SCruise Report

R/V *Roger Revelle* Cruise RR0901

10 January 2009 to 24 February 2009

Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean

DIMES Cruise US1

Deployment Cruise

Chief Scientist
James R. Ledwell
Woods Hole Oceanographic Institution
jledwell@whoi.edu

Brian Guest, Leah Houghton, and Cynthia Sellers
Woods Hole Oceanographic Institution

Stewart C. Sutherland
Lamont-Doherty Earth Observatory

Peter Lazarevich and Nicolas Wienders
Florida State University

Ryan Abernathey and Cimarron J. L. Wortham
Massachusetts Institution of Technology

Byron Kilbourne
University of Washington

Magdalena Carranza and Uriel Zajaczkovski
University of Buenos Aires

Jonathan Meyer and Meghan K. Donohue
Scripps Institution of Oceanography

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1. Introduction

1.1. Objectives

DIMES (Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean) is a study of mixing and the dynamics of the Antarctic Circumpolar Current (ACC). The objectives of this, the first cruise for DIMES, on R/V *Roger Revelle*, were to deploy a number of various kinds of neutrally buoyant floats, along with sound sources to track them, and a tracer. The target for the floats and for the tracer release was the 27.9 kg/m^3 neutral density surface, located in the deeper region of the Upper Circumpolar Deep Water, one to two hundred meters below the oxygen minimum layer. This surface is at a depth of about 2000 m north of the Subantarctic Front (SAF) of the ACC shoals, to less than 1000 m depth south of the Polar Front (PF) (Fig. 1.1.1), and blends with the mixed layer near Antarctica in winter.

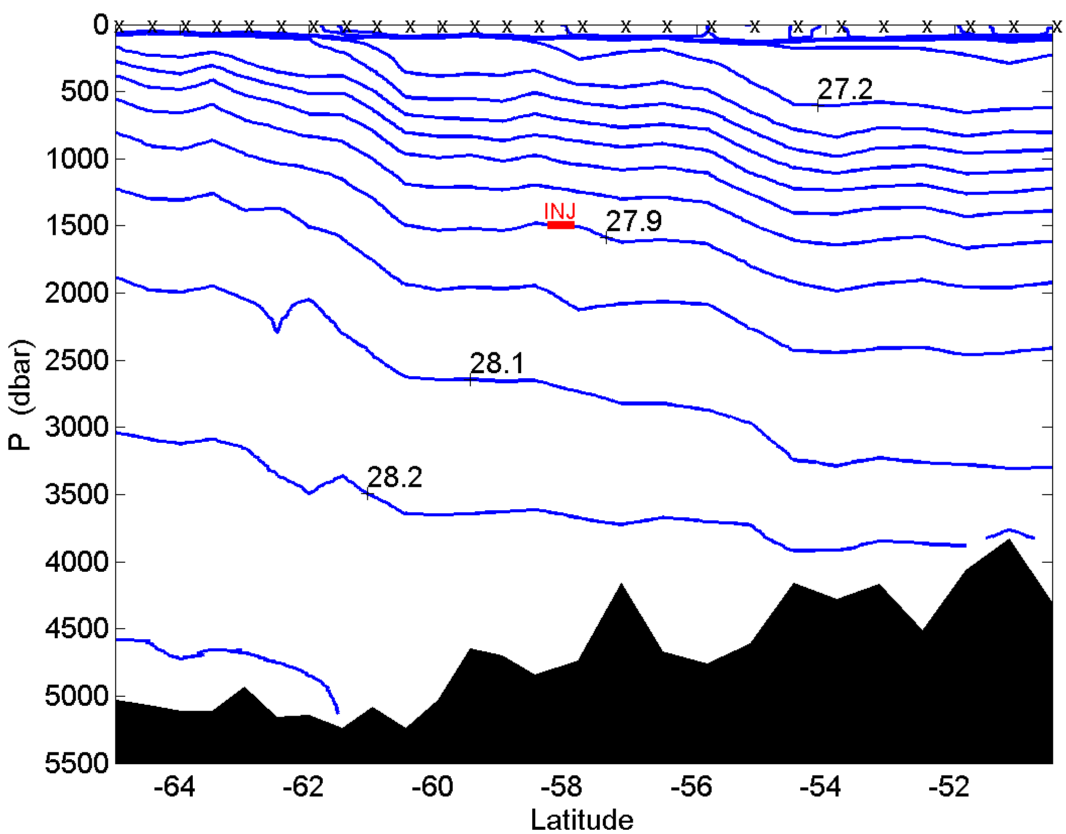


Fig. 1.1.1. Neutral density from Section P18 at 105^{o}W of the World Ocean Circulation Experiment (WOCE). The red bar marked "INJ" indicates the approximate location of the tracer release in the context of this section.

2. Cruise Narrative

2.1. Underway Measurements

R/V *Roger Revelle* departed Punta Arenas on 10 January 2009, after several days of mobilization. An Event Log for the cruise is given in Appendix B. Meteorological data, described in Section 3, were recorded throughout the cruise. The recording of other underway data (Table 2.1.1) commenced once *Revelle* left the Chilean Exclusive Economic Zone (EEZ).

Table 2.1.1. Underway Data Streams

Instrument	Type	Property	Report Section
Thermosalinograph 1	Seabird	Temperature	4
		Salinity	
		Chlorophyll	
		Oxygen	
Thermosalinograph 2	Seabird	Temperature	4
		Salinity	
150 kHz NB ADCP	RDI	Velocity to 400 m	5.1
40 kHz ADCP	HDSS	Velocity to 1200 m	5.2
140 kHz ADCP		Velocity to 400 m	
Multibeam echosounder	Kongsberg-Simrad EM120	Bathymetry	6
EchoSounder	Knudsen	Depth, bottom profile	

XBTs (expendable bathythermographs) dropped approximately daily to provide the sound speed profile for the Multibeam system, also provided information on the hydrography of the upper 1000 m along the ship track, and were helpful in identifying fronts. The XBT program is described in Section 2.5.

2.2. Mooring Deployments

The first major deployments of the cruise were of sound sources for the RAFOS float program (RAFOS is the second generation of SOFAR, SOund Fixing And Ranging, spelled backwards). Figure 2.2.1 shows the cruise track heading west and the locations of the sound sources. Information on the sources, the moorings supporting them and the topography around them is in Section 7. Four SOLO (Sounding Oceanographic

Langrangian Observatory) floats that had been specially equipped with RAFOS receivers were deployed along the track between some of the sound sources to provide early feedback on the functioning of the sources. The SOLO floats are programmed to come to the surface every 10 days and relay data via System ARGOS. They are described in more detail in Section 8.

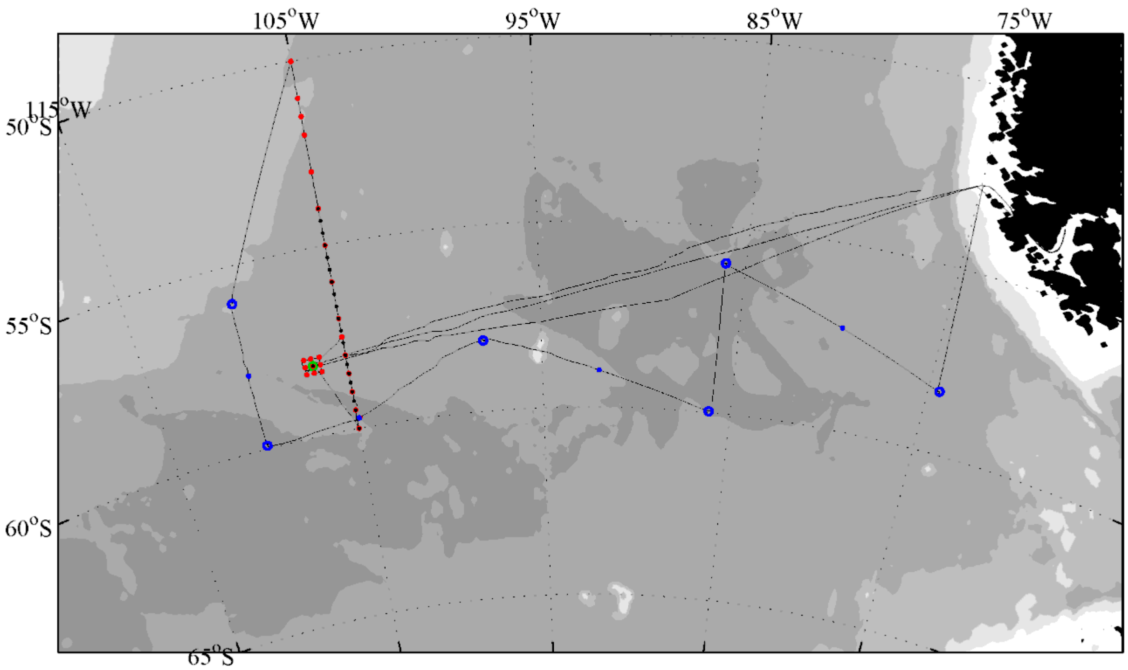


Fig. 2.2.1. Cruise Track and Operations. The sound sources (blue circles) were deployed on the initial track to the west. Four SOLO floats with RAFOS receivers (small blue circles) were deployed along the ship track between sound sources. The red dots indicate CTD/LADCP stations (see also Fig. 2.9.1); one or more XBT's were often dropped between CTD stations (Fig. 2.5.2). The black dots show RAFOS deployment locations along the CTD line (see Fig. 12.2). Surface drifters were also deployed along this line (Fig. 13.1). The green area surrounded by a rectangle of CTD stations shows the tracer release and tracer sampling region. Four Shearmeters, three EM-APEX floats and two SOLO floats (without RAFOS receivers) were deployed in this area (Fig. 2.9.1). The extra two lines between the tracer injection area and Chile reflect the trip made for a medical emergency in the middle of the cruise.

2.3. Front Identification

A satellite map of absolute dynamic topography shows several bands of relatively strong currents within the ACC, separated by weaker currents, eddies and still areas (Fig. 2.3.1). The altimetry shows a strong jet just south of the 1000 mm contour in Fig. 2.3.1 across the region. XBT 05, dropped near the sound source at 58°S, 98°W (Mooring Site 4) and near the northern edge of this jet, found the temperature at 400 m to be 4.37°C, suggesting that we were in the SAF (Fig. 2.3.2). Orsi *et al*. (1995) report that the temperature north of the SAF at 400 m is usually greater than 4 to 5^{o}C, so this result is a bit ambiguous. XBT 06, on the southern side of the same jet, at 60^{o}S, 105^{o}S revealed a temperature minimum with a value of 1.3^{o}C at 180 m depth (Fig. 2.3.2), clearly characteristic of a site south of, or within, the Polar Front (Orsi *et al*., 1995). Apparently, the two jets were somewhat merged in this segment of the ACC.

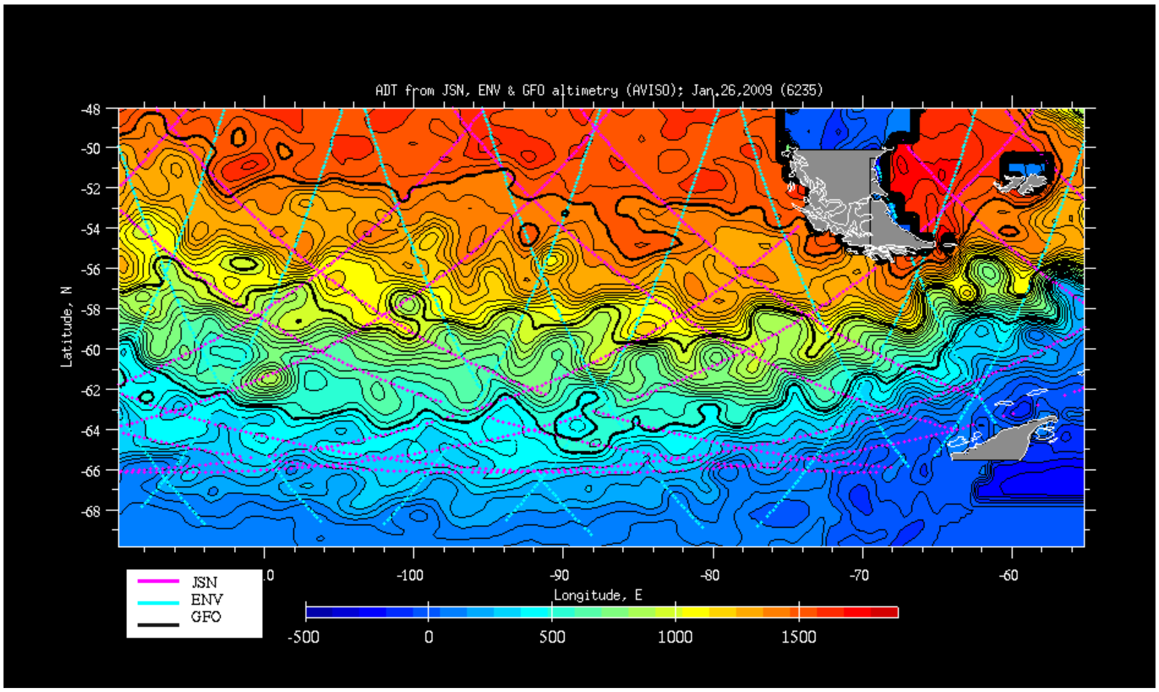


Fig. 2.3.1. Absolute Dynamic Topography (ADT) on 26 January 2009 based on the AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic Data, Collective Localisation Satellites; France) data set. The scale is in mm, and the contour interval is 50 mm, with bold contours at 500, 1000, and 1500 mm. A collection of these figures for different dates and an animation from 1 December 2008 to 19 February 2009 are available in the cruise-data directory as described in Appendix E. The procedure for making these maps is described in Section 9. The maps and data were provided from shore by Valery Kosneyrev.

The first CTD/LADCP (Conductivity-Temperature-Depth/Lowered Acoustic Doppler Current Profiler) profile was taken at the same location as XBT 06, near 60^{o}S, 105^{o}W. It showed the 27.9 kg/m^{3} neutral density surface, the target surface for the float and tracer release, to lie at 1093 m depth, giving another indication that this station is south of the Polar Front (see Fig. 1.1.1; the CTD program is described in Section 10).

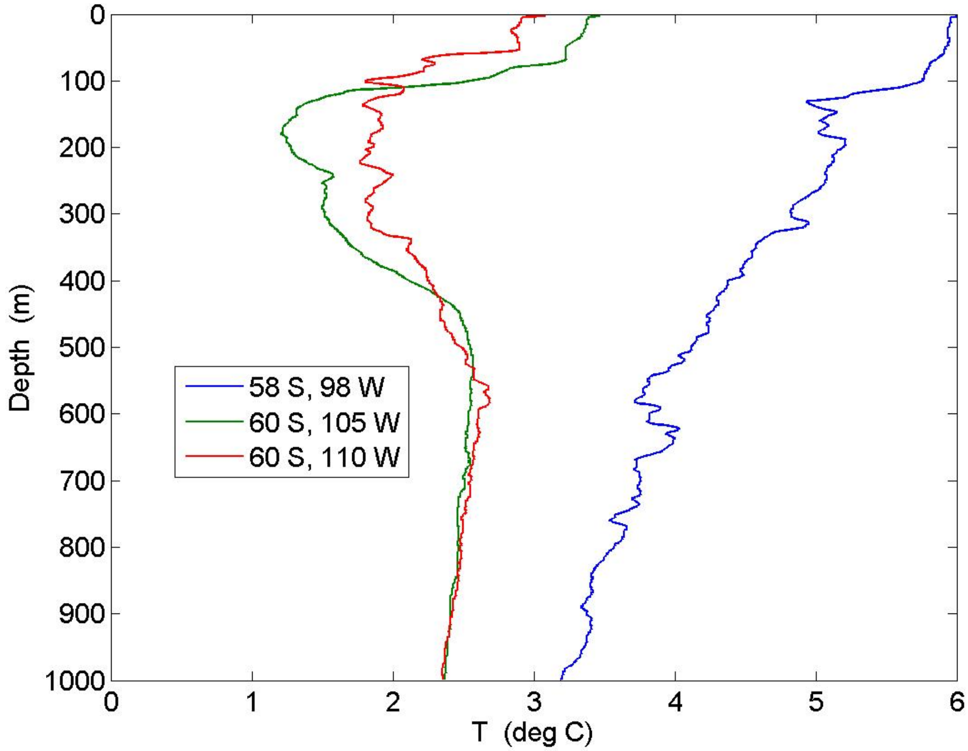


Fig. 2.3.2. XBT profiles from north (blue, XBT05) and south (red and green, XBT06 and 07) of the jet which lies just south of the 1000 mm ADT contour in Fig. 2.3.1. From these profiles we surmise that the jet is associated with the Polar Front. The XBT program is described in Section 2.5.

2.4. CTD/LADCP Line

After the last mooring was deployed at 56^{o}S, 110^{o}W, we proceeded to 50^{o}S, 105^{o}W to start a line of CTD/LADCP stations to the south. The line was planned with a CTD cast every degree and with XBT drops every third of a degree in between. Extra CTD casts were planned where the altimetry indicated the presence of jets. We were aided in this with line plots of ADT along 105^{o}W, such as those shown in Figure 2.4.1. A jet appeared to be present between 51 and 52^{o}S, so a CTD station was inserted at 51.5^{o}S. The CTD section was interrupted after the station at 58^{o}S due to the medical emergency which sent us back to Punta Arenas. The first part of the section was occupied from 0700 on 22 January to 1500 on 25 January. The section was finally completed after our return from Chile, and after the tracer was released, from 2300 on 11 February to 1000 on 13 February 2009. For this second part we occupied CTD stations every 0.5 degrees from 60^{o}S to 57.5^{o}S, with XBT drops mid-way between stations.

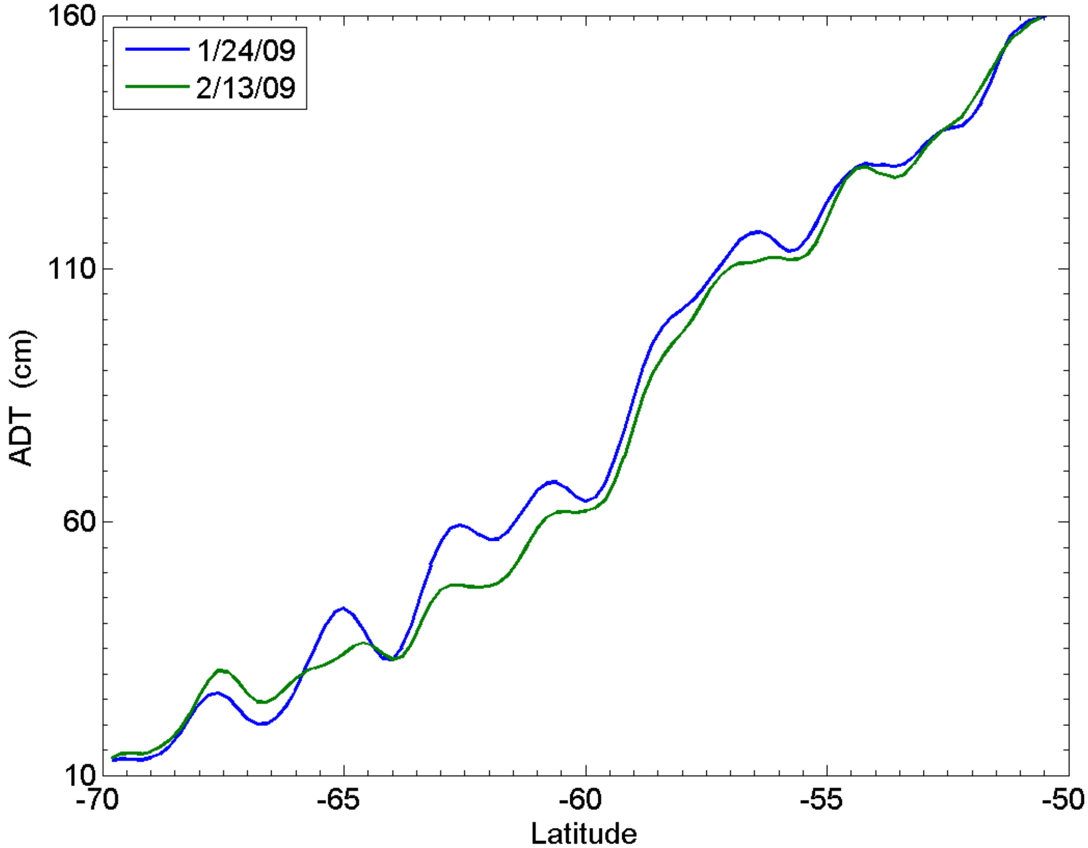


Fig. 2.4.1. Absolute Dynamic Topography (ADT) along 105°W, on 24 January (blue) and 13 February 2009 (green). These are slices from the same data source as for Fig. 2.3.1. Satellite data from 3 days beyond the given dates as well as data prior to the dates were used in the estimates.

A section of neutral density and zonal geostrophic velocity, relative to 3000 m, from the combined CTD stations is shown in Fig. 2.4.2. Note that the meridional gradient of density at constant depth shows the main SAF to be spread out between 53°S and 57°S. The jet near 51°S is referred to herein as the Northern Subantarctic Front (NSAF).

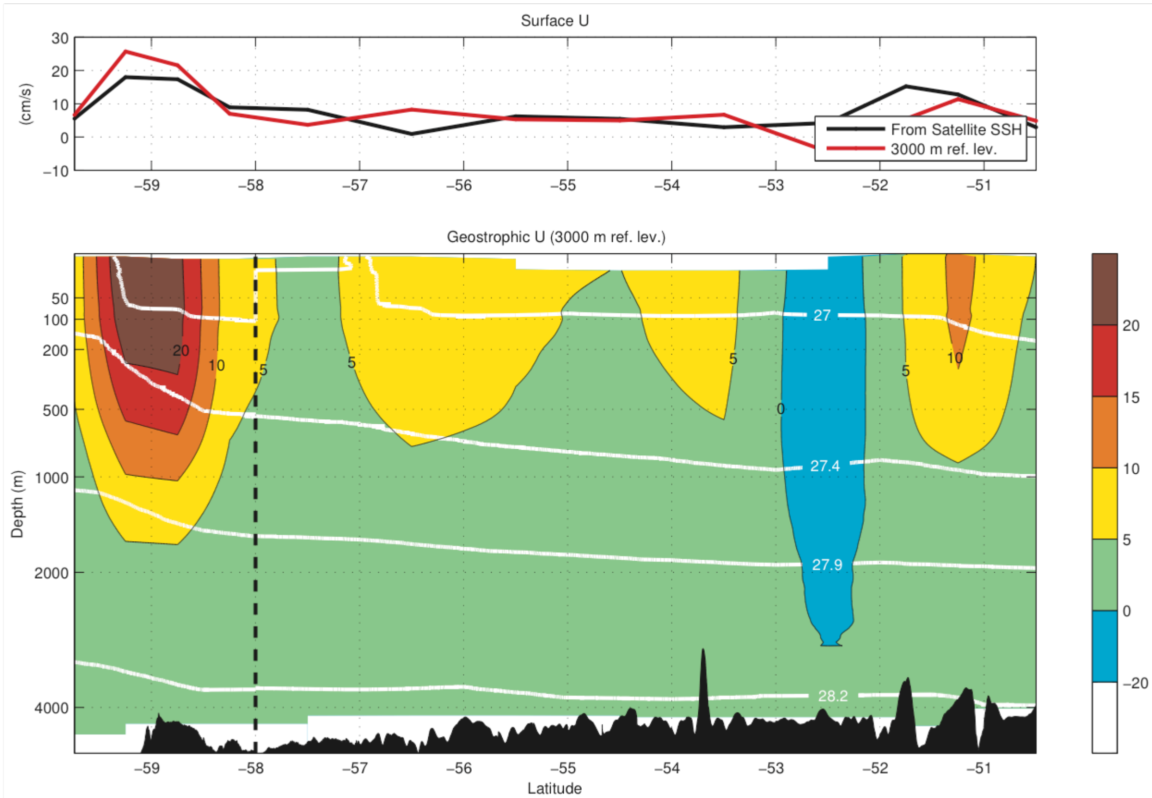


Fig. 2.4.2. Neutral density (kg/m^3; white lines) and zonal geostrophic velocity (cm/s; color) sections from the combined CTD stations from 50^{o}S to 60^{o}S. The dashed vertical line indicates the break of nearly 3 weeks at 58^{o}S. The geostrophic velocity is calculated assuming a level of no motion at 3000 dbar. The jet associated with the polar front is centered at 59^{o}S. The surface velocity estimated in this way (red) is compared in the upper panel with the surface geostrophic velocity (black) based on the sea surface height (i.e., the ADT) from the satellite altimetry.

2.5. XBT Series

As described above, XBTs were launched along the CTD line to supplement it in locating fronts. Two types of XBT were used: Type TF which can be launched at ship speeds of up to 20 knots and which record to 1000 m, and Type T5 which are launched at ship speed of up to 6 knots and record to 1830 m depth. We primarily used T5's for the section. However, spurious peaks in the record frequently occurred despite persistent efforts to track the problem down. As a result, full records were seldom obtained. If a record was corrupted at depths shallower than 400 m, then another probe was usually launched, so that we would have data to at least 400 m at every station. All of the XBT profiles obtained between 50 and 60^{o}S, along with temperature profiles from the CTD stations, are plotted in Fig. 2.5.1. Figure 2.5.2 shows the location of the XBT drops. Appendix D contains a list of XBT drops. XBT data can be obtained at the cruise-data website as described in Appendix E.

The Polar Front is evident in this picture, south of 58°S where the temperature at the shallow temperature minimum increases from less than 2°C to more than 3°C. As for ADT and the geostrophic velocity, the SAF is less evident. According to Orsi *et al*. (1995), the temperature at 400 m is greater than 4 to 5°C north of the SAF. By this criterion the SAF is south of 54°S in our section, where T at 400 m is approximately 5.3°C. We do see an increase in the meridional temperature gradient to the south of this point in Fig. 2.5.1. We also see a great deal more T/S (Temperature-Salinity) structure south of 54°S. There is also a jet, however, between 51 and 52°S, as seen in Figs. 2.4.1 and 2.4.2.

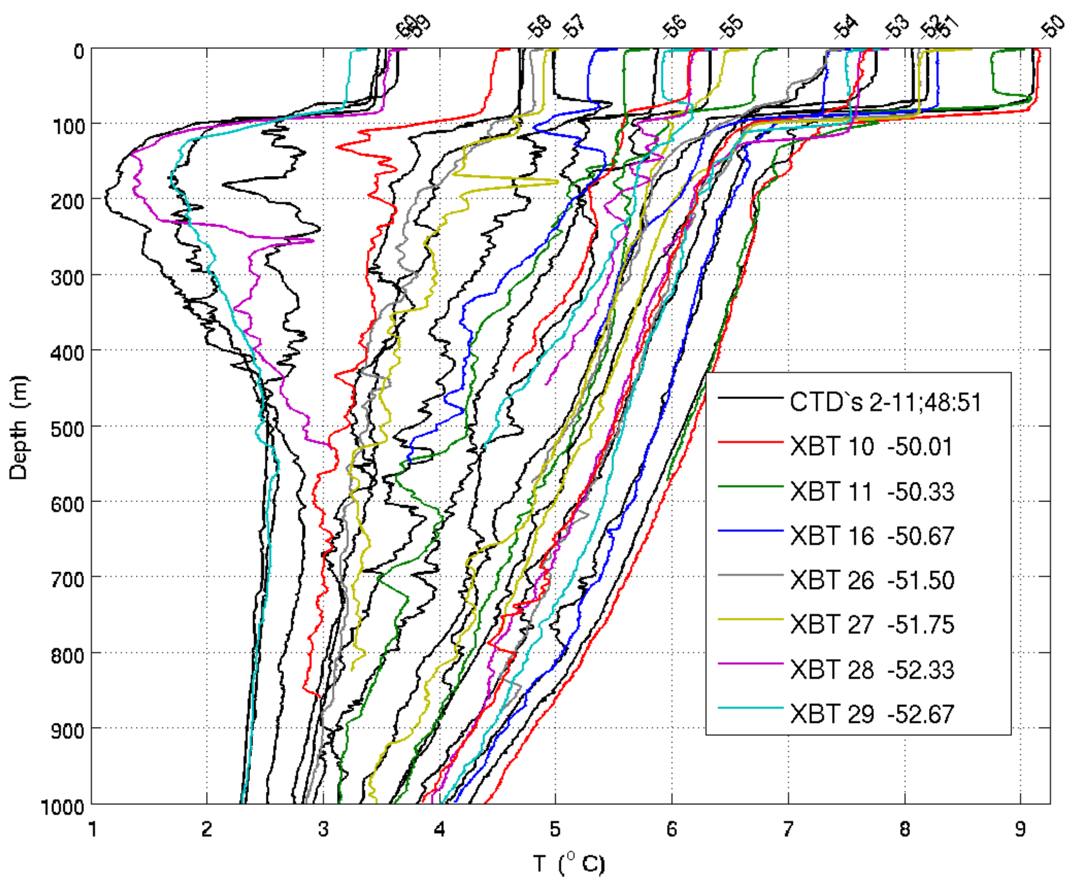


Fig. 2.5.1. Temperature profiles from 50°S to 60°S along 105°W. XBT profiles are plotted in color in repeated cycles in the color order shown in the legend for the first seven records. Temperature generally decreases toward the south. CTD profiles are plotted in black, with their latitudes shown along the top for the profiles at integer degrees. There is a profile of at least one kind or another every 1/3 degree between 50°S and 58°S and every ¼ degree between 58°S and 60°S.

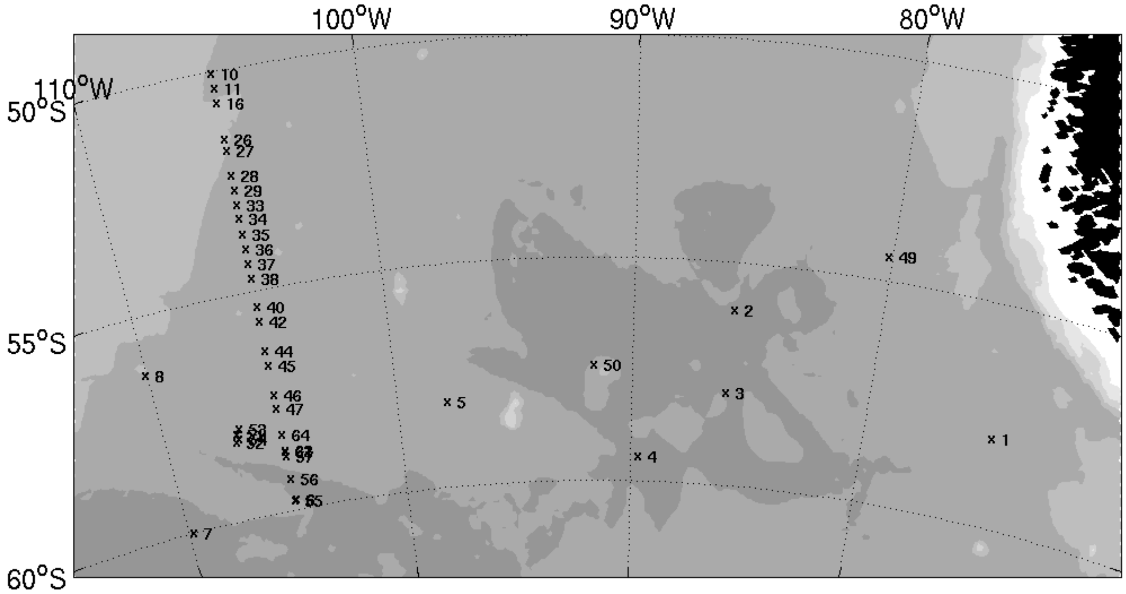


Fig. 2.5.2. Location of XBT drops.

2.6. RAFOS Deployments

RAFOS floats were deployed in triplets along the CTD line, starting at 54°S, and at every CTD and XBT station south to 57 - 40°S, so every third of a degree between 22 and 25 January. Deployments were curtailed at that point due to the medical evacuation. Two triplets of RAFOS floats were also released near the center of the tracer streaks, described below, on 3 and 5 February, and two more during sampling of the tracer, on 9 and 16 February. Release of triplets of RAFOS floats along 105°W commenced again, every ¼ degree from 60°S to 58°S, between 12 and 13 February while we finished the CTD/XBT line. The RAFOS program is described in more detail in Section 12.

2.7. Surface Drifters

A total of 15 type SVP BD2 surface drifters, provided by NOAA/AOML in Miami, were released during the cruise. Three drifters were released near 110°W in the vicinity of the last mooring deployment. Individual drifters were released at 55°S, 56°S, and 57°S during the first part of the CTD section at 105°W. Triplets of drifters were released at 60°S, 59°S, and 58°S along 105°W during the second part of the CTD section. More details on the drifters are given in Section 13.

2.8. Medical Evacuation – End of Leg 1

Once the CTD was on board at the end of Cast 11 at 58°S, 105°W, 1630 Z on 25 January, we left the site promptly to return to Punta Arenas due to a serious health problem suffered by the ship's cook. We arrived in Punta Arenas on 29 January, left the cook off, and started steaming back to our operational area, returning to work early on 3 February 2009. Approximately 8.5 days were lost to the evacuation. Interesting bathymetric data from the EM 120 multibeam system were obtained along the track back and forth to Punta Arenas. Multibeam data are described in detail in Section 6.

2.9. Tracer Release

The tracer, 76.5 kg of trifluoromethyl sulfur pentafluoride (CF_3SF_5), was released in two streaks, centered near 58.1°S, 106.7°W (Fig. 2.9.1). The location was chosen as being near a stagnation point in the surface geostrophic flow estimated from satellite altimetry, to simplify finding the tracer later. Deployment of the first injection streak started at 0445 Z on 3 February and the second injection streak was finished at 0418 Z on 5 February 2009. The target used for the injection was the 34.6077 kg/m^3 (uncalibrated) potential density surface, referenced to 1500 dbar pressure (σ_{1500}). A more accurate estimate of the density of the release, based on later calibrations, was 34.6137 $\pm$ 0.0010 kg/m^3 (see Section 10). This density surface corresponds closely with the 27.9 kg/m^3 neutral density surface and the 27.6745 kg/m^3 potential density surface, referenced to the surface (σ_0), at the location of the injection. Statistics for the injection are summarized in Table 2.9.1. Details on calibration of the CTD salinity are presented in Section 10, and details on the injection are presented in Section 17.

Table 2.9.1. Injection Statistics

Quantity	Units	Mean or Total	Std Deviation
Pressure	dbar	1572	7.7
Temperature	°C	2.2945	0.0029
Salinity (raw)		34.6478	0.00053
σ_{1500} (raw)	kg/m^3	34.6077	0.00038
Salinity (corrected)		34.6553* $\pm$ 0.001	
σ_{1500} (corrected)	kg/m^3	34.6137* $\pm$ 0.001	
Amount Injected		76.5 kg	

*An argument can be made for smaller corrections to the salinity and density. See Section 10. Also note that the tracer was found during initial sampling to be centered 2 to 6 meters deeper than the isopycnal surface of the injection, as described in Section 2.13.

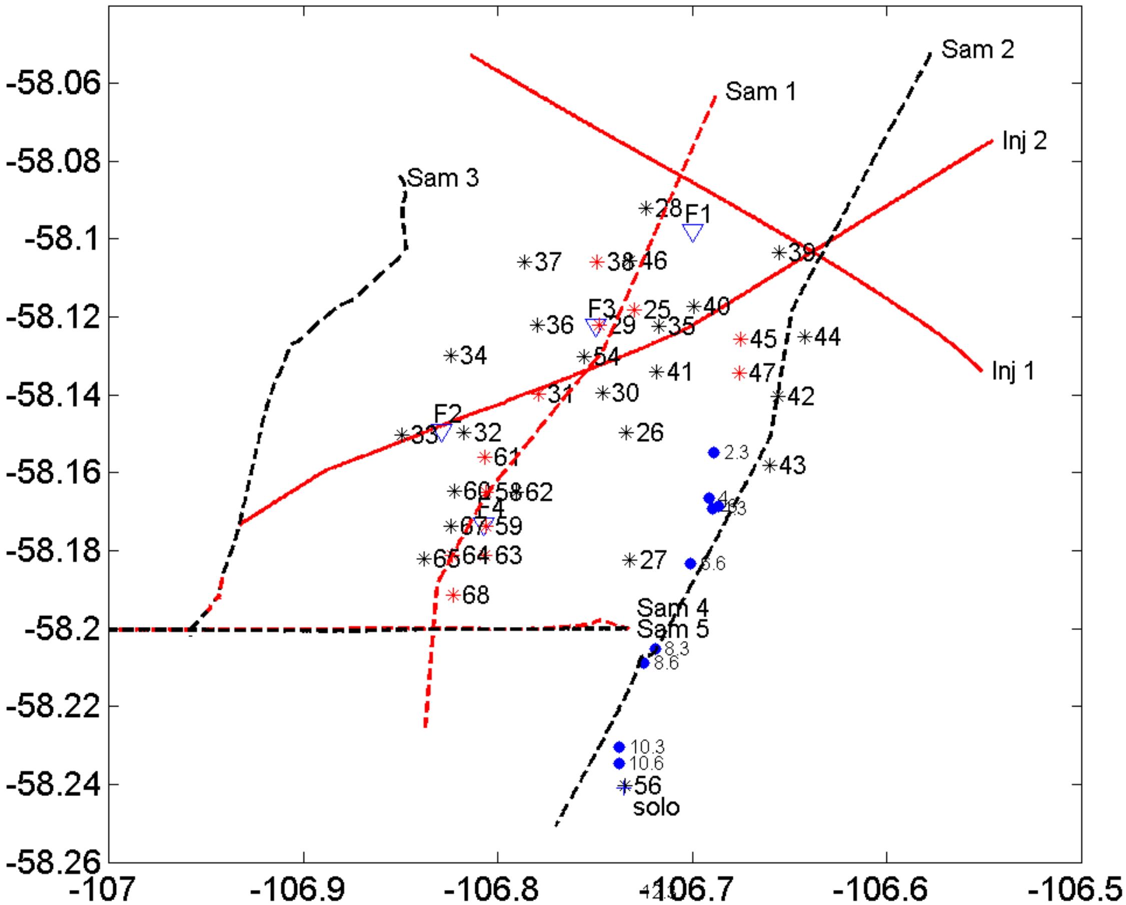


Fig. 2.9.1. Tracer injection and sampling tracks, and float positions. Solid red lines: injection tracks; dashed lines: sampling tow tracks, with red indicating tracer found, black not found; Sampler tow 2 actually did find some tracer, but none at the target density surface. The labels are near the starting end of the tow tracks. Sampler tow 4 at 58.2°S found tracer the first time through, but the array did not trip properly so few samples were obtained. On the repeat, Sampler tow 5, no tracer was found. The numbered asterisks indicate CTD stations, red indicates tracer found, black not found. The inverted blue triangles, labeled F1 through F4, mark the release position of sets of floats. Release F1 was done shortly after Inj 1; F2 after Inj2; F3 after CTD 35; and F4 after Sam 2 and CTD 65. At each location a Shearmeter and 3 RAFOS floats were released. A SOLO float was released at F1 and F2. EM-APEX floats were released at F1, F3 and F4. The SOLO float from F1 went to near Station 56 after 10 days, as did the EM-APEX float from F1, the surface locations of which are shown with numbered blue dots, the numbers indicating the days since release. The SOLO float from F2 was not heard from.

2.10. Shearmeter Floats

Four Shearmeter floats were released during the tracer release in the area of the tracer patch, at the sites labeled F1 through F4 in Fig. 2.9.1. Triplets of RAFOS floats were also released at these sites. The Shearmeters are 7-meter long, neutrally buoyant floats that rotate in response to the magnitude of the vertical gradient of the horizontal velocity, the number of rotations being counted with the aid of a compass on board. They also carry a CTD at the top end and a temperature sensor at the bottom end, and RAFOS receivers so that their trajectories may be obtained. They are programmed to come to the surface after approximately 1 year. The Shearmeter at F4 returned to the surface, having dropped its weight. An attempt was made to find and recover it, but it could not be seen. The Shearmeter program is described in detail in Section 15.

2.11. EM-APEX Floats

Three EM-APEX Floats were released in the area of the tracer patch (Fig. 2.9.1). These floats are equipped with electromagnetic current meters and CTDs. They cycle between the surface and 200 dbar every 3 days, obtaining shear profiles. Between profiles they rest at 1500 dbar for 2 days. Their data are transmitted by the Iridium system every time they come to the surface. The EM-APEX floats are described in more detail in Section 14.

The first of the EM-APEX floats, deployed after the first tracer streak, moved to the south over the subsequent 10 days (Fig. 2.9.1). However, it made several excursions to the surface in this time to check its proper operation, and apparently the velocity differences between the level of the tracer and shallower waters caused it to become separated from the tracer patch, since attempts to find tracer near its location at 10 days were unsuccessful (Fig. 2.9.1, CTD 58 and Sampler Tow 2). The same was true of the SOLO float released at the same time as the EM-APEX float. The SOLO float did not make excursions to the surface once it descended. However, it may have become separated from the tracer patch because it was released in its cardboard box, which may take many hours to disintegrate, allowing the float to descend. In that time it may have drifted south away from the tracer patch, since the surface geostrophic velocity was to the south.

2.12. CTD Box Survey around the Tracer Patch

After the tracer streaks were deployed the injection system was packed away, and components heavy with tracer, such as the accumulators, the injection pumps, and the cylinders of CF_3SF_5 were vented, and the ship was generally aired out. During this time nine CTD stations, arranged in a box pattern around the tracer patch, were occupied to estimate the subinertial velocity field from geostrophy, to try to anticipate which way the tracer would move (Fig. 2.12.1). According to the estimates of the velocity field at 1500 dbar, the tracer was released in an area of low velocity, with meridional convergence and zonal divergence, i.e., near a hyperbolic point in the flow. This is roughly in agreement with the geostrophic surface velocity pattern from satellite-derived sea surface topography (Fig. 2.12.2), which is perhaps not surprising since the velocities at 1500 dbar were estimated using the surface velocities as a reference. However, the minimum velocity appears to be about 30 km further south for the surface currents than at 1500 dbar.

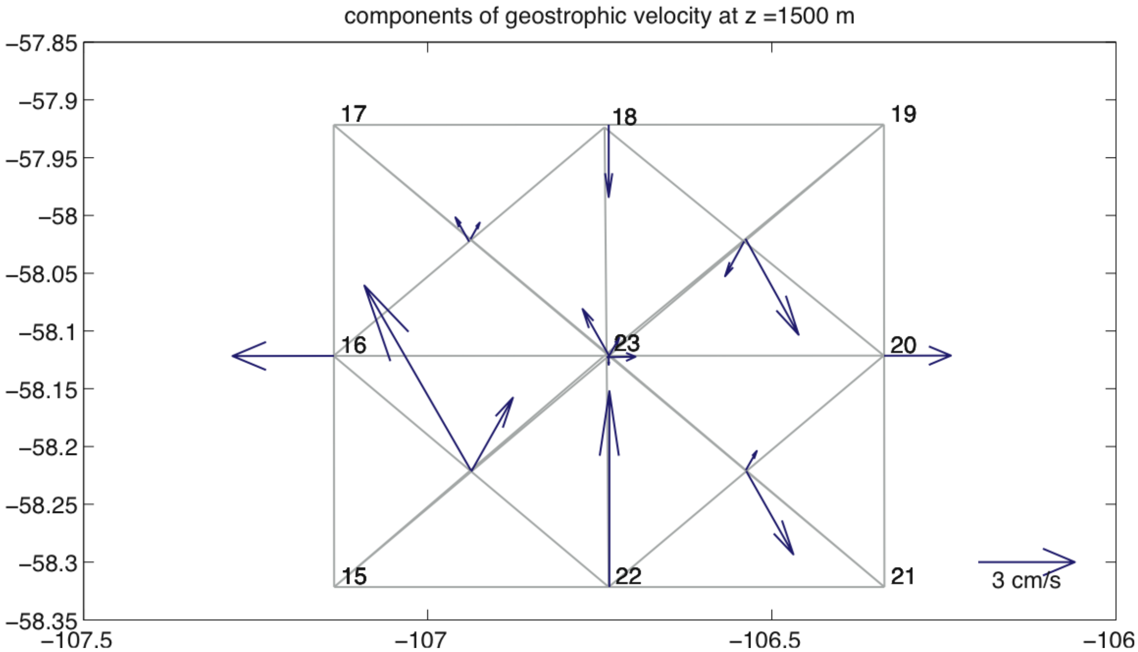


Fig. 2.12.1. CTD stations around the tracer patch and geostrophic velocity at 1500 dbar relative to the surface. The arrows indicate the speed of the current at 1500 dbar in the direction normal to the lines between stations. The directions of the arrows in the interior of the box are offset a little from the normal direction for clarity. The tracer streaks were deployed near the middle of the box. The edge length of the overall box is 44.4 km. The stations were occupied in the order shown by the numbers at time intervals of 6.2 hours to attempt to minimize the effect of any internal semidiurnal tidal variations in the density field. That is, the odd numbered stations are all at the same phase of the semidiurnal tide, and the even numbered stations are all at the opposite phase. Geostrophic calculations have been done only for station pairs that are in phase.

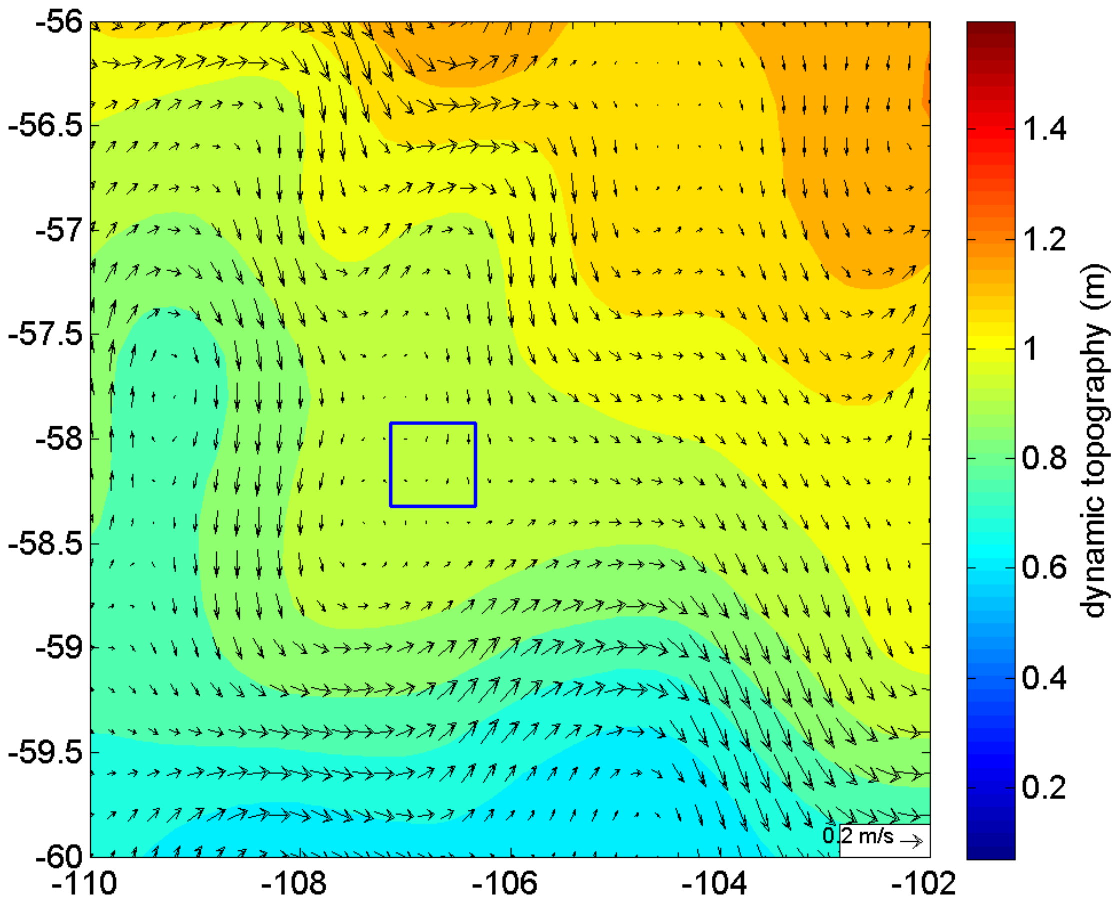


Fig. 2.12.2. Geostrophic surface velocity in the region of the tracer release, from satellite-derived absolute dynamic topography, for 13 February 2009. The square marks the area of the CTD box survey shown in Fig. 2.9.1.

2.13. Surveying of the Tracer Patch

Two different methods were used to sample the initial condition of the tracer: CTD/Rosette casts and a towed array of special samplers. The CTD/Rosette system could be deployed in rougher conditions than the towed array. However, the CTD/Rosette obtains samples at a point and is likely to miss tracer in a streaky field, even if it is deployed in the general area of the tracer. The seas did become rough toward the end of the CTD box survey, and in fact were deemed too rough to do anything but more CTD casts. We postponed any plans to finish the CTD line at 105^{o}W because conditions were too rough to deploy RAFOS floats without harming them. Hence from 9 to 11 February we hunted for tracer, when the sea state and wind allowed, with the CTD/Rosette system, occupying stations 25 through 47 shown in Fig. 2.9.1. (CTD 24 was a cast to 500 meters, where all the Niskin bottles were tripped, to test for CF_3SF_5 contamination from the injection. The bottles, which had been stowed in the forward hold, sealed in large plastic bags, proved to be clean.) The rationale for choice of station locations is explained in Section 16.

As Fig. 2.9.1 shows, encounters with the tracer were rare during this search. Casts 25, 29, 31, 38, 45, and 47 each found at least a little tracer, while the others showed none. Casts 29, 38 and 47 gave full tracer profiles with peak concentrations on the order of 1000 fM. Tracer concentrations were on the order of 10 fM for Casts 31 and 47, and so do not contribute very much to the mean. One sample from Cast 25 gave a concentration that was off scale for the analysis system, while the others were near zero, and so this profile is suspect. The profile from Cast 38 is shown in Fig. 2.13.1, as an example. All of the profiles are shown in Section 18, both as a function of height above the target potential density surface and as a function of potential density.

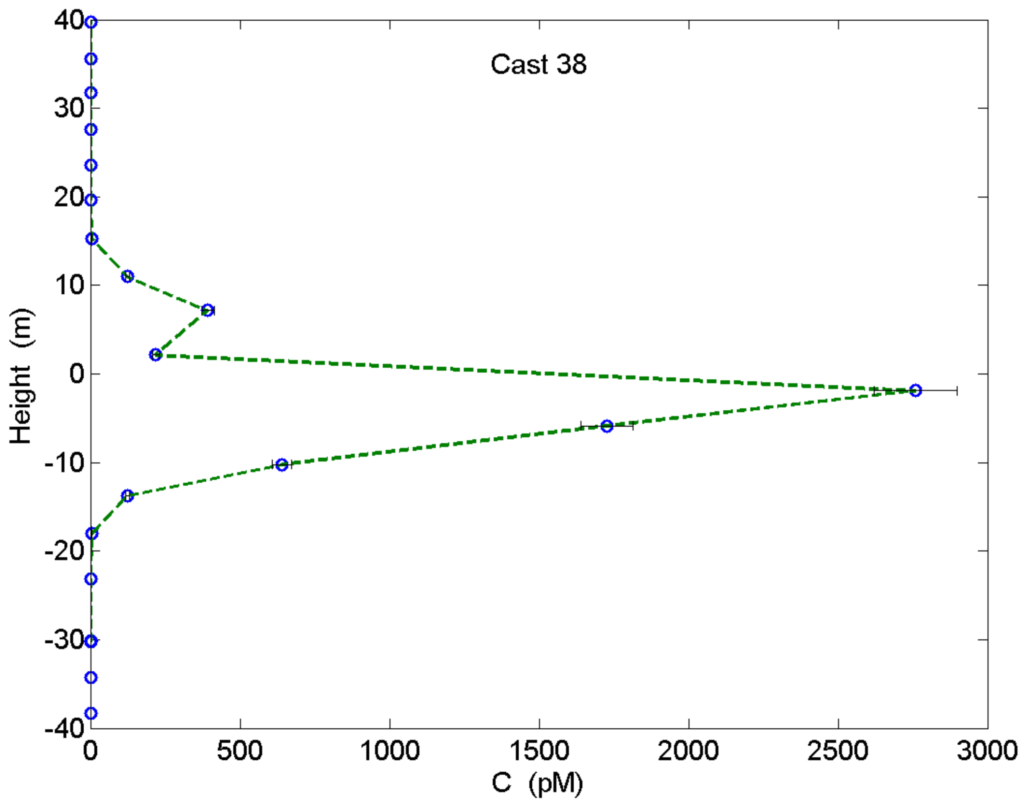


Fig. 2.13.1. Tracer concentration versus height above the target density surface, CTD Cast 38. The samples were from 4-liter Niskin bottles in the CTD/Rosette system.

The weather promised to be calm for the few days after 11 February, and so we moved to 105^{o}W to finish the CTD/XBT line and release the rest of the RAFOS floats and the surface drifters at this time, as described in Sections 2.4 through 2.7. We returned for more sampling of the tracer patch from 13 to 19 February 2009. During the CTD line we set up the apparatus for the towed sampling system, and so were able during this last period of the cruise to alternate between sampling tows and CTD/Rosette casts, as dictated by the weather.

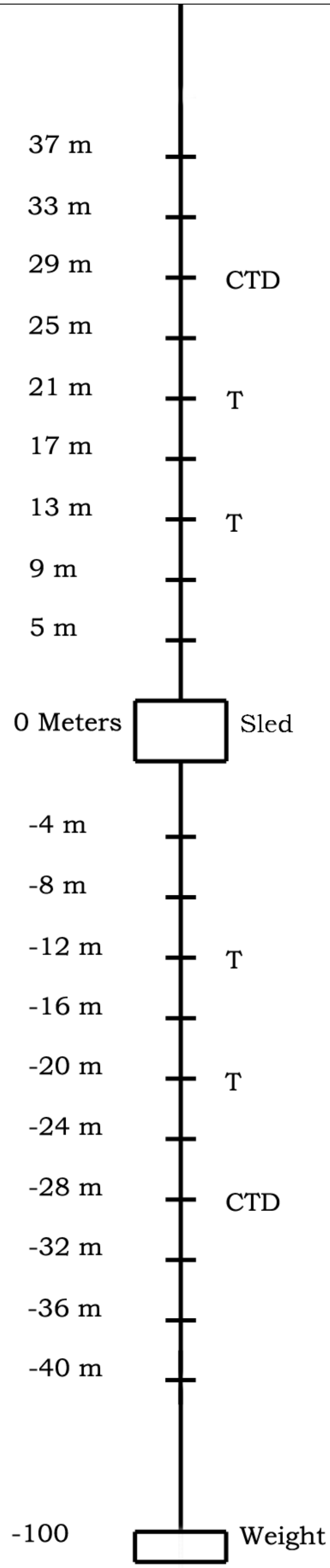
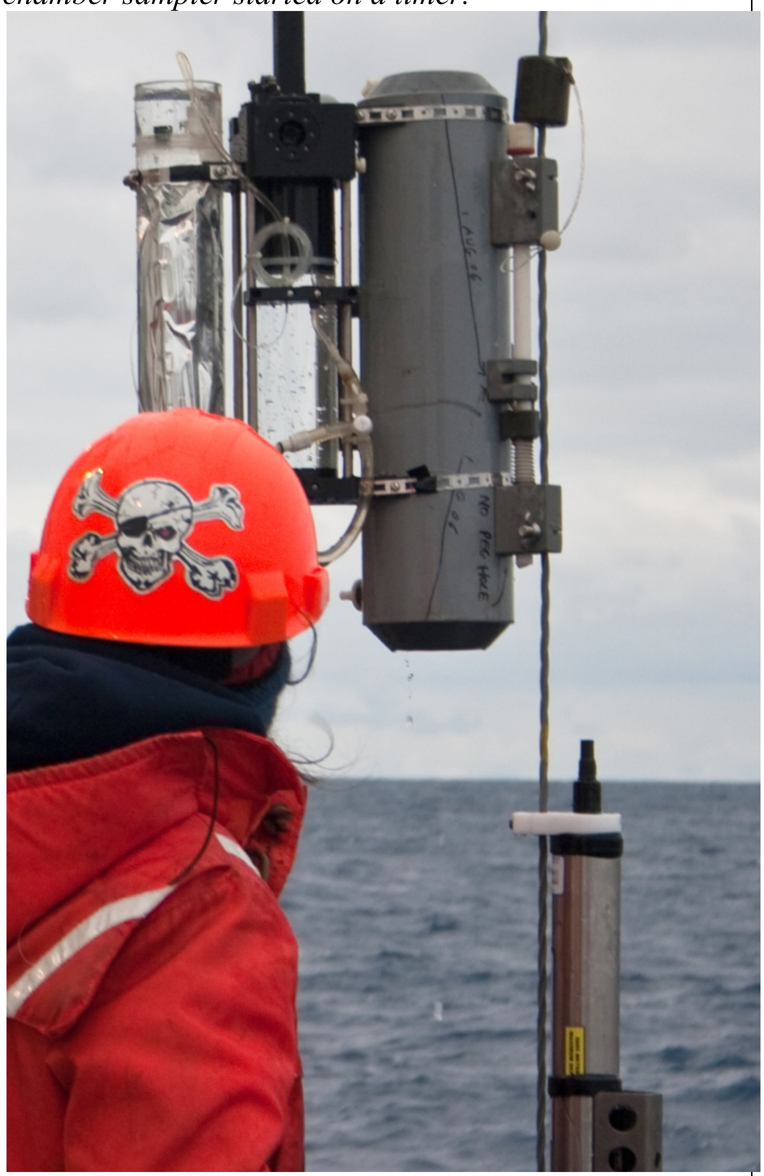


Fig. 2.13.2. Sampling Array. There is an integrating sampler (photo below) at each hatch mark, with height above the central sled marked to the left. The CTDs are SeaBird SBE-37's, hung just below the associated integrating samplers (photo below). The temperature sensors ('T') are SeaBird SBE-39's, hung below their associated samplers. On the sled is an integrating sampler, a SeaBird 9plus CTD used to control the tow, a rosette pylon with five 1.2-liter Niskin bottles, and a 50-chamber sampler with valve, controller and battery. The integrating samplers above the sled were triggered with a messenger sent from the ship. The rosette pylon was used to trigger the sampler on the sled and the messenger for the samplers below the sled. The 50-chamber sampler started on a timer.



The towed sampling array consisted of a set of 21 integrating samplers arranged in a vertical array, and a set of 50 syringe samples at the center of the array, with a CTD/Rosette, mounted on an aluminum sled (Fig. 2.13.2). The integrating samplers took 850 ml of water into a metal-lined bag over a period of 10 hours while the array was towed at a speed of 1 to 1.2 knots through the water. The samplers were spaced 4 meters apart (5 meters for the sampler immediately above the central sled), with 10 samplers above the sled on the CTD wire and 10 below the sled on an auxiliary hydrowire, and were tripped by mechanical messenger. A 580-lb weight was placed at the bottom of this wire. There was also an integrating sampler on the sled. The 50 syringes filled sequentially along the tow track, each one taking 12 minutes to fill. Five 1.2-liter Niskin bottles were mounted on the rosette pylon with the CTD on the sled, and were tripped periodically during the tow for salinity calibration.

The central sled was held as close as possible to the target density surface using the same feedback system between the CTD and the winch as was used for the tracer injection. Excursions of the sampling sled are larger than for the injection sled because the sampling sled was attached directly to the CTD cable rather than towed at the end of a tether. The integrating samplers were approximately at fixed heights relative to the target surface, but not at fixed densities. In order to account for density excursions as a function of position and to obtain data on the strain field a set of conductivity, pressure and temperature sensors were included in the vertical array of samplers (Fig. 2.13.2). These sampled every 5 seconds. An example of the temperature time series from these sensors is shown in Fig. 2.13.3. Details on these sensors, more figures, are given in Section 10.5. Intercalibrations of the sensors are also described in Section 10.5.

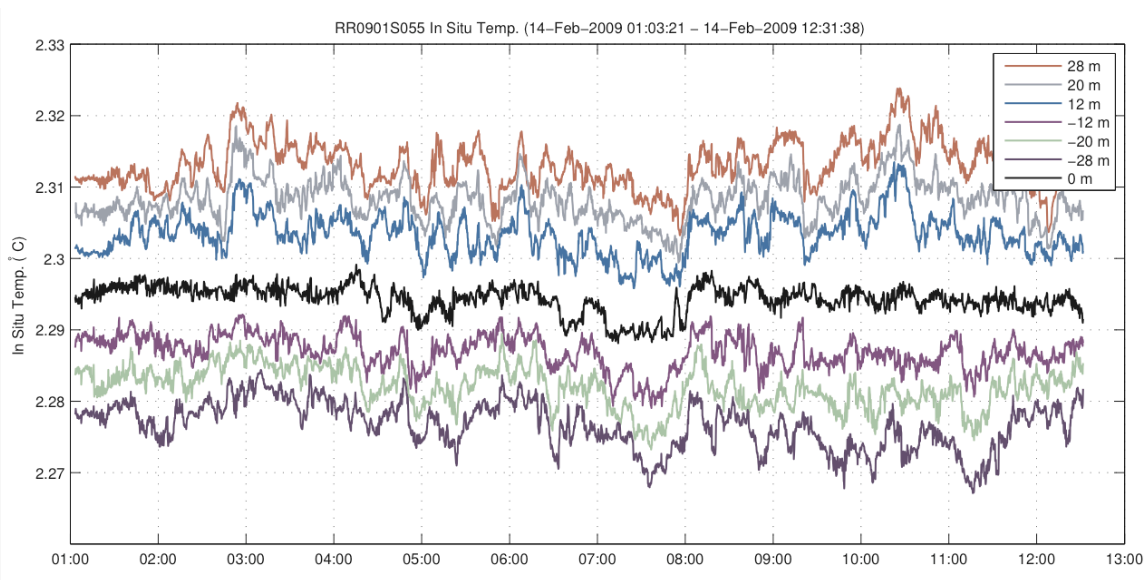


Fig. 2.13.3. Time series of in situ *temperatures from sensors in the sampling array for Sampler Tow 1 (Cast 55). Height above the central sled (at 0 m) is given in the key. Time into the tow, in hours:minutes is given on the abscissa.*

The vertical array of integrating samplers gives the vertical profile of the tracer concentration, averaged along the tow tracks, which were on the order of 20 km long. The five tracks occupied during the cruise are shown in Fig. 2.9.1. Some tracer was found on each of these tracks except the 5th one. Malfunctions of the samplers on Sampler Tow 4 rendered the vertical profile of little use – most of the middle samples were lost. The profiles for the first three tows and their mean are shown in Fig. 2.13.4. The method of gas chromatographic analysis for the tracer is described in Section 18.

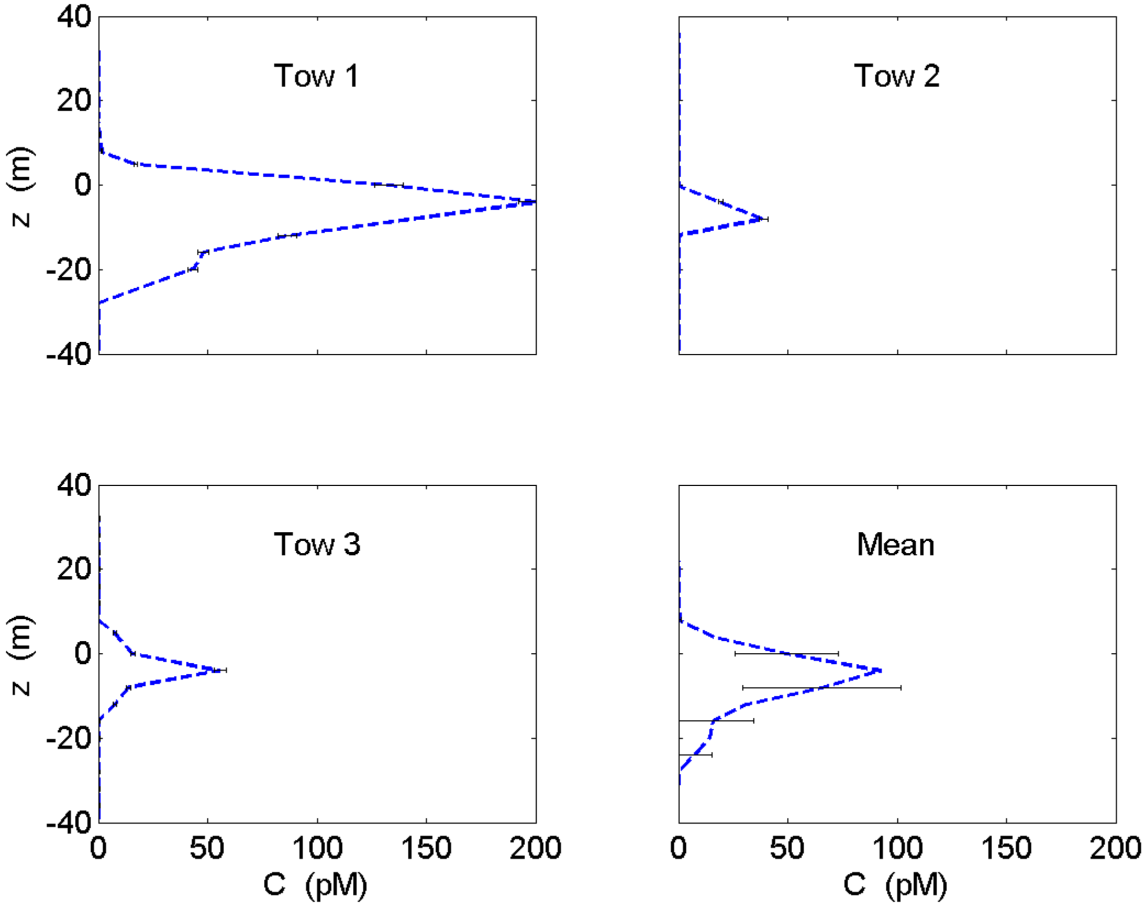


Fig. 2.13.4. Tracer profiles from Sampler Tows 1, 2 and 3 (Casts 55, 57, and 66). The ordinates represent height above the sampler sled, which was towed along the target potential density surface.

As mentioned above, on the sampling sled is a set of 50 syringes which fill sequentially along the tow track, with nominally 12 minutes taken to fill each syringe. The syringes do not always fill properly, due to friction in the system or misalignment of the 50-port valve used. Nevertheless, this system gives an idea of where along the tow tracks tracer was found and of the length scales of streakiness of the tracer patch at this point in the experiment, 10 to 14 days after the tracer injection. Results from the 50-chamber samplers are shown in Fig. 2.13.5.

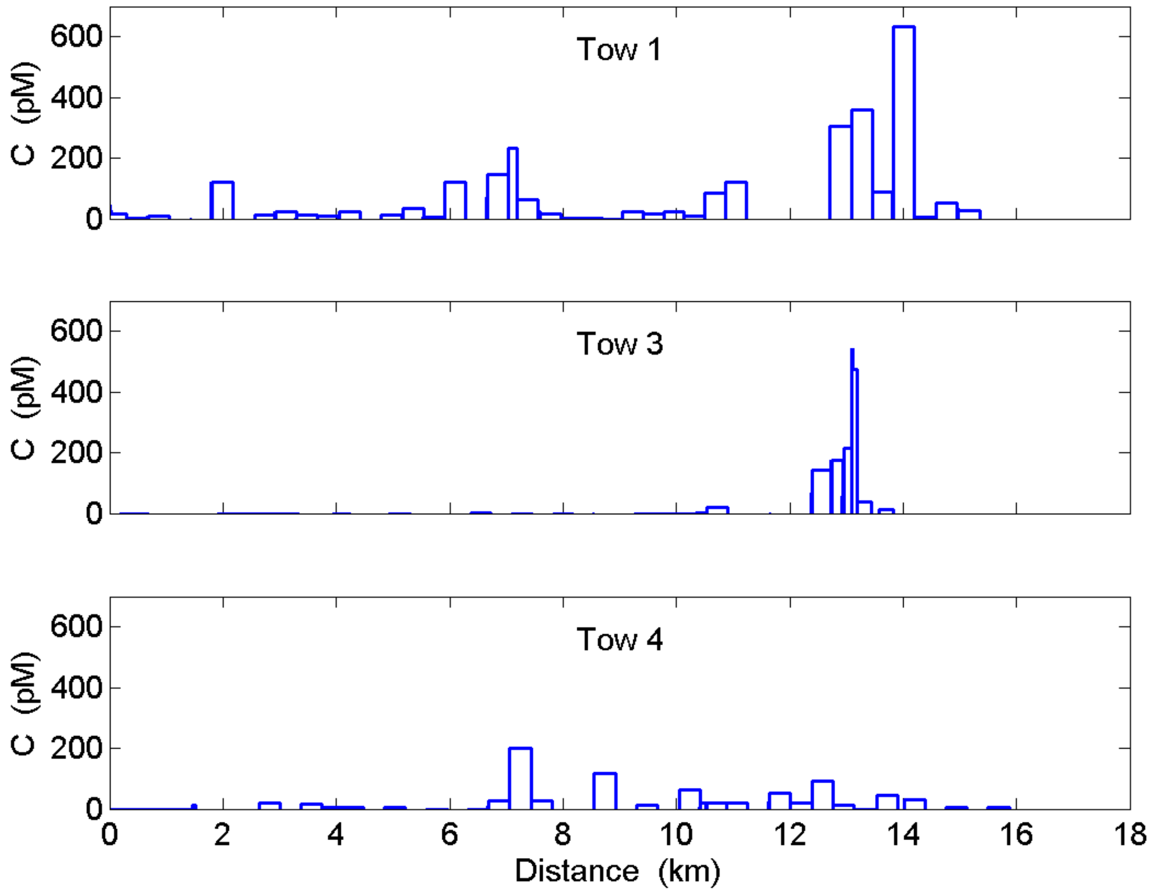


Fig. 2.13.5. Tracer transects from the 50-chamber sampler along the tow tracks. Each bar represents one sample. Where there is no bar, even at C=0, the syringe failed to fill. Abnormally thin bars occur when the control system sensed a stuck syringe and moved on before the normal 12 minutes were up.

It was possible to do CTD/Rosette casts during the period of the sampler tows, while the towed system was being prepared for the next tow, or when the weather was bad. CTD casts 56 through 68 were done during this period, with casts 58, 59, 61, 63, and 68 finding at least some tracer. Casts 58 and 59 were particularly rich in tracer. Individual profiles from all the CTD casts that found tracer are shown in Section 18. The mean of all of them, as a function of density, is shown in Fig. 2.13.6. This mean can be transformed into depth coordinates using the mean depth versus density relation for this set of CTD profiles (Fig. 2.13.7 and Fig. 2.13.8).

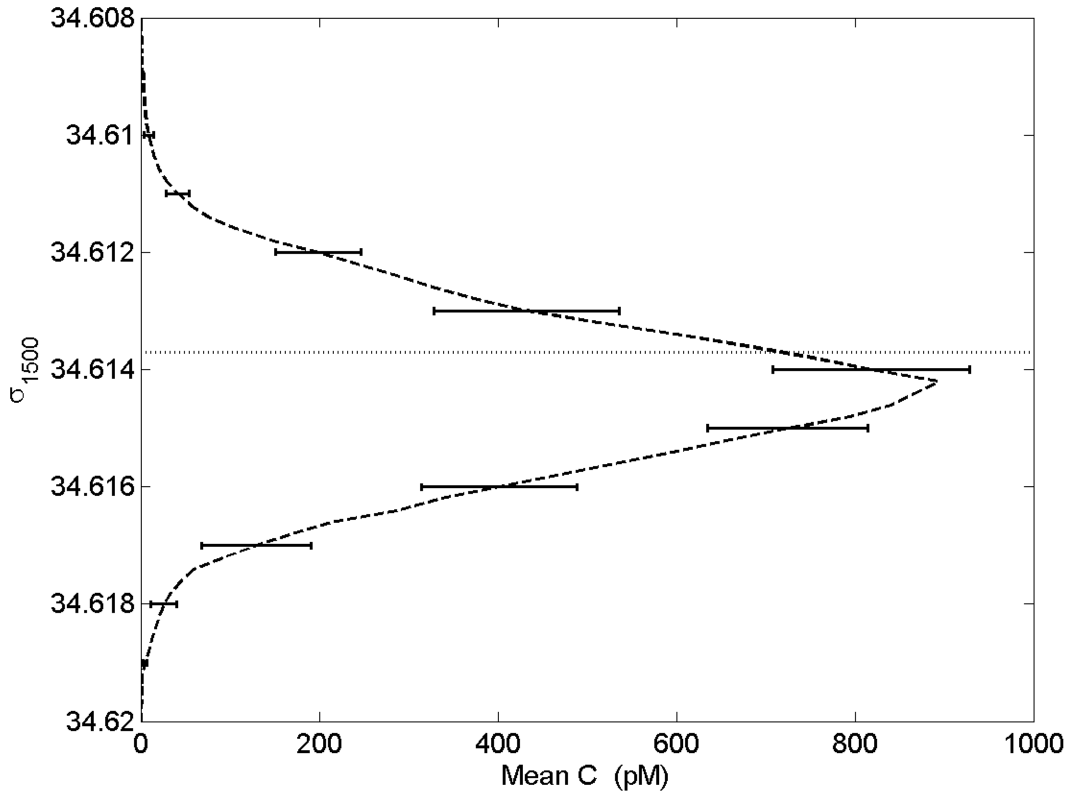


Fig. 2.13.6. Mean tracer concentration as a function of σ_{1500} for all the CTD/Rosette casts in the tracer patch. The dotted line shows the target density. It appears that the tracer sank a little, the turbulent wake of the injection sled being insufficiently energetic to erase the density anomaly of the tracer completely. Salinity calibrations have been applied to both the target density and the CTD/Rosette densities (Section 10.5).

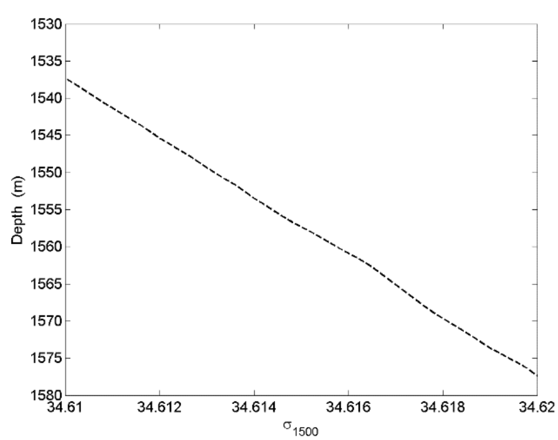


Fig. 2.13.7. Mean depth as a function of σ_{1500} for all the CTD/Rosette casts that found tracer (11 casts). This function is used to transform the profile in Fig. 2.13.6 into depth coordinates in Fig. 2.13.8. The mean density gradient from the slope of this line is -2.7 x10^{-4} kg m^{-4}.

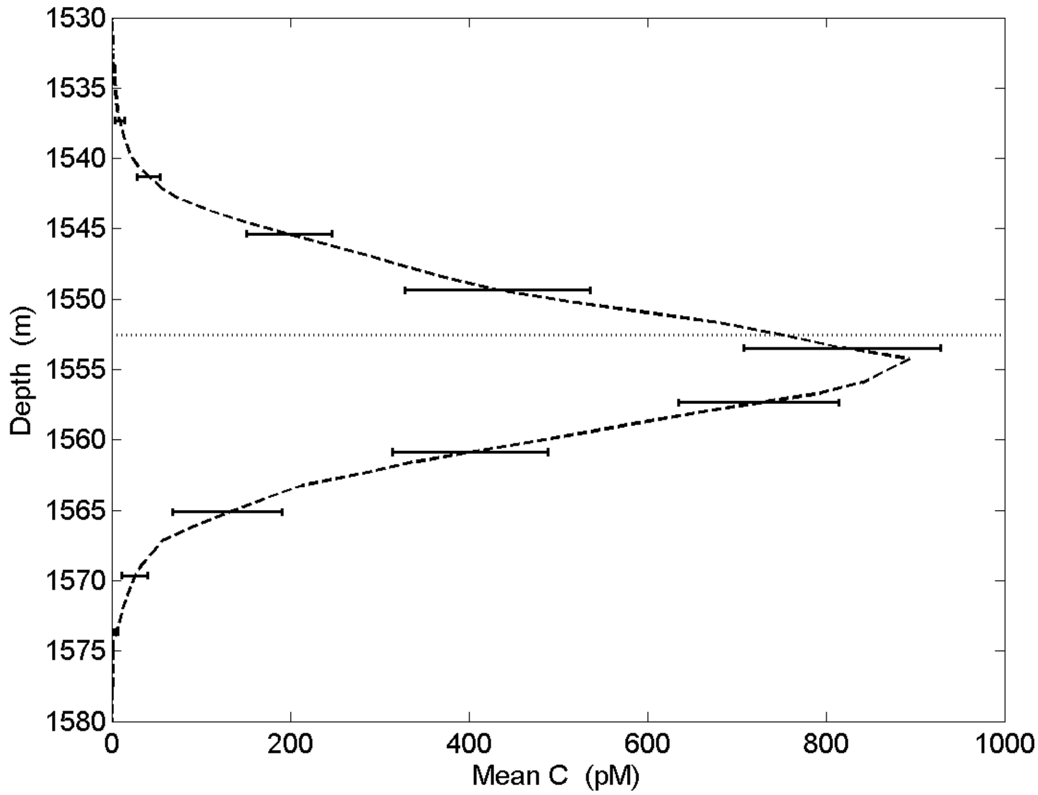


Fig. 2.13.8. Mean tracer profile as a function of depth. This profile is derived from the profile of mean tracer versus density (Fig. 2.13.6) and the mean depth versus density (Fig. 2.13.7). The dotted line shows the mean depth of the target isopycnal surface.

2.14. Initial Diapycnal Distribution of the Tracer Patch

The mean profile from the towed array, shown in Fig. 2.13.4, and the mean profile from the CTDs (Fig. 2.13.8) show the peak of the tracer to be about 4 meters and 2 meters, respectively, below the target potential density surface (Table 2.14.1), and, especially in the case of the towed samplers, a lower tail that is broader than the upper tail. Sinking of the tracer plume between injection and initial sampling has been observed in most of the other tracer release experiments of this type. The tracer, which will make the water relatively dense even after dissolution, appears to cause the plume to sink a few meters before the plume comes to equilibrium with surrounding waters by a combination of the sinking and dispersion.

The mean profiles in Figs. 2.13.4 and 2.13.8 and the moments of the tracer distribution, listed in Table 2.14.1, give us an estimate of the initial condition for estimates of diapycnal diffusivity from the tracer within DIMES. The second moment was about 40 m^2, and the center of mass about 2 to 4 meters below the target density surface, about 9 days after the injection. Further analysis is required to assign uncertainties to these estimates, and the results themselves will be uncertain. However, unless the diapycnal diffusivity is unusually small in this area of the ocean, uncertainties in the initial condition will contribute little to uncertainties in the diffusivity.

Table 2.14.1. Statistics of the Initial Tracer Distribution

	CTD Casts	Sampler Tows
Number of casts with tracer	9	3
First Moment (m)	–2.0	–6.5*
2^{nd} Moment (m^2)	30.7	41.1
rms spread (m)	5.5	6.4

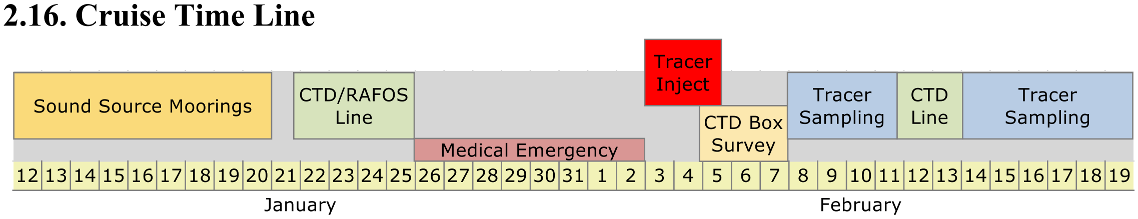
*Though the first moment of the mean profiler from the towed system was -6.5 m, the peak was approximately 4 m below the target surface (see Fig. 2.14.4).

2.15. CTD Calibrations

Two SeaBird SBE 9*plus* CTDs were used during the cruise, one, provided by SIO, on the CTD/Rosette frame for all of the CTD casts, called the STS CTD, and the other, brought by the WHOI tracer group, on the tracer injection sled and the tracer sampling sled, the TRE CTD. Calibration data for the sensors on these instruments, and other details, are given in Section 10.1. Salinity samples were taken from a few of the 4-liter Niskin bottles on the rosette frame for many of the CTD/Rosette casts, and four or five salinity samples were taken from 1.2-liter Niskin bottles from each sampling and injection tow. The salinometer on the ship was not working well enough to rely on salinity analyses of samples on board. Hence, salinity bottles were shipped back to WHOI for analysis. Corrections of the conductivities and salinities are discussed in Section 10.3 and 10.4. A temperature correction of 0.00012^{o}C was subtracted from the STS CTD temperature; none for the TRE CTD.

As noted in Section 2.13, several internally recording sensors were deployed in the sampling array, four SBE 39 temperature sensors and 2 SBE 37 CTDs. These were intercalibrated with one another and with one or the other of the SBE 9*plus* CTDs on two occasions. During Cast 51 all the sensors were bundled together on the CTD/Rosette frame for comparison with the STS CTD. On Cast 70 they were all bundled together on the sampling sled for comparison with the TRE CTD. As a result, we obtained an indirect comparison of the two SBE 9*plus* CTDs, through the other sensors. This comparison was crucial in comparing the tracer profiles from the rosette with those from the towed array. The raw density reported by the TRE CTD turned out to be about 0.003 kg/m^3 lower than that reported by the SIO CTD. Details of the intercalibrations of the various sensors are described in Section 10.5.

2.16. Cruise Time Line



3. Meteorological and Surface Seawater Measurements

3.1. Location of the Instruments

R/V *Roger Revelle* is equipped with a meteorological mast which is located on the bow of the ship. This mast has sensors measuring air temperature, barometric pressure and wind speed and direction 17.0 m above the mean water level (W #2). At the same level, a module provides the water vapor content in the air and precipitation. Higher on the bow mast, 20.7 m above the mean water line, different radiometers measure long and short wave radiation, and Photosynthetically Active Radiation (PAR). Wind speed and direction sensors are also placed on the Main mast of the ship (W #1).

Two thermosalinographs provide surface water properties along the ship's track. One of these thermosalinographs (TSG #1) is located in the bow thruster room (see Figure 3.1.1) about 2.1 m from the seawater intake. Here, seawater is continuously pumped at a flow rate of ~ 1.4 l/min and measurements of surface temperature and conductivity are made. From this site, the seawater flows through a pipe in the interior of the ship into the second thermosalinograph system (TSG #2) which is installed in the Hydro Lab. The uncontaminated seawater feeds a vortex debubbler. The output of the debubbler supplies the flow-thru system. A fluorometer, oxygen sensor and flow meter are placed in the water line before the flow enters the TSG #2.

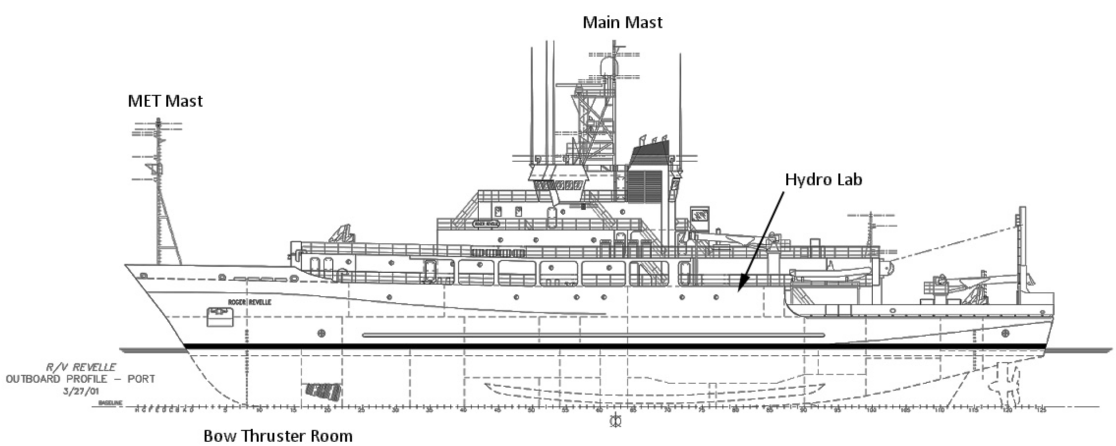


FIG. 3.1.1. R/V Revelle *portside plot. MET mast, Main mast, Hydro Lab and the Bow Thruster Room locations are indicated.*

All meteorological variables and sea surface data are recorded at 30 second intervals on the ship's MET data acquisition system. These data are merged with ships navigation, gyrocompass and time server.

3.2. Description of the Sensors

The accuracy, range and calibration specifications for the sensors are listed in Tables 3.2.1, 3.2.2 and 3.2.3. All sensor tolerance and accuracy values listed in this section are taken from the manufacturers' specification sheets. They are derived under laboratory conditions and do not necessarily indicate the accuracies that may be expected in actual shipboard installations. They do not take into account the effects of ship motion, solar radiation, shipboard structural interference and thermal radiation effects of the ship itself. On *Revelle* the placement of the radiation sensors on the bow of the ship minimizes some of the ship structural radiation effects.

The following is a brief description of the sensors used on R/V *Revelle* and their measuring principle.

Wind Speed and Direction
The primary sensor for wind speed and direction is a Vaisala Model WS425 Ultrasonic Wind Sensor, mounted on the meteorological mast on the bow of the ship (the MET mast), 17.1 meters above the mean water line. There are 3 transponders arranged in a circle, with 120 degrees between them. There are 3 paths at 60 degree angles to one another between transponder pairs. The time of transit for sound is measured in both directions to determine the speed of the wind along each path. The plane of the transponders is no doubt assumed to be horizontal, and speed and direction are calculated from the transit times, with some redundancy. The sensor was last calibrated in December 2004. There was also an RM Young 5300 propeller/vane wind speed and direction sensor on the main mast, which gave useful data.

Atmospheric Pressure, Air Temperature, and Relative Humidity
Pressure is measured on the MET mast with a Vaisala PTB 101C sensor. The Relative Humidity (RH) module located in the MET mast combines a high accuracy, capacitance type humidity sensor and precision Platinum RTD temperature sensor in one probe. Capacitance sensors operate on the principle that changes in relative humidity cause the capacitance of a sensor to change in a detectable and repeatable fashion. Because of the nature of the measurement, capacitance humidity sensors are combined with a transmitter to produce a higher-level voltage or current signal. Capacitance sensors are affected by temperature such that accuracy decreases as temperature deviates from the calibration temperature.

Long Wave Radiation Sensor
The PIR, or pyrgeometer, is a radiometer that measures thermal infrared irradiance. The pyrgeometer works on the principle that radiant energy is converted to heat energy which, in turn, is measured by a thermopile. Isolation of long-wave radiation from solar short-wave radiation in daytime is accomplished by using a silicone dome. The inner surface of this hemisphere has a vacuum-deposited interference filter with a transmission range of approximately 3.5 to 50 µm. The detector senses a net signal from a number of sources which includes emissions from targets in its field of view, emission from the case of the instrument, and emission from the dome. To resurrect the true environmental thermal infrared irradiance, temperatures of the detector, case, and dome are monitored with thermistors. Because the case is shielded from the sun, its temperature represents the air temperature and therefore is a proxy for the degree of thermal emission by the atmosphere. The dome, however, is not protected from solar heating. Therefore, the

difference between the thermal emissions of the case and dome represents an erroneous signal that must be removed. An empirical calibration equation accounts for all of these effects and converts the three measured temperatures to an estimate of the true environmental thermal infrared irradiance, in watts per square meter.

Short Wave Radiation sensor

The PSP, or pyranometer, is a radiometer designed for the measurement of sun and sky radiation flux density (in watts per meter square) totally or in defined broad wavelength bands on a planar surface from a field of view of 180 degrees. For a flux density or irradiance measurement it is required by definition that the response to "beam" radiation varies with the cosine of the angle of incidence. In order to attain the proper directional and spectral characteristics, the pyranometer's main components are: a thermopile sensor with a black coating, and a glass dome. This dome limits the spectral response from 300 to 2,800 nm, while preserving the 180 degree field of view. The black coating on the thermopile sensor absorbs the solar radiation. This radiation is converted to heat. The heat flows through the sensor to the pyranometer housing. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation.

Surface PAR

The QSR-2000 Hemispherical Quantum Scalar Reference Sensor measures total incident Photosynthetically Active Radiation (PAR) (400-700 nm) from the sun and sky. The QSR Series features a patented solid teflon spherical collector with hemispherical field-of-view cutoff plate, ensuring uniform directional response over 2π steradians. An aluminum-encased optical fiber funnels flux from the collector to a silicon photodetector that has a flat quantum response over PAR.

Precipitation

The precipitation measurement is made with a capacitive transducer and electronic circuit that produce a calibrated voltage output. Self-contained thermostatically controlled heaters allow operation at temperatures as low as -20°C. Collected snow is melted and measured as rainfall equivalent. Precipitation is collected in a catchment funnel which has a cross sectional area of 100 cm^2. Captured precipitation drains from this funnel into a measuring tube which has a cross sectional area of 20 cm^2. Since the area of the catchment funnel is 5 times that of the measuring tube, 1 mm of captured precipitation produces a 5 mm column of water in the measuring tube. A capacitive transducer in the center of the measuring tube senses the water column height. A self -contained electronic circuit converts the capacitance value to a calibrated voltage output that is proportional to collected precipitation. Periodic interrogation by a data logging system allows computation of total precipitation and rate. Additional precipitation starts a self-siphon process which empties the measuring tube in approximately 30 seconds. The water column in the tube returns to a level representing 0 mm of precipitation and the voltage output goes to 0 VDC. Additional precipitation begins filling the measuring tube again and the cycle is repeated. Evaporation of water remaining in the measuring tube is negligible between siphoning events.

Thermosalinographs
The SBE 45 MicroTSG Thermosalinograph is a high-accuracy instrument, designed for shipboard determination of sea surface (pumped-water) conductivity and temperature. Salinity and sound velocity can also be computed. MicroTSG is designed for a flow rate of 0.6 to 1.8 l/min. Bubbles in the plumbing of a flow-through system are a common problem and will cause noisy salinity data. A de-bubbling device is needed to separate bubbles from the water before it enters the MicroTSG if the hull intake is not placed far from bubble sources. On R/V *Revelle* the water intake is placed 4-5 m below mean water level which ensures a bubble free flow into the TSG #1, in the bow thruster chamber. TSG #2, installed in the Hydro Lab, is provided with a vortex debubbler which removes nuisance air bubbles in the flow before sending the water into bubble sensitive instruments.

Chlorophyll sensor
A fluorometer mounted in the TSG #2 flow system allows estimation of relative chlorophyll by directly measuring the amount of fluorescence emission from the water sample. The sample is pumped through a quartz tube mounted along the long axis of the instrument. These samples, when excited by an internal light source, absorb energy in certain regions of the visible spectrum and emit a portion of this energy as fluorescence at longer wavelengths. This fluorometer is designed to measure the fluorescence of chlorophyll-containing phytoplankton, which absorb light of wavelengths between 400 and 520 nm and emit light between 670 and 730 nm. The instrument uses two bright blue LEDs (centered at approximately 470 nm and modulated at 1 kHz) to provide the excitation. Blue interference filters are used to reject the small amount of red light emitted by the LEDs. A detector positioned at 90 degrees to the axis of the LED mounts measures the emitted light from the sample volume. The approximately 0.25 cm^3 sample volume is defined by the intersection of the excitation light with the field of view of the detector, within the quartz flow tube. A red interference filter is used to discriminate against the scattered blue excitation light. The red fluorescence emitted at 90 degrees is synchronously detected at 1 kHz by a silicon photodiode. The instrument contains two LEDs, doubling the excitation light, as well as mirrors and lenses to optimize the instrument's performance.

Oxygen sensor
The SBE 43 sensor determines dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through the membrane from the water sample to the working electrode. At the working electrode (cathode), oxygen gas molecules are converted to hydroxyl ions (OH^-) in a series of reaction steps where the electrode supplies four electrons per molecule to complete the reaction. The sensor counts oxygen molecules by measuring the electron current delivered to the reaction. At the other electrode (anode), silver chloride is formed and silver ions ($Ag+$) are dissolved into solution. Consequently, the chemistry of the sensor electrolyte changes continuously as oxygen is measured, resulting in a slow but continuous loss of sensitivity that produces a continual, predictable drift in the sensor calibration with time. This electro-chemical drift is accelerated at high oxygen concentrations and falls to zero when no oxygen is being consumed. Membrane fouling also contributes to drift by altering the oxygen

diffusion rate through the membrane, thus reducing sensitivity. By recognizing fouling, both episodic and gradual in nature, and promptly cleaning the sensor, accuracy can be restored.

The oxygen sensor consumes the oxygen in the water very near the surface of the sensor membrane. If there is not an adequate flow of new water past the membrane, the sensor will give a reading that is lower than the true oxygen concentration. Additionally, if the flow rate is not constant, the sensor response time will vary, causing dynamic error. Maximum accuracy requires that water be pumped at rates from 1.2 to 2.4 l/min. Temperature differences between the water and oxygen sensor can lead to errors in the oxygen measurement. The SBE 43 minimizes this difference by using materials that equilibrate rapidly with the environment and incorporating a thermistor placed under the membrane, at the cathode, for accurate temperature compensation.

Table 3.2.1. Meteorological and Underway Seawater System Sensor Specifications

Sensor	Manufacturer	Model	Serial	Calibration Date	Location
Air Temperature	RM Young	41342LC	3942	24-Oct-2007	MET Mast 56' above MWL
Barometric Pressure	Vaisala	PTB101C	Y1640005	25-Oct-2006	MET Mast 56' above MWL
Relative Humidity	RM Young	41382V	10956	30-Oct-2007	MET Mast 56' above MWL
Precipitation	RM Young	50202	0590	17-Nov-2006	MET Mast 56' above MWL
Wind #1	Vaisala	WS425-A2C2B	Y2040003	10-Dec-2004	MET Mast 56' above MWL
Long Wave Radiation	Eppley Labs	PIR	31217F3	02-Dec-2005	MET Mast 68' above MWL
Short Wave Radiation	Eppley Labs	PSP	27711F3	03-Jan-2006	MET Mast 68' above MWL
Surface PAR	Biospherical Instruments	QSR-2200	20307	10-Jan-2008	MET Mast 68' above MWL
Wind #2	RM Young	5300	Unknown	Unknown	Main Mast 82' above MWL
Thermo-salinograph #1	Seabird	SBE45	0082	Jun-2008	Bow thruster UCW intake
FlowMeter	Flocat	C-ES45-B003	02021287	13-May-2003	Bow thruster Rm SB45 TSG Loop
Thermo-salinograph #2	Seabird	SBE45	0055	Jun-2008	Aft Hydro Lab
FlowMeter	Flocat	C-ES45-B003	11020895	11-Nov-2001	FLO-Thru system Hydro Lab
Oxygen	Seabird	SBE43	0091	04-Dec-2007	FLO-Thru system Hydro Lab
Fluorometer	Wetlabs	Wetstar	WS3S-1142	07-Nov-2005	FLO-Thru system Hydro Lab

Table 3.2.2. Surface Seawater Sensors

Sensor	Manufacturer	Model	Range	Accuracy
Thermo-salinograph (2)	Seabird	SBE-45	Temp -5 to +35 C Cond 0 to 70 mS/cm	± 0.002 Deg C ± 0.003 Deg C
Fluorometer	Wetlabs	WetStar	0.03 to 75 ug/l	Not Specified
Water Temperature	Omega	ON-403-PP	Temp -5 to +35 C	± 0.02 Deg C
Oxygen	Seabird	SBE-43	120% surf saturation	2 %
Hull mounted Sea Surface Temperature	STS	SEG-14	Temp -2 to +35 C	± 0.1 Deg C
Flow meter (2)	FLO-CAT	C-ES45-B003	0.38-37.9 LPM	± 1% FS

Table 3.2.3. Meteorological Sensors

Sensor	Manufacturer	Model	Range	Accuracy
Air Temperature	RM Young	41342LC	-50.0 to +50.0 C	+/- 0.3 Deg C
Barometric Pressure	Vaisala	PTB101C	900-1100 mb	+/- 0.3 mb
Relative Humidity	RM Young	41382V	RH 0-100% Tmp –50 to +50 C	+/-2.0% +/- 0.3 Deg C
Precipitation	RM Young	50202	0-50 mm	+/- 1.0 mm
Wind #1	Vaisala	WS425-A2C2B	Dir 0-360 Deg Spd 0-65 m/s	+/- 2.0 Deg +/- 0.14 m/s
Long Wave Radiation	Eppley Labs	PIR	3.5-50 um 4 uv/(W/m^2) Response Time 2 s	+/- 1% Linearity
Short Wave Radiation	Eppley Labs	PSP	285-2800nm 9 uv/W/M2 Response Time 1 s	+/- 0.5% Linearity
Surface PAR	Biospherical Instruments	QSR-2200	400-700nm 1.4e-5uE/(cm^2 s) to 0.5uE/(cm^2 s)	Not Specified
Wind #2	RM Young	5300		

3.3. Data Processing and Results

Note: The figures for this section often cover only part of the cruise; figures of the same type, covering other time periods of the cruise, can be found in the cruise-data directory described in Appendix E. Data are available for all sensors for all of the cruise, as described in Section 3.4.

Wind speed and direction
Atmospheric pressure, and wind speed and direction from the sensors on the MET mast are shown in Fig. 3.3.1, for 12 to 21 January 2009. For comparison true wind speeds at the MET mast and at the main mast are shown in Fig. 3.3.2, and wind directions in Fig. 3.3.3, with data captured every 30 seconds, for 12 January to 20 February 2009. The anemometer placed in the MET mast appears to be less noisy when it comes to wind direction. The wind speed comparison didn't show significant sustained differences between them. Note that the response time of the sonic anemometer on the MET mast is given in the specifications as 0.35 s. It would be better if 30-s averages were recorded, but the record appears to be of instantaneous values, and the ship motion appears to be aliased into the record. The mean wind speed at the MET mast for the whole data record was 10.8 m/s, the standard deviation was 3.9 m/s, and the maximum true wind speed recorded was 30.3 m/s. The length of the data record, excluding dropouts, was 39.0 days. There were certainly times when the relative wind was from the stern and the MET mast was in the shadow of the ship. At those times the Young anemometer on the main mast was more reliable, but still perhaps not accurate due to shadowing and distortion from the ship.

Air Temperature, Relative Humidity, Dew Point and Precipitation
There are two RM Young platinum resistance thermometers on the MET mast, one is part of the relative humidity sensor. Records from the two are compared in Fig. 3.3.4, for 12 January to 20 February 2009. Air temperature and RH are shown in Fig. 3.3.5 for 12 to 25 January 2009. Records of dew point and precipitation are shown in Fig. 3.3.6 for 12 to 20 January 2009.

Radiation Measurements
Long and short wave radiation measurements are shown in Fig. 3.3.7, for 12 to 25 January 2009. A record of Photosynthetically Available Radiation (PAR) is shown in Fig. 3.3.15 for the same period.

TSG flow rates
Once out of Chilean waters, on January 12 at 0820 Z, the pump that feeds the TSG systems was turned on and the data acquisition system was initiated. During the first week of underway measurements the flow on TSG #2 was very erratic according to the flow meter recordings, though actual flow seemed steady (e.g. sometimes the flow was reported as 0 l/m, despite water flowing). Figure 3.3.8 shows the flow rates of both TSG systems and their difference. The flow recorded by TSG #1's (blue line) was steady, while that recorded by TSG #2 (red line) was very noisy. The large offsets in the flow

rate are due to attempts to fine-tune the flow. Due to the problems encountered with the flow rate, the filters in the TSG system were cleaned every two days during the cruise.

TSG Temperature and Salinity

Despite the noise seen in the flow rate through TSG #2, temperature and salinity data didn't seem to be affected to a large extent (Figures 3.3.9 and 3.3.10). However, while processing the data from the TSG's, all recordings with flow rates exceeding 2 l/m and below 0.5 l/m were discarded. Moreover, TSG #1 was taken as more reliable and all TSG #2 recordings with temperature differences exceeding 0.5^{o}C and salinity differences exceeding 0.05 were discarded due to the unsteady flow reported by the flow meter in TSG #2. During CTD stations, the pumping system of the ship was shut off in order to prevent erroneous measurements from the CTD sensors. This resulted in standing water in the TSG systems, reflected as spikes in the temperature (see Figure 3.3.9). These spikes were removed from the time series by allowing temperature to vary by no more than 0.1^{o}C every minute, and salinity by no more than 0.05. Surface water salinity and temperature from TSG #1 were compared with data from the SIO SBE 9*plus* in the CTD/Rosette system, at a nominal depth of 4 m in Fig. 3.3.11. Records of SST, SSS and σ_t, from TSG #1 for 12 to 25 January 2009 are shown in Fig. 3.3.12. Color-coded plots of SST and SSS along nearly the full ship's track are shown in Fig. 3.3.13 and 3.3.14, respectively.

Surface Oxygen and Chlorophyll

Since the oxygen and chlorophyll retrievals come from the TSG #2 system and these measurements could be sensitive to the flow rate, bad data were also removed from these time series as well as from derived parameters (e.g., density and sound velocity), following the above criteria. However, oxygen measurements can be seriously affected when the flow rate is not steady and therefore care should be taken when analyzing oxygen data from this cruise. Oxygen and Chlorophyll time records are shown in Fig. 3.3.15, for 12 to 25 January 2009.

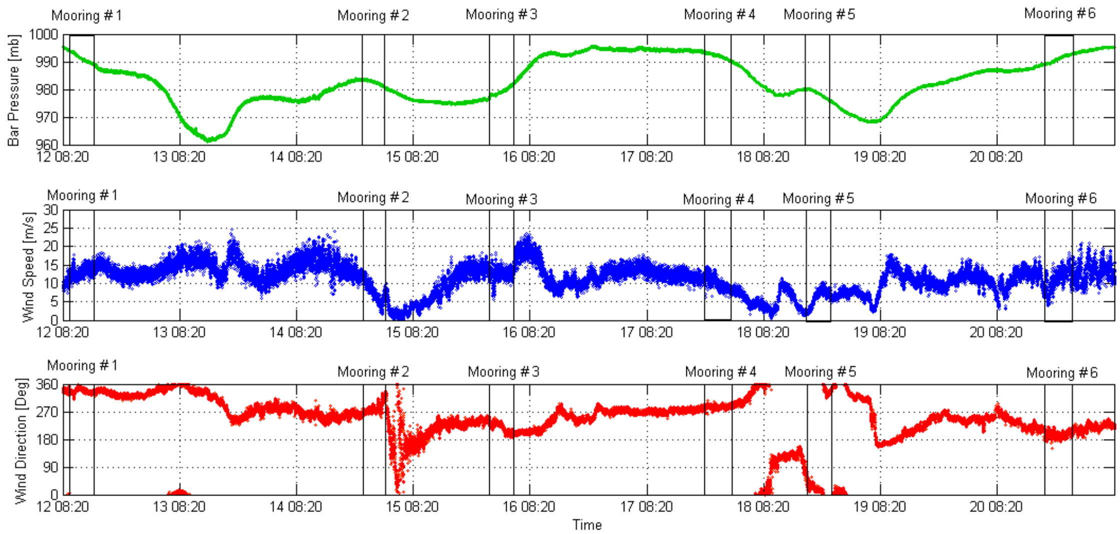


Fig. 3.3.1. Barometric Pressure, Wind Speed, and Direction recorded at the MET mast, 12 to 21 January 2009.

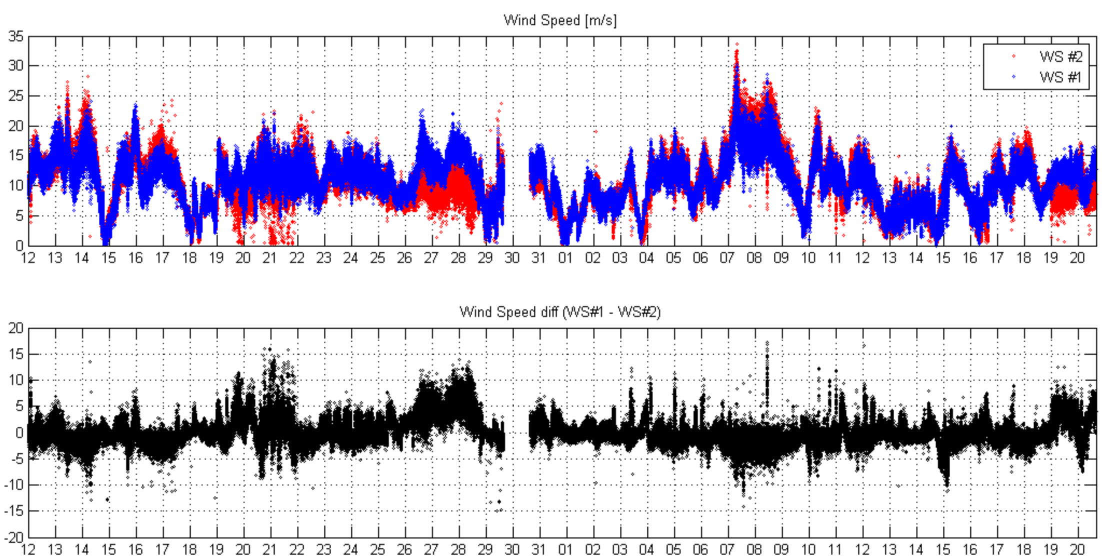


Fig. 3.3.2. True Wind Speed measured at the MET mast (blue circles) and at the Main mast (red circles), and their difference (black circles), 12 January to 20 February, 2009.

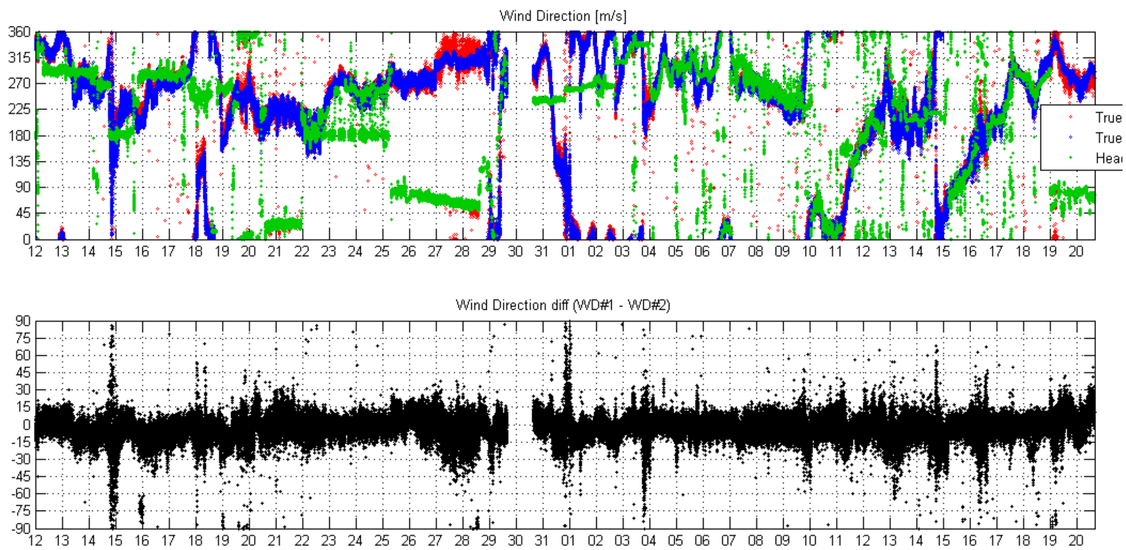


Fig. 3.3.3. True Wind Direction measured at the MET mast (blue circles) and at the Main mast (red circles), and their difference (black circles), 12 January to 20 February, 2009. Ship's Heading is shown with green dots.

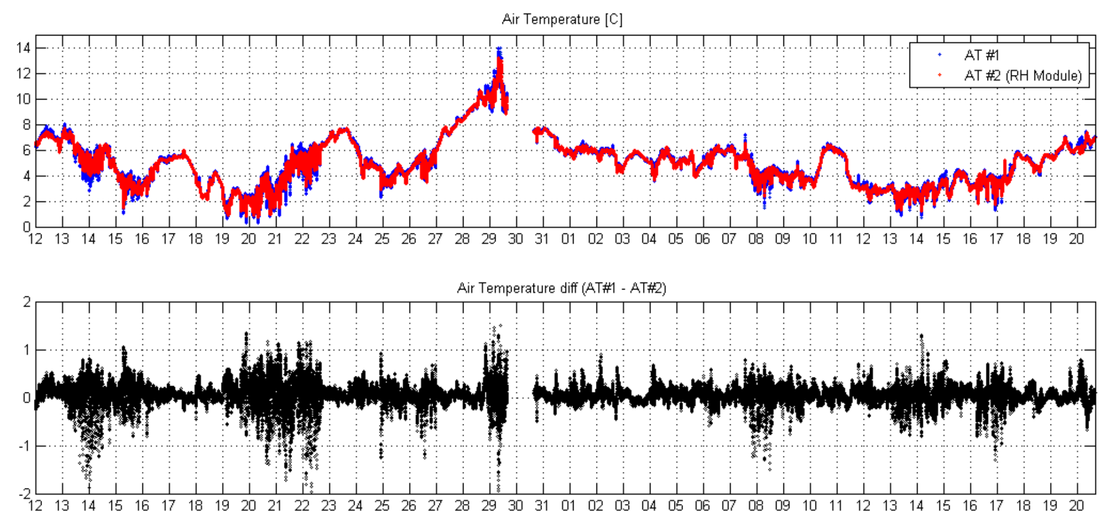


Fig. 3.3.4. Air Temperature (blue circles) measured at the MET mast and Air Temperature recorded with the RH Module (red circles) located in the MET mast, and their difference (black circles), 12 January to 20 February 2009.

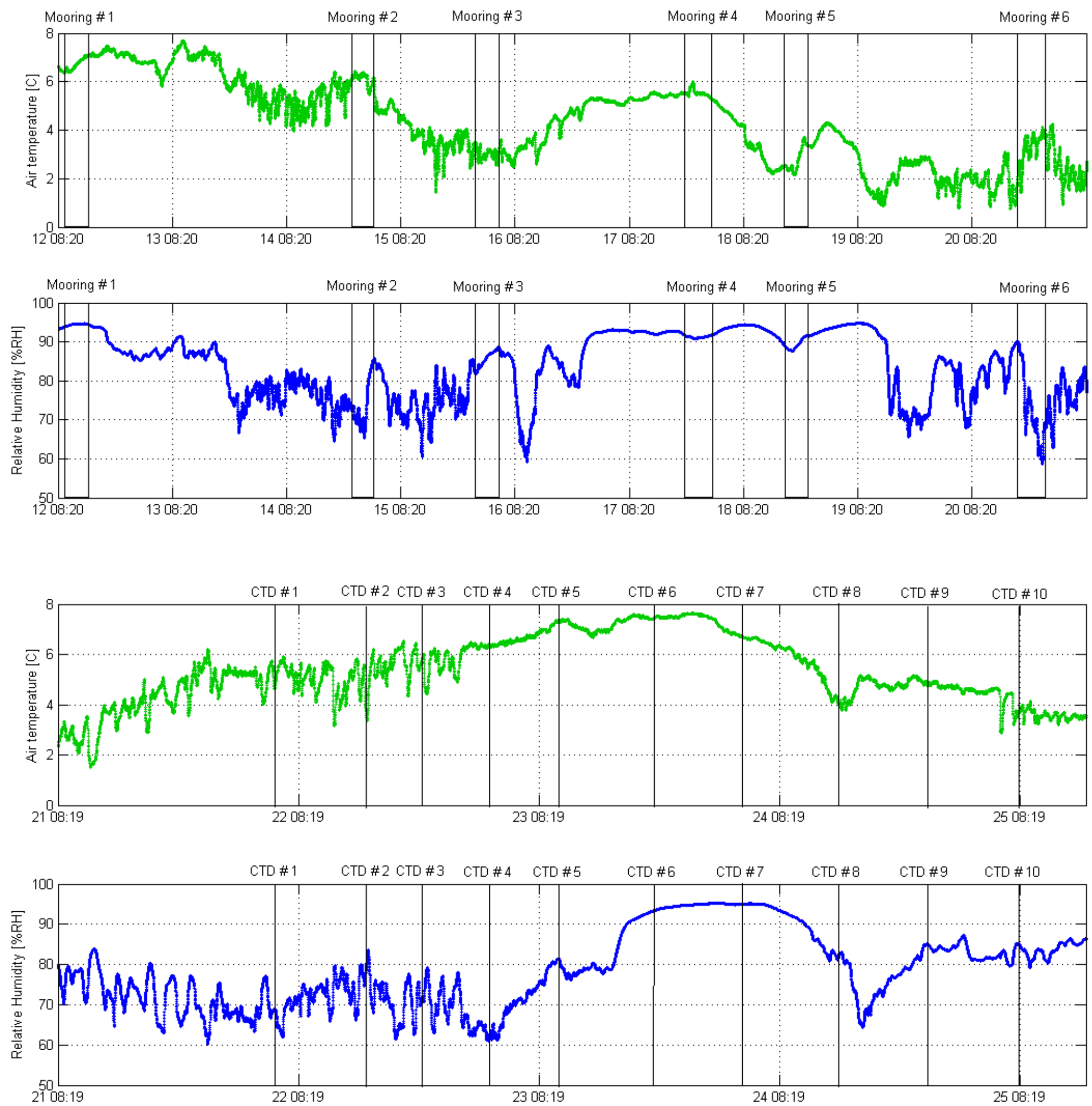


Fig. 3.3.5. Air Temperature and Relative Humidity measured at the MET mast, 12 to 25 January, 2009.

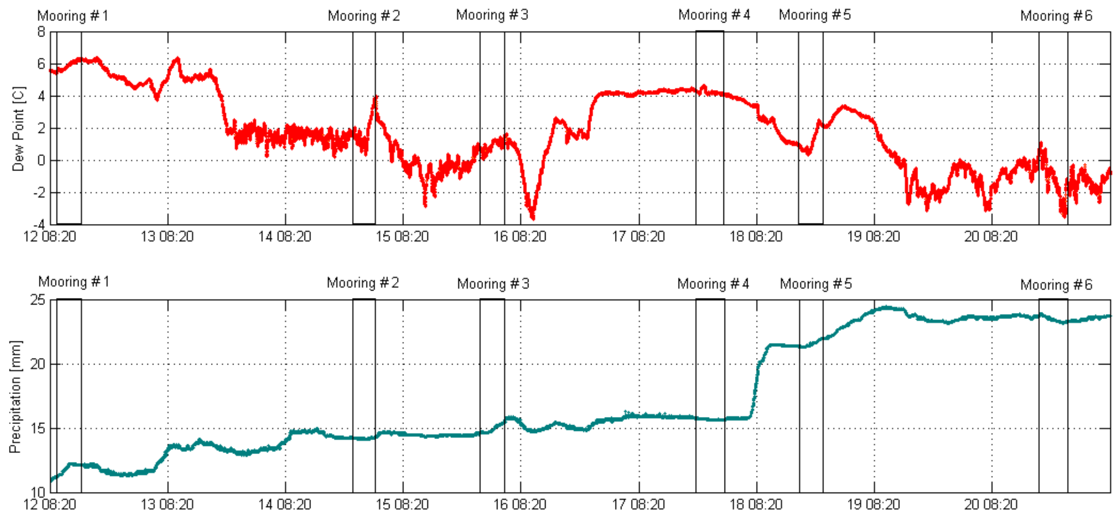


Fig. 3.3.6. Dew Point and Precipitation measured at the MET mast, 12 to 20 January 2009.

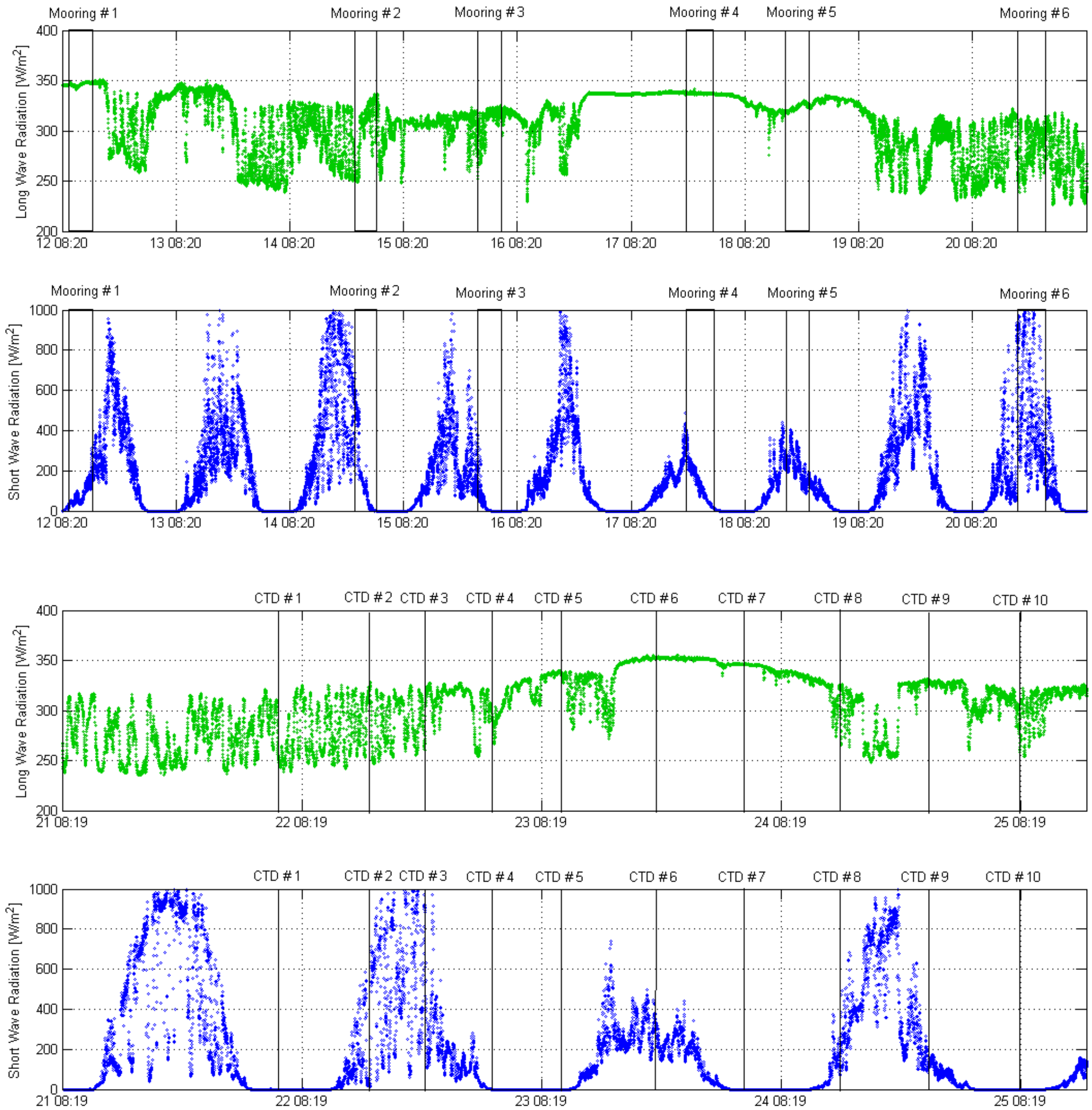


Fig. 3.3.7. Long Wave and Short Wave Radiation, 12 to 25 January 2009.

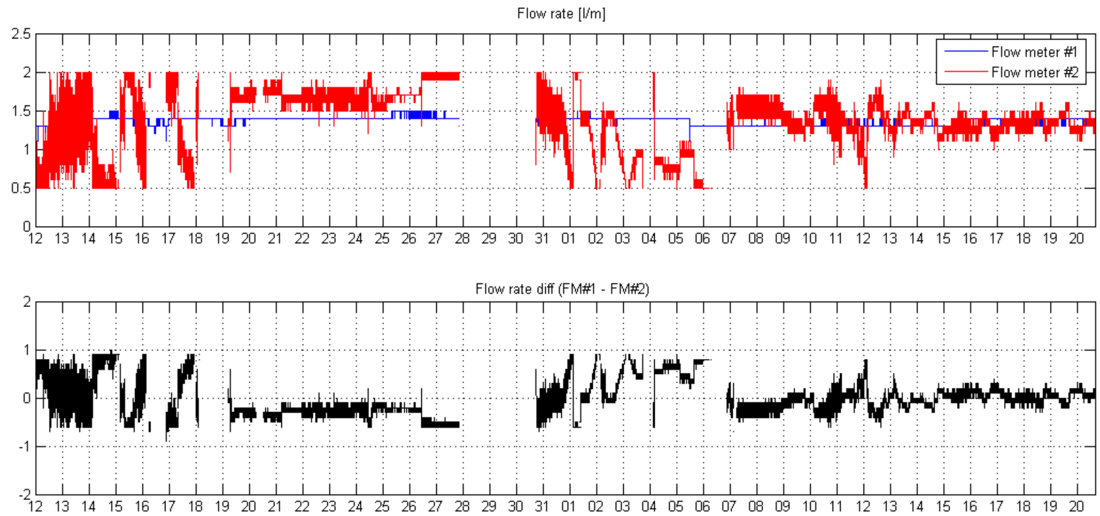


Fig. 3.3.8. Flow rates measured in TSG #1 (blue line) and TSG #2 (red line), and their difference (black line), 12 January to 20 February 2009.

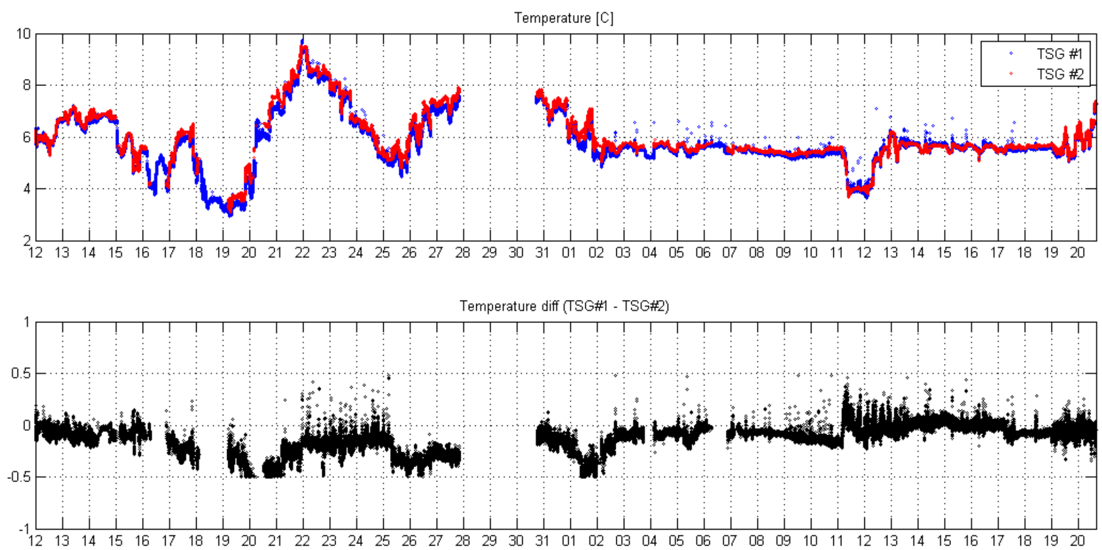


Fig. 3.3.9. Surface Temperature measured in TSG #1 (blue circles) and TSG #2 (red circles), and their difference (black circles), 12 January to 20 February 2009.

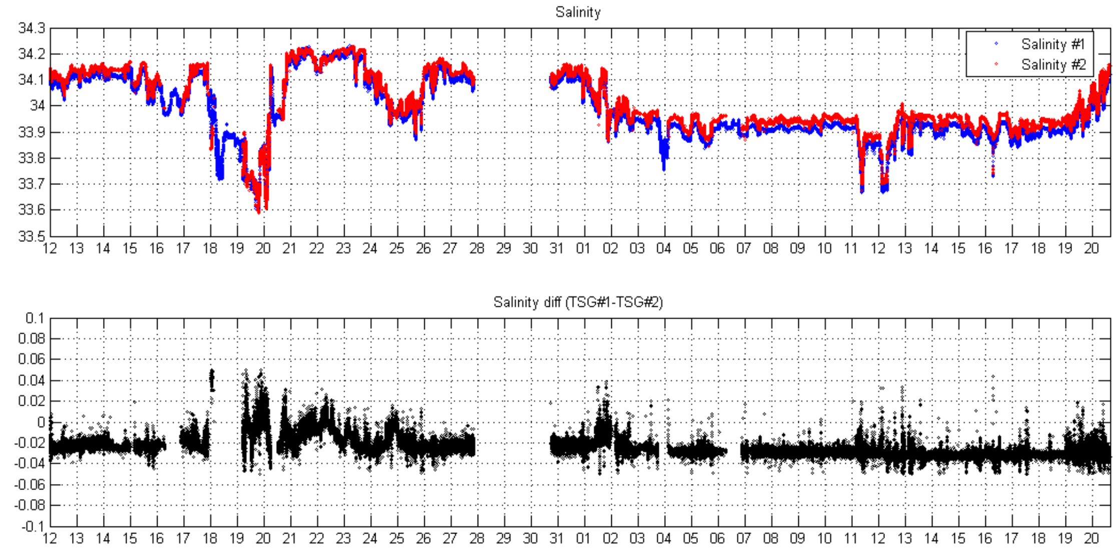


Fig. 3.3.10. Surface Salinity measured in TSG #1 (blue circles) and TSG #2 (red circles), and their difference (black circles), 12 January to 20 February 2009.

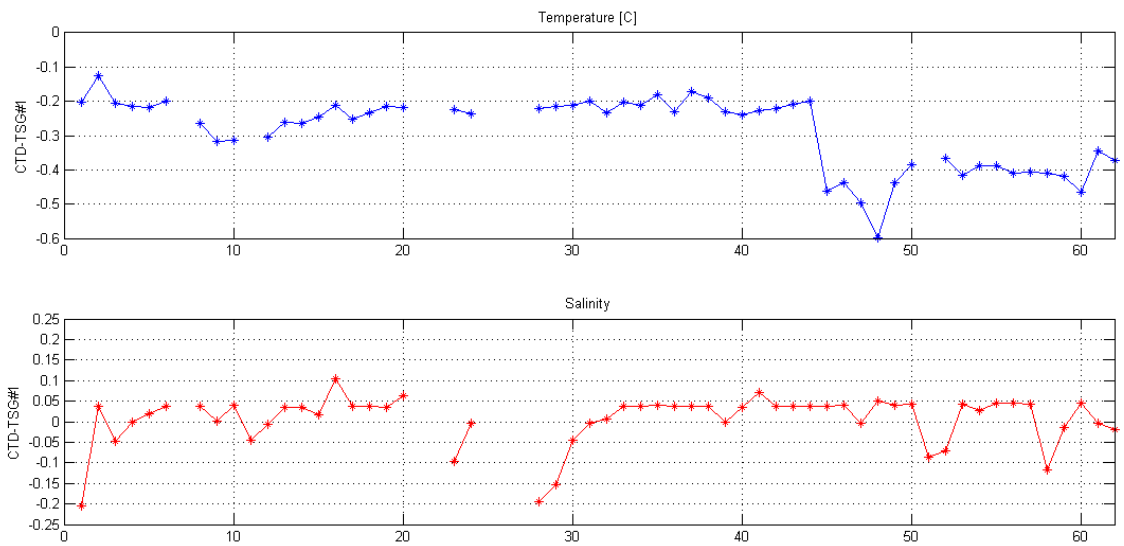


Fig. 3.3.11. Temperature and Salinity from the CTD at 4 m minus SST and SSS from TSG #1.

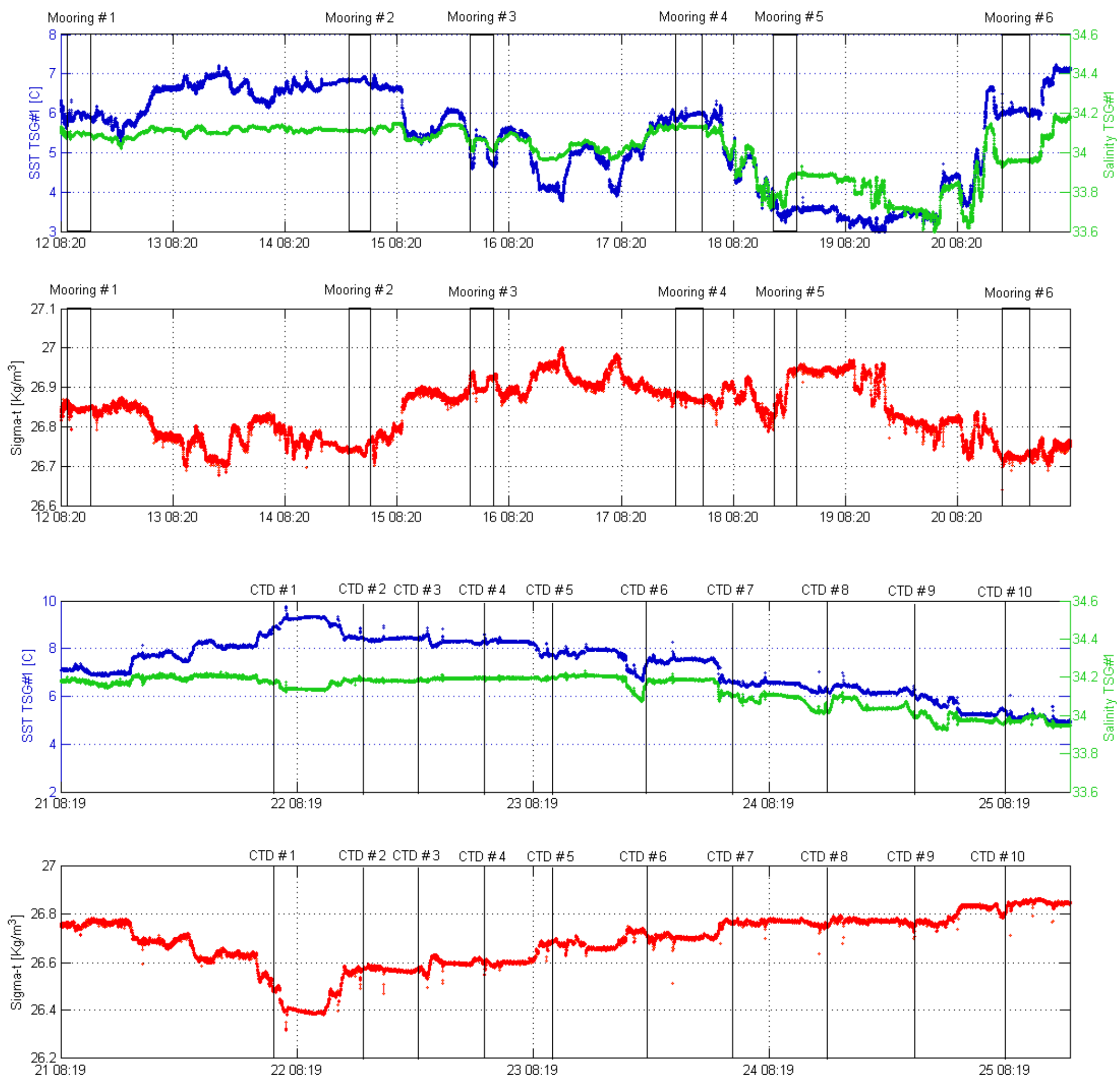


Fig. 3.3.12. Surface Temperature (blue circles) and Surface Salinity (green circles) are shown in the upper panel. Surface Density derived from TSG #1 is also shown in the lower panel (red circles), 12 to 25 January 2009.

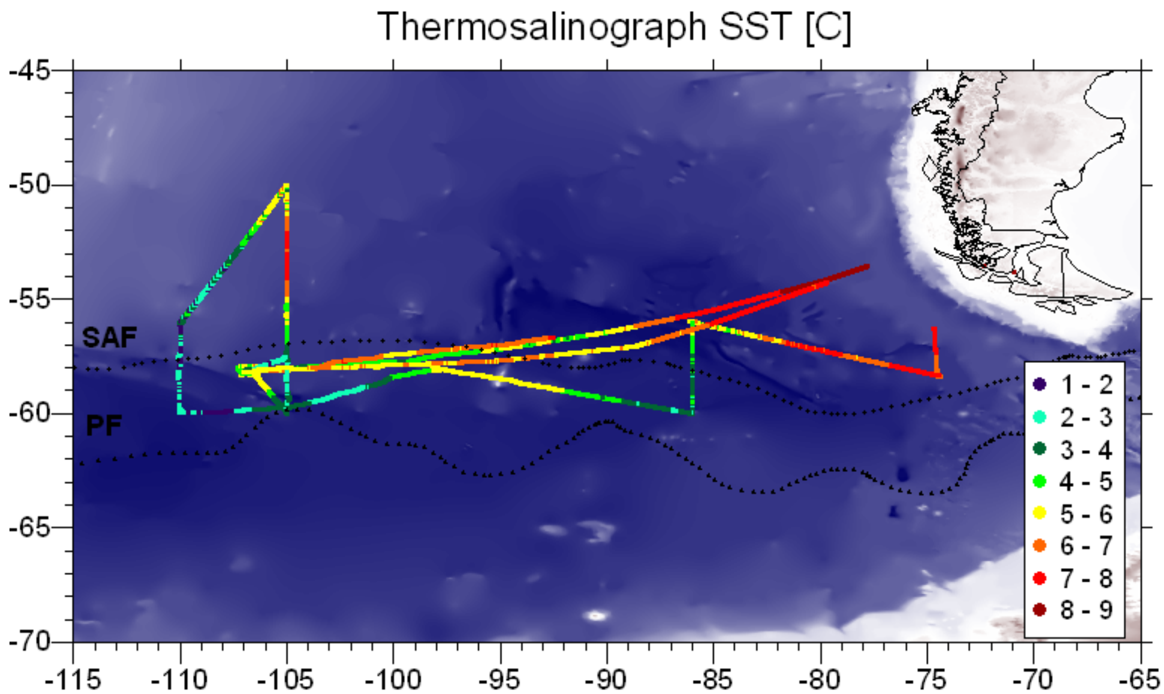


Fig. 3.3.13. Surface Temperature recorded at TSG #1 along the ship's track. The positions of the SubAntartic Front and Polar Front according to Orsi et al. *[1995] are indicated in black.*

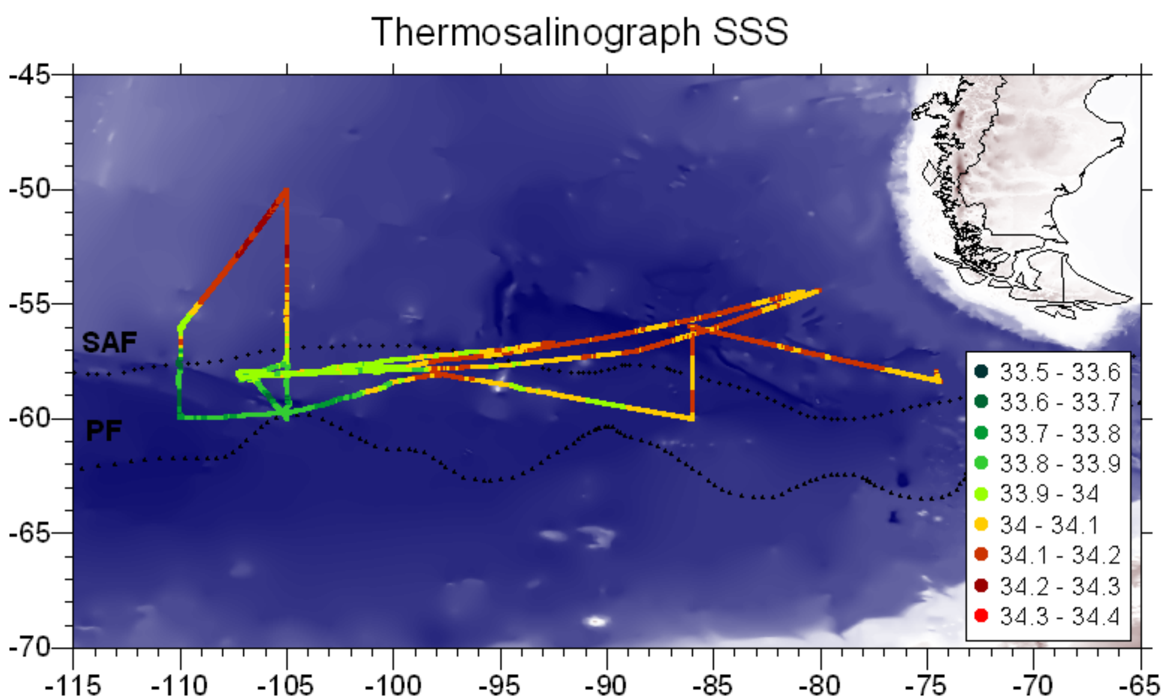


Fig. 3.3.14. Surface Salinity derived from TSG #1 along the ship's track. The positions of the SubAntartic Front and Polar Front according to Orsi et al. *[1995] are indicated in black.*

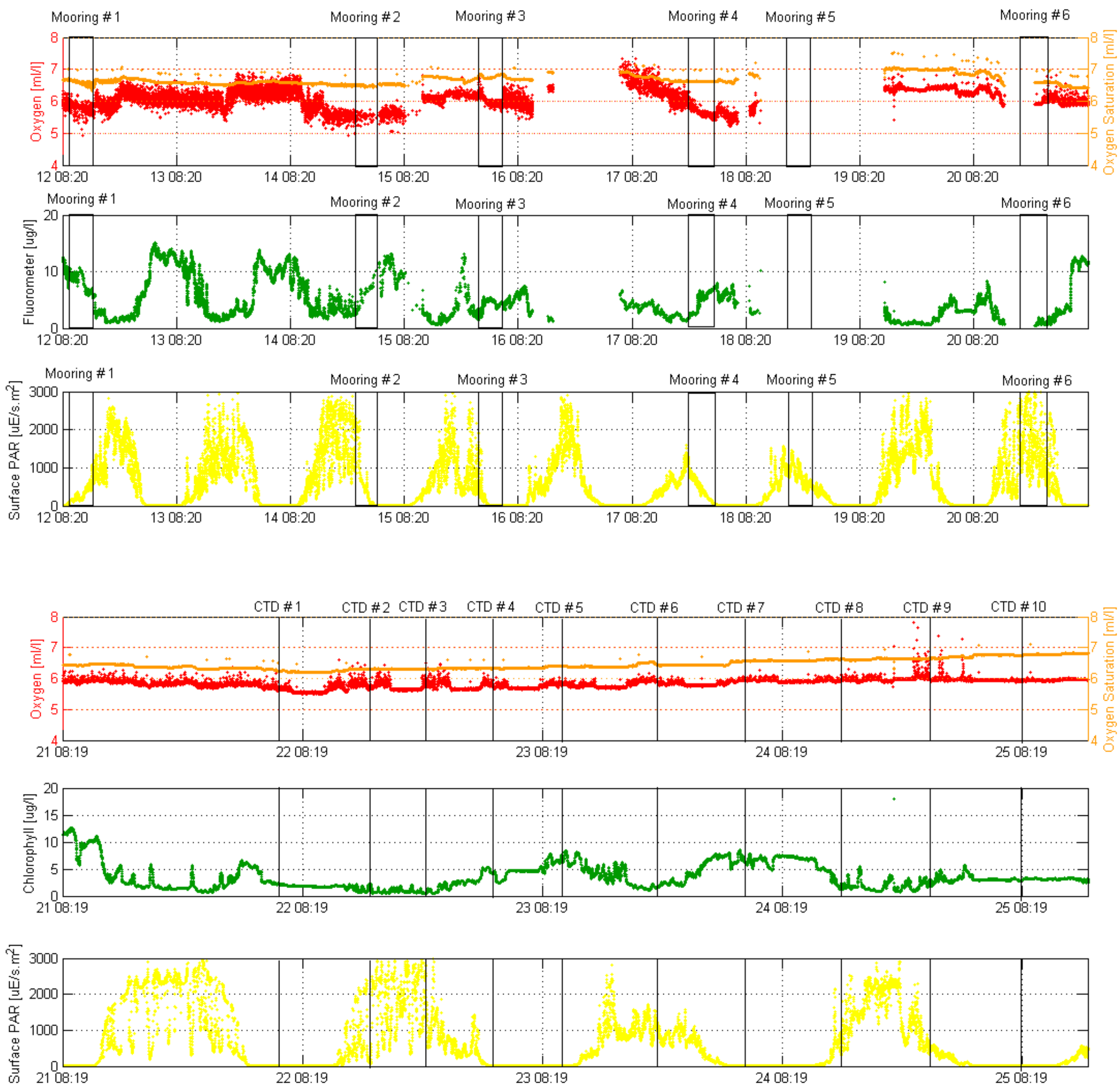


Fig. 3.3.15. Oxygen (red circles) and Oxygen Saturation (green circles) are shown in the upper panel. Chlorophyll concentration (green circles) derived from the fluorometer in the TSG #2 System and Surface PAR (yellow circles) are shown in the middle and lower panel respectively, 12 to 25 January 2009.

3.4. Guide to Underway Data and Processing Software

The meteorological data are saved every 30 seconds in a MATLAB file called met-data.mat, which contains a single structure called md. This file can be found in the cruise-data directory described in Appendix E. The MATLAB m-file called metdata_processing.m cleans the data by various criteria, documented within the program, and saves those data in metdata_clean.mat, which contains a new, cleaned up structure, also called md, with contents:

md =

data: [112293x66 double]
textdata: {4x65 cell}
colheaders: {1x65 cell}

The variables are:

```
% VARIABLES *.MET -----------------------------------------------------
----
  % col  1: '#Time'
  % col  2: 'AT'     AIR TEMPERATURE [deg C]
  % col  3: 'BP'     BAROMETRIC PRESSURE [mb]
  % col  4: 'BC'     BAROMETRIC PRESSURE TEMPERATURE [deg C]
  % col  5: 'RH'     RELATIVE HUMIDIY [%RH]
  % col  6: 'RT'     AIR TEMPERATURE (RH MODULE) [deg C]
  % col  7: 'DP'     DEW POINT [deg C]
  % col  8: 'LD'     LWR DOME TEMPERATURE [deg K]
  % col  9: 'LB'     LWR BODY TEMPERATURE [deg K]
  % col 10: 'LT'     LWR Thermopile [Volts]
  % col 11: 'LW'     Long Wave Radiation (LWR) [W/M^2]
  % col 12: 'SW'     Short Wave Radiation (SWR)[W/M^2]
  % col 13: 'PA'     Surface PAR [uE/Second/Meter^2]
  % col 14: 'PR'     Precipitation [mm]
  % col 15: 'WS'     Rel Wind Speed [M/S]
  % col 16: 'WD'     WD Rel Wind Direction [Deg] (Direction wind is
coming from)
  % col 17: 'TW'     True Wind Speed [M/S]
  % col 18: 'TI'     True Wind Direction [Deg] (Direction wind is
coming from)
  % col 19: 'WS-2'
  % col 20: 'WD-2'
  % col 21: 'TW-2'
  % col 22: 'TI-2'
  % col 23: 'TT'    THERMOSALINOGRAPH TEMPERATURE [deg C]
  % col 24: 'TC'    Thermosalinograph Conductivity [mS/cm]
  % col 25: 'SA'    SALINITY
  % col 26: 'SD'    Sigma-t [Kg/m^3]
  % col 27: 'SV'    Sound Velocity
  % col 28: 'FI'    USW Flow Meter [LPM]
  % col 29: 'TT-2'
  % col 30: 'TC-2'
  % col 31: 'SA-2'
  % col 32: 'SD-2'
  % col 33: 'SV-2'
  % col 34: 'OC'    Oxygen Current [ua]
  % col 35: 'OT'    Oxygen Temperature [Deg C]
  % col 36: 'OX'    Oxygen [ml/l]
  % col 37: 'OS'    Oxygen Saturation value ml/l
  % col 38: 'WT'    Auxiliary water Temp Deg C
  % col 39: 'FL'    Fluorometer [ug/l]
  % col 40: 'FI-2'
  % col 41: 'VP'    VRU Pitch [Deg]
  % col 42: 'VR'    VRU Roll [Deg]
  % col 43: 'VH'    VRU Heave [Meters]
  % col 44: 'VY'
```

```
% col 45: 'VX'
% col 46: 'BT'    Bottom Depth [Meters]
% col 47: 'BT-2'
% col 48: 'SH'    Ashtech Heading Deg
% col 49: 'SM'    Ashtech Pitch Deg
% col 50: 'SR'    Ashtech Roll Deg
% col 51: 'LA'    Latitude  [Decimal format Deg]
% col 52: 'LO'    Longitude [Decimal format Deg]
% col 53: 'GT'    GPS Time of Day [GMT Secs 0-86400]
% col 54: 'CR'    Ships Course (GPS COG) [Deg]
% col 55: 'SP'    Ship's Speed (GPS SOG) [Knts]
% col 56: 'ZD'
% col 57: 'GA'
% col 58: 'GS'
% col 59: 'GY'    Ships Heading (Gyrocompass) [Deg]
% col 60: 'ZO'    Winch Wire Out [Meters]
% col 61: 'ZS'    Winch Speed [MPM]
% col 62: 'ZT'    Winch Tension LBS
% col 63: 'ZO-2'
% col 64: 'ZS-2'
% col 65: 'ZT-2'
% col 66: Dia Juliano
```

md.data(:,66) has the time, in days AD.

Positions must be obtained elsewhere.

4. Hull-Mounted Acoustic Doppler Current Profilers (ADCPs)

4.1. RDI 150 kHz Narrowband ADCP

R/V *Revelle* is equipped with an R. D. Instruments 150 kHz narrowband ADCP (NB150) that acquired data nearly continually during the cruise, except inside the Exclusive Economic Zone of Chile. The result is two continuous records, one from 12 through 27 January and the other from 31 January through 22 February, corresponding to the first and second legs of the cruise. However, due to a bug in the processing routine, the data for the second leg of the cruise are split into several files, as will be discussed below.

This instrument performed well throughout the majority of the cruise, typically recording velocities to 250 m depth. However, data quality was significantly degraded in rough conditions, especially when traveling up-swell, as on 13-14 January. Aside from poor data quality while traveling up-swell, the performance of the NB150 does not appear to be affected by ship speed or heading.

Data acquisition is handled automatically through UHDAS with CODAS processing. The system receives data about the ships heading, position, and attitude from the GP90 GPS, Sperry Gyro, Ashtech, and PHINS to calculate absolute water velocities. Automatically processed data are available aboard the ship in real time from the ship's network, and raw data are available with a short time delay. The automatically processed data are in 10-meter x 15-minute averaging bins. The stated vertical resolution of the instrument is 8 m, and improved vertical and temporal resolution are likely attainable by reprocessing the raw data.

Processed data are provided in the ADCP folder in the cruise-data directory described in Appendix E. Due to data collection and processing issues, the raw data files are divided into sections RR0901a, RR0901b, and RR0901c. After the cruise, Jules Hummon reprocessed the data into one file for the entire cruise. File contour_uv.mat contains east (odd columns) and north (even columns) components of velocity. File contour_xy.mat contains the corresponding longitude, latitude, and time vectors. Unprocessed data are available by contacting the Chief Scientist.

The performance of the NB150 is easily monitored from the computer lab since the status of the instrument and recent measurements are displayed on a computer there (Fig. 4.1.1).

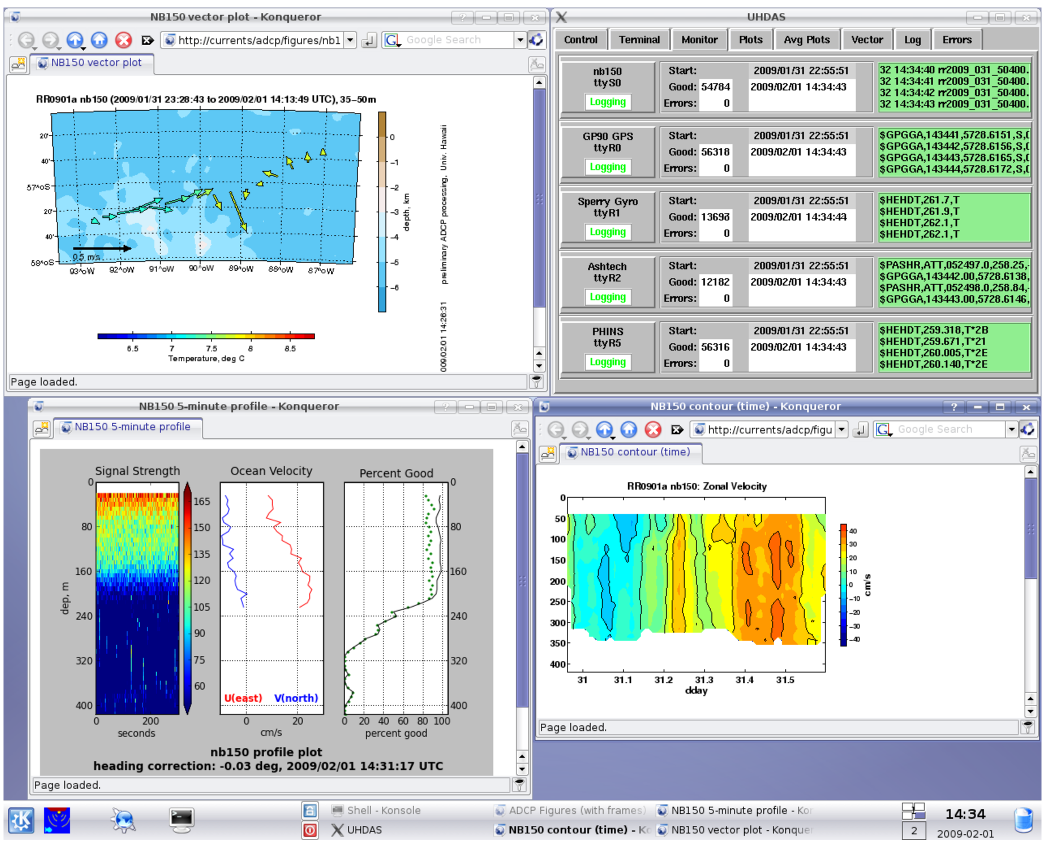


Fig. 4.1.1. A screenshot from the computer used to monitor the NB150 showing (clockwise from upper left) a vector plot of near-surface currents along the cruise track, a summary of data streams from the NB150 and various navigational instruments, a contour plot of zonal velocity over the past 24 hours, and a summary of the profiles taken over the last five minutes.

Figure 4.1.2 shows an example of the velocities measured by the NB150, recorded during the first portion of the CTD line at 105°W. Using maps of dynamic topography and hydrography, it was possible to calculate the geostrophic zonal velocity along the CTD line for comparison with the NB150 velocities. This comparison is discussed in Section 9.

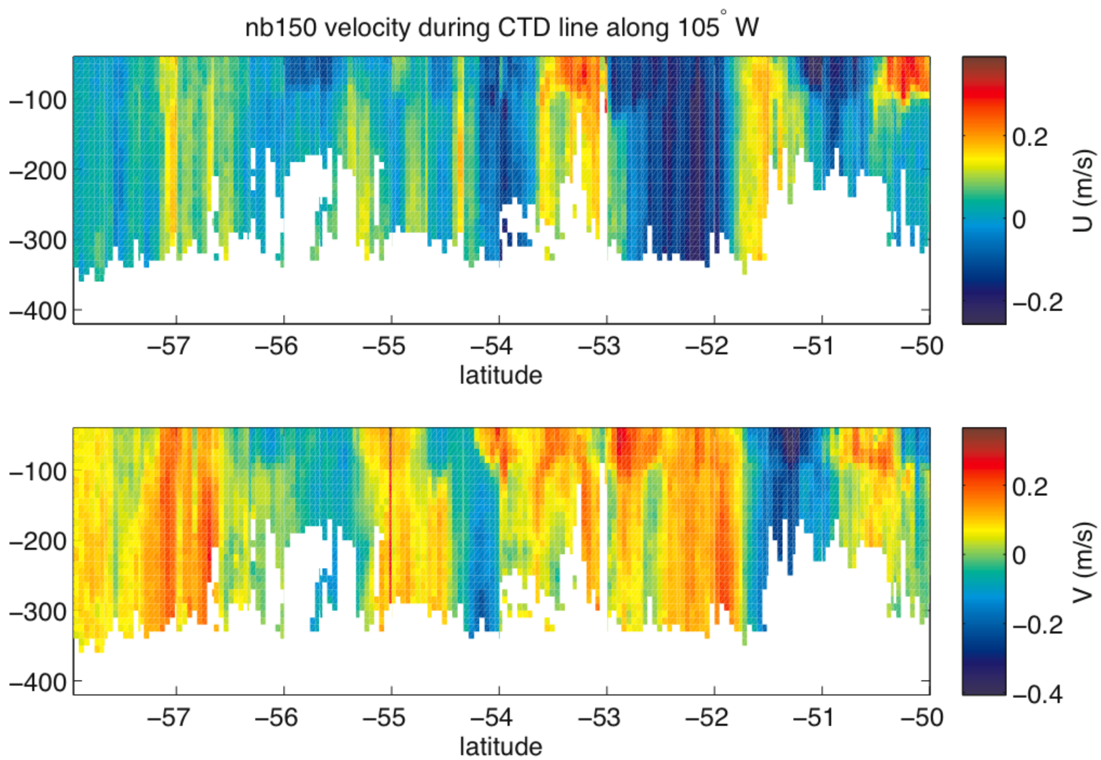


Fig. 4.1.2. Zonal (u) and meridional (v) velocity measured by the NB150 during the first portion of the CTD line at 105°W.

4.2. Hydrographic Doppler Sonar System (HDSS)

We were unable to obtain useful data from this system, partly due to lack familiarity with the system and partly due to malfunctions of the system, it appears. The designers of the HDSS, led by Rob Pinkel at SIO, evaluated the system on the leg after ours and they report that the 50 kHz sonar was operating properly, while the 140 kHz system was affected by a failed pressure sensor in the sonar well. Also, they found that the processing software was weighting noisy echos more than clean returns, affecting the real-time displays. Pinkel's group intends to reprocess the data in the near future.

5. Teledyne R. D. Instruments Doppler Volume Sampler (DVS)

5.1. Introduction

The Doppler Volume Sampler (DVS) provided by TRDI for use during the DIMES US1 cruise is an acoustic Doppler current profiler, optimized for very short ranges. The DVS operates at 2400 kHz, and can be configured to measure velocity in up to 5 bins, with a maximum range of 5 m from the transducer face. The DVS was deployed on the tracer injection sled during both injection tows, with the goals of comparing the DVS velocity with that from other sensors such as the ship's ADCP, and of measuring the currents at the depth of the injection.

5.2. DVS Setup and Compass Calibration

We followed the TRDI documentation to set up the instrument. The steps were as follows:

1. Connect the battery. This required opening the chassis.

2. Connect the cable to the computer and test the com port using the TRDI software.

3. Compass calibration. We performed the compass calibration on the beach near the dock, in order to remove the influences of the ship's magnetic field and ship motion. The calibration procedure described in the documentation was very difficult to perform due to the weight of the instrument. Furthermore, the instrument did not acquire enough data points for calibration (20 data points are required) while moving through the calibration procedure as described. In the end we devised a new procedure, which resulted in a successful calibration. The steps were:

   a. First, follow step 1 of the manual: hold the instrument at a 20° angle (pointed up) and rotate it slowly about a vertical axis going through its center, maintaining a roughly constant orientation of the instrument relative to the surroundings (e.g. keep transducer 1 pointing North). It helped to have one person kneel and balance the instrument on his knee while performing the rotation.
   b. Hold the instrument at a 20-30° angle (pointed up) and rotate the instrument slowly about a vertical axis going through its center, keeping the same side of the instrument pointing up. This step was easiest with two people.
   c. After completing one rotation of the instrument, rotate it 90° about its own long axis and repeat with the new side pointing up.
   d. Repeat steps (b) and (c) until one revolution has been made with each side of the instrument pointing up, and 20 samples have been collected.

5.3. Mounting on Injection Sled

The DVS was designed for mounting on a mooring wire, but Brian Guest designed a custom bracket for attachment to the injection sled. We had to drill holes in the aluminum sled chassis in order to attach the bracket. We mounted the instrument on the rear of the sled on the port side, as illustrated in Fig. 5.3.1. We were unable to orient the instrument with its "forward" heading in line with the sled without blocking access to the data port or having the glass flotation balls block one of the transducer beams. However, the velocities are "absolute" thanks to the internal compass. The heading offset does affect the pitch and roll measurements.

Fig. 5.3.1. The DVS mounted on the rear of the injection sled, port side.

5.4. Configuration

On the first injection tow, Cast 12, we configured the DVS to take as many samples as possible for the duration of the injection. The DVS software included a configuration wizard to choose configuration parameters. Based on the expected duration of the injection cast, the software recommended saving a sample every two seconds. The maximum spatial range for the instrument is only 5 m. Initially we configured it with 5 bins each 1 m. However, the return strength was low from the outer 4 bins when the instrument was at depth. It appears that there are not enough scatterers beyond the first meter at depth to provide a good signal.

For the second injection we decided to concentrate on just the closest 1 m, so we configured the instrument with 5 bins of 20 cm each. The results in this case were better, especially near the surface. However, at depth, there was still poor performance in the outermost bins. Consequently, we have reliable velocity data only very close to the sled. It is likely that the velocities obtained in the 50 cm near the sled depict the sled's turbulent wake rather than any flow of oceanographic interest.

We did not delete the data between injections 1 and 2. We mistakenly thought that the instrument was configured to overwrite old data once it reached the end of its memory.

However, instead it simply stopped recording once the memory was filled. Fortunately, we were still able to capture several hours of data using the new configuration parameters on the second injection.

5.5. Pitch and Roll

Perhaps the most useful results from the DVS are measurements of the pitch and roll experienced by the sled during the injection tows. The heading, pitch, and roll in the DVS reference frame during the two injection tows are shown in Figs 5.5.1 and 5.5.2. The DVS was oriented such that measured pitch corresponds to forward-starboard/aft-port motion of the sled, while roll corresponds to forward-port/aft-starboard motion of the sled. During both injection tows, the DVS recorded pitch of around 26° and roll around 19°.

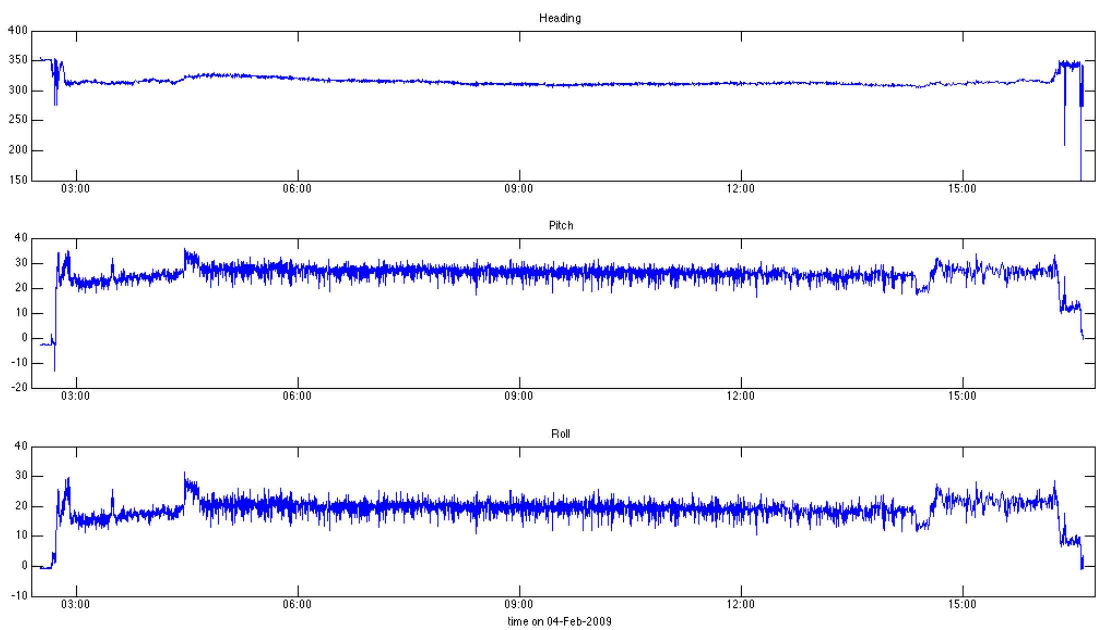


Fig. 5.5.1. Heading, pitch, and roll measured by the DVS during the first injection tow (Cast 12).

The course over ground of the ship during the first injection tow was 300°. The heading of the instrument relative to magnetic north was 315° to 320°. The compass declination at our location was 34°, so the true heading was 349 to 354°, so the instrument was rotated 49° to 54° clockwise from the centerline of the sled. The pitch and roll readings from the DVS imply that the mean pitch of the sled was approximately 32.2° upward, while there was also a list to the port side of approximately 8.4° (see Fig. 5.5.3). Both of these departures from horizontal were caused in part by the added weight of the DVS, which was not compensated by buoyancy elements added to the sled. Contributions to the pitch were also due to the high weight of the primer fluid on the sled and the load of tracer. Contributions to the roll would come from the primer fluid and tracer being moved to the port side by the accumulator pistons. Also, the CTD, rosette pylon and ICU at the front of the sled are not symmetrical with respect to the roll direction.

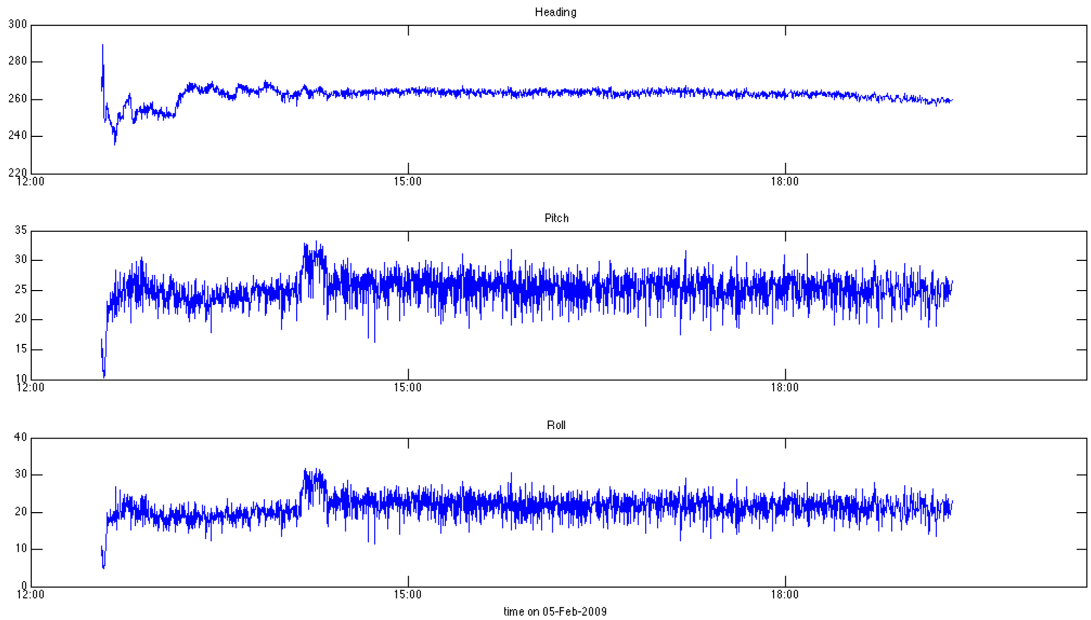


Fig. 5.5.2. As Fig. 5.5.1, but for the second injection tow (Cast 14).

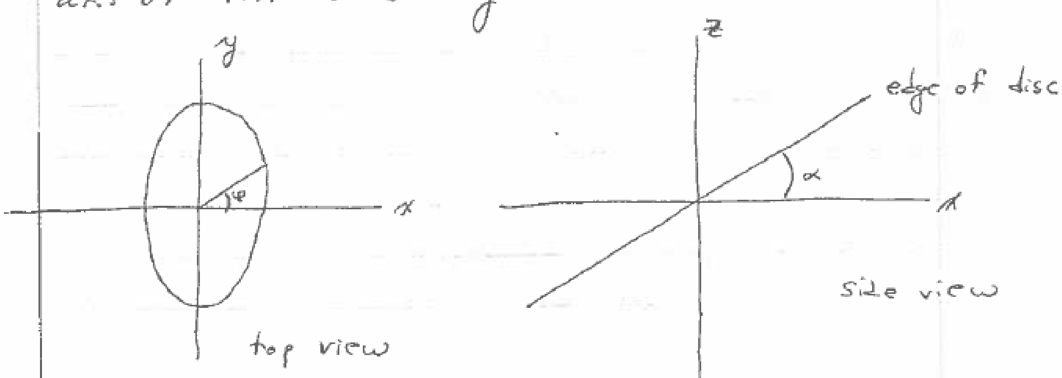
Fig. 5.5.3 (next pages). Derivation for calibrating pitch and roll of the DVS on the tracer injection sled relative to the sled forward direction. Motion sensor - pitch/roll transformation to other axes.

3/31/09 -1

Motion Sensor – Pitch/Roll Transformation to Other Axes

The DVS on the tracer injection sled measured pitch, roll and heading. But the "forward" or pitch direction was rotated by about 30° relative to the forward direction of the sled (clockwise). The mean pitch recorded was ~27° and the mean roll was ~19°. We would like to know the pitch and roll of the sled relative to the sled forward direction.

A useful starting point is to consider a disc of unit radius which is tilted up in the x-direction above the x-y plane. That is the axis of tilt is the y-axis:



and then to ask what the angle of elevation is for a line segment whose projection on the x-y plane is at angle φ ccw from the x axis.

We have

$$z = x \tan \alpha$$

everywhere in the plane of the disc

On the edge of the unit disc we have

$$x = \cos\alpha \cos\varphi \qquad y = \sin\varphi$$

The angle of elevation at φ is then

$$\tan\beta = \frac{z}{\sqrt{x^2+y^2}} = \frac{x\tan\alpha}{\sqrt{x^2+y^2}}$$

$$= \frac{\cos\alpha\cos\varphi\tan\alpha}{\sqrt{\cos^2\alpha\cos^2\varphi + \sin^2\alpha}}$$

$$\tan^2\beta = \frac{\tan^2\alpha}{1+\tan^2\varphi/\cos^2\alpha} = \frac{\sin^2\alpha}{\cos^2\alpha + \tan^2\varphi} \quad (1)$$

Now for our problem with the sled, we know the ~~angl~~ angle of elevation along the ~~pit~~ DVS pitch and roll directions, β_1 and β_2, respectively from which we can determine the angles φ and α. ~~Eliminating~~ Solving for α in terms of φ and β_1 from (1) we find

$$\cos^2\alpha = \frac{1-\tan^2\varphi\tan^2\beta_1}{1+\tan^2\beta_1} \quad (2)$$

Then eliminating α from (1) with β_2 inserted and $\varphi+\pi/2$ for the roll axis we find

$$\Phi = \frac{\left[(B_2-B_1) \pm \sqrt{(B_1-B_2)^2 + 4B_1B_2(1+B_2)(1+B_1)}\right]}{2B_1(1+B_2)} \quad (3)$$

where $\Phi = \tan^2\varphi$, $B_1 = \tan^2\beta_1$, $B_2 = \tan^2\beta_2$

For example, the mean ~~pitch~~ DVS pitch angle during most of injection 1 was ~27° and the mean roll angle was ~19°. Using these for B_1 and B_2, and choosing the '+' sign in the solution (3) for a positive $\tan^2\varphi$ we find that $\varphi \approx 34.7°$ and then from (2) $\alpha = 33.5°$

Now the DVS true heading during the tow was 349 to 354°, while the COG for the ship and presumably the sled heading was ~300°. So the pitch direction was about ~~45~~ 50° cw from the ~~stead~~ sled axis. So the tilt direction of the disc was $-50° + 34.7° = -15.3°$ from the sled axis. Thus the pitch direction of the sled is at $\varphi_p = 15.3°$ from the tilt ~~axis~~ direction and the roll direction is at $\varphi = 90° + 15.3° = 105.3°$. We can again use (1) to obtain the sled pitch and roll angles:

$$\tan^2\beta_{p,r} = \frac{\sin^2\alpha}{\cos^2\alpha + \tan^2\varphi_{p,r}} \quad \text{for } \beta_p \text{ or } \beta_r$$

We find $\beta_p = 32.2°$ (pitch)

$\beta_r = -8.4°$ (roll)

(We choose the negative value for β_r because $\varphi_r > 90°$. The sled is listing to port due to the weight of the DVS and of the tracer + primer in the accumulators)

5.6. Velocity Comparisons

Probably the best way to determine the fidelity of the velocity is, for the first deployment, to compare the velocity in the outer bins with the velocities from the hull-mounted NB150 in the upper 300 meters of the water column, as the injection sled was lowered and raised.

6. EM 120 Multibeam Echosounder

6.1. Description

The EM 120 Multibeam echosounder from Kongsberg-Simrad was used for bathymetric surveying. The system has an operating frequency of 12 kHz, suitable for deep ocean waters, and 191 beams, producing a maximum area coverage per swath of 25 km. The transducer system comprises one projector array, which is mounted along the ships keel line, and a separate receive array, which is mounted in the athwartship direction. Survey data were acquired and visualized in real time using Kongsberg's multibeam echosounder software Seafloor Information System (SIS); Figure 6.1 shows a screenshot of the software.

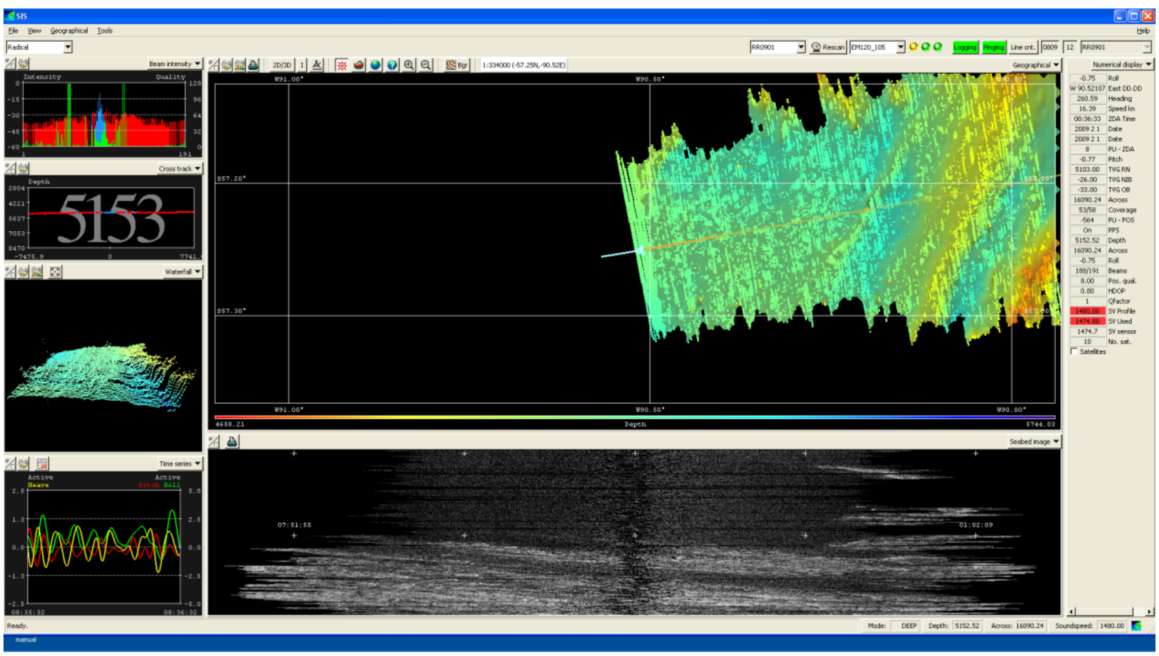


Fig. 6.1.1 Seafloor Information System was used to visualize survey data in real time.

6.2. Data Acquisition

Low quality data were encountered during parts of the cruise (Fig. 6.2.1). These low quality data were attributed to bubbles originating at the sea surface and drawn under the hull along flow lines. Bubbles generate noise which can cause reception problems, but they also absorb acoustic energy which can affect signal transmission as well.

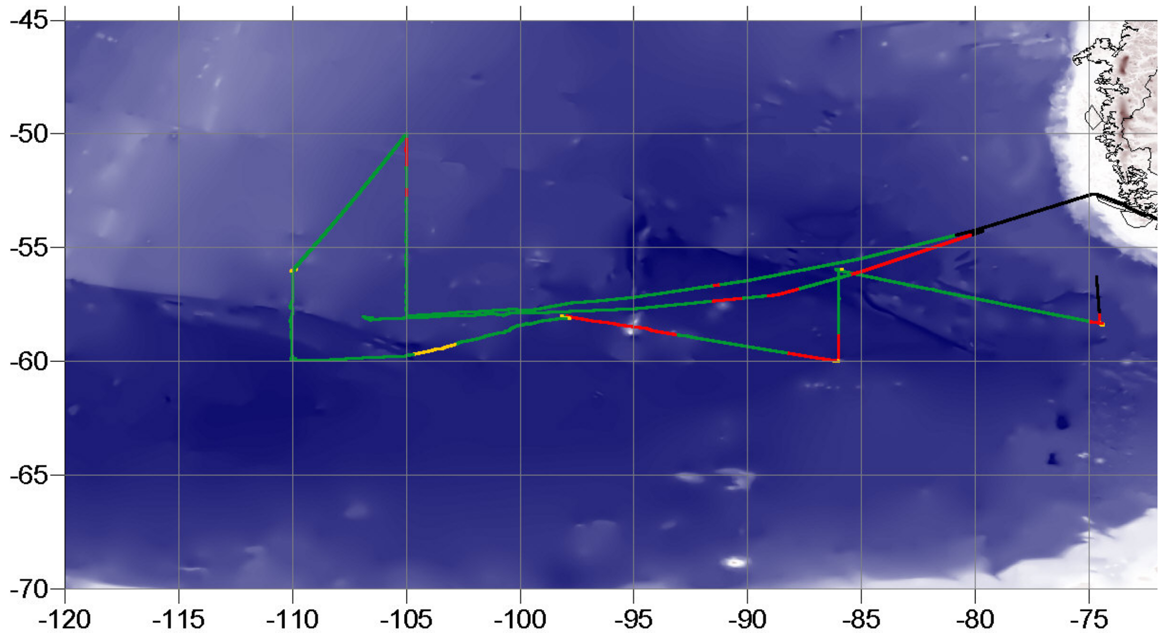


Fig. 6.2.1. Map of R. Revelle *cruise track. Sections in green (red) indicate good (bad) quality of multibeam data, sections in yellow indicate the site of an event (CTD station, mooring, tracer area, etc) and sections in black show missing data.*

There are two fundamental sound speed measurement inputs into multibeam sonar systems. These are the speed of sound at the keel of the ship in the vicinity of the sonar array, and the profile of sound speed in the water column. The former is used in the sonar's beam forming while the latter is used more directly in the bathymetry calculations. The sound speed at the keel of the ship, local to the array, affects the directivity of the beams produced by the sonar. The result is that the sonar is not exactly looking in the expected direction, introducing considerable error. Sound profiles of the water column, estimated with expendable bathythermographs, were regularly uploaded to the data acquisition system in order to minimize the error.

6.3. Multibeam Data Processing Steps

Survey data were processed with the open-source package MB-System, http://www.ldeo.columbia.edu/res/pi/MB-System/. A brief description of the processing steps is given below. Tables 6.3.1 and 6.3.2 at the end of the section give details of the processed files and the structure of the directory “em120_processed”.

1. Data format conversion

   The data format of EM120 Simrad multibeam is supported by MB-System as format 56. Since this data format does not store beam flags, the only choice during the processing is to null the flagged beams. This precludes unflagging flagged beams later determined to be good. Also, the raw EM120 format has no space to store the rebinned sidescan, so any corrections or other processing applied to the sidescan is lost. To overcome these restrictions, the raw data format was converted to a native MB-System format (id 57) using the *mbcopy* command.

> mbcopy -F-1 -I input_filename.all -O output_filename.mb57

2. Generation of filename list for batch processing

   The command *mbdatalist* is used to create the list of files to be processed. The filenames contained in the list are usually constrained to geographic boundaries of interest.

   > ls | grep .all$ > list0
   > mbdatalist –F–1 –I list0 > list1

3. Ancillary data

   The next step is the generation of ancillary data files. Three types of files are created for each data file. The info files (.inf suffix) contains meta-data and statistics (geographic, temporal and depth bounds, ship track information, and numbers of flagged or zero beams). The fast bathymetry (.fbt suffix) and fast navigation (.fnv suffix) files contain bathymetry and navigation data, respectively, in a format that can be read and processed by the MB-System package. These files are created using *mbdatalist* with the following syntax:

   > mbdatalist –F–1 –I list1 –N –V

4. Automatic bathymetry editing

   The command *mbclean* flags bad beams in swath sonar bathymetry data. Simple artifact detection algorithms are applied to the bathymetry before manual edition. The locations of beams are estimated using the navigation and heading of the ship. Ship turns often cause beams of adjacent pings to overlap, causing the distances between these beams to become quite small. This can, in turn, magnify noise in the bathymetry data to produce slope estimates which are excessively large. The applied algorithms are an attempt to automatically identify and flag these anomalous beams. The −D option sets the minimum and maximum allowed distances between beams. Both values are expressed in terms of fractions of the local median depth. Thus, −D0.01/0.20 indicates a minimum distance of 10 meters and a maximum distance of 200 meters for a local median depth of 1000 meters. The −C option specifies the maximum acceptable slope. If no units are specified then the default units are used (tangents). The −M2 option indicates that both beams associated with excessive slopes will be flagged. Therefore, −C3.0 and −M2 will flag all beams associated with slopes greater than 70 degrees, approximately. The −G option sets the range of acceptable depth values relative to low and high fractions of the local median depth. The median depth is obtained from the current ping and the pings immediately before and after that ping. Then, for –G0.70/1.30, all depth values less than 0.7 times the median depth or more than 1.3 times the median depth will be flagged. For the options describe above, *mbclean* is invoked with the following syntax:

> mbclean –F–1 –I list1 –M2 –C3.0 –D0.01/0.20 –G0.70/1.30 –V

5. Manual bathymetry editing

   The command *mbedit* is an interactive editor used to identify and flag artifacts in swath sonar bathymetry data. It is used after *mbclean* for manual inspection and removal of possible bad data not detected with automatic algorithms. To open a file for inspection the command is invoked with the following syntax:

   > mbedit –I filename.mb57

6. Processing of swath bathymetry data

   The previous steps have automatically created or edited the parameter files (file extension .par) to identify what options are to be applied to the sonar data. The command *mbprocess* uses these parameters to complete the final step of applying the changes to the data. For each file to be processed (file extension .mb57) a processed file is created (suffix p.mb57). The command is invoked with the following syntax:

   > mbprocess –F–1 –I list1

7. Generation of processed filename list for gridding

   Analogous to step 2, the command *mbdatalist* is used to create the list of processed files.

   > ls | grep p.mb57$ > list2
   > mbdatalist –F–1 –I list2 > list3

8. Gathering information of processed files

   The command *mbinfo* reads a swath sonar data file or files and outputs information about the files with some basic statistics. In particular it displays the geographic bounding box of the data, useful for the generation of the gridded data. Also reported are the numbers and percentages of good, zero, and flagged data values (good values are those which are neither zero nor flagged as bad). The command can be invoked using the following syntax:

   > mbinfo –F–1 –I list3

9. Gridding

The command *mbgrid* is used to grid bathymetry data contained in a set of swath sonar data files. A weighted average gridding scheme is used. The weighting function is giving by:

$$W(r) = A\, e^{-r^2 a^{-2}}$$

Where *r* is the distance from the center of the grid point to the data point, *a* is the distance at which the weighting function falls to e^{-1} of its maximum value, and *A* is a normalizing factor set so that the sum of all the weights adds to a value of 1. The grid is generated in geographic coordinates using the WGS84 horizontal datum. Grid spacing and geographic boundaries are specified with the options –E and –R respectively. The output file is in GMT netCDF 4-byte float format. The following syntax is used to invoke the command:

> mbgrid –I list3 –E150/0/m! –R west/east/south/north
> ./list3.cmd

10. Conversion of GMT netCDF to Arcview ASCII

Gridded data in GMT netCDF format are converted to ASCII format using the *mbm_grd2arc* command. The command is invoked with the following syntax:

> mbm_grd2arc –I input.grd –O output.arc

Plotting of processed data was made with Surfer. Figures 6.3.1 and 6.3.2 show examples of the processed bathymetric data; additional figures can be found at /em120_processed/plots.

Sample Plot

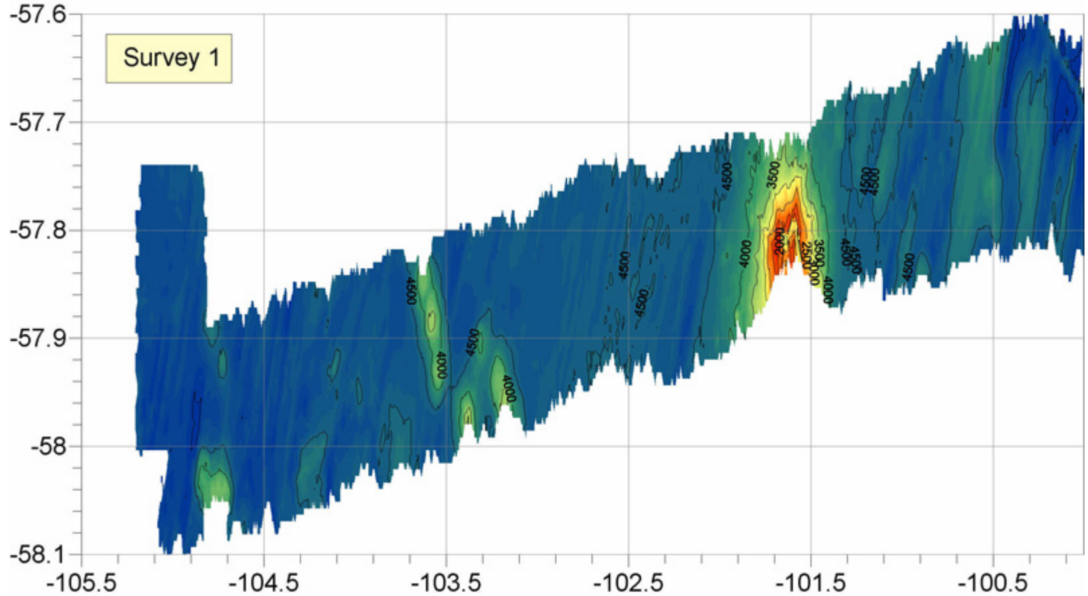


Fig. 6.3.1. Processed data with MB-System software. Example of Contour gridding. including seamount at 101.5°W, 57.8°S.

Sample Plot

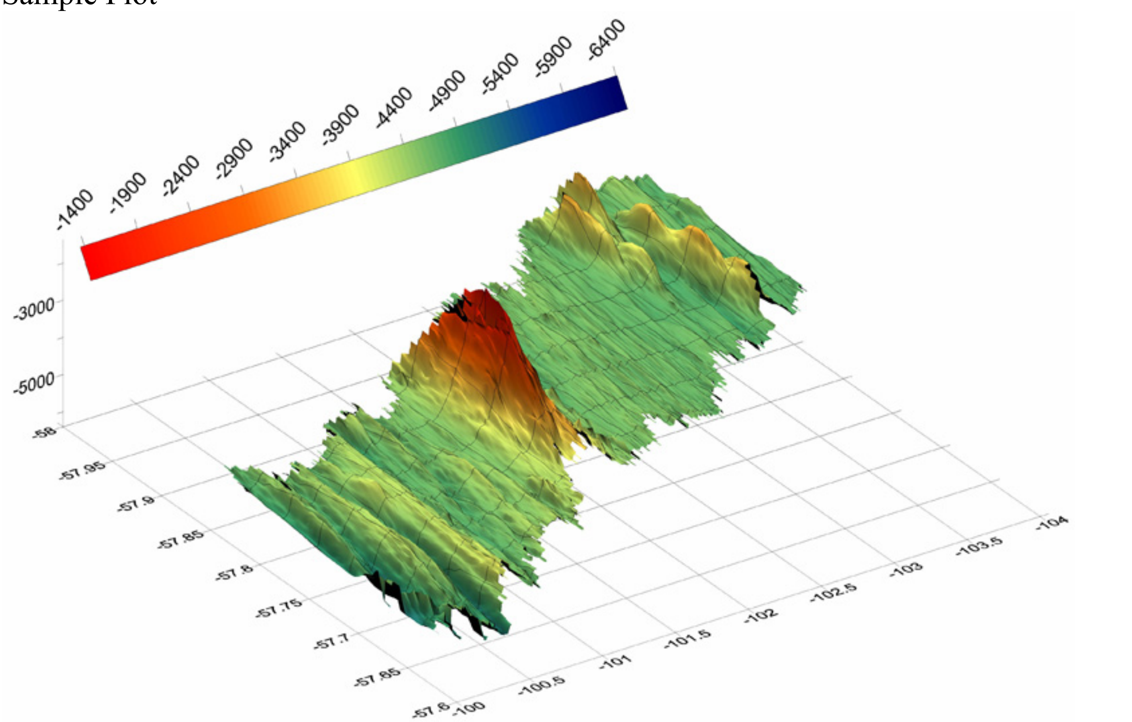


Fig. 6.3.2. Processed data with MB-System software. Orthographic view (same domain as Fig. 6.3.1).

Table 6.3.1. Details of Processed Files Sorted by Task

Begin		End		Directory	Description
Index	Date	Index	Date		
3	1/12/09 9:40	14	1/12/09 15:05	/data/moorings/#1	mooring #1
15	1/12/09 15:06	82	1/14/09 0:39	/data/s01	transit mooring #1 - #2
83	1/14/09 0:40	112	1/15/09 3:03	/data/moorings/#2	mooring #2
113	1/15/09 3:04	153	1/15/09 23:33	/data/s02	transit mooring #2 - #3
154	1/15/09 23:34	169	1/16/09 5:38	/data/moorings/#3	mooring #3
170	1/16/09 5:39	247	1/17/09 19:40	/data/s03	transit mooring #3 - #4
248	1/17/09 19:41	261	1/18/09 2:17	/data/moorings/#4	mooring #4
262	1/18/09 2:18	291	1/18/09 17:17	/data/s04	transit mooring #4 - #5
290	1/18/09 17:18	303	1/18/09 23:17	/data/moorings/#5	mooring #5
304	1/18/09 23:18	388	1/20/09 17:47	/data/s05	transit mooring #5 - #6
389	1/20/09 17:48	399	1/20/09 23:17	/data/moorings/#6	mooring #6
400	1/20/09 23:18	463	1/22/09 7:30	/data/s06	transit mooring #6- CTD line
464	1/22/09 7:47	625	1/25/09 16:17	/data/CTD	CTD line - part 1
626	1/25/09 16:18	747	1/28/09 4:59	/data/s07	transit CTD line - EEZ
748	1/31/09 1:48	897	2/3/09 4:47	/data/s08	transit EEZ - Injection site
898	2/3/09 4:48	1269	2/11/09 6:34	/data/injection	Injection/Sampling site
1270	2/11/09 6:35	1303	2/11/09 23:33	/data/s09	transit Injection site - CTD line
1304	2/11/09 23:34	1373	2/13/09 10:34	/data/CTD	CTD line - part 2
1374	2/13/09 10:35	1386	2/13/09 17:04	/data/s10	transit CTD line - Injection site
1387	2/13/09 17:05	1655	2/19/09 8:15	/data/injection	Injection/Sampling site
1656	2/19/09 8:16			/data/s11	transit Injection site - EEZ

Table 6.3.2. Contents of Directory /em120_processed

Subdirectory	Description
/data/…/ancillary	Ancillary data of processed files sort by event (see Table 6.3.1)
/data/…/raw_id57	Raw data in MB-System format (see processing steps) sort by event (see Table 6.3.1)
/data/…/processed	Processed files sort by event (see Table 6.3.1)
/output_ascii	Grid Bathymetry in ASCII format sort by event (see Table 6.3.1)
/output_netcdf	Grid Bathymetry in netcdf format sort by event (Table 6.3.1)
/plots	Plots of selected areas
/scripts	Scripts (matlab and bash)

6.4. Multibeam Data Access

Multibeam data for the cruise are available to the public at http://www.marine-geo.org/tools/search/entry.php?id=RR0901. Access to the processed data is described at the cruise-data website discussed in Appendix E.

7. Sound Source Moorings

As part of the DIMES experiment an array of 6 acoustic sound source moorings were deployed to provide tracking for an assortment of drifting receivers. The mooring locations are shown in Fig. 2.2.1 (Section 2), and were deployed from east to west along the outbound cruise track. The sources transmit a 260-Hz, 80-second long swept signal that can be heard by the drifting instruments for an estimated 900 km. Two different types of sources were used, one manufactured by the University of Rhode Island (URI) and the other by Webb Research Corporation (WRC). WRC sources have been the standard for many years and have proved to be very reliable. The URI sources are a relatively new design that offers the benefits of a smaller, lighter, and more power-efficient design. Mooring diagrams are included at the end of this section.

The first mooring (Mooring # 6 in the mooring plans) was deployed on 12 January 2009 and consisted of URI sound source #39 (Fig. 7.1). The mooring was designed for a water depth of 4400 meters based on historic charts of the area. To be certain of the water depth, a survey of the proposed mooring location was conducted using the ship's multibeam survey system. Starting from a point 2 miles upwind from the anchor drop site, the sea floor depth was mapped to 4 miles downwind of the anchor drop site, for a total of 6 miles surveyed (Fig. 7.2). Once an area was located that provides a relatively flat area to shoot for, the depth was noted and any adjustments to the length of the mooring made at the very end of the mooring. In this case the bottom depth was about 250 meters greater than the target depth, so a 300 meter shot of 3/16" wire rope was added just above the anchor.

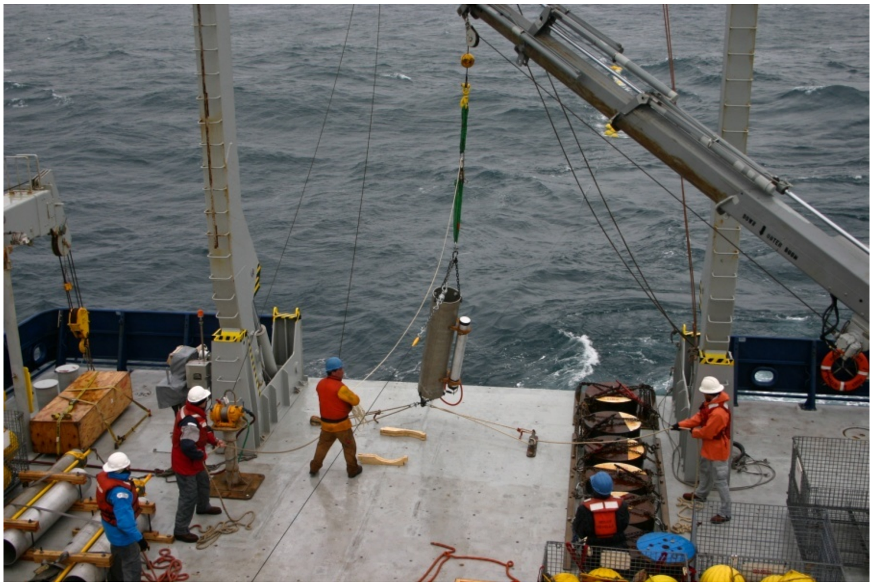


Fig. 7.1. Deployment of the first mooring (Photo by Uriel Zajaczkovski).

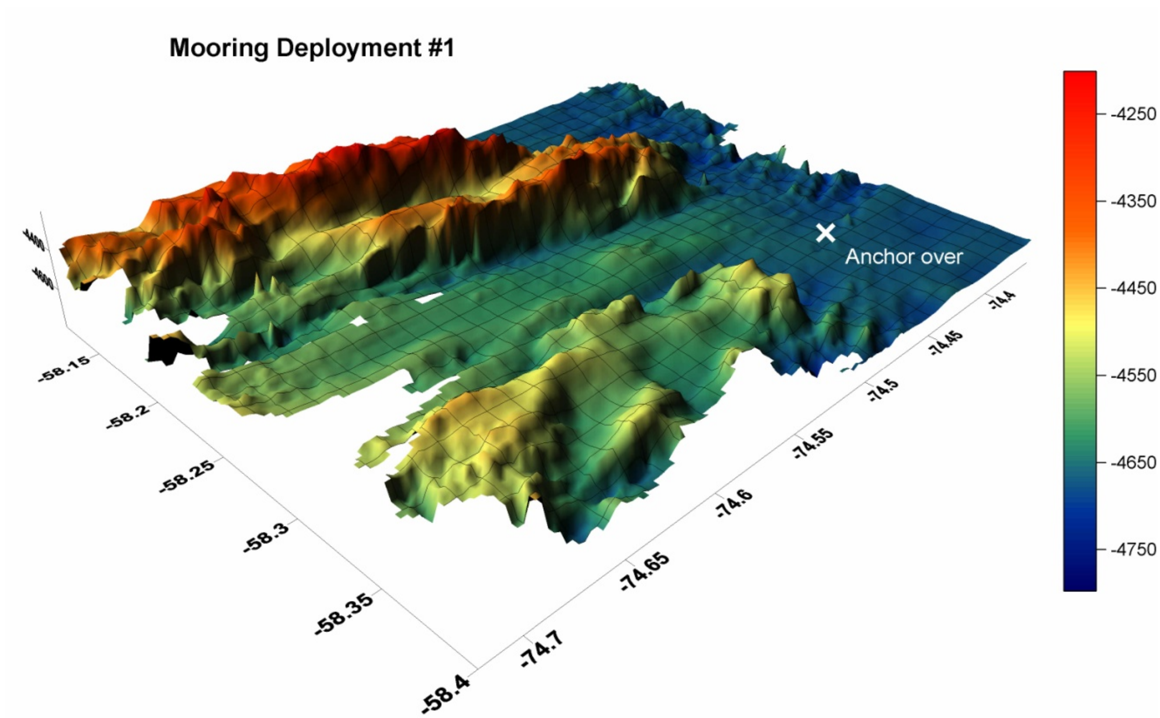


Fig. 7.2. Bathymetry in the region of the first mooring deployment. Similar images for the other moorings are included at the end of this section. The multibeam data and processing are described in Section 6. Data are in \em120 and \em120_processed. Contour maps for the mooring sites are included in \em120_processed\plots.

Fig. 7.3. Ship's Resident Marine Technician Meghan Donohue operates the TSE mooring deployment winch (Photo by Uriel Zajackovski).

The light weight and small size made the URI sound source much simpler to deploy than WRC sources, and was especially nice considering there were seas of 15 ft and winds around 20 knots. The top of the mooring consisted of twenty-six 17" Benthos glass spheres for floatation which was deployed first. The sound source was attached to a 50 meter shot of 3/16" plastic jacketed wire rope, separating it from the floatation. Attached to a quick release mechanism, the source was then hoisted over the stern by crane. In this case, the quick release failed and the lifting sling had to be cut in order to free the source. Upon examining the problematic release it was discovered that it had been over stressed during some other use, causing a bend in the release bail. A spare release was borrowed from the R/V *Revelle* for use on the remainder of the deployments during the cruise. Once the sound source had been freed from the release mechanism, long shots of wire rope and Yalex Dacron line were spooled from the TSE mooring winch (Fig. 7.3). Upon reaching the end of the mooring components on the winch, the mooring was attached to two (2) 1" diameter stopper lines. At this point it was disconnected from the winch and then connected to a 5 meter shot of 3/8" chain that was attached to a 2400 lb anchor. With all hardware in place, the load of the mooring was transferred to a slip line that eased out allowing the load to be transferred to the now unlashed anchor. As the load was completely transferred, the slip line was hauled back.

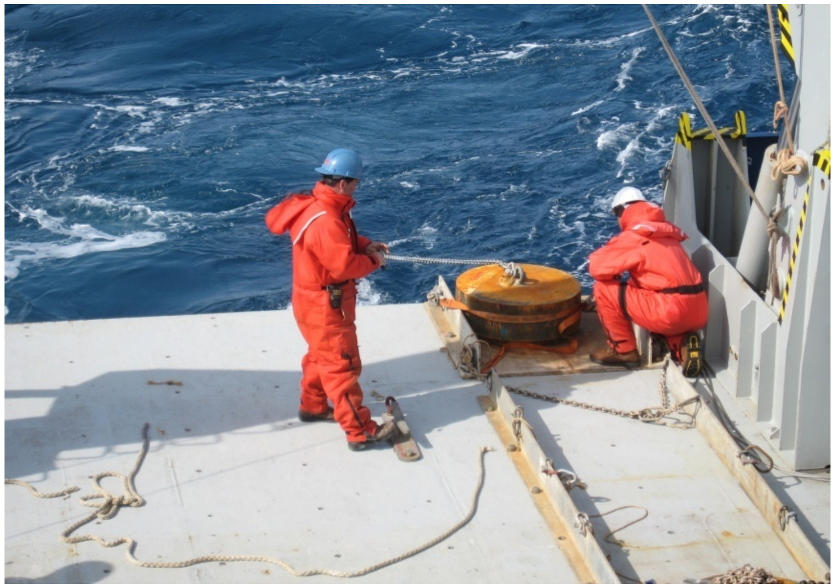


Fig. 7.4. Ratchet strap anchor launch method (Photo by Jon Meyer).

The original plan to deploy the anchor was to use a trip plate, a large and heavy steel plate that is then lifted by crane on one end, tipping the plate and allowing the anchor to slide off. This process was changed to a much simpler method: a 2” ratchet strap was placed around the midsection of the anchor and as the ratchet was operated, it forced the anchor off the stern of the ship (Fig. 7.4). This proved to be so simple that it was used on all subsequent deployments.

In between each mooring deployment, the next mooring was wound onto the TSE winch. The shots of wire rope and Dacron were provided on wooden reels and mounted on a tension cart to provide a strain on the lines during transfer to the winch (Fig. 7.5).

Fig. 7.5. Winding cart in use (Photo by Jon Meyer).

The second mooring deployed (Mooring #5) was a WRC sound source, comprising two large tubes attached to a strongback, all weighing a total of approximately 900 lbs (Fig. 7.6). One pressure case houses a large quantity of batteries and the electronics; the other tube is the acoustic resonator. In order to deploy these sources, a lifting bridle made from ½" line was spliced to the ends of the strongback. Four tag lines were utilized to control the source as it was lifted over the stern. It was decided to lift the sound source using the capstan as opposed to the crane for these deployments. The line was fed through a block on the A frame and forward to the capstan. This method shortened the time it took to get the source over the stern. The process was to bring in the A-frame until the block was over the center of gravity of the source, lift the source about 1 foot off the deck with the capstan, take the A-frame out while maintaining the height of the source off the deck with the capstan (Fig. 7.6). Once the A-frame was outboard, the capstan would lower the source into the water and the quick release would be tripped.

These methods were used on each of the remaining moorings and each went smoothly. The only complication was with the 3rd deployment, Mooring #4. During the deployment, one of the slip lines attached to the URI sound source fouled in the chain, requiring it to be cut free, leaving about 10 feet of line still entangled with the chain. This also happened to the slip line attached to the anchor chain and it too had to be cut. Each mooring was designed for a specific depth of water +/- 100 meters. In some instances it was necessary to adjust the length of the mooring due to actual measured water depths. A list of those adjustments is in Table 7.1. Table 7.2 shows the deployment schedule. The original mooring plans are shown in Figs. 7.7–7.10. At the end of this section are bathymetry images (similar to Fig. 7.2) of the other mooring deployments (Figs. 7.11–7.15).

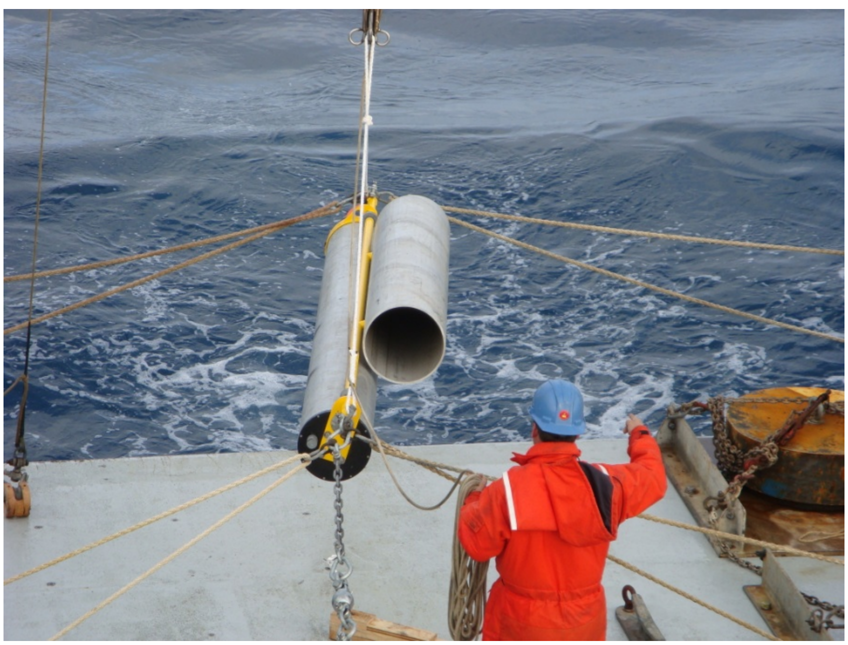


Fig. 7.6. Deploying a WRC source using the capstan. The quick release can be seen at top, attached to the bridle (Photo by Jim Ledwell).

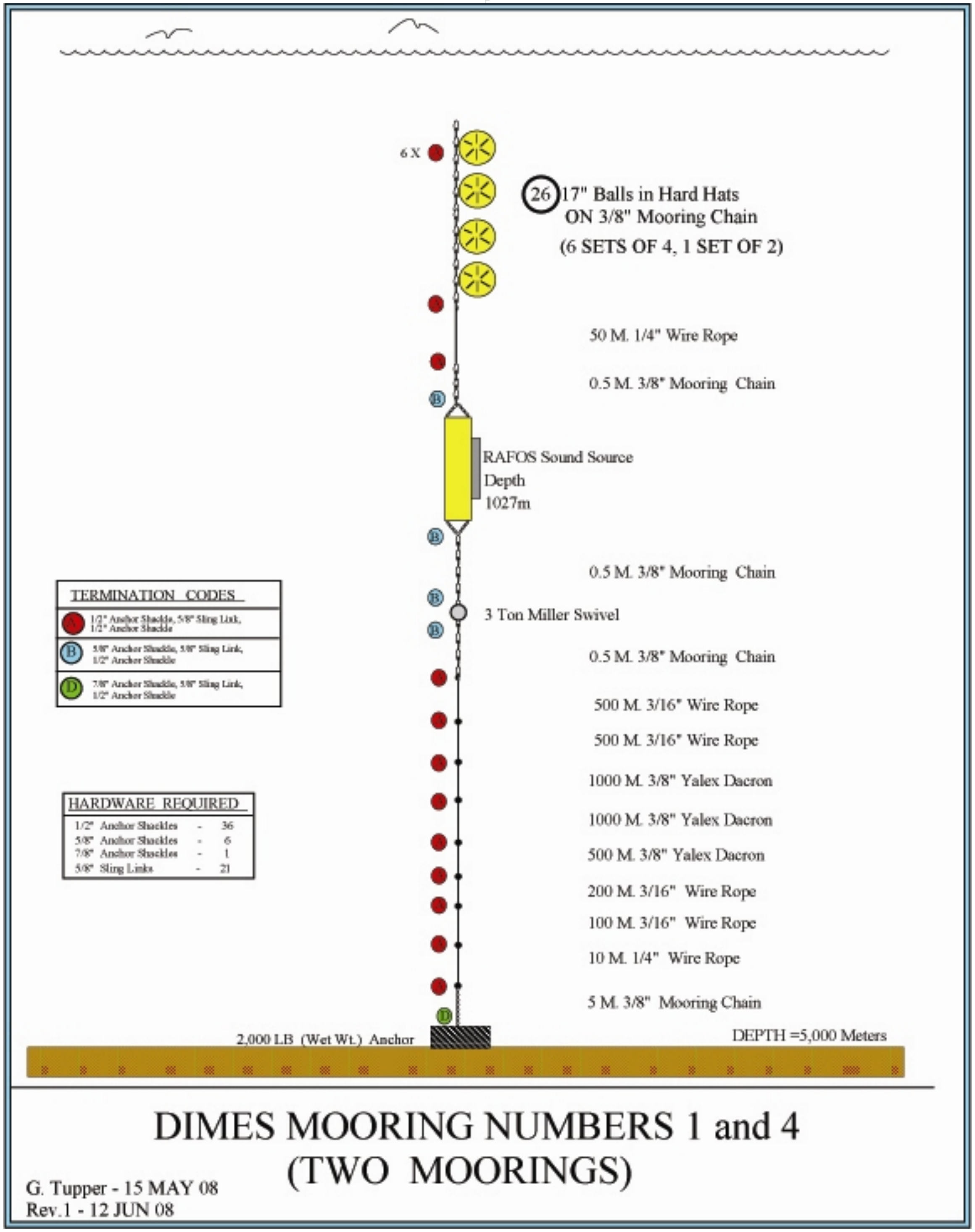
Table 7.1. Adjustments Made to the Mooring Line Lengths

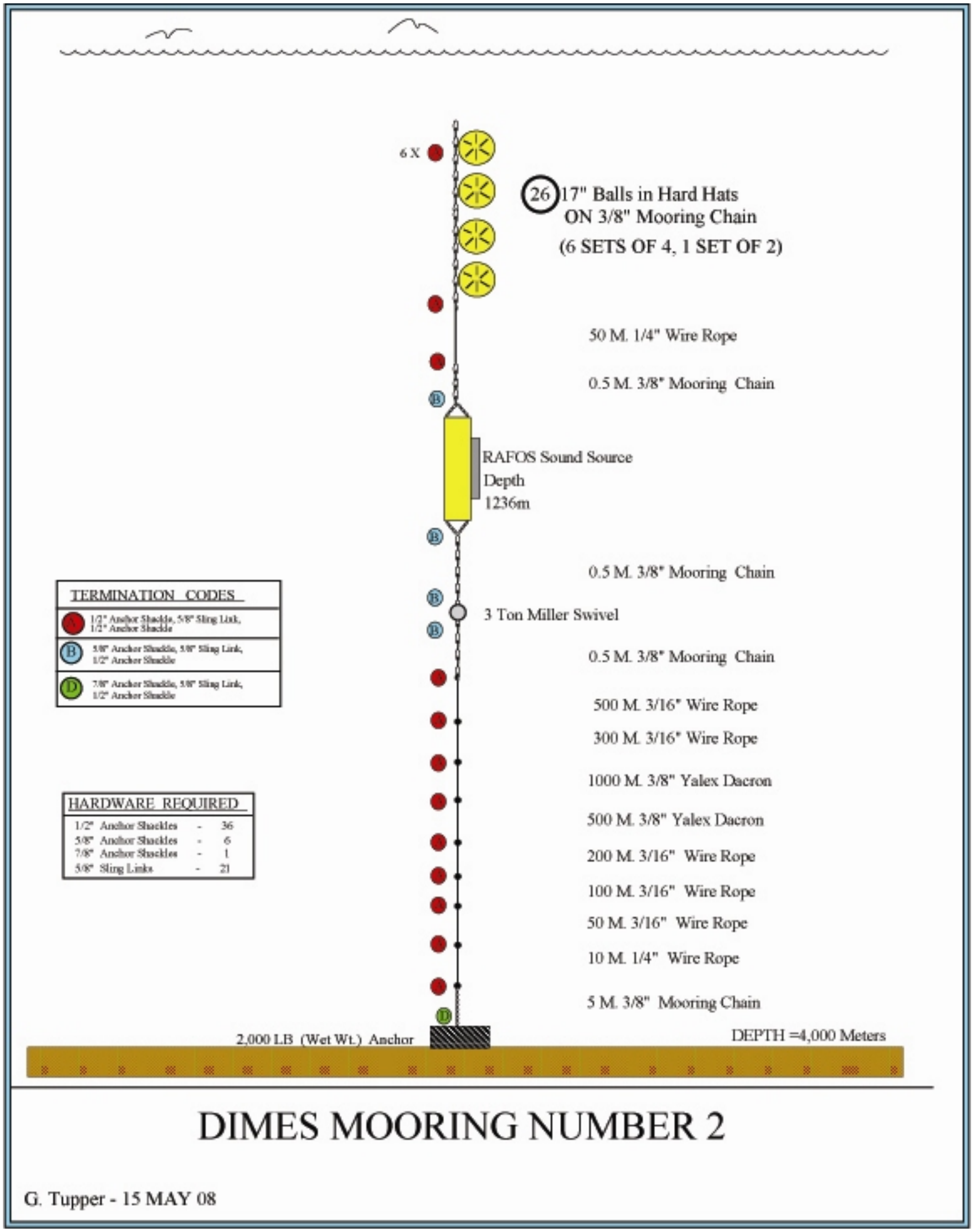
Mooring #	Design Depth	Deployment order	Adjustment	Source Depth
1	5000 meters	5	0 meters	
2	4000 meters	6	+ 200 meters	
3	4800 meters	4	0 meters	
4	5000 meters	3	0 meters	
5	5000 meters	2	0 meters	
6	4400 meters	1	+ 300 meters	

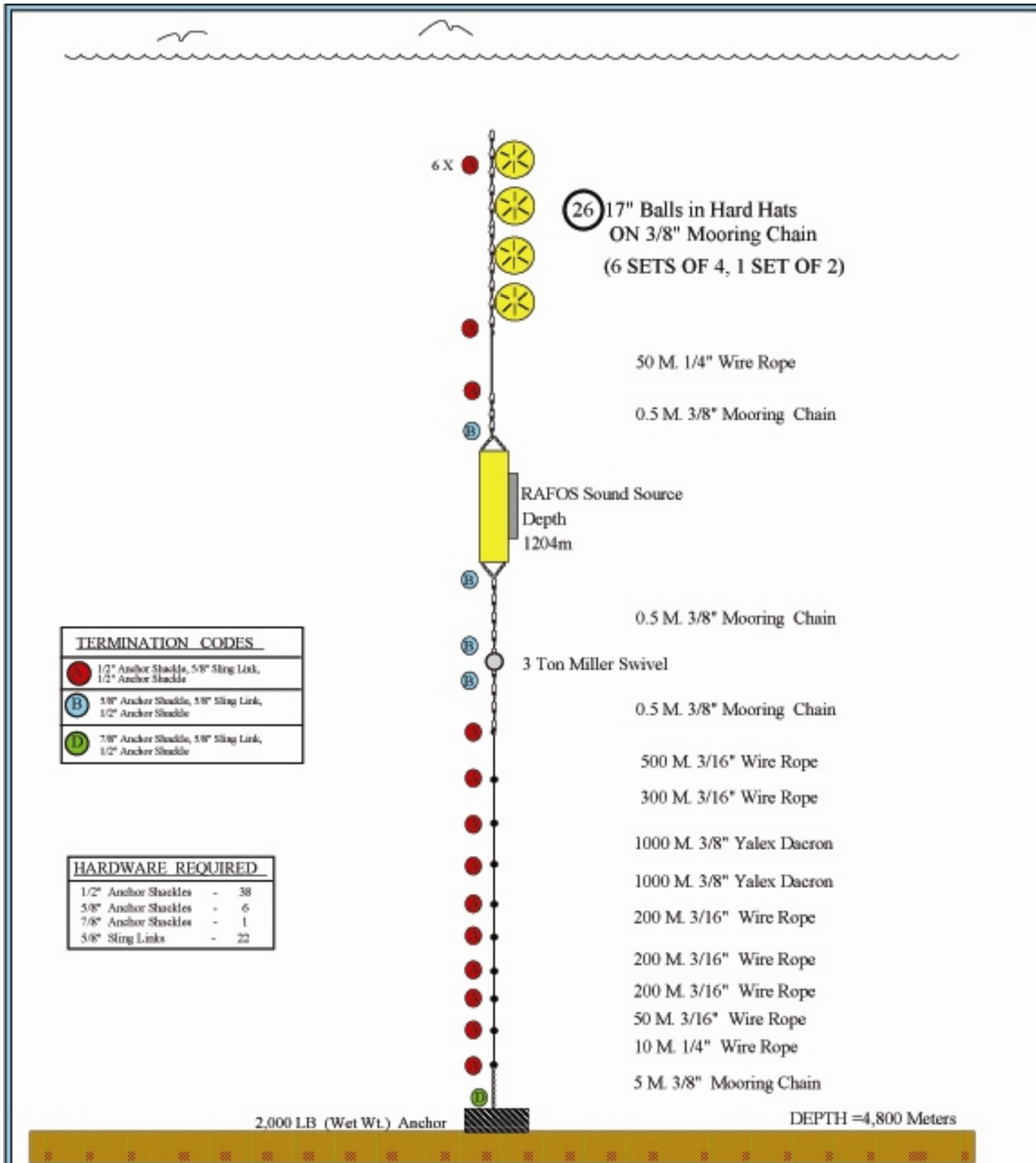
Table 7.2. Sound Source Schedule and Launch Position Data (in order of deployment)

Mooring #	Pong	Source Number	Date	Time Z	Start Lat	Start Long	Anchor Over Lat	Anchor Over Long
6	0105 Z	URI #39	01/12/09	1447 Z	58-23.36 S	74-21.94 W	58-20.06 S	74-24.84 W
5	0145 Z	WRC #52	01/15/09	0239 Z	55-57.80 S	85-52.03 W	55-57.78 S	85-59.18 W
4	0135 Z	URI #40	01/16/09	0456 Z	59-55.99 S	86-02.76 W	59-57.93 S	86-09.2
3	0125 Z	URI #37	01/18/09	0148 Z	58-07.49 S	97-50.30 W	58-06.08 S	97-57.55 W
1	0105 Z	URI #38	01/19/09	2205 Z	59-52.04 S	109-52.95 W	59-54.84 S	109-59.63 W
2	0115 Z	WRC #53	01/20/09	2233 Z	55-56.75 S	109-49.59 W	55-59.76 S	109-54.61 W

Figs. 7.7–7.10 (next pages). Original mooring plans.

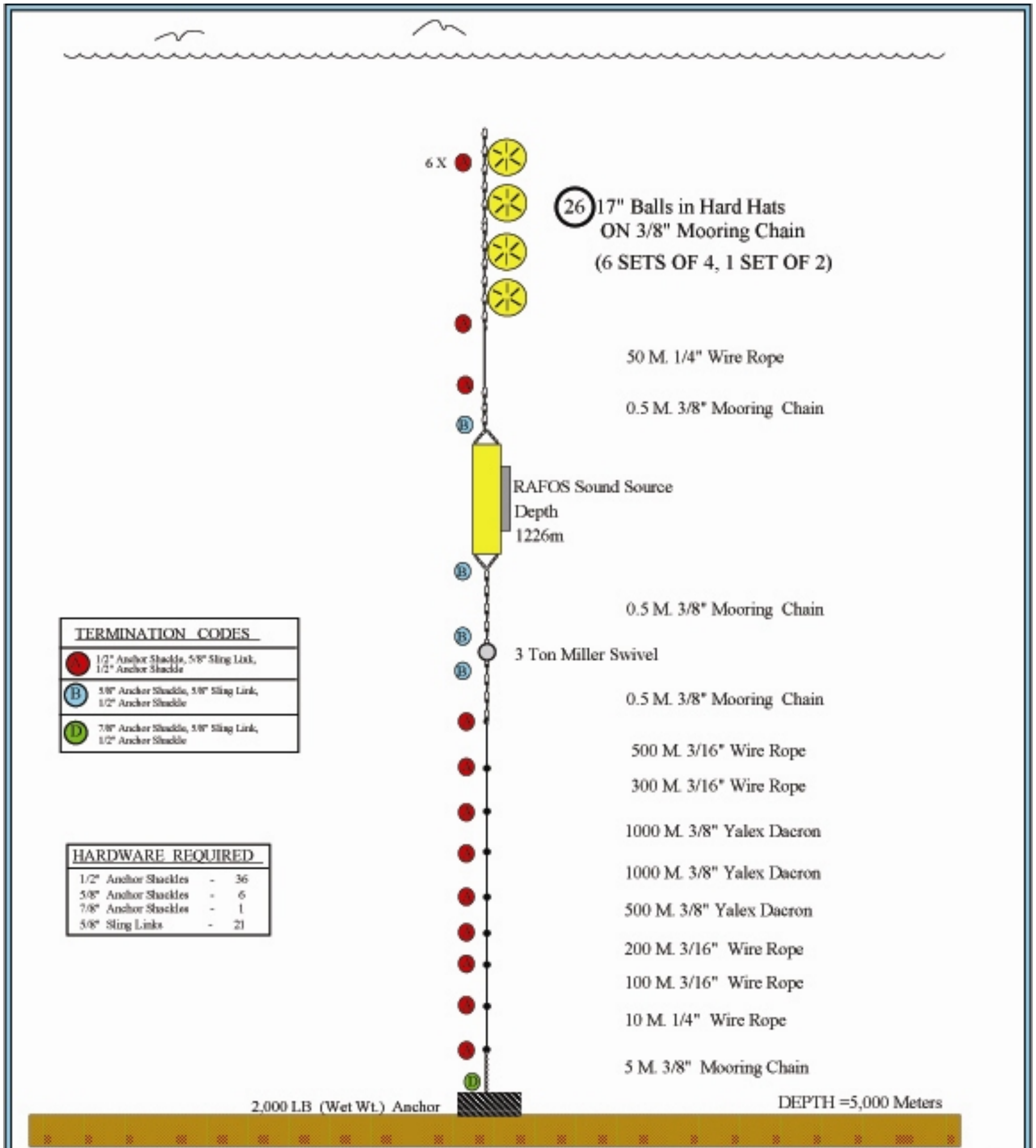

6 X
26 17" Balls in Hard Hats
ON 3/8" Mooring Chain
(6 SETS OF 4, 1 SET OF 2)
50 M. 1/4" Wire Rope
0.5 M. 3/8" Mooring Chain
RAFOS Sound Source
Depth
1027m
0.5 M. 3/8" Mooring Chain
3 Ton Miller Swivel
0.5 M. 3/8" Mooring Chain
500 M. 3/16" Wire Rope
500 M. 3/16" Wire Rope
1000 M. 3/8" Yalex Dacron
1000 M. 3/8" Yalex Dacron
500 M. 3/8" Yalex Dacron
200 M. 3/16" Wire Rope
100 M. 3/16" Wire Rope
10 M. 1/4" Wire Rope
5 M. 3/8" Mooring Chain
2,000 LB (Wet Wt.) Anchor
DEPTH =5,000 Meters
TERMINATION CODES
A 1/2" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
B 5/8" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
D 7/8" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
HARDWARE REQUIRED
1/2" Anchor Shackles - 36
5/8" Anchor Shackles - 6
7/8" Anchor Shackles - 1
5/8" Sling Links - 21
DIMES MOORING NUMBERS 1 and 4
(TWO MOORINGS)
G. Tupper - 15 MAY 08
Rev.1 - 12 JUN 08


6 X
26 17" Balls in Hard Hats
ON 3/8" Mooring Chain
(6 SETS OF 4, 1 SET OF 2)
50 M. 1/4" Wire Rope
0.5 M. 3/8" Mooring Chain
RAFOS Sound Source
Depth
1236m
0.5 M. 3/8" Mooring Chain
3 Ton Miller Swivel
0.5 M. 3/8" Mooring Chain
500 M. 3/16" Wire Rope
300 M. 3/16" Wire Rope
1000 M. 3/8" Yalex Dacron
500 M. 3/8" Yalex Dacron
200 M. 3/16" Wire Rope
100 M. 3/16" Wire Rope
50 M. 3/16" Wire Rope
10 M. 1/4" Wire Rope
5 M. 3/8" Mooring Chain
2,000 LB (Wet Wt.) Anchor
DEPTH =4,000 Meters
TERMINATION CODES
A 1/2" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
B 5/8" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
D 7/8" Anchor Shackle, 5/8" Sling Link, 1/2" Anchor Shackle
HARDWARE REQUIRED
1/2" Anchor Shackles - 36
5/8" Anchor Shackles - 6
7/8" Anchor Shackles - 1
5/8" Sling Links - 21
DIMES MOORING NUMBER 2
G. Tupper - 15 MAY 08



DIMES MOORING NUMBER 3

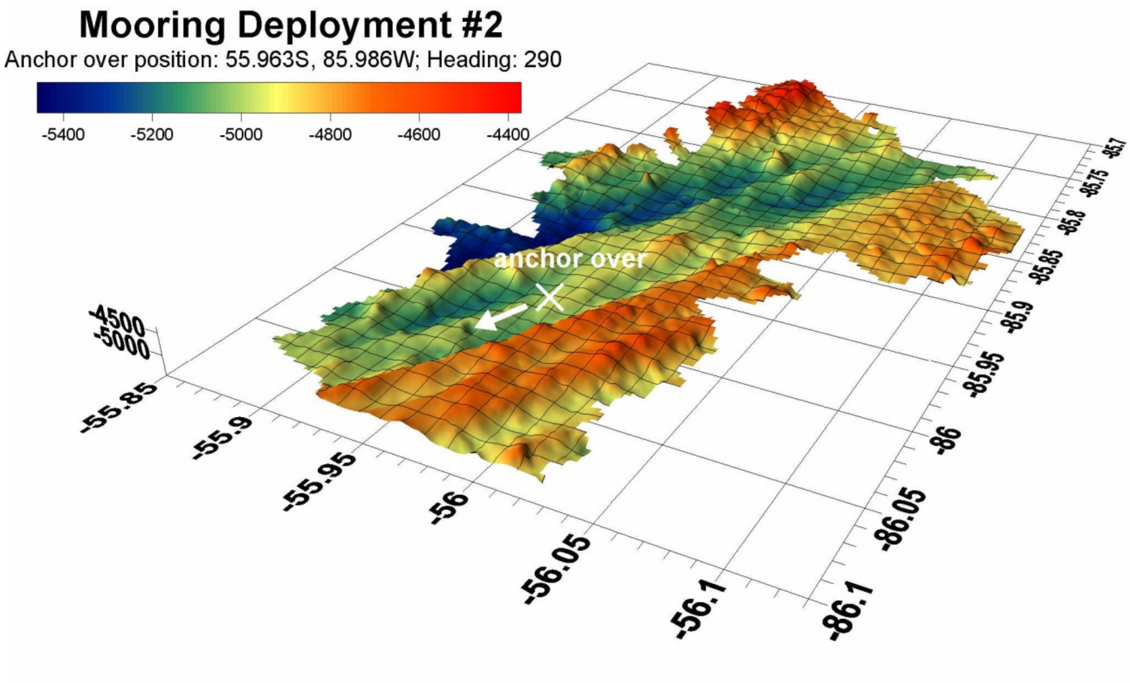
G. Tupper - 15 MAY 08

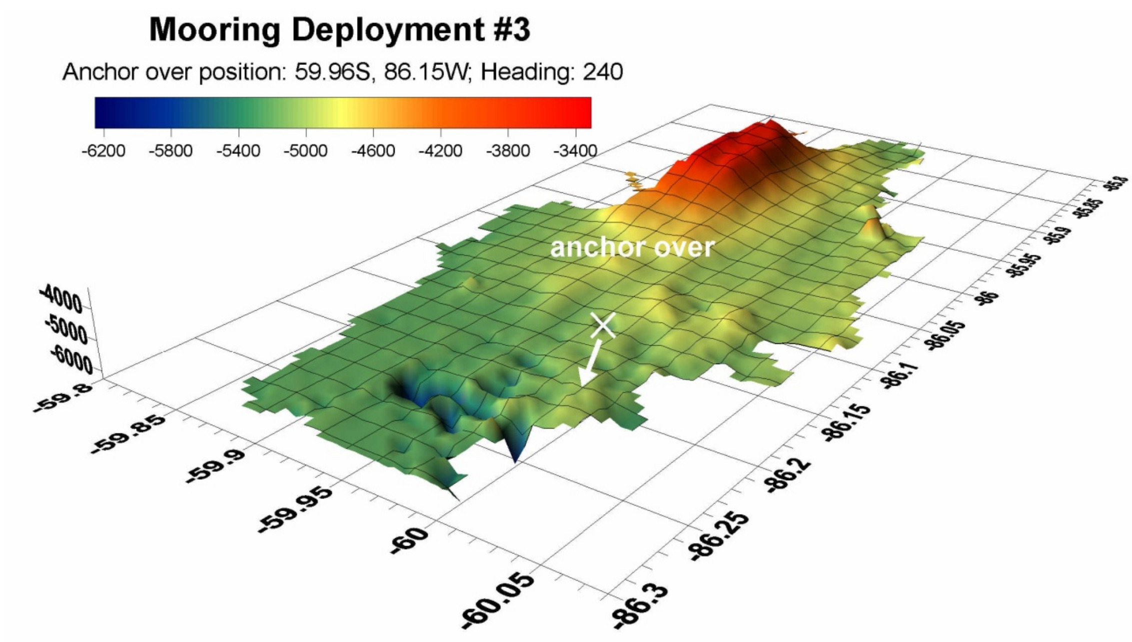


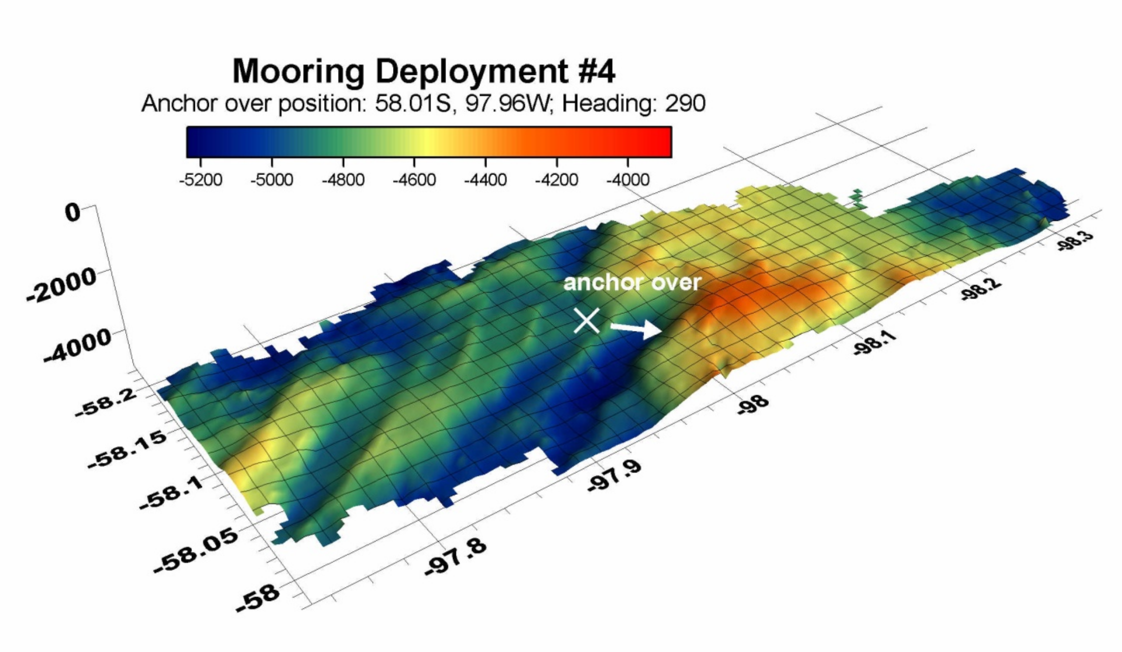
DIMES MOORING NUMBER 5

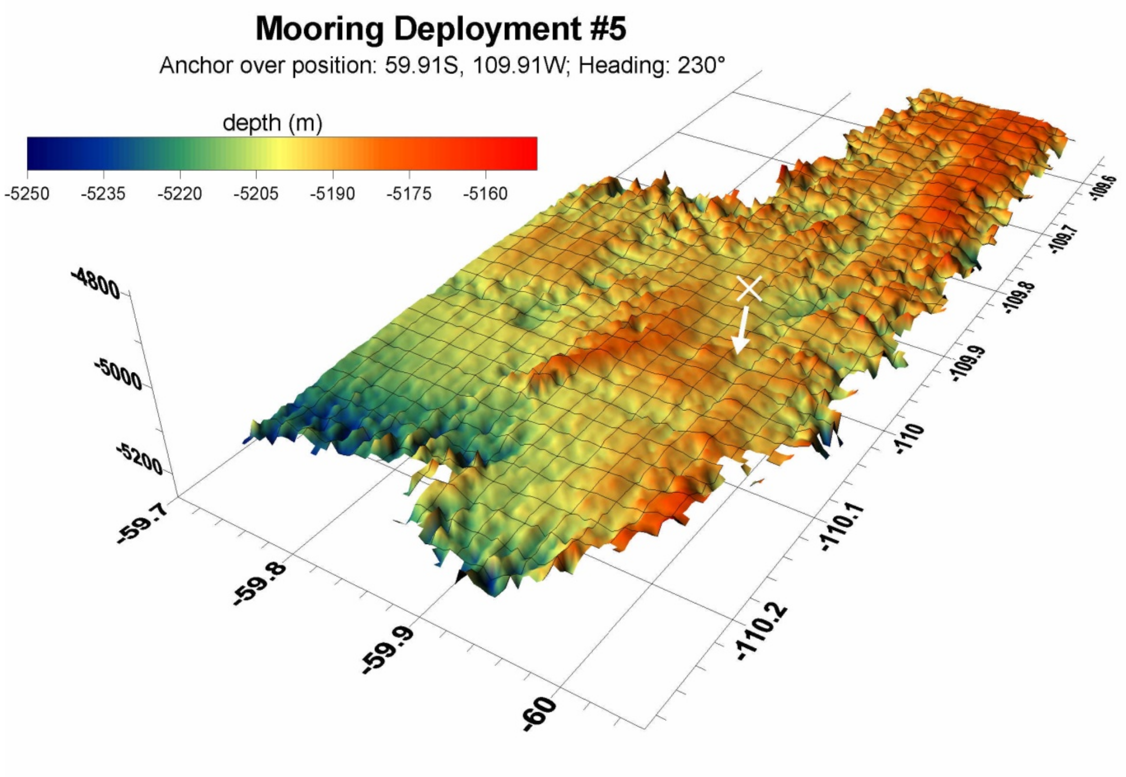
G. Tupper - 15 MAY 08
Rev 1 - 12 JUN 08

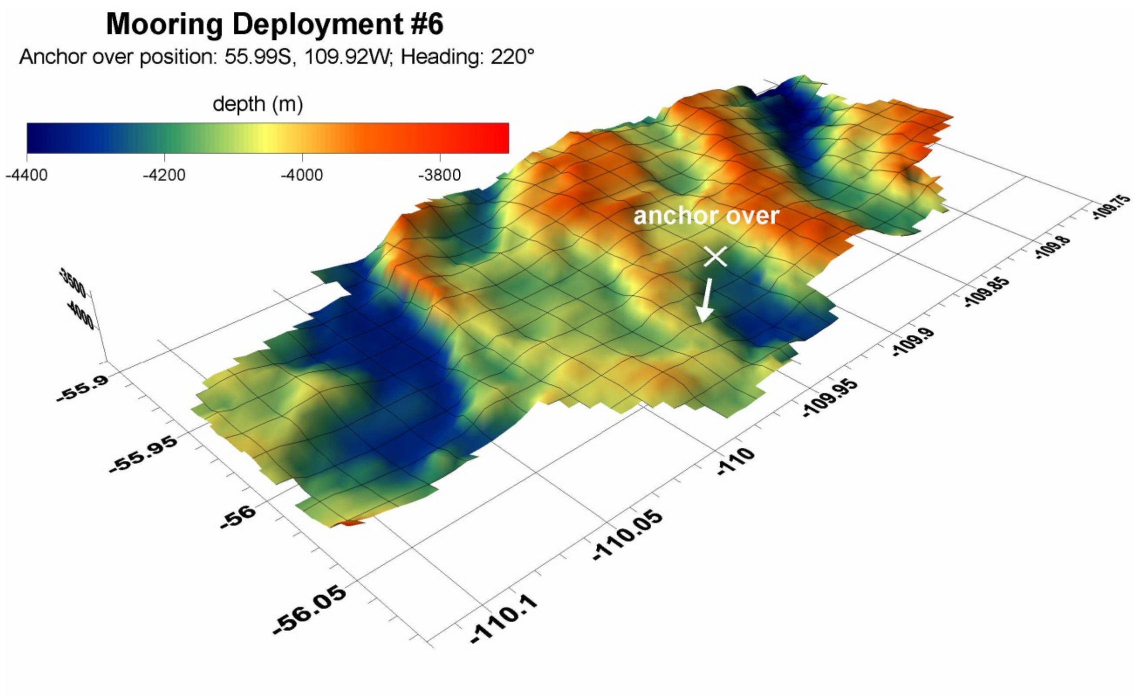
Figs. 7.11-7.15 (below). Orthographic images of the bottom surveys for the mooring deployment sites from the multibeam data (Produced by Uriel Zajaczkovski).






Mooring Deployment #4
Anchor over position: 58.01S, 97.96W; Heading: 290
-5200
-5000
-4800
-4600
-4400
-4200
-4000
0
-2000
-4000
anchor over
-58.2
-58.15
-58.1
-58.05
-58
-97.8
-97.9
-98
-98.1
-98.2
-98.3


Mooring Deployment #5
Anchor over position: 59.91S, 109.91W; Heading: 230°
depth (m)
-5250
-5235
-5220
-5205
-5190
-5175
-5160
-4800
-5000
-5200
-59.7
-59.8
-59.9
-60
-110.2
-110.1
-110
-109.9
-109.8
-109.7
-109.6



8. SOLO Float Deployments
Contributed by Nicolas Wienders, FSU

Six solo floats were deployed during the cruise (Table 8.1). They were programmed to drift at the tracer injection depth and to come back to the surface every ten days. The first four floats were equipped with RAFOS receivers, to check the functioning of the sound sources. Consequently they were deployed between sound sources, in the first part of the cruise, when moorings were deployed. More precisely one was deployed between moorings 1 and 2, one between moorings 3 and 4, one between moorings 4 and 5 and one between moorings 5 and 6 (Fig. 8.1). The last two SOLO floats did not have RAFOS receivers but were deployed at the injection site, to help predict the tracer displacements prior to sampling.

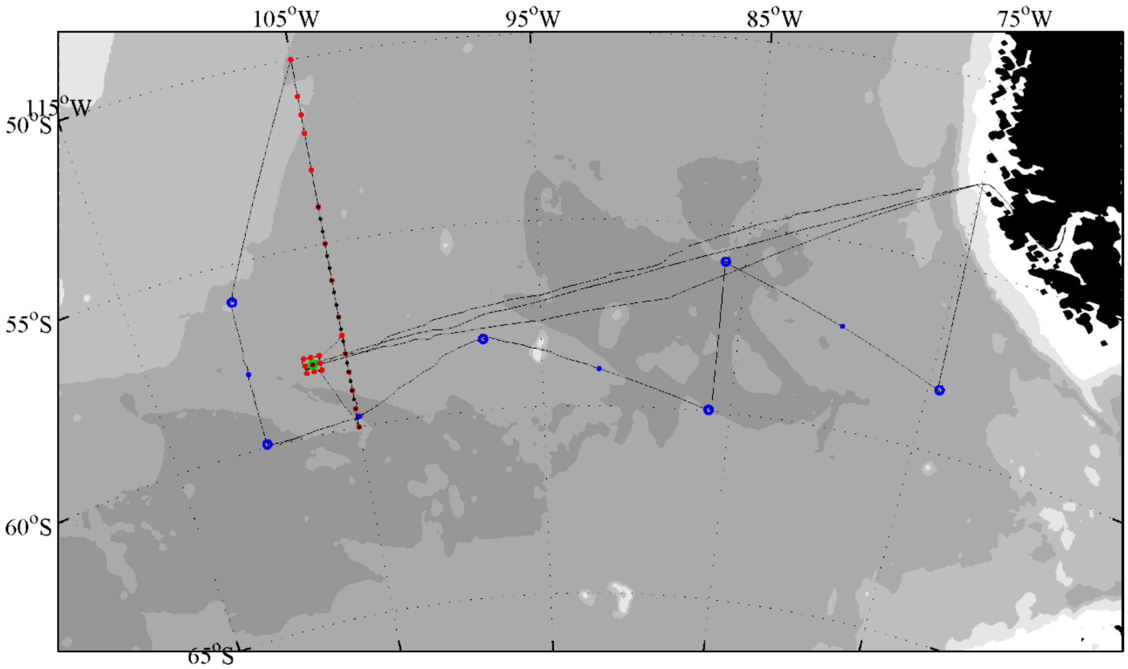


Fig. 8.1. SOLO float launch locations. The first four SOLO floats were deployed on the outbound part of the track at the small blue dots, between sound source moorings (large blue dots). The other two SOLO floats were deployed in the region of the tracer deployment indicated by the green area surrounded by the red square of CTD stations.

Most SOLO floats functioned as expected. The primary result is that all the sound sources were heard, some of them at much greater distance than expected (> 1000 km). The second float launched had a flaw and could not listen to any source. All of the floats, except for the last one deployed, have been cycling correctly and have been transmitting through the ARGOS system.

One remark must be made about the way the floats are deployed. The cardboard and the quick release provide an efficient and protective way for deploying the instruments. However, the floats may drift too far when in the box, at the surface. First the water soluble tape must dissolve, then the cardboard must get wet, etc. We can estimate that the float might drift more than a mile in active regions like the ACC before actually sinking. This might be the reason we never found tracer at the location indicated by the SOLO float deployed at the site of the injection. For this reason, the last SOLO float was deployed without using the cardboard box, simply using slip lines.

Position data from the floats can be obtained through Service ARGOS. The drifters will soon be declared in the ARGO program and position and profile data may then obtained in near real time through the ARGO GTS and DAC centers.

Float 84815, released with the tracer, reported to ARGOS for the first time at 58° 14' 27"S, 106° 44' 07"W on 14 February 2009 at 13:52:59, 10.8 days after deployment. It had traveled 15.94 km at 188 degrees, at a mean speed of 1.7 cm/s over that time. Float 84818 was not heard from again.

Table 8.1. List of SOLO floats released.

Date	Time (Z)	Latitude	Longitude	S/N	PTT	RAFOS receiver?
01/13/2009	1133	57.2452 S	79.9052 W	902	84825	yes
01/16/2009	2315	59.0063 S	92.0493 W	905	84828	yes
01/19/2009	0332	59.7186 S	104.8877 W	906	84829	yes
01/20/2009	0753	57.9801 S	110.0275 W	904	84827	yes
02/03/2009	1852	58.0955 S	106.6987 W	886	84815	no
02/05/2009	1517	58.1485 S	106.8295 W	889	84818	no

9. Altimetry

Contributed by Valery Kosnyrev, WHOI

9.1. Objective Analysis of the Altimetry Data

Daily altimetry maps of the sea surface in the region of the experiment were constructed using an Objective Analysis (OA) procedure applied to along-track Sea Level Anomaly (SLA) data, a product of AVISO (http://www.aviso.oceanobs.com/). These data can be downloaded from the AVISO website as ASCII files with a time delay 3 days. Altimetry data come in separate files for each of the satellites: Jason, Envisat, and GOES. Unfortunately, data from GOES were not available at the time of the cruise, so Jason and Envisat data were used. AVISO adds the Mean Dynamic Topography (MDT) from Rio, *et al.* (2005); (Fig. 9.1.1) to the sea level anomaly to obtain Absolute Dynamic Topography (ADT). MDT is the Sea Surface Height, with that due to variations in the gravity field subtracted.

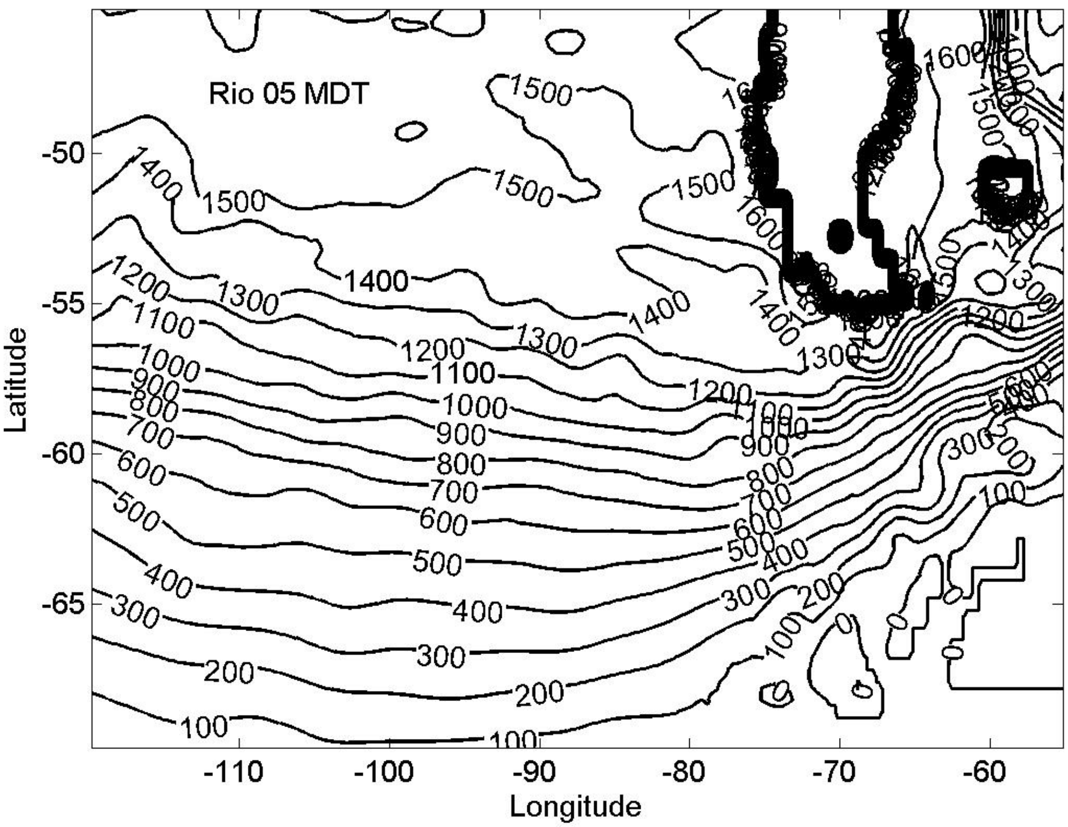


Fig. 9.1.1. Mean Dynamic Topography, from Rio et al. *(2005), in mm.*

As a first step, along track data for a specific domain (time, longitude, latitude, and SLAs) were extracted from NC-formatted files, sorted in time, and then written in one common file, which was used for OA-mapping. This file was processed to find and exclude outliers. Note that AVISO data usually come as high quality data, so that outliers are very seldom found.

The OA algorithm interpolates data from satellite tracks onto a regular (or irregular) grid, covering the domain of interest, with further mapping of the interpolated field. First of all, SLAs in a data file, which includes data from all available tracks for a given number of days (usually, 90-100), are averaged and this average is subtracted from all SLAs in a file. Then, for each point in the mapping grid, OA looks for data points within search radius R_s (in space), and R_t (in time). Using a space-time autocorrelation function, all these data points are weighted and sorted. An interpolated SLA value is calculated for each grid point of the map. Of course, data from the latest tracks are of higher priority. If there are fewer than N_p points found in search radius R_s, points from earlier tracks are considered and weighted. As soon as N_p points are found, they are used to calculate the interpolated SLA value at a given point. When SLAs in all grid points are calculated, the earlier subtracted average is added to the value at each grid point.

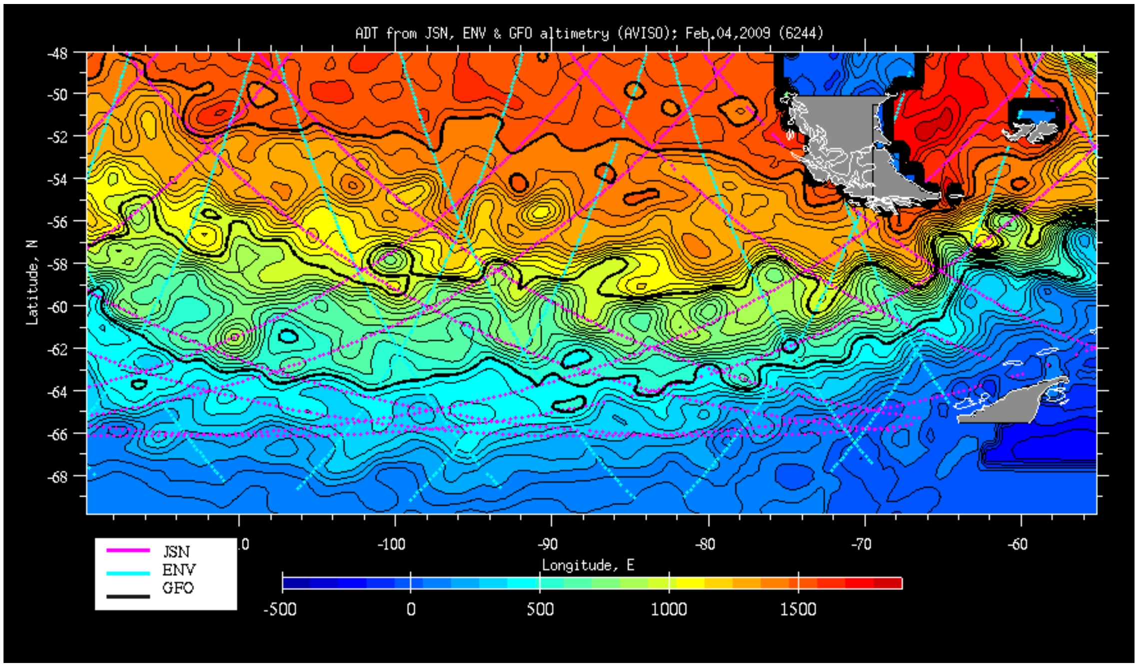


Fig. 9.1.2 Absolute Dynamic Topography from AVISO data estimated for 4 February 2009 using the methods described in this section. The contour interval is 5 mm, with heavy lines drawn at 500, 1000, and 1500 mm. Satellite tracks within ±1 day of the estimation date are shown. The tracer was injected between 3 and 5 February, near 106.7°W, 58.1°S.

All interpolated data are accompanied by SLA error estimates, providing an OA interpolated altimetry map, and an error map. When calculating the very latest possible map, usually on the day of the latest altimetry data, we search only backwards in time. If we would like to draw this map later, data forward in time will also be used. So, two maps for the same day may be a bit different if they are produced at different times. This is the case when we produce the latest map, and then later produce this map as a frame in an animation.

The autocorrelation function has the form described in the Appendix of Siegel et al. (1999), and the parameters are close to those that were used. The phase speed, C_f, was set to zero for the DIMES calculations. A map of ADT for 4 February 2009, roughly the time of the tracer injection, is shown in Fig. 9.1.2 for the overall region of the cruise, and Fig. 9.1.3 shows a detail of ADT and inferred geostrophic surface velocity in the region of the tracer release.

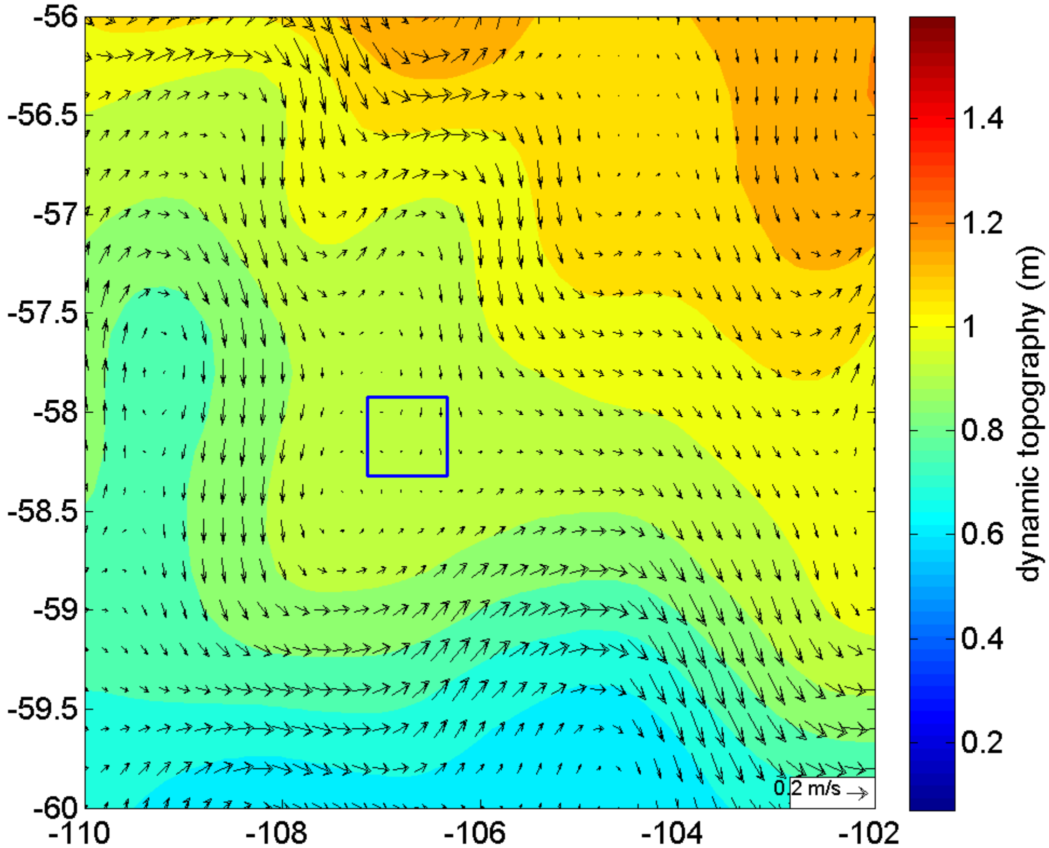


Fig. 9.1.3. Absolute Dynamic Topography at the time of the tracer injection, and surface geostrophic velocity inferred from ADT. The blue square shows the area of the tracer release.

An animation of ADT for the period from 1 December 2008 to a recent date is available at: http://science.whoi.edu/users/valery/altimetry/. It is occasionally updated. Click on "the latest adt animation" under the "DIMES Project."

10. CTD Program

10.1. Overview; Cast Summary

As noted earlier, two Seabird SBE 9*plus* CTD systems were used on the DIMES US1 cruise. One was provided by Scripps Institution of Oceanography as part of the ship's equipment (called the STS CTD) and the other was the Tracer Release Experiment CTD from Woods Hole Oceanographic Institution (called the TRE CTD). Both the STS and TRE CTD's had dual pumped C/T sensors and a pressure sensor for the primary variables. The STS CTD also had an auxiliary SBE 43 Oxygen sensor. Table 10.1.1 lists the serial numbers of the sensors used. Appendix C contains the CTD cast list.

Table 10.1.1. CTD Sensor Serial Numbers and Calibration Dates

Sensor Type	Serial No.	Calibration Date
STS CTD Cast 1:		
Pressure	0777	04 June 08
Primary Temperature	4209	30 May 2008
Primary Conductivity	2115	23 May 2008
Secondary Temperature	4588	23 May 2008
Secondary Conductivity	3057	02 May 2008
Oxygen	1136	28 May 2008
STS CTD Casts 2–11;16-54; 56; 58:66, 68:		
Pressure	0777	04 June 08
Primary Temperature	4209	30 May 2008
Primary Conductivity	2819	21 May 2008
Secondary Temperature	4588	23 May 2008
Secondary Conductivity	3057	02 May 2008
Oxygen	1136	28 May 2008
TRE CTD Casts 12–14; 55; 57; 66; 69:71		
Pressure	59933	31 Oct 2008
Primary Temperature	1085	25 Jul 2008
Primary Conductivity	224	25 Jul 2008
Secondary Temperature	1080	25 Jul 2008
Secondary Conductivity	763	09 Jul 2008
NOTE: Secondary conductivity on the TRE CTD was unusable for the entire cruise. It shows a very large, pressure dependent, difference from the primary sensor.		

The rosette pylons were SeaBird SBE 32 Water Samplers. The STS CTD started the cruise with 22 x 4-liter Niskin bottles on the rosette frame, at positions 1 through 20, 22, and 23. After Cast 28 Niskin #1 broke and was not used thereafter. The Niskin bottles were used for salinity samples for most casts and for tracer samples for many casts. Height above the bottom was determined for each cast from LADCP data when the cast was within 250 m of the bottom. For many of the tracer sampling casts the CTD was only lowered to 1800 m and height above bottom was not determined.

Seventy-one CTD casts of different types were conducted during the cruise. Some were normal vertical CTD/Rosette profiles, done with the STS CTD. Others were tracer injection tows or tracer sampling tows, done with the TRE CTD. The tows comprise a vertical profile from the surface to an isopycnal surface at or below the target isopycnal, a tow along the isopycnal surface several miles long, and a vertical profile back up to the surface. The casts are numbered sequentially, regardless of which CTD was used or whether the cast was a tow or a profile. They are distinguished in the event log with a prefix 'C' for profile, 'R' for injection tow, and 'S' for sampling tow.

Cast 1 (C001 in the event log) was an isolated cast to test the STS CTD, but it served another very useful purpose. It was conducted near 60°S, 105°W and confirmed the inference from XBT profiles that we were south of the Polar Front at that point. Casts 2 through 11 comprised the first part of the section at 105°W, from 50°S to 58°S. Casts 12 through 14 were the injection casts with the TRE CTD, called R012 through R014. Casts 15 through 23 comprised a grid of stations around the injection area, at 12 nautical mile spacing. Cast 24 was a cast to 500 meters to determine whether the 4-liter Niskin bottles had been contaminated with tracer during the injection. They were found to be clean. Casts 25 through 47 comprised the first phase of the tracer search, and were all done with the STS CTD/Rosette. Casts 48 through 53 completed the section at 105°W and were done northward, from 60°S to 57.5°S.

On Cast 51 the SBE 37 and SBE 39 sensors were attached to the CTD/rosette frame for intercalibration with one another and the STS CTD. Casts 54 through 71 completed the tracer survey. Of these, Casts 55, 57, 66, 69, 70, and 71 (labeled S055, etc, with the 'S' for 'Sample') were done with the TRE CTD, and except for Cast 70, were long tows of the sampling array. Cast 70 was a short tow, on which the SBE 37 and SBE 39 sensors were mounted on the sled for intercalibration again with one another, and this time with the TRE CTD. The rest of casts 55 through 71, i.e., 54, 56, 58-65, 67, and 68 were CTD/Rosette casts with the STS CTD. Table 10.1.2 summarizes CTD cast groupings.

Table 10.1.2. Grouping of CTD Casts

Casts	Dates	CTD	Purpose	Comments
1	18 Jan	STS	Test; Identify front.	
2-11	22–25 Jan	STS	Line at 105°W; 50°S to 58°S	
12-14	3–5 Feb	TRE	Tracer injection	Cast 13 was aborted.
15-23	5–7 Feb	STS	Grid around tracer area	
24	8 Feb	STS	Niskin tracer blank test	
25-47	8–11 Feb	STS	Tracer search	
48-53	11–13 Feb	STS	Line at 105°W; 60 to 57.5°S	Intercalibration on Cast 51.
54-71	13–18 Feb	Mixed	Tracer search	55, 57, 66, 69-71 with sampling sled and TRE CTD. Others with rosette and STS CTD. Sensors ere intercalibrated on Cast 70.

Cast Notes:
Cast 1: The primary conductivity sensor (s/n 2115) was bad, the secondary sensor was used.
Cast 2: An altimeter was added but did not work well; we suspected interference with the LADCP as well. The primary conductivity sensor was replaced.
Cast 3: The altimeter was removed.
Cast 8: We noticed a salinity difference of 0.003. We started soaking both sensors in soapy water between all casts.
Cast 13 was aborted due to what turned out to be battery problems with the injection system.
Casts 15-18: No Niskin bottle samples were taken.
Cast 19 is in two parts. The up-cast is in a separate file.
Casts 24–47, 54, 56, and 59–64, and 68 went to 1800 meters with water samples taken for tracer at 4-m intervals above and below the injection density.
Casts 58 and 65 went to 50 m above the bottom and were also tracer sampling casts.
Cast 48: The last 2000 m of the upcast are in a separate file (48A).
Cast 51 included the SBE 37 microcat CTD's and the SBE 39 temperature probes on the rosette frame with the STS CTD for calibration.
Cast 70 included the SBE 37 microcat CTD's and the SBE 39 temperature probes on the sampling sled for calibration.

10.2. CTD Processing

STS CTD data were processed using the Seabird Processing package, Seasoft. The following steps were performed for 24 hz data, creating files with extension .hf:

Datcnv
Wildedit
Alignctd
Filter
CellTM

STS CTD data were further processed into 1-meter, 1-second, and 1-dbar files. The additional steps performed on the .hf files to arrive at these files were:

LoopEdit
Binavg
Derive (to compute potential temperature and sigma-theta)

The values suggested by SeaBird were used in Align, Filter, and CellTM. In LoopEdit all pressure reversals were excluded. The parameters actually used are always listed in the header of each file, along with the history of the processing steps applied to the file.

TRE CTD data were taken at 1 hz, averaged over 24 scans, and no further processing was performed.

10.3. Salinity Calibration: TRE CTD

We were unable to obtain useful data from the Autosal aboard *Revelle*, and therefore we collected salinity samples to be analyzed at WHOI for absolute calibration of the two CTD's. The variability of the results was still disappointing.

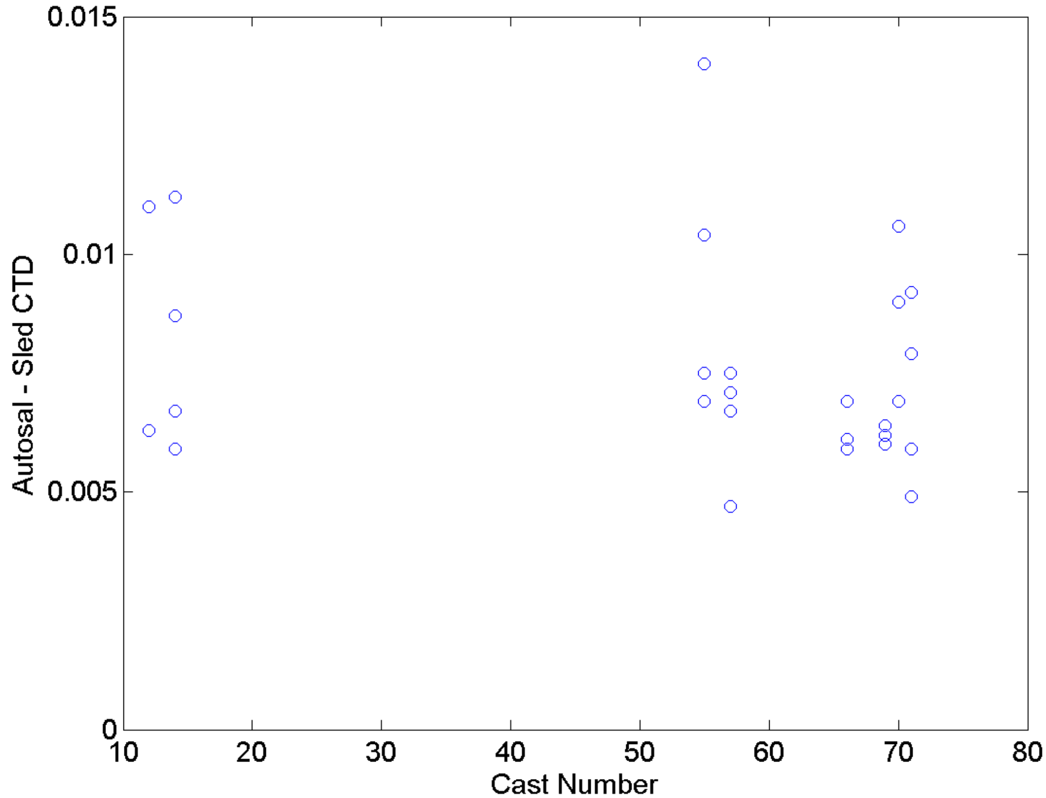


Fig. 10.3.1. Difference between the WHOI laboratory salinometer analysis of bottle samples and the salinity calculated from the TRE CTD primary sensor set. All samples are from approximately 1500 dbar, where the tracer was released. There are 30 points on the graph, but a few of them overlie one another.

As noted above, two CTDs were used during the cruise, the TRE CTD for tracer injection and towed tracer sampling, and the STS CTD for normal CTD/Rosette casts. Figure 10.3.1 shows the difference between the WHOI Autosal salinity and the salinity from the TRE CTD primary sensor pair for samples from the injection and sampling tows. (The secondary conductivity sensor was not working properly). There were 35 samples in all, but the difference for 5 of these was below −0.01, i.e. well off the graph, and were discarded as outliers. Statistics for the remaining 30 samples are shown in Table 10.3.1. The upshot is that according to the bottle samples, TRE CTD salinities for the injection and sampling tow data were low by 0.0075. This correction is rather large for properly handled Seabird sensors, and is not consistent with the comparisons of CTDs to be discussed below. A possible contributor to the high scatter and the large correction is that handling of the 1.2-liter Niskin bottles from the injection and sampling sleds was awkward, and the Niskin bottles were small. The Niskin bottles were mounted horizontally in the sleds and were removed and supported manually by one person while samples were drawn by another, on deck. The samples may also have suffered from the small total volume of the Niskin bottles of 1.2 liters. On the other hand the scatter of these calibration samples is no greater than the scatter of the calibration samples from the 4-liter Niskins on the STS CTD, described below. These samples were taken more normally than those from the TRE Niskins. Hence, because of the relatively large number of samples from the tracer injection depth at or near the time of injection, this calibration will be used. It must be admitted that the choice of this calibration was influenced by the observation that this calibration puts the tracer peak from this cruise close to the same density at which it was found in the survey conducted twelve months later, in 2010.

Table 10.3.1. Statistics for WHOI Autosal – CTD Sensor Salinity

	TRE CTD
No. of samples	30
Mean	0.0075
Std. Dev.	0.0021
Std. Error	0.0004

10.4. Calibration of the STS CTD Primary Conductivity Sensor

Water samples taken in salinity bottles from the 4-liter Niskin bottles in the STS CTD/Rosette system were also returned to Woods Hole and analyzed on the Autosal salinometer at Woods Hole in May 2009 by David Wellwood. There were 68 samples in all, but again the scatter was large. Five analyses were discarded as being too far from the others to be credible. Conductivities were back-calculated by Cindy Sellers from the salinities reported by Wellwood, using Philip Morgan's seawater property toolbox. The difference in conductivity between the Autosal analysis and that reported by the STS CTD primary conductivity sensor, ΔC_0, varied from 0.000 to 0.015 mS/cm for the remaining 63 samples. The five discarded values were:

0.0294
0.0183
0.0189
0.0834
–0.0030

A scatter plot of the remaining 63 points as a function of pressure, and various curve fits to the data to be discussed below, are shown in Fig. 10.4.1. Table 10.4.1 lists some relevant statistics. We describe here a sequence of attempts that were made to devise a calibration curve for the sensors. The third one is the one used.

A linear fit to all 63 samples gives the following formula for ΔC_0 as a function of pressure, P, shown as the dash-dot line in Fig. 10.4.1 (see also Table 10.4.1):

$$\Delta C_0 = 0.0040 \text{ mS cm}^{-1} + (5.2 \times 10^{-7} \text{ mS cm}^{-1} \text{ dbar}^{-1}) (P - 3439 \text{ dbar}) \qquad \text{(Fit 1)}$$

Fit 1 was not used; see Fit 3.

This formula gives a value of 0.0030 mS/cm at 1500 m, the approximate depth of the tracer injection. The uncertainty in the slope, though, leads to an uncertainty of more than 0.0006 mS/cm at 1500 m. One could easily argue for a value of 0.002 mS/cm or less, however, from the samples taken at 1500 dbar, if the two high points at that pressure were ignored. Note that deep Niskin bottles were preferentially sampled during the cruise because of the constancy of the temperature and conductivity at great depth.

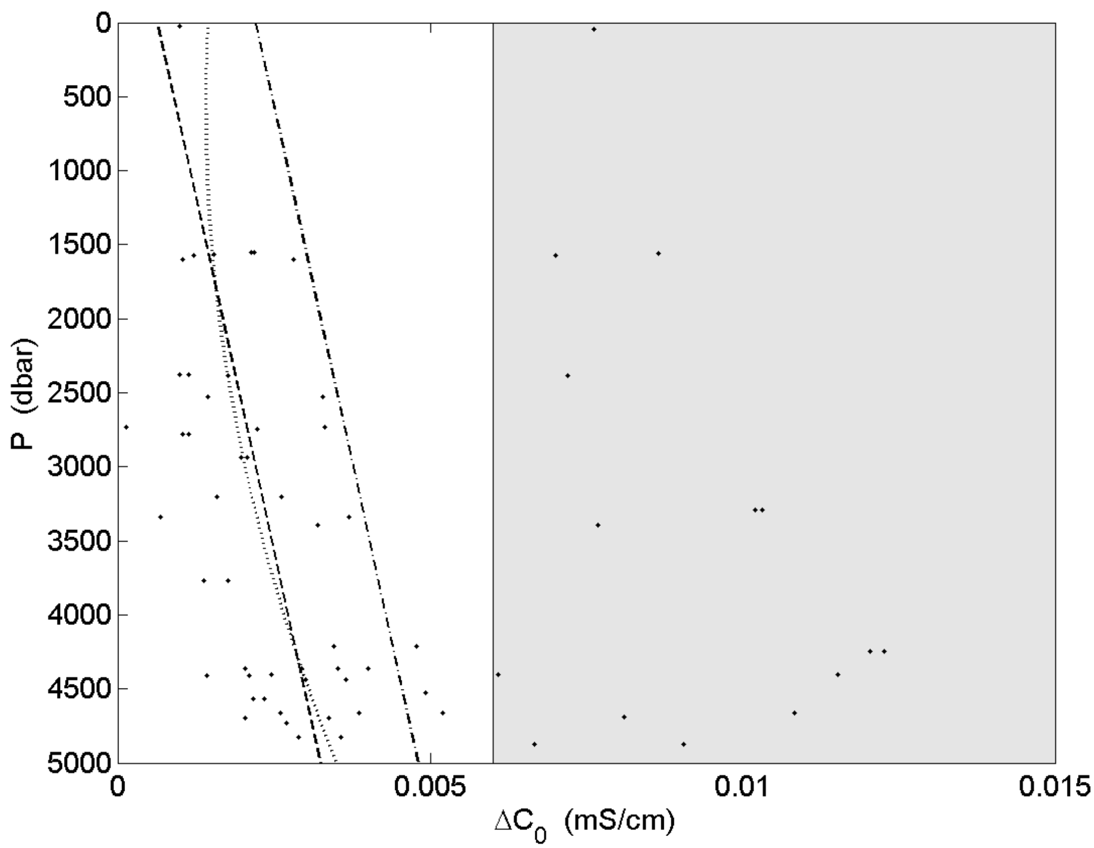


Fig. 10.4.1. Scatter plot of ΔC_0 as a function of pressure. The dashed-dot line is a linear fit to all the points shown (Fit 1). The dashed line is a linear fit to the points outside the shaded area (Fit 2). The dotted curve is a quadratic fit to the points outside the shaded area (Fit 3).

If we exclude all the samples with $\Delta C_0 >$ 0.0060 mS/cm, we obtain perhaps a more credible correction. The number of samples is reduced from 63 to 48, but the standard deviation of ΔC_0 is reduced from 0.0032 to 0.0012, a value that might be expected of the calibration if it were done better. The dependence on pressure is not changed, no doubt fortuitously, but the mean correction is reduced from 0.0040 to 0.0024 mS/cm. The fit of the pressure dependence gives 0.0014 mS/cm at 1500 dbar. The slope of the linear fit seems too strong and therefore to give too small a correction at 1500 dbar. The formula for this fit, shown as the dashed line in Fig. 10.4.1, is:

$\Delta C_0 = 0.0024\ \mathrm{mS\ cm^{-1}} + (5.2 \times 10^{-7}\ \mathrm{mS\ cm^{-1}\ dbar^{-1}})\ (P - 3439\ \mathrm{dbar})$ (Fit 2)

Fit 2 was not used; see Fit 3.

Table 10.4.1. Statistics of $\Delta C_0 = C_{autosal} - C_0$ (units: mS/cm)

	Most points	**Only $\Delta C_0 < 0.006$**
Data restriction	$0 < \Delta C_0 < 0.015$	$0 < \Delta C_0 < 0.006$
Number of samples	63	48
Mean	0.0040	0.0024
Std. deviation	0.0032	0.0012
Std. Error	0.00040	0.00014
Linear fit to pressure:		
Mean pressure	3439 dbar	3431
Intercept	0.0022 at P = 0	0.00063
Slope	5.20 E-07 $\mathrm{dbar^{-1}}$	5.23E-07 $\mathrm{dbar^{-1}}$
Std Error of the Slope	3.16 E-07 $\mathrm{dbar^{-1}}$	1.30 E-07 $\mathrm{dbar^{-1}}$
Probability that slope > 0	~95%	>99.9%

Fit 2 (dashed line) in Fig. 10.4.1 seems too low at 4500 dbar and at 1500 dbar and too high at 3000 dbar. Furthermore there is only one sample above 1500 dbar, near P = 0, so any pressure-dependent extrapolation into that region seems unwarranted. The quality of the data certainly does not justify a higher order fit. In fact one could argue for just a constant correction to the conductivity. However, it turns out that a quadratic fit to the data alleviates all of the problems mentioned, and gives a nearly constant correction for P < 1500 dbar (Fig. 10.4.1, dotted curve).

Quadratic correction of conductivity as a function of pressure (Fit 3)

The formula for the recommended correction, Fit 3, is:

$\Delta C_0 = [0.0014418 - (1.2015 \times 10^{-7}\ \mathrm{dbar^{-1}})\ P + (1.0620 \times 10^{-10}\ \mathrm{dbar^{-2}})\ P^2]\ \mathrm{mS/cm}$ (Fit 3)

where the correction should be valid over the range of pressures from 0 to 5000 dbar. The only cast that went deeper than 5000 dbar was Cast 001, which went to approximately 5450 dbar. The formula there gives $\Delta C_0 = 0.0039$ mS/cm, which seems well within uncertainty limits, and so will be accepted.

The uncertainty in the correction to the conductivity would be approximately $\pm$0.001 mS/cm, if one were blind to the points that have been excluded. However, given that the mean of all 63 points was 0.0040 mS/cm and the mean of the 48 points, with $\Delta C_0 > 0.006$ excluded, was 0.0024 mS/cm, we place the uncertainty in the calibration at $\pm$0.002 mS/cm.

In summary, Fit 3 will be used to correct the primary conductivity sensor for the STS CTD downcasts. This correction is to be added to the recorded conductivity in the raw data file. It will be applied to processed STS CTD files before archiving. Again, the uncertainty in the correction is placed at $\pm$0.002 mS/cm.

The conductivity correction at 1572 dbar, the mean pressure of the injection, is 0.0015 mS/cm, which gives a salinity correction of 0.0019 at the conditions of the injection. This value differs from the correction of 0.0018 mS/cm for conductivity for the STS CTD from the mean of just the six accepted samples from near 1500 dbar, but the two values are well within the uncertainty of the calibration.

As will be seen below, this correction at 1572 dbar is not consistent with the correction applied to the TRE CTD sensors, when the TRE and STS CTDs are intercalibrated through the SBE 37 sensors. Rather, the best estimate of the correction to be applied to the salinity for the bottle trips during tracer sampling is +0.0037.

10.5. CTD Intercalibrations

10.5.1 Overview

During tracer sampling, internally recording instruments, two SBE 37 (MicroCat CTDs) and four SBE 39 with temperature sensors only, were attached to the CTD wire to measure the tilt of the sampling array and the temperature profile variability during the tow. So that these data could be used with the SBE 9*plus* (9+ for short) data, and to help intercalibrate the STS CTD with the TRE CTD, during Cast 51 the six instruments were attached to the CTD frame for inter-calibration with the STS CTD. During Cast 70 the instruments were attached to the sampling sled for comparison with the TRE CTD. SBE 37 and SBE 39 data are available at the cruise-data website as described in Appendix E.

10.5.2. TRE SBE 9+ CTD versus SBE 37 and 39 Sensors

The inter-calibration during cast 70 had all instruments mounted on the sampling sled, less than 10 cm apart. The sled was held at a constant depth of approximately 1550 m for approximately 12 minutes. Calibration was performed using the data gathered while the sled was at this depth. The internally recording instruments sampled at 5 second intervals, while the 9+ data were sampled at 24 hz and averaged in 1-s bins. The 9+ data were resampled to the SBE 37 and 39 time grids by binning the 9+ data in the vicinity of each SBE 37 and 39 time grid point.

Table 10.5.2.1. TRE SBE9*plus* - SBE 37 and 39 Sensors, Cast 70

Sensor Serial No.	Quantity	Mean difference	Rms difference
0646	Temperature	+0.00164	0.00065
0650	Temperature	+0.00220	+0.00084
0651	Temperature	+0.00173	0.00075
0652	Temperature	+0.00182	0.00037
5916	Temperature	+0.00104	0.00030
5937	Temperature	+0.00075	0.00029
5916	Pressure	−5.70	0.88
5937	Pressure	+32.85	0.94
5916	Conductivity	+0.000305	0.000033
5937	Conductivity	−0.000076	0.000033
5916	Salinity	+0.00610	0.00033
5937	Salinity	−0.01783	0.00030
744 CTD samples were binned into 142 five-second averages. Note the large pressure difference for S/N 5937.			

Time series of the difference between the 0.2-hz 37 and 39 sensor values, corrected by adding the mean differences in Table 10.5.2.1, and the TRE CTD sensor values, are shown in Fig. 10.5.2.1.

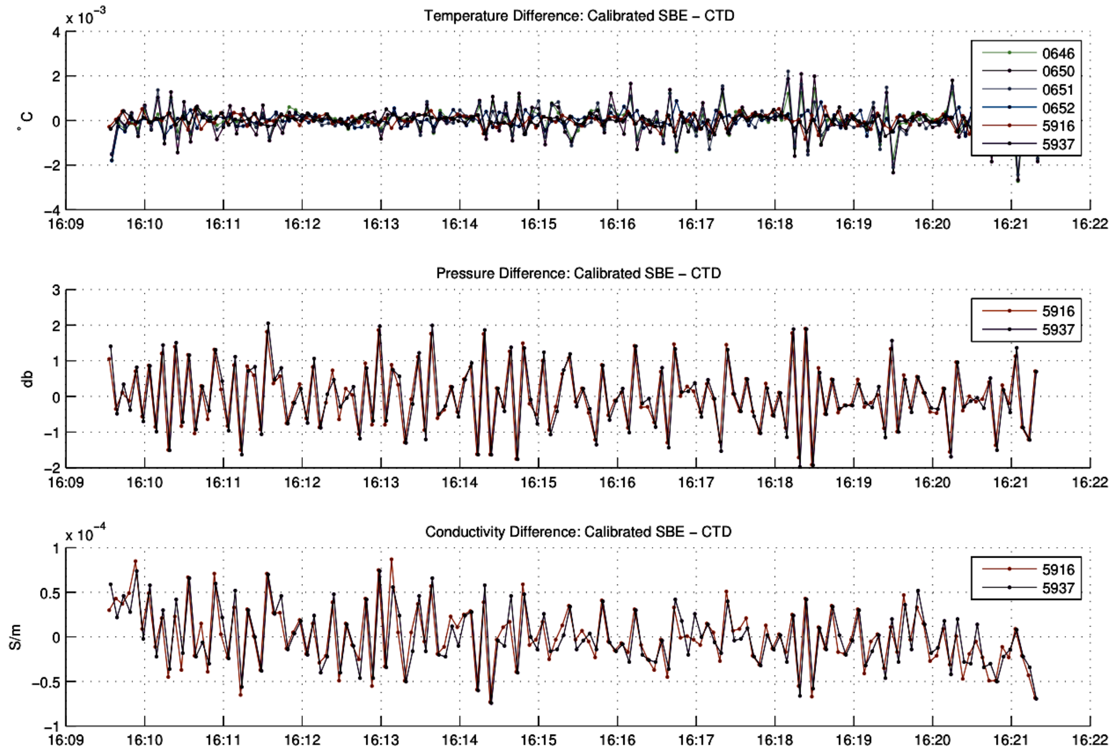


Fig. 10.5.2.1. "Corrected" SBE 37 and 39 data, relative to the TRE CTD versus time during the calibration period, Cast 70.

10.5.3. STS SBE 9+ CTD versus SBE 37 and 39 Sensors

On Cast 51 the SBE 37 and 39 instruments were attached to the rosette frame about half a meter above the CTD sensors. The 24 hz STS CTD 9+ data were averaged over bins centered near each SBE 32 and 39 recording time.

Table 10.5.3.1. STS SBE9*plus* - SBE 37 and 39 Sensors, Cast 51

SBE 39 (0646, 0650, 0651) and Microcat (5916, 5937) Calibration vs. STS SBE 9+ CTD. 13057 CTD samples binned into 110 five-second samples. Summary of Cast 51			
Sensor Serial No.	**Quantity**	**<CTD-standalone>**	**Standard Deviation**
0646	Temperature	+0.00194	±0.00046
0650	Temperature	+0.00270	±0.00051
0651	Temperature	+0.00209	±0.00053
5916	Temperature	+0.00113	±0.00068
5937	Temperature	+0.00090	±0.00063
5916	Pressure	−4.7	±2.4
5937	Pressure	+33.4	±0.6
5916	Conductivity	+0.000777	±0.000093
5937	Conductivity	+0.000265	±0.000032
5916	Salinity	+0.01071	±0.00052
5937	Salinity	−0.01474	±0.00064

Time series of the difference between the 0.2-hz 37 and 39 sensor values, corrected by adding the mean differences in Table 10.5.3.1, and the STS CTD sensor values are shown in Fig. 10.5.3.1.

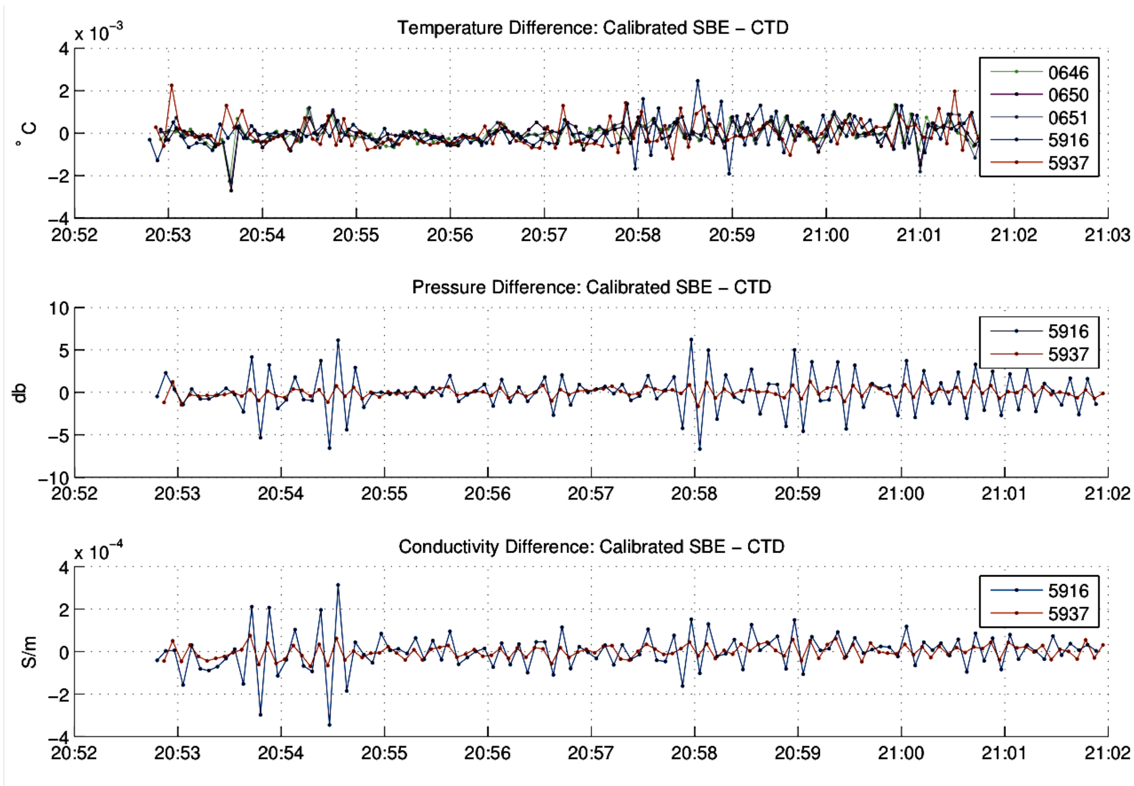


Fig. 10.5.3.1. "Corrected" SBE 37 and 39 data relative to the STS CTD versus time during the calibration period, Cast 51.

10.5.4. Intercalibration of STS CTD and TRE CTD

The WHOI autosal read 0.0075 (n=30; SE=0.0004) higher than the towed TRE CTD, and, according to the quadratic fit with pressure, 0.0019 (SE = 0.0003) higher than the SIO Rosette STS CTD, according to the bottle samples brought back to WHOI. According to the WHOI autosal, then, the STS CTD salinity was higher than the TRE CTD by 0.0056. According to the combined intercalibrations of Cast 51 for the STS CTD and Cast 70 for the TRE CTD, the STS CTD read higher than the TRE CTD by 0.0046 according to SBE 32 sensor 5916 and higher by 0.0031 for SBE 37 sensor 5937 (See Tables 10.5.2.1 and 10.5.3.1). The mean of these two is 0.0038, but the uncertainty is large due to the large difference of 0.0015 between the two sensors. This result is not quite consistent with the result from the WHOI Autosal, which would give a difference of 0.0075 - 0.0019 = 0.0056 through the quadratic fit, Fit 3 above, at 1572 dbar. However, the correction of 0.0019 for the STS CTD is based on a fit to all the Autosal data from the cruise and over a wide range of pressure, while the Autosal samples for the TRE CTD are all from the target density surface near the time of the release.

At any rate it was decided to add 0.0075 to correct the TRE CTD salinity for US1. This correction was made to netCDF files for the TRE CTD available at the cruise-data website as described in Appendix E. To summarize here the corrections for the STS CTD: 0.0037 is added to the salinities for the tracer bottle samples taken near the target density surface, while Curve Fit 3 is used to correct the conductivity from the downcast data, and this curve fit gives a salinity correction of 0.0019 at the target density.

10.6. Towed Array Results

Figure 10.6.1, a repeat of Fig. 2.9.1, shows the tow tracks for the array of integrating samplers and CTD sensors. Figures 10.6.2 through 10.6.6 show time series of T, P, S, and γ_n (neutral density) for each sampler tow (Casts 55, 57, 66, 69, and 71). The sensors were mounted at fixed distances above and below a central sled on which was mounted the TRE 9+ CTD. The sled is maintained within about 1 meter of the target isopycnal surface with the automated winch system. All seven of the instruments have temperature sensors. The time series of temperature, seen in the top panel of each set, give a measure of the variations in stratification along the tow tracks, which are on the order of 20 km long. Three of the instruments, including the CTD, include pressure sensors. Their time series, seen in the second panel of each set, measure variations of the vertical position of the target isopycnal surface along the track, due to internal waves and other fine structure. The purpose of the pressure sensors above and below the sled was to measure the wire angle, since the distance between sensors is known. Two of the instruments, plus the central CTD, include conductivity sensors. These time series, in the third panel of each set, combined with the temperature time series, may tell us how much of the temperature variations are compensated by salinity variations. Some idea of density compensation is also given by the time series of neutral density, seen in the bottom panels for the instruments with both conductivity and temperature. These give a more direct record of stratification than the T-sensors, but for fewer layers.

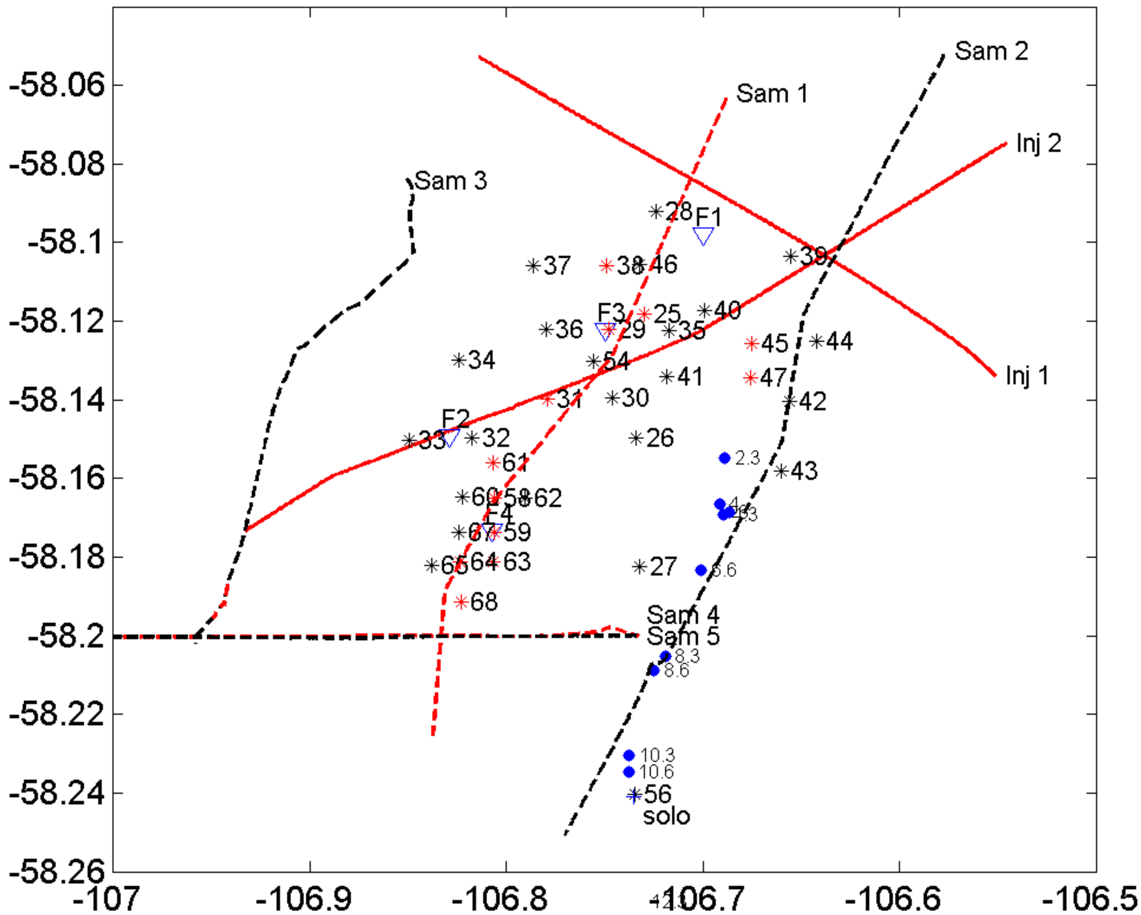


Fig. 10.6.1. Sampler tow tracks (Sam 1 through Sam 5). The solid red lines show the tracer injection tracks. The dashed lines show sampling tow tracks, with red indicating tracer found at the target density surface, black not found; Sampler tow 2 (Sam 2) actually did find some tracer, but none at the target density surface. The labels are near the starting end of the tow tracks. Sampler tow 4 at 58.2ºS found tracer the first time through, but the array did not trip properly so few samples were obtained. On the repeat, Sampler tow 5, no tracer was found. This figure is a repeat of Fig. 2.9.1, where the other features are explained.

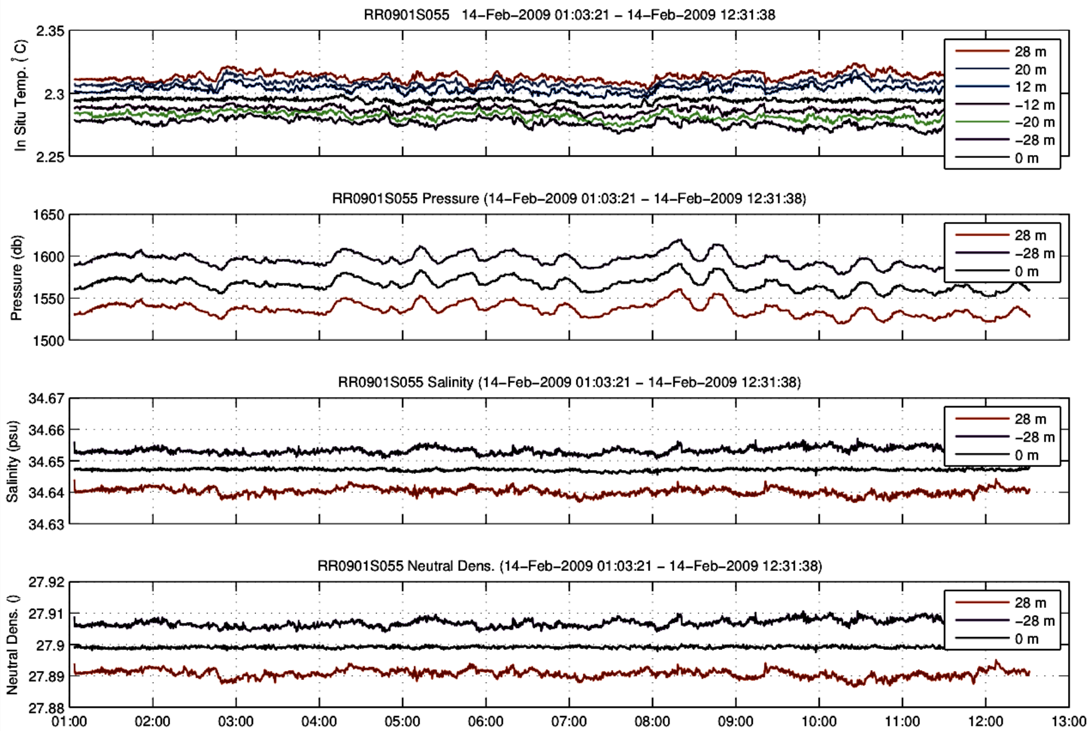


Fig. 10.6.2. Sampler tow 1 (Cast 55) towed sensor array signals. The TRE CTD is at 0 m, and the SBE 35 and 37 instruments are distributed along the upper and lower wire at the indicated distances from the CTD. The tow track is labeled Sam 1 in Fig. 10.6.1.

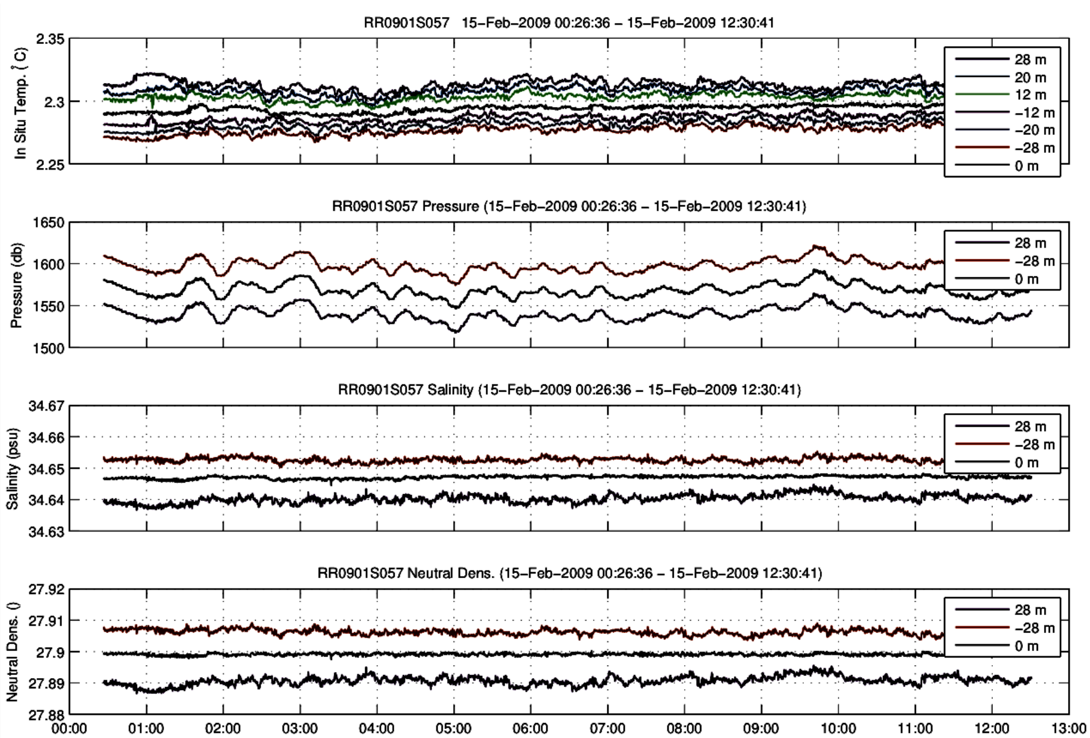


Fig. 10.6.3. Sampler Tow 2 (Cast 57), Sam 2 in Fig. 10.6.1. See caption for Fig. 10.6.2.

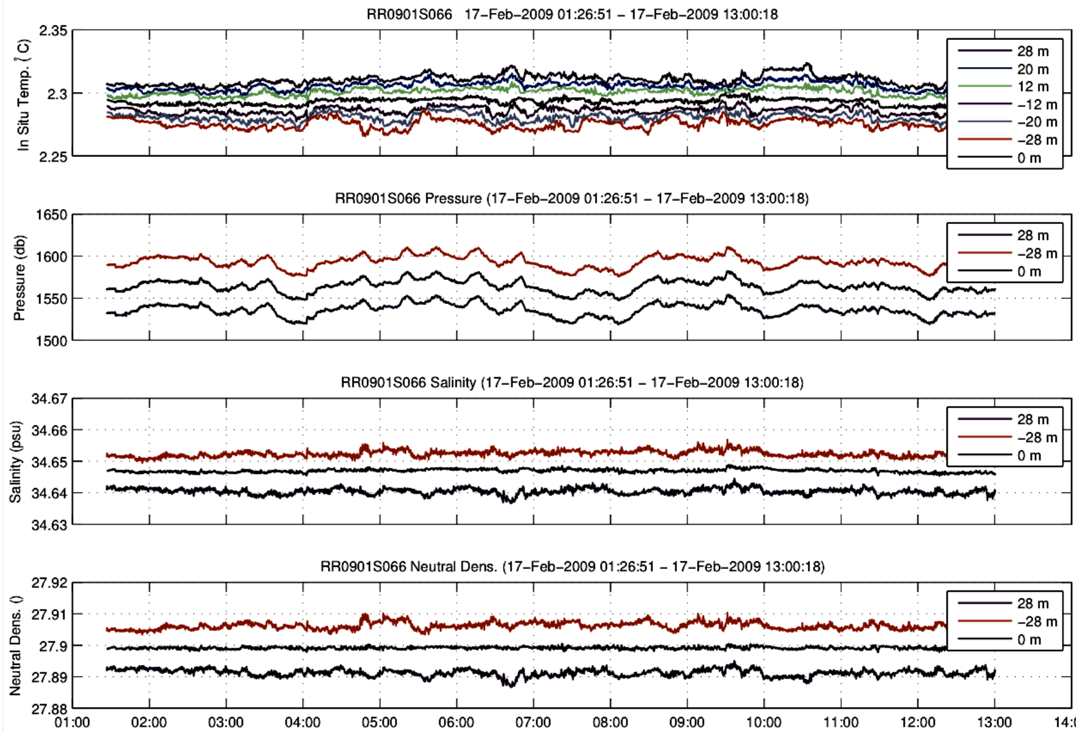


Fig. 10.6.4. Sampler tow 3 (Cast 66), Sam 3 in Fig. 10.6.1. See caption for Fig. 10.6.2.

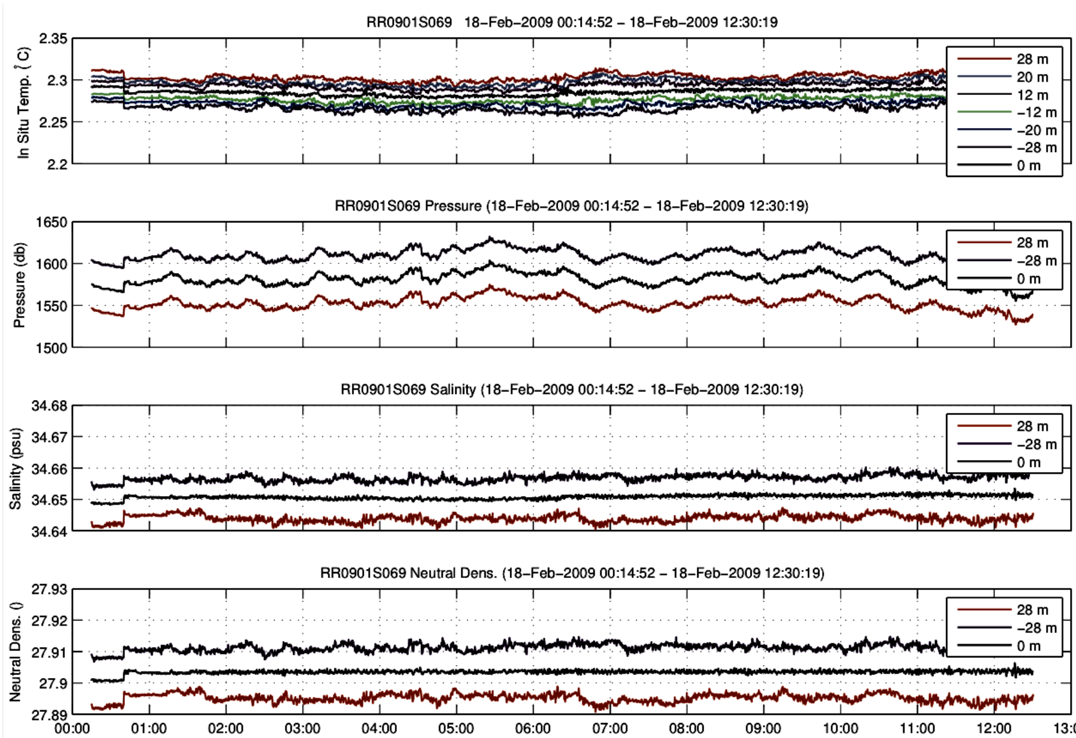


Fig. 10.6.5. Sampler tow 4 (Cast 69), Sam 4 in Fig. 10.6.1. See caption for Fig. 10.6.2.

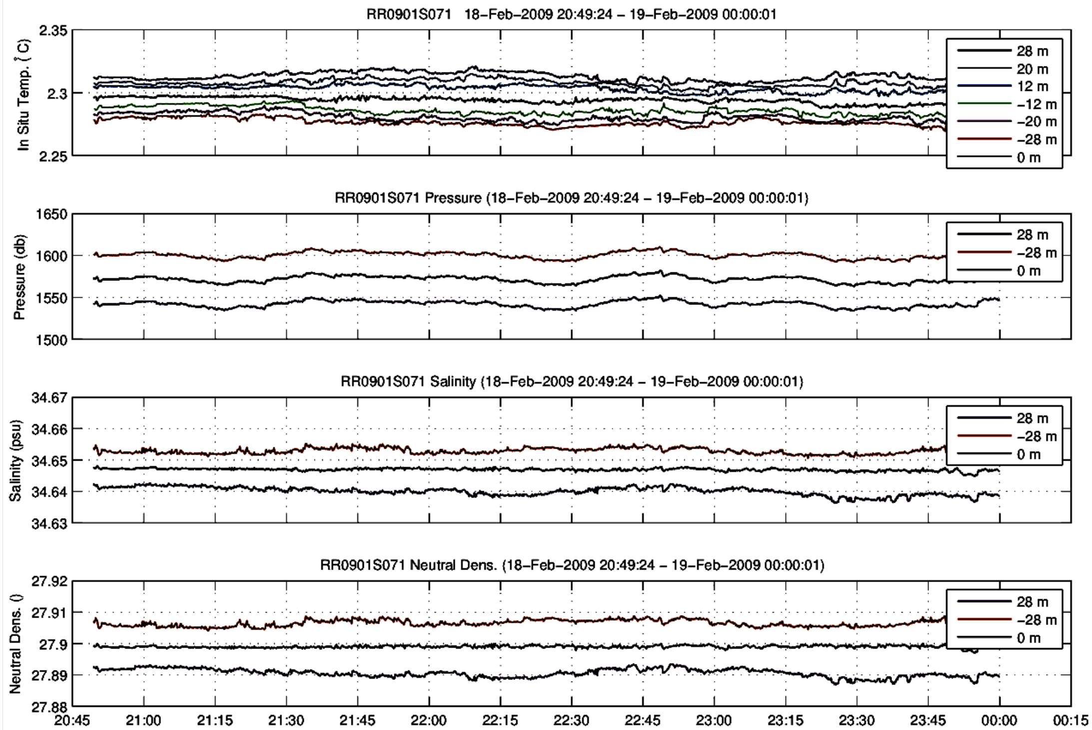


Fig. 10.6.6. Sampling tow 5 (Cast 71), Sam 5 in Fig. 10.6.1. See caption for Fig. 10.6.2. The record shown is only the first three hours of the 10-hour tow.

11. Lowered Acoustic Doppler Current Meter Measurements

Contributed by Peter Lazarevich, FSU

11.1. Introduction

The technique of Lowered Acoustic Doppler Current Meter profiling, or LADCP for short, is a relatively recent innovation in the field of oceanography. It involves using an acoustic profiling instrument (ADCP), mounted to a frame, which is lowered by wire through the water, typically to the full ocean depth. The ADCP transmits acoustic pulses at a certain frequency, which travel away from the instrument. These pulses encounter small bubbles, tiny micro-organisms, sharp density gradients, or the bottom, and have a chance of reflecting back towards the ADCP. The refection comes back towards the ADCP not as a sharp pulse, but continuously over time. Objects closer to the ADCP will reflect the pulses sooner than those that are more distant. Furthermore, if there is any motion of the reflecting objects, and thus the water, relative to the ADCP, the reflection will be Doppler-shifted. It is this Doppler shift, as a function of distance from the ADCP, which is the primary measurement made. The result is an estimation of the water velocity profile near the instrument. When used in a lowered mode, one can generate a water velocity profile for the entire water column.

There are several prerequisites for collecting useful LADCP profiles. First, the ADCP must be configured to run in lowered mode. Second, the ADCP must be attached to a suitable frame (heavy and stable) for deep casts. Third, CTD (conductivity, temperature, depth) measurements must be collected simultaneously with the ADCP. Fourth, navigational data must be collected during the cast. And finally, ship-based ADCP measurements, if available, must be formatted in a certain fashion.

11.2. Instrument Description

LADCP measurements were made with an RDI WHS300 ADCP, mounted in a downlooking configuration onto the CTD frame (Fig. 11.2.1). This instrument pings at 300 kHz and has an internal battery and memory for data storage. The CTD was a Sea-Bird SBE-9*plus* system with dual temperature and conductivity sensors. Ship navigation data were automatically recorded during the cast and incorporated into the CTD data files. The shipbased-ADCP measurements were made with an RDI 150 kHz Narrowband unit.

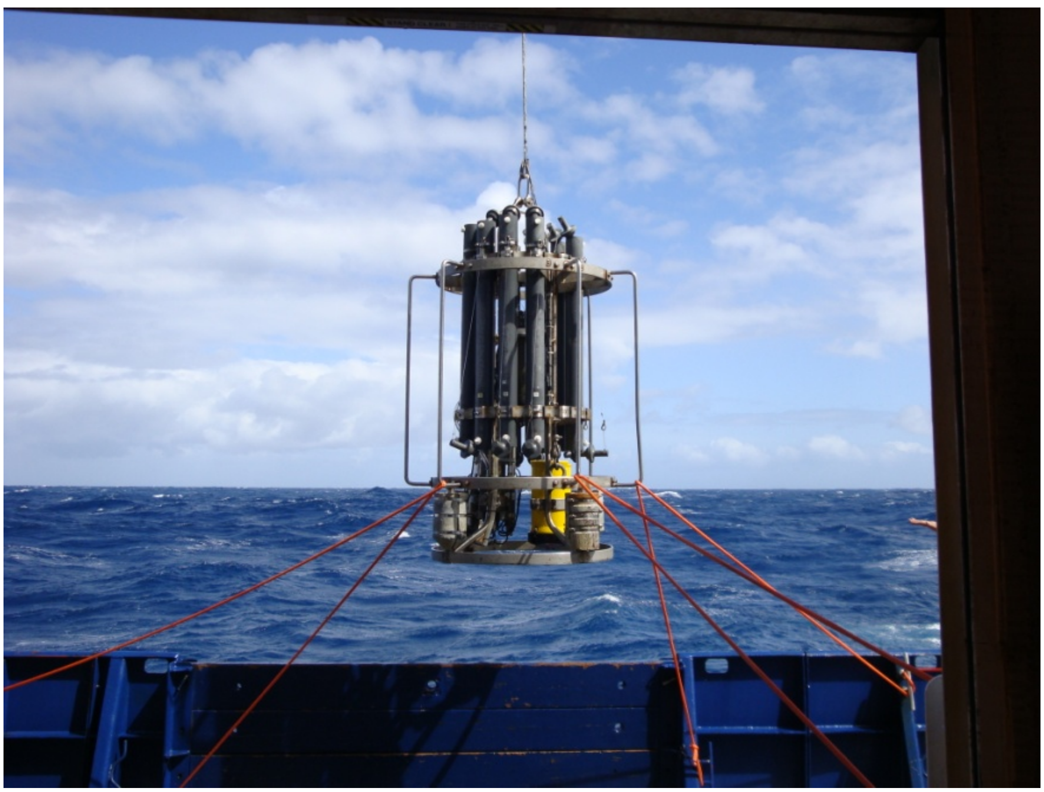


Fig. 11.2.1. The LADCP (yellow and black unit to the lower right) mounted within the CTD frame.

11.3. Data Processing Methods

LADCP data were processed using the "LDEO" software. This was originally written by Martin Visbeck while at the Lamont-Doherty Earth Observatory (LDEO) at Columbia University, and has been significantly revised and improved by Andreas Thurnherr (LDEO). The software is a collection of MATLAB scripts that read the raw LADCP, CTD, shipbased-ADCP (SADCP) and navigation data files, merges these data, and then computes velocity profiles and other statistics. The latest version of the software is available at the following location: http://www.ldeo.columbia.edu/cgi-bin/ladcp-cgi-bin/hgwebdir.cgi/LADCP_acquire/.

The LDEO software is reasonably straightforward to work with and requires only a modest amount of adjustment to produce some initial results. However, the software is quite complex and involves many processing steps and user-defined parameters. The LADCP data presented here are based upon a nearly 'default' implementation of the software. Only a few parameters have been altered and these are noted below. For a complete description of the software, see the user's guide written by Andreas Thurnherr, located at the above http site.

The first step is to configure the ADCP instrument for lowered mode operation and specify parameters which fine-tune the handling of the raw data onboard the instrument. A list of these parameters is shown in Table 11.3.1.

Table 11.3.1. LADCP Settings for Lowered Mode Operation

Command	**Description**
EX11111	use Earth coordinate system and tilt sensors
LF0000	ignore the first 0m of the profile data
LN20	number of depth cells for lowered mode = 20
LP1	pings per ensemble = 1
LS0800	depth cell size = 8 m
LV175	ambiguity velocity = 175 cm/s radial
LW1	narrow bandwidth option
TE00:00:01.00	time per ensemble = 1 s
TP00:00.00	time between pings = 0 s

Next, several Matlab files must be modified to both indicate the location of the LADCP, CTD, GPS, and SADCP data files and to specify the format in which these parameters are stored. These files are: set_cast_params.m, loadctd.m, loadctdprof.m, loadnav.m, and loadsadcp.m.

Finally, several user-defined parameters were changed from their default values, as shown in Table 11.3.2. These parameters control how the software handled spike filtering and bottom-track detection. The spike filter was turned on and set to a modest level. Also, the bottom track range was adjusted to better match our observed ranges. Finally, we chose not to mask any bins. The default setting is to remove the first bin, but we did not find the need to do so.

Table 11.3.2. Values for Several of the User-defined Parameters within the LDEO Software

Parameter Setting	Description
p.btrk range = [200 20]	bottom track range from 200 to 20 m
p.edit mask dn bins = [ ]	do not mask any bins
p.edit spike filter = 1	turn spike filter on
p.edit spike filter max curv = 5	spike filter level = 5

11.4. The LADCP Casts

A total of 30 LADCP casts were made: 1 trial profile, 16 profiles along the RAFOS float deployment line, 2 during the tracer injection sled tows, 9 profiles in a grid around the tracer site, and 2 profiles at the tracer injection site. All of these, except for the two sled tows, were full-depth CTD stations, where the depths varied between 3,700m and 5,400m deep. The two sled tows were 11 hour-long at approximately 1,600m. Station locations are shown below in Fig. 11.4.1. LADCP data and figures are available at the cruise-data website as described in Appendix E.

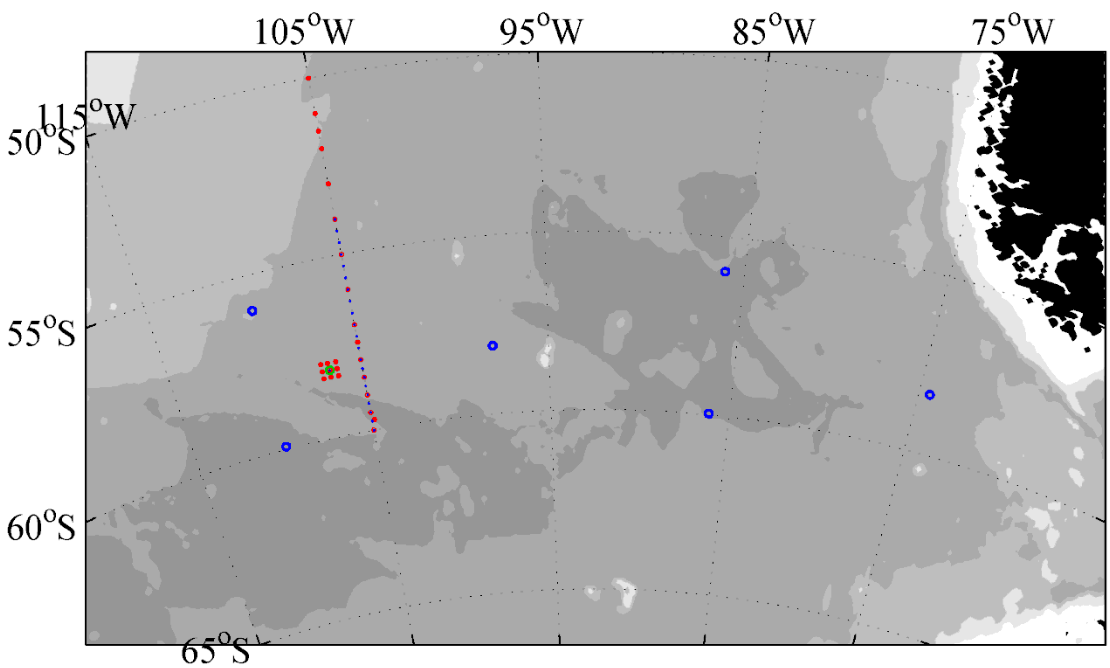


Fig. 11.4.1. The DIMES study area, showing the CTD/LADCP cast locations (red dots). Also shown are the locations of the moorings (large blue circles), RAFOS floats (small blue dots), and tracer injection site (green dot).

Table 11.4.1 is a summary of the LADCP casts. It lists the filename of the raw LADCP data file, the type of cast made, the approximate location, whether any floats were deployed, and any special comments about the LADCP configuration or profile, or difficulties in the data processing.

Table 11.4.1. Summary of the LADCP Casts

Cast	Filename	Type of cast	Location (approx.)		Floats Deployed	Comments
1	RR0901L001	CTD – trial	59°43′S	104°52′W		
2	RR0901L002	CTD – line	50°00′S	105°00′W		Wideband mode
3	RR0901L003	CTD – line	51°00′S	105°00′W		Wideband mode
4	RR0901L004	CTD – line	51°30′S	105°00′W		
5	RR0901L005	CTD – line	52°00′S	105°00′W		
6	RR0901L006	CTD – line	53°00′S	105°00′W		
7	RR0901L007	CTD – line	54°00′S	105°00′W	RAFOS	
8	RR0901L008	CTD – line	55°00′S	105°00′W	RAFOS	
9	RR0901L009	CTD – line	56°00′S	105°00′W	RAFOS	
10	RR0901L010	CTD – line	57°00′S	105°00′W	RAFOS	
11	RR0901L011	CTD – line	58°00′S	105°00′W		
12	RR0901L012	Sled – tow	58°06′S	106°42′W	Float Fest	5s ensemble interval
13	RR0901L014	Sled – tow	58°09′S	106°50′W	Float Fest	5s ensemble interval
14	RR0901L015	CTD – grid	58°19′S	107°08′W		Large up/down bias
15	RR0901L016	CTD – grid	58°07′S	107°08′W		
16	RR0901L017	CTD – grid	57°55′S	107°08′W		
17	RR0901L018	CTD – grid	57°55′S	106°46′W		
18	RR0901L019	CTD – grid	57°55′S	106°20′W		
19	RR0901L020	CTD – grid	58°07′S	106°20′W		
20	RR0901L021	CTD – grid	58°19′S	106°20′W		
21	RR0901L022	CTD – grid	58°19′S	106°44′W		Weak CTD correlation
22	RR0901L023	CTD – grid	58°07′S	106°44′W		No bottom track
23	RR0901L048	CTD – line	59°59′S	105°00′W	RAFOS	No SADCP
24	RR0901L049	CTD – line	59°30′S	105°00′W	RAFOS	No SADCP
25	RR0901L050	CTD – line	59°00′S	105°00′W	RAFOS	No SADCP
26	RR0901L051	CTD – line	58°30′S	105°00′W	RAFOS	No bottom track
27	RR0901L052	CTD – line	58°00′S	105°00′W	RAFOS	
28	RR0901L053	CTD – line	57°30′S	105°00′W		
29	RR0901L058	CTD – tracer	58°10′S	106°48′W		No SADCP, bottom track
30	RR0901L065	CTD – tracer	58°11′S	106°50′W	Float Fest	

11.5. Initial Results from the Injection Sled Tows

The LADCP was installed on the injection sled for the two injection tows. It was hoped that we could make use of velocity measurements during the tow to better predict the movement of the tracer patch during the following weeks. However, there was a substantial tilt observed by the ADCP during the entire tow, roughly 20 to 30 degrees from the vertical. This was perhaps due to a weight excess from additional instrumentation installed on the sled, including the ADCP.

The results from the first tow, made on 3 February 2009, are shown in Figs. 11.5.1 and 11.5.2.: the first shows the CTD data and the second is the estimation of the mean water velocities below the sled. The second figure was generated by subtracting both the ship's lateral velocity and the CTD vertical velocity from the ADCP velocity record. First, the records were filtered with a 5-minute time window, to remove the substantial amount of high-frequency noise in the records. Then, an average velocity was obtained from the ADCP profile by using only a portion of the profile, roughly from 30 to 60 m below the sled. The result one hopes to observe is a near-zero vertical velocity, W. However, as shown in the lower panel of Fig. 11.5.2, the vertical velocity is roughly 2 to 5 cm/s, which is comparable to the horizontal velocities, U and V. Also note that W appears to be dependent upon the vertical velocity of the sled, as it is biased lower for the descent and higher for the ascent. Two likely explanations for this are: 1) that the ADCP magnetic compass was not perfectly aligned with the vertical or 2) the ADCP did not precisely correct for the large tilt. Both of these would result in a component of the horizontal velocity, dominated by the tow speed, to affect the estimate for the vertical velocity.

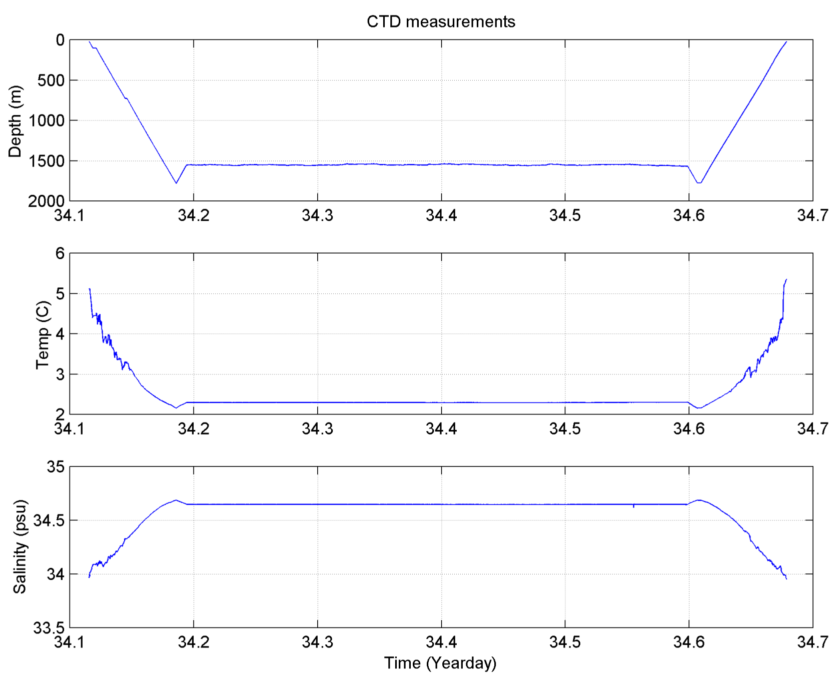


Fig. 11.5.1. The time series of CTD data during the first injection sled tow (Cast 12). Shown are depth, temperature, and salinity. The time axis is given in day of the year, day 34 corresponding to 3 February 2009.

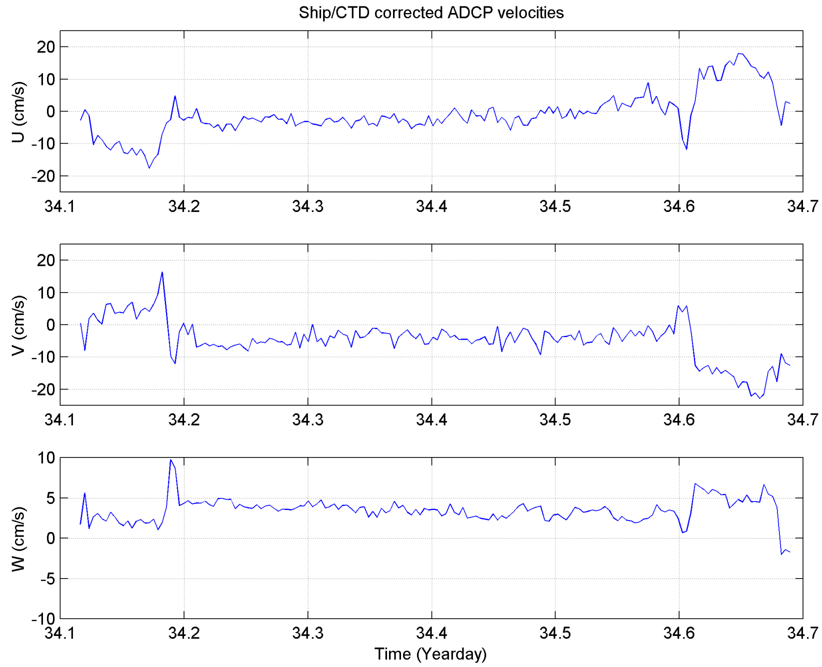


Fig. 11.5.2. Time series of ship/CTD-corrected LADCP velocities, or mean water velocities, during the first injection sled tow. Shown are U, V, and W.

11.6. Initial Results from the CTD/LADCP Profiles

Summary plots from the LDEO software are shown below for a single station, Cast 9 at 56°S 105°W, as these results are representative.

Figure 11.6.1 shows the main results from this cast: the vertical profile of east-west (U) and north-south (V) velocities and their associated errors (main panel). The mean velocity was 2 cm/s eastward. The velocity error was between 2 and 4 cm/s, with the higher values near the bottom of the profile. The smaller panel below the main panel shows a zoomed-in view of the velocity profile within the bottom-tracked portion of the profile. Between 50 and 150 m off the bottom, we measured a velocity of about 6 cm/s to the northeast.

Fig. 11.6.2 shows the time series of vertical velocity (descent/ascent rate) and sensor readings from the ADCP. Of special note are the tilt and heading records. The tilt was almost always less than 2°, which indicates that the CTD frame was very stable in the water during both the downcast and upcast. However, the CTD frame was observed to spin on the wire about 30 rotations during this cast. In fact, several of the earlier casts had about 100 rotations. While these rotations are not thought to degrade the LADCP measurement, they do indicate the potential for the CTD wire to twist and kink-up. As the cruise progressed, the number of rotations became less and less, and twisting of the wire was never an issue.

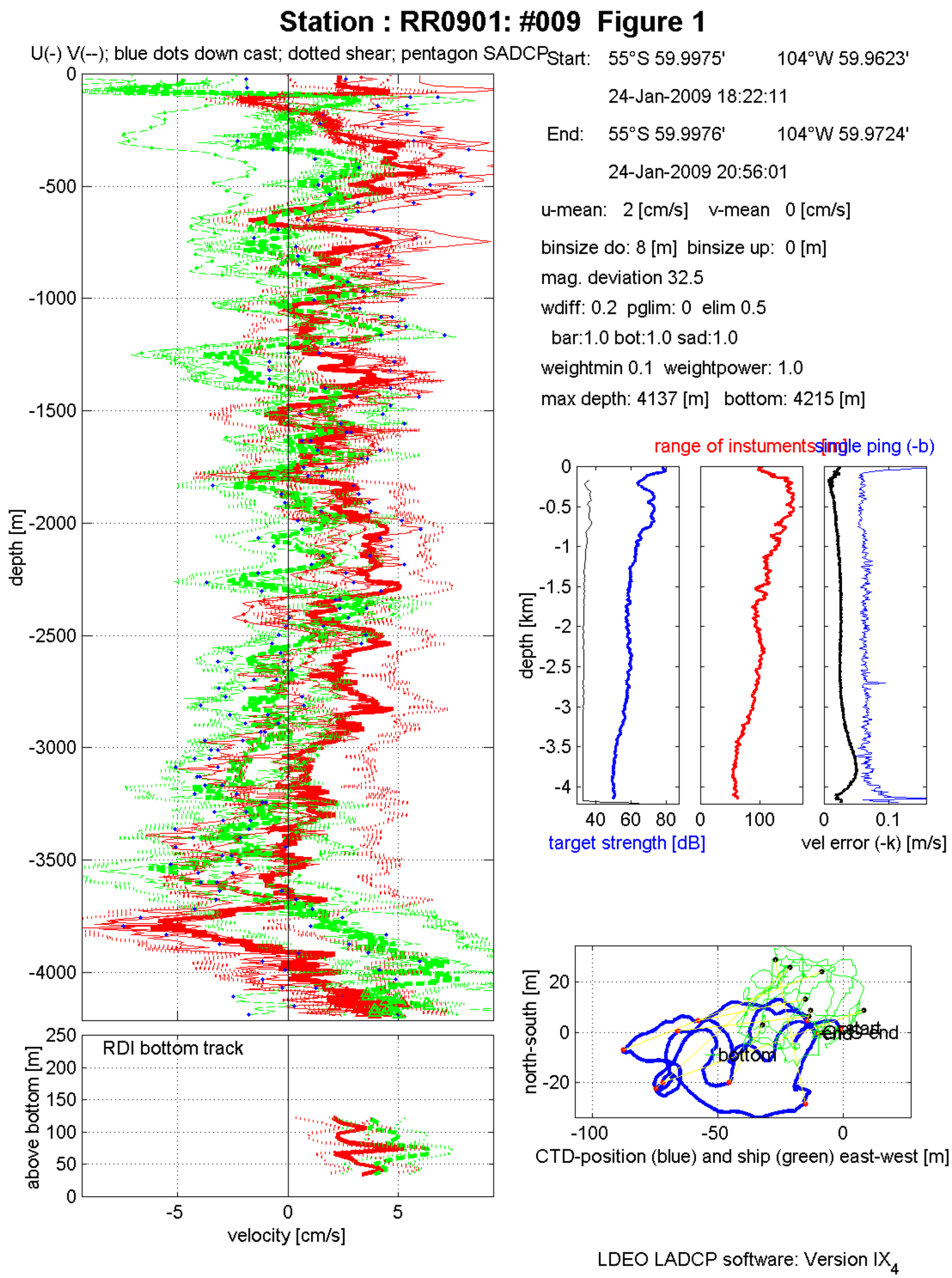


Fig. 11.6.1. Processed profile data from the CTD/LADCP station at 56°S, 105°W, on 24 January 2009. The panels on the left show U, in red, and V, in green, current profiles for the entire water column (upper panel) and near the bottom (lower panel). The heavy lines indicate the mean velocity and the thin lines the velocity error. The panels on the right show diagnostic output from the ADCP, plus the estimated horizontal displacement of the CTD/LADCP relative to the ship during the profile.

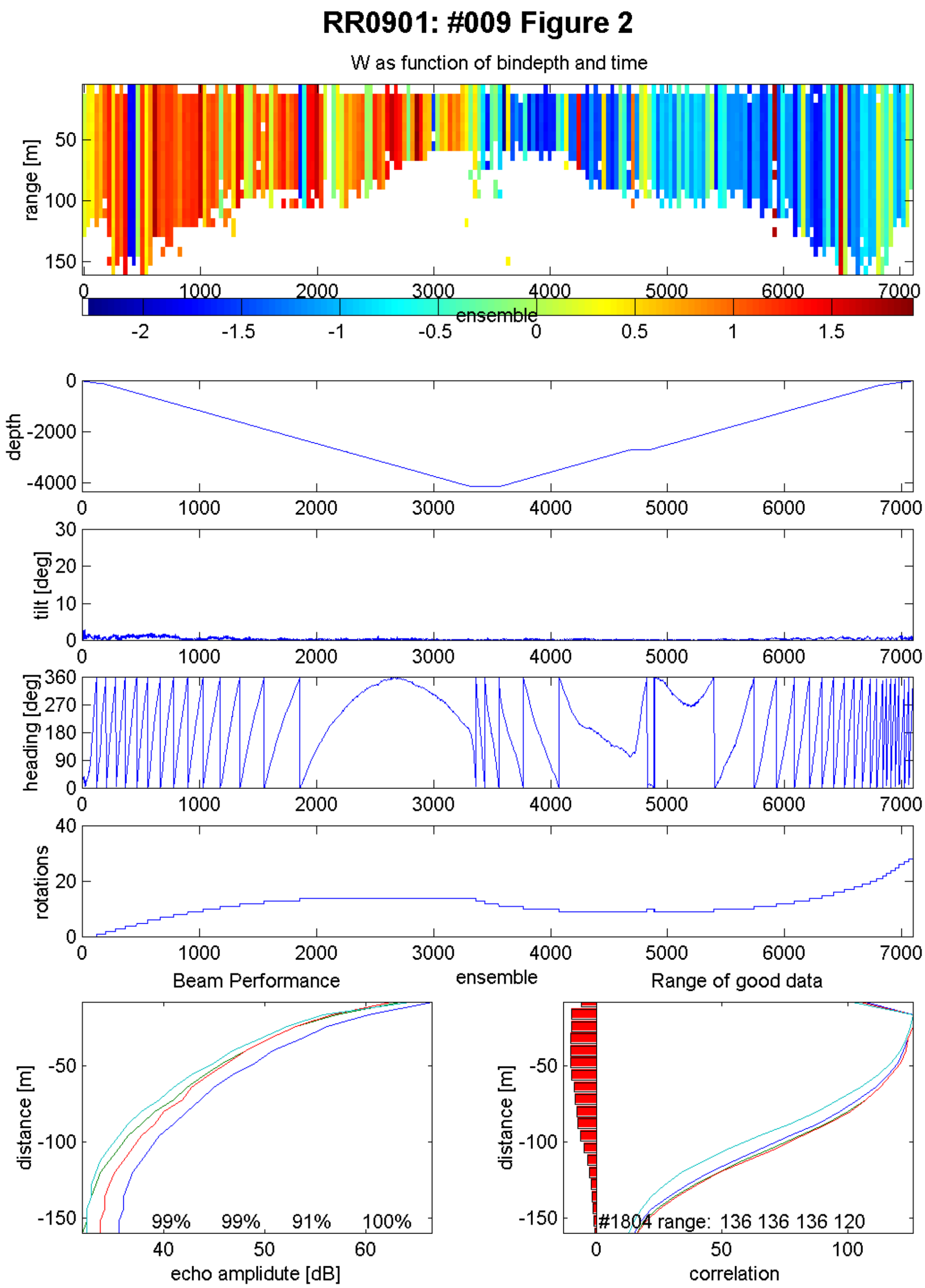


Fig. 11.6.2. Processed instrument data from the same station. The upper panel shows the binned vertical velocity profile as a function of time (ping/ensemble). The next four panels show the depth (in meters), tilt, heading, and accumulated rotations of the CTD frame. Tilts were almost always less than 5°, although excessive rotations (~100) were observed on the first several casts and thereafter slowly decreased. The bottom panels show diagnostic results from each of the four transducer heads on the ADCP.

12. RAFOS Program

The RAFOS floats were manufactured by SEASCAN, Inc., in Falmouth, Massachusetts. Each float was set up to drift on the $\sigma_\theta = 27.673$ kg/m^3 isopycnal surface. Each float is properly ballasted and has a corresponding compressee (Fig. 12.1).

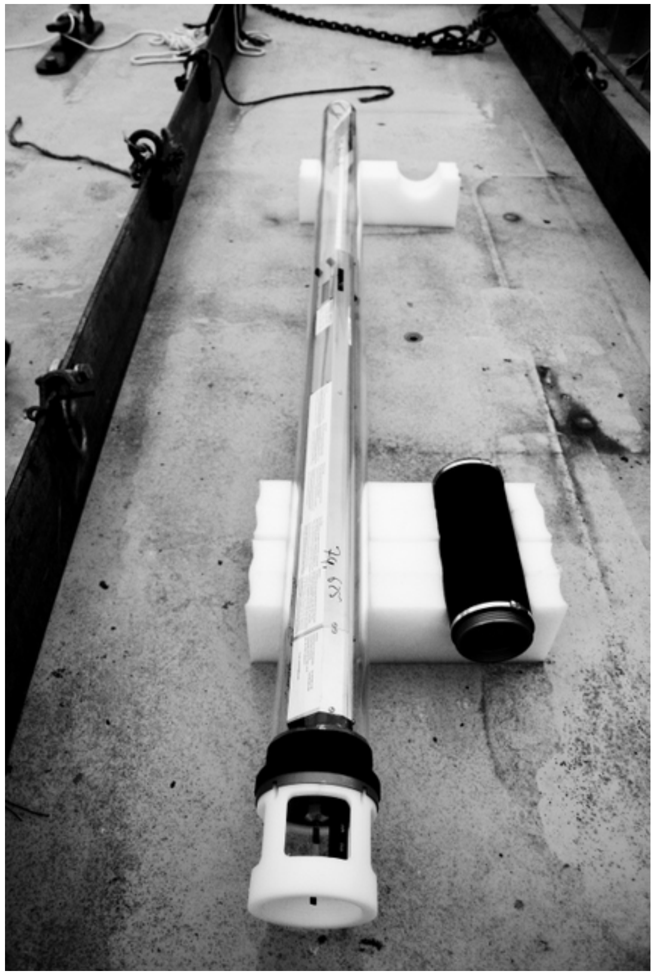


Fig. 12.1. RAFOS float with the compressee/drop-weight detached.

75 RAFOS floats were deployed: 20 prepared by the WHOI group, and 55 by the FSU group. These floats were deployed in triplets along the CTD line at 105°W, starting at 54°S, and at every CTD and XBT station south to 57°40'S, so every third of a degree. Figure 12.2 shows the RAF0S float launch locations. Floats were not released at 58°S due to the need to depart for the medical emergency. The 105°W section was completed later, with the remaining floats deployed from 60°S to 58°S. Three batches of three RAFOS floats were also deployed near the tracer injection site. Most floats were programmed for a two year mission. A group of three was deployed for a mission of 300 days, along with Shearmeter #2, also deployed for a mission of 300 days, so that they surface before US2, the next DIMES cruise scheduled to sample tracer. The last three RAFOS floats were deployed in the area of the tracer patch, along with the last EM-

APEX float and the last Shearmeter, having been programmed for a mission of three years to test the longevity of the instruments. See Table 12.1 for a list of RAFOS float releases.

The floats were deployed using a plastic tube, half immersed in the water, and three tag lines (Fig. 12.3). Starch connectors ensured a quick release and dive of the instruments. Four unsuccessful launches were noted. In three cases the compressee was lost. In one case the compressee was still attached, but the float remained at the surface. One matter of concern is that two of the floats which lost their compressee during the deployment remained at the surface in a horizontal position. This is not optimal for data transmission and worrisome, given that all the floats will drop their compressee at the end of their mission to come back to the surface and transmit their data.

Next year, 105 additional floats will be deployed. 50 of them prepared by the FSU group and 55 of them by the WHOI group, making a total of 180 floats for DIMES.

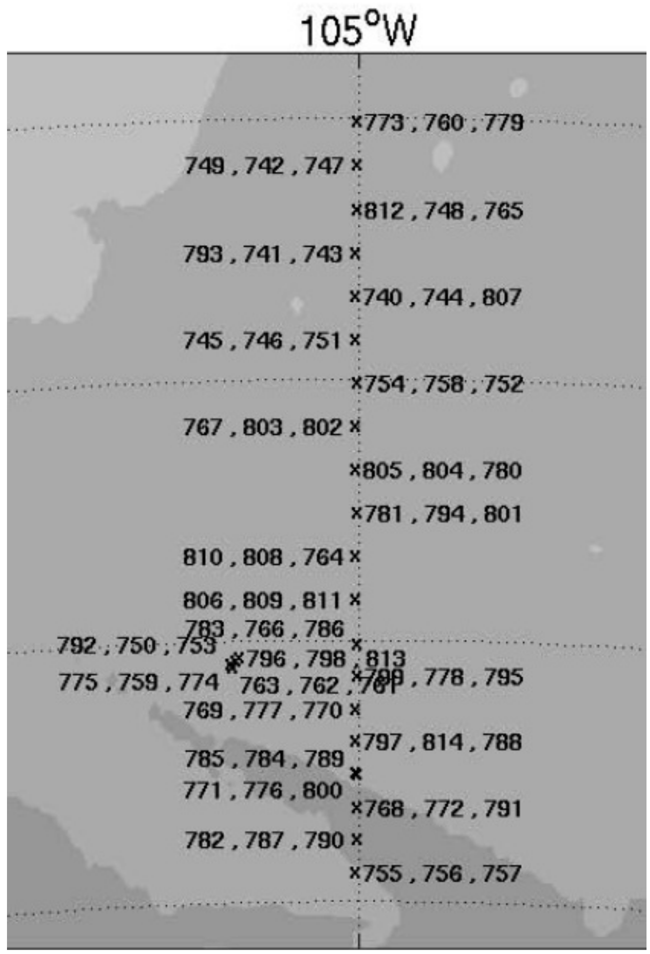


Fig. 12.2. RAFOS float launch locations. The floats were launched in triplets at the positions marked with an 'x'. Latitude is indicated by the slightly curved dotted lines, from top to bottom at 54, 56, 58, and 60 S. There are three 'x's close together, near 106.7 W, 58.1 S, in the area of the tracer release.

Table 12.1. List of RAFOS Float Releases

Float S/N	ARGO ID	ARGOS ID #h	Launch date	Launch time (Z)	Latitude	Longitude
773	820095F	88965	20090124	0121	53 59.99 S	104 59.98 W
760	81FD18B	88952	20090124	0126	53 59.99 S	104 59.98 W
779	82009BE	88971	20090124	0128	54 00.00 S	104 59.97 W
749	849B26A	89430	20090124	0329	54 19.97 S	104 59.96 W
742	84947F2	89423	20090124	0332	54 19.96 S	104 59.93 W
747	849B24C	89428	20090124	0335	54 19.95 S	104 59.87 W
812	820FCC7	89004	20090124	0545	54 40.10 S	104 59.93 W
748	849B25F	89429	20090124	0547	54 40.10 S	104 59.94 W
765	81FD1D4	88957	20090124	0550	54 40.11 S	104 59.95 W
793	820AF98	88985	20090124	1109	55 00.00 S	105 00.02 W
741	84947E1	89422	20090124	1116	55 00.00 S	105 00.04 W
743	849B200	89424	20090124	1114	55 00.00 S	105 00.03 W
740	84947D4	89421	20090124	1336	55 19.88 S	105 00.04 W
744	849B213	89425	20090124	1329	55 19.86 S	105 00.05 W
807	820FC79	88999	20090124	1333	55 19.86 S	105 00.04 W
745	849B226	89426	20090124	1606	55 39.97 S	105 00.05 W
746	849B235	89427	20090124	1600	55 39.97 S	105 00.01 W
751	849B28B	89432	20090124	1602	55 39.96 S	105 00.03 W
754	849B2BE	89435	20090124	2107	55 59.99 S	104 59.96 W
758	849B2F2	89439	20090124	2112	55 59.99 S	105 00.02 W
752	849B298	89433	20090124	2110	55 59.97 S	104 59.94 W
767	81FD1F2	88959	20090124	2314	56 19.58 S	105 00.15 W
803	820FC35	88995	20090124	2309	56 19.58 S	105 00.00 W
802	820FC26	88994	20090124	2312	56 19.59 S	105 00.09 W
805	820FC5F	88997	20090125	0128	56 40.02 S	105 00.09 W
804	820FC4C	88996	20090125	0122	56 40.04 S	105 00.18 W
780	82009C7	88972	20090125	0125	56 40.03 S	105 00.11 W
810	820FCAD	89002	20090125	0858	57 20.02 S	105 00.71 W
808	820FC8B	89000	20090125	0851	57 19.99 S	105 00.44 W
764	81FD1C7	88956	20090125	0855	57 20.01 S	105 00.59 W
781	82009D4	88973	20090125	0652	56 59.59 S	104 59.99 W
794	820AFAD	88986	20090125	0655	56 59.99 S	105 00.00 W
801	820FC13	88993	20090125	0649	56 59.59 S	105 00.01 W
806	820FC6A	88998	20090125	1102	57 39.84 S	105 00.22 W
809	820FC98	89001	20090125	1105	57 39.84 S	105 00.46 W
811	820FCBE	89003	20090125	1108	57 39.89 S	105 00.46 W
796	820AFC7	88988	20090203	1758	58 05.88 S	106 42.07 W
798	820AFE1	88990	20090203	1800	58 05.88 S	106 42.06 W
813	820FCD4	89005	20090203	1802	58 05.88 S	106 42.04 W
775	8200979	88967	20090205	1504	58 08.92 S	106 49.73 W
759	849E100	89440	20090205	1509	58 08.92 S	106 49.74 W
774	820096A	88966	20090205	1512	58 08.92 S	106 49.75 W
792	820AF8B	88984	20090209	2324	58 07.30 S	106 45.02 W

Table 12.1. List of RAFOS Float Releases, continued

Float S/N	ARGO ID	ARGOS ID #h	Launch date	Launch time (Z)	Latitude	Longitude
750	849B279	89431	20090209	2331	58 07.34 S	106 45.13 W
753	849B2AD	89434	20090209	2327	58 07.32 S	106 47.07 W
771	8200935	88963	20090212	0122	58 58.96 S	105 00.01 W
776	820098B	88968	20090212	0119	59 58.97 S	105 00.01 W
800	820FC00	88992	20090212	0125	59 58.96 S	105 00.01 W
755	849B2C7	89436	20090212	0305	59 44.88 S	105 00.13 W
756	849B2D4	89437	20090212	0302	59 44.87 S	105 00.17 W
757	849B2E1	89438	20090212	0302	59 44.87 S	105 00.17 W
782	82009E1	88974	20090212	0801	59 30.07 S	104 59.99 W
787	820AF35	88979	20090212	0804	59 30.13 S	104 59.98 W
790	820AF6A	88982	20090212	0806	59 30.14 S	104 59.98 W
768	8200900	88960	20090212	1002	59 15.01 S	104 59.87 W
772	820094C	88964	20090212	1005	59 15.07 S	104 59.86 W
791	820AF79	88983	20090212	1008	59 15.10 S	104 59.87 W
785	820AF13	88977	20090212	1448	59 00.04 S	104 59.68 W
784	820AF00	88976	20090212	1446	59 00.05 S	104 59.68 W
789	820AF5F	88981	20090212	1450	59 00.03 S	104 59.67 W
797	820AFD4	88989	20090212	1636	58 44.94 S	105 00.08 W
814	820FCE1	89006	20090212	1641	58 44.94 S	105 00.12 W
788	820AF4C	88980	20090212	1639	58 44.93 S	105 00.10 W
769	8200913	88961	20090212	2149	58 30.17 S	105 00.05 W
777	8200998	88969	20090212	2146	58 30.11 S	105 00.06 W
770	8200926	88962	20090212	2151	58 30.17 S	105 00.04 W
799	820AFF2	88991	20090212	2335	58 15.04 S	104 59.96 W
778	82009AD	88970	20090212	2337	58 15.07 S	104 59.97 W
795	820AFB2	88987	20090212	2339	58 15.08 S	104 59.98 W
783	82009F2	88975	20090213	0437	58 00.01 S	104 59.93 W
766	81FD1E1	88958	20090213	0440	58 00.02 S	104 59.92 W
786	820AF26	88978	20090213	0444	58.00.03 S	104 59.88 W
763	81FD1BE	88955	20090216	1919	58 10.37 S	106 48.43 W
762	81FD1AD	88954	20090216	1921	58 10.36 S	106 48.44 W
761	81FD198	88953	20090216	1929	58 10.31 S	106 48.49 W

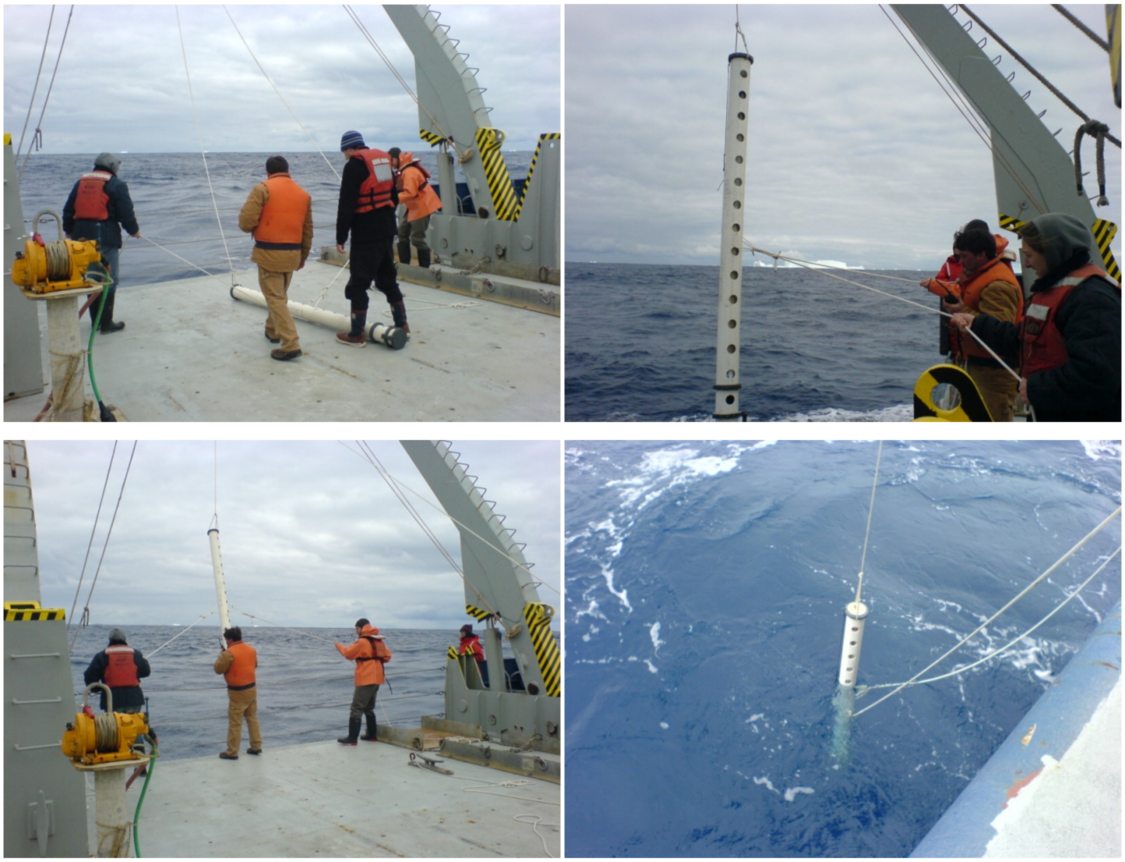


Fig. 12.3. Different steps of a RAFOS float deployment.

13. Surface Drifters

Fifteen surface drifters were provided by the NOAA/AOML group in Miami for deployment during the cruise. They were all of the SVP BD2 type, transmitting every two hours through System ARGOS their position, the water surface temperature, and the barometric pressure.

Three drifters from NOAA/AOML were released near 110ºW in the vicinity of the last mooring deployment. Three more were released along 105ºW during the CTD section prior to the medical evacuation. The remaining nine drifters were deployed in triplets, when we returned to the 105ºW section, at latitudes 58ºS, 59ºS and 60ºS. Deployments in triplets allows a study of pair dispersion at small scales. At the time of release the Polar Front was centered on 59ºS. Figure 13.1 shows a map of the drifter release sites.

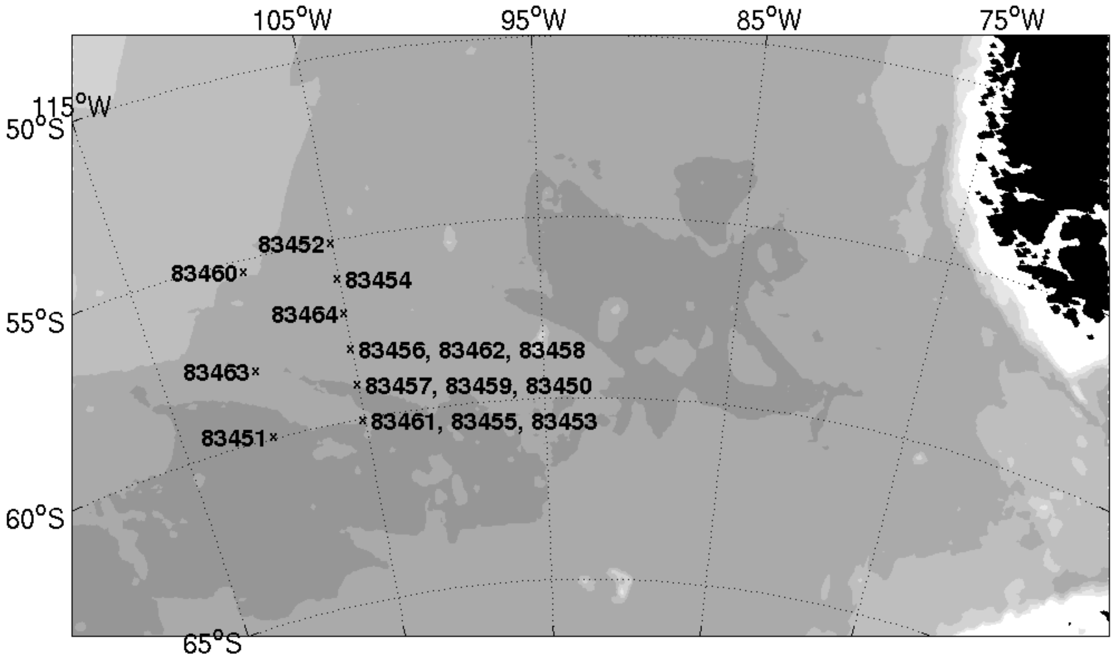


Fig. 13.1. Map of drifter release sites.

The deployment of the drifters is quite simple, consisting in simply removing the plastic wrapping and throwing the buoy, the tether, and the drogue all together, still enveloped in the cardboard and paper tape, as shown in Fig 13.2. For a faster switch to operational mode, one can manually remove the attached magnet. Only one of the buoys was seen losing its cardboard protection quickly after launching.

All but one of the drifters are now transmitting flawlessly. The trajectory data, temperature and pressure data can be obtained at the following NOAA website, using the drifter's WMO ARGOS number:

http://www.aoml.noaa.gov/phod/trinanes/xbt.html (select GTS buoys)

Table 13.1 contains information about the NOAA/AOML SVP BD2 drifter release sites.

Table 13.1. NOAA/AOML SVP BD2 Drifter Release Sites

Date	Time (Z)	Latitude	Longitude	ID	WMO
1/19/2009	1818	59.9018 S	110.0005 W	83451	34514
1/20/2009	0745	58.0119 S	110.0352 W	83463	34532
1/21/2009	0237	55.2954 S	109.3743 W	83460	34512
1/24/2009	1115	55.0002 S	104.9997 W	83452	34516
1/24/2009	2115	56.0052 S	105.0042 W	83454	N/A
1/25/2009	0700	57.0003 S	105.0018 W	83464	34534
2/12/2009	0131	59.9832 S	104.9993 W	83461	34904
2/12/2009	0131	59.9832 S	104.9993 W	83455	34542
2/12/2009	0132	59.9833 S	104.9993 W	83453	34541
2/12/2009	1456	59.0023 S	104.9970 W	83457	34544
2/12/2009	1457	59.0028 S	104.9977 W	83459	34902
2/12/2009	1459	59.0037 S	104.9988 W	83450	34540
2/13/2009	0448	58.0007 S	104.9975 W	83456	34543
2/13/2009	0445	58.0010 S	105.0070 W	83462	34905
2/13/2009	0456	58.0002 S	105.0090 W	83458	34545

Fig. 13.2. Surface Drifter in its cardboard wrapping (Photo by Magdelana Carranza).

14. EM-APEX Floats

Three EM-APEX (Electro-Magnetic Autonomous Profiling Explorer) floats were deployed during the cruise. The EM-APEX float is an APEX float manufactured by Webb Research Company (WRC), modified to measure water velocities while vertically profiling using electric currents generated by motional induction of seawater. These floats contain an internal buoyancy control system for profiling and parking at depths to 2000 m. The floats are equipped with a Sea-Bird SBE 41 CTD, magnetic compass, tilt sensor, GPS, and an Iridium satellite modem for communication with shore. These floats are modified from the original APEX model in two ways. Five electrodes are mounted externally. Four electrodes are mounted orthogonal to the vertical axis of the float and to each other. The fifth electrode serves as a reference. Vanes were added externally to rotate the float as it moves vertically through the water column. The expected operational endurance of the float is 150 full depth profiles. The EM-APEX floats weigh 28 kg and are cylindrical in shape with a 16.5 cm diameter and 135 cm height without antenna.

Velocity measurements are calculated using motional induction. The motion of seawater through the Earth's magnetic field produces electric current and magnetic fields. The horizontal component of an electric field observed by a platform moving with the surrounding water is

$$\nabla_h \phi_a = -F_z (v - \overline{v}^*) \times k - J^* / \sigma$$

where ϕ_a is the apparent potential around a moving sensor, $-F_z$ is the vertical component of the Earth's magnetic field, σ is the electrical conductivity, ν is the local water velocity, $\overline{v}^*$ is a vertically integrated, conductivity weighted, ocean velocity, and J^* are non local electric currents (Sanford 2005). Only ν varies with depth. The other terms represent an unknown depth-independent offset which can be found using an independent velocity measurement.

The initial sequence of profiles serves as a checkout of float parameters and helps resolve bias in the data due to diurnal fluctuation of the Earth's magnetic field. The float descends to 1500 m, returns to the surface, then descends to 1500 m, parks at the target density surface, and descends to 2000 m before returning to the surface for a total of four profiles per cycle. The time spent at the target density surface is initially brief, so that the float profiles continuously until the mission parameters have been tuned. Once the float is tuned for the target density, the parking time is increased to approximately 34 hours. The time spent profiling during each cycle is approximately 14 hours, giving the entire cycle a period of 48 hours. The profiling schedule can be changed via satellite to accommodate changing mission priorities.

The first EM-APEX float (4087) was released on 3 February 2009, 4 hours after the end of the first tracer release streak in the middle of the release track. The second float (4086) was released during the tracer survey on 9 February 2009 between CTD Casts 35 and 36. The third float (3767) was released on 16 Feburary 2009, just prior to tracer Sampling Tow 3. Further details on release locations and times are in the Event Log. If the floats were initially with the tracer patch, tracer sampling revealed that separation between the floats and the tracer occurred by the time position data were obtained from the floats. The first float, 4087, drifted south southwest from its deployment site. The second float, 4086, drifted south southwest from its deployment site. The third float, 3767, drifted southeast from its deployment site, on a trajectory overlapping that of float 4087.

EM-APEX float 4087 was deployed first at 58° 5.82' S 106° 41.93' W at 1842 GMT on 3 February, 2009. The initial attempt to launch the float by slip line failed due to the slip line becoming entangled in the vanes and antenna. The float was recovered and inspected for damage. No damage was found as a result of the initial launch, and the float was successfully launched using a line and dissolving quick release. This float was programmed to surface and transmit information seven hours after launch, but did not transmit for several days. It was determined that the float's internal vacuum may have been set too high, and that it may be have had trouble maintaining buoyancy. This float did surface and transmit data for each profile, and appears to be operating normally at the time of this report.

EM-APEX float 4086 was deployed at 58° 7.38' S 106° 45.24' W at 2338 GMT on 9 February, 2009. This float was deployed using the dissolving quick release method pioneered on the first deployment. This float was programmed to surface and transmit data after one descent and ascent cycle; approximately a seven hour period. The float surfaced as expected and at the time of this report was operating normally.

EM-APEX float 3767 was deployed at 58° 10.31' S 106° 48.49' W at 1929 GMT on 16 February, 2009. This float was also deployed using a dissolving quick release. The float surfaced and transmitted data on time and at the time of this report appeared to be operating normally.

A link to the EM-APEX data is provided at the cruise-data website as described in Appendix E.

15. Shearmeters

15.1. Overview

Four (4) shearmeters, developed at the Woods Hole Oceanographic Institution, were deployed during the cruise. Equipped with a buoyancy engine from an APEX float (Webb Research Corp), these neutrally buoyant instruments descend to a predetermined depth of 1500 meters where they remain for their 1 year mission. The goal was to deploy these floats in the tracer patch. Shearmeters include in their sensor suite a Seabird 41CP CTD sensor. Using the information collected by the CTD, the instrument calculates the depth of the target density and adjusts its ballast via the APEX pump, maintaining the same nominal depth as the tracer injection.

Also as part of DIMES, 6 sound source moorings were deployed in conjunction with 75 RAFOS floats. The Shearmeters contain a RAFOS receiver card and hydrophone which allow them to be tracked acoustically during the mission, giving a location of the instrument every 24 hours. At the end of the instrument's mission, it will drop 5 kg of ballast weight and rise to the surface, transmitting its data via Iridium satellite.

Table 15.1.1. Shearmeter Mission Parameters

Shearmeter	**#2**	**#3**	**#4**	**#5**
Profile Duration	365 Days	300 days	365 Days	365 days
Delay Start	10 min	10 min.	10 min.	10 min
RAFOS Window #1	0105 Z	0105 Z	0105 Z	0105 Z
RAFOS Window #2	0125 Z	0125 Z	0125 Z	0125 Z
RAFOS Window #3	0145 Z	0145 Z	0145 Z	0145 Z
Listing Interval	19 min	19 min.	19 min.	19 min
Target Sig-Theta	27.67450	27.67450	27.67450	27.67450
Sig-Theta Range	0.06000	0.01800	0.01800	0.01800
Sig-Theta Pump Factor	710.41748	710.41748	710.41748	710.41748
Target Temp	2.2870 C	2.2870 C	2.2870	2.2870 C
Target Range	0.0200 C	0.0200 C	0.0200 C	0.0200
Temp Pump Factor (ml/deg C)	265.58789	265.58789	265.58789	265.58789
Min. db/min.	6.000	6.000	6.000	6.000
Max Operational Press	1700.00	1700.00	1700.00	1700.00
Abort Press	2100.00	2100.00	2100.00	2100.00
Launch Date	02/03/2009	02/05/2009	02/16/2009	02/09/2009
Launch Time	18:19:03 Z	14:57:00 Z	09:11:00 Z	23:02:00 Z
Launch Lat	58-05.86 S	58-08.95 S	58-10.38 S	58-07.28 S
Launch Long	106-61.99 W	106-49.77 W	106-48.42 W	106-65.00 W
Surface Date	02/03/2010	12/02/2009	02/16/2010	02/09/2010

15.2. Problems

Shearmeter 02 had a problem that failed to be noticed until after its deployment. During setup just prior to deployment a log file is saved of all communications between the operator and the instrument. This instrument, during routine checkout suddenly changed the date stored in the clock by 1 year. On 02/03/2009 it believes it to be 02/03/2010 and is scheduled to surface one year later. This should not be a problem with the operation of the float but it is an error with the clock date that should be noted. Also, the value of the σ_θ range was entered as 0.06 not 0.018 as desired.

Shearmeter 03 had no problems but the log file of the prelaunch checkout ended prior to the instrument being put into the run mode. This does not affect the instrument in any way.

Shearmeter 04 had a problem addressing the clock module. The clock is the heartbeat of the instrument and without it the instrument would abort its mission shortly after deployment. Working with Steve Faloutico via email, the problem was found. Due to a problem with the component layout of the main circuit board, a modification was required. A jumper wire was attached to the collector of a surface mount transistor to correct the problem, but the wire had broken free. This transistor provides the clock wakeup line. The modification was repaired and the instrument was monitored for 7 days before deployment.

Word was received from Steve Faloutico and Tim Duda on 2/17/09 that Shearmeter 04 had surfaced just 2 hours and 20 minutes after deployment. The files that were sent to WHOI via Iridium indicated that the instrument was ballasted incorrectly and dropped the ballast weights at 2180 meters, which is the preset bailout depth.

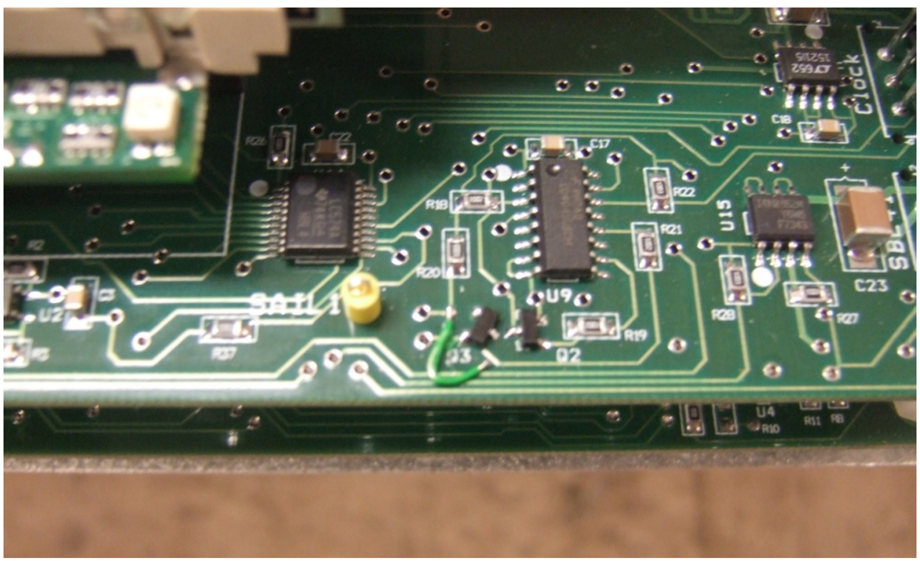


Fig. 15.2.1. Broken solder joint at Q3 in Shearmeter 04.

15.3. Deployment

A new deployment system conceived by Tim Duda, Brian Guest and Dan Duffany was put to the test and worked flawlessly. The design is an aluminum cradle which is attached to a crane or other lifting method (see Fig. 15.3.1). The instrument is supported in the cradle and lifted over the side. When deployment is desired, a line which is attached to a lever arm below the bridle is pulled. This rotates the cradle about 90 degrees and the Shearmeter rolls out and into the water. Improvements that could be made to this device would be to make it longer so that placement with regard to the instrument's center of gravity would not be as critical.

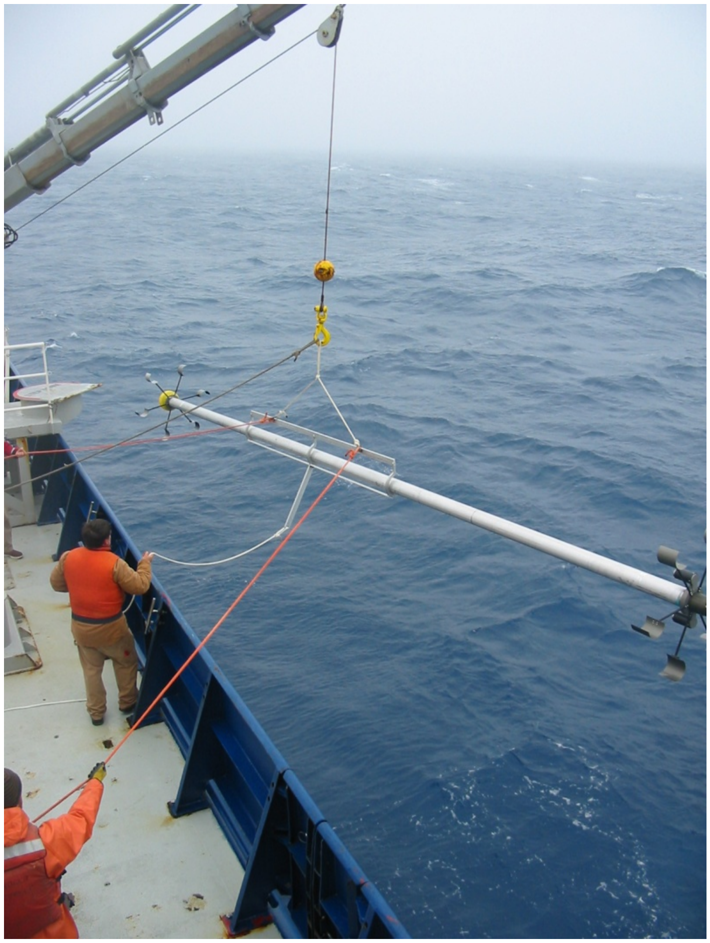


Fig. 15.3.1. Shearmeter deployment.

16. Tracer tracking

The material in this section simply collects and repeats information from Sections 2.9 through 2.13. It was written on 2 November 2014, based on that information, from examination of Fig. 2.9.1 and from recollection of events.

As mentioned in Section 2.9, the tracer was released near an apparent stagnation point in the flow, estimated from sea surface altimetry. We desired a stagnation point because of uncertainty in the flow direction and the hope that the flow velocity would at least be small. We assumed that the flow pattern at the depth of the tracer release would be similar to that at the surface, with lower velocities, i.e., that the flow was approximately "equivalent barotropic" as has been found generally for the ACC.

The flow field at depth was estimated more directly after the injection, and before sampling, with geostrophic calculations using the CTD box survey around the injection track area, as described in Section 2.12. This survey indicated a velocity of about 0.02 m/s to the NNE at the center of the release area. CTD stations 25-28, at the start of the first period of tracer search, which took place from 3 to 6 days after the end of the tracer release, were aimed at finding the core of the tracer. Station 25 did indeed find tracer, but the other three did not. The rest of the stations, from 29 through 47 were chosen to try to find more of the streak of tracer found at Station 25, and to delimit it.

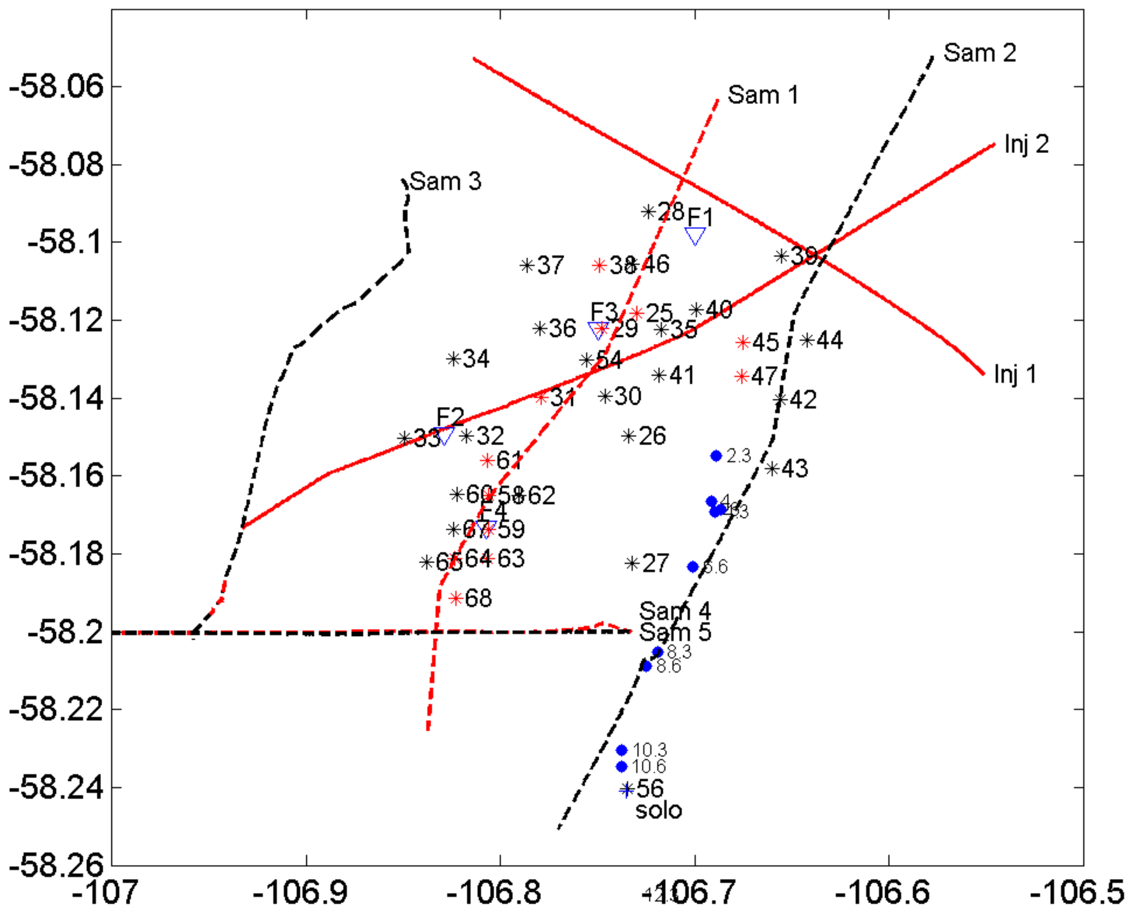


Fig. 16.1 (repeat of Fig. 2.9.1). Tracer injection and sampling tracks, and float positions. Solid red lines: injection tracks; dashed lines: sampling tow tracks, with red indicating tracer found, black not found; Sampler tow 2 actually did find some tracer, but none at the target density surface. The labels are near the starting end of the tow tracks. Sampler tow 4 at 58.2°S found tracer the first time through, but the array did not trip properly so few samples were obtained. On the repeat, Sampler tow 5, no tracer was found. The numbered asterisks indicate CTD stations, red indicates tracer found, black not found. The inverted blue triangles, labeled F1 through F4, mark the release position of sets of floats. Release F1 was done shortly after Inj 1; F2 after Inj2; F3 after CTD 35; and F4 after Sam 2 and CTD 65. At each location a Shearmeter and 3 RAFOS floats were released. A SOLO float was released at F1 and F2. EM-APEX floats were released at F1, F3 and F4. The SOLO float from F1 went to near Station 56 after 10 days, as did the EM-APEX float from F1, the surface locations of which are shown with numbered blue dots, the numbers indicating the days since release. The SOLO float from F2 was not heard from.

Tracer sampling was interrupted by completion of the line of CTD stations and RAFOS deployments along 105 W. After this line was completed, we returned to the survey more of the tracer patch with both CTD/Rosette casts and with the towed array, from 8.5 to 14 days after the end of the release.

CTD Station 56 was chosen to check for tracer at the location of the SOLO float that surfaced 10 days after deployment, a location which agreed with the trajectory of the EM-APEX float released at the same location as the SOLO float (Location F1 in Fig. 16.1; the EM-APEX trajectory is shown by blue dots denoted with the time in days since release in the figure). No tracer was found at this one station and so we went back to obtaining a more complete view of the streak that had been found with the earlier phase of sampling. In this second phase we occupied CTD stations 57 to 58 and sampling tows 1 through 5, with the results shown in Fig. 16.1.

The overall impression from Fig. 16.1, not accounting for the unknown advection during the survey period, is that we surveyed a narrow patch of tracer about 10 km long trending from SSW to NNE, with a leg at the northern end out about 6 km to the ENE. This pattern reflects the shape of the southern half of the injection pattern, perhaps rotated and shifted to the west a bit.

It is important to know whether we sampled a substantial fraction of the tracer released or just a small fragment, to have confidence in the initial condition in density space. The integral of the mean concentration curve from the CTD stations that found tracer, shown in Fig. 2.13.6, is approximately 1.4 x 10^{-5} moles/m^2. Fig. 2.13.5 suggests that the width of the streak is at least 1 km; the features seen in that figure are of at least this scale and there are several in each tow. If we assume this value of 1 km as the width of the streak we sampled and we assume a length of 10 km, which is the approximate length suggested by Fig. 16.1, we have a streak area of 10^7 m^2, and so an amount of tracer on the order of 140 moles. The amount of tracer released was 390 moles, and so we argue that we sampled at least a third of the tracer released.

17. Tracer Injection

The tracer was injected in two streaks. A map in coordinates fixed to the earth is shown in Figure 2.9.1, repeated in Fig. 16.1. The amount injected in the first streak was approximately 42 kg, and in the second 36 kg, for a total of 78 kg. These weights were determined on a rolling ship with an electronic balance, the output of the balance being fed to a computer and averaged over approximately 2 minutes. The estimates may be low, because the amount of tracer transferred from the tanks in which they were sent was 81.3 kg, according to a full weight determined on shore and a weight after the transfer, determined with the electronic balance on the ship, but on a calmer day than the days of the injection. It did not seem that we lost 3 kg during the transfer, which was very well controlled. On the other hand, there were impurities in the tracer tanks. Fluorochemika certified that 98% of the material was CF_3SF_5. It is likely, and it appeared from analysis later on, that a good deal of the remainder was SF_6.

The pump rate setting was constant at 125 for both pumps for the first injection, and gave an orifice pressure of about 2100 psi. However, the injection control unit on the sled was changed between the two deployments in the process of troubleshooting after the aborted tow between the two successful ones. The actual pump rate at setting 125 for the first ICU was measured on deck with Vertrel at 45 ml/min, independent of pressure at the outlet. The second ICU controllers were not calibrated, and apparently a setting of 125 gave a lower pump rate.

The pressure readings during the second streak were much more erratic and much lower than during the first streak. Pump 1 pressures read 500 to 1000 psi, relative to a zero of about -760 psi for much of the cast, but later in the cast surged to more than 2000 psi at times and at other times fell to near zero. Pump 2 pressures read 1000 to 1500 psi, and were more steady than Pump 1 pressures. The pressure gauges are known to be erratic and the amplifiers for the pressure output in the ICUs were made in our laboratory and not standardized. We assumed that the difference between the two casts was due to a change in pressure gauge behavior rather than a difference in the calibration of the pump speed setting. However, this assumption appears to have been wrong. The erratic pressure for Pump 1 is attributed to a failing channel. With one channel working a pressure of around 1000 psi would be expected. The surges to 2000 psi may have been due to the other channel occasionally working properly. Malfunctioning check valves would account for this behavior. The low pressure at Pump 2 can be attributed to a lower pump rate than during the first deployment. These interpretations are consistent with the longer time required to deploy the second streak.

The sled was not ideally ballasted for this injection. We added an LADCP and an RDI DVS without adding any buoyancy, in an effort to measure the velocity of the water relative to the sled for tracking purposes. Also the Vertrel is much denser than the propanol, the old primer fluid. Hence, the sled did not float at the surface, and when the fenders collapsed at depth, it would have been even heavier. Data from the DVS show that the sled towed at an angle of about 20 degrees with the nose higher than the tail. On the second cast we added a fourth accumulator filled with air. This would give extra flotation at the surface, but would add the weight in water of the empty accumulator (22 kg - the weight of water displaced, so perhaps 16 kg) at depth when the air would have been compressed.

A plot of hydrographic parameters measured during the first injection streak is shown in Fig. 17, and statistics from both streaks and are listed in Table 17.1. The rms potential density excursion during overall injection was 3.8×10^{-4} kg/m^3, corresponding to an rms depth excursion relative to the target density surface of 1.5 m in the mean vertical density gradient 2.6 x 10^{-4} kg/m^4.

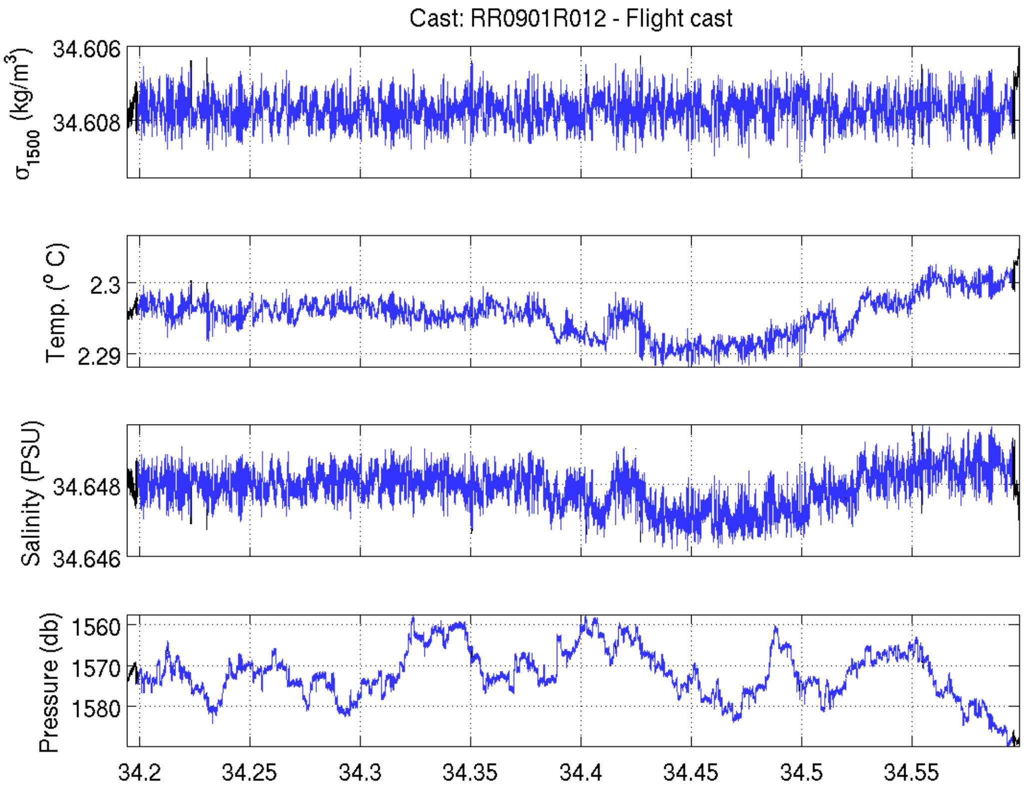


Fig. 17.1. CTD parameters, uncalibrated, during the first tracer injection tow. The decimal day of the year in 2009 is along the horizontal axis. Data frequency is 1 Hz.

Table 17.1. Injection streak statistics.

Streak	1st Streak		2nd Streak		Combined	
Cast No.	RR0901R012		RR0901R014		(weighted)*	
	Mean or total	Standard Deviation	Mean or total	Standard Deviation	Mean or Total	Standard Deviation
Duration (h)	9.46		13.85			
Amount (kg)	42.0		35.8		77.8	
Number of samples	34056		49865		83921	
Pressure (dbar)	1572.9	6.1	1570.9	9.3	1572.0	7.7
Temperature (°C)	2.295	0.0028	2.294	0.0031	2.2945	0.0029
Salinity[1]	34.6554	0.00053	34.6551	0.00053	34.6553	0.00053
σ_{1500}	34.6137	0.00035	34.6136	0.00041	34.6137	0.00038

*Weighted by the amount of tracer injected in each streak
[1]Salinities have been corrected by adding 0.0075; potential densities adjusted accordingly.

18. Tracer Analysis

Tracer concentrations were analyzed by extracting the gases dissolved in each sample into a nitrogen "head space" and injecting an aliquot of the head space gas onto a column in a Shimadzu GC8A gas chromatograph equipped with an electron capture detector. The extractions into the gas phase were carried out in 100-ml syringes. In the case of the integrating samplers, an aliquot of sample water was drawn from the 850-ml sample bags into a 100-ml glass syringe. To prepare the head space the volume of water was reduced to 30 ml, and nitrogen was added at 1 atmosphere pressure to bring the total volume in the syringe to 100 ml. Then the syringe was shaken for two minutes to equilibrate the dissolved tracer between the two phases.

In the case of the multichamber sampler, the amount of water in the syringes was limited to approximately 62 ml by the design of the sampling system. This volume was reduced to 20 ml and approximately 42 ml of nitrogen were added. Then the syringes were shaken manually, 25 at a time, in a rocking frame that accommodated a syringe carousel, for five minutes. The volumes of water in these syringes were manipulated with a simple hydraulic system, and the nitrogen aliquot was pushed through the GC sample loop with the same hydraulic system.

The gas chromatograph was set up similarly to that described by Wanninkhof et al. [1991] for head space samples. The column used to separate the CF_3SF_5 peak from most other peaks was a 1.8 m long x 0.083 cm internal diameter stainless steel tube packed with 100/120 mesh Molecular Sieve 5A. However, it was necessary to remove as much oxygen as possible from the sample by interposing a catalyst of heated, hydrogen-enriched, copper granules, between the injection loop and the columns. It was found that the temperature of this catalysts had to be limited to less than approximately 350 C to avoid reducing the CF_3SF_5.

Concentrations from the integrating samplers and from the 50-chamber sampler were shown in Section 10. Profiles from the CTD casts that found concentrations of tracer significantly above zero are shown in Fig. 18.1. The uncertainty assigned to individual head-space measurements was 5% of the concentration. Sample loops of 0.11 ml and 0.60 ml were used with three CF_3SF_5 standards in nitrogen with molar mixing ratios of 105, 736, and 6491 parts per trillion for calibration.

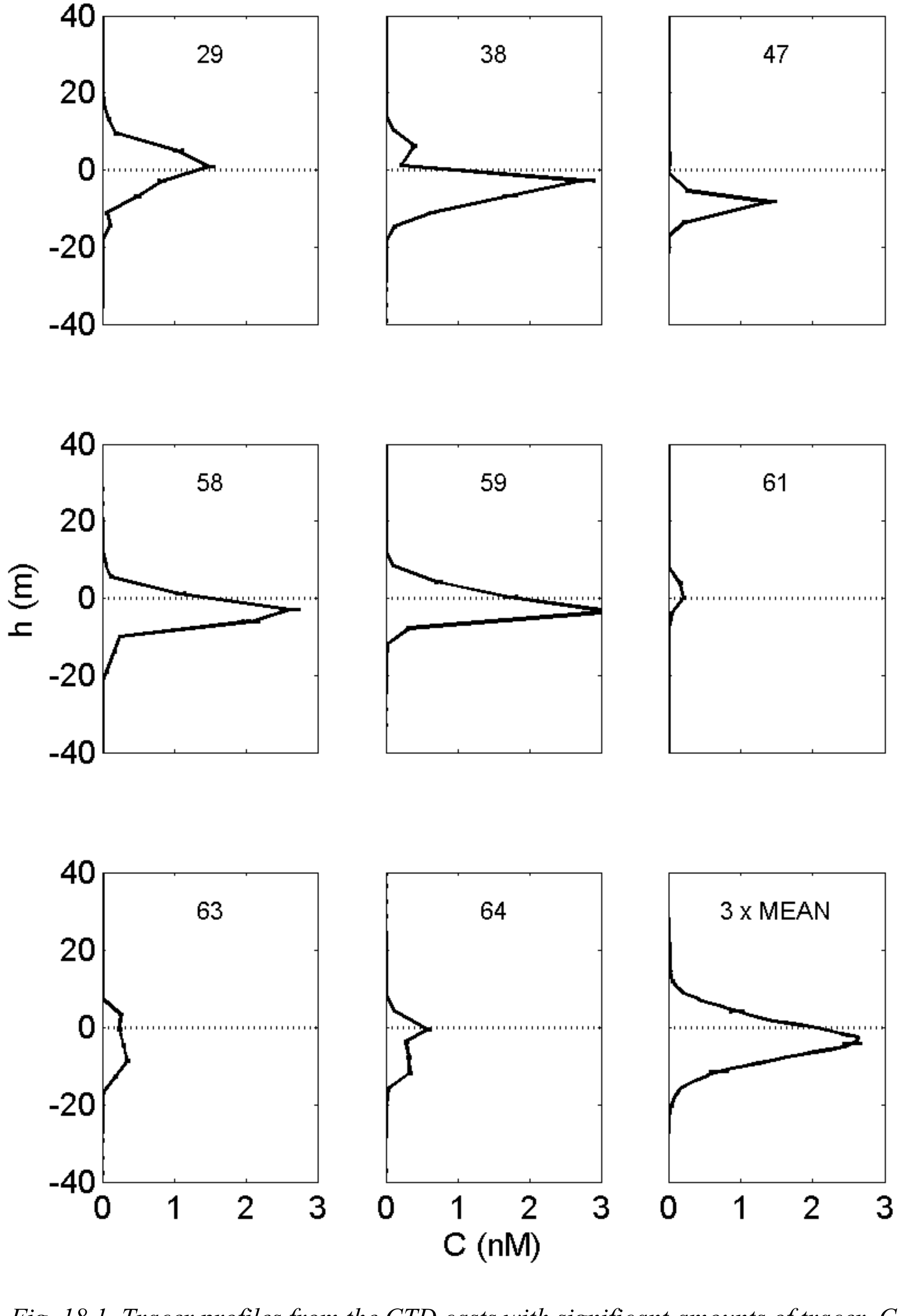


Fig. 18.1. Tracer profiles from the CTD casts with significant amounts of tracer. Cast numbers are indicated. The panel in the lower right is the mean of all the profiles with any tracer at all, including some not shown, multiplied by 3. h *is height above the target density surface.* C *is concentration in nanomoles/liter.*

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Appendices

Appendix A. Science Party

James R. Ledwell, WHOI
Brian Guest, WHOI
Leah Houghton, WHOI
Cynthia Sellers, WHOI
Stewart C. Sutherland, LDEO
Peter Lazarevich, FSU
Byron Kilbourne, UW/APL
Magdelena Carranza, UBA
Uriel Zajaczkovsk, UBA (now at SIO)
Nicolas Wienders, FSU
Cimarron J. L. Wortham, MIT/WHOI
Ryan Abernathey, MIT
Jonathan C. Meyer, SIO, Ship's Tech.
Meghan K. Donohue, SIO, Ship's Tech.

FSU: Florida State University
LDEO: Lamont-Doherty Earth Observatory
MIT: Massachusetts Institute of Technology
SIO: Scripps Institute of Oceanography
UBA: University of Buenos Aires, Argentina
UW/APL: University of Washington, Applied Physics Laboratory
WHOI: Woods Hole Oceanographic Institution

Appendix B. Event Log

EVENT LOG										
DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901										
10 January to 23 February 2009										
Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/10/2009	1100	53	0.09	71	54.60	53.1515	71.8200	Depart Punta Arenas		
1/12/2009	0808	57	56.13	74	32.87	57.9355	74.5478	Leaving Chilean Waters		
1/12/2009	0808	57	56.13	74	32.87	57.9355	74.5478	150 Khz narrow band ADCP Started		
1/12/2009	0809	57	56.13	74	32.87	57.9355	74.5478	Knudsen SubBottom Profiler Started		
1/12/2009	0810	57	56.60	74	32.85	57.9433	74.5475	HDSS 50 Khz Started		
1/12/2009	0811	57	56.60	74	32.85	57.9433	74.5475	HDSS 140 KHz Started		
1/12/2009	0814	57	56.60	74	32.85	57.9433	74.5475	FD XBT	1	11164; 1000 m
1/12/2009	0820	57	58.90	74	32.60	57.9817	74.5433	Thermosalinograph Started		
1/12/2009	0902	58	7.90	74	32.00	58.1317	74.5333	Simrad EM-120 Multibeam Started		
1/12/2009	0910	58	6.60	74	31.80	58.1100	74.5300	HDSS 50 KHz Restarted		
1/12/2009	0934	58	6.60	74	31.80	58.1100	74.5300	EM120 stopped to change roll offset from		
1/12/2009	0935	58	6.60	74	31.80	58.1100	74.5300	0.18 to 0.10 deg; EM120 Restarted		
1/12/2009	0947	58	17.42	74	33.81	58.2903	74.5635	Survey line south started; EM120 center depths recorded		
1/12/2009	1040	58	23.60	74	21.70	58.3933	74.3617	Track north started for deployment; depths recorded.		
1/12/2009	1447	58	20.06	74	24.85	58.3343	74.4142	Sound Source	39	URI Source, anchor in.
1/13/2009	1133	57	14.71	79	54.31	57.2452	79.9052	SOLO FLOAT	902	w. RAFOS Receiver; 84825

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/14/2009	1100	56	1.30	85	53.50	56.0217	85.8917	FD XBT	2	11167; bad below 576 m
1/14/2009	1138							new sound speed profile applied to EM-100		
1/14/2009	~11-1400							Bottom survey for mooring deployment		
1/14/2009	2200							Started setting up for mooring deployment		
1/15/2009	0030							Sound source in water		
1/15/2009	0239	55	57.78	85	59.18	55.9630	85.9863	Sound source	52	Anchor away, Webb Source
1/15/2009	1245	57	53.34	86	0.01	57.8890	86.0002	FD XBT	3	11163; suspect below 250 m
1/16/2009	0000									mooring site survey
1/16/2009	0226									sound source in the water
1/16/2009	0456	59	57.93	86	9.22	59.9655	86.1536	Sound Source	40	Anchor away; URI source; 5016 m
1/16/2009	1544	59	24.35	89	38.30	59.4058	89.6383	FD XBT	4	11166; suspect below 275 m
1/16/2009	2315	59	0.38	92	2.96	59.0063	92.0493	SOLO FLOAT	905	w. RAFOS receiver; 84828
1/17/2009	1945	58	2.41	97	49.87	58.0402	97.8312	FD XBT	5	11160; good to 1000 m

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/18/2009	0148	58	6.06	97	57.60	58.1010	97.9600	Sound Source	37	Anchor away, Older URI source
1/18/2009	2246	59	43.75	104	53.75	59.7292	104.8958	FD XBT	6	11159; good to 1000 m
1/18/2009	2346	59	42.85	104	52.08	59.7142	104.8680	CTD	C001	zmax=5325; zbot=5450; hab=125 m
										primary C wrong; use secondary
										CT; only Niskin 4 closed
1/19/2009	0332	59	43.12	104	53.26	59.7186	104.8877	SOLO FLOAT	906	w. RAFOS receiver; 84829
1/19/2009	1615	59	56.63	109	43.24	59.9438	109.7207	XBT	7	11162; 1000 m
1/19/2009	1818	59	54.11	110	0.03	59.9018	110.0005	Surface Drifter		
1/19/2009	2205	59	54.84	109	54.63	59.9140	109.9105	Sound Source	38	URI HP Source; anchor away
1/20/2009	0745	58	0.72	110	2.11	58.0119	110.0352	Surface Drifter	83463	
1/20/2009	0753	57	58.81	110	1.65	57.9801	110.0275	SOLO FLOAT	904	84827
1/20/2009	1635	56	16.40	110	0.01	56.2733	110.0002	FD XBT	8	11158; 1000 m
1/20/2009	2233	55	59.76	109	54.61	55.9960	109.9102	Sound Source	53	20146, Webb Source

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/21/2009	0237	55	17.73	109	22.46	55.2954	109.3743	Surface Drifter	83460	
1/21/2009	1652	52	40.86	107	8.95	52.6809	107.1491	T5 XBT	9	336849; 2 bad spikes; to 1830 m
1/22/2009	0730	50	0.01	104	59.90	50.0002	104.9983	CTD	C002	Start of CTD line
1/22/2009	1033	50	4.93	105	0.28	50.0822	105.0046	T5 XBT	10	336850; spikes beyond 1000m
1/22/2009	1231	50	19.71	105	0.01	50.3286	105.0002	T5 XBT	11	336851; bad past 570 m
1/22/2009	1240	50	20.33	105	0.02	50.3388	105.0003	T5 XBT	12	336852; bad past 322 m; spd 3 kt
1/22/2009	1326							Test XBT	13	ok
1/22/2009	1438							Test XBT	14	Changed launcher; ok
1/22/2009	1448	50	39.86	105	0.56	50.6643	105.0094	T5 XBT	15	336853; bad past 600 m
1/22/2009	1501	50	40.42	105	1.73	50.6736	105.0288	FD XBT	16	11165; ok but for dropouts
1/22/2009	1715	50	59.98	104	59.96	50.9996	104.9993	CTD	C003	

XBTs 13, 14, 17 through 20, and 22 through 25 were all lab tests.

Note: XBTs 9 through 26 all done at 5 kts, except for 12 (and the tests), which was at 3 kt.

XBTs 30-32 were bucket tests.

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/22/2009	2023							Test XBT	17	ok
1/22/2009	2047							Test XBT	18	bad
1/22/2009	2058							Test XBT	19	bad
1/22/2009	2100							Test XBT	20	Launcher changed back; ok
1/22/2009	2138	51	14.91	104	59.98	51.2485	104.9997	T5 XBT	21	336864; Bad past 140 m
1/22/2009	2313							CTD	C004	
1/22/2009	2329							Test XBT	22	ground test
1/22/2009	2335							Test XBT	23	ground test
1/22/2009	2339							Test XBT	24	ground test
1/22/2009	2358							Test XBT	25	ground test
1/23/2009	0138	51	30.20	105	0.21	51.5033	105.0035	FD XBT	26	bad past 800 m

XBTs 13, 14, 17 through 20, and 22 through 25 were all lab tests.

Note: XBTs 9 through 26 all done at 5 kts, except for 12 (and the tests), which was at 3 kt.

XBTs 30-32 were bucket tests.

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/23/2009	0625	52	0.01	105	0.01	52.0002	105.0002	CTD	C005	
1/23/2009	0945	52	20.06	104	59.98	52.3343	104.9997	T5 XBT	28	336856; Good to 1315
1/23/2009	1142	52	40.21	104	59.95	52.6702	104.9992	T5 XBT	29	336857; Good to 1490
1/23/2009	1350	52	59.90	104	59.99	52.9983	104.9998	CTD	C006	
1/23/2009	1643	53	0.01	105	0.33	53.0002	105.0055	FD XBT	33	11157; bad patch? 600-830 m
1/23/2009	1834	53	19.00	105	0.43	53.3167	105.0072	T5 XBT	34	336858; bad below 1410 m
1/23/2009	2036	53	39.89	104	59.99	53.6648	104.9998	T5 XBT	35	336859; bad below 380 m
1/23/2009	2356	53	59.99	104	59.99	53.9998	104.9998	CTD	C007	
1/24/2009	0121	53	53.99	104	59.98	53.8998	104.9997	RAFOS	773	first RAFOS; 88965
1/24/2009	0126	53	53.99	104	59.98	53.8998	104.9997	RAFOS	760	88952
1/24/2009	0128	54	0.00	104	59.97	54.0000	104.9995	RAFOS	779	88971
1/24/2009	0143	54	0.87	104	59.92	54.0145	104.9987	FD XBT	36	good to 1000 m
1/24/2009	0329	54	19.97	104	59.96	54.3328	104.9993	RAFOS	749	89430

XBTs 13, 14, 17 through 20, and 22 through 25 were all lab tests.

Note: XBTs 9 through 26 all done at 5 kts, except for 12 (and the tests), which was at 3 kt.

XBTs 30-32 were bucket tests.

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/24/2009	0332	54	19.96	104	59.93	54.3327	104.9988	RAFOS	742	89423
1/24/2009	0335	54	19.95	104	59.87	54.3325	104.9978	RAFOS	747	89428
1/24/2009	0341	54	19.99	105	0.15	54.3332	105.0025	T5 XBT		336860; good to 1830 m
1/24/2009	0545	54	40.10	104	59.93	54.6683	104.9988	RAFOS	812	89004
1/24/2009	0547	54	40.10	104	59.94	54.6683	104.9990	RAFOS	748	89429
1/24/2009	0550	54	40.11	104	59.95	54.6685	104.9992	RAFOS	765	88957
1/24/2009	0554	54	40.13	105	0.18	54.6688	105.0029	T5 XBT	38	340469; good to 444 m
1/24/2009	0924	55	0.01	104	59.98	55.0002	104.9997	CTD	C008	
1/24/2009	1109	55	0.00	105	0.02	55.0000	105.0003	RAFOS	793	floated to surface; 88985
1/24/2009	1116	55	0.00	105	0.04	55.0000	105.0007	RAFOS	741	89422
1/24/2009	1114	55	0.00	105	0.03	55.0000	105.0005	RAFOS	743	89424
1/24/2009	1115	55	0.01	104	59.98	55.0002	104.9997	Drifter	83452	
1/24/2009	1329	55	19.86	105	0.05	55.3310	105.0008	RAFOS	744	89425
1/24/2009	1333	55	19.86	105	0.04	55.3310	105.0007	RAFOS	807	88999
1/24/2009	1336	55	19.88	105	0.04	55.3313	105.0007	RAFOS	740	89421

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/24/2009	1344	55	19.92	105	0.50	55.3321	105.0084	T5 XBT	39	340641; no good
1/24/2009	1349	55	20.01	105	1.01	55.3336	105.0168	T5 XBT	40	340642; good to 530 m
1/24/2009	1600	55	39.97	105	0.01	55.6662	105.0002	RAFOS	746	89427
1/24/2009	1602	55	39.96	105	0.03	55.6660	105.0005	RAFOS	751	89432;
1/24/2009	1606	55	39.97	105	0.05	55.6662	105.0008	RAFOS	745	floated to surface; 89426
1/24/2009	1612	55	40.03	105	0.39	55.6672	105.0065	T5 XBT	41	failed at 258 m
1/24/2009	1615	55	40.20	105	0.83	55.6700	105.0138	T5 XBT	42	good to 427 m
1/24/2009	1634	55	41.74	105	1.86	55.6957	105.0310	FD XBT	43	failed at 277 m
1/24/2009	1935	55	59.99	104	59.98	55.9998	104.9997	CTD	C009	target = 1729
1/24/2009	2107	55	59.99	104	59.96	55.9998	104.9993	RAFOS	754	89435
1/24/2009	2110	55	59.97	104	59.94	55.9995	104.9990	RAFOS	752	89433
1/24/2009	2112	55	59.99	105	0.02	55.9998	105.0003	RAFOS	758	89439
1/24/2009	2115	56	0.31	105	0.25	56.0052	105.0042	Drifter	83454	
1/24/2009	2309	56	19.58	105	0.00	56.3263	105.0000	RAFOS	803	88995
1/24/2009	2312	56	19.59	105	0.09	56.3265	105.0015	RAFOS	802	89994
1/24/2009	2314	56	19.58	105	0.15	56.3263	105.0025	RAFOS	767	88959

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/24/2009	2317	56	19.69	105	0.17	56.3282	105.0028	T5 XBT	44	good to 1166 m
1/25/2009	0128	56	40.02	105	0.09	56.6670	105.0015	RAFOS	805	88997
1/25/2009	0122	56	40.04	105	0.18	56.6673	105.0030	RAFOS	804	88996
1/25/2009	0125	56	40.03	105	0.11	56.6672	105.0018	RAFOS	780	88972
1/25/2009	0133	56	40.06	105	0.33	56.6677	105.0055	T5 XBT	45	good to 550, perhaps
1/25/2009	0509	56	59.99	105	0.01	56.9998	105.0002	CTD	C010	target z = 1610 m
1/25/2009	0649	56	59.59	105	0.01	56.9932	105.0002	RAFOS	801	88993
1/25/2009	0652	56	59.59	104	59.99	56.9932	104.9998	RAFOS	781	88973
1/25/2009	0655	56	59.99	105	0.00	56.9998	105.0000	RAFOS	794	88986
1/25/2009	0700	57	0.02	105	0.11	57.0003	105.0018	Drifter	83464	
1/25/2009	0858	57	20.02	105	0.71	57.3337	105.0118	RAFOS	810	89002
1/25/2009	0851	57	19.99	105	0.44	57.3332	105.0073	RAFOS	808	89000
1/25/2009	0855	57	20.01	105	0.59	57.3335	105.0098	RAFOS	764	88956
1/25/2009	0904	57	20.07	105	1.14	57.3345	105.0190	T5 XBT	46	340465; good to 1010 m
1/25/2009	1102	57	39.84	105	0.22	57.6640	105.0037	RAFOS	806	88988

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 1										
1/25/2009	1105	57	39.85	105	0.37	57.6642	105.0062	RAFOS	809	89001
1/25/2009	1108	57	39.89	105	0.46	57.6648	105.0077	RAFOS	811	89003
1/25/2009	1115	57	39.96	105	1.18	57.6660	105.0197	T5 XBT	47	340466; good to 825 m, maybe
1/25/2009	1451	58	0.00	105	0.00	58.0000	105.0000	CTD	C011	
1/25/2009	1630	58	0.00	105	0.00	58.0000	105.0000	leave site		med. emergency; returning to Punta Arenas.
1/27/2009	1710	55	28.77	85	2.24	55.4795	85.0373	ADCP off		140 khz HDSS off; to test 40 khz HDSS
1/28/2009	0500	54	26.00	80	48.26	54.4334	80.8043	All but MET off		Entering Chilean waters.

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
1/29/2009	1500	53	10.92	70	53.48	53.1820	70.8913			Turned around off Punta Arenas
1/31/2009	0120	54	22.96	80	0.73	54.3827	80.0122	TSG1		underway instruments started
								TSG2		started later
								EM120 MB		
								ADCP		
								HDSS 40		
								HDSS 140		
	0128							XBT	48	wrong type entered; redo
1/31/2009	0137	54	24.51	80	5.43	54.4085	80.0905	TP XBT	49	11171; 1000 m
2/1/2009	1116	57	21.23	80	5.43	57.3538	80.0905	TP XBT	50	11174; 1000 m
2/3/2009	0445	58	7.93	106	33.29	58.1322	106.5548	Start Inject 1	R012	First Injection Streak
	1418	58	3.16	106	49.18	58.0527	106.8197	End Inject 1	R012	
2/3/2009	1713	58	2.28	106	51.69	58.0380	106.8615	TP XBT	51	11177; 1000 m

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/3/2009	1758	58	5.88	106	42.07	58.0980	106.7012	RAFOS	796	88988
	1800	58	5.88	106	42.06	58.0980	106.7010	RAFOS	813	89005
	1802	58	5.88	106	42.04	58.0980	106.7007	RAFOS	798	88990
	1830	58	5.86	106	41.99	58.0977	106.6998	Shearmeter	2	first Shearmeter
	1842	58	5.82	106	41.93	58.0970	106.6988	EM-APEX	4087	
	1852	58	5.73	106	41.92	58.0955	106.6987	SOLO	886	
2/3/2009	1949	58	10.70	106	33.21	58.1783	106.5535	Inject attempt	R013	Aborted at c. 238 m; bad batteries
2/4/2009	1424	58	4.51	106	32.88	58.0752	106.5480	Start Inject 2	R014	2nd Injection Streak
2/5/2009	0418	58	10.34	106	55.79	58.1723	106.9298	End Inject 2	R014	
2/5/2009	1457	58	8.95	106	49.77	58.1492	106.8295	Shearmeter	2	300-day mission
	1504	58	8.92	106	49.73	58.1487	106.8288	RAFOS	775	88967, 300-day mission
	1509	58	8.92	106	49.74	58.1487	106.8290	RAFOS	759	89440, 300-day mission
	1512	58	8.92	106	49.75	58.1487	106.8292	RAFOS	774	88966, 300-day mission

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/5/2009	1517	58	8.91	106	49.77	58.1485	106.8295	SOLO	889	
	1555	58	12.37	106	58.47	58.2062	106.9745	TP XBT	52	11178; 1000m
	1806	58	19.30	107	8.15	58.3217	107.1358	CTD	C015	
2/6/2009	0020	58	7.28	107	8.20	58.1213	107.1367	CTD	C016	
2/6/2009	0628	57	55.31	107	8.22	57.9218	107.1370	CTD	C017	
2/6/2009	1236	57	55.65	106	45.59	57.9275	106.7598	CTD	C018	
2/6/2009	1410	57	55.51	106	45.03	57.9252	106.7505	TP XBT	53	11175; 1000 m
2/6/2009	1850	57	55.28	106	20.28	57.9213	106.3380	CTD	C019	
2/7/2009	0055	58	7.29	106	20.24	58.1215	106.3373	CTD	C020	
2/7/2009	0716	58	19.30	106	20.19	58.3217	106.3365	CTD	C021	
2/7/2009	1323	58	19.30	106	44.16	58.3217	106.7360	CTD	C022	
2/7/2009	2330	58	7.25	106	44.35	58.1208	106.7392	CTD	C023	
2/8/2009	0438	58	6.99	106	44.01	58.1165	106.7335	CTD	C024	
2/8/2009	0645	58	7.09	106	43.81	58.1182	106.7302	CTD	C025	
2/8/2009	1331	58	8.99	106	44.04	58.1498	106.7340	CTD	C026	
2/8/2009	1629	58	10.81	106	43.80	58.1802	106.7300	CTD	C027	

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/8/2009	1930	58	5.53	106	43.22	58.0922	106.7203	CTD	C028	
2/9/2009	0516	58	7.33	106	44.87	58.1222	106.7478	CTD	C029	
2/9/2009	0730	58	8.37	106	44.77	58.1395	106.7462	CTD	C030	
2/9/2009	1015	58	8.40	106	46.75	58.1400	106.7792	CTD	C031	
2/9/2009	1305	58	8.98	106	49.04	58.1497	106.8173	CTD	C032	
2/9/2009	1407	58	9.00	106	49.14	58.1500	106.8190	TP XBT	54	
2/9/2009	1528	58	8.96	106	50.88	58.1493	106.8480	CTD	C033	
2/9/2009	1822	58	7.76	106	48.39	58.1293	106.8065	CTD	C034	
2/9/2009	2054	58	7.34	106	43.05	58.1223	106.7175	CTD	C035	
2/9/2009	2301	58	7.28	106	45.00	58.1213	106.7500	Shearmeter	3	S/N 5
2/9/2009	2324	58	7.30	106	45.02	58.1217	106.7503	RAFOS	792	88984
2/9/2009	2327	58	7.32	106	47.07	58.1220	106.7845	RAFOS	753	89434
2/9/2009	2331	58	7.34	106	45.13	58.1223	106.7522	RAFOS	750	89431
2/9/2009	2338	58	7.38	106	45.24	58.1230	106.7540	EM-APEX	2	
2/10/2009	0042	58	7.38	106	46.66	58.1230	106.7777	CTD	C036	
2/10/2009	0311	58	6.35	106	47.18	58.1058	106.7863	CTD	C037	

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/10/2009	0510	58	6.33	106	44.94	58.1055	106.7490	CTD	C038	
2/10/2009	0736	58	6.22	106	39.32	58.1037	106.6553	CTD	C039	
2/10/2009	0931	58	7.06	106	31.96	58.1177	106.5327	CTD	C040	
2/10/2009	1209	58	8.06	106	43.10	58.1343	106.7183	CTD	C041	
2/10/2009	1455	58	8.43	106	39.38	58.1405	106.6563	CTD	C042	
2/10/2009	1721	58	9.48	106	39.61	58.1580	106.6602	CTD	C043	
2/10/2009	1958	58	7.53	106	38.62	58.1255	106.6437	CTD	C044	
2/10/2009	2251	58	7.55	106	40.54	58.1258	106.6757	CTD	C045	
2/11/2009	0120	58	6.34	106	43.93	58.1057	106.7322	CTD	C046	
2/11/2009	0340	58	8.07	106	40.56	58.1345	106.6760	CTD	C047	
2/11/2009	2342	59	58.96	104	59.97	59.9827	104.9995	CTD	C048	
2/12/2009	0119	59	58.97	105	0.01	59.9828	105.0002	RAFOS	776	88968
2/12/2009	0122	59	58.96	105	0.01	59.9827	105.0002	RAFOS	771	88963
2/12/2009	0125	59	58.96	105	0.01	59.9827	105.0002	RAFOS	800	88992
2/12/2009	0131	59	58.99	104	59.96	59.9832	104.9993	Drifters	83461	
2/12/2009	0131	59	58.99	104	59.96	59.9832	104.9993	Drifters	83455	

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time (GMT)	Latitude (S) deg	min	Longitude (W) deg	min	Latitude decimal degrees	Longitude decimal degrees	Event	Number	Comments
Leg 2										
2/12/2009	0132	59	59.00	104	59.96	59.9833	104.9993	Drifters	83453	
2/12/2009	0258	59	44.90	105	0.16	59.7483	105.0027	RAFOS	757	89438
2/12/2009	0302	59	44.87	105	0.17	59.7478	105.0028	RAFOS	756	89437
2/12/2009	0305	59	44.88	105	0.13	59.7480	105.0022	RAFOS	755	89436
2/12/2009	0316	59	44.97	104	59.93	59.7495	104.9988	TP XBT	55	OK to 900 m; S. of PF
2/12/2009	0622	59	30.00	104	59.98	59.5000	104.9997	CTD	C049	
2/12/2009	0801	59	30.07	104	59.99	59.5012	104.9998	RAFOS	782	88974
2/12/2009	0804	59	30.13	104	59.98	59.5022	104.9997	RAFOS	787	88979
2/12/2009	0806	59	30.14	104	59.98	59.5023	104.9997	RAFOS	790	88982
2/12/2009	1002	59	15.01	104	59.87	59.2502	104.9978	RAFOS	768	88960
2/12/2009	1005	59	15.07	104	59.86	59.2512	104.9977	RAFOS	772	88964
2/12/2009	1008	59	15.10	104	59.87	59.2517	104.9978	RAFOS	791	88983
2/12/2009	1018	59	15.49	104	59.89	59.2582	104.9982	T5 XBT	56	OK to 1100 m
2/12/2009	1151	59	0.00	104	59.95	59.0000	104.9992	CTD	C050	
2/12/2009	1446	59	0.05	104	59.68	59.0008	104.9947	RAFOS	784	one of these seen at surface
2/12/2009	1448	59	0.04	104	59.68	59.0007	104.9947	RAFOS	785	lying on its side (possibly 785)

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/12/2009	1450	59	0.03	104	59.67	59.0005	104.9945	RAFOS	789	
2/12/2009	1456	59	0.14	104	59.82	59.0023	104.9970	Drifters	83457	100-150 m apart
2/12/2009	1457	59	0.17	104	59.86	59.0028	104.9977	Drifters	83459	
2/12/2009	1459	59	0.22	104	59.93	59.0037	104.9988	Drifters	83450	
2/12/2009	1636	58	44.94	105	0.08	58.7490	105.0013	RAFOS	797	
2/12/2009	1641	58	44.94	105	0.12	58.7490	105.0020	RAFOS	814	
2/12/2009	1639	58	44.93	105	0.10	58.7488	105.0017	RAFOS	788	
2/12/2009	1747	58	37.65	104	59.02	58.6275	104.9837	TF XBT	57	
2/12/2009	1747	58	37.65	104	59.03	58.6275	104.9838	TF XBT	61	
2/12/2009	1753	58	36.51	104	59.22	58.6085	104.9870	TD XBT	62	
2/12/2009	1949	58	30.02	105	0.00	58.5003	105.0000	CTD	C051	Intercomparison of microcats
2/12/2009	2146	58	30.11	105	0.06	58.5018	105.0010	RAFOS	777	88969
2/12/2009	2149	58	30.17	105	0.05	58.5028	105.0008	RAFOS	769	88961
2/12/2009	2151	58	30.17	105	0.04	58.5028	105.0007	RAFOS	770	88962; stayed 15 s at surface
2/12/2009	2335	58	15.04	104	59.96	58.2507	104.9993	RAFOS	799	88991
2/12/2009	2337	58	15.07	104	59.97	58.2512	104.9995	RAFOS	778	88970

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/12/2009	2339	58	15.08	104	59.98	58.2513	104.9997	RAFOS	795	88978
2/12/2009	2346	58	15.18	105	0.01	58.2530	105.0002	TF XBT	64	
2/13/2009	0248	57	59.99	104	59.68	57.9998	104.9947	CTD	C052	Bottom; salinity at Targ surface.
2/13/2009	0437	58	0.01	104	59.93	58.0002	104.9988	RAFOS	783	88975
2/13/2009	0440	58	0.02	104	59.92	58.0003	104.9987	RAFOS	766	88958; lost compressee
2/13/2009	0444	58	0.03	104	59.88	58.0005	104.9980	RAFOS	786	88978
2/13/2009	0448	58	0.04	104	59.85	58.0007	104.9975	Drifters	83456	
2/13/2009	0445	58	0.06	105	0.42	58.0010	105.0070	Drifters	83462	
2/13/2009	0456	58	0.01	105	0.54	58.0002	105.0090	Drifters	83458	
2/13/2009	0908	57	29.99	104	59.96	57.4998	104.9993	CTD	C053	Bottles at bottom
2/13/2009	1705	58	7.81	106	45.36	58.1302	106.7560	CTD	C054	Salinity at Target
2/14/2009	0112	58	3.78	106	41.29	58.0630	106.6882	Sampling Tow	S055	High Tracer
2/14/2009	1230	58	13.52	106	50.25	58.2253	106.8375	End		
2/14/2009	1717	58	14.42	106	44.09	58.2403	106.7348	CTD	C056	No tracer
2/15/2009	0100	58	3.10	106	34.60	58.0517	106.5767	Sampling Tow	S057	Very Little Tracer
2/15/2009	1230	58	15.06	106	46.26	58.2510	106.7710	End		

EVENT LOG, continued

DIMES DEPLOYMENT CRUISE; US1; R/V ROGER REVELLE; RR0901

10 January to 23 February 2009

Date	Time	Latitude		Longitude		Latitude	Longitude	Event	Number	Comments
	(GMT)	(S)		(W)		decimal	decimal			
		deg	min	deg	min	degrees	degrees			
Leg 2										
2/15/2009	1643	58	9.90	106	48.37	58.1650	106.8062	CTD	C058	High Tracer
2/15/2009	1941	58	10.42	106	48.38	58.1737	106.8063	CTD	C059	High Tracer
2/15/2009	2220	58	9.89	106	49.34	58.1648	106.8223	CTD	C060	No tracer
2/16/2009	0025	58	9.36	106	48.41	58.1560	106.8068	CTD	C061	Medium tracer
2/16/2009	0221	58	9.90	106	47.44	58.1650	106.7907	CTD	C062	no tracer
2/16/2009	1135	58	10.88	106	48.39	58.1813	106.8065	CTD	C063	Medium tracer
2/16/2009	1339	58	10.92	106	49.35	58.1820	106.8225	CTD	C064	Medium tracer
2/16/2009	1640	58	10.92	106	50.28	58.1820	106.8380	CTD	C065	no tracer
2/16/2009	1911	58	10.38	106	48.42	58.1730	106.8070	Shearmeter	4	
2/16/2009	1917	58	10.39	106	48.41	58.1732	106.8068	RAFOS	763	88955
2/16/2009	1919	58	10.37	106	48.43	58.1728	106.8072	RAFOS	762	88954
2/16/2009	1921	58	10.36	106	48.44	58.1727	106.8073	RAFOS	761	88953
2/16/2009	1929	58	10.31	106	48.49	58.1718	106.8082	EM-APEX	3767	"sweet"
2/17/2009	0130	58	5.06	106	51.16	58.0843	106.8527	Sampling Tow	S066	Third Sampling Tow
2/17/2009	1131	58	12.13	106	57.53	58.2022	106.9588		S066	end
2/17/2009	1540	58	10.42	106	49.46	58.1737	106.8243	CTD	C067	No tracer
2/17/2009	1754	58	11.49	106	49.38	58.1915	106.8230	CTD	C068	Small, deep, tracer
2/18/2009	0100	58	11.99	106	44.02	58.1998	106.7337	Sampling Tow	S069	Start
2/18/2009	1100	58	12.13	106	57.53	58.2022	106.9588		S069	End
2/18/2009	1609	58	12.55	107	7.04	58.2092	107.1173	Calibration	S070	At target surface
2/18/2009	2100	58	12.00	106	44.04	58.2000	106.7340	Sampling Tow	S071	Start
2/19/2009	0630	58	12.00	107	2.10	58.2000	107.0350		S071	End
2/19/2009	0800	58	12.00	107	2.10	58.2000	107.0350			Heading back to Punta Arenas
2/19/2009	2256	57	38.27	101	37.97	57.6378	101.6328	TP XBT	65	

Appendix C. CTD Cast List

CTD Cast List										
Cast #	**Date 2009**	**Time GMT**	**Lat Deg (S)**	**Lon Deg (W)**	**Max Depth (m)**	**EM120 Depth (m)**	**HAB LADCP (m)**	**Type**	**Instr.**	**Comments**
1	Jan 18	23:58	59.7142	104.8675	5327	5450	110	Deep Survey	STS	
2	Jan 22	07:29	50.0002	104.9992	4015	4047	17	Deep Survey	STS	Repl. Sensor
3	Jan 22	17:15	50.9995	104.9993	4332	4380	50	Deep Survey	STS	
4	Jan 22	23:11	51.4995	105.0000	4323	4367	34	Deep Survey	STS	
5	Jan 23	05:04	52.0000	104.9998	4443	4501	37	Deep Survey	STS	
6	Jan 23	13:49	52.9982	104.9998	4167	4325	63	Deep Survey	STS	
7	Jan 23	22:39	53.9998	104.9992	4323	4361	22	Deep Survey	STS	
8	Jan 24	08:04	54.9985	104.9985	4352	4395	34	Deep Survey	STS	
9	Jan 24	18:20	55.9997	104.9985	4137	4237	63	Deep Survey	STS	
10	Jan 25	03:46	56.9995	104.9988	4601	4654	36	Deep Survey	STS	
11	Jan 25	13:12	57.9987	104.9983	4778	4870	63	Deep Survey	STS	
12	Feb 03	02:37	58.1329	106.5534	NaN	NaN	NaN	Inject 1 Start	TRE	
12	Feb 03	14:22	58.0525	106.8144	NaN	NaN	NaN	Inject 1 Ends	TRE	
13	Feb 03	19:49	58.1784	106.5534	NaN	NaN	NaN	Inject ABORTED	TRE	
14	Feb 04	14:23	58.1364	106.7686	NaN	NaN	NaN	Inject 2 Starts	TRE	
14	Feb 05	04:20	58.1730	106.9321	NaN	NaN	NaN	Inject 2 Ends	TRE	
15	Feb 05	16:51	58.3215	107.1358	4154	4221	54	Deep Survey	STS	no niskins
16	Feb 05	23:02	58.1215	107.1365	4382	4418	18	Deep Survey	STS	no niskins
17	Feb 06	05:09	57.9217	107.1365	4498	4618	88	Deep Survey	STS	no niskins
18	Feb 06	11:14	57.9238	106.7430	4460	4550	74	Deep Survey	STS	no niskins
19	Feb 06	17:28	57.9213	106.3373	4572	4631	41	Deep Survey	STS	
20	Feb 06	23:49	58.1213	106.3373	3700	3785	53	Deep Survey	STS	
21	Feb 07	05:55	58.3215	106.3363	4541	4584	18	Deep Survey	STS	
22	Feb 07	12:05	58.3215	106.7368	4281	4356	20	Deep Survey	STS	
23	Feb 07	22:18	58.1193	106.7390	4083	4620	NaN	Deep Survey	STS	
24	Feb 08	04:19	58.1172	106.7333	502	4543	NaN	1800M Sample	STS	
25	Feb 08	06:10	58.1188	106.7300	1804	4534	NaN	1800M Sample	STS	
26	Feb 08	13:30	58.1498	106.7337	1796	4761	NaN	1800M Sample	STS	
27	Feb 08	16:28	58.1800	106.7297	1796	4615	NaN	1800M Sample	STS	
28	Feb 08	19:29	58.0920	106.7205	1793	4554	NaN	1800M Sample	STS	
29	Feb 09	04:42	58.1212	106.7445	1805	4611	NaN	1800M Sample	STS	
30	Feb 09	07:31	58.1397	106.7460	1805	4582	NaN	1800M Sample	STS	
31	Feb 09	10:14	58.1398	106.7797	1794	4731	NaN	1800M Sample	STS	
32	Feb 09	13:04	58.1495	106.8172	1795	4804	NaN	1800M Sample	STS	
33	Feb 09	15:28	58.1493	106.8478	1796	4566	NaN	1800M Sample	STS	
34	Feb 09	18:22	58.1293	106.8232	1795	4628	NaN	1800M Sample	STS	
35	Feb 09	20:54	58.1222	106.7167	1805	4740	NaN	1800M Sample	STS	
36	Feb 10	00:08	58.1225	106.7768	1804	4849	NaN	1800M Sample	STS	
37	Feb 10	02:38	58.1058	106.7862	1803	4746	NaN	1800M Sample	STS	
38	Feb 10	04:45	58.1053	106.7480	1804	4654	NaN	1800M Sample	STS	
39	Feb 10	07:02	58.1035	106.6550	1803	4737	NaN	1800M Sample	STS	
40	Feb 10	09:31	58.1172	106.6992	1793	4728	NaN	1800M Sample	STS	
41	Feb 10	12:08	58.1340	106.7183	1793	4755	NaN	1800M Sample	STS	
42	Feb 10	14:53	58.1407	106.6562	1794	4761	NaN	1800M Sample	STS	
43	Feb 10	17:20	58.1582	106.6600	1793	4666	NaN	1800M Sample	STS	
44	Feb 10	19:57	58.1255	106.6435	1797	4772	NaN	1800M Sample	STS	

CTD Cast List, continued										
Cast	Date	Time	Lat	Lon	Max	EM120	HAB			
#	2009	GMT	Deg (S)	Deg (W)	Depth	Depth	LADCP	Type	Instr.	Comments
					(m)	(m)	(m)			
45	Feb 10	22:16	58.1257	106.6757	1805	4730	NaN	1800M Sample	STS	
46	Feb 11	00:48	58.1062	106.7330	1804	4604	NaN	1800M Sample	STS	
47	Feb 11	03:06	58.1343	106.6758	1805	4667	NaN	1800M Sample	STS	
48	Feb 11	22:19	59.9823	105.0005	4634	4701	21	Deep Survey	STS	
49	Feb 12	04:58	59.4988	104.9973	4732	4800	24	Deep Survey	STS	
50	Feb 12	11:52	59.0000	104.9990	4480	4573	70	Deep Survey	STS	
51	Feb 12	18:31	58.4990	105.0007	4284	4562	NaN	Deep Survey	STS	Intercalibrate
52	Feb 13	01:22	57.9992	104.9972	4833	4872	18	Deep Survey	STS	
53	Feb 13	07:45	57.4995	104.9988	4605	4680	45	Deep Survey	STS	
54	Feb 13	16:32	58.1302	106.7565	1794	4613	NaN	1800M Sample	STS	
55	Feb 13	01:07	58.0630	106.6882	NaN	NaN	NaN	Sample 1 Start	TRE	
55	Feb 14	12:30	58.2253	106.8375	NaN	NaN	NaN	Sample 1 End	TRE	
56	Feb 14	16:42	58.2395	106.7353	1793	4593	NaN	1800M Sample	STS	
57	Feb 14	01:00	58.0517	106.5667	NaN	NaN	NaN	Sample 2 Start	TRE	
57	Feb 14	12:30	58.2511	106.7711	NaN	NaN	NaN	Sample 2 End	TRE	
58	Feb 15	15:20	58.1653	106.8075	4422	4753	NaN	1800M Sample	STS	
59	Feb 15	19:04	58.1735	106.8065	1790	4510	NaN	1800M Sample	STS	
60	Feb 15	21:46	58.1647	106.8227	1790	4820	NaN	1800M Sample	STS	
61	Feb 15	23:50	58.1557	106.8078	1790	4836	NaN	1800M Sample	STS	
62	Feb 16	01:47	58.1647	106.7907	1790	4549	NaN	1800M Sample	STS	
63	Feb 16	10:59	58.1817	106.8075	1791	4479	NaN	1800M Sample	STS	
64	Feb 16	13:04	58.1822	106.8218	1791	4621	NaN	1800M Sample	STS	
65	Feb 16	15:17	58.1820	106.8385	4620	4783	133	1800M Sample	STS	
66	Feb 16	01:22	58.0844	106.8526	NaN	NaN	NaN	Sample 3 Start	TRE	
66	Feb 16	13:00	58.2190	106.9843	NaN	NaN	NaN	Sample 3 End	TRE	
67	Feb 17	15:05	58.1733	106.8235	1789	4726	NaN	1800M Sample	STS	
68	Feb 17	17:18	58.1908	106.8227	1791	4515	NaN	1800M Sample	STS	
69	Feb 17	01:00	58.1998	106.7340	NaN	NaN	NaN	Sample 4 Start	TRE	
69	Feb 17	12:30	58.1998	107.0881	NaN	NaN	NaN	Sample 4 End	TRE	
70	Feb 17	16:09	58.2091	107.1173	NaN	NaN	NaN	Intercalibrate	TRE	
71	Feb 18	21:00	58.2000	106.7340	NaN	NaN	NaN	Sample 5 Start	TRE	
71	Feb 16	06:30	58.2000	106.7340	NaN	NaN	NaN	Sample 5 End	TRE	

Appendix D. XBT Drop List

R/V *Roger Revelle* Cruise RR0901; DIMES Cruise US1; 10 Jan–23 Feb 2009
XBT Drop List

Max. Depth listed is maximum depth with good data.
Several probes were used to diagnose problems.
Drops containing no data were eliminated from this list.

Please contact Chief Scientist, Jim Ledwell, before use of these data in publications
jledwell@whoi.edu

Drop #	Date	Time (GMT)	Lat. Deg (S)	Lon. Deg (W)	Maximum Depth (m)	Probe Type	S/N
1	01/12/2009	08:15	57.9562	74.5461	997.9	TF	00011164
2	01/14/2009	11:00	56.0221	85.8933	575.5	TF	00011167
3	01/15/2009	12:45	57.8889	86.0002	249.6	TF	00011163
4	01/16/2009	15:44	59.4058	89.6384	269.5	TF	00011166
5	01/17/2009	19:14	58.0402	97.8312	997.9	TF	00011160
6	01/18/2009	22:46	59.7292	104.8958	997.9	TF	00011159
7	01/19/2009	16:15	59.9438	109.7207	997.9	TF	00011162
8	01/20/2009	16:34	56.2733	110.0002	997.9	TF	00011158
10	01/22/2009	10:33	50.0082	105.0046	1029.0	T5	00336850
11	01/22/2009	12:30	50.3286	105.0002	572.4	T5	00336851
12	01/22/2009	12:40	50.3388	105.0003	321.6	T5	00336852
16	01/22/2009	15:01	50.6736	105.0287	997.9	TF	00011165
21	01/22/2009	21:38	51.2485	104.9997	150.0	T5	00336854
26	01/23/2009	02:01	51.5033	105.0035	876.6	TF	00011161
27	01/23/2009	03:27	51.7514	104.9997	769.5	T5	00336855
28	01/23/2009	09:45	52.3344	104.9996	1314.7	T5	00336856
29	01/23/2009	11:42	52.6702	104.9992	1489.7	T5	00336857
33	01/23/2009	16:42	53.0002	105.0055	997.9	TF	00011157
34	01/23/2009	18:34	53.3167	105.0072	1417.7	T5	00011158
35	01/23/2009	20:36	53.6648	104.9998	391.9	T5	00011159
36	01/24/2009	01:43	54.0145	104.9987	575.5	TF	00011169
37	01/24/2009	03:41	54.3332	105.0025	1828.2	T5	00336860
38	01/24/2009	05:53	54.6688	105.0029	446.0	T5	00340469
40	01/24/2009	13:49	55.3335	105.0168	530.0	T5	00340462
41	01/24/2009	16:12	55.6672	105.0064	257.5	T5	00340463
42	01/24/2009	16:15	55.6686	105.0139	426.9	T5	00340464
43	01/24/2009	16:34	55.6956	105.0310	287.0	TF	00011170
44	01/24/2009	23:17	56.3281	105.0028	1165.8	T5	00340468
45	01/25/2009	01:33	56.6677	105.0056	549.6	T5	00340472
46	01/25/2009	09:03	57.3344	105.0190	1009.6	T5	00340465
47	01/25/2009	11:15	57.6661	105.0196	824.4	T5	00340466
49	01/31/2009	01:36	54.4085	80.0905	997.9	TF	00011173

R/V *Roger Revelle* Cruise RR0901; DIMES Cruise US1; 10 Jan–23 Feb 2009 XBT Drop List, continued							
Max. Depth listed is maximum depth with good data. Several probes were used to diagnose problems. Drops containing no data were eliminated from this list. Please contact Chief Scientist, Jim Ledwell, before use of these data in publications jledwell@whoi.edu							
Drop #	Date	Time (GMT)	Lat. Deg (S)	Lon. Deg (W)	Maximum Depth (m)	Probe Type	S/N
50	02/01/2009	11:16	57.3539	91.5679	997.9	TF	00011174
51	02/03/2009	17:13	58.0379	106.8614	997.9	TF	00011177
52	02/05/2009	15:55	58.2061	106.9746	997.9	TF	00011178
53	02/06/2009	14:09	57.9252	106.7505	997.9	TF	00011175
54	02/09/2009	14:52	58.1500	106.8190	522.7	TF	00011172
55	02/12/2009	03:16	59.7496	104.9988	532.4	TF	00011179
56	02/12/2009	10:11	59.2540	104.9977	1098.8	T5	00340467
57	02/12/2009	16:44	58.7500	105.0028	860.7	T5	00340470
61	02/12/2009	17:47	58.6275	104.9838	997.9	TF	00010230
62	02/12/2009	17:53	58.6084	104.9870	758.0	TD	00687410
64	02/12/2009	23:46	58.2530	105.0001	889.5	TF	00011301

Appendix E. Data Access

Data from this cruise are maintained at the U.S. DIMES website http://dimes.ucsd.edu or at sites linked from there. The path to a RR0901 directory or data file should be clear once a user accesses the FILES section of that site, though the detailed path may change from time to time. Navigating from a subdirectory level to a higher directory or to the topmost level of the File Listing is achieved by clicking ⇑ Parent directory (rather than the browser's back arrow). In some cases only processed data are at the site. In other cases raw data and/or intermediate products are included as well. Data at various levels of processing, if not at the site, can in most cases be obtained from the originator of the data, whose names may be at the head of the appropriate section of this report or contact Jim Ledwell (jledwell@whoi.edu) for more information. Much of the data should be available at the National Oceanographic Data Center and, for the raw multibeam bathymetry, the National Geophysical Data Center, sometime in 2012. The Rolling Deck to Repository (R2R) program at http://www.rvdata.us promises to serve as a portal to the underway data and CTD data, and already catalogs data files from the cruise, though not the data themselves.

We will attempt to document the data and keep this documentation up to date in text files stored with the data in their directories and subdirectories. We request that those interested in using the data from this cruise contact the originators of the data, or the chief scientist. Originators can make sure the version of the data with which users wish to work is the most current, can help to avoid redundant efforts, and can assist with interpretation of the data. Data originators will appreciate the opportunity to join as coauthors on publications relying on the data, but they may also simply wish to indicate the most appropriate way to acknowledge and attribute the data source.