U.S. Department of the Interior
U.S. Geological Survey

Current data from the northern Gulf of Mexico

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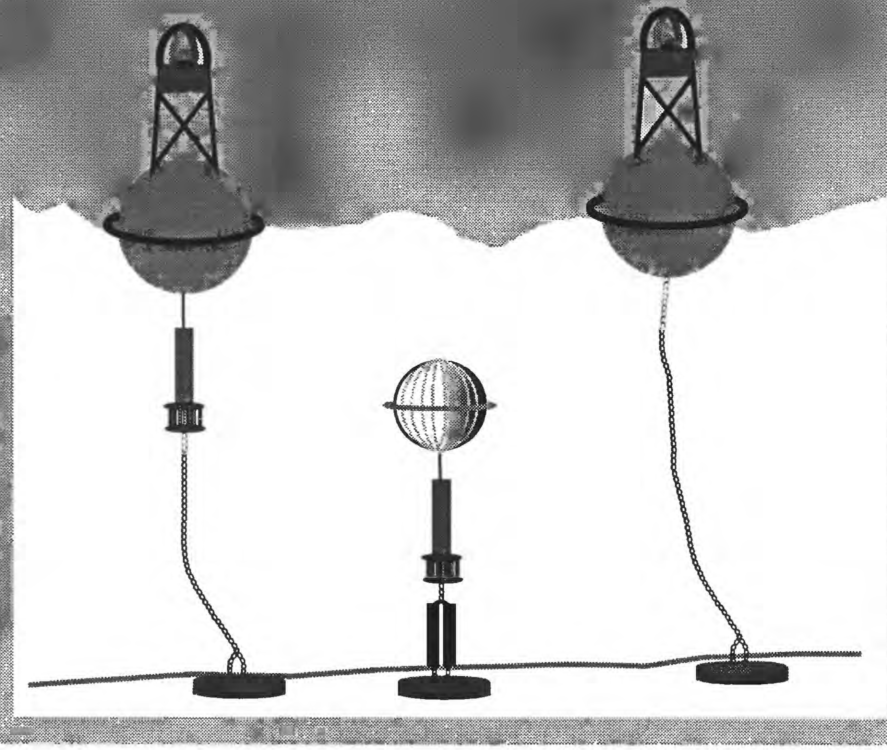

Open-File Report 95-633

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ABSTRACT

A 20-month study of the circulation patterns and the processes that resuspend and transport sediment and/or pollutants within Mobile Bay, Alabama and over the adjacent gulf-coast shelf began in July, 1990. This report depicts data that was collected by one mooring deployed during the study. The single mooring monitored near-surface and near-bottom current, temperature, salinity and water clarity in 30 m of water on the shelf. This report also presents some statistical parameters derived from the data, together with wind and sea level data for the time spanning the entire study (July 1990 - March 1992).

INTRODUCTION

In July, 1990, a 20-month investigation of the circulation and related transport of suspended materials was begun over the shelf off Mobile Bay, along the northern coast of the Gulf of Mexico (Figure 1). The study was part of a larger program to measure the transport of materials and the associated pollutants within Mobile Bay, Alabama and to determine the exchange of materials between Mobile Bay and the coastal ocean. To monitor coastal ocean processes, a single mooring was deployed in 30 m of water on the shelf (Figure 1). The information gathered by the mooring was designed to provide both a basic description of the circulation patterns in the region and an understanding of important physical processes, especially those processes that control the resuspension and transport of sediment and associated pollutants.

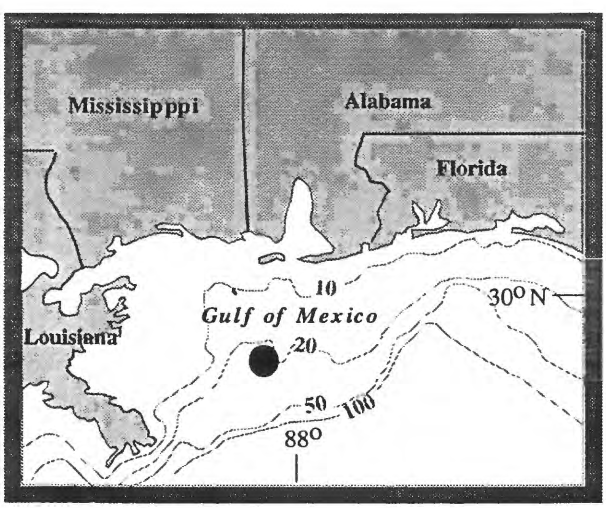

Figure 1. Mooring location in the northern Gulf of Mexico.

This report describes the data set collected by the instrument mooring (July 1990 - March 1992, Figure 2). The principal data collected in this portion of the field program include records of current speed and direction, temperature, salinity and water clarity measured at the site on the shelf. A detailed description of the moored instruments is given in the next section. Subsequent sections present statistical quantities for the entire data set and depict the characteristics of the hour-averaged and subtidal records.

Description of the moored array

The coastal-ocean field program consisted of several elements. An instrument mooring was deployed on the continental shelf in 30 m of water, offshore of the entrance to Mobile Bay (Figure 1). The mooring was designed to monitor conditions of the water so that reasonably stable estimates of the processes controlling circulation and sediment transport on the shelf and process controlling the possible exchange of shelf water with Mobile Bay could be made. Wind and sea level measurements were obtained at several sites along the coast by the National Data Buoy Office and the National Ocean Services office.

The mooring site is generally outside the influence of the plume from Mobile Bay. Hence, the mooring monitored the general shelf environment (Stumpf, et al., 1993). The water depth is deep enough so that all instruments operate within their design specifications.

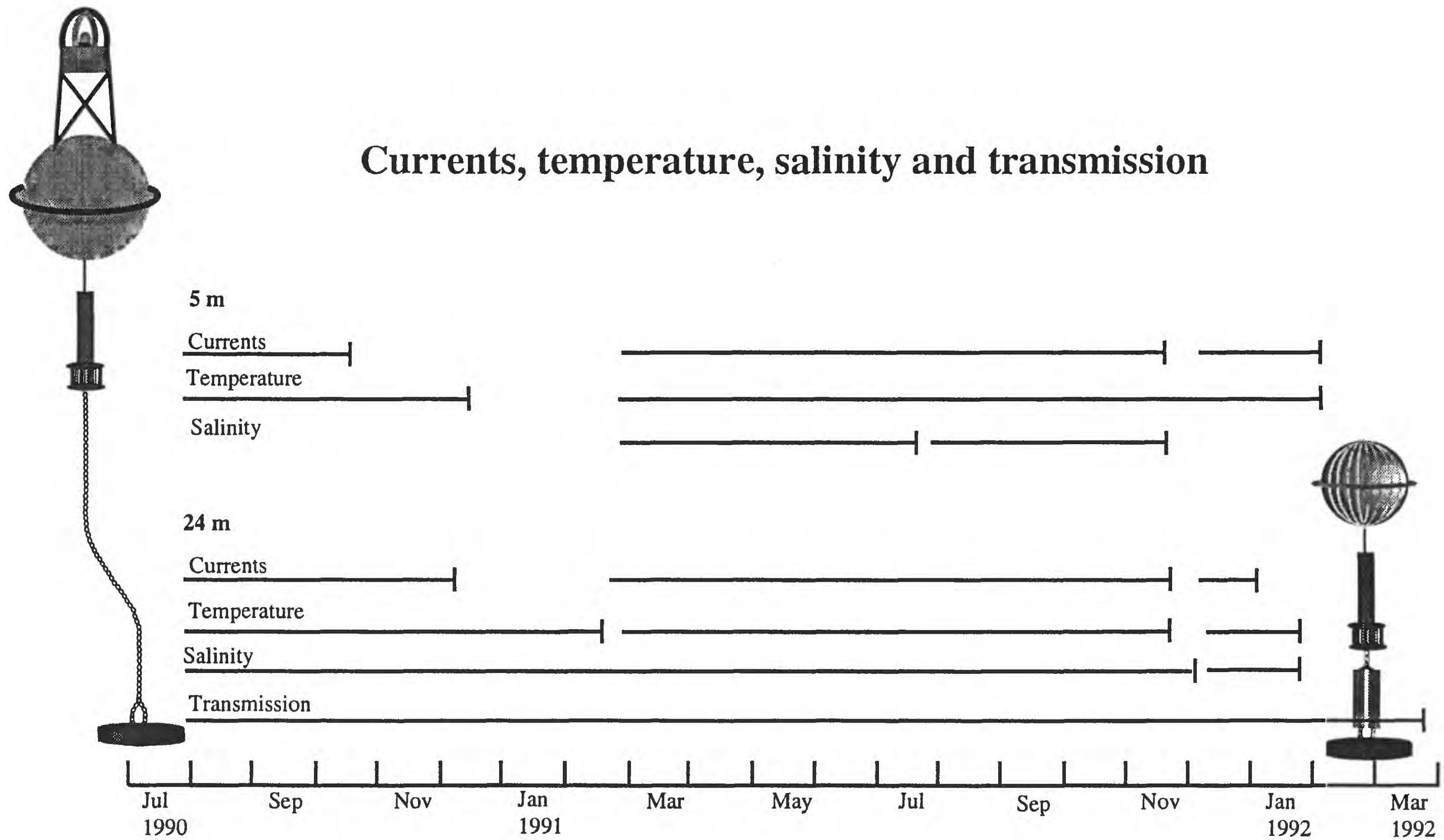

Figure 2. Timelines showing the dates when valid current, temperature, salinity and attenuation data existed.

Instrumentation

The near-surface instruments on the offshore mooring were attached 5 m below a single surface buoy. A second surface buoy was deployed near the first and both were used to mark the measurement site (Figure 3). A subsurface mooring was deployed between the 2 surface buoys, with a suite of near-bottom instruments located 6 m above the sea bed (6 mab). Either a single or dual acoustic release package was used to connect the subsurface mooring to the anchor.

Two types of current meters were used (Table 1), EG&G vector-averaging current meters (VACM) and EG&G vector-measuring current meters (VMCM), with the VMCM deployed near the surface when it was available. A VTCT is also referred to in this report. The VTCT is a vector averaging current meter with a transmissometer attached to it to record transmission data. Both types of current meters are specifically designed to measure currents even when high-frequency oscillatory currents from large surface waves are present. A detailed description of the design and measurement characteristics of these instruments is provided by McCullough, 1975, Mero, 1982 and Beardsley et al., 1987. Both types of current meters measured the average current direction and speed every 3.75 minutes.

To measure water clarity (transmission), Sea Tech transmissometers with a 25 cm path length were used. The data were recorded on a Sea Cat data logger or a modified VACM data logger. Poison rings were used to inhibit fouling of the lens. The clear water reading for each transmissometer was recorded before each deployment. The relation between the transmissometer reading and the amount of material resuspended in the water column was derived using calibration procedures described in Moody, et al., 1987. The sample rate was 3.75 minutes (Table 1).

Sea Bird conductivity cells were used to obtain conductivity measurements. The data were recorded on either a Sea Cat data logger or a modified VACM data logger. Each conductivity cell was calibrated by the manufacturer's specifications before each deployment. The sample rate was the same as for the current meter (Table 1).

Water temperature was measured with temperature sensors installed in the VMCM's, VACM's, VTCT's or Sea Bird data logger. All temperature sensors were calibrated by the manufacturer's specifications before deployment. The sample rate was the same as for the current meter (Table 1).

Mooring	Water Depth (m)	Start Time (M/D/Y)	Stop Time (M/D/Y)	Instrument	Position		Sensor Depth (m)	Data Type	Sample Interval (minutes)
					Latitude	Longitude			
350-1	30	07/28/90	10/18/90	VACM	29 57.72 N	088 10.44 W	5.0	C,T	3.75
350-2	30	07/28/90	12/06/90	VACM	29 57.66 N	088 10.35 W	24.0	C,T,S	3.75
376-1	30	02/26/91	05/10/91	VACM	29 57.77 N	088 10.80 W	5.0	C,T,S	3.75
376-3	30	02/22/91	05/10/91	VTCT	29 57.77 N	088 10.70 W	24.0	C,T,S,A	3.75
380-2	30	05/11/91	07/30/91	VMCM	29 57.87 N	088 10.67 W	5.0	C,T,S	3.75
380-3	30	05/11/91	07/30/91	VTCT	29 57.85 N	088 10.73 W	24.0	C,T,S,A	3.75
385-1	30	07/30/91	11/19/91	VMCM	29 57.81 N	088 10.85 W	5.0	C,T	3.75
385-2	30	07/30/91	12/07/91	VTCT	29 57.80 N	088 10.95 W	24..0	C,T,S,A	3.75
391-1	30	12/07/91	02/04/92	VMCM	29 57.81 N	088 10.85 W	5.0	C,T	3.75
391-2	30	12/11/91	03/20/92	VTCT	29 57. 81 N	088 10.85 W	24.0	C.T.S.A	7.5

Table 1. - Data availability for all moorings in the Gulf of Mexico.

VACM = Vector averaging current meter (measures current and temperature) A = attenuation C = current data
VMCM = Vector measuring current meter (measures current and temperature S = salinity T = sea temperature
VTCT = Vector averaging current meter (measures current, temperature and transmission)

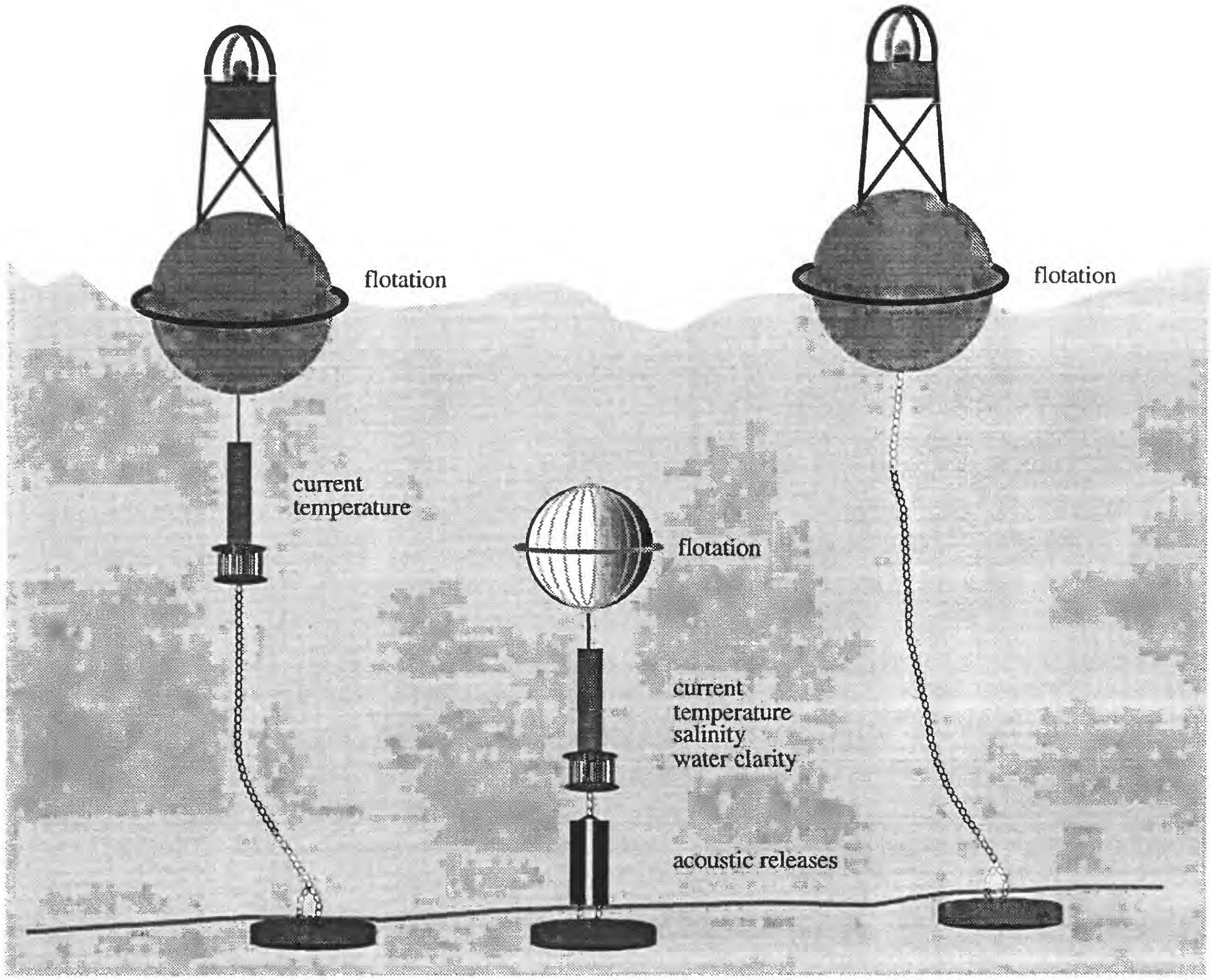

Figure 3. Instrument setup. Moorings were about 100-150 meters apart in 30 meters of water.

Data sets and statistical methods

This report is a statistical and pictorial description of the data collected during the deployment period. The data sets from each instrument package have been decoded, transcribed into scientific units and passed through several processing steps. The data were checked for quality and errors caused by instrument noise or failures, using programs developed at Woods Hole Oceanographic Institute (Tarbell, et al, 1988). The data were then analyzed using standard time series and statistical procedures. These procedures included plotting the temporal structures and calculating the means, standard deviations, maximum values, minimum values and spectra of each data variable (Appendix A, B, D). In addition, tidal amplitudes were calculated using standard processing packages developed by Foreman (1977, 1978). Spectral plots of currents, wind and sea level were used to depict the frequency characteristics of the data set. All times are in Greenwich mean time (GMT). The units for the currents are centimeters per second (cm/s), temperature degrees Celsius (^{o}C) and salinity parts per thousand (ppt).

The basic sample interval for all variables was 3.75 minutes (Table 1). All data in this report have been averaged into records that have an hour sample interval (denoted hour-averaged records). The data have also been lowpass filtered to remove oscillations with periods shorter than 33 hours. Since the majority of the variability at the shorter periods is due to tidal forcing, these lowpass-filtered records are referred to as subtidal records.

Moored current observations

The currents at the mooring site have been rotated into a coordinate system that is aligned with, or perpendicular to, the alongshelf isobaths. The positive alongshelf direction is east, or 90°; positive onshelf is north, or 0°.

Error bars at the 95% confidence level have been calculated for the mean along and on-shelf currents. The error bars around the mean value indicate how stable the calculated mean is. In order for a reliable mean direction to be estimated, the error bars can not span an interval that includes zero. Significant mean directions have been highlighted in the tables.

The formula for the error bar around the mean is

$$\frac{\Phi t_{m;\alpha/2}}{\sqrt{m+1}} \quad (1)$$

where is the student t statistic with m degrees of freedom at the confidence level. is the standard deviation of the subtidal data set. The degrees of freedom of a record is the record length divided by the autocorrelation scale. The autocorrelation scale is calculated from the subtidal records. For both along and on-shelf currents, the autocorrelation scale is 2 days.

Several sections of this data report contain a series of figures that display characteristics of the measured currents. The time series of the hour-averaged and subtidal along and onshelf currents are in Appendix B. The hour-averaged currents are shown first (Appendix B, pgs. B1-B2), the subtidal currents follow (pg. B3-B4). An additional plot type, vector plots of the subtidal currents, are also shown in Appendix B. These figures display the direction and amplitude of the current vectors simultaneously.

The energy in the currents at the measurement site is depicted as a function of the frequency in Appendix B. A variance-conserving autospectra is calculated for the along and onshelf currents. We chose a variance-conserving spectra in order to highlight those frequencies that had the largest energies; the dominant processes occupy the biggest areas on the plots. The tidal frequencies generally have a large fraction of the energy; these large spectral peaks are found at frequencies above 10^{-5} hertz (1.2 days).

All spectra for the instrument mooring are calculated with similar Fourier transform parameters. Each record was divided into pieces 292 days long that overlapped each other by 50% (Table B1). Each piece was windowed with a Hanning window shape in order to reduce leakage of energy from the dominant frequencies into the less energetic frequency bands. The spectra for all pieces at one location were averaged together.

Moored temperature, salinity and attenuation observations

The mean, standard deviation, minimum and maximum values for both the hour-averaged and subtidal temperature and salinity data sets are listed in Tables A3 and A4. Plots of all the data are located in Appendix C. Both the hour-averaged and subtidal data are depicted for temperature and salinity.

Plots of the transmission data are included in this report. The transmission data have been edited for obvious spikes and other bad data. Because transmission is an optical measurement, it is subject to fouling from growth of organisms on the lenses. The gradual decrease in measured clarity over periods of a month or more caused by biological fouling of the lens has not been removed from the data record and should be ignored. However, the large, daily oscillations seen in the transmission record in summer and fall are real, since the oscillation is just as strong at the end of a deployment period in July as it is near the middle of the next deployment in September (Figure C5).

Wind and sea level observations

For the same time period of this study, records of wind velocity and atmospheric pressure at Dauphin Island, Alabama and sea level at Dauphin Island and Pensacola, Florida were obtained from the National Data Buoy Office and the National Ocean Service (Table 2, Figures 4 and 5).

The hourly observations of wind velocity were converted into estimates of wind stress because wind stress represents the actual force that causes water to move over the shelf and slope. Wind stress was calculated from the formula by Wu (1980).

$$\tau = \rho c_D \mathbf{W}|\mathbf{W}| \qquad (2)$$

where ρ is the air density (0.0012 g cm^{-3}), c_D the drag coefficient and W the wind velocity. The drag coefficient increases with wind strength

$$c_D = \left(0.8 + 0.065|W_{10}|\right) \times 10^{-3} \qquad (3)$$

where W_{10} is the wind speed 10 m above the surface in meters per second. The wind stress was lowpass filtered and rotated into an along/onshelf coordinate system. The positive alongshelf wind stress direction is 90°, parallel to the alongshelf topography. The positive onshelf direction is 0°.

The coastal sea level records were converted into records of synthetic subsurface pressure (SSP) by adding atmospheric pressure to the sea level records. SSP is a better representation of the pressure forces that cause currents to move along the coast because changes in sea level caused by high and low pressure systems are removed from the record. The mean was removed from each SSP record. The record was lowpass filtered to remove the tidal signal.

The wind stress and sea level information are presented in appendix D. The tidal amplitudes computed from the unfiltered sea level records are given in Table D2. The basic statistics for the subtidal wind stress records are given in Table D3. The subsequent pages display the temporal and spectral plots of winds stress and SSP data.

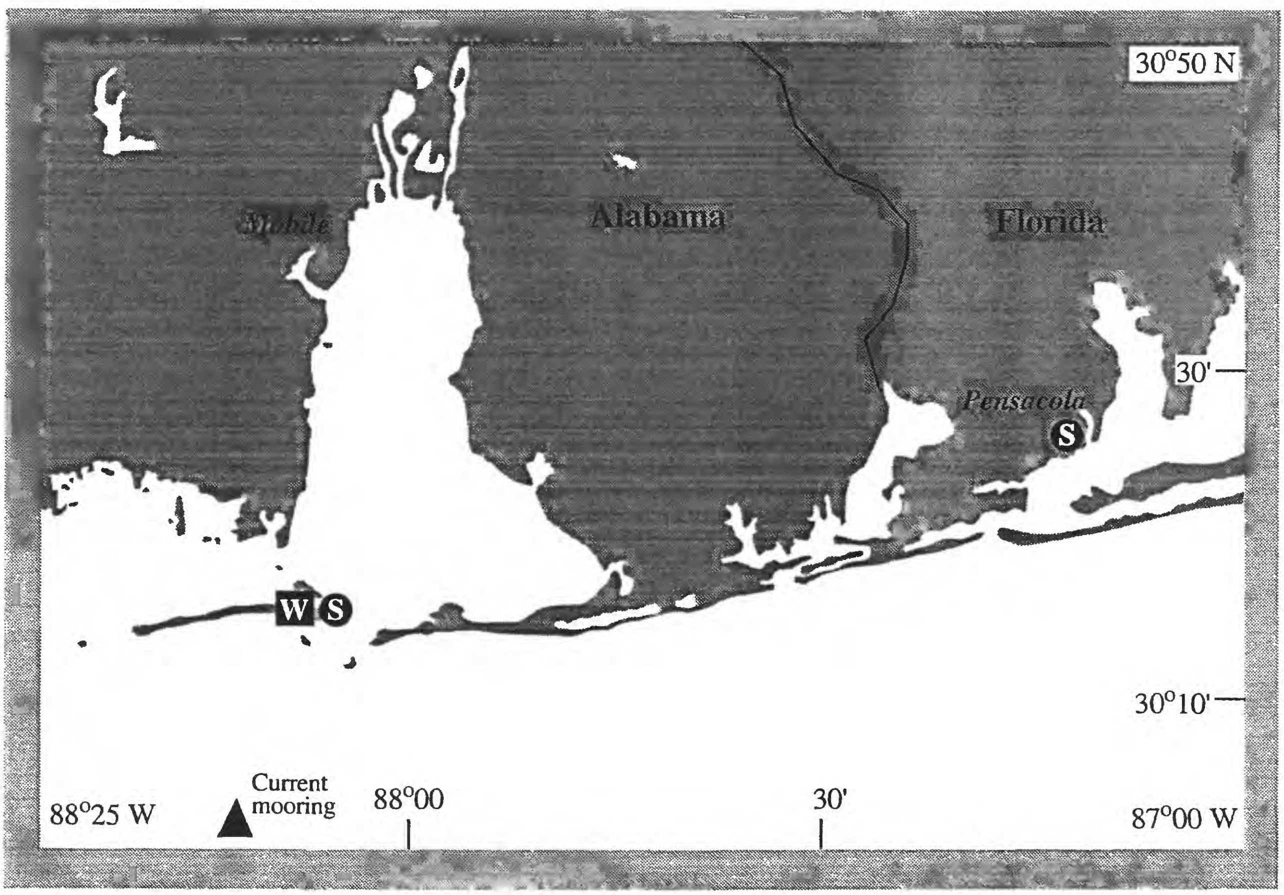

Figure 4. Wind W and sea level S stations at Dauphin Island, Alabama and Pensacola, Florida.

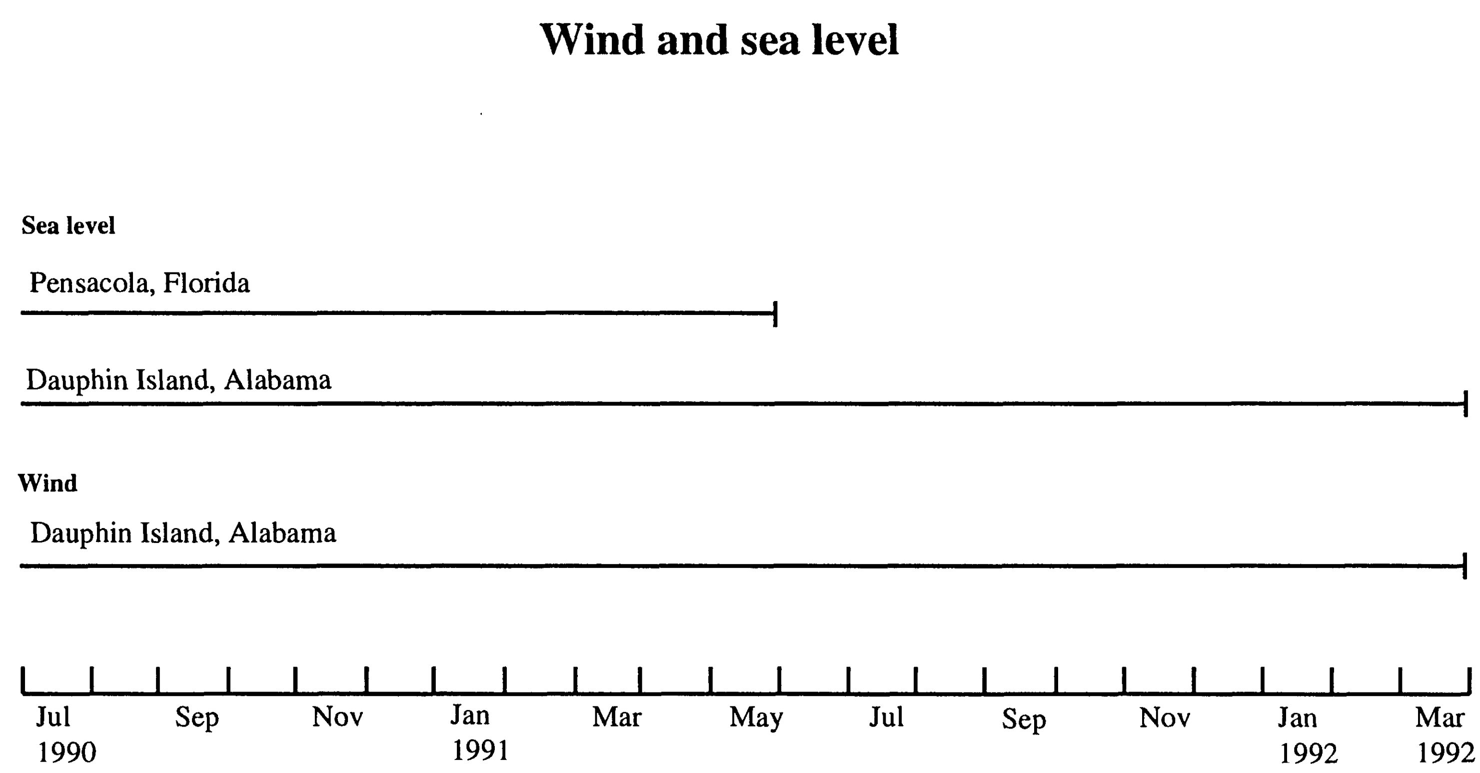

Figure 5. Timelines showing the dates when valid sea level and wind data exists.

Data Type/Station	Water Depth (m)	Start Time (M/D/Y)	Stop Time (M/D/Y)	Position Latitude	Position Longitude	Data Type	Sample Interval (minutes)
Sea level							
Dauphin Island, AL	1	07/01/90	03/30/92	30 18.0 N	088 06.0 W	SL	60
Pensacola, Fl	1	07/01/90	05/30/91	30 24.2 N	087 12.8 W	SL	60
Buoy wind							
Dauphin Island, AL	n/a	07/01/90	04/01/92	30 18.0 N	088 06.0 W	ST,P,AT,W	60

Table 2. Sea level, surface wind and buoy wind data available.

ST = sea temperature
P = atmospheric pressure
SL = sea level
AT = air temperature
W = wind (speed and direction)

ACKNOWLEDGMENTS

We would like to thank William Strahle, Marinna Martini, Richard Rendigs, Joseph Newell, and Allan Gunter for preparing, deploying and recovering the many types of instruments used in this project. Francis Hotchkiss decoded and cleaned up the raw data sets.

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Appendix A - Tables

Mooring	Water Depth (m)	Start Time GMT (M/D/Y)	Stop Time GMT (M/D/Y)	Sensor Depth (m)	Onshelf Mean	Onshelf SD	Onshelf Max	Onshelf Min	Alongshelf Mean	Alongshelf SD	Alongshelf Max	Alongshelf Min	Max Speed
350-1	30	07/28/90	10/18/90	5.0	2.5 ±2.8	17.7	57.7	-41.6	3.1 ±5.7	20.5	74.5	-45.0	75.8
350-2	30	07/28/90	12/06/90	24.0	0.7 ±1.3	6.7	25.8	-31.9	0.6 ±2.3	8.2	26.7	-27.1	36.6
376-1,380-2,385-1	30	02/26/91	11/19/91	5.0	0.6 ±1.9	15.1	58.3	-70.8	-4.0 ±3.5	18.8	79.8	-65.4	80.3
376-3,380-3,385-2	30	02/22/91	12/0791	24.0	0.4 ±1.0	7.9	37.9	-34.1	-0.7 ±2.2	10.9	28.5	-62.8	62.9
391-1	30	12/07/91	02/04/92	5.0	1.1 ±3.4	9.6	32.1	-33.2	-6.2 ±7.6	15.4	31.9	-53.6	54.9
391-2	30	12/11/91	03/20/92	24.0	2.4 ±4.9	5.6	20.8	-14.2	-0.9 ±9.4	9.4	20.5	-31.2	31.3

Table A1. - Hour-averaged horizontal current components (cm/s). Means in bold type are significantly different from zero at the 95% confidence level.

Mooring	Water Depth (m)	Start Time GMT (M/D/Y)	Stop Time GMT (M/D/Y)	Sensor Depth (m)	Onshelf Mean	Onshelf SD	Onshelf Max	Onshelf Min	Alongshelf Mean	Alongshelf SD	Alongshelf Max	Alongshelf Min
350-1	30	07/28/90	10/18/90	5.0	2.5 ±2.8	5.9	15.0	-13.1	3.5 ±5.7	12.1	30.3	-27.3
350-2	30	07/28/90	12/06/90	24.0	0.6 ±1.3	3.7	15.1	-12.4	0.6 ±2.3	6.3	14.6	-20.5
376-1,380-2,385-1	30	02/26/91	11//19/91	5.0	0.5 ±1.9	7.8	30.7	-35.8	-4.0 ±3.5	14.2	37.1	-46.1
376-3,380-3,385-2	30	02/22/91	12/0791	24.0	0.4 ±1.0	4.3	20.8	-23.4	-0.8 ±2.2	9.2	22.0	-30.3
391-1	30	12/07/91	02/04/92	5.0	1.2 ±3.4	5.9	17.6	-20.22	-6.3 ±7.6	13.2	21.2	-34.2
391-2	30	12/11/91	03/20/92	24.0	2.4 ±4.9	4.5	14.8	-10.4	-1.6 ±9.4	8.7	14.9	-23.2

Table A2. - Low-passed horizontal current components (cm/s)

Mooring	Water Depth (m)	Start Time GMT (M/D/Y)	Stop Time GMT (M/D/Y)	Sensor Depth (m)	Temperature (C) Mean	Temperature (C) SD	Temperature (C) Max	Temperature (C) Min	Salinity (ppt) Mean	Salinity (ppt) SD	Salinity (ppt) Max	Salinity (ppt) Min
350-1	30	07/28/90	12/12/90	5.0	**26.4 ±3.5**	3.7	31.8	19.2	— —	—	—	—
350-2	30	07/28/90	12/12/90	24.0	**24.3 ±1.8**	1.9	28.8	19.2	**35.8 ±0.5**	0.5	36.5	34.4
376-1,380-2,385-1	30	02/26/91	07/22/91	5.0	— —	—	—	—	**31.0 ±2.5**	2.9	34.8	22.2
376-1,380-2,385-1	30	02/26/91	12/07/91	5.0	**24.8 ±2.3**	4.1	30.9	16.2	— —	—	—	—
376-3,380-3,385-2	30	02/22/91	12/0791	24.0	**24.3 ±2.0**	3.5	30.5	17.7	**34.1 ±0.5**	0.8	35.4	31.0
391-1	30	12/07/91	02/04/92	5.0	**17.2 ±2.9**	1.0	19.4	14.9	— —	—	—	—
391-2	30	12/11/91	01/21/92	24.0	18.0 —	1.0	20.6	16.1	34.8 —	0.4	35.9	31.9

Table A3. - Hour-averaged temperature and salinity. Means in bold type are significantly different from zero at the 95% confidence level.

Mooring	Water Depth (m)	Start Time GMT (M/D/Y)	Stop Time GMT (M/D/Y)	Sensor Depth (m)	Temperature (C) Mean	Temperature (C) SD	Temperature (C) Max	Temperature (C) Min	Salinity (ppt) Mean	Salinity (ppt) SD	Salinity (ppt) Max	Salinity (ppt) Min
350-1	30	07/30/90	12/11/90	5.0	**26.6 ±3.5**	3.6	31.3	19.2	— —	—	—	—
350-2	30	07/30/90	12/10/90	24.0	**24.4 ±1.8**	1.9	28.2	19.3	**35.8 ±0.5**	0.5	36.6	34.5
376-1,380-2,385-1	30	02/28/91	07/21/91	5.0	— —	—	—	—	**30.9 ±2.5**	2.8	34.8	24.5
376-1,380-2,385-1	30	02/28/91	12/06/91	5.0	**24.8 ±2.3**	4.1	30.7	16.3	— —	—	—	—
376-3,380-3,385-2	30	02/24/91	12/0691	24.0	**24.3 ±2.0**	3.5	30.2	17.9	34.1 ±0.5	0.8	35.2	31.3
391-1	30	12/09/91	02/03/92	5.0	**17.2 ±2.9**	1.0	19.5	15.3	— —	—	—	—
391-2	30	12/13/91	01/20/92	24.0	18.0 —	1.0	20.4	16.4	34.8 —	0.4	35.8	34.0

Table A4. - Low-passed temperature and salinity. Means in bold type are significantly different from zero at the 95% confidence level..

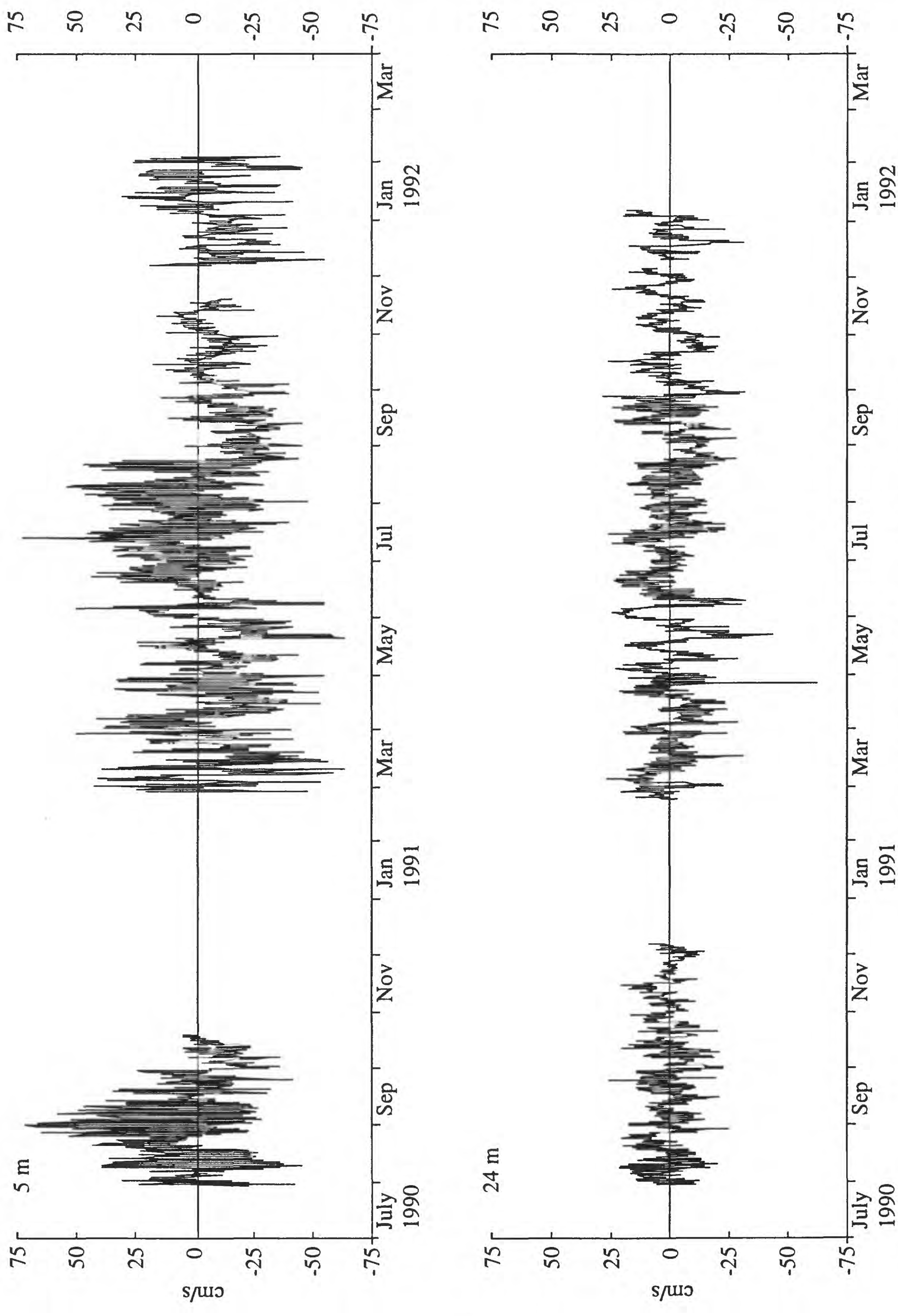
Mooring	Sensor depth (m)	Start time GMT (M/D/Y)	Stop time GMT (M/D/Y)	O_1			K_1		
				Major axis (cm/s)	Minor axis (cm/s)	Inclination (degrees)	Major Axis (cm/s)	Minor axis (cm/s)	Inclination (degrees)
350-1	5.0	07/28/90	10/17/90	6.5	-5.2	130.2	19.4	2.5	40.1
350-2	24.0	07/28/90	12/06/90	1.8	-0.2	120.6	3.8	-2.7	128.2
376-1,380-2,385-1	5.0	02/26/91	11/19/91	4.0	-2.3	106.7	5.3	-3.2	084.8
376-3,380-3,385-2	24.0	02/22/91	12/0791	1.6	0.1	121.6	3.3	-2.0	112.8
391-1	5.0	12/07/91	02/04/92	2.2	-1.6	128.5	5.2	-3.2	141.0
391-2	24.0	12/11/91	01/06/92	2.5	-0.5	138.1	1.4	0.4	132.9

TableA5. - Diurnal tidal currents. A negative minor axis indicates a clockwise rotation for the tidal currents. The inclination angle is counterclockwise from east.

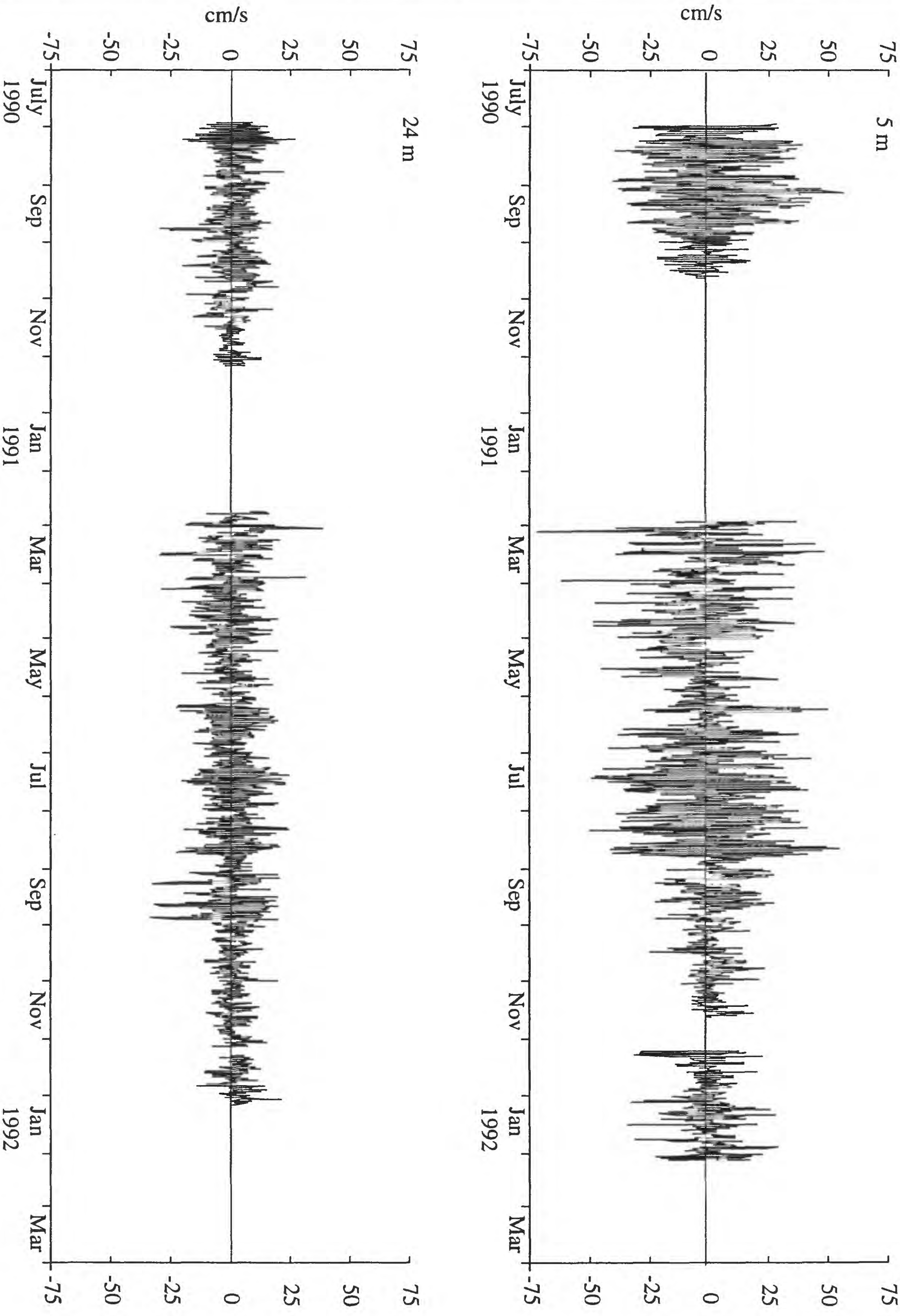
Mooring	Sensor depth (m)	Start time GMT (M/D/Y)	Stop time GMT (M/D/Y)	M_2			S_2		
				Major axis cm/s	Minor axis cm/s	Inclination degrees	Major Axis cm/s	Minor axis cm/s	Inclination degrees
350-1	5.0	07/28/90	10/17/90	1.6	-0.7	101.3	0.6	-0.2	123.9
350-2	24.0	07/28/90	12/06/90	0.8	0.3	127.5	0.2	0.2	109.3
376-1,380-2,385-1	5.0	02/26/91	11/19/91	0.6	0.4	096.3	0.8	-0.4	128.1
376-3,380-3,385-2	24.0	02/22/91	12/0791	0.8	0.2	113.4	0.4	0.0	138.7
391-1	5.0	12/07/91	02/04/92	1.2	0.0	138.6	0.9	0.2	024.1
391-2	24.0	12/11/91	01/06/92	0.6	0.2	090.3	1.8	-0.5	155.6

Table A6. - Semidiurnal tidal currents. A negative minor axis indicates a clockwise rotation for the tidal currents. The inclination angle is counterclockwise from east.

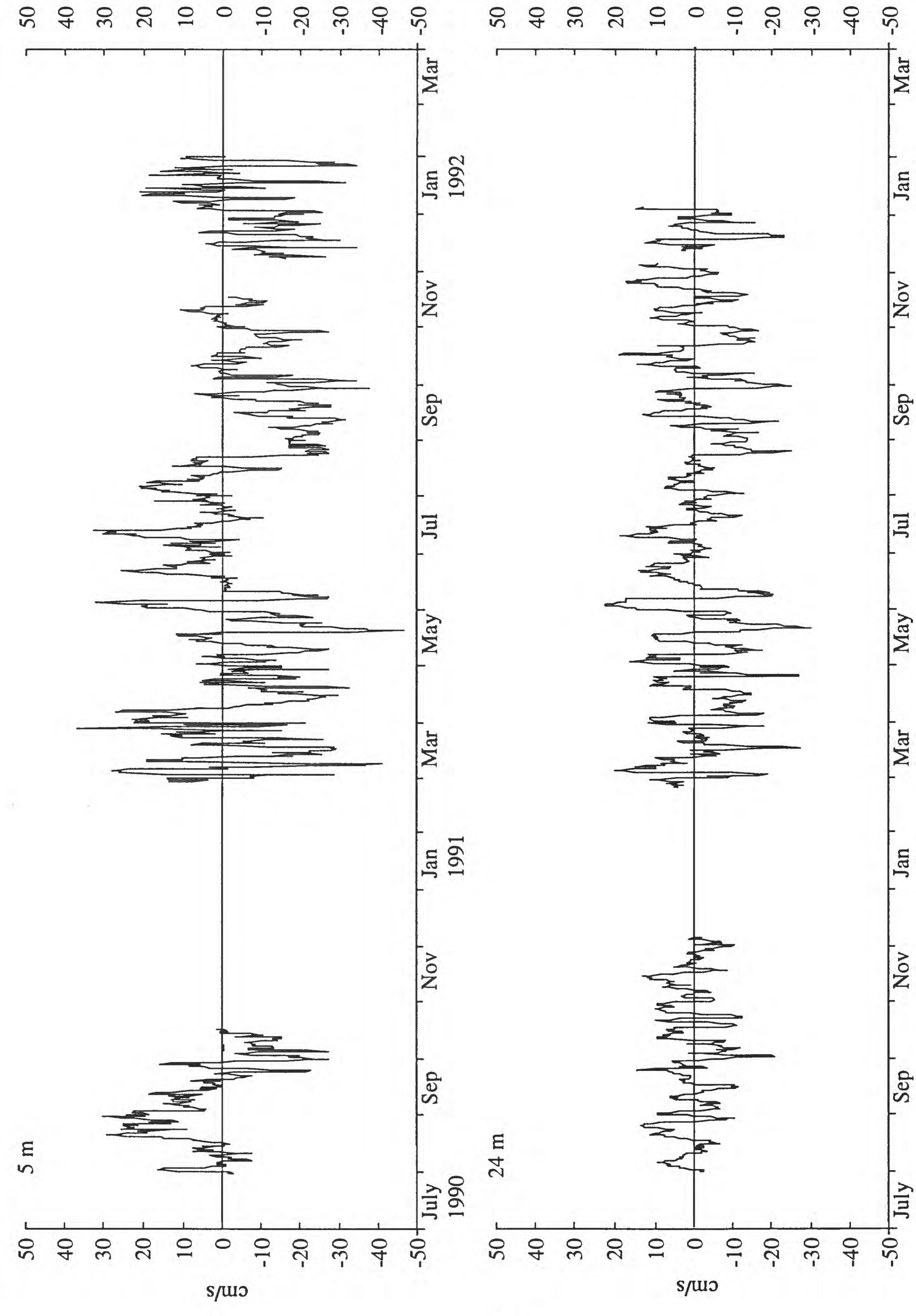
Appendix B - Time series, subtidal current vectors and variance conserving autospectra



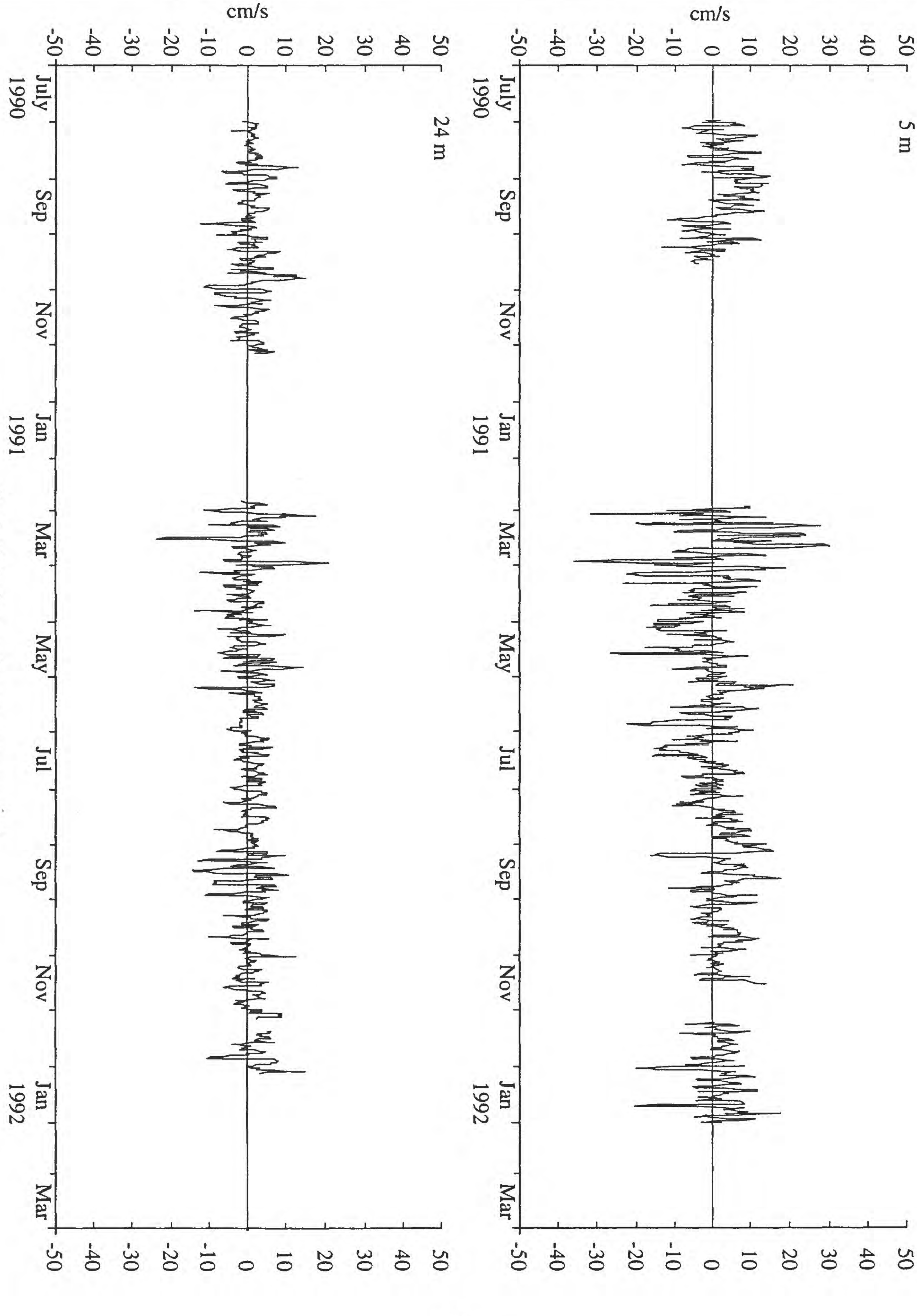
Hour-averaged alongshore current



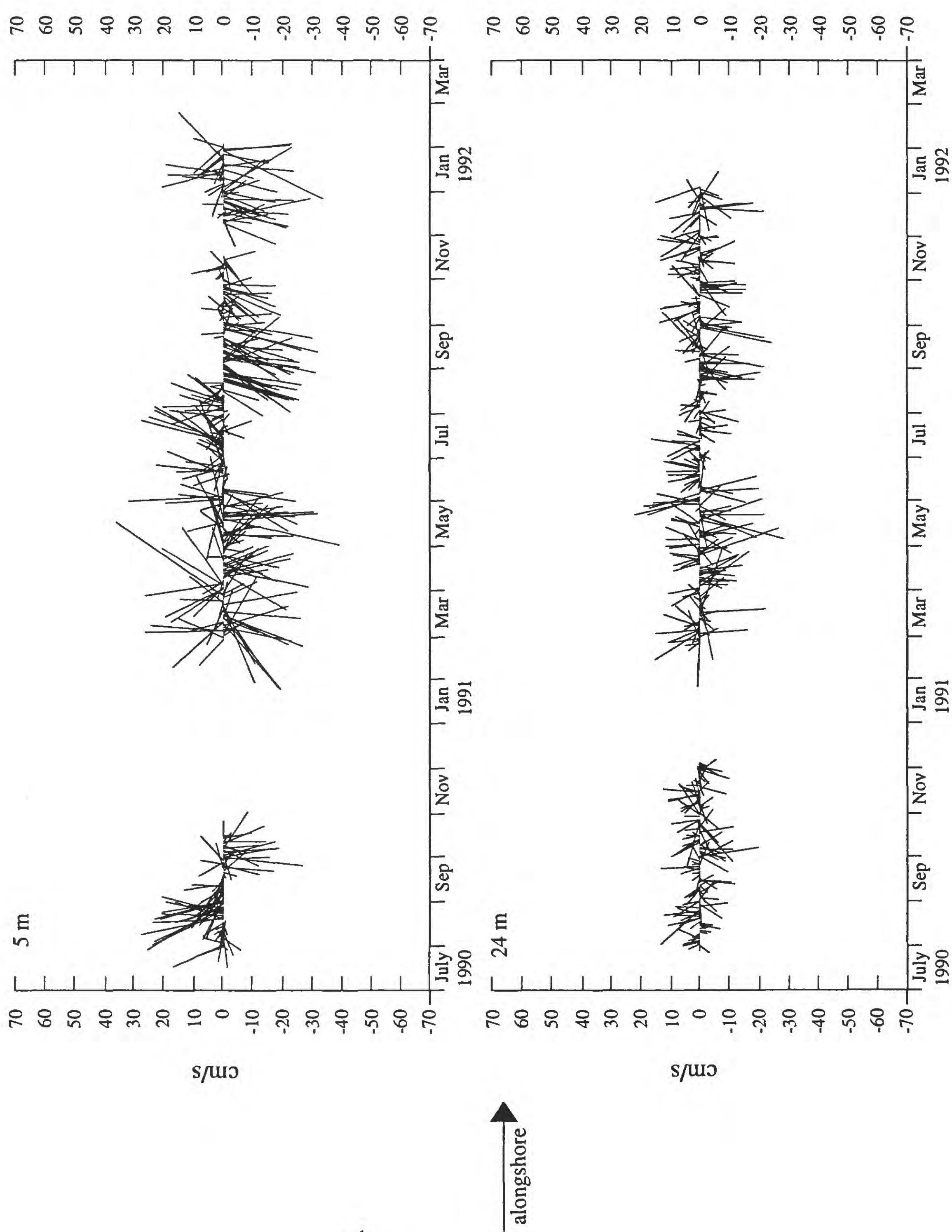
Hour-averaged onshore current



Subtidal alongshore current



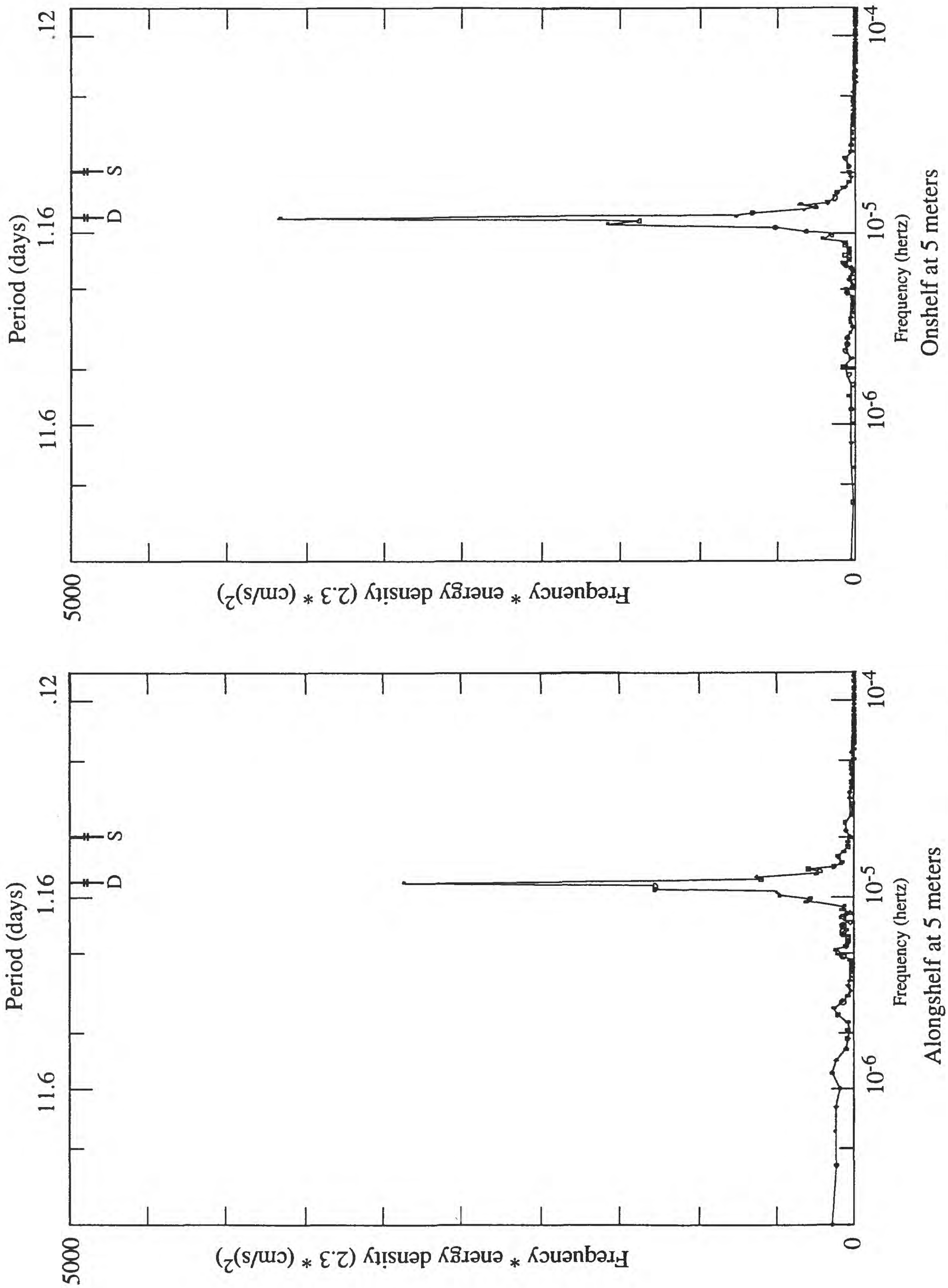
Subtidal onshore current



Subtidal current vectors

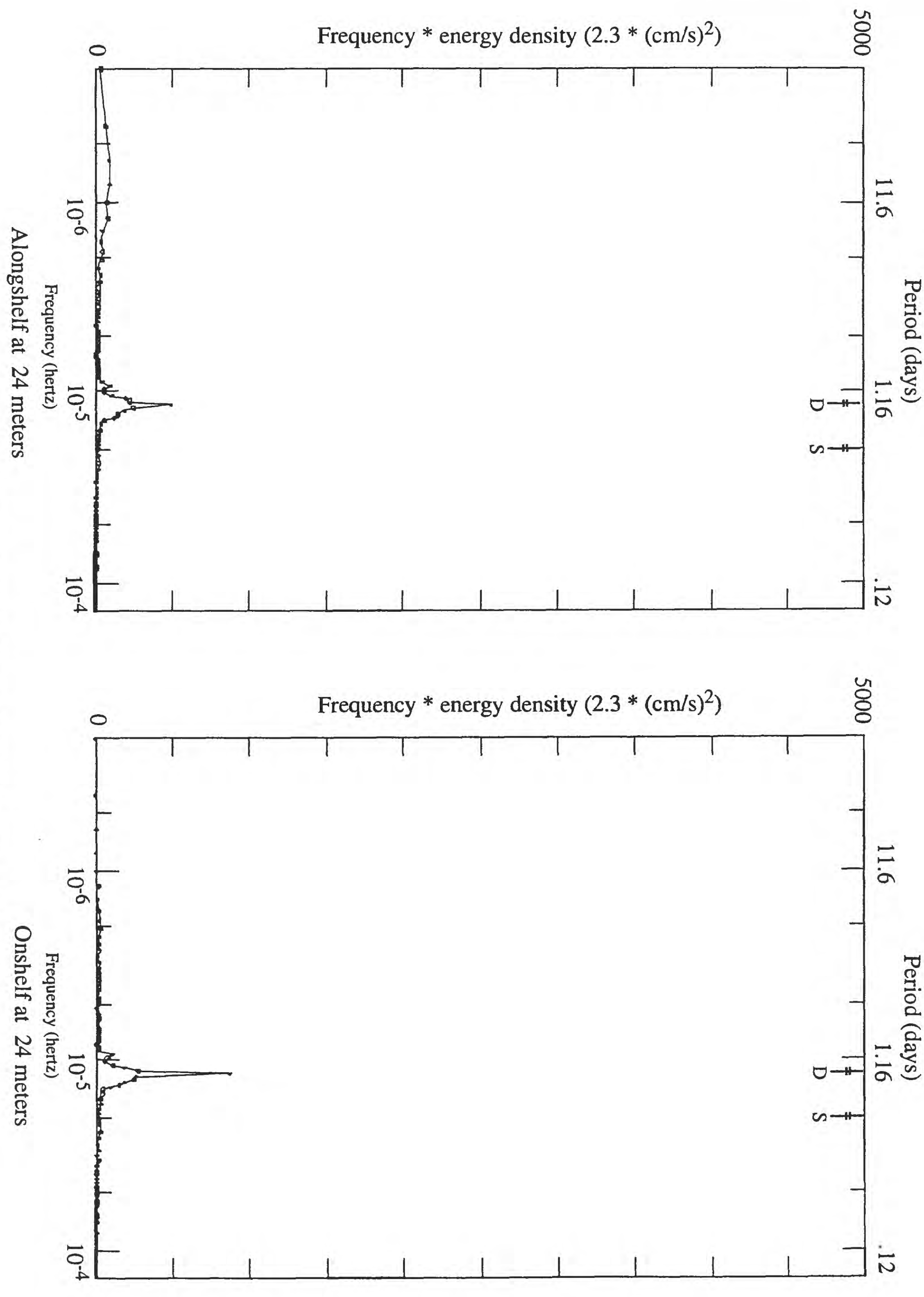
Instrument depth	Start time GMT (M/D/Y)	Stop time GMT (M/D/Y)	Piece length hours
5	02/26/91	11/19/91	1368
19	2/26/91	11/19/91	1368

Table B1. - Dates and piece lengths used for the spectral plots.



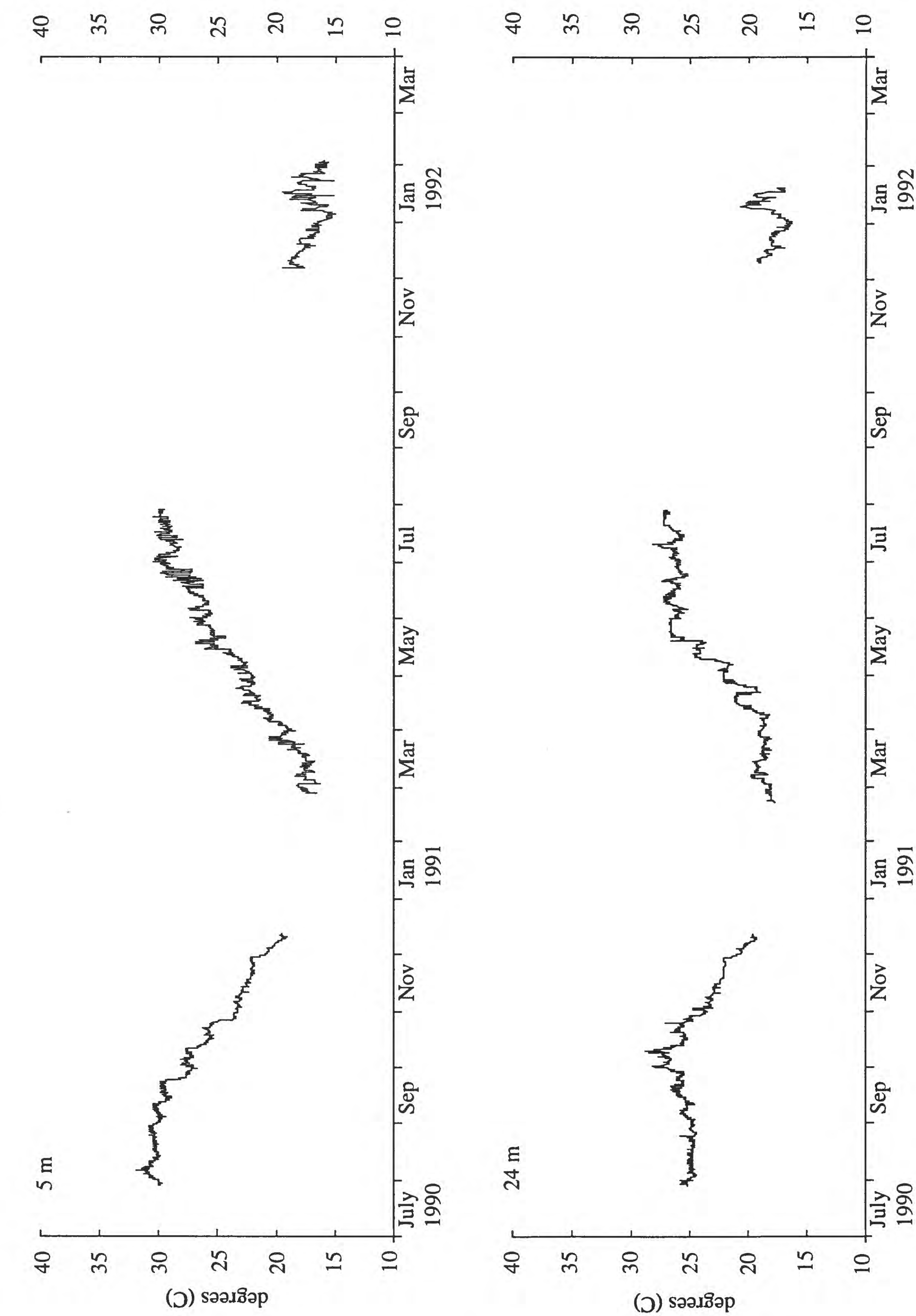
Variance conserving autospectra currents

(D = diurnal, S = semidiurnal)

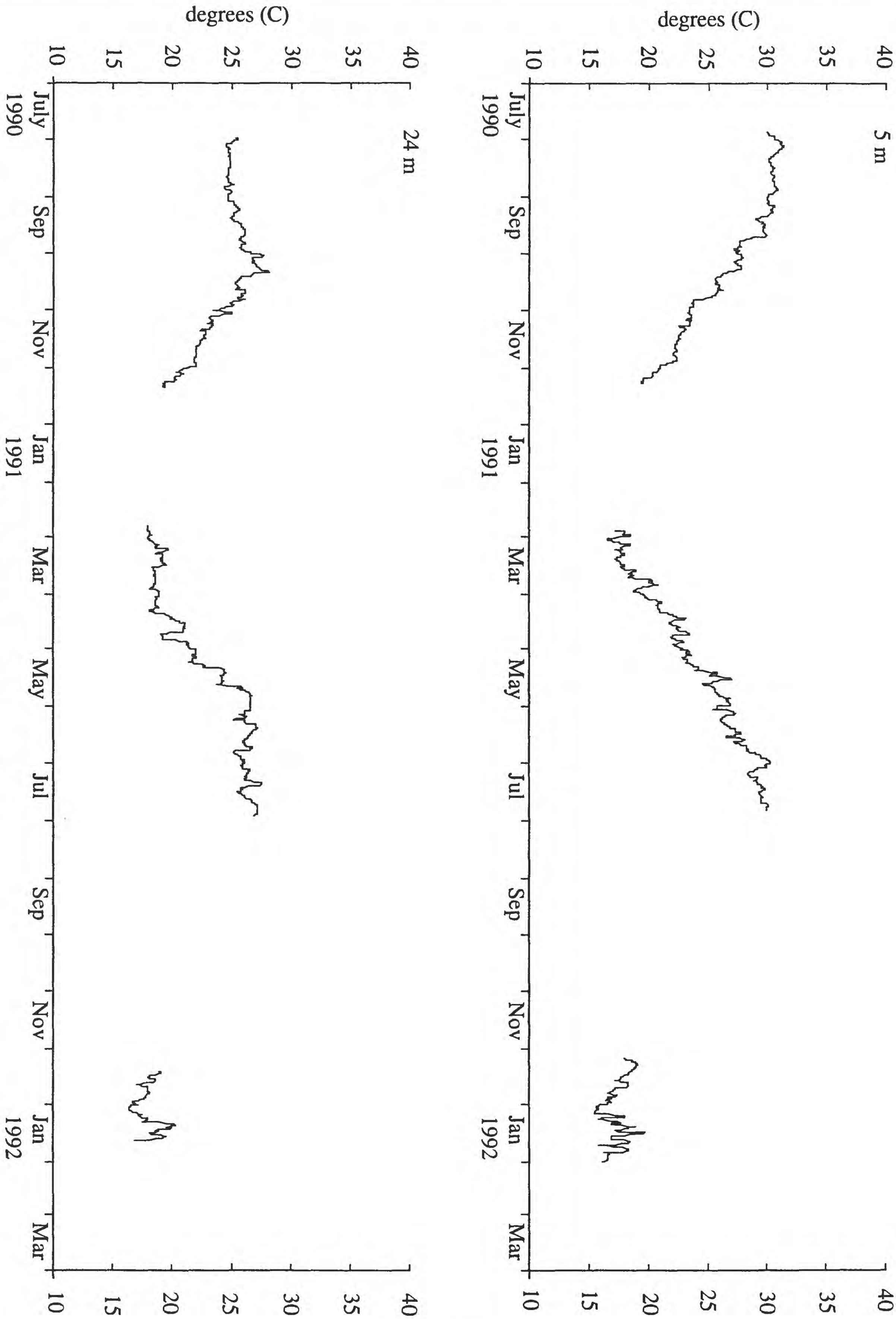


Variance conserving autospectra currents
(D = diurnal, S = semidiurnal)

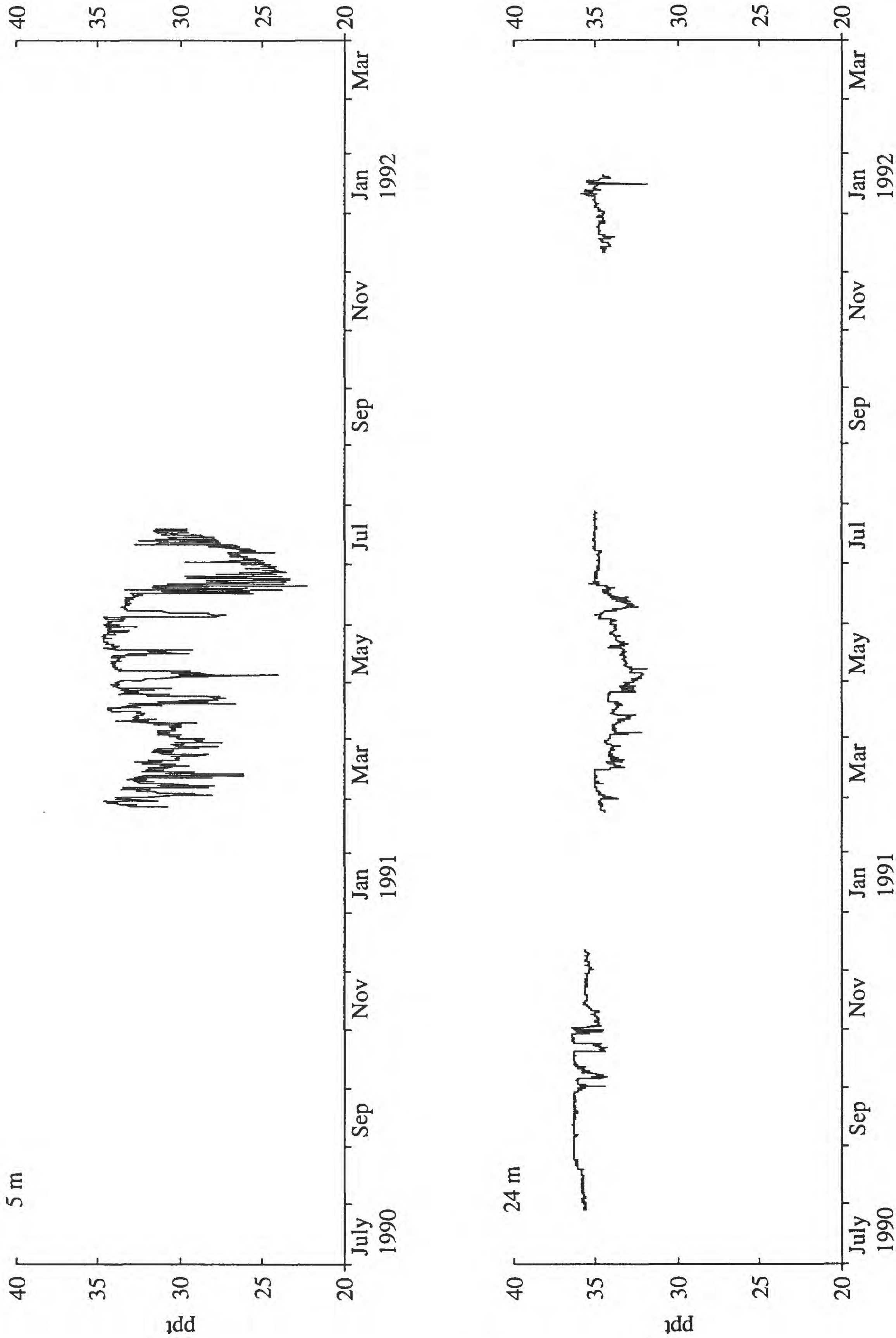
Appendix C - Temperature, salinity and transmission data



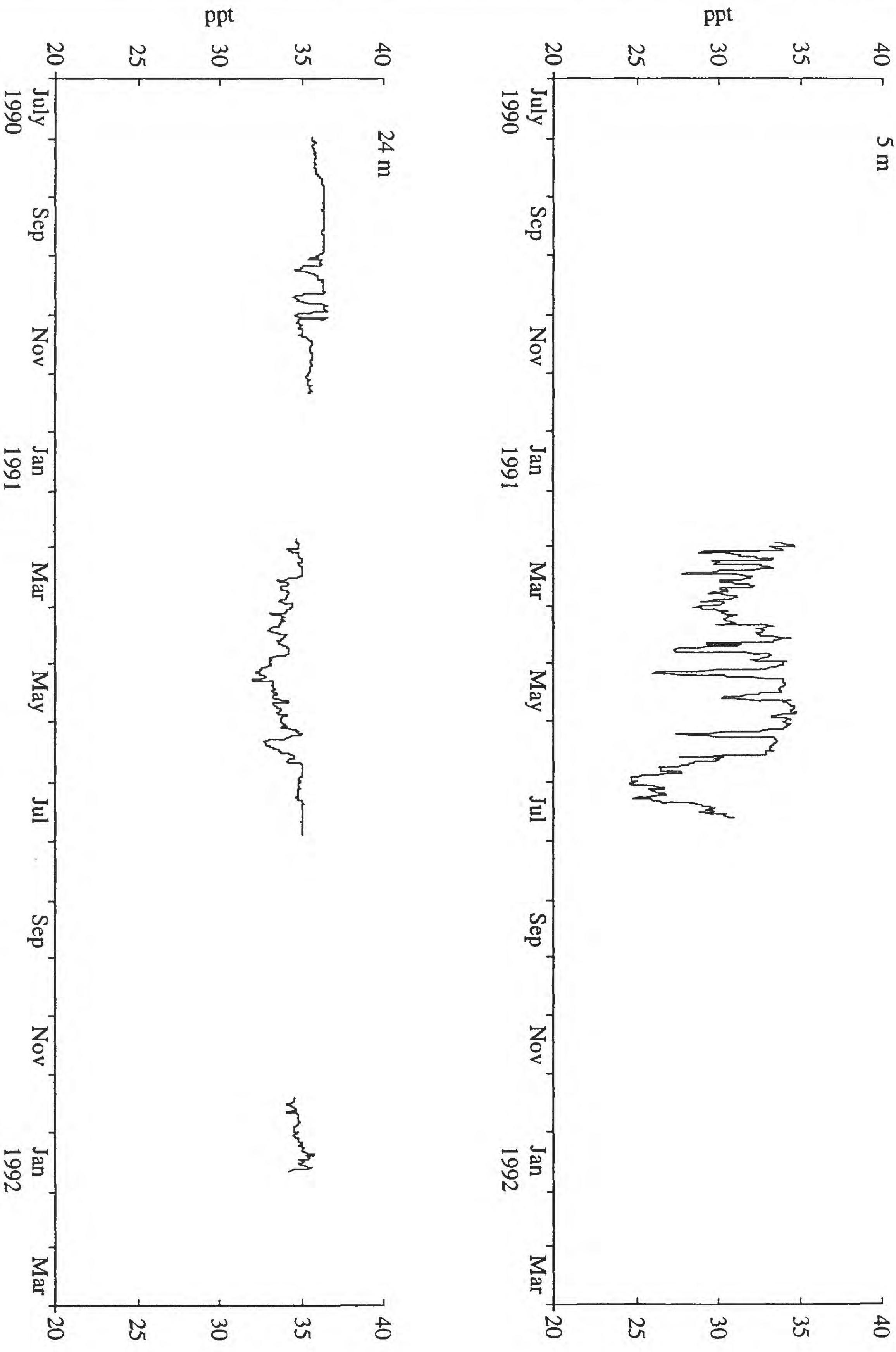
Hour-averaged temperature



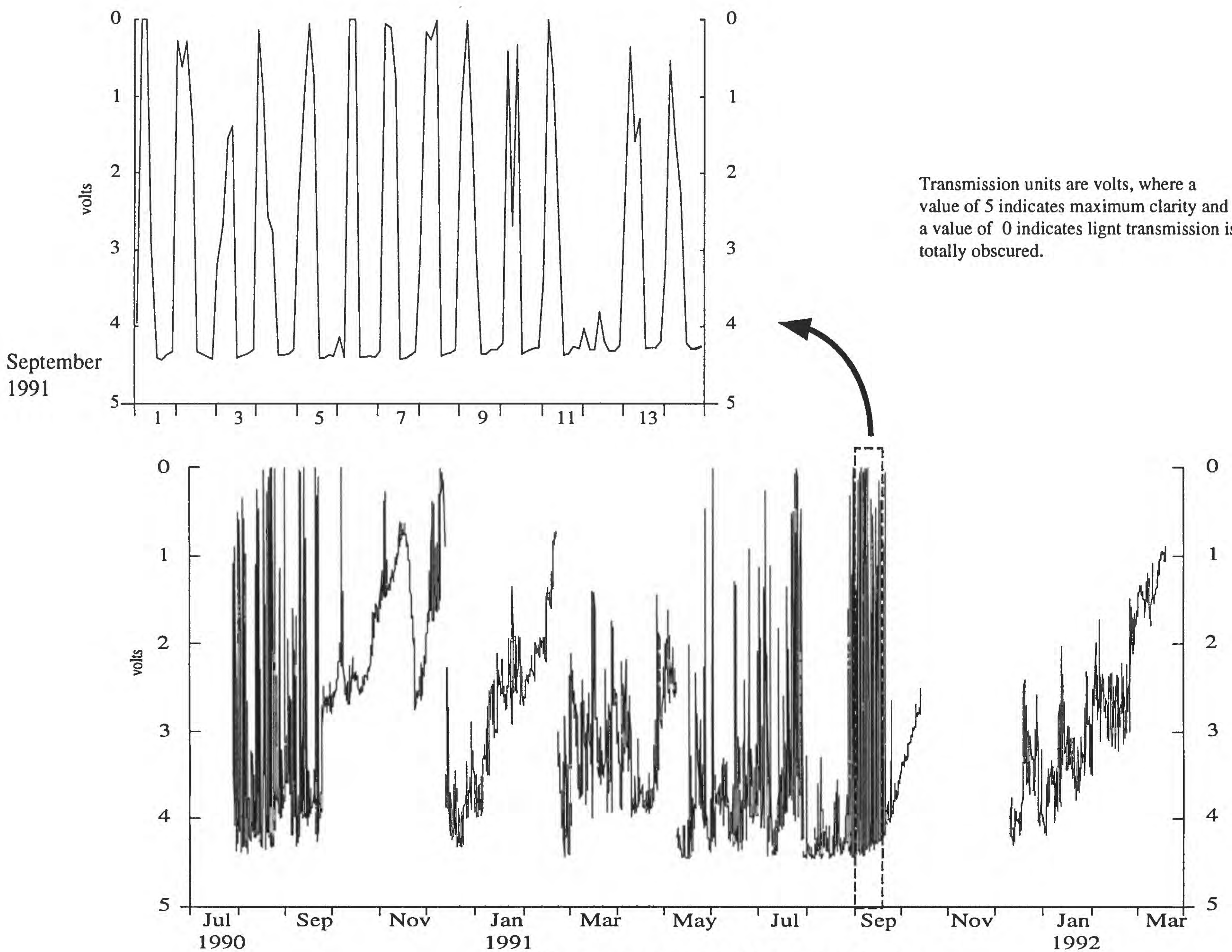
Lowpassed temperature



Hour-averaged salinity



Lowpassed salinity



Hour-averaged transmission

Appendix D - Wind and sea level data

Station	Start time GMT (M/D/Y)	Stop time GMT (M/D/Y)	Piece length (hours)
Buoy wind			
Dauphin Island, Alabama (CMAN station)	07/01/90	04/01/92	1170
Sea level			
Dauphin Island, Alabama	07/01/90	03/30/92	1170
Pensacola, Florida	07/01/90	05/30/91	1170

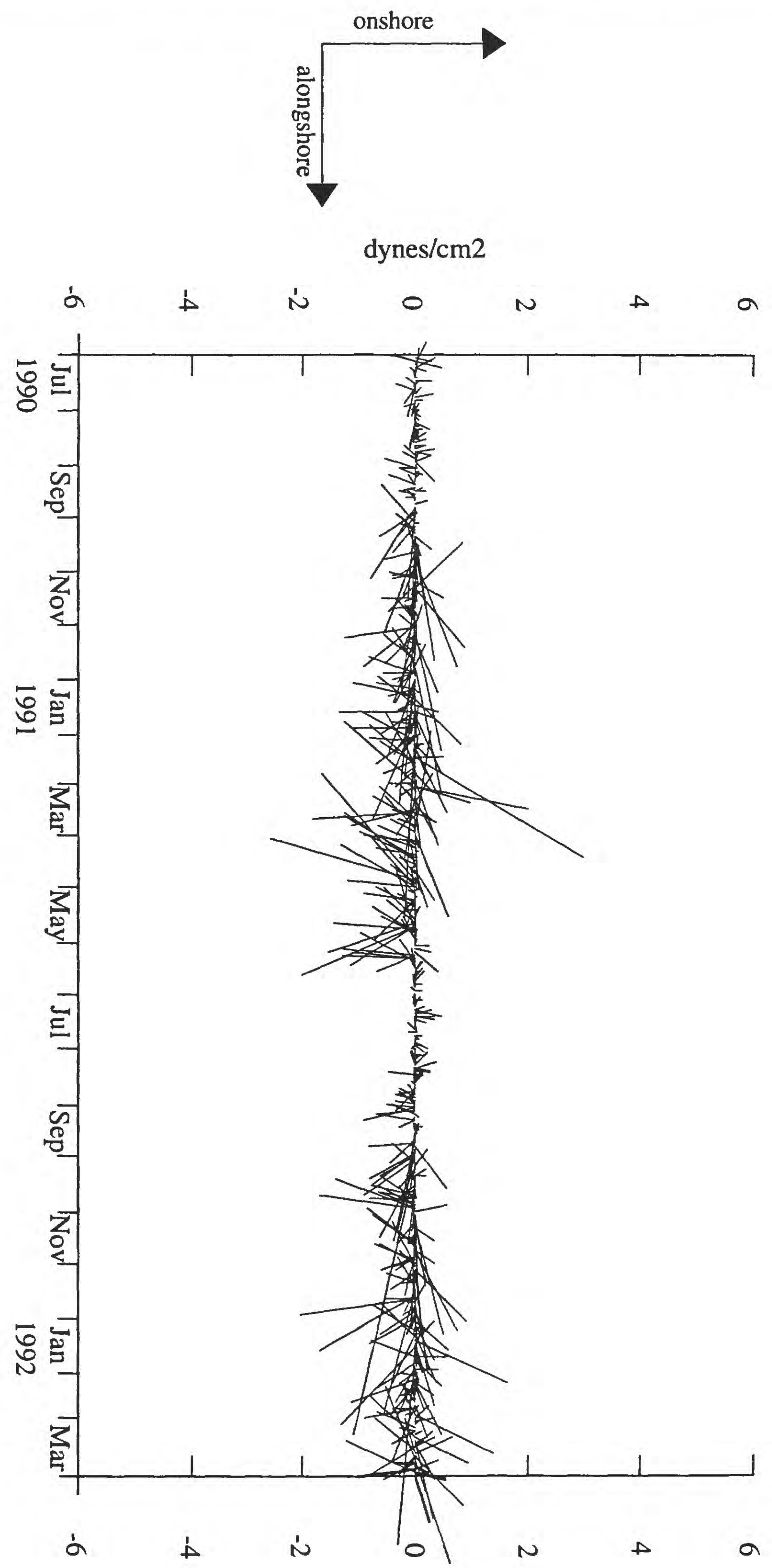
Table D1. Dates and piece lengths used for wind and sea level spectral plots.

Station	Start time (GMT) (M/D/Y)	Stop time GMT (M/D/Y)	O_1 (cm)	K_1 (cm)	M_2 (cm)	S_2 (cm)
Dauphin Is, Alabama	07/01/90	3/30/92	12.3	12.7	1.6	0.8
Pensacola, Florida	07/01/90	5/30/90	13.1	13.6	2.1	0.6

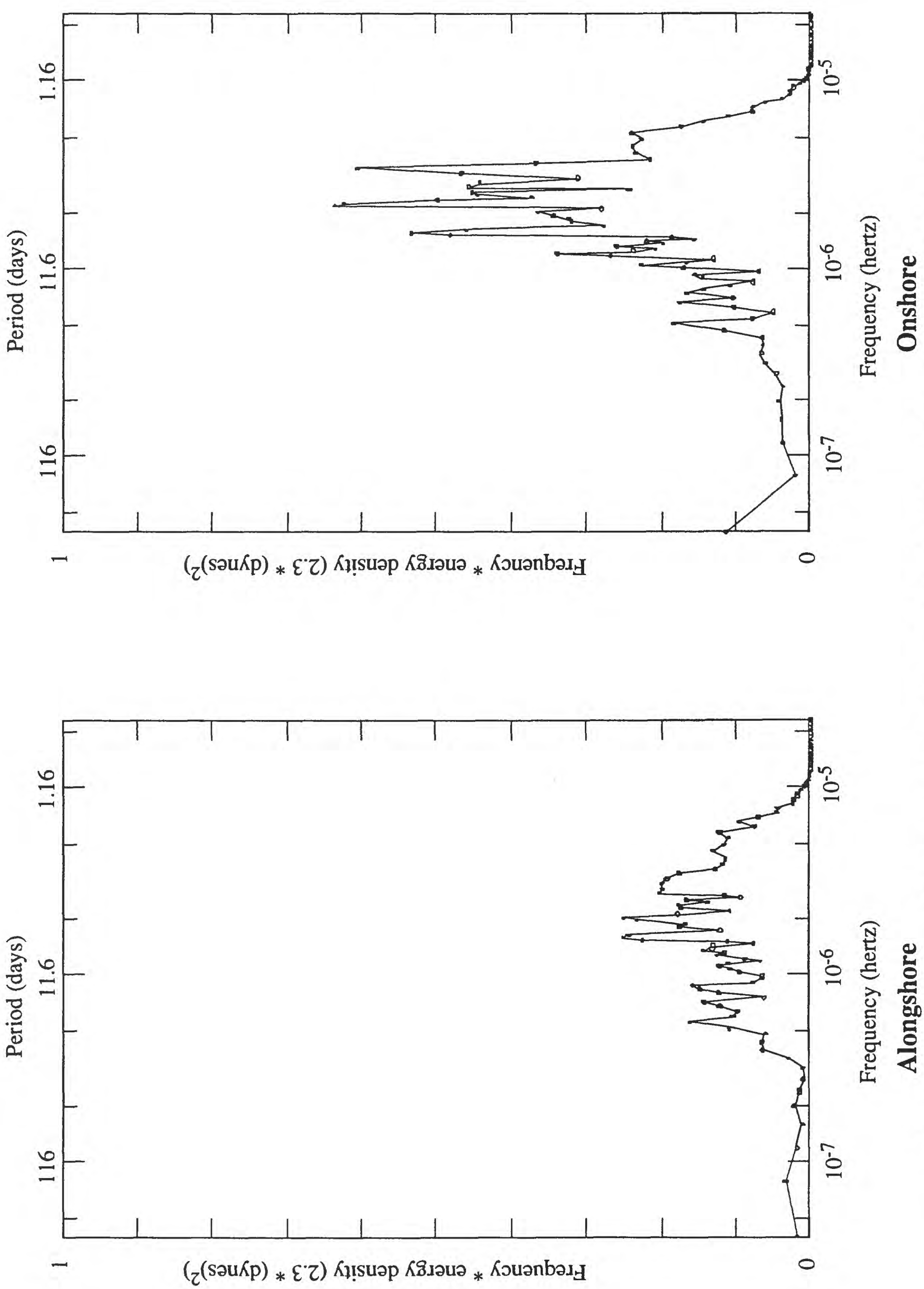
Table D2. Sea level tidal components.

Component	Start time GMT (M/D/Y)	Stop time GMT (M/D/Y)	Dauphin Island			
			Mean	SD	Max	Min
Onshelf	07/01/90	04/01/92	-0.1 ±0.1	0.6	-4.9	2.3
Alongshelf	07/01/90	04/01/92	-0.1 ±0.1	0.5	3.0	-2.6

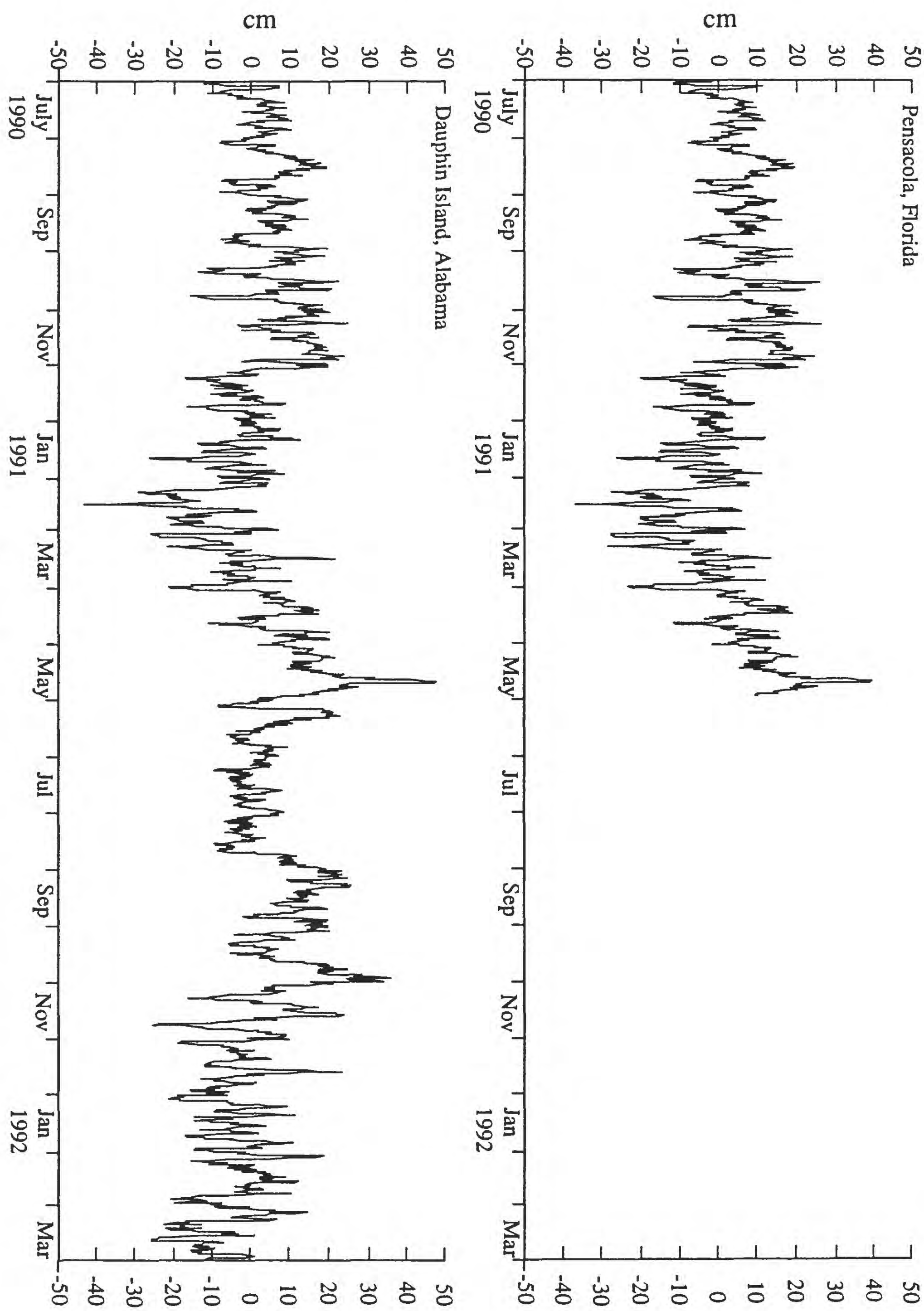
Table D3. Lowpassed horizontal wind stress components (cm/s) for Dauphin Island, Alabama.



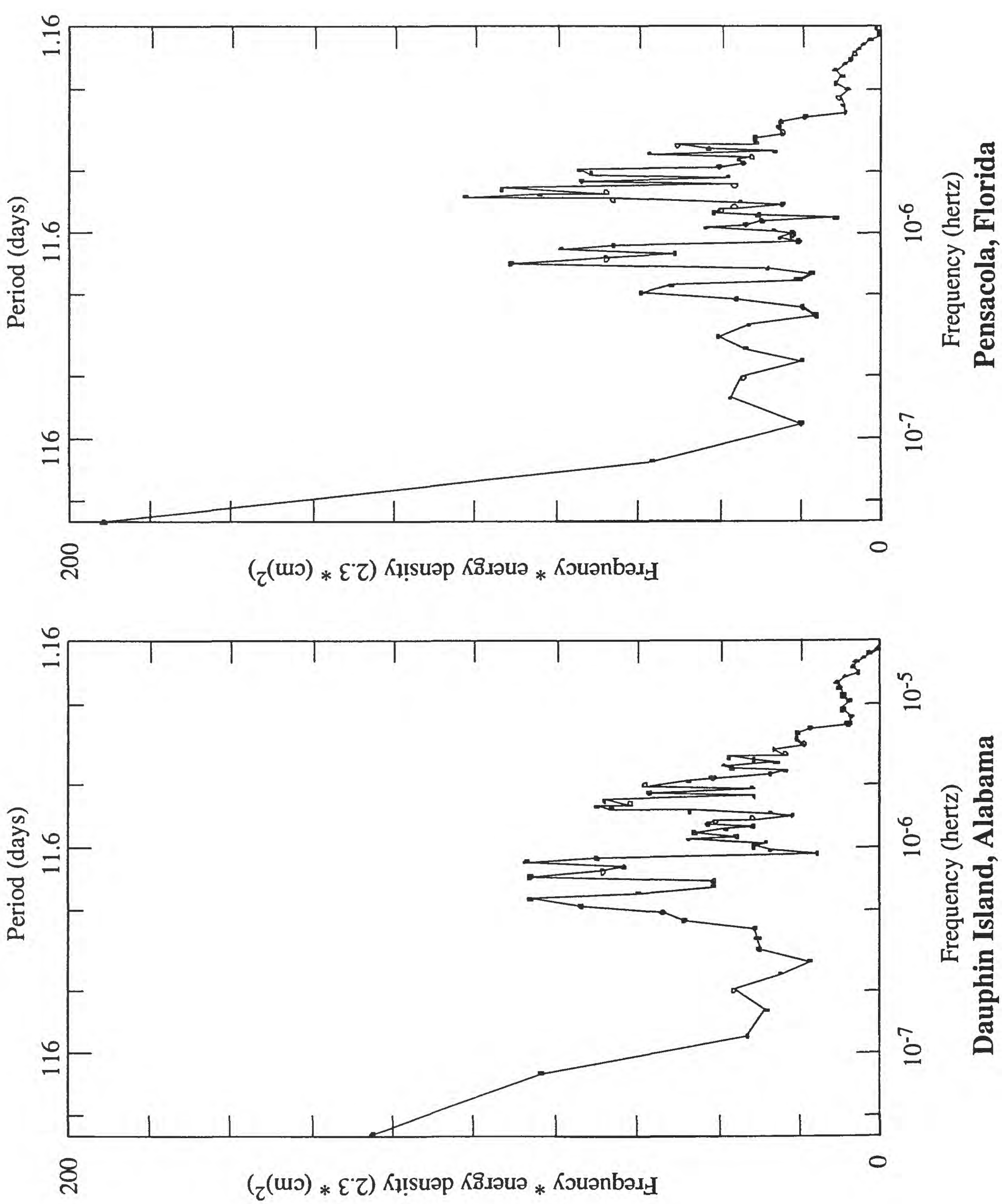
Low-passed NODC wind stress vectors for Dauphin Island, Alabama



Variance conserving autospectra winds for Dauphin Island, Alabama



Subtidal synthetic subsurface pressure



Variance conserving autospectra for subtidal synthetic subsurface pressure*

(*The lowpassed data was used for these plots so that the record would not be dominated by the tides)