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Table of Contents

Cruise Objectives

The overall objectives of the cruise were to examine the cross-frontal flow and mixing at the front located on the northeast peak of Georges Bank. To address these goals, we proposed to:

(1) conduct hydrographic and turbulence surveys of the frontal structure using a towed body (SeaSoar) containing a CTD, fluorometer and transmissometer, a turbulence measuring package (MicroSoar) attached to the SeaSoar and two shipboard ADCPs;

(2) deploy either a surface, ARGOS-tracked drifter or a subsurface, acoustically-tracked, isopycnal COOL float;

(3) and conduct small-scale hydrographic surveys around the Lagrangian drifter/float.

In addition, severe winter weather had taken a heavy toll on the moorings at the northeast peak. We would deploy new Northern Flank Deep (NFD) and Eastern Flank (EF) surface moorings.

Cruise Narrative

On Sunday, 28 March at 1300 EST (1800 UTC*) we departed Woods Hole to the location of the Northern Flank Deep (NFD) mooring site (approximately 42° 10' N, 66° 42' W). Departure was delayed three hours from the originally planned departure time. This delay was due to the extra time required to load the mooring equipment which was done before the SeaSoar equipment was loaded onto the ship.

Throughout the cruise, several underway measurements were continuously recorded. Sea surface temperature and salinity were obtained from the ship's intake water. Standard meteorological measurements were obtained using the IMET system. Figure 1 shows the wind speed that was recorded throughout the cruise. (A time-line of the major events is also shown on that figure.) Throughout the cruise, water velocities were measured with two acoustic Doppler current profilers.

On March 29th at 1630, we arrived at the site of the NFD mooring. The mooring deployment started at 1700 with the anchor for the discus mooring released at 1903 (42° 9.79' N, 66° 42.18' W). On the way to the eastern flank (EF) mooring site, we steamed past the northern flank shallow (NFS) mooring for a visual check and everything appeared fine. The deployment of the EF discus mooring was started at 2240. At 0030, 30 March, the anchor of the EF mooring was released (41° 44.25' N, 66° 6.52' W).

In order to deploy the SeaSoar for the first time in daylight hours, a water velocity/depth survey for a portion (lines 4-7) of the radiator pattern [Figure 2] was completed overnight. Shortly after the start of this survey, the observed velocities were obviously incorrect. It appeared to be a problem with the gyro input to the acoustic

* For the remainder of this report, all times will be reported as UTC.

Doppler current profilers (ADCPs) and was quickly corrected (at 0340). The survey was completed at approximately 1100.

The first SeaSoar tow was started at 1310. However, there appeared to be a ground loop problem with the fluorometer pump. The SeaBird deck unit was producing many errors when the pump was turned on. The SeaSoar was recovered and modifications made while we steamed back to the start of the radiator pattern (7S). The SeaSoar was redeployed at 1540 but there still appeared to be a problem with the fluorometer pump. We decided to complete the radiator pattern with the fluorometer pump turned off. The radiator pattern started at 1710.

At 2312, the SeaSoar had collided with the bottom at least four times. The control computer was receiving the bottom depth from the Knudsen 3.5-kHz echosounder. Due to acoustically noisy surface conditions, the Knudsen was producing depth drop-outs and interferring with the automated SeaSoar flight program; thus, a valid depth range of 150-300 m was set while we were in deep water. As we approached the slope, this depth range was not changed and an incorrect bottom depth was supplied to the SeaSoar control computer. Shortly after this time, the MicroSoar started to act strangely. The MicroSoar was powered down. On restart, it started normally but began to draw more current. It was not clear whether the sensors were damaged and started to leak. (It turns out that this was the case and the pressure case had flooded.) Around the same time, the data stream from the SeaSoar was being interrupted after turns at the top and bottom of each cycle. Later, this drop-out rate decreased and finally disappeared. We decided to continue the radiator pattern before recovering the SeaSoar/MicroSoar and undertake repairs and assess the status of the MicroSoar.

At 1759, 31 March, the radiator pattern was completed (Map 1 [Figure 1]). Linda Fayler adjusted the grounding of the power supply for the fluorometer and the CTD drop-outs associated with the pump on disappeared. At 1832, the SeaSoar/MicroSoar was recovered. It was evident that the MicroSoar sensors took the brunt of the collision with the bottom. We removed the MicroSoar from the SeaSoar and the SeaSoar's weight was attached. Meanwhile, we slowly steamed to the NFD site to see whether Ostrom and Dunn could talk to the acoustic release of the old NFD mooring array and determine its position. They were able to determine the location and planned to drag for the instruments from the F/V Alpha-Omega.

On April 1 at 0500, a CODE-style surface drifter (Drifter #2, ARGOS ID 27614) was deployed at 42° 11.64' N, 66° 36.67' W. While waiting for the deployment of the SeaSoar, we listened to the ARGOS transmissions from the drifter with the GONIO receiver. At 0516, the SeaSoar was deployed but there appeared to be a problem with the deck unit — a constant error light. The SeaSoar was brought back on board and there were no errors with the deck unit. Willis and Fayler started trouble shooting but could not determine the problem. At 0815, the SeaSoar was re-deployed and errors occurred again. The Sea-Bird deck unit was replaced and the error occurrence rate decreased. The original deck unit was tried again and the error rate was low also for this unit. It was decided to use the SeaSoar as-is on the butterfly survey patterns (e.g., Figure 12) around the surface drifter. The butterfly pattern was started at 0855. At 2129, we lost power on the SBE deck unit (a fuse was blown). After the fuse was replaced, the SeaSoar was still not responding to any control signals. The SeaSoar was recovered at 42° 10.36' N, 66° 31.55' W. The slip ring assembly had fallen off the winch hub and the cable had parted. The cable was reterminated at this end. At 0004 on April 2nd, the surface drifter was recovered at 42° 3.52' N, 66° 33.12' W.

At 0132 on April 2nd, another surface drifter (Drifter #1, ARGOS ID 27613) was deployed at 42° 9.78' N, 66° 33.20' W. At 0240, the SeaSoar was deployed but, again, continuous errors occurred on the Sea-Bird deck unit after the CTD entered the water. At 0319, the SeaSoar was brought back on board. Meanwhile, the GPS positions received from the surface drifter were invalid. We decided to recover the surface drifter while it was night and we could see the drifter's flasher. At 0348, the drifter was recovered at 42° 11.61' N, 66° 34.54' W. An ADCP survey for part of the radiator pattern (3S to 1N) was completed over night.

On April 2nd at 1300, Ostrom, Dunn and Medeiros were transferred to the F/V Alpha-Omega via small boat. They would try to retrieve the instruments from the previous NFD mooring*. After the transfer, the R/V Oceanus did a sail-by for a photo-op before recovering the Zodiac.

At 1530, we began a slow transit to 7S. The Oceanus's SBE 911+ CTD was borrowed (the primary OSU CTD was damaged before the cruise and SeaSoar tows to this point were completed with the OSU's backup CTD) and installed in the SeaSoar to determine if the OSU CTD was the source of the problems. As well, we decided to move the radiator pattern 3 nm northward [Figure 2] to cover more of the stratified region and less of the well-mixed part of the bank. At 1915, the SeaSoar was deployed at the new 7S location. No errors were received on the SBE deck unit. The radiator pattern was completed on April 3rd at 1925. The SeaSoar was recovered at 42° 21.87' N, 66° 44.28' W. The signal to the CTD was lost while the SeaSoar was on the deck. The slip ring assembly fell off the hub again and the wire at that end had to be reterminated.

At 2120 on April 3rd, COOL Float #1 was deployed at 42° 13.18' N, 66° 31.00' W and programmed to surface 62 hours later. Based on the tidal excursions of the surface drifter, the horizontal extent of the butterfly pattern was increased to 10 nm in the north-south (cross-bank) direction and to approximately 5 nm in the along-bank direction. At 2230, another conductor was lost on the tow cable. During retermination at 0040, two additional wires were found to be bad near the drum end. It was decided to complete the remainder of the cruise using the remaining five good conductors.

On April 4th, at 0305, the SeaSoar butterfly pattern was started at 42° 13.41' N, 66° 34.36' W. Seas picked up around 1900 (Julian Day 94.8) but we continued the butterfly

* They were successful in the dragging operation. The mooring was hooked approximately 50 meters from the initial anchor site to the southeast. The Alpha Omega was able to maneuver in tight quarters near the replacement discus mooring which at times was 20 m from the ship, criss-crossing back and forth bisecting the potential path that the mooring had dragged prior to failing and going adrift. The mooring was hooked on the 8th pass across this line. All the mooring's instrumentation was recovered undamaged.

pattern. At 2250, seas had increased to the level that we could not maintain enough ship speed (7 kts) to allow the SeaSoar to fly. We started hauling in wire to prepare to heave-to and ride out the storm. At 2306, we stopped steaming and started to drift to the northwest; the SeaSoar was dangling at approximately 70 m depth behind the ship.

At 2125 on April 5th, seas had decreased enough and SeaSoar-ing on the butterfly pattern resumed. The SeaSoar was recovered at 0419 on April 6th having completed one butterfly pattern after the storm. The COOL float was sighted on the surface at 0633 and recovered by 0705 (42° 13.276' N, 66° 33.637' W). Then, we headed to 1N to do the radiator pattern from west to east.

At 0850, we attempted to launch the SeaSoar but noticed a few of the armor strands were broken near the wet end termination. The tow cable was reterminated by 1350. The radiator pattern was started at 1430 on April 6th and completed at 1731 on April 7th. One additional north-south line east of line 7 (line 8) was done.

COOL float #1 was deployed on April 7th at 2008 (42° 13.8819' N, 66° 37.9475' W). It was programmed to surface 34 hours later. One minute later, a surface drifter (Drifter #2, ARGOS ID 27614) was deployed. The SeaSoar was deployed at 2042 for the start of the butterfly pattern (42° 12.71' N, 66° 34.65' W). At 0841 on April 8th, the SeaSoar snagged on some lobster gear and had to be recovered at 0926. Minor repairs were made to the SeaSoar and it was re-deployed at 1334. Again, at 1637, the SeaSoar was caught on fishing gear. The SeaSoar was freed without having to bring it on board. The SeaSoar was recovered at 0426 on April 9th in preparation of the recovery of the COOL float and surface drifter. At 0433, we headed to the predicted COOL float location. The COOL float was recovered at 0636. We headed east to the predicted location of the surface drifter (we had not received any GPS fixes from it for more than a day). There was no sign of the drifter at the predicted location. We conducted a search grid to 4 nm east of the last butterfly pattern with east-west lines spaced 2 nm apart northwards until dawn. With no sign of the drifter, either visually or electronically, we decided to start the SeaSoar radiator pattern at 8N.

April 9th, 1220, another SeaSoar radiator pattern was started. At approximately 2350, we received an ARGOS message (via e-mail) with possible drifter locations. One of the messages had good GPS information stating the drifter was on the other side of the Northeast Channel. At 0121 on April 10th, the SeaSoar radiator pattern was suspended at 5N. We headed for the drifter location at 12+ kts. At a range of several miles, the flasher on the drifter was spotted. At 0312, the surface drifter was recovered at 42° 36.478' N, 66° 36.372' W. We headed back to the radiator pattern location to resume the survey. The SeaSoar was deployed at 0437 at the location of 4N and the radiator pattern was completed at 1740 (1N). We continued northwards to 42° 24.96' N along the same line to map the cold plume before heading eastward.

In order to determine the variability of the frontal region over a tidal cycle, our next plan of action was to make repeated SeaSoar transects along line 3 for 24 hours. On April 10th at 1858, we headed south from 42° 24.75' N to 3N. The repeated line survey started at 1927. Weather predictions had gale winds (> 35 kts) occurring on Georges Bank for Monday (12 April). At 1226 on April 11th, the SeaSoar was recovered at 42° 0.00 'N, 66° 36.00' W at the Captain's request. The latest weather forecast at that time was predicting storm conditions (with winds up to 60 kts). We decided to head in one day early to avoid the storm. At 1300 on April 12th, the R/V Oceanus arrived at Woods Hole.

Overall, we had a very successful cruise. We completed four large-scale (30×40 km) detailed CTD/ADCP surveys across the front on the northeast peak of Georges Bank [Figure 2]. As well, three sets of high resolution, small-scale (18×10 km) surveys were conducted around either a surface or subsurface water parcel tagged with a drifter or COOL float for several tidal cycles. Finally, one of the north-south transect lines was repeatly surveyed, 5 times over a 24 hour period, to investigate the evolution of the front over a couple of tidal cycles.

SeaSoar Measurements. Jack Barth

To measure the hydrographic and bio-optical properties over the northern flank of Georges Bank, we deployed the towed, undulating vehicle SeaSoar. SeaSoar was towed using a 9/16" 7-conductor hydrographic cable and profiled from the sea surface to 115 m over deep water and to within 10-15 m of the bottom over the Bank. Cycle time in deep water was about 6.5 minutes resulting in surface points being separated by 1.3 km at the ship's typical 7 knot tow speed — horizontal separation between profiles at mid-depth is half this value. Cycles over the shallow Bank, 0–70 m, took 2 minutes so surface points where separated by 420 m. Bottom avoidance was accomplished by using Oceanus' 3.5-kHz Knudsen echosounder as input to the OSU SeaSoar flight control software.

The SeaSoar was equipped with a Seabird 911+ CTD with pumped, dual T/C sensors pointing forward through the nose of SeaSoar. Fluorescence was measured with a WETLabs WETStar fluorometer mounted inside the SeaSoar body and water was pumped to it from an intake located adjacent to the T/C sensors in the nose of SeaSoar. Light transmission was measured with a Seatech 25-cm pathlength transmissometer mounted on top of SeaSoar. In addition, engineering information (pitch, roll, propellor rotation rate) was obtained from sensors aboard the vehicle. All data were sent topside where they were merged with GPS location and time before archiving. The data were averaged over one second from which realtime displays of hydrographic and bio-optical properties were made. On the bottom of SeaSoar, a new microstructure instrument MicroSoar (Dillon et al., 1999) was mounted (see separate section).

SeaSoar was towed across the northern flank of Georges Bank in three basic patterns. A large-scale map, 30-35 km alongshelf (E-W) and 40 km cross-shelf (N-S), was occupied four times by towing SeaSoar along N-S lines separated by 5 km in about 24 hours [Figures 3-11]. Maps were made on 30-31 March, 2-3 April, 6-7 April and 9-10 April. The maps delineate the boundary between well-mixed water over the Bank and stratified water offshore. The presence of cold-fresh Scotian Shelf water over the northern part of the study region was also documented. Cross-shelf lines revealed variability over the tidal cycle in subsurface thermohaline properties as slope water moved on and off the Bank.

A second sampling design was a butterfly pattern extending 18 km across the shelf and 10 km alongshelf which took about 7 hours to occupy [Figure 12]. The sampling pattern was repeated in conjunction with surface drifter and subsurface COOL float releases. The pattern was repeated in place or shifted to the east depending on the location of the drifter or float [Figure 12]. The butterfly sampling took place three times: 1-April tracking a surface GPS drifter; 4-6 April tracking a COOL float; and 7-9 April tracking both a surface GPS drifter and a subsurface COOL float.

A final SeaSoar sampling pattern was a repeat line along a N-S line at 66 37'W (line 3 in Figure 2), occupied 5 times during 10-11 April. This was intended to document the temporal variability along a single 40-km cross-shelf transect.

In summary, over 7-1/2 days of continuous data were collected with SeaSoar profiles on and off the steep northern flank of Georges Bank.

MicroSoar Measurements. David Ullman

As a part of our investigation of cross-frontal transport on Georges Bank, we planned to quantify the spatial variability of the turbulent dissipation rate, a measure of small scale turbulent mixing, in a frontal zone on the northern flank of the Bank. MicroSoar is an instrument package designed to measure turbulent microstructure using robust, fast-response temperature and conductivity probes (Dillon et al., 1999). Its sensors are sufficiently small that accurate measurements can be made from a towed body and, unlike the case of instruments that measure velocity microstructure, their signals are not extremely sensitive to instrument vibration.

For this cruise, MicroSoar was mounted on the underside of SeaSoar. Because of the high data acquisition rate ($\sim$ 1 Mbyte/min), data collected by MicroSoar cannot be transmitted in real time to the deck of the ship via the towing wire as is done with the CTD and other sensors carried by SeaSoar. Data is therefore written to the hard disk of MicroSoar's onboard computer, which has a capacity of 4 Gbyte, enabling data to be collected for about 3 days. After this period, the SeaSoar is brought on deck and MicroSoar data is downloaded to a deck computer via a fast ethernet connection. During a SeaSoar tow, a reduced set of MicroSoar data is sent to the deck computer via the SeaSoar CTD to enable monitoring of the instrument's performance.

MicroSoar was first deployed on SeaSoar at 13:50 on March 30th. A problem with SeaSoar forced a recovery almost immediately. After repairs, SeaSoar was back in the water at 17:10. For approximately the next 6 hours, MicroSoar collected data. There were sporadic problems with the pressure signal that we attributed to the improper positioning of ballast weights attached to the nose cone of MicroSoar. In addition, the conductivity signal was occasionally observed to be out of range, indicating that the sensitivity of the conductivity sensor needed adjustment. However, before any adjustments could be made, at 23:10 the SeaSoar hit the seafloor with MicroSoar taking the brunt of the impact. With MicroSoar drawing twice normal electric current, the instrument was shut down. When finally brought to the surface, we found the sensors destroyed and the pressure case filled with seawater. Because this occurred before we were able to download data, no turbulence data were obtained during this cruise.

ADCP Measurements. Sandra Fontana

Both the 150-kHz narrowband and 300-kHz broadband RDI acoustic Doppler current profilers (ADCPs) were in operation throughout the cruise. Real-time running contour plots of the velocities from the narrowband ADCP were displayed continuously. The narrowband was initially configured to run using Charlie Flagg's *autoadcp* mode, in which the configuration files change automatically based on specific geographic regions. After the mooring work was completed, the autoadcp mode was abandoned in favor of a fixed configuration file (beginning on March 30th at 00:40, when the first SeaSoar survey began). The ensemble length was set to 150 seconds (from 300 seconds). The pulse length and bin length were both set to 8 meters, and bottom track data were collected during the entire time. The configuration was changed back to *autoadcp mode* at 16:05 on April 11th, shortly after the start of the return transit to Woods Hole.

The Ashtech 3DF attitudinal GPS data were collected every 1/2 second. The data were then averaged over the ensemble length by the user exit program `ue4`, with the Ashtech-gyro difference stored in a user buffer (in the pingdata files). Positions from the P-Code navigation data were extracted at the beginning and end of each ensemble and stored in the user buffer by `ue4`. The Ashtech data will be used in post-processing to correct for gyrocompass variations to determine the transducer offset and more accurate final velocities.

The broadband data were collected with RDI's TRANSECT software (version 2.80). Both raw and averaged data were recorded. The data were averaged over 150 seconds. Gyro and navigation data were recorded. Cell length was set to 4 meters, and bottom track data were also collected.

Figures 13 to 16 show velocities obtained from the 150-kHz for the same depths and transects of the radiator pattern as shown earlier for the SeaSoar data.

COOL Float/ Drifter Measurements. Dave Hebert

A major aspect of this cruise was to map the change in the hydrographic structure of the front from a Lagrangian point of view. Thus, the plan was to survey around the position of a subsurface isopycnal float. The dominant current advecting the float would be the M_2 tide. The subsurface float would be tracked acoustically. Since we had not tried to do SeaSoar surveys while following a subsurface float whose position would only be detected at ranges of a few kilometers, we decided to test the tracking/surveying logistics using a GPS/ARGOS surface drifter.

After completing our first radiator pattern, we deployed a GPS/ARGOS "Davis"-type (e.g. a CODE-style) surface drifter purchased from Brightwaters Instrument Corporation (Model 115). This drifter, drogued for the top 1.5 m, obtains its GPS location every 15 minutes and transmits the last 7 positions via ARGOS every 90 s. On the ship, a GONIO ARGOS receiver was used to intercept the ARGOS messages when we were within range. A computer attached to the receiver displayed the drifter positions obtained. ARGOS messages from the drifter were transmitted also to the ship via normal twice daily e-mail transfers. The surface drifter was equiped with a night-time flasher. The trajectory of the surface drifter was predicted using the shipboard ADCP data and the tidal model developed by Charlie Flagg (BNL). For the first deployment, the tidal displacement ellipse was larger than expected. The mean translation was to the south-east. For the 1.5 tidal periods of the deployment, the float remained mainly within the first butterfly survey pattern. The prediction of the drifter's location agreed well with the observed location (which was finally obtained from a direct download from the recovered drifter).

Given the great success of tracking and SeaSoar-ing around the surface drifter, the subsurface isopycnal COastal Ocean Lagrangian (COOL) float (Hebert et al., 1997) was deployed. This isopycnal float was ballasted for the $\sigma_t = 26.1$ surface. The COOL float contains a compass and vanes angled at 15° to horizontal. Thus, a diapycnal velocity past the float will make the float rotate and this rotation rate is measured using a compass. The COOL float has a 12-kHz pinger which sends an 8-ms ping every 8 s. The float is tracked acoustically. During the cruise, the acoustic transmission was the best we have ever seen — we could detect the float over 7 km away. Compass angle, pressure and temperature were recorded every 64 s [Figure 17].

Given the great success of tracking the COOL float during the first deployment, we decided to deploy a surface drifter at the same place as our next COOL float deployment. Since the original target density deployment was near the maximum depth of the SeaSoar cycle (Figures 6 and 11), we decided to decrease the target density of the float by approximately 1.5 σ_t units. (It was not until after this deployment that we realized that there were problems with the ballasting of the COOL floats using the recently moved GSO Equipment Development Laboratory's pressure vessel. This resulted in the floats being ballasted approximately 0.3 σ_t units heavier than desired.) As before, compass angle, pressure and temperature were recorded every 64 s during the mission [Figure 18].

The tracking and prediction of the surface drifter during the second deployment was not as successful as the first time. The drifter had a problem with its ARGOS transmitter (the manufacturer has determined the problem and corrected it in other units) and was advected during a storm in a direction not expected by the observed ADCP measurements or tidal model. Fortunately, a good set of GPS positions were obtained through an ARGOS message which allowed the drifter to be recovered.

Mooring Deployments. Will Ostrom and Dave Hebert

Severe winter weather took a toll on the moorings on Georges Bank for several reasons. One modification to the replacement moorings was a larger surface buoy - a 3 m discus buoy. Two replacement surface moorings, the northern flank deep (NFD) [Figure 19] and eastern flank (EF) [Figure 20], were deployed during the cruise. The date, time of deployment and mooring position are:

Northern Flank Deep - NFD	29 Mar 99	1903 UTC	42° 09.7939' N	66° 42.1864 W
Eastern Flank - EF	30 Mar 99	0031 UTC	41° 44.2629' N	66° 06.5229' W

The WHOI Upper Ocean Processes (UOP) Group, mid-span deployment technique was used to deploy both moorings. This method is a two-phase operation. The first phase of the operation requires the upper 40 meters of instrumentation to be deployed vertically over the ship's rail along side the discus buoy. This is done in individual segments starting at the 40 meter mooring segment and working up to the apex of the bridle. The second phase involves the deployment of the discus buoy. By dividing the deployment into two separate operations, the near-surface instrumentation can be deployed individually in a safe and controlled manner. When the 40 meters of instrumentation is lowered and the static weight of that instrumentation string is transferred to the discus bridle, the buoy's stability during the crane lift and deployment is greatly improved.

The following narrative details the procedure used to deploy NFD and EF discus moorings. The primary deck machinery and handling gear used for the deployments are: the TSE mooring winch, the Oceanus crane, 7/8" diameter Samson deck stopper lines, 3 ton Release-O-Matic hook, Bally vertical quick release hook, 3/4" chain grabs, 2 ton snap hooks, portable deck cleats, 3/3" nylon tag lines and 100 meter 7/16" diameter wire rope hauling wire. The personnel required for the deployment are the crane operator, TSE winch operator, 3 wire/slip line handers, 2 instrument handlers, quick release person and deck supervisor. The moorings were deployed under the supervision of Ostrom and Dunn, with the assistance of several of the scientific personnel and some of the crew.

The initial preparations prior to starting the deployment of the NFD mooring required the 7/16" wire rope hauling wire be pre-wound onto the TSE winch drum. This wire was then paid out and lead aft around the transom of the ship and back, out board along the starboard rail just forward of the apex of the discus bridle. A 18.7 m 7/16" wire rope shot was then shackled and cotter pined to the end of the hauling wire. The 30-m SEACAT was shackled to the free or top end of the 18.7 m wire shot. There were three hauling wire handlers positioned at the following locations: head of the TSE winch, transom and starboard rail, just aft of the discus buoy hull.

The ship's crane boom was positioned over the rail edge along side the apex of the discus bridle with an extension so that the craness whip had a vertical lift of 40 feet. A 13.7 m wire rope shot was shackled to the top of the 30-m SEACAT load bar. A 3/4" chain shackle and 7/8" end link were secured to the free end of the 13.7 m wire shot. A 5/8" pin shackle and 5/8" pear ring were shackled to the 7/8" end link. A 4 foot Lift-All sling was then bent in a barrel hitch through the 5/8" pear ring. The Lift-All sling was then passed onto the crane whip hook. The addition of the 5/8" shackle, ring and sling were used to improve the handling of the crane whip hook. The whip was raised up lifting the 7/16" wire shot, SEACAT and hauling wire up over the ship's rail. The crane then boomed out board slightly and lowered the whip. The TSE winch simultaneously paid out the hauling wire. The three wire handlers managed the wire around the transom and up along the starboard rail. When the upper end of the 7/16" wire shot was approximately 1 meter above the ship's rail, a stopper line was hooked onto the 7/8" end link shackled to the swaged termination. The stopper line was secured to a deck cleat. The crane hook was removed from the sling and the 5/8" screw pin shackle was removed from the stopped off wire shot. The 15-m SEACAT with a 8.26 m wire shot shackled to the top of the instrument was then shackled to the stopped off 7/8" end link. The 5/8" screw pin shackle was again shackled to the free end of the 8.26 m wire shot's end link. The same process of utilizing the crane whip to lift up the wire shot and SEACAT, taking the hanging mooring tension and lowering simultaneously as the TSE winch was paying out the hauling wire was repeated. The bottom of the 5-m VMCM was shackled onto the stopped off 8.26 m wire shot. The 5/8" screw pin shackle and sling were secured to the end link shackled to the top end of the VMCM. The entire length of the 0.9 m shot of 3/4" chain shackled to the top of the VMCM was left loose in order to allow the instrument, once being lowered by the crane to hang vertically out board of the rail and still allow the chain to be shackled to the discus bridle cleaves.

The second phase of the deployment was to launch the discus buoy. Three slip lines were positioned each at the bridle, inboard buoy deck bail and aft leading tower bail. Each slip line was revved through its bail and down to a portable deck cleat. The bridle slip line and aft lead slip lines controlled the forward and aft motion of the buoy; the inboard deck bail slip line checked the motion of the discus as the crane swung out board during the crane lift this maintained the correct orientation for the discus buoy so that the quick release hook could be released and cleared away from the discus tower.

The crane was then repositioned over the discus main lifting bail with approximately 45 feet of boom extension. The crane's hook, secured to a Release-O-Matic release hook, was then hooked to the main lifting bail. The three slip lines were drawn tight and moderate tension applied to the release hook from the crane. The chain lashing that was securing the discus to the deck was then removed. The discus buoy was lifted by the crane as the slip lines checked the buoy's motion. The slip lines were removed in the following order: aft tower, bridle and the in board deck bail. The quick release hook was tripped when the discus had settled out in the sea. Following the buoy being released, the ship steamed ahead at 0.5 knots causing the discus, 40 meters of mooring string and 40 meters hauling wire to come around to the stern of the ship. Once the mooring had centered itself aft of the ship, the TSE winch slowly hauled up the hauling wire until the bottom termination of the 18.7 m wire shot was 2 meters up onto the fantail. The end link that was shackled to the wire shot was stopped off to a deck cleat and the winch hauling wire was removed. Two, 23.7 m wire shots were shackled to the hauling wire and wound onto the TSE winch. The 50-m, 75-m and 100-m SEACATs were deployed over the stern. The mooring was stopped off at the 5-m 3/4" chain shot shackled to the 100-m SEACAT; 160 m of 3/4" chain was then wound onto the TSE winch. The free end of the 3/4" chain was then shackled to the stopped off 5 m shot. The ship's speed was increased to 1.5 to 2 knots and the 3/4" chain that was paid out. The bitter end of the 3/4" chain secured the winch hauling wire was stopped off, leaving approximately 8 m of chain free. This allowed the end of the 3/4" chain to be passed out board of the A-frame and secured to the 5000 lb. anchor. A Bally release hook was hooked through a pear ring shackled onto the 3/4" chain approximately 0.5 m away from the anchor's eye bolt. The ship's crane was positioned over the anchor so that the crane whip tended aft. The crane whip hook was lowered and attached to the Bally hook. The bridge informed the deck supervisor in increments of 3 and 1 minute warnings of approaching the anchor drop position. At the 3 minute warning the lashing on the anchor was removed and the stopped off 3/4" chain was transferred to a 45 ft. 3/4" nylon slip line. At the 1 minute warning the slip line was eased out, transferring the mooring tension to the anchor. When the slip line had been pulled clear, the anchor was lifted by the crane and lowered 2 m into the water. The Bally hook trip line was secured to a deck cleat; and upon notification from the bridge, the crane whip lowered tripping the hook which cast the anchor away. The deployment of the EF mooring [Figure 20] was done in the same manner.

After the deployments, Ostrom attempted to communicate and range on the previous NFD mooring's acoustic release. He was successful in determining its location. Ostrom and Dunn were transferred to the trawler F/V Alpha-Omega to recover the instruments associated with the earlier NFD mooring. The instruments from the previous NFD mooring was recovered successfully.

References

Dillon, T., J.A. Barth, A. Erofeev and G. May. 1999: MicroSoar: A new instrument for measuring microscale turbulence from rapidly moving submerged platforms, *J. Atmos. Ocean. Techn.* (submitted)

Hebert, D., M. Prater, J. Fontaine and T. Rossby. 1997: Results from the test deployments of the COastal Ocean Lagrangian (COOL) float, *GSO Technical Report*, **97-2**, University of Rhode Island, 27p.

Appendix 1. Personnel List

Scientific Personnel

David Hebert	University of Rhode Island	Chief Scientist
John A. Barth	Oregon State University	co-Chief Scientist
David Ullman	University of Rhode Island	Scientist
J. Marcus Willis	Oregon State University	Marine Techn.
Linda Fayler	Oregon State University	Marine Techn.
James R. Fontaine	University of Rhode Island	Technician
Sandra A. Fontana	University of Rhode Island	Technician
Robert T. O'Malley	Oregon State University	Technician
Paula Perez-Brunius	University of Rhode Island	Grad. Student
Jennifer Marie Friese	Oregon State University	Grad. Student
Xiaodong Liang	University of Rhode Island	Grad. Student
William Ostrom	Woods Hole Oceanographic Inst	Mooring Techn.
James Dunn	Woods Hole Oceanographic Inst	Mooring Techn.
Laura Goepfert	Woods Hole Oceanographic Inst	SSSG Techn.

Ship Personnel

Lawrence T. Bearse	Master
Courtenay Barber III	Ch. Mate
Anthony D. Mello	2^{nd} Mate
Jeffrey M. Stolp	Bos'n
Orville B. Kenerson	OS
James R. Ryder	AB
Horace Medeiros*	AB
Peter J. Liarikos*	AB
Ernest Wegman	Chief Engineer
J. Kevin Kay	Jr. Engineer
Alberto Collasius, Jr.	Jr. Engineer
Torii Corbett	Steward
Constance J. McGrath	Mess Attendant

* 2 Apr 99 At Sea:

Embark:	Debark:
Peter J. Liarikos	Horace Medeiros
	William Ostrom
	James Dunn

Appendix 2. Figures

Figure Captions:

Figure 1. Wind speed measured throughout the cruise. Above each panel, shaded boxes represent the time periods for major events conducted throughout the cruise.

Figure 2. Location of radiator patterns for large scale CTD/ADCP surveys and the Northern Flank Deep (NFD) and Shallow (NFS) moorings. On April 2nd, the radiator pattern was changed from the initial location (solid lines) to 3 nm farther north (dashed lines). The line 8S-8N was only completed a couple of times.

Figure 3. Horizontal map of temperature at depths of 11 and 61 m for the second radiator pattern survey.

Figure 4. Horizontal map of salinity at depths of 11 and 61 m for the second radiator pattern survey.

Figure 5. Horizontal map of $\sigma!_t$ at depths of 11 and 61 m for the second radiator pattern survey.

Figure 6. Cross-section (line 7) of temperature, salinity and σ_t for the second radiator pattern survey.

Figure 7. Cross-section (line 7) of fluorometer and transmissometer voltage for the second radiator pattern survey

Figure 8. Horizontal map of temperature at depths of 11 and 61 m for the fourth radiator pattern survey.

Figure 9. Horizontal map of salinity at depths of 11 and 61 m for the fourth radiator pattern survey.

Figure 10. Horizontal map of σ_t at depths of 11 and 61 m for the fourth radiator pattern survey.

Figure 11. Cross-section (line 5) of temperature, salinity and σ_t for the fourth radiator pattern survey.

Figure 12. Maps of temperature on a $\sigma_t = 26.0$ while tracking the COOL float. The butterfly pattern was moved eastward to follow the COOL float. In each panel, the location of the first fix of the COOL float for the pattern is shown as an open circle. Additional fixes are solid circles.

Figure 13. Horizontal velocity at depths of 11 and 61 m along ship track for the second radiator pattern survey

Figure 14. Cross-section (line 7) of eastward and northward velocity for the second radiator pattern survey.

Figure 15. Horizontal velocity at depths of 11 and 61 m along ship track for the fourth radiator pattern survey

Figure 16. Cross-section (line 5) of eastward and northward velocity for the fourth radiator pattern survey.

Figure 17. Time series of compass angle, pressure and temperature for the first deployment of COOL Float 1.

Figure 18. Time series of compass angle, pressure and temperature for the second deployment of COOL Float 1.

Figure 19. Schematic of the mooring deployed at the Northeast Flank Deep (NFD) location.

Figure 20. Schematic of the mooring deployed at the Eastern Flank (EF) location.

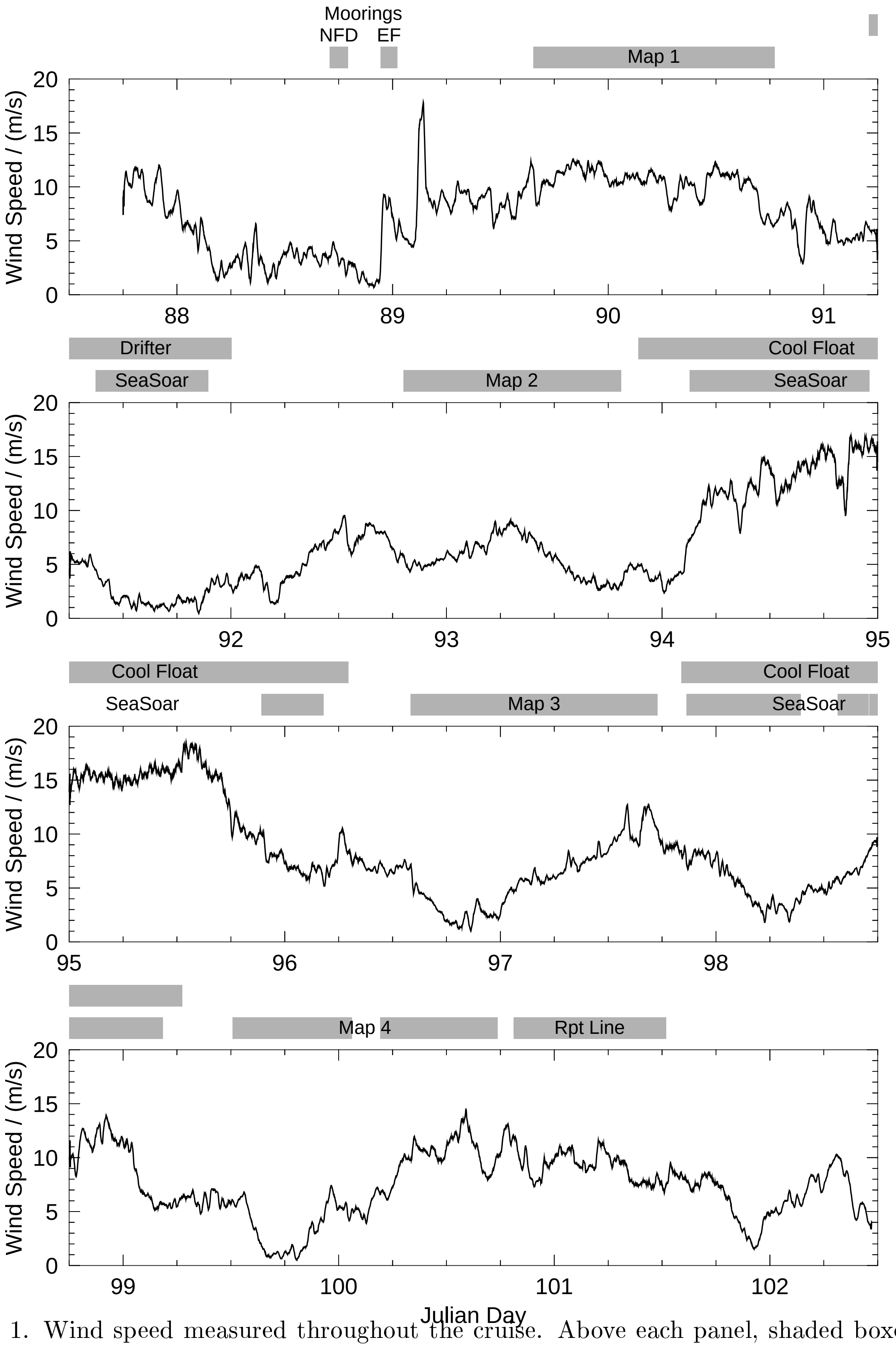

Figure 1. Wind speed measured throughout the cruise. Above each panel, shaded boxes represent the time periods for major events conducted throughout the cruise.

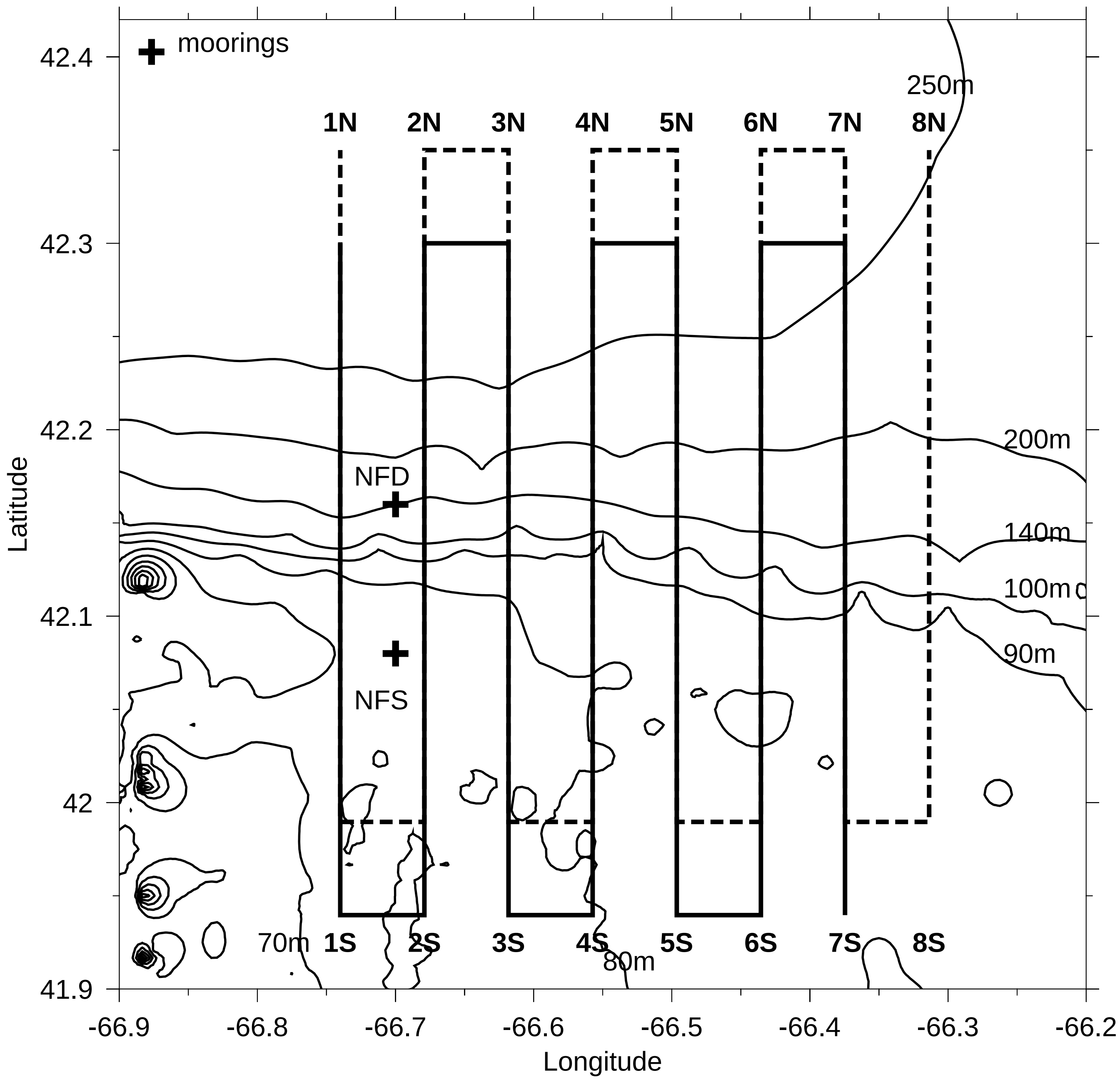

Figure 2. Location of radiator patterns for large scale CTD/ADCP surveysand the Northern Flank Deep (NFD) and Shallow (NFS) moorings. On April 2nd, the radiator pattern was changed from the initial location (solid lines) to 3 nm farther north (dashed lines). The line 8S-8N was only completed a couple of times.

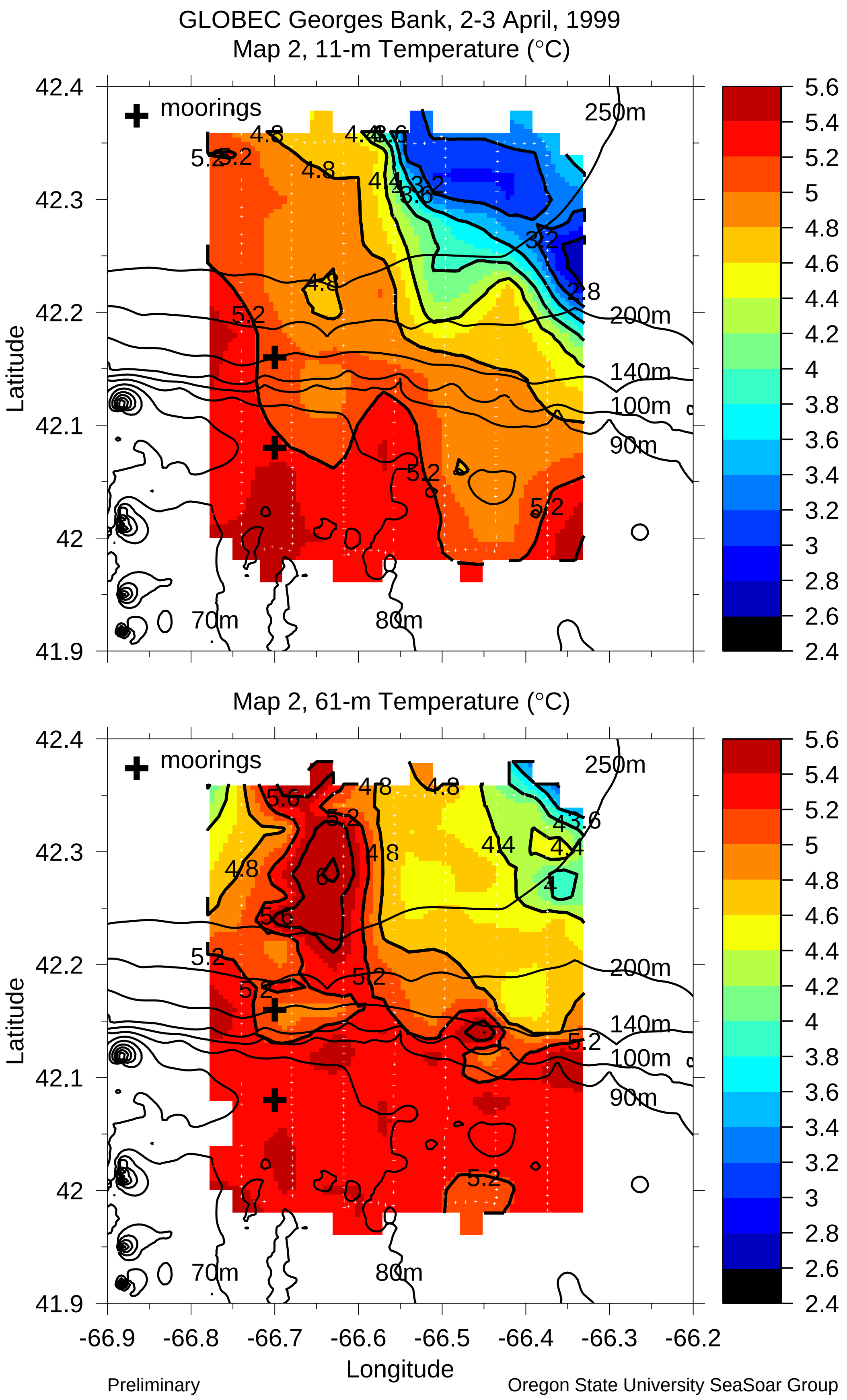

Figure 3. Horizontal map of temperature at depths of 11 and 61 m for the second radiator pattern survey.

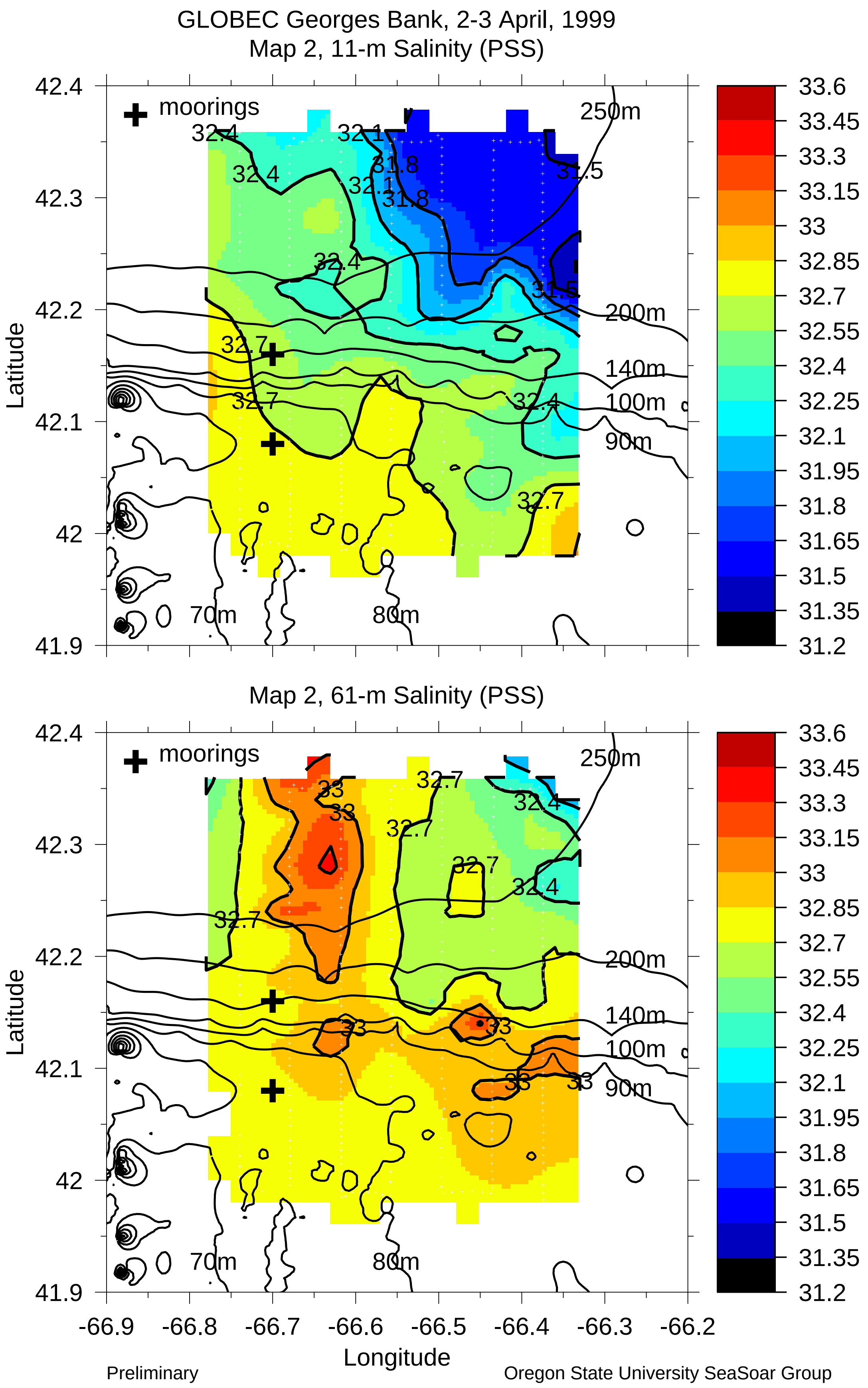

Figure 4. Horizontal map of salinity at depths of 11 and 61 m for the second radiator pattern survey.

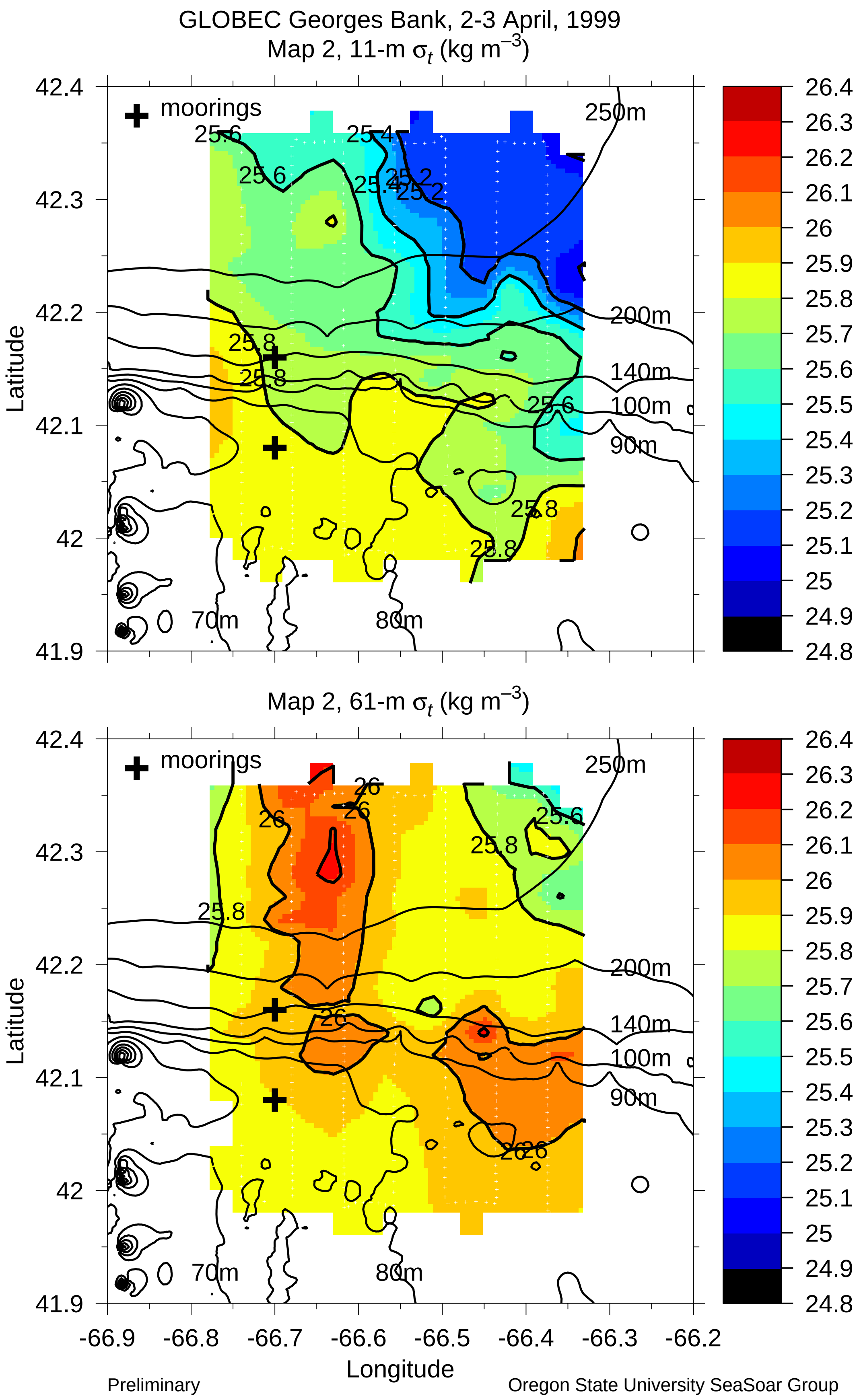

Figure 5. Horizontal map of $\sigma!_t$ at depths of 11 and 61 m for the second radiator pattern survey.

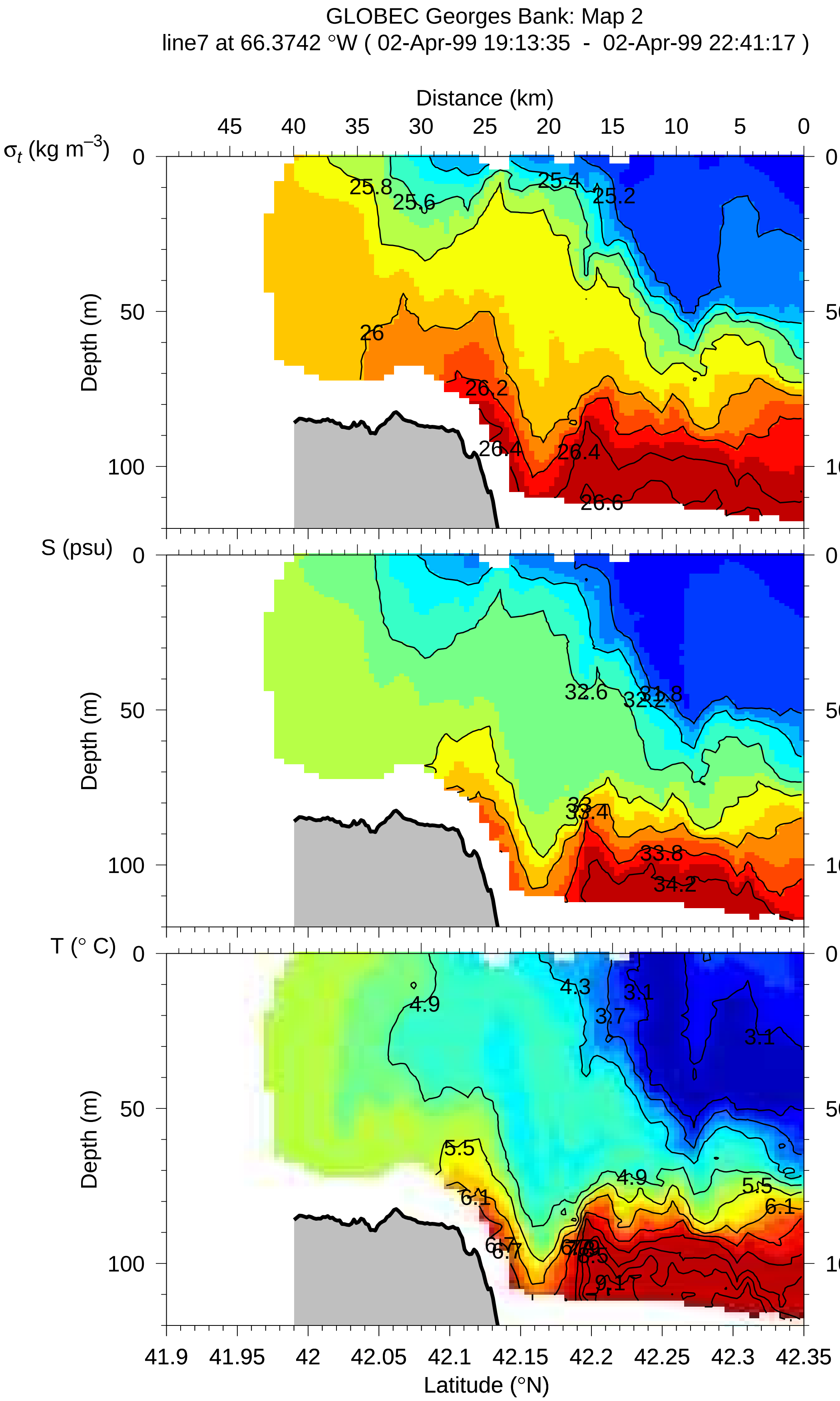

Figure 6. Cross-section (line 7) of temperature, salinity and σ_t for the second radiator pattern survey.

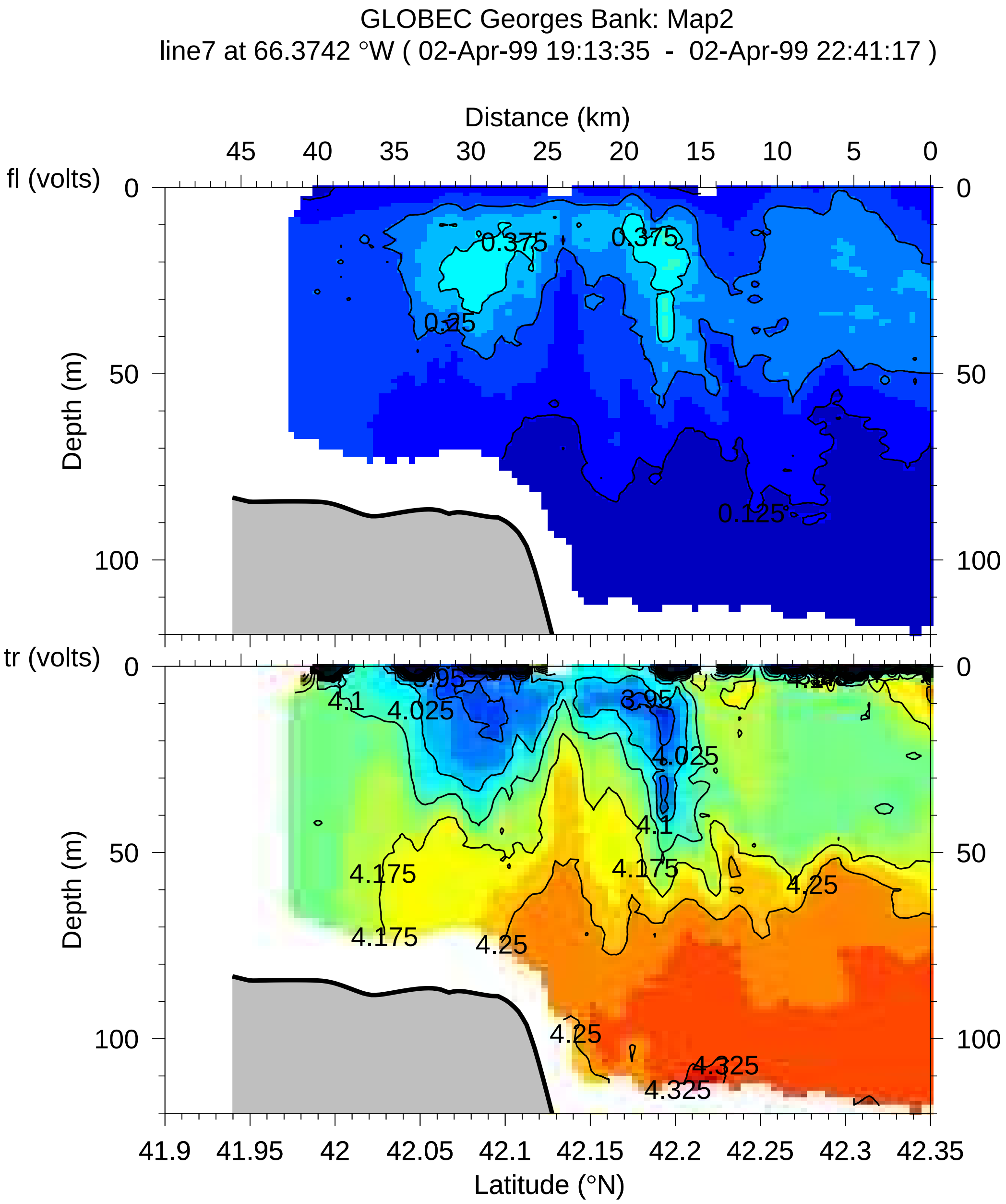

Figure 7. Cross-section (line 7) of fluorometer and transmissometer voltage for the second radiator pattern survey.

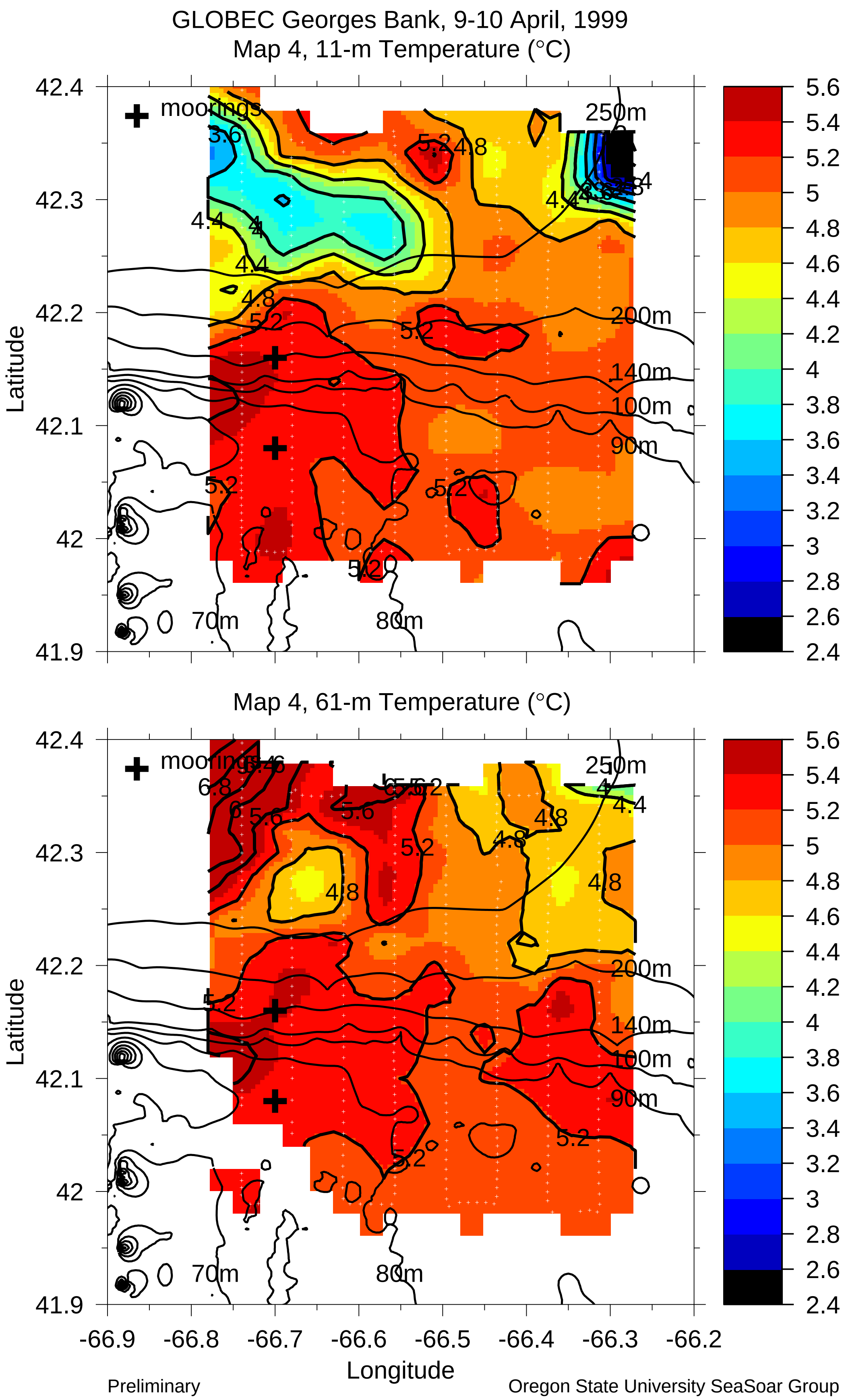

Figure 8. Horizontal map of temperature at depths of 11 and 61 m for the fourth radiator pattern survey.

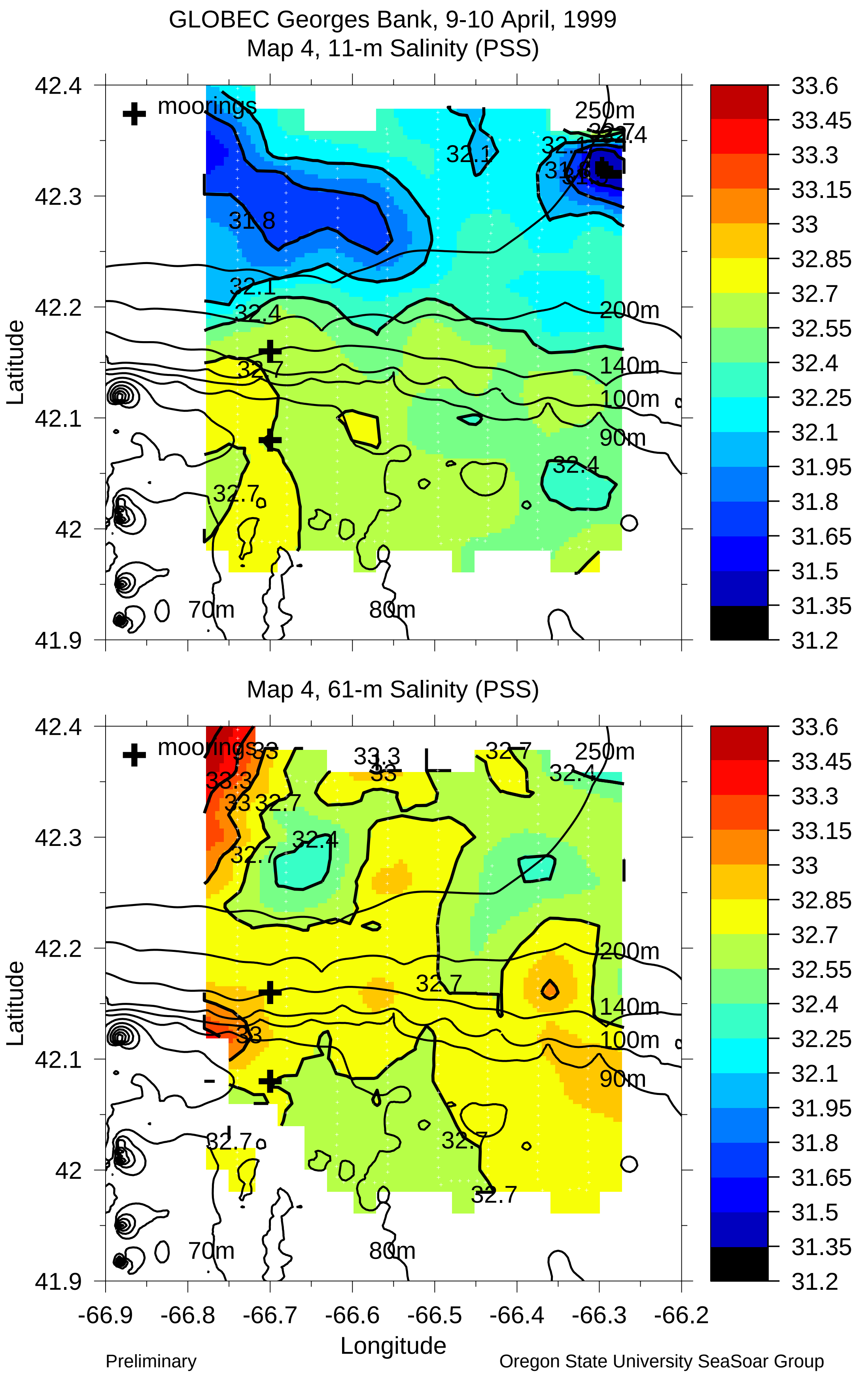

Figure 9. Horizontal map of salinity at depths of 11 and 61 m for the fourth radiator pattern survey.

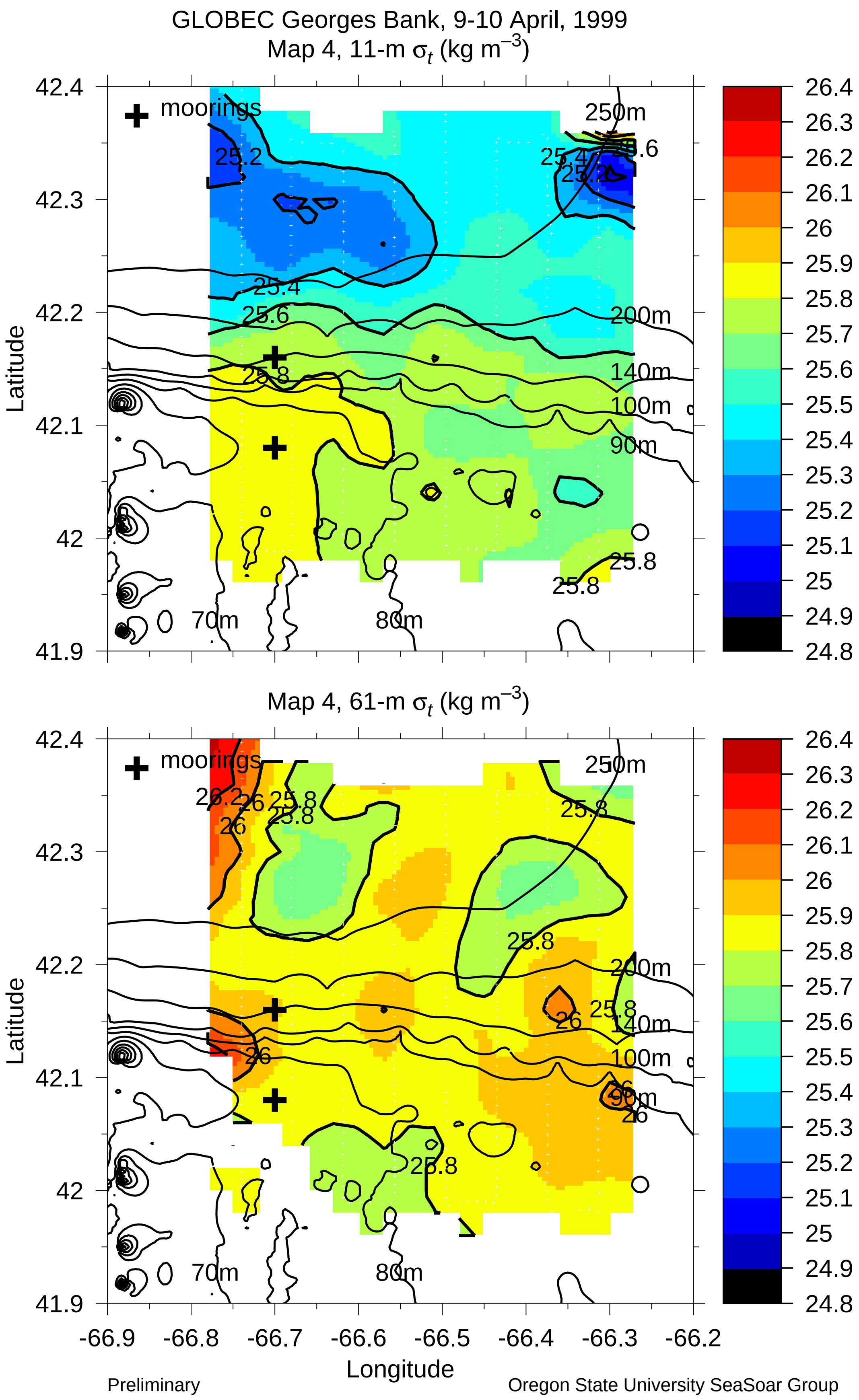

Figure 10. Horizontal map of σ_t at depths of 11 and 61 m for the fourth radiator pattern survey.

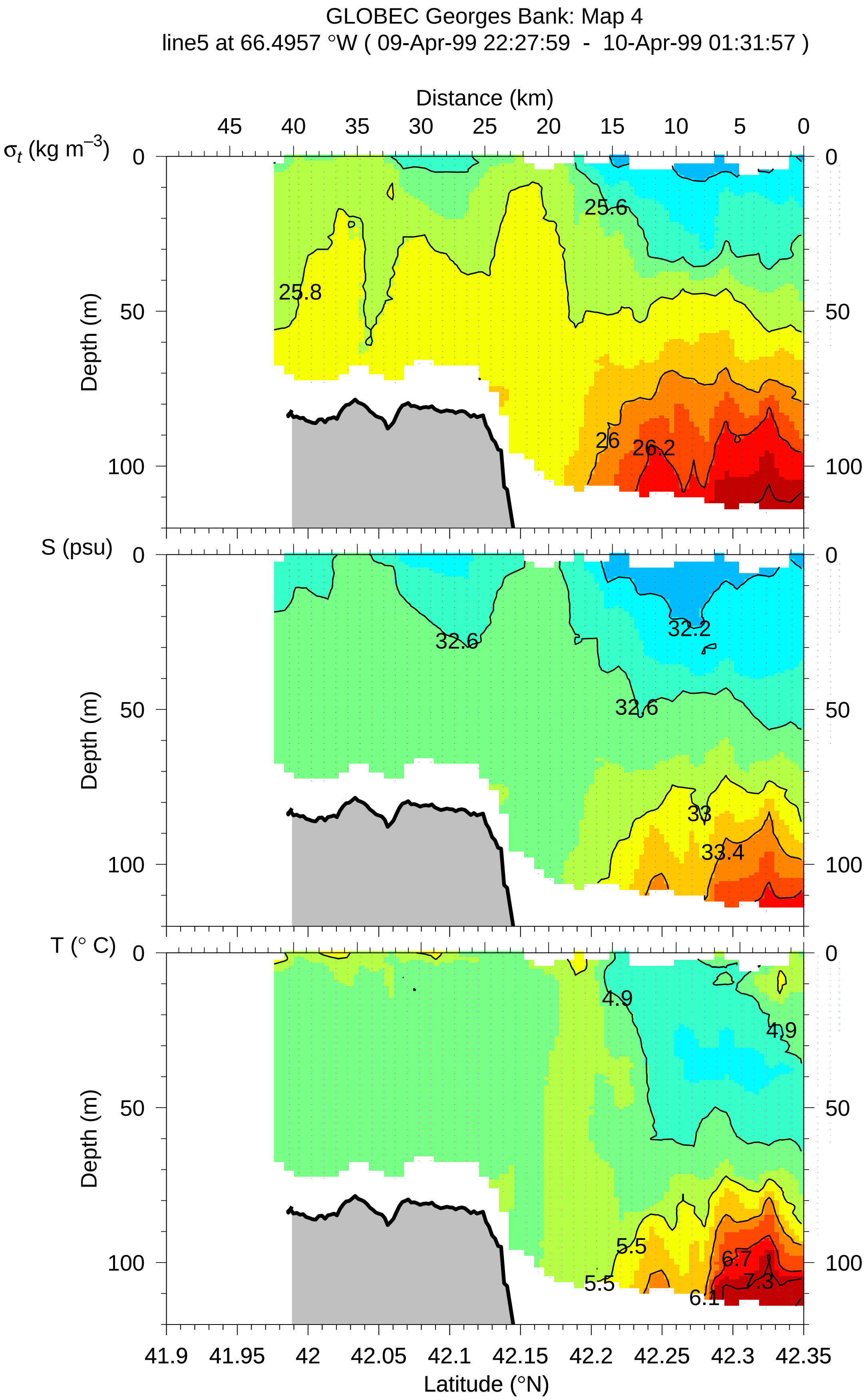

Figure 11. Cross-section (line 5) of temperature, salinity and σ_t for the fourth radiator pattern survey.

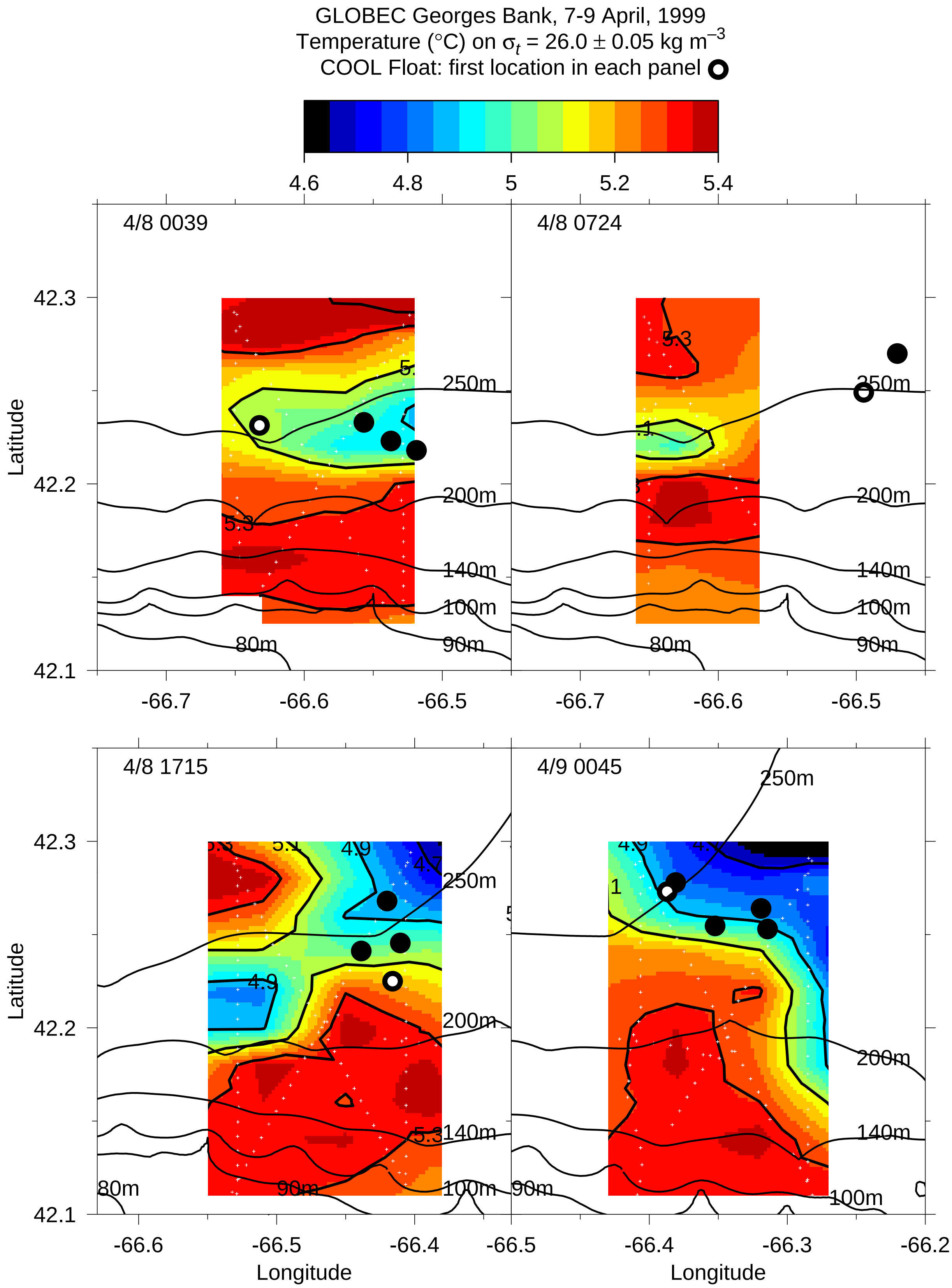

Figure 12. Maps of temperature on a $\sigma_t = 26.0$ while tracking the COOL float. The butterfly pattern was moved eastward to follow the COOL float. In each panel, the location of the first fix of the COOL float for the pattern is shown as an open circle. Additional fixes are solid circles.

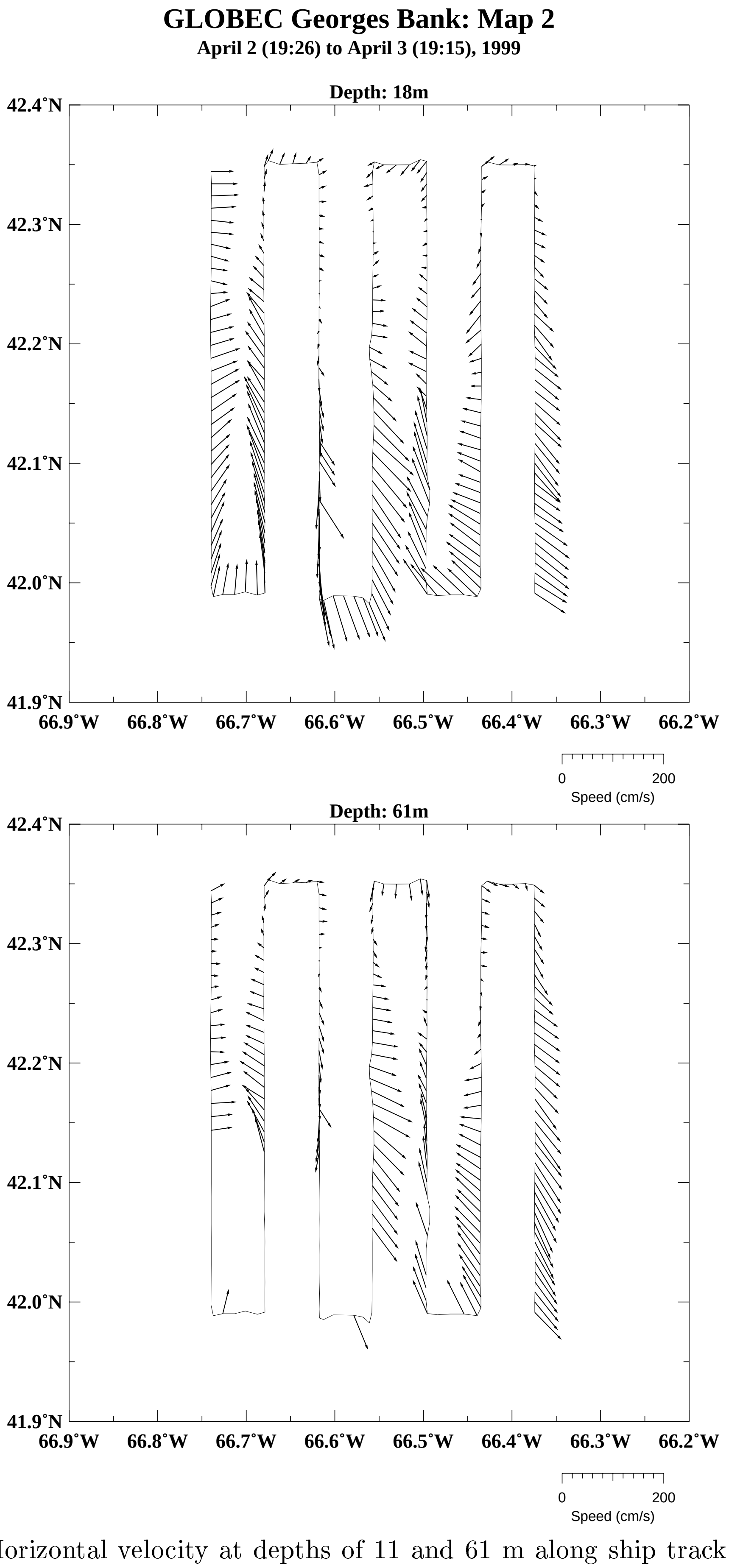

Figure 13. Horizontal velocity at depths of 11 and 61 m along ship track for the second radiator pattern survey

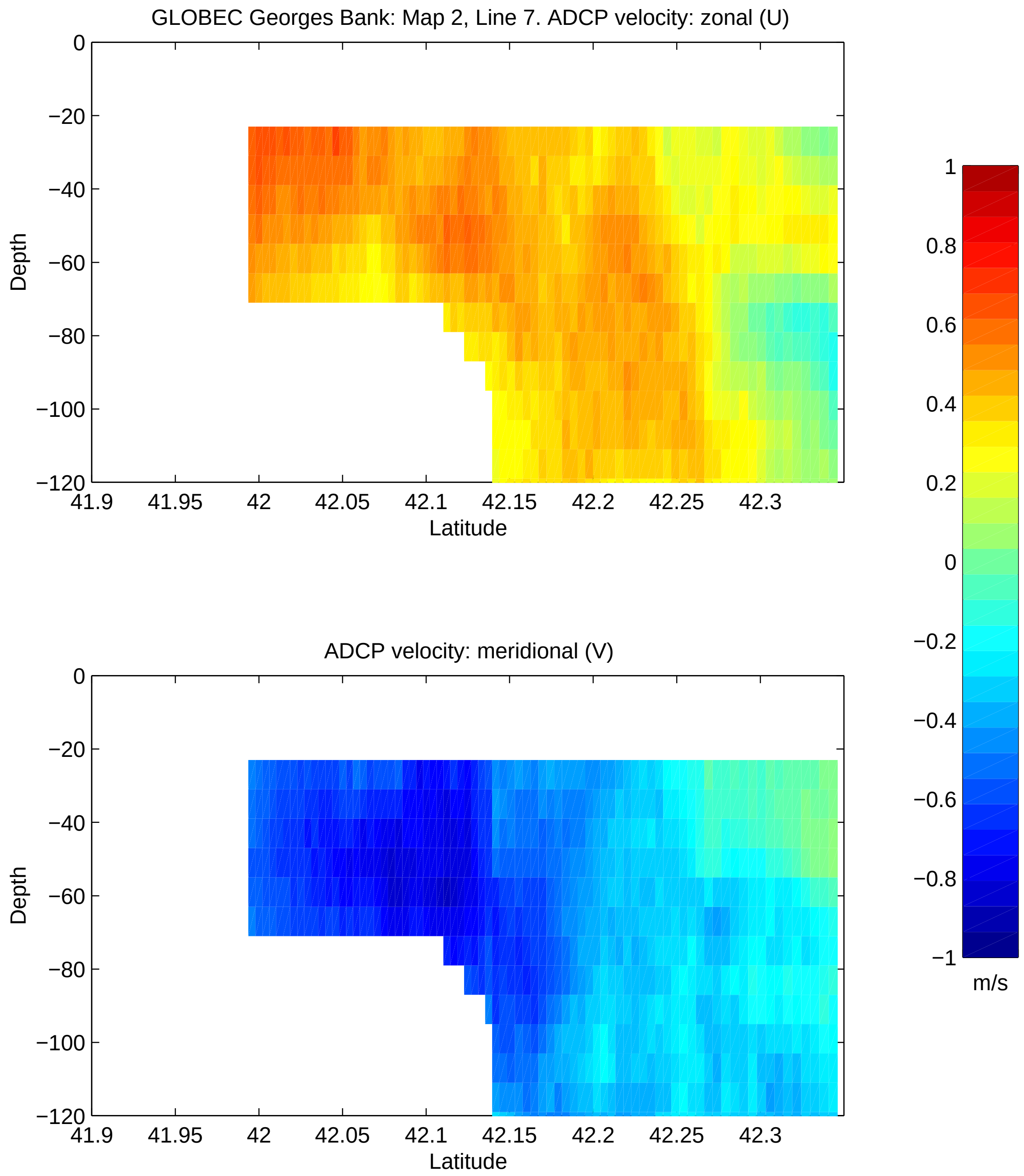

Figure 14. Cross-section (line 7) of eastward and northward velocity for the second radiator pattern survey.

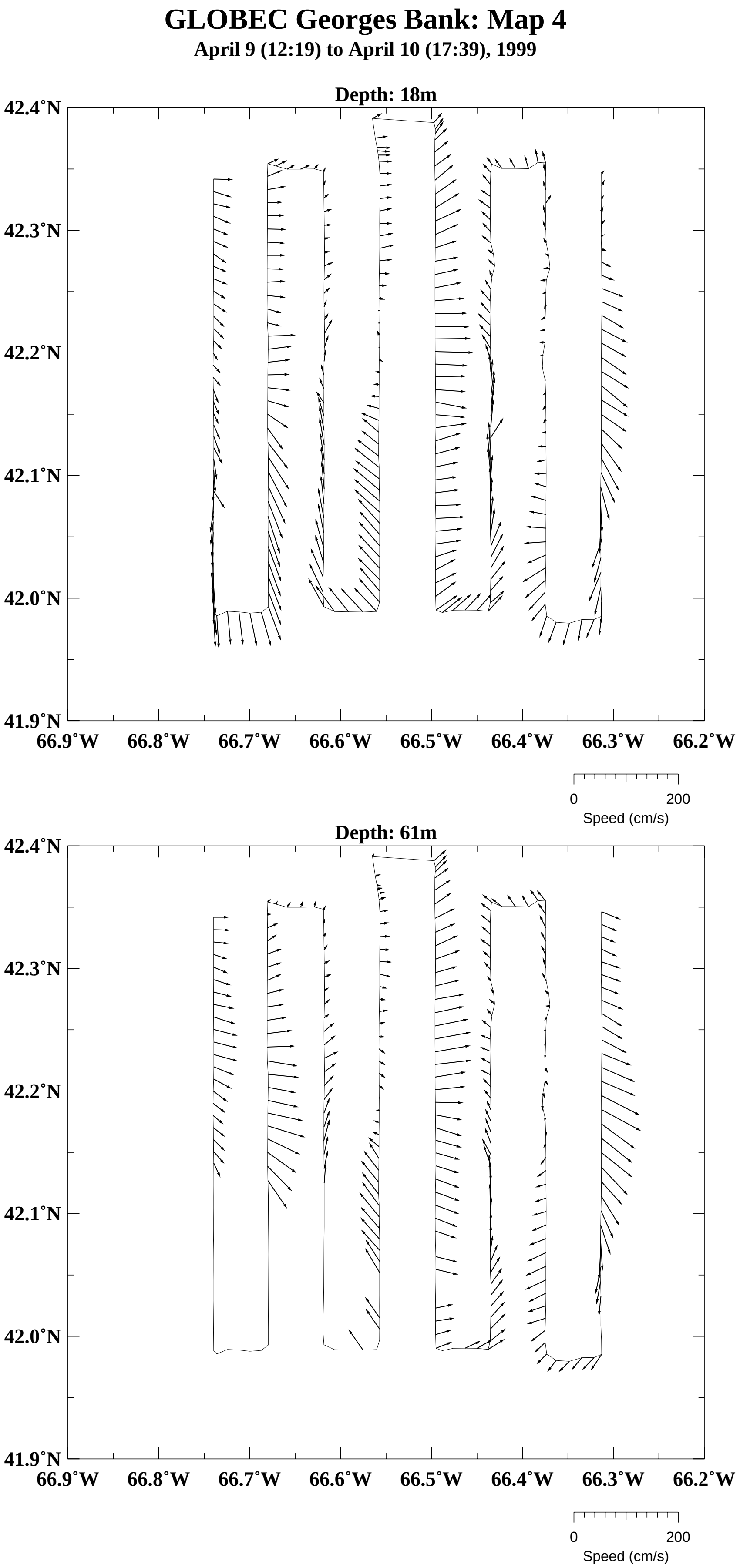

Figure 15. Horizontal velocity at depths of 11 and 61 m along ship track for the fourth radiator pattern survey

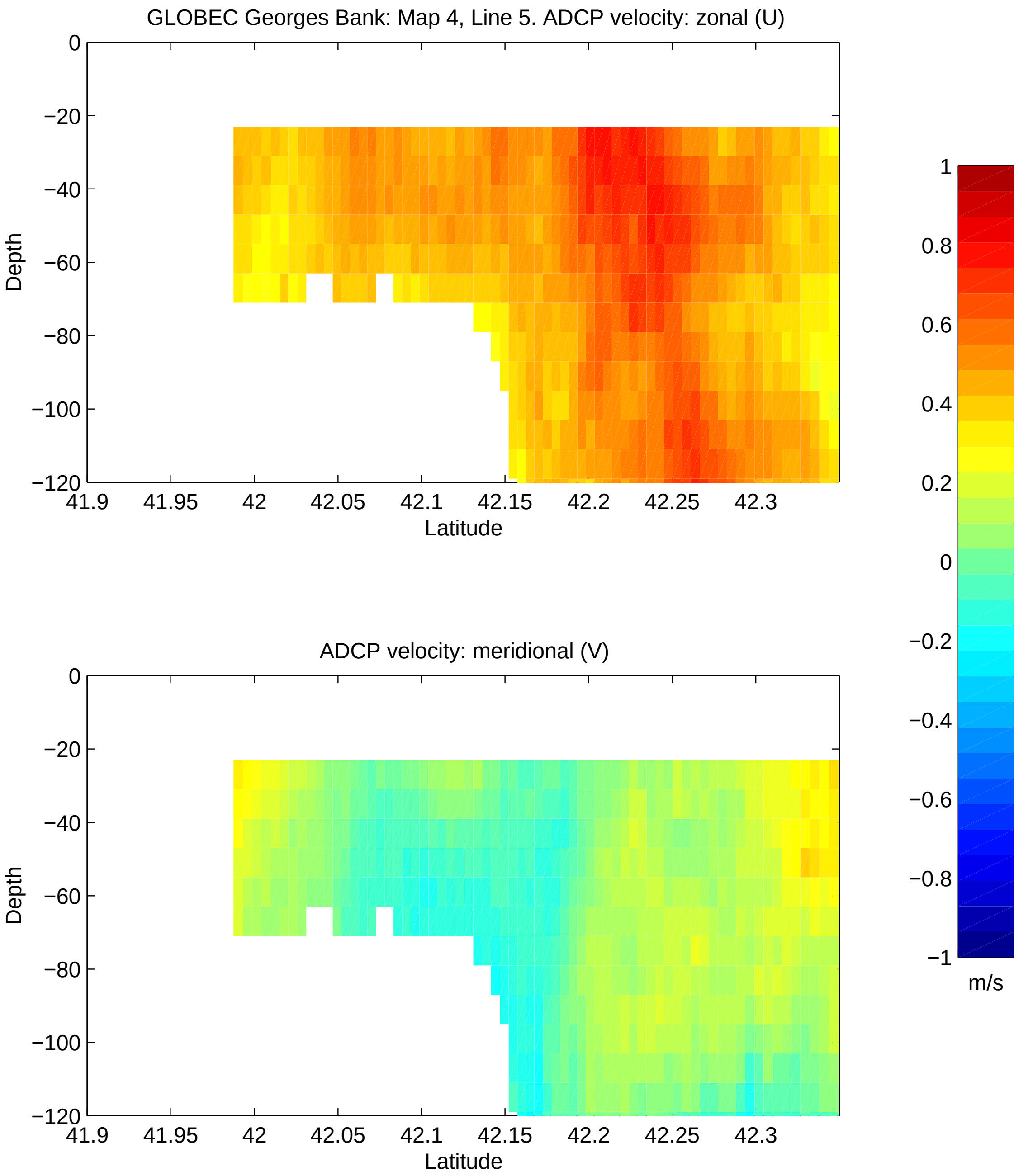

Figure 16. Cross-section (line 5) of eastward and northward velocity for the fourth radiator pattern survey.

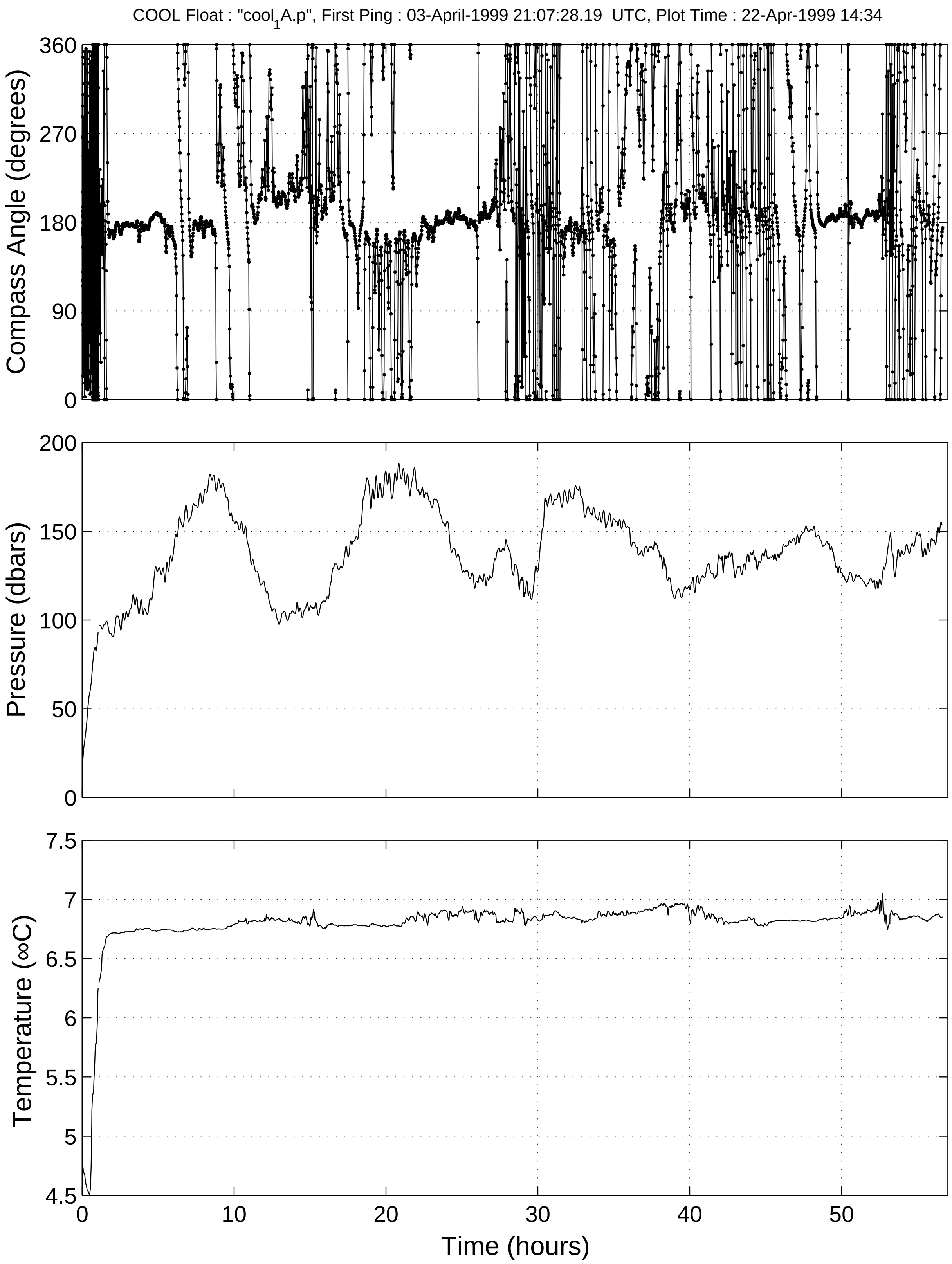

Figure 17. Time series of compass angle, pressure and temperature for the first deployment of COOL Float 1.

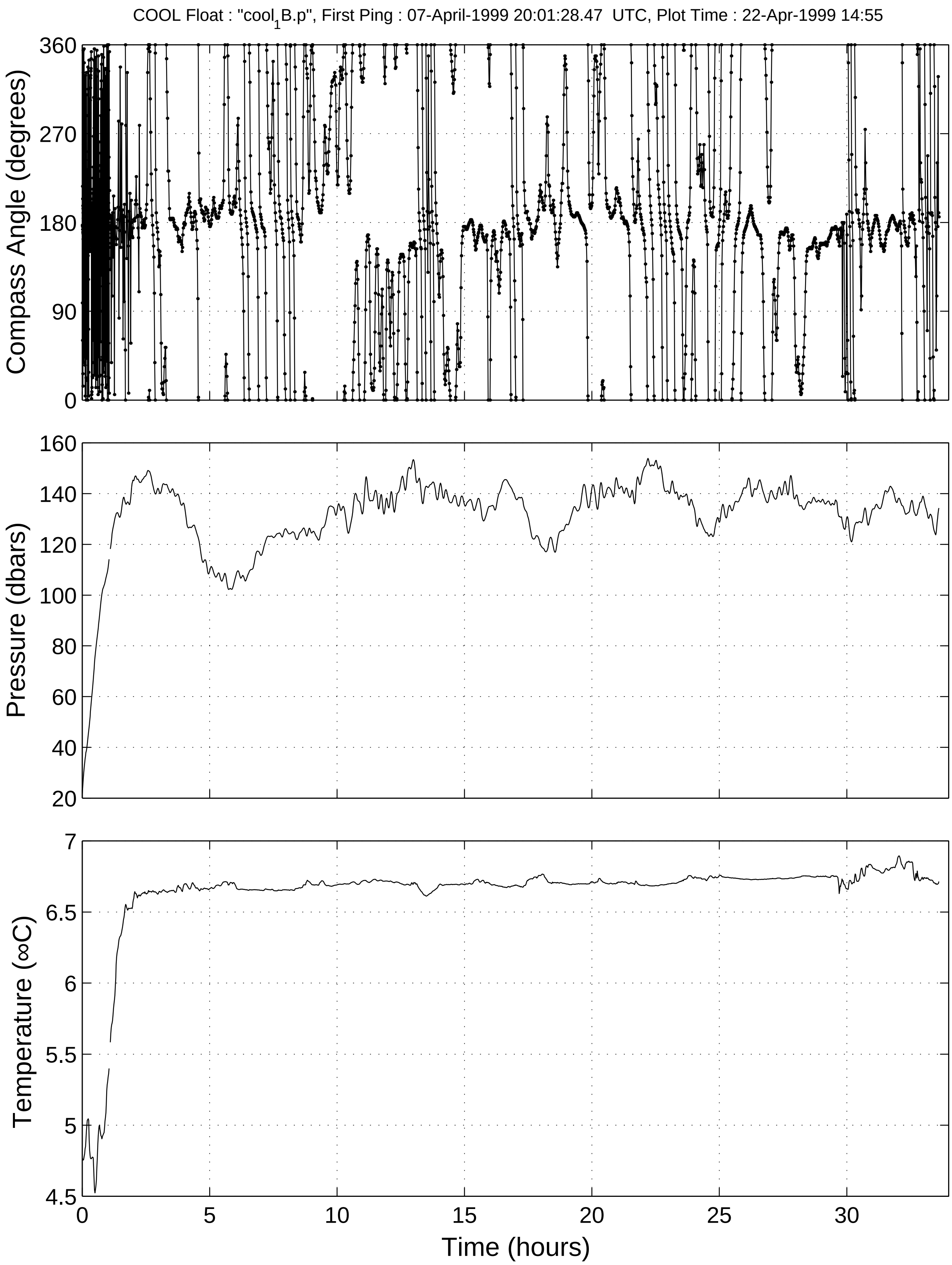

Figure 18. Time series of compass angle, pressure and temperature for the second deployment of COOL Float 1.

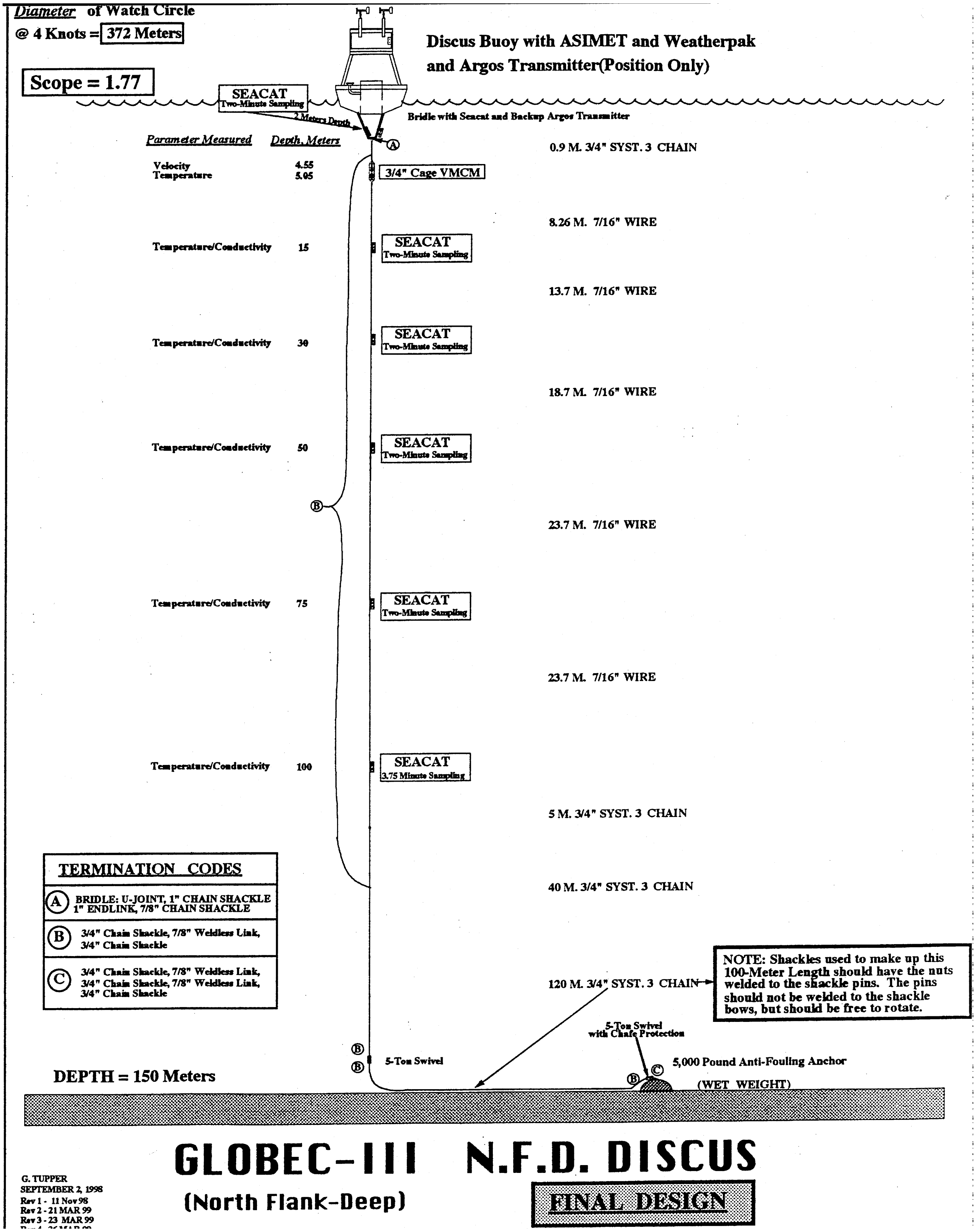

Figure 19. Schematic of the mooring deployed at the Northeast Flank Deep (NFD) location.

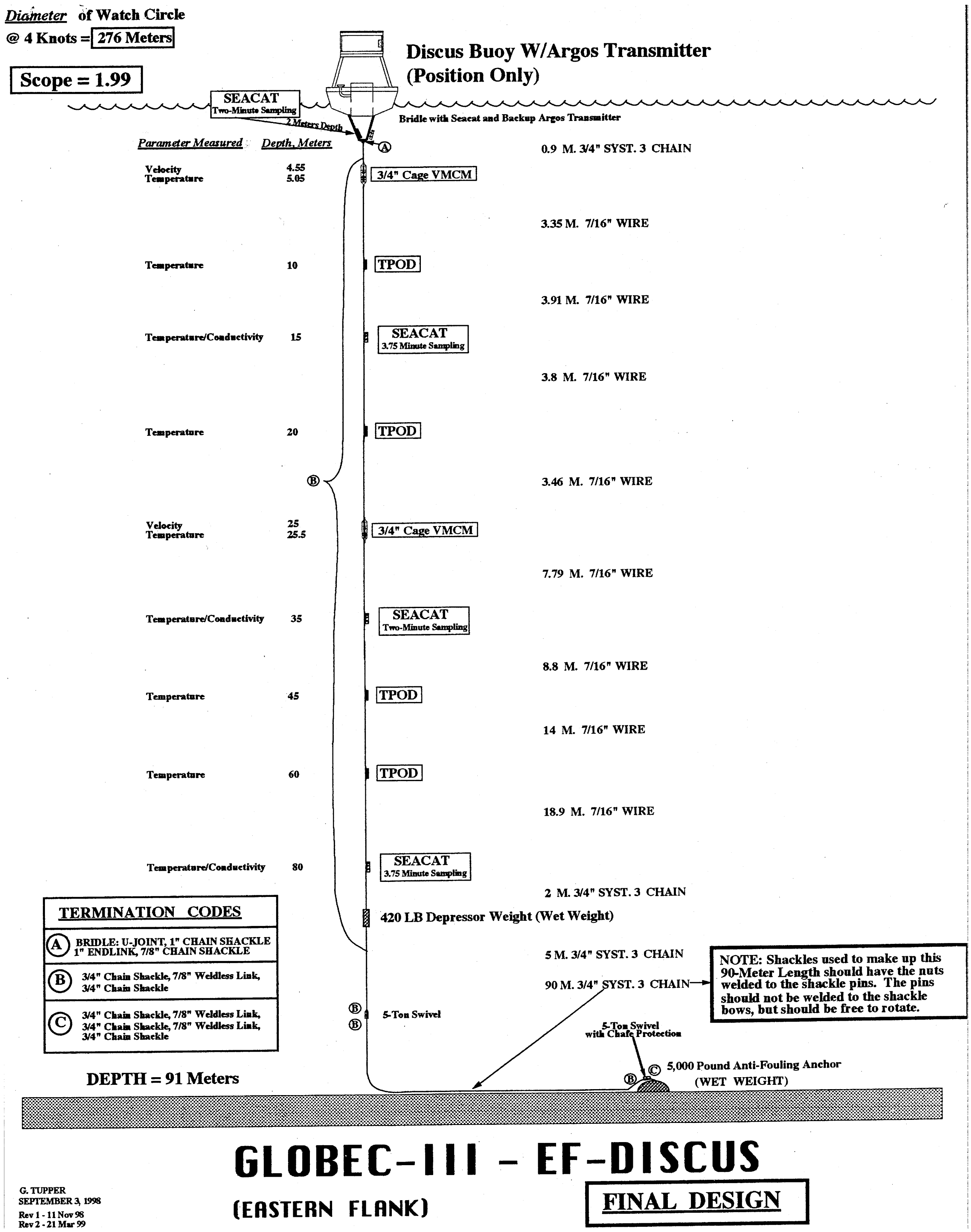

Figure 20. Schematic of the mooring deployed at the Eastern Flank (EF) location.

Appendix 3. Event Log

Event #	Instrument	Station	Date/Time (UTC)	S/E	Latitude (N)	Longitude (W)	Comments
1	Mooring	NFD Discus	29 Mar 99 / 1700 29 Mar 99 / 1903	S E	42 09.40 42 09.79	66 41.90 66 42.18	Deployment of surface mooring 140 m - anchor away
2	Mooring	EF Discus	29 Mar 99 / 2240 30 Mar 99 / 0031	S E	41 44.16 41 44.25	66 06.55 66 06.52	Deployment of surface mooring 95 m - anchor away
3	ADCP	Survey 1	30 Mar 99 / 0254 30 Mar 99 / 1100	S E	41 56.378 41 56.378	66 33.437 66 22.475	Start at 4S; gyro input for incorrect until 03:40 End at 7S
4	SeaSoar/ MicroSoar	Tow 1	30 Mar 99 / 1310 30 Mar 99 / 1455	S E	41 56.29 42 00.84	66 22.26 66 21.89	Radiator pattern Recover to rewire fluorometer; steam back to original start
5	SeaSoar/ MicroSoar	Tow 2	30 Mar 99 / 1540 31 Mar 99 / 1832	S E	41 57.25 42 20.68	66 21.97 66 43.47	Radiator pattern
6	Drifter #2	Lagr 1	01 Apr 99 / 0500 02 Apr 99 / 0004	S E	42 11.64 42 03.52	66 36.72 66 33.12	ARGOS/GPS surface drifter
7	SeaSoar	Tow 3	01 Apr 99 / 0855 01 Apr 99 / 2129	S E	42 12.00 42 10.36	66 36.72 66 31.55	Butterfly pattern
8	Drifter #1	Lagr 2	02 Apr 99 / 0132 02 Apr 99 / 0348	S E	42 09.78 42 11.61	66 33.20 66 34.54	 GPS on drifter not working
9	ADCP	Survey 2	02 Apr 99 / 0527 02 Apr 99 / 1246	S E	41 56.69 42 18.00	66 36.98 66 44.40	Start at 3S Stop at 2N
10	SeaSoar	Tow 4	02 Apr 99 / 1912 03 Apr 99 / 1925	S E	41 58.78 42 21.87	66 22.16 66 44.28	Radiator pattern
11	Cool Float #1	Lagr 3	03 Apr 99 / 2120 06 Apr 99 / 0705	S E	42 13.18 42 13.276	66 31.00 66 33.637	Float on sigma-t=26.1 surface

Event #	Instrument	Station	Date/Time (UTC)	S/E	Latitude (N)	Longitude (W)	Comments
12	SeaSoar	Tow 5	04 Apr 99 / 0305 06 Apr 99 / 0419	S E	42 13.41 42 17.456	66 34.36 66 38.808	Butterfly pattern. Suspended from 04/2306 to 05/2125
13	SeaSoar	Tow 6	06 Apr 99 / 1401 07 Apr 99 / 1731	S E	42 16.75 42 22.487	66 38.82 66 18.765	Radiator Pattern
14	Cool Float #1	Lagr 4	07 Apr 99 / 2008 09 Apr 99 / 0636	S E	42 13.88 42 15.28	66 37.95 66 21.14	Deployed (Compresse 1B)
15	Drifter #2	Lagr 5	07 Apr 99 / 2009 10 Apr 99 / 0312	S E	42 13.85 42 36.48	66 37.96 66 36.37	Drifter (ARGOS ID 27614) Recovered - north side of NE Channel
16	SeaSoar	Tow 7	07 Apr 99 / 2042 08 Apr 99 / 0926	S E	42 12.71 42 15.38	66 34.65 66 31.36	Butterfly Pattern Recovered - Tangled with Fixed Gear
17	SeaSoar	Tow 8	08 Apr 99 / 1334 08 Apr 99 / 1700	S E	42 12.55 42 14.91	66 27.00 66 30.366	Re-deployed - Butterfly Pattern fishing gear caught -redeployed as tow 9
18	SeaSoar	Tow 9	08 Apr 99 / 1703 09 Apr 99 / 0426	S E	42 14.91 42 13.357	66 30.366 66 21.046	SeaSoar redeployed - transect continued
19	SeaSoar	Tow 10	09 Apr 99 / 1212 10 Apr 99 / 0130	S E	42 21.2 42 21.2	66 18.85 66 29.89	Start of Radiator (8N) head to get Drifter
20	SeaSoar	Tow 11	10 Apr 99 / 0437 11 Apr 99 / 1227	S E	42 21.84 42 0.00	66 33.55 66 38.00	Deploy at 4N - completed radiator, started Repeat Line 3. Recovery before transit to Woods Hole