WHOI-96-06

Woods Hole Oceanographic Institution

Coastal Ocean Processes Inner-Shelf Study: Coastal and Moored Physical Oceanographic Measurements

by

Carol A. Alessi, Steven J. Lentz, and Jay Austin

May 1996

Technical Report

Funding was provided by the National Science Foundation
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Abstract

To improve our understanding of the physical and biological processes influencing planktonic larval distributions over the inner shelf, an interdisciplinary field program funded by the National Science Foundation's Coastal Ocean Processes program (CoOP) was conducted near Duck, North Carolina in the southern portion of the Middle Atlantic Bight. The field program took place from August to December, 1994 and included both moored and shipboard measurements of physical, biological and sedimentological variables.

This report summarizes the observations from one component of this field program, a moored array of physical oceanographic and meteorological instruments. This component of the field program consisted of a cross-shelf array of three surface/subsurface mooring pairs in 13 m, 20 m and 25 m of water supporting instruments to measure currents, temperature and conductivity, a suite of meteorological instruments on surface buoys at the 20 -m and 25 -m site, and an along-shelf array of temperature, conductivity and bottom pressure sensors mounted on jetted pipes along the 5-m isobath and on moorings along the 20-m isobath. The report includes descriptions of the cross-shelf and along-shelf arrays, the four types of instruments used (VAWRs, VMCMs, SeaCats, and SeaGauges), and the data return from the field program. Statistical and graphical summaries of the atmospheric (wind, air temperature, barometric pressure, relative humidity, short- and long-wave radiation), and oceanic (current, water temperature, conductivity and bottom pressure) measurements are presented.

1. Introduction

To improve our understanding of the physical and biological processes influencing planktonic larval distributions over the inner-shelf, an interdisciplinary field program funded by the National Science Foundation's Coastal Ocean Processes program (CoOP) was conducted in the southern portion of the Middle Atlantic Bight. Past studies of the relationships between physical processes and larval settlement have been hindered by limitations in measuring changes in planktonic larval distributions on the same time and space scales as the physics (Butman, 1987; Levin, 1990; GLOBEC, 1988, 1991a,b,c). Therefore this field program included two complementary observational approaches: deployment of a fixed array of biological and physical instruments, and detailed shipboard surveys of the region acquiring both biological and physical measurements. This study (referred to as the CoOP inner-shelf study in the remainder of this report) was planned and conducted by a group of seven principal investigators from five institutions representing the disciplines of biology, geology, and physical oceanography. The principal investigators and their technical responsibilities are listed in Table 1.

The CoOP inner-shelf field program was conducted on the North Carolina shelf between Chesapeake Bay and Oregon Inlet, focusing on the inner-shelf near Duck, from August to December 1994. The inner-shelf is defined as the portion of the continental shelf shoreward of where the surface and bottom boundary layers interact (about three surface Ekman layer depths, Mitchum and Clarke, 1986) and seaward of the surf zone, spanning water depths of roughly 5—30 m (Figure 1). The inner-shelf is most studied at its shoreward (surf zone) and seaward (traditional shelf studies) boundaries, with far fewer measurements in the depth range of 4 to 15 m.

In the CoOP inner-shelf field program the observations were concentrated between the 4-m and 25-m isobaths. The site near Duck was chosen for its relatively simple, straight shoreline and parallel isobaths which may minimize biological, hydrodynamical and sedimentological variation in the along-shelf direction. There were two intensive study periods representative of strong (August) and weak (October) stratification (Figure 2a, from Boicourt, 1973), when most of the shipboard surveys and the fixed array biological and bottom boundary layer measurements were made. Figure 2b shows two sections collected during the CoOP inner-shelf field program from the *R/V Cape Hatteras* during August 1994, representative of strong stratification, and Figure 2c shows data collected during October 1994, a period of weak stratification. The fixed array physical oceanography measurements spanned the intervening month of September to provide continuity between the two intensive study periods.

This report focuses on one component of the interdisciplinary CoOP inner-shelf field program, a moored array of physical oceanographic and meteorological instruments. This component of the field program consisted of a cross-shelf array of three surface/subsurface mooring pairs in 13, 20, and 25 m of water supporting instruments to measure currents, temperature and conductivity, a suite of meteorological instruments on surface buoys at the 20-m and 25-m site, and an along-shelf array of temperature, conductivity and bottom pressure sensors mounted on jetted pipes roughly along the 6-m isobath and on moorings along the 20-m isobath. The other major physical oceanographic components of the CoOP inner-shelf field program were an array of nearshore moorings and extensive shipboard hydrographic surveys (Table 1).

Table 1: Principal Investigators and Technical Responsibilities

		Physical Oceanography
S. J. Lentz	WHOI	Acquisition and analysis of the current, temperature, and conductivity measurements on the 13, 20, and 25 m moorings, and for the alongshelf array of bottom pressure/ temperature/conductivity measurements.
J. Largier	SIO	Large-scale CTD surveys, anchor stations, and small boat CTD surveys.
R. T. Guza	SIO	All aspects of the current meters, pressure sensors, and thermistors in 8 m and shallower locations.
		Biological Oceanography
C. A. Butman	WHOI	Moored larval pumps and colonization tray.
A. L. Shanks	UO	Shipboard and pier larval pump sampling and beach surveys.
		Geological Oceanography and Ocean Engineering
L. D. Wright	VIMS	Bottom-boundary-layer instrumentation systems (tetrapods), and conducting surveys of bottom and substrate characteristics (e.g., side-scan sonar, coring, bottom photography, etc.)
O. S. Madsen	MIT	Modeling of wave current boundary layers.

Notes:

WHOI:	Woods Hole Oceanographic Institution	SIO:	Scripps Institution of Oceanography
MIT:	Massachusetts Institute of Technology	VIMS:	Virginia Institute of Marine Science
UO:	University of Oregon		

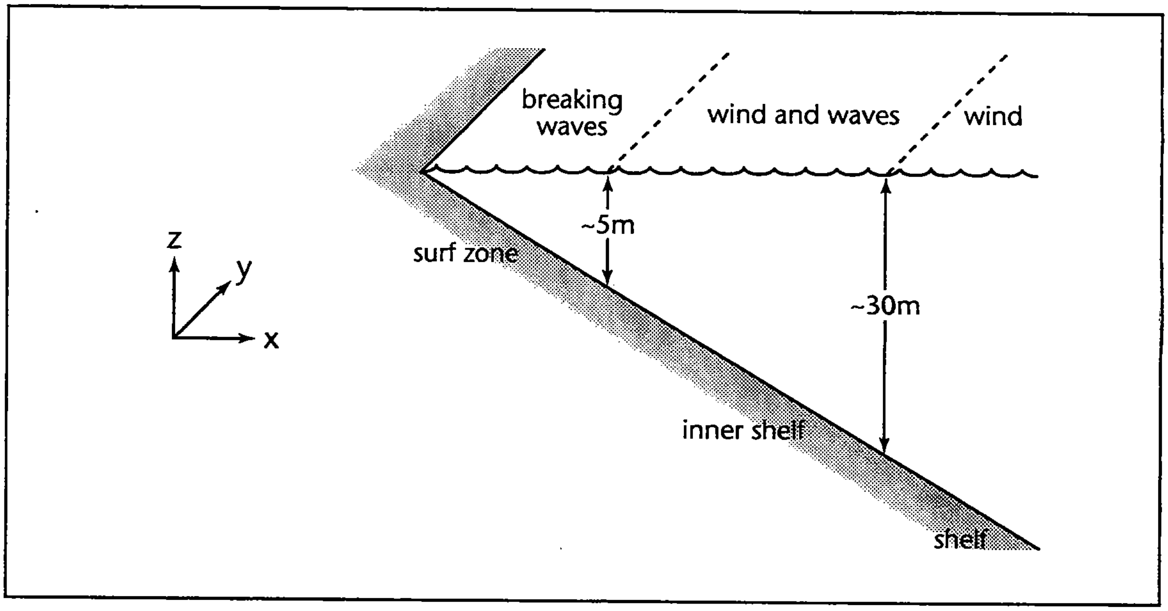


Figure 1: Cartoon showing various regions of the shelf and the principal driving forces of the flows in those regions. The coordinate system used is also shown.

The scientific objectives of the physical oceanographic component include determining:

- the role of the wind stress, waves, and pressure gradients in the along-shelf momentum balance as a function of cross-shelf position;
- the processes influencing the vertical and cross-shelf structure of the cross-shelf velocity field; and
- the processes influencing the temporal evolution and vertical and cross-shelf structure of the density field.

The objective of this report is to present statistical and graphical summaries of data from the physical oceanography component of the CoOP inner-shelf study. This includes the 13-m, 20-m, and 25-m mooring sites and the along-shelf array of temperature, conductivity and bottom pressure instruments. This report is organized in the following way:

- Section 2 gives a description of the cross-shelf and along-shelf array design, the placement of instruments at the various measurement sites, associated data return, and problems affecting the data return.

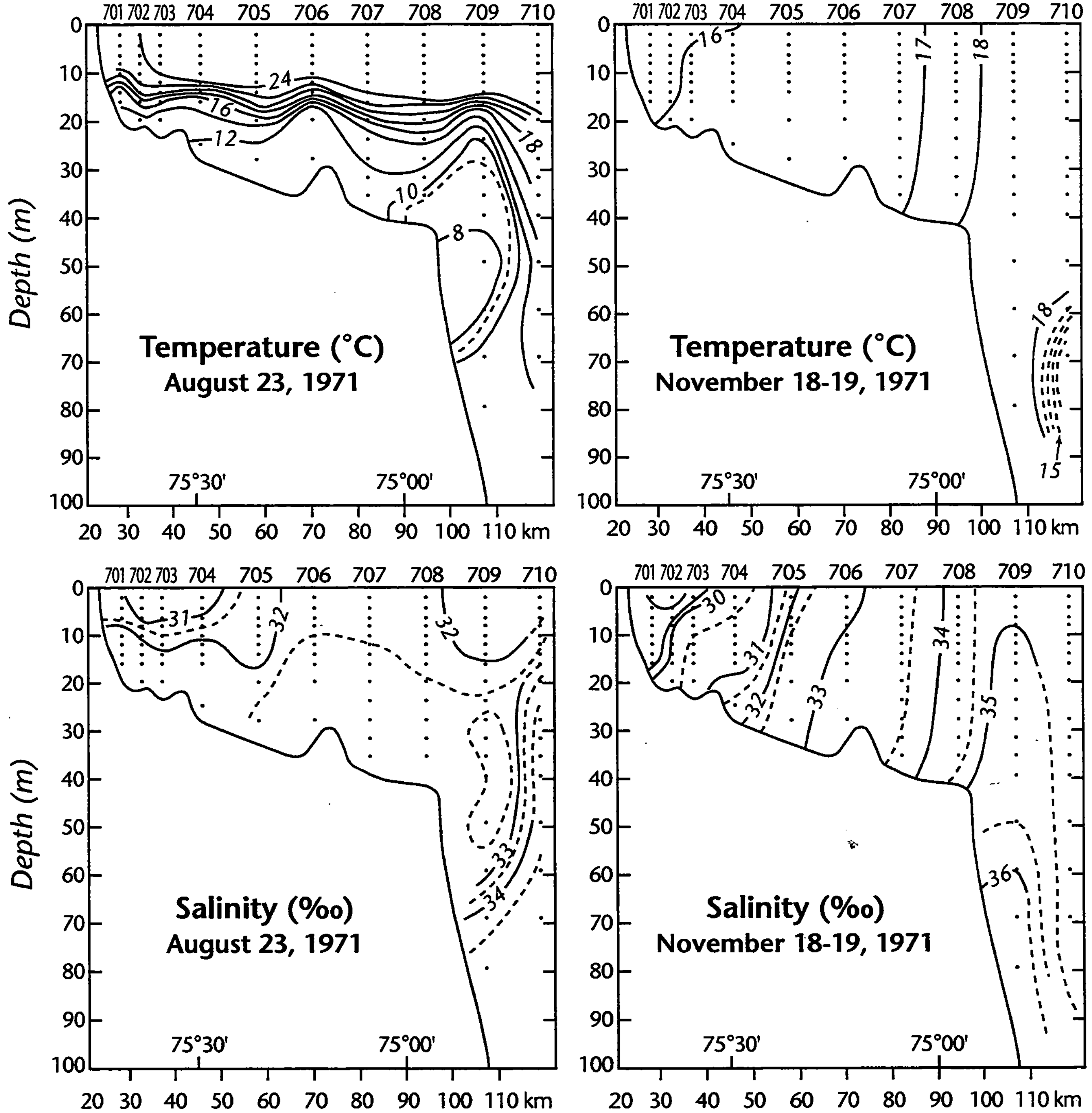


Figure 2a: Temperature/Salinity transects near Duck, NC (Boicourt, 1973) showing the temperature and salinity structure out to 120 km offshore.

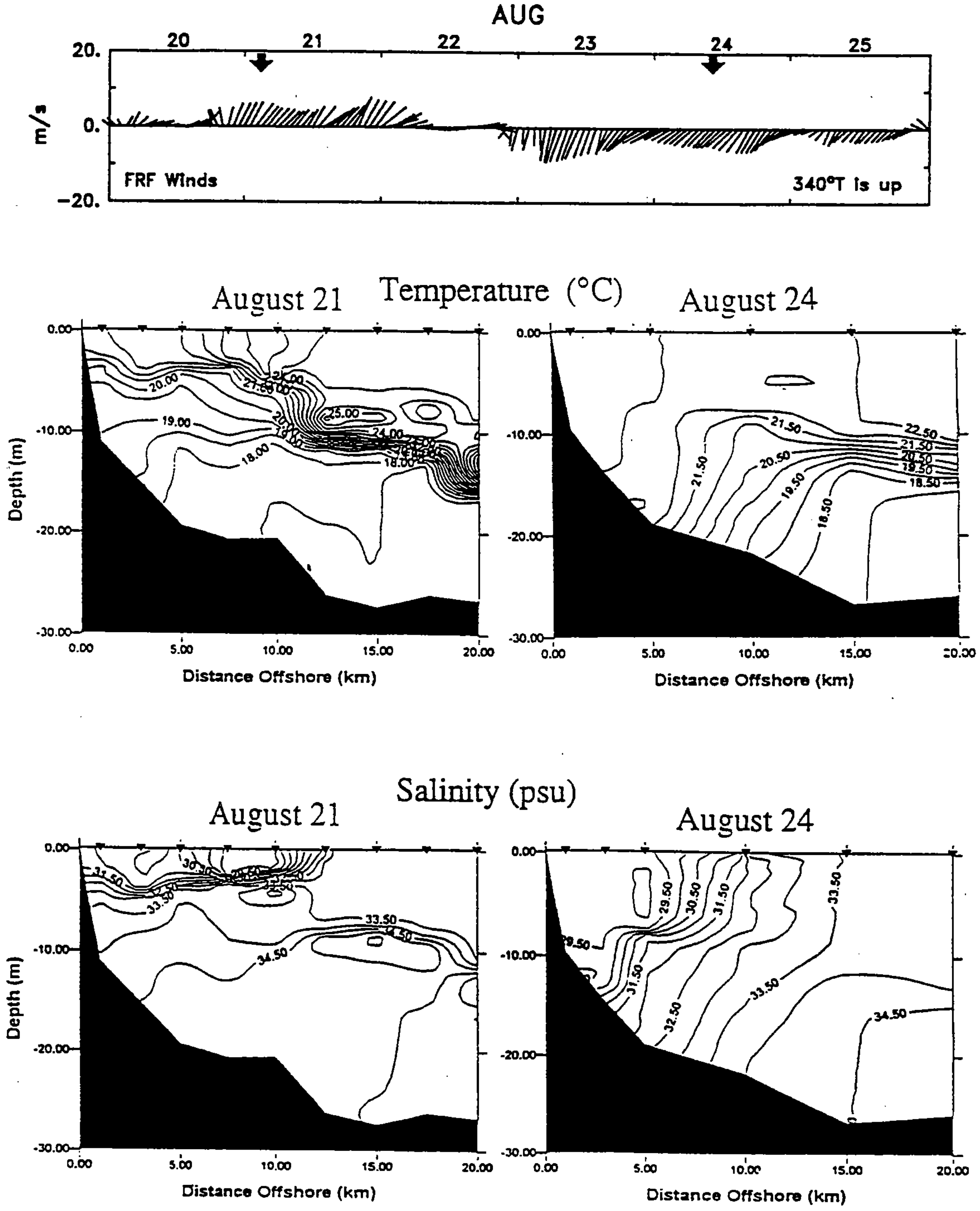


Figure 2b: Temperature/Salinity sections out to 20 km along the central line from shipboard surveys taken on August 21 (lefthand figures) and August 24 (righthand figures). For reference, a time series of wind vectors from the FRF pier is shown at the top. A vector toward the top of the page indicates alongshore winds toward 340°T. Bold arrows indicate when sections were taken.

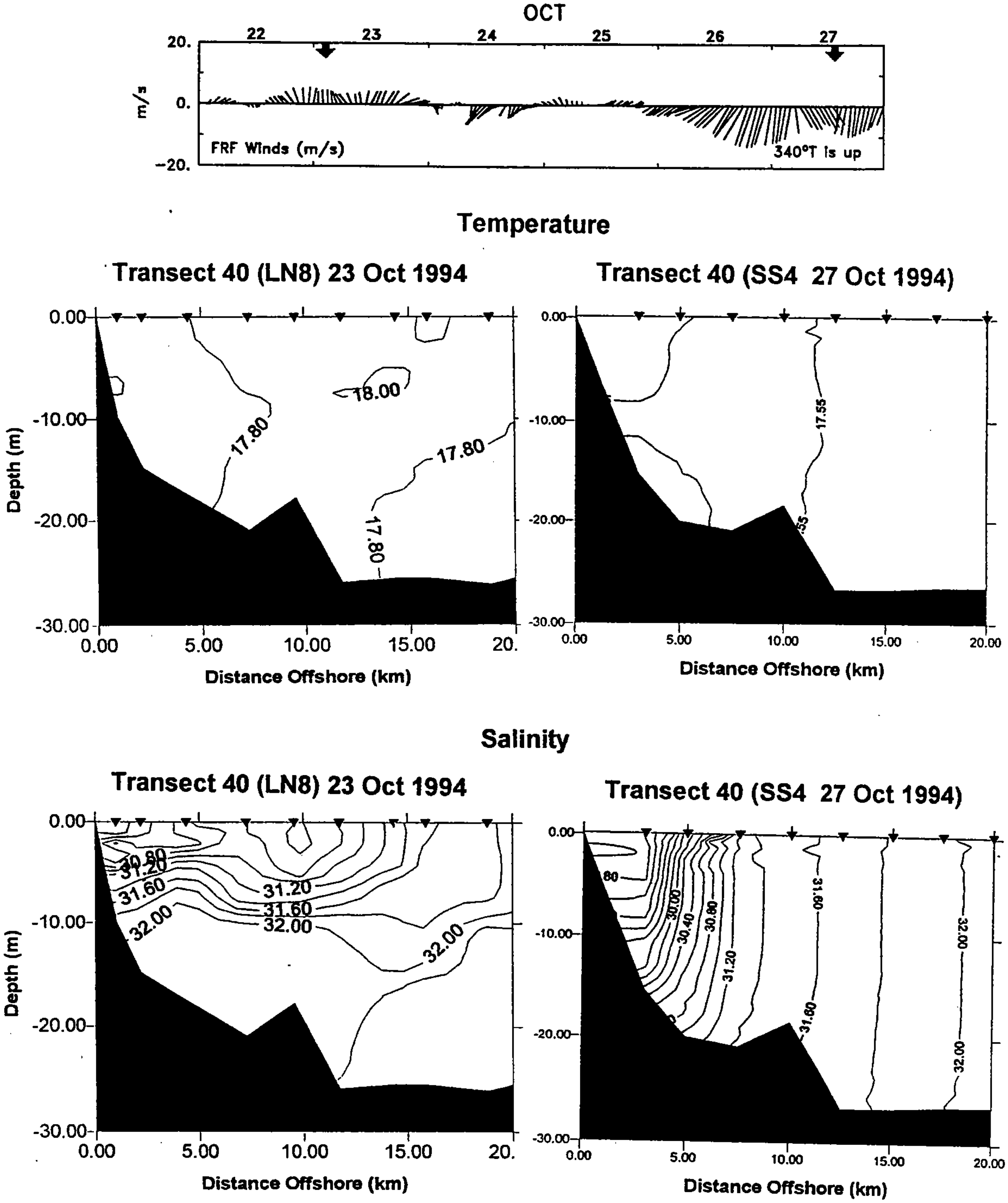


Figure 2c: Temperature/Salinity sections out to 20 km along the central line from shipboard surveys taken on October 23 and October 27. For reference, a time series of wind vectors from the FRF pier is shown at the top. Bold arrows indicate when sections were taken.

- Section 3 gives a description of the four types of instruments used in the WHOI physical oceanography cross-shelf and along-shelf arrays including accuracy specifications.
- Section 4 describes general processing of the data including the coordinate system used, and a description of the meteorological and oceanic data analysis procedures. This includes comparisons made with other instruments collecting the same type of data to detect any systematic errors.
- Section 5 contains a description of the time series data presentation.
- The basic statistics of the hourly-averaged data covering the entire time period for each record are presented in Section 6.
- Time series plots for each instrument are presented in Section 9. This includes the coastal and moored meteorological measurements, moored velocity measurements, and the temperature, conductivity, and salinity measurements.

2. Description of the Inner-Shelf Arrays

The focal point of the physical oceanographic component of the CoOP inner-shelf study was a cross-shelf three-element array of surface/subsurface mooring pairs measuring winds, currents, temperature, and conductivity (discussed in Section 2.1), and an along-shelf array of temperature, conductivity, and bottom pressure sensors mounted on jetted pipes along the shore and deeper sensors mounted on surface moorings (Section 2.2). A location map of the cross-shelf moored array sites is shown in Figure 3 along with the sea level and coastal wind stations and the along-shelf array. The U.S. Army Corps of Engineers CERC Field Research Facility (FRF) is located at Duck. Collaboration with FRF allowed access to supplementary data on winds, waves, inshore currents, and accurate bathymetric surveys. Listed in Table 2 are the locations of various sites, abbreviated station names, water depths, and positions.

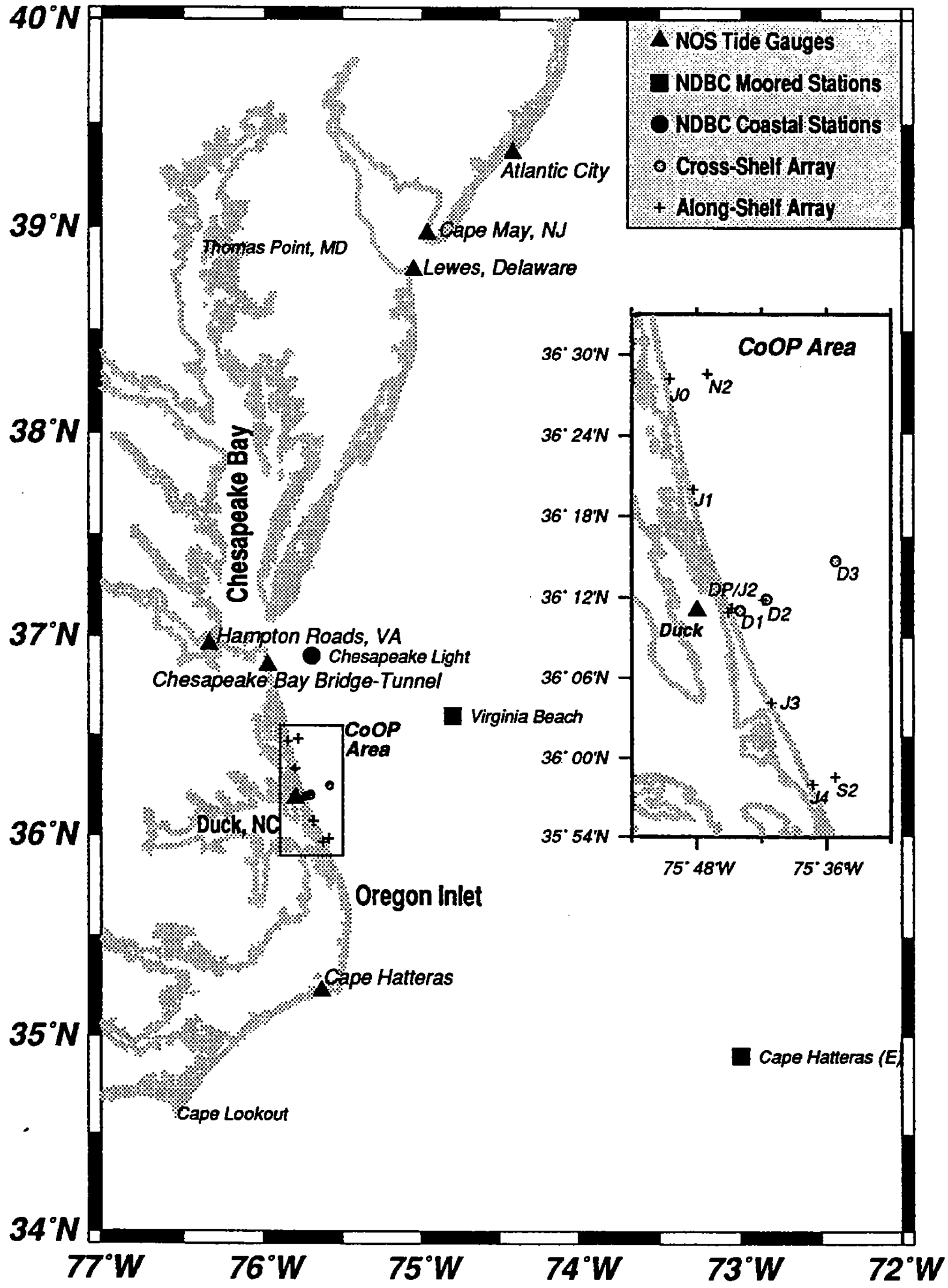


Figure 3: Location Map of the cross- and along-shelf array sites, sea level and coastal wind stations. The inset shows the cross-shelf mooring pairs deployed along the central-line, perpendicular to the coast near Duck (labelled D1, D2 and D3), and the bottom pressure sites (labelled J0, J1, J2, J3, and J4). The FRF pier (located at Duck) extends 500m offshore.

Table 2: CoOP Station Information

Station	Data Source	Abbreviation	Water Depth (m)	Location (°N/°W)	
Along-Shelf and Cross-Shelf Arrays:					
FRF Pier, Duck, NC	WHOI SeaCats	DP	8.0	36°10.91′	75°45.09′
13m Surface Mooring	WHOI 964	D1	13.0	36°11.00′	75°44.01′
13m Subsurface Mooring	WHOI 965	D1	13.5	36°11.03′	75°43.93′
20m Surface Mooring	WHOI 963	D2	21.0	36°11.88′	75°41.68′
20m Subsurface Mooring	WHOI 966	D2	19.5	36°11.85′	75°41.54′
25m Surface Mooring	WHOI 962	D3	26.0	36°14.64′	75°35.00′
25m Subsurface Mooring	WHOI 967	D3	25.5	36°14.70′	75°35.18′
Northern 20m TG Mooring	WHOI NTG	N2	19.4	36°28.54′	75°47.03′
Northern 20m SeaCat Mooring	WHOI NSC	N2	18.5	36°28.54′	75°46.95′
Central Line - 20m Site	WHOI CTG	D2	21.3	36°11.82′	75°41.85′
Southern 20m SeaCat Mooring	WHOI SSC	S2	20.5	35°58.57′	75°35.21′
Southern 20m TG Mooring	WHOI STG	S2	20.8	35°58.49′	75°35.23′
31.6km N of Central 6m Site	WHOI TG	J0	4.8	36°27.66′	75°50.53′
17.1km N of Central 6m Site	WHOI TG	J1	6.5	36°19.98′	75°48.30′
Central Line - 6m Site	WHOI TG	J2	6.1	36°11.24′	75°44.76′
16.9km S of Central 6m Site	WHOI TG	J3	4.2	36°02.79′	75°40.39′
25.9km S of Central 6m Site	WHOI TG	J4	5.1	35°58.43′	75°37.77′
National Data Buoy Center – Operational Moored Buoys and C-MAN Stations:					
Chesapeake Light	NDBC C-MAN	CL	–	36°54.00′	75°42.00′
Virginia Beach, VA	NDBC 44014	VA	–	36°36.00′	74°48.00′
East of Cape Hatteras	NDBC 41001	EH	–	34°54.00′	73°00.00′
Sea Level Data from Shore-Based Tide Gauges (TG):					
Sandy Hook, NJ	NOS TG	SH	–	40°28.00′	74°00.60′
Atlantic City, NJ	NOS TG	AC	–	39°21.30′	74°25.10′
Cape May, NJ	NOS TG	CM	–	38°58.10′	74°57.60′
Lewes, DE	NOS TG	LE	–	38°46.90′	75°07.20′
Hampton Roads, VA	NOS TG	HR	–	36°56.80′	76°19.80′
Chesapeake Bay Bridge-Tunnel	NOS TG	CB	–	36°58.10′	76°06.80′
Duck, NC	NOS TG	DU	–	36°11.00′	75°44.60′
Cape Hatteras, NC	NOS TG	CH	–	35°13.40′	75°38.10′
Duke Marine Lab, NC	NOS TG	ML	–	34°43.00′	76°40.40′
Wilmington, NC	NOS TG	WL	–	34°13.60′	77°57.20′

2.1 Cross-Shelf Array Design

The WHOI component of the cross-shelf moored array consists of six moorings (three surface/subsurface pairs) along the 13-m, 20-m, and 25-m isobaths. A schematic showing the planned layout of the individual moorings and tripods at the 13-m, 20-m, and 25-m sites is shown in Figure 4. Planned horizontal separation of various platforms at individual mooring sites was 100 m. (Placement of various platforms was largely dictated by deployment and recovery ship schedules.) Also shown in Figure 4 are additional measurements made by programs supported by the Office of Naval Research (ONR) and the Ocean Margins Program (OMP) funded by the Department of Energy (DOE).

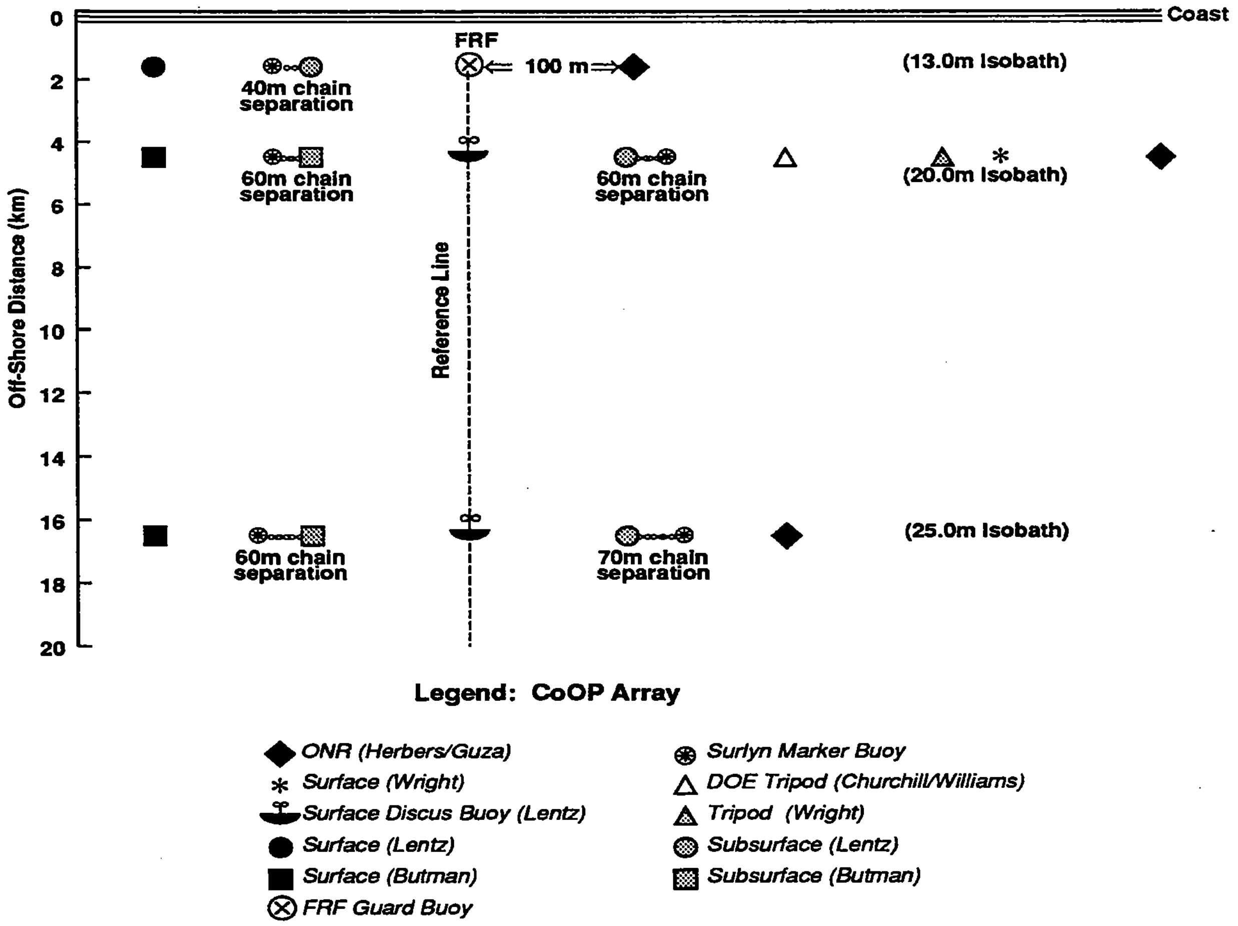


Figure 4: Planned layout of the individual moorings and tripods, and measurements made by programs supported by ONR and DOE.

A schematic of the complete CoOP inner-shelf cross-shelf array of instruments is shown in Figure 5. The three main cross-shelf mooring pairs of the WHOI physical oceanography component are labeled D1 (13 m), D2 (20 m), and D3 (25 m). The three surface/subsurface pairs supported EG&G Vector Measuring Current Meters (VMCMs), and SeaCats. At these 3 locations, current, temperature, and conductivity sensors spanned the water column with vertical spacings of about 3 m. This vertical sensor spacing was based on previous observations from a mooring deployed on the 30-m isobath as part of the Coastal Ocean Dynamics Experiment (CODE). A comparison of the cross-shelf currents made during CODE at five instrument depths suggested that there can be considerable variation in the cross-shelf flow over vertical scales of a few meters (Lentz, 1994). The mooring designs used at sites D1, D2 and D3 are described next.

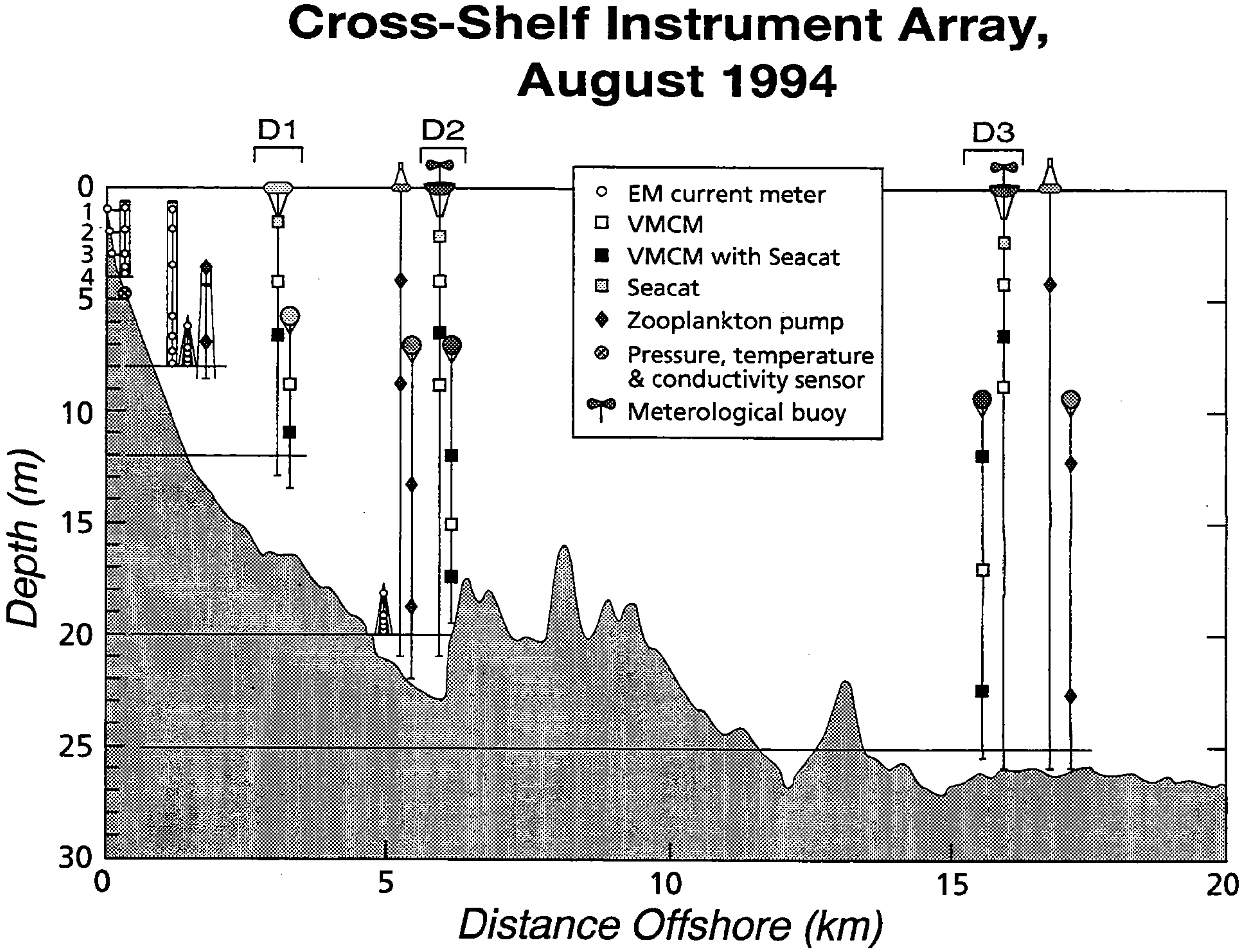
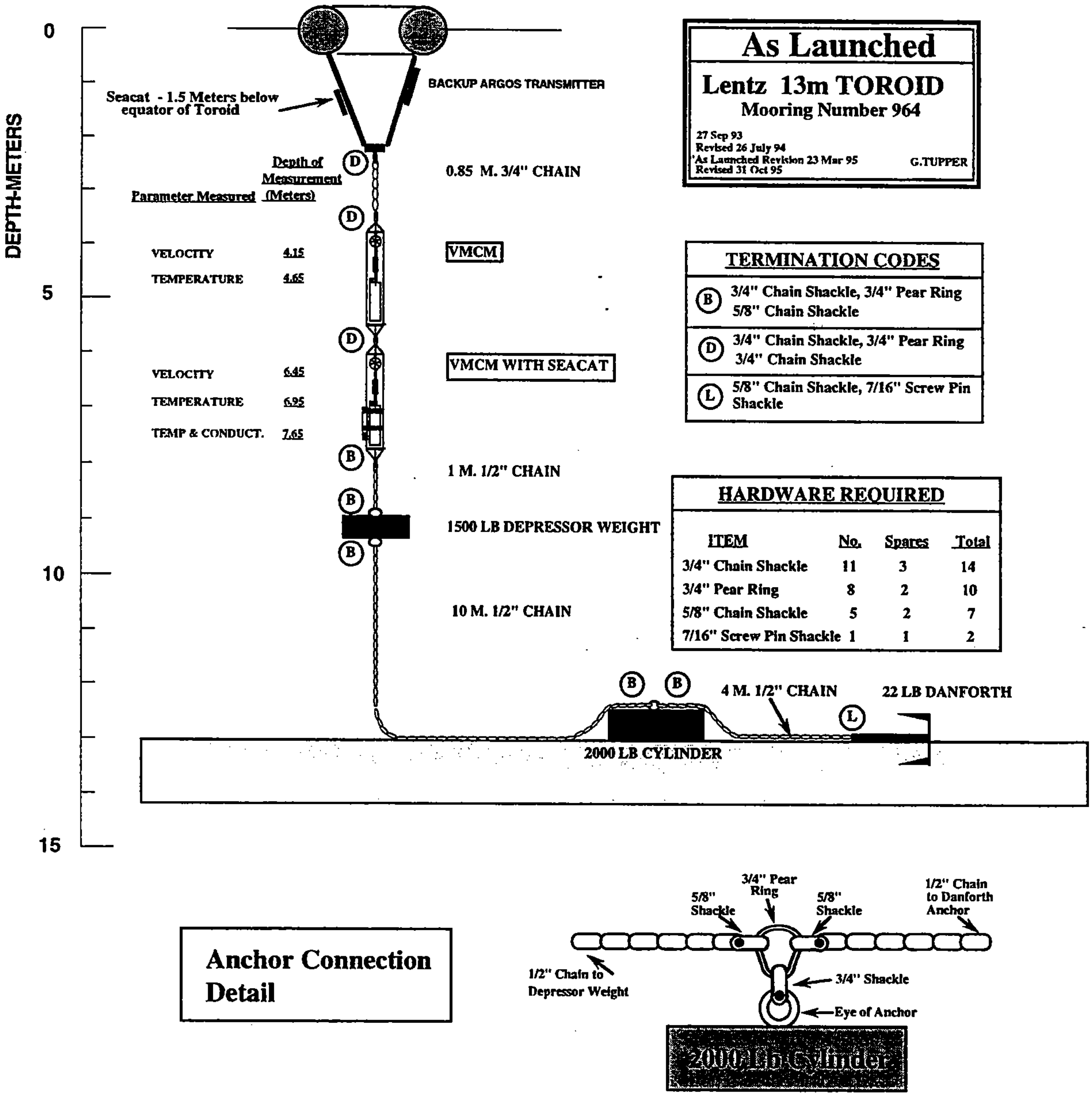


Figure 5: Schematic of the cross-shelf array of fixed instruments along the central line during August 1994. (EM = electromagnetic, VMCM = vector measuring current meter, SeaCat = self-contained temperature and conductivity recorder).

2.1.1 13-m Site

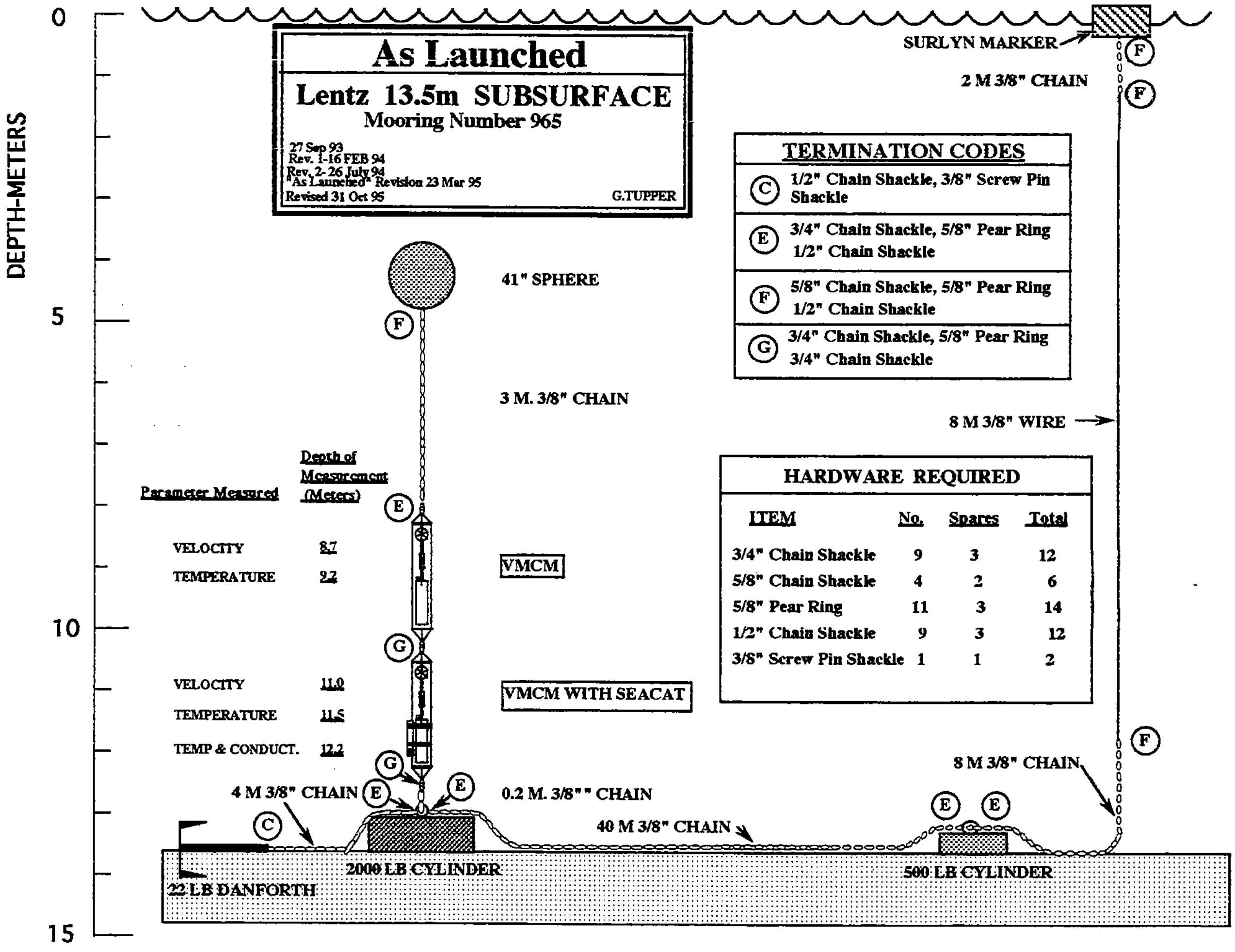
The 13-m surface mooring (Figure 6) used an SIO-designed 3-m toroid as the flotation and supported a SeaCat attached to the bridle of the toroid, and two standard VMCMs. A second SeaCat was mounted on the lowest VMCM. A 1500-pound depressor weight was attached to the mooring line about 1 m below the lowest VMCM to keep the instruments as vertical as possible.



ITEM	No.	Spares	Total
3/4" Chain Shackle	11	3	14
3/4" Pear Ring	8	2	10
5/8" Chain Shackle	5	2	7
7/16" Screw Pin Shackle	1	1	2

Figure 6: Surface mooring at site D1.

The subsurface mooring (Figure 7) at the 13-m site supported two VMCMs with a SeaCat mounted on the lowest VMCM. The mooring was tethered to a Surlyn marker float approximately 3 feet in diameter that was used to recover the mooring. See Section 2.3.1 for a summary of the data return at the D1 site and problems with the mooring design that led to hardware failure. The VMCM and SeaCat instruments are discussed in Sections 3.1 and 3.2, respectively.



Parameter Measured	Depth of Measurement (Meters)
VELOCITY	8.7
TEMPERATURE	9.2
VELOCITY	11.0
TEMPERATURE	11.5
TEMP & CONDUCT.	12.2

TERMINATION CODES

Ⓒ	1/2" Chain Shackle, 3/8" Screw Pin Shackle
Ⓔ	3/4" Chain Shackle, 5/8" Pear Ring 1/2" Chain Shackle
Ⓕ	5/8" Chain Shackle, 5/8" Pear Ring 1/2" Chain Shackle
Ⓖ	3/4" Chain Shackle, 5/8" Pear Ring 3/4" Chain Shackle

HARDWARE REQUIRED

ITEM	No.	Spares	Total
3/4" Chain Shackle	9	3	12
5/8" Chain Shackle	4	2	6
5/8" Pear Ring	11	3	14
1/2" Chain Shackle	9	3	12
3/8" Screw Pin Shackle	1	1	2

Figure 7: Sub-surface mooring at site D1.

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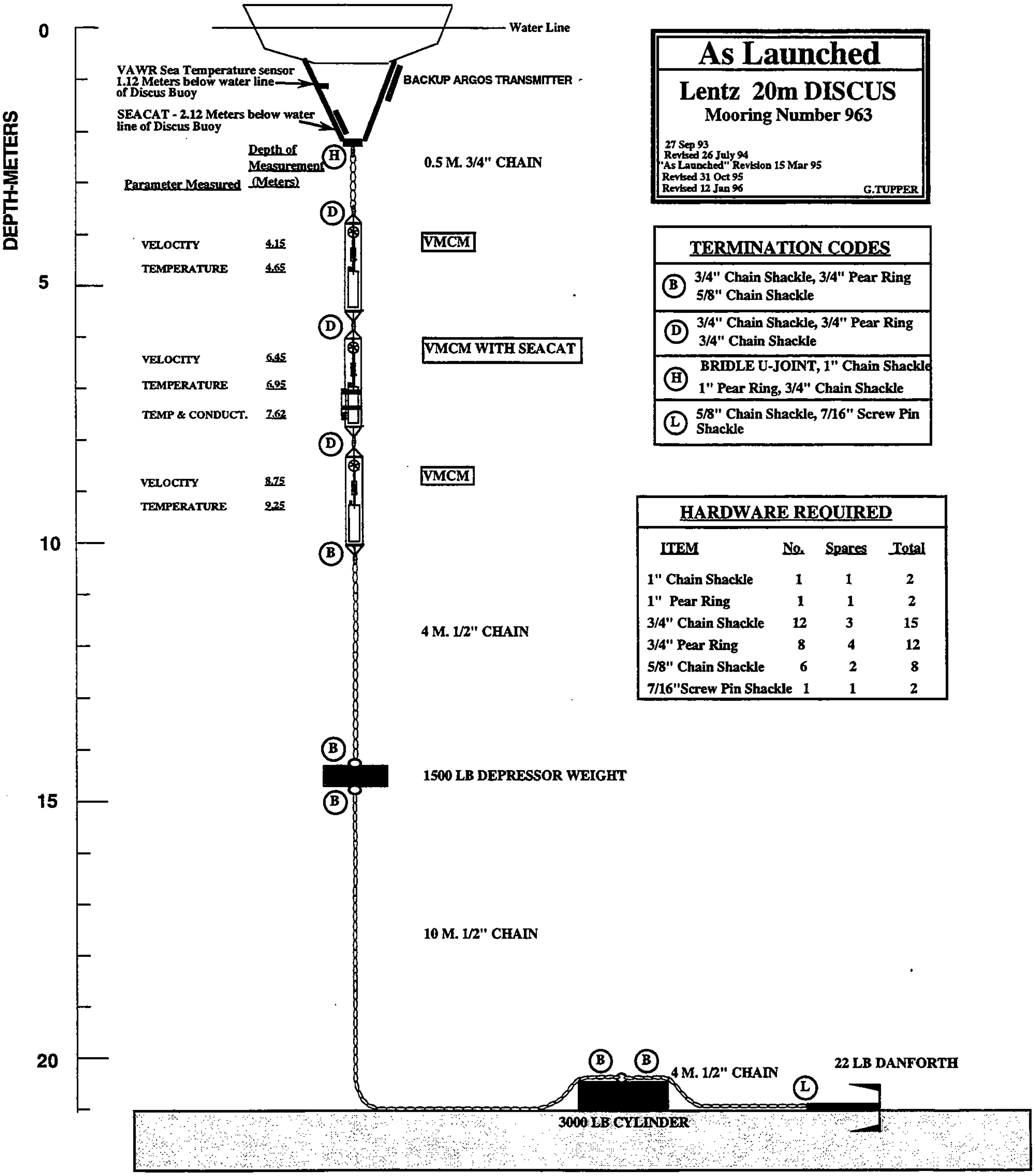
2.1.2 20-m Site

The 20-m and 25-m sites utilized a WHOI-designed 3-m-diameter discus buoy to support both meteorological and oceanographic instrumentation. The meteorological instrumentation included a Vector Averaging Wind Recorder (VAWR) equipped with a suite of sensors to measure wind speed and direction, air temperature, insolation (short-wave solar radiation), downward long-wave radiation, relative humidity and barometric pressure all at approximately 3 m above the sea surface, and water temperature at 1 m below the sea surface. A schematic of the discus buoy showing the configuration of the meteorological sensors mounted on the tower of the buoy is shown in Section 3.3.

The two discus moorings were set with depressor weights 4 m below the lowest VMCM to keep the mooring line vertical during strong currents. See Section 2.3.2 for a description of the mooring design which led to hardware failure for the surface moorings.

The meteorological and oceanographic sensors deployed at sites D1, D2, and D3 as part of the cross-shelf array are listed in Table 3. A description of each instrument type and sensor specifications are given in Section 3.

Beneath the 20-m discus buoy (Figure 8) was a water temperature sensor at 1.12 m below the surface, and a separate SeaCat at 2.12 m below the water line (both sensors attached to the bridle), and three VMCMs attached to the mooring line beneath the bridle. A SeaCat was mounted on the middle VMCM.



Parameter Measured	Depth of Measurement (Meters)
VELOCITY	4.15
TEMPERATURE	4.65
VELOCITY	6.45
TEMPERATURE	6.95
TEMP & CONDUCT.	7.62
VELOCITY	8.75
TEMPERATURE	9.25

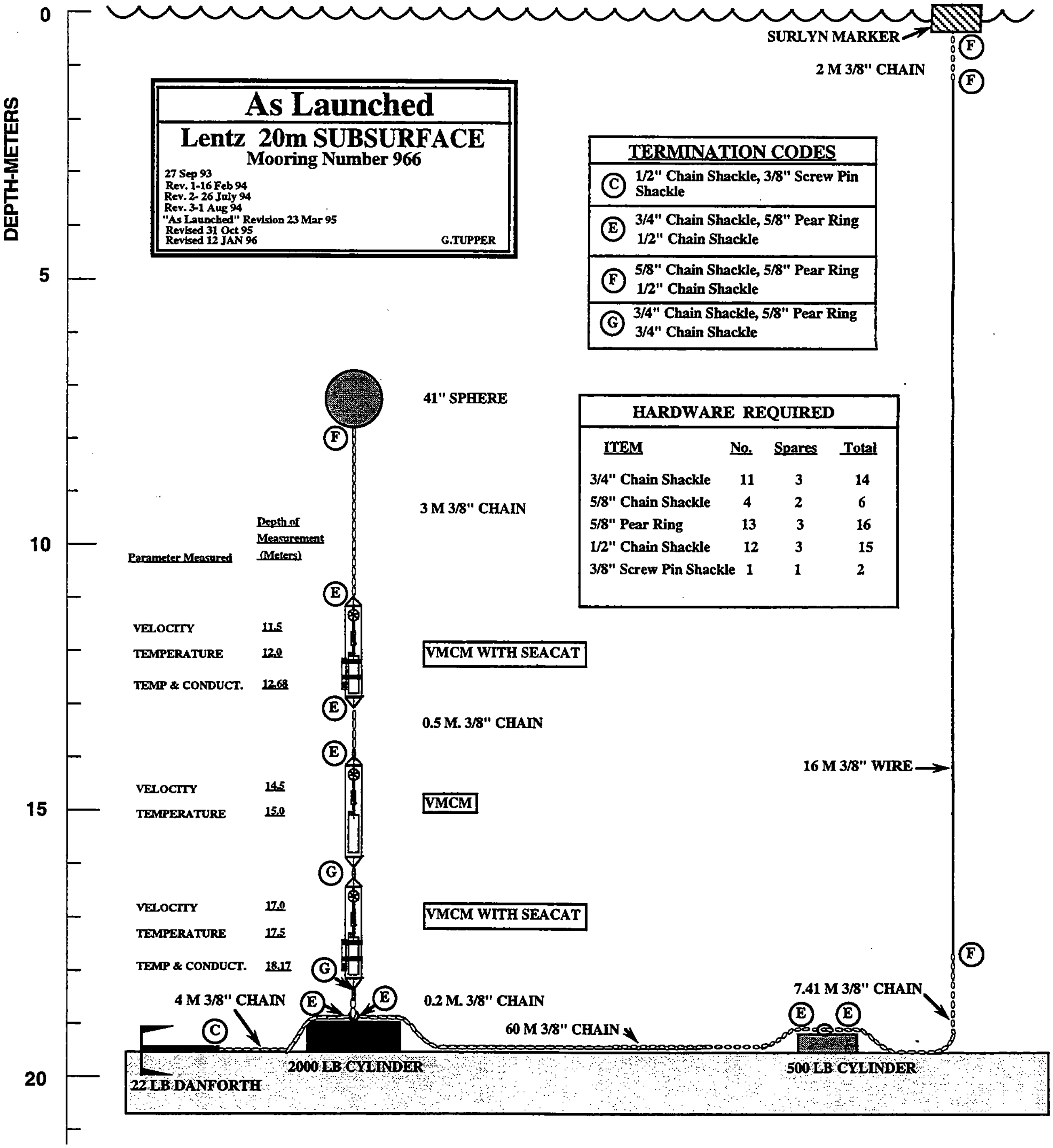
TERMINATION CODES	
Ⓑ	3/4" Chain Shackle, 3/4" Pear Ring 5/8" Chain Shackle
Ⓓ	3/4" Chain Shackle, 3/4" Pear Ring 3/4" Chain Shackle
Ⓗ	BRIDLE U-JOINT, 1" Chain Shackle 1" Pear Ring, 3/4" Chain Shackle
Ⓛ	5/8" Chain Shackle, 7/16" Screw Pin Shackle

HARDWARE REQUIRED

ITEM	No.	Spares	Total
1" Chain Shackle	1	1	2
1" Pear Ring	1	1	2
3/4" Chain Shackle	12	3	15
3/4" Pear Ring	8	4	12
5/8" Chain Shackle	6	2	8
7/16"Screw Pin Shackle	1	1	2

Figure 8: Surface mooring at site D2.

The 20-m subsurface mooring (Figure 9) supported three VMCMs and two SeaCats. The SeaCats were mounted on the shallowest and deepest VMCMs on the subsurface mooring. The mooring was tethered to a Surlyn marker float approximately 3 feet in diameter which was used to recover the mooring. See Section 2.3.2 for a summary of the data return at the D2 site.



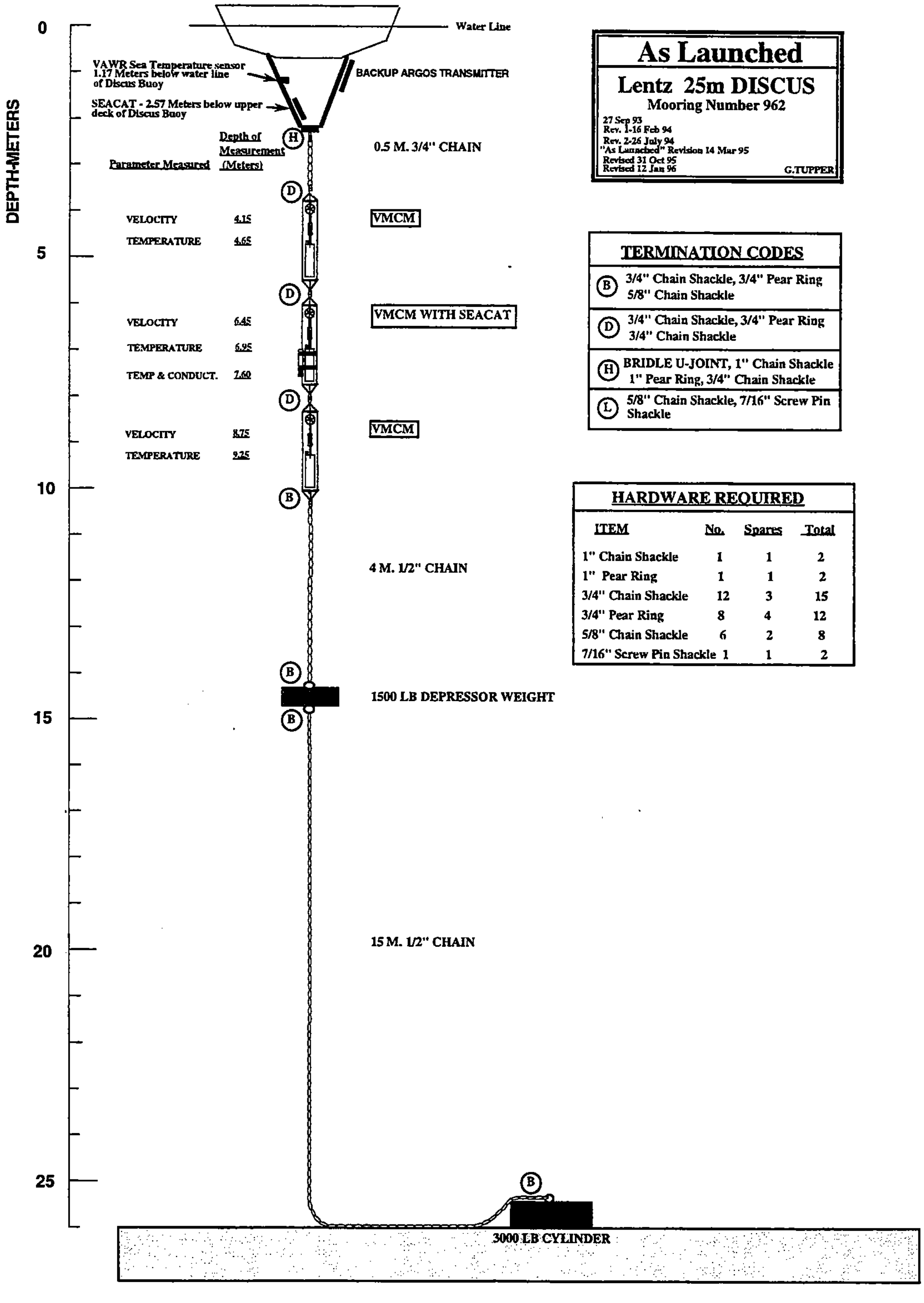
HARDWARE REQUIRED

ITEM	No.	Spares	Total
3/4" Chain Shackle	11	3	14
5/8" Chain Shackle	4	2	6
5/8" Pear Ring	13	3	16
1/2" Chain Shackle	12	3	15
3/8" Screw Pin Shackle	1	1	2

Figure 9: Sub-surface mooring at site D2.

2.1.3 25-m Site

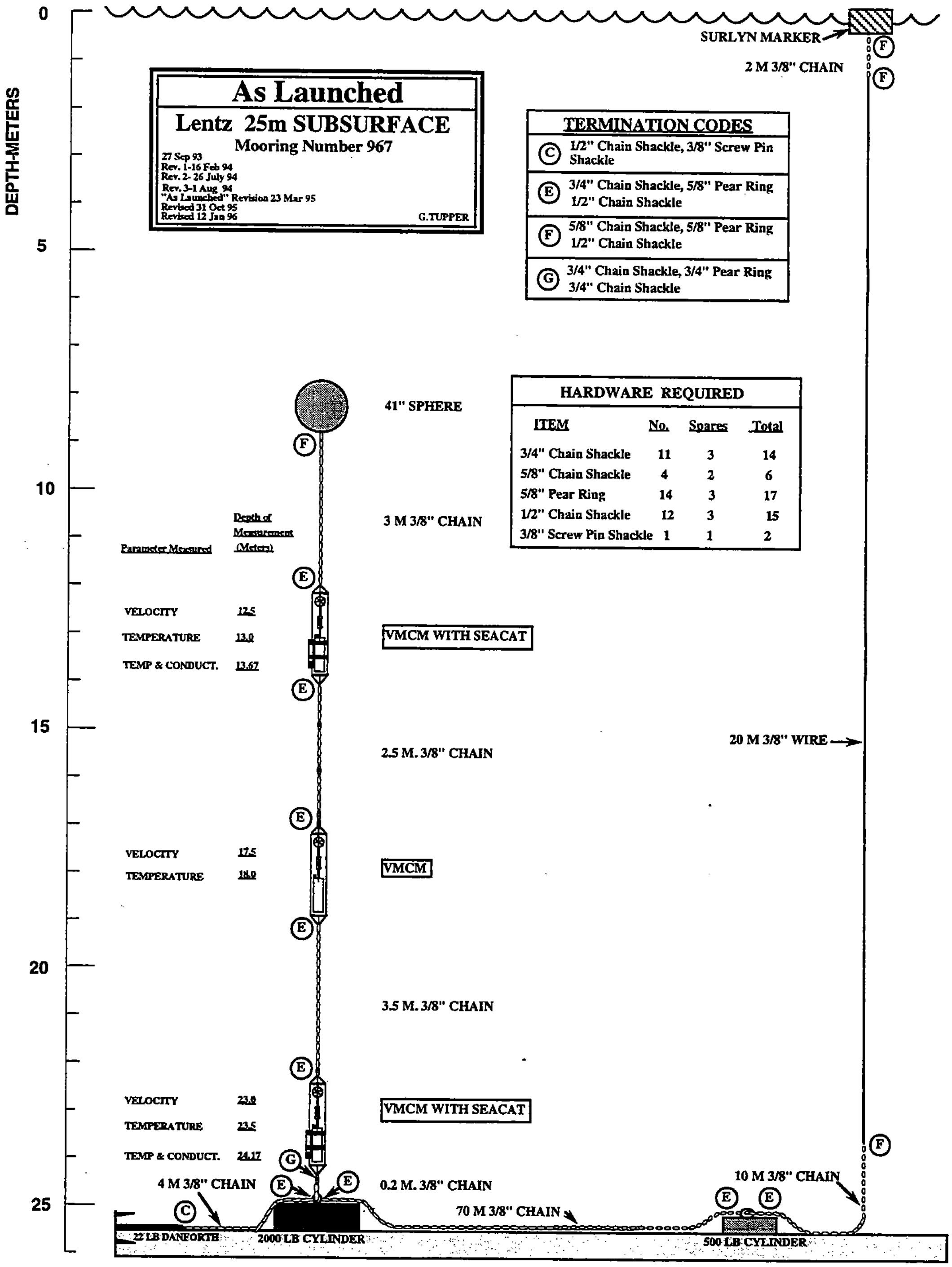
The 25-m surface mooring (Figure 10) had the same configuration as the 20-m surface mooring. Mounted on the bridle was a water temperature sensor at 1.17 m and a SeaCat at 2.17 m below the water line. Below the bridle were three VMCMs with a SeaCat mounted on the middle VMCM.



ITEM	No.	Spares	Total
1" Chain Shackle	1	1	2
1" Pear Ring	1	1	2
3/4" Chain Shackle	12	3	15
3/4" Pear Ring	8	4	12
5/8" Chain Shackle	6	2	8
7/16" Screw Pin Shackle	1	1	2

Figure 10: Surface mooring at site D3.

The 25-m subsurface mooring (Figure 11) supported three VMCMs and two SeaCats. The SeaCats were mounted on the shallowest, and deepest VMCMs on the subsurface mooring. The mooring was tethered to a Surlyn marker float approximately 3 feet in diameter which was used to recover the mooring. See Section 2.3.3 for a summary of the data return at the D3 site.



As Launched

Lentz 25m SUBSURFACE

Mooring Number 967

27 Sep 93
Rev. 1-16 Feb 94
Rev. 2- 26 July 94
Rev. 3-1 Aug 94
"As Launched" Revision 23 Mar 95
Revised 31 Oct 95
Revised 12 Jan 96

G.TUPPER

TERMINATION CODES
Ⓒ 1/2" Chain Shackle, 3/8" Screw Pin Shackle
Ⓔ 3/4" Chain Shackle, 5/8" Pear Ring 1/2" Chain Shackle
Ⓕ 5/8" Chain Shackle, 5/8" Pear Ring 1/2" Chain Shackle
Ⓖ 3/4" Chain Shackle, 3/4" Pear Ring 3/4" Chain Shackle

HARDWARE REQUIRED

ITEM	No.	Spares	Total
3/4" Chain Shackle	11	3	14
5/8" Chain Shackle	4	2	6
5/8" Pear Ring	14	3	17
1/2" Chain Shackle	12	3	15
3/8" Screw Pin Shackle	1	1	2

Parameter Measured	Depth of Measurement (Meters)
VELOCITY	12.5
TEMPERATURE	13.0
TEMP & CONDUCT.	13.67
VELOCITY	17.5
TEMPERATURE	18.0
VELOCITY	23.0
TEMPERATURE	23.5
TEMP & CONDUCT.	24.17

Figure 11: Sub-surface mooring at site D3.

Table 3: Cross-Shelf Moored Array - Instrumentation Summary

Instrument Type-#	Variable Measured	Sensor Depth (m)	Record Rate (min)	Comments
13.0m Surface Mooring Site (D1)				**36°11.00′N 75°44.01′W**
SeaCat-142	cd,wt	1.50	4.0	
VMCM-035	vel	4.15	4.0	
T-314	wt	4.65	4.0	
VMCM-013	vel	6.45	4.0	
T-134	wt	6.95	4.0	
SeaCat-141	cd,wt	7.65	4.0	
13.5m Subsurface Mooring Site (D1)				**36°11.03′N 75°43.93′W**
VMCM-041	vel	8.70	4.0	
T-243	wt	9.20	4.0	
VMCM-012	vel	11.00	4.0	
T-054	wt	11.50	4.0	
SeaCat-991	cd,wt	12.20	4.0	
21.0m Surface Mooring Site (D2)				**36°11.88′N 75°41.68′W**
VAWR-712	ws	-3.37	7.5	Gap, Note 1
	wd	-3.09	7.5	
T-5862	at	-2.71	7.5	
S25417	sw	-3.42	7.5	
L27027	lw	-3.42	7.5	
V-023-001	rh	-2.71	7.5	
40411	ap	-2.78	7.5	
T-5510	wt	1.12	7.5	
SeaCat-143	cd, wt	2.12	4.0	
VMCM-022	vel	4.15	4.0	
T-334	wt	4.65	4.0	
VMCM-010	vel	6.45	4.0	
T-067	wt	6.95	4.0	Short, Note 2
SeaCat-995	cd,wt	7.62	4.0	
VMCM-002	vel	8.75	4.0	
T-313	wt	9.25	4.0	
19.5m Subsurface Mooring Site (D2)				**36°11.85′N 75°41.54′W**
VMCM-026	vel	11.50	4.0	Intermittent, Note 3
T-131	wt	12.00	4.0	
SeaCat-72	cd,wt	12.68	4.0	
VMCM-032	vel	14.50	4.0	
T-061	wt	15.00	4.0	
VMCM-031	vel	17.00	4.0	
T-158	wt	17.50	4.0	
SeaCat-146	cd,t	18.17	4.0	

Table 3: Cross-Shelf Moored Array - Instrumentation Summary (continued)

Instrument Type-#	Variable Measured	Sensor Depth (m)	Record Rate (min)	Comments
26.0m Surface Mooring Site (D3)				**36°14.64'N 75°35.00'W**
VAWR-713	ws	-3.35	7.5	no data
	wd	-3.07	7.5	no data
T-5863	at	-2.71	7.5	no data
S26195	sw	-3.42	7.5	no data
L27237	lw	-3.42	7.5	no data
V-025-001	rh	-2.71	7.5	no data
44149	ap	-2.78	7.5	no data
T-5565	wt	1.17	7.5	no data
SeaCat-927	cd,wt	2.17	4.0	2 gaps, Note 4
VMCM-17/36/17	vel	4.15	4.0	"
T-166/856	wt	4.65	4.0	"
VMCM-001	vel	6.45	4.0	"
T-130	wt	6.95	4.0	"
SeaCat-928	cd,wt	7.60	4.0	"
VMCM-019	vel	8.75	4.0	"
T-112	wt	9.25	4.0	"
25.5m Subsurface Mooring Site (D3)				**36°14.70'N 75°35.18'W**
VMCM-023	vel	12.50	4.0	
T-769	wt	13.00	4.0	
SeaCat-144	cd, wt	13.67	4.0	
VMCM-028	vel	17.50	4.0	
T-076	wt	18.00	4.0	
VMCM-020	vel	23.00	4.0	
T-032	wt	23.50	4.0	
SeaCat-929	cd, wt	24.17	4.0	Gap, Note 5

ap: Atmospheric Pressure
cd: Conductivity
lw: Long-wave Radiation
at: Air Temperature
rh: Relative Humidity
ws,dr: Wind Speed, Direction
br: Barometric Pressure
wt: Water Temperature
sw: Short-wave Radiation

VMCM: standard vector measuring current meter - velocity (vel) and wt
VAWR: vector averaging wind recorder standard met package.

Note 1: The surface mooring at the 20-m site came ashore September 4th and was redeployed on October 4th resulting in a one month gap in the data for all instruments mounted on the surface mooring.

Note 2: Second deployment, no temperature (sensor failure).

Note 3: Intermittent problem with velocity measurement at 11.5 m. See Section 2.3.2 for discussion.

Note 4: The surface mooring at site D3 was redeployed twice. The first occurred early September when the VAWR failed to transmit data. The top current meter was damaged during recovery operations and replaced with a spare, resulting in a 7 hour gap in the data. The second redeployment was to replace mooring hardware. The top current meter was damaged during recovery operations and replaced with a spare, resulting in a 3 -hour gap in the data.

Note 5: Conductivity is bad between October 12 @1336Z and October 20 @0056Z, resulting in a 7.5-day gap.

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2.2 Along-Shelf Array Design

The along-shelf array consisted of eight SeaGauges and four SeaCats. The objective was to make estimates of the along-shelf pressure gradient and to monitor along-shelf variations in the temperature/salinity fields. Sections 3.2 and 3.4 contain descriptions of the SeaCats and SeaGauges, respectively, including sensor specifications. A summary of the SeaCats and SeaGauges deployed as part of the along-shelf array is listed in Table 4.

Two (out of 4) SeaCats were mounted on one of the FRF pier pilings (Site DP) at 4 and 7 m below the surface (the FRF pier extends 500 m offshore). The remaining two SeaCats were mounted on independent moorings at sites N2 and S2. The SeaCat moorings consisted of a Surlyn guard buoy with the instrument mounted on the bridle at 1 m depth (Figure 12).

Five (out of 8) SeaGauges were mounted on jetted pipes along the 6-m isobath[1] with approximately 15-km sensor separation, north (sites J0, J1), south (sites J3, J4), and at the central mooring line (site J2). The remaining three SeaGauges were located along the 20-m isobath with along-shelf separations of approximately 30 km, north at site N2, south at site S2, and at the central mooring line at site D2. The SeaGauge moorings consisted of a Surlyn marker float approximately 3 feet in diameter, with the instrument mounted on a 1,000-lb anchor (Figure 13).

A schematic of the along-shelf bottom pressure array is shown in Figure 14. The along-shelf sensor separation is based on the bottom pressure sensor accuracy (about 1 mb) and a previous analysis of sea level data in this region suggesting along-shelf pressure gradient fluctuations of around 3×10^{-6} m/s^2 (Masse, 1988). This suggests a sensor separation of 30 km. The 15-km sensor separation along the 6-m isobath detected shorter scale variations in the along-shelf pressure gradient not resolved by the widely spaced sea level stations used by Masse, thus allowing characterization of the near-bottom along-shelf variability in the temperature/salinity field on scales of 15 km.

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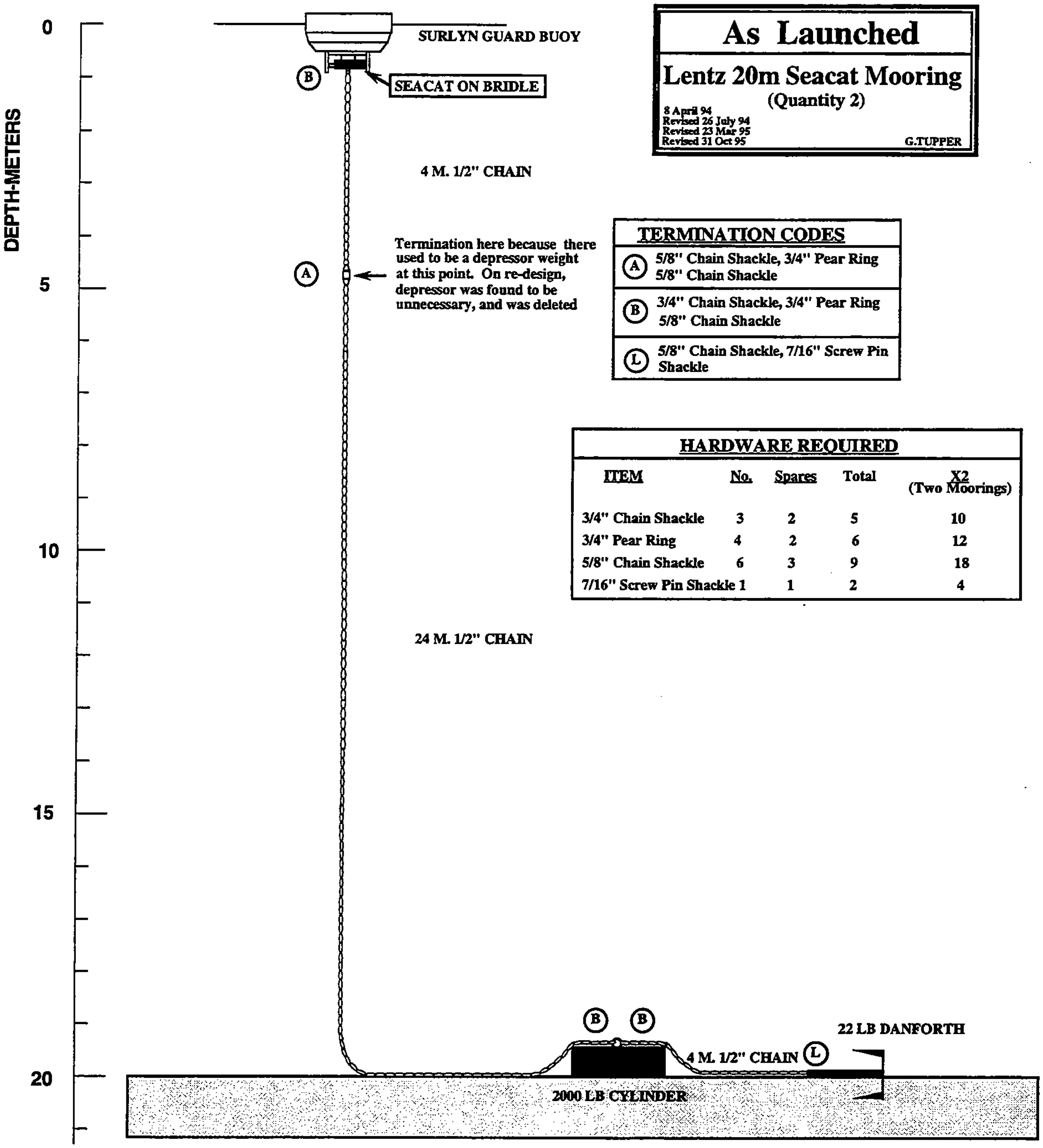
[1] The actual water depths of the SeaGauges jetted into the bottom of the ocean varied between 4.2 m and 6.5 m due to choices of location and tidal variation.



As Launched

Lentz 20m Seacat Mooring
(Quantity 2)
8 April 94
Revised 26 July 94
Revised 23 Mar 95
Revised 31 Oct 95
G.TUPPER

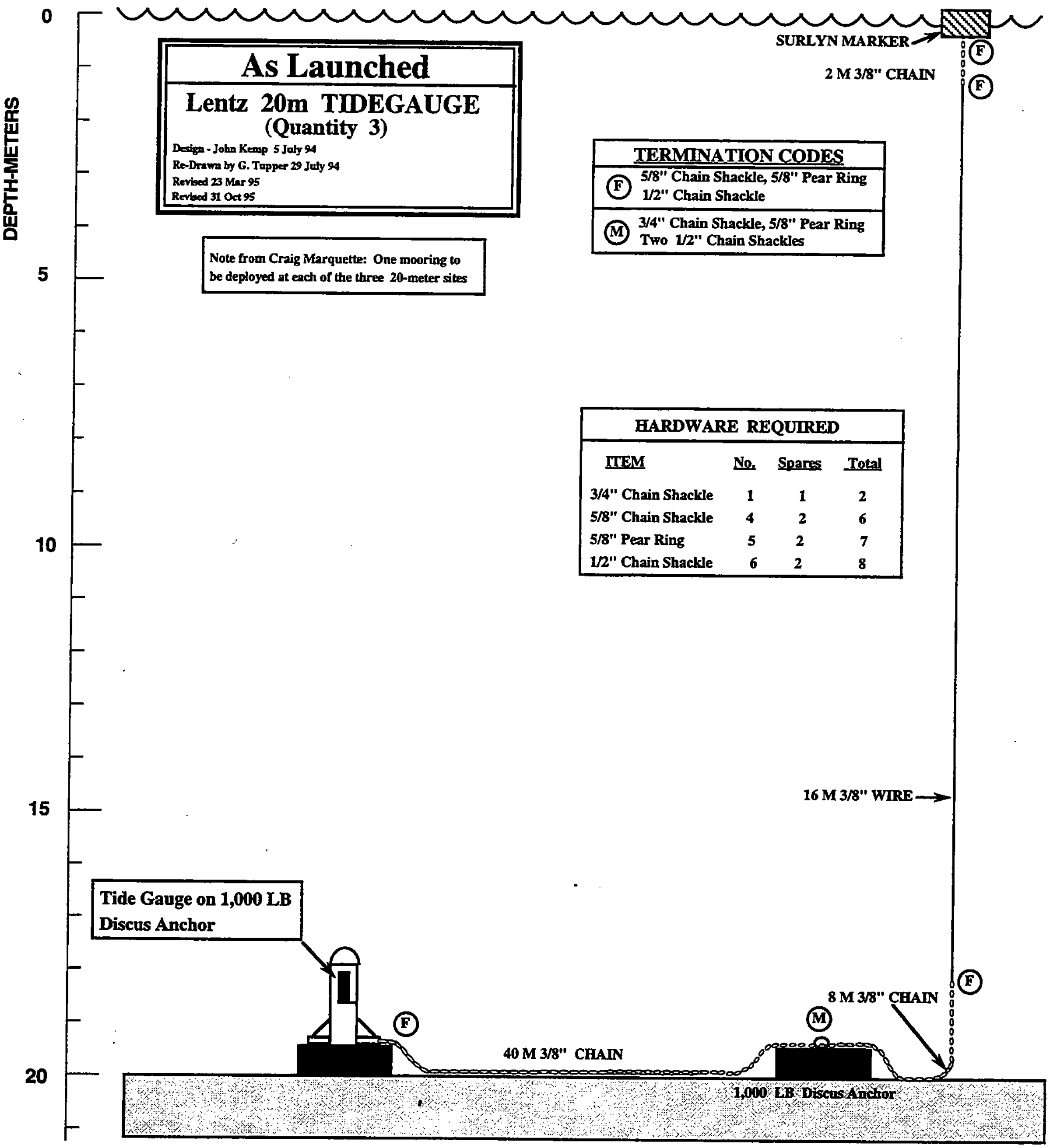
TERMINATION CODES

Code	
Ⓐ	5/8" Chain Shackle, 3/4" Pear Ring 5/8" Chain Shackle
Ⓑ	3/4" Chain Shackle, 3/4" Pear Ring 5/8" Chain Shackle
Ⓛ	5/8" Chain Shackle, 7/16" Screw Pin Shackle

HARDWARE REQUIRED

ITEM	No.	Spares	Total	X2 (Two Moorings)
3/4" Chain Shackle	3	2	5	10
3/4" Pear Ring	4	2	6	12
5/8" Chain Shackle	6	3	9	18
7/16" Screw Pin Shackle	1	1	2	4

Figure 12: SeaCat mooring at sites N2, and S2. The SeaCat mooring consisted of a Surlyn guard buoy with the instrument mounted on the bridle at 1-m depth.



ITEM	No.	Spares	Total
3/4" Chain Shackle	1	1	2
5/8" Chain Shackle	4	2	6
5/8" Pear Ring	5	2	7
1/2" Chain Shackle	6	2	8

Figure 13: SeaGauge mooring at sites N2, D2, and S2. The SeaGauge moorings consisted of a Surlyn marker float approximately 3 feet in diameter, with the instrument mounted on a 1,000-lb anchor.

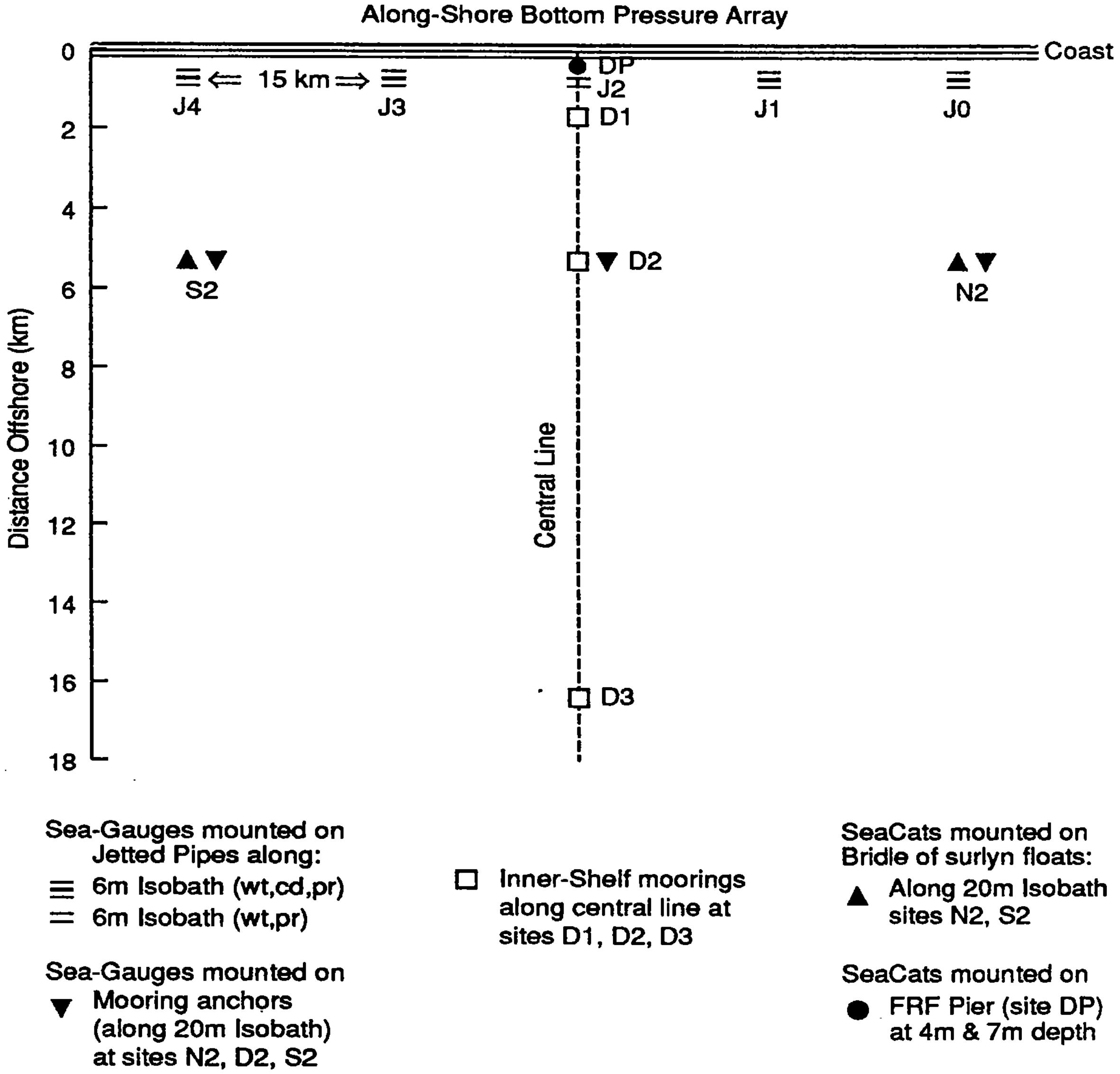


Figure 14: Schematic of the along-shelf array. Two SeaCats were mounted on the FRF pier (Site DP) at 4 and 7 m below the surface. The remaining two SeaCats were mounted on independent moorings at sites N2 and S2. Five SeaGauges were mounted on jetted pipes along the 6-m isobath with a 15-km sensor separation, north (sites J0, J1), south (sites J3, J4), and at the central mooring line (site J2). The remaining three SeaGauges were located along the 20-m isobath with along-shelf separations of 30 km, north at site N2, south at site S2, and at the central mooring line at site D2.

Table 4: Along-Shelf Array - Instrumentation Summary

Station (Mooring Type)	Water Depth (m)	Location °N/ °W	Instrument Type-#	Variable Measured	Sensor Depth (m)	Record Rate (min)	Comments
FRF Pier (DP)							
Duck, NC	8.0	36°10.91′	SeaCat-68	wt,cd	4.0	4.0	
DP		75°45.09′	SeaCat-73	wt,cd	7.0	4.0	Note 1
Jetted Pipes at sites J0, J1, J2, J3, J4							
J0	4.8	36°28.20′ 75°50.50′	SeaGauge #44	wt,cd,pr	4.3	4.0	
J1	6.5	36°19.98′ 75°48.30′	SeaGauge #41	wt,cd,pr	5.9	4.0	
J2	6.1	36°11.24′ 75°44.76′	SeaGauge #47	wt,pr	5.6	4.0	
J3	4.2	36°04.20′ 75°41.10′	SeaGauge #43	wt,cd,pr	3.7	4.0	Note 2
J4	5.1	35°58.00′ 75°37.30′	SeaGauge #49	wt,cd,pr	4.6	4.0	Note 3
SeaCats(SC) and Sea-Gauges(TG) at sites N2, D2 and S2							
N2 Surlyn Guard SC on Bridle	18.5 NSC	36°28.54′ 75°46.95′	SeaCat-71	wt,cd	0.67	4.0	
N2 Surlyn Marker TG on anchor	19.4 NTG	36°28.54′ 75°47.03′	SeaGauge #45	wt,cd,pr	18.6	4.0	
D2 Surlyn Marker TG on anchor	21.3 CTG	36°11.82′ 75°41.85′	SeaGauge #48	wt,pr	20.7	4.0	
S2 Surlyn Guard SC on Bridle	20.5 SSC	35°58.57′ 75°35.21′	SeaCat-70	wt,cd	0.63	4.0	
S2 Surlyn Marker TG on anchor	20.8 STG	35°58.49′ 75°35.23′	SeaGauge #46	wt,cd,pr	20.2	4.0	Note 4

pr: Pressure
NSC: Northern SC mooring
NTG: Northern TG mooring

wt: Water Temperature
CTG: Central TG mooring

cd: Conductivity
SSC: Southern SC mooring
STG: Southern TG mooring

Note 1: Conductivity looks pretty bad and is only useful qualitatitively.

Note 2: The sensor got buried sometime after October 17th causing the temperature data to be low-pass filtered. The conductivity sensor got buried around this time and is clearly bad. The conductivity data were truncated October 17th.

Note 3: The conductivity time series was truncated October 17th. The conductivity sensor may have lasted slightly longer, but the exact time it started to foul is not clear.

Note 4: The conductivity time series is questionable.

2.3 Data Return

All of the instrumentation was deployed in late July and early August of 1994. Most of the instruments were deployed on 11 moorings, and five instruments were mounted on jetted pipes along the shore. See Sections 2.1 and 2.2 for a complete description of the cross-shelf and along-shelf array designs. There were two major problems affecting the data return: 1) surface mooring failure, and 2) fouling of the near bottom conductivity cell. Despite problems with the surface mooring design which led to hardware failure (discussed below), we ended up with a fairly complete data set.

2.3.1 13-m Site

There was some concern about the 13-m surface (toroid) mooring as it had the same mooring configuration as the 20-m discus mooring that broke loose during the Labor Day weekend storm, see Section 2.3.2 below for details. During the October cruise, when the 20-m surface mooring was redeployed, divers inspected the hardware on the 13-m toroid mooring and found that all components looked fairly good. However, during a mid-October storm, the 13-m toroid buoy, trailing its two VMCMs, was retrieved from Southern Shores, about 1 mile south of the Duck pier. Mooring failure was at a threaded rod through the depressor weight, which was fractured across the threads and showed severe chafing wear from the depressor weight sliding up and down.

The data return from the shallowest surface current meter mooring is complete for the 66.5 days it was deployed. The SeaCat data at 8 m ran for only 62 days. The 13-m subsurface mooring was recovered early (1 November) because of concern about mooring failure and to eliminate the need for the *R/V Endeavor* to go into the shallower 13-m site in winter. The data return from the 13-m subsurface mooring is complete for the 86 days it was deployed.

2.3.2 20-m Site

The discus buoy at the 20-m site broke free during a northeaster that blew through the area over Labor Day weekend and came ashore at Kittyhawk (south of FRF), 29 days after deployment. The surface mooring was salvaged on the beach and shipped to WHOI for repair. The mooring was redeployed one month later, resulting in a month-long gap in the data for all instruments on the 20-m surface mooring. The mooring failed at the 1500 -lb depressor weight that hangs about 5 m above the bottom to keep the instruments vertical. The depressor weight was sliding up and down on the central rod and eventually broke the weld. The buoy was redeployed in early October with a newly cast depressor weight of slightly different shape. The actual weight remained unchanged, but it was more cylindrical and elongated (15" diameter by 30" long) as opposed to a wide flat disk. Additionally, all new hardware was used (chain, shackles, and pear rings), and a 1" shackle at the eye bolt of the depressor weight was used instead of the 3/4" shackle that showed signs of advanced wear.

During a mid-October storm, the refurbished 20-m surface mooring "walked" south approximately 200 m, and held position. Mid-November, during Hurricane Gordon, the 20-m surface mooring broke free and drifted ashore without the tower which contained the VAWR meteorological package. We got back all the current meters from the mooring, and the VAWR was eventually recovered. Thus, the data return from the 20-m discus mooring is only 2 months long, with a month-long data gap between each month (the time between mooring recovery and redeployment), rather than the complete four-month deployment period. The 6-m VMCM water temperature sensor for the second setting returned no data because it was improperly wired. The 20-m subsurface mooring was recovered intact and the data return was complete.

The VMCM at the top of the 20-m subsurface mooring (11.5 m) had an intermittent problem with its lower rotor. This problem occurred when the current was coming from a particular quadrant relative to the VMCM ($-120 \geq 0$) and disappeared for the last month of the deployment. The intermittency and orientation of the problem suggest that it may have been due to a foreign object getting entangled in the VMCM cage bars and interfering with the lower rotor. Table 5 lists the five time periods when the intermittent problem occurred.

Table 5: Intermittent Time Periods for Velocity: D2 at 11.5 m

1994 Year Day	Start Time (GMT)	End Time (GMT)	No. Days
235.4 – 239.0	**August 23 @ 0900**	**August 27 @ 0000**	**3.6**
245.0 – 250.0	**September 02 @ 0000**	**September 07 @ 0000**	**5.0**
265.0 – 266.2	**September 22 @ 0000**	**September 23 @ 0448**	**1.2**
283.6 – 284.5	**October 10 @ 1424**	**October 11 @ 1200**	**0.9**
288.0 – 289.7	**October 15 @ 0000**	**October 16 @ 1648**	**1.7**

A corrected time series (used throughout this report) was created by setting the cross-shelf and along-shelf velocities of the VMCM during the times listed above to either: the average of the cross-shelf and along-shelf velocities from the VMCM above and the one below, or the cross-shelf and along-shelf velocities from the VMCM below when no data were available from the VMCM above.

2.3.3 25-m Site

Twenty-six days after deployment, the 25-m surface mooring was recovered to repair the Argos transmitter in the VAWR. During mooring recovery operations, the top current meter (4 m) was damaged and subsequently replaced with a spare. The Argos transmitter on the discus buoy was repaired and the mooring was redeployed, resulting in a 7-hour data gap. A few days later, Argos transmission failed again. It was determined the failure was inside the instrument.

During the October redeployment cruise, a dive was made on the 25-m discus mooring to inspect the hardware. The divers found the mooring to be literally hanging by threads. The mooring was recovered, and redeployed with all new chain and hardware, including the modified depressor weight (more cylindrical, less disk-shaped). Again, during redeploymemt operations, the top current meter (4 m) was damaged and replaced with a spare. The recovery and redeployment resulted in a 3-hour data gap.

During the mid-October storm, the 25-m surface mooring "walked" approximately 2 km south and held position. Six days before Hurricane Gordon, the mooring broke free, drifted into about 30 feet of water (about 30 miles South of FRF), and held position. During Hurricane Gordon, the 25-m mooring came ashore without the VAWR meteorological package, which was apparently torn off as the mooring came through the surf zone. Other than the two weeks of Argos telemetry data, there are no VAWR meteorological data. All the current meters were recovered and the data return was good. The 25-m subsurface mooring was recovered intact and the data return was complete.

2.3.4 Sites DP, N2, S2, and Jetted Pipes

The SeaCat instruments mounted on the FRF pier (site DP) were deployed and recovered by divers Kimball Millikan and Tom Moore from Scripps Institution of Oceanography. Both instruments were working at the time of recovery and the data return was complete. The SeaCat instruments on the remaining surface moorings at sites N2 and S2, as well as the five shallow tide gauges mounted on jetted pipes, were all recovered intact. The SeaGauge instruments, which were located along the 20-m isobath, were also recovered intact. All the instruments returned complete temperature, conductivity and pressure data except the two southern 6-m instruments which apparently were buried around October 20. This affected only the conductivity data which was useless after October 17. Problems with the conductivity cells are outlined in Section 4.2 and 4.4, where comparisons for evaluating the SeaCats and SeaGauges are discussed. The data return timeline for conductivity and salinity is shown in Section 2.4.

2.4 Data Return Timeline

Summaries of the instrumentation deployed during the CoOP inner-shelf study were given in Tables 3 and 4. Timelines showing the data return for the various instruments are shown in Figures 15, 16, and 17. The initial deployment positions and dates, events which led to mooring turnarounds, and recovery dates are listed in Appendix 1.

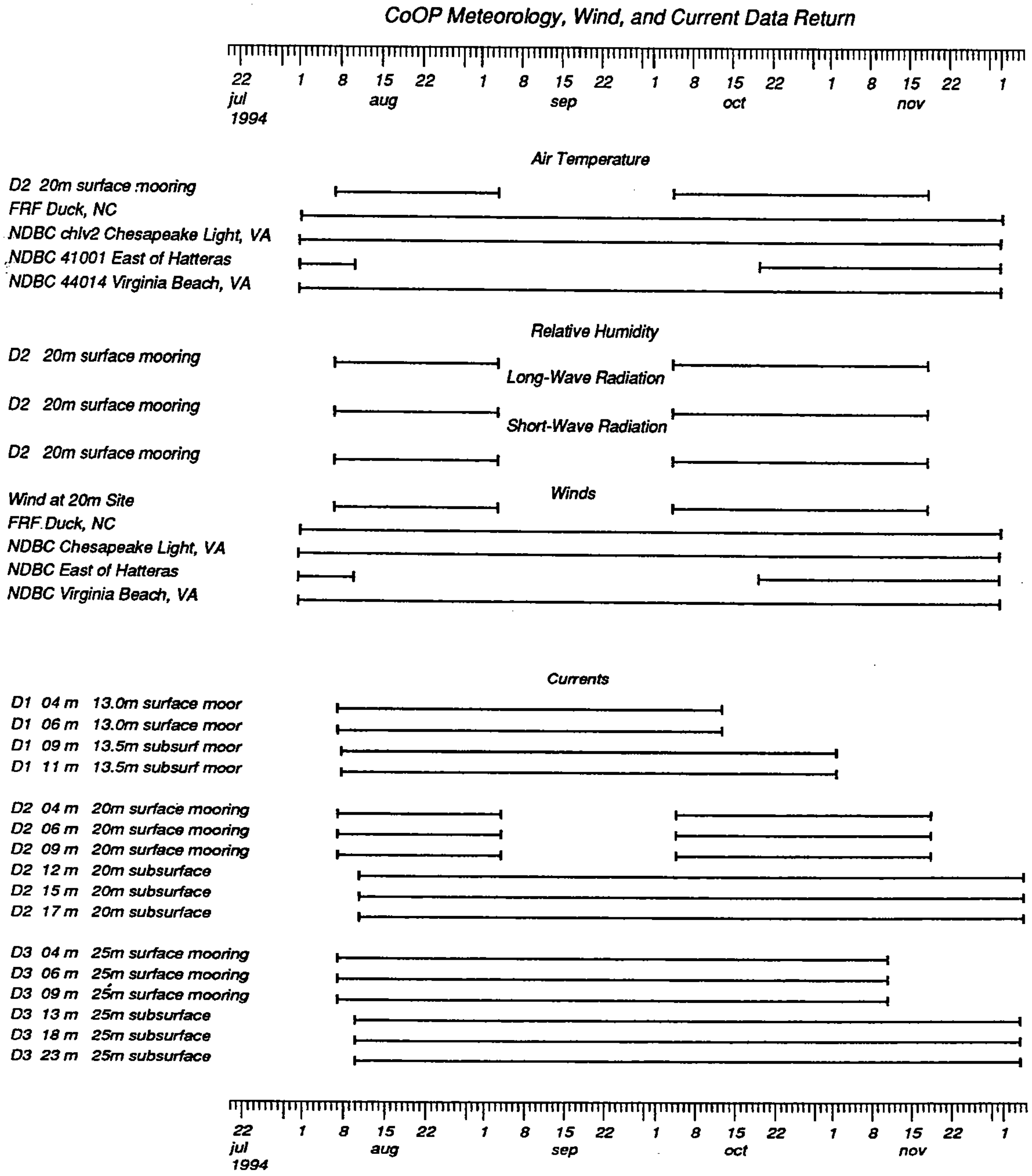


Figure 15: Data return timeline for meteorology, wind and current.

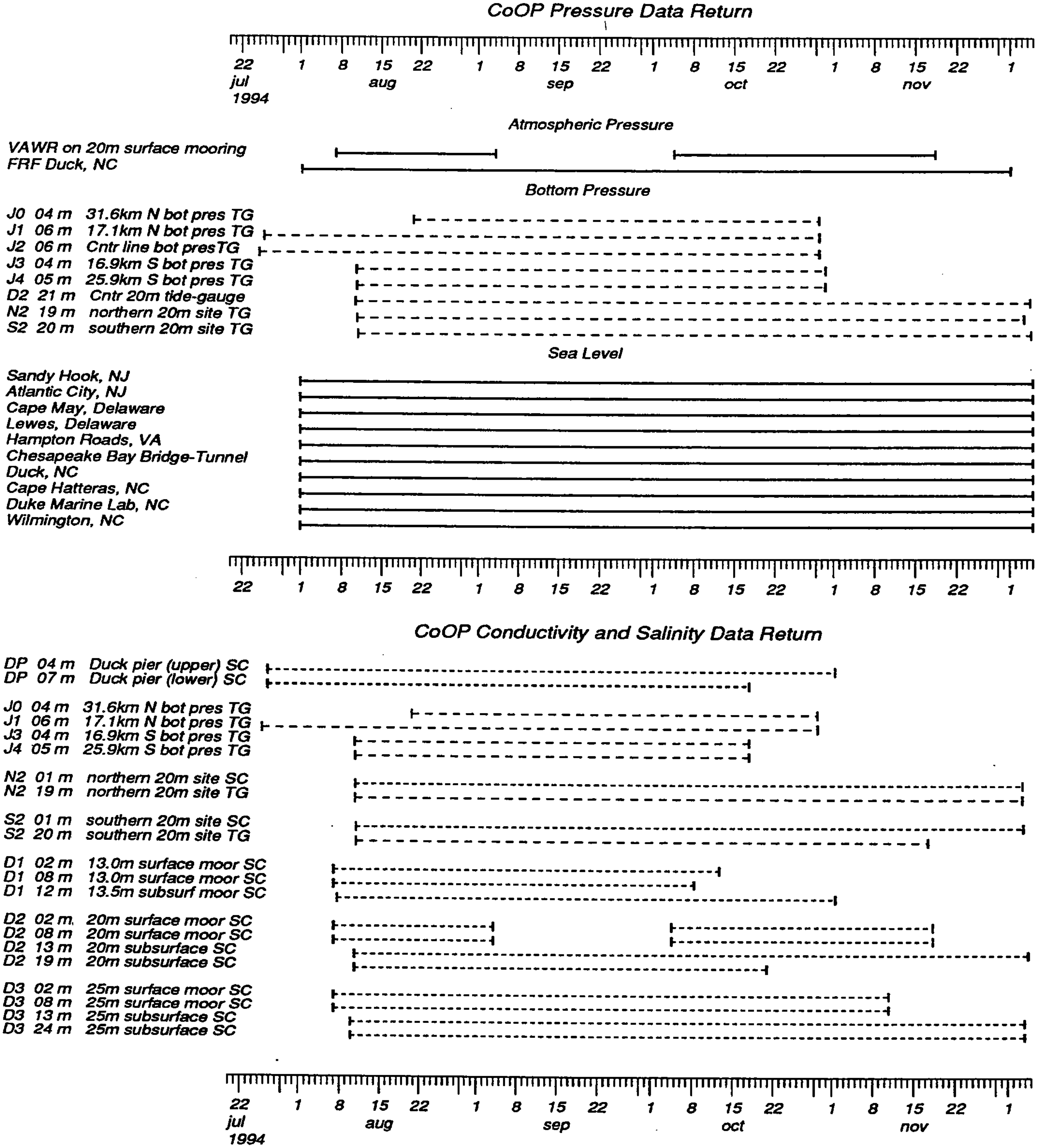


Figure 16: Data return timeline for pressure, conductivity, and salinity.

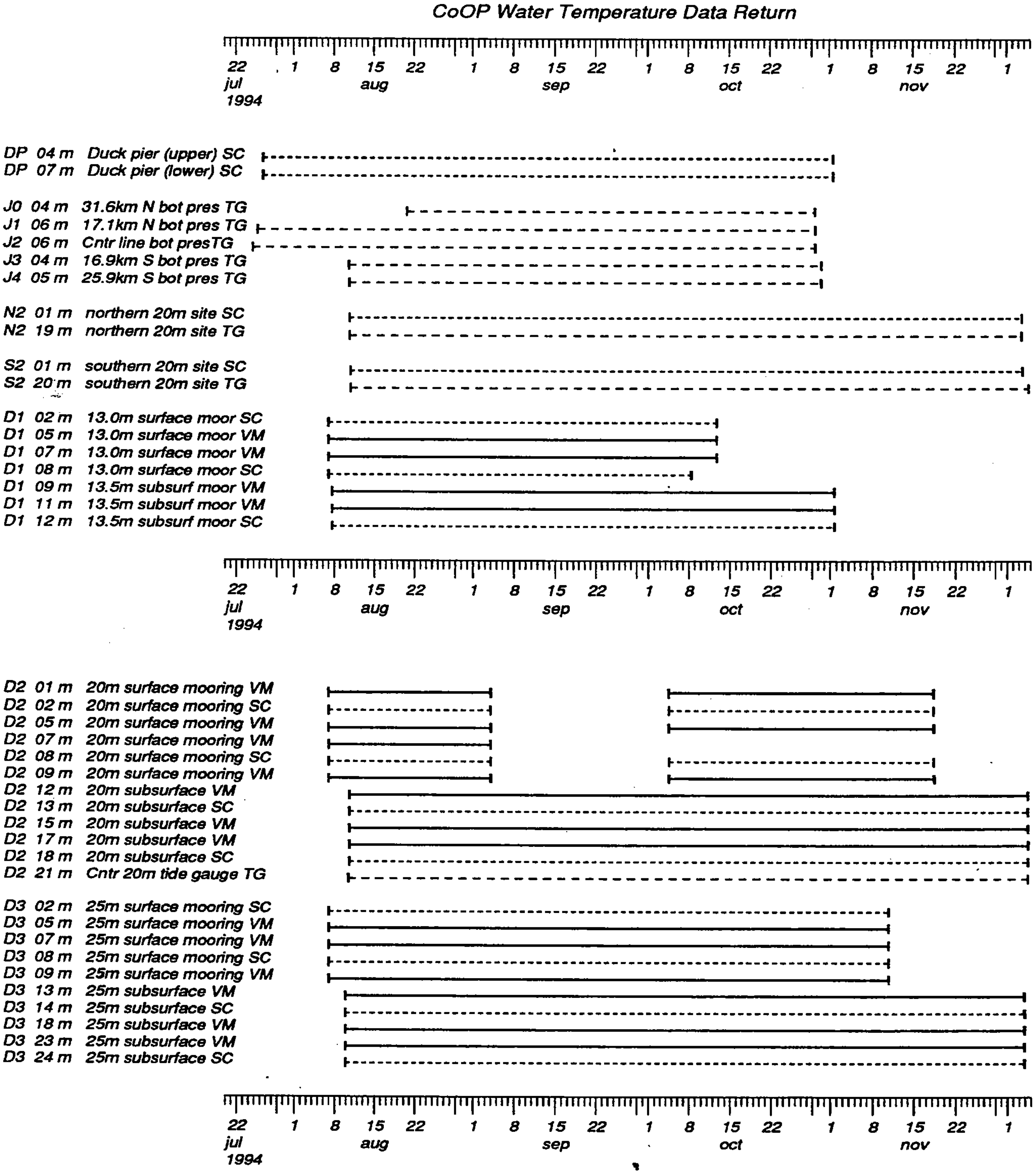

CoOP Water Temperature Data Return

Figure 17: Data return timeline for water temperature.

3. Instrumentation

A total of 39 recording instruments were deployed during the CoOP inner-shelf study. There were 16 VMCMs, 13 SeaCats, 2 VAWRs, and 8 SeaGauges. The second meteorological package (VAWR) located at the 25-m site, 17 km offshore, was not recovered. The instrumentation deployed is summarized in Tables 3 and 4. The accuracy specifications for the VMCM, SeaCat, VAWR, and SeaGauge instruments are listed in Tables 6, 7, 8, and 9, respectively. The instrument specifications were supplied by WHOI's Upper Ocean Processes Group.

3.1 VMCM

The Vector Measuring Current Meter (VMCM) was developed in the late 1970s by Weller and Davis (1980) in an effort to obtain accurate current measurements in the upper ocean wave zone. The 16 WHOI VMCMs were modified versions of the EG&G Sea Link instrument. The standard WHOI VMCM recording package included a temperature sensor (thermistor) installed in an external fast response pod, mounted on the upper pressure housing plate. Additional information on the external temperature pod is described in Trask *et al.*, (1989), as well as some historical information on the VMCM (i.e. propeller bearings, blade materials, and cage redesign). The VMCM recorded data internally every 4 minutes. Its specifications are listed in Table 6 ann record formats are listed in Section 3.1.2.

To complement the standard VMCM temperature measurements and obtain direct measurements of conductivity to allow estimation of salinity, self-contained temperature-conductivity units built by SeaBird Electronics called SeaCats were mounted on 8 VMCMs. Figure 18 shows three VMCMs after recovery. The outer VMCMs have SeaCats (described in Section 3.2) mounted on the instruments.

3.1.1 Specifications

Table 6: VMCM Specifications

Current Sensor:	
Calibration Constant	9.36 cm flow/sensor count (2.67 rev/meter of flow)
Linearity	± 1% (2 cm/sec < V < 4 m/sec)
Cosine Response	± 1% (0 – 360°)
Threshold	0.9 cm/sec
Flux Gate Compass:	
Resolution	1.4°(8 bit digital output)
Accuracy	< 5°@ 110 mgauss horizontal field
Tilt Capability	± 15°
Tape Recorder:	
Capacity	11.5 megabits total. 300 ft. tape certified Phillips cassette
Record Interval	2 seconds – 2 hours using VMCM V02 firmware.
Sample Interval	V02 firmware controlled from 0.25 sec to 2.0 sec

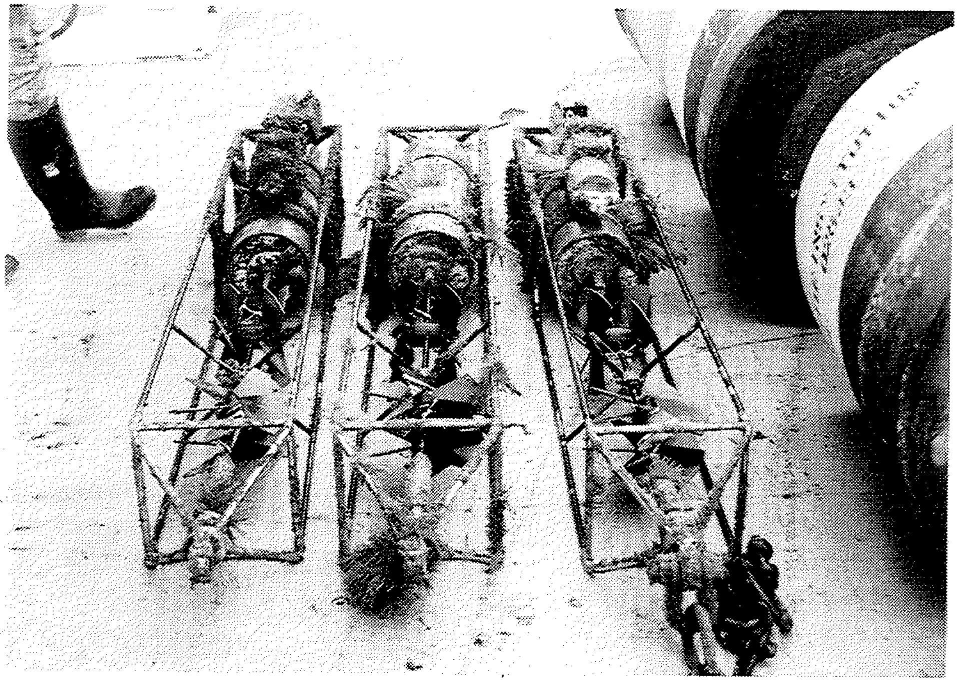


Figure 18: Photograph of VMCMs after recovery. The two outer VMCMs have SeaCats mounted on the instruments.

3.1.2 VMCM Record Format

- **Record Counter (Time):**
  The first 16 bits (4 characters) of data comprise the record number. The counter is incremented once each data record. The first record number is one and used to initialize the instrument. The data and length of the first record may be invalid and should be ignored. Record two contains data for the first record interval. After 65535 records, the record counter will reset to zero and begin its normal counting.

- **North Vector:**
  Each vector is scaled from a 24 bit accumulator and stored in a 16 bit floating-point representation. This vector is the algebraic sum of the NORTH component of current flow from each sample.

- **East Vector:**
  Each vector is scaled from a 24 bit accumulator and stored in a 16 bit floating-point representation. This vector is the algebraic sum of the EAST component of current flow from each sample.

- **Rotor 2 (X Current Flow - Upper):**
  The rotor counts are an algebraic sum of the counts for a record interval. Rotor counts are scaled from a 24 bit accumulator and stored as a 16 bit floating number.

- **Rotor 1 (Y Current Flow - Lower):**
  The rotor counts are an algebraic sum of the counts for a record interval. Rotor counts are scaled from a 24 bit accumulator and stored as a 16 bit floating number.

- **Compass:**
  The compass field is an 8 bit 2's complement number (-128 to $+128$ decimal). The stored value is measured at the beginning of the last sample of the record interval.

- **Temperature:**
  One temperature sample is taken just before the end of the last record interval. For the CoOP inner-shelf study, the range was -5°C to $+30$°C, with 10m°C accuracy.

3.2 SeaCat

The SeaCat is a temperature-conductivity recorder manufactured by SeaBird Electronics, Inc. of Bellevue, Washington. The SeaCat measures the conductivity to 0.0001 S/m and temperature to 0.001°C. The SeaCat takes a measurement over a fixed time interval of 0.125 seconds. Each SeaCats had an anti-fouling cylinder attached to the end of their conductivity cell to prevent biological fouling.

The instruments were controlled using SeaSoft, software supplied by SeaBird, and developed specifically for these instruments. The SeaCat units were all started at WHOI before being loaded on the ship. They were programmed to start at the same time, to coincide with the other instruments, with a 4 minute record rate. Prior to deployment, the SeaCats were plugged into a terminal to see if they were running, and if the data looked reasonable. If the unit wasn't sending data to the terminal, the data were dumped and inspected. If the data looked okay, the instrument was restarted, attached to the appropriate VMCM or buoy, and antifouling plugs were attached to the ends of the conductivity cells to prevent sensor fouling.

3.2.1 Specifications

The following are the manufacturer's quoted accuracies for the SeaCats.

Table 7: SeaCat Specifications

	Temperature	Conductivity
Measurement Range	**−5 to + 35°C**	**0 to 7 Siemens/meter**
Accuracy	**0.01°C/6 months**	**± 0.001 S/m/month**
Resolution	**0.001°C**	**0.0001 S/m**
Sensor Calibration	**−1 to +31°C**	**0 to 7 S/m**
Time	**burst sampled for 0.125 seconds at the end of the 4 minute cycle.**	**burst sampled for 0.125 seconds at the end of the 4 minute cycle.**

3.3 VAWR

The WHOI discus buoys were instrumented to measure wind speed and direction at approximately 3.3 m height with Vector-Averaging Wind Recoders (VAWRs). The VAWR system was developed for surface meteorological measurements during CODE-1 and CODE-2 (Dean and Beardsley, 1988). The present WHOI VAWR meteorological package was equipped with an integral wind vane and 3-cup anemometer set developed by G. Gill, purchased from R. M. Young Company, and modified to provide appropriate digital signals to the vector computer circuits in the VAWR. In addition, the VAWR was instrumented to measure air and sea surface temperature, short-wave and long-wave radiation, relative humidity, and barometric pressure.

Air temperature was sensed at 2.7 m height above sea level using a thermistor sensor which is protected in an acetal housing installed in a multi-plate radiation shield. Water temperature was measured at 1.12 m below the sea surface using a thermistor sensor installed in a pressure protected aluminum enclosure attached to the bridle under the discus. The VAWR long-wave insolation measurement was made with an Eppley (model 8-48) pyranometer. The sensor was mounted on the buoy at 3.42 m above the water in a fixed position to allow for minimum obstruction by other sensors. Changes in atmospheric pressure were detected by a quartz crystal transducer manufactured by Paroscientific. Relative humidity measurements were made at 2.7 m above sea level using a circuit, supplied by Vaisala, with a "Humicap" sensor element. Additional information about each sensor can be found in the report by Trask *et al.*, (1989). A specification summary for the VAWR sensors used in the CoOP inner-shelf study appears in Table 8; the sensor heights above the water line are summarized in Table 3.

A schematic of the discus buoy showing the configuration of the meteorological sensors mounted on the tower of the 3-meter-diameter discus buoy is shown in Figure 19a. In addition to the sensors, mounted on one side of the discus buoy was a steering vane approximately 2 feet in length. The steering vane kept the buoy and its sensors oriented into the wind. It was located opposite the face of the sensors and is not shown in the schematic.

The VAWR's sample interval was 7.5 minutes. The recorded time corresponds to the center of the data sample for wind speed, wind direction, insolation, and long-wave radiation, all of which are averaged over the sample interval. Relative humidity and barometric pressure are burst averages in the middle of the recording interval, water temperature is averaged over the first half of the recording interval, and air temperature is averaged over the second half of the recording interval. A specification summary for the VAWR sensors used during the CoOP inner-shelf study are shown in Table 8, and graphically shown in Figure 19b.

The VAWR recorded all data internally on a cassette tape every 7.5 minutes. Each of the discus buoys had an Argos satellite transmitter which provided buoy position information during the experiment as well as telemetered data via the Service Argos System. Details of the transmitted data can be found in Appendix 2. The meteorological observations from the Argos transmitted data and the 20 m VAWR are shown in Figures A2.1 and A2.2.

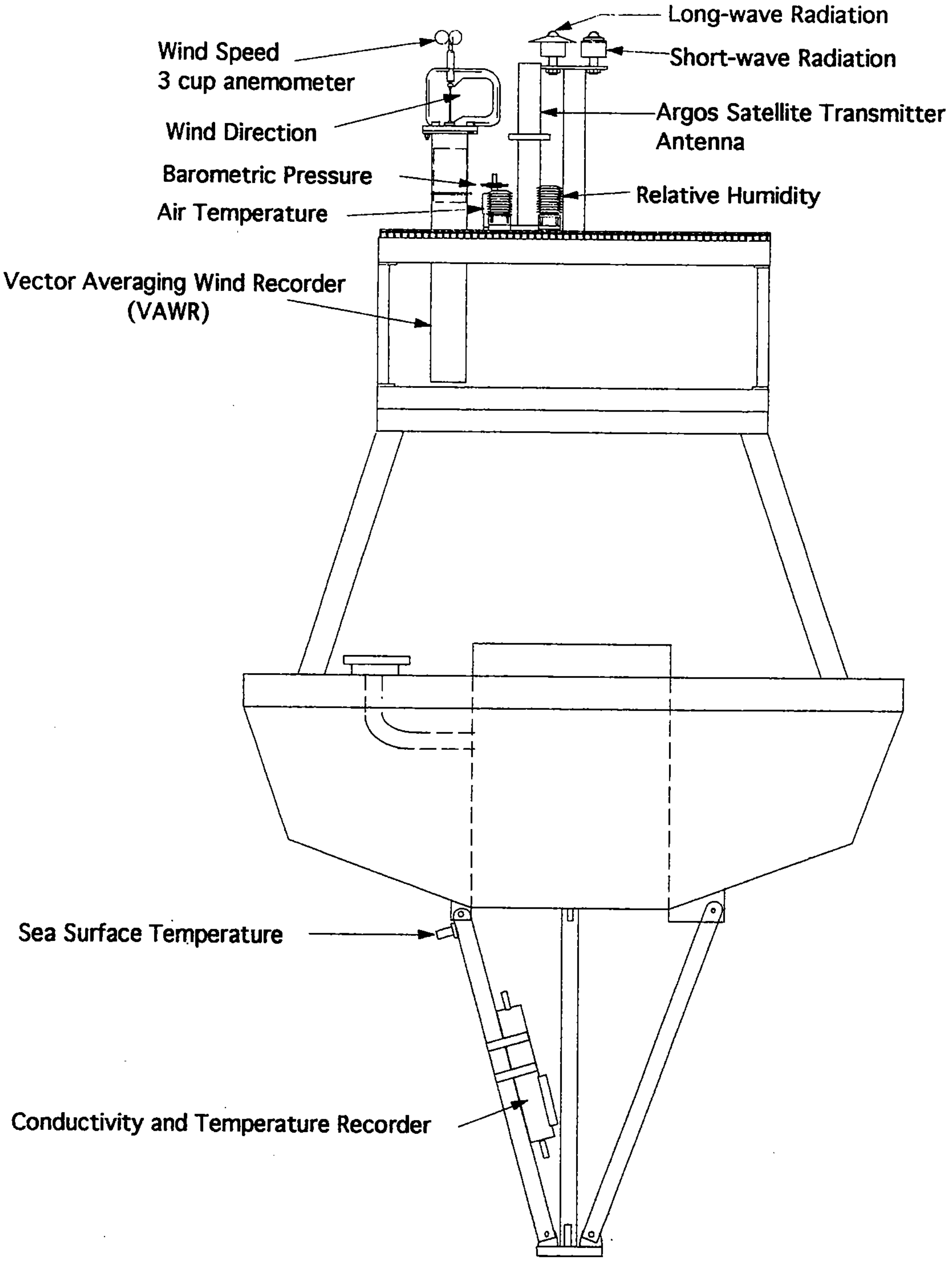


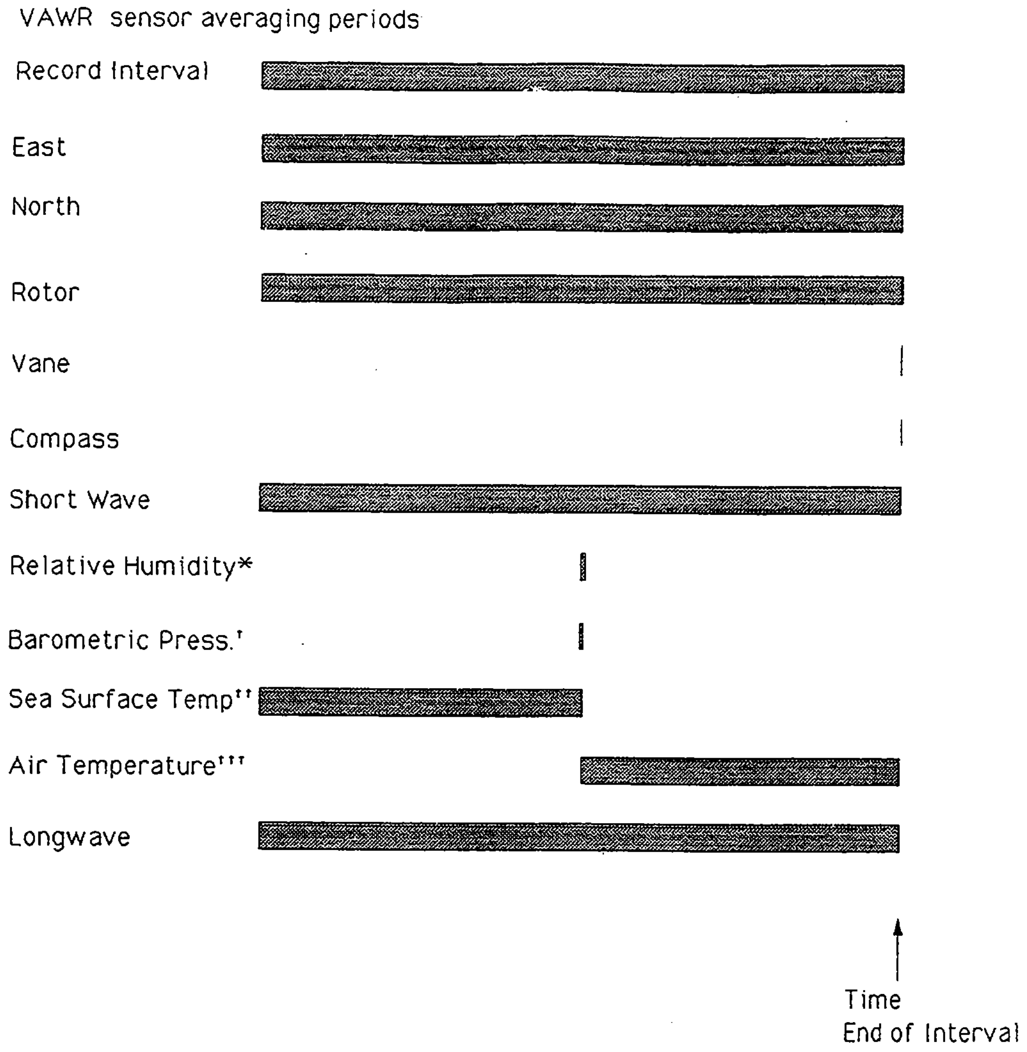
Figure 19a: Schematic of the discus buoy with meteorological instrumentation used in the CoOP inner-shelf study.

3.3.1 Specifications

Table 8: VAWR Specifications

Parameter	Sensor Type	Accuracy	Record Time
Wind Speed	R.M. Young 3-cup Anemometer	± 2% 0.7 m/s	Vector Averaged
Wind Direction	Integral Vane w/ vane follower WHOI/EG&G	± 1 bit 5.6°	Vector Averaged
Insolation	Pyranometer Eppley 8-48	± 3% of reading	Averaged over record interval
Long-Wave Radiation	Pyrgeometer Eppley PIR	± 10%	Averaged Over record interval
Relative Humidity	Vaisala Humicap 0062HMP	± 2% RH	3.515 Seconds Average Note 1
Barometric Pressure	Paroscientific Model 216-B-101	± 0.2 mbars wind < 20 m/s	2.636 Seconds Average Note 1
Sea Temperature	Thermistor Thermometrics 4K @ 25°C	± 0.005°C	Averaged over 1/2 record time Note 2
Air Temperature	Thermistor Yellow Springs 5K @ 25°C	± 0.2°C wind > 5 m/s	Averaged over 1/2 record time Note 3

1. Relative Humidity and Barometric Pressure are averaged in the middle of the recording interval for the time noted.
2. Sea Temperature is measured during the first half of the recording interval.
3. Air Temperature is measured during the second half of the recording interval.



* Relative humidity sensor is on for 7 seconds and counted for 3.515 seconds

' Barometric Pressure sensor is on for 4.39 seconds and counts for 2.636 seconds

'' Sea surface temperature is averaged during the first half of the record rate. Actual averaging interval is half the record rate minus 1.7578125 seconds (delay and settle time from SST to AT)

''' Air temperature is counted for the second half of the averaging interval. The air temp average interval is half the record rate minus 1.7578125.

Recorded compass and vane information is the last sample taken in the record interval.

Figure 19b: VAWR sensor averaging periods used in the CoOP inner-shelf study. A vector computer calculates and stores east and north wind component displacement past the rotor. The average of these vector components over the record interval are permanently stored on magnetic tape.

3.4 SeaGauge

The SeaBird SeaGauge is a tide and wave recorder. The SeaGauge measures the absolute pressure with a high precision Paroscientific Digiquartz pressure transducer that has an accuracy of about 3 mm depth equivalent for the 45 psia full scale pressure transducer used.

For the CoOP inner-shelf research program, it was desired to measure near-bottom pressure with a relative accuracy of 1 mb. The SeaGauge was selected for its accurate relative pressure measurements. The measurement is made by continuously integrating the pressure signal, over the record cycle, to average out the surface wave signal. The SeaGauge was set up with a 4 minute record cycle to match up with other instruments.

Upon inspection of the instrument, it was determined that testing needed to be done to see what effect currents would have on the pressure sensor (Bernoulli effect). The pressure is transferred to the pressure transducer via a small oil-filled bladder connected to the transducer by a small piece of tubing. The bladder is in a covered cavity in the bail attached to the end of the instrument. The cavity cover is a rectangular plate. There are four small holes through the cover and the bail in the corners of the cavity. Testing indicated that current speed and direction variations caused significant pressure variations. To reduce this problem a new parallel plate pressure port was developed. The results of the port development and testing (C. Marquette, personal communication) indicated that the new pressure port would reduce the effect of current on the pressure signal to less than 1 mb in a 1-knot current.

During initial testing, a temperature-dependent pressure signal was detected in one of the instruments (SeaGauge #47). The unit was sent back to SeaBird for correction. The cavity in which the oil-filled pressure bladder was mounted was too small and was squeezing the pressure bladder due to temperature expansion and contraction of the cavity. The production bladder was larger than the prototype that was sent to SeaBird, thus resulting in too small a cavity being designed. Sea-Bird came up with new specifications on the cavity and will retrofit any SeaGauge where the cavity was too small. This was done with SeaGauge #47.

Figure 20 shows an example of the SeaGauge mounted on pipes that were jetted into the bottom by divers from an inflatable boat in 4 to 6 meters of water along the coast. Figure 21 shows SeaGauges mounted on anchors which were deployed from the *R/V Endeavor* in 20 meters of water.

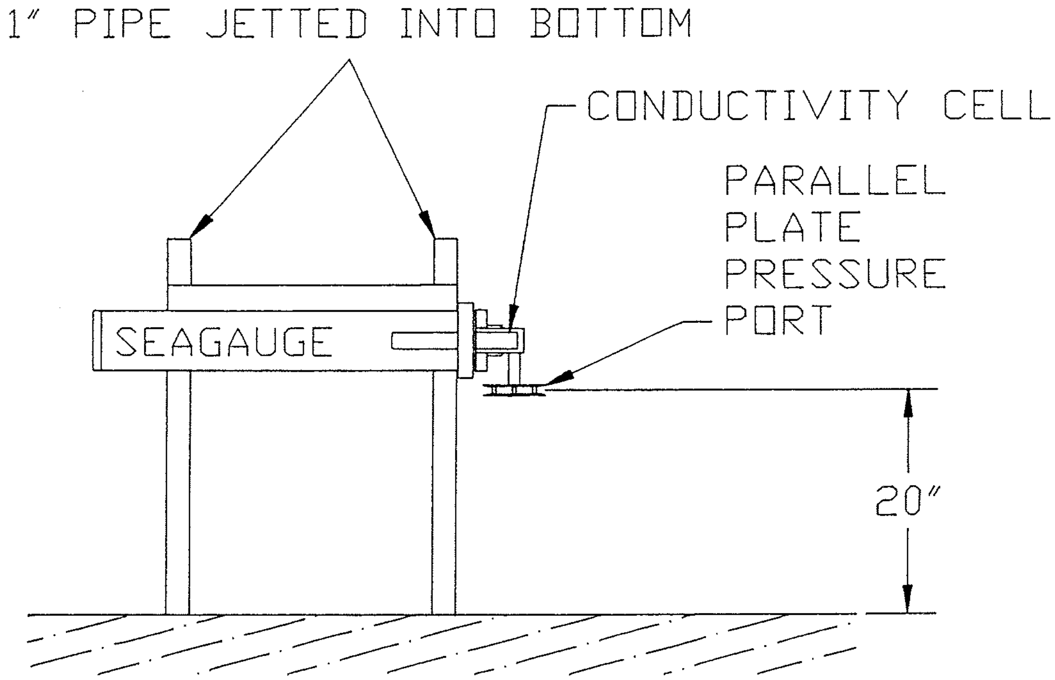


Figure 20: Drawing of a SeaGauge mounted on jetted pipes.

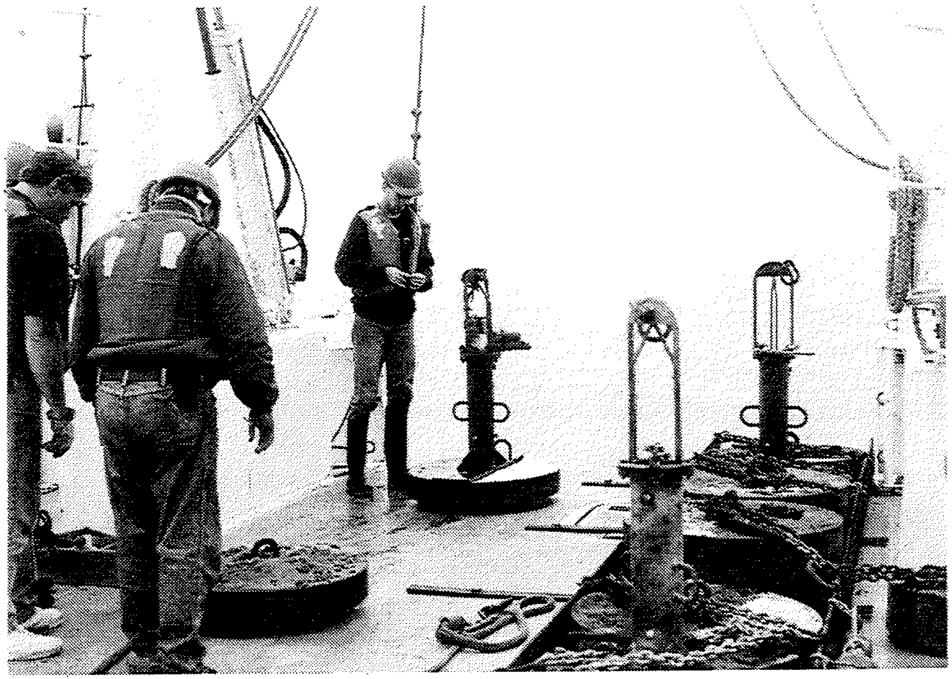


Figure 21: Photograph of SeaGauges mounted on anchors.

3.4.1 Specifications

The following are the manufacturer's quoted accuracies for the SBE 26 SeaGauge Wave and Tide Recorder.

Table 9: SeaGauge Specifications

Pressure:	
Measurement Range	0 to 21 meters (45 psia full scale)
Accuracy	0.01% FS (3 mm for 45 psia range)
Tide Resolution	0.2 mm with 1 minute integration 0.01 mm with 15 minute integration
Wave Resolution	0.4 mm with 0.25 sec integration 0.1 mm with 1 second integration
Sensor Calibration	0 psia to full scale pressure
Time	averages over 4 minutes and records time at the end of the 4 minute cycle.
Temperature:	
Measurement Range	−5 to + 35°C.
Accuracy	0.02°C.
Resolution	0.01°C.
Sensor Calibration	−1 to +31°C.
Time	burst sampled for 0.125 seconds at the end of the 4 minute cycle.
SBE 4 Conductivity Sensor:	
Measurement Range	0 to 7 Siemens/meter
Accuracy	± 0.0003 S/m/month (typical) ± 0.001 S/m/month (guaranteed) (Not applicable in areas of high biofouling or high contamination.)
Resolution	0.00002 S/m
Time	burst sampled for 0.125 seconds at the end of the 4 minute cycle.

4. Data Processing

This section provides a description of the data processing methods used to produce the final data sets (both meteorological and oceanographic) presented in this report. For all vector and scalar variables that were sampled at intervals less than one hour, hourly values were formed by vector or scalar averaging, centering time on the hour (*e.g.*, the value assigned to 1200 is an average of data collected between 1130 and 1230). The resultant vector current and wind data collected in the CoOP inner-shelf region have been rotated into a standard coordinate system, with one component aligned parallel with the coastline and local shelf topography near the 20 m mooring line. This coordinate system is oriented 20°counterclockwise with respect to true north so that the along-shelf component is positive towards 340°T and the cross-shelf component is positive towards 70°T. Throughout this report, time is in GMT.

The remainder of this section describes initial processing and evaluation procedures for each instrument type. Comparisons with measurements obtained by other instruments provided an assessment of data quality and a rationale for eliminating bad data from records. The data sources and types, intercomparison methods and results are described next.

4.1 VMCM

The WHOI VMCM's recorded data internally on standard magnetic cassette tapes. The data were transcribed onto 9-track tapes, converted to scientific units, and edited using the standard current meter processing system developed at WHOI. The data for each instrument were truncated to remove launch and retrieval transients, then checked for unrealistic data values.

The VMCMs sample interval was 4 minutes. The VMCM measures the average water velocity over the sample interval and takes a burst sample of temperature at the end of the sample interval. The recorded time corresponds to the end of sample interval which is the time used for the temperature measurement. For velocity, the standard current meter processing system shifts the time to the middle of the sample interval.

To complement the VMCM water temperature record, self-contained temperature-conductivity units, SeaCats, were mounted on eight VMCMs. An initial assessment of the VMCM temperature data was made by comparing them to temperatures from the SeaCats. During the preliminary assessment of data quality, since these temperature sensor pairs were about 70 cm apart, it was expected that the VMCM and nearby SeaCat data would coincide. Temperature differences of 0.01 – 0.02°C were observed, even during well-mixed periods. These temperature differences (VMCM-SeaCat) exhibited a clear dependence on temperature suggesting a slight problem with the calibration of either the VMCM or SeaCat thermistors. The next section describes the calibration process and a summary of the results.

4.1.1 Calibration and Measurement Process

The thermistors on the VMCMs were calibrated in a series of bath tests to relate temperature to the resistance of the thermistor. The numbers computed were used as input into a program which computes three constants (A-B-C) used in the thermistor equation (Payne *et al.*, 1976). The VMCM electronics are calibrated separately to determine the relationship between resistance and frequency counts. The output count values were used as input into a curve-fitting program which computes two constants, R_t and F_t. Once these two fits are done, a final "bath-test" check was done where the whole system was put together and checked before being sent into the field. In general, these pre-cruise bath checks revealed 0.005°C or less error. After mooring recovery, the VMCMs were subjected to another bath test in order to determine whether there was any drift of calibration during the experiment. For the VMCM, there appeared to be errors on the order of 0.01°C to 0.05°C in post-cruise bath tests.

The SeaCats were calibrated at the SeaBird Calibration center in Bellingham, Washington. Both pre- and post-calibrations revealed very little systematic error in their measurements. Because of this, the problem was assumed to be with the VMCM temperature measurements.

The R_t and F_t values were rechecked to see if these were the cause of the errors, and substantial differences were found for many of the VMCMs. The VMCMs were then subjected to another bath test using the new R_t and F_t values. The results show the RMS errors were much smaller, indicating that the R_t and F_t may have changed due possibly to a shift in the value of a potentiometer in the VMCM.

4.1.2 Summary of Results

Applying the new R_t and F_t values eliminated the dependence of the VMCM-SeaCat temperature difference on temperature. This suggests the potentiometers shifted prior to the instrument deployment. However, even with the new R_t and F_t values, there were still biases in the VMCM-SeaCat temperature differences. In cases where this bias was greater than 0.01°C the bias was removed by adding a constant offset to the VMCM temperatures. These corrections are listed below for each VMCM.

4.1.3 13-m Site

There were four VMCMs at the 13-m site (Figures 6, 7, and Table 3).

- **13-m site, thermistor at 4.65 m.** There was a small, 0.01°C bias both before and after the recalibration. No adjustments were made to the data.
- **13-m site, thermistor at 6.95 m.** A large, +0.024°C bias was removed.
- **13-m site, thermistor at 9.20 m.** There was a small, −0.006°C bias before the recalibration, and a −0.008°C bias after the recalibration. No adjustments were made to the data.
- **13-m site, thermistor at 11.50 m.** A bias of +0.014°C was removed.

4.1.4 20-m Site

There were six VMCMs at the 20-m site (Figures 8, 9, and Table 3).

- **20-m site, thermistor at 4.65 m.** This has a small, +0.006°C, bias. No adjustments were made to the data.
- **20-m site, thermistor at 6.95 m.** This VMCM worked only during the August deployment, so there are not much data available for determining a bias. The bias is on the order of 0.01°C. No adjustments were made to the data.
- **20-m site, thermistor at 9.25 m.** A bias of +0.013°C was removed.
- **20-m site, thermistor at 12.00 m.** No appreciable bias was observed.
- **20-m site, thermistor at 15.00 m.** No appreciable bias was observed.
- **20-m site, thermistor at 17.50 m.** The electronics on this VMCM were not recalibrated, as the VMCM had already been redeployed in another experiment. The temperature difference has a linear trend as a function of temperature. At 15°C, the difference is 0.01°C, and at 25°C, the difference is 0.002°C.

4.1.5 25-m Site

There were six VMCMs at the 25-m site (Figures 10, 11, and Table 3).

- **25-m site, thermistor at 4.65 m.** No appreciable bias was observed.
- **25-m site, thermistor at 6.95 m.** There is a small, 0.006°C bias. No adjustments were made to the data.
- **25-m site, thermistor at 9.25 m.** A large, +0.05°C bias in the recalibrated data was removed.
- **25-m site, thermistor at 13.00 m.** There is a small, 0.008°C error. No adjustments were made to the data.
- **25-m site, thermistor at 18.00 m.** There is a small, 0.006°C error. No adjustments were made to the data.
- **25-m site, thermistor at 23.50 m.** The electronics on this VMCM were not recalibrated, as it had already been redeployed in another experiment. The temperature difference has a linear trend as a function of temperature. At 15°C the difference is 0.011°C, and at 25°C the difference is 0.002°C.

4.2 SeaCats

The SeaCats had pre- and post-deployment calibrations done by SeaBird Electronics at the Northwest Regional Calibration Center. SeaBird supplied the calibration coefficients. Pre-deployment calibration coefficients were used for all instruments. Pre- and post-temperature calibrations were within 0.005°C for all the SeaCats over the calibration range of about 0 – 30°C, with one exception. The exception was a 0.01°C discrepancy at 3°C for the deeper SeaCat mounted on the pier. Pre- and post-calibrations for conductivity generally differed by less than 0.01 S/m. There were three exceptions, the near bottom SeaCats on the 13-m and 20-m moorings had maximum differences between the pre- and post-calibrations of 0.04 and 0.022 S/m respectively. The 7.65-m SeaCat on the 13-m mooring had a maximum difference of 0.4 S/m due to a large grain of sand lodged in the cell. This undoubtedly happened when this mooring broke and came ashore; there is no indication of a corresponding problem in the data.

The data was uploaded onto an IBM compatible personal computer and converted into ASCII format using SeaSoft software supplied by SeaBird. The temperature and conductivity time series were examined for glitches and timing errors. Then the temperature and conductivity measurements were compared with other measurements on the same mooring and with temperature and conductivity measurements described below. Comparisons between coincident measurements provided us with a rationale for eliminating bad data, particularly from the moored conductivity sensors, which are prone to fouling and drift. Comparisons revealed that near-bottom moored sensors displayed the most problems. Bias and drift corrections applied to the near-bottom conductivities are listed below. After processing was completed on the temperature and conductivity data, salinity and density time series were estimated using the formulation of Fofonoff and Millard (1983).

4.2.1 Comparison Data Sources and Types

Moored Buoys

There were a total of 13 SeaCATs located on the main transect line, in the cross-shelf direction. Three were mounted on the bridles of the surface floats, eight were mounted on VMCMs, and two were located near the end of the FRF pier, at 4-m and 7-m depth. Two SeaCATs were mounted on the bridle of independent moorings located north and south of the central line (see Figure 14, schematic of the along-shelf array). SeaCat sensor locations and depths are in listed Section 2.2, Table 4.

R/V Cape Hatteras

CTD surveys were made by the *R/V Cape Hatteras* (RVCH) during the months of August and October. The RVCH uses a SeaBird 911Plus CTD with redundant temperature and conductivity sensors. The RVCH data can be compared to the 13-m, 20-m and 25-m mooring sites. During October, nine casts were made at the 13-m site, and 14 were made at each of the 20-m and 25-m sites. The N2 and S2 SeaCat moorings fell between two shipboard CTD transects, so the closest CTD stations were more than 10 km from these sites and hence no comparisons are presented.

R/B Moby Duck

The *R/B Moby Duck* (RBMD) was a small inflatable raft which was used for high horizontal resolution nearshore CTD surveys, using a hand-deployed General Oceanics CTD package. These data were compared to the pier SeaCats and the SeaCats at the 13-m and 20-m mooring sites (D1 and D2). The surveys did not return the exact position of the cast, so only the nominal intended position of the cast is known. There were 37 casts made at each station.

FRF Pier CTD

Daily CTD casts were made at the end of the FRF pier with an Ocean Sensors OS200. These casts were close to the location of the two SeaCats on the pier. Ninety-seven casts were made at the end of the pier.

4.2.2 Comparison Method

To compare the temperature and conductivity, the depth of a particular moored element was specified, nearest CTD casts from each central line transect were selected, and an interpolated value of conductivity at the specified depth was computed. If the cast did not extend to the depth of the moored conductivity cell, the deepest conductivity reading was used and the depth difference was noted. Large vertical conductivity gradients could lead to exaggerated errors due to uncertainties in sensor depths. Consequently, the vertical gradient in conductivity was estimated by taking the difference of the conductivity values from 0.5 m above and below the specified depth (if this was out of range of the CTD cast, the vertical gradient over the deepest meter of the cast was used). The 4-minute moored data were interpolated to get the mooring values at the times of the CTD casts. Thus the maximum time difference between the moored observation and the cast is 2 minutes. The resulting conductivity differences were plotted as a function of time. The vertical gradient of conductivity was also plotted with the differenced data to indicate the amount of scatter possibly due to vertical separations. Systematic differences are assumed to be an indication of instrument error, due to either drift or fouling.

4.2.3 Summary of Results

There were no problems with the SeaCat temperatures, with one exception being the 7.62-m instrument on the 20-m mooring which had a bias relative to surrounding instruments. The comparisons of the conductivities from the moored instruments and the shipboard and FRF pier CTD data showed generally good agreement in the upper water column, but problems with the moored conductivity cells near the bottom. For the comparisons with SeaCats in the upper water column, mean differences were typically 0.01 S/m or less and standard deviations were 0.1 S/m or less. At least some of this discrepancy can be attributed to real spatial variations in conductivity and the separation between the measurements. Near the bottom mean conductivity differences were generally 0.2 – 0.03 S/m and standard deviations were 0.1 – 0.5 S/m. Time series clearly reveal that the near-bottom conductivities (see also the SeaGauges section 5.4) at each of the four sites had problems starting around October 19th. There was a prolonged period of large waves, October 10 – 20, with significant wave heights generally in excess of 2 m and peak significant wave heights over 4 m on

October 15. Transmissivity observations in the region suggest there were very high suspended sediment concentrations several meters above the bottom during this period. It seems likely that the degradation of the near-bottom conductivities is due to suspended sediment getting into the cells.

Corrections applied to the temperature and conductivity data are listed below. These included, primarily, truncating some of the conductivity time series and removing biases or trends based on the comparisons described above.

4.2.4 FRF Pier

Comparisons indicate the conductivity data at 7-m depth is of poor quality and is only useful for qualitative comparisons. There is a gap in the conductivities August 15 – 23 when the data were clearly bad, and the time series was truncated at October 17.

4.2.5 13-m Site

The 7.65-m conductivities had a drift of 1.5×10^{-3} S/m/day beginning September 7 which was removed. A bias of 0.009 S/m was also added to the entire conductivity record.

4.2.6 20-m Site

A bias of $-0.16°$C was removed from the temperatures. A bias of 0.13 S/m was added to the conductivities from the second deployment of the 7.62-m cell.

A drift of 1.17×10^{-3} S/m/day beginning October 11 was removed from the 13.18 m conductivities.

The 18.17-m conductivity time series was truncated at October 21. A drift of -1.67×10^{-3} S/m/day beginning October 11 was removed from the 18.17-m conductivities. There were also numerous (243) single point glitches in the conductivities after September 17 which were replaced using linear interpolation.

4.2.7 25-m Site

A drift of 0.53×10^{-3} S/m/day beginning September 27 was removed from the 13.17-m conductivities.

A drift of 1.94×10^{-3} S/m/day from October 7 to 25, a bias of 0.035 S/m from October 25 to November 17, and a bias of 0.055 S/m from November 17 to the end of the record were removed from the 23.57-m conductivities.

4.2.8 North and South 20-m Sites

No corrections were made to the conductivity time series from the SeaCats on these two moorings.

4.3 VAWR

The data collected with the VAWR were recorded internally on standard magnetic cassette tapes and transcribed onto 9-track tapes at WHOI. The data were then converted to scientific units and edited using the standard current meter processing system developed at WHOI (Tarbell *et al.*, 1988).

Prior to deployment, the air and water temperature sensors as well as the relative humidity sensors were calibrated at WHOI. The calibrations for the atmospheric pressure sensors were done by the manufacturer and checked at a WHOI test site facility. The short-wave and long-wave radiation sensors were calibrated by the manufacturer. The wind direction sensor readings were compared with a known bearing at a WHOI test site. Pre-cruise direction comparison tests can be found in Appendix 3.

In order to detect glitches or systematic error with the VAWR data, comparisons were made with other instruments collecting meteorological data. In all, there were three sources of data:

- Meteorological Buoy (VAWR), moored at the 20-m isobath, 5 km offshore of Duck NC,
- Field Research Facility (FRF), located on the shore at Duck, NC, and
- R/V *Cape Hatteras* (RVCH), a research ship in the vicinity during the time period.

4.3.1 Data Sources and Types

VAWR Meteorological Buoy

The VAWR had a full complement of meteorological instruments and was moored 5 km offshore of Duck, in 20 m of water. Data were collected from August 7th through September 4th, and October 4th through November 18th, and consisted of:

- Air Temperature (2.71 m above sea level),
- Water temperature (1.12 m below sea level),
- Relative Humidity (2.71 m above sea level),
- Downward Short-wave and Long-wave Insolation (3.42 m),
- Barometric Pressure (2.78 m), and
- Wind Speed and Direction (3.37 m and 3.09 m).

FRF

The FRF provided continuous data for all of 1994. The sampling scheme was to take 2 Hz data for 170 minutes and then a 10 minute break. These data are averaged at FRF into five unevenly spaced records every 3 hours. The averaged data were then interpolated at WHOI to form a times series of evenly spaced hourly values. The data available consist of:

- Barometric Pressure (Yellow Springs Instrument Co., located in an instrument shelter 43 m inshore of the dune),
- Air Temperature (Yellow Springs Instrument Co., located in an instrument shelter 43 m inshore of the dune), and
- Wind Speed and Direction (F420 Anemometer, National Weather Service, located at 19.5 m above sea level at the end of the pier).

R/V Cape Hatteras

The data collected by the *R/V Cape Hatteras* were taken during two cruises that span July 27 through August 30 and September 26 through October 31. Each of these time periods has sporadic dropouts when the data acquisition system was not turned on or not working. The sampling rate was once every 15 seconds, which was block averaged to form hourly data. The data available consist of:

- Sea Surface Temperature (Yellow Springs Instruments, Model 701 Temperature Probe, located at sea level),
- Barometric Pressure (Atmospheric Instrument Research, Model AIR-DB-1A, located 3 m above sea level),
- Air Temperature and Relative Humidity (RM Young, Model 41372C, located 15.25 m above sea level), and
- Wind Speed and Direction (RM Young, Model 05103, located 15.25 m above sea level).

Since the ship covered a large area of the shelf during the cruises, only data taken within 5 km of the 20-m buoy were used for comparisons. This was about 20% of the total data set in both months.

4.3.2 Summary of Results

The hourly meteorological data from the FRF and the RVCH were compared to the 20-m buoy data. Every attempt was made to "deglitch" the data. The RVCH data was prone to "data dropout", where it would return 0 a significant portion of the time. Data from the FRF and the RVCH were plotted against the data from the buoy, and plots of the time series from each were made. In addition, some basic statistics were computed for each comparison. In the following comparisons, the August time period is August 7 to September 4. The October time period is October 4–31 for the RVCH comparisons and October 4–November 18 for the FRF comparisons. Results of the comparisons are summarized in Table 10.

Table 10: Meteorological Comparison Results

FRF		Mean	Std. Dev.	Corr.	Slope
WS	August	−0.450	0.860	0.970	0.970
	October	−0.620	1.100	0.970	0.980
WD*	August	4.700	6.500	–	–
	October	15.600	7.100	–	–
AT	August	0.801	1.732	0.816	0.910
	October	−0.533	1.325	0.915	1.190
BP	August	−0.532	0.891	0.982	0.940
	October	−2.510	2.998	0.957	0.900

RVCH		Mean	Std. Dev.	Corr.	Slope
WS	August	−0.720	1.250	0.900	0.700
	October	−0.280	0.570	0.980	0.950
WD	August	−10.150	15.200	–	–
	October	−5.470	7.200	–	–
AT	August	1.200	1.732	0.820	0.910
	October	1.170	1.370	0.940	1.030
BP	August	0.070	0.304	0.990	0.990
	October	−0.030	0.260	0.990	1.000
RH	August	−4.800	7.960	0.790	1.030
	October	−6.650	9.260	0.930	1.360
WT	August	0.360	1.460	0.490	0.630
	October	−0.030	0.390	0.950	0.900

*** The wind direction statistics are only for records where the wind speed was > 4 m/s.**

The mean and standard deviations are for the difference time series of the RVCH or the FRF minus the buoy. Correlation is the correlation between the time series, and the slope is the result of a linear regression analysis fitting the buoy data to the RVCH or FRF data.

4.3.3 Wind

The FRF anemometer is on a tower at the end of the pier at 19.5 m height. The buoy anemometer was at 3.3 m height, and positioned so that it was always upwind of the main mass of the buoy (the steering vane on the buoy kept it headed into the wind). The RVCH had two anemometers, both located at approximately 15 m height, one on each side of the ship. The RVCH data were processed such that only data from the upwind side of the boat were used (utilizing data from the ship's gyrocompass). As the anemometers were at different heights and the wind speed in the atmospheric boundary layer is heavily dependent on height, a direct comparison is not possible for wind speed. To compare the velocity time series, a series of routines based on the Large and Pond (1981) bulk parameterizations were used to convert the buoy wind speed at 3.3 m to the corresponding expected wind speed at 15 m or 19.5 m.

The FRF and buoy wind speeds compared favorably in both months. The wind directions compared well in August, but not so well in October, with a mean difference of approximately 11°. The mean difference is largest during onshore winds, which are more prevalent during October. This may account for the difference in the error between the two months, as opposed to a change in the instrument. It should also be noted that wind speeds were higher in October, and scatter is generally smaller with higher wind speed. It may be that the 10° error is always present, but not detectable in the August data because of additional scatter.

The RVCH and the buoy compared well in wind speed, means and standard deviations of the differences were about 1 m/s, and fairly well in wind direction, with mean differences of approximately 10° and 5° for August and October. The scatter in the direction was very small for points where the ship was within 5 km of the buoy.

4.3.4 Air Temperature (AT)

The FRF temperature sensor was located about 40 m inland and had a strong diurnal signal relative to the buoy. Presumably this represents at least in part a real temperature difference between the land and water. Consequently comparisons are not very useful for instrument evaluation. The RVCH temperature sensor had severe data quality problems, with 13% of the air temperatures being returned as 0. In addition, it appears that the temperature resolution was only 2°C.

4.3.5 Barometric Pressure (BP)

Differences between the buoy and the RVCH were extremely small, with correlation coefficients greater than 0.99 for both time periods and regression coefficients near 1.00. There was one event about 12 hours long when in August where the *R/V Cape Hatteras* read 1 mb low. The comparison was not heavily dependent on horizontal separation.

The comparison between the buoy and the FRF revealed some systematic problems with the FRF instrument. (Note the 20-m barometric pressure measurements also agreed well with surrounding NDBC buoy data, see Figure 27). The FRF sensor apparently rounds off to the nearest millibar, and in August it was rounding down. This contributed to an average offset between the instruments of 0.53 mb. There was one event on August 12 when the FRF read 6 mb low for about 1 day. In October, the comparison degrades further, with the FRF reading, on average, 2.51 mb low, and the correlation coefficient dropping to 0.95.

4.3.6 Relative Humidity (RH)

Only the buoy and the RVCH had RH sensors. The comparison in the two months revealed that the sensor on the RVCH tended to clip the signal at 90% humidity, not recording any values greater than this. The general trends of the humidity signal did match, however, with correlation coefficients of 0.92 and 0.96 for August and October, respectively. For RH below 75%, the RVCH read 12% lower than the buoy, fairly consistently.

4.3.7 Water Temperature (WT)

The RVCH data suffered once again from severe dropout noise, much like the AT signal, but what data were left compared well to the buoy. The October data compared better but this may be due to the lack of strong surface stratification during October, as the sensors were not at the same depth. Also, data quality from the RVCH was higher during October.

4.4 SeaGauges

The data were uploaded onto an IBM compatible personal computer and converted into ASCII format using SeaSoft software supplied by SeaBird and developed specifically for this instrument. The temperature and conductivity data were processed and evaluated in the same way as the SeaCats' data. After processing was completed on the temperature and conductivity data, salinity and density time series were estimated using the formulation of Fofonoff and Millard (1983).

The time of each pressure sample was shifted forward by 2 minutes because the recorded time is the end of the sample period (4 minutes) and the pressure is averaged over the sample period. Pressure measurements from the three SeaGauges mounted on anchors along the 20-m isobath were subject to sudden shifts when the anchors dropped due to scouring during large storms. These anchor shifts were identified by comparing the pressure records from the 20-m SeaGauges with the corresponding pressure records from the 6-m SeaGauges directly onshore.

The SeaCats had pre- and post-deployment calibrations done by SeaBird Electronics at the Northwest Regional Calibration Center. SeaBird supplied the calibration coefficients. Pre-deployment calibration coefficients were used for all instruments. Pre- and post-temperature calibrations were within 0.02°C for all the SeaGauges. Pre- and post-calibrations for conductivity differed by less than 0.01 S/m with one exception. The SeaGauge at the 6-m northern site had a maximum difference between pre- and post-calibrations of 0.04 S/m. Pre- and post-calibrations of pressure agreed to within 0.02%, which corresponds to about 0.5 mb for the 20 m sites.

4.4.1 Summary of Results

There were no problems with the temperature measurements from the SeaGauges. There were problems with many of the conductivity measurements from the SeaGauges because they were near the bottom. Bias and drift corrections applied to the conductivities are listed in Section 4.4.2. The only problem with the bottom pressure measurements were anchor shifts for the three SeaGauges along the 20-m isobath (Table 11).

Table 11: Bottom Pressure Anchor Shifts

Site along 20-m isobath	SeaGauge Number	Shift	Time of Shift
North (N2)	45	8 mb	September 4
		5 mb	September 22
		25 mb	October 15
Central (D2)	48	9 mb	September 4
		1 mb	September 22
		24 mb	October 15
South (S2)	46	8 mb	October 4
		3 mb	October 22
		30 mb	November 18

4.4.2 Conductivity

Shallow SeaGauge J3: Conductivity time series truncated at 20:48 October 17. The sensor probably got buried about this time.

Shallow SeaGauge J4: Offset of 0.25 S/m was added from 20:32 October 7 to 9:48 October 11. Time series was also truncated at 20:48 October 17. This sensor was also probably buried about this time.

Southern 20-m SeaGauge: Time series was truncated at 13:16 November 17. This conductivity cell seemed to have intermittent fouling problems and hence the data are of questionable quality.

4.5 NOS Sea Level Data

Sea level data were obtained from (and maintained by) the National Ocean Service (NOS) of NOAA. The hourly heights received were formatted on diskette, with 64 ASCII characters per line. The tide gauges continuously measured sea level heights relative to the land adjacent to the station location. A constant offset was applied to each station to refer values to mean sea level (MSL).

Table 12 lists the ten long-term operating tide stations used in this report by NOAA/NOS station number, name, and last installation date for each station. It is not within the scope of this report to show historic data, but they may be obtained from NOS. The location (latitude and longitude) of each tide station were listed in Table 2.

Table 12: Long-Term Operating NOS Tide Stations

NOAA Station Number	Tide Station Name	Last Installation Date Recorded
8531680	Sandy Hook, NJ	January 1, 1910
8534720	Atlantic City, NJ	August 15, 1911
8536110	Cape May Ferry Terminal, NJ	October 25, 1965
8557380	Lewes, Ft. Miles, DE	June 1, 1952
8638610	Hampton Roads, Sewells Point, VA	July 1, 1927
8638863	Chesapeake Bay Bridge Tunnel	January 26, 1975
8651370	Duck FRF Pier, NC	December 1, 1977
8654400	Cape Hatteras Fishing Pier, NC	May 24, 1973
8656483	Duck Marine Lab, NC	January 16, 1973
8658120	Wilmington, NC	April 4, 1935

4.6 NDBC Coastal Wind Stations

To augment the moored VAWR records, coastal wind and meteorology data were obtained from the National Data Buoy Center (NDBC) who produced from its Marine Environmental Buoy Database a set of CD-ROMs containing marine meteorological, oceanographic, and wave spectra data. The data files on the CD-ROMs contain meteorological and oceanographic data collected by moored buoys and C-MAN (Coastal-Marine Automated Network) stations operated by the NOAA National Data Buoy Center. Stations of the C-MAN type are located on piers, offshore towers, lighthouses, and beaches with exposure to the marine environment. The location of the operational moored buoys and C-MAN station data used in this report were summarized in Table 2. The sensor height(+)/depth(−) information for each station are listed in Table 13. Operational specifications are listed in Table 14. There are no water temperature data recorded for buoys 44014 and 41001 during the CoOP inner-shelf study. The program used to read the air-sea parameters was written by Hans C. Graber (RSMAS/University of Miami) and Michael Caruso (WHOI).

Table 13: National Data Buoy Center Stations

Station and Anemometer Height (m)			BP (m)	AT (m)	WT (m)
44014	Virginia Beach, VA	5.0	0.0	5.0	−0.5
41001	East of Cape Hatteras	5.0	0.0	5.0	−0.5
chlv2	Chesapeake Light	43.3	41.5	22.1	0.0

Table 14: National Data Buoy Center Operational Specifications

Measurement	Sensor-Type	Reporting Range	Sampling Frequency	Averaging Period
Wind Direction (unit vector avg.)	Vane and digital magnetic compass	0 to 355 deg.	1 Hz	8 min
Wind Speed (scalar avg.)	Vane-directed impeller	0 to 61.8 m/s	1 Hz	8 min
Air Temperature (AT)	Thermistor	−40 to 50 deg. C	1 Hz	8 min
Bar. Pressure (BP)	Variable Capacitance	900 to 1100 mb	1 Hz	8 min
Surface Water Temperature (WT)	Thermistor	−6.7 to 40.6 deg. C	1 Hz	8 min

5. Description of Data Presentation

The remainder of this report provides the basic statistics and a graphical summary of the measurements obtained from the physical oceanographic component of the CoOP inner-shelf study described above. The CoOP inner-shelf data set presented here consists of edited, one hour averaged time series of the measured variables. The data presentation covers the time period between August 5th and December 4th, 1994. The vector plots are subsampled every six hours for clarity in presentation.

The locations of the moorings (D1, D2, D3, N2, and S2), and instrument sites (DP, J0, J1, J2, J3, and J4) were shown in Figure 3. The planned layout of the mooring/instrument locations were shown in Figures 4 and 14. Basic statistics are shown in Table 15. The meteorological presentation includes data from the VAWR at site D2, two NDBC meteorological moorings, one NDBC C-MAN station, and from FRF. Information about these five stations can be found in Tables 2, 3, and 14. Composite vector plots of the wind data are presented in Figure 22. Composite stacked line plots of each wind velocity component are shown in Figures 23 and 24. The time-series for each instrument have been stacked for easy comparison. All wind (and current) time series have been rotated into the standard coordinate system (along-shelf is positive towards 340°T, cross-shelf is positive towards 70°T). Time series of the hourly averaged VAWR atmospheric pressure, air temperature, relative humidity, and long- and short-wave radiation are shown in Figure 25. Composite plots of air temperature and atmospheric pressure from the five meteorological stations are shown in Figures 26 and 27, respectively. A composite plot of the surface water temperature from the VAWR (site D2), and NDBC Chesapeake Light (site CL) is shown in Figure 28.

Bottom pressures (millibars) are shown as composite plots in Figures 29 and 30. The time series for sea level (centimeters) are shown in Figure 31 and are stacked vertically on the same time base. The sea level stations are plotted from north to south, onshore to offshore. Locations for the sea level pressure stations were listed in Table 2 and shown in Figure 3.

Composite vector plots of the WHOI moored currents are presented in Figure 32. Composite stacked line plots of each current velocity component are shown in Figures 33 and 34. The time-series for each instrument have been stacked for easy comparison.

Composite stacked plots of the hourly averaged individual salinity, conductivity, and temperature records by mooring/instrument-site are presented in Figures 35–49. The time series for each VMCM measurement depth (currents and temperature) are plotted on the same time base in the form of vector and line plots, of the hourly averaged current components and water temperature, and are shown in Figures 50–65. The instrument depths noted by each record plotted have been rounded to the nearest integer. The actual measured instrument sensor depths were listed in Tables 3 and 4 (Instrumentation Summaries, Section 2), and Table 15 (Statistics, Section 6).

6. Statistics

The basic statistics for the hourly-averaged data covering the entire time period for each record are shown in Table 15.

Table 15: Statistics of Hourly-Averaged Data

Sta	Water Depth (m)	GMT Start Time (y m d/hm)	GMT Stop Time (y m d/hm)	Days	Sensor Height (m)	Mean	Std Dev	Max	Min
Cross-Shelf Wind (m/s)									
D2	21.0	940807/0100	940904/0000	28	-3.37	-0.70	4.07	8.55	-11.30
D2	21.0	941004/1500	941118/0800	45	-3.37	-2.12	5.00	13.02	-13.58
FR	-	940801/0700	941201/0400	122	-19.50	-0.71	4.73	13.37	-15.83
CL	-	940801/0000	941130/0700	121	-43.30	-0.57	5.95	17.58	-21.34
VA	-	940701/0000	941130/2300	153	-5.00	0.63	4.74	14.72	-16.59
EH	-	940801/0000	940921/0700	51	-5.00	-0.28	5.71	14.87	-22.93
Along-Shelf Wind (m/s)									
D2	21.0	940807/0100	940904/0000	28	-3.37	-0.09	3.52	8.39	-8.06
D2	21.0	941004/1500	941118/0800	45	-3.37	-1.98	4.00	7.01	-12.86
FR	-	940801/0700	941201/0400	122	-19.50	-1.45	5.00	13.62	-16.40
CL	-	940801/0000	941130/0700	121	-43.30	-0.46	5.58	22.03	-20.62
VA	-	940701/0000	941130/2300	153	-5.00	-0.26	5.12	15.66	-15.25
EH	-	940801/0000	940921/0700	51	-5.00	0.52	5.42	12.40	-16.09
Atmospheric Pressure (mbars)									
D2	21.0	940807/0100	940904/0000	28	-2.78	1018.19	3.79	1025.94	1006.91
D2	21.0	941004/1500	941118/0800	45	-2.78	1019.12	5.67	1028.65	996.74
FR	-	940801/0700	941201/0400	122	–	1016.83	4.83	1027.61	995.00
CL	-	940801/0000	941130/0700	121	-41.50	1018.84	5.16	1029.70	996.00
VA	-	940701/0000	941130/2300	153	0.00	1018.58	4.56	1028.40	997.30
EH	-	940801/0000	940921/0700	51	0.00	1018.42	4.97	1027.60	1002.70
Air Temperature (°C)									
D2	21.0	940807/0100	940904/0000	28	-2.71	23.09	1.76	28.12	19.42
D2	21.0	941004/1500	941118/0800	45	-2.71	17.12	2.17	22.48	10.82
FR	-	940801/0700	941201/0400	122	–	19.46	4.82	32.14	3.33
CL	-	940801/0000	941130/0700	121	-22.10	18.75	4.23	31.70	3.00
VA	-	940701/0000	941130/2300	153	-5.00	21.18	4.09	28.40	5.10
EH	-	940801/0000	940921/0700	51	-5.00	21.63	3.33	28.40	9.80
Surface Water Temperature (°C)									
CL	-	940801/0000	941118/1200	110	0.00	20.43	2.62	25.30	15.80
D2	21.0	940807/0100	941018/1800	73	1.12	19.62	2.44	25.33	15.30
Relative Humidity (%)									
D2	21.0	940807/0100	940904/0000	28	-2.71	86.17	7.83	97.63	60.72
D2	21.0	941004/1500	941118/0800	45	-2.71	78.55	11.24	97.93	52.06
Long-Wave Insolation (W/m^2)									
D2	21.0	940807/0100	940904/0000	28	-3.42	393.37	28.06	455.25	321.97
D2	21.0	941004/1500	941118/0800	45	-3.42	337.86	36.42	415.94	263.51

Table 15: Statistics of Hourly-Averaged Data (continued)

Sta	Water Depth (m)	GMT Start Time (y m d/hm)	GMT Stop Time (y m d/hm)	Days	Sensor Height (m)	Mean	Std Dev	Max	Min
				Short-Wave Insolation (W/m^2)					
D2	21.0	940807/0100	940904/0000	28	-3.42	236.42	310.04	1010.55	4.17
D2	21.0	941004/1500	941118/0800	45	-3.42	161.14	234.32	813.08	4.09
				Bottom Pressure (mbars)					
J0	4.8	940820/1700	941029/1300	70	4.30	1454.47	38.84	1553.25	1364.97
J1	6.5	940725/1800	941029/1400	96	5.90	1610.44	38.85	1710.63	1520.09
J2	6.1	940724/2200	941029/1400	97	5.60	1587.02	38.30	1686.12	1500.17
J3	4.2	940810/1600	941030/1400	81	3.70	1392.48	38.28	1496.40	1302.78
J4	5.1	940810/1700	941030/1300	81	4.60	1477.30	38.04	1579.87	1387.89
N2	19.4	940810/1800	941203/1100	115	18.60	2870.15	41.49	2986.21	2770.72
D2	21.3	940810/1200	941204/1200	116	20.70	3084.15	40.46	3189.67	2987.00
S2	20.8	940810/2200	941204/1600	116	20.20	3032.24	39.49	3133.46	2938.19
				Sea Level (cm)					
SH	0.0	940801/0000	941231/2300	153	0.00	7.68	54.98	131.06	-151.18
AC	0.0	940801/0000	941231/2300	153	0.00	9.07	47.76	122.83	-135.64
CM	0.0	940801/0000	941231/2300	153	0.00	9.50	56.08	143.56	-140.82
LE	0.0	940801/0000	941231/2300	153	0.00	8.22	48.94	134.11	-134.42
HR	0.0	940801/0000	941231/2300	153	0.00	11.62	33.37	129.84	-76.50
CB	0.0	940801/0000	941231/2300	153	0.00	14.44	34.16	127.41	-80.16
DU	0.0	940801/0000	941231/2300	153	0.00	12.02	39.98	115.21	-98.15
CH	0.0	940801/0000	941231/2300	153	0.00	14.32	37.01	145.69	-89.31
ML	0.0	940801/0000	941231/2300	153	0.00	14.59	36.74	116.43	-80.47
WL	0.0	940801/0000	941231/2300	153	0.00	8.72	47.50	110.64	-102.11
				Conductivity (S/m)					
D1	13.0	940807/0100	941012/1900	67	1.50	4.35	0.25	4.87	3.83
D1	13.0	940807/0100	941008/1100	62	7.65	4.49	0.17	4.81	4.04
D1	13.5	940807/1600	941101/1600	86	12.20	4.43	0.23	4.77	3.69
D2	21.0	940807/0100	941018/1800	73	2.00	4.26	0.32	4.86	3.41
D2	21.0	940807/0100	941018/1800	73	7.62	4.35	0.29	4.93	3.70
D2	19.5	940810/1600	941204/1300	116	12.68	4.35	0.32	4.87	3.63
D2	19.5	940810/1600	941020/2300	71	18.17	4.53	0.16	4.85	3.95
D3	26.0	940807/0100	941110/1800	96	2.17	4.54	0.26	5.09	3.67
D3	26.0	940807/0100	941110/1800	96	7.60	4.61	0.29	5.64	4.13
D3	25.5	940809/2300	941203/2100	116	13.67	4.45	0.28	5.13	3.75
D3	25.5	940809/2300	941203/2100	116	24.17	4.46	0.24	5.11	3.95
DP	8.0	940726/1700	941101/1400	98	4.00	4.23	0.33	4.83	3.41
DP	8.0	940726/1700	941008/1900	74	7.00	4.22	0.29	4.78	3.40
J0	4.8	940820/1700	941029/1300	70	4.30	4.06	0.35	4.70	3.23
J1	6.5	940725/1800	941029/1400	96	5.90	4.11	0.27	4.62	3.29
J3	4.2	940810/1600	941017/2000	68	3.70	4.25	0.30	4.83	3.46
J4	5.1	940810/1700	941017/2000	68	4.60	4.27	0.30	4.78	3.58
N2	18.5	940810/1800	941203/1300	115	0.67	4.13	0.36	4.83	3.10
N2	19.4	940810/1800	941203/1100	115	18.60	4.17	0.30	4.61	3.49
S2	20.5	940810/2200	941204/1600	116	0.63	4.26	0.37	5.04	3.29
S2	20.8	940810/2200	941117/1200	99	20.20	4.38	0.26	4.79	3.58

Table 15: Statistics of Hourly-Averaged Data (Continued)

Sta	Water Depth (m)	GMT Start Time (y m d/hm)	GMT Stop Time (y m d/hm)	Days	Sensor Height (m)	Mean	Std Dev	Max	Min
Salinity (psu)									
D1	13.0	940807/0100	941012/1900	67	1.50	30.25	2.14	34.98	24.94
D1	13.0	940807/0100	941008/1100	62	7.65	31.79	1.72	35.03	27.08
D1	13.5	940807/1600	941101/1600	86	12.20	32.24	1.50	35.10	27.87
D2	21.0	940807/0100	941018/1800	73	2.12	31.03	1.50	34.37	26.24
D2	21.0	940807/0100	941018/1800	73	7.62	31.95	1.32	34.69	28.31
D2	19.5	940810/1600	941204/1300	116	12.68	32.30	1.33	35.10	28.79
D2	19.5	940810/1600	941020/2300	71	18.17	33.03	1.26	35.11	29.06
D3	26.0	940807/0100	941110/1800	96	2.17	32.12	1.06	34.37	27.69
D3	26.0	940807/0100	941110/1800	96	7.60	32.86	0.88	35.84	31.37
D3	25.5	940809/2300	941203/2100	116	13.67	33.10	1.02	35.25	31.01
D3	25.5	940809/2300	941203/2100	116	24.17	33.38	1.02	35.24	31.62
DP	8.0	940726/1700	941101/1400	98	4.00	30.45	2.42	34.93	24.29
DP	8.0	940726/1700	941008/1900	74	7.00	30.17	2.35	34.26	23.94
J0	4.8	940820/1700	941029/1300	70	4.30	28.81	2.41	34.24	23.36
J1	6.5	940725/1800	941029/1400	96	5.90	29.76	2.29	33.81	23.61
J3	4.2	940810/1600	941017/2000	68	3.70	29.85	2.23	34.26	23.29
J4	5.1	940810/1700	941017/2000	68	4.60	30.05	2.15	34.18	24.73
N2	18.5	940810/1800	941203/1300	115	0.67	30.10	1.82	34.72	25.30
N2	19.4	940810/1800	941203/1100	115	18.60	31.18	1.61	34.75	27.72
S2	20.5	940810/2200	941203/1600	115	0.63	30.91	1.59	35.17	25.66
S2	20.8	940810/2200	941117/1200	99	20.20	32.01	1.77	35.25	26.34
Sigma-Theta (kg/m^3)									
D1	13.0	940807/0100	941012/1900	67	1.50	20.69	1.81	25.37	15.80
D1	13.0	940807/0100	941008/1100	62	7.65	22.04	1.58	25.46	17.89
D1	13.5	940807/1600	941101/1600	86	12.20	22.70	1.29	25.52	18.81
D2	21.0	940807/0100	941018/1800	73	2.12	21.83	1.14	24.60	18.64
D2	21.0	940807/0100	941018/1800	73	7.62	22.62	0.99	25.10	20.13
D2	19.5	940810/1600	941204/1300	116	12.68	23.00	0.98	25.51	20.22
D2	19.5	940810/1600	941020/2300	71	18.17	23.29	1.21	25.52	20.41
D3	26.0	940807/0100	941110/1800	96	2.17	22.27	0.93	23.84	18.24
D3	26.0	940807/0100	941110/1800	96	7.60	22.90	0.46	24.49	21.34
D3	25.5	940809/2300	941203/2100	116	13.67	23.58	0.77	25.61	22.23
D3	25.5	940809/2300	941203/2100	116	24.17	23.87	0.87	25.69	22.22
DP	8.0	940726/1700	941101/1400	98	4.00	21.26	2.04	25.39	16.13
DP	8.0	940726/1700	941008/1900	74	7.00	20.99	2.06	25.45	15.86
J0	4.8	940820/1700	941029/1300	70	4.30	19.91	1.96	24.74	14.77
J1	6.5	940725/1800	941029/1400	96	5.90	20.82	2.08	25.08	15.53
J3	4.2	940810/1600	941017/2000	68	3.70	20.56	1.84	24.83	15.38
J4	5.1	940810/1700	941017/2000	68	4.60	20.72	1.77	24.61	16.36
N2	18.5	940810/1800	941203/1300	115	0.67	21.15	1.59	25.17	16.10
N2	19.4	940810/1800	941203/1100	115	18.60	22.26	1.24	25.27	19.74
S2	20.5	940810/2200	941203/1600	115	0.63	21.67	1.28	24.85	18.38
S2	20.8	940810/2200	941117/1200	99	20.20	22.58	1.45	25.27	18.47

Table 15: Statistics of Hourly-Averaged Data (Continued)

Sta	Water Depth (m)	GMT Start Time (y m d/hm)	GMT Stop Time (y m d/hm)	Days	Sensor Height (m)	Mean	Std Dev	Max	Min
Cross-Shelf Velocity (cm/s)									
D1	13.0	940807/0100	941012/1900	67	4.15	-1.47	4.61	12.36	-21.85
D1	13.0	940807/0100	941012/1900	67	6.45	-0.17	4.06	17.58	-18.32
D1	13.5	940807/1600	941101/1600	86	8.70	-0.86	4.03	24.82	-17.59
D1	13.5	940807/1600	941101/1600	86	11.00	-0.12	4.12	24.38	-18.75
D2	21.0	940807/0100	940904/0000	28	4.15	-1.56	7.53	23.19	-29.72
D2	21.0	940807/0100	940904/0000	28	6.45	1.61	7.23	26.81	-15.10
D2	21.0	940807/0100	940904/0000	28	8.75	0.55	6.12	22.53	-20.28
D2	19.5	940810/1600	941204/1300	116	11.50	-0.61	5.19	24.37	-19.99
D2	19.5	940810/1600	941204/1300	116	14.50	-0.90	5.06	23.27	-23.36
D2	19.5	940810/1600	941204/1300	116	17.00	-1.70	4.96	18.75	-21.70
D3	26.0	940807/0100	941110/1800	96	4.15	-1.87	9.42	35.41	-41.93
D3	26.0	940807/0100	941110/1800	96	6.45	-1.99	7.03	21.40	-34.87
D3	26.0	940807/0100	941110/1800	96	8.75	-1.32	5.71	19.49	-21.51
D3	25.5	940809/2300	941203/2100	116	12.50	-2.22	6.71	28.40	-32.65
D3	25.5	940809/2300	941203/2100	116	17.50	-1.90	5.92	25.99	-22.95
D3	25.5	940809/2300	941203/2100	116	23.00	-1.81	5.75	20.12	-25.03
Along-Shelf Velocity (cm/s)									
D1	13.0	940807/0100	941012/1900	67	4.15	-13.38	28.45	38.40	-102.08
D1	13.0	940807/0100	941012/1900	67	6.45	-9.83	22.71	28.86	-85.25
D1	13.5	940807/1600	941101/1600	86	8.70	-7.28	17.07	25.50	-80.34
D1	13.5	940807/1600	941101/1600	86	11.00	-4.74	12.36	20.56	-64.50
D2	21.0	940807/0100	940904/0000	28	4.15	-10.86	23.89	40.35	-69.13
D2	21.0	940807/0100	940904/0000	28	6.45	-10.00	20.84	31.11	-73.43
D2	21.0	940807/0100	940904/0000	28	8.75	-8.58	19.26	38.98	-74.59
D2	19.5	940810/1600	941204/1300	116	11.50	-5.02	17.63	47.39	-75.48
D2	19.5	940810/1600	941204/1300	116	14.50	-4.21	15.22	37.09	-64.45
D2	19.5	940810/1600	941204/1300	116	17.00	-2.37	11.79	27.27	-52.02
D3	26.0	940807/0100	941110/1800	96	4.15	-9.86	17.10	44.17	-62.42
D3	26.0	940807/0100	941110/1800	96	6.45	-8.17	15.36	43.85	-58.66
D3	26.0	940807/0100	941110/1800	96	8.75	-6.20	14.45	48.30	-54.80
D3	25.5	940809/2300	941203/2100	116	12.50	-5.20	17.61	61.50	-74.65
D3	25.5	940809/2300	941203/2100	116	17.50	-3.67	16.75	43.61	-69.47
D3	25.5	940809/2300	941203/2100	116	23.00	-2.73	12.02	26.09	-57.55

Table 15: Statistics of Hourly-Averaged Data (Continued)

Sta/ Inst Type[1]	Water Depth (m)	GMT Start Time (y m d/hm)	GMT Stop Time (y m d/hm)	Days	Sensor Height (m)	Mean	Std Dev	Max	Min
Water Temperature (°C)									
DP sc	8.0	940726/1700	941101/1400	98	4.00	20.05	2.31	24.26	14.74
DP sc	8.0	940726/1700	941101/1400	98	7.00	19.74	2.22	24.03	14.50
J0 tg	4.8	940820/1700	941029/1300	70	4.30	20.47	2.17	24.64	15.64
J1 tg	6.5	940725/1800	941029/1400	96	5.90	19.72	2.40	24.11	14.11
J2 tg	6.1	940724/2200	941029/1400	97	5.60	19.81	2.34	24.01	14.50
J3 tg	4.2	940810/1600	941030/1400	81	3.70	20.48	2.17	25.12	15.99
J4 tg	5.1	940810/1700	941030/1300	81	4.60	20.44	2.15	24.68	15.68
N2 sc	18.5	940810/1800	941203/1300	115	0.67	19.37	3.17	25.80	11.27
N2 tg	19.4	940810/1800	941203/1100	115	18.60	18.30	2.14	22.08	13.44
S2 sc	20.5	940810/2200	941203/1600	115	0.63	19.75	2.96	24.92	11.83
S2 tg	20.8	940810/2200	941204/1600	116	20.20	18.87	2.34	23.41	13.57
D1 sc	13.0	940807/0100	941012/1900	67	1.50	21.69	1.40	24.92	17.52
D1 vm	13.0	940807/0100	941012/1900	67	4.65	21.33	1.37	24.01	17.46
D1 vm	13.0	940807/0100	941012/1900	67	6.95	21.03	1.43	23.99	17.17
D1 sc	13.0	940807/0100	941008/1100	62	7.65	21.02	1.44	23.97	17.14
D1 vm	13.5	940807/1600	941101/1600	86	9.20	19.94	1.81	23.94	16.78
D1 vm	13.5	940807/1600	941101/1600	86	11.50	19.81	1.76	23.78	16.91
D1 sc	13.5	940807/1600	941101/1600	86	12.20	19.77	1.75	23.77	16.95
D2 vawr	21.0	940807/0100	941018/1800	73	1.12	19.62	2.44	25.33	15.30
D2 sc	21.0	940807/0100	941018/1800	73	2.12	19.54	2.36	24.71	15.30
D2 vm	21.0	940807/0100	941018/1800	73	4.65	19.39	2.19	24.31	15.56
D2 vm	21.0	940807/0100	940904/0000	28	6.95	21.21	1.66	23.93	17.80
D2 sc	21.0	940807/0100	941018/1800	73	7.62	19.22	2.11	23.87	15.59
D2 vm	21.0	940807/0100	941018/1800	73	9.25	19.06	2.02	23.88	15.70
D2 vm	19.5	940810/1600	941204/1300	116	12.00	18.77	2.46	23.65	13.48
D2 sc	19.5	940810/1600	941204/1300	116	12.68	18.75	2.44	23.64	13.48
D2 vm	19.5	940810/1600	941204/1300	116	15.00	18.68	2.34	23.47	13.49
D2 vm	19.5	940810/1600	941204/1300	116	17.50	18.63	2.26	23.11	13.54
D2 sc	19.5	940810/1600	941204/1300	116	18.17	18.63	2.25	23.14	13.58
D2 tg	21.3	940810/1200	941204/1200	116	20.70	18.60	2.23	23.32	13.51
D3 sc	26.0	940807/0100	941110/1800	96	2.17	21.04	2.19	25.08	17.09
D3 vm	26.0	940807/0100	941110/1800	96	4.65	20.89	2.10	25.46	17.11
D3 vm	26.0	940807/0100	941110/1800	96	6.95	20.80	2.06	26.83	17.10
D3 sc	26.0	940807/0100	941110/1800	96	7.60	20.80	2.06	27.05	17.11
D3 vm	26.0	940807/0100	941110/1800	96	9.25	20.72	1.97	26.48	17.16
D3 vm	25.5	940809/2300	941203/2100	116	13.00	18.94	2.24	23.70	13.71
D3 sc	25.5	940809/2300	941203/2100	116	13.67	18.85	2.20	23.45	13.73
D3 vm	25.5	940809/2300	941203/2100	116	18.00	18.58	2.12	23.22	13.89
D3 vm	25.5	940809/2300	941203/2100	116	23.50	18.57	2.05	22.80	14.58
D3 sc	25.5	940809/2300	941203/2100	116	24.17	18.58	2.05	22.80	14.61

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[1] sc=SeaCat, vm=VMCM, tg=tide gauge

7. Acknowledgments

The efforts of a great many people contributed to the success of the Physical Oceanographic component of the CoOP inner-shelf study described here. The authors would like to take this opportunity to express their appreciation to Craig Marquette for his part in the design and execution of the bottom pressure array, and management of the field work. The moorings were designed by George Tupper and prepared by the WHOI Rigging Shop under the direction of David Simoneau. The instrumentation was prepared by Bryan Way and Craig Marquette. Will Ostrom was instrumental in preparing the moorings for deployment and supervising the deployment and recovery operations during the cruise. Thanks also to Walt Waldorf, from Oregon State University, for his help in providing the CoOP inner-shelf study CTD sections.

The officers and crew of the *R/V Endeavor* (University of Rhode Island) did a fine job of handling the ship for deployments and recoveries, contributing significantly to the safety of the seagoing operations. The authors would like to express their appreciation to the U.S. Army Corps of Engineers CERC Field Research Facility (FRF) for providing essential support to the field program. This study was supported by the Ocean Sciences Division of the National Science Foundation under Grant OCE-9221615, and this support is gratefully acknowledged.

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9. Data Presentation

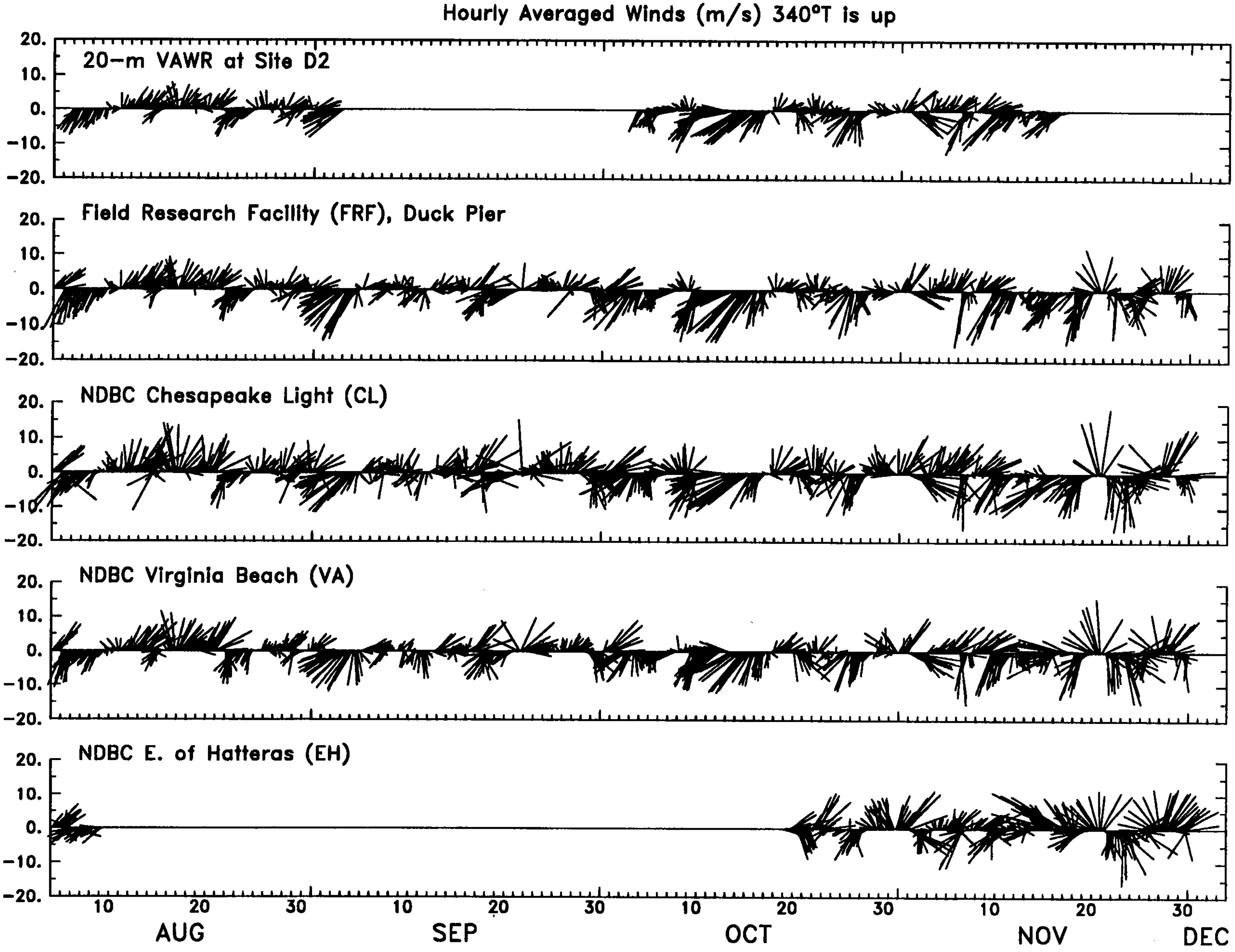

Hourly Averaged Winds (m/s) 340°T is up
20-m VAWR at Site D2
Field Research Facility (FRF), Duck Pier
NDBC Chesapeake Light (CL)
NDBC Virginia Beach (VA)
NDBC E. of Hatteras (EH)
20.
10.
0.
-10.
-20.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 22

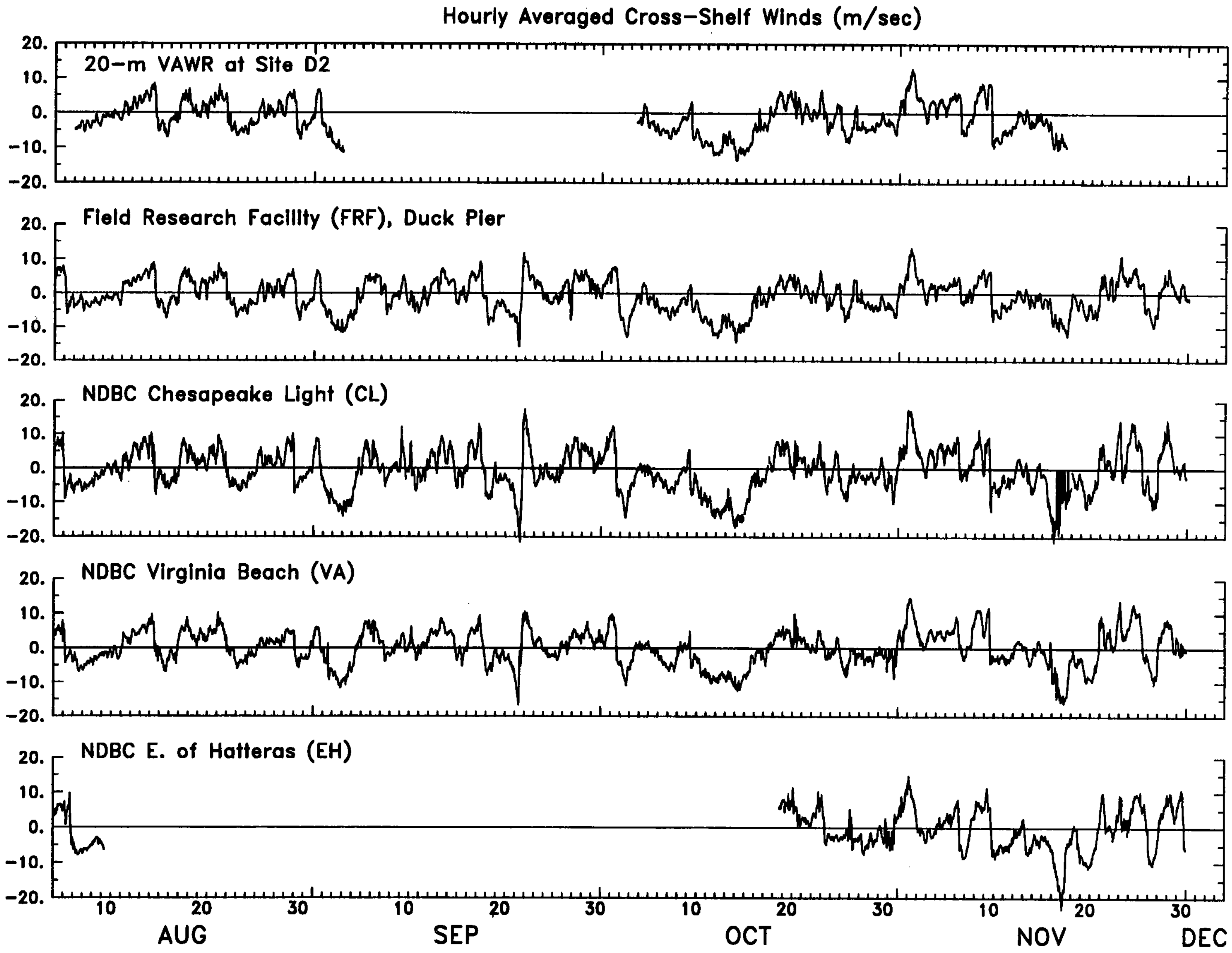

Hourly Averaged Cross-Shelf Winds (m/sec)
20-m VAWR at Site D2
Field Research Facility (FRF), Duck Pier
NDBC Chesapeake Light (CL)
NDBC Virginia Beach (VA)
NDBC E. of Hatteras (EH)
20.
10.
0.
-10.
-20.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 23

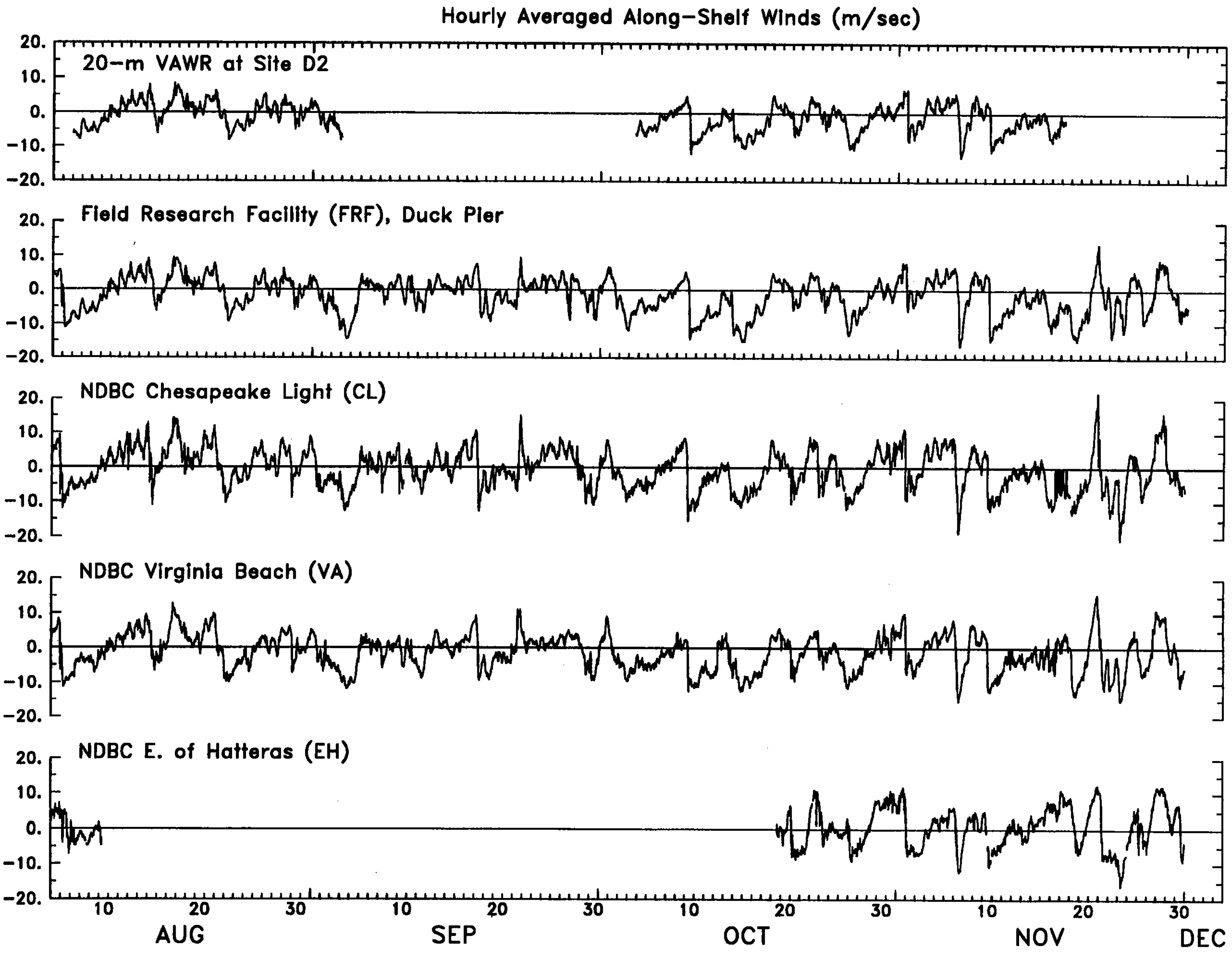

Hourly Averaged Along−Shelf Winds (m/sec)
20−m VAWR at Site D2
Field Research Facility (FRF), Duck Pier
NDBC Chesapeake Light (CL)
NDBC Virginia Beach (VA)
NDBC E. of Hatteras (EH)
20.
10.
0.
−10.
−20.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 24

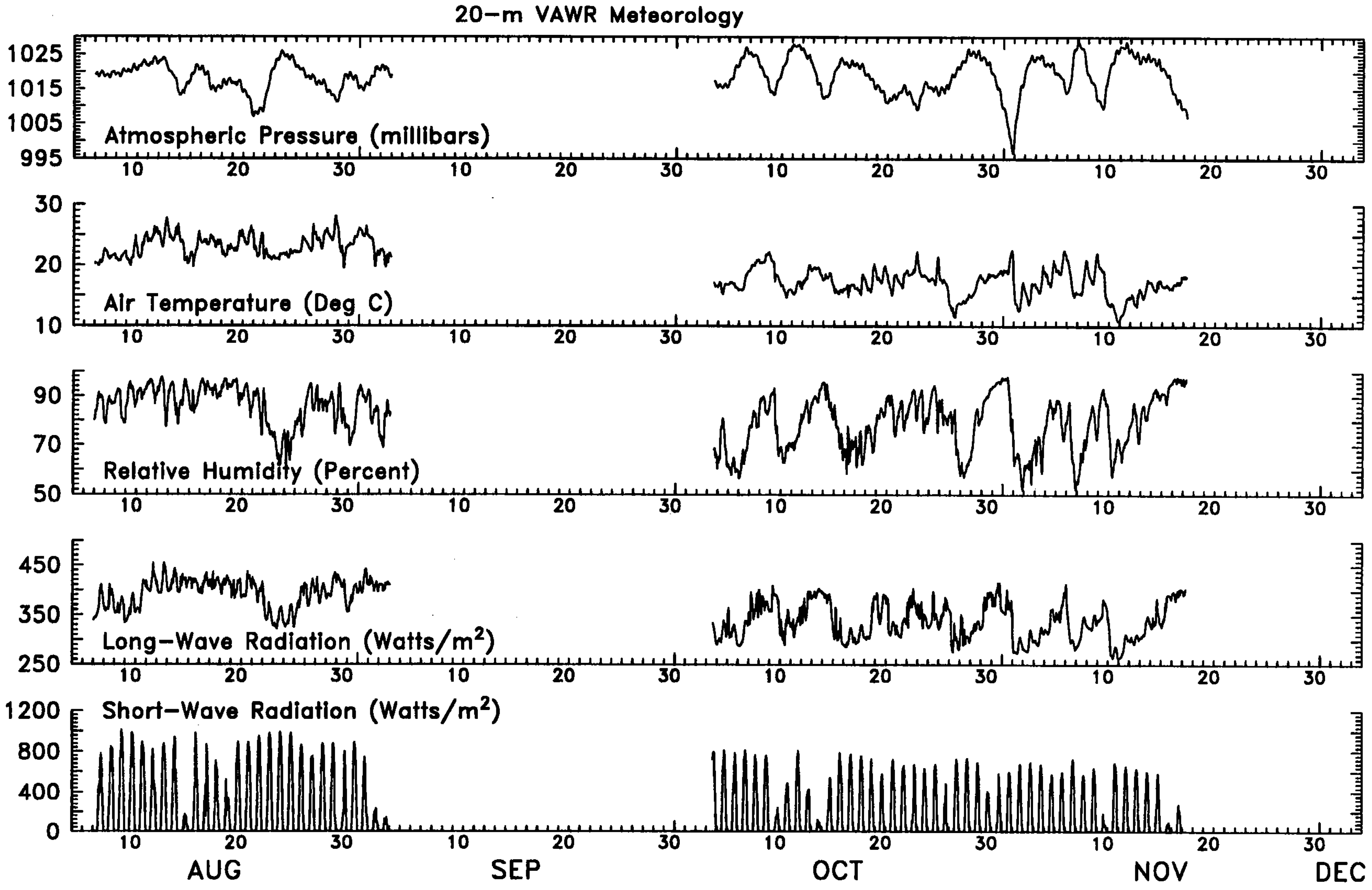

20-m VAWR Meteorology
Atmospheric Pressure (millibars)
1025
1015
1005
995
Air Temperature (Deg C)
30
20
10
Relative Humidity (Percent)
90
70
50
Long-Wave Radiation (Watts/m²)
450
350
250
Short-Wave Radiation (Watts/m²)
1200
800
400
0
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 25

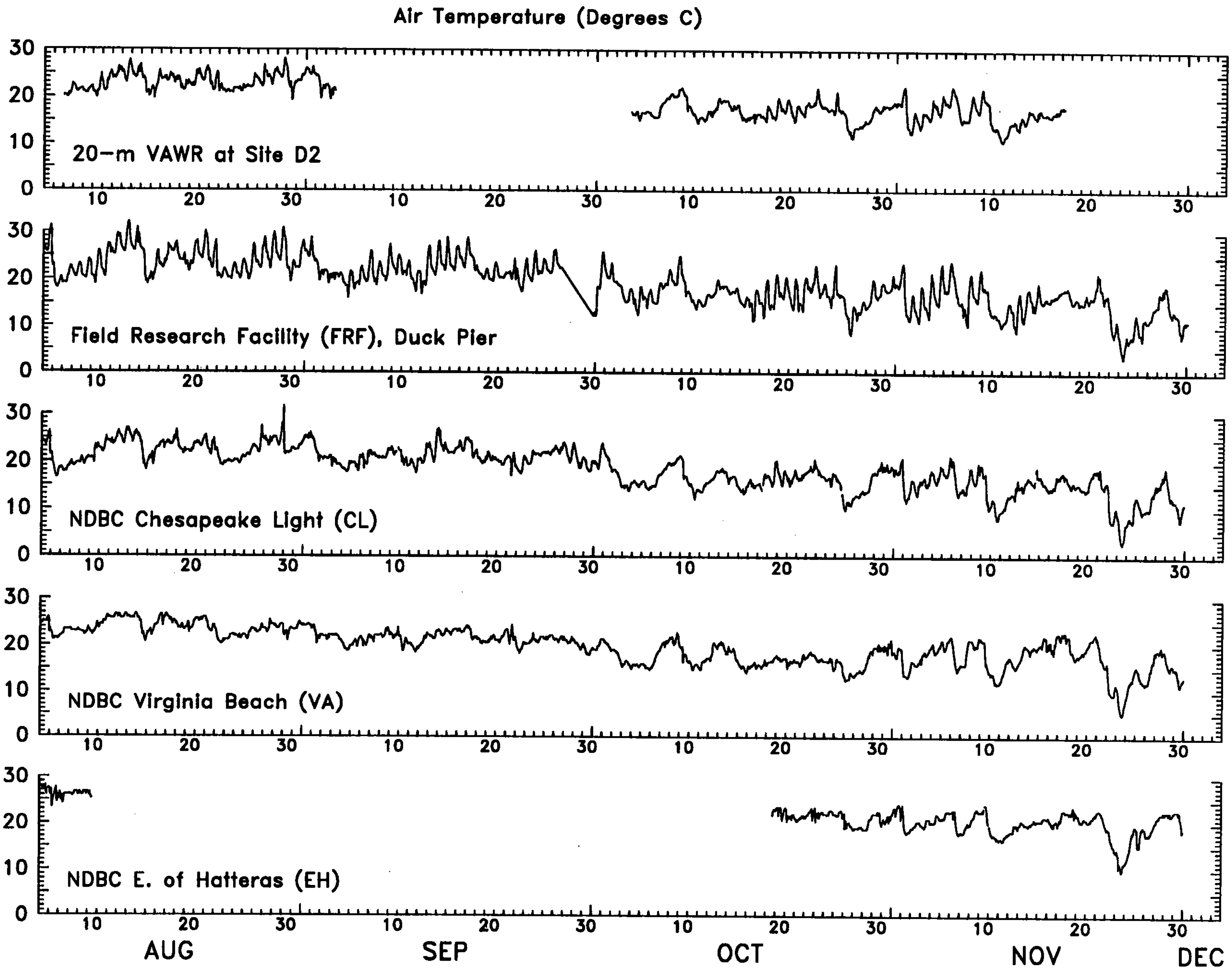

Air Temperature (Degrees C)
20–m VAWR at Site D2
Field Research Facility (FRF), Duck Pier
NDBC Chesapeake Light (CL)
NDBC Virginia Beach (VA)
NDBC E. of Hatteras (EH)
30
20
10
0
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 26

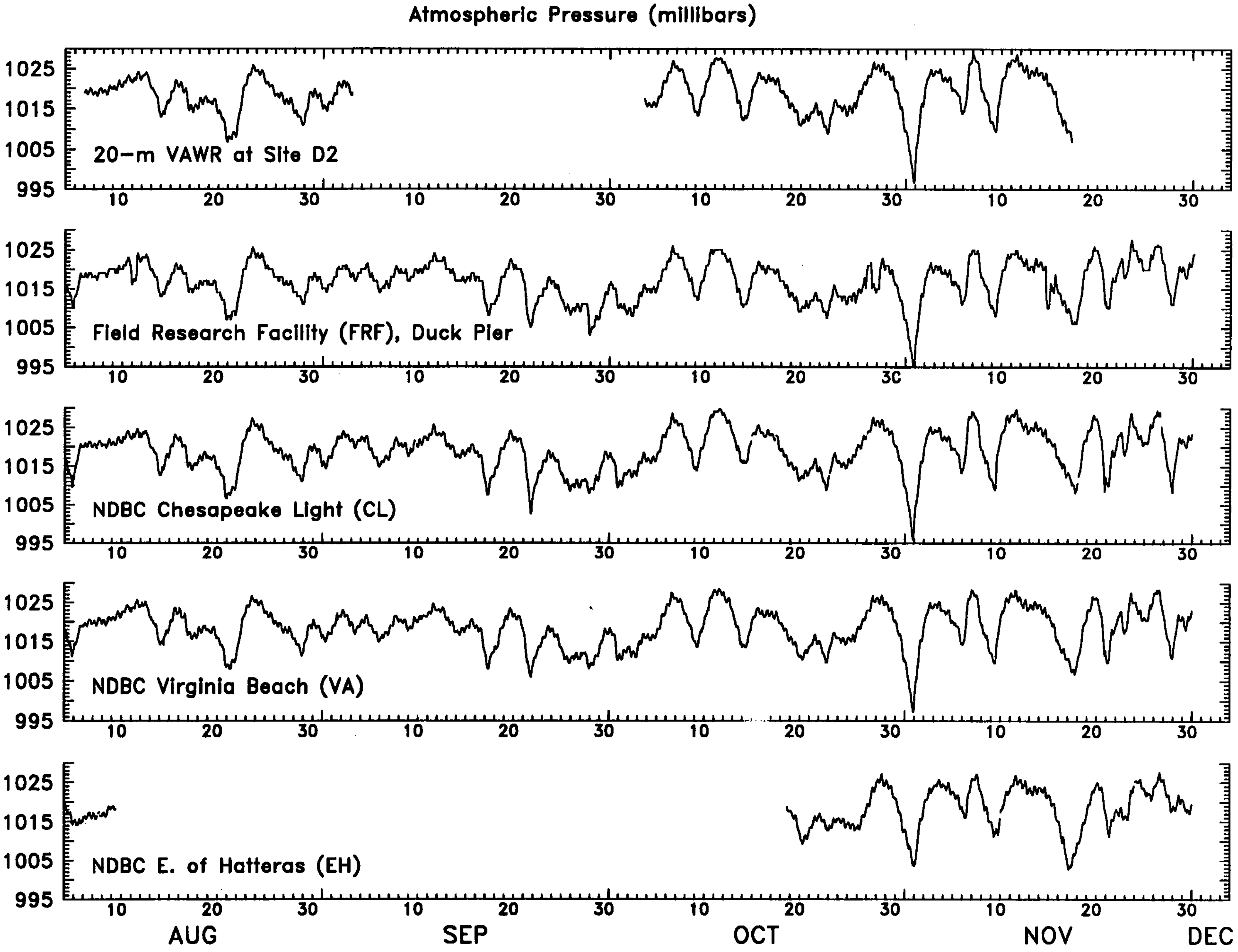

Atmospheric Pressure (millibars)
20–m VAWR at Site D2
Field Research Facility (FRF), Duck Pier
NDBC Chesapeake Light (CL)
NDBC Virginia Beach (VA)
NDBC E. of Hatteras (EH)
1025
1015
1005
995
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 27

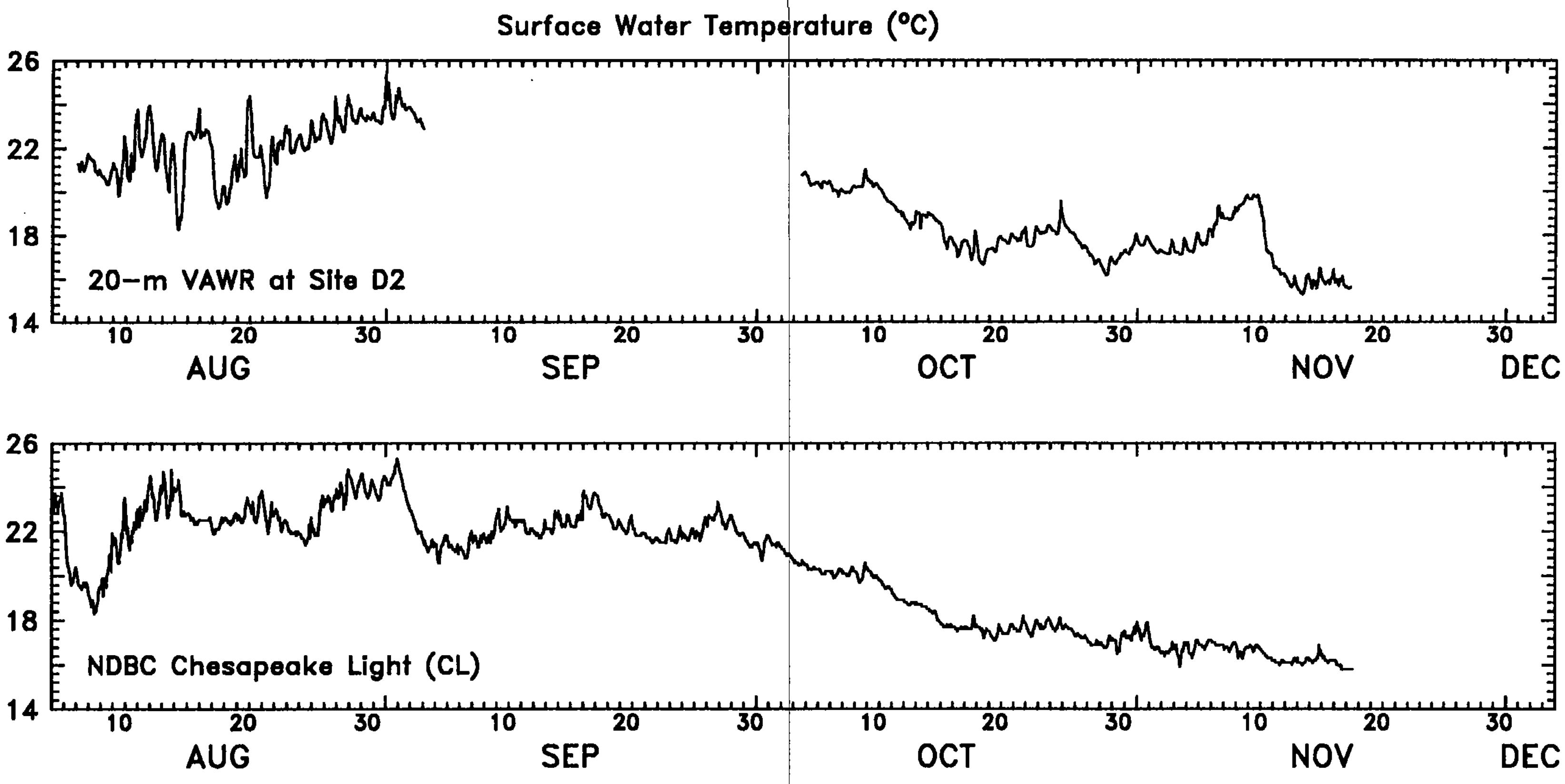

Surface Water Temperature (°C)
20–m VAWR at Site D2
NDBC Chesapeake Light (CL)
26
22
18
14
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 28

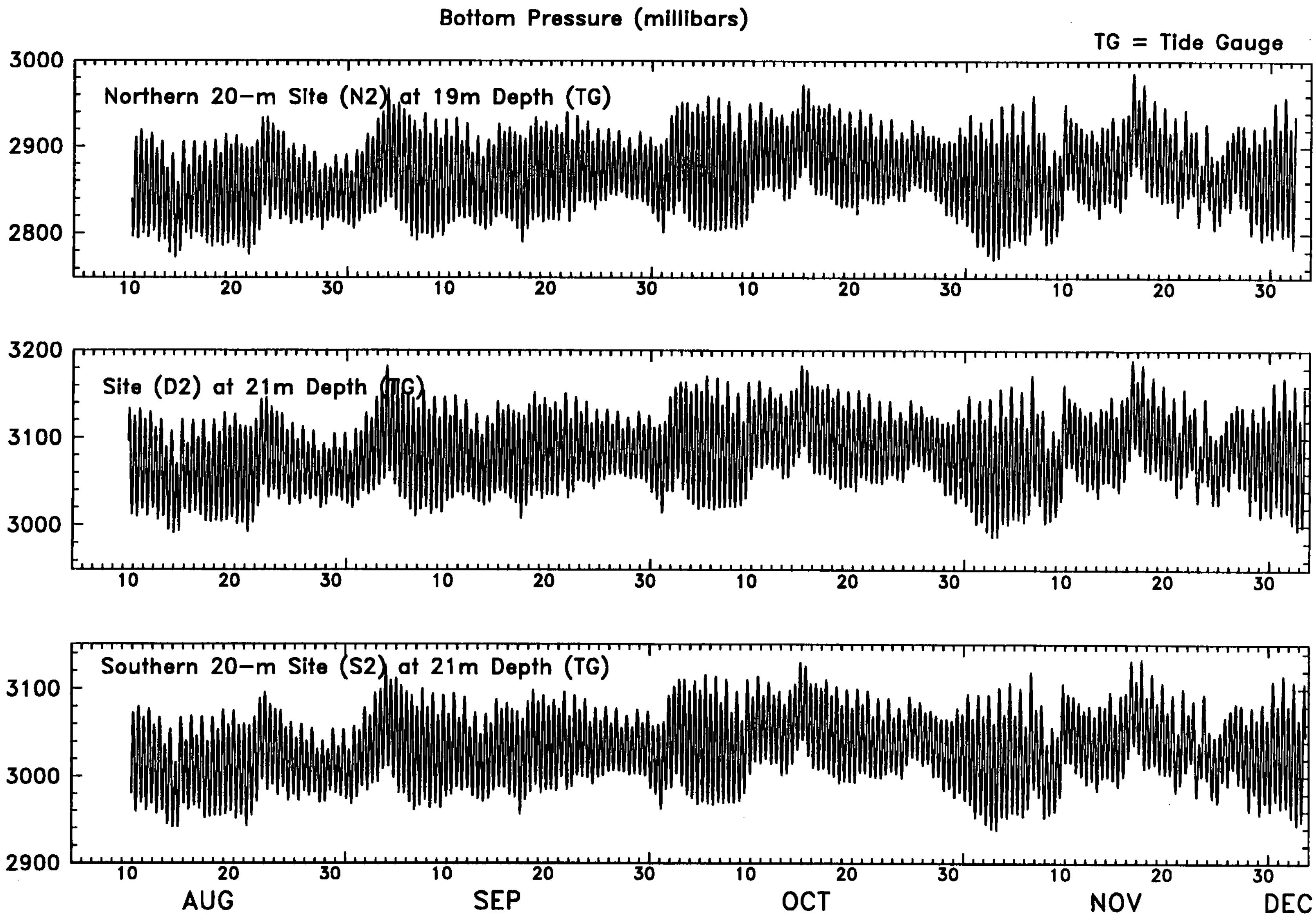

Bottom Pressure (millibars)
TG = Tide Gauge
Northern 20–m Site (N2) at 19m Depth (TG)
3000
2900
2800
Site (D2) at 21m Depth (TG)
3200
3100
3000
Southern 20–m Site (S2) at 21m Depth (TG)
3100
3000
2900
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 29

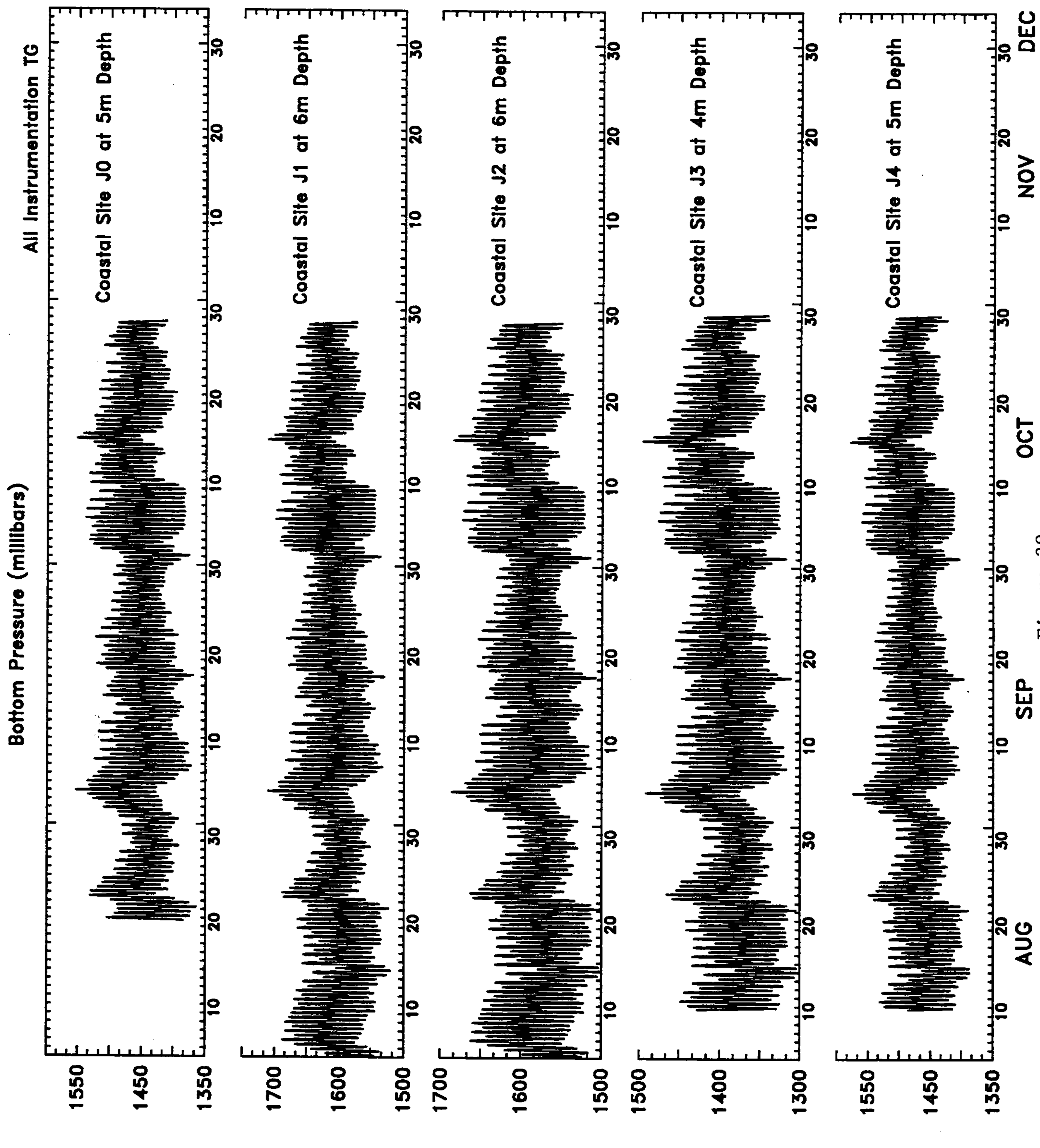

Bottom Pressure (millibars)
All Instrumentation TG
Coastal Site J0 at 5m Depth
Coastal Site J1 at 6m Depth
Coastal Site J2 at 6m Depth
Coastal Site J3 at 4m Depth
Coastal Site J4 at 5m Depth
1550
1450
1350
1700
1600
1500
1700
1600
1500
1500
1400
1300
1550
1450
1350
10
20
30
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 30

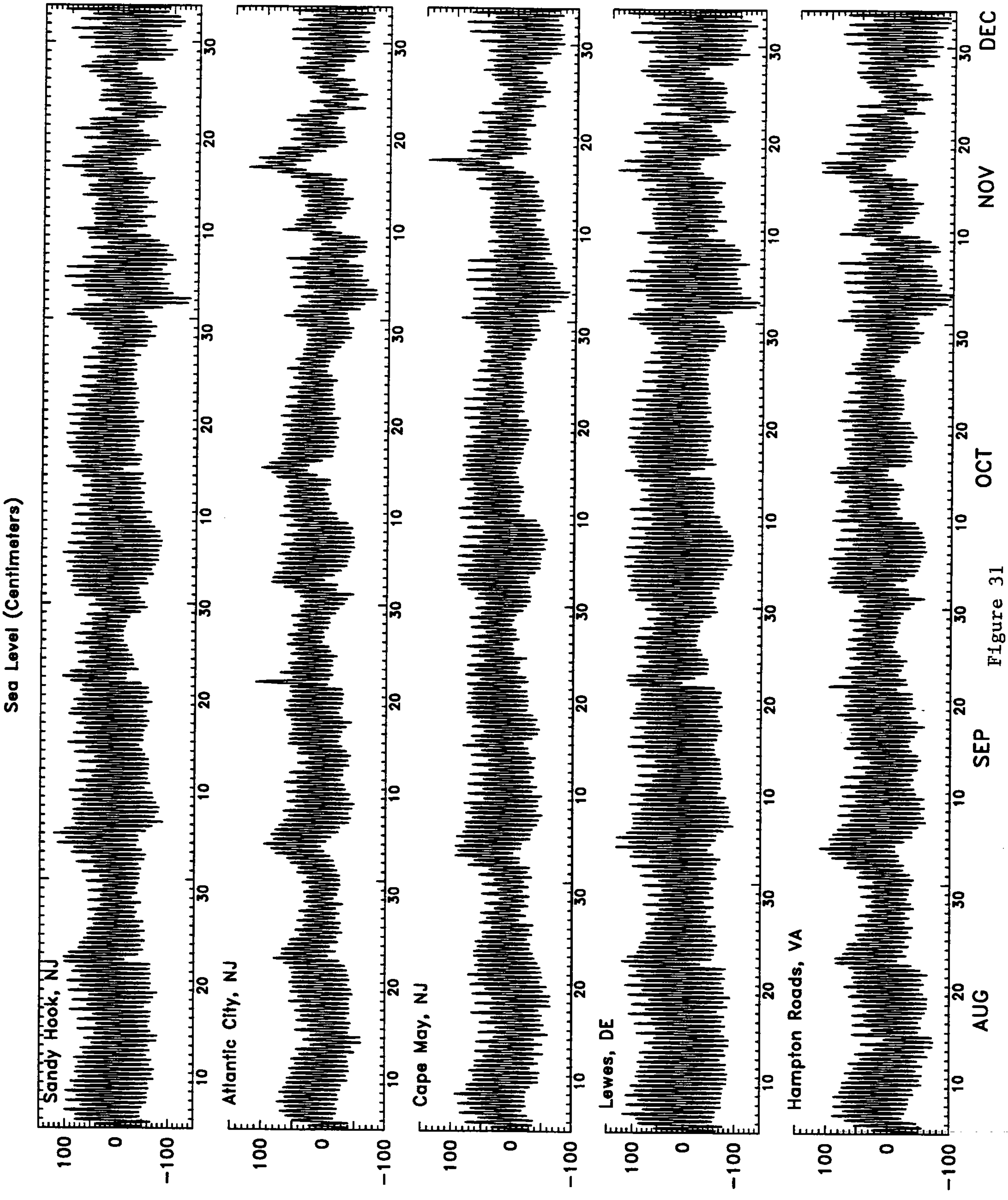

Sea Level (Centimeters)
Sandy Hook, NJ
Atlantic City, NJ
Cape May, NJ
Lewes, DE
Hampton Roads, VA
100
0
−100
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 31

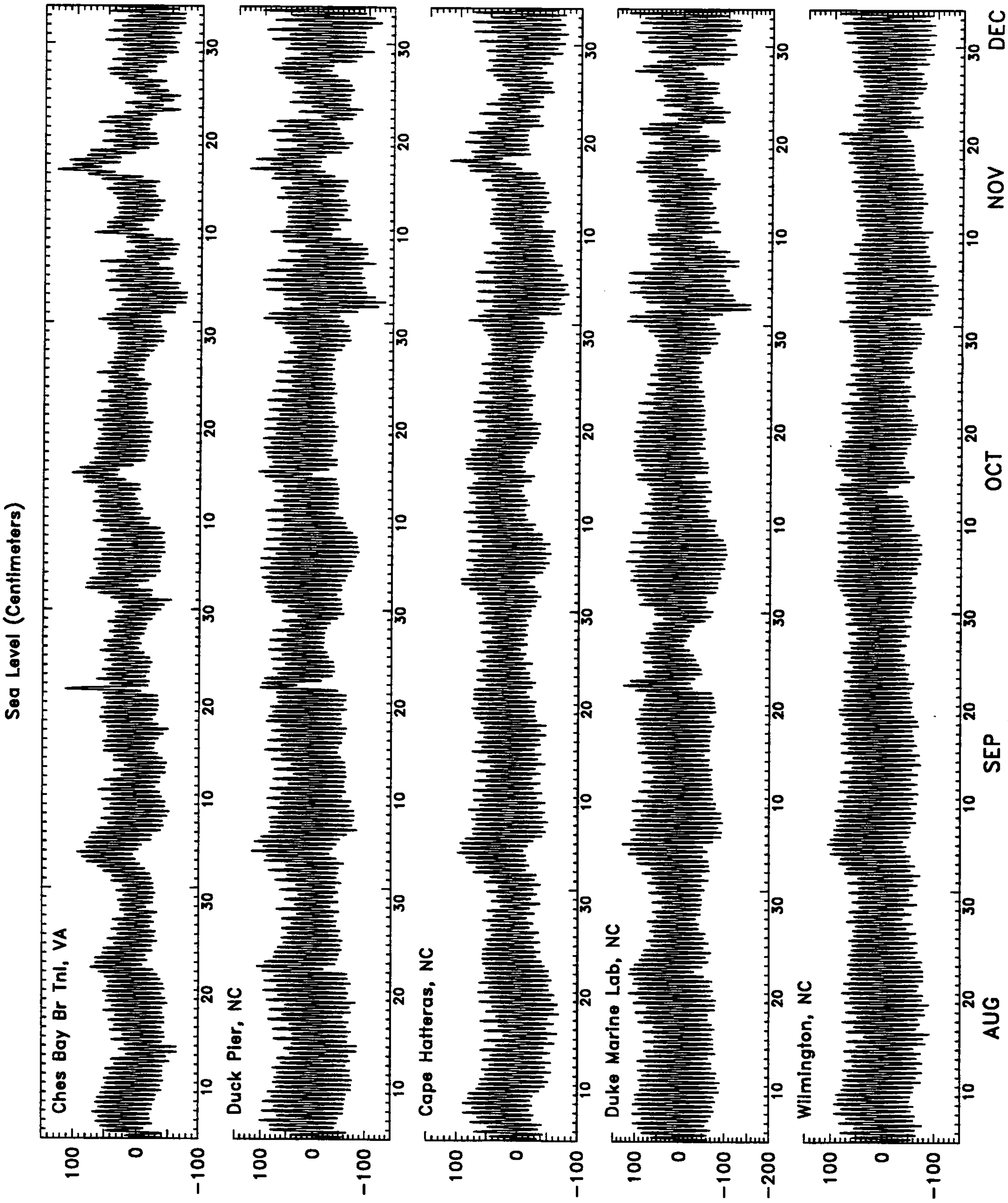


Figure 31 (cont.)

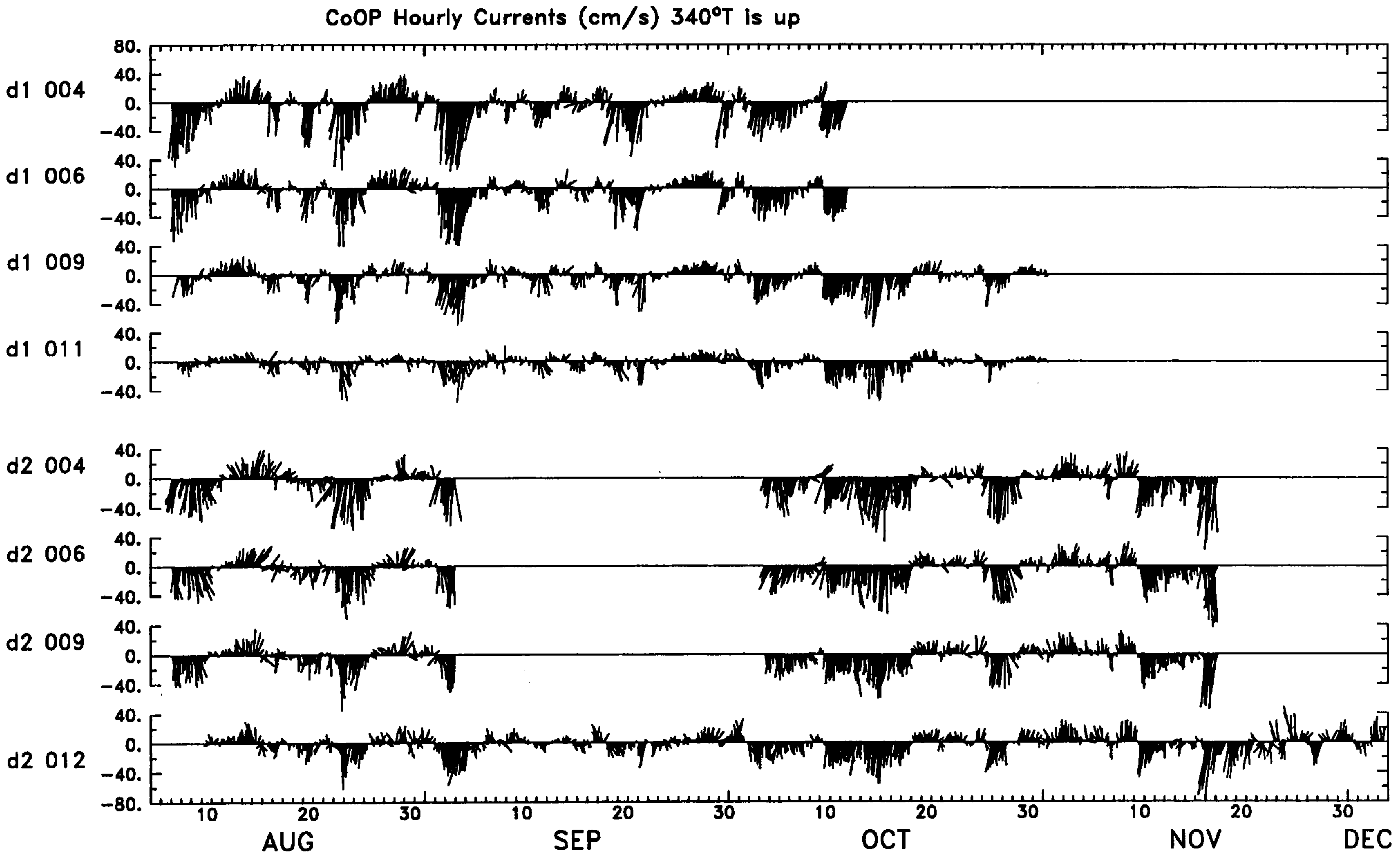
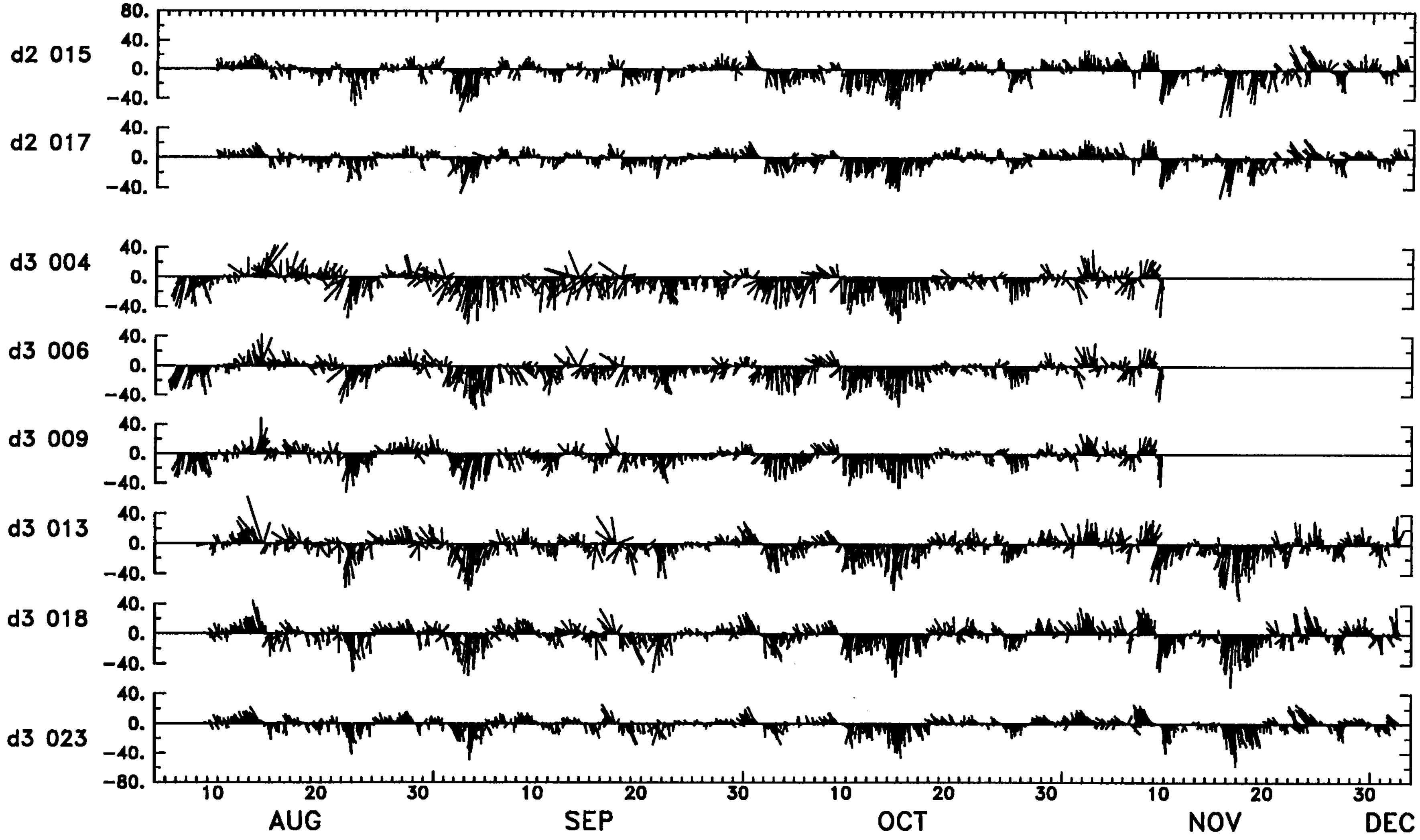

CoOP Hourly Currents (cm/s) 340°T is up
d1 004
d1 006
d1 009
d1 011
d2 004
d2 006
d2 009
d2 012
80.
40.
0.
-40.
-80.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 32



CoOP Hourly Currents (cm/s) (continued) 340°T is up

Figure 32 (cont.)

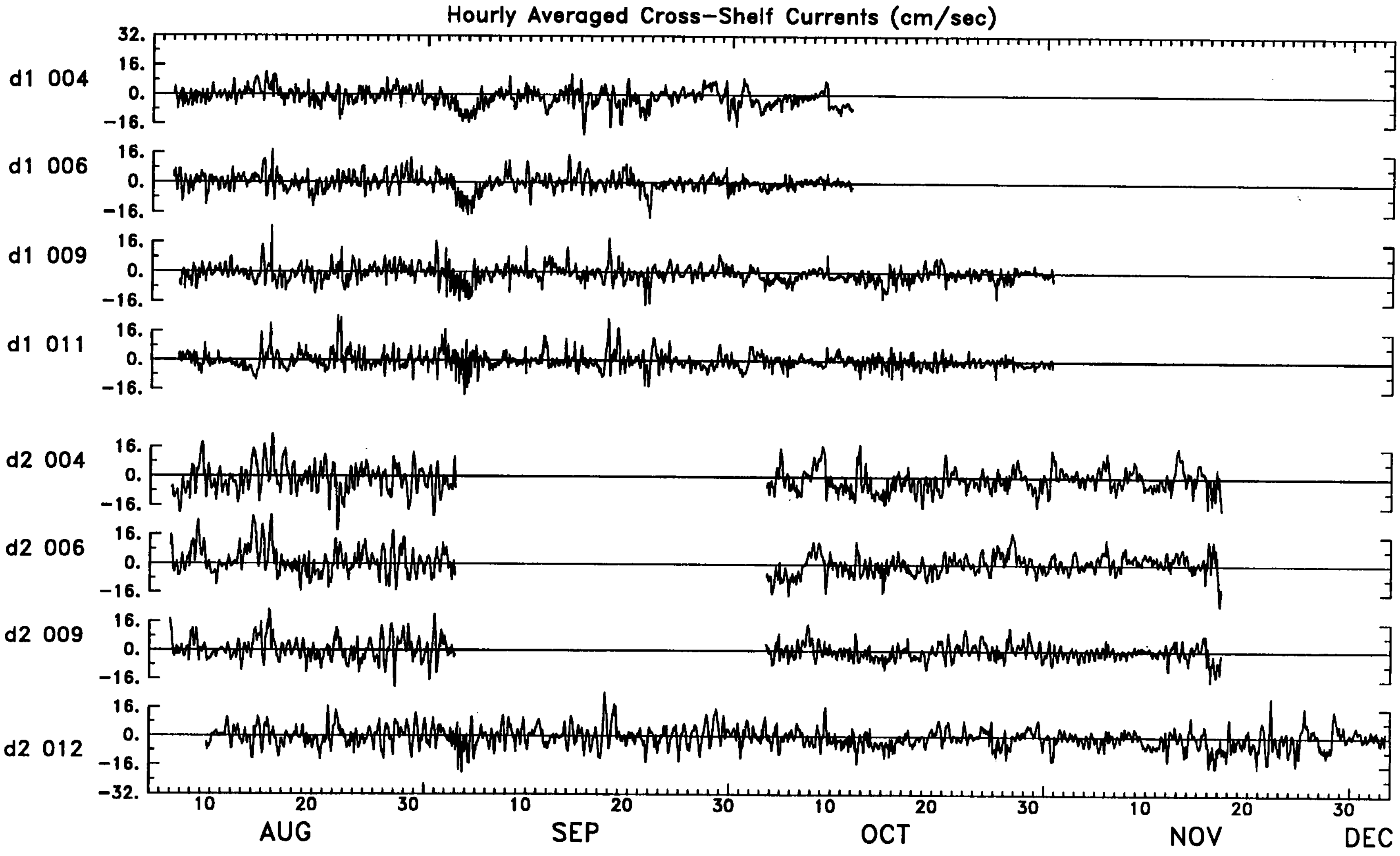

Hourly Averaged Cross-Shelf Currents (cm/sec)
d1 004
d1 006
d1 009
d1 011
d2 004
d2 006
d2 009
d2 012
32.
16.
0.
-16.
-32.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 33

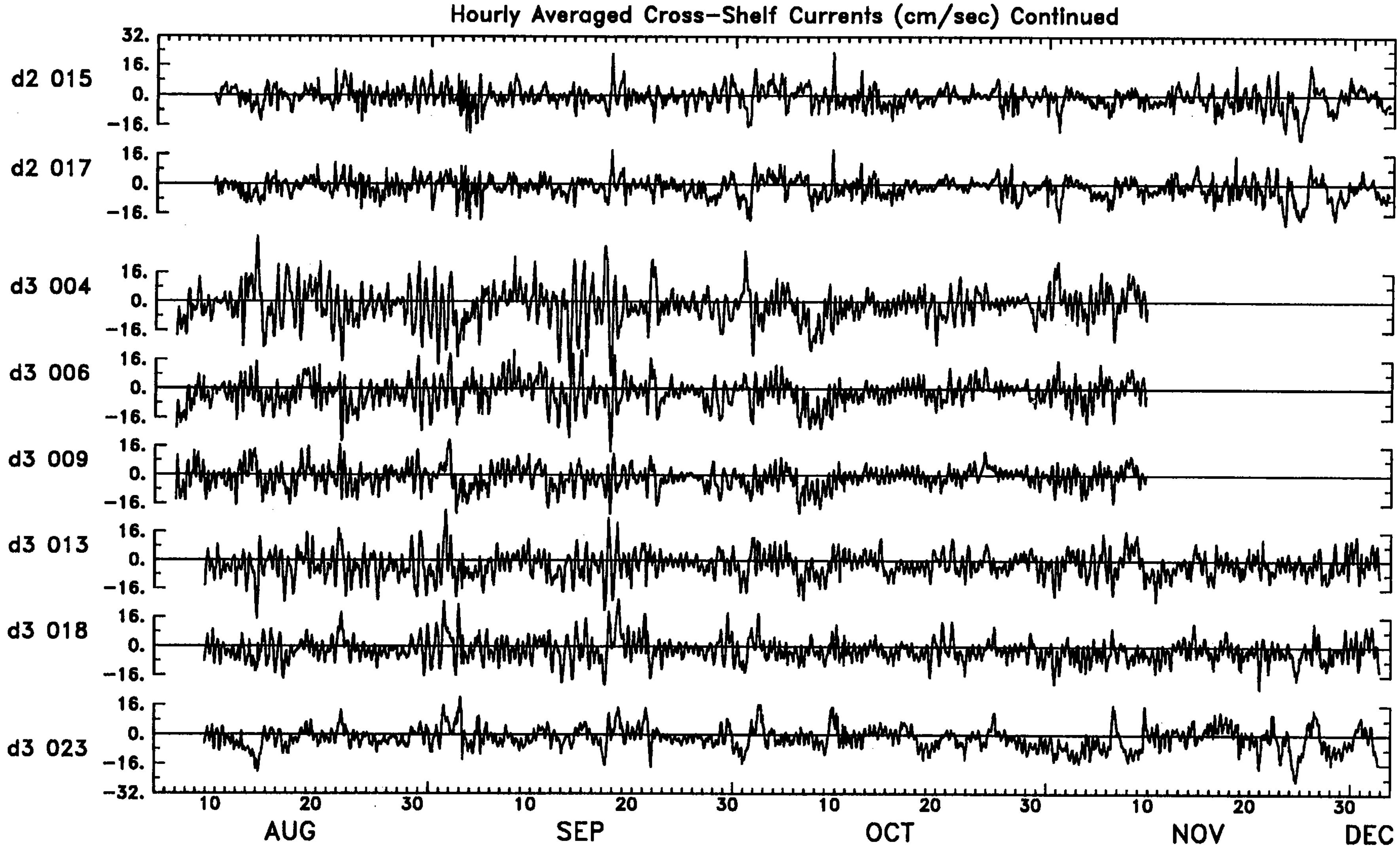


Figure 33 (cont.)

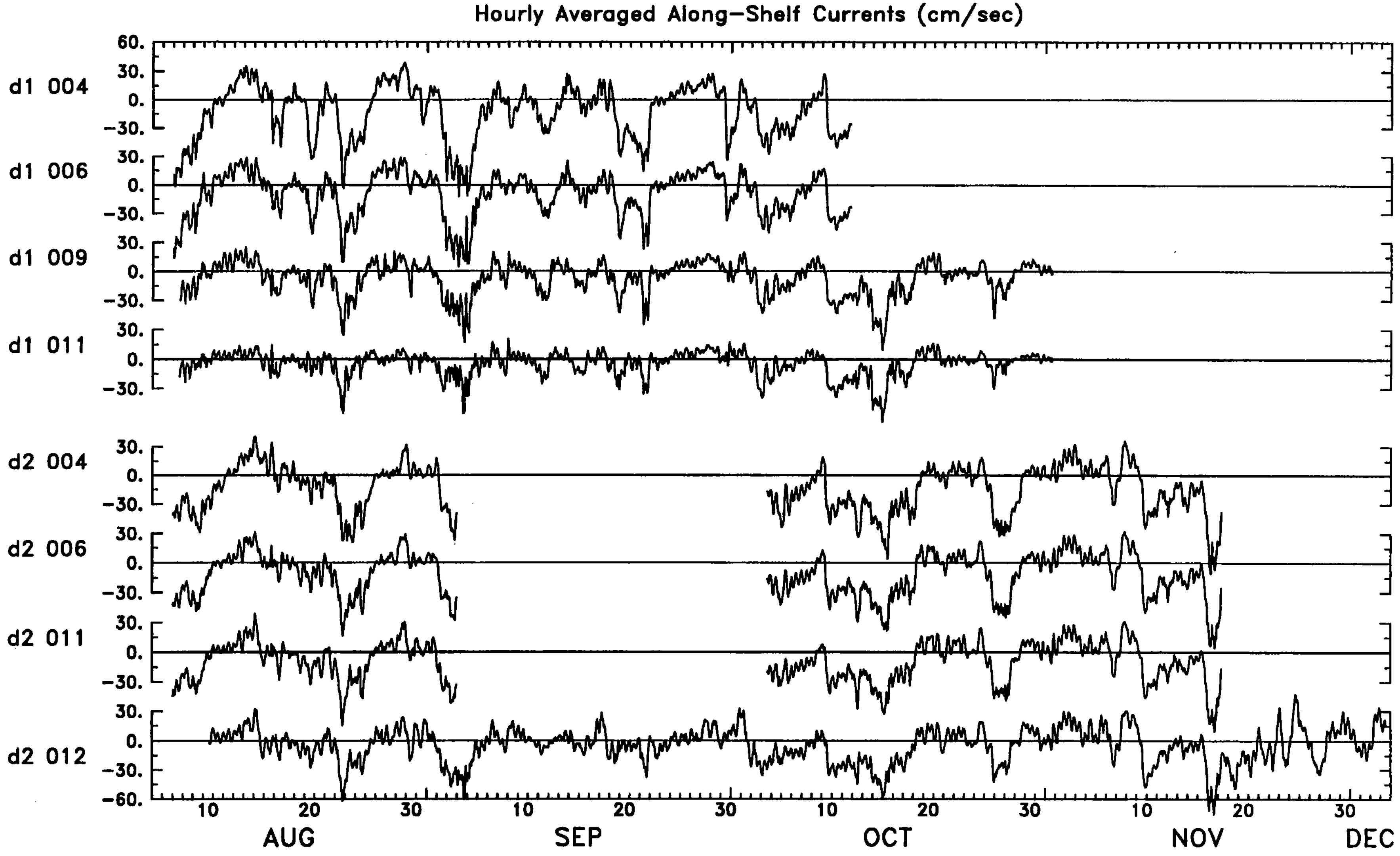

Hourly Averaged Along-Shelf Currents (cm/sec)
d1 004
d1 006
d1 009
d1 011
d2 004
d2 006
d2 011
d2 012
60.
30.
0.
-30.
-60.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 34

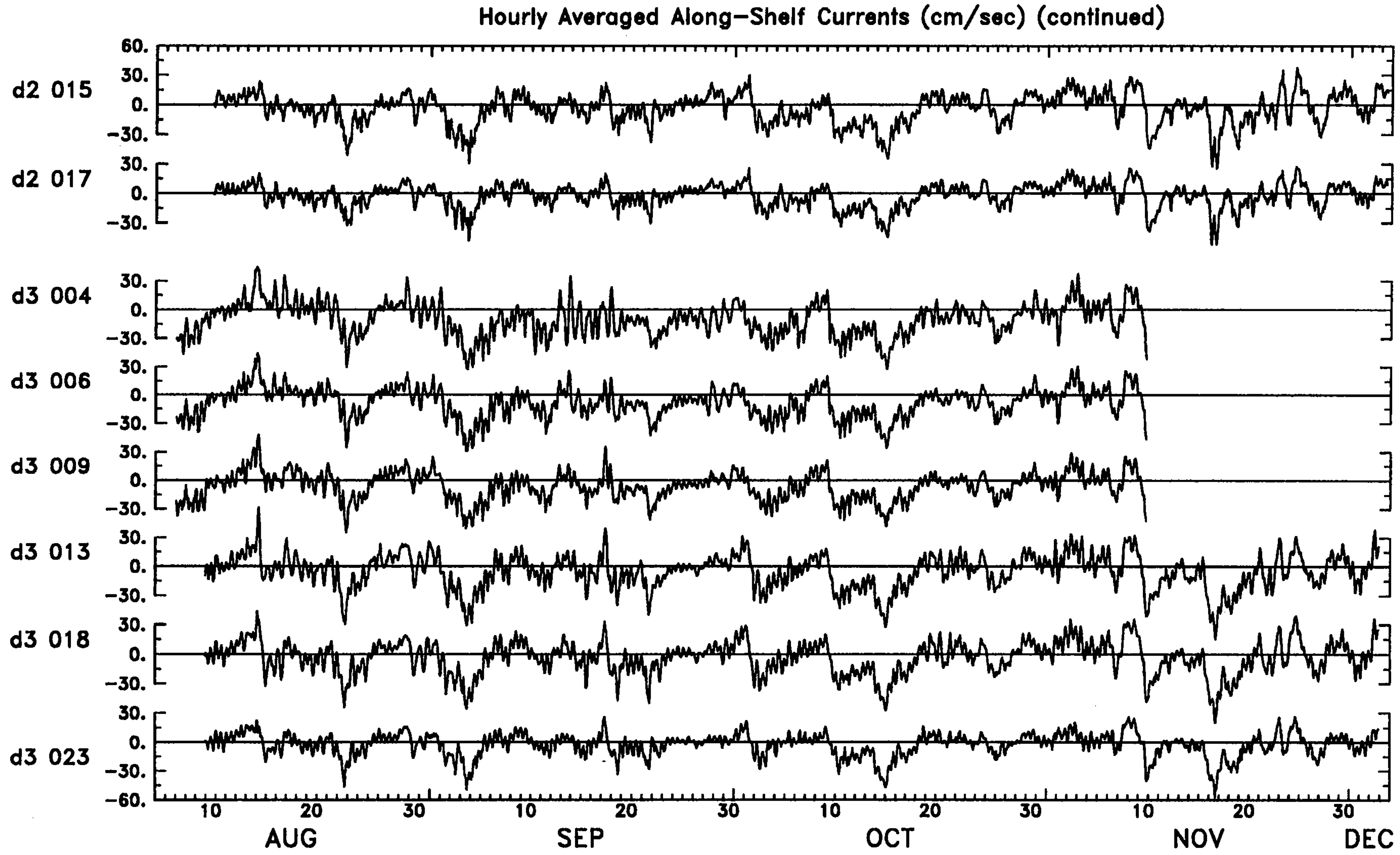


Figure 34 (cont.)

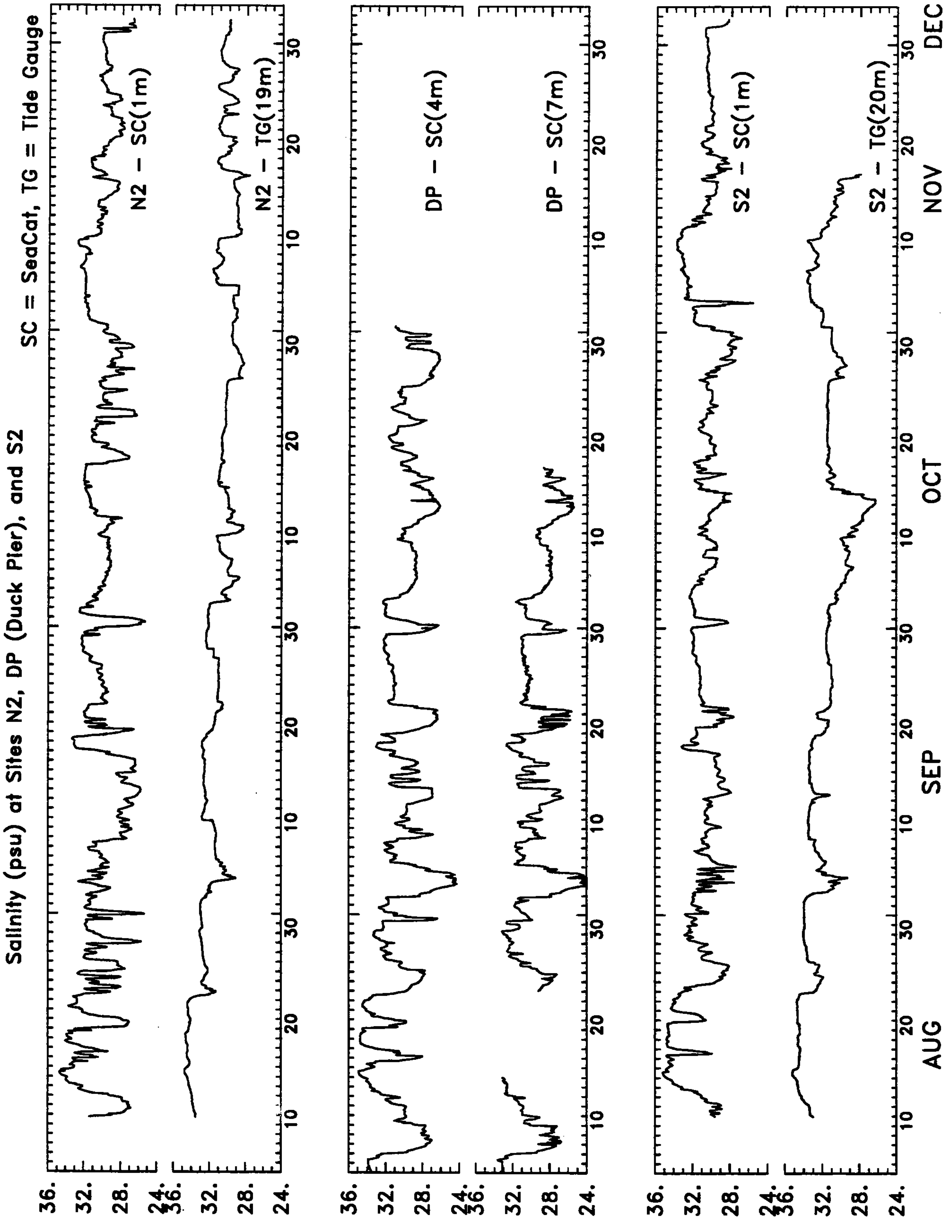

Salinity (psu) at Sites N2, DP (Duck Pier), and S2
SC = SeaCat, TG = Tide Gauge
N2 – SC(1m)
N2 – TG(19m)
DP – SC(4m)
DP – SC(7m)
S2 – SC(1m)
S2 – TG(20m)
36.
32.
28.
24.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 35

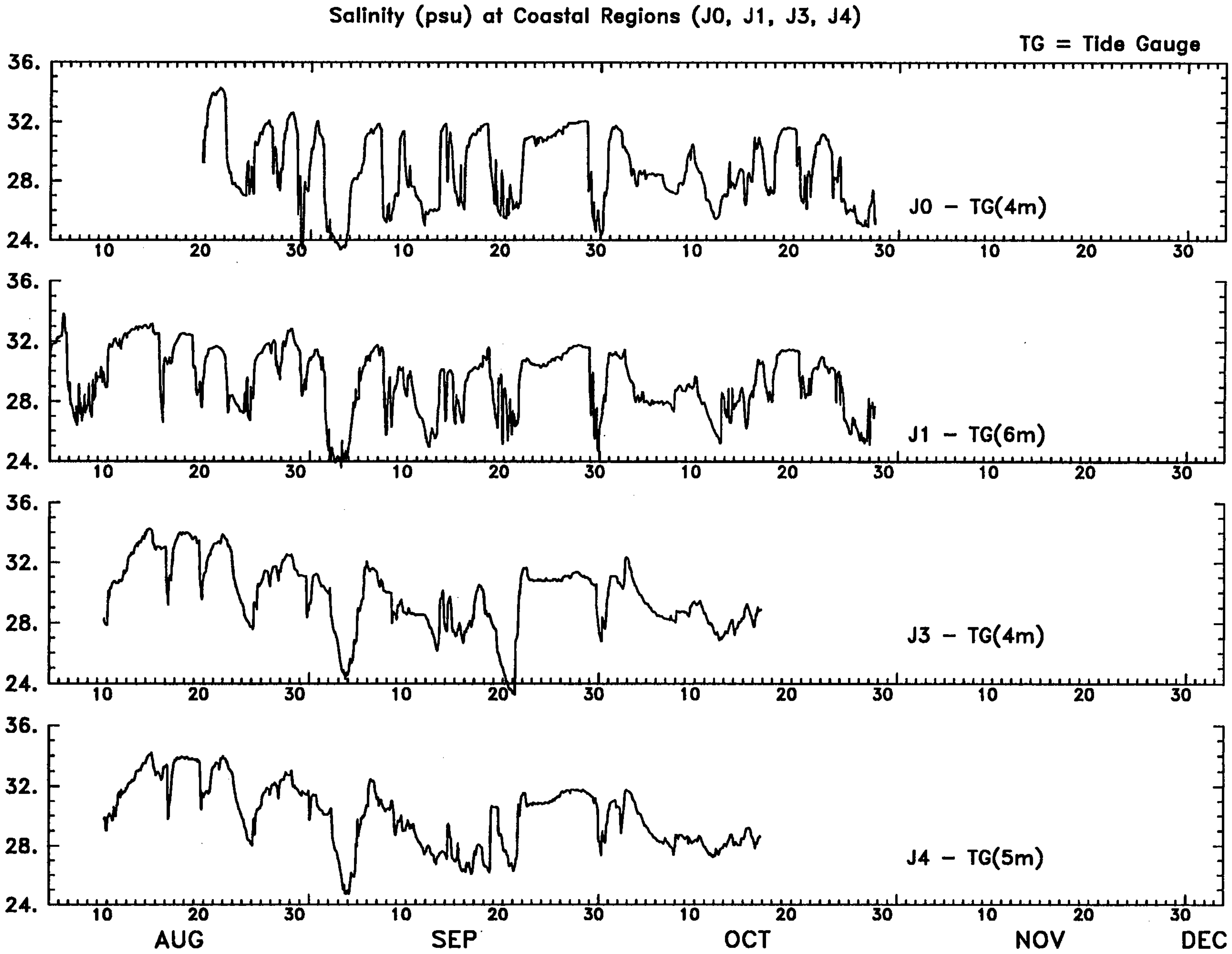

Salinity (psu) at Coastal Regions (J0, J1, J3, J4)
TG = Tide Gauge
J0 – TG(4m)
J1 – TG(6m)
J3 – TG(4m)
J4 – TG(5m)
36.
32.
28.
24.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 36

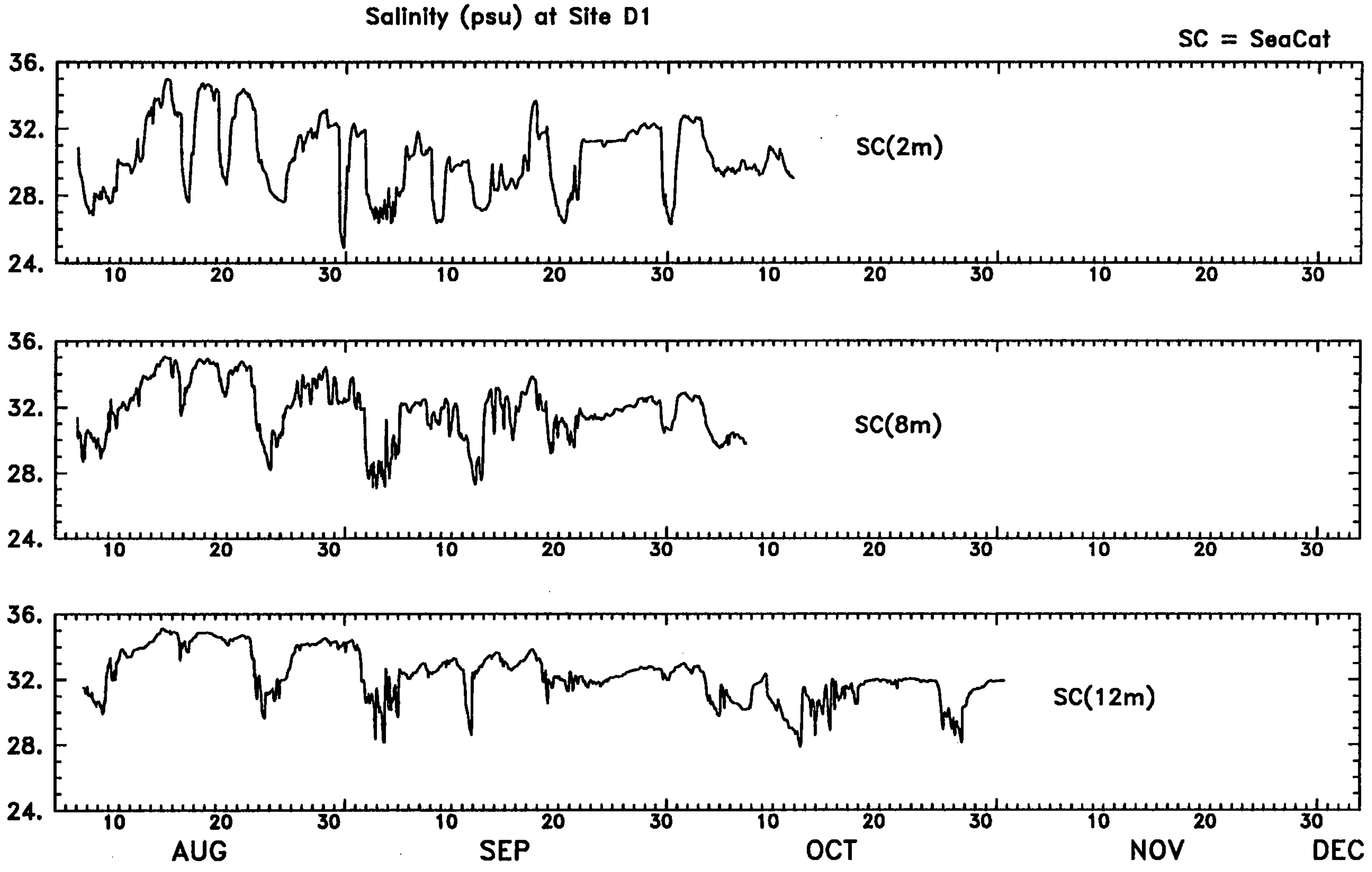

Salinity (psu) at Site D1
SC = SeaCat
SC(2m)
SC(8m)
SC(12m)
36.
32.
28.
24.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 37

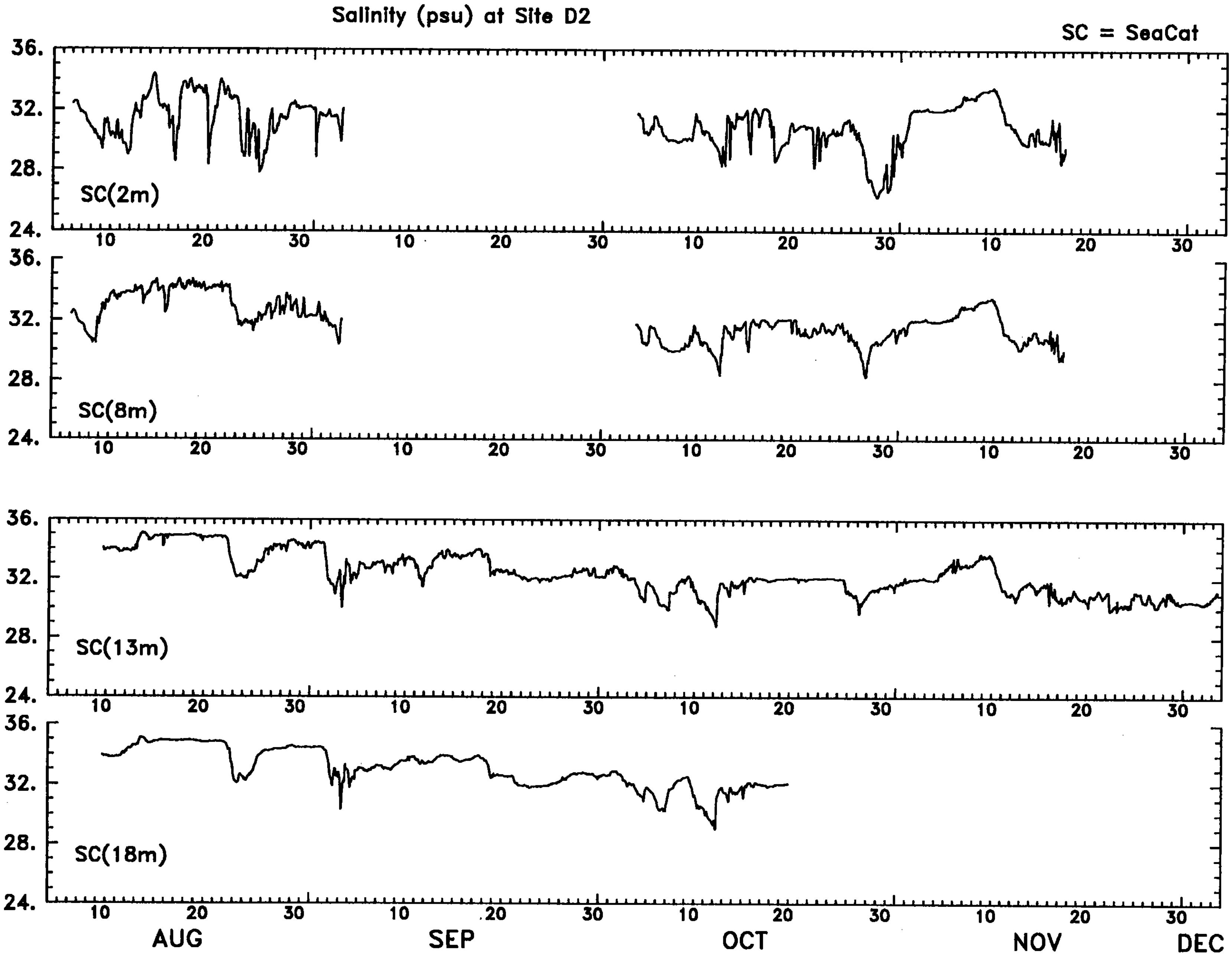

Salinity (psu) at Site D2

Figure 38

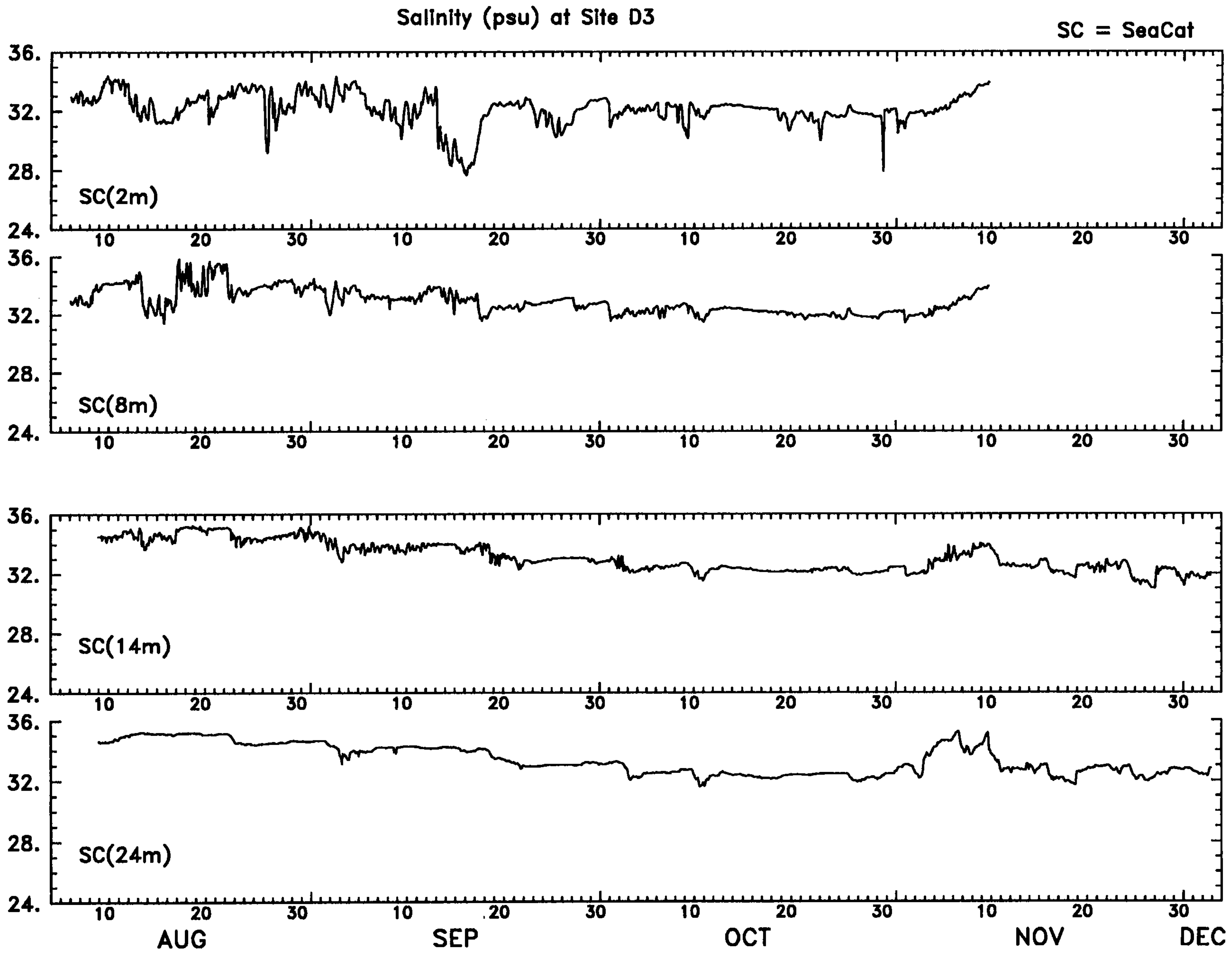

Salinity (psu) at Site D3
SC = SeaCat
SC(2m)
SC(8m)
SC(14m)
SC(24m)
36.
32.
28.
24.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 39

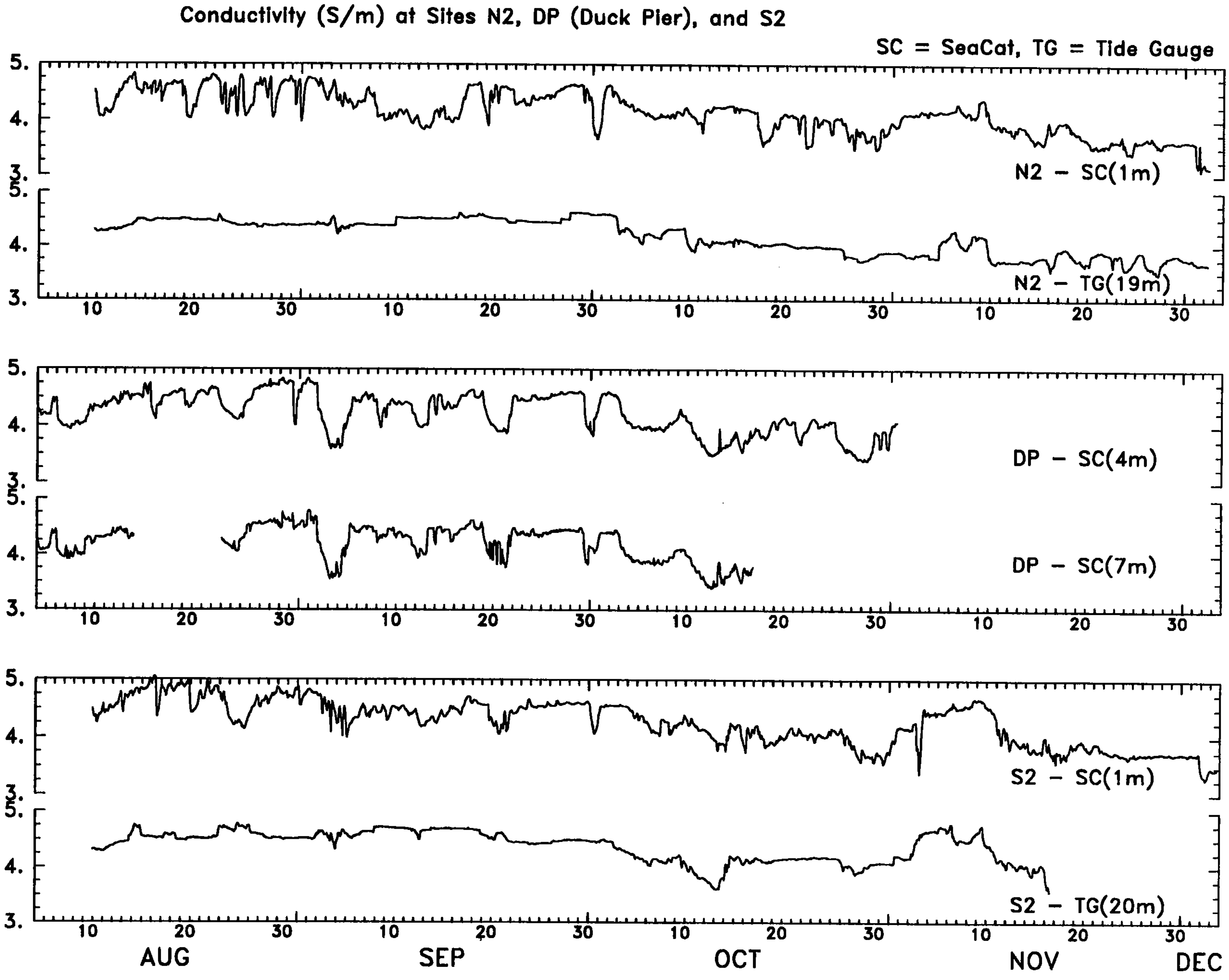

Conductivity (S/m) at Sites N2, DP (Duck Pier), and S2
SC = SeaCat, TG = Tide Gauge
N2 - SC(1m)
N2 - TG(19m)
DP - SC(4m)
DP - SC(7m)
S2 - SC(1m)
S2 - TG(20m)
5.
4.
3.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 40

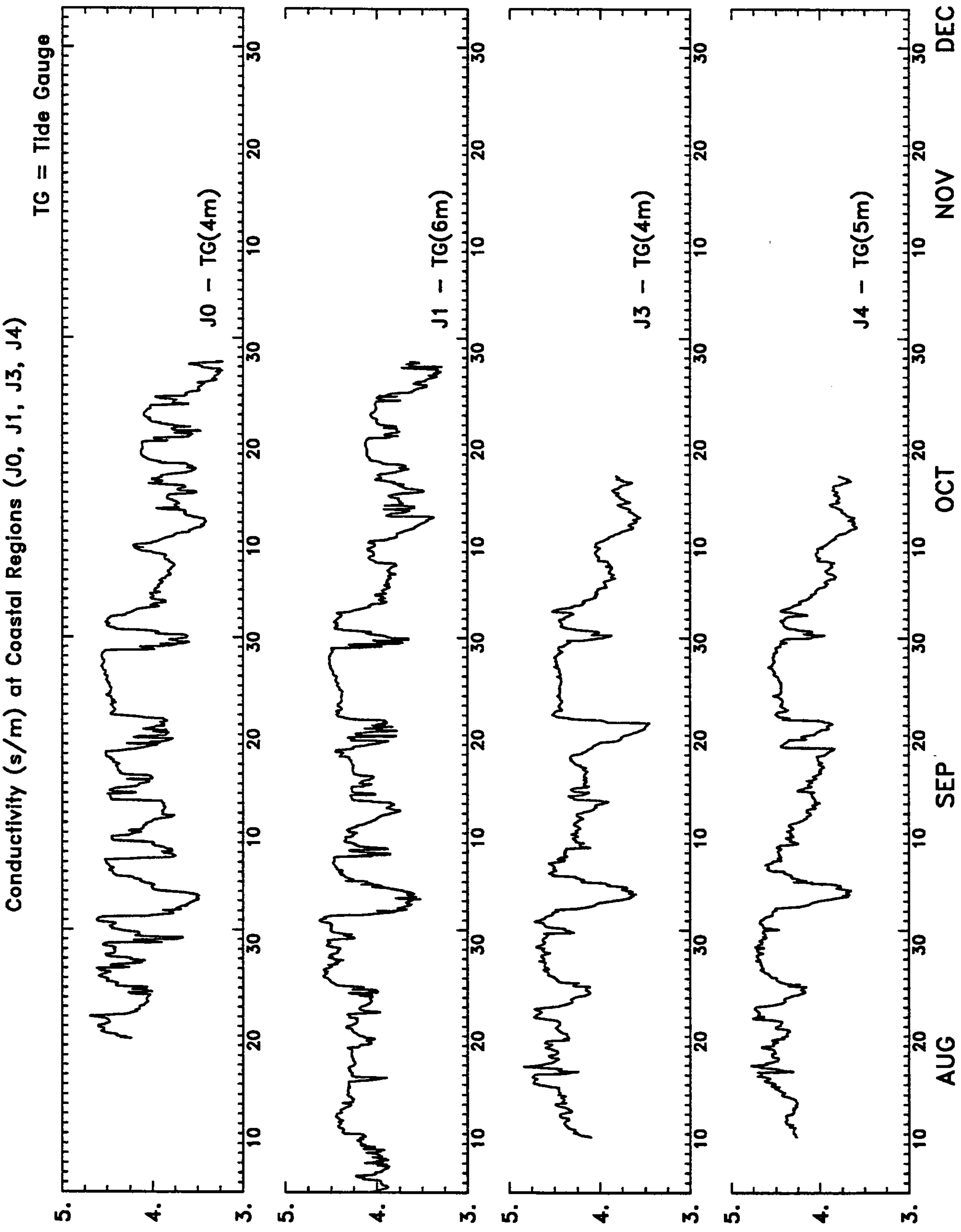

Conductivity (s/m) at Coastal Regions (J0, J1, J3, J4)
TG = Tide Gauge
J0 – TG(4m)
J1 – TG(6m)
J3 – TG(4m)
J4 – TG(5m)
5.
4.
3.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 41

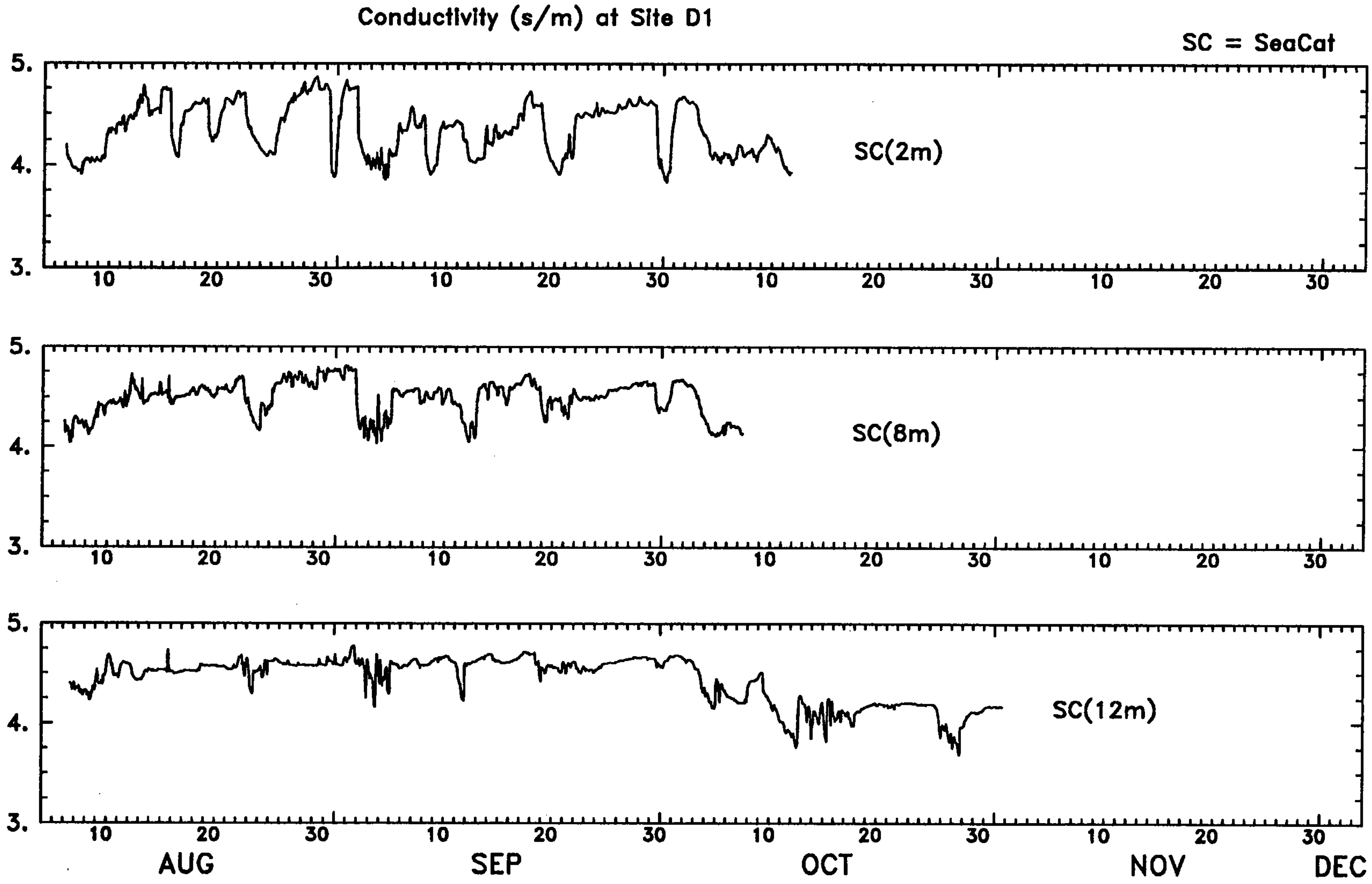

Conductivity (s/m) at Site D1
SC = SeaCat
SC(2m)
SC(8m)
SC(12m)
5.
4.
3.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 42

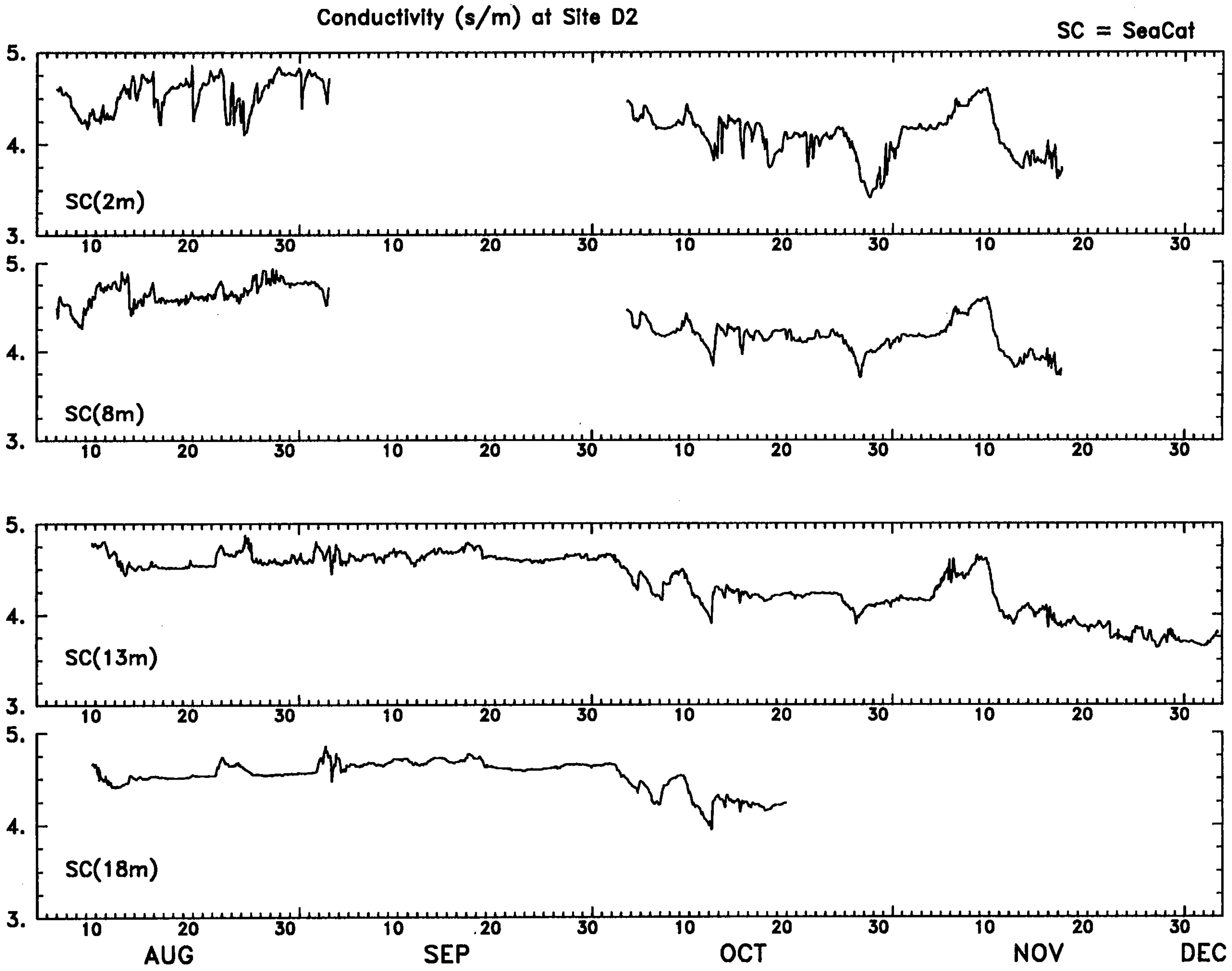

Conductivity (s/m) at Site D2
SC = SeaCat
SC(2m)
SC(8m)
SC(13m)
SC(18m)
5.
4.
3.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 43

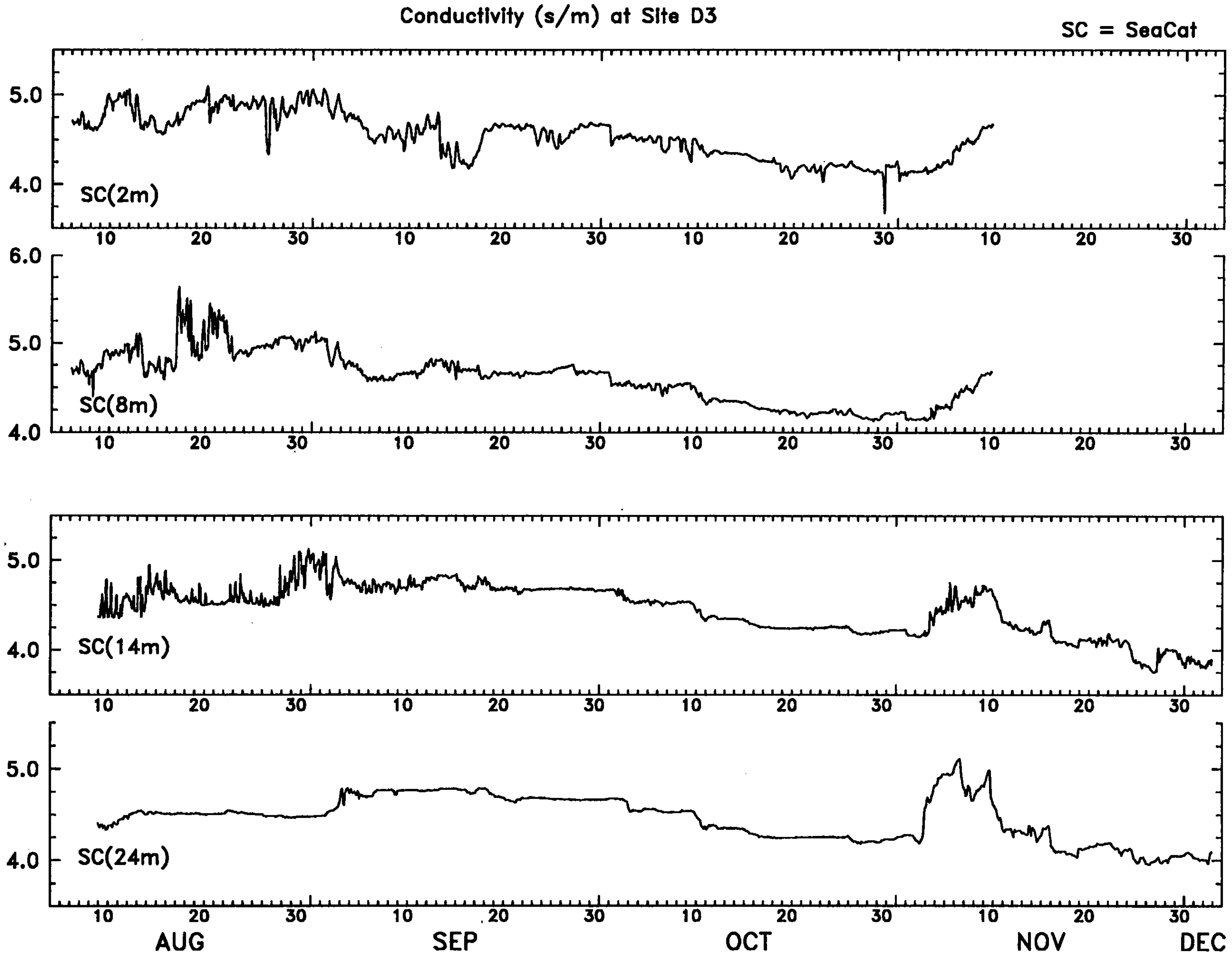

Conductivity (s/m) at Site D3
SC = SeaCat
5.0
4.0
SC(2m)
10
20
30
10
20
30
10
20
30
10
20
30
6.0
5.0
4.0
SC(8m)
5.0
4.0
SC(14m)
5.0
4.0
SC(24m)
AUG
SEP
OCT
NOV
DEC

Figure 44

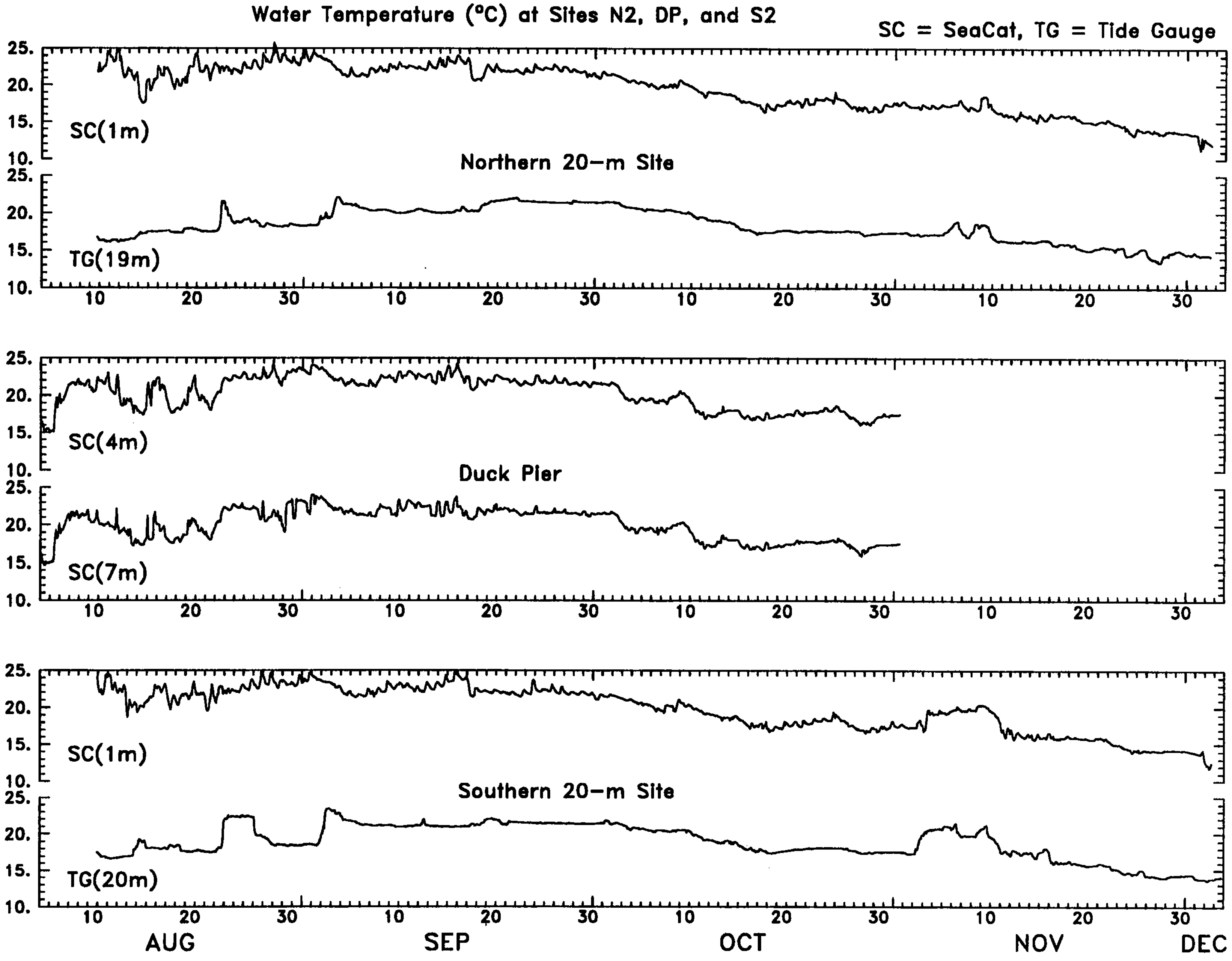

Water Temperature (°C) at Sites N2, DP, and S2
SC = SeaCat, TG = Tide Gauge
SC(1m)
Northern 20–m Site
TG(19m)
SC(4m)
Duck Pier
SC(7m)
SC(1m)
Southern 20–m Site
TG(20m)
25.
20.
15.
10.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 45

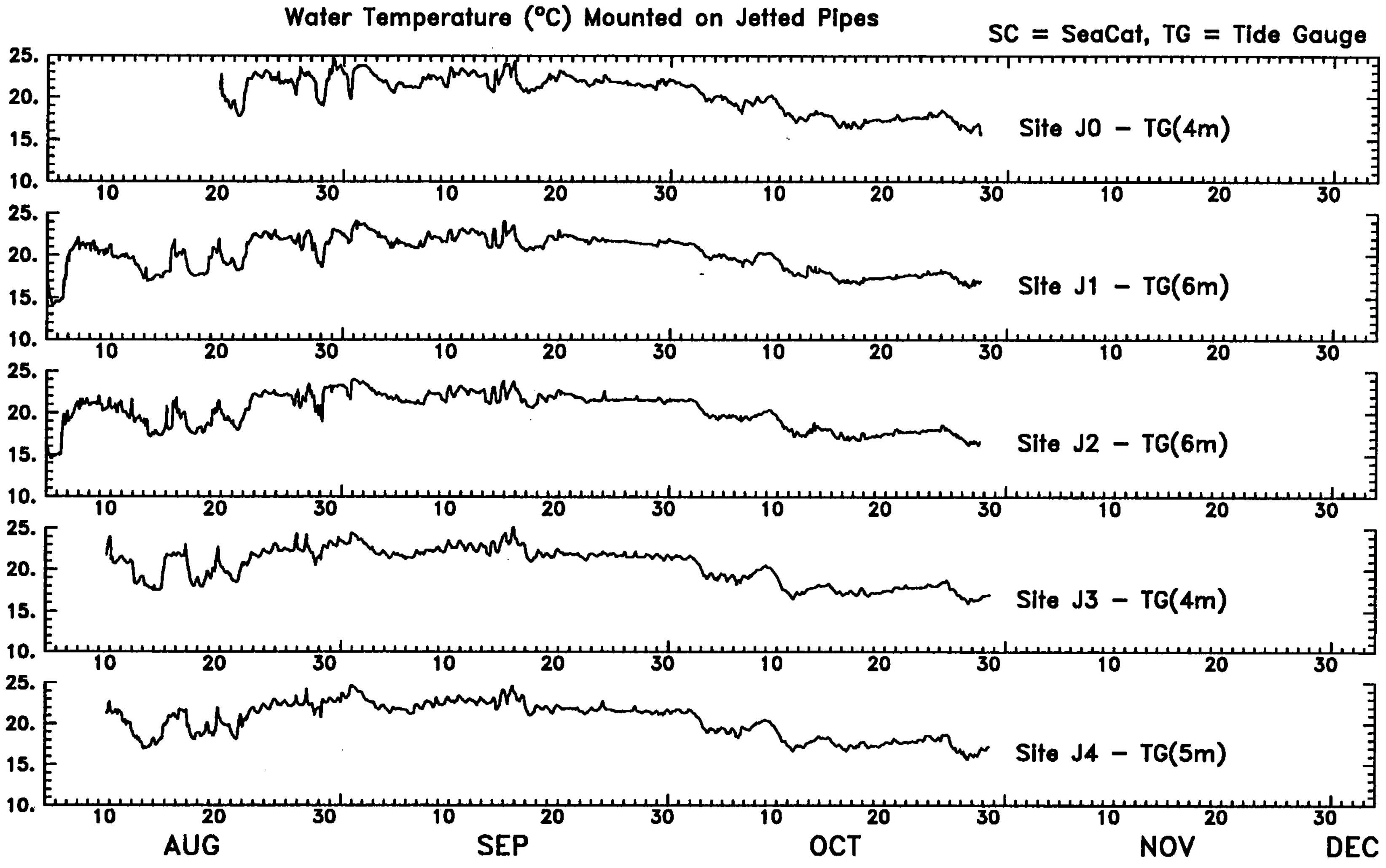
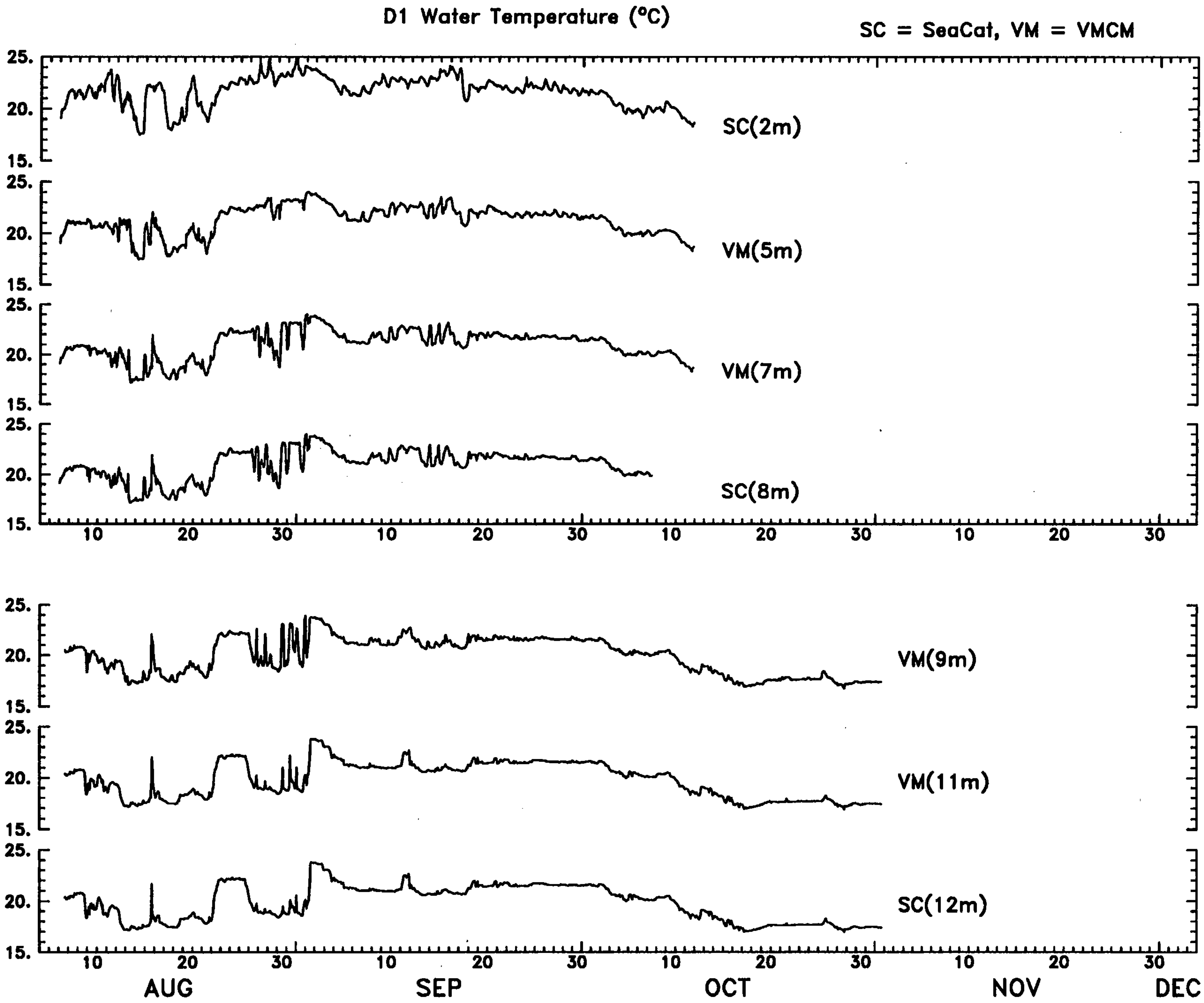

Water Temperature (°C) Mounted on Jetted Pipes
SC = SeaCat, TG = Tide Gauge
Site J0 – TG(4m)
Site J1 – TG(6m)
Site J2 – TG(6m)
Site J3 – TG(4m)
Site J4 – TG(5m)
25.
20.
15.
10.
10
20
30
AUG
SEP
OCT
NOV
DEC

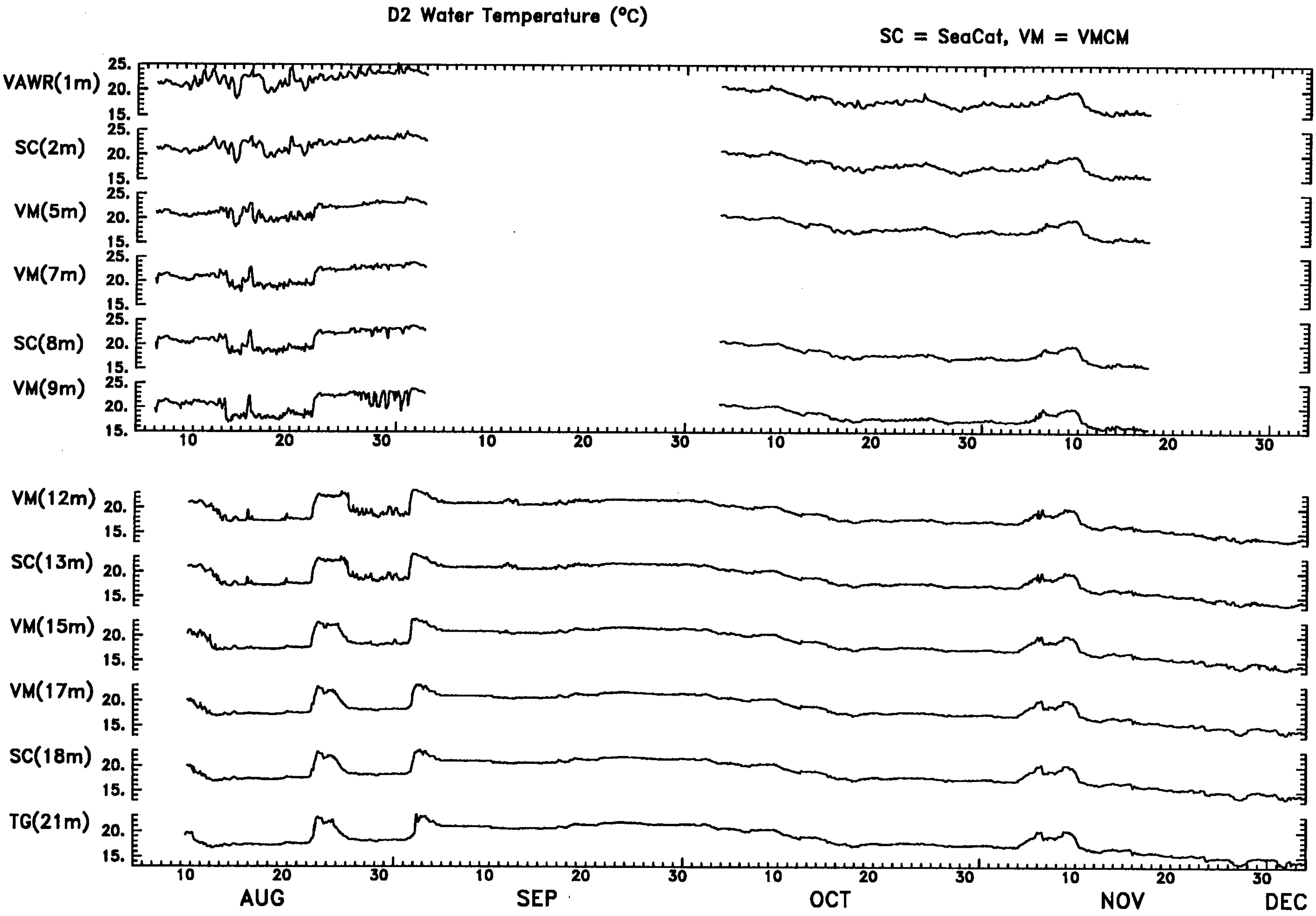
Figure 46



D1 Water Temperature (°C)

SC = SeaCat, VM = VMCM

Figure 47



D2 Water Temperature (°C)
SC = SeaCat, VM = VMCM
VAWR(1m)
SC(2m)
VM(5m)
VM(7m)
SC(8m)
VM(9m)
VM(12m)
SC(13m)
VM(15m)
VM(17m)
SC(18m)
TG(21m)
25.
20.
15.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 48

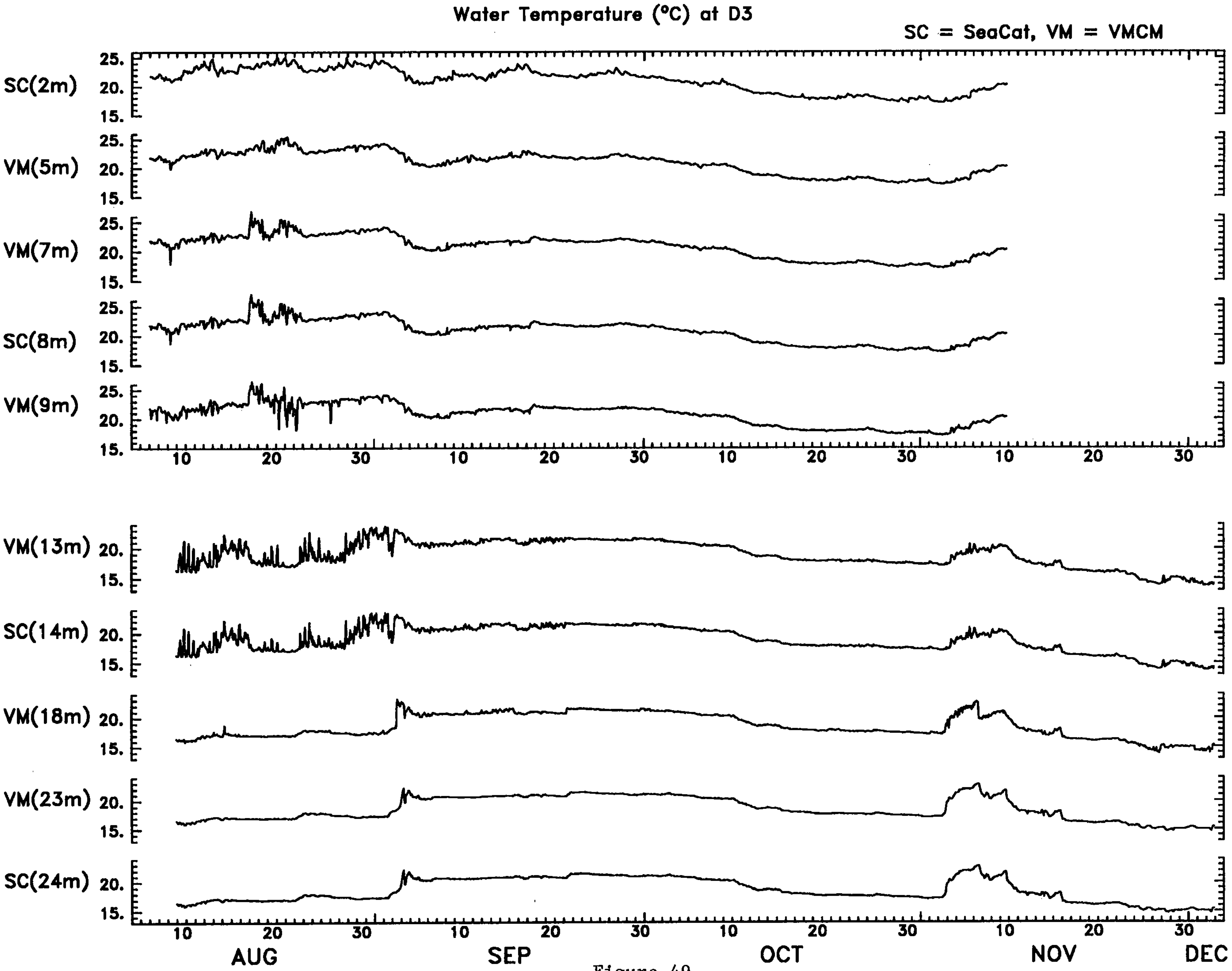

Water Temperature (°C) at D3
SC = SeaCat, VM = VMCM
SC(2m)
VM(5m)
VM(7m)
SC(8m)
VM(9m)
VM(13m)
SC(14m)
VM(18m)
VM(23m)
SC(24m)
25.
20.
15.
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 49

D1 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 4m

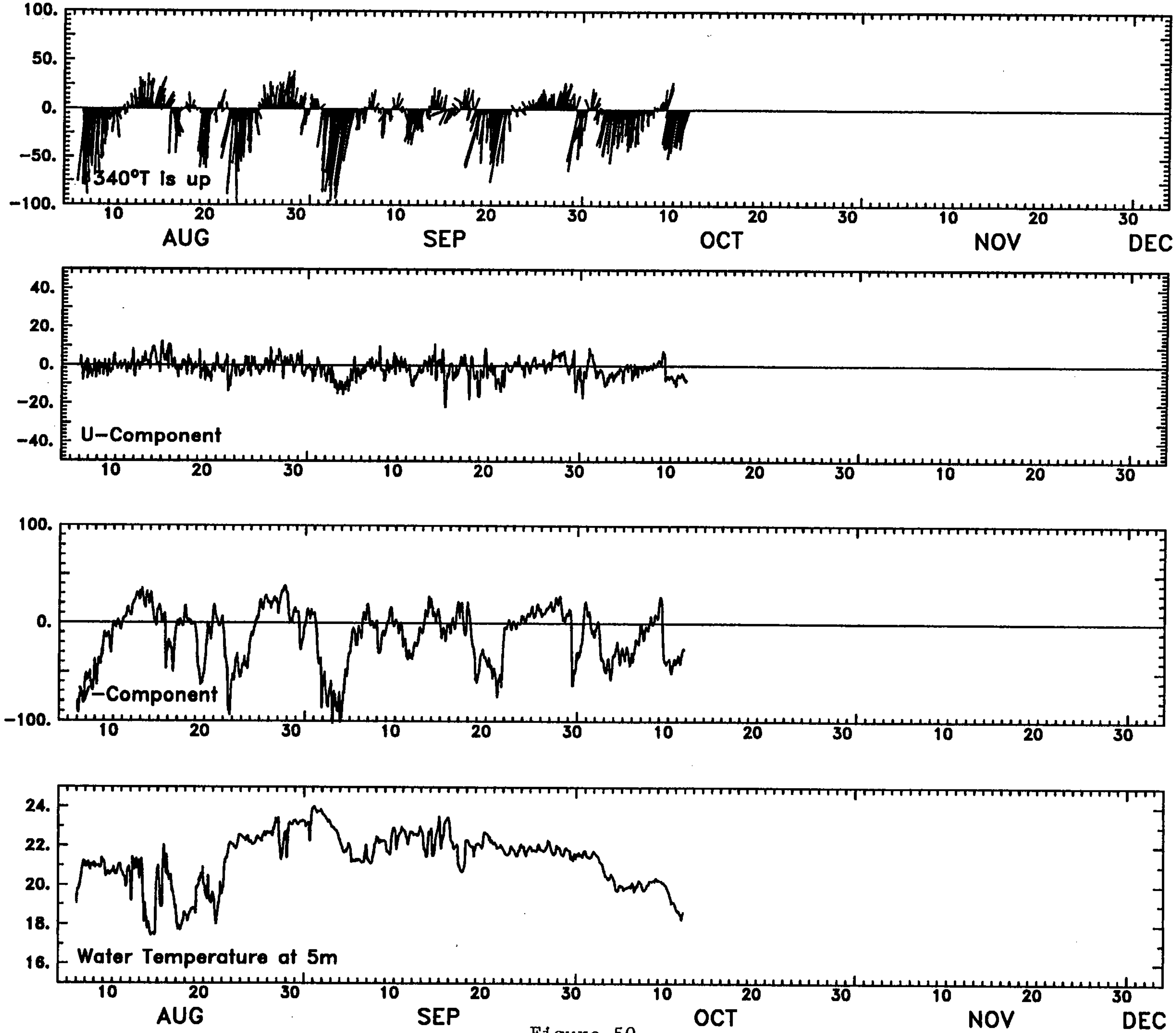


Figure 50

D1 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 6m

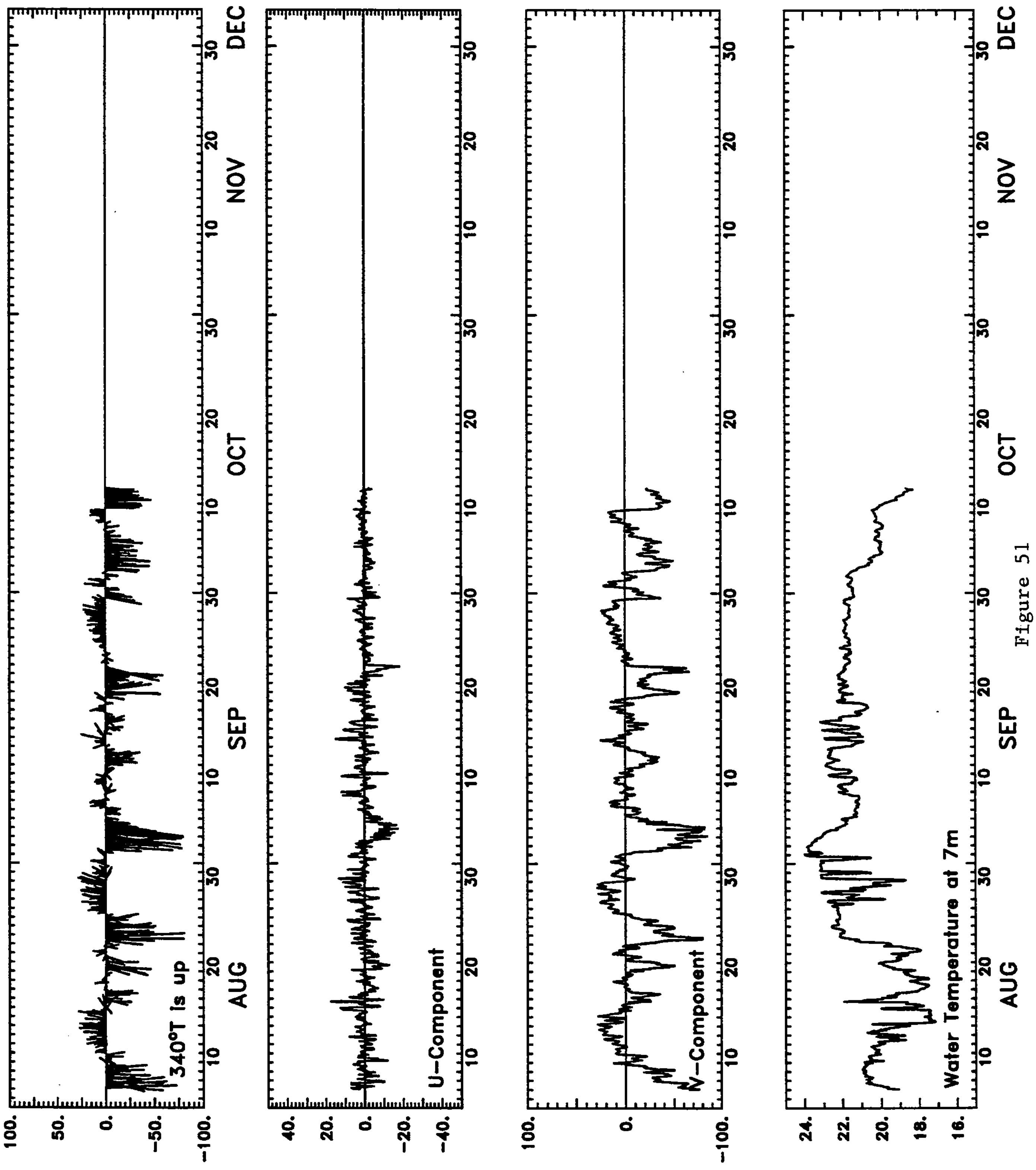


Figure 51

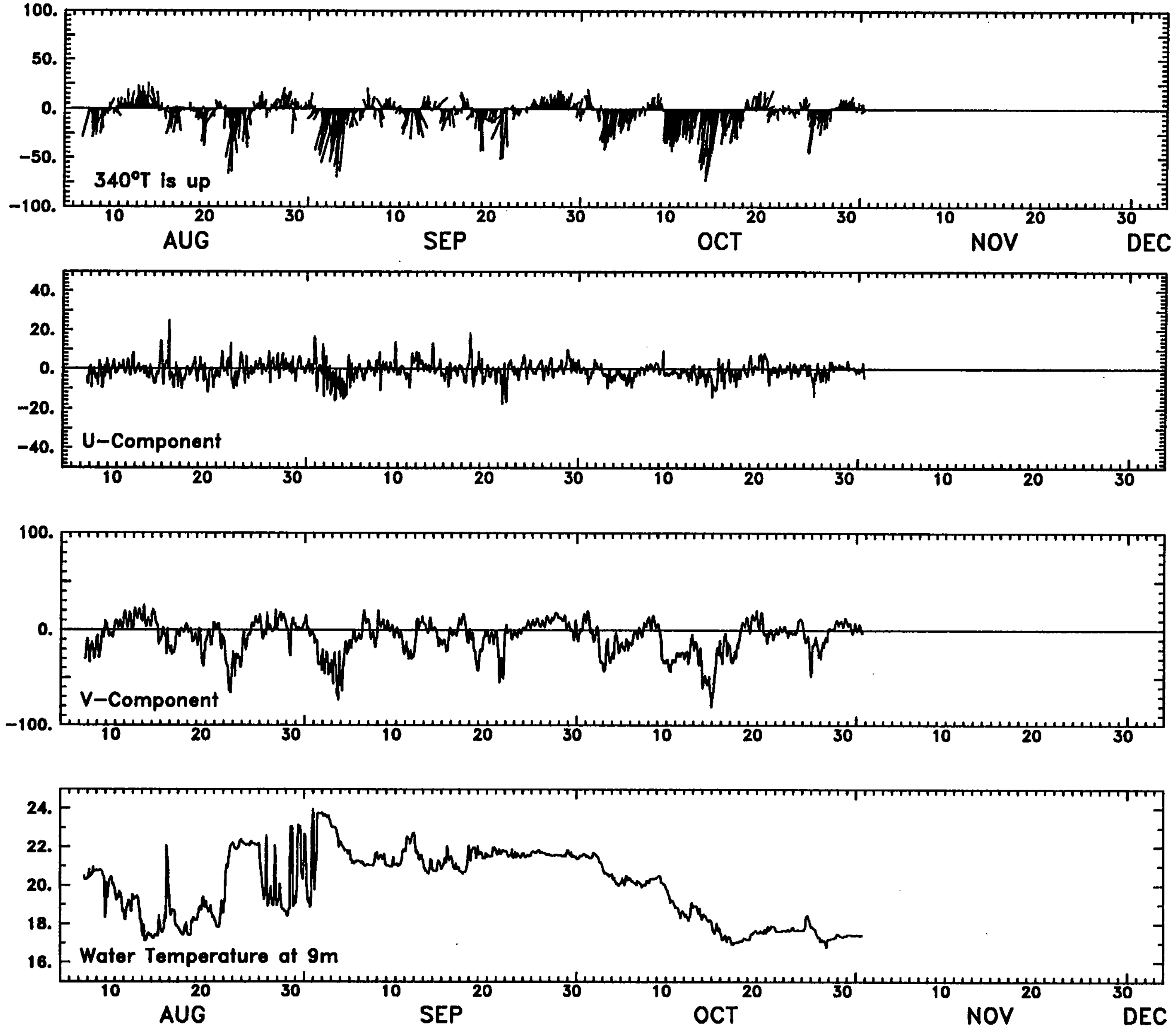

D1 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 9m

Figure 52

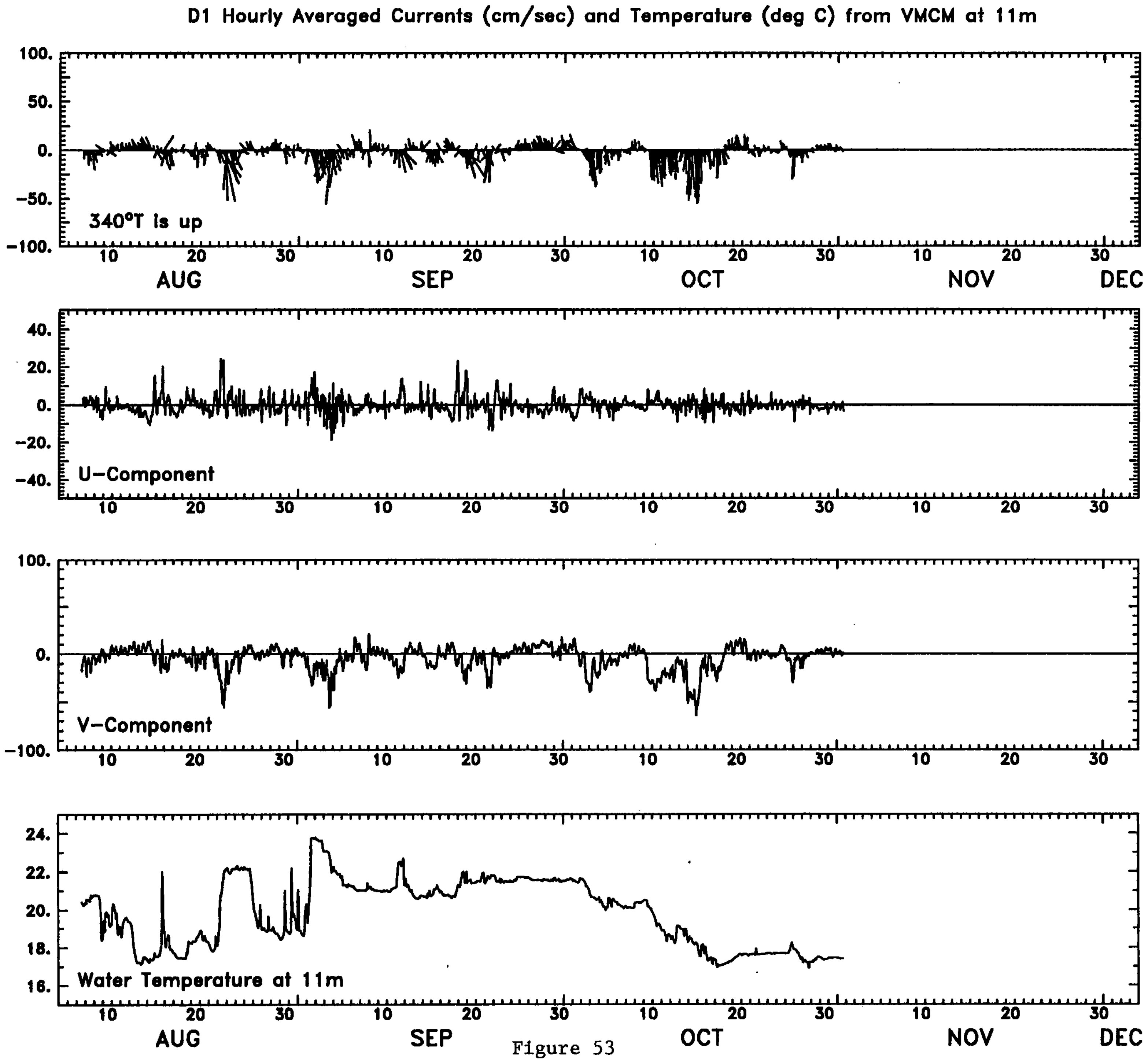

D1 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 11m
100.
50.
0.
-50.
-100.
340°T is up
40.
20.
0.
-20.
-40.
U-Component
100.
0.
-100.
V-Component
24.
22.
20.
18.
16.
Water Temperature at 11m
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 53

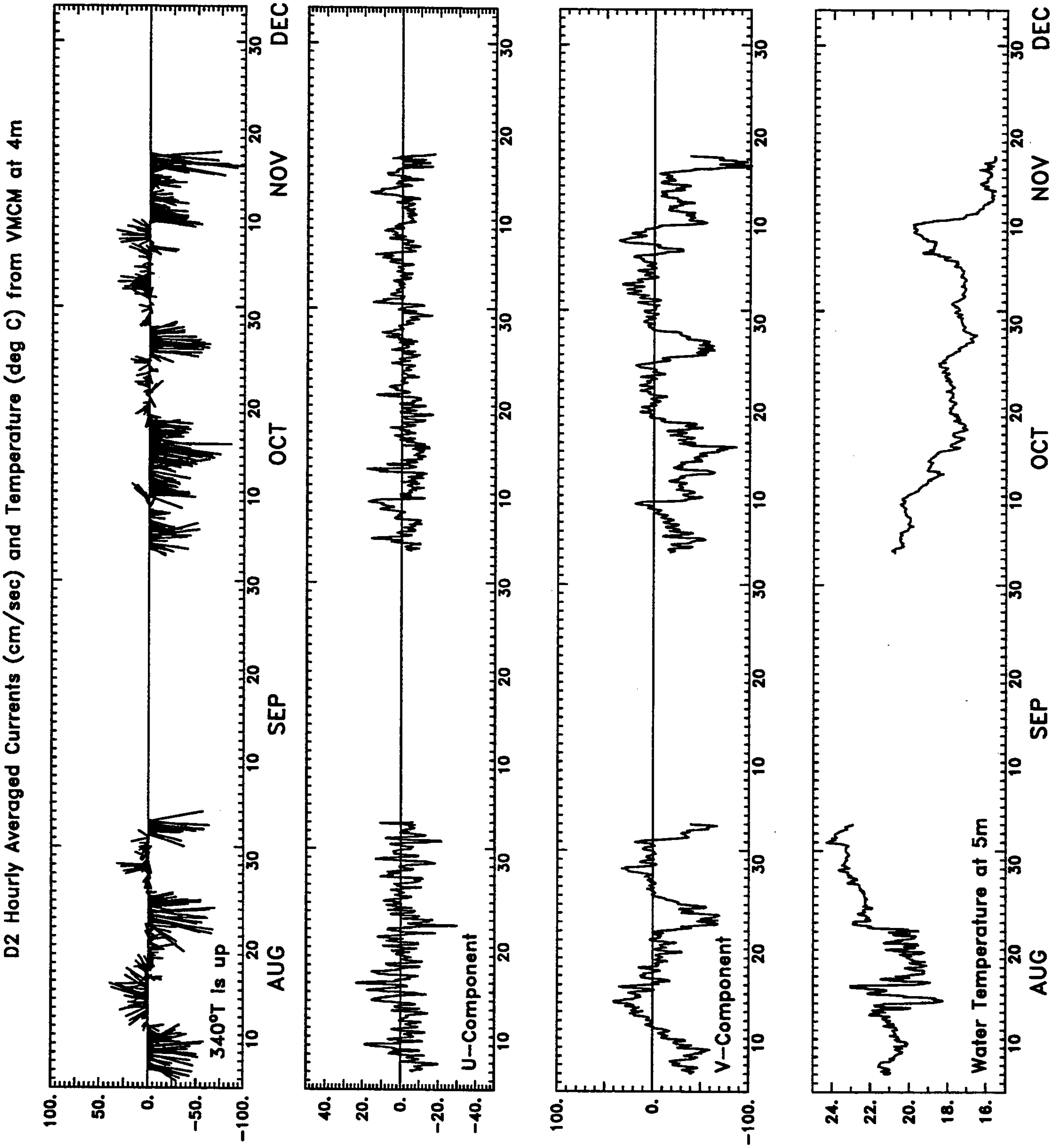

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 4m
340°T is up
100.
50.
0.
-50.
-100.
U-Component
40.
20.
0.
-20.
-40.
V-Component
100.
0.
-100.
Water Temperature at 5m
24.
22.
20.
18.
16.
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 54

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 6m

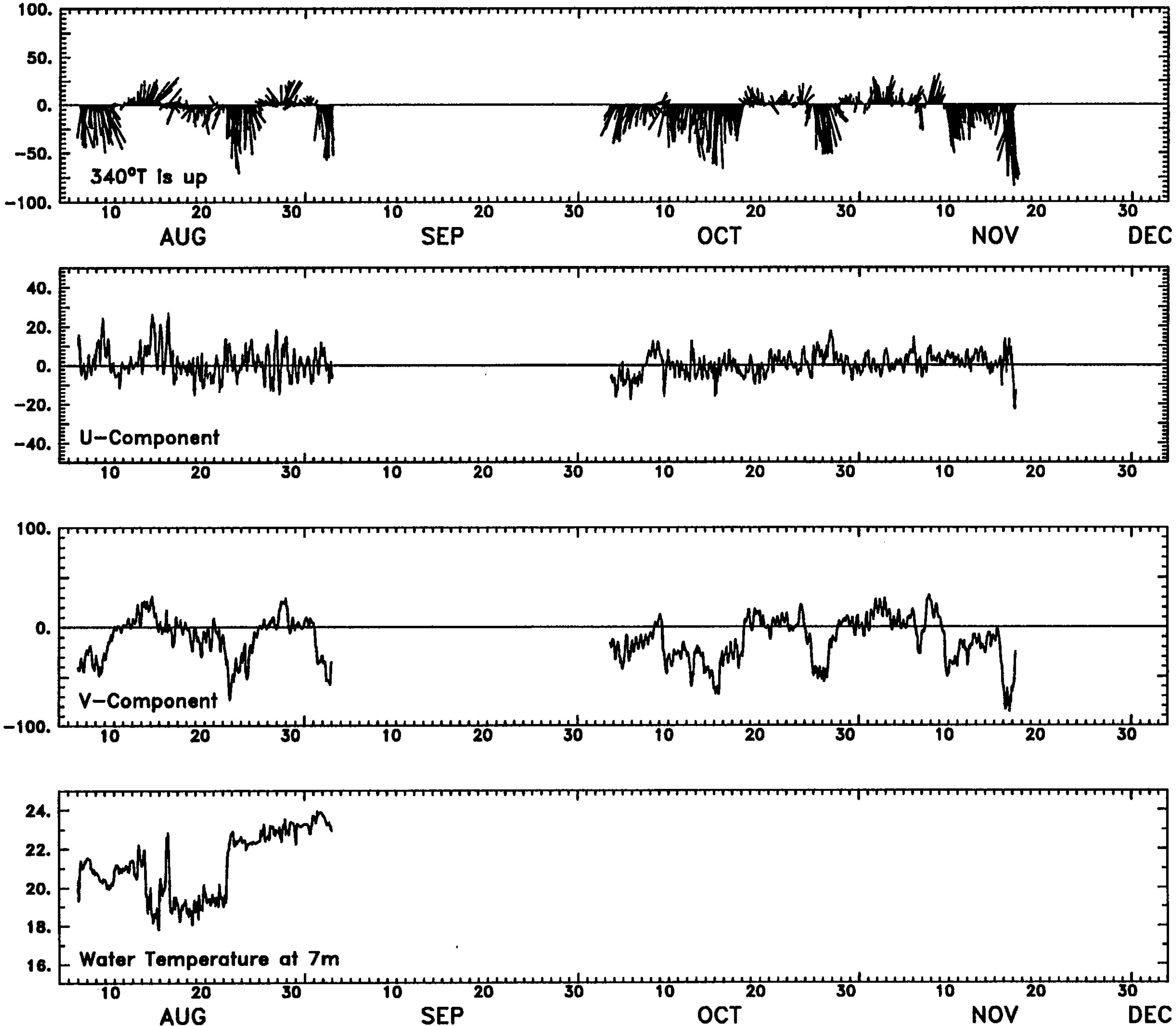


Figure 55

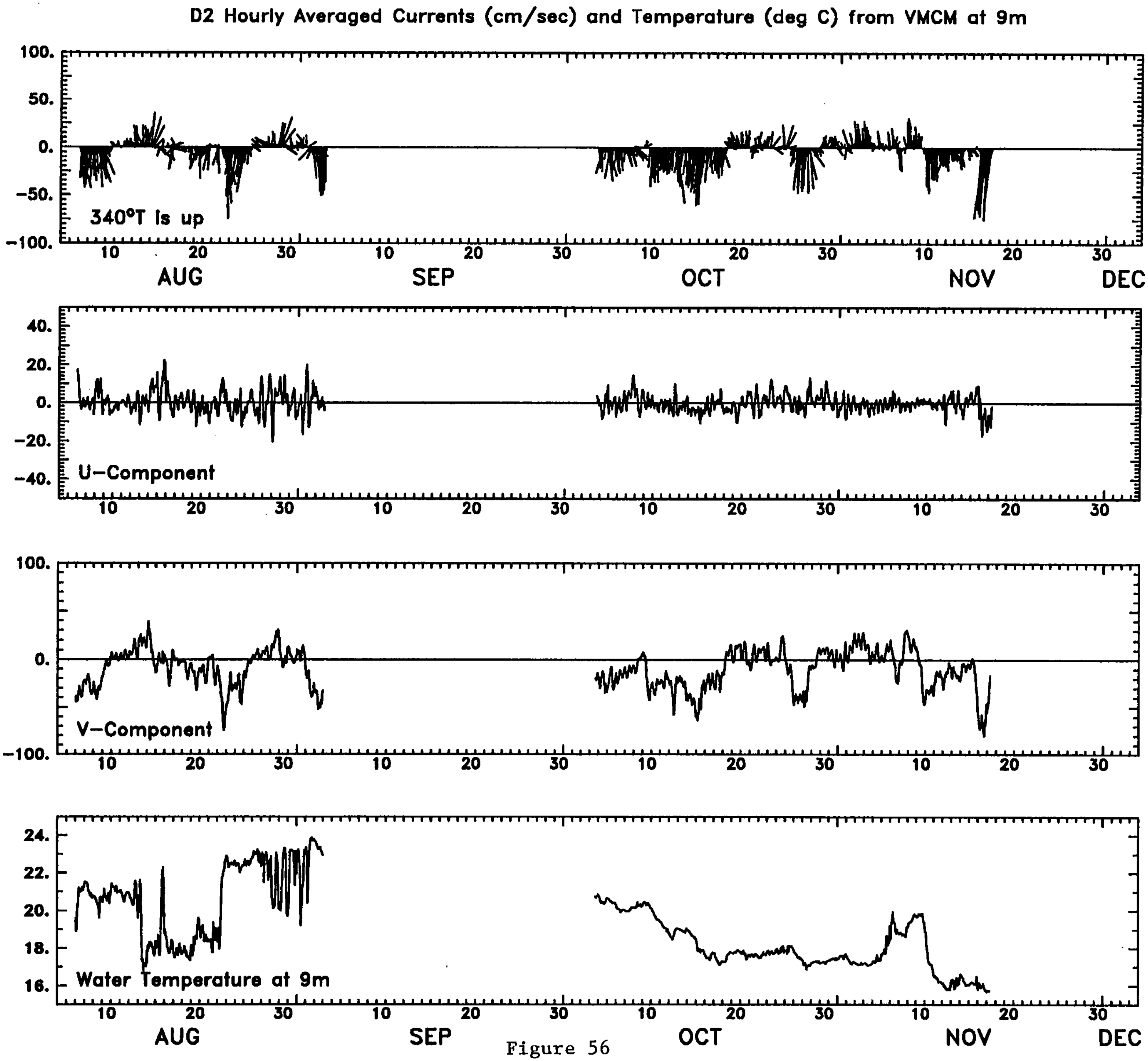

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 9m
100.
50.
0.
-50.
-100.
340°T is up
40.
20.
0.
-20.
-40.
U-Component
100.
0.
-100.
V-Component
24.
22.
20.
18.
16.
Water Temperature at 9m
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 56

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 12m

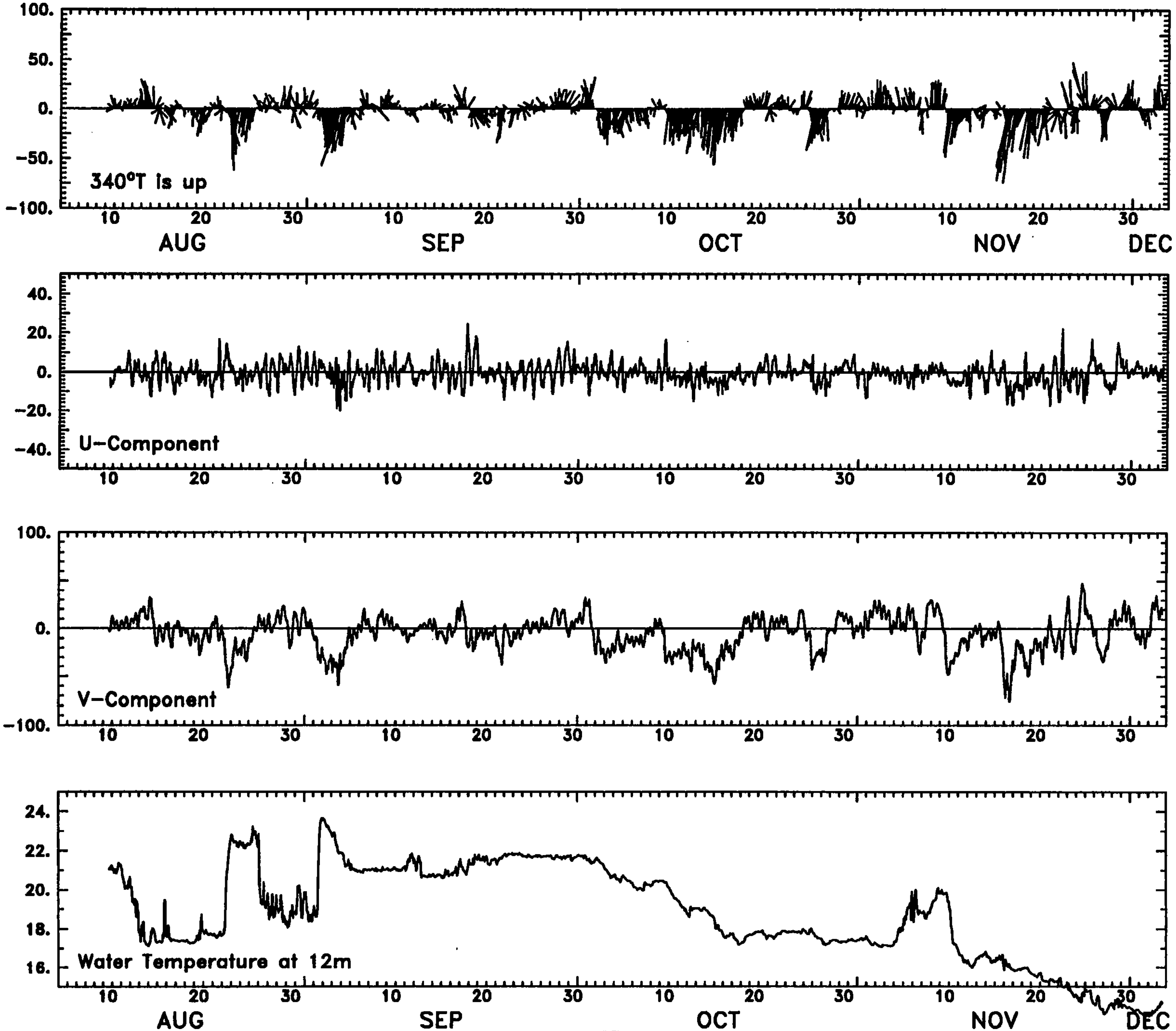


Figure 57

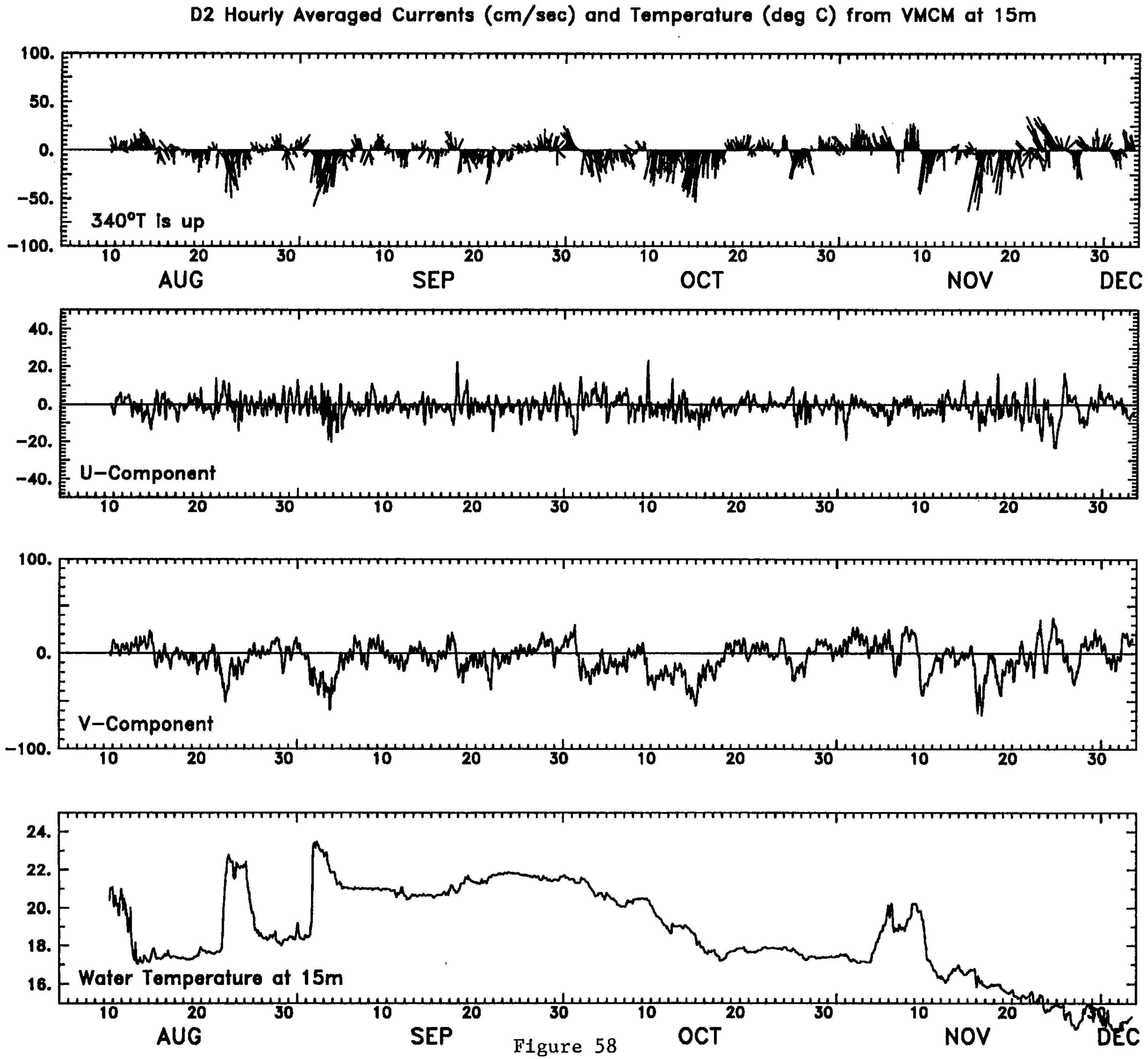

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 15m
100.
50.
0.
-50.
-100.
340°T is up
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC
40.
20.
0.
-20.
-40.
U-Component
100.
0.
-100.
V-Component
24.
22.
20.
18.
16.
Water Temperature at 15m

Figure 58

D2 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 17m

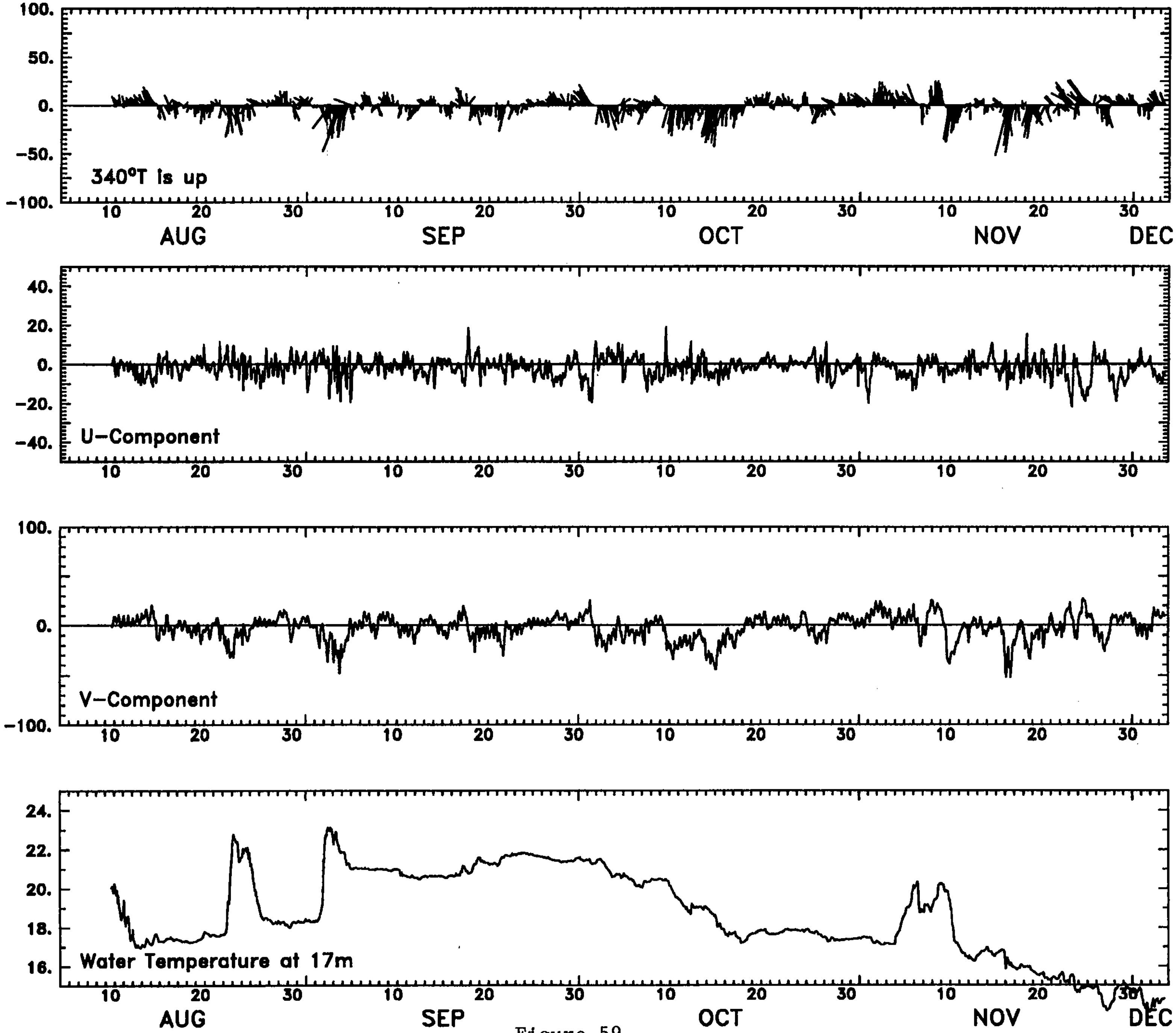
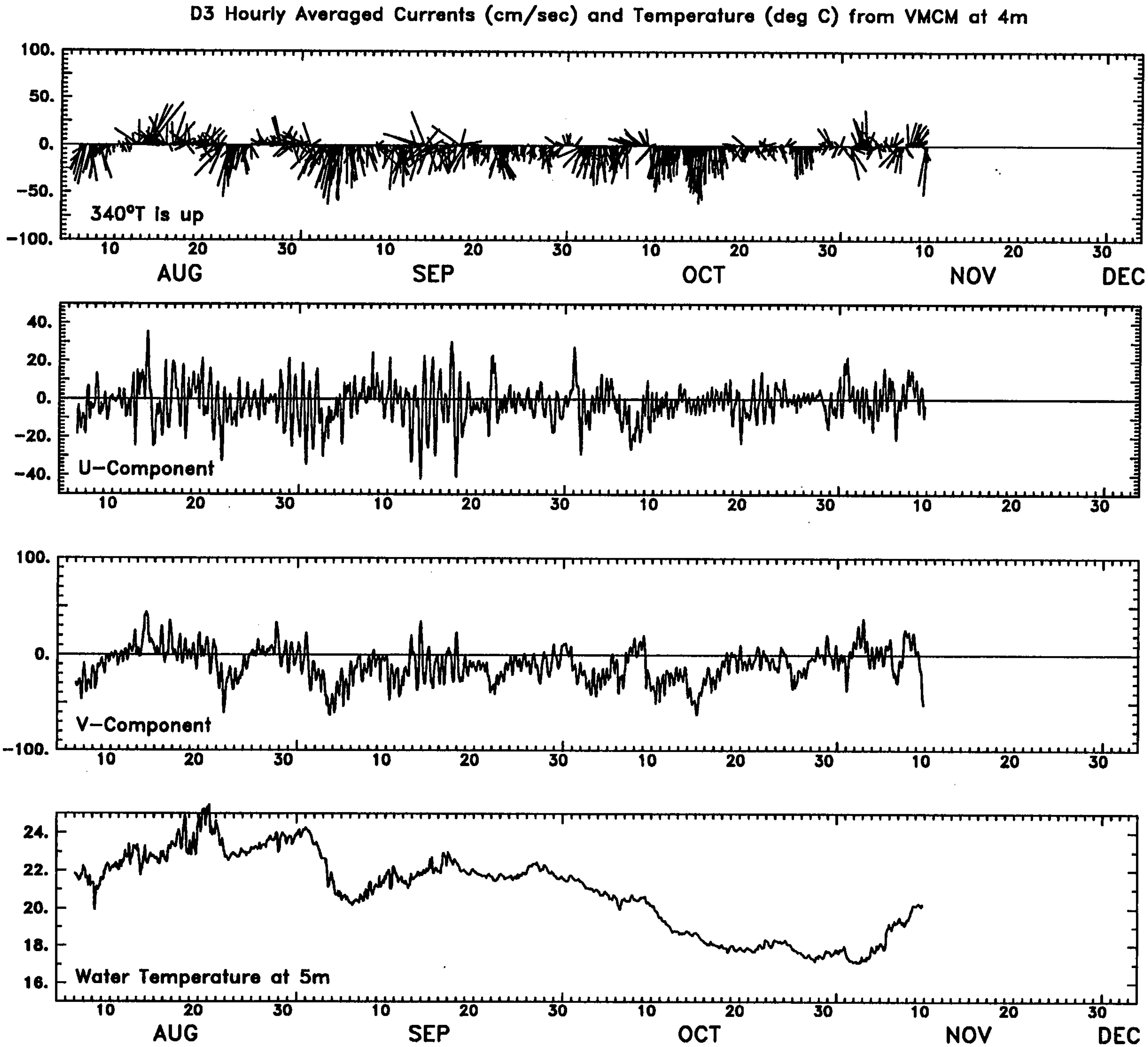


Figure 59



D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 4m

Figure 60

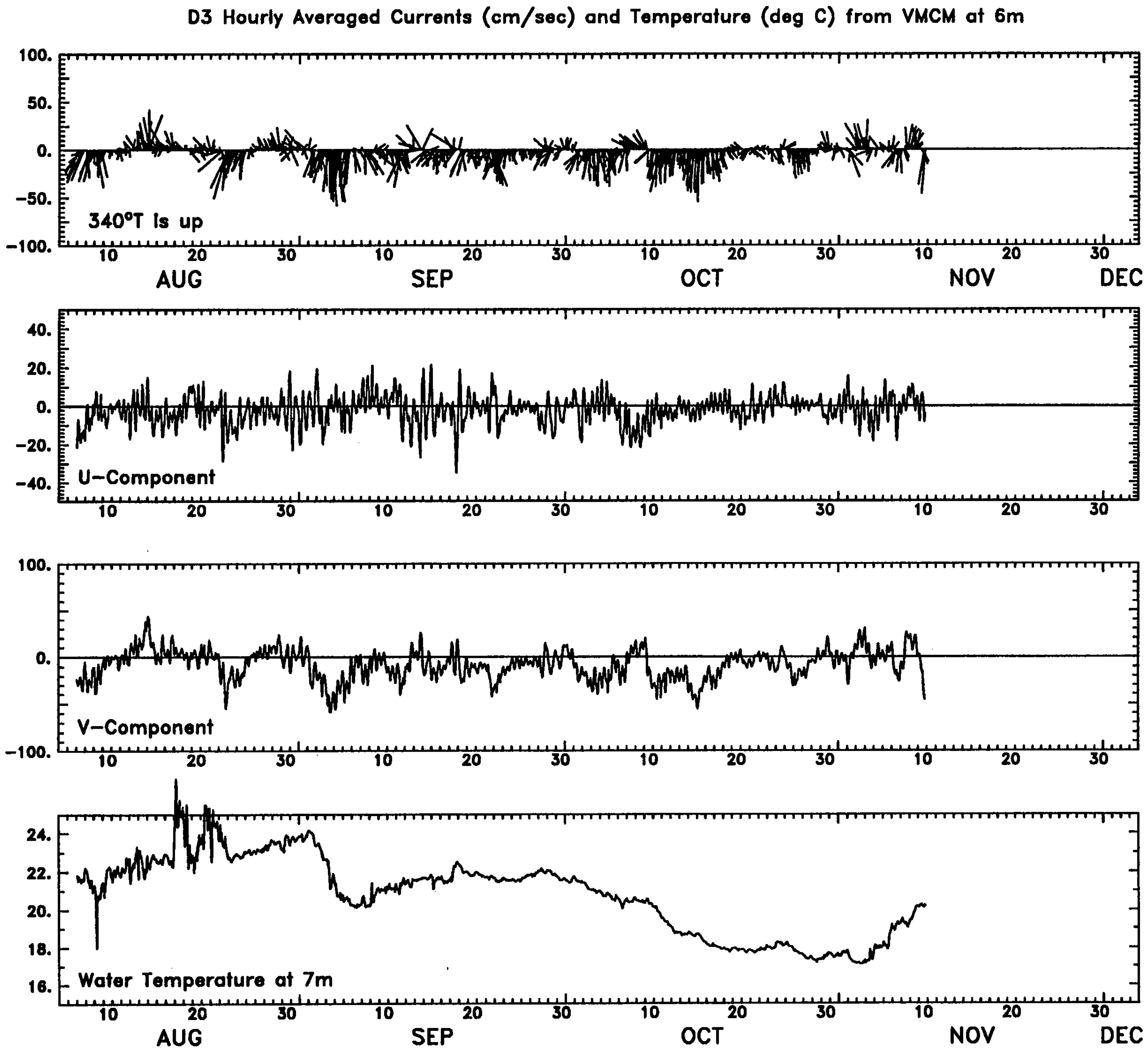

D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 6m
100.
50.
0.
-50.
-100.
340°T Is up
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC
40.
20.
0.
-20.
-40.
U-Component
100.
0.
-100.
V-Component
24.
22.
20.
18.
16.
Water Temperature at 7m

Figure 61

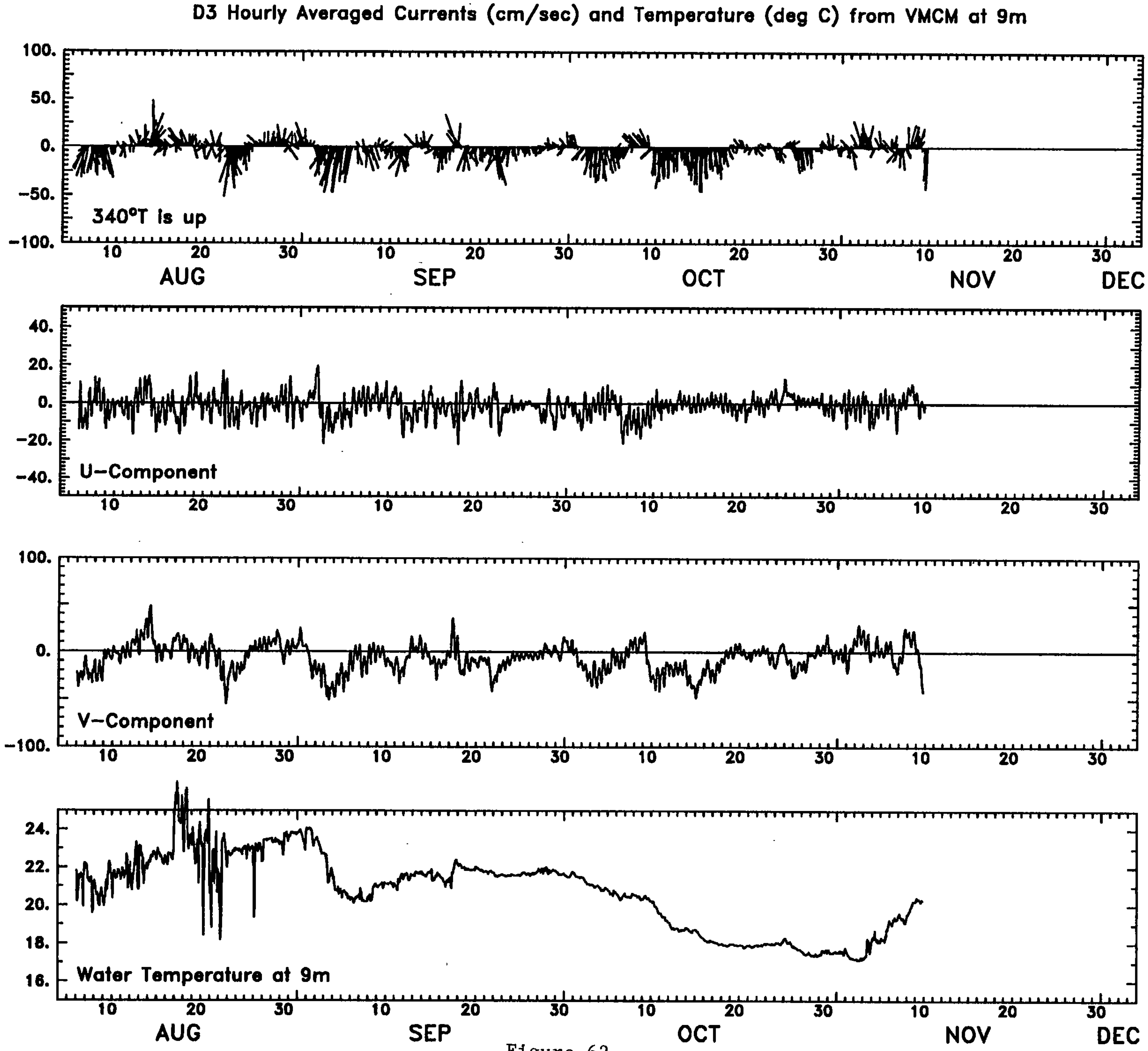

D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 9m
100.
50.
0.
-50.
-100.
340°T is up
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC
40.
20.
0.
-20.
-40.
U-Component
100.
0.
-100.
V-Component
24.
22.
20.
18.
16.
Water Temperature at 9m

Figure 62

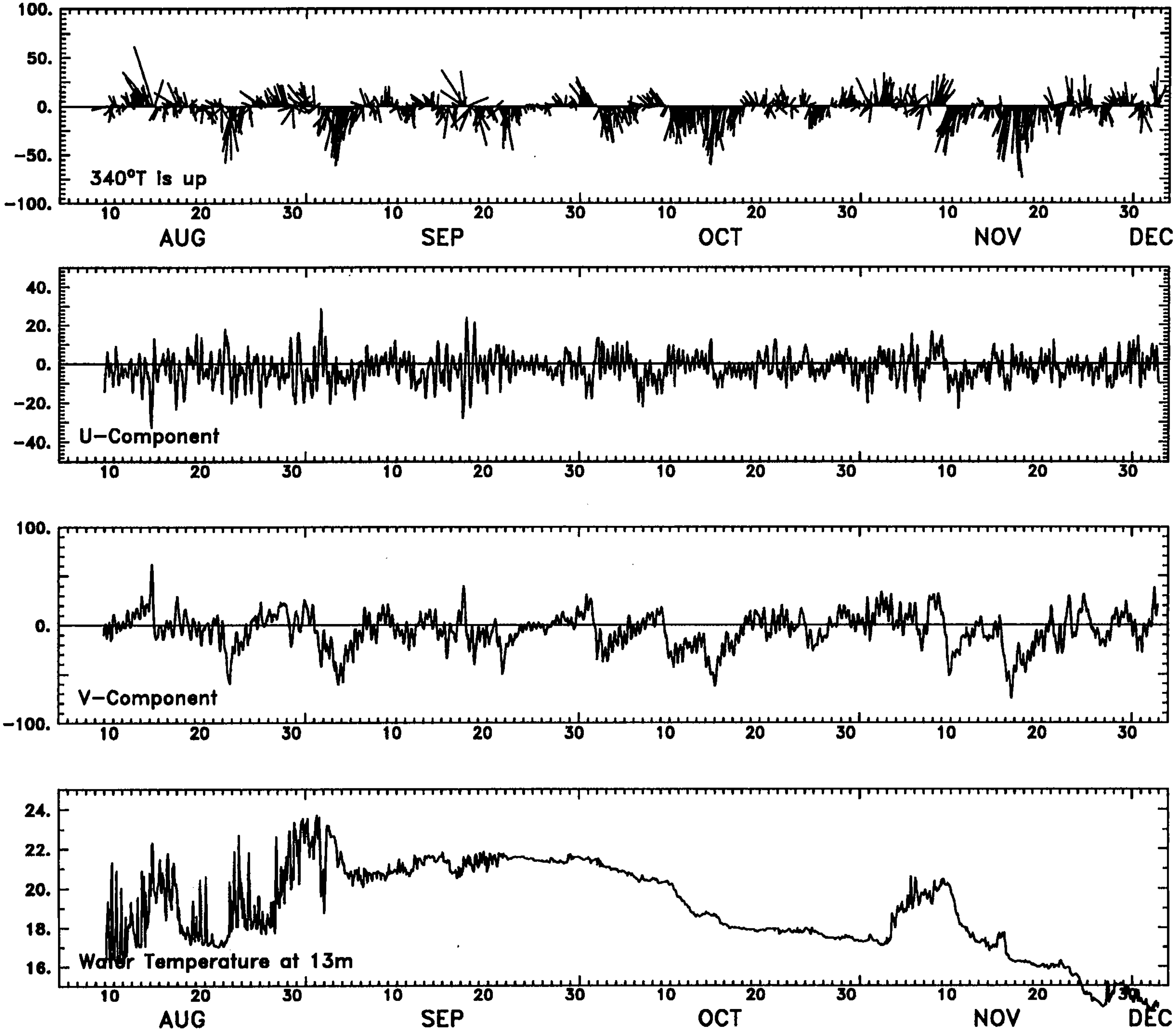

D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 13m

Figure 63

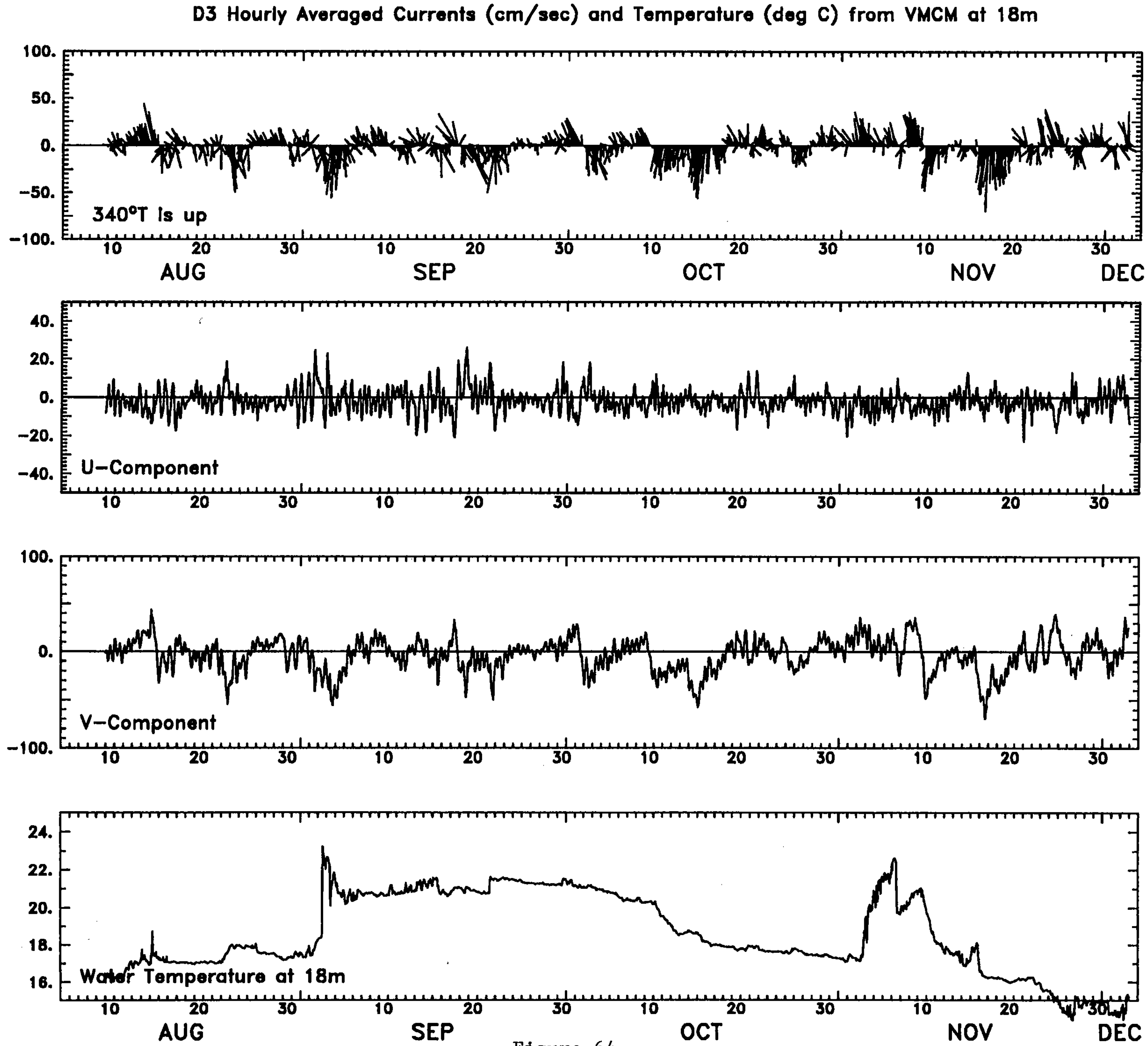
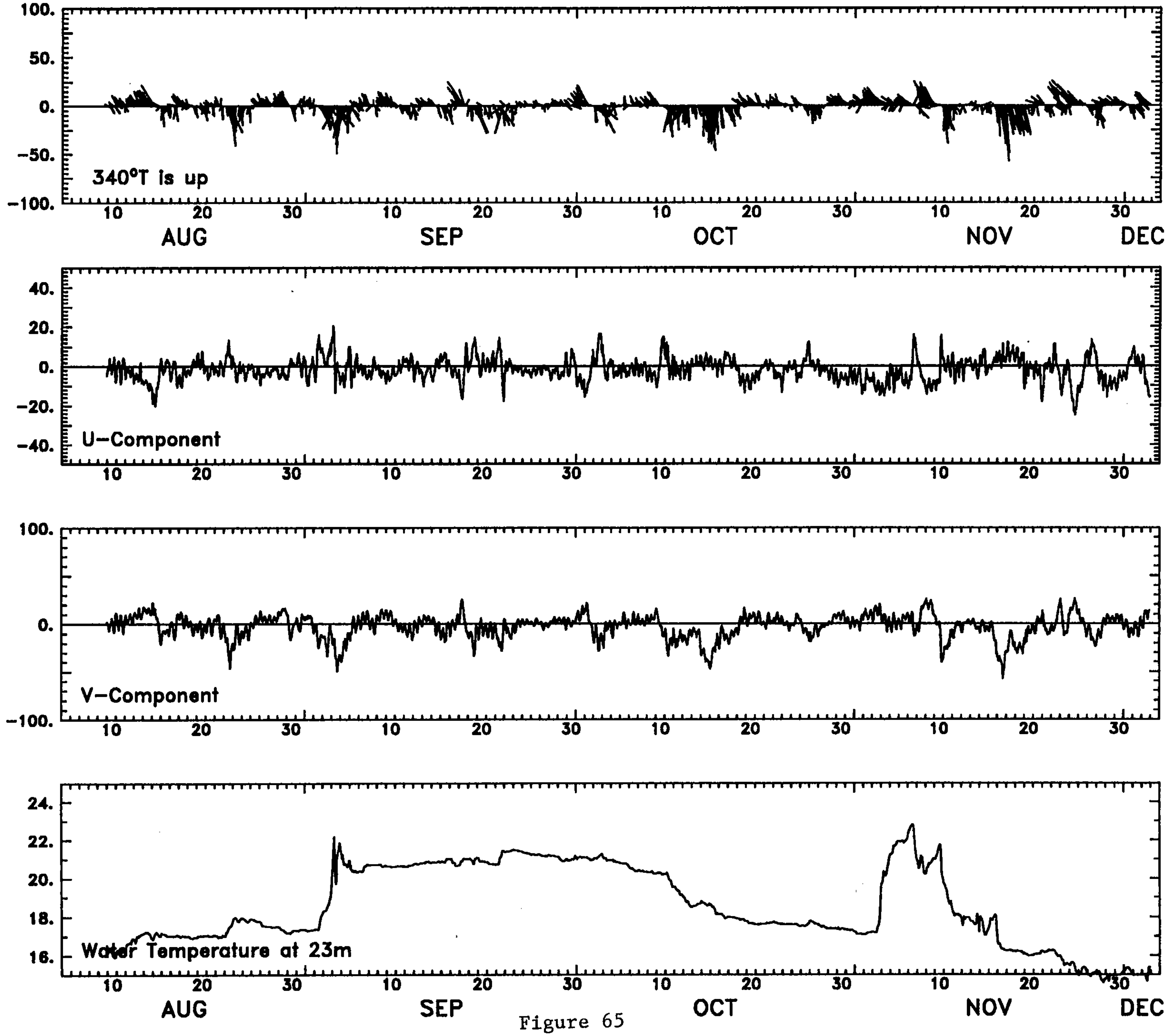

D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 18m
100.
50.
0.
-50.
-100.
340°T Is up
U-Component
40.
20.
0.
-20.
-40.
V-Component
100.
0.
-100.
Water Temperature at 18m
24.
22.
20.
18.
16.
10
20
30
10
20
30
10
20
30
10
20
30
AUG
SEP
OCT
NOV
DEC

Figure 64



D3 Hourly Averaged Currents (cm/sec) and Temperature (deg C) from VMCM at 23m

Figure 65

Cruise Chronology – Deployment

by S. J. Lentz

Cruise objective was to deploy 15 instrument moorings: 4 plankton pump moorings, 6 current meter moorings, 3 bottom pressure (SeaGauges) moorings, and 2 guard moorings with near-surface temperature/conductivity (SeaCat) instruments. For details of the CoOP Inner-Shelf mooring deployment proceedures, see Appendix 4.

Cruise Report for *R/V Endeavor* EN-249 August 4 - 13, 1994

Scientific Crew: Steve Lentz (chief scientist), Lisa Garland, Vicki Starczak, Craig Marquette, Willie Ostrom, Bryan Way, and Jay Austin.

Marine Technician: Tom Orvosh (URI)

August 4 — Departed Woods Hole at 7:00 pm on August 4, six days later than scheduled. The *R/V Endeavor* developed a problem (shaft cutlass bearing) on the cruise right before ours and had to go into the yard at Newport RI to get it fixed. We were unable to load everything for all 15 moorings because of the weight limit on the load. On August 3rd and 4th we loaded enough equipment to deploy the 20- and 25-m surface discus moorings and the surface toroid and subsurface moorings at the 12-m site. We trucked the anchors and three deck boxes for the other moorings to Little Creek, Virginia, where we planed to pick them up on Monday (August 7), after deploying the four moorings mentioned above. We had about a 36-hour transit and hoped to be on station for the first mooring deployment the morning of August 6.

August 5 — Steamed all day, going was a little rough and slower than expected. Most recent estimate is that we wouldn't reach the mooring site until about 3:00 pm the next day. Went over the mooring deployment procedure with Willie. Willie, Lisa and Jay did some setup. Bryan checked the VMCMs and the VAWRs, all fine was far as I knew.

25-m Site

August 6 — Made good time during the night because the wind came around from the south to from the north. We arrived on station at the 25-m site at about 8:00 am (local time). The R6 buoy and Herbers/Guza buoys were both clearly visible; it was hard to find

Pietrafesa's surface buoy which was only a small yellow sphere with a short vertical pole. Actual deployment took about an hour and was completed at 11:41 local time (15:41 UT). A line parted just at the end of the deployment, when the discus buoy was going into the water, which gave the buoy a good jerk, otherwise the deployment went very smoothly. Position was 36°14.63′N, 75°35.00′W in 25.8 m of water.

20-m Site

We set the deck for the 20-m site and deployed it after lunch. The only hitch was the crane lost power for about 10 mins. with the current meters up in the air. Deployment was completed at 15:07 (local time). Position was 36°11.88′N, 75°41.67′W in 21 m of water. Everything went very smoothly.

12-m Site

The 12-m surface mooring components were moved into place in the late afternoon and the mooring was deployed after dinner. Again the deployment went very smoothly and was completed at 18:36 local time. Position was 36°10.99′N, 75°44.02′W in 13.5 m of water. This is slightly deeper than planned and farther southeast from the FRF buoy than planned.

August 7 — We set the deck in the morning in preparation for deploying the 12-m subsurface mooring. Willie did a pull test on the small capstan to check that it would lift the 2000-lb anchor through the A-frame. However, when we began deploying the mooring it couldn't pull the anchor off the deck. The deck was reset using the ship's capstan and we moved back into position. However, the operation took long enough that we had drifted out of position, so I asked the captain to reposition us again, prior to finally deploying the mooring. The 2000- lb anchor touched bottom at 14:19 UT at 36°11.031′N, 75°43.933 W in about 13.6 m of water. The 500-lb anchor off the ground line went down 2 minutes later at 36°11.040′N, 75°43.890′W on a heading of about 60 deg. T.

Following the mooring deployment the deck was cleaned up, and Tom, Jay and I prepared for a CTD transect along the central mooring line. I generally followed Walt's positions but added two stations near our moorings. We started the CTD transect after lunch (12:44) and completed the transect of 12 stations at about 19:30. We had a little trouble on the first station at the 20 m site and redid it. Consequently we never went into the 12-m site as I had originally planned. After the second station things went smoothly and the data looked interesting.

We then steamed toward Little Creek, Virginia and planed to arrive the next morning to load the rest of the anchors and hardware.

August 8 — We arrived in Little Creek, Virginia about 9:00 am (local time) and the truck arrived shortly after we got there. We loaded in the morning and left Little Creek at 4:30 in the afternoon. The later departure was due to time needed to work on the *R/V Endeavor*. Jay and I spent time trying to post-process the CTD data we took but had little success. The marine tech was not familiar with the program to do the post-processing and there was no manual on board. I wanted to have a cleaner picture of the data we had so we could change our procedure if necessary. We steamied back to the 20-m site with the hope of putting four moorings in the next day. We had beautiful weather the last few days and I really enjoyed being at sea.

20-m Site

August 9 — We had a great day, deployed 5 moorings despite a problem with the capstan. Started setting up at 4:30 am for the 20-m surface plankton pump mooring. This deployment went very smoothly and we had the mooring in the water before 7:00 am. Position was 36°12.024′N, and 75°41.772′W. After breakfast we set up for the 20-m subsurface plankton pump mooring and began deployment at about 9:00 am. The block on the A-frame got jammed and the 2000-lb anchor was swinging from one side of the boat to the other until the jam came free. We had to replace the wire rope which got hammered. After that the ship's capstan stopped working. Finally got the capstan fixed and completed the mooring deployment at 10:17. Position was 36°12.028′N, 75°41.724′W.

25-m Site

To give the crew time to fix the capstan we moved to the 25-m site and began setup at about 10:45 for the surface plankton pump mooring. Everything went smoothly and the deployment was started about 12:00 and completed by 12:30. Position was 36°14.433′N, 75°34.890′W. By this time the capstan was fixed, so we set up to deploy the subsurface plankton pump mooring at the 25-m site. The deployment began around 1:30 and was completed about 2:00. This deployment went smoothly. Position was 36°14.550′N, 75 34.868′W. Things were going well so we pushed on and set up the 25-m subsurface current meter mooring. We began the deployment at 4:00 pm and completed it at 4:30 with no problems. Position was 36°14.697′N, 75 35.176′W. The Guza/Herbers and Pietrafesa's buoys were both still on station. It was another beautiful day and evening.

20-m Site

August 10 — Another good day. It was flat calm when I got up about 5:00 am. We set the deck to do the SeaGauge mooring at the central 20-m site and completed the deployment by 7:00 am. Position was 36°11.82′N, 75 41.85′W. Set the deck for the 20-m subsurface current meter mooring after breakfast. Completed the deployment by 9:30 am; position was 36°11.85′N, 75°41.54′W. Wright's guard buoy and the Herbers/Guza buoy were both there. I also saw one of the white floats marking Sandy Williams's tripod. We then steamed to the northern site, which took about 1.5 hours. We deployed the surface guard buoy with a SeaCat before lunch. The mooring position was 36°28.53′N, 75°46.95′W. We deployed the SeaGauge mooring right after lunch at about 12:30; position 36°28.54′N, 75°47.03′W.

We then steamed to the southern station to put in the last two moorings. The steam took about 3 hours. During preparations for the northern mooring Craig found a problem with one of the SeaCats, it was not outputting data to his computer when he interrogated it. On the steam down Craig dumped the data from that SeaCat, and, after several tries at getting things set up correctly we were able to convert the data from hex to ascii and show that the SeaCat was working. We arrived at the northern site at about 3:30 and deployed the surface guard with the last SeaCat by 3:40. The position was 35°58.57′N, 75°35.21′W. We then deployed the SeaGauge, finishing before 4:00 pm. Position was 35°58.49′N, 75°35.23′W. We were missing two shots of 16-m wire. We improvised and used 3/8" chain. One of the wire shots had been mashed by a swinging anchor, but there were no spares and we were one short even if this hadn't happened.

CTD Surveys

We then did the large-scale CTD survey Walt laid out working from south to north. There was a problem at the start; for some reason the computer logging the data from Mark III unit wasn't getting any input. For unknown reasons, however, the system started working again and we were able to start the survey about 9:00 pm (local time).

August 11 — Proceeding with the CTD survey we were at the central line moving onshore. Saw one of the Herbers/Guza buoys near 36°23.0′N, 75°16.3′W at 10:40 am (local time). Everything was present at the 25-m site as we went by at 1:30 pm (local time) (Pietrafesa, Herbers/Guza, two surlyn markers for subsurface mooring, surlyn buoy for plankton pumps, and discus buoy. Saw everything at the 20-m site including at least one of the small white floats over Sandy's tripod. While we were at the 20-m CTD station, the *R/V Hatteras* sent over a zodiac to transfer Lisa Garland. After completing the transfer, we proceeded with the CTD survey. I could see both our toroid and the surlyn marker buoy at the 12-m site.

August 12 — Finished the CTD survey at 4:44 am; we did a total of 74 CTD stations: 13 along the central line on August 7 and 61 during the large scale survey from 9:00 pm

August 10 to 5:00 am August 12. We arrived at Nauticus Pier in Norfolk at about noon, ending a very successful cruise.

August 14 — Talked to Jan (marine tech) today. He noticed that the fast response thermistor on the CTD was flaky, which explains the noisy data.

Table A1.1 lists the CTD transects along the central line for August 7th, and the large-scale survey beginning August 10th, 1994.

Table A1.1: CTD Locations

CoOP Cruise EN249 First CTD transect along central line August 7, 1994

cast number	latitude deg min	longitude deg min	depth m	time UT
1	36 11.58	75 41.97	20	16:44
2	36 11.66	75 42.00	20	17:05
3	36 12.65	75 40.61	20	17:36
4	36 13.16	75 39.18	20	18:09
5	36 13.78	75 37.87	26	18:37
6	36 14.52	75 35.18	26	19:15
7	36 15.43	75 33.48	26	19:46
8	36 16.95	75 30.94	24	20:20
9	36 18.13	75 27.88	29	21:00
10	36 19.37	75 24.63	26	21:44
11	36 20.51	75 22.04	30	22:15
12	36 21.65	75 18.96	28	22:49
13	36 22.94	75 16.31	33	23:18

CoOP Cruise EN249 Large-scale CTD survey Starts August 10, 1994

cast number	latitude deg min	longitude deg min	depth m	time UT
14	35 42.4	75 28.4	19	1:07
15	35 43.2	75 26.2	20	1:40
16	35 44.5	75 23.4	22	2:08
17	35 45.4	75 20.2	21	2:40
18	35 46.8	75 17.5	35	3:10
19	35 58.8	75 17.1	30	4:28
20	35 57.7	75 20.0	32	4:28
21	35 56.7	75 22.7	21	5:33
22	35 55.3	75 25.7	22	5:09
23	35 54.1	75 28.5	20	6:46
24	35 53.0	75 31.8	14	7:20
25	36 1.9	75 38.2	14	8:48
26	36 2.6	75 36.6	21	9:13
27	36 2.9	75 35.5	19	9:31
28	36 3.4	75 33.9	18	9:53
29	36 4.3	75 32.3	25	10:13
30	36 4.8	75 31.2	26	10:32
31	36 5.4	75 29.8	26	10:54
32	36 5.9	75 28.1	25	11:16
33	36 7.5	75 25.1	27	11:47

CoOP Cruise EN249 Large-scale CTD survey Starts August 10, 1994

cast number	latitude deg min	longitude deg min	depth m	time UT
34	36 8.4	75 22.1	31	12:17
35	36 10.0	75 19.4	31	12:45
36	36 10.9	75 16.7	34	13:10
37	36 23.0	75 16.2	33	14:28
38	36 23.0	75 16.3	33	14:30
39	36 21.7	75 18.9	28	14:52
40	36 20.5	75 22.0	30	15:19
41	36 19.4	75 24.6	27	15:45
42	36 18.2	75 27.7	30	16:19
43	36 17.0	75 30.9	25	16:47
44	36 15.5	75 33.6	27	17:16
45	36 14.5	75 36.4	27	17:42
46	36 13.8	75 37.9	26	18:03
47	36 13.2	75 39.2	21	18:24
48	36 12.6	75 40.7	21	18:45
49	36 11.0	75 42.3	18	19:17
50	36 11.6	75 43.7	15	19:58
51	36 21.5	75 47.8	8	21:18
52	36 21.9	75 46.5	17	21:39
53	bad cast			
54	36 22.6	75 45.1	17	22:20
55	36 23.4	75 43.6	17	22:44
56	36 23.8	75 42.2	19	23:02
57	36 24.5	75 40.7	21	23:23
58	36 25.2	75 39.3	22	23:52
59	36 25.9	75 37.5	22	00:16
60	36 26.9	75 34.7	25	00:50
61	36 28.1	75 31.8	24	01:17
62	36 29.3	75 28.7	30	01:45
63	36 30.7	75 25.8	27	02:12
64	36 38.5	75 34.5	19	03:25
65	36 37.2	75 37.2	17	03:51
66	36 36.0	75 40.2	17	04:22
67	36 34.9	75 43.0	21	04:53
68	36 34.9	75 43.1	21	04:57
69	36 33.7	75 46.0	21	05:27
70	36 32.4	75 48.7	13	05:55
71	36 42.6	75 52.5	14	07:09
72	36 43.7	75 49.5	16	07:38
73	36 45.0	75 46.4	17	08:11
74	36 46.3	75 43.6	18	08:44

Cruise Chronology - Recovery

by S. J. Lentz

The primary cruise objective was to recover the seven remaining instrumented moorings: 2 surface moorings, 2 subsurface current meter moorings and 3 subsurface tide gauge moorings. A secondary objective was to complete a large-scale CoOP inner-shelf CTD survey. See Table A1.2 for additional mooring deployment and recovery information. Table A1.2 lists the initial deployment positions and dates, events which led to mooring turnarounds, and recovery dates.

Cruise Report for *R/V Endeavor* EN-258 December 1 – 7

Scientific Crew: Steve Lentz (chief scientist), Craig Marquette, Larry Costello, Paul Bouchard, Ed Dever, Jay Austin

Marine Technician: Tom Orvosh

December 1 - Departed Woods Hole at 1:30 pm. We planed to be on station to recover the northern tide gauge mooring early on the morning of December 3. We ended up with only the SeaBird CTD and no spare CTD.

20-m Site

December 3 — The weather was nice and the steam to the northern site was uneventful. We got to the site sometime around 11 pm and began setting up to recover the northern tide gauge mooring at about 5:30 am. We waited till there was enough light to spot the small surlyn marker and began the recovery at about 6:30 am. After clipping into the surlyn marker buoy, the line went under the ship and got caught in the screw. The bull line was cut through and came free. After a few minutes the surlyn buoy came to the surface with only the pickup hook on it. The ship tried to find divers and finally got hold of the *R/V Hatteras*, which had three divers aboard. ~~While waiting for the~~ *R/V Hatteras* we proceeded with recovery of the tide gauge mooring restarting at 9:07 am. The capstan failed before we got the first anchor on board. The capstan was full of water from the rough weather on the previous cruise. We proceeded using the crane and finished recovering the mooring at about 10:20 am. Tide gauge looked fine.

We proceeded to set the deck for recovery of the surlyn surface buoy and began recovery at 10:36 am. We recovered this buoy over the starboard side using the crane and completed the recovery at about 11:05. SeaCat on this buoy looked fine.

The divers from the *R/V Hatteras* arrived just after lunch (about 12:30) and confirmed that the pickup sling and a section of the bull rope were jammed in the screw. They were unable to pull it out by hand. A line was hooked to the sling and rigged through the A-frame. We used this to try pulling the jammed line out, first by hand, then with an air tugger and finally with the ship's crane. Not one of these attempts was successful, and the line parted when the crane was pulling. The divers went back down and cut as much of the line off as they could, but a small (maybe 1 ft) section was still jammed. The ship was then declutched to see if this piece would spin out. Subsequent inspection by the divers indicated that it had come out as it was no longer visible.

25-m Site

We then steamed to the 25-m site and set up for dragging. We knew we would need to drag for the 25-m subsurface current meter mooring because the surlyn marker buoy had come ashore 15 October. In preparation we developed a dragging plan to lay out two marker buoys at the locations of the subsurface mooring and of the original surlyn marker buoy noted in the mooring logs. We then planned to make several dragging passes through these buoys. We also borrowed Dave Aubrey's side-scan sonar as a backup method for searching for the mooring.

We arrived at the 25-m site at 2:49 and deployed two marker buoys, the first was (fortuitously as it turns out) about 100 m south of the subsurface mooring location from deployment. The second marker was right on the location where the surlyn marker buoy had been. Our first dragging pass was near the northern marker buoy, which got picked up by the drag hooks. We redeployed the northern marker buoy and made two more passes north of the subsurface mooring without success. The first mate aboard the *R/V Endeavor* then made one pass south of the subsurface mooring location and hooked into the mooring at 5:05 pm. When the drag hooks came up we were within a few feet of the 500-lb anchor. We proceeded to recover the mooring using the winch. When the subsurface float came to the surface, we stopped off the anchor and then completed the recovery from the subsurface float end. This worked well, as none of the current meters was damaged. The recovery of the 25-m subsurface mooring was completed at 6:20 pm. All the current meters looked good. Despite the various problems a very successful day. We planed to begin recovery of the two moorings at the 20-m site early the next morning.

20-m Site

December 4 — Started setting up to recover the 20-m tide gauge at 6:00 am. The surlyn markers for both the tide gauge and subsurface mooring were present. Recovery started at 7:12 am. Hooked into the surlyn marker which then went under the ship and got stuck. Fortunately the ship was able to back off the surlyn marker. On our second attempt we backed onto the buoy and used the crane to recover over the back of the fantail. The rest of the tide gauge recovery went smoothly and was completed at 8:31 am. Polypro line was wrapped around the tide gauge tower.

Set up for recovery of 20-m subsurface current meter mooring and began recovery at 9:20 am. Recovery went smoothly and was completed at 10:12. Current meters all looked fine, though it looked like the deepest one had been pretty close to the bottom.

Steamed to the southern site and set up to recover the southern tide gauge. Began recovery of southern tide gauge at 12:20 and completed recovery at 12:52. Recovery went smoothly again. Started recovery of the last mooring, surlyn guard buoy, at 13:12 and finished at 13:30. Danforth anchor was wrapped around main chain maybe two meters above the anchor. We had perfect weather again!!!

CTD Surveys

We then steamed to the south to begin a large-scale CTD survey. Began the large scale CTD survey at 4:55 pm. Jay, Paul and Ed were one shift and Craig, Larry and Steve are the other. We didn't start displaying light transmission and fluorometer until the fifth CTD cast. At this point we realized that the pump wasn't turning on till a depth of 10–15 m. The pump turns on 45 seconds after the conductivity measurement exceeds a certain very low value. However, the manual states that if all the air isn't purged before the pump starts it doesn't get properly primed. We believe this was the problem. So on subsequent casts we took the CTD down to 5 m immediately and waited there until the transmissometer and fluorometer turned on, which was about 10 seconds after the pump turned on. While this took a little more time and would make editing of the data more work, it seemed to solve the problem. We were also having some problems with the computer communication locking up occasionally. Otherwise, the survey went smoothly through the night of December 4. Remarkably, the water column was stratified in both temperature and salinity, presumably due to the calm and warm weather we were having.

December 5 — When I woke up this morning at about 8:00 am the CTD was not functioning. We spent the next 7 hours working on the CTD. We finally determined there were two sources to the problems. First there was a problem in a short piece of cable that connected the CTD to either the lab computer when downloading the data or to the wire during the cast. We removed this piece of cable and plugged directly into the pump which solved our major problem. The second problem arose because somehow the default baud rate setting had been changed from 600 to 9600. We were finally able to continue the CTD survey. We then worked our way onshore along the central line. The sea state picked up during the night and there were rougher seas all day.

December 6 — The rest of the CTD survey went smoothly and we finished this morning at 9:18 am. Early the evening before I had problems with the computer locking up and having to be reset. However, I think it was because I was exiting Seasave before the CTD was turned off. I had no further problems when I waited to exit Seasave till after the CTD was off. We ended up completing 50 casts of the large-scale survey, having left off some of the shallowest stations. It was flat calm again and we then steamed back to Woods Hole. A very successful trip as we accomplished everything we set out to do.

December 7 — Due to arrive at WHOI at 1:00 pm. Spent some of the previous day looking at the CTD data with Jay and Ed. There seemed to be a problem with conductivity. It may have been associated with the pump not working properly, possibly due to air in the lines not bleeding out properly. In any case the recorded conductivities yielded unrealistic density profiles. We compared the conductivity to the temperature and it looked like the conductivity lagged temperature in many cases. This was one reason why I think there was a problem with the pump. There were also some substantial differences between the upcasts and the downcasts, particularly near the surface.

Epilogue. Apparently the oxygen sensor being at the top of the CTD package and the lack of a bleeder hole resulted in air remaining in the line and the pump not functioning properly. Jay had looked carefully at the CTD data and I think the data will only be useful in a qualitative context.

Table A1.2 Mooring Deployment and Recovery Information

Station (mooring type)	Deployment (GMT)	Recovery (GMT)	Position (GPS)	
Three Surface/Subsurface Pairs				
D1 (13-m Surface)	**6 August 1994**	**12 October 1994**	**36°11.002′N**	**75°44.010′W**
* 12 October 1994 Surface mooring beached trailing 2 VMCMs.				
D1 (13-m Subsurface)	**7 August 1994**	**1 November 1994**	**36°11.040′N**	**75°43.890′W**
* Early recovery 1 November 1994 *R/V Cape Hatteras.*				
D2 (20-m Surface)	**6 August 1994**	**18 November 1994**	**36°11.882′N**	**75°41.675′W**
* Mooring broke free 4 September 1994 and recovered at Kittyhawk. Returned to WHOI for repair. * 4 October 1994 — Redeployed. * 15 October 1994 mooring drifted South approximately 200 m and held position. * Mooring beached 18 November 1994.				
D2 (20-m Subsurface)	**10 August 1994**	**4 December 1994**	**36°11.851′N**	**75°41.544′W**
* Normal recovery operations *R/V Endeavor*				
D3 (25-m Surface)	**6 August 1994**	**16 November 1994**	**36°14.640′N**	**75°35.000′W**
* 1 September 1994 — Redeployed. Argos transmission failure (VAWR failed to transmit data). Top current meter was damaged during recovery operations and replaced with a spare. * 5 September 1994 VAWR failed to transmit data. * 4 October 1994 — **Redeployed.** Top current meter was damaged during recovery operations and replaced with a spare.			**(36°14.454′N**	**75°35.424′W)**
* 15 October 1994 mooring drifted South 2 km and held position. * 10 November 1994 mooring broke free and drifted South into 30 feet of water and held position. * Mooring beached 16 November 1994.				
D3 (25-m Subsurface)	**09 August 1994**	**3 December 1994**	**36°14.697′N**	**75°35.176′W**
* Needed to drag for the mooring as the marker buoy came ashore early October.				
SeaCats and Tide Gauges				
N2 (20 m NSC)	**10 August 1994**	**3 December 1994**	**36°28.532′N**	**75°46.946′W**
DP (Duck Pier)	**26 July 1994**	**8 November 1994**	**36°10.910′N**	**75°45.090′W**
S2 (20 m SSC)	**10 August 1994**	**4 December 1994**	**35°58.576′N**	**75°35.207′W**
N2 (20 m NTG)	**10 August 1994**	**3 December 1994**	**36°28.537′N**	**75°47.028′W**
D2 (20 m CTG)	**10 August 1994**	**4 December 1994**	**36°11.823′N**	**75°41.850′W**
S2 (20 m STG)	**10 August 1994**	**4 December 1994**	**35°58.489′N**	**75°35.226′W**
J0 (Jetted Pipe)	**20 August 1994**	**29 October 1994**	**36°27.661′N**	**75°50.528′W**
J1 (Jetted Pipe)	**25 July 1994**	**29 October 1994**	**36°19.979′N**	**75°48.303′W**
J2 (Jetted Pipe)	**24 July 1994**	**29 October 1994**	**36°11.238′N**	**75°44.760′W**
J3 (Jetted Pipe)	**10 August 1994**	**30 October 1994**	**36°02.786′N**	**75°40.385′W**
J4 (Jetted Pipe)	**10 August 1994**	**30 October 1994**	**35°58.434′N**	**75°37.773′W**

Appendix 2: Data from Service Argos

by Richard E. Payne

The Argos system provided continually updated environmental data sets from the WHOI VAWRs mounted on the 20-m and 25-m moored buoys.

The data were recorded internally by the VAWR (7.5-minute sample rate) as well as transmitted to us through the Service Argos system. Transmitted data included 7.5-minute averages of north and east vector averaged wind components, air temperature, sea surface temperature, relative humidity, barometric pressure, short-wave solar irradiance, long-wave irradiance, battery voltage, and mooring tension.

In addition to being written to tape, each data record was written to 1 of 24 buffers in the transmitter. As a new record is written to buffer 1, the other records are shifted by one buffer and the oldest record is discarded. The transmitter cycles through the 24 buffers, sending the contents of successive buffers on 3 Argos transmitter identification numbers, each at 90-second intervals. The 24 buffers represent 3 hours of data which was transmitted in 12 minutes. The length of time a satellite is high enough above the horizon to receive transmissions varies from one pass to another, but the redundancy in the VAWR transmissions resulted in only a few short gaps per day.

The data were downloaded in bulk by NASA, then transmitted via a communications satellite to the Argos center in France where they were split into files by transmitter identification number. Data headed for WHOI were transmitted via communications satellite to the Argos center in Washington, DC. Our data were sent to us via the Internet as a single file per day. This file was processed automatically upon arrival at WHOI and accumulated as an ASCII file for each instrument.

The pre-deployment meteorological observations from the WHOI test site (Appendix 3) and Argos monitoring compared well.

Figure A2.1 shows the Argos data obtained from the 20-m VAWR during October. Figure A2.2 shows the VAWR data which were recorded on magnetic tape and processed at WHOI. Figure A2.3 shows the two weeks of Argos data obtained from the VAWR at the 25-m site (Section 2.3.3).

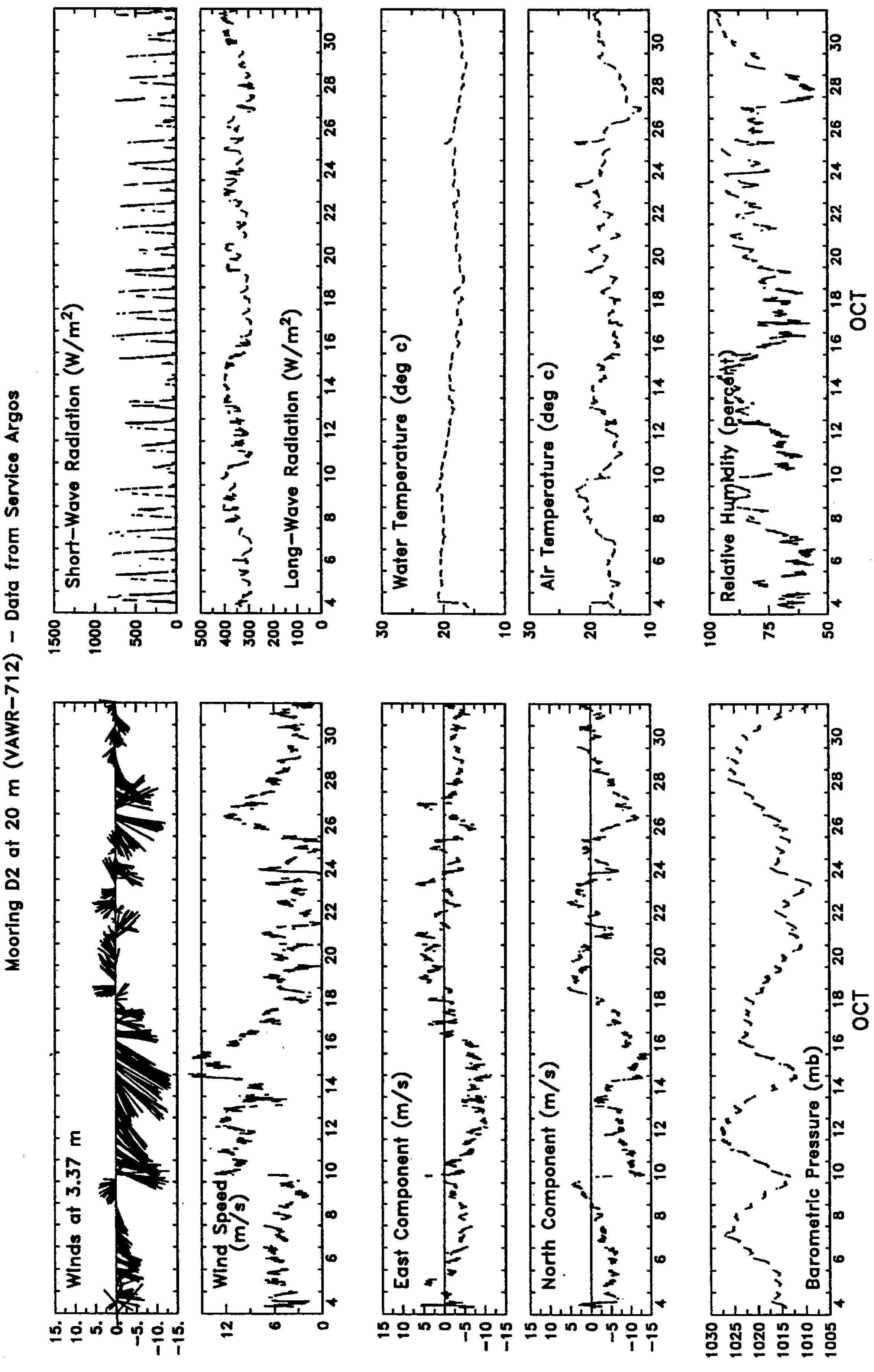


Figure A2.1: Argos data obtained from the 20-m VAWR during October 1994.

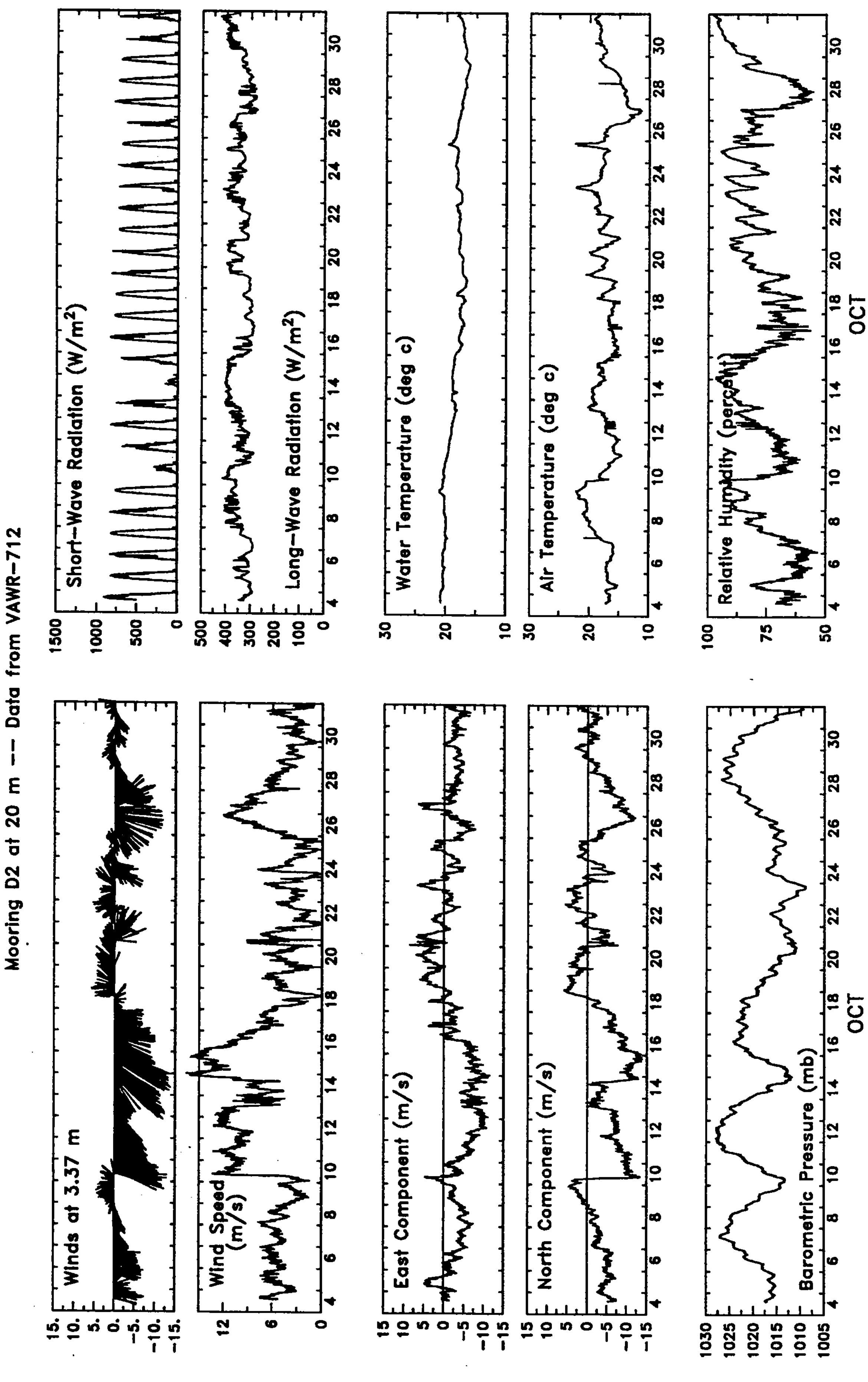


Figure A2.2: Data recorded on magnetic tape and processed at WHOI from the 20-m VAWR during October 1994.

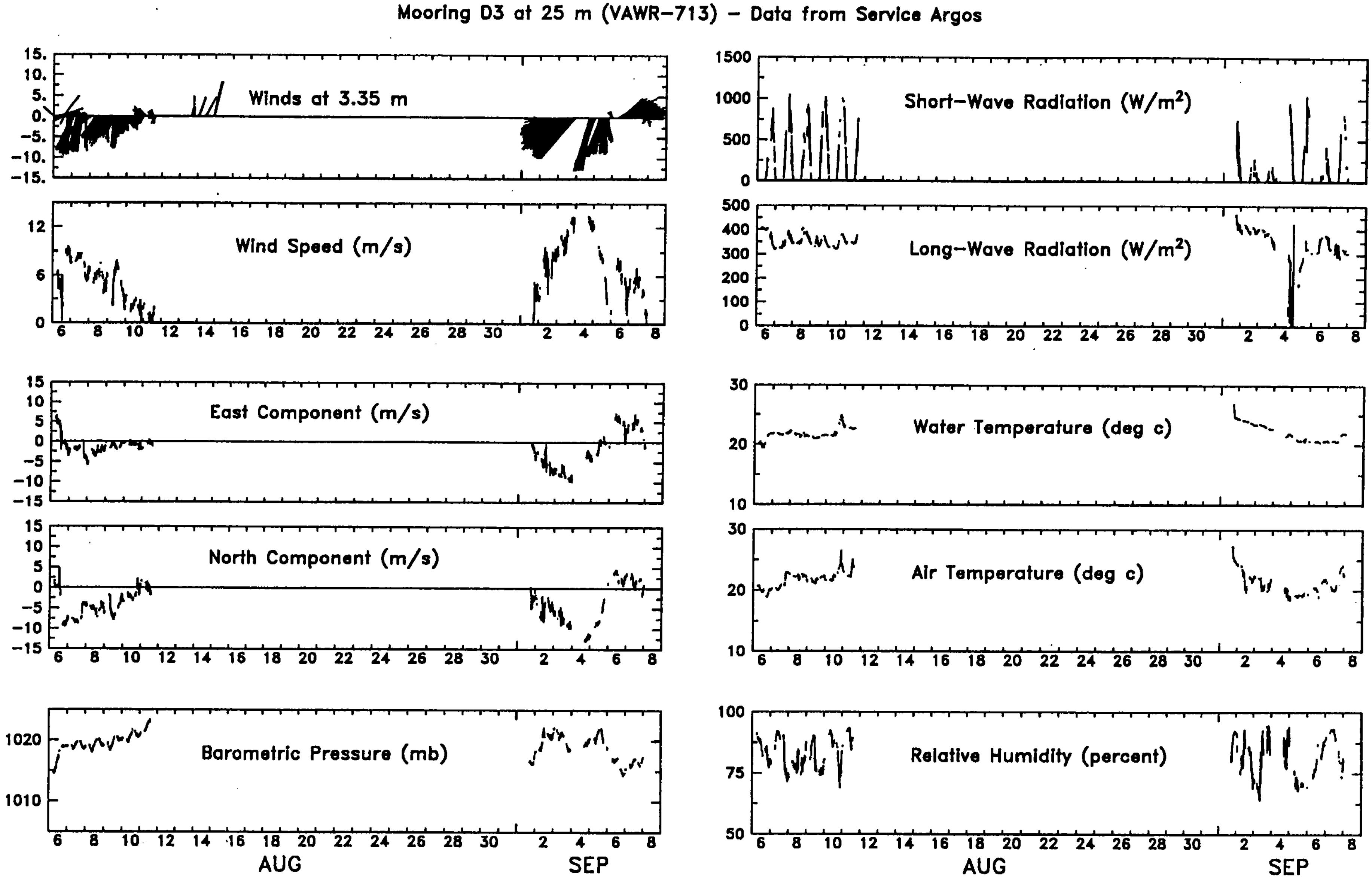


Figure A2.3: Two weeks of Argos data obtained from the 25-m VAWR.

Appendix 3: Wind Direction Comparison Tests

by Richard P. Trask

Part of the preparation of the meteorological packages included checking the wind direction sensors. This consisted of placing each buoy on a test station that could be rotated through 360° and directing the wind vane to a fixed target at 60° intervals. The direction is then computed from the instrument compass and vane direction.

The test site in Woods Hole was located at the southern corner of the Clark - South Laboratory parking area. This site showed little horizontal or vertical spatial variation in the magnetic field. The discus buoys were mounted each in turn on a wooden and masonite turntable, and the direction of a tree near the Clark building was measured from six orientations. At each of the six positions the wind vane was aligned to the tree by eye and the data were read directly from the instrument. The compass and vane positions were then added to obtain the wind vane direction in oceanographic convention. The magnetic bearing to the tree from the test site was 309.0°. Figures A3.1 and A3.2 show the results of those spin tests for the CoOP inner-shelf VAWR direction sensors.

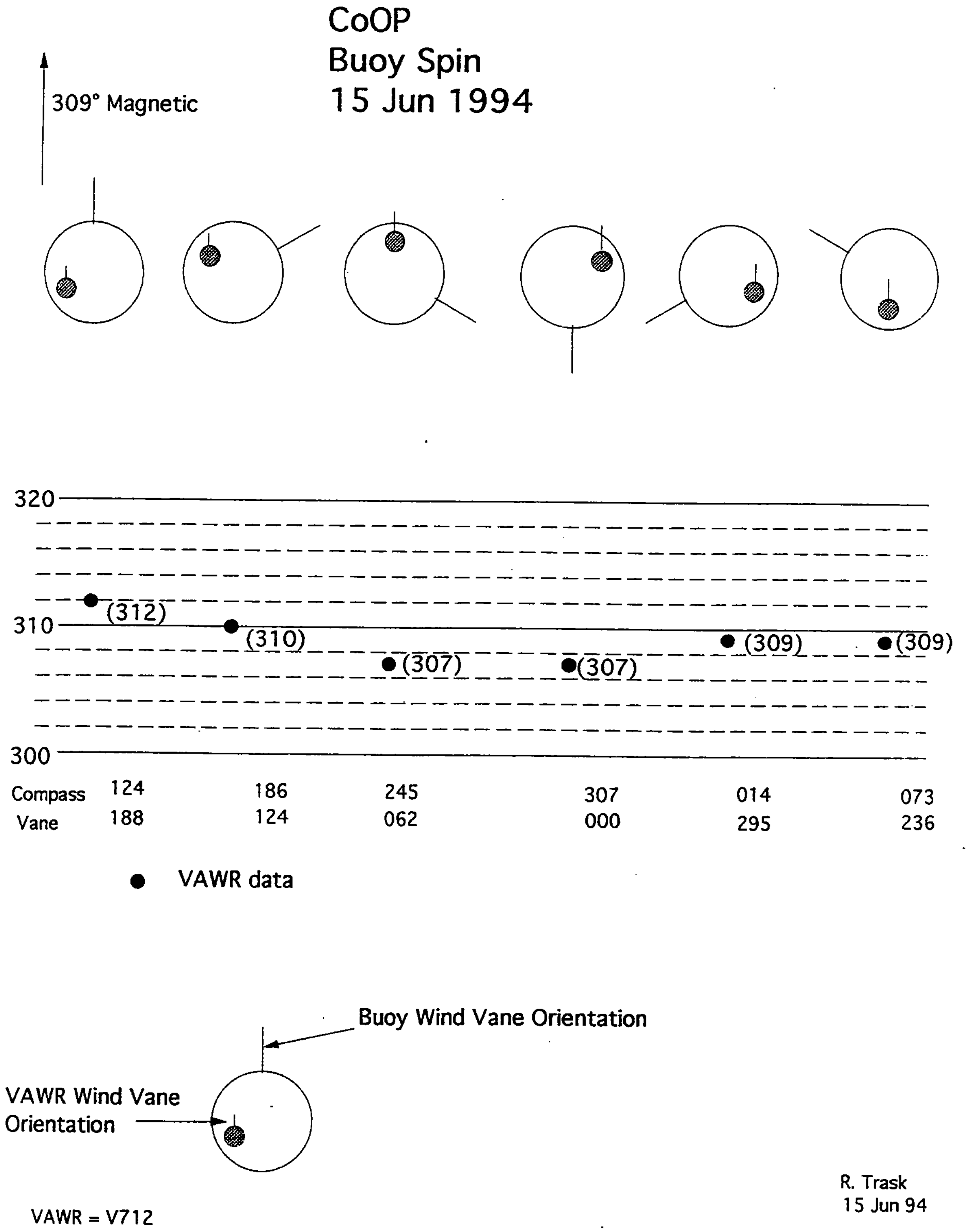


Figure A3.1: Spin-test results for the 20-m VAWR direction sensor used in the CoOP inner-shelf study.

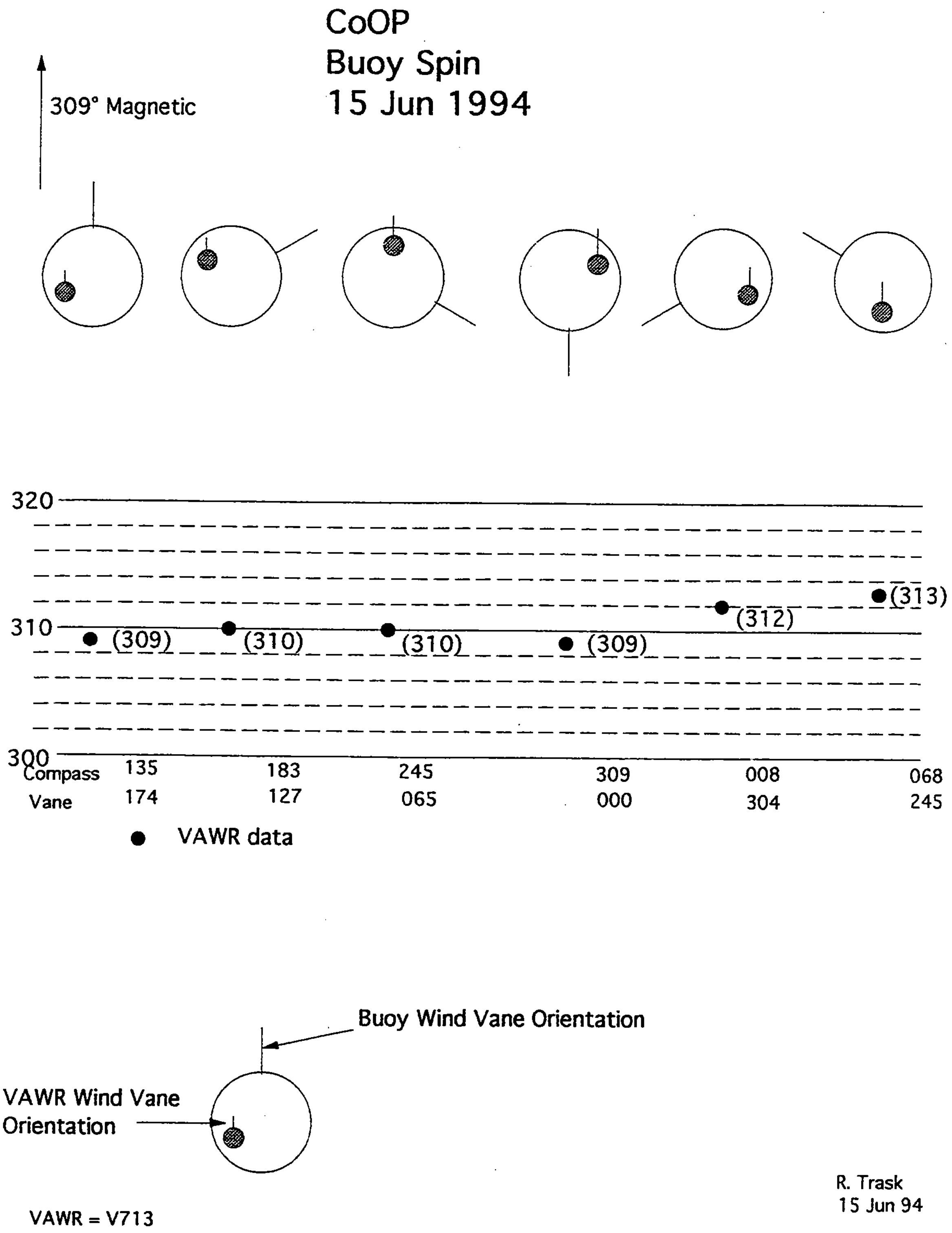


Figure A3.2: Spin-test results for the 25-m VAWR direction sensor used in the CoOP inner-shelf study.

Appendix 4: CoOP Inner-Shelf Study Mooring Deployment Procedures

by Will Ostrom

The CoOP inner-shelf moorings deployed from the *R/V Endeavor* utilized procedures which are unlike those used by the Upper Ocean Processes Group in setting deep ocean moorings.[1] The CoOP inner-shelf moorings were set in very shallow water ranging from 12.5 m to 25 m deep. The two discus and toroid surface moorings were deployed anchor first because of the short scope in their design (Figures 6, 8, and 10). The problem which will arise with an anchor first deployment is that there is potential for the mooring's anchor to ground out on the bottom, causing the ship to be anchored.

Using the 25-m mooring as a case example (Figure A4.1), the following deployment procedures were used. The bottom anchor and the shackled adjacent 15-m length of 1/2"-chain were lowered over the side of the ship first, using the ship's crane whip. A 1/2" chain grab was used to hook into a bite of the chain, so that the vertical lift by the crane could be made manageable. The crane lowered the chain and bottom anchor until there was approximately 14 m of 1/2" chain free at its end. This segment of the mooring was stopped off to the deck using a 1/2" chain grab shackled to a 1" diameter stopper line, and the crane whip was removed.

The next component in the mooring to be lowered was the 1500-lb. depressor weight. A 1-m shot of 1/2" chain was pre-attached to the bottom of the depressor weight to allow for easier hook up to the top end of the hanging 14-m shot of 1/2" chain.

A side chain, approximately 4 m long, was shackled to the top of the depressor weight. This chain was used to take the load off the depressor, 1/2" chain section and bottom anchor, and to keep the bottom anchor 2 to 3 meters off the bottom while the upper instrumentation and surface buoy were being deployed. The crane was hooked into the side chain leaving approximately 1.5 m free on its end. The 4-m shot of 1/2" chain was shackled to the top of the depressor weight, and the free end was tied off to a tag line and tended towards the instrument staging area. The crane was repositioned over the depressor weight and the crane whip/chain grab hooked into the side chain leaving approximately 1.5 m free to its end. The hanging mooring tension was taken up on the crane whip and the deck stopper was removed, transferring the line tension to the side chain. The crane whip was then lowered until the depressor weight was just below the sea surface. The distance that the side chain could be lowered before the bottom anchor grounded out was predetermined and so happened that the depressor weight was just awash at the sea surface. The side chain was then stopped off with a 1/2" chain grab to the deck, and the crane whip was removed (Figure A4.2).

The three VMCMs were positioned in the instrument staging area and shackled together (Figure A4.3). The crane was then brought into position over the top end of the upper

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[1] UOP tech. report #93-3 appendix 8

current meter. The crane whip hook, fitted with a 3/4" chain grab, was then hooked at the mid-point of the 5-m length of the 3/4" chain attached to the upper VMCM. The crane whip raised the string of VMCMs off the deck so that all three instruments hung vertically over the free end of the 4-m shot of 1/2" mooring chain. The bitter end of the 4-m shot was then shackled onto the bottom of the deepest instrument. The crane boom then swung forward towards the apex of the discus bridle and lowered the three VMCMs into the water (Figure A4.4). The free end of the 3/4" chain was brought into position so that its end could be shackled to the discus clevis bail. Once this connection had been made, the crane whip and 3/4" chain grab were lowered and removed, allowing the 3 VMCMs to hang from the discus bridle (Figure A4.5).

The crane boom was then re-positioned in preparation to lift the discus into the water. Four 3/4" diameter nylon slip lines were then reeved through the discus tower, hull, and bridle. These lines were used to steady and orient the buoy hull during its lift into the water. The crane whip was fitted with a Release-O-Matic hook and positioned onto the main lifting bail.

The side chain's stopped-off end on deck was fitted with a 1/2" shackle and 5/8" pear ring. Two deck cleats were positioned and bolted to the ship's deck on either side of the chain grab stopper holding the side chain. A length of 3/4" Samson 2&1 line was reeved through the 5/8" pear ring, and the running ends of this line were brought up tight against the pear ring and cleated down onto the two deck cleats. The stopper/chain grab holding the side chain was removed allowing the Samson slip line to take the tension off the suspended anchors. Using this 2 cleat slip-line system enabled the line handler to quickly un-cleat and remove the slip line from either side once the discus had been successfully deployed. With the 4 slip lines in place the discus was then lifted clear off the deck. The order in which the slip lines were removed was: outboard hull, outboard tower, bridle, and inboard hull bail. The inboard hull slip line was kept in place just after the release of the discus. This line prevented the discus from potentially spinning and fouling the release hook pull line once it settled out in the water. The discus was swung out board 10 m perpendicular from the ship and lowered down to a point where the hull was afloat. The slip lines were cleared and the quick release hook pulled, freeing the discus from the crane. The side chain slip line at that point was released and pulled clear, allowing the mooring to anchor itself. The deployment duration was approximately 45 minutes.

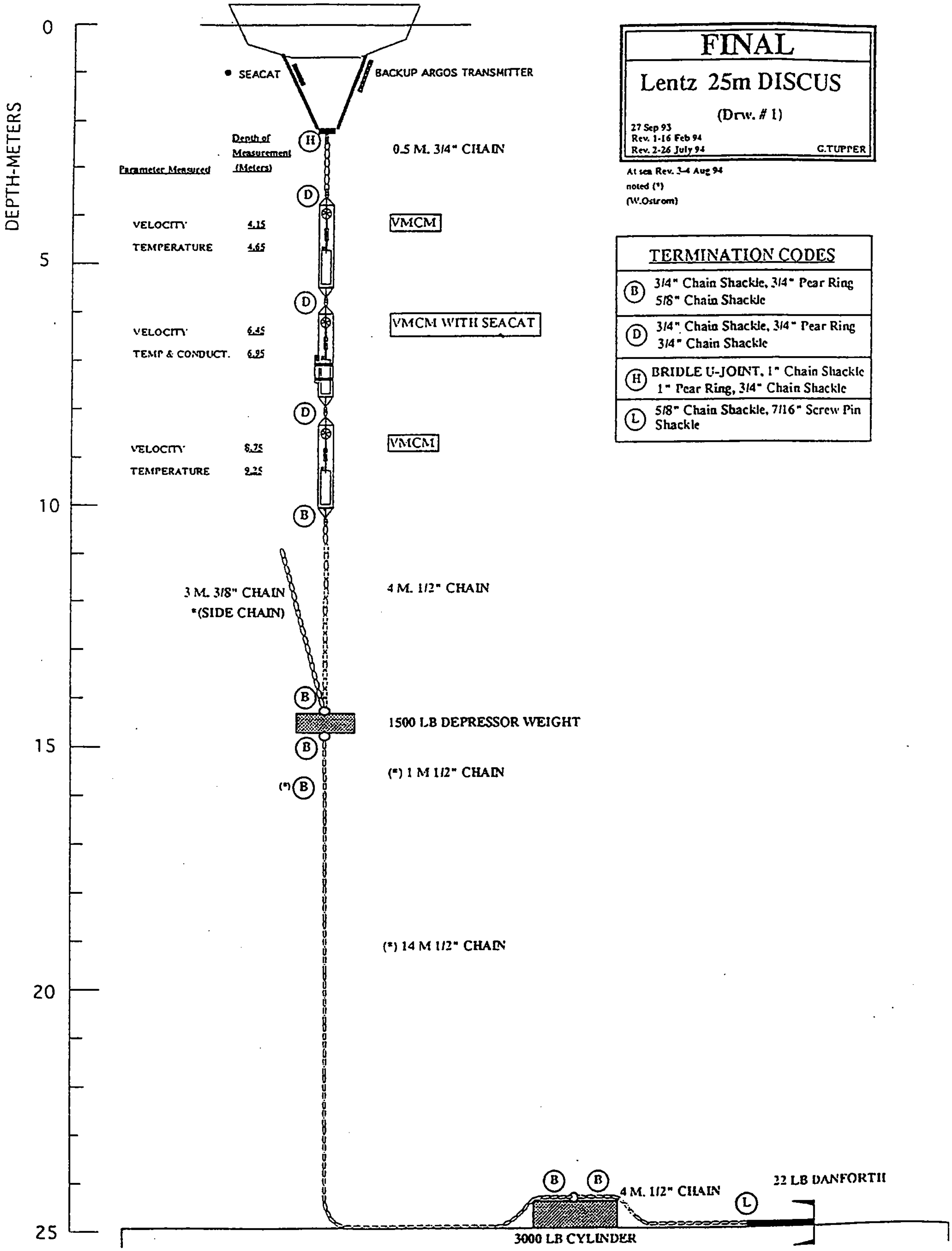

Figure A4.1: 25-m discus deployment case example.

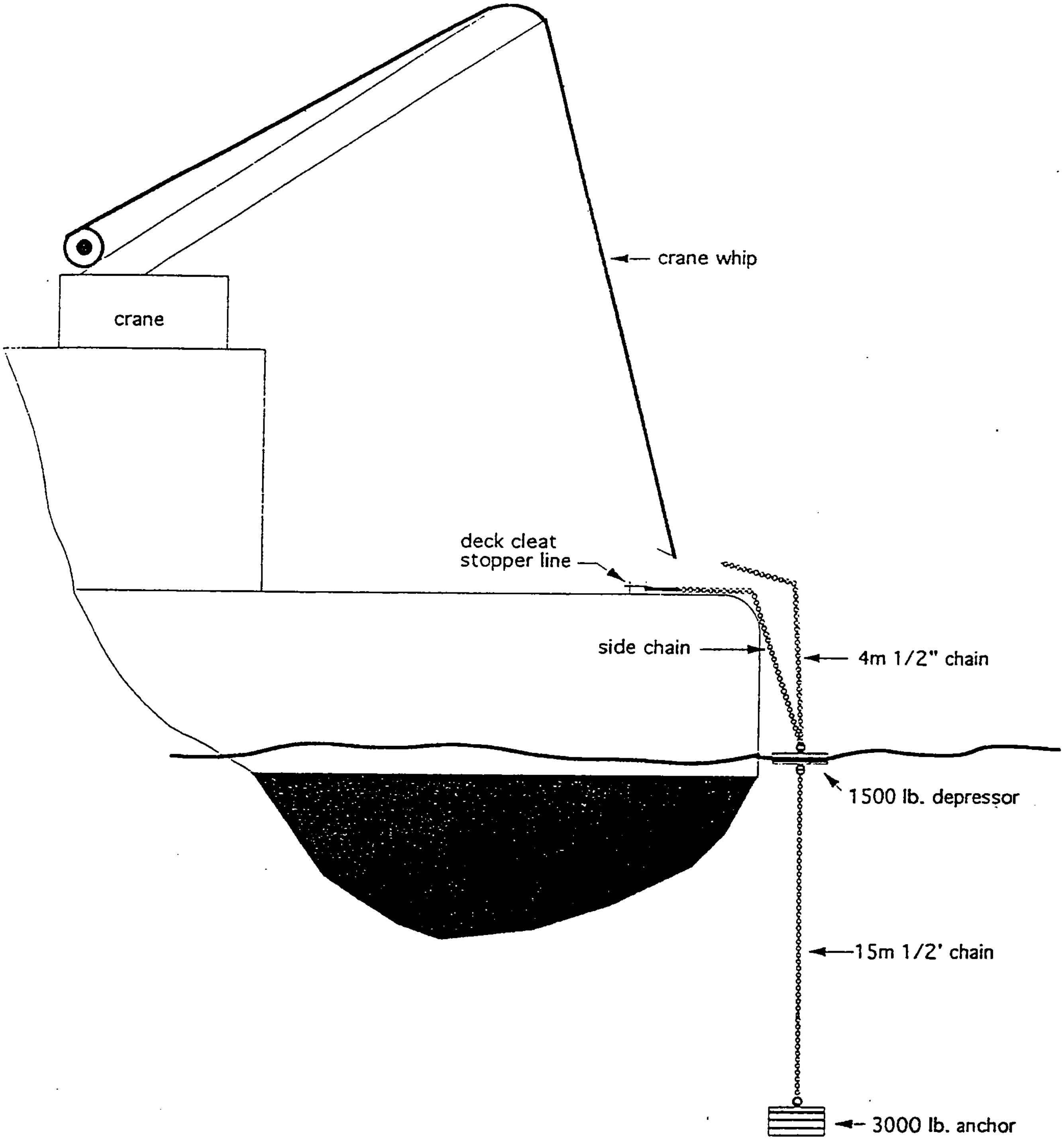

Figure A4.2: 25-m Discus Anchor Deployment.

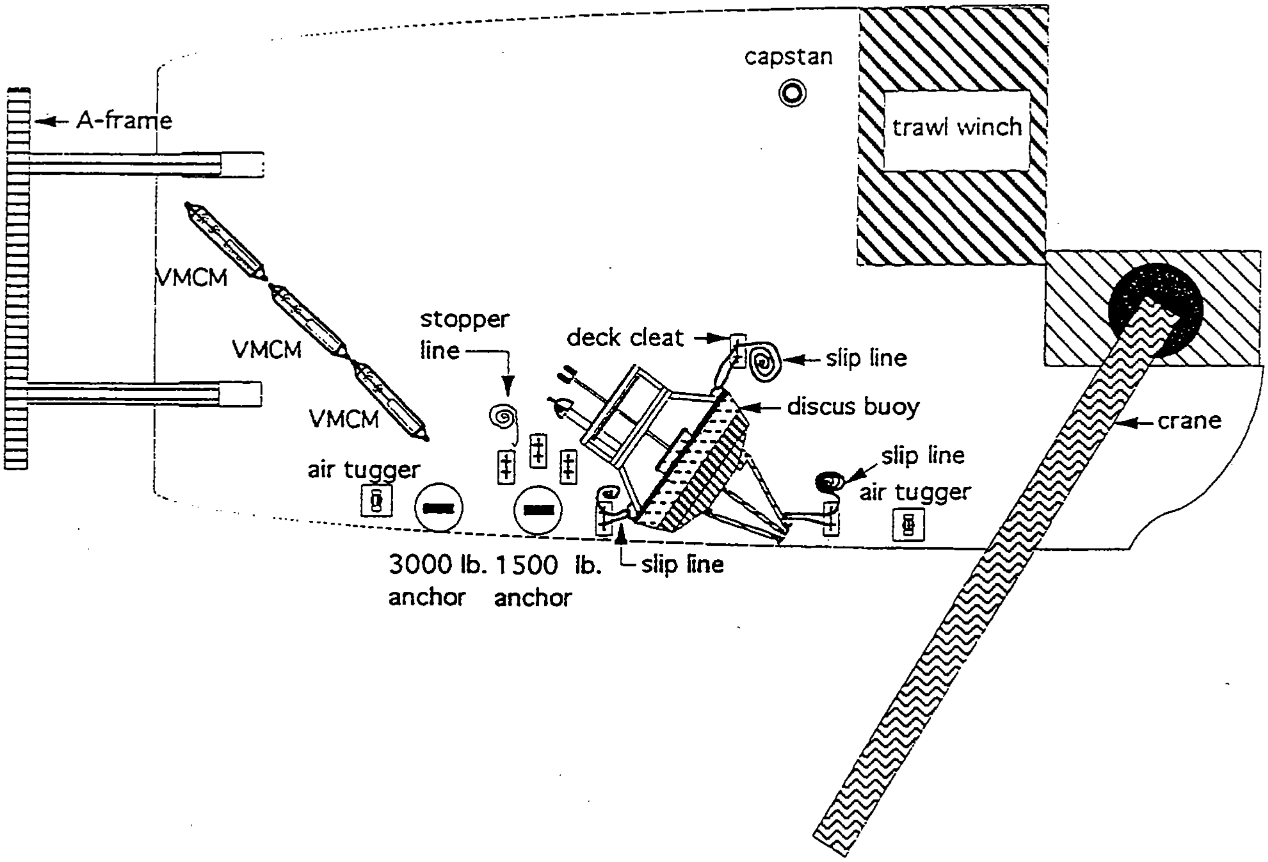

Figure A4.3: 25-m CoOP inner-shelf *R/V Endeavor* Fantail Layout.

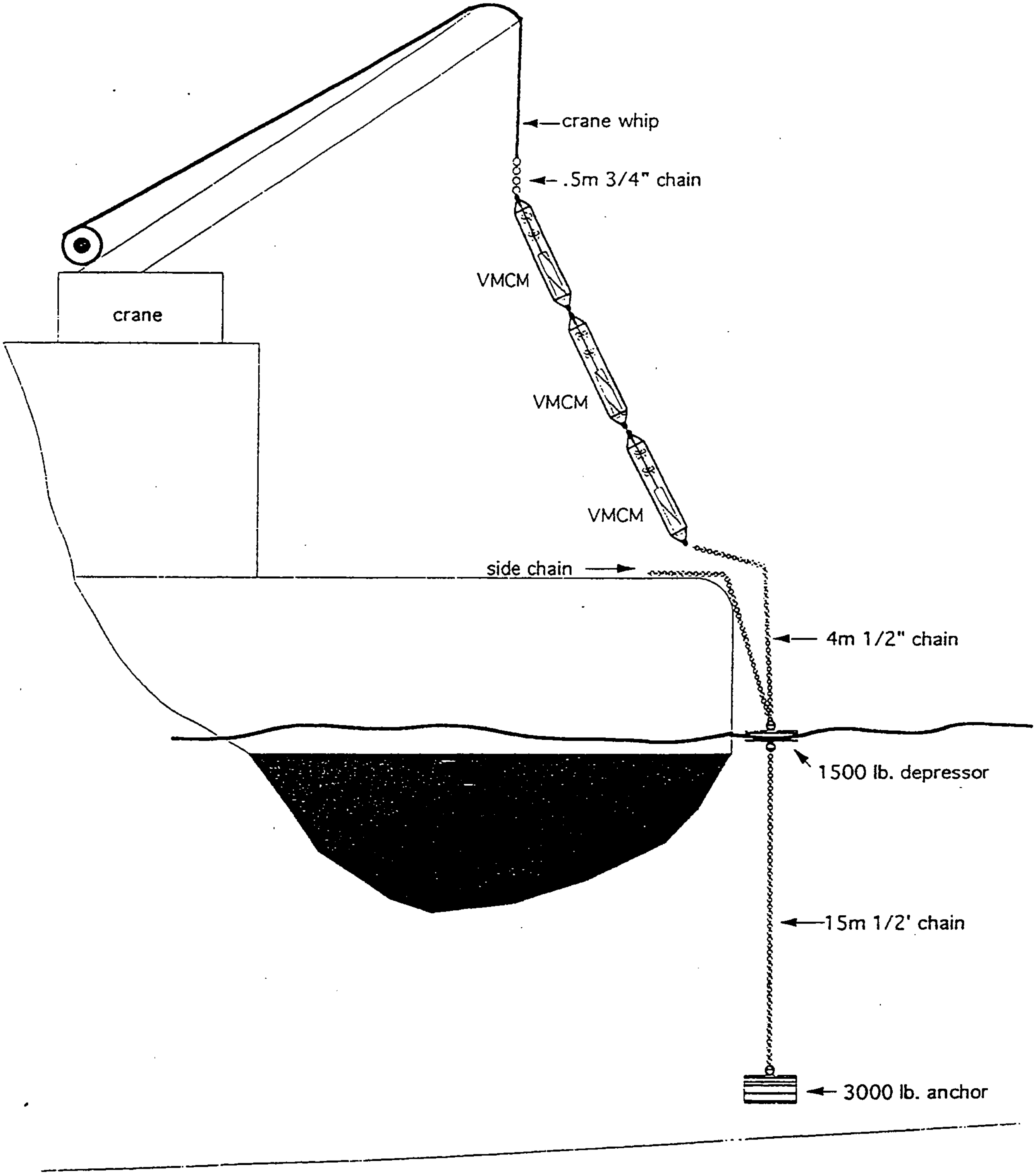

Figure A4.4: Stern View 25-m Instrument Lowering.

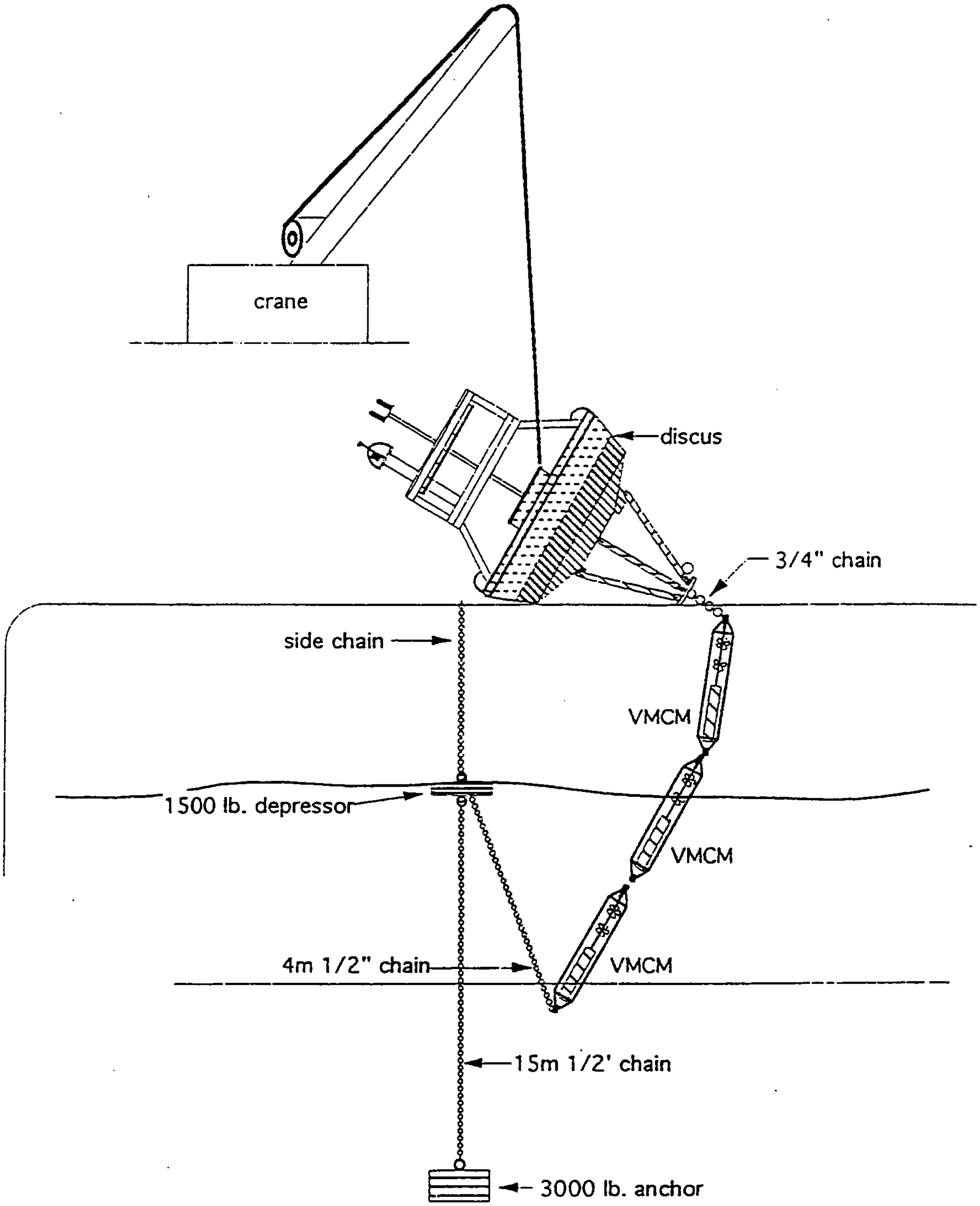

Figure A4.5: Starboard View 25-m Instrument Lowering.

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REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-96-06	2.	3. Recipient's Accession No.

4. Title and Subtitle Coastal Ocean Processes Inner-Shelf Study: Coastal and Moored Physical Oceanographic Measurements	5. Report Date May 1996 6.
7. Author(s) Carol A. Alessi, Steven J. Lentz, and Jay Austin	8. Performing Organization Rept. No. WHOI-96-06
9. Performing Organization Name and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) OCE-9221615 (G)
12. Sponsoring Organization Name and Address National Science Foundation	13. Type of Report & Period Covered Technical Report 14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-96-06.

16. Abstract (Limit: 200 words)

To improve our understanding of the physical and biological processes influencing planktonic larval distributions over the inner shelf, an interdisciplinary field program funded by the National Science Foundation's Coastal Ocean Processes program (CoOP) was conducted near Duck, North Carolina in the southern portion of the Middle Atlantic Bight. The field program took place from August to December, 1994 and included both moored and shipboard measurements of physical, biological and sedimentological variables.

This report summarizes the observations from one component of this field program, a moored array of physical oceanographic and meteorological instruments. This component of the field program consisted of a cross-shelf array of three surface/subsurface mooring pairs in 13 m, 20 m and 25 m of water supporting instruments to measure currents, temperature and conductivity, a suite of meteorological instruments on surface buoys at the 20 -m and 25 -m site, and an along-shelf array of temperature, conductivity and bottom pressure sensors mounted on jetted pipes along the 5-m isobath and on moorings along the 20-m isobath. The report includes descriptions of the cross-shelf and along-shelf arrays, the four types of instruments used (VAWRs, VMCMs, SeaCats, and SeaGauges), and the data return from the field program. Statistical and graphical summaries of the atmospheric (wind, air temperature, barometric pressure, relative humidity, short- and long-wave radiation), and oceanic (current, water temperature, conductivity and bottom pressure) measurements are presented.

17. Document Analysis a. Descriptors

inner-shelf
oceanographic instrumentation
marine meteorology

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement Approved for public release; distribution unlimited.	19. Security Class (This Report) UNCLASSIFIED 20. Security Class (This Page)	21. No. of Pages 154 22. Price

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