Cruise Report

R/V ENDEAVOR Cruise 267 Leg 2 to Georges Bank

8 - 19 June 1995

Acknowledgements

We gratefully acknowledge the very able assistance provided by the Officers, Crew, and Marine Technician of the R/V ENDEAVOR. Their professional expertise and willingness to apply it to special problems that arose during the cruise, made it possible to accomplish nearly all of our research goals and objectives.

This report was prepared by Cabell Davis, Bob Campbell, Dian Gifford, Stephan Plourde, and Jeff Van Keuren with assistance from others in the scientific party. This cruise was sponsored by the National Science Foundation with additional support for supplies from the NOAA, NURP program.

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1. Introduction

1.1 Purpose of the Cruise

The overall goal of the U.S. GLOBEC Georges Bank Program is to determine how population dynamics interacts with physical processes in controlling the abundance of key animal species on the bank, namely cod and haddock and the dominant spring copepods *Calanus* and *Pseudocalanus*. The program consists of several components including field and laboratory studies for estimating population structure and vital rates as well as modeling and retrospective analyses to synthesize the empirical information. The field program is in its first major sampling year and is focussing on how the development of vernal physical stratification affects the population dynamics of the target species. The field program involves process cruises to experimentally measure the vital rates and fine-scale vertical migration behaviors in relation to the physical properties of the water column, and broad-scale cruises to map the distribution of physical and biological properties of the Bank. The process cruises were further divided into those focusing on the larval cod and haddock and those focusing primarily on *Calanus* and *Pseudocalanus*.

The present cruise aboard the R/V ENDEAVOR was the last in a series of five zooplankton process cruises spaced at roughly monthly intervals.

The **two main objectives** of the second leg of this cruise were:

1) to determine the vital rates and vertical migration behaviors of *Calanus* and *Pseudocalanus* in relation to local circulation and hydrography, and

2) to measure, in three dimensions (using the VPR system mounted on the ROV JASON), the swimming behaviors of *Calanus* and *Pseudocalanus* together with the physical microturbulence in order to determine the mechanisms of aggregation of these copepods at the pycnocline.

The first objective was the same as that for all other process cruises, while the second objective was specific to the second leg of this cruise.

The vital rate and behavioral information provided by our process cruises together with the larger-scale context of population distribution provided by the broadscale cruises will be incorporated into models of biological-physical processes controlling population dynamics of these species.

Our specific objectives were:

(1) **to measure vital rates including feeding, birth, development, and growth rates of *Calanus finmarchicus* and *Pseudocalanus* spp. while following a drogue in the stratified and well mixed areas of the bank.**

(2) **to measure the fine-scale (cm) vertical and horizontal distributions of these species in relation to hydrography and other planktonic and particulate matter.**

(3) **to measure the three-dimensional swimming paths of *Calanus finmarchicus* and *Pseudocalanus* spp. together with 3-D paths of passive particles.**

(4) **to conduct a hydrographic and plankton survey using the VPR in the vicinity of the Great South Channel to determine the location of dense patches of *Calanus finmarchicus* in relation to hydrography and to measure the physical turbulence and swimming behaviors of *C. finmarchicus* in these patches.**

(5) **a final engineering objective was to determine the feasibility of using intermediate sized UNOLS vessels for JASON operations.**

1.2 Cruise overview

During this cruise, the work during the daylight morning hours involved the usual station-keeping near a drifter with the usual CTD, zooplankton pump, and net sampling. In the afternoon, VPR/JASON operations were conducted to measure in situ swimming behaviors and microturbulence in 3-D. The ship's ADCP unit was used to make continuous measurements of the water current profile under the ship, in order to construct the local current fields at each site. These data will be used to help in the interpretation of all the other observations made on the cruise.

Two principal sites were occupied (both were drifter sites), one in the stratified southern flank and one in the mixed area (Figure 1). Station #1 was chosen based on information from the first leg and previous broadscale cruise which found higher concentrations of *Calanus* and gadoid larvae in this area of the bank. It was also upstream of the Eulerian sampling site occupied by Neil Oakey on the R/V *Seward Johnson.* This station was chosen as the best location to deploy our first ARGOS/GPS drifter since it was within the stratified region but far enough away from the bank edge that the drifter would not be carried off the bank. A large warm-core ring was observed in satellite images of the bank and appeared to be pulling bank water out into the Slope Water (Figure 2). Station #2 was chosen, as usual, in the mixed area next to the long-term crest mooring site. After sampling was completed at the stratified and crest sites, a VPR towyo transect was made from the stratified region toward the Slope Water and, as it turned out, through a shelf water streamer being pulled off the bank by the ring (Figure 3). VPR/JASON deployments were made in all of these areas: mixed region, stratified site, streamer and Slope Water. A fourth region sampled was the western edge of the bank and Gulf of Maine just north

of the Great South channel. A VPR survey was made in this region together with a transect in which a Right Whale (feeds primarily on *Calanus*) was followed while towyoing the VPR. A dense layer of *Calanus* was found near the bottom (from 80 m down to 10 m off the bottom which.was at 160 m).

A priority was assigned to each of the major cruise activities so that in event of worse-than-expected weather, the most relevant work could be completed. The highest priority was given to station #1, where the gadoid eggs were observed, followed in terms of priority by station #2, the VPR Slope Water transect, and the Great South Channel region. Weather limitations during the last day two days of the cruise made it impossible to sample using the VPR/JASON system, so that no behavioral information inside the deep *Calanus* patch could be obtained.

In general, all of the major cruise objectives listed above were achieved, except for the last part of (4) which as just stated was impossible to achieve due to bad weather. Although we obtained some useful behavioral information from the VPR/JASON system, a considerable amount of cumbersome maneuvering was required resulting in useful data being obtained only about 10 % of the time or less. It was concluded that a ship with dynamic positioning and a reasonably powerful bow-thruster is essential for positioning the ship relative to JASON. A large amount of time was wasted trying to position the ship manually using the *Endeavor's* weak bow-thruster to obtain slack in the tether between JASON and the clump weight MEDIA (the latter hung directly down from the crane boom off the starboard aft quarter). Thus, most of the time was spent dragging JASON by its tether during which no useful data were obtained. The short periods of slack tether, however, enabled us to use the VPR/JASON system as a maneuverable underwater microscope (which was its intended use) and excellent video of motions of small plankton and passive particles was obtained for the first time in the open sea, and, likewise, micro-turbulence was observed and documented directly using the video.

A list of personnel is given in Appendix I, and a formal log of the sampling events (with correct times and locations) is given in Appendix II.

2. Cruise Narrative

Day 1 (Thursday 6/8/1995)

Departed Woods Hole at 0815. We were delayed leaving by a day to avoid bad weather on Georges Bank (remnants of Hurricane Alison).

Day 2 (Friday 6/9/1995)

We arrived at the Beardsley hydroline station 4 (40 59.6 N 67 39.6 W) at 0327 and began towing the VPR (VPR-1) towards the northeast to locate a patch of *Calanus*. The VPR tow ended at

0604 at 41 01.8 N 67 28.3 W. A few *Calanus* were observed along the tow path, but no large concentrations were found. At 0630 we transferred new MOCNESS nets to R/V *Albatross IV* and then made surface and vertical net tows at 0748 (41 00 N 67 29 W) to determine the species composition of the zooplankton. *Pseudocalanus* was dominant and several *Calanus* were observed together with other copepods.

We then steamed southeast about 3 miles to find more *Calanus* and made a net tow at 0851 (40 57.02 N 67 26.92 W). The species composition was the same as at the previous station. A CTD cast was made to check for intrusion of Slope Water, and none was found. So it was decided that the site was adequate for launching the GPS/ARGOS drifter.

The ARGOS/GPS drifter (drogued at 5 m) was launched at 0949 at 40 57 N 67 27 W, and the following general daily sampling routine began and was used for the rest of the time at this drifter station with the exception that a MOCNESS tow and a night pump cast were not made on the first day due to time constraints of the Durbin group.

Daily Schedule:

0000-0400 Towed-VPR

0900 MOCNESS

1000 Zooplankton Pump

1100 CTD/Hydro

1200 Live zooplankton net tows

1300-2030 VPR/JASON deployment

2200 CTD

2230 Zooplankton Pump

See event log (Appendix II) for exact times of these daily operations.

From 1400-1720, practice maneuvering was done using the *Endeavor*'s bow thruster, since the main screw was not used during JASON deployments. At 1745, we returned to the drifter and made a test deployment of JASON/VPR (VPR-2J) while keeping JASON on its deployment rope. Electrical problems were found with the VPR system on JASON and the rest of the evening was spent trouble-shooting the system, so that no night VPR sled tow was made.

Day 3 (Saturday 6/10/1995)

A CTD component was transferred to the R/V Oceanus at 0630. A diaphragm pump cast (at 1140) was added to the daily morning schedule. A test launch of JASON/VPR (VPR-3J) was made at 1425 followed by a full launch from 1510-2032. The ship's mates tried to maneuver the ship to keep slack in JASON's tether using only the bow thruster, and after some practice we were able to obtain some useful data.

A CTD and zooplankton pump cast were made at 2204 and 2225 respectively.

Day 4 (Sunday 6/11/1995)

A VPR sled towyo (VPR 4) was made around the drifter 0022-0407. An attempt was made to follow a grid around the drifter using another GPS drifter on the ship, the GONIO receiver, and a MATLAB program. The error and delays in the GPS data made this approach not useful, so we decided to simply move around the drifter using the program's display as a rough guide. The fog made it impossible to see the drifter during this period. The drifter moved towards the ST1 array and became too close to follow, so we decided to simply move around the array and *the R/V Seward Johnson.*

The morning sampling routine was followed as scheduled, and an afternoon/evening VPR-JASON (VPR-5J) deployment was highly successful due to calm wind and glassy seas. JASON was retrieved at 2024, followed by a CTD cast (no pump cast was made).

Day 5 (Monday 6/12/1995)

A VPR/JASON deployment (VPR-6J) was made from 0055-0154, but the wind (12-15 knots) caused the ship to drift through the water faster than JASON was able to move toward it. Thus JASON was dragged through the water, and we could not get any slack in the tether. A. Bowen decided it was too risky to try to maneuver with the bow thruster at night, so the tow was aborted. A VPR sled towyo (VPR 7) was made from 0215-0415 about 12 km to the east, ending north-northeast the R/V *Seward Johnson.* The ship then steamed back to the drifter. A dense *Chaetoceros socialis* patch was observed in the southeast corner of the triangle.

The morning sampling was done according to schedule except that no zooplankton pump cast was made. The VPR sled (VPR-8) was deployed at 1344 in a triangular transect starting about a mile from the drifter to about 1 mile northwest of the *Seward Johnson*, then south for 4 miles at a distance of about 1 mile from the *Seward Johnson*, then back to and around the drifter (~1 nm radius) about 2115.

CTD and zooplankton pump casts were made from 2200-2300.

Day 6 (Tuesday 6/13/1995)

A VPR transect (VPR-9) from the drifter to the south (about 12 nm) was made from 0012-0417. A dense *Chaetoceros socialis* patch was found at the southern end of this transect. We then steamed back to the drifter.

We then stayed by the drifter until the sampling began. The morning sampling went according to schedule, (pump, CTD, net tows) except that the drifter was retrieved just before the net tows were made at 1231.
We then steamed to a location (40 42 N 67 42 W) just north of where we had seen the *Chaetoceros socialis* patch and made a VPR tow (VPR-10) toward the south from 1524-1758 looking for the patch. A CTD cast was made at 1818 followed by a pump cast at 1910.

We steamed to Beardsley hydroline station #4 to begin a VPR transect (VPR-11) across the tidal mixing front toward the crest mooring. At this station, the Durbin group first made a net haul for RNA/DNA at 2142, then the VPR was deployed at 2208. During the transect, near the middle of the front (41 03.39 N 67 36.37), the ship was slowed to 1-2 knots, and a second net tow was made at 2300 while the VPR remained in the water.

Day 7 (Wednesday 6/14/1995)

The VPR tow ended at 0005 in the well-mixed water north of the front (41 07.7 N 67 36.57 W), and a third net tow was made.

We steamed about 3 nm back into the front (41 05.47 N 67 36.21 W) and made a VPR-JASON deployment (VPR-12J) from 0105-0348.

We then steamed to the crest mooring and launched the drifter at 0735 at 41 23.8 N 67 33.6 W. An exploratory net tow for species composition was made at 0752 followed by a pump cast at 0847, CTD at 0925, and net tows at 0946. A VPR transect (VPR-13) to the north from the drifter was made from 1049-1322. The ship remained by the drifter until night sampling with nets (2136), CTD (2202), and pump (2212).

Day 8 (Thursday 6/15/1995)

The VPR was towed in a 1-2 nm "box" pattern (VPR-14) around the drifter from 0016-0407, and the ship stood by the drifter until morning sampling which included a pump cast (1004), CTD (1059), and net tows (1210).

The drifter was retrieved at 1548, and we steamed to a "*Chaetoceros socialis*" station at 40 40.0 N 67 42.0 W. A CTD cast was made but no fluorescence maximum was found, indicating no

Chaetoceros were present. We steamed a few miles to the west to 40 40.0 N 67 22.43 W, where we found the *Chaetoceros* patch. CTD and net tows were made at 2217 and 2251, respectively.

Day 9 (Friday 6/16/1995)

Plans for a VPR-JASON launch were aborted during pre-deployment test where a fiber was found to be broken.

A VPR transect (VPR-15) across the shelf/slope front was made from 40 41.0 N 67 48.30 W to 40 18.1 N 67 22.43 W. A CTD cast was made at 1019 but was terminated early due to a problem with the traction head. At 1116 a deep MOCNESS tow was made.

A successful VPR-JASON deployment (VPR-16J) was made at the Slope Water station from 1309-1507.

After the JASON was aboard, we began steaming toward the Great South Channel station at 41 16 N 68 48 W and stopped in the Shelf/Slope front at the southern end of the *Chaetoceros* patch (40 27 N 67 30.5 W) to make net tows. A CTD cast was made at 1803 but no fluorescence maximum was observed, so we continued along the GSC line about 5 nm to 40 34.2 N 67 40.2 W, where a second CTD cast was made at 1946 and *Chaetoceros* were found.

A VPR-JASON deployment (VPR-17J) was made at 2126 at the same location and excellent observations were made in the *Chaetoceros* patch.

Day 10 (Saturday 6/17/1995)

JASON was retrieved at 0106 and we steamed to the GSC location.
We reached the GSC around 0830 and began looking for right whales as a sign of *Calanus* patches. We steamed northeast along the 50 fathom line, and began a zigzag VPR transect (VPR-18) along the western bank back and forth across the 100 m isobath to map hydrography and *Calanus* distributions.

Day 11 (Sunday 6/18/1995)

The main part of the VPR transect ended at 0910 and we continued to towyo to the northeast toward the first turn in the transect (end of leg 1). Right whales were observed, and we turned and followed one of them while towyoing the VPR. A dense patch of *Calanus* was found between 80 m and the bottom at 140 m. At 1256 the VPR tow ended, and we steamed back a few miles to where the *Calanus* layer was dense (41 27.8 N 68 32.03 W). A MOCNESS, net tow, CTD-light cast, and CTD cast were made from 1325-1540. A net tow was made to collect

Calanus for Wagner and Van Keuren. No VPR/JASON deployment in the patch could be made due to strong winds.

A VPR towyo (VPR-19) was made across the Great South Channel starting at 2246.

Day 12 (Monday 6/19/1995)

The VPR tow ended at 0405, and we steamed for Woods Hole at 0415. We docked at Woods Hole at 1630.

3. Individual Reports

3.1 . Copepod development, growth, and vertical distribution:

Zooplankton Abundance, Physiological Condition, and Growth Rates
(E. Durbin, A. Durbin, R. Campbell, J. Gibson, and M. Wagner)

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.

(5) To estimate the development rates of the naupliar stages of the target copepod species at the drifter locations in ship board incubations.

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 also used to sample the larger zooplankton and rarer species that might not be quantitatively sampled by the pump.

The first drifter deployment for the second leg was located on the southern flank at station 7. The dominant copepod appeared to be *Pseudocalanus spp. Centropages typicus* and *Temora longicornis* were also numerous. *Calanus finmarchicus* was less abundant with younger stages (nauplii to C3) being most prevalent. By the second day at this site older stages of *Calanus* (C3 through adult) were more abundant, but younger stages were still present and this pattern continued for the remainder of the station. Most of the *Calanus* were found above and within the thermocline day and night. Higher

proportions of *Pseudocalanus* as well as decaying phytoplankton were found in the bottom layer.

At the second drifter station (station 12) on the crest, *Centropages hamatus* was by far the most numerous copepod. Older stages of *Calanus* were present, but in very low abundance. Stage C5 was the dominant *Calanus* stage, while adults and C4s were difficult to find. There were very few copepod naupliar stages of any species present at this station.

On June 15 and 16 three stations were occupied along a transect line from the crest into slope water. At the two shallow stations, located near the tidal mixing front and the shelf - slope front, Calanus was dominant with all stages present. In this region a peak in fluorescence was found at the base of the thermocline located on top of a cold pool of water. This fluorescence peak was due to a thin layer of *Chaetoceros socialis* colonies. A zooplankton pump sample found high concentrations of all stages of *Calanus* within and above this layer, although the naupliar stages appeared to be more abundant within the layer. At the deep station, located in 1600 meters of water, a MOCNESS tow to 400 meters did not find any significant numbers of *Calanus*.

A MOCNESS tow was also taken in the Great South Channel in the region where right whales were observed. A layer of *Calanus* was found deep, between the bottom and 80 meters, while very little biomass was observed above 40 meters.

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 um) 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, 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 chilled sea 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.

In addition, development rates of *Calanus* and *Pseudocalanus* naupliar stages were determined in 100 liter mesocosms. Artificial cohorts were created by sieving a 150 um net sample through a 200 um sieve. The artificial cohort (150 to 200 um) was then added to the mesocosms (20 copepods / liter) that had been filled by a diaphragm pump

with 100 um filtered water pumped from the chlorophyll maximum layer. The mesocosms were temperature controlled with circulating chilled sea water. The mesocosms were sampled once a day for three days with a 150 um sieve towed from the bottom to the surface of the tanks. The samples were preserved in 4% formaldehyde for later enumeration and stage determination for calculation of development rates.

3.2 Copepod feeding:

Ingestion of Phytoplankton, Nanozooplankton and Microzooplankton by *Calanus finmarchicus* (D. Gifford and M. Seiracki)

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 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 was 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 EN267, we performed our 51st feeding experiment with *Calanus finmarchicus* on Georges Bank. We measured clearance and ingestion rates of copepodid stages C4, C5, and adult females at two drifter stations, Station 9, located on the southern flank, and Station 12, located on the bank crest. Experiments done on the southern flank, where the water column was strongly stratified, measured ingestion rates of *C. finmarchicus* on prey assemblages collected from the middle of the mixed layer, from the chlorophyll maximum at 25m, and from below the chlorophyll maximum at 50m. 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.

We did one set of feeding experiments in a 20-m thick subsurface layer of *Chaetoceros socialis*, located at ~30 m depth on the southern flank (Station 14). Analysis of individual colonies sorted from water collected from the layer revealed that plant pigments consisted of 300 pg ± 100 s.d. chlorophyll a per colony and 800 pg ± 300 s.d. phaeopigment per colony. The dominance of phaeopigment suggested that the layer contained senescent cells at the end of their bloom period. Ancillary samples collected for analysis of major nutrients will assist in evaluating this possibility. Preliminary analysis of the results of experiments done with copepods fed the natural prey assemblage collected from the layer indicated, to our surprise, that *C. finmarchicus* females consumed the *C. socialis* colonies. Because *C. socialis* colonies are nearly as large as the copepods, we hypothesize that this interaction must involve a raptorial feeding mechanism. Preliminary examination of bulk seawater collected from the layer indicated that the layer also contained a diverse protozoan assemblage. Microscopic analyses at our home laboratories will reveal the extent to which the copepods consumed these items.

Ancillary activities included collection of nutrient samples for our GLOBEC colleagues James Bisagni and Jay O'Reilly, and collection of light data by Jeffrey Van Keuren, a postdoctoral investigator with the program.

3.3 Copepod egg production:

Egg production of dominant copepods species on Georges Bank.
(J.A. Runge and S. Plourde)

Copepod egg production rates were measured at the six drifter stations, as well as at Sta. A6 along the hydro line, Sta. 07 and 17 in the Great South Channel and STA16 off the Southern Flank (140 m deep). Egg laying of *Calanus finmarchicus* and egg extrusion rates of *Pseudocalanus* spp. were observed at drifters stations. Egg production of *Centropages typicus, C. hamatus* and *Temora longicornis* were observed where these species made up a significant proportion of the total female population.

Although conditions, in terms of extent of stratification and phytoplankton composition, were clearly different between the southern flank, bank and northeast flank drifter sites, *Calanus* egg production rates were consistently high at all stations, except for the Bank Crest during the second leg and the Great South Channel stations. For other stations, mean rates ranged between 55 and 75 eggs female^{-1} d^{-1}, which is equivalent to 6.5-8.5% of female body weight. This implies that females were able to sustain high, near maximal egg production rates regardless of the particular environmental conditions. Lower rates measured at the Crest station during the second leg (c.a. 20 eggs female^{-1} d^{-1}), due to a low spawning frequency (c.a. 55%), suggested that population at this site changed between the 2 legs (c.a. 2 weeks). At the Great South Channel stations, egg laying rates were near zero. At this point, we attribute this result to life history differences between the Great South Channel and Georges Banks populations rather than to extensive food limitation.

Incubations for assessment of hatching success of the eggs were conducted. These samples have been preserved for later analysis. In general, however, the majority of eggs laid appeared to be viable, with the exception of the second day of drifter Sta. 05, when a substantial proportion of the eggs appeared to be developing abnormally.

Incubations for *Pseudocalanus* egg extrusion rates and Centropages and *Temora* egg laying rates were preserved for later analysis. Pump samples will be analyzed for the *Pseudocalanus* egg ratio. Pump and MOCNESS samples taken at the drifter stations will be analyzed for female copepod abundance, so that the rate of daily input of eggs into the water column at each station can be estimated.

3.4 Copepod behavior and micro-mesoscale distributions of plankton:

Video Plankton Recorder Sampling of plankton behavior and micro-mesoscale distributions (C. Davis and S. Gallager)

The objective of the VPR sampling during the process cruises is two-fold:

1) to measure the 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). We are especially interested in determining whether or not the target species aggregate at the pycnocline during spring stratification of the water column.

2) to measure the swimming behaviors of these species in three dimensions together with motions of passive particles to determine how the species' swimming motions interact with physical microturbulence to form aggregations at the pycnocline.

Comparative day/night sampling of these variables will provide insights into the diel swimming 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).

To measure micro-finescale distributions (including vertical), the sampling design involved slowly towyoing the VPR in the vicinity of the drifter. In this way, both the 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.

For *in situ* measurements of zooplankton swimming behaviors and passive particle motions in three-dimensions, a two-axis VPR system was mounted on a 2 meter square frame affixed to the front of the ROV JASON. The separation distance between the cameras and strobes along both axes was 2 m. The cameras were aligned such that the centers of the two imaged volumes coincided and were nearly orthogonal to each other. Magnification of both cameras was adjusted to give 6 cm fields of view. One camera was positioned to provide a top-down view (x,y), while the other was positioned to provide a side view (y,z). The red-filtered strobes were aligned with the cameras viewing axes but slightly off axis such that only forward scattered light was imaged. For deployment and retrieval, the JASON/VPR first was placed off the starboard side using DSL's articulating Hyab crane. JASON then swam aft of the ship to the end of its tether (50 m) using its own thrusters. The clump-weight/interface unit, MEDIA, then was lifted over the starboard side using the main crane boom and the USGS winch. The crane boom remained just off the starboard side such that the cable down to MEDIA was about 3 m from the side of the ship. During deployment, operation, and retrieval, the ship's propellers remained declutched. Once deployed, the ship would attempt to maneuver using only the bow thruster to keep slack in the tether which ran between JASON and MEDIA. This proved very difficult, and only during calm periods (<10-15 knot winds) could the system be used effectively.

The sampling design with the VPR/JASON system involved video taping the plankton for periods of 0.5-1.0 hours within each layer. Good data were obtained only when the tether was slack and the VPR/JASON was moving slowly forward and then slowly stopped. In this way, we knew that only new, undisturbed water was being sampled. This situation occurred only about 10 % of the time during each sampling period in each layer. The layers sampled were roughly at 10 m intervals from the surface to 10-20 m off the bottom.

The chronology of sampling with the towed-VPR and with the VPR/JASON system is given in the cruise narrative. All VPR deployments are numbered consecutively with VPR/JASON deployments denoted as VPR-#J.

A total of 19 VPR deployments were made, 7 with the VPR/JASON system and 12 with the towed VPR. Locations of these deployments are shown in Figure 4. Hydrographic data plus fluorescence and beam attenuation from the towed system are shown in Figures 5-20. In the stratified region, temperature ranged from near 6.5 ^{0}C at the bottom to about 10.5 ^{0}C at the surface (eg. Figs. 7-8). In the well mixed area, temperature was 10.3 ^{0}C (Figs. 14-15). *Calanus* and *Pseudocalanus* were the principal copepods observed on the south flank, while *Centropages* dominated the mixed site. Small medusae (about 2 cm diameter), which may have been hydroid medusae, were abundant in both the mixed and stratified areas. During a relatively long towyo (VPR-8) from the south flank drifter toward the southeast around the R/V *Seward Johnson* and back around the drifter, a dense

layer of *Chaetoceros socialis* was found just below the thermocline in the southeastern region of the towyo (see fluorescence plot in Fig. 10, units = volts). On a later towyo (VPR-15), we made a transect from the south flank into the Slope Water across the shelf/slope front and found the *Chaetoceros* layer extended well off the bank in the shelf water streamer as did the subsurface "cold band" of bank water (Figs. 3 and 16). Thus, the front was leaning way over toward the south due to the streamer (Fig. 16). We also made a towyo transect across the tidal mixing front to map the transition from stratified to mixed conditions (Fig. 13).

A towyo survey (Fig. 18) was conducted along the western edge of the bank and in the Gulf of Maine north of the Great South Channel (the former SCOPEX region) to map this input/output region of the bank and to locate dense patches of *Calanus finmarchicus* known to occur in this region. The plan was to locate a patch and use the VPR/JASON system to measure swimming behaviors of individual *Calanus* within the patch to examine mechanisms of patch formation. A program was written in matlab to plot the number of in-focus images extracted vs time as an index of *Calanus* abundance (Fig. 19). This method worked well for the Gulf of Maine where most of the particles were *Calanus*, but in the shallower regions on the bank, the particles were largely marine snow. The survey revealed high concentrations of *Calanus* at the surface in the Gulf of Maine along the northern portion of the survey. The *Calanus* abundance dropped to undetectable levels ($<100\ m^{-3}$) in the shallower regions up on the bank where marine snow occurred in huge abundances ($>10^9\ m^{-3}$).

As we were sampling along this survey track, zig-zagging on and off the bank towards the southwest, we found that *Calanus* occurred primarily off bank and in the upper 50 m of the water column. Upon reaching the cleft in the 100m isobath, which marks the northern center of the Great South Channel, we began towyoing along a straight transect back to the starting point of the survey. At this point, we towyoed only in the upper 50 m since no *Calanus* had been observed below that depth. Although we were further into the Gulf of Maine (Fig.18), no *Calanus* were observed. We then sighted Right whales which are known to feed on *Calanus*, so we began following one of the whales and decided to towyo to the bottom. We found a dense layer of *Calanus* between 80 m to 10 m off the bottom at 160 m. These copepods were likely in diapause and rich in lipids. Net samples of *Calanus* were collected and frozen for subsequent analysis.

Two daytime VPR/JASON deployments were made at the stratified site on 6/10-11 (VPR-3J and VPR-5J). Excellent video recordings were obtained on the second deployment. Swimming behaviors of *Calanus*, other copepods, larvaceans and hydroid medusae were recorded at various depths in the water column. Small, circular, swimming patterns of protozoa were also seen. Many *Rhizosolenia* type diatoms and some *Chaetoceros socialis* colonies were observed on both deployments.

A nighttime VPR/JASON deployment was made in the tidal mixing front within weakly stratified waters on 6/12 from 0055-0148, but conditions were marginal and the tow was terminated. A daytime VPR/JASON deployment was made in the Slope Water at the end of the VPR-15 transect line across the streamer. Very few plankton were observed at this station.

The final VPR/JASON deployment (VPR-17J) was made in the Shelf-Slope front/streamer on 6/16 at 2126. Excellent video of *Calanus* swimming was obtained together with video of nauplii, medusae, and ctenophores. Excellent footage was obtained within the dense *Chaetoceros socialis* layer. *Calanus* were observed swimming within this layer, and appeared to be feeding on the *Chaetoceros*. D. Gifford and M. Seiracki then conducted a grazing experiment which confirmed that *Calanus* did in fact eat the large *Chaetoceros* colonies. This last VPR/JASON deployment was the best one, and several long sequences of undisturbed water were obtained.

In all, the cruise was highly successful in terms of both the towed system as well as the VPR/JASON system. *In situ* 3-D swimming behaviors of small plankton were obtained for the first time in the open sea, and the information gleaned from these data will help improve our current models of plankton aggregation. The high-resolution towyo data on *Calanus,* other plankton and environmental variables will provide new insights into the mechanisms of fine-mesoscale transport of plankton in the sea.

Appendix I. Personnel List

Scientific

Name	Title	Organization
1. Cabell Davis	Chief Scientist	WHOI, Woods Hole, MA
2. Scott Gallager	Scientist	WHOI, Woods Hole, MA
3. Hidekatsu Yamazaki	Scientist	Fisheries U. Tokyo, Tokyo
4. Dian Gifford	Scientist	URI, Narragansett, RI.
5. Bob Campbell	Scientist	URI, Narragansett, RI.
6. Mike Seiracki	Scientist	BLOS, Boothbay, ME
7. Andy Bowen	Chief JASON Engineer	WHOI, Woods Hole, MA
8. Stephan Plourde	Research Associate	UQAR, Rimouski, Canada
9. Carin Ashjian	Posdoc	WHOI, Woods Hole, MA
10. Jeff VanKeuren	Postdoc	URI, Narragansett, RI.
11. Phil Alatalo	Research Associate	WHOI, Woods Hole, MA
12. Tom Crook	JASON Engineer	WHOI, Woods Hole, MA
13. Skip Gleason	JASON Engineer	WHOI, Woods Hole, MA
14. Bob Elder	JASON Engineer	WHOI, Woods Hole, MA
15. Will Sellers	JASON Engineer	WHOI, Woods Hole, MA
16. Melissa Wagner	Graduate Student	URI, Narragansett, RI
17. Jim Gibson	Research Assistant	URI, Narragansett, RI
18. Bill Fanning	Marine Technician	URI, Narragansett, RI.

ENDEAVOR Officers and Crew

18. Captain Thomas Tyler	Master
19. Everett McMun	Chief Mate
20. Steve Vetra	Mate
21. Jack Buss	Bos'n
22. Jay St. Germain	Able-Seaman
23. Glen Prouty	Able-Seaman
24. Bijan Emami	Able-Seaman
25. Jim Cobleigh	Chief Engineer
26. Tim Varney	Assistant Engineer
27. Richard Smith	Assistant Engineer
28. Daniel Butler	Steward/Cook
29. Brian D. Miller	Cook/Messman

Appendix II. Cruise Event Log

				Local		Local	GMT	GMT				Water	Cast		
event#	Instr	cast#	Sta#	Mth	Day	hhmm	Day	hhmm	s/e	Lat	Lon	Depth	Depth	PI	Region
EN16095.001	VPR	1	9	6	9	328	9	728	s	4059.85	-6739.54	60	50	Davis	Process
	VPR	1	9	6	9	603	9	1003	e	4102.29	-6727.88			Davis	Process
EN16095.002	ZPN	32	9	6	9	748	9	1148	s	4100.00	-6729.00	65	60	Durbin	Process
EN16095.003	ZPN	33	9	6	9	815	9	1215	s	4100.29	-6729.20	65	10	Durbin	Process
EN16095.004	ZPN	34	9	6	9	857	9	1257	s	4057.02	-6726.92	75	70	Durbin	Process
EN16095.005	ZPN	35	9	6	9	915	9	1315	s	4057.02	-6726.92	75	10	Durbin	Process
EN16095.006	NB-CTD	201	9	6	9	928	9	1328	s	4057.10	-6726.96	74	69	Davis	Process
	NB-CTD	201	9	6	9	944	9	1344	e	4057.01	-6726.97			Davis	Process
EN16095.007	DFT	6	9	6	9	950	9	1350	s	4057.01	-6726.97	74	10	Durbin	Process
EN16095.008	ZPP/CTD	202	9	6	9	1024	9	1424	s	4056.74	-6726.84	75	70	Durbin	Process
	ZPP/CTD	202	9	6	9	1050	9	1450	e	4056.53	-6726.93			Durbin	Process
EN16095.009	NB-CTD	203	9	6	9	1124	9	1524	s	4056.08	-6726.28	76	60	Davis	Process
	NB-CTD	203	9	6	9	1139	9	1539	e	4055.86	-6726.46			Davis	Process
EN16095.010	NB-CTD	204	9	6	9	1218	9	1618	s	4055.61	-6726.37	76	25	Davis	Process
	NB-CTD	204	9	6	9	1229	9	1629	e	4055.43	-6726.56			Davis	Process
EN16095.011	ZPN	36	9	6	9	1245	9	1645	s	4055.90	-6726.46	75	65	Durbin	Process
EN16095.012	ZPN	37	9	6	9	1300	9	1700	s	4055.90	-6726.46	75	50	Durbin	Process
EN16095.013	VPR	2	9	6	9	1850	9	2250	s	4055.95	-6730.07	21	Surface	Davis	Process
	VPR	2	9	6	9	1910	9	2310	e	4056.01	-6730.31			Davis	Process
EN16095.014	NB-CTD	205	9	6	9	2148	10	148	s	4056.20	-6728.87	74	70	Davis	Process
	NB-CTD	205	9	6	9	2158	10	158	e	4056.04	-6728.87			Davis	Process
EN16195.001	MOC1	13	9	6	10	906	10	1306	s	4057.09	-6733.78	70	60	Durbin	Process
	MOC1	13	9	6	10	918	10	1318	e	4057.32	-6733.26	70		Durbin	Process
EN16195.002	ZPP/CTD	206	9	6	10	1000	10	1400	s	4057.04	-6732.60	71	66	Durbin	Process
	ZPP/CTD	206	9	6	10	1020	10	1420	e	4056.86	-6732.50			Durbin	Process
EN16195.003	NB-CTD	207	9	6	10	1100	10	1500	s	4056.32	-6732.25	73	67	Davis	Process
	NB-CTD	207	9	6	10	1116	10	1516	e	4056.08	-6732.24			Davis	Process
EN16195.004	DPP	5		6	10	1139	10	1539	s	4055.83	-6731.90		25	Durbin	Process
	DPP	5		6	10	1155	10	1555	e	4055.83	-6731.90			Durbin	Process
EN16195.005	ZPN	38	9	6	10	1200	10	1600	s	4054.71	-6732.56	70	25	Durbin	Process
EN16195.006	ZPN	39	9	6	10	1215	10	1615	s	4054.71	-6732.56	70	35	Durbin	Process
EN16195.007	ZPN	40	9	6	10	1230	10	1630	s	4054.71	-6732.56	70	25	Durbin	Process
EN16195.008	NB-CTD	208	9	6	10	1250	10	1650	s	4054.68	-6732.59	74	69	Davis	Process
	NB-CTD	208	9	6	10	1305	10	1705	e	4054.41	-6732.88			Davis	Process
EN16195.009	VPR/JASON	3	9	6	10	1430	10	1830	s	4053.20	-6733.09	49	25	Davis	Process
	VPR/JASON	3	9	6	10	2035	11	35	e	4055.55	-6738.64	51		Davis	Process
EN16195.010	NB-CTD	209	9	6	10	2203	11	203	s	4056.19	-6735.46	70	65	Davis	Process
	NB-CTD	209	9	6	10	2214	11	214	e	4056.18	-6735.29			Davis	Process
EN16195.011	ZPP/CTD	210	9	6	10	2225	11	225	s	4056.12	-6735.22	70	65	Durbin	Process
	ZPP/CTD	210	9	6	10	2247	11	247	e	4055.94	-6735.07			Durbin	Process
EN16295.001	VPR	4	9	6	11	23	11	423	s	4054.85	-6734.49	66	56	Davis	Process
	VPR	4	9	6	11	405	11	805	e	4050.98	-6730.50	76		Davis	Process
EN16295.002	MOC1	14	9	6	11	905	11	1305	s	4054.53	-6741.01	68	58	Durbin	Process
	MOC1	14	9	6	11	917	11	1317	e	4054.90	-6740.42	68		Durbin	Process
EN16295.003	ZPP/CTD	211	9	6	11	1002	11	1402	s	4055.14	-6740.51	68	63	Durbin	Process
	ZPP/CTD	211	9	6	11	1025	11	1425	e	4055.26	-6740.27			Durbin	Process
EN16295.004	NB-CTD	212	9	6	11	1102	11	1502	s	4055.31	-6739.78	68	50	Davis	Process
	NB-CTD	212	9	6	11	1119	11	1519	e	4055.20	-6729.54			Davis	Process
EN16295.005	ZPN	41	9	6	11	1200	11	1600	s	4054.22	-6738.19	70	35	Durbin	Process
EN16295.006	ZPN	42	9	6	11	1215	11	1615	s	4054.22	-6738.19	70	35	Durbin	Process
EN16295.007	VPR	5	9	6	11	1435	11	1835	s	4052.07	-6738.25	67	50	Davis	Process
	VPR	5	9	6	11	2028	12	28	e	4054.66	-6743.51	63		Davis	Process
EN16295.008	NB-CTD	213	9	6	11	2202	12	202	s	4055.35	-6741.39	68	62	Davis	Process
	NB-CTD	213	9	6	11	2215	12	215	e	4055.51	-6741.14			Davis	Process
EN16395.001	VPR/JASON	6	9	6	12	55	12	455	s	4054.23	-6738.81	65	55	Davis	Process
	VPR/JASON	6	9	6	12	153	12	553	e	4053.52	-6738.44	66		Davis	Process
EN16395.002	VPR	7	9	6	12	215	12	615	s	4052.92	-6738.37	67	60	Davis	Process
	VPR	7	9	6	12	420	12	820	e	4053.16	-6729.90	73		Davis	Process
EN16395.003	MOC1	15	9	6	12	910	12	1310	s	4053.89	-6744.83	65	55	Durbin	Process
	MOC1	15	9	6	12	921	12	1321	e	4053.65	-6744.87	66		Durbin	Process
EN16395.004	NB-CTD	214	9	6	12	1101	12	1501	s	4055.20	-6744.04	65	60	Davis	Process
	NB-CTD	214	9	6	12	1117	12	1517	e	4055.52	-6743.50			Davis	Process
EN16395.005	ZPN	43	9	6	12	1230	12	1630	s	4053.88	-6744.86	65	45	Gifford	Process
EN16395.006	VPR	8	9	6	12	1344	12	1744	s	4055.48	-6739.38	63	53	Davis	Process
	VPR	8	9	6	12	2120	13	120	e	4053.40	-6743.42	65		Davis	Process
EN16395.007	NB-CTD	215	9	6	12	2201	13	201	s	4054.87	-6743.68	64	59	Davis	Process
	NB-CTD	215	9	6	12	2214	13	214	e	4055.06	-6743.42			Davis	Process

EN16395.008	ZPP/CTD	216	9	6	12	2229	13	229	s	4055.19	-6743.29	65	59.5	Durbin	Process
	ZPP/CTD	216	9	6	12	2252	13	252	e	4055.51	-6742.81			Durbin	Process
EN16495.001	VPR	9	9	6	13	14	13	414	s	4055.24	-6741.50	63	50	Davis	Process
	VPR	9	9	6	13	423	13	823	e	4034.53	-6741.61	96		Davis	Process
EN16495.002	ZPP/CTD	217	9	6	13	1000	13	1400	s	4054.15	-6745.56	64	59.5	Durbin	Process
	ZPP/CTD	217	9	6	13	1025	13	1425	e	4054.82	-6745.40			Durbin	Process
EN16495.003	NB-CTD	218	9	6	13	1100	13	1500	s	4055.17	-6745.23	65	60.8	Davis	Process
	NB-CTD	218	9	6	13	1115	13	1515	e	4055.39	-6745.03			Davis	Process
	DFT	6	9	6	13	1215	13	1615	e	4055.60	-6744.10			Durbin	Process
EN16495.004	ZPN	44	9	6	13	1230	13	1630	s	4055.82	-6743.30	60	45	Durbin	Process
EN16495.005	ZPN	45	9	6	13	1245	13	1645	s	4055.82	-6743.30	60	55	Durbin	Process
EN16495.006	VPR	10	10	6	13	1524	13	1924	s	4046.51	-6742.00	65	55	Davis	Process
	VPR	10	10	6	13	1800	13	2200	e	4039.27	-6743.08	73		Davis	Process
EN16495.007	NB-CTD	219	10	6	13	1822	13	2222	s	4040.13	-6742.51	77	71	Davis	Process
	NB-CTD	219	10	6	13	1842	13	2242	e	4040.09	-6743.08			Davis	Process
EN16495.008	ZPP/CTD	220	10	6	13	1910	13	2310	s	4040.10	-6743.60			Durbin	Process
	ZPP/CTD	220	10	6	13	1952	13	2352	e	4040.97	-6743.51			Durbin	Process
EN16495.009	ZPN	46	11A	6	13	2142	14	142	s	4059.79	-6738.80	65	50	Durbin	Process
EN16495.010	VPR	11	11A	6	13	2210	14	210	s	4059.12	-6738.87	63	55	Davis	Process
EN16495.011	ZPN	47	11B	6	13	2300	14	300	s	4103.89	-6737.61	50	25	Durbin	Process
	VPR	11	11B	6	14	11	14	411	e	4007.78	-6736.48	53		Davis	Process
EN16595.001	ZPN	48	11C	6	14	15	14	415	s	4107.40	-6736.00	50	40	Durbin	Process
EN16595.002	VPR/JASON	12	11D	6	14	55	14	455	s	4105.46	-6736.18	53		Davis	Process
	VPR/JASON	12	11D	6	14	343	14	743	e	4101.48	-6734.04	59		Davis	Process
EN16595.003	DFT	7	12	6	14	735	14	1135	s	4123.76	-6733.60	40	10	Durbin	Process
EN16595.004	ZPP/CTD	221	12	6	14	846	14	1246	s	4125.85	-6735.92	35	32	Durbin	Process
	ZPP/CTD	221	12	6	14	906	14	1306	e	4126.63	-6730.52			Durbin	Process
EN16595.005	NB-CTD	222	12	6	14	925	14	1325	s	4127.25	-6736.45	35	30	Davis	Process
	NB-CTD	222	12	6	14	936	14	1336	e	4127.73	-6736.71			Davis	Process
EN16595.006	ZPN	49	12	6	14	946	14	1346	s	4130.00	-6736.70	30	25	Durbin	Process
EN16595.007	ZPN	50	12	6	14	955	14	1355	s	4130.00	-6736.70	30	25	Durbin	Process
EN16595.008	ZPN	51	12	6	14	1005	14	1405	s	4130.00	-6736.70	30	20	Durbin	Process
EN16595.009	VPR	13	12	6	14	1029	14	1429	s	4131.32	-6736.57	34	25	Davis	Process
	VPR	13	12	6	14	1324	14	1724	e	4142.18	-6733.45	35		Davis	Process
EN16595.010	NB-CTD	223	12	6	14	2155	15	155	s	4127.14	-6735.58	40	35	Davis	Process
	NB-CTD	223	12	6	14	2201	15	201	e	4127.40	-6735.68			Davis	Process
EN16595.011	ZPP/CTD	224	12	6	14	2211	15	211	s	4127.67	-6735.85	40	25	Durbin	Process
	ZPP/CTD	224	12	6	14	2225	15	225	e	4128.14	-6735.92			Durbin	Process
EN16695.001	VPR	14	12	6	15	18	15	418	s	4130.70	-6734.07	26	20	Davis	Process
	VPR	14	12	6	15	408	15	808	e	4125.18	-6730.28	24		Davis	Process
EN16695.002	MOC1	16	12	6	15	912	15	1312	s	4123.32	-6735.59	44	30	Durbin	Process
	MOC1	16	12	6	15	919	15	1319	e	4123.69	-6736.16	40		Durbin	Process
EN16695.003	ZPP/CTD	225	12	6	15	1002	15	1402	s	4124.94	-6736.50	43	38	Durbin	Process
	ZPP/CTD	225	12	6	15	1019	15	1419	e	4125.51	-6736.60			Durbin	Process
EN16695.004	NB-CTD	226	12	6	15	1058	15	1458	s	4126.88	-6736.09	40	32	Davis	Process
	NB-CTD	226	12	6	15	1111	15	1511	e	4127.31	-6736.85			Davis	Process
EN16695.005	ZPN	52	12	6	15	1215	15	1615	s	4129.45	-6735.86	35	25	Durbin	Process
	DFT	7	12	6	15	1545	15	1945	e	4128.49	-6728.70			Durbin	Process
EN16695.006	NB-CTD	227	13	6	15	2110	16	110	s	4039.81	-6742.40	79	74	Davis	Process
	NB-CTD	227	13	6	15	2123	16	123	e	4039.73	-6742.52			Davis	Process
EN16695.007	NB-CTD	228	14	6	15	2217	16	217	s	4040.03	-6748.57	82	77	Davis	Process
	NB-CTD	228	14	6	15	2235	16	235	e	4040.05	-6748.75			Davis	Process
EN16695.008	ZPN	53	14	6	15	2251	16	251	s	4040.06	-6748.84	75	60	Durbin	Process
EN16795.001	VPR	15	14	6	16	37	16	437	s	4041.12	-6748.48	78	70	Davis	Process
	VPR	15	14	6	16	917	16	1317	e	4017.80	-6722.40	1450	350	Davis	Process
EN16795.002	NB-CTD	229	15	6	16	1018	16	1418	s	4017.62	-6723.20	1605	309	Davis	Process
	NB-CTD	229	15	6	16	1050	16	1450	e	4017.07	-6723.63			Davis	Process
EN16795.003	MOC1	17	15	6	16	1117	16	1517	s	4017.75	-6723.10	1600	400	Durbin	Process
	MOC1	17	15	6	16	1219	16	1619	e	4017.29	-6726.71	1500		Durbin	Process
EN16795.004	VPR/JASON	16	15	6	16	1308	16	1708	s	4017.56	-6723.28	1550	30	Davis	Process
	VPR/JASON	16	15	6	16	1507	16	1907	e	4018.23	-6722.99	1600		Davis	Process
EN16795.005	ZPN	54	16	6	16	1645	16	2045	s	4026.43	-6730.08	140	120	Durbin	Process
EN16795.006	ZPN	55	16	6	16	1700	16	2100	s	4026.43	-6730.08	140	100	Durbin	Process
EN16795.007	NB-CTD	230	16	6	16	1802	16	2202	s	4027.07	-6730.51	146	100	Davis	Process
	NB-CTD	230	16	6	16	1817	16	2217	e	4026.82	-6730.31			Davis	Process
EN16795.008	NB-CTD	231	17	6	16	1945	16	2345	s	4033.98	-6740.46	109	103	Davis	Process
	NB-CTD	231	17	6	16	2005	17	5	e	4033.61	-6740.55			Davis	Process
EN16795.009	VPR/JASON	17	17	6	16	2120	17	120	s	4034.19	-6740.51	104	30	Davis	Process

	VPR/JASON	17	17	6	17	106	17	506	e	4036.71	-6740.68		50	Davis	Process
EN16895.001	VPR	18	18	6	17	1142	17	1542	s	4127.82	-6832.18	91	85	Davis	Process
	VPR	18	18	6	17	1220	17	1620	e	4127.38	-6831.84			Davis	Process
EN16895.002	ZPN	56	19	6	17	1415	17	1815	s	4114.60	-6902.45	148	100	Runge	Process
EN16895.003	VPR	18B	18	6	17	1434	17	1834	s	4127.05	-6831.29	91	85	Davis	Process
	VPR	18B	18	6	18	1258	18	1658	e	4113.72	-6903.82	144		Davis	Process
EN16995.001	MOC1	18	19	6	18	1326	18	1726	s	4114.56	-6903.62	150	139	Durbin	Process
	MOC1	18	19	6	18	1349	18	1749	e	4114.89	-6904.43	148		Durbin	Process
EN16995.002	CTD/LIGHT	232	19	6	18	1455	18	1855	s	4114.60	-6902.24	153	45	Van Keuren	Process
	CTD/LIGHT	232	19	6	18	1510	18	1910	e	4114.71	-6902.02			Van Keuren	Process
EN16995.003	NB-CTD	233	19	6	18	1539	18	1939	s	4114.28	-6903.42	152	100	Davis	Process
	NB-CTD	233	19	6	18	1600	18	2000	e	4114.67	-6902.86			Davis	Process
EN16995.004	ZPN	57	19	6	18	2010	19	10	s	4112.47	-6856.33	145	80	Durbin	Process
EN16995.005	VPR	19	19	6	18	2248	19	248	s	4114.97	-6855.09	101	90	Davis	Process
	VPR	19	19	6	19	400	19	800	e	4127.96	-6925.66	45		Davis	Process

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	Diaphragm Pump
CTD/LIGHT	Neal Brown CTD with light sensor attached

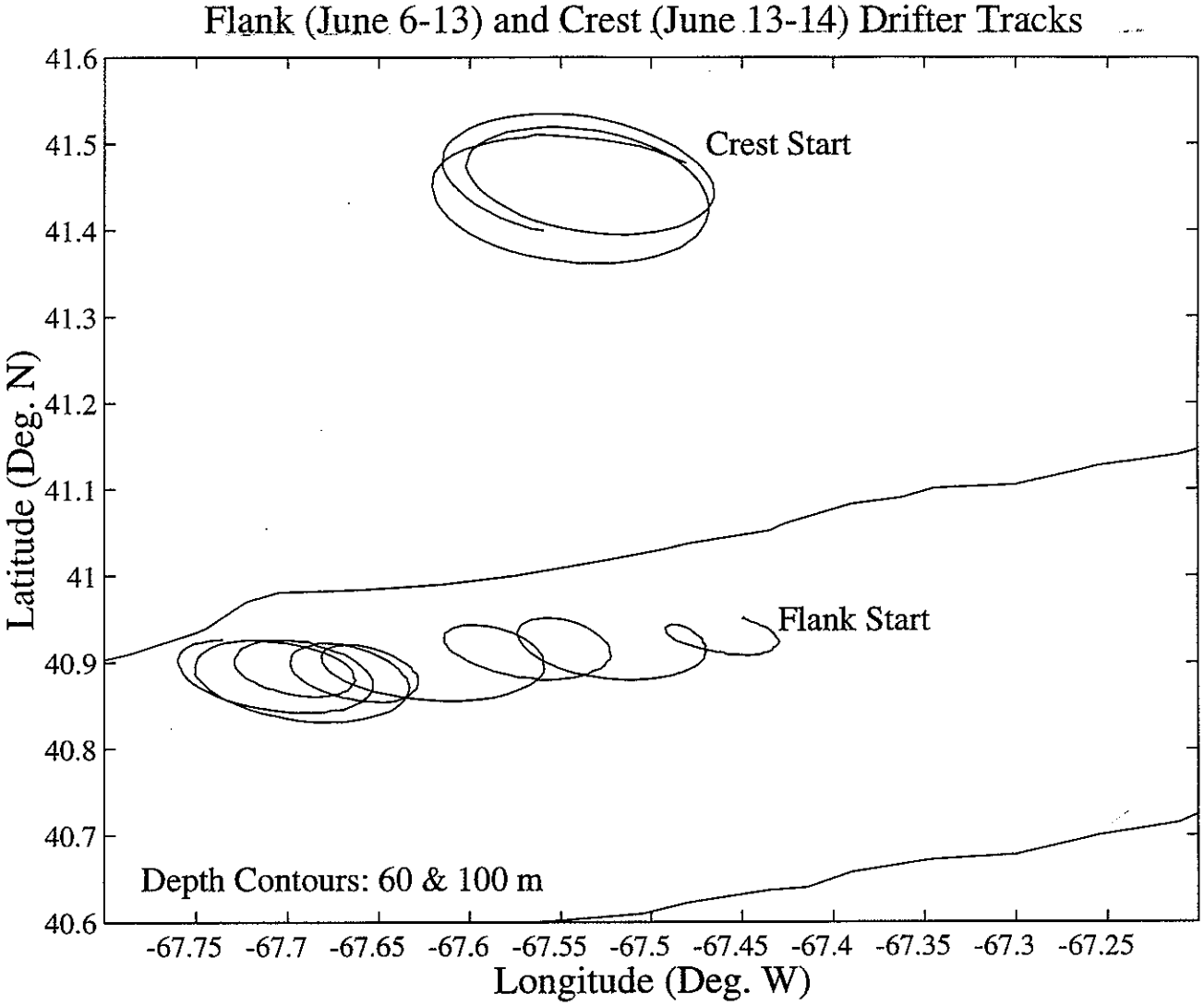
Flank (June 6-13) and Crest (June 13-14) Drifter Tracks
Crest Start
Flank Start
Depth Contours: 60 & 100 m
Latitude (Deg. N)
Longitude (Deg. W)
41.6
41.5
41.4
41.3
41.2
41.1
41
40.9
40.8
40.7
40.6
-67.75
-67.7
-67.65
-67.6
-67.55
-67.5
-67.45
-67.4
-67.35
-67.3
-67.25

Figure 1

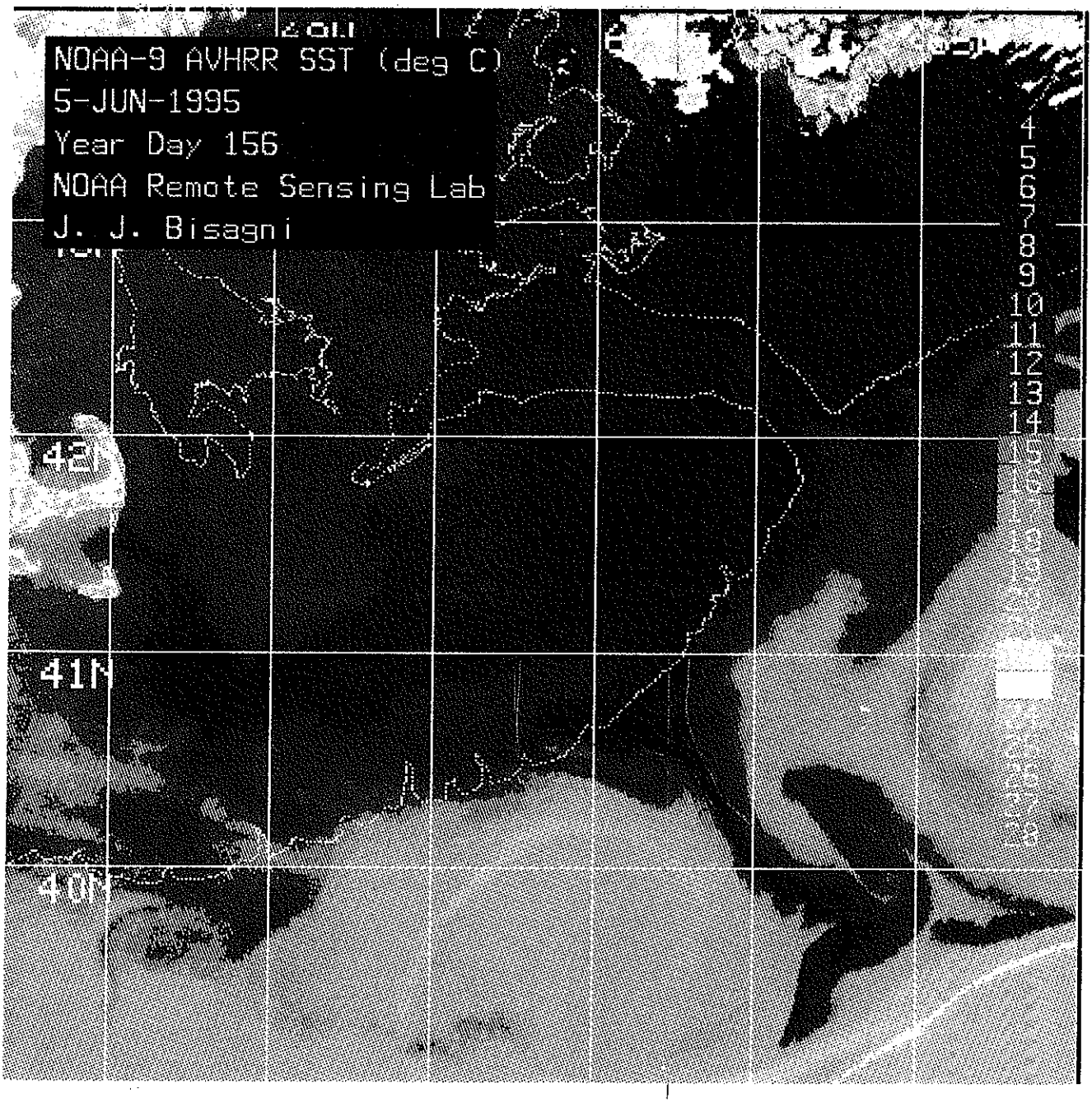
NOAA-9 AVHRR SST (deg C)
5-JUN-1995
Year Day 156
NOAA Remote Sensing Lab
J. J. Bisagni
4
5
6
7
8
9
10
11
12
13
14
41N
40N

Figure 2

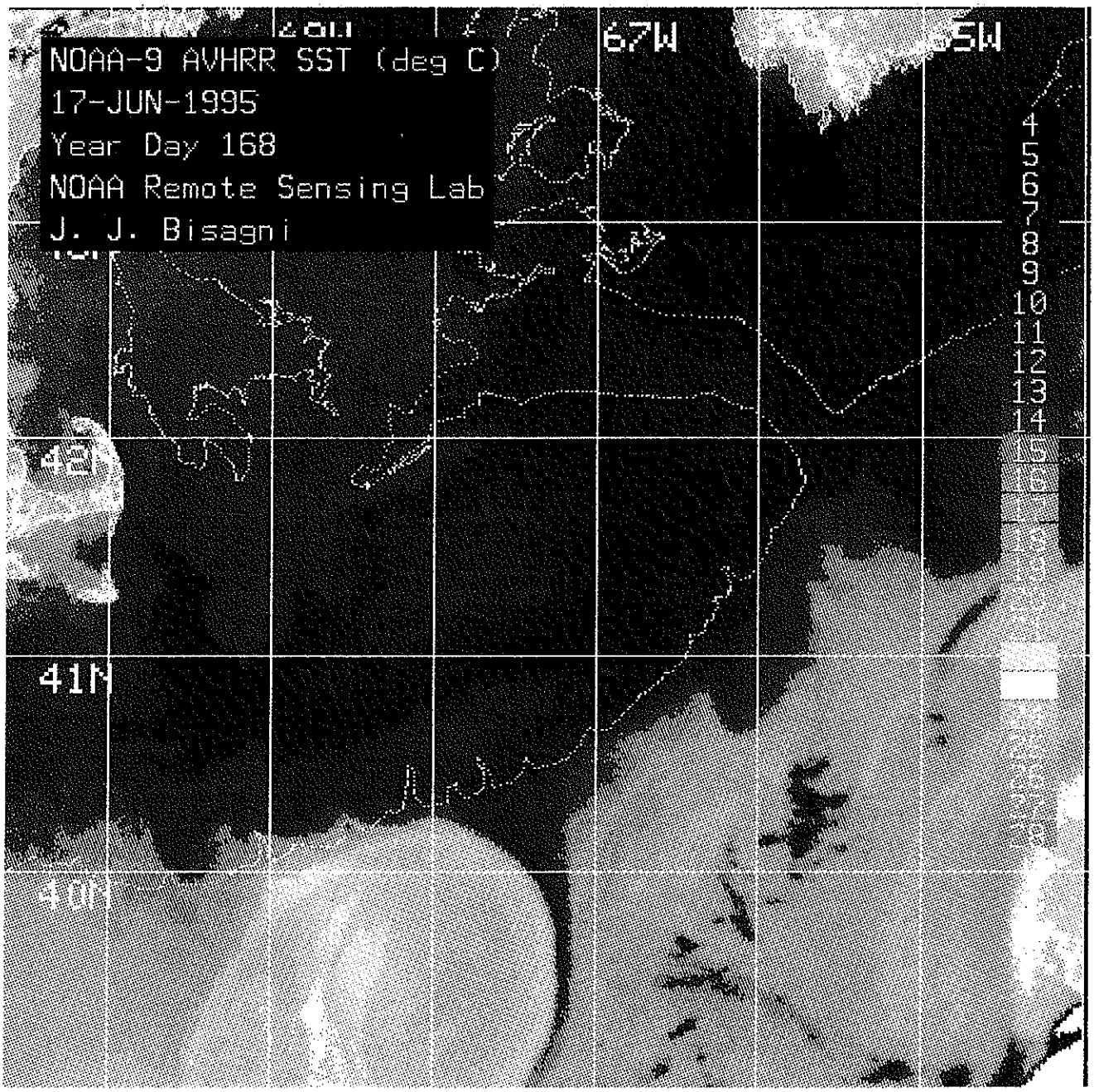
NOAA-9 AVHRR SST (deg C)
17-JUN-1995
Year Day 168
NOAA Remote Sensing Lab
J. J. Bisagni
67W
5W
41N
4 5 6 7 8 9 10 11 12 13 14

Figure 3

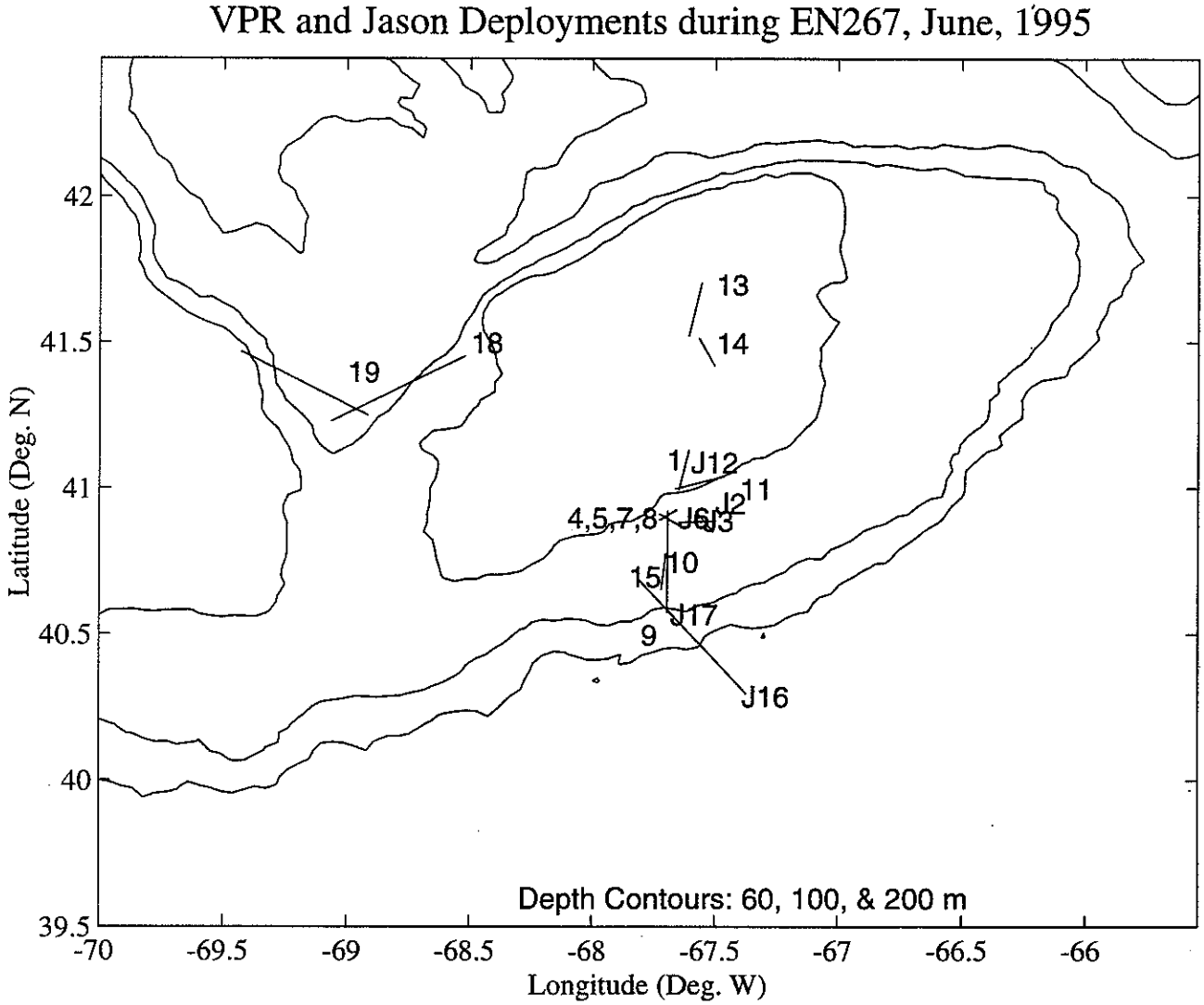
VPR and Jason Deployments during EN267, June, 1995
Latitude (Deg. N)
Longitude (Deg. W)
42
41.5
41
40.5
40
39.5
-70
-69.5
-69
-68.5
-68
-67.5
-67
-66.5
-66
13
14
18
19
1/J12
11
J2
4,5,7,8
J6
J3
10
15
J17
9
J16
Depth Contours: 60, 100, & 200 m

Figure 4

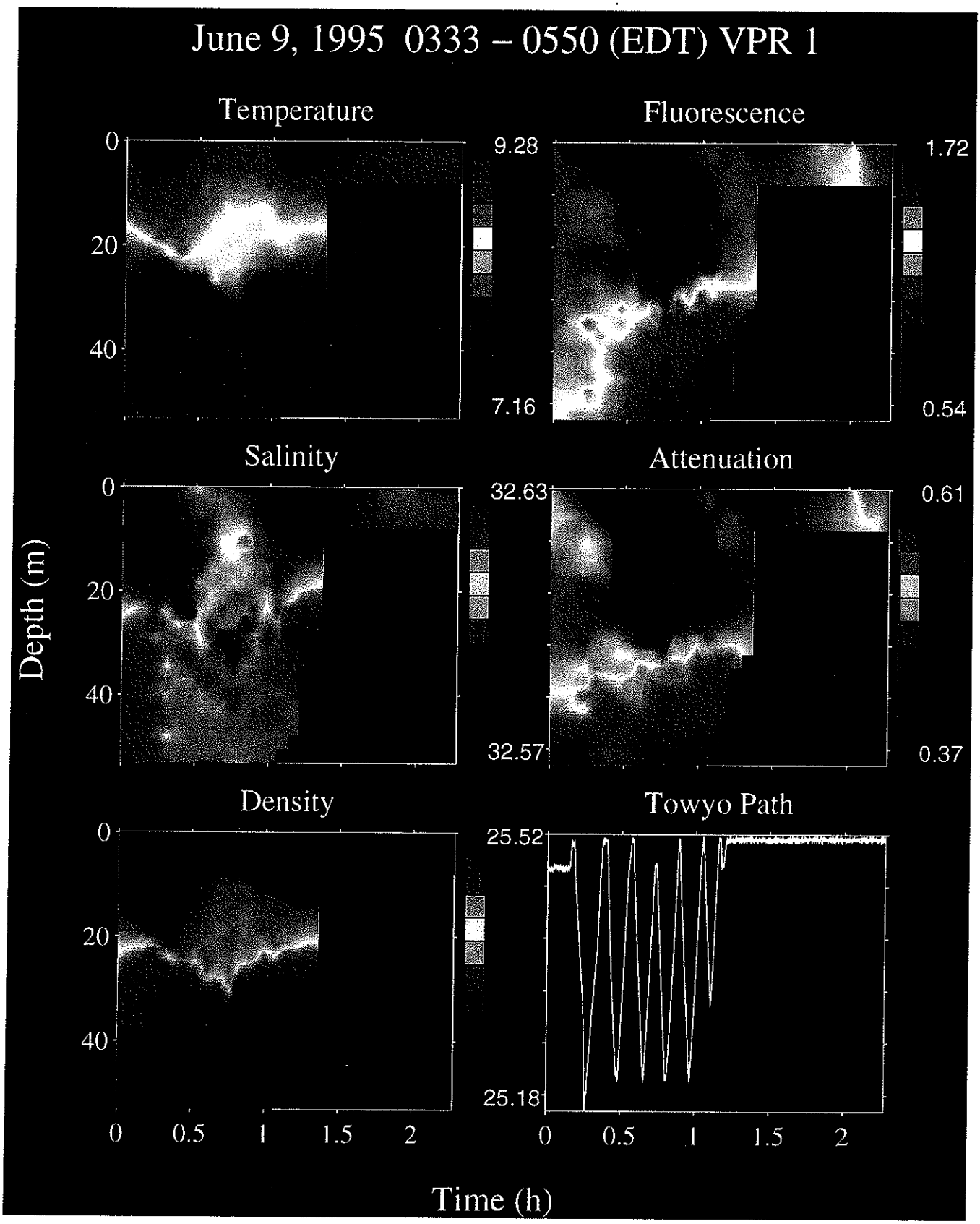
June 9, 1995 0333 – 0550 (EDT) VPR 1
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
9.28
7.16
1.72
0.54
32.63
32.57
0.61
0.37
25.52
25.18
0
0.5
1
1.5
2
Time (h)

Figure 5

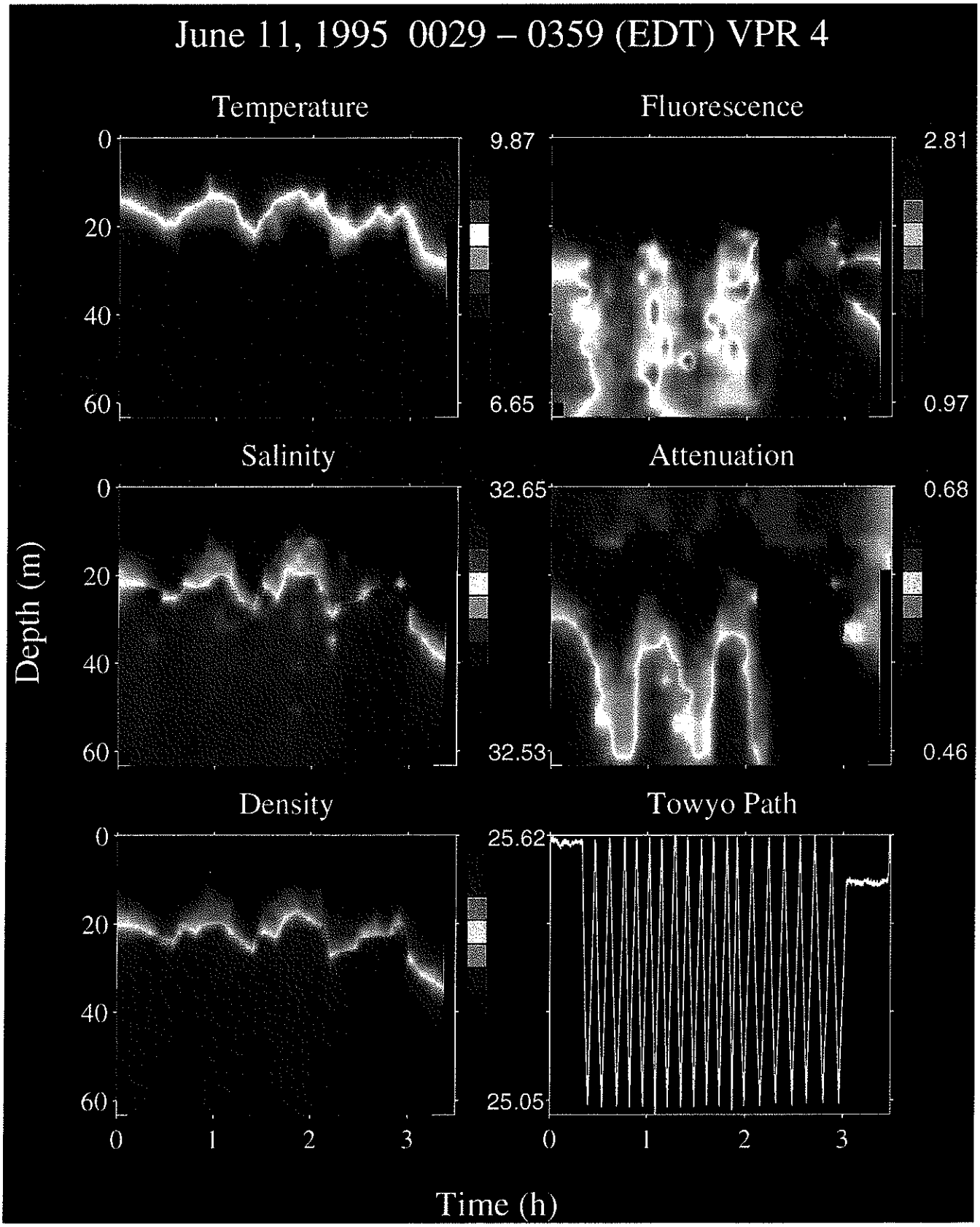
June 11, 1995 0029 – 0359 (EDT) VPR 4
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
60
9.87
6.65
2.81
0.97
32.65
32.53
0.68
0.46
25.62
25.05
0
1
2
3

Figure 6

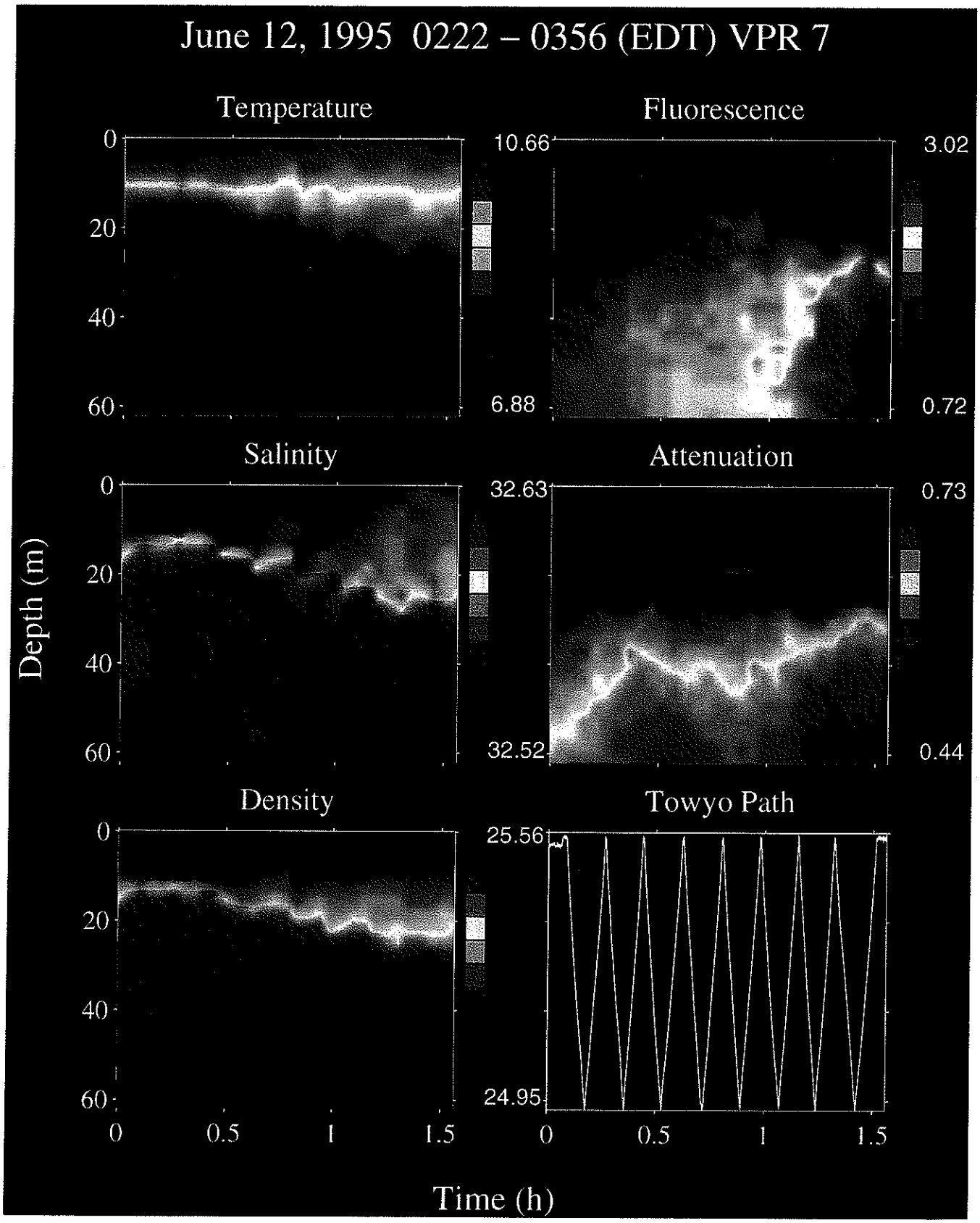
June 12, 1995 0222 – 0356 (EDT) VPR 7
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
60
10.66
6.88
3.02
0.72
32.63
32.52
0.73
0.44
25.56
24.95
0
0.5
1
1.5

Figure 7

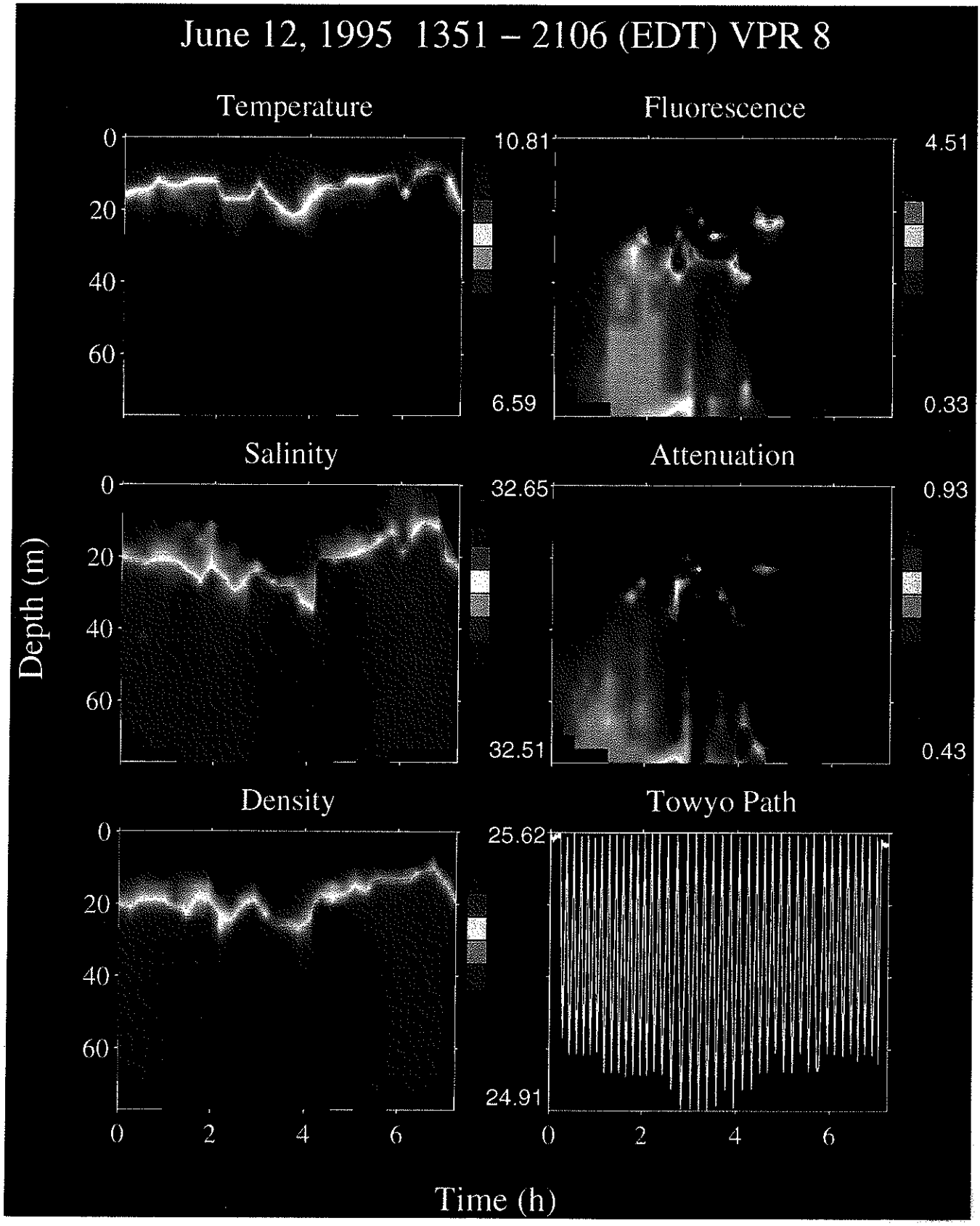
June 12, 1995 1351 – 2106 (EDT) VPR 8
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
60
10.81
6.59
4.51
0.33
32.65
32.51
0.93
0.43
25.62
24.91
0
2
4
6

Figure 8

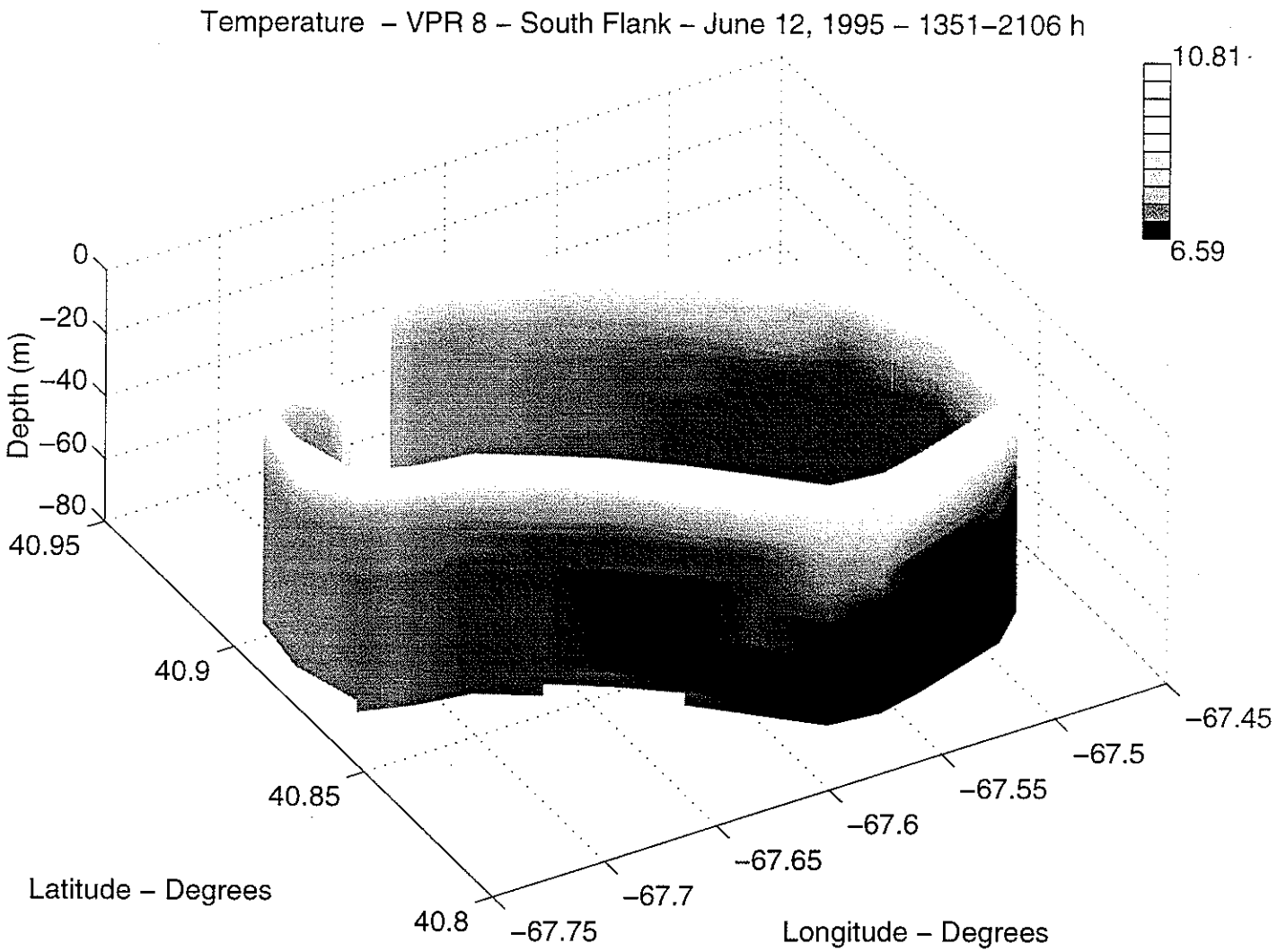
Temperature – VPR 8 – South Flank – June 12, 1995 – 1351–2106 h
10.81
6.59
0
–20
–40
–60
–80
Depth (m)
40.95
40.9
40.85
40.8
Latitude – Degrees
–67.75
–67.7
–67.65
–67.6
–67.55
–67.5
–67.45
Longitude – Degrees

Figure 9

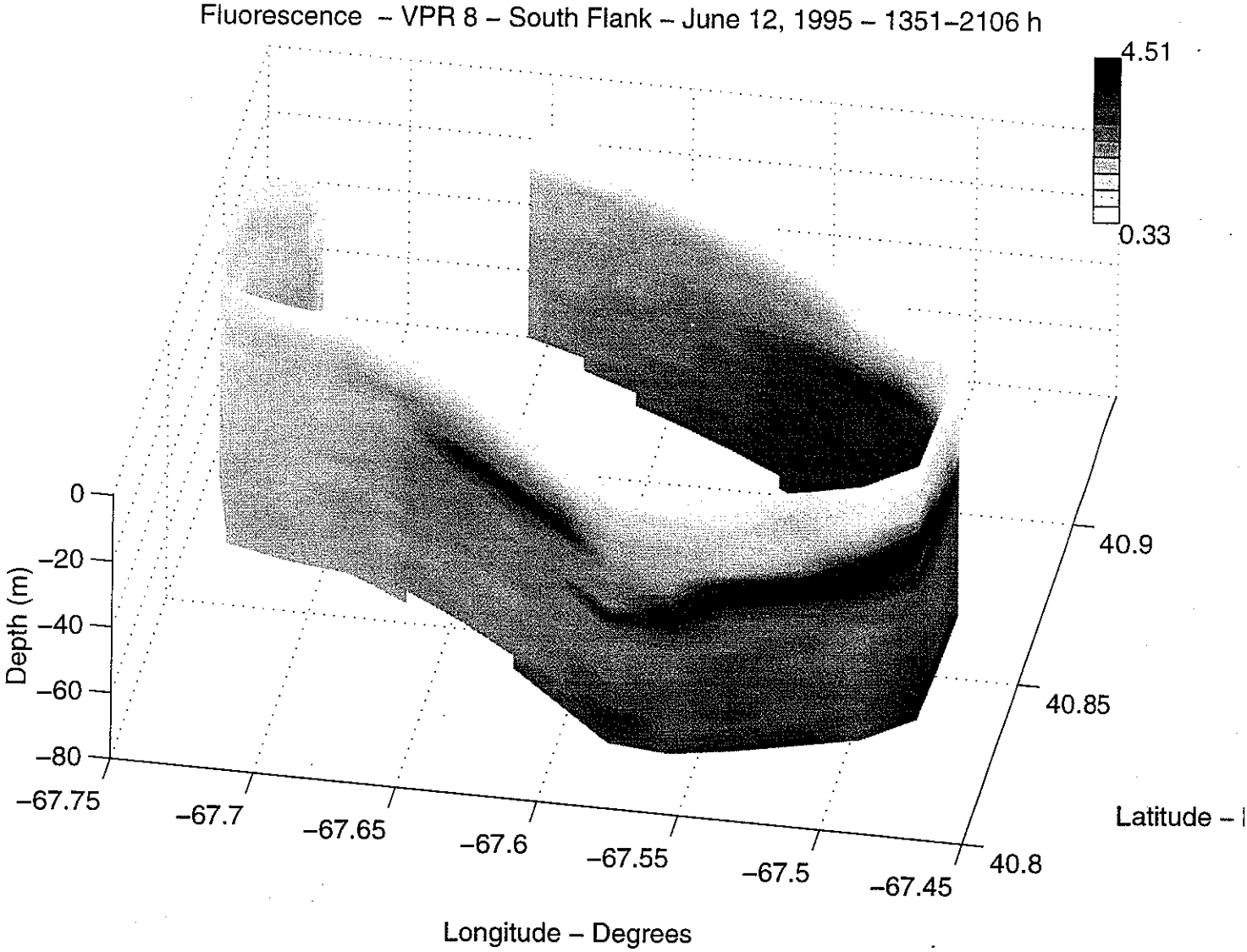
Fluorescence – VPR 8 – South Flank – June 12, 1995 – 1351–2106 h
4.51
0.33
0
−20
−40
−60
−80
Depth (m)
−67.75
−67.7
−67.65
−67.6
−67.55
−67.5
−67.45
Longitude – Degrees
40.9
40.85
40.8
Latitude – I

Figure 10

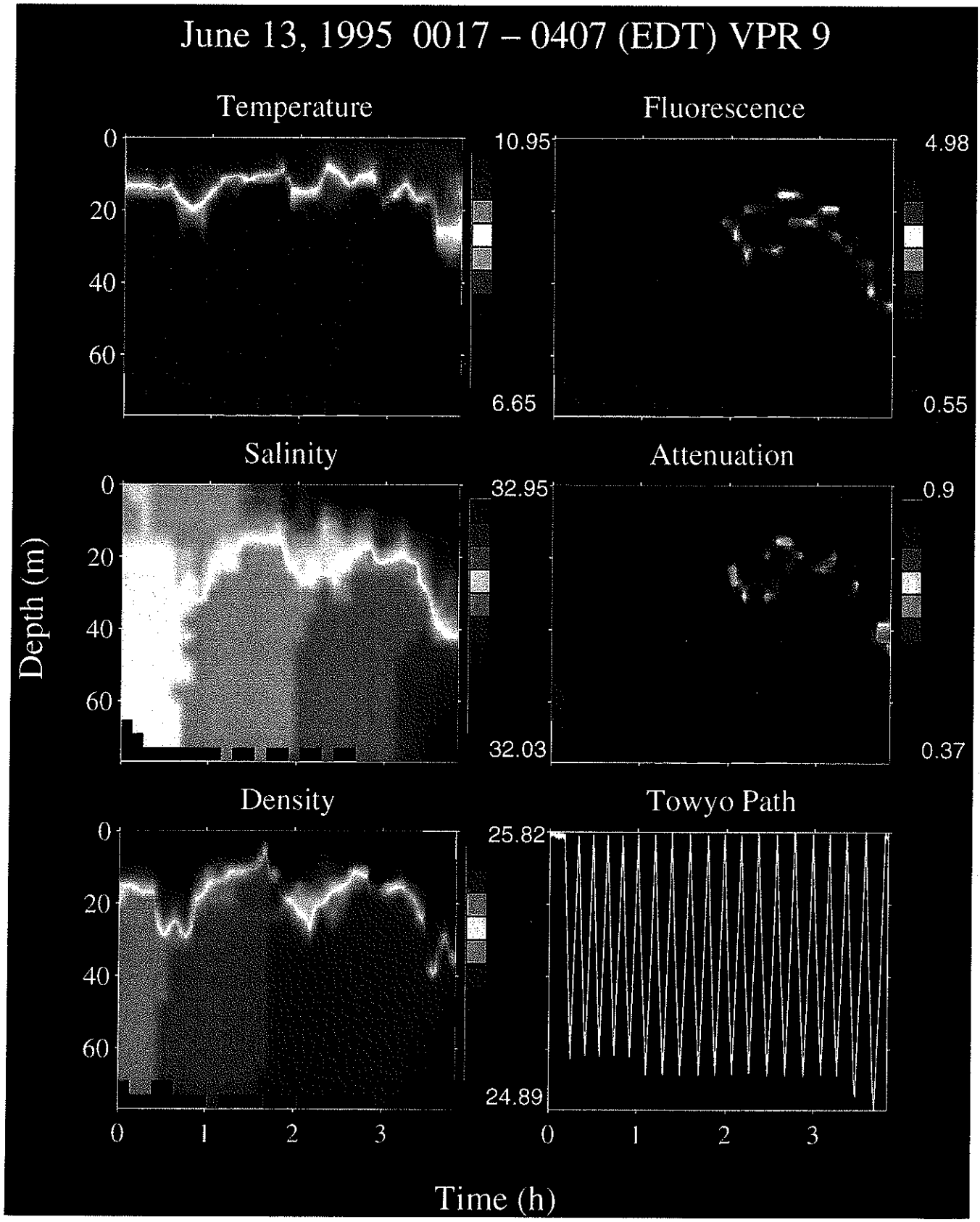
June 13, 1995 0017 – 0407 (EDT) VPR 9
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
60
10.95
6.65
4.98
0.55
32.95
32.03
0.9
0.37
25.82
24.89
0
1
2
3
Time (h)

Figure 11

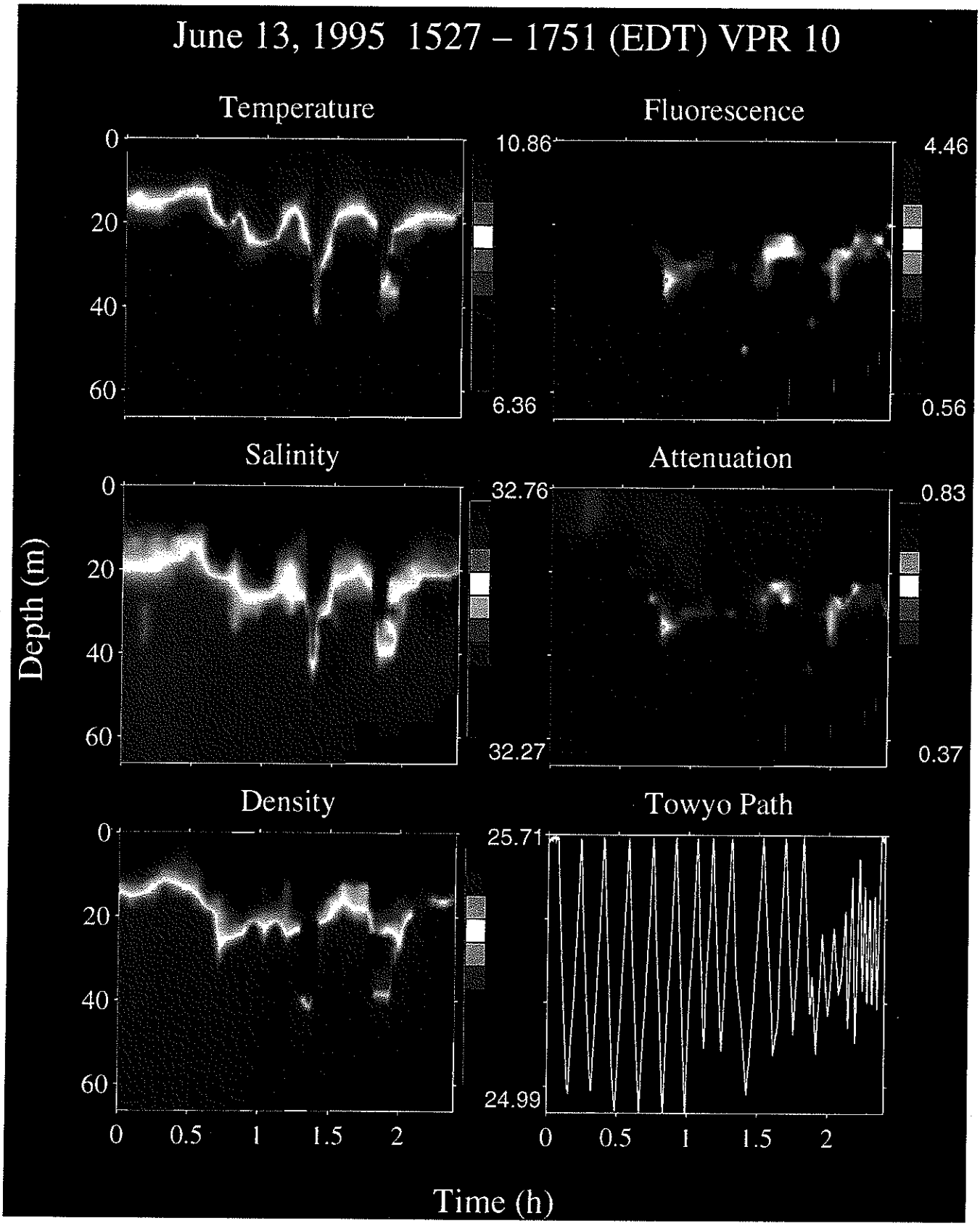
June 13, 1995 1527 – 1751 (EDT) VPR 10
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
60
10.86
6.36
4.46
0.56
32.76
32.27
0.83
0.37
25.71
24.99
0
0.5
1
1.5
2

Figure 12

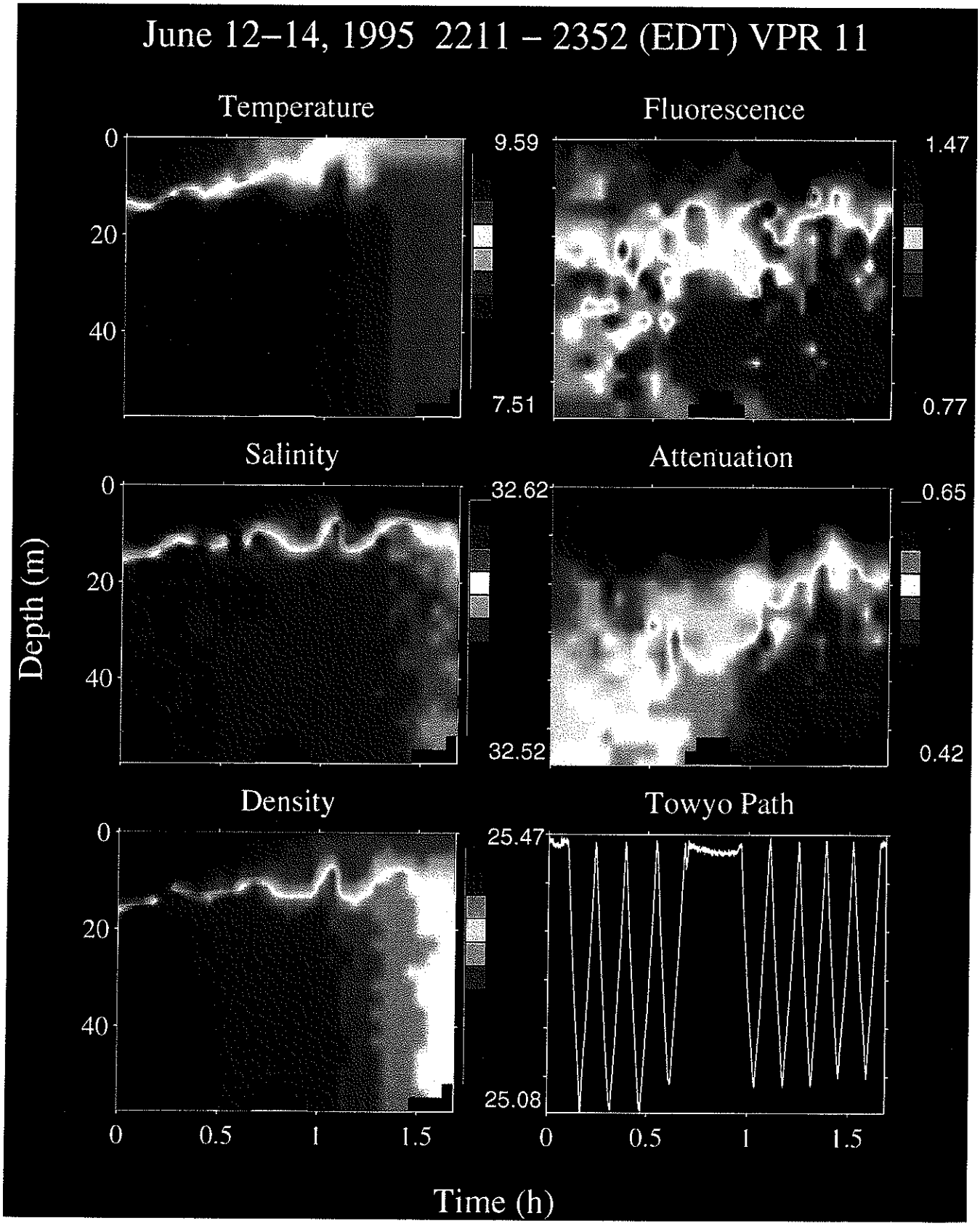
June 12–14, 1995 2211 – 2352 (EDT) VPR 11
Temperature
9.59
7.51
Fluorescence
1.47
0.77
Salinity
32.62
32.52
Attenuation
0.65
0.42
Density
Towyo Path
25.47
25.08
Depth (m)
0
20
40
0
0.5
1
1.5
Time (h)

Figure 13

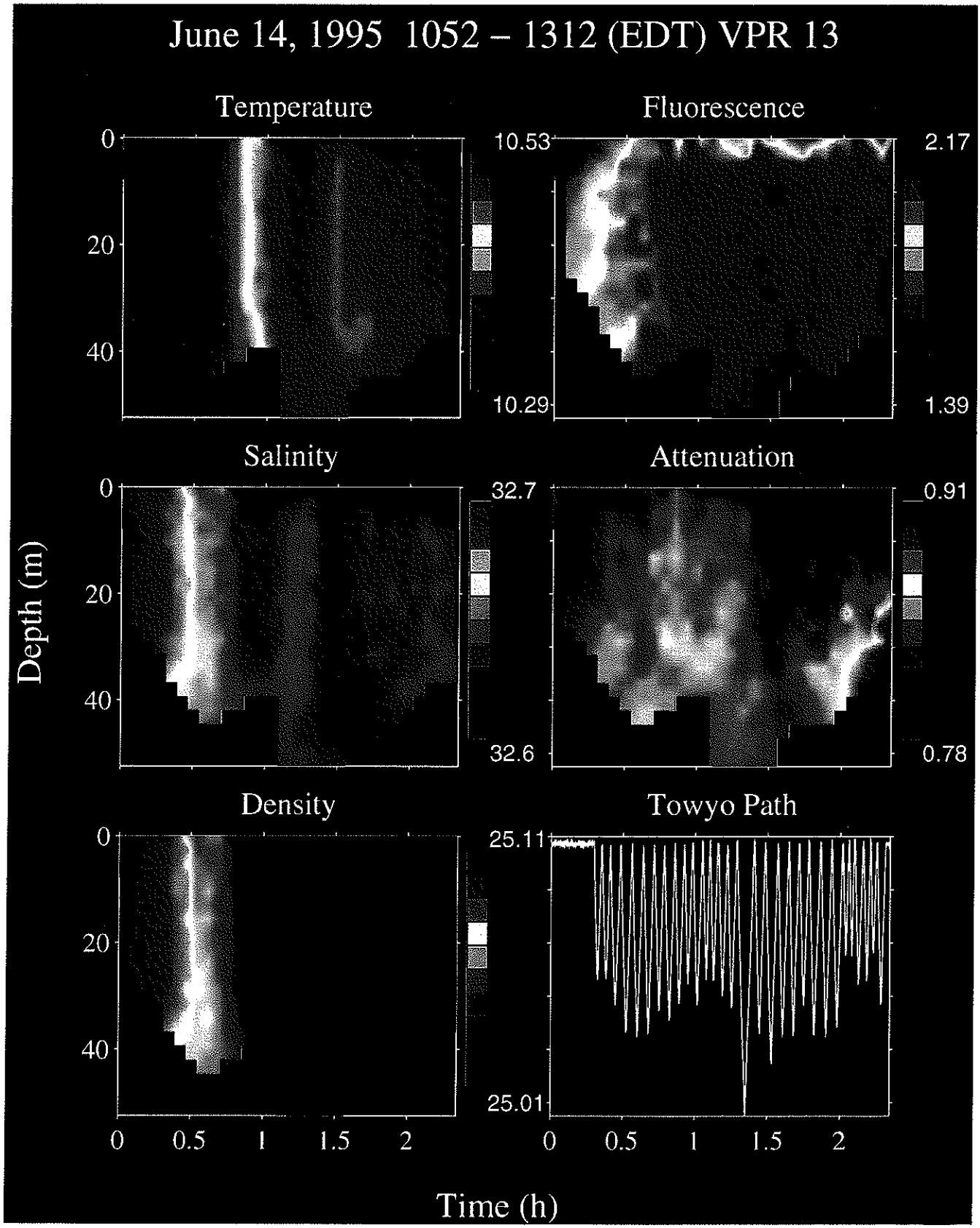
June 14, 1995 1052 – 1312 (EDT) VPR 13
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
10.53
10.29
2.17
1.39
32.7
32.6
0.91
0.78
25.11
25.01
0
0.5
1
1.5
2

Figure 14

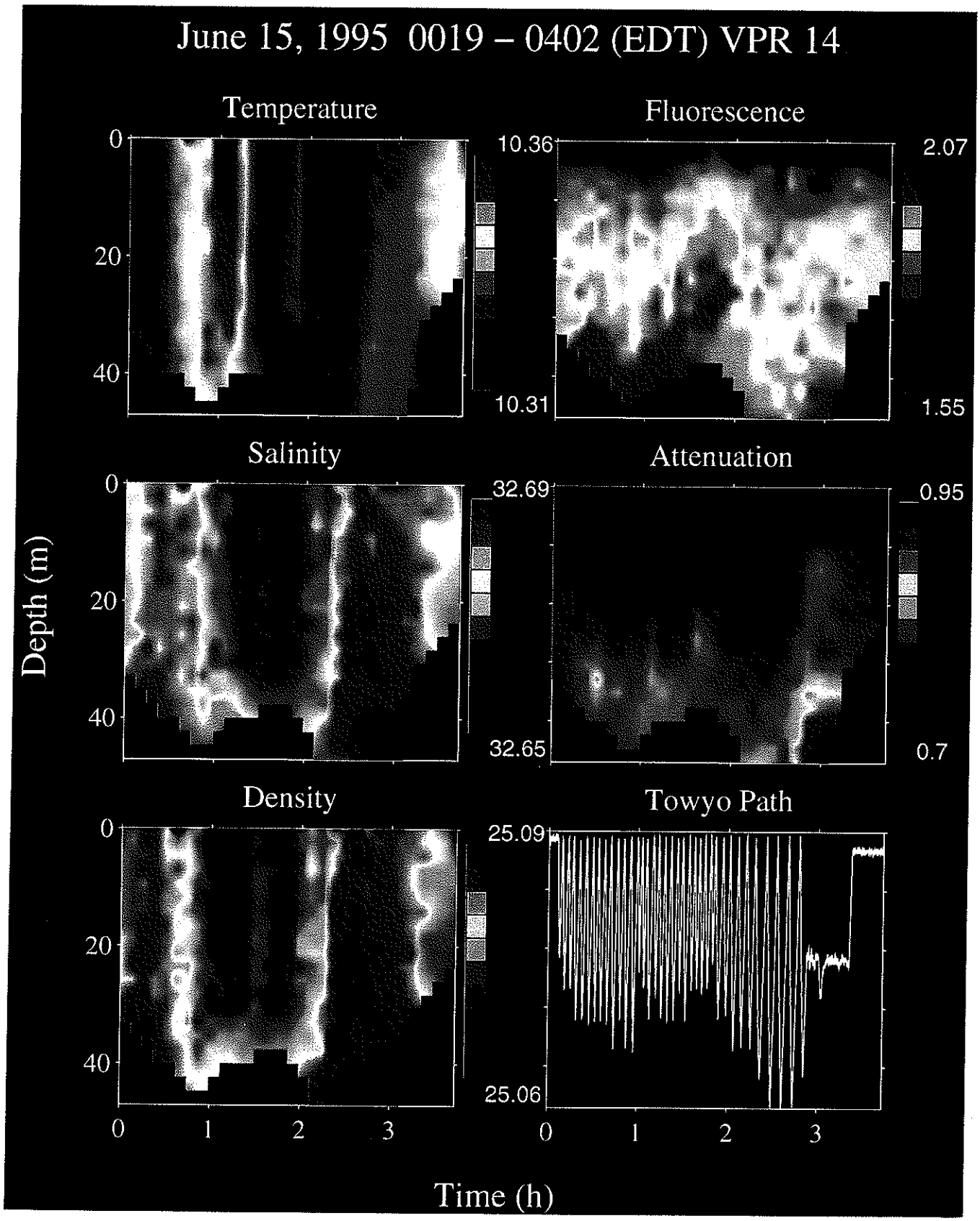
June 15, 1995 0019 – 0402 (EDT) VPR 14
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
10.36
10.31
2.07
1.55
32.69
32.65
0.95
0.7
25.09
25.06
0
1
2
3
Time (h)

Figure 15

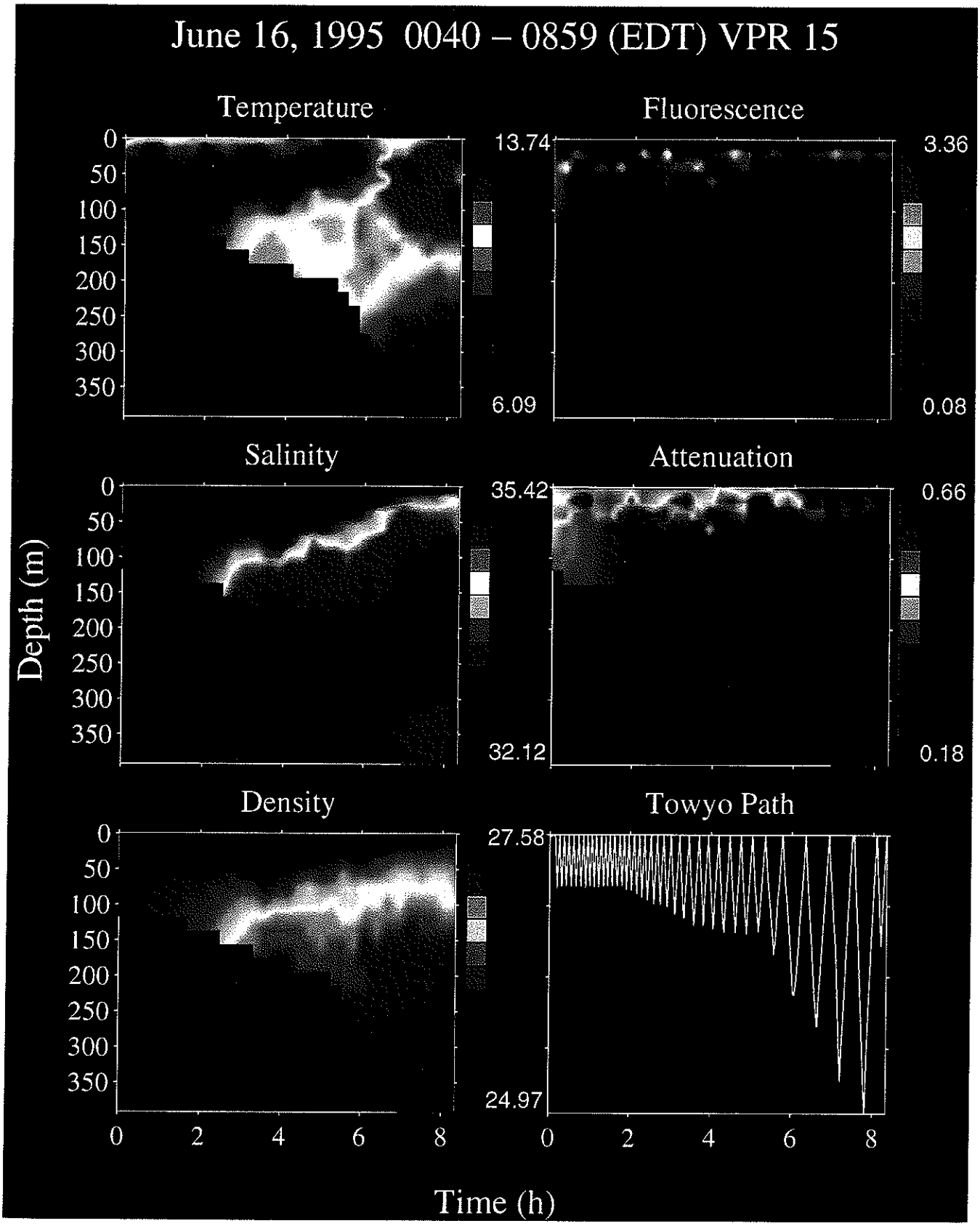
June 16, 1995 0040 – 0859 (EDT) VPR 15
Temperature
Fluorescence
13.74
6.09
3.36
0.08
Salinity
Attenuation
35.42
32.12
0.66
0.18
Density
Towyo Path
27.58
24.97
Depth (m)
0
50
100
150
200
250
300
350
0
2
4
6
8
Time (h)

Figure 16

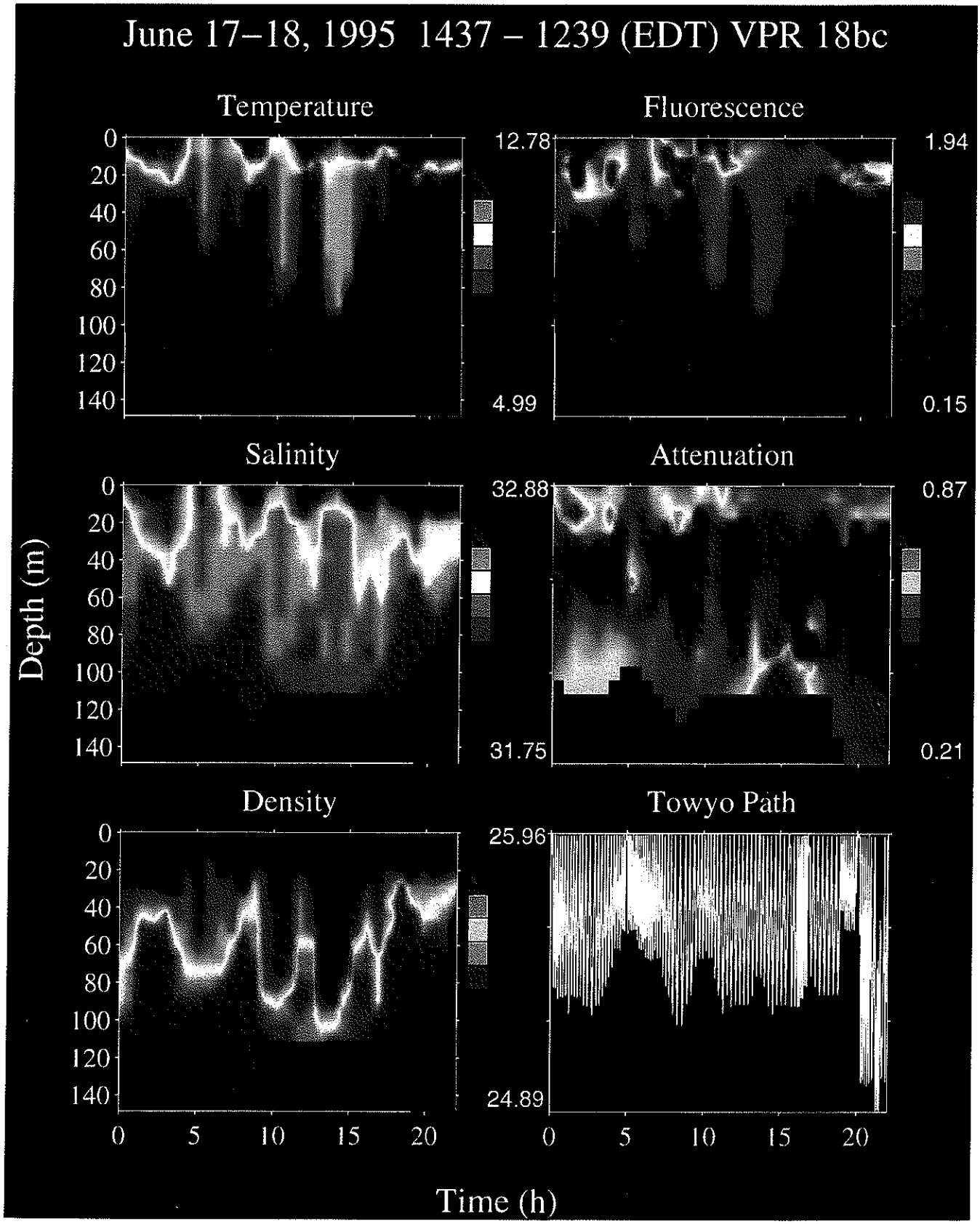
June 17–18, 1995 1437 – 1239 (EDT) VPR 18bc
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
0
20
40
60
80
100
120
140
12.78
4.99
1.94
0.15
32.88
31.75
0.87
0.21
25.96
24.89
0
5
10
15
20
Time (h)

Figure 17

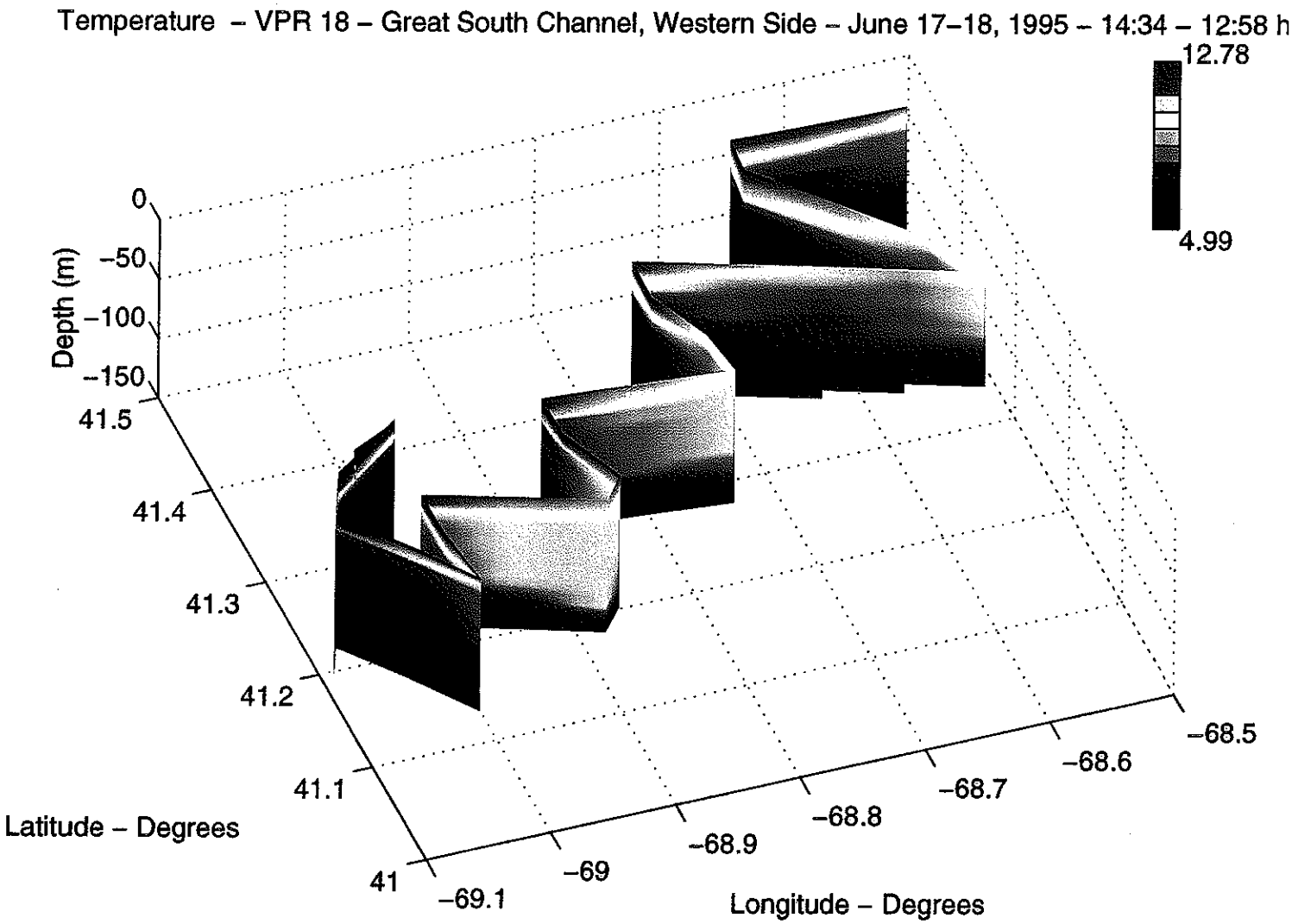
Temperature – VPR 18 – Great South Channel, Western Side – June 17–18, 1995 – 14:34 – 12:58 h
12.78
4.99
Depth (m)
0
–50
–100
–150
41.5
41.4
41.3
41.2
41.1
41
Latitude – Degrees
–69.1
–69
–68.9
–68.8
–68.7
–68.6
–68.5
Longitude – Degrees

Figure 18

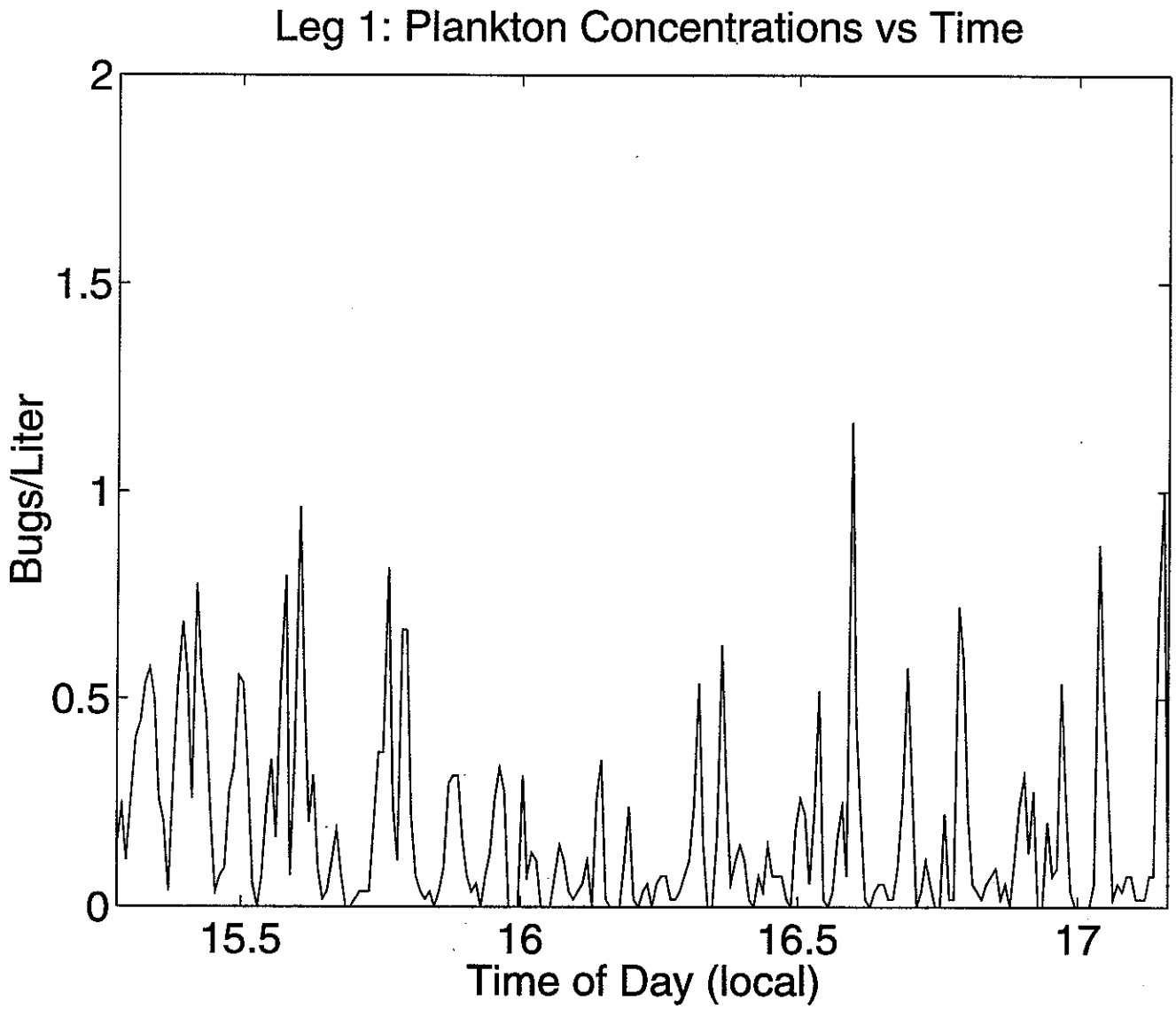
Leg 1: Plankton Concentrations vs Time
Bugs/Liter
2
1.5
1
0.5
0
15.5
16
16.5
17
Time of Day (local)

Figure 19

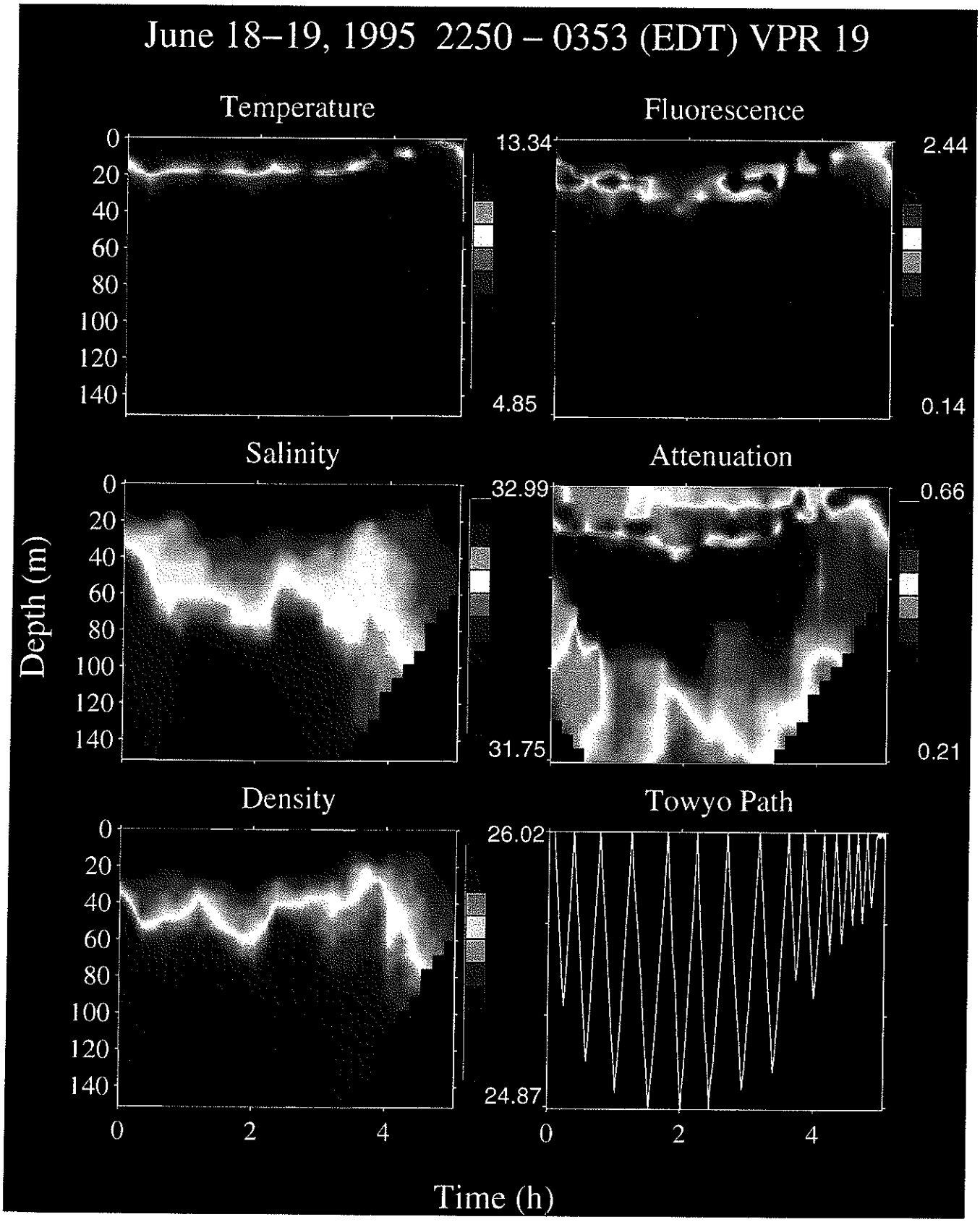
June 18–19, 1995 2250 – 0353 (EDT) VPR 19
Temperature
Fluorescence
Salinity
Attenuation
Density
Towyo Path
Depth (m)
Time (h)
0
20
40
60
80
100
120
140
13.34
4.85
2.44
0.14
32.99
31.75
0.66
0.21
26.02
24.87
0
2
4

Figure 20