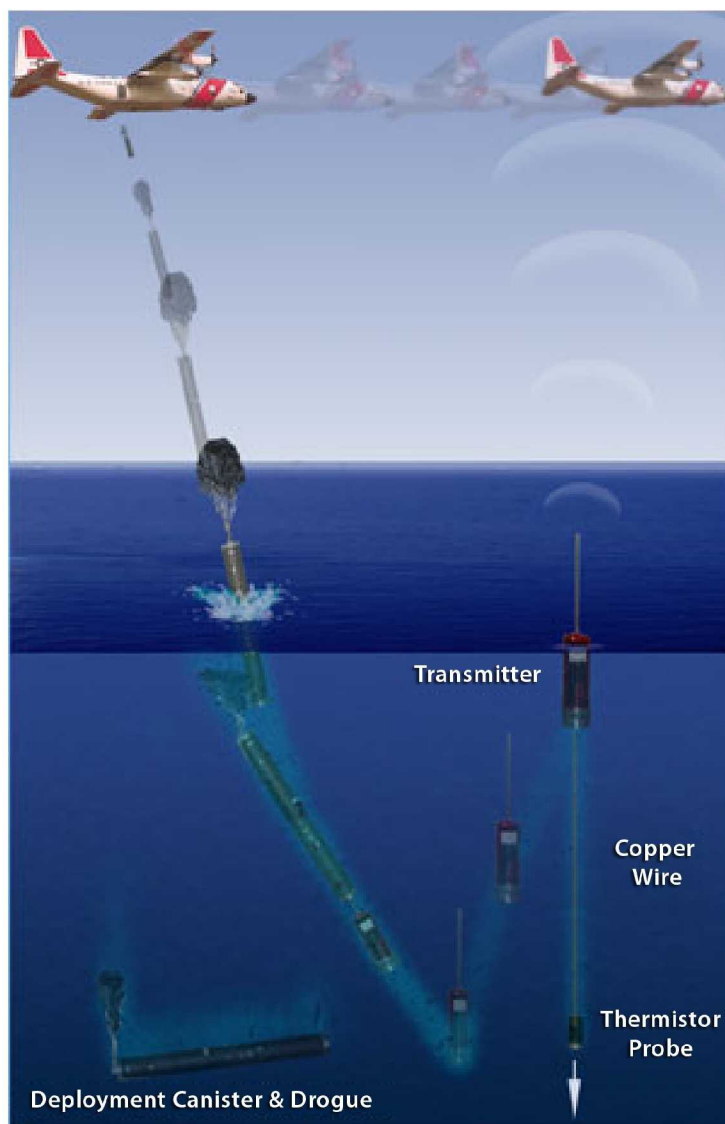


2009 Goose Bay Experiment Ocean Measurements Part I: Data

S. Daniel Jacob and David M. Le Vine



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S. Daniel Jacob and David M. Le Vine

NASA Goddard Space Flight Center, Greenbelt, Maryland

National Aeronautics and
Space Administration

**Goddard Space Flight Center
Greenbelt, Maryland 20771**

Available from:

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Abstract

During late February and early March 2009, a field experiment was performed using the NASA P3 over the Labrador Sea. During this experiment, expendable probes deployed from the aircraft acquired ocean mixed layer temperature, salinity and currents. Probes were deployed during three flights of the four. Overall 7 AXBTs, 15 AXCTDs and 7 AXCPs were deployed with a success rate of nearly 70%. This is much lower than expected based on prior experience deploying from other aircraft. But given the difficulties associated with the Pneumatic Sonobuoy Launch Tube mechanism on the NASA P3, this rate likely can be improved significantly by using a different deployment mechanism. Additionally, two sets of collocated measurements of AXBTs, AXCPs and AXCTDs were made to verify the drop rates and measurements of the old AXBTs. While there were differences in the measurements, the old AXCTDs are performing well. The expendable data from the experiment are compared to the Argo profiles in the region to check for consistency. Comparisons indicate all the expendable probes acquired useful data and are well within the range of values measured by Argo floats.

1. Introduction:

The microwave brightness temperature of the sea surface at the Aquarius measurement frequency (L-band) is subject to large variability due to surface roughness induced by winds. Past observations indicate that the brightness temperatures increase by more than 0.1 K for an increase in winds of 1 m/s. With a needed measurement accuracy of 0.1 K to produce a sea surface salinity accurate to 0.2 PSU, this roughness effect needs to be quantified and removed from the Aquarius measured brightness temperatures. While measurements were made in the past in low wind conditions using the aircraft based NASA Jet Propulsion Laboratory's Passive Active L-Band System (PALS) to relate in situ sea surface salinity to brightness temperatures and radar cross-sections, the focus of the current experiment was to acquire data during high wind conditions (winds > 10 m/s). The goal of the Goddard component is to acquire near-surface salinity and temperature to provide in situ validation data for the remotely sensed measurements.

The NASA-P3 aircraft situated at the Wallops Flight Facility provided the observational platform for this experiment. This experiment was initially scheduled for the hurricane season in 2008. The original plan was to fly in the rear quadrants of a hurricane in clear sky conditions and acquire both the remotely sensed and in situ data in high wind conditions. This would have provided an ideal test case, as there would have been sea surface salinity changes induced by strong precipitation associated with the hurricane. In addition, we would have been able to use the ocean measurements to quantify heat and salt content changes and to quantify associated budgets. However, PALS could not be mounted on the NASA P3 in time for the hurricane season due to a radome issue. The NASA P3 was not available during the 2009 hurricane season, and therefore a decision was made to acquire data in the Labrador Sea during February-March, 2009. This was communicated to the Goddard team late in the year. With the primary goal of quantifying changes in salinity and temperature in the hurricane wake using the in situ measurements gone due to the change in plan, the main objective of the GSFC activity was to provide the in situ salinity and temperature data for PALS. Secondary objectives included comparison of different types of expendable probes and validation of a newer probe. As the region of high winds targeted by PALS measurements was limited to a very small spatial region, the focus was also placed on acquiring data along transects to provide useful ocean measurements.

This data report provides a detailed description of the observational effort and data from the ocean measurement component. The report is organized as follows: In section 2, the data acquisition system and its set up are described. In section 3, flight plans; data locations and sensor success rate are presented. In the following section, data inter-comparison from different types of probes and Argo profiles is presented. All the processed expendable data are presented in Appendix along with brief description of observations. The scientific analysis and inter-comparison with satellite data will be part of a future research.

2. Equipment Setup:

The three types of oceanographic probes, i.e. Airborne eXpendable Conductivity, Temperature and Depth (AXCTD) probes, the Airborne eXpendable Current Profilers (AXCP) and the Airborne eXpendable Bathy-Thermographs launched from the aircraft have a salt water battery that gets activated when the probe hits the ocean surface. As the probe descends in the water column, a transmitter fitted on to a float at the surface starts transmitting the radio signal containing data. Receivers in the airplane demodulate the signal and send it to the data processor and an audio recorder. The analog audio signal from the receiver is digitized by the data processors and sent to the computer where the data are processed to obtain temperature, salinity and current velocity depending on the type of probe. Probes of three different VHF channels can be in the water at the same time and the computer can be switched to see different probes in real-time although data from multiple probes cannot be seen simultaneously in one computer. The receivers are connected to an external antenna mounted on the fuselage to receive the radio signals. Figure 1 shows a schematic of a general setup.

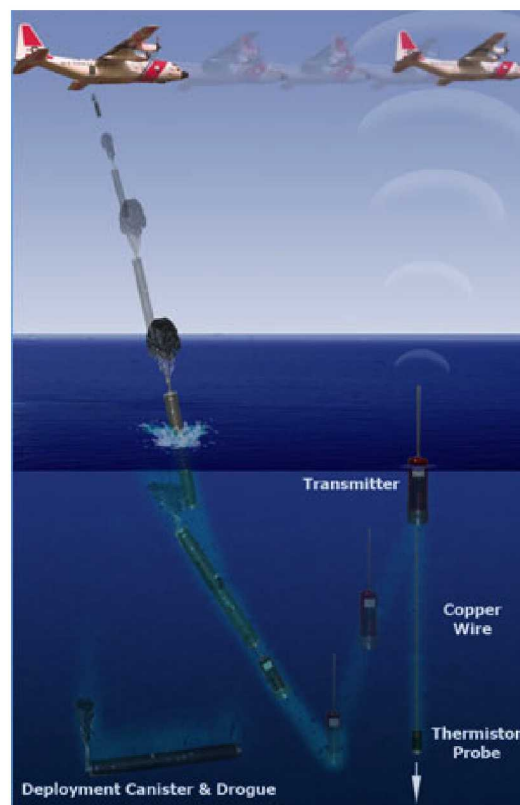


Figure 1: Schematic showing the operation of air-deployed expendable probes.

The expendable probes are built to the US Navy standard sonobuoy sizes and are either launched from inside the aircraft cabin or they are placed in the designated exterior holes in the fuselage prior to take

off and launched using the explosive cartridge activated device (CAD) in flight. A similar aircraft to the NASA P3, the NOAA P3s are equipped with the CAD launch mechanism to launch the probes at altitudes where cabin pressurization is required. At lower altitudes, a free fall chute is used that goes from the cabin to below the fuselage where the probe will exit when deployed. Since probes exiting the free fall chute will be subject to strong airflow below the aircraft, the chute sufficiently extends from the fuselage to prevent the probe being lifted by the airflow and hitting the fuselage. In the US Air Force implementation that was recently used in the Western Pacific, a mechanically operated chute with gate valves on each end was used to deploy the probes from a pressurized cabin even from an altitude of 27000 ft. While the capability to deploy expendables existed in the NASA P3 in the past, this had been removed. For this field experiment, a Pressure-actuated Sonobuoy Launch Tube (PSLT) was fitted on the NASA P3 aircraft. While the NOAA and Air Force launch mechanisms using free-fall chutes from inside the cabin are relatively simple, this mechanism used compressed air to push the expendable probe at speeds such that it cleared the airframe. In addition, the PSLT approach required sonobuoy launch containers and the associated lids that were not readily available.

For the Labrador Sea experiment, the schedule called for upload of the equipment by January 2009. The Goddard team had all the equipment needed for the experiment ready the previous summer for the hurricane season and therefore the upload of equipment for the ocean measurements was completed on time. While the installation aboard the NASA P3 went smoothly, one of the differences of installing equipment on the NASA P3 being a research aircraft compared to the NOAA P3 is that, the science investigators are responsible for the work on the install. In contrast, each piece of equipment and cabling is mounted and checked by the aircraft technical crew on the NOAA P3. The receivers, data processors, data logging computers and data recorders were mounted on a double rack in the NASA P3 and tested out on the ground before the test flight. To protect against equipment failure during the experiment, two sets of receivers and two sets of recorders were setup to provide primary and backup data recordings. While this setup worked very well during the test flight, the PSLT failed to deploy an AXCTD after deploying two AXBTs successfully.

3. Flight Plan:

As mentioned in the introduction, the main goal of the experiment was to make measurements in high wind regions. While the historical Quikscat analyses showed strong winds in this region, weather controlled day-to-day flight planning. Using a combination of latest data from QuikSCAT, forecast surface fields from global general circulation models and guidance from the local airport weather office,

fly/ no-fly decisions were made each morning at 10 am local time. The NASA P3 pilots coordinated with the air-traffic controller to permit flights in a rectangular box over much of the Labrador Sea so that the flight tracks could target the region where high winds were forecast. The detailed flight plan was made at 10 am in the morning of the flight with the take off at 3pm, local Goose Bay time. The planned altitude of the flight was 12000 ft. Ocean expendables were deployed on three of the total of four flights. In the following section, each of the flights is described along with the number of expendables deployed.

3.1 Data:

A. Flight 1:

In the first flight on 20 Feb 2009, the region of interest with about 40 kt winds was located around 50° N latitude and 42° W longitude. Based on the flight pattern consisting of circles, crosses and wing-wags to cover a range of incidence angles for PALS, it was planned to deploy 10 expendable probes during different legs of the pattern. Our goal was to space the ocean measurements such that each of the different flight patterns would have sufficient in situ verification data. The PSLT mechanism worked well for the first two AXBT deployments during this flight and both the AXBTs acquired useful data. However, the probe launch mechanism failed during the third probe (the first AXCTD) and could not be fixed in flight. Therefore, no additional probes could be deployed during this flight. The P3 crew tried to fix the PSLT on the ground the following day, however, it was diagnosed that the actuator mechanism that closes the automatic exterior door on the fuselage had failed and could not be fixed on site due to the lack of parts. Given the remoteness of Goose Bay, it was decided that replacement parts couldn't be located and mailed for fixing the door in a timely fashion. Additionally, the lead pilot, Mr. Mike Singer, mentioned that the overall success rate of the PSLT was only 50% even with a working actuator mechanism (based on experience during test flights). Therefore, an alternative approach of deploying the probes from an unpressurized cabin free falling through the PSLT chute was chosen for the subsequent flights. Details of probe deployment are presented in Table 1 for this flight.

Number	Type and Channel	Lat	Lon	MLT (°C)	MLD (m)
1	BT 14	50.52	-46.65	6.2	125
2	BT 12	50.10	-42.80	11.0	300

Table 1: Details of Deployed probes during the first Goose Bay research flight (RF01).

B. Flight 2:

A second research flight was conducted on the 26 February 2009. Because of the difficulties encountered with the PSLT during the first research flight, as mentioned earlier, a decision was made to deploy the probes free fall from the planned altitude of 12000 ft. During the test flight from Wallops, it was discovered that there was a switch in the aircraft that cut-off electric power to the cabin, if the cabin was unpressurized above 10000 ft of altitude due to power converter issues. However, on further analysis, due to the tireless effort of Mr. George Postell, pilot and chief of the P3 Wallops Flight Facility, it was discovered that the pressure switch could be disabled safely as the updated aircraft power system did not need the safety cut off. Therefore, the aircraft technical crew disabled the cut-off switch. This was helpful because in a smaller region over the Labrador Sea, the air traffic control did not allow the P3 to fly below 10000ft. In addition, Dr. Steve Dinardo of JPL did not want to fly below 12000 ft although Dr. Simon Yueh reiterated that there was no such limitation for PALS. While some initial concerns were raised about the durability of computer hard disks and other hardware at this altitude, everyone involved was satisfied that this was an acceptable and safe approach for the crew and the hardware.

The general region of interest during this second flight was located around 55° N latitude and 43° W longitude where winds in excess of 45 kts were forecast. It was planned to deploy a total of 10 probes during this research flight to limit the amount of time the cabin will stay depressurized. After an initial ferry to the region of interest, the aircraft cabin was depressurized. This approach of free fall deployment of expendable probes still needed to use the sonobuoy launch container (SLC) with the lid, so that the probe casing and the parachute cleared the fuselage without getting stuck to the chute door. However, the probe was subjected to a minor jolt as the SLC hit its stop in the chute and the probe was pushed out along with the SLC lid out of the chute. While 80% of the probes deployed turned on once they hit the water, the wire between the transmitter and the sensor broke on some probes preventing probes from transmitting data up to their design depth. Overall, only five probes obtained useful data. The AXBTs are more rugged and less complicated in their construction, however, the AXCPs and AXCTDs have more complicated electronics and therefore subject to additional failures. Although this free fall approach allowed us to deploy the probes, failure rates were much higher than what has been seen in other experiments. Details of probes deployed are shown in Table 2 for this flight. Clearly, a better deployment approach with a free fall chute extending out of the fuselage would have reduced the shock on the probes and reduced the failure rates. This was confirmed by the fact that AXBTs deployed from a pressurized cabin using a mechanically operated chute from an altitude of 27000 ft had a success rate in excess of 98% (Dr. Peter Black, personal communication). Based on this, the NASA P3 crew agreed to deploy the probes with as little force as possible on subsequent flights.

Number	Type and Channel	Lat	Lon	MLT (°C)	MLD (m)
1	BT 16	55.0	-44.7	4	> 300
2	CP 12	54.96	-44.07	Wire Break	
3	CTD 14	54.99	-45.02	Failed	
4	CTD 12	54.75	-44.90	3.9	75
5	BT 16	54.64	-44.86	Wire Break	
6	CTD 14	54.59	-44.69	3.8	175
7	CTD 12	54.78	-46.08	Failed	
8	CTD 16	54.88	-46.92	Wire Break	
9	CP 14	54.90	-47.52	8	Wire Break
10	CTD 12	54.40	-47.60	3.3	190

Table 2: Probes deployed during the second Goose Bay research flight (RF02).

C. Flight 3:

While there were no problems with the equipment due to the lack of pressurization in the cabin at 12000 ft (for less than 2 hours), one of the science crew from Purdue University had an interaction to a prescription medication that he was taking during this flight even before the depressurization. Instead of tasking a substitute who was already in Goose Bay to operate the instrument, the JPL crew decided against flying unpressurized at 12000 ft. A lower maximum altitude of 8500 ft to fly unpressurized was imposed upon future missions citing equipment and crew safety by JPL. We were not informed directly or in time of this decision although it primarily affected our part of the experiment. We had to gather this information from an oblique remark by a crewmember. This was further complicated because the Canadian air traffic control needed a minimum of 24 hours during the week and 72 hours during the weekend to modify the clearance to fly lower (8500 ft) than the 10000 ft floor that was originally granted. By the time these restrictions were known on Friday, February 27, 2009 it was too late to make a change to the flight plan for Saturday to Monday. With winds in excess of 60 kts forecast on Monday, March 2, 2009, clearance could not be obtained to fly lower than 10000ft during the third research flight. A decision was made to fly anyway, but at higher altitude and without deployment of the probes. Therefore, no in situ near-surface salinity or temperature was available for validation of PALS

measurements during this flight although winds exceeded 50 kts. A huge opportunity to get measurements along a section in the Labrador Sea was lost.

Number	Type and Channel	Lat	Lon	MLT (°C)	MLD (m)
1	CTD 16	53.15	-44.97	5	71
2	CP 12	53.15	-45.54	Stuck in Canister	
3	CTD 14	53.50	-45.99	Stuck in Canister	
4	CTD 16	53.50	-46.59	Failed	
5	CP 14	53.50	-47.25	6.2	95
6	BT 16	53.50	-47.36	5.3	78
7	CTD 12	53.50	-47.50	4.7	Not Well Defined
8	CTD 14	53.50	-48.50	3.8	90
9	CP 16	53.50	-49.00	Stuck in Canister	
10	CTD 12	53.50	-49.50	4.4	160
11	BT 14	53.50	-49.75	4.2	135
12	CP 16	53.50	-50.00	4.2	Not Well Defined
13	CTD 12	53.50	-50.60	Stuck in Canister	
14	CTD 16	53.50	-51.10	3.5	Not Well Defined
15	CP 12	53.50	-51.60	1.3	Not Well Defined
16	CTD 14	53.50	-52.10	-1.7	40
17	BT 14	53.50	-53.50	-1.8	45

Table 3: Probes deployed during the fourth Goose Bay research flight (RF04).

D. Flight 4:

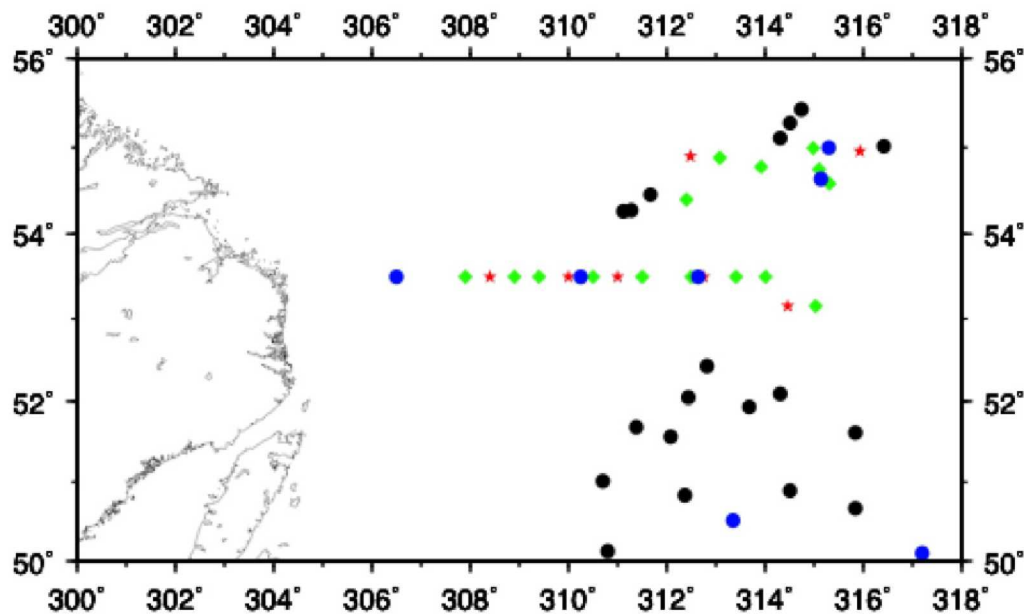


Figure 2: Geographic locations of probe deployments. Blue circles denote AXBT, green diamonds denote AXCTD and red stars denote AXCP locations respectively. The black dots indicate locations of Argo profiling floats in the region.

The fourth research flight was conducted on March 5, 2009. Clearance was obtained to fly at an altitude of 8500 ft in the experimental region with the turn point at 45 W and 53 N. Given the proposed flight track, it was decided to deploy the expendable probes along a straight line segment to get ocean state along a section that also included the Labrador current. Our preference was to deploy the probes on our way out to the turn around point as there still would be sun light to avoid ice edges. However, we were informed, without justification, that the probes would have to be deployed along way back to Goose Bay. The probes were deployed on the return flight track from the turn around point. Overall, 17 probes were deployed during this flight (Table 3). While there was only one outright failure, four other probes were stuck in the canister, causing no data transmission. This failure mode is primarily due to the deployment approach (i.e. the crew had tried their best to reduce the force with which the probe was being pushed out of the SLC in order to reduce the failure mode encountered in flight 2).

To compare the thermal structure from each of the different type of probes and assess their fall rate, three pairs of the probes were deployed next to each other. In addition, current profilers were deployed in the Labrador Current region to get a velocity measurement inside of this south flowing current. Overall, 12 expendable probes acquired useful data during this flight (Table 3).

4. Data Analysis:

The real time digital data of temperatures, currents and salinity obtained by the data acquisition system generally contain isolated spikes. Additionally, the starting depth of good data is subject to more uncertainty in real time data due to external noise. Therefore, the first step in the data analysis is to reprocess the audio signals from the expendable probes recorded by digital equipment aboard the plane in a controlled laboratory setting. While this is a time consuming process, it is necessary for ensuring better quality data. Data from all the three flights are reprocessed using the recorded audio signals from the probes and prepared for further analysis. Reprocessed digital data from all of the probes are then subjected to noise screening and filtered with a seven point median filter. From our previous experience of processing the data from the Eastern Pacific Investigation of Climate in 2001 and the hurricane research programs in 1999, 2000 and 2002, such a filter works very well to remove isolated noise spikes. The noise removed vertical profiles are then interpolated to fixed depth intervals of 1 m to compare data from different types of probes. These comparisons are discussed in the following section. All of the processed data from the three flights are presented graphically in the Appendix. In section 4.2, the data are compared with nearby Argo floats to provide an independent quality check on the data. The location of all of the data from the probes and the Argo floats used in the analysis are shown in Figure 2.

4.1 Profiles from Different Types of Probes:

As mentioned earlier, three types of expendable floats were used in the experiment to obtain ocean structure in the Labrador Sea region. The AXBTs originally belonged to Navy but were past their prime useable date. They were made available free of cost to the project through multiple sources. These types of probes have been in use for more than 40 years in the science community. The AXCPs measure currents and temperatures and have been in use for a number of years. While the AXBTs used are limited to a maximum depth of 300m, the AXCPs are designed to measure up to a depth of 1500m. In the last decade, the AXCTDs were developed with a design depth of 1000m. Three sets of these probes were deployed in close proximity to each other during the last research flight. Because the AXBTs were limited to 300m, the comparisons were made only to this depth and are shown in Fig.3. In the first set, the AXCP was deployed first, followed by an AXBT and an AXCTD (near 312.75 E longitude and 53.5 N latitude in Fig.2). While the deployment locations are very close to each other for this set, the data show significant difference between the probes all the way to 300m. As this region has a lot of eddies it is possible that the probes sampled different sides of the eddy. Between the AXCTD and the AXCP, a temperature difference in excess of 1° C is seen in the mixed layer. The difference reduces below 100m depth and starts to diverge below a depth of 200m. Further analysis is required to understand the variability observed by this set of probes.

In the second set, the AXCTD was deployed first followed by an AXBT and an AXCP (near 310.25 E longitude and 53.5 N latitude in Fig.2). Clearly, a reduction in the near surface temperature is seen as we

approach closer to the coast. While the AXCTD and AXBT show a similar temperature structure, below a depth of 225m, the AXCP shows almost a 0.5°C warming of the sub layers. The third set of probes (the first three probes from the left along 53.5°N latitude in Fig.2 - 15, 16 and 17 in Table 2) was deployed closer to the coast with the AXBT and AXCTD in the continental shelf region with a depth of about 300m. The near surface temperatures are below 0°C in the shelf with the ice edge is not too far to the west of these deployments. The AXCP was deployed first, followed by the AXCTD and AXBT. The AXBT and AXCTD vertical temperature profiles compare reasonably well with some differences at 200m depth shown in the AXCTD measurement perhaps due to some mixing. However, as seen in Fig.3, the measured thermal structure below 250m converges for the three probes. Overall, the probes including the old AXBTs performed very well. These data are compared to the available Argo floats in the next section.

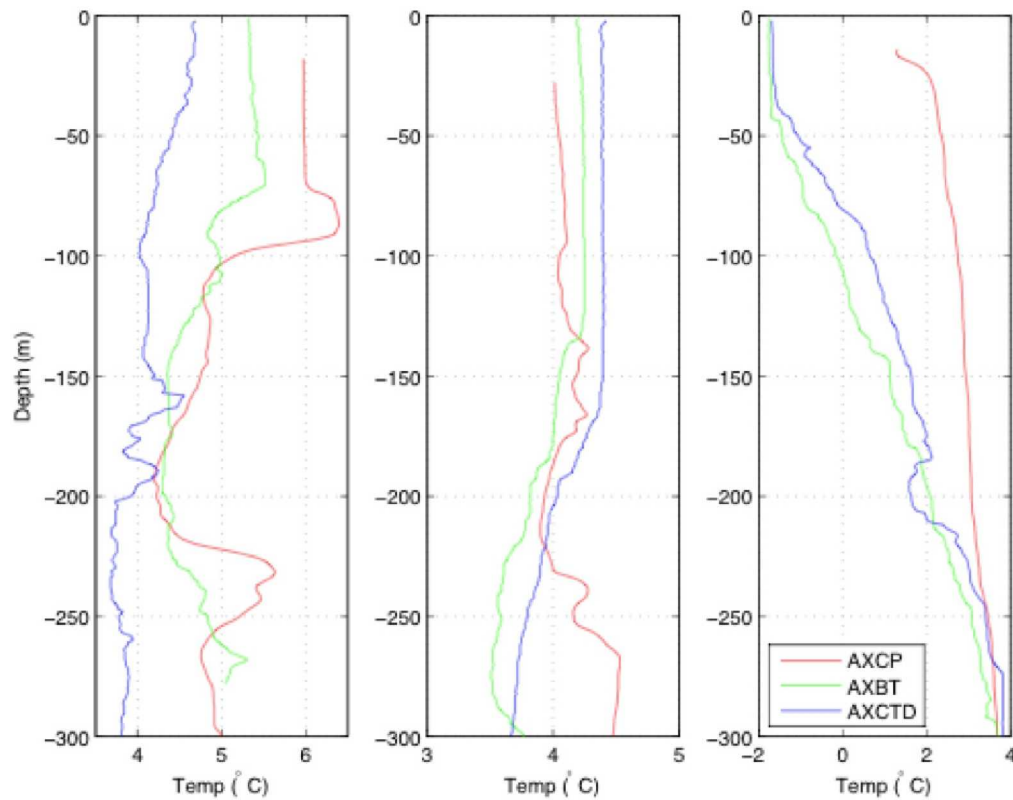


Figure 3: Comparison of temperature profiles from different types of floats deployed near to each other.

4.2 Argo Profiling Floats:

To compare the expendable data to the data from Argo profiling floats, we consider the floats in the general region from Feb 15, 2009 to March 15, 2009. There were about 20 float profiles in this region and locations are shown in Fig.2. The data from these profiles are processed similar to the expendable probe data and re-sampled to uniform depth levels of 5 m. While there is a lot of eddy activity in the region, the vertical temperature and salinity structure are compared to the expendable probe data in

the vicinity. In addition, the temperature-salinity relationship from the AXCTDs is compared to those from Argo float profiles. Due to temporal and spatial differences, only qualitative comparisons are performed and are limited to four nearest Argo profiles within a 2° radius of the expendable location. The comparisons are shown in Figs. 4-8 for two AXBTs from flight 1, one AXCTD from flight 2 and two AXCTDs from flight 4 respectively.

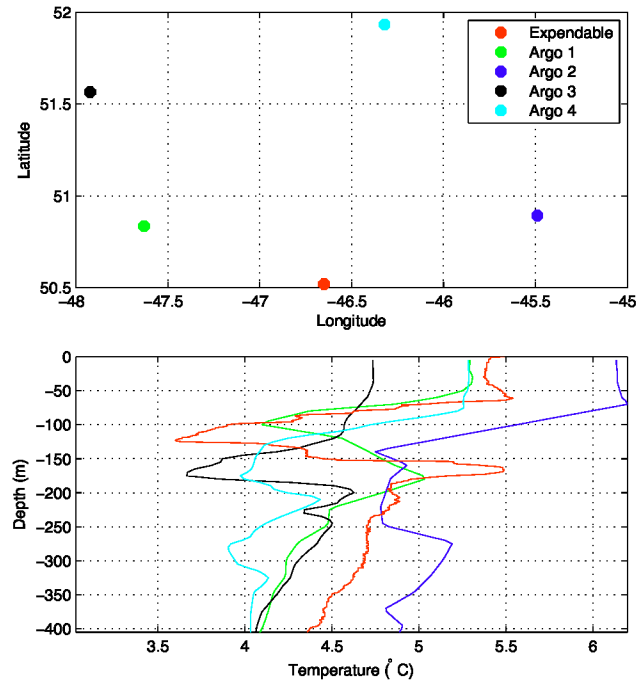


Figure 4: Comparison of the first AXBT Temperature profile from flight 1 to a nearby Argo float profile. The top panel shows the location of ABXT with a red circle. The Argo float profile locations are shown with green, blue, black and cyan symbols with increasing great circle distances from the expendable. In the bottom panel, the data from these profiles within two degrees are compared to the expendable measurement in red. Green, blue, black and cyan represent Argo profiles for increasing distances. The AXBT measurement agrees well with the nearest Argo temperature profile.

In figure 4, the first AXBT from the first flight was compared to the nearest four Argo profiles. While some of the Argo profiles are separated by as much as 10 days, the data from the nearest float (shown in green) compares very well with the temperature measured by the AXBT (shown in red). In particular, the stratification structure in the upper ocean is very similar with more extreme values measured by the AXBT. The second AXBT during the research flight appears to have landed in the North Atlantic Drift with surface temperatures reaching 11° C with a mixed layer depth of about 350 m (Figure 5). Although the nearest Argo profile was separated by about a degree to the west, this showed a near surface temperature of 10.5° C with comparable mixed layer depth. The farthest Argo profile shows a lower

near surface temperature of 6° C that was in the subpolar gyre past the subtropical-subpolar gyre boundary.

Qualitative comparison of an AXCTD from the second research flight with the nearest Argo profiles is shown in figure 6. The closest Argo profile is to the northeast of the expendable location and compares reasonably well with the expendable data. The other three Argo profiles were to the northwest and are very close in geographical location to each other and therefore measured similar salinity and temperature profiles. Although all the profiles converge below a depth of 400 m, the AXCTD data shows a lower salinity near the surface that gradually converges toward the nearest Argo profile. It should be noted here that the AXCTD salinity data is not averaged significantly and is at 1 m resolution where as the Argo sampling is much coarser and is resampled to 5 m in the vertical here. This leads to a noisy fine scale structure in the salinity profile. Although a 20-point boxcar filter will smooth out this structure, it was decided to compare data with minimal smoothing.

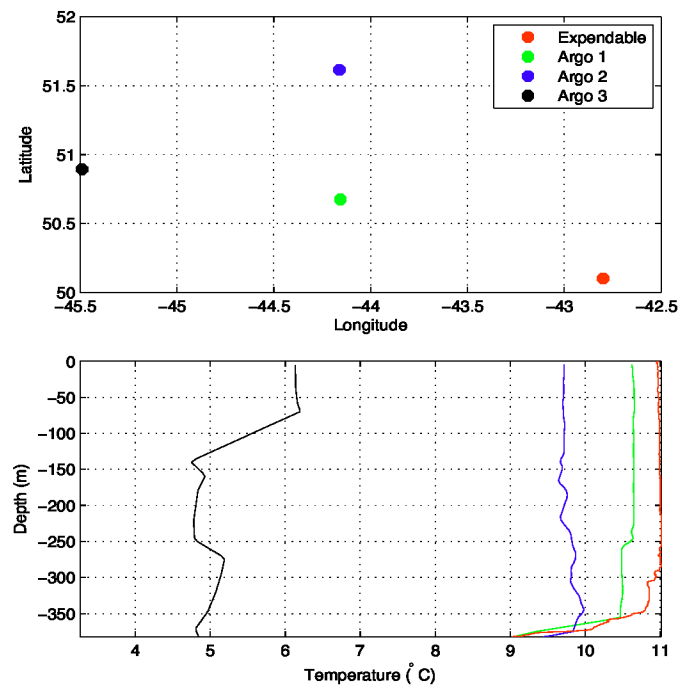


Figure 5: Same as figure 4 but for the second profile from flight 1. This AXBT was deployed near the North Atlantic drift, so shows much higher temperature. Toward the coast, the temperatures reduce for profiles in the sub-polar gyre.

Comparisons of two AXCTD profiles of salinity and temperature to the Argo profiles are shown in Figs. 7 and 8. Although all of the Argo profiles are to the south of the expendable deployment location of the AXCTD (Fig.7), the AXCTD data compares better with the Argo profiles to the southwest. The nearest Argo profile appears to be in the transition zone between the subtropical and subpolar gyres and is therefore warmer and more saline near the surface than the AXCTD data. Data from profiles further to

the west compare qualitatively better as seen in Fig. 7. In contrast, the AXCTD data shown in Fig.8 compares well with the Argo profile to the east of its deployment location. Clearly, the oceanographic variability due to eddies and other circulation features in this transition zone complicate the one to one comparison.

To further confirm the performance of the expendable probes, temperature and salinity values from all of the AXCTDs are compared with those from Argo profiles in the region in Fig.9. As seen in the figure, the AXCTD measurements compare extremely well and are within the range of values measured by Argo floats. While the Argo floats have much more accurate salinity and temperature sensors, we conclude, based on the comparisons that the AXCTDs performed extremely well during this deployment.

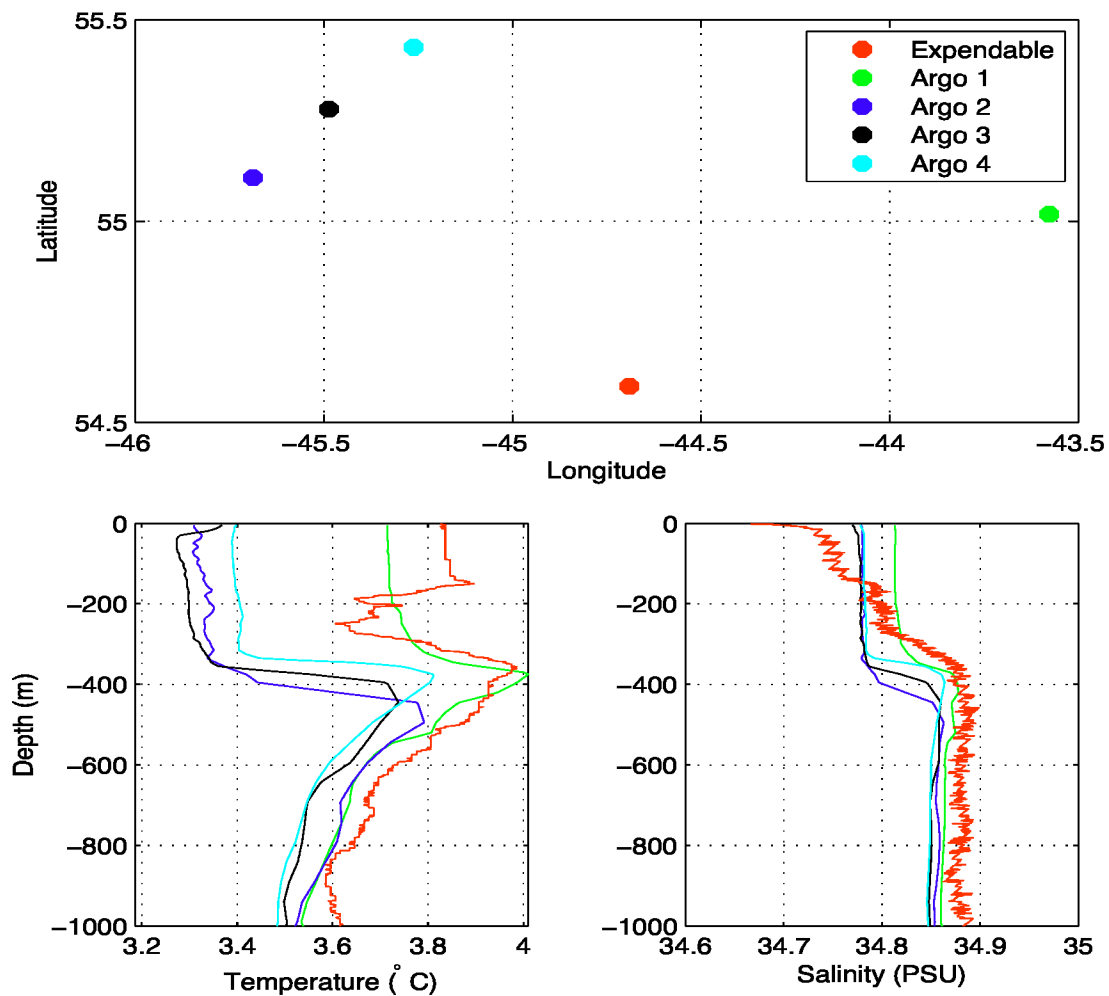


Figure 6: Comparison of nearest Argo Temperature and Salinity profiles with an AXCTD profile from flight 2 (Profile 6). Measurements compare very well with the Argo data. The small-scale noise in the AXCTD is well within the measurement noise range of the instrument of 0.05 PSU. As the experiment was conducted in the sub-tropical to sub-polar gyre transition zone, the Argo profile in the right region will compare better to the Expendable profile data.

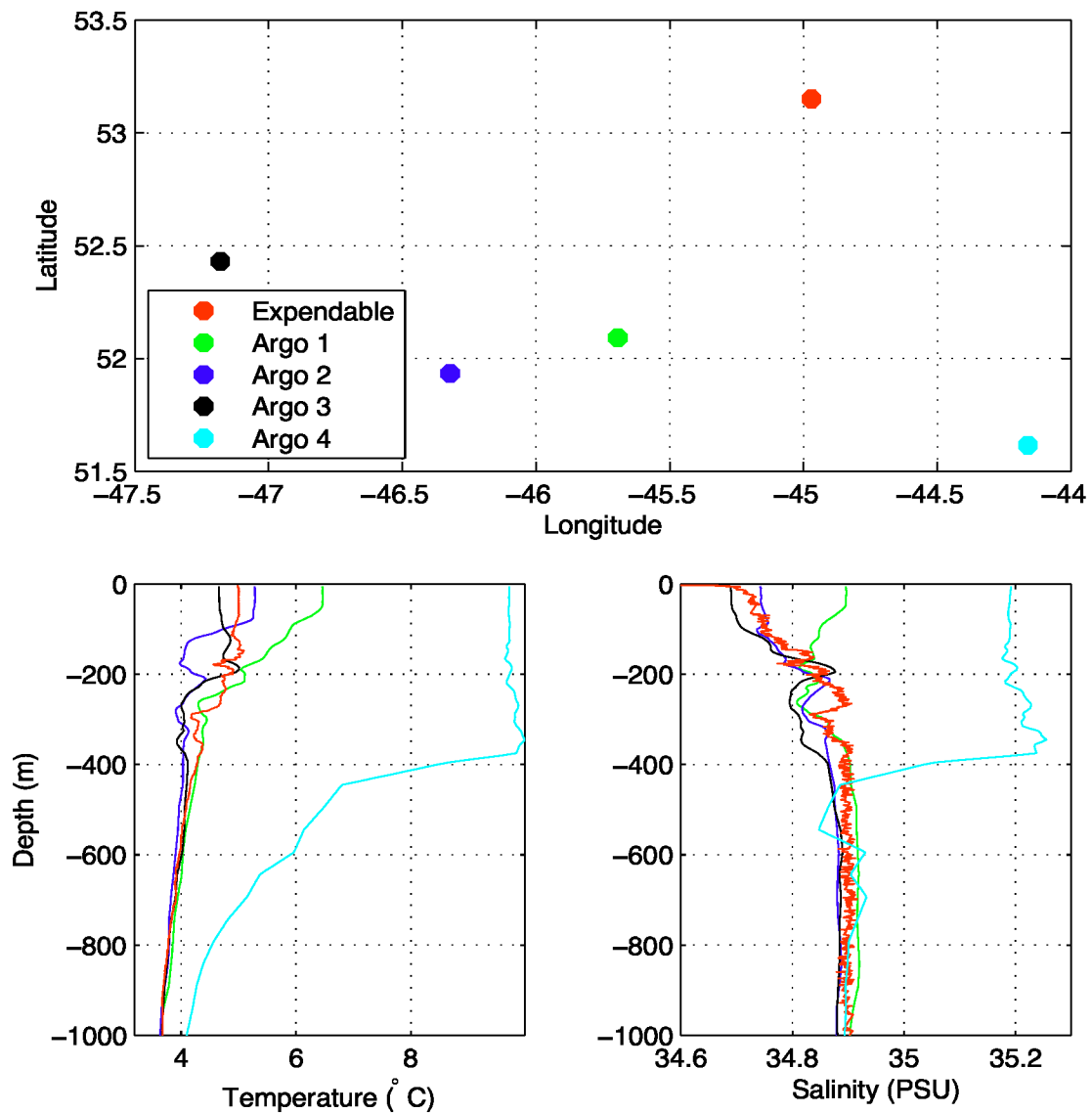


Figure 7: Comparison of nearest Argo Temperature and Salinity profiles with an AXCTD profile from flight 4 (Profile 1). The farthest Argo profile (indicated in cyan) is clearly in the subtropical gyre boundary and therefore is in warmer and more saline watermass. While the measured profile compares qualitatively with the other three Argo profiles, the profile shown in black (third farthest from the Expendable location) compares better to the AXCTD data.

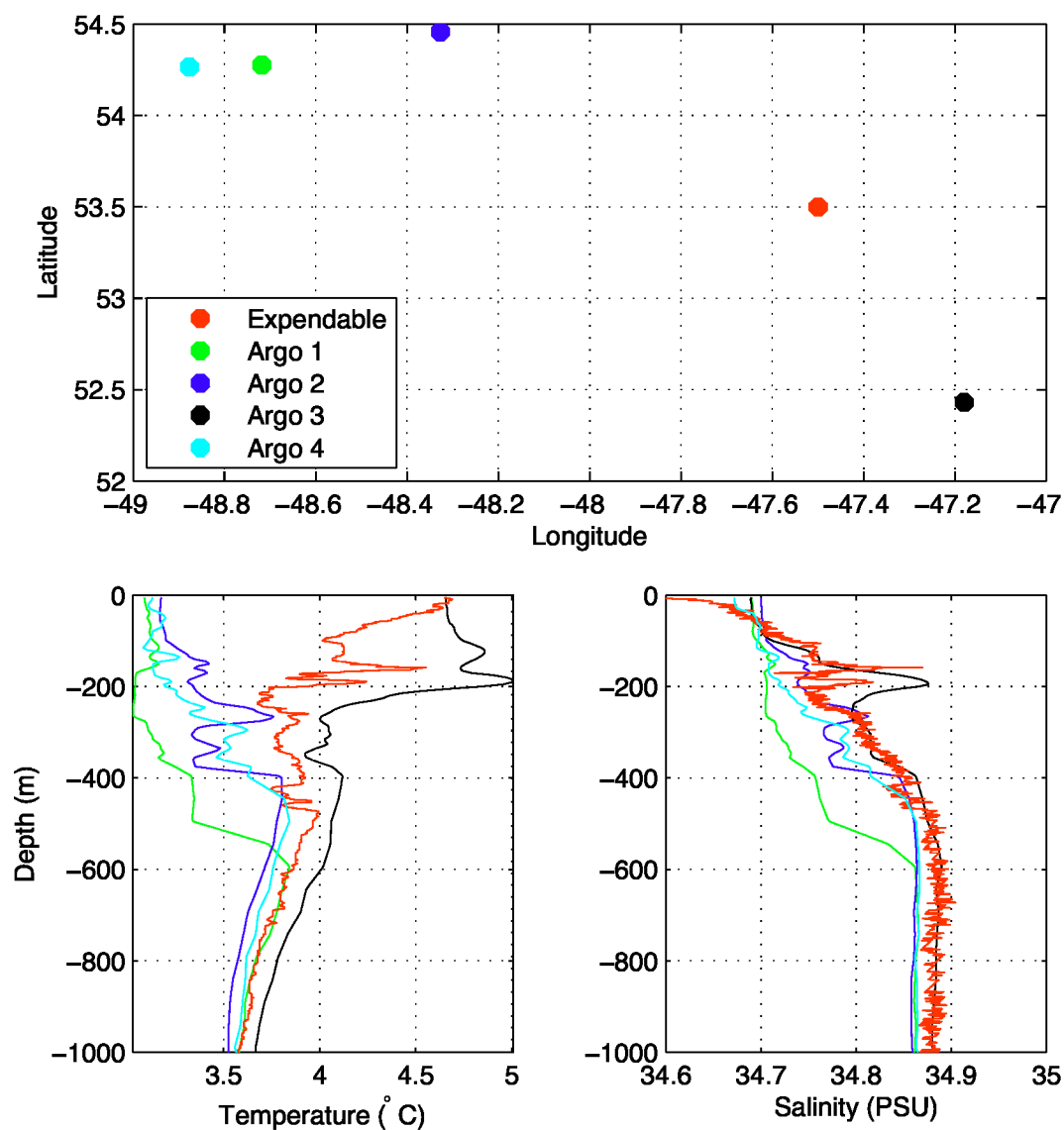


Figure 8: Same as Figure 7, but for another AXCTD profile from flight 4 (Profile 6). While temperatures from three Argo profiles compare well with each other, the expendable measurement compares better with the third farthest profile. Salinity profiles do not show significant differences although one Argo profile shows smaller salinity values in the 200 to 600 m depth range. Overall, the Argo profiles compare well with the expendable measurements.

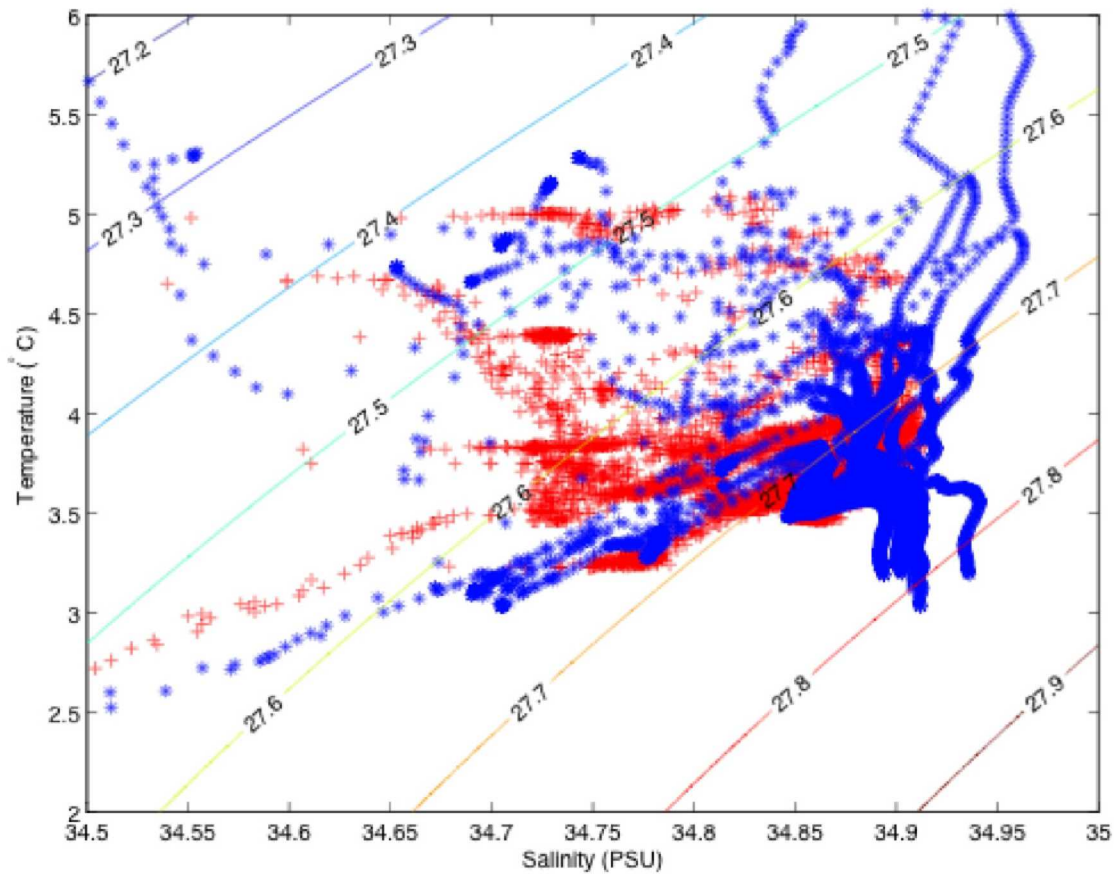


Figure 9: Temperature- Salinity values from the AXCTDs (red +) and the Argo profiles (blue *) in the region. The range of AXCTD measurements of temperature and salinity agree well with the Argo measurements.

5. Summary and Conclusions:

A field experiment was planned to quantify roughness effects on the microwave brightness temperatures in high wind conditions to improve the sea surface salinity retrieval algorithms. To provide the surface boundary conditions and in situ temperature and salinity, expendable profilers were deployed as part of this effort. The initial plan was to fly in the rear-quadrant of select Atlantic hurricanes, which would have allowed us to quantify the precipitation effects on salinity. However, due to technical issues, the experiment was conducted in Labrador Sea during February-March 2009. The experimental hardware and expendable probes were acquired in late 2008 and the data receiving equipment was installed in the NASA P3 during January-February 2009.

The expendable ocean probes deployed from the aircraft acquired ocean mixed layer temperature, salinity and currents during the research flights. Due to the limitations of the aircraft probe launch mechanism and changes in the flight rules, the probes were deployed only during three flights of the four. Overall 7 AXBTs, 15 AXCTDs and 7 AXCPs were deployed with a success rate of nearly 70%. The older, more rugged (and free) AXBTs had the success rate of 86%, where as the AXCPs had the least success rate (50%). While there were only 3 total failures in which the probes did not turning on, this useable data success rate is much lower than what we have come to expect from previous experience. This was primarily due to the difficulties associated with the Pneumatic Sonobuoy Launch Tube mechanism.

The signal recorded on the plane was reprocessed in the lab and the data profiles were filtered to remove isolated spikes. It was decided not to smooth the data excessively to maintain measured variability although some of the small-scale noise can be removed for science studies. All the temperature, salinity and current data are of very good quality except for one probe that gave noisy current measurements. The data from the expendables are compared with data from the Argo floats in the region to provide a consistency check. While the comparison is qualitative due to space-time sampling limitations of Argo, the expendable data compares extremely well with the Argo data. The temperature-salinity measurements from the expendables are well within the range of Argo float measurements in the region. Direct measurements of ocean currents were made in the Labrador Current and vicinity by the AXCPs deployed during the fourth flight. These measurements indicate a near constant 20-22 cm/s current flowing south westward very close to the coast from near the surface to a shelf depth 450 m. One other AXCP measured a maximum southeastward flowing current of 30 cm/s magnitude. The AXCTDs from the new vendor performed very well, confirmed by the comparison to AXBT and Argo profile data. Measurement of salinity profiles will help explain vertical temperature variability consistent with static stability.

Overall, the ocean component of this experiment was a huge success given the constraints. Useful data were obtained that not only provided in situ surface conditions to the remote sensing component (Appendix B), but also will allow us to assess synoptic variability of temperature and salinity in the region to address circulation variability supplementing satellite and other in situ data. While marginally more expensive, air deployed expendables allows us to sample the ocean quickly at fixed locations and in inhospitable environments and provide an alternative way to observe the oceans.

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Appendix A: Data Profiles

All of the data profiles collected during the three of the four flights are shown in this appendix. It should be noted here that the data are processed with minimal smoothing to maintain all the structure in the raw data. Appropriate smoothing will be performed in the science analysis.

Flight 1:

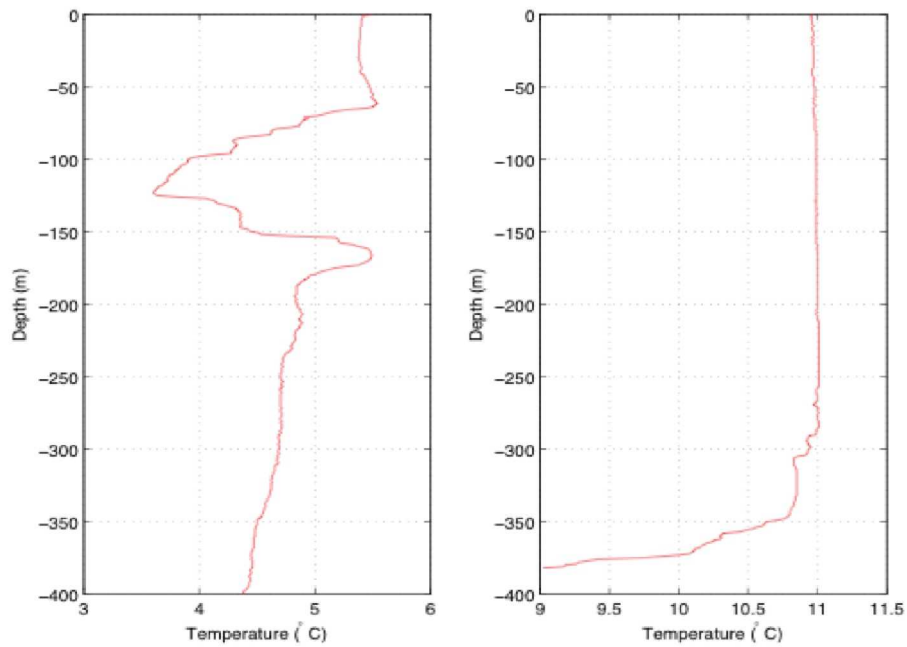


Figure A1: Data from two AXBTs deployed during the first flight. The temperatures indicate that the second AXBT was deployed in the North Atlantic drift. The locations are listed in Table 1 with the first AXBT profile on the left panel.

Flight 2:

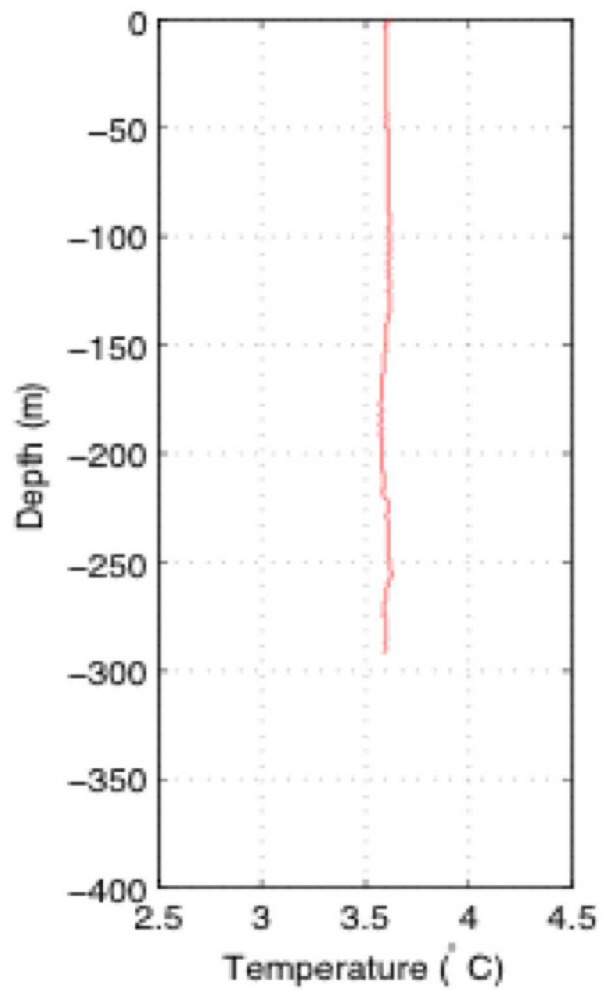


Figure A2: Data from the AXBT deployed during flight 2 (Probe Number 1 in Table 2). The mixed layer was uniform with the temperature of about 3.6° C.

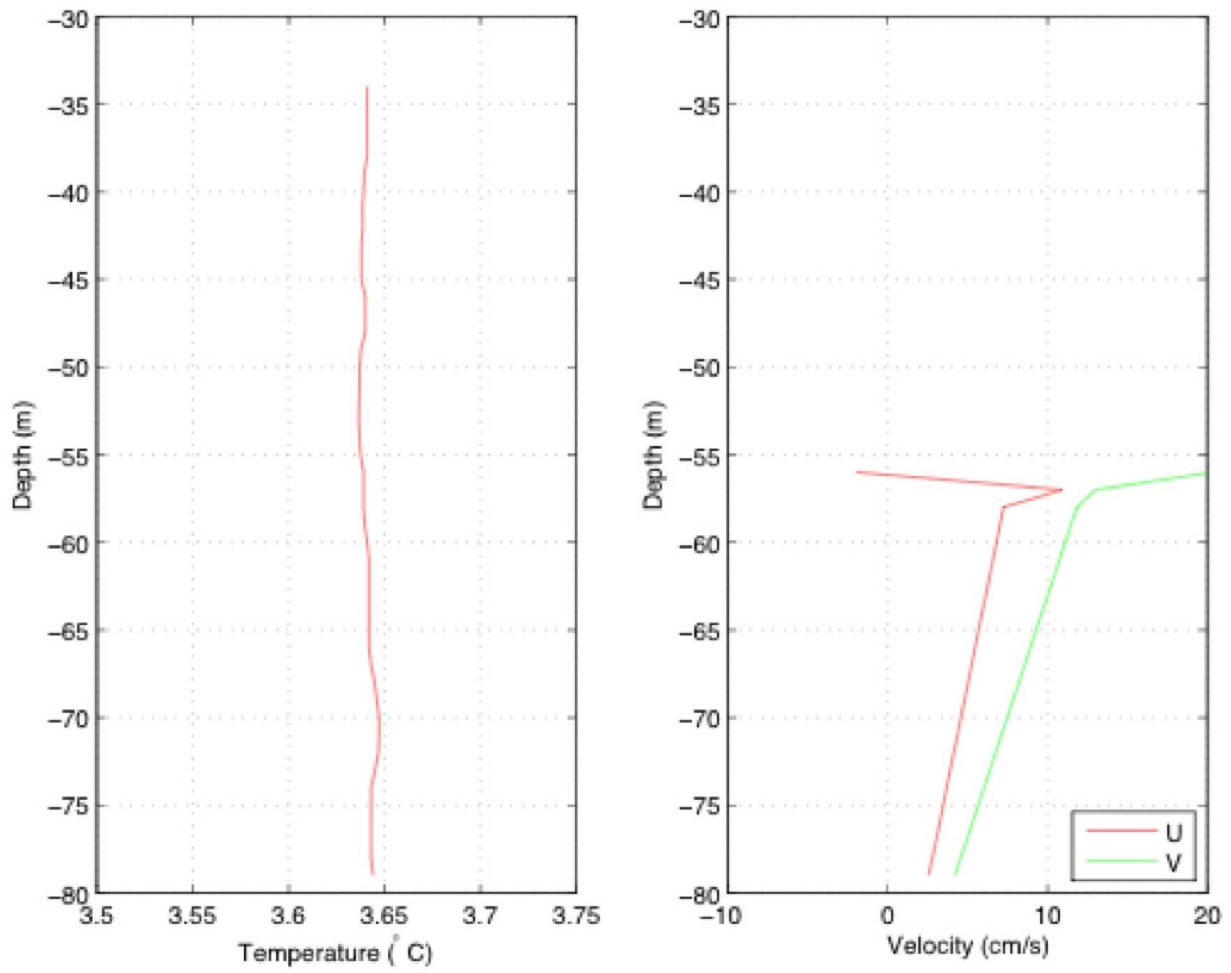


Figure A3: Data from probe number 2 in Table 2, an AXCP. The wire connecting the antenna to the sensor broke at 80 m depth limiting the data acquisition.

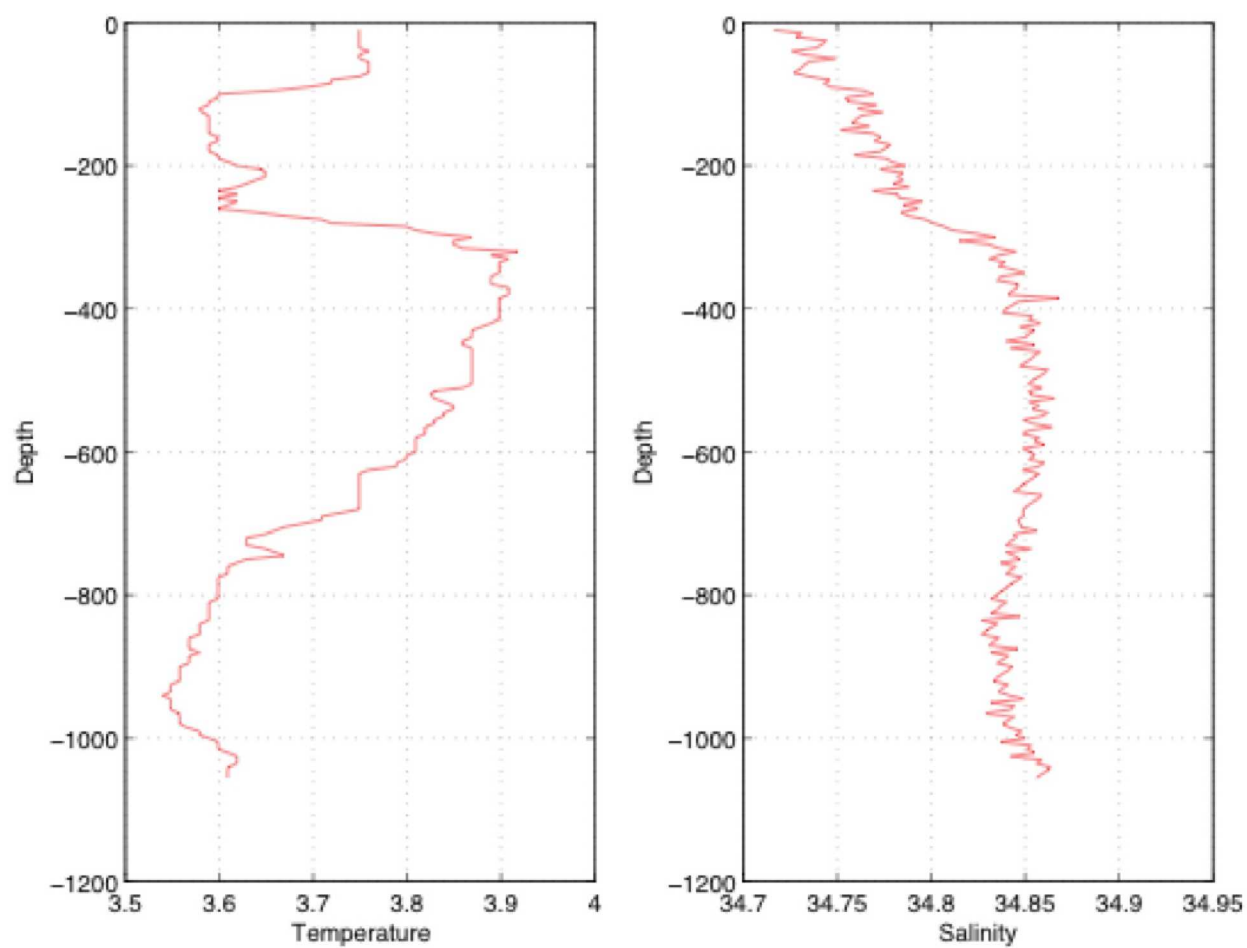


Figure A4: Data from probe number 4 in Table 2, an AXCTD. The sensor acquired data up to its design depth of 1000 m. The salinity data is minimally smoothed and resampled to 1 m vertical resolution and therefore contains wiggles less than 0.05 PSU, the design accuracy of the AXCTD conductivity sensor.

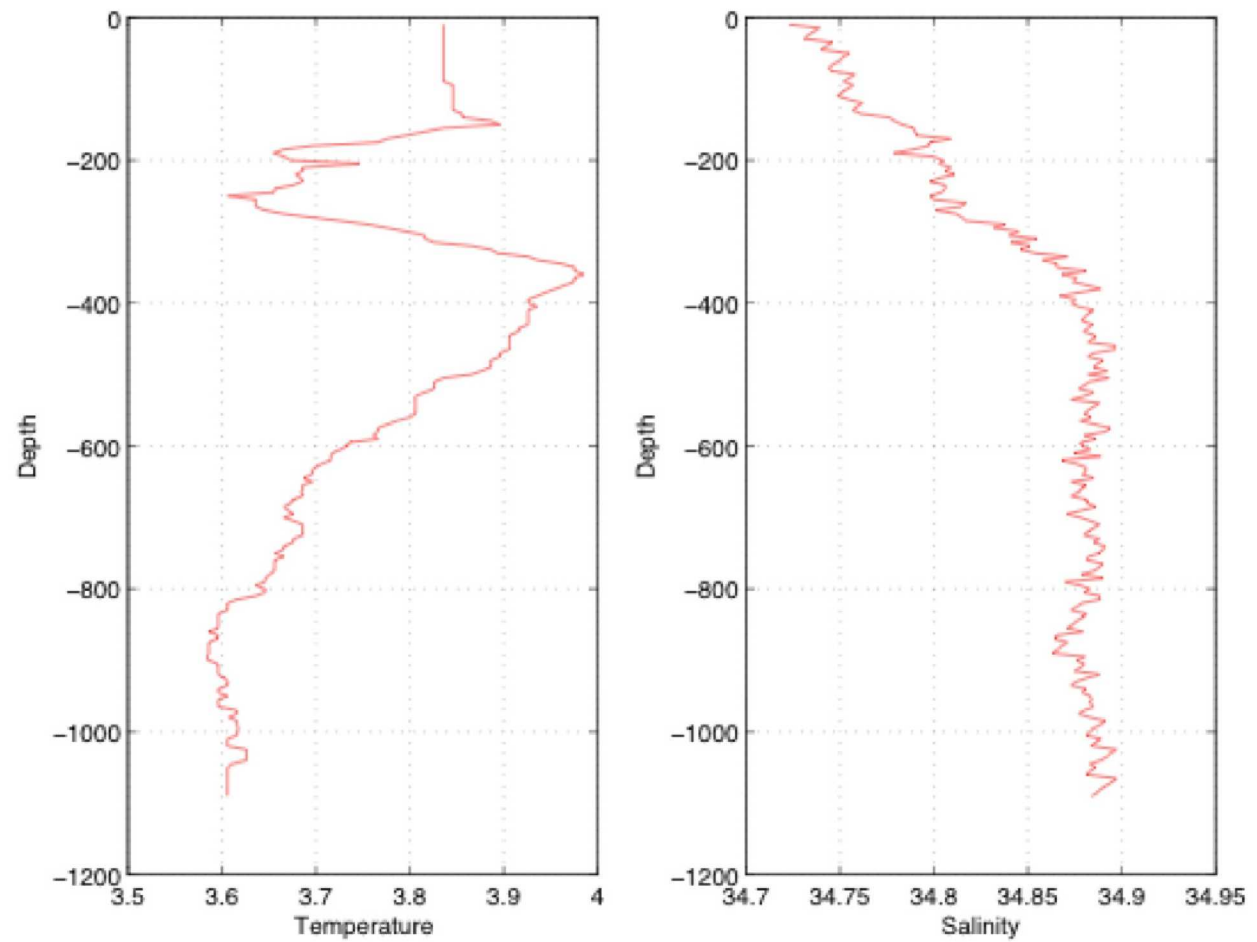


Figure A5: Data from probe number 6 in Table 2, an AXCTD. The stratification shows the importance of salinity in maintaining the static stability.

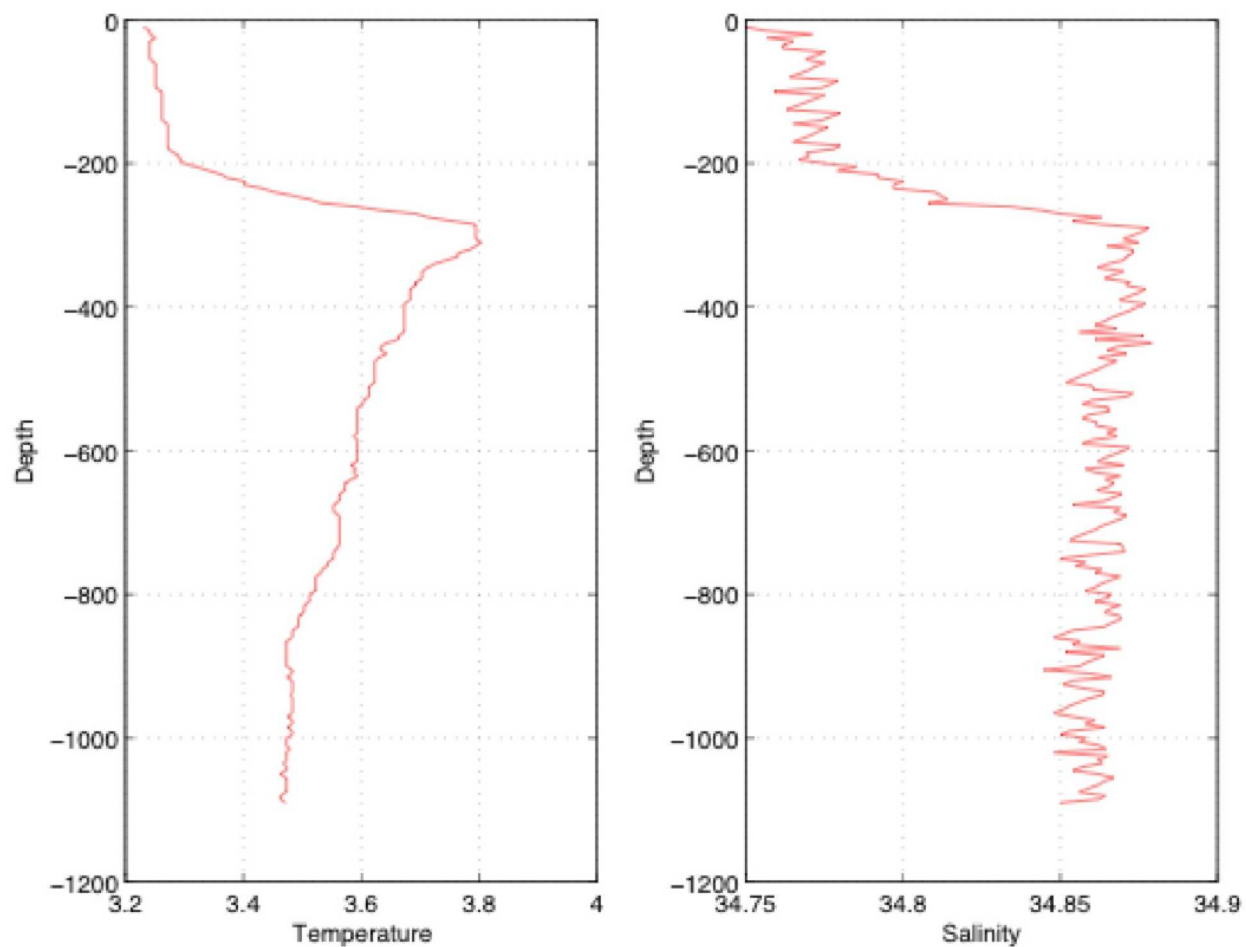


Figure A6: Data from probe number 10 in Table 2, an AXCTD from flight 2. The sensor gave very good data up to its design depth. The surface is colder and fresher maintaining static stability.

Flight 4:

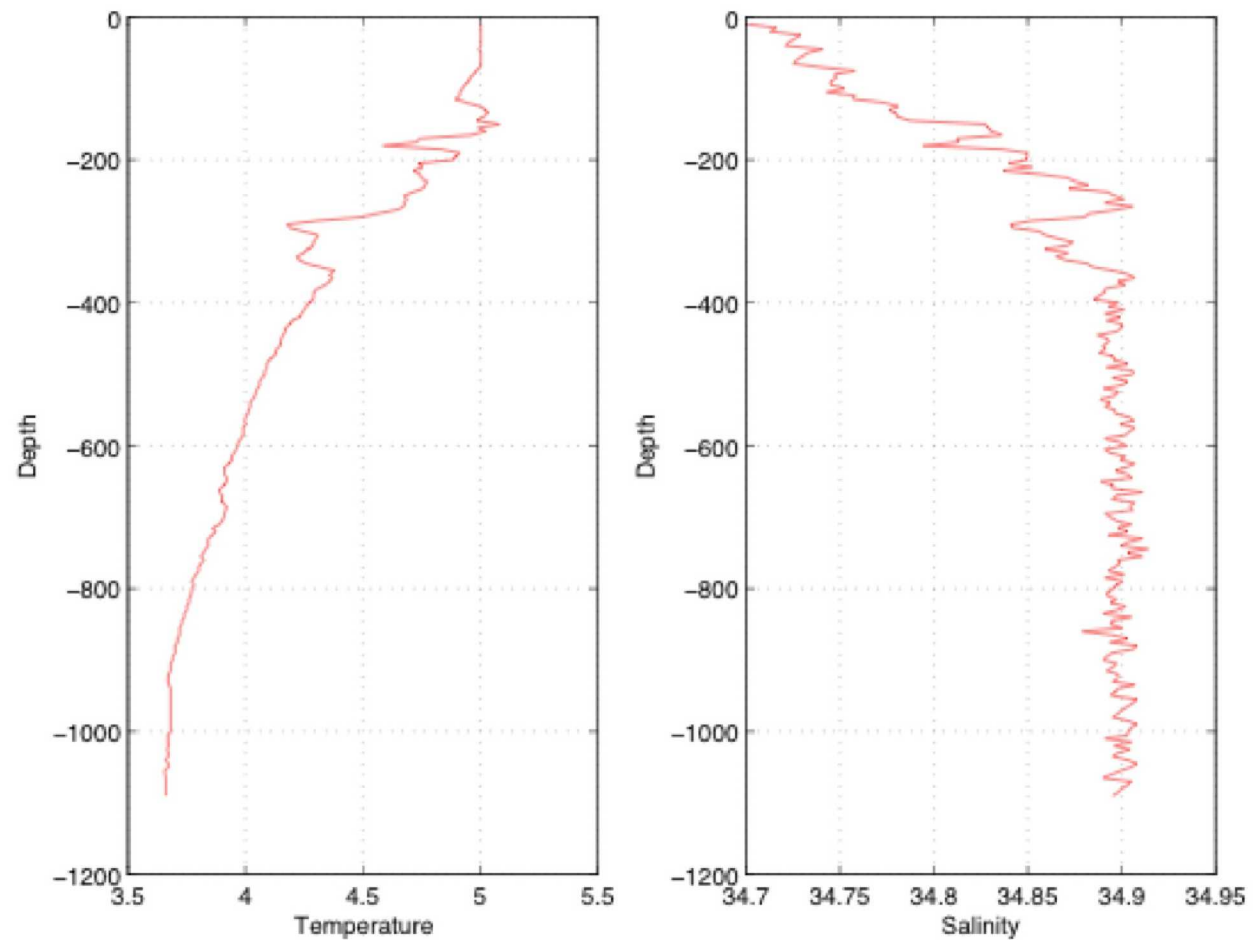


Figure A7: Temperature and Salinity data from probe number 1 in Table 3 from flight 4. The vertical profiles show a complicated structure in the upper ocean.

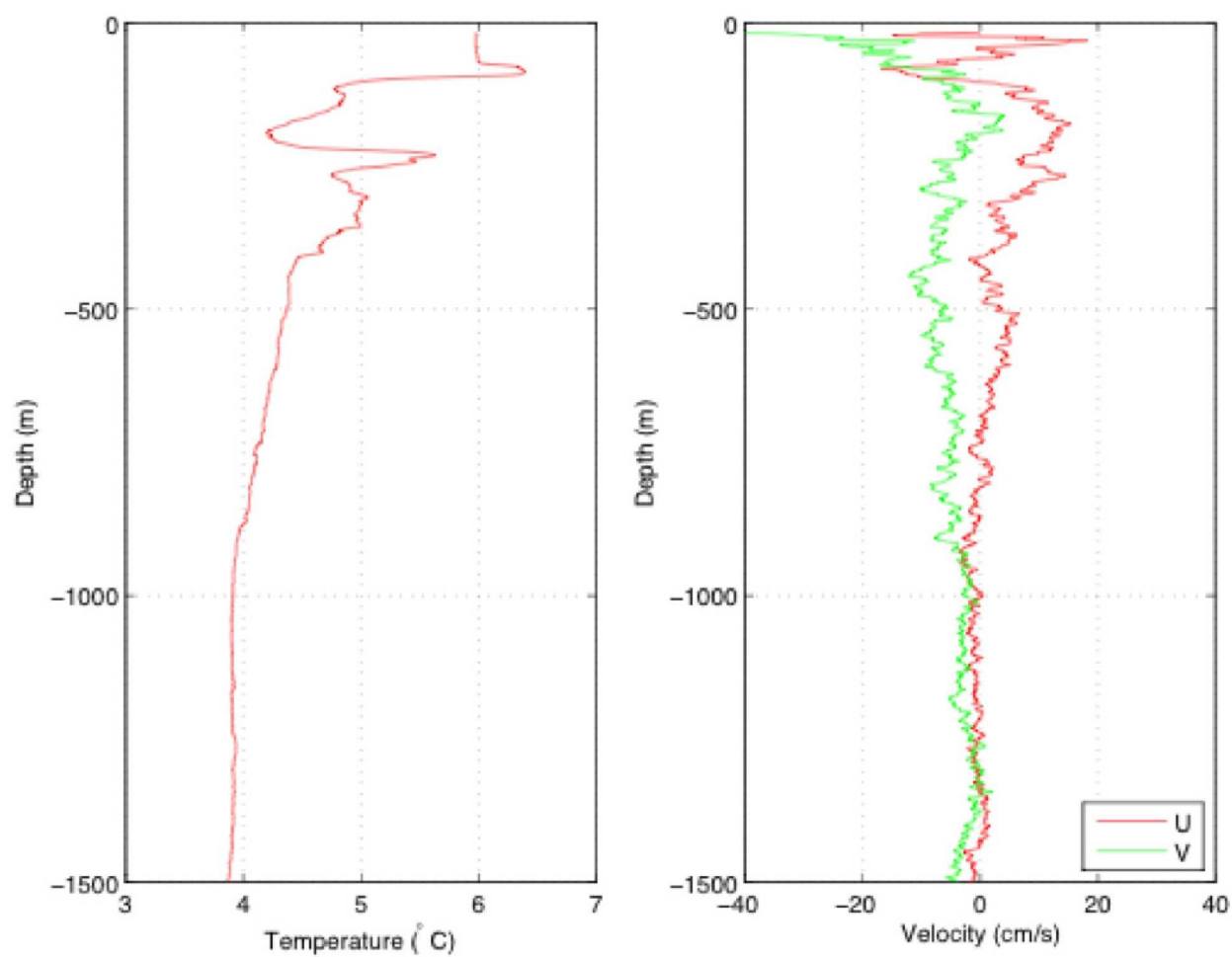


Figure A8: Data from probe number 4, an AXCP from flight 4. The probe worked well to a design depth of 1500 m. The current measurements indicate a southeastward flowing current from 200m to 1000m depth.

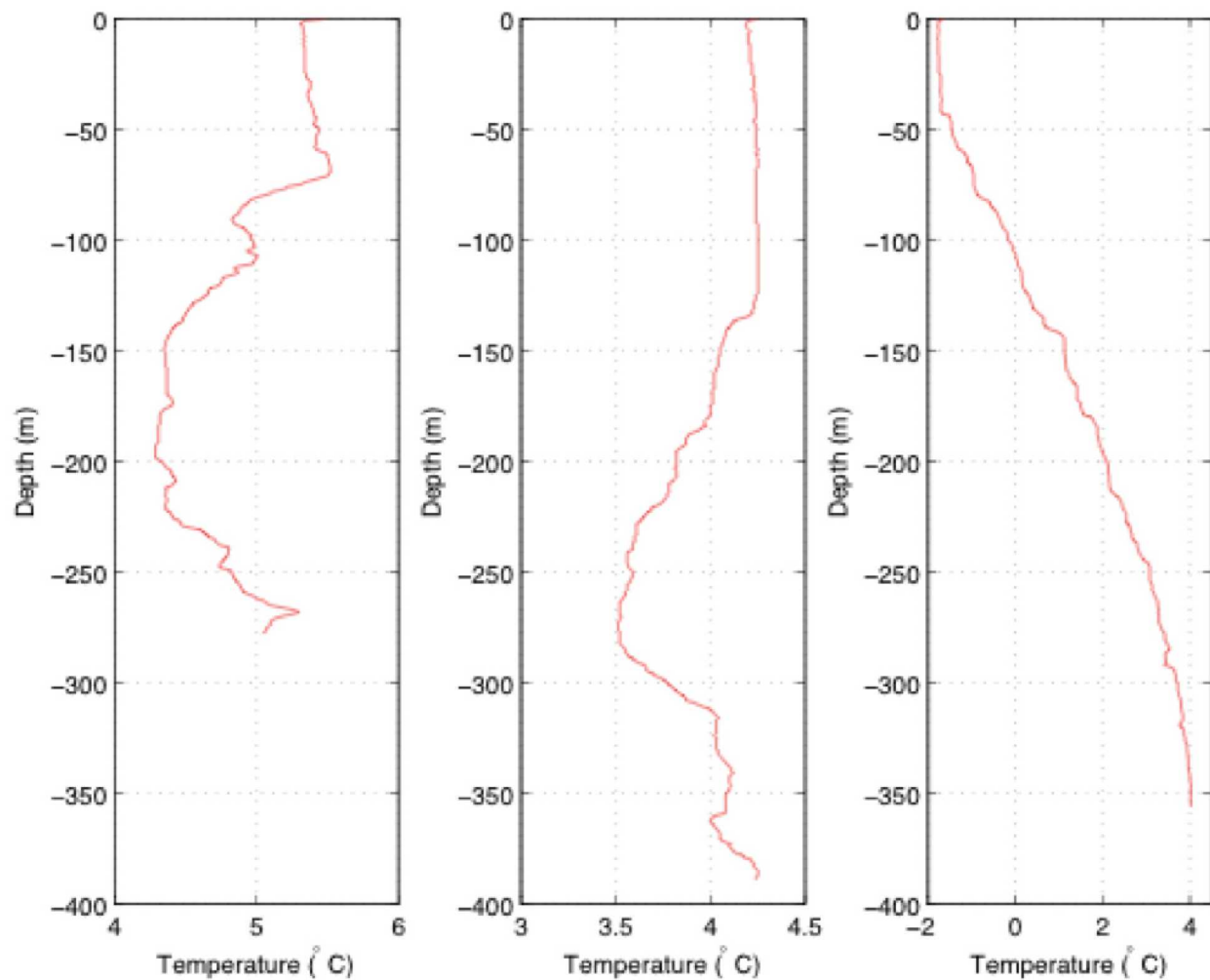


Figure A9: Data from three AXBTs (probe numbers 6, 11 and 17 in Table 3) from the fourth flight. Left panel to right panel, the measurement locations are from east to west show the changes in stratification. The right panel AXBT profile is closer to the continental shelf, with near temperatures below 0° C. This lower surface temperature is also seen in nearby AXCTD and AXCP data.

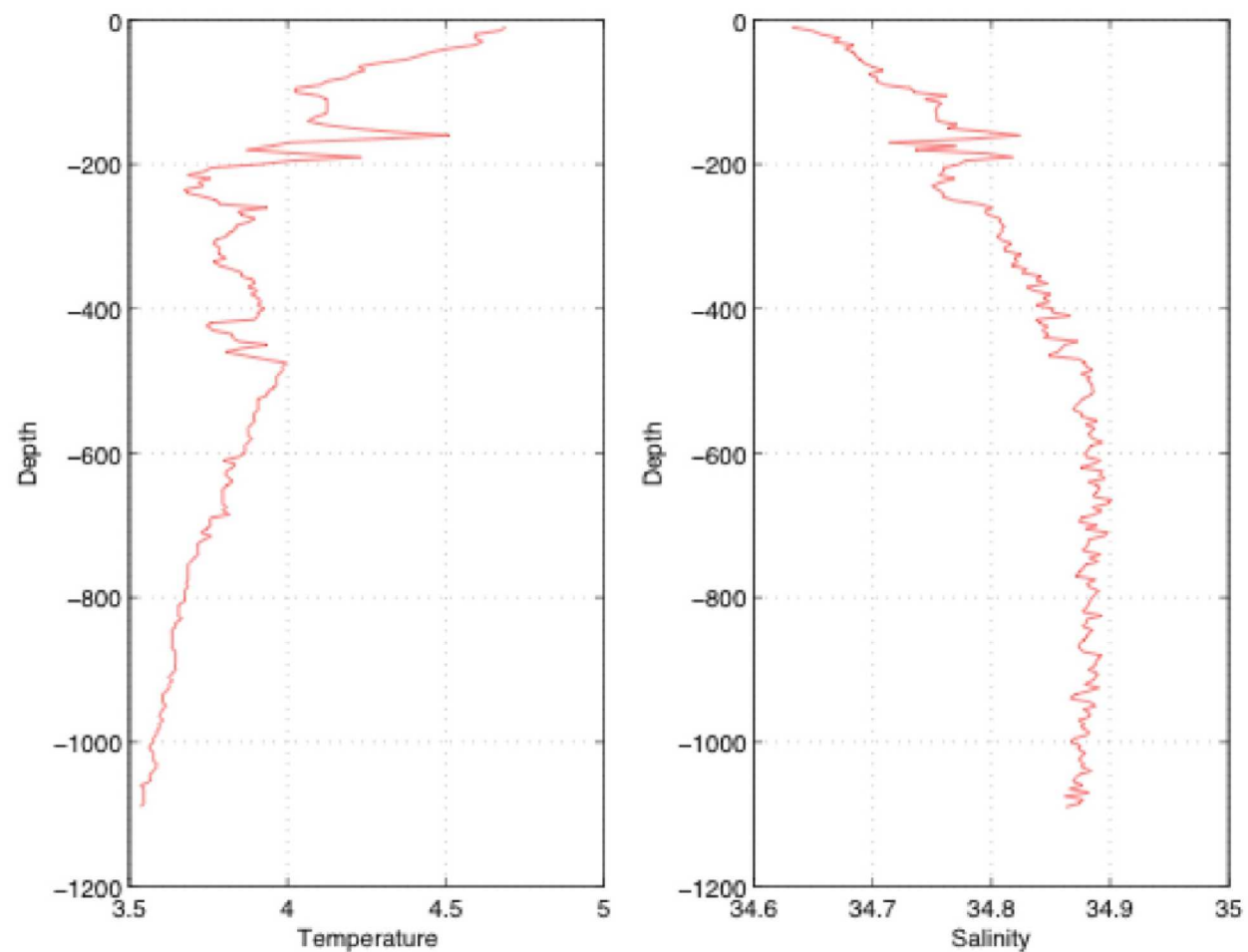


Figure A10: Data from probe number 7 in Table 3, an AXCTD. The oceanic mixed layer is not well defined.

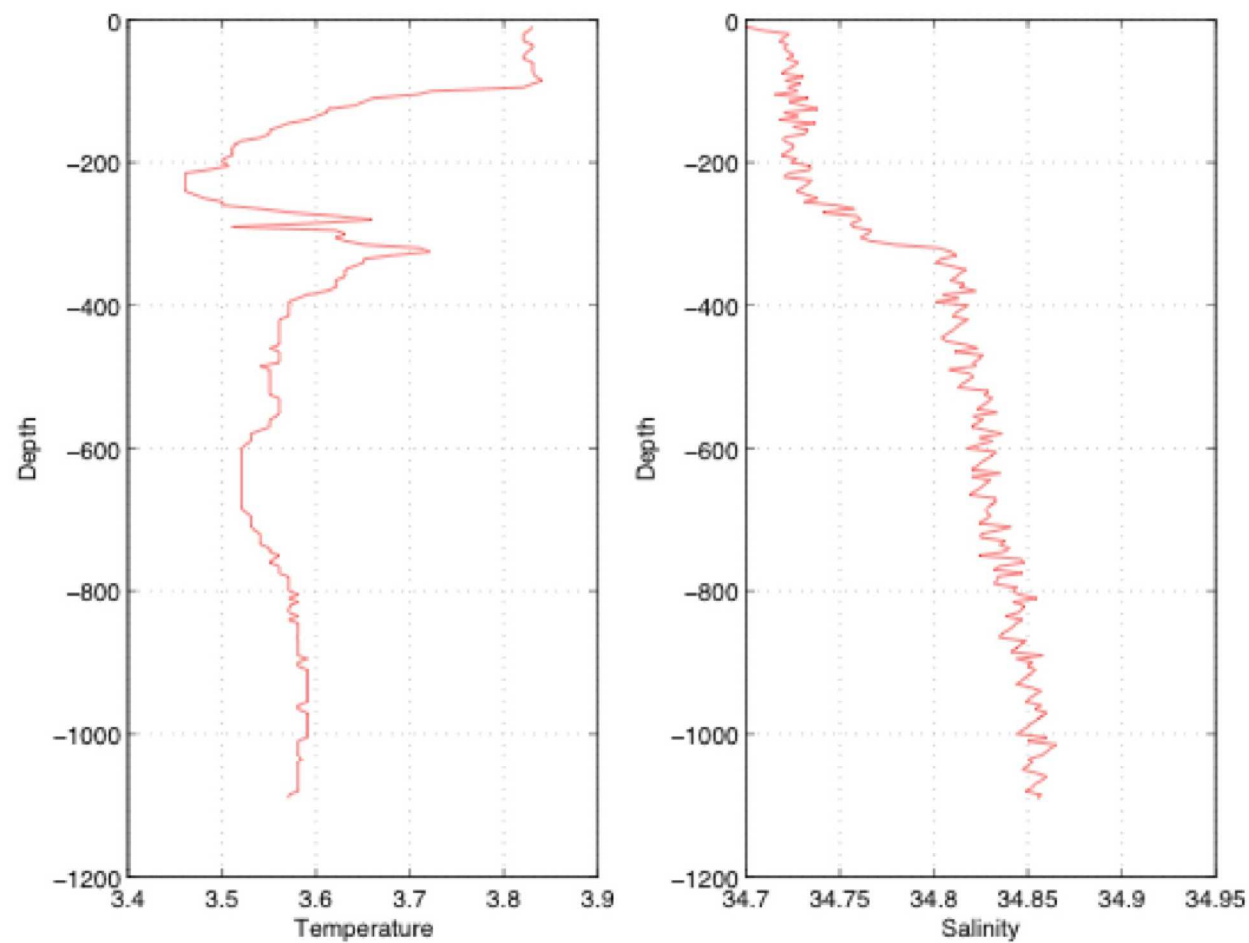


Figure A11: Data from probe number 8 in Table 3, an AXCTD. While the mixed layer defined by temperature is not very deep, the salinity appears uniform up to a depth of 220 m.

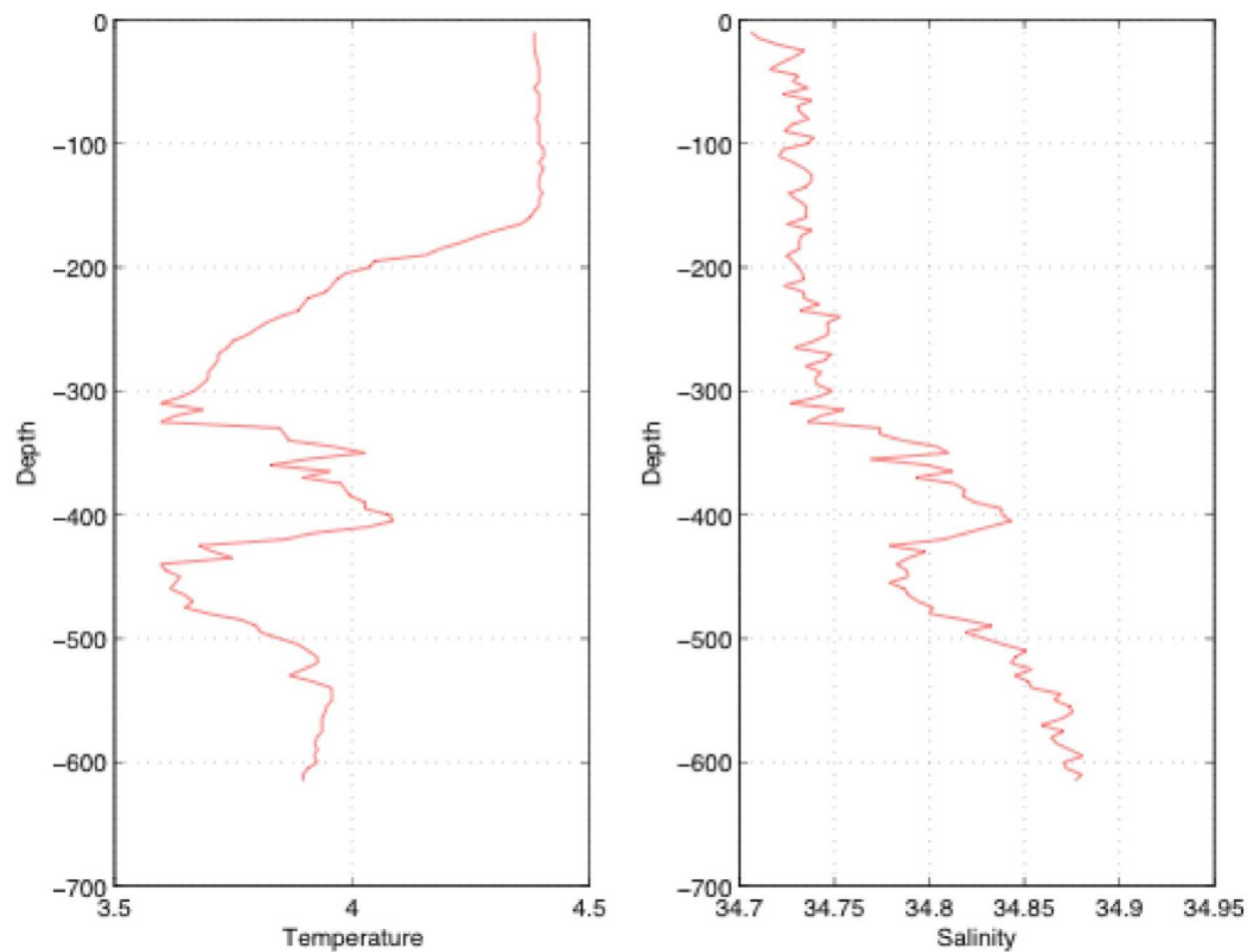


Figure A12: Data from probe number 10 in Table 2, an AXCTD. The wire connecting the sensor to the transmitter broke at 600 m, reducing the data.

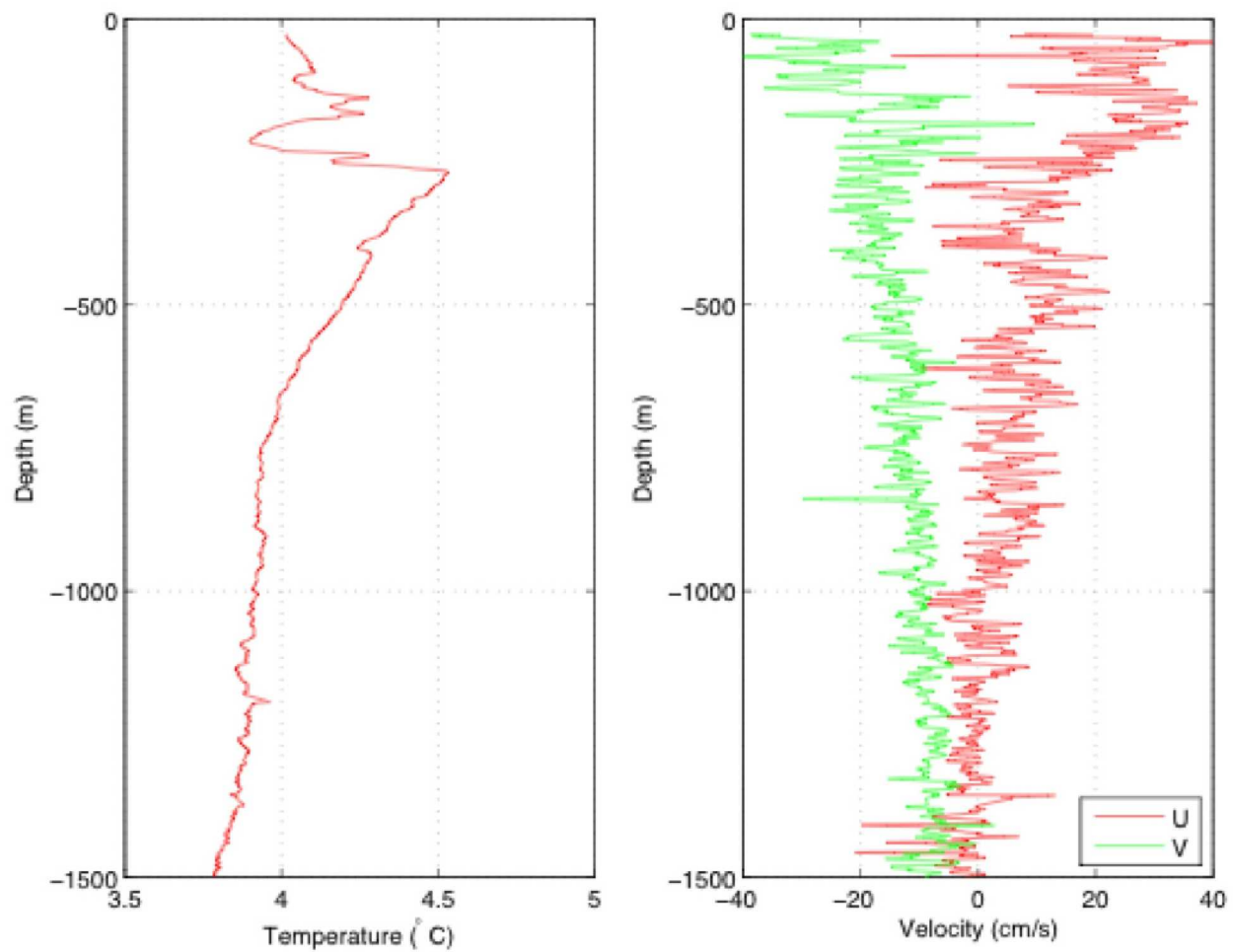


Figure A13: Data from probe number 12 in Table 3, an AXCP. While the probe operated up to its design depth of 1500 m, the current profile is contaminated by instrument noise and velocity errors are higher. The velocity measurement shows a southeastward flowing current of approximately 30 cm/s magnitude in the upper ocean.

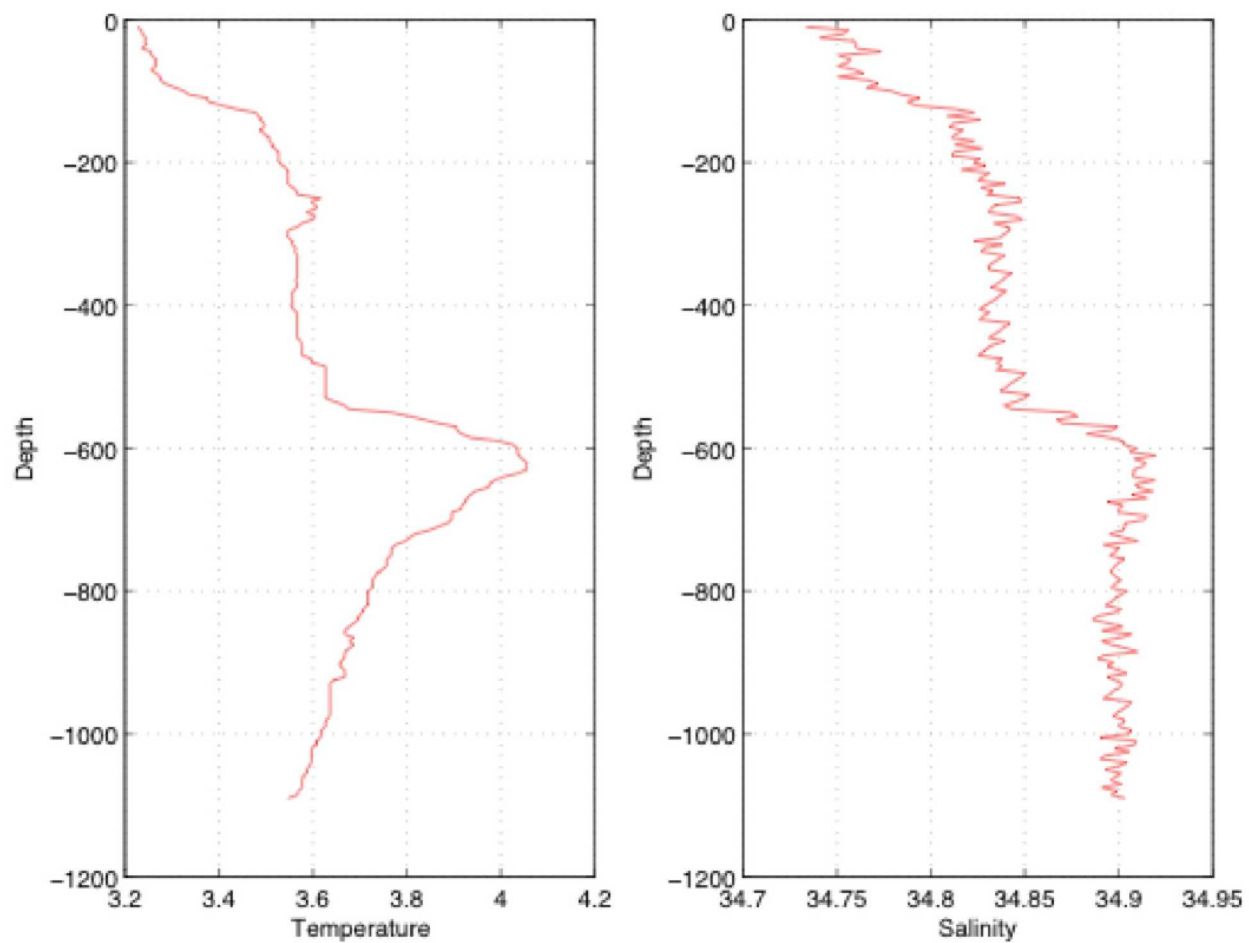


Figure A14: Data from probe number 14 in Table 3, an AXCTD. The probe operated up to its design depth of 1000 m. Salinity is compensating temperature in maintaining static stability.

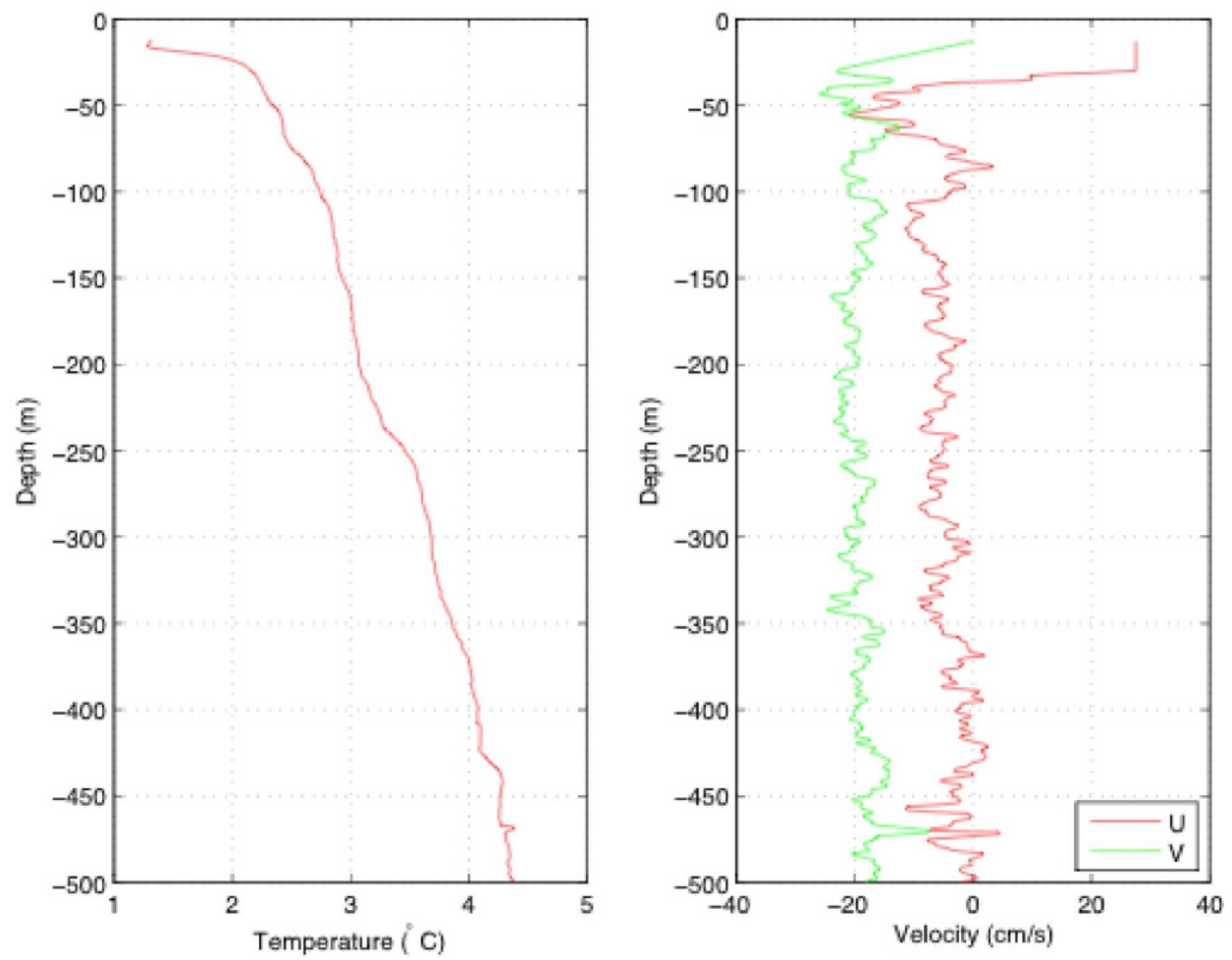


Figure A15: Data from probe number 15 in Table 3, an AXCP. The probe hit the ocean floor at approximately 500 m depth. The measured velocities indicate a southward flowing Labrador current that appears to extend all the way to continental shelf floor.

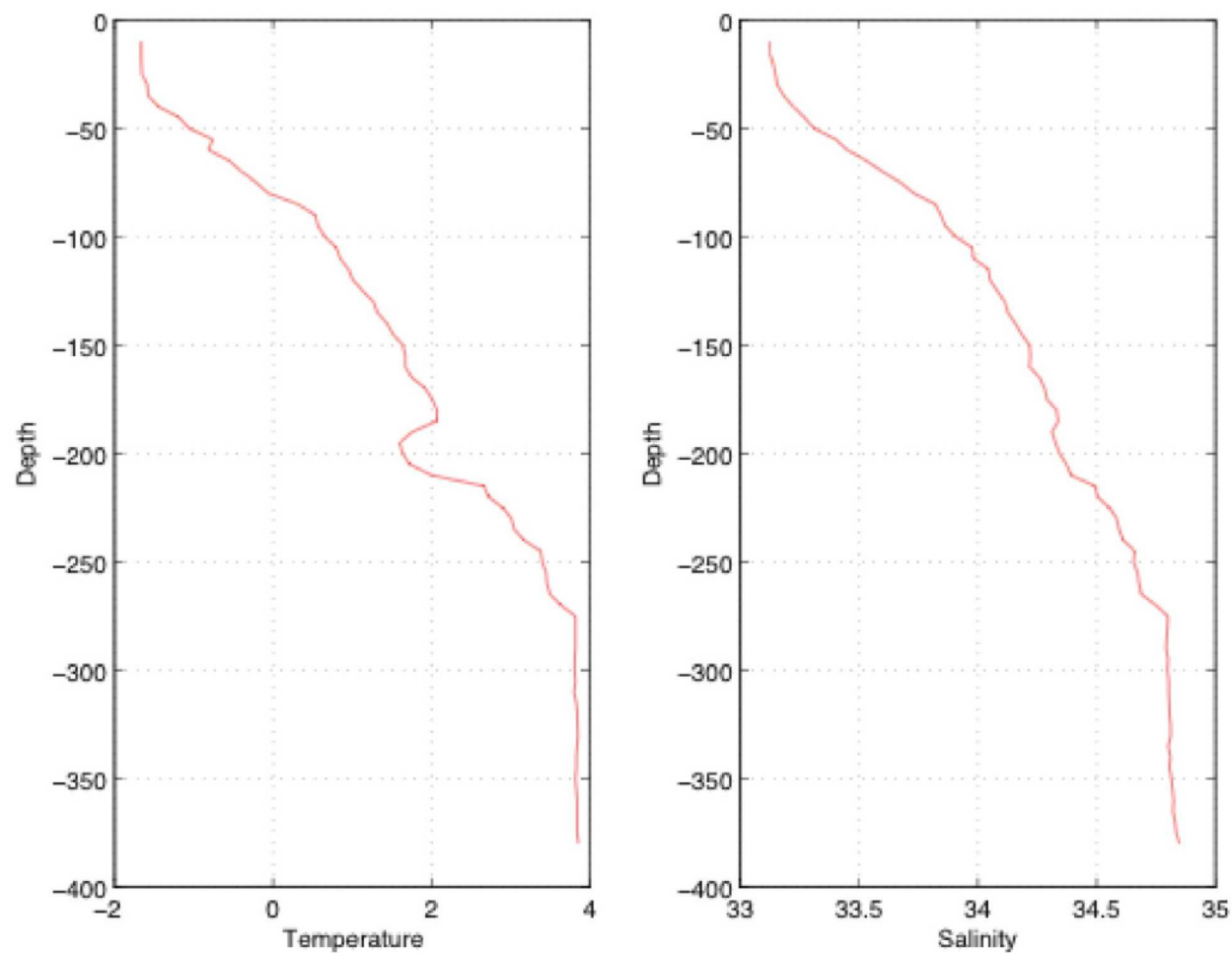


Figure A16: Data from probe number 16 in Table 3, an AXCTD. While the probe hit the ocean floor at 400 m, the measurements are consistent with the other two nearby expendable probes. There is clearly a well-mixed bottom layer extending from 270 m depth, perhaps due to the southward flowing Labrador Current.

Appendix B: Surface Data Provided to the Remote Sensing Component

Flight 1:

Number	Type and Channel	Lat	Lon	T (°C)
1	BT 14	50.52	-46.65	6.2
2	BT 12	50.10	-42.80	11.0

Table B1: Near-surface temperatures from flight 1.

Flight 2:

Number	Type and Channel	Lat	Lon	T (°C)	S (psu)
1	BT 16	55.0	-44.7	4	-
4	CTD 12	54.75	-44.90	3.9	34.6
6	CTD 14	54.59	-44.69	3.8	34.7
9	CP 14	54.90	-47.52	8	-
10	CTD 12	54.40	-47.60	3.3	34.4

Table B2: Near-surface temperatures and salinities from flight 2.

Flight 4:

Number	Type and Channel	Lat	Lon	T (°C)	S (PSU)
1	CTD 16	53.15	-44.97	5	33.0
5	CP 14	53.50	-47.25	6.2	-
6	BT 16	53.50	-47.36	5.3	-
7	CTD 12	53.50	-47.50	4.7	34.5
8	CTD 14	53.50	-48.50	3.8	34.6
10	CTD 12	53.50	-49.50	4.4	34.6
11	BT 14	53.50	-49.75	4.2	-
12	CP 16	53.50	-50.00	4.2	-
14	CTD 16	53.50	-51.10	3.5	34.7
15	CP 12	53.50	-51.60	1.3	-
16	CTD 14	53.50	-52.10	-1.7	33
17	BT 14	53.50	-53.50	-1.8	-

Table B3: Near-surface temperatures and salinities from flight 4.

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14. ABSTRACT During late February and early March 2009, a field experiment was performed using the NASA P3 over the Labrador Sea. During this experiment, expendable probes deployed from the aircraft acquired ocean mixed layer temperature, salinity and currents Probes were deployed during three flights of the four. Overall 7 AXBTs, 15 AXCTDs and 7 AXCPs were deployed with a success rate of nearly 70%. This is much lower than expected based on prior experience deploying from other aircraft. But given the difficulties associated with the Pneumatic Sonobuoy Launch Tube mechanism on the NASA P3, this rate likely can be improved significantly by using a different deployment mechanism. Additionally, two sets of collocated measurements of AXBTs, AXCPs and AXCTDs were made to verify the drop rates and measurements of the old AXBTs. While there were differences in the measurements, the old AXCTDs are performing well. The expendable data from the experiment are compared to the Argo profiles in the region to check for consistency. Comparisons indicate all the expendable probes acquired useful data and are well within the range of values measured by Argo floats.					
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