Robert C. Groman

Cruise Report

R/V ENDEAVOR Cruise 266 to Georges Bank

26 April - 9 May 1995

Acknowledgements

This report was prepared by the Chief Scientist, with contributions from all scientific investigators. Jeff Van Keuren compiled the Event Log, for which all of the scientific participants in EN266 are in his debt.

We are grateful for the excellent support provided by the Captain and crew of RV *Endeavor*. Their continuing professional efforts have greatly assisted us in accomplishing our programmatic goals.

This cruise was sponsored by the National Science Foundation and the National Oceanic and Atmospheric Administration. All data contained in this report are to be considered preliminary.

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OBJECTIVES OF THE CRUISE.

EN266 was the fourth of five process oriented cruises fielded by the U.S.-GLOBEC program in 1995. Scientific efforts on these cruises were focused on measurement of vital physiological rates of target species on Georges Bank, primarily the calanoid copepods *Calanus finmarchicus* and *Pseudocalanus* spp. Specific objectives were:

(1) To measure growth rates, production, and egg laying rates of target zooplankton species (E. Durbin, A. Durbin and J. Runge).

(2) To measure feeding rates on phytoplankton, nanozooplankton and microzooplankton by target zooplankton species (D. Gifford and M. Sieracki).

(3) To examine the distribution and abundance of target zooplankton species on sub-bankwide scales using the Video Plankton Recorder (C. Davis and S. Gallager).

(4) To collect hydrographic data along a transect (Hydroline A) between the Bank crest and the southern flank of the Bank (R. Beardsley and R. Limeburner).

The primary work mode on the cruise consisted of station-keeping. Station-keeping activities consisted of experimental work to measure vital physiological rates in conjunction with twice daily hydrocasts, MOCNESS, pump sampling, and VPR tows. Stations were located in on the bank crest (the "well mixed" station) and on the southern flank (the "stratified" station).

Ancillary activities included collection of visible and UV light profiles by J. Van Keuren, a postdoctoral investigator with the program, and studies of the effects of UV light on planktonic protozoa by E. Martin, a University of Rhode Island graduate student.

Despite some unforeseen weather-from-hell at the end of the cruise, EN266 was an unqualified success. All major scientific objectives were accomplished, thanks to R.V. *Endeavor*'s capable and helpful captain and crew.

CRUISE NARRATIVE.

Background. A sea surface temperature map processed and analyzed from AVHRR data by James Bisagni and associates at the National Marine Fisheries Service Narragansett Laboratory showed 7-8°C water over most of the Bank, and a plume of

colder 4-5°C water extending from the Scotian Shelf, across the Northeast Channel, and onto the northeast peak of the Bank (Figure 1). Meterological data collected from *Endeavor*'s environmental sensing system during EN266 are shown in Figures 2, 3, and 4.

Drifter Station 1. R.V. *Endeavor* departed Narragansett at 1115 hours on 26 April 1995, following a short delay to repair a malfunctioning winch. Sailing conditions were ideal, with clear, sunny skies and calm seas. We arrived at Drifter Station 1 on the southern flank (41°20.07'N; 66°55.52'W) at 0630 hours on 27 April, and deployed an ARGOS drifter (Figure 5). Drifter Station 1 was occupied for 72 hours. The site was chosen on the basis of larval fish distributions collected during prior GLOBEC larval fish and broadscale survey cruises. A larval cod maximum was located at ~40° 50'N; 67° 20'W on 10-12 April by GLOBEC's larval fish group. By the time a subsequent broadscale survey cruise arrived in the area, that patch was no longer present, but another larval cod maximum was located, centered at ~41° 30'N; 66° 40'W on 20 April. We chose to initiate Drifter Station 1 of EN266 midway between these two maxima, reasoning that the drifter would move south and west along the ~90 m isobath.

Station keeping activities began with a CTD cast and ring-net tows to characterize the water column and the zooplankton assemblage, followed by rosette casts and diaphragm pump deployments to collect water for experiments. A series of net tows with 150 μm and 333 μm mesh nets were done to collect live zooplankton for experiments. Vital rates measured were growth, feeding and egg-laying of target copepod species. CTD, optics, and zooplankton pump deployments were done at approximately 1100 and 2100 each day to collect data on hydrography and zooplankton distribution and abundance. Hydrographic measurements included conductivity, salinity, fluorometry and transmissometry. Discrete water samples were collected from each daytime CTD cast for analysis of size-fractionated chlorophyll (total, <20 μm and <5 μm) and microplankton (i.e., phytoplankton and protozoa). Microplankton samples were collected for analysis by automated epifluorescence microscopy and inverted microscopy in order to describe the entire suite of micro- and nanoplankton prey potentially available to target copepods. Discrete samples were collected from the first CTD cast at station for analysis of major nutrients and particulate organic carbon. The MOCNESS was deployed once at each station, usually during the second night of station-keeping. The VPR was deployed for a 6-hour period once each day and night on station.

The first hydrocast showed the water column to be nearly isothermal, with some slight surface warming. The weather remained warm and calm, and stratification continued to develop during the time the station was occupied. The stratification was eroded by winds just prior to our departure for Station 2, with the result that water column was again well mixed on 30 April. However, the mean water temperature had increased by slightly more than 0.1 °C. The drifter was entrained in the tidal ellipse, and showed a net southwest movement during the time it was deployed (Figure 5). Upon completion of activities at Drifter Station 1, the ARGOS drifter was left in place.

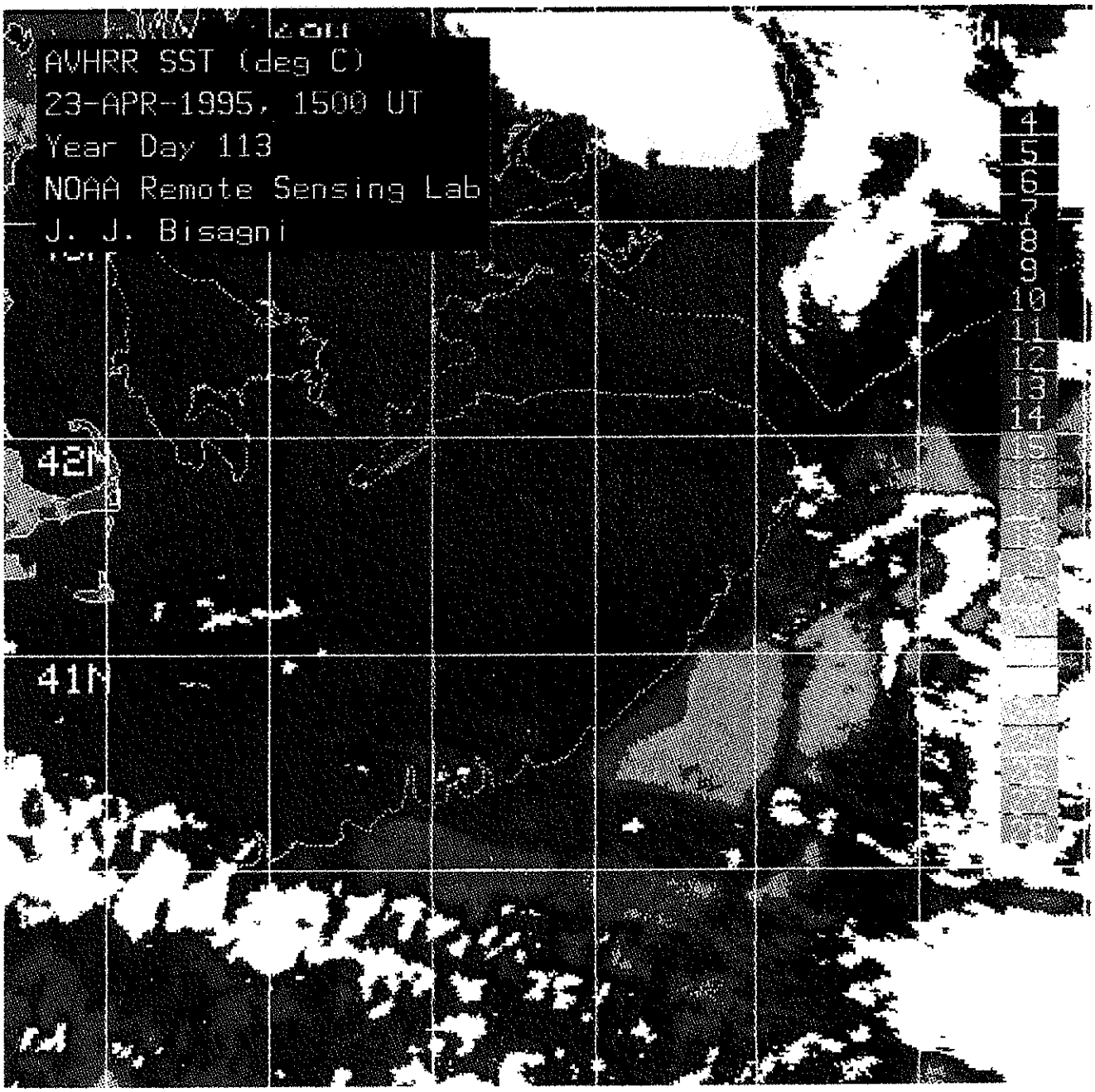

Figure 1. AVHRR image of sea surface temperature on 23 April 1995. The 100 m isobath is shown. Magenta areas on the northeast peak represent cold water from the Scotian Shelf. The magenta streamer traversing the Bank from southeast to northwest represents clouds.

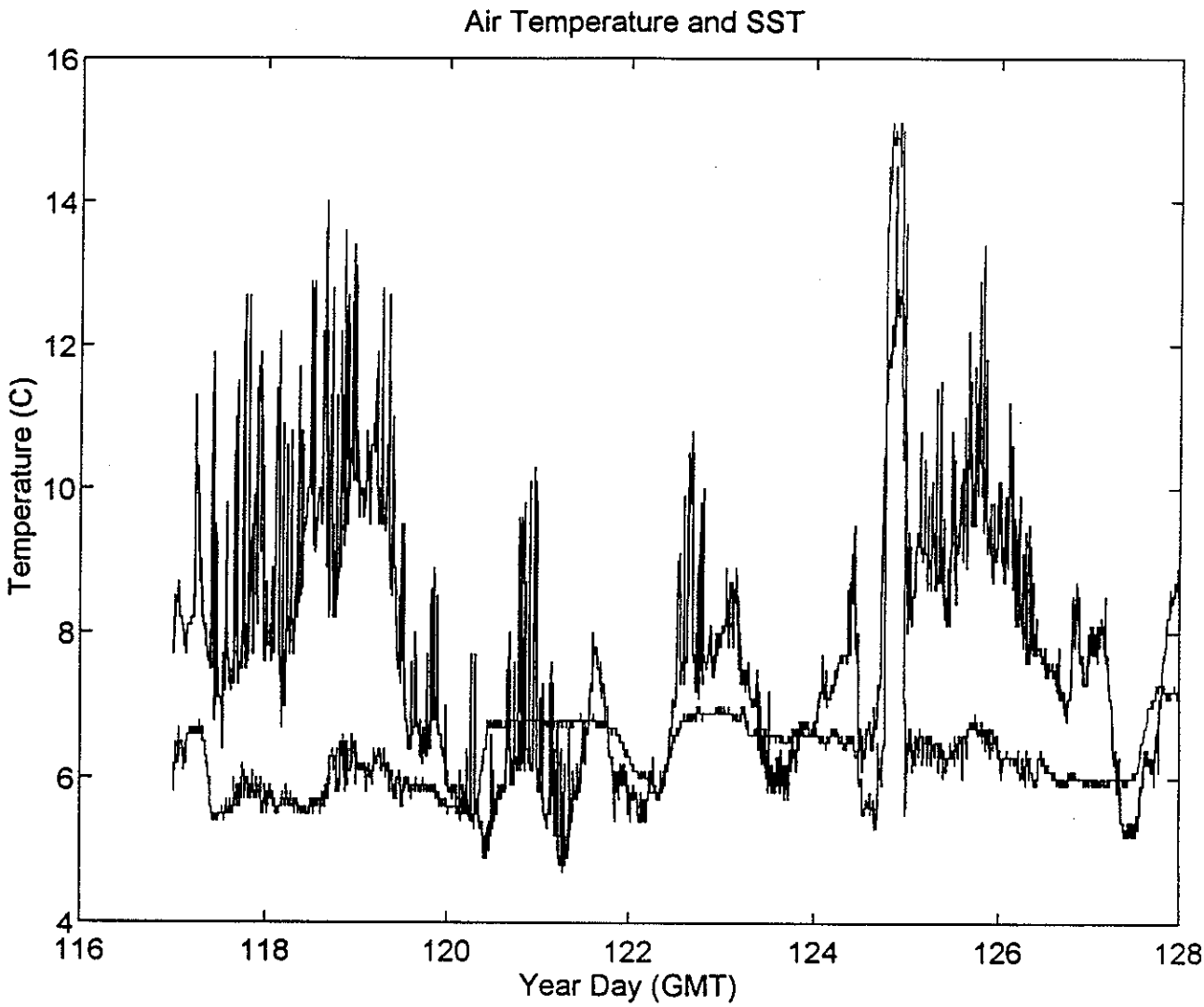

Figure 2. Sea surface temperature (recorded in well 5 m below surface) and air temperature (shipboard RM Young system) during cruise. Lower (less variable) line is SST.

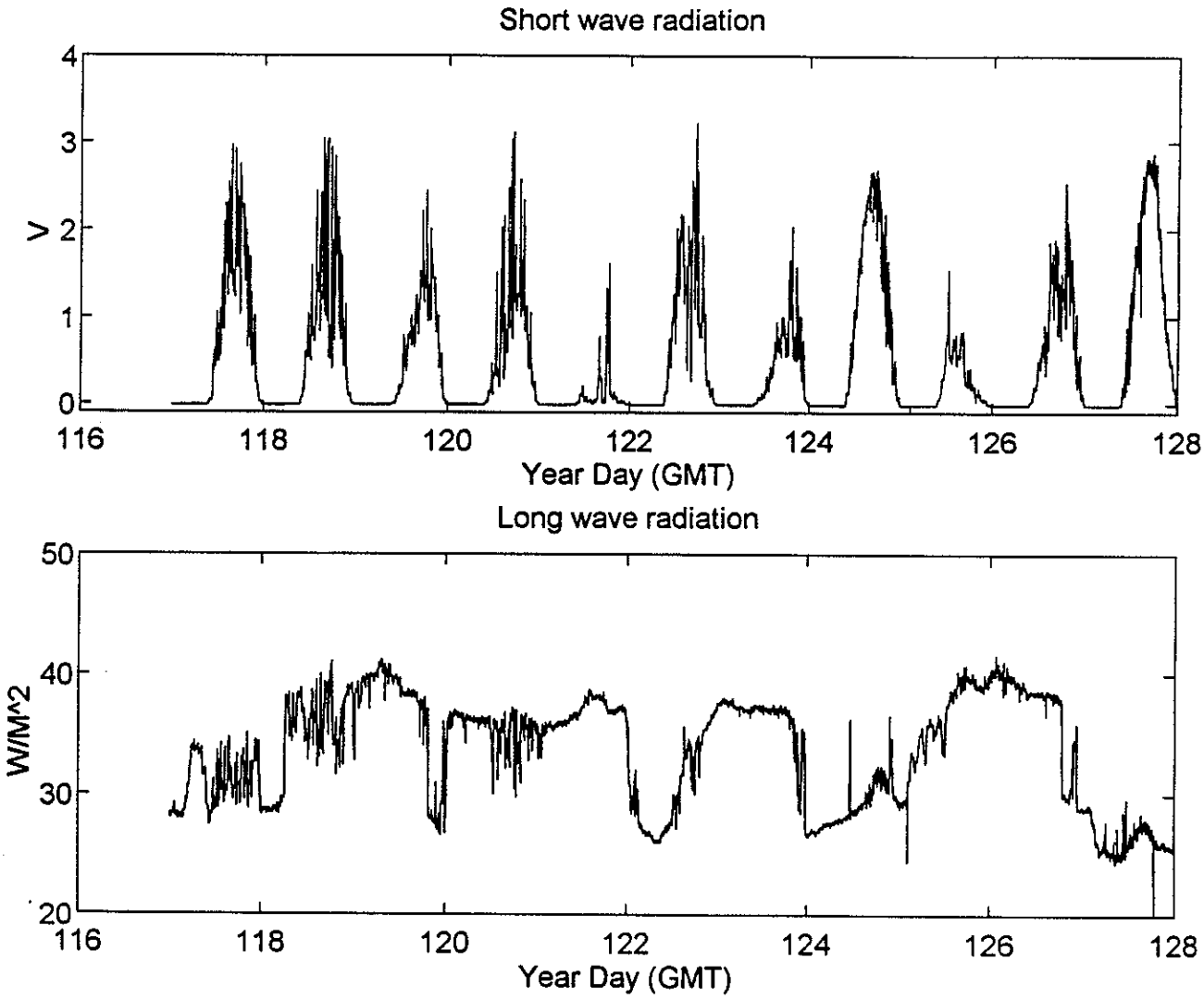

Figure 3. Short-wave and long wave radiation recorded by shipboard RM Young system. Calibration data for Short-wave sensor was unavailable.

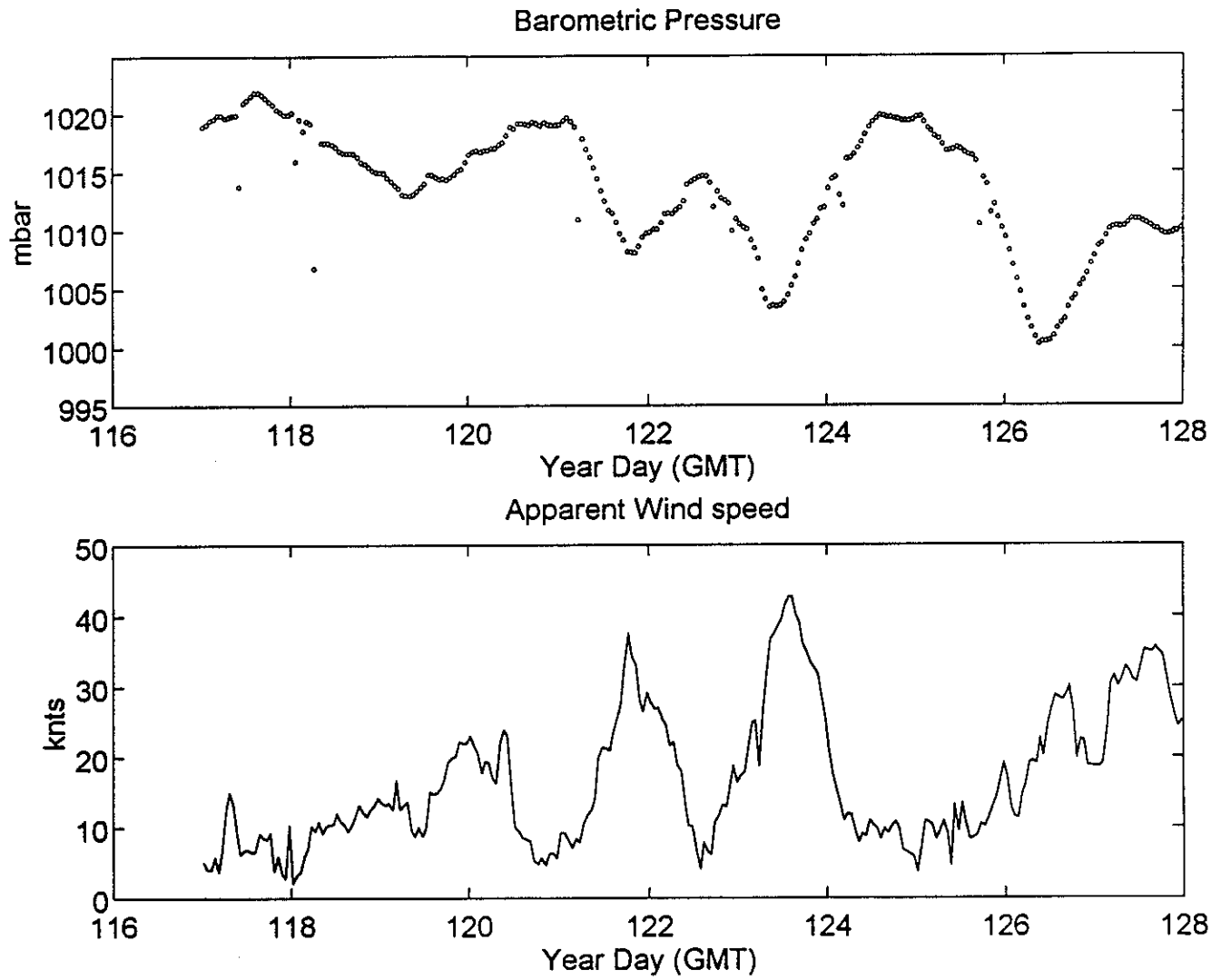

Figure 4. Hourly averages of barometric pressure and apparent wind speed recorded by shipboard RM Young system.

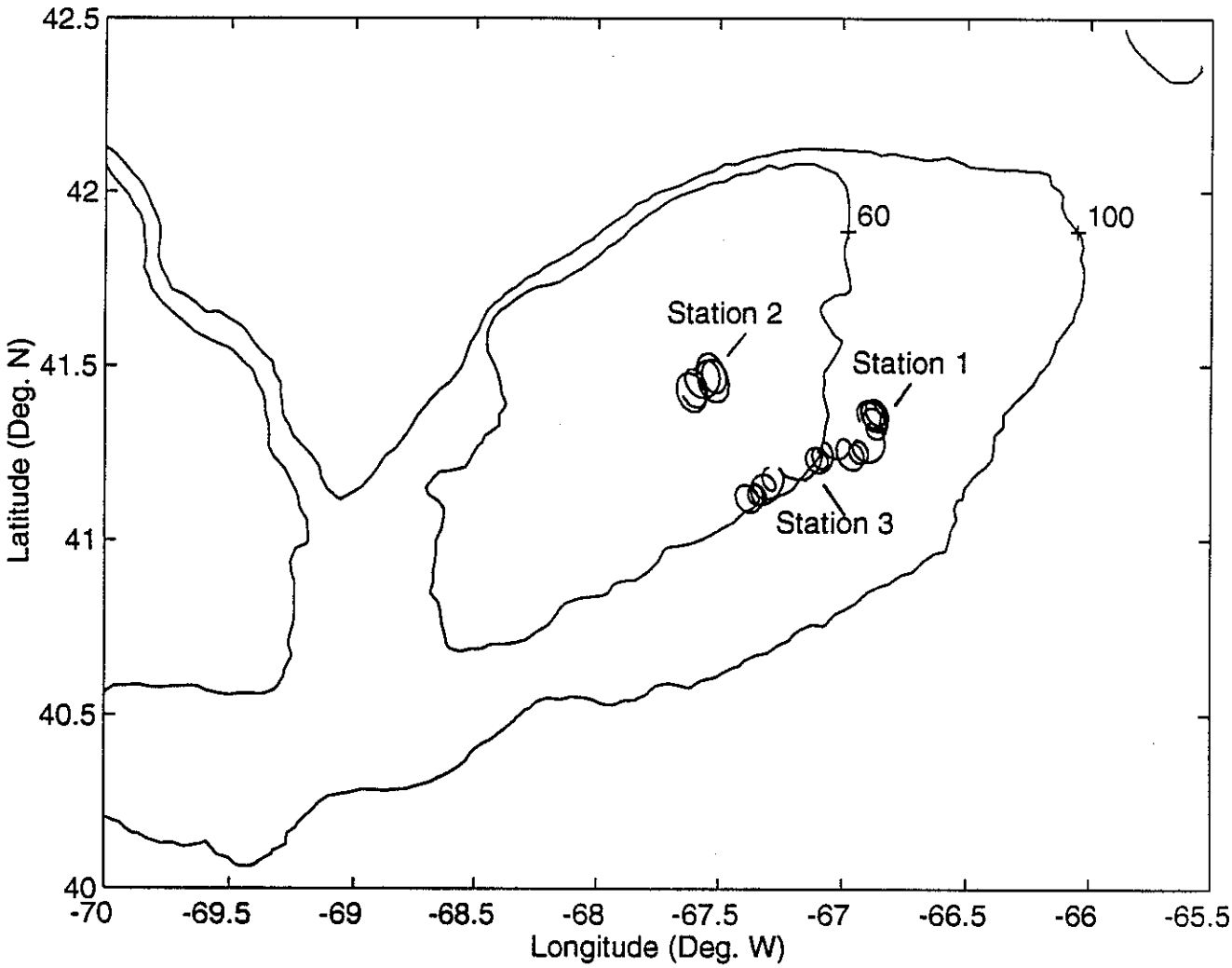

Figure 5. Drifter station locations and drifter tracks during EN266.

Nets from pump casts and MOCNESS tows at this station were brown, clogged with *Coscinodiscus* cells. Hydroid colonies were abundant. *Temora longicornis* appeared to be the dominant copepod species, followed by *Pseudocalanus spp.*, and *Calanus finmarchicus*. The most abundant *Calanus* stages were C3 and C4. Few nauplii of any copepod species were observed. The VPR showed *Calanus* in the top 1 meter of the water column during both day and night. Net tows revealed that older life history stages dominated this layer of *Calanus*. A few *Pseudocalanus* and *Temora* were also present, but the layer was devoid of hydroids, contained few large phytoplankton cells, and had low chlorophyll levels. Hydroids and large phytoplankton were present deeper in the water column. When observed under the microscope, the hydroids appeared to stun the *Calanus*, leading us to suspect that the copepods were confined to the shallow surface layer in order to avoid the hydroids. After the wind increased on the third day at Station 1, the layer disappeared.

Drifter Station 2. On 30 April, we moved to Drifter Station 2 on the Bank crest (Figure 5), arriving at 0700 hours. A second ARGOS drifter was deployed at this station, which was occupied for 72 hours. The drifter was entrained in the tidal ellipse, showing a net southwest movement during the time the station was occupied (Figure 5). Station keeping activities followed the same routine as at Station 1. Deteriorating weather The drifter was retrieved at the end of activities at Drifter Station 2. High winds and seas interrupted over-the-side work on 1-3 May. The drifter was retrieved at 2247 on 3 May.

The water column at this station was well mixed. Late stage *Calanus* (C5 and adult) were the numerically dominant copepods. *Temora* sp. and *Centropages hamatus* were abundant, with *Centropages typicus* and *Pseudocalanus spp.* also present. Few nauplii of any species or early copepodid stages of *Calanus* were present. Chaetognaths were common, and hydroids and diatoms were less abundant than at Station 1.

Hydroline A. Hydrographic Section A was occupied from 0950 to 1945 on 4 May. The hydroline began on the Bank crest, (41° 9'N; 67° 47'W) and ended in the slope water (40° 31'N; 67° 17'W). A complete description of the hydroline is given in the hydrographer's report below.

Drifter Station 3. On 4 May we returned to the first ARGOS drifter on the southern flank. In the four days since we had occupied the drifter station, the drifter had moved approximately 25 miles west along the southern flank (Figure 5). The first CTD cast at the reoccupied station revealed that some stratification had occurred during our absence. The mixed layer deepened during the 24 hours we revisited the station. However, the final CTD cast showed cooler surface temperatures. This was the only CTD cast at Stations 1 and 3 that showed any significant salinity structure. Once again, a surface layer of *Calanus* was present. Copepodid stages 1, 2, and 3 were dominant and there were some naupliar stages, but few C5s and adults. There were few hydroids. Our impression was that this was not the water mass in which the drifter had been deployed.

On 6 May deteriorating wind and sea conditions prevented further over-the-side work. We rode out the storm comfortably until 7 May, watching videos from *Endeavor*'s dubious cinematic archives and reading a variety of trash from our personal libraries, but were unable to return to work. EN266 returned to Narragansett one day early on 8 May, arriving at 1430 hours. The cruise was successful despite its early termination. We were able to accomplish our major objectives, with the exception of one cross-Bank VPR transect.

INDIVIDUAL SCIENCE REPORTS

I. HYDROGRAPHY

A. Hydrography: water column (Paul Robbins)

This report summarizes CTD operations and hydrography for GLOBEC process cruise EN266. Unless otherwise noted, all times are specified in GMT and dates as year day.

1) General CTD operations

Conductivity, temperature, and pressure were measured with a University of Rhode Island Neil Brown Mark III CTD (S/N 1088). Chlorophyll fluorescence was measured with a SeaTec flourometer, S/N 117S. Light transmission was measured with 25 cm path length SeaTec transmissometer, S/N 121D. The flourometer was also used for MOCNESS tows which required removal from the rosette frame 3 times during the cruise. Data was acquired using the General Oceanics Inc. CTD Data Acquisition Module version 5.2. The CTD data stream was concurrently recorded to audio cassettes for archive/backup. Water samples for shipboard salinity analysis were collected using General Oceanics 10 liter Go-flo sampling bottles. Shipboard salinity analysis was performed by Dave Nelson on an Autosal model 8400A.

CTD casts were performed 4 times a day at stations following drogued drifters. Two of these casts were 'conventional' CTD casts including water collection for shipboard salinity analysis and biological experiments. The conventional casts were typically performed as soon as a new drifter station was occupied and at 1300 and 2200 thereafter. The lowering and raising rates of these casts were 30 m/min. The other two daily casts were zooplankton pumping stations for Ted Durbin's group conducted at about 0900 and 2100. A flexible hose was attached to the rosette frame in order to pump water from depth to the surface for filtering and plankton collection. CTD data were acquired during these pumping stations but no bottles were tripped for shipboard salinity analysis. Winch speeds for pumping stations were typically 20 m/min for the downcast and 4 m/min for the upcast. The following CTD cast numbers were pump stations: 2, 6, 7, 9, 13, 15, 18, 20, 23, 38 and 40. Locations of CTD casts are shown in Figure 6.

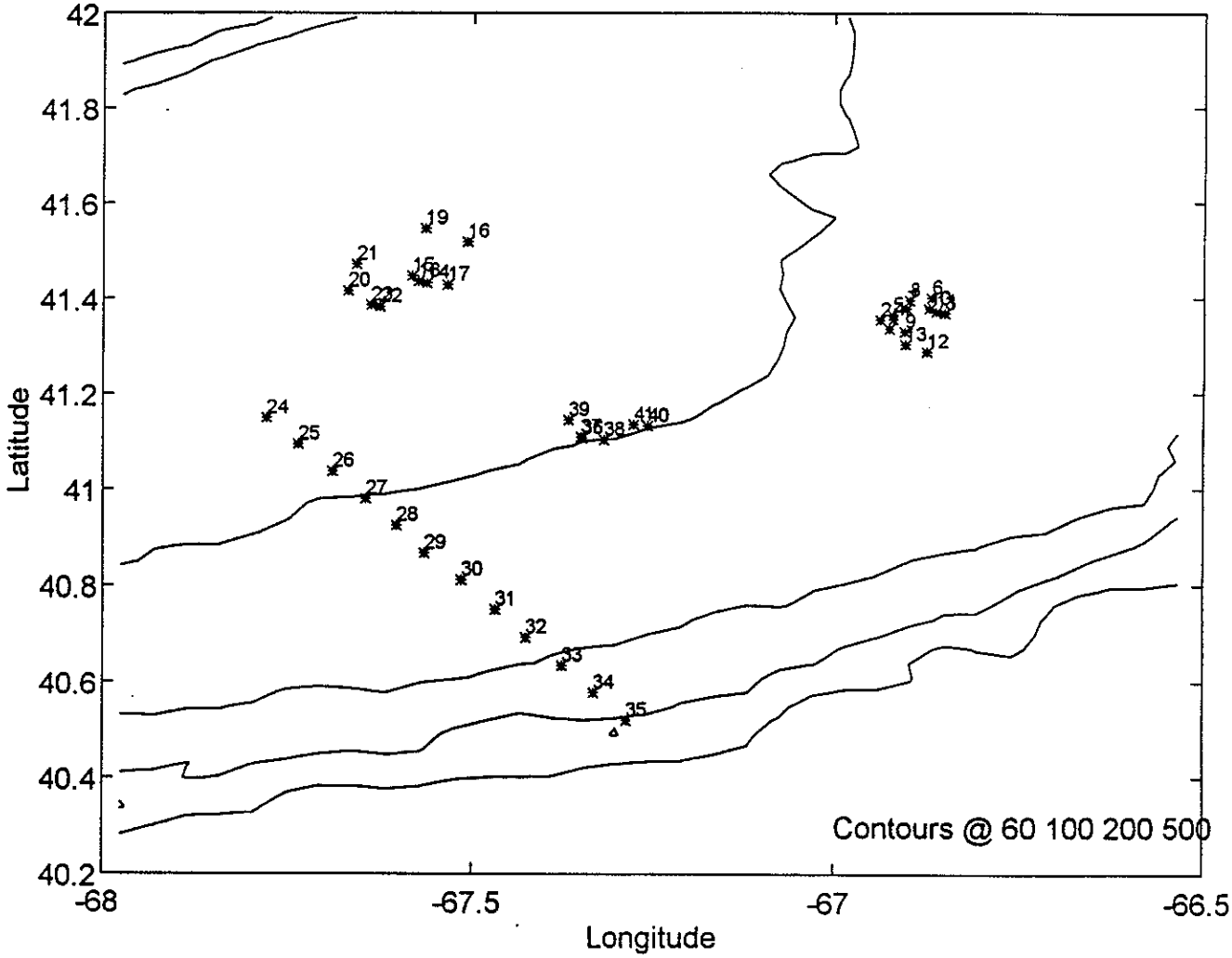

Figure 6. CTD cast locations on EN266.

Drifter 1 was deployed near GLOBEC broad scale Station 20. CTD casts (numbers 1-13; Day 117 1100 to Day 120 0100) conducted following the drifter for the first three days were labeled Station 1. The initial casts at Station 1 revealed a water column with uniform temperature and salinity indicating recent mixing to the bottom. The mean water temperature had increased by about 0.7°C since the prior process cruise (EN264) with no significant changes in salinity. The observed change in heat content would have required a surface heat input of approximately 100 W/m^2 during the 23 days since last occupation.

During the first three days of occupation significant temperature stratification was observed. The stratification was not accompanied by significant salinity changes and is therefore likely due to surface heat exchange, principally solar heating. The vertical temperature difference the first day reached 0.6°C (cast 3) and a maximum of 0.9 degrees (cast 6) was observed on the second day. The stratification observed to form over the three days of occupation at station 1 was completely eroded by winds just prior to the ship's departure for station 2. The water column was again uniformly mixed at cast 12. However, the mean water column temperature had increased by slightly more than 0.1 degrees compared to cast 3. Evolution of stratification at Drifter Station 1 is shown in Figure 7.

Drifter 2 was deployed near the GLOBEC crest mooring. The accompanying CTD casts (numbers 14-23; Day 120 1200 to Day 123 0100) were labeled Station 2. All of these casts revealed a uniform water column. As at Station 1, compared to the prior occupation, the mean temperature had increased while salinity remained roughly constant. The temperature increase of 1.4 degrees is again consistent with a 100 W/m2 surface heat input since the EN264 occupation.

After the survey of Hydrographic Line-A (discussed below) we returned to the site of the first drifter (casts 36-41; Day 125 0130 to Day 126 0200). The reoccupation of the lagrangian drifter station was designated Station 3. The first reoccupation cast (36) showed that some stratification had occurred during our absence (delta-T = 0.55). The mixed layer deepened during most of the 24 hours of occupation. The final cast (41) revealed cooler surface temperatures. Cast 41 was the only cast at Stations 1 and 3 which showed any significant salinity structure. Surface salinity dropped by 0.01 psu with a step up to formerly observed salinity at the base of the mixed layer. T-S plots for Stations 1, 2, and 3 are shown in Figures 8 and 9.

3) Hydrographic Line A.

Hydrographic Section A (casts 24-35) on the southern edge of Georges Bank was occupied on May 4 (Day 124) from 0950 to 1945. Countours of salinity, temperature, fluorescence, and transmission are shown in Figures 10 and 11. The first three stations (closest to the crest) revealed a water column uniform in temperature and salinity. Both temperature and salinity decreased away from the crest. Station A-4 (cast 27) showed

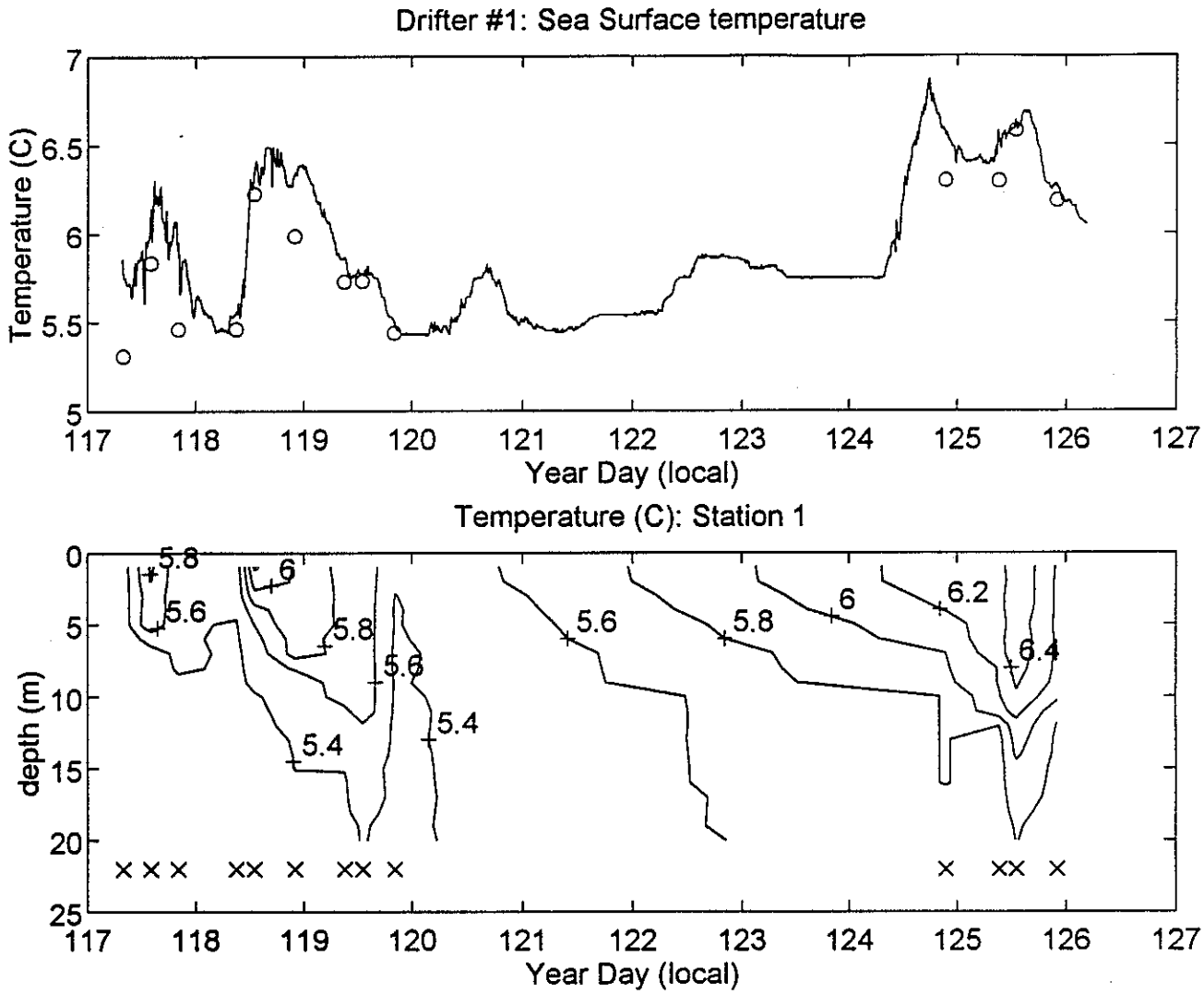

Figure 7. Evolution of stratification at drifter station 1. Upper panel shows temperature recorded by ARGOS drifter (solid line) and 1 dbar temperature for each ctd cast at stations 1 and 3. Lower panel is contours of temperature in upper 20 meters of water column observed by the ctd. X's along lower portion of plot indicate time of ctd casts. No ctd casts were performed at this site between year day 120 and 124. Temperature contours in this region are simple linear interpolation between last cast at station 1 and first cast at station 3.

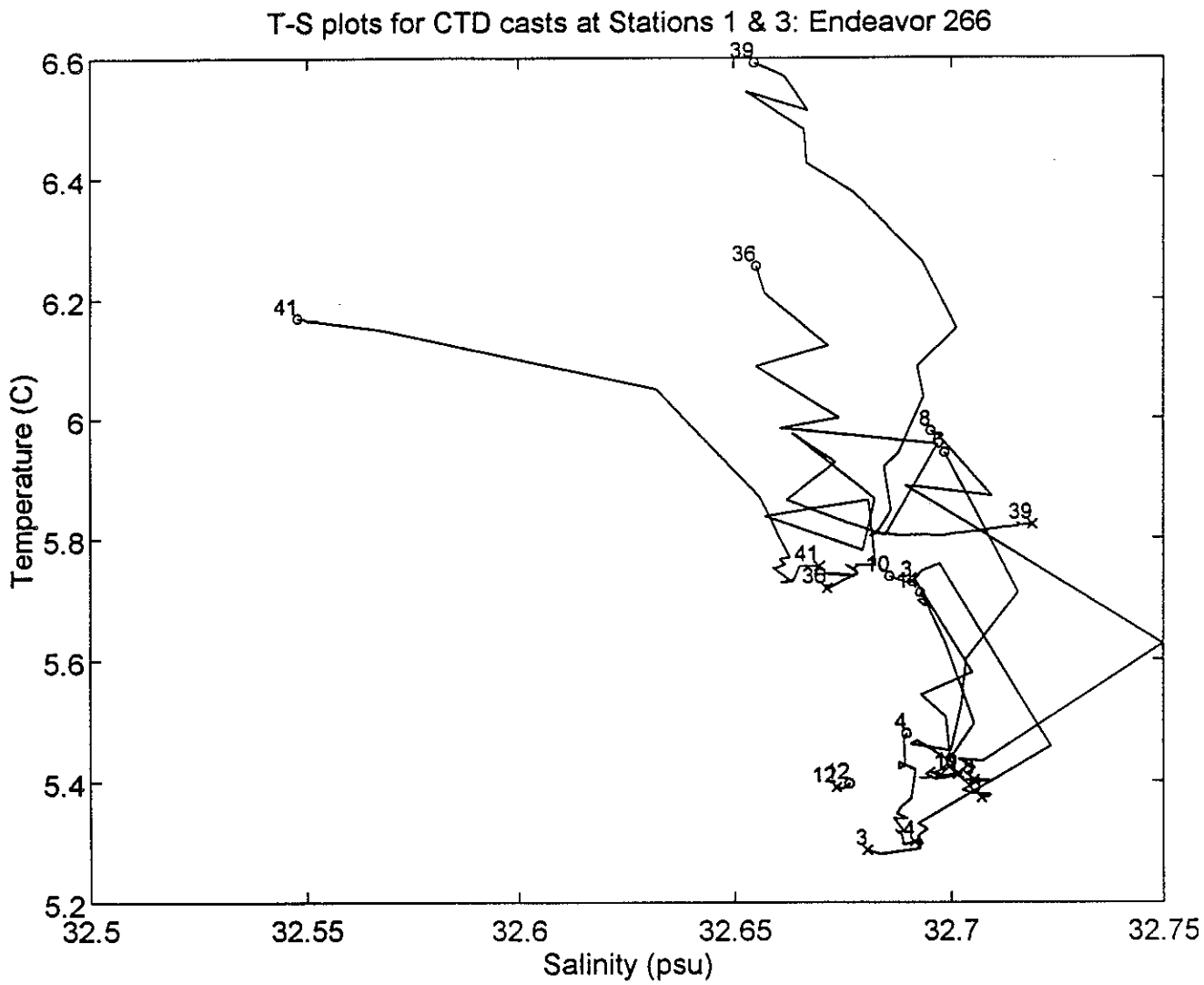

Figure 8. Temperature-Salinity diagram for ctd casts at stations 1 and 3 following ARGOS drifter 1. Numbers indicate cast number. Small open circles locate the surface T-S values for each station and x's indicate bottom T-S. Casts with erroneous negative salinity anomalies are truncated above anomaly.

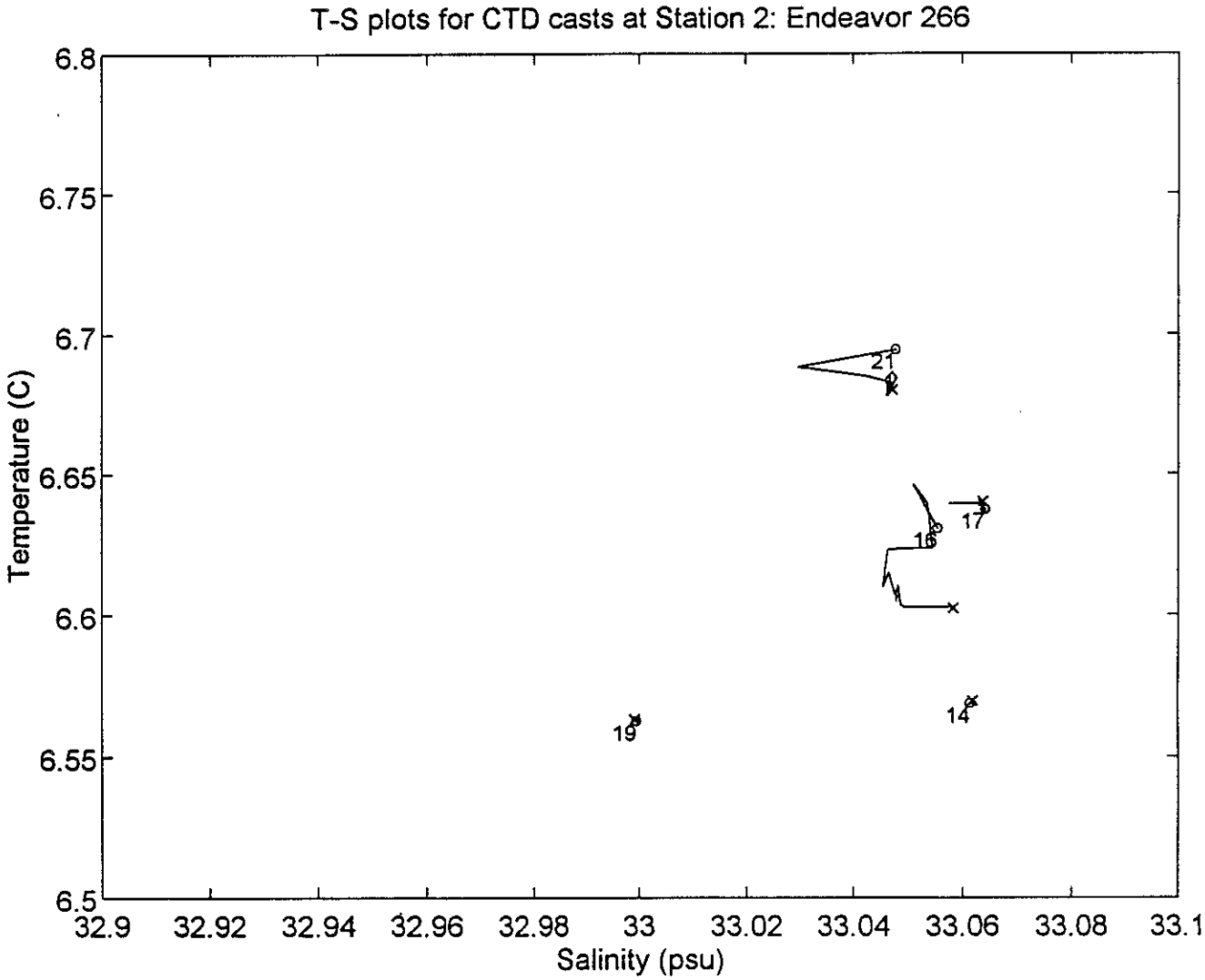

Figure 9. Temperature-Salinity diagram for ctd casts at station 2 following ARGOS drifter 2. Numbers indicate cast number. Small open circles locate the surface T-S values for each station and x's indicate bottom T-S.

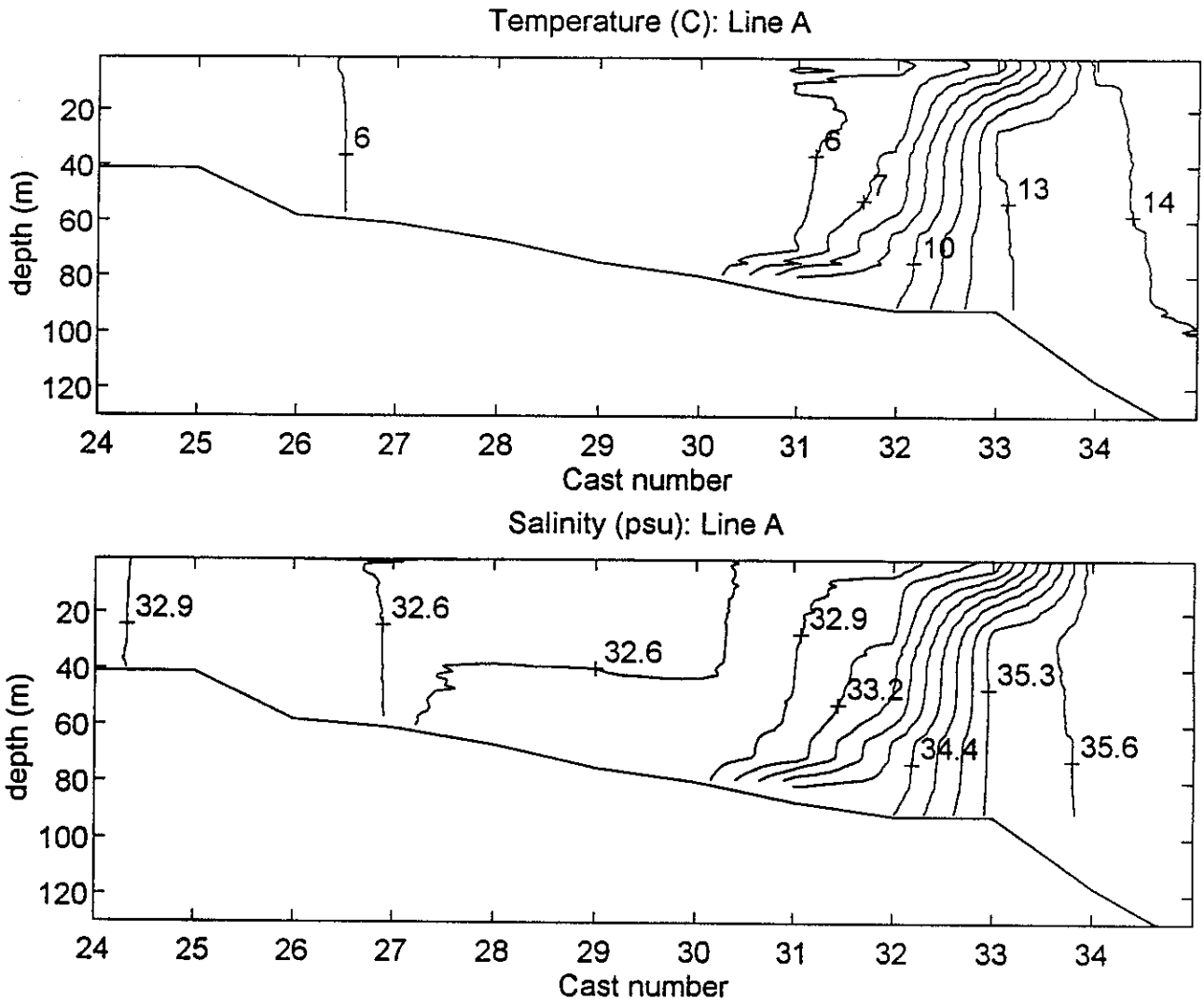

Figure 10. Contours of temperature and salinity along Hydrographic line A.

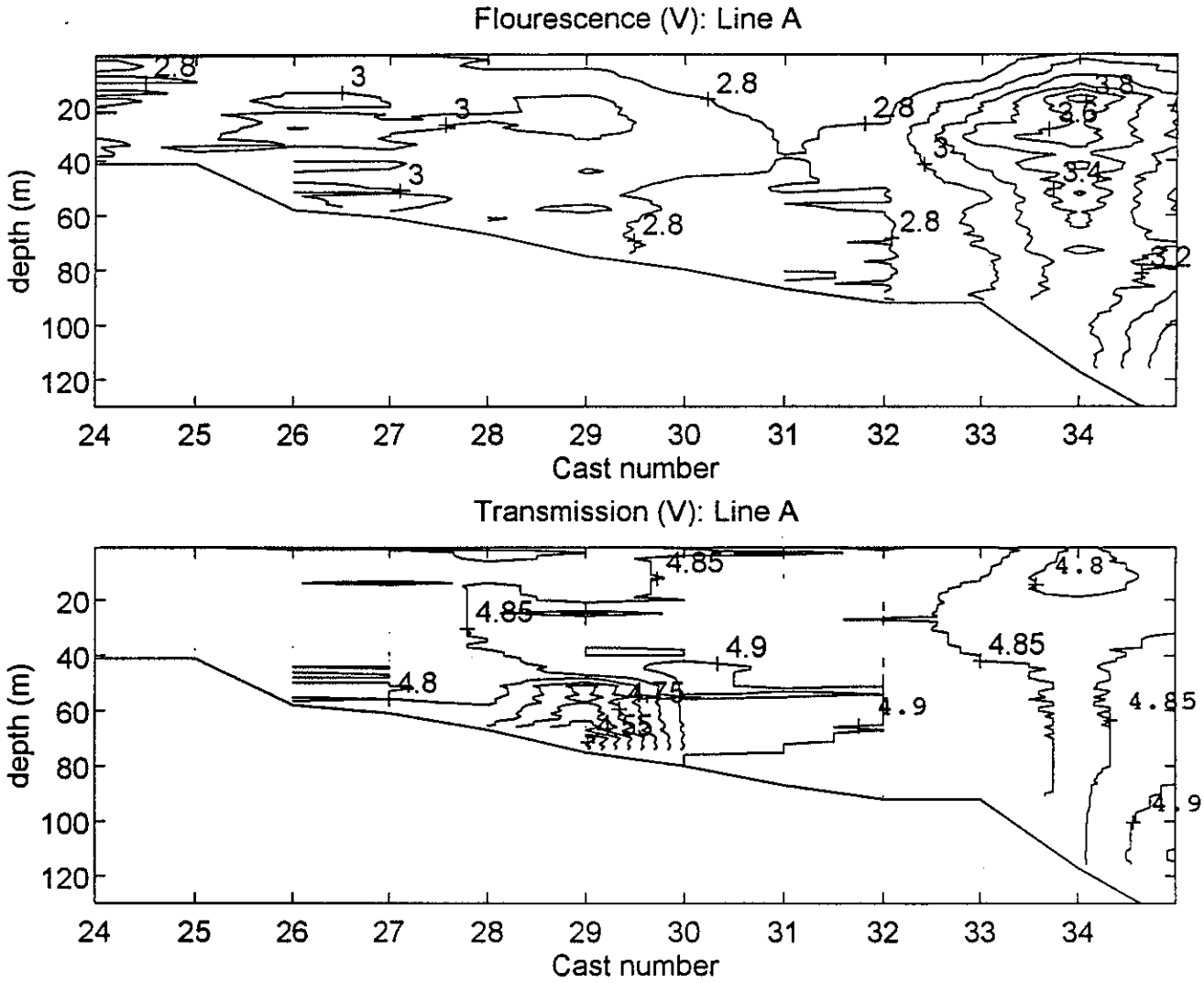

Figure 11. Contours of fluorescence and transmission along Hydrographic line A.

slight stratification with a fresh cold lens in the top 5 meters (delta-T = .06, delta-s ~ =03). This surface lens of cold fresh water deepened to about 40 meters at the following station and persisted until Station A-7 (Cast 30). At Station A-8 (Cast 31) warm salty slope water was evident in the deepest 20 m of the water column. The shelf-break front was captured dramatically in casts A-8 through A-10. Across 8 nautical miles the surface temperature rose by 5.0°C and salinity increased by 2.9 psu. The shelf-break front was also distinctly visible on the ships's radar as a line of strong radar returns. On the shoreward (Georges Bank) side of the front the radar return from surface waves was significantly lower then the radar return of waves in the slope water. The final two stations of the transect (Casts 34 and 35) showed a reversal in the temperature gradient, with temperature decreasing with depth. In comparison to previous process cruises (EN262 and EN264) the shelf break front was much tighter and located further shoreward. This could be a response to the strong north-easterly winds experienced just prior to the commencement of the hydrographic survey.

Fluorescence along line A was relatively low at Station A-1 (below 2.8V). Between Stations A-2 and A-6 there was a subsurface maximum (peak value > 3.2V) centered at about 30 meters. This feature extended across the boundary from the well mixed crest water into the fresh cold water lens described above. A relative minimum in fluorescence was observed from casts A-7 to A-9. This region was roughly coincident with the water just inshore of the shelf-break front. Values of fluorescence increased across the shelf-break front with the largest values observed at Station A-11 (cast 34) where the peak value at 20 m exceeded 3.8 V. Station A-11 was the first station clearly seaward of the shelf-break front.

Light transmission tended to increase away from the crest except for the bottom of cast 29 where very low values were observed. There is no corresponding feature in fluorescence at cast 29 suggesting the feature may be due to suspension of inorganic material. Transmission in the region of the shelf-break front appeared to vary inversely with fluorescence indicating that the variations in transmission are due to the presence of phytoplankton.

5) Calibration

Salinity samples were collected at every station in order to provide a reference for CTD calibration. The CTD (S/N 1088) was determined (after removing clearly erroneous bottles) to be 0.028 psu (CTD read slightly saltier) with no significant trend over the course of the cruise (Figure 12).

6) Technical problems

A large number of casts (3,5,6,8,9,12,14,16,18,19,20,21,22,23,25,29,39,37,38 and 41) revealed regions (from 2 to 50 m thick) of negative salinity anomalies (0.01 to 0.05 psu)

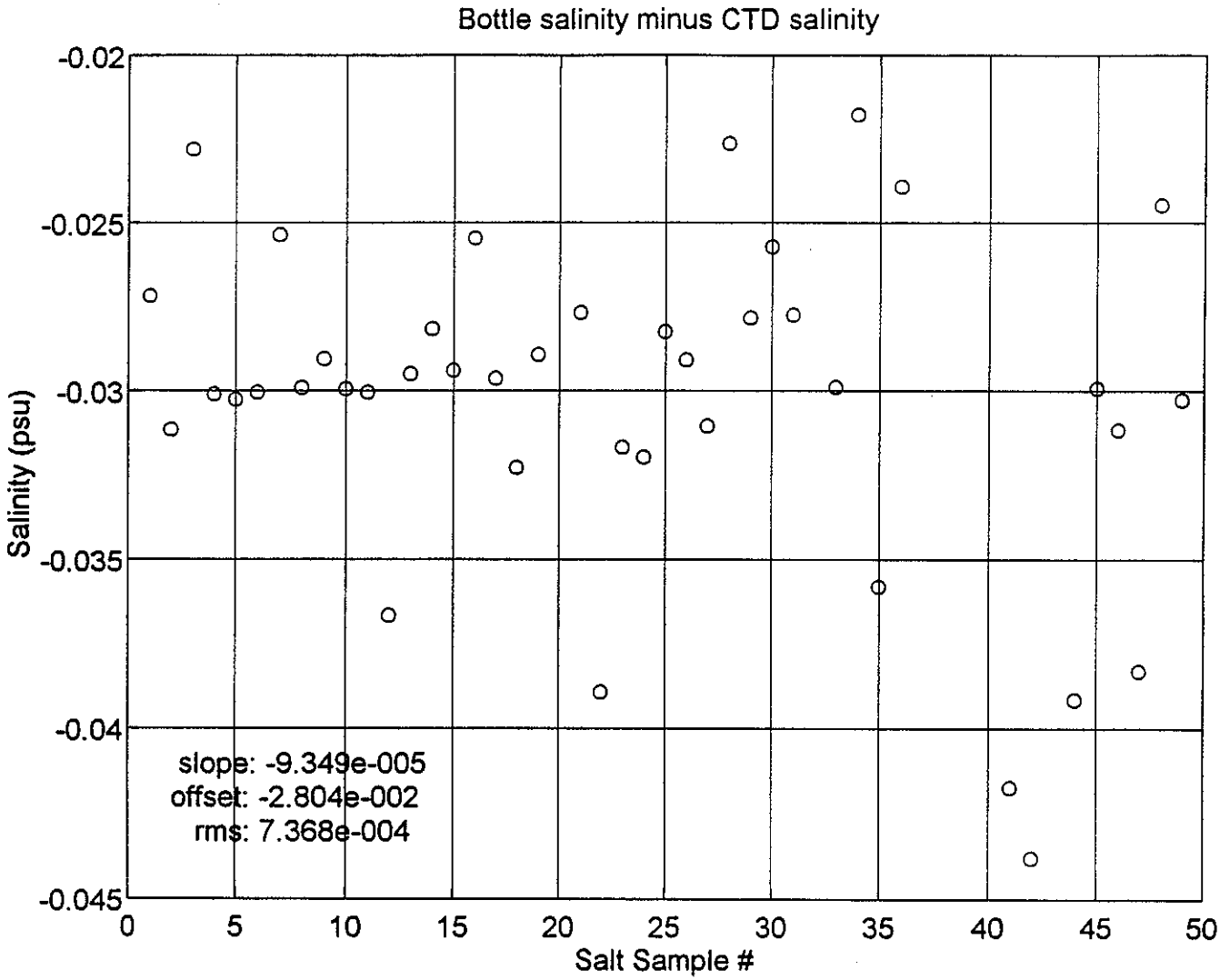

Figure 12. Calibration of Neil Brown CTD. Least square fit of data yield and offset of 0.0280 psu and slope of -9.3e-5 with respect to salt bottle sample number.

(Figures 13A and 13B). Many of these negative salinity anomalies occurred at stations where the temperature structure suggested a uniformly mixed region of the water column. Additionally, the negative anomalies in salinity were not coincident with any apparent anomalies in temperature, fluorescence, or transmission indicating that the problem was not associated with the A/D conversion within the CTD or the subsequent decoding within the deck unit.

After Cast 21 we decided to exchange the CTD (S/N 1088) with the backup CTD (S/N 1295N) in order to determine if problem was associated with a faulty conductivity cell in CTD 1088. Casts 22 and 23 were performed with CTD 1295N. The negative salinity anomaly features observed using CTD 1088 were also observed using CTD 1295N. Additionally, fluorescence on casts 22 and 23 was about 1 volt higher than previous station 2 casts and the transmissometer reading was fixed at 4.5 V. Because of the apparent problems with fluorescence and transmission and the continuation of the negative salinity anomalies, we decided to exchange the CTD's again and return to using S/N 1088. Marine Technician Dave Nelson examined CTD 1088 afterward with a digital multimeter and discovered that the A/D channel for transmission was pegged at 4.5 V.

Because the exchange of CTD's did not solve the problem of negative salinity anomalies, it is likely that CTD 1088 was functioning normally and that some other cause was behind the observed anomalies. The MOCNESS and VPR data showed large concentrations of gelatinous plankton and marine snow in the water column throughout the cruise. It is possible that some of this biological material is fouling the conductivity cell for short periods during the downcast, thereby altering the observed conductivity. Indeed, most of the observed anomalies can be correlated with instances of large fluorescence peaks at the same locations.

CTD cable connections at the termination caused intermittent but recurrent problems during the later portion of the cruise. The CTD is connected to the center conducting cable of the hydrowire via 4 single pin Mecca connectors. Routine operation required these connections to be disconnected several times each day in order to use the hydrowire for optics casts, pump casts and net tows. Two of the single wire cables broke during the cruise and were repaired. Subsequently, there were intermittent problems with open circuits on the CTD power connection. Unwrapping the connections and simply checking the physical connections of all the Mecca connectors typically provided a short term remedy for this problem. On May 6, Dave Nelson rewired all the connections between the deck unit and the CTD. However, no CTD casts were performed after this date.

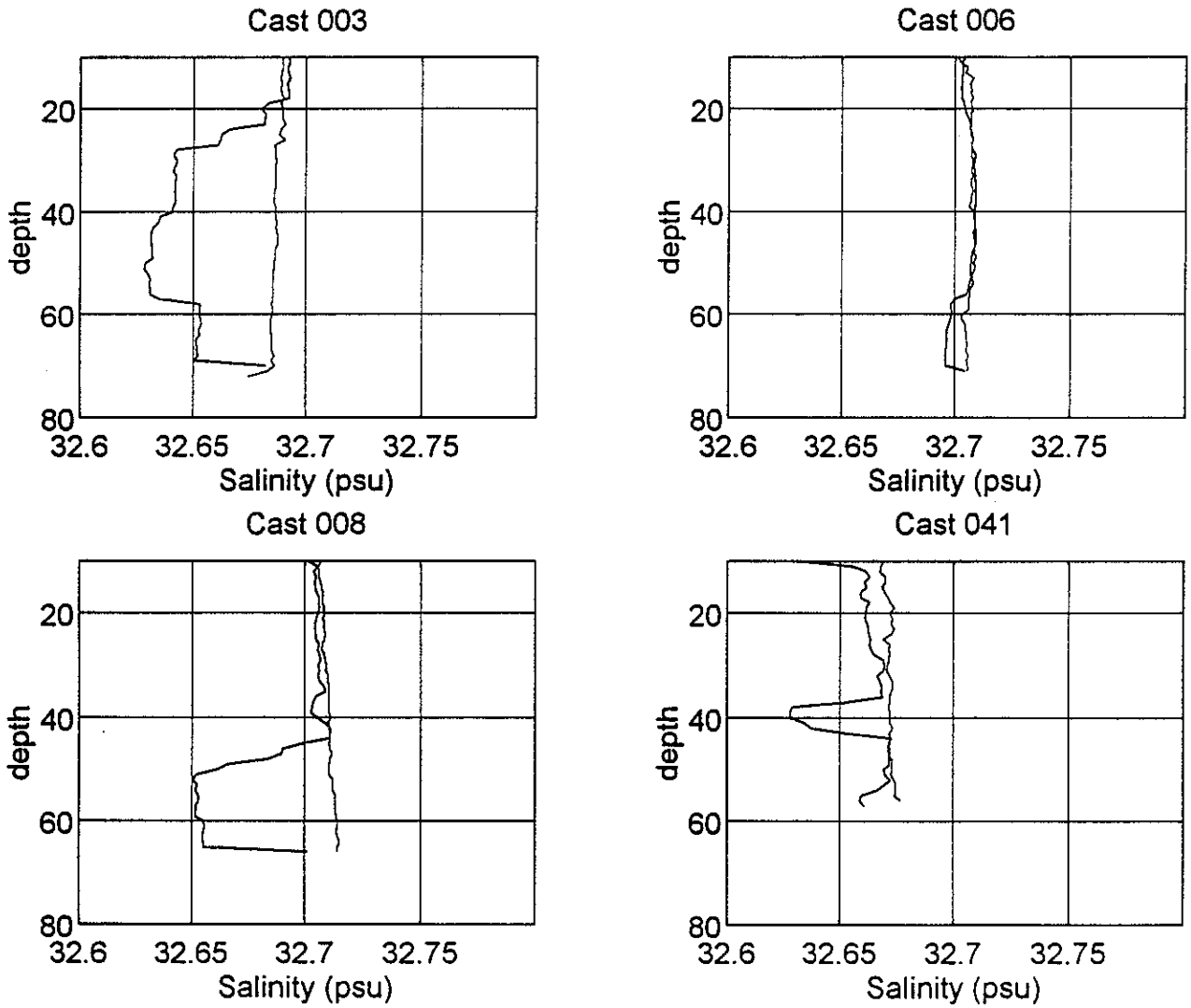

Figure 13A. CTD salinity data (1 dbar averages) comparing down and up cast at selected stations illustrating possibly erroneous negative salinity anomalies. Downcast is heavy line while upcast is light line.

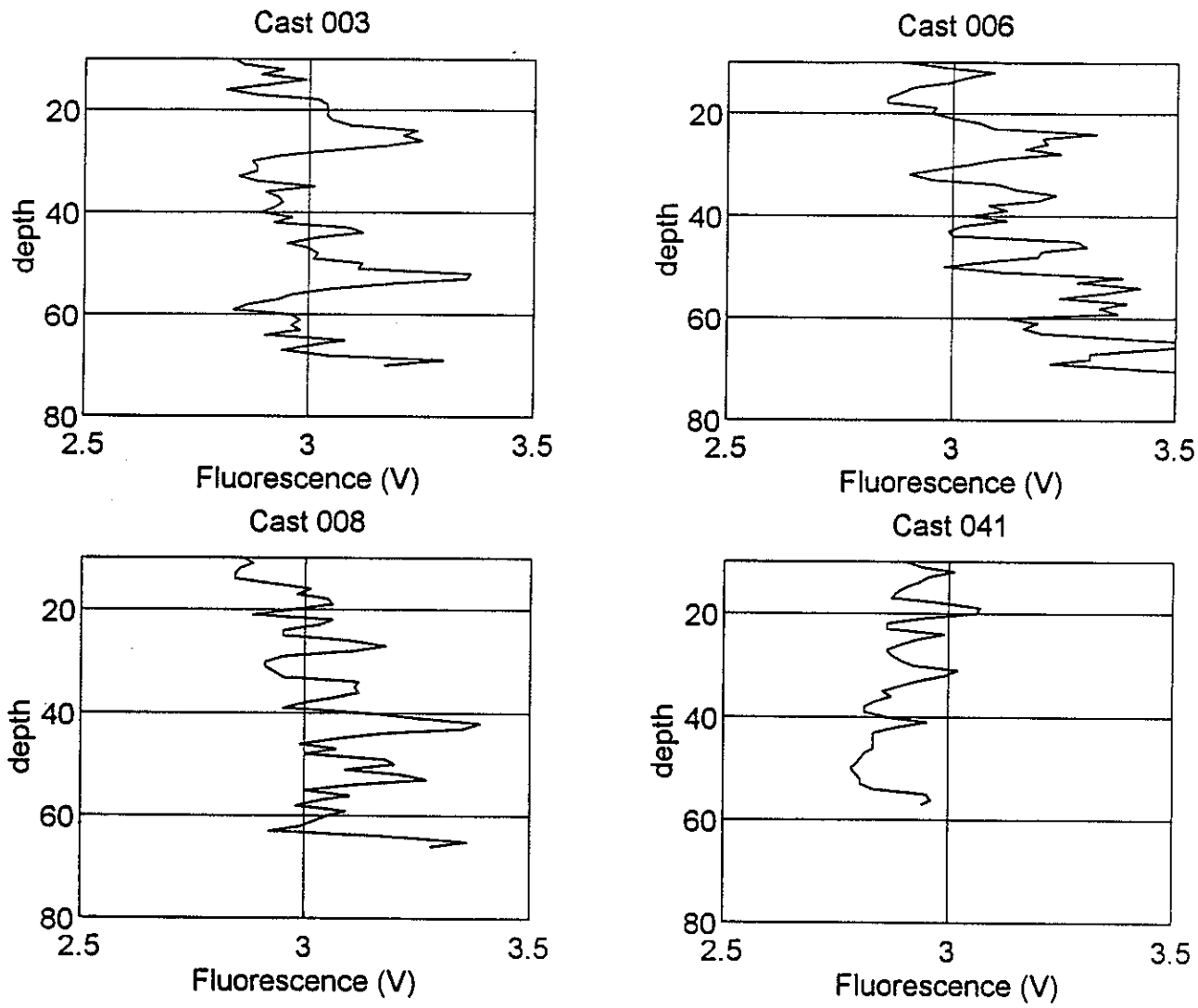

Figure 13B. Fluorometer output at same stations as Figure 8A. Negative salinity anomalies appear well correlated with regions of high fluorescence.

B. Hydrography: Biology and Chemistry (Dian Gifford, Mike Sieracki, Scott Gallager and Phil Alatalo).

1. Size fractionated chlorophyll (Dian Gifford and Mike Sieracki). Samples were collected for analysis of chlorophyll and phaeopigment from all daytime CTD casts at each drifter station. Three size fractions were collected: total, <20 μm, and <5 μm. Water was collected in teflon-lined Go-flo bottles, and drained through silicone tubing into opaque bottles. Size fractionation was done by gently pouring a subsample from each collecting bottle through either a 20 μm or a 5 μm mesh. 50-ml samples were collected on GF/F glass fiber filters, transferred directly into 5 ml of 90% acetone, extracted in the freezer, in the dark for 24 hours, and analyzed by fluorometry using a Turner Designs Model-10 fluorometer. All samples were run in triplicate.

Large cells dominated the phytoplankton at the beginning of drifter Station 1, with 80% of the chlorophyll >20 μm, 3% 5-20 μm, and 17% <5 μm. A subsurface chlorophyll maximum developed with the onset of stratification. The maximum contained an increasing proportion of smaller cells, reflected by 47% of the chlorophyll >20 μm, 18% 5-20 μm, and 35% <5 μm. In contrast, 60% of the chlorophyll at the surface layer was >20 μm, 40% 5-20 μm, and 0% <5 μm.

2. Nutrients and POC (Dian Gifford). Samples were collected from the first daytime CTD cast at each drifter station for onshore analysis of nutrients and particulate organic carbon. Water for nutrient analysis was filtered through GF/F glass fiber filters into precleaned 100-ml plastic bottles. The deionized water stored in the bottles was discarded, the bottles were rinsed twice with filtered sample, then filled to 3/4 level with sample, closed, and stored frozen pending analysis in the home laboratory. 100-ml of water for POC analysis was filtered through precombusted GF/F glass fiber filters. The filters were frozen pending analysis in the home laboratory.

3. Nano- and Microzooplankton.

a. Microscopy (Dian Gifford and Mike Sieracki). Samples were collected from every daytime CTD cast at both drifter stations. Samples for analysis of microzooplankton (20-200 μm) were collected by draining water from the Go-flo bottles directly into 250 ml bottles containing 25 ml of acid Lugol's preservative, for a final concentration of 10% (vol/vol) acid Lugols. These samples will be processed ashore using an inverted microscope. Samples for analysis of nanozooplankton (2-20 μm) were collected by draining water from the Go-flo bottles directly into collecting bottles. The water was preserved with 3% glutaraldehyde, stained with a combination of DAPI and proflavine, and filtered onto 0.8 μm Nuclepore filters. The filters were mounted on microscope slides and frozen for later analysis by image-enhanced epifluorescence microscopy at the home laboratory.

b. Video analysis (Scott Gallager, Linda Davis, and Phil Alatalo). One of the objectives of the GLOBEC Georges Bank program is to characterize the potential prey field of cod larvae with respect to abundance, size, and motility of potential prey. We hypothesize that newly-hatched cod larvae will feed on soft-bodied protozoans and that feeding success will relate to size, density, and motility patterns of prey. Experiments to measure ingestion of protozoa by cod larvae were done on the two prior process cruises, EN262 and EN264. Samples were collected on EN266 as part of an on-going survey of the seasonal changes in the prey field throughout the water column on George's Bank.

Surface water samples were collected with a tethered 1-l beaker, while near-bottom and 1-m subsurface samples were collected using Go-flo bottles deployed on the CTD. Tissue culture flasks were filled gently with 200 ml of sample and placed in an incubator at 5°C. The filming apparatus consisted of a B/W high-resolution Pulnix camera fitted with a Nikor 50 mm macrolens which was mounted on a frame opposite a fiber-optic ring illuminator. The frame was suspended on bungee-cord inside the 5°C incubator, thereby reducing the ship's vibrations and keeping the sample cool during filming. Although a far-red filter apparatus is normally used in conjunction with the illuminator, lighting limitations prevented its use on this cruise. Each sample was placed on a flask holder on the frame such that the field of view was 15 mm. Samples were recorded for 12 minutes on SVHS format using a Panasonic AG1960 video recorder. Microzooplankton abundance and prey motility patterns are to be analyzed onshore using Motion Analysis EV software. Post-cruise processing will yield particle size distribution and motility spectra associated with each particle. Results will be compared with species composition and abundance in the microzooplankton fraction preserved in acid Lugol's solution by Dian Gifford and Mike Sieracki.

Preliminary results indicate a general decline in both number and size of microzooplankton compared to earlier cruises. While very few microzooplankton were observed at Stations 1 and 2, Station 3 showed a dramatic increase in numbers of very small as well as medium to large microzooplankton. Differences between samples at various depths were minimal. Results were compared to macroplankton observations from pumps and the Video Plankton Recorder (VPR).

Large diatoms were fairly abundant on the Southern Flank (Station 1), though reduced in numbers from the bloom conditions observed in March and early April. Few medium to large protozoans were observed. Very small plankton, possibly phytoplankton, dominated the assemblage. VPR images showed large (~2cm) marine snow particles and abundant hydroid colonies in the water column. The well-mixed region on the crest of the Bank (Station 2) showed even fewer microplankton than on the Southern Flank. Large diatoms were present along with small to medium-sized protozoans exhibiting very little motion. This region was characterized by small amounts of marine snow, large and abundant hydroid colonies, and a "bloom" of cerianthid larvae.

Following a storm on May 3, Station 3 on the Southern Flank was characterized by a significant increase in abundance of all sizes of microplankton. Microscopic examination showed *Phaeocystis* colonies, *Coscinodiscus* sp., and polychaete larvae, in addition to numerous ciliate protozoans. Following the hydroline transect, sampling showed an increase in medium to large protozoans at Station 3. Copepod nauplii were also recorded for the first time. In contrast, VPR images showed a dramatic reduction of marine snow and hydroids together with an abundance of younger stage copepods and some pteropods. An intrusion of a different water mass may explain the sudden change in both macro- and microzooplankton composition. Sampling along Hydroline A at the shelfwater break showed large concentrations of small microplankton, particularly at 115 meters depth. A few large protozoans were observed in the 1-meter subsurface sample.

C. Hydrography: Optics (Jeff Van Keuren).

The overall objective of my work is to characterize the ultra-violet (UV) and visible light regimes encountered by organisms living on Georges Bank throughout the critical early development period of the key cod and haddock larvae, and the copepod Calanus finmarchicus. My primary objective on EN266 was to extend the time series of GLOBEC Process cruise continuous surface measurements and underwater profiles of downwelling irradiance data (ultra-violet, PAR). Ultimately, the light data will be integrated with ADCP data on zooplankton abundance and biomass, and zooplankton distributions in relation to the light field will be examined.

During this 13-day cruise, light profiles of four narrow band UV channels (308nm, 320nm, 340nm, 380nm) as well as broad-band PAR (400-700nm) were taken at the three time-series stations visited (Stations 1-3) as well as at GLOBEC mooring site "ST-1" and hydroline station "A-11". Strong winds and high seas associated with the three gale-force storms which occurred during this cruise prevented optical casts at additional sites elsewhere across the Bank. Surface irradiance values for each of these five wavebands were also continuously logged throughout the cruise using masthead-mounted deck sensors. These daytime surface irradiance measurements were complimented by broad-band twilight/nocturnal light records generated by a logging PMT-based system as well as observations of existing cloud conditions. No underway analyses of these data were possible due to weather conditions. The UV component of this work is being done in conjunction with Dr. Albert Hanson, University of Rhode Island.

II. Zooplankton Abundance, Physiological Condition, and Growth Rates (E. Durbin, A. Durbin, R. Campbell, J. Gibson, and G. Teegarden)

Objectives:

(1) To determine the abundance and stage composition of the target zooplankton species (*Calanus finmarchicus* and *Pseudocalanus*

spp.) at the proposed drifter locations on Georges Bank and at several off-bank stations.

(2) To determine the size (length, carbon, and nitrogen) and condition (condition factor and RNA/DNA ratio) of *Calanus finmarchicus* over different regions of the bank.

(3) To correlate growth and development rates of *Calanus finmarchicus* copepodite stages and egg production rates of adult females with RNA/DNA ratios in ship board incubations, and compare these results with the RNA/DNA ratios of field collected copepods to estimate growth rate in the field.

(4) To determine if growth and development rates of *Calanus finmarchicus* copepodite stages are food limited on Georges Bank.

Zooplankton were collected twice each day at the drifter locations. A zooplankton pump equipped with 50 μm mesh nets, that quantitatively retains all of the nauplii of the target copepod species, was used as our primary sampling tool, and sampled the following depth intervals: bottom-40m, 40-15m, and 15m-surface. In addition, a 1 m^2 MOCNESS equipped with 150 μm mesh nets, and towed over the same depth intervals as the pump, was used once at the beginning of each drifter site to sample the larger zooplankton and rarer species that might not be quantitatively sampled by the pump. A MOCNESS tow was also taken in the slope water at the end of the hydro line and sampled from the bottom-100m, 100-40m, 40-15m, and 15m-surface.

At Station 1, the site of the first drifter deployment located on the southern flank, the nets from the pump casts and MOCNESS tow were brown. The nets were clogged with phytoplankton and there were large numbers of hydroid colonies. The dominant copepod appeared to be *Temora longicornis*, followed by *Pseudocalanus spp.*, and *Calanus finmarchicus*. The most abundant *Calanus* stages were C3 and C4 and there were few nauplii of any species present. For the first two days at this station there was very little wind and the seas were quite calm. The VPR group reported observing *Calanus* in the top 1 meter both day and night, so we took a net tow at 1 meter and found that almost all the copepods were *Calanus*, dominated by older stages. A few *Pseudocalanus* and *Temora* were also present but no hydroids and little of the *Coscinodiscus* prevalent at lower depths. On the third day, when the wind picked up this layer disappeared.

At the second drifter station (Station 2, on the crest), the numerically dominant copepods were late stage *Calanus* (C5 and adult), *Temora* and *Centropages hamatus* were abundant, and *Centropages typicus* and *Pseudocalanus spp.* were also present. There were very few younger stages of *Calanus*; and almost no naupliar stages of any species present. Chaetognaths were common, while hydroids and diatoms were less

abundant than at Station 1.

Four days after we left the first drifter we returned to it (Station 3) and found that it had moved 25 miles west along the southern flank. There was layer of *Calanus* (mainly younger stages) at the surface. *Calanus* copepodite stages 1, 2, and 3 were dominant, there were some naupliar stages, but very few C5s and adults. Also, there were very few hydroids. This did not appear to be the same water mass in which the drifter was originally deployed, where *Temora* was the dominant copepod and C3 and C4 were the most abundant *Calanus* stages.

We found very low zooplankton biomass in the MOCNESS tow taken in the slope water at the end of the hydro line (Station 12a). There were a few *Calanus* stage C5 in the surface and bottom samples, but most of the copepods were other slope water species. At the drifter stations, as well as at several other locations on and off the bank, *Calanus finmarchicus* N6 through adult were routinely collected with live net hauls (150 and 335 μm) for size (length, carbon, and nitrogen) and condition (condition factor and RNA/DNA ratio) measurements. Copepods, under anesthetic (MS222), were sorted from the net haul using a dissecting microscope, their images recorded with a video system for later length measurements, and then placed in either a tin boat and dried over desiccant for carbon and nitrogen analysis or put into cryotubes and frozen in liquid nitrogen for RNA/DNA determinations.

Experiments were conducted on board ship to determine the relationships between RNA/DNA ratio and growth, and RNA/DNA ratio and development rate of *Calanus finmarchicus* copepodites, and whether growth and/or development rate were food limited. These experiments will be used to estimate growth and development rates from the RNA/DNA ratios of the field collected copepods. Copepodites of a specific stage were sorted (unanesthetized) from a live net tow under a dissecting microscope (st. 1: C3, C4, C5; st. 2: C4, C5; st. 3: C1, C2, C3, C4), incubated in 8 l polycarbonate bottles filled with ambient surface water or ambient water enriched with phytoplankton cultures (*Tetraselmis sp.* and *Heterocapsa triquetra*) and placed in a water bath (temperature controlled with circulating surface water). Measurements were taken for initial size and condition, and final measurements of size and condition (noting any molting that had occurred) were made after a two day incubation.

We found differences in molting rate over a two day incubation between stations, as well as between stages of development, and between ambient and enriched treatments (Table 1). At station 1, molting rates were low and similar for all stages in the ambient treatment (8 to 12%), while molting rates for stage C4 were slightly enhanced on the enriched diet (17 vs 8%). At Station 2, molting rates for C4 were higher than those found at Station 1 (ambient: Station 2, 31% vs Station 1, 8%) and did not appear to be significantly enhanced on the enriched diet (ambient, 31% vs enriched, 36%). However, molting rates for C5 were still low and were enhanced on the enriched diet (15 vs 0%). At Station 3, molting rates were very high for the younger stages (C1, 81%; C2, 49%; C3,

35%). There was a decrease in molting rate found with increased stage of development, and this was also observed at Station 2, but not Station 1. In addition, molting rates were reduced for stages C3 and C4 in the enriched treatment compared with the ambient treatment (C2, 61 vs 37%; C3, 42 vs 28%). This was an interesting result that had not been observed on previous cruises; and data from RNA/DNA, carbon, and nitrogen analysis should shed further light on these findings. These results suggest that: 1) development rates of specific stages of *Calanus* were not constant at different locations on the bank, 2) the degree to which food limitation of development rate was important varied between stations as well as between stages at a given location, and 3) there were stage specific differences in development rate at a given location. A comparison of these results with carbon and nitrogen specific growth rates as well as RNA/DNA ratios should be interesting.

Table 1. *Calanus finmarchicus*. Percentage of copepodites of different stages molting during 2 day ship board incubations at the drifter locations.

Station	Stage	Treatment	% Molting
01	C3	ambient	10
	C4	ambient	8
		enriched	17
	C5	ambient	12
02	C4	ambient	31
		enriched	36
	C5	ambient	0
		enriched	15
03	C1	ambient	81
	C2	ambient	61
		enriched	37
	C3	ambient	42
		enriched	28
	C4	ambient	13

In summary, we were able to meet most of our objectives despite the significant amount of time lost due to weather. We will be able to obtain good estimates of zooplankton abundance, physiological condition, and growth rates at the drifter locations. However, our geographic coverage on the bank and at several off-bank stations is lacking; most notably the northeast peak region, Georges Basin, and the Great South Channel.

III. Egg production of dominant copepod species on Georges Bank (Stéphane Plourde and Jeffrey A. Runge).

Objectives:

(1) To measure egg production rates of dominant copepod species on Georges Bank.

(2) To test the hypothesis that copepod population egg production (eggs m-2 d-1), determined by specific egg laying (eggs f-1 d-1) and abundance of females (f m-2), varies through time and between regions of the Bank.

(3) To establish a predictive relationship between *Calanus finmarchicus* egg production rates (eggs f-1 d-1) and reproductive index (state of gonad maturity).

(4) To measure egg viability of *C. finmarchicus* .

Calanus finmarchicus. Egg laying rates and viability were measured on 3 consecutive days at Station 1 (Southern Flank) and Station 2 (Bank Crest), and during a 1-day return to the Southern Flank (Station 3). Station 1 was chosen based on the spatial distribution of cod larvae determined during a cruise prior to ours. Additionally, experiments were done at Hydro Line Station 6 (Southern Flank) in water depth comparable to Station 1. Females were abundant at all sites. The methods are described ed at length in preceding cruise reports. In brief, females were collected with a 333-μm mesh size plankton net gently towed from c.a. 5-10 m of the bottom to the surface. Catches were diluted in filtered sea water, 40 healthy females were sorted quickly and then incubated individually in 50-ml dishes filled with filtered seawater for 24 h. Incubations were done at ambient surface temperature, which was ~6-7 $^{\circ}$C. Eggs were counted and removed every 8 h and kept at 10 $^{\circ}$C. The prosome length of females used in experiments was measured once/station to determine the relationship between clutch size and body size. To measure egg viability, we incubated 200 eggs until hatching. About 300 eggs were stained with Trypan Blue solution to color dead eggs. Both batches of eggs were composed of randomly picked eggs laid by all females. All nauplii and eggs were preserved at the end of the experiments.

In order to establish the relationship between egg production rate and reproductive index, we sorted 30-40 females from the same catches that females used in experiments come from. The animals were preserved immediately in 4% formalin. Their gonad development state, based on size, pigmentation and the distribution of oocytes in the genital tract, will be determined later in the laboratory.

Twenty-four *C. finmarchicus* females were picked at each of Stations 1, 2 and 3 to measure body size and carbon content. Prosome length was measured, females were rinsed in fresh water and then placed individually in pre-weighed CHN boats. Samples were kept in dessicant pending analysis in the home laboratory. Body carbon content data will be used to calculate weight specific egg production rates (% body carbon f^{-1} d^{-1}) in order to normalize differences in egg laying rates between stations and cruises.

Other species. We did egg laying experiments with other abundant copepod species. Egg production measurements with *Pseudocalanus* spp. (relatively abundant in Southern Flank waters but low at the Bank Crest) were made at Stations 1, 3 and hydroline station 6. *Temora longicornis* females were very abundant at all stations except Station 3, which allowed us to do a total of 5 experiments. Finally, we did 2 experiments with both *Centropages typicus* and *C. hamatus*, which were restricted primarily to the Bank Crest (Station 2). Females were incubated for 24 h at ~6-7 °C in 45-ml culture flasks filled with ambient sea water collected from the chlorophyll maximum using Go-flo bottles on the CTD-rosette. The water was filtered through a 73 μm mesh to remove any eggs. Eggs and females were preserved in flasks at end of experiments for later enumeration and measurements.

C. finmarchicus egg production rates ranged from ~46 eggs f^{-1} d^{-1} and 55 eggs f^{-1} d^{-1}. The single experiment done at Hydroline Station 6 showed a markedly lower egg laying rate (11 eggs f^{-1} d^{-1}), explained by the lower spawning frequency (0.25 compared to 0.70 to 0.90 at other stations). Female prosome length at Station 1 was ~2.800 mm and females laid >60 eggs $clutch^{-1}$. Spawning frequency was typically 0.70. At Station 2, 90% of females laid eggs with a slightly smaller clutch size (~ 55 eggs $clutch^{-1}$), determined by the smaller females body size (~2.680 mm prosome length). Females at Hydroline Station 6 were the same size as those at Station 1, but were less mature (more females bearing spermatophore, large oil sac, early states of gonad maturation). General observations suggest that these females have recently been recruited into the population.

Egg production rates for other species were not analyzed during the cruise, but some observations have been made. Fewer than 10% of *Pseudocalanus* spp. females were observed carried egg sacs. Most *C. typicus*, *C. hamatus* and *T. longicornis* females showed developed gonads, suggesting that they were laying eggs at high rates. Only at Hydroline Station 6 did *T. longicornis* females fail to exhibit highly developed gonads.

IV. Ingestion of phytoplankton, nanozooplankton and microzooplankton by *Calanus finmarchicus* (Dian Gifford and Mike Sieracki).

The objective of our research is to define the diet of *Calanus finmarchicus*, with particular attention to ingestion of nano- and microzooplankton. Specifically, we (1) measure ingestion rates of all available copepodid stages of *C. finmarchicus* in controlled experiments and (2) characterize the potential prey field of *C. finmarchicus* by measuring the vertical distributions of size fractionated chlorophyll a, nanozooplankton and microzooplankton.

At the stratified site on the southern flank, approximately 50% of the chlorophyll was <5 μm, 75% was <20 μm, and 29% was >20 μm. Preliminary analysis of epifluorescence samples confirmed that the phytoplankton was dominated by cells <20 μm in size, including prymnesiophytes, cryptophytes, and small diatoms. Phototrophic dinoflagellates were not abundant, although *Ceratium* spp. were present. The nano- and microzooplankton were dominated by small flagellates, with relatively high numerical abundances of heterotrophic dinoflagellates (up to 300/ml), mixotrophic ciliates including *Laboea strobila* and *Tontonia* spp., and *Mesodinium rubra*. At the mixed station on the bank crest, 45% of the chlorophyll was <5 μm, 88% was <20 μm, and 12% was >20 μm. Microscopic analysis revealed that the phytoplankton at this station was dominated by chain colonies of *Pseudonitzschia* spp., cyanobacteria, and cryptophytes. Heterotrophic dinoflagellates and ciliates dominated the microzooplankton.

During EN266, we performed our 40th feeding experiment with *Calanus finmarchicus* on Georges Bank. We measured clearance and ingestion rates of copepodid stages C4, C5, and adult females at three drifter stations, Stations 1 and 3, located on the southern flank, and Station 2, located on the bank crest.

Experiments done on the southern flank, where the water column had begun to stratify, measured ingestion rates of *C. finmarchicus* on prey assemblages collected from the middle of the mixed layer and from the chlorophyll maximum below the mixed layer. Experiments done on the bank crest, where the water column was well mixed, measured ingestion rates of *C. finmarchicus* on prey assemblages collected from the middle of the water column at approximately 15m. Preliminary examination of the chlorophyll data indicates that the copepods' grazing activity on chlorophyll at both drifter stations was low, but where present, was focused on particles >5 μm, particularly particles 5-20 μm in size. Microscopic analysis of nano- and microplankton samples at our home laboratories will reveal the extent to which feeding was concentrated on heterotrophic food items.

V. Video Plankton Recorder Sampling of micro-mesoscale plankton distributions (Cabell Davis, Phil Alatalo, and Andy Girard).

The goal of the VPR sampling during the process cruises is to measure the micro-finescale distributions of *Calanus* and *Pseudocalanus* together with other plankton and seston in relation to physical properties of the water column over micro-fine scales (microns to a few kilometers). Comparative day/night sampling of these variables will provide insights into the vertical migration behavior of the plankton. These data will help us understand the physical and biological mechanisms controlling patch formation in plankton, and will provide insights into the role of vernal stratification in concentrating these organisms, which serve as food for larval fish (eg. cod and haddock).

The sampling design involved slowly towyoing the VPR in a 2 km square grid centered on the drifter. In this way, both the finescale vertical and horizontal distributions of plankton, seston, and hydrography in the vicinity of the drifter could be determined. The VPR (Davis et al, 1992a,b) was configured with two cameras set at two different magnifications and viewing concentric volumes. The high magnification camera had a field of view of 5.8w x 4.8h mm and the low magnification camera had a field of view of 37w x 27h mm. The video from the underwater unit was transmitted to the ship via fiber optic cable and was recorded on board the ship using broadcast quality SONY BETACAM SP Recorders and 90 tapes (Model 55). The video also was fed into and image processor and SUN workstation to extract in-focus subimages and store them to disk. The VPR also contained a MOCNESS sensor package which included SeaBird temperature and conductivity sensors, a pressure sensor, a SeaTech fluorometer and transmissometer, an angle indicator, and a flowmeter. These ancillary data were recorded to computer hard disk on shipboard 2 times per second.

In general, the cruise was successful in terms of basic VPR sampling requirements, but, due to bad weather, we were not able to conduct a cross-bank towyo transect, as we had in the previous three cruises. Nonetheless, thirteen good VPR tows were made in the local vicinity of the drifters at each station (Figure 13), six at the south flank site (Station 1), four at the mixed area site (Station 2), and three at the return to the south flank site (Station 3). The VPR instrumentation worked perfectly throughout the cruise. The strobe bulb burned out once and had to be replaced. The wire jumped sheaves on two occasions, once at the crane boom and once on the traction head, due to rolling seas. Fifty two 1.5-hour video tapes were used representing 16.2 million individual video fields. Half of the video (i.e. from the low magnification camera) was processed in real time and thousands of images of plankton were recorded on disk and will be analyzed in the laboratory.

Calanus and *Pseudocalanus* were observed to be the dominant copepods at all sites on the bank. During the first tow (VPR 1 - day tow) (Figure 14), at Station 1 on the south flank, we found *Calanus* in the thin, warm, surface (< 5.0 m) layer. This layer resulted

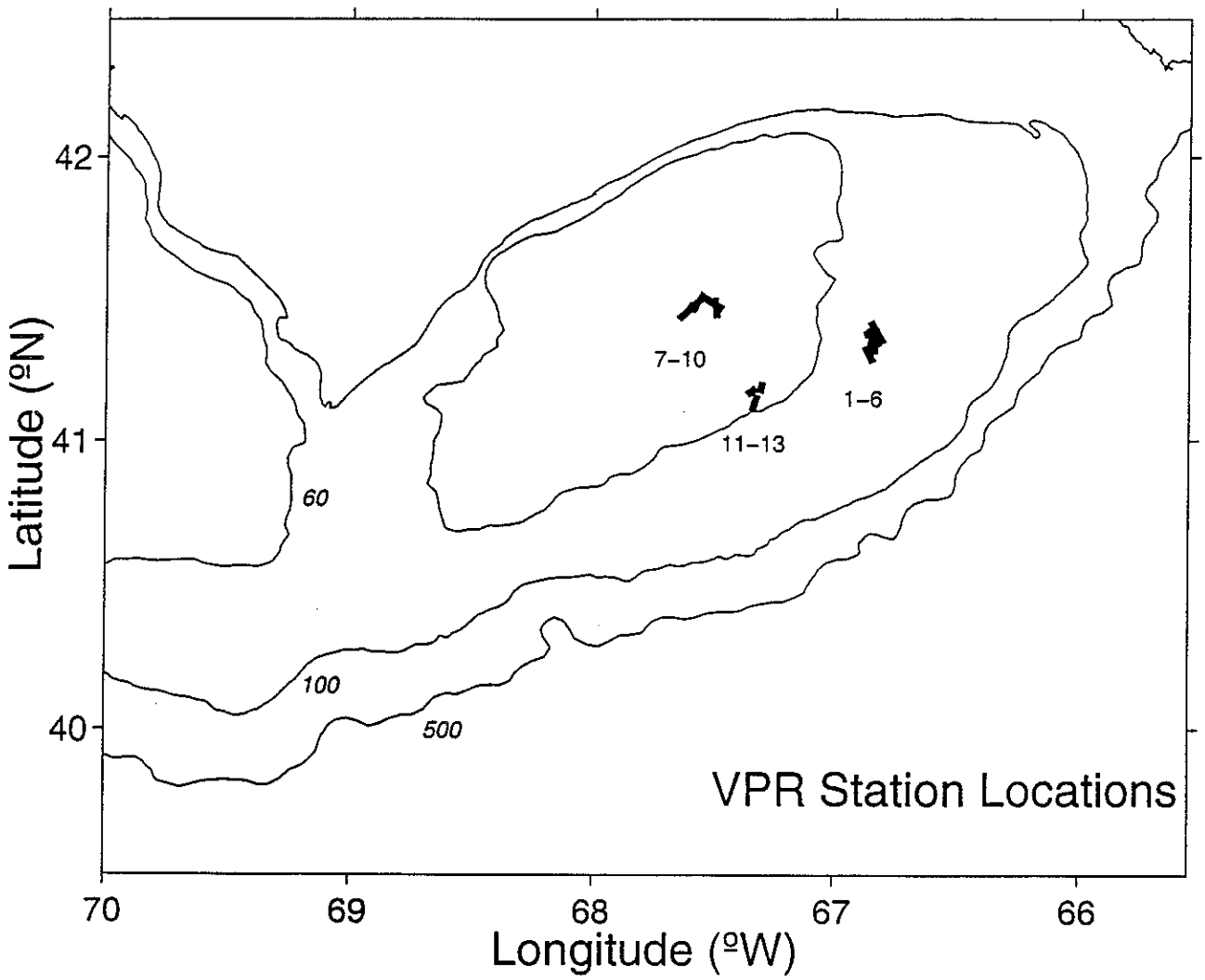

Figure 13. Location of VPR tows during EN266.

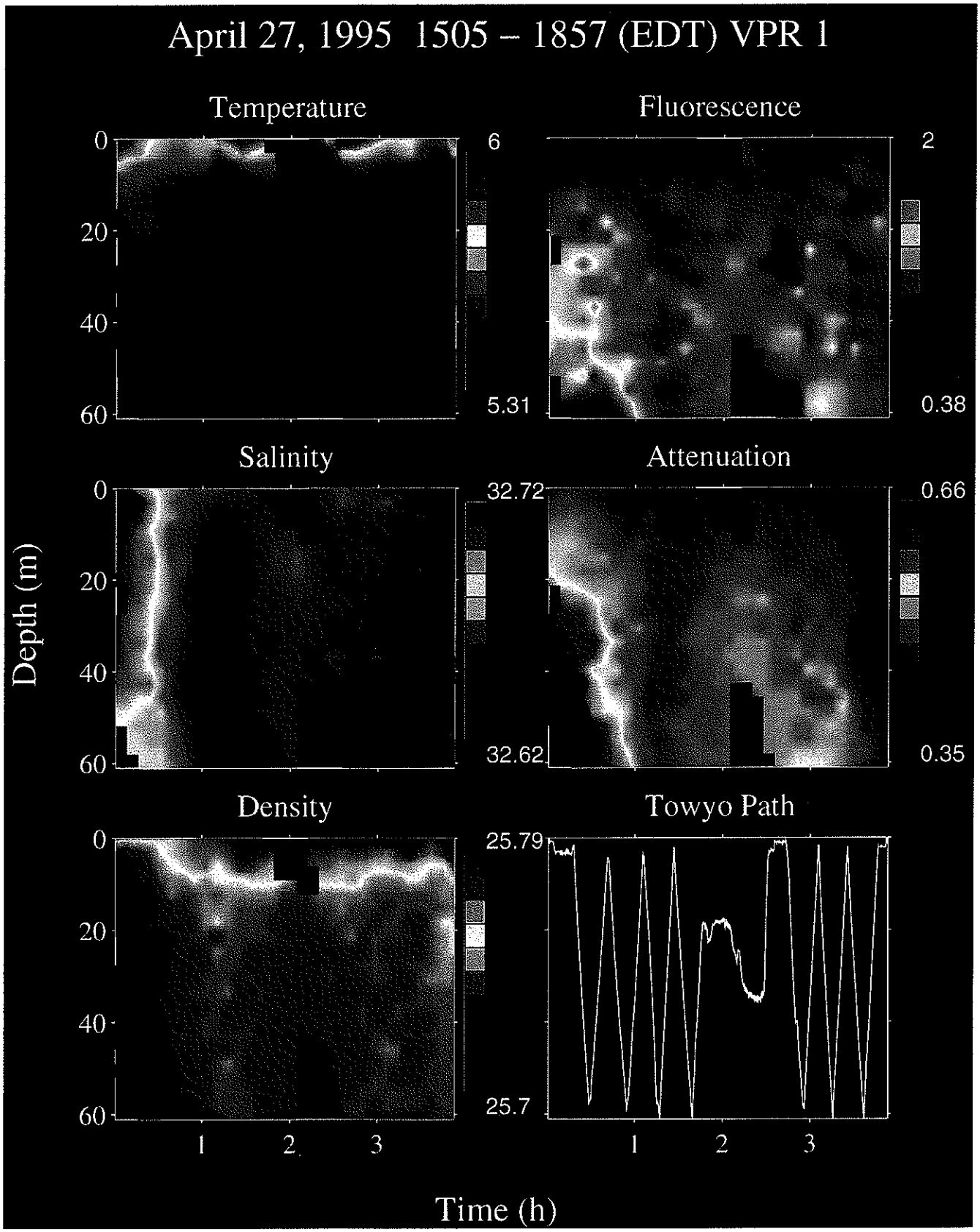

Figure 14. VPR 1.

from a vernal warming event due to calm winds and seas; salinity was uniform throughout the water column. The surface layer also had lower fluorescence and beam attenuation, and the water appeared quite "clear" on the video. Colonies of hydroid polyps, which are usually characteristic of the well mixed area, were found throughout the water column in large numbers, but the colonies appeared fragmented and not in good health. Very large clumps of marine snow were found in the lower half of the water column, consisting of diatoms and old hydroid colonies. Both fluorescence and beam attenuation were higher in the lower portion of the water column, coinciding with the dense layer of marine snow. The corresponding night tow (VPR 2) (Figure 15) was made in flat calm seas and revealed a similar hydrographic properties to the day tow. *Calanus* was still contained in the warm upper layer, but, unlike the day tow, there were many predatory forms present in this layer as well, including fish larvae, chaetognaths, ctenophores, and gammarid amphipods. Other vairables were distributed the same as during the day tow. Slight horizontal gradients in all variables were observed during most tows. VPR tows 3 (day) (Figure 16) and 4 (night) (Figure 17) were repeats of tows 1 and 2 and showed similar distributions. Tows 5 (day) (Figure 18) and 6 (night) (Figure 19), still at Station 1, were made during windy conditions and the warm layer had mixed down to 10-20 m by tow 5 and the water column was completely mixed by tow 6. The *Calanus* distributions mirrored that of temperature, i.e. by tow 5 the *Calanus* were restricted to 10-20 m and by tow 6 were distributed uniformly through the water column.

In the mixed area (Station 2), the water was warmer (6.7-6.8 °C) and saltier (33.01-33.04 psu) than at Station 1 (after mixing, temperature: 5.43-5.52 °C, salinity: 32.61-32.65 psu). The water column appeared to develop slight stratification during the day (eg. 0.1 °C for VPR 7 & 9) (Figures 20 and 22), but was well mixed at night (VPR 8 & 10) (Figures 21 and 23). We observed many larvae, which we believe to be cerianthids, distributed throughout the water column with perhaps greater concentration near the surface. Large, apparently healthy, hydroid colonies were also present in large numbers, throughout the water column as were diatoms (*Chaetoceros socialis, Coscinodiscus*) and the dinoflagellate (*Ceratium*) sp. *Pseudocalanus* were also observed. The night tows revealed higher concentrations of amphipods, medusae, and copepods at the surface. The storm between VPR 8 & 9 had apparently little effect on the plankton composition. Surprisingly little marine snow was present at this station.

Upon return to the stratified site (Station 3) (Figures 24-26), we found a warm surface layer (< 5 m) containing smaller copepods, younger life stages of *Calanus*. As before (Station 1), fluorescence and beam attenuation were very low in this layer and were highest near the bottom. There was little other than copepods in the shallow surface layer. The marine snow was smaller than before and appeared primarily as vertical strands (1 cm). Hydroids were about 1/4 of their former concentration at this site. Ninety percent of the observed plankton were copepods. Strong winds caused the shallow mixed layer to deepen to 10-15 m by tow 13.

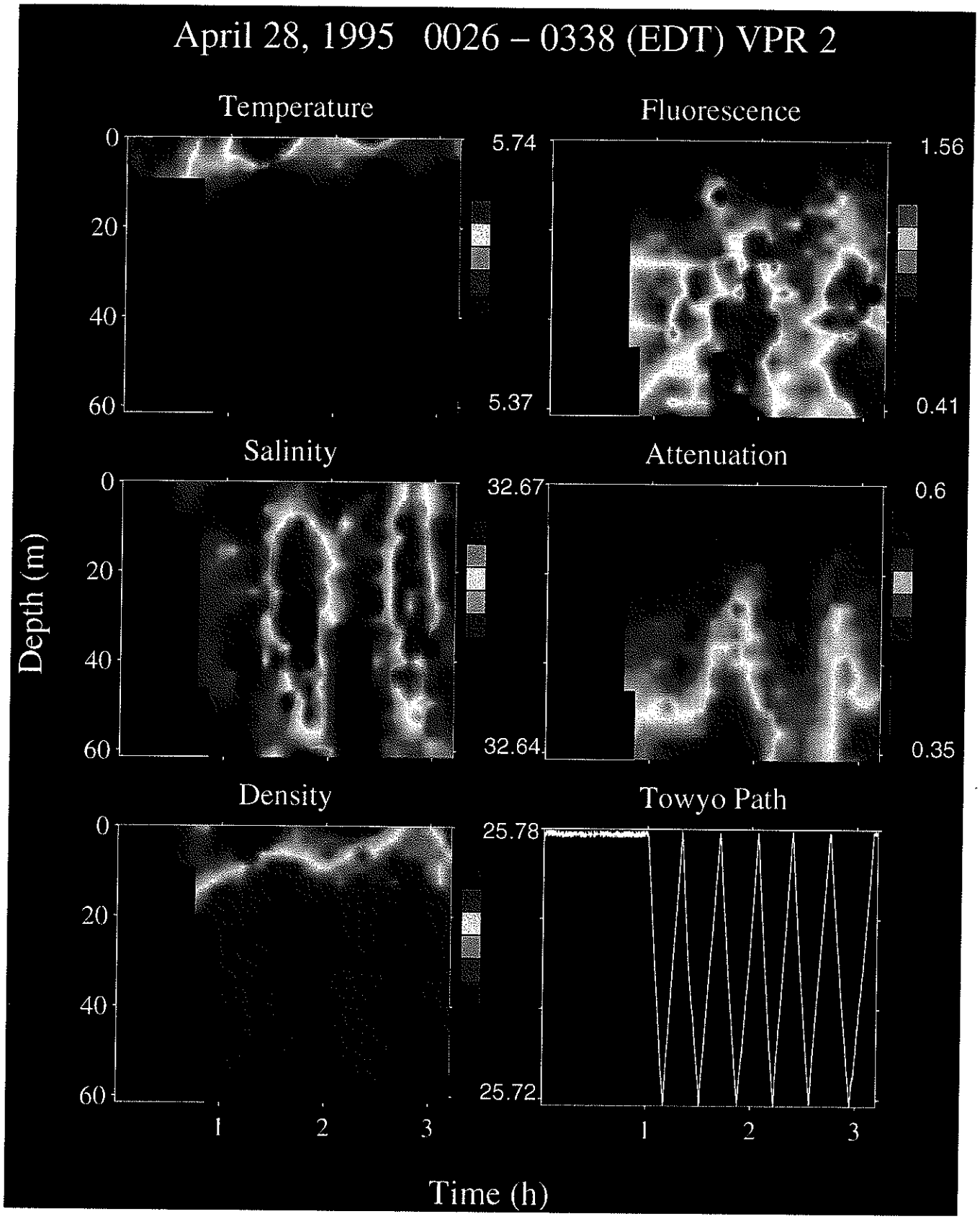

Figure 15. VPR 2.

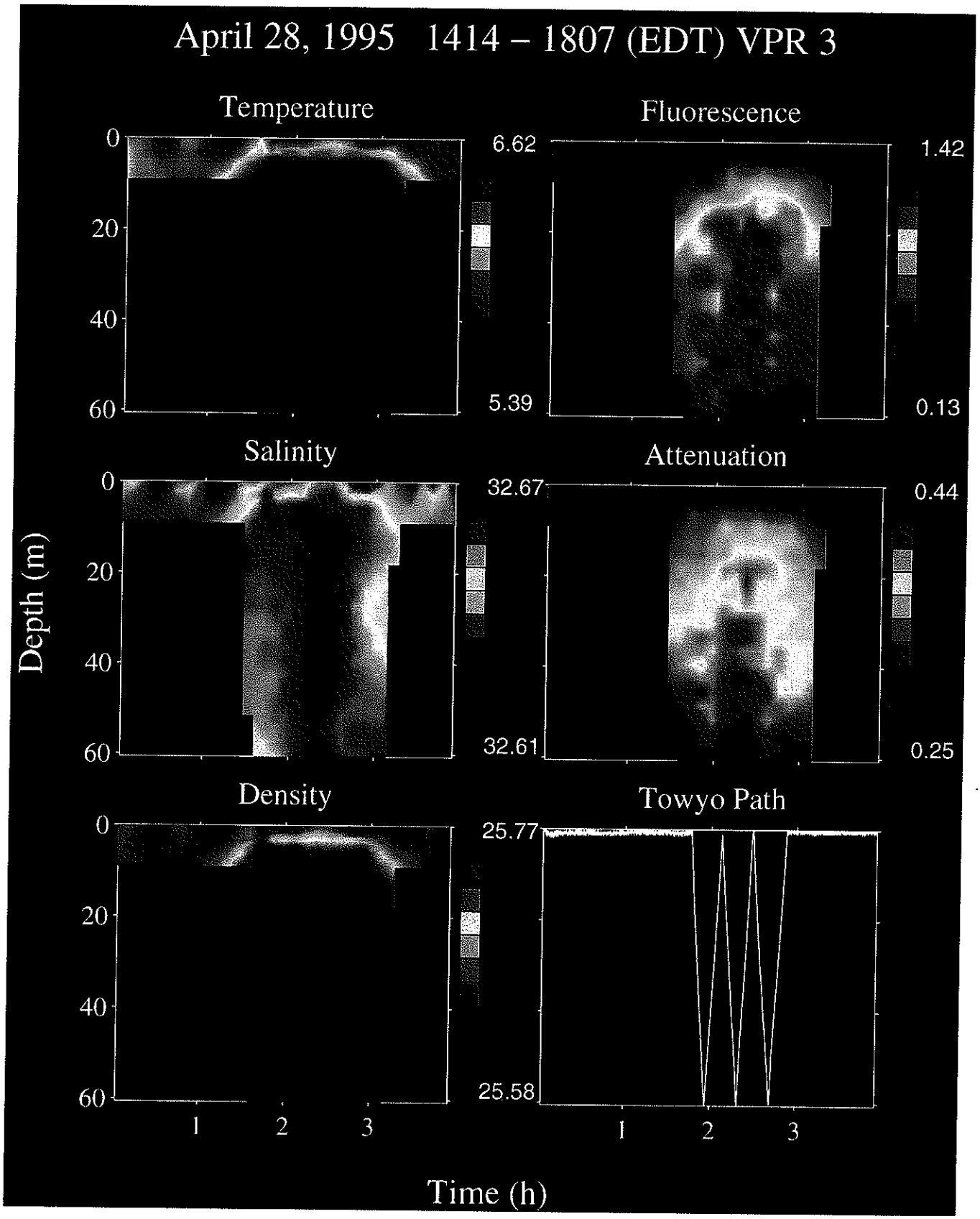

Figure 16. VPR 3.

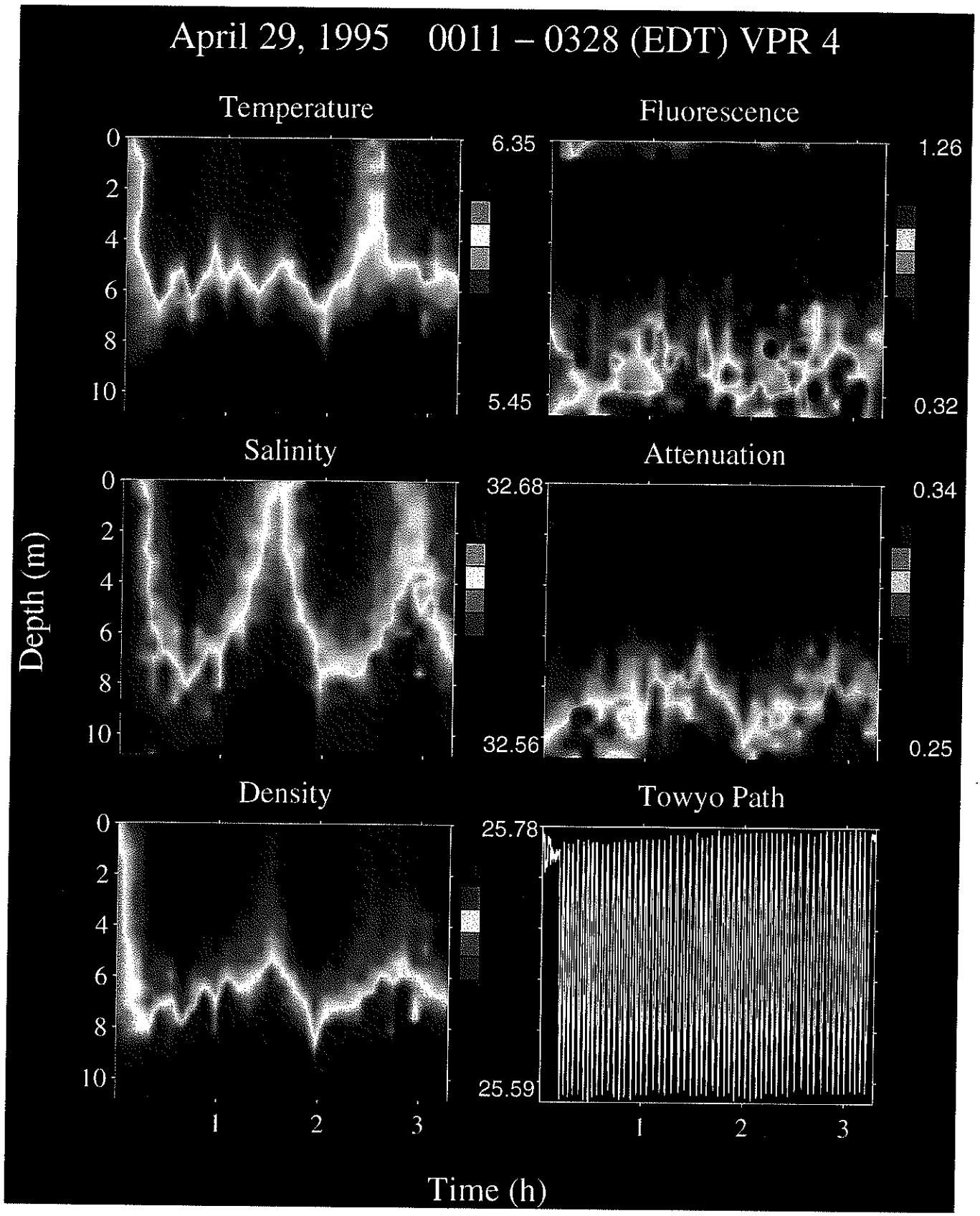

Figure 17. VPR 4.

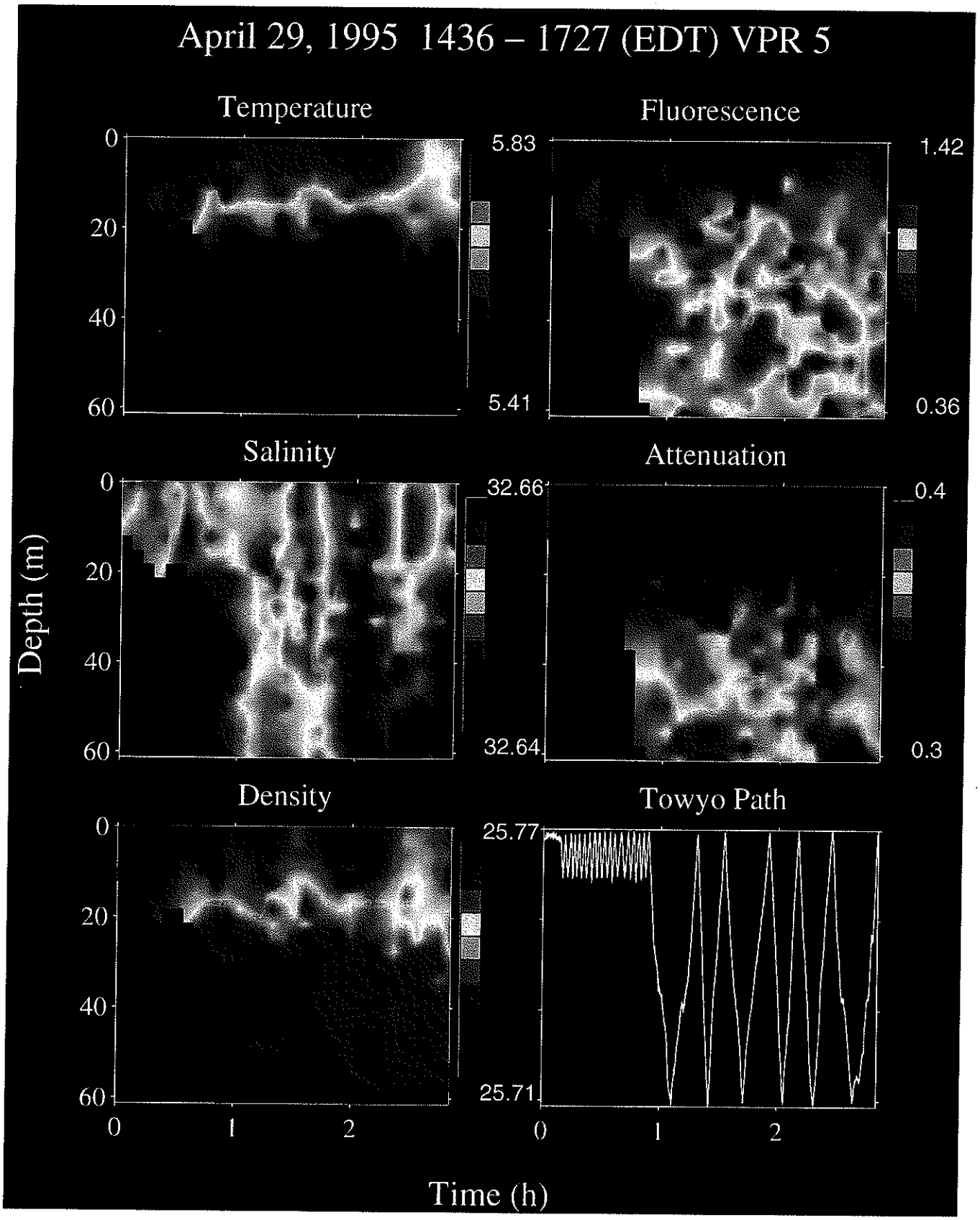

Figure 18. VPR 5.

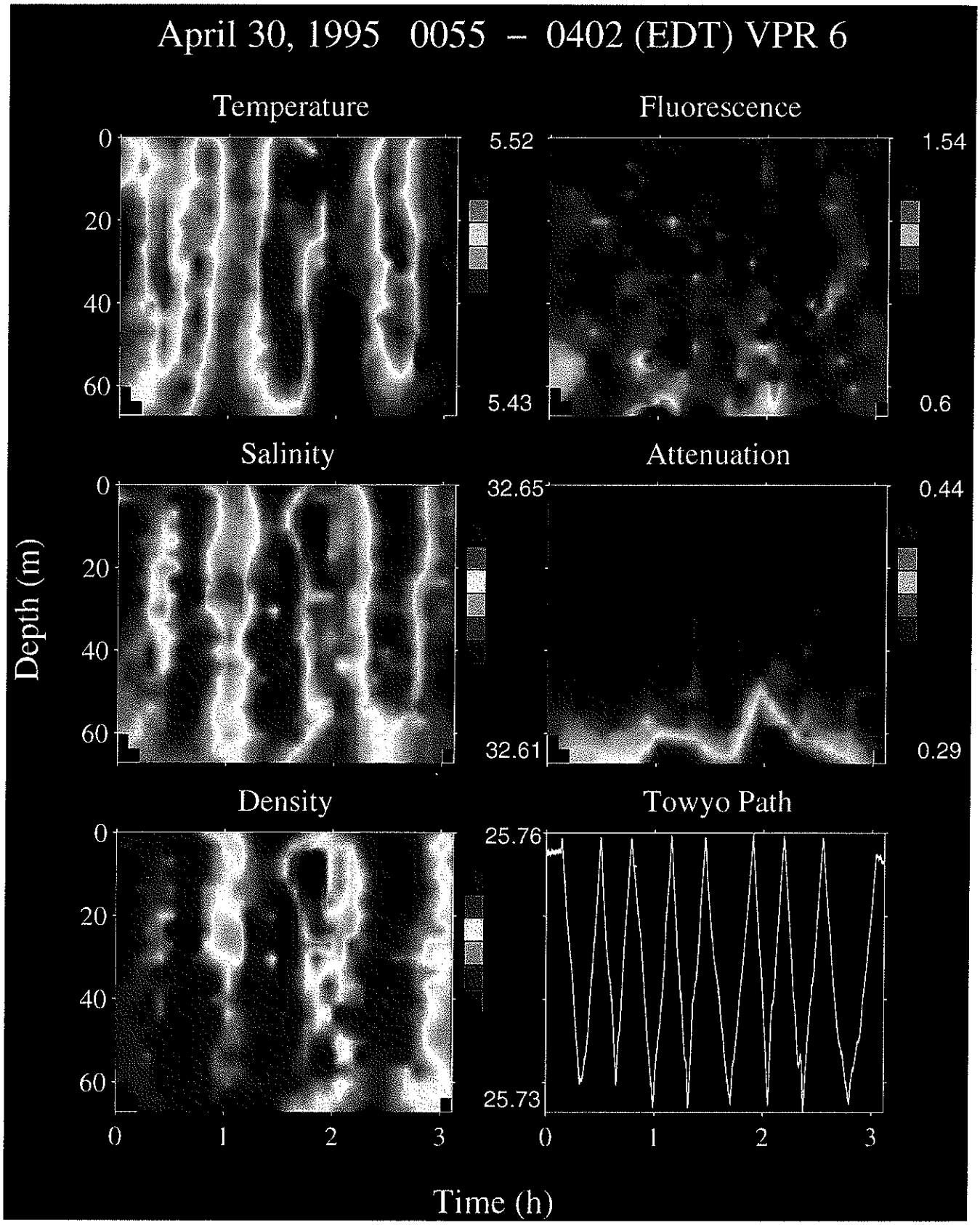

Figure 19. VPR 6.

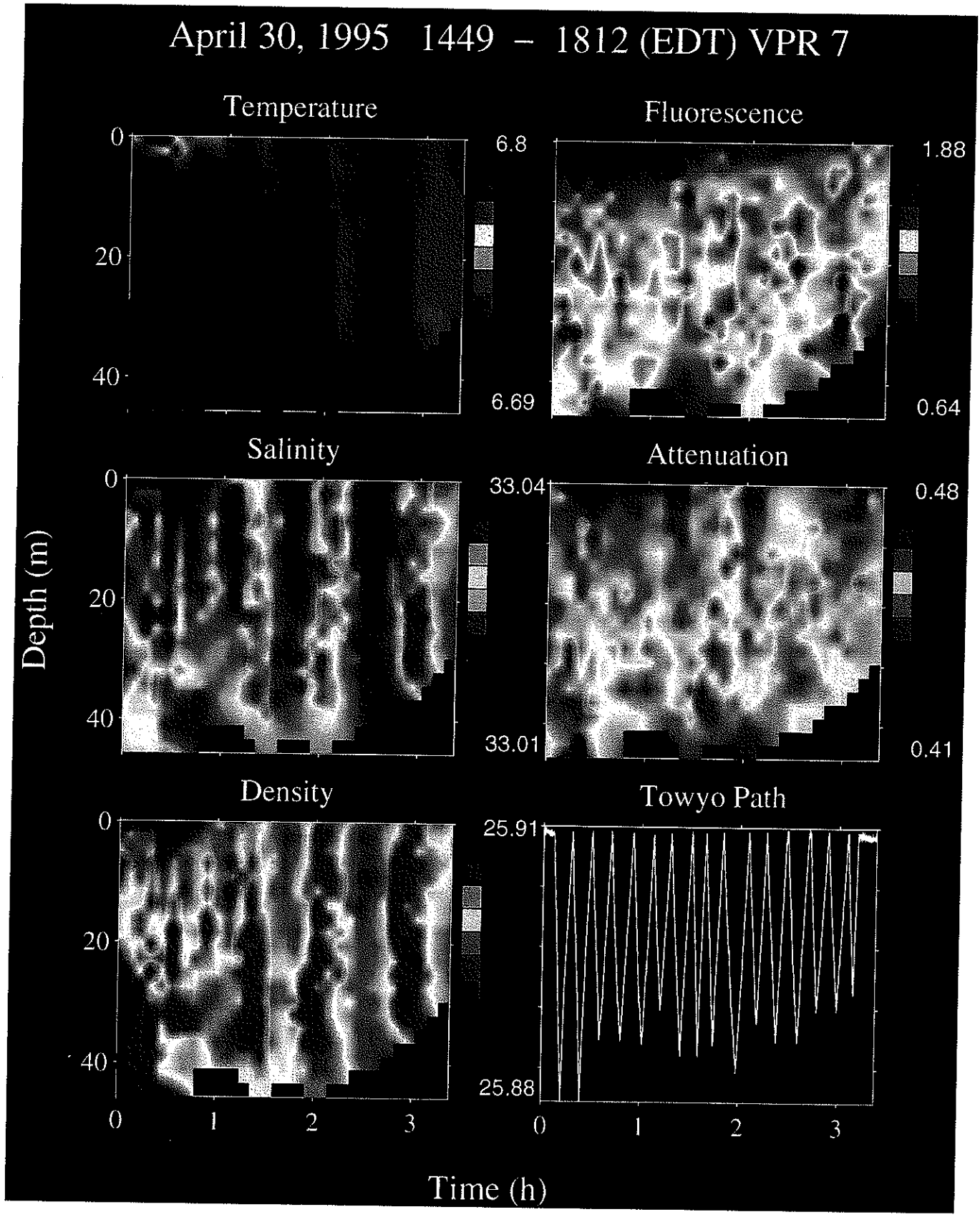

Figure 20. VPR 7.

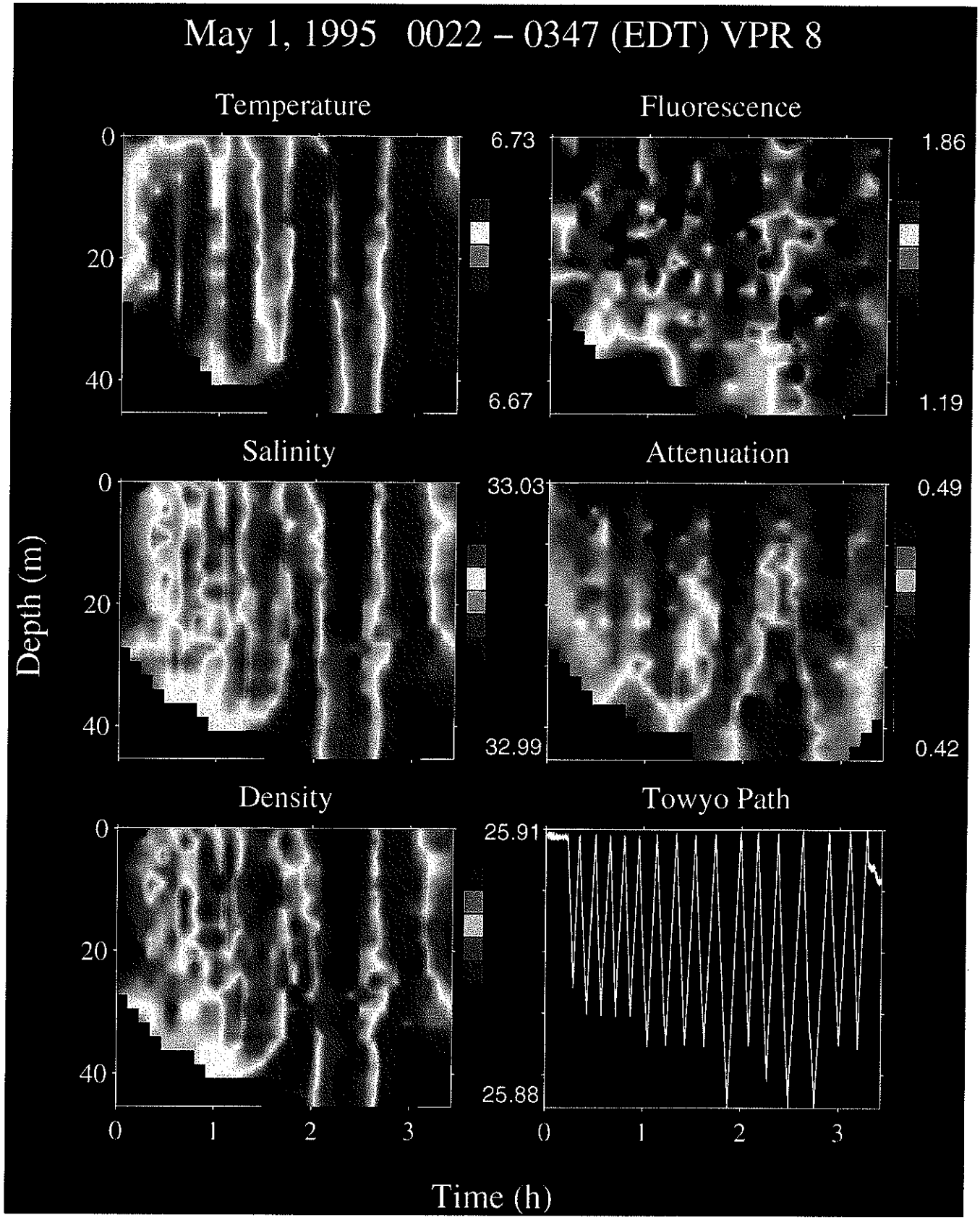

Figure 21. VPR 8.

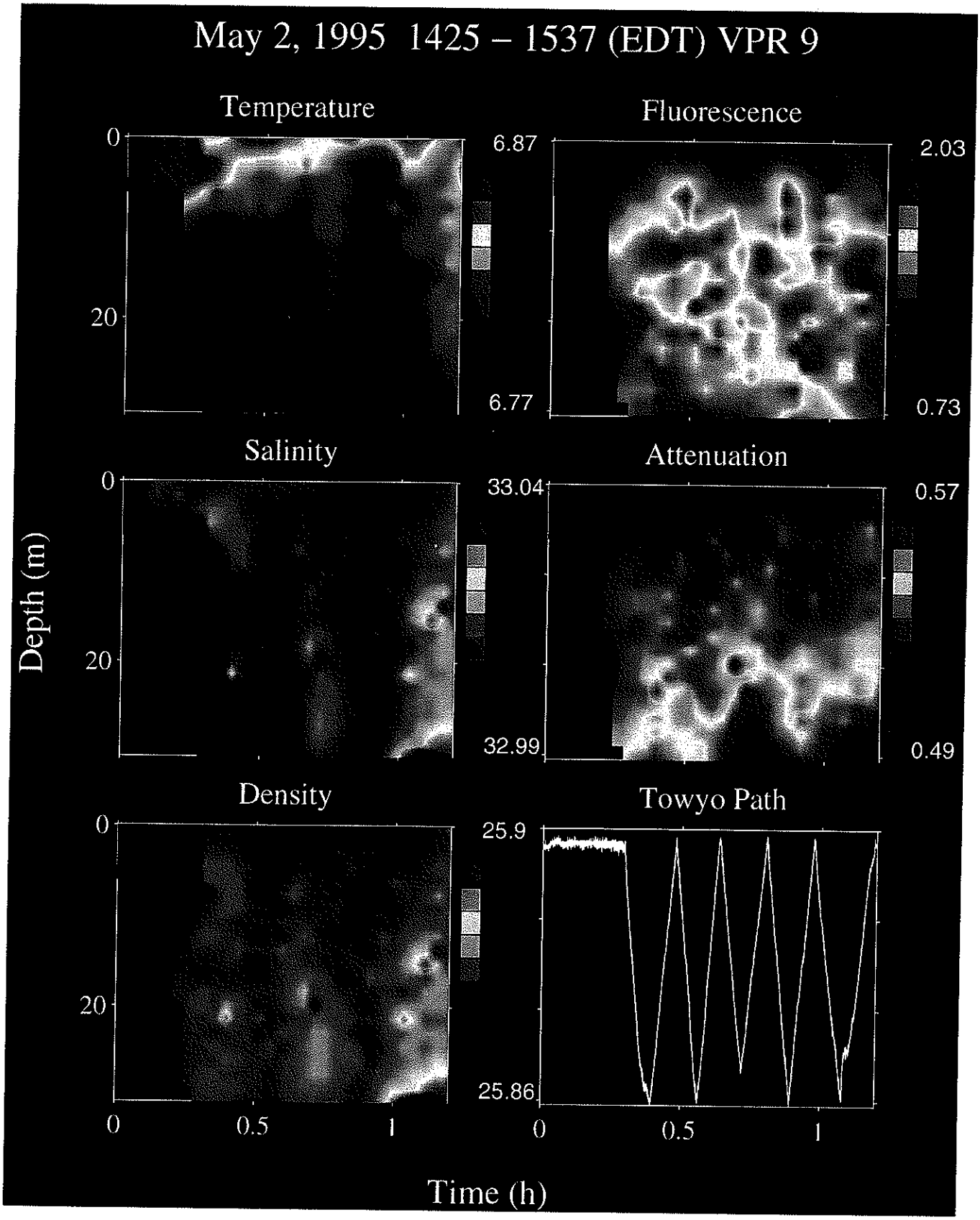

Figure 22. VPR 9.

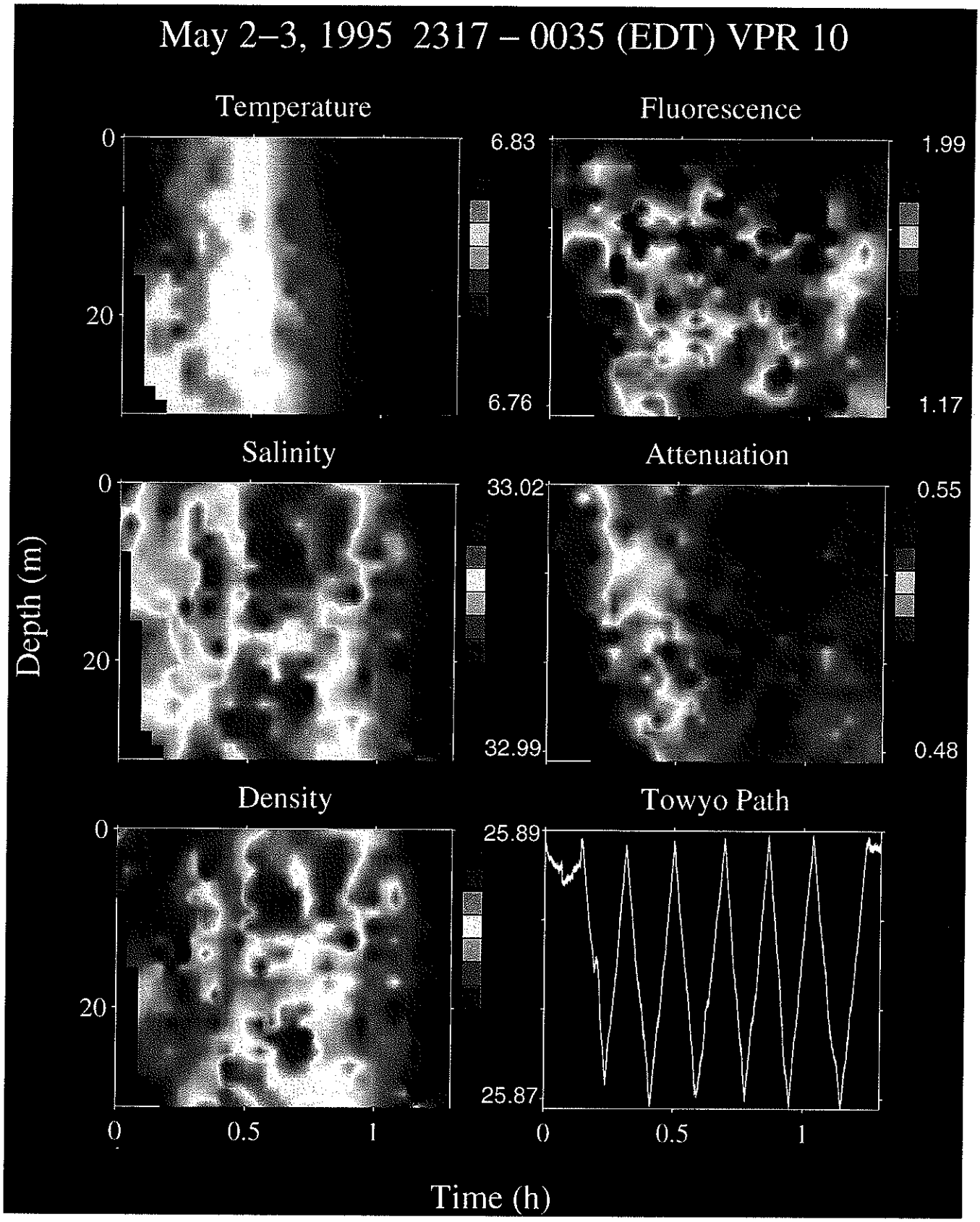

Figure 23. VPR 10.

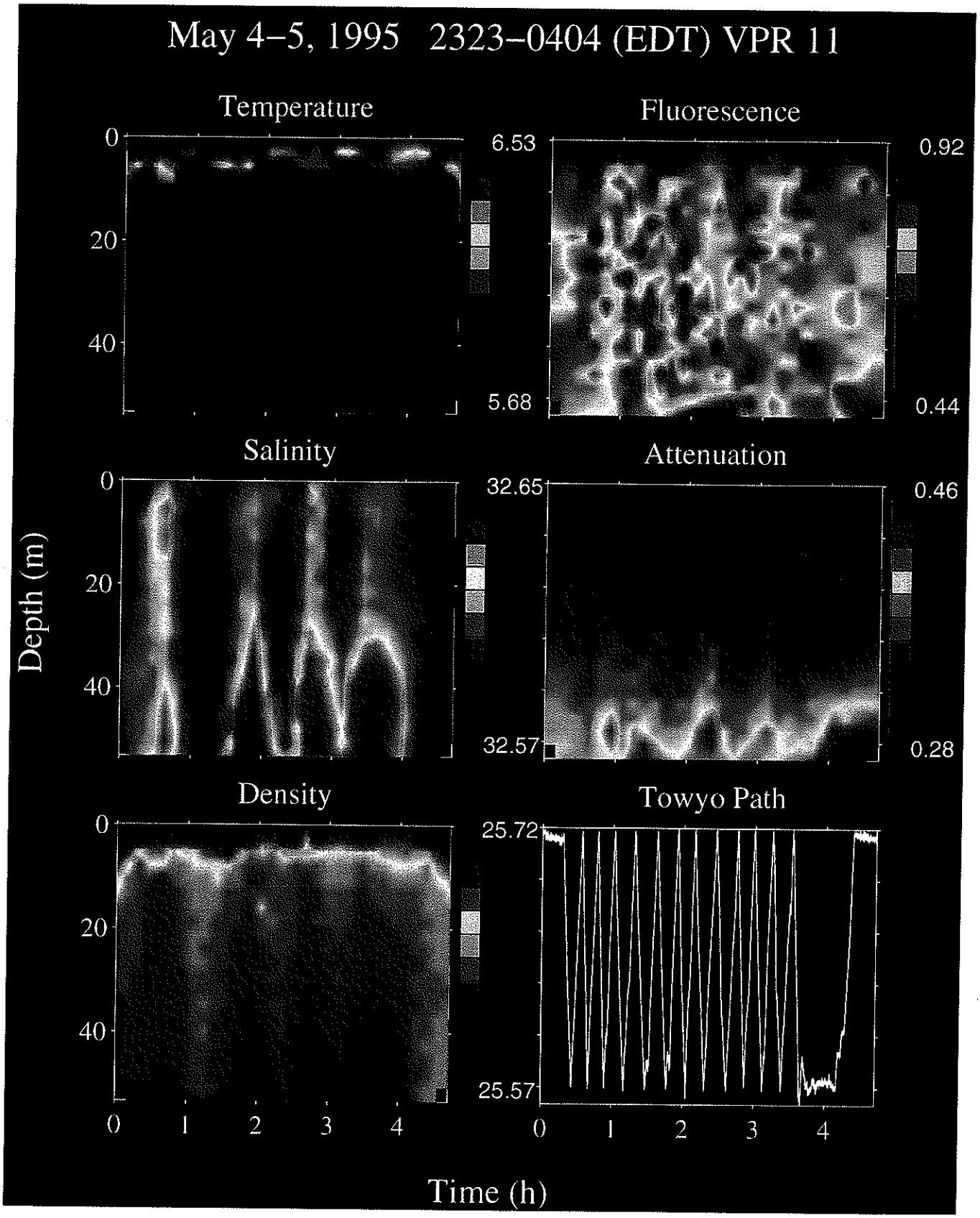

Figure 24. VPR 11.

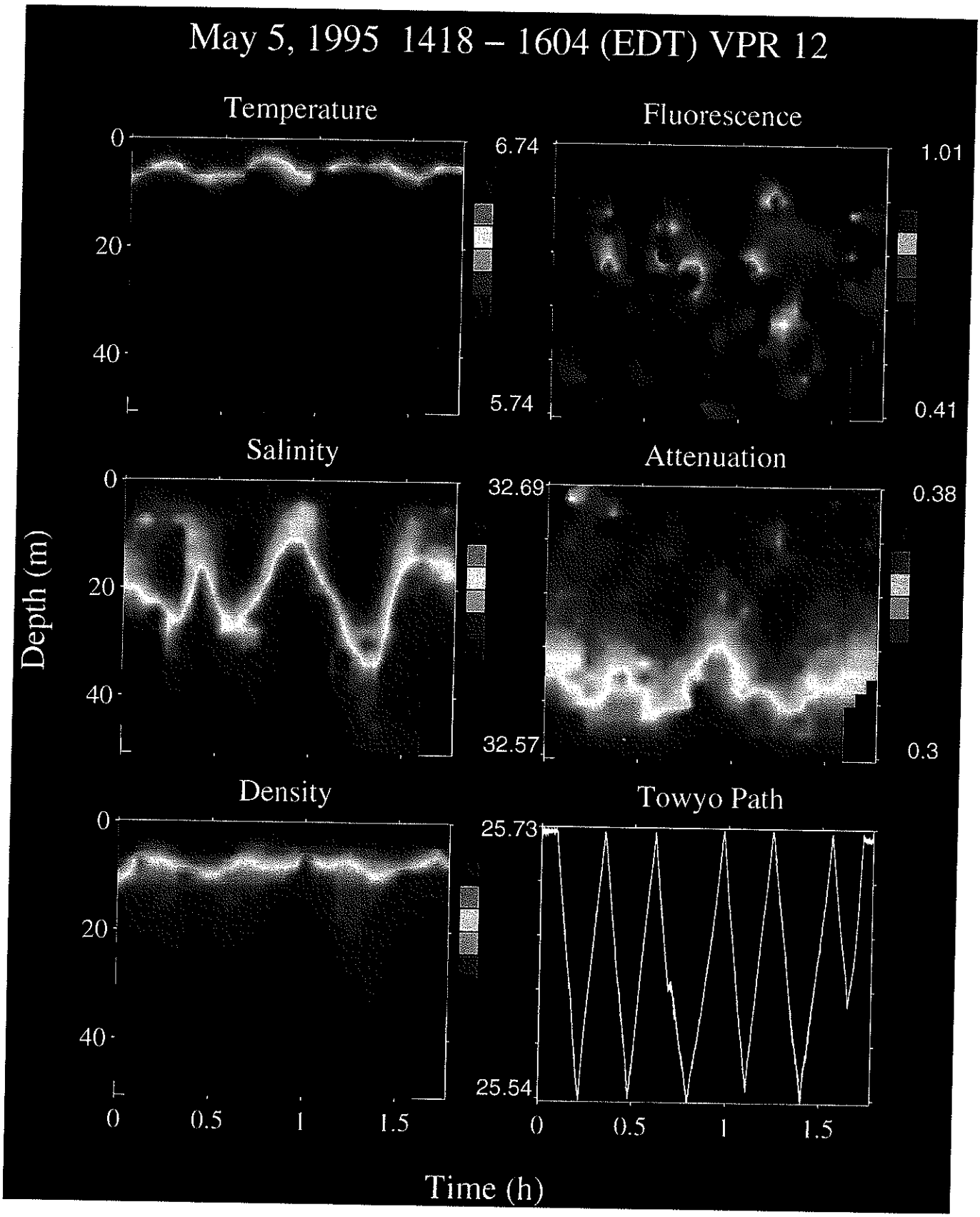

Figure 25. VPR 12.

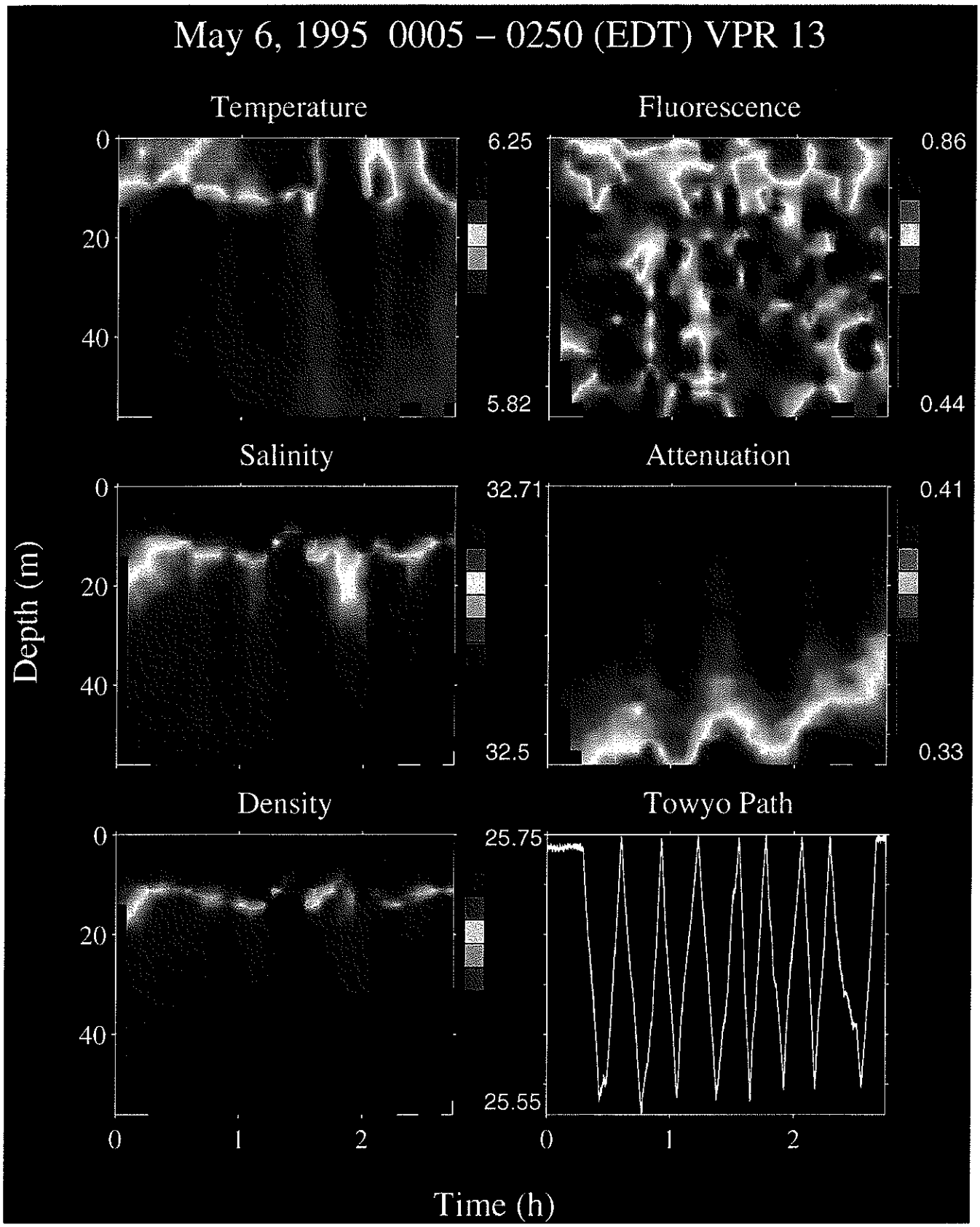

Figure 26. VPR 13.

VI. Solar Ultra-Violet (UV) Radiation and Planktonic Protozoan Survival (Elena Martin, Dian Gifford, Jeff Van Keuren, Al Hanson)

During EN266 three 2-day UV-exclusion incubation experiments were performed to determine the effects of ambient UV radiation on planktonic protozoa as part of my Ph.D. dissertation research. For the experiments, whole water samples were taken using Go-flo bottles from Stations 1, 2, and 3 (CTD casts 1, 17 and 36, respectively). Within each experiment 1-liter samples containing in situ protozoan and phytoplankton communities were incubated in UV transparent polyethylene bags suspended in flowing seawater under three conditions: Full sunlight; -UVB (280-320nm) mylar filtered sunlight; and UV (280-380nm) polycarbonate filtered sunlight. Initial (day 0) and final (day 2) samples were collected for microzooplankton enumeration (preserved in acid Lugols), chlorophyll concentration and nutrients. Epiflourescence slides were also made for microflagellate enumeration. Microzooplankton samples will be analyzed onshore.

In addition to the UV survival experiments a bag toxicity experiment was performed to determine if the bags themselves effected micro-zooplankton survival. Filtered water from Station 1 was exposed to UV in polyethylene bags and polycarbonate bottles for three days. Whole water from Station 2 was then added and incubated for 2 more days under -UV conditions. Microzooplankton, chlorophyll and nutrients were sampled at the end of the experiment. Microzooplankton survival will be compared between treatments by enumeration onshore.

UV light profiles were collected using the PUV-500 light meter at 1200 h every day to characterized UV light attenuation with in the water column, while shipboard incident UV was monitored all day using a PUV-510 light meter.

Science Personnel

Dian Gifford	University of Rhode Island	Chief Scientist
Cabell Davis	Woods Hole Oceanographic Institution	Scientist
Robert Campbell	University of Rhode Island	Scientist
Jeffrey VanKeuren	University of Rhode Island	Postdoctoral Scientist
Jeffrey Brown	Bigelow Laboratory for Ocean Sciences	Scientist
Philip Alatalo	Woods Hole Oceanographic Institution	Scientist
Stephane Plourde	Department of Fisheries and Oceans, Canada	Scientist
James Gibson	University of Rhode Island	Scientist
Andrew Girard	Woods Hole Oceanographic Institution	Scientist
David Nelson	University of Rhode Island	Marine Technician
Elena Martin	University of Rhode Island	Graduate Student
Paul Robbins	Woods Hole Oceanographic Institution	Graduate Student
Greg Teegarden	University of Rhode Island	Graduate Student

Ship's Personnel

Thomas Tyler	Master
Everett McMunn	Chief Mate
Robert Bates	Second Mate
Stephen Vetra	Boatswain
Glen Prouty	Able Seaman
David Rocha	Able Seaman
Paul Griffin	Able Seaman
William Appleton	Chief Engineer
James Cobleigh	Assistant Engineer
Timothy Varney	Assistant Engineer
Alexandre Bird	Steward/Cook
Brian Miller	Cook.Messman

APPENDIX 1. EN266 EVENT LOG

EN 266 Event Log

Event #	Instrumen	Cas	Sta	Local Mt	Local Da	Local hhmm	GM Day	GMT hhmm	s/e	Latitude	Longitude	Water Depth	Cast Dept	PI	Region
EN11795.001	DFT	1	1	4	27	642	27	1042	s	4120	6655.360	71	10	Durbin	Process
EN11795.002	PPN	1	1	4	27	658	27	1058	s	4120	6655.36	71	0.5	Durbin	Process
EN11795.003	NB-CTD	1	1	4	27	703	27	1103	s	4120.201	6655.511	69	64	Gifford	Process
	NB-CTD	1	1	4	27	717	27	1117	e	4120.500	6655.900			Gifford	Process
EN11795.004	ZPP/CTD	2	1	4	27	803	27	1203	s	4121.356	6656.278	69	64	Durbin	Process
	ZPP/CTD	2	1	4	27	839	27	1239	e	4121.975	6656.251			Durbin	Process
EN11795.005	MOC1	1	1	4	27	930	27	1330	s	4123.800	6656.800	68	55	Durbin	Process
	MOC1	1	1	4	27	948	27	1348	e	4124.400	6656.900	68		Durbin	Process
EN11795.006	ZPN	1	1	4	27	1100	27	1500	s	4123.560	6652.280	65	55	Durbin	Process
EN11795.007	ZPN	2	1	4	27	1110	27	1510	s	4123.560	6652.280	65	55	Durbin	Process
EN11795.008	DPP	1	1	4	27	1137	27	1537	s	4123.780	6654.170	71	5	Durbin	Process
	DPP	1	1	4	27	1149	27	1549	e	4129.740	6653.780			Durbin	Process
EN11795.009	PAR/PUV	1	1	4	27	1309	27	1709	s	4122.740	6651.640	69	40	VanKeuren	Process
	PAR/PUV	1	1	4	27	1323	27	1723	e	4122.450	6651.280			VanKeuren	Process
EN11795.010	NB-CTD	3	1	4	27	1407	27	1807	s	4122.153	6651.000	74	69	Gifford	Process
	NB-CTD	3	1	4	27	1418	27	1818	e	4121.850	6650.459			Gifford	Process
EN11795.011	VPR	1	1	4	27	1502	27	1902	s	4122.329	6652.865	69	59	Davis	Process
	VPR	1	1	4	27	1900	27	2300	e	4123.140	6648.810	72		Davis	Process
EN11795.012	NB-CTD	4	1	4	27	2015	28	15	s	4121.527	6655.189	71	66	Gifford	Process
	NB-CTD	4	1	4	27	2022	28	22	e	4121.830	6655.197			Gifford	Process
EN11895.001	VPR	2	1	4	28	26	28	426	s	4123.950	6651.540	70.3	60.3	Davis	Process
	VPR	2	1	4	28	348	28	748	e	4119.730	6649.170	70.9		Davis	Process
EN11895.002	PPN	2	1	4	28	900	28	1300	s	4121.680	6655.300	66	0.5	Durbin	Process
EN11895.003	ZPP/CTD	5	1	4	28	906	28	1306	s	4121.941	6655.229	71	66	Durbin	Process
	ZPP/CTD	5	1	4	28	930	28	1330	e	4121.723	6655.246			Durbin	Process
EN11895.004	DPP	2	1	4	28	1018	28	1418	s	4123.350	6654.620	71	15	Durbin	Process
	DPP	2	1	4	28	1034	28	1434	e	4123.690	6654.460			Durbin	Process
EN11895.005	ZPN	3	1	4	28	1100	28	1500	s	4124.85	6653.45	66	55	Durbin	Process
EN11895.006	ZPN	4	1	4	28	1110	28	1510	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.007	ZPN	5	1	4	28	1120	28	1520	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.008	ZPN	6	1	4	28	1130	28	1530	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.009	ZPN	7	1	4	28	1145	28	1545	s	4124.85	6653.45	66	45	Durbin	Process

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EN11895.010	ZPN	8	1	4	28	1200	28	1600	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.011	ZPN	9	1	4	28	1210	28	1610	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.012	ZPN	10	1	4	28	1220	28	1620	s	4124.85	6653.45	66	45	Durbin	Process
EN11895.013	PAR/PUV	2	1	4	28	1249	28	1649	s	4124.208	6652.430	74	40	VanKeuren	Process
	PAR/PUV	2	1	4	28	1302	28	1702	e	4124.090	6652.140			VanKeuren	Process
EN11895.014	NB-CTD	6	1	4	28	1308	28	1708	s	4124.064	6652.020	74	70	Gifford	Process
	NB-CTD	6	1	4	28	1317	28	1717	e	4123.970	6651.810			Gifford	Process
EN11895.015	VPR	3	1	4	28	1412	28	1812	s	4123.320	6650.460	70.5	60	Davis	Process
	VPR	3	1	4	28	1823	28	2223	e	4119.720	6651.400	69		Davis	Process
EN11895.016	ZPP/CTD	7	1	4	28	2106	29	106	s	4122.817	6654.099	72	65	Durbin	Process
	ZPP/CTD	7	1	4	28	2126	29	126	e	4123.451	6654.152			Durbin	Process
EN11895.017	NB-CTD	8	1	4	28	2203	29	203	s	4123.770	6653.880	70	65	Gifford	Process
	NB-CTD	8	1	4	28	2210	29	210	e	4123.975	6653.765			Gifford	Process
EN11995.001	VPR	4	1	4	29	10	29	410	s	4125.270	6651.200	70.5	60	Davis	Process
	VPR	4	1	4	29	340	29	740	e	4120.480	6648.130	72		Davis	Process
EN11995.002	ZPP/CTD	9	1	4	29	904	29	1304	s	4119.888	6654.248	72	65	Durbin	Process
	ZPP/CTD	9	1	4	29	927	29	1327	e	4120.093	6654.360			Durbin	Process
EN11895.003	ZPN	11	1	4	29	1020	29	1420	s	4124.600	6653.000	72	1	Durbin	Process
EN11995.004	ZPN	12	1	4	29	1100	29	1500	s	4121.920	6654.460	66	5	Durbin	Process
EN11995.005	ZPN	13	1	4	29	1110	29	1510	s	4121.920	6654.460	66	2	Durbin	Process
EN11995.006	PAR/PUV	3	1	4	29	1213	29	1613	s	4122.450	6653.390	73	40	VanKeuren	Process
	PAR/PUV	3	1	4	29	1222	29	1622	e	4122.390	6652.100			VanKeuren	Process
EN11995.007	NB-CTD	10	1	4	29	1304	29	1704	s	4122.682	6652.199	74	67	Gifford	Process
	NB-CTD	10	1	4	29	1316	29	1716	e	4122.466	6652.733			Gifford	Process
EN11995.008	NB-CTD	11	1	4	29	1346	29	1746	s	4122.297	6651.671	74	68	Gifford	Process
	NB-CTD	11	1	4	29	1358	29	1758	e	4122.042	6651.315			Gifford	Process
EN11995.009	VPR	5	1	4	29	1430	29	1830	s	4121.670	6650.690	69	60	Davis	Process
	VPR	5	1	4	29	1737	29	2137	e	4118.230	6650.140	70.7		Davis	Process
EN11995.010	NB-CTD	12	1	4	29	2015	30	15	s	4117.362	6652.560	72	69	Gifford	Process
	NB-CTD	12	1	4	29	2023	30	23	e	4117.504	6652.806			Gifford	Process
EN11995.011	ZPP/CTD	13	1	4	29	2106	30	106	s	4118.200	6654.200	72	65	Durbin	Process
	ZPP/CTD	13	1	4	29	2139	30	139	e	4118.949	6655.265			Durbin	Process
EN12095.001	VPR	6	1	4	30	53	30	453	s	4119.930	6652.590	68	60	Davis	Process
	VPR	6	1	4	30	412	30	812	e	4116.480	6650.660	68		Davis	Process
EN12095.002	DFT	2	2	4	30	735	30	1135	s	4125.600	6732.900	45	10	Durbin	Process

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EN12095.003	NB-CTD	14	2	4	30	809	30	1209	s	4125.947	6733.708	41	33	Gifford	Process
	NB-CTD	14	2	4	30	814	30	1214	e	4126.031	6733.867			Gifford	Process
EN12095.004	ZPP/CTD	15	2	4	30	900	30	1300	s	4126.842	6734.876	41	33	Durbin	Process
	ZPP/CTD	15	2	4	30	912	30	1312	e	4127.181	6735.137			Durbin	Process
EN12095.005	MOC1	2	2	4	30	1007	30	1407	s	4128.600	6735.500	35	30	Durbin	Process
	MOC1	2	2	4	30	1018	30	1418	e	4129.610	6735.350	35		Durbin	Process
EN12095.006	MOC1	3	2	4	30	1030	30	1430	s	4130.200	6735.000	43	33	Durbin	Process
	MOC1	3	2	4	30	1039	30	1439	e	4130.850	6734.770	38		Durbin	Process
EN12095.007	ZPN	14	2	4	30	1100	30	1500	s	4131.380	6734.280	30	25	Durbin	Process
EN12095.008	ZPN	15	2	4	30	1115	30	1515	s	4131.380	6734.280	30	25	Durbin	Process
EN12095.009	PAR/PUV	4	2	4	30	1311	30	1711	s	4131.830	6732.180	44	30	VanKeuren	Process
	PAR/PUV	4	2	4	30	1319	30	1719	e	4131.740	6731.960			VanKeuren	Process
EN12095.010	NB-CTD	16	2	4	30	1413	30	1813	s	4131.083	6730.420	44	40	Gifford	Process
	NB-CTD	16	2	4	30	1421	30	1821	e	4130.865	6730.224			Gifford	Process
EN12095.011	VPR	7	2	4	30	1443	30	1843	s	4130.280	6729.770	42.6	35	Davis	Process
	VPR	7	2	4	30	1822	30	2222	e	4125.910	6729.180	39		Davis	Process
EN12095.012	NB-CTD	17	2	4	30	2004	1	4	s	4125.742	6732.118	43	38	Gifford	Process
	NB-CTD	17	2	4	30	2011	1	11	e	4125.870	6732.419			Gifford	Process
EN12195.001	VPR	8	2	5	1	21	1	421	s	4130.930	6733.680	37	35	Davis	Process
	VPR	8	2	5	1	354	1	754	e	4127.730	6727.710	41		Davis	Process
EN12195.002	ZPP/CTD	18	2	5	1	905	1	1305	s	4126.160	6734.416	39	33	Durbin	Process
	ZPP/CTD	18	2	5	1	918	1	1318	e	4126.633	6734.717			Durbin	Process
EN12195.003	ZPN	16	2	5	1	1100	1	1500	s	4130.310	6734.920	35	25	Durbin	Process
EN12195.004	ZPN	17	2	5	1	1110	1	1510	s	4130.310	6734.920	35	25	Durbin	Process
EN12195.005	ZPN	18	2	5	1	1120	1	1520	s	4130.310	6734.920	35	26	Durbin	Process
EN12195.006	PAR/PUV	5	2	5	1	1232	1	1632	s	4132.270	6734.400	32	30	VanKeuren	Process
	PAR/PUV	5	2	5	1	1244	1	1644	e	4132.530	6734.400			VanKeuren	Process
EN12195.007	NB-CTD	19	2	5	1	1256	1	1656	s	4132.826	6733.754	32	26	Gifford	Process
	NB-CTD	19	2	5	1	1303	1	1703	e	4132.982	6733.347			Gifford	Process
EN12295.001	ZPP/CTD	20	2	5	2	1036	2	1436	s	4124.950	6740.110	34	30	Durbin	Process
	ZPP/CTD	20	2	5	2	1055	2	1455	e	4125.468	6740.468			Durbin	Process
EN12295.002	ZPN	19	2	5	2	1115	2	1515	s	4126.810	6740.040	39	30	Durbin	Process
EN12295.003	ZPN	20	2	5	2	1130	2	1530	s	4126.810	6740.040	39	30	Durbin	Process
EN12295.004	PAR/PUV	6	2	5	2	1152	2	1552	s	4126.810	6740.040	37	30	VanKeuren	Process
	PAR/PUV	6	2	5	2	1203	2	1603	e	4127.017	6740.000			VanKeuren	Process

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EN12295.005	NB-CTD	21	2	5	2	1308	2	1708	s	4128.314	6739.344	37	30	Gifford	Process
	NB-CTD	21	2	5	2	1315	2	1715	e	4128.424	6739.117			Gifford	Process
EN12295.006	VPR	9	2	5	2	1423	2	1823	s	4128.900	6736.320	39	35	Davis	Process
	VPR	9	2	5	2	1535	2	1935	e	4127.590	6734.030			Davis	Process
EN12295.007	NB-CTD	22	2	5	2	2100	3	100	s	4122.978	6737.498	36	30	Gifford	Process
	NB-CTD	22	2	5	2	2107	3	107	e	4123.060	6737.830			Gifford	Process
EN12295.008	ZPP/CTD	23	2	5	2	2115	3	115	s	4123.170	6738.278	32	30	Durbin	Process
	ZPP/CTD	23	2	5	2	2125	3	125	e	4123.358	6738.784			Durbin	Process
	DFT	2	2	5	2	2247	3	247	e	4124.950	6738.800		10	Durbin	Process
EN12295.009	VPR	10	2	5	2	2315	3	315	s	4125.660	6738.730	37	35	Davis	Process
	VPR	10	2	5	3	45	3	445	e	4130.330	6732.670			Davis	Process
EN12495.001	NB-CTD	24	A-1	5	4	553	4	953	s	4108.932	6746.562	44	39	Gifford	Process
	NB-CTD	24	A-1	5	4	600	4	1000	e	4108.751	6746.423			Gifford	Process
EN12495.002	NB-CTD	25	A-2	5	4	637	4	1037	s	4105.600	6744.080	43	40	Gifford	Process
	NB-CTD	25	A-2	5	4	642	4	1042	e	4105.371	6744.010			Gifford	Process
EN12495.003	NB-CTD	26	A-3	5	4	716	4	1116	s	4102.228	6741.218	58	57	Gifford	Process
	NB-CTD	26	A-3	5	4	722	4	1122	e	4102.104	6741.146			Gifford	Process
EN12495.004	NB-CTD	27	A-4	5	4	755	4	1155	s	4058.846	6738.562	67	60	Gifford	Process
	NB-CTD	27	A-4	5	4	802	4	1202	e	4058.801	6738.566			Gifford	Process
EN12495.005	NB-CTD	28	A-5	5	4	844	4	1244	s	4055.460	6736.090	72	65	Gifford	Process
	NB-CTD	28	A-5	5	4	852	4	1252	e	4055.430	6736.061			Gifford	Process
EN12495.006	NB-CTD	29	A-6	5	4	930	4	1330	s	4052.029	6733.790	76	73	Gifford	Process
	NB-CTD	29	A-6	5	4	940	4	1340	e	4052.086	6733.7			Gifford	Process
EN12495.007	ZPN	21	A-6	5	4	1000	4	1400	s	4052.170	6733.830	72	55	Durbin	Process
EN12495.008	ZPN	22	A-6	5	4	1010	4	1410	s	4052.170	6733.830	72	55	Durbin	Process
EN12495.009	PAR/PUV	7	A-6	5	4	1025	4	1425	s	4052.170	6733.690	76	46	VanKeuren	Process
	PAR/PUV	7	A-6	5	4	1034	4	1434	e	4052.310	6733.870			VanKeuren	Process
EN12495.010	NB-CTD	30	A-7	5	4	1130	4	1530	s	4048.727	6730.898	84	78	Gifford	Process
	NB-CTD	30	A-7	5	4	1137	4	1537	e	4048.811	6731.053			Gifford	Process
EN12495.011	NB-CTD	31	A-8	5	4	1236	4	1636	s	4045.085	6728.168	89	84	Gifford	Process
	NB-CTD	31	A-8	5	4	1245	4	1645	e	4045.192	6728.334			Gifford	Process
EN12495.012	NB-CTD	32	A-9	5	4	1325	4	1725	s	4041.550	6725.580	96	90	Gifford	Process
	NB-CTD	32	A-9	5	4	1332	4	1732	e	4041.600	6725.728			Gifford	Process
EN12495.013	NB-CTD	33	A-1	5	4	1410	4	1810	s	4038.060	6722.550	96	89	Gifford	Process
	NB-CTD	33	A-1	5	4	1420	4	1820	e	4038.042	6722.778			Gifford	Process

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EN12495.014	NB-CTD	34	A-1	5	4	1454	4	1854	s	4034.682	6719.879	118	115	Gifford	Process
	NB-CTD	34	A-1	5	4	1506	4	1906	e	4034.703	6719.990			Gifford	Process
EN12495.015	NB-CTD	35	A-1	5	4	1542	4	1942	s	4031.163	6717.087	139	133	Gifford	Process
	NB-CTD	35	A-1	5	4	1553	4	1953	e	4031.211	6717.208			Gifford	Process
EN12495.016	MOC1	4	A-1	5	4	1620	4	2020	s	4031.200	6716.600	140	126	Durbin	Process
	MOC1	4	A-1	5	4	1645	4	2045	e	4031.300	6717.000			Durbin	Process
EN12495.017	PAR/PUV	8	A-1	5	4	1654	4	2054	s	4031.200	6717.000	118	45	VanKeuren	Process
	PAR/PUV	8	A-1	5	4	1706	4	2106	e	4031.266	6717.130			VanKeuren	Process
EN12495.018	NB-CTD	36	3	5	4	2133	5	133	s	4106.385	6720.894	62	55	Gifford	Process
	NB-CTD	36	3	5	4	2142	5	142	e	4106.467	6720.941			Gifford	Process
EN12495.019	ZPP/CTD	37	3	5	4	2209	5	209	s	4106.481	6720.993	63	57	Durbin	Process
	ZPP/CTD	37	3	5	4	2240	5	240	e	4106.701	6720.950			Durbin	Process
EN12495.020	VPR	11	3	5	4	2320	5	320	s	4106.150	6720.340	60	50	Davis	Process
	VPR	11	3	5	5	410	5	810	e	4109.670	6719.050	54		Davis	Process
EN12595.001	ZPP/CTD	38	3	5	5	918	5	1318	s	4106.173	6719.060	62	55	Durbin	Process
	ZPP/CTD	38	3	5	5	941	5	1341	e	4106.205	6719.415			Durbin	Process
EN12595.002	MOC1	5	3	5	5	1014	5	1414	s	4106.200	6719.300	61	50	Durbin	Process
	MOC1	5	3	5	5	1029	5	1429	e	4106.2	6718.8	63		Durbin	Process
EN12595.003	ZPN	23	3	5	5	1100	5	1500	s	4106.750	6720.920	58	10	Durbin	Process
EN12595.004	ZPN	24	3	5	5	1110	5	1510	s	4106.750	6720.920	58	5	Durbin	Process
EN12595.005	PAR/PUV	9	3	5	5	1217	5	1617	s	4107.600	6721.630	60	40	VanKeuren	Process
	PAR/PUV	9	3	5	5	1230	5	1630	e	4107.930	6721.770			VanKeuren	Process
EN12595.006	NB-CTD	39	3	5	5	1302	5	1702	s	4108.675	6722.023	59	56	Gifford	Process
	NB-CTD	39	3	5	5	1312	5	1712	e	4108.891	6722.076			Gifford	Process
EN12595.007	VPR	12	3	5	5	1414	5	1814	s	4109.690	6721.630	54	50	Davis	Process
	VPR	12	3	5	5	1606	5	2006	e	4111.060	6719.330	46		Davis	Process
EN12595.008	ZPP/CTD	40	3	5	5	2113	6	113	s	4107.956	6715.360	61	54	Durbin	Process
	ZPP/CTD	40	3	5	5	2135	6	135	e	4107.936	6715.888			Durbin	Process
EN12595.009	NB-CTD	41	3	5	5	2204	6	204	s	4108.045	6716.550	60	55	Gifford	Process
	NB-CTD	41	3	5	5	2209	6	209	e	4108.093	6716.713			Gifford	Process
EN12695.001	VPR	13	3	5	6	1	6	401	s	4110.010	6718.360	55	50	Davis	Process
	VPR	13	3	5	6	302	6	702	e	4112.380	6717.730	53		Davis	Process
	DFT	1	1	5	6	438	6	838	e	4112.600	6717.500		10	Durbin	Process

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KEY TO INSTRUMENTS USED:

NB-CTD	Neal Brown CTD
VPR	Video Plankton Recorder
DFT	Drifter - (water mass following)
MOC1	1m MOCNESS
ZPP/CTD	Zooplankton Pump on CTD
ZPN	Zooplankton Net Tow
DPP	Diaphram Pump
PPN	Phytoplankton Net Tow
PAR/UV	PAR/UV Light Profile