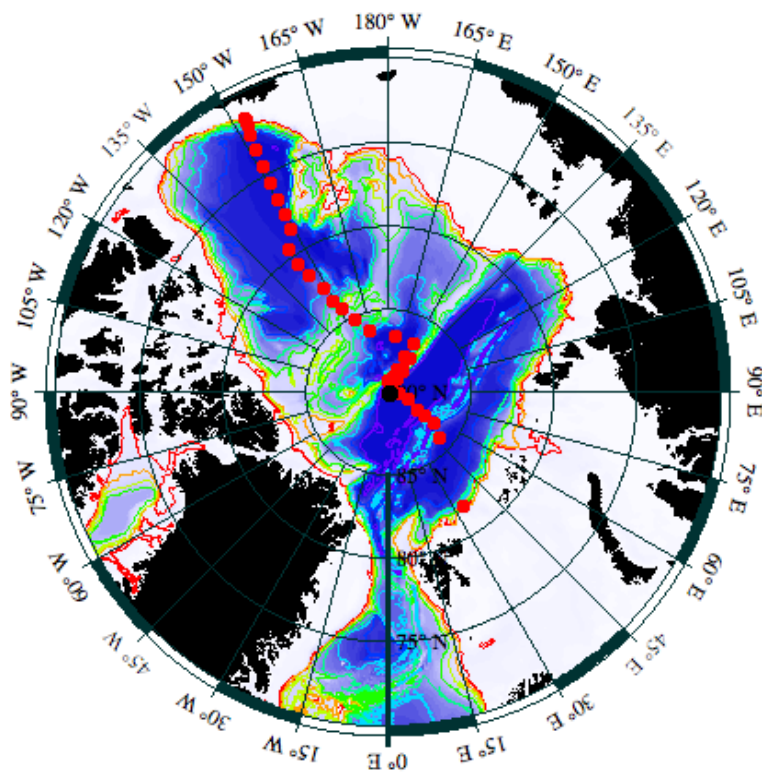


CRUISE REPORT: ODEN05

(Updated FEB 2010)



A. HIGHLIGHTS

CRUISE SUMMARY INFORMATION

Section designation	ODEN05
Expedition designation (ExpoCodes)	77DN20050819
Chief Scientists	Anders Karlqvist/SPRS
Dates	2005 AUG 20 – 2005 SEP 25
Ship	<i>R/V ODEN</i>
Ports of call	Barrow, Alaska to Longyearbyen, Spitsbergen
Stations	48
Geographic boundaries	89° 59.2 N 173° 51.67 W 174° 13.32 E 71° 23.08 N
Floats and drifters deployed	0
Moorings deployed or recovered	0

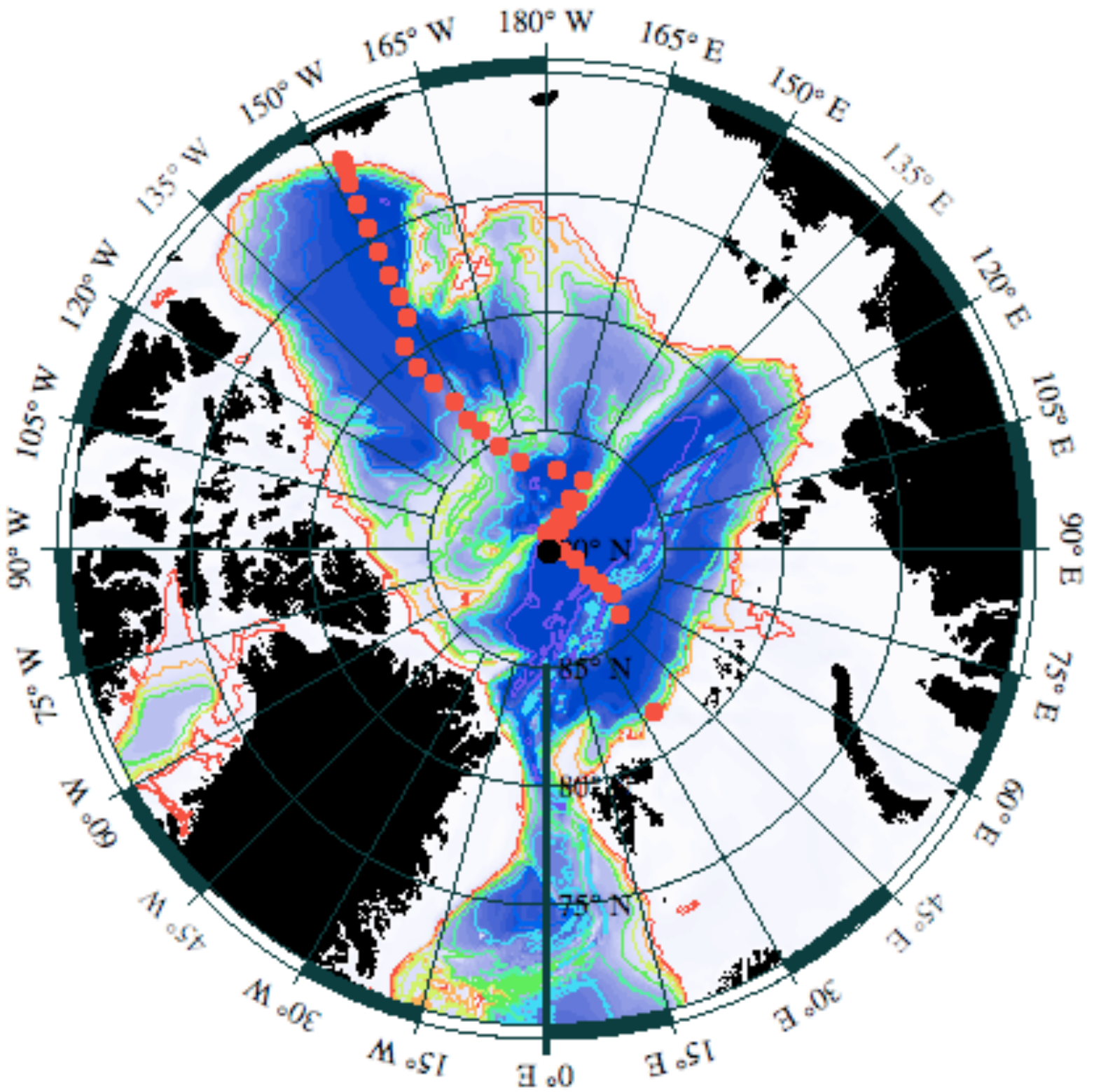
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LINKS TO TEXT LOCATIONS

Shaded sections are not relevant to this cruise or were not available when this report was compiled

Cruise Summary Information	Hydrographic Measurements
Description of Scientific Program	CTD Data:
Geographic Boundaries	Acquisition
Cruise Track (Figure): PI CCHDO	Processing
Description of Stations	Calibration
Description of Parameters Sampled	Temperature Pressure
Bottle Depth Distributions (Figure)	Salinities Oxygens
Floats and Drifters Deployed	Bottle Data
Moorings Deployed or Recovered	Salinity
	Oxygen
Principal Investigators	Nutrients
Cruise Participants	Carbon System Parameters
	CFCs
Problems and Goals Not Achieved	Helium / Tritium
Other Incidents of Note	Radiocarbon
Underway Data Information	References
Navigation Bathymetry	Nutrients
Acoustic Doppler Current Profiler (ADCP)	CFCs
Thermosalinograph	Carbon System Parameters
XBT and/or XCTD	
Meteorological Observations	Acknowledgments
Atmospheric Chemistry Data	
Data Processing Notes	

Station Locations • ODEN05 • 2005 • Karlqvist • R/V Oden



Summary

A hydrographic survey of the Arctic Ocean was carried out from the Swedish IceBreaker Oden between Barrow, Alaska and Longyearbyen, Spitsbergen. The expedition departed Barrow on 19 August 2005, then completed a transect of the Canada Basin. The Oden joined forces with the USCGC Healy near the end of that transect, then surveyed the Lomonosov Ridge area. The ships reached the North Pole on September 12, then continued across the Amundsen Basin to the Gakkel Ridge and the Nansen Basin. The cruise ended in Longyearbyen on 25 September 2005.

xx full-depth CTD/rosette/LADCP casts and xx shallow rosette casts were completed during the cruise. xx microstructure casts were also done, and multiple ice stations for ancillary programs were occupied during the expedition.

Salinity, dissolved oxygen, and nutrients were analyzed for up to 36 water samples from each cast of the principal CTD/rosette program. Other parameters sampled and analyzed on-board included chloro-fluorocarbons, halocarbons, dissolved inorganic carbon, total alkalinity, pH, sulfur hexafluoride and mercury. Other samples were collected for later analysis for Helium/tritium/radiocarbons, several other radiochemicals, dissolved organic matter and several biology programs.

Introduction

A sea-going science team from multiple oceanographic institutions in Europe, Canada and the United States participated in this expedition. Several other science programs were supported with no dedicated cruise participant. The major programs, plus the on-board science team and their responsibilities, are listed below.

Principal Programs

Analysis	Institution	Principal Investigator
CTDO/S/O ₂ /Nutrients	UCSD/SIO	James H. Swift
Halocarbons/Biology	Chalmers University	Katarina Abrahamsson
CFC	BIO	Peter Jones
³ He/ ³ H/ δ ¹⁸ O/ ¹⁴ C	LDEO	Peter Schlosser
Mercury	Göteborg University	O. Lindqvist
DIC/TALK/pH/SF ₆	Göteborg University	Leif Anderson
¹²⁹ I	Univ.Pierre et Marie Curie	Jean-Claude Gascard
DOM/Triple-O/Haardt Fluorometer	TAMU-Galveston	Rainer Amon
POP/Muir	NILU	Henrik Kylin
²²⁶ Ra	Univ.of Quebec Montreal	Sandrine Solignac
Animal Ecology	Lund University	Thomas Alerstam
Atmospheric & Bio Optics	Eotvos Univ. Budapest	Gabor Horvath
Bird Navigation	Lund University	Susanne Åkesson
Microstructure/LADCP/Floats	WHOI	Peter Winsor
XBTs	IfM-U.Hamburg/WHOI	Detlef Quadfasel/Peter Winsor

Principal Programs of AOS-2005

Personnel

Shipboard Duties	Name	Affiliation	email
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Artist	Beatrice Uusma Schyffert		bea.uusma.schyffert@telia.com

Narrative

The Healy – Oden Transarctic Expedition (HOTRAX)
The Baltic Sea Portal http://www.itameriportaali.fi/en_GB/
BERT RUDELS AND MAIJU LOIVULA, 5.6.2006

The 19th of August 2005, 2 days behind schedule, the Swedish icebreaker Oden anchored off Barrow, Alaska for exchange of crew and scientists before starting the third leg of the Beringa – 05 expedition. Oden had already in late June left Göteborg, crossed the North Atlantic and passed through the Northwest Passage into the Arctic Ocean. Now the fieldwork in the Beringia region was completed and the return voyage across the Arctic Ocean could start. The waiting scientists, mostly oceanographers but also ice researchers and biologists, had flown with a Swedish air force C-130 (Hercules) from Stockholm via Longyearbyen and Fairbanks to Barrow and were brought onto the ship by helicopter, one Alaskan helicopter and one brought from Sweden inside the Hercules. At 6 am on the 20th of August Oden weighed anchor and sailed towards the Canada Basin and the first oceanographic station.

The oceanography programme on Oden was a joint effort involving scientists from Sweden, Canada, Finland, France, Germany and the United States. Its overarching objective was to study the role of the Arctic Ocean in the global climate system. An important part of the programme was to determine the distribution, circulation and transformation of the different water masses in the Arctic Ocean – the Atlantic water advected into the Arctic Ocean via Fram Strait and the Barents Sea, the Pacific water entering through Bering Strait, as well as the waters formed within the Arctic Ocean: the polar mixed layer, the halocline and the different deep waters. One aim was to discover how much the waters formed in the Arctic Ocean contribute to the global thermohaline circulation. These studies require information about the distribution of salinity, temperature and other parameters in the water columns. Salinity and temperature are measured throughout the water column by continuously recording CTDs (conductivity-salinity-depth), while other parameters demand water sampling and analyses onboard and perhaps also in laboratories on land.

The initial plan was that Oden should take the first complete synoptic hydrographic section across the 4 major basins of the Arctic Ocean, the Canada Basin, the Makarov Basin, the Amundsen Basin and the Nansen Basin. At the Alpha-Mendeleyev Ridge between the Canada and Makarov basins a meeting was planned with the US coastguard cutter Healy, who was conducting mainly geological and geophysical studies of the sea floor. During the rest of the cruise the two ships were to work together, completing the HOTRAX transect, Oden assisting Healy when she was running seismic, and Healy's side-scan echo sounder helping to find the deepest passage across the Lomonosov Ridge, where Oden were to study the exchange of deep waters between the Makarov and Amundsen basins. Above all, the presence of a second icebreaker instilled a sense of security, should the ice conditions become extreme or should an engine breakdown occur.

The ice conditions during the cruise were hard and the progress was slow through most of the Canada Basin. After some initial problems with the winch the CTD stations and the water sampling could nevertheless proceed according to plan. The meeting with the US icebreaker Healy was, however, delayed and the two ships met at the Alpha – Mendeleyev Ridge on the 31st of August, two days later than expected. Here the ice conditions were somewhat easier and both seismic studies and coring from Healy and hydrography casts from Oden could be carried out as the two ships proceeded together.¹

Due to misunderstandings from the side of the manufacturer of XBTs (expendable bathythermographs) _ of the probes to be used to obtain a fine scale temperature section across the Arctic Ocean was not delivered in Barrow on time. The XBT programme was then changed to mainly cover the Canada Basin. After the rendezvous it was found possible to obtain additional XBTs from Healy, and a second XBT

section across the Nansen Basin and the boundary current entering through Fram Strait could be planned.

The ice conditions in the Makarov Basin worsened gradually and the sailing was eventually restricted to the directions of the major leads. The ships were forced towards the west, around the deeper part of the Makarov Basin. Not until near the Lomonosov Ridge did the icebreakers turned northward into the deeper part of the Makarov Basin. One short CTD section was then taken from the deep basin to the crest of the Lomonosov Ridge.

Oden and Healy continued to a depression, or sub-basin, in the central Lomonosov Ridge to study the bathymetric features of the sub-basin and to examine if an exchange of deep water from the Amundsen Basin to the Makarov Basin took place there. The ice was fairly light and after a side-scan survey of the sill of the sub-basin towards the Makarov Basin had been made the two ships could work independently. Oden made several CTD casts to study the water masses in the sub-basin and at the sill to the Makarov Basin. As the ships attempted to leave the Lomonosov Ridge the ice again was heavier and they could not enter the Amundsen Basin on a direct course towards the North Pole. The ships had to move along the ridge towards Greenland and leave the ridge on the Greenland side of the entrance from the Amundsen Basin to the sub-basin in the ridge.

The two ships reached the North Pole on the 13th of September, later than any previous ship. This was subsequently found to be almost too late in the season. Once the sun is gone, winter rules. The ice conditions in the Amundsen Basin and over the Gakkel Ridge gradually became more difficult, but a reduced number of stations could still be taken. After the Gakkel Ridge the ice conditions were much worse and the time schedule could no longer be assessed. The two captains then decided to inhibit the station work to avoid unreparable delays. The Nansen Basin was crossed at a speed of 1-2 knots and only the second XBT section, extending across the front between recirculating Atlantic water in the northern Nansen Basin and the boundary current entering through Fram Strait, was taken as the ship fought their way through the ice. When Oden and Healy finally got out of the ice, a last CTD station was occupied at the continental slope north of Nordaustlandet. The ships parted and Oden sailed for Longyearbyen, where the scientists left the ship.

Some preliminary results

The low salinity Polar surface water, originating from the Siberian shelf seas and the runoff from the Siberian rivers, which during the years in the 1990s with strong positive North Atlantic Oscillation (NAO) index (the difference in sea level pressure between the Azores and Iceland) had been forced into the Makarov and Canada Basin had now returned to the Amundsen Basin. The low salinity surface water separates the ice cover from the heat residing in the sub surface warmer Atlantic layer and its presence protects the ice from heat flux from below, which otherwise could affect its thickness.

The extended pulse of warm Atlantic water that in the early 1990s was observed to enter the Arctic Ocean and spread along the Siberian continental slope had now reached the southern Canada Basin. It had also penetrated from the Chukchi Cap into the northern Canada Basin, while colder and older, Atlantic water from the southern Canada Basin had been displaced northward along the American continental slope and entered the northern Canada Basin from the American side along the Alpha Ridge. In the Makarov Basin the warm pulse had recirculated around the basin, first along the Mendelejev and Alpha ridges to the American slope and then back towards Siberia along the Lomonosov Ridge. By contrast the warm Atlantic water had now left the Amundsen Basin and been replaced by a colder Atlantic inflow making the maximum temperature of the Atlantic water on Amundsen Basin side of the Lomonosov Ridge equal to that on the Makarov Basin side. That the water moved in different directions on the two sides of the ridge was nevertheless evident by the presence in the Amundsen Basin of less saline and colder intermediate layer, originating from the Barents Sea inflow branch below the Atlantic water. Over the Gakkel Ridge the

temperature of the Atlantic water again increased, signalling a recirculation of a new pulse of warm Atlantic water towards Fram Strait. At the last station, taken at the continental slope northeast of Svalbard still warmer and more saline Atlantic water was observed, indicating another pulse of warm Atlantic water entering the Arctic Ocean through Fram Strait.

The study of the deeper passage in the Lomonosov Ridge showed, not the expected inflow of colder Amundsen Basin water into the Makarov Basin, but a flow of warmer and more saline Makarov Basin deep (2000m) water into the Amundsen Basin. This inflow, not earlier observed, continued along the ridge towards Greenland, but it is likely to contribute to the mid-depth (1700m) salinity maximum present in most of the Amundsen Basin. Whether an overflow of Amundsen Basin water occurs elsewhere or only happens intermittently remains so far unknown.

The Oden and Healy expeditions were organised and mainly supported by the Swedish Polar Secretariat and by the US National Science Foundation. The participation of FIMR was partly supported by the Academy of Finland.

Description of Measurement Techniques

1. CTD/Hydrographic Measurements Program

The basic CTD/hydrographic measurements consisted of salinity, dissolved oxygen and nutrient measurements made from water samples taken on CTD/rosette casts, plus pressure, temperature, salinity, dissolved oxygen, transmissometer, Seapoint fluorometer and Haardt fluorometer from CTD profiles. A total of 48 CTD/rosette casts were made, usually to within 5-10 meters of the bottom. No major problems were encountered during the operation. The distribution of samples is illustrated in figures 1.0 and 1.1.

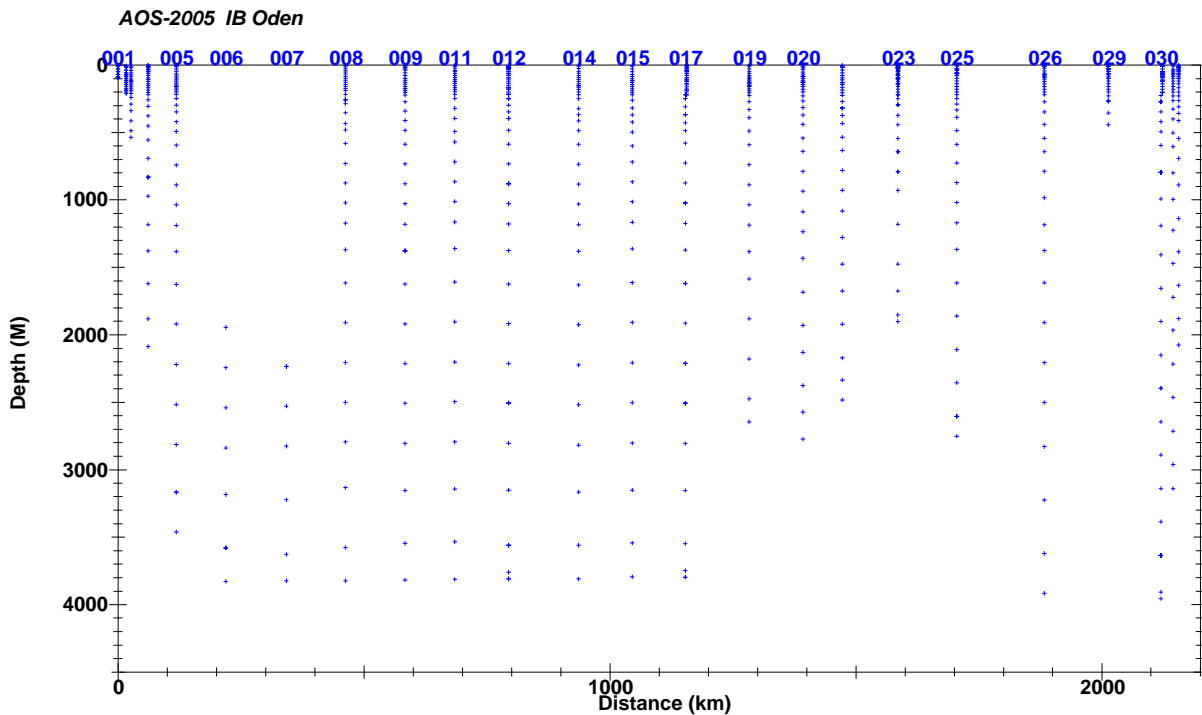


Figure 1.0 Sample distribution, stations 1-32 (Canadian Basin).

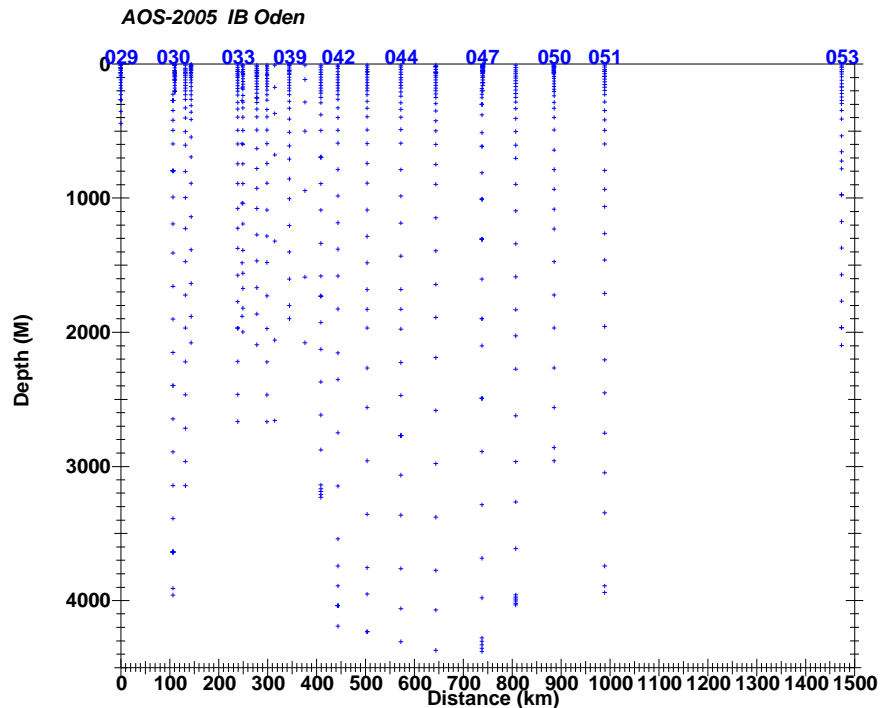


Figure 1.1 Sample distribution, stations 29-53.

1.1. Water Sampling Package

LADCP/CTD/rosette casts were performed with a package consisting of a 36-bottle rosette frame (STS), a 36-place pylon (SBE32) and 36 10-liter Bullister bottles (STS). Underwater electronic components consisted of a Sea-Bird Electronics (SBE) *9plus* CTD (STS #381) with dual pumps, dual temperature (SBE3*plus*), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs 25cm C-Star) and two fluorometers (Seapoint/chlorophyll a and Haardt/CDOM); an SBE35RT Digital Reversing Thermometer; an RDI LADCP (Workhorse 150kHz) and an altimeter (Simrad 807 or Benthos 916D).

The CTD electronics unit, with pressure sensor at the bottom, was mounted vertically in an SBE CTD frame attached to the bottom center of the rosette frame. Both pairs of SBE4C conductivity and SBE3*plus* temperature sensors and their respective pumps were mounted vertically as recommended by SBE. The SBE43 dissolved oxygen sensor was attached to the rosette frame and plumbed into the primary side between the conductivity sensor and pump. Pump discharges were attached to the outside corners of the CTD cage and plumbed to terminate at the same height and orientation as the T/C duct. The entire cage assembly was then mounted on the bottom cross-bracing of the rosette frame, offset from center to accommodate the LADCP lower head, and also secured to frame struts at the top. The SBE35RT temperature sensor was mounted vertically and equidistant between the primary and secondary T/C intake ducts. The altimeter was mounted on the inside of a support strut adjacent to the bottom frame ring. The transmissometer and fluorometers were mounted horizontally along the rosette frame adjacent to the CTD. The LADCP lower head was vertically mounted inside the bottle ring on the opposite side of the frame from the CTD. The upper head was mounted above the operating height of the bottle. Physical constraints required the head to be directly above the bottles.

The rosette system was suspended from a purposely built 2-32 P2 XXS 6000m two-conductor coaxial 8.15mm cable. The center 7-strand 20 AWG conductor was used for signal and power. The outer coaxially wrapped 15 AWG conductor was used for signal and power return. The double lay armor served only as the strength member.

The IB Oden's bow-mounted Seaproof Solutions winch was used for all Rosette casts. Electrical retermination was done twice between August 21-23 (after stations 6 and 7) while troubleshooting intermittent power/signal problems. The problem was finally traced to faulty slings, when shorting of the

center conductor to ground remained after cast recovery. Sliprings were replaced with a spare set supplied with the winch.

Each bottle on the rosette was assigned a unique number, 1-36. These bottle numbers were maintained independently of the bottle position on the rosette and were used for sample identification. A unique "BIO" number sticker was attached to each bottle before cast deployment. A number was used exactly once, to identify a unique station-cast-bottle combination. No bottles were replaced on this cruise, although various parts on bottles were occasionally changed or repaired.

The deck watch prepared the rosette 10-20 minutes prior to each cast. For this cruise, sample spigots were replaced with 1/4" PVC ball valves to facilitate CFC gas sampling requirements. 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 LADCP was turned on. As directed by the deck watch leader, the CTD was powered-up and the data acquisition system started. Once the bow wash system was turned ON and the sea area forward of the bow was clear of ice, the rosette was moved into position on the bow beneath the A-frame. During below freezing deployments, warm saltwater was continuously passed over the sensors until the package was suspended 1.5m above the deck; then the tubing was removed and the package lowered expeditiously into the water. The winch was remotely controlled from the deck while the A-frame operator telescoped the package up and over the 1.6m rail, then down 6m to the sea surface.

The package was lowered to 10-15 meters below the surface until sensors equilibrated. Once the package was in the water, the A-frame telescope was retracted to bring the wire closer to the hull for protection against ice. The winch operator retired to the control area of the CTD container, by the console operator. When readings stabilized after the pumps turned on, the CTD console operator directed the winch operator to bring the package close to the surface, pause for typically 10 seconds and begin the descent.

Each rosette cast was usually lowered to within 5-10 meters of the bottom.

Recovering the package at the end of the deployment was essentially the reverse of launching. Minor exterior freezing of the sample valve tips and dripping water from the frame were observed on casts where air temperature was below -6°C. The rosette was moved into the CTD container for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on the sample log.

Routine CTD maintenance included rinsing the sensors, carousel, and frame with fresh water between casts. Due to the potential for freezing, fresh water was not kept in the sensor lines between casts. Rosette maintenance was performed on a regular basis. O-rings were regularly inspected and changed as necessary, and bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired as needed. A few ball valves had to be replaced with spigots when they were broken off during rosette recoveries.

1.2. Underwater Electronics Packages

CTD data were collected with a SBE9*plus* CTD (STS #727). The instrument provided channels with pressure, dual temperature (SBE3*plus*), dual conductivity (SBE4C), dissolved oxygen (SBE43), transmissometer (Wetlabs C-Star), two fluorometers (Seapoint for chlorophyll a, Haardt for CDOM) and altimeter (Simrad 807 or Benthos 916D). The CTD supplied a standard Sea-Bird format data stream at a data rate of 24 frames/second (fps).

Sea-Bird SBE32 36-place Carousel Water Sampler	S/N 3213290-0113
Sea-Bird SBE35RT Digital Reversing Thermometer	S/N 3528706-0035
Sea-Bird SBE9 <i>plus</i> CTD	S/N 09P31807-0727
Paroscientific Diquartz Pressure Sensor	S/N 90577
Sea-Bird SBE3 <i>plus</i> Temperature Sensor	S/N 03P-2202 (Primary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2113 (Primary)
Sea-Bird SBE43 DO Sensor	S/N 43-0244 (stations 1-25)
Sea-Bird SBE43 DO Sensor	S/N 43-0185 (stations 26-)
Sea-Bird SBE3 <i>plus</i> Temperature Sensor	S/N 03P-4308 (Secondary)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-2818 (Secondary, stations 1-25)
Sea-Bird SBE4C Conductivity Sensor	S/N 04-1919 (Secondary, stations 26-)
Wetlabs C-Star Transmissometer	S/N CST-479DR
Seapoint Fluorometer	S/N 2749
Haardt Fluorometer	S/N 12030 (TAMU/Galveston)
Simrad 807 Altimeter	S/N 4051 (stations 1-41)
Benthos 916D Altimeter	S/N 850 (stations 42-)
RDI Broadband 150khz LADCP	S/N xxx (stations 1-17)
RDI Broadband 150khz LADCP	S/N xxx (stations 19-)
LADCP Battery Pack	

Table 1.2.0 AOS-2005 Rosette Underwater Electronics.

The CTD was outfitted with dual pumps. Primary temperature, conductivity and dissolved oxygen were plumbed on one pump circuit, and secondary temperature and conductivity on the other. The CTD and sensors were deployed in a vertical orientation. The primary temperature and conductivity sensors (T1 #03P-4213 and C1 #04-2659) were used for reported CTD temperatures and conductivities on all casts. The secondary temperature and conductivity sensors were used for calibration checks.

The SBE9*plus* CTD and the SBE35RT Digital Reversing Thermometer were both connected to the SBE32 36-place pylon providing for single-conductor sea cable operation. A custom-built 6000m-long 8.15mm cable with two coaxial conductors was used to connect the underwater package to the SBE11*plus* deck unit in the CTD container control station. The center, stranded 20 AWG conductor was used for signal and power. The outer, coaxially wrapped conductor was used for signal and power return. The armor served only as the strength member. Power to the SBE9*plus* CTD (and sensors), SBE32 pylon, SBE35RT and altimeter was provided through the sea cable by the SBE11*plus* deck unit.

1.3. Navigation and Bathymetry Data Acquisition

Navigation data were acquired by one of the Linux workstations beginning 21 August 2005 (UTC) from a Garmin GPS-17 unit mounted on top of the rosette container. Date, time, Position, speed and course were acquired at 1-second intervals.

Very intermittent bathymetry data were available from the Oden's echosounder via the ship's webserver. The bridge provided approximate charted depths as available at cast time; when the Healy was nearby, Seabeam data were used to estimate bottom depths.

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 2 Linux. Each PC workstation was configured with a color graphics display, keyboard, trackball, 120 GB disk, and DVD+RW drives. Two systems shared a single display, keyboard and trackball due to limited space in the cast control room. One of the 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, and provided for CTD and hydrographic data management and backup. Hardcopy capability was provided by an HP Officejet d155xi network printer.

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, and bathymetry when available from the Oden displays or Healy Seabeam website.

CTD deployments were initiated by the console watch after the ship stopped on station. The watch maintained a console operations log containing a description of each deployment, a record of every attempt to close a bottle and any pertinent comments. The deployment software presented a short dialog instructing the operator to turn on the deck unit, to 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. 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 initiated to display the progress of the deployment. GPS time and position were automatically logged at 1 second resolution during the cast. Both raw and processed (2 Hz time-series) CTD data were automatically backed up by one of the other workstations via ethernet.

Once the deck watch had deployed the rosette, the winch operator immediately lowered it to 10-15 meters. The CTD pumps were configured with an 8 second startup delay, and were on by the time the rosette reached 10 meters. The console operator checked the CTD data for proper sensor operation, then instructed the winch operator to bring the package to the surface and descend to a target depth (wire-out). The lowering rate was normally 60-65 meters/minute for this package.

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 and wire-out 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 10 meters of the bottom.

Bottles were closed on the upcast 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.

Raw CTD data are initially 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 are applied at this time.

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. Adjustments to pressure, temperature and conductivity determined from comparisons to other sensors and to check samples 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 CTD data were filtered, response-corrected and decimated to a 2 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. All data were stored on disk and were additionally 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 at the completion of deployment for potential problems. Data from the two CTD temperature sensors were examined, compared with SBE35RT Digital Reversing Thermometer data and checked for sensor drift. CTD conductivity sensors were compared and calibrated by examining differences between CTD and check-sample conductivity values. The CTD dissolved oxygen sensor data were calibrated to check-sample data. Additionally, deep theta-salinity and theta-O₂ comparisons were made between down and up casts as well as with adjacent deployments.

The initial 10-meter yoyo in each deployment, where the package was lowered and then raised back to the surface to start the SBE pumps, was omitted during the generation of the 2 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 db pressure-series down-cast data.

The sensors were exposed to below-freezing air temperatures during the last few stations. Water in the pump tubes near the sensors at least partially froze before the casts at stations 108 and 109. The pump tubes were cleared with warm water prior to deployment, and none of the sensors appear to have been adversely affected.

Two CTD casts are reported for stations 9, 31, 61 and 93. The rosette was lowered to approximately 250m on the first cast at each station to collect water for CDOM only. These shallow casts were not processed beyond the initial block-averaging and automated post-cast processing. The second cast reported at each of these stations was the standard deep cast.

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.

CTD #381 with pressure transducer #58952 was used for P16S-2005.

Pressure calibrations were last performed on CTD #381 at the ODF Calibration Facility (La Jolla) on 16 November 2004. The Paroscientific Digiquartz pressure transducer 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 03P-4213, secondary S/N 03P-4226) were calibrated at ODF on 16 November 2004.

The primary and secondary SBE4 conductivity sensors (S/N 04-2659 and S/N 04-2319) were both calibrated on 16 November 2004 at SBE.

The SBE35RT Digital Reversing Thermometer (S/N 35-0035) was calibrated on 15 September 2004 at ODF.

1.7. CTD Shipboard Calibration Procedures

CTD #381 was used for all AOS-2005 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) on all casts. The SBE35RT Digital Reversing Thermometer (S/N 35-0035) served as an independent temperature calibration check. *In-situ* salinity 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 for CTD #381 (Pressure S/N 58952) were applied to raw pressure data during each cast. Out-of-water pressure values were running 1.0-1.2 decibars at cast start, and 0.6-0.7 decibars at cast end. The pressure was

offset by -0.7 decibars at the surface, sloping to 0 correction at 5000 decibars, for stations 1-57. After air and sea-surface temperatures cooled off, the offset was reduced to -0.5 decibars at the surface (sloping to 0 at 5000 decibars) for stations 58-87, and to -0.3 decibars at the surface (sloping to 0 at 3000 decibars) for stations 88-111.

Start and end pressures were tabulated for each cast to check for calibration shifts. The start pressures were between 0 and 0.6 decibars, and the end pressures were between 0 and -0.2 decibars.

The post-cruise CTD #381 pressure calibration results are pending.

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. The primary (T1, S/N 03P-4213) and secondary (T2, S/N 03P-4226) SBE3*plus* temperature sensors were used the entire cruise without replacement.

Two independent metrics of calibration accuracy were examined. The primary and secondary temperatures were compared at each rosette trip, and the SBE35RT (S/N 35-0035) temperatures were compared to primary and secondary temperatures at each rosette trip.

The T1 sensor appeared to have a slow, steady drift with station number, relative to the SBE35RT: +0.5 to +1.0 mdegC from stations 1-111. The T2 sensor was less stable, starting 1.0 mdeg.C high, drifting to 0, then back to 0.8 mdeg.C high. The sensor calibration histories were examined, and the SBE35RT was deemed most likely of the 3 to be correct. Offsets were calculated from SBE35RT-T1 differences, using data below 1500 decibars. The offsets, shifting slightly for each station, were applied to T1 data. There did not appear to be any residual pressure effect on the T1 or SBE35 sensors. The T2 sensor was not corrected.

Figures 1.7.2.0 and 1.7.2.1 show T1-T2 residual differences after shipboard correction of T1 only. The shipboard-final T1 and SBE35RT comparisons are summarized in figures 1.7.2.2 and 1.7.2.3.

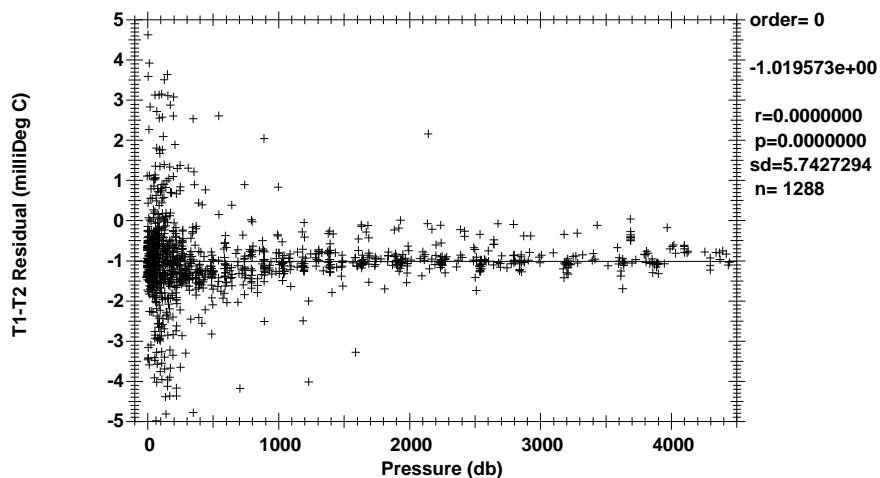


Figure 1.7.2.0 Primary and secondary temperature differences by pressure, all pressures.

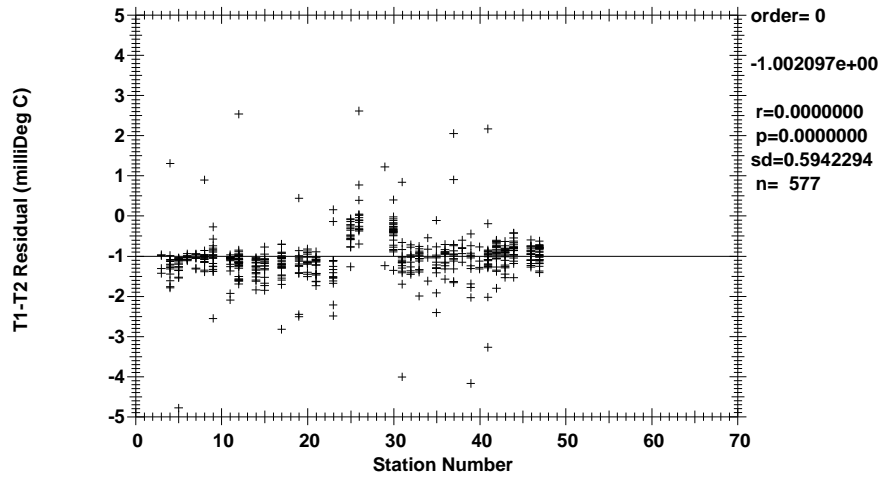


Figure 1.7.2.1 Primary and secondary temperature differences by cast, $p > 1000$ db.

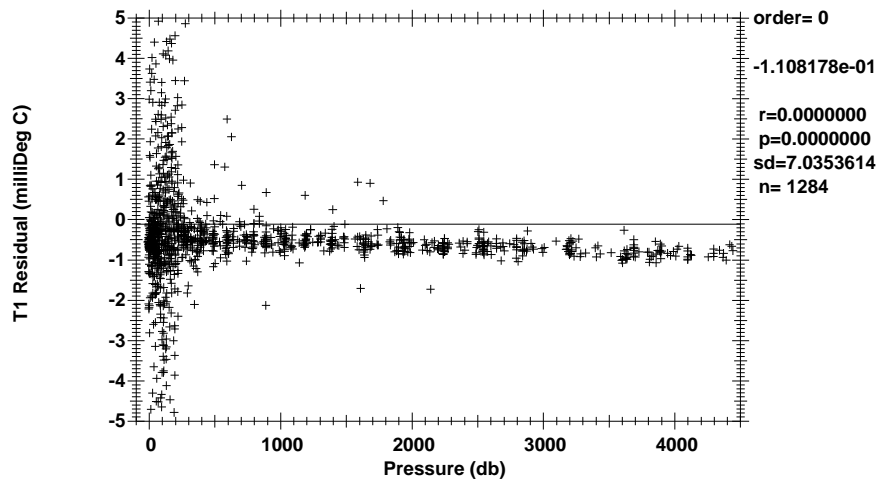


Figure 1.7.2.2 T1 and SBE35RT temperature differences by pressure, all pressures.

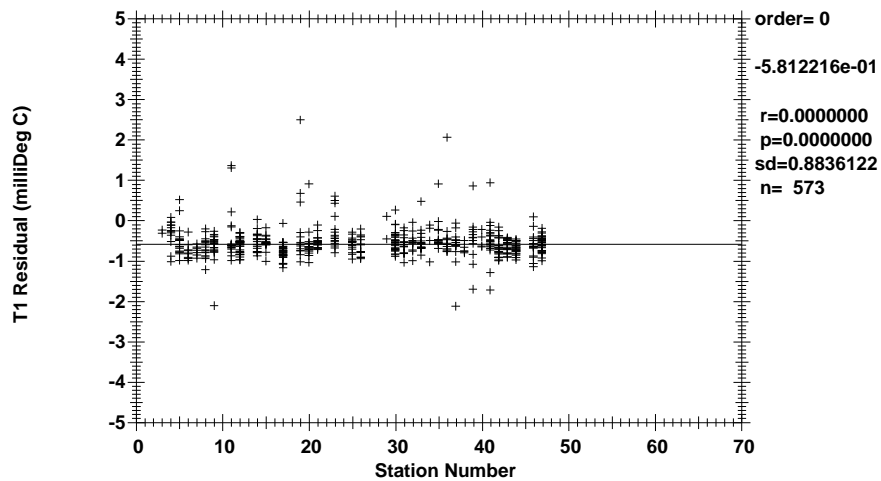


Figure 1.7.2.3 T1 and SBE35RT temperature differences by cast, $p > 1000$ db.

Post-cruise calibrations for all the temperature sensors are pending.

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.

The same primary (C1 - S/N 04-2659) and secondary (C2 - S/N 04-2319) SBE4 conductivity sensors were used on all of AOS-2005. C1 was used for all reported CTD conductivities; C2 was used as a calibration check on the primary sensor.

Comparisons between the primary and secondary sensors, and between sensors and check sample conductivities, were used to derive conductivity sensor corrections. The average C1-C2 differences were about +0.001 mS/cm at the start of the cruise, increased to +0.0015 by station 25, then dropped to +0.0005 by station 40. The differences abruptly shifted at station 50, after the sensors were cleaned with Triton X (according to SBE specs). After a few more stations, the averages stabilized a bit, varying between +0.001 and +0.0015 mS/cm for the rest of the cruise. Another cleaning with Triton X between stations 92 and 93 appeared to have no effect on either C1 or C2 data. The bottle-C1 average values were less consistent, and varied more than 0.002 mS/cm.

The differences between sensors and bottles were considered at the same time as deep theta-salinity overlays of consecutive stations were examined for both T1C1 and T2C2 sensor pairs. C1 offsets were adjusted by as much as ± 0.0005 mS/cm for a few casts to provide deep theta-salinity consistency, and had the effect of "normalizing" some of the differences between sensors and bottle data. A second-order pressure-dependent slope was fit to the adjusted bottle-C1 differences, omitting stations 1-20 to eliminate any possibility of residual Autosal suppression issues at the shallow end. The resulting correction (on the order of +0.001 mS/cm at 0 decibars, -0.001 mS/cm at 3500 decibars and -0.0006 mS/cm at 5700 decibars) was applied to all C1 data. C2 data were not corrected.

Shipboard overlays of deep theta-salinity profiles were checked for cast-to-cast consistency after the corrections were applied. Stations 50-74 (after the first Triton X cleaning) were adjusted slightly, to better align the profiles and the bottle-C1 differences. Most deep profiles of adjacent casts agreed to within ± 0.0001 -2 mS/cm.

The comparison of the primary and secondary conductivity sensors by station, after applying shipboard corrections, is summarized in figure 1.7.3.0.

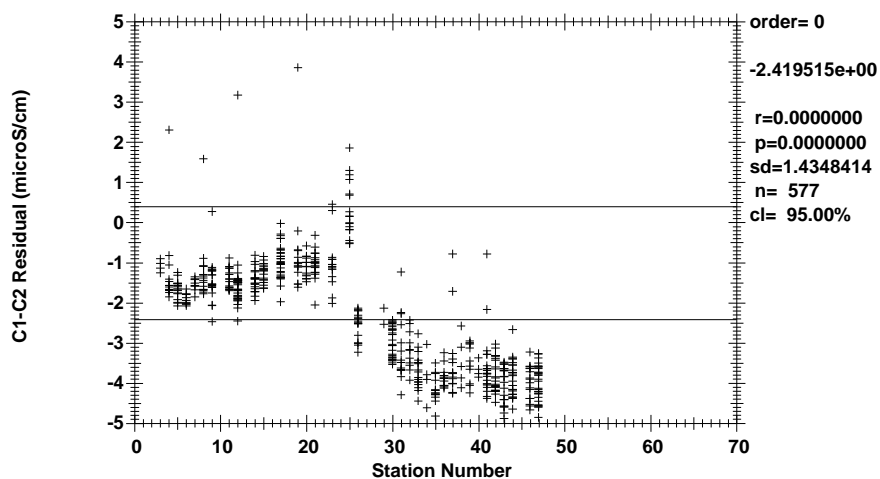


Figure 1.7.3.0 C1 and C2 conductivity differences by cast, p>1000db.

