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Woods Hole Oceanographic Institution

CLIMODE Subsurface Mooring Report: November 2005 - November 2007

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John M. Lund, Xujing Jia Davis, Andrée L. Ramsey, Fiammetta Straneo,
Dan Torres, Jamie Palter, Stefan Gary, Dave Fratantoni

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Technical Report

Funding was provided by the Division of Ocean Sciences of the National Science Foundation
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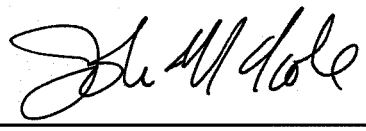

John M. Toole, Chair

Department of Physical Oceanography

CLIvar MOde Water Dynamic Experiment (CLIMODE) Subsurface Mooring Data Report

Abstract

Two years of temperature, salinity, current, and nutrient data were collected on four subsurface moorings as part of the 2 year field component of the CLIMODE experiment. The moorings were located in North Atlantic's subtropical gyre, south-east of the Gulf Stream. Two moorings, the most heavily instrumented, were close to the Gulf Stream, in the region where cold air outbreaks force large air-sea fluxes and where Eighteen Degree Water outcrops. Two other moorings were located farther south and carried more limited instrumentation. The moorings were initially deployed in November of 2005, turned around in November of 2006 and finally recovered in November of 2007. During the first year, the moorings close to the Gulf Stream suffered considerable blow down, and some of the instruments failed. During the second year, the blow down was greatly reduced and most instruments collected a full year worth of data.

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I. Introduction to CLIMODE

CLIMODE is a project to study the dynamics of 'Eighteen Degree Water' (**EDW**), the subtropical mode water of the North Atlantic (The Climode Group, 2009). **EDW** is but one example of a pervasive tendency for mode waters to form adjacent to strong baroclinic fronts in all the world's oceans. **EDW** is a canonical example of subtropical mode water, typically found in regions of significant air-sea exchange. **EDW** is created in the winter just south of the Gulf Stream, by convection in the presence of strong shear, with competing effects of vertical/lateral mixing and advection/stirring colluding to set its properties. This project stems from two years of **CLIVAR** planning (with advice and support of both the Atlantic and **US CLIVAR** committees) to develop an experiment to attack a key process that is poorly understood and poorly represented in ocean climate models - i.e. the treatment of convection, eddy, and mixing processes in setting properties of subtropical mode waters, the associated air-sea interaction, and the exchange of fluid between the mixed layer and the upper ocean. The scientific goals of **CLIMODE** are focused in 4 areas:

- Air Sea Interaction
- Eddies and Mixing
- Subduction and Circulation
- Modeling

The program is a mix of *in situ* and satellite-based observations combined with modeling which will, over the five year period beginning October 2004, lead to improved parameterization of air-sea fluxes in a high exchange region of the oceans, and improved ocean physics in climate models, capturing the eddy-mixed layer interactions in a region with both strong flows within the ocean and atmosphere and large wintertime exchange between the ocean and atmosphere in order to develop better climate models.

This data report describes and summarizes the data collected and the data processing for the four subsurface moorings deployed from November 2005 to November 2007. Basic data plots are included in the Appendix and are grouped by mooring number. Data processing procedures for each instrument will be discussed in Section IV. The ship's data, drifter data, float data, and data collected by the sea surface flux mooring will be addressed in other reports.

II. Mooring Deployment and Overview

Four subsurface moorings, A, B, C and D, were deployed for a 2 year period beginning in November 2005 and ending in November 2007 in the North Atlantic subtropical gyre, south-east of the Gulf Stream (Figure 1). This is a region where cold air outbreaks force large air-sea fluxes and Eighteen Degree Water (**EDW**) outcrops. The primary goal of the moorings was to observe the formation and subduction of Eighteen Degree Water.

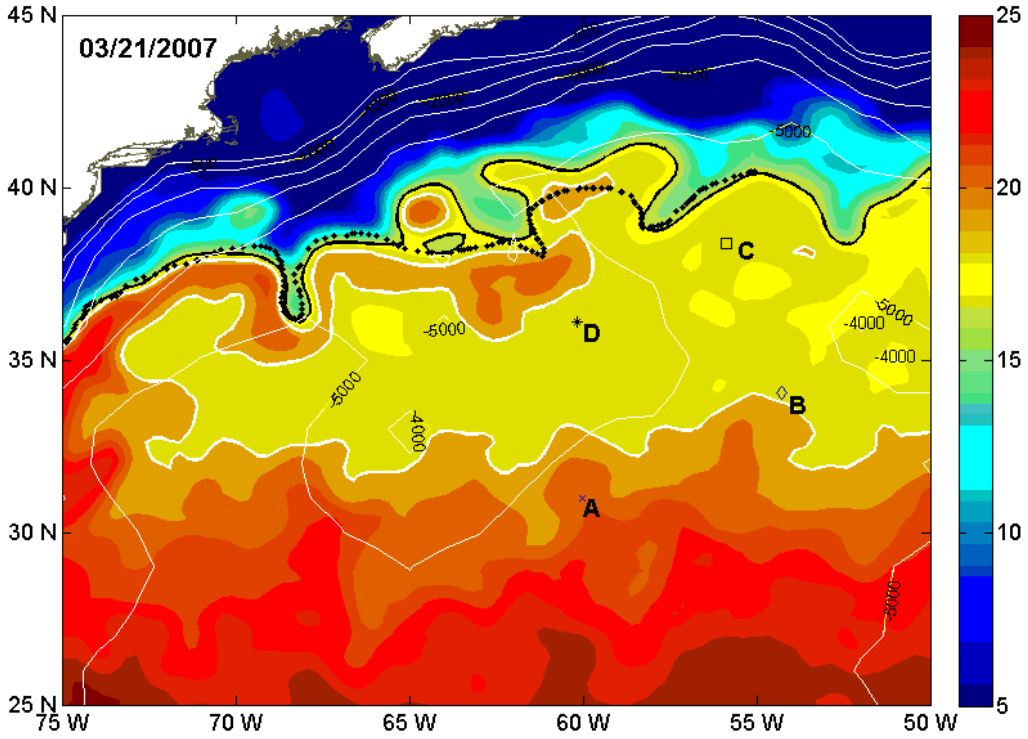

Figure 1: Map showing mooring locations labeled A,B,C,D on the contoured SST field for March 21st 2007 (from NOAA OISST GHRSST product, courtesy of K. Kelly). Overlaid is the mean Gulf Stream position from AVHRR data (see www.climode.org) and the bathymetric contours (white).

Moorings A and B were primarily sound source moorings, for the tracking of the CLIMODE floats, and their limited instrumentation included EG&G Sealink Vector Averaging Current Meters (VACMs) and SeaBird SBE-39 temperature loggers. These instruments were positioned between 325 meters to 1,000 meters for Mooring A, and between 325 meters to 850 meters for Mooring B. Moorings C and D were configured to collect data in the upper 600 meters of the water column using a 300 kHz RDI Acoustic Doppler Current Meter (ADCP), an ISUS Nitrate Sensor, two SeaBird SBE-37

MicroCAT recorders (one with pressure and without pressure), a McLane Moored Profiler (MMP), and an Aanderaa Recording Current Meter (RCM). In addition to the various water current and water property instruments, all moorings had University of Rhode Island sound sources that emitted a precisely timed pong tone once daily. The daily pongs were used to track the underwater bobbing floats that are part of the CLIMODE data set.

The total number of instruments deployed over the two year period included:

- 10 SeaBird SBE-39 temperature recorders
- 3 EG&G Sealink Vector Averaging Current Meters
- 4 SeaBird SBE-37 temperature and salinity recorders (two with pressure)
- 2 RDI Acoustic Doppler Current Profilers
- 2 McLane Moored Profilers
- 2 Aanderraa Recording Current Meters
- 2 ISUS nitrate sensors
- 4 URI sound sources

Detailed information regarding location, depth, dates, and instrumentation placement for each of the four moorings is listed in Table 1. Schematic drawings for each mooring can be found in Appendix G.

A standard notation is introduced for each instrument which identifies the instrument type, mooring, year, and the target depth at which the instrument was to be deployed. For example, ‘mcA_323’ indicates an SBE-37 or SBE-39 located on Mooring A at a target depth of 323 meters. For moorings C and D, the addition of the number ‘1’ or ‘2’ indicates the first or second year of the deployment. For example, ‘rcmD1_637’ indicates data from an Aanderaa RCM deployed on Mooring D during the year 2005-2006 at a target depth of 637 meters.

Table 1: Detailed description of mooring locations, dates, and instrumentation for Moorings A and B (2005 – 2007)

Mooring ID	Water Depth	Date Deployed	Date Recovered	Latitude	Longitude
Mooring A	5748 m	November 20, 2005	November 12, 2007	30° 59.15 N	60° 00.50 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
SBE-39	323 m	0078	mcA-323	30 min samples, full record (35691)	
VACM	380 m	589 (11662)	vacmA-380	no temp or pressure after 11/13/2006	
Sound Source	440 m	22	ssA-440		
SBE-39	441 m	262	mcA-441	30 min sample, full record (35692)	
SBE-39	542 m	261	mcA-542	30 min sample, full record (35692)	
SBE-39	642 m	341	mcA-642	30 min sample, full record (35692)	
SBE-39	843 m	336	mcA-843	30 minute sample, full record (35694)	
VACM	1054 m	179 (11667)	vacmA-1054	30 records/min, full data set	
Mooring B	5541 m	November 18, 2005	November 10, 2007	34° 02.47 N	54° 15.86 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
SBE-39	326 m	080	mcB-326	30 min samples, full record (35595)	
VACM	383 m	0115 (11672)	vacmB-383	30 records/min, full data set	
Sound Source	544 m	21	ssB-544		
SBE-39	545 m	339	mcB-545	30 min sample, full record (35600)	
SBE-39	645 m	333	mcB-645	30 min sample, full record (35602)	
SBE-39	746 m	334	mcB-746	30 min sample, full record (35606)	
SBE-39	846 m	337	mcB-846	30 min sample, full record (35693)	

Table 2: Detailed description of mooring locations, dates, and instrumentation for Moorings C1 and D1 (2005 – 2006)

Mooring ID	Water Depth	Date Deployed	Date Recovered	Latitude	Longitude
Mooring C1	5300 m	November 17, 2005	November 26, 2006	38° 22.22 N	55° 52.08 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
ADCP	60 m	2127	adcpC1-60	10 months of data; low battery power	
ISUS Nitrate Sensor	66 m	79	isusC1-66	Communication problem, erratic data	
SBE-37 w/press	67 m	2140	mcC1-67	5 min sample, odd data samples	
MMP	76-640 m	110	mmpC1-76-640 mpC1-76-640_ts	~6 hour interval, problems with data	
SBE-37	634 m	2034	mcC1-634	5 min sample	
Aanderraa RCM	636 m	156	rcmC1-636	30 min interval, full record	
Sound Source		24	ssC1-		
Mooring D1	4894 m	November 15, 2005	November 22, 2006	36° 05.33 N	60° 10.63 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
ADCP	62 m	2231	adcpD1-62	Full data record, 30 minute sampling	
ISUS Nitrate Sensor	68 m	78	isusD1-68	20 samples/hour, low nitrate concentrations	
SBE-37 w/press	70 m	2139	mcD1-70	5 min sample, odd sampling	
MMP	68-674 m	118	mmpD1-68-674	~6 hour interval, problems with data	
SBE-37	633 m	2045	mcD1-633	5 min samples, no salinity data	
Aanderaa RCM	637 m	159	rcmD1-637	30 min sample, full record	
Sound Source	647 m	23	ssD1-647		

Table 3: Detailed description of mooring locations, dates, and instrumentation for Moorings C2and D2 (2006 – 2007)

Mooring ID	Water Depth	Date Deployed	Date Recovered	Latitude	Longitude
Mooring C2	5298 m	November 26, 2006	November 9, 2007	38° 22.27 N	55° 51.48 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
ADCP	60 m	2222	adcpC2-60	Two data files with 3 ½ hour gap in between	
ISUS Nitrate Sensor	66 m		isusC2-66	Not deployed, poor data quality	
SBE-37 w/press	68 m	2140	mcC2-68	5 min sample	
MMP	68-628 m	112	mmpC2-68-628	~9 hour interval	
SBE-37	632 m	2031	mcC2-632	5 min interval, odd sampling	
Aanderraa RCM	636 m	148	rcmC2-636	1 hour interval	
Sound Source		24	ssC2-		
Mooring D2	4900 m	November 23, 2006	November 7, 2007	36° 05.94 N	60° 10.15 W
Instrument Type	*Target Depth*	*Serial Number*	*Nomenclature*	*Comments*	
ADCP	56 m	2225	adcpD2-56	Full data record, 30 minute sampling	
ISUS Nitrate Sensor	62 m	78	isusD2-62	20 samples per hour for 344 days	
SBE-37 w/press	64 m	2139	mcD2-64	5 min sample, odd sampling	
MMP	66-674 m	113	mmpD2-66-674	~9 hour sampling	
SBE-37	628 m	1645	mcD2-628	5 min samples, full record	
Aanderaa RCM	632 m	149	rcmD2-632	1 hour interval	
Sound Source	641 m	23	ssD2-641		

III. Mooring configuration and data recovery

All mooring operations were conducted from the *R/V Oceanus*. Moorings A and B were deployed in November 2005 and recovered in November 2007. Moorings C1 and D1 were deployed in November 2005 and recovered in November 2006. The data were downloaded from each instrument. The instruments were then checked for any failures or disturbances. The Sea-Bird SBE-37 MicroCATS with pressure and ISUS nitrate samplers were equipped with new batteries, reprogramed, and were redeployed on Moorings C2 and D2. The URI sound sources were shut down while on deck but were neither serviced nor replaced. The ADCPs, MMPs, RCMs, and SBE-37 w/out pressure were replaced with new instruments for the 2006-2007 deployment. The new moorings were deployed within 24 hours at approximately the same locations and were named C2 and D2. They were recovered one year later, in November 2007.

A. Mooring A

Mooring A was deployed November 20, 2005 in 5748 meters of water. The instruments included an array of five Sea-Bird SBE-39 temperature recorders, two Vector Averaging Current Meters (VACM), and one University of Rhode Island (URI) sound source.

SeaBird SBE-39 All five of the Sea-Bird SBE-39 temperature recorders instruments were calibrated by the manufacturer prior to deployment and were configured to sample every 30 minutes. Clocks were checked upon recovery and found to have drifted less than one minute (see Table 2). The data return for the SBE-39s was 100% data.

Table 4: SBE-39 temperature recorder time drift for Mooring A

	Mooring A	
Instrument	*Serial Number*	*Time drift*
SBE39	0078	-46 sec
SBE39	262	+24 sec
SBE39	261	+7 sec
SBE39	341	-21 sec
SBE39	336	-53 sec

EG&G Sealink VACM The VACM calibrations were checked a month prior to deployment. If the calibrations were older than one year, the VACMs were recalibrated. Temperature and compass headings were also checked prior to deployment. VACM S/N 11662, located at 380 meters, returned with only a partial data record. Temperature and pressure were not recorded after November 13, 2006. VACM S/N

11667, located at 1054 meters, returned with a full two-year record of temperature, pressure, and current.

B. Mooring B

Mooring B was deployed November 18, 2005 in 5541 meters of water. The mooring was recovered one year later on November 26, 2006. The instruments included an array of five Sea-Bird SBE-39 temperature recorders, one Vector Averaging Current Meters (VACM), and one University of Rhode Island (URI) sound source.

SeaBird SBE-39 As with the SBE-39s from Mooring A, all five temperature recorders instruments were calibrated by the manufacturer prior to deployment and were configured to sample every 30 minutes. The clocks were checked upon recovery and found to have only a slight time drift, with -69 seconds being the largest (see Table 3). The five SBE-39 temperature loggers from Mooring B had a data return of 100%.

Table 5: SBE-39 temperature recorder time drift for Mooring B

	Mooring B	
Instrument	*Serial Number*	*Time drift*
SBE39	0080	-36 sec
SBE39	339	-1 sec
SBE39	333	-69 sec
SBE39	334	-27 sec
SBE39	337	-7 sec

EG&G Sealink VACM The VACM calibration was checked one month prior to deployment. If the calibration was older than one year, the VACM was recalibrated. Temperature and compass headings were also checked prior to deployment. The VACM S/N 11672, located at 383 meters, returned with a full two-year record of temperature, pressure, and current.

C. Mooring C1

Mooring C1 was deployed on November 17, 2005 in 5300 meters of water. It was equipped with one ADCP, one ISUS Nitrate Sensor, one SBE-37 with pressure, one SBE-37 without pressure, one MMP, one RCM, and one URI sound source.

ADCP The ADCP (S/N 2127) on C1 was positioned at 60 meters. The temporal sampling rate was 30 minutes and the spatial sampling was 22 bins at five meters per bin. Upon recovery, it was determined that the battery of the ADCP

died after about ten months of being in the water. The last sample was recorded on September 6, 2006. The battery voltage was 26.43 volts.

ISUS Nitrate Sensor The ISUS Nitrate Sensor (S/N 079) on C1 was located at a depth of 66 meters, in between the ADCP and the SBE-37 w/pressure. Upon recovery, we were unable to communicate with isusC1_66, even though there was no obvious sign of leakage or flooding and the casing was intact. Various computers and cables were tried, but finally the instrument had to be disassembled and the flash drive removed. A disconnected electronic component (probably a capacitor) was discovered during the disassembly but even after it was re-soldered to the board, the ISUS still would not communicate.

The flash card contained approximately 70 days of data and showed that the last day of data collection was February 4, 2006. The last error message was:

01/01/2006 00:00:27: ERROR: Suspension failed due to bad wakeup time. Skip to next.

The limited data do appear to have recorded some of the high current events inferred from the SBE-37 pressure data located one meter below the ISUS. During these events, the mooring was blown down as deep as 600 meters from its target depth. Both mooring C1 and D1 nitrate concentration rise sharply when the sensors descended into the nutricline during times of strong currents. However, the calculated nitrate concentrations for this instrument were much lower (<-15) than those for pure water during laboratory testing and may signal early problems with the accuracy of the sensor.

ISUS 079 was not redeployed on Mooring C2 due to its communication failure. The data from year one was too erratic to be useful. It was returned to Satlantic in Halifax for repairs.

SeaBird SBE-37 w/pressure The SBE-37 S/N 2140 was located 67 meters and positioned just below the ISUS Nutrient Sensor and was equipped to measure temperature (T), salinity (S), and pressure (P). It recorded data from November 11, 2005 to November 26, 2006, with a sampling interval of 5 minutes.

Data from the SBE-37 instruments equipped with a pressure gauge from both Moorings C and D display an erratic sampling scheme. The instruments were set to sample every 300 seconds. The data returned show that the instrument appears to have burst sampled, sampling every 300 seconds for approximately 21 hours and then turning off for an equivalent time interval. Unfortunately, the data sets were cleared from the instruments

before the data gaps were noticed. The manufacturer checked the instruments and was unable to reproduce the failure.

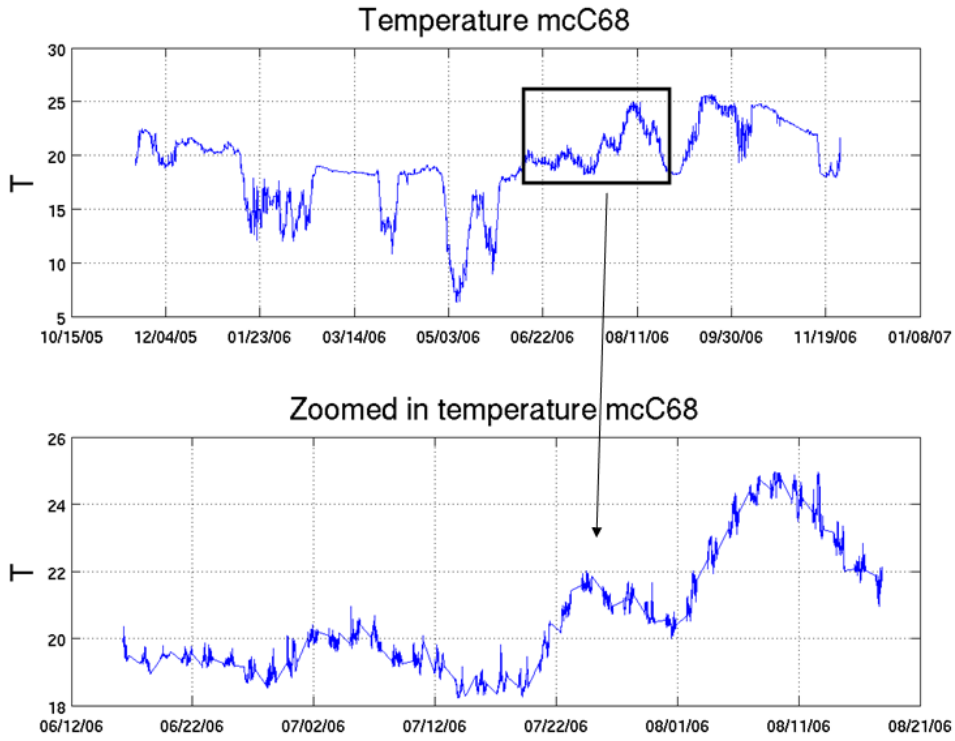

Figure 2: Mooring C1 SBE-37 temperature during 2005-2006 observation record (top, ºC) and the zoomed in temperature showing the odd sampling behavior. As measured by Seabird SBE37 SN 2140, nominally 68 meters deep.

The odd burst sampling was later traced to a corrupt version of Seasoft v1.5. A test was done in the lab when the instruments returned from recalibration. The failure was reproducible on the factory inspected and recalibrated instruments (with new firmware) as well as on another set of MicroCATS with the same firmware as was deployed during the CLIMODE project. It was found that the data sets uploaded on the same computer used at sea caused the same apparent burst sampling. All the data were there, but failed to upload. Uploading the test instruments in the lab with the same version of Seasoft on a different computer did not produce gaps in the data record. Once a newer version the Seasoft software was installed on the original computer it no longer introduced gaps into the record.

MMP The MMP located on Mooring C1 (S/N 110) profiled between 76 meters to 640 meters. The first profile for the MMP was recorded on November 17, 2005. It did not record its second profile until November 26, 2005. It

continued to profile once every six hours until January 14, 2006 when the motor shaft broke. After the shaft broke there is a single data point at variable depths. The MMP recorded the single data point once every six hours until May 1, 2006, at which time the MMP recorded data at on odd time interval, oscillating between 10 hours and 38 hours. The time series of vertical velocity should not be trusted. The MMP measured temperature (T), salinity (S), Pressure (P), as well as zonal, meridional, and vertical velocities (U, V, and W). Calculated variables of Stability (N), Potential temperature (θ) and Potential density (σ_t) are also part of the processed data.

SeaBird SBE-37 The SBE-37 (S/N 2034) located at 630 meters measured temperature and conductivity, but was not equipped with a pressure gauge. The SBE-37 was programmed for a five minute sample interval. A full data record was downloaded from the instrument. Fortunately, this instrument did not suffer the same data loss during upload as the upper two SBE-37s with pressure. This instrument communicates using RS-232 protocol and did not get corrupted during the upload. erratic

Aanderra-RCM The RCM (S/N 156) located on C1 was positioned at 636 meters, just below the SBE-37 discussed above. The RCM measured zonal and meridional velocities (u, v). Time coverage is from November 7, 2005 to December 7, 2006. The sampling interval was every 30 minutes. A full data record was retrieved from the instrument.

D. Mooring D1

Mooring D1 was deployed on November 15, 2005 in 4894 meters of water. The mooring was recovered one year later on November 22, 2006. It was equipped with one ADCP, one ISUS Nitrate Sensor, one SBE-37 with pressure, one SBE-37 without pressure, one MMP, one RCM, and one URI sound source.

ADCP The ADCP (S/N 2231) on D1 was positioned at 62 meters. The temporal sampling rate was 30 minutes and the spatial sampling was 22 bins at five meters per bin. The ADCP collected a full year of data. Pitch and roll angles during the deployment remained less than +/- 3 degrees. The peaks are well correlated with blow down events indicated by the pressure signal in the upper SBE37 data. The heading data is reassuring and indicates that the mooring ball is not spinning or oscillating violently when the mooring is blown over.

ISUS Nitrate Sensor The ISUS Nitrate Sensor (S/N 078) was recovered from Mooring D1 at roughly 10:30AM, 372 days after its deployment. The battery was disconnected, the ISUS was removed from its tension bar, and its outside casing was cleaned. In the main laboratory, the instrument was connected to a 12-V power source

and to an HP laptop via serial port. Downloading was initiated using a hyperterminal, which allows access to the internal flash drive of the ISUS. After 100 days of data were batch downloaded using the DAD (Download All Data) command, a glitch in the ISUS software aborted downloading. The remaining data files were downloaded manually in batches of three. About 100 files were accidentally left on the ISUS internal flash drive. This was not a major concern since there was ample disk space for the 2007 sampling year, despite this abandoned data.

During the manual download, other tasks were completed to ready the ISUS for deployment the next day: the probe tip was cleaned with isopropyl alcohol on a cotton swab, the pressure purge valve was placed on the new battery, the dummy-plugs were greased, and the copper bio-fouling guard was cleaned and its O-ring was greased. It is interesting to note that the swab that cleaned the probe tip did seem to show a residue of algae, although the plastic components inside the copper biofouling had a thin film of algae. The exterior of the copper biofouling guard was not noticeably damaged or corroded.

Finally, the ISUS was switched back to scheduled mode and left for the mooring crew to connect to the new battery and tension bar for deployment at first light. Jeff Lord connected the new battery and tension bar and the ISUS entered the water at 13:04 UTC. The anchor on Mooring D2 dropped at 21:24:15 UTC. Given the water depth at the new anchor position (4900m, after fallback calculations), ISUS should reside between 70m and 80m (neglecting the impact of currents) for this second year of deployment.

SeaBird SBE-37 w/ pressure The SBE-37 with pressure (S/N 2139) was located at 70 meters, just below the ISUS Nitrate Sensor. The SBE-37 was programmed for a five minute sampling interval and measured temperature (T), salinity (S), and pressure (P). The first records were on November 10, 2005 and the last records were on November 27, 2006. As discussed above for Mooring C1, the SBE-37 data upload process only returned approximately half of the data for the 2005-2006 deployment.

MMP The profiling range for the MMP (S/N 118) on Mooring D1 was 68 meters to 674 meters. Profiles began on November 16, 2005 and were made every six hours until March 18, 2006. The MMP was recovered with a dead battery. Communication was not possible through the COMM port. Only 4 days of velocity data were logged before the Acoustic Current Meter, ACM stopped working on November 30, 2005 at 18:00:00. The velocity data should not be trusted. Time was recorded properly until December 1, 2005 at 00:00. From that point forward, time did not change for the remainder of the data record. Pressure data show the mooring was blown

over a number of times during the passage of rings or meanders in the Gulf Stream. MMP 118 was later found to also have a broken motor shaft.

SeaBird SBE-37 The SBE-37 (S/N 2045) located at 634 meters did not have a pressure gauge, and only measured temperature (T), and salinity (S). The time coverage is from November 10, 2005 to November 24, 2006, with a sampling interval of 5 minutes. Although the instrument was set up to measure salinity, the conductivity cell was damaged resulting in a reading of zero for all salinity data. Temperatures were approximately 16° Celsius, except when the mooring was blown over and the sensor was moved into deeper, colder water. The temperature readings during these events would drop below 10° Celsius.

Aanderra RCM The RCM (S/N 159) located on D1 was positioned at 638 meters, just below the SBE-37. The RCM measured zonal and meridional velocities (u, v) using a 30 minutes sampling interval. Data was collected from November 7, 2005 to December 7, 2006. A full data record was retrieved from the instrument.

E. Mooring C2

Mooring C2 was deployed on November 26, 2006 in 5298 meters of water. The mooring was recovered one year later on November 9, 2007. It was equipped with one ADCP, one SBE-37 with pressure, one SBE-37 without pressure, one MMP, one RCM, and one URI sound source.

ADCP The ADCP used for C2 (S/N 2222) was a fresh ADCP, and was not one that was just recovered and then redeployed. It was positioned at 60 meters, and had a 30 minute sampling interval. The ADCP was setup to measure 22 bins, each bin being five meters. The ADCP data was collected in two files. The first file started on November 26, 2006 and ended on July 4, 2007 at 10:00:00. The second file started on July 4, 2007 13:33:34 and collected its last measurement on September 23, 2007. There is a three and a half hour time delay in between the last measurement of the first file and the first measurement in the second file. The reason for this stopping and starting of data collection is not clear at this point, although it may be related to the battery performance. The two files were combined for processing and contain measurements for zonal and meridional velocities, temperature, and pressure.

ISUS Nitrate Sensor The ISUS (S/N 079) was not deployed on Mooring C2 due to instrument failure and poor data quality observed during the first deployment on Mooring C1.

SeaBird SBE-37 w/ pressure The SBE-37 (S/N 2140) located at 68 meters, measured temperature (T), salinity (S), and pressure (P). This particular instrument had been used on mooring C1. When it was recovered from C1, the data was uploaded onto a computer. The instrument was then cleaned up, the battery was replaced, and new poison cells were installed. The time was set and the instrument was redeployed on C2. The first measurement was collected on November 27, 2006 and the last measurement was collected on November 9, 2007, with a sampling interval of five minutes. Data was measured and recorded during the entire year; however, only half of the data were recovered due to a problem with the uploading software. There is a detailed discussion of this issue in the *Mooring C1* section under the *SBE-37 with pressure* heading.

MMP The profiling range for the MMP on Mooring C2 (S/N 112) was 76 meters to 640 meters. Profiles began on November 27, 2006 and ended on November 9, 2007, with a sampling interval of approximately nine hours. The MMP measured temperature (T), salinity (S), and pressure (P). It also calculated potential temperature and potential density to include in the output data record.

SeaBird SBE-37 The SBE-37 (S/N 2031) located at 632 meters measured temperature (T) and salinity (S). Data were collected from November 1, 2006 to November 10, 2007, with a sampling rate of five minutes.

Aanderra RCM The RCM (S/N 148) located on C2 was positioned at 636 meters, just below the SBE-37. The RCM measured zonal and meridional velocities (u, v) using a 60 minute sampling interval. Data was collected from November 23, 2006 to November 9, 2007. A full data record was retrieved from the instrument.

F. Mooring D2

Mooring D2 was deployed on November 23, 2006 in 4900 meters of water. The mooring was recovered a year later on November 7, 2007. It was equipped with one ADCP, one ISUS Nitrate Sensor, one SBE-37 with pressure, one SBE-37 without pressure, one MMP, one RCM, and one URI sound source.

ADCP The ADCP used for D2 (S/N 2225) was positioned at 65 meters, just above the ISUS nitrate sensor. The ADCP collected data from November 22, 2006 to November 8, 2007, sampling at 30 minute intervals. The ADCP was setup to measure 22 bins, each bin being five meters. Measured variables include zonal and meridional velocities, temperature and pressure.

ISUS Nitrate Sensor The ISUS 078 Nitrate Sensor was deployed at a depth of 62 meters on Mooring D2. It was positioned below the ADCP and above the SBE-37 w/pressure. It was programmed to sample at a rate of 20 samples per hour and collected data for 344 days.

SeaBird SBE-37 w/ pressure The SBE-37 (S/N 2139) located at 70 meters, measured temperature (T), salinity (S), and pressure (P). The data record begins on November 24, 2006 and ends on November 8, 2007. The sampling rate was programmed for five minutes intervals. This instrument was subject to the same SeaSoft firmware issue that plagued the other shallow water SBE-37s located on C1, C2, and D1. The instrument collected all the data, but during the download process, only part of the data was extracted and saved onto the computer. For a detailed discussion of this issue, see the *Mooring C1* section under the *SBE-37 with pressure* heading.

MMP The profiling range for the MMP on Mooring D2 (S/N 113) was 68 meters to 674 meters. Profiles began on November 24, 2006 and ended on November 7, 2007, with a sampling interval of approximately nine hours. The MMP measured temperature (T), salinity (S), and pressure (P). It also calculated potential temperature and potential density to include in the output data record.

SeaBird SBE-37 The SBE-37 (S/N 1645) located at 628 meters measured temperature (T) and salinity (S). The sampling interval for the SBE-37 was five minute intervals. Samples were collected during the entire deployment, beginning on November 23, 2006 and ending on November 8, 2007.

Aanderra RCM The RCM (S/N 149) located on D2 was positioned at 632 meters, just below the SBE-37. The RCM measured zonal and meridional velocities (u, v) using a 60 minute sampling interval. Data was collected from November 23, 2006 to November 7, 2007. A full data record was retrieved from the instrument.

VI. Data Processing

Data processing is described by instrument. If special processing was required then it is discussed individually in the instrument section

A. SeaBird SBE-37 and SBE-39

The raw SeaBird data, which is in ASCII format, was read into MATLAB using a function similar to the function *mc_read_DT.m*. This function loads the SBE-37 and SBE-39 data and calculates the data fields and saves them in a structure. The output units for conductivity are in S/m, and these are converted to mS/m. The calibration offsets are

then applied to the raw temperature and conductivity. Salinity is then computed using the measured pressure or the pressure from the log book. If no pressure was measured, depth is also calculated using the value for the log book. Data that was collected pre- and post-deployment is edited from the file. This can be accomplished by using date and time values or using the pressure record, when available. The last step is to compute the speed of sound values using either the fixed depth from the log book, computing it from salinity, temperature, and pressure, or extracting it from the raw ASCII file. The data are save in a MATLAB structure array and are named using the convention described at the end of the section *II. Mooring and Deployment Overview*.

B. EG&G Sealink VACM

VACM tapes were uploaded by Brian Hogue and raw data were saved on an ftp site. A series of programs including shell scripts, awk, and MATLAB were used to convert the raw *.hex data. During the processing, pressure calibration, time correction, and conversion from counts to engineering data are output to a *.mat file. Pressure spikes that occurred prior to and during the deployment are edited and replaced with flag values.

C. RDI ADCP

The binary ADCP data was first read into MATLAB, where the data could be examined and basic editing took place. A depth array was calculated using the corrected transducer depth. The array was calculated for all bins collected for convenience. Each depth corresponds to the center of each bin. Depth refers to positive meters below the surface. Since each ADCP was set up to collect data beyond the surface, negative values are out of the water and used as a criteria to set the velocity data out of the water equal to 'NaNs'. Also, due to side lobe interference, additional data proportional to the cosine of the beam angle was also edited by setting it to NaN, using the following formula:

$$cos20 = (BS/2) + (tr\_depth–(tr\_depth.*cos(BA))$$

Where: BS = bin size
BA = beam angle

Approximately 8% of the water column velocity data was lost due to side lobe interference.

If the ADCP clock drifted during the deployment, a correction was applied. The ADCP pressure values were converted from decaPascals to decibars. Data that was collected before and after the ADCP was in the water was eliminated. The SBE-37 data, located at approximately the same depth, was interpolated onto the ADCP time grid and added to

the final *.mat file and save using the naming convention described at the end of the section *II. Mooring and Deployment Overview*.

D. ISUS Nutrient Sampler

Mooring D1 ISUS 078 *Jamie Palter, Duke University*

The Mooring D ISUS (serial number 78) collected binary, full-frame data for 20 seconds (approximately 20 data points) each hour from November 14, 2005 through November 21, 2006. Before deployment, standards of known nitrate concentration were used to create a calibration curve of ISUS-calculated nitrate versus known concentration, (Figure 3).

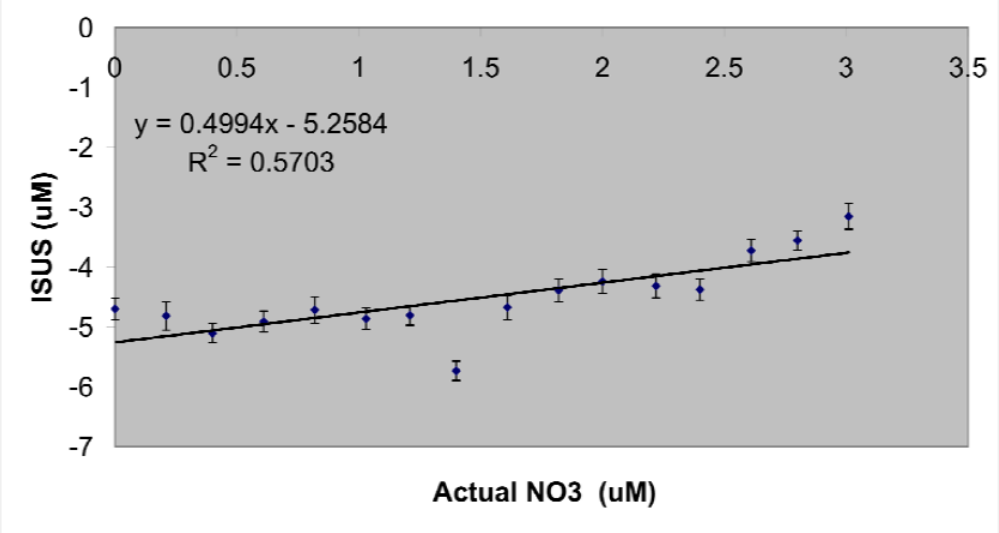

Figure 3: Results for laboratory calibration of ISUS 078. ISUS nitrate versus actual nitrate concentration (error bars are +- 1SD for each sampling period)

A best fit line was calculated from the laboratory tests and used to convert the nitrate calculated from the original calibration coefficients to an estimate of actual nitrate for the data collected between November 2005 and November 2006. These are the data that are used for all analyses to date. The results are plotted as a time series in Figure 4 (top panel).

During the one year deployment, the corrected nitrate values declined steadily, clearly suggesting instrument drift. After averaging each 20 second data collection period, a linear trend was subtracted from the estimated nitrate concentrations for all data collected above 100 meters. This linear trend was subtracted from all data, regardless of the depth at which it was collected (Figure 4 second panel). Unfortunately, the resulting time series of residuals yields negative nitrate concentrations at various times.

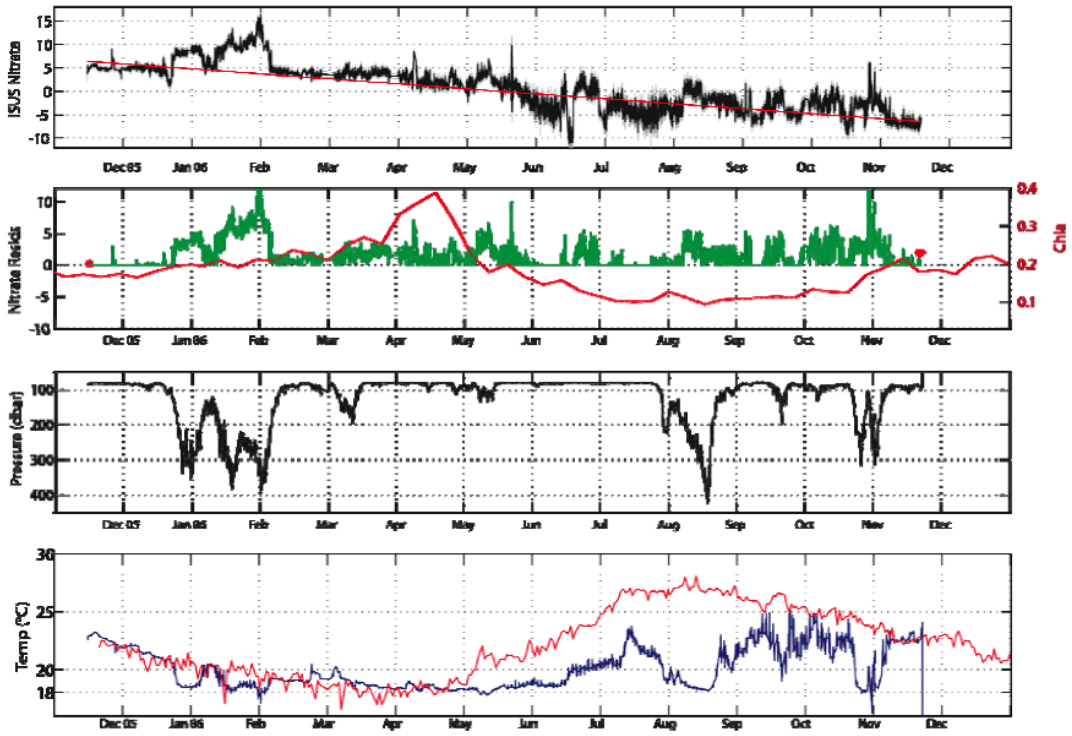

Figure 4: Data from the moored instrumentation during year 1 at mooring D1. Top panel - ISUS 078 nitrate corrected using the calibration samples (green) and a linear regression line (red) constructed from all data collected above 100 dbar and averaged for each 20 second sampling session. Second panel - The nitrate residuals (green) calculated as the difference between the corrected ISUS nitrate data and the linear regression (with all negative nitrate concentrations as zero), and 8-day SeaWifs chlorophyll (red) averaged over a 10 x20 box centered at Mooring D. Third panel - The pressure recorded by the SeaBird MicroCAT (S/N 2139) located two meters below the ISUS on the mooring line. Bottom panel - Temperature from the same MicroCAT (blue) and SST (red) interpolated from satellite data to the mooring D1 location. Tick marks appear on approximately the first day of each month.

The hydrographic profiles collected during deployment and recovery allow comparison of the corrected ISUS nitrate to the actual nitrate at the beginning and end of the time series (Figure 4 second panel – red stars). In addition, a comparison of bottle nitrate to ISUS nitrate over the top several hundred meters of the water column, using the data from the first and last blow down events when the ISUS was plunged deeper into the water (see the pressure time series for the SeaBird Microcat just below the ISUS—Figure 4 third panel). Figure 5 shows a comparison of the nitrate profiles created by the blow-down events and those from the bottle data collected during deployment and recovery cruises. The corrected ISUS nitrate values agree well with the bottle data for values greater than 0µM, especially during the first blow-down event. However, in water with

nitrate concentrations approaching zero, the ISUS nitrate concentrations are highly variable and often negative.

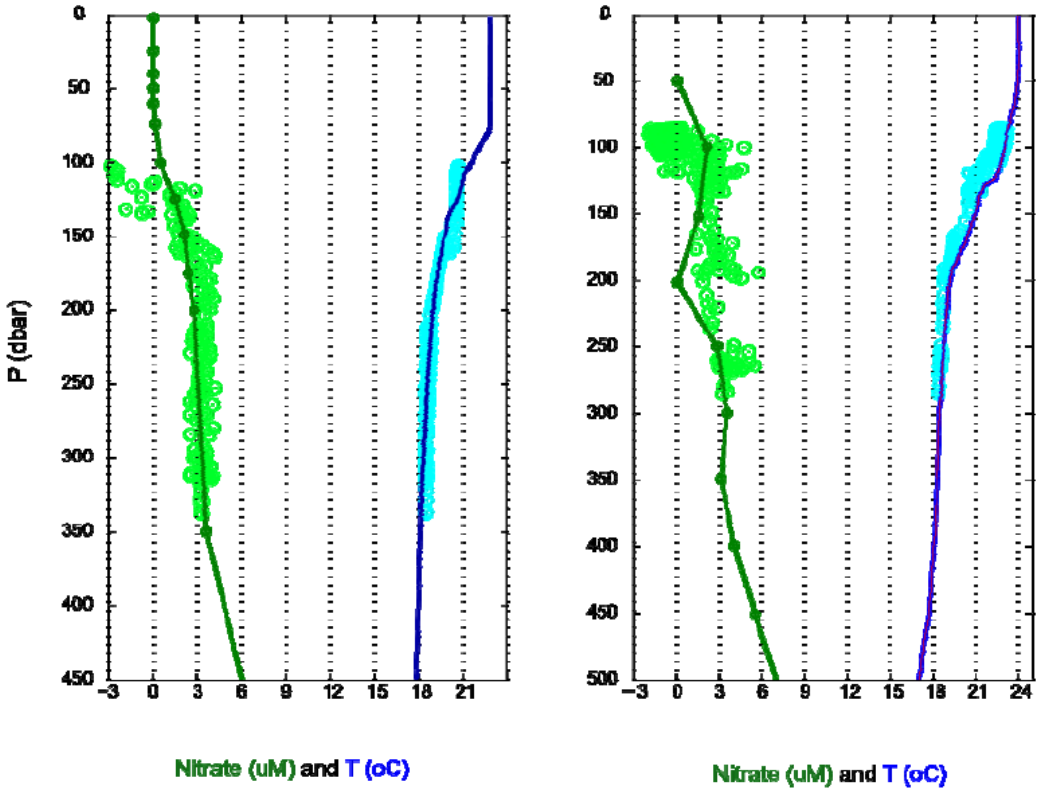

Figure 5: Nitrate (green) and temperature (blue) profiles from hydrographic data (darker, solid lines) and from moored instrumentation during blow-down events (lighter dots). Left panel - Hydrographic data from November 15, 2005 during CLIMODE deployment cruise plotted with mooring data from Dec 21, 2005 to Jan 1, 2006. Right panel - Hydrographic data from Nov 23, 2006 during CIMODE recovery and redeployment cruise plotted with mooring data from November 2 to 17, 2006. Note that the ISUS data at 200 meters in left panel was collected on November 4, 2006, more than two weeks before the bottle data was collected. Therefore, the anomalously low nitrate at 200 meters may not have been present at the time of the ISUS observations.

Accepting the assumption that the ISUS was in water with zero nitrate whenever it measured a negative nitrate concentration, we see that at Mooring D1, the water column was fully depleted in nitrate at the ISUS depth (nominally 79 meters) from November 14, 2005 the deployment date, through the onset of the first blow-down event (Figure 4 second and third panels). The target depth of the MicroCAT SBE-37 (~80 meters) was generally within the mixed layer, as seen from the satellite SST interpolated to the Mooring D1 location, which matches closely with the temperatures at 80 meters (red

curve, Figure 4 bottom panel). The SST data is a blended, gap-filled, daily, 0.25ºC product made available at http://www.ghrsst-pp.org/L4-Gridded-SST.html.

During the blow-down event beginning on Dec 15, 2005, the ISUS and MicroCAT were plunged from 80dbar to a maximum of 390dbar on Feb 1, 2006. As the sensors crossed 120dbar, they measured nitrate concentrations above zero and temperatures below 20ºC for the first time, suggesting that the sensors descended into the seasonal thermocline / nutricline (Figure 4 second to bottom panels). The sensors continued to descend in the water column and recorded a corresponding decrease in temperature and increase in nitrate from Dec 15 – Dec 21, 2005. At this time, the temperature and nitrate concentrations stabilized at 18.5ºC and 3.5µM, although the sensors continued to descend deeper into the water column from 200dbar to 350dbar, clearly suggesting that there a remnant EDW layer with low vertical property gradients at these depths. When the sensors crossed 350dbar, they again entered a part of the water column with stronger vertical gradients: the nitrate concentration rose to 10µM at 390dbar and the temperature decreased to 17.2ºC.

By mid-February, the current relaxed and the sensors ascended to their target depths where they encountered slightly warmer temperatures (19ºC), and more nitrate-depleted water (1µM). As the winter progressed, the water column slowly lost heat, and the temperature at less than 90dbar descended towards 18ºC. During this period, the ISUS recorded noisy nitrate concentrations, frequently fluctuating between zero and 3µM, with a mean of 1.2µM, and satellite chlorophyll (averaged over a 10º x 10º box centered at Mooring D) rose precipitously (Figure 4 second panel, red line). Finally, in the second week of April, with the sensors resting at approximately 80dbar, the temperature of the mixed layer fell to 18ºC, nitrate concentrations hovered between 3 and 4µM, and satellite chlorophyll hit its peak value for the year. These were the conditions as EDW was being formed.

Within days, seasonal stratification of the water column began, with SSTs rapidly diverging from the temperature at the instrument depth, and in mid-June the temperature at the instrument depth rose quickly to 20ºC. After restratification began, nitrate concentrations plummeted and remained at zero until an August blow-down event, except for an inexplicable 2-week excursion to nearly 5µM towards the end of June. These unusual results in June and the following months came six months after deployment, when the ISUS was at the limits of its expected, accurate lifespan.

Mooring D2 ISUS 078 *Stefan Gary, Duke University*

ISUS 078 was redeployed in scheduled data collection mode and programmed to collect nitrate concentration data several times each day. The instrument logged the date and time of each measurement interval and logged the nitrate concentration, root mean square

error in nitrate, instrument internal temperature, spectrometer and lamp temperature, internal humidity, battery voltage, and various intermediate spectrometer parameters that were used by the instrument to compute the nitrate concentration. During this most recent deployment, 149913 separate measurements were made over 344 days of deployment (Figure 6). The instrument failed to wake up and take data for seven days for unknown reasons. These no-data days were also observed during the previous deployment of ISUS 078.

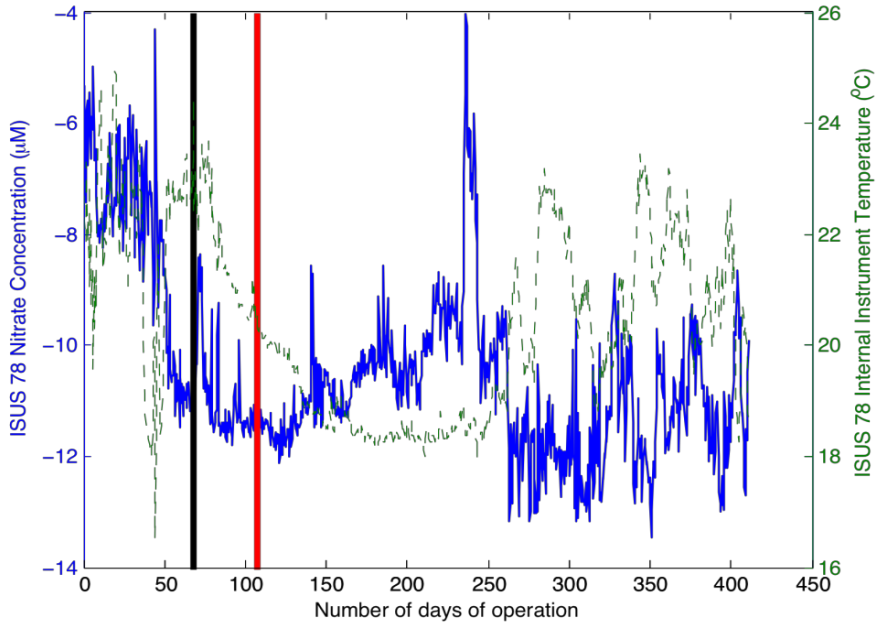

Figure 6: ISUS 78 Nitrate concentration

Before cleaning the exterior or downloading data from the instrument, an attempt was made to calibrate the ISUS for potential drift by submerging the probe tip. The figure shows the raw data, which is currently being calibrated and analyzed in the context of the data from the other moored instruments.

E. MMP

The final output of MMP data processing is a gridded data set of temperature, salinity, pressure, and east and north current components. Nominal temperature and pressure calibrations from laboratory tests are used to correct the data prior to gridding. Both a Cubic and quadratic fit of the laboratory calibration data were checked. The quadratic fit looked good and was used to adjust the temperature and pressure data. Nominal ACM calibration files contain scale factors which correct for ACM heading and speed bias.

Temperature and salinity reference files were created using ship board CTD data at adjacent stations.

MMP data for 2005-2006 C1 and D1 had to be processed in two batches. MMP-110, located on C1, data was divided into profiles that occurred prior to the MMP getting stuck on the wire and those that occurred after. Similarly, the data from MMP-118, located on D1, were divided into batches of profiles when the ACM was functioning and batches of profiles when the ACM stopped functioning.

Applying the post-cruise T/C scaling factors did not improve the Θ/S relationship on the Mooring C data so the nominal calibrations were used. A 0.018 bias was added to the conductivity data on Mooring D to adjust the MMP data towards the reference CTD profiles. The data were re-gridded after the bias was applied.

F. Aanderaa RCM

The raw RCM data was initially sent to Nelson Hogg who read the original ASCII file with Aanderraa software and provided WHOI with the time and scaling information. The ASCII dates were converted into date, year, day, and MATLAB datenum. Data that were collected prior to and after deployment were converted to 'NaNs'. These values were determined using the log books and plotting the data.

Heading data were converted from magnetic north to true north using a geomagnetic model. Each point was converted individually to correct for the temporal change in magnetic variation. The magnetic variation ranged from -17.86 degrees to -17.72 degrees during the year-long deployment.

Current speeds were adjusted for speed of sound. The speed of sound was computed using the SBE-37 data positioned at approximately the same depth as the RCM. In the case of Mooring D1, where the deep SBE-37 failed to record salinity, a fixed salinity of 36.1 ppt was used. The 36.1 ppt value was the average salinity from the deep SBE-37 on Mooring C1 (S/N 2034). The temperature data from the RCM had an unknown scaling factor and therefore, was not used. The SBE-37 data was edited and interpolated onto the RCM time grid. Speed of sound scaling factor was applied:

$$rcm\_speed = rcm\_speed * (MC\_sound\_speed/1500)$$

Another scale factor of 1.1 was applied to the RCM speed. This scale factor comes from Nelson Hogg and was determined empirically. The final *.mat file includes the SBE-37 data and is named using the convention described at the end of the section *II. Mooring and Deployment Overview*.

V. Mooring Data

The following tables show bulk statistics from the mooring instruments and the Appendices contain time series plots from all six Moorings. Moorings A and B were deployed for the full 2 year field duration and were not serviced after the first year. These figures show the two-year time series. Moorings C and D were recovered half way through the program to service instruments. These time series plots are shown as C1 and D1 for the first deployment year and C2 and D2 for the second deployment year.

Table 6: SBE-39 Temperature (°C) Statistics for Mooring A

Mooring A	Target Depth	Minimum Temperature	Maximum Temperature	Average Temperature	Standard Deviation
sn0078	323 m	15.2281	19.8396	18.5616	0.3006
sn0262	441 m	12.7638	18.7366	18.0068	0.3891
sn0261	542 m	10.7106	18.2164	17.3351	0.6509
sn0341	642 m	8.679	17.5259	15.9223	0.8266
sn0336	843 m	6.3815	13.75	11.9167	0.9049

Table 7: SBE-39 Temperature (°C) Statistics for Mooring B

Mooring B	Target Depth	Minimum Temperature	Maximum Temperature	Average Temperature	Standard Deviation
sn0080	326 m	11.7817	20.2087	17.9987	0.953
sn0339	545 m	7.5499	18.198	16.3713	1.9046
sn0333	645 m	6.5399	17.6321	14.7997	2.1938
sn0334	746 m	5.8696	16.604	12.8431	2.1877
sn0337	846 m	5.2594	14.6827	10.776	1.9617

Table 8: VACM Statistical Data for Moorings A and B

Mooring	VACM	Target Depth	Variable	Minimum	Maximum	Average	Standard Deviation
A	11662	380 m	Pressure (db)	234.53	654.47	259.5	62.22
			Temp (°C)	14.08	18.79	18.2	0.41
			U (cm/s)	0	-49.25	-0.99	12.71
			V (cm/s)	0	-34.22	-0.58	8.66
A	11667	1054 m	Pressure (db)	912.56	1314.04	928.61	40.92
			Temp (°C)	5.43	9.21	7.91	0.55
			U (cm/s)	0	26.65	-0.46	6.16
			V (cm/s)	0	22.58	0.81	5.06
B	11672	383 m	Pressure (db)	236.59	594.06	290.02	76.55
			Temp (°C)	10.41	19.19	17.7	1.11
			U (cm/s)	0	30.55	0.72	5.79
			V (cm/s)	0	-43.71	-1.26	6.6

Table 9: Statistical Data for Mooring C1 (2005 – 2006)

Instrument	Serial Number	Target Depth	Variable	Minimum	Maximum	Average	Standard Deviation
SBE-37	2140	68 m	Temp (°C)	6.3601	25.6204	19.1673	3.5711
			Salinity (psu)	34.7956	36.9918	36.3995	0.3819
			Pressure (db)	66.756	782.308	171.041	163.641
MMP	110	76 – 640 m	Temp (°C)	14.5357	22.0719	18.4103	0.3005
			Salinity (psu)	35.922	36.8042	36.5271	0.0416
			U (cm/s)	-30.5065	62.9236	15.3318	2.7756
			V (cm/s)	-49.2876	41.7136	-13.7237	3.0098
SBE-37	2034	630 m	Temp (°C)	4.2894	17.3133	12.759	4.1706
			Salinity (psu)	35.1763	36.6467	36.084	0.3717
RCM	156	636 m	U (cm/s)	-41.7262	48.4431	-2.9788	13.2932
			V (cm/s)	-44.5654	46.8002	-2.7321	16.4631
			SPD (cm/s)	0.3262	49.9939	19.2205	9.728

Table 10: Statistical Data for Mooring D1 (2005 – 2006)

Instrument	Serial Number	Target Depth	Variable	Minimum	Maximum	Average	Standard Deviation
SBE-37	2139	70 m	Temp (°C)	16.1791	25.1616	20.0545	1.7428
			Salinity (psu)	34.7956	36.9918	36.3995	0.3819
			Pressure (db)	66.756	782.308	171.041	163.641
MMP	118	68 – 674 m	Temp (°C)	11.2845	22.467	17.918	0.4224
			Salinity (psu)	35.4511	36.8768	36.5064	0.0705
			U (cm/s)	-21.6363	19.2378	17.5582	0.5389
			V (cm/s)	-19.8953	10.4356	-18.6871	0.5087
SBE-37	2045	634 m	Temp (°C)	6.0361	16.8113	14.1787	2.2115
			Salinity (psu)	N/A			
RCM	159	638 m	U (cm/s)	-24.9768	48.4237	7.0877	12.6989
			V (cm/s)	-44.0426	33.7295	-6.3353	12.9667
			SPD (cm/s)	0	49.2872	17.9261	9.9203

Table 11: Statistical Data for Mooring C2 (2006 – 2007)

Instrument	Serial Number	Target Depth	Variable	Minimum	Maximum	Average	Standard Deviation
SBE-37	2140	68 m	Temp (°C)	10.6769	24.8652	18.9369	2.1215
			Salinity (psu)	34.8112	37.1076	36.5538	0.2217
			Pressure (db)	83.4190	604.5700	179.6491	127.5639
MMP	112	68 – 628 m	Temp (°C)	6.1459	24.6561	17.2149	0.5416
			Salinity (psu)	34.8440	36.7871	36.4011	0.0662
			U (cm/s)	-57.2071	83.9723	0.9047	1.9234
			V (cm/s)	-77.4053	68.0418	-0.5664	2.0693
SBE-37	2031	632 m	Temp (°C)	21.9037	4.3044	12.6538	3.4116
			Salinity (psu)	34.9987	36.7685	36.0331	0.3361
RCM	148	636 m	U (cm/s)	-43.4145	43.0431	-0.1583	15.3997
			V (cm/s)	-41.0737	43.7277	-1.8743	15.1203
			SPD (cm/s)	0	49.3608	19.7374	8.9276

Table 12: Statistical Data for Mooring D2 (2006 – 2007)

Instrument	Serial Number	Target Depth	Variable	Minimum	Maximum	Average	Standard Deviation
SBE-37	2139	64 m	Temp (°C)	17.6767	24.0635	19.9820	1.4740
			Salinity (psu)	35.5752	36.9398	36.6371	0.1053
			Pressure (db)	92.2130	253.0920	103.5866	17.9612
MMP	113	66 - 626 m	Temp (°C)	13.0742	23.4947	17.8971	0.3437
			Salinity (psu)	35.7021	36.8377	36.5016	0.0438
			U (cm/s)	-45.3917	40.6016	-1.3880	2.2507
			V (cm/s)	-52.5782	50.9859	0.1599	2.3182
SBE-37	1645	628 m	Temp (°C)	8.5836	16.6780	14.6405	0.8827
			Salinity (psu)	35.5287	36.5717	36.2158	0.1334
RCM	149	632 m	U (cm/s)	-29.5803	40.4818	0.7493	9.2792
			V (cm/s)	-35.0784	36.0344	-0.3758	11.2111
			SPD (cm/s)	0	42.8730	12.8027	6.9690

CLIMODE website: http://www.climode.org/index.html

The CLIMODE Group, 2009: Observing the cycle of convection and restratification over the Gulf Stream system and the subtropical gyre of the North Atlantic Ocean: preliminary results from the CLIMODE field campaign. *Bull. Amer. Meteor. Soc. 90, 1337-1350.*

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Appendix A: Mooring A time series plots

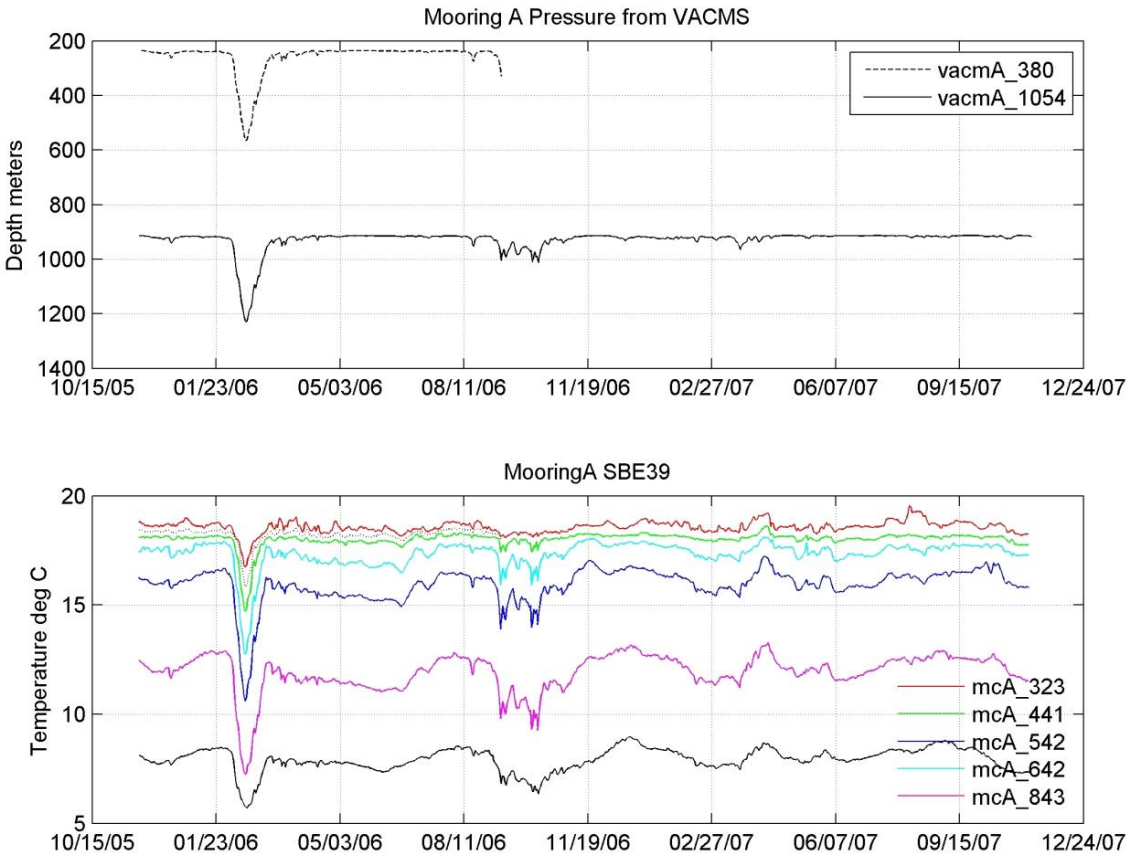

Figure A-1: Mooring A. Daily averaged pressure (dbar) time series data from VACMs (top panel, 11662 solid, 11667 dashed) showing blow down events. Bottom panel shows daily average temperature (°C) time series from SBE39s, VACM 11662 (solid) and 11667 (dashed). Temperatures decrease when instruments are blown down to deeper depths.

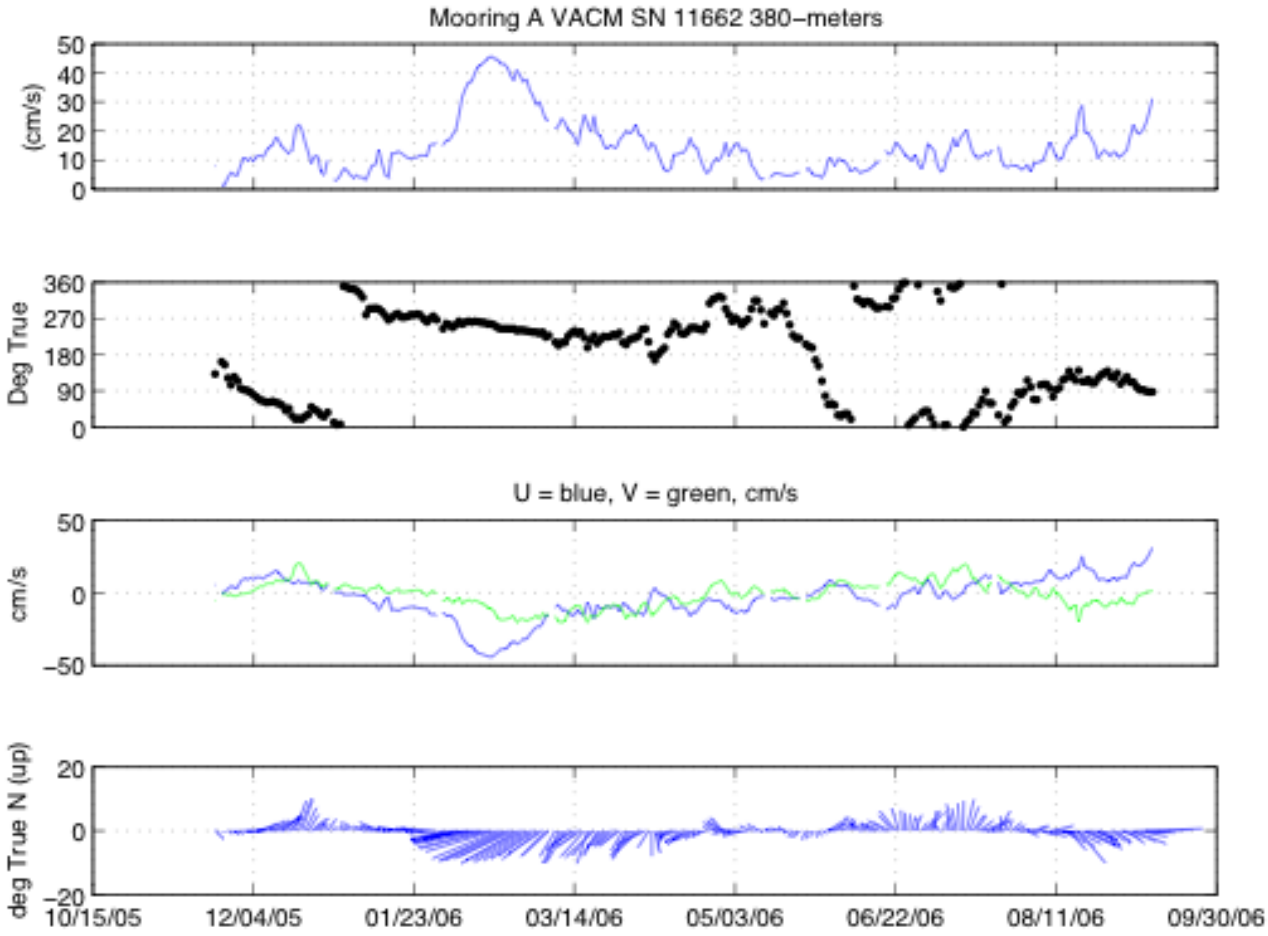

Figure A-2: Mooring A. VACM time series data from 11662, nominally 380 meters. Speed (top, cm/s), Direction (second, degrees), U & V (third, cm/s), and Velocity stick plot (bottom, cm/s).

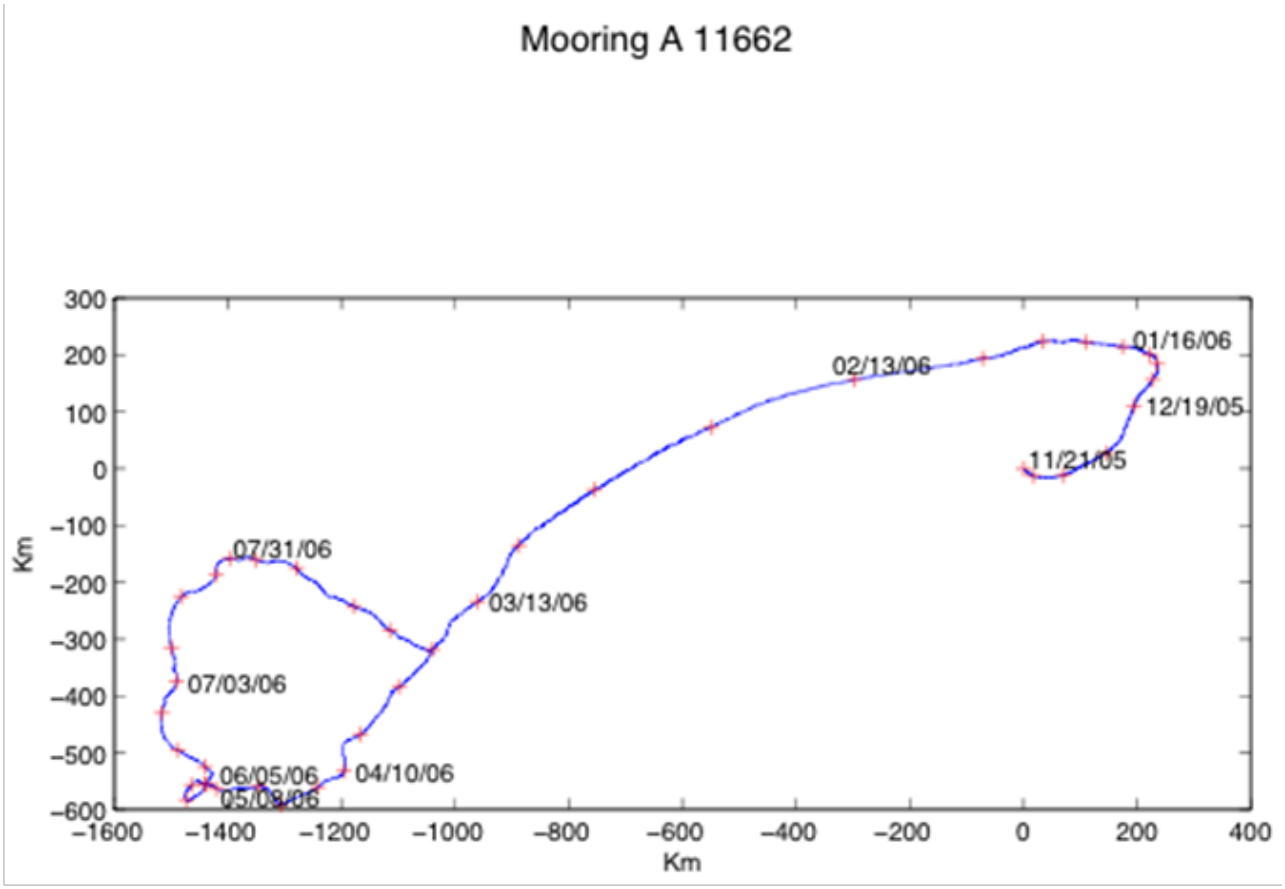

Figure A-3: Mooring A. Progressive vector diagram of current data measured by VACM 11662, nominally 380 meters. Weekly indications (red plus signs) are labeled at approximate monthly intervals.

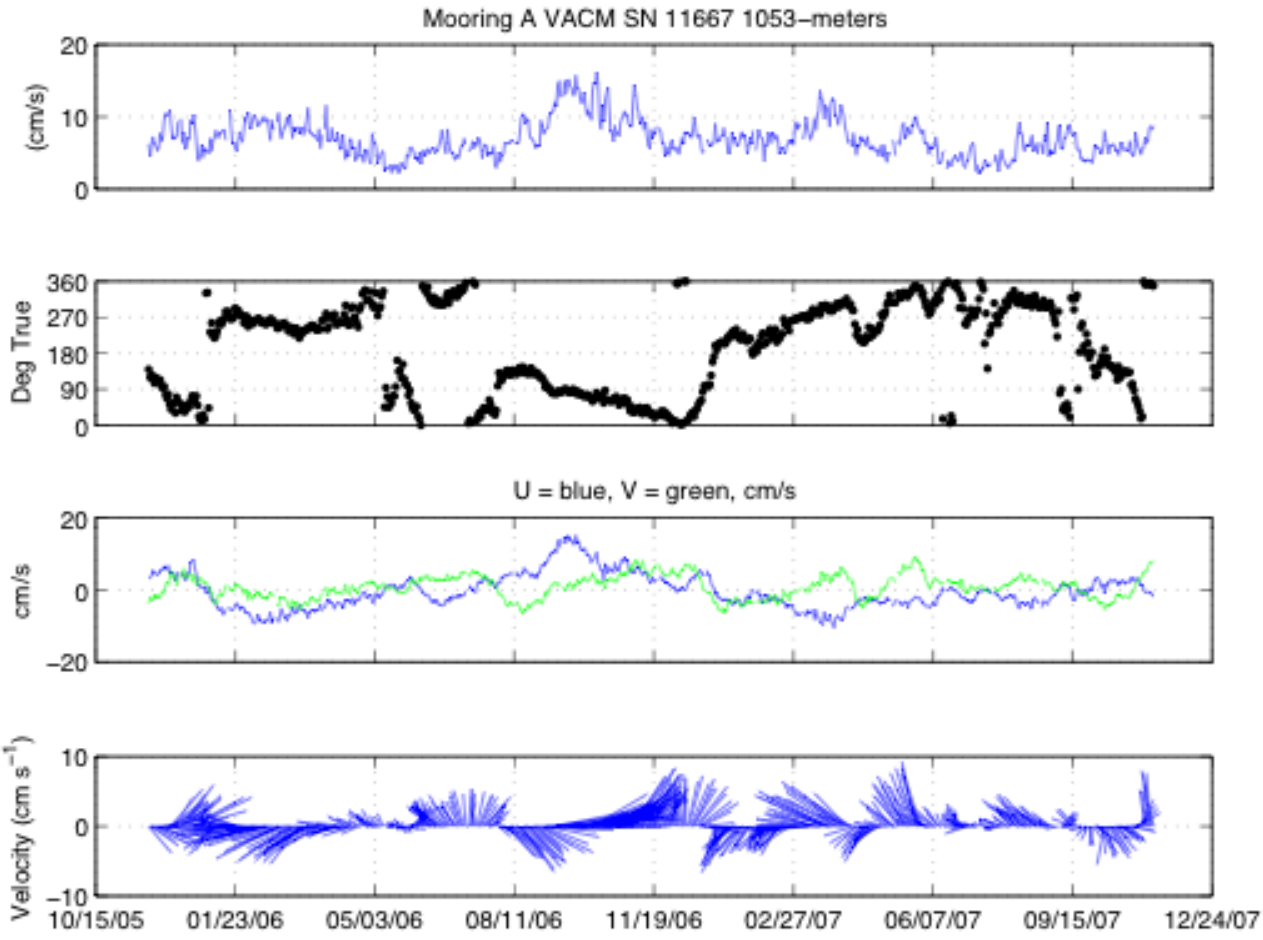

Figure A-4: Mooring A. VACM time series data from 11667, nominally 1053 meters. Speed (top, cm/s), Direction (second, degrees), U & V (third, cm/s), and Velocity stick plot (bottom, cm/s).

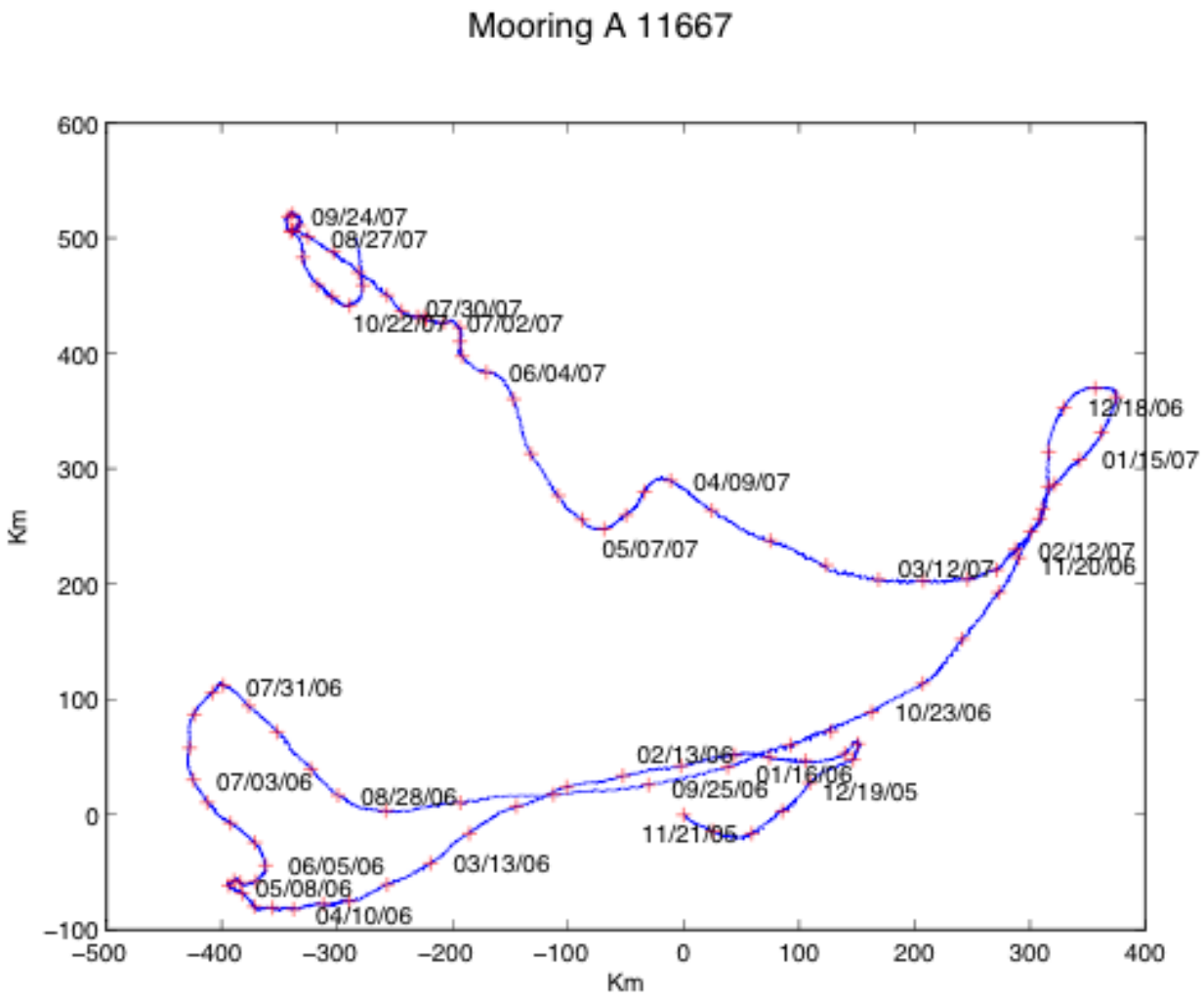

Figure A-5: Mooring A. Progressive vector diagram of current data measured by VACM 11667, nominally 1053 meters. Weekly indications (red plus signs) are labeled at approximate monthly intervals.

Appendix B: Mooring B time series plots

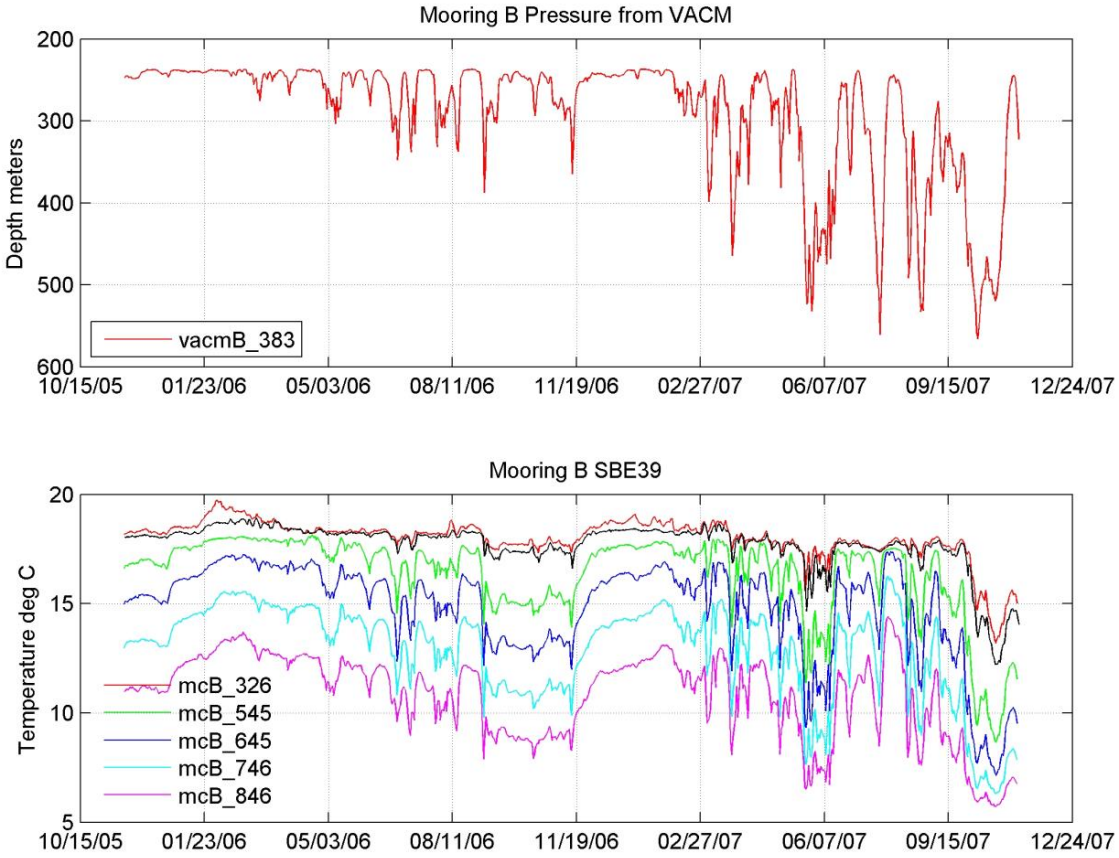

Figure B-1: Mooring B. Daily averaged pressure (dbar) time series data from VACM 11672 (top panel) showing blow down events. Bottom panel shows daily average temperature (°C) time series from SBE39s and VACM 11672 (black). Temperatures decrease when instruments are blown down to deeper depths.

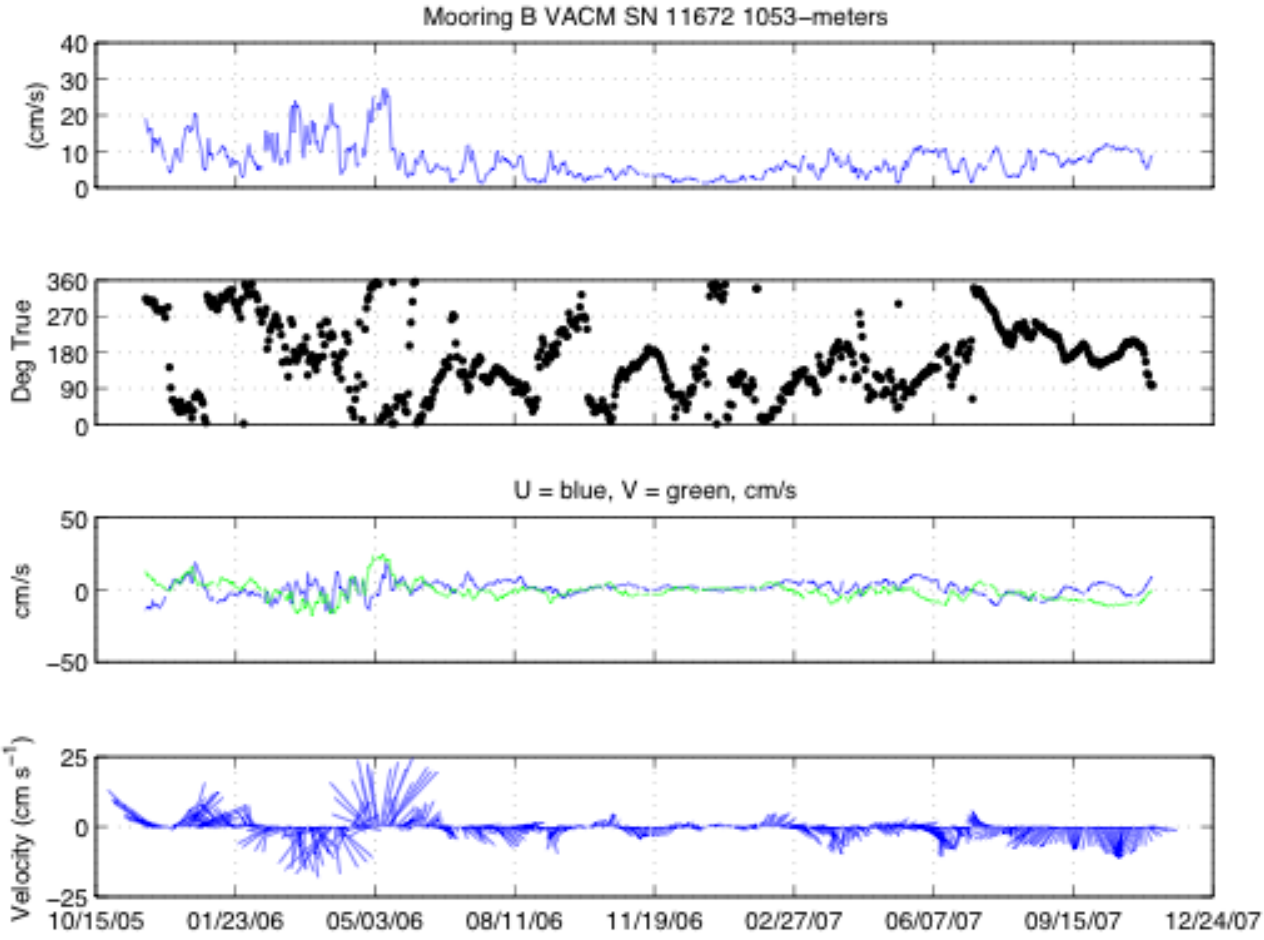

Figure B-2: Mooring B. VACM data from 11672, nominally 383 meters. Speed (top, cm/s), Direction (second, degrees), U & V (third, cm/s), and Velocity stick plot (bottom, cm/s).

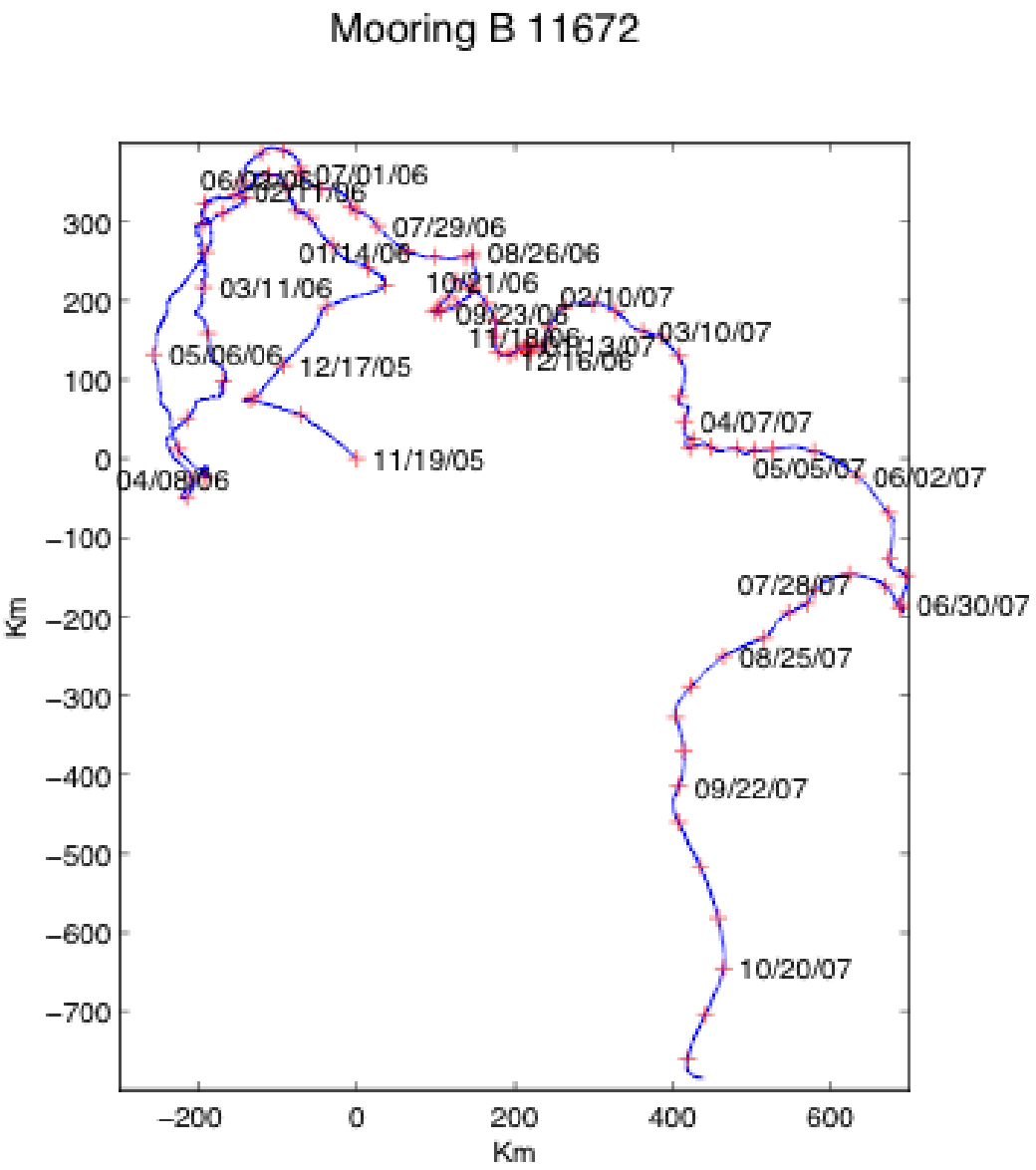

Figure B-3: Mooring B. Progressive vector diagram of current data measured by VACM 11672 nominally 383 meters. Weekly indications (red plus signs) are labeled at approximate monthly intervals.

Appendix C: Mooring C1 time series plots 2005 - 2006

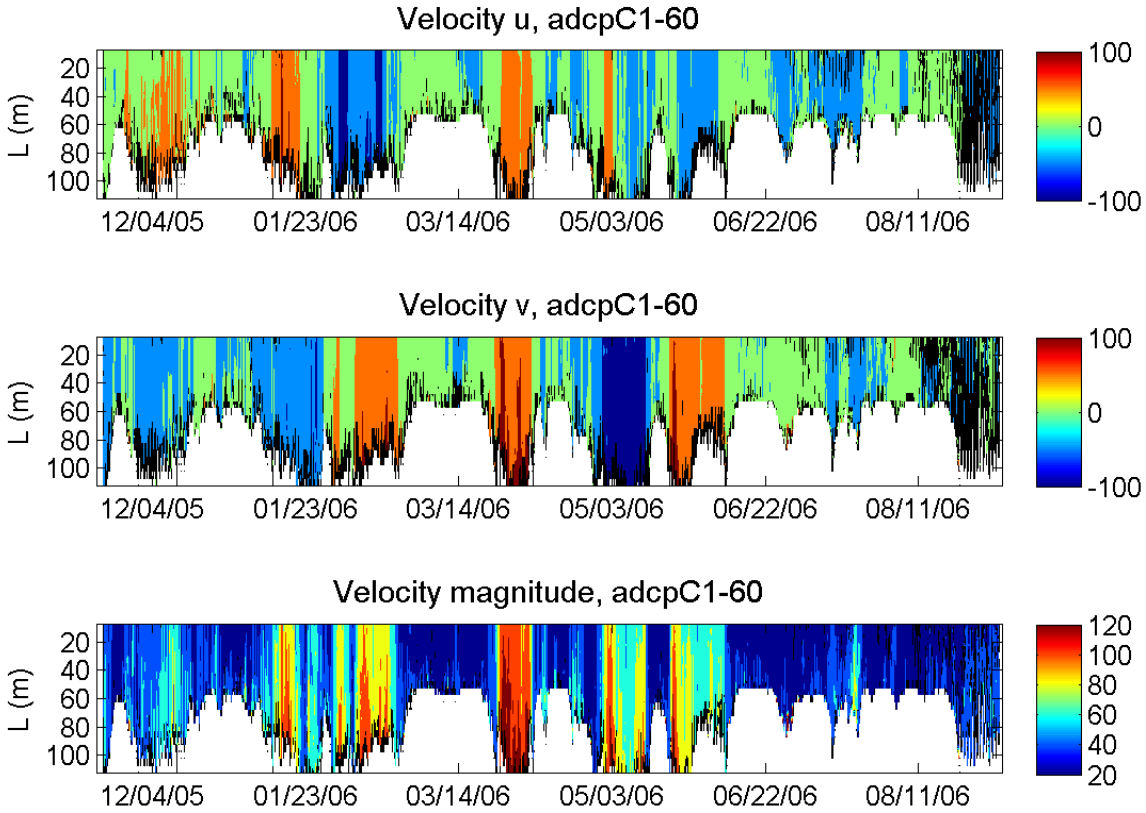

Figure C-1: Mooring C1. ADCP 2127 time series data, nominally 60 meters, collected from November 7, 2005 to September 6, 2006: velocity U (top, cm/s), velocity V (middle, cm/s), and velocity magnitude (bottom, cm/s).

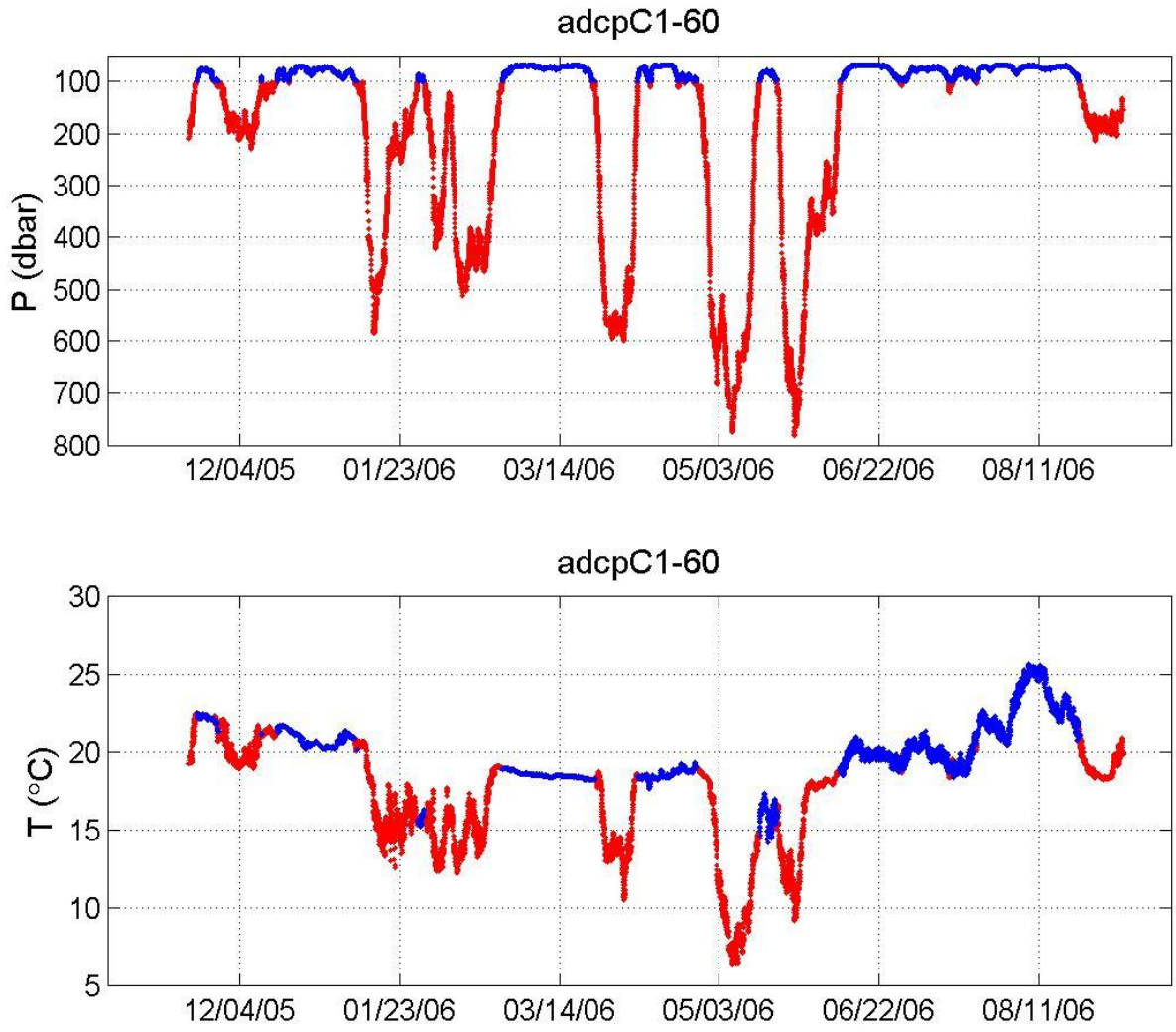

Figure C-2: Mooring C1. ADCP 2127 time series data, nominally 60 meters, collected from November 7, 2005 to September 6, 2006: pressure (top, dbar) and temperature (bottom, °C). The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

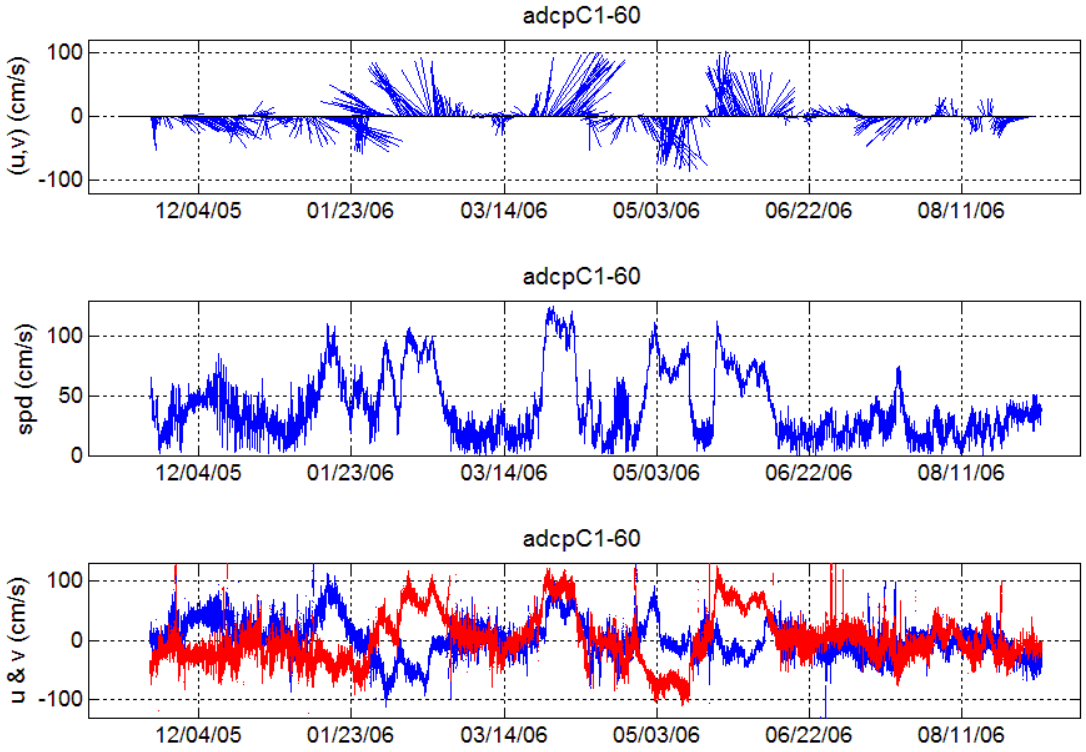

Figure C-3: Mooring C1. ADCP 2127 time series data, nominally 60 meters, collected from November 7, 2005 to September 6, 2006: velocity stick plot (top, cm/s), velocity magnitude (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

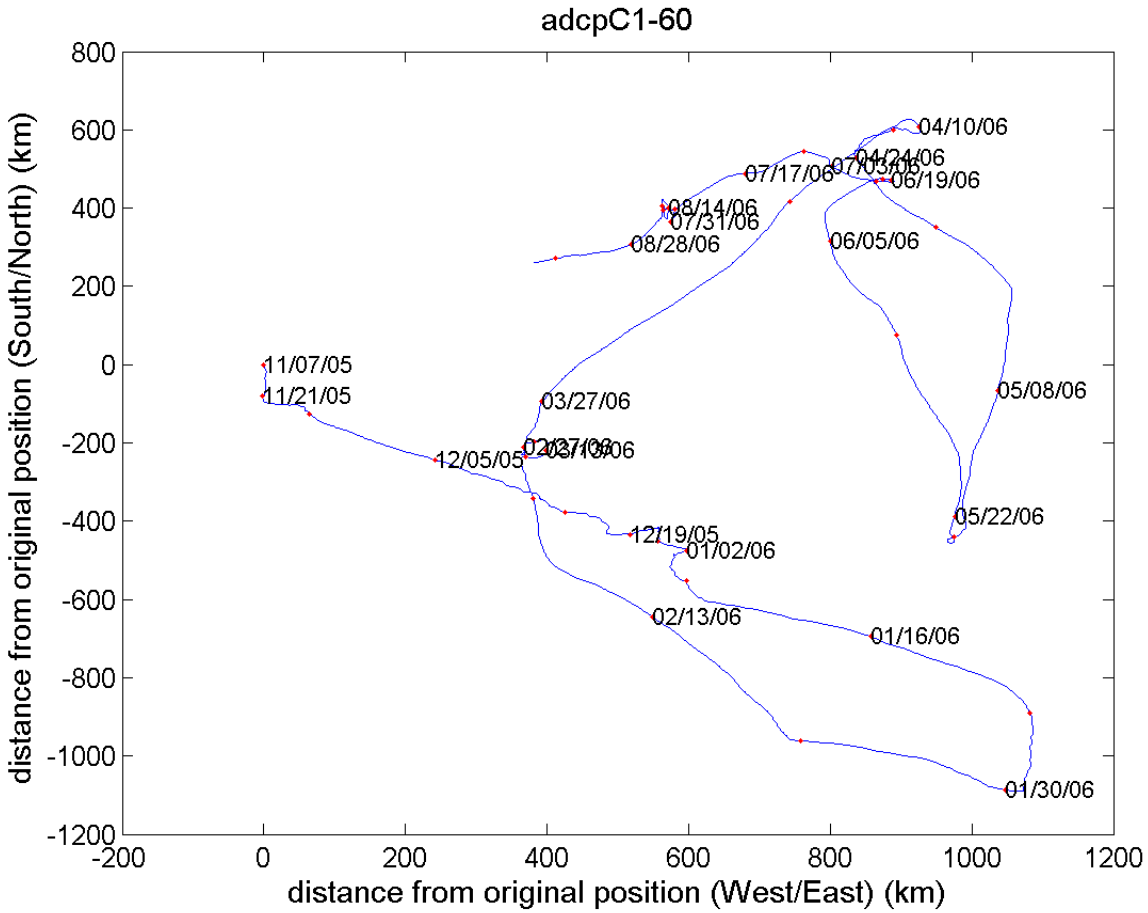

Figure C-4: Mooring C1. Progressive vector diagram of current data measured by ADCP 2127, nominally 60 meters collected from November 7, 2005 to September 6, 2006. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

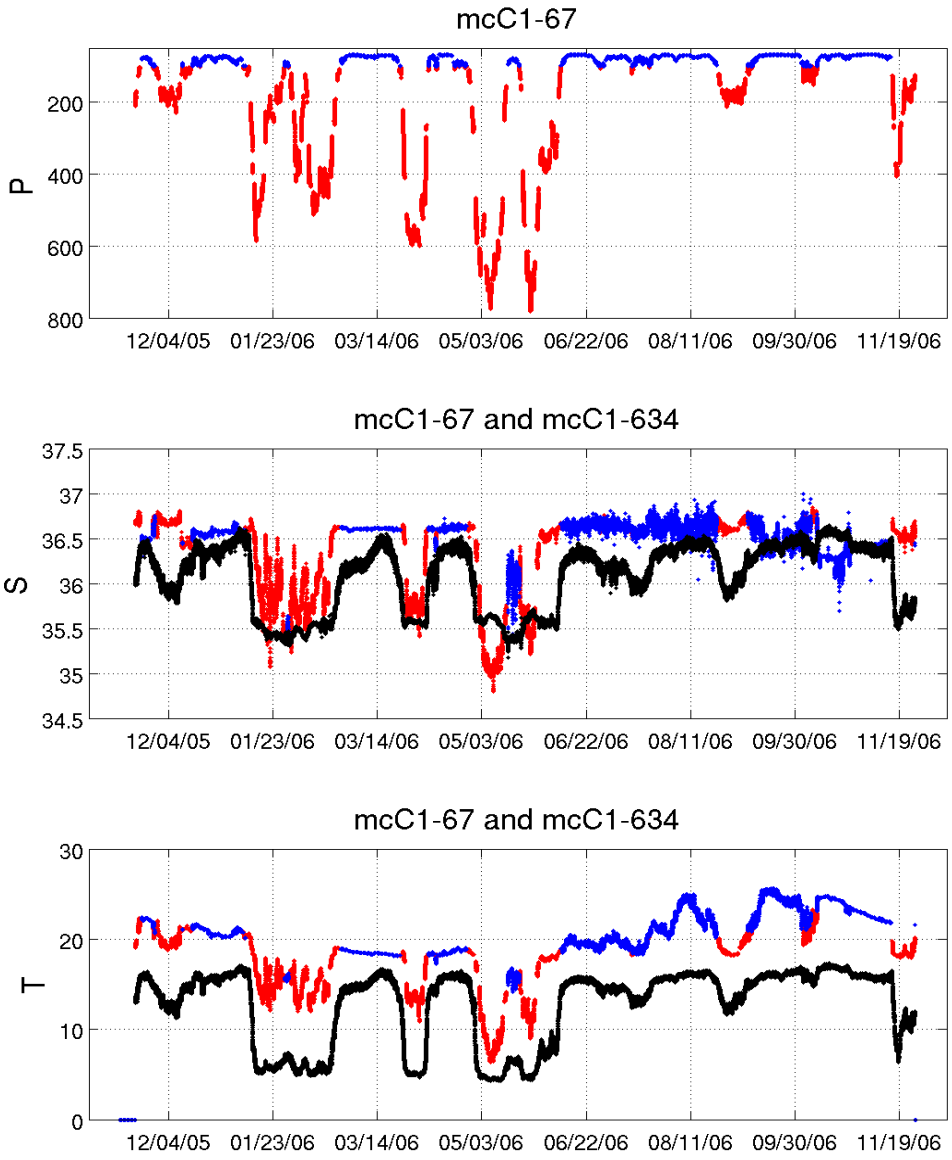

Figure C-5: Mooring C1. SBE37 2140, nominally 67 meters, and SBE37 2034, nominally 634 meters, time series data collected from November 17, 2005 to November 26, 2006: SN2140 pressure (top, dbar), SN2140 & SN2034 salinity (middle, psu), and SN2140 & SN2034 temperature (bottom, ºC). SN2140 plotted in red and blue, where the red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar. SN2034 plotted in black.

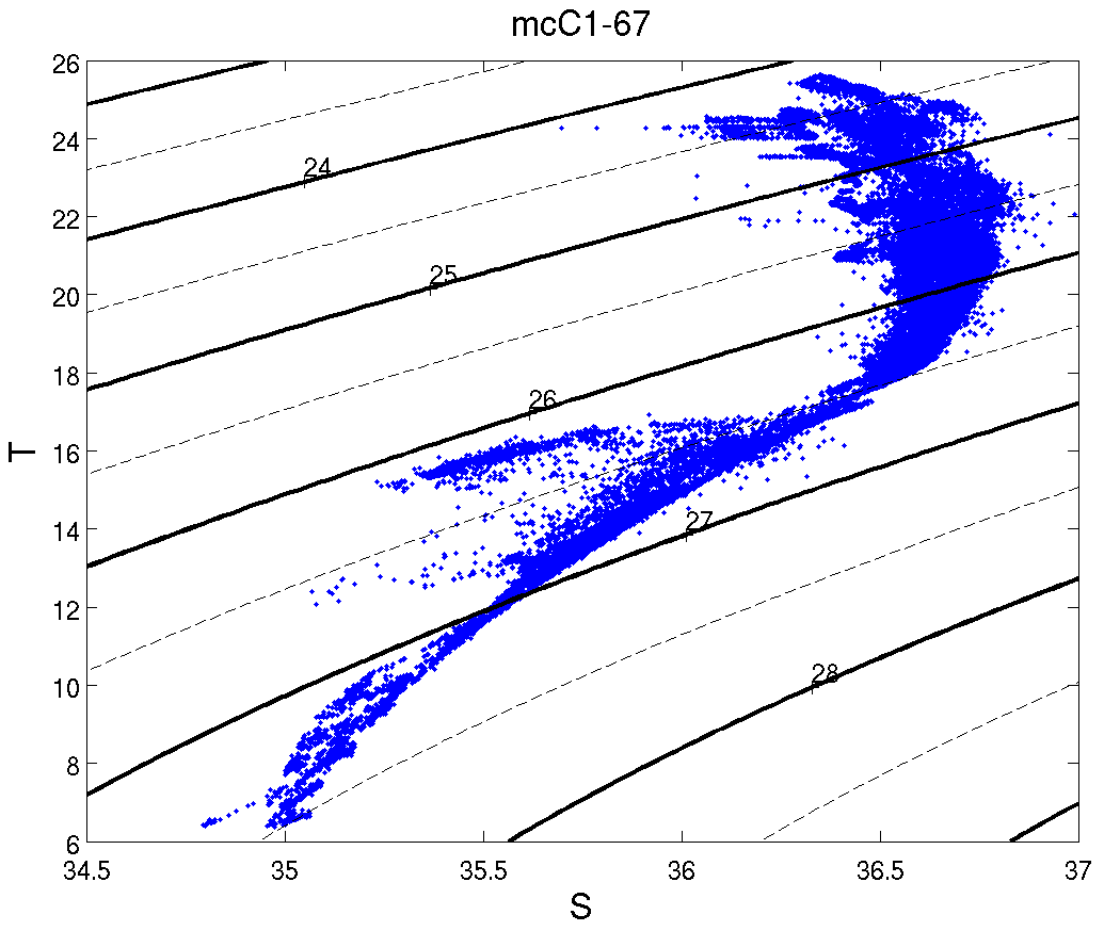

Figure C-6: Mooring C1. T/S properties of the sea water for SBE37 2140, nominally 67 meters, collected from November 17, 2005 to November 26, 2006.

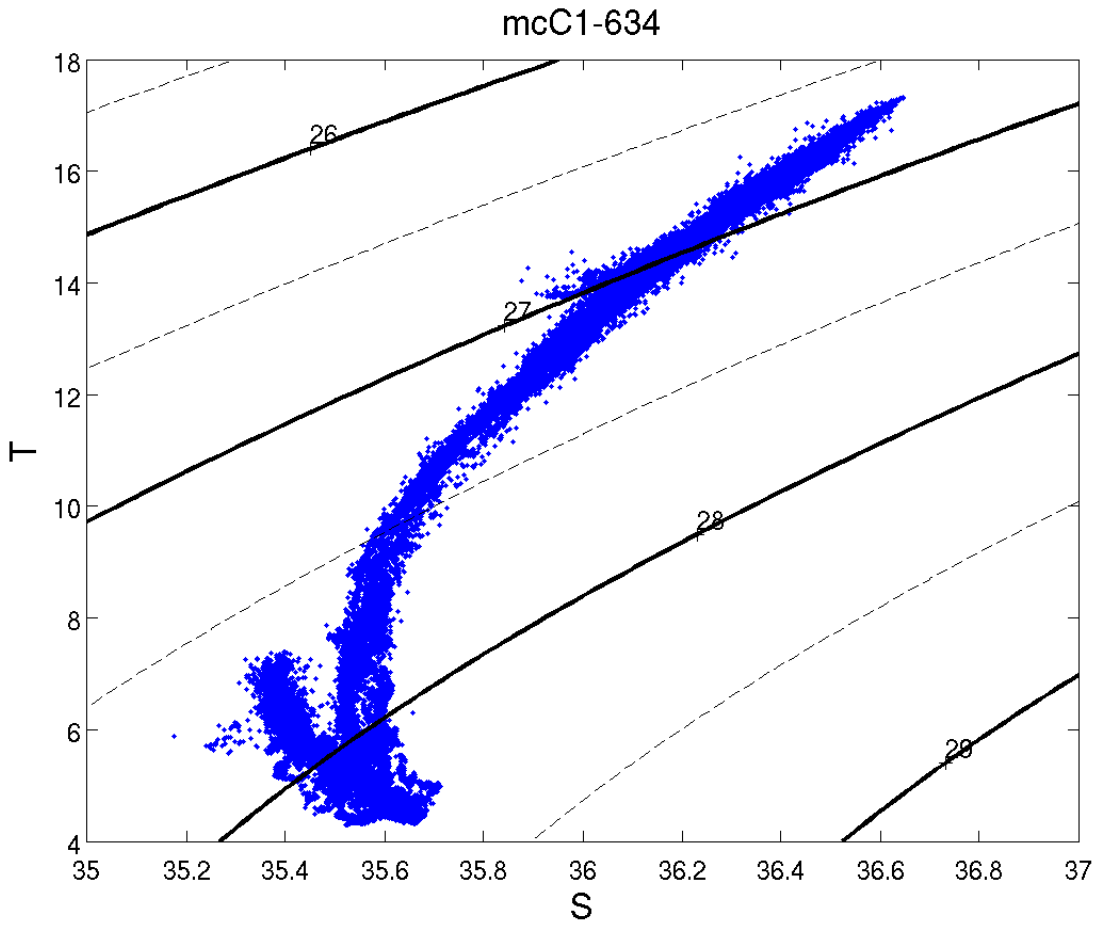

Figure C-7: Mooring C1. T/S properties of the sea water for SBE37 2034, nominally 634 meters, collected from November 17, 2005 to November 26, 2006.

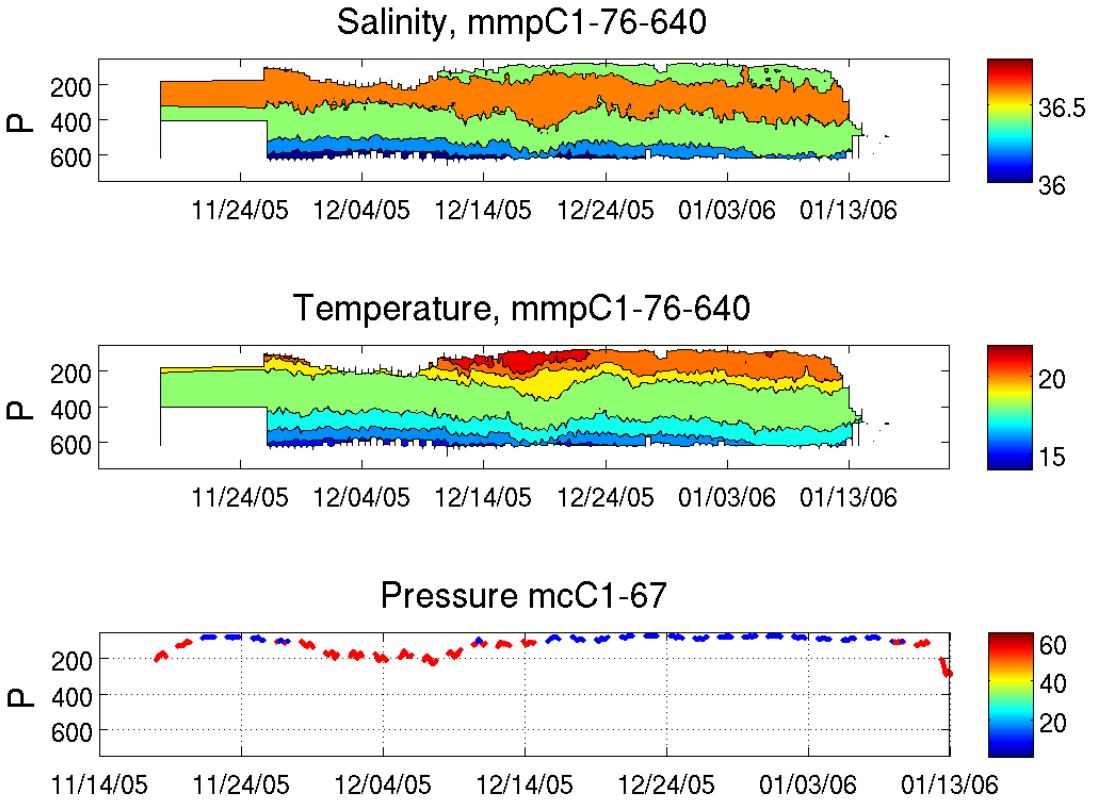

Figure C-8: Mooring C1. MMP 110 time series data, nominally 76 to 640 dbar, collected from November 17, 2005 to January 16, 2006: salinity (top, psu) and temperature (middle, °C). Corresponding SBE37 2140, nominally 67 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

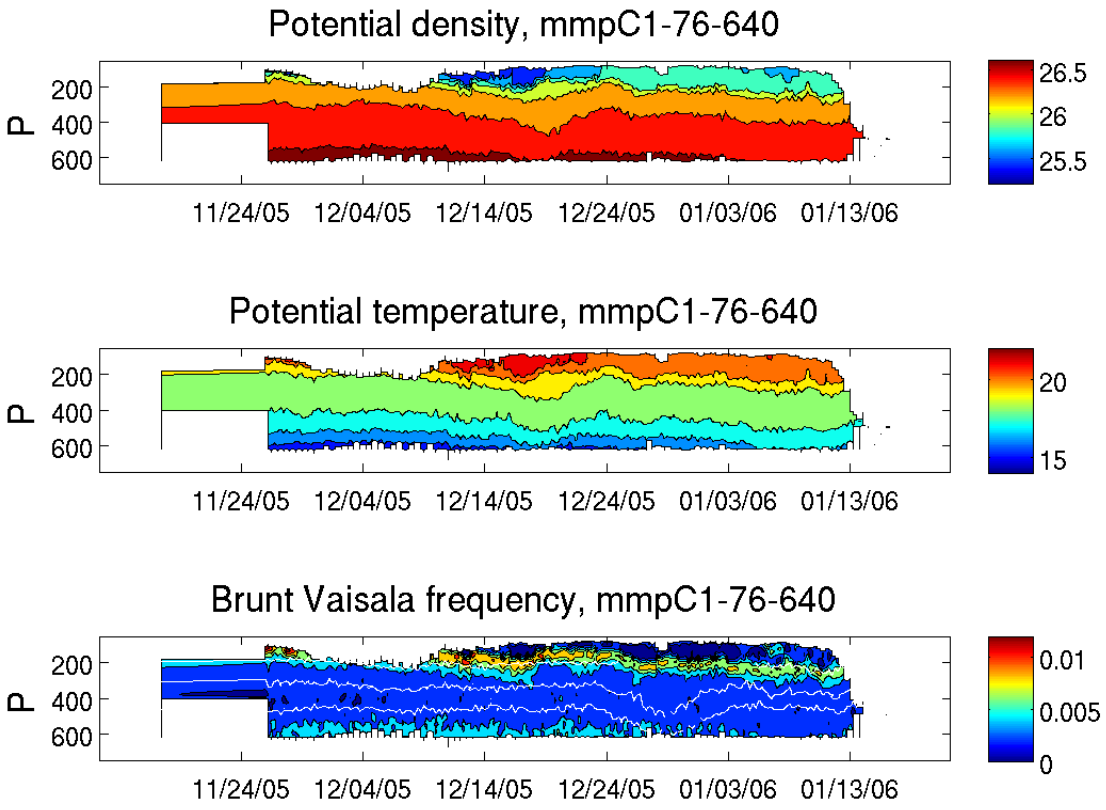

Figure C-9: Mooring C1. MMP 110 time series data, nominally 76 to 640 dbar, collected from November 17, 2005 to November 16, 2006: potential density (top, kg/m^3), potential temperature (middle, °C), and Brunt Vaisala frequency (bottom, 1/s). The white lines in bottom panel are 18°C, 18.5°C, and 19°C isotherms.

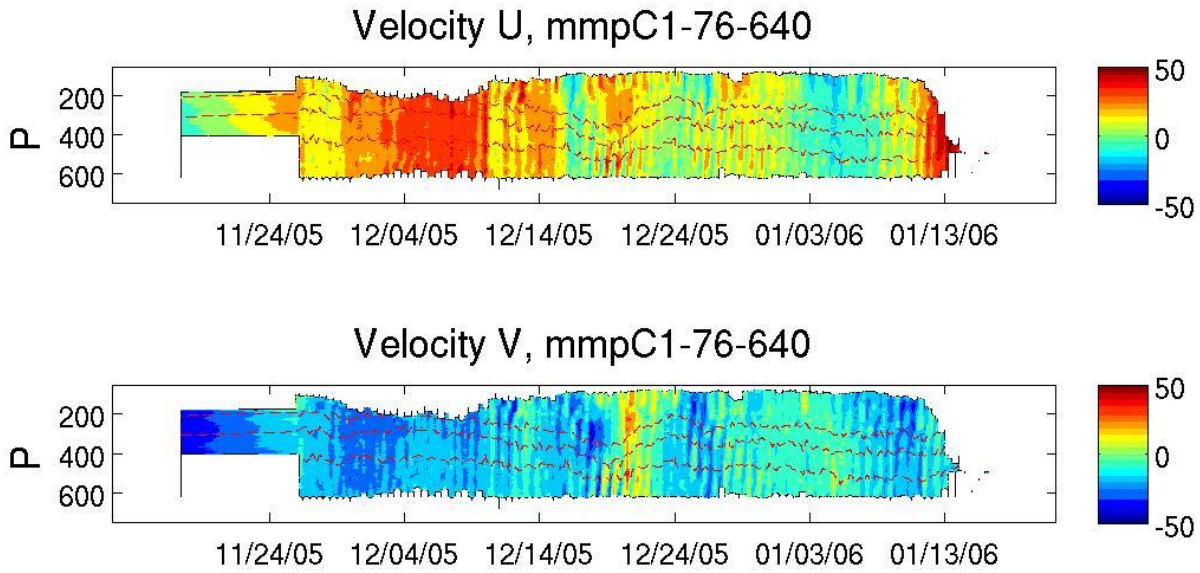

Figure C-10: MMP 110 time series data, nominally 76 to 640 dbar, collected from November 17, 2005 to November 16, 2006: velocity U (top, cm/s) and velocity V (bottom, cm/s). The red dashed lines are 18°C, 18.5°C, and 19°C isotherms.

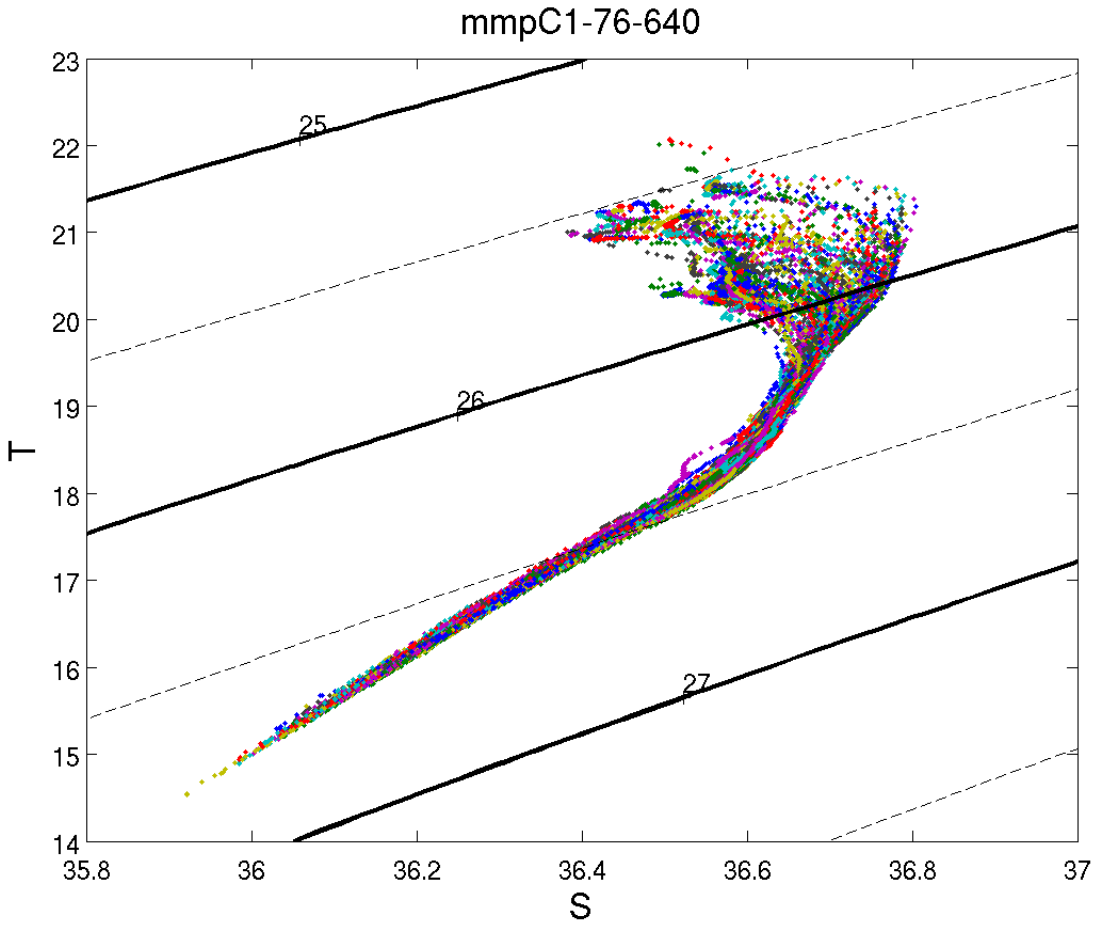

Figure C-11: Mooring C1. T/S properties of the sea water for MMP 110, nominally 76 to 640 dbar, collected from November 17, 2005 to January 16, 2006.

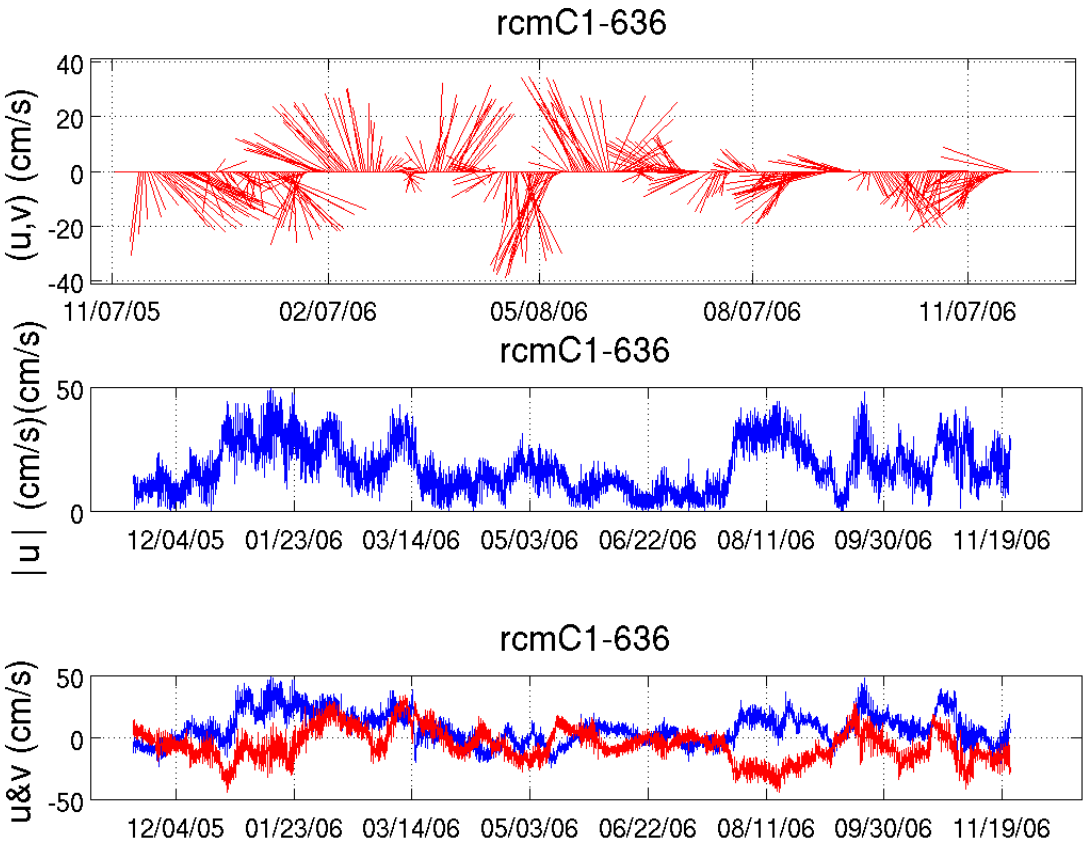

Figure C-12: Mooring C1. Aanderaa RCM 156 daily averaged time series data, nominally 636 meters, collected from November 17, 2005 to November 26, 2006: velocity stick plot (top, cm/s), velocity speed (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

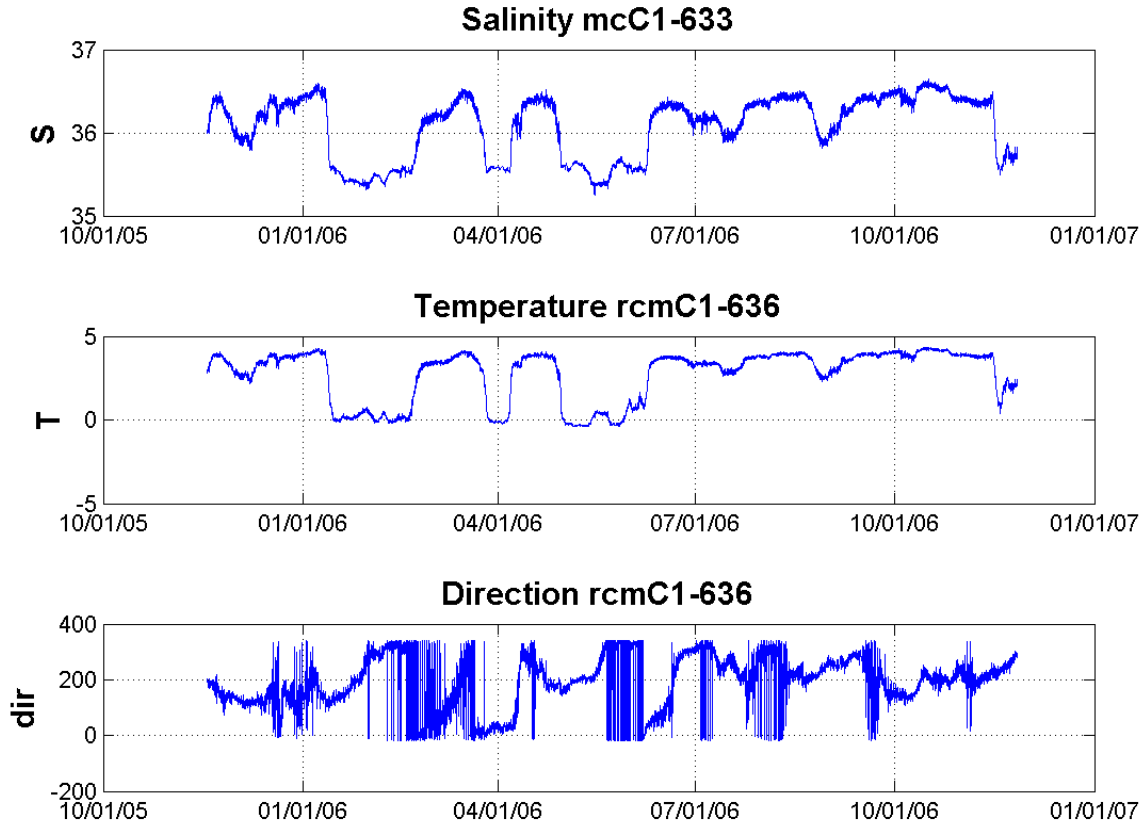

Figure C-13: Mooring C1. SBE37 2034, nominally 634 meters, daily averaged salinity (top, psu) and Aanderaa RCM 156 daily averaged time series data, nominally 636 meters, temperature (middle, °C), and current direction (bottom, degrees). Both collected from November 17, 2005 to November 26, 2006.

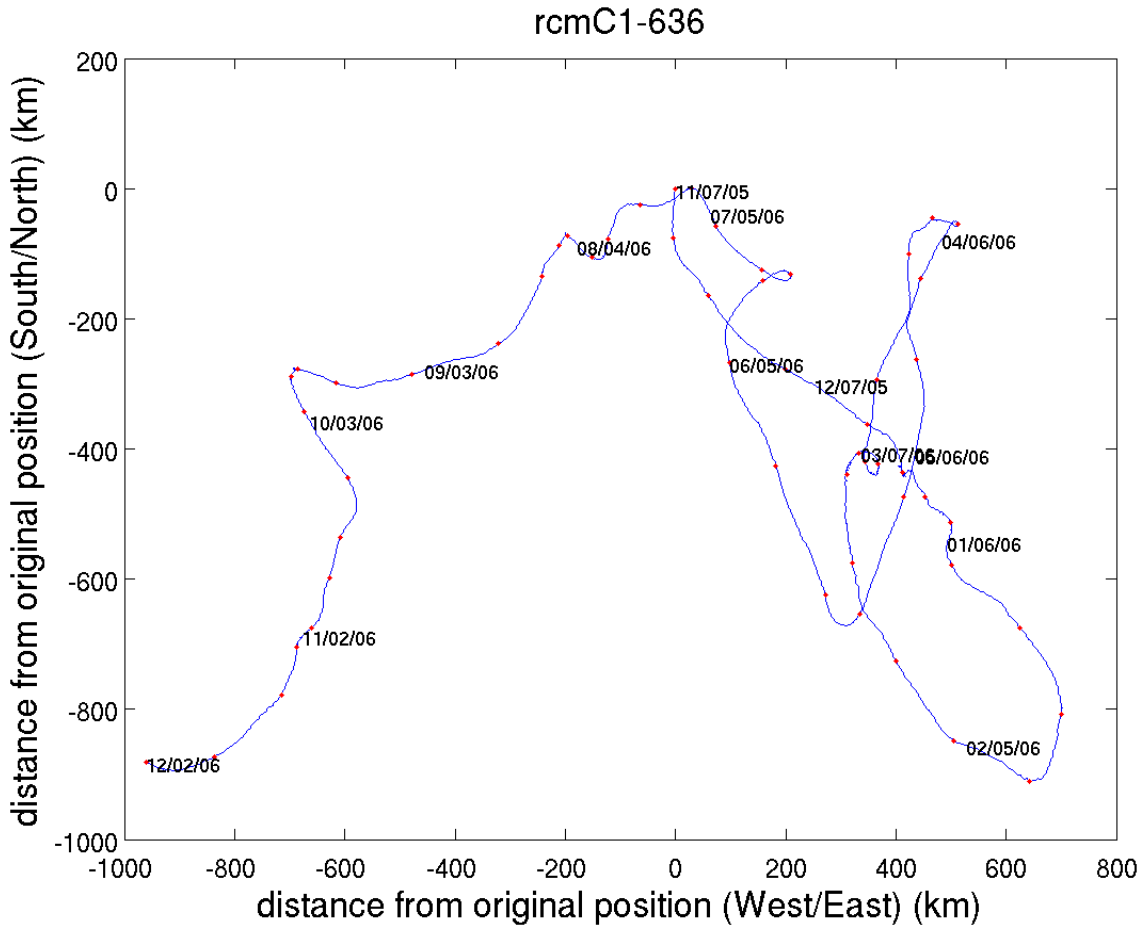

Figure C-14: Mooring C1. Progressive vector diagram of current data measured by Aanderaa RCM 156, nominally 636 meters, collected from November 17, 2005 to November 26, 2006. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

Appendix D: Mooring D1 time series plots 2005 – 2006

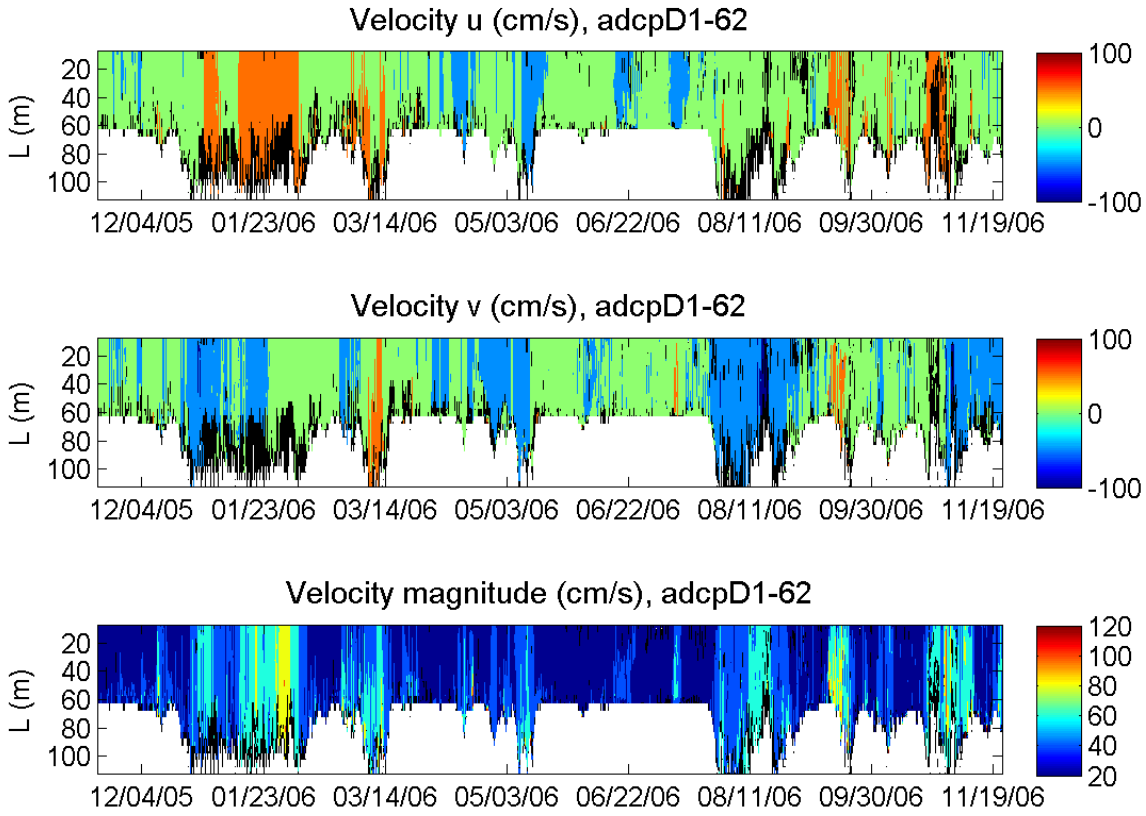

Figure D-1: Mooring D1. ADCP 2231 time series data, nominally 62 meters, collected from November 15, 2005 to November 22, 2006: velocity U (top, cm/s), velocity V (middle, cm/s), and velocity magnitude (bottom, cm/s).

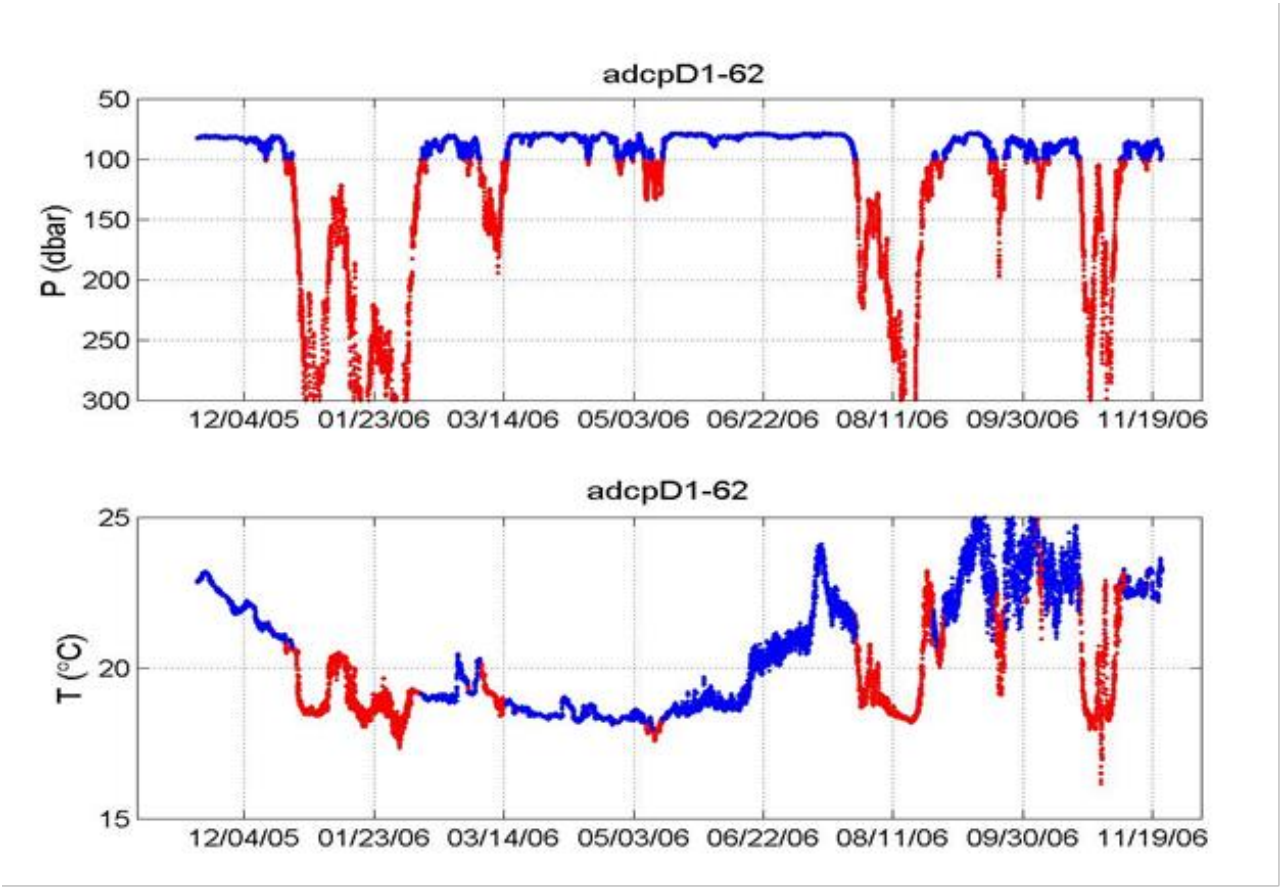

Figure D-2: Mooring D1. ADCP 2231 time series data, nominally 62 meters, collected from November 15, 2005 to November 22, 2006: pressure (top, dbar) and temperature (bottom, °C). The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

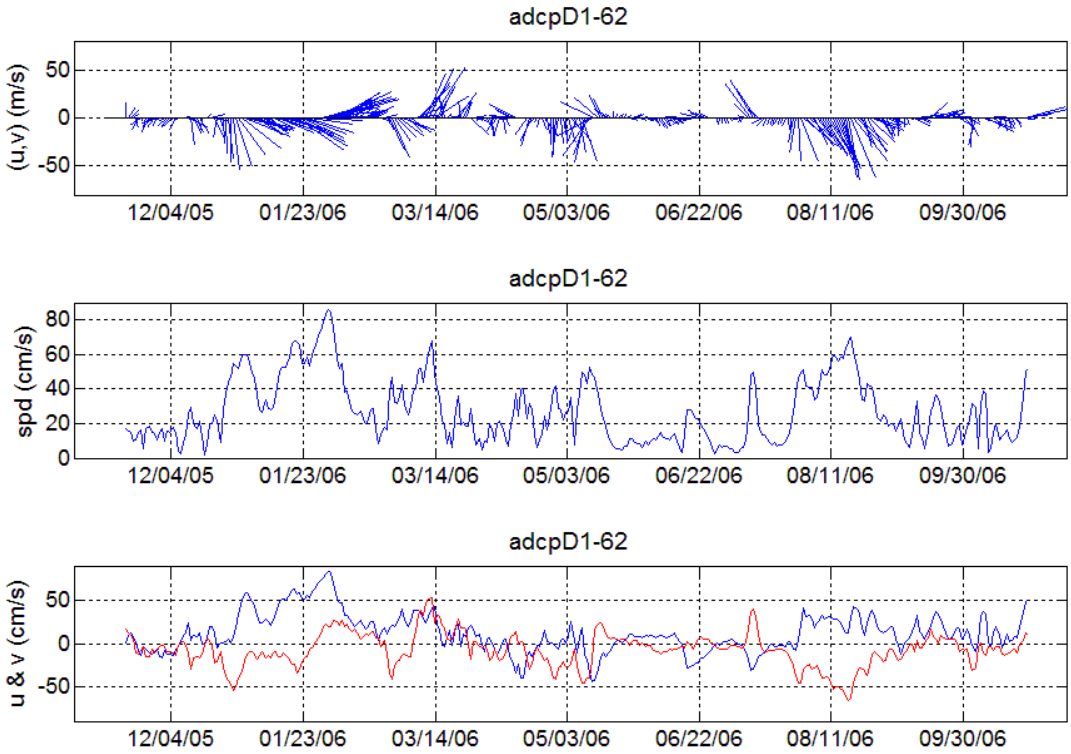

Figure D3: Mooring D1. ADCP 2231 time series data, nominally 62 meters, collected from November 15, 2005 to November 22, 2006: velocity stick plot (top, cm/s), velocity magnitude (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

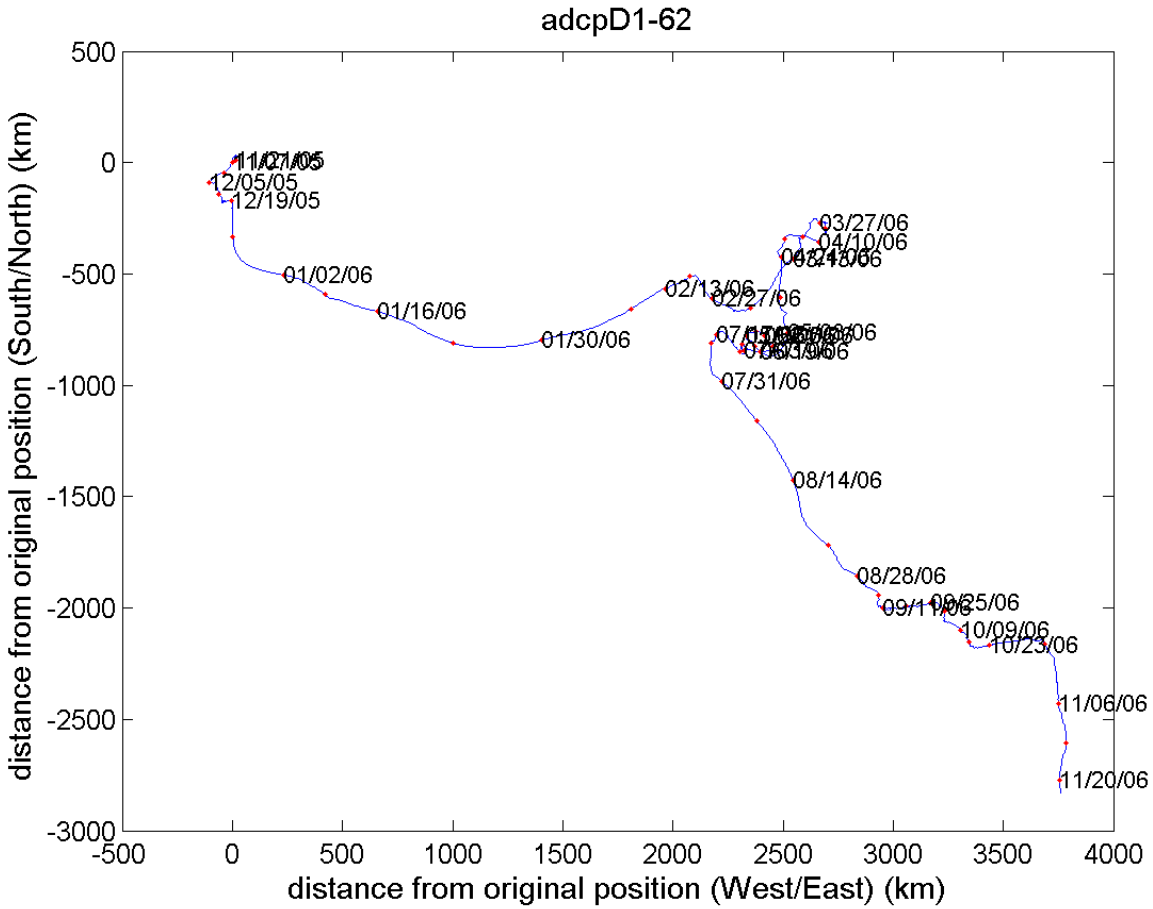

Figure D-4: Mooring D1. Progressive vector diagram of current data measured by ADCP 2231, nominally 62 meters collected from November 15, 2005 to November 22, 2006. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

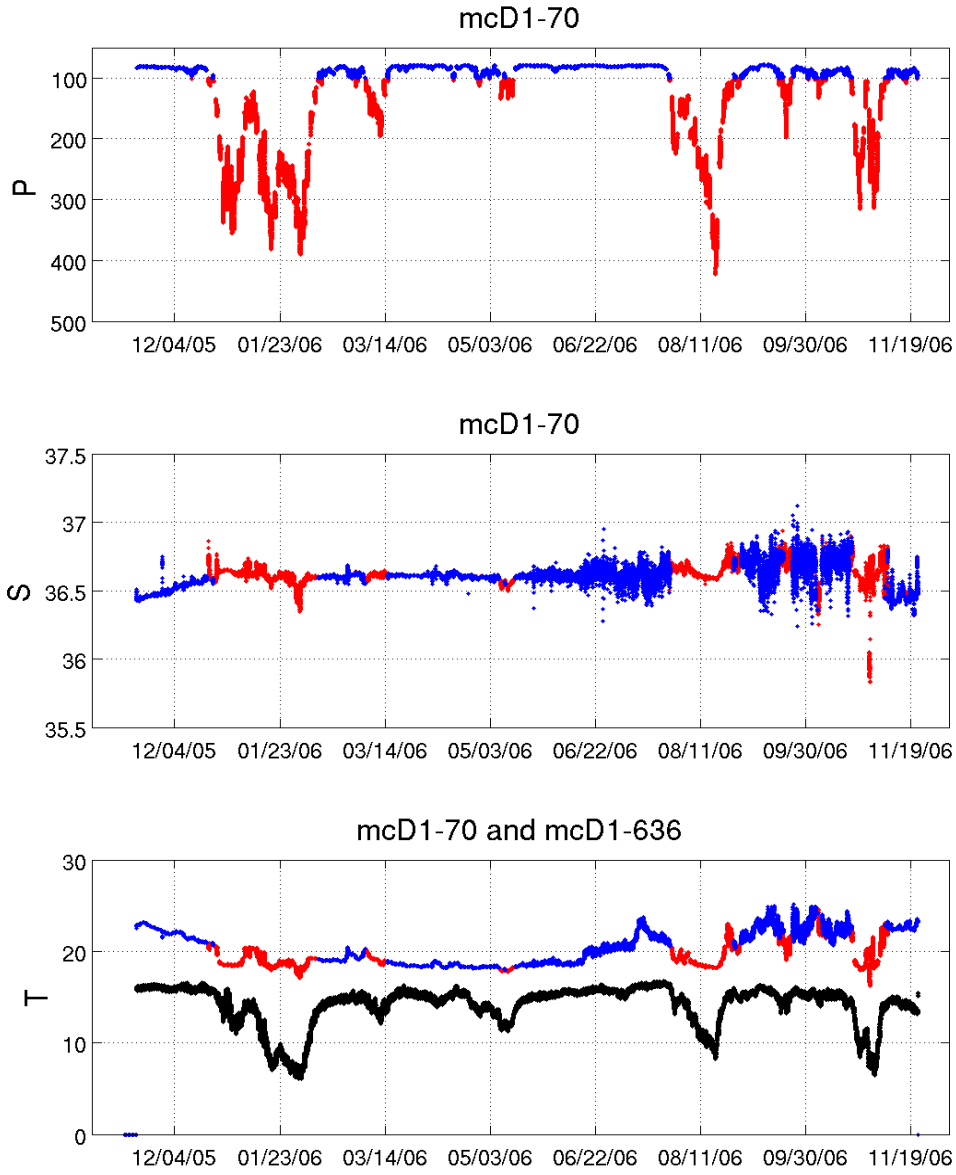

Figure D-5: Mooring D1. SBE37 2139, nominally 70 meters, and SBE37 2045, nominally 633 meters, time series data collected from November 15, 2005 to November 22, 2006: SN2139 pressure (top, dbar), SN2139 salinity (middle, psu), and SN2139 & SN2045 temperature (bottom, ºC). SN2139 plotted in red and blue, where the red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar. SN2045 plotted in black.

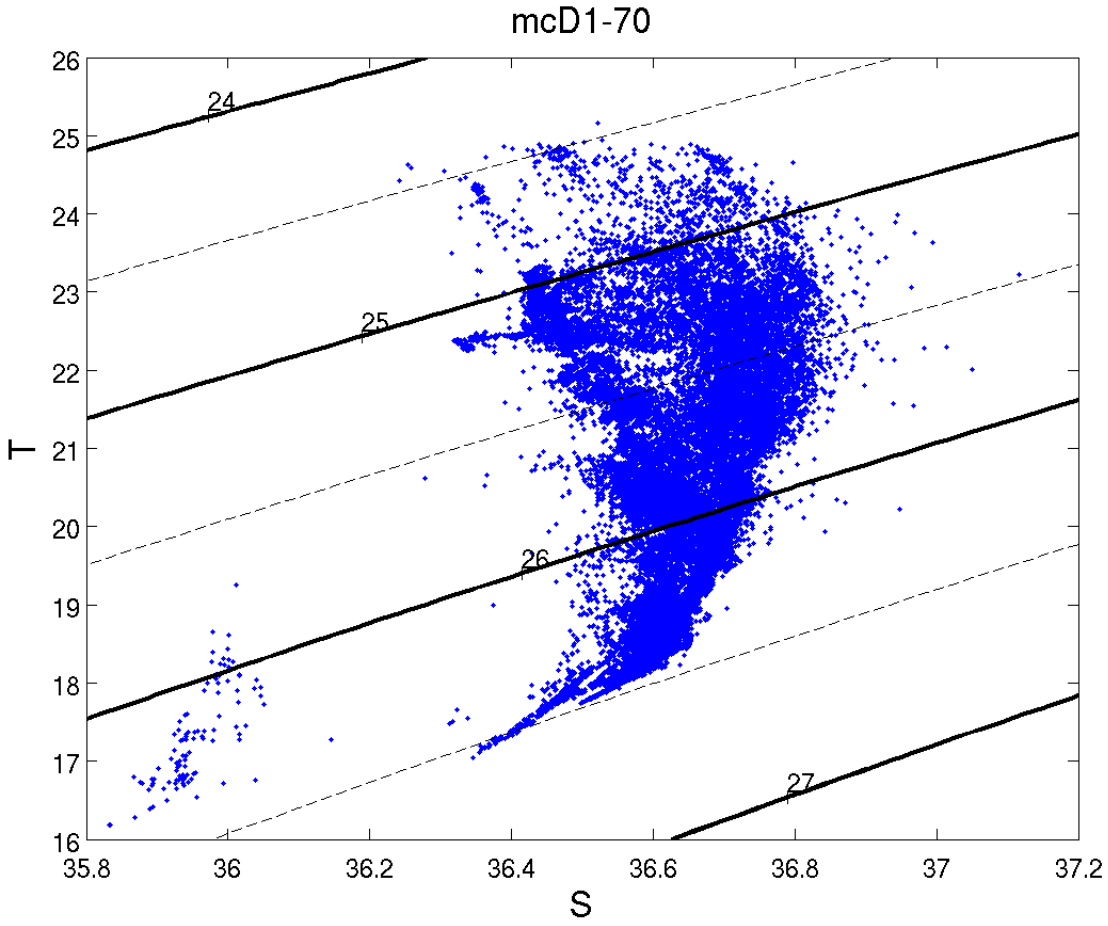

Figure D-6: Mooring D1. T/S properties of the sea water for SBE37 2139, nominally 70 meters, collected from November 15, 2005 to November 22, 2006.

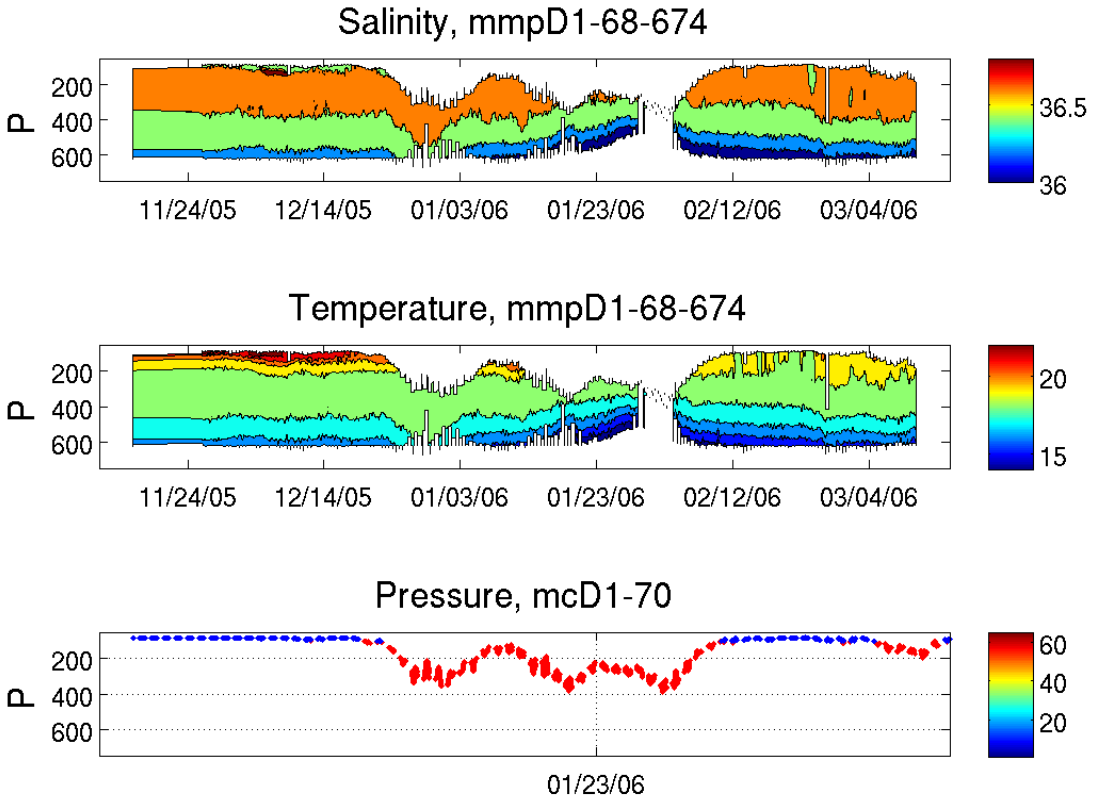

Figure D-7: MMP 118 time series data, nominally 68 to 674 dbar, collected from November 15, 2005 to March 10, 2006: salinity (top, psu) and temperature (middle, °C). Corresponding SBE37 2139, nominally 70 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

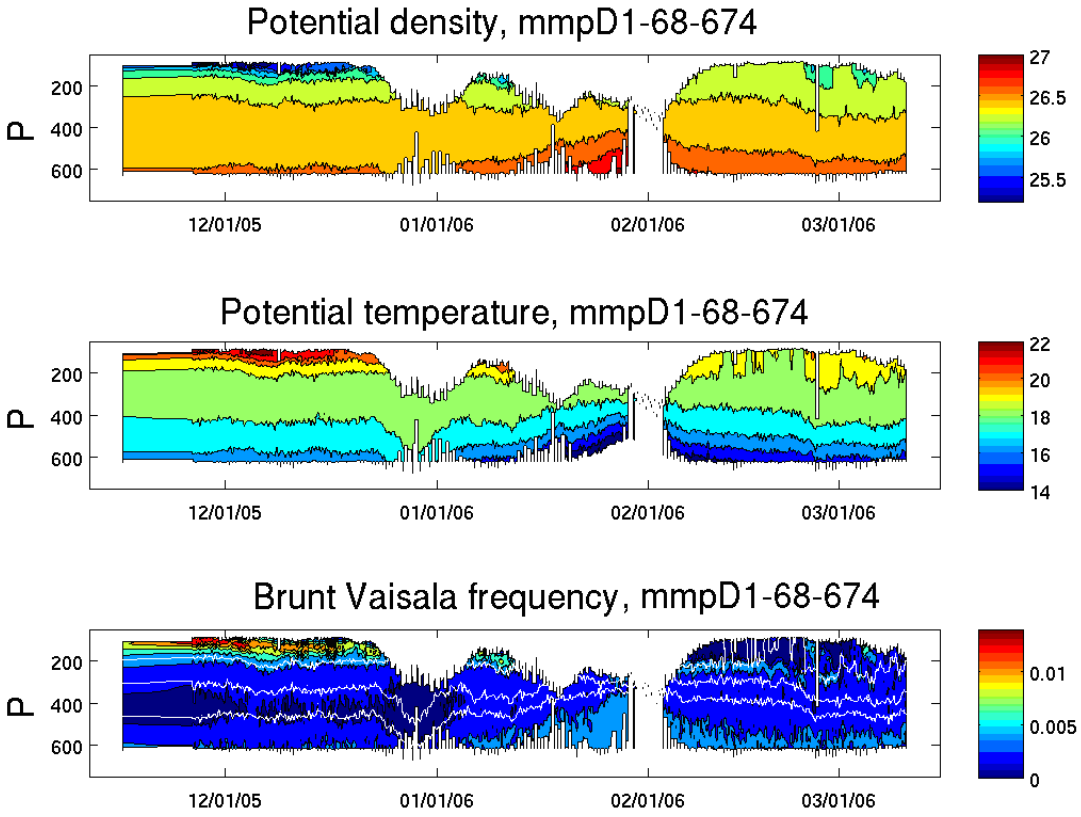

Figure D-8: Mooring D1. MMP 118 time series data, nominally 68 to 674 dbar, collected from November 15, 2005 to March 10, 2006: potential density (top, kg/m^3), potential temperature (middle, ºC), and Brunt Vaisala frequency (bottom, 1/s). The white lines are 18ºC, 18.5 ºC and 19 ºC isotherms.

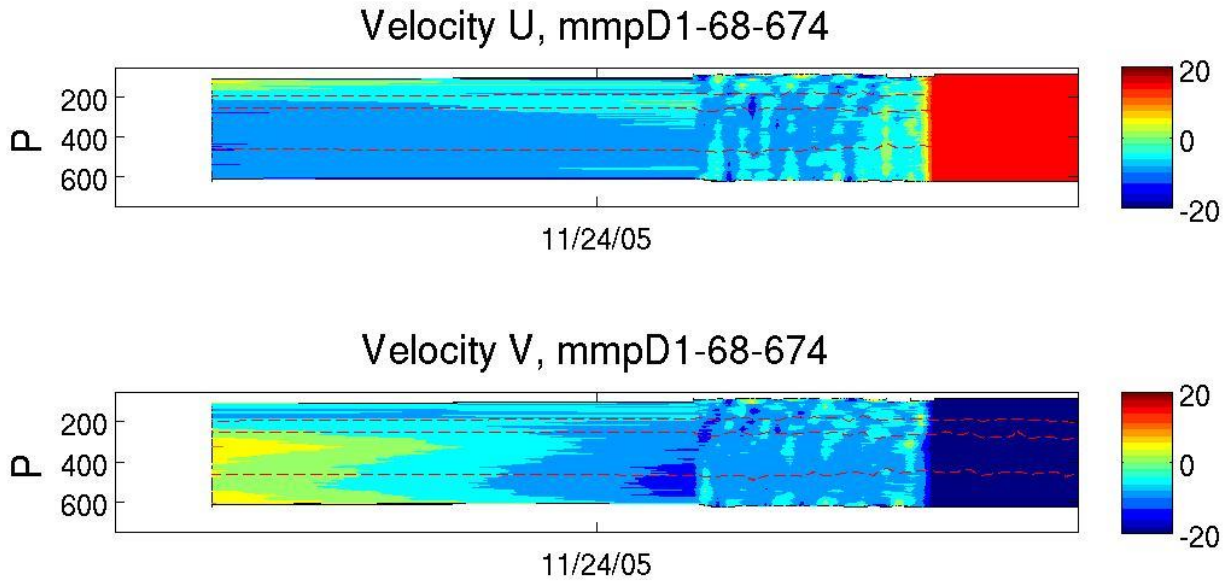

Figure D-9: Mooring D1. MMP 118 time series data, nominally 68 to 674 dbar, collected from November 15, 2005 to March 10, 2006: velocity U (top, cm/s) and velocity V (bottom, cm/s). The red dashed lines in bottom panel are 18°C, 18.5°C, and 19°C isotherms.

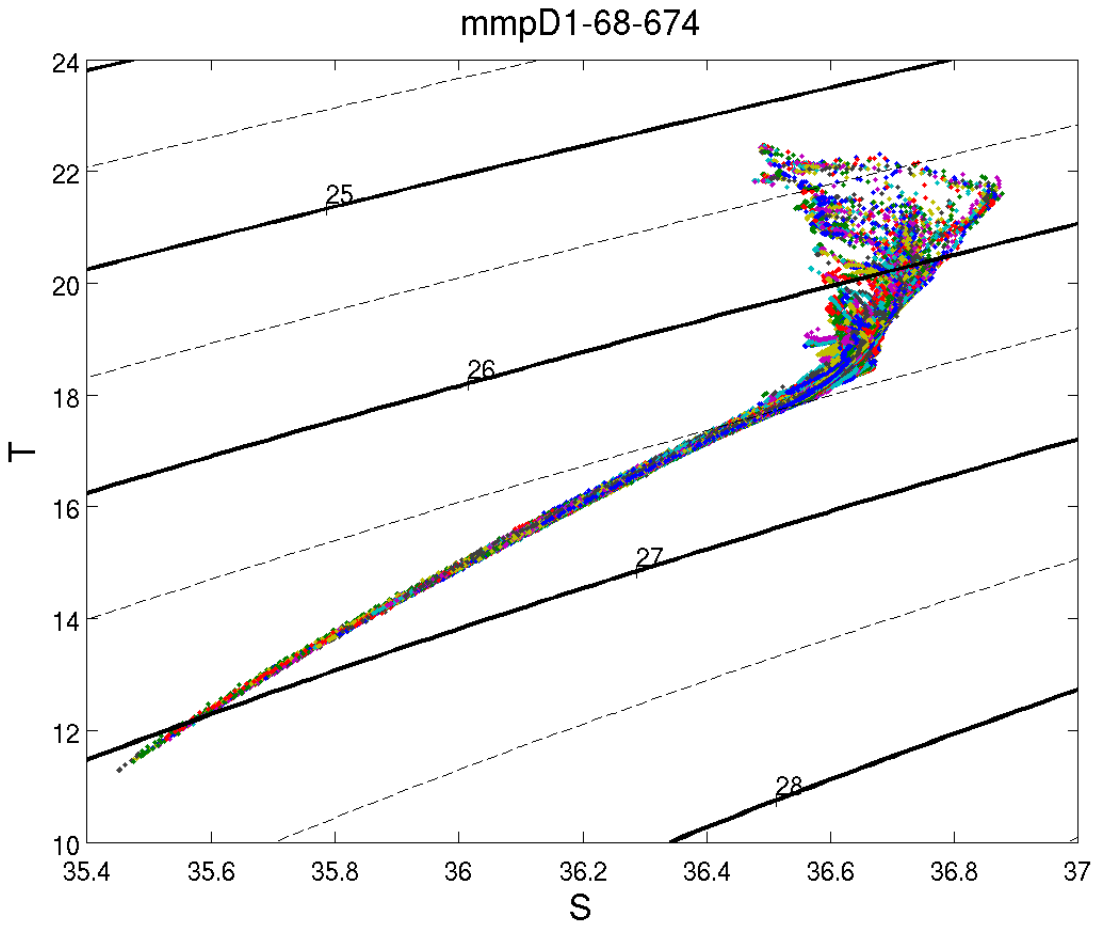

Figure D-10: Mooring D1. T/S properties of the sea water for MMP 118, nominally 68 to 674 dbars, collected from November 15, 2005 to March 10, 2006.

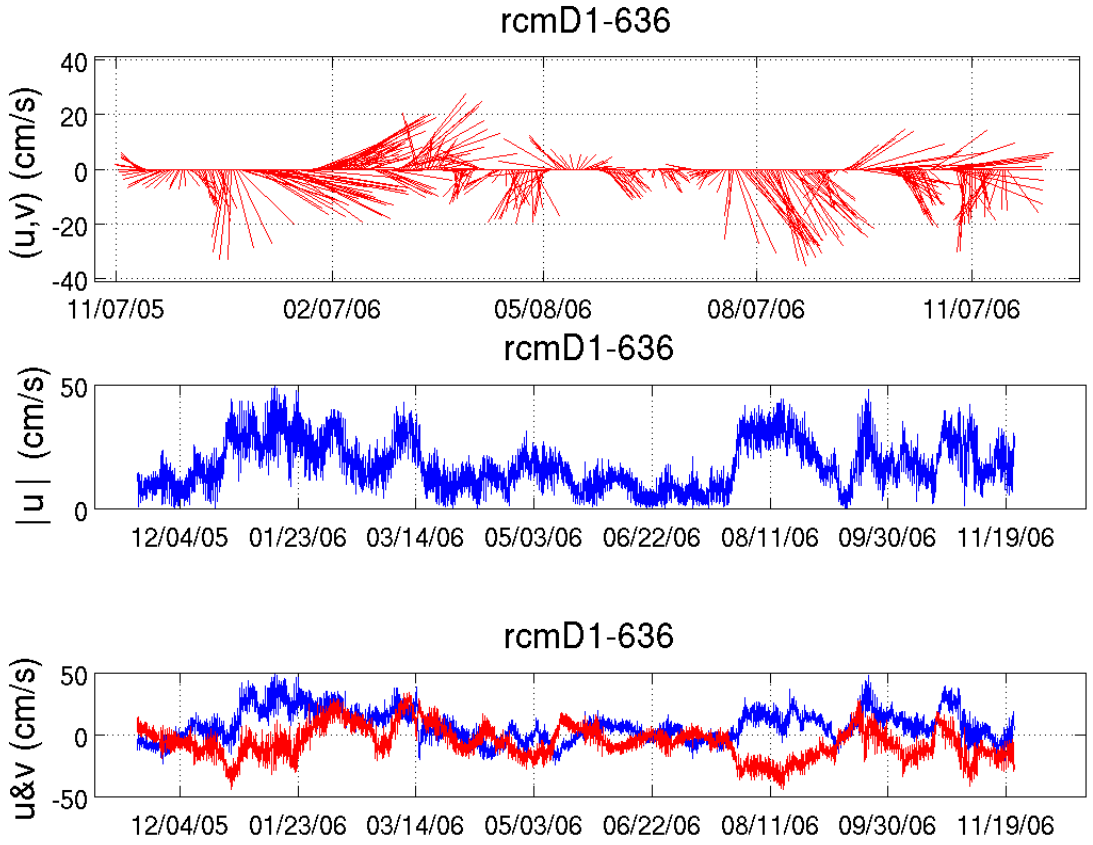

Figure D-11: Mooring D1. Aanderaa RCM 159 daily averaged time series data, nominally 636 meters, collected from November 15, 2005 to November 22, 2006: velocity stick plot (top, cm/s), velocity speed (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

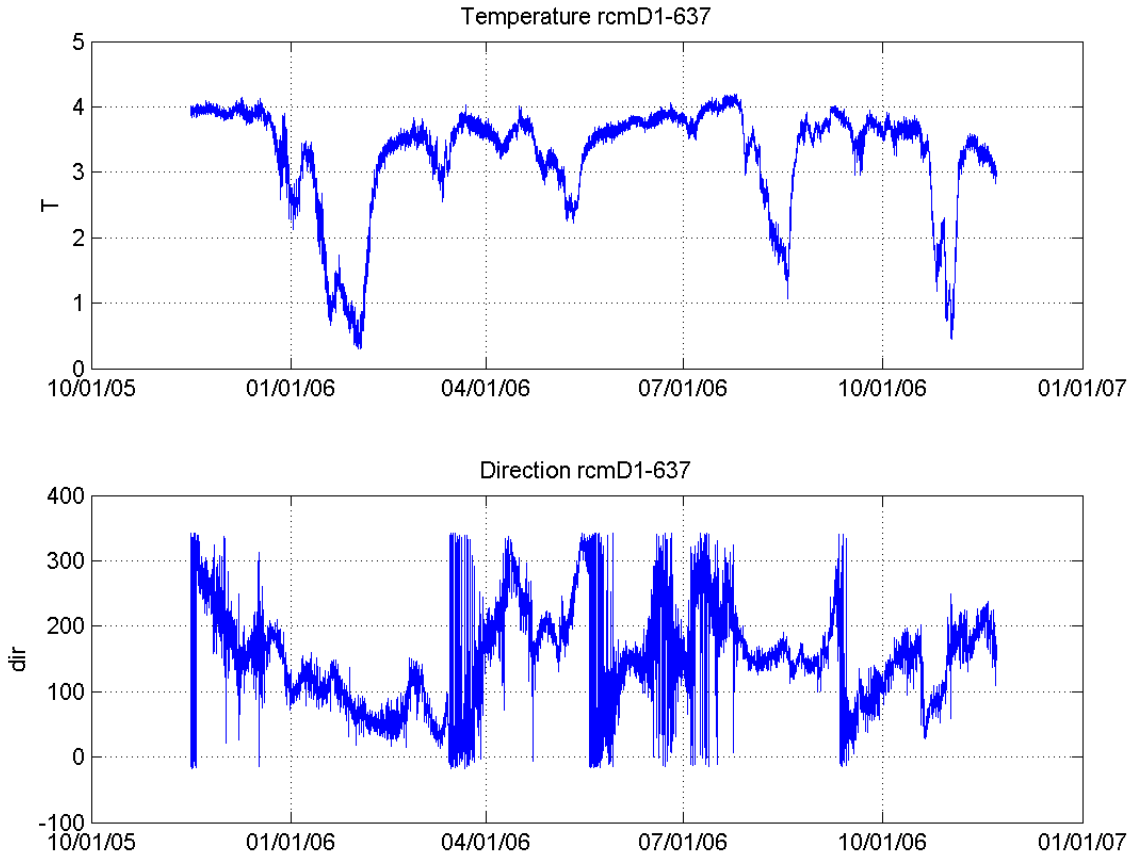

Figure D-12: Mooring D1. Aanderaa RCM 159 daily averaged time series data, nominally 636 meters, collected from November 15, 2005 to November 22, 2006: temperature (top, °C) and current direction (bottom, degrees). The corresponding SBE37 2045, nominally 633 meters, did not record salinity.

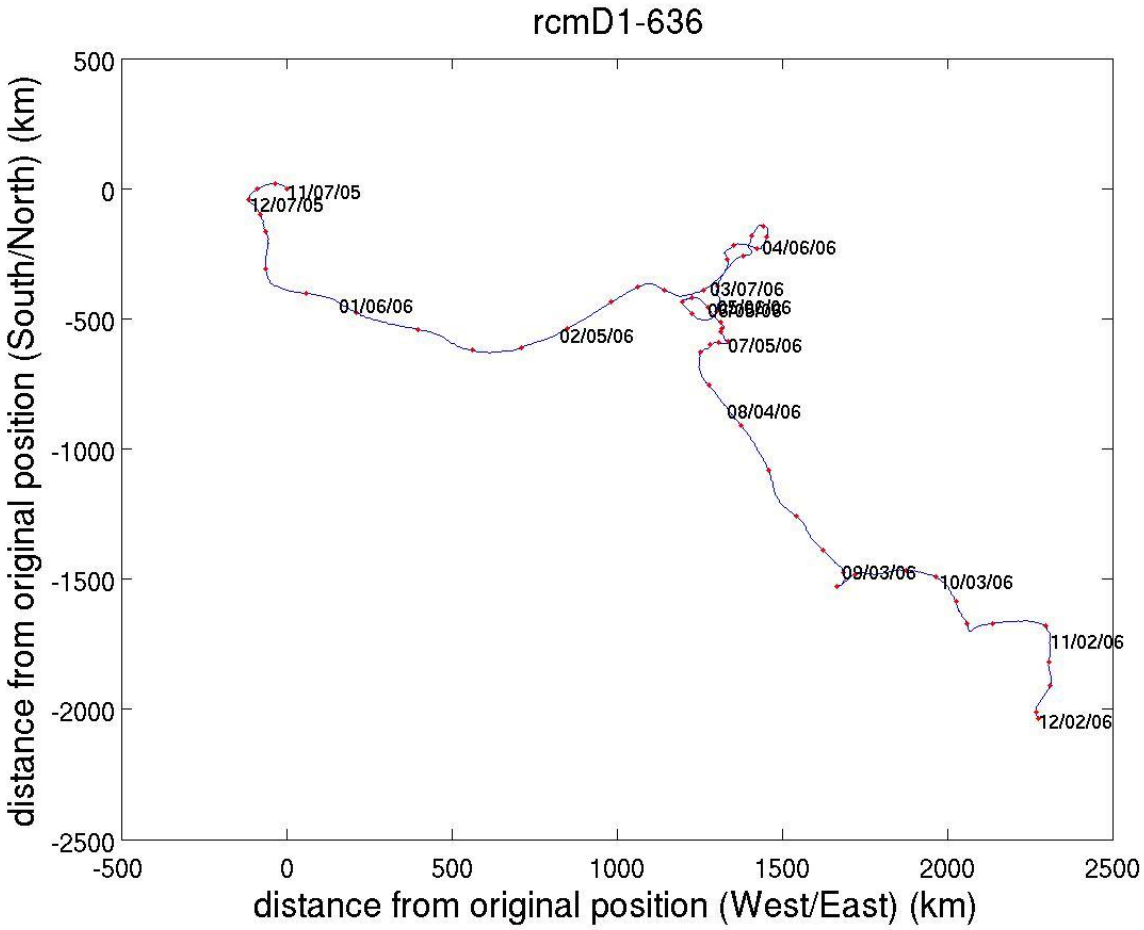

Figure D-13: Mooring D1. Progressive vector diagram of current data measured by Aanderaa RCM 159, nominally at 637 meters collected from November 15, 2005 to November 22, 2006. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

Appendix E: Mooring C2 time series plots 2006 – 2007

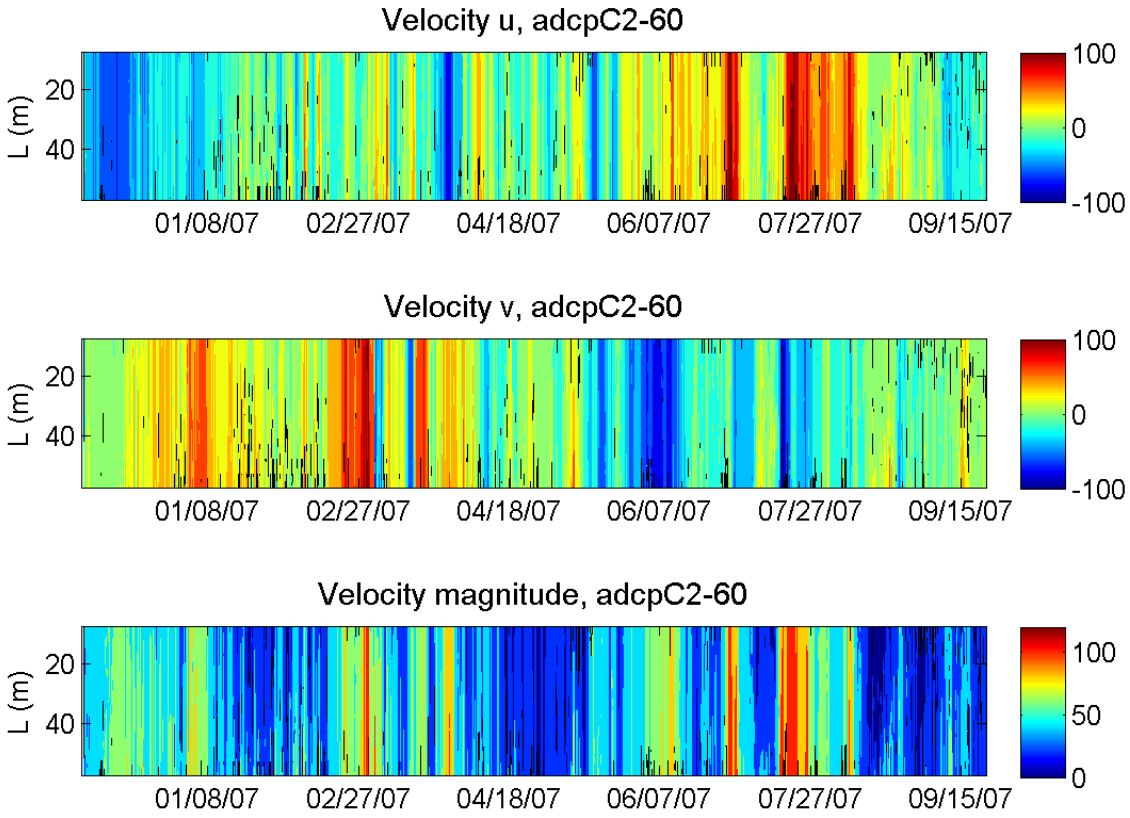

Figure E-1: Mooring C2. ADCP 2222 time series data, nominally 60 meters, collected from November 26, 2006 to November 9, 2007: velocity U (top, cm/s), V (middle, cm/s), and velocity magnitude (bottom, cm/s).

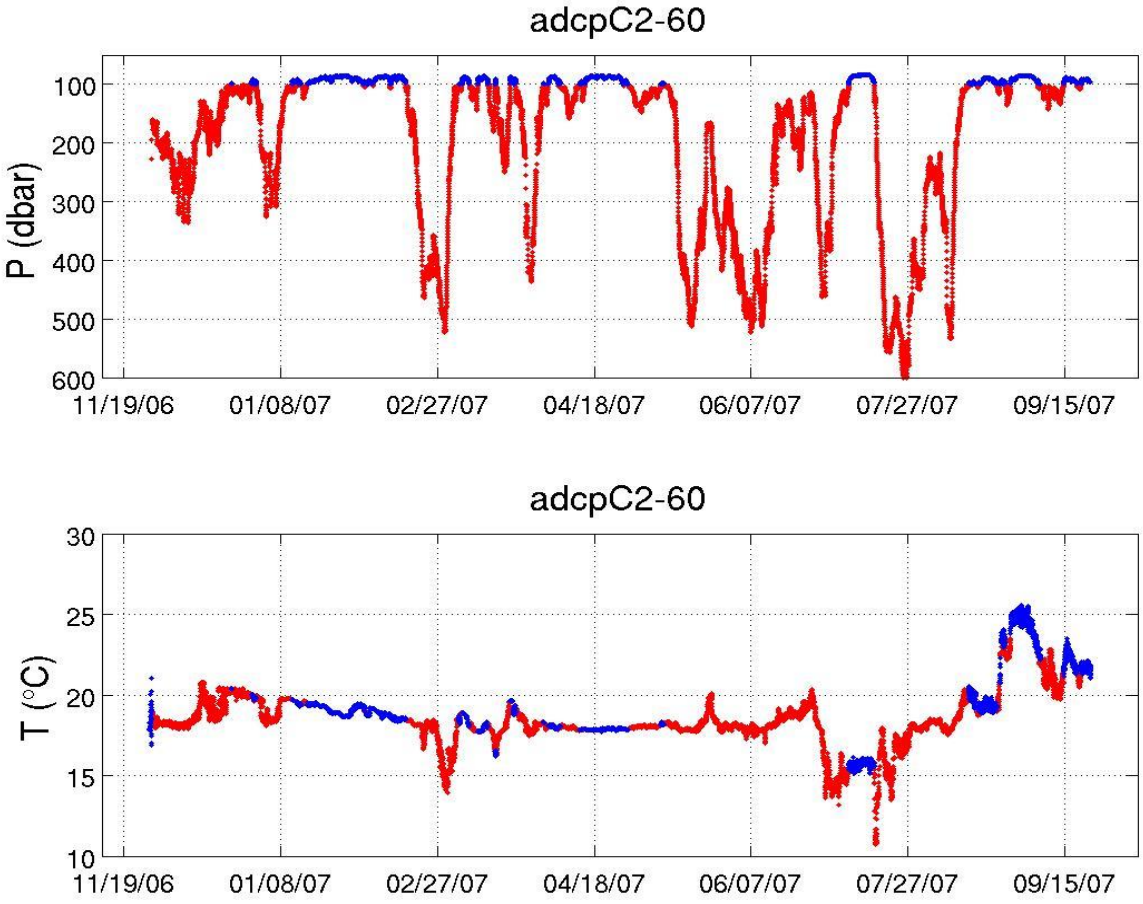

Figure E-2: Mooring C2: ADCP 2222 time series data, nominally 60 meters, collected from November 26, 2006 to November 9, 2007: pressure (top, dbar) and temperature (bottom, °C). The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

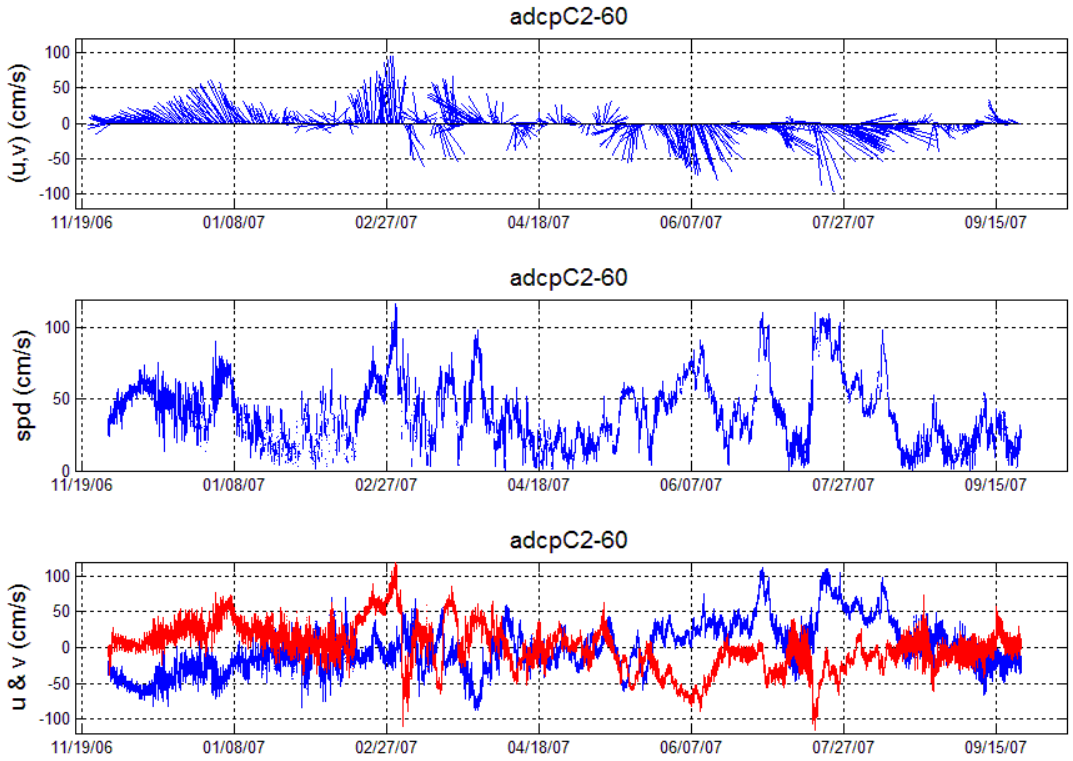

Figure E-3: Mooring C2. ADCP 2222 time series data, nominally 60 meters, collected from November 26, 2006 to November 9, 2007: velocity stick plot (top, cm/s), velocity magnitude (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

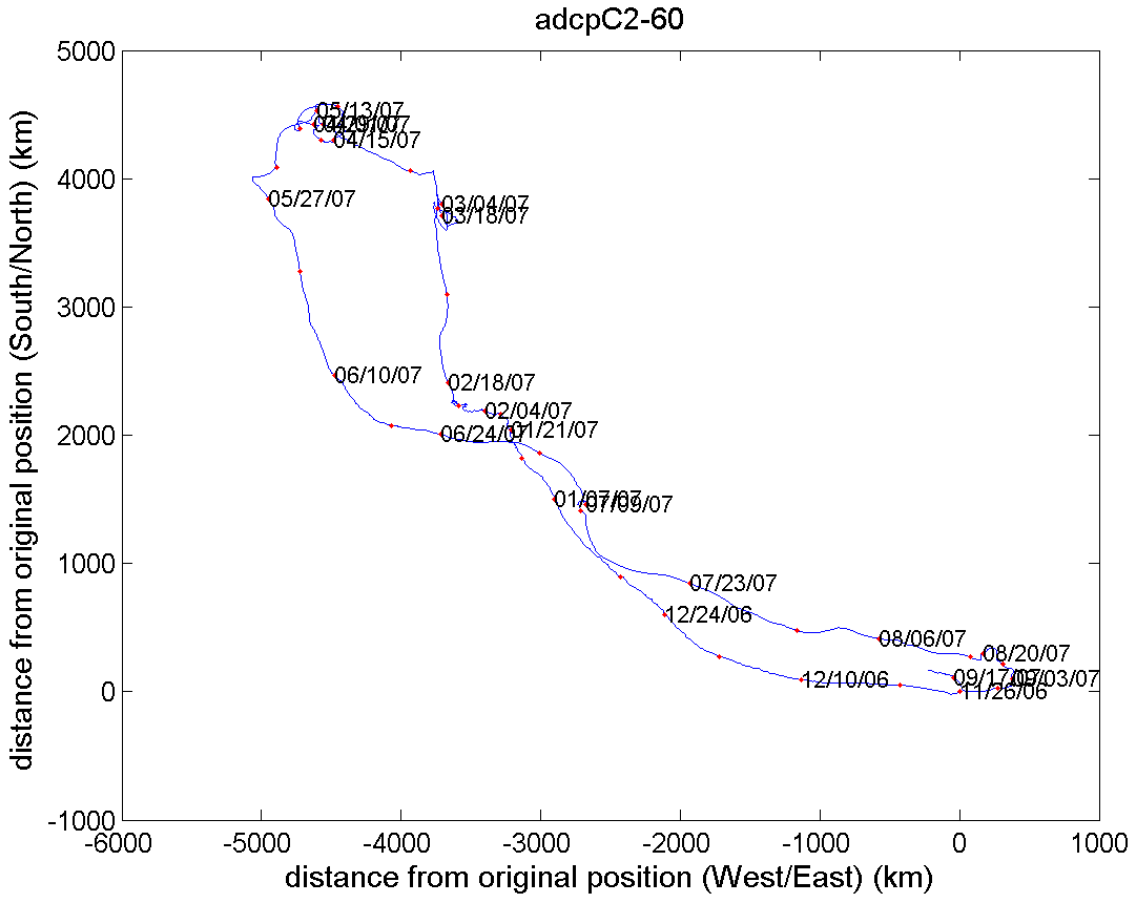

Figure E-4: Mooring C2. Progressive vector diagram of current data measured by ADCP SN 2222, nominally 60 meters collected from November 26, 2006 to November 9, 2007. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

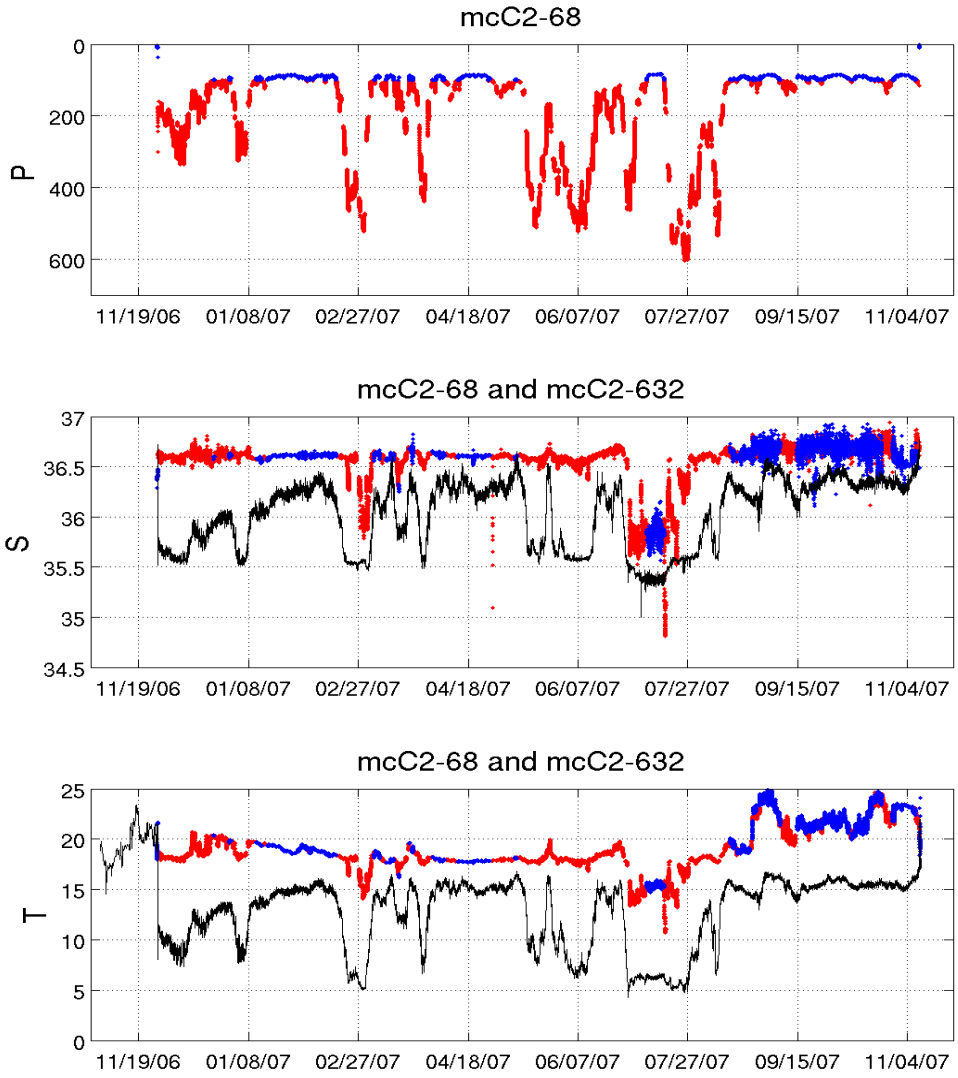

Figure E-5: Mooring C2. SBE37 2140, nominally 68 meters, and SBE37 2031, nominally 632 meters, time series data collected from November 26, 2006 to November 9, 2007: SN2140 pressure (top, dbar), SN2140 & SN 2031 salinity (middle, psu), and SN2140 & SN 2031 temperature (bottom, °C). SN2140 plotted in red and blue, where the red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar. SN2031 plotted in black.

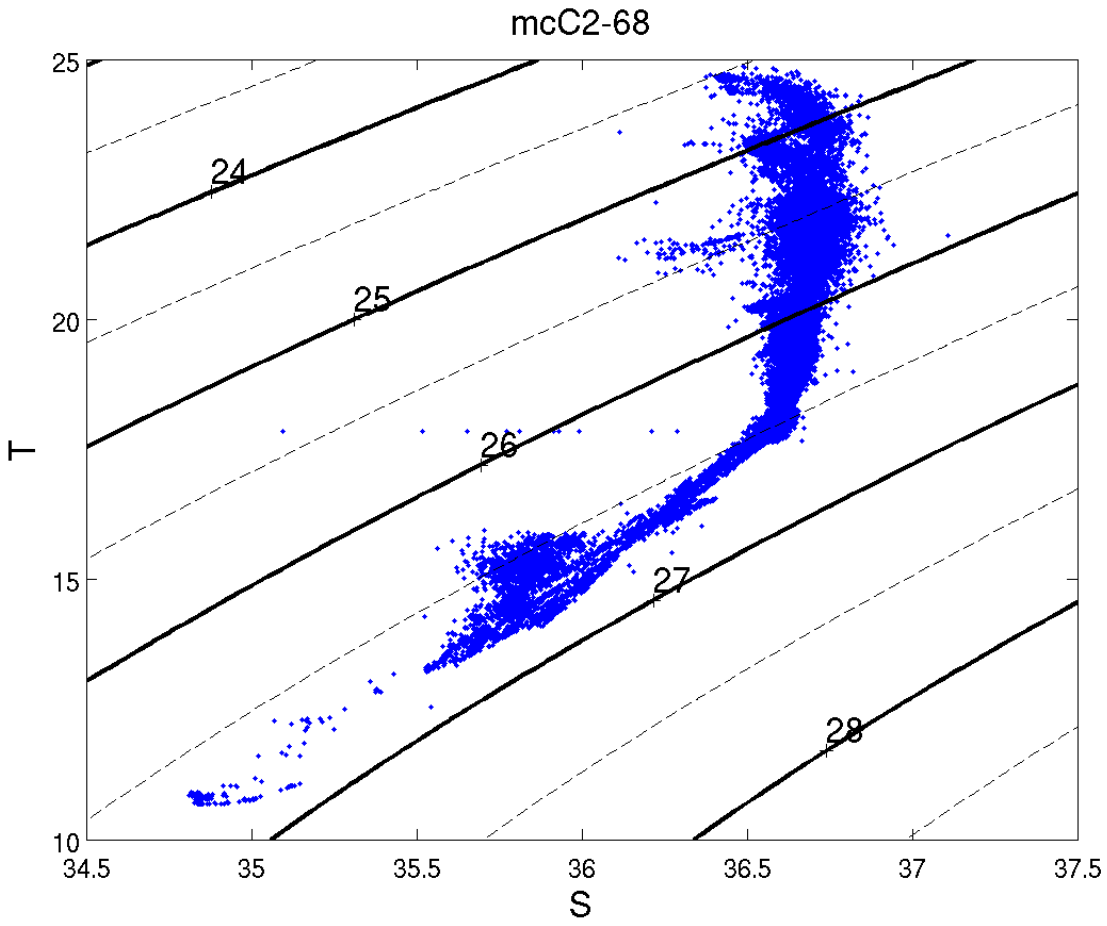

Figure E-6: Mooring C2. T/S properties of the sea water for SBE 2140, nominally 68 meters, collected from November 27, 2006 to November 9, 2007.

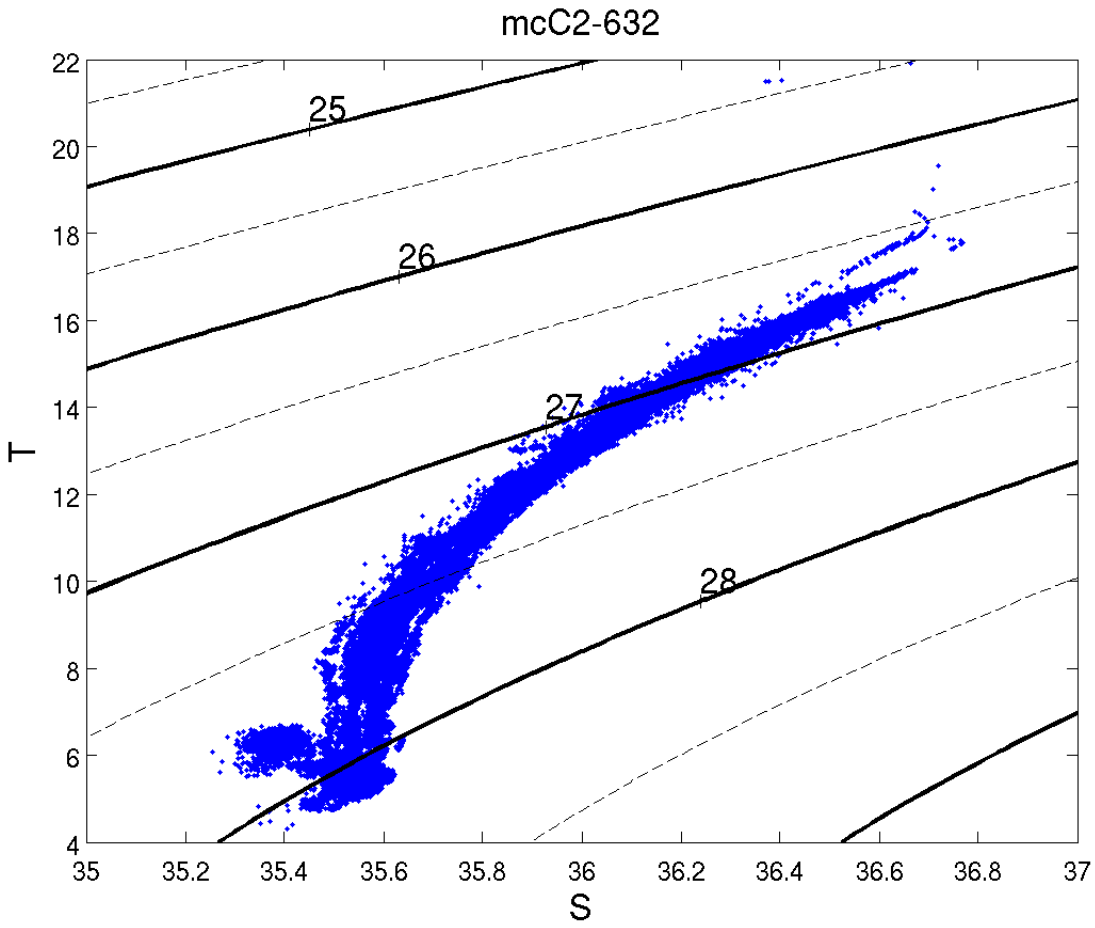

Figure E-7: Mooring C2. T/S properties of the sea water for SBE 2031, nominally 632 meters, collected from November 27, 2006 to November 9, 2007.

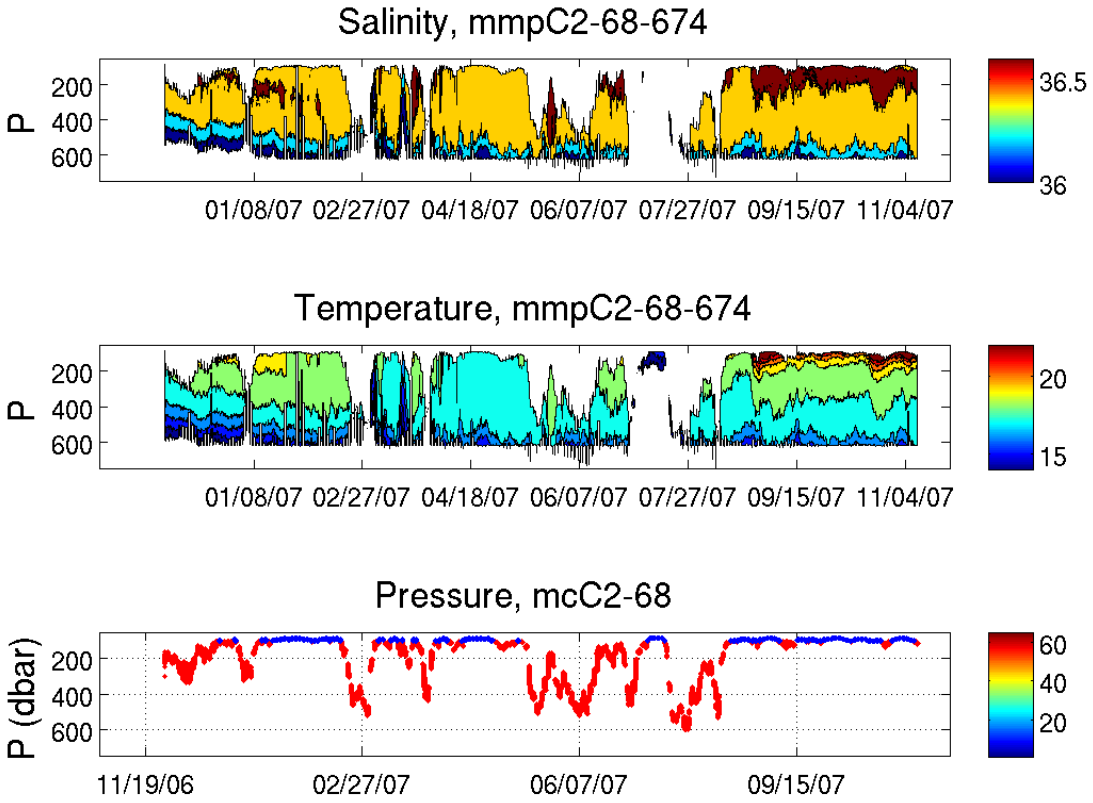

Figure E-8: Mooring C2. MMP 112 time series data, nominally 68 to 674 dbar, collected from November 26, 2006 to November 9, 2007: salinity (top, psu) and temperature (middle, °C). Corresponding SBE37 2140, nominally 68 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

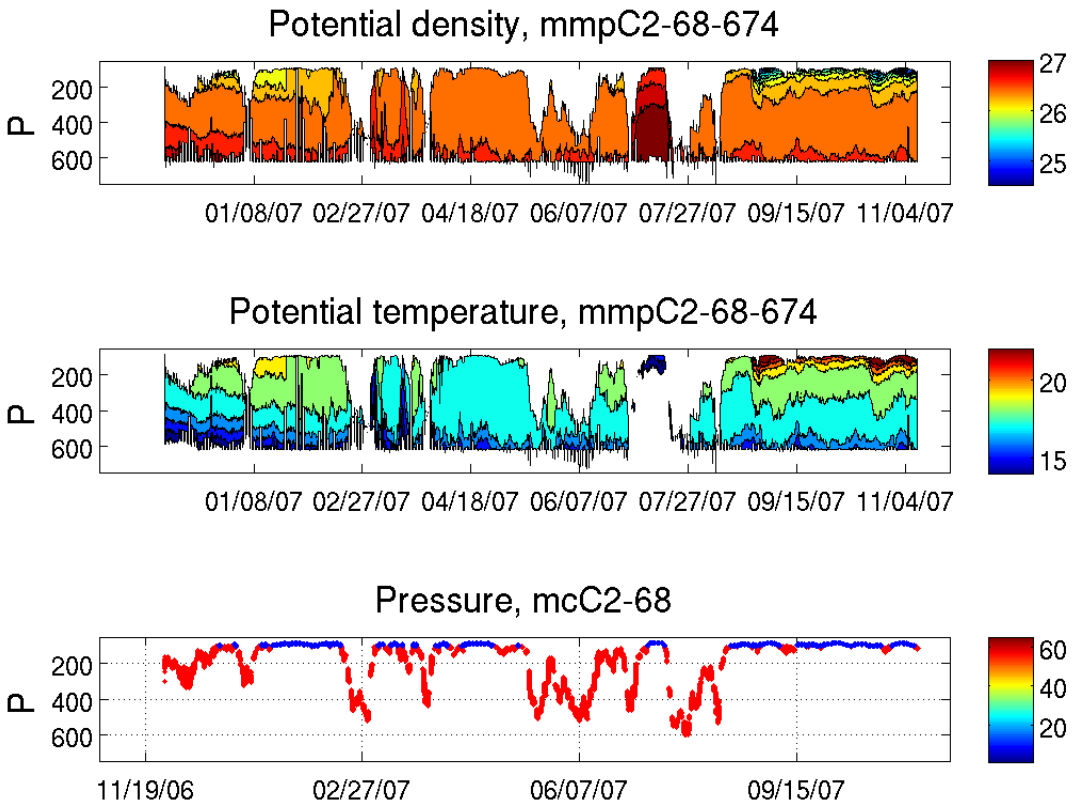

Figure E-9: Mooring C2. MMP 112 time series data, nominally 68 to 674 dbar, collected from November 26, 2006 to November 9, 2007: potential density (top, kg/m^3), potential temperature (middle, °C). Corresponding SBE37 2140, nominally 68 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

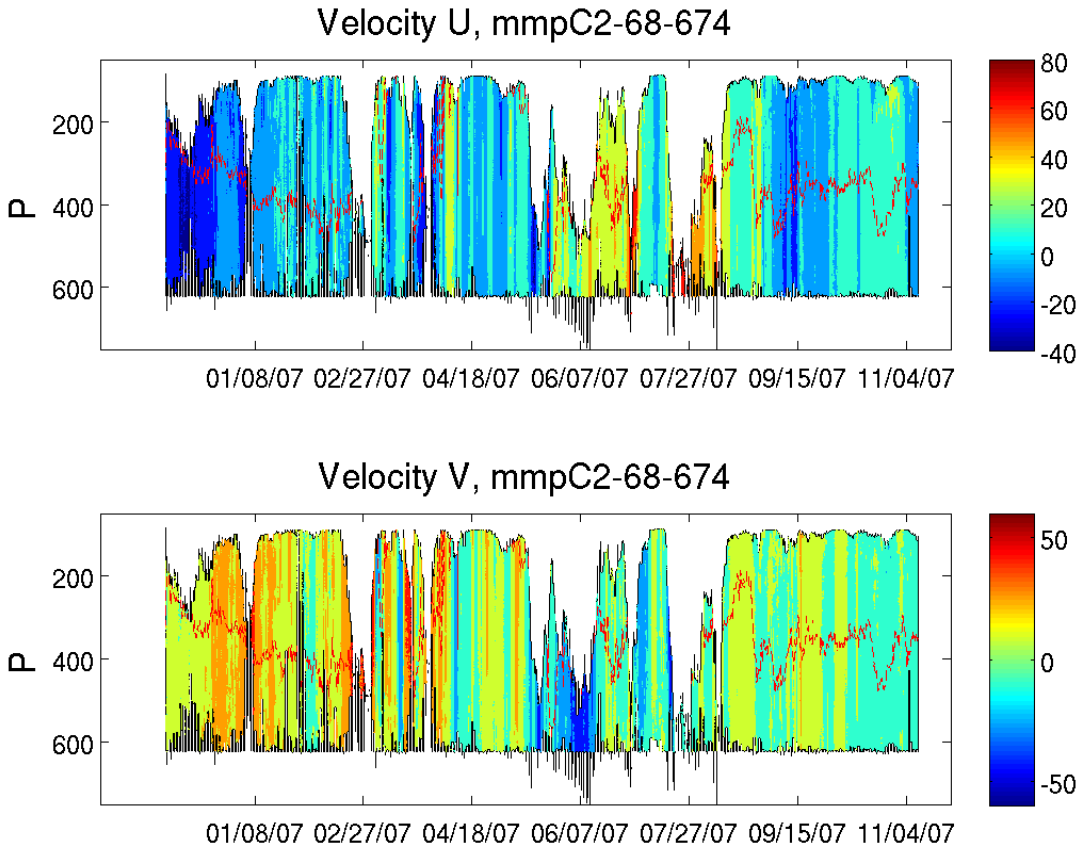

Figure E-10: Mooring C2. MMP 112 time series data, nominally 68 to 674 dbar, collected from November 26, 2006 to November 9, 2007: velocity U (top, cm/s), velocity V (bottom, cm/s). The red dashed lines are 18°C isotherms.

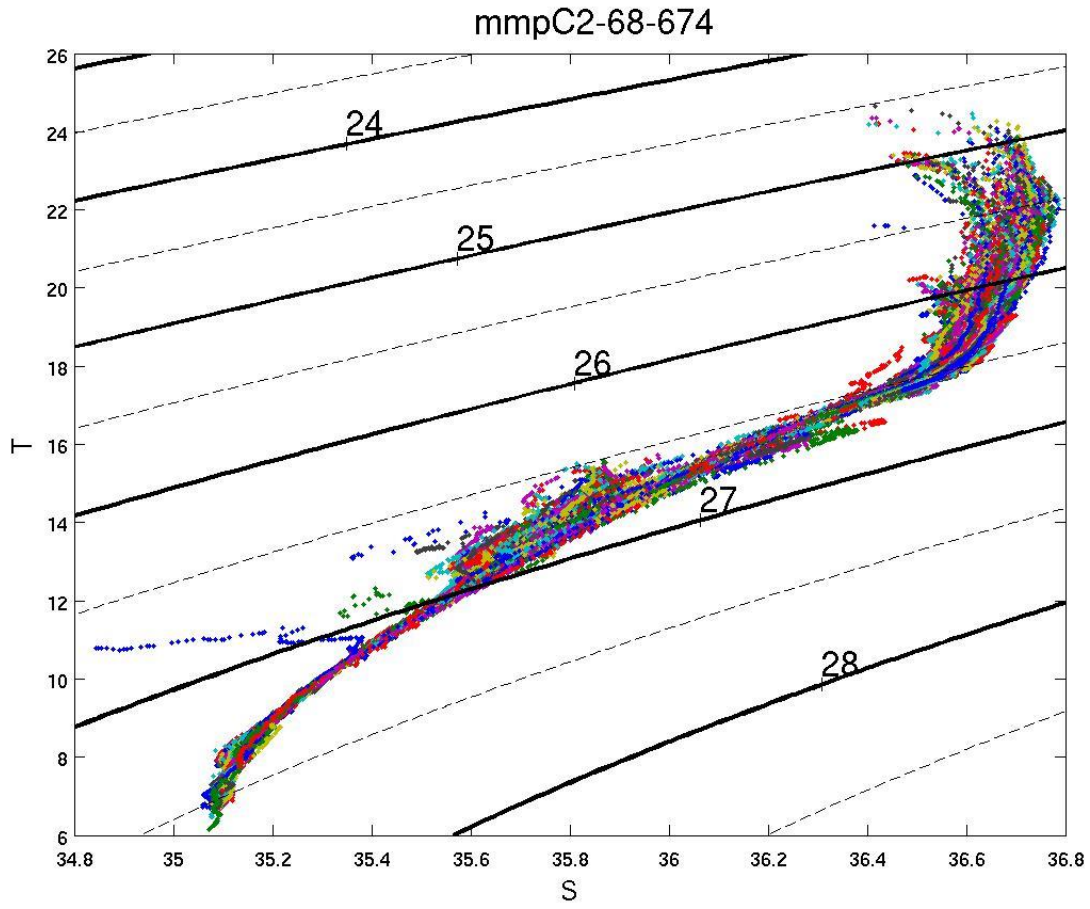

Figure E-11: Mooring C2. T/S properties of the sea water for MMP SN 112, nominally 68 to 674 dbar, collected from November 26, 2006 to November 9, 2007.

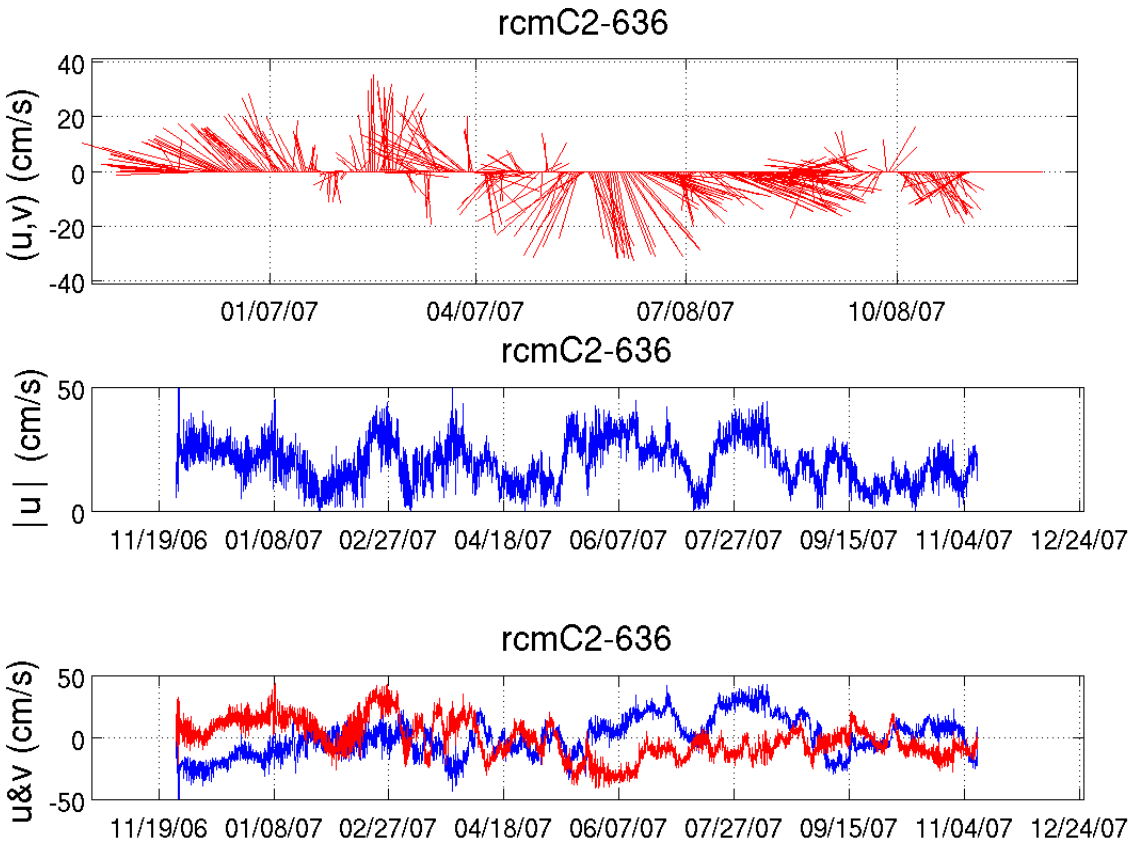

Figure E-12: Mooring C2. Aanderaa RCM 148 daily averaged time series data, nominally 636 meters, collected from November 126, 2006 to November 9, 2007: velocity stick plot (top, cm/s), velocity speed (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

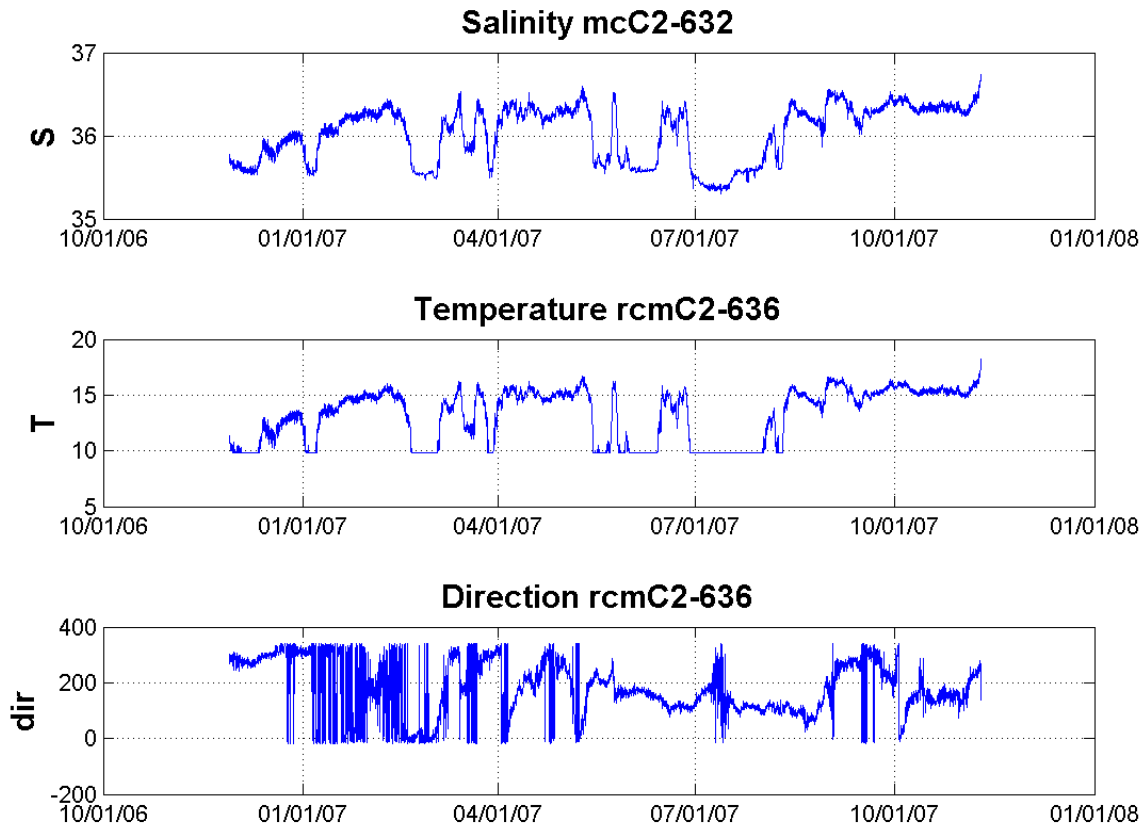

Figure E-13: Mooring C2. SBE37 2031, nominally 632 meters, daily averaged salinity (top, psu) and Aanderaa RCM 148 daily averaged time series data, nominally 636 meters, temperature (middle, °C), and current direction (bottom, degrees). Both collected from November 23, 2006 to November 9, 2007

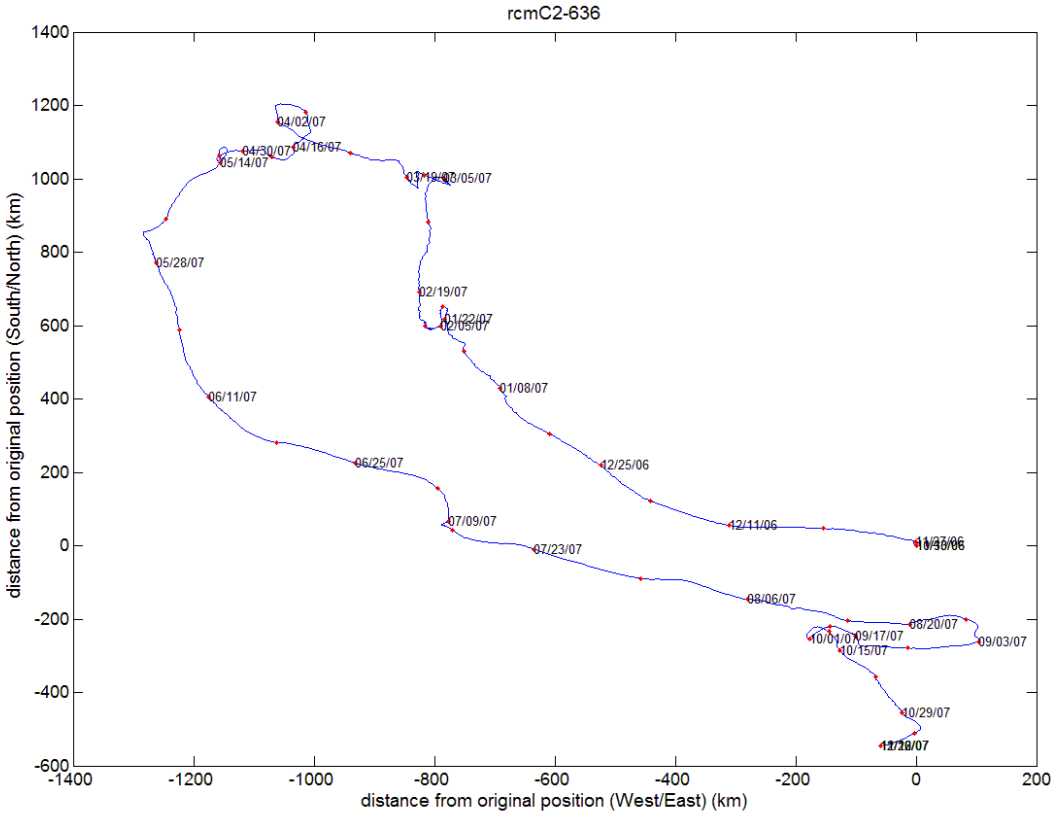

Figure E-14: Mooring C2. Progressive vector diagram of current data measured by Aanderaa RCM 148, nominally 636 meters, collected from November 26, 2006 to November 9, 2007. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

Appendix F: Mooring D2 time series plots 2006 – 2007

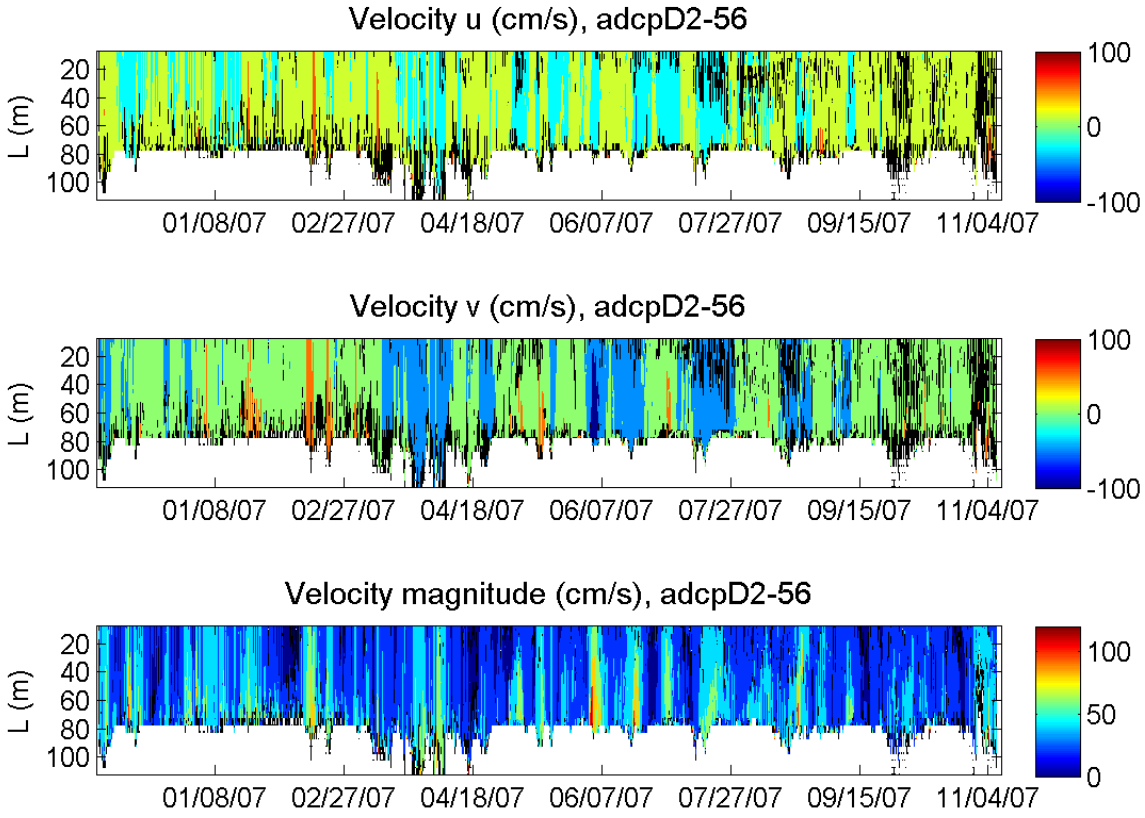

Figure F-1: Mooring D2. ADCP 2225 time series data, nominally 56 meters, collected from November 23, 2006 to November 7, 2007: velocity U (top, cm/s), velocity V (middle, cm/s), and velocity magnitude (bottom, cm/s).

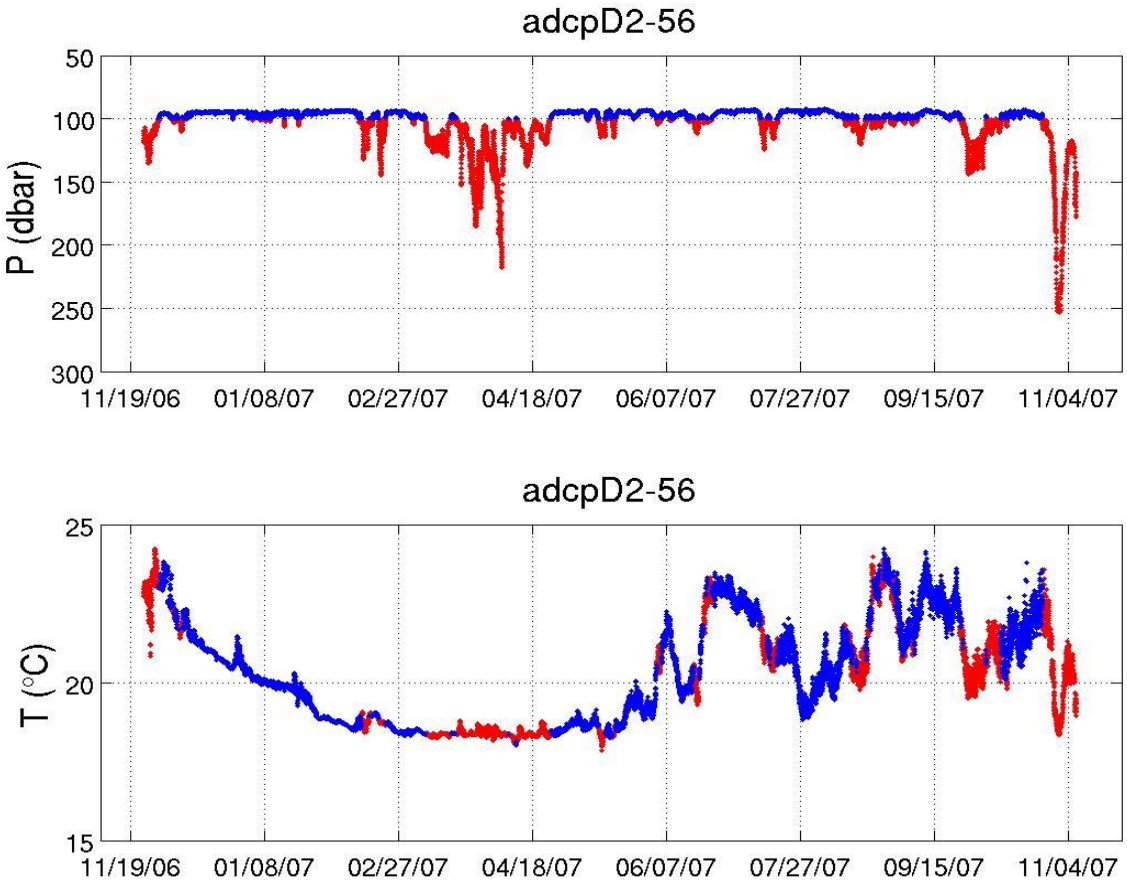

Figure F-2: Mooring D2. ADCP 2225 time series data, nominally 56 meters, collected from November 23, 2006 to November 7, 2007: pressure (top, dbar) and temperature (bottom, °C). The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

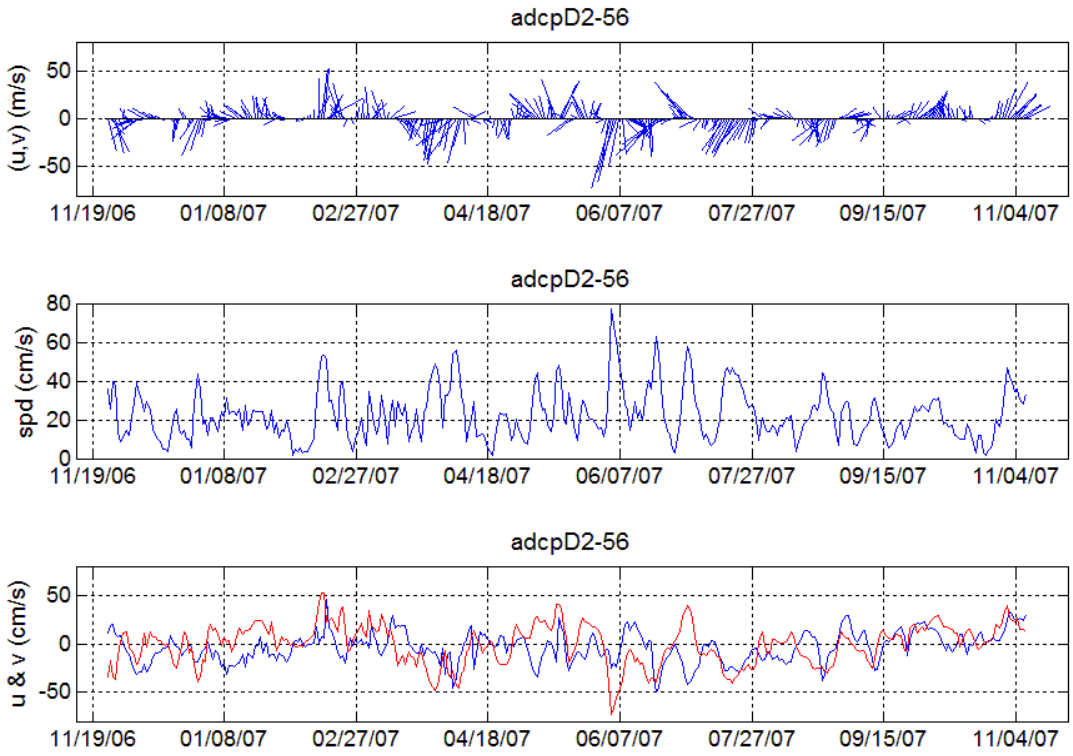

Figure F-3: Mooring D2. ADCP 2225 time series data, nominally 56 meters, collected from November 23, 2006 to November 7, 2007: velocity stick plot (top, cm/s), velocity magnitude (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

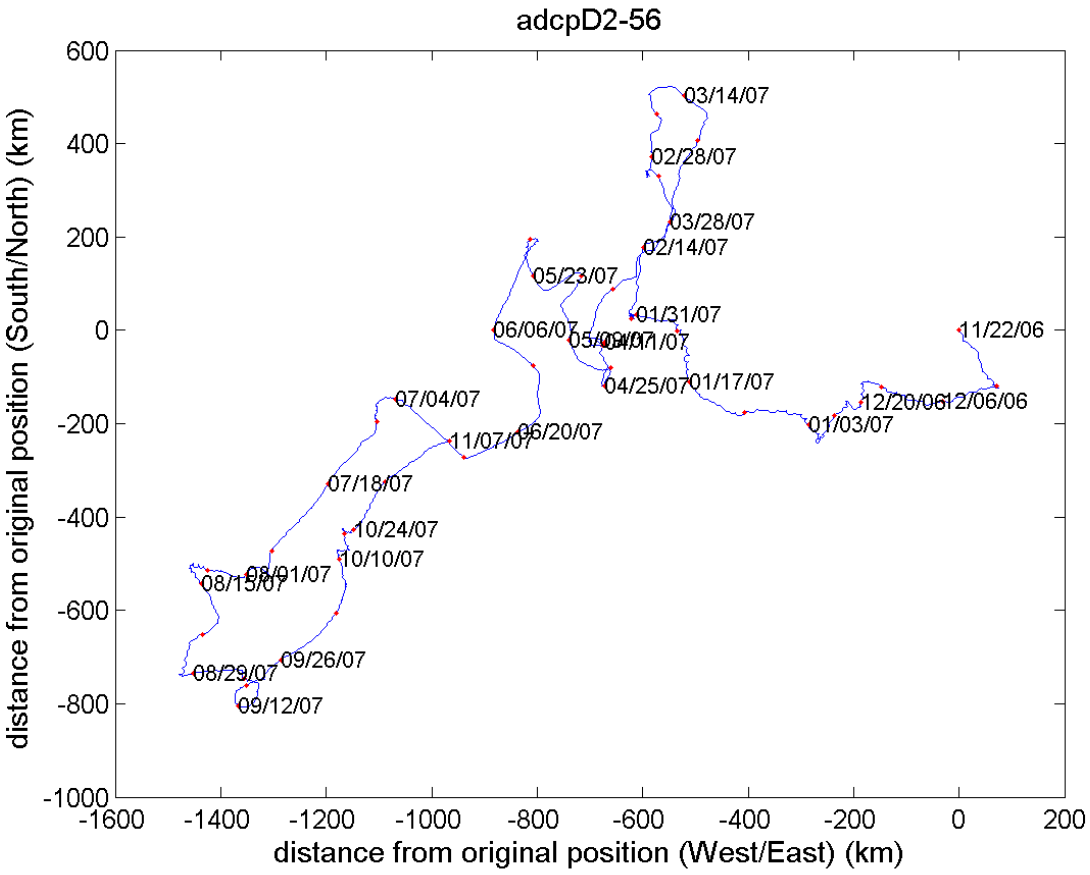

Figure F-4: Mooring D2. Progressive vector diagram of current data measured ADCP 2225, nominally 56 meters, collected from November 23, 2006 to November 7, 2007. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

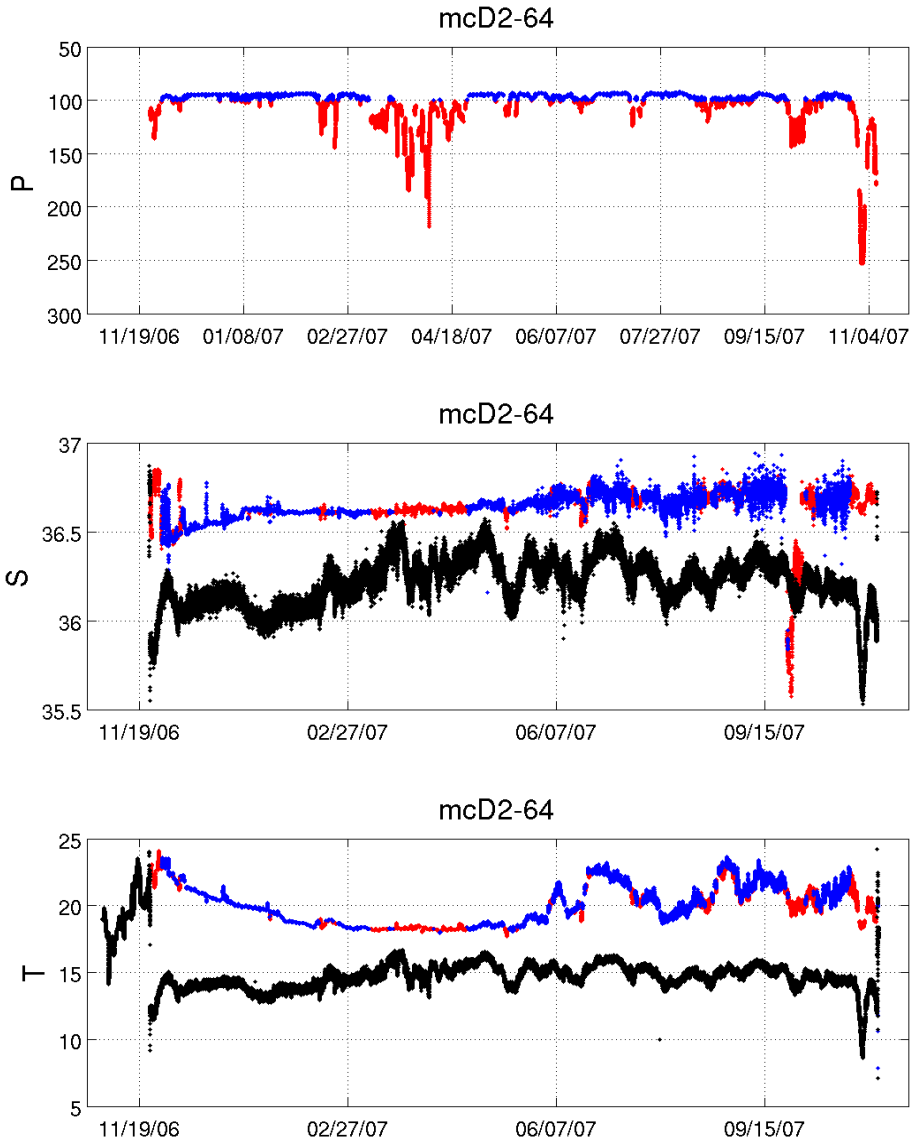

Figure F-5: Mooring D2. SBE37 2139, nominally 64 meters, and SBE37 1645, nominally 628 meters, time series data collected from November 23, 2006 to November 7, 2007: SN2139 pressure (top, dbar), SN2139 & SN1645 salinity (middle, psu), and SN2139 & SN1645 temperature (bottom, ºC). SN2139 plotted in red and blue, where the red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar. SN1645 plotted in black.

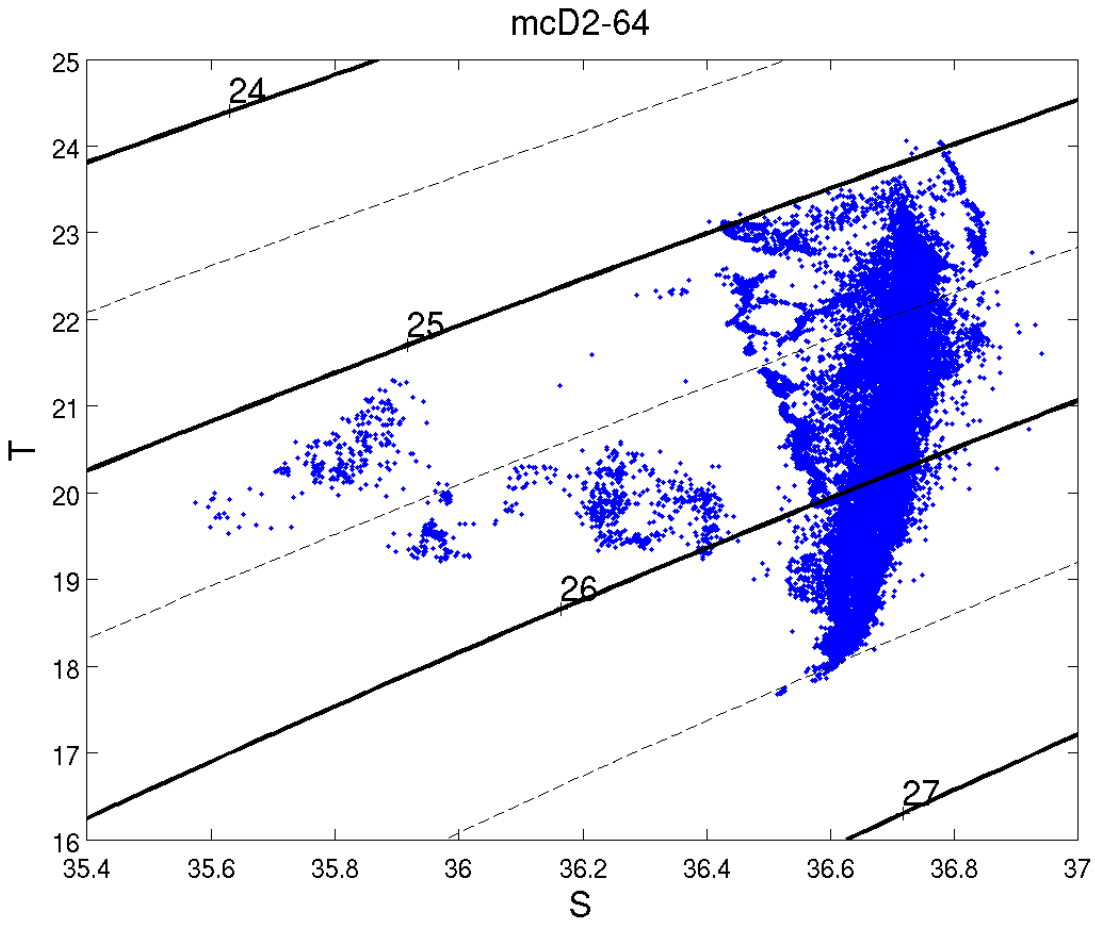

Figure F-6: Mooring D2. T/S properties of the sea water for SBE37 2139, nominally 64 meters, collected from November 23, 2006 to November 7, 2007.

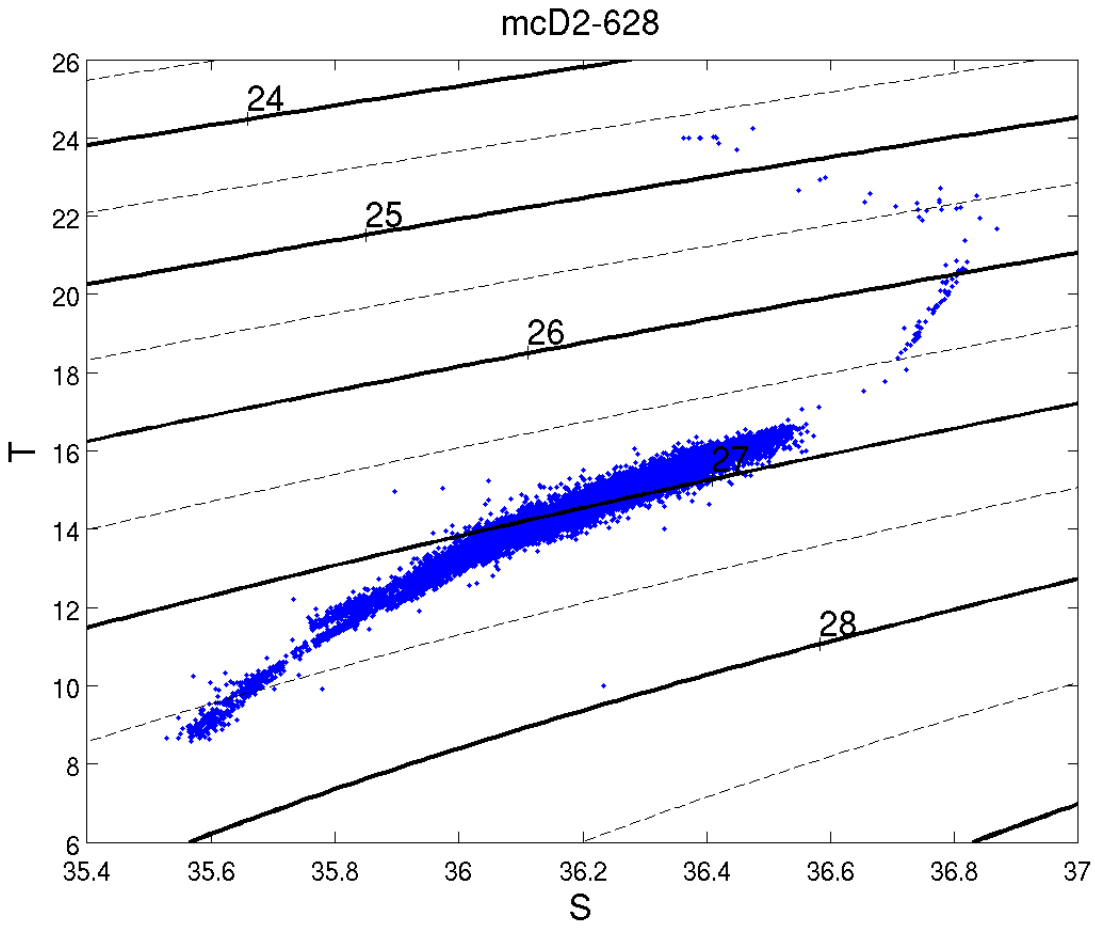

Figure F-7: Mooring D2. T/S properties of the sea water for SBE37 1645, nominally 628 meters, collected from November 23, 2006 to November 7, 2007.

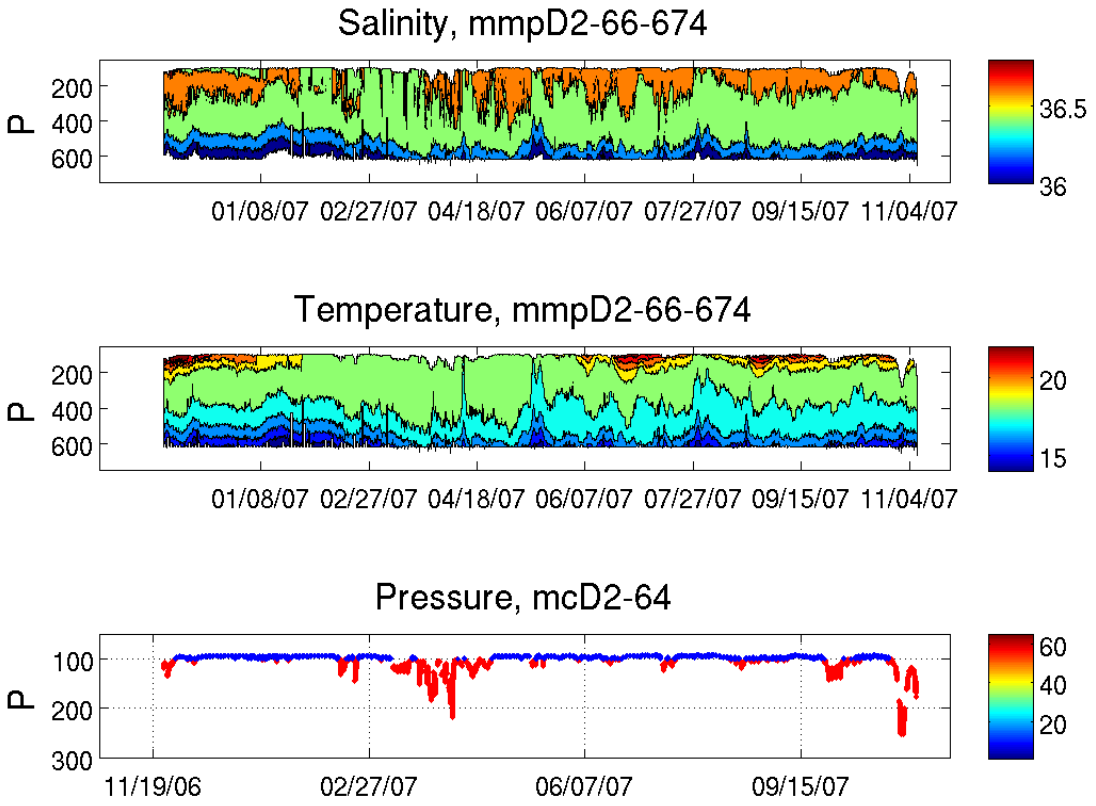

Figure F-8: Mooring D2. MMP 113 time series data, nominally 66 to 626 dbar, collected from November 23, 2006 to November 7, 2007: salinity (top, psu) and temperature (middle, °C). Corresponding SBE37 2139, nominally 64 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

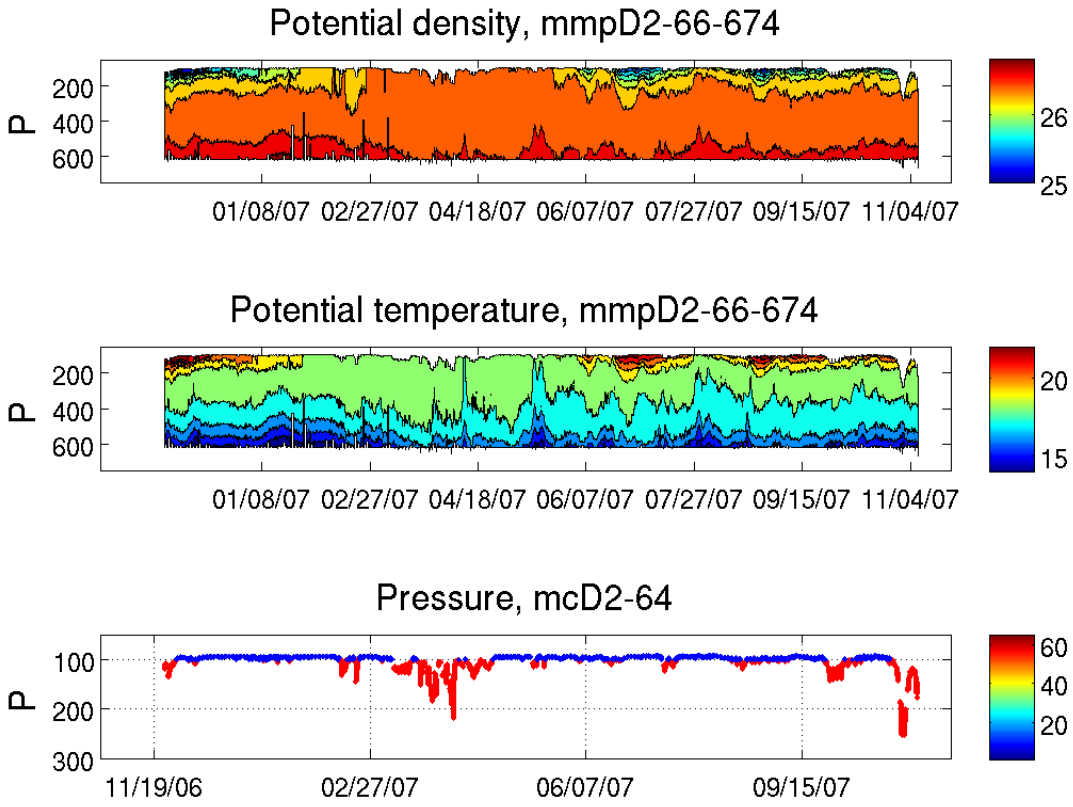

Figure F-9: Mooring D2. MMP 113 time series data, nominally 66 to 626 dbar, collected from November 26, 2006 to November 9, 2007: potential density (top, kg/m^3), potential temperature (middle, °C). Corresponding SBE37 2139, nominally 64 meters, pressure (bottom, dbar), plotted in red and blue. The red line represents the time period when the pressure is larger than 100 dbar indicating a blowdown event, and the blue represents the time period when the pressure is smaller than 100 dbar.

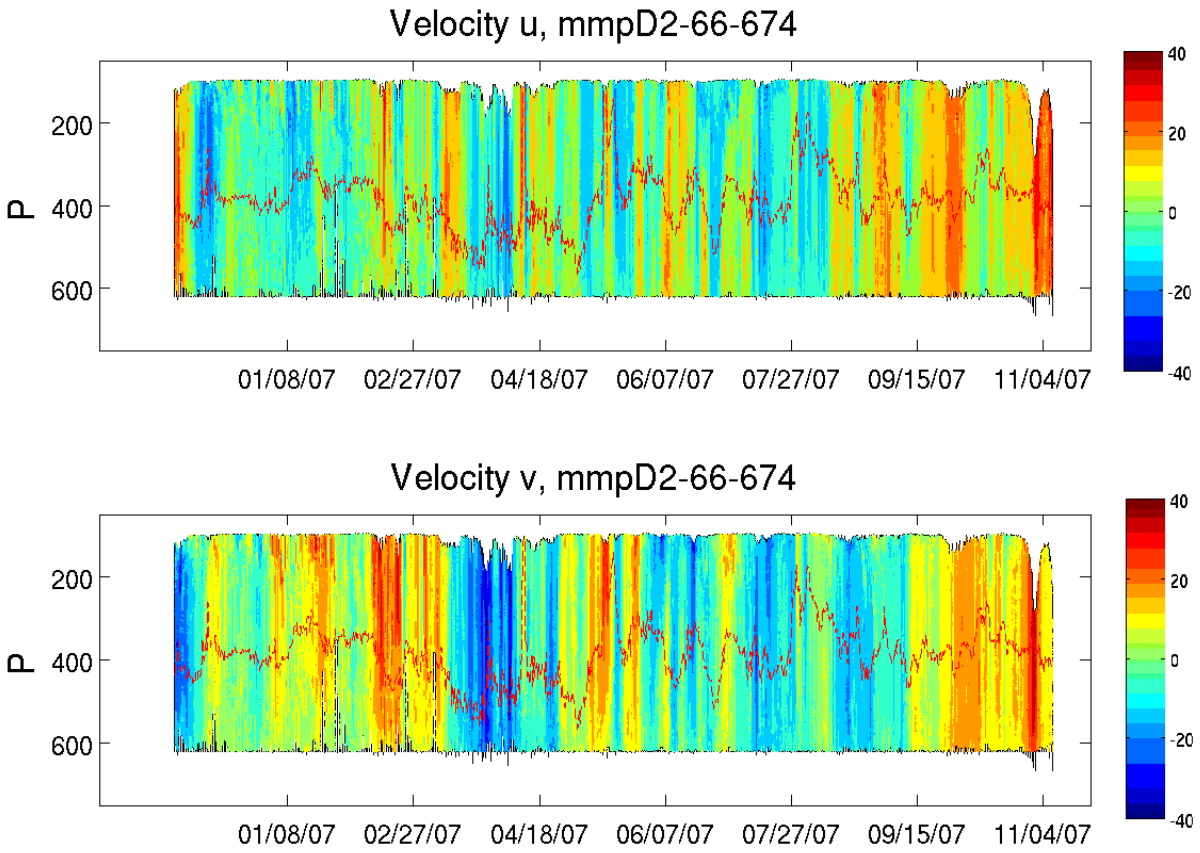

Figure F-10: Mooring D2. MMP 113 time series data, nominally 66 to 626 dbar, collected from November 26, 2006 to November 9, 2007: velocity U (top, cm/s) and velocity V (bottom, cm/s). The red dashed lines are 18°C isotherms.

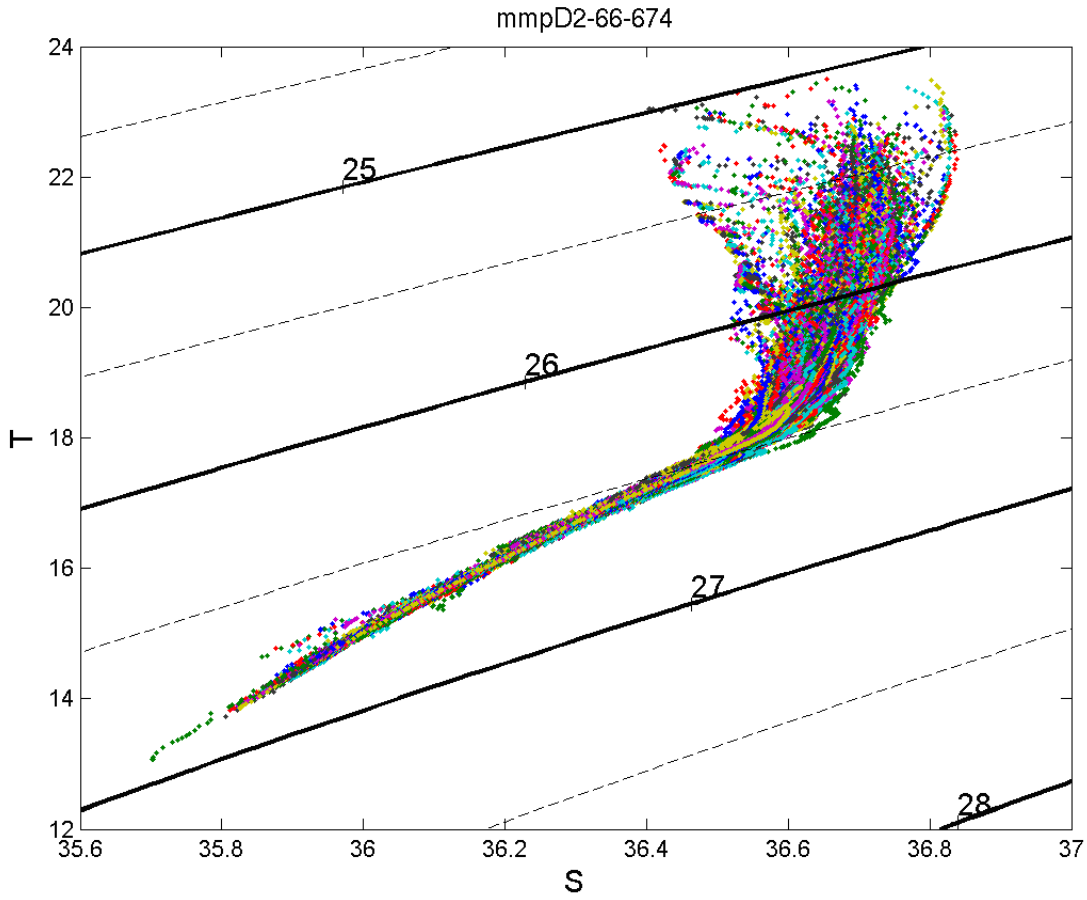

Figure F-11: Mooring D2. T/S properties of the sea water for MP 113, nominally 66 to 626 dbar, collected from November 23, 2006 to November 7, 2007.

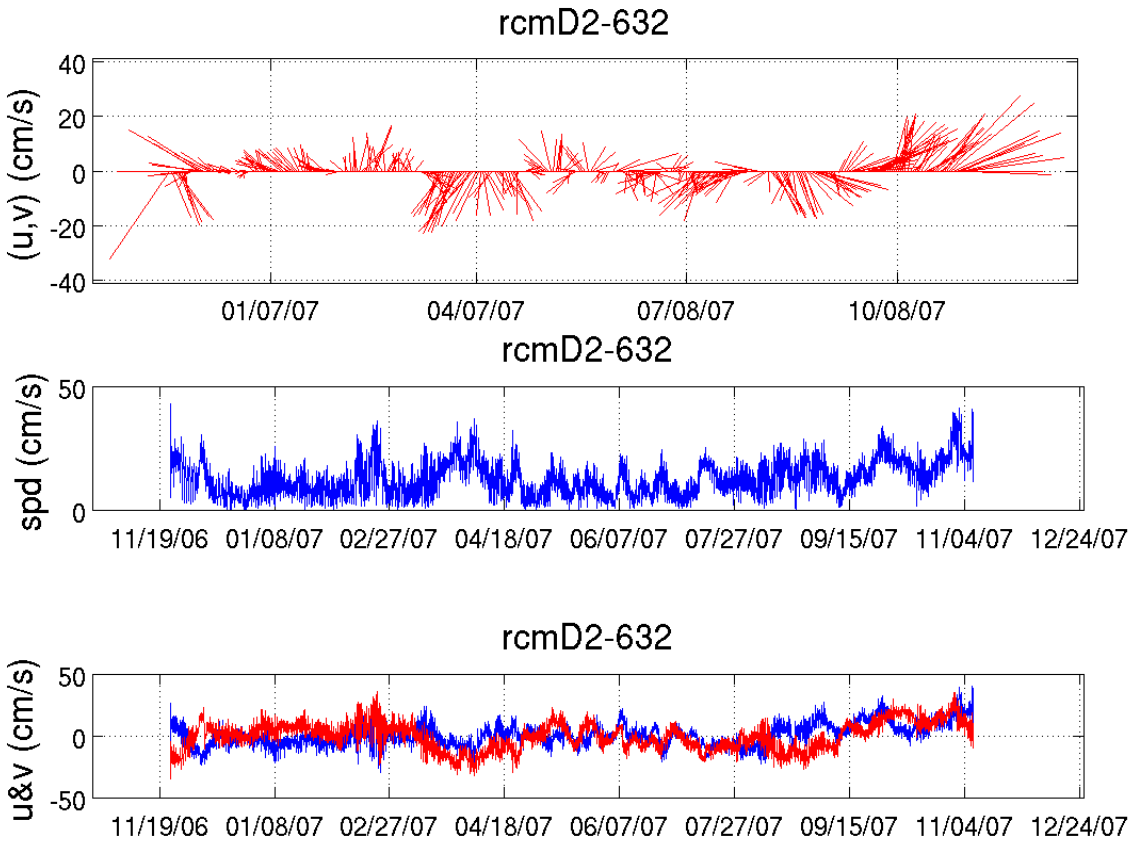

Figure F-12: Mooring D2. Aanderaa RCM 149 daily averaged time series data, nominally 632 meters, collected from November 26, 2006 to November 9, 2007: velocity stick plot (top, cm/s), velocity speed (middle, cm/s), and U (blue) & V (red) (bottom, cm/s).

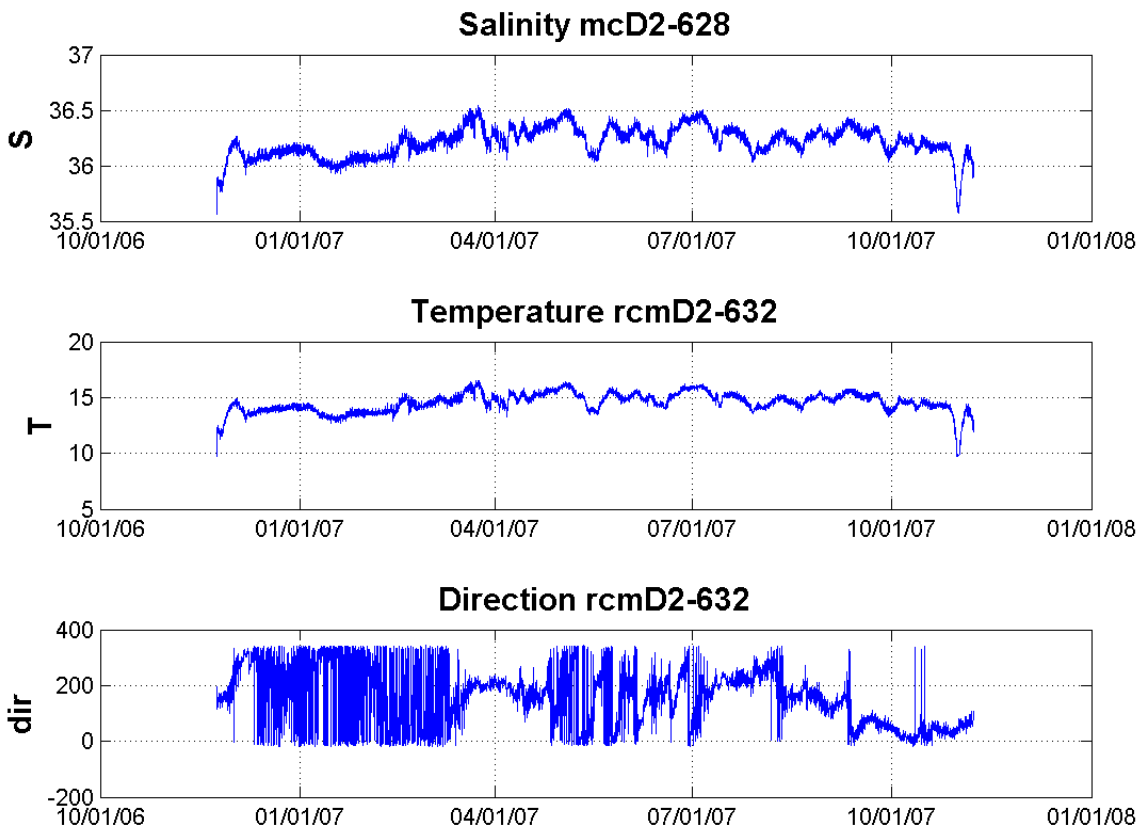

Figure F-13: Mooring D2. SBE37 1645, nominally 628 meters, daily averaged salinity (top, psu), and Aanderaa RCM 149 daily averaged time series data, nominally 632 meters, temperature (middle, °C), and current direction (bottom, degrees). Both collected from November 23, 2006 to November 7, 2007.

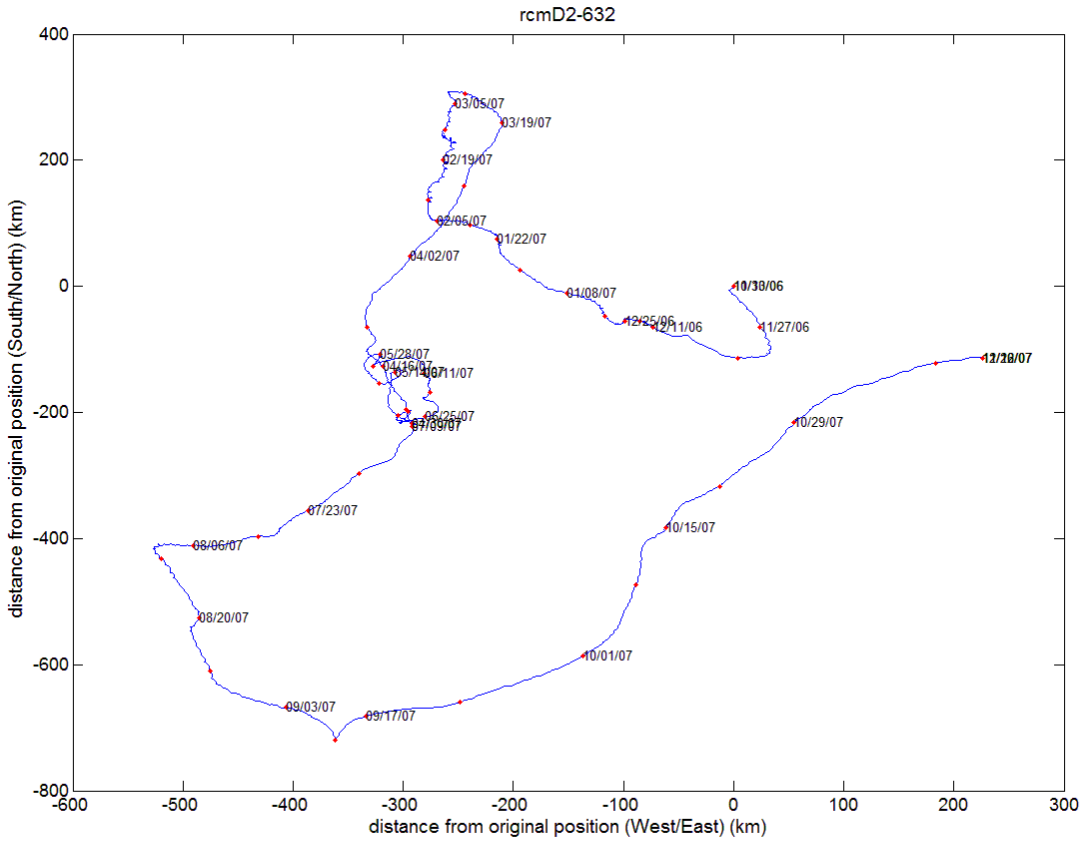

Figure F-14: Mooring D2. Progressive vector diagram for current data measured by Aanderaa RCM 149, nominally at 632 meters collected from November 23, 2006 to November 7, 2007. Weekly indicators (red plus sign) are labeled at approximate monthly intervals.

Appendix G: Mooring Diagrams

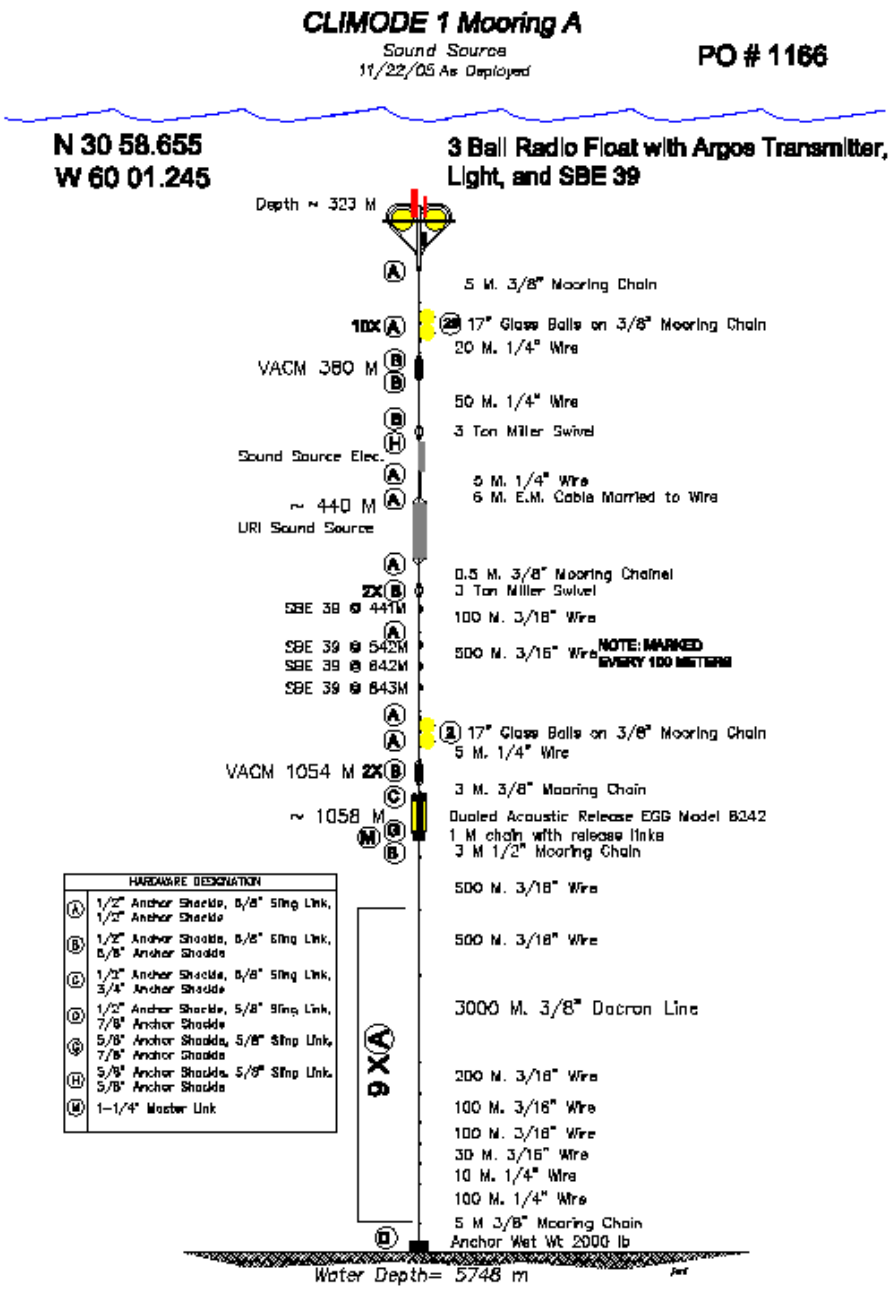

Figure G-1: Schematic drawing for Mooring A, 2005 - 2007.

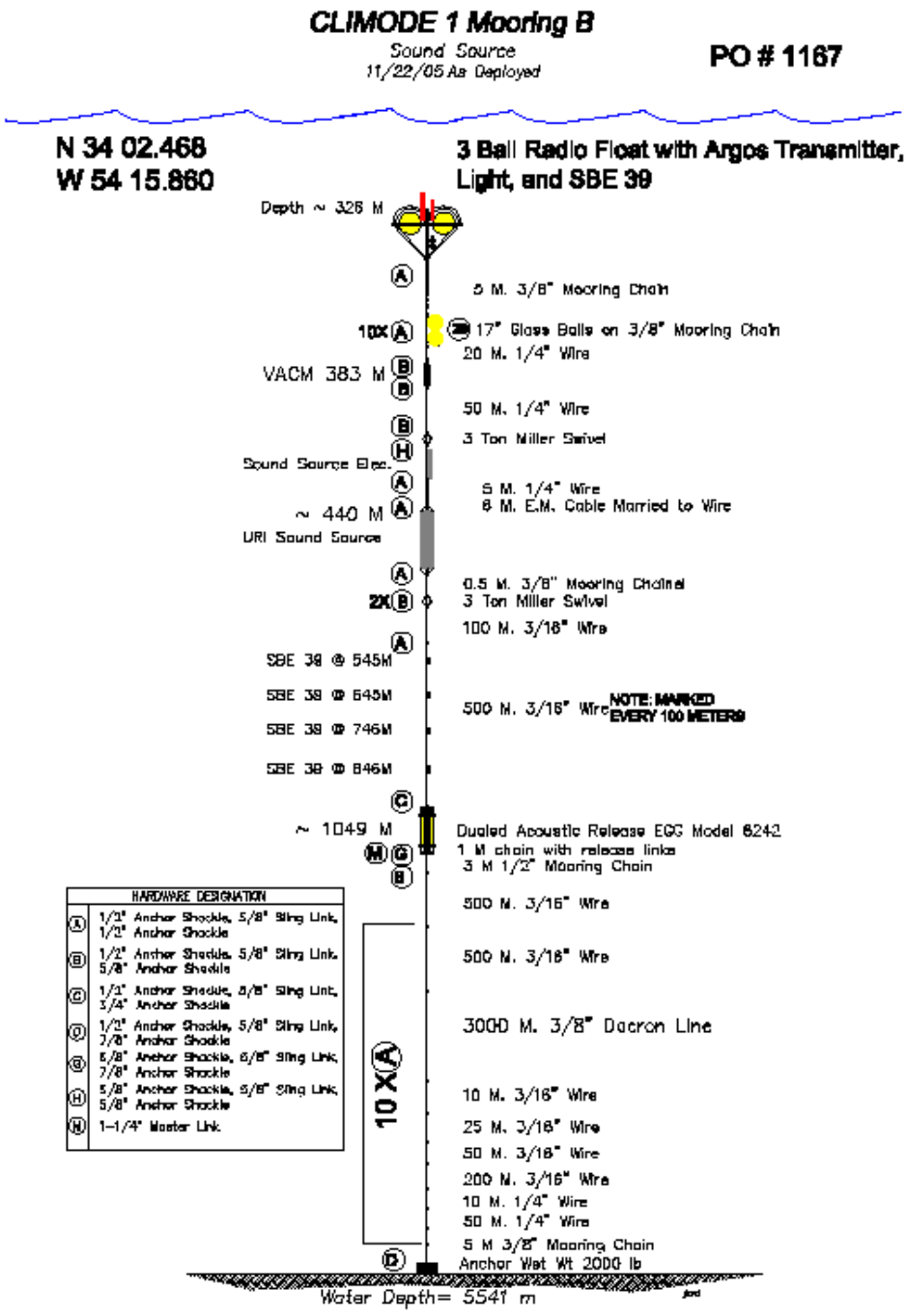

Figure G-2: Schematic drawing for Mooring B, 2005 - 2007.

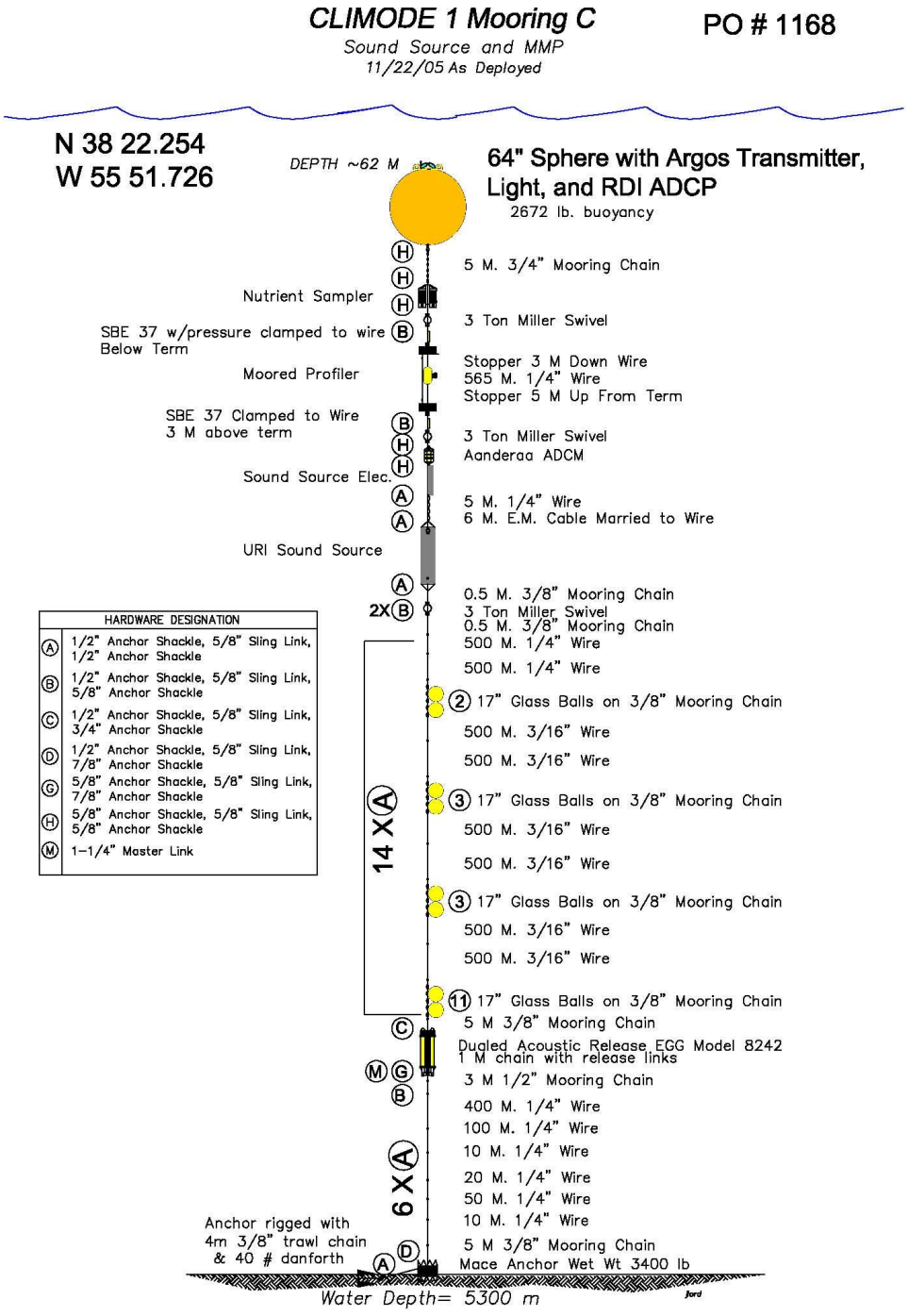

Figure G-3: Schematic drawing for Mooring C1, 2005 – 2006.

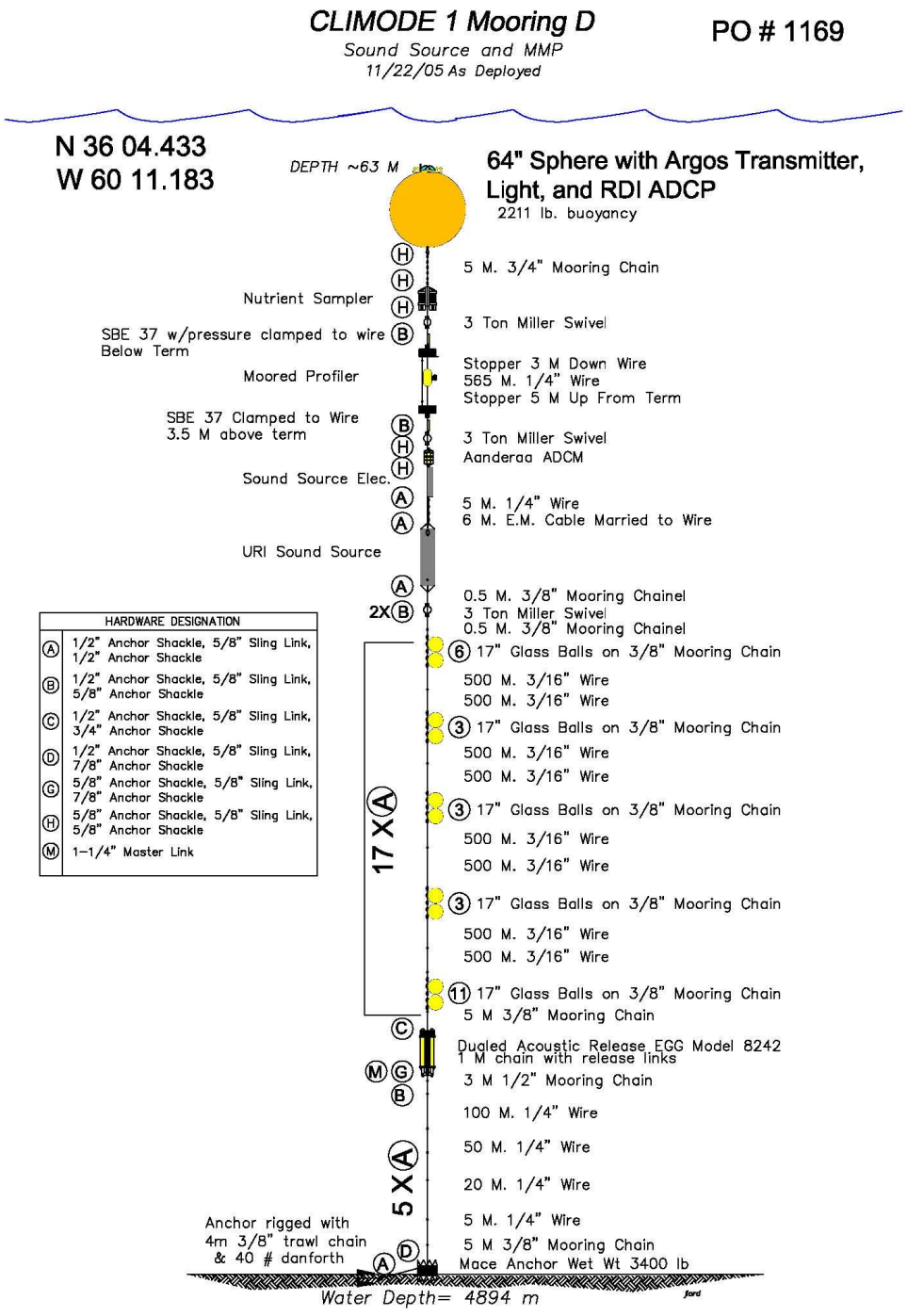

Figure G-4: Schematic drawing for Mooring D1, 2005 – 2006.

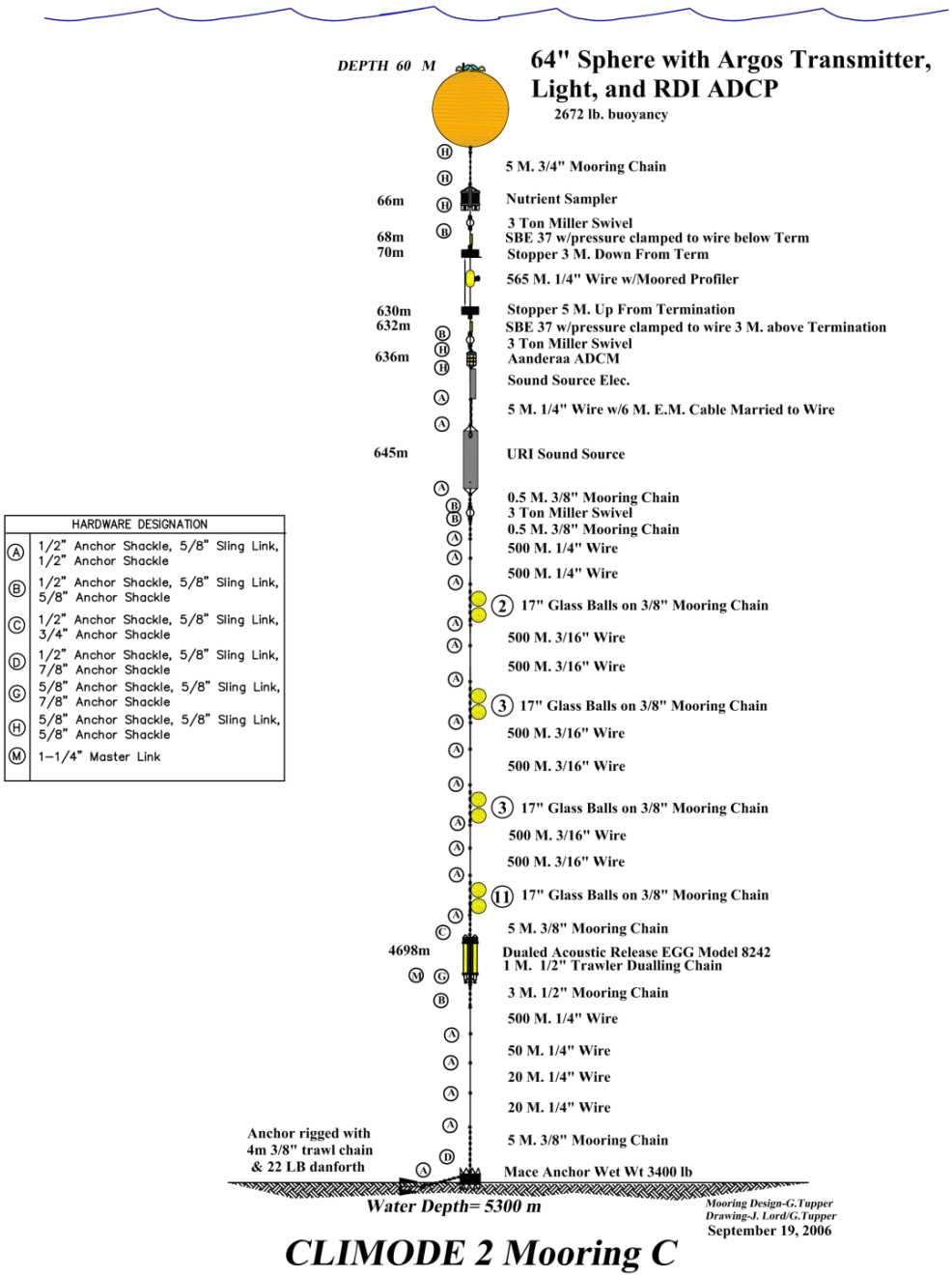

Figure G-5: Schematic drawing for Mooring C2, 2006 – 2007.

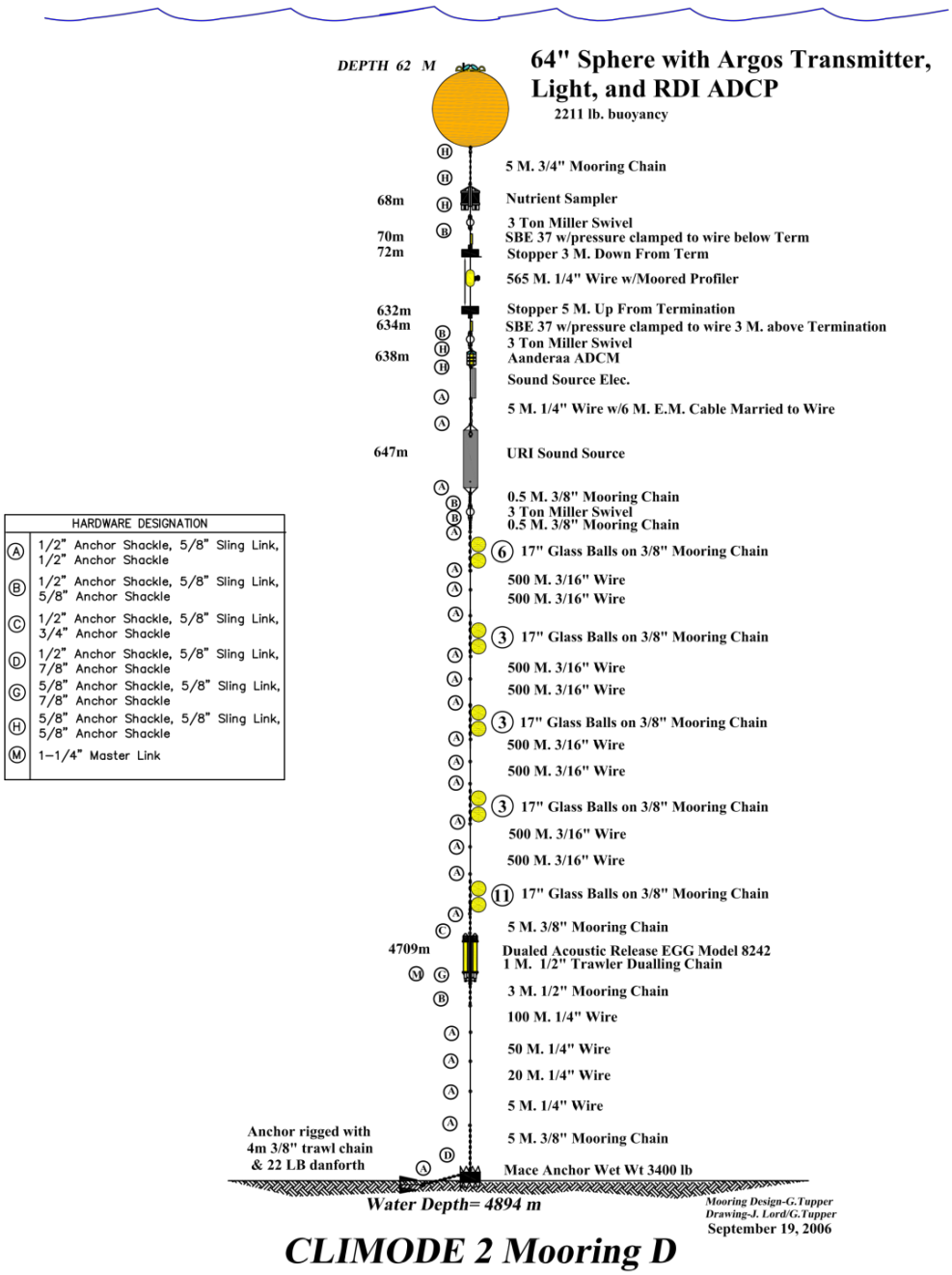

Figure G-6: Schematic drawing for Mooring D2, 2006 – 2007.

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16. Abstract (Limit: 200 words)
Two years of temperature, salinity, current, and nutrient data were collected on four subsurface moorings as part of the 2 year field component of the CLIMODE experiment. The moorings were located in North Atlantic's subtropical gyre, south-east of the Gulf Stream. Two moorings, the most heavily instrumented, were close to the Gulf Stream, in the region where cold air outbreaks force large air-sea fluxes and where Eighteen Degree Water outcrops. Two other moorings were located farther south and carried more limited instrumentation. The moorings were initially deployed in November of 2005, turned around in November of 2006 and finally recovered in November of 2007. During the first year, the moorings close to the Gulf Stream suffered considerable blow down, and some of the instruments failed. During the second year, the blow down was greatly reduced and most instruments collected a full year worth of data.

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Gulf Stream
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