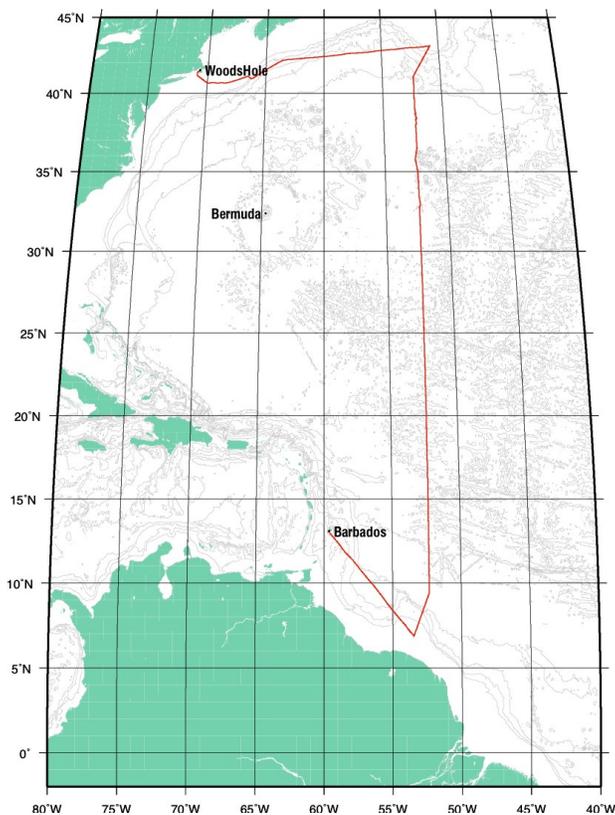


CRUISE REPORT: A20

(Updated JUL 2012)



Highlights

Cruise Summary Information

WOCE Section Designation	A20
Expedition designation (ExpoCodes)	33AT20120419
Chief Scientists	Dr. Michael McCartney/WHOI
Dates	Apr 19, 2012 - May 15, 2012
Ship	<i>R/V ATLANTIS</i>
Ports of call	Bridgetown, Barbados - Woods Hole, MA
Geographic Boundaries	43° 6.31' N 53° 28.77' W 50° 43.88' W 6° 52.08' N
Stations	83
Floats and drifters deployed	0
Moorings deployed or recovered	0

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Links To Select Topics

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	CTD Data:
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	Bottle Data
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	
Thermosalinograph	
XBT and/or XCTD	
Meteorological Observations	Acknowledgments
Atmospheric Chemistry Data	
Data Processing Notes	

US Global Ocean Carbon and Repeat Hydrography Program Section CLIVAR A20

RV Atlantis AT20

19 April 2012 - 15 May 2012

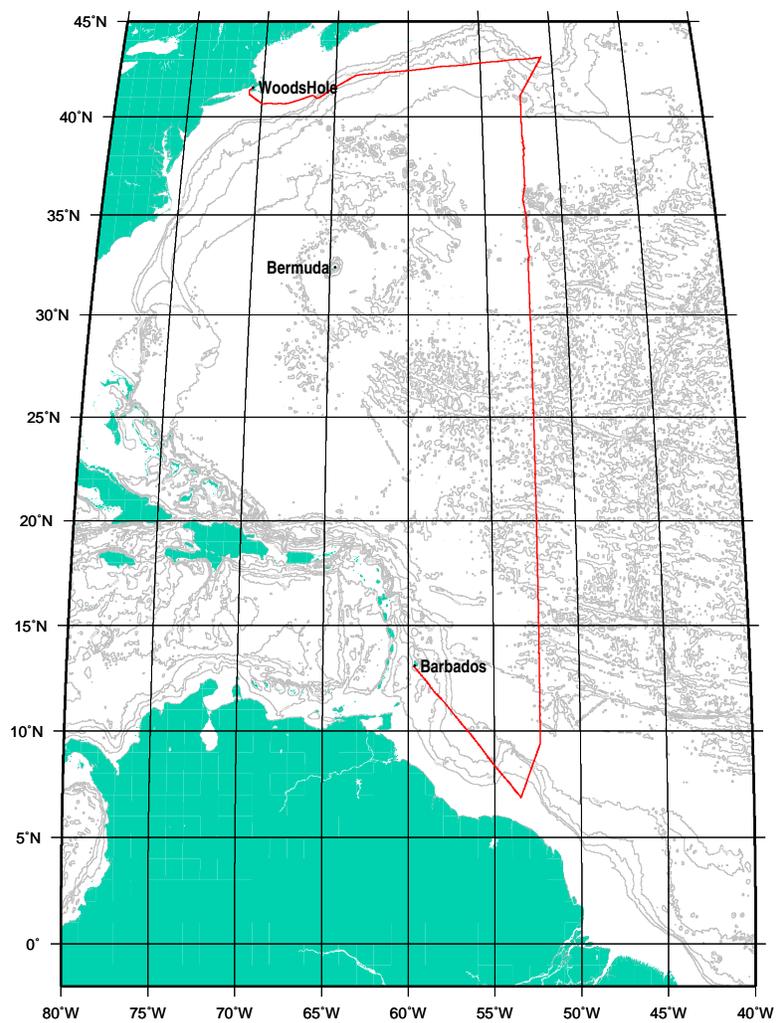
Bridgetown, Barbados - Woods Hole, Massachusetts

Chief Scientist: Dr. Michael McCartney

Woods Hole Oceanographic Institution

Co-Chief Scientist: Dr. Donglai Gong

Woods Hole Oceanographic Institution



Cruise Report

14 May 2012

Narrative

A20 station planning and implementation, and an overview of the circulation encountered.

Section designation: CLIVAR A20

Expedition: 33AT20120419

Chief Scientist: Dr. Michael McCartney, Woods Hole Oceanographic Institution

Ship: R/V Atlantis 20-01

Ports: Bridgetown, Barbados - Woods Hole, MA

Dates: 19 April - 15 May 2012

Cruise Narrative

The 2012 A20 section follows the WOCE A20 section completed in 1997, which itself was repeat of a CTD hydrography section made in 1983 (McCartney, 1993). The main change from WOCE A20 was a slight eastward shift of the South American (SA) continental shelf stations from the Suriname EEZ to the French Guiana EEZ. For the cruise there were 86 stations planned, and a total of 83 stations were actually completed. Unlike previous north to south transects, the 2012 survey was a south to north transect; the April-May timing matched that for the 1983 occupation, while WOCE A20 itself was in July-August, and a 2003 repeat in this program of repeating WOCE sections was in Sept.-Oct. The full suite of physical and chemical measurements will be inter-compared for three occupations across a 15 year span, while the 1983 section will extend the comparison to a 29 year span for T,S,P, Oxygen, Silicate, Phosphate and Nitrate/Nitrite. See the accompanying station map and property sections for the highlights described in [Appendix F](#).

The 2012 A20 survey did not use the same stations from the previous two A20 surveys (1997 and 2003). The planning objective was to balance station resolution with available time for sampling. The survey was divided into shelfbreak, slope, continental rise, and basin segments. Station spacing was kept even for each segment of the survey. Closely spaced station spacing of 4.6 nm was used on the SA shelf (Sta 1-7), the stations opened up to 10.6 nm in the SA slope region (Sta 8-20), and 13.3 nm at the SA continental rise (Sta 21-23). The station spacing remained relative tight out to 4900 m in order to resolve the southern crossing of the Deep Western Boundary Current (DWBC). The station spacing between 10 N and 21 N were approximately 40 nm (sta 24-39) and between 21 N and 38 N were 45 nm (sta 40-62). Station 59 was moved by 8 nm westward from its original location along 52 20W in order to avoid a sea mount. While basin interior spacing of 40-45 nm was sufficient for resolving mesoscale features in the upper ocean, it likely did not resolve patterns of abyssal circulation around regions of rough topography in the central basin.

In the south, a well-developed North Brazil Current in the upper kilometer of the waters over the upper continental slope, with southwest surface speeds in excess of 45 cm/sec in the LADCP data. Underway Shipboard ADCP measurements during the transit from Barbados to Station 1 of A20 and during the first few stations indicate a clockwise veering of the North Brazil Current from southwest to northeast over a distance of 450 km. Over the continental shelf of French Guiana we encountered a thin (10-20m) layer of dilute Amazon River water atop the Current - spanning about 400 km. This was extraordinary in that its surface salinity was lower than 26. It appears from our examination of all the NODC archive data (Bottle, CTD and ARGO) that this is an extreme event, larger in span, and lower in salinity, than ever directly measured (salinities this low have been restricted to the continental shelf in that data base). Included in the figure set are illustrations of the feature in salinity, silicate, total carbon and alkalinity: consistent with its distant origin in the Amazon at the equator, as its elevated silicate, and strongly depressed total carbon and alkalinity - the latter a player in setting the upper ocean conditions as a carbon sink in the western tropical North Atlantic. We appear to have captured a mesoscale process that is conveying Amazon-flavored shelf water offshore into the deep ocean. At its northern edge there is some evidence (a station profile and the underway thermosalinograph) for it being eroded by the action of surface waves crewing on the edge. The plume also thickens significantly at its offshore edge with distinctive salinity and alkalinity signal detectable down to depth of 50m. This could be a result of the entrainment and mixing of the river water with offshore water. In the middle of the feature the interface at its base is remarkable thin (not shown - it requires examination of the 0.5 second averaged CTD data time series).

Beneath, and down-slope of, the Brazil Current, we measured a strong DWBC flowing southeast. Part of what emerged from the 1983 occupation of this section, and additional nearby sections and measurements (Friedrichs and

Hall, 1982, Schmitz and McCartney, McCartney, 1993 and Johns and Fratantoni, 1993) was the concept of a "too-strong" DWBC - transporting 2 or 3 times the expected transport net export of the cold limb of the meridional overturning circulation. The reason for this is a "Guiana Abyssal Gyre" that returns a large part of the Lower North Atlantic Deep water (LNADW) back northward in the western Basin (rather than exporting south across the equator. This recirculation crosses A20, partly by a narrow recirculation immediately north of the DWBC, and the rest in a near bottom westward flow near 15 N (around 1000 km on the section plot. This recirculating water is mixed with the transequatorial flow of Antarctic Bottom Water (AABW). This mixing is the cause for the band of LNADW/AABW with water mass characteristics that are intermediate between those of the boundary current regime and those of the mid basin area of the section. The mixing is much enhanced by bottom intensified mixing over the rough topography of the Mid-Atlantic Ridge's western flank (Mauritzen et al, 2002) For the southern half of the A20 transect, at depths above the upper North Atlantic Deep Water reside the Antarctic Intermediate Water (AAIW). The thickness of this water mass is approximately 1000 m with a mean depth of approximately 800-1000 m. The AAIW is significantly fresher than the surrounding water masses below and above it with a salinity minima of 34.6. The AAIW also has distinctive geochemical properties such as low dissolved oxygen, high nutrients, and much lower level of man-made transient tracers such as CFCs and CCL4. Interestingly, the low salinity core and the geochemical property core maxima/minima associated with the AAIW are not necessarily collocated at the same depth. This is likely a result of mixing and biogeochemical processes in the upper ocean that differentially modify AAIW's vertical property distribution after its formation. The northward influence of the AAIW does not appear to extend past 25 N along the A20 section.

Sea Surface Temperature map indicated that the Gulf Stream (GS) at 52 W was located between 38 and 39 N. This was a distinctly more southerly location compared to its climatological mean location, and at the southerly limit of its meander envelope. However, the GS path was apparently nearly stationary at this location for at least a two weeks period leading up to our crossing. Four stations spaced 20 nm apart were allocated for sampling the GS core (sta 63-65), and the GS cooperated by being where we had planned for it. Lowered ADCP indicate that the GS had a strong baroclinic structure in the upper 1000 m with a maximum velocity of 98 cm/s, and near bottom a barotropic flow contribution of 25 cm/s was deduced. Two aspect features disrupted the situation to the immediate south of the GS where the "Worthington Gyre" westward recirculation would be anticipated. First, its southerly position placed the south edge of the GS only about 250 km north of the Corner Rise Seamounts intersection with the section. Second, a cyclonic cold core ring was observed south of the Gulf Stream at 35 N, with a center indicated as slightly west of the section by there being a northward velocity component to the ring vector velocity in the LADCP and underway SADCP data. The ring primarily influenced flow field in the upper 2000 m with a maximum speed of 40 cm/s. Separation of the Ring and Worthington Gyre velocity contributions, for that area the north of the seamounts and south of the GS, remains for future analysis by combined ADCP and hydrographic shear.

North of the Gulf Stream, the spacing was opened up again to 42 nm in the slope sea until 41 N (sta 66-68). No Warm Core Rings were observed in the slope region. There appears to be a very strong Northern Recirculation Gyre (NRG) structure emerging from the left side of the GS, with the nearly eastward GS flow transitioning to a northwest flow nearly paralleling the western flank of the Grand Banks (which lies Northwest of this part of the section). As anticipated by Hogg, Pickart and colleague in their papers inferring the NRG, this recirculation has a significant barotropic component in the LADCP data, about 29 cm/sec . with surface velocity to the Northwest of about 55 cm/sec indicating a baroclinic addition of 25 cm/sec. The NRG element is limited to the gentle bottom slope southward of the continental slope, consistent with Hogg and Stommel (1985) deduction of a potential vorticity - constraint on the recirculation. In the southern part of the continental slope region of the Grand Banks, the station spacing was 13.3 nm (69-77). The water mass on the continental slope below 4500 m is a blend of Antarctic Bottom Water (AABW) and Denmark Strait Overflow Water (DSOW). Above 4500m the DSOW and lighter northern components become predominant in the narrow DWBC that flows northwest along the Grand Banks. On the shallowest part of the continental shelf of the Grand Banks, the spacing was 3.4 nm (sta 78-83). Cold Labrador Sea coastal water with temperature less than 3 degrees were observed on the shelf and shelf Break, while just offshore of the shelfbreak, a significant southeast flow of Labrador Current flow with velocity in excess of 30 cm/s was measured, indicative of the retroflexion of the Labrador Current in this general area (Fratantoni and McCartney, 2010). A weaker shelfbreak flow to the northwest (~15 cm/s) shoreward of the Labrador Current retroflexion is seen in the underway SADCP data. CTD rosette operation switched from the starboard winch (0.322 inch wire) to the port side traction winch using a much heavier 0.681 inch wire at station 37. The traction winch was not operational for most of the preceding (A22) leg, but it was repaired during the first half of this A22 cruise. Many long hours were put into that repair, in port and during this leg, by the ship's able engineers, and it was successful - and much

appreciated. The reason for the switch was mainly to keep the samplers dry and safe in the Jason hangar during rough seas - and in particular to avoid losing station time by heaving to while sampling. By eliminating the spray from the sea, there is also a lessened chance of sample contamination during sampling. It was fortunately that no significant weather was encountered during the cruise. The seas were generally 2-5 ft and the winds were generally less than 25 knots. In terms of sampling, the chemistry samplers took on average 1.5-2 hours to sample the entire CTD rosette. For the deep and closely-spaced stations, the ship sometimes would arrive on station before the bottle sampling is done. For most of the cruise, this was not an issue. Sampling was completed on May 11, 2012 20:00 UTC. Major data quality issues encountered during the sampling were a systematic bias between the two CFC systems onboard and no pH measurements past station 66. The cause of the CFC bias is currently under investigation. When the measurement bias combined with the alternating sampling routine of the two CFC teams resulted in the appearance of oscillatory banded structures in the along transect CFC data (see plots). CFC-11 measurements suffered the most from this effect. Extreme care should be taken when interpreting station to station variability in the CFC measurements. pH measurements were not available for stations past 66 due to broken sensors.

Principal Programs of CLI VAR A20

Program	Affiliation	Principal Investigator	email
CTDO/Rosette, Nutrients, O ₂ Salinity, Data Processing	UCSD/SIO	James H. Swift	jswift@ucsd.edu
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³ He- ³ H	WHOI	Bill Jenkins	wjenkins@whoi.edu
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Dissolved Organic Carbon (DOC)/ Total Dissolved Nitrogen (TDN)	UM/RSMAS	Dennis Hansell	dhansell@rsmasmatm.edu
Underway pCO ₂ with underway T&S	NOAA/AOML	Rik Wanninkhof	Rik.Wanninkhof@noaa.gov
Carbon Isotopes ¹³ C/ ¹⁴ C-DIC	WHOI PU	Ann McNichol Robert Key	amcnichol@whoi.edu key@princeton.edu
Level III Programs			
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Surface Skin SST	UM/RSMAS	Peter Minnett	pminnett@rsmas.miami.edu
Oxygen Isotope	WHOI	Rachel Stanley	rstanley@whoi.edu
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* Affiliation abbreviations listed on page 5

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* Affiliation abbreviations are listed on page 5

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Jerry Graham	Able-Bodied Seaman	
Jim McGill	Able-Bodied Seaman	
Patrick Neumann	Able-Bodied Seaman	
Ronnie Whims	Ordinary Seaman	
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Darren Whittaker	Oiler	
Matthew Slater	Oiler	
Nick Alexander	Oiler	
Leroy Walcott	Wiper/Ordinary Seaman	
Brendon Todd	Steward	steward@atlantis.who.edu
Mark Nossiter	Cook	
Janusz Mlynarski	Mess Attendant	

KEY to Institution Abbreviations	
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
DUKE	Duke University
LDEO	Lamont-Doherty Earth Observatory
MWJ	Marine Works Japan Ltd.
NOAA	National Oceanic and Atmospheric Administration
ODF	Oceanographic Data Facility (SIO/STS)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
RSMAS	Rosenstiel School of Marine and Atmospheric Science (UM)
RT-E	Research Technicians - Electronics (SIO/STS)
RU	Rutgers University
SIO	Scripps Institution of Oceanography (UCSD)
SSSG	Shipboard Scientific Services Group (WHOI)
STS	Shipboard Technical Support (SIO)
TAMU	Texas A&M University
UCOL	University of Colorado
UCSD	University of California, San Diego
UH	University of Hawaii
UT	University of Texas
UM	University of Miami
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution

Hydrographic/CTD Data, Salinity, Oxygen and Nutrients

PI: Dr. James H. Swift

Cruise Participants: *Oceanographic Data Facility and Research Technicians*

Shipboard Technical Support/Scripps Institution of Oceanography

La Jolla, CA 92093-0214

The CLIVAR A20 repeat hydrographic line was reoccupied for the US Global Ocean Carbon and Repeat Hydrography Program (sometimes referred to as "CLIVAR/CO2") during April-May 2012 from RV Atlantis during a survey consisting of CTD/rosette/LADCP stations and a variety of underway measurements. The ship departed Bridgetown, Barbados on 19 April 2012 and arrived Woods Hole, Massachusetts on 15 May 2012 (UTC dates).

CTDO data and water samples were collected on each CTD/rosette/LADCP cast, usually to within 10 meters of the bottom. Water samples were measured on board as tabulated in the Bottle Sampling section.

A sea-going science team gathered from 12 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed in the Narrative section.

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

A total of 83 CTD/rosette/LADCP casts were made. Most casts were lowered to within 10m of the bottom. Stations 3 through 7 and Station 81 through 83 came within 5m of the bottom as requested by the Co-Chief Scientist, Dr. Donglai Gong, for the shelf sampling. Under the watchful eye of SSSG and the SIO/STS technician, the CTD watchstanders accomplished this task.

Hydrographic measurements consisted of salinity, dissolved oxygen and nutrient water samples taken from each rosette cast. Pressure, temperature, conductivity/salinity, dissolved oxygen, and transmissometer data were recorded from CTD profiles. Current velocities were measured by the RDI workhorse LADCP. The distribution of samples are shown in the following figure.

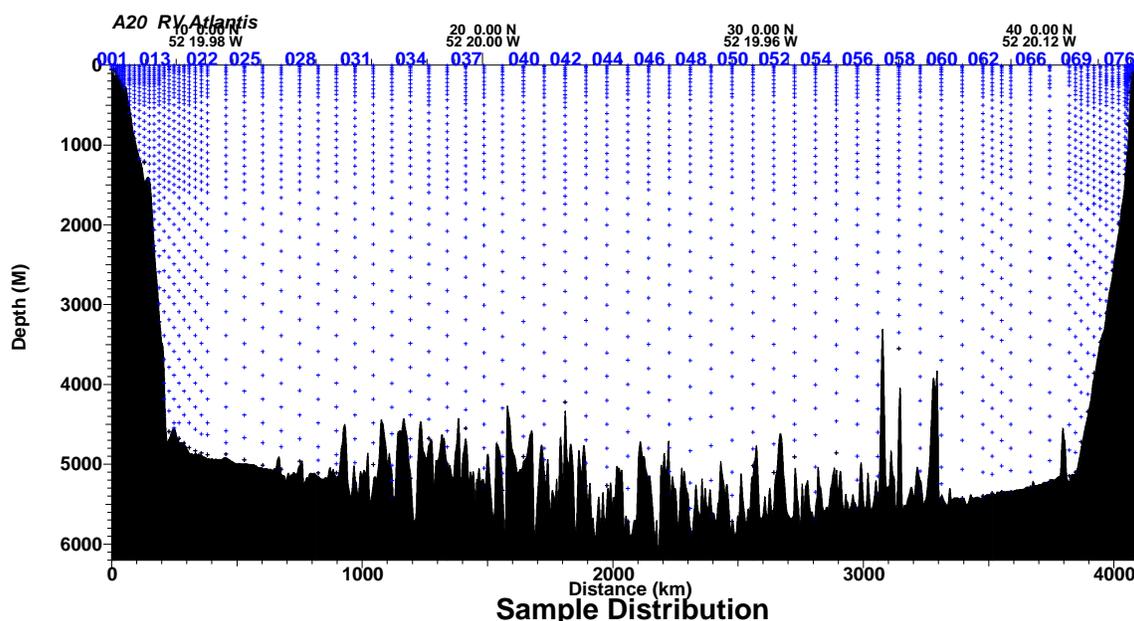


Figure 1.0 CLIVAR A20 Sample distribution, stations 1-83.

The expedition sampling plan for individual measurements is included in [Appendix E](#).

1.1. Water Sampling Package

CTD/rosette/LADCP casts were performed with a package consisting of a 36-bottle rosette frame (SIO/STS), a 36-place carousel (SBE32) and 36 10.0L Bullister bottles (SIO/STS) with an absolute volume of 10.4L. Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD with dual pumps (SBE5), dual temperature (SBE3*plus*), reference temperature (SBE35RT), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs), altimeter (Simrad) and LADCP (RDI).

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 dissolved oxygen sensors and their respective pumps and tubing were mounted vertically in the CTD cage, as recommended by SBE. Pump exhausts were attached to the CTD cage on the side opposite from the sensors and directed downward. The transmissometer was mounted horizontally near the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring. The 150 KHz downward-looking Broadband LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD. Its battery pack was located on the opposite side of the frame, mounted on the bottom of the frame. Table 1.1.0 shows height of the sensors referenced to the bottom of the frame.

Instrument	Height in cm
Temperature/Conductivity Inlet	9
SBE35	9
Altimeter	2
Transmissometer	5
Pressure Sensor, inlet to capillary tube	17
Inner bottle midline	109
Outer bottle midline	113
LADCP face midline (bottom)	7
Zero tape on wire	280

Table 1.1.0 Heights referenced to bottom of rosette frame

A few mis-trips were encountered on this expedition. Most could be explained as improper set-up of the bottles during cocking. However, bottle 11 exhibited random tripping incidents starting on Station 26. Other stations affected were 39, 52 59, 63 and 74. These mis-trips are documented in [Appendix C](#), Bottle Quality Comments. The CTD Electronics Technician stated it was not the carousel. Starting at Station 67, it was decided to trip bottles 11 and 12 at the same depth to ensure that different maintenance scenarios had in fact changed the reaction of bottle 11. At Station 69, the bottle was raised in the scallop of the rosette frame. None of the techniques made any difference, and at Station 76 the bottle and tripping position were no longer employed.

1.2. Deck and CTD Console Operations

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. The deployment area was secured with signs and rope barriers to safely secure the area for the duration of the cast. Once stopped on station, the LADCP data acquisition was started from a computer station in a lab space adjacent to the secure sampling area. Once started, the cables to the LADCP were disconnected and replaced with dummy plugs. At least 3 minutes prior to the package deployment, the CTD was powered-up and the data acquisition system was started from the Computer Lab. The rosette was then unstrapped from its location in the sampling area and moved out to the deployment location using an air-powered winch with a cart and track system. At the deployment location the rosette cart was secured to the track, tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports.

In the Computer Lab, the deployment and acquisition software presented a short dialog instructing the operator to turn on the deck unit, to examine the on-screen CTD data displays and to notify the deck watch that this was accomplished and the lab was ready for deployment. The console watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any relevant comments.

Once cleared by the bridge and the console operator, the deck watch leader directed the winch operator to raise the package. The boom and rosette were extended outboard and the package was quickly lowered into the water. Tag lines were removed and the package was lowered to a depth of 10 meters. The CTD sensor pumps were configured

with a 5-second start-up delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation and waited for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth. While at the surface, the winch operator would re-zero the wire-out reading before the descent. The winch operator then took the package down to 100 meters and stopped the winch for approximately 10-15 seconds while control of the winch was transferred to an operator in the Computer Lab.

Most rosette casts were lowered to within 10 meters of the bottom using the altimeter, CTD depth, winch wire-out, and multi-beam depth to determine the distance. The CTD profiling rate was monitored in meters of winch wire-out per minute. The profiling rate was not allowed to exceed speeds of 30m/min to a depth of 200m and 60m/min when below 200m. As the package descended toward the target depth, the descent rate was reduced to 30m/min at 100m off of the bottom, 20m/min at 50m off of the bottom, and 10m/min at 20m off of the bottom. These speeds were further reduced if required by the sea cable tension and sea state experienced during the cast.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles.

For each up cast, the winch operator was directed to stop the winch at up to 36 pre-determined sampling depths. These standard depths were staggered every station using 3 sampling schemes. To ensure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. An additional 10 seconds elapsed before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings. The Computer Lab winch operator transferred control of the winch back to the ship's winch operator at a bottle stop around 100 meters below the surface. The deck watch leader directed the package to the surface for the final bottle stop before recovery.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the additional use of poles and snap-hooks attached to tag lines and air-powered winches for controlled recovery. The rosette was secured on the cart and moved forward to its secure sampling location. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Each bottle on the rosette had a unique serial number, independent of the bottle position on the rosette. Sampling for specific programs was outlined on sample log sheets prior to cast recovery or at the time of collection.

Routine CTD maintenance was performed between casts, which included soaking the conductivity and oxygen sensors with 1% Triton-X solution to maintain sensor stability and eliminate accumulated bio-films. Rosette and bottle maintenance was also performed on a regular basis including inspecting valves and o-rings for leaks and rinsing the carousel with fresh water.

For stations 1 to 36, the rosette was secured for sampling in the covered portion of the starboard quarterdeck. This was a non-ideal location for sampling as it was not protected from weather conditions. After sampling for Station 36 was completed, the rosette was moved to the port side to utilize the protection of the ROV hangar during sampling and to employ the 0.681" fiber optic cable. The port-side boom clearance required that the package be lifted through an opening in the port bulwarks. Life-lines were strung across this opening between casts to ensure the area would be safe. The life-lines were removed during the launching and recovery of the CTD. During the profiling at Station 37, the cart and tracks were installed, allowing for the rosette to be moved into the ROV hangar for sampling. This arrangement was used for the remaining stations.

1.3. Underwater Electronics

The SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second. The sensors and instruments used during CLIVAR A20, along with pre-cruise laboratory calibration information, are listed below in [Table 1.3.0](#). Copies of the pre-cruise calibration sheets for various sensors are included in [Appendix D](#).

Instrument/Sensor*	Mfr.§/Model	Serial Number	CTD Channel	Stations Used	Pre-Cruise Calibration Date	Facility§
Carousel Water Sampler	SBE32 (36-place)	3216715-0187	n/a	1-83	n/a	n/a
Reference Temperature	SBE35	3528706-0035	n/a	1-83	16-Feb-2012	SIO/STS
CTD	SBE9plus SIO	09P39801-0796		1-83		
Pressure	Paroscientific Digiquartz 401K-105	796-98627	Freq.2	1-83	25 Oct 2011	SIO/STS
Primary Pump Circuit						
Temperature (T1)	SBE3plus	03P-4924	Freq.0	1-83	24 Oct 2011	SIO/STS
Conductivity (C1a)	SBE4C	04-3369	Freq.1	1-45	21 Feb 2012	SBE
Conductivity (C1b)	SBE4C	04-3429	Freq.1	46-86	21 Feb 2012	SBE
Pump	SBE5T	05-4374		1-83		
Secondary Pump Circuit						
Temperature (T2)	SBE3plus	03P-4907	Freq.3	1-83	08 Feb 2012	SIO/STS
Conductivity (C2)	SBE4C	04-3399	Freq.4	1-86	21 Feb 2012	SBE
Pump	SBE5T	05-4160		1-53		
Pump	SBE5T	05-4377		54-83		
Dissolved Oxygen	SBE43	43-0614	Aux2/V2	1-53, 55-83	18 Feb 2012	SBE
Dissolved Oxygen	SBE43	43-0186	Aux2/V2	54	18 Feb 2012	SBE
Transmissometer (TAMU)	WET Labs C-STAR	CST-327DR	Aux2/V3	1-43	30 Nov 2010	WET Labs
Transmissometer	WET Labs C-STAR	CST-492DR	Aux2/V3	44-83	02 Dec 2008	WET Labs
Altimeter (500m range)	Simrad 807	9711091	Aux1/V0	1-83		
Load Cell/Tension (WHOI)	3PSInc LP-5K-2000	A0512124	Aux3/V4	1-83		
LADCP Down (UH)	RDI Workhorse 150kHz	16283		1-83		
Deck Unit (in lab)	SBE11plus V2	11P21561-0518		1-83		

* All sensors belong to SIO/STS/ODF, unless otherwise noted.

§ SBE = Sea-Bird Electronics

Table 1.3.0 CLIVAR A20 Rosette Underwater Electronics.

An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks. The SBE35RT was utilized per the manufacturer's specifications and instructions, as described on the Sea-Bird Electronics website (<http://www.seabird.com>).

The SBE9plus CTD was connected to the SBE32 36-place carousel, providing for sea cable operation. The Markey DESH-5 starboard/aft winch, with an 0.322" EM sea cable, was used for Stations 1 through 36. The 0.681" fiber optic cable on the RV Atlantis's Markey DUTW-9-11 port-side winch was used for all remaining casts.

A new termination was done before the first use of each sea cable. Only one conductor in the DESH-5 three-conductor wire was used for power and signal; the sea cable armor was used for ground. Two inner conductors from the 0.681" fiber optic cable were used, one for power and signal, the other for ground (return). Power to the SBE9plus CTD and sensors, SBE32 carousel and Simrad altimeter was provided through the sea cable from the SBE11plus deck unit in the computer lab.

1.4. Navigation and Bathymetry Data Acquisition

Navigation data were acquired at 1-second intervals from the ship's SeaNav 2050 GPS receiver by a Linux system beginning 19 April 2012 at 1330z, before the RV Atlantis left the dock in Bridgetown, Barbados.

Centerbeam bathymetric data from the Kongsberg EM-122 multibeam echosounder system were available shortly after leaving port. Bottom depths associated with rosette casts were recorded on the Console Logs during deployments.

Depth data displayed by the ship were 6m deeper than the data from the feed. The 6m hull depth offset was added to STS stored depth data for all events in the hydrographic database.

Corrected multibeam center depths are reported for each cast event in the WOCE and Exchange format files.

1.5. CTD Data Acquisition and Processing

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and four networked generic PC workstations running CentOS-5.6 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball and DVD+RW drive. One system had a Comtrol Rocketport PCI multiple port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

One of the workstations was designated as the CTD console and was connected to the CTD deck unit via RS-232. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. Another of the workstations was designated as the website and database server and maintained the hydrographic database for A20. Redundant backups were managed automatically.

Shipboard CTD data processing was performed automatically during and after each deployment using SIO/STS CTD processing software v.5.1.6-1.

During acquisition, the raw CTD data were converted to engineering units, filtered, response-corrected, calibrated and decimated to a more manageable 0.5-second time series. Pre-cruise laboratory calibrations for pressure, temperature and conductivity were also applied at this time. The 0.5-second time series data were used for real-time graphics during deployments, and were the source for CTD pressure and temperature data associated with each rosette bottle. Both the raw 24 Hz data and the 0.5-second time series were stored for subsequent processing. During the deployment, the raw data were backed up to another Linux workstation.

At the completion of a deployment a sequence of processing steps were performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was generated from the down cast data. The pressure-series data were used by the web service for interactive plots, sections and CTD data distribution. Time-series data were also available for distribution through the website.

CTD data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check sample conductivity values. CTD dissolved oxygen sensor data were calibrated to check sample data.

As bottle salinity and oxygen results became available, they were used to refine shipboard conductivity and oxygen sensor calibrations. Theta-Salinity and theta- O_2 comparisons were made between down and up casts as well as between groups of adjacent deployments.

A total of 83 casts were made using the 36-place CTD/LADCP rosette. Further elaboration of CTD procedures specific to this cruise are found in the next section.

Secondary T/C sensors were used for all reported CTD data because:

- the same sensor pair was used throughout the cruise,
- down/up data agreed better than primaries,
- there was less low-level noise in the data.

The following table identifies problems noted during specific casts (NOTE: mwo = meters of wire out on winch):

station/ cast	Comment
15/1	Stopped at 4100m down: pressure 4160, bouncing altimeter. 500-640db has pronounced features on upcast not present on downcast (mostly in TCO, not so visible in transmissometer).
16/1	Wire out zeroed unexpectedly at depth of 160m down. Wire out rezeroed at ctd depth of 200m, 5-sec pause during the re-zeroing. Paused at bottle trip 13 1579db.

station/ cast	Comment
21/1	Transmissometer had two large jumps on downcast at ~650m and ~800m. Scattering has been seen on last few stations, not enough time to clean the instrument and check it out (close stations). All other sensors appear okay. 1-minute stop at 204dbar for winch hand-off between deck and lab, TCS + offset and density -0.013 offset. Code 3 for TS at 204dbar in ctdq file.
34/1	1381db stopped to check wire (1369mwo before bottle 16. Found a fish hook type kink in the wire. Will investigate at next station on up cast.
35/1	Stop at 1670m to repair wire, strand of wire was broken and taped to repair. Transmissometer cable changed after cast.
36/1	Transmissometer cable changed prior to this cast. 1675.4m, the CTD was stopped to inspect the wire.
37/1	Starboard 0.681" fiber optic cable employed. 1625UTC winch stopped itself, 2306m 2280mwo, started again at 1633UTC. Someone outside setting up the track system bumped the emergency stop.
43/1	Large discontinuity in transmissometer signal, and noise below 1000m. Cast delayed screw loose in winch drum junction box. CTD at 200mwo out on way down. Cast resumed at 1317, stopped at 1310.
44/1	Transmissometer changed with CST-492DR prior to cast.
46/1	Primary conductivity changed to 04-3429 prior to cast.
54/1	CTDO sensor changed to 43-0186 prior to cast to check noise level.
55/1	CTDO sensor changed back to 43-0614 (orig.) and pump2 changed to 05-4377 before cast. The winch was paused at ~139m for a couple of minutes to check into C1/C2 disagreement (resolved post-cast by using correct configuration data).
62/1	Stopped at 200m on the down cast. 2220 to 2222. Ship needed to reposition because the wire angle was coming into the ship.
63/1	Winch stopped at 36m, 0408UTC to 0414UTC to reposition because of inboard wire angle. Stopped again 0428UTC, 460m, large fluctuation in tension, restarted within 10 seconds.
65/1	675-800m slowed to 50m/min because of tension fluctuations on the winch.
81/1	Lab performed winch operations from the surface on down, back up to 35m, just before the surface bottle was tripped.

1.6. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to CLIVAR A20. The sensors and calibration dates are listed in [Table 1.3.0](#). Copies of the calibration sheets for Pressure, Temperature, Conductivity, and Dissolved Oxygen sensors, as well as factory and deck calibrations for the TAMU and SIO/STS Transmissometers, are in [Appendix D](#).

1.7. CTD Shipboard Calibration Procedures

CTD #796 was used for all CTD/rosette/LADCP casts during A20. The CTD was deployed with all sensors and pumps aligned vertically, as recommended by SBE.

The SBE35RT Digital Reversing Thermometer (S/N 3528706-0035) served as an independent calibration check for T1 and T2 sensors. *In situ* salinity and dissolved O_2 check samples collected during each cast were used to calibrate the conductivity and dissolved O_2 sensors.

1.7.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 796-98627) was calibrated in October 2011 at the SIO/STS Calibration Facility. The calibration coefficients provided on the report were used to convert frequencies to pressure. The SIO/STS pressure calibration coefficients already incorporate the slope and offset term usually provided by Paroscientific.

Typically, CTDs are calibrated horizontally but deployed vertically. This usually necessitates the application of an offset in order to obtain a reading of zero decibars on the deck. A review of this showed that an offset of -0.7 dbar

was needed. This offset was applied to all casts on A20.

Residual pressure offsets (the difference between the first and last submerged pressures) varied from -0.14 to +0.22 dbar. Pre- and post-cast on-deck/out-of-water pressure offsets varied from -0.07 to +0.33 dbar before the casts, and -0.12 to +0.30 dbar after the casts.

1.7.2. CTD Temperature

Each cast on A20 utilized two SBE3*plus* temperature sensors (T1:03P-4924 and T2:03P-4907).

Calibration coefficients derived from the pre-cruise calibrations, plus shipboard temperature corrections determined during the cruise, were applied to raw primary and secondary sensor data during each cast.

A single SBE35RT (3528706-0035) was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a horizontal plane with the T1 and T2 sensing elements. The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001°C/year. The SBE35RT on CLIVAR A20 was set to internally average over 5 sampling cycles (a total of 5.5 seconds).

Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary temperature were compared with each other and with the SBE35RT temperatures.

Both temperature sensors were first examined for drift with time using the more stable SBE35RT in range of deeper trip levels (1200-6000 dbar). Neither T1 nor T2 required a time-based correction, however they both required a slight offset to give values consistent with those of the SBE35RT (about -0.0009°C for T1 and about +0.0007°C for T2). None of the sensors exhibited a temperature-dependent slope.

The final corrections for T2 temperature data reported on CLIVAR A20 are summarized in [Appendix A](#). All corrections made to T2 temperatures had the form:

$$T2_{ITS90} = T2 + t_0$$

Residual temperature differences after correction are shown in figures 1.7.2.0 through 1.7.2.8.

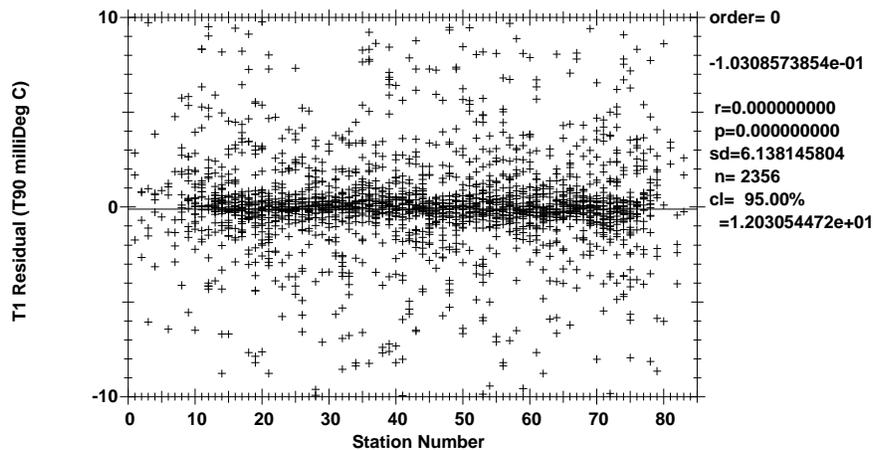


Figure 1.7.2.0 SBE35RT-T1 by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

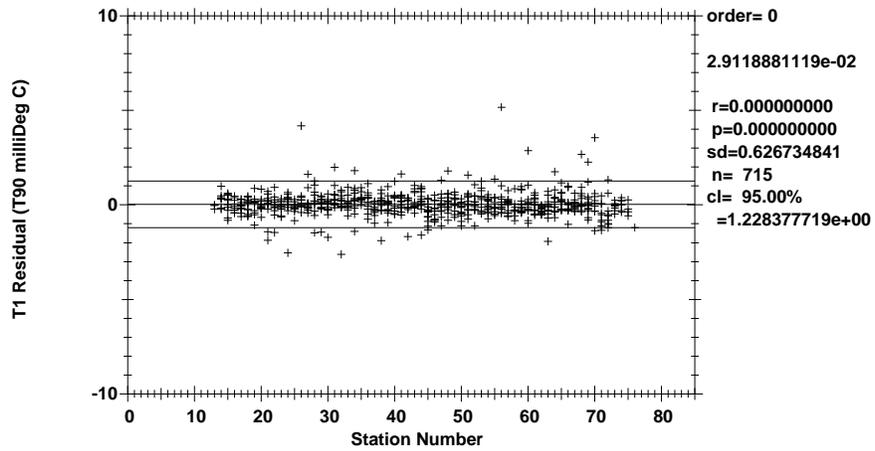


Figure 1.7.2.1 Deep SBE35RT-T1 by station (Pressure >= 2000dbar).

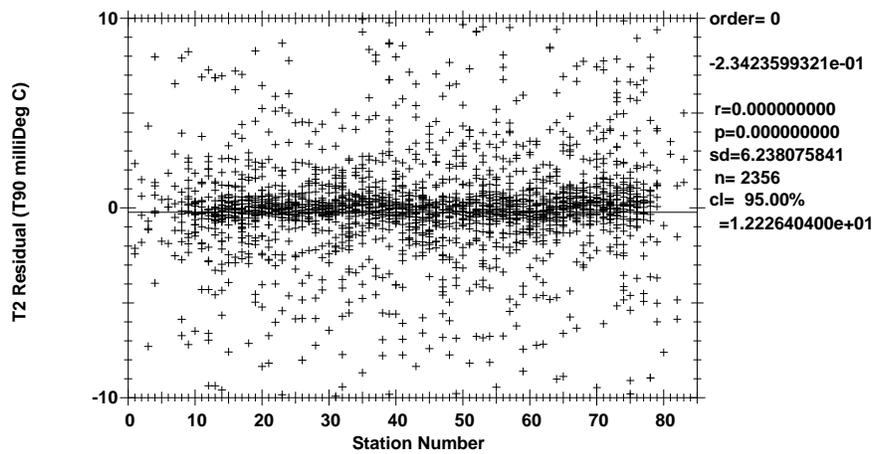


Figure 1.7.2.2 SBE35RT-T2 by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

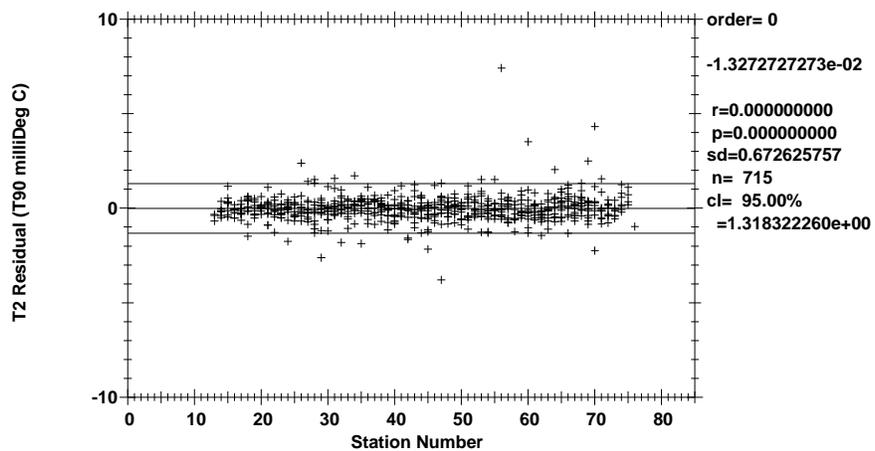


Figure 1.7.2.3 Deep SBE35RT-T2 by station (Pressure >= 2000dbar).

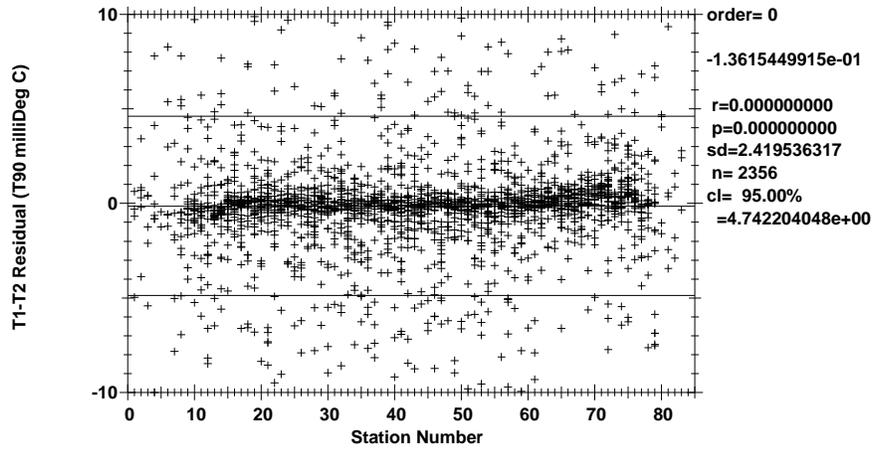


Figure 1.7.2.4 T1-T2 by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

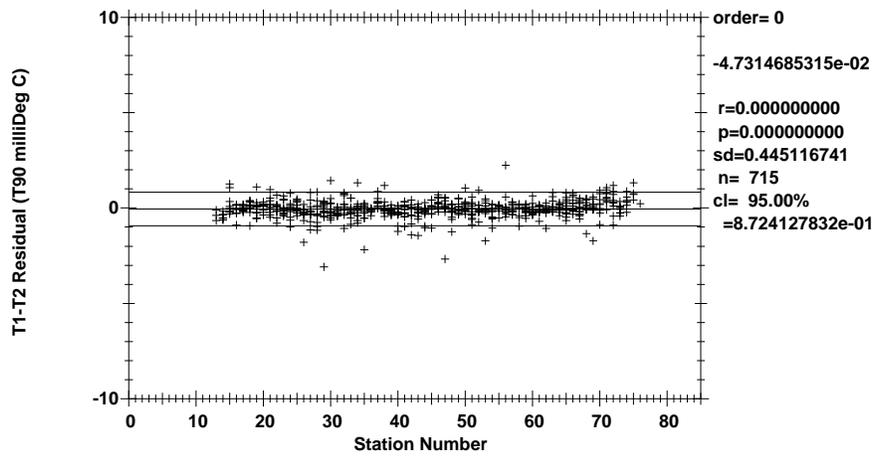


Figure 1.7.2.5 Deep T1-T2 by station (Pressure ≥ 2000 dbar).

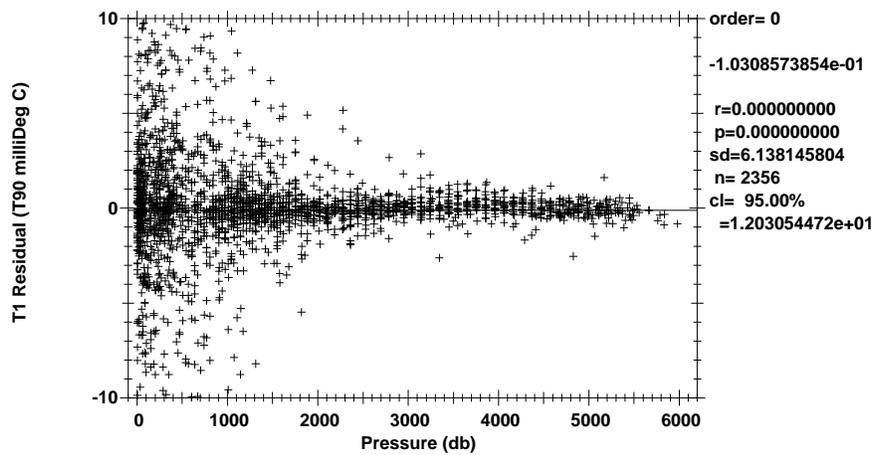


Figure 1.7.2.6 SBE35RT-T1 by pressure ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

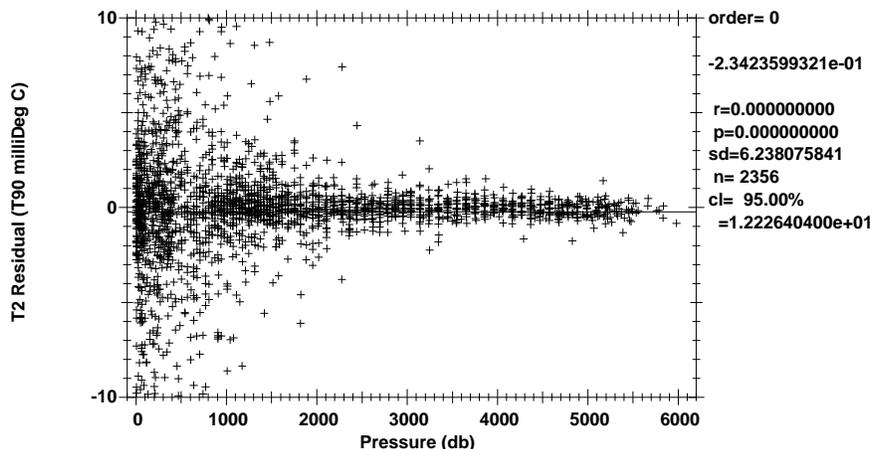


Figure 1.7.2.7 SBE35RT-T2 by pressure ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

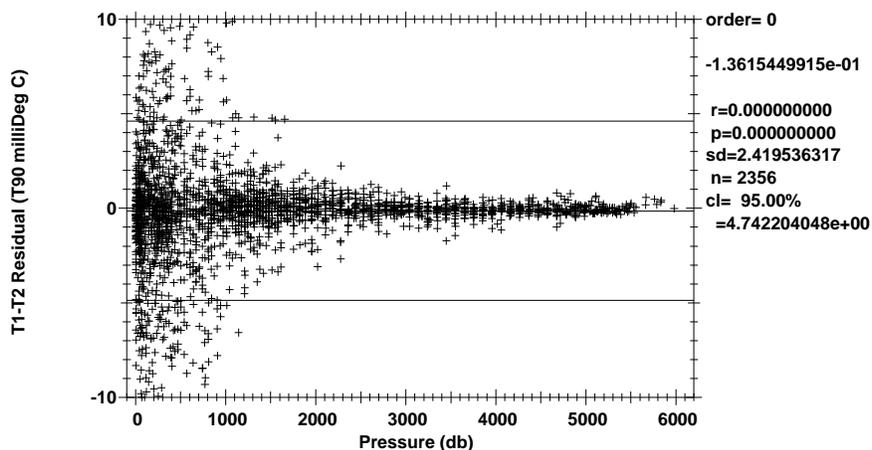


Figure 1.7.2.8 T1-T2 by pressure ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

The 95% confidence limits for the mean low-gradient differences are $\pm 0.01223^{\circ}\text{C}$ for SBE35RT-T2 and $\pm 0.00474^{\circ}\text{C}$ for T1-T2. The 95% confidence limit for deep temperature residuals (where pressure $> 2000\text{db}$) is $\pm 0.00132^{\circ}\text{C}$ for SBE35RT-T2 and $\pm 0.00087^{\circ}\text{C}$ for T1-T2.

1.7.3. CTD Conductivity

Two SBE4C primary conductivity sensors (C1a: 04-3369/stas:1-45 and C1b: 04-3429/stas:46-81) and one secondary conductivity sensor (C2: 04-3399) were used during CLIVAR A20. Secondary sensor data were used to report final CTD data because they performed better than the primary sensors on the previous leg (CLIVAR A22).

Calibration coefficients derived from the pre-cruise calibrations were applied to convert raw frequencies to conductivity. Shipboard conductivity corrections, determined during the cruise, were applied to primary and secondary conductivity data for each cast.

Corrections for both CTD temperature sensors were finalized before analyzing conductivity differences. Two independent metrics of calibration accuracy were examined. At each bottle closure, the primary and secondary conductivity were compared with each other. Each sensor was also compared to conductivity calculated from check sample salinities using CTD pressure and temperature.

The differences between primary and secondary temperature sensors were used as filtering criteria for all conductivity fits to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in [figure 1.7.3.0](#).

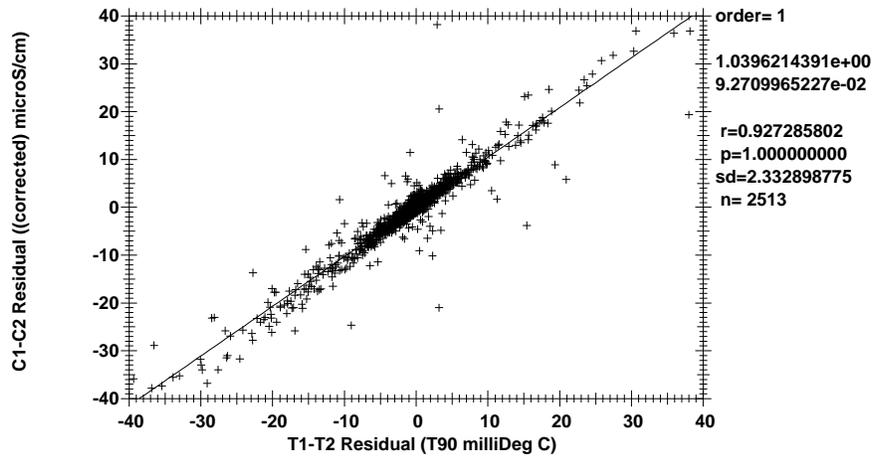


Figure 1.7.3.0 Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.7.3.1 through 1.7.3.3.

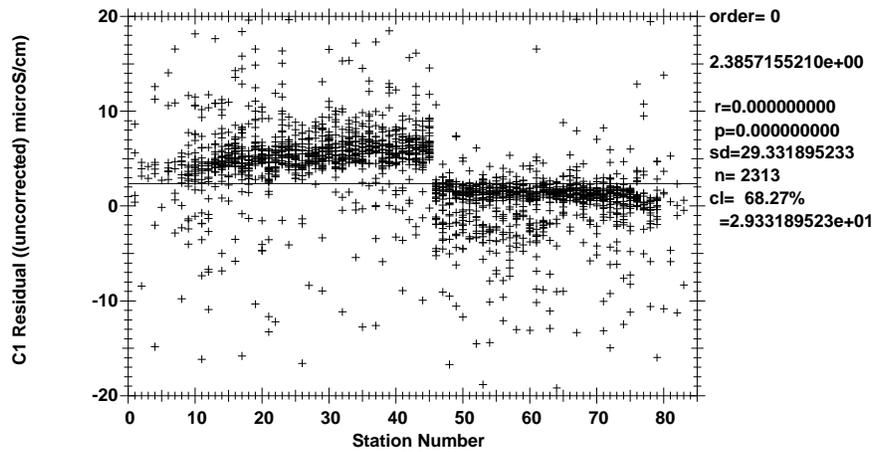


Figure 1.7.3.1 Uncorrected $C_{Bottle} - C1$ by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

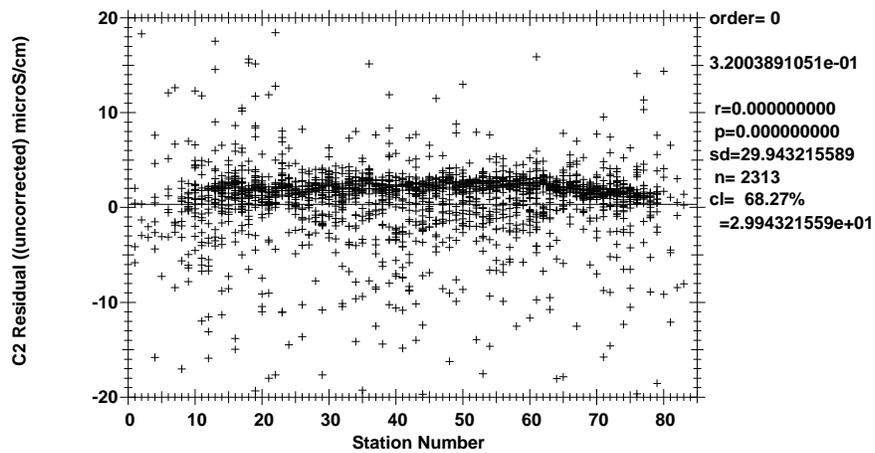


Figure 1.7.3.2 Uncorrected $C_{Bottle} - C2$ by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

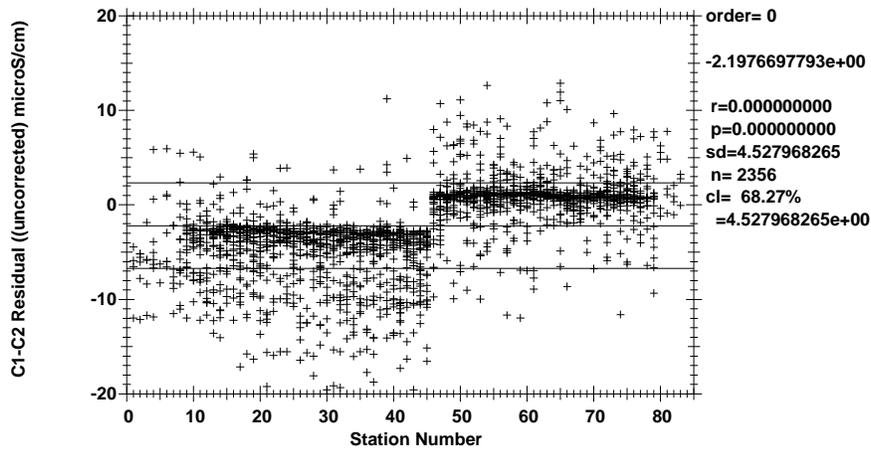


Figure 1.7.3.3 Uncorrected $C_1 - C_2$ by station ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

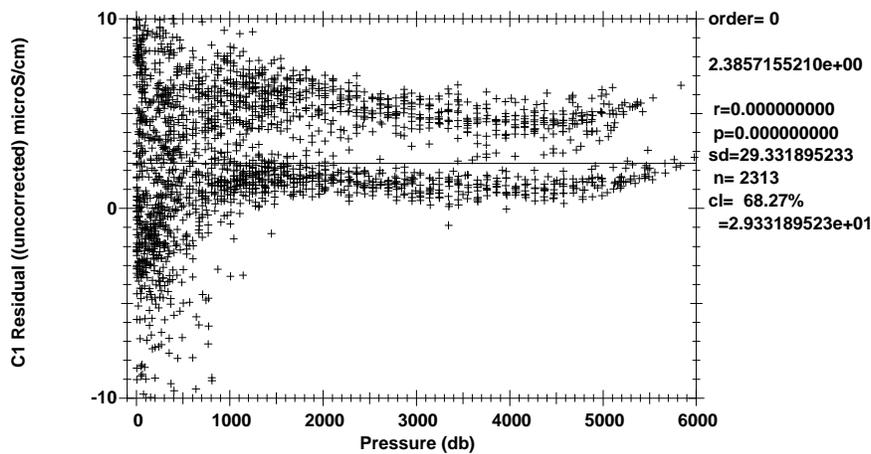


Figure 1.7.3.3 Uncorrected $C_{\text{Bottle}} - C_1$ by pressure ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

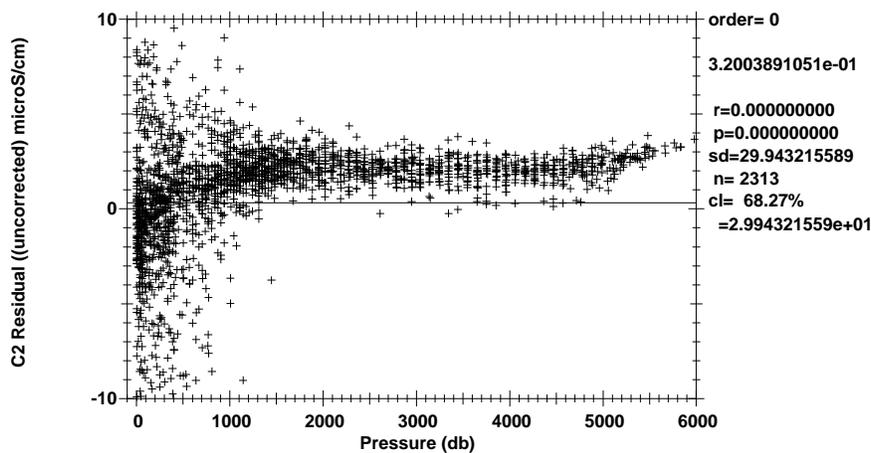


Figure 1.7.3.3 Uncorrected $C_{\text{Bottle}} - C_2$ by pressure ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

Calibrations to the conductivity sensors were performed underway and were updated as needed. As the cruise continued, analysts began to note an anomalous upturn in $C_{\text{Bottle}} - C_{\text{CTD}}$ towards the bottom of the deepest casts (5000-6000 dbar). Starting at about 5000 dbar, $C_{\text{Bottle}} - C_{\text{CTD}}$ showed a rise with pressure resulting in a final offset of +0.0015 mS/cm in $C_{\text{Bottle}} - C_{\text{CTD}}$ at around 6000 dbar. This peculiar phenomenon was observed in all 3 conductivity

sensors (C1a, C1b, and C2). During final calibrations, all underway corrections were cleared and reevaluated. It was found that doing the same type of corrections to each of the three conductivity sensors resulted in consistent, acceptable data with the slopes removed.

First, a second-order correction was applied to $C_{Bottle} - C_{CTD}$ versus pressure. This fit was applied to remove the deep upturn feature. In order to minimize the effects of this correction on the surface samples, different depth ranges were considered. It was found that the pressure range of 1400-6000 dbar was optimal for sensors C1a and C1b while the pressure range of 1500-6000 dbar was optimal for C2.

$C_{Bottle} - C_{CTD}$ differences were then evaluated for response to temperature and/or conductivity, which typically shifts between pre- and post-cruise SBE laboratory calibrations. A comparison of these residual C1a, C1b, and C2 differences showed additional small conductivity-dependent corrections were required. For C1a, this correction lowered near-surface values by about 0.0005 mS/cm compared to the deepest data. For C1b, this correction was similar and lowered near-surface values by about 0.0003 mS/cm compared to the deepest data. C2 also showed a strong first-order dependence on conductivity. The C2 correction raised near-surface values by about 0.0003 mS/cm.

Next, offsets for each conductivity sensor were evaluated for drift with time using $C_{Bottle} - C_{CTD}$ differences from a deeper, limited pressure range (1200-2500 dbars for C1a,C1b; 1500-2500 for C2). As a result of the previously mentioned calibrations, a second order correction was needed for all three sensors with respect to time.

After these corrections, none of the conductivity sensors showed the original deep, pressure-related offsets. Details on these corrections can be found in [Appendix A](#).

Deep Theta-S overlays showed that deep CTD data overlaid well for the data reported. The residual conductivity differences after correction are shown in figures 1.7.3.4 through 1.7.3.15.

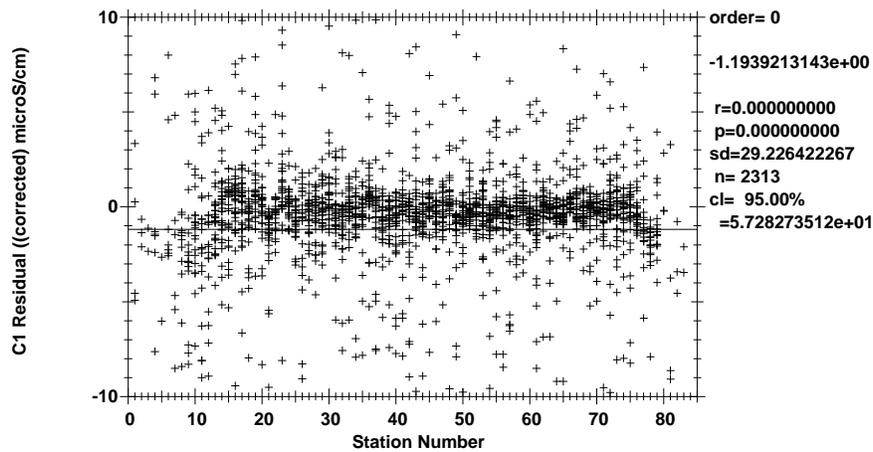


Figure 1.7.3.4 Corrected $C_{Bottle} - C1$ by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

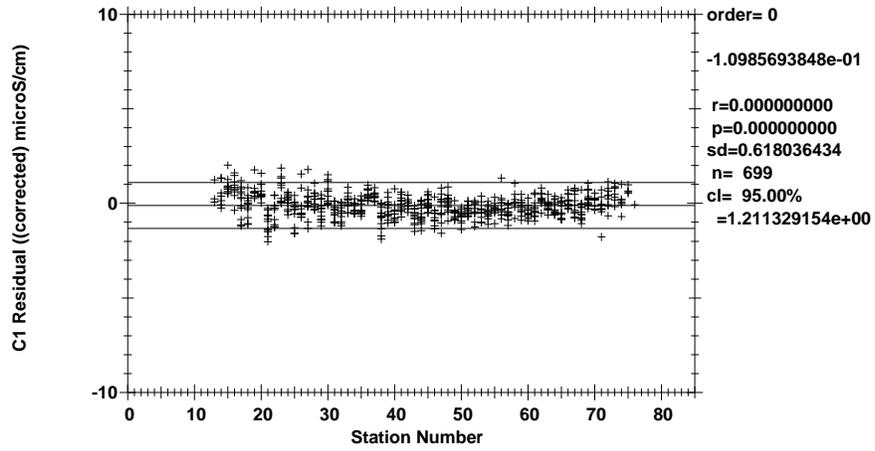


Figure 1.7.3.5 Deep Corrected $C_{Bottle} - C1$ by station (Pressure ≥ 2000 dbar).

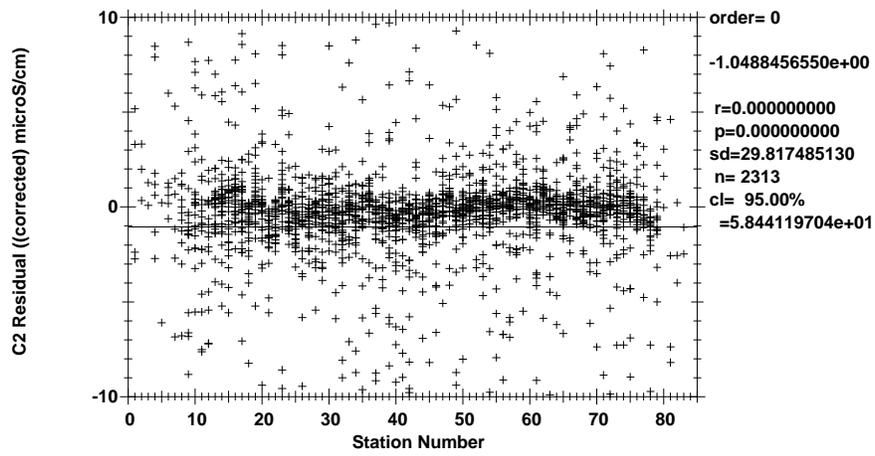


Figure 1.7.3.6 Corrected $C_{Bottle} - C2$ by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

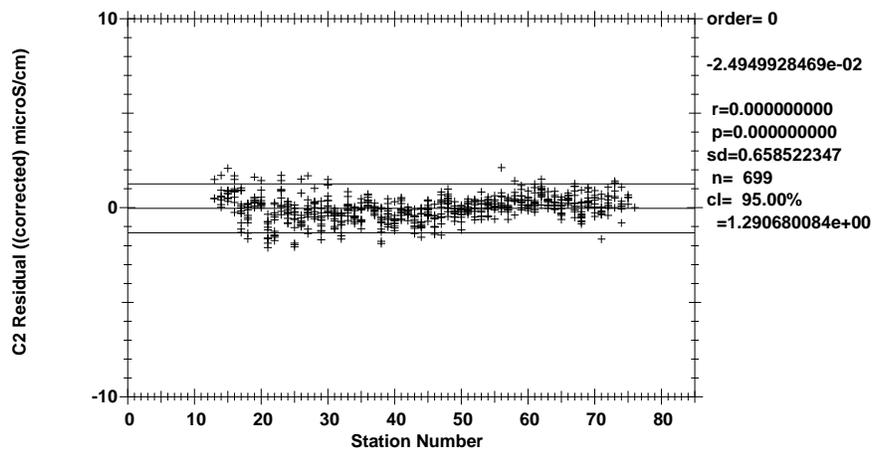


Figure 1.7.3.7 Deep Corrected $C_{Bottle} - C2$ by station (Pressure ≥ 2000 dbar).

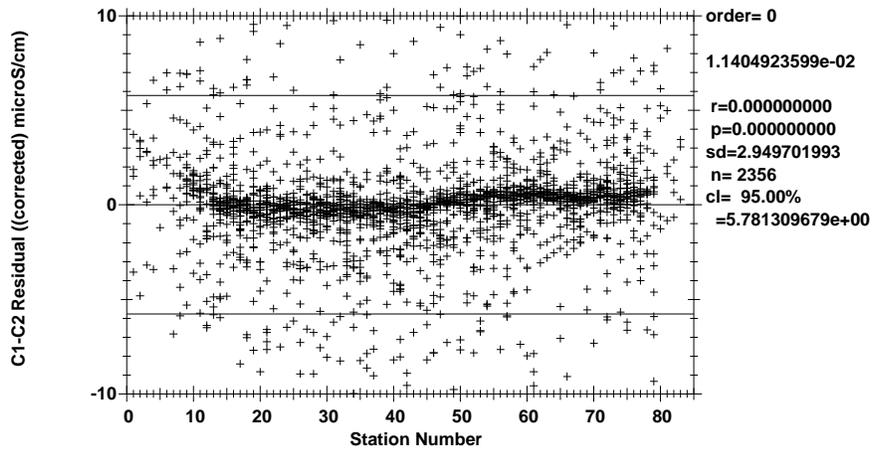


Figure 1.7.3.8 Corrected $C1 - C2$ by station ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

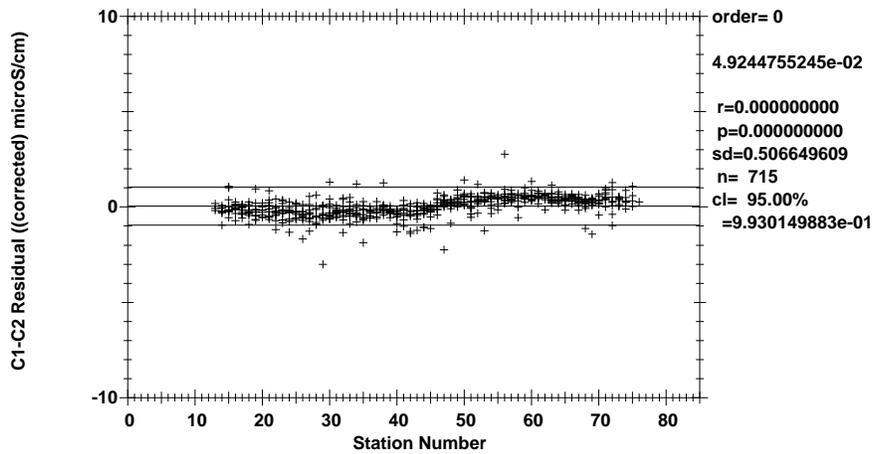


Figure 1.7.3.9 Deep Corrected $C1 - C2$ by station (Pressure ≥ 2000 dbar).

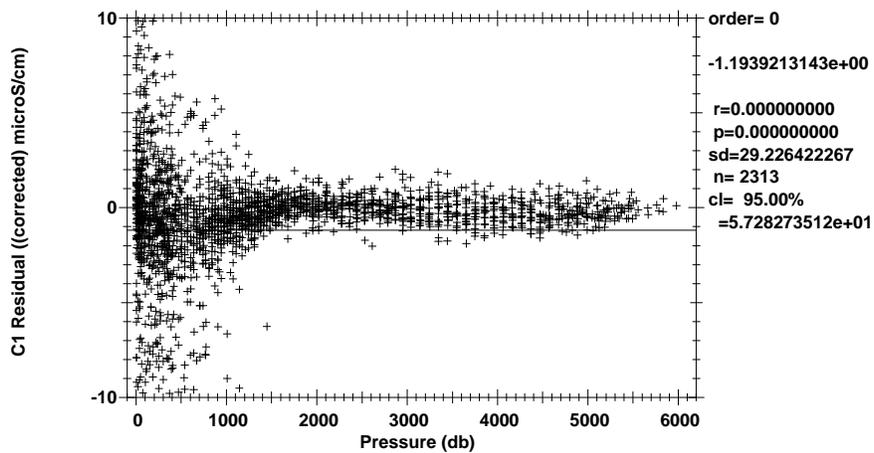


Figure 1.7.3.10 Corrected $C_{\text{Bottle}} - C1$ by pressure ($-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$).

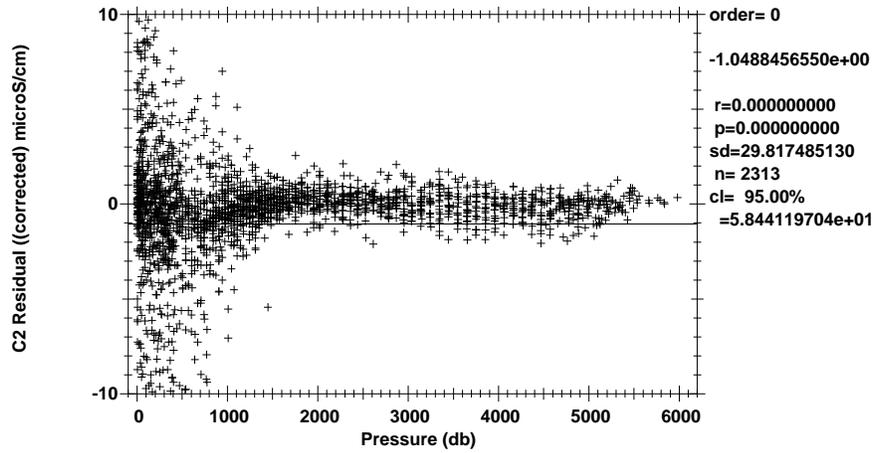


Figure 1.7.3.11 Corrected $C_{Bottle} - C_2$ by pressure ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

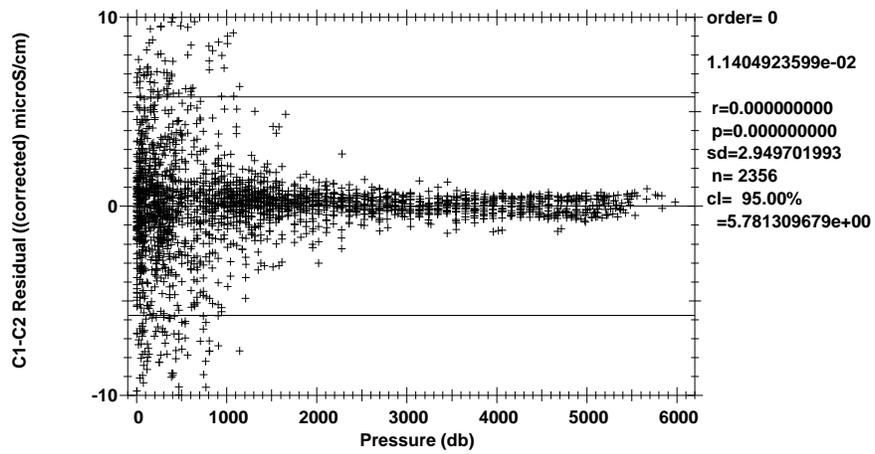


Figure 1.7.3.12 Corrected $C_1 - C_2$ by pressure ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

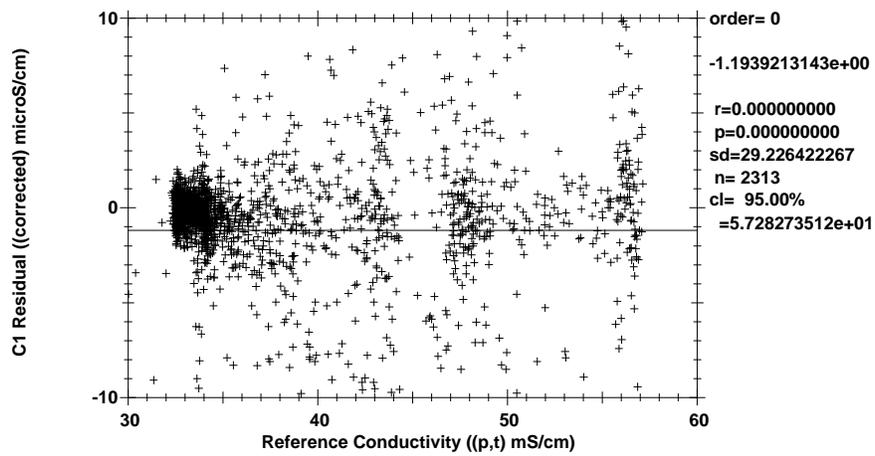


Figure 1.7.3.13 Corrected $C_{Bottle} - C_1$ by conductivity ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

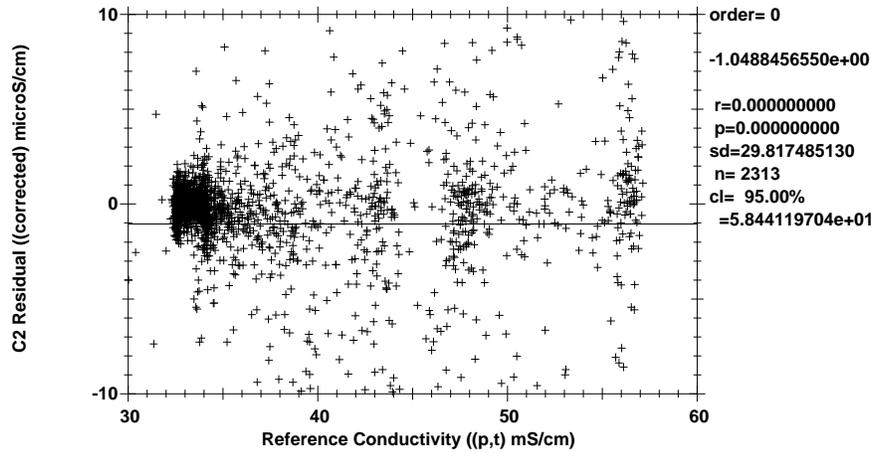


Figure 1.7.3.14 Corrected $C_{Bottle} - C2$ by conductivity ($-0.01^{\circ}\text{C} \leq T1-T2 \leq 0.01^{\circ}\text{C}$).

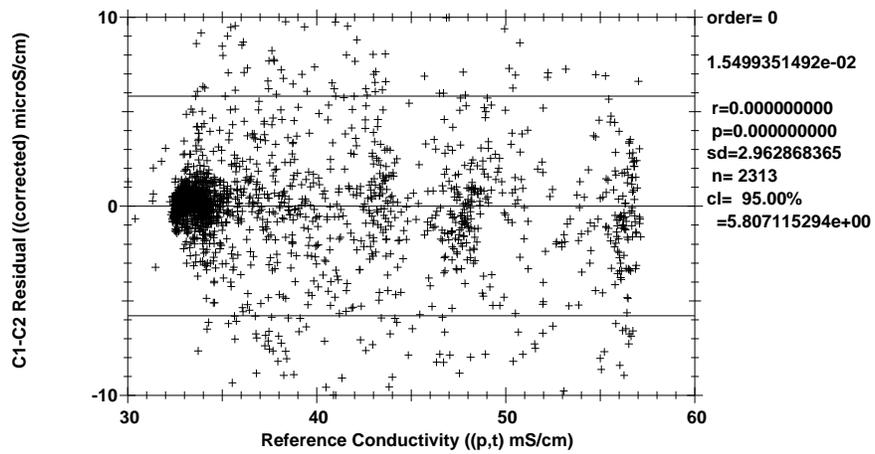


Figure 1.7.3.15 Corrected $C1 - C2$ by conductivity ($-0.01^{\circ}\text{C} \leq T1-T2 \leq 0.01^{\circ}\text{C}$).

The final corrections for the secondary sensors used on CLIVAR A20 are summarized in [Appendix A](#). Corrections made to C2 conductivity sensor had the form:

$$C2_{cor} = C2 + c_1 C2 + c_0$$

Salinity residuals after applying shipboard P/T/C corrections are summarized in [figures 1.7.3.16](#) through [1.7.3.18](#). Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

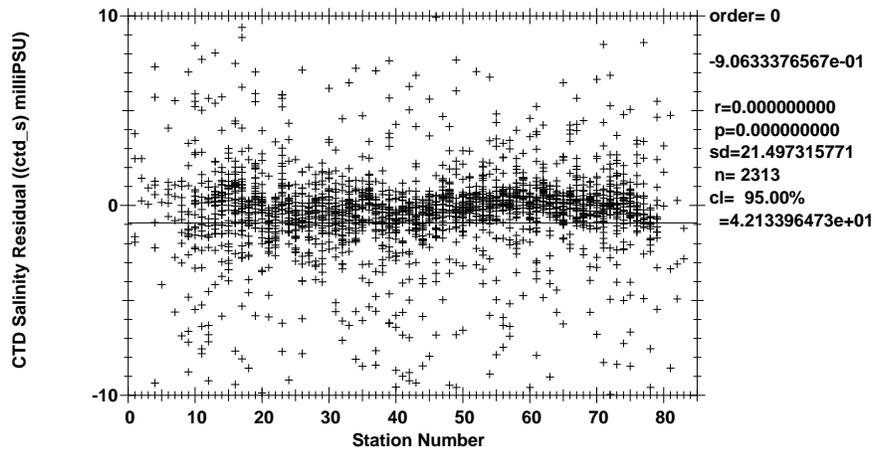


Figure 1.7.3.16 Salinity residuals by station ($-0.01^{\circ}\text{C} \leq T1-T2 \leq 0.01^{\circ}\text{C}$).

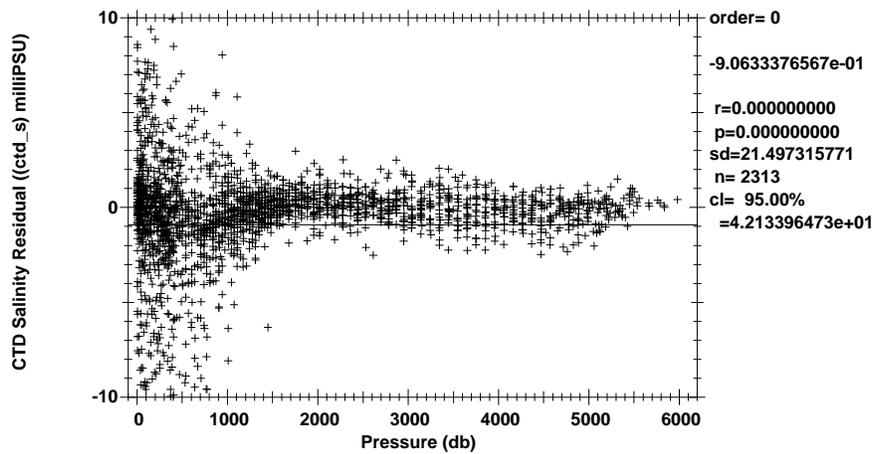


Figure 1.7.3.17 Salinity residuals by pressure ($-0.01^{\circ}\text{C} \leq T1-T2 \leq 0.01^{\circ}\text{C}$).

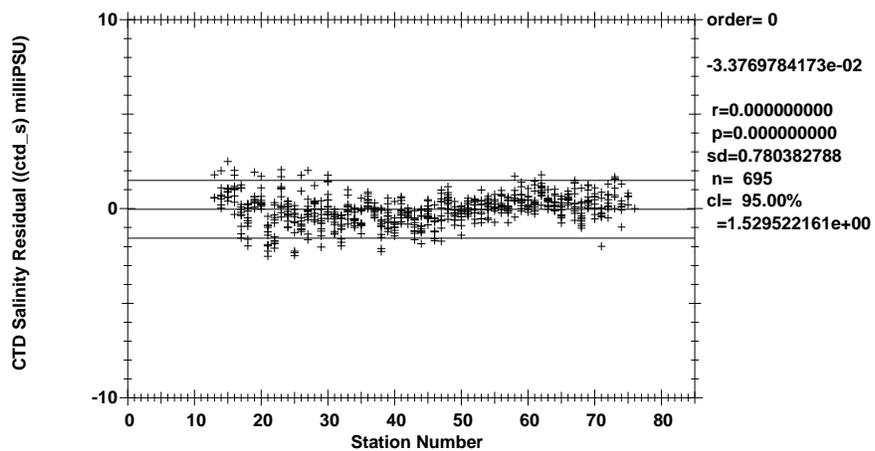


Figure 1.7.3.18 Deep Salinity residuals by station (Pressure ≥ 2000 dbar).

Figures 1.7.3.17 and 1.7.3.18 represent estimates of the salinity accuracy of CLIVAR A20. The 95% confidence limits are ± 0.0015 PSU relative to bottle salinities for deep salinities, and ± 0.0421 PSU relative to bottle salinities for all salinities, where $T1-T2$ is within $\pm 0.01^{\circ}\text{C}$.

1.7.4. CTD Dissolved Oxygen

A single SBE43 dissolved O_2 sensor (DO/43-0614) was used during most of CLIVAR A20. A backup sensor (DO/43-0186) was used on station 54 only, in order to see if some of the low-level noise in the oxygen sensor went away. The DO sensor was plumbed into the T2/C2 pump circuit after C2.

The DO sensor was calibrated to dissolved O_2 bottle samples taken at bottle stops by matching the down cast CTD data to the up cast trip locations on isopycnal surfaces, then calculating CTD dissolved O_2 using a DO sensor response model and minimizing the residual differences from the bottle samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in three stages.

The time constants for the lagged terms in the model were first determined for the sensor. These time constants are sensor-specific but applicable to an entire cruise. Next, casts were fit individually to bottle sample data. Consecutive casts were compared on plots of Theta vs O_2 to verify consistency.

At the end of the cruise, standard and blank values for bottle oxygen data were smoothed, and the bottle oxygen values were recalculated. The changes to bottle oxygen values were small and had minimal effect on the CTD oxygen fits determined during the cruise.

CTD dissolved O_2 residuals are shown in figures 1.7.4.0-1.7.4.2.

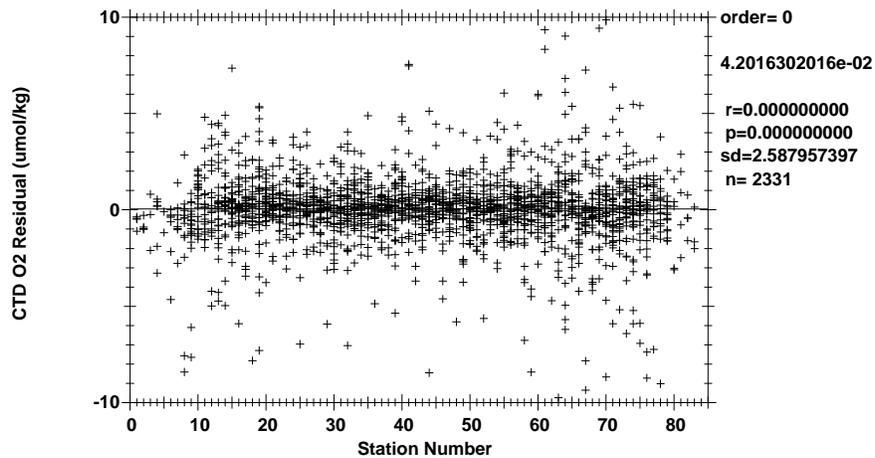


Figure 1.7.4.0 O_2 residuals by station ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

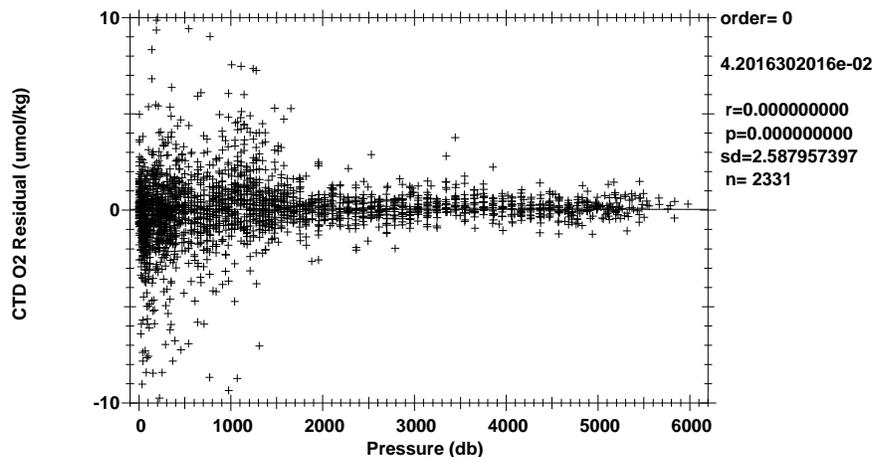


Figure 1.7.4.1 O_2 residuals by pressure ($-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$).

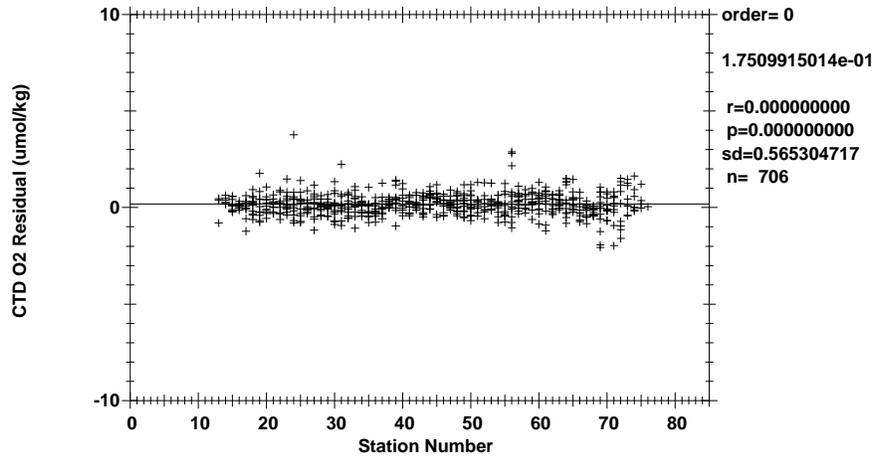


Figure 1.7.4.2 Deep O₂ residuals by station (Pressure >= 2000dbar).

The standard deviations of 2.588 $\mu\text{mol/kg}$ for all oxygens and 0.565 $\mu\text{mol/kg}$ for deep oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O₂ data.

The general form of the SIO/STS DO sensor response model equation for Clark cells follows Brown and Morrison [Brow78], Millard [Mill82] and Owens & Millard [Owen85]. SIO/STS models DO sensor responses with lagged CTD data. *In situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response (τ_p), a slow (τ_{Tf}) and fast (τ_{Ts}) thermal response, package velocity (τ_{dP}), thermal diffusion (τ_{dT}) and pressure hysteresis (τ_h) are fitting parameters. Once determined for a given sensor, these time constants typically remain constant for a cruise. The thermal diffusion term is derived by low-pass filtering the difference between the fast response (T_s) and slow response (T_l) temperatures. This term is intended to correct non-linearities in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved O₂ concentration is then calculated:

$$O_2 ml/l = [C_1 \cdot V_{DO} \cdot e^{(C_2 \frac{P_h}{5000})} + C_3] \cdot f_{sat}(T, P) \cdot e^{(C_4 T_l + C_5 T_s + C_7 P_l + C_6 \frac{dO_c}{dt} + C_8 \frac{dP}{dt} + C_9 dT)} \quad (1.7.4.0)$$

where:

$O_2 ml/l$	Dissolved O_2 concentration in ml/l;
V_{DO}	Raw sensor output;
C_1	Sensor slope
C_2	Hysteresis response coefficient
C_3	Sensor offset
$f_{sat}(T, P)$	O_2 saturation at T,P (ml/l);
T	<i>in situ</i> temperature (°C);
P	<i>in situ</i> pressure (decibars);
P_h	Low-pass filtered hysteresis pressure (decibars);
T_l	Long-response low-pass filtered temperature (°C);
T_s	Short-response low-pass filtered temperature (°C);
P_l	Low-pass filtered pressure (decibars);
$\frac{dO_c}{dt}$	Sensor current gradient (μ amps/sec);
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
dT	low-pass filtered thermal diffusion estimate ($T_s - T_l$).
$C_4 - C_9$	Response coefficients.

CTD $O_2 ml/l$ data are converted to μ mol/kg units on demand.

1.8. Bottle Sampling

At the end of each rosette deployment water samples were drawn from the bottles in the following order:

- CFC-11, CFC-12, CFC-113, SF_6 and CCL_4
- 3He
- Dissolved O_2
- Oxygen Isotopes
- Dissolved Inorganic Carbon (DIC)
- pH
- Total Alkalinity
- ^{13}C - and ^{14}C -DIC
- Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN)
- Tritium
- Nutrients
- ^{14}C -DOC
- Salinity
- Stable Isotope Probing

The correspondence between individual sample containers and the rosette bottle position (1-36) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and insure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log.

Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis. Oxygen, nutrient and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data management.

1.9. Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.23) running on a Linux system. A web service (OpenACS 5.5.0 and AOLServer 4.5.1) front-end provided ship-wide access to CTD and water sample data. Web-based facilities included on-demand arbitrary property-property plots and vertical sections as well as data uploads and downloads.

The sample log (and any diagnostic comments) was entered into the database once sampling was completed. Quality flags associated with sampled properties were set to indicate that the property had been sampled, and sample container identifications were noted where applicable (e.g., oxygen flask number).

Analytical results were provided on a regular basis by the various analytical groups and incorporated into the database. These results included a quality code associated with each measured value and followed the coding scheme developed for the World Ocean Circulation Experiment Hydrographic Programme (WHP) [Joyc94].

Table 1.9.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

		Rosette Samples Stations		1- 83					
		Reported	WHP Quality Codes						
		levels	1	2	3	4	5	7	9
Bottle	2554	0	2541	0	11	0	0	2	
CTD Salt	2554	0	2553	1	0	0	0	0	
CTD Oxy	2545	0	2545	0	0	0	0	9	
Salinity	2535	0	2506	4	25	4	0	15	
Oxygen	2545	0	2525	4	16	1	0	8	
Silicate	2542	0	2527	0	15	0	0	12	
Nitrate	2542	0	2527	0	15	0	0	12	
Nitrite	2542	0	2527	0	15	0	0	12	
Phosphate	2542	0	2527	0	15	0	0	12	

Table 1.9.0 Frequency of WHP quality flag assignments.

Additionally, data investigation comments are presented in [Appendix C](#).

Various consistency checks and detailed examination of the data continued throughout the cruise. Chief Scientist, Mike McCartney, reviewed the data and compared it with historical data sets.

1.10. Salinity Analysis

Equipment and Techniques

A Guildline Autosol 8400B salinometer (S/N 65-740) was used for this cruise which was located located in RV Atlantis's Hydro Lab. The salinometer utilizes National Instruments interface to decode Autosol data and communicate with windows based acquisition PC.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 4-18 hours after collection. The salinometers were standardized for each group of analysis (up to 36 samples) using at least two fresh vials of standard seawater per group.

Salinometer measurements were aided by a computer using LabVIEW software developed by SIO/STS. The software maintained an Autosol log of each salinometer run which included salinometer settings and air and bath temperatures. The air temperature was displayed and monitored via digital thermometer. The program guided the

operator through the standardization procedure and making sample measurements.

Standardization procedures included flushing the cell at least 2 times with a fresh vial of Standard Seawater (SSW), setting the flow rate to a low value during the last fill, and monitoring the STD dial setting. If the STD dial changed by 10 units or more since the last salinometer run (or during standardization), another vial of SSW was opened and the standardization procedure repeated to verify the setting.

Samples were run using 2 flushes before the final fill. The computer determined the stability of a measurement and prompted for additional readings if there appeared to be drift. The operator could annotate the salinometer log, and would routinely add comments about cracked sample bottles, loose thimbles, salt crystals or anything unusual about the sample.

A system of fans were used to expedite equilibrating salinity samples. Cases of samples were placed on a frame with a fan attached to help bring them to room temperature. They were removed and set on a shelf near the Autosal for storage for further equilibration. The next or current case to be run sat to the left of the Autosal, next to the standard seawater. The amount of time each case spent at each location varied depending on sample temperature and rate of analysis by the operator.

General maintenance was performed on the salinometer on regular or as needed basis. These steps include checking that bubbles were not forming on the coils and a cleaning with soapy water, followed by rinses with DI water then three to four flushing with old standard seawater.

Sampling and Data Processing

A total of 2539 salinity samples were measurements were made. 134 vials of standard seawater (IAPSO SSW) were used.

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with the sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and kept closed with Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to sample collection, inserts were inspected for proper fit and loose inserts replaced to insure an airtight seal. The equilibration times were logged for all casts. The samples were measured with an external thermometer by placing the probe against the salinity bottle for 2-3 minutes. When the temperature was close to the bath temperature, 1-2 degrees the samples for the cast were analyzed. Laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference between the initial vial of standard water and the next one run as an unknown was applied as a linear function of elapsed run time to the measured ratios. The corrected salinity data were then incorporated into the cruise database.

Data processing included double checking that the station, sample and box number had been correctly assigned, and reviewing the data and log files for operator comments. Discrete salinity data was compared to CTD salinities and were used for shipboard sensor calibration.

Laboratory Temperature

The salinometer water bath temperature was maintained slightly higher than ambient laboratory air temperature at 24°C. The ambient air temperature varied from 21 to 24°C during the cruise.

Standards

IAPSO Standard Seawater Batches P-153 was used to standardize all stations.

Analytical Problems

There were no major difficulties. Individual problems which may have affected a particular data value are tabulated in [Appendix C](#).

Results

The estimated accuracy of bottle salinities run at sea is usually better than ± 0.002 PSU relative to the particular standard seawater batch used.

1.11. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light. The titration of the samples and the data logging were controlled by ODF PC software compiled in LabVIEW. Thiosulfate was dispensed by a Brickman Dosimat 665 buret driver fitted with a 1.0 mL buret. The ODF method used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard ($\sim 0.012N$) and thiosulfate solution (~ 55 gm/l). Standard KIO_3 solutions prepared ashore were run daily (approximately every 2-4 stations), unless changes were made to the system or reagents. Reagent/distilled water blanks were also determined daily, or more often if a change in reagents required it to account for presence of oxidizing or reducing agents.

Sampling and Data Processing

2545 samples were analyzed on CLIVAR A20. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Six different cases of 24 flasks each were rotated by station to minimize any potential flask calibration issues. Using a silicone drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. The sample drawing temperatures were measured with an electronic resistance temperature detector (Omega™ HH370 RTD) embedded in the drawing tube. These temperatures were used to calculate $\mu\text{mol/kg}$ concentrations, and as a diagnostic check of bottle integrity. Reagents ($MnCl_2$ then $NaI/NaOH$) were added to fix the oxygen before stoppering. The flasks were shaken to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes. A water seal was applied to the rim of each bottle in between shakes.

The samples were analyzed within 1-2 hours of collection, and the data incorporated into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The thiosulfate normalities and blanks were monitored for possible drifting or possible problems when new reagents were used. An average blank and thiosulfate normality were used to recalculate oxygen concentrations. The same batch of thiosulfate prepared before departure was used for the duration of the cruise. In addition, no titrator equipment changes were made, allowing for all standardization and blank calculations throughout all stations to be averaged. The difference between the original and "smoothed" data averaged 0.15% over course of the cruise.

Bottle oxygen data was reviewed ensuring proper station, cast, bottle number, flask, and draw temperature were entered properly. Comments made during analysis were reviewed. All anomalous actions were investigated and resolved. If an incorrect end point was encountered, the analyst re-examined raw data and the program recalculated a correct end point.

After the data was uploaded to the database, bottle oxygen was graphically compared with CTD oxygen and adjoining stations. Any points that appeared erroneous were reviewed and comments were made regarding the final outcome of the investigation. These investigations and final data coding are reported in [Appendix C](#).

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water to determine flask volumes at ODF's chemistry laboratory. This was done once before using flasks for the first time and periodically thereafter when a suspect volume is detected. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 mL Dosimat buret used to dispense standard iodate solution.

Standards

Liquid potassium iodate standards were prepared and tested in 6 liter batches and bottled in sterile glass bottles at ODF's chemistry laboratory prior to the expedition. The normality of the liquid standard was determined by calculation from weight of powder temperature of solution and flask volume at 70°C. The standard was supplied by

Alfa Aesar (lot B05N35) and has a reported purity of 99.4-100.4%. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

Analytical Problems

Analytical problems experienced were minimal. Those issues experienced were caused by unknown malfunctions in the LabVIEW titration software, and did not result in lost samples or erroneous endpoints.

The first typically occurred on titrations following an endpoint that had been aborted, resulting in the program going into a very-low dispensing mode before the titration had neared the endpoint. To prevent the sample from titrating for a length of time that might have affected the titration, the volume of thiosulfate would be dispensed and the sample would be aborted, then restarted. The previously dispensed volume was then added to volume dispensed during the second titration. This solution always resulted in an endpoint that closely matched the adjacent bottle points and the CTD profile.

There were a couple of instances where the titrator rig went prematurely into the low dispensing mode due to direct sunlight shining on the sample bath and ultra-violet light sensor. The issue was noticed and sources of direct natural light were then covered at times when sunlight might affect the detection limits of the rig.

1.12. Nutrient Analysis

Summary of Analysis

2542 samples from 83 CTD stations.

The cruise started with new pump tubes and they were changed once after station 044. Two sets of primary/secondary standards were made during the course of the cruise. The cadmium column efficiency was checked when nitrate sensitivity dropped. A column was replaced if the efficiency was below 97%.

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate plus nitrite, and nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). After each run, the charts were reviewed for any problems and final concentrations (in μM or micromoles per liter) were calculated using SEAL Analytical AACE 6.07 software.

The analytical methods used are described by Gordon *et al.* [Gord92], Hager *et al.* [Hage68] and Atlas *et al.* [Atla71]. The details of modification of analytical methods used for this cruise are also compatible with the methods described in the nutrient section of the GO-SHIP repeat hydrography manual [Hyde10].

Nitrate/Nitrite Analysis

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample was passed through a cadmium column where the nitrate was reduced to nitrite. This nitrite was then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a red dye. The sample was then passed through a 10mm flowcell and absorbance measured at 540nm. The procedure was the same for the nitrite analysis but without the cadmium column.

REAGENTS

Sulfanilamide

Dissolve 10g sulfanilamide in 1.2N HCl and bring to 1 liter volume. Add 2 drops of 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle.

Note: 40% Surfynol 465/485 is 20% 465 plus 20% 485 in DIW.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N)

Dissolve 1g N-1-N in DIW, bring to 1 liter volume. Add 2 drops 40% surfynol 465/485 surfactant. Store at room temperature in a dark poly bottle. Discard if the solution turns dark reddish brown.

Imidazole Buffer

Dissolve 13.6g imidazole in ~3.8 liters DIW. Stir for at least 30 minutes to completely dissolve. Add 60 ml of $CuSO_4$ + NH_4Cl mix (see below). Add 4 drops 40% Surfynol 465/485 surfactant. Let sit overnight before proceeding. Using a calibrated pH meter, adjust to pH of 7.83-7.85 with 10% (1.2N) HCl (about 20-30 ml of acid, depending on exact strength). Bring final solution to 4L with DIW. Store at room temperature.

NH_4Cl + $CuSO_4$ mix

Dissolve 2g cupric sulfate in DIW, bring to 100 ml volume (2%). Dissolve 250g ammonium chloride in DIW, bring to 1 liter volume. Add 5ml of 2% $CuSO_4$ solution to this NH_4Cl stock. This should last many months.

Phosphate Analysis

Ortho-Phosphate was analysed using a modification of the Bernhardt and Wilhelms [Bern67] method. Acidified ammonium molybdate was added to a seawater sample to produce phosphomolybdic acid, which was then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample was passed through a 10mm flowcell and absorbance measured at 820nm.

REAGENTS

Ammonium Molybdate

H_2SO_4 solution: Pour 420 ml of DIW into a 2 liter Erlenmeyer flask or beaker, place this flask or beaker into an ice bath. SLOWLY add 330 ml of concentrated H_2SO_4 . This solution gets VERY HOT!! Cool in the ice bath. Make up as much as necessary in the above proportions.

Dissolve 27g ammonium molybdate in 250ml of DIW. Bring to 1 liter volume with the cooled sulfuric acid solution. Add 3 drops of 15% DDS surfactant. Store in a dark poly bottle.

Dihydrazine Sulfate

Dissolve 6.4g dihydrazine sulfate in DIW, bring to 1 liter volume and refrigerate.

Silicate Analysis

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67]. Acidified ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample was passed through a 10mm flowcell and measured at 660nm.

REAGENTS

Tartaric Acid

Dissolve 200g tartaric acid in DW and bring to 1 liter volume. Store at room temperature in a poly bottle.

Ammonium Molybdate

Dissolve 10.8g Ammonium Molybdate Tetrahydrate in 1000ml dilute H_2SO_4 *. *(Dilute H_2SO_4 = 2.8ml concentrated H_2SO_4 or 6.4ml of H_2SO_4 diluted for PO_4 moly per liter DW) (dissolve powder, then add H_2SO_4) Add 3-5 drops 15% SDS surfactant per liter of solution.

Stannous Chloride stock (as needed)

Dissolve 40g of stannous chloride in 100 ml 5N HCl. Refrigerate in a poly bottle.

NOTE: Minimize oxygen introduction by swirling rather than shaking the solution. Discard if a white solution (oxychloride) forms.

working: (every 24 hours) Bring 5 ml of stannous chloride stock to 200 ml final volume with 1.2N HCl. Make up daily - refrigerate when not in use in a dark poly bottle.

Sampling

Nutrient samples were drawn into 40 ml polypropylene screw-capped centrifuge tubes. The tubes and caps were cleaned with 10% HCl and rinsed 2-3 times with sample before filling. Samples were analyzed within 1-3 hours after sample collection, allowing sufficient time for all samples to reach room temperature. The centrifuge tubes fit directly onto the sampler.

Data collection and processing

Data collection and processing was done with the software (ACCE ver 6.07) provided with the instrument from Seal Analytical. After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (μM) were calculated, based on a linear curve fit. Once the run was reviewed and concentrations calculated a text file was created. That text file was reviewed for possible problems and then converted to another text file with only sample identifiers and nutrient concentrations that was merged with other bottle data. The values are converted to micro-moles per kilogram when merged with the CTD trip information and other bottle data.

Standards and Glassware calibration

Primary standards for silicate (Na_2SiF_6), nitrate (KNO_3), nitrite (NaNO_2), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co. and/or Fisher Scientific. The supplier reports purities of >98%, 99.999%, 97%, and 99.999 respectively.

All glass volumetric flasks and pipettes were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed out to 0.1 mg prior to the cruise. The exact weight was noted for future reference. When primary standards were made, the flask volume at 20°C, the weight of the powder, and the temperature of the solution were used to buoyancy correct the weight, calculate the exact concentration of the solution, and determine how much of the primary was needed for the desired concentrations of secondary standard. Primary and secondary standards were made up every 7-10 days. The new standards were compared to the old before use.

All the reagent solutions, primary and secondary standards were made with fresh distilled deionized water (DIW).

Standards used for the analysis were a combination of reference materials for nutrients in seawater (RMNS) and a dilution of the secondary standard. The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama *et al.* [Aoya06] [Aoya07] [Aoya08] and Sato *et al.* [Sato10].

RMNS batches BS, BU, BT, and BD were used on this cruise. The high working standard was made up using the in house secondary standard and low nutrient seawater (LNSW). Surface water having low nutrient concentration was taken and filtered using 0.45 micrometer pore size membrane filter. This water was stored in 20 liter cubitainer within a cardboard box. The concentrations of nutrient of this water were measured carefully in Jul 2008. Standardizations were performed at the beginning of each group of samples. Two different batches of LNSW were used on the cruise. The first was used for stations 1-35 and a different batch of LNSW was used for stations 36-83.

Std.	N+N	PO4	SiO3	NO2	
BS	0.10	0.065	1.69	0.03	
BU	4.13	0.387	21.21	0.07	
BT	19.10	1.35	42.83	0.48	
BD	30.59	2.244	67.27	0.05	
Std5	46.54	3.645	91.66	1.51	sta 1-35
Std5	46.56	3.650	91.66	1.52	sta 36-82

Table 1.12.0 CLIVAR A20 Concentration of RMNS and high standard (μM)

Quality Control

All data were reported in μM (micromoles/liter). NO_3 , PO_4 , and NO_2 were reported to two decimal places and SiO_3 to one. Accuracy is based on the quality of the standards; the levels were:

Parameter	Accuracy (μM)
NO_3	0.05
PO_4	0.02
SiO_3	2-4
NO_2	0.05

Table 1.12.1 CLIVAR A20 Nutrient Accuracy

Precision numbers for the instrument were the same for NO_3 and PO_4 and a little better for SiO_3 and NO_2 (1 and 0.01 respectively).

The detection limits for the methods/instrumentation were:

Parameter	Detection Limits (μM)
NO_3+NO_2	0.02
PO_4	0.02
SiO_3	0.5
NO_2	0.02

Table 1.12.2 CLIVAR A20 Nutrient Detection Limits

As is standard ODF practice, a deep calibration *check* sample was run with each set of samples and the data are tabulated below.

Parameter	Concentration (μM)
NO_3	18.22 +/- 0.07
PO_4	1.22 +/- 0.01
SiO_3	18.81 +/- 0.20

Table 1.12.3 CLIVAR A20 Concentrations of deep sample

Analytical Problems

Nitrate sensitivity was low on some stations due to cadmium column degradation. Column reduction efficiencies were monitored and a number of column changes were made over the course of the cruise. The degradation of the columns was eventually tracked to the pH of the imidazole buffer solution. The pH had not been adjusted sufficiently. Once the pH was adjusted and monitored, nitrate sensitivity remained consistent.

References

Aoya06.

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Appendix A

CLIVAR A20: CTD Temperature and Conductivity Corrections Summary

Sta/ Cast	ITS-90 Temperature Coefficients		Conductivity Coefficients			
	corT = T + t0 t0		corC = cp2*corP ² + cp1*corP + c1*C + c0 cp2	cp1	c1	c0
001/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.010934
002/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.010950
003/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.010964
004/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.010977
005/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.010992
006/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011010
007/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011029
008/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011053
009/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011079
010/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011107
011/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011137
012/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011167
013/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011199
014/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011241
015/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011283
016/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011333
017/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011383
018/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011439
019/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011483
020/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011526
021/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011570
022/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011611
023/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011649
024/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011701
025/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011751
026/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011796
027/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011842
028/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011884
029/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011921
030/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011958
031/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.011992
032/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012022
033/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012051
034/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012078
035/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012105
036/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012127
037/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012146
038/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012160
039/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012172
040/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012181
041/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012187
042/01	0.000668		1.42084e-10	-9.37089e-07	-2.51102e-04	0.012190

Sta/ Cast	ITS-90 Temperature Coefficients	Conductivity Coefficients			
	$corT = T + t0$ t0	$corC = cp2*corP^2 + cp1*corP + c1*C + c0$			
		cp2	cp1	c1	c0
043/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012191
044/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012188
045/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012183
046/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012174
047/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012163
048/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012148
049/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012130
050/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012109
051/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012084
052/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012057
053/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.012029
054/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011997
055/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011959
056/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011922
057/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011881
058/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011835
059/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011793
060/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011743
061/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011690
062/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011635
063/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011593
064/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011545
065/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011499
066/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011436
067/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011369
068/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011300
069/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011247
070/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011200
071/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011147
072/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011094
073/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011048
074/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.011005
075/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010960
076/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010920
077/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010881
078/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010854
079/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010828
080/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010805
081/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010789
082/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010779
083/01	0.000668	1.42084e-10	-9.37089e-07	-2.51102e-04	0.010769

Appendix B

Summary of CLIVAR A20 CTD Oxygen Time Constants (time constants in seconds)

Pressure Hysteresis (τ_h)	Temperature		Pressure Gradient (τ_p)	O_2 Gradient (τ_{og})	Velocity (τ_{dP})	Thermal Diffusion (τ_{dT})
50.0	Long(τ_{TL})	Short(τ_{TS})	0.50	8.00	200.00	300.0
	300.0	4.0				

CLIVAR A20: Conversion Equation Coefficients for CTD Oxygen (refer to Equation 1.7.4.0)

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
001/01	4.935e-04	-0.1696	5.1724	-9.481e-03	1.567e-02	-5.812e-02	-9.613e-04	-5.812e-02	5.940e-02
002/01	4.539e-04	-0.1752	3.9570	-1.181e-05	1.068e-02	-1.591e-01	-1.003e-04	-1.591e-01	4.886e-02
003/01	5.283e-04	-0.2997	2.6955	4.508e-03	3.649e-03	-6.730e-02	-7.410e-04	-6.730e-02	1.708e-02
004/01	9.011e-04	-0.3731	-2.7434	-1.424e-02	-1.792e-04	1.071e-01	-4.543e-04	1.071e-01	6.782e-03
005/01	4.633e-04	-0.1916	-0.5219	3.830e-03	5.575e-03	-5.343e-02	-8.053e-04	-5.343e-02	-4.247e-03
006/01	2.842e-04	-0.0167	3.9831	1.509e-02	5.730e-03	-6.946e-02	-3.027e-03	-6.946e-02	6.815e-03
007/01	4.385e-04	-0.1487	-0.7868	4.939e-03	5.131e-03	-5.372e-02	-1.265e-04	-5.372e-02	-3.610e-03
008/01	4.536e-04	-0.1384	-1.3149	6.990e-03	1.339e-03	-7.890e-02	1.244e-04	-7.890e-02	3.489e-03
009/01	3.631e-04	-0.1210	-0.4579	1.227e-02	4.517e-03	-4.476e-02	-1.975e-03	-4.476e-02	-1.411e-02
010/01	6.857e-04	-0.2504	-1.7640	-8.749e-03	2.670e-03	3.852e-02	-1.765e-03	3.852e-02	1.248e-02
011/01	6.040e-04	-0.1632	-2.1268	-8.582e-03	6.023e-03	1.785e-02	-6.788e-04	1.785e-02	1.926e-02
012/01	6.900e-04	-0.3252	0.6216	-6.867e-05	-2.806e-03	7.057e-03	4.958e-04	7.057e-03	1.258e-03
013/01	5.533e-04	-0.0910	-0.8293	-1.084e-02	9.914e-03	-9.832e-03	-3.590e-03	-9.832e-03	2.173e-02
014/01	6.306e-04	-0.2507	0.6591	6.355e-03	-8.563e-03	1.120e-02	-2.482e-03	1.120e-02	1.460e-02
015/01	5.970e-04	-0.2294	-0.0297	-1.919e-03	2.047e-03	-1.738e-03	-2.620e-03	-1.738e-03	2.325e-03
016/01	5.946e-04	-0.2303	-0.1418	-2.172e-03	2.533e-03	-1.653e-02	-5.913e-03	-1.653e-02	-1.984e-04
017/01	5.882e-04	-0.2308	-0.0798	-4.218e-03	5.409e-03	-2.414e-03	-3.896e-03	-2.414e-03	-4.501e-03
018/01	5.816e-04	-0.2008	-0.1435	1.248e-03	-1.295e-03	-7.265e-03	1.483e-03	-7.265e-03	7.459e-03
019/01	5.979e-04	-0.2341	-0.0715	-2.809e-03	2.958e-03	-9.153e-03	-9.877e-03	-9.153e-03	-3.305e-04
020/01	6.033e-04	-0.2485	-0.0579	-5.152e-04	9.644e-04	-7.341e-03	1.400e-04	-7.341e-03	-9.332e-04
021/01	5.960e-04	-0.2306	-0.0699	-2.053e-03	2.675e-03	-4.824e-03	-5.245e-04	-4.824e-03	1.321e-03
022/01	5.874e-04	-0.2130	-0.1086	-2.498e-03	3.132e-03	-8.830e-03	1.620e-03	-8.830e-03	2.845e-03
023/01	6.031e-04	-0.2418	-0.0721	-2.871e-03	3.011e-03	-1.094e-02	1.332e-03	-1.094e-02	-2.110e-03
024/01	6.013e-04	-0.2354	-0.0628	-8.599e-03	9.083e-03	-8.616e-03	-9.184e-06	-8.616e-03	-3.826e-03
025/01	5.993e-04	-0.2377	-0.0181	-3.701e-03	4.386e-03	4.422e-03	-3.607e-04	4.422e-03	-1.296e-03
026/01	5.960e-04	-0.2067	-0.1163	-2.949e-03	2.707e-03	-1.897e-02	3.864e-03	-1.897e-02	6.637e-03
027/01	5.993e-04	-0.2306	-0.0994	-2.993e-03	3.125e-03	-1.734e-02	-7.103e-03	-1.734e-02	-7.628e-04
028/01	6.086e-04	-0.2510	-0.0500	-2.815e-03	3.092e-03	-1.006e-02	-2.306e-03	-1.006e-02	-4.835e-03
029/01	5.780e-04	-0.2050	-0.1113	-6.723e-03	7.690e-03	-2.378e-03	1.077e-03	-2.378e-03	4.470e-04
030/01	5.968e-04	-0.2159	-0.0966	-3.644e-03	3.988e-03	-1.162e-02	7.215e-04	-1.162e-02	6.057e-03
031/01	5.910e-04	-0.2162	-0.0653	-3.517e-03	4.051e-03	1.538e-03	9.464e-04	1.538e-03	4.640e-03
032/01	5.990e-04	-0.2394	-0.0938	-1.926e-03	2.713e-03	-1.345e-02	-3.786e-04	-1.345e-02	-3.911e-03
033/01	5.685e-04	-0.1777	-0.1049	-1.123e-02	1.194e-02	4.849e-03	3.449e-03	4.849e-03	-2.817e-04
034/01	5.828e-04	-0.1838	-0.1231	-1.030e-02	1.061e-02	-1.149e-02	-4.156e-04	-1.149e-02	4.754e-03
035/01	6.180e-04	-0.2514	-0.0116	3.182e-03	-3.353e-03	-3.179e-03	3.389e-03	-3.179e-03	4.610e-03
036/01	5.847e-04	-0.2222	-0.1579	-2.753e-03	4.073e-03	-1.610e-02	-1.063e-03	-1.610e-02	-2.610e-03

Sta/ Cast	O_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
037/01	5.637e-04	-0.1984	-0.2587	-3.595e-03	5.822e-03	-2.150e-02	-1.198e-03	-2.150e-02	-1.874e-03
038/01	5.981e-04	-0.2340	-0.0452	3.358e-03	-3.077e-03	1.801e-03	3.642e-03	1.801e-03	3.227e-03
039/01	5.943e-04	-0.2130	-0.0360	-5.956e-03	6.027e-03	-2.559e-03	1.463e-03	-2.559e-03	9.214e-04
040/01	6.001e-04	-0.2434	-0.0397	-4.333e-03	5.185e-03	1.684e-03	8.446e-03	1.684e-03	-2.829e-03
041/01	6.070e-04	-0.2575	-0.0583	-8.980e-04	1.623e-03	-7.878e-03	2.976e-03	-7.878e-03	-2.939e-03
042/01	5.971e-04	-0.2211	-0.1044	-3.578e-03	3.853e-03	-1.140e-02	1.296e-03	-1.140e-02	1.586e-03
043/01	5.750e-04	-0.2220	-0.1711	-7.556e-03	1.006e-02	-1.440e-02	4.639e-04	-1.440e-02	-1.233e-02
044/01	5.753e-04	-0.2153	-0.1511	-4.280e-03	6.184e-03	-9.960e-03	2.355e-03	-9.960e-03	-6.306e-03
045/01	5.904e-04	-0.2113	-0.1050	-7.487e-03	8.268e-03	-9.981e-03	1.320e-03	-9.981e-03	-2.565e-03
046/01	6.025e-04	-0.2382	-0.0080	-2.314e-03	3.181e-03	4.658e-03	5.190e-03	4.658e-03	1.655e-03
047/01	5.647e-04	-0.1943	-0.1583	-1.086e-02	1.289e-02	-1.129e-02	-2.487e-04	-1.129e-02	-1.199e-02
048/01	5.724e-04	-0.1933	-0.1274	-7.987e-03	9.700e-03	-4.380e-03	-2.323e-03	-4.380e-03	-3.057e-03
049/01	5.735e-04	-0.2089	-0.1299	-3.212e-03	5.368e-03	-8.411e-03	2.913e-03	-8.411e-03	-6.063e-03
050/01	5.957e-04	-0.2228	-0.0976	-1.778e-03	2.352e-03	-1.202e-02	5.220e-03	-1.202e-02	-2.137e-03
051/01	5.403e-04	-0.1529	-0.2718	-1.085e-02	1.386e-02	-1.070e-02	6.670e-03	-1.070e-02	-7.928e-03
052/01	5.384e-04	-0.1642	-0.3035	-1.328e-02	1.724e-02	-1.919e-02	-4.722e-04	-1.919e-02	-1.499e-02
053/01	6.049e-04	-0.2433	-0.0664	-2.197e-03	3.033e-03	-7.965e-03	5.316e-03	-7.965e-03	-2.669e-03
054/01	4.302e-04	-0.1402	-0.1483	-1.081e-02	1.406e-02	-1.128e-02	-1.207e-03	-1.128e-02	-6.520e-03
055/01	5.617e-04	-0.1869	-0.2829	-7.966e-03	1.039e-02	-3.385e-02	2.376e-03	-3.385e-02	-8.820e-03
056/01	5.824e-04	-0.2200	-0.1379	-3.803e-03	5.491e-03	-1.460e-02	6.287e-03	-1.460e-02	-1.021e-02
057/01	6.320e-04	-0.2900	0.0070	5.548e-03	-5.652e-03	-3.251e-03	-2.499e-03	-3.251e-03	1.375e-03
058/01	5.745e-04	-0.2314	-0.1936	-1.738e-03	5.080e-03	-3.788e-03	3.511e-03	-3.788e-03	-6.553e-03
059/01	6.519e-04	-0.3189	0.0285	8.318e-03	-9.087e-03	-6.305e-03	3.817e-03	-6.305e-03	3.132e-03
060/01	5.991e-04	-0.2198	-0.0994	-1.935e-03	1.847e-03	-1.300e-02	-4.333e-04	-1.300e-02	1.023e-03
061/01	5.931e-04	-0.2433	-0.1160	7.700e-04	1.131e-03	-1.343e-02	2.934e-03	-1.343e-02	-5.623e-03
062/01	5.760e-04	-0.1841	-0.1508	-1.026e-02	1.089e-02	-1.160e-02	-1.381e-03	-1.160e-02	-2.815e-03
063/01	6.122e-04	-0.2684	-0.0508	5.204e-03	-2.515e-03	-7.700e-03	-1.681e-03	-7.700e-03	8.168e-04
064/01	5.134e-04	-0.1294	-0.4462	-2.715e-02	3.276e-02	-3.046e-02	-2.971e-04	-3.046e-02	-3.303e-02
065/01	6.336e-04	-0.2951	0.0243	1.205e-02	-1.259e-02	8.141e-03	1.093e-03	8.141e-03	5.925e-03
066/01	5.748e-04	-0.1994	-0.1575	-6.022e-03	7.373e-03	-4.783e-03	2.536e-03	-4.783e-03	-8.981e-03
067/01	6.067e-04	-0.2264	-0.0302	-5.511e-03	4.925e-03	-6.974e-04	-1.579e-03	-6.974e-04	-3.390e-04
068/01	6.486e-04	-0.3200	0.0913	1.505e-02	-1.489e-02	1.217e-02	-3.213e-03	1.217e-02	7.255e-03
069/01	5.866e-04	-0.2141	-0.0418	-9.791e-03	1.227e-02	9.464e-03	5.963e-03	9.464e-03	-3.599e-03
070/01	6.414e-04	-0.2646	0.0025	1.518e-03	-4.081e-03	-7.900e-03	4.075e-03	-7.900e-03	7.121e-03
071/01	6.127e-04	-0.2627	-0.1348	2.366e-03	-7.110e-04	-1.608e-02	2.437e-03	-1.608e-02	-2.474e-03
072/01	5.535e-04	-0.2488	2.4873	-3.401e-03	1.253e-02	3.111e-02	2.146e-03	3.111e-02	-1.664e-02
073/01	6.249e-04	-0.2949	1.8216	1.581e-03	8.623e-04	1.469e-02	1.635e-03	1.469e-02	-3.632e-04
074/01	5.834e-04	-0.2746	2.2811	3.211e-03	2.534e-03	2.661e-02	-4.298e-04	2.661e-02	-6.160e-03
075/01	4.986e-04	-0.2667	3.8579	1.012e-02	1.128e-02	5.550e-02	3.276e-03	5.550e-02	-1.340e-02
076/01	6.293e-04	-0.2813	0.1863	2.532e-03	-4.920e-04	3.004e-03	5.593e-03	3.004e-03	1.572e-03
077/01	7.398e-04	-0.2530	-0.4560	-1.780e-02	-7.416e-03	-3.730e-03	4.724e-03	-3.730e-03	1.856e-02
078/01	7.629e-04	-0.2730	0.1139	-1.900e-02	-6.780e-03	1.935e-02	7.319e-03	1.935e-02	1.841e-02
079/01	5.961e-04	-0.2285	0.2909	3.046e-03	-8.263e-04	2.552e-03	4.247e-03	2.552e-03	-5.945e-03
080/01	6.151e-04	-0.2559	-0.2517	2.514e-04	6.042e-04	-6.932e-04	4.380e-03	-6.932e-04	-6.376e-03
081/01	4.312e-04	0.1909	-3.8899	-5.310e-04	-5.226e-03	5.128e-02	1.805e-04	5.128e-02	1.413e-02
082/01	3.451e-04	0.2025	4.7111	6.023e-03	1.830e-02	6.185e-02	2.775e-03	6.185e-02	2.852e-02
083/01	3.677e-04	-0.2507	3.0392	6.596e-02	4.216e-02	-5.521e-02	1.257e-02	-5.521e-02	-6.434e-02

Appendix C

CLIVAR A20: Bottle Quality Comments

Comments from the Sample Logs and the results of STS/ODF's data investigations are included in this report. Units stated in these comments are degrees Celsius for temperature, Unless otherwise noted, milliliters per liter for oxygen and micromoles per liter for Silicate, Nitrate, Nitrite, and Phosphate. The sample number is the cast number times 100 plus the bottle number. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and re-reading of charts (i.e. nutrients).

Station /Cast	Sample No.	Quality Property	Code	Comment
1/1	101	bottle	2	Spigot was found to be leaking by CFC sampler. This was a spit from the spigot. Oxygen as well as salinity and nutrients are acceptable.
1/1	101	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients.
2/1	105	salt	2	Salinity high due to large amount of variation in CTD profile within surface waters. Salinity agrees with adjacent stations.
3/1	107	salt	2	Salinity low due to large amount of variation in CTD within surface waters. Salinity agrees with adjacent stations.
4/1	101	bottle	2	Spigot was found to be leaking by CFC sampler. Only CFCs and O2 drew samples. O-rings were replaced on spigot before next cast. Oxygen, salinity and nutrients are acceptable.
4/1	104	o2	3	Oxygen very high. no comments on sample log or data file. Coding as questionable due to unknown error.
4/1	105	salt	2	Salinity low due to variability in surface waters.
5/1	107	bottle	2	Bottle reported empty for salts and nutrients. Both salinity and nutrient samples recorded on sample tags, which were found in sample cases afterward.
7/1	102	o2	2	Sample was overtitrated and backtitrated. Oxygen is acceptable.
7/1	112	salt	2	Large fluctuations at bottle stop in the middle of a very sharp/high gradient area. Bottle salinity is consistent with adjacent bottles and stations. CTD is acceptable on it's own, picking up deeper water.
8/1	107	bottle	2	Spigot was reported to be pushed in. No water coming out. Sampler was not pushing in the spigot properly, instructions were given and sampling proceeded.
8/1	110	bottle	9	A transcription error was made on the Sample Log sheet. The 200 intended depth was not sampled, the Sample Log indicated it was duplicated at bottle 11.
8/1	111	bottle	2	Console operator did not wait 30 seconds before tripping. Duplicate, 12, was tripped to account for this. Bottle tripped in a gradient before rosette was fully stopped, code CTD salinity questionable.
8/1	111	ctds2	3	
8/1	111	reft	3	Unstable SBE35RT reading in high gradient zone. SBE35RT -0.25/-0.03 vs CTDT1/CTDT2. Code questionable.
8/1	112	reft	3	Unstable SBE35RT reading in high gradient zone. SBE35RT -0.19 vs CTDT2. Code questionable.
8/1	119	bottle	9	Bottle not recorded as being tripped on Sample Log. Bottle was not noticed to have been tripped. No samples were collected.
9/1	107	bottle	2	Spigot was left open. Samples drawn. O2 and Salinity fit closely to CTD profile.
10/1	121	bottle	2	Spigot pin misaligned and/or bent.

Station /Cast	Sample No.	Quality Property	Code	Comment
11/1	104	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations. Variation seen in CTD profile, difference is between the bottle 1 meter above the CTD. Salinity as well as oxygen and nutrients are acceptable.
11/1	119	o2	4	Sample evidently drawn from bottle 20 rather than 19. Value too high and extremely close to 20. Other parameters do not correspond to difference seen in O2.
11/1	124	o2	3	Surface bottle o2 is high compared with CTD and adjoining stations; using it throws off the entire CTDO fit. Code questionable.
11/1	124	salt	2	4 attempts for a good salinity reading. Additional readings resulted in an acceptable salinity. Salinity as well as oxygen and nutrients are acceptable.
12/1	113	no2	4	
12/1	113	no3	4	
12/1	113	po4	4	Nutrient sample was missed during sampling, took water from salinity bottle, which compromised the salinity and did not produce a good nutrient sample. Code nutrients bad.
12/1	113	salt	4	Nutrient sample was missed during sampling, took water from salinity bottle, which compromised the salinity. Code salinity bad.
12/1	113	sio3	4	
13/1	111	o2	2	Oxygen is a high compared to CTDO, this is an oxygen gradient and is acceptable. Salinity and nutrients verify that this bottle tripped properly.
13/1	114	o2	2	O2 draw temperature not consistent with surrounding Niskins. Oxygen plots are consistent with adjacent bottles, as are other parameters. Suspect that thermometer went to hold mode. Oxygen is acceptable as well as salinity and nutrients.
13/1	115	o2	4	O2 analyst reported running 15 and 16 back to back accidentally. 15 value bad and 16 lost.
13/1	116	o2	5	O2 analyst reported running 15 and 16 back to back accidentally. 15 value bad and 16 lost.
13/1	118	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations. CTD salinity is lower in this area. Salinity as well as oxygen and nutrients are acceptable.
13/1	123	o2	2	Oxygen mis-sampled, thought there was a problem, but did not re-draw. No oxygen sample drawn for this sample, code oxygen lost. Flask numbers are scratched out on Sample Log sheet, analysis indicates there was a sample drawn.
13/1	130	reft	3	Stable reading though offset by ~0.2 C from CTDT
13/1	130	salt	2	Bottle salinity is high compared with CTD, oxygen and nutrients are acceptable.
13/1	131	salt	2	Bottle salinity is low compared with CTD, salinity max and gradient, lots of variation in the CTD. Salinity as well oxygen and nutrients are acceptable.
14/1	101	bottle	2	Small amount of leaking from stop-cock. Oxygen as well as salinity and nutrients are acceptable.
14/1	107	salt	2	Bottle salinity is high compared with CTD, suspect Southern Ocean effect. Salinity as well as oxygen and nutrients are acceptable.
14/1	120	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient. Salinity as well as oxygen and nutrients are acceptable.
14/1	132	no2	9	Not enough water in bottle. Nutrients and salinity not drawn, sampling error, spigot not pushed in properly.
14/1	132	no3	9	Not enough water in bottle. Nutrients and salinity not drawn, sampling error, spigot not pushed in properly.
14/1	132	po4	9	Not enough water in bottle. Nutrients and salinity not drawn, sampling error, spigot not pushed in properly.
14/1	132	salt	9	Not enough water in bottle. Nutrients and salinity not drawn, sampling error, spigot not pushed in properly.
14/1	132	sio3	9	Nutrients and salinity not drawn, sampling error, spigot not pushed in properly.

Station /Cast	Sample No.	Quality Property	Code	Comment
15/1	107	salt	2	Bottle salinity is high compared with CTD, could be the Southern Ocean effect seen in all other parameters. SiO3 indicates this is not a bottle problem although there are salinity differences in this bottle which are not on all stations. Salinity as well as oxygen and nutrients are acceptable.
15/1	123	o2	2	Oxygen appears high compared with adjoining stations. There is a feature in the up trace of the CTD that is not seen in the down. Salinity is lower as well as nutrients. DIC, CFC and pH also show this feature.
15/1	132	salt	2	Bottle salinity is high compared with CTD, salinity maximum, variation in CTD at trip, upwelling. Salinity as well as oxygen and nutrients are acceptable.
16/1	108	salt	2	Bottle salinity is high compared with CTD, agrees with bottle salinity on adjoining stations.
16/1	125	bottle	2	Spigot was pushed in during cast. Oxygen as well as salinity and nutrients are acceptable.
16/1	131	salt	2	Bottle salinity is high compared with CTD, agrees with bottle gradient data on adjoining stations. Salinity, oxygen and nutrients are acceptable.
16/1	136	salt	2	3 attempts for a good salinity reading. Suspect cell was not flushed well enough for low salinity. Additional readings agree and salinity as well as oxygen and nutrients are acceptable.
17/1	107	o2	2	Oxygen appears low compared with adjoining stations, nutrients are high, salinity does not show a significant feature. CTD agrees with the oxygen and salinity, data are acceptable.
18/1	105	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
18/1	124	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations for gradient, could be 1 meter bottle vs. CTD difference. Salinity as well as oxygen and nutrients are acceptable.
19/1	104	o2	2	Forgot to extract water off top before opening lid. Oxygen is acceptable.
19/1	107	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations within measurement specifications. Possibly not rinsed well enough during sampling. Salinity as well as oxygen and nutrients are acceptable.
20/1	107	salt	2	Bottle salinity is high compared with CTD, O2 low, nutrients high features in CTD trace. PI suspects Southern Ocean waters. Salinity as well as oxygen and nutrients are acceptable.
20/1	110	salt	2	Bottle salinity is high compared with CTD, slightly high within specs could be a bottle rinsing problem during draw. Salinity as well as oxygen and nutrients are acceptable.
20/1	117	o2	2	Sample was overtitrated and backtitrated, overshot endpoint.
20/1	118	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient. Salinity as well as oxygen and nutrients are acceptable.
20/1	133	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient. Salinity as well as oxygen and nutrients are acceptable.
20/1	136	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient. Salinity as well as oxygen and nutrients are acceptable.
21/1	101	o2	2	Added previous thio amount to volume. O2 communication error, program went to low O2 mode and started dispensing very slowly. Analyst recorded the amount of thio dispensed before shutting down the computer and restarting. Oxygen is acceptable.
21/1	104	salt	2	3 attempts for a good salinity reading. Erratic readings, possible contamination. Salinity as well as oxygen and nutrients are acceptable.
21/1	109	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
21/1	112	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
21/1	118	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations for gradient. Salinity as well as oxygen and nutrients are acceptable.
21/1	133	o2	4	O2 appears to have been drawn from 34, analyst stated that was a possibility, had realized sampling was off by one and tried to reconcile. Code Oxygen bad.
21/1	136	salt	2	Bottle salinity is high compared with CTD, strong gradient could be the difference between the CTD and bottle placement, 1 meter. Salinity as well as oxygen and nutrients are acceptable.
22/1	118	bottle	2	Vent slightly open, half turn, CFC sampled, did not feel it was a problem.
22/1	120	salt	2	3 attempts for a good salinity reading. Program resolved salinity discrepancy. Thimble came out with cap, possible contamination. Salinity is within measurement specifications. Salinity as well as oxygen and nutrients are acceptable.
22/1	131	o2	2	O2 sampler did not realize the draw thermometer went to hold mode, came back after all other sampling was finished, should not be a problem with O2 conversion to mass units.
22/1	135	salt	2	Bottle salinity is high compared with CTD, agree with gradient bottles at adjoining stations. Salinity, oxygen and nutrients are acceptable.
23/1	108	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Thimble came off with cap, possible contamination. Code salinity bad. Oxygen and nutrients are acceptable.
23/1	119	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient. Salinity as well as oxygen and nutrients are acceptable.
24/1	101	o2	2	Ship vibration during oxygen sample; odd trace, endpoint okay. Forgot wake-up sample. Oxygen as well as salinity and nutrients are acceptable.
24/1	107	o2	2	Oxygen check endpoint, averaged values. Oxygen is slightly high compared with CTDO, agrees with adjoining stations. Oxygen as well as salinity and nutrients are acceptable.
24/1	118	o2	2	Oxygen check endpoint, used recalculated value. Oxygen as well as salinity and nutrients are acceptable.
24/1	123	o2	2	Oxygen possibly saw bubbles, but they disappeared after shaking. Oxygen check endpoint, used recalculated value. Oxygen as well as salinity and nutrients are acceptable.
24/1	129	o2	2	Oxygen redrawn, bubbles in flask. Oxygen as well as salinity and nutrients are acceptable.
24/1	133	o2	2	Oxygen very small bubble at top of flask under lid. Oxygen as well as salinity and nutrients are acceptable.
24/1	134	o2	2	Oxygen very small bubble at top of flask under lid. Oxygen as well as salinity and nutrients are acceptable.
24/1	134	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations gradient bottle salinity. Salinity as well as oxygen and nutrients are acceptable.
24/1	135	o2	2	Oxygen very small bubble at top of flask under lid. Oxygen as well as salinity and nutrients are acceptable.
24/1	136	o2	2	Oxygen very small bubble at top of flask under lid. Oxygen as well as salinity and nutrients are acceptable.
25/1	107	po4	2	Nutrients appear low compared with adjoining stations, oxygen is higher than adjoining stations and agrees with CTDO, salinity does not show this feature, real feature data are acceptable.
25/1	134	salt	4	Bottle salinity is low compared with CTD and adjoining stations in gradient. 4 attempts for a good salinity reading. Code salinity bad, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
26/1	111	bottle	4	Oxygen, nutrient, salinity and CFC data indicate bottle closed at the same depth as bottle 10. Code as mis-trip.
26/1	111	no2	4	Oxygen, nutrient, salinity and CFC data indicate mis-trip. Code nutrients bad.
26/1	111	no3	4	Oxygen, nutrient, salinity and CFC data indicate mis-trip. Code nutrients bad.
26/1	111	o2	4	Oxygen, nutrient, salinity and CFC data indicate mis-trip. Code oxygen bad.
26/1	111	po4	4	Oxygen, nutrient, salinity and CFC data indicate mis-trip. Code nutrients bad.
26/1	111	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Salinity was either mis-drawn from bottle 10 or salinometer operator did not change the sample after analysis of 11. Mis-trip of bottle, code salinity bad.
26/1	111	sio3	4	Oxygen, nutrient, salinity and CFC data indicate mis-trip. Code nutrients bad.
26/1	112	bottle	2	Dripping from spigot, vents slightly open.
26/1	115	no2	4	Nutrients mis-drawn with bottle 17.
26/1	115	no3	4	Nutrients mis-drawn with bottle 17.
26/1	115	po4	4	Nutrients mis-drawn with bottle 17.
26/1	115	salt	4	Bottle salinity is low compared with CTD, also low with adjoining stations. Nutrients are high. Suspect that salinity and nutrients were done by the same sampler and they were drawn from bottle 17. Oxygen is acceptable, CFC, DIC, pH and alkalinity are all acceptable. Code salinity and nutrients bad.
26/1	115	sio3	4	Nutrients mis-drawn with bottle 17.
26/1	116	bottle	4	Oxygen, nutrient and dic data indicate bottle closed shallower than expected. pH, alkalinity as well as DIC sampled. Code as mis-trip.
26/1	116	no2	4	Nutrient, o2 and dic data indicate bottle mis-tripped. Code nutrients bad.
26/1	116	no3	4	Nutrient, o2 and dic data indicate bottle mis-tripped. Code nutrients bad.
26/1	116	o2	4	Bottle o2 extremely low, but draw temp looks ok: bottle mis-tripped. Code oxygen bad.
26/1	116	po4	4	Nutrient, o2 and dic data indicate bottle mis-tripped. Code nutrients bad.
26/1	116	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Bottle mis-tripped, code salinity bad.
26/1	116	sio3	4	Nutrient, o2 and dic data indicate bottle mis-tripped. Code nutrients bad.
26/1	118	bottle	2	Valve open. Oxygen is lower than CTDO and agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
26/1	125	salt	2	Bottle salinity is low compared with CTD, gradient agreement with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
27/1	113	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Code salinity questionable, oxygen and nutrients are acceptable.
28/1	101	o2	2	Oxygen wake-up not run before samples. Oxygen appears acceptable.
28/1	104	bottle	2	Nozzle very tight, hard to push in. Oxygen as well as salinity and nutrients are acceptable.
28/1	123	bottle	4	Bottle appears to have mis-tripped, lower in the water column. Oxygen high, nutrients low, CFC, Helium and Tritium sampled at this level.
28/1	123	no2	4	
28/1	123	no3	4	
28/1	123	o2	4	
28/1	123	po4	4	
28/1	123	salt	4	Bottle salinity is high compared with CTD and adjoining stations.
28/1	123	sio3	4	
28/1	130	salt	2	Bottle salinity is high compared with CTD, agrees with other gradient bottle salinity, variation in CTD trace at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
28/1	131	bottle	4	Bottle mis-tripped. Oxygen is high compared with CTD in a gradient, nutrients are high on the station profile and compared with adjoining stations.

Station /Cast	Sample No.	Quality Property	Code	Comment
28/1	131	no2	4	
28/1	131	no3	4	
28/1	131	o2	4	
28/1	131	po4	4	
28/1	131	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Bottle mis-tripped, all parameters coded bad, bottle coded did not trip as scheduled. CFC, Helium, oxygen isotopes, DIC, pH, alkalinity sampled.
28/1	131	sio3	4	
29/1	117	no2	4	
29/1	117	no3	4	
29/1	117	po4	4	
29/1	117	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Appears to have been drawn from bottle 16 as well as nutrients. Oxygen is acceptable and a different sampler. Code salinity and nutrients bad.
29/1	117	sio3	4	
30/1	102	o2	2	Very small bubble under lid of oxygen flask before opening.
30/1	105	o2	2	Bubbles dispensed with acid for oxygen, but none visible in dispenser tip.
30/1	106	salt	3	Bottle salinity is high compared with CTD and adjoining stations. Could be a sampling error, not rinsing the bottle well enough. Code salinity questionable, oxygen and nutrients are acceptable.
30/1	109	o2	2	Bubbles dispensed with acid for oxygen, but none visible in dispenser tip.
30/1	116	o2	2	Oxygen end point checked and recalculated.
30/1	118	o2	2	Low oxygen end point.
30/1	123	o2	2	Sample was overtitrated and backtitrated.
30/1	133	salt	2	Bottle salinity is high compared with CTD, agreement with salinity maximum and large gradient of adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
31/1	101	o2	2	Oxygen wake-up sample not run. Oxygen as well as salinity and nutrients are acceptable.
32/1	113	salt	4	3 attempts for a good salinity reading. Salinity thimble came off with cap, probable contamination in the negative direction. Salinity high compared with CTD and adjoining stations. Code salinity bad, oxygen and nutrients are acceptable.
32/1	122	salt	4	Salinity bottle not filled to the shoulder, bottle ran out, training on sampling was done and used more water. Salinity low compared with adjoining stations. Code salinity bad, oxygen and nutrients are acceptable.
33/1	103	salt	3	Bottle salinity is high compared with CTD and adjoining stations, just out of measurement specifications. No analytical problems noted. Code salinity questionable, oxygen and nutrients are acceptable.
33/1	112	o2	2	May have contaminated oxygen sample with waste water while trying to get drop off thio dispenser tip. Oxygen as well as salinity and nutrients are acceptable.
36/1	130	salt	5	Salinity lost during analysis, operator error.
37/1	101	o2	2	Oxygen titrator wake-up sample not run. Oxygen as well as nutrients are acceptable.
37/1	104	bottle	2	pH sampler reported water level possibly low. Suspect bottle is okay and sampler was not getting the same flow rate as next bottle sampled. No issue with enough water for salinity. Salinity as well as oxygen and nutrients are acceptable.
37/1	133	bottle	2	Bottle not tripped at 65m, console operators switched duties and did not realize it had not been tripped, only 35 bottles for this station.
38/1	101	o2	2	Excess MnCl2 added to oxygen sample. May not have been the case as the oxygen is acceptable. Batteries on O2 draw temperature, thermometer replaced for bottle 13, will use previous station draw temperatures.

Station /Cast	Sample No.	Quality Property	Code	Comment
38/1	106	salt	2	4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
38/1	119	salt	2	4 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
38/1	121	o2	2	Oxygen may have mis-drawn either 21 or 22, redrew 21. Sample was 0.008 higher than the original draw and acceptable.
38/1	125	salt	2	Bottle salinity is low compared with CTD, agrees with trend of adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
38/1	129	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
39/1	111	bottle	4	Bottle appears to have mis-tripped higher in the water column. Oxygen and nutrients are low. Code bottle did not trip as scheduled, salinity, oxygen and nutrients bad.
39/1	111	no2	4	
39/1	111	no3	4	
39/1	111	o2	4	
39/1	111	po4	4	
39/1	111	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Bottle mis-tripped, code bottle did not trip as scheduled and other parameters bad.
39/1	111	sio3	4	
39/1	114	no3	2	Nutrients appear low compared to adjoining stations, oxygen is higher and the feature appears real although it does not show in salinity.
39/1	134	salt	2	Bottle salinity is low compared with CTD, agrees gradient bottle salinity with adjoining stations.
40/1	106	no3	2	Nutrients appear low compared to adjoining stations, oxygen is higher and the feature appears real although it does not show in salinity.
40/1	114	o2	2	Oxygen sample redrawn, took second sample, large difference between the two, 0.130.
40/1	136	o2	2	Oxygen temperature take from sea surface temperature reading.
41/1	111	salt	3	Bottle salinity is high compared with CTD and adjoining stations. Heavy sampling on the bottle could have affected the salinity. Code salinity questionable, oxygen and nutrients are acceptable.
41/1	116	bottle	4	First sampler found that spigot was pushed in. This bottle had a problem that appears as a mis-trip. Code bottle did not trip as scheduled and data bad. CFC, Helium, Tritium, oxygen isotopes, DOC sampled at this level.
41/1	116	no2	4	
41/1	116	no3	4	
41/1	116	o2	4	
41/1	116	po4	4	
41/1	116	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Bottle mis-tripped, code bottle did not trip as scheduled and salinity bad.
41/1	116	sio3	4	
41/1	120	o2	2	Ar sampled before oxygen. Oxygen is acceptable.
41/1	122	salt	2	Bottle salinity is low compared with CTD, agrees with gradient bottle on adjoining stations.
41/1	124	salt	2	Bottle salinity is low compared with CTD, agrees with gradient bottle on adjoining stations.
42/1	107	o2	2	Oxygen redrawn, initial flask broke. Oxygen is acceptable as are salinity and nutrients.
42/1	118	bottle	2	Top valve was found open by first sampler. Oxygen is acceptable as are salinity and nutrients.

Station /Cast	Sample No.	Quality Property	Code	Comment
42/1	126	bottle	2	Top valve was found open by first sampler. Oxygen is acceptable as are salinity and nutrients.
44/1	101	o2	2	Oxygen forgot reagents, realized after drawing. Performed a redraw. Oxygen as well as salinity and nutrients are acceptable.
44/1	125	salt	2	Salinity is about 3/4 full, ran out of water. Salinity is slightly low, but with measurement specifications. Salinity as well as oxygen and nutrients are acceptable.
44/1	132	o2	2	Sample was overtitrated and backtitrated, overshot first endpoint. Oxygen is acceptable.
45/1	110	o2	2	Oxygen endpoint questionable checked and used recalculated value. Oxygen as well as salinity and nutrients are acceptable.
45/1	125	o2	2	Oxygen endpoint questionable checked and used recalculated value. Oxygen as well as salinity and nutrients are acceptable.
47/1	111	bottle	2	Ran out of water on 14C/DOC, no water for salinity. Heavy sampling scheme and poor rinsing methods led to running out of water.
47/1	118	bottle	2	Ran out of water on 14C/DOC, no water for salinity. Heavy sampling scheme and poor rinsing methods led to running out of water.
47/1	121	bottle	2	Ran out of water on 14C/DOC, no water for salinity. Heavy sampling scheme and poor rinsing methods led to running out of water.
47/1	122	salt	2	Bottle salinity is low compared with CTD, agrees with gradient bottle salinity on adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
47/1	128	bottle	2	Ran out of water on 14C/DOC, no water for salinity. Heavy sampling scheme and duplicates led to running out of water.
47/1	131	o2	2	Flask differs from that in box file, 28 & 31 were switched in box. Oxygen is acceptable.
48/1	125	salt	2	Bottle salinity is low compared with CTD, agrees with gradient bottles from adjoining stations. Appears to be the 1 meter difference between the CTD and the bottle as are bottles 23 and 24. Salinity, oxygen and nutrients are acceptable.
49/1	107	no2	4	
49/1	107	no3	4	
49/1	107	po4	4	Nutrients are high, no analytical problem noted. Nutrients could have been switched with 6, that does not account for salinity.
49/1	107	salt	4	Bottle salinity is low compared with CTD, also low with adjoining stations. 3 attempts for a good salinity reading. Nutrients are high. Oxygen and CFC are acceptable. Code salinity and nutrients bad. Not certain what caused this, not a drawing problem, but salinity did have issues in obtaining a good reading.
49/1	107	sio3	4	
49/1	111	bottle	2	Spigot was open and dripping.
50/1	124	salt	2	Bottle salinity is high compared with CTD, agrees with other gradient bottle on adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
51/1	132	salt	2	Bottle salinity is high compared with CTD and adjoining stations. Salinity was switched with 33, reversed the two and agreement is acceptable.
51/1	133	salt	2	Bottle salinity is low compared with CTD and adjoining stations. Salinity was switched with 32, reversed the two and agreement is acceptable.
52/1	111	bottle	4	Bottle was leaking from bottom end cap, not enough water for salinity. Oxygen and nutrients were the only samples drawn, code bottle leaking, samples bad.
52/1	111	no2	4	
52/1	111	no3	4	
52/1	111	o2	4	Oxygen is high, code bad.
52/1	111	po4	4	
52/1	111	sio3	4	

Station /Cast	Sample No.	Quality Property	Code	Comment
52/1	136	bottle	2	Bottle was tripped 7 seconds early, operator mis-calculation on the time. Bottle data is acceptable.
53/1	101	o2	2	Oxygen combined total of 2 slow + 1 normal speed titration. Oxygen is acceptable.
53/1	104	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Low sample fill in bottle. Appears to match bottle 3 values. Possible niskin 3 was sampled twice. Code salinity bad.
53/1	126	salt	2	4 attempts for a good salinity reading. First reading was manually entered and salinity appears reasonable. Thimble came out with cap, probable contamination. Salinity as well as oxygen and nutrients are acceptable.
53/1	130	o2	2	Oxygen redrawn. Oxygen as well as salinity and nutrients are acceptable.
54/1	117	salt	3	Bottle salinity is high compared with CTD and adjoining stations. No analytical problem noted, no heavy sampling. Code salinity questionable, oxygen and nutrients are acceptable.
54/1	123	salt	2	Bottle salinity is low compared with CTD, agrees with bottle data in gradient area. Salinity as well as oxygen and nutrients are acceptable.
54/1	124	salt	2	Bottle salinity is low compared with CTD, agrees with bottle data in gradient area. Salinity as well as oxygen and nutrients are acceptable.
55/1	126	o2	2	Oxygen program went to low O2 mode, aborted to restart program. Added original amount of thio to the value after restart. Oxygen is acceptable.
56/1	106	bottle	2	Bottle leaked, vent slightly open. Oxygen, salinity and nutrients are acceptable.
56/1	107	o2	2	Oxygen flasks switched 7 & 8, from last use. This and the previous station, 52, flask positions were reported properly. Oxygen is acceptable.
56/1	108	o2	2	Oxygen does appear high compared with CTDO, agrees with adjoining station. Oxygen is acceptable.
56/1	109	no2	9	No nutrients drawn, sampling error.
56/1	109	no3	9	No nutrients drawn, sampling error.
56/1	109	po4	9	No nutrients drawn, sampling error.
56/1	109	salt	9	No salts drawn, sampling error.
56/1	109	sio3	9	No nutrients drawn, sampling error.
56/1	111	o2	2	Oxygen does appear high compared with CTDO, agrees with adjoining station. Oxygen is acceptable. Salinity and nutrients verify this bottle tripped properly.
56/1	121	bottle	2	Bottle tripped 8 seconds early, mis-calculated the wait time. Salinity, oxygen and nutrients are acceptable.
56/1	123	salt	2	Bottle salinity is low compared with CTD, agrees with gradient bottle in adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
56/1	126	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
57/1	118	salt	5	Salt bottle fell out of analyzers hand. Bottle broken sample lost.
58/1	122	salt	2	Bottle salinity is low compared with CTD, agrees with bottles of adjoining stations for gradient. Salinity as well as oxygen and nutrients are acceptable.
59/1	111	bottle	4	Bottle mis-tripped appears to have closed at bottle 3 level. Code bottle did not trip as schedule, salinity, oxygen and nutrients bad. CFC and DOC sampled on this bottle.
59/1	111	no2	4	
59/1	111	no3	4	
59/1	111	o2	4	
59/1	111	po4	4	
59/1	111	salt	4	Bottle salinity is low compared with CTD and adjoining stations. Bottle mis-tripped appears to have closed at bottle 3 level.
59/1	111	sio3	4	

Station /Cast	Sample No.	Quality Property	Code	Comment
59/1	123	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations bottles in gradient. Variation of CTD data at bottle trip. Salinity as well as oxygen and nutrients are acceptable.
59/1	126	salt	4	4 attempts for a good salinity reading. Readings kept increasing, thimble came out with cap, probable contamination. Code salinity bad, oxygen and nutrients are acceptable.
59/1	127	no2	9	No nutrients drawn, sampling error.
59/1	127	no3	9	No nutrients drawn, sampling error.
59/1	127	po4	9	No nutrients drawn, sampling error.
59/1	127	salt	9	No salts drawn, sampling error.
59/1	127	sio3	9	No nutrients drawn, sampling error.
61/1	101	no2	2	NO2 high compared with adjoining stations, there is a steep transmissometer signal. Analyst: Rechecked peaks, this and Station 62 show no analytical problem. NO2 as well as other nutrients, salinity and oxygen are acceptable.
61/1	101	salt	2	Bottle salinity is low compared with CTD and adjoining stations. Analyst ran sample before the SSW causing a problem for correction to the data over time. Corrected files and salinity is acceptable as are oxygen and nutrients.
61/1	113	salt	2	3 attempts for a good salinity reading. Salinity as well as oxygen and nutrients are acceptable.
61/1	124	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations in gradient area. Salinity as well as oxygen and nutrients are acceptable.
62/1	105	o2	4	Overshot endpoint, could not recover; oxygen value is high, code bad.
62/1	106	o2	3	O2 aborted first run: low o2 mode, very slow. Restarted program bad endpoint. Changed dirty bathwater, rebooted program. Then ran over-titration and back titration, final result slightly low. Code questionable.
62/1	107	o2	4	O2 bubble in flask at endpoint, including over titration and back titration. oxygen value is high, code bad.
62/1	127	bottle	2	Tripped bottle 5 seconds early. Salinity, oxygen and nutrients are acceptable.
63/1	111	bottle	4	Appears to have mis-tripped again. Other than SIO/STS/ODF measurements, CFC, DOC and SIP were sampled. Code bottle did not trip as scheduled and samples bad, 4. Very similar values as bottle 15, could have tripped together.
63/1	111	no2	4	
63/1	111	no3	4	
63/1	111	o2	4	
63/1	111	po4	4	
63/1	111	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Mis-tripped, code salinity bad.
63/1	111	sio3	4	
63/1	133	salt	2	Bottle salinity is high compared with CTD, gradient, agrees with adjoining stations. Salinity, oxygen and nutrients are acceptable.
64/1	119	o2	3	Oxygen high compared to CTDO and adjoining station profile. Code salinity questionable, salinity and nutrients are acceptable.
65/1	102	bottle	2	Oxygen and nutrients appear high, salinity and oxygen high, salinity has good agreement with CTD, DIC and Alkalinity also show this feature. Data is acceptable.
65/1	136	salt	2	Bottle salinity is high compared with CTD, agrees with adjoining stations, there is variation in the CTD at the trip. Salinity as well as oxygen and nutrients are acceptable.
66/1	102	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Bottle appears to have been mis-drawn from bottle 3. Code salinity bad, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
66/1	111	bottle	4	Oxygen/sio3 low; po4/no3 high; salinity high and CFC only other parameter sampled, mis-trip. Code bottle did not trip as scheduled all samples bad.
66/1	111	no2	4	
66/1	111	no3	4	
66/1	111	o2	4	
66/1	111	po4	4	
66/1	111	salt	4	Bottle data matched 22 Mis-trip. Bottle salinity is high compared with CTD and adjoining stations, mis-tripped.
66/1	111	sio3	4	
66/1	113	bottle	2	Vent was found open before sampling.
66/1	135	salt	2	Bottle salinity is low compared with CTD, gradient, agrees with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
67/1	113	salt	4	3 attempts for a good salinity reading. Thimble came off with cap. erratic readings, possible contamination. Salinity high compared with CTD, agrees fairly well with adjoining stations. Code salinity bad, oxygen and nutrients are acceptable.
68/1	111	salt	2	3 attempts for a good salinity reading. Salinity agrees well with CTD, adjoining stations and duplicate trip with bottle 12.
69/1	111	bottle	2	Bottle re-positioned on rosette frame prior to this cast, moved up in the bottle slot. This is an attempt to get consistent correct tripping. Salinity, oxygen and nutrients were taken on this duplicate tripped bottle.
70/1	117	o2	2	Oxygen check endpoint, looks low. Recalculated endpoint. Oxygen as well as nutrients are acceptable.
70/1	121	o2	2	Oxygen appears high compared with adjoining stations, agrees with CTDO. Nutrients verify the feature is real. Oxygen and nutrients are acceptable.
71/1	105	salt	2	Bottle salinity is low compared with CTD, agrees with adjoining stations. Suspect operator made an error during analysis. Salinity is within measurement specification. Salinity as well as oxygen and nutrients are acceptable.
71/1	114	o2	2	Oxygen aborted run, forgot to put thio tip in sample, second abort, program froze just as plot started, try restart. Program froze at first low-o2 0.0007ml, reboot. 3 titers added together. Oxygen is acceptable.
71/1	115	o2	2	Oxygen left on low o2, stop, then continue with normal rate; add to previous titer for full value, sum of previous 2 titers (low o2, stopped, restarted). Oxygen is acceptable.
74/1	111	bottle	4	Bottle appears to have mis-tripped. Oxygen draw temperature, salinity is high and oxygen is low. No other properties sampled.
74/1	111	no2	4	Nutrients are high, bottle mis-tripped.
74/1	111	no3	4	Nutrients are high, bottle mis-tripped.
74/1	111	o2	4	Oxygen does not agree with station profile and adjoining stations. Code bottle mis-tripped and oxygen bad.
74/1	111	po4	4	Nutrients are high, bottle mis-tripped.
74/1	111	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Bottle mis-tripped. Oxygen draw temperature is high and oxygen is low. Code salinity bad.
74/1	111	sio3	4	Nutrients are high, bottle mis-tripped.
74/1	122	salt	4	Bottle salinity is high compared with CTD and adjoining stations. It appears there were many sampling or analysis errors on this station. Salinity appears to have been drawn from bottle 23. Code salinity bad. Oxygen and nutrients are acceptable.
74/1	123	bottle	2	Vent open. Oxygen as well as salinity and nutrients are acceptable, as salinity is corrected.
74/1	123	salt	2	Bottle salinity is low compared with CTD and adjoining stations. Appears the salinometer operator used the wrong suppression switch setting. Correct the file and salinity is acceptable. Salinity, oxygen and nutrients are acceptable.

Station /Cast	Sample No.	Quality Property	Code	Comment
74/1	127	salt	4	Bottle salinity is high compared with CTD and adjoining stations. Appears to have been switched with 29 during analysis or sampling. Switched 27 and 29 resulting in 29 being acceptable, but the values from salinity bottle 29 do not fit the station profile at bottle 27 level. Code salinity bad. Oxygen and nutrients are acceptable.
74/1	129	salt	2	Bottle salinity is high compared with CTD and adjoining stations. Appears to have been switched with 27 during analysis or sampling. Switched 27 and 29 resulting in 29 being acceptable, but the values from salinity bottle 29 do not fit the station profile at bottle 27 level. Salinity, oxygen and nutrients are acceptable.
76/1	110	salt	5	Salinity sample not analyzed, operator error.
76/1	112	bottle	2	Bottle 11 displayed unknown reasons for not tripping properly. It was removed from service on this station, 76, and will not be employed for the remainder of the expedition.
76/1	130	o2	2	Oxygen thio tip not in flask, abort/restart, program froze, rebooted computer, titrator dispensed in low oxygen mode, combined titration value. Oxygen as well as salinity and nutrients are acceptable.
76/1	131	salt	2	Bottle salinity is low compared with CTD, gradient, acceptable with adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
77/1	104	salt	5	Salinity sample not analyzed, operator error.
77/1	123	salt	2	Bottle salinity is low compared with CTD, gradient, agrees with trend of adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
79/1	117	bottle	2	Spigot was open. Oxygen as well as nutrients are acceptable.
80/1	107	refl	3	SBE35RT unstable reading vs. CTDT1/CTDT2, code questionable.
80/1	107	salt	2	Bottle salinity is low compared with CTD, lots of variation in CTD at trip, gradient, agrees with trend of adjoining stations. Salinity as well as oxygen and nutrients are acceptable.
80/1	109	refl	3	SBE35RT unstable reading vs. CTDT1/CTDT2, code questionable.

Appendix D

CLIVAR A20: Pre-Cruise Sensor Laboratory Calibrations

CTD 796 Sensors - Table of Contents				
CTD Sensor	Manufacturer and Model No.	Serial Number	Station Number	Appendix D Page (Un-Numbered)
PRESS (Pressure)	Digiquartz 401K-105	0796	1-83	1
T1 (Primary Temperature)	SBE3 <i>plus</i>	03-4924	40-83	5
C1 (Primary Conductivity)	SBE4C	04-3369	1-45	6
C1 (Primary Conductivity)	SBE4C	04-3429	1-46	7
O2 (Dissolved Oxygen)	SBE43	43-0614	1-81	8
T2 (Secondary Temperature)	SBE3 <i>plus</i>	03-4907	1-83	9
C2 (Secondary Conductivity)	SBE4C	04-3399	1-83	10
REFT (Reference Temperature)	SBE35	35-0035	1-83	11
TRANS (Transmissometer)	WETLabs C-Star	CST-327DR	1-43	12
TRANS (Transmissometer)	WETLabs C-Star	CST-493DR	44-83	13

Pressure Calibration Report

STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0796
CALIBRATION DATE: 25-OCT-2011
Mfg: SEABIRD Model: 09P CTD Prs s/n:

C1= -4.967252E+4
C2= 8.659237E-1
C3= 9.895243E-3
D1= 3.845316E-2
D2= 0.000000E+0
T1= 2.989468E+1
T2= -1.252866E-4
T3= 3.487851E-6
T4= 1.015145E-8
T5= 0.000000E+0
AD590M= 1.28520E-2
AD590B= -8.71454E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336

t0=t1+t2*td+t3*td*td+t4*td*td*td

w = 1-t0*t0*f*f

Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

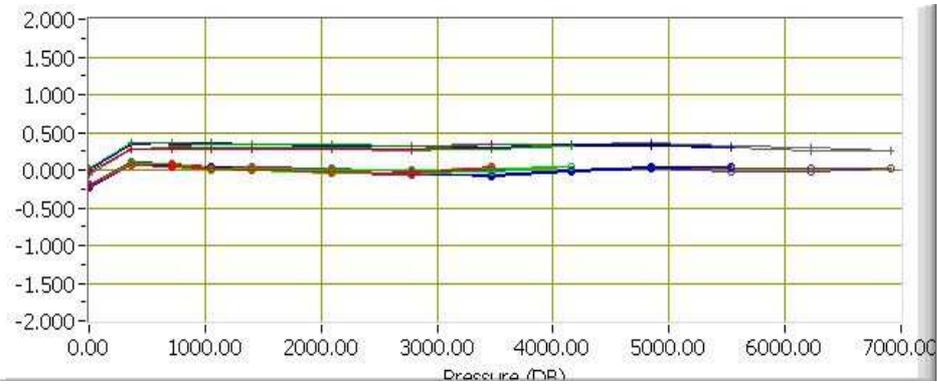
SBE9	SBE9	SBE9	Ruska-SBE9	Ruska-SBE9		
Freq	Ruska	New_Coefs	Prev_Coefs	New_Coefs	Trprs	Bath_Temp
33456.613	0.18	0.40	-0.03	-0.22	27.21	27.394
33634.161	364.98	364.91	0.28	0.06	27.26	27.396
33800.830	709.16	709.11	0.28	0.04	27.28	27.398
33966.550	1053.33	1053.31	0.28	0.02	27.31	27.399
34131.382	1397.59	1397.59	0.27	-0.00	27.34	27.402
34458.276	2086.07	2086.10	0.28	-0.02	27.38	27.402
34781.631	2774.62	2774.65	0.28	-0.04	27.39	27.403
35101.523	3463.25	3463.21	0.34	0.03	27.41	27.402
34781.631	2774.62	2774.66	0.27	-0.04	27.44	27.403
34458.266	2086.07	2086.09	0.29	-0.01	27.45	27.403
34131.368	1397.59	1397.58	0.28	0.01	27.46	27.403
33966.535	1053.33	1053.31	0.28	0.02	27.49	27.404
33800.804	709.16	709.10	0.30	0.06	27.49	27.403
33634.124	364.98	364.89	0.31	0.09	27.52	27.404
33457.116	0.18	0.40	0.03	-0.22	16.38	15.944
33634.609	364.98	364.89	0.36	0.09	16.38	15.944
33801.228	709.16	709.08	0.37	0.08	16.38	15.944
33966.921	1053.33	1053.30	0.34	0.03	16.39	15.944
34131.706	1397.59	1397.57	0.33	0.02	16.39	15.944
34458.512	2086.07	2086.07	0.34	0.01	16.39	15.944
34781.784	2774.62	2774.62	0.33	-0.00	16.39	15.944
35101.618	3463.25	3463.23	0.33	0.01	16.39	15.944
35418.115	4151.95	4151.91	0.32	0.03	16.39	15.944
35101.639	3463.25	3463.28	0.29	-0.03	16.39	15.944
34781.805	2774.62	2774.67	0.28	-0.05	16.39	15.944

Pressure Calibration Report STS/ODF Calibration Facility

34458.534	2086.07	2086.11	0.29	-0.04	16.38	15.944
34131.719	1397.59	1397.60	0.31	-0.01	16.37	15.944
33966.937	1053.33	1053.33	0.30	-0.00	16.37	15.944
33801.249	709.16	709.12	0.33	0.04	16.37	15.944
33634.619	364.98	364.91	0.34	0.07	16.37	15.944
33456.684	0.18	0.41	0.01	-0.23	6.75	7.107
33634.143	364.98	364.90	0.34	0.07	6.78	7.107
33800.733	709.16	709.10	0.35	0.06	6.84	7.106
33966.374	1053.33	1053.28	0.36	0.05	6.86	7.106
34131.133	1397.59	1397.57	0.35	0.02	6.89	7.106
34457.884	2086.07	2086.09	0.33	-0.02	6.91	7.106
34781.092	2774.61	2774.65	0.32	-0.04	6.94	7.106
35100.886	3463.24	3463.32	0.28	-0.07	6.96	7.106
35417.299	4151.94	4151.96	0.32	-0.02	6.96	7.106
35730.475	4840.70	4840.68	0.33	0.02	6.99	7.106
36040.493	5529.51	5529.46	0.31	0.04	7.02	7.106
35730.468	4840.70	4840.65	0.35	0.04	7.02	7.106
35417.298	4151.94	4151.94	0.34	0.01	7.04	7.105
35100.886	3463.24	3463.30	0.30	-0.05	7.04	7.106
34781.105	2774.61	2774.65	0.33	-0.03	7.07	7.106
34457.910	2086.07	2086.11	0.32	-0.04	7.09	7.106
34131.159	1397.59	1397.58	0.34	0.01	7.12	7.106
33966.403	1053.33	1053.29	0.35	0.04	7.12	7.106
33800.763	709.16	709.10	0.35	0.06	7.14	7.106
33634.164	364.98	364.88	0.37	0.10	7.14	7.106
33455.693	0.18	0.37	-0.06	-0.19	-1.40	-1.286
33633.127	364.98	364.87	0.27	0.10	-1.38	-1.286
33799.694	709.16	709.08	0.28	0.08	-1.35	-1.287
33965.315	1053.33	1053.28	0.28	0.05	-1.32	-1.287
34130.038	1397.59	1397.55	0.29	0.03	-1.30	-1.287
34456.724	2086.07	2086.05	0.33	0.03	-1.25	-1.287
34779.895	2774.62	2774.64	0.31	-0.02	-1.21	-1.286
35099.609	3463.25	3463.25	0.34	-0.01	-1.20	-1.287
35415.997	4151.95	4151.96	0.34	-0.01	-1.20	-1.287
35729.123	4840.70	4840.68	0.36	0.02	-1.17	-1.287
36039.105	5529.51	5529.50	0.33	0.02	-1.14	-1.287
36346.008	6218.40	6218.39	0.29	0.02	-1.14	-1.287
36649.907	6907.34	6907.32	0.25	0.02	-1.12	-1.287
36346.028	6218.40	6218.43	0.25	-0.02	-1.12	-1.287
36039.121	5529.51	5529.53	0.30	-0.01	-1.12	-1.287
35729.144	4840.70	4840.69	0.35	0.01	-1.09	-1.287
35416.021	4151.95	4151.96	0.33	-0.02	-1.09	-1.287
35099.656	3463.25	3463.30	0.29	-0.06	-1.07	-1.286
34779.943	2774.62	2774.69	0.26	-0.07	-1.07	-1.286
34456.784	2086.07	2086.11	0.27	-0.04	-1.07	-1.286
34130.089	1397.59	1397.58	0.27	0.01	-1.07	-1.286
33965.364	1053.33	1053.29	0.28	0.04	-1.04	-1.287
33799.741	709.16	709.08	0.29	0.08	-1.04	-1.287
33633.177	364.98	364.87	0.28	0.11	-1.04	-1.287
33455.732	0.18	0.34	-0.02	-0.16	-1.04	-1.287

Pressure Calibration Report

STS/ODF Calibration Facility



28-Apr-10-27.4	
New-27.4	
28-Apr-10-15.9	
New-15.9	
28-Apr-10-7.1	
New-7.1	
28-Apr-10--1.3	
New--1.3	

Temperature Calibration Report

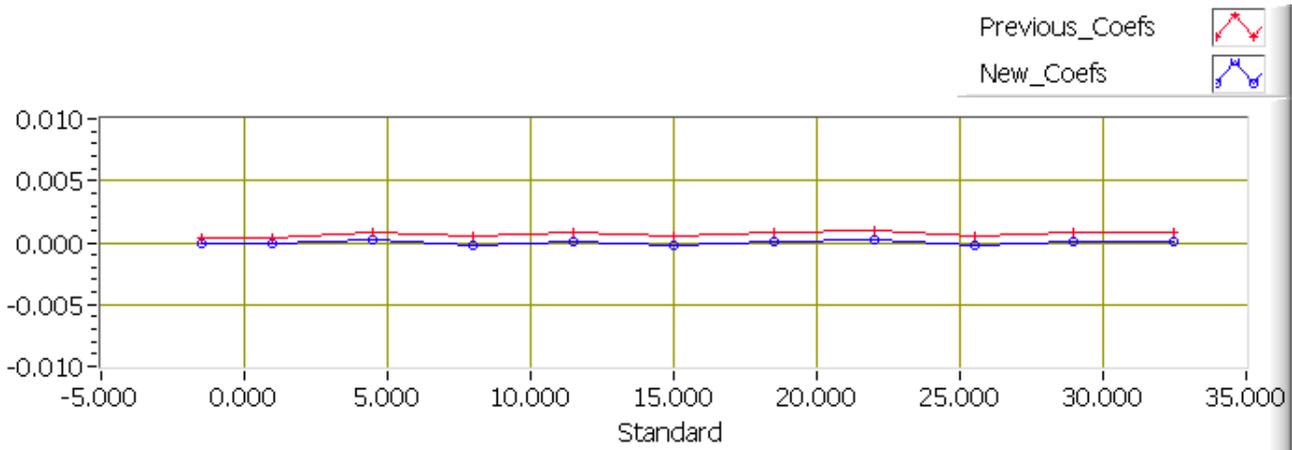
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4924
CALIBRATION DATE: 10-Feb-2012
Mfg: SEABIRD Model: 03
Previous cal: 24-Oct-11
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.32850794E-3	a = 4.32869684E-3	
h = 6.33103361E-4	b = 6.33309185E-4	
i = 1.98816686E-5	c = 1.99127639E-5	
j = 1.63362653E-6	d = 1.63497710E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149
Temperature ITS-90 = 1/[g+h[ln(f0/f)]+i[ln2(f0/f)]+j[ln3(f0/f)]] - 273.15 (°C)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]] - 273.15 (°C)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
2869.5251	-1.5071	-1.5071	0.00042	-0.00000
3035.9032	0.9936	0.9937	0.00045	-0.00007
3280.3812	4.4949	4.4947	0.00085	0.00023
3538.7458	7.9962	7.9964	0.00048	-0.00022
3811.3185	11.4982	11.4981	0.00088	0.00014
4097.7655	14.9910	14.9912	0.00052	-0.00024
4399.9336	18.4941	18.4940	0.00088	0.00012
4717.0819	21.9934	21.9932	0.00096	0.00020
5050.0467	25.4943	25.4945	0.00058	-0.00019
5398.7301	28.9934	28.9934	0.00079	0.00002
5763.9048	32.4945	32.4945	0.00080	0.00002



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SENSOR SERIAL NUMBER: 3369
CALIBRATION DATE: 21-Feb-12

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHIJ COEFFICIENTS

g = -1.06925850e+001
h = 1.62141377e+000
i = -2.92127126e-003
j = 3.29098643e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 6.89638781e-007
b = 1.61372298e+000
c = -1.06769768e+001
d = -7.85663411e-005
m = 6.3
CPcor = -9.5700e-008 (nominal)

BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.57223	0.00000	0.00000
-0.9984	34.8995	2.81079	4.90152	2.81077	-0.00001
1.0001	34.8994	2.98240	5.00872	2.98242	0.00002
15.0001	34.8998	4.28078	5.75483	4.28076	-0.00002
18.5001	34.8989	4.62815	5.93845	4.62817	0.00001
29.0001	34.8977	5.71416	6.47859	5.71417	0.00001
32.5001	34.8922	6.08774	6.65412	6.08773	-0.00001

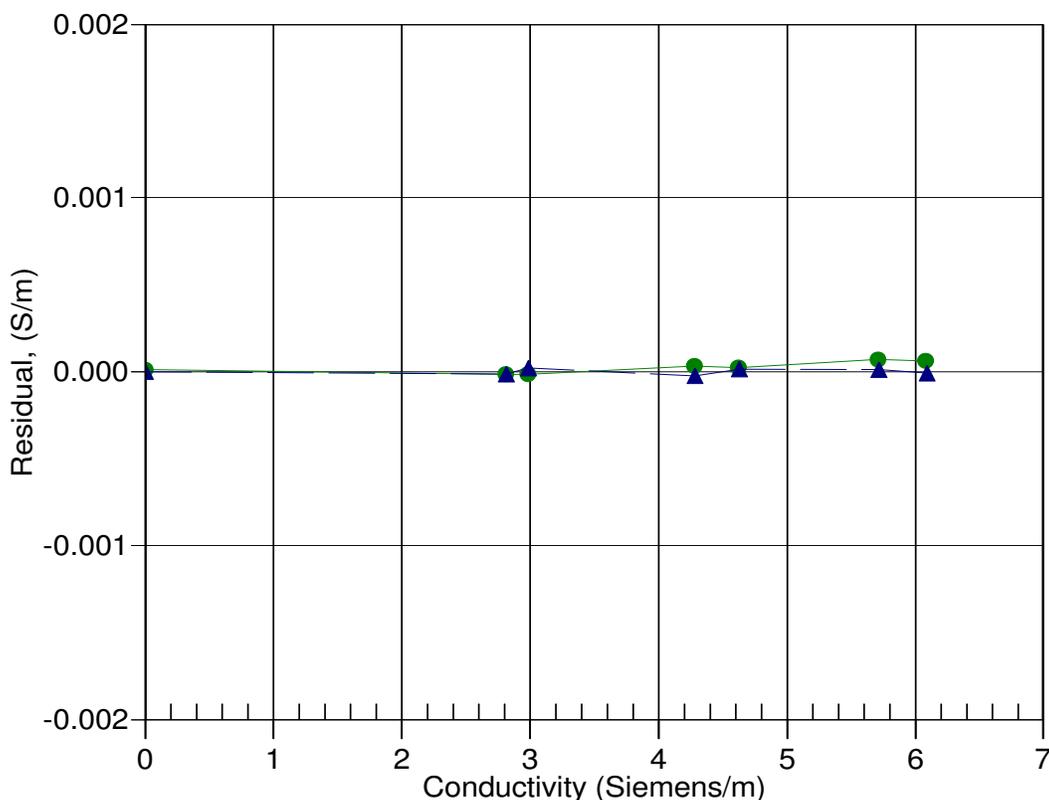
Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \epsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter

t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ϵ = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients

Date, Slope Correction



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SENSOR SERIAL NUMBER: 3429
CALIBRATION DATE: 21-Feb-12

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHIJ COEFFICIENTS

g = -9.87142635e+000
h = 1.51947165e+000
i = -2.38692213e-003
j = 2.74076567e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 8.96941212e-007
b = 1.51324658e+000
c = -9.85902121e+000
d = -8.15513231e-005
m = 6.1
CPcor = -9.5700e-008 (nominal)

BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.55247	0.00000	0.00000
-0.9984	34.8995	2.81079	5.00787	2.81078	-0.00001
1.0001	34.8994	2.98240	5.11972	2.98242	0.00002
15.0001	34.8998	4.28078	5.89700	4.28075	-0.00003
18.5001	34.8989	4.62815	6.08803	4.62817	0.00001
29.0001	34.8977	5.71416	6.64949	5.71418	0.00002
32.5001	34.8922	6.08774	6.83180	6.08772	-0.00002

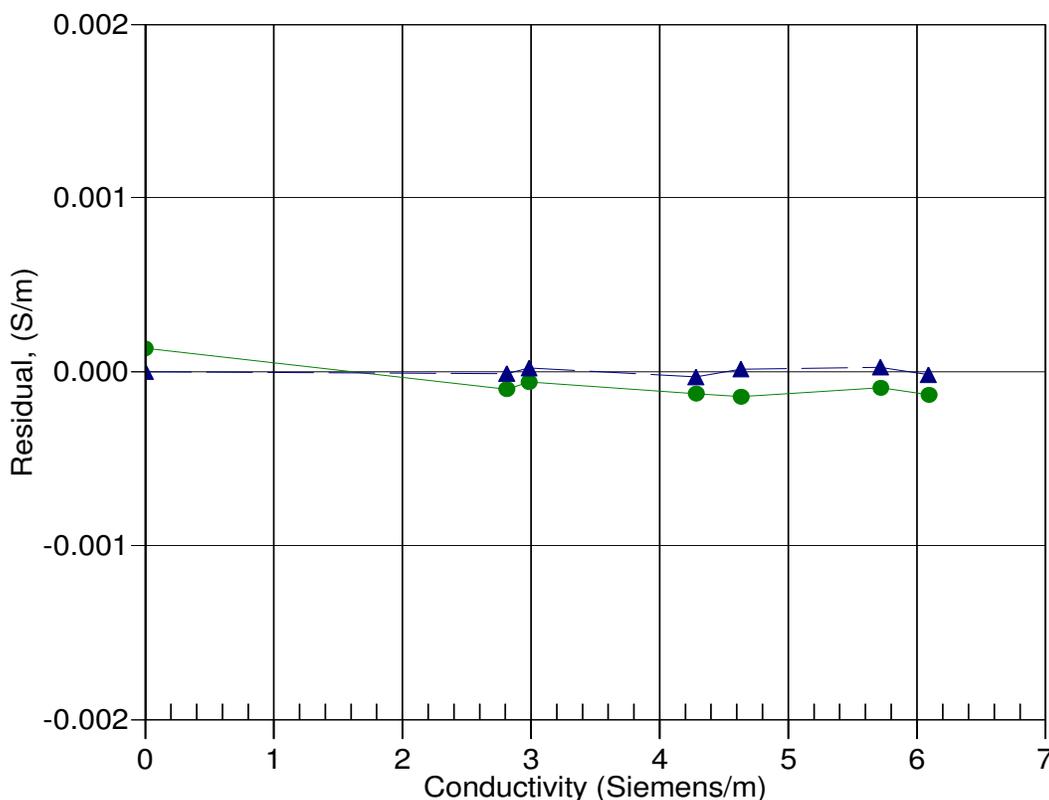
Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \epsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter

t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ϵ = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients

Date, Slope Correction



● 22-Jul-11 1.0000238
▲ 21-Feb-12 1.0000000

Temperature Calibration Report

STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 4907
CALIBRATION DATE: 08-Feb-2012
Mfg: SEABIRD Model: 03
Previous cal: 24-Oct-11
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS ITS-T90	
g = 4.34511554E-3	a = 4.34530983E-3	
h = 6.37076838E-4	b = 6.37285168E-4	
i = 2.09177953E-5	c = 2.09494275E-5	
j = 1.75265860E-6	d = 1.75407135E-6	
f0 = 1000.0	Slope = 1.0	Offset = 0.0

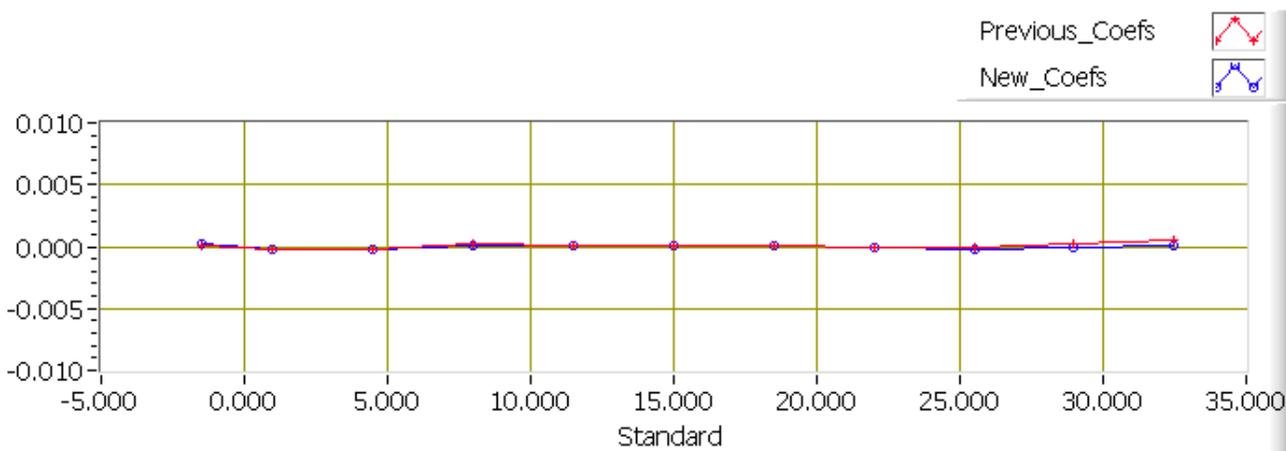
Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149

Temperature ITS-90 = $1/[g+h[\ln(f_0/f)]+i[\ln^2(f_0/f)]+j[\ln^3(f_0/f)]] - 273.15$ (°C)

Temperature IPTS-68 = $1/[a+b[\ln(f_0/f)]+c[\ln^2(f_0/f)]+d[\ln^3(f_0/f)]] - 273.15$ (°C)

T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-T90	SBE3 ITS-T90	SPRT-SBE3 OLD Coefs	SPRT-SBE3 NEW Coefs
2934.7645	-1.5052	-1.5054	0.00007	0.00019
3104.4010	0.9939	0.9941	-0.00018	-0.00016
3353.7376	4.4942	4.4945	-0.00021	-0.00027
3617.2191	7.9958	7.9956	0.00022	0.00015
3895.1951	11.4971	11.4970	0.00012	0.00008
4187.3291	14.9903	14.9902	0.00007	0.00006
4495.5142	18.4935	18.4934	0.00008	0.00009
4818.9334	21.9927	21.9927	-0.00005	-0.00005
5158.5360	25.4947	25.4949	-0.00010	-0.00016
5514.0269	28.9933	28.9933	0.00017	-0.00002
5886.2702	32.4937	32.4936	0.00050	0.00008



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SENSOR SERIAL NUMBER: 3399
CALIBRATION DATE: 21-Feb-12

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHIJ COEFFICIENTS

g = -1.01511715e+001
h = 1.53536729e+000
i = -2.28594877e-003
j = 2.63108407e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.06291609e-006
b = 1.52937173e+000
c = -1.01389439e+001
d = -7.94633515e-005
m = 6.0
CPcor = -9.5700e-008 (nominal)

BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.57477	0.00000	0.00000
-0.9984	34.8995	2.81079	4.99973	2.81077	-0.00001
1.0001	34.8994	2.98240	5.11060	2.98242	0.00002
15.0001	34.8998	4.28078	5.88148	4.28075	-0.00003
18.5001	34.8989	4.62815	6.07103	4.62817	0.00002
29.0001	34.8977	5.71416	6.62833	5.71417	0.00001
32.5001	34.8922	6.08774	6.80936	6.08773	-0.00001

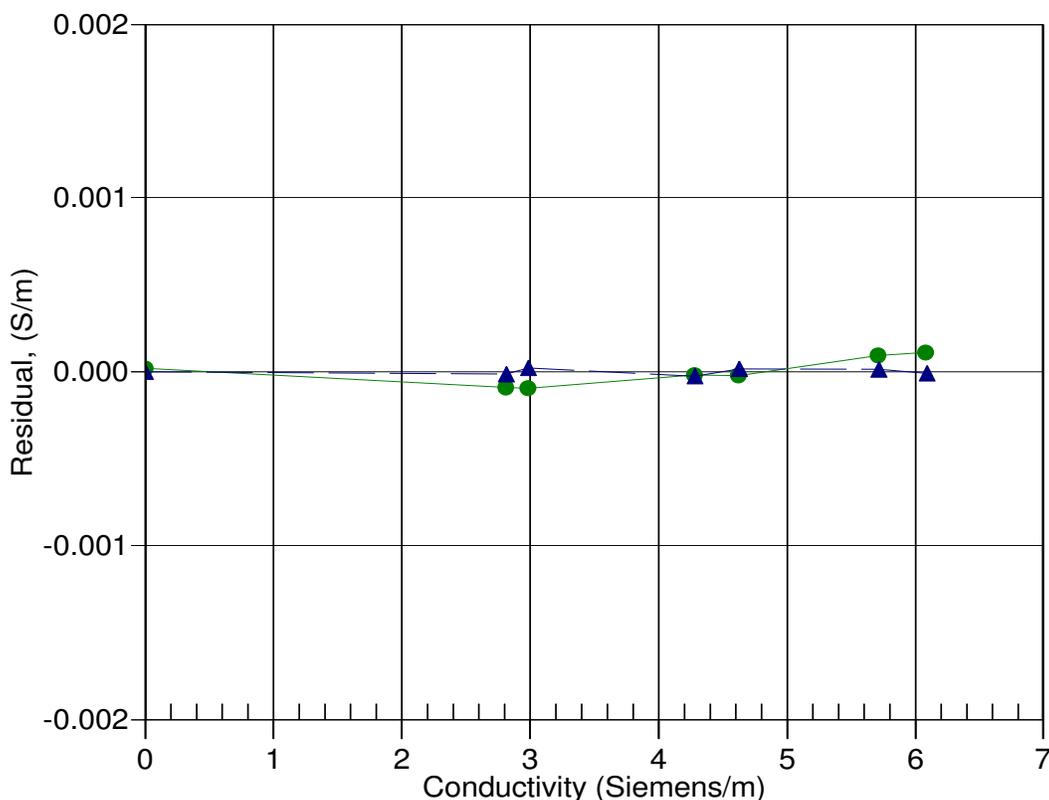
Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \epsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter

t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ϵ = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients

Date, Slope Correction



● 14-Sep-11 0.9999963
▲ 21-Feb-12 1.0000000

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SENSOR SERIAL NUMBER: 0614
CALIBRATION DATE: 18-Feb-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4835

Voffset = -0.5013

Tau20 = 2.48

A = -3.3775e-003

B = 1.2081e-004

C = -1.8327e-006

E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2

D2 = -4.64803e-2 H2 = 5.00000e+3

H3 = 1.45000e+3

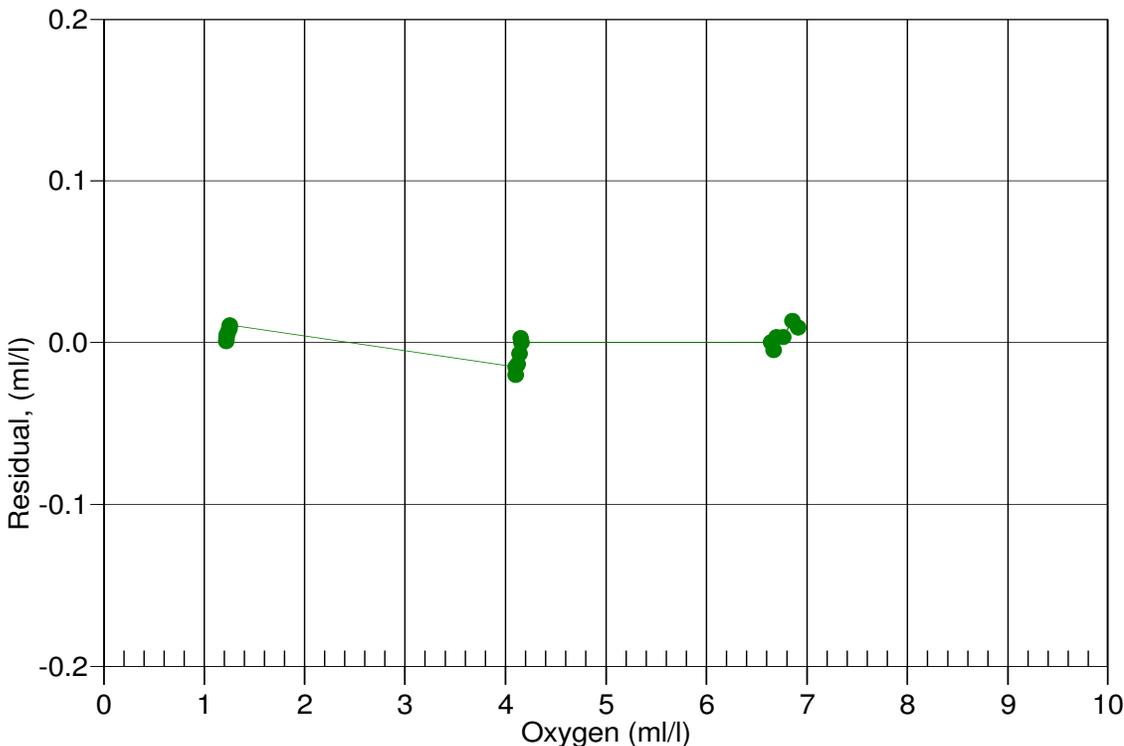
BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.22	2.00	0.05	0.764	1.22	0.00
1.23	6.00	0.05	0.798	1.23	0.00
1.23	12.00	0.05	0.849	1.23	0.01
1.24	20.00	0.04	0.921	1.25	0.01
1.25	26.00	0.04	0.979	1.26	0.01
1.26	30.00	0.05	1.019	1.27	0.01
4.10	6.00	0.05	1.488	4.09	-0.02
4.10	2.00	0.05	1.380	4.08	-0.02
4.12	12.00	0.05	1.659	4.11	-0.01
4.14	20.00	0.04	1.893	4.13	-0.01
4.15	30.00	0.05	2.196	4.15	0.00
4.16	26.00	0.04	2.076	4.16	-0.00
6.64	26.00	0.05	3.019	6.65	0.00
6.67	30.00	0.05	3.222	6.66	-0.00
6.69	20.00	0.04	2.756	6.70	0.00
6.76	12.00	0.05	2.408	6.77	0.00
6.85	6.00	0.05	2.159	6.87	0.01
6.91	2.00	0.05	1.990	6.92	0.01

$$\text{Oxygen (ml/l)} = \text{Soc} * (\text{V} + \text{Voffset}) * (1.0 + \text{A} * \text{T} + \text{B} * \text{T}^2 + \text{C} * \text{T}^3) * \text{OxSol}(\text{T}, \text{S}) * \exp(\text{E} * \text{P} / \text{K})$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU] K = temperature [deg K]

OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen

Date, Delta Ox (ml/l)



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SENSOR SERIAL NUMBER: 0186
CALIBRATION DATE: 15-Feb-12

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.3734
Voffset = -0.5041
Tau20 = 1.56

A = -2.5169e-003
B = 2.0275e-004
C = -2.9766e-006
E nominal = 0.036

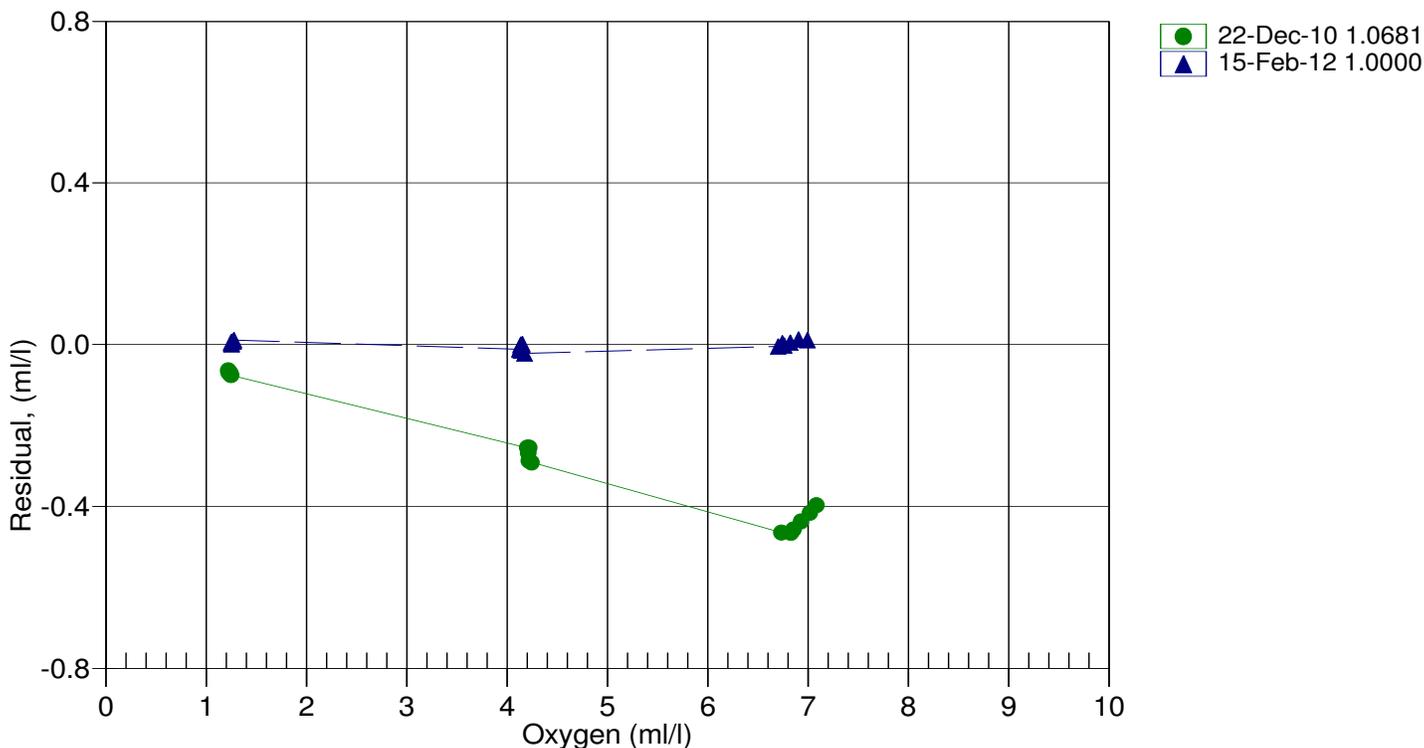
NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2
D2 = -4.64803e-2 H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.25	12.00	0.03	0.952	1.25	0.01
1.25	6.00	0.03	0.893	1.25	0.00
1.25	2.00	0.03	0.853	1.26	0.00
1.26	20.00	0.03	1.034	1.27	0.01
1.27	26.00	0.03	1.096	1.28	0.01
1.28	30.00	0.04	1.139	1.29	0.01
4.12	12.00	0.03	1.973	4.11	-0.01
4.13	20.00	0.03	2.230	4.13	-0.00
4.14	26.00	0.04	2.420	4.14	0.00
4.14	6.00	0.03	1.783	4.12	-0.02
4.15	30.00	0.04	2.552	4.15	0.00
4.17	2.00	0.03	1.658	4.15	-0.02
6.70	30.00	0.04	3.807	6.70	-0.01
6.75	26.00	0.04	3.628	6.75	0.00
6.76	20.00	0.03	3.330	6.76	-0.00
6.82	12.00	0.03	2.943	6.82	0.00
6.90	6.00	0.03	2.648	6.91	0.01
6.99	2.00	0.04	2.451	7.00	0.01

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T² + C * T³) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU] K = temperature [deg K]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen

Date, Delta Ox (ml/l)



Temperature Calibration Report

STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 16-Feb-2012
Mfg: SEABIRD Model: 35
Previous cal: 27-Oct-11
Calibration Tech: CAL

ITS-90_COEFFICIENTS

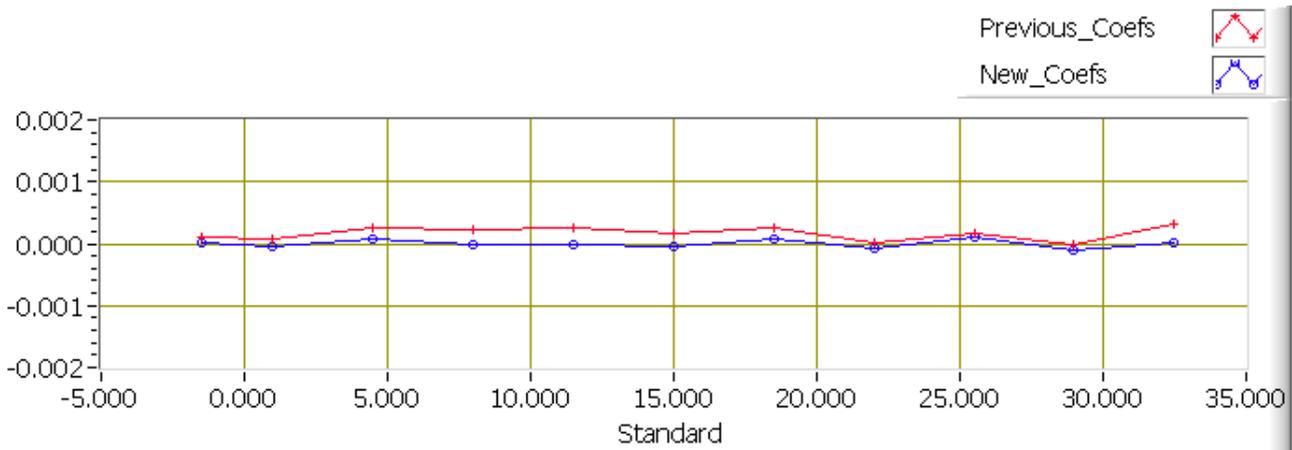
a0 = 3.491354356E-3
a1 = -8.999088258E-4
a2 = 1.472396592E-4
a3 = -8.336052929E-6
a4 = 1.820067296E-7
Slope = 1.000000 Offset = 0.000000

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149

Calibration Standard: Mfg: ASL Model: F18 s/n: 245-5149

Temperature ITS-90 = $1/[a_0+a_1[\ln(f)]+a_2[\ln^2(f)]+a_3[\ln^3(f)]+a_4[\ln^4(f)]] - 273.15$ (°C)

SBE35 Count	SPRT ITS-T90	SBE35 ITS-T90	SPRT-SBE35 OLD Coefs	SPRT-SBE35 NEW Coefs
659024.3000	-1.5058	-1.5058	0.00011	0.00001
590655.1500	0.9937	0.9938	0.00007	-0.00005
507831.3000	4.4948	4.4947	0.00026	0.00007
437794.8000	7.9964	7.9964	0.00023	-0.00002
378443.5750	11.4979	11.4979	0.00026	-0.00001
328132.9000	14.9908	14.9909	0.00018	-0.00006
285158.1500	18.4934	18.4933	0.00026	0.00009
248511.1500	21.9909	21.9910	0.00001	-0.00009
217094.7750	25.4936	25.4935	0.00016	0.00012
190156.6750	28.9927	28.9928	-0.00002	-0.00010
166962.4250	32.4946	32.4946	0.00032	0.00003



Transmissometer Air Calibration M&B Calculator
 Wilf Gardner / Mary Jo Richardson Texas A&M

	CST-327-DR		Air Cal Date	28-Mar-12		
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.752			4.649		
Water Reading	4.66			N/A		
Blocked Reading	0.059			0.059		
Air Temp.	12.875	12.884	12.997	13.088	13.134	13.168
M	20.044			Air Temp. Average		13.024
B	-1.183					

	CST-327-DR		Air Cal Date	14-Apr-12		
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.752			4.611		
Water Reading	4.66			N/A		
Blocked Reading	0.059			0.06		
Air Temp.	29.342	29.365	29.329	29.380	29.452	29.432
M	20.216			Air Temp. Average		29.383
B	-1.213					

	CST-327-DR		Air Cal Date	26-Apr-12		
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.752			4.695		
Water Reading	4.66			N/A		
Blocked Reading	0.059			0.06		
Air Temp.						
M	19.850			Air Temp. Average		26.100
B	-1.191			Air temp taken from wrong source.		

REMOVED from service 1 May 2012 - erratic readings at depth.

PO Box 518
620 Applegate St.
Philomath, OR 97370



(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date December 2, 2008 S/N# CST-493DR Pathlength 25 cm

	Analog meter
V_d	0.060 V
V_{air}	4.825 V
V_{ref}	4.734 V

Temperature of calibration water	21.9 °C
Ambient temperature during calibration	22.7 °C

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x): $Tr = e^{-cx}$

To determine beam transmittance: $Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})$

To determine beam attenuation coefficient: $c = -1/x * \ln(Tr)$

V_d Meter output with the beam blocked. This is the offset.

V_{air} Meter output in air with a clear beam path.

V_{ref} Meter output with clean water in the path.

Temperature of calibration water: temperature of clean water used to obtain V_{ref} .

Ambient temperature: meter temperature in air during the calibration.

V_{sig} Measured signal output of meter.

Transmissometer Air Calibration M&B Calculator
SIO/STS Transmissometer

	CST-493-DR		Air Cal Date	1-May-12		
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.825			4.688		
Water Reading	4.734			N/A		
Blocked Reading	0.06			0.057		
Air Temp.	25.750	25.752	25.750	25.623	25.620	25.567
M	19.857			Air Temp. Average		25.677
B	-1.132					

	CST-493-DR		Air Cal Date	12-May-12		
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.825			4.701		
Water Reading	4.734			N/A		
Blocked Reading	0.06			0.056		
Air Temp.	18.041	18.049	18.055	18.051	18.044	18.055
M	19.797			Air Temp. Average		18.049
B	-1.109					

Appendix E

CLIVAR A20: Sampling Plan																										
Rev: 2012-05-10 12:30 EDT																										
Sta #	Scheme	latdeg	latmin	londeg	lonmin	Depth	Dist (nm)	BEAT ME!	Smethie	Jenkins	ODF	Jenkins	Greeley	Millero/Dicks	McNichol/Ke	Hansell	Jenkins	ODF	Druffel	ODF	Seyler	Total Water (L)	Sta #			
								start time (EDT)	CFCs/SF6	Helium	O2	O2/Ar	DIC	pH	TALK	13C/14C	DI	OC/TDN	Fritium	Nuts	14C/DO	Salt	SIP	-Druffel-Seyle		
1	I-N	6	52.09	-53	28.74	76	0	04/21/12 11:52	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	1	
2	II-N	6	56.30	-53	26.86	116	4.6	04/21/12 13:23	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5	12	6.15	2	
3	III-N	7	0.50	-53	24.98	127	4.6	04/21/12 14:42	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	3	
4	I-N	7	4.71	-53	23.10	119	4.6	04/21/12 15:58	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	4	
5	II-N	7	8.92	-53	21.22	190	4.6	04/21/12 17:22	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	5	
6	III-N	7	13.12	-53	19.34	219	4.6	04/21/12 19:08	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	6	
7	I-N	7	17.33	-53	17.45	266	4.6	04/21/12 20:54	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	7	
8	II-N	7	27.15	-53	13.06	490	10.8	04/21/12 23:18	2		0.95	0.5	0.7	0.75	0.45					0.3		0.5		6.15	8	
9	III-N	7	36.98	-53	8.65	894	10.8	04/22/12 01:52	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	9	
10	I-N	7	46.80	-53	4.25	1177	10.8	04/22/12 04:36	2	1	0.95	0.5	0.7	0.75	0.45				1.25	0.3		0.5		8.4	10	
11	II-N	7	56.63	-52	59.84	1447	10.8	04/22/12 07:43	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	11
12	III-N	8	6.45	-52	55.43	1437	10.8	04/22/12 10:43	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	12	
13	I-N	8	16.27	-52	51.01	2243	10.8	04/22/12 14:01	2	1	0.95	0.5	0.7	0.75	0.45				0.15	1.25	0.3		0.5		8.55	13
14	II-M	8	26.09	-52	46.59	3084	10.8	04/22/12 18:32	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	14	
15	III-G	8	35.91	-52	42.17	3843	10.8	04/22/12 23:06	2		0.95		0.7	0.75	0.45	1	0.15			0.3		0.5		6.8	15	
16	I-F	8	45.73	-52	37.75	4685	10.8	04/23/12 04:36	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	16	
17	II-F	8	55.55	-52	33.32	4553	10.8	04/23/12 10:18	2	1	0.95	0.5	0.7	0.75	0.45				0.15	1.25	0.3		0.5		8.55	17
18	III-F	9	5.37	-52	28.88	4723	10.8	04/23/12 16:48	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	18	
19	I-F	9	15.18	-52	24.44	4736	10.8	04/23/12 22:24	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	19
20	II-F	9	25.00	-52	20.00	4864	10.8	04/24/12 03:54	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	20	
21	III-F	9	38.31	-52	20.00	4868	13.3	04/24/12 09:30	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	21
22	I-E	9	51.62	-52	20.00	4893	13.3	04/24/12 15:00	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	22	
23	II-E	10	4.93	-52	20.00	4936	13.3	04/24/12 20:27	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	23
24	III-E	10	44.85	-52	20.00	4916	40	04/25/12 03:54	2	1	0.95	0.5	0.7	0.75	0.45					1.25	0.3		0.5		8.4	24
25	I-E	11	24.78	-52	20.00	4996	40	04/25/12 11:21	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	25
26	II-E	12	4.70	-52	20.00	5057	40	04/25/12 18:48	2		0.95		0.7	0.75	0.45					0.3		0.5	6	5.65	26	
27	III-E	12	44.62	-52	20.00	5129	40	04/26/12 02:36	2		0.95		0.7	0.75	0.45	1	0.15			0.3	2	0.5		6.8	27	
28	I-E	13	24.54	-52	20.00	5014	40	04/26/12 10:12	2	1	0.95	0.5	0.7	0.75	0.45					1.25	0.3		0.5		8.4	28
29	II-E	14	4.46	-52	20.00	5148	40	04/26/12 17:42	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	29
30	III-E	14	44.38	-52	20.00	5166	40	04/27/12 01:18	2		0.95		0.7	0.75	0.45					0.3		0.5	6	5.65	30	
31	I-E	15	24.29	-52	20.00	5126	40	04/27/12 08:55	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	31
32	II-E	16	4.20	-52	20.00	5227	40	04/27/12 16:16	2	1	0.95	0.5	0.7	0.75	0.45					1.25	0.3		0.5		8.4	32
33	III-E	16	44.11	-52	20.00	5090	40	04/27/12 23:55	2		0.95		0.7	0.75	0.45					0.3		0.5	6	5.65	33	
34	I-E	17	24.01	-52	20.00	5094	40	04/28/12 07:52	2		0.95		0.7	0.75	0.45	1	0.15			0.3		0.5		6.8	34	
35	II-F	18	3.92	-52	20.00	4766	40	04/28/12 16:41	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	35
36	III-E	18	43.82	-52	20.00	5008	40	04/29/12 01:11	2	1	0.95	0.5	0.7	0.75	0.45					1.25	0.3		0.5		8.4	36
37	I-F	19	23.71	-52	20.00	4690	40	04/29/12 09:47	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	37
38	II-D	20	3.61	-52	20.00	5251	40	04/29/12 17:14	2		0.95		0.7	0.75	0.45					0.3		0.5		5.65	38	
39	III-D	20	43.50	-52	20.00	5198	40	04/30/12 01:23	2		0.95		0.7	0.75	0.45	1	0.15			0.3		0.5		6.8	39	
40	I-E	21	28.62	-52	20.00	4964	45.2	04/30/12 09:20	2		0.95		0.7	0.75	0.45					0.3		0.5	4.5	5.65	40	
41	II-E	22	13.73	-52	20.00	5106	45.2	04/30/12 17:17	2	1	0.95	0.5	0.7	0.75	0.45				0.15	1.25	0.3		0.5		8.55	41
42	III-C	22	58.84	-52	20.00	4327	45.2	05/01/12 01:14	2		0.95		0.7	0.75	0.45					0.3		0.5	4.5	5.65	42	
43	I-B	23	43.94	-52	20.00	5113	45.2	05/01/12 09:11	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	43
44	II-B	24	29.04	-52	20.00	5464	45.2	05/01/12 17:08	2	1	0.95	0.5	0.7	0.75	0.45					1.25	0.3		0.5		8.4	44
45	III-D	25	14.14	-52	20.00	5750	45.2	05/02/12 01:05	2		0.95		0.7	0.75	0.45				0.15		0.3		0.5		5.8	45
46	I-B	25	59.23	-52	20.00	5180	45.2	05/02/12 09:02	2		0.95		0.7	0.75	0.45					0.3		0.5	4.5	5.65	46	
47	II-D	26	44.32	-52	20.00	4956	45.2	05/02/12 17:08	2		0.95		0.7	0.75	0.45	1	0.15			0.3	2	0.5		6.8	47	
48	III-F	27	29.40	-52	20.00	5795	45.2	05/03/12 01:14	2		0.95		0.7	0.75	0.45					0.3		0.5	4.5	5.65	48	
49	I-C	28	14.48	-52	20.00	5428	45.2	05/03/12 09:50	2	1	0.95	0.5	0.7	0.75	0.45				0.15	1.25	0.3		0.5		8.55	49

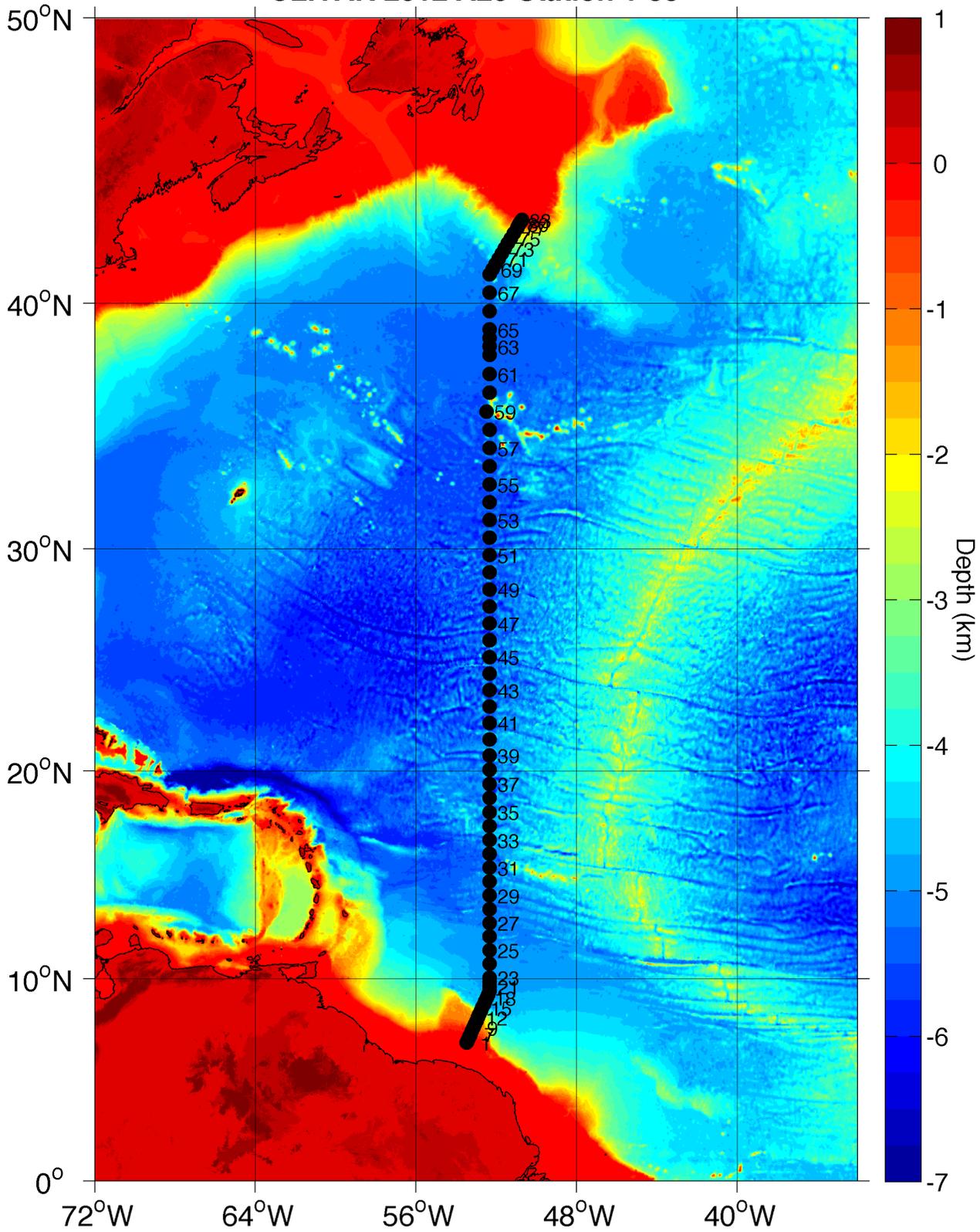
50	II-C	28	59.55	-52	20.00	5734	45.2	05/03/12 18:02	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	50
51	III-	29	44.62	-52	20.00	5167	45.1	05/04/12 02:32	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	51
52	I-	30	29.68	-52	20.00	5475	45.1	05/04/12 10:32	2		0.95		0.7	0.75	0.45	1	0.15		0.3		0.5		6.8	52
53	II-	31	14.73	-52	20.00	5103	45.1	05/04/12 18:26	2	1	0.95	0.5	0.7	0.75	0.45		0.15	1.25	0.3		0.5		8.55	53
54	III-	31	59.79	-52	20.00	5535	45.1	05/05/12 02:26	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	54
55	I-	32	44.83	-52	20.00	5119	45.1	05/05/12 10:38	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	55
56	II-	33	29.87	-52	20.00	5566	45.1	05/05/12 18:38	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	56
57	III-	34	14.91	-52	20.00	5424	45.1	05/06/12 02:38	2	1	0.95	0.5	0.7	0.75	0.45		0.15	1.25	0.3		0.5		8.55	57
58	I-	34	59.94	-52	20.00	4280	45.1	05/06/12 11:08	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	58
59	II-	35	44.96	-52	30.20	5196	45.1	05/06/12 18:08	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	59
60	III-	36	29.98	-52	20.00	5403	45.1	05/07/12 02:02	2	1	0.95	0.5	0.7	0.75	0.45			1.25	0.3		0.5		8.4	60
61	I-	37	14.99	-52	20.00	5457	45.1	05/07/12 10:02	2		0.95		0.7	0.75	0.45	1	0.15		0.3		0.5		6.8	61
62	II-	37	60.00	-52	20.00	5414	45.1	05/07/12 18:02	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	62
63	III-	38	20.00	-52	20.00	5366	20	05/07/12 23:56	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5	4.5	5.8	63
64	I-	38	40.00	-52	20.00	5339	20	05/08/12 06:14	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	64
65	II-	38	60.00	-52	20.00	5349	20	05/08/12 12:08	2	1	0.95	0.5	0.7	0.75	0.45		0.15	1.25	0.3		0.5		8.55	65
66	III-	39	42.01	-52	20.00	5289	42.1	05/08/12 19:48	2		0.95		0.7	0.75	0.45				0.3		0.5	4.5	5.65	66
67	I-	40	24.01	-52	20.00	5211	42.1	05/09/12 03:42	2		0.95		0.7	0.75	0.45	1	0.15		0.3	2	0.5		6.8	67
68	II-	41	6.00	-52	20.00	5225	42.1	05/09/12 11:36	2	1	0.95	0.5	0.7	0.75	0.45			1.25	0.3		0.5		8.4	68
69	III-	41	17.49	-52	11.12	5120	13.3	05/09/12 17:24	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	69
70	I-	41	28.97	-52	2.18	4761	13.3	05/09/12 22:33	2		0.95		0.7	0.75	0.45				0.3		0.5	4.5	5.65	70
71	II-	41	40.43	-51	53.20	4405	13.3	05/10/12 03:57	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	71
72	III-	41	51.88	-51	44.16	3920	13.3	05/10/12 09:03	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	72
73	I-	42	3.32	-51	35.07	3485	13.3	05/10/12 13:42	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	73
74	II-	42	14.75	-51	25.92	3113	13.3	05/10/12 17:50	2	1	0.95	0.5	0.7	0.75	0.45			1.25	0.3		0.5		8.4	74
75	III-	42	26.17	-51	16.71	2638	13.3	05/10/12 21:56	2		0.95		0.7	0.75	0.45	1	0.15		0.3	2	0.5		6.8	75
76	I-	42	37.57	-51	7.46	2076	13.3	05/11/12 01:46	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	76
77	II-	42	48.96	-50	58.14	1455	13.3	05/11/12 05:16	2		0.95		0.7	0.75	0.45		0.15		0.3		0.5		5.8	77
78	III-	42	51.86	-50	55.80	1197	3.4	05/11/12 07:55	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	78
79	I-	42	54.75	-50	53.46	928	3.4	05/11/12 10:13	2	1	0.95	0.5	0.7	0.75	0.45		0.15	1.25	0.3		0.5		8.55	79
80	II-	42	57.65	-50	51.11	466	3.4	05/11/12 12:25	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	80
81	III-	43	0.54	-50	48.76	190	3.4	05/11/12 13:37	2		0.95		0.7	0.75	0.45				0.3		0.5		5.65	81
82	I-	43	3.44	-50	46.41	124	3.4	05/11/12 14:43	2		0.95	0.5	0.7	0.75	0.45				0.3		0.5		6.15	82
83	II-	43	6.33	-50	44.05	106	3.4	05/11/12 15:37	2		0.95	0.5	0.7	0.75	0.45				0.3		0.5		6.15	83
84	III-	43	9.22	-50	41.69	97	3.4	05/11/12 16:37			0.95								0.3		0.5		1.75	84
85	I-	43	12.11	-50	39.33	96	3.4	05/11/12 17:31			0.95	0.5							0.3		0.5		2.25	85
86	II-	43	15.00	-50	36.96	84	3.4	05/11/12 18:25			0.95								0.3		0.5		1.75	86

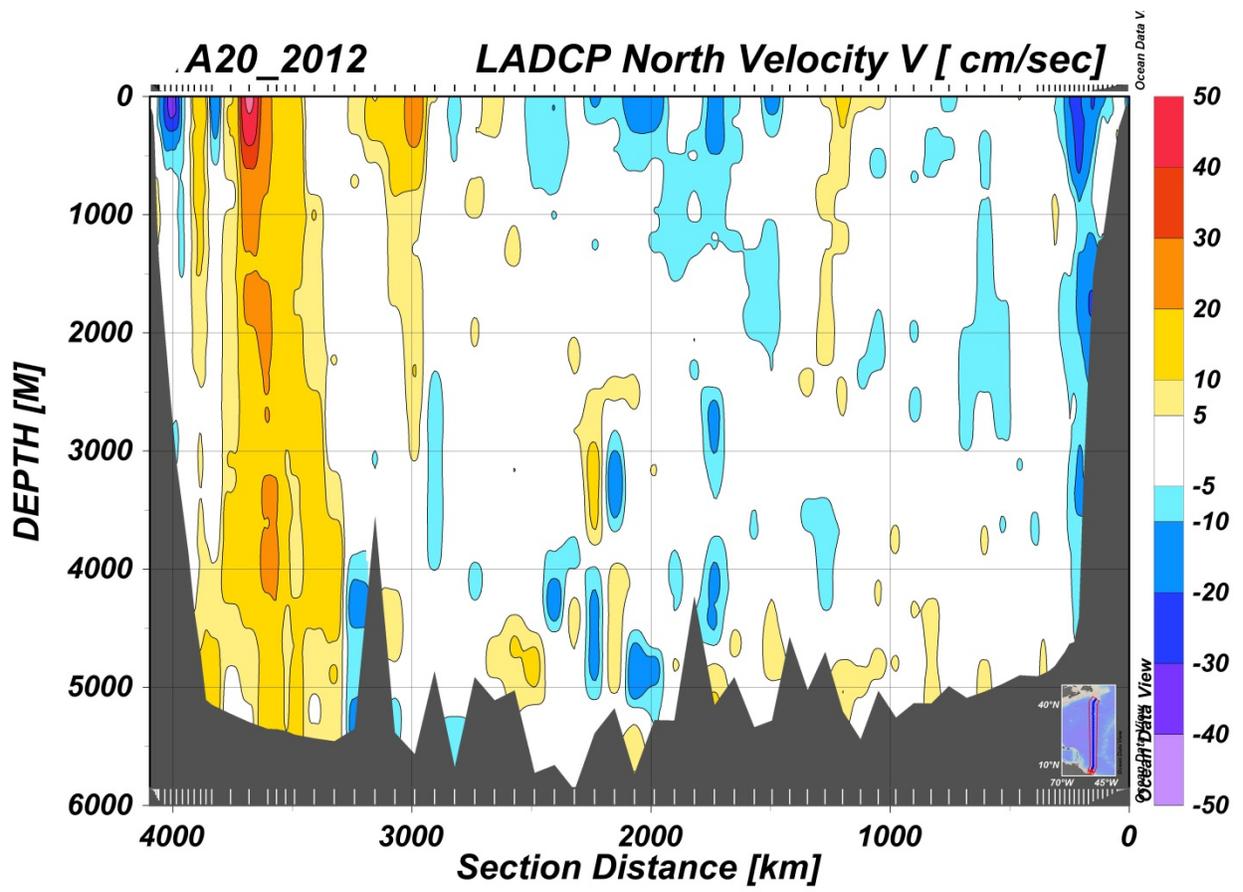
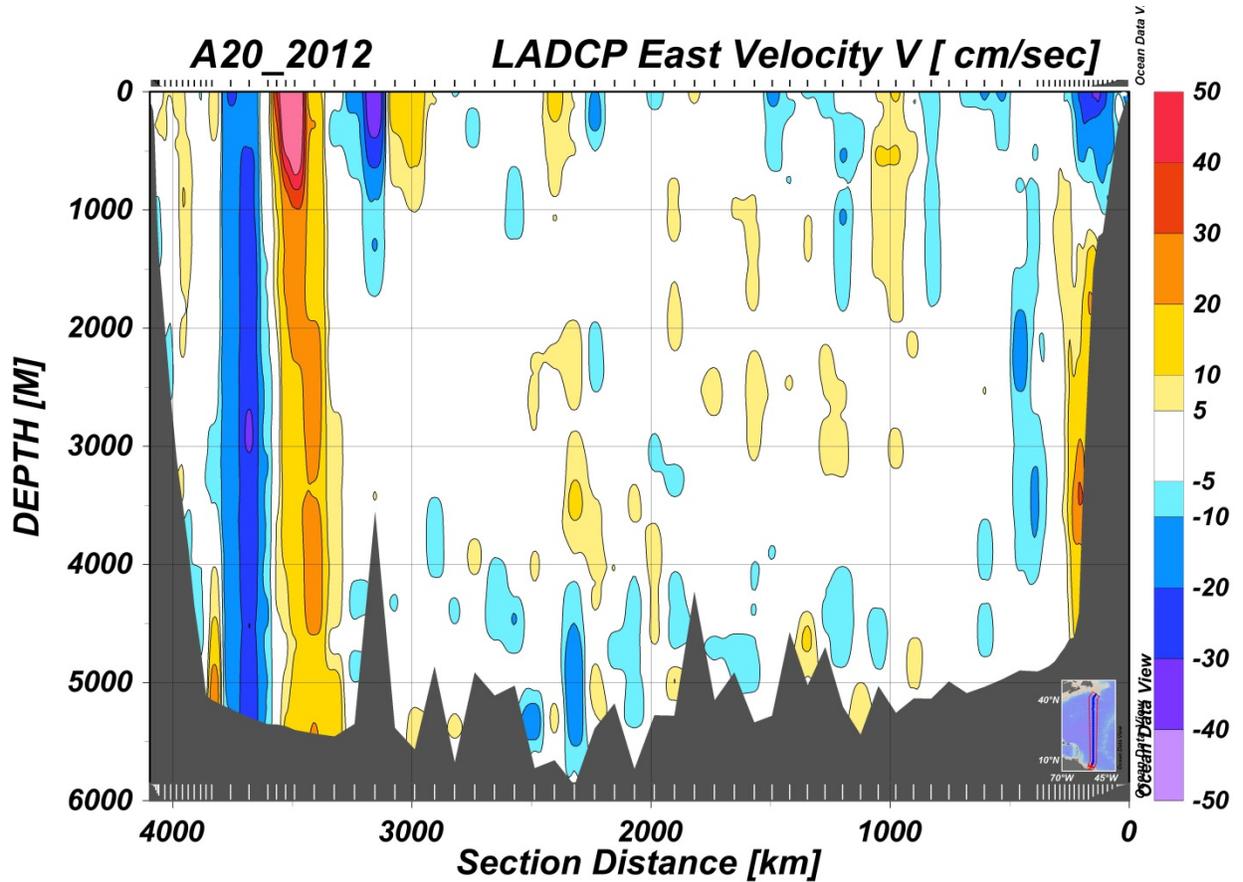
Appendix F

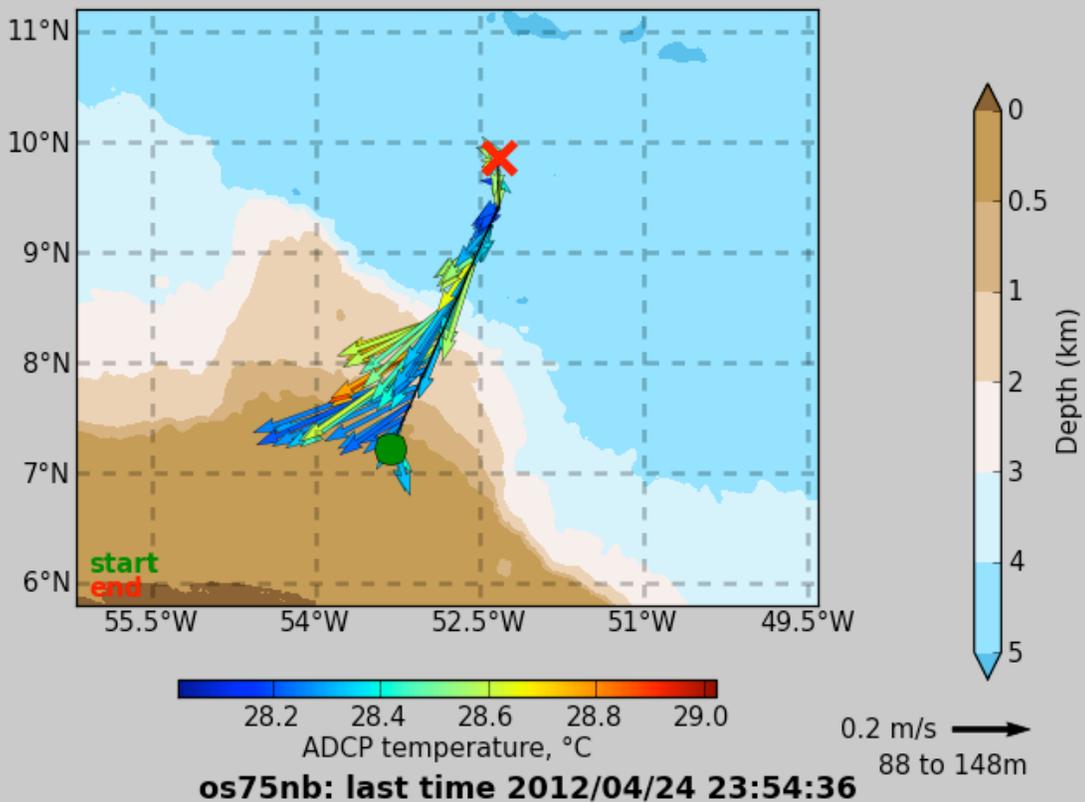
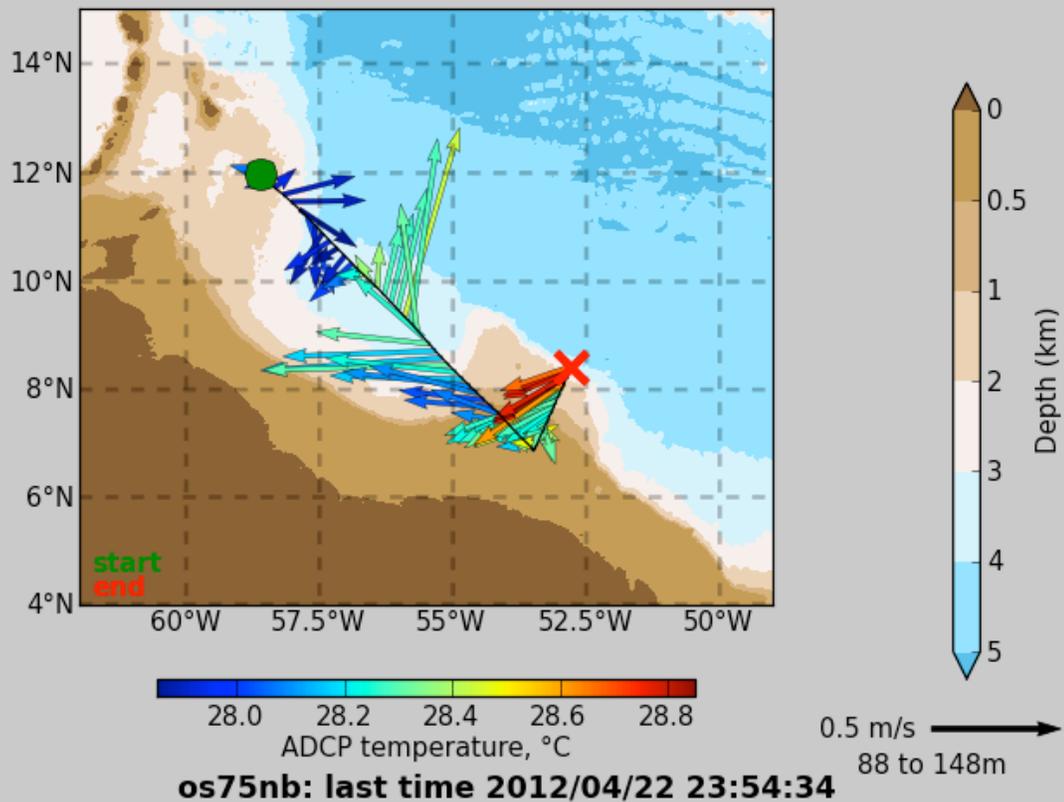
CLIVAR A20: Plots

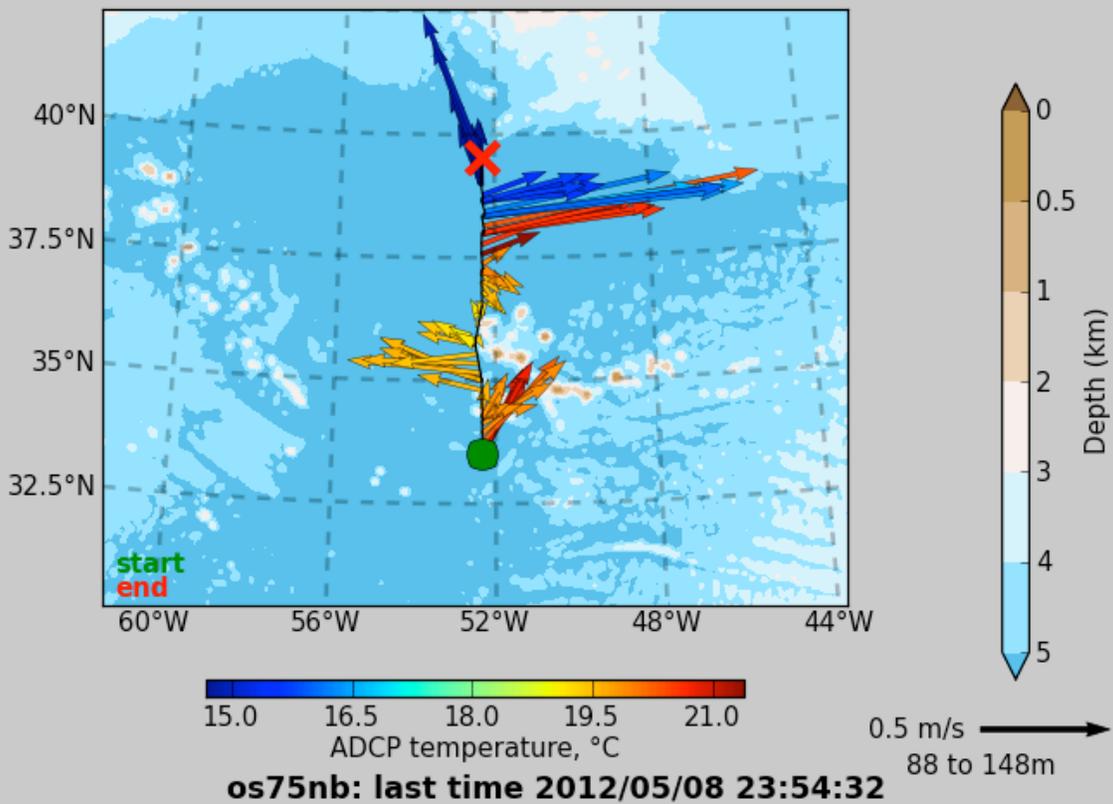
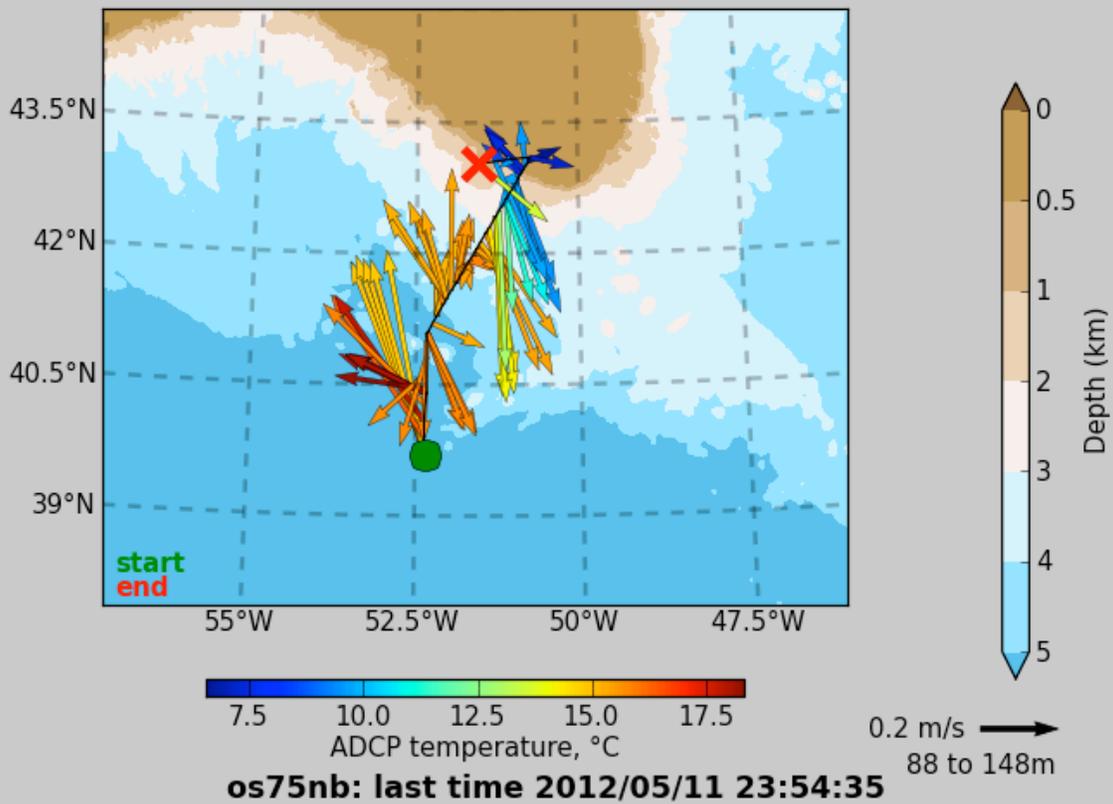
Plots - Table of Contents
Cruise Trackmap - Stations 1-83
LADCP East Velocity V [cm/sec]
LADCP North Velocity V [cm/sec]
ADCP Temperature and Velocity - 2012-04-22 [m/s]
ADCP Temperature and Velocity - 2012-04-24 [m/s]
ADCP Temperature and Velocity - 2012-05-11 [m/s]
ADCP Temperature and Velocity - 2012-05-08 [m/s]
Potential Temperature
CTD Salinity
Neutral Density [kg/m^3]
CTD Oxygen [$\mu\text{mol/kg}$]
Nitrate [$\mu\text{mol/kg}$]
Phosphate [$\mu\text{mol/kg}$]
Silicate [$\mu\text{mol/kg}$]
CFC-113 [pmol/kg]
CFC-11 [pmol/kg]
CFC-12 [pmol/kg]
Alkalinity [$\mu\text{mol/kg}$]
Total Carbon - DIC [$\mu\text{mol/kg}$]
pH
CCL4 [pmol/kg]
CTD Salinity
Silicate [$\mu\text{mol/kg}$]
Alkalinity [$\mu\text{mol/kg}$]
Total Carbon - DIC [$\mu\text{mol/kg}$]
Potential Temperature [degC]
CTD Salinity
Neutral Density [kg/m^3]
CTD Oxygen [$\mu\text{mol/kg}$]
Nitrate [$\mu\text{mol/kg}$]
Phosphate [$\mu\text{mol/kg}$]
Silicate [$\mu\text{mol/kg}$]
CFC-113 [pmol/kg]
CFC-11 [pmol/kg]
CFC-12 [pmol/kg]
Total Carbon - DIC [$\mu\text{mol/kg}$]
Alkalinity [$\mu\text{mol/kg}$]
pH
Sampling Bottle Depths

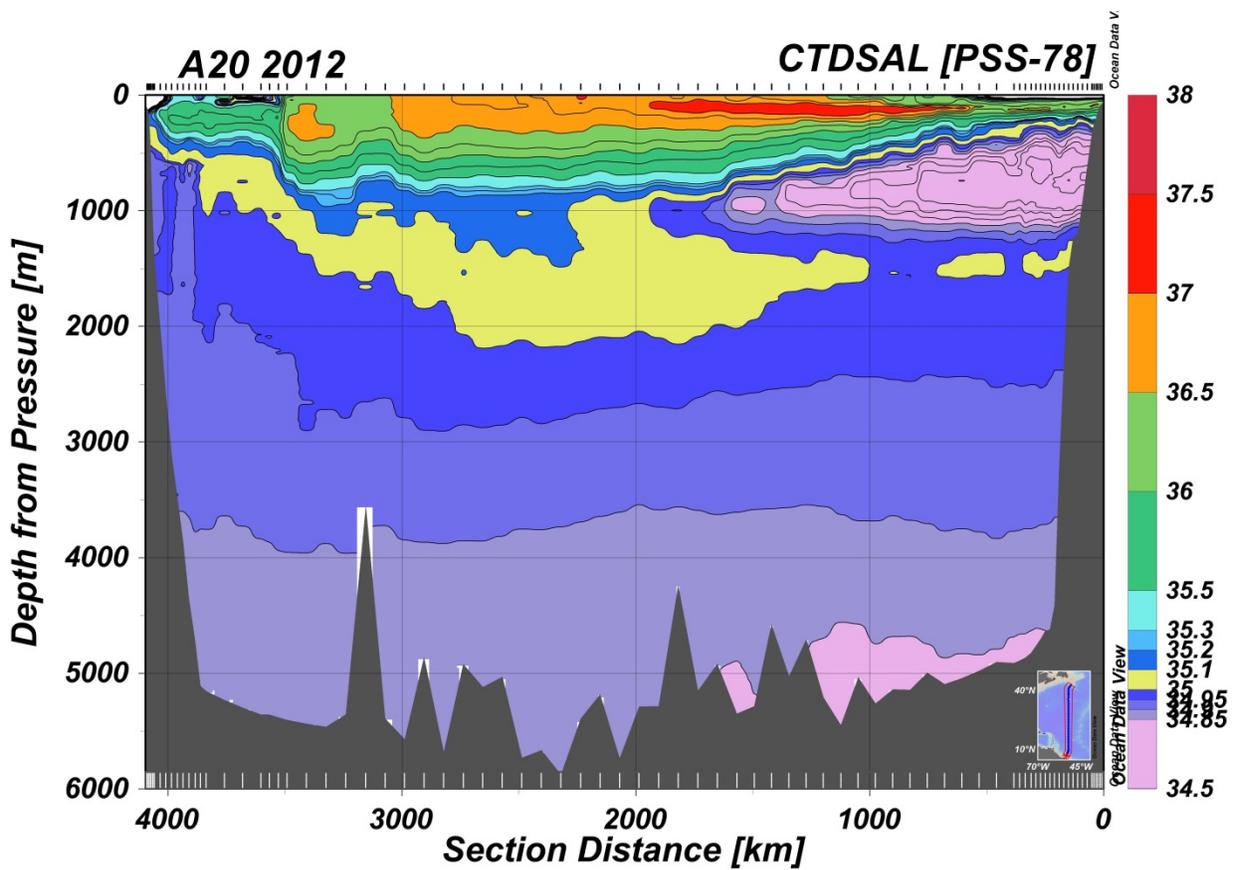
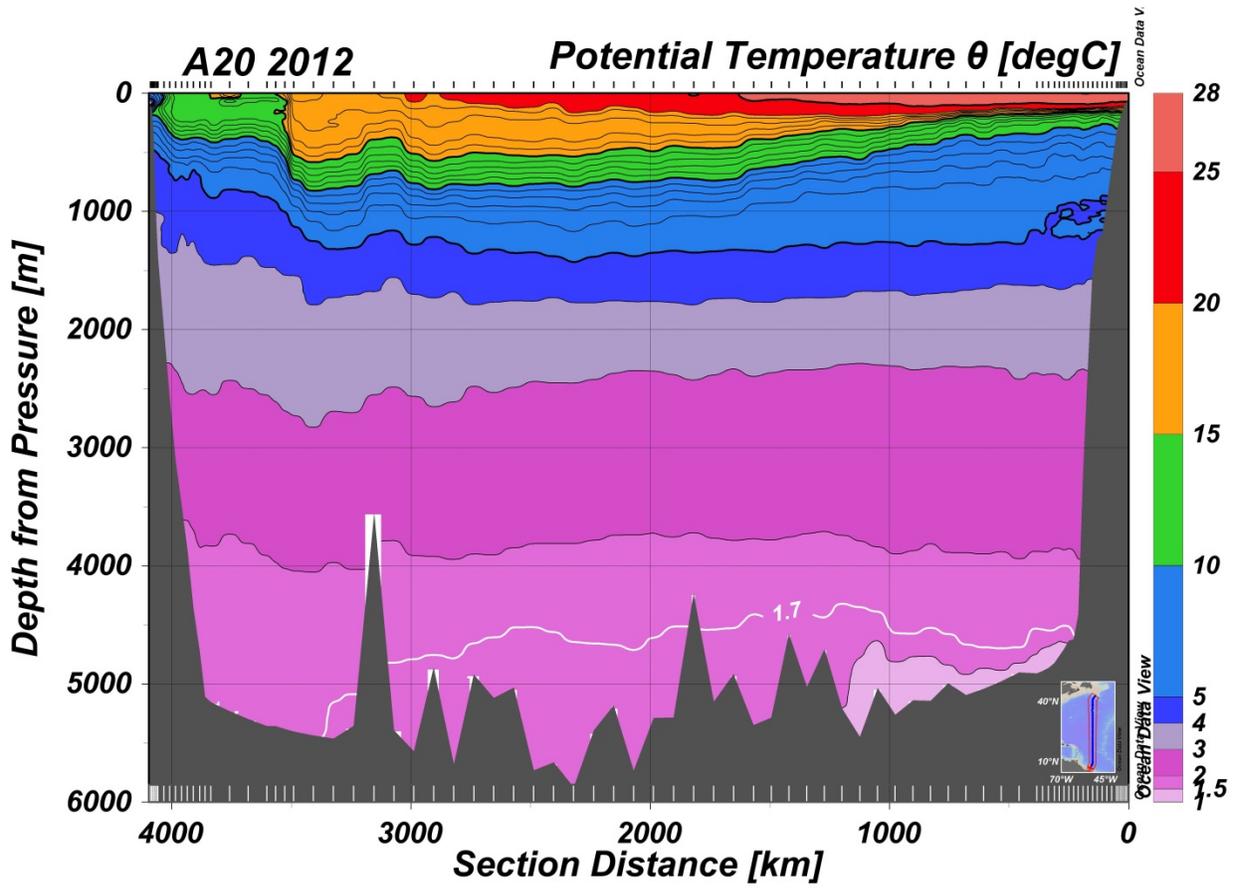
CLIVAR 2012 A20 Station 1-83

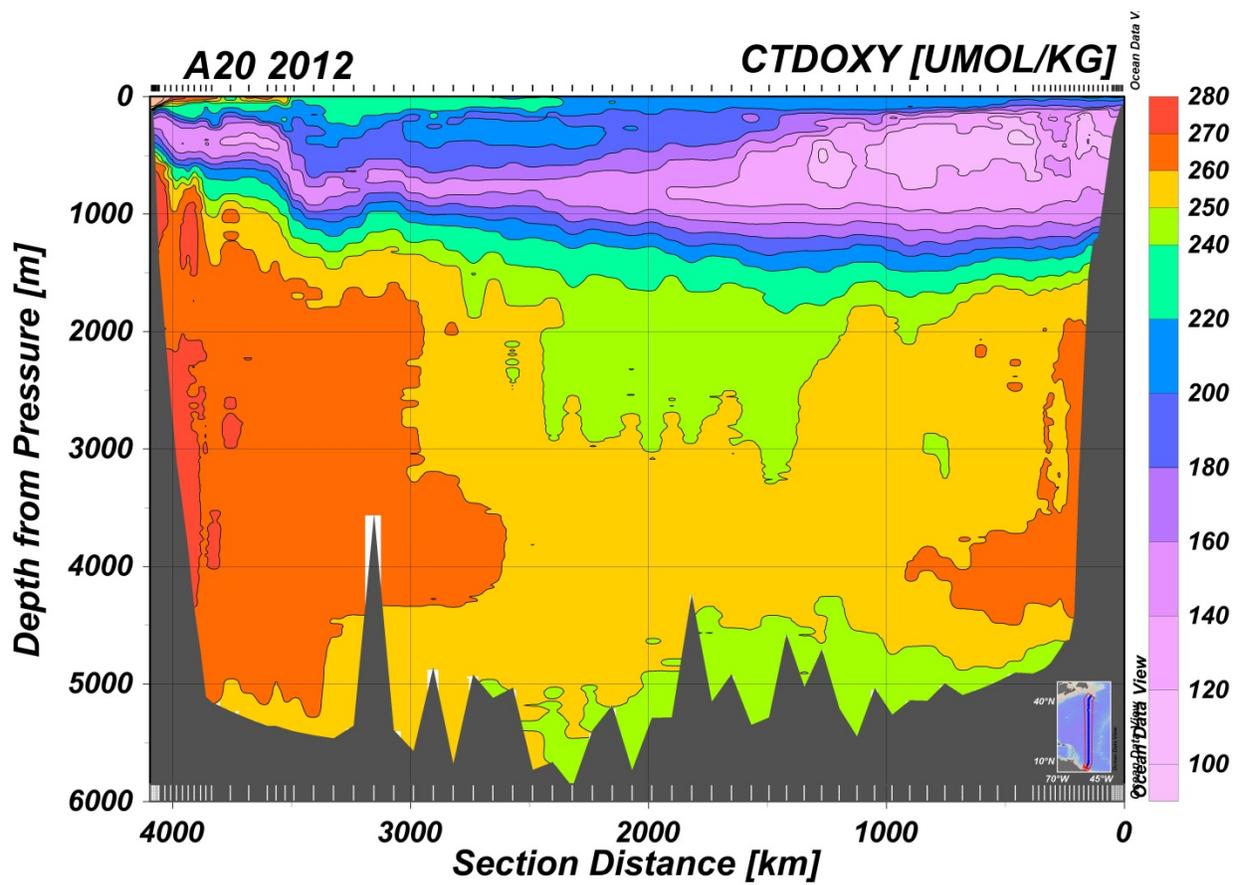
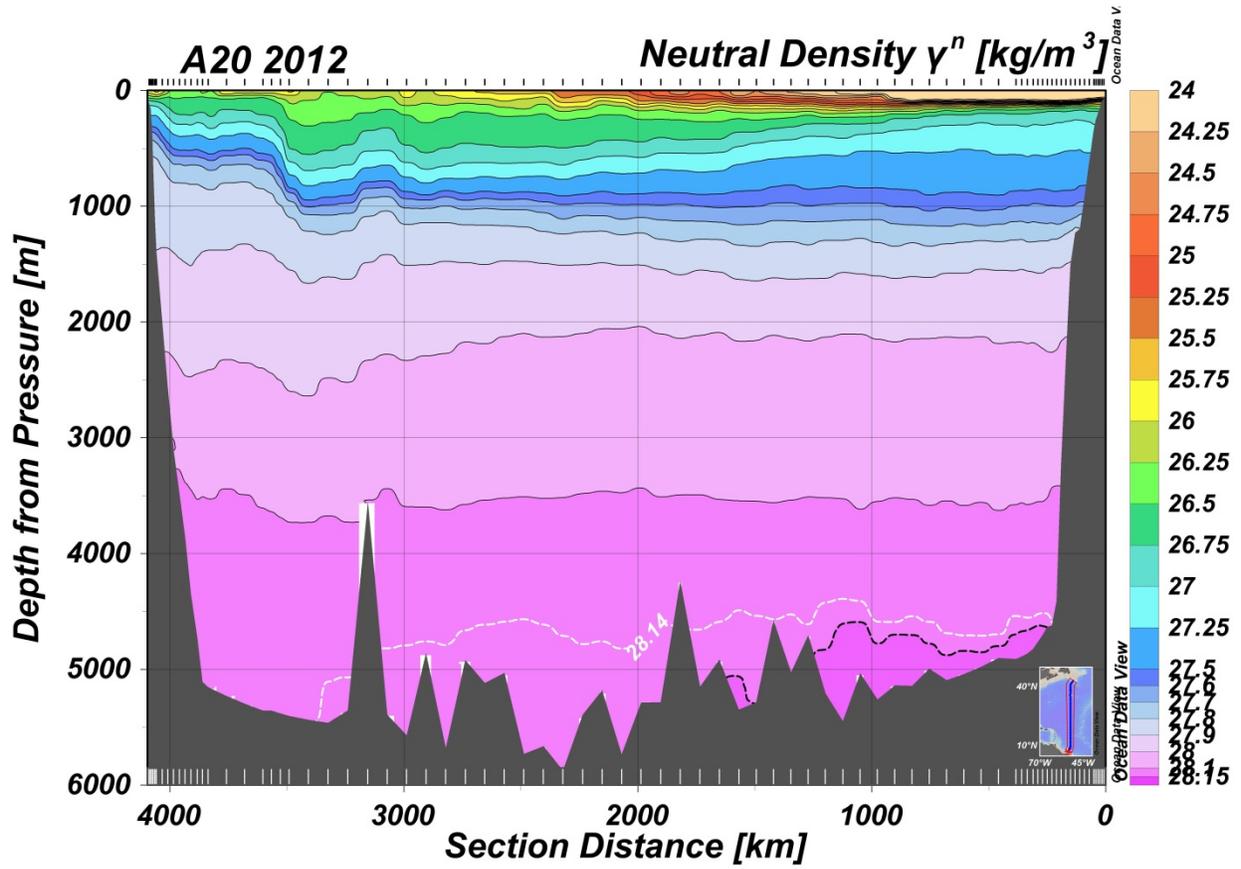


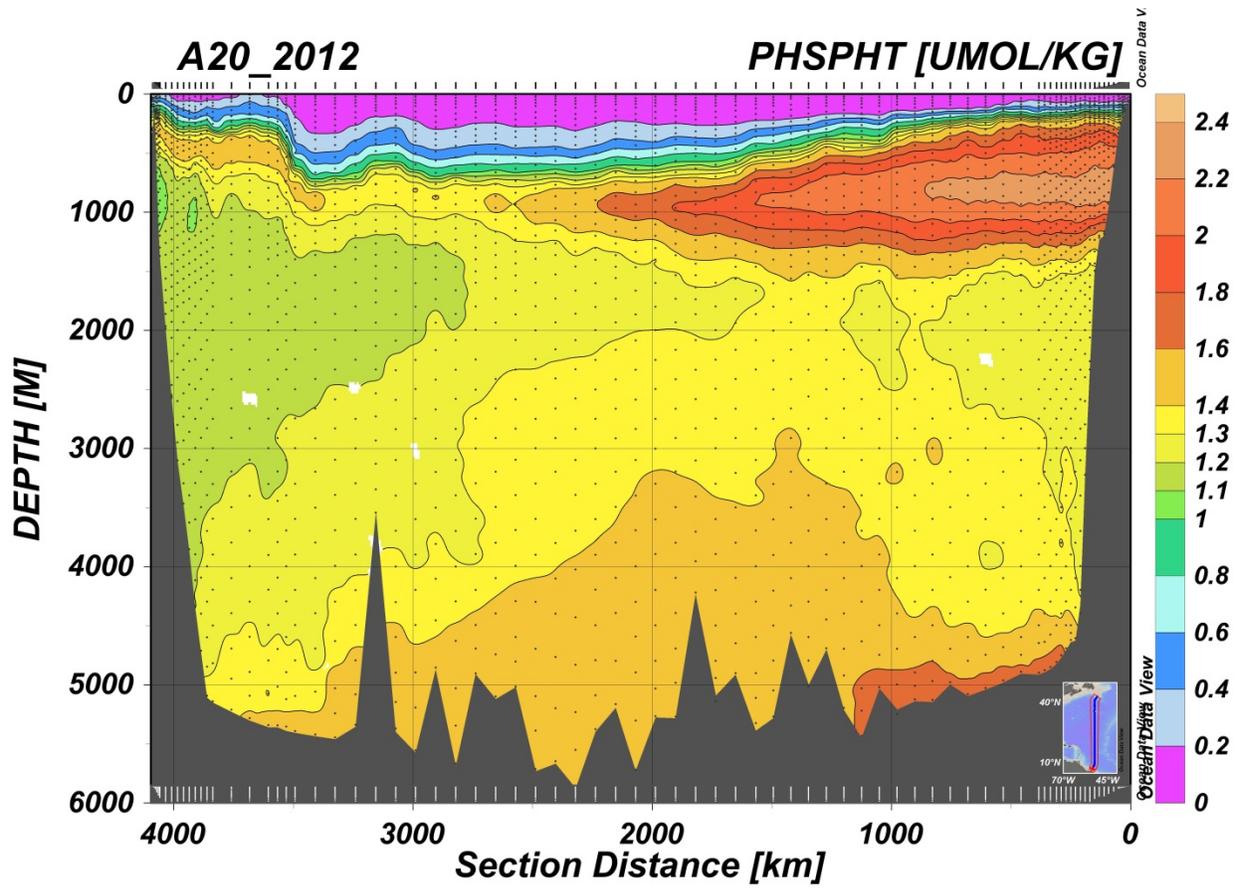
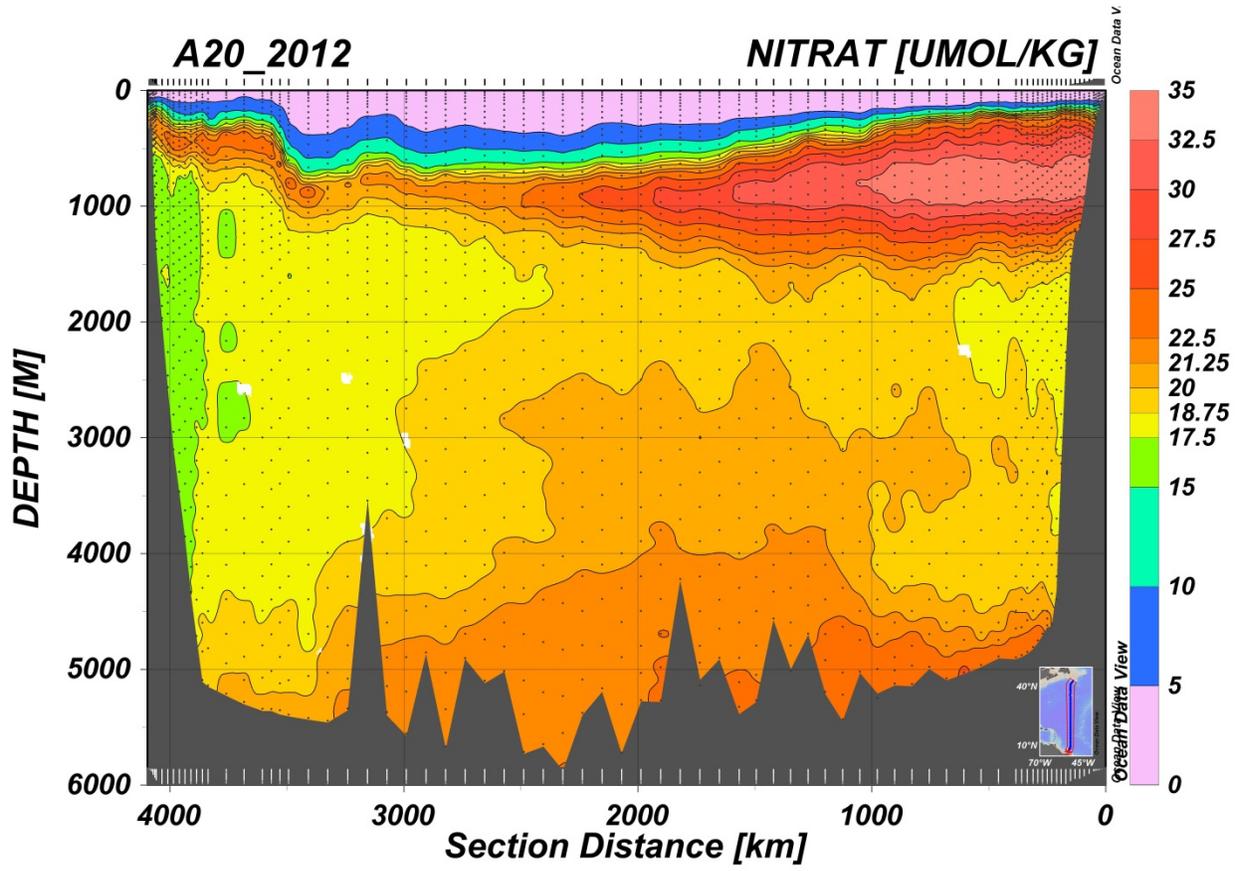


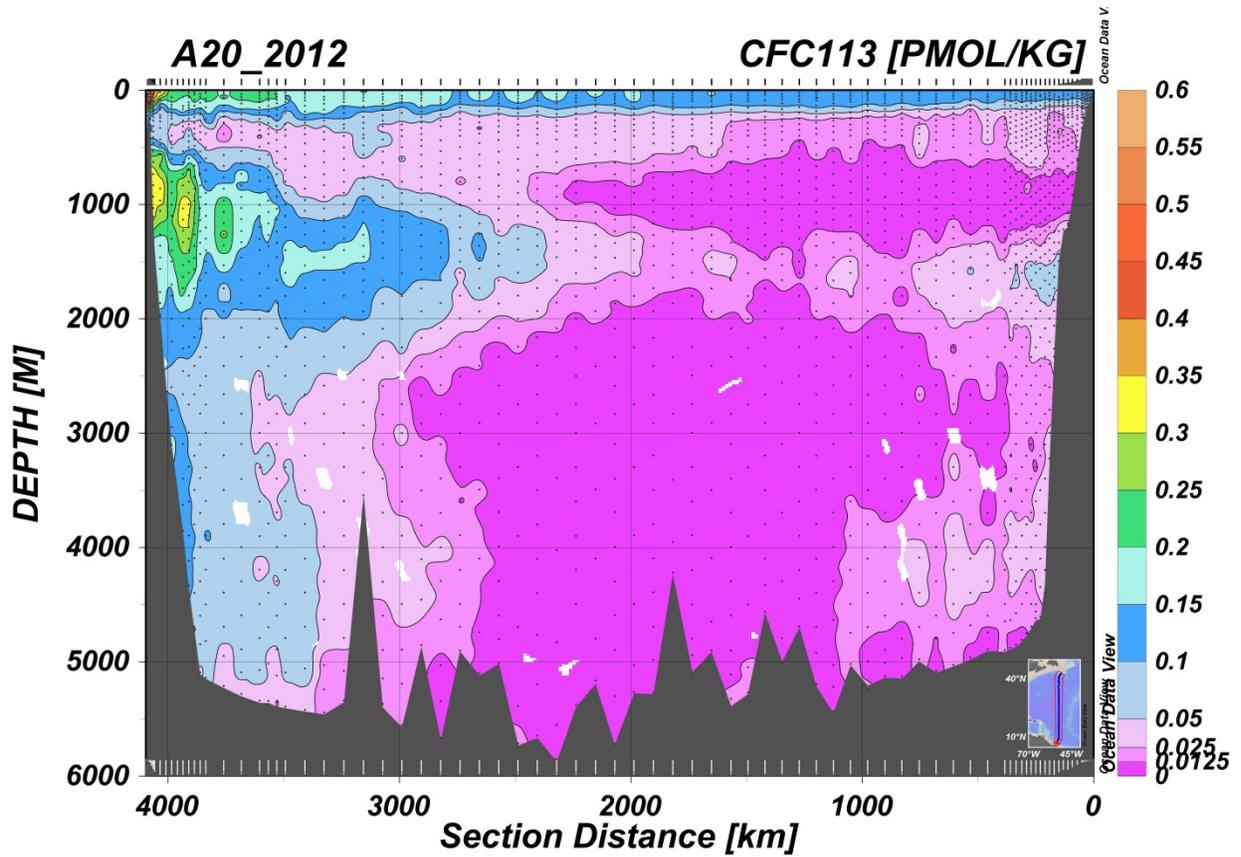
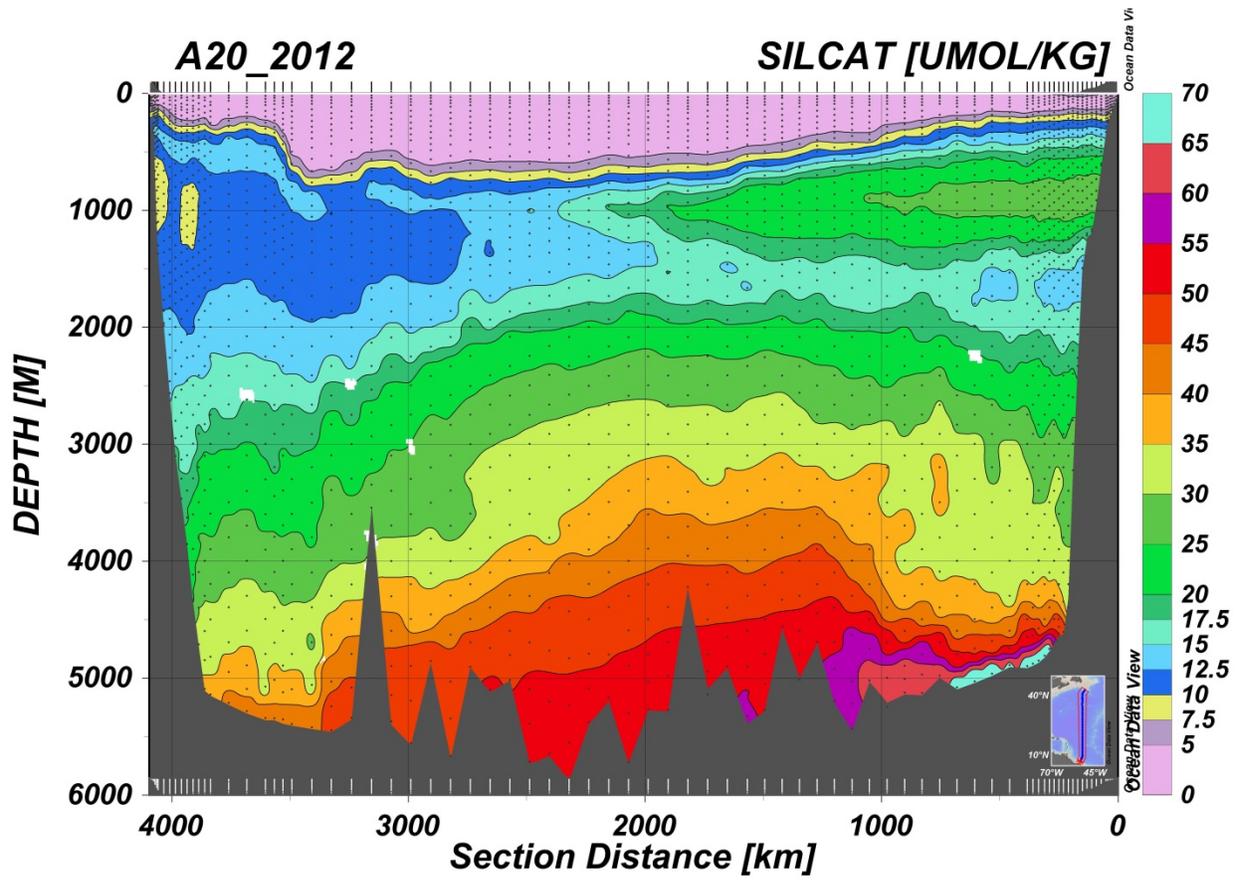


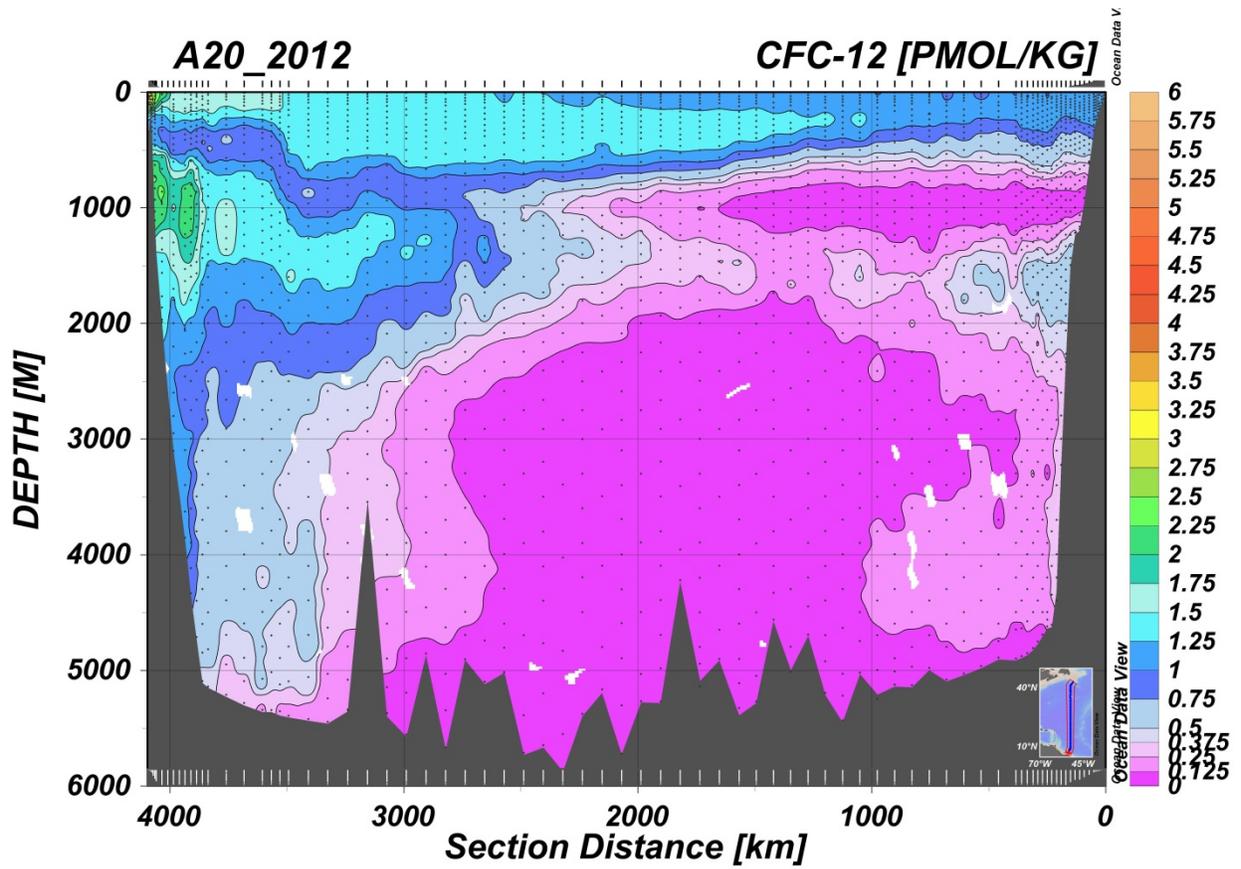
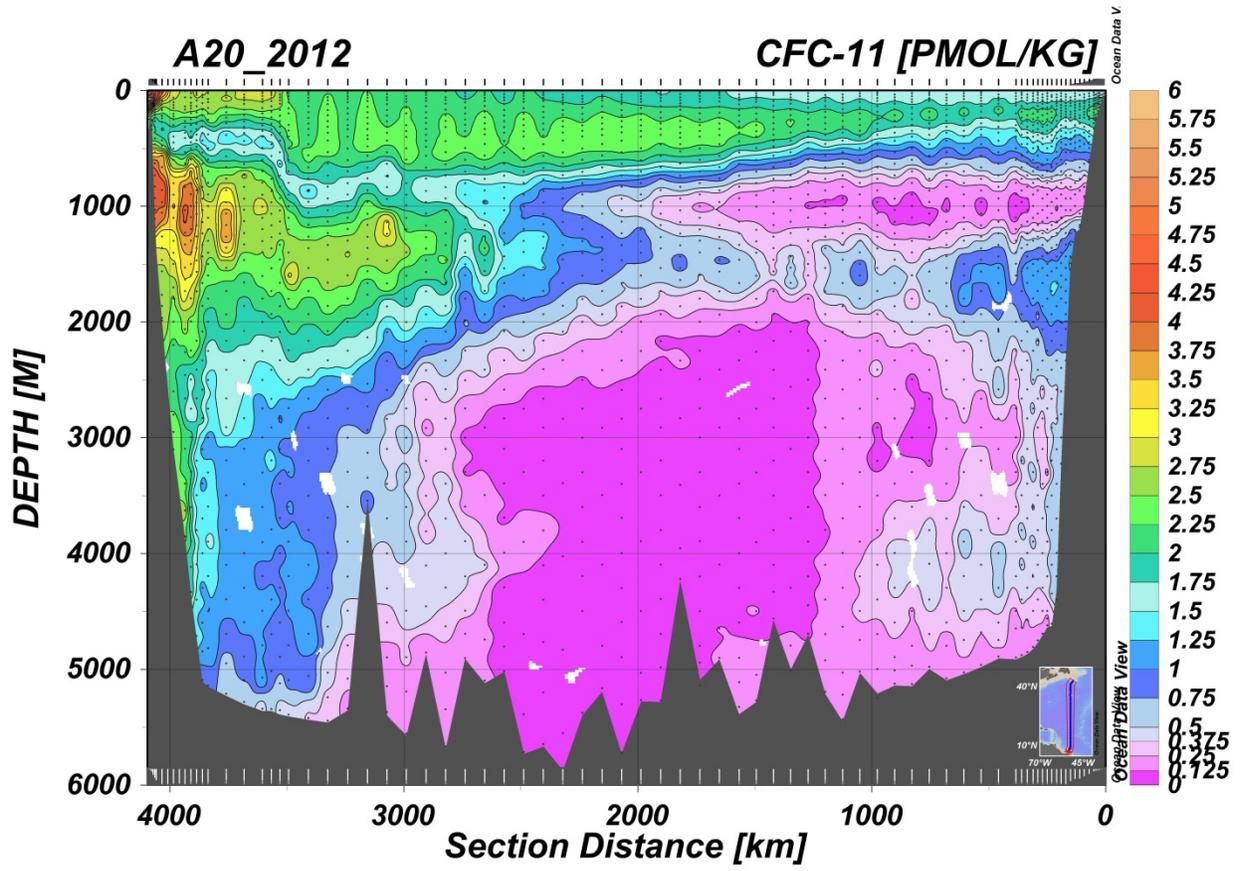


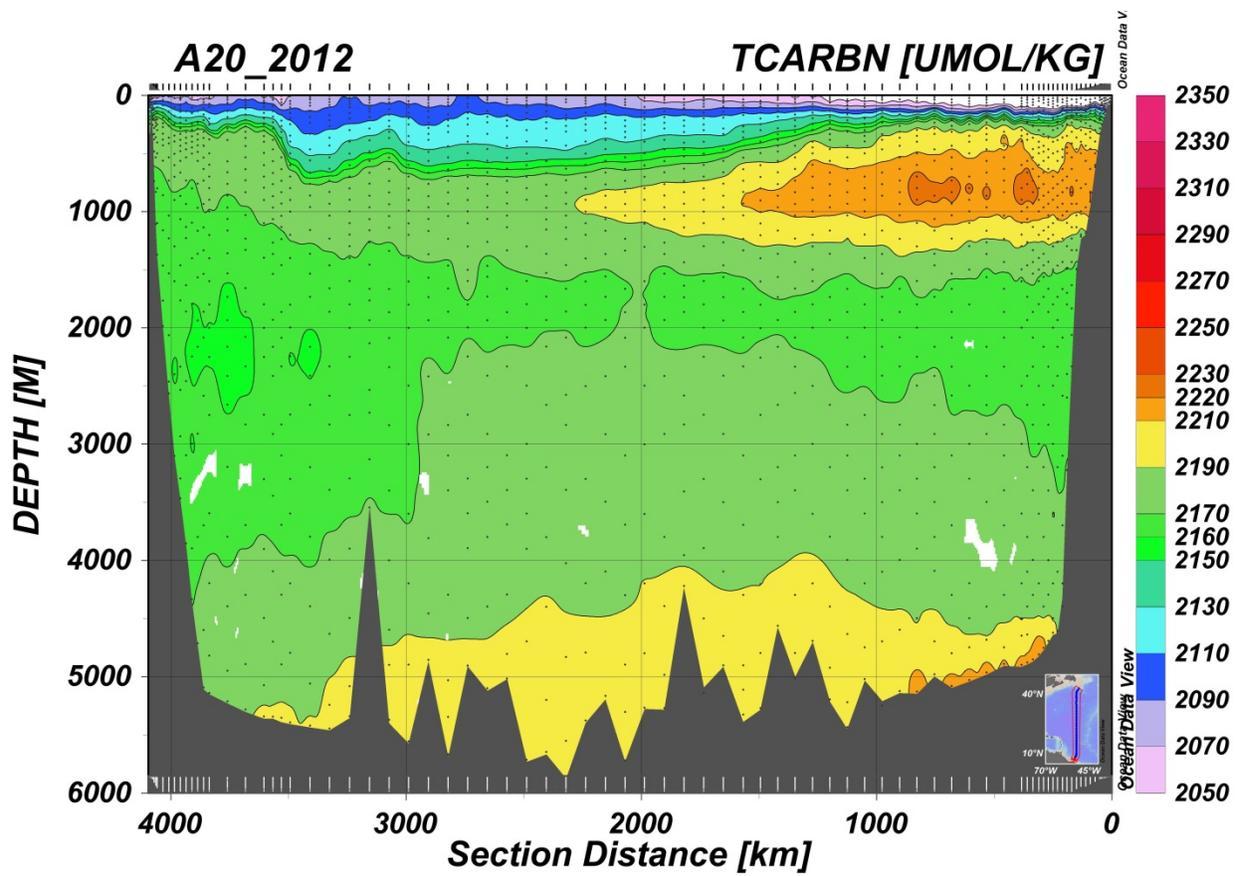
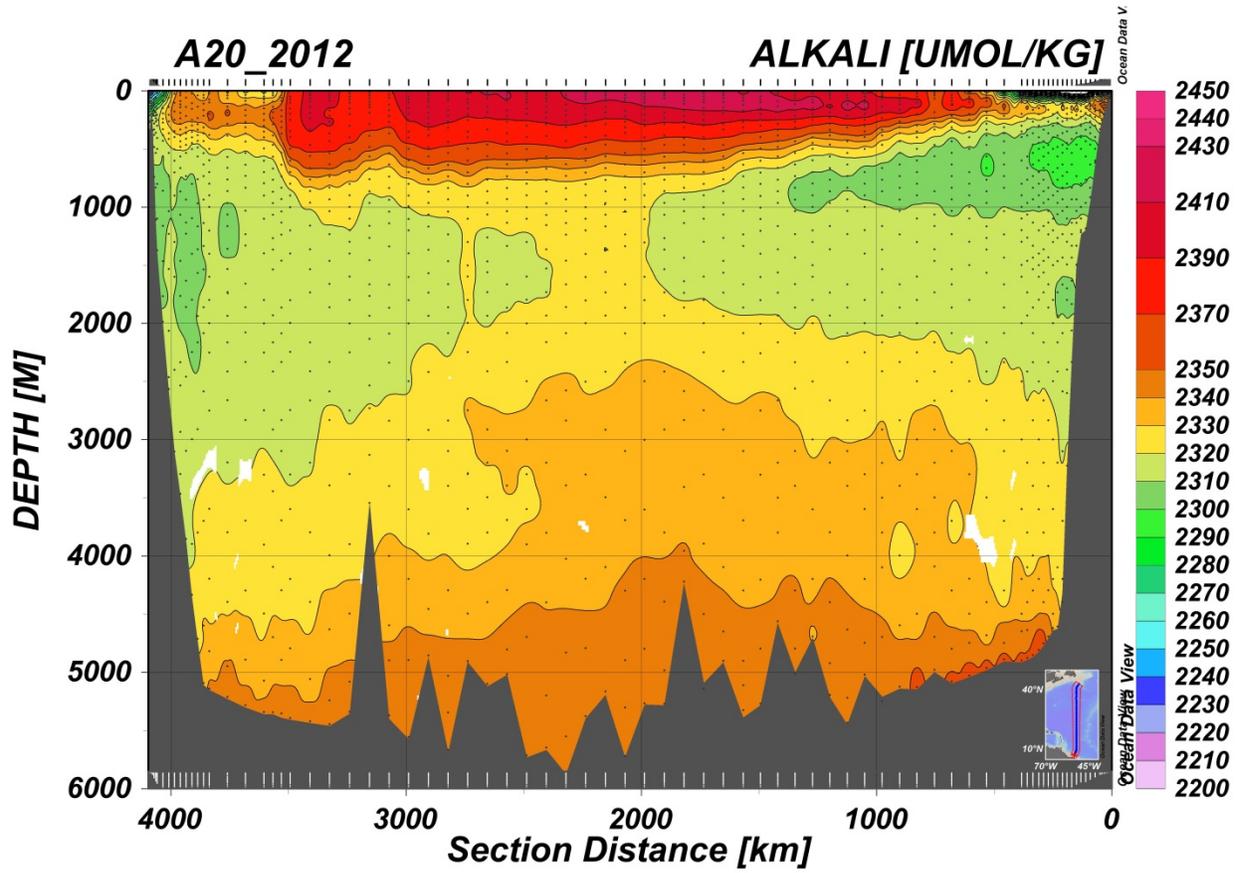


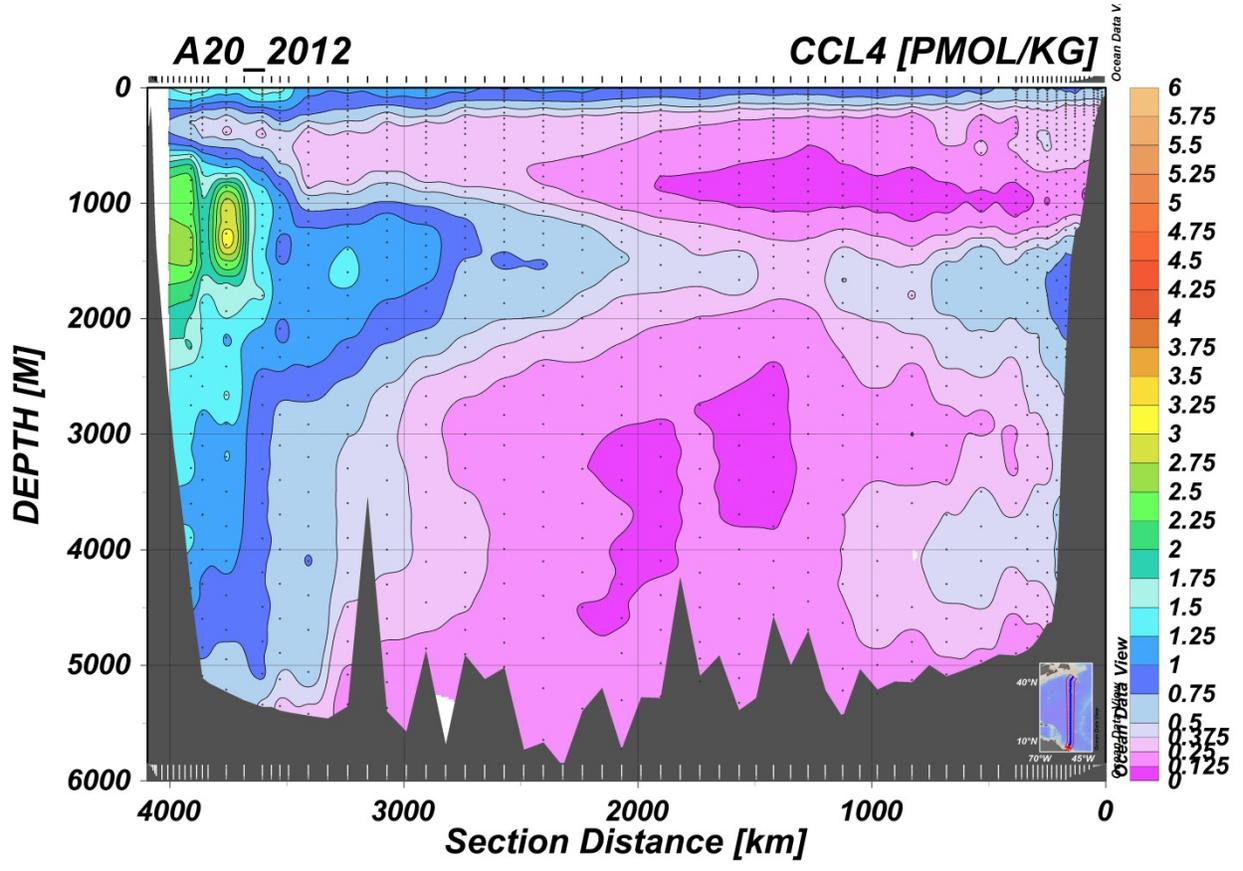
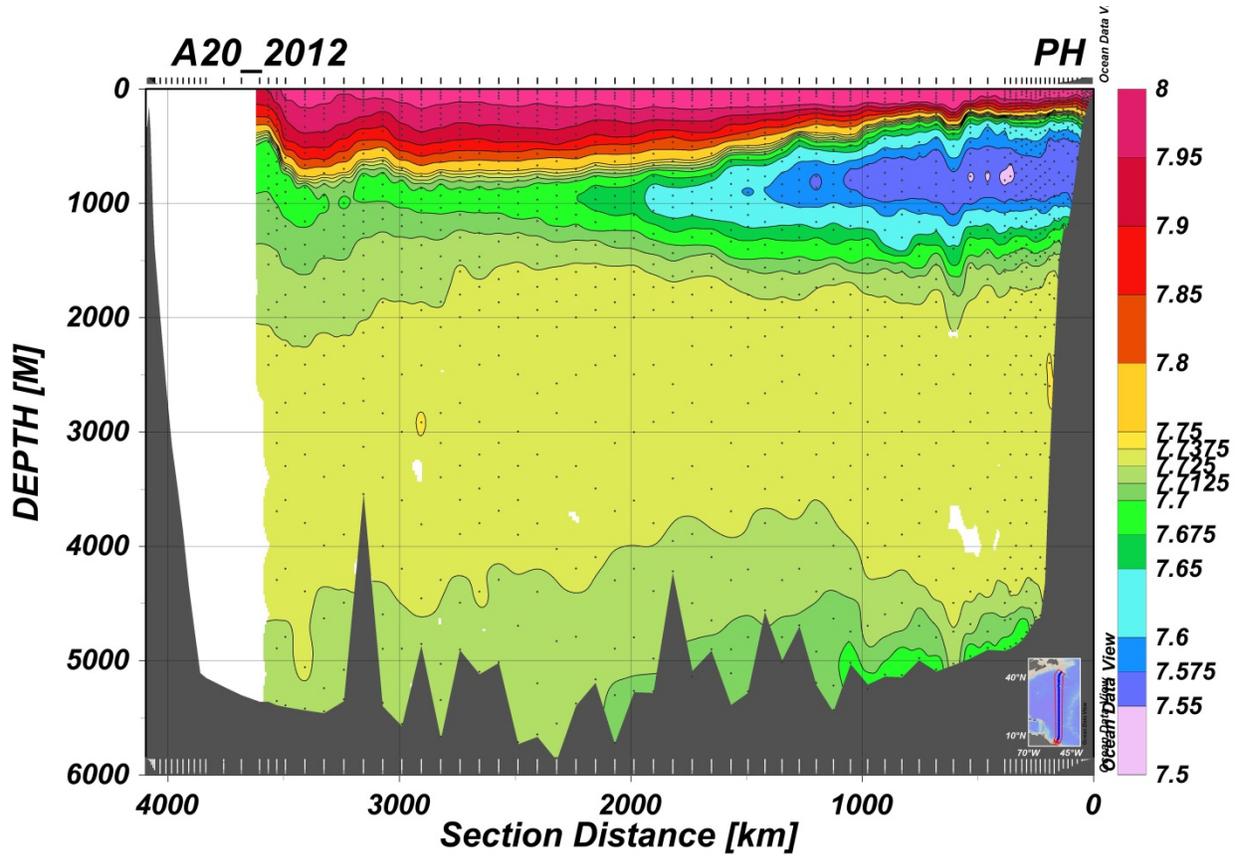


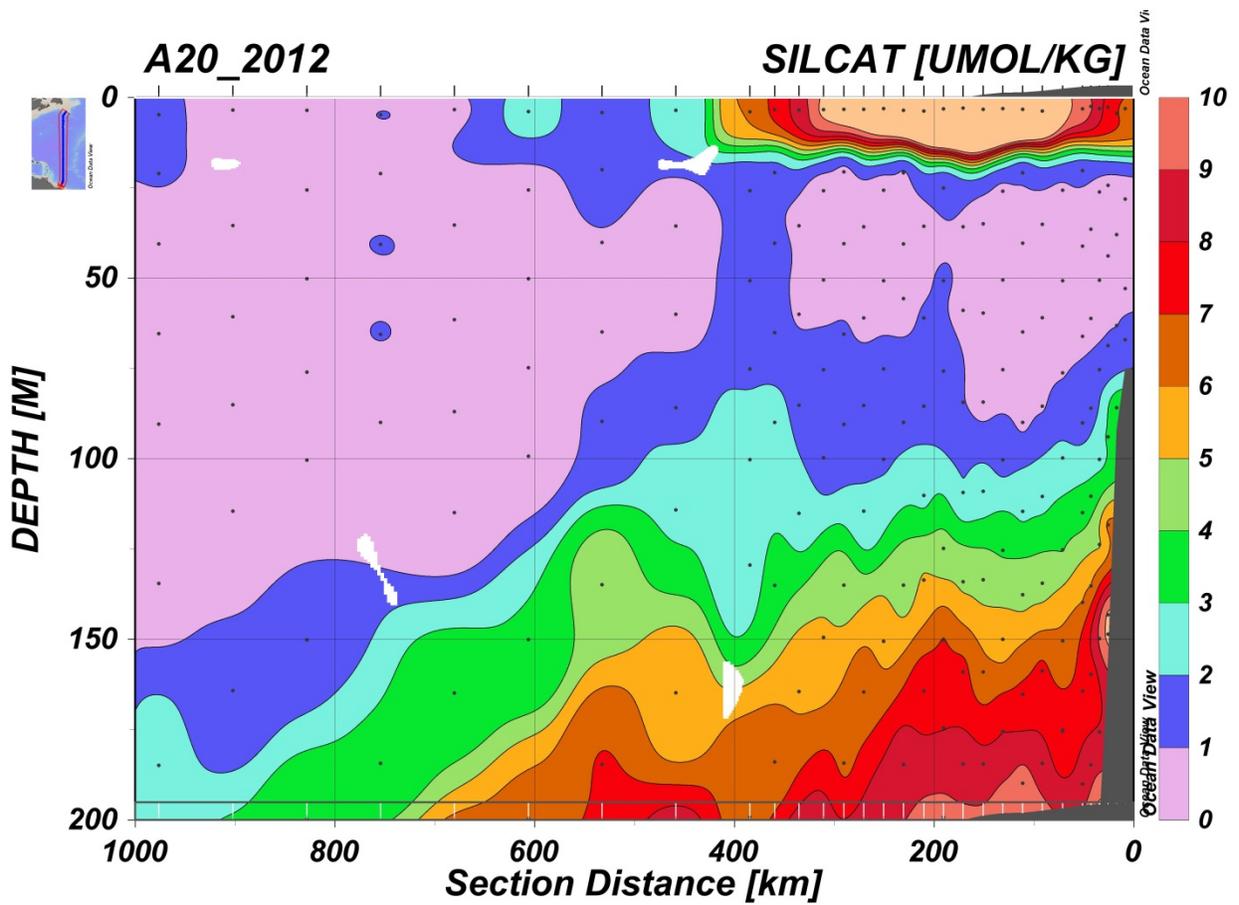
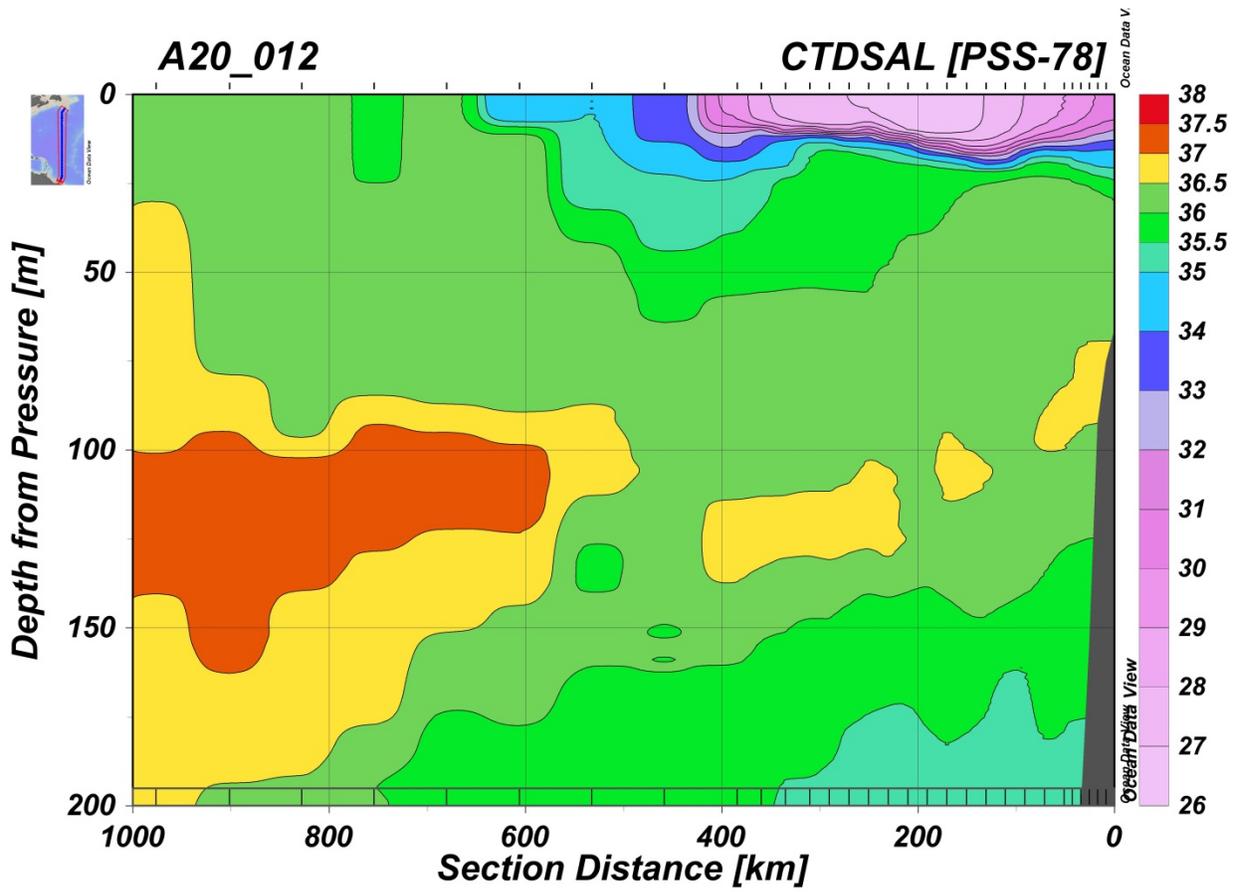


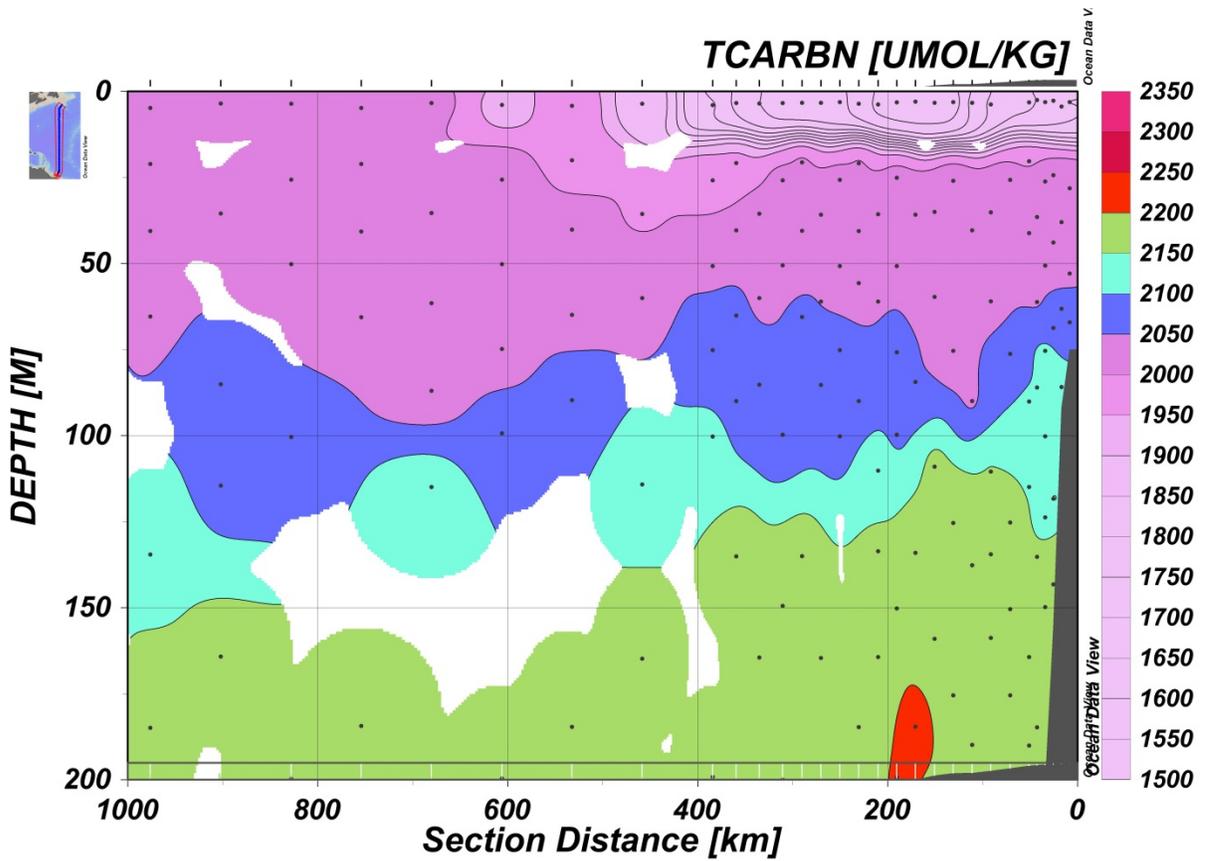
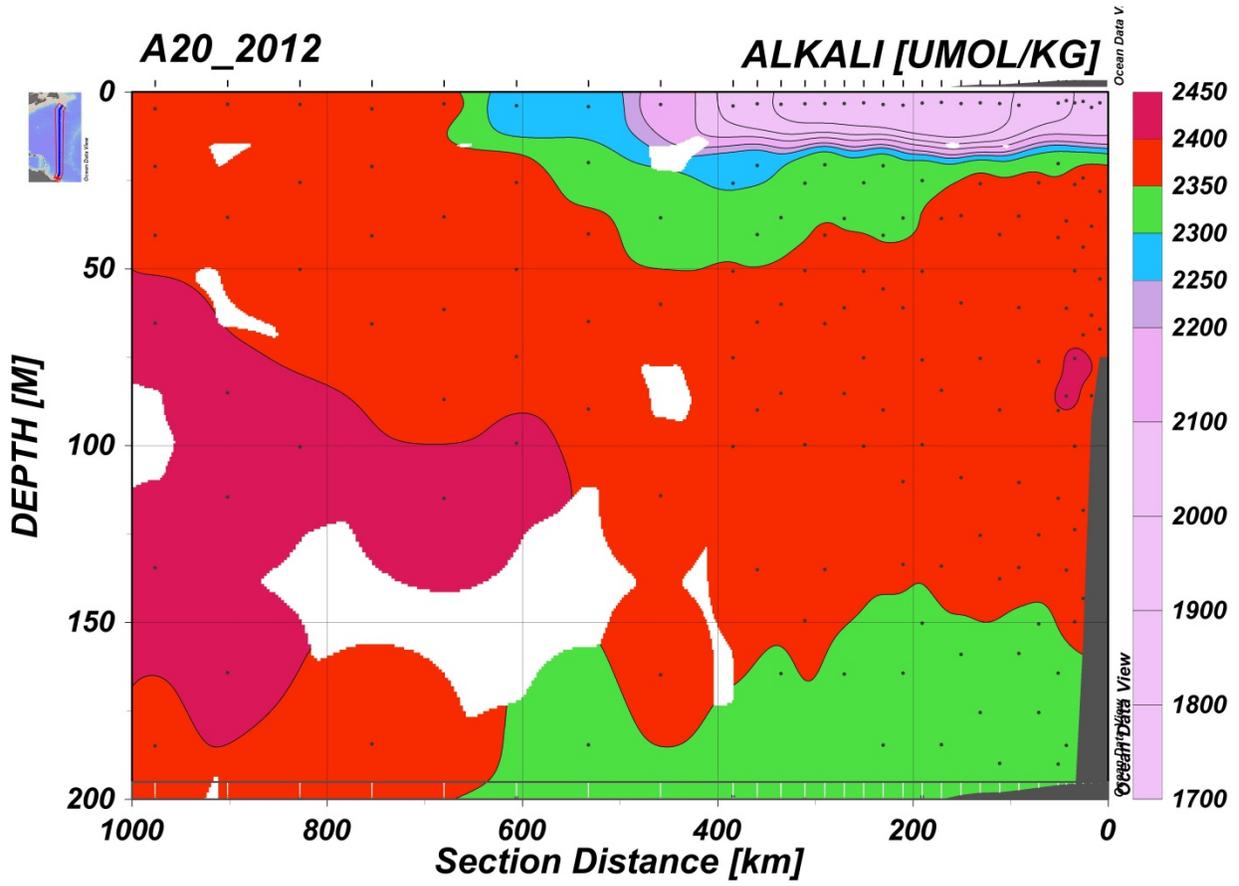


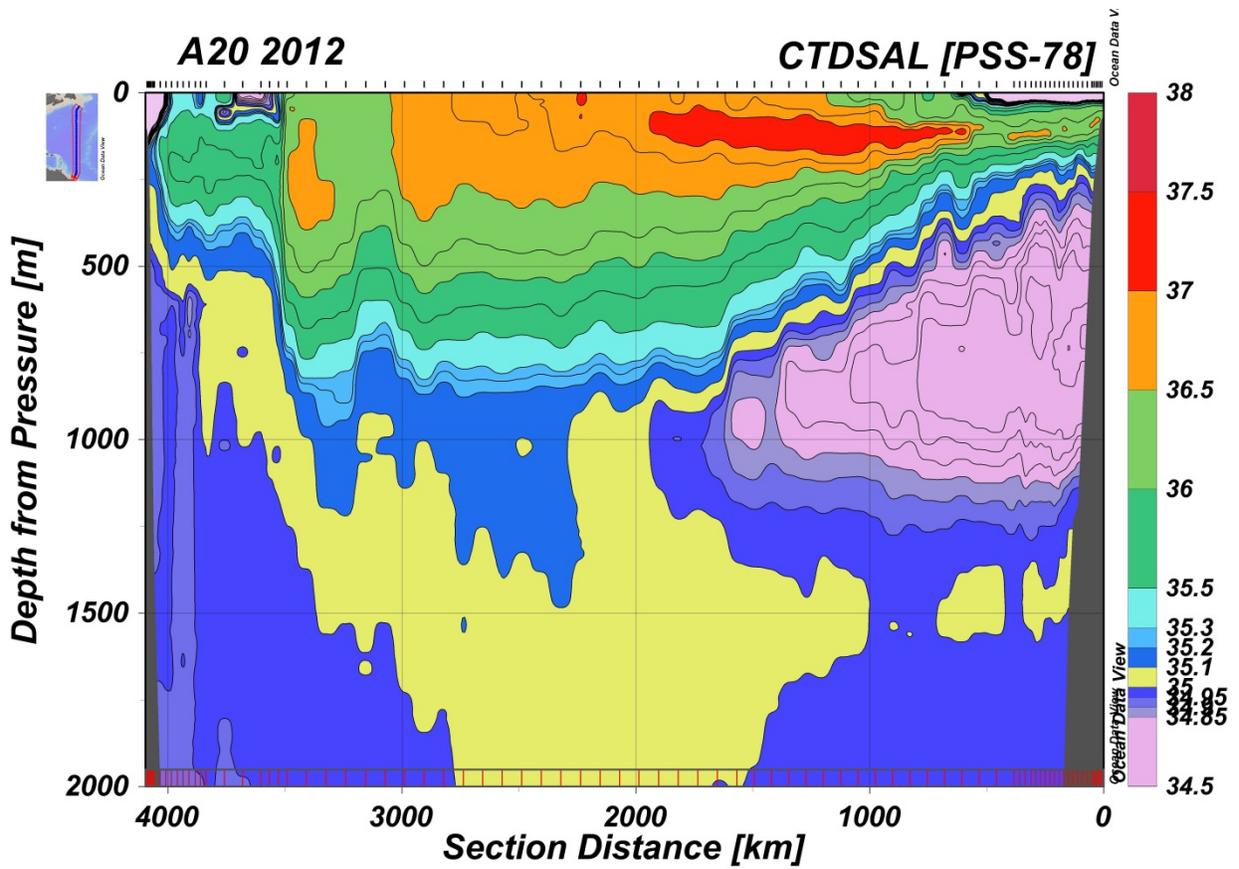
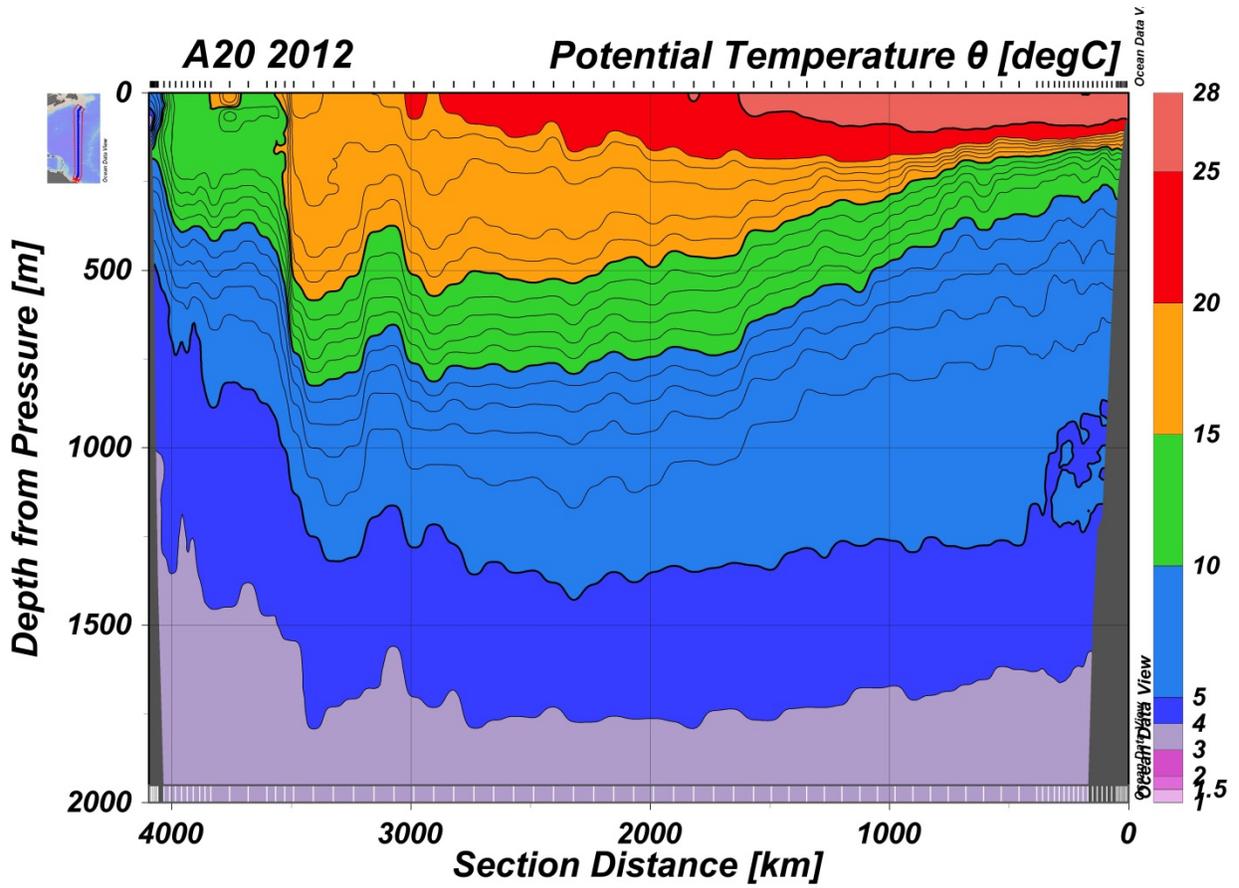


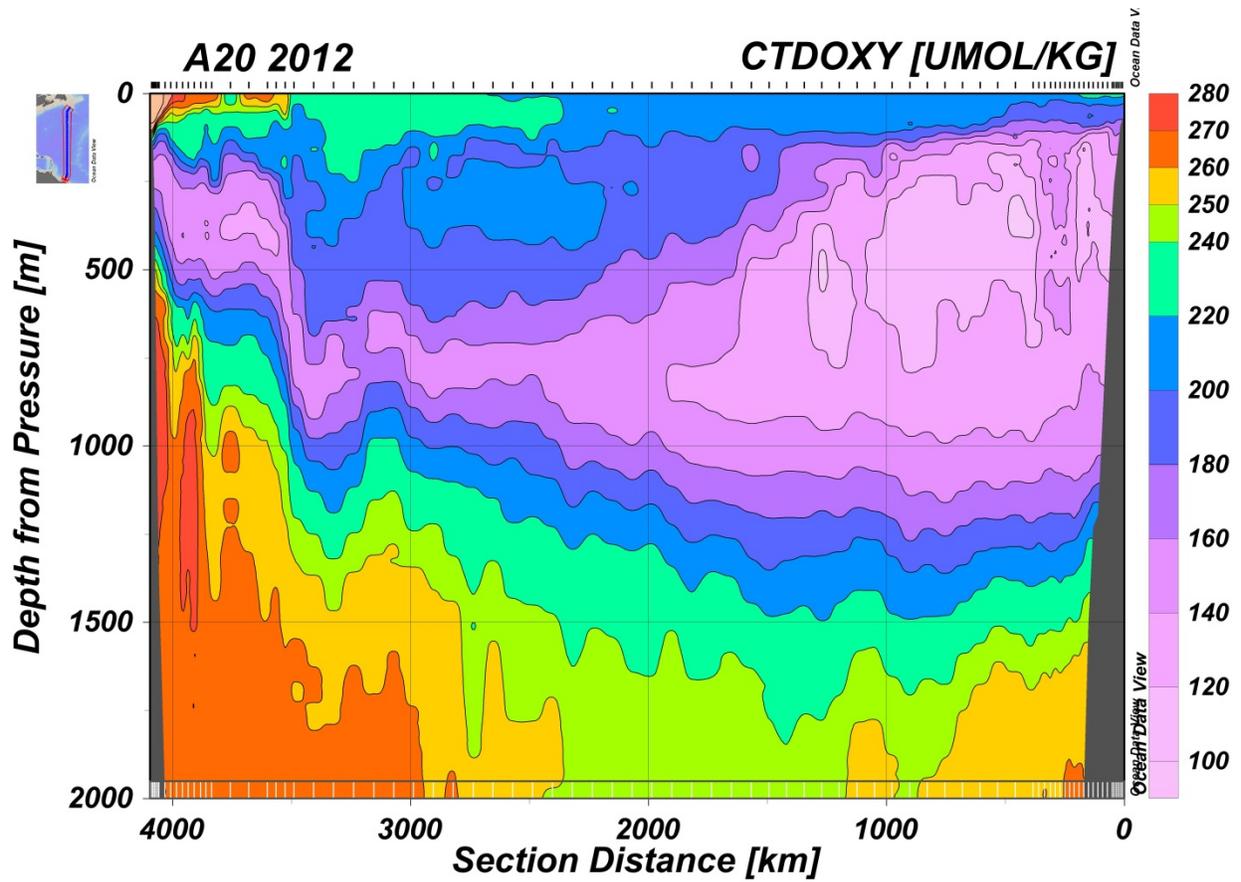
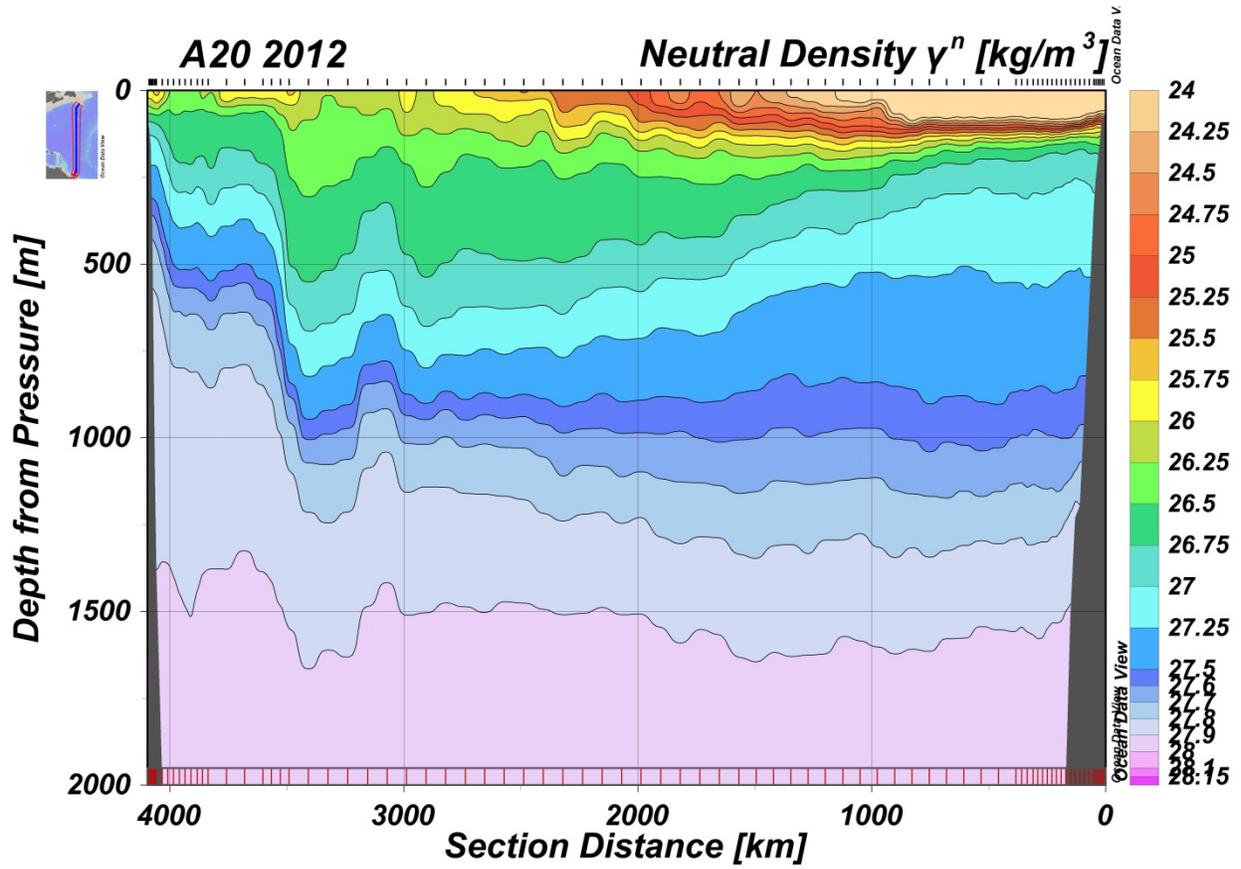


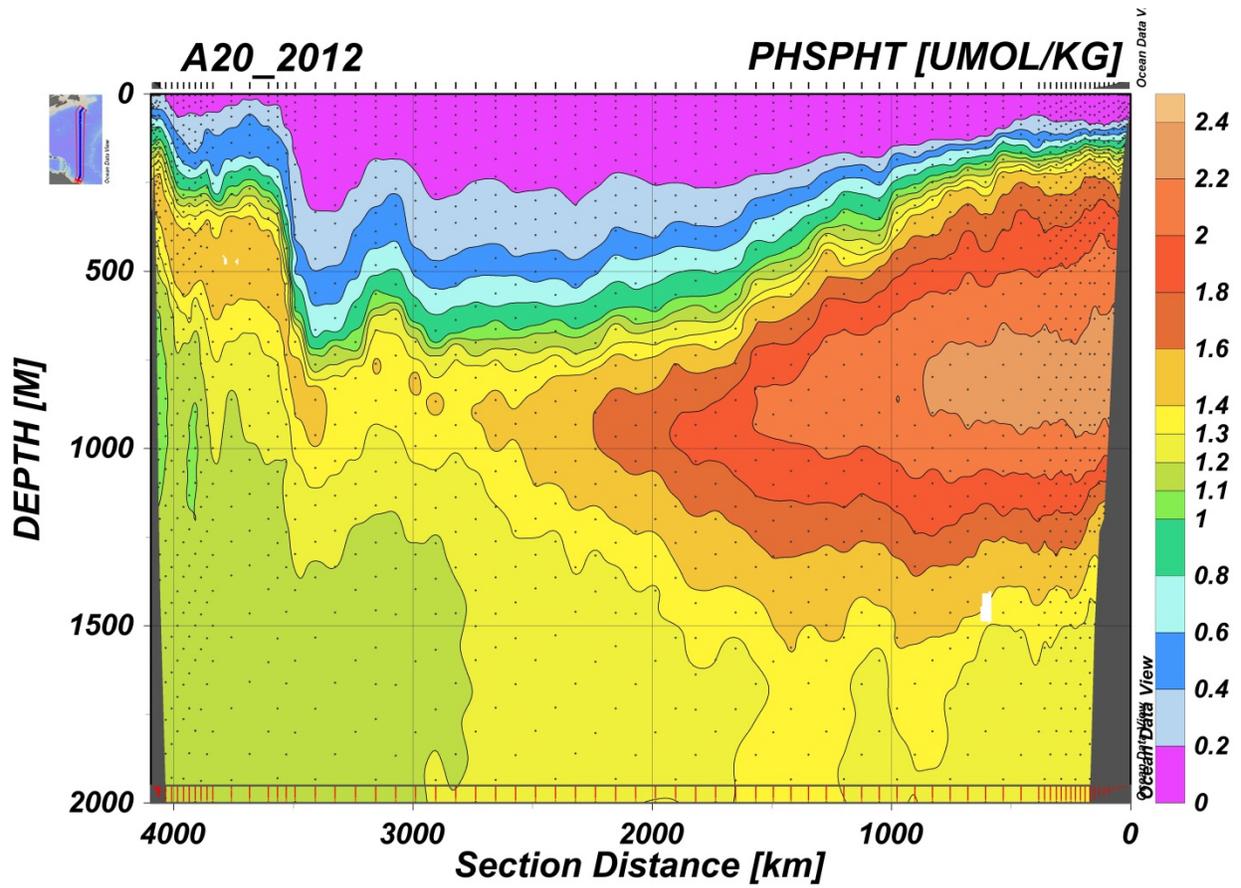
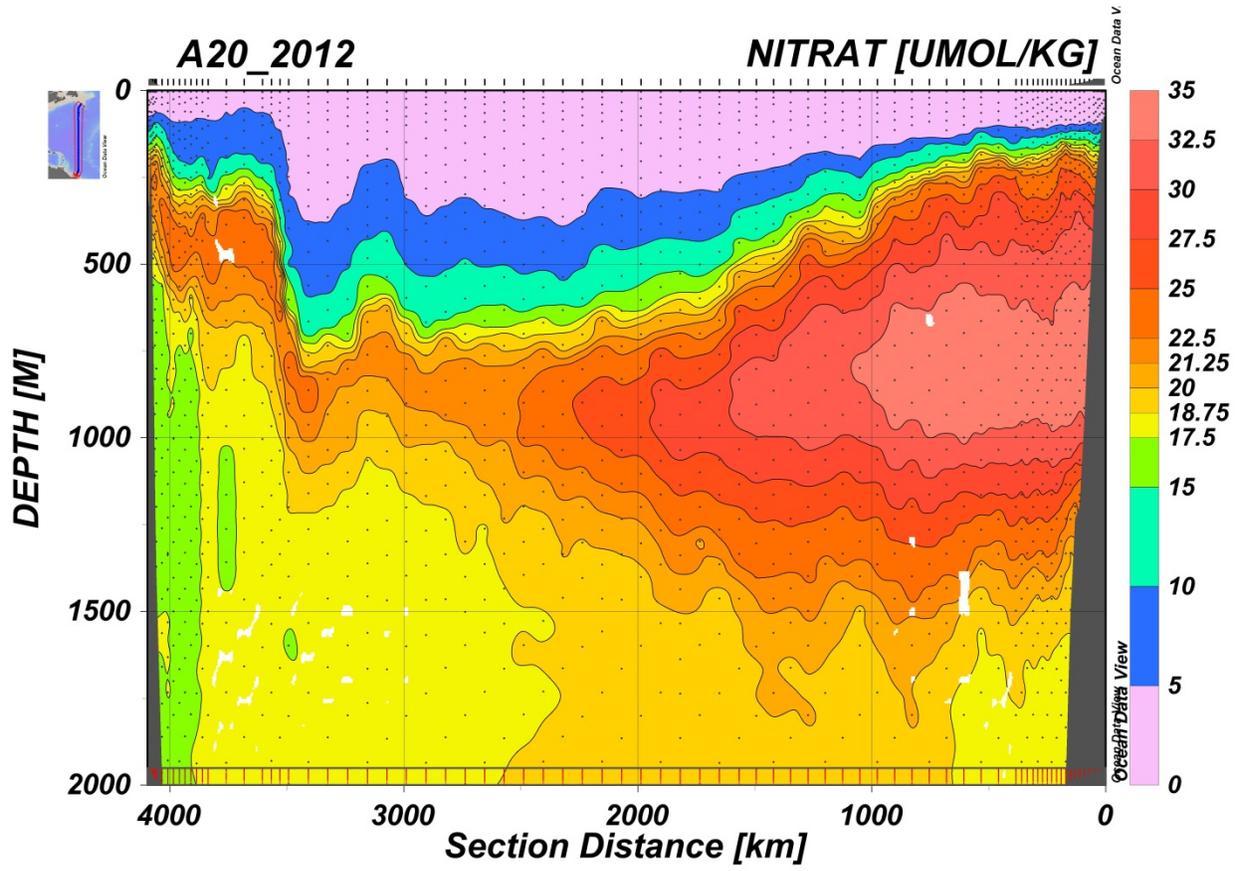


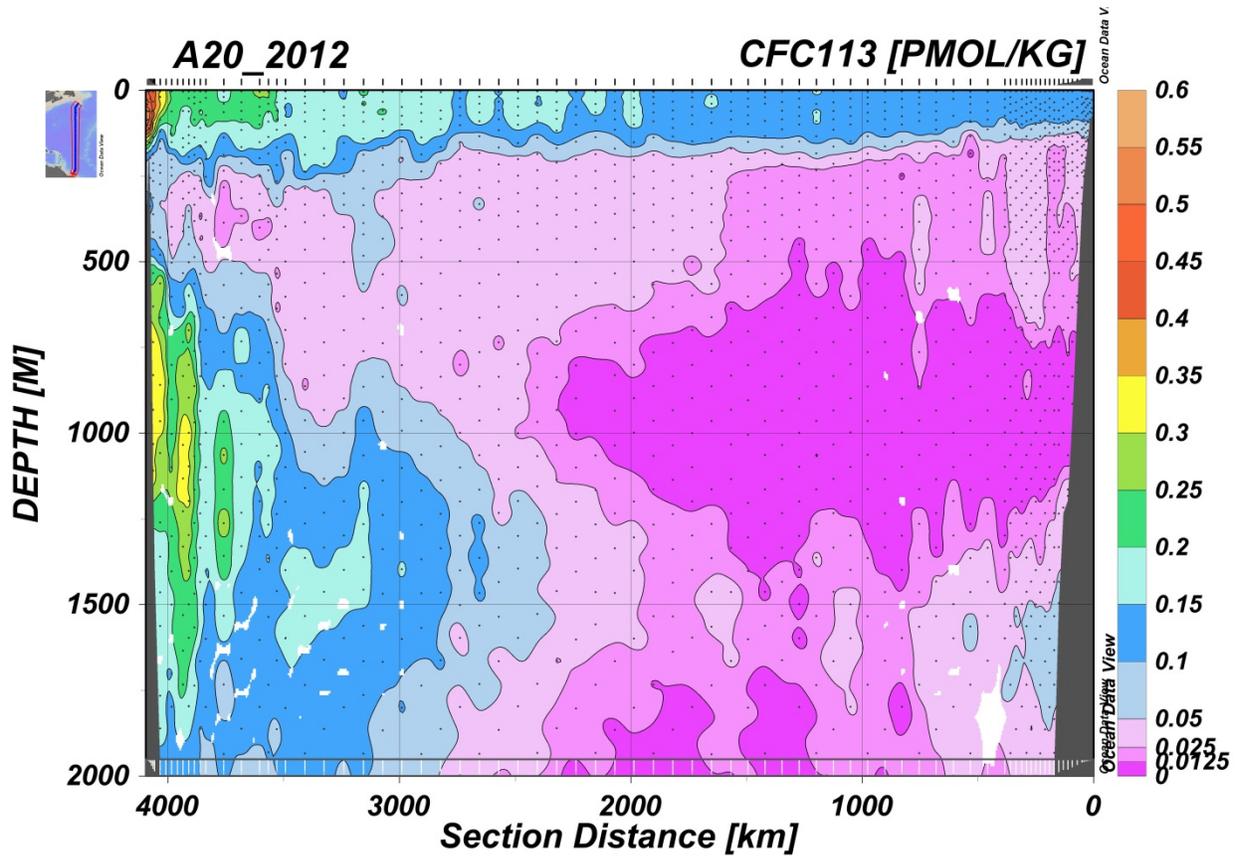
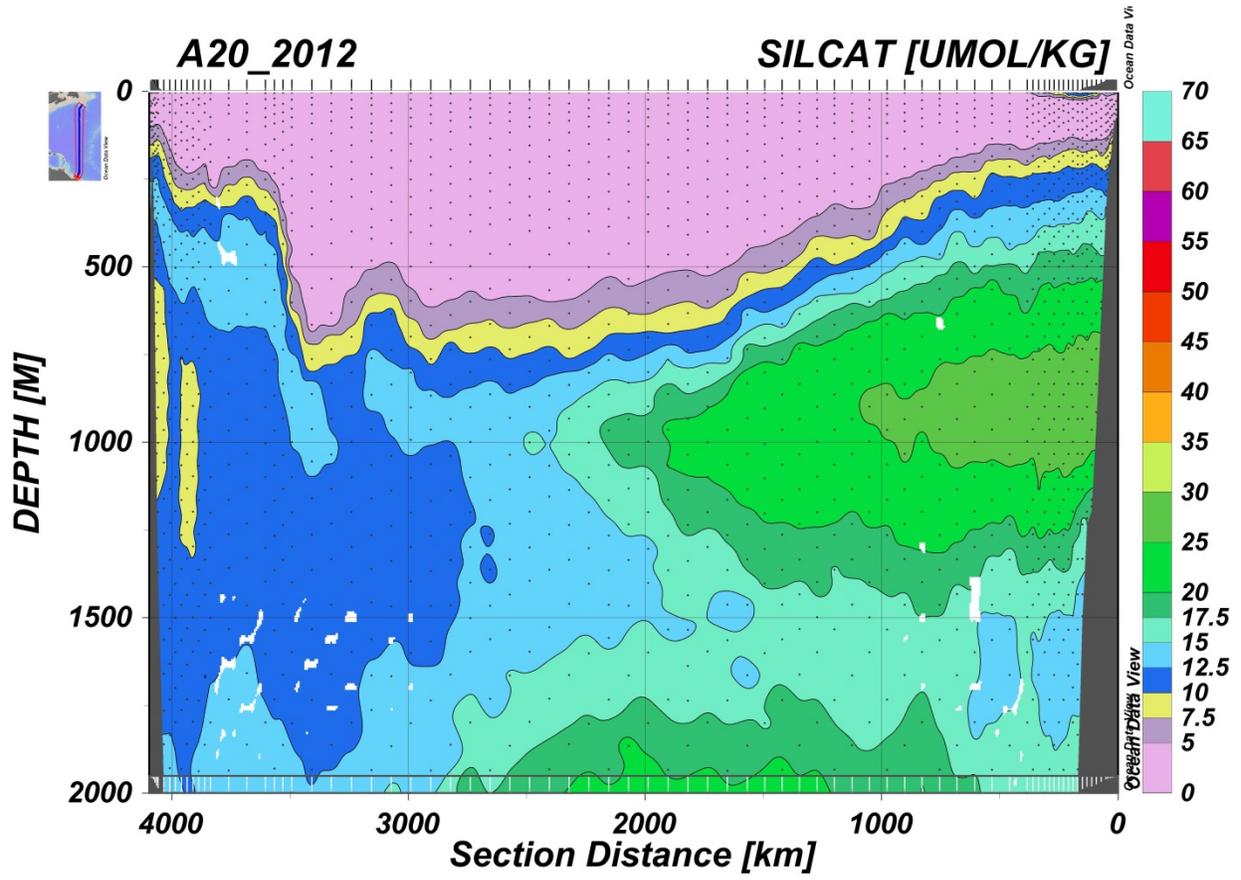


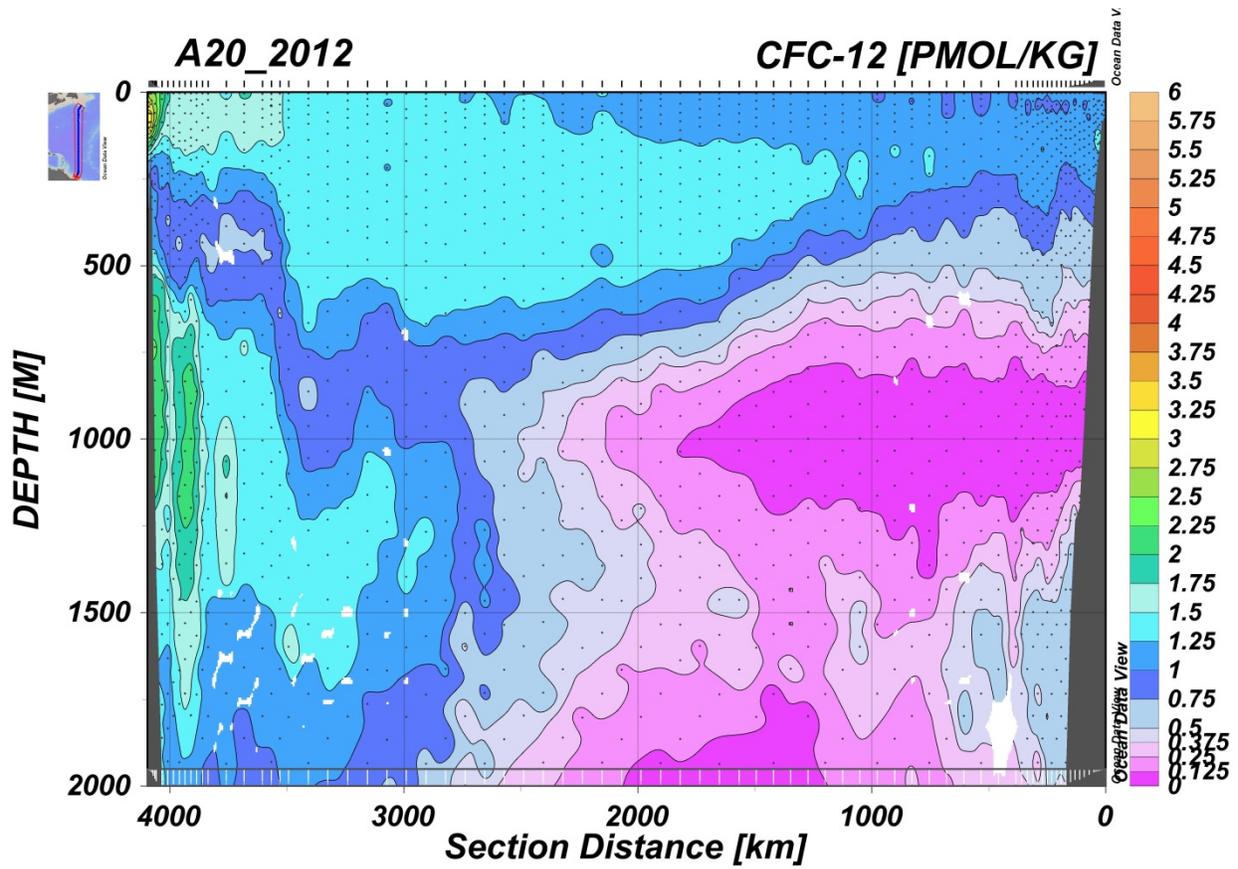
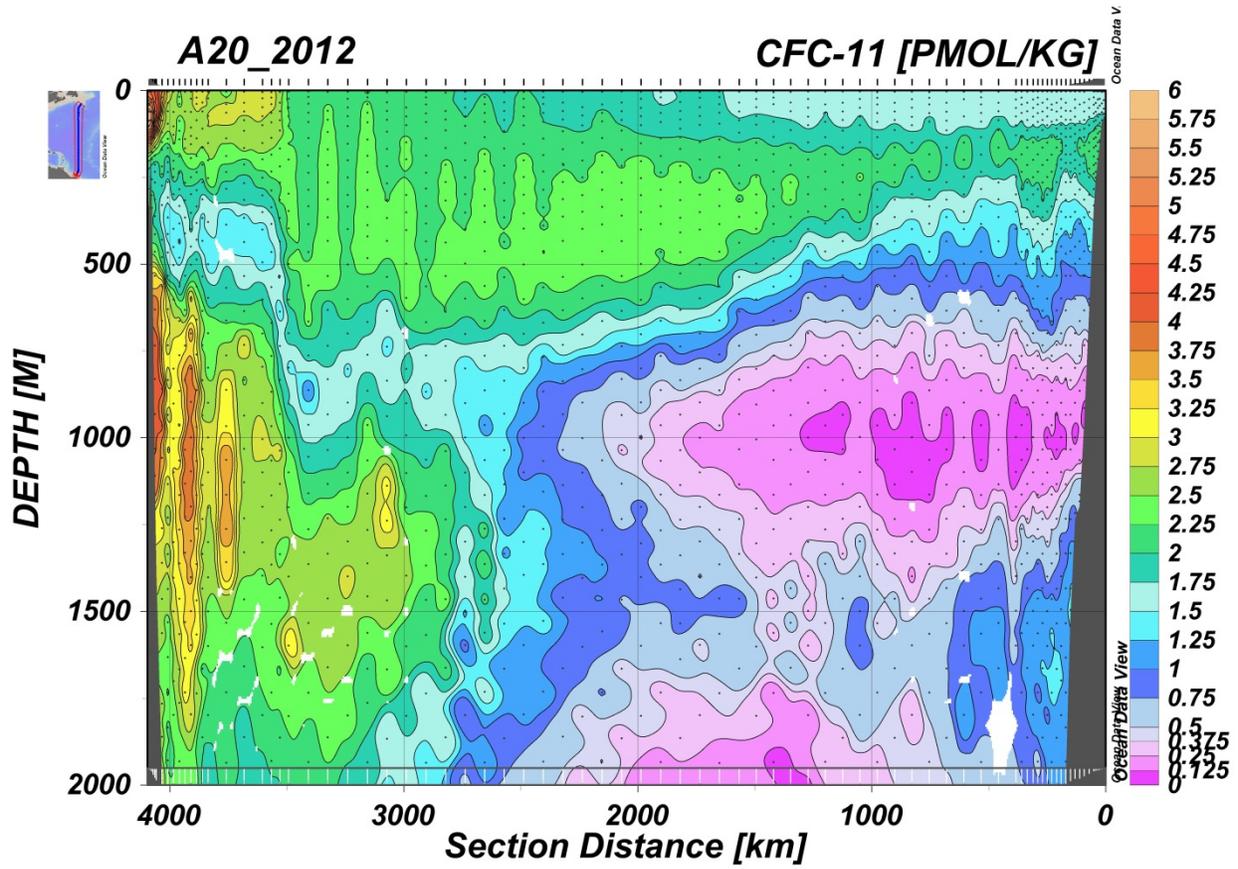


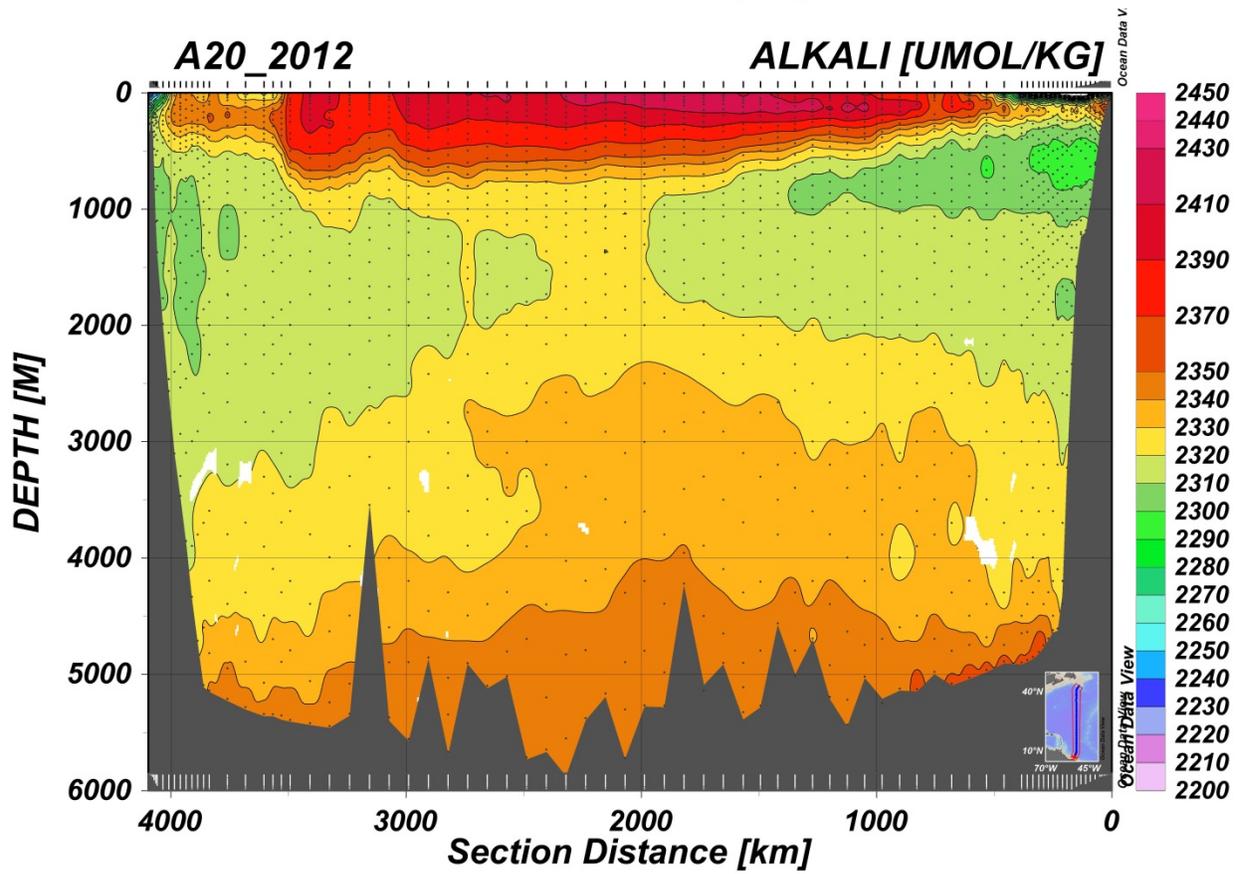
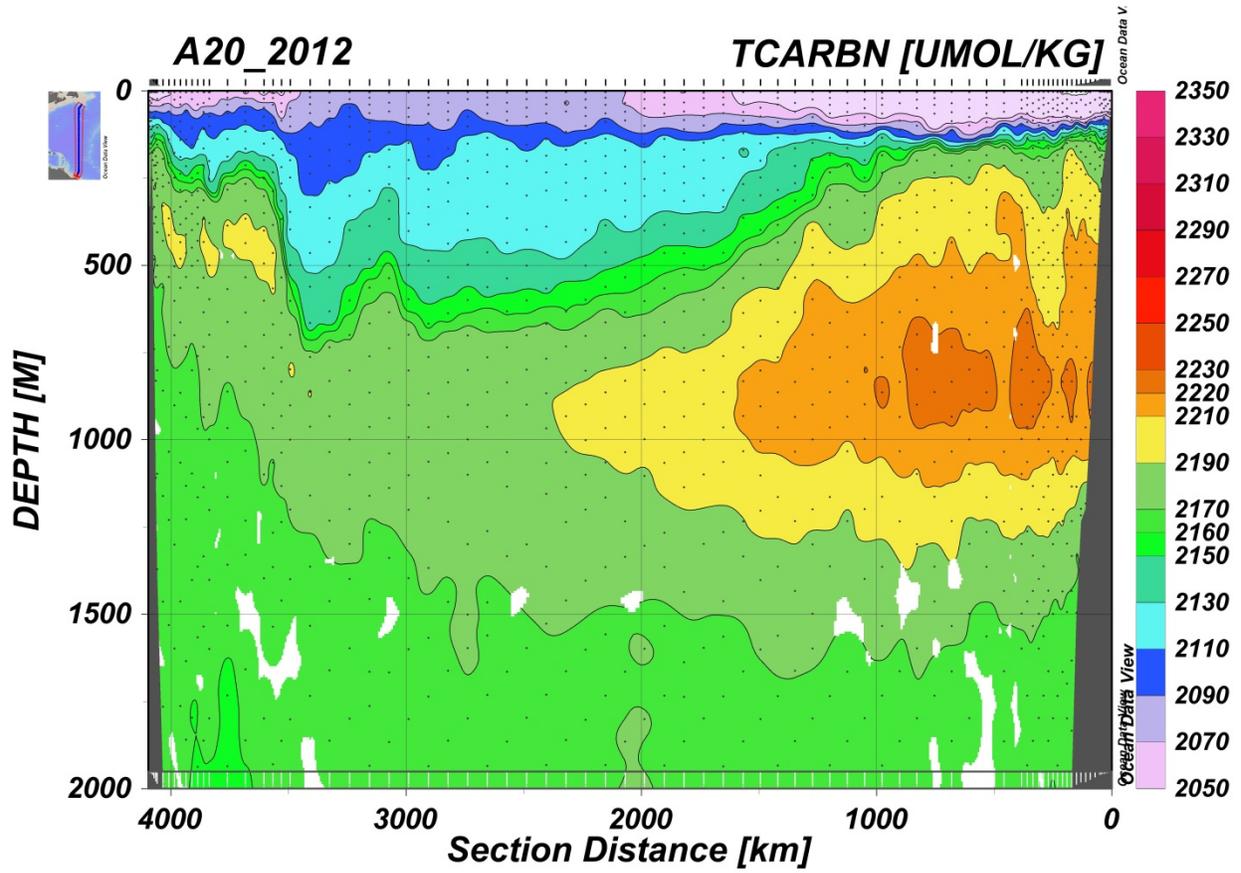


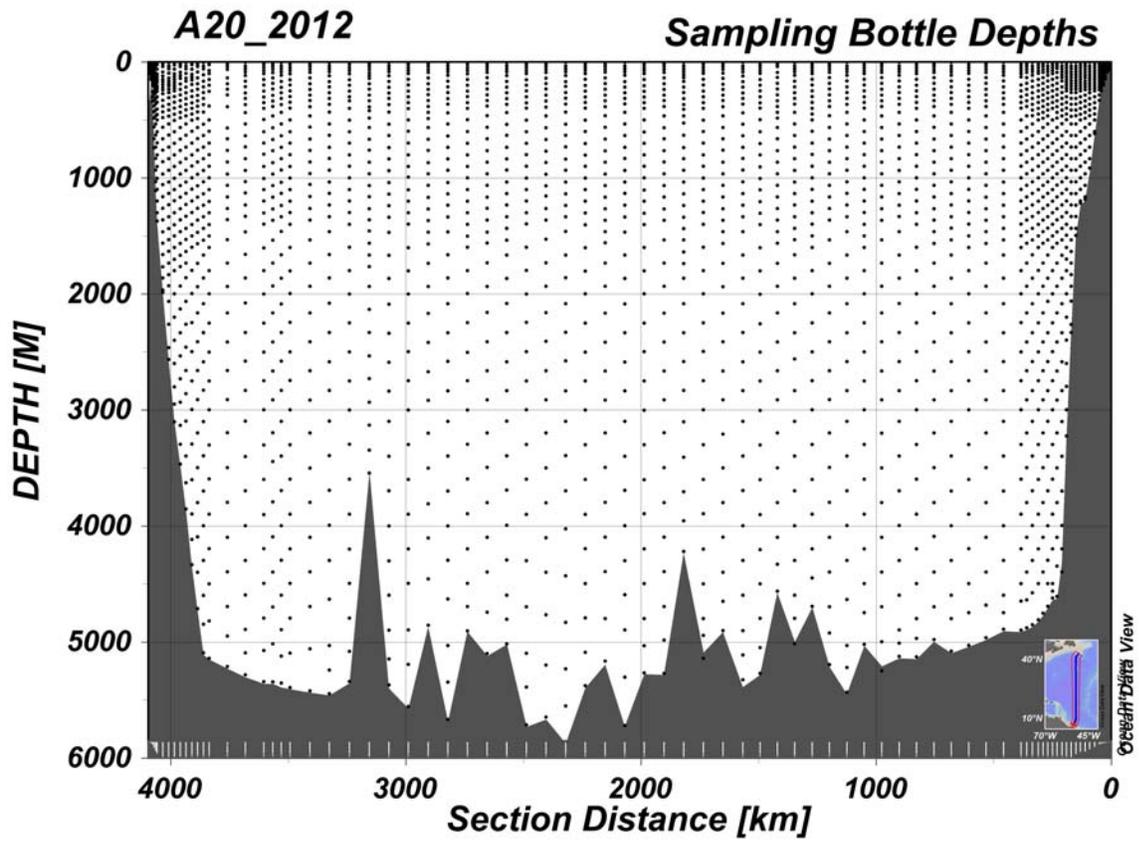
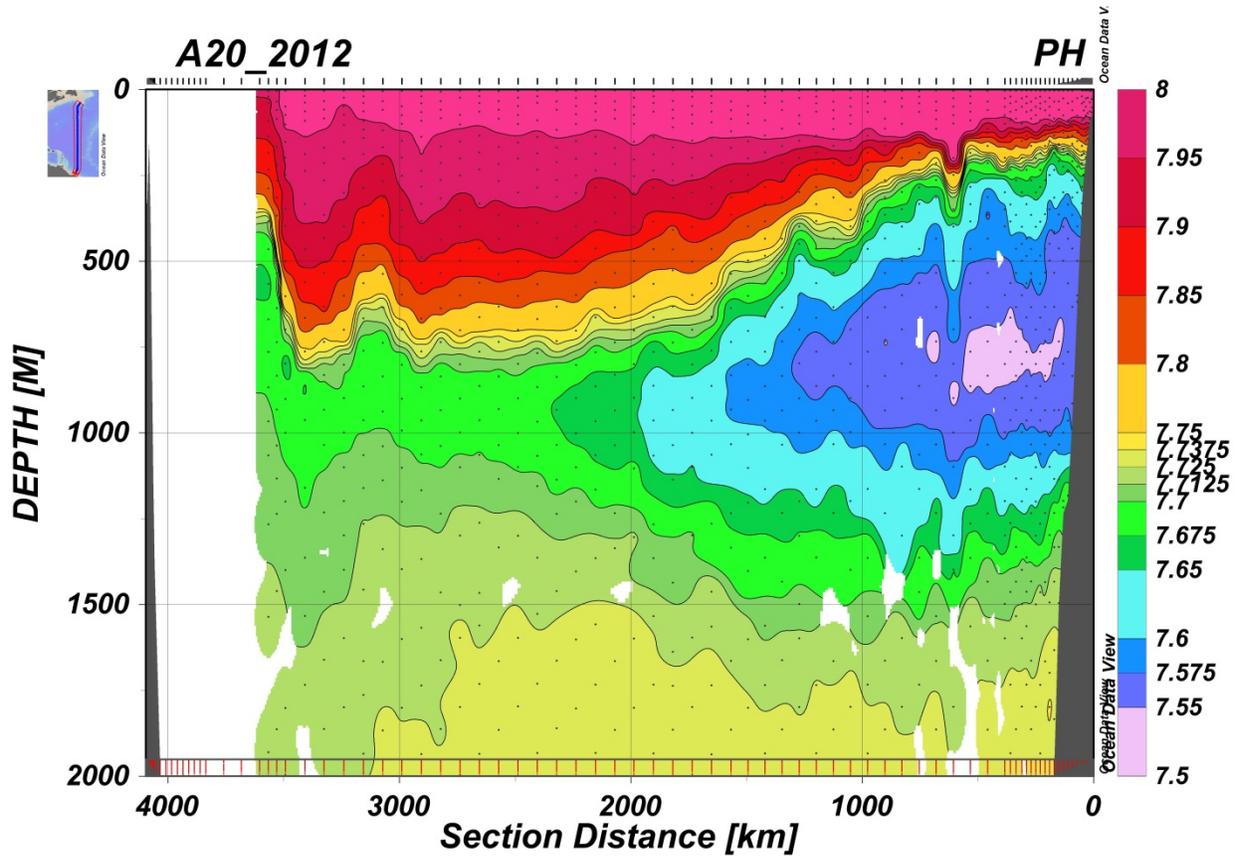












A20 (2012) LADCP cruise report (05/12/2012)

=====

Chief Scientist: *Michael McCartney*

Ship: *R/V Atlantis Cruise AT20*

Dates: *04/18/2012 - 05/15/2012*

Ports: *Bridgetown, Barbados to Woods Hole, Massachusetts, USA*

ADCP/LADCP PI: *Eric Firing, University of Hawaii*

LADCP operator: *Lora Van Uffelen*

Alternate LADCP Data Collector: *Stefan Gary*

A University of Hawaii (UH) system was used to collect Lowered Acoustic Doppler Current Profiler (LADCP) data. Preliminary processing was completed during the cruise using Lamont-Doherty Earth Observatory (LDEO) LADCP software.

LADCP System Setup

One 36-bottle CTD rosette was used during the whole cruise. On deck, the rosette was moved into and out of the sampling area atop a plywood platform mounted on two tracks. Initially installed on the starboard side of the ship, operations were switched to the port side of the ship after the first 36 casts to utilize a sheltered sampling hangar once the port-side winch was deemed adequate.

One WH150-kHz LADCP (serial number 16283), was secured to the rosette, facing downward, along with an oil-filled 58V rechargeable lead-acid battery pack. The installation on deck consisted of a Lenovo T41 laptop computer for data acquisition and a Lenovo R52 laptop for data processing, as well as an American Reliance Inc. (AMREL) battery charger/power supply. The LADCP heads and battery pack were mounted inside the 36-bottle rosette frame and connected using a custom designed, potted star cable assembly. The head was placed looking downward underneath the bottles at approximately the same height as the CTD instruments. The battery pack and LADCP were mounted on opposite sides of the rosette frame center to avoid unequal balancing.

The power supply and data transfer was handled independently from any CTD connections. While on deck, the instrument communication was set up by means of a network of RS-232 and USB cables, using LDEO LADCP software for data processing (using version IX_6beta) in Matlab [Thur08]. Additional scripts, authored by Prof. Eric Firing and the group at the University of Hawaii, were written for Python and used for instrument control and data transmission. The command file used in communication with the LADCP is shown below:

CR1

WM15

TC2

TB 00:00:02.20

TE 00:00:01.00

TP 00:00.00

WN40

WS0800

WT1600

WF1600

WV330

EZ0011101

EX00100

CF11101
LZ30,230
CLO

The LADCP and CTD acquisition computer clocks both used NTP to stay in sync with the ship clock and to assure that the absolute time recorded by the CTD and LADCP be the same.

LADCP Operation and Data Processing

Upon arrival at each station, the LADCP heads were switched on for data acquisition using the LADCP software. Communication between the computer and the instrument was then terminated, the power cable was disconnected, and all connections were sealed with dummy plugs. After each cast, the data and the power supply cable was rinsed with fresh water and reconnected to the computer and battery charger; the data acquisition was terminated; the battery was charged; and the data was downloaded using the LADCP software. It took about 45 minutes to download the data and approximately 60 minutes to fully recharge the battery.

Within 10 hours after each cast, the data were preliminarily processed, combining CTD, GPS, and shipboard ADCP data with the data from the LADCP, thus producing both shear and inverse solutions for the absolute velocities. The preliminary processing produced velocity profiles, rosette frame angular movements, and velocity ascii and Matlab files. Plots (velocity profiles from each cast and transects showing the values of U and V along the course of the cruise) were put on a website that was made available to all computers on the local network. Ascii files consisting of columns of Pressure, U, and V data were also produced and made available via the website.

Problems

Initial communication problems between the acquisition computer and the instrument were resolved during a test/training cast on deck prior to the first cast at station 001_01. The problem was resolved by replacing the USB-to-serial cable with 2-port FTDI USB-to serial connector and using /dev/ttyUSB1 instead of /dev/ttyUSB0. The change from "USB0" to "USB1" was also made in ladcp_wh150.py.

Intermittently received timeout errors during data download. All data was subsequently downloaded successfully.

Battery was not fully charged at outset of cruise, and did not fully charge for the first 9 stations, which were shallow and close together, but this never presented a problem in data acquisition. After this time, there was sufficient time for the battery to fully charge between stations. Battery usage was routinely monitored using plot_PTCV.py. The battery was vented every few days to ensure that the gas bubble did not stretch the membrane on the battery.

The LADCP was repositioned on the rosette, prior to Station 45 as it appeared to have gradually slid downward from its initial position. It was raised approximately 6cm, to ensure that the heads would not come in contact with the plywood platform that the rosette rested upon on deck.

Preliminary results

Data was successfully collected on all 83 stations sampled during the cruise.

The latitude-depth section measured at stations 1-83 of zonal (U) and meridional (V) velocity is shown in the attached file (U_V_depth_lat_section_LDEO.ps). A few prominent features are:

* The Gulf Stream, clearly evident around approximately 38-39degN (Stations 62-64), extending to full ocean depth, with a maximum eastward-flowing current of almost 98 cm/s.

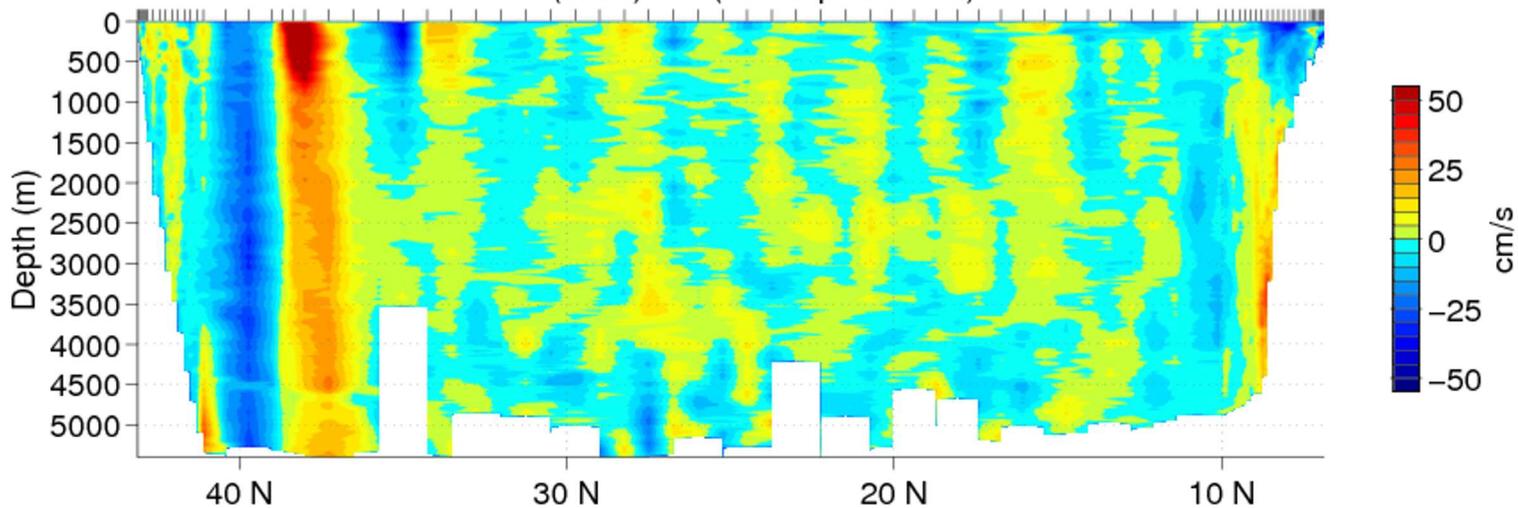
* An eddy in the upper ~1000m from approximately 33-35degN (Stations 56-58).

* Suggestion of a deep western boundary current off the shelf around ~8-9degN (Stations 13-16).

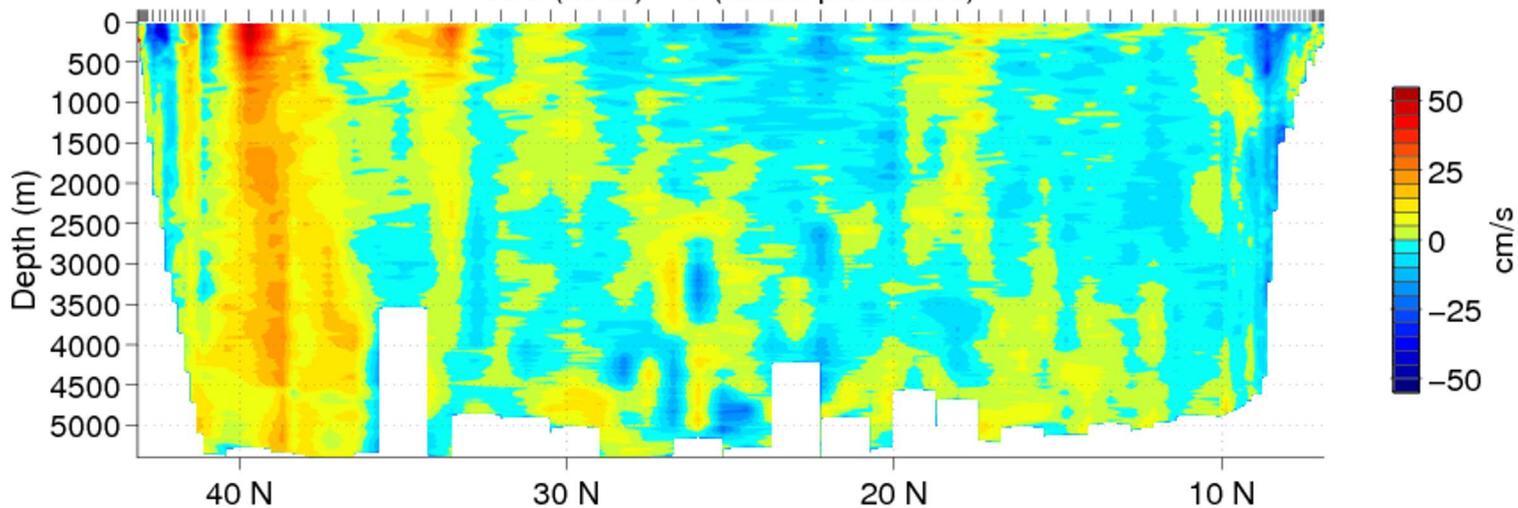
References

* Thurnherr, A. M., *How To Process LADCP Data With the LDEO Software (last updated for version IX.5)* July 9, 2008.

A20 (2012) – U (LDEO processed)



A20 (2012) – V (LDEO processed)



Shipboard Acoustic Doppler Current Profiler

CLIVAR/CO2 A20

R/V Atlantis Cruise AT20

2012/04/18-2012/05/15

Julia Hummon University of Hawaii

The R/V Atlantis has a permanently-mounted 75kHz acoustic Doppler current profiler ("ADCP", Teledyne R.D.Instruments) for measuring ocean velocity. During the cruise prior to A22, an additional higher frequency ADCP (300kHz Workhorse) was installed, and remained on the ship for the A22/A20 CLIVAR cruises.

Specialized software developed at the University of Hawaii has been installed on this ship for the purpose of ADCP acquisition, processing, and figure generation during each cruise. The acquisition system ("UHDAS", University of Hawaii Data Acquisition System) is an Open Sources suite, written in C and Python. UHDAS acquires data from the ADCPs, gyro heading (for reliability), Phins heading (for increased accuracy), and GPS positions from various sensors. An additional Phins is also logged.

Single-ping data are converted from beam to earth coordinates using known transducer angles and gyro heading, and are corrected by the average phins-gyro difference over the duration of the averaging interval.

Groups of single-ping ocean velocity estimates must be edited averaged to decrease measurement noise. These groups commonly comprise 5 minutes) or 2 minutes for WH300). Bad pings must be removed prior to averaging. UHDAS uses a CODAS (Common Oceanographic Data Access System) database for storage and retrieval of averaged data. Various post-processing steps can be administered to the database after a cruise is over, but the at-sea data should be acceptable for preliminary work.

UHDAS provides access to regularly-updated figures and data over the ship's network via samba share and nfs export, as well as through the web interface. The web site has regularly-updated figures showing the last 5-minute ocean velocity profile with signal return strength, and hourly contour and vector plots of the last 3 days of ocean velocity.

The LADCP data processing uses recent shipboard velocities as one of the constraints.

Shipboard Doppler sonar work on this cruise

During the cruise, the Ocean Surveyor was run in "interleaved" pinging mode, where it can sample in broadband mode (higher resolution, reduced range) and in narrowband mode (coarser resolution, increased depth range) with alternating pings. These are processed into two separate datasets.

Data quality

Typical ADCP data quality issues are

- - clock errors
- - heading correction

- data loss or compromise:

- - data loss due to bad weather, bubbles, etc
- - data compromise due to deep scattering layers
- - depth penetration

clock:

The ADCP computer was synced to the network time server during the cruise. This worked fine; times are in UTC; decimal days for processed ADCP data are zero-based, i.e. 2012/01/01 12:00:00 is 0.500000

heading:

Gyro headings were corrected using the Phins. Heading correction is critical to minimize cross-track errors induced by errors in heading. A one degree heading error results in a 10cm/s cross-track error in shipboard ADCP data if the ship is travelling at 12kts.

data loss or compromise:

ADCP system and data were monitored remotely during the cruise. Nothing was seen during the cruise that points to data loss or compromise. Additional bottom editing will probably be necessary in the water near Puerto Rico, as odd artifacts appeared at depth in the remote monitoring plots.

Overview

All in all, the instrument, ancillary devices, and acquisition system performed well.

References:

UHDAS+CODAS Documentation

http://currents.soest.hawaii.edu/docs/adcp_doc/index.html

6 Chlorofluorocarbon (CFC) and Sulfur Hexafluoride (SF6) Measurements

PI: *William Smethie, LDEO (bsmethie@ldeo.edu)*

Cruise Participants: *Eugene Gorman, LDEO*

Lucia Upchurch, The University of Texas at Austin

Samples for the analysis of dissolved CFC-11, CFC-12, CFC-113 and SF6 were collected from approximately 1200 of the Niskin water samples collected during the expedition. When taken, water samples for CFC analysis were the first samples drawn from the 10-liter bottles. Care was taken to coordinate the sampling of CFCs with other samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, dissolved oxygen, alkalinity and dissolved inorganic carbon samples were collected within several minutes of the initial opening of each bottle. To minimize contact with air, the CFC samples were collected from the Niskin bottle petcock using PVC tubing flushed of air bubbles and filled into a 500-ml glass bottle. The glass bottle was placed into a plastic overflow container and filled from the bottom. The overflow water filled the container to a depth greater than the height of the glass bottle. The stopper was held in the overflow container or briefly in the sample stream to be rinsed. When the overflow container was filled, it (and the glass bottle) were lowered to remove the PVC tubing and the glass bottle was stoppered under water. A plastic cap was snapped on to hold the stopper in place. Samples were analyzed within 12 hours of sample collection and the temperature of the water bath noted immediately prior to analysis.

For atmospheric sampling, a 200 cm³ gas-tight, glass syringe was used to collect samples from the bow of the ship. Samples were injected directly into a calibrated sample loop and then sent to the traps and then columns of the analytical instrumentation. Average atmospheric concentrations determined during the cruise were 241 parts per trillion (ppt) for CFC-11, 536 ppt for CFC-12, 77 ppt for CFC-113, and 7.5 ppt for SF6.

Concentrations of CFC-11, CFC-12, CFC-113, and SF6 in air samples, seawater and gas standards were measured by shipboard electron capture gas chromatography (EC-GC). Samples were introduced into the GC-EC via a dual purge and trap system. CFCs were purged from ~20 mL water samples while SF6 was purged from a larger ~350 mL volume using UHP nitrogen. Samples were purged using flows of approximately 60-80 mL min⁻¹ for CFCs and 80-90 mL min⁻¹ for SF6. Purge gas was passed through a magnesium perchlorate dryer prior to reaching traps constructed from ~3 inches of 1/16 inch stainless steel tubing containing either Carbograph 1AC (for CFCs) or Carboxen 1000 (for SF6). Traps were held at approximately -80 C (CFCs) and -60 C (SF6) using a liquid CO₂ cooling (Scientific Instrument Services, Inc.) for the 5 minute duration of trapping. Following collection, the traps are isolated and flash-heated by direct resistance to ~120 C (for CFCs) and ~150 C (for SF6) to desorb collected chemicals for further separation and detection.

Separation of SF₆ was accomplished using a both a packed precolumn (~3' long) and analytical column (~6' long) containing 80/100 mesh molecular sieve 5A and held at 100 C. The precolumn was switched out and backflushed after 2 minutes to prevent N₂O from entering the main column and prevent background chemicals from increasing the detector baseline. CFCs were separated using a series of three packed columns: a Poracil B precolumn (~ 4 feet), a Carbograph 1AC analytical column (~ 6 feet), and a short column (~5 cm) containing 80/100 mesh molecular sieve 5A. Following release from the trap, the short column containing molecular sieves was switched out of the system and backflushed immediately following exit of CFC 12 (~1.8 min) to remove potential interference of nearby SF₆ and N₂O. The precolumn was switched out after 2 min and backflushed following exit of CFC-113. This prevented buildup of chemicals on the column that could increase the system background.

The analytical system was calibrated frequently using standard gases of known CFC and SF₆ compositions. Gas sample loops of known volume were thoroughly flushed with standard gas and injected into the system. Loops equilibrated with atmosphere and the temperature and pressure was recorded so that the amount of gas injected could be calculated. The procedures used to transfer the standard gas to the trap, precolumns, main chromatographic columns and EC detector were similar to those used for analyzing water samples. Two different sizes of gas sample loops were used. Multiple injections of these loop volumes could be made to allow the system to be calibrated over a relatively wide range of concentrations. Air samples and system blanks (injections of loops of CFC-free gas) were injected and analyzed in a similar manner. The typical analysis time for samples was ~11.0 min.

Concentrations of the CFCs in air, seawater samples and gas standards are reported relative to the SIO98 calibration scale (Cunnold, et. al., 2000). Concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in the parts per trillion (ppt) range. Dissolved CFC concentrations are given in units of picomoles per kilogram seawater (pmol kg⁻¹), and SF₆ in femtomoles per kilogram seawater (fmol kg⁻¹). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting multiple sample loops of gas from a working standard (cylinder 35060 for CFC-11: 591.03 ppt, CFC-12: 443.6 ppt, CFC 113: 249.6 and SF₆: 2.6 ppt) into the analytical instrument. Full-range calibration curves were run three times during the cruise. Single injections of a fixed volume of standard gas at one atmosphere were run much more frequently to monitor short-term changes in detector sensitivity. The SF₆ peak was often on a small bump on the baseline, resulting in a large dependence of the peak area on the choice of endpoints for integration. Estimated accuracy is +/-2%. Precision for CFC-12, CFC-11, CFC-113 and SF₆ was less than 1%. Estimated limit of detection is 1 fmol kg⁻¹ for CFC-11, 3 fmol kg⁻¹ for CFC-12 and 0.05 fmol kg⁻¹ for SF₆.

The efficiency of the purging process was evaluated periodically by re-stripping water samples and comparing the residual concentrations to initial values.

Analytical Difficulties. Analytical difficulties were minimal over the course of the cruise. Once the stripping chamber was overfilled due to user error, causing the loss of several samples earlier on. CFC-12 was often not trapped as the liquid CO₂ supply from a given tank ran out and the cooling traps did not reach the required temperature to hold this chemical effectively. Midway to the end, the CFC stripping chamber would occasionally become clogged and not fill or drain properly causing the loss of a few CFC samples. A rinse with fresh water would restore the valve to proper working order.

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CFC-11, CFC-12, CFC-113, CCl₄ and SF₆

PI: Rana Fine, University of Miami, RSMAS

Analysts: David Cooper and Rebecca Rolph

Sample Collection

All samples were collected from depth using 10.4 liter Niskin bottles. None of the Niskin bottles used showed a CFC contamination throughout the cruise. All bottles in use remained inside the CTD hanger between casts.

Sampling was conducted first at each station, according to WOCE protocol. This avoids contamination by air introduced at the top of the Niskin bottle as water was being removed. A water sample was collected from the Niskin bottle petcock using viton tubing to fill a 300 ml BOD bottle. The viton tubing was flushed of air bubbles. The BOD bottle was placed into a plastic overflow container. Water was allowed to fill BOD bottle from the bottom into the overflow container. The stopper was held in the overflow container to be rinsed. Once water started to flow out of the overflow container the overflow container/BOD bottle was moved down so the viton tubing came out and the bottle was stoppered under water while still in the overflow container. A plastic cap was snapped on to hold the stopper in place. One duplicate sample was taken on most stations from random Niskin bottles. Air samples, pumped into the system using an Air Cadet pump from a Dekoron air intake hose mounted high on the foremast were run when time permitted. Air measurements are used as a check on accuracy.

Equipment and technique

CFC-11, CFC-12, CFC-113, CCl₄ and SF₆ were measured on 39 stations (station 2 and odd stations 1 through 75) for a total of 1212 samples. Even stations and odd stations 81 and 83 were sampled and analyzed by the LDEO CFC group. Analyses were performed on a gas chromatograph (GC) equipped with an electron capture detector (ECD). Samples were introduced into the GC-EDC via a purge and dual trap system. 202 ml water samples were purged with nitrogen and the compounds of interest were trapped on a main Porapak N/Carboxen 1000 trap held at ~ -15°C with a Vortec Tube cooler. After the sample had been purged and trapped for 6 minutes at 250ml/min flow, the gas stream was stripped of any water vapor via a magnesium perchlorate trap prior to transfer to the main trap. The main trap was isolated and heated by direct resistance to 150°C. The desorbed contents of the main trap were back-flushed and transferred, with helium gas, over a short period of time, to a small volume focus trap in order to improve chromatographic peak shape. The focus trap was Porapak N and is held at ~ -15°C with a Vortec Tube cooler. The focus trap was flash heated by direct resistance to 180°C to release the compounds of interest onto the analytical pre-columns. The first precolumn was a 5 cm length of 1/16" tubing packed with 80/100 mesh molecular sieve 5A. This column was used to hold back N₂O and keep it from entering the main column. The second pre-column was the first 5 meters of a 60 m Gaspro capillary column with the main column consisting of the

remaining 55 meters. The analytical pre-columns were held in-line with the main analytical column for the first 35 seconds of the chromatographic run. After 35 seconds, all of the compounds of interest were on the main column and the pre-column was switched out of line and back-flushed with a relatively high flow of nitrogen gas. This prevented later eluting compounds from building up on the analytical column, eventually eluting and causing the detector baseline signal to increase.

The samples were stored at room temperature and analyzed within 12 hours of collection, with the exception of stations 73 and 75. These were analyzed approximately 24 hours after collection. Every 10 to 18 measurements were followed by a purge blank and a standard. The surface sample was held after measurement and was sent through the process in order to “restrip” it to determine the efficiency of the purging process.

Calibration

A gas phase standard, 35060, was used for calibration. The concentrations of the compounds in this standard are reported on the SIO 2005 absolute calibration scale. 5 calibration curves were run over the course of the cruise. Estimated accuracy is +/- 2%. Precision for CFC-12, CFC-11, and SF₆ was less than 2%. Estimated limit of detection is 1 fmol/kg for CFC-11 and CCl₄, 3 fmol/kg for CFC-12 and CFC-113, and 0.4 fmol/kg for SF₆

Results/Data

The preliminary data submitted to the onboard database are labeled “good” for F12 & F11 throughout the cruise and “good” for F113 & CCl₄ on stations 1-61. SF₆ data throughout the cruise and for F113 & CCl₄ on stations 63-71 are labeled “questionable” due to poor precision. No SF₆, F113 or CCl₄ data were submitted after cast 71 due to analytical problems. Final data analysis, quality control and inter-system calibration will be performed by the project PIs at a later time.

Helium and Tritium

PI: William Jenkins

Cruise Participant: Zoe Sandwith

Helium and Tritium samples were collected roughly once per day at 17 stations during A20.

Helium Sampling

24 helium samples were drawn at 14 of the stations and 8-16 niskins were sampled at 3 of the shallower stations. Although not all 36 niskins were sampled, depths were chosen to obtain an accurate cross-section of the entire water column. A duplicate was taken at every other station. Helium samples were taken in custom-made stainless steel cylinders and sealed with rotating plug valves at either end. The sample cylinders were leak-checked prior to the cruise.

Samples were drawn using tygon tubing connected to the niskin bottle at one end and the cylinder at the other. Cylinders are thumped with a bat while being flushed with water from the niskin to remove bubbles from the sample. After flushing roughly 1 liter of water through them, the plug valves are closed. Due to the nature of the o-ring seals on the sample vessels, they must be extracted within 24 hours.

Eight samples at a time were extracted using our 'At Sea Extraction' line in the Bio-Analytical Lab. The stainless steel sample cylinders are attached to a vacuum manifold and pumped down to less than $2e-7$ torr using a diffusion pump for a minimum of 1 hour to check for leaks. The sections are then isolated from the vacuum manifold and introduced to reservoir cans which are heated to $>80C$ for roughly 10 minutes. Glass bulbs are attached to the sections and immersed in ice water during the extraction process. After 10 minutes of extraction, each bulb is flame sealed and packed for shipment back to WHOI. The extraction cans and sections are cleaned with distilled water and isopropanol, and then dried between each extraction. Prior to the cruise, all vacuum components were cleaned, serviced and checked for leaks. The glass bulbs are baked to $640C$ for 6 hours and cooled slowly in an oven receiving a steady flow of nitrogen.

368 helium samples were taken, which includes 8 duplicate samples. 3 were lost due to glass cracking during the flame-sealing, and 2 were lost due to a leak developing a weld of a sample chamber after the sample was taken. Therefore, 363 helium samples are being sent to WHOI for analysis on a mass spectrometer.

No major problems were encountered during the cruise for the helium at-sea extractions. The temperature in the lab was slightly higher than is preferred for the operation of the -130°C cold trap, and the water cooled diffusion pump, resulting in some strain on the equipment, but this did not appear to affect the extraction process. The temperature improved with our transit northwards, and by the last week of sampling, the room temperature was down into a more desirable range.

Tritium Sampling

Tritium samples were drawn from the same stations and bottles as those sampled for helium, with the exception of the helium duplicates. A duplicate tritium was taken on stations where no helium duplicate was being taken. Tritium samples were taken using tygon tubing to fill 1 liter glass jugs. The jugs were baked in an oven, backfilled with argon, and the caps were taped shut prior to the cruise. While filling, the jugs are placed on the deck and filled to about 2 inches from the top of the bottle, being careful not to spill the argon. Caps were replaced and taped shut with electrical tape before being packed for shipment back to WHOI.

369 tritium samples were taken, which includes 9 duplicates. Tritium samples will be degassed in the lab at WHOI and stored for a minimum of 6 months before mass spectrometer analysis.

No issues were encountered while taking tritium samples.

Dissolved Inorganic Carbon (DIC)

PI: *Richard Feely, NOAA/PMEL*

Rik Wanninkhof, NOAA/AOML

Cruise Participants: *Cynthia Peacock, NOAA/PMEL/UW/JISAO*

Bob Castle, NOAA/AOML

The DIC analytical equipment (DICE) was designed based upon the original SOMMA systems (Johnson, 1985, '87, '92, '93). These new systems have improved on the original design by use of more modern National Instruments electronics and other available technology. These 2 DICE systems (PMEL-1 and PMEL-2) were set up in a seagoing container modified for use as a shipboard laboratory on the aft working deck of the *R/V Atlantis*. In the coulometric analysis of DIC, all carbonate species are converted to CO₂ (gas) by addition of excess hydrogen to the seawater sample. The evolved CO₂ gas is carried into the titration cell of the coulometer, where it reacts quantitatively with a proprietary reagent based on ethanolamine to generate hydrogen ions. These are subsequently titrated with coulometrically generated OH⁻. CO₂ is thus measured by integrating the total charge required to achieve this. (Dickson, et al 2007).

Each coulometer was calibrated by injecting aliquots of pure CO₂ (99.995%) by means of an 8-port valve outfitted with two calibrated sample loops of different sizes (~1ml and ~2ml) (Wilke et al., 1993). The instruments were each separately calibrated at the beginning of each ctd station with a minimum of two sets of the gas loop injections. Over 140 loop calibrations were run on each system during this cruise.

Secondary standards were run throughout the cruise (at least one per station) on each analytical system. These standards are Certified Reference Materials (CRMs), consisting of poisoned, filtered, and UV irradiated seawater supplied by Dr. A. Dickson of Scripps Institution of Oceanography (SIO). Their accuracy is determined manometrically on land in San Diego. DIC data reported to the database have been corrected to the batch 117 CRM value. The reported CRM value for this batch is 2009.99 μmol/kg. The average measured values (in μmol/kg during this cruise) were 2009.33 for PMEL-1 and 2010.95 for PMEL-2.

The DIC water samples were drawn from Niskin-type bottles into cleaned, pre-combusted 300mL borosilicate glass bottles using silicon tubing. Bottles were rinsed twice and filled from the bottom, overflowing by at least one-half volume. Care was taken not to entrain any bubbles. The tube was pinched off and withdrawn, creating a 5mL headspace, and 0.125mL of 50% saturated HgCl₂ solution was added as a preservative. The sample bottles were sealed with glass stoppers lightly covered with Apiezon-L grease, and were stored in a 20°C water bath for a minimum of 20 minutes to bring them to temperature prior to analysis.

About 1,790 samples were analyzed for discrete DIC. Greater than 10% of these samples were taken as replicates as a check of our precision. These replicate samples were typically taken from the surface, oxygen minimum, and bottom bottles. The replicate samples were interspersed throughout the station analysis for quality assurance and integrity of the coulometer cell solutions and no systematic differences between the replicates were observed. The absolute average difference from the mean of these replicates is 0.7 $\mu\text{mol/kg}$.

The DIC data reported at sea is to be considered preliminary until further shoreside analysis is undertaken.

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A20 Alkalinity

(Laura Fantozzi and Emily Bockmon, laboratory of Andrew G. Dickson, Marine Physical Laboratory, Scripps Institution of Oceanography)

Samples were taken at every station, depending on cast depth the number of niskins sampled varied. Bottles were chosen to match DIC's sample choices. Samples were collected in 250 ml Pyrex bottles. A headspace of approximately 5 milliliters was removed and 0.06 milliliters of saturated mercuric chloride solution was added to each sample. The samples were capped with a glass stopper with a Teflon sleeve. All samples were equilibrated to 20 degrees Celsius using a Thermo Scientific RTE7 water bath.

Samples of volume 92.873 ± 0.017 ml were prepared using a volumetric pipette and a system of relay valves and air pumps, controlled by a laptop using LabVIEW 2011. The temperature of the samples at time of dispensing was taken automatically by a computer using a DirecTemp surface probe, to convert this volume to mass for analysis.

Samples were analyzed using an open beaker titration procedure using two thermostated 250ml beakers; one sample being titrated while the second was being prepared and equilibrating to the system temperature close to 20 degrees C. After an initial aliquot of approximately 2.2 mls of standardized hydrochloric acid (~ 0.1 Molar HCl in ~ 0.6 M NaCl solution), the sample was stirred for 5 minutes to remove liberated carbon dioxide gas. The stir time has been minimized by bubbling air into the sample at a rate of 200 scc/m. After equilibration, 19 aliquots of 0.04 mls were added. The data within the pH range of 3.5 to 3.0 were processed using a non-linear least squares fit from which the alkalinity value of the sample was calculated (Dickson, et.al., 2007). This procedure was performed automatically by a computer running LabVIEW 2011.

Viewing vertical section of Alkalinity over the first 40 Stations, we became concerned about high and low features that appear to alternate on the scale of a station or two between Station 020 and 040. The changes are generally between 2-10 $\mu\text{mol kg}^{-1}$. These "waves" in the data are especially visible in the upper 1000 meters, where there is the alkalinity minimum. We were concerned that it might be evidence of a difference in analyzer, temperature or time of day, although the reference materials show no differences. After examining profiles from Salinity, DIC, and several nutrients, we determined that these waves were in fact true features, and not an artifact of the alkalinity titration. They have no correspondence with the person who sampled or analyzed.

Additionally a feature was noticed in Station 053, different from the surrounding features. Alkalinity values appear high between 1000-2000 meters, bottles 113-117. This deviation seems to be mimicked in Salinity but further investigation into these high values could be worthwhile.

Stations 077 and 078 had especially high CRM values, an average of 6.05 $\mu\text{mol kg}^{-1}$ higher than the certified value. The high values occurred right after an acid bottle change. It is likely that the concentration of this bottle of acid was not correct which caused the high CRM values. This bottle of acid was switched out for a new one and the CRM values decreased back to what had been normal for the cruise. An adjustment for this problem will be made in the subsequent data analysis.

For most casts two duplicates were taken and analyzed. Throughout the cruise, a total of 139 duplicates were analyzed and gave a pooled standard deviation of $1.08 \mu\text{mol kg}^{-1}$.

Dickson laboratory Certified Reference Materials (CRM) Batch 117 was used to determine the accuracy of the analysis. The certified value for Batch 117 is $2239.18 \pm 0.64 \mu\text{mol kg}^{-1}$. The reference material was analyzed 155 times throughout the stations.

The data should be considered preliminary since the correction for the difference between the CRMs stated and measured values has yet to be finalized and applied. Additionally, the correction for the mercuric chloride addition has yet to be applied.

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Discrete pH Analyses

PI: *Dr. Andrew Dickson*

Ship technicians: *J. Adam Radich and Kristin Jackson*

Sampling

Samples were collected in 250 mL borosilicate glass bottles and sealed using grey butyl rubber stoppers held in place by aluminum crimp caps. Each bottle was rinsed a minimum of 2 times, then filled and allowed to overflow by approximately half to one full volume. A 1% headspace was then removed from the bottles using an Eppendorf pipette and poisoned with 60 μ L of mercuric chloride (HgCl_2) prior to sealing with the aluminum caps. Each bottle was additionally pre-heated for approximately 16 minutes in a thermostat bath set to 25°C prior to analysis. Samples were collected from the same Niskin bottles as total alkalinity or dissolved inorganic carbon in order to completely characterize the carbon system, and duplicate bottles were also taken (3-4) on random Niskins for each station throughout the course of the cruise. All data should be considered preliminary.

Analysis

pH (μ mol/kg H_2O) on the total scale was measured using an Agilent 8453 spectrophotometer according to the methods outlined by Clayton and Byrne (1993). A Thermo NESLAB RTE-7 recirculating water bath was used to maintain spectrophotometric cell temperature at 25.0°C during the analyses. A custom 10cm flow through jacketed cell was filled autonomously with samples using a Kloehn V6 syringe pump. The sulfonephthalein indicator m-cresol purple (mCp) was used to measure the absorbance of light measured at two different wavelengths (434 nm, 578 nm) corresponding to the maximum absorbance peaks for the acidic and basic forms of the indicator dye. A baseline absorbance was also measured and subtracted from these wavelengths. The baseline absorbance was determined by averaging the absorbances from 730-735nm. The samples were run using the tungsten lamp only. The blank and absorbance spectrum were measured 6 times in rapid succession and then averaged. The ratios of absorbances at the different wavelengths were input and used to calculate pH on the total scales, incorporating temperature and salinity into the equations. The salinity data used was obtained from the conductivity sensor on the CTD. The salinity data was later corroborated by shipboard measurements. Temperature of the samples was measured immediately after spectrophotometric measurements using a YSI 4600 thermometer.

Reagents

The mCp indicator dye was made to a concentration of 2.0mM in 100ml batches as needed. A total of 2 batches were used during the cruise. The pHs of the two batches were adjusted to approximately 7.9 and 7.8 using dilute solutions of HCl and NaOH and a pH meter calibrated using NBS buffers. The indicator was provided by Dr. Robert Byrne of the University of South Florida, and was purified using the HPLC technique described by Liu et al., 2011.

Standardization/Results

The precision of the data can be accessed from measurements of duplicate analyses, certified reference material (CRM) Batch 117 (provided by Dr. Andrew Dickson, UCSD), and TRIS buffer Batch 10 (provided by Dr. Andrew Dickson, UCSD). CRMs were measured at least once a

shift, and bottles of TRIS buffer were measured periodically throughout the cruise. The precision obtained from 182 duplicate analyses was found to be ± 0.0005 .

Data Processing

The addition of an indicator dye perturbs the pH of the sample and the degree to which pH is affected is a function of the differences between the pH of the seawater and the pH of the indicator. Therefore, a correction is applied to all samples measured for a given batch of dye. To determine this correction samples of varying pH and water composition were randomly run with a single injection of dye and then again with a double injection of dye on a single bottle. Making two measurements from a single bottle was found to be valid after a small study during the cruise on 22 bottles with varying pH showed a precision for consecutive measurements of ± 0.0004 .

To determine this correction the change in the measured absorbance ratio R where $R = (A_{578} - A_{base}) / (A_{434} - A_{base})$ is divided by the change in the isosbestic absorbance (A_{iso} at 488nm) observed from two injections of dye to one ($R'' - R'$) / ($A_{iso}'' - A_{iso}'$) is plotted against the measured R value for the single injection of dye is then plotted and fitted with a linear regression. From this fit the slope and y-intercept (b and a respectively) are determined by:

$$\Delta R / \Delta A_{iso} = bR' + a \quad (1)$$

From this the corrected ratio (R) corresponding to the measured absorbance ratio if no indicator dye were present can be determined by:

$$R = R' - A_{iso}' (bR' + a) \quad (2)$$

Preliminary data has not been corrected for the perturbation.

Problems

Very few problems occurred during the course of the cruise. The biggest problem that did occur was tiny bubbles forming inside the cell due to cold samples de-gassing as they were heated up rapidly. To combat this cuvette cleaner was used randomly over the first handful of days. This was later abandoned and the cells were instead flushed with air and then filled with DI water and allowed to soak in-between stations. This proved the most effective and prior to running a given station junk surface seawater was flushed through the cell and system and any bubbles that were formed were tapped out by hand. Stations were additionally analyzed starting with the surface samples and finishing with the deep cold bottom samples to reduce the build up of bubbles. However, in battling with bubbles from cold samples, both of the custom glass pH jacketed cells were broken beyond use, which led to no measurements being able to be made on samples after station 64.

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Dissolved Organic Carbon and Total Dissolved Nitrogen

PI: Dennis Hansell, RSMAS, University of Miami

Participant: Silvia Gremes-Cordero, RSMAS, University of Miami

The goal of the group is to obtain Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN) along the Atlantic A20 line, in order to better understand the cycle of carbon in the ocean, both in time and spatial scales.

DOC samples were obtained approximately every other station from station 11. Depending on the station 20-36 Niskin bottles were sampled (1181 samples). Toward the end of the cruise Niskin #11 was removed due to malfunctioning, making 35 the samples available.

At the top 250m of the water column, inline filtering was performed, using GF/F glass fiber filters that were previously cleaned with 10% HCl solution and rinsed with the Mili-Q water available on board. Filtering is conducted to avoid the inclusion of particles (present in the upper 250 m of the water column) in the samples. High density polyethylene 60 ml bottles were rinsed 3 times before the sampling, and posteriorly frozen at -20 C° in the walk-in freezer. Frozen samples will be shipping back to University of Miami at the end of the cruises.

TDN samples will be analyzed for the upper 200 m from the same samples.

fCO₂ (underway)

Robert Castle, AOML

PI: Rik Wanninkhof, AOML

An automated underway fCO₂ measurement system was installed in the Hydro Lab of the R/V Atlantis for the A20 cruise. The system is a model 8050 built by General Oceanics (GO). The final data will be available on AOML's web page (<http://www.aoml.noaa.gov/ocd/gcc>).

Early instrument designs are discussed in Wanninkhof and Thoning (1993) and in Feely et al. (1998). The current design as well as the data processing procedure is detailed in Pierrot et al. (2009).

Seawater continuously flows through a closed, water-jacketed equilibration chamber at approximately 1 liter/minute. A spiral nozzle creates a conical spray that enhances the gas exchange with the enclosed gaseous headspace. During "water" analyses this overlying headspace is pushed through an infrared analyzer (Licor model 6262) and returned to the equilibrator. During air analyses, outside air is pulled from an inlet on the forward mast and pushed through the analyzer. The pressure and temperature inside the equilibrator are constantly being measured. With knowledge of the sea-surface temperature and salinity, along with all the parameters measured by the system, one can calculate the fugacity of CO₂ in the seawater and the atmosphere above it.

To ensure the accuracy of analyzer output, four standard gases are analyzed approximately every 3.25 hours. These standards (serial numbers JB03284 [287.45 ppm], JA02646 [463.00 ppm], JB02140 [356.84 ppm], and JB03268 [384.14 ppm]) were purchased from Scott-Marrin and calibrated using gases from NOAA/ESRL in Boulder, CO and primary reference standards from the laboratory of Dr. Charles Keeling, which are directly traceable to the WMO scale. In addition, approximately every 26 hours, the zero and span of the Licor are set using ultrapure (CO₂-free) air for the zero and the 463 ppm standard for the span. After the standards five air analyses and 66 water analyses are done. With continuous operation, the system provides approximately 460 water analyses per day. The system operated continuously during the cruise but there were 2 periods of insufficient water flow. The first occurred on April 30 at 23:35 GMT and lasted until May 1 at 01:35. The second occurred on May 8 from 13:10 to 15:40 GMT. Water analyses in these periods were bad but air analyses were not affected. Preliminary examinations of the data show good analyses but final fugacity values will require some time due to the volume of the data.

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Carbon ISOTOPES (C-13/C-14)

PIs: Ann McNichol, WHOI; Robert Key, Princeton

Participant: Silvia Gremes-Cordero, RSMAS, University of Miami

¹³C/¹⁴C water samples were drawn routinely from the Rosette casts, every 6-7 stations approximately. In total, 12 stations were sampled (164 samples) and duplicates were obtained in three different stations (43,65,71). In some of the sampled stations, 16 Niskin were sampled in the upper 1000m, and in the rest 24-26 bottles were sampled in the lower and upper 1000m, when Alkalinity values were obtained.

Samples were collected in 500 ml glass stoppered bottles. First, the stopper was removed from the dry flask and placed aside. Using silicone tubing, the flasks were rinsed well with the water from the Niskin bottle. While keeping the tubing near the bottom of the flask, the flask was filled and allowed to overflow about half its volume. Once the sample was taken, a small amount (~30 cc) of water was removed to create a headspace and ~1.2 µl of 50% saturated mercuric chloride solution was added.

After all samples were collected from a station, the neck of each flask was carefully dried using Kimwipes. The stopper, previously lubricated with Apiezon grease, was inserted into the bottle. The stopper was examined to insure that the grease formed a smooth and continuous film between the flask and bottle. A rubber band was wrapped over the bottle to secure the stopper.

The samples will be analyzed at the National Ocean Sciences AMS lab in Woods Hole, MA using published techniques.

Reference:

McNichol, A., Quay, P. D., Gagnon, A. R., Burton, J. R., "Collection and Measurement of Carbon Isotopes in Seawater DIC", *WHP Operations and Methods-March 2009*.

Radiocarbon ($\Delta^{14}\text{C}$) measurements of Marine Dissolved Organic Carbon

PI: Ellen R. M. Druffel, University of California Irvine

Participant: Silvia Gremes-Cordero, RSMAS, University of Miami

Project Goal: DOC $\Delta^{14}\text{C}$ profiles in the North Atlantic will establish a better understanding of the timescale of DOC cycling. Black carbon $\Delta^{14}\text{C}$ measurements will quantify the concentration of BC in the surface and deep Atlantic Ocean.

Preparations:

Three DOC $\Delta^{14}\text{C}$ profiles were collected at different depths along the cruise transit line for a total of 33 samples. Samples depths coincided with Alkalinity, DIC ^{14}C (Ann McNichol) and [DOC] samples taken from the same niskins. At depths above 400m, water was filtered using a custom made stainless steel filter holder.

Dissolved Organic Carbon samples were collected using 1-L amber boston round bottom bottles with Teflon lined caps. The glass bottles were previously cleaned with soap and water, soaked in 10% HCl, rinsed with DI water, then baked at 550°C for two hours. The caps were washed in soap and water, flushed with 10% HCl, rinsed with DI, then air-dried. The stainless steel filter holder was cleaned with soap and water, flushed with 10% HCl, rinsed with DIC, the air-dried. Filters were baked at 550°C for two hours, and placed in a pyrex petri dish covered in baked out aluminum foil to keep clean.

No samples were processed aboard the Atlantis. All samples were frozen at -20°C in freezers, which were then sent back to the Druffel Lab.

DOC $\Delta^{14}\text{C}$ method:

In the Druffel Lab at UC Irvine, bulk DOC will be oxidized using a 1220-W ultra violet Hg-arc light source modified for a 900 ml volume and lower blank technique (Beaupre et al., 2007). Following the production of CO_2 , aliquots are taken for $\Delta^{13}\text{C}$ and $\Delta^{14}\text{C}$ analysis.

Radiocarbon measurements for DOC and BC samples are reported as ^{14}C in per mil (Stuiver and Polach, 1977) and are corrected for extraneous carbon introduced during sample processing. Stable carbon isotope measurements will be performed on splits of the CO_2 at the UCI Keck Carbon Cycle AMS Laboratory. Carbon dioxide will be quantified manometrically, reduced to graphite using iron powder as a catalyst with H_2 as a reductant.

References:

- Beaupre, S.R., Druffel, E.R.M. and Griffin, S., 2007. A low blank photochemical extraction system for concentration and isotopic analyses of marine dissolved organic carbon. *Limnology and Oceanography: Methods*, 5:174-184.
- Brodowski, A., Rodionov, A., Haumaier, L., Gaser, B. and Amelung, W., 2005. Revised blackcarbon assessment using benzene polycarboxylic acids. *Organic Geochemistry*.1299-1300 pp.
- De Jesus, Roman (2008), Natural abundance radiocarbon studies of dissolved organic carbon (DOC) in the marine environment. Doctoral Thesis, U.C. San Diego, pp. 83
- Ziolkowski, L., 2009. Radiocarbon of Black Carbon in Marine Dissolved Organic Carbon. Doctoral Thesis, U.C. Irvine, Irvine, 117 pp.
- Ziolkowski, L., Druffel, E. 2010. Quantification of Extraneous Carbon during Compound Specific Radiocarbon Analysis of Black Carbon. *Anal. Chem*, 81, 10158-10161

Summary of Transmissometer Sampling Procedure

PI: W.D. Gardner, Texas A&M Department of Oceanography

Mary Jo Richardson, Texas A&M Department of Oceanography

Cruise Participants: Robert Palomares, Courtney Schatzman, Kristin Sanborn SIO/STS

TRANSMISSOMETER:

Instrument: WetLabs C-Star Transmissometer 327DR

AIR CALIBRATION:

- Calibrated the transmissometer in the lab at beginning and end of the cruise with a pigtail cable attachment to CTD.
- Wash and dried the windows with Kimwipes and distilled water.
- Compare the output voltage with the Factory Calibration data.
- Recorded the final values for unblocked and blocked voltages on the TRANSMISSOMETER CALIBRATION/CAST LOG. In most cases recorded the approximate air temperature as well.

OPERATION:

- With the transmissometer connected to the CTD, cleaned and dried optical windows. Block the light path in the center of the instrument with your fingers or a paper towel and measure the output voltage. Took reading of the output (voltage or counts) through the CTD and record the value on the "TRANSMISSOMETER CALIBRATION/CAST LOG". If the new value is substantially different, wash the windows with slightly soapy water or alcohol and rinsed with fresh water, then wipe dry. Checked output voltage again for stable readings then ceased drying the transmissometer windows; typically employing one or two, wipes with Kimwipes, of each window. This was done before cast, at the beginning and end of the cruise as well as every 20 casts. Temperature disequilibrium and condensation on windows will cause erratic readings.
- Washed the windows before every cast. Rinsed both windows with a distilled water bottle that contains 2-3 drops of liquid soap. This was the last thing before the CTD went in the water.
- Rinse instrument with fresh water at end of cruise.

Date	Blocked Value Vd	Unblocked Value Vair	Air T (°C)	Remarks
11/30/11	0.059	4.752	21.5	
		4.660	21.3	Factory Calibration
2/23/11	0.056	4.707		
3/12/11	0.056	4.673	5.8	
3/22/11	0.056	4.675	6.0	
4/04/11	0.056	4.652	5.8	
4/14/11	0.057	4.666	7.2	
4/19/11	0.059	4.665	8.3	
4/20/11	0.059	4.690	20	

Sea surface skin temperature group

PI: Peter Minnett, University of Miami, RSMAS

Participant: Silvia Gremes-Cordero, University of Miami, RSMAS

The purpose of the RSMAS remote sensing activities on the Atlantis is to make measurements that can be used to assess the accuracies of the Sea-Surface Temperature (SST) measured by imaging infrared radiometers on satellites. These include the new VIIRS (Visible Infrared Imaging Radiometer Suite) on the Suomi-NPP (National Polar-orbiting partnership) satellite that was launched at the end of October 2011. The measurements taken from the Atlantis will also be used to evaluate the accuracies of the SSTs derived from the Advanced Very High Resolution Radiometers (AVHRRs) on the NOAA and EUMETSAT polar-orbiting meteorological satellites, the Moderate Resolution Imaging Spectroradiometers (MODIS) on the NASA satellites Terra and Aqua, and the SEVIRI (Spinning Enhanced Visible Infra-Red Imager) on the Meteosat Second Generation geostationary satellite of EUMETSAT.

The Skin SST, measured radiometrically, cloud coverage and water vapor content in the air column were obtained continuously with the instrumentation described below. These additional measurements are taken to help characterize the atmospheric conditions that influence the accuracy of the SST measurement from space.

The data were regularly downloaded into an external hard drive every 2-3 days. Sporadic noise noticeable in the spectra was related to solvable technical problems. There were no gaps in data recording in this particular period (leg A20).

M-AERI

Our main piece of equipment is the M-AERI (Marine-Atmosphere Emitted Radiance Interferometer – see Minnett et al., 2001). It consists in 2 main components: an external unit that is mounted on the O2 deck of the ship, and an electronics rack that is installed inside the vessel (in the Main Lab, in our case), the two being linked by an umbilical bundle of about 5 cm diameter and 60 m in length. The external unit comprises the Fourier Transform infrared (FTIR) interferometer assembly, is a bulky piece of equipment which sits on a table that mounts on the railing where it can view the surface of the sea ahead of the bow wave, at an angle of about 55° to the vertical ([Figure 1](#)). Maintenance of the equipment requires a daily cleaning of the mirror with Q-water, acetone and alcohol.



Figure 1. The M-AERI mounted on the *R/V Atlantis*

The system operates at an output rate of 1 complex spectrum (interferogram) per second. It runs continuously under computer control, except for a brief period beginning at 0:00 UTC, when the computer reboots and starts the new files.

Microwave Radiometer

We set up a Microwave Radiometer where it has a clear view from zenith to the horizon. It measures atmospheric water content. The instrument mounts conveniently on the stand shown in the photo (Figure 2). Power for this instrument is provided via cables into the Lab.



Figure 2. Microwave radiometer on *R/V Atlantis*

The sky camera

The sky camera system is mounted in an unobstructed area for the best possible view of the dome of the sky, such as on the bridge top (Figure 3). Power is supplied from to the Lab where the images are acquired by a laptop computer 120 V A/C, 50 watts.

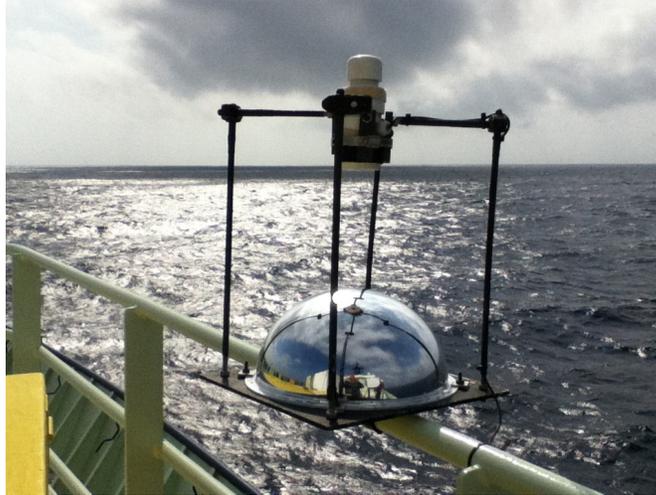


Figure 3. The sky camera mounted on the *R/V Atlantis*

O₂/Ar and Triple Oxygen Isotopes

PI: Rachel Stanley

Cruise Participant: Zoe Sandwith

Sampling for O₂/Ar and Triple Oxygen Isotopes occurred roughly once per day at 25 stations throughout the cruise. Both analyses are performed from the same ~300 mL sample. Of these stations, 3 were 'deep profiles' where 22 depths were sampled, 2 were 'mid-depth profiles' where 15 depths were sampled, and 3 were 'shallow profiles', where 9 depths were sampled. These profiles were spaced among the basin, with a deep profile occurring near each end of the basin, and one in the middle. The mid-depth profiles were spaced between the deep, and the shallow depth profiles scattered between these. For the other 17 stations, only the surface niskin was sampled. On the last two stations, the surface sample was duplicated. A total of 141 samples were taken includes 2 duplicates. 1 sample was lost due to a breach of the vacuum of the flask during sampling, however there was not enough water in the budget for that niskin for resampling.

Samples were taken via silicon tubing into custom made flasks. These had been cleaned, poisoned with 100 µL dried saturated mercuric chloride solution, then evacuated to 10⁻⁷ torr prior to the cruise. The flasks were filled halfway (roughly 300 mL), allowing for a degassing headspace.

Samples will be sent to WHOI for processing and analysis on a mass spectrometer.

Stable Isotope Probing

PI: Lee Kerkhof

Cruise Participant: Lauren Seyler

Sampling for stable isotope probing (SIP) occurred roughly once per day at 16 stations throughout the cruise. Of these, SIP microcosms were set up at 13 stations, while at the other 3 stations samples were taken to be used in DNA/RNA analysis. At each station, water was taken from at least three distinct zones in the water column, based on data from the CTD: the middle of the mixed layer, the oxygen minimum zone (or as near to it as possible), and the middle of the bathypelagic zone. At 7 stations, samples were also drawn from the bottom-most bottle for DNA/RNA analysis. Bottles were chosen based on the sampling plans of the members of the science crew; since a minimum of 4.5 L of water was required for SIP and DNA/RNA analysis, bottles were chosen that were being sampled from the least.

To set up SIP microcosms, 1 L samples of water from each depth were amended with one or more of the following stable isotope-labeled substrates: ¹³C sodium acetate, ¹³C urea, ¹³C sodium bicarbonate, ¹³C algal lipid extract, or ¹⁵N algal protein extract. ¹²C sodium acetate, ¹²C urea, ¹²C sodium bicarbonate, and ethanol were also used as controls. These microcosms were then incubated in a plastic trash can on deck that was covered and given a constant inflow of surface sea water to maintain a stable temperature. Incubations were allowed to run for either 24 or 48 hours, after which biomass was collected on a 0.2- μ m filter using vacuum filtration. For those stations that were only used for DNA/RNA analysis, duplicate 0.5-L samples were taken from all four depths and biomass was immediately collected using vacuum filtration. These filters were then stored at -70 degrees. After arrival at Woods Hole, these samples will be stored in liquid nitrogen and taken to Rutgers University for further processing and analysis.

Students at Sea

The NSF physical oceanography grant for the US Global Ocean Carbon and Repeat Hydrography Program supports participation of physical oceanography and CFC students on program cruises. Below are statements from the student participants on A20 (Atlantis).

Sarah Brody - (Duke University)

Participating in the CLIVAR A20 cruise on the RV Atlantis gave me a unique opportunity to learn how hydrographic data is collected, processed, and analyzed. As one of the students on the CTD watch, I got the chance to assist with many different aspects of the data-gathering process, including operating the CTD console, preparing the rosette for deployment, taking nutrient and salt samples, keeping track of the different samples being taken, recovering and deploying the CTD/rosette package, and driving the winch that brings the package to depth. Doing these different jobs gave me insight into all parts of the CTD data-collection process. I am very glad that the students on the CTD watch were given the chance to be so involved in the different steps of handling the CTD, and am thankful to everyone who patiently trained us to do these jobs. Additionally, through sampling and keeping track of the different samplers, I learned about the breadth of data being collected on this cruise, and what the different measurements will be used to determine. Most of all, I gained an appreciation for the difficulty inherent in collecting hydrographic data.

While I now understand how difficult it can be to collect high-quality hydrographic data, I also learned how much a detailed hydrographic section like the CLIVAR A20 cruise can reveal about physical and chemical processes at play in the area we covered. During the cruise, I learned how to use Ocean Data View to download and examine the data we collected. From looking at the data using ODV and from talks with the chief scientists, I gained some understanding of Atlantic basin ocean circulation. For example, I learned about the water masses that make up the bottom waters of the North Atlantic, and the way in which those water masses change from Antarctic bottom water to Denmark sill overflow water as we moved north, with mixing of those water masses evident in the profiles we examined. I also spent some time examining the unusually low-salinity surface water we encountered at the beginning of the section. The low salinity water originates from Amazon river discharge and forms a lens over the ocean water; however, the lens we saw was anomalous in both its extent and intensity. I plan to continue to look at this low-salinity water, together with LADCP current-profiler data, in the last few days of the cruise. The physical oceanography I learned about on this cruise, together with the mechanics of hydrographic sampling I became familiar with, made the CLIVAR A20 cruise a valuable experience for me.

Katherine McCaffrey (University of Colorado at Boulder, Cooperative Institute for Research in Environmental Sciences)

My experience at sea has been very rewarding. As a graduate student studying physical oceanography and ocean turbulence in the land-locked state of Colorado, I was eager to experience the other side of the field: observation. I work with data, models and a lot of theory so it was spectacular to see the theory in action in the ocean. It helped me to appreciate the amount of detail needed to collect data worthy of analyzing, and the difficulties presented by the moving, changing ocean. Spending a month on a boat with 25 other scientists was a mixture of fun (singing while sampling), stress (rushing from sampling to getting the next cast in the water), boredom (watching the CTD go down for hours), and excitement as we worked together to discover what is happening in the ocean below us.

On the CTD watch, I was in charge of prepping the niskin bottles, deploying and recovering the rosette from the deck with the ship's deck crew, running the CTD console, and driving the winch. It was fascinating to me that each time we brought the rosette out of the water, it contained information from more than five thousand meters below the ocean surface – information that only we know so far. Though the console and winch-driving proved challenging in their monotony, it was interesting to watch the temperature, salinity, dissolved oxygen and transmissometer data come in. Many fruitful discussions were stemmed from an interesting and perhaps unexpected signature on the plots, like the drop in temperature and salinity at the ocean bottom in the southern portion of the section, revealing the Deep Western Boundary Current. Learning to use Ocean Data View also helped to visualize and analyze what is happening along the section we observed, and the skills gave me the ability to plot things that are particularly interesting to me, like spiciness and temperature on pressure versus potential density levels. I am eager to return home to Colorado to use the ADCP, temperature, and salinity data collected on A20 to further my research in ocean turbulence as well.

Thanks for a great time out here!

--Katie

Stefan Gary (Duke University)

The past month of participation in the CLIVAR A20 cruise has been a very intense and productive time in my development as an oceanographer. This was my first experience of a long-distance hydrographic section. Although I had been on CTD watch for a few scattered stations on a previous cruise, this cruise was very different because we took many more samples at many more stations, coordinated with many research groups (each one specializing in a

different measurement), and always needed to keep an eye on the clock in order to complete the section in the allotted time. In the process, I drew samples for salts, nutrients, total dissolved organic carbon, and total alkalinity, I learned, in detail, how samples are processed and quality controlled to become data, I operated an LADCP, CTD console, and two different types of winches, and I participated in the deployment and recovery of the CTD and rosette package. I also helped with the rescue of a storm petrel.

Beatriz Ramos

Before this cruise, I used a large amount of historical hydrographic data. At the time, I was not aware of precisely how many people and how much effort is required to realize basin-scale hydrographic sections. The most important result of this cruise for me has been the opportunity to meet and work beside oceanographic data collection experts. Personally and professionally, this month of constant, uninterrupted teamwork has meant a great deal to me. As we steam back to port, I find myself more rooted in the oceanographic community as well as with a renewed excitement for and commitment to my career in physical oceanography.

On 16th of April I flew from Spain to Barbados, in a couple of days I would be on board in the R/V Atlantis ship during the next month. It would be my first cruise and my position would be CTD watch. On 21st of April we had the first station. My shift was from midnight to noon so my first night was a challenge. During the first shifts I learned to run the CTD software, to be the sample cop and to collect nutrients and salts samples. We were three in the group so teamwork was very important to develop an efficient job. On the second week I was trained to drive the CTD, it was a high responsibility, maximum attention was required. Also I wanted to learn as much as I could, so between casts I was reading some papers about North Atlantic currents. It was a perfect opportunity because I was surrounded by very good scientists. It has been a very positive experience and I really hope this cruise is the first of many.

Rebecca Rolph

CFC Analyst

Student Report.

I have learned more being at sea than I could have ever done in any classroom setting. Going to class several times a week cannot give you the same level of personal communication and connection that I have experienced on this cruise. Living with a range of scientists whose backgrounds all involve different specializations allowed for the opportunity to have great discussions that would have not been possible otherwise. It also gave me a real appreciation for what oceanographic data is available because I have now experienced first-hand the great amount of hard work and effort involved to collect such data.

CFC systems vary because they are custom-made and modified over the years. However, learning about the system I was working with will undoubtedly help me with future systems—I

gained experience following flow diagrams, and basic necessary components should be similar in other systems. I also learned about common problems that can occur in CFC systems, and how best to systematically work through to find where they are. However, I can see that one of the best ways to understand a system is to actually build it, but this would take a long term of full-time dedication. If I were to work on one of these systems again, perhaps drawing my own flow-diagram would be a good thing to do right at the beginning.

My personal experience on this ship has definitely solidified my desire to continue work in oceanography. I understand it is difficult, especially in the start, when the learning curve is very steep. But in the end, when discussing the results of the different systems on the ship, and how the many different aspects of oceanography all are connected, really keeps me enthusiastic to continue with research.

CCHDO Data Processing Notes

Date	Person	Data Type	Action	Summary
2012-05-29	<i>K Sanborn</i>	BTL	Submitted	hy1 file to go online
2012-05-29	<i>K Sanborn</i>	CrsRpt	Submitted	PDF format, to go online
2012-05-29	<i>K Sanborn</i>	BTL	Submitted	sea file to go online
2012-05-29	<i>K Sanborn</i>	SUM	Submitted	to go online
2012-05-29	<i>A Quintero</i>	CTD	Submitted	to go online
2012-05-30	<i>C Berys</i>	CTD/BTL/SUM	Website Updated	Available under 'Files as received'
				<p>File a20_hy1.csv containing Exchange bottle data, submitted by Kristin Sanborn on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20.sea containing Exchange bottle file, submitted by Kristin Sanborn on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20.sum containing WOCE SUM file, submitted by Kristin Sanborn on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-ct1.zip containing Exchange CTD file, submitted by Alex Quintero on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-ctd.zip containing WOCE CTD file, submitted by Alex Quintero on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-nc.zip containing NetCDF CTD file, submitted by Alex Quintero on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p> <p>File A20_CruiseReport.pdf containing Cruise Report, submitted by Kristin Sanborn on 2012-05-29, available under 'Files as received', unprocessed by CCHDO.</p>
2012-06-27	<i>C Berys</i>	CTD/BTL	Website Updated	Available under 'Files as received'
				<p>File a20.sea containing WOCE bottle data, submitted by Mary Johnson on 2012-06-26, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20.sum containing WOCE SUM data, submitted by Mary Johnson on 2012-06-26, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-ct1.zip containing Exchange CTD data, submitted by Mary Johnson on 2012-06-26, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-ctd.zip containing WOCE CTD data, submitted by Mary Johnson on 2012-06-26, available under 'Files as received', unprocessed by CCHDO.</p> <p>File a20-nc.zip containing NetCDF CTD data, submitted by Mary Johnson on 2012-06-27, available under 'Files as received', unprocessed by CCHDO.</p> <p>File A20_CruiseReport.pdf containing cruise documentation, submitted by Mary Johnson on 2012-06-26, available under 'Files as received', unprocessed by CCHDO.</p>
2012-07-26	<i>J Kappa</i>	CrsRpt	Submitted	to go online
				<p>I've placed 2 new versions of the cruise report:</p> <p>a20_33AT20120419do.pdf a20_33AT20120419do.txt</p> <p>into the co2clivar/atlantic/a20/a20_33AT20120419/ directory.</p> <p>Both docs include summary pages and CCHDO data processing notes.</p> <p>The pdf version also includes a linked Table of Contents and links to figures, tables and appendices.</p> <p>Both will be available on the cchdo website following the next update script run.</p>