# ACT0213

R/V Knorr, KN197-6

13 February 2013 to 03 March 2013

Cape Town, South Africa - Cape Town, South Africa

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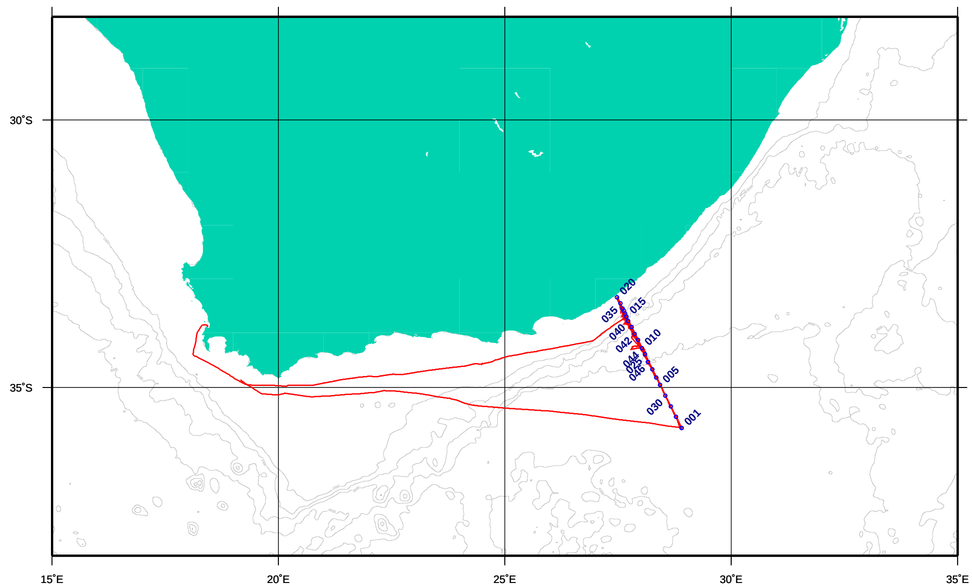


## Cruise Report
## 02 March 2013

*Data Submitted by:*
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## Summary

A hydrographic survey consisting of Rosette/CTD/LADCP sections, underway shipboard ADCP in the Agulhas was carried out early 2013. The R/V Knorr departed Cape Town, South Africa on 13 February 2013.

57 Rosette/CTD/LADCP casts were made. Water samples (up to 12) and CTD data were collected on each Rosette/CTD/LADCP cast, usually made to within 5-40 meters of the bottom. Salinity, dissolved oxygen samples were analyzed for up to 12 water samples from each cast of the principal Rosette/CTD/LADCP program. Concurrent temperature, conductivity, dissolved oxygen measurements were made at the time samples were taken.

The cruise ended in Cape Town, South Africa 03 March 2013.


## Description of Measurement Techniques

### 1. CTD/Hydrographic Measurements

ACT0213 Hydrographic measurements consisted of salinity, dissolved oxygen water samples taken from most of the 57 Rosette casts. Pressure, temperature, conductivity/salinity, dissolved oxygen, data were recorded from CTD profiles. The distribution of samples is shown in the following 2 figures.

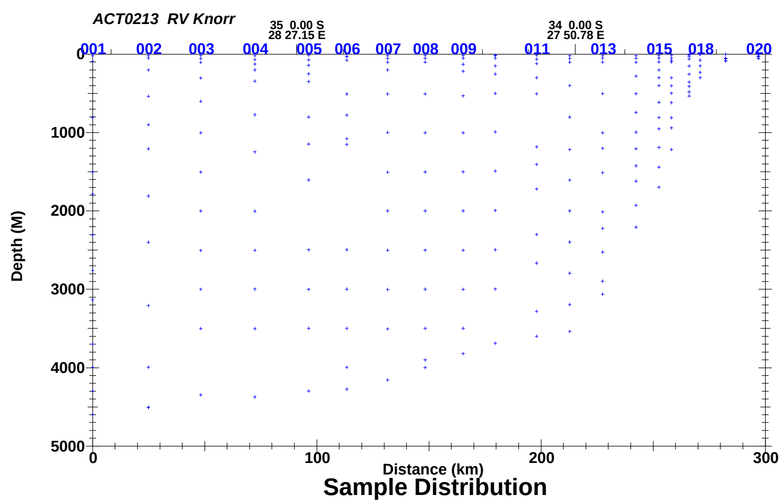


**Figure 1.0** ACT0213 Sample distribution, stations 1-20.

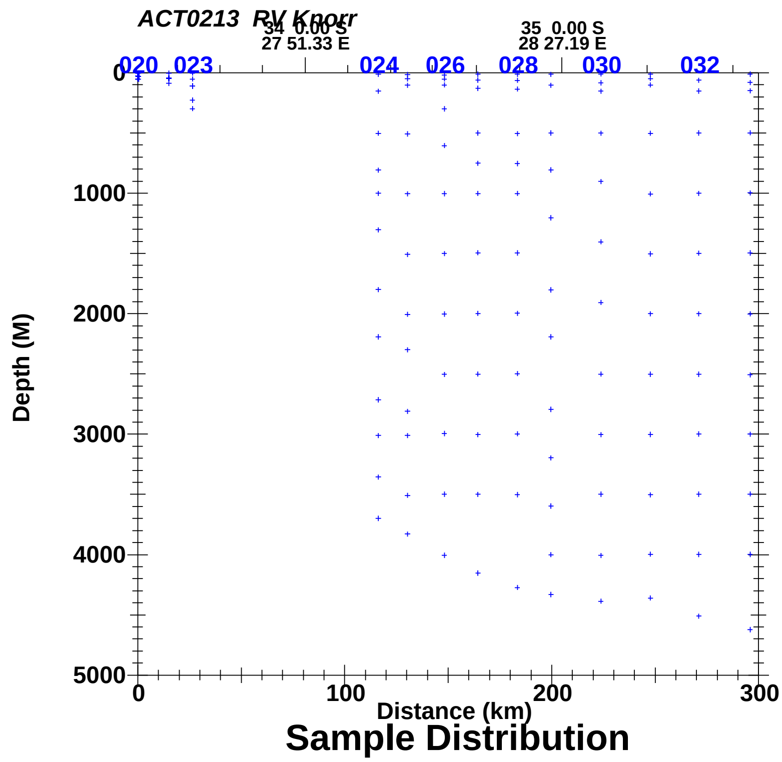


**Figure 1.0** ACT0213 Sample distribution, stations 21-33.

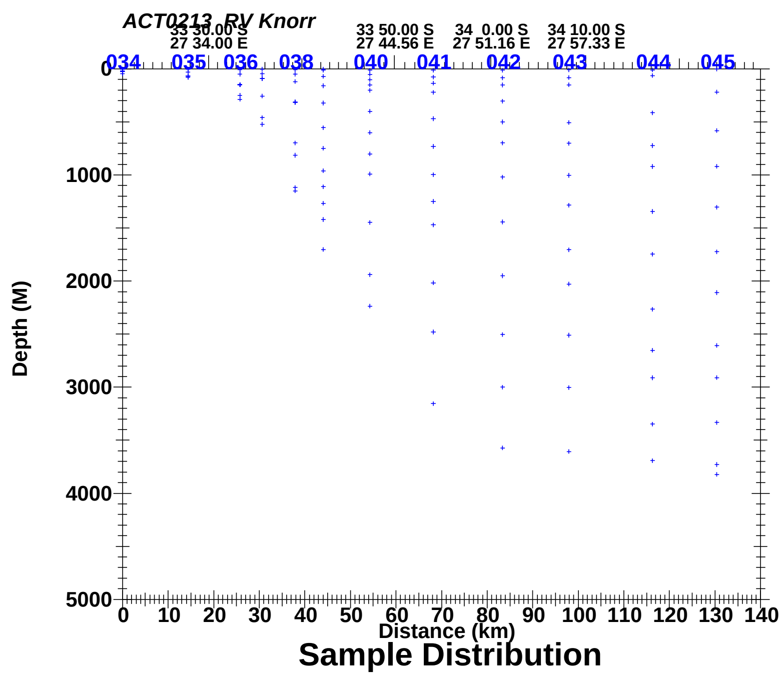


**Figure 1.0** ACT0213 Sample distribution, stations 34-46.

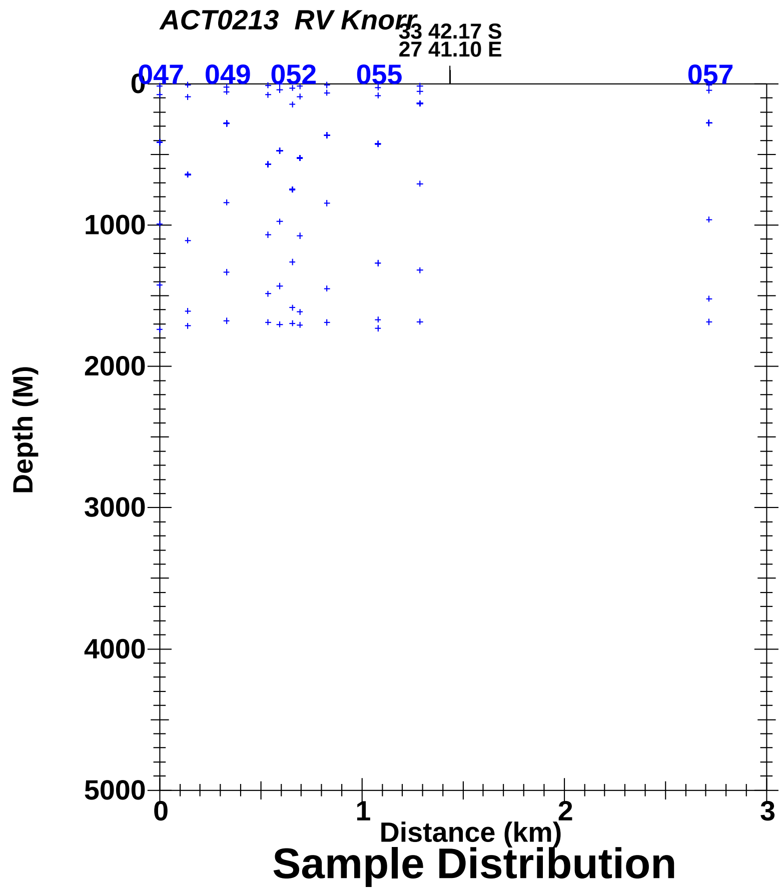


**Figure 1.0** ACT0213 Sample distribution, stations 47-57.

### 1.1. Water Sampling Package

Rosette/CTD/LADCP casts were performed with a package consisting of a 12-bottle rosette frame (SIO/STS), a 12-place carousel (SBE32) and 12 10.0L Niskin bottles (SIO/STS). Underwater electronic components consisted of a Sea-Bird Electronics SBE9*plus* CTD with dual pumps (SBE5), dual temperature (SBE3*plus*), single dual conductivity (SBE4C), dissolved oxygen (SBE43), altimeter.

The CTD was mounted vertically in an SBE CTD cage attached to the bottom of the rosette frame and located to one side of the carousel. The SBE4C conductivity, SBE3*plus* temperature and SBE43 dissolved oxygen sensors and their respective pumps and tubing were mounted in the CTD cage, as recommended by SBE. Pump exhausts were attached to the sensor bracket on the side opposite from the sensors. The altimeter was mounted on the inside of the bottom frame ring. The 300 KHz LADCP (RDI) was mounted vertically on one side of the frame between the bottles and the CTD as well as above the CTD. Its battery pack was mounted on the bottom of the frame.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The sea cable was terminated at the beginning of ACT. Reterminations were performed prior to station 30 when a kink was found in the winch wire just above termination. Kink was from an unknown source. The R/V Knorr's DESH-6 winch was used for all casts.

The deck watch prepared the rosette 10-30 minutes prior to each cast. The bottles were cocked and all valves, vents and lanyards were checked for proper orientation. Once stopped on station, the rosette was moved out from the forward hanger to the deployment location under the squirt-boom using an air-powered cart and tracks. The CTD was powered-up and the data acquisition system started from the computer lab. The rosette was unstrapped from the air-powered cart. Tag lines were threaded through the rosette frame and syringes were removed from CTD intake ports. The winch operator was directed by the deck watch leader to raise the package. The squirt-boom and rosette were extended outboard and the package was quickly lowered into the water. Tag lines were removed and the package was lowered to 10 meters, until the console operator determined that the sensor pumps had turned on and the sensors were stable. The winch operator was then directed to bring the package back to the surface, re-zero the wire-out reading, and begin the descent.

Most rosette casts were lowered to within 5-40 meters of the bottom, using the altimeter, winch pay-out, CTD depth and echosounder depth to determine the distance.

For each up cast, the winch operator was directed to stop the winch between 3-12 standard sampling depths. These depths were staggered every station. To insure package shed wake had dissipated, the CTD console operator waited 30 seconds prior to tripping sample bottles. An additional 10 seconds elapsed before moving to the next consecutive trip depth, to allow the SBE35RT time to take its readings.

Recovering the package at the end of the deployment was reverse of launching, with the additional use of poles and snap-hooks to attach tag lines. The rosette was secured on the cart and moved into the aft hanger for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

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

Routine CTD maintenance included soaking the conductivity and oxygen sensors in fresh water between casts to maintain sensor stability.

### 1.2. Navigation and Bathymetry Data Acquisition

Navigation data was acquired at 1-second intervals from the ship's GP90 GPS receiver by a Linux system beginning February 13 2013.

The bottom depths reported in the data transmittal files were recorded on the Console Logs during acquisition, and later input manually into the postgreSQL database. Knudsen depths were typically reported, unless depth data were not available.

### 1.3. Underwater Electronics

An SBE35RT reference temperature sensor was connected to the SBE32 carousel and recorded a temperature for each bottle closure. These temperatures were used as additional CTD calibration checks.

The SBE9*plus* CTD was connected to the SBE32 24-place carousel providing for single-conductor sea cable operation. The sea cable armor was used for ground (return). Power to the SBE9*plus* CTD (and sensors), SBE32 carousel, Benthos PSA-916 100m altimeter and Tritech 250m altimeter.

| Instrument/Sensor | Mfr./Model | Serial Number | A/D Channel | Stations Used |
|---|---|---|---|---|
| Carousel Water Sampler | Sea-Bird SBE32 (24-Pl.) | 3231095-0450 | n/a | 1-57 |
| CTD | Sea-Bird SBE9*plus* | 830 | n/a | 1-9 |
| Pressure | Paroscientific Digiquartz | 58952 | n/a | 1-9 |
| CTD | Sea-Bird SBE9*plus* | 462 | n/a | 10-57 |
| Pressure | Paroscientific Digiquartz | 99676 | n/a | 1-9 |
| Primary Temperature (T1) | Sea-Bird SBE3*plus* | 03P-2333 | n/a | 1-9 |
| Primary Temperature (T1) | Sea-Bird SBE3*plus* | 03P-4360 | n/a | 10-57 |
| Primary Conductivity (C1) | Sea-Bird SBE4C | 04-1744 | n/a | 1-9 |
| Primary Conductivity (C1) | Sea-Bird SBE4C | 04-3042 | n/a | 10-57 |
| Dissolved Oxygen | Sea-Bird SBE43 | 43-1136 | Aux4/V6 | 1-9 |
| Dissolved Oxygen | Sea-Bird SBE43 | 43-0113 | Aux3/V5 | 10-57 |
| Primary Pump | Sea-Bird SBE5T | 05-3245 | n/a | 1-9 |
| Primary Pump | Sea-Bird SBE5T | 05-5284 | n/a | 10-57 |
| Secondary Temperature (T2) | Sea-Bird SBE3*plus* | 03P-4532 | n/a | 1-9 |
| Secondary Temperature (T2) | Sea-Bird SBE3*plus* | 03P-2774 | n/a | 10-57 |
| Secondary Conductivity (C2) | Sea-Bird SBE4C | 04-2115 | n/a | 1-9 |
| Secondary Conductivity (C2) | Sea-Bird SBE4C | 04-3089 | n/a | 10-57 |
| Secondary Pump | Sea-Bird SBE5T | 05-2788 | n/a | 1-9 |
| Secondary Pump | Sea-Bird SBE5T | 05-3107 | n/a | 10-57 |
| Altimeter | Tritech, 250m | 221666 | Aux3/V4 | 1 |
| Altimeter | Benthos, 100m | 1182 | Aux3/V4 | 2-5 |
| Altimeter | Benthos, 100m | 1247 | Aux3/V4 | 5-57 |
| Altimeter | Tritech, 250m | 221666 | Aux2/V2 | 5-9 |
| Reference Temperature | Sea-Bird SBE35 | 35-0034 | n/a | 1-8 12-57 |
| Deck Unit (in lab) | Sea-Bird SBE11 | 11P-0384 | n/a | 1-57 |

**Table 1.3.0** ACT0213 Rosette Underwater Electronics.

### 1.4. CTD Data Acquisition and Rosette Operation

The CTD data acquisition system consisted of an SBE-11*plus* (V2) deck unit and two networked generic PC workstations running CentOS-5.8 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball and DVD+RW drive. One system had a Comtrol Rocketport PCI multiple port serial controller providing 8 additional RS-232 ports. The systems were interconnected through the ship's network. These systems were available for real-time operational and CTD data displays, and provided for CTD and hydrographic data management.

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

Once the deck watch had deployed the rosette, the winch operator lowered it to 10 meters. The CTD sensor pumps were configured with an 5-second startup delay after detecting seawater conductivities. The console operator checked the CTD data for proper sensor operation and waited for sensors to stabilize, then instructed the winch operator to bring the package to the surface and descend to a specified target depth (pay-out). The profiling rate was no more than 60m/min depending on sea cable tension and sea state.

The progress of the deployment and CTD data quality were monitored through interactive graphics and operational displays. Bottle trip locations were transcribed onto the console and sample logs. The sample log was used later as an inventory of samples drawn from the bottles. The altimeter channel, CTD depth, winch pay-out and bathymetric depth were all monitored to determine the distance of the package from the bottom, allowing a safe approach at depth.

Bottles were closed on the up cast by operating an on-screen control. The winch operator was given a target pay-out for the bottle stop, proceeded to that depth and stopped.

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

### 1.5. CTD Data Processing

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

At the completion of a deployment a sequence of processing steps were performed automatically. The 0.5-second time series data were checked for consistency, clean sensor response and calibration shifts. A 2-decibar pressure series was then generated from the down cast. Both the 2-decibar pressure series and 0.5-second time series data were made available for downloading, plotting and reporting on the shipboard cruise website.

CTD/rosette data were routinely examined for sensor problems, calibration shifts and deployment or operational problems. The primary and secondary temperature sensors (SBE3*plus*) were compared to each other and to the SBE35 temperature sensor. CTD conductivity sensors (SBE4C) were compared to each other, then calibrated by examining differences between CTD and check sample conductivity values. The CTD dissolved oxygen sensor data were calibrated to check sample data. Additional Salinity and $O_2$ comparisons were made with respect to isopycnal surfaces between down and up casts as well as with adjacent deployments. Vertical sections were made of the various properties derived from sensor data and checked for consistency.

The primary temperature and conductivity sensors were used for reported CTD temperatures and conductivities.

### 1.6. CTD Acquisition and Data Processing Problems

Station 001/01 was reset midway through up-cast at 3175m on a 4700m cast after the fourth bottle had been triggered. The cast was restarted and the two resulting data files were concatenated and a 9 minute lag was removed from the meta data files. The 4 initial bottles triggered for the restart cast were omitted along with 9min lag for reporting and fitting purposes but preserved in backup data files. The reset continued to be problematic for bottle data alignment against the CTD values at same depth. The low gradient region bottles were coded questionable and omitted from fitting routine.

The Tritech altimeter was used on cast 001/01 and again from casts 005/01-009/01. It held a steady 5V signal signal through out casts with out typical noise disruption. It is believed the signal was not recognized by the acquisition software. 3 Benthos model 916s were employed on all casts. Benthos S/N 1182 was used 002/01-005/01, S/N 41631 for casts 005/01-009/01. Benthos 1182 responded at depths < 30m above bottom. It is believe that casts were reaching depths > 30m off bottom due to a large error in Knudsen system settings thus the initial S/N 1182 had not performed consistently.

After station 009/01 cable communications failed to the carousel on the eighth consecutive bottle trigger. After review of casts 008/01 it was found a similar communications failure had been noted by console operator for trips 11 and 12 and miss reported as lanyard misalignment by deck-technicians. In by deck-technicians. In the interest of saving time a back-up CTD was used for the remainder of the cruise, casts 010/01-057/01. After 009/01 SBE35RT was returned to use on cast 0012/01 once an adapter cable could be constructed for the alternate CTD/carousel unit.

After the alternate CTD was put in use it was found that the primary plumb line had not been connected through SBE43 to SBE5T. Initially it was believed the software configuration files were incorrect. Secondary temperature and conductivity were sound fit and reported. Dissolved oxygen was not reported for cast 010/01.

Numerous miss-trips were noted on console logs and omitted from fitting routine.

### 1.7. CTD Sensor Laboratory Calibrations

Laboratory calibrations of the CTD pressure, temperature, conductivity and dissolved oxygen sensors were performed prior to ACT0213. The calibration dates are listed in table 1.7.0.

| Sensor | S/N | Calibration Date | Calibration Facility |
|---|---|---|---|
| Paroscientific Digiquartz Pressure | 830/99686 | 15 Nov 2012 | STS/ODF |
| Sea-Bird SBE3*plus* T1 Temperature | 03P-2333 | 08 Nov 2012 | STS/ODF |
| Sea-Bird SBE3*plus* T2 Temperature | 03P-4532 | 06 Nov 2012 | STS/ODF |
| Sea-Bird SBE4C C1 Conductivity | 04-1744 | 07 Dec 2012 | SBE |
| Sea-Bird SBE4C C2 Conductivity | 04-2115 | 07 Dec 2012 | SBE |
| Sea-Bird SBE43 Dissolved Oxygen | 43-1136 | 06 Dec 2012 | SBE |
| Sea-Bird SBE35 Reference Temperature | 35-0034 | 012 Dec 2012 | STS/ODF |
| Paroscientific Digiquartz Pressure | 462/58952 | 15 Mar 2012 | SBE |
| Sea-Bird SBE3*plus* T1 Temperature | 03P-4532 | 21 Dec 2012 | SBE |
| Sea-Bird SBE3*plus* T2 Temperature | 03P-2774 | 21 Dec 2012 | SBE |
| Sea-Bird SBE4C C1 Conductivity | 04-3042 | 29 Nov 2012 | SBE |
| Sea-Bird SBE4C C2 Conductivity | 04-3089 | 29 Nov 2012 | SBE |
| Sea-Bird SBE43 Dissolved Oxygen | 43-0113 | 18 Dec 2012 | SBE |
| Sea-Bird SBE35 Reference Temperature | 35-0034 | 012 Dec 2012 | STS/ODF |

**Table 1.7.0** ACT0213 CTD sensor laboratory calibrations.

### 1.8. CTD Shipboard Calibration Procedures

During ACT CTD set up 830 was used for CTD/rosette/LADCP casts 1-9, and CTD set up 462 for stations 10-57

The SBE35RT Digital Reversing Thermometer (S/N 3528706-0034) served as an independent calibration check for T1 and T2 on stations 1-9 and 12-57 *In-situ* salinity and dissolved $O_2$ check samples collected during each cast were used to calibrate the conductivity and dissolved $O_2$ sensors.

Rapid variability in the environment observed on many of the deployments in sensor and check sample comparisons. An additional metric of typical variability was inferred from comparing primary and secondary temperature data. This metric was used to filter check sample comparisons for calibration purposes.

#### 1.8.1. CTD Pressure

The Paroscientific Digiquartz preddssure transducer (S/N ?????) was calibrated in ??? 20?? at the STS/ODF Calibration Facility.

Convertion coefficients for both Paroscientific Digiquarts pressure transducers provided with-in calibrations reports were used to convert frequencies to pressure. Calibration correction slope and offset were then applied to pressures during each cast. Pre- and post-cast on-deck/out-of-water pressure offsets varied from -0.1 to -0.3db for 830 CTD setup (stations 1-9). Pre- and post-cast on-deck/out-of-water pressure offsets varied from -1.3 to +3.5db for the 462 CTD setup (stations 10-57).

### 1.8.2. CTD Temperature

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

A single SBE35RT was used as a tertiary temperature check. It was located equidistant between T1 and T2 with the sensing element aligned in a plane with the T1 and T2 sensing elements. The SBE35RT Digital Reversing Thermometer is an internally-recording temperature sensor that operates independently of the CTD. It is triggered by the SBE32 carousel in response to a bottle closure. According to the manufacturer's specifications, the typical stability is 0.001°C/yr. The SBE35RT on ACT was set to internally average over an 8 second period.

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

Note that a temperature slope of 0.00024 was applied to each sensor to convert from the ITS-90 calibration to IPTS-68. Reported sensor data have been converted to ITS-90.

Due to alternate CTD configuration, temperature calibrations for 1-9 were applied independent of calibration for stations 10-57.

All corrections made to CTD temperatures had the form:

$$T_{cor} = T + tp_2 P^2 + tp_1 P + t_0$$

Residual temperature differences after correction are shown in figures 1.8.2.0 through 1.8.2.1.

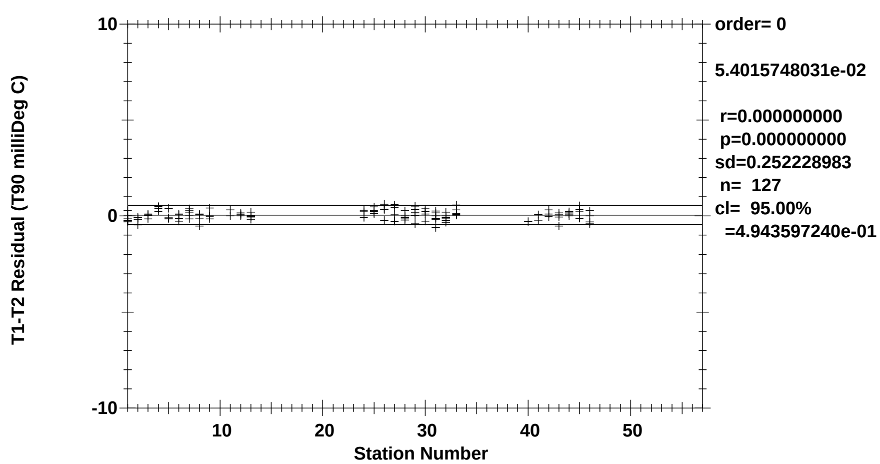


**Figure 1.8.2.0** T1-T2 by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

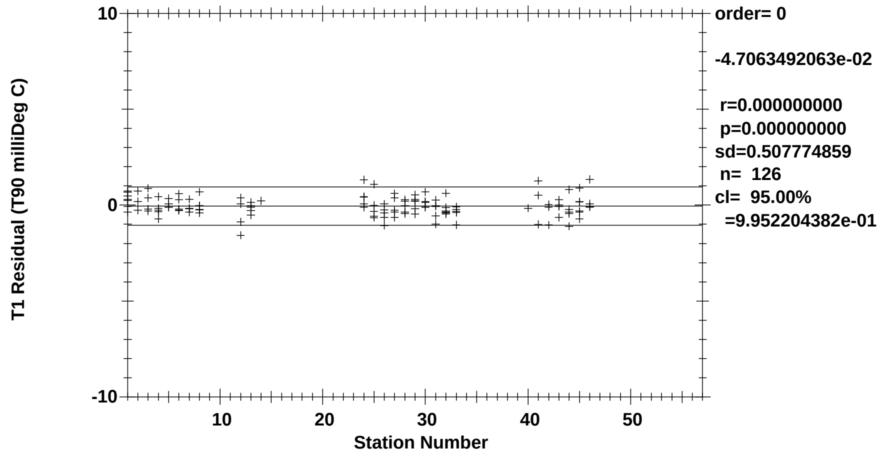


**Figure 1.8.2.1** SBE35RT-T1 by station (-0.01°C $\leq T1 - T2 \leq$ 0.01°C).

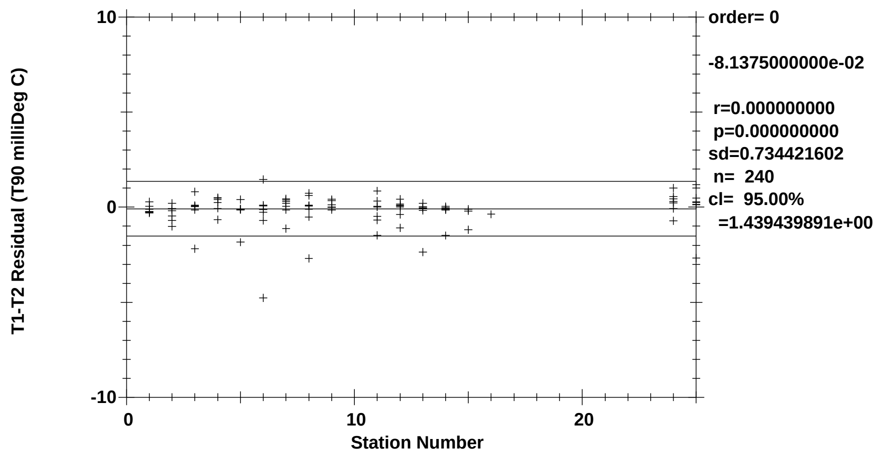


**Figure 1.8.2.2** Deep T1-T2 by station (Pressure > 1000dbar).

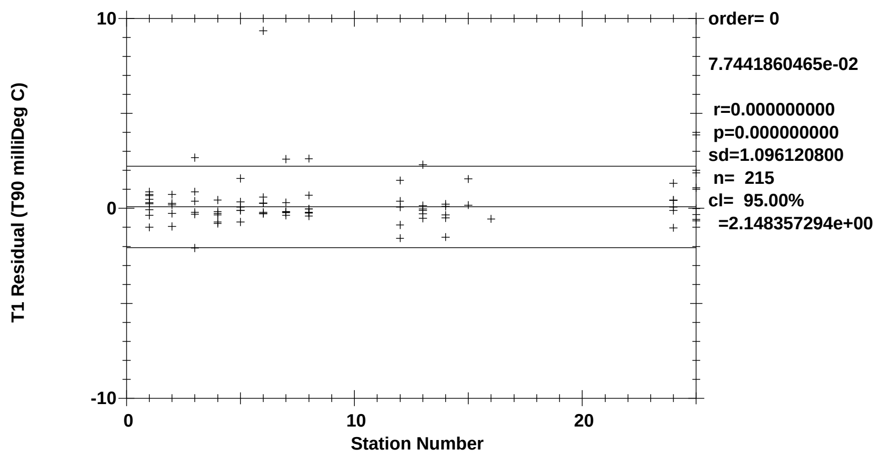


**Figure 1.8.2.3** Deep SBE35RT-T1 by station (Pressure > 1000dbar).

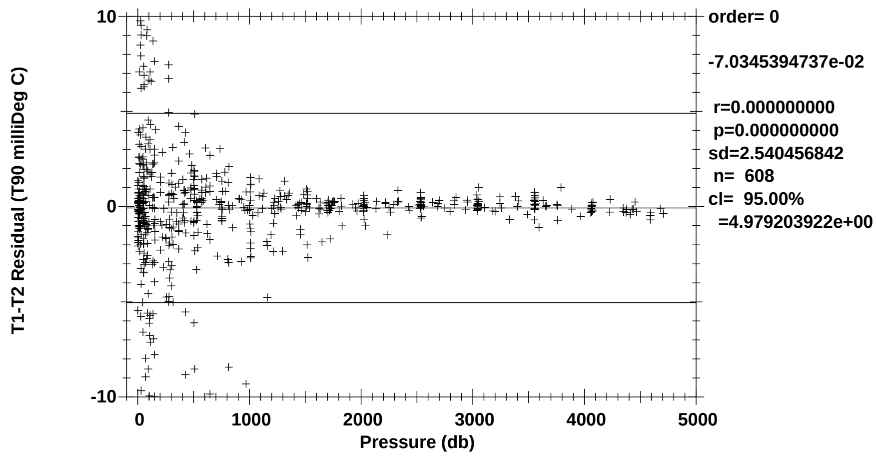


**Figure 1.8.2.4** T1-T2 by pressure (-0.01°C $\leq T1-T2 \leq$ 0.01°C).

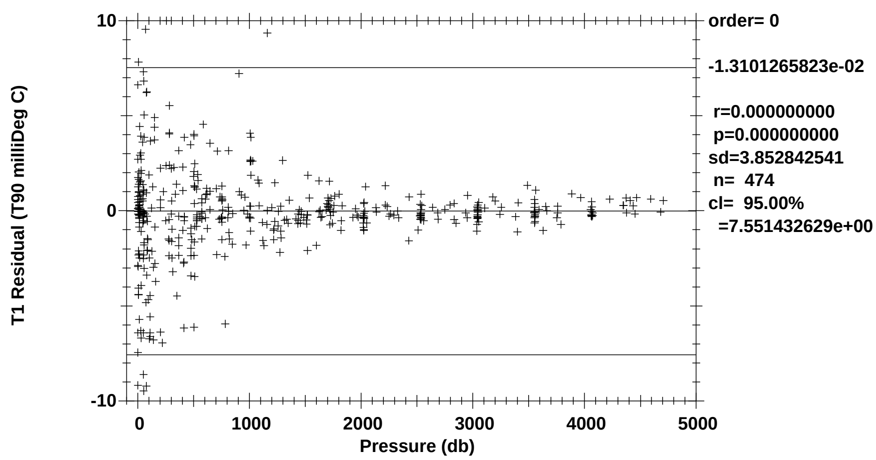


**Figure 1.8.2.5** SBE35RT-T1 by pressure (-0.01°C $\leq T1-T2 \leq$ 0.01°C).

The 95% confidence limits for the mean low-gradient (typically pressure > 1000dbar) bottle differences are ±0.000494°C for T1-T2, ±0.000995°C for SBE35R T-T1.

### 1.8.3. CTD Conductivity

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

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

The differences between primary and secondary temperature sensors were used as filtering criteria to reduce the contamination of conductivity comparisons by package wake. The coherence of this relationship is shown in figure 1.8.3.0.

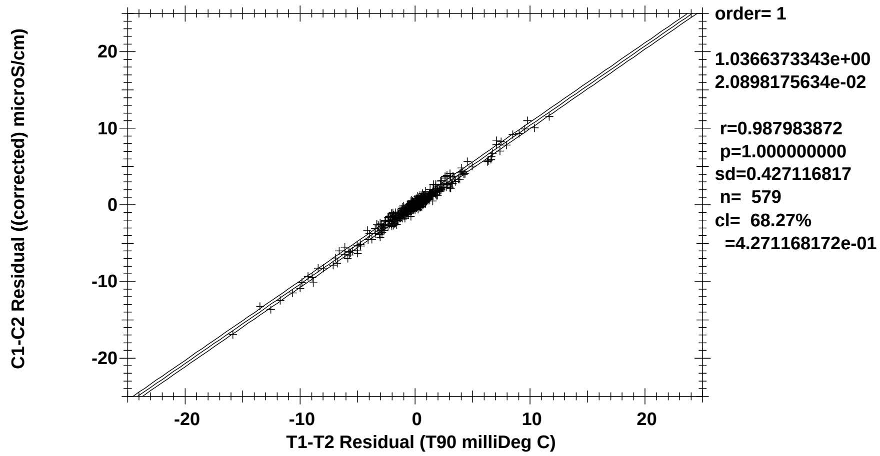


**Figure 1.8.3.0** Coherence of conductivity differences as a function of temperature differences.

Uncorrected conductivity comparisons are shown in figures 1.8.3.1 through 1.8.3.3.

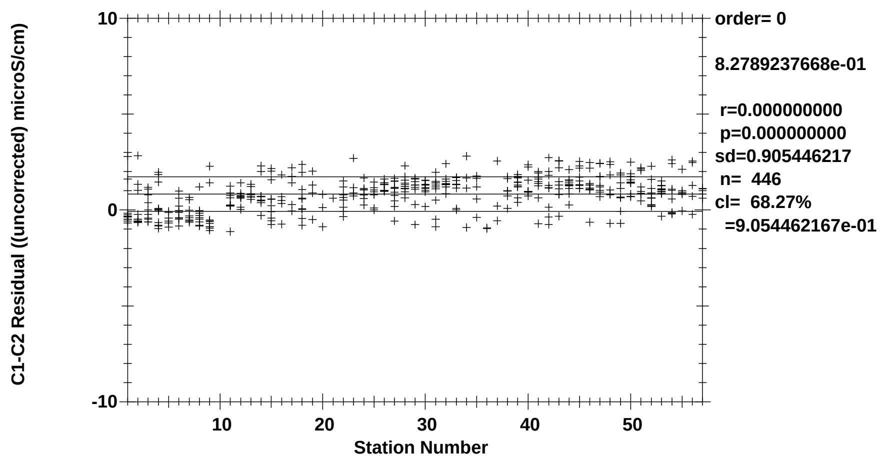


**Figure 1.8.3.1** Uncorrected $C1-C2$ by station (-0.01°C $\leq T1-T2 \leq$ 0.01°C).

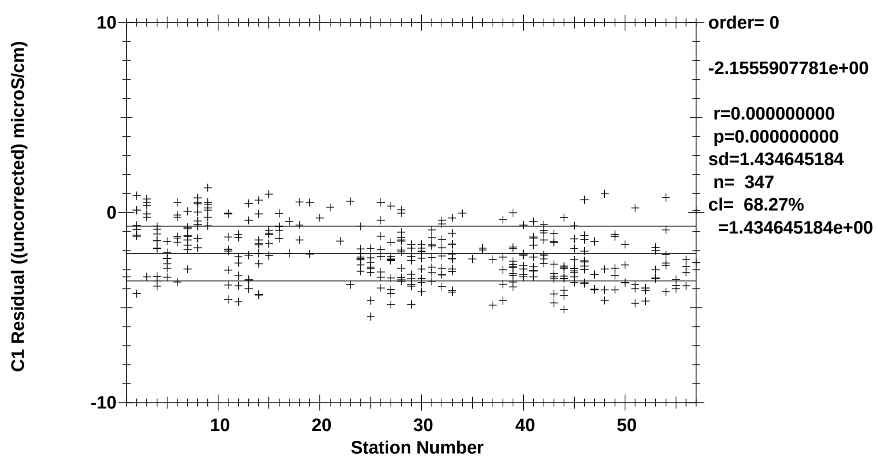


**Figure 1.8.3.2** Uncorrected $C_{Bottle}-C1$ by station (-0.01°C $\leq T1-T2 \leq$ 0.01°C).

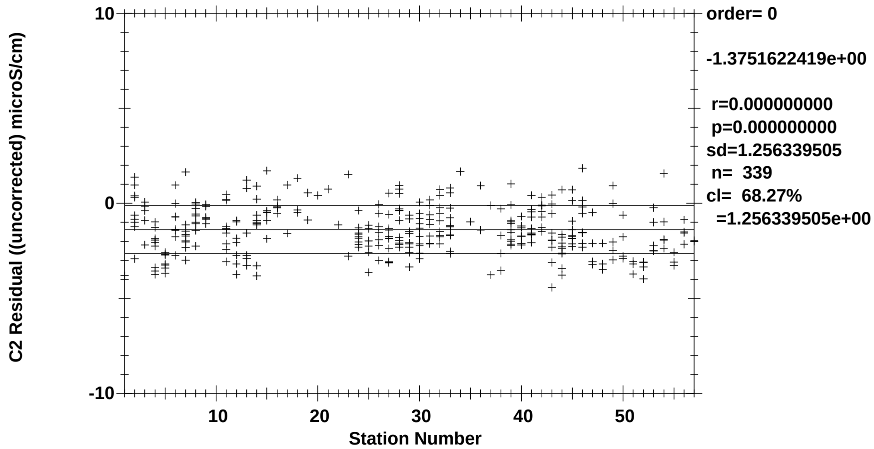


**Figure 1.8.3.3** Uncorrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

First-order time-dependent drift corrections (changing conductivity offset with time) were determined for each sensor. After applying the drift corrections, second-order pressure responses were evident for each conductivity sensor.

$C_{Bottle} - C_{CTD}$ differences were then evaluated for response to temperature and/or conductivity, which typically shifts between pre- and post-cruise SBE laboratory calibrations. Temperature and conductivity responses essentially showed the same picture, so each sensor was fit to conductivity response. Both C1 and C2 required a second-order correction.

After conductivity responses were corrected, the pressure-dependent correction for C1 required a minor adjustment to flatten out the deep end.

The residual differences after correction are shown in figures 1.8.3.4 through 1.8.3.12.

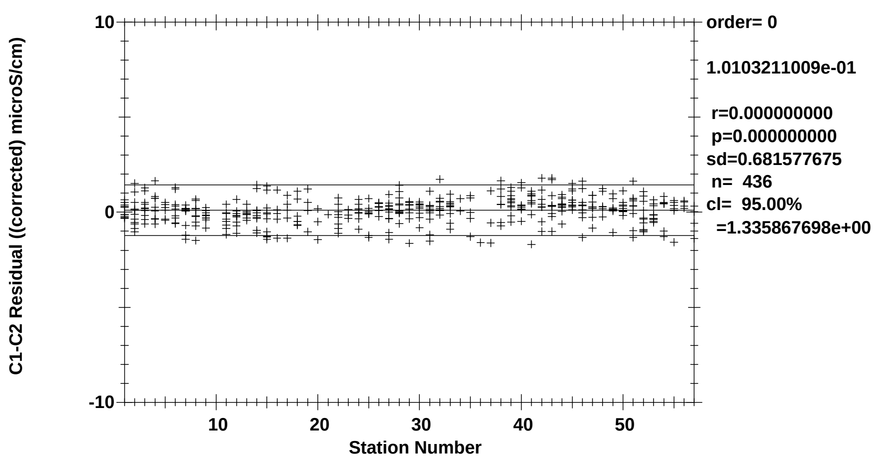


**Figure 1.8.3.4** Corrected $C1 - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

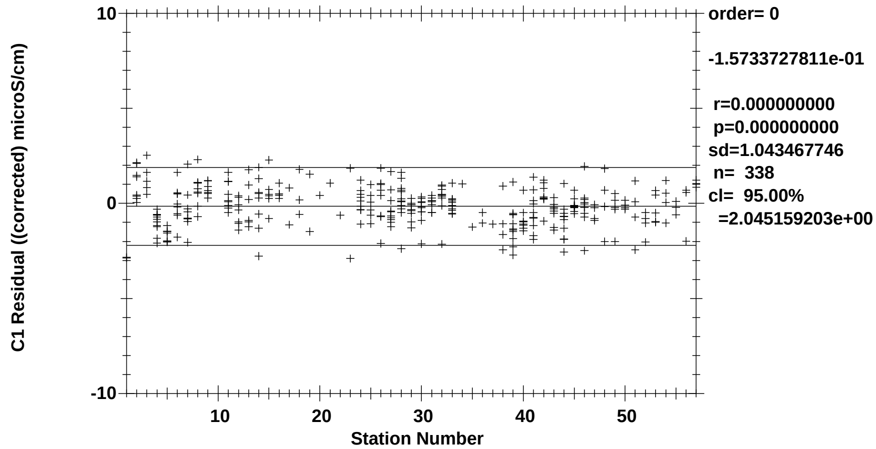


**Figure 1.8.3.5** Corrected $C_{Bottle} - C1$ by station (-0.01°C ≤T1-T2≤0.01°C).

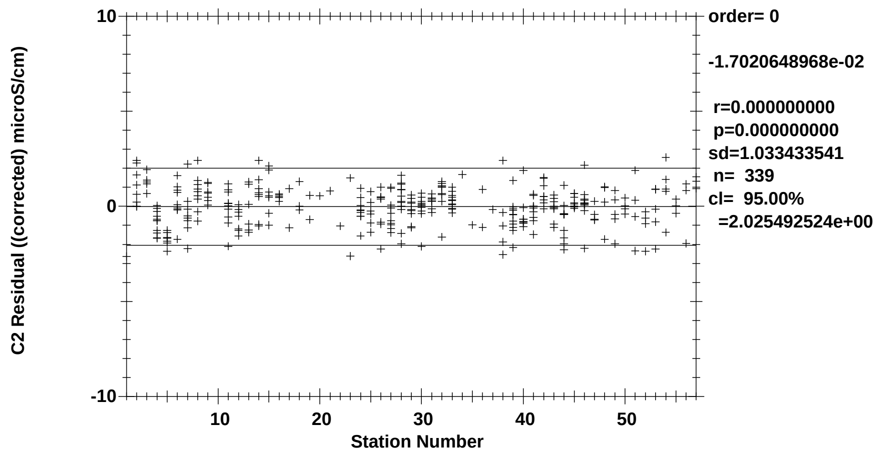


**Figure 1.8.3.6** Corrected $C_{Bottle} - C2$ by station (-0.01°C ≤T1-T2≤0.01°C).

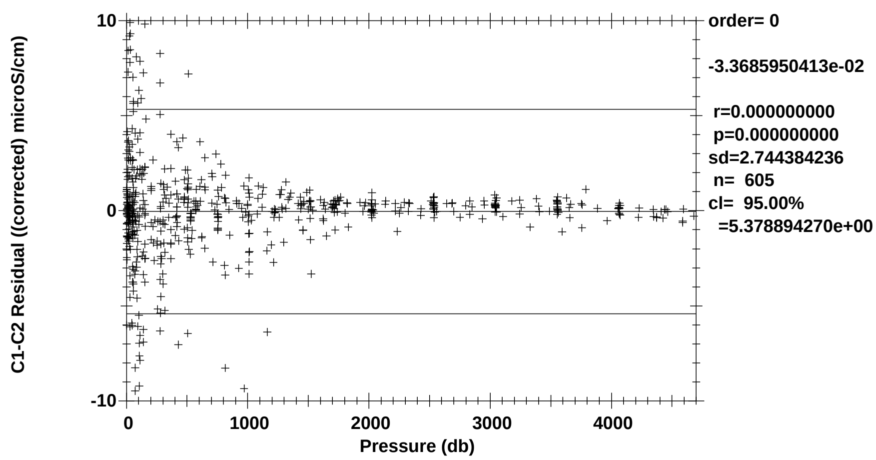


**Figure 1.8.3.7** Corrected $C1 - C2$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

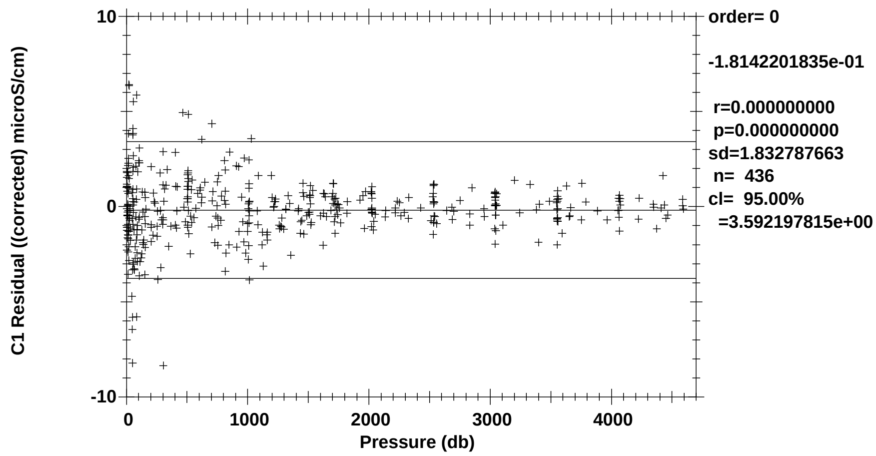


**Figure 1.8.3.8** Corrected $C_{Bottle} - C1$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

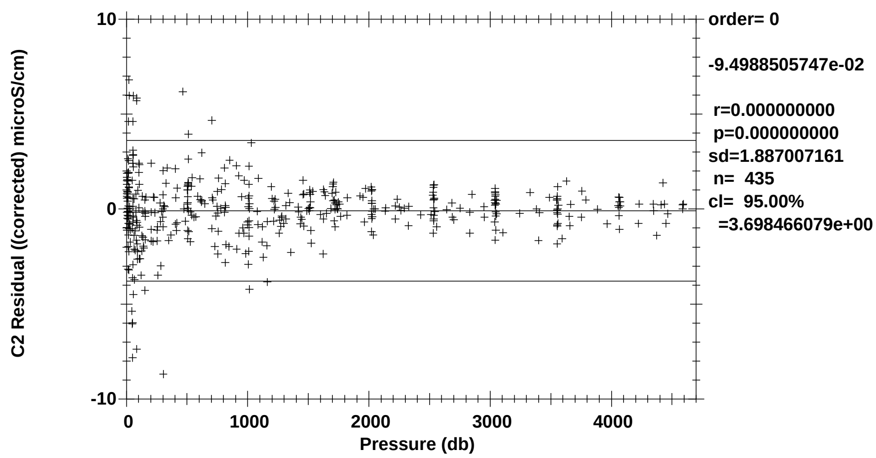


**Figure 1.8.3.9** Corrected $C_{Bottle} - C2$ by pressure (-0.01°C ≤T1-T2≤0.01°C).

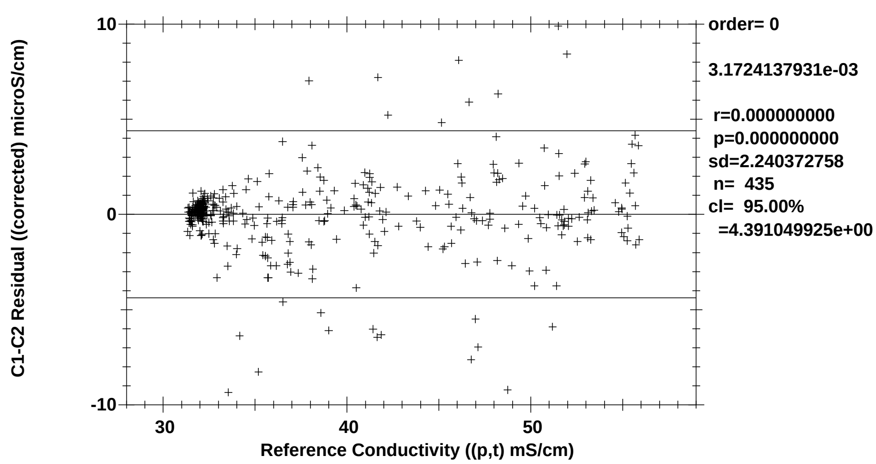


**Figure 1.8.3.10** Corrected $C1 - C2$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

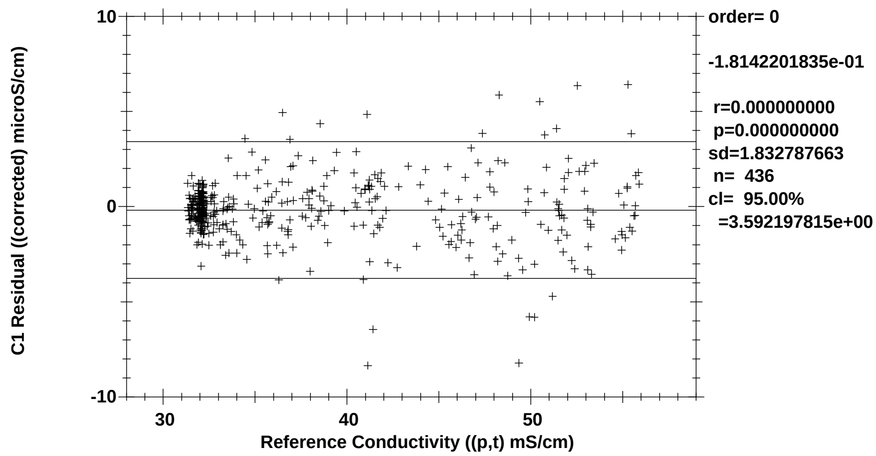


**Figure 1.8.3.11** Corrected $C_{Bottle} - C1$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

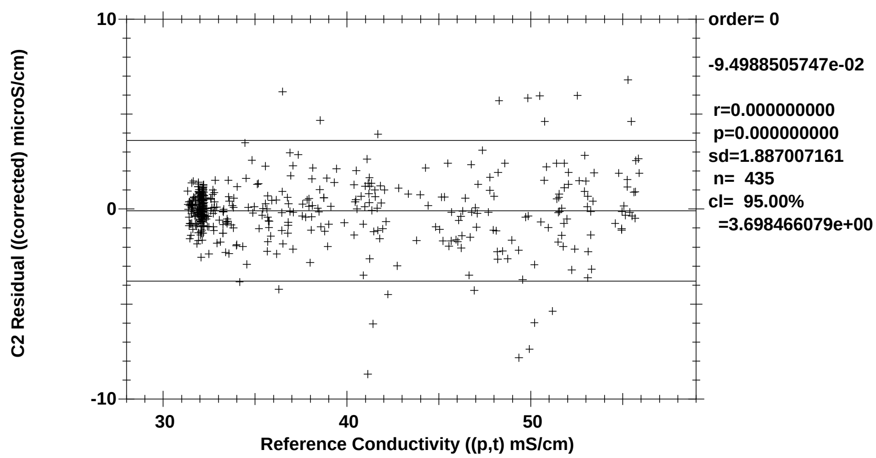


**Figure 1.8.3.12** Corrected $C_{Bottle} - C2$ by conductivity (-0.01°C ≤T1-T2≤0.01°C).

Corrections made to all conductivity sensors had the form:

$$C_{cor} = C + cp_2P^2 + cp_1P + cp_0C^2 + c_2C^2 + c_1 + c_0$$

Only CTD and bottle salinity data with "acceptable" quality codes are included in the differences.

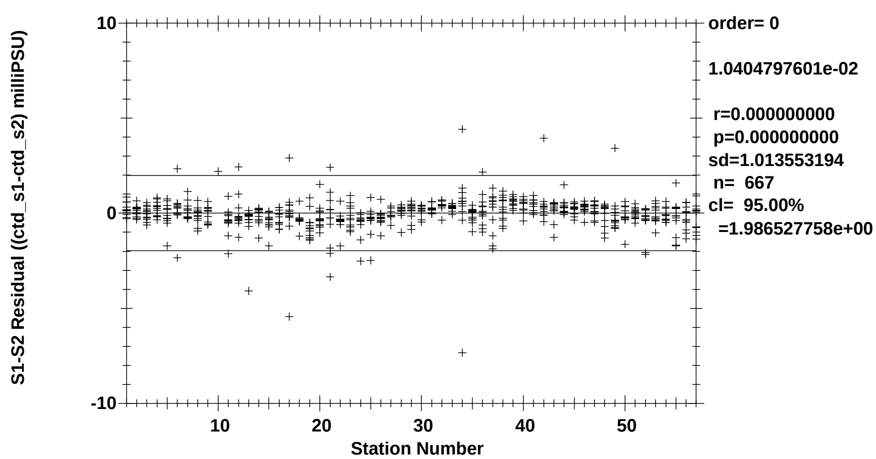


**Figure 1.8.3.13** Salinity residuals by station (-0.01°C ≤T1-T2≤0.01°C).

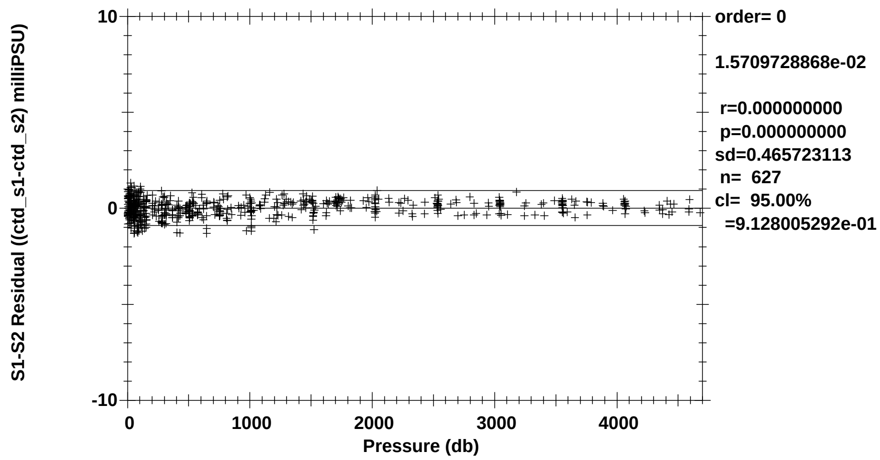


**Figure 1.8.3.14** Salinity residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

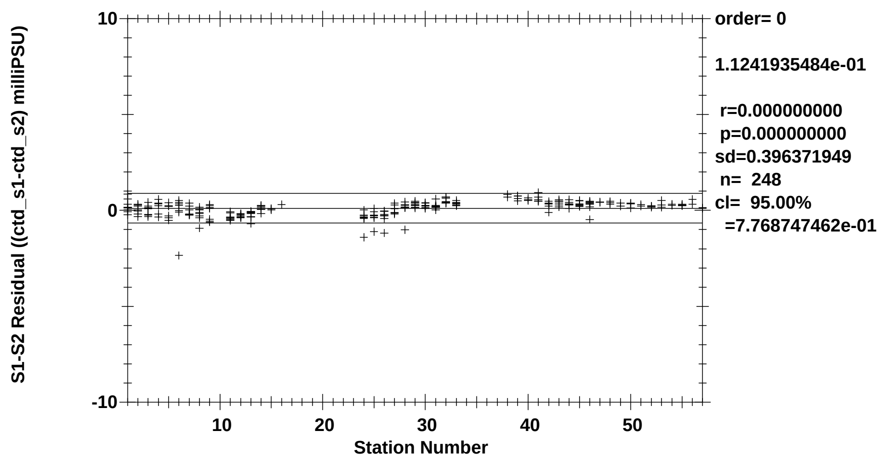


**Figure 1.8.3.15** Salinity residuals by station (Pressure>2000db)

Figures 1.8.3.14 and 1.8.3.15 represent estimates of the deep salinity accuracy of ACT0213. The 95% confidence limits are ±0.000777 PSU relative to deep bottle salinities, and ±0.000913 PSU relative to all bottle salinities where T1-T2 is within ±0.01°C.

### 1.8.4. CTD Dissolved Oxygen

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

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

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

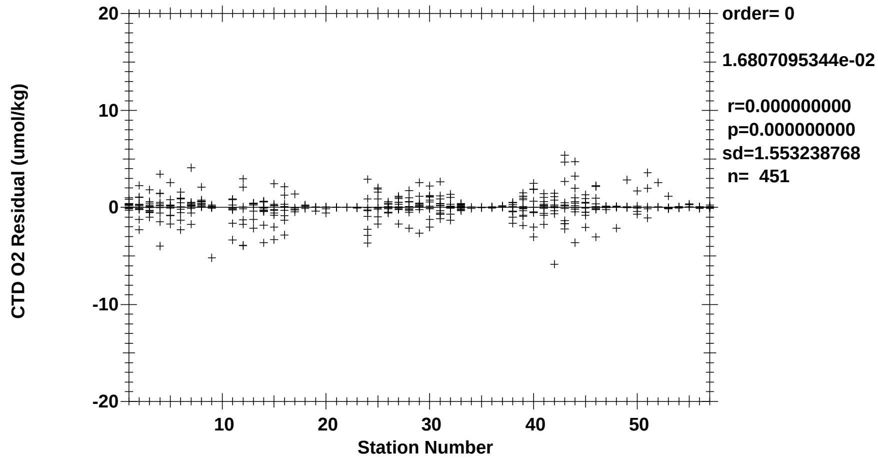


**Figure 1.8.4.0** $O_2$ residuals by station (-0.01°C ≤T1-T2≤0.01°C).

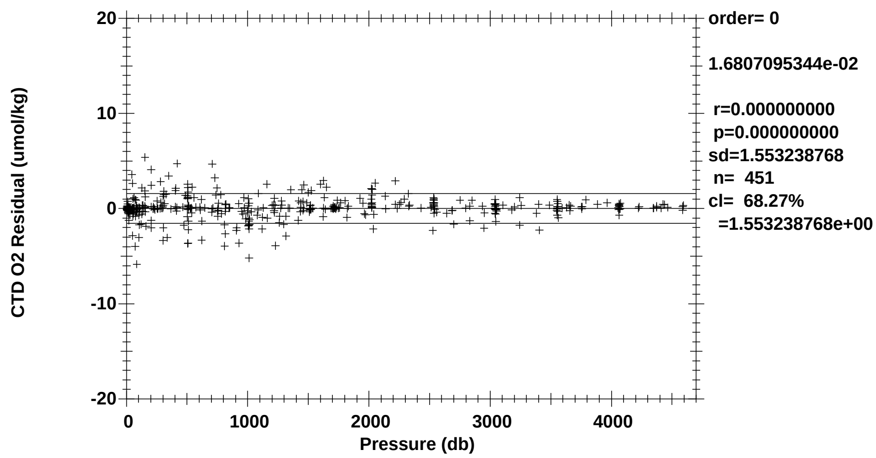


**Figure 1.8.4.1** $O_2$ residuals by pressure (-0.01°C ≤T1-T2≤0.01°C).

A standard deviation of 1.55 umol/kg for low gradient deep CTD oxygen residuals is an indication of consistent dependable dissolved oxygen data.

The general form of the ODF DO sensor response model equation for Clark cells follows Brown and Morrison [Brow78], and Millard [Mill82], [Owen85]. ODF models DO sensor secondary responses with lagged CTD data. *In-situ* pressure and temperature are filtered to match the sensor responses. Time constants for the pressure response $\tau_p$, 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 ($T_l$) temperatures. This term is intended to correct non-linearities in sensor response introduced by inappropriate analog thermal compensation. Package velocity is approximated by low-pass filtering 1st-order pressure differences, and is intended to correct flow-dependent response. Dissolved $O_2$ concentration is then calculated:

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

where:

| | |
|---|---|
| $O_2 ml/l$ | Dissolved $O_2$ concentration in ml/l |
| $V_{DO}$ | Raw sensor output |
| $C_1$ | Sensor slope |
| $C_2$ | Hysteresis response coefficient |
| $C_3$ | Sensor offset |
| $f_{sat}(T, P)$ | $O_2$ saturation at T,P (ml/l) |
| $T$ | *insitu* temperature (°C) |
| $P$ | *insitu* pressure (decibars) |
| $P_h$ | Low-pass filtered hysteresis pressure (decibars) |
| $T_l$ | Long-response low-pass filtered temperature (°C) |
| $T_s$ | Short-response low-pass filtered temperature (°C) |
| $P_l$ | Low-pass filtered pressure (decibars) |
| $\frac{dO_c}{dt}$ | Sensor current gradient ($\mu$amps/sec) |
| $\frac{dP}{dt}$ | Filtered package velocity (db/sec) |
| $dT$ | low-pass filtered thermal diffusion estimate ($T_s$ - $T_l$) |
| $C_4 - C_8$ | Response coefficients |

### 1.9. Bottle Sampling

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

- $O_2$
- Salinity

The correspondence between individual sample containers and the rosette bottle position (1-12) from which the sample was drawn was recorded on the sample log for the cast. This log also included any comments or anomalous conditions noted about the rosette and bottles. One member of the sampling team was designated the *sample cop*, whose sole responsibility was to maintain this log and ensure that sampling progressed in the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log. Drawing oxygen samples also involved taking the sample draw temperature from the bottle. The temperature was noted on the sample log and was sometimes useful in determining leaking or mis-tripped bottles.

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

### 1.10. Bottle Data Processing

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

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

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

Table 1.10.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property:

| Rosette Samples Stations - 57 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Reported | WHP Quality Codes | | | | | | |
| | levels | 1 | 2 | 3 | 4 | 5 | 7 | 9 |
| Bottle | 683 | 0 | 523 | 0 | 0 | 0 | 0 | 159 |
| CTD Salt | 683 | 0 | 679 | 3 | 0 | 0 | 0 | 0 |
| CTD Oxy | 522 | 0 | 489 | 27 | 5 | 2 | 0 | 159 |
| Salinity | 522 | 0 | 489 | 27 | 5 | 2 | 0 | 159 |
| Oxygen | 683 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1.10.0** Frequency of WHP quality flag assignments.

Various consistency checks and detailed examination of the data continued throughout the cruise.