CRUISE KN204-1: FINAL REPORT

Introduction

This final report for cruise KN204-1 combines three documents. This introduction summarizes 46 peer-reviewed publications that use data from this cruise. It is followed by a summary of the cruise itself, its sampling effort and some of its initial shipboard results. It is then followed by a report summarizing the hydrographic work accomplished by the SIO ODF group

GEOTRACES GA-03 publications

Testing models of thorium and particle cycling in the ocean using data from station GT11-22 of the U.S. GEOTRACES North Atlantic section
Paul Lerner, Olivier Marchal, Phoebe J. Lam, Robert F. Anderson, Ken Buesseler, Matthew A. Charette, et al.
Deep Sea Research Part I: Oceanographic Research Papers, Volume: 113 (2016)

Water mass mixing: The dominant control on the zinc distribution in the North Atlantic Ocean
Saeed Roshan, Jingfeng Wu
Global Biogeochemical Cycles, Volume: 29, Issue: 7 (2015)

The distribution of dissolved copper in the tropical-subtropical north Atlantic across the GEOTRACES GA03 transect
Saeed Roshan, Jingfeng Wu
Marine Chemistry, Volume: 176 (2015)

Mercury in the Anthropocene Ocean
Carl Lamborg, Katilin Bowman, Chad Hammerschmidt, Cindy Gilmour, Kathleen Munson, Noelle Selin,
Oceanography, Volume: 27, Issue: 1 (2014)

The distribution of dissolved copper in the tropical-subtropical north Atlantic across the GEOTRACES GA03 transect
Saeed Roshan, Jingfeng Wu
Marine Chemistry, Volume: 176 (2015)

Marine Chemistry, Volume: 177 (2015)
The GEOTRACES Intermediate Data Product 2014
Edward Mawji, Reiner Schlitzer, Elena Masferrer Dodas, Cyril Abadie, Wafa Abouchami, Robert F. Anderson, et al.
Marine Chemistry, Volume: 177 (2015)

Radium isotope distributions during the US GEOTRACES North Atlantic cruises
Matthew A. Charette, Paul J. Morris, Paul B. Henderson, Willard S. Moore
Marine Chemistry, Volume: 177 (2015)

Nitrate isotope distributions on the US GEOTRACES North Atlantic cross-basin section: Signals of polar nitrate sources and low latitude nitrogen cycling
Dario Marconi, M. Alexandra Weigand, Patrick A. Rafter, Matthew R. McIlvin, Matthew Forbes, Karen L. Casciotti,
Marine Chemistry, Volume: 177 (2015)

Water mass mixing: The dominant control on the zinc distribution in the North Atlantic Ocean
Saeed Roshan, Jingfeng Wu
Global Biogeochemical Cycles, Volume: 29, Issue: 7 (2015)

Processes controlling the distributions of Cd and PO 4 in the ocean
Paul Quay, Jay Cullen, William Landing, Peter Morton
Global Biogeochemical Cycles, Volume: 29, Issue: 6 (2015)

Aerosol water soluble organic matter characteristics over the North Atlantic Ocean: Implications for iron-binding ligands and iron solubility
Andrew S. Wozniak, Rachel U. Shelley, Stephanie D. McElhenie, William M. Landing, Patrick G. Hatcher
Marine Chemistry, Volume: 173 (2014)

The composition of dissolved iron in the dusty surface ocean: An exploration using size-fractionated iron-binding ligands
Jessica N. Fitzsimmons, Randelle M. Bundy, Sherain N. Al-Subiai, Katherine A. Barbeau, Edward A. Boyle
Marine Chemistry, Volume: 173 (2015)

Size-fractionated major particle composition and concentrations from the US GEOTRACES North Atlantic Zonal Transect
Phoebe J. Lam, Daniel C. Ohnemus, Maureen E. Auro
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)

The organic complexation of dissolved iron along the U.S. GEOTRACES (GA03) North Atlantic Section
Kristen N. Buck, Bettina Sohst, Peter N. Sedwick
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Copper distribution and speciation across the International GEOTRACES Section GA03
Jeremy E. Jacquot, James W. Moffett
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

The isotopic signature and distribution of particulate iron in the North Atlantic Ocean
Brandi N. Revels, Daniel C. Ohnemus, Phoebe J. Lam, Tim M. Conway, Seth G. John
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

A zonal picture of the water column distribution of dissolved iron(II) during the U.S. GEOTRACES North Atlantic transect cruise (GEOTRACES GA03)
P.N Sedwick, B.M. Sohst, S.J. Ussher, A.R. Bowie
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Elemental ratios and enrichment factors in aerosols from the US-GEOTRACES North Atlantic transects
Rachel U. Shelley, Peter L. Morton, William M. Landing
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Dynamic variability of dissolved Pb and Pb isotope composition from the U.S. north Atlantic GEOTRACES transect
Abigail E. Noble, Yolanda Echegoyen-Sanz, Edward A. Boyle, Daniel C. Ohnemus, Phoebe J. Lam, Rick Kayser, et al.

Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)
Introduction to the U.S. GEOTRACES North Atlantic Transect (GA-03): USGT10 and USGT11 cruises
Edward A. Boyle, Robert F. Anderson, Gregory A. Cutter, Rana Fine, William J. Jenkins, Mak Saito
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Impact of end-member mixing on depth distributions of δ13C, cadmium and nutrients in the N. Atlantic Ocean
Paul Quay, Jingfeng Wu
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)

Partitioning of dissolved iron and iron isotopes into soluble and colloidal phases along the GA03 GEOTRACES North Atlantic Transect
Jessica N. Fitzsimmons, Gonzalo G. Carrasco, Jingfeng Wu, Saeed Roshan, Mariko Hatta, Christopher I. Measures, et al.
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Cadmium in the North Atlantic: Implication for global cadmium–phosphorus relationship
Jingfeng Wu, Saeed Roshan
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

The distributions of helium isotopes and tritium along the U.S. GEOTRACES North Atlantic sections (GEOTRACES GAO3)
W.J. Jenkins, D.E. Lott, B.E. Longworth, J.M. Curtice, K.L. Cahill
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Water mass analysis for the U.S. GEOTRACES (GA03) North Atlantic sections
W.J. Jenkins, W.M. Smethie, E.A. Boyle, G.A. Cutter
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Mercury in the North Atlantic Ocean: The U.S. GEOTRACES zonal and meridional sections
Katlin L. Bowman, Chad R. Hammerschmidt, Carl H. Lamborg, Gretchen Swarr
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Oxygen and hydrogen isotope signatures of Northeast Atlantic water masses
Antje H.L. Voelker, Albert Colman, Gerard Olack, Joanna J. Waniek, David Hodell
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Comparison of particulate trace element concentrations in the North Atlantic Ocean as determined with discrete bottle sampling and in situ pumping
Benjamin S. Twining, Sara Rauschenberg, Peter L. Morton, Daniel C. Ohnemus, Phoebe J. Lam
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Thorium-234 as a tracer of particle dynamics and upper ocean export in the Atlantic Ocean
S.A. Owens, S. Pike, K.O. Buesseler
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)

Coupling of the distribution of silicon isotopes to the meridional overturning circulation of the North Atlantic Ocean
Mark A. Brzezinski, Janice L. Jones
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

230Th and 231Pa on GEOTRACES GA03, the U.S. GEOTRACES North Atlantic transect, and implications for modern and paleoceanographic chemical fluxes
Christopher T. Hayes, Robert F. Anderson, Martin Q. Fleisher, Kuo-Fang Huang, Laura F. Robinson, Yanbin Lu, et al.
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Biogeochemistry of dissolved arsenic in the temperate to tropical North Atlantic Ocean
Oliver Wurl, Rachel U. Shelley, William M. Landing, Gregory A. Cutter
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

210Po and 210Pb distribution, dissolved-particulate exchange rates, and particulate export along the North Atlantic US GEOTRACES GA03 section
S. Rigaud, G. Stewart, M. Baskaran, D. Marsan, T. Church
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Sources of iron and phosphate affect the distribution of diazotrophs in the North Atlantic
Jenni-Marie Ratten, Julie LaRoche, Dhwani K. Desai, Rachel U. Shelley, William M. Landing, Ed Boyle, et al.
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Cycling of lithogenic marine particles in the US GEOTRACES North Atlantic transect
Daniel C. Ohnemus, Phoebe J. Lam
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2015)

Characterizing marine particles and their impact on biogeochemical cycles in the GEOTRACES program
Robert F. Anderson, Christopher T. Hayes
Progress in Oceanography, Volume: 133 (2015)

Intensity of Th and Pa scavenging partitioned by particle chemistry in the North Atlantic Ocean
Christopher T. Hayes, Robert F. Anderson, Martin Q. Fleisher, Sebastian M. Vivancos, Phoebe J. Lam, Daniel C. Ohnemus, et al.
Marine Chemistry, Volume: 170 (2015)

Biogeochemical cycling of cadmium isotopes along a high-resolution section through the North Atlantic Ocean
Tim M. Conway, Seth G. John
Geochimica et Cosmochimica Acta, Volume: 148 (2015)

Separating biogeochemical cycling of neodymium from water mass mixing in the Eastern North Atlantic
Torben Stichel, Alison E. Hartman, Brian Duggan, Steven L. Goldstein, Howie Scher, Katharina Pahnke
Earth and Planetary Science Letters, Volume: 412 (2015)

The distribution of dissolved manganese in the tropical–subtropical North Atlantic during US GEOTRACES 2010 and 2011 cruises
Jingfeng Wu, Saeed Roshan, Gedun Chen
Marine Chemistry, Volume: 166 (2014)

The biogeochemical cycling of zinc and zinc isotopes in the North Atlantic Ocean
Tim M. Conway, Seth G. John
Global Biogeochemical Cycles, Volume: 28, Issue: 10 (2014)

An overview of dissolved Fe and Mn Distributions during the 2010–2011 U.S. GEOTRACES north Atlantic Cruises: GEOTRACES GA03
Mariko Hatta, Chris I Measures, Jingfeng Wu, Saeed Roshan, Jessica N. Fitzsimmons, Peter Sedwick,
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)

Dissolved Al in the zonal N Atlantic section of the US GEOTRACES 2010/2011 cruises and the importance of Hydrothermal inputs
Chris Measures, Mariko Hatta, Jessica Fitzsimmons, Peter Morton
Deep Sea Research Part II: Topical Studies in Oceanography, Volume: 116 (2014)

Quantification of dissolved iron sources to the North Atlantic Ocean
Tim M. Conway, Seth G. John
Nature, Volume: 511, Issue: 7508 (2014)

Assessment and comparison of Anopore and cross flow filtration methods for the determination of dissolved iron size fractionation into soluble and colloidal phases in seawater
Jessica N. Fitzsimmons, Edward A. Boyle
Limnology and Oceanography-Methods, Volume: 12 (2014)

A role for scavenging in the marine biogeochemical cycling of zinc and zinc isotopes

Seth G. John, Tim M. Conway

Earth and Planetary Science Letters, Volume: 394 (2014)

Cruise Report for Knorr 204-01 (November 6- December 11, 2011)

The U.S. GEOTRACES North Atlantic Transect – 2011 Shipboard Team

January 26, 2012

Prelude:

This cruise resumed the first U.S. survey section as part of our participation in an international program named GEOTRACES. In October 2010, the section began, departing Lisbon towards Mauritanea (and ultimately intended, Bermuda and Woods Hole), but problems with the ship's propulsion system terminated the 2010 cruise in the Cape Verde Islands. The section completion effort resumed again in November 2011, sailing in the reverse direction (Woods Hole to Bermuda to the Cape Verde Islands).

As before, a major challenge in organizing this cruise was the fact that requests from participating groups were made for ~10 berths more than the ship's capacity of 32. Fortunately, compared to the previous year's cruise where only 31 science berths were available because of accommodation of a foreign observer, we had the full 32 available in 2011. In addition, two of 2010's scientists developed sample storage methods that eliminated the need to do shipboard analyses, so in effect we had three berths more available than the previous year. During the pre-cruise planning meeting at Old Dominion University (ODU) in March 2011, discussion focused around how we would accomplish cruise objectives within this improved berthing limitation. We established three core groups whose responsibilities included (1) four individuals (Morton, Fitzsimmons, Bundy, and Shelley, one more than the previous year) staging for and sampling of the trace-metal clean GO-FLO carousel, (2) three individuals (Pahnke, Hayes, and Longworth) staging Niskin rosette casts and sampling with the assistance of the ODF team, and (3) five individuals staging McLane pumping casts (Morris, Ohnemus, Pike, Rigaud, and Owens, one more than the previous year), and (4) Four berths for the ODF rosette, nutrient, salinity, and data management effort (one extra compared to the previous year; Johnson, Miller, Palomares, and Schatzman). There was common effort towards these and other jobs, but each group was responsible for organizing itself and its helpers during deck activities. In addition to these teams, Geoff Smith maintained an underway fish for clean trace metal samples. Aguilar-Islas and Shelley undertook atmospheric aerosol sampling. Standard hydrographic analyses (salinity, dissolved oxygen, and micromolar nutrients) were carried out by the Ocean Data Facility (ODF) group, along with CTD data reduction and archiving, as well as primary data management operations. We felt that this latter function was extremely important for a GEOTRACES cruise from the viewpoint of metadata assembly and data submission requirements to BCO-DMO and ultimately to the GEOTRACES data assembly center at BODC. Low-level nanomolar nutrient analyses were carried out by Cutter's ODU group. Sampling for properties such as stable isotopes, dissolved inorganic carbon, radiocarbon, etc. was accomplished by designated cruise participants in addition to their own programmatic responsibilities. At the ODU planning meeting, sampling protocols and a skeleton cast plan were slightly revised from the previous year's efforts, which were further refined on board as the scope and scale of sampling requirements became clearer.

Prior to the KNORR's departure from Woods Hole in November, the Dynacon winch and A-Frame for the GEOTRACES trace metal clean carousel were mounted on the ship. In addition, the chemical reagents required for the cruise were secured in the chemistry van on the 02 level. Early on the first day, six laboratory vans were loaded onto the ship, 4 on the main deck and 2 on the 01 level. Although equipment and supplies were stored in the scientific hold, limited space meant that other items had to be kept in the laboratory space, and packing boxes were left behind in Woods Hole until demobilization when the ship returned in late December. A leased freezer van was mounted on the 02 level, and a bulwark was fabricated and installed on the forward side of the van to protect the machinery from salt spray and waves. Finally, a large number of compressed gas cylinders (nearly 60) were mounted and secured on racks both on the 01 level and in the aft hangar. We are grateful to

Eric Benway, Chad Smith and the Port Office for their assistance in arranging these modifications.
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[1] **The U.S. GEOTRACES Atlantic Shipboard Team:** E.A. Boyle and G.A. Cutter (Co-chief Scientists), A. Aguilar-Islas, K. Bowman, R. Bundy, G. Carrasco-Rebaza, J. Fitzsimmons, C. Hayes, B. Gipson, E. Gorman, C. Hammerschmidt, M. Hatta, J. Jacquot, M. Johnson, B. Longworth, C. Measures, M. Miller, P. Morris, P. Morton, D. Ohnemus, S. Owens, K. Pahnke, R. Palomares III, S. Pike, S. Rauschenberg, S. Rigaud, M. Johnson, C. Schatzman, R. Shelley, G. Smith, B. Sohst, L. Zimmer, A. Zafereo, A. Simoneau

Please note that the results presented here are both preliminary and proprietary to the individual investigators.

Cruise Narrative and Preliminary Observations:

Cruise mobilization commenced on November 2 in the port of Woods Hole. Space on the ship was at a premium. A major challenge for managing deck space was the large number (48) of pallet boxes required for gear and sample storage. This challenge was met in part by storing some on the main deck while the remainder were deployed on the 02 and 01 levels. Because there was no elevator service to the 02 level, scientists had to carry heavy (~20 liter, literally tons in total) containers up the steep stairway; it would be better if there were some mechanical way to do this. We are grateful to the ship's crew (and in particular the chief mate) for their patience, assistance, and advice during this trying process.

Over the course of 4 days (Nov. 2-5), the shipboard scientific team and several other scientists and Chad Smith worked hard loading gear on board, securing equipment, setting up the laboratory vans (including connecting electric, water, and compressed air supplies), and assembling the trace metal clean areas (bubbles) using plastic sheeting and HEPA filters. Liquid nitrogen tanks were topped up. Gas tank regulators were installed and tubing connected to equipment. CTD rosettes were assembled and connected to the conducting wires, and various sampling and sample processing systems were set up. Because the first station was just ten hours steaming from the dock, we held our first cruise science meeting in the Smith Building two days before departure. We discussed some changes to the shipboard routine. Pete Morton maintained a "Microsoft Project" document to arrange shipboard events and schedule our time. We also brought shipboard pagers so that in principle we could alert people without having to track them down physically (more about this later in the "lessons learned" section).

Figure 1: *KN204-01 stations*

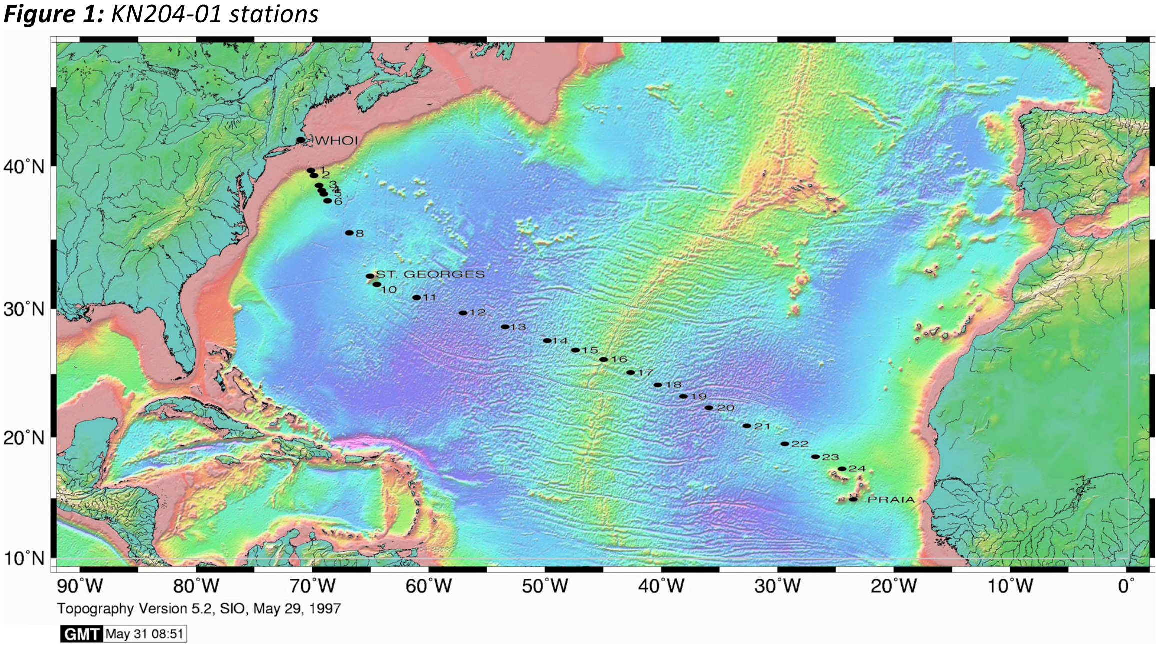


Table 1: US GT-NAT-2011 Stations

Port	US GT NAT-2011 Station Number	Latitude, °N	Longitude, °W	Bottom Depth, m (*)	Arrived on station	Station type	Comments
Woods Hole MA		41.52	70.67				
	1	39.70	69.80	2094	11/6/11 19:30	super	
	2	39.35	69.54	2514	11/8/11 21:30	full	
	3	38.67	69.11	3345	11/9/11 8:00	full	
	4	38.32	68.87	3327	11/12/11 0:20	full-2GTC	
	5	38.09	68.70	3771	11/13/11 14:50	demi	
	6	37.62	68.38	4640	11/13/11 21:30	full+1GTC	bottom nepheloid layer
	8	35.42	66.52	5015	11/16/11 8:00	full+1GTC	bottom nepheloid layer
St. Georges, Bermuda		32.33	64.75				
	10	31.75	64.17	4628	11/19/11 14:30	super+1GTC	BATS;crossover,reoccupation,time-series
	11	30.82	60.78	5512	11/22/11 1:30	demi	
	12	29.70	56.83	5751	11/23/11 1:00	super+1GTC	
	13	28.64	53.23	4283	11/25/11 13:45	demi	
	14	27.58	49.63	4313	11/26/11 10:45	full	
	15	26.86	47.23	3544	11/28/11 1:10	demi	
	16	26.14	44.83	3710	11/28/11 15:15	super	TAG hydrothermal vents
	17	25.14	42.52	3667	11/30/11 21:00	demi	
	18	24.15	40.22	4410	12/1/11 12:45	full	
	19	23.24	38.04	5180	12/3/11 4:00	demi	
	20	22.33	35.87	5940	12/3/11 18:45	super+1GTC	CFC11 rise in bottom waters
	21	20.88	32.63	5404	12/6/11 11:15	demi	
	22	19.43	29.38	5093	12/7/11 8:00	full	
	23	18.39	26.77	4325	12/9/11 2:45	demi	
	24	17.40	24.50	3610	12/9/11 17:15	full	TENATSO; re-occupation, time-series
Praia, CVI		14.92	23.52				

Note: no station 7 or 9 occcupation; pre-cruise plan station numbers were retained to avoid confusion

* Bottom depth for ODF deep cast

The first station occupation began about ten hours after departing Woods Hole the morning of November 6, and was a designated super-station. Fortunately, the weather was relatively warm and the seas were calm, so that given the previous year's experience, operations proceeded smoothly and efficiently from the start. Prior to departure, the GEOTRACES carousel (GTC) GOFlo bottles were filled with low-metal surface seawater stored in cubitainers from the previous year's cruise. Upon arriving on station, the bottles were emptied and the GTC was lowered to ~200 m depth in "blue water" for rinsing, emptied on board, and then sent back down for sample acquisition. We collected samples for shipboard Zn analyses (to assess contamination) by two methods (voltammetry-Carrasco and flow injection fluorescence-Measures/Hatta) to verify trace metal integrity. Measures/Hatta also measured shipboard Fe using flow injection colorimetry. Although there were some slightly high Zn measurements (that did not match between the two methods), no clear problems were identified we concluded that the bottles were working properly from the beginning. Zn analyses by the fluorescence method were continued throughout the cruise and continued to appear satisfactory. The shipboard Fe data was similarly satisfactory.

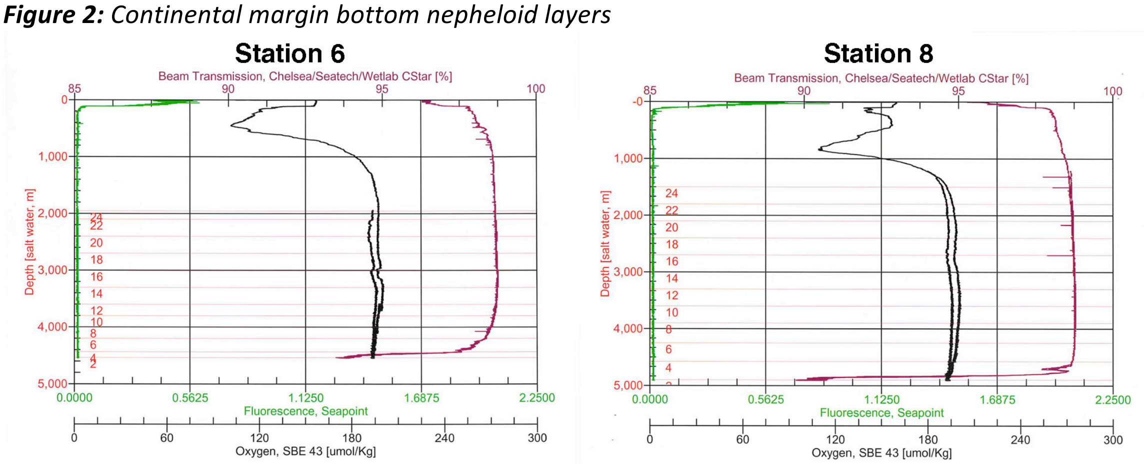
The Niskin rosette was equipped with a nephelometer and an altimeter to enable close bottom approaches. This allowed us to sample full depth profiles to within 10-15 m of the bottom for the rosette casts. The GTC carousel was more problematic, lacking an altimeter, so we generally tried to stay 20-30m about the Knudsen depth although we hit bottle twice despite this precaution.

After 48 hours on “superstation” 1, steaming time between the next three “full” stations was only 2-4 hours, and sample processing and sleep time were inadequate, so up to 8 hours of no deck operations were incorporated into the schedule for these stations. It took some time to work out an optimal schedule of events, so this period was difficult for some of the teams. We skipped two GTC casts at (full) station 4 so that we could do a 3rd GTC cast on the deepest stations (6, 8, 10, 12, 20).

After station 4 (Nov. 11-Nov. 15), weather conditions deteriorated, with a hurricane passing between our position and Bermuda (influencing our weather for about 2 days), followed by three more days of sustained winds in excess of 25 knots. These winds did not prevent station work but slowed the ship to a maximum speed of less than 9 knots during this period (7.5 knots during station 6 steam-backs). Station 6 in the Gulf Stream required a lot of steaming back to station given our drift during each cast, so this station required much more time than planned for (51 hours compared to 29 in the original plan). Between these two factors (weather and steaming back to station), we lost more time than was built into the station plan and had to eliminate 6 hours of demi stations (7 and 9). We retained the original station numbering-position plan to avoid confusion, but it should be clear that stations numbered 7 and 9 were not occupied.

At station 6, we encountered a very strong bottom nepheloid layer, detectable below 4200m but most strongly expressed below 4400m, where the beam transmission on the GTC carousel dropped from ~98.5% in the deep clearwater layer to ~93% near the bottom (figure 2). The near-bottom nepheloid layer was even stronger at station 8 which had a minor transmission minimum at 4600m but the strongest near the bottom (~90% beam transmission at ~5900m). These nepheloid layers were easily visible on the pump cast filters.

Figure 2: *Continental margin bottom nepheloid layers*



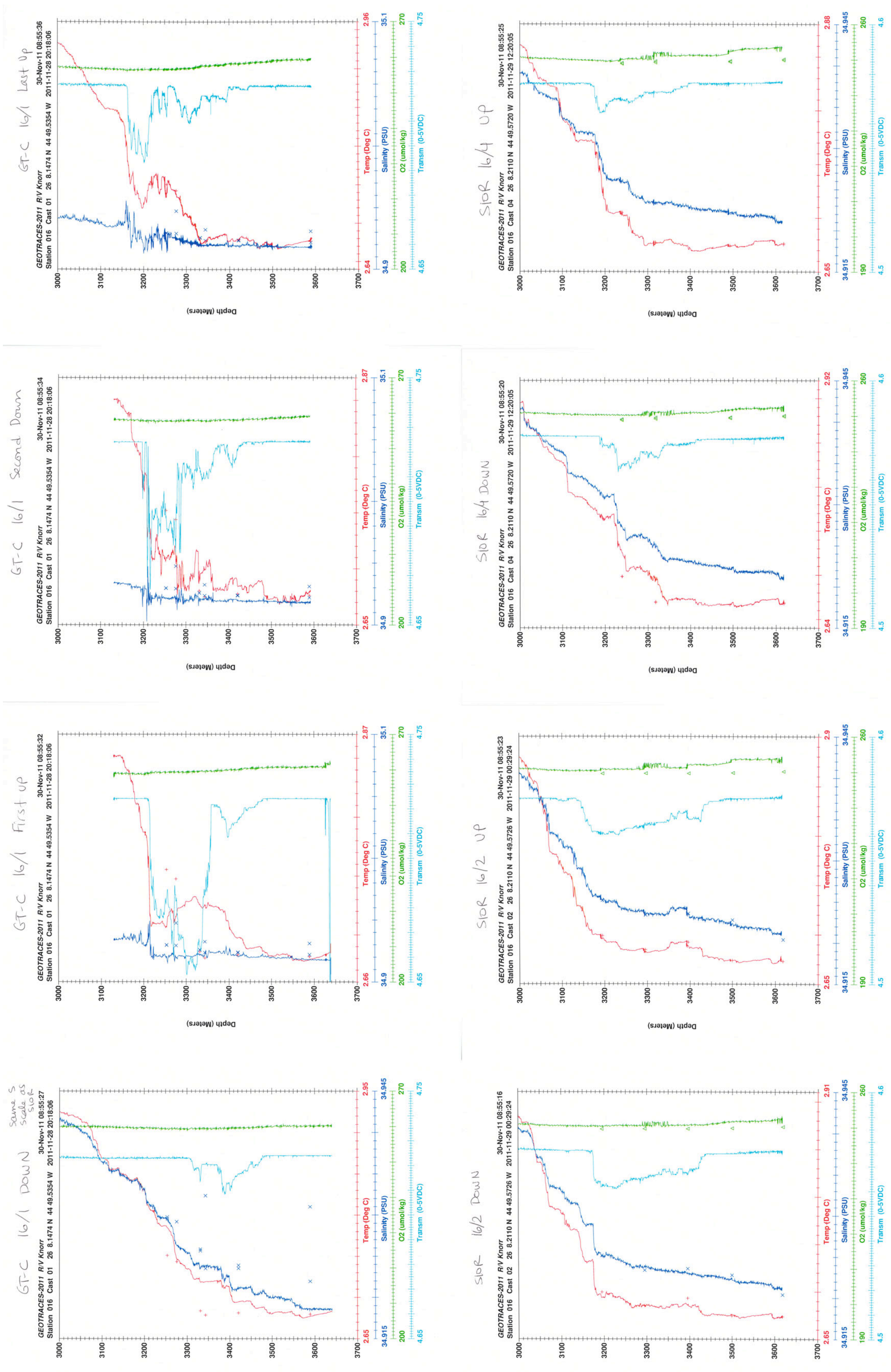
After a much-appreciated rest day during the Bermuda port stop (Friday morning, November 18, for the purpose of unloading some samples, and taking on fuel and food), we resumed our work on Saturday morning, November 19. The day began with news that the -20°C freezer van compressor had an electrical short, but after a brief return to the dock it was established that no spare parts or repair would be possible on short notice, so we steamed to Station 9 (BATS) to continue science work on the assumption that we could steam back to Bermuda after the station if a freezer van repair option became available. As it developed, there was no viable freezer van repair or replacement option, so we then continued steaming along the cruise track as planned with hopes that the van would survive the trip (with a backup of other science freezers and the ship's galley's freezer). The crew found that the problem was a short in one of the fans that blow air across the cooling coils into the freezer van, and that the compressors themselves were functioning. By minimizing access to the freezer van, a single fan proved adequate until the ship returned to Woods Hole.

Stations 9-15 were carried out as planned with no surprises. Station 9 was at the BATS site and represents the trifecta as a re-occupation station (from the 2008 GEOTRACES IC 1 cruise), a crossover station (with the Netherlands meridional section), as well as a forming a connection to ongoing BATS time-series observations.

Station 16 was sited at TAG hydrothermal field at coordinates provided by Peter Rona, and we spotted the hydrothermal plume on first (deep) GTC cast. This was very exciting, but during this first cast we also banged the GTC onto a small basalt glass peak that did not show on Knudsen sonar scan or SeaBeam (the basalt glass identification was established by rock fragments embedded into the GTC powder coating upon returning to the deck). Some repairs were required on some sensors and the upper Ti harness was bent, but the GTC was restored to full functioning by the next station. The hydrothermal plume was clearly evident as a chocolate brown layer on the pump cast sample. The transmissometers encountered the plume eight times (on two down and up cycles of the GTC on the first cast, and two down and up casts of the ODF rosette. The plume transmission was variable in intensity and depths between these encounters, no doubt a result of the extreme near-field siting.

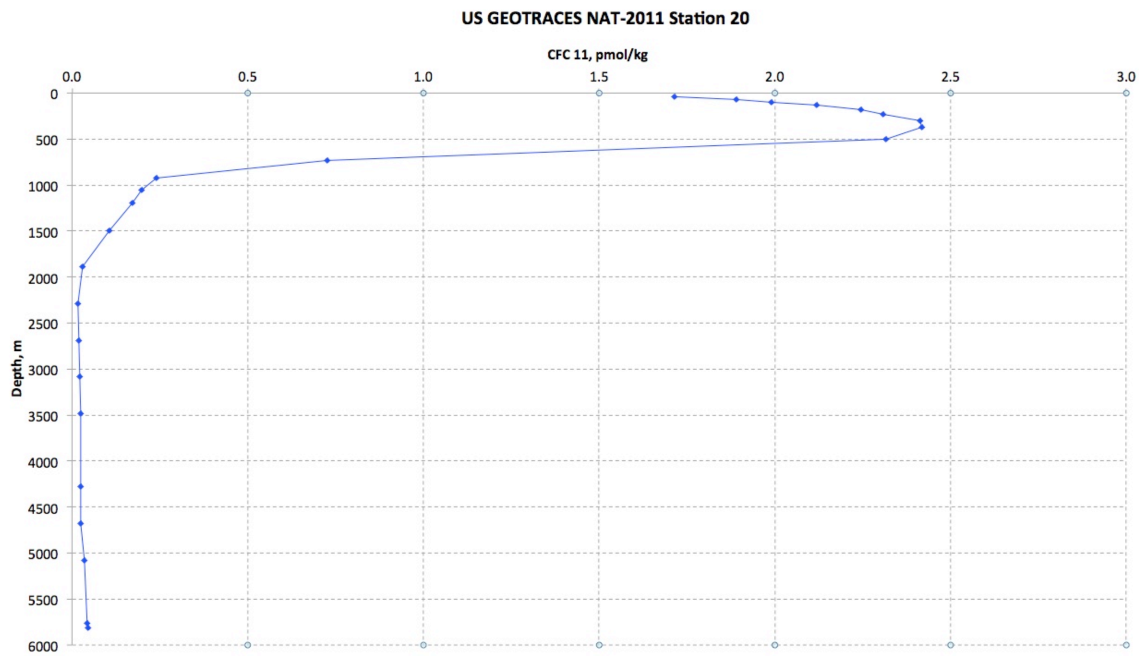
We should also note that out of concern that the hydrothermal plume might contaminate the GOFlo samplers, we used 12 "B" (reserve) team GOFlos for the plume GTC cast.

Figure 3. CTD casts through TAG hydrothermal plume. Top row: GTC casts; down and up casts from a single deployment. Bottom row: ODF casts, down and up casts from two deployments.



At our deepest station in the eastern basin (station 20), Eugene Gorman observed a small but significant increase in CFC-11 in the nearest bottom samples (detectable at 5100m, but higher at 5700m, figure 4) . This station was south of the eastward expression of the Kane Fracture Zone (figure 1) and these higher CFC-11 concentrations must reflect transport of a component of a relatively recent bottom water component formed within the past 6 decades, perhaps through that fracture zone or perhaps through the Vema Fracture Zone to the south (McCartney ref.).

Figure 4: Plot of CFC-11 at Station 20. Measurements were made by Eugene Gorman of Bill Smethie's laboratory. Data are preliminary and may change by as much as 1-2%. Note the significant rise in concentration near the bottom (5940 m).



The rest of the stations went well with no particular surprises, although we had a problem on the station 22 pump cast where a messenger hung up on worn Vectran® pump cable and would have run into the shiv were it not for the sharp eyes of Amy Simoneau ,who stopped the winch just in time.

We finished the cruise with station 24 at the TENATSO time series site, providing an overlap with both an ongoing time series as well as our US-GT-NAT-2010 cruise from the previous year.

Sampling and Analysis Accomplished:

Not counting test casts for mechanical evaluation and rinsing of bottles, a total of 39 casts were made with the GEOTRACES carousel, and 65 ODF-Niskin rosette casts were completed. For the former system, 924 salinity and nutrient measurements were made for evaluation of bottle integrity, calibration check on the CTD, and generation of property profiles. For the latter casts, >773 oxygen, nutrient and salinity samples were drawn and analyzed for similar reasons. In addition, 100 nutrient, salinity and oxygen samples were drawn from the deep pump cast Niskin bottles. Having this data nearly real- time after the analyses were completed was a real boon to the chief scientist, as it provided rapid assessment of sampling quality and strategies.

Reports on sampling activities and individual groups participating in the cruise:

(1) GEOTRACES carousel sampling: The Cutter (ODU) group provided the GEOTRACES sampling system, including the Dynacon winch with 7800m of Kevlar cable with conductors, A-frame, clean lab, and Seabird carousel/CTD with 24 12L GO-Flo bottles (and 14 spares). Peter Morton (FSU), Jessica Fitzsimmons (MIT) and Randelle Bundy (SIO) were the "super technicians" in charge of the trace element sampling logistics with assistance from Rachel Shelley, while Ed Boyle and Greg Cutter were in charge of the overall operation. In total, 39 hydrocasts were conducted and 2 GO-Flos per depth were triggered, one for filtration with 0.2µm Pall Acropak-200™ Supor® capsule filters and one for 25mm membrane filtration (Supor, 0.4 µm). An average of 17 sample bottles were filled from each Acropak-filtered GO-Flo, and 6 from the membrane-filtered GO-Flo. The membranes were then stored for subsequent particle analyses by Ben Twining (Bigelow Lab) and Bill Landing (FSU). For the 21 stations occupied, this represented the acquisition of 8940 trace element samples! Shipboard analyses of Al, Fe, and Zn indicated multiple sporadic (e.g., not confined to a single GO-Flo or element) contamination events in the first 2 stations, but with very few questionable results.

Table 2: GTC samples

Number of Samples	Size (ml)	Property	P.I.
488	125	Fe, Al, Mn, Zn	Measures & Hatta
623	60	Total & reactive Co	Saito & Noble
470	2000	Hg & Hg speciation	Lamborg
187	125	Nanomolar nutrients	Cutter
434	425	Fe speciation	Buck
35	425	Fe speciation	Bundy
336	850	Cu speciation	Moffett & Jacquot
924	500	Salinity	ODF
924	30	Nutrients	ODF
370	125	Fe	Sedwick
350	60	Fe(II)	Sedwick
350	125	Multi-element trace metal	Landing
584	1000	Fe, Mn, Cu, Cd, Zn	Wu
74	1000	Zr, Hf, Nb, Ta	Orians & McAlister
350	500	Al, Sc, Ti, Mn, Fe, Co, Ni, Cu, Zn, Ga, Cd, Pb	Bruland & Smith
115	500	Total As, As(III), monomethyl and dimethyl As	Cutter
38	60	Os	Sharma
288	150	N- and O-isotope analysis of NO3	Casciotti
48	300	Shipboard Zn analysis for contam.	Boyle & Carrasco
27	500	Zn speciation	Boyle & Carrasco
376	2000	Total Pb, Pb isotopes	Boyle
82	500	Total Pb, Pb isotopes, demi stations	Boyle
28	1000	Cr(total) and Cr(III) isotopes	Boyle
1492	30	Fe colloids	Boyle & Fitzimmons
12	1000-2000	Fe colloid isotopes	Boyle & Fitzimmons
350	125	Mn, V, REE, Ga	Shiller
38	500	Ti	Murray
931	1000	Fe isotopes	John
465	2000-8000	Particulate samples for trace metals	Twining

(2) Sampling on the ODF (30 liter Niskin) rosette was performed for non-contamination prone elements and compounds. Filtered samples for non-contamination prone elements were collected from the ODF Niskin rosette (12 x 30L Niskin bottles) using AcroPak 500 filter cartridges with a Supor 0.45/0.8µm membrane attached to Teflon-lined Tygon tubing. The samples for radioactive and radiogenic isotopes (Th, Pa, Nd, Pb, Po, Pu) were acidified with 6 N hydrochloric acid (optima grade: Pa, Th, Nd; trace-metal grade: Pb, Po, Pu) to a pH of ~2 within two hours of collection. These samples were parafilmed, double-bagged, and stored in pallet boxes. In addition to depths from the ODF casts, 5 L filtered samples were taken for the Th/Pa and Nd isotopes groups from the towed surface fish at stations for which this sampling system was available. All samples for nitrogen isotopes were frozen at -20°C. At three stations (1, 10, 16), we separated 15mL from 14-16 the Th-Pa samples into 50mL centrifuge tubes containing an Amicon Ultra centrifugal filter insert (UltraCel - 10K) and centrifuged the samples for 20 mins at 3,500 rpm. The filter inserts were then removed and the centrifuges capped and parafilmed. These filtrates were acidified with 60 µl of 6 N optima grade hydrochloric acid and will be analyzed for colloidal 232Th.

TABLE 3. ODF rosette samples

Number of Samples	Size (ml)	Property	P.I.
339	500	Dissolved inorganic carbon & alkalinity	Millero & Bates
335	500	^{13}C and ^{14}C	Quay
58		O_2/Ar	Quay
431	50	$^{3}He/^{4}He$, dissolved He, Ne	Jenkins
433	1000	^{3}H	Jenkins
773	30	Nutrients	ODF
774	250	Dissolved oxygen	ODF
796	500	Salinity	ODF
432	500	CFCs and SF6	Smethie
344	25	^{18}O in H_2O	Coleman
24	100	^{17}O in H_2O	Luz
333	125	Hg Thiols	Hammerschmidt
333	30	Ba concentration	McManus
298	5000	^{232}Th, ^{230}Th, ^{231}Pa, ^{232}Th colloids	Anderson, Edwards, Moran, Robinson, Pahnke, Scher, Goldstein
298	5000	Nd isotopes	Anderson, Edwards, Moran, Robinson, Pahnke, Scher, Goldstein
238	5000	Rare Earth Elements	Anderson, Edwards, Moran, Robinson, Pahnke, Scher, Goldstein
81	20000	^{210}Pb, ^{210}Po	Church
154	2000	Si isotopes	Brzezinski
107	20000	^{239}Pu, ^{240}Pu, ^{137}Cs, ^{237}Np	Kenna
120	4000	HPLC pigments	Hooker
385	4000	^{234}Th	Buesseler
385	20	^{238}U	Buesseler
96	500	flow cytommetry, metagenomic and qPCR	Chisholm
107	2000	NIF-H RNA analysis	LaRoche
333	60	^{15}N-NO_3	Casciotti/Sigman

(3) Pumped Sampling of size-fractionated suspended particulate matter: Size-fractionated suspended (<51 micron) and sinking (>51 micron) particulate matter was collected via dual-flowpath in situ pumps at fourteen stations, up to 16 depths per station. The dual flowpath design allowed simultaneous collection of particles on quartz fiber *(QMA)* filters for particulate organic carbon and other analyses and on Supor (polyethersulfone) filters for trace element, isotopic, and biogenic silica analyses. Typical volumes filtered were ~1100L through the quartz filter and ~500L through the Supor filter over a 4 hr pumping period. Filters were processed at sea using trace-metal clean techniques in a clean space. All filters were photographed, misted lightly to remove salts, subsampled for distribution to groups that required fresh samples, and the remainder dried for later subsampling and analysis on land. QMA filters were dried at 60°C overnight, and supor filters were dried at room temperature overnight in a laminar flow hood and then frozen at -20°C to retard potential aging of amorphous oxyhydroxides.

Particle subsamples were or will be distributed to nine groups for analysis of major particulate phase composition (Lam) proteins (Saito), and a broad suite of particulate trace elements and isotopes including e_{Nd} and rare earth elements (Pahnke, Scher, Goldstein), $^{231}Pa/^{230}Th$ AND ^{232}Th (Anderson, Edwards, Moran, Robinson), ^{234}Th AND ^{228}Th (Buesseler), Pu/Cs/Np (Kenna), Hg (Lamborg and Hammerschmidt), $^{210}Pb/^{210}Po$ (Baskaran, Church, Stewart), Fe isotopes (John), Bioreactive trace metals (Twining), and total and acid leachable trace metals (Lam).

Table 4: Some samples collected from the McLane casts

Number of Samples	Size (ml)	Particulate Property	P.I.
150		>53 μm 234Th	Buesseler
222		1-53 μm 234Th	Buesseler
100	500	Pump Niskin salinities	ODF
100	30	Pump Niskin nutrients	ODF

(4) Underway trace element clean towed fish sampling: As part of the U. S. GEOTRACES North Atlantic project Professor Ken Bruland's research group was funded to deploy our surface tow-fish (the GeoFish) for the collection of 0.5 liter samples to provide high resolution data along surface transects between and upon arrival at the vertical stations for assaying a suite of contamination prone trace metals (Sc, Ti, Mn, Fe, Co, Ni, Cu, Zn, Ga, Cd, and Pb) in the dissolved (<0.2µm filtered) and unfiltered, weak acid dissolvable (at pH 1.7), phases in surface sea water. Geoffrey Smith was responsible for operating the GeoFish for the collection of our surface samples every two hours during transit between stations. We also were funded to obtain 0.5L samples from each depth of the GEOTRACES rosette vertical profiles as part of a library for future studies and to assay the superstation profile samples for this suite of trace metals to complement the vertical U.S. GEOTRACES profile data obtained by others. Smith provided four hundred sixty two (462) 0.5L bottles for the vertical profile samples to the GEOTRACES sampling team and performed onboard acidification for long term preservation of these samples and those collected for Mukul Sharma. Smith also periodically collected a subset of filtered surface samples between stations for Bill Landing and Alan Shiller. In addition to these samples, Smith supplied large volumes of 0.2µm filtered surface water for Ana Aguilar-Islas and Bill Landing's, and Phoebe Lam's groups for aerosol and particulate leaching experiments respectively.

During the U.S. GEOTRACES North Atlantic 2011 cruise from Woods Hole to the Cape Verde Islands, Nov. 6 to Dec. 11, 2011, Smith performed one hundred and twelve GeoFish sampling events and collected the following samples:

Table 5: Surface trace metal clean "fish" samples

Number of Samples	Size (ml)	Property	P.I.
108	500	Total As, As(III), monomethyl and dimethyl As	Cutter
6	4000	HPLC pigments	Hooker
112	500	Al, Sc, Ti, Mn, Fe, Co, Ni, Cu, Zn, Ga, Cd, Pb	Bruland & Smith
61	125	total dissolvable trace metals	Bruland & Smith
106	50	nutrients	ODF
31	500	salinity	ODF
39	125	Nanomolar nutrients	Cutter
13	125	Multi-element trace metal	Landing
13	125	Mn, V, REE, Ga	Shiller

(5) The coupled biogeochemistries of arsenic and phosphate. Arsenic and phosphorus are chemically and biochemically very similar, so much so that arsenate (AsV) is toxic to phytoplankton due to its substitution in ATP, effectively decoupling energy metabolism. This toxicity is therefore a function of arsenic's chemical speciation, but also the arsenate:phosphate ratio; in oligotrophic waters where phosphate concentrations drop below 10 nmol/L , arsenate is > 10 nmol/L and toxicity is a problem. However, many phytoplankton are able to ameliorate As toxicity by reducing arsenate to arsenite (AsIII) and/or methylating it to mono (MMAs) and dimethyl As (DMAs); these compounds are non-toxic to phytoplankton. Interestingly, in these same conditions of low phosphate phytoplankton are already experiencing P stress or even limitation, so it is possible that reduced and methylated As can function as markers/tracers of P stress. On the transect to date the coupled biogeochemical cycling of As and P were examined by determining the concentrations of reactive phosphate and nitrate+nitrite continuously (every 30 sec) along the cruise track from pumped and filtered"clean towed fish" using colorimetry and liquid core waveguides. Arsenic speciation (total inorganic, arsenite, MMAs, and DMAs) was also determined every 2 hours along the track, together with assays of alkaline phosphatase activity at 6 hour intervals, both from tow fish samples.

(6) Aerosol and Rain Sampling: Aerosol and rainfall samples were collected on the GEOTRACES North Atlantic section cruise (cruise KN204-01) using three high-volume aerosol samplers and two automated rain samplers. Aerosols were collected on acid-cleaned Whatman-41 (cellulosic) filters (for inorganic trace elements and isotopes – TEIs) and pre-combusted quartz microfiber (QMA) filters (for organic species, Hg, and nitrogen compounds). One sampler was equipped with a 5-stage Sierra-style slotted cascade impactor to collect size fractionated aerosols (from >7µm to <0.49 µm). With collaboration from researchers around the world, the 24-hour integrated aerosol samples, and event-based rain samples, will be analyzed for a large suite of TEIs. All aerosol samples will be analyzed for ultra-pure water soluble, seawater soluble, and total (residual) TEIs. The rain samples will be analyzed, both filtered and unfiltered, to quantify the soluble and particulate TEI concentrations. Air mass back-trajectories for all sampling days have been modeled using the NOAA HYSPLIT program. The seawater and ultra high purity (UHP) water aerosol solubility samples will be analyzed at Florida State University for Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb using a shore-based, off-line column extraction method prior to determination by high- resolution magnetic sector ICPMS using isotope dilution.

Replicate samples were obtained from 16 additional aerosol collections (13 x 47mm Whatman-41 filters per collection), and a subset of these replicates were leached on board using instantaneous and slow leaching protocols. The slow leaching protocol uses large volumes (~15 L) of filtered surface seawater, and compares concentrations of iron from leached and unleached filters. The instantaneous leaches were performed with filtered surface seawater (200 ml) and with Milli-Q water (200 ml), and leachates were collected for the analysis of size fractionated iron (<0.02um, and

<0.4um), redox speciation and organic speciation of iron. Organic speciation analysis will be carried-out by Kristen Buck (BIOS) as part of a collaborative study.

In total twelve slow leaches (each in triplicate) and fourteen instantaneous leaches (in duplicate) were carried out on board with freshly collected aerosols (N. American, maritime and N. African origin) and freshly collected filtered surface seawater. Surface seawater was obtained from the UCSC surface sampler (GEOFish). Fourteen instantaneous leaches with Milli-Q water were carried out on replicate filters Filters not leached onboard were frozen and will be taken back to the lab for subsequent leaching and/or analysis of totals. Solutions from leaches and digestions will be analyzed at the University of Alaska Fairbanks.

(7) Fe speciation: A total of 460 samples were collected on the second leg of the cruise: 434 from the full and super station depth profiles (all depths) and 26 from the seawater leaches of aerosols collected by Dr. Ana Aguilar-Islas (University of Alaska, Fairbanks), 12 sets of seawater leaches of collected aerosols, and their associated seawater blanks, will be analyzed for dissolved Fe speciation. Final Fe speciation data (ligand concentrations and conditional stability constants) from station profiles and aerosol leaches will be worked up when dissolved Fe totals are finalized.. All leg 2 samples for Fe speciation were stored frozen (-20º C) following collection. Roughly half of these samples were offloaded during the port stop in Bermuda; the remainder will be retrieved during the R/V Knorr offload scheduled 27 December 2011 in Woods Hole, MA.

(8) Mercury: The Lamborg and Hammerschmidt groups were funded to receive samples from the various sampling systems, conduct on board determinations of 4 dissolved Hg species and also preserve samples for analysis back on shore (dissolved and particulate thiols and particulate Hg species). The mercury group sent two participants on the US GEOTRACES North Atlantic cruise, including Katlin Bowman, a Master's Student at Wright State University and PI Hammerschmidt. This fieldwork contributes to Ms. Bowman's thesis research, and analysis of the preserved thiol samples will comprise WHOI PhD student Tristan Kading's generals project. The mercury group occupied a UNOLS fleet 20' van outfitted with ceiling HEPA units. The space worked well and suited their needs. In the future, a clean van may not be necessary if they could include equipment to make the space adequately clean. Inside, Bowman and Hammerschmidt operated two Hg species analysis systems, one for mono- and dimethylmercury and the other for total and elemental Hg. The particulate samples will be analyzed for total and monomethylmercury at Wright State, while the thiols will be determined at WHOI.

(9) Particulate Analysis: Samples for Synchrotron X-ray Fluorescence (SXRF) and ICP-MS analyses were collected at 23 stations during the GEOTRACES North Atlantic Section cruise. At each station, unfiltered water samples (250 mL) were taken for SXRF samples from the GEOTRACES GO-Flo rosette from the surface mixed layer and the deep chlorophyll maximum layer. Cells were preservation with 0.25% trace-metal clean buffered glutaraldehyde and centrifuged onto C/formvar-coated Au and Al TEM grids. Using an inverted Leica microscope, transmitted light (differential interference contrast) and chlorophyll autofluorescence images of the cells were collected along with X,Y,Z coordinates on the grids. One-hundred eighty-five grids were prepared for analysis. Bulk particulate samples were collected at each depth sampled using the GEOTRACES GO-Flo rosette. The filtration was performed directly from pressured GO-Flo bottles onto membranes (25mm Supor 0.45µm polyethersulfone) which were mounted in Swinnex polypropylene filter sandwiches. An average of 8.5L of water was filtered through each membrane. Four-hundred sixty-five samples are being stored for analysis via ICP-MS. Before 10 of the stations, bulk particle samples were collected from surface waters with the towed fish. Water from the fish was collected in a 10-L acid-washed carboy and distributed among three, 4L carboys. These were pressurized with 0.2-µm filtered air to force water through replicate 25-mm Supor 0.45µm membranes held in Swinnex polypropylene filter sandwiches. At each station, one of the three replicate filters was oxalate soaked then rinsed with chelexed NaCl, the other two filters remained untreated. These replicate filters will be used to compare methods for isolating trace elements in biogenic particulate matter at a later date.

(10) Copper Speciation: To measure Cu speciation, Jeremy Jacquot used an electrochemical method called competitive ligand exchange adsorptive cathodic stripping voltammetry (CLE-ACSV), which allows one to determine the concentration of organic ligands binding free Cu (Cu^{2+}) and their binding strength. In order to calculate [Cu^{2+}], I will need to find [Cu_T] by using isotope dilution with an inductively coupled plasma mass spectrometry (ICP-MS) system at USC. In total, he obtained 336 850-milliliter filtered samples from the GEOTRACES rosette (125 ml for the totals analysis with ICP-MS and 725 ml for the speciation work) and 96 500-milliliter samples for the Chisholm filtration work.
(11) **Al, Fe, and Mn onboard measurements:** Sampling for dissolved Al, Fe, and Mn was accomplished using 12 L GO-FLO bottles on the GEOTRACES 24 place rosette. The University of Hawaii group (Measures and Hatta) performed shipboard determinations on subsamples of water taken from these bottles collected using an Acropak filter by the subsampling team. Dissolved trace elements were determined on samples drawn at each of the 11 stations where the GEOTRACES rosette was deployed. Additionally, surface samples were also collected arriving on or departing from station from the UCSC towed fish. In addition, a limited number of samples was collected between stations by this means. In total trace element determinations were made on 249 discrete samples. Data generated onboard were submitted to the shipboard data assembly system and each parameter on each subsample was assigned a quality flag. Dissolved Al, Fe and Mn were determined on these water samples using Flow Injection Analysis. Precisions of each method were established by replicate determination of the same sample at the beginning of a day's run the values were typically: approximately 2% for Al at 10nM; 2% for Fe at 1 nM, and ~ 4% for Mn at 1 nM. In addition to the shipboard determinations 1L samples were collected for shore-based ICPMS determinations of dissolved and dissolvable Fe, Mn, Zn and Cd, by isotope dilution by co PI J. Wu, (University of Miami). These samples were acidified on board, within a few hours of collection. Ultrafiltration of 25 samples was also performed at station 5 for subsequent shore-based determination of the colloidal fraction at the University of Miami.
(12) Cobalt Analysis: The Saito/Noble group collected samples from all GTC casts, and all arriving-on-station Towfish samples, totaling 239 samples. All of these were preserved by storage in a gas-tight sealed bag containing an oxygen scrubber. The samples will be analyzed onshore for total dissolved cobalt after a UV oxidation step using adsorptive cathodic stripping. In addition to total dissolved

cobalt, all samples will be analyzed for labile cobalt after an equilibration period with the electroactive ligand, dimethylglyoxime, using adsorptive cathodic stripping voltammetry.
(13) Radium Isotopes: Radium Isotopes: To measure the quartet of radium isotopes (^{224}Ra, ^{223}Ra, ^{228}Ra and ^{226}Ra) to quantify horizontal and vertical transport of dissolved trace elements and isotopes (TEIs), as well as shorter lived thorium isotopes: ^{234}Th and ^{228}Th, used to quantify particle scavenging, vertical fluxes and remineralization rates of bioactive and/or particle reactive TEIs. At all 14 full and super stations a 16 point in situ pump profile was carried out. Eight pumps were deployed for an upper water column shallow pump cast and then turned around to be deployed again for a lower water column deep pump cast. The pumps were hung on a 3/8" plastic coated Vectran line and were programmed to pump for 4 hours, which typically pumped a total of 1500-1700 l of seawater. The pumps used were modified McLane in situ pumps, which were outfitted to accommodate 2 * 142 mm filter heads containing different filter types (see cruise report by Dan Ohnemus). After water had passed through the dual filter heads the streams were joined passed through a MnO_2 impregnated Cuno acrylic cartridge filter for scavenging dissolved radium and thorium isotopes. Three flow meters at various points along the pump plumbing allowed accurate determination of water filtered. After recovering the cartridges from the pumps, they were rinsed with radium-free fresh water to remove salt and then dried to dampness before measurement of the short-lived radium isotopes on board the ship. ^{224}Ra ($t_{1/2}$ = 3.7 d) and ^{223}Ra ($t_{1/2}$ = 11.4 d) were measured on the Radium Delayed Coincidence Counter (RaDeCC) system and were typically measured <24 h after sample collection. All the Cuno cartridge samples for radium were taken and

processed by Paul Morris. The scavenging efficiencies of the Cuno cartridge filters for radium and thorium will be validated by a discrete seawater sample taken in parallel with every pump depth sampled. For shallow pump depths this sample was taken from the niskin rosette and for the deep pump casts a 30 l Niskin bottle was hung next to each pump and triggered with a messenger. For ^{226}Ra, 20-25 l of seawater was passed over a column of MnO_2 impregnated acrylic fiber, which is known to remove radium at 100% efficiency. These samples were bagged and will be analyzed for ^{226}Ra through it daughter, ^{222}Rn back in the lab at WHOI. For details of ^{234}Th determination refer to the ^{234}Th cruise report by Stephanie Owens. Stephanie was responsible for taking both the ^{226}Ra and the ^{234}Th samples, and she is processing the ^{234}Th samples. In total 224 MnO_2 cartridge samples were taken, with 224 corresponding ^{226}Ra calibration samples.

At 21 stations (14 full and super stations + 7 demi stations) a surface for radium was collected from a high volume deck pump. 390 l of filtered seawater was rapidly collected into barrels and then subsequently passed through MnO_2 acrylic fiber for determination of all 4 radium isotopes. These samples were processed in a similar manner to the MnO_2 cartridges for short-lived radium isotopes while on board ship. Sampling was carried out by Stephanie Owens and Paul Morris and shipboard analysis was done by Paul Morris. 21 surface samples were taken in this way.

***(14)* Thorium-234 and -228**: On the GEOTRACES 2011 Atlantic Leg, Stephanie Owens and Steve Pike were responsible for the collection and processing of samples for ^{234}Th and ^{228}Th. At each regular and super station, samples for total ^{234}Th were collected from a 30L shallow Niskin cast and Niskin bottles attached to the wire during deep pump casts. All sample processing and preliminary sample analysis by beta counting was completed on board, a requirement because of the short half-life of ^{234}Th (24.1 days). At regular and super stations, 21-point profiles were collected with 16 of those depths matching the *in situ* pump depths while the additional depths were used to obtain higher resolution through the euphotic zone. A surface sample was collected using a pump located on the port side of the ship. At demi-stations, 13-point profiles were collected from the shallow Niskin cast and the surface pump. In all 385 samples (4 L each) were collected for total ^{234}Th at 5 super stations, 9 full stations, and 8 demi-stations. Archive samples for ^{238}U (20 mL) were concurrently collected with all ^{234}Th samples.

Samples for particulate ^{234}Th and ^{228}Th were obtained from the in situ pump casts. Specifically, material from 53 µm screens was rinsed onto silver filters and counted for ^{234}Th (all shallow screens were counted, while deep screens were only counted at super stations, n = 150). All QMA filters (n = 222), shallow and deep, were sub-sampled for ^{234}Th, which was counted immediately while the remainders of the filters were stored for ^{228}Th analysis on shore. These samples will also be analyzed for their organic carbon content in order to determine ^{234}Th/POC ratios. This ratio can be used to estimate the POC export flux based on the ^{234}Th flux determined by the total ^{234}Th measurements described above. The combined measurement of ^{234}Th and ^{228}Th will be used to obtain insight into particle dynamics taking place in the water column.

(15) Biogeotraces Sampling: Jeremy Jacquot collected filters from 12 stations for the Chisholm group that will be used to conduct flow cytommetry and qPCR analyses. He also collected filters for metagenomic samples from 7 stations. Ed Boyle collected 96 samples for the La Roche group and performed reduced-pressure filtration. These samples were kept frozen at -70°C and then shipped to Kiel.

(16) CFC and SF_6 Sampling: was done on deep and shallow Niskin casts at each regular and super-station (for a total of 24 depths per station) and the Niskin cast at all demi-stations (12 depths per station). Samples were analyzed on board and the data reported to the ODF data manager and made available to cruise participants. A total of 432 samples were taken and analyzed.

(17) Tritium and helium sampling: Tritium and ^3He sampling were done on all regular, super-, and demi-stations. A total of 431 ^3He and 433 tritium samples were taken. The ^3He samples were taken in crimped copper tubing and the tritium samples were stored in pre-cleaned, argon-filled 1 liter flint glass bottles.

(18) NASA Sampling: the Cutter group collected 120 four-liter particulate samples that were stored frozen for pigment analyses by the NASA lab of Stan Hooker.

(19) Compilation of samples taken and associated metadata: was accomplished during the cruise by assembling all CTD cast information, cast sheets, and event logs and entering them into a database. ODF staff member Mary Johnson was responsible for this task and for quality checking and merging the relevant information. As a consequence, we have a complete record of all samples taken on the cruise, and their relationship to critical metadata parameters (time, location, etc). Bottle data have been compared to the sensor records in order to check instrument calibration and to establish bottle integrity against pre/post tripping and leakage. The hydrographic data (temperature, salinity, oxygen, nutrients) have been quality controlled and merged into a relational database for use by cruise participants. This data was available in near-real time to cruise participants. For example, CTD data was usually available for plotting within an hour or two of the cast, and the discrete hydrographic measurements (oxygen, nutrients, and salinity) were available within a day or two of the station.

Lessons Learned:

We learned that the experience from the intercalibration cruises and the previous year's cruise have honed the US GEOTRACES team into an efficient and reliable system.

We learned that it would be wise to have an altimeter installed on the GTC to avoid crashing into the bottom, as we did twice with the Knudsen/CTD depth method despite trying to stay 20-30m above the bottom. This is a budget item for the Pacific cruise, so it will be achieved on future US GEOTRACES cruises.

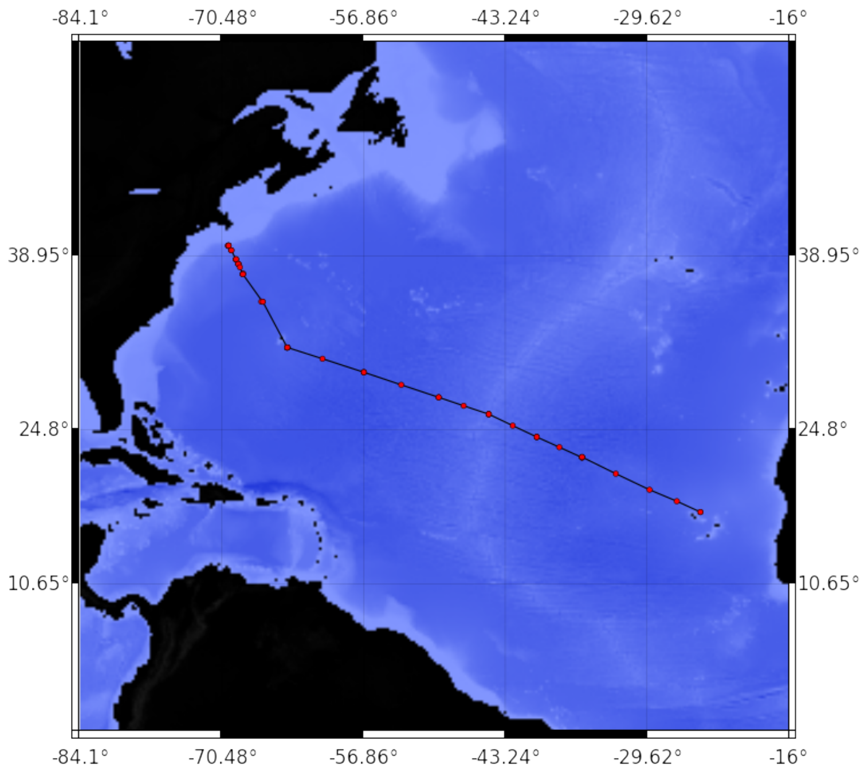
We learned that because of the multiple deep casts for full and super GEOTRACES stations, it is important to incorporate surface current strength into the cruise planning process because its consequences for time spent steaming back to station. On this cruise, we had not planned for this loss of time. Station 6 in the Gulf Stream was the most problematical. That factor combined with bad weather resulted in us being six hours short of station time on the WHOI to Bermuda leg, and hence the cancellation of two demi stations.

We learned that it will be important to treat the Vectran cable (used for the McLane pump casts) more carefully, namely by using a winch that can level-wind the cable rather than spaghetti-wind it. Damage to the cable on this cruise resulted in a stuck messenger, loss of some appropriate Niskin samples to match the pumps, and could have resulted in driving the messenger through the shiv which would damage it and could have been a major safety hazard.

Final Note: We can safely regard this effort as a success. There were a lot of moving parts in the GEOTRACES machinery, and things worked remarkably well. All this was down to a group of motivated, hard working, and cooperative scientists that worked together well. Shipboard science support techs Anton Zafereo and Amy Simoneau performed their duties exceptionally well. It should also be said that the Knorr's crew were extraordinarily helpful and went out of their way to make this a safe and productive cruise. We are grateful to Captains Kent Sheasley (KN204-01A) and Adam Seamans (KN204-01B) for their efforts and hospitality.

CRUISE REPORT: GT11

(Updated OCT 2013)



Highlights

Cruise Summary Information

WOCE Section Designation	**GT11**
Expedition designation (ExpoCodes)	**316N20111106**
Chief Scientists	**Dr. Edward Boyle / MIT/WHOI**
Dates	2011 NOV 06 - 2011 DEC 11
Ship	*R/V KNORR*
Ports of call	Woods Hole, MA - Praia, Cabo Verde
Geographic Boundaries	39° 42' 5" N 69° 51' 52" W 24° 30' W 17° 24' N
Stations	22
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	

GEOTRACES 2011

R/V Knorr, KN204A/B

06 November 2011 - 11 December 2011

Woods Hole, MA - Praia, Cabo Verde

Chief Scientist: Dr. Edward Boyle

Woods Hole Oceanographic Institution

Co-Chief Scientist: Dr. Gregory Cutter

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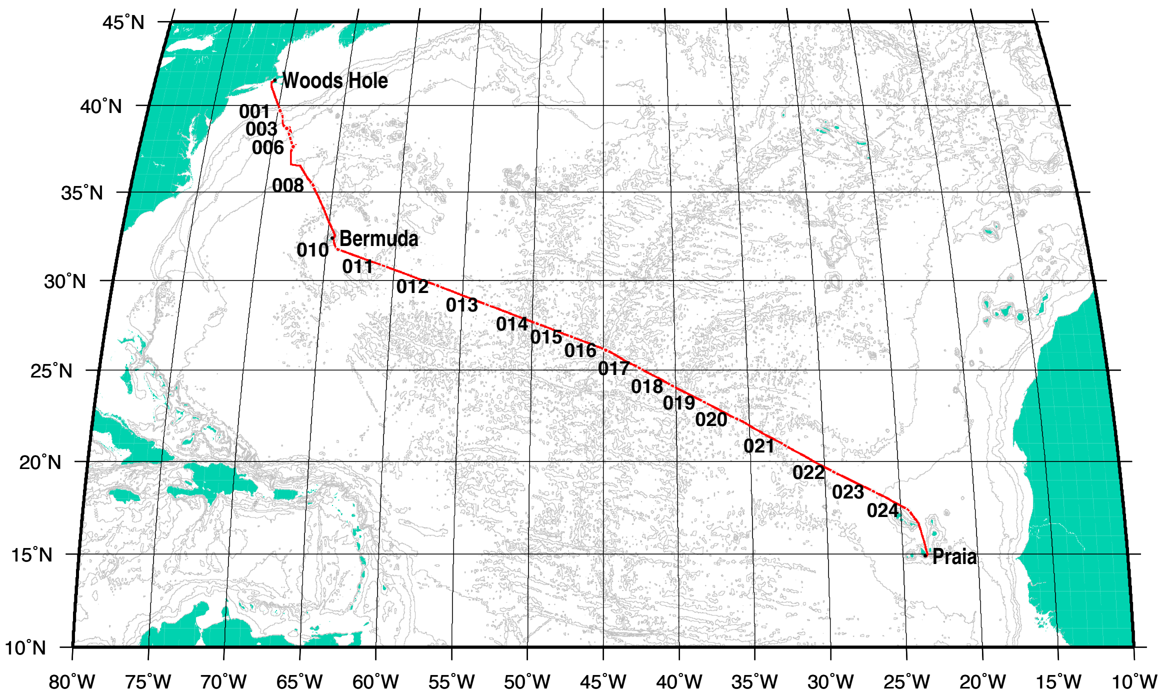

STS Cruise Report
11 December 2011

Data Submitted by:

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Summary

A hydrographic survey consisting of rosette/CTD sections and Bio-Optical casts in the mid-latitude eastern Atlantic Ocean was carried out during November-December 2011. The R/V Knorr departed Woods Hole, MA on 6 November 2011. The cruise ended in Praia, Cabo Verde on 11 December 2011.

Introduction

A sea-going science team gathered from 14 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed below.

Principal Programs of GEOTRACES 2011

ODU/15L GoFlo CTDO/Rosette			
Program	Affiliation*	Princ. Investigator	email
CTD/Rosette Data NanoMolar Nutrients As Sb Se AP	ODU	Gregory Cutter	gcutter@odu.edu
Salinity Nutrients	UCSD/SIO	James H. Swift	jswift@ucsd.edu
Mercury	WHOI	Carl Lamborg	clamborg@whoi.edu
Fe Al Mn Zn	UH	Chris Measures	chrism@soest.hawaii.edu
Mn V Ga REE	USM	Alan Shiller	alan.shiller@usm.edu
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Fe Colloids	MIT RSMAS	Ed Boyle Jingfeng Wu	eaboyle@mit.edu jwu@rsmas.miami.edu
Cobalt	WHOI WHOI	Mak Saito Abigail Noble	msaito@whoi.edu anoble@whoi.edu
Fe Fe(II)	ODU	Peter Sedwick	psedwick@odu.edu
Fe Speciation L1/K1 L2/K2	BIOS	Kristen Buck	kristen.buck@bios.edu
Dissolved Trace Metals: Al Cd Co Cu Ga Fe Pb Mn Ni Sc Ag Ti Zn	UCSC	Ken W. Bruland	bruland@ucsc.edu
Particulate/Cellular Trace Metals: Al P Mn Fe Co Ni Cu Zn Cd Element Analysis of Phytoplankton	BLOS	Benjamin Twining	btwining@bigelow.org
Dissolved/Particulate Trace Metals: Mn Fe Co Ni Cu Zn Cd Pb	FSU	William Landing	wlanding@fsu.edu
Dissolved Trace Metals: Fe Al Zn Cd Mn	RSMAS	Jingfeng Wu	jwu@rsmas.miami.edu
Copper, Copper Speciation	USC	James Moffett	jmoffett@usc.edu
d ^{56}Fe d ^{57}Fe	SC	Seth John	sjohn@geol.sc.edu
Osmium	DART	Mukul Sharma	mukul.sharma@dartmouth.edu
Titanium	BU/URI	Rick Murray	rickm@bu.edu
Zirconium Hafnium	UBC UBC	Jason McAlister Kristin Orians	jmcalist@eos.ubc.ca korians@eos.ubc.ca

* Affiliation abbreviations listed on page 5

SIOR/30L Niskin CTD/Rosette			
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CTD/Rosette Data diss.O_2 Salinity Nutrients On-Board Data Website Data Management	UCSD/SIO	James H. Swift	jswift@ucsd.edu
CFCs SF_6	LDEO	William Smethie	bsmeth@ldeo.columbia.edu
$^3He/^4He$ diss.He ^3H, Ne	WHOI	William Jenkins	wjenkins@whoi.edu
^{14}C ^{13}C	UW WHOI/NOSAMS	Paul Quay William Jenkins	pdquay@u.washington.edu wjenkins@whoi.edu
DIC Total Alkalinity	RSMAS BIOS	Frank Millero Nick Bates	fmillero@rsmas.miami.edu nick.bates@bios.edu
$^{18}O-H_2O$	INETI UChicago	Antje Voelker Albert Colman	antje.voelker@ineti.pt asc25@uchicago.edu
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^{234}Th ^{238}U	WHOI	Ken Buesseler	kbuesseler@whoi.edu
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DNA comp. of N-fixing organisms	IFM-G	Julie LaRoche	jlaroche@ifm-geomar.de
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^{210}Po ^{210}Pb	UDEL	Thomas M. Church	tchurch@udel.edu
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Plutonium	LDEO	Bob Anderson	boba@ldeo.columbia.edu
17O-O2 OxyArgon	UW	Paul D. Quay	pdquay@uw.edu
O17Delta	HUJ	Boaz Luz	Boaz.Luz@huji.ac.il

* Affiliation abbreviations listed on page 5

McL-Prof McLane *in situ* Pump Profiles			
Program	Affiliation*	Princ. Investigator	email
SBE19 CTD Data ^{234}Th ^{238}Th	WHOI	Ken Buesseler	kbuesseler@whoi.edu
Radium Isotopes	WHOI SC	Matthew Charette Willard S. Moore	mcharette@whoi.edu moore@geol.sc.edu
Particulate Th Pa	LDEO URI UMN WHOI	Robert F. Anderson Brad Moran Larry Edwards Laura Robinson	boba@ldeo.columbia.edu moran@gso.uri.edu edwar001@umn.edu lrobinson@whoi.edu
Particulate/Cellular Trace Metals: Al P Mn Fe Co Ni Cu Zn Cd	BLOS	Benjamin Twining	btwining@bigelow.org
Particulate Trace Metals: Fe Aa Mn Cd Cu Zn POC $CaCO_3$ bSi	WHOI	Phoebe J. Lam	pjlam@whoi.edu
Particulate ^{210}Pb ^{210}Po	WSU	Mark Baskaran	ag4231@wayne.edu

* Affiliation abbreviations listed on page 5

Towed Surface Fish			
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Particulate/Cellular Trace Metals: Al P Mn Fe Co Ni Cu Zn Cd Element Analysis of Phytoplankton	BLOS	Benjamin Twining	btwining@bigelow.org
NanoMolar Nutrients As AP Se	ODU	Gregory Cutter	gcutter@odu.edu
Dissolved/Particulate Trace Metals: Mn Fe Co Ni Cu Zn Cd Pb	FSU	William Landing	wlanding@fsu.edu
Aerosol-derived Dissolved Fe	UAF	Ana M. Aguilar-Islas	amaguilarislas@alaska.edu
Aerosol Leaching Studies Trace Metal Conc.: Mn V Ga REE	USM	Alan Shiller	alan.shiller@usm.edu
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* Affiliation abbreviations listed on page 5

Miscellaneous Sampling			
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Aerosol Sampler - Dissolved Fe	UAF	Ana M. Aguilar-Islas	amaguilarislas@alaska.edu
Ship's Underway Sensors	WHOI	Knorr SSSG Technicians	sssg@knorr.whoi.edu

* Affiliation abbreviations listed on page 5

Shipboard Scientific Personnel on GEOTRACES 2011

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* Affiliation abbreviations are listed on page 5

KEY to Institution Abbreviations	
BIOS	Bermuda Institute of Ocean Sciences
BLOS	Bigelow Laboratory for Ocean Sciences
BU	Boston University
DART	Dartmouth College
FSU	Florida State University
HUJ	The Hebrew University of Jerusalem - Institute of Earth Sciences
IFM-G	(IFM-GEOMAR) Leibniz-Institut für Meereswissenschaften an der Universität Kiel
IMROP	Mauritanian Institute for Oceanographic Research and Fisheries
INETI	Instituto Nacional de Engenharia, Tecnologia e Inovação (Portugal)
LDEO	Lamont-Doherty Earth Observatory
MIT	Massachusetts Institute of Technology
MPI-B	Max-Planck-Institut für Marine Mikrobiologie, Bremen
NASA	National Aeronautics and Space Administration
NOSAMS	National Ocean Science AMS Facility (WHOI)
ODU	Old Dominion University
PU	Princeton University
SC	University of South Carolina
SSSG	Shipboard Scientific Services Group (WHOI)
STS/ODF	Shipboard Technical Support/Oceanographic Data Facility (UCSD/SIO)
STS/RT	Shipboard Technical Support/Research Technicians (UCSD/SIO)
SIO/GRD	Geosciences Research Division (UCSD/SIO)
UAF	University of Alaska, Fairbanks
UBC	University of British Columbia
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
UCSD/SIO	University of California, San Diego/Scripps Institution of Oceanography
UDEL	University of Delaware
UH	University of Hawaii
UMN	University of Minnesota
UM/RSMAS	University of Miami/Rosenstiel School of Marine and Atmospheric Science
URI	University of Rhode Island
USC	University of Southern California
USM	University of Southern Mississippi
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution
WSU	Wayne State University

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

Two types of rosette/SBE9*plus* CTD casts (65 SIOR/30L-Niskin and 40 GT-C/15L-GoFlo) were made at 22 station locations during GEOTRACES 2011. 13 shallow and 13 deep McLane pump profiles were done at all Full and Super Stations, with an SBE19*plus* CTD attached to the end of the wire.

Station Type	Station Numbers*	Total Casts	Cast Types
Super†	1,10,12,16,20	10-11	1 Shallow/1 Deep GT-C/15L GoFlo 3 Shallow/3 Deep SIOR/30L Niskin 1 Shallow/1 Deep McLane Pump (1 Mid-Depth or "plume" GT-C/15L GoFlo)
Full	2,3,4,6,8,14,18,22,24	6-7	1 Shallow/1 Deep GT-C/15L GoFlo‡ 2 Shallow/1 Deep SIOR/30L Niskin 1 Shallow/1 Deep McLane Pump (1 Mid-Depth GT-C/15L GoFlo)
Demi	5,11,13,15,17,19,21,23	2	1 Shallow GT-C/15L GoFlo 1 Shallow SIOR/30L Niskin

* Stations 7 and 9 were skipped due to time constraints

† Extra GT-C cast on station 10; cast 9 "skipped" on station 12

‡ No GoFlo casts on station 4

Table 1.0 GEOTRACES 2011 Station/Cast Summary

Hydrographic measurements consisted of salinity and nutrient water samples taken from each rosette cast, plus dissolved oxygen from each SIOR rosette cast. In addition, salinity samples were taken from the surface pump at one SIOR *U*/ ^{234}*Th* cast per station, and from Niskins attached to the wire at each deep-cast McLane pump. Pressure, temperature, conductivity/salinity, dissolved oxygen, transmissometer and fluorometer data were recorded from all CTD/rosette profiles. No major problems were encountered during the operation.

The distribution of samples is shown in figures 1.0 and 1.1.

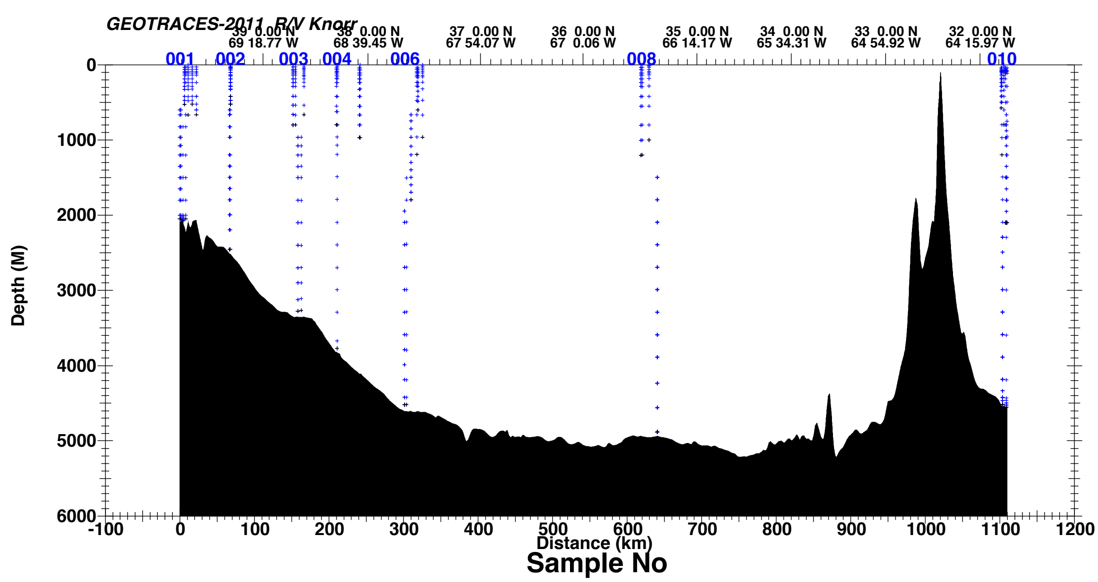

Figure 1.0 GEOTRACES 2011 Sample distribution, Leg 1: stations 1-(10).

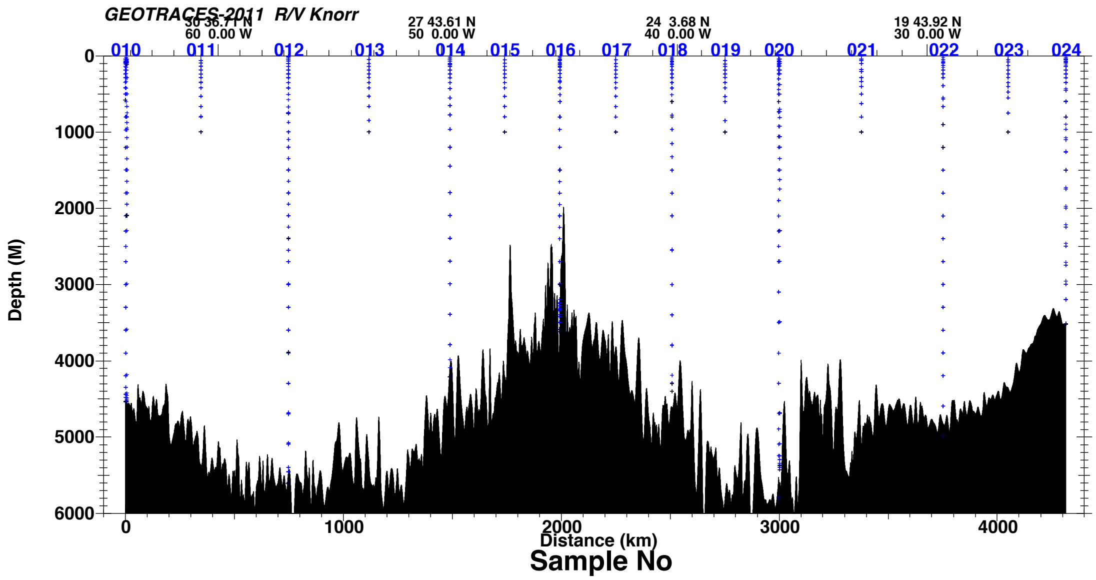

Figure 1.1 GEOTRACES 2011 Sample distribution, Leg 2: stations 10-24.

1.1. SIOR/30L-Niskin Water Sampling Package

SIOR/30L-Niskin Rosette/CTD casts were performed with a package consisting of a 12-bottle rosette frame (SIO/STS), a 24-place carousel (SBE32) and 12 30L General Oceanics bottles with an absolute volume of 30L each. 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 (WET Labs C-Star), fluorometer (Seapoint SCF) and altimeter (Tritech LPRA-200 or Simrad 807). A second dissolved oxygen plus oxygen temperature sensor (JFE Advantech RINKO-III) was incorporated into the data stream for future sensor evaluation; it was not processed for this cruise.

The CTD was mounted horizontally in an SBE CTD cage attached to and centered on the bottom of the rosette frame, allowing free flow of water to the temperature sensor. The SBE3*plus* temperature, SBE4C conductivity and SBE43 dissolved oxygen sensors and their respective pumps and tubing were mounted horizontally in the CTD cage. The transmissometer was mounted horizontally, and the fluorometer was mounted horizontally near the bottom of the rosette frame. The altimeter was mounted on the inside of the bottom frame ring.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated at the beginning of GEOTRACES 2011. The R/V Knorr's Markey DESH-5 winch was used for all casts.

The deck watch prepared the rosette 5-15 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, the rosette was moved out from the forward hangar to the deployment location under the squirt boom using an air-powered cart and tracks. The CTD was powered-up and the data acquisition system started from the main lab. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. The rosette was unstrapped from the air-powered cart. The winch operator was directed by the deck watch leader to raise the package. The squirt boom was extended outboard and the rosette package was quickly lowered into the water between the Geo-Fish boom and its aft tag line. Rosette tag lines were removed and the package was lowered to 10 meters, until the console operator determined that the sensor pumps had turned on and the sensors were stable. The winch operator was then directed to bring the package back to the surface, re-zero the wireout and start the descent.

Most deep rosette casts were lowered to within 5-25 meters of the bottom, using the altimeter, winch wireout, CTD depth and echosounder depth to determine the distance.

For each up cast, the winch operator was directed to stop the winch at up to 12 pre-determined sampling depths, determined by the GEOTRACES program participants prior to the cruise. To ensure that package shed wake had dissipated, the CTD console operator waited 30 to optimally 60 seconds prior to tripping sample bottles. An additional 10-second wait was required after tripping a bottle before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings. The deck watch leader directed the package to the surface after the last bottle trip.

Recovering the package at the end of the deployment was essentially the reverse of launching, with the additional use of poles and snap-hooks to attach tag lines to the deck mounted air tuggers. The rosette was secured on the cart and moved into the forward hangar for sampling. 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. Only one bottle was changed out during the cruise: rosette position 5 (S/N 5 to S/N 15) was changed out before station 10 cast 6 due to a leaking bottom cap. A piece of plastic debris was later found to be embedded in its o-ring.

Sampling for specific programs was outlined on sample log sheets prior to cast recovery or at the time of collection.

Routine CTD maintenance included soaking the conductivity and oxygen sensors in fresh water between casts to maintain sensor stability, and putting dilute 0.1% Triton-X solution through the conductivity sensors to eliminate any accumulating bio-films. Rosette maintenance was performed on a regular basis. Valves and o-rings were inspected for leaks. The rosette, CTD and carousel were rinsed with fresh water as part of the routine maintenance.

1.2. SIOR Underwater Electronics and Laboratory Calibrations

The SIOR SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 frames/second. The sensors and instruments used during GEOTRACES 2011, along with pre-cruise laboratory calibration information, are listed below. Copies of the pre-cruise calibration sheets for various sensors are included in Appendix D.

Instrument/Sensor	Mfr./Model*	Serial Number	CTD Channel	Pre-Cruise Calibration Date	Facility*
Carousel Water Sampler	SBE32 (24-Pl.)	3231807-0456	n/a		
CTD	SBE9*plus*	09P41717-0831	n/a		
Pressure	Paroscientific Digiquartz 401K-105	831-58952	Freq.2	25-Oct-2011	SIO/STS
Primary					
Temperature (T1)	SBE3*plus*	03P-4907	Freq.0	24-Oct-2011	SIO/STS
Conductivity (C1)	SBE4C	04-2112	Freq.1	14-Sep-2011	SBE
Dissolved Oxygen	SBE43	43-0875	Aux2/V2	09-Sep-2011	SBE
Pump	SBE5T	05-4890	n/a		
Secondary					
Temperature (T2)	SBE3*plus*	03P-4138	Freq.3	28-Oct-2011	SIO/STS
Conductivity (C2)	SBE4C	04-2659	Freq.4	21-Sep-2011	SBE
Pump	SBE5T	05-4374	n/a		
Transmissometer	WETLabs C-Star	CST-491DR	Aux1/V1†	Nov/Dec-2011	Shipboard
Chlorophyll Fluorometer	Seapoint	SCF2758	Aux3/V4†	n/a	Seapoint‡
Altimeter	Tritech LRPA-200	221666	Aux1/V0		
Diss. Oxygen/Oxy Temp. (Experimental)§	RINKO-III ARO-CAV	84	Aux4/ V6+V7	21-Oct-2011	JFE Advantech
Reference Temperature	SBE35RT	3528706-0035	n/a	27-Nov-2011	SIO/STS
Deck Unit (in lab)	SBE11*plus* V2	11P21561-0518	n/a		

* SBE = Sea-Bird Electronics
† Transm. and Fluorm. Channels switched for stations 21-24 only (V1/V4)
‡ Fluorometer used 10x cable
§ Removed for Station 8 and Station 20/Casts 4-11

Table 1.2.0 GEOTRACES 2011 SIO 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 in SBE's manual (*http://www.seabird.com/pdf_documents/manuals/36_015.pdf*).

The SBE9*plus* CTD was connected to the SBE32 24-place carousel providing for single-conductor sea cable operation. The sea cable armor was used for ground (return). Power to the SBE9*plus* CTD (and sensors), SBE32 carousel and Tritech LPRA-200 altimeter was provided through the sea cable from an SIO/STS SBE11*plus* deck unit in the main lab.

1.3. Navigation and Bathymetry Data Acquisition

Navigation data were acquired at 1-second intervals from the ship's C&C Technologies C-Nav DGPS receiver by a Linux system beginning November 4, 2011, starting a few days before the ship departed Woods Hole until after the ship docked in Praia, Cabo Verde on December 11.

12KHz single-beam bathymetric data from the Knudsen 320B Series Black Box were fed realtime into the STS acquisition system and merged with navigation data. Incoming depth data were already corrected for hull depth, and sound velocity values were intermittently adjusted by the SSSG Technicians as the cruise progressed. No additional corrections to the data were applied.

Bottom depths associated with rosette casts were also recorded on the Console Logs during deployments. The automatically recorded Knudsen depths were extracted from the stored navigation data and used for cast event depths. There was a single 16-minute gap in the acquired navigation/bathymetry data (underway between stations 10 and 11) that did not affect station data.

1.4. SIOR CTD Data Acquisition and Rosette Operation

The SIOR CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and two 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 the CTD console and was connected to the CTD deck unit with two RS-232 cables, one feed for the CTD signal and the other a modem channel for carousel communication. The CTD console provided an interface and operational displays for controlling and monitoring a CTD deployment and closing bottles on the rosette. The other workstation was designated as the website and database server, and maintained the hydrographic database for GEOTRACES 2011. Redundant backups were managed automatically. Both PCs were synced with the ship's timeserver on a regular basis to keep accurate UTC time.

SIOR CTD deployments were initiated by the console operator after the ship stopped on station. The acquisition program was started and the deck unit turned on at least 2 minutes prior to package deployment. The 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. 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 had been accomplished.

After the deck watch deployed the rosette, the winch operator lowered it to 10 meters, deeper for heavier seas. 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 (wire-out). The profiling rate was typically 30m/min in the top 100m and 60m/min deeper than 100m, depending on sea cable tension and sea state.

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. The altimeter channel, CTD depth, winch wire-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach to 5-10 meters.

Bottles were closed on the up-cast by operating an on-screen control. The winch operator was directed to slow to 30m/min at 100m above the target depth, then the final wireout was adjusted using the altimeter reading. Bottles were tripped 30-40 seconds after the package stopped to allow the rosette wake to dissipate and the bottles to flush. The winch operator was instructed to proceed to the next bottle stop at least 10 seconds after closing bottles to ensure that stable CTD data were associated with the trip and to allow the SBE35RT temperature sensor to take a measurement at the bottle trip.

After the last bottle was closed, the package was brought on deck. Once the rosette was on deck, the console operator terminated the data acquisition, turned off the deck unit and assisted with rosette sampling.

1.5. SIOR CTD Data Processing

Shipboard CTD data processing was performed automatically at the end of each deployment using SIO/STS CTD processing software v.5.1.6-1. Raw GT-C CTD data and bottle trips, acquired by SBE Seasave V 7.17a on a Windows XP workstation, were also imported into the Linux processing system, providing a backup of the raw data.

Pre-cruise laboratory calibrations were applied, then CTD data were processed into a 0.5-second time series, bottle trips were extracted, and a 1-decibar down-cast pressure series of the data was created. The pressure-series data were used by the web service for interactive plots, sections and CTD data distribution. Time-series data, and eventually basic up-cast pressure-series data, were also available for distribution through the website.

SIOR CTD data were examined at the completion of each deployment for clean corrected sensor response and any calibration shifts. As bottle salinity and oxygen results became available, they were used to refine shipboard conductivity and oxygen sensor calibrations.

Theta-S and theta-O_2 comparisons were made between down and up casts as well as between groups of adjacent deployments. Vertical sections of measured and derived properties from sensor data were checked for consistency.

1.6. SIOR CTD Shipboard Calibration Procedures

CTD #831 was used for all SIOR Rosette/CTD casts during GEOTRACES 2011. The CTD was deployed with all sensors and pumps aligned horizontally, due to limited vertical clearance inside the 12-place/30L rosette. The primary temperature sensor (T1/03P-4907) and conductivity sensor (C1/04-2112) were used for all reported CTD data.

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

1.6.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 831-58952) 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; then the calibration correction slope and offset were applied to the converted pressures during each cast.

An additional -0.3 dbar offset was applied to all SIOR CTD data after evaluating surface air pressures during the first 3 SIOR casts. These 3 casts were re-averaged, and the correction was applied during acquisition for the remaining casts. Pre- and post-cast on-deck/out-of-water residual pressure offsets varied from -0.22 to 0.11 dbar before the casts, and -0.31 to 0.06 dbar after the casts. No further adjustments were required for pressure.

1.6.2. CTD Temperature

The same primary (T1/03P-4907) and secondary (T2/03P-4138) temperature sensors were used during all GEOTRACES 2011 casts. 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 was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a 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 GEOTRACES 2011 was set to internally average over a single 1.1-second period.

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.

A single temperature correction was required for each sensor during GEOTRACES 2011. Both primary and secondary temperature sensors exhibited a linear pressure response compared to the SBE35RT. Offsets for T1 drifted less than 0.0015°C over 5 weeks, and were adjusted as a function of time at the end of the cruise. T2 offsets remained fairly stable with time.

The final corrections for the primary temperature sensor used on GEOTRACES 2011 is summarized in Appendix A. All corrections made to CTD temperatures had the form: $T_{cor} = T + tp_1 P + t_0$

Residual temperature differences after correction are shown in figures 1.6.2.0 through 1.6.2.5.

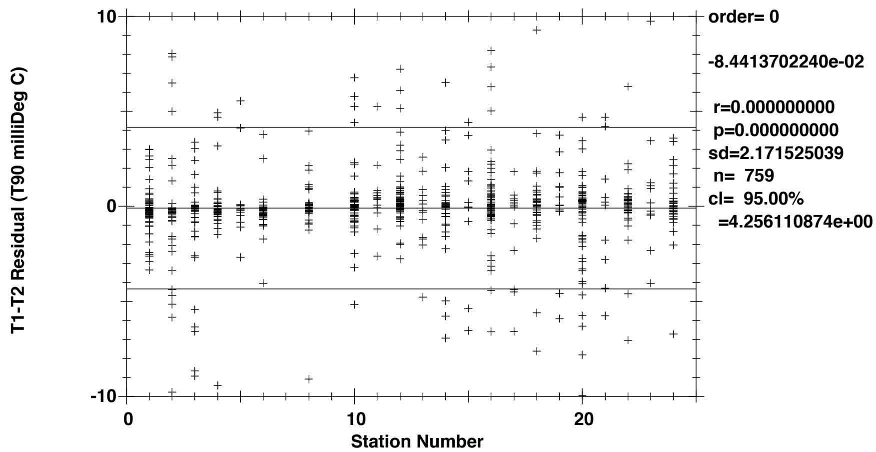

Figure 1.6.2.0 T1-T2 by station (-0.01°C ≤ $T1 - T2$ ≤ 0.01°C).

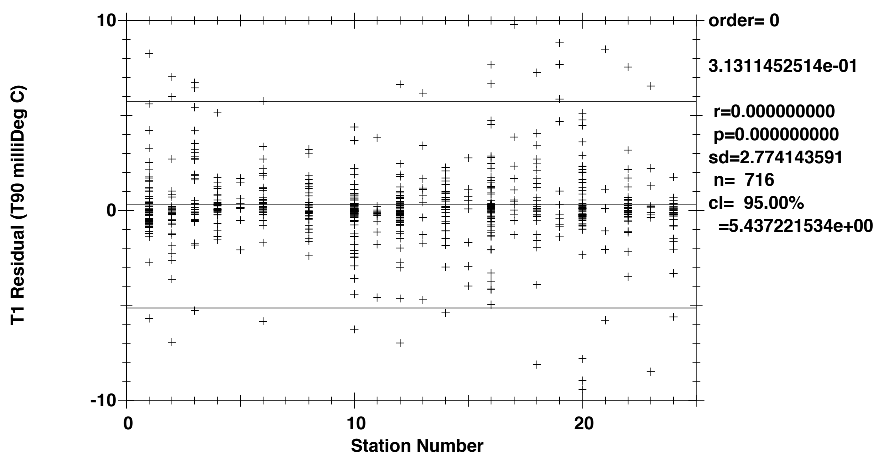

Figure 1.6.2.1 SBE35RT-T1 by station (-0.01°C ≤ $T1 - T2$ ≤ 0.01°C).

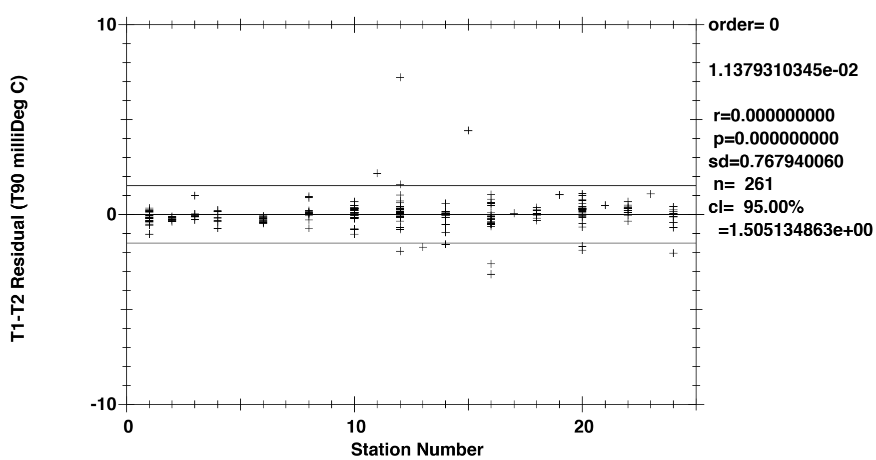

Figure 1.6.2.2 Deep T1-T2 by station (Pressure > 1000dbar).

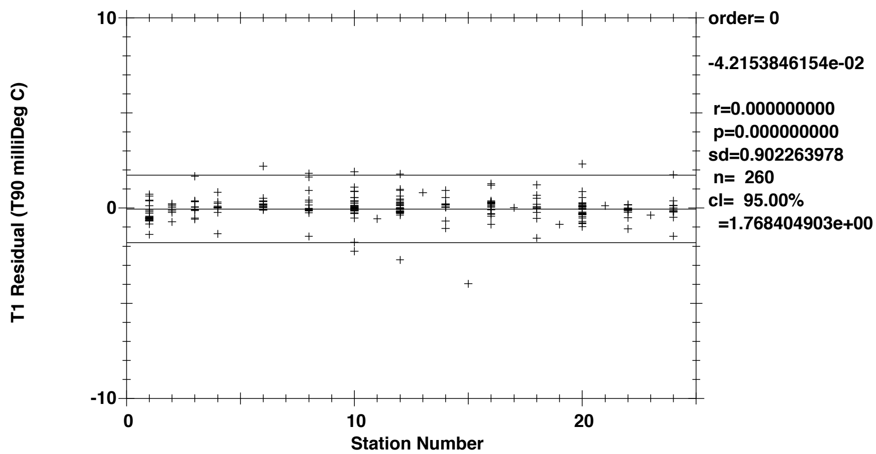

Figure 1.6.2.3 Deep SBE35RT-T1 by station (Pressure > 1000dbar).

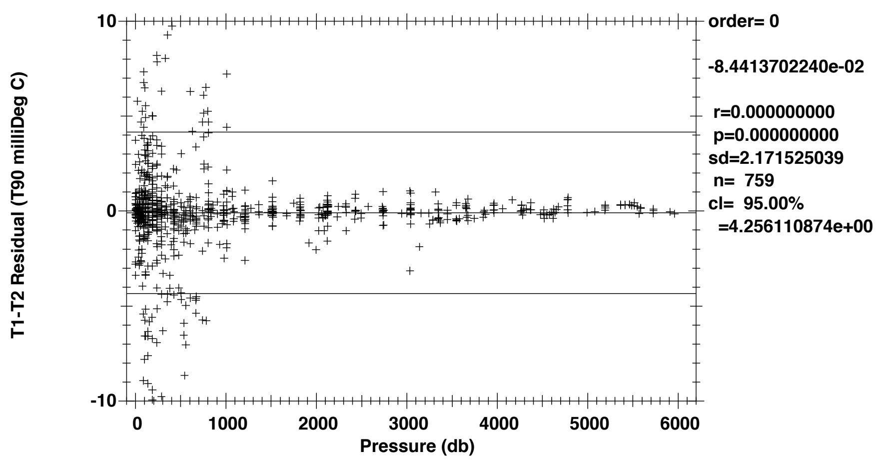

Figure 1.6.2.4 T1-T2 by pressure (-0.01°C $\leq T1 - T2 \leq$0.01°C).

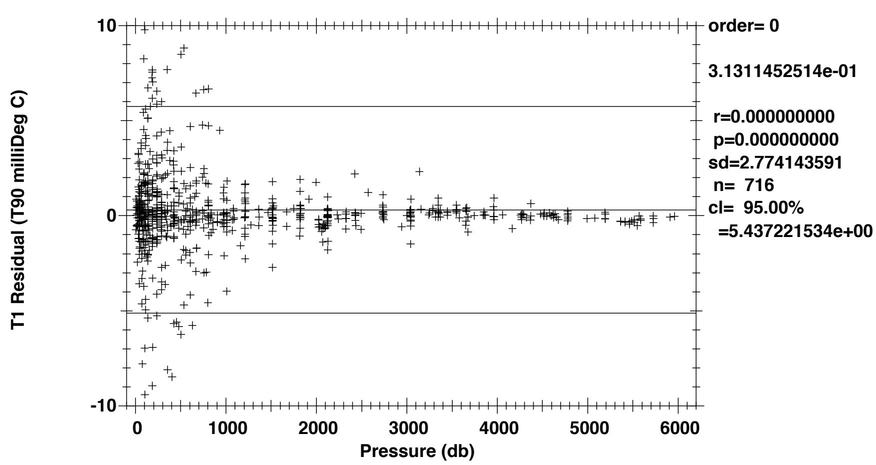

Figure 1.6.2.5 SBE35RT-T1 by pressure (-0.01°C $\leq T1 - T2 \leq$0.01°C).

The 95% confidence limits for the mean low-gradient differences are ±0.0015°C for T1-T2, ±0.0018°C for SBE35RT-T1. The 95% confidence limit for deep temperature residuals (where pressure > 1000dbar) is ±0.0015°C for T1-T2 and ±0.0018°C for SBE35R T-T1.

1.6.3. CTD Conductivity

The same primary (C1/04-2112) and secondary (C2/04-2659) conductivity sensors were used during all GEOTRACES 2011 casts. 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 to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 1.6.3.0.

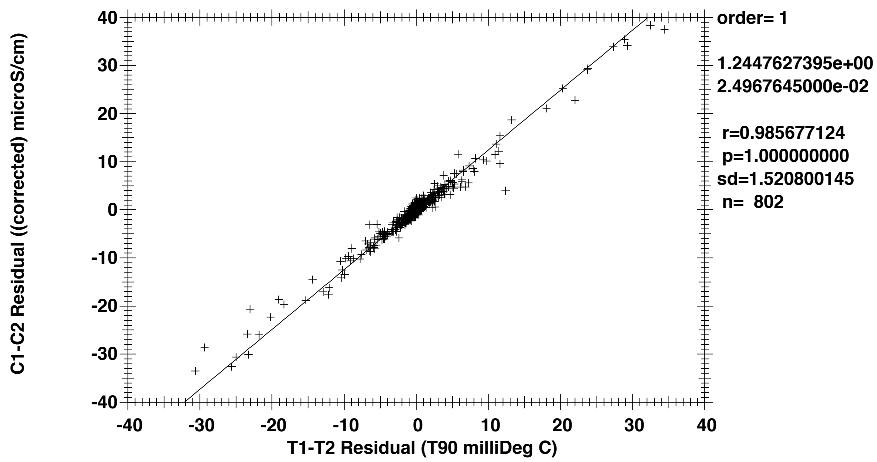

Figure 1.6.3.0 Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.6.3.1 through 1.6.3.3.

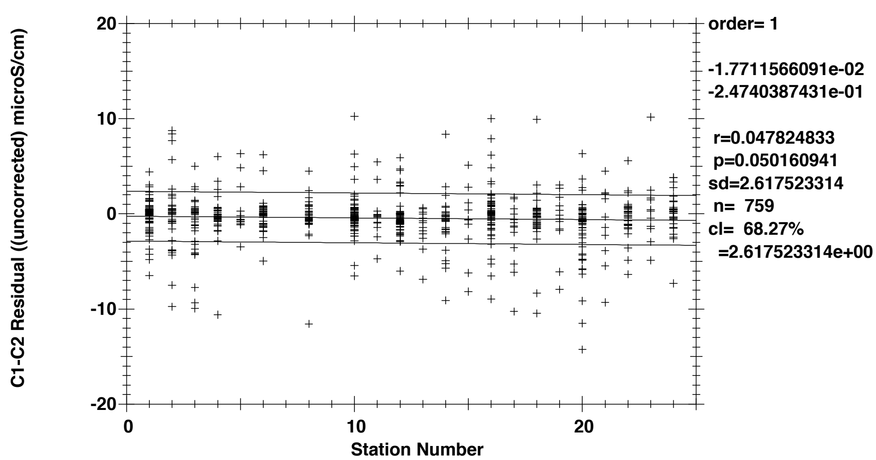

Figure 1.6.3.1 SIOR Uncorrected $C1 - C2$ by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

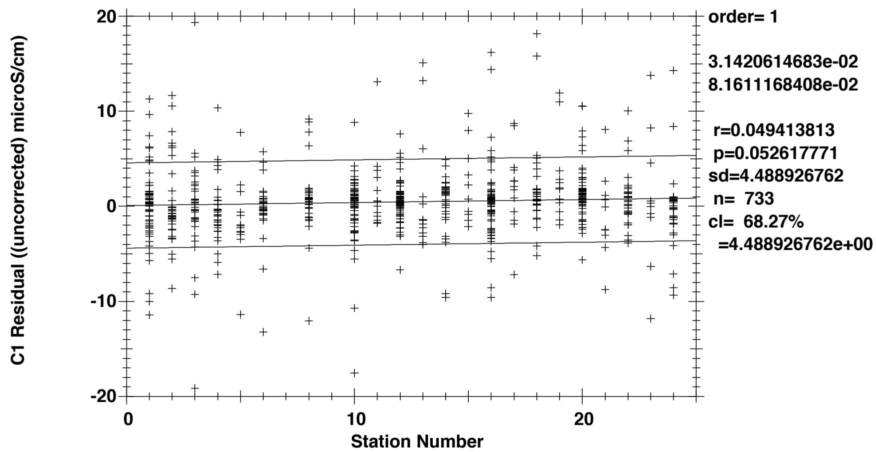

Figure 1.6.3.2 SIOR Uncorrected $C_{Bottle} - C1$ by station (-0.01°C ≤$T1 - T2$≤0.01°C).

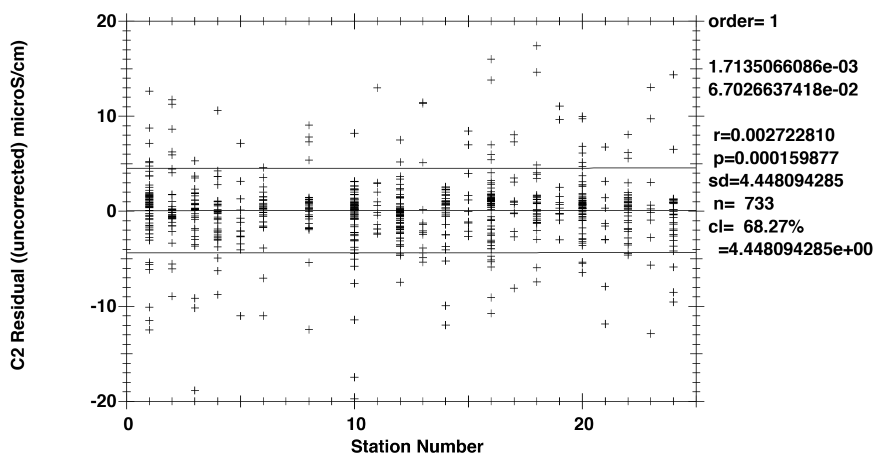

Figure 1.6.3.3 SIOR Uncorrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

Conductivity differences were examined for changes dependent on time, pressure or conductivity. A pressure dependence was observed for C1, and a conductivity dependent response was seen for C2. Linear C1(P) and C2(C) corrections were determined separately, using $C_{Bottle} - C1_{CTD}$ differences for stations 1-14 only, using data at all pressures where T1-T2 differences were within ±0.005°C. These corrections were applied to all SIOR CTD casts on GEOTRACES 2011.

Conductivity and salinity differences were re-examined at the end of the cruise, after the T1 offsets were adjusted. T1 offsets re-aligned the salinity differences, so the conductivity corrections required no change.

The residual C1-C2 and Bottle-C1 differences after correction are shown in figures 1.6.3.4 through 1.6.3.11.

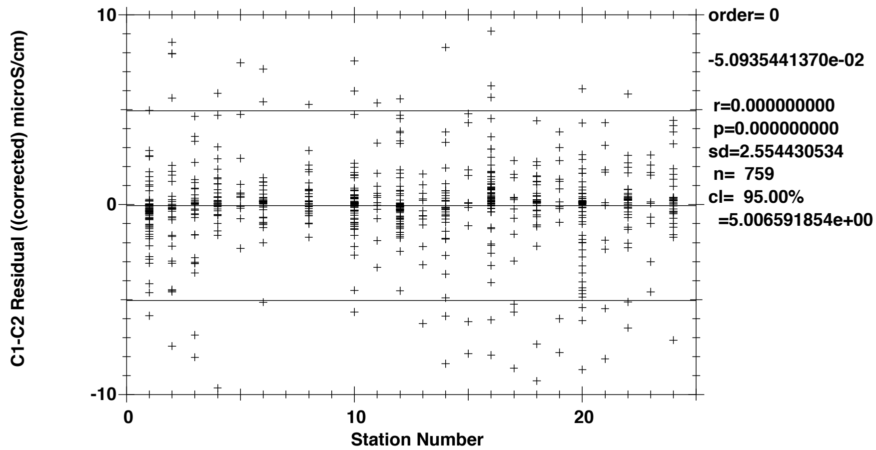

Figure 1.6.3.4 SIOR Corrected $C1 - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

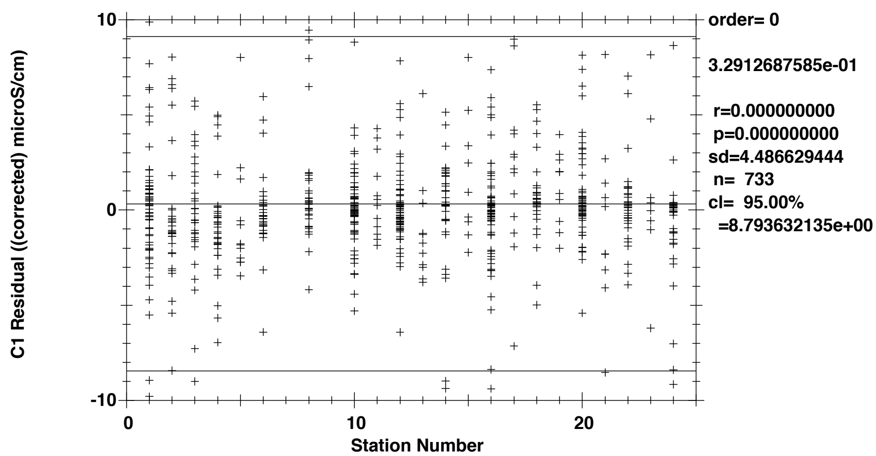

Figure 1.6.3.5 SIOR Corrected $C_{Bottle} - C1$ by station (-0.01°C ≤T1-T2≤0.01°C).

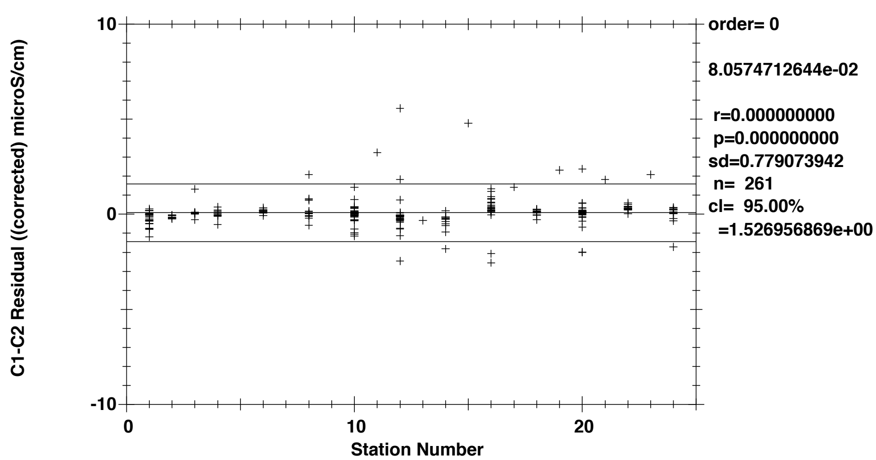

Figure 1.6.3.6 SIOR Deep Corrected $C1 - C2$ by station (Pressure >= 1000dbar).

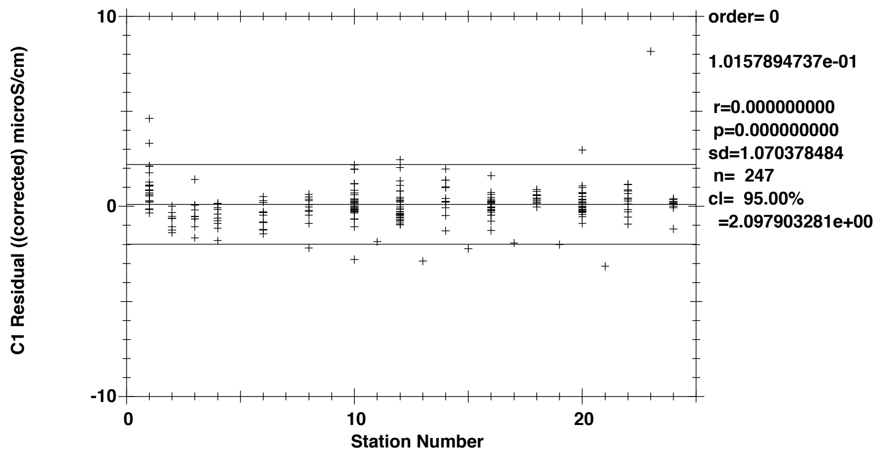

Figure 1.6.3.7 SIOR Deep Corrected $C_{Bottle} - C1$ by station (Pressure >= 1000dbar).

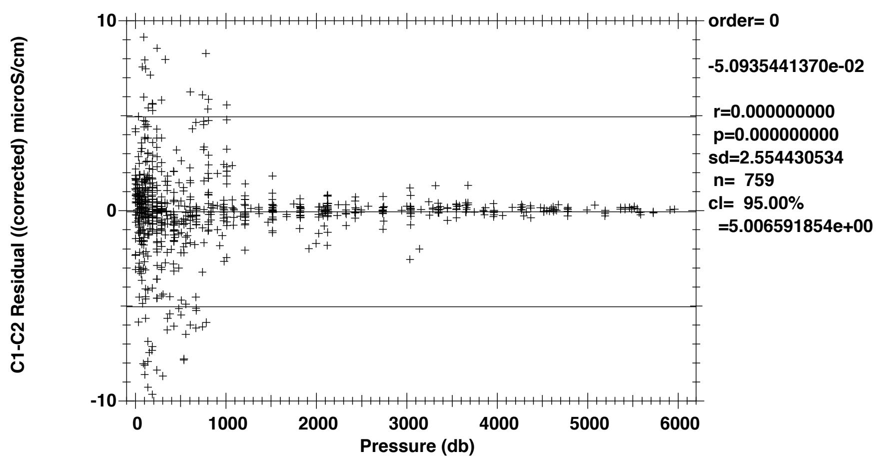

Figure 1.6.3.8 SIOR Corrected $C1 - C2$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

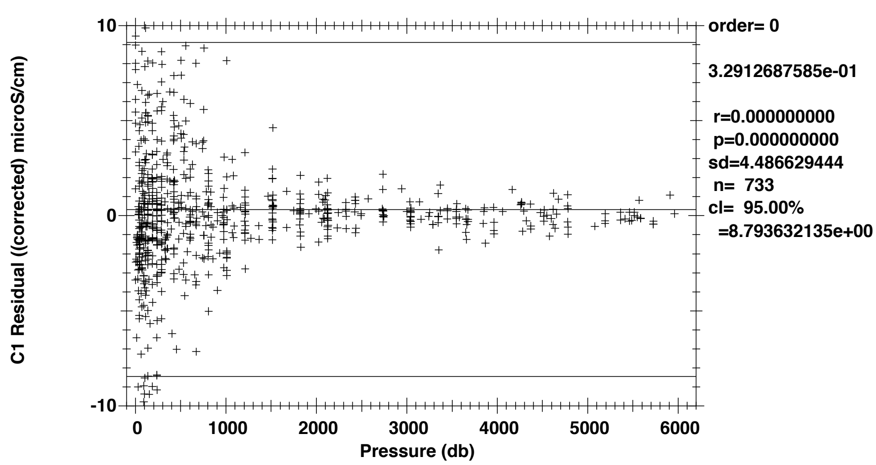

Figure 1.6.3.9 SIOR Corrected $C_{Bottle} - C1$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

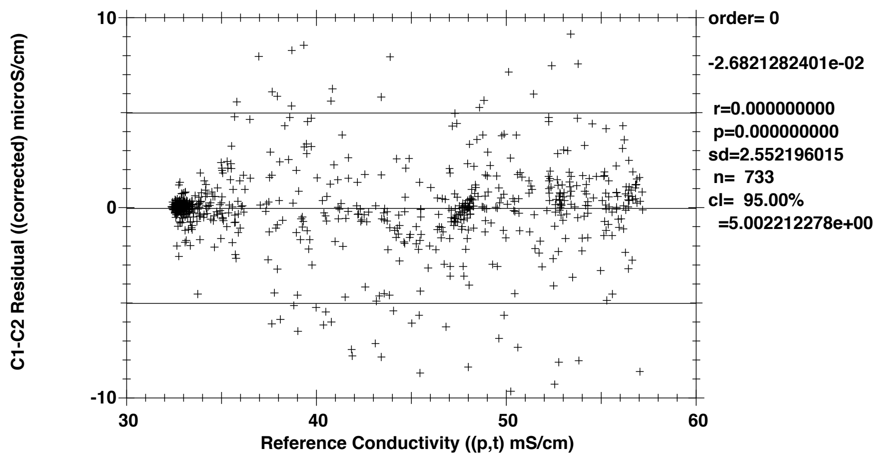

Figure 1.6.3.10 SIOR Corrected $C1 - C2$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

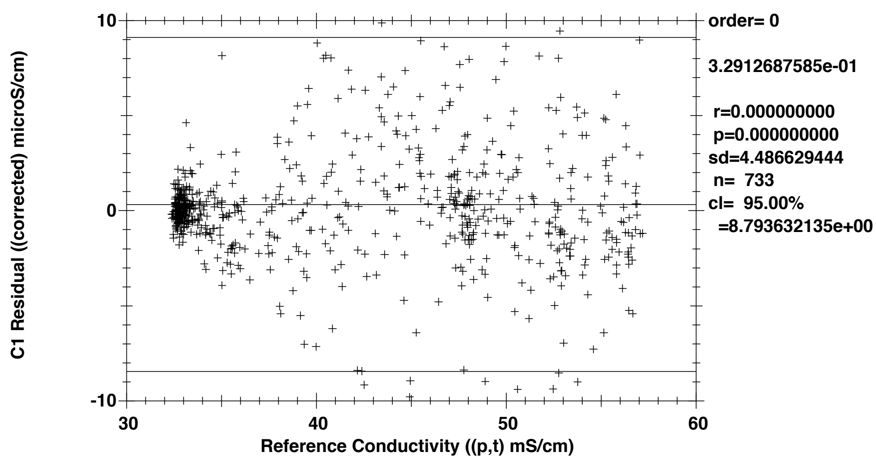

Figure 1.6.3.11 SIOR Corrected $C_{Bottle} - C1$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

Corrections for both SIOR conductivity sensors are listed below:

C1 sensor corrections: $C_{cor} = C + 3.3869e-07 \cdot P - 0.000259$
C2 sensor corrections: $C_{cor} = C - 1.0745e-04 \cdot C + 0.004254$

The final corrections for C1 are also summarized in Appendix A.

Salinity residuals after applying shipboard P/T/C corrections are summarized in figures 1.6.3.12 through 1.6.3.14. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

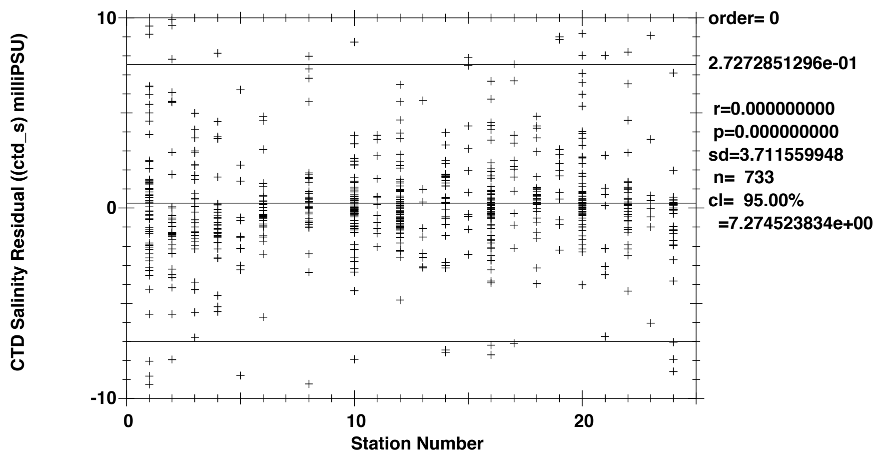

Figure 1.6.3.12 Salinity residuals by station (-0.01°C ≤T1-T2≤0.01°C).

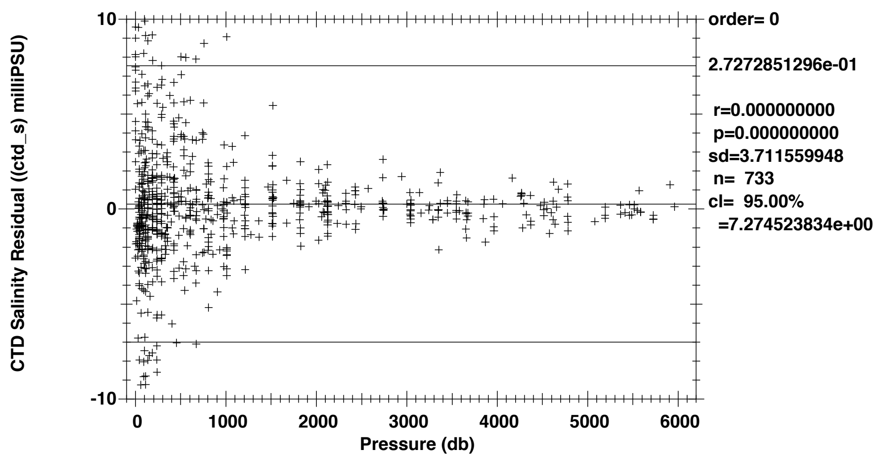

Figure 1.6.3.13 Salinity residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

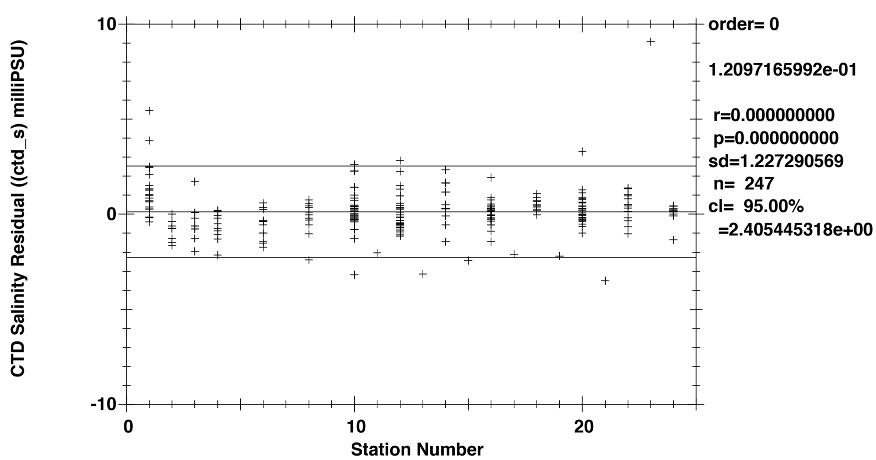

Figure 1.6.3.14 Deep Salinity residuals by station (Pressure >= 1000dbar).

Figures 1.6.3.13 and 1.6.3.14 represent estimates of the salinity accuracy of GEOTRACES 2011. The 95% confidence limits are ±0.0024 PSU relative to bottle salinities for deep salinities, and ±0.0073 PSU relative to bottle salinities for all salinities, where T1-T2 is within ±0.01°C.

1.6.4. CTD Dissolved Oxygen

A single SBE43 dissolved O_2 sensor (DO/43-0875) was used during GEOTRACES 2011. The sensor was plumbed into the primary T1/C1 pump circuit after C1.

The DO sensor was calibrated to dissolved O_2 check 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 check 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. Then casts were fit individually to check-sample data.

GEOTRACES 2011 had numerous casts with deep check samples only. In those cases, shallower sample data from other casts at the same station were used to fit the upper end of the CTDO_2 data.

All casts within a station, and from nearby stations, were examined using plots of Pressure and/or Theta vs O_2 to check for consistency.

Standard and blank values for check sample oxygen titration data were smoothed, and the oxygen values recalculated, prior to the final fitting of CTD oxygen.

CTD dissolved O_2 residuals are shown in figures 1.6.4.0-1.6.4.2.

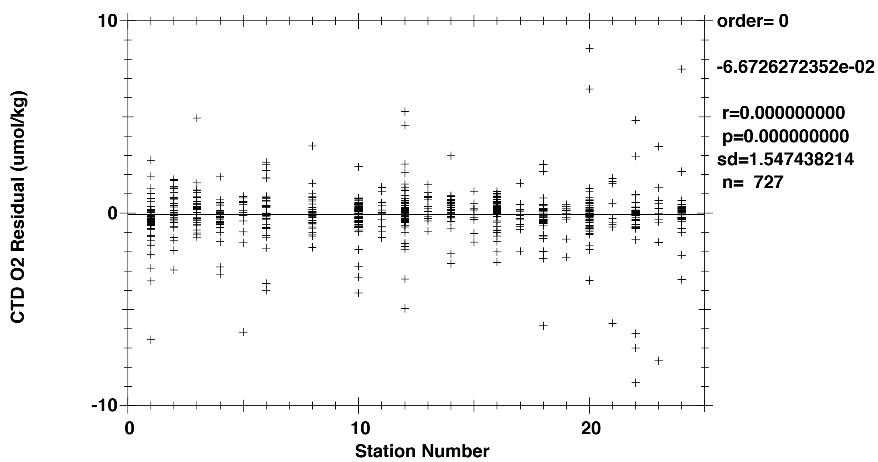

Figure 1.6.4.0 O_2 residuals by station (-0.01°C ≤T1-T2≤0.01°C).

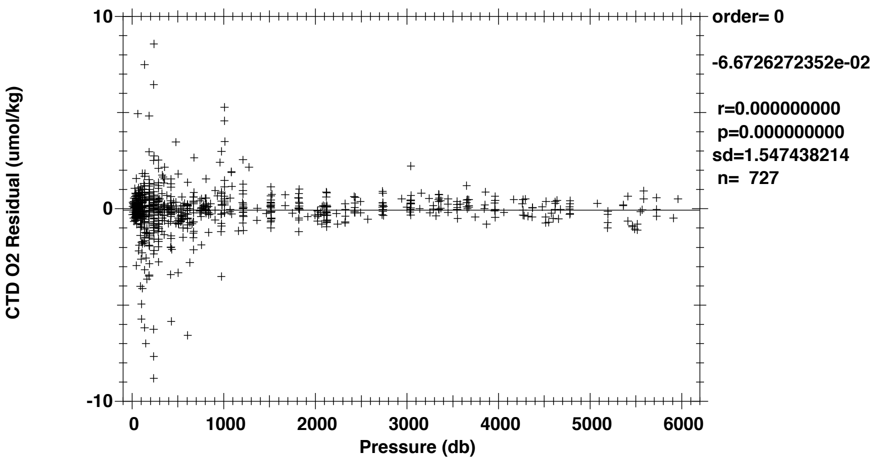

Figure 1.6.4.1 O_2 residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

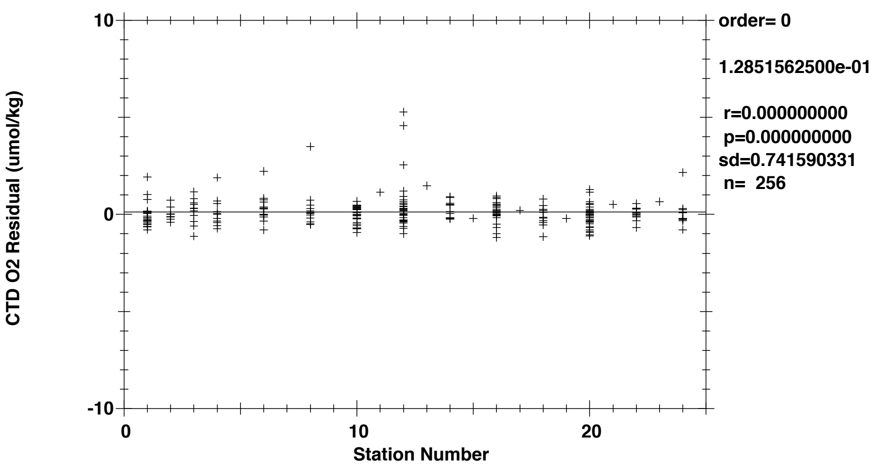

Figure 1.6.4.2 Deep O_2 residuals by station (Pressure >= 1000dbar).

The standard deviations of 0.74 μmol/kg for deep oxygens and 1.55 μmol/kg for all oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the SIO/STS DO sensor response model equation for Clark cells follows Brown and Morrison [Brow78], and Millard [Mill82], [Owen85]. SIO/STS models DO sensor secondary 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 O_2 concentration is then calculated:

$$O_2ml/l = [C_1 V_{DO} e^{(C_2 \frac{P_h}{5000})} + C_3] \cdot f_{sat}(T,P) \cdot e^{(C_4 T_l + C_5 T_s + C_7 P_l + C_6 \frac{dO_c}{dt} + C_8 \frac{dP}{dt} + C_9 dT)} \tag{1.6.4.0}$$

where:

O_2ml/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	*in situ* temperature (°C);
P	*in situ* 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 (μamps/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_2ml/l data are converted to μmol/kg units on demand.

1.7. SIOR Bottle Sampling

At the end of each rosette deployment water samples were drawn from the 30L Niskin bottles in the following order:

SIOR/30L-Niskin Cast Sampling Order							
	Demi	Super/Full (Nd/230Th)		Super/Full (234Th/Ra/Pigs)	Super Only (Pb-Po/Pu/Si)		Pu
Parameters Sampled	Shallow	Shallow	Deep	Shallow	Shallow	Deep	Deep
CFCs,SF_6	x	x	x				
He	x	x	x				
O_2	x	x	x	x	x	x	x
Nutrients	x	x	x	x	x	x	x
Salinity	x	x	x	x	x	x	x
^{14}C and ^{13}C		x	x				
^{3}H	x	x	x				
DIC / Total Alk.		x	x				
$^{18}O - H_2O$		x	x				
^{234}Th				x			
^{238}U				x			
^{226}Ra				x			
Chisholm DNA		x		x			
LaRoche DNA		x					
d $^{15}N - NO_3$	x	x	x				
Thiols		x	x				
Ba		x	x				
Th / Pa / Nd REE(UH)		x	x		(x)		
Pb-Po					x	x	
Si Isotopes					x	x	
Pu-Cs					x	x	x

The correspondence between individual sample containers and the rosette bottle position from which the sample was drawn was recorded on the sample log for the cast. These bottle positions were numbered 1-12 for the SIOR/30L Niskin Rosette, and "13" for samples drawn from the Radium UW pump and associated with SIOR casts. This log also included any comments or anomalous conditions noted about the rosette and bottles.

Normal sampling practice for the 30L Niskin rosette 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.

1.8. STS/ODF Bottle Data Processing

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.23-1) running on a CentOS-5.6 Linux system. A web service (OpenACS 5.3.2 and AOLServer 4.5.1-1) 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 were 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 STS, and by other analytical groups near the end of the cruise, then 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 1.8.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

STS/ODF Samples Stations 1- 24								
	Reported	WHP Quality Codes						
	levels	1	2	3	4	5	7	9
Bottle	1750		1734	6	7			3
SIOR CTD Salt	780		780					
SIOR CTD Oxy	772		772					8
Salinity	1720		1655	48	17			30
Oxygen	772		770		2	2		6
Silicate	1698		1690		7			31
Nitrate	1698		1688	1	8			31
Nitrite	1698		1689	1	7			31
Phosphate	1698		1685	2	10			31

Table 1.8.0 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.

1.9. Salinity

Equipment and Techniques

A single Guildline Autosal 8400B salinometer (S/N 57-396) located in the Knorr's O1 lab was used for all salinity measurements. This salinometer had been modified to include a communication interface for computer-aided measurement, a higher capacity pump and two temperature sensors. These sensors were used to measure air and bath temperatures.

Samples were analyzed after they had equilibrated to laboratory temperature, usually within 12-29 hours after collection. The salinometer was standardized for each group of analyses, 20 to 60 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 a log of each salinometer run, including salinometer settings and air and bath temperatures. The air temperature was displayed and monitored using a 48-hour strip-chart in order to observe cyclical changes. The program also guided the operator through the standardization procedure and making sample measurements. The analyst was prompted to change samples and flush the cells between readings.

Normal standardization procedures included flushing the cell at least 2 times with a fresh vial of IAPSO Standard Seawater (SSW), setting the flow rate as low as possible 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 was 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 problems in the salinometer log, and routinely added comments about cracked sample bottles, loose thimbles, salt crystals, sample volume or anything unusual about the sample or analysis.

Cases of samples were stacked next to the Autosal while equilibrating to room temperature. The temperature of the deepest sample (coldest) and surface sample (warmest) were monitored to determine when the case was ready to be analyzed.

Sampling and Data Processing

A total of 1852 salinity measurements were made, including 924 from the GTC rosette casts, 796 from the SIO rosette casts, 100 from deep pump niskins, 31 fish samples, and 1 underway radium bag.

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 draw and equilibration times were logged for all casts. 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. The salinity data were 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 21.5 to 26 °C during the cruise.

The ambient room temperature also maintained a steady observable 24-hour cycle that was dependent on environmental conditions. There were occasional temperature spikes that brought the room temperature above bath temperature. At these times, or when room temperature was on the daily rise, an analysis run would be delayed until room temperature had again stabilized below bath temperature. This meant runs were usually done between 2200 and 0700 local time.

Standards

IAPSO Standard Seawater (SSW) Batch P-153 was used to standardize all runs. Approximately 110 bottles of SSW were used during GEOTRACES 2011.

1.10. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an SIO/STS 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 PC LabVIEW software developed by SIO/STS. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 mL buret. ODF 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 (~0.012N) and thiosulfate solution (~55 gm/l). Pre-made liquid potassium iodate standards were run daily. Reagent/distilled water blanks were also determined daily, or more often if a change in reagents required it to account for the presence of oxidizing or reducing agents.

Sampling and Data Processing

774 oxygen measurements were made from the SIO 30L Niskin rosette. Samples were collected for dissolved oxygen analyses soon after the rosette was brought on board. Two different 24-flask cases were alternated by cast to minimize flask calibration issues, if any. Using a Tygon and 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 (RTD) embedded in the drawing tube. These temperatures were used to calculate μmol/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 twice (10-12 inversions each time) to assure thorough dispersion of the precipitate: once immediately after drawing, and then again after about 20 minutes.

The samples were analyzed within 24 hours of collection, and the data were 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.

Bottle oxygen data were reviewed, ensuring station, cast, bottle number, flask, and draw temperature were entered properly. Any comments made during analysis were also reviewed, making certain that any anomalous actions were investigated and resolved.

After the data were uploaded to the database, oxygen was graphically compared with CTD oxygen and adjoining stations. Any suspicious-looking points 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 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. 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.

1.11. Nutrient Analysis

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). After each run, the charts were reviewed for any problems during the run, any blank was subtracted, and final concentrations (micromoles/liter) were calculated.

The analytical methods used are described by Gordon *et al.* [Gord92] Hager *et al.* [Hage68] and Atlas *et al.* [Atla71].

Silicate

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67]. An acidic solution of 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. Tartaric acid was also added to impede PO_4 color development. The sample was passed through a flowcell and the absorbance measured at 660nm.

Reagents

Tartaric Acid (ACS Reagent Grade)

200g tartaric acid dissolved in DW and diluted to 1 liter volume. Stored at room temperature in a polypropylene bottle.

Ammonium Molybdate

10.8g Ammonium Molybdate Tetrahydrate dissolved in 1000ml dilute H_2SO_4*.

*(Dilute H_2SO_4 = 2.8ml conc H_2SO_4 to a liter DW). Added 3 drops 15% ultra pure SDS per liter of solution.

Stannous Chloride (ACS Reagent Grade)

Stock solution:

40g of stannous chloride dissolved in 100 ml 5N HCl. Refrigerated in a polypropylene bottle.

Working solution:

5 ml of stannous chloride stock diluted to 200 ml final volume with 1.2N HCl. Made up daily and stored at room temperature when not in use in a dark polypropylene bottle.

NOTE: Oxygen introduction was minimized by swirling rather than shaking the stock solution.

Nitrate + Nitrite

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For the nitrate analysis, the seawater sample was passed through a cadmium reduction column where nitrate was quantitatively reduced to nitrite. Sulfanilamide was introduced to the sample stream followed by N-(1-naphthyl)ethylenediamine dihydrochloride which coupled to form a red azo dye. The stream was then passed through a flowcell and the absorbance measured at 540nm. The same technique was employed for nitrite analysis, except the cadmium column was not present.

Reagents

Sulfanilamide (ACS Reagent Grade)

10g sulfanilamide dissolved in 1.2N HCl and brought to 1 liter volume. Added 5 drops of 40% surfynol 465/485 surfactant. Stored at room temperature in a dark polypropylene bottle.

N-(1-Naphthyl)-ethylenediamine dihydrochloride (N-1-N) (ACS Reagent Grade)

1g N-1-N in DIW, dissolved in DW and brought to 1 liter volume. Added 2 drops 40% surfynol 465/485 surfactant. Stored at room temperature in a dark polypropylene bottle. Discarded if the solution turned dark reddish brown.

Imidazole Buffer (ACS Reagent Grade)

13.6g imidazole dissolved in ~3.8 liters DIW. Stirred for at least 30 minutes until completely dissolved. Added 60 ml of NH_4Cl + $CuSO_4$ mix (see below). Added 4 drops 40% Surfynol 465/485 surfactant. Using a calibrated pH meter, adjusted to pH of 7.83-7.85 with 10% (1.2N)HCl(about 20-30ml of acid, depending on exact strength). Final solution brought to 4L with DIW. Stored at room temperature.

NH_4Cl **+** $CuSO_4$ **mix**:

2g cupric sulfate dissolved in DIW, brought to 100 ml volume (2%) 250g ammonium chloride dissolved in DIW, brought to 1 liter volume. Added 5ml of 2% $CuSO_4$ solution to the NH_4Cl stock.

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

Prepared solution at least one day before use to stabilize.

Phosphate

Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] technique. An acidic solution of ammonium molybdate was added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The reaction product was heated to ~55°C to enhance color de velopment, then passed through a flowcell and the absorbance measured at 820nm.

Reagents

Ammonium Molybdate (ACS Reagent Grade)

H_2SO_4 solution:

420 ml of DIW poured into a 2 liter Ehrlenmeyer flask or beaker, this flask or beaker was placed into an ice bath. SLOWLY added 330 ml of conc H_2SO_4. This solution gets VERY HOT!!

27g ammonium molybdate dissolved in 250ml of DIW. Brought to 1 liter volume with the cooled sulfuric acid solution. Added 5 drops of 15% ultra pure SDS surfactant. Stored in a dark polypropylene bottle.

Dihydrazine Sulfate (ACS Reagent Grade)

6.4g dihydrazine sulfate dissolved in DIW, brought to 1 liter volume and refrigerated.

Sampling and Data Processing

1904 nutrient samples were analyzed from 22 stations:924 from GTC rosette casts, 773 from SIO 30L Niskin rosette casts, 100 from deep pump niskins, 106 from the fish and 1 from the underway radium bag. New pump tubes were installed before the cruise and every 2 weeks during the cruise. Four sets of primary/secondary standards were made up over the course of the cruise. The first was compared to standards brought from shore and each subsequent set was compared to the previous set to ensure continuity between standards. The cadmium column reduction efficiency was checked periodically and ranged between 94%-100% and was replaced when less than 98%.

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

Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at 1 atm pressure (0 db), *in situ* salinity, and an assumed lab temperature of 20°C.

Standards and Glassware

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%, The standards were dried for approx 4hrs and allowed to cool down in a desiccator before they were weighed out to 0.01mg. The dry standard is diluted to 1L and the temperature of the solution was recorded. The exact weight, the temperature, and the calibrated volume of the flask were then used to calculate the concentration of the primary standard, and how much of this standard was needed for the desired concentration of secondary standard. The new standards were compared to the old before use. Standardizations were performed at the beginning of each group of analyses with working standards prepared prior to each run from a secondary. The secondary standards were prepared aboard ship by dilution from dry, pre-weighed primary standards. A set of 7 different standard concentrations (Table 1.11.0) were analyzed periodically to determine the deviation from linearity, if any, as a function of concentration for each nutrient.

std	N+N	PO4	SiO3	NO2
1)	0.0	0.0	0.0	0.0
2)	7.75	0.6	30	0.25
3)	15.50	1.2	60	0.50
4)	23.25	1.8	90	0.75
5)	31.00	2.4	120	1.00
6)	38.75	3.0	150	1.25
7)	46.50	3.6	180	1.50

Table 1.11.0 GEOTRACES 2011 Standard Concentrations (μmol/L)

All glass volumetric flasks were gravimetrically calibrated prior to the cruise. The primary standards were dried and weighed prior to the cruise. The exact weight was noted for future reference.

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

Working standards were made up in low nutrient seawater (LNSW). LNSW was collected off the coast of California and filtered before use at sea during the first part of the cruise. Additional LNSW was collected on the transit between stations 11 and 12, and filtered before use.

All data were initially reported in micromoles/liter. NO3, PO4, and NO2 were reported to two decimal places, and SIL to one. Accuracy was based on the quality of the standards, and is listed with instrument precision in Table 1.11.1:

Nutrient Reported	Accuracy (μmol/L)	Precision (μmol/L)
NO3	0.05	0.05
PO4	0.004	0.004
SIL	2-4	1
NO2	0.05	0.01

Table 1.11.1 GEOTRACES 2011 Nutrient Accuracy and Precision

The detection limits for the methods/instrumentation are shown in Table 1.11.2: (in micromoles/liter):

Nutrient Measured	Detection Limit (μmol/L)
NO3+NO2	0.02
PO4	0.02
Sil	0.5
NO2	0.02

Table 1.11.2 GEOTRACES 2011 Nutrient Detection Limits

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Appendix A

GEOTRACES 2011: CTD Temperature and Conductivity Corrections Summary

Sta/	ITS-90 Temperature Coefficients corT = tp1∗corP + t0		Conductivity Coefficients corC = cp1∗corP + c0	
Cast	tp1	t0	cp1	c0
001/02	-9.4431e-08	-0.000644	3.38690e-07	-0.000259
001/04	-9.4431e-08	-0.000628	3.38690e-07	-0.000259
001/06	-9.4431e-08	-0.000621	3.38690e-07	-0.000259
001/07	-9.4431e-08	-0.000614	3.38690e-07	-0.000259
001/09	-9.4431e-08	-0.000604	3.38690e-07	-0.000259
001/10	-9.4431e-08	-0.000599	3.38690e-07	-0.000259
002/02	-9.4431e-08	-0.000589	3.38690e-07	-0.000259
002/05	-9.4431e-08	-0.000570	3.38690e-07	-0.000259
002/06	-9.4431e-08	-0.000565	3.38690e-07	-0.000259
003/02	-9.4431e-08	-0.000535	3.38690e-07	-0.000259
003/05	-9.4431e-08	-0.000511	3.38690e-07	-0.000259
003/06	-9.4431e-08	-0.000504	3.38690e-07	-0.000259
004/01	-9.4431e-08	-0.000470	3.38690e-07	-0.000259
004/03	-9.4431e-08	-0.000458	3.38690e-07	-0.000259
004/04	-9.4431e-08	-0.000450	3.38690e-07	-0.000259
005/02	-9.4431e-08	-0.000430	3.38690e-07	-0.000259
006/03	-9.4431e-08	-0.000411	3.38690e-07	-0.000259
006/06	-9.4431e-08	-0.000385	3.38690e-07	-0.000259
006/08	-9.4431e-08	-0.000379	3.38690e-07	-0.000259
008/02	-9.4431e-08	-0.000342	3.38690e-07	-0.000259
008/04	-9.4431e-08	-0.000332	3.38690e-07	-0.000259
008/06	-9.4431e-08	-0.000322	3.38690e-07	-0.000259
010/02	-9.4431e-08	-0.000238	3.38690e-07	-0.000259
010/04	-9.4431e-08	-0.000227	3.38690e-07	-0.000259
010/06	-9.4431e-08	-0.000217	3.38690e-07	-0.000259
010/08	-9.4431e-08	-0.000198	3.38690e-07	-0.000259
010/10	-9.4431e-08	-0.000193	3.38690e-07	-0.000259
010/12	-9.4431e-08	-0.000186	3.38690e-07	-0.000259
011/02	-9.4431e-08	-0.000156	3.38690e-07	-0.000259
012/02	-9.4431e-08	-0.000127	3.38690e-07	-0.000259
012/04	-9.4431e-08	-0.000116	3.38690e-07	-0.000259
012/06	-9.4431e-08	-0.000104	3.38690e-07	-0.000259
012/08	-9.4431e-08	-0.000089	3.38690e-07	-0.000259
012/10	-9.4431e-08	-0.000084	3.38690e-07	-0.000259
012/12	-9.4431e-08	-0.000073	3.38690e-07	-0.000259
013/02	-9.4431e-08	-0.000045	3.38690e-07	-0.000259
014/02	-9.4431e-08	-0.000018	3.38690e-07	-0.000259
014/04	-9.4431e-08	-0.000009	3.38690e-07	-0.000259
014/06	-9.4431e-08	-0.000002	3.38690e-07	-0.000259
015/02	-9.4431e-08	0.000033	3.38690e-07	-0.000259
016/02	-9.4431e-08	0.000059	3.38690e-07	-0.000259
016/04	-9.4431e-08	0.000075	3.38690e-07	-0.000259

Sta/ Cast	ITS-90 Temperature Coefficients corT = tp1*corP + t0 tp1	t0	Conductivity Coefficients corC = cp1*corP + c0 cp1	c0
016/06	-9.4431e-08	0.000086	3.38690e-07	-0.000259
016/08	-9.4431e-08	0.000095	3.38690e-07	-0.000259
016/10	-9.4431e-08	0.000100	3.38690e-07	-0.000259
016/11	-9.4431e-08	0.000103	3.38690e-07	-0.000259
017/02	-9.4431e-08	0.000125	3.38690e-07	-0.000259
018/02	-9.4431e-08	0.000146	3.38690e-07	-0.000259
018/04	-9.4431e-08	0.000155	3.38690e-07	-0.000259
018/06	-9.4431e-08	0.000166	3.38690e-07	-0.000259
019/02	-9.4431e-08	0.000199	3.38690e-07	-0.000259
020/02	-9.4431e-08	0.000218	3.38690e-07	-0.000259
020/04	-9.4431e-08	0.000228	3.38690e-07	-0.000259
020/06	-9.4431e-08	0.000240	3.38690e-07	-0.000259
020/08	-9.4431e-08	0.000256	3.38690e-07	-0.000259
020/09	-9.4431e-08	0.000261	3.38690e-07	-0.000259
020/11	-9.4431e-08	0.000272	3.38690e-07	-0.000259
021/02	-9.4431e-08	0.000304	3.38690e-07	-0.000259
022/02	-9.4431e-08	0.000331	3.38690e-07	-0.000259
022/04	-9.4431e-08	0.000341	3.38690e-07	-0.000259
022/06	-9.4431e-08	0.000351	3.38690e-07	-0.000259
023/02	-9.4431e-08	0.000387	3.38690e-07	-0.000259
024/02	-9.4431e-08	0.000407	3.38690e-07	-0.000259
024/04	-9.4431e-08	0.000416	3.38690e-07	-0.000259
024/06	-9.4431e-08	0.000424	3.38690e-07	-0.000259

Appendix B

Summary of GEOTRACES 2011 CTD Oxygen Time Constants

(time constants in seconds)

Pressure Hysteresis (τ_h)	Temperature Long(τ_{Tl})	Temperature Short(τ_{Ts})	Pressure Gradient (τ_p)	O_2 Gradient (τ_{og})	Velocity (τ_{dP})	Thermal Diffusion (τ_{dT})
150.0	300.0	2.0	0.50	8.00	0.00	275.0

GEOTRACES 2011: Conversion Equation Coefficients for CTD Oxygen

(refer to Equation 1.6.4.0)

Sta/ Cast	O_cSlope (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)
001/02	5.307e-04	-0.280	0.123	1.186e-02	-1.344e-02	9.469e-05	2.547e-03	0	0.007120
001/04	5.307e-04	-0.280	0.123	1.186e-02	-1.344e-02	9.469e-05	2.547e-03	0	0.007120
001/06	5.812e-04	-0.385	0.060	2.224e-02	-2.500e-02	1.226e-04	3.251e-03	0	0.012562
001/07	1.800e-04	-0.115	4.213	6.807e-02	-1.163e-02	-8.203e-05	1.042e-03	0	-0.036245
001/09	6.319e-04	-0.279	-1.478	-1.733e-02	4.553e-03	2.442e-04	4.002e-03	0	-0.002805
001/10	7.057e-04	-0.430	-0.488	2.809e-03	-1.657e-02	6.561e-05	1.975e-03	0	0.012886
002/02	4.822e-04	-0.206	0.069	-3.766e-03	2.002e-03	1.161e-04	-2.902e-03	0	-0.004414
002/05	2.626e-04	-0.170	7.186	5.691e-02	-2.069e-02	-9.903e-04	3.141e-03	0	-0.019929
002/06	8.406e-05	-0.043	9.024	8.060e-02	5.220e-03	-5.925e-04	1.267e-03	0	-0.073472
003/02	5.031e-04	-0.231	0.437	1.364e-03	-1.533e-03	-3.023e-05	1.079e-03	0	-0.006319
003/05	5.148e-04	-0.256	0.485	4.714e-03	-5.511e-03	4.544e-06	-4.506e-03	0	-0.001009
003/06	7.322e-04	-0.343	-0.595	-3.200e-03	-1.210e-02	-7.084e-06	2.325e-03	0	0.018321
004/01	3.857e-04	-0.128	0.097	6.861e-03	1.522e-03	1.118e-04	1.184e-03	0	-0.009109
004/03	5.488e-04	-0.319	0.309	1.250e-02	-1.369e-02	4.996e-05	-3.389e-03	0	0.006702
004/04	4.228e-04	-0.118	-0.477	1.227e-03	2.163e-03	1.793e-04	2.655e-03	0	-0.000059
005/02	3.275e-04	-0.206	2.122	1.359e-02	8.562e-03	-1.756e-04	-5.252e-03	0	-0.031078
006/03	5.098e-04	-0.284	0.097	1.317e-02	-1.234e-02	1.250e-04	-4.468e-03	0	-0.004818
006/06	4.408e-04	-0.220	0.640	-2.590e-03	8.965e-03	3.735e-05	-1.946e-03	0	-0.021980
006/08	4.875e-04	-0.202	-0.839	-6.835e-03	7.115e-03	3.286e-04	1.058e-03	0	-0.000838
008/02	4.770e-04	-0.330	0.736	1.753e-02	-9.860e-03	-7.475e-06	-1.977e-03	0	-0.018516
008/04	3.985e-04	-0.294	1.280	2.901e-02	-1.270e-02	-6.355e-05	-7.790e-03	0	-0.020884
008/06	5.386e-04	-0.332	0.152	2.531e-03	-2.294e-03	1.106e-04	-4.558e-03	0	-0.001037
010/02	5.011e-04	-0.240	-0.025	5.380e-03	-4.776e-03	1.361e-04	2.572e-03	0	0.000470
010/04	5.160e-04	-0.254	0.212	-1.973e-03	1.763e-03	7.531e-05	-4.861e-03	0	-0.001821
010/06	3.895e-04	-0.196	0.560	6.353e-03	5.249e-03	1.129e-04	1.188e-03	0	-0.016832
010/08	5.181e-04	-0.253	0.419	-1.746e-03	1.242e-03	1.850e-05	4.891e-04	0	-0.003675
010/10	5.068e-04	-0.240	0.146	-3.392e-03	3.447e-03	9.400e-05	-3.792e-03	0	-0.001658
010/12	4.691e-04	-0.224	-0.032	1.800e-03	1.425e-03	1.686e-04	4.710e-04	0	-0.006538
011/02	4.960e-04	-0.252	1.001	-4.116e-03	5.959e-03	-9.718e-05	-1.624e-03	0	-0.010196
012/02	5.177e-04	-0.252	0.009	-7.074e-04	1.770e-04	1.259e-04	2.455e-03	0	0.001696
012/04	5.117e-04	-0.261	0.132	-1.038e-03	1.588e-03	1.042e-04	-2.978e-04	0	-0.002720
012/06	3.770e-04	-0.177	0.339	4.079e-03	8.038e-03	1.497e-04	-3.917e-03	0	-0.018656
012/08	2.253e-04	-0.128	2.062	2.329e-02	1.165e-02	2.458e-06	-3.017e-03	0	-0.048678
012/10	4.987e-04	-0.231	0.072	-2.319e-03	3.207e-03	1.165e-04	1.838e-03	0	-0.000282
012/12	5.167e-04	-0.260	0.251	-1.325e-03	1.594e-03	6.807e-05	1.443e-03	0	-0.005893
013/02	1.098e-03	-0.307	-1.814	-3.762e-02	3.832e-03	7.828e-05	-8.878e-05	0	0.022364

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)
014/02	4.165e-04	-0.215	0.686	3.085e-03	5.948e-03	5.392e-05	1.200e-03	0	-0.018545
014/04	3.716e-04	-0.213	0.992	9.015e-03	5.491e-03	8.196e-05	-7.981e-04	0	-0.018181
014/06	5.112e-04	-0.227	0.299	-2.254e-03	1.822e-03	4.650e-05	3.832e-03	0	0.000749
015/02	3.435e-04	-0.192	1.044	1.381e-02	3.560e-03	1.059e-04	2.503e-03	0	-0.016679
016/02	4.955e-04	-0.217	0.095	-6.348e-03	6.827e-03	1.063e-04	-1.251e-03	0	-0.006571
016/04	5.225e-04	-0.225	0.280	-3.440e-05	-1.744e-03	4.207e-05	-5.626e-03	0	0.007437
016/06	3.495e-04	-0.157	1.074	7.457e-03	7.184e-03	-1.018e-05	9.900e-04	0	-0.024677
016/08	5.642e-04	-0.241	-0.131	-2.679e-03	-2.251e-03	8.780e-05	3.659e-03	0	0.008115
016/10	4.218e-04	-0.207	0.754	7.444e-03	6.574e-04	2.908e-05	1.283e-03	0	-0.007976
016/11	6.535e-04	-0.267	-0.661	-1.321e-02	2.233e-03	1.714e-04	6.896e-04	0	0.015335
017/02	4.472e-04	-0.241	0.941	4.576e-03	2.196e-03	-2.454e-05	6.442e-04	0	-0.011364
018/02	5.562e-04	-0.305	-0.011	-5.165e-03	3.175e-03	1.543e-04	-9.023e-04	0	-0.003869
018/04	5.065e-04	-0.227	0.143	-2.943e-03	2.919e-03	9.044e-05	6.947e-04	0	0.000053
018/06	2.754e-04	-0.090	2.416	2.108e-02	8.744e-04	-1.801e-04	-6.205e-04	0	-0.015463
019/02	1.383e-03	-0.854	-1.296	-3.535e-02	-2.115e-04	2.323e-04	-5.782e-04	0	0.019778
020/02	2.492e-04	-0.131	1.865	2.829e-02	1.065e-03	6.460e-05	3.031e-03	0	-0.020324
020/04	5.028e-04	-0.229	0.074	-7.308e-04	1.150e-03	1.132e-04	3.118e-03	0	0.000431
020/06	5.892e-04	-0.177	-1.971	-1.316e-02	4.357e-03	3.648e-04	1.758e-03	0	0.013938
020/08	4.707e-04	-0.191	-0.265	-2.512e-03	4.371e-03	2.105e-04	3.635e-03	0	0.001636
020/09	5.106e-04	-0.250	0.081	-5.168e-03	5.323e-03	1.168e-04	-9.869e-03	0	-0.009098
020/11	5.116e-04	-0.277	0.035	-7.243e-03	8.868e-03	1.457e-04	3.809e-04	0	-0.018095
021/02	1.867e-04	-0.084	3.164	5.115e-02	-1.172e-02	-9.497e-06	5.608e-03	0	0.004357
022/02	8.321e-04	-0.347	-1.173	-2.414e-02	3.657e-03	1.849e-04	3.689e-03	0	0.017924
022/04	5.087e-04	-0.272	0.033	-2.943e-03	4.554e-03	1.456e-04	-4.829e-04	0	-0.019641
022/06	8.321e-04	-0.347	-1.173	-2.414e-02	3.657e-03	1.849e-04	3.689e-03	0	0.017924
023/02	2.365e-04	-0.085	2.675	2.056e-02	8.579e-03	-6.397e-05	1.887e-03	0	-0.006819
024/02	3.015e-04	-0.101	2.438	1.712e-03	1.733e-02	-1.628e-04	-5.769e-03	0	0.007132
024/04	5.185e-04	-0.234	0.159	-4.998e-03	4.232e-03	8.141e-05	7.513e-03	0	-0.005013
024/06	5.143e-04	-0.238	0.077	-1.511e-02	1.496e-02	6.790e-05	3.137e-04	0	-0.025253

Appendix C

GEOTRACES 2011: Bottle Quality Comments

Comments from the Sample Logs and the results of SIO/STS's data investigations are included in this report. Units stated in these comments are degrees Celsius for temperature, micromoles per kilogram 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
1/2	201	po4	3	value is high compared to cast and similar depths on other casts, no analytical errors noted.
1/2	204	bottle	2	Lanyard spigot slow and weeps after sampling started.
1/2	206	bottle	9	Bottle did not trip. Lanyard caught on 2 latches.
1/2	207	bottle	2	Bottom cap weeping after sampling started. Probably due to stiff/hard o-rings.
1/4	407	salt	3	Salt value low compared to CTDS1/CTDS2 at 2040db, code questionable.
1/4	410	salt	2	Bottle salt value agrees with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_22, Rim chip - seal does NOT appear to be compromised. Old injury, not from this cruise.
1/4	411	salt	2	Bottle salt value agrees with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_23, readings kept climbing, cause unknown. Salt value reasonable for water depth (1510m) and agrees with CTDS1/CTDS2.
1/6	601	o2	5	Sample lost. Analytical program froze, manual system reboot.
1/7	707	salt	2	Bottle salt value agrees with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_7 got distracted and pulled sample bottle before second reading. No reason to suspect reading otherwise.
1/7	711	reft	3	SBE35RT +0.013 vs CTDT: taken at top of thermocline, in a gradient. Code questionable.
1/7	712	salt	3	Salt value -0.025 vs CTDS, at small gradient in mixed layer. code questionable.
1/9	906	bottle	9	Bottle did not trip: Loading error, lanyard caught on 2 latches.
1/9	907	reft	3	SBE35RT -0.011 vs CTDT, reading unstable: taken in a small gradient. Code questionable.
1/9	911	reft	3	SBE35RT +0.015 vs CTDT, reading unstable, taken in a gradient. Code questionable.
1/10	1005	reft	3	unstable SBE35T reading, taken in a small gradient. Code questionable.
1/10	1006	reft	3	unstable SBE35T reading, taken in a small gradient. Code questionable.
1/10	1011	salt	3	Salt value +0.035 vs CTDS, middle of high gradient. Code questionable.
2/2	211	salt	2	Bottle salt compares well with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_11: Rim chip, Seal is NOT compromised, did not notice it before but could be old injury as it is small.
2/5	506	reft	3	SBE35T -0.015/-0.020 vs CTDT1/CTDT2; unstable SBE35T reading. Code questionable.
2/5	507	o2	2	Sample run out of order. Flasks match sample log sheet, however values more closely match water column when switched with 508 flask 882.

Station /Cast	Sample No.	Quality Property	Code	Comment
2/5	508	o2	2	Sample run out of order. Flasks match sample log sheet, however values more closely match water column when switched with 507 flask 886.
2/5	509	o2	5	Sample accidentally destroyed.
2/5	511	salt	2	Bottle salt compares well with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_23: thimble came out with cap, probable contamination from liquid under cap.
2/6	605	salt	2	Bottle salt compares well with CTD, water column and adjacent parameters, code acceptable. Analyst: SaltBtl_29: first reading anomalous, suspect air bubble in coil arm.
2/6	608	reft	3	Somewhat unstable SBE35T reading in gradient. Code questionable.
2/6	608	salt	3	Salt value -0.025 vs CTDS, high gradient region. Code questionable.
2/6	610	reft	3	Unstable SBE35T reading in gradient. Code questionable.
2/6	610	salt	3	Salt value +0.04 vs CTDS, bottom of mixed layer. Code questionable.
3/2	206	salt	2	Analyst: SaltBtl_6: thimble came out with cap. Readings erratic.
3/2	207	bottle	2	Guide pin came out of spigot stem, replaced after sampling.
3/2	209	reft	3	very unstable SBE35T reading in gradient. Code questionable.
3/5	501	salt	3	Bottle salt value is +0.020 vs. CTD, high for low gradient region, code questionable.
3/5	508	po4	2	Analyst: po4 value is slightly high, no analytical errors noted.
3/6	607	o2	2	Bottle o2 value +0.0.242ml/l vs. CTD. High gradient region, water column changing rapidly in Gulf stream. Value matches up-trace. Code acceptable.
3/6	609	o2	2	Bottle o2 value +0.453ml/l vs. CTD. High gradient region, water column changing rapidly in Gulf stream. Value matches up-trace. Code acceptable.
3/6	609	salt	3	Bottle salt value is +0.040 vs. CTD, in high gradient region. Code questionable.
4/1	101	reft	3	SBE35T +0.014 vs CTDT; unstable SBE35T reading in a small gradient. Code questionable.
4/1	103	reft	3	SBE35T -0.015 vs CTDT; unstable SBE35T reading in a gradient. Code questionable.
4/1	104	bottle	9	Bottle 4 did not trip, cocked on wrong latch.
4/1	107	reft	3	SBE35T -0.025/-0.035 vs CTDT1/CTDT2; unstable SBE35T reading. Code questionable.
4/1	107	salt	2	Bottle salt value agrees with CTD, water column and adjacent parameters. Analyst: SaltBtl_6, thimble came out with cap. Possible contamination.
4/1	112	salt	2	Bottle salt value agrees with CTD, water column and adjacent parameters. Analyst: SaltBtl_11, readings erratic.
4/3	302	salt	4	Bottle salt value high vs CTDS1/CTDS2 for low gradient region of water column, code questionable. Analyst: SaltBtl_14; thimble came out with cap, initial large jump, suspect contamination.
4/4	408	o2	2	Possible bubble in o2 flask. ANALYST: O2 values nominal.
5/2	202	reft	3	SBE35T -0.006 vs CTDT; somewhat high for deeper reading. Code questionable.
5/2	209	o2	2	Bottle o2 value -0.267ml/l less than CTD. Tripped in high gradient region, value matches water column trend. Code acceptable.
5/2	210	reft	3	SBE35T -0.030/-0.025 vs CTDT1/CTDT2; unstable SBE35T reading. Code questionable.
5/2	213	salt	2	Surface Pump sample.
6/3	305	salt	2	Bottle value agrees with CTD values and water column trend, code acceptable. Analyst: SaltBtl_5; thimble came out with cap - reading erratic.
6/3	306	salt	3	Deep salinity +0.005 vs CTD, code questionable.

Station /Cast	Sample No.	Quality Property	Code	Comment
6/6	602	salt	2	Bottle value agrees with CTD values and water column trend, code acceptable. Analyst: SaltBtl_14; thimble came out with cap - probable contamination.
6/6	606	reft	3	SBE35T +0.012 vs CTDT; unstable SBE35T reading, in a gradient. Code questionable.
6/6	607	salt	3	bottle salt +0.06 vs CTDS, in gradient. Code questionable.
6/6	608	salt	3	bottle salt -0.055 vs CTDS, in gradient. Code questionable.
6/8	807	reft	3	SBE35T +0.017 vs CTDT; Unstable in high gradient region; code questionable.
8/2	206	salt	2	Bottle salt value agrees with CTD and water column profile, code acceptable. Analyst: SaltBtl_6: thimble came out with cap - probable contamination.
8/4	404	salt	2	Bottle salt value agrees with CTD and water column profile, code acceptable. Analyst: SaltBtl_16: thimble came out with cap, possible contamination.
8/4	408	o2	2	Bottle o2 value 0.371 ml/l less vs CTD. Value matches trend in water column and up-trace, in high gradient region. Code acceptable.
8/6	601	bottle	4	salt, o2, CFC and nutrient values indicate this bottle probably tripped at the same depth as shallowest bottle (1500m). Possibly a lanyard hangup until last trip (niskins 1 and 12 are next to each other on rosette). Code as tripped at different depth than expected.
8/6	601	no2	4	deepest and shallowest (1500m) nutrient values similar: see bottle comment. Code bad.
8/6	601	no3	4	deepest and shallowest (1500m) nutrient values similar: see bottle comment. Code bad.
8/6	601	o2	4	deepest o2 value aligns with CTDO, but o2 draw temp high and deepest and shallowest o2 values match; see bottle comment. Code bad.
8/6	601	po4	4	deepest and shallowest (1500m) nutrient values similar: see bottle comment. Code bad.
8/6	601	salt	4	deepest salt value is +0.11 vs CTDS: matches 1500m salt value; see bottle comment. Code bad.
8/6	601	sio3	4	deepest and shallowest (1500m) nutrient values similar: see bottle comment. Code bad.
8/6	604	po4	3	value is high and does not match GT-C cast values for similar depth
8/6	604	salt	4	Bottle salt high for CTD trend in low gradient region, code questionable.
8/6	607	bottle	3	Bottle 7 bottom cap jarred loose during recovery, top cap did not seal: shut on bottle 6 lanyard line. Broke pressure seal and allowed leaking.
8/6	607	no2	4	water likely not from proper depth due to lanyard issue
8/6	607	no3	4	value low, water likely not from proper depth due to lanyard issue
8/6	607	o2	4	Bottle o2 value low, leaky niskin. Code bad.
8/6	607	po4	4	value low, water likely not from proper depth due to lanyard issue
8/6	607	salt	4	salt value high, leaky niskin. Code bad.
8/6	607	sio3	4	value low, water likely not from proper depth due to lanyard issue
8/6	608	salt	4	Bottle salt value does not agree with CTD profile. Analyst: SaltBtl_32: thimble came out with cap, readings very erratic, probable contamination.
10/2	202	reft	3	SBE35T -0.015 vs CTDT; unstable SBE35T reading, in a gradient. Code questionable.
10/4	405	bottle	3	bottom cap leak after sampling started, could not make it stop. Samples taken asap, shutting vent between samples. A piece of plastic debris was later found in lower cap o-ring.
10/4	409	no2	3	value high compared to casts at overlapping depths, no analytical errors noted
10/6	605	bottle	2	Niskin s/n 5 replaced from spares before cast (using Niskin s/n 15).

Station /Cast	Sample No.	Quality Property	Code	Comment
10/6	609	reft	3	SBE35T +0.06/+0.05 vs CTDT1/CTDT2; very unstable SBE35T reading, in a gradient. Code questionable.
10/8	804	salt	2	Bottle salt value agrees with CTD values and water column trend, code acceptable. Analyst: SaltBtl_16: thimble came out with cap - readings erratic.
10/8	811	salt	2	Bottle salt value agrees with CTD values and water column trend, code acceptable. Analyst: SaltBtl_23: thimble came out with cap, readings erratic.
10/10	1009	salt	3	Deep salinity value +0.007 vs CTDS; code questionable.
10/12	1202	o2	2	Particulates in o2 flask.
10/12	1211	reft	3	SBE35T -0.065/-0.060 vs CTDT1/CTDT2; unstable SBE35T reading. Code questionable.
11/2	213	salt	2	Analyst: Salt 13 is surface pumped sample associated with cast
12/2	210	reft	3	SBE35T -0.06 vs CTDT; very unstable SBE35T reading, in a gradient. Code questionable.
12/4	403	salt	3	Bottle salt value low vs. CTD in low gradient region, but falls with in water column trend, code questionable.
12/4	406	salt	3	Bottle salt value low vs. CTD in low gradient region, but falls with in water column trend, code questionable.
12/4	412	salt	2	Bottle value agrees closely with CTD, water column trend and adjacent parameters, code acceptable. ANALYST: Thimble came out with cap, probably contamination.
12/6	613	salt	2	Bottle value agrees closely with CTD, water column trend and adjacent parameters, code acceptable. ANALYST: Is surface pumped sample associated with cast.
13/2	213	salt	2	ANALYST: 13 is surface pumped sample associated with cast.
14/2	210	reft	3	SBE35T +0.01 vs CTDT; unstable SBE35T reading, in a gradient. Code questionable.
14/2	211	reft	3	SBE35T +0.024 vs CTDT; unstable SBE35T reading, in a gradient. Code questionable.
14/4	403	salt	4	Bottle value high for CTD in transition region. Code bad due to analyst remark. ANALYST: thimble came out with cap - probably contamination.
14/4	409	o2	2	OT 0.5538 Abnormal finish first titrate. No slope. After back titration good curve. Bottle value appears good.
14/6	611	bottle	2	vent possibly not shut tight.
14/6	612	salt	2	Bottle value agrees with CTD profile, code acceptable. ANALYST: thimble came out with cap, possible contamination.
16/4	406	salt	2	Bottle value higher than general trend vs. CTD, however still with in acceptable limits. ANALYST: Salt 6; Thimble came out with cap, readings erratic.
16/6	613	salt	2	0013: Salt/niskin 13, surface pumped sample associated with cast.
16/11	1107	salt	2	Bottle salt values agree with CTD trend. ANALYST: SaltBtls 19-21 (samps.1107,1108,1110) placed in crate in wrong order, not noticed until SaltBtl 19 (samp.1110) was being analyzed. Samples collected in correct order. (Data file corrected.)
16/11	1108	salt	2	Bottle salt values agree with CTD trend. ANALYST: SaltBtls 19-21 (samps.1107,1108,1110) placed in crate in wrong order, not noticed until SaltBtl 19 (samp.1110) was being analyzed. Samples collected in correct order. (Data file corrected.)
16/11	1110	salt	2	Bottle salt values agree with CTD trend. ANALYST: SaltBtls 19-21 placed in crate in wrong order, not noticed until SaltBtl 19 (samp.1110) was being analyzed. Samples collected in correct order. (Data file corrected.)
17/2	213	salt	2	ANALYST: Salt 13 is surface pump sample associated with cast.

Station /Cast	Sample No.	Quality Property	Code	Comment
18/2	207	reft	3	SBE35 and CTDT2 vs CTDT1 very different through high gradient. Code questionable.
18/2	207	salt	3	Bottle salt value unstable through high gradient. Code questionable.
18/6	609	reft	3	SBE35T +0.027 vs CTDT; very unstable SBE35T reading in gradient. Code questionable.
19/2	205	o2	2	Bottle value aligns to CTD profile, code acceptable. 1756 stopper in 1730 flask.
19/2	206	o2	2	Bottle value aligns to CTD profile, code acceptable. 1730 stopper in 1756 flask.
19/2	213	salt	2	Value is acceptable. ANALYST: Salt 13 is surface pumped sample associated with cast.
20/2	201	reft	3	Deep SBE35T -0.008 vs CTDT; unstable SBE35T reading. Code questionable.
20/2	203	bottle	2	735m bottle accidentally tripped 5m too deep, on-the-fly while winch slowing near target.
20/2	203	reft	3	SBE35T, CTDT1, CTDT2 all disagree; very unstable SBE35T reading on-the-fly. Code questionable.
20/2	209	reft	3	very unstable SBE35T reading in gradient. Code questionable.
20/2	210	reft	3	SBE35T, CTDT1, CTDT2 all disagree; unstable SBE35T reading in gradient. Code questionable.
20/6	602	bottle	2	second bottle fired at 735m unintentionally, while still stopped for sample 601.
20/6	613	salt	2	Salt 13, is surface pumped sample associated with cast.
20/8	805	reft	3	very unstable SBE35T reading in gradient. Code questionable.
20/8	811	reft	3	SBE35T, CTDT1, CTDT2 all disagree; very unstable SBE35T reading in gradient. Code questionable.
20/9	908	salt	3	Deep salinity is +0.008 vs CTDS; code questionable.
20/11	1109	reft	3	SBE35T, CTDT1, CTDT2 all disagree; in gradient. Code questionable.
20/11	1111	reft	3	SBE35T +0.028 vs CTDT; unstable SBE35T reading in gradient. Code questionable.
21/2	204	bottle	2	"Bottle 4, 5 or 6 bottom cap was popped open by tag line during recovery; difficult to see which bottle was snapped."
21/2	205	bottle	2	"Bottle 4, 5 or 6 bottom cap was popped open by tag line during recovery; difficult to see which bottle was snapped."
21/2	205	reft	3	SBE35T, CTDT1, CTDT2 all disagree; very unstable SBE35T reading. Code questionable.
21/2	206	bottle	2	"Bottle 4, 5 or 6 bottom cap was popped open by tag line during recovery; difficult to see which bottle was snapped."
21/2	211	reft	3	SBE35T +0.018 vs CTDT; unstable SBE35T reading in gradient. Code questionable.
22/2	203	salt	3	Bottle salt value high by 50 units in high gradient region. Code questionable.
22/2	208	salt	3	Bottle salt value low by 30 units in high gradient region. Code questionable.
22/6	613	salt	2	Salt 13 is surface pumped sample associated with cast.
23/2	211	reft	3	SBE35T, CTDT1, CTDT2 all disagree; unstable SBE35RT reading in gradient. Code questionable.
23/2	213	salt	2	ANALYST: Salt 13 is surface pumped sample associated with cast.
24/2	206	salt	3	Bottle salt value -0.040 with CTD in high gradient region. Code questionable.
24/2	208	reft	3	SBE35T, CTDT1, CTDT2 all disagree; in gradient. Code questionable.
24/2	209	reft	3	SBE35T, CTDT1, CTDT2 all disagree; very unstable SBE35T reading in gradient. Code questionable.

Appendix D

GEOTRACES 2011: Pre-Cruise Sensor Laboratory Calibrations

SIOR CTD 831 Sensors - Table of Contents			
CTD Sensor	Manufacturer and Model No.	Serial Number	Appendix D Page (Un-Numbered)
*PRESS (Pressure)	Digiquartz 401K-105	98627	1-3
*T1 (Primary Temperature)	Sea-Bird SBE3*plus*	03P-4907	4
*C1 (Primary Conductivity)	Sea-Bird SBE4C	04-2112	5
*O2 (Dissolved Oxygen)	Sea-Bird SBE43	43-0857	6
T2 (Secondary Temperature)	Sea-Bird SBE3*plus*	03P-4138	7
C2 (Secondary Conductivity)	Sea-Bird SBE4C	04-2659	8
*TRANS (Transmissometer)	WETLabs C-Star	CST-491DR	9
*REFT (Reference Temperature)	Sea-Bird SBE35	3528706-0035	10

* data reported for these sensors during GEOTRACES 2011

Pressure Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0831
CALIBRATION DATE: 25-OCT-2011
Mfg: SEABIRD Model: 09P CTD Prs s/n:

C1= -4.346480E+4
C2= -2.379132E-1
C3= 1.292515E-2
D1= 3.298162E-2
D2= 0.000000E+0
T1= 3.004630E+1
T2= -4.377857E-4
T3= 3.900833E-6
T4= 4.644562E-9
T5= 0.000000E+0
AD590M= 1.28916E-2
AD590B= -8.23481E+0
Slope = 1.00000000E+0
Offset = 0.00000000E+0

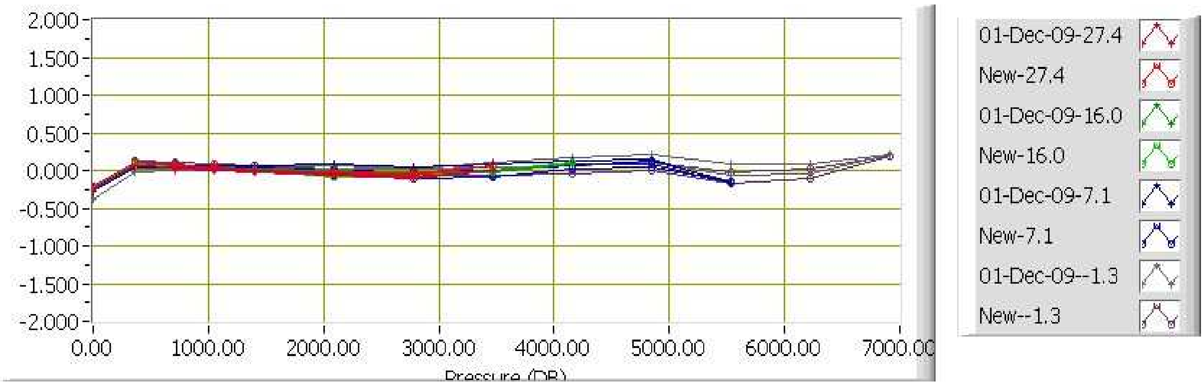
Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

SBE9 Freq	Ruska	SBE9 New_Coefs	Ruska-SBE9 Prev_Coefs	Ruska-SBE9 New_Coefs	Tprs	Bath_Temp
33298.121	0.18	0.39	-0.25	-0.21	29.01	27.401
33499.871	364.98	364.88	0.06	0.10	29.01	27.401
33689.143	709.16	709.10	0.03	0.06	29.01	27.401
33877.201	1053.33	1053.29	0.02	0.04	29.01	27.401
34064.133	1397.59	1397.59	-0.01	0.01	29.01	27.401
34434.505	2086.07	2086.10	-0.05	-0.03	29.02	27.401
34800.405	2774.62	2774.66	-0.08	-0.04	29.02	27.401
35161.942	3463.25	3463.18	-0.00	0.07	29.02	27.401
34800.418	2774.62	2774.68	-0.10	-0.06	29.02	27.401
34434.507	2086.07	2086.11	-0.06	-0.04	29.01	27.401
34064.140	1397.59	1397.60	-0.02	-0.01	29.01	27.401
33877.214	1053.33	1053.32	-0.00	0.01	29.01	27.401
33689.152	709.16	709.12	0.02	0.04	29.01	27.401
33499.883	364.98	364.90	0.04	0.07	29.01	27.401
33294.784	0.18	0.40	-0.26	-0.22	16.98	15.945
33496.496	364.98	364.89	0.07	0.08	16.99	15.946
33685.734	709.16	709.11	0.05	0.05	17.01	15.947
33873.763	1053.33	1053.30	0.04	0.03	17.03	15.947
34060.662	1397.59	1397.58	0.03	0.01	17.06	15.948
34430.965	2086.07	2086.11	-0.01	-0.03	17.07	15.948
34796.809	2774.62	2774.68	-0.04	-0.06	17.08	15.948
35158.313	3463.25	3463.25	-0.01	-0.00	17.11	15.948
35515.603	4151.95	4151.83	0.08	0.11	17.12	15.948
35158.329	3463.25	3463.26	-0.02	-0.01	17.14	15.948
34796.830	2774.62	2774.66	-0.03	-0.05	17.16	15.948

Pressure Calibration Report
STS/ODF Calibration Facility

34431.025	2086.07	2086.15	-0.05	-0.08	17.17	15.948
34060.710	1397.59	1397.59	0.02	0.00	17.19	15.948
33873.831	1053.33	1053.31	0.02	0.02	17.21	15.948
33685.801	709.16	709.10	0.06	0.06	17.23	15.949
33496.575	364.98	364.88	0.07	0.09	17.24	15.949
33291.668	0.18	0.40	-0.28	-0.22	8.60	7.109
33493.357	364.98	364.90	0.05	0.07	8.60	7.109
33682.566	709.16	709.11	0.04	0.04	8.60	7.109
33870.564	1053.33	1053.30	0.05	0.03	8.60	7.109
34057.419	1397.59	1397.56	0.07	0.03	8.60	7.109
34427.668	2086.07	2086.06	0.08	0.01	8.60	7.109
34793.470	2774.62	2774.64	0.05	-0.03	8.60	7.109
35154.933	3463.25	3463.24	0.09	0.01	8.60	7.109
35512.209	4151.95	4151.87	0.14	0.07	8.60	7.109
35865.447	4840.70	4840.58	0.15	0.12	8.62	7.109
36214.911	5529.51	5529.66	-0.16	-0.15	8.63	7.109
35865.475	4840.70	4840.65	0.08	0.05	8.60	7.109
35512.236	4151.95	4151.92	0.08	0.02	8.60	7.109
35154.979	3463.25	3463.32	0.00	-0.08	8.60	7.109
34793.512	2774.62	2774.72	-0.03	-0.11	8.60	7.109
34427.709	2086.07	2086.14	-0.00	-0.07	8.60	7.109
34057.434	1397.59	1397.59	0.05	0.00	8.60	7.109
33870.560	1053.33	1053.30	0.06	0.03	8.60	7.109
33682.554	709.16	709.09	0.07	0.06	8.60	7.109
33493.344	364.98	364.88	0.08	0.10	8.60	7.109
33287.699	0.18	0.40	-0.39	-0.22	-0.25	-1.287
33489.367	364.98	364.88	-0.02	0.10	-0.23	-1.287
33678.560	709.16	709.07	0.00	0.08	-0.21	-1.287
33866.570	1053.33	1053.29	-0.01	0.04	-0.18	-1.287
34053.419	1397.59	1397.57	0.01	0.02	-0.18	-1.287
34423.646	2086.07	2086.10	0.02	-0.03	-0.18	-1.287
34789.425	2774.61	2774.67	0.03	-0.06	-0.15	-1.287
35150.852	3463.24	3463.24	0.11	0.01	-0.13	-1.287
35508.098	4151.94	4151.88	0.18	0.06	-0.13	-1.287
35861.320	4840.70	4840.60	0.22	0.10	-0.09	-1.287
36210.681	5529.51	5529.53	0.08	-0.02	-0.07	-1.287
36556.144	6218.40	6218.39	0.08	0.01	-0.07	-1.287
36897.827	6907.34	6907.15	0.20	0.18	-0.07	-1.286
36556.216	6218.40	6218.51	-0.05	-0.11	-0.05	-1.286
36210.764	5529.51	5529.67	-0.07	-0.16	-0.05	-1.286
35861.412	4840.70	4840.71	0.10	-0.01	-0.02	-1.287
35508.209	4151.94	4151.99	0.07	-0.04	-0.02	-1.287
35150.949	3463.24	3463.32	0.03	-0.07	-0.02	-1.287
34789.512	2774.61	2774.68	0.01	-0.07	0.01	-1.287
34423.725	2086.07	2086.05	0.06	0.02	0.03	-1.287
34053.498	1397.59	1397.52	0.06	0.07	0.03	-1.287
33866.650	1053.33	1053.25	0.04	0.08	0.03	-1.287
33678.670	709.16	709.06	0.02	0.10	0.03	-1.287
33489.477	364.98	364.85	0.01	0.13	0.03	-1.286
33287.825	0.18	0.38	-0.37	-0.20	0.03	-1.286

Pressure Calibration Report
STS/ODF Calibration Facility



Temperature Calibration Report
STS/ODF Calibration Facility

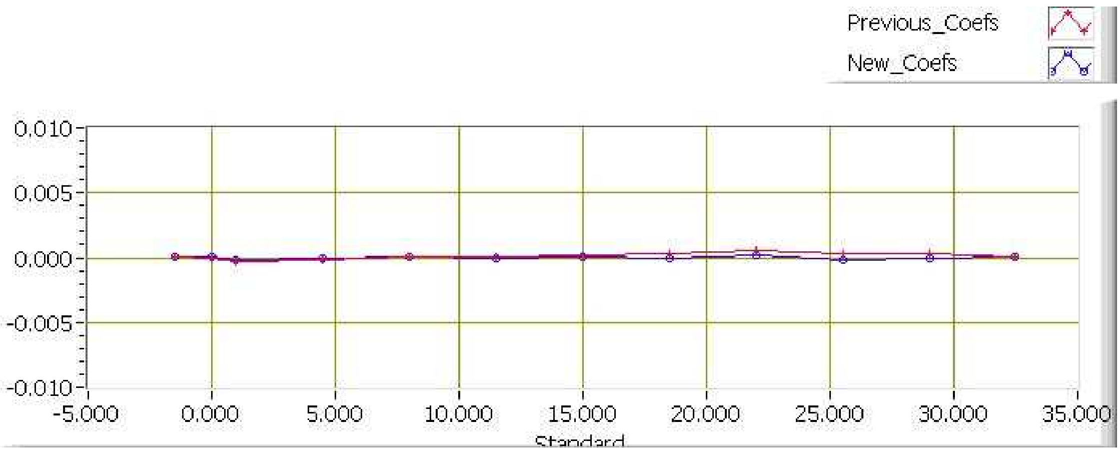
SENSOR SERIAL NUMBER: 4907
CALIBRATION DATE: 24-Oct-2011
Mfg: SEABIRD   Model: 03
Previous cal: 22-Apr-10
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS
g = 4.34480848E-3	a = 4.34500270E-3
h = 6.36403384E-4	b = 6.36611557E-4
i = 2.04302343E-5	c = 2.04617541E-5
j = 1.63599217E-6	d = 1.63737826E-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 (℃)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (℃)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-90	SBE3 ITS-90	SPRT-SBE3 Old_Coefs	SPRT-SBE3 New_Coefs
2934.4902	-1.5093	-1.5094	0.00004	0.00010
3036.0752	-0.0004	-0.0004	-0.00011	0.00001
3104.2949	0.9924	0.9925	-0.00029	-0.00014
3353.6748	4.4935	4.4936	-0.00021	-0.00006
3617.1816	7.9952	7.9951	0.00003	0.00010
3895.2129	11.4972	11.4972	0.00006	0.00000
4187.3604	14.9906	14.9906	0.00021	0.00001
4495.4922	18.4931	18.4932	0.00026	-0.00008
4818.9395	21.9930	21.9928	0.00061	0.00019
5158.5801	25.4951	25.4952	0.00029	-0.00014
5514.1113	28.9939	28.9939	0.00028	-0.00004
5886.5479	32.4958	32.4958	0.00011	0.00005



Temperature Calibration Report
STS/ODF Calibration Facility

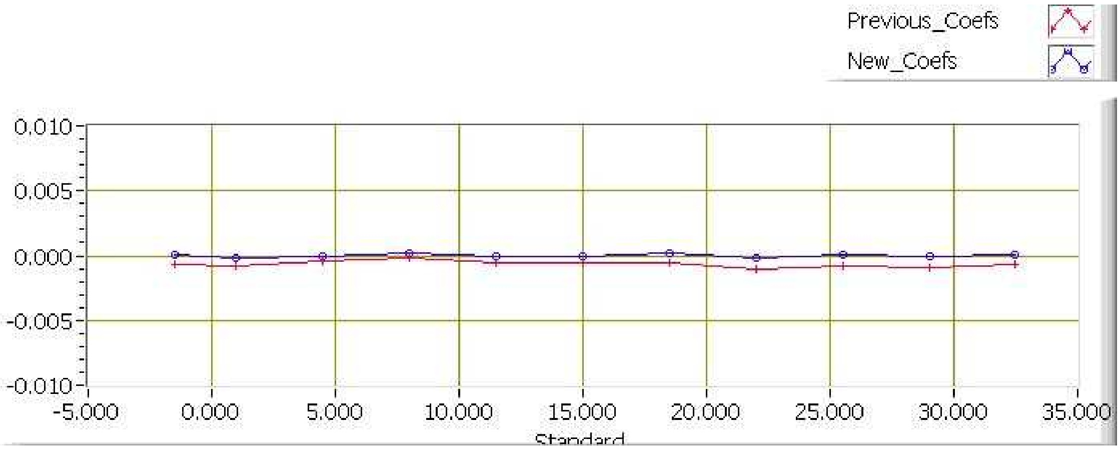
SENSOR SERIAL NUMBER: 4138
CALIBRATION DATE: 28-Oct-2011
Mfg: SEABIRD   Model: 03
Previous cal: 25-Nov-09
Calibration Tech: CAL

ITS-90_COEFFICIENTS	IPTS-68_COEFFICIENTS
g = 4.40204321E-3	a = 4.40225621E-3
h = 6.50910584E-4	b = 6.51127657E-4
i = 2.35304373E-5	c = 2.35636652E-5
j = 2.07695726E-6	d = 2.07851141E-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 (℃)
Temperature IPTS-68 = 1/{a+b[ln(f0/f)]+c[ln2(f0/f)]+d[ln3(f0/f)]} - 273.15 (℃)
T68 = 1.00024 * T90 (-2 to -35 Deg C)

SBE3 Freq	SPRT ITS-90	SBE3 ITS-90	SPRT-SBE3 Old_Coefs	SPRT-SBE3 New_Coefs
3158.9814	-1.5071	-1.5072	-0.00072	0.00012
3339.5400	0.9932	0.9934	-0.00079	-0.00018
3604.7871	4.4955	4.4955	-0.00046	-0.00003
3884.6318	7.9954	7.9952	-0.00021	0.00019
4179.9102	11.4978	11.4979	-0.00056	-0.00010
4489.9121	14.9911	14.9911	-0.00061	-0.00002
4817.4775	18.5022	18.5021	-0.00059	0.00014
5159.3965	21.9925	21.9927	-0.00100	-0.00016
5519.1230	25.4953	25.4952	-0.00083	0.00008
5895.5020	28.9946	28.9946	-0.00093	-0.00004
6289.4004	32.4961	32.4961	-0.00071	0.00002



SEA-BIRD ELECTRONICS, INC.

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2112
CALIBRATION DATE: 14-Sep-11

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

GHIJ COEFFICIENTS

g = -1.01626223e+001
h = 1.47247509e+000
i = -3.14226663e-003
j = 3.03890595e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.95053704e-008
b = 1.46330826e+000
c = -1.01413802e+001
d = -7.52590029e-005
m = 7.8
CPcor = -9.5700e-008 (nominal)

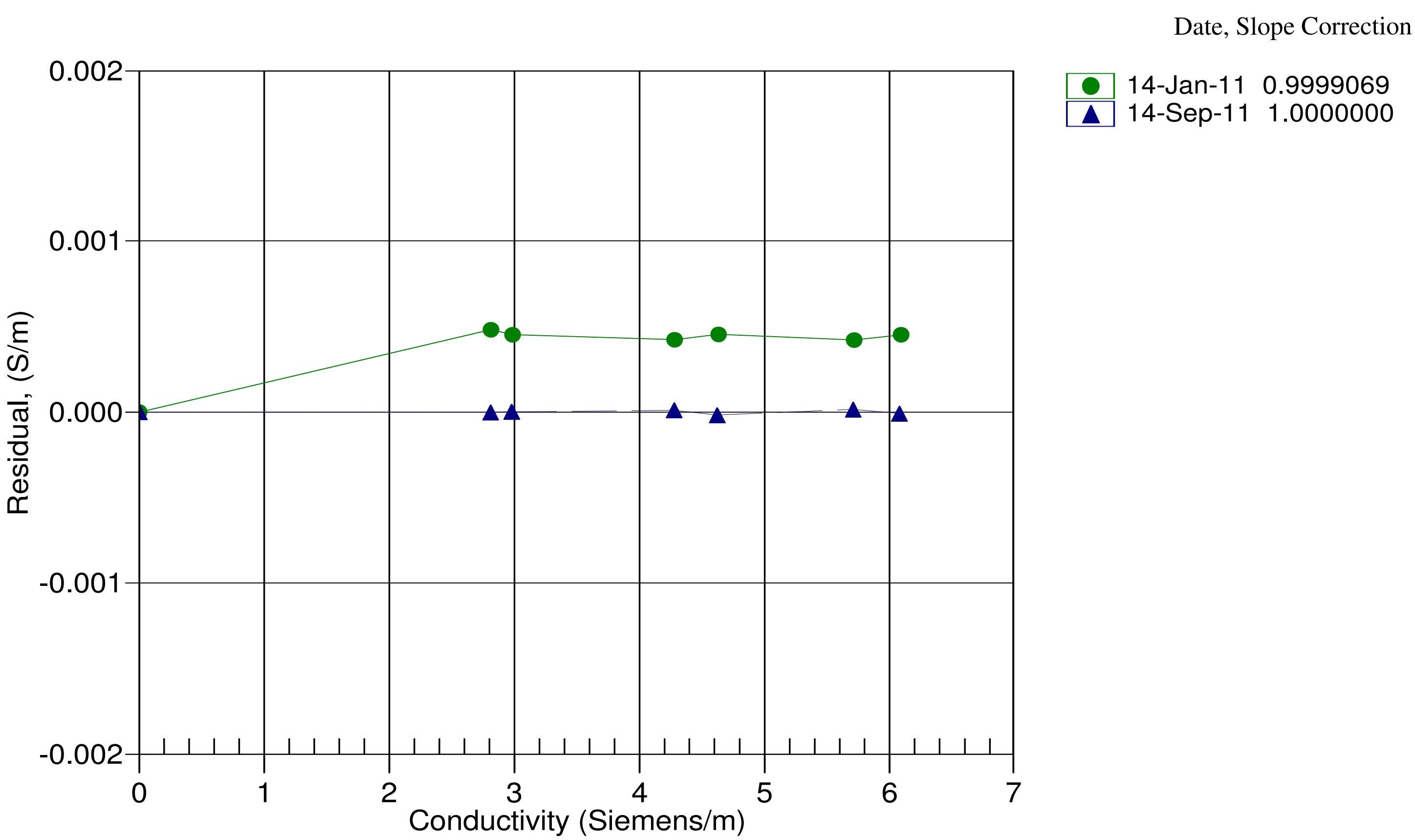
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.63263	0.00000	0.00000
-1.0000	34.8474	2.80685	5.10958	2.80685	-0.00000
1.0000	34.8480	2.97842	5.22298	2.97842	0.00000
15.0000	34.8490	4.27520	6.01094	4.27521	0.00001
18.5000	34.8491	4.62225	6.20471	4.62223	-0.00002
29.0000	34.8463	5.70668	6.77421	5.70669	0.00002
32.5000	34.8376	6.07928	6.95898	6.07927	-0.00001

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

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

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

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



SEA-BIRD ELECTRONICS, INC.

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2569
CALIBRATION DATE: 14-Sep-11

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

GHIJ COEFFICIENTS

```
g = -1.04823756e+001
h =  1.58881172e+000
i = -3.22372504e-004
j =  1.20250728e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  7.15426801e-005
b =  1.58804947e+000
c = -1.04809602e+001
d = -8.25722294e-005
m =  4.1
CPcor = -9.5700e-008 (nominal)
```

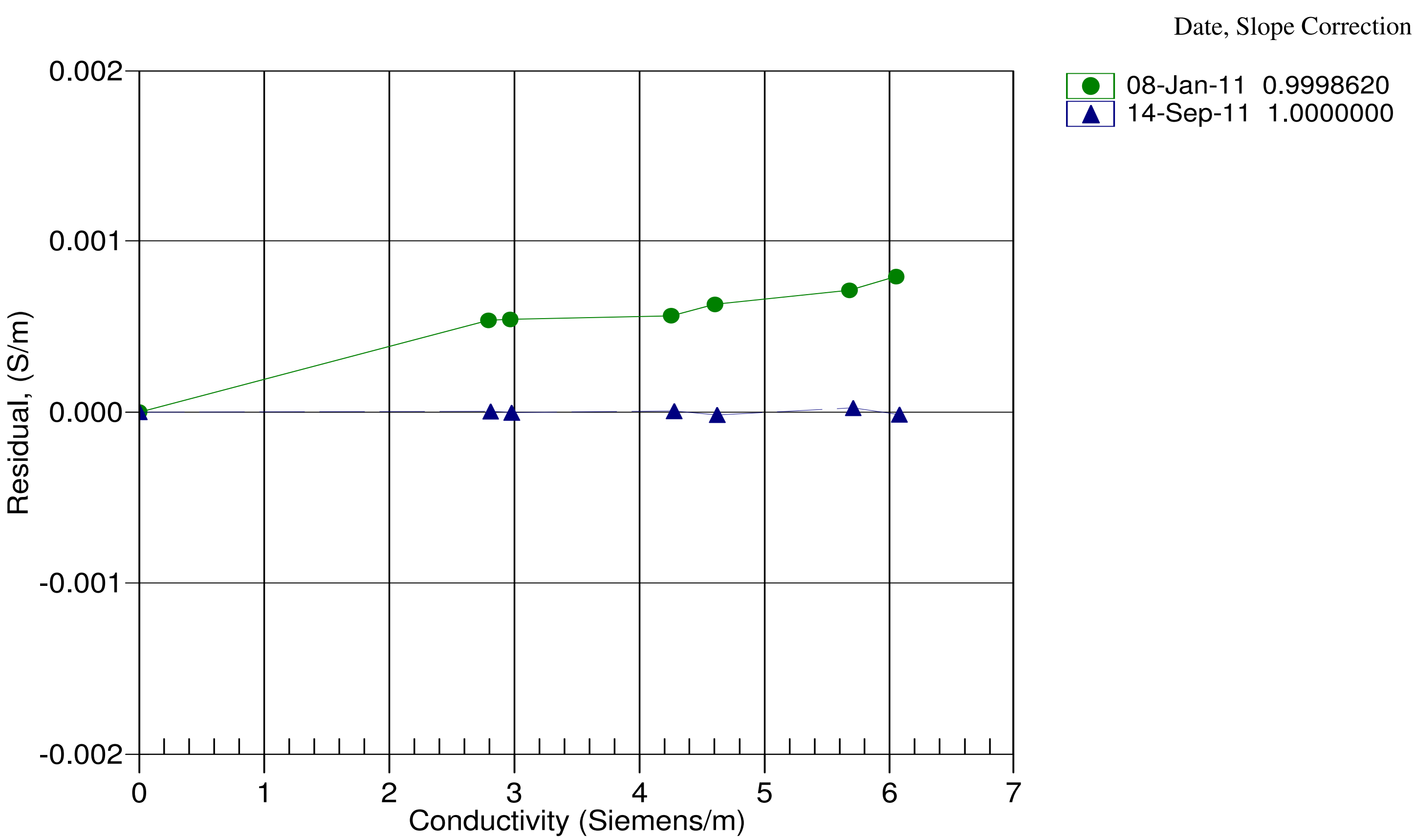
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56861	0.00000	0.00000
-1.0000	34.8474	2.80685	4.92378	2.80685	0.00000
1.0000	34.8480	2.97842	5.03202	2.97841	-0.00000
15.0000	34.8490	4.27520	5.78461	4.27521	0.00001
18.5000	34.8491	4.62225	5.96982	4.62223	-0.00002
29.0000	34.8463	5.70668	6.51451	5.70670	0.00002
32.5000	34.8376	6.07928	6.69132	6.07927	-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



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0875
CALIBRATION DATE: 09-Sep-11p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.3947
Voffset = -0.5236
Tau20 = 1.70

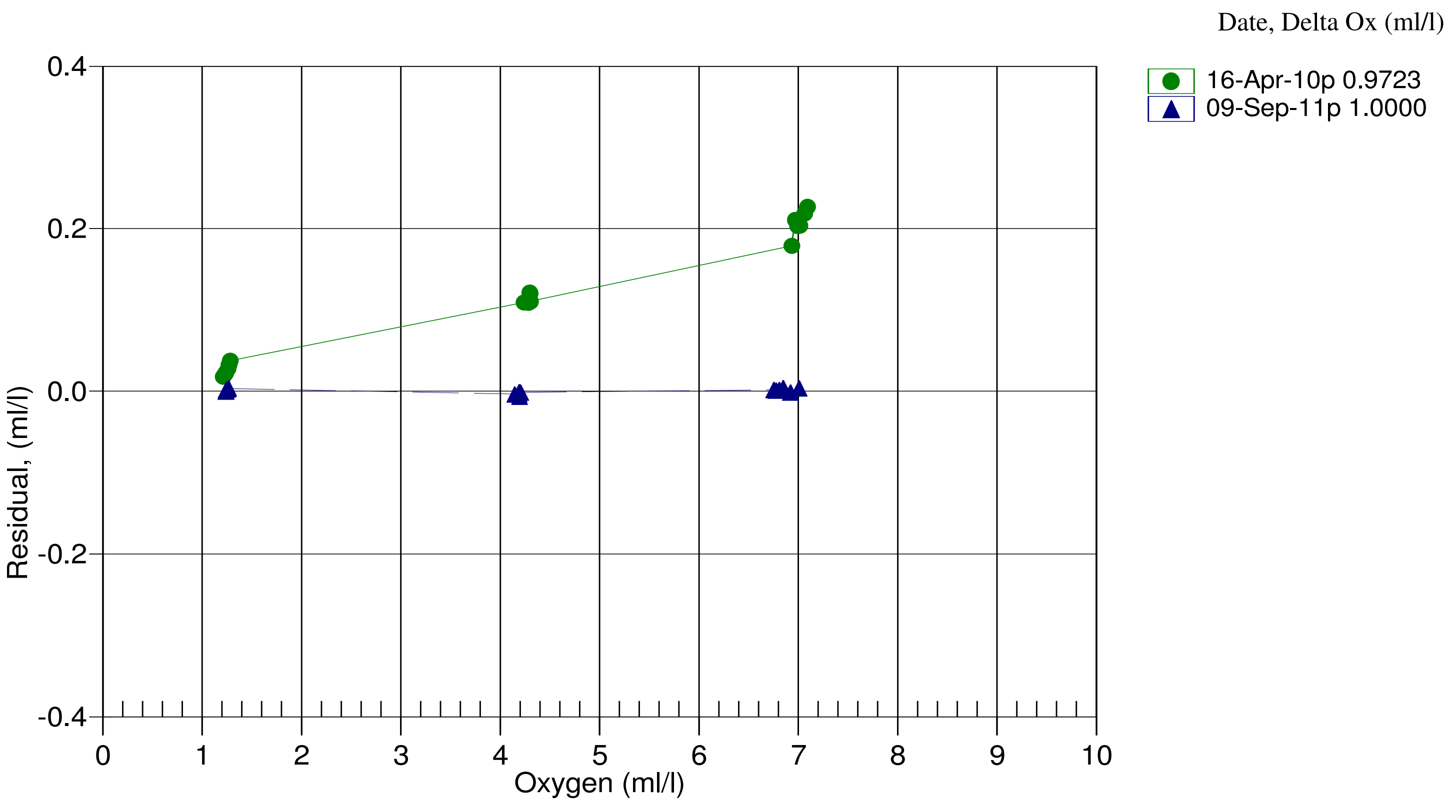
A = -3.3211e-003
B = 2.2067e-004
C = -3.8411e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.30000e-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)
1.24	2.00	0.07	0.850	1.24	-0.00
1.24	6.00	0.07	0.891	1.24	0.00
1.25	12.00	0.07	0.951	1.25	0.00
1.26	20.00	0.06	1.030	1.26	0.00
1.26	26.00	0.06	1.090	1.26	0.00
1.26	30.00	0.06	1.134	1.27	0.00
4.15	2.00	0.08	1.615	4.14	-0.00
4.19	6.00	0.07	1.757	4.18	-0.00
4.19	12.00	0.07	1.951	4.18	-0.00
4.19	20.00	0.07	2.207	4.19	-0.00
4.19	26.00	0.06	2.401	4.19	-0.01
4.21	30.00	0.07	2.548	4.20	-0.00
6.75	30.00	0.07	3.775	6.75	0.00
6.77	26.00	0.06	3.563	6.78	0.00
6.81	20.00	0.07	3.261	6.81	0.00
6.84	12.00	0.07	2.860	6.85	0.00
6.92	6.00	0.07	2.563	6.92	-0.00
7.00	2.00	0.08	2.370	7.01	0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * 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



Transmissometer Air Calibration M&B Calculator

CST-491-DR			Air Cal Date		13 Nov. 2011	
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.864			4.712		
Water Reading	4.752			N/A		
Blocked Reading	0.061			0.059		
Air Temp.	18.885	18.880	18.875	18.920	18.970	18.971
M	19.848		Air Temp. Average			18.917
B	-1.171					

CST-491-DR			Air Cal Date		22 Nov. 2011	
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.864			4.698		
Water Reading	4.752			N/A		
Blocked Reading	0.061			0.059		
Air Temp.	21.576	21.595	21.609	21.619	21.633	21.632
M	19.908		Air Temp. Average			21.611
B	-1.175					

CST-491-DR			Air Cal Date		10 Dec. 2011	
	Factory Cal Sheet Info			AVG Deck/Lab Readings		
Air Reading	4.864			4.657		
Water Reading	4.752			N/A		
Blocked Reading	0.061			0.059		
Air Temp.	23.050	23.020	23.020	23.060	23.050	23.020
M	20.086		Air Temp. Average			23.037
B	-1.185					

Suggestion was made that perhaps the transmissometer was clamped to tightly - misaligning the light path. Loosened clamps and took an additional voltage reading - 4.657. Clamping was not the issue with the transmissometer.

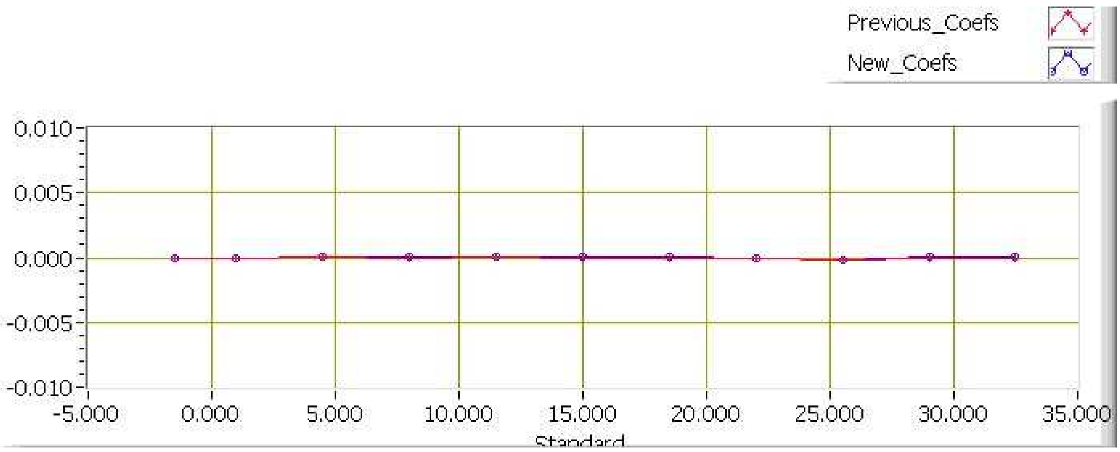
Temperature Calibration Report
STS/ODF Calibration Facility

SENSOR SERIAL NUMBER: 0035
CALIBRATION DATE: 27-Oct-2011
Mfg: SEABIRD   Model: 35
Previous cal: 20-Jun-09
Calibration Tech: CAL

ITS-90_COEFFICIENTS
a0 = 4.096000500E-3
a1 = -1.088470980E-3
a2 = 1.692763430E-4
a3 = -9.479887040E-6
a4 = 2.042562640E-7
Slope = 0.999999 Offset = -0.000014

Calibration Standard: Mfg: ASL   Model: F18   s/n: 245-5149
Temperature ITS-90 = 1/{a0+a1[ln(f)]+a2[ln2(f)]+a3[ln3(f)]+a4[ln4(f)} - 273.15 (℃)

SBE35 Res	SPRT ITS-90	SBE35 ITS-90	SPRT-SBE35 Old_Coefs	SPRT-SBE35 New_Coefs
-1.5072	-1.5073	-1.5072	-0.00010	-0.00009
0.9932	0.9931	0.9932	-0.00010	-0.00008
4.4942	4.4943	4.4942	0.00010	0.00012
7.9954	7.9954	7.9954	0.00000	0.00002
11.4977	11.4978	11.4977	0.00010	0.00012
14.9924	14.9924	14.9924	0.00000	0.00003
18.4965	18.4965	18.4965	0.00000	0.00003
21.9926	21.9925	21.9926	-0.00010	-0.00007
25.4950	25.4948	25.4950	-0.00020	-0.00016
28.9955	28.9955	28.9955	0.00000	0.00004
32.4958	32.4958	32.4958	0.00000	0.00004



CCHDO Data Processing Notes

Date	Person	Data Type	Action	Summary
2013-08-07	Johnson, Mary	CTD	Submitted	to go online (2nd half)

These are the second half of what GEOTRACES calls "NAZT" (North Atlantic Zonal Transsect). The transsect was resumed from the west side in 2011, with stations again starting from "1". These are the CTD data from the "SIOR" rosette only. Jim Swift has the bottle exchange files to review, and will submit them separately.

Date	Person	Data Type	Action	Summary
2013-08-07	Swift, Jim	BTL	Submitted	to go online (2nd half)

These are edited versions of the BCO-DMO files for the ODF rosette data from the two US GEOTRACES Atlantic cruise legs, here containing only the routine hydrography data. The ocean carbon data will be provided when they are available.

Date	Person	Data Type	Action	Summary
2013-08-07	Swift, Jim	BTL	Re-submitted	to go online (2nd half)

These are edited version of the bottle data files at BCO-DMO for the ODF and Cutter rosettes from the two US GEOTRACES Atlantic cruises. The files contain only the routine hydrographic data. The ocean carbon data from the ODF rosette casts will be added when available. ODF rosette bottle data files have "SIOR" in the file name. Cutter rosette bottle data files have "GT-C" in the file name.

Date	Person	Data Type	Action	Summary
2013-08-16	Staff, CCHDO	CTD	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.
gt11_ct1.zip
gt11_CruiseReport.zip

Date	Person	Data Type	Action	Summary
2013-08-16	Staff, CCHDO	BTL	Website Update	Available under 'Files as received'

The following files are now available online under 'Files as received', unprocessed by the CCHDO.
gt10_GT-C_edit_hy1.csv
gt11_SIOR_edit_hy1.csv
gt10_SIOR_edit_hy1.csv
gt11_GT-C_edit_hy1.csv

Date	Person	Data Type	Action	Summary
2013-08-20	Lee, Rox	maps	Website Update	Map created

```
==============================
316N20111106 processing - Maps
==============================
2013-08-20
R Lee
.. contents:: :depth: 2
Process
=======
Changes
-------
- Map created from gt11_SIOR_edit_hy1.csv
Merge
-----
Directories
===========
:working directory:
  /data/co2clivar/atlantic/316N20111106/original/2013.08.20_maps_RJL
:cruise directory:
  /data/co2clivar/atlantic/316N20111106
Updated Files Manifest
======================
- 316N20111106_trk.gif
- 316N20111106_trk.jpg
```

2013-10-11 Berys, Carolina CTD Website Update Exchange and netCDF files online

```
=============================
316N20111106 processing - CTD
=============================
2013-10-11
C Berys
.. contents:: :depth: 2
Submission
==========
============ ================== ========== ========= ====
filename     submitted by       date       data type id
============ ================== ========== ========= ====
gt11_ct1.zip Mary Carol Johnson 2013-08-07 CTD       1046
============ ================== ========== ========= ====
Parameters
----------
gt11_ct1.zip
~~~~~~~~~~~~
- CTDPRS [1]_
- CTDTMP [1]_
- CTDSAL [1]_
- CTDOXY [1]_
- TRANSM [1]_
- FLUORM [1]_
- CTDDEPTH [1]_
- CTDNOBS
- CTDETIME
.. [1] parameter has quality flag column
Process
=======
Changes
-------
gt11_ct1.zip
~~~~~~~~~~~~
- files renamed
Conversion
----------
======================= ==================== =======================
file                    converted from       software
======================= ==================== =======================
316N20111106_nc_hyd.zip 316N20111106_hy1.csv hydro 0.8.0-50-g4bae068
======================= ==================== =======================
All converted files opened in JOA with no apparent problems.
Directories
===========
:working directory:
  /data/co2clivar/atlantic/316N20111106/original/2013.10.11_CTD_CBG
:cruise directory:
  /data/co2clivar/atlantic/316N20111106
Updated Files Manifest
======================
- 316N20111106_ct1.zip
- 316N20111106_nc_ctd.zip
```

2013-11-31 Kappa, Jerry CrsRpt Website Update New PDF verstion online

I've placed a new PDF version of the cruise report: 316N20111106_do.pdf
into the directory: co2clivar/atlantic/316N20111106/ .

It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes, as well as a linked Table of Contents and links to figures, tables and appendices.