONGITUDE	INSTRUMENT/ WATER DEPTH (m)	TIME OF DEPLOYMENT (MDT = Z + 6)	RECOVERY
1	Sea Data DWCM 635-9	69°20.5'N	136°59.3'W	8/9	July 15 0415	NR
2	Sea Data DWCM 621	69°35.4'N	133°0.0'W	2.4/3.5	Aug. 27 1445	Sept. 17 1115
2	InterOcean CM S4	69°35.4'N	133°0.0'W	2.5/3.5	Aug. 27 1445	Sept. 17 1115
3	Sea Data DWCM 635-9	69°35.4'N	133°0.0'W	3.8/5.0	Aug. 27 1555	Sept. 17 1045
4	EG & G Smart ACM	69°35.4'N	133°0.0'W	4.0/5.0	Aug. 27 1555	Sept. 17 1045

Notes: DWCM - Directional Wave Current Meter
CM - Current Meter
ACM - Acoustic Current Meter
NR - Not Recovered

2.2 OCEANOGRAPHIC INSTRUMENTS

Directional wave and current measurements (DWCM) were obtained using a Sea Data model 621 instrument. The manufacturer's specifications for instrument performance are provided in Table 2. The Sea Data DWCM measured pressure, and east-west and north-south velocity components at one second intervals. The instrument was programmed to burst sample, providing 1024 consecutive one second measurements (17.07 minutes) every three hours.

Two different current meters, the EG & G Smart Acoustic Current Meter (SACM) and the InterOcean model S4, were used at the nearshore measurement sites. Both current meters and the Sea Data DWCM are true vector averaging current meters, having no moving parts; these attributes make the instruments well suited to measuring currents in the presence of large orbital wave velocities. Technical specifications and accuracies for the SACM and S4 are given in Table 2.

TABLE 2

Manufacturers' specifications for the Sea Data model 621, InterOcean S4 and EG & G Smart ACM.

SENSORS	TYPE	RANGE	ACCURACY	RESOLUTION
(a) Sea Data model 621 directional wave/current meter				
Velocity	Marsh-McBirney electromagnetic 2 axis	±3.0 m/s	0.02 + 2% of signal (steady rate)	0.0015 m/s
Pressure (Depth)	strain gauge	(69 m)	(0.69 m)	(0.017 m)
Direction	digicourse compass	0 to 360°	5°	1.4°
Clock	quartz crystal	---	30 secs/year	---
(b) InterOcean model S4 current meter				
Velocity	electromagnetic 2 axis	0 to 3.5 m/s	2% signal + .01 m/s	0.002 m/s
Direction	flux-gate magnetometer	0-360°	2°	0.5°
Temperature	semiconductor	-5 to +45°C	0.2°C	0.05°C
Conductivity	conductive	1-70 mmho/cm	0.2	0.1
Pressure (Depth)	semiconductor	(0-1000 m)	(2.5 m)	(1 m)
Clock	quartz crystal	---	12 months/ year	---
(c) EG & G Smart ACM				
Velocity	acoustic phase shift	0 to 3.6 m/s	0.01 m/s or 3% of signal	0.001 m/s
Direction	magnetic compass	0 to 360°	5°	0.1°
Temperature	thermistor	-2 to 3.5°C	0.05°C	0.01°C

The InterOcean S4 was programmed to measure velocity components averaged over three minutes, once each fifteen minutes. The other measured quantities (pressure, temperature, conductivity and compass heading) were measured once each hour.

With the EG & G SACM, velocity component averages were averaged and recorded at 10 minute intervals. Instantaneous temperature samples were also recorded at 10 minute intervals.

3. DATA PROCESSING

3.1 DIRECTIONAL WAVE AND CURRENT MEASUREMENTS

The data recorded on the Sea Data model 621 were converted from the cassette data tape to 9-track computer tape. The reading and conversion of the raw data were of high quality with only 11 parity errors (out of 26611 logical records). However, the output from the data conversion was found to contain extended sequences of 1 bits added to the data stream. These additional bits, apparently introduced by the data reader device, had to be manually removed from the raw data set.

The raw data were then converted to engineering units using the nominal conversion formulae supplied by the manufacturer:

Velocity components (m/s) = $1.48866 \times 10^{-3} * N$

Pressure (dbars) = $0.01682*N$

Compass = $1.40625*N$

where N is the raw count recorded by the instrument for each raw channel. Note that pressure in decibars (dbars) is almost exactly equal to depth in metres.

At this stage, examination of the converted data revealed occasional occurrences of large errors in all channels. Most of these errors occurred as groups of eight successive records having particularly suspect values. The cause of these errors appears to be related to a problem in internal buffering of the raw data within the Sea Data instrument (or on conversion to computer tapes), since the pressure and velocity components are stored in groups of eight before being written to tape.

The erroneous data (occurrences are summarized in Table 3) were replaced by the mean value of the appropriate channel. Another problem occurred in the latter half of the Sea Data 621 burst records (beginning in the burst data of 2200 September 3). Toward the last part of the burst record, the velocity component and pressure samples would be suddenly shifted or offset by a constant amount, which varied in amplitude among the burst records (typically 0.05 to 0.3 dbars; 0.05 to 0.3 m/s). For purposes of data display and subsequent analyses, the last 128 burst samples were not used for burst data obtained after 2200 September 3. (In the burst data of 2200 September 3, the offset occurred earlier in the record, with the result that the last 384 burst samples were omitted.)

Finally, the spectral plots computed for purposes of wave analysis (see below) revealed the presence of a 0.25 Hz (4 second period) noise in the pressure data. The amplitude of this narrow-banded noise was small, amounting to approximately 0.04 dbars. A correction was made to all wave spectra to eliminate this error.

TABLE 3

Burst sampled data sets in which erroneous measurements (velocity components and pressures) were manually corrected through substitution of the channel mean.

BURST NO.	START TIME	NO. OF LOGICAL RECORDS CORRECTED
36	1600 August 27	16
40	0400 August 28	8
48	0400 August 29	8
67	0300 August 31	8
81	0700 September 2	8
96	0400 September 4	8
110	2200 September 5	24
135	0100 September 9	8
202	1000 September 17	128

WAVE ANALYSES

Using the DWCM data, both nondirectional and directional wave parameters were computed. Initially, the near-bottom pressure and current components were used to compute the sea-level pressure (or surface) displacements and velocity components by applying frequency dependent scaling factors computed from linear wave theory (Grosskopf et al., 1983):

$$K_p\ (f) = \cosh\ [k(h + z)]/\cosh\ [kh] \qquad \text{(pressure)}$$

$$K_u\ (f) = \cosh\ [k(h + z)]/\sinh\ [kh] \qquad \text{(velocity)}$$

where "f" is the natural frequency, "h" is the water depth and "z" is the measurement depth. The wavenumber, "k", is computed according to deep water wave approximation:

(i.e. for $kh > \pi/2$, $0.90 < \tanh kd < 1$):

$$k = 4\pi^2 f^2/g$$

The individual burst records (consisting of 1024 one second samples) were subdivided into eight blocks of 128 samples for the wave analysis.

Using the above equations for pressure and velocity attenuation factors, correction factors were computed and applied to each fourier transform, derived from the burst-sampled blocks (see Table 4).

TABLE 4

Correction factors for pressure and velocity fluctuations applied to the Sea Data model 621 DWCM data ($h = 3.5$ m, $z = 2.4$ m).

CENTRE FREQUENCY (Hz)	PERIOD (s)	CORRECTION FACTOR PRESSURE
0.001	1000.	1.000
0.183	5.46	1.101
0.217	4.61	1.202
0.241	4.15	1.312
0.256	3.91	1.404
0.271	3.69	1.502
0.282	3.55	1.600
0.293	3.41	1.701
0.302	3.31	1.796
0.311	3.22	1.900
0.318	3.14	2.002
0.332	3.01	2.204
0.344	2.91	2.403
0.354	2.28	2.610
0.363	2.75	2.800
0.372	2.69	3.008
0.383	2.61	3.291
0.396	2.51	3.674
0.405	2.47	4.007

The nondirectional wave parameters, significant wave height (H_s) and peak period (T_p) were then computed. The valid data from each burst record were divided into blocks of 128 one second samples. Using the fourier coefficients from each data block, following correction for pressure attenuation with depth, the mean auto-spectrum was computed. The area (A) within the auto-spectrum over frequencies from 0.02 (50 seconds) to 0.4 (2.5 seconds) was used to compute the significant wave height:

$$T_s = (8*A)^{1/2}$$

with the peak period determined as the inverse of the centre frequency of the band containing the largest spectral density.

A directional wave parameter, the mean wave energy direction (MWED), was computed for each burst data set as:

$$MWED = 1/2 \arctan [2\langle u'v'\rangle/(\langle u'^2\rangle-\langle v'^2\rangle)]$$

where u' and v' are the wave orbital velocity components. This parameter has been shown by Hodgins et al. (1986) to agree well with mean wave directions from directional wave spectral analysis in the Beaufort Sea.

3.2 CURRENT METERS

The raw data stored in memory on both the InterOcean S4 and EG & G SACM instruments were initially transferred to Arctic Sciences mini-computer through an RS-232 serial interface. Both current meter records were converted to scientific units. The current directions were converted from geomagnetic to true geographic coordinates, using a magnetic variation of 40 degrees. The data sets were scrutinized for erroneous or suspect values, with five or fewer corrections made to either record. The pressure data from the InterOcean S4 is incorrect, as the pressure is constant for all but the first two days of data collection.

The current meter data records were then processed to provide standard display products, time series plots, derived statistical parameters (mean, standard deviation, maximum and minimum) and joint bivariate distribution of current speed and direction.

3.3 ANCILLARY DATA

Information on meteorological and ice conditions was also acquired for this study. The meteorological measurements were obtained from the Canadian Climate Centre of Atmospheric Environment Service, from their weather station at the Tuktoyaktuk, N.W.T. airport. Measurements were available every hour with the exception of 2300 to 0500 local (MDT) time. For this study, we examined wind speed and direction, along with air pressure and air temperature measurements.

Information on regional sea-ice coverage was also prepared for this study at bimonthly intervals. The original data were obtained from the Ice Centre of the Atmospheric Environment Service. Four ice concentration categories were used to classify ice conditions: 0 - open water; A - 1 to 4 tenths;

B - 5 to 7 tenths; and C - 8 to 10 tenths. The ice charts are presented in Appendix A.

4. RESULTS

In this report, preliminary quantitative results are presented for the current and wave measurements obtained in the coastal zone near Tibjak Point.

4.1 WEATHER AND ICE CONDITIONS

The areal extent of the sea-ice in the early summer of 1987 was extraordinarily small in comparison with previous years. The ice extent during July and August in 1987 (Appendix A) was compared with similar maps of sea-ice extent over a 29 year period (1955 to 1960 inclusive and 1964 to 1986 inclusive), currently being complied for another project (Fissel et al., 1988). The area of sea-ice in July, 1987 was less than that of any other year examined. The reduction in sea-ice extent in early and mid-July was considerable, even in comparison with the ice extent of 1980 and 1982, the two previous years having the smallest areas of sea-ice.

The meteorological conditions in the summer of 1987, as plotted in Figure 3, indicate that weak to moderate easterly wind conditions prevailed at Tuktoyaktuk through July and the first half of August. From August 20 to September 14, a sequence of west to north-westerly wind events occurred. Easterly winds dominated the latter half of September and most of October.

During the August 27-September 17 period of coastal current and wave measurements, the most intense wind events of the summer season were measured at Tuktoyaktuk, just 15 km south of the Tibjak Point measurement locations. Strong wind events, having speeds of up to 15 m/s, occurred on August 28 and again on August 31 (Figure 4). Wind events of somewhat reduced magnitude (up to 12-13 m/s) were measured on September 5-6, September 8-9 and September 13.

In all cases, the winds were blowing from the west or northwest. Due to the conspicuous absence of sea-ice over the continental shelf, the wind fetch from the northwest exceeded 500 km on August 27, being reduced to approximately 400 km by September 10, due to advection of pack ice by the northwesterly winds (see Appendix A). In summary, the wind and ice conditions experienced during late August and early September were unusually favourable for the generation of large waves on the coastline.

4.2 COASTAL CURRENTS

The current measurements at sites 2 and 3 are displayed in the form of time series plots (Figures 5 and 6), basic statistics (Table 5), and joint bivariate distributions of speed and direction (Figures 7 and 8).

At both measurement sites, the direction distribution of currents was bimodal, setting in the along-shore direction either to the north-northwest or

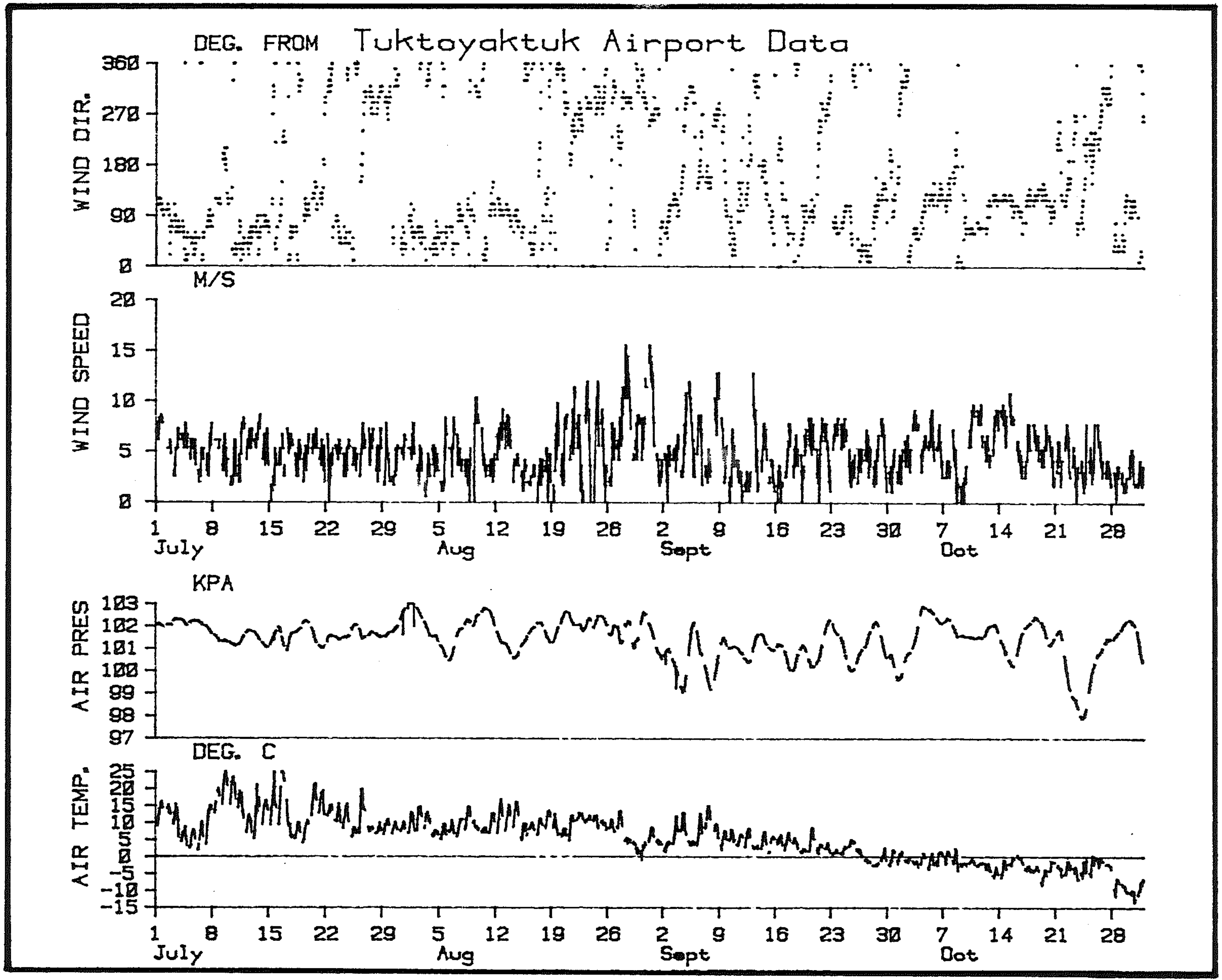

Figure 3: Measurements of wind speed and direction, air pressure and temperature at Tuktoyaktuk Airport, July 1-October 31, 1987.

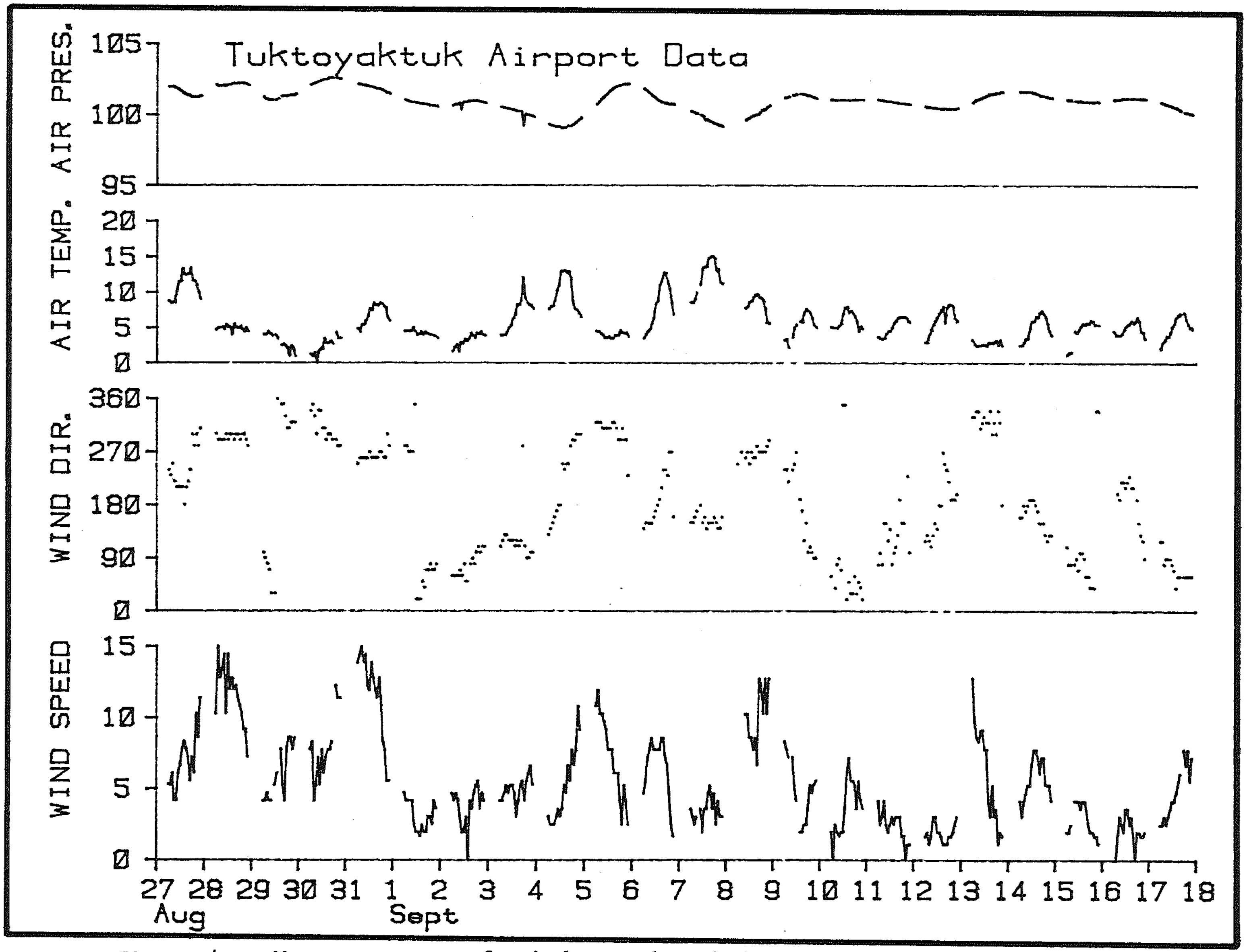

Figure 4: Measurements of wind speed and direction, air pressure and temperature at Tuktoyaktuk Airport, August 27-September 17, 1987.

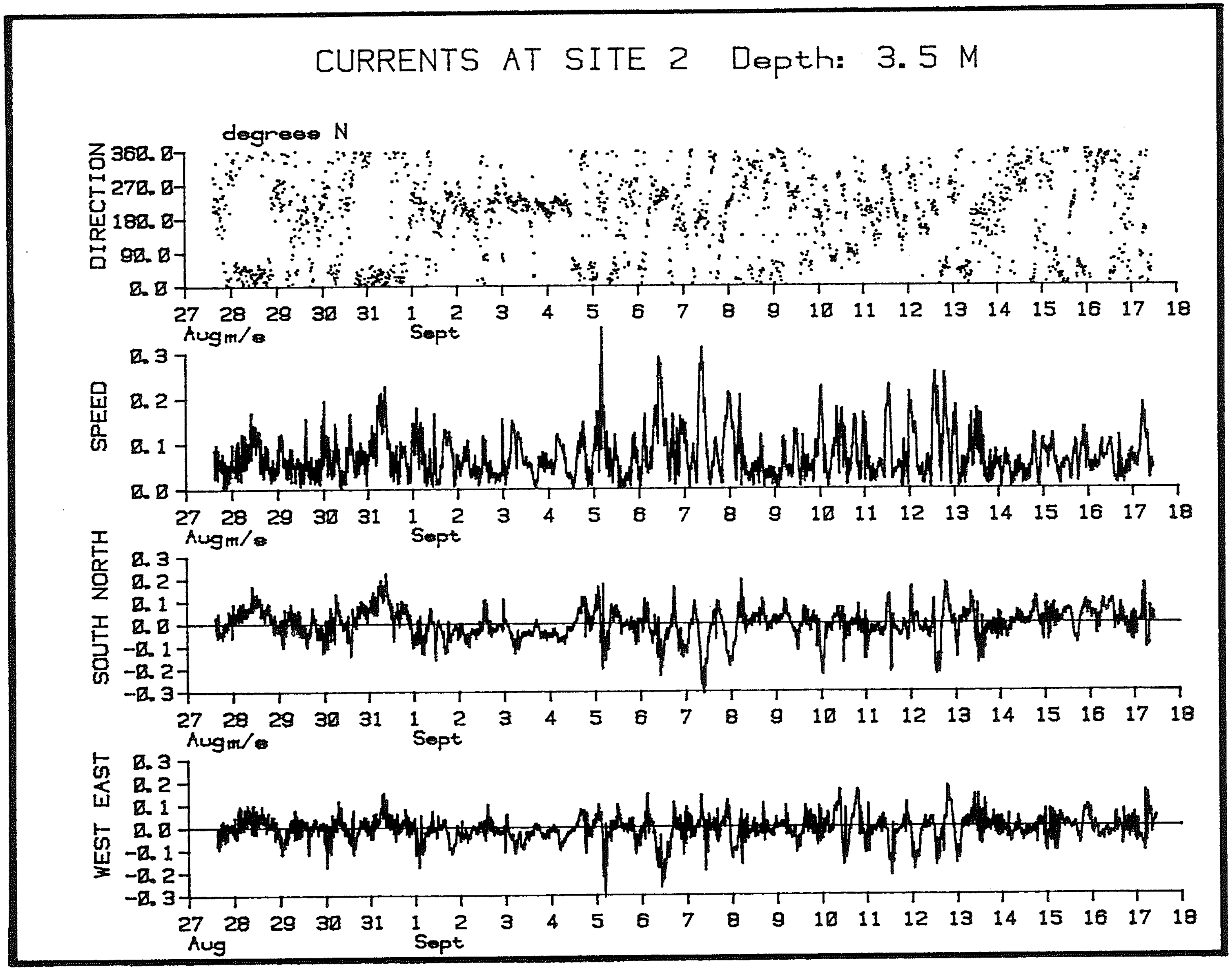

Figure 5A: Currents measured at site 2 - water depth 3.5 m, sensor depth 2.5 m.

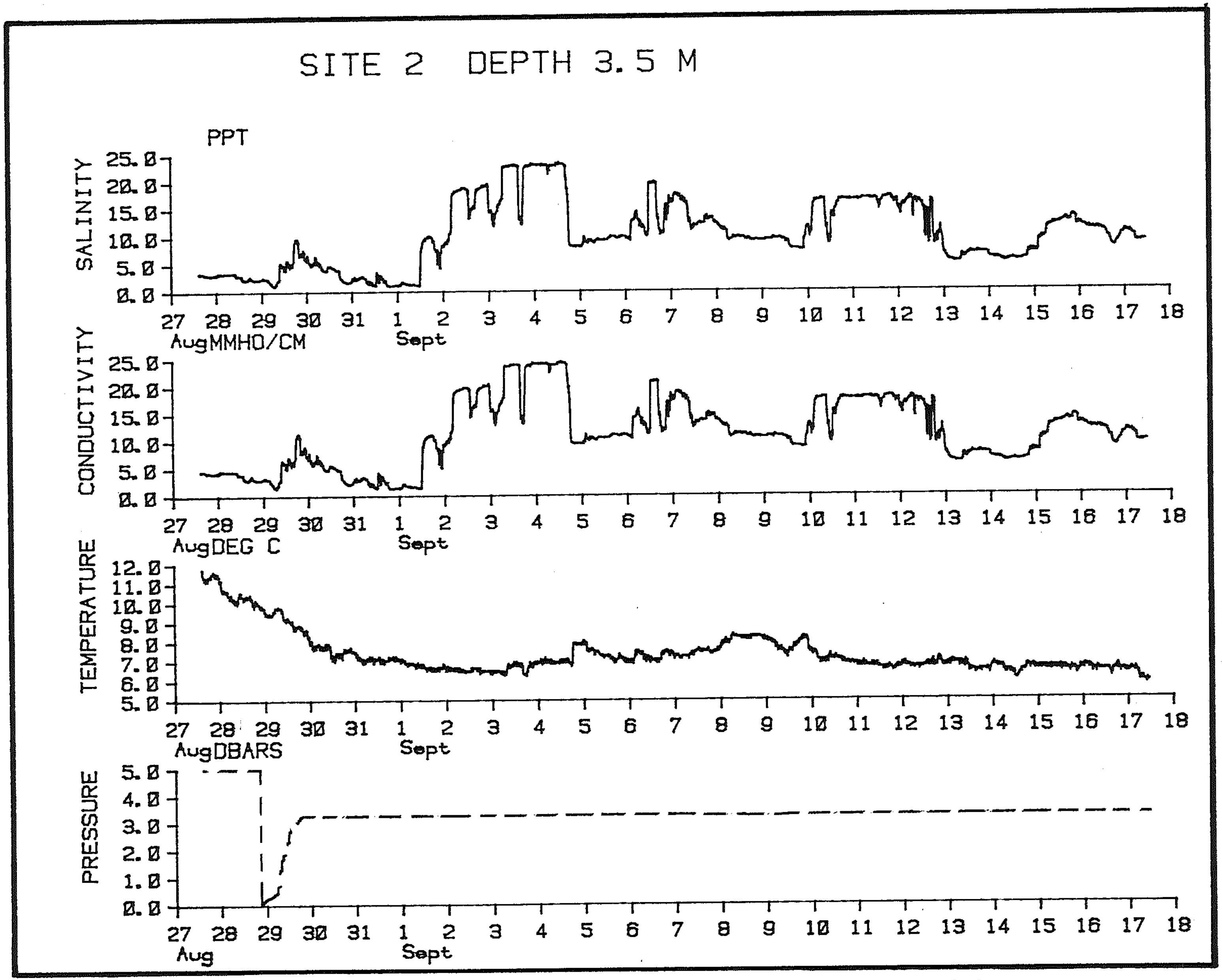

Figure 5B: Water properties measured at site 2 - water depth 3.5 m, sensor depth 2.5 m.

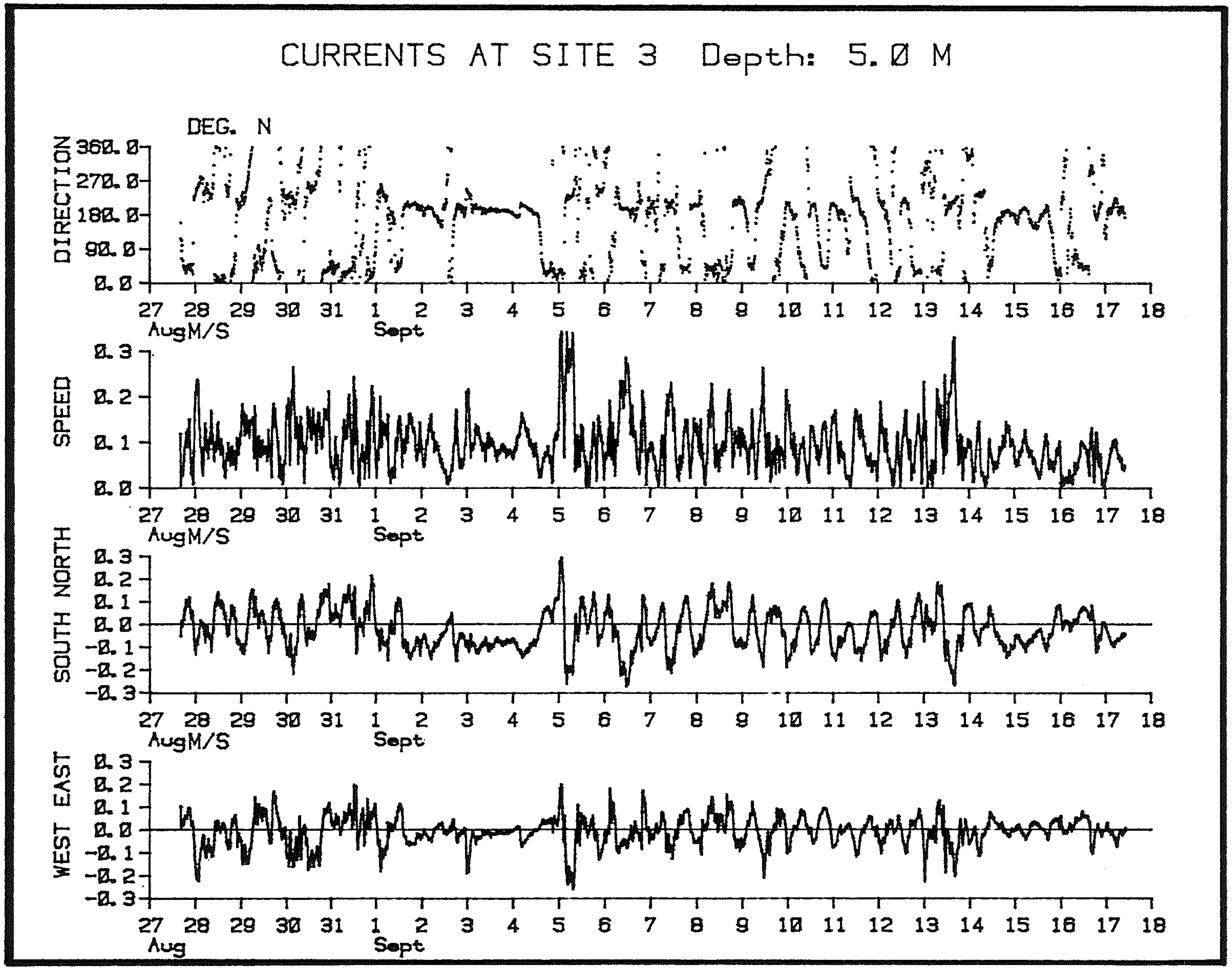

Figure 6A: Currents measured at site 3 - water depth 5.0 m, sensor depth 4.0 m.

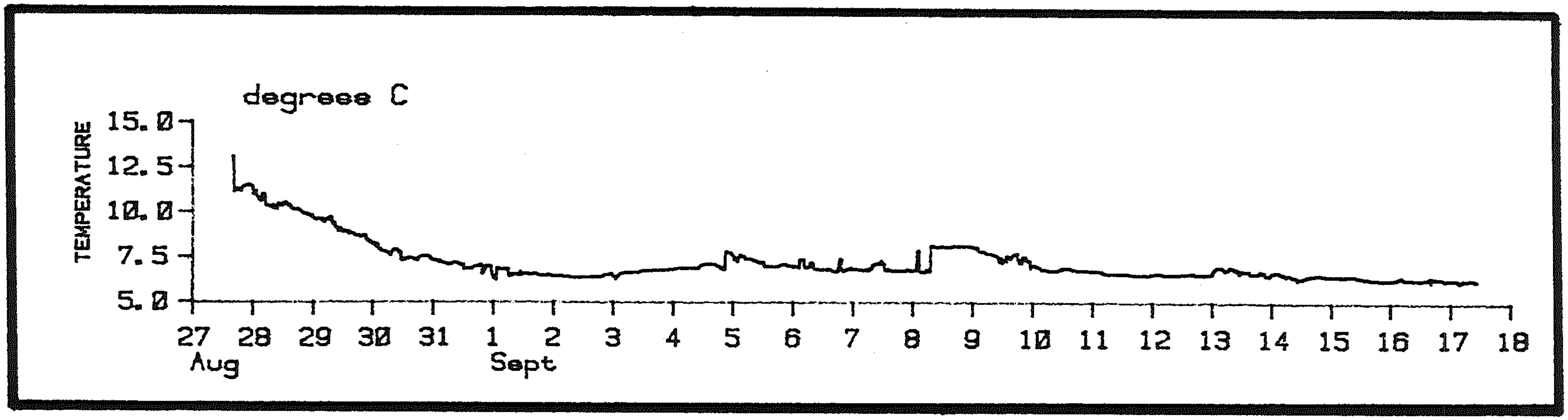

Figure 6B: Temperatures measured at site 3 - water depth 5.0 m, sensor depth 4.0 m.

TABLE 5

STATISTICS FROM CURRENT METER DATA AT SITE 2: WATER DEPTH 3.5 M

start date is 1987 8 27 14 48 0.0
stop date is 1987 9 17 10 48 0.0

QUANTITY	UNITS	MEAN	STD.DEV.	MAXIMUM	MINIMUM
ns_velocity	m/s	-0.0037	0.0668	0.224	-0.310
ew_velocity	m/s	-0.0104	0.0600	0.179	-0.309
speed	m/s	0.0719	0.0506	0.356	0.000
direction	degrees tru	255.2	75.7	359.9	0.0
conductivity	mS	11.27	5.98	24.5	1.3
temperature	degrees C	7.32	1.11	11.76	5.75
salinity	ppt	10.20	5.85	23.49	1.00
pressure	dbar	---------Data not valid--------------			

STATISTICS FROM CURRENT METER DATA AT SITE 3: WATER DEPTH 5.0 M

start date is 1987 8 27 16 20 0.0
stop date is 1987 9 17 10 20 0.0

QUANTITY	UNITS	MEAN	STD.DEV.	MAXIMUM	MINIMUM
ns_velocity	m/s	-0.0241	0.0865	0.294	-0.275
ew_velocity	m/s	-0.0091	0.0641	0.198	-0.259
speed	m/s	0.0958	0.0556	0.342	0.002
direction	deg. N	159.9	91.4	359.7	0.1
temperature	degrees C	7.21	1.10	13.04	6.18

```
DISTRIBUTION OF CURRENT SPEED AND DIRECTION AT SITE 3
                                                  WATER DEPTH 5.0 M


start date 1987 8 27 16 20 0 stop date is 1987 9 17 10 20 0


                       speed()
     0.02 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56
       TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO
     0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60
DIR                                                                             PERCENT
   0    8   27   23    4    1                                                       2.2
  10   10   29   25    8    2    2    1                                             2.7
  20    7   45   49   23   21    2    1                                             5.2
  30   12   46   54   44   24   11    1    1    6                                   7.0
  40   12   57   62   36   14                                                       6.3
  50   10   28   21    6    7    2    1                                             2.6
  60   10   19   12    4    5                                                       1.8
  70    9   14    6    4    3                                                       1.3
  80    8   16    7                                                                 1.1
  90    5   10    5         1                                                       0.7
 100    2   14    1                                                                 0.6
 110   12   10    4    1                                                            0.9
 120    5    9    2    1                                                            0.6
 130    9   14    1         1                                                       0.9
 140   18   26    1                                                                 1.6
 150    7   40    9                                                                 2.0
 160   16   46   21    3    1                                                       3.1
 170    7   48   60   10                                                            4.4
 180   10  104  106   22    7    3    1                                             8.9
 190    4   64  137   52   13   22    8    1                                       10.6
 200   10   36   71   95   22   14    1                                             8.7
 210   10   26   55   36   23    9    3    3    5                                   6.0
 220    9   17   26   36   18    5    7    9    3                                   4.6
 230   11   20   24   25   11    7    1    4    2                                   3.7
 240    6   10   20   19    9    7    1                                             2.5
 250    5   10   11   11    4    6                                                  1.6
 260    4    9    6    6    2                                                       0.9
 270    3    8    4    2                                                            0.6
 280         6    5    3    1                                                       0.5
 290    2    5    9    8    1                                                       0.9
 300    3    2    5    7                                                            0.6
 310    5    8    1    4                                                            0.6
 320    6    3   10    3                                                            0.8
 330    4    6   10    2                                                            0.8
 340    6    9    5    4    2                                                       0.9
 350   16   15   16    7         1                                                  1.9

      9.9       31.0        6.8        0.9        0.6        0.0        0.0        0.0
          30.0       17.0        3.2        0.6        0.0        0.0        0.0

NO. OF RECORDS 2851
NO. OF RECORDS BELOW STALL SPEED (0.02 ) 138
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Figure 7: Distribution of current speed and direction at site 2 - water depth 3.5 m.

```
DISTRIBUTION OF CURRENT SPEED AND DIRECTIONS AT SITE 2
                                           WATER DEPTH 3.5 M

start date 1987 8 27 20 48 0 stop date is 1987 9 17 16 48 0


                         speed(m/s)
     0.02 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56
       TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO   TO
     0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36 0.40 0.44 0.48 0.52 0.56 0.60
DIR                                                                            PERCENT
   0    7   27   16    3    5    1                                                 3.3
  10   12   20   20    7    4                                                      3.5
  20   14   23   24   10    2                                                      4.1
  30   14   34   15    8    2                                                      4.1
  40   14   31   20    9    1    4    2                                            4.5
  50    5   25   14    3    1                                                      2.7
  60    7   16    7    2    2                                                      1.9
  70    4   12    8    5    1                                                      1.7
  80    9   12    4    5    1                                                      1.7
  90    7    2    2    1                                                           0.7
 100    6    5    2    2                                                           0.8
 110    5         3    1                                                           0.5
 120    6    8    3                                                                0.9
 130    8   13    9    2    2                                                      1.9
 140    2   22    8    7                                                           2.2
 150    5   25    7    6    2                                                      2.5
 160   12   15    4    2         2                                                 1.9
 170   16   19   10    3    4    1    4                                            3.2
 180    9   30    5    5    3    4         2                                       3.2
 190   17   30   10    7   11    3    1                                            4.4
 200   16   45   12   11    2    2    1                                            4.9
 210   14   36   11    6    5    4    1    1                                       4.3
 220   27   37   25   15    3    3    1    1                                       6.2
 230   15   23   28   12    5    1    4                                            4.9
 240   16   17    9    6    2         1                                            2.8
 250   15   14   10    4              2                                            2.5
 260   23   20    4    4    7                                                      3.2
 270   13   23   19    1    3                                                      3.3
 280    9   15   10   10    1    1                                                 2.6
 290    7   13    6    3    3    1              1                                  1.9
 300   11   11    2    3    5                                                      1.8
 310    5   14    7    3    3    1                                                 1.8
 320    3   23    6    2                                                           1.9
 330   12   19    9    1    2                                                      2.4
 340    6   14   26    1    1    1                                                 2.7
 350   14   26   12    2    1                                                      3.1

     21.4      21.5       4.7       0.9       0.1       0.0       0.0       0.0
          40.0       9.6       1.6       0.2       0.0       0.0       0.0

NO.     OF RECORDS 1798
NO.     OF RECORDS BELOW STALL SPEED (0.02 m/s) 203
```

Figure 8: Distribution of current speed and direction at site 3 - water depth 5.0 m.

south-southwest. The net flow over the 21 day long record was to the south with only a small vector magnitude of 0.011 and 0.026 m/s at sites 2 and 3 respectively.

Semi-diurnal current variations were prominent at site 3, having typical amplitudes of 0.10 m/s. These variations result from tidal flows and inertial oscillations. Interestingly, the semi-diurnal variations measured at the shallower site 2 had reduced amplitude and were noticeably less regular, or sinusoidal, in character.

The coupling observed between low-frequency (sub-tidal) currents and the local winds was remarkably poor by comparison with results obtained in deeper shelf waters of the Beaufort Sea (eg. Fissel and Birch, 1984). At sites 2 and 3, the currents exhibited only a modest and short duration increase in amplitude during the strongest wind events of August 28 and August 31. The largest currents measured at both sites occurred on September 5 (speeds of 0.35 m/s), and were associated with the moderate northwesterly wind event of this date. Similarly, another modest wind on September 13 resulted in larger currents than the more intense wind events of late August.

Water properties measured at site 2 exhibit very pronounced changes due to the passage of wind events. Each northwesterly wind event was marked by the presence of low water salinity, and to a lesser degree, somewhat warmer temperatures. The low salinity water likely reflects the advection of Mackenzie River-influences past the coastal measurement site by the west to northwesterly wind events.

The data from the Sea Data DWCM can also be analysed to provide more information on mean currents and water levels (Figure 9), in addition to the wave properties (Section 4.3). Like the conventional current meters, the strongest mean currents (over individual bursts) occurred on September 5, having a magnitude of 0.38 m/s setting alongshore to the northeast. The changes in mean pressure demonstrate that significant increases in water level occurred during each northwesterly wind event. Positive storm surges occurred during each of the five wind events, with amplitudes ranging from 0.8 m (August 31) to 0.4 m (September 8-9). The water level variations associated with storm surges appear to be much larger than the semi-diurnal tidal variations, having amplitudes of 0.2 m.

4.3 WAVE ANALYSES

The burst data collected with the Sea Data DWCM at site 2 (see example in Figure 10) were subjected to spectral wave analysis techniques to compute appropriate wave parameters. The nondirectional parameters, wave height (H_s) and peak period (T_p), are presented in Figure 11. The directional wave parameters (MWED and the maximum and root-mean square amplitude of current fluctuations), are shown in Figure 12. The auto-spectra of the surface wave field for selected large wave events are contained in Appendix B.

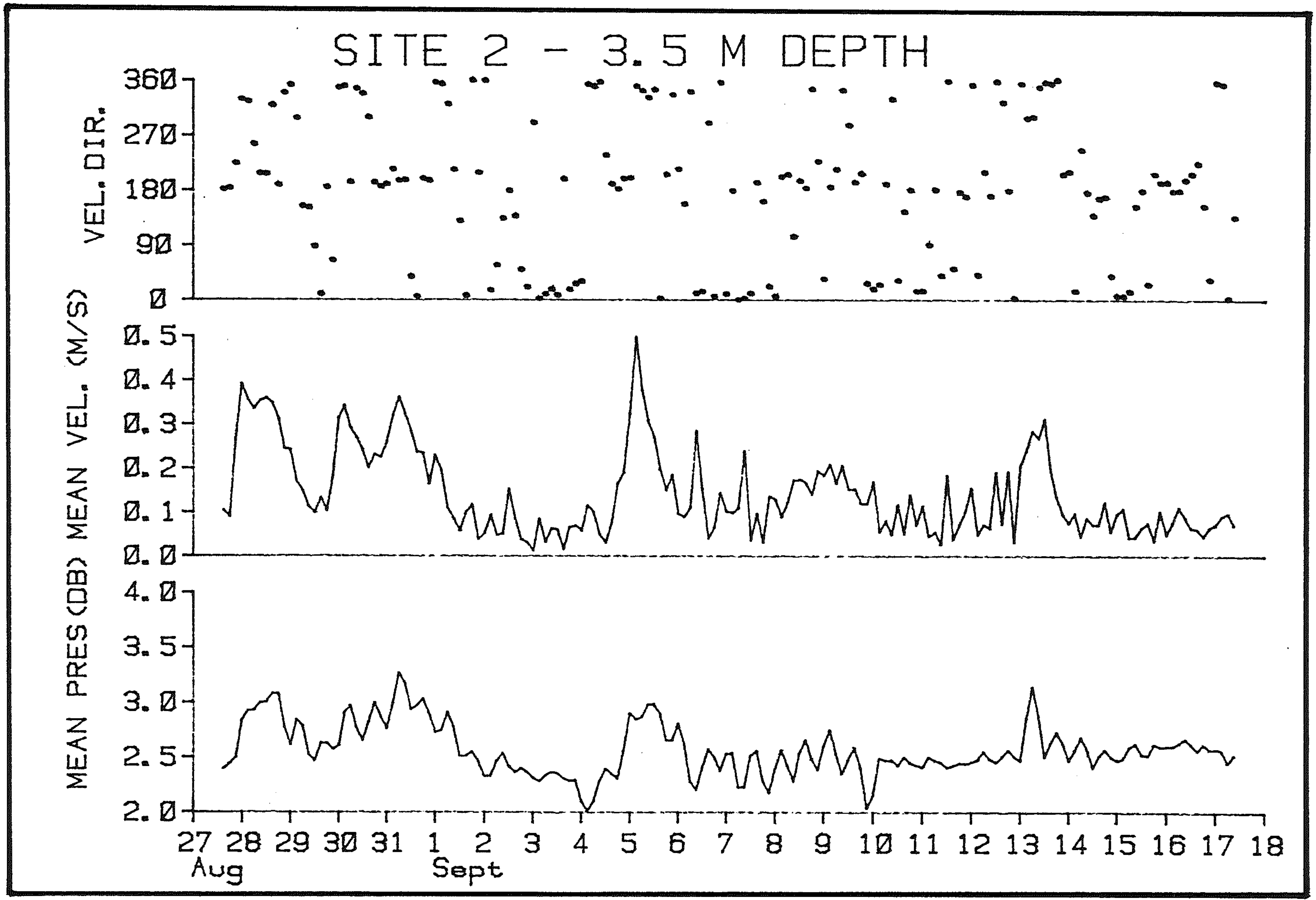

Figure 9: Time series plot of pressure, vector-averaged current velocity magnitude, and direction, as computed as the mean of each three-hourly burst data set from the Sea Data DWCM.

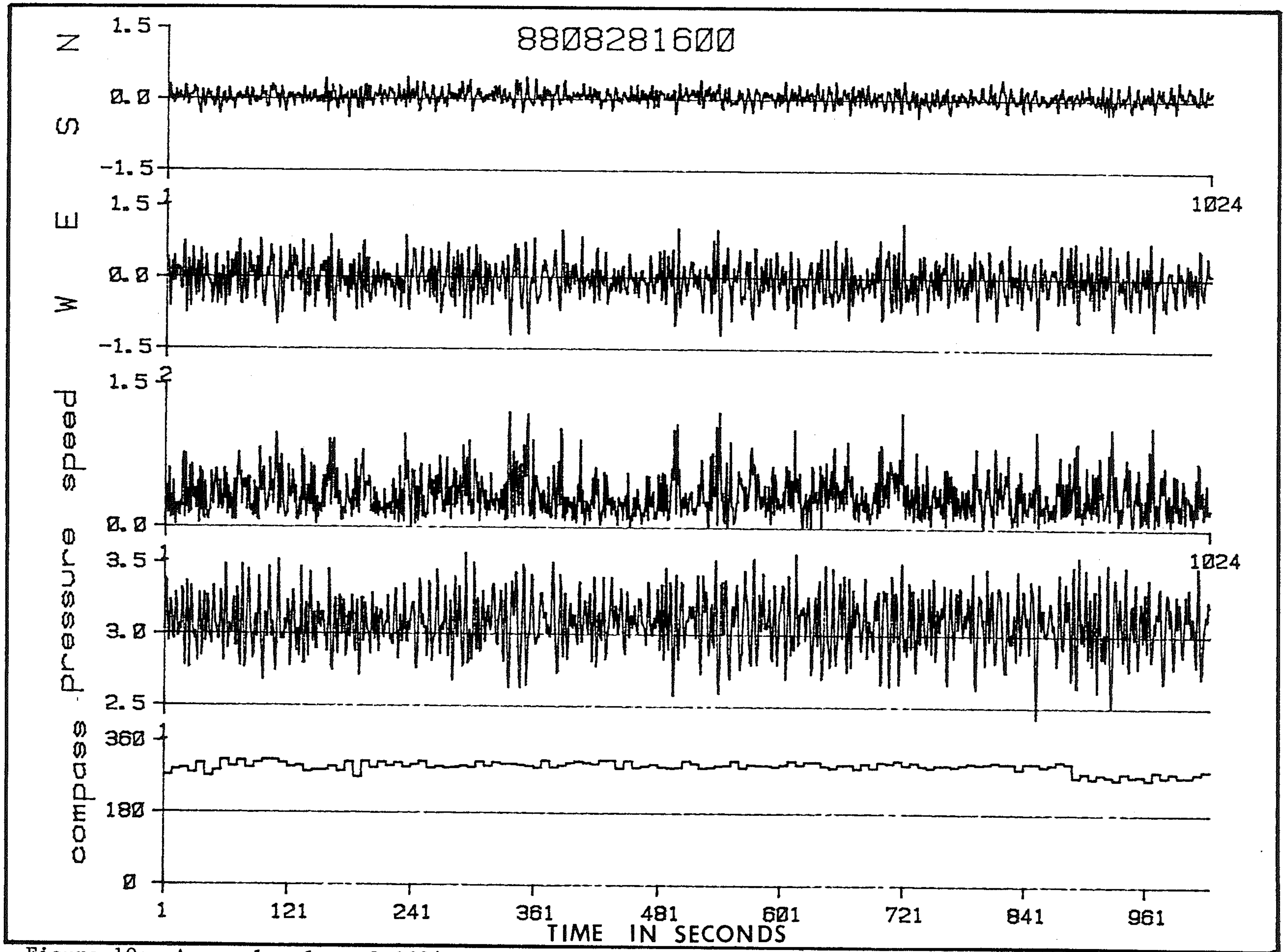

Figure 10: A sample plot of 1024 burst samples of velocity components and pressure, collected at one second intervals. The data displayed were collected at site 2 at 1600 MDT, August 28, 1987, during strong westerly winds.

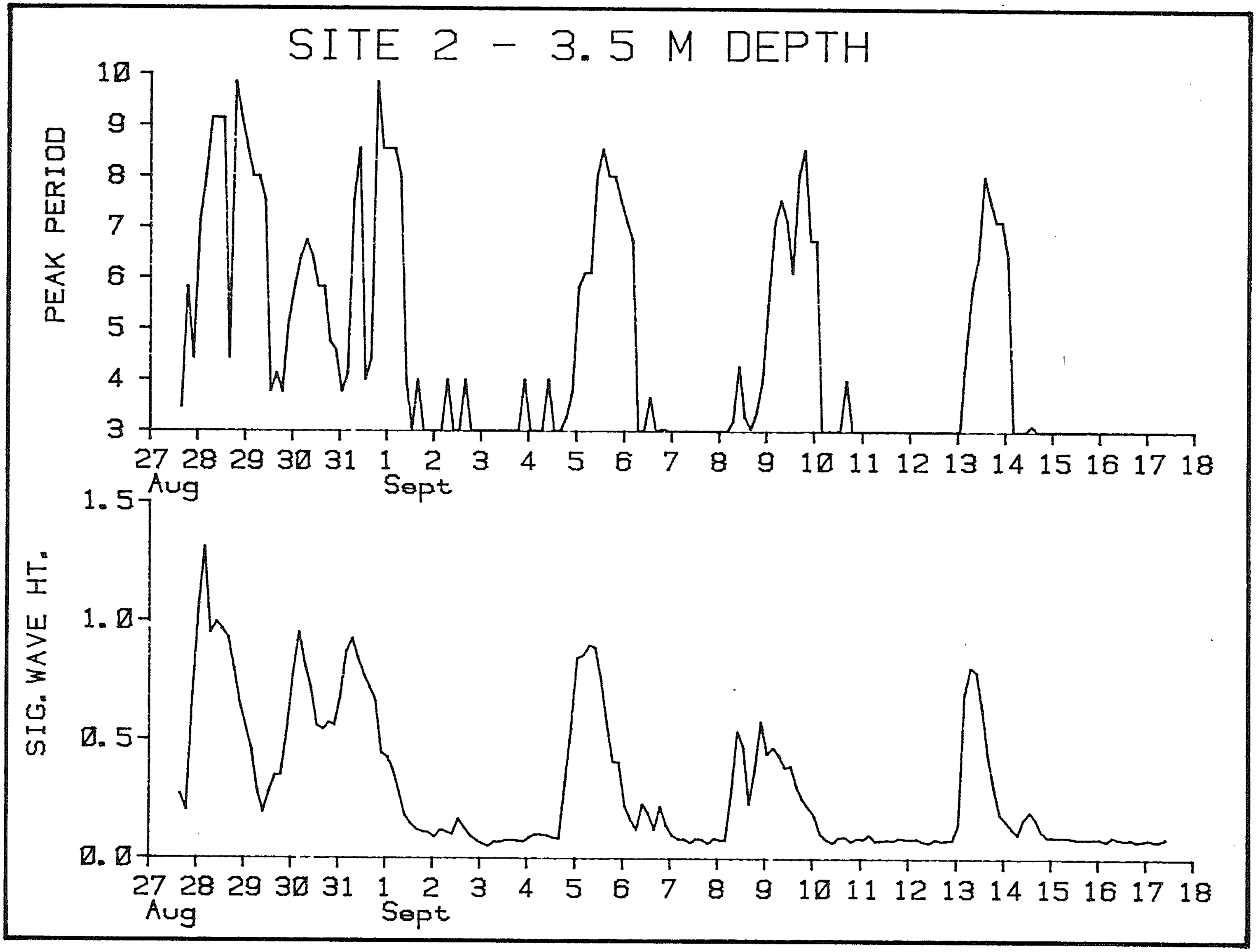

Figure 11: Significant wave height and peak period computed from burst-sampled pressure data at site 2.

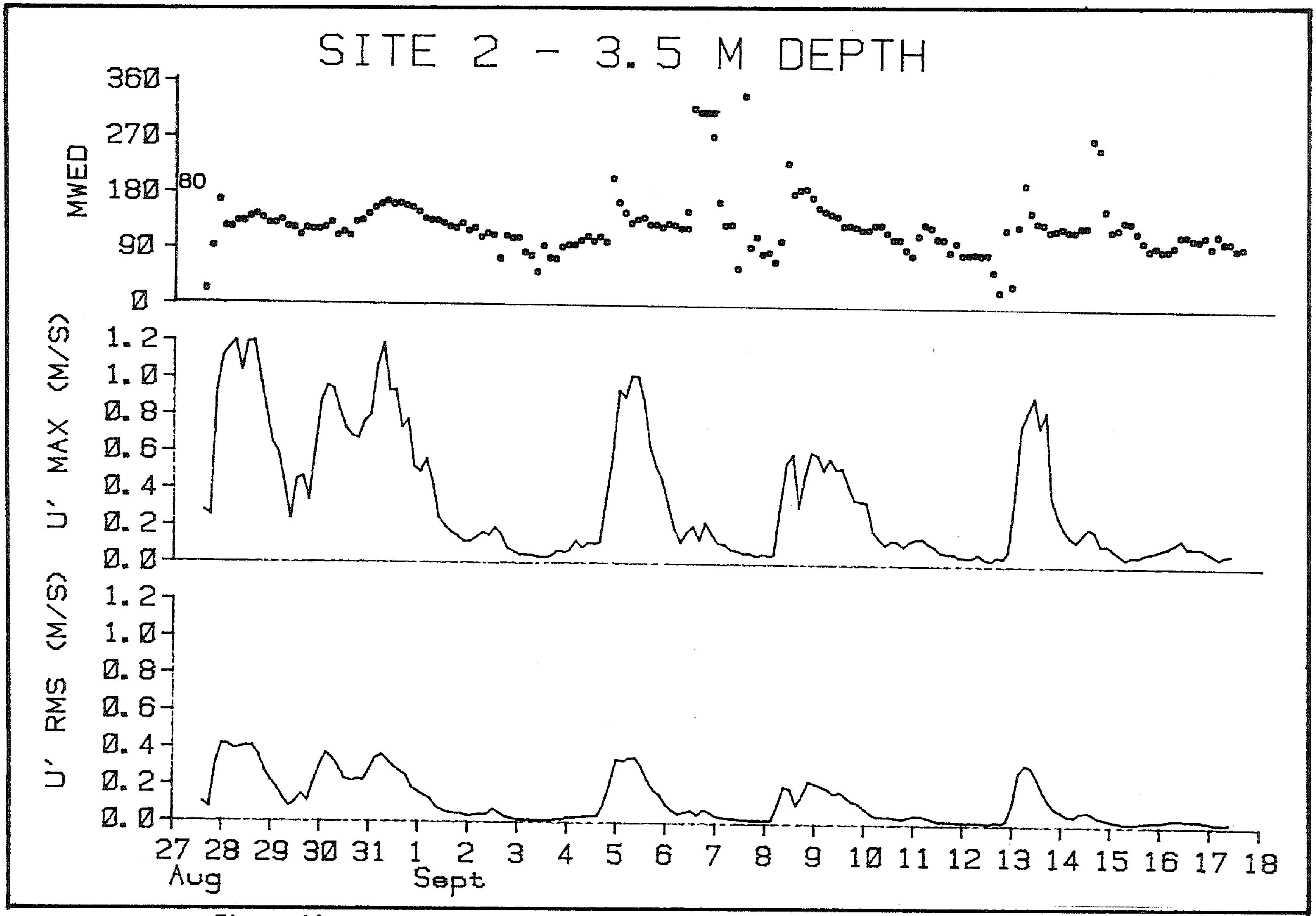

Figure 12: Mean wave energy direction (MWED), and the maximum and root-mean-square magnitudes of velocity fluctuations computed from burst-sampled velocity data at site 3.

Statistical summaries of wave height and peak period for site 2 are presented in Figure 13 (Bivariate distribution of significant wave height and peak period) and Figure 14 (Percent exceedance of significant wave height and maximum wave height).

The results from the wave analyses reveal a very significant response of the wave field to local wind. During each west to northwesterly wind event, a marked increase in wave height and peak period was observed. Significant wave heights ranged from 0.57 to 1.31 m, with peak periods ranging from 6.5 to 9.8 seconds (Figure 11). As one might expect, the response of waves to local winds is not perfectly correlated (eg. two-peaked variations of August 30-31). However, the wave field response appears to be better correlated to winds than are the observed mean currents.

The directional distribution of the wave field is presented in Figure 15. The directions were determined from the wave orbital current fluctuations (MWED) parameter. In Figure 15, the frequency of waves by direction is displayed, along with frequency of wave energy. The latter parameter, wave energy, was computed as:

$$E = (1/8)\rho \; g \;\; H^2_s * L$$

where ρ is density, g is acceleration due to gravity and L is the peak period wavelength. The frequency of wave energy was found by dividing the total energy from all waves in each direction sector by the total energy of all waves measured at site 2.

The fluctuations in currents due to surface waves (Figure 12) also exhibit a marked increase in magnitude during each wind event. As expected, wave orbital current fluctuations (MWED) are directed toward the shore, and are nearly perpendicular to the mean currents setting in the alongshore direction (Figure 15). The current fluctuations measured during wind events range in amplitude from 0.20 to 0.41 m/s. The peak values measured in individual burst ranged from 0.65 to 1.31 m/s. Peak levels of velocity fluctuations associated with waves typically exceed the magnitude of the mean alongshore flows by factors of 3 to 10.

4.4 SUMMARY

An extensive set of current and directional wave data were collected within 700 m of the Beaufort Sea coastline over a 21 day period. During this period, a combination of five significant wind events and a comparatively large open water fetch resulted in sizable wave activity within the coastal zone. The wave events had a significant wave height of 0.6 to 1.3 m, and peak periods of 6.5 to 9.8 seconds.

Large wave orbital velocities were measured during wind events, with typical amplitudes of 0.2 to 0.4 m/s and peak values of up to 1.3 m/s. The wind-driven alongshore currents were generally of low amplitude (up to

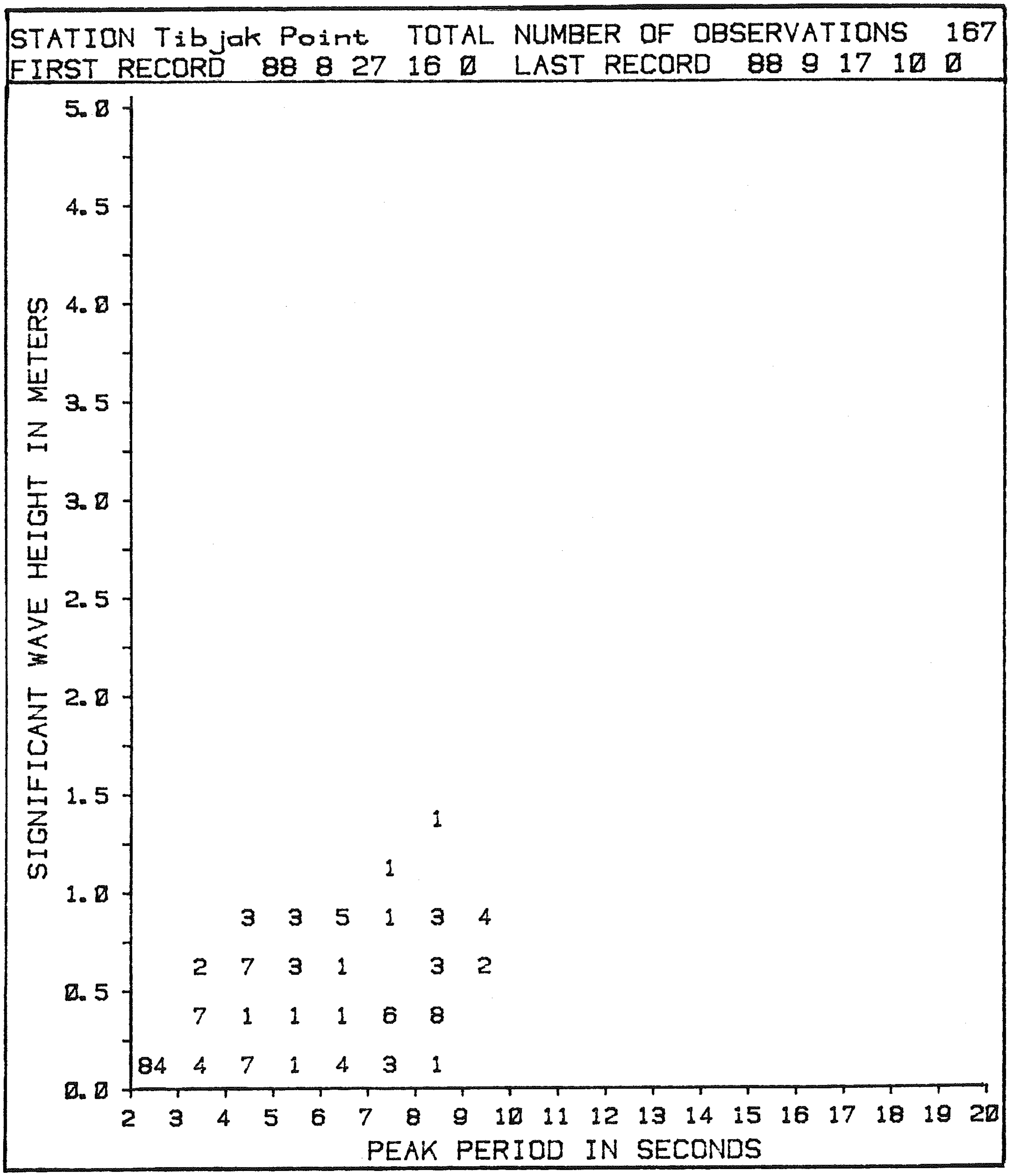

Figure 13: Joint bivariate distribution of significant wave height and peak period for site 2.

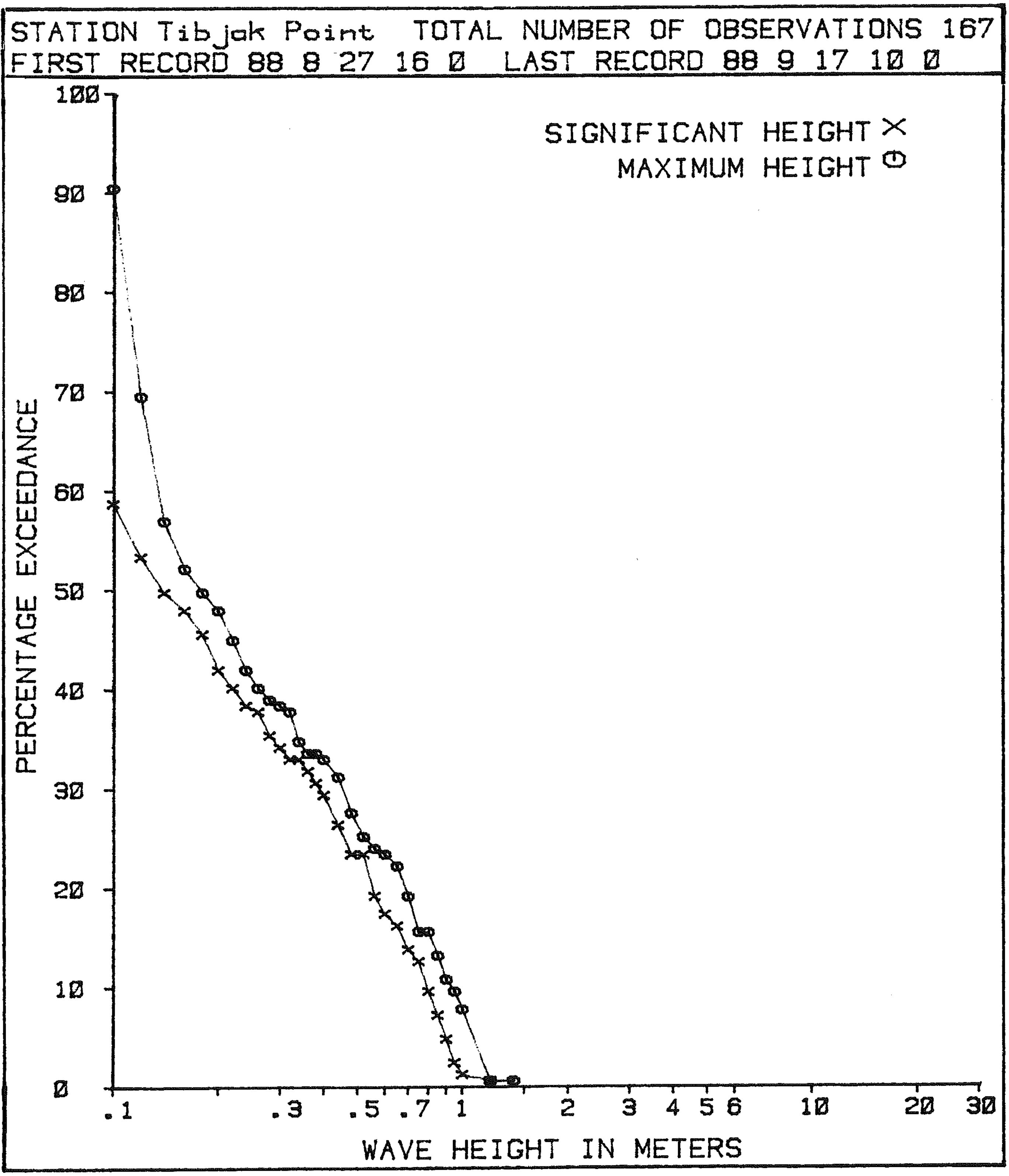

Figure 14: The percent exceedance diagram for significant wave height and maximum wave height.

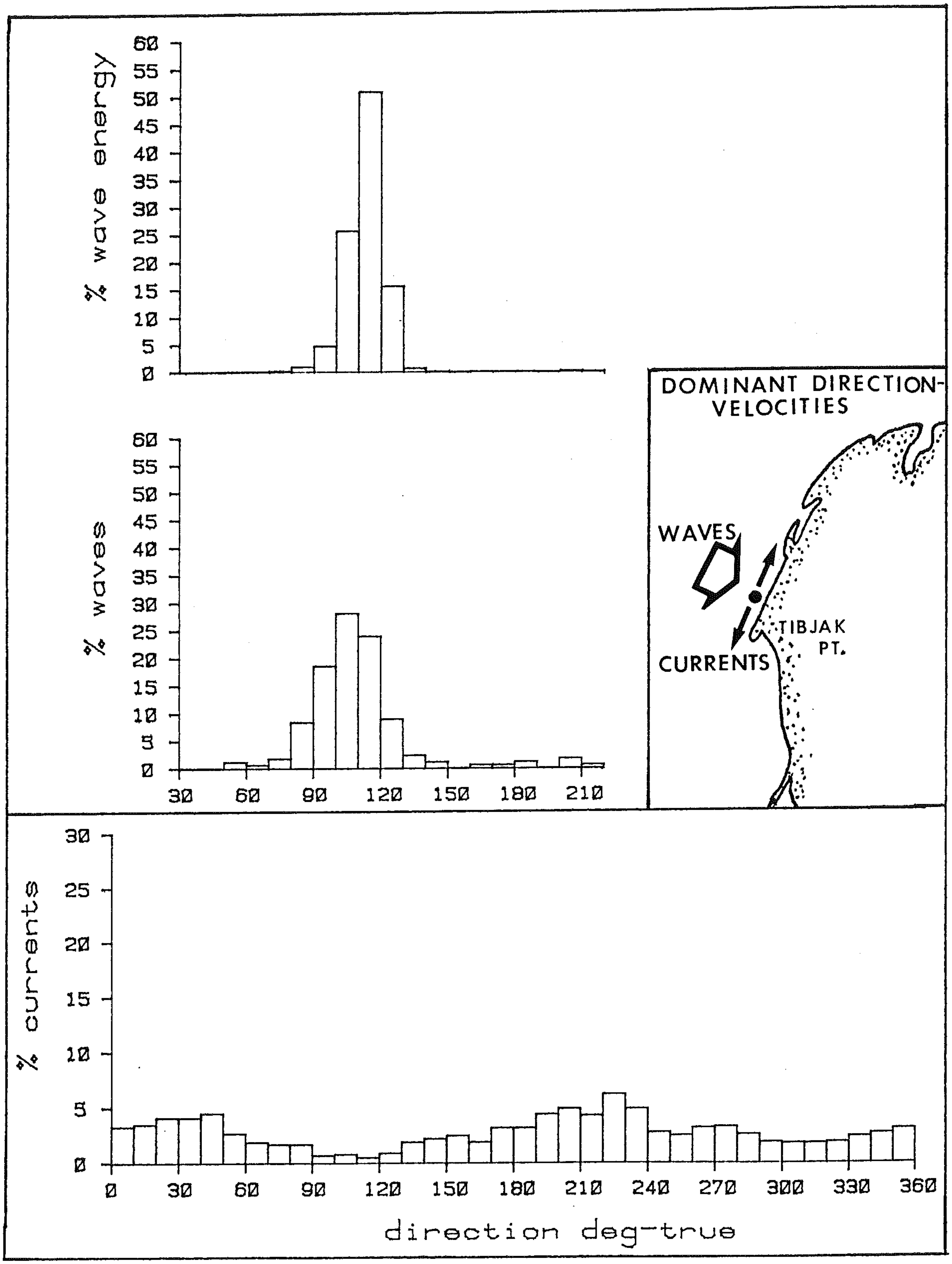

Figure 15: The directional distribution of wave occurrence and wave energy (upper panel) and mean currents (lower panel) for site 2 off Tibjak Point (see insert).

0.35 m/s), and were not well correlated to wind and wave activity. Peak current fluctuation amplitudes greatly exceeded the alongshore current by a factor ranging from 3 to 10.

Wave and current data were simultaneously obtained further from shore: at two sites in 5 to 10 m water depth (Seaconsult Ltd., 1987), and at various sites around the Amauligak drill site in 30 m water depth (Fissel et al., 1987). Further analyses of the data from the present study, together with the other simultaneous studies, should provide new insights into the wave regime and sediment transport potential in the Canadian Beaufort Sea.

5. REFERENCES

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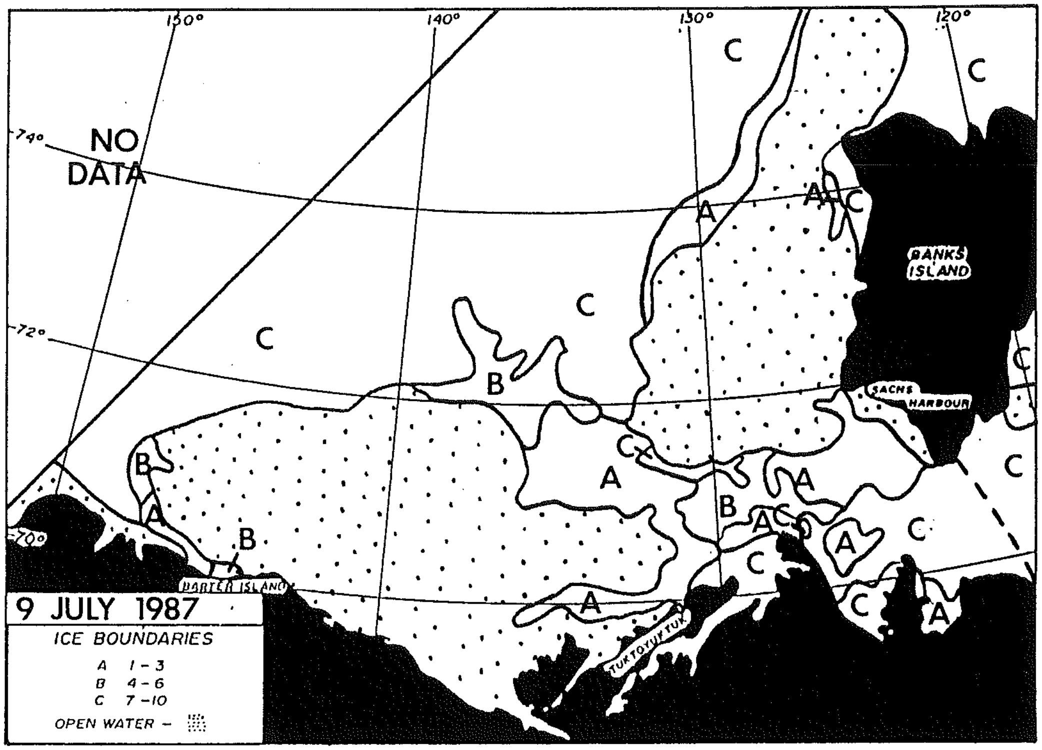
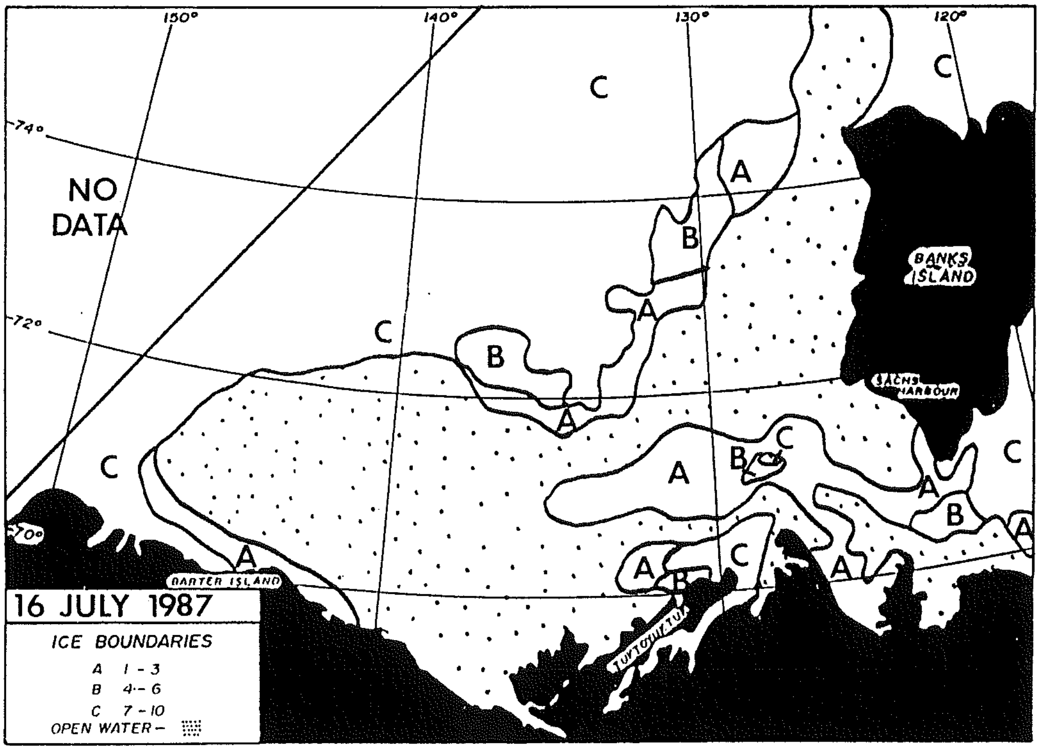
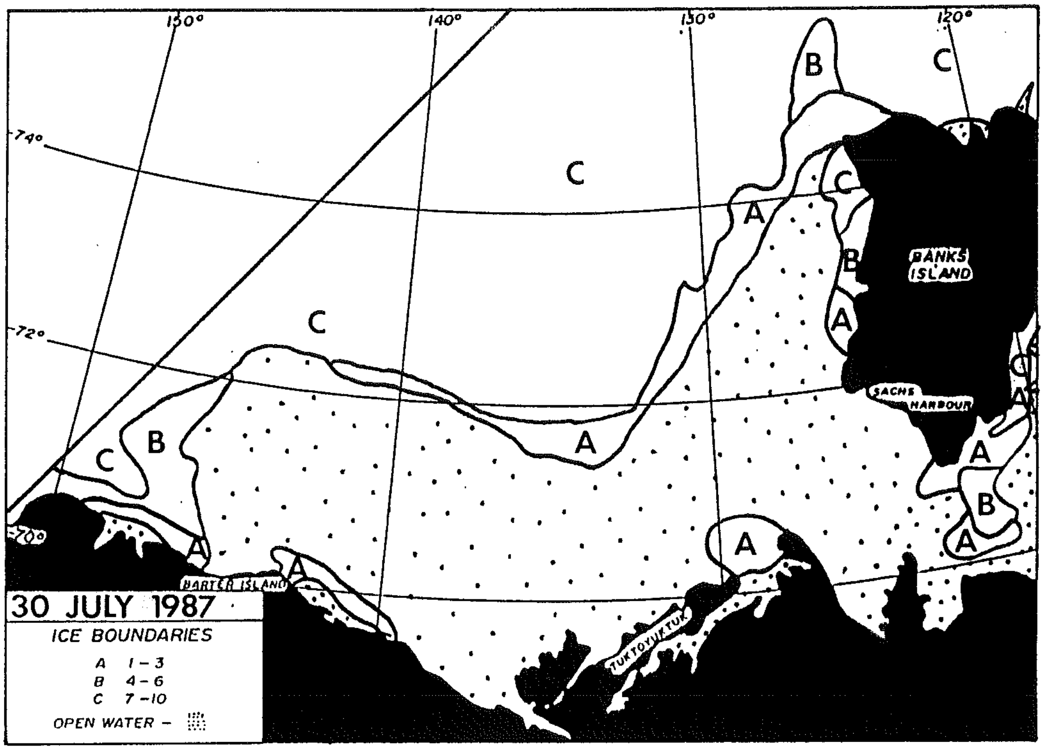
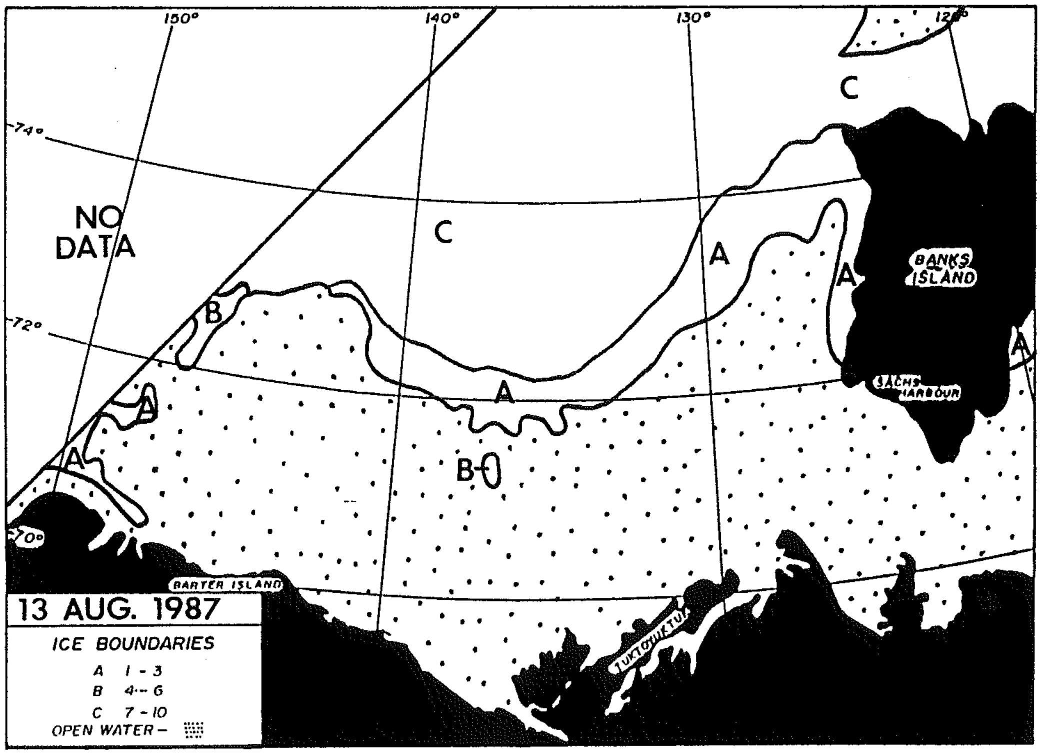
Seaconsult Marine Research Ltd., 1987. Sediment-Storm Interaction Study. NOGAP B6 Interim Data Processing Report Unpublished report for Institute of Ocean Sciences by Seaconsult Marine Research Ltd., Vancouver. 46 p.

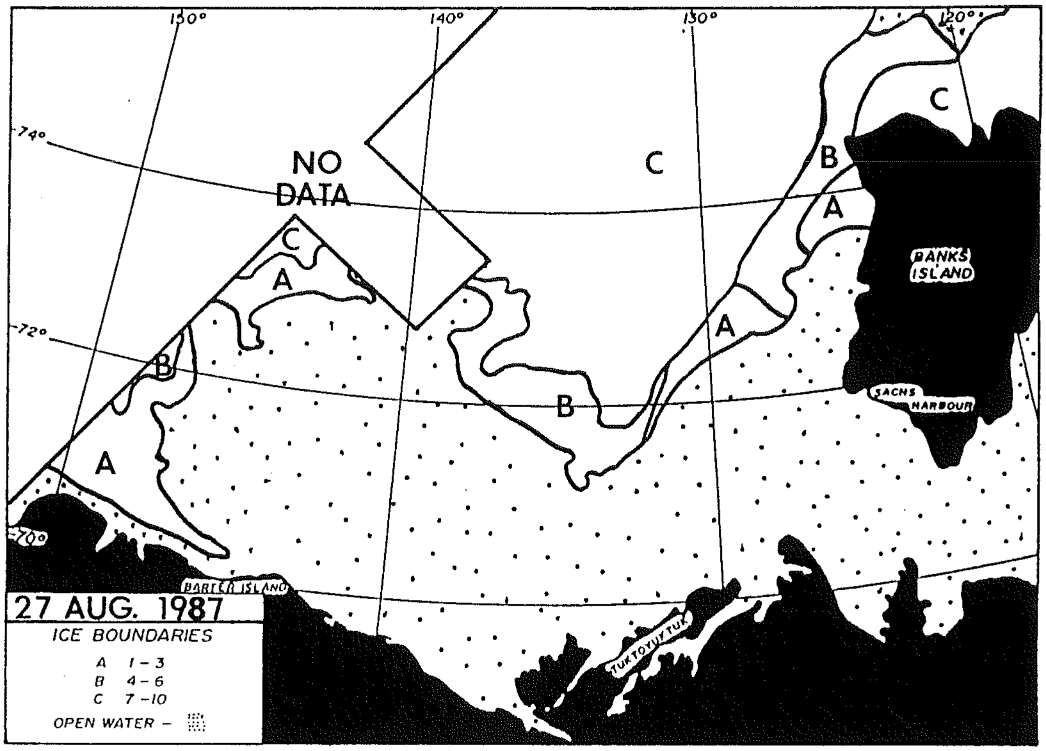
APPENDIX A
Bimonthly Ice Charts, Summer 1987


150°
140°
130°
120°
74°
72°
70°
NO DATA
BANKS ISLAND
SACHS HARBOUR
BARTER ISLAND
TUKTOYAKTUK
A
B
C
9 JULY 1987
ICE BOUNDARIES
A 1 - 3
B 4 - 6
C 7 - 10
OPEN WATER -

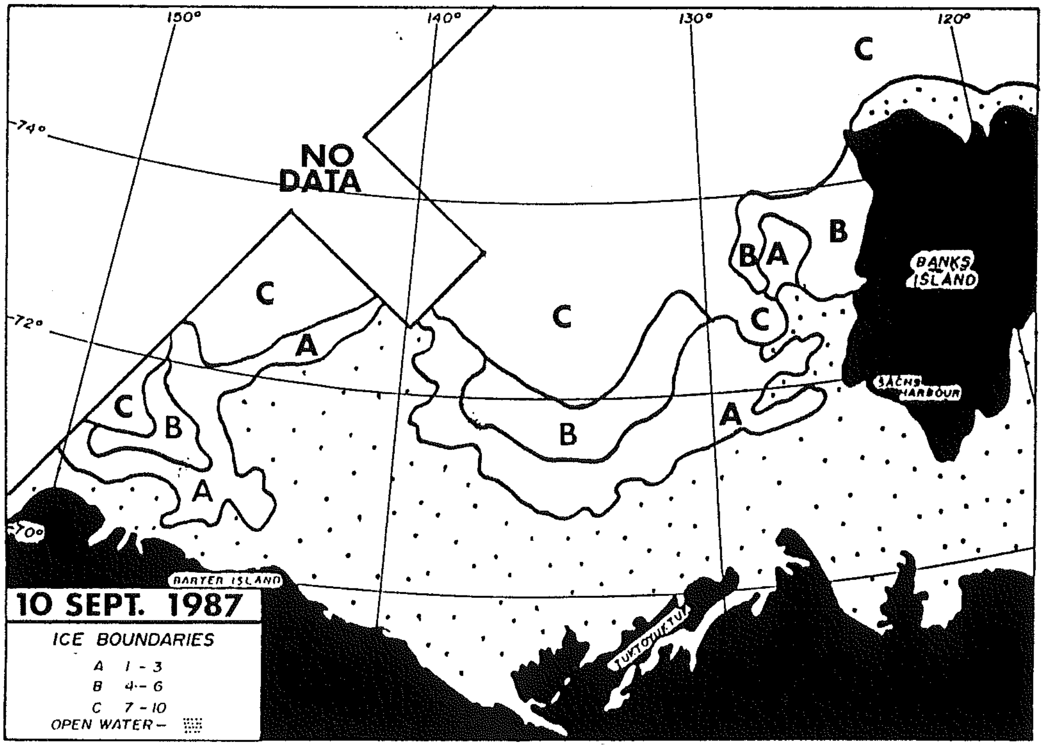

150°
140°
130°
120°
74°
72°
70°
NO DATA
BANKS ISLAND
SACHS HARBOUR
BARTER ISLAND
TUKTOYAKTUK
A
B
C
16 JULY 1987
ICE BOUNDARIES
A 1 - 3
B 4 - 6
C 7 - 10
OPEN WATER -


150°
140°
130°
120°
74°
72°
70°
A
B
C
BANKS ISLAND
SACHS HARBOUR
BARTER ISLAND
TUKTOYUKTUK
30 JULY 1987
ICE BOUNDARIES
A 1 - 3
B 4 - 6
C 7 - 10
OPEN WATER - ⁙


150°
140°
130°
120°
74°
72°
70°
NO DATA
A
B
C
BANKS ISLAND
SACHS HARBOUR
BARTER ISLAND
TUKTOYUKTUK
13 AUG. 1987
ICE BOUNDARIES
A 1 - 3
B 4 - 6
C 7 - 10
OPEN WATER - ⁙

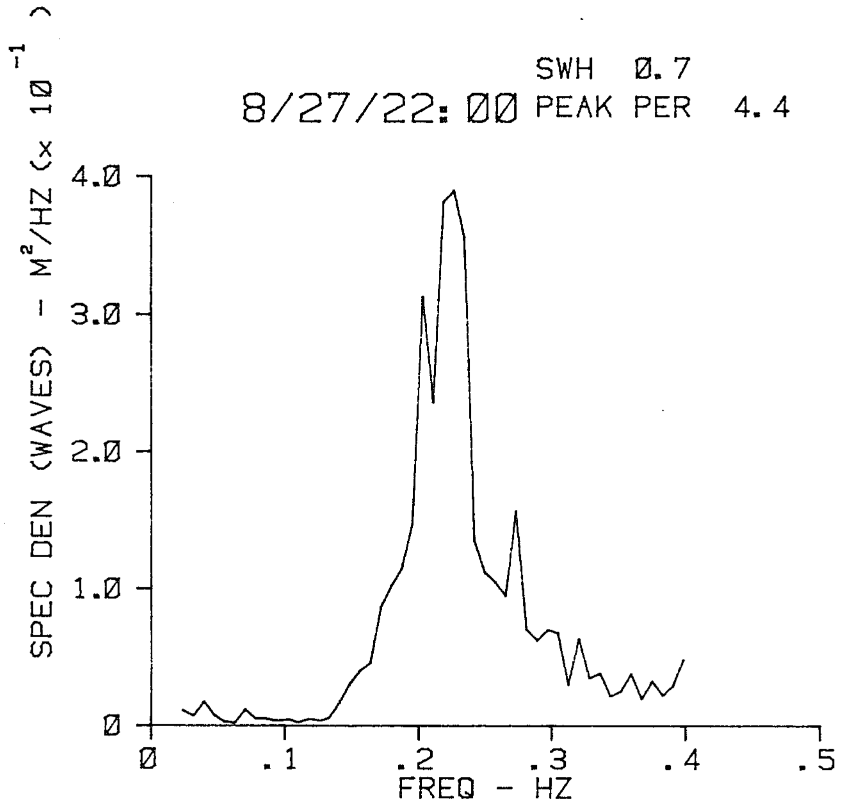


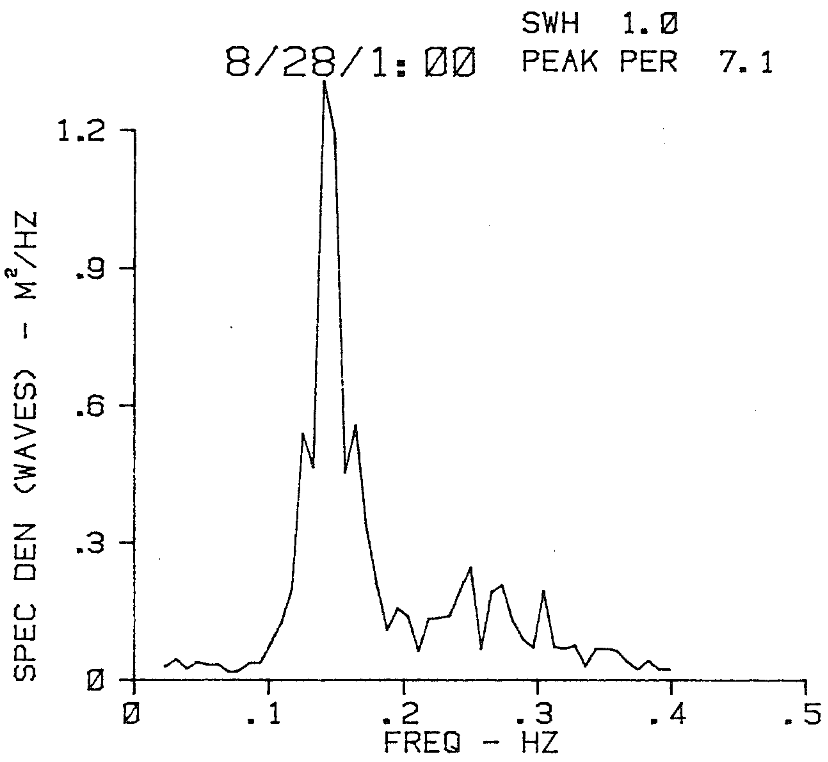
27 AUG. 1987

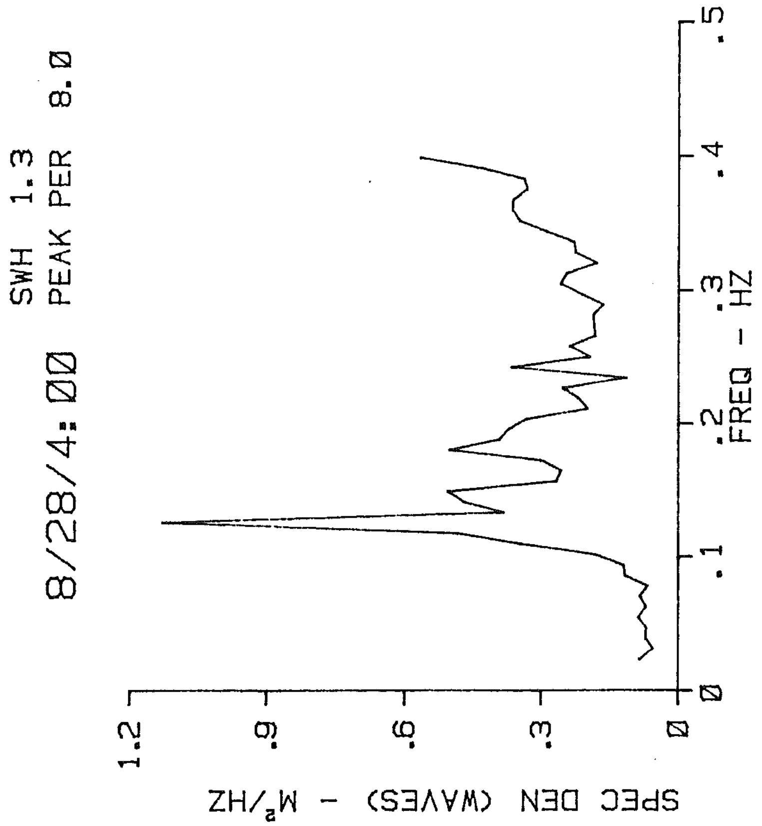


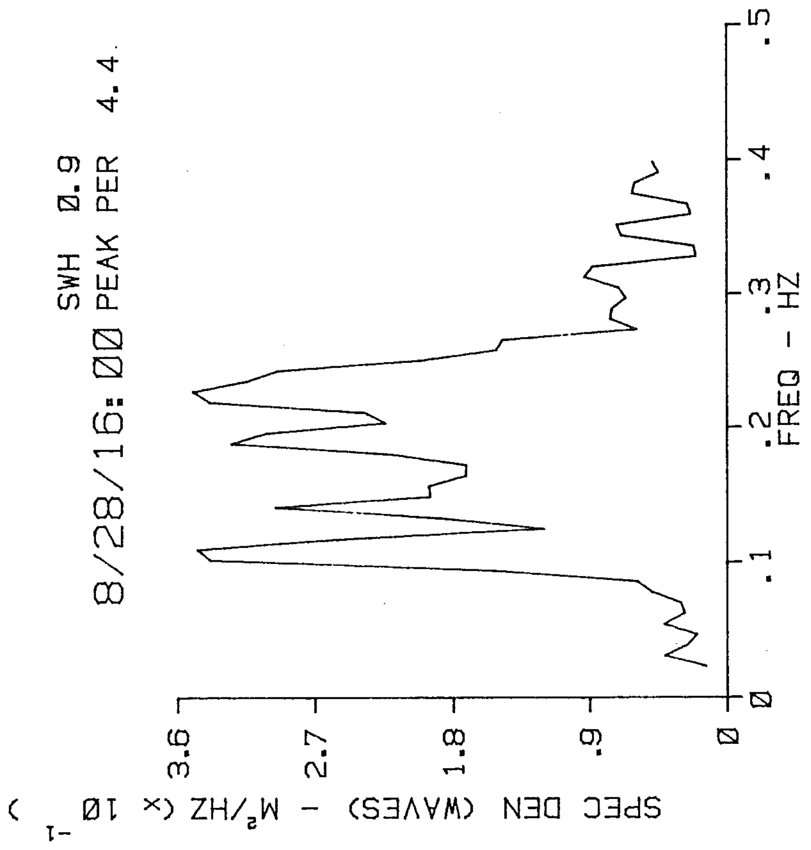
10 SEPT. 1987

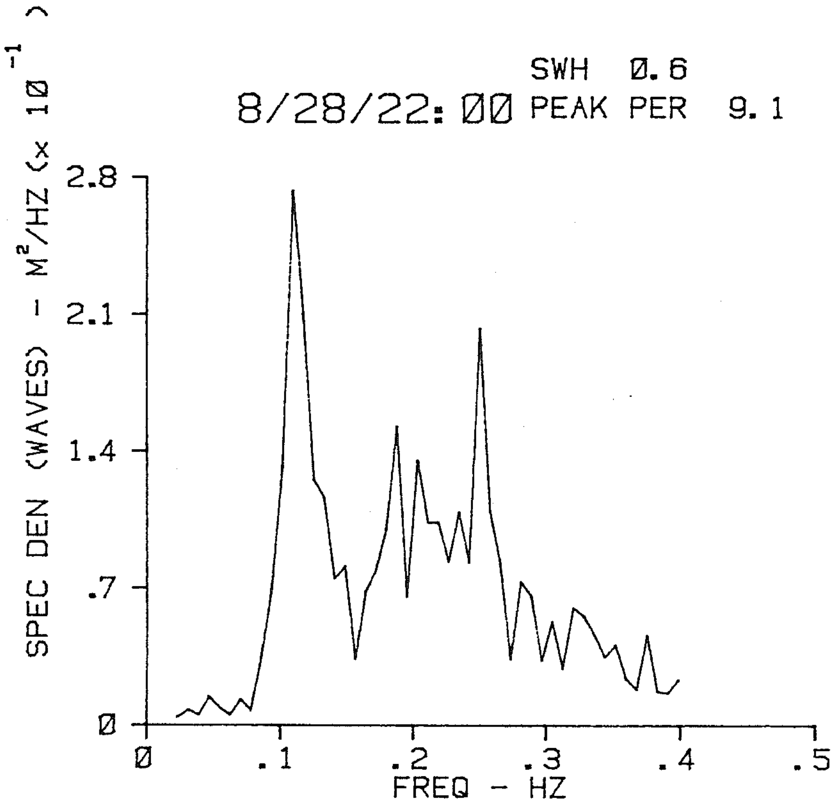
APPENDIX B
Selected Surface Wave Spectra From DWCM Burst Records, Site 2

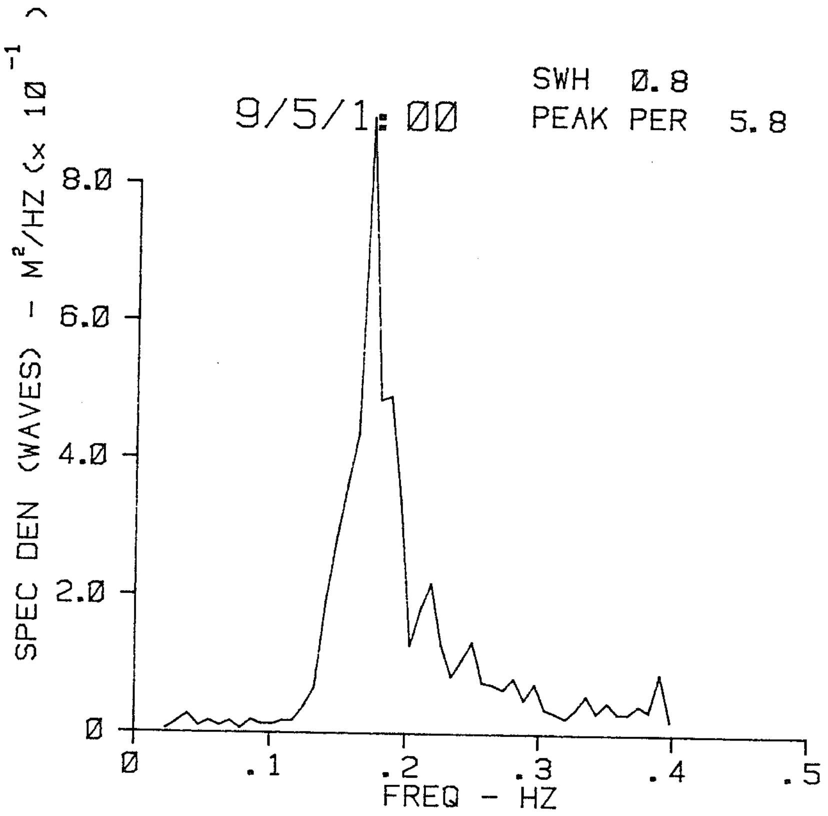

SWH 0.7
8/27/22:00 PEAK PER 4.4
SPEC DEN (WAVES) - M²/HZ (x 10⁻¹)
4.0
3.0
2.0
1.0
0
0
.1
.2
.3
.4
.5
FREQ - HZ

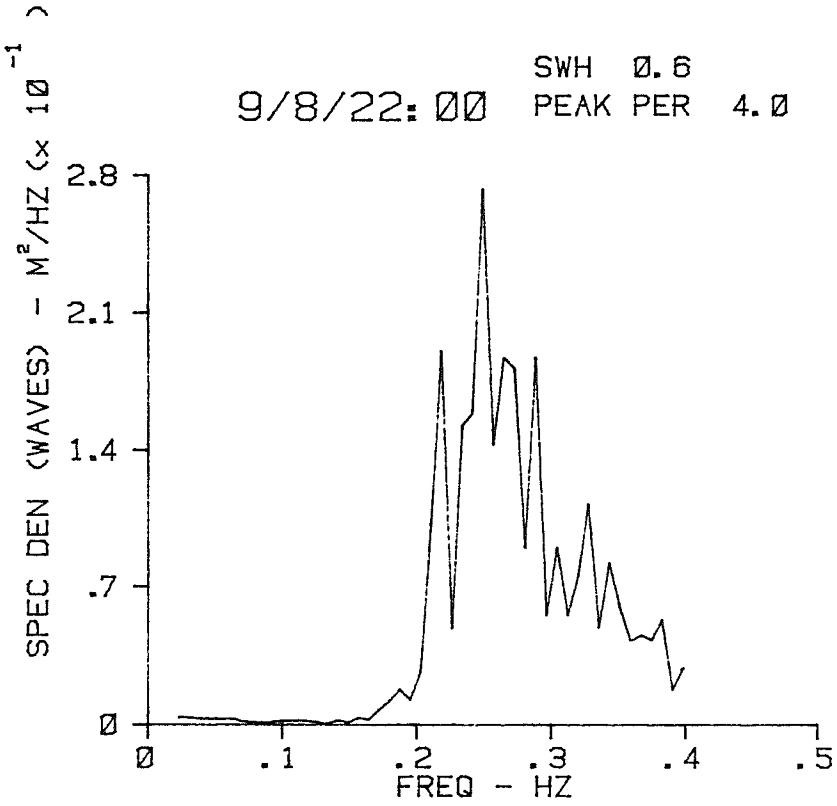

SWH 1.0
8/28/1:00 PEAK PER 7.1
SPEC DEN (WAVES) - M²/HZ
1.2
.9
.6
.3
0
0
.1
.2
.3
.4
.5
FREQ - HZ


8/28/4:00
SWH 1.3
PEAK PER 8.0
SPEC DEN (WAVES) - M²/HZ
0
.3
.6
.9
1.2
0
.1
.2
.3
.4
.5
FREQ - HZ

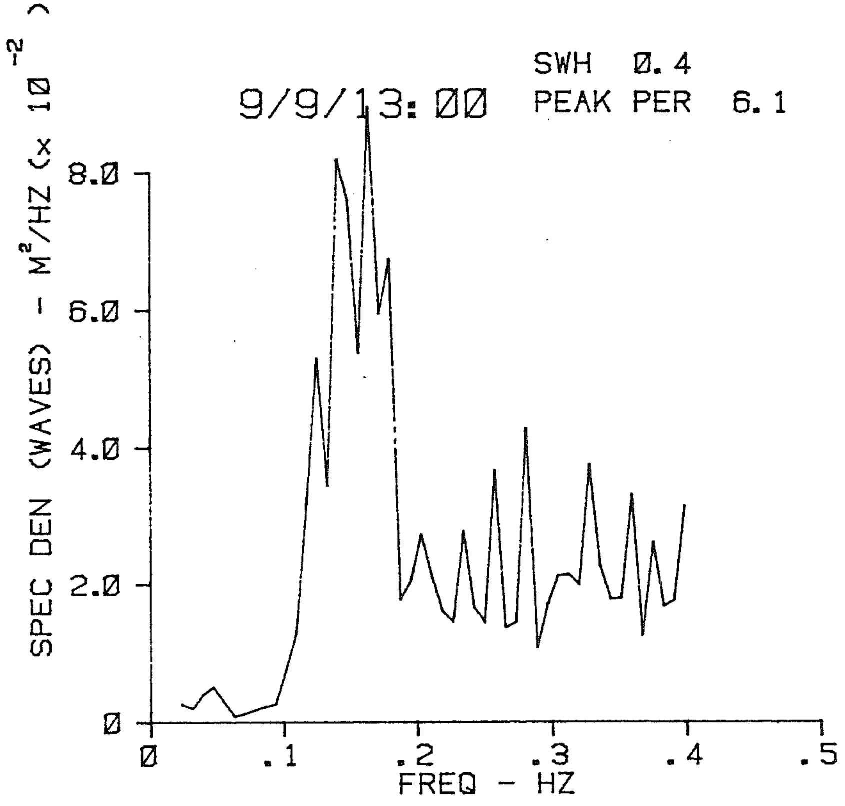

8/28/16:00
SWH 0.9
PEAK PER 4.4
SPEC DEN (WAVES) - M²/HZ (x 10⁻¹)
0
.9
1.8
2.7
3.6
0
.1
.2
.3
.4
.5
FREQ - HZ


8/28/22:00
SWH 0.6
PEAK PER 9.1
SPEC DEN (WAVES) - M^2/HZ (x 10^{-1})
2.8
2.1
1.4
.7
0
0
.1
.2
.3
.4
.5
FREQ - HZ


9/5/1:00
SWH 0.8
PEAK PER 5.8
SPEC DEN (WAVES) - M^2/HZ (x 10^{-1})
8.0
6.0
4.0
2.0
0
0
.1
.2
.3
.4
.5
FREQ - HZ



9/8/22:00 SWH 0.6 PEAK PER 4.0



9/9/13:00 SWH 0.4 PEAK PER 6.1