

## U.S. GEOTRACES EPZT

R/V Thomas G. Thompson (TGT303)

25 October 2013 - 20 December 2013

Manta, Ecuador - Papeete, Tahiti, French Polynesia

Chief Scientist: Dr. James Moffett

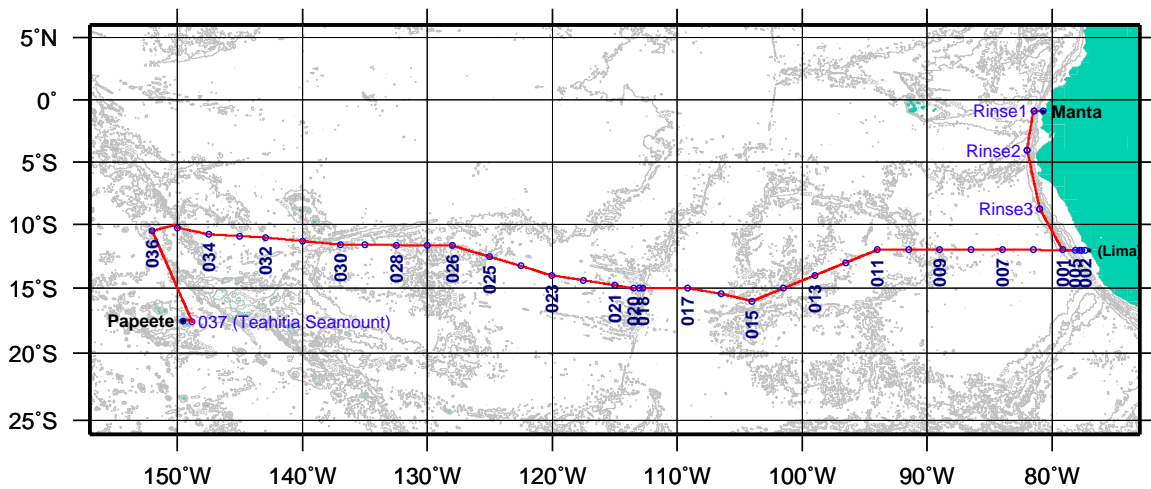
University of Southern California

Co-Chief Scientist: Dr. Christopher German

Woods Hole Oceanographic Institution

Co-Chief Scientist: Dr. Gregory Cutter

Old Dominion University



**STS Cruise Report**  
**15 August 2014**



## Principal Programs of U.S. GEOTRACES EPZT

GT-C (ODU/12L GoFlo) CTDO/Rosette + Super-GeoF Depart-Station Samples				
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email	
CTD/Rosette Data NanoMolar Nutrients As Sb Se I †TDS	ODU	Gregory Cutter	gcutter@odu.edu	
‡Salinity ‡Nutrients	SIO	James H. Swift	jswift@ucsd.edu	
Hg (Total Hg only for Super-GeoF)	WSU WHOI	Chad Hammerschmidt Carl Lamborg	chad.hammerschmidt@wright.edu clamborg@whoi.edu	
‡Al ‡Mn †Fe	NOAA	Joseph Resing	Joseph.Resing@noaa.gov	
Co Speciation	WHOI	Mak Saito	msaito@whoi.edu	
Cu Speciation	SIO	Katherine Barbeau	kbarbeau@ucsd.edu	
Fe Speciation	BIOS	Kristen Buck	kristen.buck@bios.edu	
Fe	ODU	Peter Sedwick	psedwick@odu.edu	
Fe(II) Total Fe, Zn, Cu, Mn	USC	James Moffett	jmoffett@usc.edu	
‡Ga Ba V Mo	USM	Alan Shiller	alan.shiller@usm.edu	
‡Po ‡Pb (shallow)	UCSC	Russ Flegal	flegal@ucsc.edu	
Po Pb (mid/deep)	MIT	Ed Boyle	eaboyle@mit.edu	
‡Dissolved Trace Metals: Al Cd Co Cu Ga Fe Pb Mn Ni Sc Ag Ti Zn La Y (filtered and unfiltered for Super-GeoF and mid-GeoF)	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	
†Particulate/Labile Trace Metals: Be Mg Al P Ca Ti V Cr Mn Fe Co Ni Cu Zn As Rb Sr Y Zr Mo Ag Cd Sn Sb Ba REE Pb <sup>232</sup> Th U	RUTG WHOI	Robert Sherrell Chris German	sherrell@marine.rutgers.edu cgerman@whoi.edu	
Dissolved Trace Metals: Fe Cu Zn Cd Mn Fe Colloids	RSMAS	Jingfeng Wu	jwu@rsmas.miami.edu	
d <sup>56</sup> Fe d <sup>66</sup> Zn d <sup>114</sup> Cd [Fe] [Zn] [Cd]	SC	Seth John	sjohn@geol.sc.edu	

\* Affiliation abbreviations are listed on page 7

† Only these samples were not collected by the Surface Fish

‡ These samples were also collected at the mid-GeoF sampling. Bruland and Resing dissolved samples were collected every 2 hours between stations along the track. Unfiltered Bruland samples were collected at every 2-hour position only until station 7; then only at mid-GeoF and super-GeoF positions.

<b>30-ODF (ODF/30L Niskin) CTD/Rosette</b> (Corer samples in a separate table)			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
CTD/Rosette Data diss.O <sub>2</sub> Nutrients Salinity On-Board Data Website Data Management	SIO	James H. Swift	jswift@ucsd.edu
CFCs SF <sub>6</sub>	RSMAS	Rana Fine	rfine@rsmas.miami.edu
diss. He Ne Ar Kr Xe <sup>3</sup> He/ <sup>4</sup> He <sup>3</sup> H <sup>13</sup> C	WHOI / NOSAMS	William Jenkins	wjenkins@whoi.edu
N <sub>2</sub> /Ar d <sup>15</sup> N-N <sub>2</sub>	UMassD	Mark Altabet	maltabet@umassd.edu
d <sup>15</sup> N-N <sub>2</sub> O d <sup>18</sup> O-N <sub>2</sub> O [N <sub>2</sub> O] d <sup>15</sup> N-NO <sub>2</sub> d <sup>18</sup> O-NO <sub>2</sub> [NO <sub>2</sub> ] d <sup>15</sup> N-NO <sub>3</sub> d <sup>18</sup> O-NO <sub>3</sub>	STANF	Karen L. Casciotti	kasciot@stanford.edu
DIC Total Alkalinity	BIOS	Nick Bates	nick.bates@bios.edu
‡DOC	UCSB	Craig Carlson	carlson@lifesci.ucsb.edu
<sup>14</sup> C	UW	Paul Quay	pdquay@u.washington.edu
‡Thiols	WHOI WSU	Carl Lamborg Chad Hammerschmidt	clamborg@whoi.edu chad.hammerschmidt@wright.edu
HPLC Pigments	UH	Robert R. Bidigare	bidigare@hawaii.edu
<sup>234</sup> Th	WHOI	Ken Buesseler	kbuesseler@whoi.edu
<sup>226</sup> Ra	WHOI SC	Matthew Charette Willard S. Moore	mcharette@whoi.edu moore@geol.sc.edu
Fe(II)	USC	James Moffett	jmoффett@usc.edu
Unfiltered Al Mn Fe	NOAA	Joseph Resing	Joseph.Resing@noaa.gov
Si Isotopes diss. SiO <sub>2</sub>	UCSB	Mark A. Brzezinski	mark.brzezinski@lifesci.ucsb.edu
‡ <sup>230</sup> Th ‡ <sup>232</sup> Th ‡ <sup>232</sup> Th Colloids ‡ <sup>231</sup> Pa ‡ <sup>231</sup> Pa Colloids	LDEO LDEO UMN UMN	Robert F. Anderson Marty Fleisher Larry Edwards Hai Cheng	boba@ldeo.columbia.edu martyq@ldeo.columbia.edu edwar001@umn.edu cheng021@umn.edu
‡Nd ‡REE	LDEO LDEO USC	Leo Pena Steven Goldstein Doug Hammond	leopoldo@ldeo.columbia.edu steveg@ldeo.columbia.edu dhammond@usc.edu
‡ <sup>210</sup> Po ‡ <sup>210</sup> Pb	WSU QCCUNY	Mark Baskaran Gillian Stewart	Baskaran@wayne.edu gillian.stewart@qc.cuny.edu
‡ <sup>239</sup> Pu, ‡ <sup>240</sup> Pu ‡ <sup>237</sup> Np ‡ <sup>137</sup> Cs ‡ <sup>134</sup> Cs	LDEO	Timothy Kenna	tkenna@ldeo.columbia.edu
‡ <sup>90</sup> Sr ‡ <sup>129</sup> I ‡ <sup>236</sup> U ‡ <sup>238</sup> U	LDEO UAB	Timothy Kenna Pere Masqué	tkenna@ldeo.columbia.edu Pere.Masque@uab.cat

\* Affiliation abbreviations are listed on page 7

‡ These samples were also collected with Super-GeoF surface fish

30-ODF Rosette Corer samples			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
<b>NIOZ Mono-Corer only:</b> <sup>232</sup> Th <sup>230</sup> Th <sup>231</sup> Pa <sup>234</sup> U <sup>238</sup> U Nd Isotopes	LDEO LDEO	Leo Pena Steven Goldstein	leopoldo@ldeo.columbia.edu steveg@ldeo.columbia.edu
<b>top layer of NIOZ Mono-Corer, and Wax Corer:</b> Particulate / Labile Trace Metals: Be Mg Al P Ca Ti V Cr Mn Fe Co Ni Cu Zn As Rb Sr Y Zr Mo Ag Cd Sn Sb Ba REE Pb <sup>232</sup> Th U	RUTG WHOI	Robert Sherrell Chris German	sherrell@marine.rutgers.edu cgerman@whoi.edu
<b>Wax Corer only:</b>  parameters TBA	UMN RUTG WHOI	Brandy Toner Robert Sherrell Chris German	toner@umn.edu sherrell@marine.rutgers.edu cgerman@whoi.edu

\* Affiliation abbreviations are listed on page 7

Aerosols (3 systems) and/or Rainwater			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
Aerosol and Rainwater: Li Na Mg Al P Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga As Se Rb Sr Zr Cd Sn Sb Cs Ba La Ce Nd Pb Th U	UAF SKIO FSU	Ana M. Aguilar-Islas Clifton Buck William Landing	amaguilarislas@alaska.edu clifton.buck@skio.uga.edu wlanding@fsu.edu
Aerosol Cu Ligands	SIO	Katherine Barbeau	kbarbeau@ucsd.edu
Aerosol Fe Ligands	BIOS	Kristen Buck	kristen.buck@bios.edu
Aerosol [Fe] [Zn] [Cd] d <sup>56</sup> Fe d <sup>66</sup> Zn d <sup>114</sup> Cd	SC	Seth John	sjohn@geol.sc.edu
Aerosol <sup>210</sup> Po <sup>210</sup> Pb	WSU QCCUNY	Mark Baskaran Gillian Stewart	Baskaran@wayne.edu gillian.stewart@qc.cuny.edu
Aerosol and Rainwater: <sup>7</sup> Be	RSMAS	David Kadko	dkadko@rsmas.miami.edu
Aerosol and Rainwater: Po Pb stable Isotopes	MIT UCSC	Ed Boyle Russ Flegal	eaboyle@mit.edu flegal@ucsc.edu
Aerosol: <sup>232</sup> Th	LDEO LDEO	Robert F. Anderson Marty Fleisher	boba@ldeo.columbia.edu martyq@ldeo.columbia.edu
Aerosol: Nd Isotopes REE	LDEO	Leo Pena	leopoldo@ldeo.columbia.edu
Aerosol and Rainwater: N Isotopes d <sup>15</sup> N-NO <sub>3</sub> d <sup>18</sup> O-NO <sub>3</sub> D <sup>17</sup> O-NO <sub>3</sub> [NO <sub>3</sub> ]	Brown	Meredith Hastings	meredith_hastings@brown.edu
Aerosol: DOM (Dissolved Organic Matter)	ODU	Andrew Wozniak	awozniak@odu.edu
Aerosol and Rainwater: Total Hg only	WHOI WSU	Carl Lamborg Chad Hammerschmidt	clamborg@whoi.edu chad.hammerschmidt@wright.edu

\* Affiliation abbreviations are listed on page 7

<b>McL-Prof (McLane Pump) Profiles</b> ( <i>in situ</i> pump filters or piggyback 30L Niskins)			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
<b>SBE19plus (SeaCAT) CTD Data</b>	WHOI	Phoebe J. Lam	pjlam@whoi.edu
<b>Niskin Bottles</b>			
<sup>234</sup> Th	WHOI	Ken Buesseler	kbuesseler@whoi.edu
<sup>226</sup> Ra	WHOI SC	Matthew Charette Willard S. Moore	mcharette@whoi.edu moore@geol.sc.edu
Organic and Inorganic Hg Thiols	WSU WHOI	Chad Hammerschmidt Carl Lamborg	chad.hammerschmidt@wright.edu clamborg@whoi.edu
Nutrients Salinity	SIO	James H. Swift	jswift@ucsd.edu
<b><i>In situ</i> pump MnO<sub>2</sub>-coated cartridges</b>			
Dissolved Radium Isotopes	WHOI SC	Matthew Charette Willard S. Moore	mcharette@whoi.edu moore@geol.sc.edu
Dissolved <sup>227</sup> Ac	USC	Doug Hammond	dhammond@usc.edu
Dissolved <sup>228</sup> Th	WHOI WHOI SC	Ken Buesseler Matthew Charette Willard S. Moore	kbuesseler@whoi.edu mcharette@whoi.edu moore@geol.sc.edu
<b><i>In situ</i> pump filters: QMA side</b>			
d <sup>15</sup> N-PN	STANF	Karen L. Casciotti	kcasciot@stanford.edu
Particulate Organic and Inorganic Hg Thiols	WSU WHOI	Chad Hammerschmidt Carl Lamborg	chad.hammerschmidt@wright.edu clamborg@whoi.edu
Particulate <sup>234</sup> Th and <sup>228</sup> Th	WHOI WHOI SC	Ken Buesseler Matthew Charette Willard S. Moore	kbuesseler@whoi.edu mcharette@whoi.edu moore@geol.sc.edu
Particulate Organic and Inorganic Carbon	WHOI	Phoebe J. Lam	pjlam@whoi.edu
Proteins	WHOI	Mak Saito	mak@whoi.edu
Particulate <sup>210</sup> Po <sup>210</sup> Pb (Super Stations Only)	WSU QCCUNY	Mark Baskaran Gillian Stewart	Baskaran@wayne.edu Gillian.Stewart@qc.cuny.edu
Particulate Anthropogenic Radionuclides: <sup>239</sup> Pu, <sup>240</sup> Pu <sup>237</sup> Np <sup>137</sup> Cs <sup>134</sup> Cs <sup>90</sup> Sr (Super Stations Only)	LDEO UAB	Timothy Kenna Pere Masqué	tkenna@ldeo.columbia.edu Pere.Masque@uab.cat
<sup>7</sup> Be (4 stations only, 3 depths in upper 200m)	RSMAS	David Kadko	dkadko@rsmas.miami.edu
<i>McL-Prof table continued on next page</i>			

\* Affiliation abbreviations are listed on page 7

<b>McL-Prof (McLane Pump) Profiles</b> ( <i>in situ</i> pump filters or piggyback 30L Niskins) - cont'd			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
<b><i>In situ</i> pump filters: Supor side</b> (142mm paired 0.8µm Supor filters and 51µm polyester prefilter)			
Particulate <sup>232</sup> Th <sup>230</sup> Th <sup>231</sup> Pa	LDEO LDEO UMN UMN	Robert F. Anderson Marty Fleisher Larry Edwards Hai Cheng	boba@ldeo.columbia.edu martyq@ldeo.columbia.edu edwar001@umn.edu cheng021@umn.edu
Particulate/Cellular Trace Metals: Al P Mn Fe Co Ni Cu Zn Cd	BLOS	Benjamin Twining	btwining@bigelow.org
Particulate Trace Metals and Major Particle Composition: Fe Al Mn Cd Cu Co Ti Ba P POC CaCO <sub>3</sub> bSi (biogenic Silica) Lithogenic Particles Fe oxyhydroxides Mn oxyhydroxides Suspended Particulate Mass	WHOI	Phoebe J. Lam	pjlam@whoi.edu
Particulate <sup>210</sup> Po <sup>210</sup> Pb	WSU QCCUNY	Mark Baskaran Gillian Stewart	Baskaran@wayne.edu gillian.stewart@qc.cuny.edu
Particulate AVS Elemental Se	ODU	Gregory Cutter	gcutter@odu.edu
Particulate Nd Isotopes and REE	LDEO LDEO USC	Leo Pena Steven Goldstein Doug Hammond	leopoldo@ldeo.columbia.edu steveg@ldeo.columbia.edu dhammond@usc.edu
Particulate Fe Speciation (XANES)	UMN WHOI	Brandy Toner Phoebe J. Lam	toner@umn.edu pjlam@whoi.edu
Particulate Fe Isotopes	SC	Seth John	sjohn@geol.sc.edu

<b>Other Sampling</b>			
Program / Parameters Measured	Affiliation*	Princ. Investigator	Email
Beryllium Pump Profiles: Total Dissolved <sup>7</sup> Be	RSMAS	David Kadko	dkadko@rsmas.miami.edu
Towed Surface Fish, Filtered and Unfiltered: Al Cd Co Cu Ga Fe Pb Mn Ni Sc Ag Ti Zn La Y (extra sampling between stations and mid-GeoF samples)	UCSC	Ken W. Bruland	bruland@ucsc.edu
Towed Surface Fish Only, Trace Metals: Li Na Mg Al P Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga As Se Rb Sr Zr Cd Sn Sb Cs Ba La Ce Nd Pb Th U (Super-GeoF and mid-GeoF only)	UAF	Ana M. Aguilar-Islas	amaguilarislas@alaska.edu
Co storage test (stas 8/1 and 34/5 only)	WHOI UCSC	Nick Hawco Claire Parker	nickhawco@gmail.com ceparker@ucsc.edu
Ship's Underway Sensors	UW	Thompson SSSG Technicians	sssg@thompson.washington.edu

\* Affiliation abbreviations are listed on page 7

# Shipboard Personnel on U.S. GEOTRACES EPZT

Name	Affiliation	Shipboard Duties	Shore Email
James Moffett	USC	Chief Scientist Fe(II) Analysis	jmoftett@usc.edu
Christopher German	WHOI	Co-Chief Scientist ODF Console Ops	cgerman@whoi.edu
Gregory Cutter	ODU	Co-Chief Scientist GoFlo Winch Ops	gcutter@odu.edu
Patrick A'Hearn	UW/SSSG	Thompson Science Support	pahearn@uw.edu
Susan Becker	SIO/STS	Nutrients / Deck	sbecker@ucsd.edu
Erin Black	WHOI	Th / Ra Sampling	ebblack@whoi.edu
Katlin Bowman	WSU	Organic Hg	bowman.49@wright.edu
Clifton Buck	SkIO	Aerosol / Fish Sampling	cliftonsuck@gmail.com
Marty Fleisher	LDEO	30-ODF Supertech	martyq@ldeo.columbia.edu
Carlos Alberto Martinez Gamboa	IMARPE	Pigments / Observer	cmartinez@imarpe.gob.pe
Jim Happell	RSMAS	CFCs / DIC Sampling	jhappell@rsmas.miami.edu
Nick Hawco	WHOI	Co Analysis	nickhawco@gmail.com
Stephen Jalickee	UW/SSSG	Thompson Science Support	jalickee@uw.edu
Mary Carol Johnson	SIO/STS	Data Manager ODF Data Processing	mcj@ucsd.edu
Brett Longworth	WHOI	3He / 3H / DIC / 13C Sampling	blongworth@whoi.edu
Melissa T. Miller	SIO/STS	Oxygen / Deck	melissa-miller@ucsd.edu
Sarah Nicholas	UMN	McLane Pumps	nich0160@umn.edu
Maria Nielsdottir	ODU	Iodide / Iodate / As	maria.nielsdottir@gmail.com
Daniel Ohnemus	WHOI	McLane Pumps SeaCAT CTD Data	dohnemus@gmail.com
Robert Palomares III	SIO/STS	ET / Salinity / Deck	rpalomares@ucsd.edu
Claire Parker	UCSC	GoFlo Sampling	ceparker@ucsc.edu
Leopoldo Pena	LDEO	30-ODF Supertech	leopoldo@ldeo.columbia.edu
Brian Peters	STANF	N and O isotopes	bpeters1@stanford.edu
Steven Pike	WHOI	McLane Pumps	spike@whoi.edu
Sara Rauschenberg	BLOS	Phytoplankton Elements Particulate TM	srauschenberg@bigelow.org
Joseph Resing	UW	Al / Mn / Fe	Joseph.Resing@noaa.gov
Laura Richards	ODU	GoFlo Sampling	lcrichar@odu.edu
Saeed Roshan	RSMAS	Colloids	sroshan@rsmas.miami.edu
Gugu Rutherford	ODU	Nanonutrients / As	grutherf@odu.edu
Virginie Sanial	WHOI	McLane Pumps / Ra	virginie.sanial@legos.obs-mip.fr
Rob Sherrell	RUTG	GoFlo Sampling	sherrell@marine.rutgers.edu
Geoffrey J. Smith	UCSC	Underway Towed Fish	geosmit@ucsc.edu
Bettina Sohst	ODU	Fe Analysis	bsohst@odu.edu
Mark Stephens	RSMAS	Be-7	mstephens@rsmas.miami.edu
Gretchen Swarr	WHOI	Inorganic Hg	gswarr@whoi.edu
Cheryl Zurbrick	UCSC	GoFlo Sampling	czurbric@ucsc.edu

\* Affiliation abbreviations are listed on page 7



KEY to Affiliation Abbreviations	
BIOS	Bermuda Institute of Ocean Sciences
BLOS	Bigelow Laboratory for Ocean Sciences
Brown	Brown University
FSU	Florida State University
IMARPE	Instituto del Mar del Perú
LDEO	Lamont-Doherty Earth Observatory
MIT	Massachusetts Institute of Technology
NOAA	National Oceanic and Atmospheric Administration
NOSAMS	National Ocean Science AMS Facility (WHOI)
ODU	Old Dominion University
QCCUNY	Queens College, The City University of New York
RSMAS	Rosenstiel School of Marine and Atmospheric Science (University of Miami)
RUTG	Rutgers University
SC	University of South Carolina
SIO	Scripps Institution of Oceanography (UCSD)
SKIO	Skidaway Institute of Oceanography (Univ. of GA)
SSSG	Shipboard Scientific Services Group (UW)
STS	Shipboard Technical Support (UCSD/SIO)
ODF	Oceanographic Data Facility (sub-group of STS)
STANF	Stanford University
UAB	Universitat Autònoma de Barcelona
UAF	University of Alaska, Fairbanks
UCSB	University of California, Santa Barbara
UCSC	University of California, Santa Cruz
UCSD	University of California, San Diego
UH	University of Hawaii
UMassD	University of Massachusetts, Dartmouth
UMN	University of Minnesota
USC	University of Southern California
USM	University of Southern Mississippi
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution
WSU	Wayne State University

## Summary

The U.S. GEOTRACES East Pacific Zonal Transect (EPZT) was occupied from 25 October 2013 - 20 December 2013 aboard R/V Thomas G. Thompson for a survey consisting of rosette/CTD casts, McLane *in situ* pump and <sup>7</sup>Be pump casts, and a variety of underway measurements. The ship departed Manta, Ecuador on 25 October 2013 and arrived in Papeete, Tahiti on 20 December 2013 (UTC dates).

A sea-going science team gathered from 15 oceanographic institutions participated on the cruise. The programs and PIs, and the shipboard science team and their responsibilities, are listed in the "Principal Programs" and "Shipboard Personnel" sections above.

Two types of rosette/SBE9plus CTD casts (ODF/30L-Niskin and GT-C/12L-GoFlo) were made at 36 station locations during U.S. GEOTRACES EPZT. Deep ODF/30L-Niskin casts included a device suspended 20 meters below the rosette, designed either to take a core sample or pick up particulates from the sea floor. Shallow and deep McLane pump profiles were done at all Full stations, with an additional mid-water profile at Super Stations. An SBE19plus CTD was attached to the end of the McLane wire on all but seven deep pump casts, when it was attached to the ODF rosette instead. Water was pumped and filtered for Beryllium-7 analysis on some stations. Underway samples were also collected for multiple programs, and 5 ARGO floats were deployed during the eastern half of the cruise for the University of Washington.

Samples analyzed on board or stored for shore analysis are tabulated in the "Bottle Sampling" section later in the documentation. 10 test/rinse cast(s) and 9 aborted/canceled cast(s) (total for all cast types) were not reported.

U.S. GEOTRACES EPZT Station/Cast Summary			
Station Type	Station Numbers	Total Casts	Cast Types
All	All but 19	1	1 Underway Surface Sample (GeoFish + "Bubble" Lab)
Super	1, 11, 18, 26, 36	15-16	1 Shallow / 1 Mid / 1-2 Deep GT-C/12L GoFlo 1 Shallow / 1 Mid / 1 Deep ODF/30L Niskin 1 Shallow / 1 Mid / 1 Deep McLane Pump 1 Pigments-Th-Ra ODF/30L Niskin 2 Shallow / 2 Deep Pb,Po-Pu-129I ODF/30L Niskin 1 Be-7 pump
Shelf	2, 3, 4, 5	4-6	1-2 GT-C/12L GoFlo 1-2 ODF/30L Niskin 1 Pigments-Th-Ra ODF/30L Niskin 1 McLane Pump
Demi	6, 8, 10, 12, 14, 16, 22, 24, 27, 29, 31, 33, 35	2	1 GT-C/12L GoFlo (~1000m depth) 1 ODF/30L Niskin (~1000m depth)
Full	7, 9, 13, 15, 17, 20, 21, 23, 25, 28, 30, 32	9-11	1 Shallow / 1 Mid / 1 Deep GT-C/12L GoFlo 1 Shallow / 1 Mid / 1 Deep ODF/30L Niskin 1 Shallow / 1 Deep McLane Pump 1 Pigments-Th-Ra ODF/30L Niskin (extra Ra cast sta 7) 1 Be-7 pump (stas 7,9,13,15,23,30,32 only)
Volcano	19	1	1 Deep ODF/30L Niskin
Hemi	34	6	1 Shallow / 1 Deep GT-C/12L GoFlo 1 Shallow / 1 Deep ODF/30L Niskin 1 McLane Pump 1 Be-7 pump
Teahitia Seamount	37	4	3 Multibeam Surveys 1 ODF/30L Niskin (no bottle samples, just automated/default CTDO processing)

## Description of Measurement Techniques

### 1. SIO/ODF CTD/Hydrographic Data: CTD, Salinity, Nutrients and Oxygen

*Oceanographic Data Facility and Research Technicians  
Shipboard Technical Support  
Scripps Institution of Oceanography  
UC San Diego  
La Jolla, CA 92093-0214*

Hydrographic measurements consisted of salinity and nutrient water samples taken from each CTD/rosette cast, plus dissolved oxygen from each ODF rosette cast. In addition, salinity and nutrient samples were taken from the surface fish and from Niskins attached to the wire at each Deep and Mid McLane pump cast.

Pressure, temperature, conductivity/salinity, dissolved oxygen, transmissometer, fluorometer, turbidity/LSS, and oxidation-reduction potential (ORP) data were recorded during all CTD/rosette profiles. Only raw voltages are reported for transmissometer, fluorometer, turbidity and ORP sensors. A Rinko optical oxygen sensor was also part of the ODF rosette, for evaluation purposes only; these data were recorded, but not processed or reported.

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

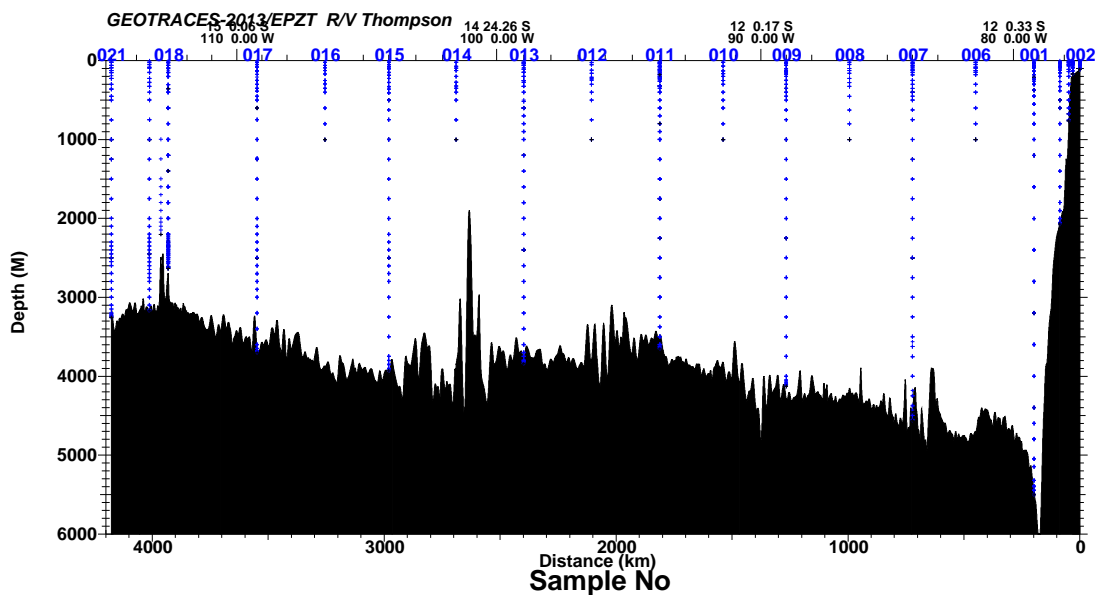


Figure 1.0 U.S. GEOTRACES EPZT Sample distribution: stations 1-21.

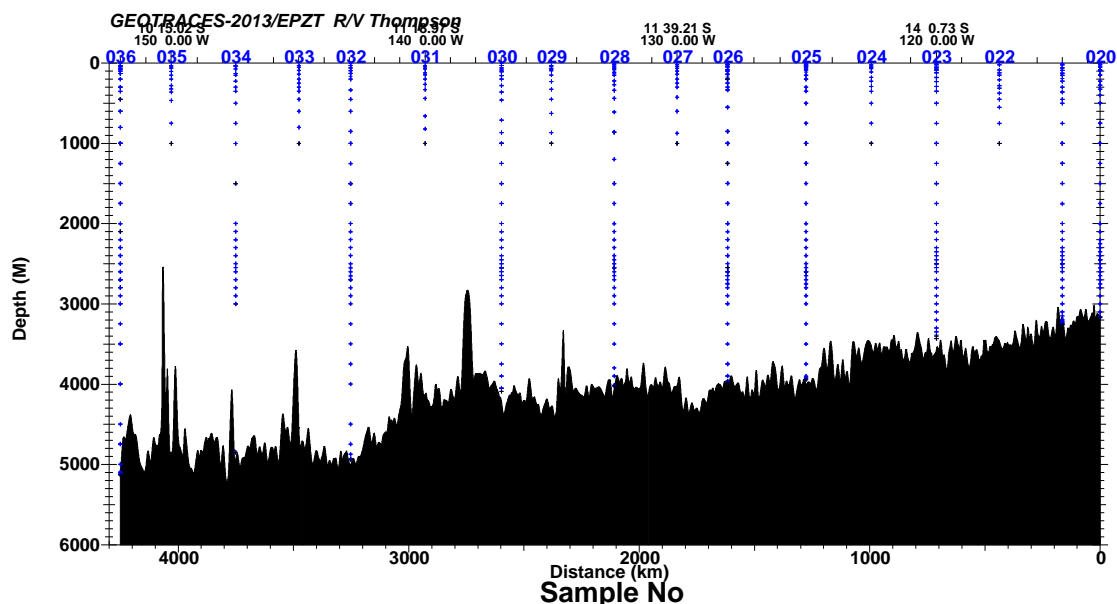


Figure 1.1 U.S. GEOTRACES EPZT Sample distribution: stations 20-36.

### 1.1. ODF/30L-Niskin Water Sampling Package

ODF/30L-Niskin Rosette/CTD casts were performed with a package consisting of a 12-bottle rosette frame (SIO/STS), a 12- or 24-place carousel (SBE32) and 12 ea. 30L General Oceanics Niskin-style bottles with an absolute volume of 30L each. A 12-place carousel was used on station 1, but had repeated trip-confirmation failures during stations 2 and 3. It was replaced with an older 24-place carousel mid-station 3, which resolved the trip-confirmation issues. Prior to station 4, the carousel head was replaced by one with titanium instead of stainless steel latches in order to resolve mechanical tripping issues. This "hybrid" carousel was used successfully for the remainder of the cruise.

Underwater electronic components consisted of a Sea-Bird Electronics CTD (SBE9*plus*) 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), Oxidation-Reduction Potention (ORP) sensor (NOAA), turbidity meter (Seapoint STM11) and altimeter (Simrad 807). A second dissolved oxygen + oxygen temperature sensor (JFE Advantech RINKO-III) was incorporated into the data stream for future sensor evaluation; it was not processed for this cruise.

Additionally, an SBE19*plus* CTD was mounted on the rosette during deep ODF casts for full and super stations beginning with station 25, since it could no longer be deployed on deep McLane pump casts after their wire was damaged.

Routine CTD maintenance included soaking the conductivity and oxygen sensors in fresh water between casts to maintain sensor stability, and syringing distilled water through the conductivity sensors to eliminate any accumulating bio-films. Rosette maintenance was performed on a regular basis. Bottle valves and O-rings were inspected for leaks. The rosette, CTD and carousel were rinsed with fresh water as part of the routine maintenance.

The sensors and instruments used during U.S. GEOTRACES EPZT, along with pre-cruise laboratory calibration information, are listed below in Table 1.1.0. Copies of the pre-cruise calibration sheets for various sensors are included in Appendix D.

**Table 1.1.0** U.S. GEOTRACES EPZT Rosette Underwater Electronics.

Instrument/Sensor	Mfr./Model*	Serial Number	CTD Channel	Stations Used (R=Rinse)	Pre-Cruise Date	Calibration Facility*
Carousel Water Sampler	SBE32 (12-Pl.) SBE32 (24-Pl.)**	3231807-0456 32xxxxx-0030	n/a n/a	R2-3/3 3/5-36		
Reference Temperature	SBE35RT	3528706-0034 3516590-0011	n/a n/a	R2-3/5 3/6-36	18-Jun-2013 18-Jun-2013	SIO/STS SIO/STS
CTD	SBE9 <i>plus</i>	09P21561-0569	n/a	R2-36		
Pressure	Paroscientific Digiquartz 401K-105	569-75672	Freq.2	R2-36	29-Jul-2013	SIO/STS
Primary Temperature (T1)	SBE3 <i>plus</i>	03P-2333	Freq.0	R2-36	20-Aug-2013	SIO/STS
Conductivity (C1)	SBE4C	04-2659	Freq.1	R2-36	28-Aug-2013	SBE
Dissolved Oxygen Pump	SBE43 SBE5T	43-0875 05-4890	Aux2/V2 n/a	R2-36 R2-36	13-Sep-2013	SBE
Secondary Temperature (T2)	SBE3 <i>plus</i>	03P-2202	Freq.3	R2-36	20-Aug-2013	SIO/STS
Conductivity (C2)	SBE4C	04-3399	Freq.4	R2-36	27-Aug-2013	SBE
Pump	SBE5T	05-1409	n/a	R2-36		
Altimeter§	Simrad 807 Tritech LRPA200	9711091 244480	Aux1/V0	R2, 1-36 R3 only	n/a n/a	n/a n/a
Chlorophyll Fluorometer§	Seapoint 6km	SCF2775	Aux1/V1	R2-36	17-Dec-2009	Seapoint
Oxidation-Reduction Potention Sensor	NOAA	ORP4†	Aux2/V3	1-36	n/a	n/a
Transmissometer	WET Labs C-Star	CST-491DR CST-400DR+	Aux3/V4	R2 only R3-36	25-Nov-2008 13-Sep-2013§	WET Labs WET Labs
Turbidity Meter (LSS)§	Seapoint 6km	STM11-14059‡	Aux3/V5	1-36	n/a	n/a
Diss. Oxygen Optode/Temp. (Experimental)	RINKO-III ARO-CAV	105	Aux4/ V6+V7	R2-36	7-Aug-2012	JFE Advantech
SeaCAT CTD	SBE19 <i>plus</i>	19P-5236‡	(internally recorded)	25-36 "Deep" casts only	unknown	unknown
Deck Unit (in lab)	SBE11 <i>plus</i> V2	11P21561-0518	n/a	R2-36		

All listed sensors / instruments belong to SIO/STS, unless otherwise noted.

+ Owned by UW      † Owned by NOAA-PMEL      ‡ Owned by WHOI

\* SBE = Sea-Bird Electronics      SIO/STS = Scripps' Shipbd. Tech. Support Calibration Facility

\*\* older-style SBE32 for 3/5-3/7; then older base with titanium head from newer-style SBE32 for stations 4-36.

§ Altimeters: Simrad 807 has a 500m range, Tritech LRPA200 has a 200m range.

Transmissometers: several shipboard "deck" calibrations also occurred during EPZT

Fluorometer used 10x cable. Turbidity meter used 5x standard gain, MCBH6M connector.

The SBE9*plus* 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 vertically near the bottom of the rosette frame. The Rinko DO sensor was mounted horizontally to the SBE9 body, and the altimeter was mounted on the inside of the bottom frame ring. The ORP was mounted vertically, adjacent to the altimeter, with the sensor end looking downward into clean water during the down-cast. The turbidity sensor was mounted to the underside of a frame support arm at approximately a 30 degree angle looking inward toward the transmissometer. Table 1.1.1 shows height of the sensors referenced to the bottom of the frame.

<b>Table 1.1.1 Heights (in cm) referenced to bottom of rosette frame</b>	
<b>Instrument/Sensor</b>	<b>Height in cm</b>
Pressure Sensor (inlet to capillary tube)	27
Temperature (probe tip at TC duct inlet)	15
SBE35RT (centered between T1/T2 on same plane)	15
Altimeter	2
Fluorometer	12
ORP	10
Transmissometer	12
Turbidity (LSS)	50
Rinko DO	28
SeaCAT CTD (stations 25,26,28,30,32,34,36 deep casts only)	15
30L-Niskin centerline	124
Reference (Surface Zero tape on wire)	280

The ODF rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable attached to the R/V Thomas G. Thompson's Markey DESH-5 (50hp) winch. One conductor in the sea cable was used for power and signal; the sea cable armor was used for ground. The ship's poured termination, done several months prior to the cruise and only used for 5 casts before EPZT, was used through the first ODF cast of station 26.

Shortly after the 10m equilibration "soak" at the start of station 26 cast 4, the ODF rosette was accidentally brought up into the overbearing block by the winch driver. Tensions exceeded 8500 lbs. for over 30 seconds. Thanks to an alert scientist sampling on deck, the rosette was safely returned to the deck. As a precautionary measure, 50m of wire was removed, and a new, standard SIO/STS full (electrical and mechanical) cable grip termination was applied prior to the next ODF cast.

## 1.2. 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 starting before ship departed Manta, Ecuador until after it docked in Papeete, Tahiti.

Center-beam bathymetric and hull-depth correction data from the Kongsberg-Simrad EM 302 Multibeam Echosounder system were acquired by the ship, and fed into the ODF Linux systems through a serial data feed. The EM 122 format in the SIO/ODF software was the same as the EM 302, and was used to acquire the depth and correct for the hull depth. Sound velocity values were intermittently adjusted by the SSSG Technicians using ODF CTD data as the cruise progressed.

Bathymetry and navigation data were merged and stored on the ODF systems, and data were made available as displays on the ODF acquisition system during casts. Bottom depths associated with rosette casts were recorded on the Console Logs during deployments. However, the automatically recorded Multibeam depths were extracted from the stored navigation data and used for cast event depths in the Exchange format files.

### 1.3. SIO/ODF CTD Data Acquisition and Rosette Operation

The SIO/ODF CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and two networked generic PC workstations running CentOS-5.9 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball and DVD+RW drive. Both systems had a Comtrol Rocketport PCI multiple port serial controller, each 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 SIO/ODF CTD console and was connected to the CTD deck unit via two RS-232 cables, one for the CTD signal feed and the other as a modem 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 EPZT. Redundant backups during casts were managed automatically. Both PCs were synced with the ship's timeserver on a regular basis to keep accurate UTC time.

The SBE9*plus* CTD supplied a standard SBE-format data stream at a data rate of 24 Hz (frames/second). The CTD was connected to an SBE32 12- or 24-place carousel, providing for sea cable operation. Power to the SBE9*plus* CTD and sensors, SBE32 carousel and Simrad altimeter was provided through the sea cable from an SIO/STS SBE11*plus* deck unit in the computer lab.

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 using Sea-Bird Electronics' recommendations (<http://www.seabird.com>).

Details about the sensors and instruments used during EPZT are listed above in table 1.1.0.

SIO/ODF 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 hand-entered metadata for 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.

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 hangar to the deployment location under the squirt boom using a pallet jack. The CTD was powered up and the data acquisition system started from the computer lab. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. The rosette was unstrapped from the pallet. 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.

On the last/deep cast of each Shelf, Hemi, Full and Super station from station 4 onward, a mono-corer was suspended below the rosette on a 20 meter braided line. An "umbrella" of plastic corrugated sheeting was placed on the line above the corer to shield it from the altimeter. This setup was hooked to the rosette before deployment, then an outrigger plank was used to push the line away from the ship. On station 18, over the East Pacific Rise, it was speculated that there would not be enough sediment depth to deploy this corer without damage, so a "wax corer" (steel ball coated with soft wax) was utilized instead on two deep casts. The SIO/ODF "Deep" cast was always the last event of the station to preclude extruded mud or sediment exiting the core on the up-cast from contaminating other samples in the water column.

Rosette tag lines were removed and the package was lowered to 10 meters, or deeper in 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 the winch operator was directed to bring the package back to the surface, re-zero the wire-out and start the descent to a specified target depth (wire-out), based on CTD depth shown on the console display.

The CTD profiling rate was at most 30m/min to 100m and up to 60m/min deeper than 100m, depending on sea cable tension and sea state. As the package descended toward the target depth, the rate was reduced to 30m/min at 100m from the bottom. Casts were lowered to pre-determined target depths, depending on the type of sampling being done. Most deep rosette casts were lowered to within 5-10 meters of the bottom, using the altimeter, winch wire-out, CTD depth and echosounder depth to determine the distance of the package from the bottom for a safe approach.

For each up-cast, the winch operator was directed to stop the winch at up to 12 pre-determined sampling depths, chosen by the GEOTRACES program participants during the first cast at each station. Bottles were closed on the up-cast by operating an on-screen control, nominally 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 measure bottle trip temperature.

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

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 rosette. Recovery of the corer was made easier with a block rigged to the aft neck of the boom, to assist in keeping the line away from the ship as well as easing the hauling-in process. The rosette was secured on the pallet and moved into the hangar for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

The console operator terminated the data acquisition, waited for the SBE35RT data to auto-upload through the deck unit modem channel, then turned off the deck unit and assisted with rosette sampling.

#### **1.4. ODF 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 trip files, 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.

SIO/ODF 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<sub>2</sub> 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.

After final processing, corrected CTDO trip data were updated into the bottle database using SIO/STS-processed data for the ODF/30L casts. Shipboard Seasave-processed CTDO values were used for the GT-C/12L casts' trip data. Only the SIO/STS processing details are documented here.

#### **1.5. SIO/ODF CTD Acquisition and Data Processing Details**

Adjustments to the conductivity "advance" time (default: 0.073 seconds) were examined by re-averaging data from the stored 24 Hz data at various time intervals, then evaluating down- and up-cast salinity spiking and noise levels in sharp gradients and in deep water for multiple casts from stations 1 and 7. An



additional 0.06-second "advance" was applied to the primary conductivity sensor, and a 0.04-second "advance" was used for the secondary. The new "advance" times were applied by re-averaging all casts from stations 1-7, and applied through real-time software starting with station 8.

The same primary and secondary sensor pairs were used through-out the cruise. Primary T/C sensors were used for all casts of reported ODF-30L CTD data: the background salinity noise level was lower than the secondary pair, and deep Theta-Salinity overlays appeared to be a bit more consistent from cast to cast.

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

<b>Sta/Cast</b>	<b>Comment</b>
Start	New, baked Viton O-rings installed on all bottles before first Rinse cast. Used Markey DESH-5 winch for ODF 30L rosette casts; used Thompson's existing termination from 2 months prior to start of EPZT. Start with Simrad altimeter (500m range).
999/05	Rinse 2 30-ODF Test cast; 0.01 mS/cm offset between C1 and C2. 12 bottles full range to calibrate O2 and check which C sensor is offset. NIOZ corer interferes with altimeter readings: 24.4m the entire cast, even though cast never went within 2000m of the sea floor. Many bottles leaked due to new O-rings settling into caps: adjusted O-rings/caps; also adjusted spigots on two bottles due to leaks.
Transit	On-deck tensiometer test done to adjust slope/offset on winch readings. During transit between Rinse 2 and Rinse 3, 7 transmissometers were collected and lab-tested for start-of-cruise characterization. Installed transmissometer 400DR (UW) to replace 491DR (SIO): had more recent factory calibration (2013 vs 2008).
998/03	Deck/air calibration done on transmissometer 400DR just prior cast. Rinse 3 30-ODF Test cast; 0.01 mS/cm offset between C1 and C2 remains. Using 200m altimeter to check interference of NIOZ corer on backup altimeter: same 24.4m readings through-out cast. Only one bottle had top-cap leak on recovery, fixed.
Stas 1-37	Back to using Simrad altimeter; added NOAA ORP and Seapoint Turbidity Meter from station 1 onward. No conductivity sensor changes: check-salts were an even split between the 2 C sensors. In addition to 0.073-second TC advance applied by Deck Unit, used additional lags through ODF software to match T/C with minimal salinity spiking: 0.06-second (primary T/C), 0.04-second (secondary T/C). Re-averaged stations 1-7 with new lags, applied realtime for station 8 onward.
002/02	Surface soak done mid-thermocline, never went back up to surface mixed layer. Using down-cast, with a few despiked O2 levels, to get near-surface O2 and T/C, almost back to mixed layer.
002/04	SBE35RT-0034 changed from 1 to 4 readings per trip prior to this cast. Cast NOT REPORTED: NIS-1, NIS-2 did not close: NO-confirms on carousel. Re-cocked rosette without sampling, and re-did as cast 5.
002/05	Bottles 1-4 did not close: 3 NO-confirms at each, with carousel repositioned between each attempt. Bottles 5-12 all got good confirms.
003/02	Cast ABORTED: NIS-1 did not fire. no SBE35RT data (intentionally). 5-10 minutes post-cast before deck unit turned off.
003/03	Fixed/switched cable prior to cast: no SBE35RT data (intentionally). Direct cable between carousel and SBE9 without SBE35RT (not a wye). Cast ABORTED: NIS-1 did not fire. 12-place carousel acting up; after this cast, changed out carousel for a UW 24-place SBE carousel (S/N 0030, an early SBE version with stainless steel latches).

<b>Sta/Cast</b>	<b>Comment</b>
003/05	24-place carousel installed prior to cast: still trip confirm problems. NO-confirm on NIS-4, repositioned twice and tried a total of 3 times. All bottles except NIS-4 and NIS-12 closed.
003/06	Switch SBE35RT from 35-0034 to 35-0011 prior to cast: still confirm problems. Cast NOT REPORTED: Bottles 1-10 did not confirm, bottles 11-12 confirmed but came up open. Only NIS-1 and NIS-6 closed. No SBE35RT data came through.
003/07	All bottles confirmed; only NIS-4, NIS-10 and NIS-12 did not close. All failures to close were mechanical issues (with carousel), not electronic communication issues.
004/02	Prior to station 4, carousel head changed out for the one on spare UW rosette (with titanium latches). No routine tripping issues from station 4 onward.
004/04	A cone-shaped cloaking device ("umbrella"), fashioned from corrugated plastic sheeting formerly used as box-spacers, was placed on wire between NIOZ corer and altimeter to mask the corer from the altimeter. It was acoustically nearly opaque, the altimeter readings were "normal", and the first core was successfully retrieved. Awkward for deployment and recovery, but it works.
005/06	"Inelegant core recovery": lost core, apparently dumped out during up-cast/recovery. Deployment/recovery procedure for corer refined/streamlined throughout the cruise.
007/02	Changed SBE35RT-0011 to use 4 readings vs. 1 before station 7/2.
007/10	Added this cast to collect Radium missed from deep pump cast 3.
007/12	NIS-12 failed to close on this cast. After station 7 complete: change configuration to use trip position 22 for NIS-12.
011/04	Exceptional ship-roll noise vs any other cast - not sure why.
012/02	Deck/air calibration done on transmissometer 400DR prior to cast, in transit to station 12.
018/16	Cast ABORTED and brought back to surface: Deck Unit turned off at 772dbar down, apparently came unplugged. Shifted power cord to UPS for Linux PCs before station 21.
018/17	New cast 17 started in-water immediately following cast 16. Apparently came out for a moment, due to big spike in density at surface. First use of Rob's wax corer: a steel fishing weight coated with wax to collect sediment from the fresh lava flow that would likely break the mono-corer.
020/02	Deck/air calibration done on transmissometer 400DR prior to this cast.
021/04	Extra trigger (op.error) after last bottle fired; removed from data files.
021/06	Winch started down from 10dbar soak without returning to surface; came back up from 30dbar, then down.
022/02	Recovered rosette pre-deployment, in water 3 minutes later.
025/09	Lam SeaCAT CTD strapped onto ODF rosette in addition to the corer. Forgot yoyo back to surface after cast start, yet console op noticed the salts did not match top 15m. No good data for top 12dbar (secondary) or 15dbar (primary); using the primary, since there's a big mixed layer and up-casts are too noisy. Surprisingly, oxygen came in very fast compared to salinity. Winch overshot 3801dbar trip by 11m, back down; after trip, cons. op. noticed winch went down, not up, for about 1 minute (45m total) to 3847dbar.

Sta/Cast	Comment
026/04	Cast ABORTED: rosette package hit the winch block on "return to surface" after soak - winch went wrong way. Scientist sampling on deck heard/saw/reported the incident promptly to winch and console ops. Over 8000lbs of pressure on the wire for more than 25 seconds at initial "two-block". Wire looked ok at 10m, but recovered to check.
026/05	Cast CANCELED: this cast was started on the console, but never went in the water: decided to re-terminate due to calculated stress on the wire from the "two-blocking". Wire reterminated with the standard SIO/STS method, after removing 50m of wire.
026/15	Winch only yoyo'd back to 11dbar after soaking at 19dbar; probably forgot to rezero the wire-out. Pressure-sequenced using the first-down (pre-soak) from 7dbar to recover some of the lost surface data.
028/02	Deck/air calibration done on transmissometer 400DR prior to cast, in transit to station 28.
030/11	T/C not stable before yoyo back to surface: noisy at start, despiking fixed most of it.
032/06	Multibeam off for about an hour starting mid-up-cast; no end reading.
035/02	CTDO O2 seems low relative to nearby casts in this minimum area (107-150 dbar); no bottles to compare with, and only a single cast on this station.
036/02	Shift in transmissometer (4.623 to 4.615) at 2400m on up-cast - ectoplasm on window? Offset persisted to 180m and surface ocean particle max.
036/15	At altim=50: slow to 20m/min, at altim=30: slow to 10m/min; bottom approach "soft and soupy". Deck/air calibration done on transmissometer 400DR 17 hrs after cast, in transit to Teahitia survey area. Later during transit, various transmissometers were collected and lab-tested for end-of-cruise characterization.
037/01	Extra station at Teahitia Seamount - not part of EPZT, "exploratory" cast only. No bottle O2 data, used CTDO corrections from cast 036/11, which gave best down/up overlay. However, CTDO looks nothing at all like station 36, or its own SBE43 or Rinko O2 unprocessed voltages. Coded CTDO2 data from this entire cast as questionable.

## 1.6. SIO/ODF CTD Sensor Laboratory Calibrations

Laboratory calibrations of the SIO/ODF CTD Pressure, Temperature, Conductivity and Dissolved Oxygen sensors, as well as the Reference Temperature sensors, were performed prior to U.S. GEOTRACES EPZT. The sensors and calibration dates are listed in Table 1.1.0. Copies of these calibration sheets, as well as manufacturer and deck calibration data for the UW Transmissometer, are in Appendix D at the end of this SIO/ODF report.

## 1.7. ODF/30L CTD Shipboard Calibration Procedures

A single SBE9plus CTD (S/N 09P21561-0569) was used for all ODF/30L rosette/CTD casts during EPZT. The CTD was deployed vertically, due to space limitations in the 12-place rosette, with all sensors and pumps aligned horizontally as recommended by SBE.

An SBE35RT Digital Reversing Thermometer served as an independent calibration check for T1 and T2 sensors. *In situ* salinity and dissolved O<sub>2</sub> check samples collected during each cast were used to calibrate the conductivity and dissolved O<sub>2</sub> sensors.

### 1.7.1. CTD Pressure

The Paroscientific Digiquartz pressure transducer (S/N 569-75672) was calibrated in July 2013 at the SIO/STS Calibration Facility. The calibration coefficients provided on the report were used to convert frequencies to pressure. The SIO/STS pressure calibration coefficients already incorporate the slope and offset term usually provided by Paroscientific.

During EPZT, the initial deck readings for pressure indicated a -0.5 decibar pressure offset was needed, typically because CTDs are calibrated horizontally but deployed vertically. This settled down to merely -0.2 decibars within a few stations. An offset of -0.2 decibars was applied to all casts by re-averaging stations 1-7, and using this offset during acquisition from station 8 onward.

Residual pressure offsets (the difference between the first and last submerged pressures, after the offset corrections) varied from -0.1 to +1.0 decibars. Pre- and post-cast on-deck/out-of-water pressure offsets varied from -0.1 to +0.5 decibars before the casts, and -0.7 to +0.1 decibars after the casts; only 2 casts were below -0.5 decibars post-cast. Most of the +0.4- and +0.5-decibar start-cast offsets were from casts where the CTD was powered on less than 4 minutes before the rosette entered the water.

### 1.7.2. CTD Temperature

The same SBE3plus primary (T1: 03P-2333) and secondary (T2: 03P-2202) temperature sensors were used during U.S. GEOTRACES EPZT. Calibration coefficients derived from the pre-cruise calibrations were applied to raw primary and secondary sensor frequencies during each cast. Corrections for both temperature sensors were determined near the end of the cruise.

Two different SBE35RT sensors (S/N 3528706-0034 for Rinse2 through station 3/5, S/N 3516590-0011 for stations 3/6 through 37) were used as a tertiary temperature check. The sensor was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements. SBE35RT Digital Reversing Thermometers are internally-recording temperature sensors that operate independently of the CTD. According to the manufacturer's specifications, the typical stability for an SBE35RT sensor is 0.001°C/year.

The SBE35RT is triggered by the SBE32 carousel in response to a bottle closure. The SBE35RT sensors on EPZT were initially set to take a single reading, but after a few casts, each sensor was re-set to internally average over a more typical 4 sampling cycles (a total of 4.4 seconds).

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

Both temperature sensors were first examined for drift with time, using the more stable SBE35RT as a reference. Bottles at all depths were used, but only for casts deeper than 2000 decibars. Using these casts avoided skewing the fit to the more numerous and less stable shallower bottle differences. A filter was also applied to omit high-gradient trip data by using only the T1-T2 differences within  $\pm 0.005^\circ\text{C}$ .

T1 needed a first-order fit vs time; T2 required a second-order fit over time, as the differences changed most rapidly at the start of the cruise. The total offset drift over the whole cruise for either sensor was less than 0.001°C.

In order to better align deeper and shallower data, a pressure correction was applied to each temperature sensor. The polynomial fits were examined using low-gradient bottles only (T1-T2 within  $\pm 0.005^\circ\text{C}$ ) for all stations, and for stations deeper than 2000 decibars only.

T1 required a simple slope vs pressure, using all stations. T2 required a second-order correction vs pressure, using only stations deeper than 2000 decibars in order to pull the deepest data in-line with the shallow and intermediate-depth data.

Neither of the temperature sensors exhibited a temperature-dependent slope, or required any further adjustment vs pressure or time.

The final corrections for T1 temperature data reported on EPZT are summarized in Appendix A. Corrections to the temperature sensors had the form:

$$T_{ITS90} = T1 + tp1 * P + t0$$

$$T_{ITS90} = T2 + tp2 * P^2 + tp1 * P + t0$$

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

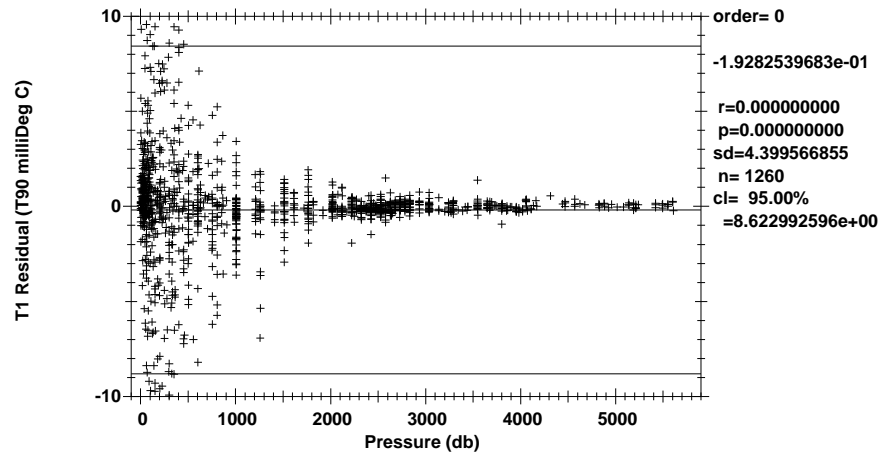


Figure 1.7.2.0 EPZT SBE35RT-T1 by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

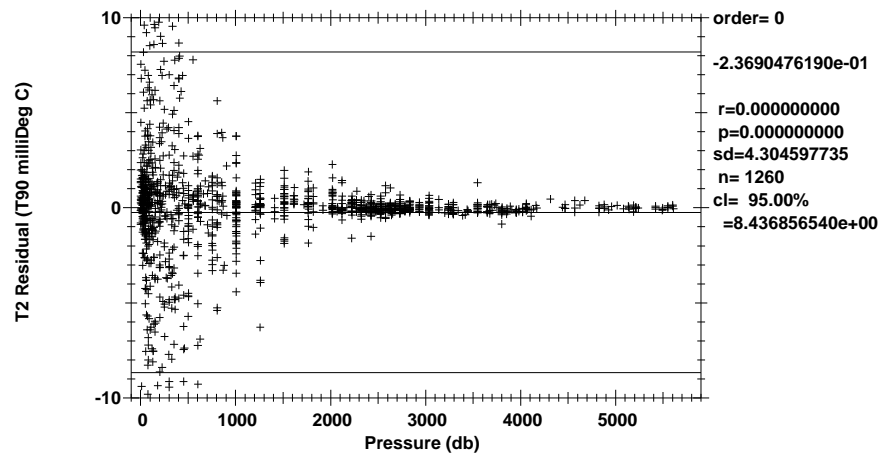


Figure 1.7.2.1 EPZT SBE35RT-T2 by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

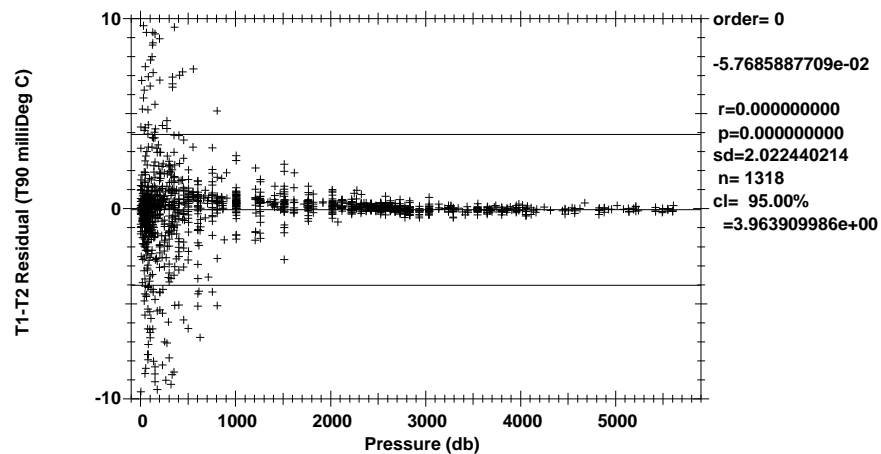


Figure 1.7.2.2 EPZT T1-T2 by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

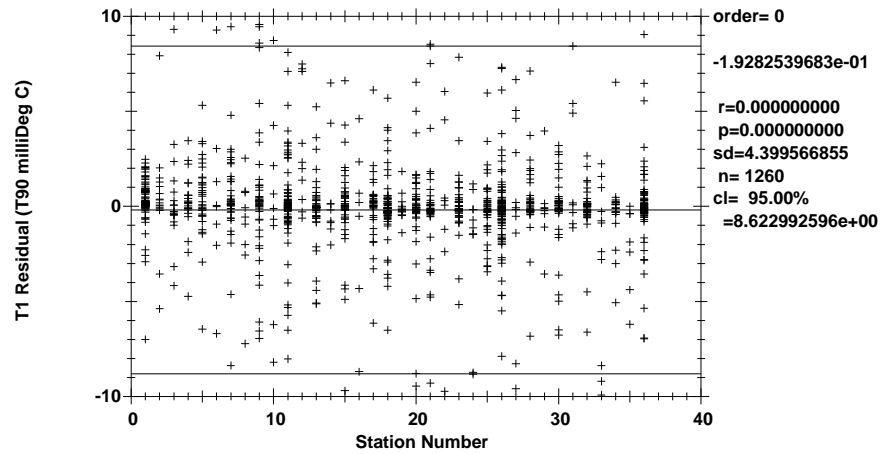


Figure 1.7.2.3 EPZT SBE35RT-T1 by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

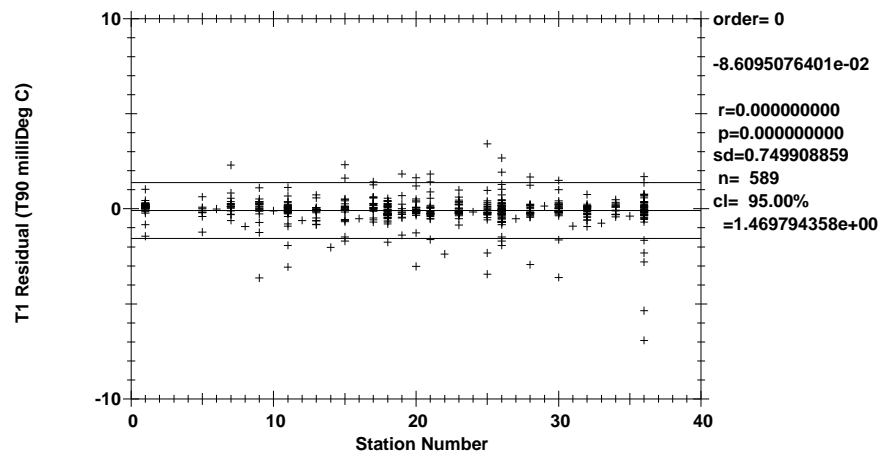


Figure 1.7.2.4 EPZT Deep SBE35RT-T1 by station (Pressure  $\geq 1000$  dbars).

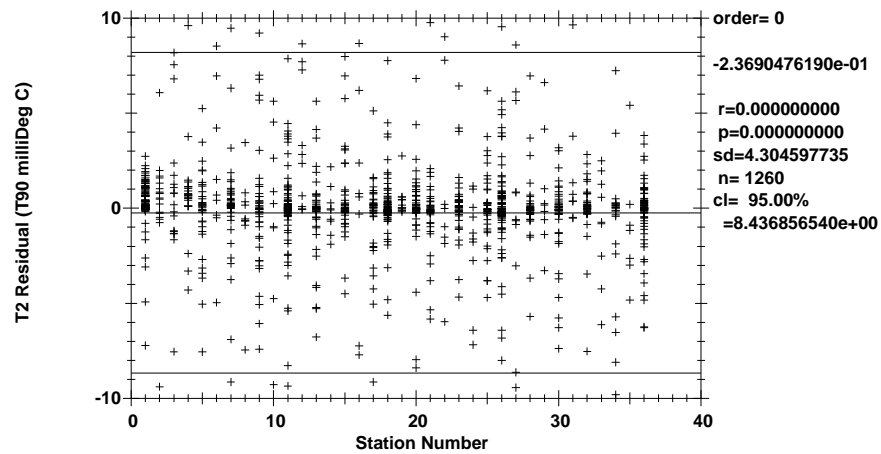


Figure 1.7.2.5 EPZT SBE35RT-T2 by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

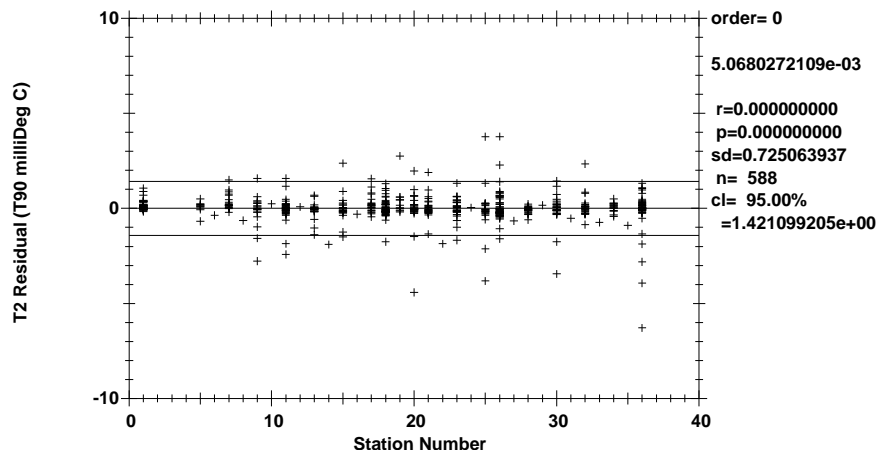


Figure 1.7.2.6 EPZT Deep SBE35RT-T2 by station (Pressure  $\geq 1000$  dbars).

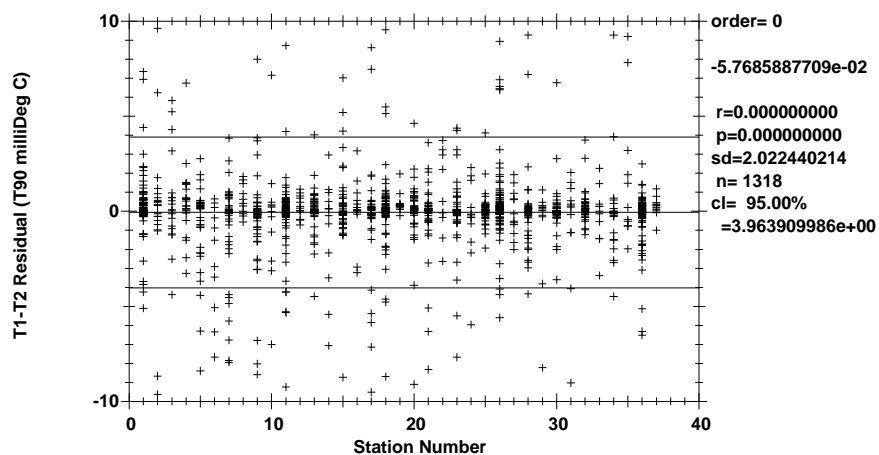


Figure 1.7.2.7 EPZT T1-T2 by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

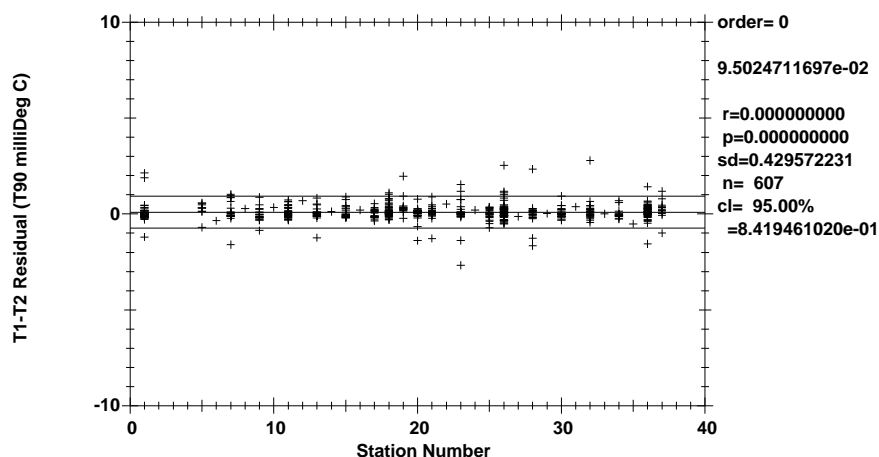


Figure 1.7.2.8 EPZT Deep T1-T2 by station (Pressure  $\geq 1000$  dbars).

The 95% confidence limits for the EPZT mean low-gradient differences are  $\pm 0.00862^{\circ}\text{C}$  for SBE35RT – T1 and  $\pm 0.00396^{\circ}\text{C}$  for T1 – T2. The 95% confidence limit for deep temperature residuals (where pressure  $> 1000$  dbars) is  $\pm 0.00147^{\circ}\text{C}$  for SBE35RT – T1 and  $\pm 0.00084^{\circ}\text{C}$  for T1 – T2.

### 1.7.3. CTD Conductivity

The same SBE4C primary (C1: 04-2659) and secondary (C2: 04-3399) conductivity sensors were used for all of EPZT. Primary T/C sensor data were used to report final CTD data for all casts.

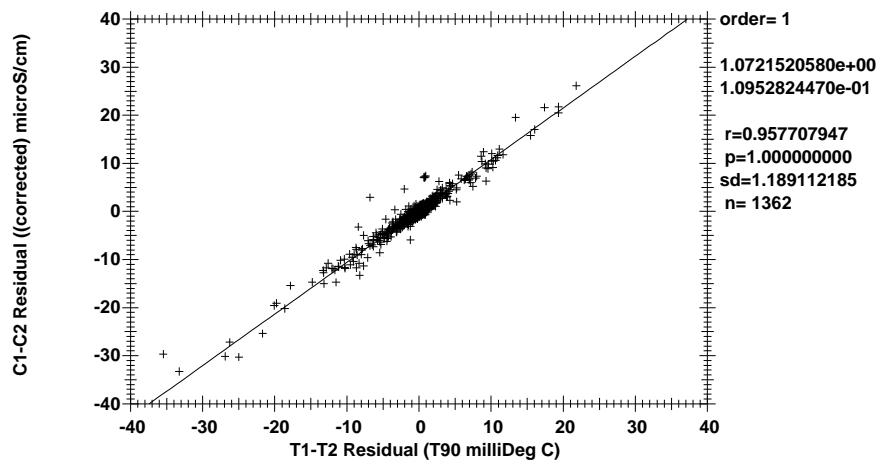
Calibration coefficients derived from the pre-cruise calibrations were applied to convert raw frequencies to conductivity. Adjustments to the default conductivity "advance" time (0.073 seconds, through the deck unit) were made while processing SBE asciihex files to half-second time-series data. An additional 0.06 seconds was used for T1/C1, and 0.04 seconds for T2/C2 data, determined from tests and plots using deep casts from stations 1 and 7.

Shipboard conductivity corrections were applied to primary and secondary conductivity data for each cast at the end of the cruise. 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.

Theta-Salinity comparisons showed that cast-to-cast deep CTD data were well-aligned before applying any offsets. Differences from all stations were included in the fits for conductivity corrections.

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



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

Uncorrected conductivity comparisons are shown in figures 1.7.3.1 through 1.7.3.3.



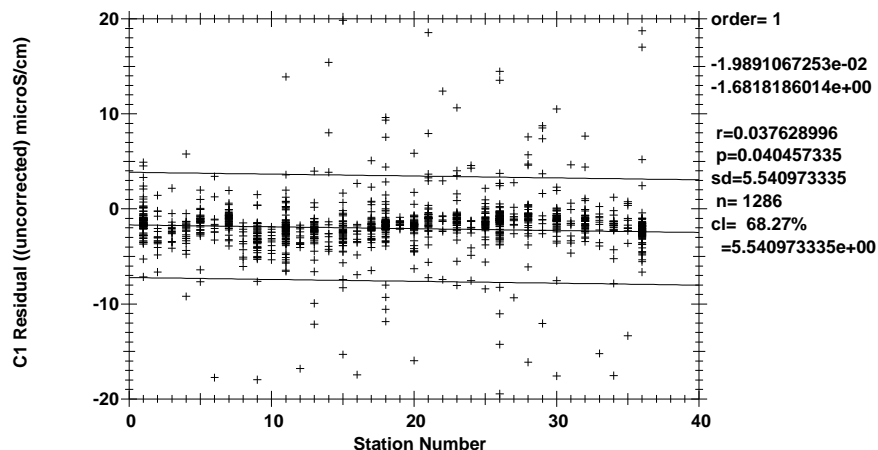


Figure 1.7.3.1 EPZT Uncorrected  $C_{\text{Bottle}} - C1$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

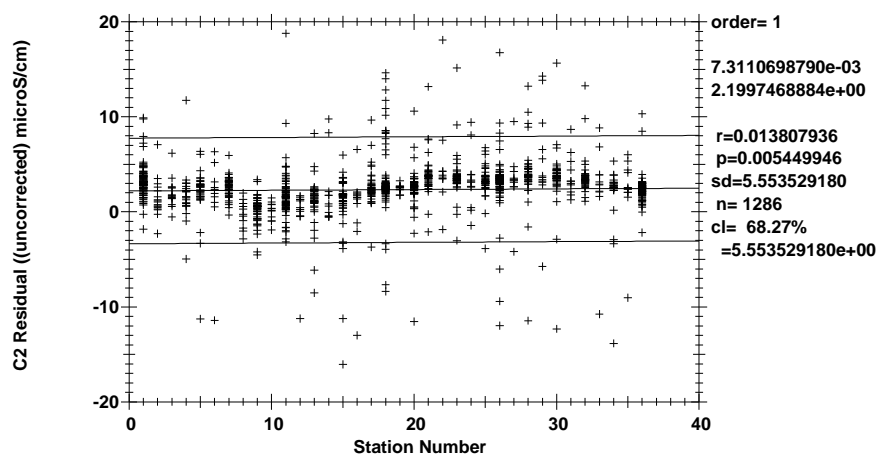


Figure 1.7.3.2 EPZT Uncorrected  $C_{\text{Bottle}} - C2$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

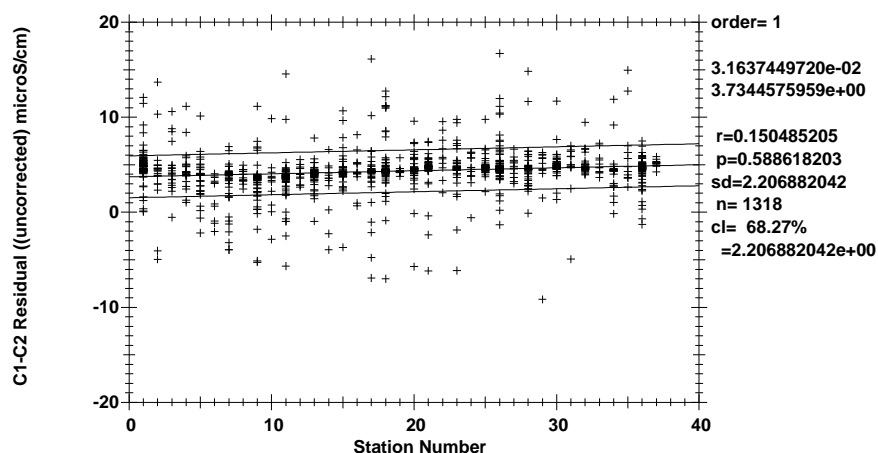


Figure 1.7.3.3 EPZT Uncorrected  $C1 - C2$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

The  $C1 - C2$  differences were fairly tight throughout the cruise, but with a definite "split" at mid-range pressures. Offsets for both C sensors were evaluated for drift with time, as well as for dependencies on pressure or conductivity, using  $C_{\text{Bottle}} - C_{\text{CTD}}$  differences. The most clearly defined dependence for both sensors was conductivity, which typically shifts between pre- and post-cruise SBE laboratory calibrations.

Parabolic fits of  $C_{\text{Bottle}} - C_{\text{CTD}}$  values for all trip data were applied to each conductivity sensor.

Time and pressure dependencies for C1 and C2 were then re-examined. C1 needed only a linear correction, and C2 required a parabolic correction as a function of pressure. A second-order fit was applied to C2 in order to pull in deep data without shifting the near-0 surface differences.

Both  $C_{\text{Bottle}} - C1$  and  $C_{\text{Bottle}} - C2$  differences shifted abruptly down, approximately -0.0015 for C1 and -0.002 for C2, between stations 7 and 8. The  $C_{\text{Bottle}} - C_{\text{CTD}}$  differences drifted slowly back up over the next 3 weeks. The C1 - C2 differences were fairly stable over the entire cruise. The Theta-S comparisons of adjacent (deep) CTD casts indicated no need for adjustment to S1.

All of these factors indicated the bottle salinity data likely shifted, not the CTD data. Statistics from the salinity runs showed a fairly steady, very small (typical) drift in the standard dial over the course of the cruise. The shift between any 2 runs would result in less than a 0.0005 change in salinity. There were no notes regarding any Autosal maintenance done between stations 7/8, and the lab temperature was fairly stable through-out the cruise. The ultimate cause of the shift could not be determined.

The residual conductivity differences after correction are shown in figures 1.7.3.4 through 1.7.3.15.

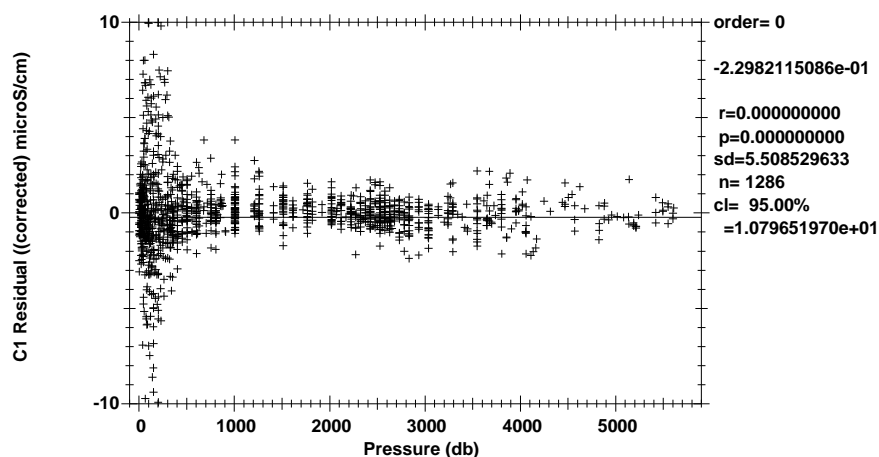


Figure 1.7.3.4 EPZT Corrected  $C_{\text{Bottle}} - C1$  by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

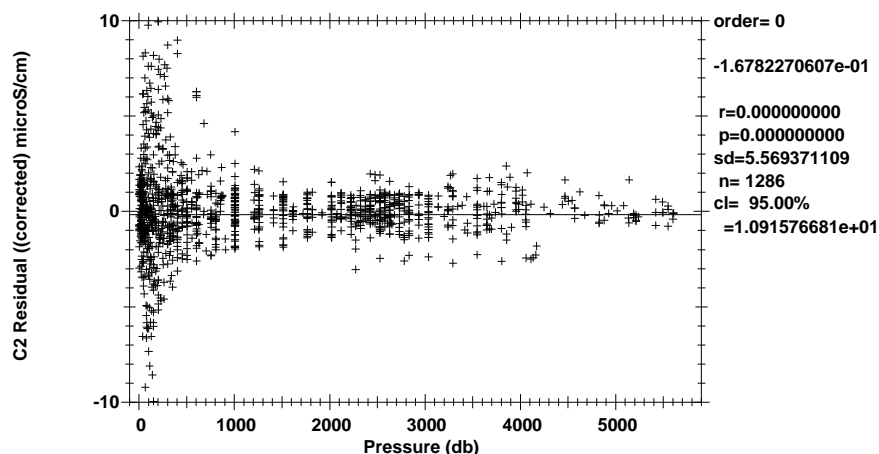


Figure 1.7.3.5 EPZT Corrected  $C_{\text{Bottle}} - C2$  by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

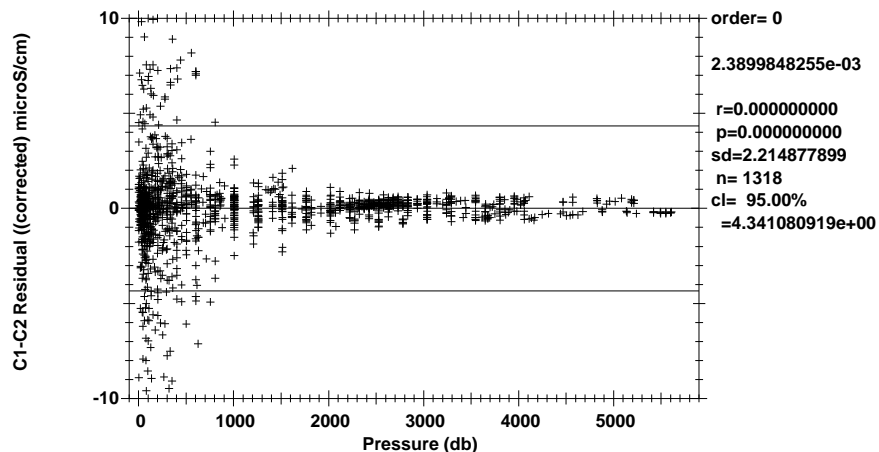


Figure 1.7.3.6 EPZT Corrected C1 – C2 by pressure ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

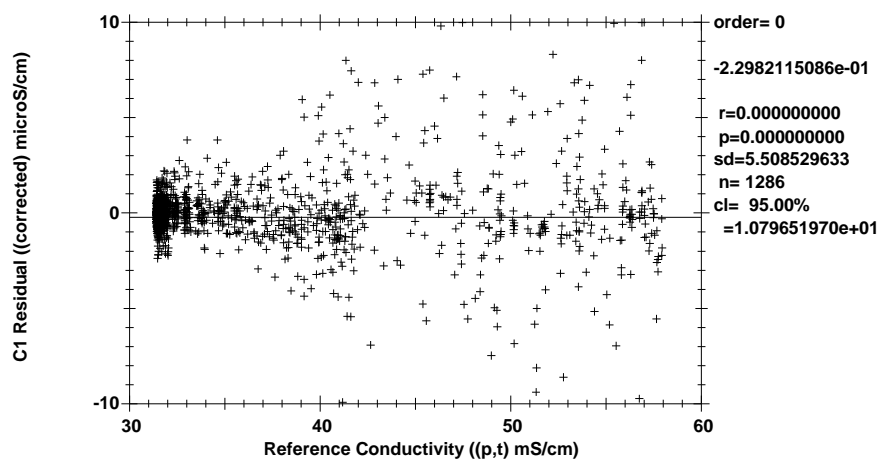


Figure 1.7.3.7 EPZT Corrected  $C_{\text{Bottle}} - C1$  by conductivity ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

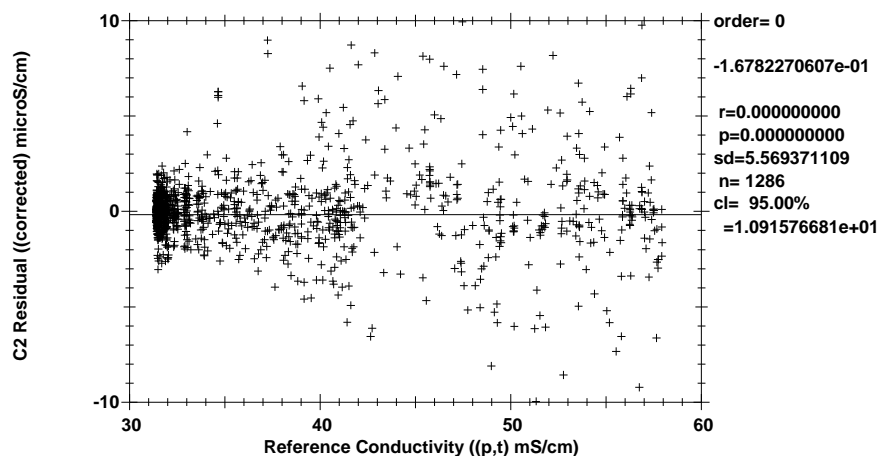


Figure 1.7.3.8 EPZT Corrected  $C_{\text{Bottle}} - C2$  by conductivity ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

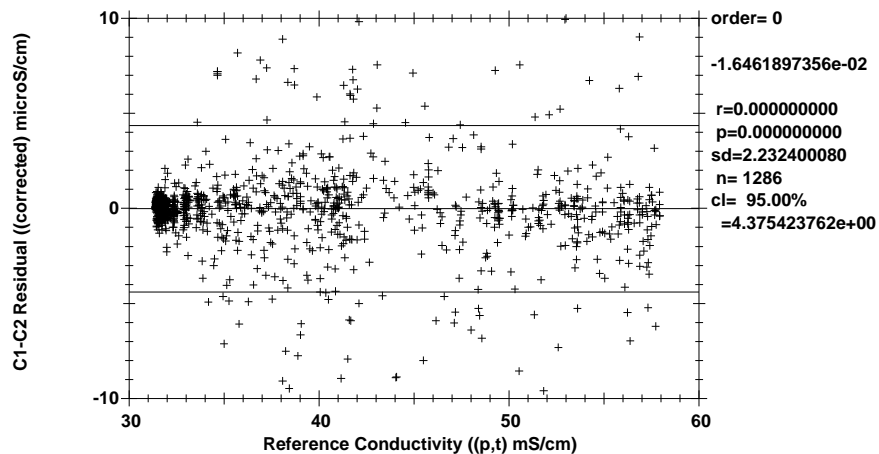


Figure 1.7.3.9 EPZT Corrected C1 – C2 by conductivity ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

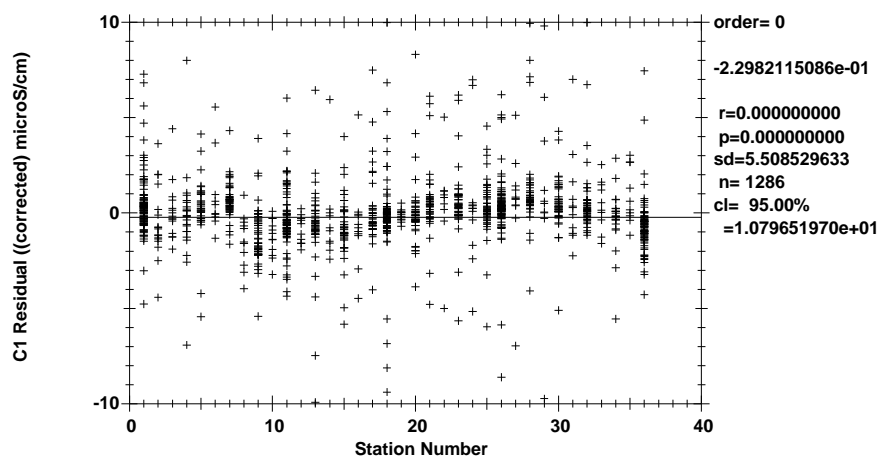


Figure 1.7.3.10 EPZT Corrected  $C_{\text{Bottle}} - C1$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

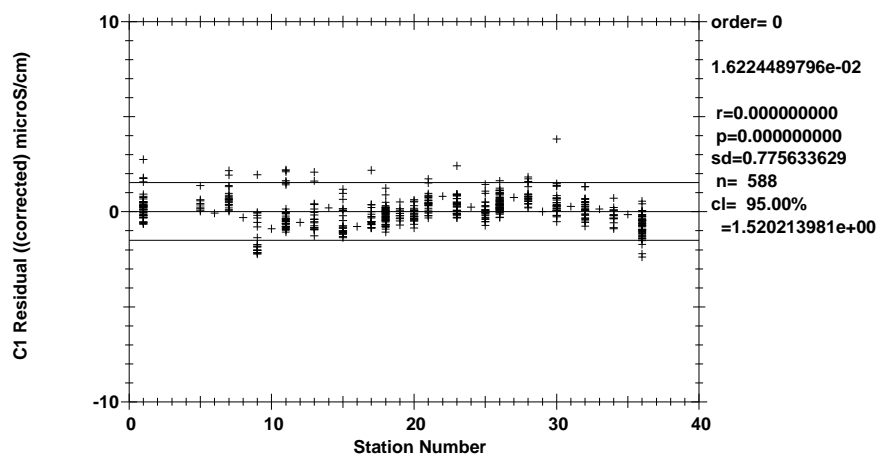


Figure 1.7.3.11 EPZT Deep Corrected  $C_{\text{Bottle}} - C1$  by station (Pressure  $\geq 1000$  dbars).

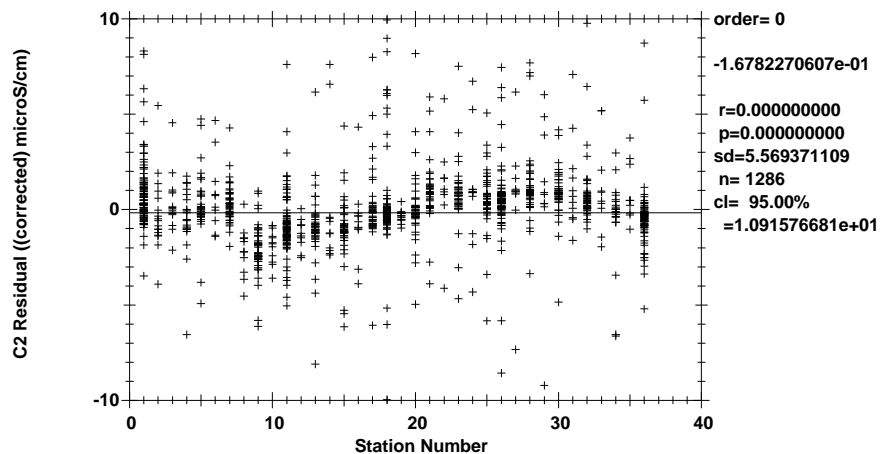


Figure 1.7.3.12 EPZT Corrected  $C_{\text{Bottle}} - C2$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).

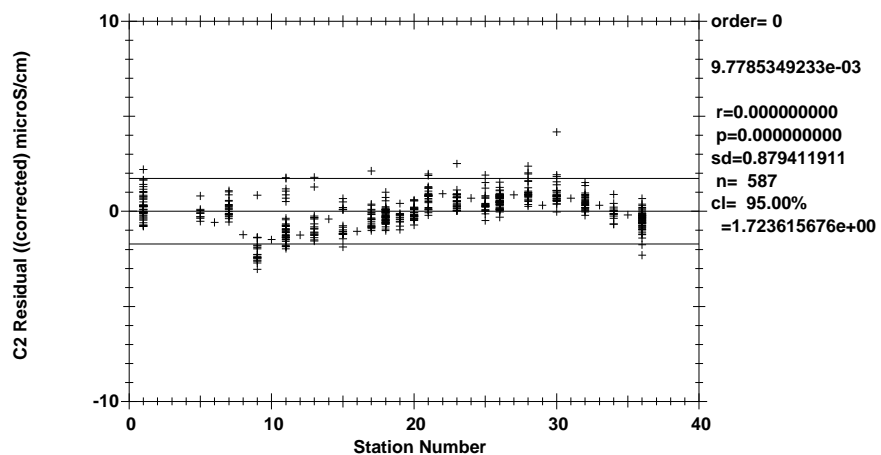


Figure 1.7.3.13 EPZT Deep Corrected  $C_{\text{Bottle}} - C2$  by station (Pressure  $\geq 1000$  dbars).

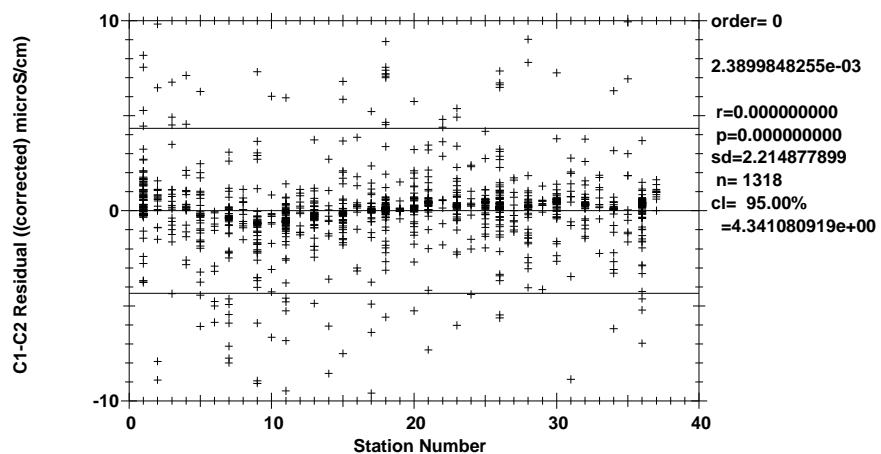
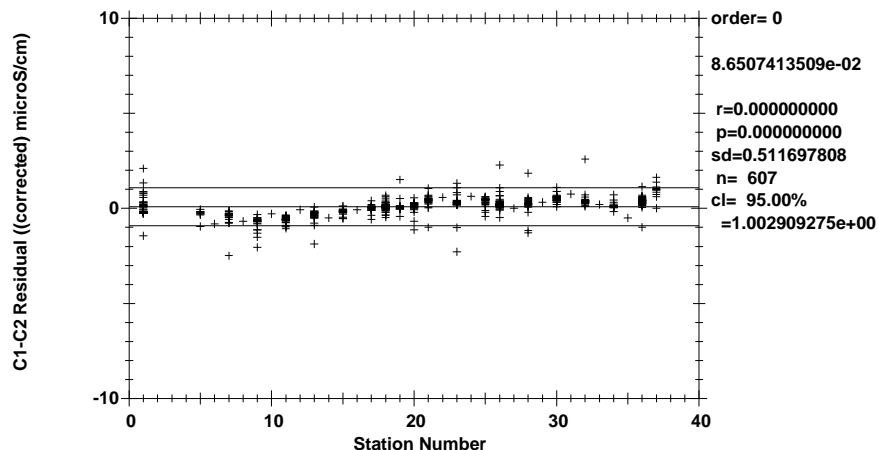


Figure 1.7.3.14 EPZT Corrected  $C1 - C2$  by station ( $-0.01^{\circ}\text{C} \leq T1 - T2 \leq 0.01^{\circ}\text{C}$ ).



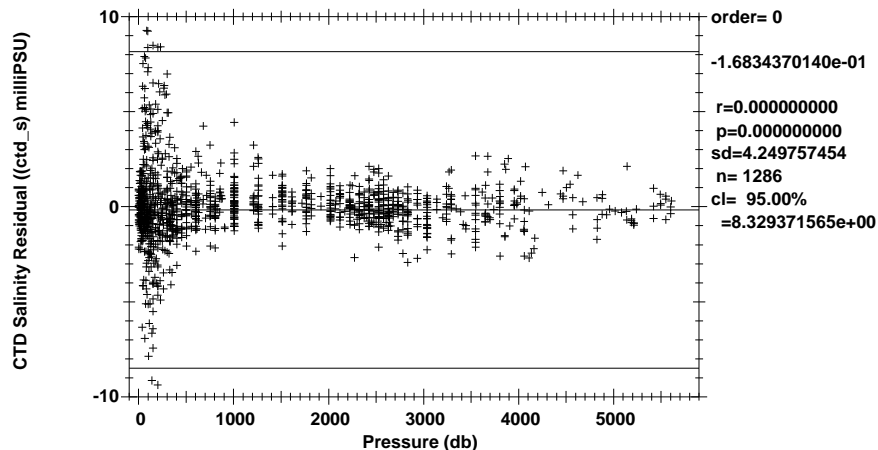
**Figure 1.7.3.15** EPZT Deep Corrected C1 – C2 by station (Pressure  $\geq 1000$  dbars).

The final corrections for the sensors used on EPZT are summarized in Appendix A. Corrections made to the conductivity sensors had the form:

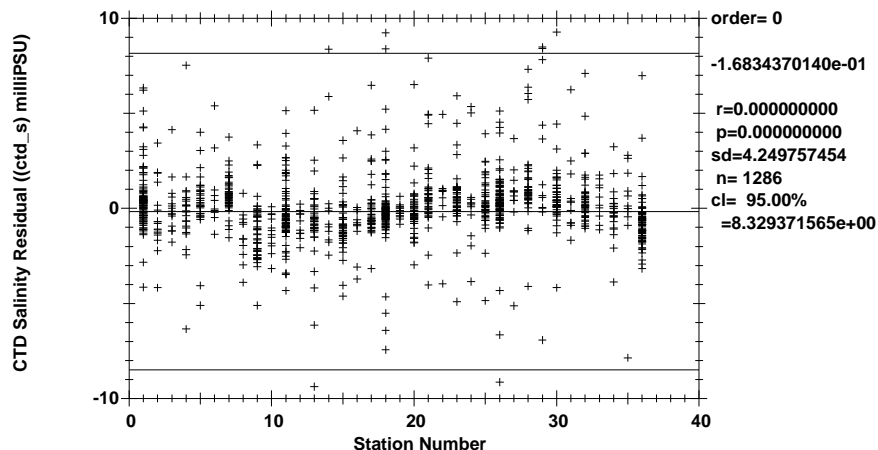
$$C1_{cor} = C1 + cp1 * P + c2 * C1^2 + c1 * C1 + c0$$

$$C2_{cor} = C2 + cp2 * P^2 + cp1 * P + c2 * C2^2 + c1 * C2 + c0$$

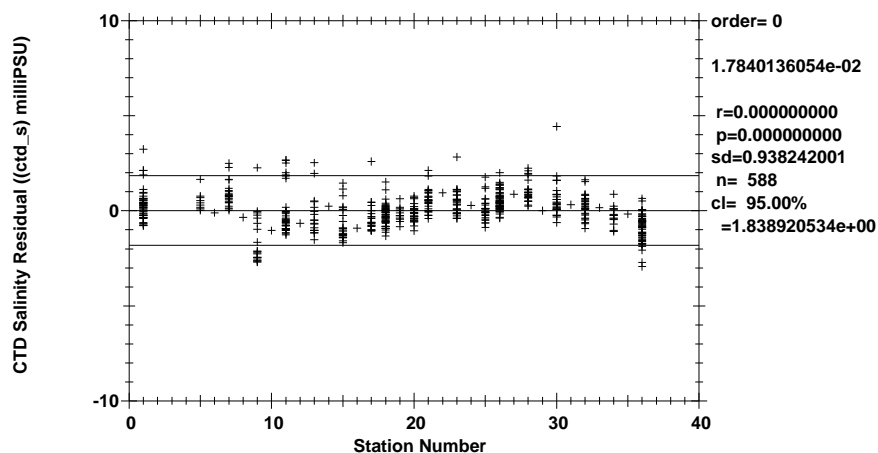
Salinity residuals after applying shipboard P/T/C corrections are summarized in figures 1.7.3.16 through 1.7.3.18. Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.



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



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



**Figure 1.7.3.18** EPZT Deep Salinity residuals by station (Pressure  $\geq 1000$  dbars).

Figures 1.7.3.17 and 1.7.3.18 represent estimates of the salinity accuracy of EPZT. The 95% confidence limits are  $\pm 0.00833$  relative to bottle salinities for all salinities, where  $T1 - T2$  is within  $\pm 0.01^{\circ}\text{C}$ ; and  $\pm 0.00184$  relative to bottle salinities for deep salinities, where pressure is more than 1000 decibars.

#### 1.7.4. CTD Dissolved Oxygen

A single SBE43 dissolved  $\text{O}_2$  sensor (DO: 43-0875) was used during EPZT. This dissolved  $\text{O}_2$  sensor was plumbed into the primary T1/C1 pump circuit after C1.

The SBE43 DO sensor was calibrated to dissolved  $\text{O}_2$  water 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  $\text{O}_2$  using a DO sensor response model and minimizing the residual differences from the bottle samples. A non-linear least-squares fitting procedure was used to minimize the residuals and to determine sensor model coefficients, and was accomplished in two 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 bottle sample data.

No bottle samples were taken in the shallower ranges of Deep and Mid casts on EPZT. Sample data from other casts at the same station or nearby stations were used in order to fit the upper parts of each deeper CTDO<sub>2</sub> cast. These bottle values were initially matched by pressure to the down-cast being fit, then adjusted shallower or deeper to maintain the original raw data "structure" of the cast. Bottle oxygen data

from nearby casts with similar deep TS structure were also used to help fit CTD O<sub>2</sub> data for casts with one or more mis-tripped bottles.

At the end of the cruise, standard and blank values for bottle oxygen data were smoothed, and the bottle oxygen values were recalculated. The changes to bottle oxygen values were less than 0.01 ml/L for all casts.

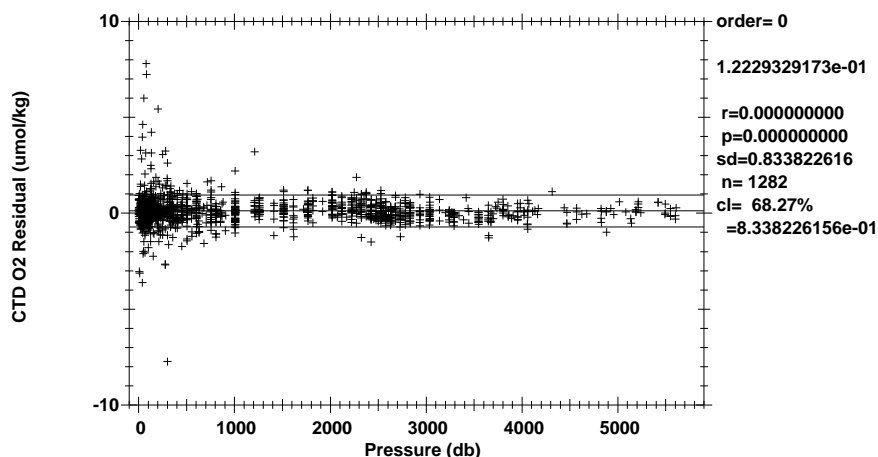
CTDO<sub>2</sub> data were re-calibrated to the smoothed bottle values post-cruise. A different fitting option was used, which included both down- and up-cast CTD data. This was cumbersome when shallow bottle data from other casts had to be merged in to the fitting files; but when both down- and up-cast data were fit to match fairly closely, the down-cast fits seem to be better and more consistent than the shipboard versions. Up-cast CTDO<sub>2</sub> data still have inherently more noise and offsetting, due to bottle stops as well as the rosette agitating the water before the CTD sensors see it; so down-cast data are still reported for each CTDO full cast wherever possible.

Overlay plots of raw CTDO<sub>2</sub> voltage for all casts within a station were also used during the final fitting process to ensure the original shallow-range relationships of the casts were maintained during the fitting process. All casts within a station, as well as nearby stations, were compared on plots of Pressure and/or Theta vs O<sub>2</sub> to verify consistency over the course of EPZT.

Final CTDO<sub>2</sub> "trip" data were first updated into the bottle database the usual way, using pressure-series down-cast data. This generated some large bottle-CTD differences, especially in higher-gradient areas, on final check-plots. Out of curiosity, time-series CTDO<sub>2</sub> data were updated into the database, with the same "down-and-up" option used during fitting. This inserted the time-series up-cast CTDO data into the database for most casts. The Deep "corer" casts were an exception, instead using down-cast time-series data, because of software "hanging" at the corer sample (sample 13 or 14), with a database "pressure" deeper than the CTD cast itself.

These mostly up-cast CTDO<sub>2</sub> data generated a bottle-CTD standard deviation one-third the size of the original update method, particularly because of better matches in higher-gradient near-surface areas. A few remaining differences were double-checked, resulting in several re-fits of CTDO<sub>2</sub> data to bottles in near-surface areas. In addition, down-cast pressure-series data were still used for the CTDO<sub>2</sub> values in the database for several casts (1/4 1/11 1/13 1/15 3/5 3/7 5/4 36/8) in order to prevent bottom-of-cast "drifty" up-cast data from skewing the results.

Final CTD dissolved O<sub>2</sub> residuals for SIO/ODF casts are shown in figures 1.7.4.0-1.7.4.2.



**Figure 1.7.4.0** EPZT O<sub>2</sub> residuals by pressure ( $-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$ ).



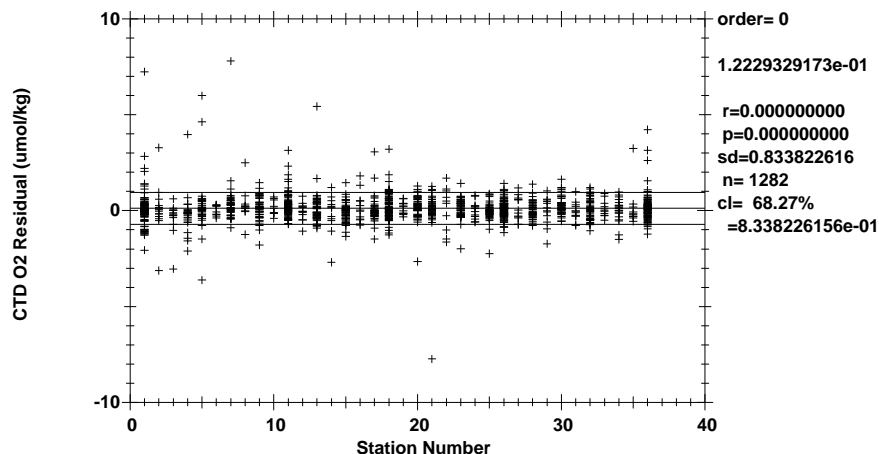


Figure 1.7.4.1 EPZT O<sub>2</sub> residuals by station ( $-0.01^{\circ}\text{C} \leq T_1 - T_2 \leq 0.01^{\circ}\text{C}$ ).

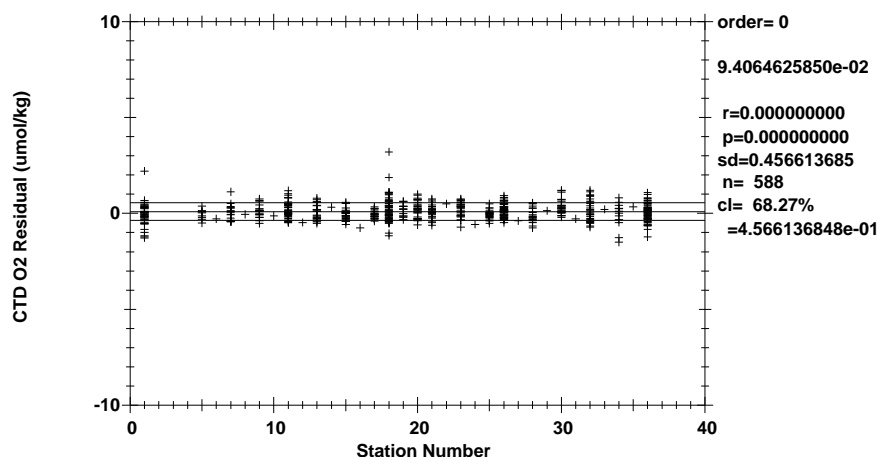


Figure 1.7.4.2 EPZT Deep O<sub>2</sub> residuals by station (Pressure  $\geq 1000$  dbars).

The standard deviations of  $0.834 \mu\text{mol/kg}$  for all oxygens and  $0.457 \mu\text{mol/kg}$  for deep oxygens are only presented as general indicators of goodness of fit. SIO/STS makes no claims regarding the precision or accuracy of CTD dissolved O<sub>2</sub> data.

The general form of the SIO/STS DO sensor response model equation for Clark-style cells follows Brown and Morrison [Brow78], Millard [Mill82] and Owens & Millard [Owen85]. SIO/STS models DO sensor responses with lagged CTD data. *In situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response ( $\tau_p$ ), a slow ( $\tau_{Tf}$ ) and fast ( $\tau_{Ts}$ ) thermal response, package velocity ( $\tau_{dp}$ ), thermal diffusion ( $\tau_{dT}$ ) and pressure hysteresis ( $\tau_h$ ) 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 ( $T_f$ ) 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<sub>2</sub> concentration is then calculated:

$$O_2 \text{ ml/L} = [C_1 \cdot V_{DO} e^{(C_2 \cdot \frac{P_h}{5000})} + C_3] \cdot f_{\text{sat}}(T, P) \cdot e^{(C_4 \cdot T_1 + C_5 \cdot T_s + C_7 \cdot P_1 + C_6 \cdot \frac{dO_c}{dt} + C_8 \cdot \frac{dP}{dt} + C_9 \cdot dT)} \quad (1.7.4.0)$$

where:

$O_2 \text{ ml/L}$	Dissolved $O_2$ concentration in ml/L;
$V_{DO}$	Raw sensor output;
$C_1$	Sensor slope
$C_2$	Hysteresis response coefficient
$C_3$	Sensor offset
$f_{\text{sat}}(T, P)$	$O_2$ saturation at T,P (ml/L);
$T$	<i>in situ</i> temperature ( $^{\circ}\text{C}$ );
$P$	<i>in situ</i> pressure (decibars);
$P_h$	Low-pass filtered hysteresis pressure (decibars);
$T_1$	Long-response low-pass filtered temperature ( $^{\circ}\text{C}$ );
$T_s$	Short-response low-pass filtered temperature ( $^{\circ}\text{C}$ );
$P_1$	Low-pass filtered pressure (decibars);
$\frac{dO_c}{dt}$	Sensor current gradient ( $\mu\text{amps/sec}$ );
$\frac{dP}{dt}$	Filtered package velocity (db/sec);
$dT$	low-pass filtered thermal diffusion estimate ( $T_s - T_1$ ).
$C_4 - C_9$	Response coefficients.

T values and coefficients used to generate the SBE43 data (ml/L) for each cast are listed in Appendix B. CTD  $O_2$  ml/L data are converted to  $\mu\text{mol/kg}$  units on demand.

Manufacturer information on the SBE43 DO sensor, a modification of the Clark polarographic membrane technology, can be found at [http://www.seabird.com/application\\_notes/AN64.htm](http://www.seabird.com/application_notes/AN64.htm).

A faster-response JFE Advantech Rinko III ARO-CAV Optical DO sensor (S/N 105), with its own oxygen temperature thermistor and not pumped, was installed on the rosette and integrated with the ODF CTD during all casts. ODF is currently evaluating this sensor, comparing its data with the SBE43 data from a recent CLIVAR cruise and considering its possible use as a primary sensor on future expeditions. Please contact ODF (odfdata@sts.ucsd.edu) for further information. Manufacturer information about the Rinko III sensor can be found at <http://www.jfe-advantech.co.jp/eng/ocean/rinko/rinko3.html>.

### 1.8. Rosette Bottle Sampling

After each rosette deployment except station 37, water samples were drawn from the bottles as follows:

Parameters Sampled	‡	Demi Shal-low	Vol-cano (19) Deep	Super / Full / Hemi / Shelf				Super Only Pu et.al/ 2 Shallow/ 2 Deep	All (exc.19) "Super-GeoFish" Surface
				Shal-low	*Mid	*Deep	**Th/Ra Pigments Shallow		
CFCs	U	x		x	x	x	x (surface)		
He and other Noble Gases	U	x	x	x	x	x	x (surface)		
N <sub>2</sub> / Ar	U	x		x	x	x			
O <sub>2</sub>	U	x	x	x	x	x	x	x	
N <sub>2</sub> O	U			x**	x	x			
Total Diss. Mn / Al / Fe	U		x		x (21)	x (18,20,21)			x
DIC	U	x		x	x	x	x (surface)		
<sup>14</sup> C / <sup>13</sup> C	U			x	x	x	x (surface)		
Nutrients	U	x	x	x	x	x	x	x	x
Salinity	U	x	x	x	x	x	x	x	x
<sup>3</sup> H	U	x		x	x	x	x (surface)		
Pigments	U						x		
<sup>234</sup> Th	U	x		x (34)			x		
<sup>226</sup> Ra	U						x		
DOC	F	x		x	x	x			x
d <sup>15</sup> N-NO <sub>2</sub>	F			x	x	x			
d <sup>15</sup> N-NO <sub>3</sub>	F			x	x	x			
Thiols	F			x**	x	x**			x
Si Isotopes	F			x**	x	x**			
Th / Pa	F			x	x	x			x
Nd / REE	F			x	x	x			x
Pb / Po	F							x	x (Super)
Pu/Np/Cs/Sr	F							x	x (Super)
<sup>129</sup> I / <sup>236</sup> U	F							x	x (Super)
NIOZ Corer	U					x (4-17,20-36)			
Wax Corer	U					x (18)			

‡ U (unfiltered) or F(filtered) sample

\* Deep, and Mid, if warranted by station's multibeam depth.

\*\* Not done/sampled on Hemi station 34.

SIO/ODF 30L Niskin serial numbers were assigned at the start of EPZT, typically corresponding to their rosette/carousel positions. Aside from various repairs along the way, one ODF 30L Niskin was changed out during this leg: NIS-2 was replaced by NIS-22 between stations 17 and 18 due to a spine leak.

Table 1.8.1 GT-C/12L-GoFlo Cast Sampling Order						
Station Type		Demi	Super / Full / Hemi / Shelf			All Super-GeoFish Surface
Parameters Sampled	‡	Shallow	Shallow	Mid*	Deep*	
<b>"Acropak" bottles:</b>						
Nutrients (ODF)	U	x	x	x	x	x
Salinity (ODF)	U	x	x	x	x	x
Total Diss. Al / Mn / Fe (Resing)	U			x	x	
d <sup>15</sup> N-NO <sub>3</sub> (Casciotti)	F	x				x
d <sup>15</sup> N-NO <sub>2</sub> (Casciotti)	F	x				x
diss. Al (Resing)	F	x	x	x	x	x
diss. Mn (Resing)	F	x	x	x	x	x
Co (Saito)	F	x	x	x	x	x
Ga / Ba / V / Mo (Shiller)	F	x	x	x	x	x
diss. Fe(II) Acropak (Moffett)	F		x	x	x	
Total diss. Fe (Moffett)	F		x (34,36)	x (36)	x (36)	x (36)
diss. Fe (Sedwick)	F		x	x	x	x
Cu speciation (Barbeau)	F		x	x	x	x
Fe speciation (Buck)	F		x	x	x	x
diss. Trace Metals (Bruland)	F	x	x	x	x	x
diss. Trace Metals (Wu)	F		x	x	x	x
Colloids (Wu)	F		x	x	x	x
Pb / Po (Flegal - shallow)	F	x	x	x	x	x
Pb / Po (Boyle - mid / deep)	F	x	x	x	x	x
Fe / Zn / Cd Isotopes (John)	F		x	x	x	x
Diss. Trace Metals (Bruland)	U					x
<b>"Particulate Membrane" bottles:</b>						
TDS (Cutter)	F	x	x	x	x	
I (Cutter)	F	x	x	x	x	x
diss. Fe(II) MOPS (Sta.1 only) or diss. Fe(II) Syringe (Moffett)	F	x	x	x	x	
Nutrients (ODF)	U	x	x	x	x	x
Salinity (ODF)	U	x	x	x	x	x
Phytoplankton (Twining) - Surface and DCM only	U	x	x			x
MMHg / DMHg / Elemental Hg (Hammerschmidt/Lamborg)	F	x	x	x	x	
Total Hg (Lamborg/Hammerschmidt)	F	x	x	x	x	x
NanoMolar Nutrients (Cutter)	F		x			x
As / Sb (Cutter)	F		x	x	x	x
Se (Cutter)	F		x	x	x	x
Partic./Cellular TM (Twining - shallow, Sherrell/German - mid/deep)	F	x	x	x	x	

‡ U (unfiltered) or F(filtered) sample

\* Deep, and Mid, if warranted by station's multibeam depth.

GT-C 12L Goflo serial numbers were assigned prior to the cruise, and were intentionally moved around to various carousel positions over the course of the expedition.

The correspondence between individual sample containers and the rosette bottle position from which the sample was drawn was recorded on the sample log for each cast. These bottle positions were numbered 1-12 for the ODF/30L Niskin Rosette, 13 for NIOZ mono-corer samples, 14 for wax corer samples, 25 for GeoFish surface samples and 1-24 for the GT-C/GoFlo Rosette. The sample 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"), which 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.

### Bottle Tripping Issues

The bottles in the table below did not close or were determined to be mistrips, usually by nutrient and dO<sub>2</sub> or dFe chemists, who analyzed and uploaded samples shortly after the casts were completed.

Individual mis-tripped bottles and all samples taken from them were quality-coded 4 (bad), since it is not clear exactly where they closed in the water column. More detailed comments appear in Appendix C.

Table 1.8.2 Bottle Mistrips or Closure Problems				
Station	Sample	Bot.Ser.No.	GEOT.No.	Comment
2	501-504	NIS-1-NIS-4	2281-2284	Niskin did not close.
2	512	NIS-12	2292	Niskin closed, but no samples taken.
3	504,512	NIS-4,NIS-12	2313,2321	Niskin did not close.
3	704	NIS-4	2334	Niskin did not close.
3	710	NIS-10	2340	Niskin did not close.
3	712	NIS-12	2342	Niskin did not close.
4	206	NIS-6	2373	Mistrip
5	520	GF-46	2478	Goflo did not fire
6	120	GF-46	3096	Goflo did not fire
7	814	GF-18	3210	Mistrip
7	1212	NIS-12	3266	Niskin did not close.
11	1310	NIS-10	3679	Niskin did not close (lanyard).
13	119-120	GF-02,GF-31	3759-3760	Mistrip
17	105	GF-05	8258	Mistrip
17	107	GF-07	8260	Mistrip; bottom ball leaked, snapped in van.
17	120	GF-20	8273	Mistrip
17	505	GF-47	8314	Mistrip
17	803	GF-47	8361	Mistrip
17	820	GF-46	8378	Spigot broke off, no samples taken.
18	201	GF-48	8410	Mistrip
18	207	GF-51	8416	Mistrip, re-snapped top ball in van.
18	221	GF-47	8430	Mistrip
23	609	NIS-9	9055	Niskin did not close, lanyard caught on latch.
28	806-807	GF-05,GF-28	9670-9671	Mistrip
30	806	GF-05	9815	Mistrip

### **1.9. SIO/STS Bottle Data Processing**

Water samples collected and properties analyzed shipboard were centrally managed in a relational database (PostgreSQL 8.1.23) running on a CentOS-5.9 Linux system. A web service (OpenACS 5.5.0 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 pressure at which each sample was tripped was marked by the CTD acquisition program for each group. A 3-second average of ODF-processed CTD trip data was loaded into the bottle database after each ODF/30L and GT-C/GoFlo cast. After ODF/30L CTD Oxygen corrections were determined, corrected CTDO values were also added to the database.

At the end of the cruise, all GT-C CTDO data were updated in the database using the post-cast Seasave-processed ".btl" file 5-second averaged CTD data, in order to include processed CTD Oxygen values. The 5-second average used resulted in slightly better agreement between CTD and GoFlo salinity values than the shorter 3-second average used for the Niskin rosette.

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 SIO/STS and other analytical groups during and at 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) [Joyce94]. In addition, non-standard quality codes "A" and "B" were used for several properties where the analysts desired to mark them as "Above" or "Below" detection limits for the analysis methods used.

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

<b>Table 1.9.0</b> Frequency of WHP quality flag assignments for STS/ODF Samples, Stations 1-37								
Reported levels		1	2	WHP Quality Codes				
				3	4	5	7	9
<b>ODF/30L Casts:</b>								
Bottle	1372	0	1346	0	13	0	0	13
Refc. Temp	1351	0	1292	59	0	0	0	21
CTD Oxy	1372	0	1371	1	0	0	0	0
CTD Salt	1372	0	1372	0	0	0	0	0
Oxygen	1341	0	1335	4	2	1	0	30
Salinity	1347	0	1339	7	1	0	0	25
Silicate	1347	0	1346	0	1	0	0	25
Nitrate	1347	0	1346	0	1	0	0	25
Nitrite	1347	0	1346	0	1	0	0	25
Phosphate	1347	0	1346	0	1	0	0	25
<b>GT-C and Super-GeoF Casts*:</b>								
Bottle	1743	0	1725	1	16	0	0	1
CTD Oxy	1612	0	1612	0	0	96	0	35
CTD Salt	1743	0	1743	0	0	0	0	0
Salinity	1739	0	1688	28	23	1	0	3
Silicate	1738	0	1721	2	15	2	0	3
Nitrate	1738	0	1721	2	15	2	0	3
Nitrite	1738	0	1721	2	15	2	0	3
Phosphate	1738	0	1723	0	15	2	0	3
* CTD Oxy and CTD Salt for GT-C casts are from Seasave-processed bottle files								

Various consistency checks and detailed examination of the data continued throughout the cruise. Data investigation comments are presented in Appendix C.

## 1.10. Salinity

### Equipment and Techniques

A single Guildline Autosol 8400B salinometer (S/N 69-180) located in the hydro 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, 36 to 72 samples, using 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

<b>Salinity Measurements Made During GEOTRACES EPZT</b>	
Cast Type	Number of Samples
30-ODF	1347
GT-C + Super-GeoF	1739
McL-Prof Niskins	204
Underway (mid-GeoF + Th)	80
Lost Samples	1
Total Salinity Samples	3371

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 21 °C. The ambient air temperature varied from 17 to 25 °C during the cruise.

There were occasional temperature spikes or drops that brought the room temperature outside of the acceptable range of the bath temperature. At these times, or when room temperature was not holding steady, an analysis run would be delayed until room temperature had again stabilized near bath temperature.

## Standards

IAPSO Standard Seawater (SSW) Batch P-155 was used to standardize all runs. 132 bottles of SSW were used during U.S. GEOTRACES EPZT.



## 1.11. 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 876 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 and reagent/distilled water blanks were run at least every other day, and when a change in reagents required it to account for the presence of oxidizing or reducing agents.

### Sampling and Data Processing

Oxygen Measurements Made During GEOTRACES EPZT	
Cast Type	Number of Samples
30-ODF	1341
Lost Samples	1
Total Oxygen Samples	1342

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  $\mu\text{mol/kg}$  concentrations, and as a diagnostic check of bottle integrity. Reagents ( $\text{MnCl}_2$  then  $\text{NaI/NaOH}$ ) were added to fix the oxygen before stoppering. 2g/L of sodium azide was added to the  $\text{NaI/NaOH}$  mixture for samples on stations 1-14 in order to counteract interference from high nitrite levels. 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 18 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 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.

## 1.12. Nutrient Analysis

### Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate+nitrite, nitrite) were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3).

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 Kirkwood *et al.* [Kirk89]. An acidic solution of ammonium molybdate was added to a seawater sample to produce silicomolybdic acid, which was then reduced to a silicomolybdenum blue complex following the addition of ascorbic acid. Oxalic acid was also added to impede  $\text{PO}_4$  color development. The sample was passed through a flowcell and the absorbance measured at 660nm.

### Reagents

#### Oxalic Acid (ACS Reagent Grade)

14.8g oxalic acid dissolved in DW and diluted to 1 liter volume. Stored at room temperature in a polypropylene bottle.

#### Ammonium Molybdate

14.8g Ammonium Molybdate Tetrahydrate dissolved in 1000ml dilute  $\text{H}_2\text{SO}_4$  \*.

\*(Dilute  $\text{H}_2\text{SO}_4$  = 54ml conc  $\text{H}_2\text{SO}_4$  to a liter DW). Added 3 drops 15% ultra pure SDS per liter of solution.

#### Ascorbic Acid (ACS Reagent Grade)

Stock solution:

2.6g of ascorbic acid dissolved in DW and diluted to 1 liter volume. Refrigerated in a polypropylene bottle.

### Nitrate + Nitrite

A modification of 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 520nm. 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 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  $\text{NH}_4\text{Cl}$  +  $\text{CuSO}_4$  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.

### **$\text{NH}_4\text{Cl}$ + $\text{CuSO}_4$ 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%  $\text{CuSO}_4$  solution to the  $\text{NH}_4\text{Cl}$  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 the Murphy and Riley [Murp62] technique. An acidic solution of ammonium molybdate and antimony potassium tartrate was added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of ascorbic acid. The reaction product was heated to ~37°C to enhance color development, then passed through a flowcell and the absorbance measured at 880nm.

### **Reagents**

#### **Antimony Potassium Tartrate stock**

2.3g antimony potassium tartrate dissolved in DW and brought up to 100ml volume. Stable for one month.

#### **Ammonium Molybdate (ACS Reagent Grade)**

Add 64ml of concentrated  $\text{H}_2\text{SO}_4$  to about 500ml DW and cool. Dissolve 6g of ammonium molybdate. Add 7ml stock antimony potassium tartrate. Dilute to 1 liter with DW. Store in a dark polypropylene bottle. Stable for one month. Must be colorless.

#### **Ascorbic Acid (ACS Reagent Grade)**

Dissolve 8g ascorbic in about 600ml DW. Add 45ml acetone and 1ml 15% ultra pure SDS. Dilute 1 liter volume. Stored in a dark polypropylene bottle and refrigerated. Stable for one week.

### **Sampling and Data Processing**

<b>Nutrient Measurements Made During GEOTRACES EPZT</b>	
Cast Type	Number of Samples
30L-ODF	1347
GT-C + Super-GeoF	1738
McL-Prof Niskins	204
Underway (mid-GeoF + Th)	69
Lost Samples	2
Total Nutrient Samples	3360

New pump tubes were installed before the cruise and after stations 15 and 24. Primary/secondary standards were made up at the beginning of the cruise and every 7-10 days thereafter. A total of 4 nitrite and 5 mixed (nitrate, phosphate, and silicate) standards were made 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 95%-100% and was replaced when less than 96%.

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 kept in a refrigerator and analyzed within fifteen hours after sample collection. They were removed from the refrigerator about an hour before being analyzed, 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 ( $\text{Na}_2\text{SiF}_6$ ), nitrate ( $\text{KNO}_3$ ), nitrite ( $\text{NaNO}_2$ ), and phosphate ( $\text{KH}_2\text{PO}_4$ ) 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 4 different standard concentrations (Table 1.12.0) were analyzed with each run of 12-30 samples to determine the deviation from linearity, if any, as a function of concentration for each nutrient.

std stations	N+N all	PO4 all	SiO3 all	NO2 1-15	NO2 16-36
1)	0.0	0.0	0	0.0	0.0
3)	15.50	1.2	60	1.50	0.50
5)	31.00	2.4	120	3.00	1.00
7)	46.50	3.6	180	4.50	1.50

**Table 1.12.0** U.S. GEOTRACES EPZT Standard Concentrations ( $\mu\text{mol/L}$ )

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 (DW).

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, through station 22. Additional LNSW was collected on the transit between Seattle and Manta, at position 27.47N 118.61W, and used for stations 23-36.

All data were initially reported in micromoles/Liter. NO<sub>3</sub>, PO<sub>4</sub>, and NO<sub>2</sub> 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 1.12.1:

Nutrient Reported	Accuracy ( $\mu\text{mol/L}$ )	Precision ( $\mu\text{mol/L}$ )
NO <sub>3</sub>	0.05	0.05
PO <sub>4</sub>	0.004	0.004
SIL	2-4	1
NO <sub>2</sub>	0.05	0.01

**Table 1.12.1** U.S. GEOTRACES EPZT Nutrient Accuracy and Precision

The detection limits for the methods/instrumentation are shown in Table 1.12.2:

Nutrient Measured	Detection Limit ( $\mu\text{mol/L}$ )
NO <sub>3</sub> +NO <sub>2</sub>	0.02
PO <sub>4</sub>	0.02
Sil	0.5
NO <sub>2</sub>	0.02

**Table 1.12.2** U.S. GEOTRACES EPZT Nutrient Detection Limits

As is standard ODF practice, a deep calibration *check* sample was run with each set of samples and the data are tabulated below. This water was collected at 2000 meters on the second rinse station, during the transit along the coast of Peru, and poisoned with mercuric chloride.

Parameter	Concentration ( $\mu\text{M}$ )
NO <sub>3</sub>	$40.03 \pm 0.22$
PO <sub>4</sub>	$2.96 \pm 0.03$
SiO <sub>3</sub>	$154.46 \pm 1.16$
NO <sub>2</sub>	$0.03 \pm 0.01$

**Table 1.12.3** U.S. GEOTRACES EPZT deep check cruise-averaged data

Reference materials for nutrients in seawater (RMNS) were also used as a check sample run occasionally. The RMNS preparation, verification, and suggested protocol for use of the material are described by Aoyama *et al.* [Aoya06] [Aoya07] [Aoya08] and Sato *et al.* [Sato10]. RMNS batch BX was used on this cruise, with each bottle being used once or twice before being discarded and a new one opened. Data are tabulated below, along with the assigned values.

Parameter	Concentration ( $\mu\text{mol kg}^{-1}$ )	Assigned
NO <sub>3</sub>	$44.27 \pm 0.23$	43
PO <sub>4</sub>	$3.04 \pm 0.03$	2.906
SiO <sub>3</sub>	$146.59 \pm 1.12$	136
NO <sub>2</sub>	$0.040 \pm 0.004$	0.034

**Table 1.12.4** U.S. GEOTRACES EPZT cruise-averaged concentration of RMNS standard

## References

Aoya06.

Aoyama, M., "Intercomparison Exercise for Reference Material for Nutrients in Seawater in a Seawater Matrix," *Technical Reports of the Meteorological Research Institute No.50*, p. 91, Tsukuba, Japan. (2006a).

Aoya08.

Aoyama, M., Barwell-Clark, J., Becker, S., Blum, M., Braga, E. S., Coverly, S. C., Czobik, E., Dahllof, I., Dai, M. H., Donnell, G. O., Engelke, C., Gong, G. C., Hong, G.-H., Hydes, D. J., Jin, M. M., Kasai, H., Kerouel, R., Kiyomono, Y., Knockaert, M., Kress, N., Kroglund, K. A., Kumagai, M., Leterme, S., Li, Y., Masuda, S., Miyao, T., Moutin, T., Murata, A., Nagai, N., Nausch, G., Ngirchchol, M. K., Nybakk, A., Ogawa, H., Ooijen, J. van, Ota, H., Pan, J. M., Payne, C., Pierre-Duplessix, O., Pujo-Pay, M., Raabe, T., Saito, K., Sato, K., Schmidt, C., Schuett, M., Shammon, T. M., Sun, J., Tanhua, T., White, L., Woodward, E. M. S., Worsfold, P., Yeats, P., Yoshimura, T., Youenou, A., and Zhang, J. Z., "2006 Inter-laboratory Comparison Study of a Reference Material for Nutrients in Seawater," *Technical Reports of the Meteorological Research Institute No. 58* (2008).

Aoya07.

Aoyama, M., Susan, B., Minhan, D., Hideshi, D., Louis, I. G., Kasai, H., Roger, K., Nurit, K., Doug, M., Murata, A., Nagai, N., Ogawa, H., Ota, H., Saito, H., Saito, K., Shimizu, T., Takano, H., Tsuda, A., Yokouchi, K., and Agnes, Y., "Recent Comparability of Oceanographic Nutrients Data: Results of a 2003 Intercomparison Exercise Using Reference Materials.," *Analytical Sciences*, 23: 115, pp. 1-1154 (2007).

Arms67.

Armstrong, F. A. J., Stearns, C. R., and Strickland, J. D. H., "The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment," *Deep-Sea Research*, 14, pp. 381-389 (1967).

Atla71.

Atlas, E. L., Hager, S. W., Gordon, L. I., and Park, P. K., "A Practical Manual for Use of the Technicon AutoAnalyzer® in Seawater Nutrient Analyses Revised," Technical Report 215, Reference 71-22, p. 49, Oregon State University, Department of Oceanography (1971).

Brow78.

Brown, N. L. and Morrison, G. K., "WHOI/Brown conductivity, temperature and depth microprofiler," Technical Report No. 78-23, Woods Hole Oceanographic Institution (1978).

Carp65.

Carpenter, J. H., "The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method," *Limnology and Oceanography*, 10, pp. 141-143 (1965).

Culb91.

Culberson, C. H., Knapp, G., Stalcup, M., Williams, R. T., and Zemlyak, F., "A comparison of methods for the determination of dissolved oxygen in seawater," Report WHPO 91-2, WOCE Hydrographic Programme Office (Aug 1991).

Gord92.

Gordon, L. I., Jennings, J. C., Jr., Ross, A. A., and Krest, J. M., "A suggested Protocol for Continuous Flow Automated Analysis of Seawater Nutrients in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study," Grp. Tech Rpt 92-1, OSU College of Oceanography Descr. Chem Oc. (1992).

Hage68.

Hager, S. W., Gordon, L. I., and Park, P. K., "A Practical Manual for Use of the Technicon AutoAnalyzer® in Seawater Nutrient Analyses.," Final report to Bureau of Commercial Fisheries, Contract 14-17-0001-1759., Oregon State University, Department of Oceanography, Reference No. 68-33. (1968).

Joyc94.

Joyce, T., ed. and Corry, C., ed., "Requirements for WOCE Hydrographic Programme Data

Reporting," Report WHPO 90-1, WOCE Report No. 67/91, pp. 52-55, WOCE Hydrographic Programme Office, Woods Hole, MA, USA (May 1994, Rev. 2). UNPUBLISHED MANUSCRIPT.

Kirk89.

Kirkwood, D. S., "Simultaneous determination of selected nutrients in seawater," *International Council for the Exploration of the Sea (ICES) Annual Report*, 29 (1989).

Mill82.

Millard, R. C., Jr., "CTD calibration and data processing techniques at WHOI using the practical salinity scale," Proc. Int. STD Conference and Workshop, p. 19, Mar. Tech. Soc., La Jolla, Ca. (1982).

Murp62.

Murphy, J. and Riley, J. P., "A modified single solution method for the determination of phosphate in natural waters," *Analytica Chimica Acta*, 27, pp. 31-36 . (1962).

Owen85.

Owens, W. B. and Millard, R. C., Jr., "A new algorithm for CTD oxygen calibration," *Journ. of Am. Meteorological Soc.*, 15, p. 621 (1985).

Sato10.

Sato, K., Aoyama, M., and Becker, S., "RMNS as Calibration Standard Solution to Keep Comparability for Several Cruises in the World Ocean in 2000s.," *Aoyama, M., Dickson, A.G., Hydes, D.J., Murata, A., Oh, J.R., Roose, P., Woodward, E.M.S., (Eds.) Comparability of nutrients in the world's ocean.*, pp. 43-56, Tsukuba, JAPAN: MOTHER TANK (2010b).

UNES81.

UNESCO, "Background papers and supporting data on the Practical Salinity Scale, 1978," UNESCO Technical Papers in Marine Science, No. 37, p. 144 (1981).

