KESS 2004 Leg 1

Kuroshio Extension System Study

R/V Thomas G. Thompson, TN168

25 April 2004 - 1 June 2004

Yokohama, Japan - Yokohama, Japan

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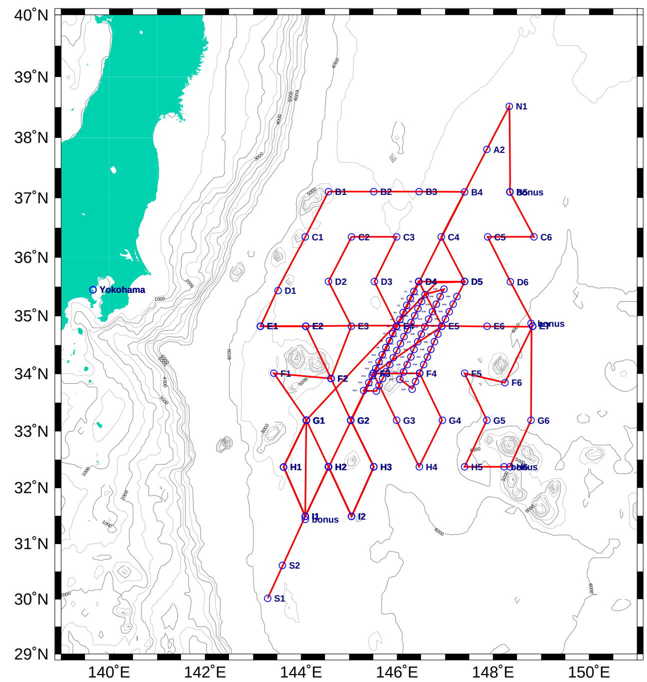

KESS 2004 Leg 1 Cruise Track

Preliminary Cruise Report

mod. 30 May 2004

Data Submitted by:

Oceanographic Data Facility

Scripps Institution of Oceanography

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Summary

A mooring deployment and hydrographic survey consisting of CPIES mooring deployments, CTD/ADCP sections and float launches was carried out in the western North Pacific April to June 2004. The R/V Thompson departed Yokohama, Japan on 25 April 2004. A total of 52 CPIES moorings were deployed, 123 CTD stations were occupied, and 4 profiling ARGO floats were launched from 25 April - 31 May. Water samples (up to 24) and CTD data were collected from CTD casts to within 100 meters of the bottom on 44 casts, and to 1200-4000 meters on the rest. Salinity was measured from every water sample taken during CTD casts. The cruise ended in Yokohama, Japan. on 1 June 2003.

Personnel

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1. Description of CTD Measurement Techniques

The basic CTD/hydrographic measurements consisted of salinity measurements made from water samples taken on CTD casts, plus pressure, temperature and salinity from CTD profiles. A total of 125 CTD casts were made, 44 of these to within 100 meters of the bottom. No major problems were encountered during the operation.

1.1. Water Sampling Package

CTD casts were performed with a package consisting of a 24-bottle rosette frame (ODF), a 24-place pylon (SBE32) and 24 2-liter bottles (ODF). Underwater electronic components consisted of a Sea-Bird Electronics (SBE) 9*plus* CTD (ODF #675) with dual pumps, dual temperature (SBE3), dual conductivity (SBE4) an SBE35RT Digital Reversing Thermometer, and a Simrad 807 altimeter.

The CTD was mounted in the SBE CTD cage with all sensors mounted vertically as recommended by SBE. Pump exhausts were attached to outside corners of the cage and directed downward. The entire cage assembly was then mounted on the bottom ring of the rosette frame, offset from center to accommodate the pylon, and also secured to frame struts at the top. The SBE35RT temperature sensor was mounted vertically and equidistant between the T1 and T2 intakes. The altimeter was mounted on the inside of a support strut adjacent to the bottom frame ring.

The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable. The R/V Thompson’s aft starboard-side CTD winch was used on all casts except 1/2-1/3 (all aborted), where the forward starboard-side winch was used. A grounding problem existed on the first 3 casts and was finally eliminated by routing the rosette return through one of the seacable conductors instead of the cable armor (as is normal practice). A single seacable termination was used for the rest of the cruise (2/1-124/1).

The deck watch prepared the rosette 5 minutes prior to each cast. All valves, vents and lanyards were checked for proper orientation. The bottles were cocked and all hardware and connections rechecked. Once stopped on station, the rosette was moved into position under the starboard boom. As directed by the deck watch leader, the CTD was powered up and the data acquisition system started. The syringes were removed from the CTD sensor intake ports. The deck watch leader directed the winch operator to raise the package, the boom and rosette were extended outboard and the package quickly lowered into the water. The package was lowered to 20 meters. The CTD console operator then directed the winch operator to bring the package close to the surface and begin the descent.

Each Bottle on the rosette had a unique serial number. This bottle identification was maintained independently of the bottle position on the rosette, which was used for sample identification. No bottles were changed or replaced on this leg, although parts of a few of them were replaced or repaired.

Recovering the package at the end of the deployment was essentially the reverse of launching. The rosette was typically sampled on deck but was moved into the CTD hangar for sampling when weather conditions required it. The bottles and rosette were examined before samples were taken, and anything unusual noted on the sample log.

Routine CTD maintenance included soaking the conductivity sensors in tap water between casts to maintain sensor stability. Rosette maintenance was performed on a regular basis. O-rings were changed as necessary and bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced as needed.

1.2. Underwater Electronics Packages

CTD data were collected with a SBE9*plus* CTD (ODF #675). This instrument provided pressure, dual temperature (SBE3), dual conductivity (SBE4) and altimeter (Simrad 807) channels. CTD #675 supplied a standard Sea-Bird format data stream at a data rate of 24 frames/second (fps).

Sea-Bird SBE32 24-place Carousel Water Sampler	S/N 0164
Sea-Bird SBE35RT Digital Reversing Thermometer	S/N 0034
Sea-Bird SBE9*plus* CTD	S/N 09P9852-0675
Paroscientific Digiquartz Pressure Sensor	S/N 88907
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-4209 (Primary)
Sea-Bird SBE3*plus* Temperature Sensor	S/N 03P-4196 (Secondary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2112 (Primary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2763 (Secondary 1/1-2/1)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2409 (Secondary 3/1-124/1)
Simrad 807 Altimeter	S/N 4051

Table 1.2.0 KESS Leg 1 Rosette Underwater Electronics.

The CTD was outfitted with dual pumps. Primary temperature and conductivity were plumbed on one pump circuit and secondary temperature and conductivity on the other. The sensors were deployed vertically. The primary temperature and conductivity sensors (T1 #4209 and C1 #2112) were used for reported CTD temperatures and conductivities on all casts. The secondary temperature and conductivity sensors (T2 #4196 and C2 #2763 casts 1/1-2/1 and #2409 casts 3/1-124/1) were used for calibration checks.

The SBE9 CTD and the SBE35RT Digital Reversing Thermometer were both connected to the SBE32 24-place pylon providing for single-conductor sea cable operation. Two of the three sea cable conductors were connected together for signal and power, the other conductor was used for the return. Power to the SBE9 CTD, SBE32 pylon, SBE35RT and Simrad altimeter was provided through the sea cable from the SBE11*plus* deck unit in the main lab.

1.3. Navigation and Bathymetry Data Acquisition

Navigation data were acquired (at 1-second intervals) from the ship’s Seanav GPS receiver by one of the Linux workstations beginning April 24. Data from the ship’s Knudsen 320B/R Echosounder (3.8 KHz transducer) were also acquired and merged with the navigation. The Knudsen bathymetry data were noisy and subject to washing out on station when the bow thrusters were engaged.

Bathymetric data from the ship’s multibeam (HydroSweep) echosounder system were also logged by the R/V Thompson’s underway system.

1.4. Real-Time CTD Data Acquisition System

The CTD data acquisition system consisted of an SBE-11*plus* deck unit and three networked generic PC workstations running Fedora 1 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball, 120 GB disk, and DVD+RW drives. Two of the three systems also had 8 additional RS-232 ports via a Rocketport PCI serial controller. The systems were networked through a 100BaseTX ethernet switch which was also connected to the ship’s network. These systems were available for real-time operational and CTD data displays, as well as providing for CTD and hydrographic data management and backup. Hardcopy capability was provided by the ship’s networked printers.

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 for controlling CTD deployments as well as real-time operational displays for CTD and rosette trip data, GPS navigation, bathymetry and the CTD winch.

CTD deployments were initiated by the console watch once the ship was stopped on station. A console operations log was maintained by the watch containing a description of each deployment, a record of every attempt to close a bottle and any pertinent comments. The deployment software presented the operator with a short dialog instructing them to turn on the deck unit, examine the on screen raw data display for stable CTD data and to notify the deck watch that this was accomplished. When the deck watch was ready to put the rosette over the side, the console watch was notified and the CTD data acquisition started. Time, GPS position and bottom depth were automatically logged at 1 second resolution. Both raw and processed (2 Hz time-series) CTD data were automatically backed up by one of the other workstations via ethernet. The deployment software display changed to indicate that a cast was in progress. A processed data display appeared, as did a rosette bottle trip display and control for closing bottles. Various real-time plots were then initiated to display the progress of the deployment.

Once the deck watch had deployed the rosette, the winch operator would immediately lower it to 20 meters. The CTD pumps were configured with a 3 second startup delay, and would be on by this time. The console operator would check the CTD data for proper operation, then instruct the winch operator to bring the package to the surface and then descend to a target depth (wire-out). The lowering rate was normally 70 meters/minute for this package, depending on sea cable tension and sea state.

The console watch monitored the progress of the deployment and quality of the CTD data through interactive graphics and operational displays. Additionally, the watch decided where to trip bottles on the up cast, noting this on the console log. The altimeter channel, CTD depth, wire-out and bathymetric depth were monitored to determine the distance of the package from the bottom. The on-screen winch and altimeter displays allowed the watch to refine the target wire-out relayed to the winch operator and safely approach to within 20-30 meters of the bottom.

Bottles were closed on the up cast by operating a "point and click" graphical trip control button. The data acquisition system responded with trip confirmation messages and the corresponding CTD data in a rosette bottle trip window on the display. All tripping attempts were noted on the console log. The console watch then directed the winch operator to raise the package up to the next bottle trip location. The console watch was also responsible for creating a sample log for the deployment which was used to record the correspondence between rosette bottles and analytical samples taken.

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

1.5. CTD Data Processing

ODF CTD processing software consists of over 30 programs running in a Linux/Unix run-time environment. The initial CTD processing program (ctdrtd/ctdba) is used either in real-time or with existing raw CTD data to:

- Convert raw CTD scans into scaled engineering units, and assign the data to logical channels
- Filter various channels according to specified criteria
- Apply sensor- or instrument-specific response-correction models
- Decimate the channels according to specified criteria
- Store the output time-series in a CTD-independent format

Once the CTD data are reduced to a standard format time-series, they can be manipulated in various ways. Channels can be additionally filtered. The time-series can be split up into shorter time-series or pasted together to form longer time-series. A time-series can be transformed into a pressure-series, or into a larger-interval time-series. The pressure, temperature and conductivity laboratory calibration coefficients are applied during the creation of the initial time-series. Adjustments to pressure, temperature and conductivity are maintained in separate files and are applied whenever the data are accessed.

The CTD data acquisition software acquired and processed the data in real-time, providing calibrated, processed data for interactive plotting and reporting during a cast. The 24 Hz data from the CTD were filtered, response-corrected and decimated to a 2.0 Hz time-series. Sensor correction and calibration models were applied to pressure, temperature, and conductivity. Rosette trip data were extracted from this time-series in response to trip initiation and confirmation signals. The calibrated 2.0 Hz time-series data, as well as the 24 Hz raw data, were stored on disk and were backed up via ethernet to a second system. At the end of the cast, various consistency and calibration checks were performed, and a 2-db pressure-series of the down cast was generated and subsequently used for reports and plots.

CTD data were examined graphically at the completion of deployment for potential problems. The two CTD temperature sensors were compared, intercompared with the SBE35RT Digital Reversing Thermometer and checked for sensor drift. CTD conductivity sensors were compared and monitored by examining differences between CTD values and check-sample conductivities. Additionally, deep theta-salinity comparisons were made between down and up casts as well as adjacent deployments.

Minor sea cable noise problems on this cruise did not significantly affect the CTD data, being filtered out during the data acquisition. No additional filtering was done on any of the CTD data.

The initial 20 M yo in each deployment resulting from lowering then raising the package to the surface to start the pumps was removed during the generation of the 2.0 db pressure-series.

Density inversions can be induced in high-gradient regions by ship-generated vertical motion of the rosette. Detailed examination of the raw data shows significant mixing can occur in these areas because of "ship roll". To minimize density inversions, a "ship-roll" filter which disallowed pressure reversals was applied during the generation of the 2.0 db pressure-series down-cast data.

1.6. CTD Laboratory Calibration Procedures

Laboratory calibrations of the CTD pressure, temperature and conductivity sensors were used to generate Sea-Bird conversion equation coefficients applied by the data acquisition software at sea.

Pressure calibrations were last performed on CTD #675 at the ODF Calibration Facility (La Jolla) 19 March 2004, immediately prior to KESS 2004 Leg 1.

The Paroscientific Digiquartz pressure transducer (S/N 88907) was calibrated in a temperature-controlled water bath to a Ruska Model 2400 Piston Gauge Pressure Reference.

The SBE3*plus* temperature sensors (primary S/N 03-4209, secondary S/N 03-4196) were calibrated at ODF on 18 March 2004.

The SBE4 conductivity sensors (primary S/Ns 04-2112 and 04-1824, secondary S/Ns 04-2763 and 04-2904) were calibrated on 30 March 2004, 06 November 2003, 31 March 2004 and 01 August 2003 at SBE respectively.

The SBE35RT Digital Reversing Thermometer (S/N 0034) was calibrated on 15 March 2004 at SBE.

1.7. CTD Shipboard Calibration Procedures

CTD #675 was used for all KESS 2004 Leg 1 casts. The CTD was deployed with all sensors and pumps aligned vertically, as recommended by SBE. Secondary temperature and conductivity (T2 & C2) sensors served as calibration checks for the reported primary temperature and conductivity (T1 & C1), except for casts 122/1-123/1 where the secondary sensor data are reported (due to C1 sensor replacement). The SBE35RT Digital Reversing Thermometer served as an independent temperature calibration check. *In-situ* salinity and dissolved O_2 check samples collected during each CTD cast were used to calibrate the conductivity sensors.

1.7.1. CTD Pressure

Pressure sensor conversion equation coefficients derived from the pre-cruise pressure calibration were applied to raw pressure data during each cast. No additional adjustments were made to the calculated pressures.

Residual pressure offsets (the difference between the first and last submerged pressures) were tabulated to check for calibration shifts. All were < 0.5db.

There was no apparent shift in pressure calibration during the cruise. This will be verified by a post-cruise laboratory pressure calibration.

1.7.2. CTD Temperature

Temperature sensor conversion equation coefficients were derived from the pre-cruise calibrations and applied to raw primary and secondary temperature data.

Two independent metrics of calibration accuracy were examined. The primary and secondary temperatures were compared at each rosette trip, and the SBE35RT temperatures were compared to primary and secondary temperatures at each rosette trip. These comparisons are summarized in figures 1.7.2.0 and 1.7.2.1.

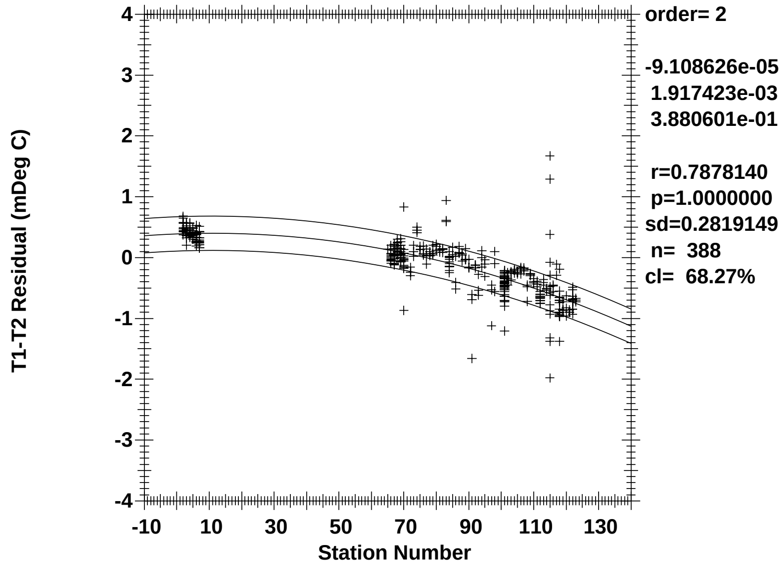

Figure 1.7.2.0 Primary and secondary temperature differences by cast, p>2000db, before correction.

The comparison between primary and secondary temperatures shows a relative drift of 0.0012°C over the measurement period. Comparisons with the SBE35RT temperature sensor (figure 1.7.2.1) attribute all of the drift to T1. After correcting for this drift, the RMS error is ±0.000177°C. The mean of the SBE35RT residuals is not zero, indicating either post-calibration sensor changes or a difference between calibration laboratories.

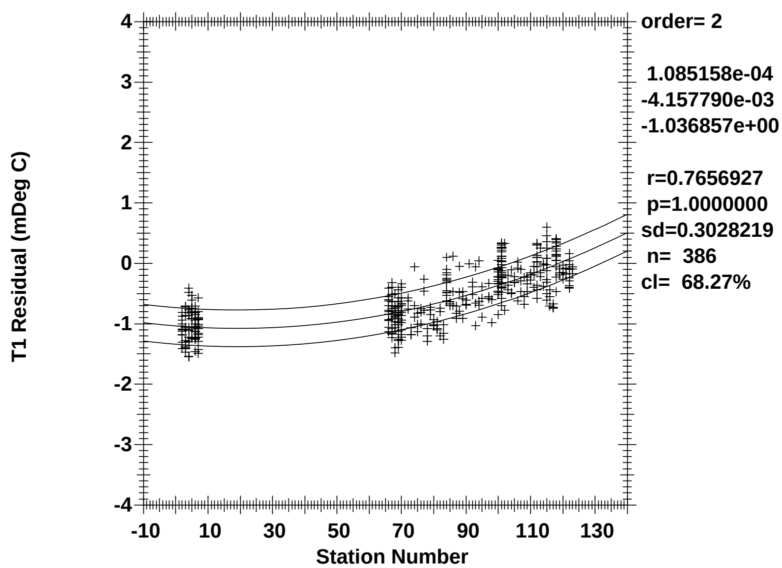

Figure 1.7.2.1 T1 and SBE35RT temperature differences by cast, p>2000db.

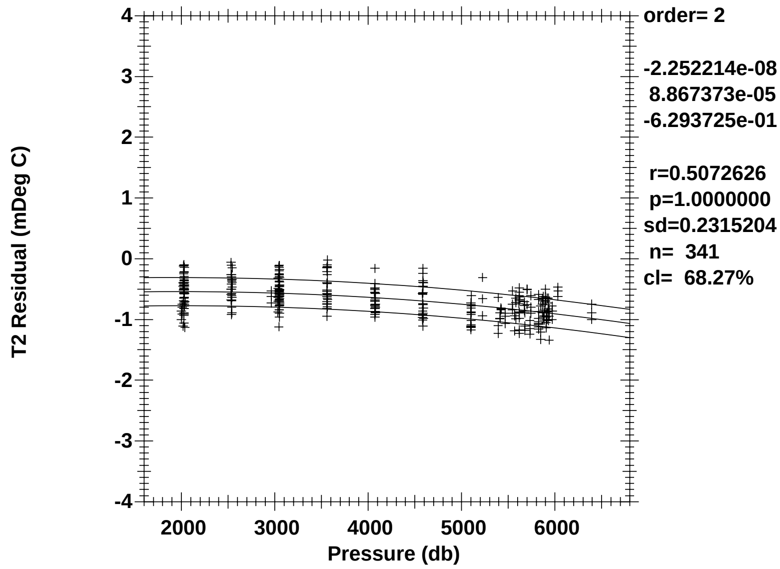

Figure 1.7.2.2 T1 and SBE35RT temperature differences by cast, p>2000db.

Further inspection of SBE35RT temperature differences reveals a small but significant pressure effect (figure 1.7.2.2). Correcting for this effect would improve (but not eliminate) the apparent calibration error between the SBE35RT, T1 and T2, however the source of this effect is not evident and so no correction has been made. Moreover the magnitude of the error residual is within the reported temperature calibration accuracy (±0.0005°C) for the calibration laboratories. Figure 1.7.2.3 shows T1-T2 residual differences after correction for drift.

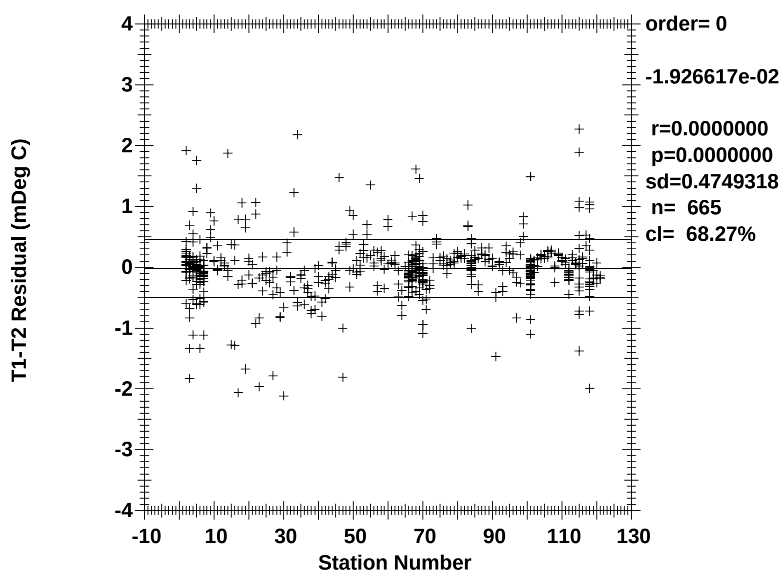

Figure 1.7.2.3 Primary and secondary temperature differences by cast, all temperatures, after correction.

1.7.3. CTD Conductivity

Conductivity sensor conversion equation coefficients were derived from the pre-cruise calibrations and applied to raw primary and secondary conductivities.

Two primary and two secondary conductivity sensors were used on KESS Leg 1: C1 S/N 2112 was used on 2/1-121/1, and was used for reported conductivity on these casts. C1 S/N 1824 was used on 122/1-123/1. C2 S/N 2763 was used on 2/1. C2 S/N 2904 was used on 3/1-123/1, and was used for reported conductivity on 122/1-123/1.

Comparisons between the primary and secondary sensors and between sensors and checksample conductivities were used to derive sensor corrections. The comparison of the primary and secondary conductivity sensors by station is summarized in figure 1.7.3.0.

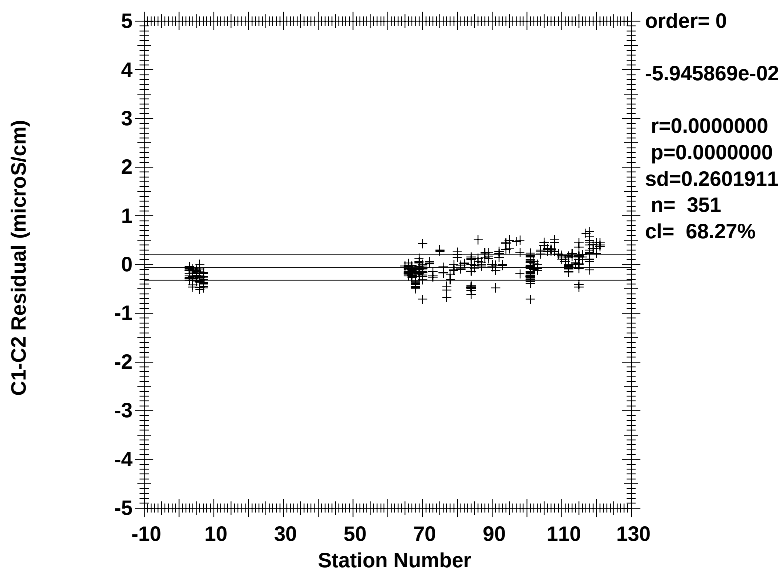

Figure 1.7.3.0 C1 and C2 conductivity differences by cast, p>2000db.

The salinity residuals after applying the shipboard calibration are summarized in figures 1.7.3.1 and 1.7.3.2.

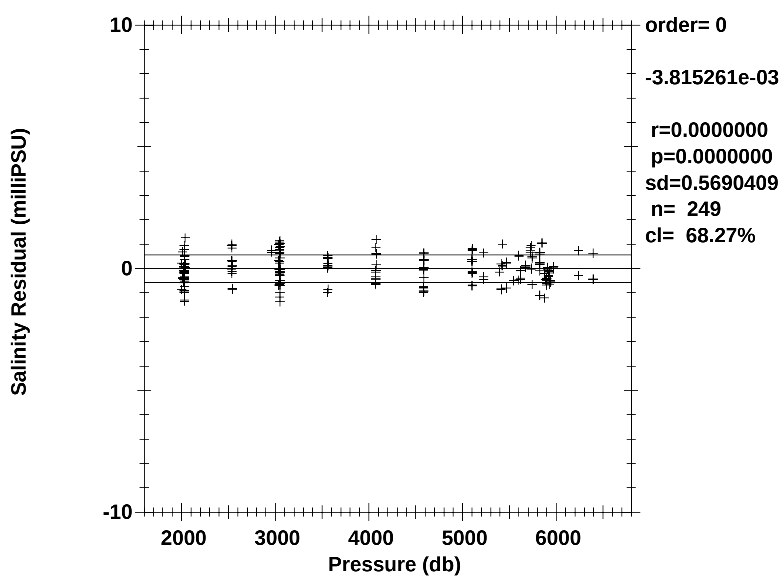

Figure 1.7.3.1 salinity residuals by pressure, p>2000db.

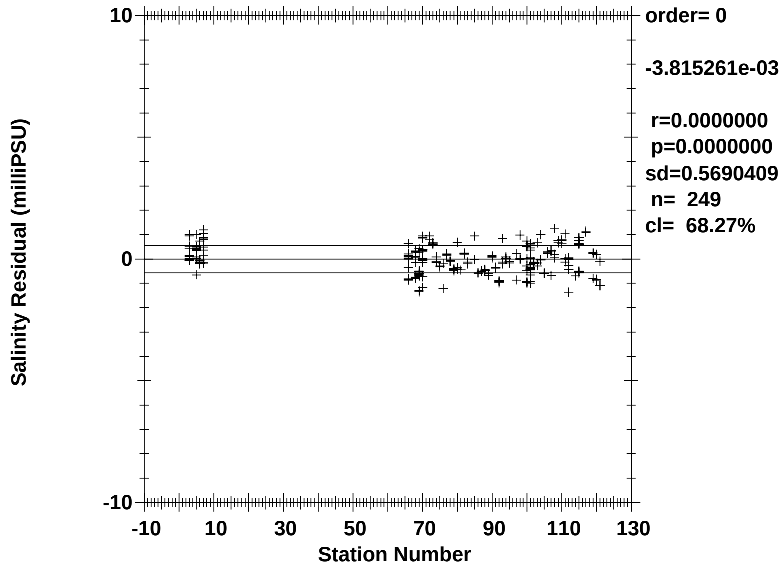

Figure 1.7.3.2 salinity residuals by cast, p>2000db.

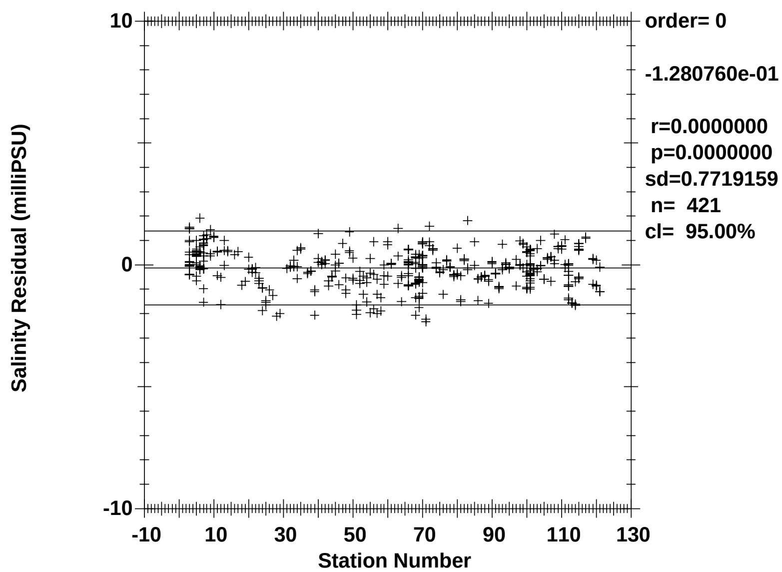

Figure 1.7.3.3 salinity residuals by cast.

Excluding thermocline and gradient values (early and late stations were shallow and also excluded), figure 1.7.3.3 represents an estimate of the salinity accuracy of CTD #675. The 95% confidence limit is ±0.0015 PSU, in agreement with the generally accepted limit of repeatability for bottle salinities (±0.002PSU).

1.8. Salinity Analysis

Equipment and Techniques

A single Guildline Autosal Model 8400A salinometer (S/N 57-396) located in the forward analytical lab was used for all salinity measurements. The salinometer was modified by ODF to contain an interface for computer-aided measurement. The water bath temperature was set and maintained at a value near the laboratory air temperature. It was set to 24°C for the entire leg.

The salinity analyses were performed after samples had equilibrated to laboratory temperature, usually within 10-12 hours after collection. The salinometer was standardized for each group of analyses (1-8 casts, up to ~24 samples) using at least one fresh vial of standard seawater per group. A computer (PC) prompted the analyst for control functions such as changing sample, flushing, or switching to "read" mode. The salinometer cell was flushed and results were logged by the computer until two successive measurements met software criteria for consistency. These values were then averaged for a final result.

Sampling and Data Processing

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to collecting each sample, inserts were inspected for proper fit and loose inserts were replaced to insure an airtight seal. The draw time and equilibration time 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 (if any) between the initial vial of standard water and one run at the end as an unknown was applied linearly to the data to account for any drift. The data were incorporated into the cruise database. 753 salinity measurements were made and approximately 60 vials of standard water were used. Temperature control was somewhat problematic and several runs were rendered unusable for calibration purposes because of a lack of temperature stability. The estimated accuracy of bottle salinities run at sea is usually better than ±0.002 PSU relative to the particular standard seawater batch used.

Laboratory Temperature

The temperature in the salinometer laboratory varied from 20.9 to 27.1°C, during the cruise. The air temperature change during any single run of samples was less than ±3.0°C.

Standards

IAPSO Standard Seawater (SSW) Batch P-144 was used to standardize all salinity measurements.

References

UNES81.

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