Cruise Report

GISR Cruise G02

R/V *Brooks McCall*

Tracer Deployment and Initial Sampling

Pensacola to Pensacola, Florida

30 July to 9 August 2012

Chief Scientist
James R. Ledwell
Woods Hole Oceanographic Institution
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R/V Brooks McCall *at the Loading Dock in Pensacola, Florida, 26 July 2012.*

26 October 2012

Acknowledgements

The skill and cooperation of the master and crew of R/V *Brooks McCall* were essential to the success of the cruise. The staff of TDI Brooks, and especially Les Bender, liason for the cruise were of great help with preparations. The work described here is part of the Gulf Integrated Spill Response Consortium (GISR), whose lead institution is Texas A&M University (TAMU). Piers Chapman, Principal Investigator for GISR has been an outstanding supporter of the tracer experiment. He, co-PI Scott Solocofsky, their administrative assistant, Laura Caldwell, and others at TAMU as well as Linda Cannata and staff at WHOI have worked hard to keep contractual and other arrangements for our work on track. Steve DiMarco and the science party of the prior GISR cruise, G01, provided hydrographic data which helped us prepare for this cruise. The moorings set during G01 served as a guide to our tracer release. Steve also encouraged graduate student Laura Spencer to join our cruise to act as a bridge between the two cruises. Numerical simulations of the motion of particles released at the time and place of the tracer release were run by Ruoying He and his group at North Carolina State University and by Ping Chang and his group at TAMU to help track the tracer. RAFOS floats were prepared by Jim Valdes at WHOI and by Brian Guest, and tracking assistance was provided by Heather Furey at WHOI. Funding for GISR is provided by British Petroleum through the Gulf of Mexico Research Institute (GOMRI), and is administered by the Consortium for Ocean Leadership.

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Cruise Personnel

Crew

Chris Opel, Master
Geno Majni, Chief Mate
Enoch Webster, Chief Engineer
Jeff Farr, ABS
Jay Stiles, OS
Ann Majni, OS
Kenneth Brown, Cook
Adam Ariganello, Navigator
William Green, Deck Boss, first leg
Larry Lane, Deck Boss, second leg
Cory Anderson, Deck/Winch

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Brian Guest	Senior Engineering Assistant	bguest@whoi.edu
Cynthia Sellers	Research Associate	csellers@whoi.edu
Leah Houghton	Research Associate	lhoughton@whoi.edu
Alexi Shalapyonok	Research Associate	alexi@whoi.edu
Laura Spencer	Graduate Student	lauraspencer@geos.tamu.edu
Xiaoyuan/Charlene Ren	Summer Student Fellow*	xiren@vassar.edu

*Most of the science party was associated with Woods Hole Oceanographic Institution (WHOI), with the exception of Laura Spencer, who was from Texas A&M University. Stew Sutherland's home institution is Lamont-Doherty Earth Observatory and Charlene Ren's home institution is Vassar College.

Cruise Objectives

The objectives of the first leg of the cruise were to deploy tracer and RAFOS floats on a surface of constant density at approximately 1100 m depth within the GISR mooring array deployed along the continental slope to the east of the Mississippi Canyon. The objectives of the second leg of the cruise were to sample the early distribution of the tracer for the initial condition of a 1-year study of dispersion a passive tracer released in deep water near the north-central boundary of the deep Gulf of Mexico. Dispersion of the tracer will be compared with realistic numerical simulations of the circulation of the Gulf. Such simulations will help in responding to accidental petroleum releases in the deep waters of the Gulf.

The Tracer

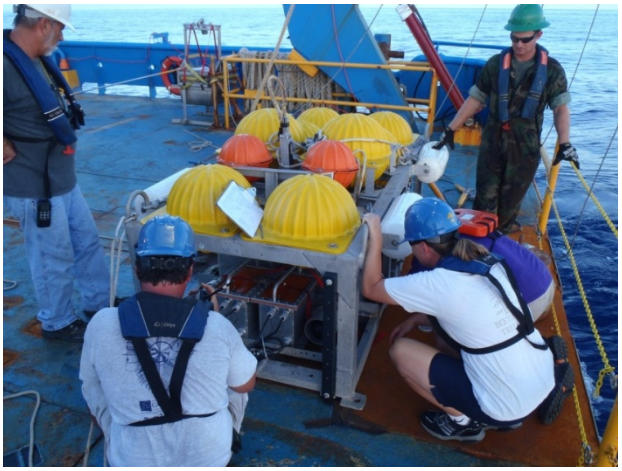
The tracer is trifluoromethyl sulfur pentafluoride, CF_3SF_5, a compound which is neither chemically nor biologically active in the ocean, and is thus harmless and conservative. The material is not generally available commercially, and that used for this experiment was manufactured specifically for our use by Fluorochemika Poland, Sp.

Injection Sled Configuration

The injection sled is an aluminum frame about 2 meters long by 1.2 meters wide by 1 meter high (Fig. 1). It houses a CTD which is used in the feedback system to tow the sled at constant density, and which also transmits commands and sensor signals between the ship and the injection system. The sled also houses a control electronics, wet-cell batteries, pumps and tracer reservoirs comprising the tracer injection system. The sled is made approximately neutrally buoyant with the glass flotation balls in hard hats along the top rail (Fig. 2). The sled is towed at the end of a 2.5-meter long tether trailing behind a pear-ring to which the termination of the CTD cable is attached from above and a 850-lb depressor weight is attached from below. The purpose of the tether is to isolate the sled from much of the vertical motions of the CTD cable.

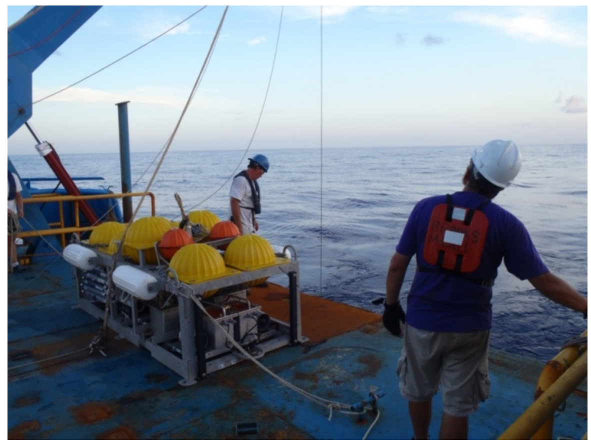
Tracer Release

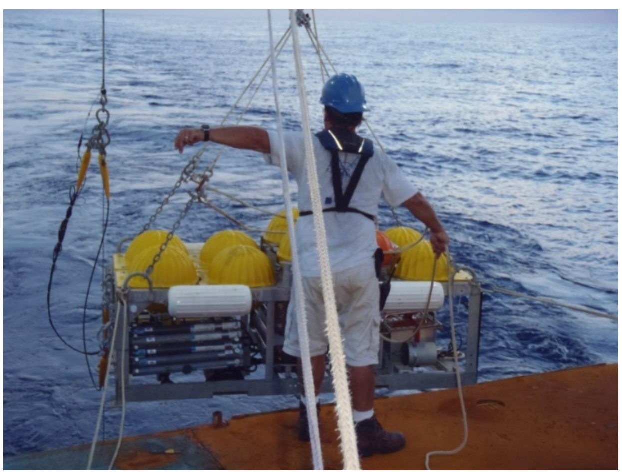
It had been planned to center the release at 28^{o}30’ N, 88^{o}30’W. However, there was a considerable line of gear on the bottom just to the northeast of this site, and trending northwest to southeast. The skipper of *Brooks McCall* had excellent images of this gear, which belonged to BP, and brought it to our attention. It was also necessary to avoid a TAMU mooring that had been placed at the location mentioned above as part of our experiment. Hence we modified the plan for the injection track. We decided to place the tracer on a line running through the mooring array, rather than offshore of it, in order to obtain as much synergy as possible between the two components of the GISR project. This decision brought the injection into shallower water than planned, which led to some of the difficulties in sampling described below, but which also seems to have resulted in a unique boundary-current tracer release experiment.



Injection sled preparations. The starboard side 25-micron orifices are mounted in the dark grey vertical bar on the starboard side of the aft end of the sled. In the picture are, from left to right, Bill Green, Brian Guest, Leah Houghton and Cory Anderson. Photo by Adam Ariganello.

Injection sled ready to go in the water. Brian Guest watching the hydroweight going down. Alexi Shalapyonok standing by. Photo by Adam Ariganello.





Brian Guest directing the deployment of the injection sled. Photo by Adam Ariganello.

Fig. 1. Injection sled preparation and deployment.

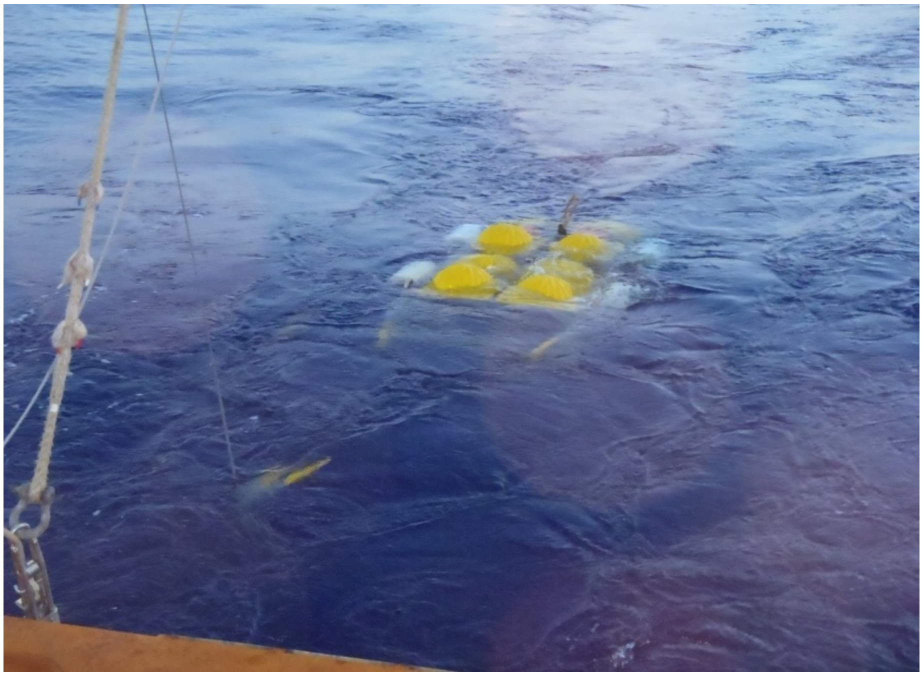


Fig. 2. Injection sled just after deployment. The sled is slightly buoyant at the surface due to the glass balls and the compressible white fenders. The sled is streaming behind the wire with the ship underway at about a knot. The yellow boots at the forward end of the sled bridle can be seen below the water surface where they are attached to the end of the CTD cable via a pear-ring. Suspended from the pear-ring is a 50-meter cable with an 850-pound hydroweight at the bottom. The sled becomes less buoyant as it descends because the fenders compress. They expand again upon surfacing to facilitate recovery.

Seventeen kilograms (actually 16.8 kg) of CF_3SF_5 were released on 28 July 2012, on two segments of a track roughly parallel to the isobaths along the continental slope bounding the northern Gulf of Mexico (Fig. 3). The target density for the release was $\sigma_1 = 32.254$ kg/m^3, where σ_1 is the potential density anomaly referenced to 1000 dbar. It is known that a small term in the formula for the primary conductivity sensor was omitted in the CTD conductivity calculation, so this density will be revised in post-processing. Also, adjustments may be made for post-cruise calibrations. The pressure on this isopycnal surface varied from approximately 1090 to 1180 dbar over the injection track (Fig. 4, bottom panel). The bottom depth along this track varied from about 1200 to1400 meters (Fig. 5). The mean "height above bottom" of the release was between 152 meters (minimum: 104 m; maximum: 248 m; standard deviation: 28 m). Statistics of the hydrographic parameters during the time the injection pumps were on are listed in Table 1. The rms density error during the release was 0.00079 kg/m^3, equivalent to about 1.6 meters in the nominal mean density gradient of 0.00048 kg/m^4. Hydrographic properties at the target density surface for the tracer release, from cruise GS01, prior to ours but near the site, are listed in Table 2.

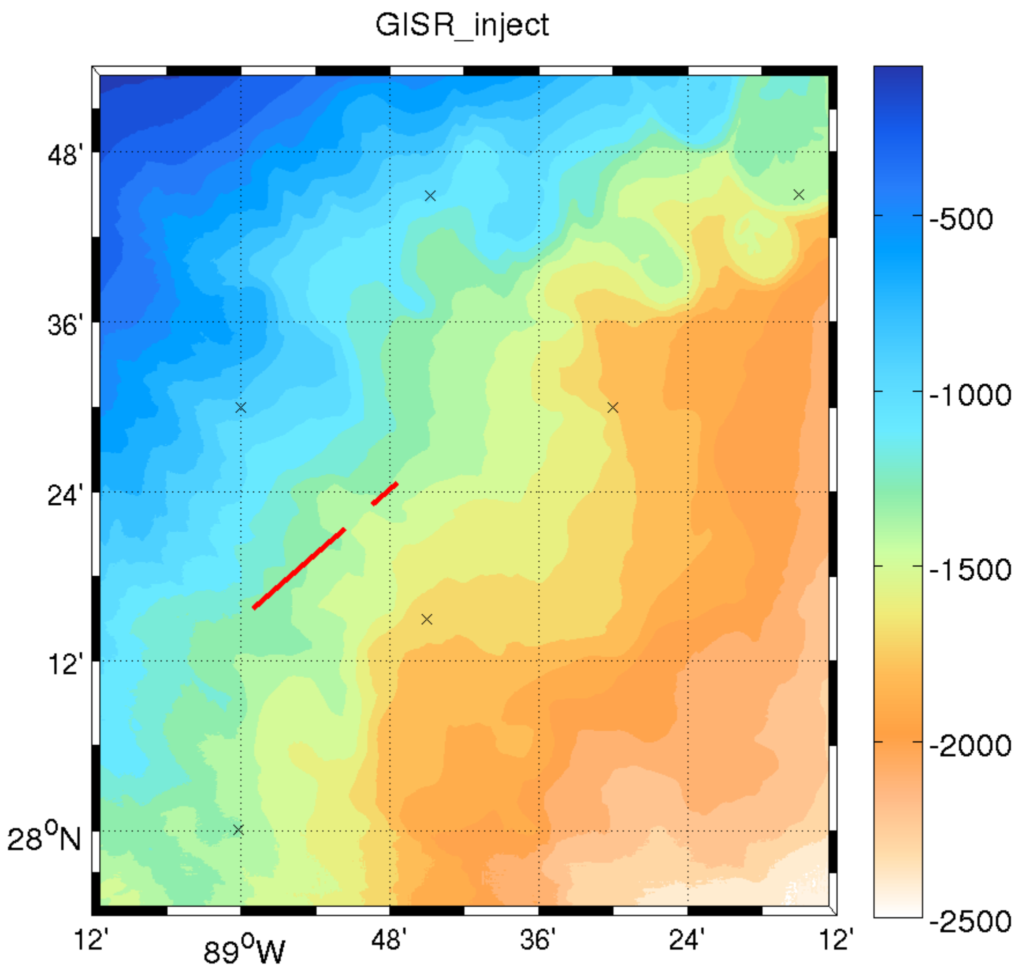


Fig. 3. Tracer Release Track (red). The positions of six current meter moorings deployed on the GISR Mooring Deployment Cruise G01, 5-11 July 2012, are shown ('x'). Bathymetry (color) is in meters. Bathymetry data in this and subsequent figures in this report are from the NOAA National Geophysical Data Center, U. S. Coastal Relief Model, available at the web site: http://www.ngdc.noaa.gov/mgg/coastal/crm.html.

The first seven hours of the tracer release were uneventful, with constant pump speed setting (setting = 75 on both pumps) and with the ship moving over ground on a course to the northeast, with the speed varying from 1.0 to 1.5 knots. Approximately 13.3 kg were released during this first streak, which has been dubbed Streak 1. At the end of this period the pumps were turned off while the package was hauled in for fear that too much wire had been paid out, given the proximity of the bottom and the risk of the hydroweight falling to the bottom if the ship were to slow or turn. More than two hours passed before adjustments had been made to the disposition of the wire and the package had settled into a stable tow again to occupy the shorter segment to the northeast of the first segment, at the same pump rates as before; approximately 3.5 kg were released in this "Streak 2". After a brief interruption to let wire out at the end of this segment, the pump batteries appeared to be depleted when attempts were made to restart the pumps, and the release came to an end.

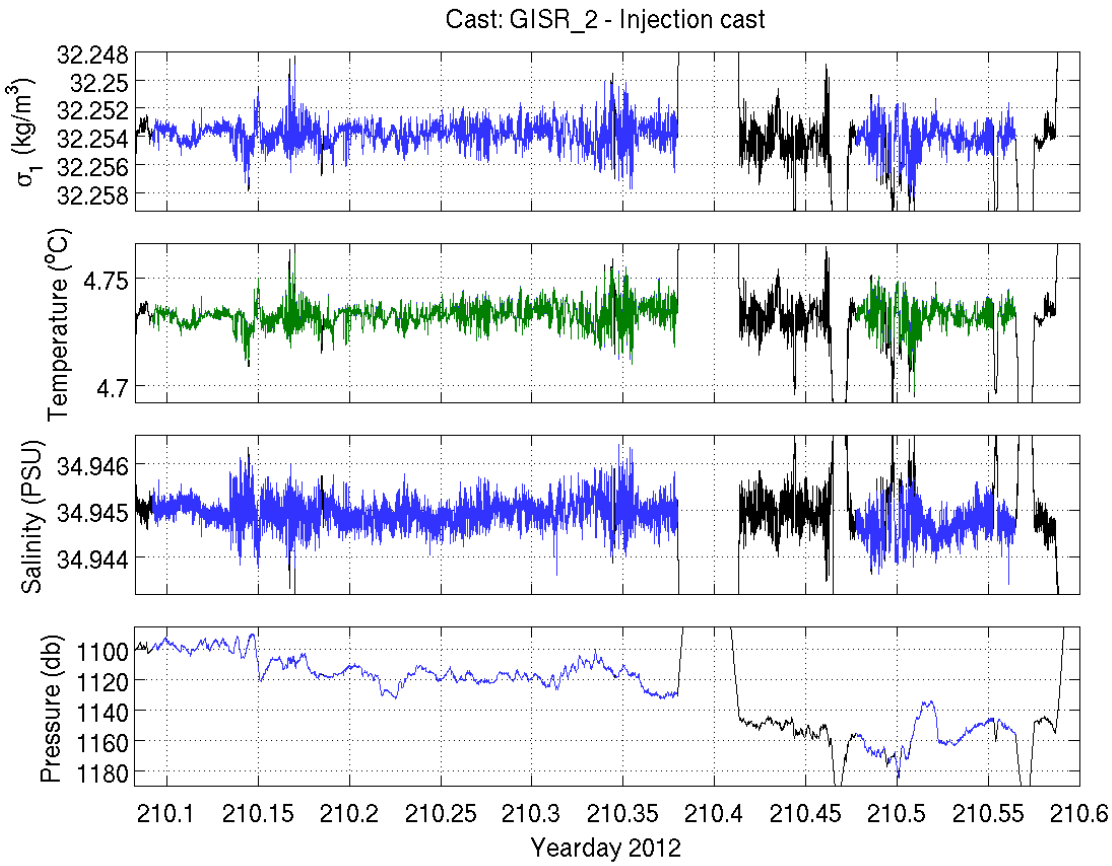


Fig. 4. Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure recorded by the CTD on the injection sled during the tracer release tow, on 28 July 2012. The records are colored blue or green when the tracer pumps were on, and black when off. Gaps appear when the sled was far away from the target density surface due to adjustments made for the disposition of the CTD sea cable.

Table 1. Hydrographic Properties During the Tracer Injection

	Mean	Standard Deviation
Salinity	34.9449	0.00029
Temperature (°C)	4.7330	0.00464
Pressure (dbar)	1122.5	20.1
Potential temperature (°C)	4.6400	0.00468
σ_1 (kg/m^3)*	32.2538	0.00079
Height above bottom (m)	152	28
Number of samples: 31157		
Sample frequency: 1 Hz		

*potential density anomaly, referenced to 1000 dbar

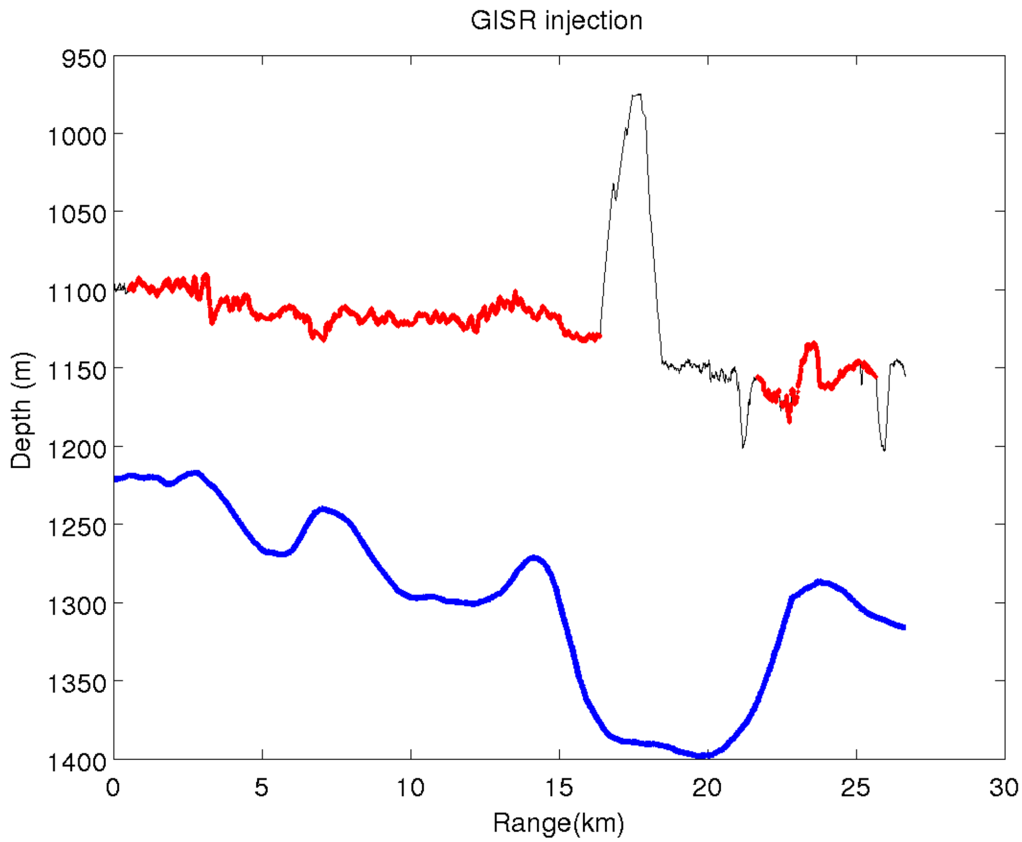


Fig. 5. Bottom depth (blue) and the depth of the tracer injection sled (red: pumps on; black: pumps off) along the deployment track shown in Fig. 3.

The total amount of tracer released was 16.8 kg. Although the injection sled had been loaded with nearly 40 kg of tracer, as proposed, we decided to inject no more tracer. The reasons were that 16.8 kg will provide more than sufficient signal for a one or two year study of dispersion in the Gulf of Mexico, and the release had gone well so far, and there is always a risk that a release can go wrong. To the risk of a rupture in the injection system, or a software or operator error putting the injection sled on the wrong density surface, is added the risk in this case of the hydroweight catching on an obstacle on the bottom, since we were towing so close to the bottom.

Appendix A includes details of CTD operations, Cast Notes, figures showing the variability of potential density anomaly, referenced to 1000 dbar, salinity, temperature, and pressure for each of the sampling tows, statistics for each tow, as well as figures showing the downcast portion of each tow.

Appendix B contains a spreadsheet of the complete Event Log.

Table 2. Hydrographic Parameters at 1100 dbar from the 9 CTD casts at and surrounding the station at 28.5°N, 88.5°W, on Cruise G01

Neutral density	γ_n	32.752	kg/m^3
Temperature (Real)	T	4.76	°C
Temperature (Potential)	T*	4.67	°C
Salinity	S	34.95	
Depth	Z	1100	m
Pressure	P	1110	dbar
Potential density	σ_θ	27.6739	kg/m^3
Pot. density referenced to 1000	$\sigma_{1.0}$	32.2540	kg/m^3
Thermal expansion coefficient	α	1.3652×10^{-4}	$°C^{-1}$
Saline contraction coefficient	β	7.6031×10^{-4}	
Adiabatic T-Gradient	Γ	9.180×10^{-5}	$°C\ m^{-1}$
Vertical T-gradient	dT/dz	2.693×10^{-3}	$°C\ m^{-1}$
Vertical S-gradient	dS/dz	-1.122×10^{-4}	m^{-1}
Effect of dT/dz on stratification	$\alpha(dT/dz + \Gamma)$	3.802×10^{-7}	
Effect of dS/dz on stratification	$-\beta(dS/dz)$	8.531×10^{-8}	
Potential density gradient	$d\sigma/dz$	-4.784×10^{-4}	kg/m^4
Buoyancy frequency squared	N^2	6.40×10^{-6}	s^{-2}
Buoyancy frequency	N	2.53×10^{-3}	s^{-1}
Buoyancy frequency (cph)	N	1.45	cph
Density ratio	R_ρ	-4.457	

Injection System Details

We injected 16.8 kg of tracer over 519 minutes of pumping, to give a mean rate of 0.032 kg/minute. The speed setting on both pumps was 75. The density of the tracer at the pressure and temperature of the injection is not well known, especially given the compression of the tracer in the pump chambers, but is probably around 1.5 kg/m^3, and so the volume flow rate was perhaps a bit greater than 20 ml/min. The readings from the pressure sensors on the outlet side of the injection pumps varied greatly, as usual, but were from 3 to 5 volts typically while the pumps were on and fell to near zero when off.

The tracer was pumped through two sets of six 25-micron orifices, one set for each pump. The sled went down with two accumulators with tracer, approximately 19 kg each, and one accumulator with approximately 10 liters of Vertrel, which is used as the primer fluid. The sled was buoyant at the surface with this load. About two hours of effort in the hot sun were required to set up 12 orifices that were spraying clearly.

One of the batteries was found not to have outgasses upon recovery of the injection sled, suggesting that this battery was defective and not providing power. This may be the reason that we ran out of power earlier than usual and also that flow rates may not have been as great at a setting of 75 as usual.

Sampling System

The tracer sampling system was composed of a central sled at the end of the CTD cable, 10 integrating samplers clamped on the CTD wire above the sled, and between 0 and 10 more integrating samples clamped on an auxiliary cable suspended below the sled. These integrating samplers take 850 ml of water into a metalized bag at a slow rate over 5 to10 hours by pumping water from behind the bag, which is housed in a plastic cylinder. The spacing between integrating samplers was usually 3 to 5 meters, and typically 4 meters. At the sled were one or two integrating samplers, a CTD which is used to keep the sled as close as possible to the potential density surface of the injection, and 50 glass syringes, which fill one at a time while the integrating samplers fill. At the bottom of the auxiliary cable, was a hydroweight, usually 850 pounds. Several versions of the auxiliary cable were used, with lengths from 20 to 50 m, and for some deployments only a short cable and 285-pound weight were suspended from the sled, with no samplers below the sled, to get the sled with its CTD close to the bottom. Also in the array were one or two SeaBird SBE 39 CTDs to obtain the wire angle and to give a record of the density stratification over the tow track by comparison with the central CTD. The integrating samplers on the cables were tripped by mechanical messenger, those on the sled were tripped from a rosette pylon mounted on the sled, and the 50-syringe sampler on the sled started on a timer.

Sampling Track Narrative

The hunt for the tracer was more difficult than anticipated because the injection track was closer to the bottom than planned. Our choices for the location and direction of the sampling tracks (Fig. 6) may seem ill advised to anyone not involved in the decisions, so here we record the reasoning behind those decisions.

First of all, it is challenge for the ship to maintain a speed of less than a few knots, while our sampling system must be towed at a speed of less than 2 knots to keep the wire angle tolerable. In fact in the present case, due to the proximity of the bottom, it was necessary to keep the ship's speed to less than 1.5 knots to avoid paying out too much wire. The best course to maintain such a low speed on *Brooks McCall* is approximately down wind. The wind speed was 5 to 10 knots for most of the cruise, usually from the southwest, south or southeast, and significant wave heights were usually less than 4 feet. These benign conditions helped the bridge maintain a low speed and steady course. Nevertheless, the captain and mate of the ship showed great skill and attention to execute the sampling tracks on this cruise, seen in the figures.

The second severe constraint to the choice of tracks on this cruise was proximity of the bottom. Sampling is done with the sampling sled maintained at the target density surface for the injection. The depth of this surface varied from around 1100 to 1200 meters. However, the tracer was often found near the 1200-meter isobath, especially when approaching the continental slope, and so the weight at the bottom of our sampling array was often uncomfortably close to the bottom. We did not think to request a Precision Depth Recorder or bring a bottom pinger to use with a PDR, and so we had no real-time measurement of the height above the bottom. We were reliant on the data from bathymetric surveys of this part of the Gulf, which appeared to be very accurate, fortunately. We dragged our bottom weight into the bottom only once.

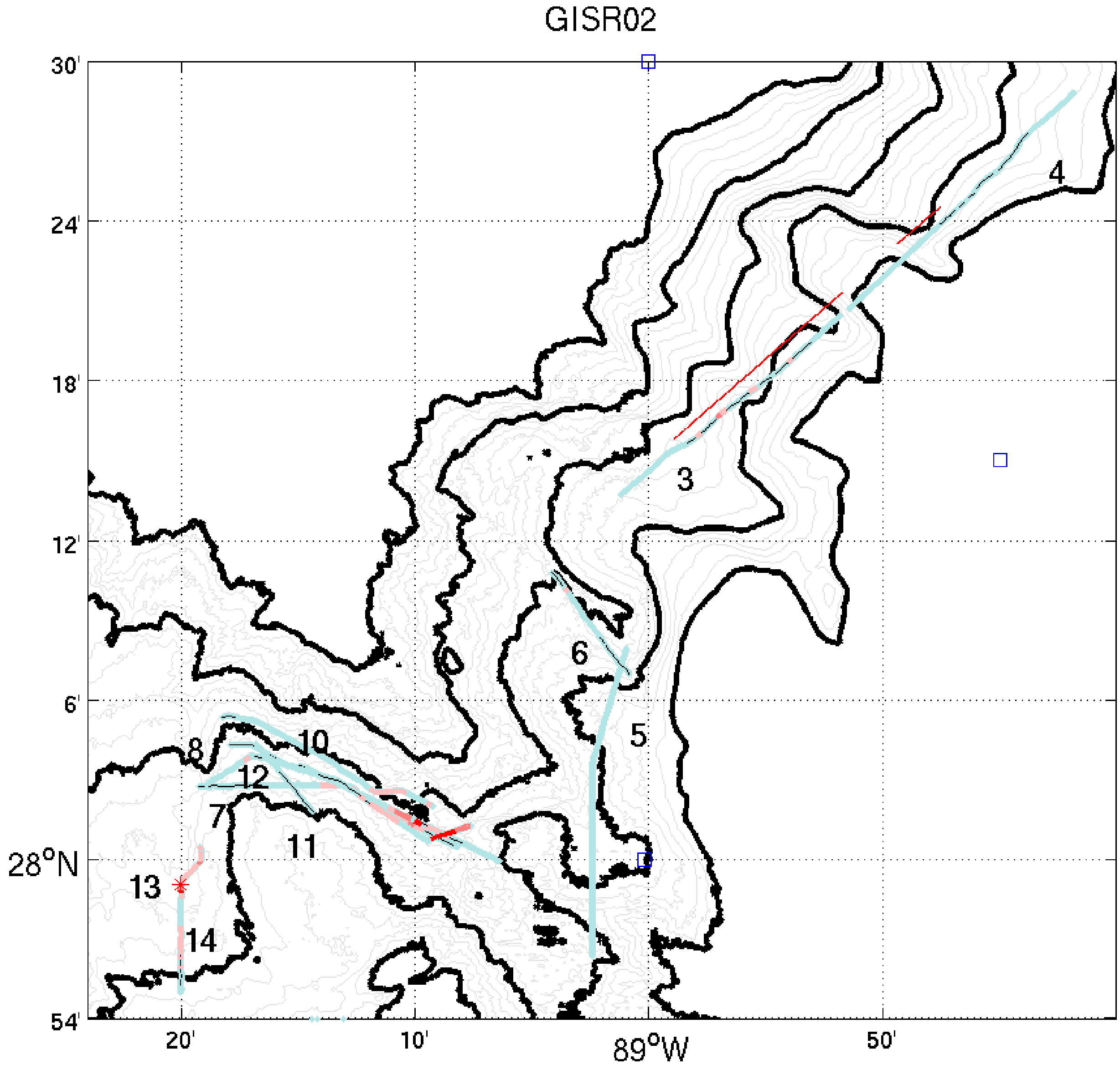


Fig. 6. Overview map. The sharp red lines in the northeast show the injection streaks. Sampling tows are shown as light blue lines, with added colors to indicate tracer found: black: no tracer, pink: less than 5 pM; red: more than 5 pM; no added color: syringes did not fill. The tows were done from south to north. Cast 9 was a station near the northwest end of Cast 10 – no tracer; Cast 13 was a station where much tracer was found (red asterisk). Blue squares: TAMU moorings. Black isobaths are drawn every 100 m from 1000 to 1400 m, from northwest to southeast. The light isobaths between these are every 20 m. A detail of Casts 7 through 14 is shown in Fig. 11.

Here is a cast by cast summary of our hunt (Cast 1 was the injection cast):

Cast 2: A cast off shore of the region of the tracer to test the equipment, especially for contamination of the ship and sampling gear from the injection cruise. The sampling gear had remained on shore, but still could pick up tracer during loading. Of particular concern was the ship's fresh water supply, which is used in the hydraulic systems in the samplers. All components of the system turned out to be clean. Many bugs in the overall sampling system and launch procedure were discovered and ironed out from the experience of this cast. However, a failure of the sea cable caused no CTD data to be collected.

Cast 3: This was the first sampler tow aimed at sampling the tracer. The tow track retraced more or less the first half of the injection tow, but 5 days later. Tow tracks are shown in Fig. 6, color coded crudely for where the tracer was found, according to the 50-syringe sampling system. The bottom 3 samplers did not fire because the messenger was caught on one of the SBE37 CTDs in the array. Only one sampler was on the sled for this cast, and it also did not fire. (Two samplers were mounted on the sled for subsequent casts.) The first sampler above the sled was about 5.5 meters above the sled, instead of the intended 4 m, due to the vagaries of launching the sled. The resulting vertical profile from the integrating samplers is shown in Fig. 7. We see a peak at 8 meters below the target surface, but there is data gap between 4 meters below and 5.5 meters above the sled, so unfortunately we can't be sure there was no tracer near the target surface.

The maximum concentration in this profile is 3 pM and the column integral of tracer is approximately 35 nanomoles/m^2. If this column integral were typical of the overall patch, then the area covered by the patch would have been approximately 2500 km^2, and the length scale of the patch would have been 50 km. The length of the initial streak was about 20 km, so an exponential growth rate of the length scale of about $2 \times 10^{-6}\ s^{-1}$ would account for the increase. It is easy to imagine the length of the streak growing at this rate, or even faster, along the isobaths. It is perhaps a little more difficult to imagine such a growth rate in the cross-isobath direction. In any case, the concentrations found were of the order of magnitude expected 5 days after injection, though it would not have been surprising to find ten times as high concentrations at this point in the experiment, based on past experience.

Due to an arithmetic error, the chief scientist underestimated the amount of tracer found by a factor of 1000 at first, and this error persisted for two or three days, causing us to believe that we were only on the periphery of the patch.

Cast 4: This tow continued to the northeast along the path of the injection (see Fig. 6). Simulations at NCSU and TAMU indicated that there would be tracer along this path and so one purpose was to test these predictions. It turned out that very little tracer was found along this track. The only sampler that came up with tracer, about 0.5 pM, was the one at 4 meters above the sled. This lack of tracer does not invalidate the simulations, since a small displacement of the actual patch from the predicted patch could cause us to miss it.

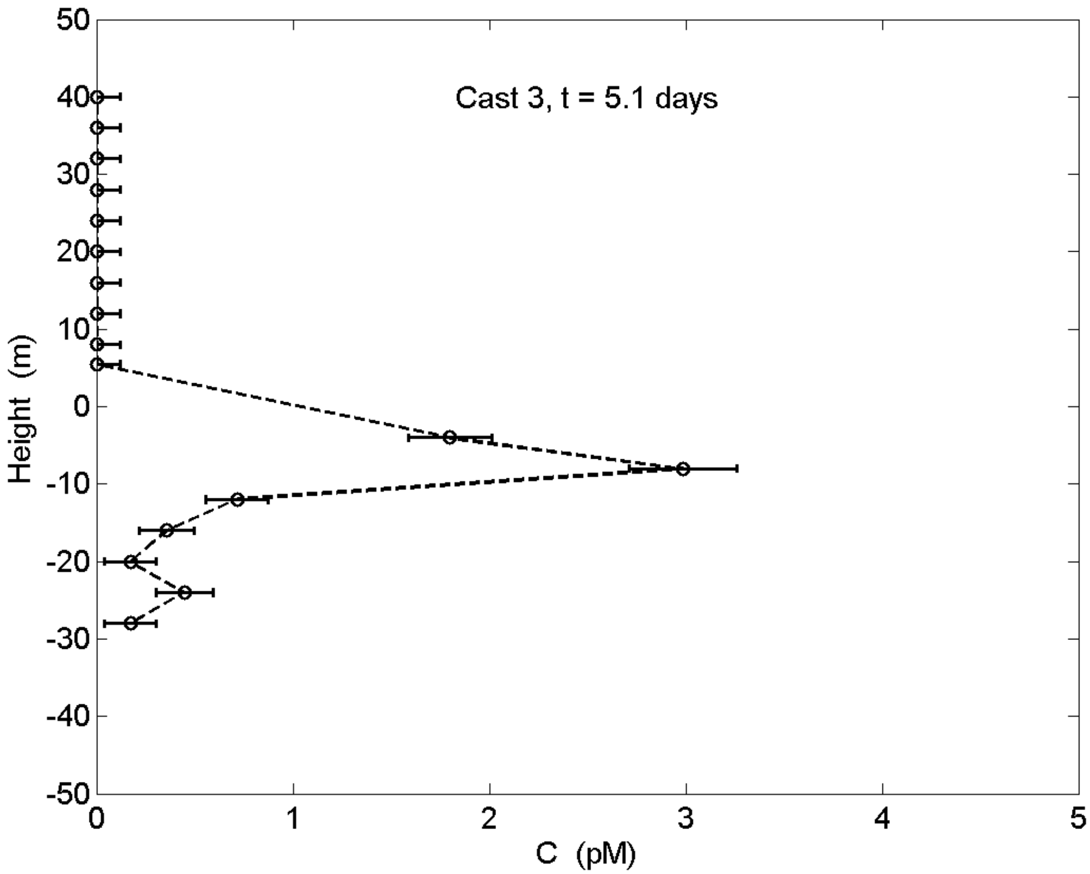


Fig. 7. Vertical tracer profile from Cast 3. The mid-time of the cast was 5.1 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

Cast 5: This tow was well to the south of the tracer release location. We were guided by the RAFOS float that was deployed during the early part of the injection and timed to come to the surface a few days later. The displacement of this float was to the southwest, and to a somewhat shallower isobath than where it was deployed (Fig. 8), giving evidence that there was a boundary current along the isobaths at the level of the tracer, with a velocity of around 3 cm/s. We used this speed and the guess that the tracer was moving along isobaths to select the location for the Cast 5 track (see Fig. 6). A few samplers found only small amounts of tracer on this track (Fig. 9). We guessed that we were too far off shore; that the tracer was hugging the boundary, as the float seemed to do, and also as appeared in the TAMU simulations for Streak 1.

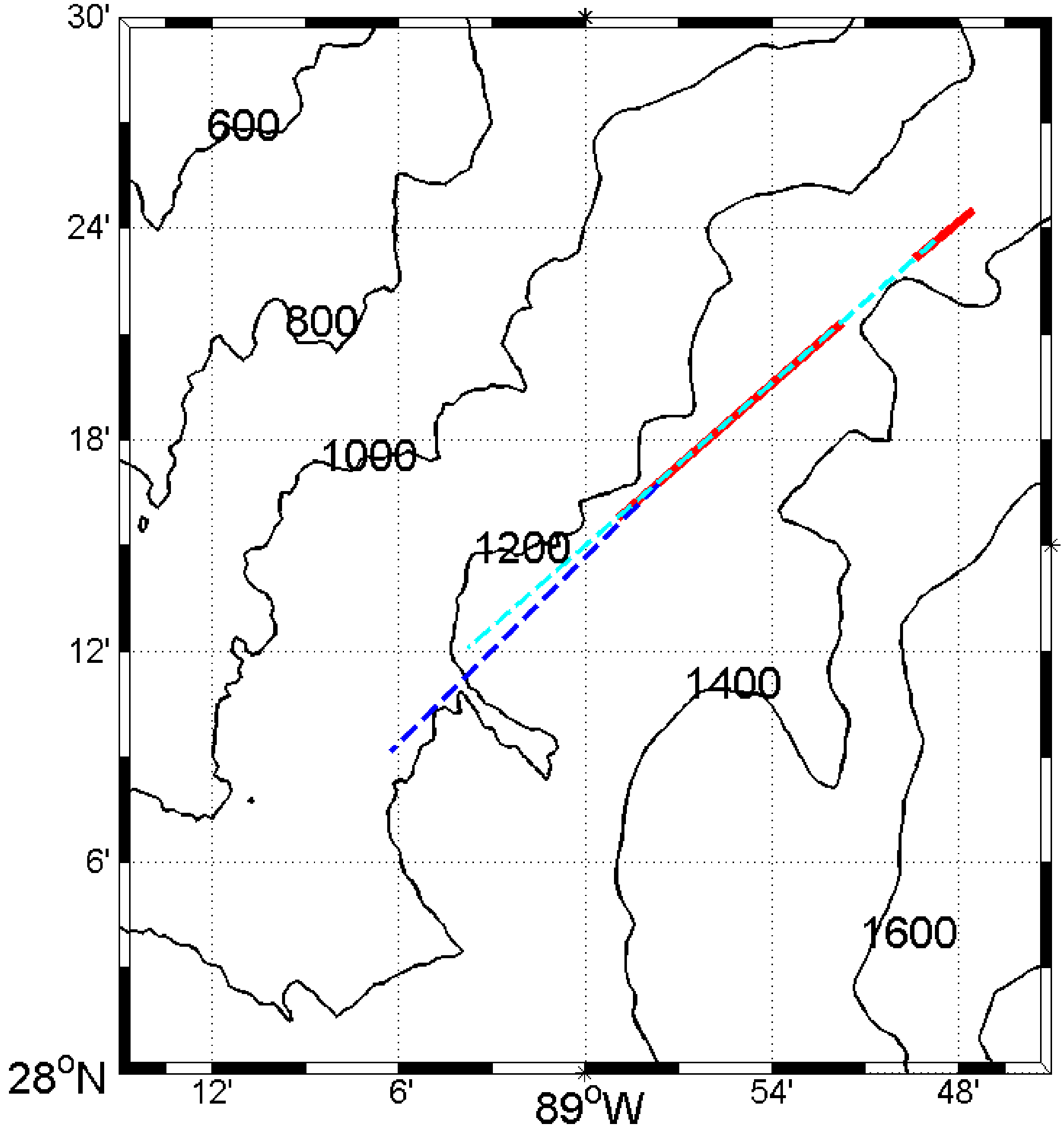


Fig 8. Displacement of the first RAFOS float (blue) and second RAFOS float (cyan) superposed on the tracer injection streaks (red). The sense of both displacements was from northeast to southwest. Contours are in meters.

As for Cast 3, the tracer found was below the target density surface. In fact the bottom sampler, 40 meters below the sampling sled, found a peak of tracer. The 50-syringe sampler failed to work at all on this tow, so we don't know where along the track tracer was found. But we note that by the end of the cruise, where we think the tracer was most likely found, the bottom of the sampling array was only 50 meters above the bottom, and this may have had something to do with us finding this deep tracer peak.

Cast 6: This tow was from the end point of Cast 5 to the northeast into shallower water (see Fig. 6 for the tow track). It was necessary to end this tow early because of the proximity of the bottom. The vertical distribution from the integrating samplers is shown in Fig. 10. The column integral was about 60 nmol/m^2, and the profile is centered just a few meters below the target surface. The 50-syringe sampler suggests that the tracer was found along the middle of the tow track when the bottom sampler was around 60 meters off the bottom.

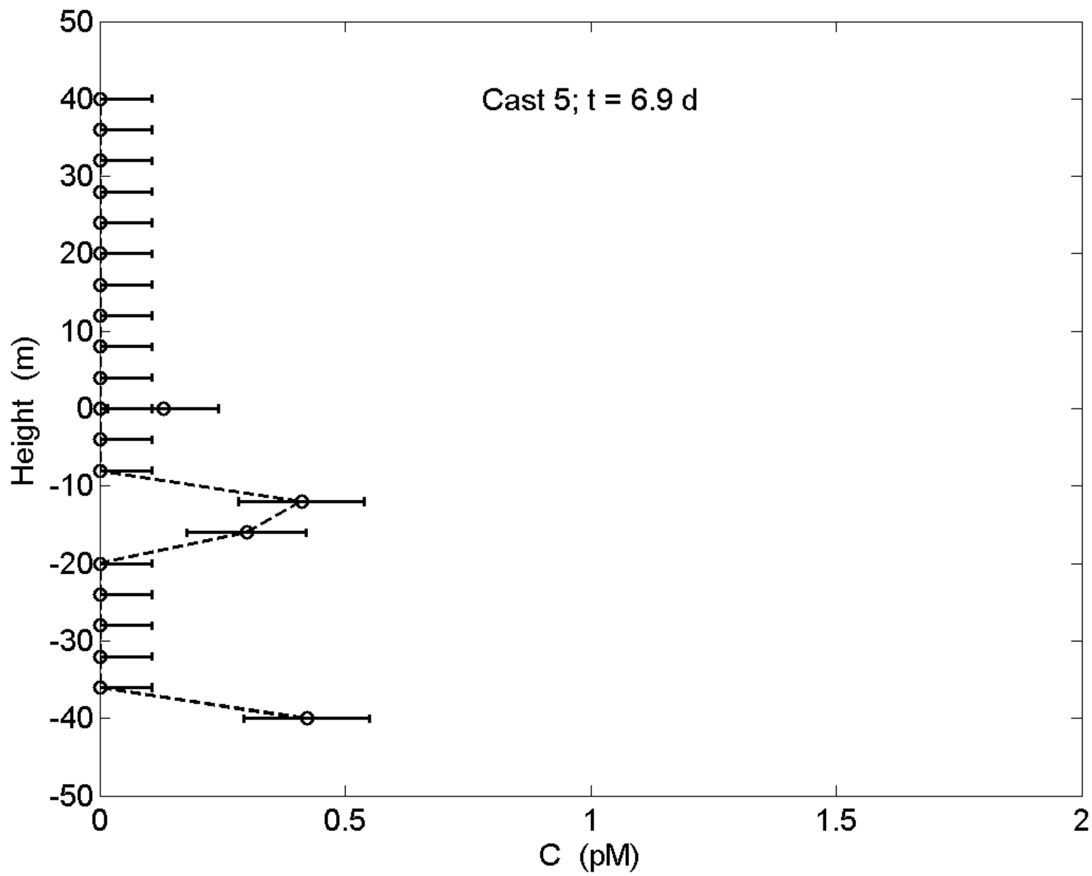


Fig. 9. Vertical tracer profile from Cast 5. The mid-time of the cast was 6.9 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

Cast 7: At some point the second short-term RAFOS float, deployed shortly after Streak 2 and in the same area as Streak 2, had surfaced and relayed its position. This float had also moved to the southwest, and to somewhat shallower water, but mostly along isobaths, and at a speed of about 6 cm/s (Fig. 8). This displacement gave us even more reason to look to the southwest, along isobaths, to sample the tracer. We estimated from the float drifts that the center of the patch was in the vicinity of the tracks for Casts 7 through 12, shown in Fig. 11, which is a detail from Fig. 6.

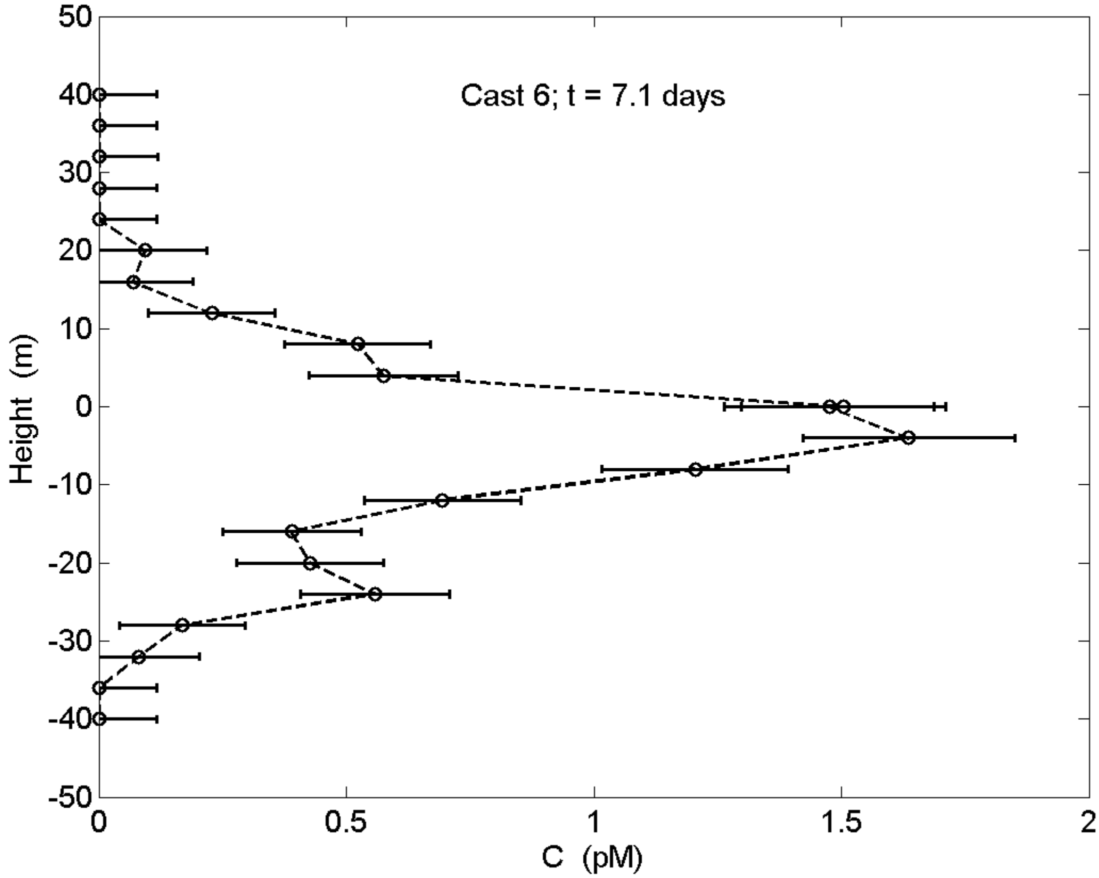


Fig. 10. Vertical tracer profile from Cast 6. The mid-time of the cast was 7.1 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

We indeed found high concentrations there, although in only a limited segment of the track. The western end of this track was diverted to be due west rather than northwest as planned, due to the descent of the target density surface toward the bottom. The top 10 samplers were not tripped for this tow because the messenger was stopped by a marking tape on the cable, 100 meters above the termination that we had not noticed. Thus, samples were obtained only from the central sled and from the samplers below the sled. The tracer was found broadly distributed with maximum concentration 16 meters below the sled (Fig. 12). The column integral of this partial profile was again about 60 nmol/m^2.

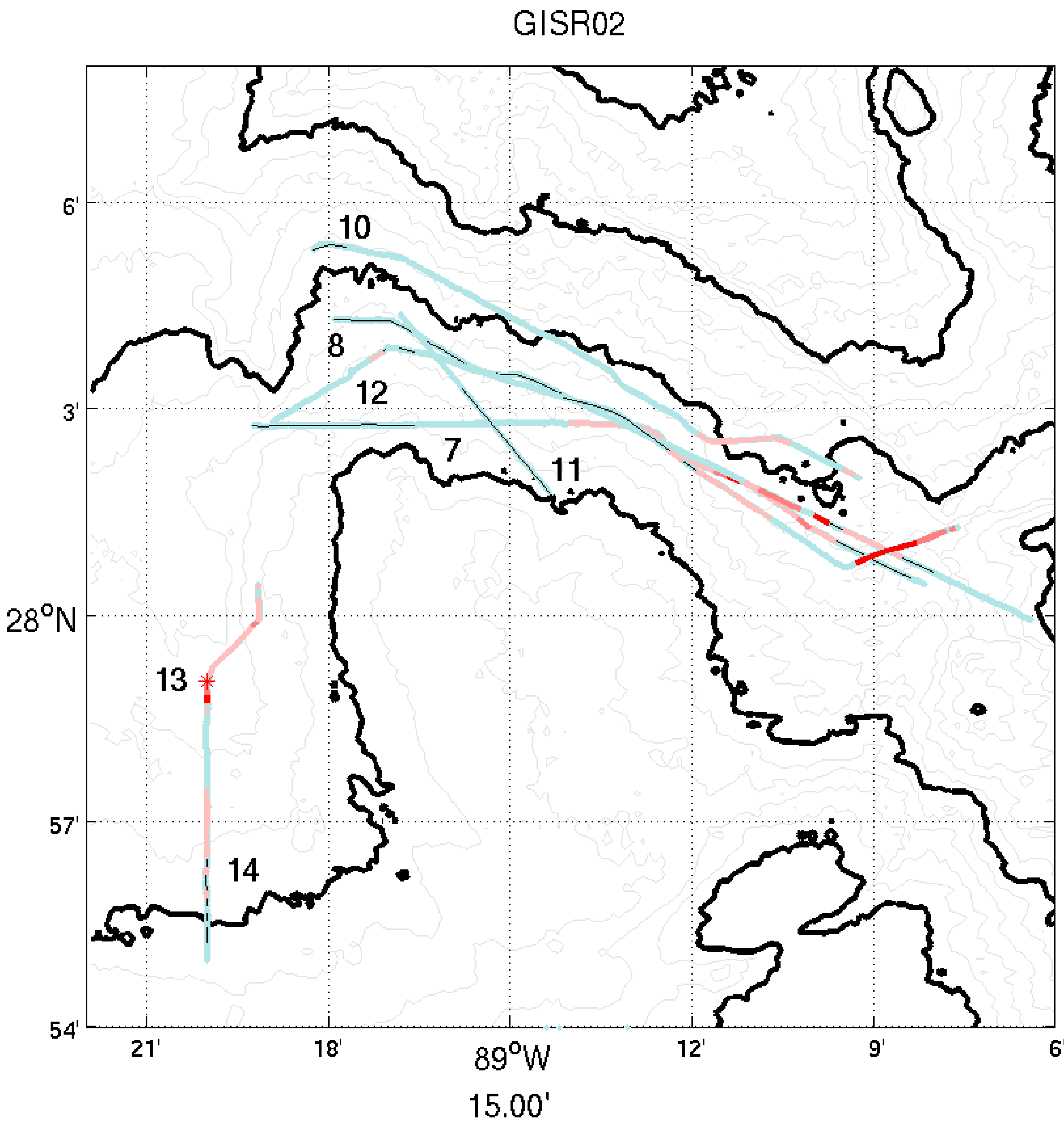


Fig. 11. Detail from Fig. 6. The color key is the same: cyan: no data from the 50-syringe samplers; pink: black C = 0; cyan: C < 5 pM; red: C > 5 pM. Casts 7, 8, and 12 lie almost on top of one another in places. Cast 7 is a simple dog-leg underneath the others, with tracer along its eastern half. Cast 8 is nearly straight with a bend to the west at the western end. Cast 12 has three segments with a pink and red southwestward segment in the east and a cyan southwestward segment in the west. Black isobaths are drawn every 100 m from 1000 to 1400 m, from north to south. The light isobaths between these are every 20 m.

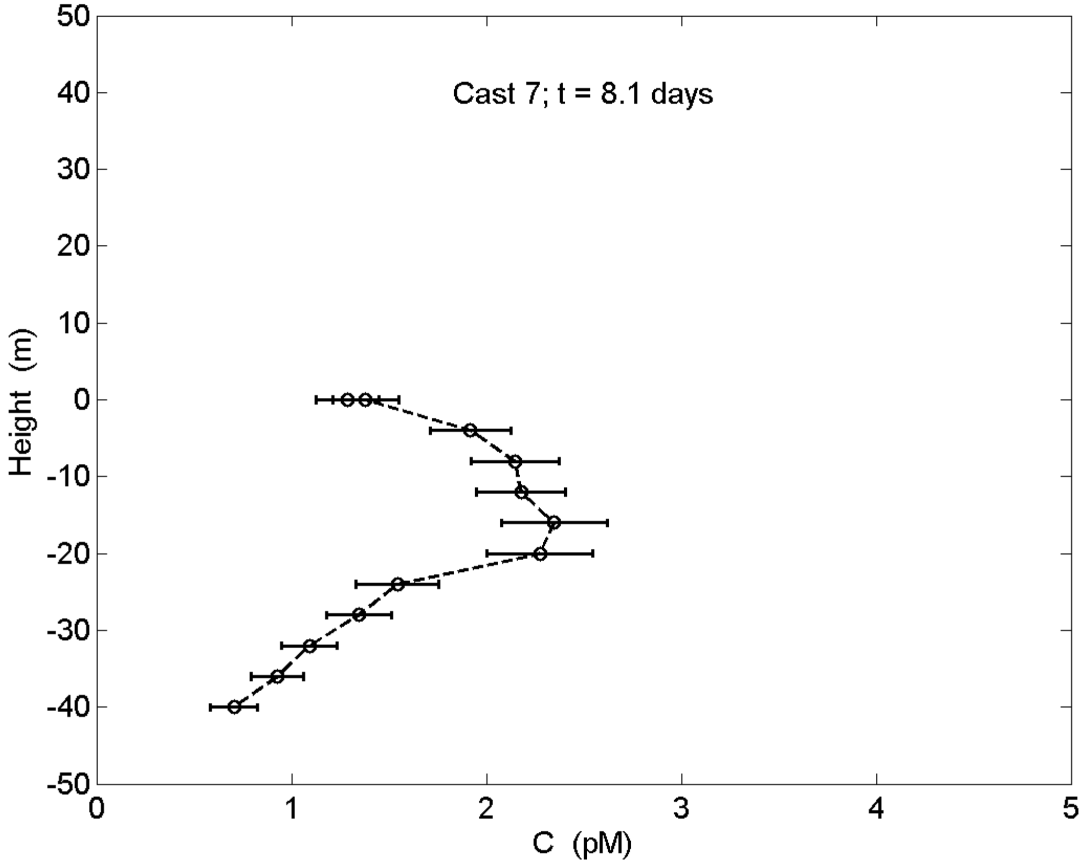


Fig. 12. Vertical tracer profile from Cast 7. The mid-time of the cast was 8.1 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

Cast 8: The length of the cable under the sampling sled was reduced from 50 meters to 20 meters in order to sample over shallower isobaths. Cast 8 was along a track a bit to the north of Cast 7. It succeeded in obtaining the samples above the sled as well as below, and found tracer in locations similar to those for Cast 7, i.e. about a third of the way along the track (Fig. 11). Because the bottom wire was short for this cast, the lower part of the profile was missed. Figure 13 shows the vertical profile. The peak concentration is 4 meters below the sampling sled, but there is a broad wing below this depth, consistent with Cast 7 (Fig. 12). The depth of the sampling system and the bottom along the track is shown in Fig. 14. According to data from the 50-syringe sampler, tracer was found between 4 and 8 km along the track, where the bottom depth is at about 1210 m, and the bottom sampler was about 54 meters above the bottom. Tracer was not found at the shallow end of the track, between 14 and 22 km, where the bottom depth was about at about 1230 m, and the bottom sampler was about 14 meters above the bottom. Figure 14 suggests that the weight hit the bottom, and this indeed was the case, but no damage was done to the equipment. The column integral represented by this profile was about 30 $nmol/m^2$.

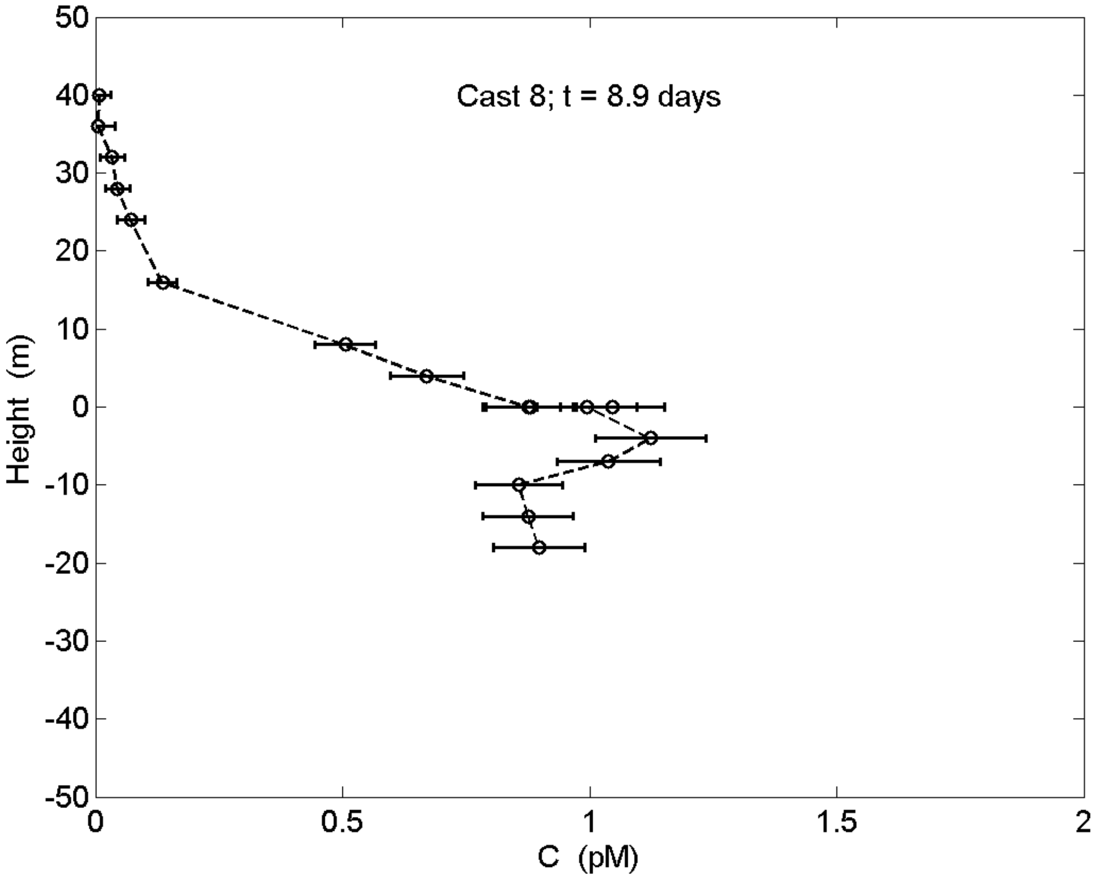


Fig. 13. Vertical tracer profile from Cast 8. The mid-time of the cast was 8.9 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

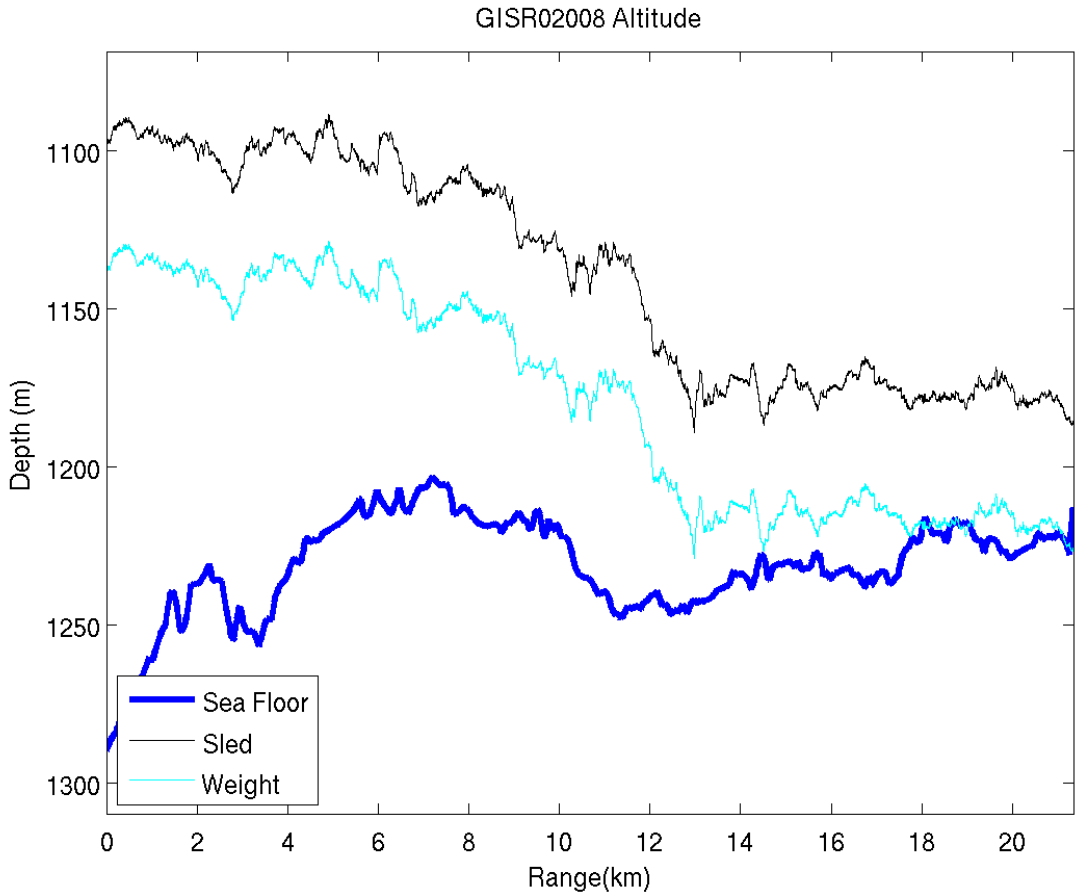


Fig. 14. The bottom depth (blue), depth of the weight at the bottom of the sampling array (cyan) and the depth of the sampling sled (black) along the tow of Cast 8. The 50-syringe sampler found tracer between 4 and 8 km range, but not between 14 and 22 km. The bottom depth is from NGDC data. We tested its accuracy in that the weight did indeed hit the bottom.

Cast 9: Advantage was taken of a few hours in the afternoon to occupy a stationary point at 28°4.8'N, 89°18'W, near the end of the track for Cast 8 where the bottom depth was at about 1220 meters, to measure short term variability of the density 20 meters off the bottom and to see whether there was tracer at that location. The lower cable was replaced by a 1-meter cable with a 285 pound weight just beneath the sled for this operation. No tracer was found at this location, consistent with the results from the 50-syringe sampler on Cast 8.

Cast 10: The lower cable was left off the array and the sled was towed at a shallower isobath (1180 to 1220 m) paralleling that of Casts 7 and 8 to determine whether the tracer had moved to regions shallower than we had been able to sample. Tracer concentrations were generally less than 0.1 pM, so quite low, with the tracer distributed rather broadly above the target surface (Fig. 15). The 50-syringe sampler found tracer again in the first third of the track (Fig. 11), although the syringes failed to fill along much of that track. The column integral is around 3 nmol/m^2 for this tow. This Cast seemed to reinforce the suspicion that not much of the tracer had moved inshore of the 1220 m isobath.

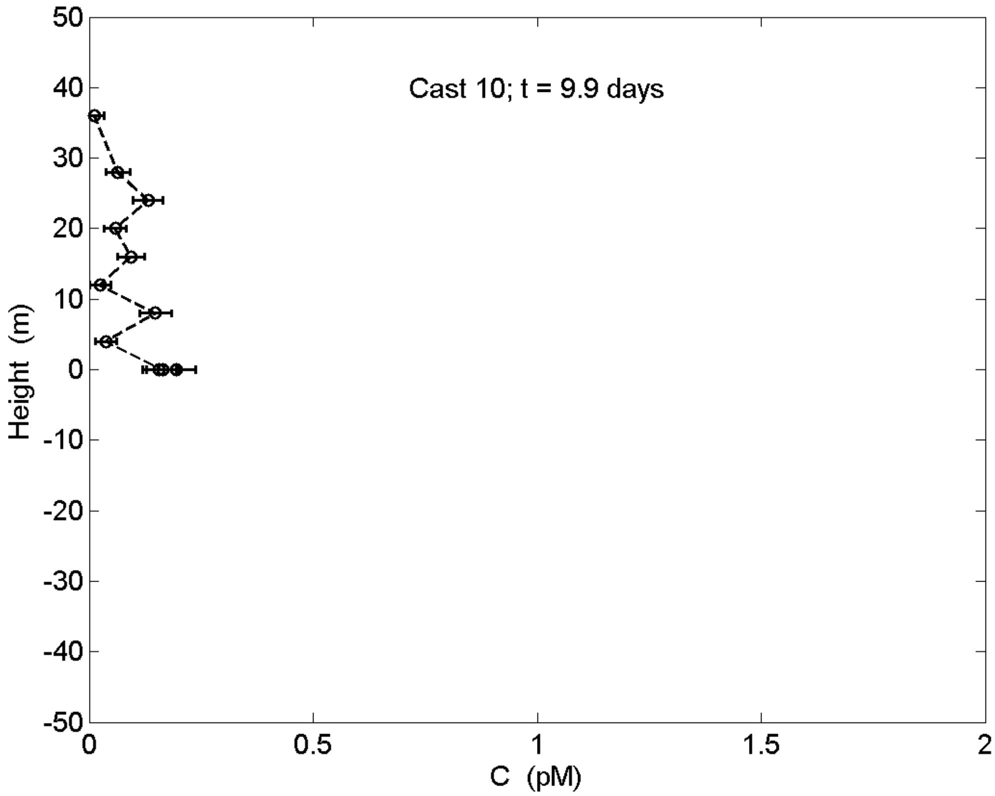


Fig. 15. Vertical tracer profile from Cast 10. The mid-time of the cast was 9.9 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

Cast 11: A plan was made to take a quick look for tracer in deeper waters in preparation for Cast 12. On Cast 11 we occupied a short line cutting across isobaths on an afternoon cast (see Fig. 11). We did not deploy the sampling array but only two samplers on the sled which were triggered to fill quickly at two points along the path. We found no tracer in either the integrating samplers or the 50-syringe sampler, but the latter returned no samples past the half-way point.

Cast 12: Given the negative result from Cast 11 we were not motivated to look for tracer at isobaths deeper than 1240 m. So the Cast 12 track was along the 1240 m isobath, roughly parallel to Casts 7, 8, and 10 (see Fig. 11). We found a strong tracer signal along the eastern third of this track, and not too far to the east of the other finds. However, we infer from the float displacement and also from the distance of the tracer we had found from the release point that the current along isobaths was about 3 nautical miles per day and so we believed that we were sampling different water on each cast.

The vertical tracer profile from Cast 12 (Fig. 16) found the tracer peaked at or just a meter or two below the target surface, with a smooth wing both above and below this level. The wing below the sled was much broader though, and was cut off at 20 meters below the sled because we were using the 20-meter cable to avoid further encounters with the bottom. The column integral for this profile was again about 30 nmol/m^2.

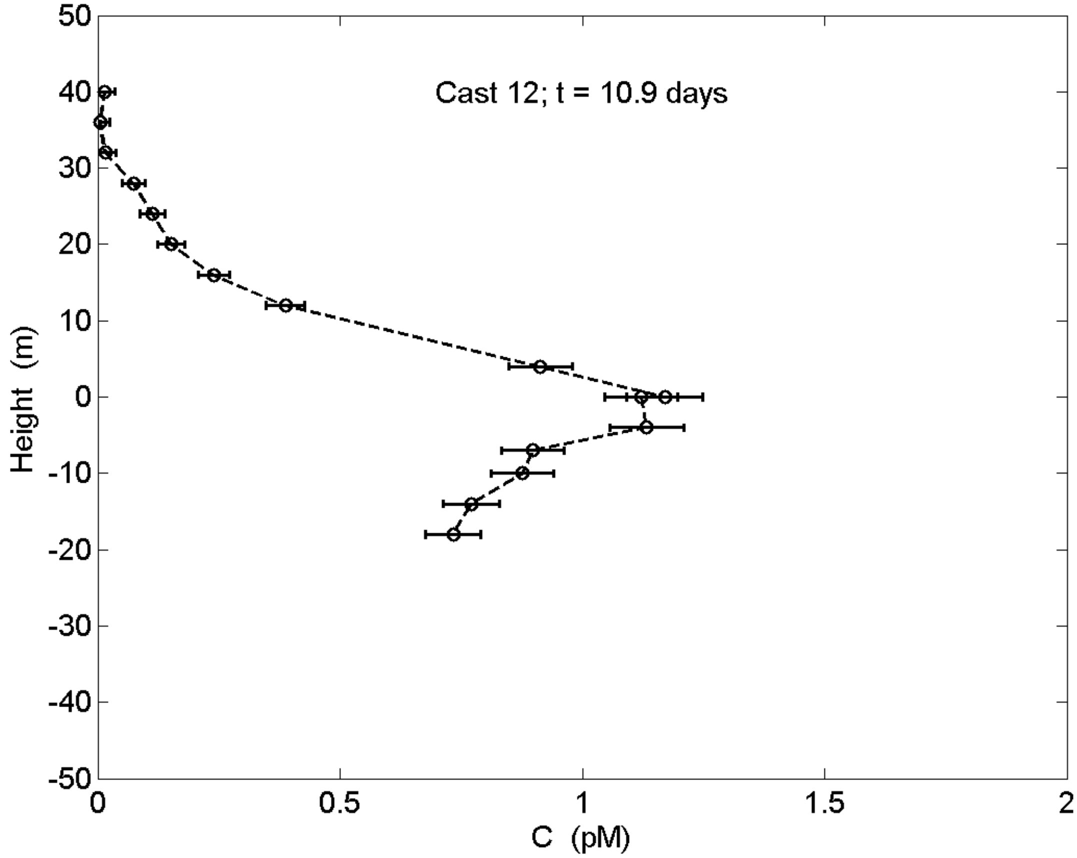


Fig. 16. Vertical tracer profile from Cast 12. The mid-time of the cast was 10.9 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

Cast 13: We estimated that at least the leading edge of the tracer should have turned the corner near the end of tows 7 and 12 in Fig. 6, and headed south by the final day of sampling. We therefore did a spot check in the afternoon in this region, well south of the western end of the previous tows (see the red asterisk marked '13' in Fig. 11). There we found large concentrations in 6-minute integrating sampler aliquots taken at three densities around the target density, i.e., essentially spot samples. A peak concentration of 14 pM was found at the target density in the central sampler, indicating that there was indeed tracer in this region.

Cast 14: As we had not delimited the deeper part of the tracer distribution very well, we took measures to sample deep in the region in the vicinity of Cast 13. We reduced the tow time to 5 hours so that we would not run into shoals. We increased the length of the lower cable to 40 meters. The results were gratifying, with the Cast yielding a complete profile that was consistent with partial views we had obtained from the other casts. The multichamber sampler was also more successful on this tow, perhaps because the pump rate was doubled, and the sampler yielded high concentrations along most of the track. The vertical profile from this cast is fairly symmetrical, although with an increase in concentration near the bottom (Fig. 17). The hot spot of tracer was found near the location of Cast 13, at bottom depth of 1250 m according to the integrating samplers (Fig. 11), although tracer was found along most of the track. The bottom sampler was within 30 meter of the bottom at this location and over the last third of the track (Fig. 18).

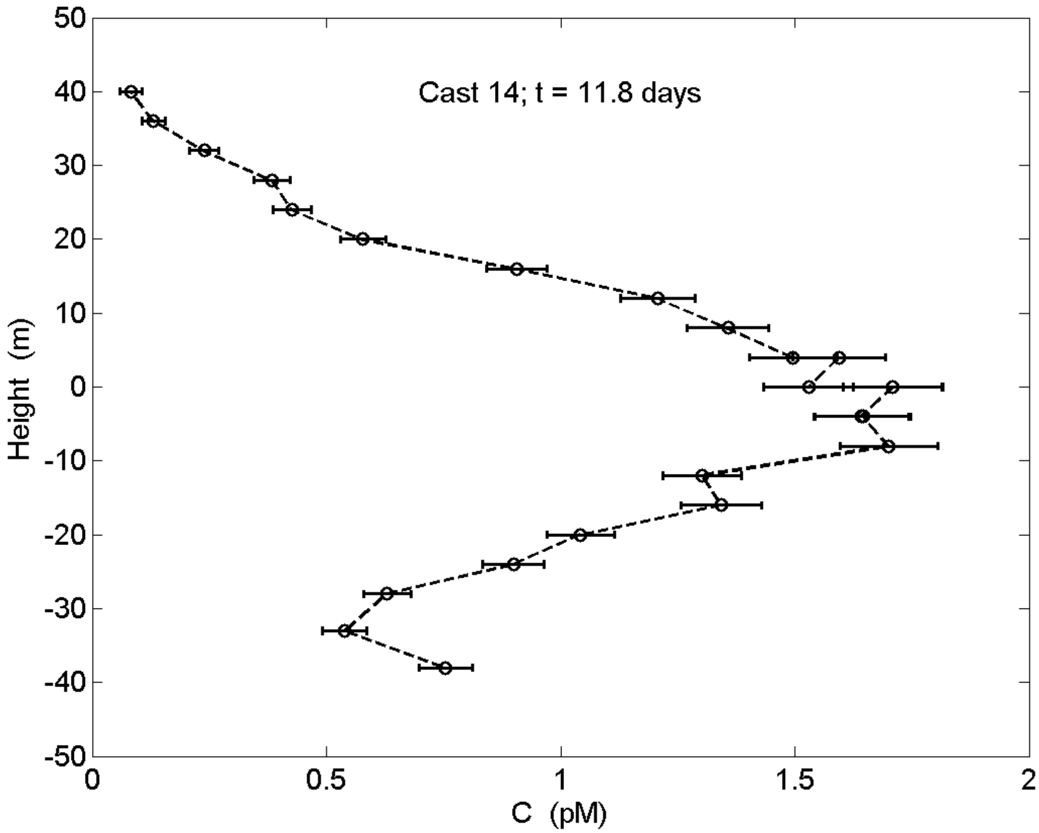


Fig. 17. Vertical tracer profile from Cast 14. The mid-time of the cast was 10.9 days after the mid-time of the injection. Tracer concentration, in pM (1 pM = 10^{-12} moles/liter) is on the horizontal axis, and nominal height above the central sled is on the vertical axis.

The column integral for this profile is about 75 nmol/m^2. This is the fullest profile obtained during the sampling cruise in both concentration and depth coverage. If we were to fit a Gaussian to this profile it would give a standard deviation of about 18 m, both above and below the target density surface. A crude estimate of the diapycnal diffusivity can be made from the formula:

$$2k = (\sigma_f^2 - \sigma_i^2)/\Delta t$$

where k is the diapycnal diffusivity, σ_f and σ_i are the final and initial standard deviations and Δt = 11.8 days is the time since injection. σ_i has never been greater than 10 m in previous injections with this same system. Hence, we estimate that $k > 10^{-4}$ m^2/s.

This diffusivity is an order of magnitude greater than found in the open ocean, suggesting that dynamics associated with boundary currents and internal waves near the continental slope along the northern Gulf of Mexico are enhancing the energy available for mixing considerably. The other tracer profiles are consistent with this interpretation, although evidence from them is fragmentary. More work is required to analyze exactly what is going on. Of particular value will be the records from the SBE37 CTDs that were incorporated in the sampling array. Comparison of those records with those from the central CTD at the sampling sled will give information on the stratification where the tracer was actually found, and closer look at the bottom depth will give information on the bottom depth and height above bottom of the sampling sled where tracer was found.

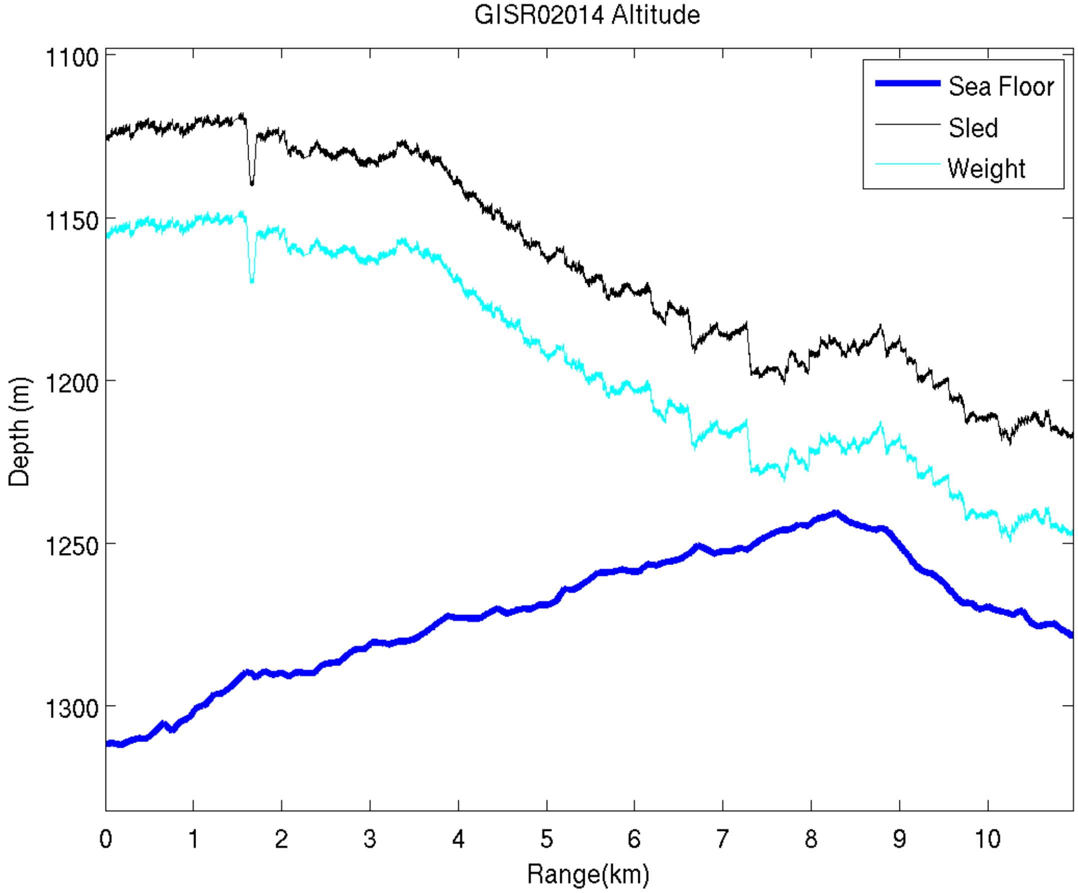


Fig. 18. The bottom depth (blue), depth of the weight at the bottom of the sampling array (cyan) and the depth of the sampling sled (black) along the tow of Cast 14. The 50-syringe sampler found tracer along much of the range, but especially beyond 7.8 km.

Table 3 lists the sampling characteristics for Casts 2–14.

Table 3. Sampling Cast Characteristics

Cast		Aux Cable Length (m)	No. of Samplers	Comments
2	Test	50	21	No contamination found
3	10-hr tow	50	21	1 sampler on sled; did not fill; lowest 3 samplers did not trip
4	10-hr tow	50	22	2 samplers on sled from here on
5	10-hr tow	50	22	
6	6-hr tow	50	22	
7	10-hr tow	50	22	Upper 10 samplers didn't trip
8	10-hr tow	20	17	
9	3-hr station	2	(2)	
10	10-hr tow	2	22	
11	Exploratory tow	2	2	No tracer
12	10-hr tow	20	17	
13	Exploratory station	2	3	Spot sample – high tracer
14	5-hr tow	40	21	

Appendices

Appendix A. CTD Operation

CTD Instrument Overview

Two Seabird SBE 9*plus* CTD units were used on the GISR02 cruise. One was the Ledwell CTD and the other was supplied Frank Bahr. The Ledwell CTD was used for the injection tow and the Bahr CTD was used for the sampling tows. Both CTD's had dual pumped C/T sensors and a pressure sensor for the primary variables There were some instrument and sensor problems during the cruise and sensors and CTD 9*plus* units were changed to diagnose and correct these problems. Table 4 lists the serial numbers of the sensors used.

A total of 14 casts were performed during the two legs of cruise. Most of these were tows with integrating samplers attached to the wire above and below the sled. A few casts had samplers only above the sled and some had no samplers except for those on the sled as indicated in Table 4.

Table 4. CTD Sensor Serial Numbers

Sensor Type	**Serial No.**	
Ledwell 9*plus* Cast 01:		
Pressure	59933	
Bahr 9*plus* Casts 03-14:		
Pressure	47053	
Cast 01:		
Primary Temperature	1085	
Secondary Temperature	1080	
Primary Conductivity	763	
Secondary Conductivity	3648	
Casts 03-14:		
Primary Temperature	1085	
Secondary Temperature	1043	
Primary Conductivity	763	
Secondary Conductivity	744	

Cast notes:

Cast 1 Injection cast
Cast 2 Sea Cable failure, no data
Cast 3 CTD fish replaced w/ Bahr CTD, secondary temperature replaced
Cast 9 Inter-calibration cast (Microcats attached to sled)

Figures 19–32 show the variability of: potential density anomaly, referenced to 1000dbar; temperature; salinity; and pressure for each of the sampling tows. Tables 5–18 show the statistics for each tow.

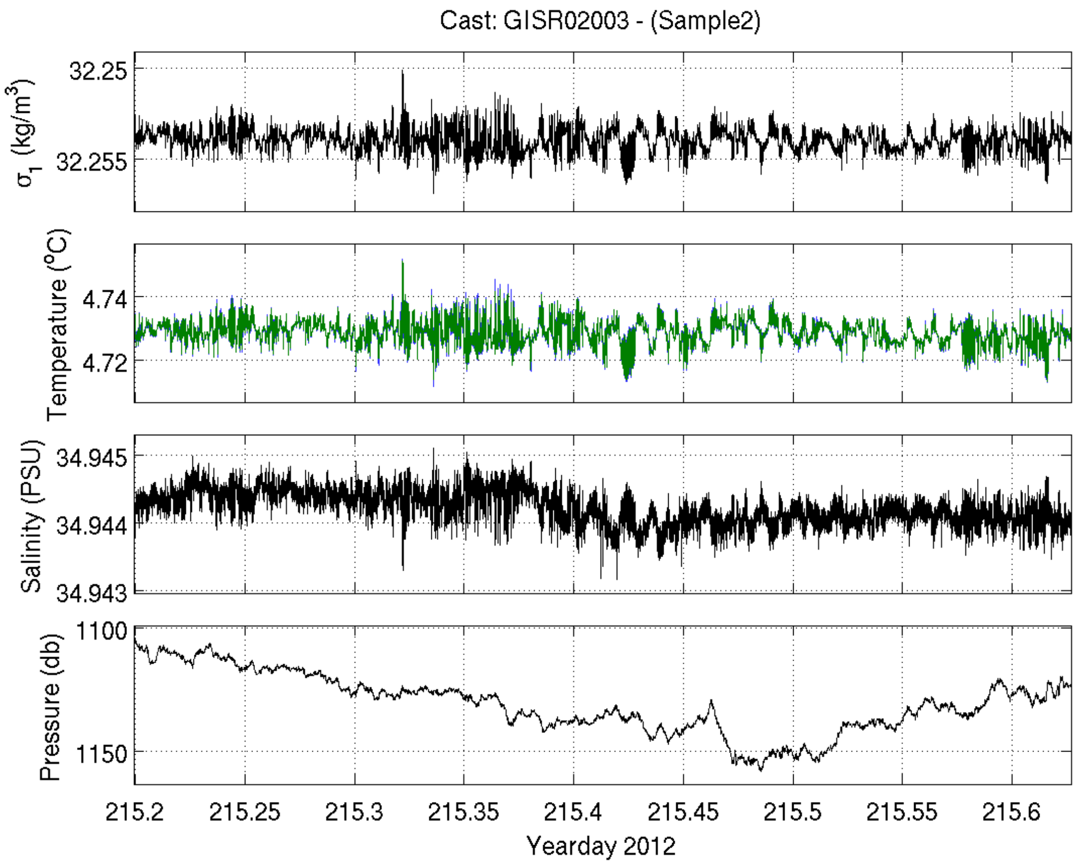


Fig.19. Cast 3 (Sample tow 2) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 5. Cast 3 (Sample tow 2) Statistics

	Mean	Standard Deviation
Sigma	32.253979	0.00060115
Salinity	34.944221	0.00023686
Temperature	4.728785	0.00356070
Pressure	1130.771394	12.04616828
Theta	4.635015	0.00373569
Number of samples used: 36938		
Duration in Seconds: 36937		

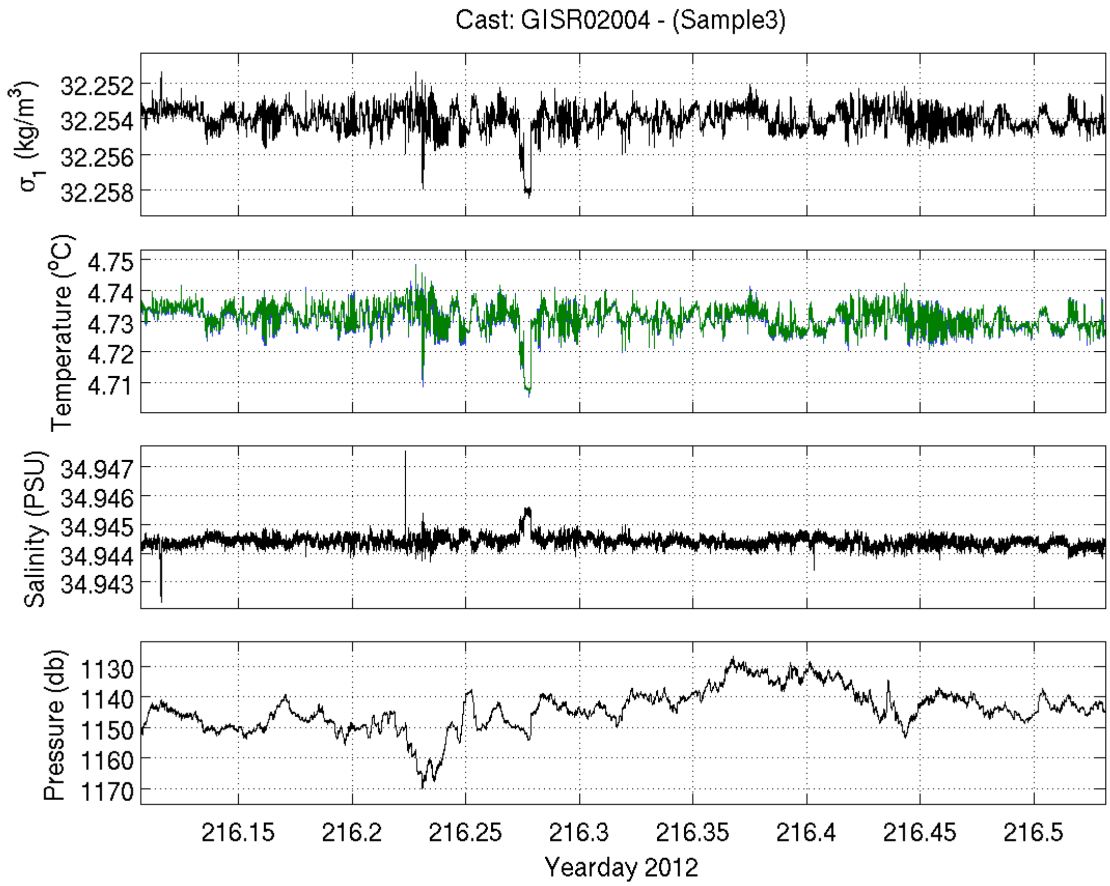


Fig. 20. Cast 4 (Sample tow 3) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 6. Cast 4 (Sample tow 3) Statistics

	Mean	Standard Deviation
Sigma	32.254012	0.00067477
Salinity	34.944408	0.00018832
Temperature	4.730841	0.00401804
Pressure	1144.049516	6.80315624
Theta	4.635842	0.00402736
Number of samples used: 36624		
Duration in Seconds: 36691		

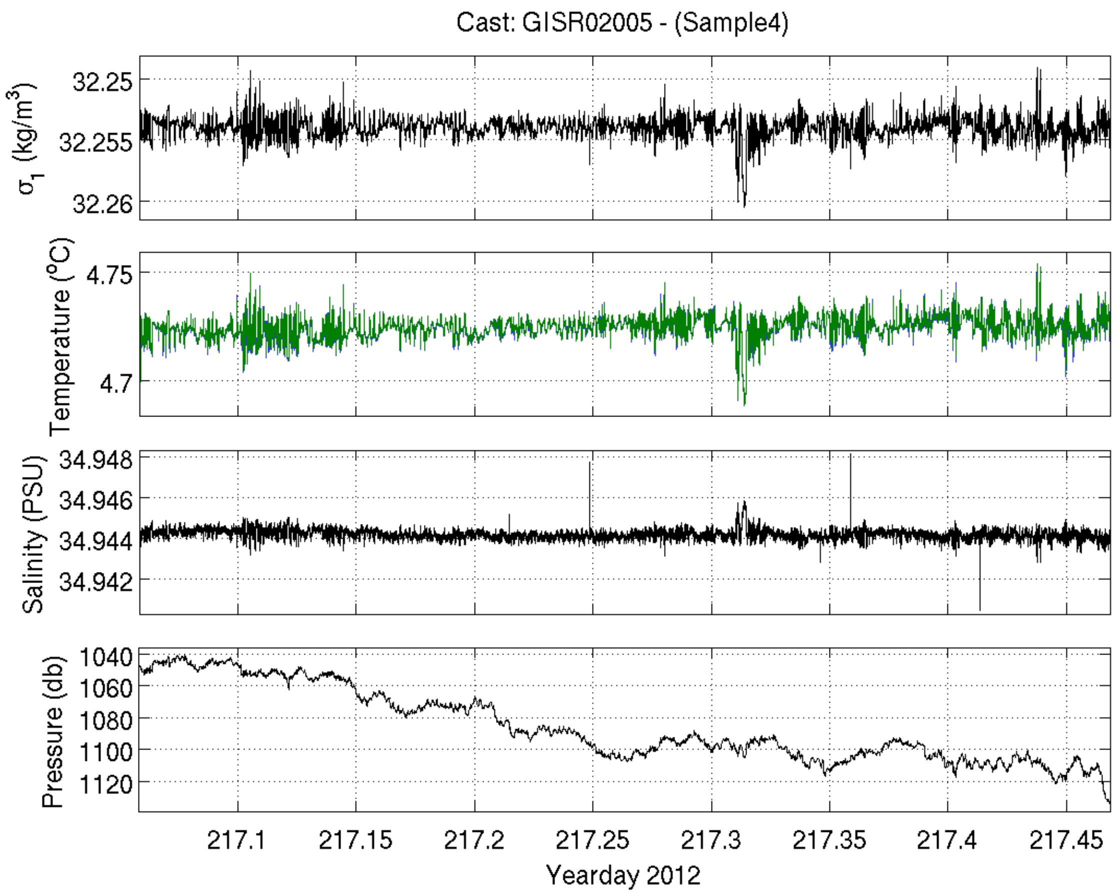


Fig. 21. Cast 5 (Sample tow 4) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 7. Cast 5 (Sample tow 4) Statistics

	Mean	Standard Deviation
Sigma	32.253998	0.00084157
Salinity	34.944199	0.00024051
Temperature	4.724394	0.00513054
Pressure	1085.656213	22.79150572
Theta	4.634753	0.00500701
Number of samples used: 35412		
Duration in Seconds: 35411		

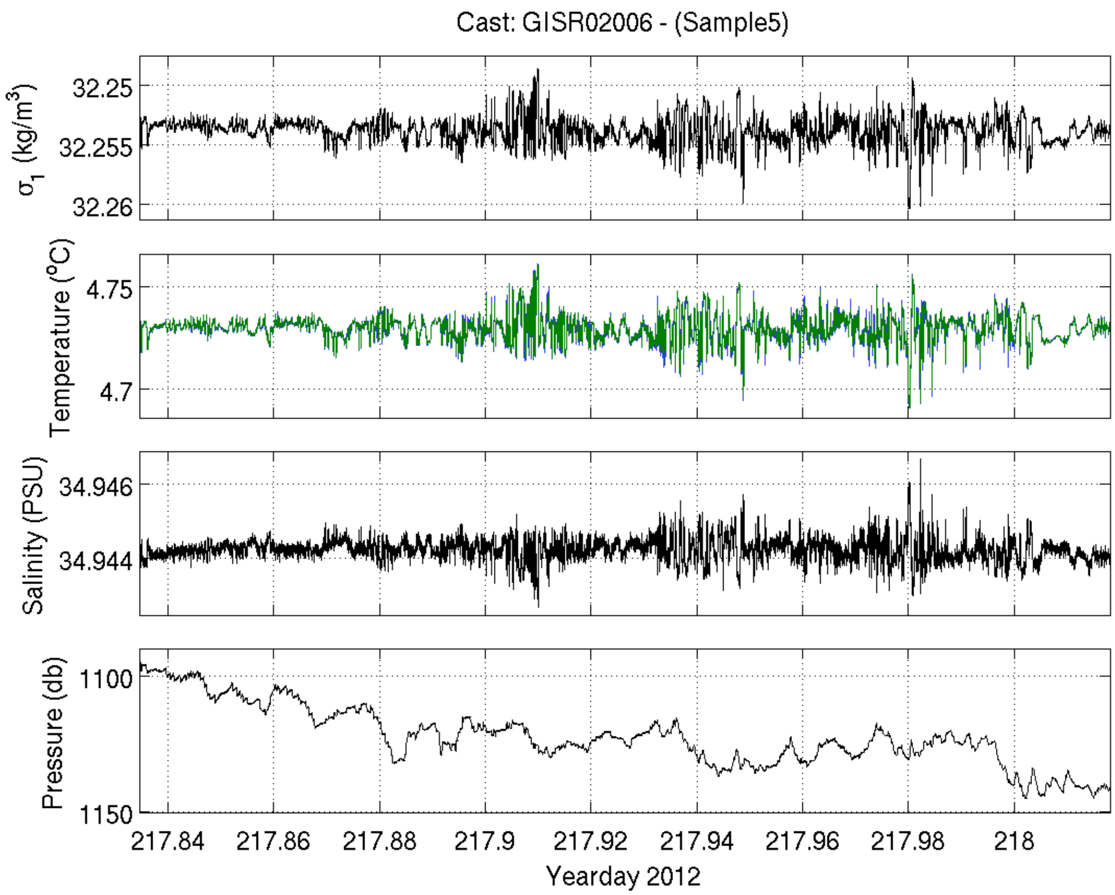


Fig. 22. Cast 6 (Sample tow 5) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 8. Cast 6 (Sample tow 5) Statistics

	Mean	Standard Deviation
Sigma	32.253904	0.00092506
Salinity	34.944145	0.00030158
Temperature	4.729381	0.00584087
Pressure	1135.915929	35.17494390
Theta	4.635129	0.00554523
Number of samples used: 34501		
Duration in Seconds: 34500		

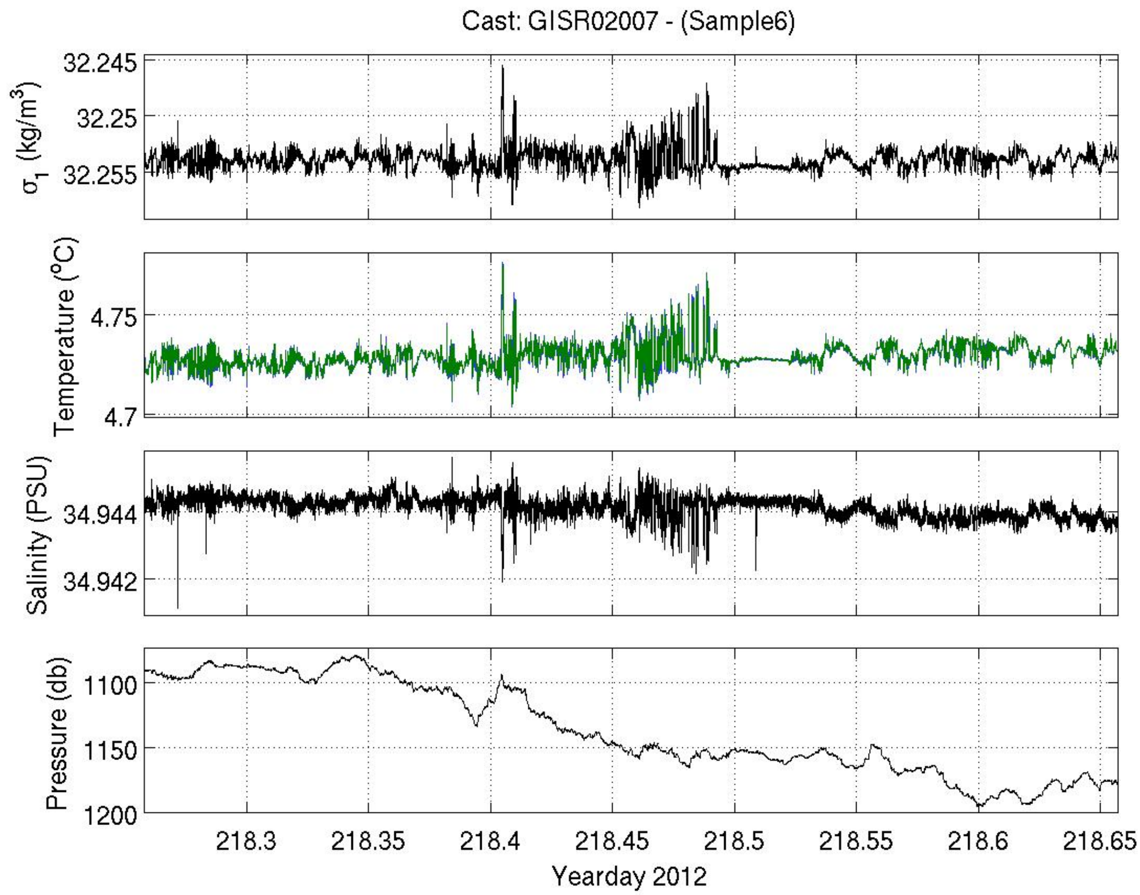


Fig. 23. Cast 7 (Sample tow 6) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 9. Cast 7 (Sample tow 6) Statistics

	Mean	Standard Deviation
Sigma	32.253904	0.00092506
Salinity	34.944145	0.00030158
Temperature	4.729381	0.00584087
Pressure	1135.915929	35.17494390
Theta	4.635129	0.00554523
Number of samples used: 34501		
Duration in Seconds: 34500		

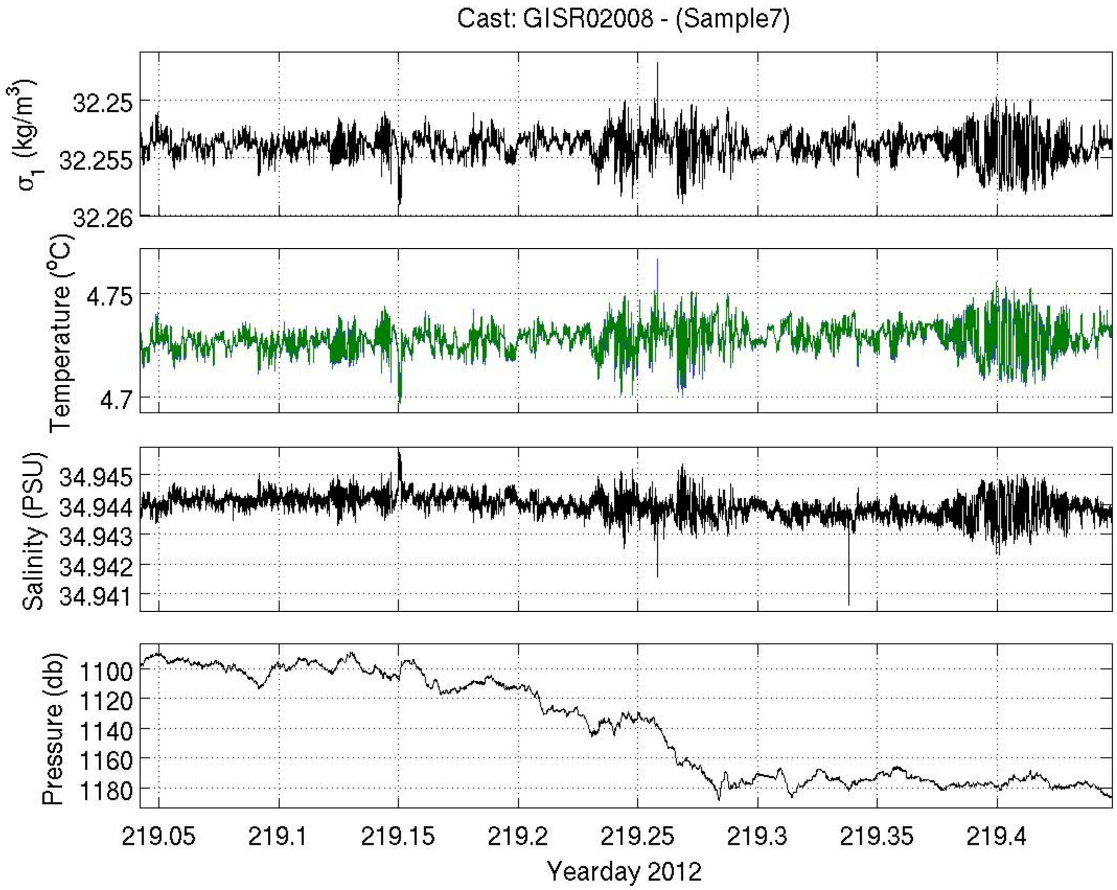


Fig. 24. Cast 8 (Sample tow 7) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 10. Cast 8 (Sample tow 7) Statistics

	Mean	Standard Deviation
Sigma	32.253932	0.00108876
Salinity	34.943967	0.00034141
Temperature	4.728502	0.00665151
Pressure	1139.711186	34.4265497
Theta	4.633913	0.00654616
Number of samples used: 35075 Duration in Seconds: 35073		

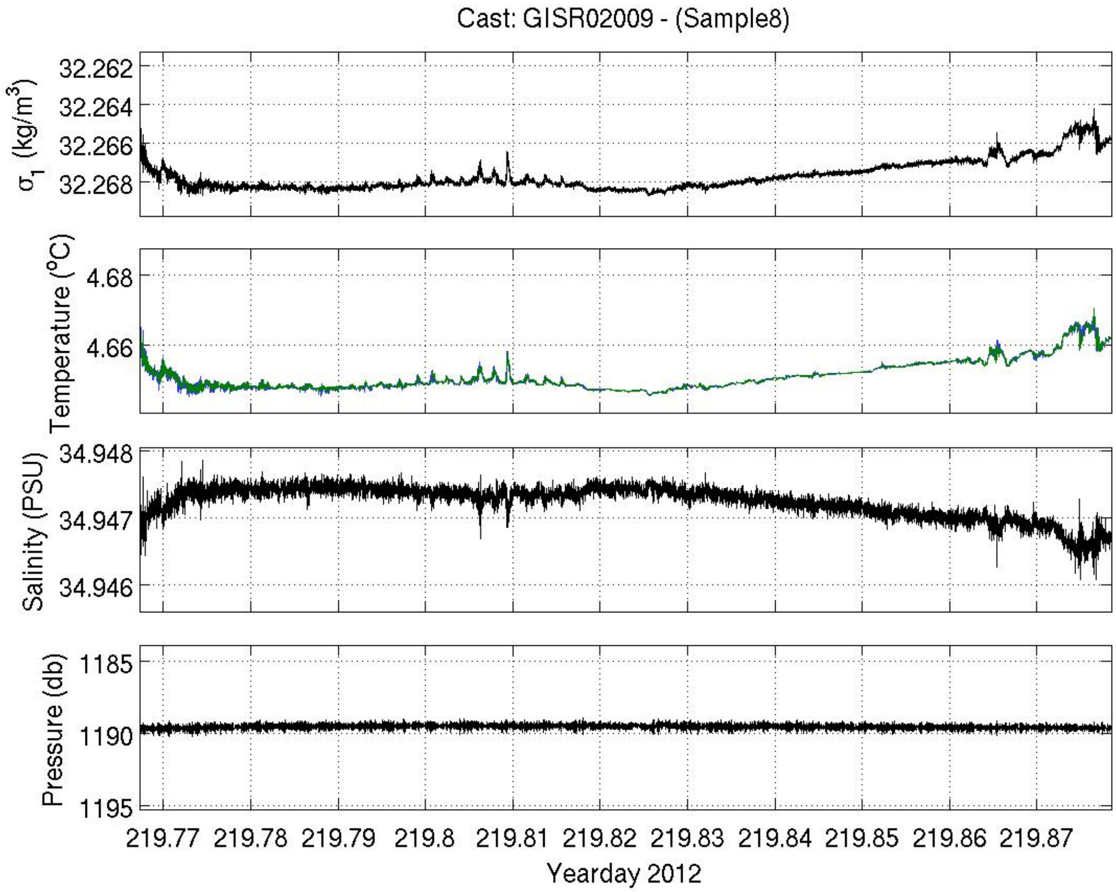


Fig. 25. Cast 9 (Sample tow 8) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 11. Cast 9 (Sample tow 8) Statistics

	Mean	Standard Deviation
Sigma	32.267676	0.00077161
Salinity	34.947234	0.00024108
Temperature	4.651029	0.00435452
Pressure	1189.513489	0.17149892
Theta	4.552578	0.00431342
Number of samples used: 9613		
Duration in Seconds: 9612		

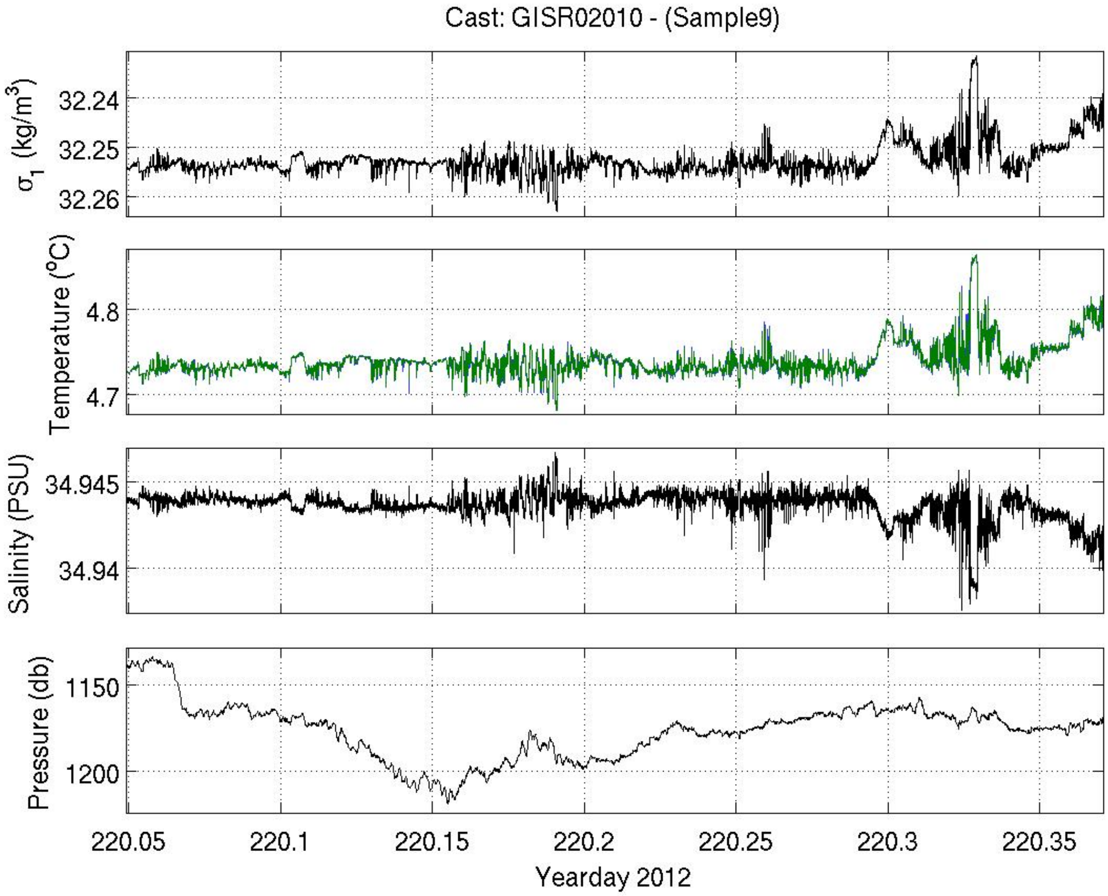


Fig. 26. Cast 10 (Sample tow 9) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 12. Cast 10 (Sample tow 9) Statistics

	Mean	Standard Deviation
Sigma	32.252556	0.00322831
Salinity	34.943666	0.00079753
Temperature	4.740204	0.01897306
Pressure	1176.380553	16.08602587
Theta	4.642164	0.01901014
Number of samples used: 27823		
Duration in Seconds: 27822		

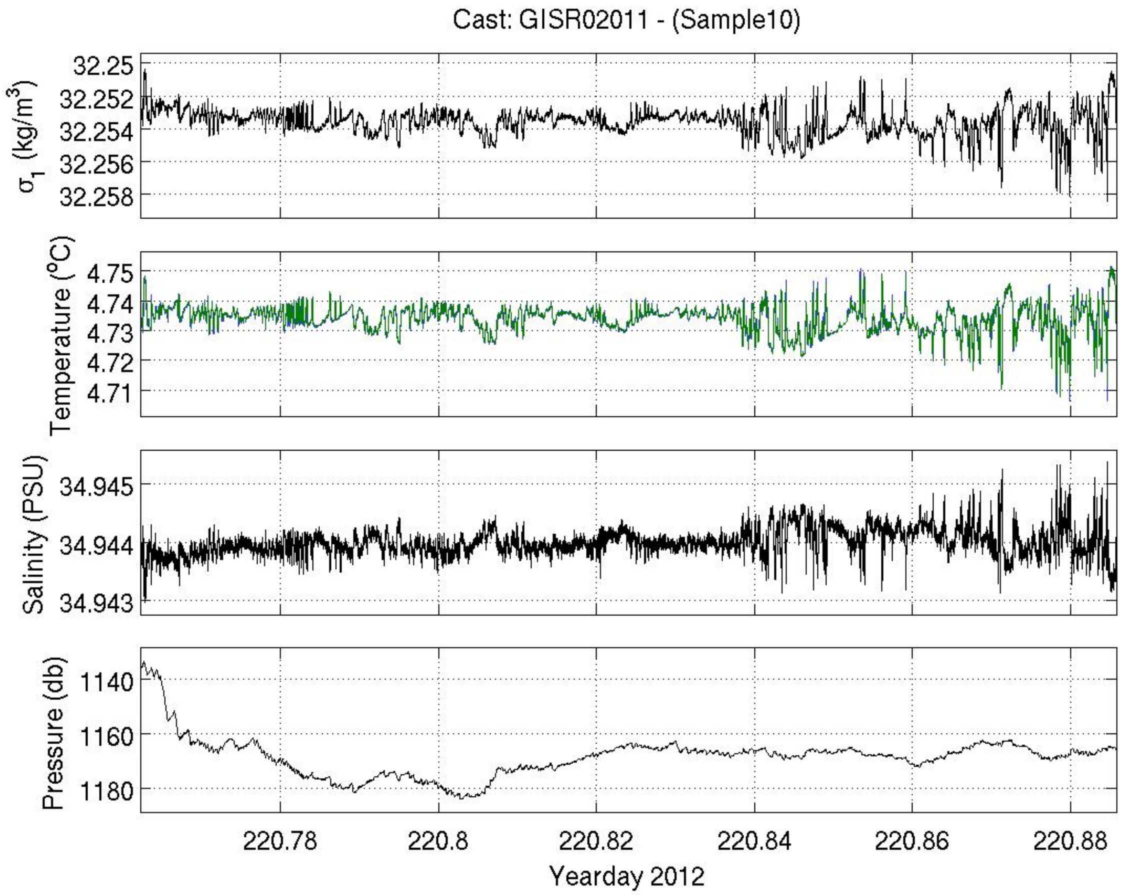


Fig. 27. Cast 11 (Sample tow 10) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 13. Cast 11 (Sample tow 10) Statistics

	Mean	Standard Deviation
Sigma	32.253574	0.00082362
Salinity	34.944001	0.00023628
Temperature	4.733960	0.00468947
Pressure	1168.507269	7.42126995
Theta	4.636698	0.00477486
Number of samples used: 10683		
Duration in Seconds: 10682		

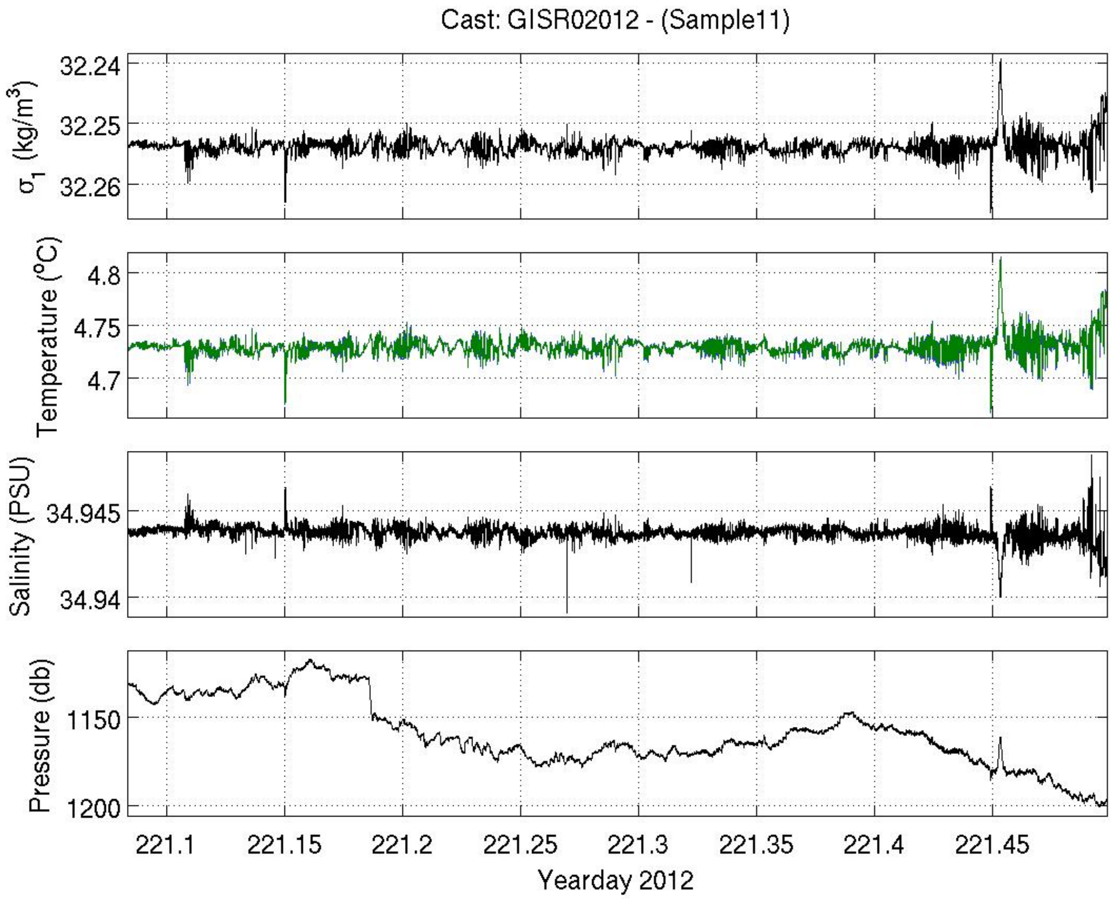


Fig. 28. Cast 12 (Sample tow 11) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 14. Cast 12 (Sample tow 11) Statistics

	Mean	Standard Deviation
Sigma	32.253827	0.00145795
Salinity	34.943742	0.00041099
Temperature	4.729762	0.00871983
Pressure	1159.216520	18.75401381
Theta	4.633386	0.00850267
Number of samples used: 35838		
Duration in Seconds: 35837		

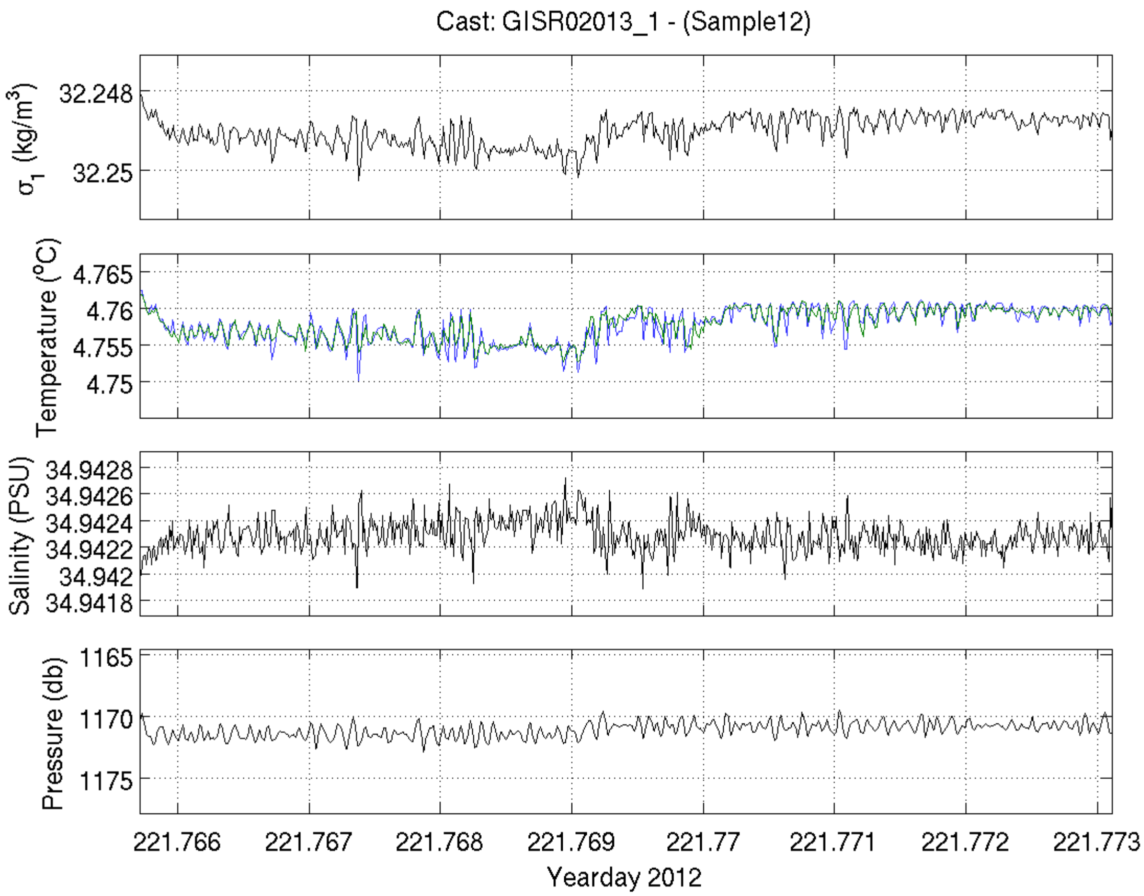


Fig. 29. Cast 13 (Sample tow 12) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during portion of cast at Sigma=32.249.

Table 15. Cast 13 (Sample tow 12) Statistics for sampler at Sigma=32.249

	Mean	Standard Deviation
Sigma	32.249001	0.00036705
Salinity	34.942289	0.00012154
Temperature	4.757791	0.00225155
Pressure	1171.067972	0.59334639
Theta	4.660087	0.00227356
Number of samples used: 641		
Duration in Seconds: 639		

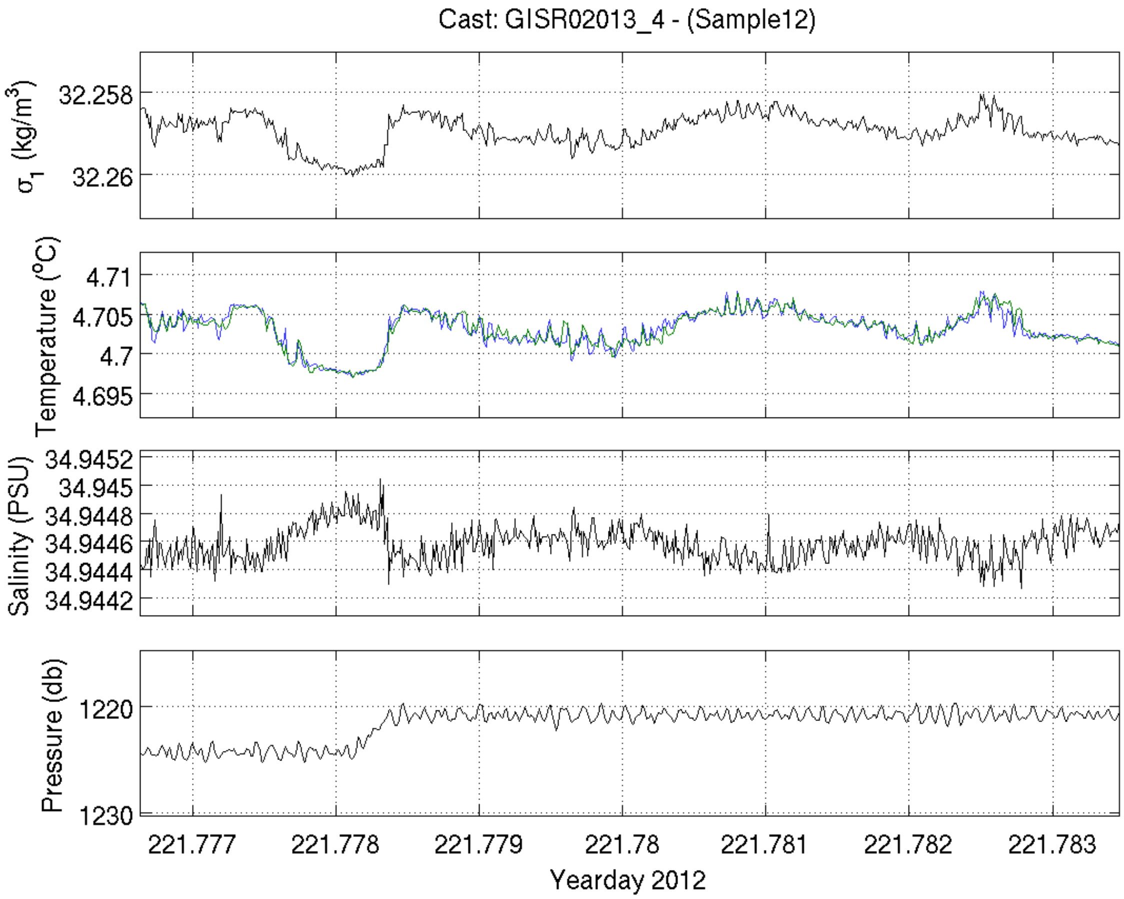


Fig. 30. Cast 13 (Sample tow 12) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during portion of cast at Sigma=32.259.

Table 16. Cast 13 (Sample tow 12) Statistics for sampler at Sigma=32.259

	Mean	Standard Deviation
Sigma	32.258916	0.00039423
Salinity	34.944584	0.00012316
Temperature	4.703091	0.00230065
Pressure	1221.589628	1.54414285
Theta	4.601228	0.00232013
Number of samples used: 591		
Duration in Seconds: 590		

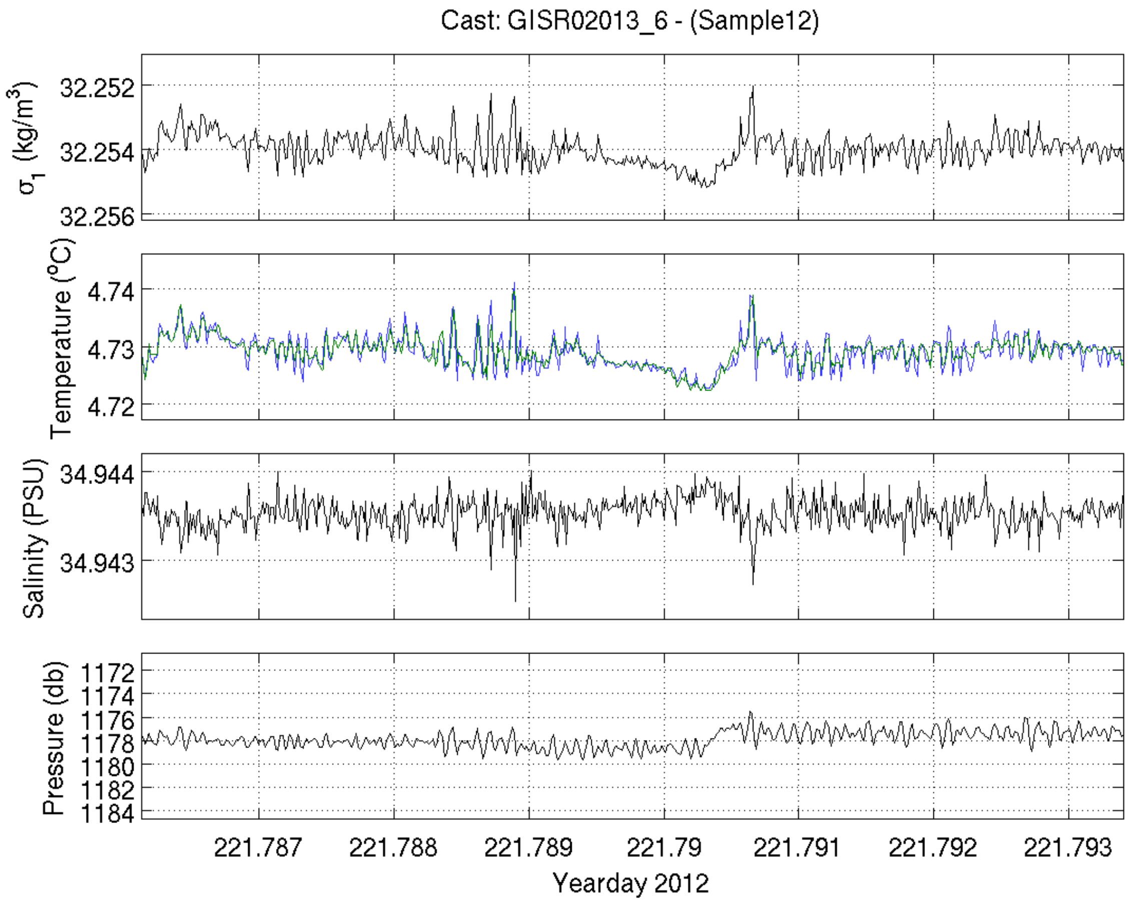


Fig. 31. Cast 13 (Sample tow 12) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during portion of cast at Sigma=32.254.

Table 17. Cast 13 (Sample tow 12) Statistics for sampler at Sigma=32.254

	Mean	Standard Deviation
Sigma	32.253995	0.00047908
Salinity	34.943530	0.00017466
Temperature	4.729043	0.00283313
Pressure	1177.867615	0.72241128
Theta	4.630968	0.00284366
Number of samples used: 629		
Duration in Seconds: 628		

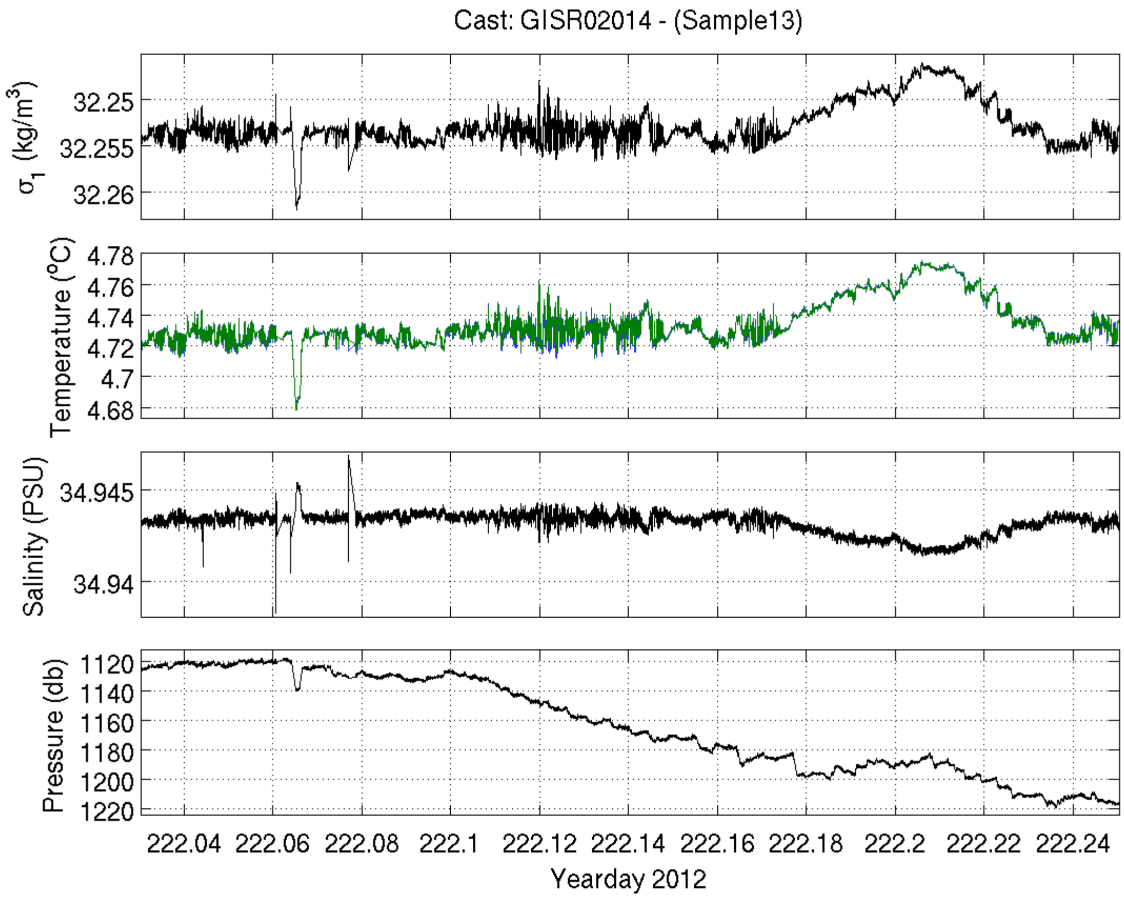


Fig. 32. Cast 14 (Sample tow 13) Potential density anomaly, referenced to 1000 dbar, temperature, salinity, and pressure variability during tow.

Table 18. Cast 14 (Sample tow 13) Statistics

	Mean	Standard Deviation
Sigma	32.252797	0.00221986
Salinity	34.943200	0.00059551
Temperature	4.734630	0.01420341
Pressure	1164.039899	32.44023205
Theta	4.637765	0.01289286
Number of samples used: 18658		
Duration in Seconds: 19008		

CTD Downcasts

Figures 33–45 show the salinity, temperature, and potential density anomaly referenced to 1000 dbar as a function of pressure for the CTD downcasts from each tow.

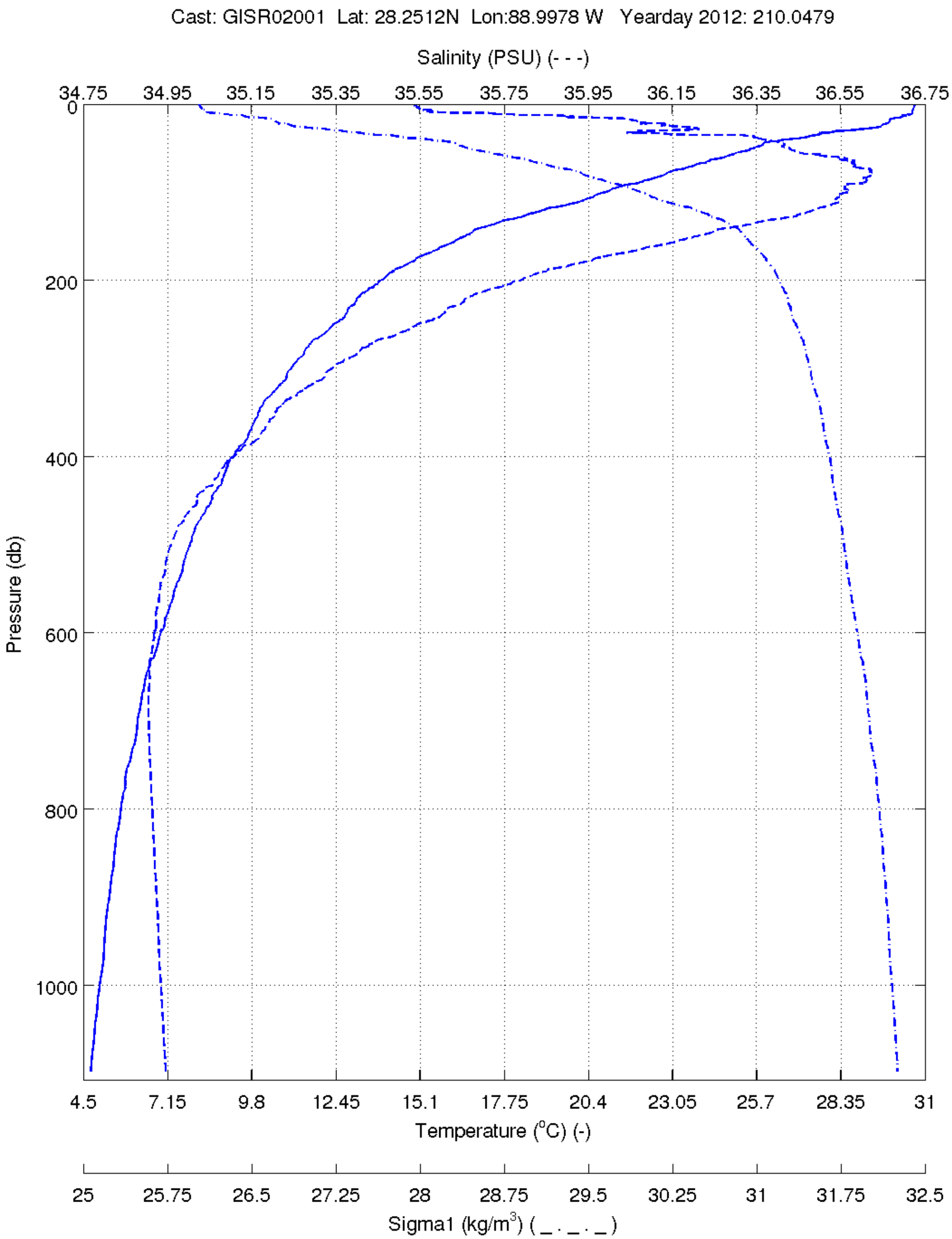


Fig. 33. Cast 1 (Inject tow) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

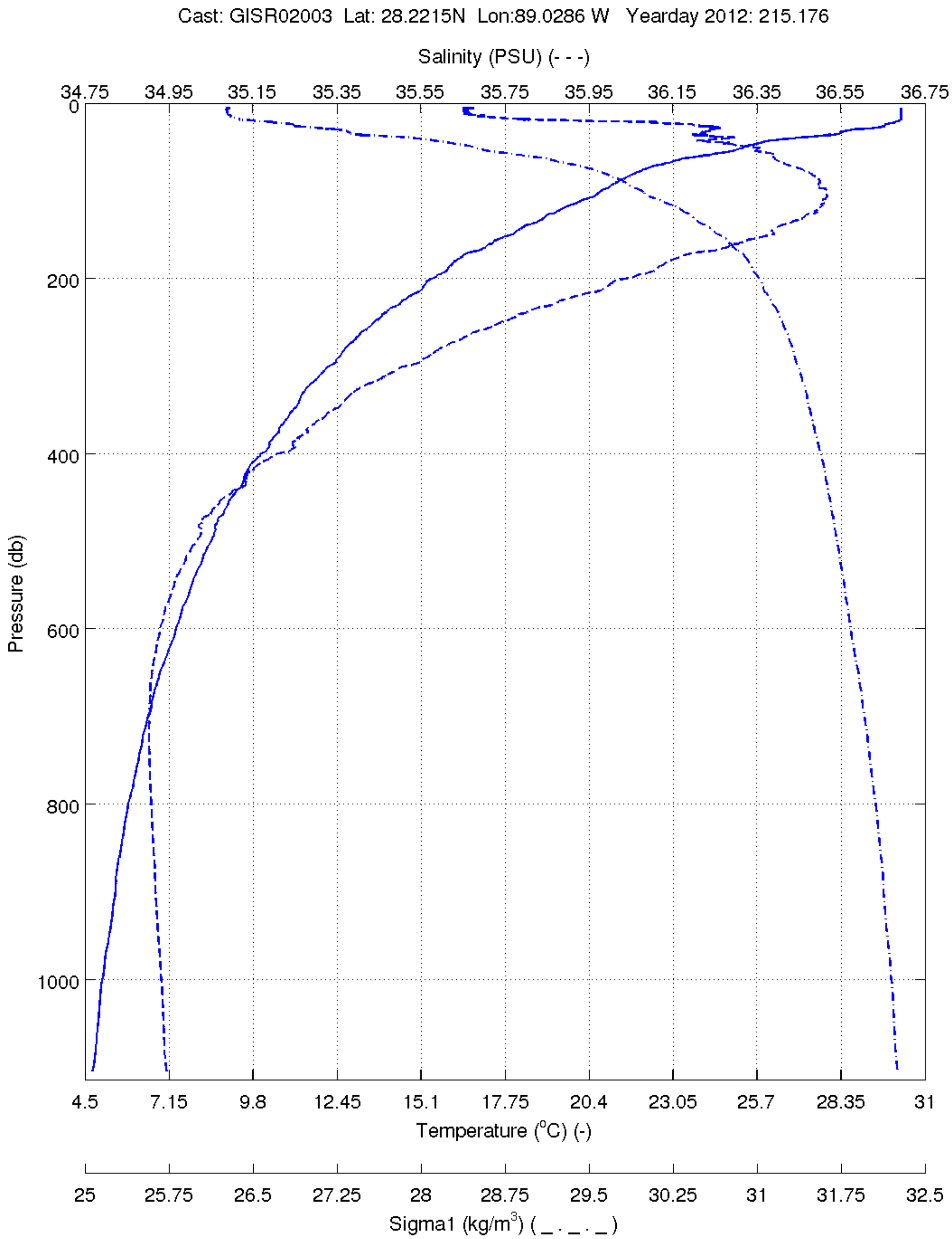


Fig. 34. Cast 3 (Sample tow 2) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

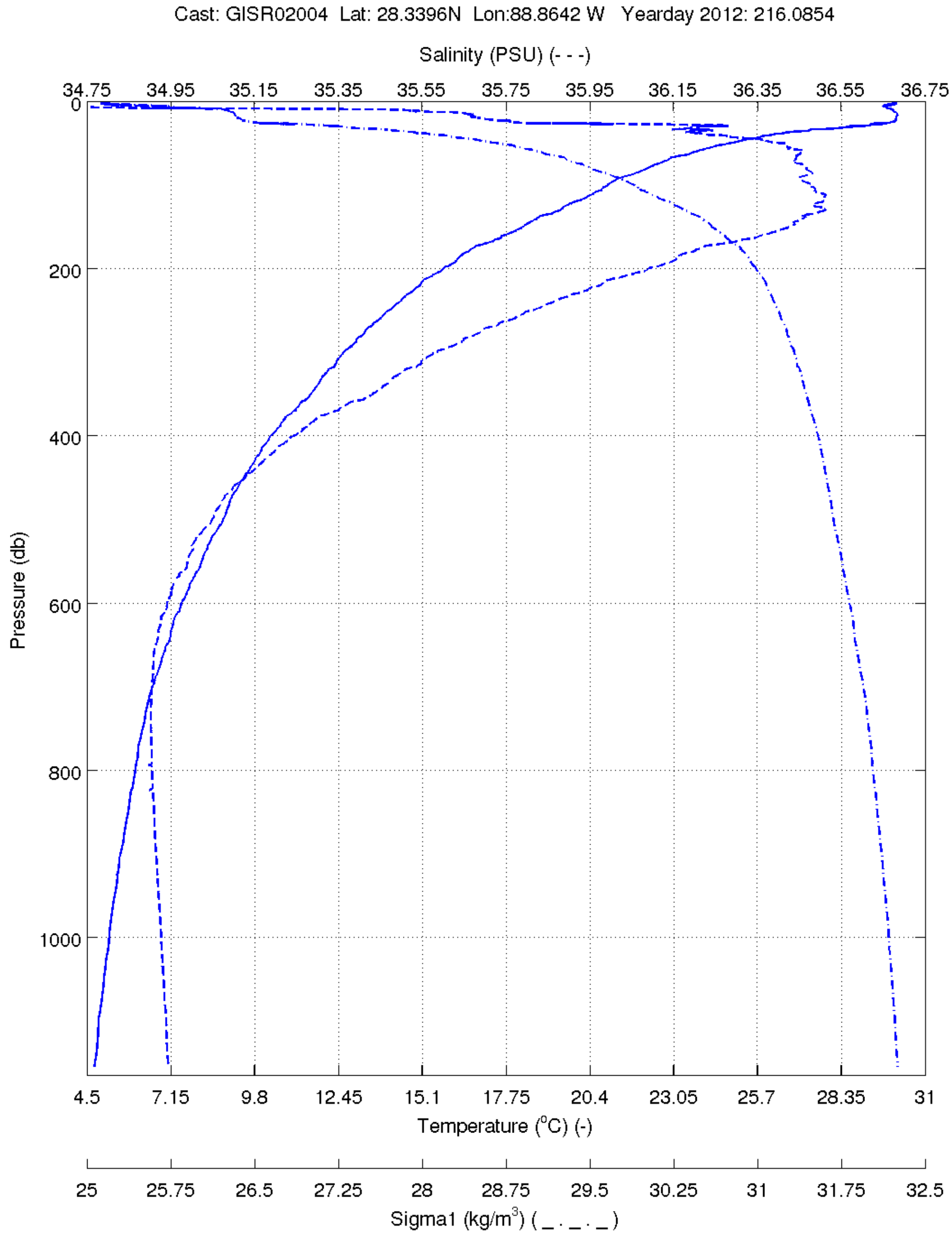


Fig. 35. Cast 4 (Sample tow 3) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

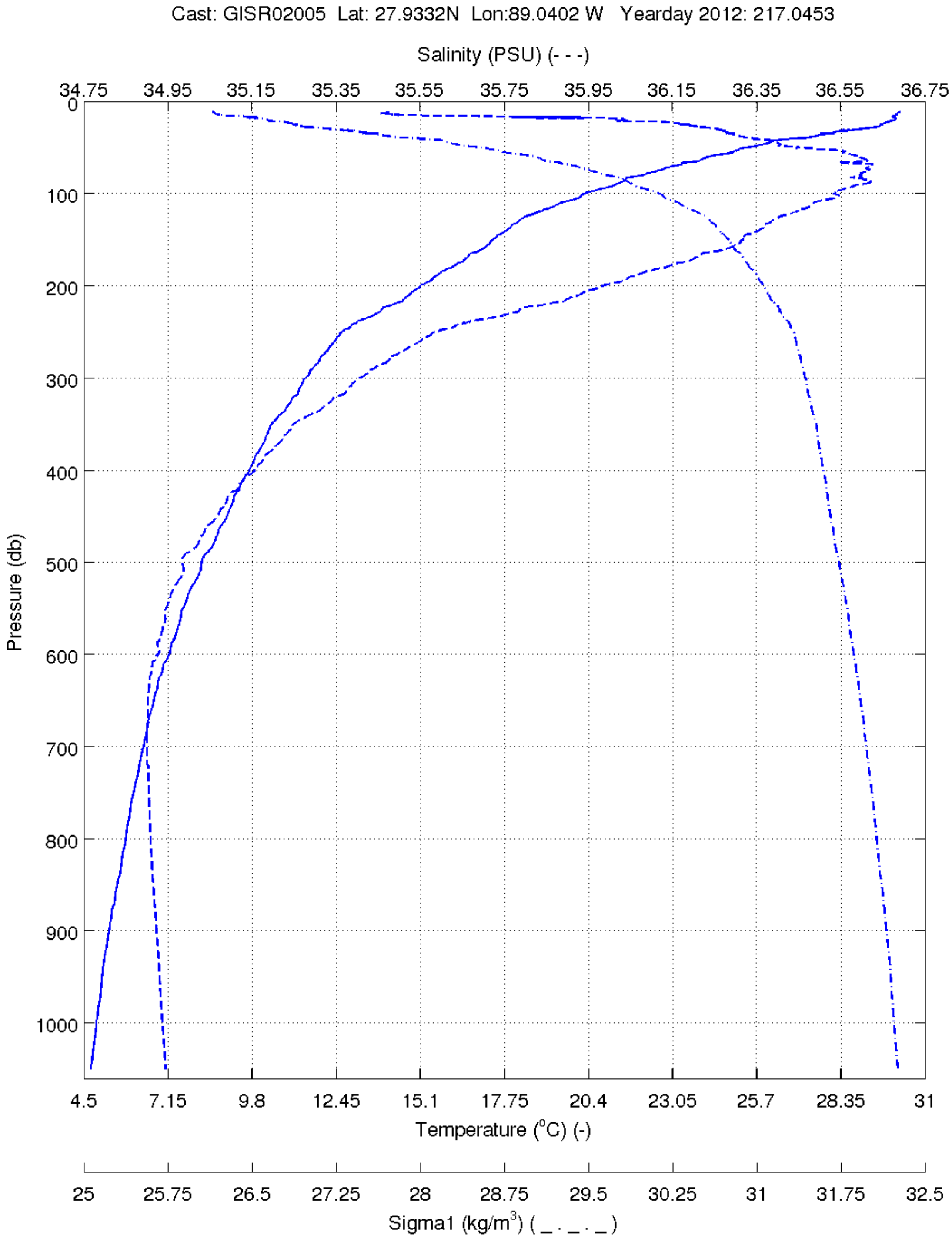


Fig. 36. Cast 5 (Sample tow 4) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

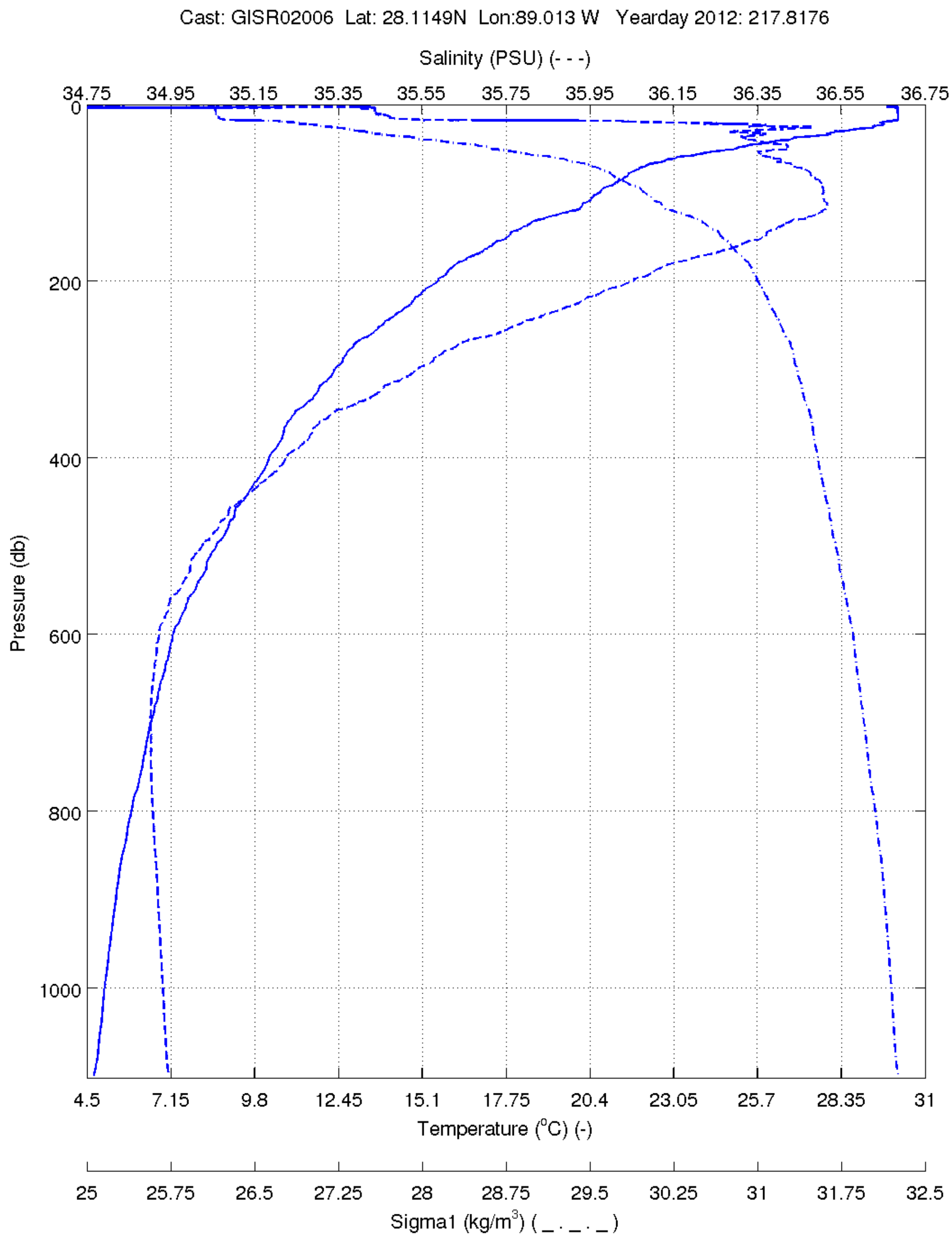


Fig. 37. Cast 6 (Sample tow 5) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

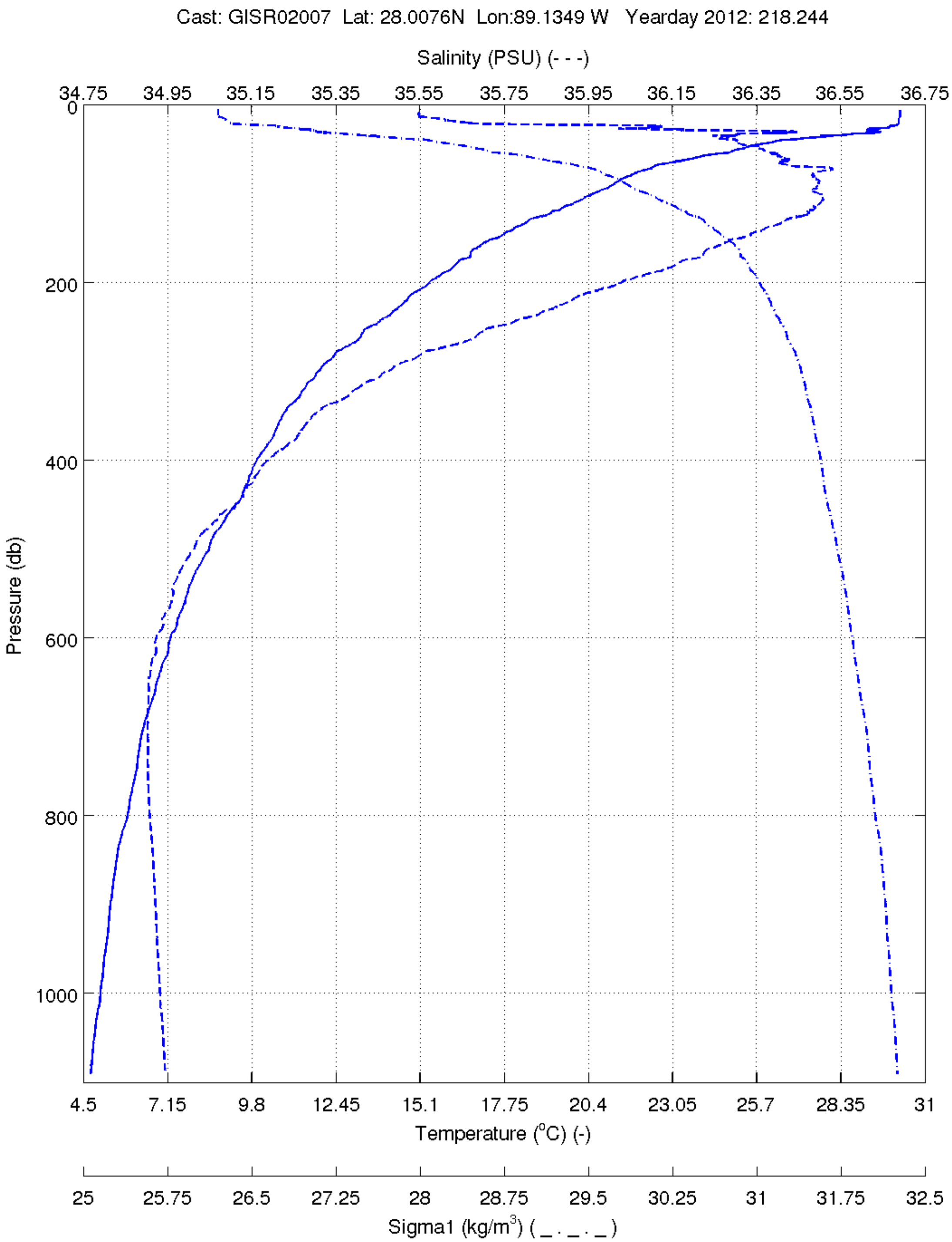


Fig. 38. Cast 7 (Sample Tow 6) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

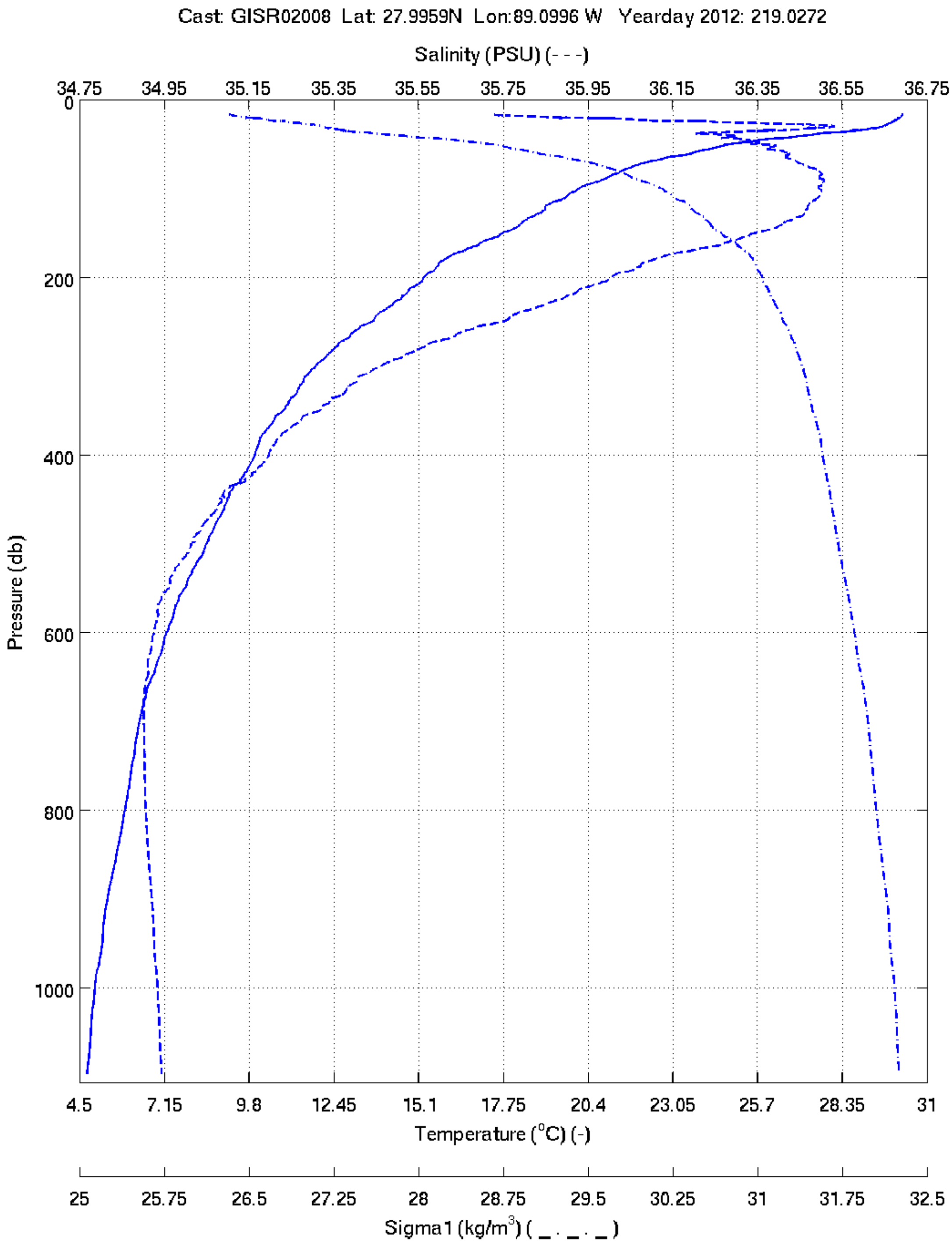


Fig. 39. Cast 8 (Sample tow 7) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

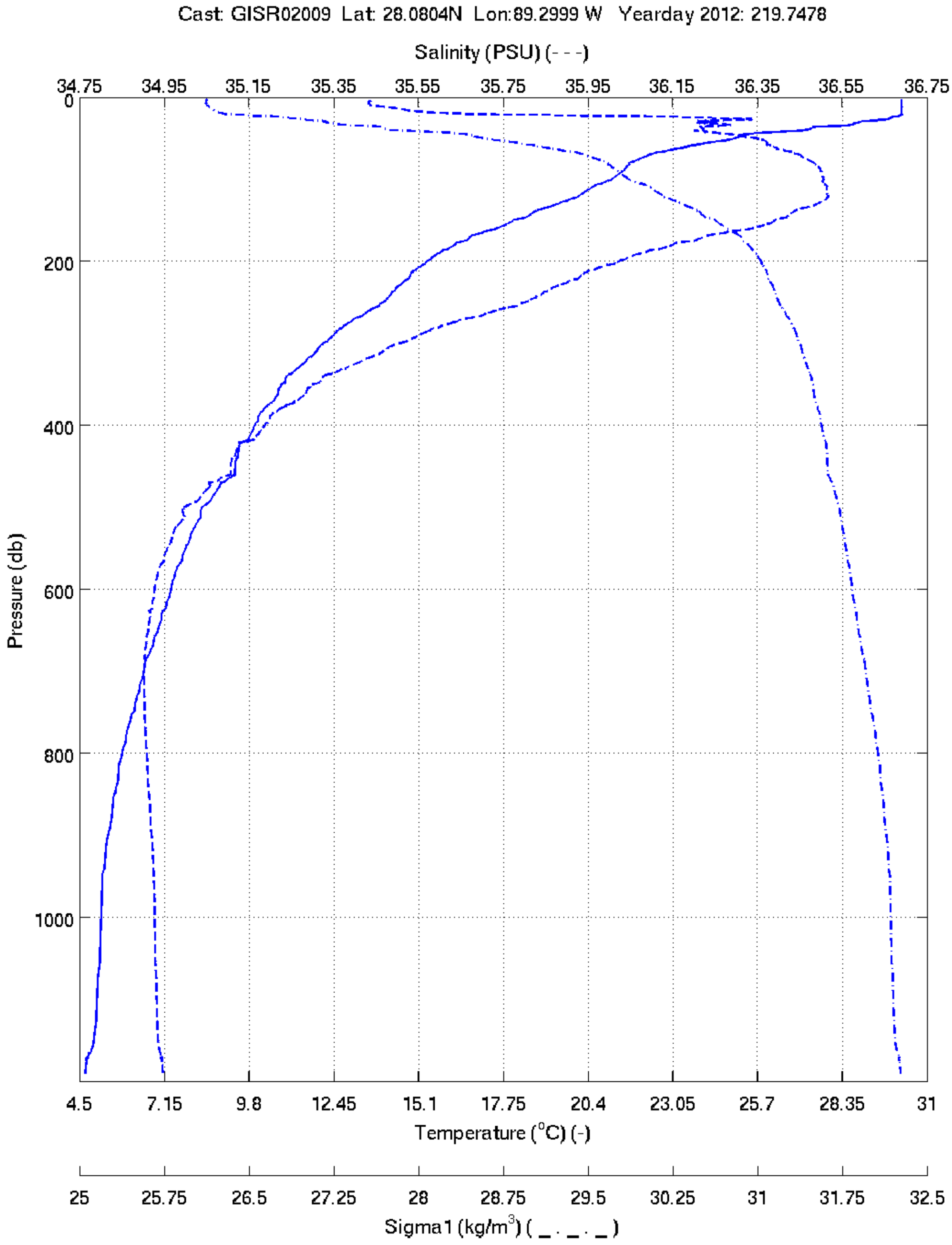


Fig. 40. Cast 9 (Sample tow 8) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

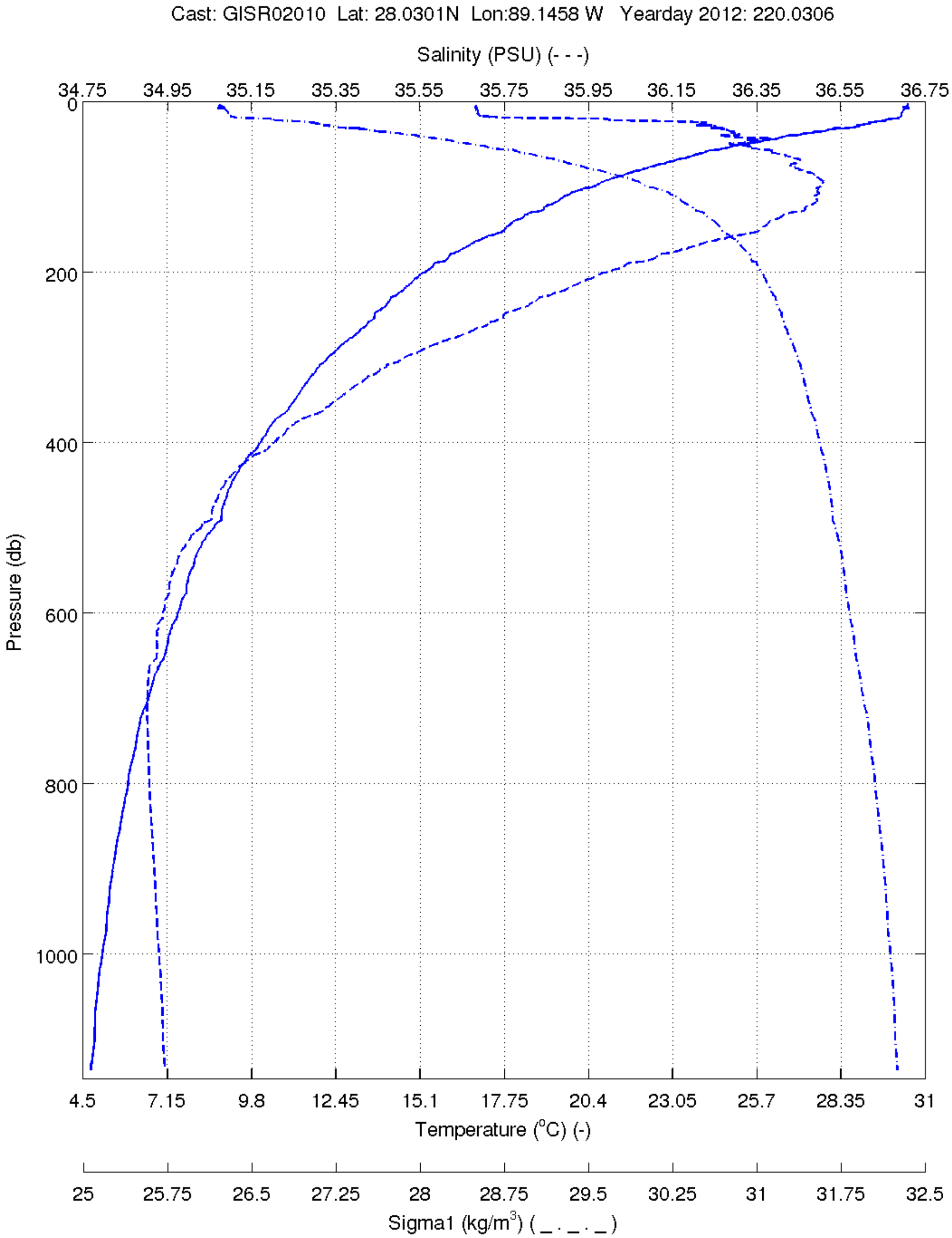


Fig. 41. Cast 10 (Sample tow 9) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

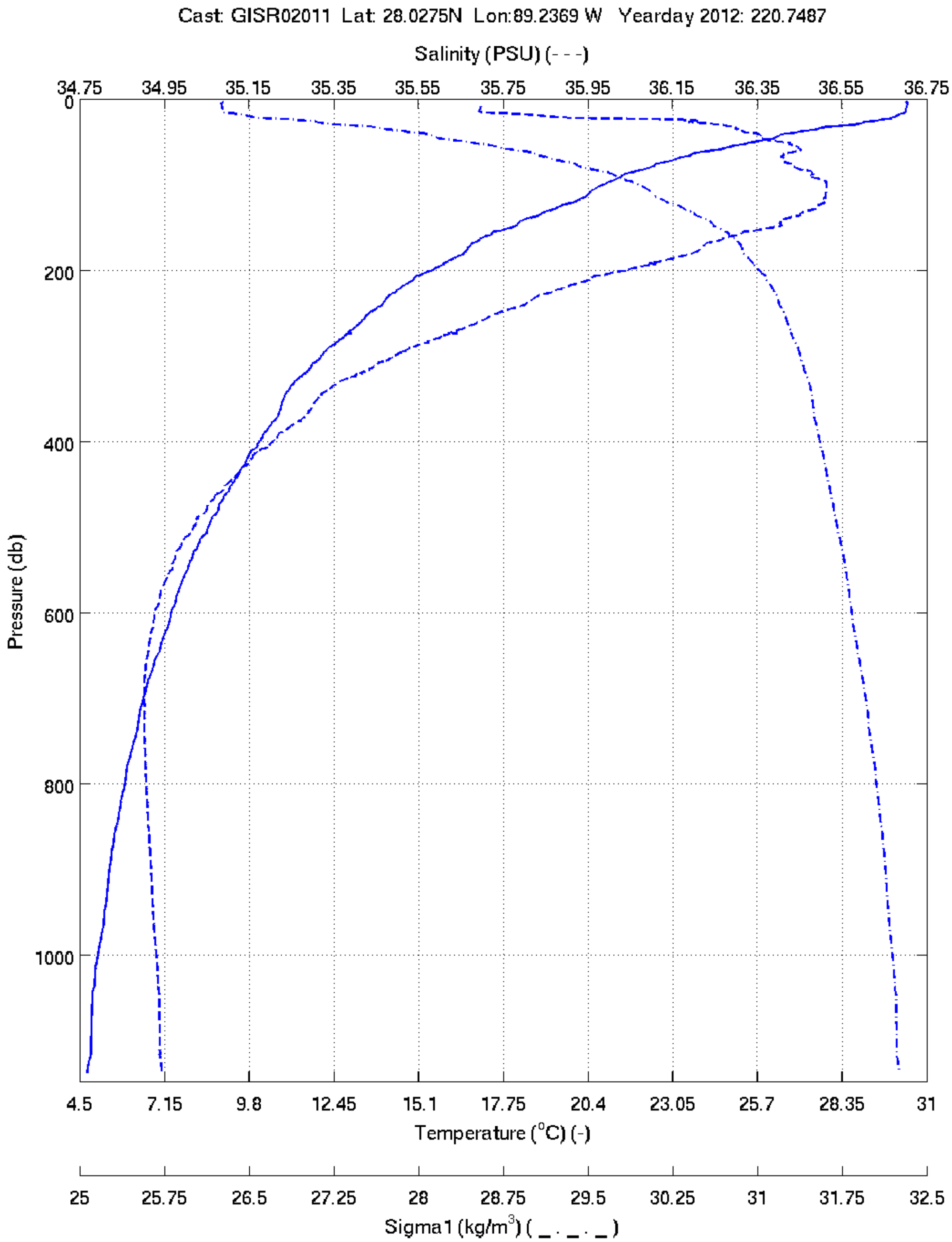


Fig. 42. Cast 11 (Sample tow 10) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

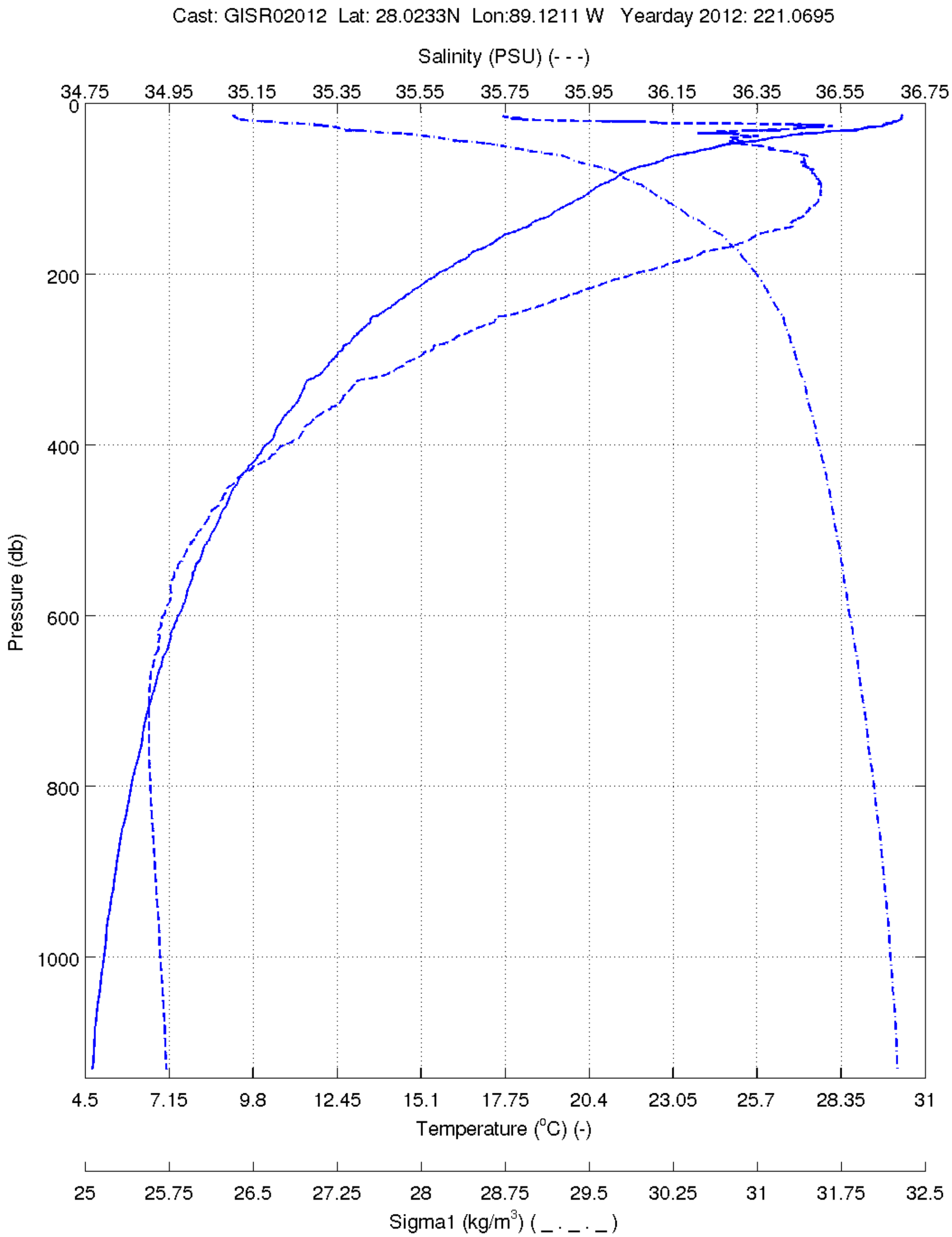


Fig. 43. Cast 12 (Sample tow 11) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

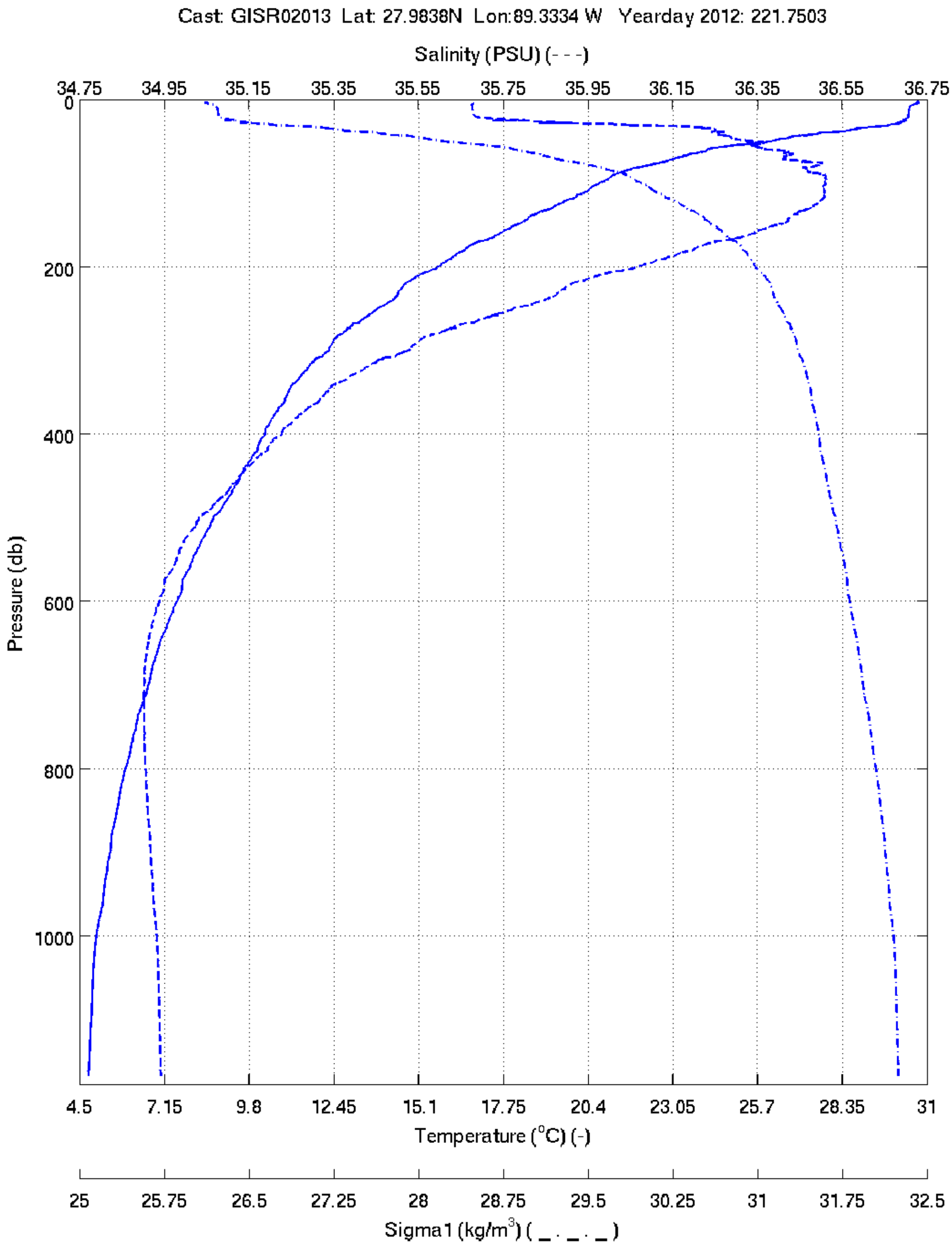


Fig. 44. Cast 13 (Sample tow 12) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

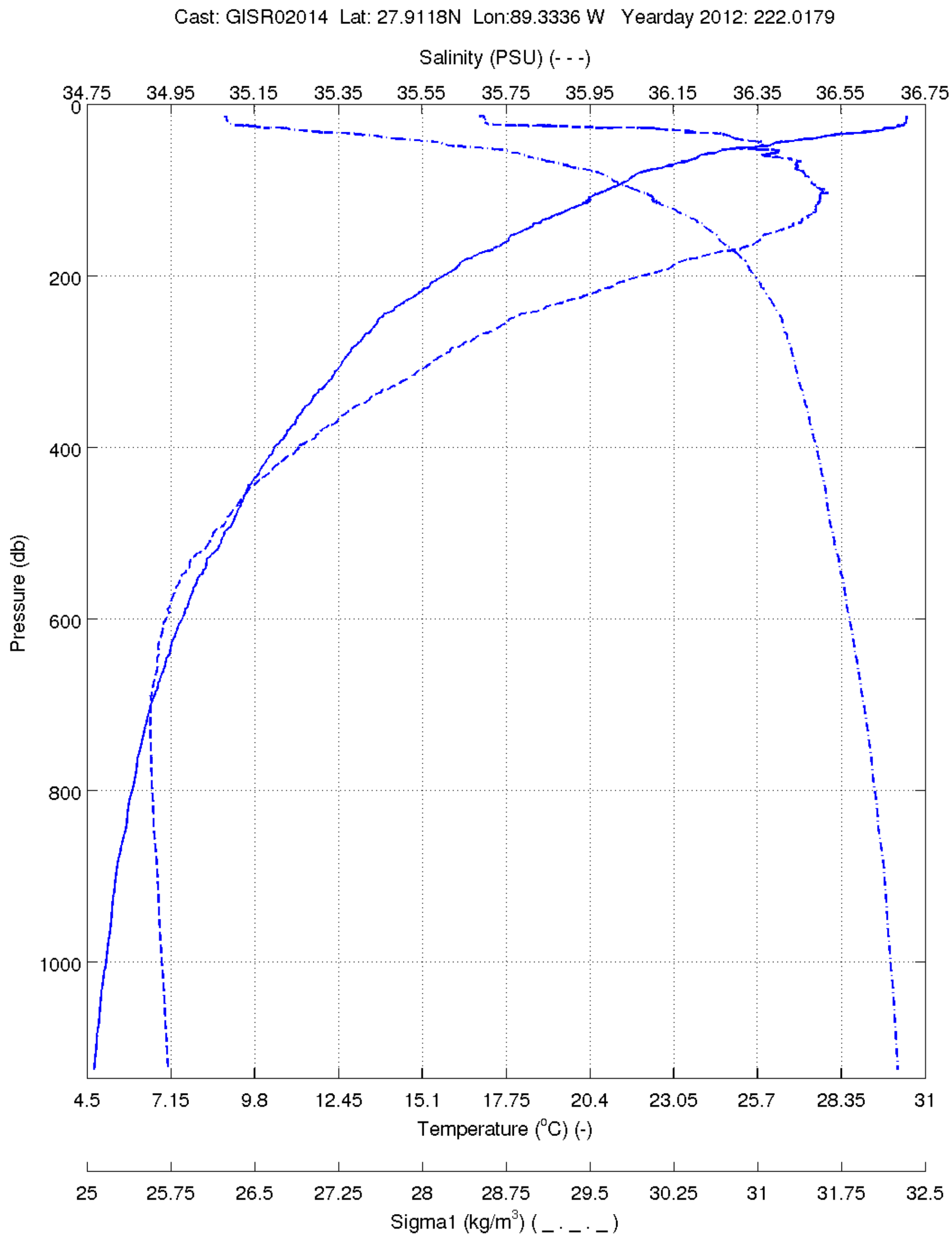


Fig. 45. Cast 14 (Sample tow 13) downcast salinity, temperature, and potential density anomaly referenced to 1000 dbar.

Appendix B. Event Log

EVENT LOG

GISR CRUISE GS02; R/V BROOKS MCCALL

26 July to 9 August 2012

Cast no.	Date GMT	Time GMT	Latitude (N) Deg	Latitude (N) Min	Longitude (W) Deg	Longitude (W) Min	Latitude (Decimal) Degree N	Longitude (Decimal) Degree W	Instrument (see key below)	Description	Serial Number
	7.25	17:00	30	24.17	87	12.68	30.4028	87.2113		Loading at Pensacola	
	7.27	01:00	30	24.17	87	12.68	30.4028	87.2113		Depart Pensicola	
	7.27	18:59	28	17.84	88	57.19	28.2973	88.9532	Drifters	Magnets removed	All five
1	7.28	00:49	28	14.81	89	0.19	28.2468	89.0032	Inj Sled	Deploy	
1	7.28	02:14	28	15.82	88	58.89	28.2637	88.9815	Inj Sled	Start Injection	
	7.28	03:29	28	16.91	88	57.49	28.2819	88.9582	RAFOS	launch float	1217
	7.28	03:29	28	16.92	88	57.49	28.2819	88.9582	RAFOS	launch float	1218
	7.28	03:29	28	16.92	88	57.49	28.2820	88.9581	RAFOS	launch float	1220
1	7.28	14:12	28	24.94	88	47.00	28.4157	88.7833	Inj Sled	End Injection, battery ran out.	
1	7.28	15:28	28	25.79	88	45.77	28.4298	88.7628	Inj Sled	Recover sled	
	7.28	16:51	28	24.27	88	47.78	28.4045	88.7963	Drifter	Deploy	1131840 8h
	7.28	17:06	28	23.78	88	48.59	28.3963	88.8098	Drifter	Deploy	1130491 1h
	7.28	17:06	28	23.78	88	48.59	28.3963	88.8098	RAFOS	launch float	1215
	7.28	17:06	28	23.78	88	48.59	28.3963	88.8098	RAFOS	launch float	1219
	7.28	17:19	28	23.18	88	49.28	28.3863	88.8213	Drifter	Deploy (into prop)	1133427 8h
	7.28	18:12	28	19.77	88	53.80	28.3295	88.8967	Drifter	Deploy	1132142 8h
	7.28	18:36	28	17.77	88	56.40	28.2962	88.9400	Drifter	Deploy	1132308 8h
	7.29	16:12	30	24.18	87	12.69	30.4030	87.2115		Arrive at Pensacola	
	7.30	21:06	28	9.19	89	6.25	28.1532	89.1042	RAFOS	1st RAFOS surfaced	1218
2	7.31	23:08	28	11.55	88	34.62	28.1925	88.5770	Array	Messenger sent; no CTD data	
2	8.1	02:19	28	12.20	88	37.70	28.2033	88.6283	Array	End of tow	
3	8.2	04:50	28	13.71	89	1.18	28.2285	89.0196	Array	Messenger sent	
3	8.2	15:02	28	20.43	88	51.81	28.3405	88.8634	Array	End of tow	
4	8.3	02:41	28	20.79	88	51.31	28.3465	88.8552	Array	Messenger sent	
4	8.3	12:45	28	28.79	88	41.78	28.4799	88.6963	Array	End of tow	

Instrument key: Array = Sampling array; RAFOS = RAFOS float; Drifters = Surface drifter; Sled = Sampling sled

EVENT LOG, continued

GISR CRUISE GS02; R/V BROOKS MCCALL

26 July to 9 August 2012

Cast no.	Date GMT	Time GMT	Latitude (N)		Longitude (W)		Latitude (Decimal)	Longitude (Decimal)	Instrument (see key below)	Description	Serial Number
			Deg	Min	Deg	Min	Degree N	Degree W			
	8.3	21:02	28	12.11	89	3.77	28.2018	89.0628	RAFOS	2nd RAFOS surfaced	1219
5	8.4	01:35	27	56.52	89	2.41	27.9420	89.0402	Array	Messenger sent	
5	8.4	11:14	28	8.15	89	0.90	28.1358	89.0150	Array	End of tow	
6	8.4	20:12	28	7.05	89	0.90	28.1176	89.0150	Array	Messenger sent	
6	8.5	00:26	28	10.82	89	4.19	28.1803	89.0698	Array	End of tow	
7	8.5	06:21	28	0.47	89	8.24	28.0078	89.1373	Array	Messenger sent; top messenger hung	
7	8.5	15:48	28	2.75	89	19.27	28.0458	89.3212	Array	End of tow	
8	8.6	01:12	28	0.02	89	6.66	28.0004	89.1110	Array	Messenger sent	
8	8.6	10:44	28	4.30	89	17.91	28.0717	89.2985	Array	End of tow	
9	8.6	17:31	28	4.82	89	18.00	28.0803	89.3001	Sled	2 Samplers fired, no array or tow.	
9	8.6	17:31	28	4.82	89	18.00	28.0803	89.3001	Microcats	Intercalibration	
9	8.6	21:52	28	4.79	89	18.00	28.0799	89.2999	Sled	End of cast	
10	8.7	01:13	28	2.00	89	9.29	28.0333	89.1548	Array	Messenger sent; no bottom array.	
10	8.7	08:54	28	5.30	89	18.29	28.0884	89.3048	Array	End of tow	
11	8.7	18:17	28	1.79	89	14.36	28.0299	89.2394	Sled	first sled canister tripped	
11	8.7	19:45	28	3.04	89	15.55	28.0507	89.2591	Sled	second sled cannister tripped	
11	8.7	21:15	28	4.39	89	16.83	28.0732	89.2805	Sled	End of tow	
12	8.8	02:10	28	1.21	89	7.81	28.0202	89.1302	Array	Messenger sent	
12	8.8	11:58	28	2.81	89	18.64	28.0468	89.3106	Array	End of tow	
13	8.8	18:23	27	59.03	89	20.00	27.9838	89.3334	Sled	1st sampler; density=32.249	
13	8.8	18:38	27	59.03	89	20.01	27.9838	89.3335	Sled	2nd sampler; density =32.259	
13	8.8	18:52	27	59.03	89	20.01	27.9839	89.3335	Sled	3rd sampler; density=32.254	
14	8.9	00:53	27	55.04	89	20.00	27.9174	89.3333	Array	Messenger sent	
14	8.9	06:00	28	0.51	89	19.18	28.0085	89.3196	Array	End of tow	

Instrument key: Array = Sampling array; RAFOS = RAFOS float
Drifters = Surface drifter; Sled = Sampling sled