Cruise Report

R/V OCEANUS Cruise 338
to Georges Bank

U. S. GLOBEC

NW ATLANTIC/GEORGES BANK STUDY

8 - 13 March 1999

Acknowledgments
R/V OCEANUS Cruise OC338
U.S. State Department Cruise No. 99-014
8 – 13 March 1999

This cruise and preliminary data report was prepared by Jim Irish, and Jim Doutt from cruise logs and notes as a first draft of the activities, positions and data collected on R/V OCEANUS Cruise OC338. We acknowledge the excellent support of Captain Larry Bearse of the R/V OCEANUS, and would especially like to thank Bos'n Jeff Stolp and Seaman Horace Medeiros for their outstanding assistance during the complicated mooring recovery and deployment operations.

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OCE-9631468

Cruise Report
R/V OCEANUS Cruise OC338
U.S. State Department Cruise No. 99-014

Table of Contents

List of Figures

List of Pictures

List of Tables

Cruise Report
GLOBEC R/V OCEANUS Cruise OC338
US State Department Cruise No. 99-014
Woods Hole to Georges Bank to Woods Hole
8-13 March 1999

Purpose:

The primary purpose of R/V OCEANUS OC338 was to turnaround the two scientific moorings at the Southern Flank and Northeast Peak Long-Term Moored Program's sites on Georges Bank. A bottom pressure instrument was also to be serviced at the southern flank site, and CTD yo-yo calibration profiles were to be taken at each site. CTD sections were to be made along standard lines. Finally, assistance would be given to the Northeast Peak Crossover Experiment's mooring retrieval and replacement operations as necessary.

Accomplishments:

The scientific mooring and bottom pressure instrument at the Southern Flank Site were serviced without incident. The scientific mooring was replaced with a new buoy, data system and SeaBird temperature and conductivity sensors. The ADCP was replaced with a new one, and the bio-optical packages and Seacats were serviced and redeployed. We then went chasing the Northeast Peak Crossover Experiment's Discus buoy that had broken loose from their Northern Flank shallow site. It was recovered near the NDBC buoy 40011 and redeployed on station the next day with the same sensors. On the way to deploy this buoy, another Crossover Experiment's buoy was spotted drifting upside down and was retrieved. Then the Long-Term Moored Program's Northeast Peak mooring was recovered, serviced and redeployed. Finally, we recovered the Crossover Experiment's Eastern Flank mooring for later replacement. This mooring did not release and we recovered the array from the top down in poor weather. It was decided not to redeploy this mooring and to bring it back home for replacement with a Discus supported mooring.

Due to a problem with water in the connector between the CTD and the winch cable, the CTD failed early in the cruise. The ship's tech was able to repair the problem by the end of the cruise, but then we were unable to do much CTD work. In Situ calibration profiles were made at the Southern Flank and Northeast Peak sites. Additionally, one offshore CTD with water samples was made before weather shut down operations.

The weather was the major problem on this cruise, as we expected during the March time. Two days were lost at the start of the cruise (the ship didn't leave port since we couldn't work). We steamed out on the third day, and had to wait during most of the forth. Then we did have two days of great weather in which we did all the mooring work. With the addition of the mooring work for the Northeast Peak Crossover Experiment, we had twice the work and half the time in which to do it. Therefore, long days were the rule. Work had to be cut short on the third good-weather day in order to arrive back in port to meet the WHOI ship schedule.

Cruise Results:

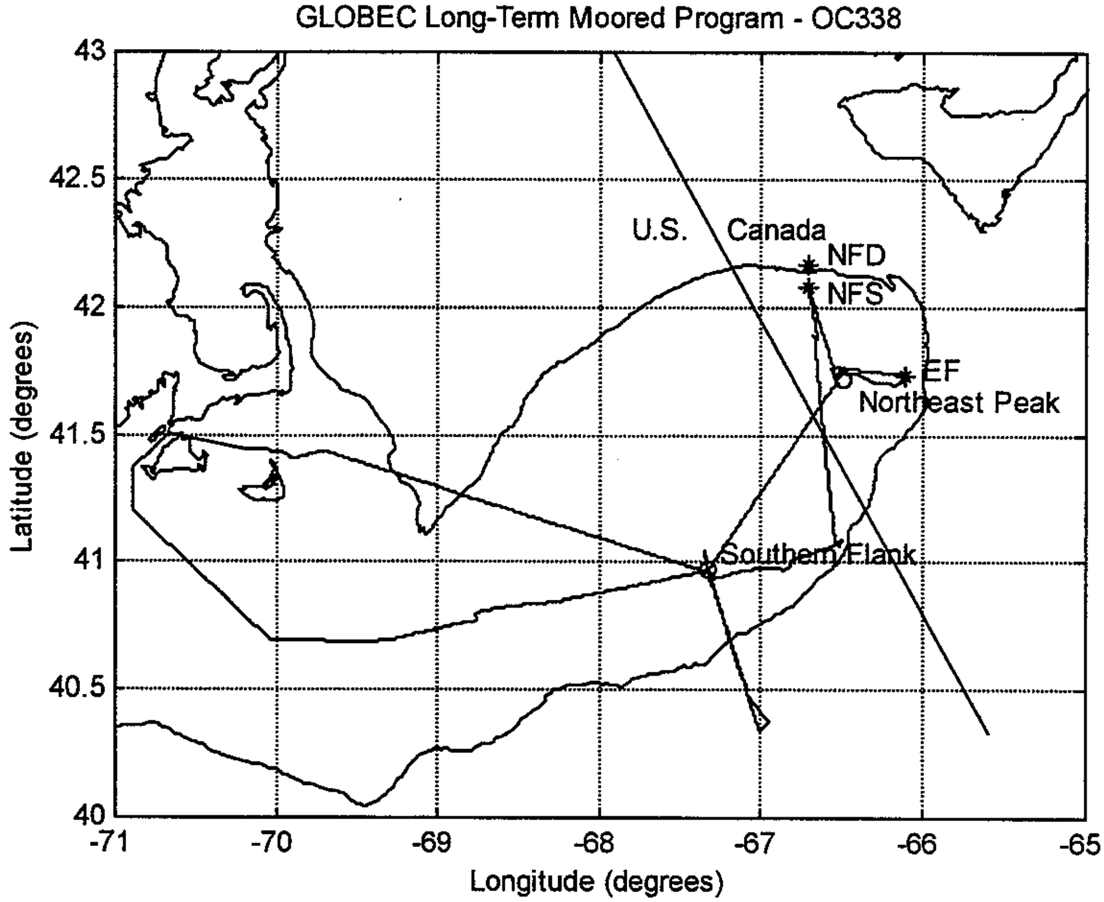


Figure 1. The R/V OCEANUS Cruise OC338 from WHOI to Georges Bank to WHOI on 8 to 13 March 1999. The cruise track is shown as a line, the southern flank and Northeast Peak Long-term moorings are shown with a 'o,' and the Northeast Peak Crossover Experiment's moorings with an '.' The Northeast Peak and Crossover Experiment moorings are in Canadian waters.*

Ship Track

The track sailed on OC338 is shown in Figure 1. Because of the poor weather, the OCEANUS sailed around Nantucket Shoals to the Southern Flank mooring site. There the moorings were checked, and a CTD profile was made. The weather was still poor, so the ship sailed offshore and we took a deep profile and fired all the bottles to collect water for other WHOI researchers. The weather was still poor, so additional CTDs were postponed until later. The ship returned to the Southern Flank mooring site and serviced instruments there as discussed below. The ship then sailed east to pick up the drifting Discus buoy, and headed north to deploy it the next morning at the NFS site. After deployment the ship went to the Northeast Peak mooring site and serviced the mooring there. Then we steamed east to the EF mooring and recovered it, back to the Northeast Peak site for a CTD, and on to the Southern Flank site to deploy the bottom pressure instrument and take a CTD calibration profile. Then we headed for WHOI through Great Round Shoals as the weather started to deteriorate.

Mooring Recovery Operations

Southern Flank Bottom Pressure: The bottom pressure instrument, deployed at the southern flank site on 7 October 1998, was the first to be recovered. It was recalled by command to an acoustic release, and returned to the surface on the buoyancy of its flotation. The acoustic release, frame and Sea Bird Seagauge pressure instrument were mildly fouled with hydroids but otherwise in good condition. The heavy barnacle growth that has been observed during the summer months during past years was not apparent at this time. The package was cleaned, the acoustic release changed, and the Seagauge pressure instrument was serviced (new batteries, data dumped, time checked and set, etc). The instrument (see Table 1 for sensor serial numbers) worked well and returned a full set of ~5 months length. The data returned (Figure 2) shows the tides and weather forced sea level variations in the pressure record, and the seasonal cooling in the temperature observations. The salinity record is lower by about 2 PSU than expected from comparisons with observations made higher in the water column. This is probably due to sand (non-conducting medium) collecting and staying in the conductivity cell.

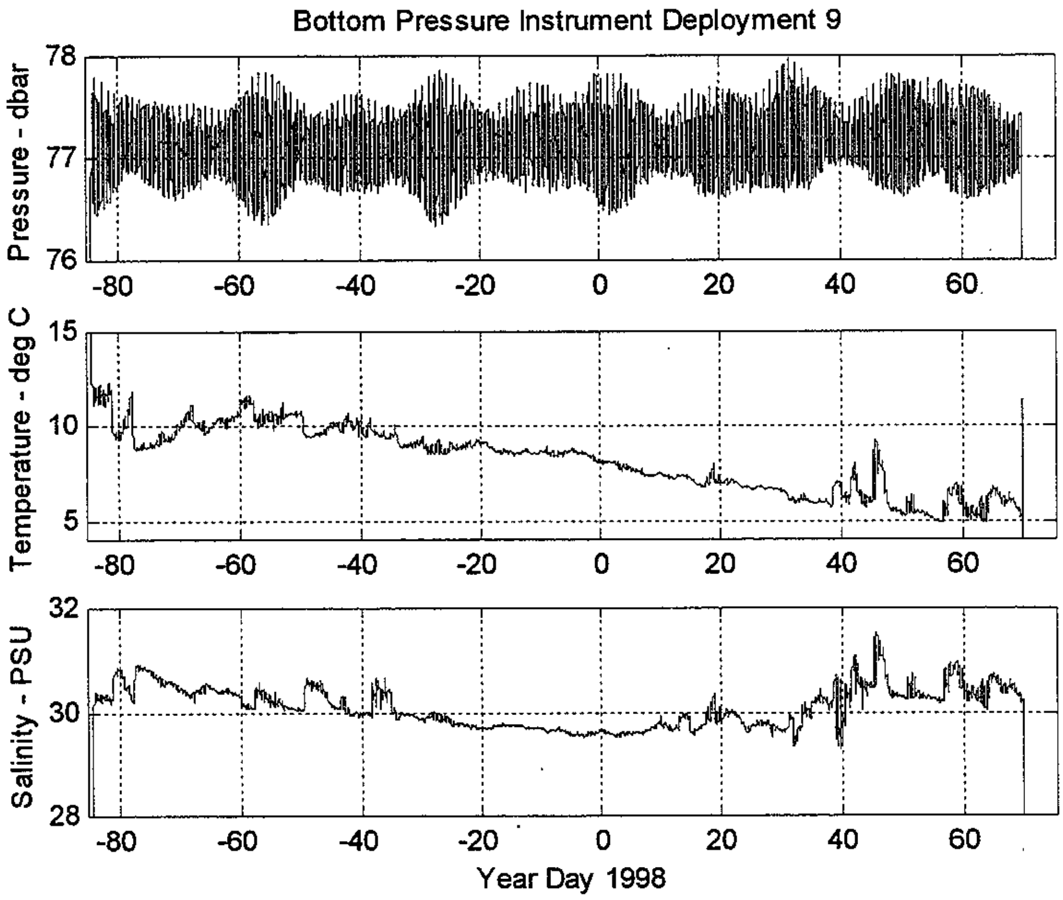


Figure 2. Bottom pressure instrument data. The top panel shows the unedited, normalized pressure record in decibars relative to one standard atmosphere. The middle panel shows the unedited, normalized temperature in degrees C. The bottom panel shows salinity calculated from raw conductivity and temperature. The sample interval in the tidal mode shown was 15 minutes. The salinity record includes an apparent sediment-induced offset and drift.

The measurement of conductivity near the bottom in high suspended sediment regions has always been a problem. During the past year the conductivity sensor was mounted horizontal and therefore probably trapped sand. The horizontal orientation was used to maximize the flushing. Because the underwater cable connecting the conductivity sensor with the Seagauge was shorter than expected, we were unable to mount the sensor at an angle on one of the side legs, so it was mounted next to the Seaguage electronics with the conductivity cell oriented vertical. This may affect data quality due to poor flushing, but not due to sediment being trapped in the conductivity cell. The next record will determine if this is a problem or not.

In addition to the 15-minute tidal samples, the bottom pressure instrument was also burst sampled for wave activity once per day for about 10 minutes starting at 0130 UTC. Because of the attenuation of surface waves with depth, waves with periods shorter than about 7 seconds were not observed at the bottom. Each burst sample consisted of 300 samples at 2-second intervals. The 2-second sample interval will resolve 7-second and longer waves. The 10-minute record length is the minimum that will obtain accurate wave statistics. The daily significant wave height (average of the highest 1/3 of the waves) as calculated by the instrument and shown in Figure 3 along with the period of the waves. The largest wave event was a storm at the end of February (26 February 1999). The storm a few days before the cruise that delayed us leaving port did not create a significant wave height larger than many other winter storms during this past year.

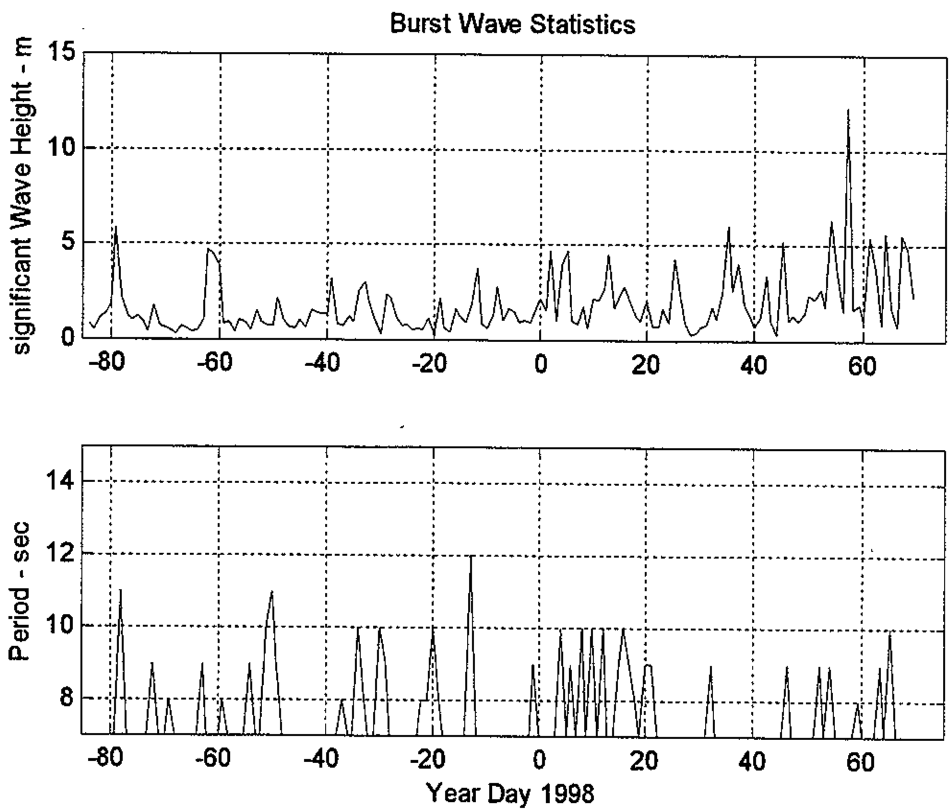


Figure 3. Wave statistics gathered once per day at 0130 UTC from the bottom pressure sensor as an indication of the long-wave activity that penetrates to the bottom in 76 meters of water. The minimum period of about 7 seconds reflects the attenuation with depth that removes the effects of waves with periods smaller than about 7 seconds.

Table 1. Sensor Type, Depth and Serial Number

				Recovered	Deployed	Recovered	Deployed
				Buoy E	Buoy D	Buoy B	Buoy B
Measurement	**Sensor Type**	**Company**	**Model**	**Serial #**	**Serial #**	**Serial #**	**Serial #**
Buoy Met	Air Temperature	Rotronics		16302	35851	WHOI1	WHOI1
	Relative Humidity	Rotronics		6302	35851	N/S	N/S
	Wind Speed and Dir	RM Young		23908	N/S	N/S	N/S
	PAR	LiCor	UWQ	4949	5018	4975	4975
	Short Wave Rad	Eppley		28300	25418	N/S	N/S
	Long Wave Rad	Eppley		2837F3	27953F3	N/S	N/S
Sea Surf	Temp at 1 m	Sea Bird	SBE-3	31624	32176	32488	32488
	Cond at 1 m	Sea Bird	SBE-4	N/S	N/S	41365	41365
Current Profiles	ADCP	RDInstruments	Workhorse	130	705	125	130
T/C at 5 m	Temp at 5 m	Sea Bird	SBE-3	31628	477	32064	32064
	Cond at 5 m	Sea Bird	SBE-4	41342	41333	41367	41367
BIOP at 10 m		Luigi		4	2	2	1
	Temp at 10 m	Sea Bird	SBE-3	478	484	490	490
	Cond at 10 m	Sea Bird	SBE-4	56	59	42182	42182
	Trans at 10 m	Sea Tech		628	620	621	621
	Fluor at 10 m	Sea Tech		306	296	296	1753
	PAR1 at 10 m	LiCor	SPQA	1659	2146	1793	1793
	PAR2 at 10 m	LiCor	SPQA	N/S	1972	N/S	N/S
	OBS at 10 m	Sea Point	STM-1	N/S	1222	1222	1222
T/C at 15 m	Temp at 15 m	Sea Bird	SBE-3	N/S	481	32431	32431
	Cond at 15 m	Sea Bird	SBE-4	N/S	41370	41890	41890
T/C at 20 m	Temp/Cond at 20 m	Sea Bird	SBE-16	1736	2006	2360	2359
T/C at 25 m	Temp at 25 m	Sea Bird	SBE-3	N/S	482	N/S	N/S
	Cond at 25 m	Sea Bird	SBE-4	N/S	41327	N/S	N/S
T/C at 30 m	Temp/Cond at 30 m	Sea Bird	SBE-16	1820	1861	2359	2360
T/C at 35 m	Temp at 35 m	Sea Bird	SBE-3	N/S	32178	N/S	N/S
	Cond at 35 m	Sea Bird	SBE-4	N/S	41625	N/S	N/S
BIOP at 40 m		Luigi		5	4	3A	3A
	Temp at 40 m	Sea Bird	SBE-3	493	478	31632	31632
	Cond at 40 m	Sea Bird	SBE-4	68	56	42186	42186
	Trans at 40 m	Sea Tech		626	628	143PR	143PR
	Fluor at 40 m	Sea Tech		305	306	290	290
	PAR at 40 m	LiCor	SQPA	1660	1659	1661	1661
T/C at 45 m	Temp at 45 m	Sea Bird	SBE-3	N/S	31629	N/S	N/S
	Cond at 45 m	Sea Bird	SBE-4	N/S	41713	N/S	N/S
T/C at 50 m	Temp at 50 m	Sea Bird	SBE-3	32173	32177	32432	32432
	Cond at 50 m	Sea Bird	SBE-4	41343	41711	41379	41379
T/C at 72 m	Temp/Cond at 72 m	Sea Bird	SBE-37	716	716	715	715
Acoustic Release		EG&G	BACS	15050	18022	17306	17306
Bottom Pressure Instrumentation							
	Pressure Instrument	Sea Bird	SBE-26	49	49	N/S	N/S
	Conductivity	Sea Bird	SBE-4	41596	41596	N/S	N/S
	Acoustic Release	EG&G	BACS	17308		N/S	N/S

Science Mooring D: The principle mooring that the program has maintained for nearly four and a half years is at the southern flank site (40° 58.0' N x 67° 19.0' W). Buoy D was deployed in October 1998 and remained in position during the winter. This servicing was scheduled to clean the bio-optical sensors and add additional temperature and conductivity sensors for the stratified summer months. The mooring was recovered after an abortive CTD yo-yo at the station (see CTD section below). The acoustic release was commanded to drop the anchor and the subsurface float brought the bottom part of the mooring to the surface. The buoy was recovered first, then the mooring cable with sensors was brought aboard down to the subsurface float and acoustic release. The bio-optical packages and subsurface float were brought aboard with the assistance of the crane, but the rest of the mooring was recovered by hand over the rail. The recovery went smoothly in spite of the higher than normal seas.

The mooring appeared to be in good shape. No sensors were damaged or missing. See Table 1 for sensor type, serial number and depth of the recovered mooring components and Figure 4 for the mooring configuration. There was light to moderate bio-fouling on the sensors,

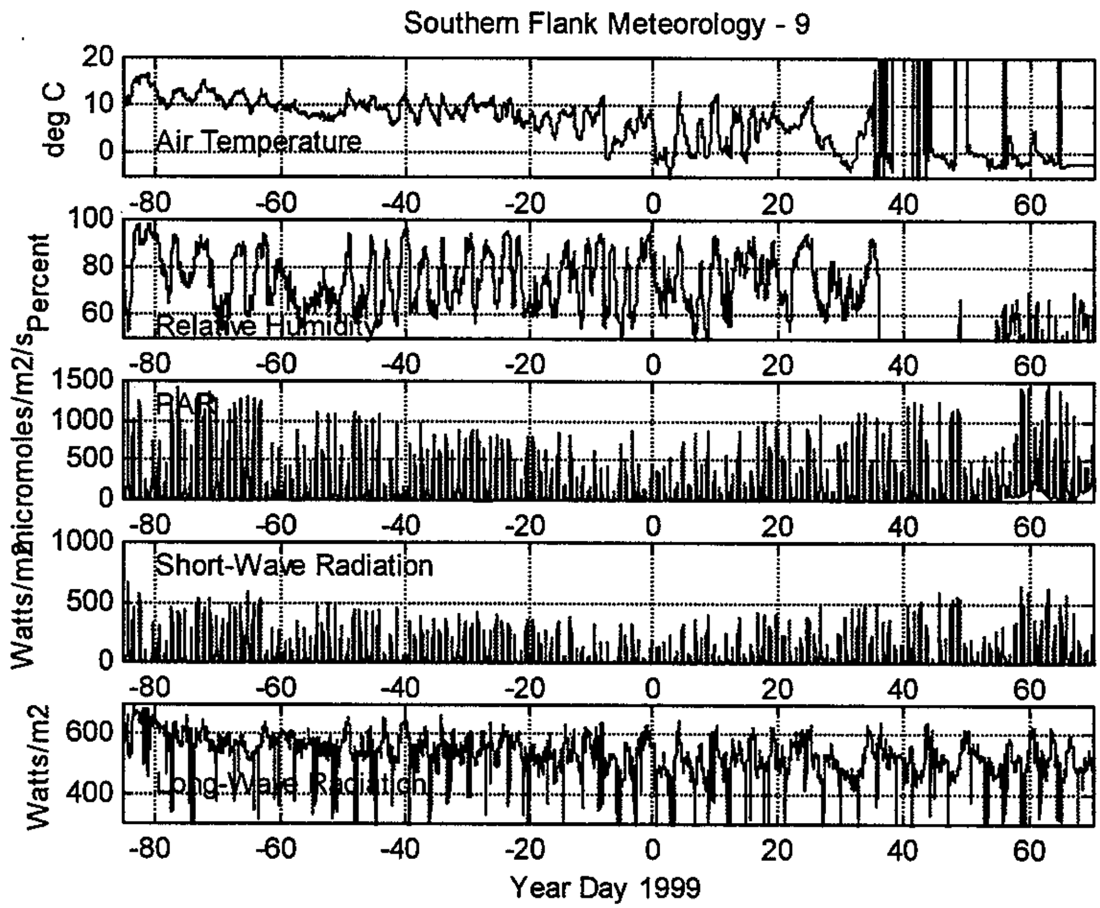


Figure 5. The Southern Flank Meteorology/Radiation. The normalized, unedited air temperature (top panel) and relative humidity (next panel) show a problem that developed in early February. The PAR and short wave radiation are next, and show similar pictures of incoming radiation. The normalized, unedited long wave radiation shows the negative going spikes due to the influence of the GOES transmissions on the sensor.

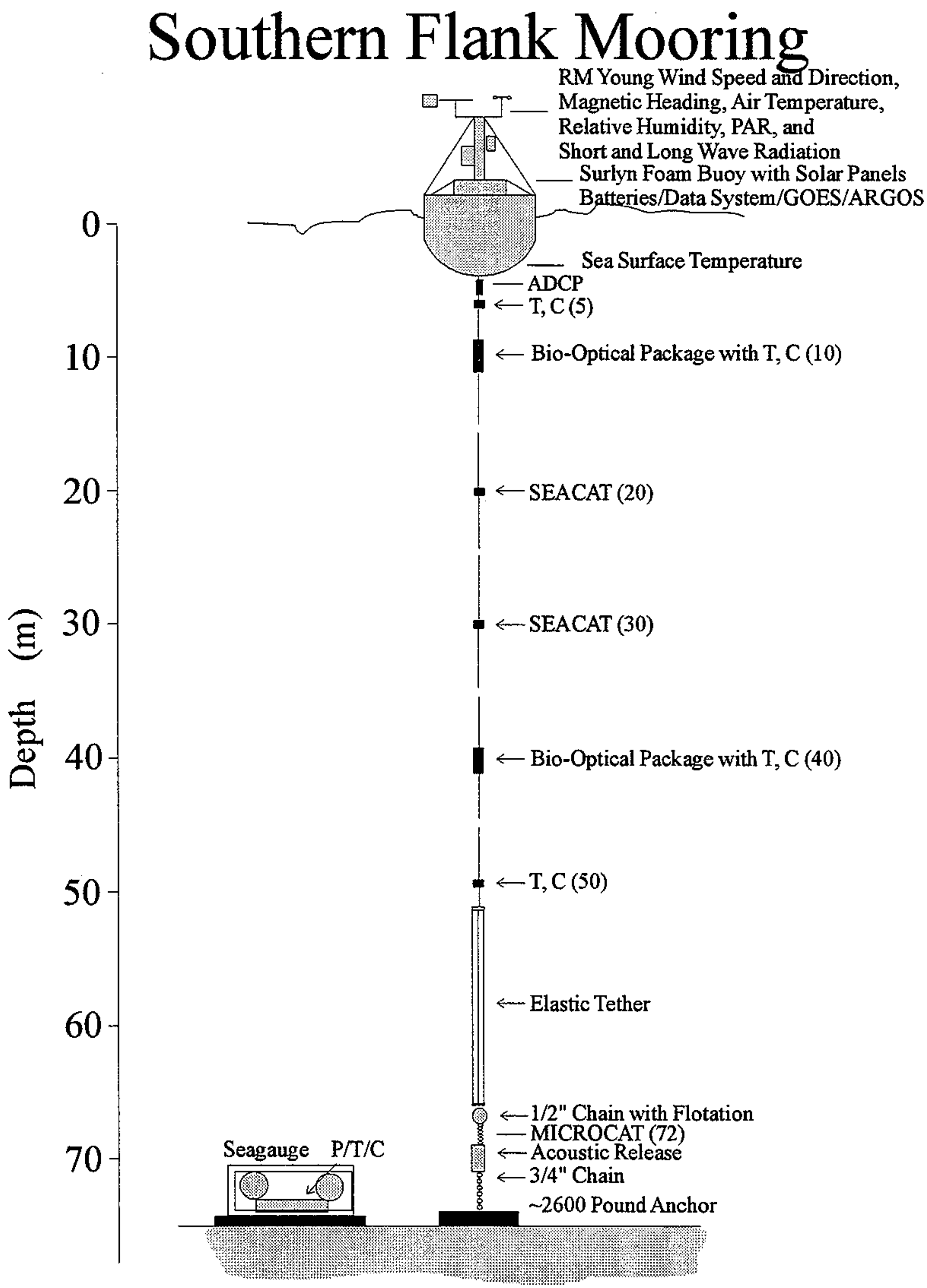


Figure 4. Southern Flank Mooring Schematic for Deployment 9. Due to the lack of vertical structure in water properties during winter months, the vertical sensor spacing was 10 meters.

with the heaviest fouling being in the surface waters. The 10-meter bio-optical package showed growth affecting results, while the 40-meter package was only lightly fouled. The poison tubes were removed from the conductivity sensors for safety in handling during cleaning and storage. The buoy itself was fairly clean, but more fouled that usual during past winters. There was some green hair on the foam flotation collar, including the deck. This is the first time we have seen things on the top of the foam flotation collar. Generally the buoy is remarkably clean when compared with the steel guard buoys moored nearby.

The buoy data system with telemetry was shut down, and the data dumped from the buoy for processing. The data return was excellent and shown in the following four figures. The air temperature/relative humidity sensor (Figure 6) had an electronic failure in early February (YD35) that lost humidity data for the rest of the experiment, and also made the temperature data suspect for the rest of the record. The radiation sensors appeared to work well, with a drift in the zero of the PAR sensor indicating some effects of the zero drift in the data system. This system zero reference was also measured and will be used to remove these effects. The long-wave radiation record also shows the effects of interference by the GOES transmitter (negative going spikes), which will also be removed during processing.

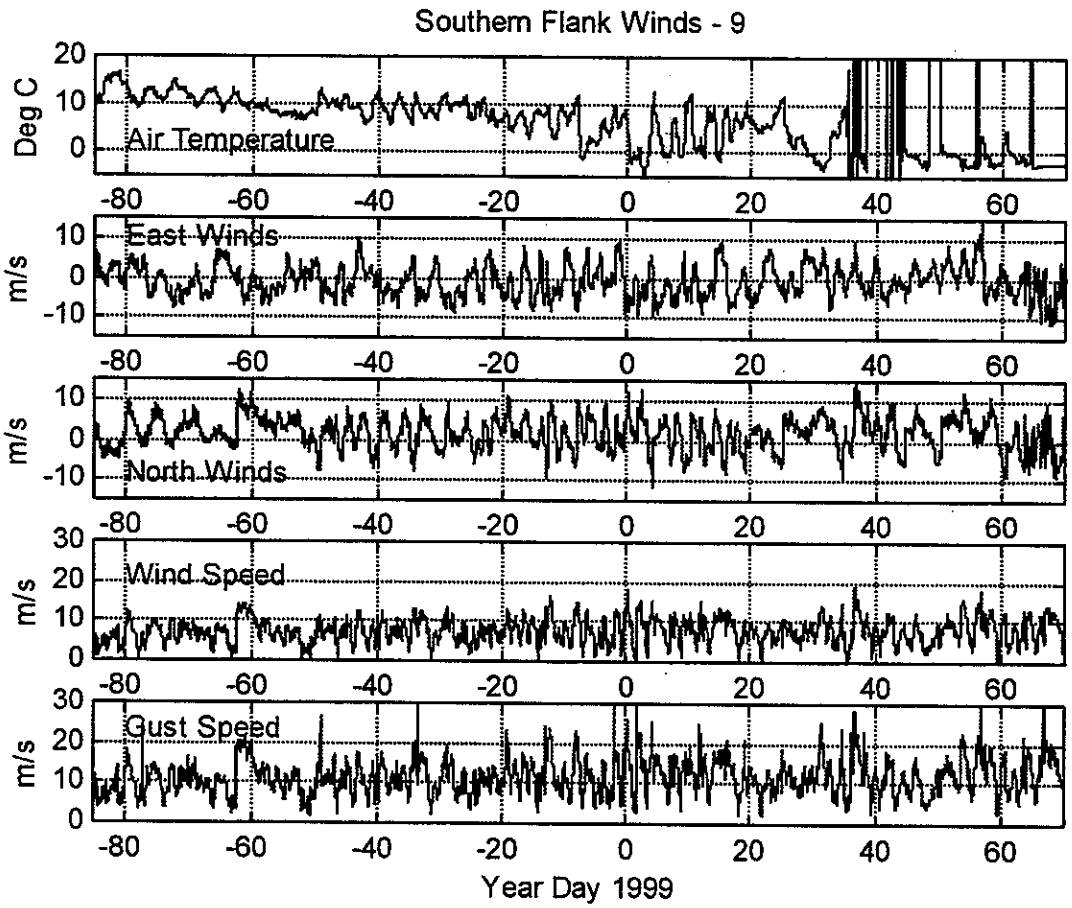


Figure 6. The Southern Flank Winds. The normalized, unedited data is plotted: air temperature, East and North winds (meteorology convention of direction from), hourly averaged wind speed, and gust (the individual 1 Hz measurement with the maximum speed during the last hour).

Another change is seen in the visual check of the data in the wind velocity components during the last week of the record in Figure 6. The "look" of the record changes indicating a possible hardware failure. The fact that the wind speed and gust do not show these effects, implies that there might be some problem with the compass or vane direction sensors that are used to calculate the vector averaged velocities but not the wind speed or gust. Further tests indicated possible failures in both the digitizer and in the wind sensor signal conditioning electronics, and not in the compass. As usual, the gust (highest reading of the 1 Hz data during the hour) is nearly twice the hourly averaged wind speed. The strongest storm was the late February storm seen in the significant wave record (Figure 3). There were about 14 storms during the past winter where the wind gust exceeded 20 m/s.

The hourly averaged temperatures on the mooring (Figure 7) appear to be good with the only problem that in the air temperature mentioned above. These temperatures (Figure 7), the Seacat temperature (Figure 9), and bio-optical package temperature (Figures 11 and 12) show a remarkably smooth and uniform winter cooling with no obvious crossover events (cool spikes in the surface waters) as seen in previous winters. The water column shows some stratification in

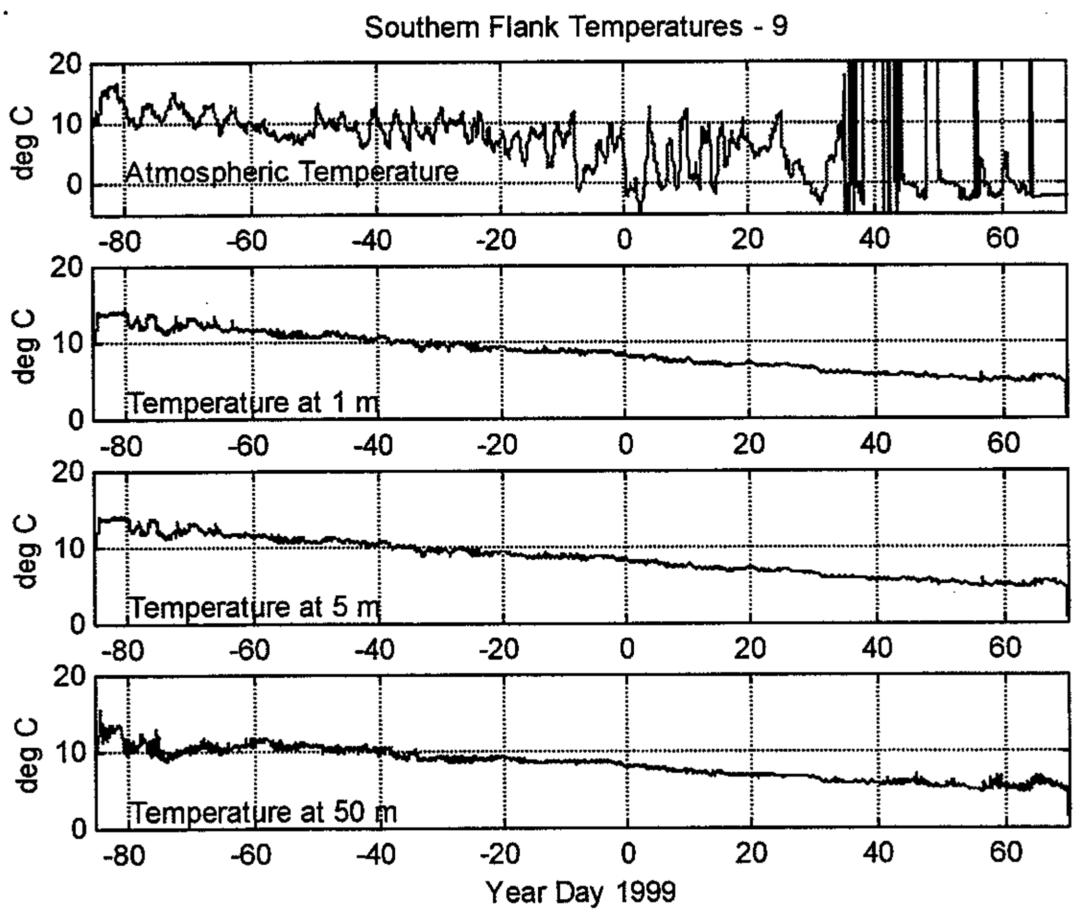


Figure 7. Southern Flank moored temperature. The normalized, unedited temperatures are shown for 1, 5, and 50 meters depth with the air temperature on the top for reference.

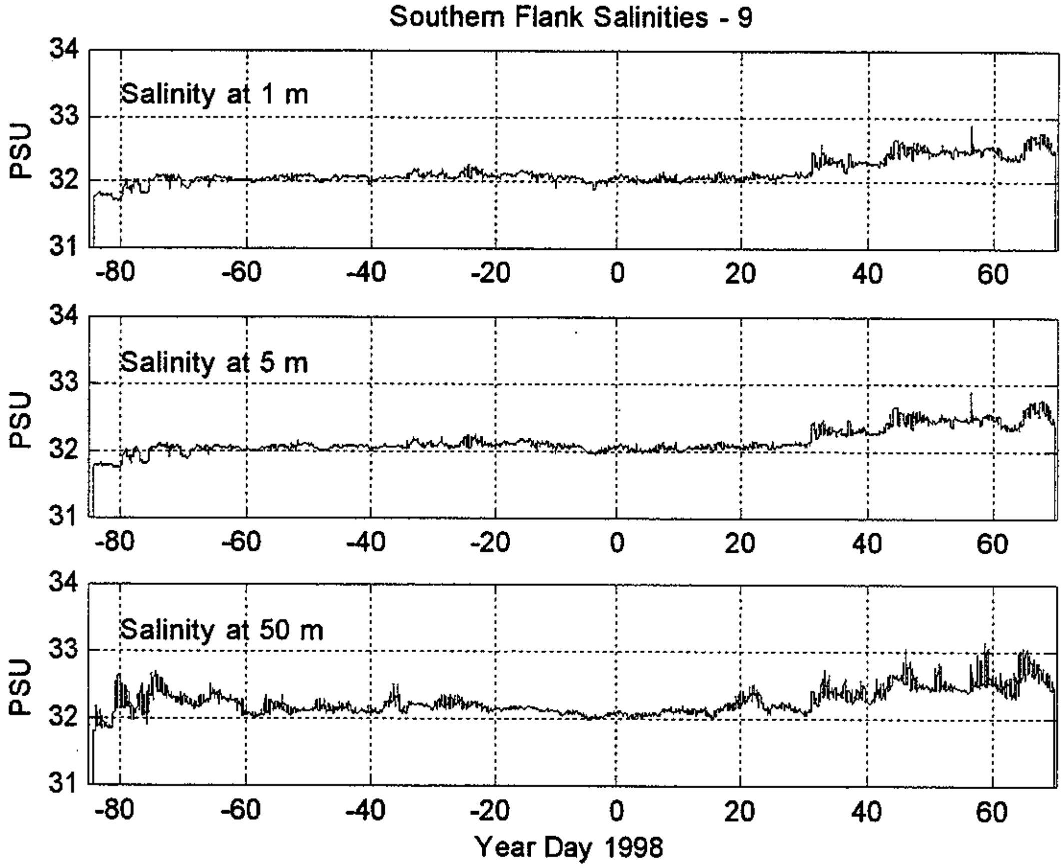


Figure 8. Southern Flank moored salinity. The normalized, unedited salinity calculated from the temperature and conductivity records is shown for depths of 1, 5, and 50 meters.

the first two weeks in the upper half of the water column (above 40 meters), but by early November the temperature is uniform to the bottom. In early February there is indication of warm intrusions in the bottom (seen at 72 meters but not at 50 meters.)

The hourly averaged salinity records (Figure 8) shows some higher salinity mixing up from the shelf slope front in the bottom layers as suggested by the deep temperatures. The salinity records from the Seacats (Figure 10) and bio-optical packages (Figures11 and 12) show the same uniform behavior with the intrusions seen in early February at 72 meters and somewhat at 50 meters. The surprising feature in these records is the increase in salinity during February and into March. During the past four years, there has been a decrease in salinity, with annual fluctuations, of about 1.5 PSU on the bank to its low of about 32 PSU this last year and this past winter. It will be interesting to see if this increase in salinity is just a few month "blip" in the long term trend toward fresher waters, or the start of a return toward the saltier values of the past.

In the 72 meter record (Figure 10) and to a lesser extent at 50 meters (Figure 8) there are indications of warmer saltier intursions throughout the late fall and early spring (year days -55, -45, 22, 50, and 57). There are temperature, but mostly salinity effects that are seen at all depths about year day 30 and during the past week of the record. These are probably due to advection of new water masses past the mooring. However, there are no indications of cooler fresher Scotian Shelf water masses seen in the surface waters as in past winters.

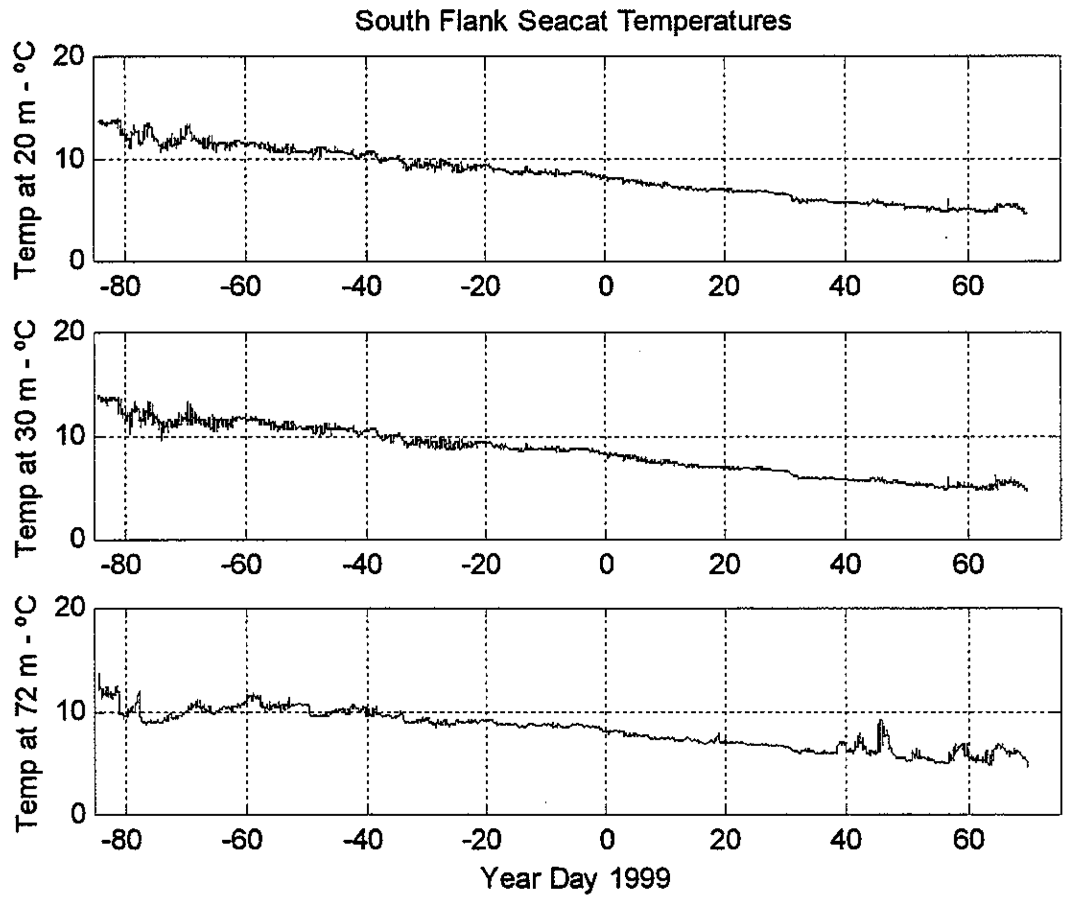


Figure 9. Seacat Temperature. The raw, normalized, but unedited temperatures are shown for 20 m (top panel), 30 m (center panel) and 72 m (bottom panel).

During this deployment, we have switched from the Sea Bird Electronics SBE-16 Seacats at the bottom of the mooring, to the newer Sea Bird Electronics SBE-37 Microcat. The ability to bolt the titanium mounting bracket to the mooring chain is very helpful, and makes the system more robust than attaching our Polypropylene mounting brackets for the older SBE-16 style sensors to the chain. The setup and data recovery software are a bit different, but appear to function and return creditable data with little effort. The advantage of the Microcat's smaller lithium battery pack over the SBE-16's packs which were required for rapid sampling to resolve internal tidal signals, should make deploying these new units in regions where equipment must be shipped much easier.

The bio-optical packages deployed at 10 and 40 meters have been in use for the last four and a half years, and have worked well. The major problem with these packages is the optical sensors which foul with time. During the winter we are able to get about 120 days (4 months) of good data before the signals appear appreciably affected by biofouling. The deeper sensors are less affected. During the summer months, the sensors will bio-foul in less than 3 months. Therefore, during this year we are attempting to service the moorings more often to provide more complete records. It should be noted that the last month of the 10-meter bio-optical package was still lost due to fouling effects. Keeping clean bio-optical sensors on moorings implies that the servicing must be more often, and will significantly increase the cost of doing bio-optical work on conventional physical property moorings

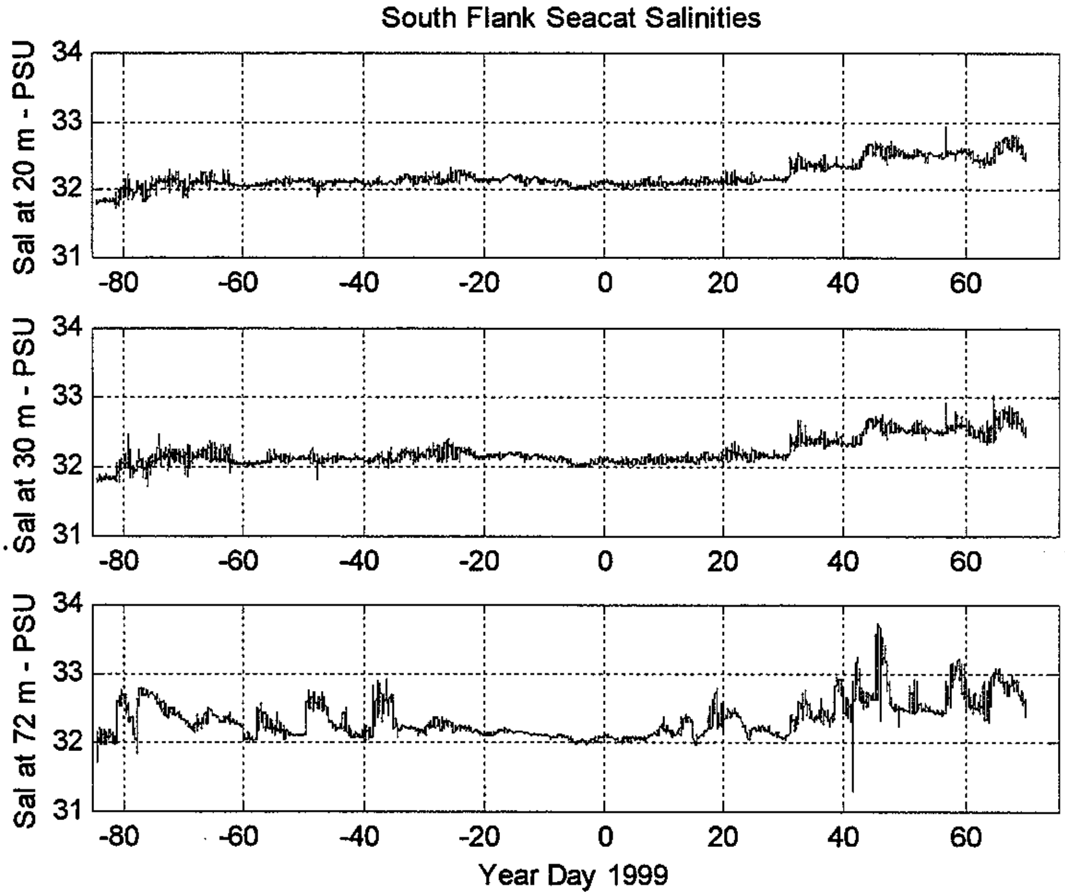


Figure 10 Seacat Salinity. The raw, normalized, but unedited salinities are shown for 20 m (top panel), 30 m (center panel) and 72 m (bottom panel).

The radiation sensors are another problem in bio-optical observations. The range of the sensors from air to Georges Bank depths, changes the signal strength several orders of magnitude. Therefore, we have attempted to optimize the 12-bit range of the analog digitizing electronics by prescaling the signal with signal conditioning amplifiers and averaging circuits. These averaging circuits have an overflow which is also kept track of, but there are still problems in its switching and recording so that at times error spikes are allowed through as seen in the averaged par records (raw plots in the bottom panel of Figures 11 and 12). These are generally easily removed since they are single point, power of two spikes. For other applications, we have also further modified these packages for other applications by the additions of cosine PAR collectors to measure upwelling and downwelling radiation as well as PAR. Finally, we have also added a Satlantic upwelling radiance and downwelling irradiance sensors with the SeaWiFS satellite wavelengths. These additions improve the radiation measurements, but do not overcome the major weakness that is inherent in these instruments, that is the biofouling.

The temperature and salinity records shown in Figures 11 and 12 agree with the neighboring Seacat and buoy temperature and salinity records. These records are spot samples at

3.75 minute intervals (16 samples per hour), and only the PAR sensors are averaged over the sample interval. The Seacats at 20 and 30 meters are sampled at 2-minute intervals, and the 72-meter Microcat is also sampled at 3.75 minutes. Therefore, these sensors tend to show more structure in the record than the buoy data which is averaged to hourly due to bandwidth limitations in the GOES satellite telemetry link. However, during the winter months this is not as significant as when the water column is stratified and internal tides are present. The salinity records in Figure 8 and 10 illustrate the higher frequency content of the more rapidly sampled sensors.

The major signal seen in the fluorometer is the large peak during the latter part of October 1998 (yd -75 to -65) when there is a significant increase in chlorophyll-a fluorescence for more than a week at 10 meters, with a hint of higher activity at 40 meters. During this time the transmissometer records show a decrease as would be expected by higher quantities of phytoplankton. There is not much else in the record until the sensors show biofouling effects near the end.

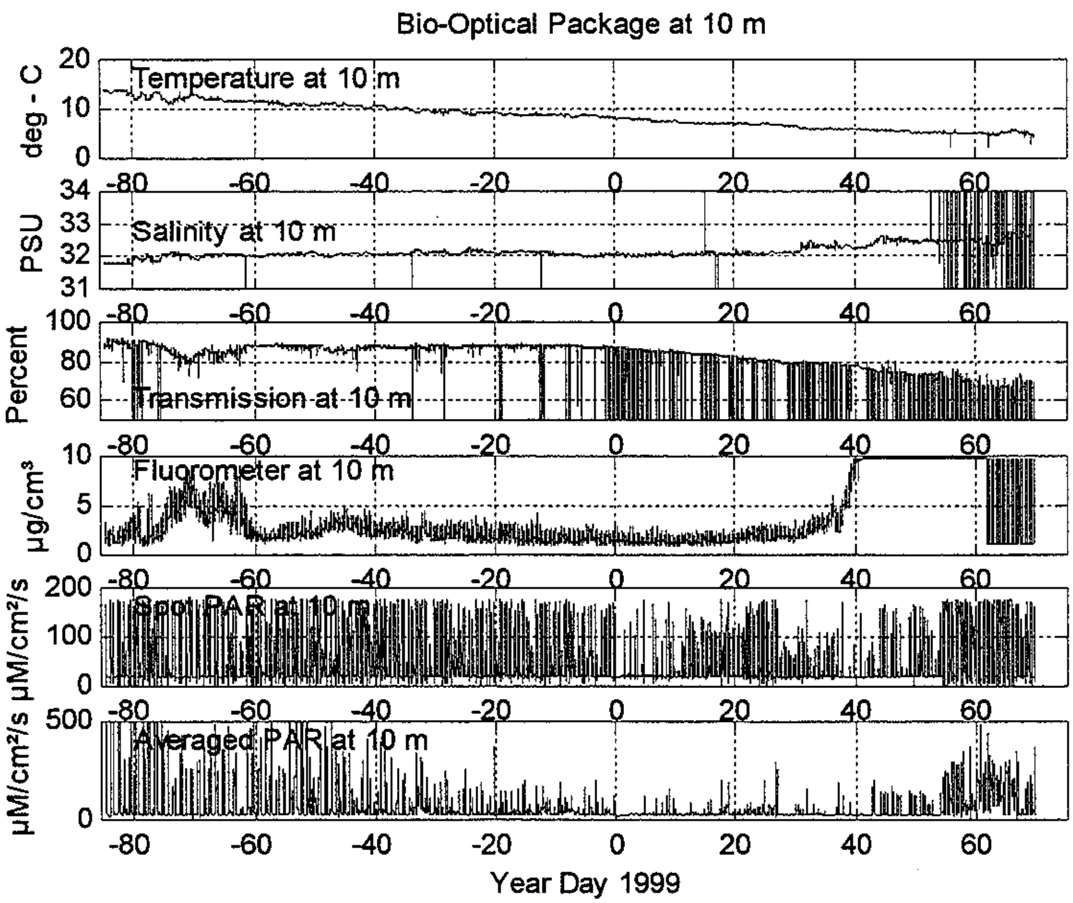


Figure 11. The unedited bio-optical results at 10 m. The top panel shows the temperature in degrees C, and the next panel the salinity in PSU. The third panel shows the beam transmissometer in percent transmission, and the fourth panel the chlorophyll-a fluorometer with nominal calibration of 10 µg/l full scale. The fifth panel shows the single spot PAR value at the time of sample. The bottom panel shows the 3.75 minute averaged PAR in microMoles/cm2/sec. The basic sample interval is 3.75 minutes or 16 samples/hour.

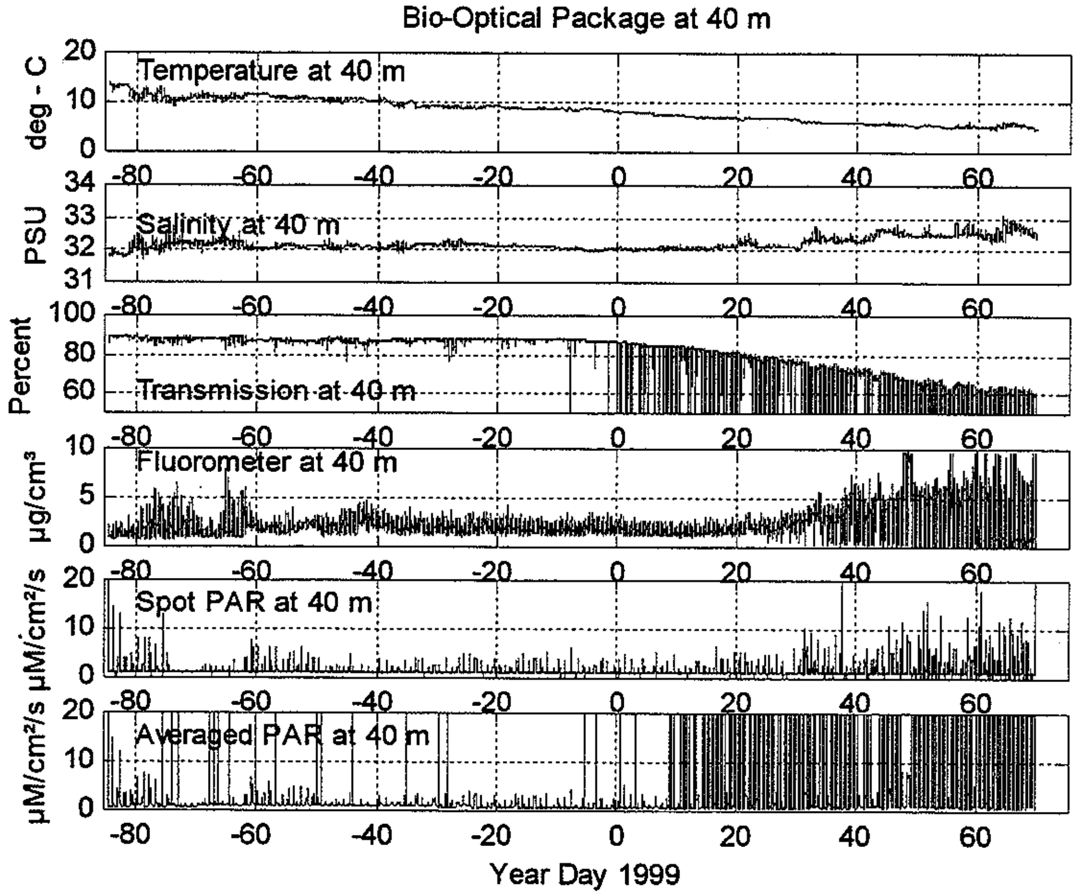


Figure 12. The unedited bio-optical results at 40 m. The top panel shows the temperature in degrees C, and the next panel the salinity in PSU. The third panel shows the beam transmissometer in percent transmission, and the fourth panel the chlorophyll-a fluorometer with nominal calibration of 10 μg/l full scale. The fifth panel shows the last individual PAR reading while the bottom panel shows the 3.75 minute averaged PAR reading in microMoles/cm2/sec. The basic sample interval is 3.75 minutes or 16 samples/hour.

The transmissometer records tend to be more "spiky" in appearance. This is probably due to the nature of the sensor. It measures the light transmitted across a 25-cm long path, and if anything were to swim into this path, it would block it completely for a period. Whenever we are recovering a mooring on Georges Bank in calm weather when we can see down into the water column as we retrieve the mooring, we see schools of small fish around the mooring cable. Therefore, we attribute some of these spikes in the transmissometer, and to a lesser extent in the fluorometer to smaller biology collecting near the mooring. Another feature of the records on Georges Bank is the high variability in time and space of the chlorophyll-a fluorescence records. We thought that the fluorometer on the CTD was not working properly at first, until we got into off Bank waters and saw more typical results. Therefore, we must characterize Georges Bank as having highly patchy nature in chlorophyll-a which shows up in the moored signals (advected past the sensor by the tidal currents which sweep out a 10-km ellipse at this site) and in the vertical CTD profiles.

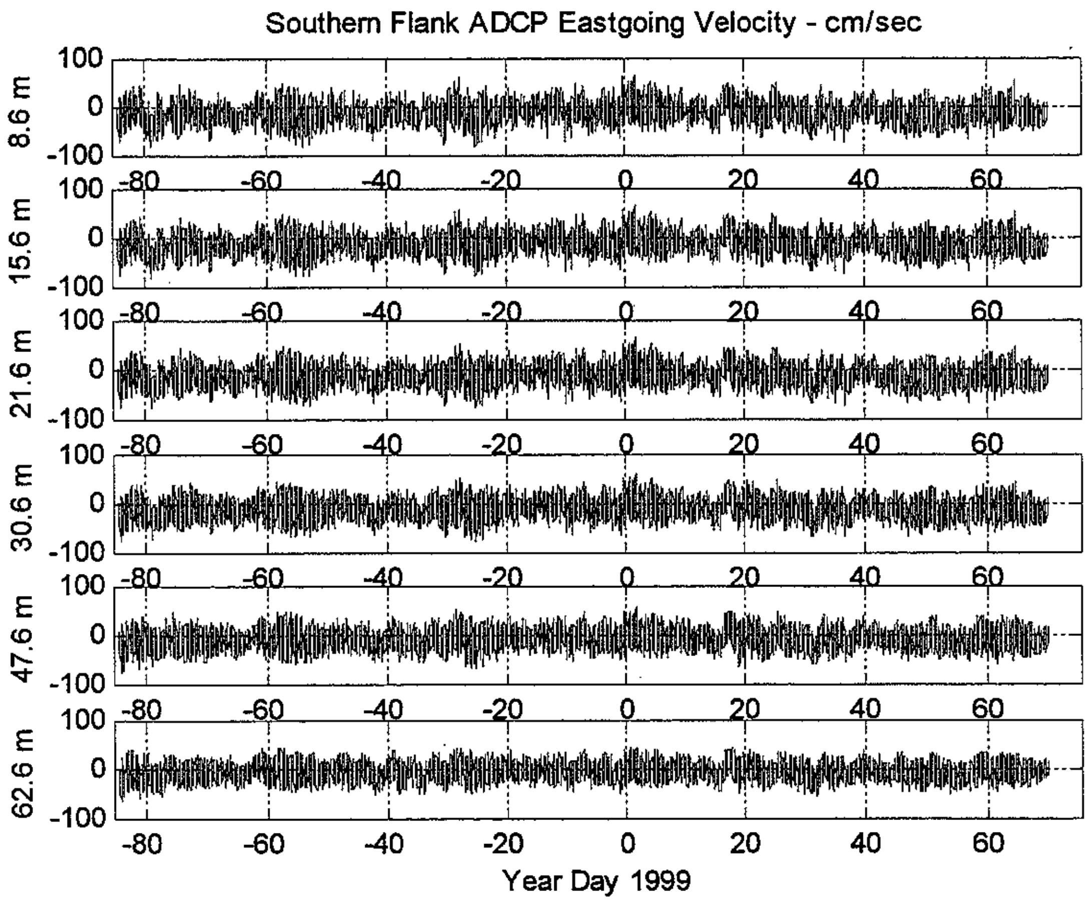


Figure 13. Southern Flank ADCP Eastgoing currents. A subset of the raw, normalized, but unedited eastgoing currents are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

The Southern Flank mooring had a downward looking Workhorse ADCP (Acoustic Doppler Current Profiler) moored at 3.5 meters depth. The ADCP sampling plan was set to measure 70 one-meter vertical depth bins and average 800 pings into one-hourly averages. The statistical uncertainty or noise with this sampling program is about 0.4 cm/sec, and is distributed as a white spectral density which matches the observations fairly well (Irish, et al., 1995). The ADCP processes the results to averages of Eastgoing, Northgoing, and vertical velocities relative to magnetic north, and gravity (instrument tilts), and also returns the amplitude of the backscattered signal (Figure 15) from each bin for each transducer. The eastgoing component (Figure 13) and Northgoing component (Figure 14) show a westward circulation along the southern flank of Georges Bank, and weather forced fluctuations, larger in the East-West component than the North-South. The North-South tidal velocities are larger, and both records are dominated by the tidal components. The amplitude of the backscattered signal shows the attenuation with distance from the transducer (the lower amplitudes in the deeper records), as well as the temporal variability due to the presence of backscatterers (biota?) in the water column. As a visual and statistical comparison/quality check, a subset of the full data set was retrieved and examined. The one-meter vertically averaged eastgoing and northgoing velocity components centered at 8.6, 15.6, 21.6, 30.6, 47.6, and 62.6-meter depths were extracted and corrected for the magnetic variation of −17.3° at the site.

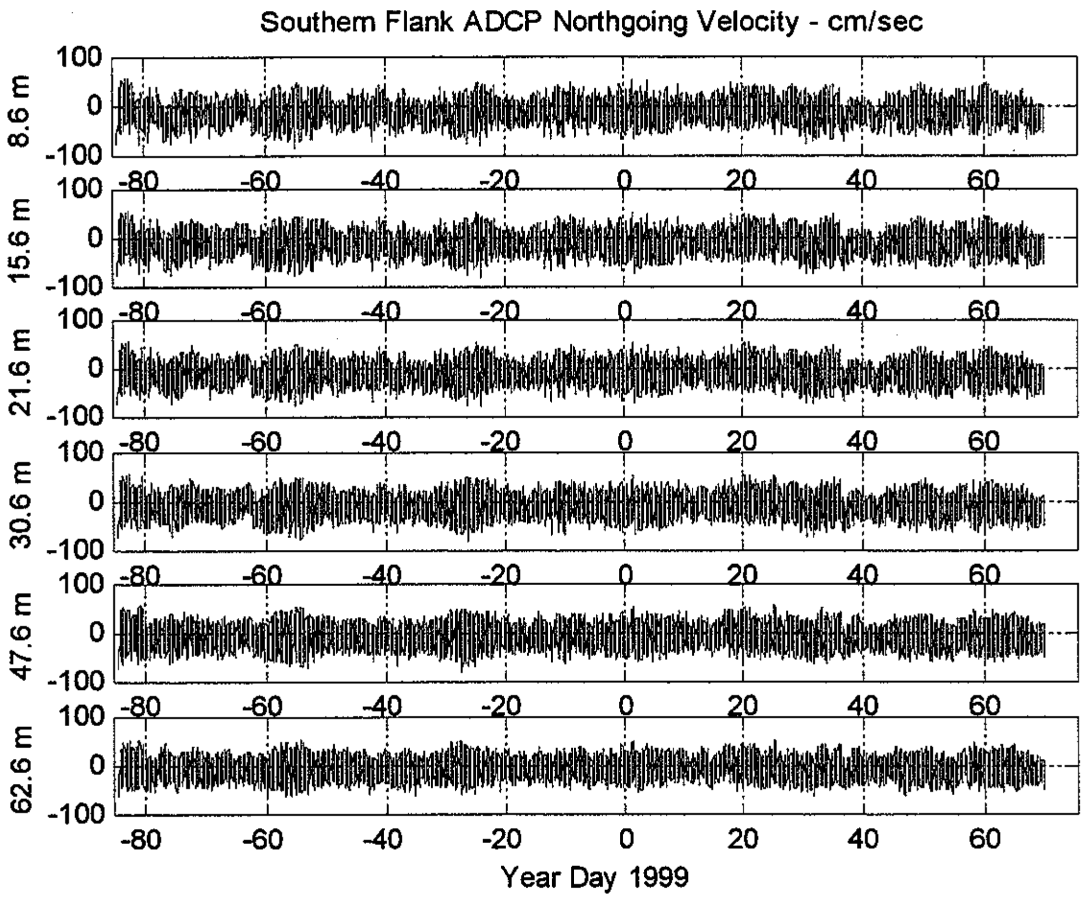


Figure 14. Southern Flank ADCP Northgoing currents. A subset of the raw, normalized, but unedited northgoing currents are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

The six selected series shown in Figures 13 and 14 were also analyzed by rotary spectral techniques for their frequency content (following the method outlined by Gonella (1972). The rotary representation (a positive and negative rotating component rather than eastgoing and northgoing component) make sense in separating and visualizing some physical phenomena. The inertial current in the Northern Hemisphere rotates clockwise, so energy at the inertial frequency should show up in only one component of the rotary representation. Also, tidal currents, if they are circularly polarized, will also show up in one component. If the tidal currents are rectilinear, than they will appear with equal amplitudes in both rotary components. Figure 16 shows the rotary representation from averages of the transforms of three blocks of 1024 one-hourly values. It is obvious that the diurnal and inertial currents are nearly circular and clockwise rotating. The semidiurnal tides are also clockwise rotating, but not quite circular as some energy appears in both components. The low and high frequency components are more nearly isotropic, being nearly equally energetic in the positive and negatively rotating components, and in the eastgoing and northgoing components. There is the hint of a 4-day (peak near the 10^{-2} cph frequency), probably due to weather forced currents.

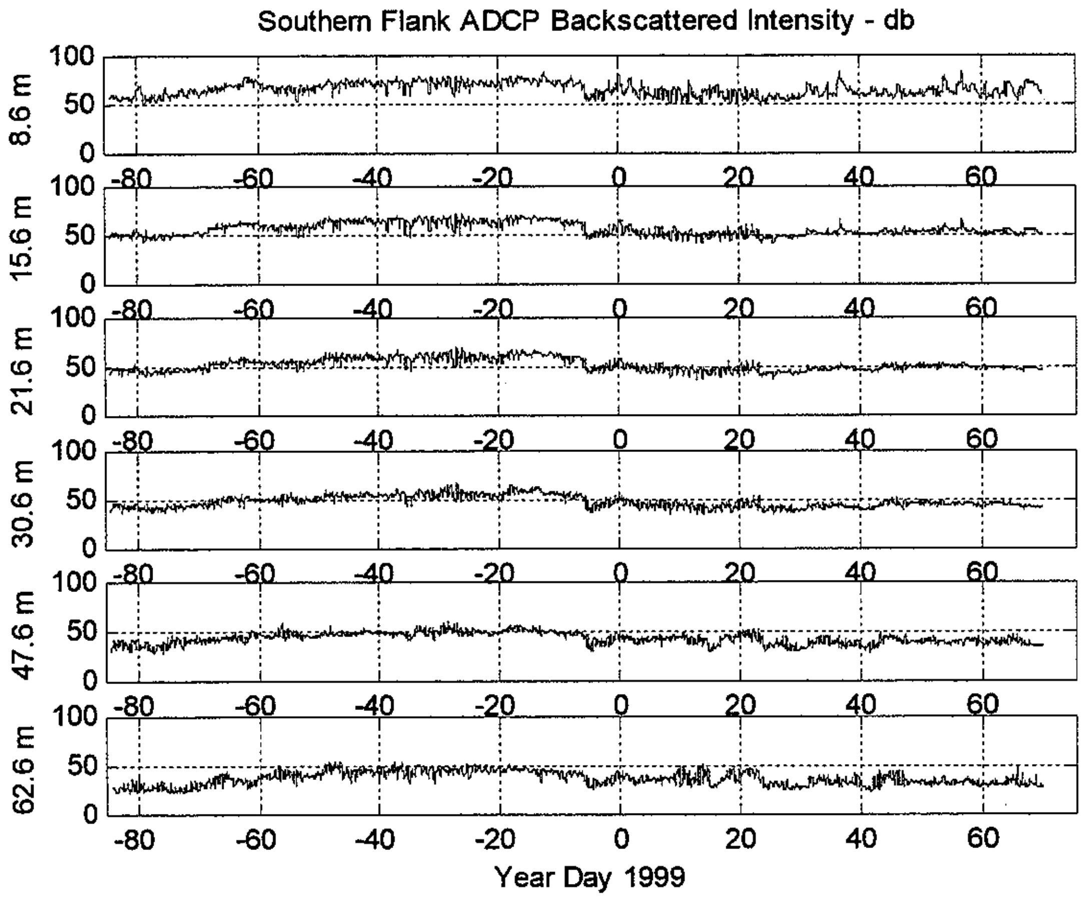


Figure 15. Southern Flank ADCP Backscattered Intensity. A subset of the raw, normalized, but unedited backscattered intensities from one transducer are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

The ADCP results from the winter were analyzed for their tidal content to check the tidal software, the ADCP normalization, and our processing techniques. For the tidal analysis, the old National Ocean Survey harmonic tidal analysis routine with improved windowing to accept any record length was used (Irish and Brown, 1986). To eliminate any problems with east and north rotation, and to allow best comparisons with the published harmonic constants from the region (Moody, et al, 1984), the analysis was resolved into elliptical representation. Because velocity records are not as "clean" as pressure records, the smaller constituents were inferred as normal practice. The record was 153 days long (3691 hours), so adequate spectral resolution separated the tidal lines from background noise. The analysis predicted 98% of observed variance in the semidiurnal tidal band. The residual record (the observed record less the predicted tides), was only 6% of the observed variance, showing that indeed the record was dominated by the tides, and particularly the M2 tide.

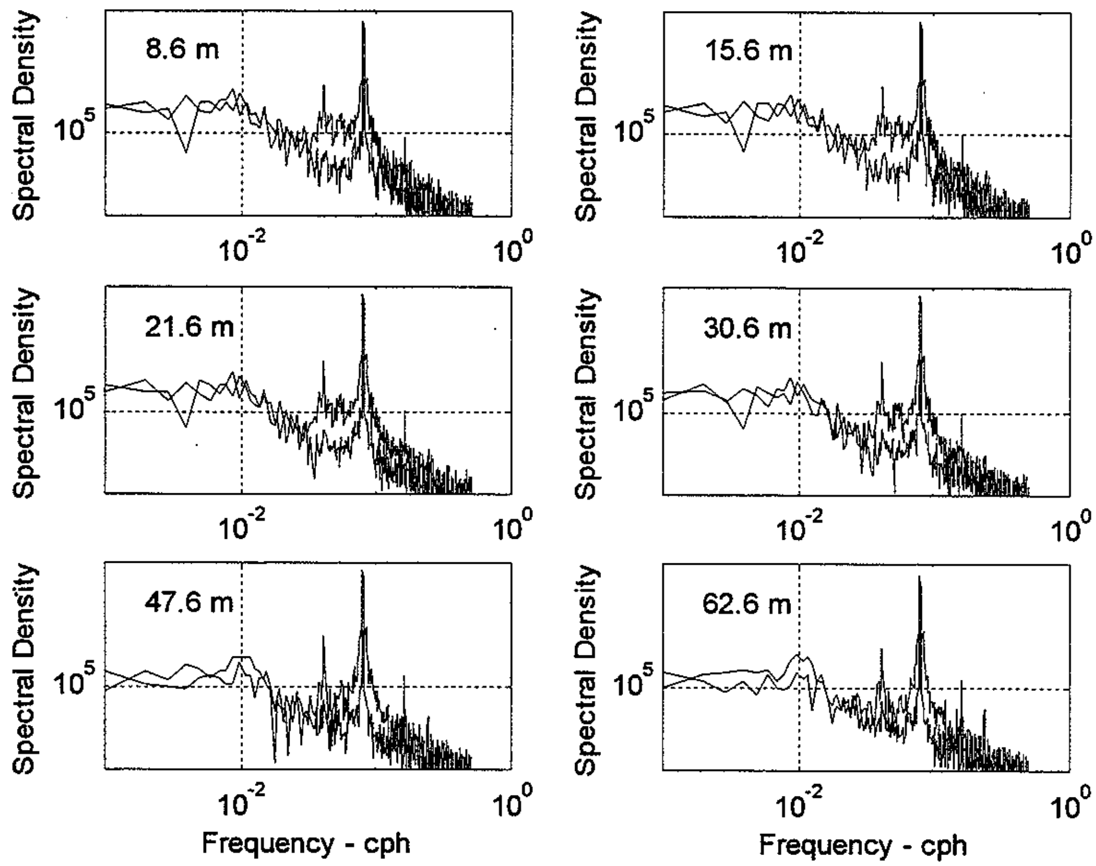


Figure 16. Rotary spectra of the Southern flank ADCP currents at the six selected depths. Three 1024 point blocks were averaged. The clockwise rotation of the tidal currents, and the decrease in inertial current with depth can be seen.

To examine the vertical structure of the tidal currents, the M2 components (containing the largest energy and accounting for about 78% of the total observed record variance) were resolved into their major and minor components (see Table 2 and Figure 17). The results from the tidal analysis and the vertical structure agree with the USGS Station A results reported in Moody, et al, (1984) from the harmonic analysis of a 957 day-long record. To make the comparison, the velocities were adjusted by the differences in depth (85 m for Station A versus 76m for the southern flank) assuming continuity of transport. The Station A analysis also broke the record up into one month sections and averaged the results to obtain the published results. Since that time, further study of tidal records has shown that this is not the optimum method and utilizing the longest record possible to get the best spectral resolution is the more optimum way of improving signal to noise and obtaining the best prediction (Irish and Signell, 1992).

The M2 component profiles (Figure 17) show the maximum flow is found below mid-depth in the 30 to 40 meter range. There is a boundary layer at the surface that slows the velocity somewhat, and a more standard boundary layer at the bottom where the velocity goes to zero. This structure is not resolved by the ADCP current profiles because the side-lobe reflections from the bottom contaminate the records below about 65 meters depth. Since the 47 m depth appears to be the most energetic, the full harmonic analysis of the eastgoing and northgoing componets for the largest 19 constituents are listed in Table 3. The phase is listed in Greenwich epoch relative to the passage of the sun or moon over the Greenwich meridian and time being in UTC.

Table 2 – Southern Flank ADCP M2 Tidal Analysis of Currents at Selected Depths

Depth	Eastgoing H(cm/s)	Eastgoing g(°)	Northgoing H(cm/s)	Northgoing g(°)	Major H(cm/s)	Minor H(cm/s)	Phase g(°)	Orient g(°)
8.6	31.29	138.2	36.44	28.8	39.63	-27.14	5.1	327.4
15.6	31.62	137.8	37.82	28.6	40.79	-27.69	6.68	329.3
21.6	31.90	137.4	37.44	28.5	40.52	-27.89	5.4	328.2
30.6	32.31	136.5	38.03	27.9	41.06	-28.36	5	328.6
47.6	31.70	131.7	38.3	23.3	41.03	-28.08	2.2	330.5
62.6	27.10	122.6	34.4	12.7	36.71	-23.88	354.1	332.6

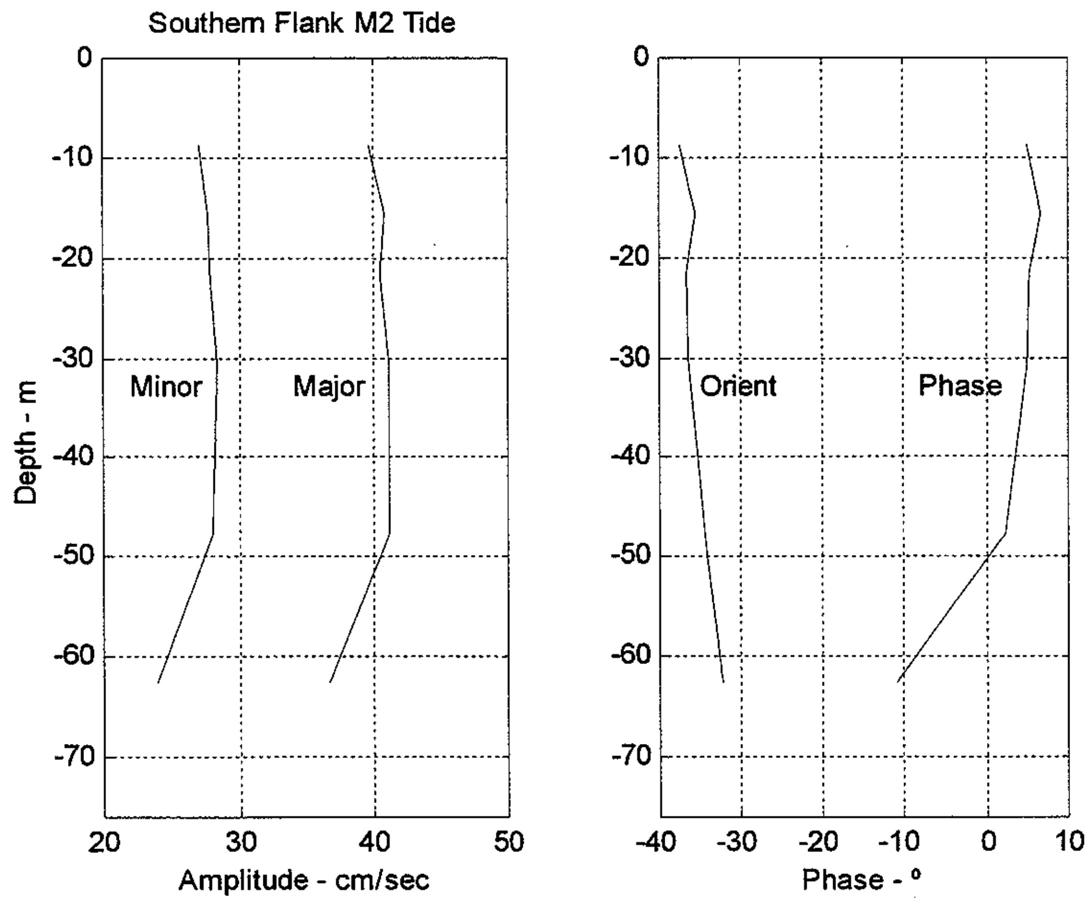


Figure 17. Southern flank ADCP M2 tidal analysis results as a function of depth as in Table 2.

The low frequency structure of the currents were examined by low-passing the current records with the D47 filter to optimally removed tidal and higher frequencies (Groves, 1955). The predicted tidal record was subtracted from the observed record and rotated 30° counter clockwise and the filter applied. The tides were first removed to reduce the energy at tidal frequencies so that the tidal filter would not have to work on the high tidal peaks (see Figure 16).

The rotation was done based on the average slope of the local depth contour, and the more general slope of the 100-m contour offshore of the mooring. The shallower contours might be better aligned with 20°. Still with this large a rotation, the average current over the 153 days was offshore (Figure 18). Also the strong down bank current is evident. There is strong variability in both components, but the along-bank component has twice as larger variations. Some of the large peaks are coherent with the wind speed, and some follow a relaxation of the wind. Although not plotted here, the average up-bank and on-bank currents do not show the peak at mid-depths as the tides, but decrease monotonically from the surface to the bottom, with a slight clockwise turning with increasing depth.

Table 3 - Harmonic Analysis of ADCP currents at 47.6 meters depth

Constituent	Eastgoing		Northgoing	
	h(cm/sec)	g(deg)	h(cm/sec)	g(deg)
M(2)	31.72 ±0.53	131.7 ± 0.8	38.40 ±0.46	23.3 ± 0.6
N(2)	6.73 ±0.53	90.1 ± 3.9	8.04 ±0.46	342.8 ± 2.9
S(2)	5.01 ±0.53	160.9 ± 5.2	6.13 ±0.46	51.5 ± 3.8
O(1)	1.52 ±0.54	109.9 ± 19.6	1.58 ±0.45	50.1 ± 15.4
K(1)	4.30 ±0.53	169.1 ± 6.1	3.80 ±0.46	94.0 ± 6.1
K(2)	1.36 ±0.53	·163.3 ± 21.4	1.67 ±0.45	53.8 ± 14.6
L(2)	0.96 ±0.52	173.2 ± 30.8	1.14 ±0.46	63.7 ± 22.3
2N(2)	0.89 ±0.52	48.6 ± 33.1	1.07 ±0.46	302.4 ± 23.9
T(2)	0.29 ±0.35	159.8 ± 78.8	0.36 ±0.37	50.4 ± 64.0
LAMBDA	0.22 ±0.29	145.3 ± 88.4	0.27 ±0.31	36.4 ± 76.5
MU(2)	0.76 ±0.49	102.4 ± 38.6	0.92 ±0.45	355.0 ± 28.2
NU(2)	1.30 ±0.52	95.7 ± 22.3	1.55 ±0.45	348.2 ± 15.5
J(1)	0.12 ±0.17	198.4 ± 99.7	0.12 ±0.18	115.8 ± 97.7
M(1)	0.12 ±0.18	139.5 ± 99.0	0.13 ±0.19	72.1 ± 96.9
P(1)	1.42 ±0.53	164.6 ± 20.5	1.26 ±0.46	90.7 ± 20.4
Q(1)	0.29 ±0.35	80.6 ± 78.9	0.31 ±0.34	28.3 ± 72.3
M(4)	0.99	269.9	1.34	
M(6)	0.43	67.7	0.56	
S(4)	0.11	302.2	0.17	

Northeast Peak Guard Moorings: During the past year, the GLOBEC Long-Term moored program did not have moorings on the Northeast Peak of Georges Bank in order to conserve resources for the GLOBEC final field year. These moorings were redeployed in November 1998 at the same time as the Northeast Peak Crossover Experiment's moorings were also being deployed. The two guard buoys had steel flotation spheres with solar powered lights and radar reflector, and were moored by all chain hardware. The two guard buoys were deployed first separated by about 0.15 nm. The buoys were oriented about NW-SE to give the best alignment for the deployment of the science buoy against the currents. The science buoy was deployed last between the two guard buoys. All buoys were deployed on 19 November 1998 at the times and positions given in Table 4. These buoys were checked on OC338 in March 1999, and they were both in position, had functioning guard lights so were not serviced.

Northeast Peak Science Mooring B: The science mooring B consisted of a steel flotation sphere with tower and solar powered data/telemetry system and light. The mooring had minimal meteorological observations, full water depth ADCP current profiles and several temperature and conductivity sensors along the mooring cable, and two bio-optical packages. The sensors, type, nominal depth and serial numbers are listed in Table 1 and shown in the schematic in Figure 19.

Table 4 – Northeast Peak Deployment Times and Positions

Mooring	Date	Time (UTC)	N Latitude	W Longitude	Depth
Guard Buoy A	19-Nov-98	1548	41° 43.947	66° 32.262	74 m
Guard Buoy S	19-Nov-98	1647	41° 43.851	66° 32.091	73 m
Science Buoy B	19-Nov-98	2027	41° 43.923	66° 32.176	73 m

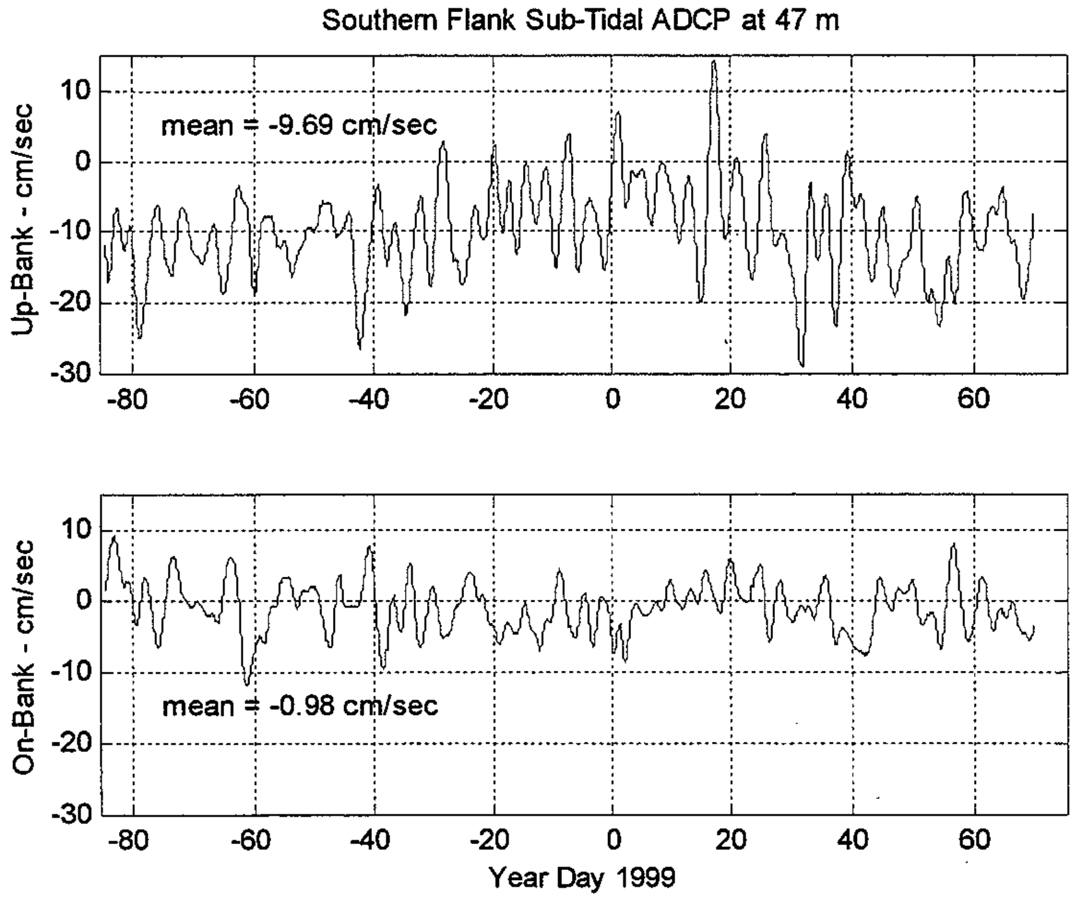


Figure 18. Lopassed velocity at 47 meters. The components shown in Figures 13 and 14 were rotated 30° counter clockwise to align the up bank component with the average bathymetry.

The buoy, sensors and mooring cable were mildly fouled. Picture 1 shows the buoy (background), 10-meter bio-optical package in the foreground and the 40-meter bio-optical package and acoustic behind it and in front of the buoy. The 10-meter bio-optical package was mildly fouled. In Picture 1 the PAR sensor (the white "light bulb" facing the camera on both packages) on the 10-meter package is heavily fouled, and only lightly fouled on the 40-meter package. The buoy, acoustic release, bio-optical packages, ADCP and mooring cable with

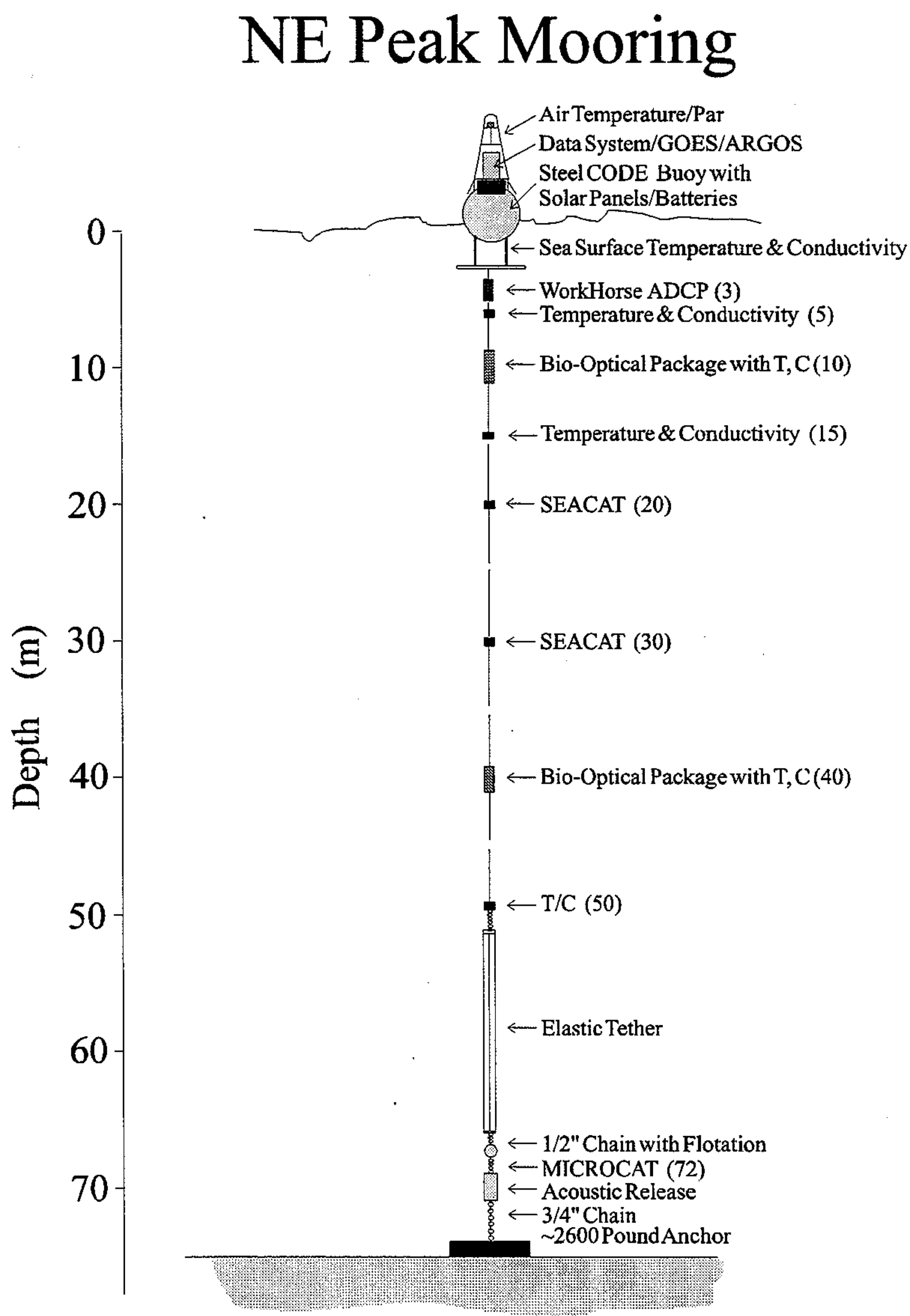
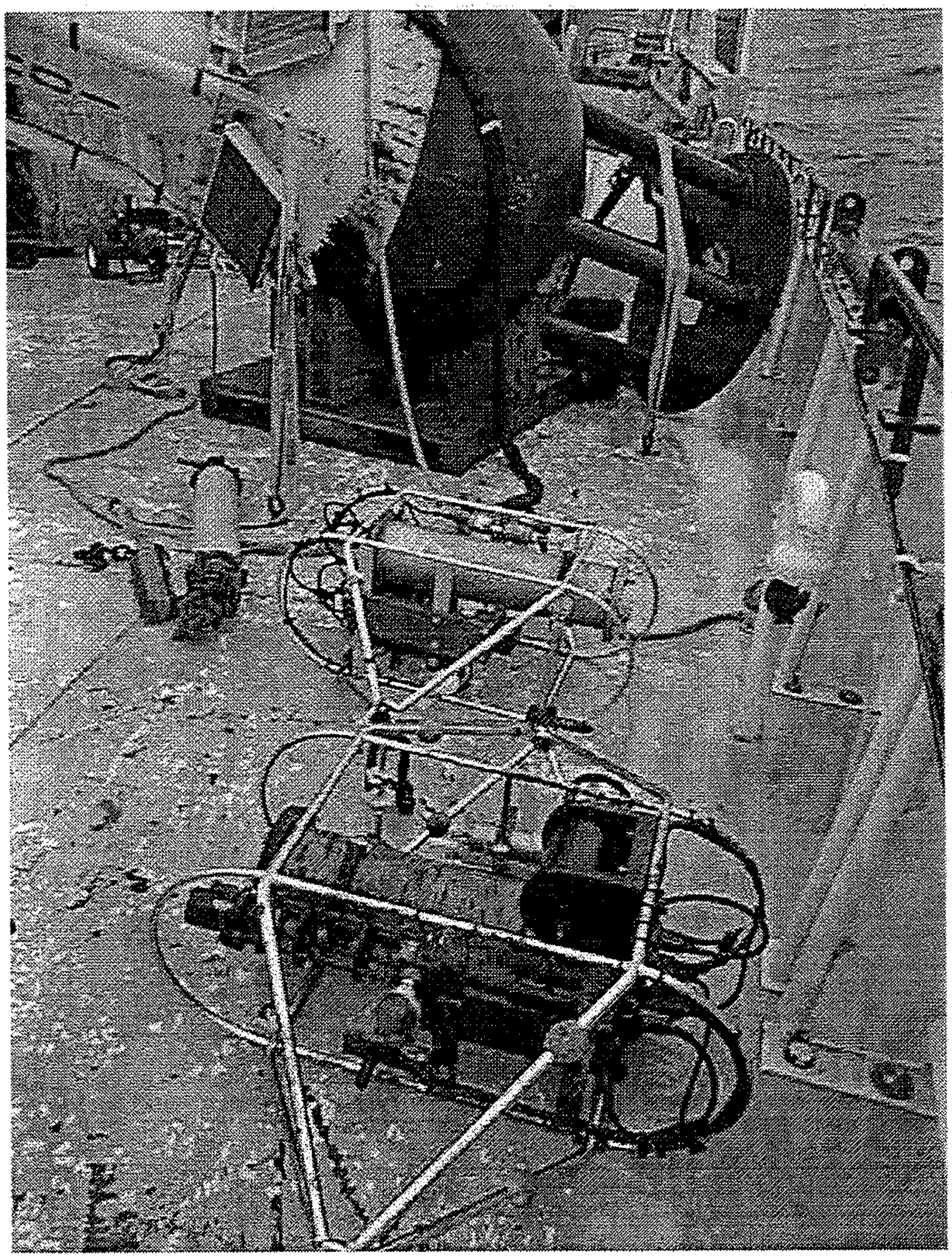


Figure 19. Northeast Peak Mooring Configuration during winter 1998-99 deployment.



Picture 1. The Northeast Peak Buoy (top) the 40 m bio-optical package (middle), and 10 m bio-optical package (bottom). The buoy shows moderate fouling, the 40 m bio-optical little, and the 10 m bio-optical moderate. The PAR sensor (light bulb closest to the bottom) is covered with fouling on the upper surface, while the 40-m PAR (rear frame) is only lightly fouled.

sensors were power washed to clean everything for redeployment. The bio-optical packages were opened, batteries and PCMCIA data storage cards changed, optical windows cleaned and readied for redeployment. The ADCP and Seacats were opened, checked and batteries changed if scheduled, and data dumped. They were also cleaned and prepared for redeployment. The buoy data was dumped and the system checked, found functioning well and the system was restarted for deployment.

As a check on the functioning of the buoy system before redeployment, the data was normalized, and plotted for visual checks in next three Figures. As a check on the system power, the batteries, and system bus voltage were recorded, and are plotted with radiation (PAR) in Figure 20. The system reached minimum power in mid-January with the colder, shorter, more overcast winter days. By mid-February, the system appears to be recharged, and so for the rest of the year, we are not utilizing the power produced by the four 10 watt solar panels. There is a visual correlation of the battery voltage with PAR as would be expected as this is the radiation producing the charging current. The bus voltage is lower than the battery voltage by the 1/3 volt drop in the Schottky diodes in the two parallel power circuits preventing a failure in one from discharging the other and stopping the system.

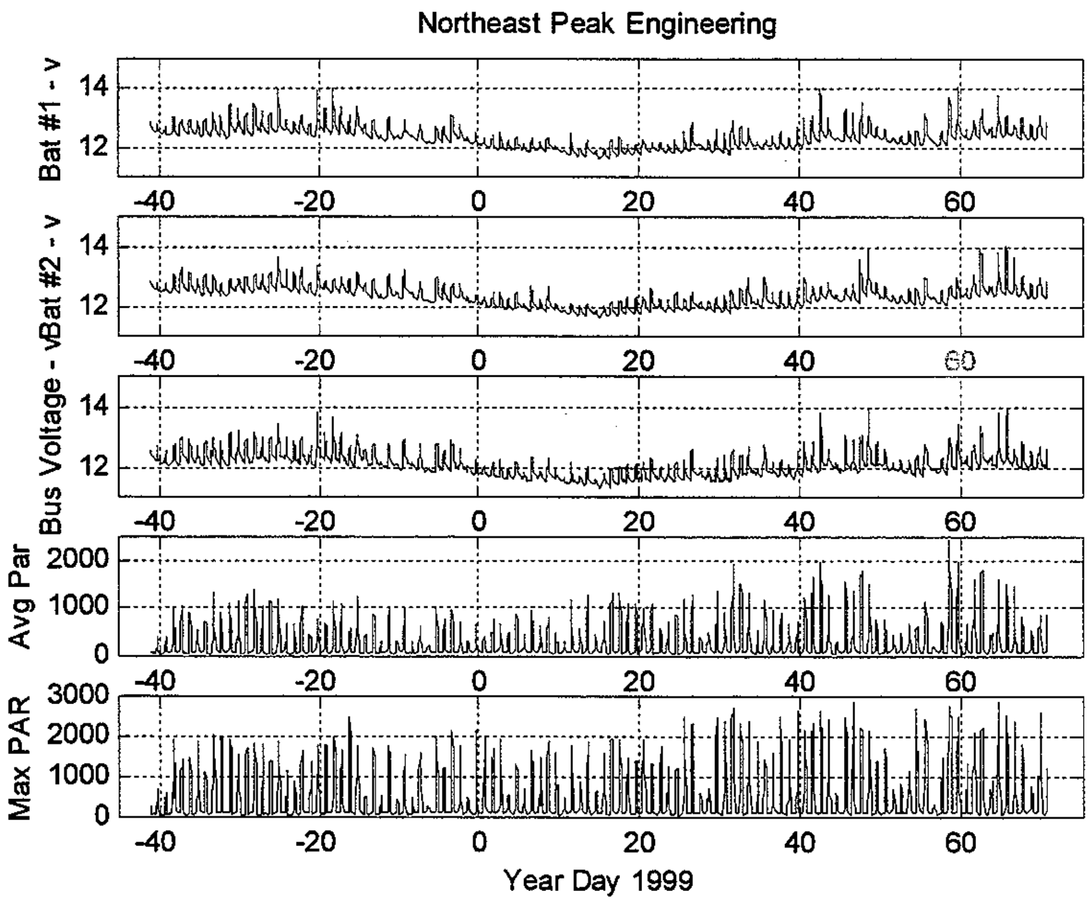


Figure 20. Northeast Peak Engineering Checks. The system batteries are shown in the top two panels and agree nicely, although #2 appears to be slightly lower. The hourly averaged PAR is shown next, with the individual 10-sec sample that is the largest during the hour shown on the bottom. The radiation (AvgPAR) and battery voltage are visually correlated with a lag.

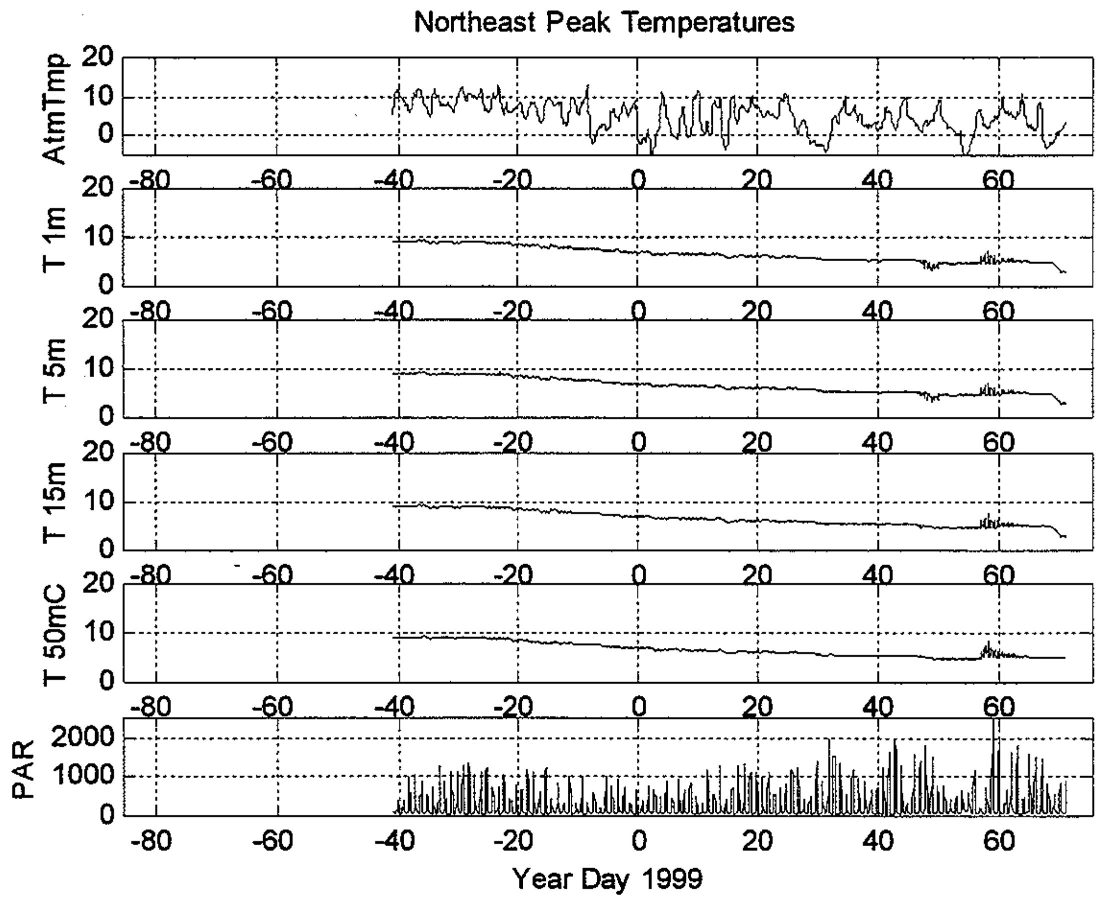


Figure 21. Northeast Peak moored temperature. The raw, normalized but unedited temperatures are shown for depths 1, 5, 15, and 50 meters depth with the air temperature in the top panel for reference.

The hourly averaged temperature and salinity values recorded in the buoy and telemetered to shore via ARGOS and GOES were next normalized and plotted in Figures 21 and 22. Other than a few spikes in salinity (probably due to contaminates in the conductivity cells during the measurement) the records appear good, so the system was determined to be OK and was prepared for redeployment. For comparison with the Southern Flank data shown above, the data from the Northeast Peak mooring were plotted on the same scales as the Southern Flank. Since the Northeast Peak deployment was a month later than the Southern Flank, there is a blank month at the start of all the records except the Northeast Peak engineering results.

The Seacats from 20, 30 and 72 meters also appeared in good shape with little fouling upon recovery. They were checked, the data dumped and restarted for redeployment. The data was also normalized and plotted in Figures 23 and 24 for visual check. Again the records appear clean with only a few spikes in the salinity records. These instruments were set to sample at a higher rate than the buoy recorded temperature and conductivity sensors. The 20 and 30 meter Seacats sampled at 2 minutes, and the 72-meter Microcat at 3.75 minutes, or 16 samples per hour which is the same sampling rate as the two Bio-optical packages at 10 and 40 meters.

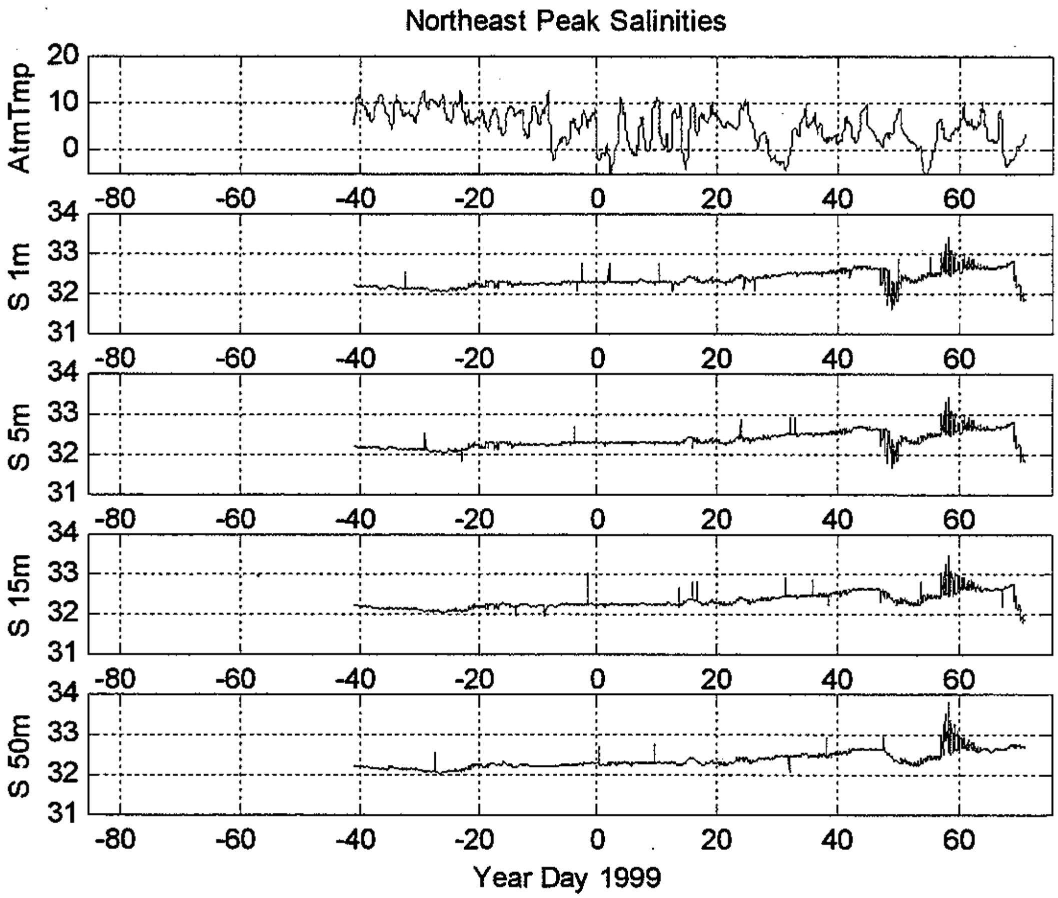


Figure 22. Northeast Peak moored salinity. The raw, normalized but unedited salinity calculated from the temperature and conductivity records is shown for depths of 1, 5, 15, and 50 meters.

The bio-optical packages deployed at 10 and 40 meters required servicing to clean the optical sensors. Some idea of the fouling can be observed in Picture 1. The PAR sensor on the top of the package, exposed to the sunlight is the first one to show fouling. The fluorometer is mounted at the bottom of the bio-optical packages, somewhat protected from falling debris and direct light, and is the last to foul. The 10 meter PAR record (Figure 25) after year day 40 does show some reduction in amplitude that is not seen in the incoming radiation on the buoy (Figure 20), which is consistent with the fouling observed in Picture 1. The 40 meter PAR sensor (Figure 26) does not show this reduction in signal. However, the 40 meter PAR record shown suffers from an uncorrected overflow error, which can be corrected for in the final processing by a first difference power of two spike detector.

Unlike the Southern Flank bio-optical records (Figures 11 and 12), the Northeast Peak fluorometer and transmissometer records do not show the signature of biofouling. We are getting over 110 days of good record at the Northeast Peak and Southern Flank sites before fouling becomes severe. We had anticipated obtaining over 120 days of good from past observations, so we are probably suffering from some more permanent window fouling which enables the biology to grow more rapidly.

The final puzzeling signal is seen in the two fluorometer records which do not appear to oscillate with tidal signals down to zero after the start of each record. There was a check of the cables, and a problem was corrected on package #1 deployed at the southern flank site, but the deck check implied that everything was functioning properly before the systems were deployed.

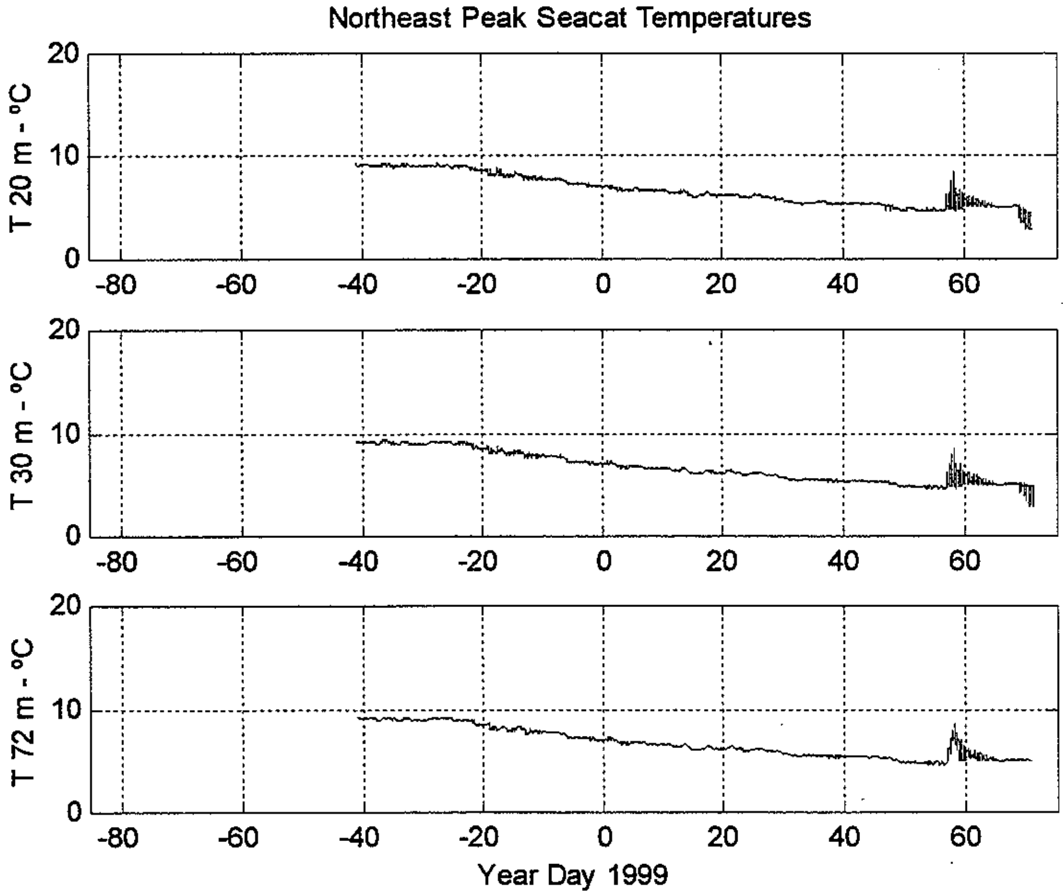


Figure 23. Northeast Peak Seacat Temperature. The raw, normalized, but unedited temperatures are shown for 20 m (top panel), 30 m (center panel) and 72 m (bottom panel).

The records from the buoy, the Seacats and the bio-optical packages can give us an idea of the physical property changes at the Northeast Peak site. This region appeared to be slightly cooler and saltier than the Southern Flank site at the same time. There is the same smooth cooling of waters at all depths during the winter. The first signature of change is mid-February (~ year day 48) when a cooler water mass is seen in the upper 10 meters of the water column (Figures 21, 23 and 25). This feature doesn't extend below 10 meters and is barely seen in the 15-meter temperature record (Figure 21) and definitely not in the 20-meter Seacat (Figure 23). However, there is a salinity signature (freshening) seen with this event which is seen in <u>all</u> salinity records from 1 to 72 meters (Figures 22, 24 and 26). This would be typical of a crossover event, which is most obvious in salinity, but has some temperature cooling as well.

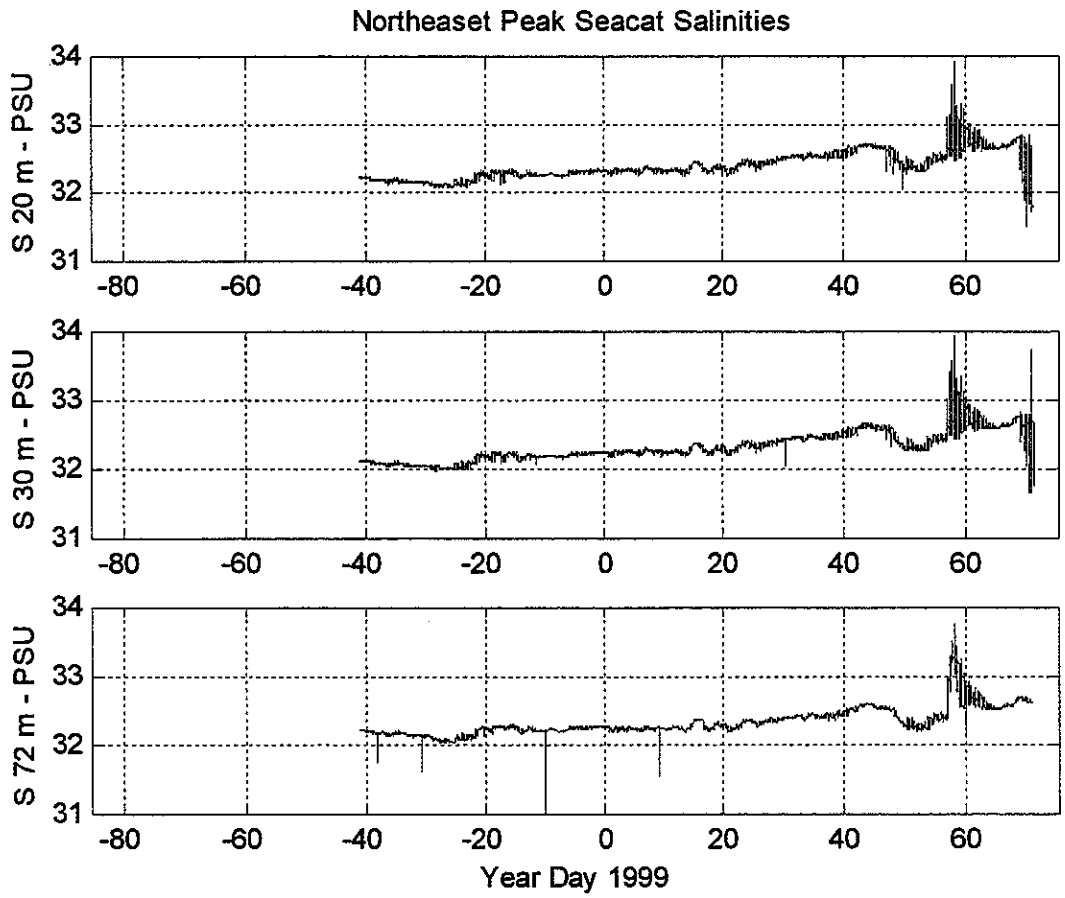


Figure 24. Northeast Peak Seacat Salinity. The raw, normalized, but unedited temperatures are shown for 20 m (top panel), 30 m (center panel) and 72 m (bottom panel).

The next event is followed by a rise in temperature and salinity with strong tidal modulation at all depths which appears at the end of February (year day 57). This signature decays by early March 1999. The most surprising event is during our turnaround servicing cruise in mid-March 1999. Half of this signature is seen at the end of this record with a significant drop in temperature (2° C) and salinity (1 PSU) at the end of the record. The other half will be recorded with the next deployment of the Northeast Peak mooring. We had planned to do some CTD survey work during the night hours, but because of the Northeast Peak Crossover Experiment mooring problems addressed on this cruise, we didn't have the time to do an extensive survey, and also we were out there without an operating CTD even if we did have the time.

The salinity records at all depths on the Northeast peak also show the 1/2 PSU rise in salinity in February and March (Figures 22, 24 and 26) which was also seen in the Southern Flank mooring (Figures 8, 10 and 12). The rise in salinity at the Northeast Peak is more regular, with a steady ramping up from late December. The Southern Flank salinities appear to step up in a series of three or four steps. At the March turnaround time and in late November, the salinities at the two sites are equal and uniform from top to bottom (before the crossover event at the end of the Northeast Peak observations). There is just the hint of some spring stratification in the Southern Flank records which will allow us to follow the stratification in the next deployment.

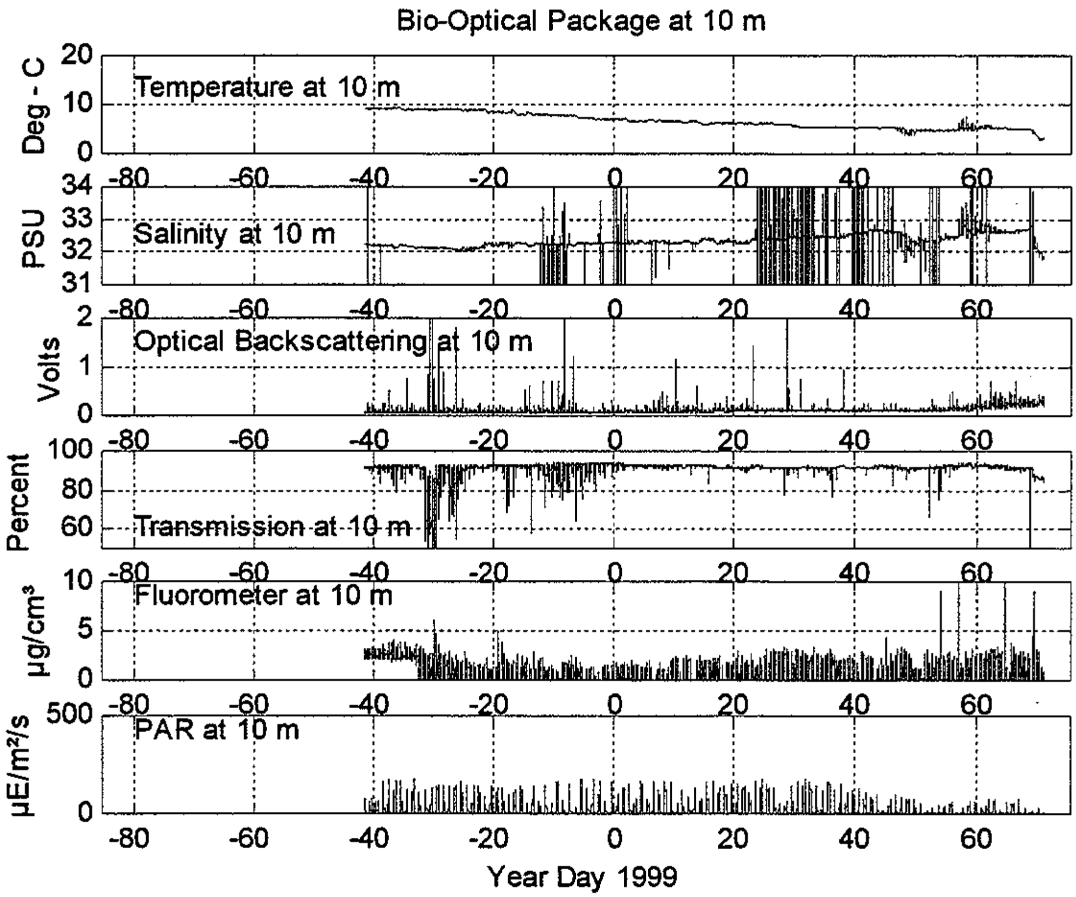


Figure 25. The unedited bio-optical results at 10 m. The top panel shows the temperature in degrees C, and the next panel the salinity in PSU. The third panel shows the Sea Point Optical Backscattering Sensor output (uncalibrated) in volts. The fourth panel shows the beam transmissometer in percent transmisiion, and the fifth panel the chlorophyll-a fluorometer with nominal calibration of 10 µg/l full scale. The bottom panel shows the 3.75 minute averaged PAR in microMoles/cm2/sec. The basic sample interval is 3.75 minutes or 16 samples/hour.

The Southern Flank Bio-optical packages observed a strong chlorophyll-a signal in late October. As the Northern Flank mooring was not deployed, we were unable to observe this signature. The rest of the record is rather uneventful. The northeast peak transmissometer records were not as "spiky" as those on the Southern Flank which we had attributed to small fish who collect around the mooring. This may be an indication of fewer of these fish at the Northeast Peak mooring site.

The ADCP current meter on the Northern Flank mooring was also dumped and the data examined. Because the Northern Flank of the Northeast Peak of Georges Bank has very strong tides, we expected them to be larger in the record. These stronger tides have also been a problem with the moorings. To set the moorings, we have often had to steam over 3 kts to make any headway against the currents at the site. There are strong weather forced currents in and out of the Northeast Channel which also affect the waters near our mooring. The record was subsampled at 8, 15, 21, 30, 47 and 62 meters depth as the Southern Flank data. The eastgoing and northgoing records at these depths are plotted in Figures 27 and 28. Because we kept the scales the same as the Southern Flank ADCP plots, the Northgoing velocities (Figure 28) go off scale. The maximum current is 105.8 cm/sec and the minimum current is -127.6 cm/sec at 8.5 meters depth. This is ±1.16 m/sec, or greater than 2 kts in and out. The mean over the record length is maximum at the surface and about 10.6 cm/sec Southgoing.

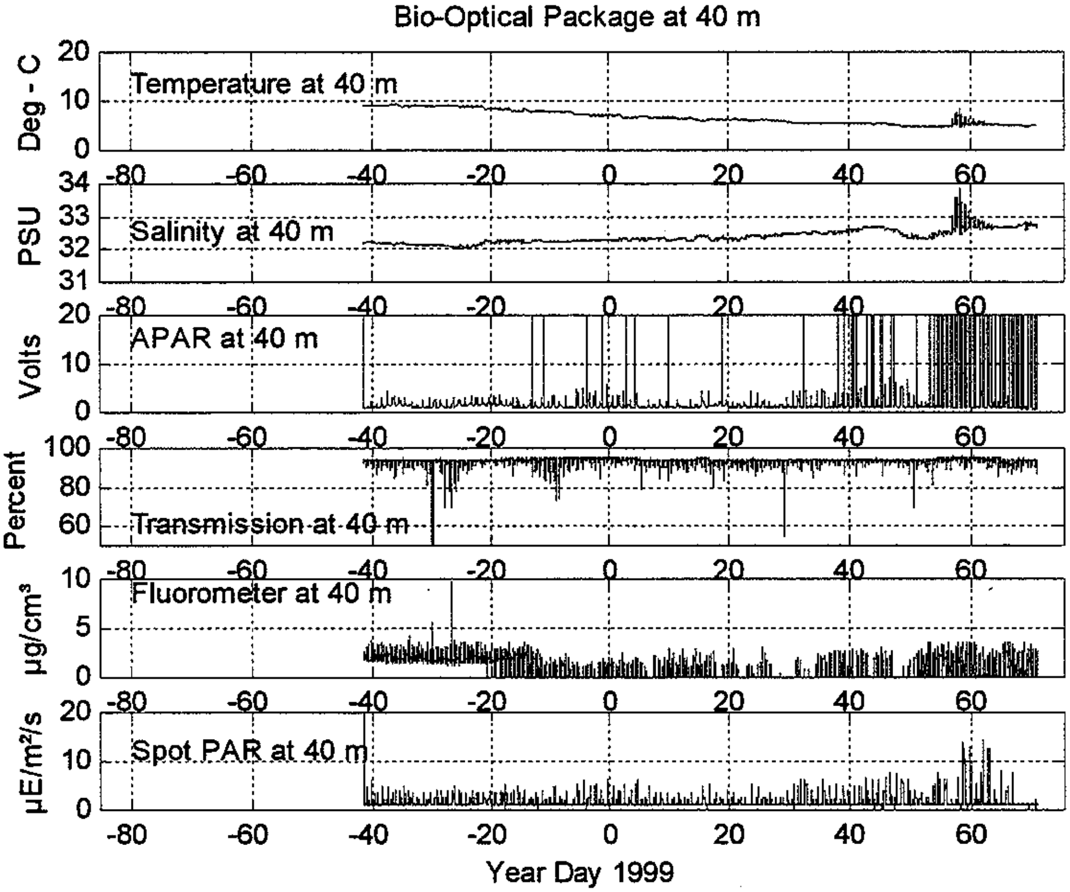


Figure 26. The unedited bio-optical results at 40 m. The top panel shows the temperature in degrees C, and the next panel the salinity in PSU. The third panel shows the beam transmissometer in percent transmission, and the fourth panel the chlorophyll-a fluorometer with nominal calibration of 10 µg/l full scale. The fifth panel shows the last individual PAR reading while the bottom panel shows the 3.75 minute averaged PAR reading in microMoles/cm2/sec. The basic sample interval is 3.75 minutes or 16 samples/hour.

To compare the tidal components with the Southern Flank and with the Moody, et al (1984) analysis of a 145 day record at the nearby station L on the Northeast Peak, a harmonic analysis was performed on the hourly data as previously discussed and the results shown in Table 5. The agreement between the two results are good.

Table 5. Northeast Peak M2 Tidal Analysi

	Depth observed-water	Major Axis (cm/sec)	Minor Axis (cm/sec)	Phase (°)	Orientation (°)
Northeast Peak	47 in 75	64.51	-42.26	7.7	328.
Moody, L	51 in 66	63.1	43.5	8.	326.

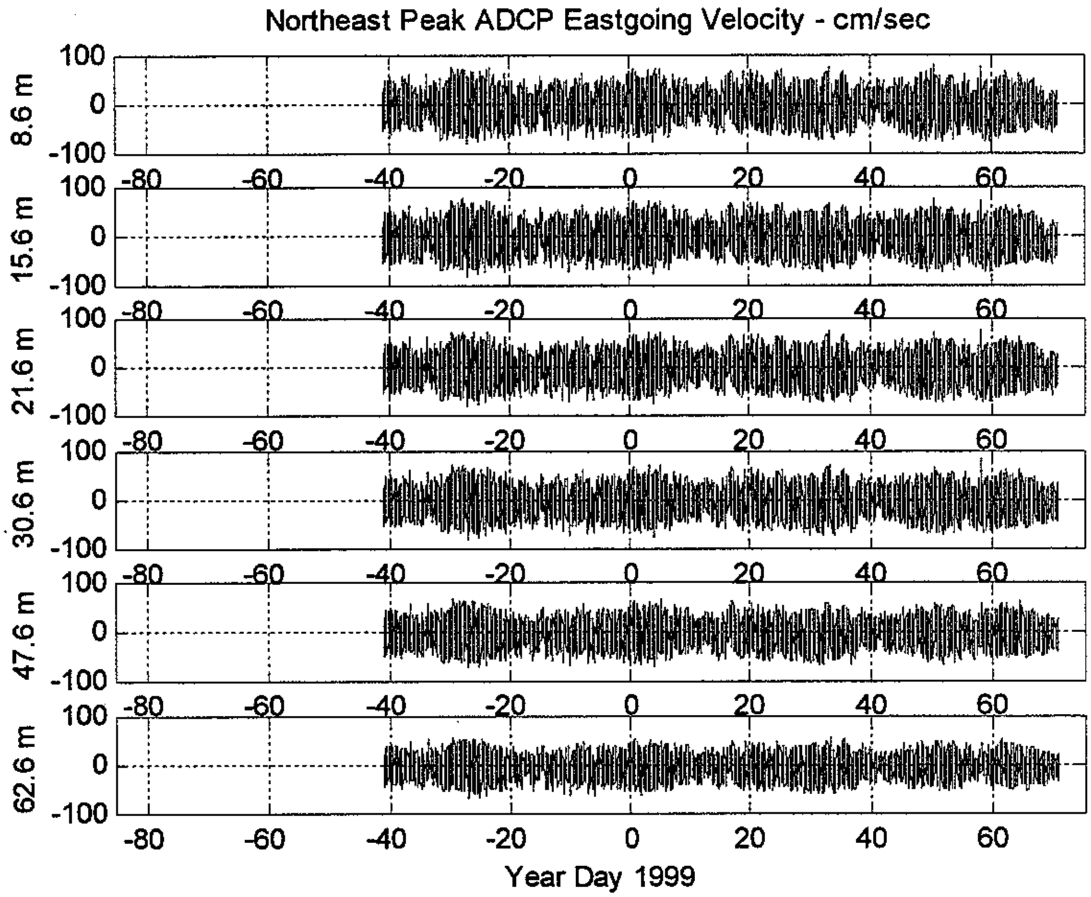


Figure 27. Northeast Peak ADCP Eastgoing currents. A subset of the raw, normalized, but unedited eastgoing currents are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

Northern Flank South Discus Buoy: The Northern Flank South (NFS) discus buoy and mooring was deployed the week before this cruise on R/V OCEANUS OC387. On 9 March 1999, while the OCEANUS was working at the Long-Term moored effort's southern flank site, a FAX and phone call alerted us to the fact that the Northeast Peak Crossover Experiment's discus mooring (NFS) had broken loose and was drifting. A plot of the track (Figure 30) showed that it was drifting almost due south at about 1 kt, most likely driven by the strong North winds. As the seas were too high to safely do mooring work, no response was made on the 9th, other than to keep track of the buoy's position.

During 10 March, the Long-Term moored effort's southern flank bottom pressure and science mooring were recovered and serviced. The science mooring was redeployed at the same site, and then, as the discus buoy was getting close to the shelf slope front and a warm core ring offshore which could carry the mooring out to the Gulf Stream and then off the Europe, it was decided to recover it during the evening hours when we would normally transit to the Northeast Peak mooring. A best guess prediction for the buoy's position at the time we anticipated to arrive at the site was made based on the drift rate of 38 nautical miles in about 38 hours. The ship headed for that site, passed about ½ nm south of the NDBC Georges Bank buoy (44011), and then the discus buoy became visible on radar and the light was seen. It was less than 1 nm from our predicted position. The buoy was successfully recovered with all mooring components and sensors in good shape down to the acoustic release. The mooring had parted below the acoustic release. Our best guess is that the acoustic release was severly shaken with the shock loading due to the weekend storm waves hitting the large bottom area of the discus buoy, and physically moved the acoustic release electronics case along the tension carrying rod to the point that the release hook opened and released the mooring.

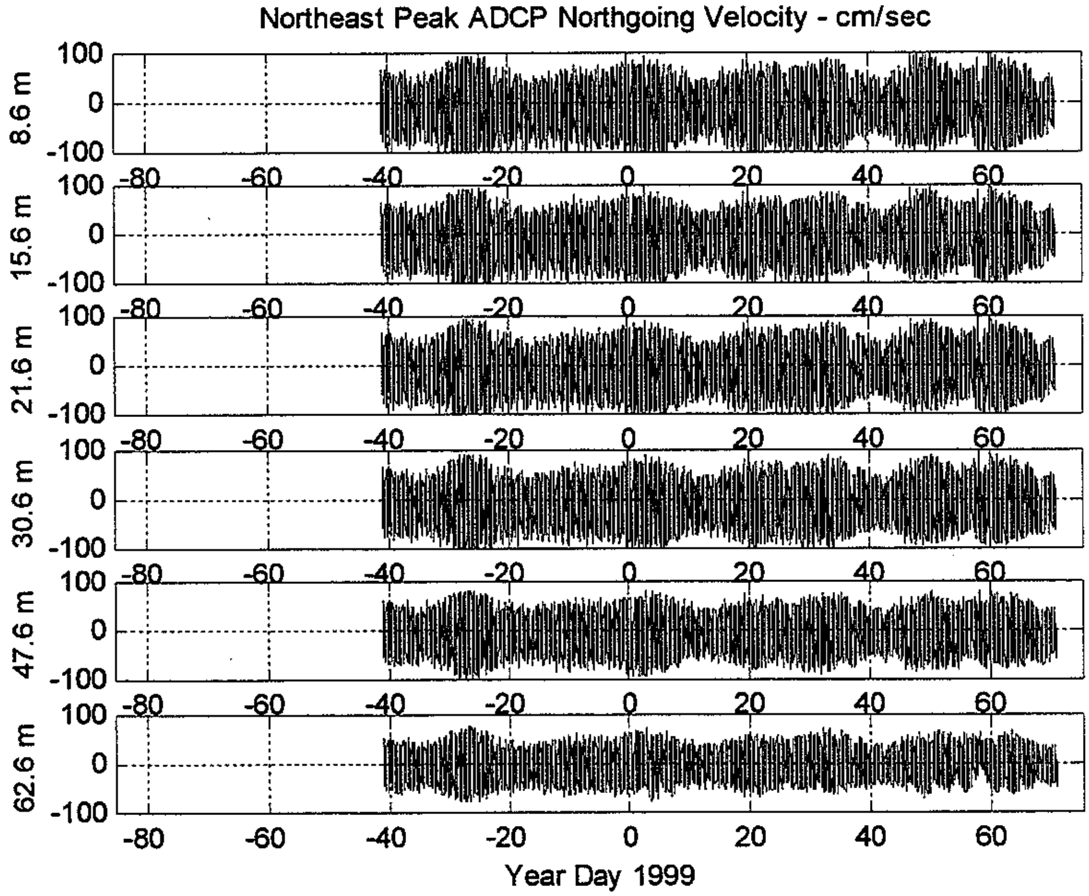


Figure 28. Northeast Peak ADCP Northgoing currents. A subset of the raw, normalized, but unedited northgoing currents are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

As the mooring hardware was in good shape, the buoy occupied the whole of the R/V OCEANUS's working deck space (see Picure 2) preventing further mooring work, and as spare anchors and mooring chain were on board, it was decided to redeploy the mooring at the NFS site first thing in the morning of 11 March 1999. While transiting to the site, the Northern Flank Deep (NFD) buoy was found freely drifting and recovered (see discussion below), probably also a mooring casualty of the storm. The NFS discus mooring with the same sensors and instrument configuration was successfully deploy (at position shown in Figure 1), but without the acoustic release first thing on 11 March 1999. The lack of acoustic release will necessitate a more difficult recovery of the mooring, but should keep the mooring in place for the rest of the deployment. As the recovery is to be in August 1999, the weather should not be a problem.

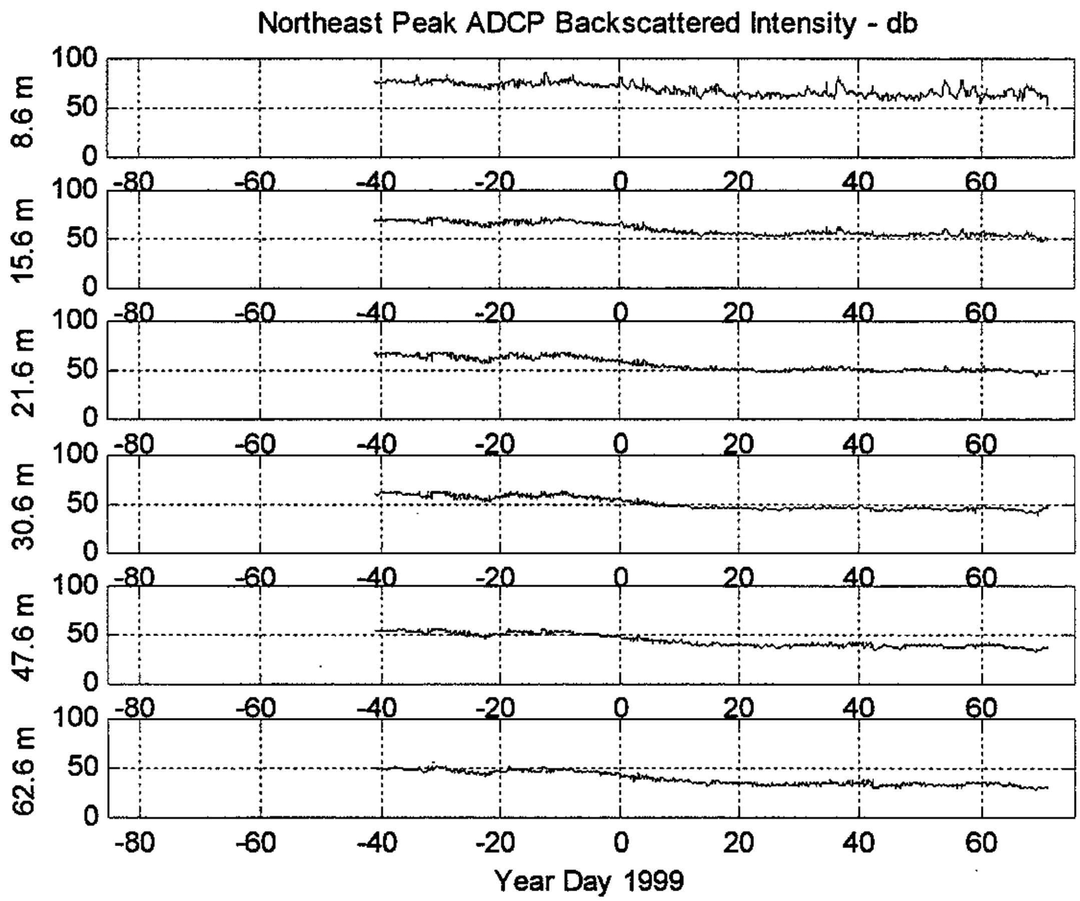


Figure 29. Northeast Peak ADCP Backscattered Intensity. A subset of the raw, normalized, but unedited backscattered intensities from one transducer are shown at 8.5, 15.5, 21.5, 30.5, 47.5 and 62.5 meters depth.

Northern Flank Deep Toroid Buoy: When steaming back to the Northern Flank Shallow (NFS) site to redeploy the discus buoy and mooring on 11 March 1999, mate, Diego Mello, sighted an odd floating object (see Picture 3 below). Closer examination proved that it was the toroid buoy from the NFD site. The mooring bridle had been torn out of the buoy, damaging the foam and fiberglass hull, and setting the buoy adrift. With no restoring force due to the mooring to keep it upright, the buoy soon turned over. The remains of the buoy were successfully recovered, and the guard light and ARGOS beacons were still working. The buoy was stowed on the starboard side deck for transport to WHOI for disassembly and disposal. The sensors should be on the bottom below the buoy deployment site with an acoustic release to aid in the recovery operation. Dragging for the bottom part of the mooring will be done as soon as an appropriate vessel can be scheduled.

Eastern Flank (EF) Toroid Buoy: The Northeast Peak Crossover Experiment had deployed three moorings as shown in Figure 25 to measure the Scotian Shelf water which periodically moves across the Northeast Channel onto Georges Bank. This mooring was the most heavily instrumented with current meters, Seacats (for temperature and conductivity), and t-pods for temperature only. The mooring had the same design as caused problems at the Northern flank sites, which resulted in the retrieval and the deployment of the discus buoy mooring at NFS. The problem was that the mooring chain which became tangled into a clump reduced the scope so the mooring was floating lower in the water, and the mooring components were subject to higher shock loading as the compliance in the mooring was considerably reduced. Therefore, a spare toroid buoy and mooring components with additional swivels were brought along on OC338 to service the EF mooring. The evening of 11 March 1999 while the Northeast Peak mooring was being serviced, the EF mooring was recovered.

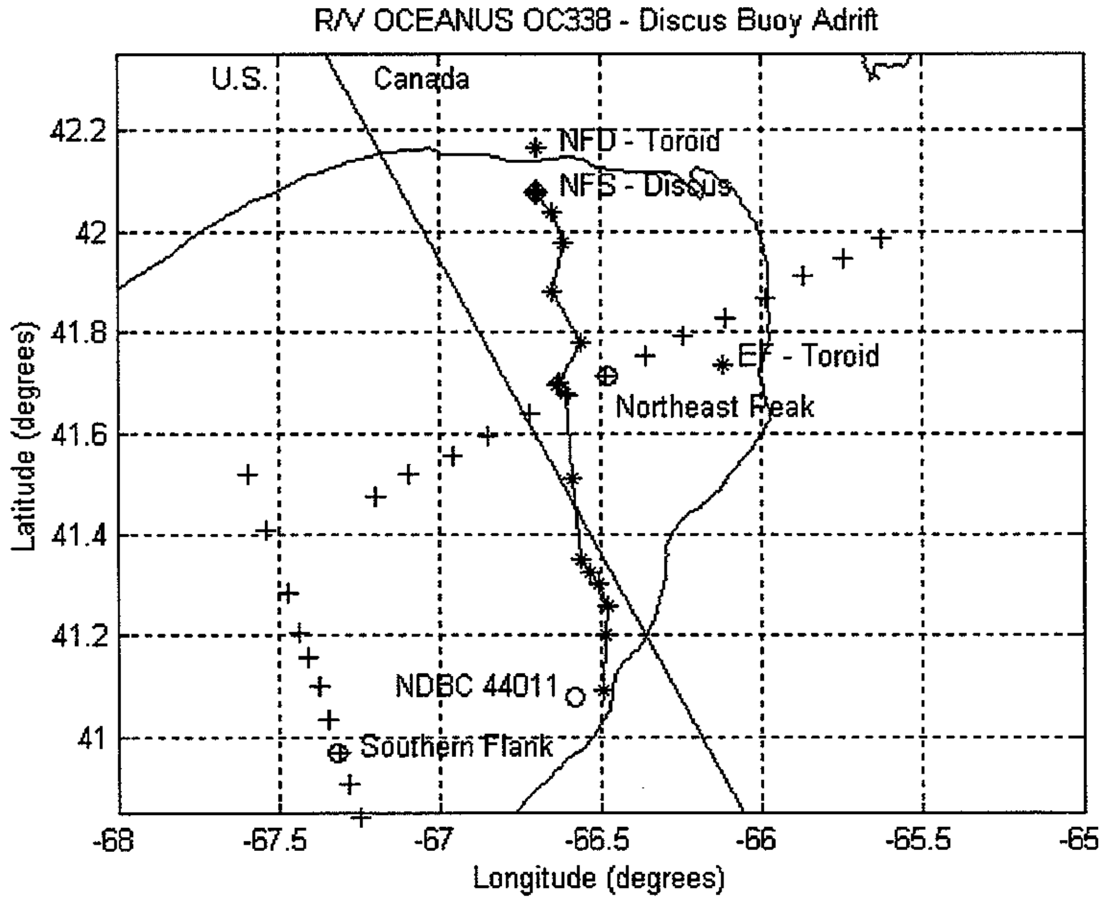
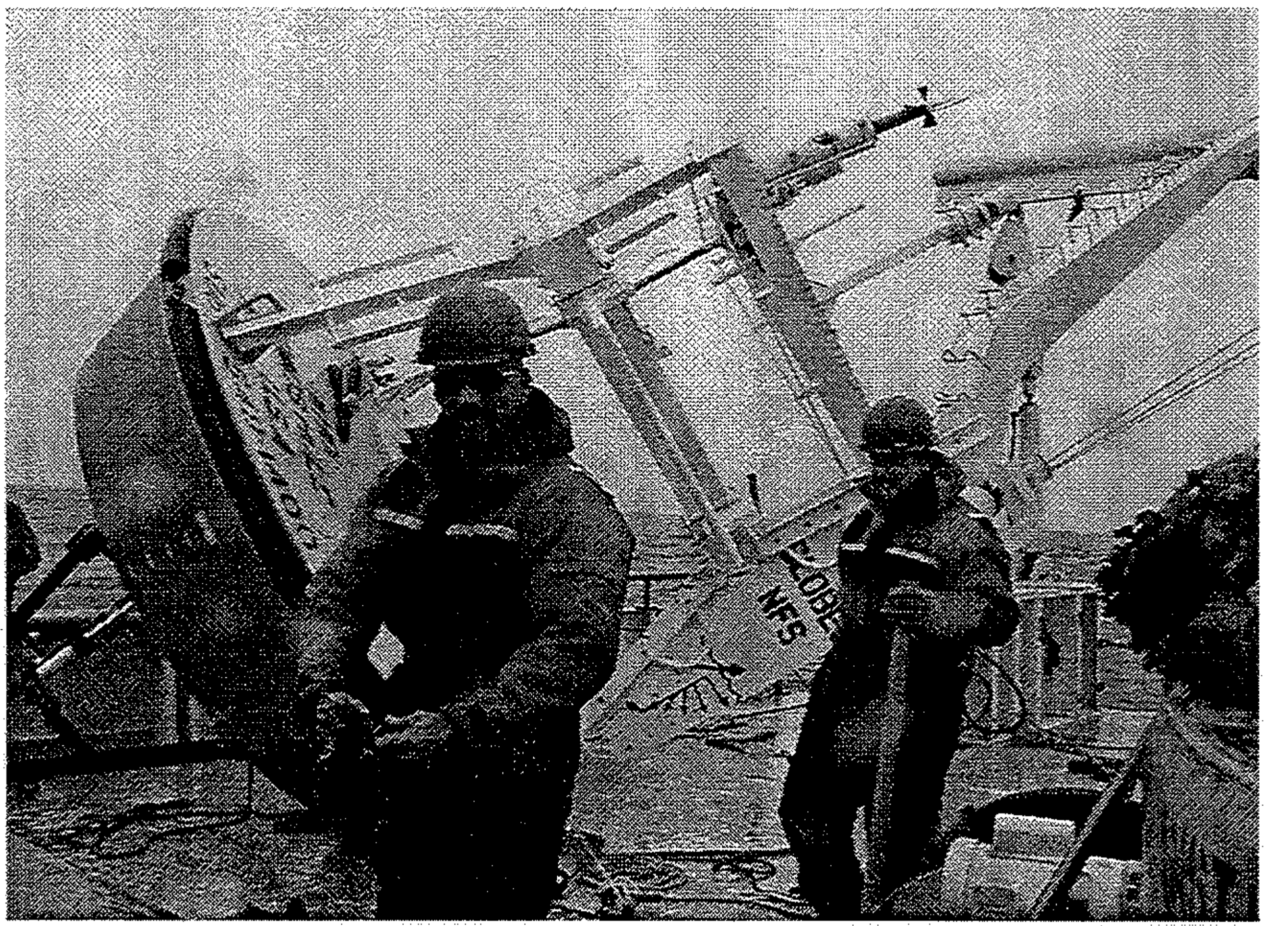


Figure 30. Crossover Experiment Discus Buoy drift path southward across Georges Bank. The three Crossover Experiment moorings are shown: Northern Flank Deep (NFD toroid), Northern Flank South (NFS – discus), and Eastern Flank (EF – toroid). The Long-Term Moored moorings sites are shown at Southern Flank and Northeast Peak. The standard CTD stations are shown as +, and the NDBC Georges Bank buoy as O.

The mooring had an old style 322 acoustic release to drop the anchor. At about 1 nm range the release was enabled with difficulty, but the release command did not appear to be acknowledged. The chirp sonar was turned off without improving the situation. The ship was moved right up to the buoy, and the transducer put in the water to command a release. A fast response was heard which implied that the release had fired. Therefore, the ship moved in to pick up the buoy. As the buoy was being swung over the rail, one of the three bands holding the mooring bridle on the bottom of the buoy broke. The buoy was quickly set back in the water and the recovery/pickup line attached to another leg. The buoy was picked up and quickly set down on deck with the bridle extending over the rail. It became evident that the anchor was still attached to the mooring, and we had the whole package to recover. The mooring line was detached from the buoy, and attached to the TSE winch tag going over the a-frame off the stern. The buoy was then moved off the rail and secured on deck. The recovery operation then proceeded slowly, with the winch taking up the mooring cable until a sensor was reached. Then the capstan was used to haul in the chain below the sensor while it was removed from the line. The winch would be reattached below the sensor, and the next piece of mooring recovered. This operation was repeated until the acoustic release was reached. When the release and last instrument were removed, the anchor and chain was released so that we did not have the danger of trying to recover it.



Picture 2. The discus buoy on deck of the R/V OCEANUS prior to deployment. Seamen Horace Medeiros and Pat Pike are setting up for deployment.

The main problem with the anchor and chain was the tangled knot of chain between the release and anchor. During recovery, the winch operator and people working with the mooring could feel the knot slipping. If it would have come free and the 3,500 pound anchor fallen down until it fetched up on the mooring line we were recovering, it probably would have broken free, causing equipment loss and personnel injury. It was only due to the experience and hard work of the ship's crew (Bos'n Jeff Stolp and seaman Horace Medeiros) and scientific personnel (chiefly Will Ostrom and Jeff Lord) that a serious problem didn't develop. Because of the problems with these mooring encountered, it was decided that the EF mooring would not be redeployed on this cruise, and that a redesign and redeployment would be attempted on OC340 in two weeks time. All sensors were successfully recovered, and the data will be dumped and instruments checked before redeployment, so no equipment or data was lost from the EF site.

Picture 3. The NSD toroid buoy with center foam plug found floating free of the mooring, upside down on the Northeast Peak of Georges Bank.

Missing Guard buoy from Southern Flank: When approaching the Southern Flank site to deploy the bottom pressure instrument in the afternoon of 12 March 1999, the three buoys (two guards and a science) were clearly seen on the radar. The seas had calmed down considerably from when the site was first checked on Tuesday 9 March 1999. About 0.9 nm to the Southwest of the mooring trio, another radar "blip" was seen. The R/V OCEANUS steamed over to investigate the radar sighting, and found the missing foam guard buoy "F." When visiting the southern flank site at night a few days previously, no flashing light was seen on this buoy, so it would be an unlighted hazard to navigation. Also, the steel guard buoy "N" had already been deployed at the southern flank site in position to replace the missing guard buoy "F". Therefore, the buoy "F" was recovered (without the mooring hardware) and returned to WHOI for cleaning and preparing for the scheduled July cruise to act as a spare guard buoy. The problem with the light was due to the pins in the watertight connector being used being pushed back and not making continuous contact. Therefore, when the light was plugged in and tested on deck it worked, and then after being deployed a while the light stopped, and perhaps was the reason the buoy was not seen and dragged out of position.

Mooring Deployment

Backup Steel Guard buoy at Southern Flank site: As a backup, a spare guard buoy and mooring hardware are taken along during servicing cruises. When it was apparent that foam guard buoy F was not on station, the backup steel guard buoy N was deployed in its place at the location shown in Table 6. The mooring was standard ½" chain in the water column and ¾" chain on the bottom with a ~2900 pound anchor that has worked well during the past four years.

Southern Flank Science Mooring E: A new southern flank mooring had been prepared for deployment during this cruise. For the wintertime when the water was relatively well mixed, the number of sensors was reduced as shown in Figure 4. For the summer stratified time, the number was increased to our usual 5 meter vertical coverage as shown below in Figure 31.

A new workhorse ADCP was deployed at this mooring site to speed turnaround of the hardware. The Seacats were redeployed in their same position. A problem was encountered with one of the bio-optical packages, so the shallow package was deployed at 40 meters, and the spare instrument was deployed at 10 meters as listed in Table 1. The acoustic release was changed as listed in Table 1. The mooring was then deployed between the two guard buoys at the position listed in Table 6 and shown in Figure 32.

Table 6 – Mooring Deployment Positions

				Deploy	Deploy	Action
Northeast Peak		Date	GMT	N. Latitude	W. Longitude	
	Guard Buoy A	19-Nov-98	1548	41° 43.947	66° 32.262	
	Science Buoy B	12-Mar-99	1430	41° 43.934	66° 32.145	Deploy
	Guard Buoy S	19-Nov-98	1647	41° 43.851	66° 32.091	
Southern Flank						
	Foam Guard Q	5-Oct-98	2059	40° 57.962	67° 19.097	
	Science Buoy D	10-Mar-99	17:43	40° 57.992	67° 18.919	Recover
	Foam Guard F	12-Mar-99	2101	40° 57.4515	67° 19.917	Recover
	Steel Guard N	10-Mar-99	1347	40° 58.052	67° 18.815	Deploy
	Science Buoy E	10-Mar-99	2121	40° 58.018	67° 19.165	Deploy
	Bottom Pressure	12-Mar-99	1521	40° 58.011	67° 19.267	Deploy

Northeast Peak Mooring B: This mooring was turned around, and redeployed in the same position (see Table 6) between the two existing guard buoys. The instrument complement remained the same and is listed in Table 1 and shown in the schematic in Figure 19.

Bottom Pressure: The bottom pressure instrument was serviced with new batteries, the time checked and reset to UTC and the instrument started. The instrument was mounted on the bottom frame as previously done, but this time the conductivity cell was mounted vertically. In the past two deployments, the conductivity record (see Figure 2) showed lower than expected salinities. This is probably due to non-conducting sediment in the conductivity cell that lowers the apparent conductivity (and salinity). By mounting the cell vertically, the sediment will fall out, and the contamination due to sediment reduced. The instrument was deployed between the Science Buoy E and Guard Buoy Q at the position listed in Table 6 and shown in Figure 32.

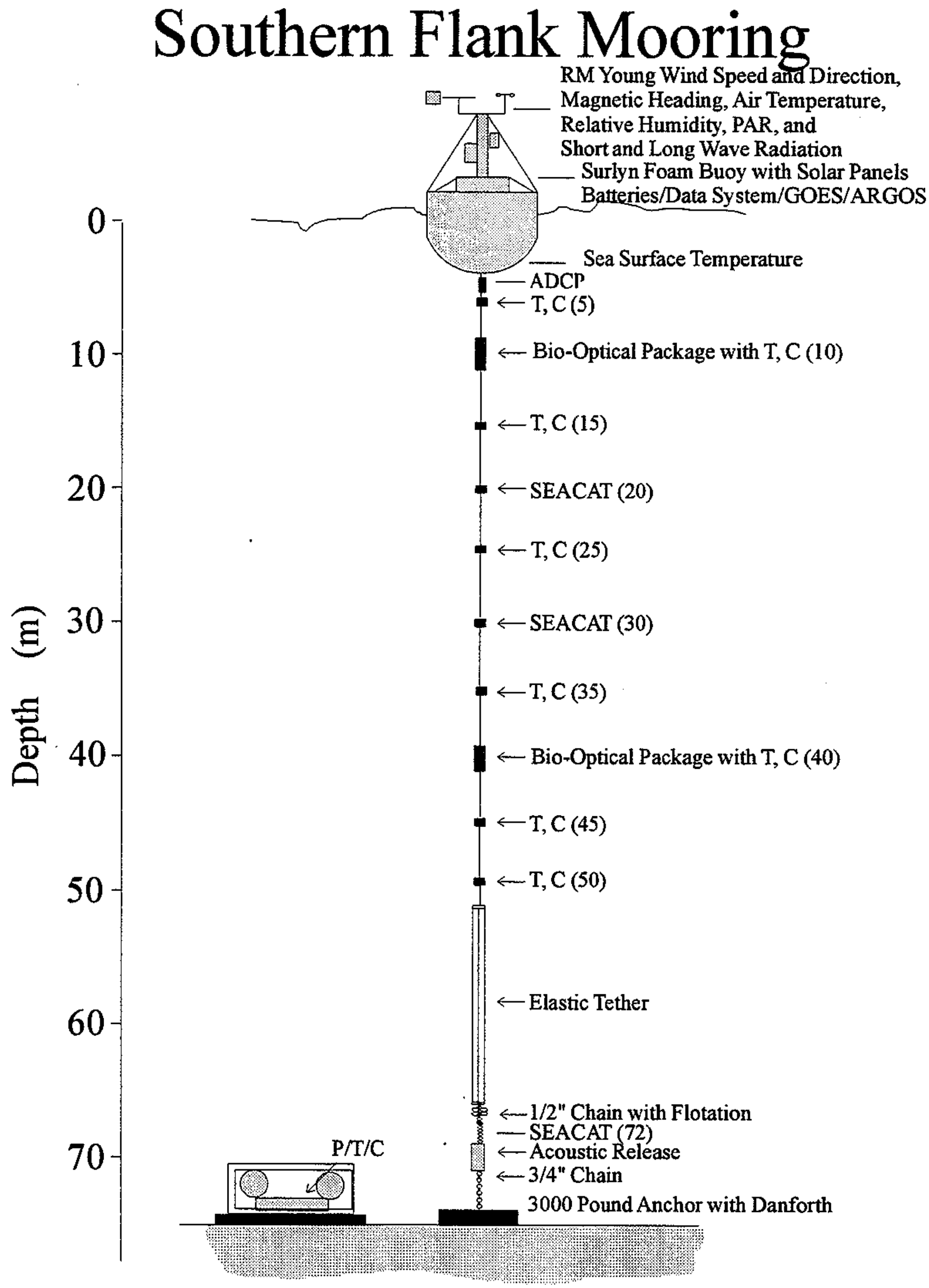


Figure 31. Southern Flank Summer Mooring Configuration for Deployment A.

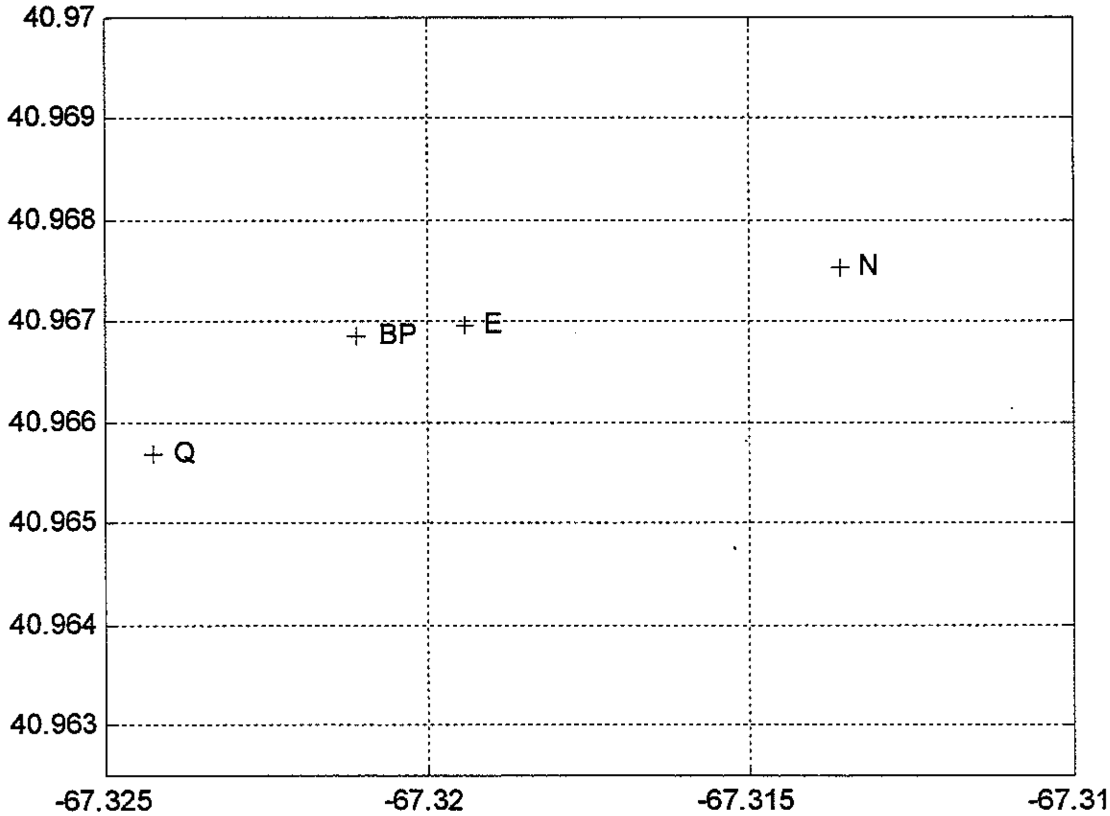


Figure 32. Southern Flank Mooring Positions for the two guard buoys, the science mooring and the bottom pressure instrument as listed in Table 3. When we arrived on the site, Buoy Q was moved to the west of the deployed position, Buoy F was missing. Buoy N was reset in the position of Buoy Q, thus separating the guard buoys. The science mooring was in position, and was redeployed in the same position.

CTD Stations

Southern Flank Mooring Site: When we arrived at the Southern flank mooring site, CTD01 was made to check out the operation of the CTD and see if the weather was safe for the 1 hour yo-yo profile. It was decided that the weather was not good enough for safe operations, so the ship steamed offshore to collect a deep-water profile and water samples where the seas were expected to be lower. On the next day, the ship returned to the southern flank mooring site and started a 1-hour yo-yo calibration series. The CTD stopped functioning after a few yos and the fish was recovered and repairs were attempted. The rest of the mooring servicing was carried about before the problem (salt water in the connector that changed the properties of the connector by forming a salt water bridge between contacts to prevent proper operation of the CTD fish.)

The profiles taken at the Southern Flank station (LT8) are shown in Figures 33 (CTD001) and 34 (CTD003). Although taken only a day apart, they show some surprising differences. The temperature has cooled down and mixed more thoroughly in the upper 40 meters of the water column. There also is a chlorophyll-a peak about 30 meters which is lacking the next day. The peak is only about 5 meters thick, and the background on day one is about the same as the profile on day two.

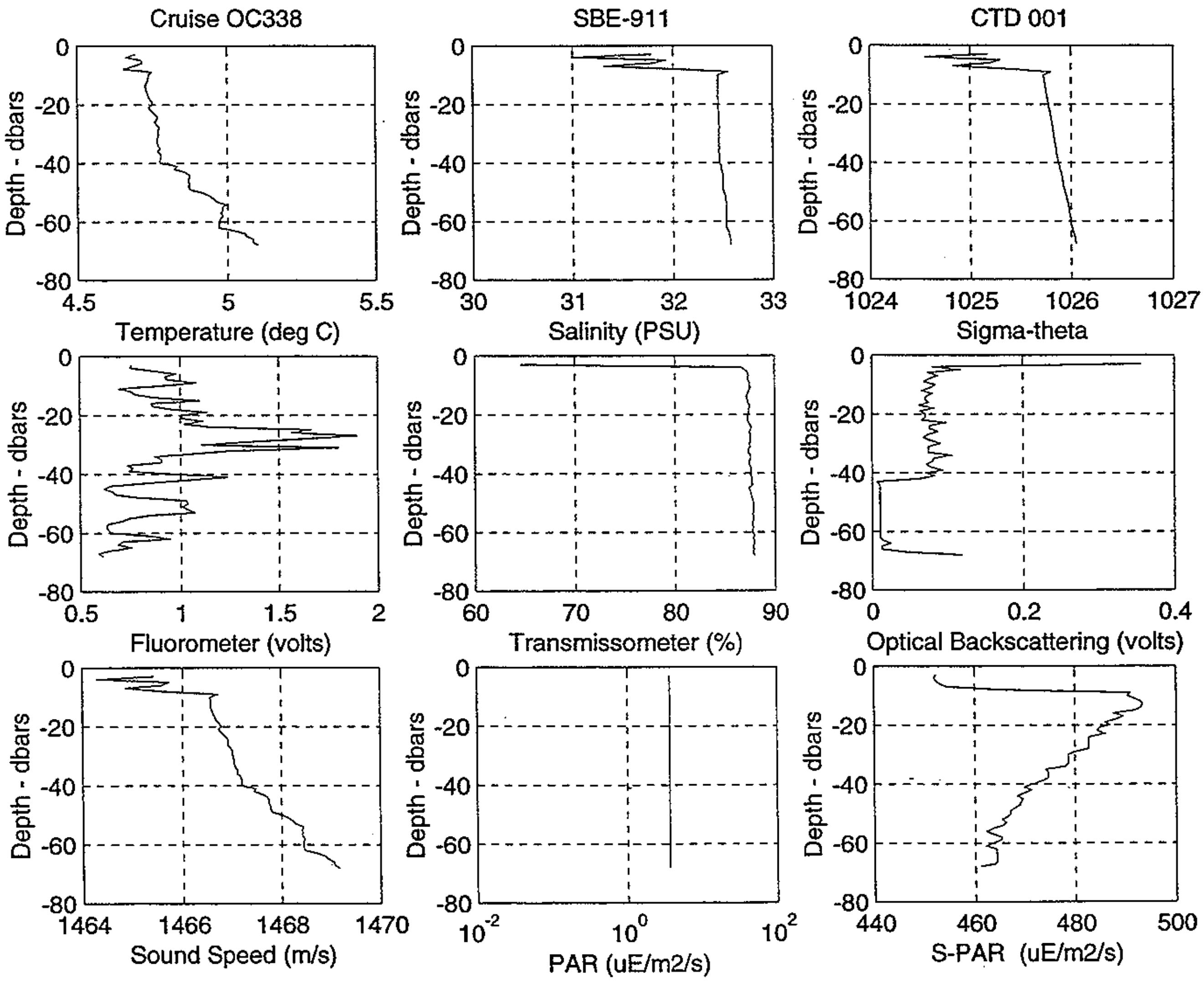


Figure 33. CTD001 summary plot taken at 1520 UTC 9 March 1999 at station LT8 (the southern flank mooring site). The PAR sensor on the fish was removed because of fear of damage during handling in the rough seas.

Deep water profile and seawater collection: Only one deep water profile was made at LT15 on 9 March. During this profile all 24 bottles on the CTD Rosette were fired to collect water samples for other WHOI investigators. When the instrument was being recovered, the OCEANUS J-frame (really a hydraulic ram) failed to operate properly (because of the weight, waves, or ?) and so no further stations were occupied on 9 March 199. CTD002 (Figure 35) shows a typical offshore profile where warm, salty Gulf Stream ring water is found in the upper 200 meters of the water column, and cooler fresher water beneath as expected. The fluorometer showed relatively higher chlorophyll-a fluorescence in this upper layer, but the level is still very low compared with typical levels on Georges Bank (see Figures 33, 34 and especially Figure 36).

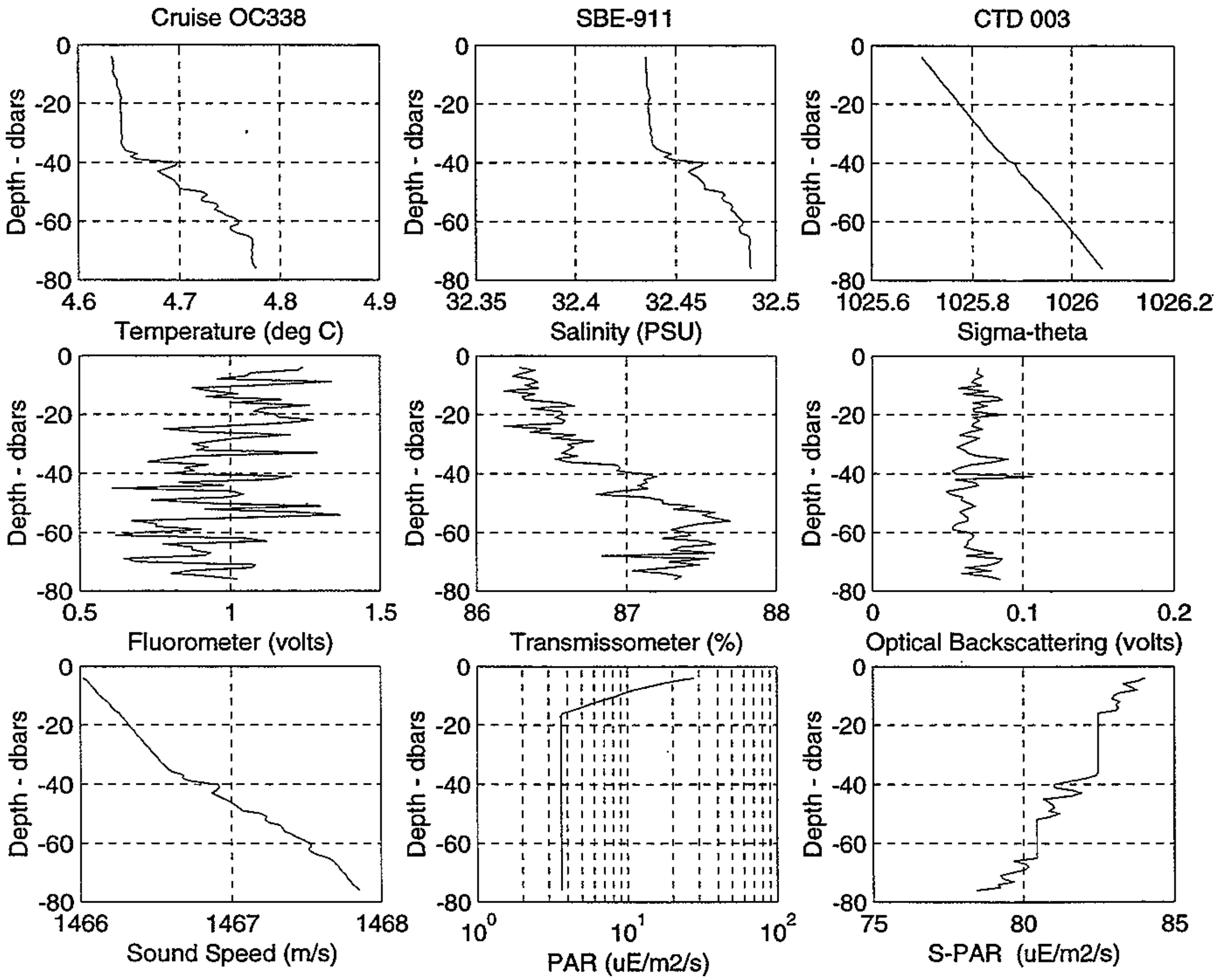


Figure 34. CTD003 summary plot taken on the morning of 10 March 1999 at station LT8 (the southern flank mooring site). This was the start of a yo-yo series that was prematurely terminated due to CTD problems after three profiles.

Northeast Peak Mooring Site: After the Northeast Peak mooring was deployed, a single profile CTD was made as a post-deployment calibration. As time was running out, and we still had work to do at the Southern Flank site, we cut short the standard yo-yo. However, it is apparent that we were in the middle of a crossover event, and the loss of the CTD to do some survey work at the Northeast Peak sites was severe. Figure 36 (CTD004) was taken near the mooring and shows the Scotian Shelf water (< 3° and < 32 PSU) in the upper 30 meters. This is accompanied by high chlorophyll-a fluorescence and lower beam transmission and higher optical backscattering values. The PAR sensor shows a typical exponential decay with depth, reaching the minimum light observable with the system at about 30 meters depth.

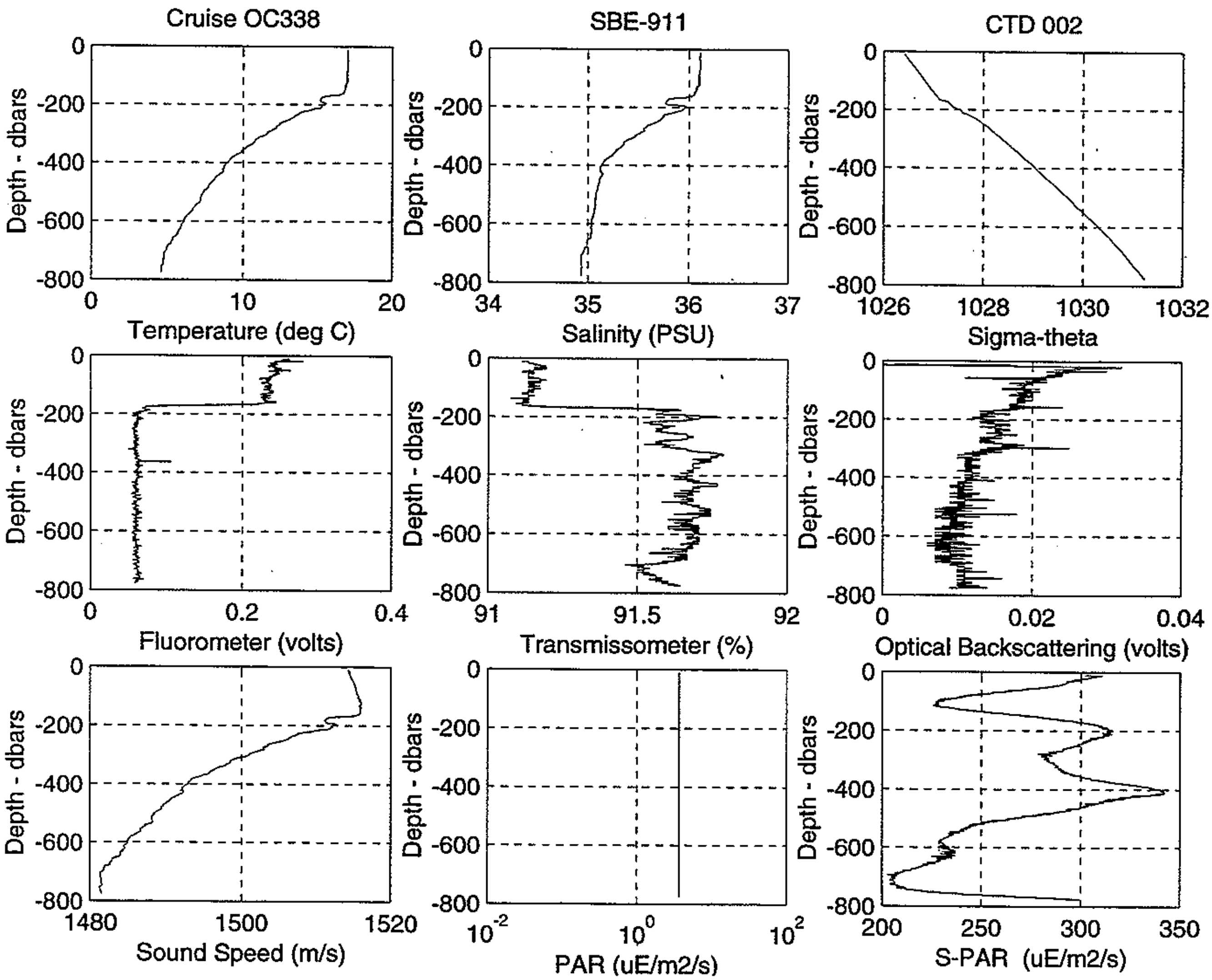


Figure 35. CTD002 summary plot taken at 1946 UTC 9 March 1999 at station LT15 (the most off-Bank profile site in our standard survey). Water samples were collected at this station for use by others back at WHOI.

References:

Gonella, J., "A rotary-component method for analyzing meteorological and oceanographic vector time series," *Deep-Sea Res.*, 19,833-847, 1972.

Groves, G.W., "Numerical Filters for Discrimination Against Tidal Periodicities," *Trans. Amer. Geophys. Union*, 36(6), 1073-1084, 1955.

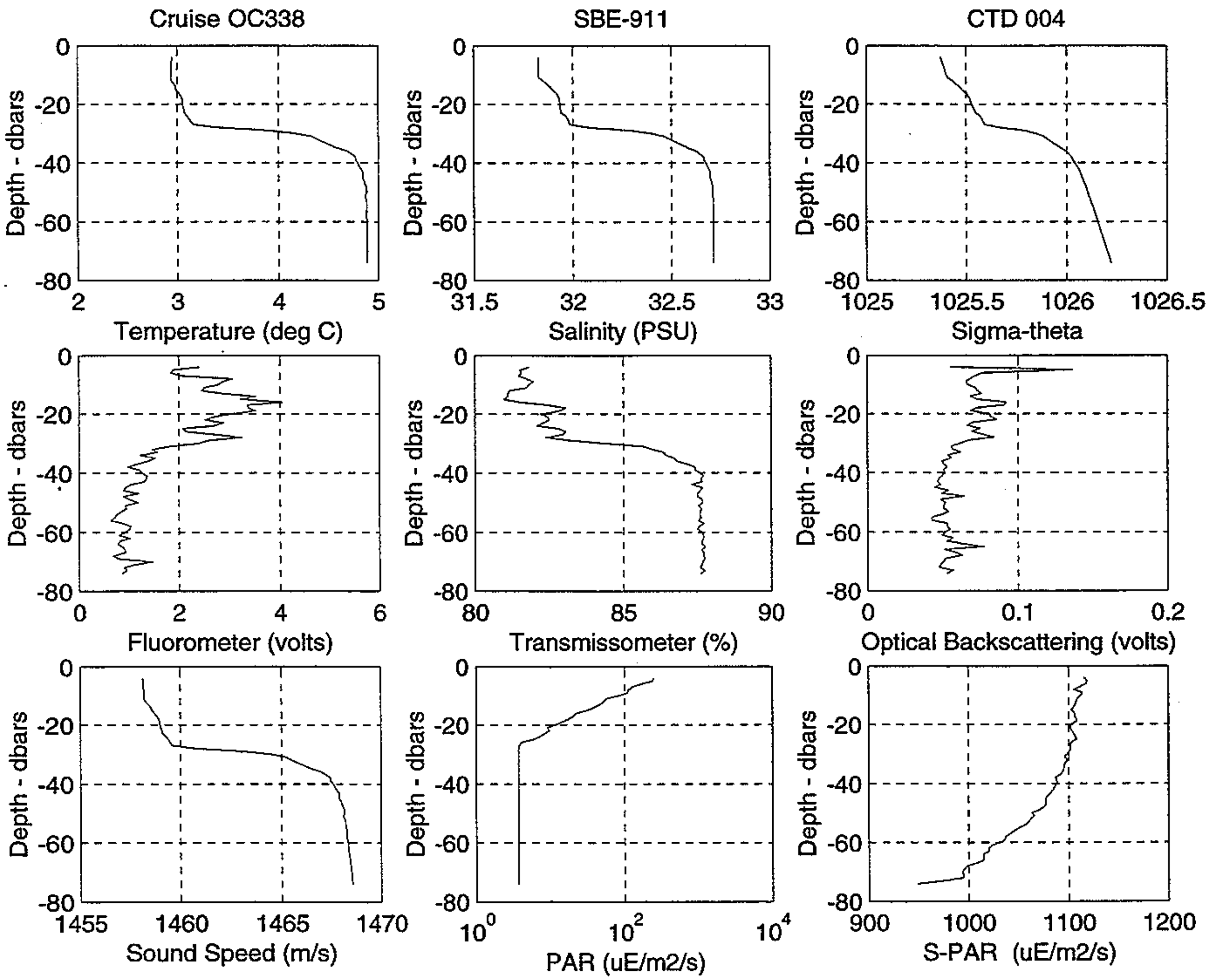


Figure 36. CTD004 summary plot taken at 0930 UTC 12 March 1999 at the Northeast Peak mooring site. The Scotian Shelf crossover water is observed in the upper 30 meters of the water column.

Irish, J.D. and W.S. Brown, "An Archiving and Analysis System for Geophysical Data," *Marine Data Systems International Symposium*, MDS86, 64-69, 1986.

Irish, J.D. and R.P Signell, "Tides of Massachusetts and Cape Cod Bays," WHOI Tech. Rept. No. WHOI-92-35, 66 pp, 1992.

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Moody, J.A., B. Butman, R.C. Beardsley, W.S. Brown, P. Daifuku, J.D. Irish, D.A. Mayer, H.O. Mofjeld, B. Petrie, S. Ramp, P. Smith, and W.R. Wright, "Atlas of Tidal Elevation and Current Observations on the Northeast American Continental Shelf and Slope," U.S. Geol. Survey Bul. 1161, 1984.

Cruise Personnel

Scientific Party

James D. Irish - Chief Scientist
Jeffrey Van Keuren, bio-optical scientist
Jeffrey Lord, deck work
William Ostrom, deck work (representing Crossover Experiment)
Scott Worrilow, acoustic releases
Warren E. Witzell, seacats and microcats
James Doutt, CTDs
Dave Schroeder, cleaning and CTDs
Laura Goepfert, SSS Tech

Ship's Party

Larry Bearse, Master
Anthony Diego Mello, Mate
Emily L. Sheasley, 2nd Mate
Jeffrey M. Stolp, Boatswain
Horace M. Medeiros, AB
Patrick Pike, AB
Oliver Kenerson, OS
Richard Morris, Chief Engineer
Shawn Mackay, Engineer
Algerto Collasius, Engineer
Keith Massa, Steward
Stephen Ramos, Mess Attendant

Table 6. R/V OCEANUS OC338 CRUISE EVENT LOG

Event	Instrument	Cast	Station	Year	Month	Day	HR:MN	S/E	N. Latitude	W. Longitude	Cast Depth	Water Depth	Comments
1	Guard Q		SF	1999	Mar	9	12:15		40° 57.942	67° 19.456		76 m	Check on Buoy Position
2	Science E		SF	1999	Mar	9	12:15		40° 57.937	67° 18.960		76 m	Check on Buoy Position
3	SBE-922+	1	LT08	1999	Mar	9	15:15	S	40° 57.20	67° 19.03	60	75 m	Bottles 1,2,3 at 65 m
							15:25	E	40° 59.21	67° 19.26			Bottle V1, (bottle 2 didn't fire
4	SBE-911+	2	LT15	1999	Mar	9	19:46	S	40° 20.39	66° 59.70	767	2060 m	Water Collected for G&G
							20:44	E	40° 21.40	66° 57.87			All fired, 4 and 19-24 didn't fire
5	Bottom Pres		SF	1999	Mar	10	11:25		40° 57.66	67° 18.86			Recovered Bottom Pressure
6	Guard N		SF	1999	Mar	10	13:46		40° 58.052	67° 18.815		76 m	Deploy Replacement Buoy
7	Science D		SF	1999	Mar	10	14:16		40° 57.65	67° 19.067			Recover Science Mooring
8	Science E		Sf	1999	Mar	10	21:12		40° 58.018	67° 19.165		76 m	CTD stopped working
9	SBE-911+	3	LT08	1999	Mar	10	21:54	S	40° 57.59	67° 19.18	69	79 m	1 hour yo-yo
							22:18	E	40° 57.32	67° 18.87			
10	NFS Discus		Adrift	1999	Mar	11	3:30		42° 05.451	66° 29.418			Recover NFS Discus Mooring
11	NFD Toroid		Adrift	1999	Mar	11	11:11		41° 53.52	66° 40.17			Recover NFD Toroid Buoy
12	NFS Discus		NFS	1999	Mar	11	15:39		41° 04.588	66° 42.091		76 m	Deploy NFS Discus Mooring
13	NEP B		NEP	1999	Mar	11	17:56		41° 43.94	66° 37.54			Recover NEP Science Mooring
14	EF Toroid		EF	1999	Mar	12	22:31		41° 44.126	66° 06.807			Recover EF Mooring
15	NEP B		NEP	1999	Mar	12	14:30		41° 43.934	66° 32.145		77 m	Deploy NEP Science Mooring
16	SBE-911+		NEP	1999	Mar	12	14:48	S	41° 43.48	66° 31.96	74	77 m	Bottles 1,2,3 all OK
							15:20	E	41° 42.91	66° 31.92			Water bottle V3
17	Bottom Pres		SF	1999	Mar	12	20:21		40° 58.011	67° 19.917		76 m	Deploy Bottom Pressure Inst.
18	Guard F		SF	1999	Mar	12	21:00		40° 57.461	67° 19.917			Recover Moved Guard F

OCEANUS OC338
Chief Scientist's Log

Friday 5 March 1999
1000 – meeting with Capt Bearse. Weather forcast looks bad for this weekend, decided to see if we could postpone departing until Monday when the weather should be subsiding. As part of package asked for extension into Saturday to allow for time to get work done. Marine office agreed so cruise is officially postponed. All deck gear is loaded, including Ostrom buoy, anchors, line spooler, in middle of deck, etc.

Saturday 6 March 1999
Irish loaded computers and Long-term mooring support gear
Power outage in morning when reviewing bio-optical package with Luigi
Power outage shut down ship computers, and workstation

Sunday 7 March 1999
Tied down computers and collected last of equipment.

Monday 8 March 1999
0730 – at ship, people arriving
Luigi with bio-optical package and support equipment
0740 – closing science buoy E – greased seal
0810 – buoy E moved over from Dyers and at ship
0840 – buoy on board and being strapped down, all science party around
Final tie down of laboratory boxes etc.
0900 – checking Kelvin ARGOS – system up too late to do today's processing
0920 – ready to depart WHOI dock
0930 – problem with ship switching control to starboard wing – holding while fixed
1032 – everything working, preparing to depart WHOI dock in 10 minutes
1045 – depart WHOI dock
Going via Nantucket Shoals
Winds still up, not dropping
Seas blocked by land so moderate

Tuesday 9 March 1999
0610 – still 24 miles from site, steaming at about 8 kts
streaks on waves, winds 25 – 30 kts and not decreased
0915 – at SF mooring site
Guard Q and Science Buoy Present – Guard F appears missing
Guard Q   40° 57.942 N x 67° 19.456 W
Science D   40° 57 937 N x 67° 18.960 W
Wind 25 kts and maybe decreasing, seas 8-10' and not subsiding
0930 – setting up for CTD
taking off PAR sensor so not damaged in seas against side of ship
replacing some lanyards on bottles because too long
Wind appears to be about 13 m/s from IMET (25 kts)
decreaseing from 16 m/s in last three hours
1020 – CTD01 about 1 nm south of buoy – single cast

temperature 4.7°C salinity 32.4 PSU
1035 – getting set for 1 hour long yo-yo CTD, repositioning ship
abandoned yo-yo as deck crew thought that recovery was a bit dicey
1045 – heading for LT15 station to start Southern Flank Long-Term CTD section
1200 – FAX and call from George Tupper about Discus buoy deployed at NFS
Appears to be loose and drifting directly south. Plotted up position.
Will keep an on position so doesn't get away into Gulf Stream.
Picking up will block all our buoy operations.
1430 – in Gulf Stream Ring?, SST is now ~17°C and SSS ~ 34 PSU
1446 – CTD02 at LT15 –
Down to 775 meters – fired all bottles for Ollie Zafiriou
2041 – CTD on deck – draining water (two bottles into each carboy)
Ship had trouble holding head during long deep cast in 30 kt winds
Ship's J-frame ram on the CTD refused to retract at the end of the cast

This is a problem encountered and reported earlier (also slow speed complained about earlier) and never corrected

Ship requested that for safety reasons we suspend science operations
1740 – at LT14, waiting for weather – wind still at 25-30 kts ship still doesn't want to risk people on deck for CTD operations
1900 – got another fix on Discus buoy – still going south at good speed.
Average speed is 1.00 kt – 33.5 nm in 33.5 hours!
Therefore, we need to get it within another 36 hours when it will begin to get offshore.

Wednesday 10 March 1999

0520 – Wind still coming down slowly – 10 m/sec, seas down a bit also
Weather workable, best we have so far
0600 Arrived at SF site, only 1 guard and science buoy visible – radar poor for searching for missing buoy if dragged out of position.
0620 - Released Southern Flank Bottom Pressure
0638 - Bottom Pressure Instrument Secure on deck
Moderate hydroid growth, no barnacles, zincs on frame all gone
Acoustic release OK, but moderate hydroid growth
Downloading data from pressure sensor
0810 - Steel Guard Buoy N ready to reset in place of foam Guard Buoy F
0847 - Deployed spare steel guard buoy N in place of missing F
40° 58.052' N x 67° 18.815' W
Single CTD before recovery to test CTD
0916 - Release command sent to Southern Flank Science mooring D
0930 - Recovered Southern Flank Science Mooring with Buoy D and full sensor array
Serviced, cleaned, dumped data, etc.
1621 - Deployed Southern Flank Science Buoy E between two guard buoys
40° 58.018' N x 67° 19.165' W
Started 1 hour yo-yo CTD – CTD out of order after 3 yo-s
Steamed over to recovered Northeast Peak Shallow Discus mooring drifting
Secured instrumentation, array, etc. on deck
Headed for Discus mooring site NFS

Trying to fix CTD and continuing to dump data
2220 - At NFS discus buoy
Wind 15-20 kts
40° 05.451' N x 66° 29.418' W
acoustic release had failed, otherwise mooring in good shape
2345 - mooring all aboard

Thursday 11 March 1999

Heading for discus NFS deployment site to redeploy
0611 - Recovered NSD toroid buoy drifting upside down,
Anchor bridle torn off
Light and ARGOS still working
1039 Redeployed discus mooring at NSF site
42° 04.588' N x 66° 42.091' W
heading back to Long-Term Program's Northeast Peak site
1256 - Send release command to NEP science mooring B
Service, clean, dump data, new batteries, restart, etc.
Steaming over to EF mooring to replace
1730 - Recovered EF toroid mooring
release didn't work so we had to pull the whole mooring piece at a time
buoy bridle broke during recovery
decision was made that redeploying this kind of mooring was asking for trouble
call to Limeburner, mooring not to be deployed, so stow pieces for transit
back to NEP site

Friday 12 March 1999

0530 – wind about 10 kts, and seas calm. Misty and foggy
Setting up Northeast Peak mooring
Buoy moved from aframe to rail
Array stretched out and untwisted
ADCP, bio-optical packages and Seacat put in line
Sensor Check
0830 – Buoy/mooring system completed and checkover connections
0845 – Start deployment 0.5 nm from site
Currents about 1.2 kts
0850 – Tether over
0900 – Towing on anchor into position – 0.6 nm to go
Currents are such that buoys are in a line with currents.
Towed about 2 kts through water and 1 kt over ground
0930 – Anchor deployed midway between two guard buoys
40° 43.934' N x 66° 32.145' W
CTD04 – mini-series at NEP mooring
Heading for Southern flank site
Mounting bottom pressure instrument with conductivity sensor vertical
1450 – arriving at site can see three buoys in a row at 1.35 nm range

also can see a fourth blip about 1 mile from Southern Flank – might be our "missing" guard buoy. Current is from the SE so deploy bottom-pressure instrument from the NW which puts the bottom pressure frame to the West of the Science buoy.

1521 - Deployed Bottom Pressure at Southern flank
40° 58.011' N x 67° 19.267' W
Disabled Acoustic release 18021 – OK
Moving over to look at "out of position" buoy
Buoy is our missing foam guard "F", so rig to recover and slip anchor

1600 – pick foam buoy F
40° 57.4615' N x 67° 19.917' W

1620 – End of science operations, heading for WHOI.
Wind speed up to ~20 kts.

Saturday 13 March 1999

0905 - Arrived at WHOI dock, ship unloaded and crew gone by noon.