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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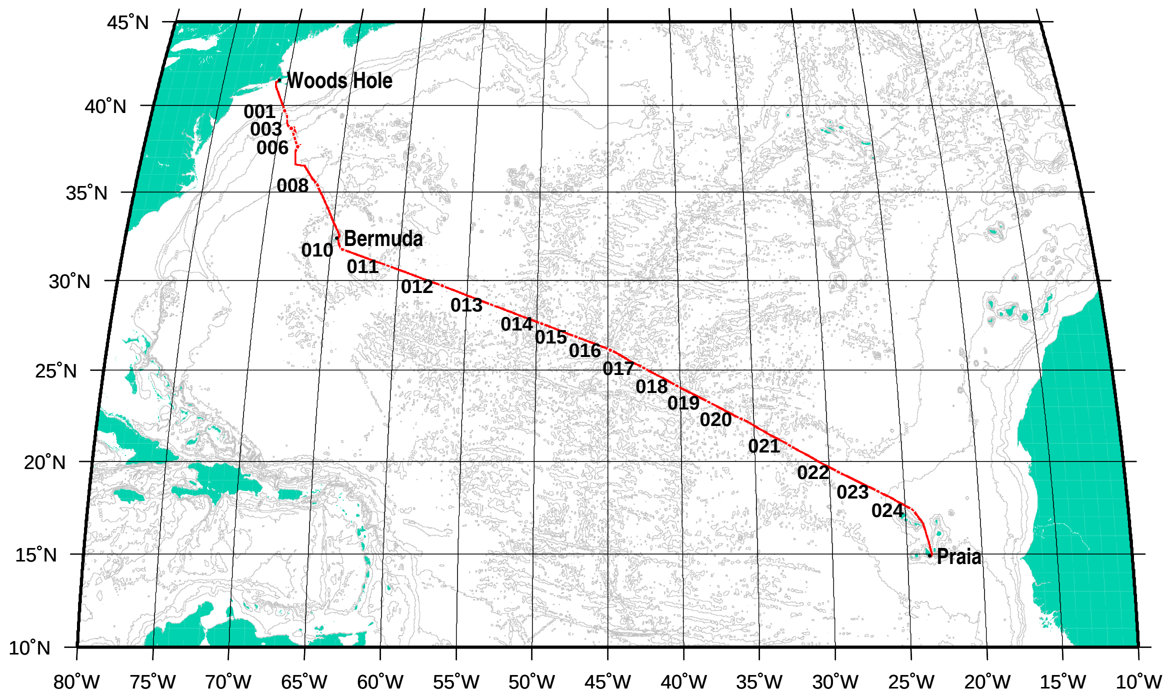

STS Cruise Report
11 December 2011

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
Pb, Pb Isotopes Cr, Cr Isotopes Polarographic Zn Zn Speciation	MIT	Ed Boyle	eaboyle@mit.edu
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			
Program	Affiliation*	Princ. Investigator	email
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
Large Volume Particles	WHOI	Phoebe J. Lam	pjlam@whoi.edu
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Mercury	WHOI	Carl Lamborg	clamborg@whoi.edu

* Affiliation abbreviations listed on page 5

Miscellaneous Sampling			
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Aerosol Sampler - Dissolved Fe	UAF	Ana M. Aguilar-Islas	amaguilarislas@alaska.edu
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* Affiliation abbreviations listed on page 5

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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.

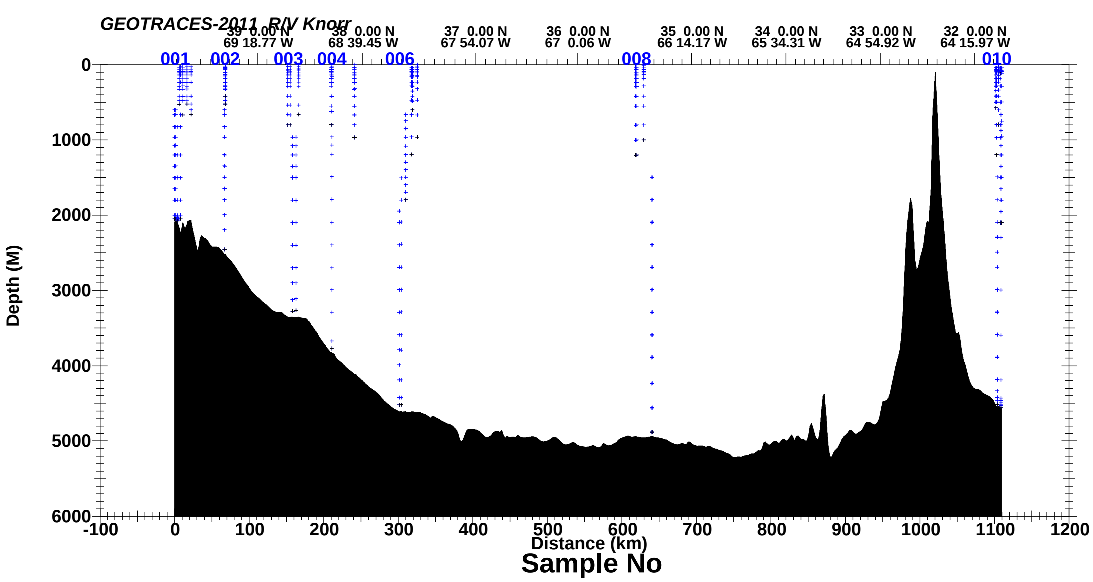

Figure 1.0 GEOTRACES 2011 Sample distribution, Leg 1: stations 1-(10).

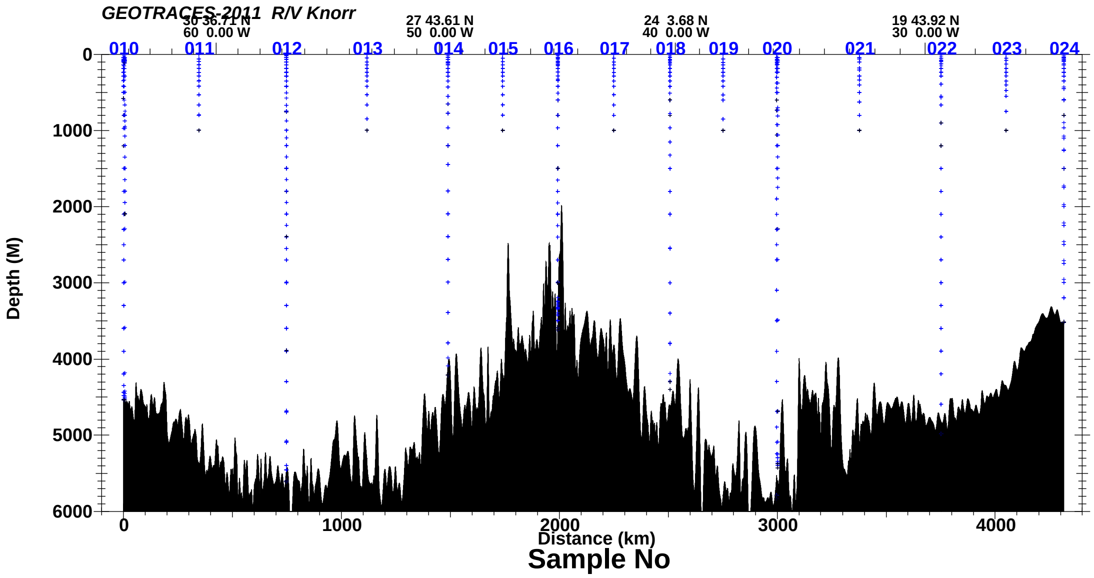

Figure 1.1 GEOTRACES 2011 Sample distribution, Leg 2: stations 10-24.

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.

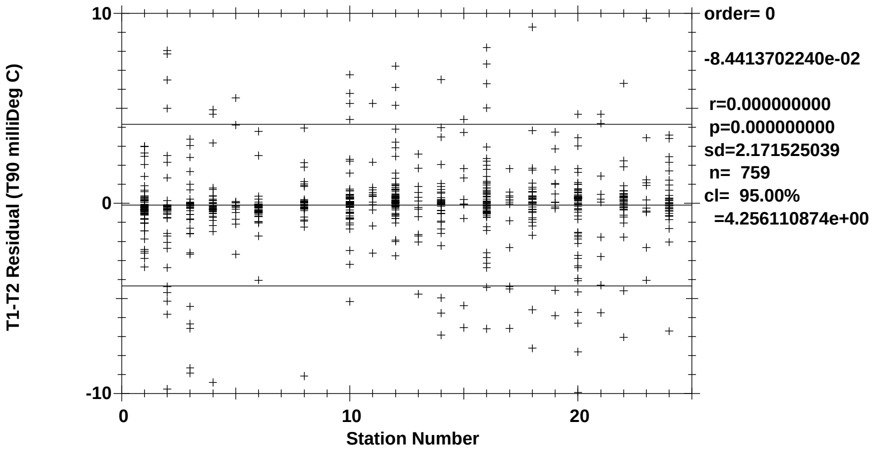

Figure 1.6.2.0 T1-T2 by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

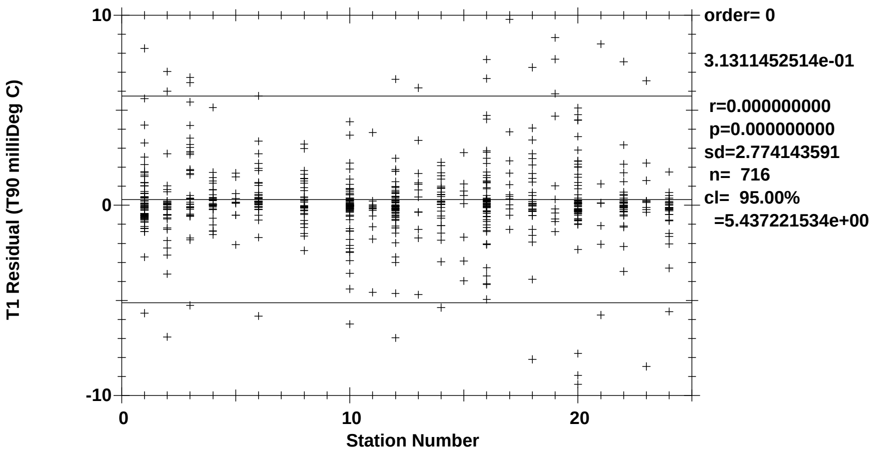

Figure 1.6.2.1 SBE35RT-T1 by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

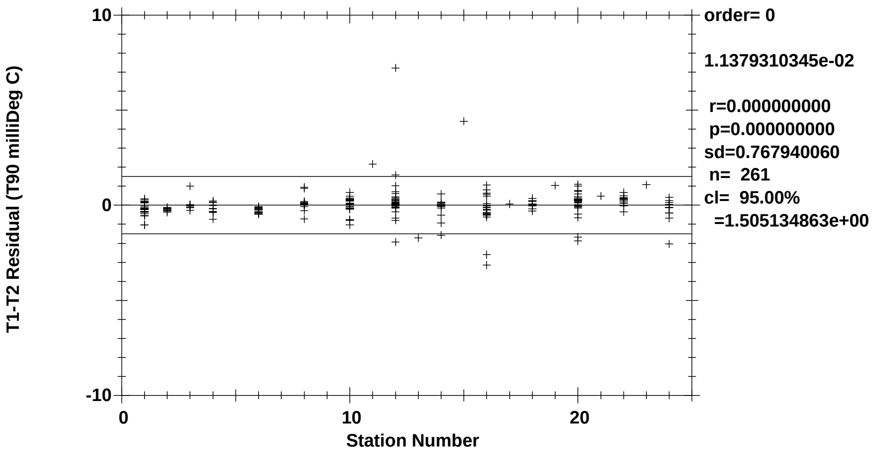

Figure 1.6.2.2 Deep T1-T2 by station (Pressure > 1000dbar).

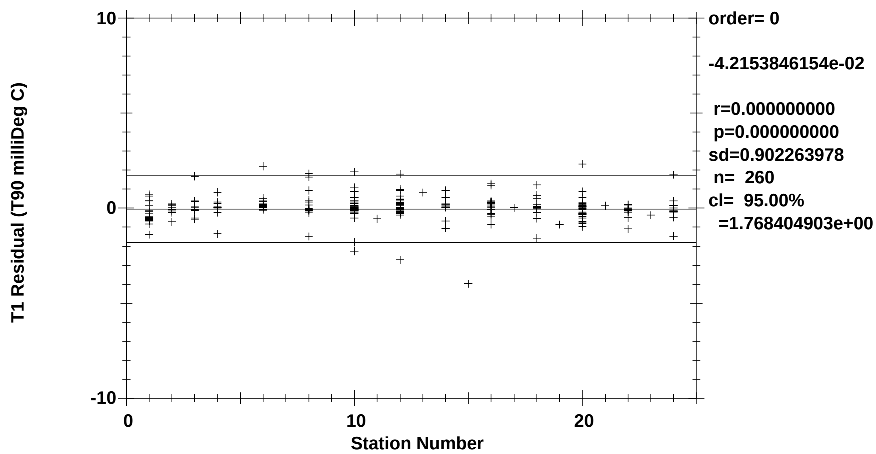

Figure 1.6.2.3 Deep SBE35RT-T1 by station (Pressure > 1000dbar).

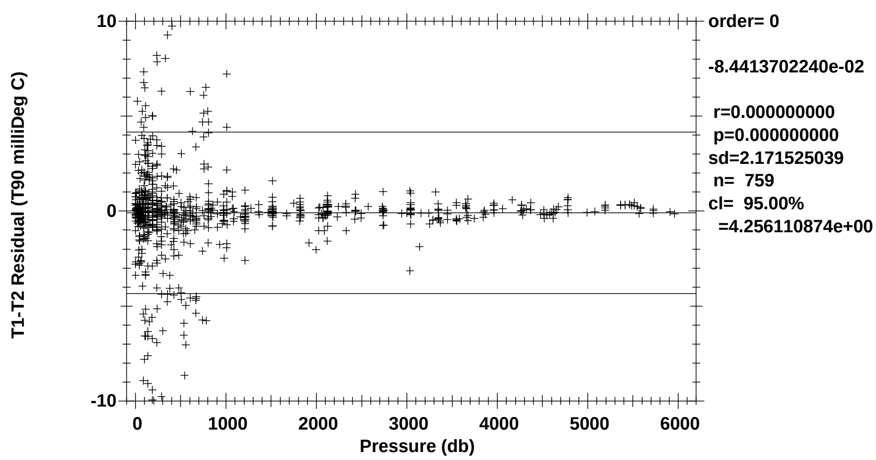

Figure 1.6.2.4 T1-T2 by pressure ($-0.01°C \leq T1 - T2 \leq 0.01°C$).

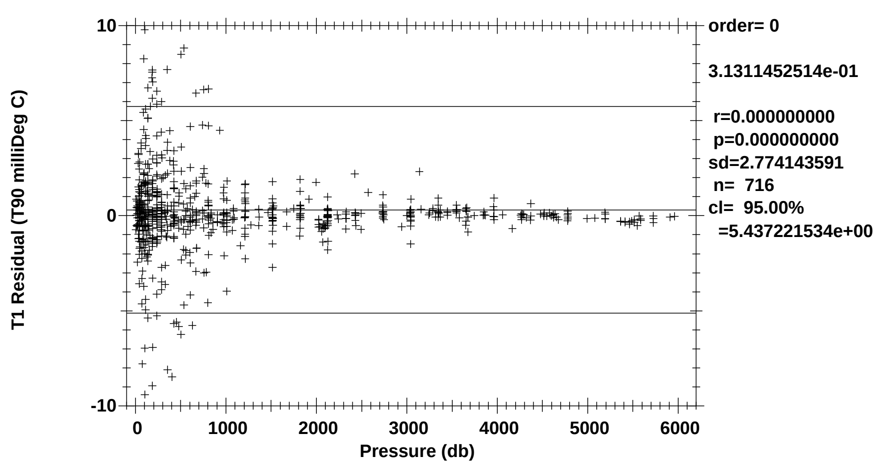

Figure 1.6.2.5 SBE35RT-T1 by pressure ($-0.01°C \leq T1 - T2 \leq 0.01°C$).

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.

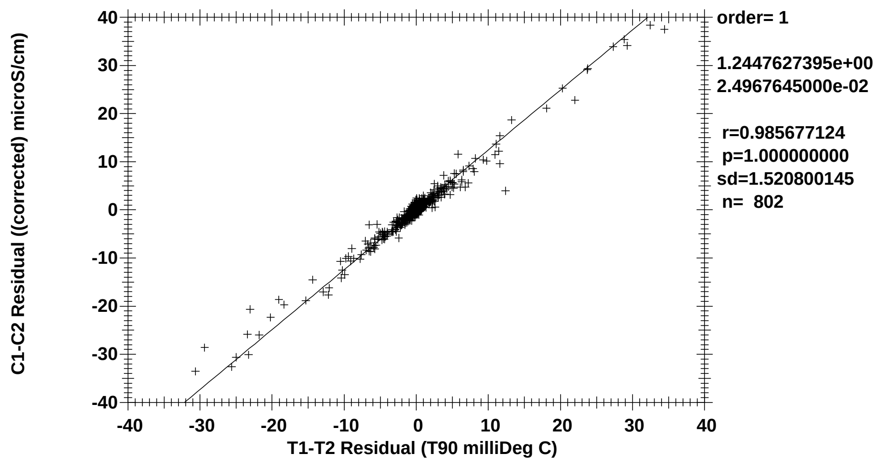

Figure 1.6.3.0 Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.6.3.1 through 1.6.3.3.

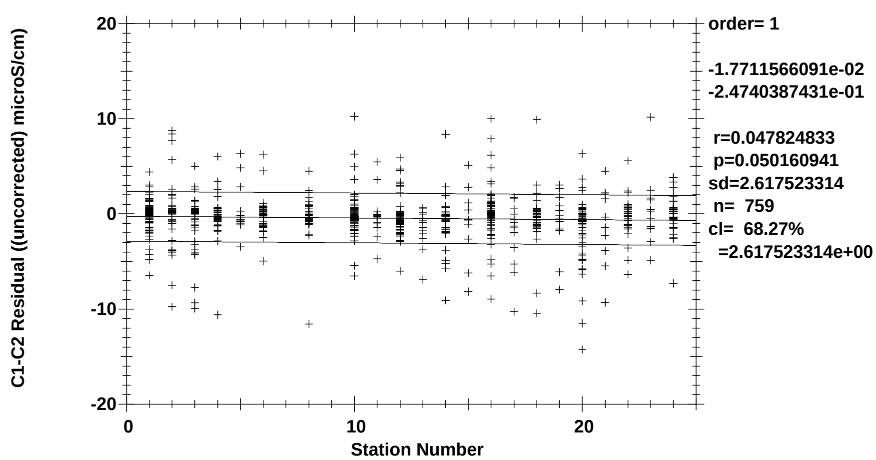

Figure 1.6.3.1 SIOR Uncorrected $C1-C2$ by station (-0.01°C $\leq T1-T2 \leq$ 0.01°C).

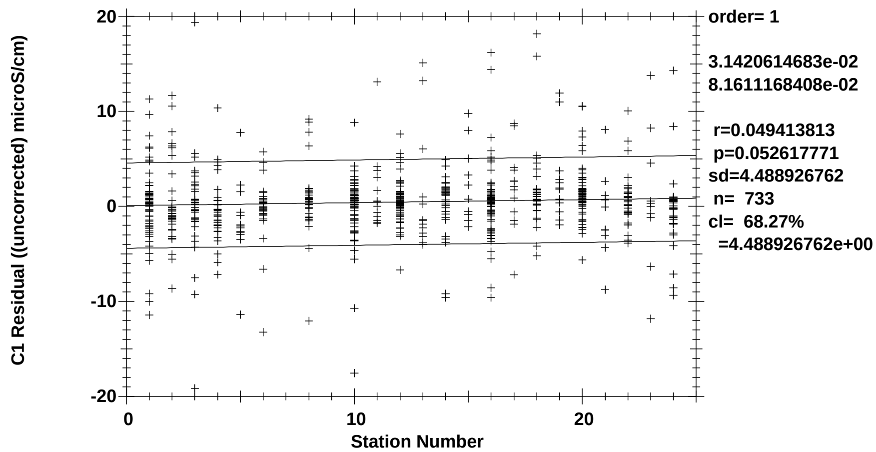

Figure 1.6.3.2 SIOR Uncorrected $C_{Bottle} - C1$ by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

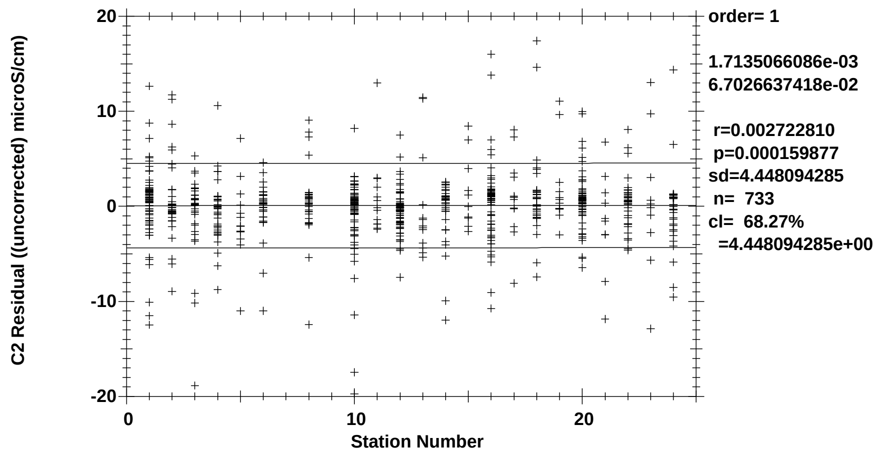

Figure 1.6.3.3 SIOR Uncorrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

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.

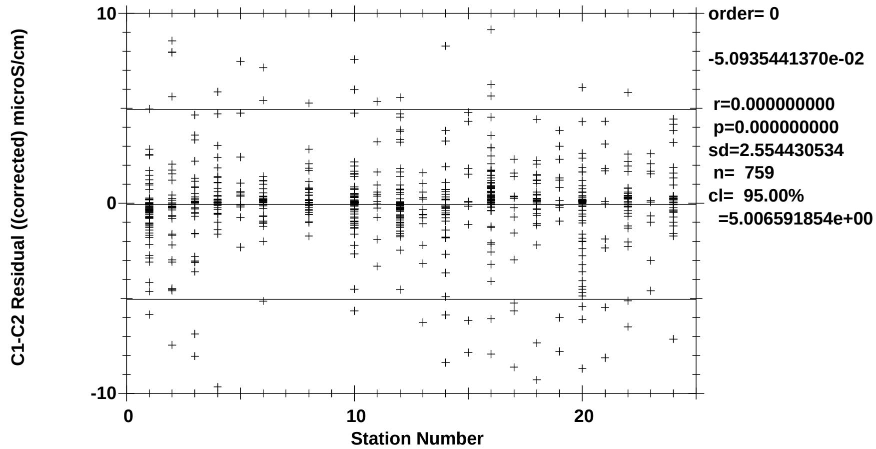

Figure 1.6.3.4 SIOR Corrected $C1-C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

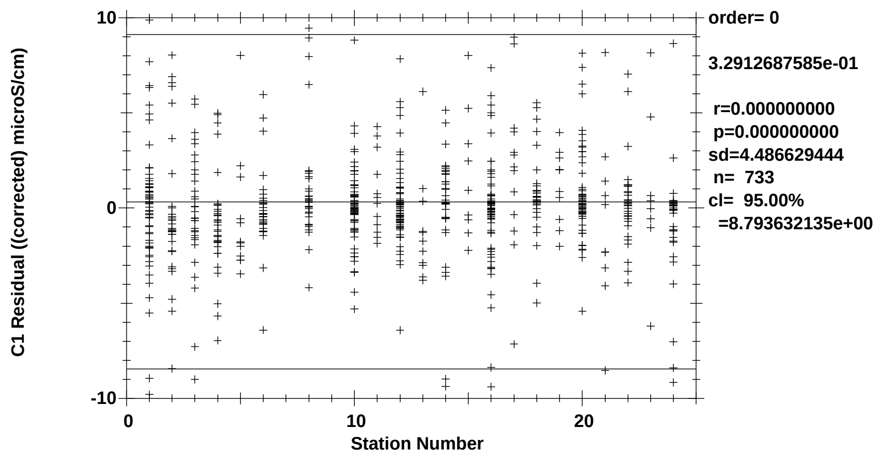

Figure 1.6.3.5 SIOR Corrected $C_{Bottle}-C1$ by station (-0.01°C ≤T1-T2≤0.01°C).

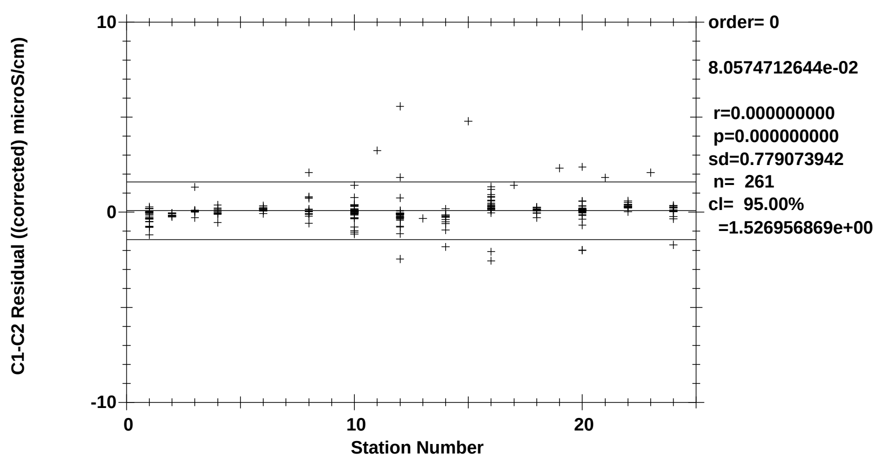

Figure 1.6.3.6 SIOR Deep Corrected $C1-C2$ by station (Pressure >= 1000dbar).

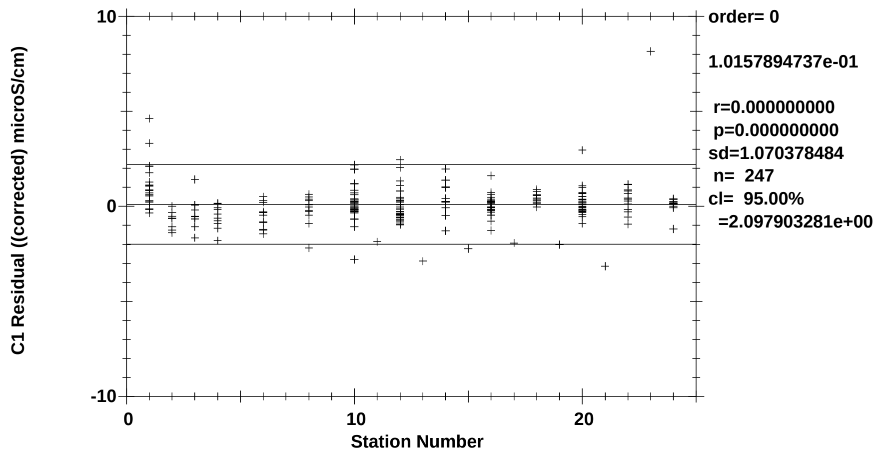

Figure 1.6.3.7 SIOR Deep Corrected $C_{Bottle} - C1$ by station (Pressure >= 1000dbar).

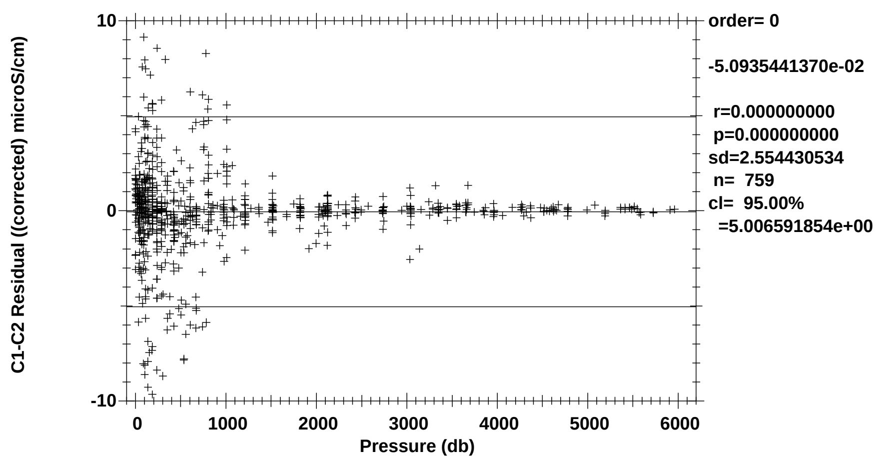

Figure 1.6.3.8 SIOR Corrected $C1 - C2$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

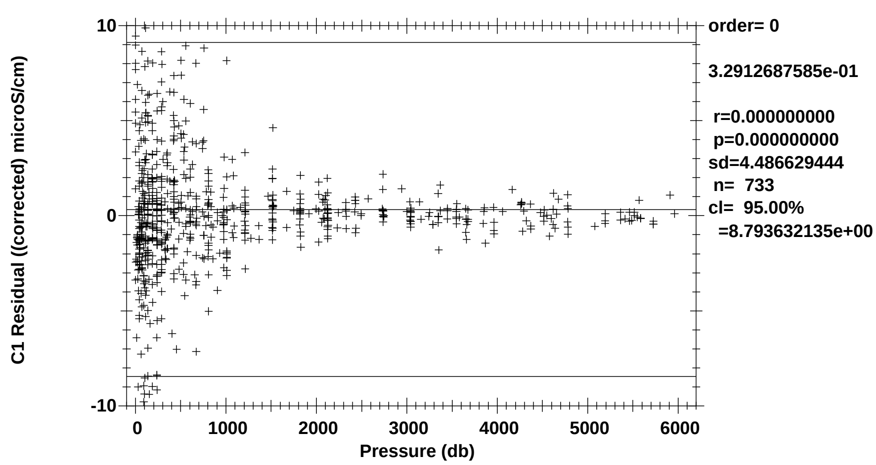

Figure 1.6.3.9 SIOR Corrected $C_{Bottle} - C1$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

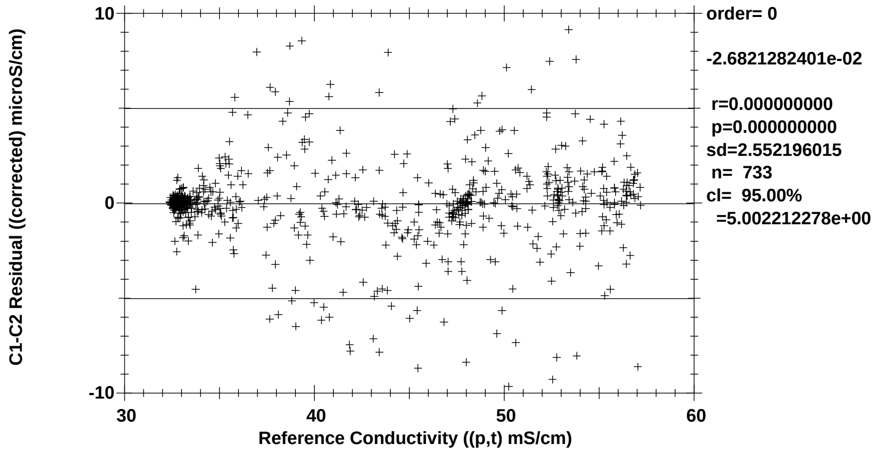

Figure 1.6.3.10 SIOR Corrected $C1-C2$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

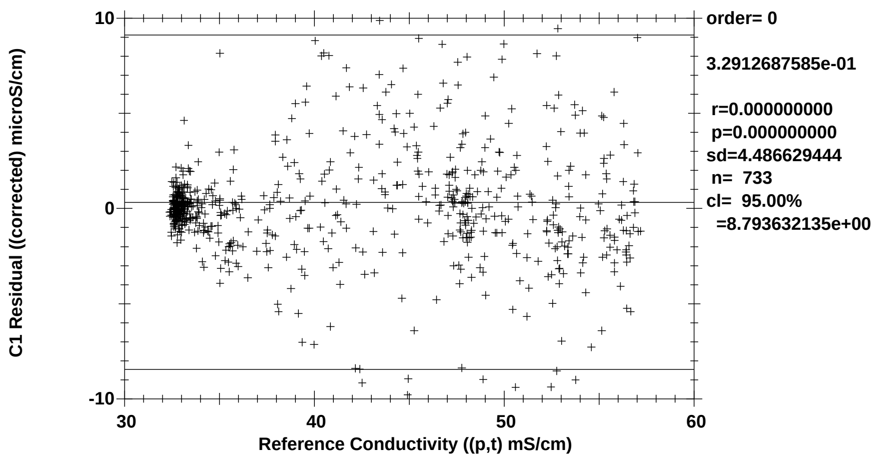

Figure 1.6.3.11 SIOR Corrected $C_{Bottle}-C1$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

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.

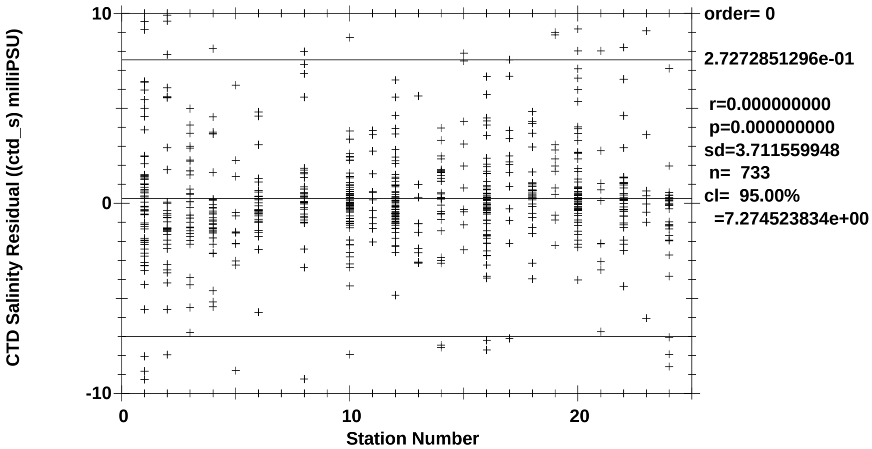

Figure 1.6.3.12 Salinity residuals by station (-0.01°C ≤T1-T2≤0.01°C).

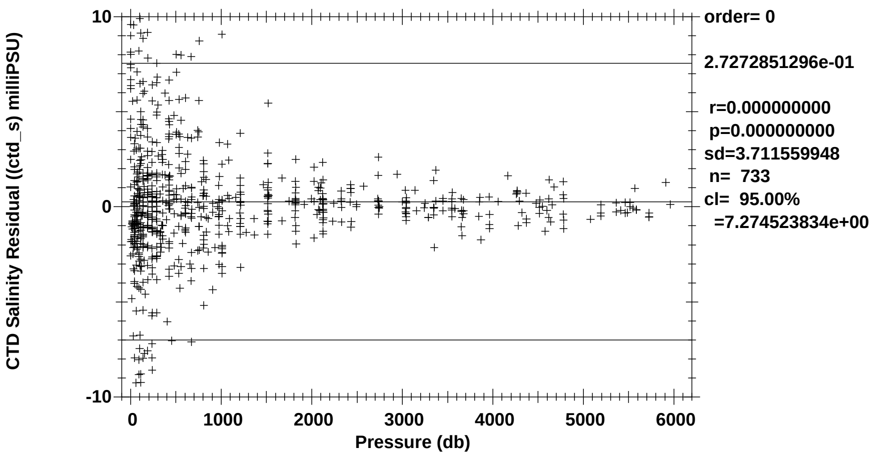

Figure 1.6.3.13 Salinity residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

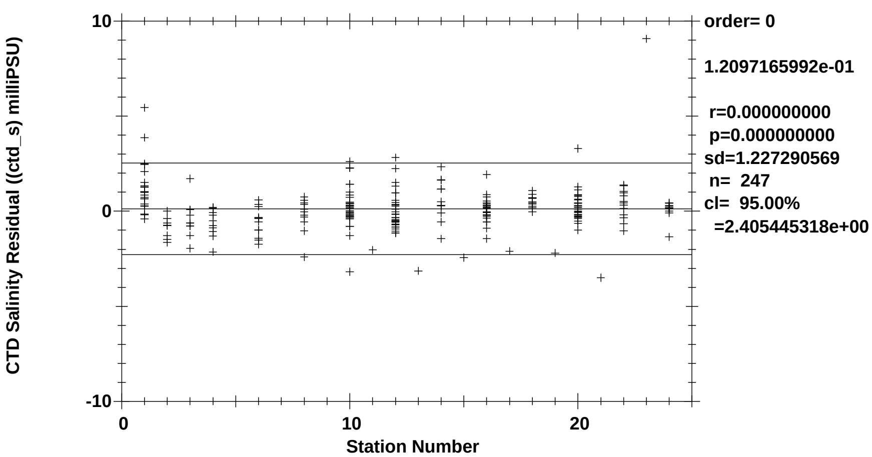

Figure 1.6.3.14 Deep Salinity residuals by station (Pressure >= 1000dbar).

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.

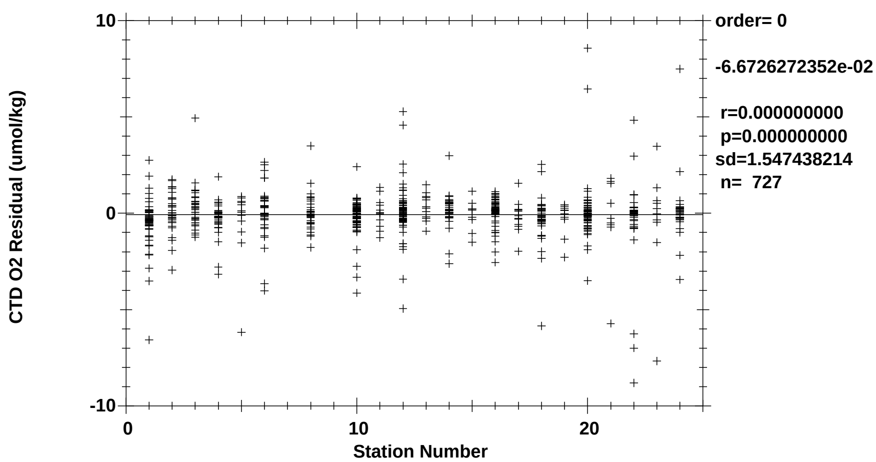

Figure 1.6.4.0 O_2 residuals by station (-0.01°C ≤T1-T2≤0.01°C).

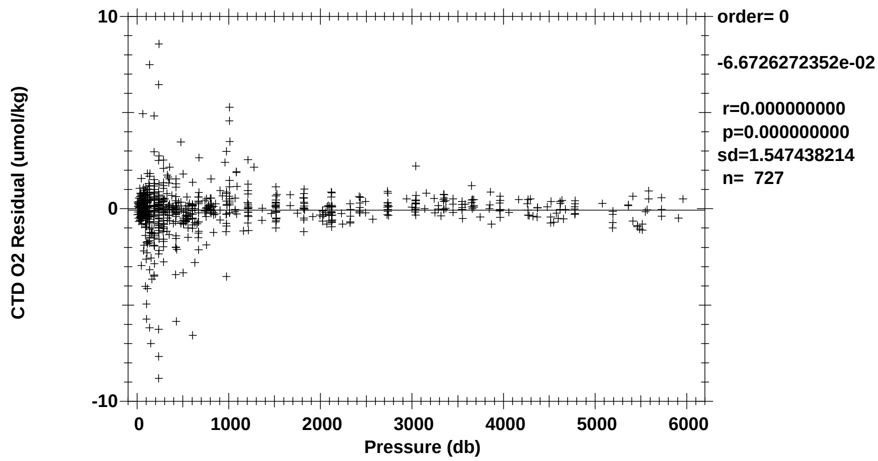

Figure 1.6.4.1 O_2 residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

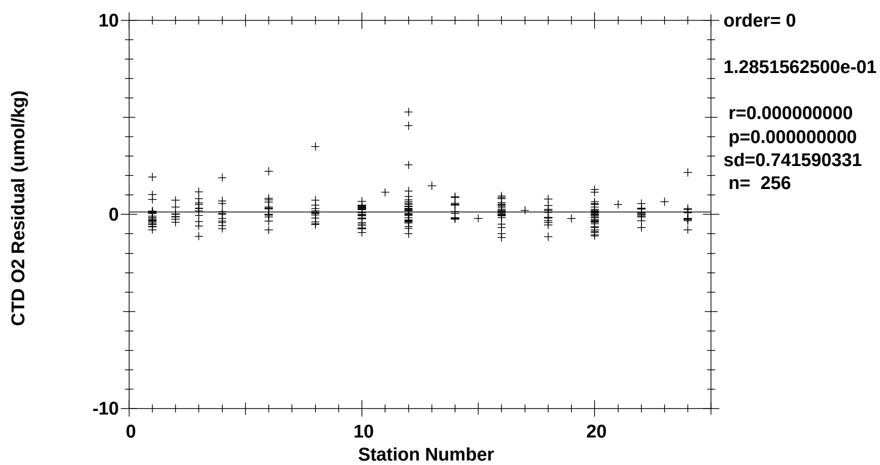

Figure 1.6.4.2 Deep O_2 residuals by station (Pressure >= 1000dbar).

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:

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

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/ Cast	ITS-90 Temperature Coefficients corT = tp1*corP + t0 tp1	t0	Conductivity Coefficients corC = cp1*corP + c0 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_c Slope (c_1)	Offset (c_3)	P_h coeff (c_2)	T_l coeff (c_4)	T_s coeff (c_5)	P_l coeff (c_6)	$\frac{dO_c}{dt}$ coeff (c_7)	$\frac{dP}{dt}$ coeff (c_8)	T_{dT} coeff (c_9)
001/02	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

* 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

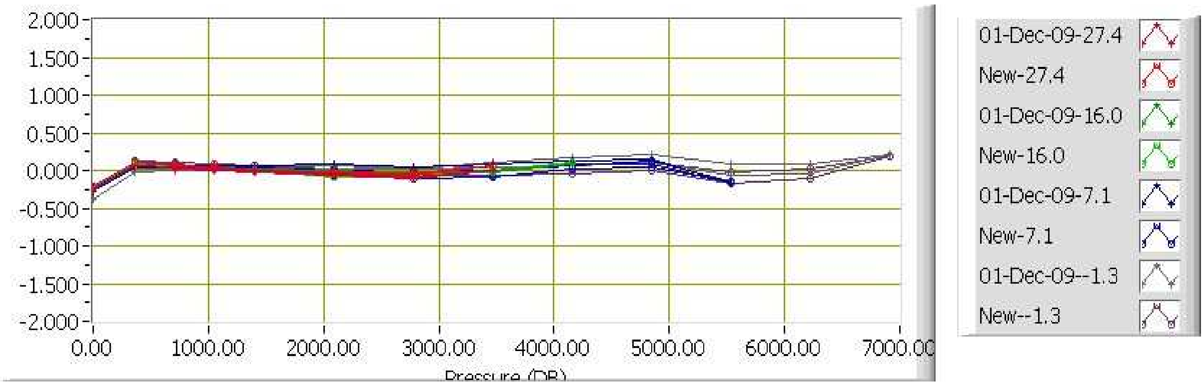
Calibration Standard: Mfg: RUSKA Model: 2400 s/n: 34336
t0=t1+t2*td+t3*td*td+t4*td*td*td
w = 1-t0*t0*f*f
Pressure = (0.6894759*((c1+c2*td+c3*td*td)*w*(1-(d1+d2*td)*w)-14.7)

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

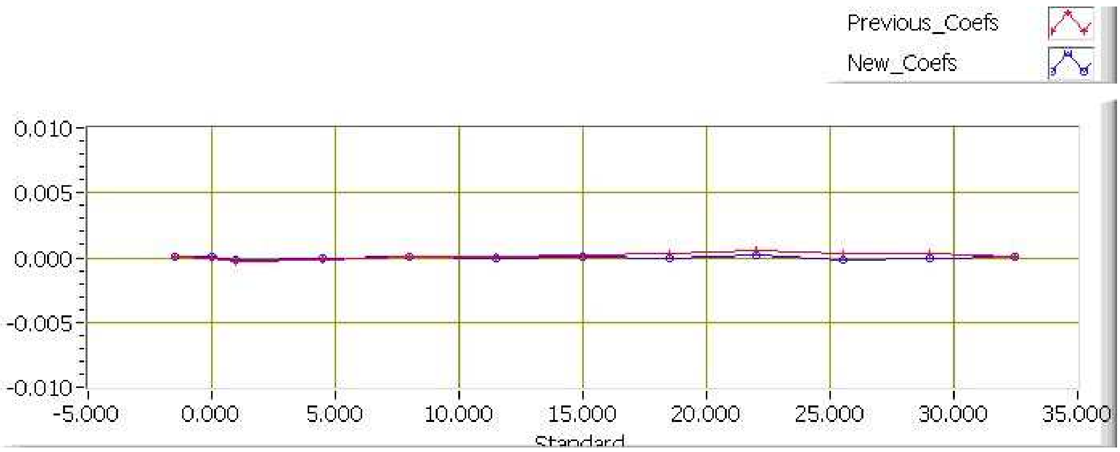
SENSOR SERIAL NUMBER: 4907
CALIBRATION DATE: 24-Oct-2011
Mfg: SEABIRD   Model: 03
Previous cal: 22-Apr-10
Calibration Tech: CAL

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

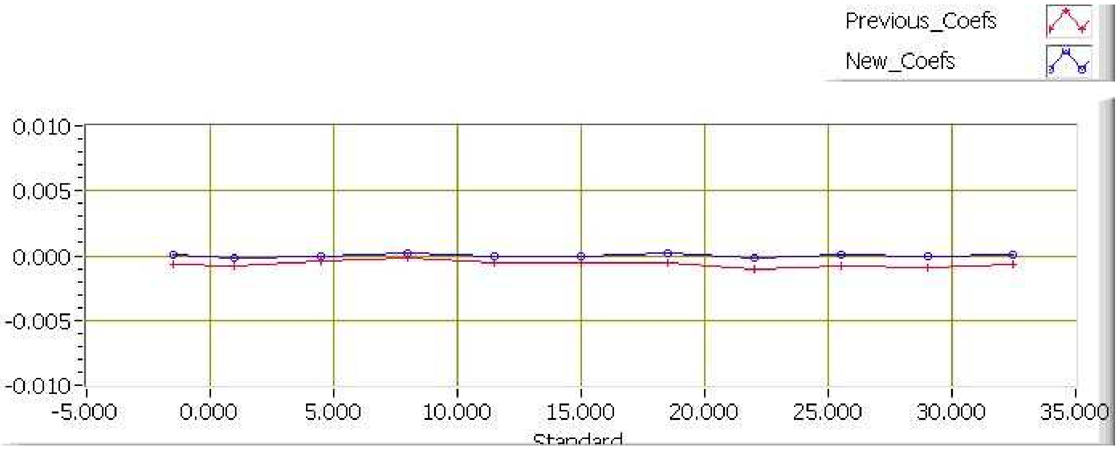
SENSOR SERIAL NUMBER: 4138
CALIBRATION DATE: 28-Oct-2011
Mfg: SEABIRD   Model: 03
Previous cal: 25-Nov-09
Calibration Tech: CAL

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)
```

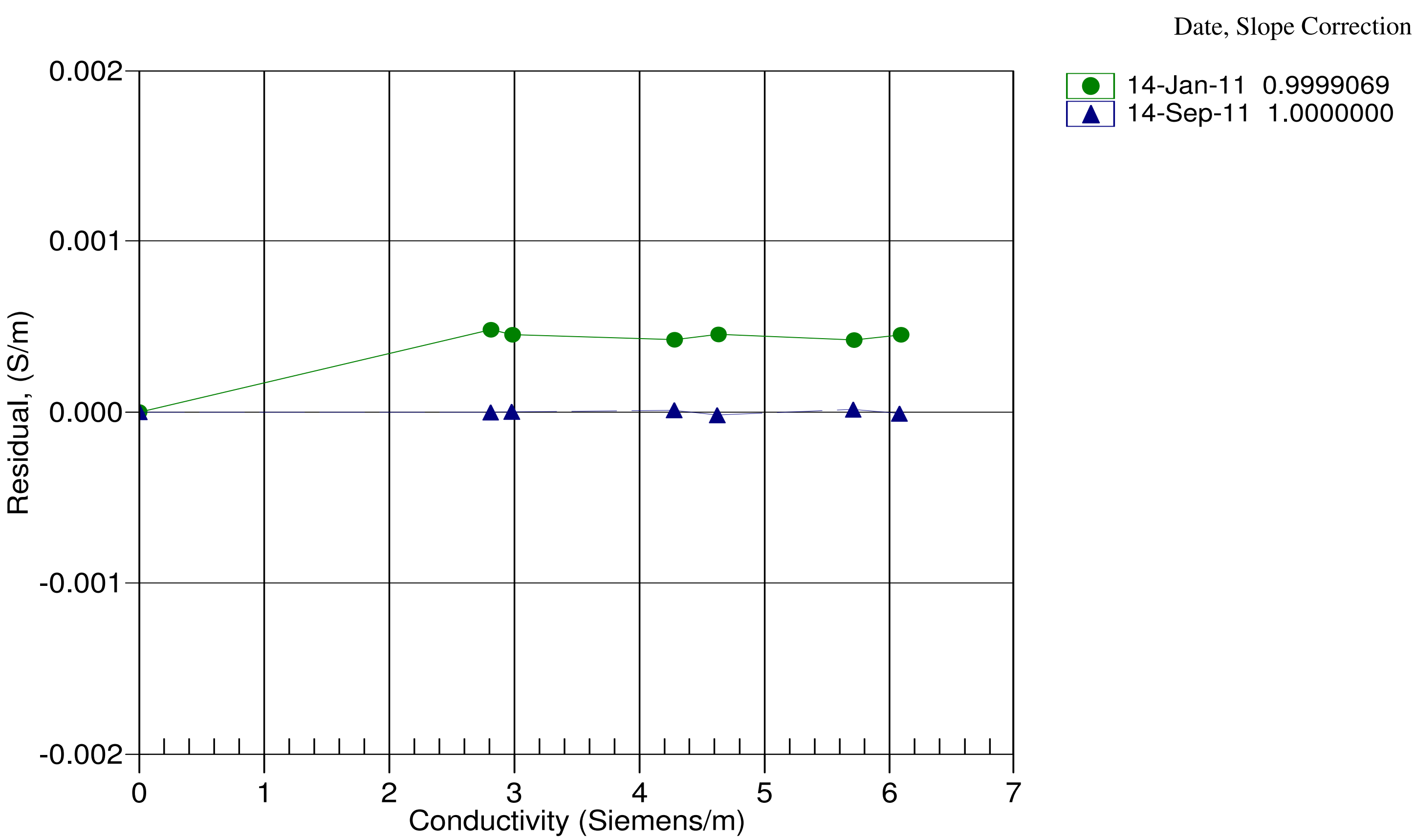
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.63263	0.00000	0.00000
-1.0000	34.8474	2.80685	5.10958	2.80685	-0.00000
1.0000	34.8480	2.97842	5.22298	2.97842	0.00000
15.0000	34.8490	4.27520	6.01094	4.27521	0.00001
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)

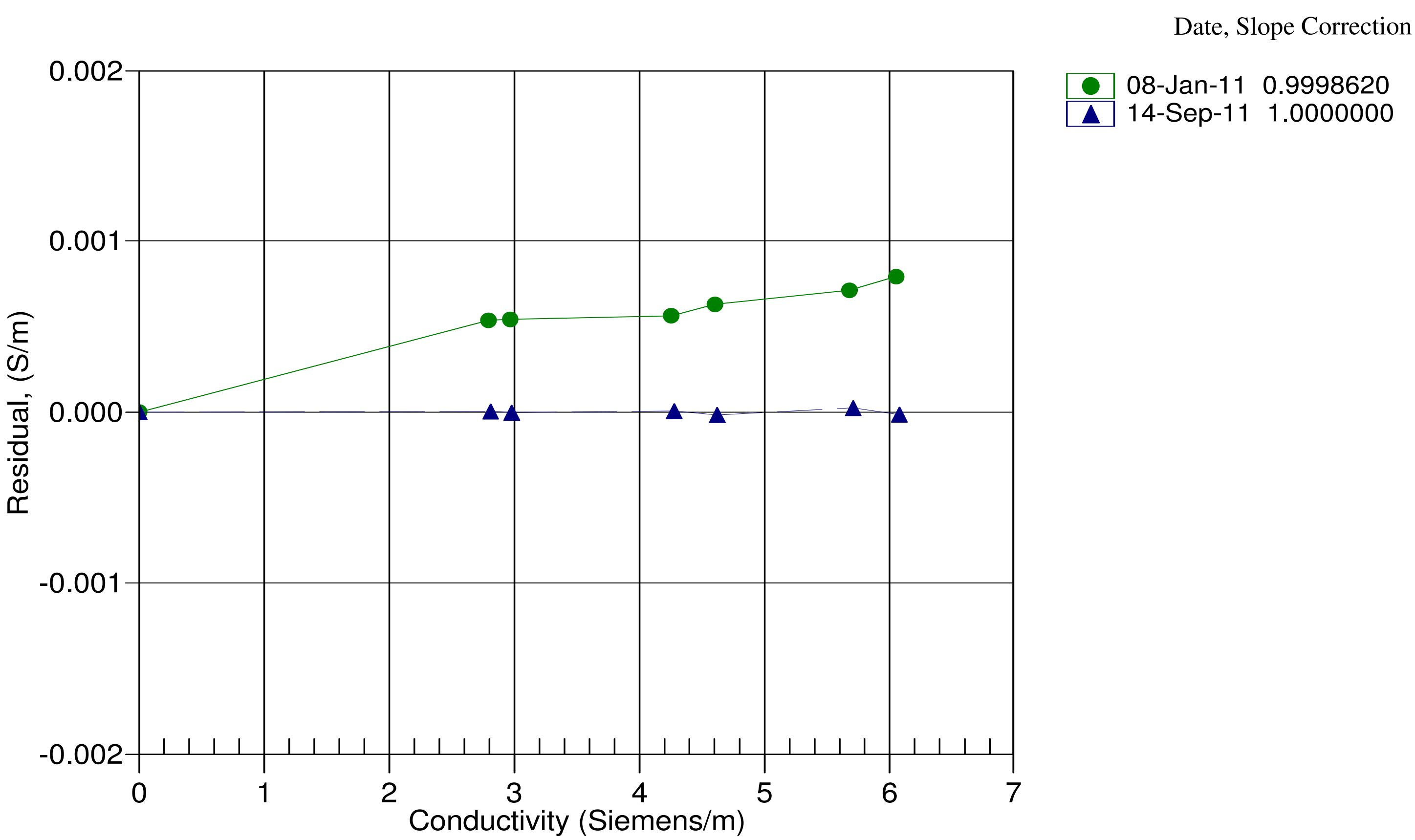
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56861	0.00000	0.00000
-1.0000	34.8474	2.80685	4.92378	2.80685	0.00000
1.0000	34.8480	2.97842	5.03202	2.97841	-0.00000
15.0000	34.8490	4.27520	5.78461	4.27521	0.00001
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 = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ 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



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

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

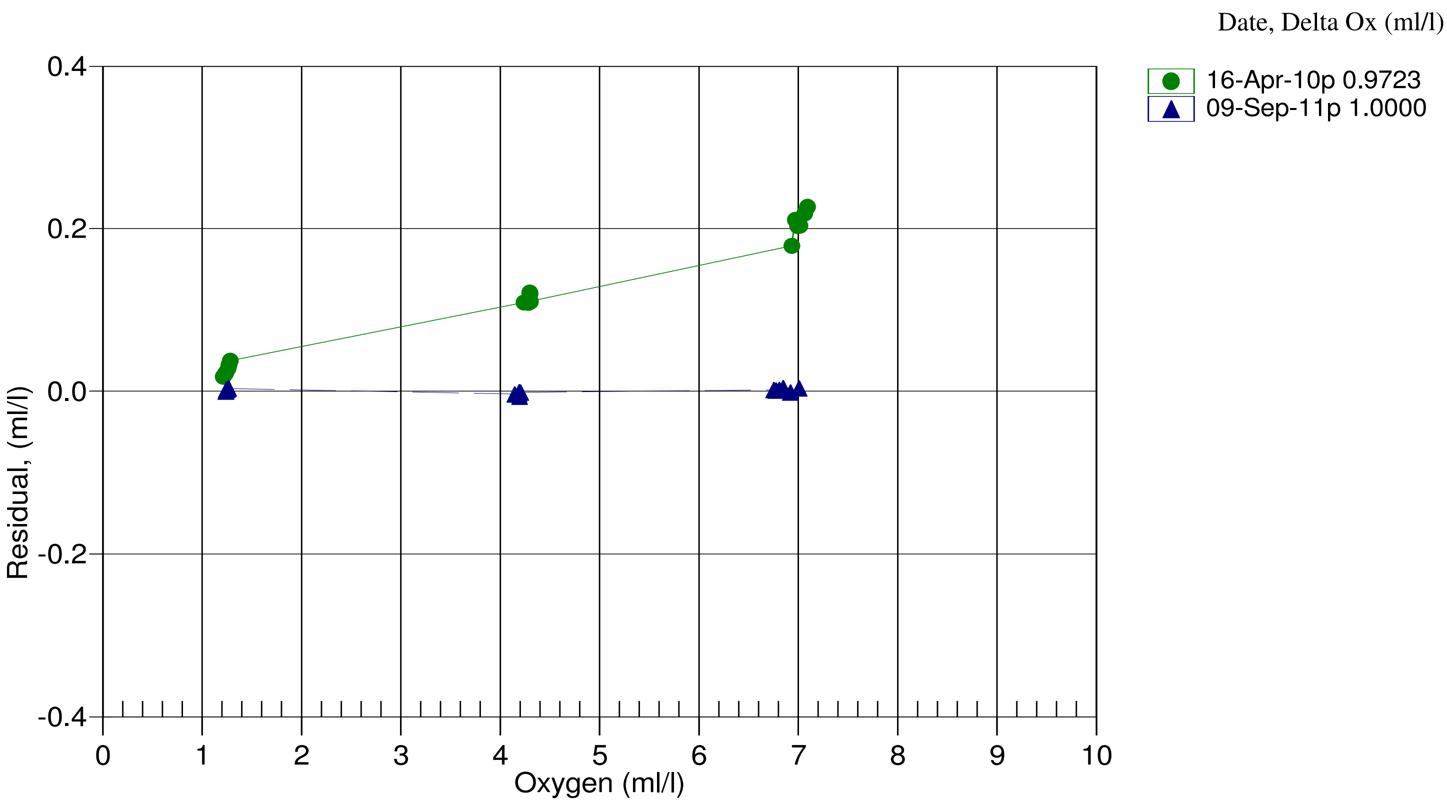
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.30000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

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