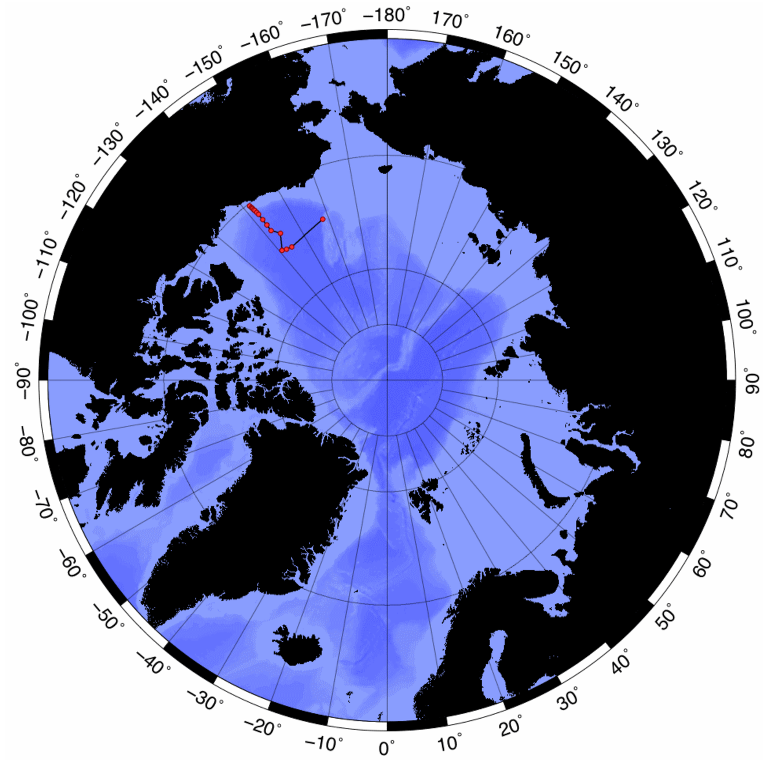
CRUISE REPORT: JOIS97

(Updated MAR 2014)



A. HIGHLIGHTS

A.1. CRUISE SUMMARY INFORMATION

WOCE Section Designation	**JOIS97**
Expedition designation (ExpoCodes)	**18SN19970924**
Chief Scientists	**Dr. James H. Swift / SIO**
Dates	1997 SEP 20 - 1997 OCT 19
Ship	*CCGS Louis S. St-Laurent*
Ports of call	Tuktoyaktuk, NWT, Canada - Cambridge Bay, NWT, Canada
Geographic Boundaries	75° 19.4' N 158° 1.20' W 140° 47.60' W 70° 11.92' N
Stations	16
Floats and drifters deployed	0
Moorings deployed or recovered	0

Chief Scientist Contact Information

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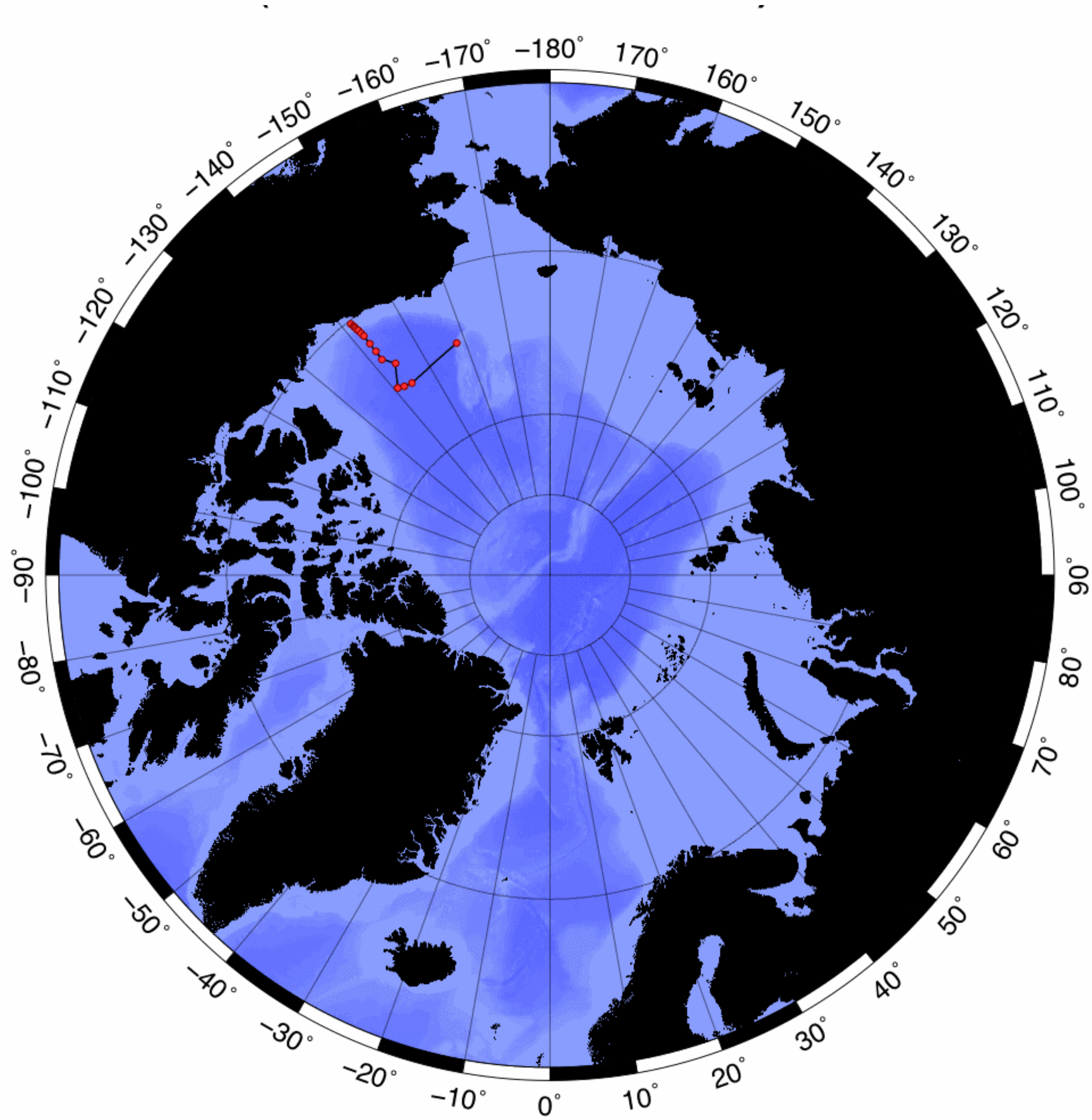
LINKS TO SELECT LOCATIONS

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 • JOIS07 • Swift • *CCGS Louis S. St-Laurent*



Acknowledgements

The SIO work was supported by the U.S. National Science Foundation via grant OPP-9709130. Special thanks to NSF program officers for arranging this ship-of-opportunity support on short notice. The work would not have been possible without the support of the Canadian Department of Fisheries and Oceans, and many colleagues at Canadian and U.S. institutions. The officers and crew of CCGS Louis S. St-Laurent ably supported the sea work.

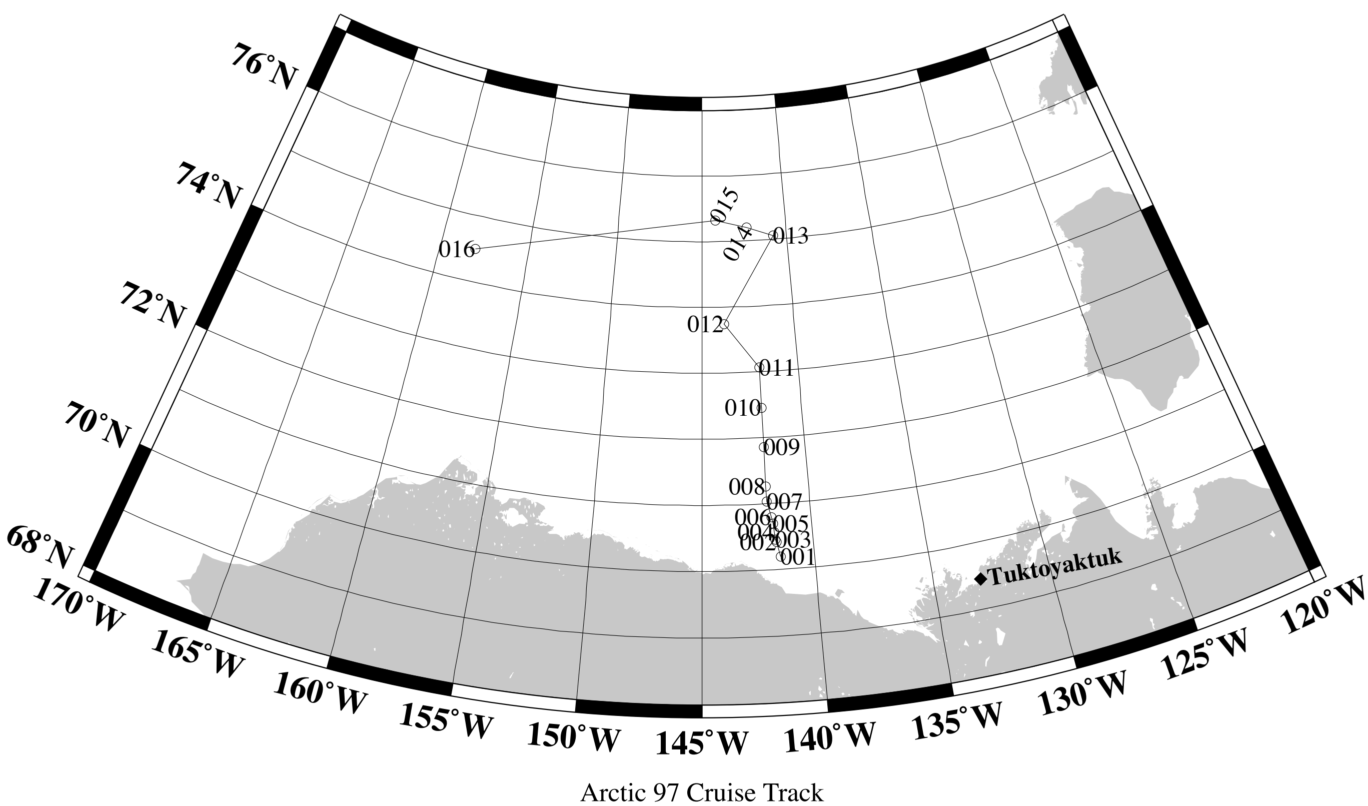
Arctic 97/JOIS Leg 4
CCGS Louis S. St-Laurent

ODF Cruise Report
October 5, 1997

Oceanographic Data Facility
Scripps Institution of Oceanography
La Jolla, Ca. 92093-0214

Summary

A ship-of-opportunity CTD/rosette section was carried out in September, 1997 north into the Canada Basin of the Arctic Ocean along ca. 140°W. The CCGS Louis S. St-Laurent departed Tuktoyaktuk, NWT on 20 September 1997. 16 CTD/Rosette stations were occupied from 24 September through 15 October. Water samples (up to 36) and CTD data were collected in most cases to within 6 meters of the bottom, for a total of 480 bottles. Salinity, dissolved oxygen and nutrient samples were analyzed from every level sampled by the rosette, with the exception of a second shallow cast for HCH on station 13. The cruise ended in Cambridge Bay, NWT on 19 October 1997.



Arctic 97 Cruise Track

Scientific Personnel		
Name	Affiliation	Duties
Swift, Jim	SIO/PORD	Chief Scientist
Adamson, Louise	IOS	HCH, TOT, TON
Boenisch, Gerhard	LDEO	Helium, Tritium, ^{18}O
Delahoyde, Frank	SIO/STS/ODF	CTD data Processing
Gershey, Bob	BIO	CFCs, CO_2
Hingston, Mike	BIO	CFCs
Masten, Douglas	SIO/STS/ODF	Nutrients
Mattson, Carl	SIO/STS/ODF	TIC/Watch Leader/ET/Rosette
Muus, Dave	SIO/STS/ODF	O_2
Poliquin, Manon	BIO	CO_2
Rusk, Steve	SIO/STS/ODF	Salts/Rosette
Sieberg, Doug	IOS/AINA	Rosette/deck
Tremblay, Bruno	LDEO	CTD/Rosette
Tuele, Darren	IOS	Rosette/Deck/Bongo tows
Zemlyak, Frank	BIO	CFCs, CO_2

Scientific Personnel Arctic 97/JOIS Leg 4

Programs

The principal programs of Arctic 97/JOIS Leg 4 are shown in Table 1.0. The SIO ODF hydrographic measurements program is described in detail in this report.

Analysis	Institution	Principal Investigator
Basic Hydrography (Salinity, O_2, Nutrients, CTD)	SIO	J.H. Swift
CFCs	BIO	E.P. Jones
He, Tr, ^{18}O	LDEO	P. Schlosser, G. Boenisch
TCO_2, Alkalinity	BIO	E.P. Jones
Ba	OSU	K. Falkner
TOC, TON	OSU	P. Wheeler
^{18}O	OSU	K. Falkner
^{129}I	BIO	J. Smith
^{137}Cs	BIO	J. Smith
HCH	IOS	F. McLaughlin, R. Macdonald
XCTD, Mooring	JAMSTEC	K. Shimada
Bongo tows	IOS	F. McLaughlin, R. Macdonald

Table 1.0 Principal Programs of Arctic 97/JOIS Leg 4

NARRATIVE

The advance plan for the expedition prepared by the SHEBA Project Office and the leaders of the Joint Ocean Ice Study (JOIS) included the following elements:

- Recovery of three JAMSTEC current meter moorings off Point Barrow, first by CCGS Laurier, and, if necessary, by CCGS Louis S. St-Laurent.
- Deployment of a JAMSTEC deep water (1500-3000 meter) current meter mooring on the Canada Basin flank of the Northwind Ridge by CCGS Louis S. St- Laurent.
- Deployment of a JAMSTEC Ice Ocean Environmental Buoy ("IOEB-2") ice drift mooring in heavy ice off Banks Island from the CCGS Des Groseilliers.
- Occupation of a continental shelf to deep basin CTD/hydrographic section from the Beaufort Sea shelf into the deep Canada Basin from CCGS Louis S. St-Laurent. [This is the program reported here.]
- Deployment of CCGS Des Groseilliers for a year-long series of measurements near 75-76°N, 142°W in an ice floe meeting project criteria set by the Surface Heat Budget of the Arctic (SHEBA) science team. This was the primary mission.

The following narrative relates principally to the activities of the Section team:

9/18 The JOIS Leg 4 Section science team boarded CCGS Louis S. St-Laurent at Tuktoyaktuk, NWT, Canada ("Tuk"), moored about 20 miles offshore. Two Section team members from Bedford Institute of Oceanography and two from the Institute of Oceanographic Sciences, Patricia Bay, were already aboard from Leg 3. Some scientists from Leg 3 remained on board, anticipating a visit by Canada Minister of Fisheries and Oceans. SHEBA and Section equipment expected in Tuk via barge from Hey River had been delayed 6-8 days and had not yet arrived at the ship.

9/19 Foggy conditions set in. The barge arrived in Tuk at night.

9/20 Still foggy. The barge was towed out to CCGS Des Groseilliers in the evening. During a planning session JAMSTEC scientist Koji Shimada indicated that the Northwind Ridge was the only acceptable site for deployment of the JAMSTEC mooring scheduled for Leg 4. JAMSTEC also had an XCTD program along the section, and IOEB-2 from the Des Groseilliers. Eddy Carmack proposed a revised science plan calling for CCGS Laurier to make the second attempt to recover the JAMSTEC Barrow Canyon mooring. The Louis sent the Laurier information about search patterns and release codes.

9/21 Due to continued heavy fog the Louis was unable to load SHEBA passengers. The Des Groseilliers completed cargo loading by early evening so the Louis came alongside with the barge in the middle. Seas were light and conditions ideal for loading, so from 7:30 pm to 2 am all hands turned out to load cargo.

9/23 Almost all Section systems ready. But the Louis still could not load the remaining SHEBA passengers due to continued fog, wind, seas, etc. Finally a tug landed them on a nearby island and the ship's helicopter picked them up. Louis still waiting for engine parts expected via air freight.

Due to the time lost from the shipment delay and the fog, the SHEBA leaders canceled the attempt to deploy the JAMSTEC Northwind Ridge mooring (at least before the SHEBA set up). The Louis was asked to begin the Section within the range of 141-145°W. The Des Groseilliers plan was also revised, with no trip to Banks Island, and that vessel then planed to proceed to ice edge at 143°W, then proceed in 50 km and attempt to deploy IOEB-2.

The Louis headed overnight from Tuk to the Mackenzie River mouth area.

9/24 Heavy fog at the airport and ship meant no possibility of transfer of engine parts so at 1100 the Louis left for the west to the 50 meter isobath along 141° 30'. This was east of the original plan, but west of the Mackenzie River delta region. The Section began after the evening meal. Finished the first four stations (planned/actual depths 50/41, 100/102, 200/247, and 500/490 meters) by midnight. All went very well. A leak test on all the unused bottles at Station 1 found one leaker, which was repaired before it ever had to be used on a real sample. Stations consist of 1 CTD cast to the bottom, and up to 30 minutes of bongo net tows. XCTDs were deployed by Koji Shimada from JAMSTEC at locations of his choosing.

The Des Groseilliers was not yet able to cross to the ice edge due to heavy load plus sea conditions.

9/25 Resumed science work at 0830 and completed four more stations (planned/actual depths 800/1035, 1100/1820, 1500/2410, and 2000/2868 meters), for eight total. It was decided that net tows and CTD casts could proceed in tandem. Lost use of the depth sounder en route to station 5. Last reading of ca. 730 meters turned out to be erroneous because the actual water depth was about 1035 m. Possible very steep bathymetry. Decided on the basis of T and S CTD profiles that the Station 4 to Station 5 transition could be interpolated, so did not try to go back for the planned intermediate depth. There was no depth sounder en route to Station 6 and so the Louis proceeded 6 miles (to the original Station 8 position) and did a cast. The Section work otherwise was nearly without flaw.

The weather was good for station work, with roll never a problem and seas and winds steadily decreasing. Air temperature slightly positive. The Louis was joined by a young golden eagle which probably got lost in the fog.

In a conversation with the Captain regarding additional stations it was clear that he strongly preferred to not do any station work after leaving the SHEBA site. But it would take more time than available to reach the ice edge at the planned 18-20 mile spacing, plus there was ca. 120 miles of ice transit to the SHEBA site, and the Des Groseilliers was expected soon at the ice edge, so it was going to be impossible to continue short spacing. The portion of the Section expected to benefit most from short spacing had been completed, and so three stations were chosen at nominal 37 mile spacing to take the Louis to the ice edge.

9/26 An almost ideal day of station work. Weather remained good with light winds (10-15 knots), air temperature near or a little above 0°C, grey skies, light seas and swell. Completed three deep stations, with the last, #11, near the ice edge. The eagle departed as the Louis neared ice floes.

The (revised) Section plan for remaining stations was to continue with 20-37 mile spacing in the ice to the SHEBA site (including a double cast near SHEBA), to do 1-2 stations north of SHEBA, and to do daily CTD casts near SHEBA, in that priority order. The first two were part of the original science plan. The Louis proceeded from Station #11 24 miles north and west, to within sight of Des Groseilliers in 8/10 loose multi-year ice.

9/27 Air temperature -4°C, winds light. Had one or more bears close by the ship overnight. There was no CTD cast at the initial rendezvous point because the captains chose to proceed directly into the ice. As the distance from Station 11 began to exceed 40 miles, it started becoming urgent to do a station. Also, the Louis received from Des Groseilliers information about a submarine visit to the SHEBA area (the SCICEX sub) with a request/demand from the US Navy for no instruments in the water during 0000Z 9/28 to 0000Z 10/2 in an area 125 km from 75° 30'N 145°W. Although the Louis was well outside the area, and somewhat outside the time, someone from SHEBA had interpreted this to mean no over the side operations beginning immediately and anywhere. The Section team finally received permission from the SHEBA Chief Scientist to do a cast if it were completed before 0000Z 9/28. A handsome lead presented itself, the Captain was persuaded to stop in it, and the Station 12 CTD cast was out of the water before 2345Z 9/27.

9/28 The vessels proceeded in 10/10ths 1st year ice with some multiyear ice. Air temperature was -8°C, sky overcast with snow flurries. Foggy in the morning improving to high clouds, some sun, and only light haze in afternoon. Had ca. 65+ miles to go (straight line) to new IOEB site (75° 10'N, 143° 20'W) ca. 50 km SE of intended SHEBA floe (75° 30'N, 141° 30'W). SHEBA team noted it will permit a CTD cast at the IOEB site.

Data quality very good. The main problem has been that that the oxygen autotitrator produces occasional bad results. Apparently this is typical of recent expeditions, but with cause unknown, except that it is thought to be some software glitch. The cut-back in the number of stations has left only single stations in many of the features. Spatial scales may thus be hard to assess for some aspects of the lateral variability. The Section CTD wire time so far was only a small part of that allotted in the pre-cruise agreement/plan.

The SHEBA team from the Des Groseilliers found a target floe for SHEBA. Meanwhile, the SHEBA team sent the Louis and the Des Groseilliers ENE to a new position for the JAMSTEC IOEB-2 drift array near 75° 10' N, 140° 20' W. The plan was to put in that array and then proceed to the new SHEBA location at 75° 30' N, 141° 30' W.

9/29 Nice morning with 10 knot winds out of the north, -10°C, mostly 10/10ths ice cover though a few leads. In the late afternoon the ships arrived at a site acceptable to the JAMSTEC IOEB-2 team. Des Groseilliers was unable to get into position next to the floe without damaging the floe and determined to try again the next day.

9/30 Mostly cloudy with some snow flurries and haze — not good long distance flying weather. Remaining -10°C and lighter wind. Des Groseilliers spent about an hour or more after first light again trying to position themselves and succeeded. The Section team did Station 13 cast 1. All went well, though for the first time the conductivity sensor froze during launch. The rosette (and sensor) was warmed in the water, raised to 5 m, and then relowered. This appeared to have changed the conductivity calibration. The Des Groseilliers spent the day implanting IOEB-2 while the Louis stood by about one mile away. JAMSTEC asked for a second CTD cast to at least 200 m after deployment of IOEB-2, and this was completed without sensor freeze problems.

10/1 The morning was cold (-15°C) with light winds and snow flurries. Visibility flat, with some haze, and this hindered helo ops, for example to deploy SHEBA remote sites and to survey the SHEBA floe. A low pressure system lay to the west just NW of Bering Strait. The vessels moved to about 600 meters from the SHEBA floe at 75° 11' N, 142° 24' W. The ice was more fragile than expected, so Des Groseilliers tried to cut her own way in. The Section team carried out CTD station 14 after 1600 l.t., when the Navy-caused ban expired. During Station 14 there was a problem on the down cast when a strand broke loose from the CTD cable and got wrapped into the rollers on the winch. This took ca. 25 minutes to fix. Otherwise the cast went OK. This was an HCH profile. A double cast was avoided because this station was only 12 miles from Station 13 and Gerhard Boenisch decided that he did not need a He/Tr profile.

10/2 The low pressure system over Bering Strait intensified, but despite early indications of worsening weather, the storm delayed, and the day turned out to be a fine one, with good visibility and contrast, good flying conditions, winds ca. 15 knots, and air temperature -13°C. The Des Groseilliers moved into the SHEBA floe after an advance team on snowmobiles picked an entry path and "docking" place. Later, the Louis followed, though about 1/4 to 1/2 mile from the other ship. The science group on the Louis had their first visit from the SHEBA leaders, who came over from Des Groseilliers. Still predictions of storm conditions.

10/3 The low pressure system moved south of SHEBA. This brought brisk winds from the east, up to 25-35 knots, with periods of blowing snow. Air temperature -10°C. Working conditions remained acceptable throughout the day, but the weather was not suitable for flying.

A polar bear came by in the morning before work parties got going. The Des Groseilliers dispatched an armed team on snowmobiles to scare it off.

10/4 The low continued to move east, well south of SHEBA. A high pressure system to the west spelled improving conditions. Morning winds were 30 knots and air temperature was -9°C. By midday visibility was very good and helicopter operations resumed. The Louis began unloading large items such as the 40-foot "Welch" van, caterpillar bulldozer, "fast track" vehicle, and some fuel drums.

10/5 High pressure building over the area. Air -15.5°C this morning, and winds remained 20 knots or better. Snow flurries and poor visibility in the morning. The Des Groseilliers team asked for assistance from extra science hands on the Louis. Jumper Bitters, the key logistics person for SHEBA, was injured in a snowmobile accident, and late in the day was airlifted to Barrow via a Twin Otter from Barrow Search and Rescue, which landed on the runway he was just on his way to improve when the accident happened.

10/6 Low pressure intensified west of Bering Strait, over Siberia, shifting wind direction somewhat. Air temperature -18°C today.

10/7 Foggy (very thin layer) morning, air temperature -19°C, dropping to -22°C. Light winds. Nice afternoon.

10/8 Air -23°C in the morning, winds light but picked up to 20 knots later in the morning and 30 by afternoon, with blowing snow by evening. Air steadily warming all day. Found out that Louis may leave as soon as 10/10 in order to put in the Northwind Ridge mooring. This has occasioned some last-minute shuffling of cargo.

10/9 Air -9°C in the morning, with some blowing snow. Louis moved to Des Groseilliers for refueling. By afternoon there was a gangway between the two vessels and some additional items were moved.

10/10 Air -16°C in the morning, and to -18°C later in the day. Louis still refueling Des Goseilliers. Had to dig the IOS Niskin bottles (for Des Groseilliers) out of the forward cargo hold, where they were deeply buried. Did not find any messengers for them. Excess ship crew moved aboard Louis from Des Groseilliers. The plan was to deliver them to Prudhoe Bay before going to Northwind Ridge. Louis to be at maximum capacity (100) until then.

10/11 Air -15°C in the morning. Good weather predicted next two days, plus ice map showed the Northwind Ridge mooring site in open water near the ice edge. Five more stations were planned, for a total of 19 this cruise. The day turned out with zero progress because the Louis developed problems with the main propulsion motor (center shaft) during the time it was leaving SHEBA, and found that without the center screw — which feeds to the rudder — it was just too hard to maneuver in the ice, so the vessel was stopped, still in the main SHEBA floe, after only a mile or so of progress. The helicopter group did not get to fly either.

10/12 Air temperature -16°C; a nice day. A low pressure system formed north of eastern Siberia, farther north than others during the last few weeks. Motor repairs completed shortly before noon, but the Louis was underway only to stop a short time later to keep helicopter operation range within bounds. The ship was less than one mile from a great lead and it took some persuading to get the Louis moved into the lead to get a station done while the ship waited for the helicopters. The Louis then departed the SHEBA vicinity for a night run through the ice.

10/13 Cloudy but good visibility. Air temperature -12°C. A very disappointing night for the Section program because the Louis steamed past both remaining fill-in station locations. The Captain's answer to the request for two "fill in" stations (for the US Navy-caused gap on the way in) was to give instructions the mates only to make maximum southward progress overnight. And when the Louis left the ice the speed had to be cut to under 8 knots for the last 17 hours of the run to Prudhoe to avoid arriving too early!

10/14 Offshore of Prudhoe Bay in the morning. Lights of drilling platforms visible. Cloudy but good visibility. Air temperature -4°C. 28 SHEBA and Des Groseilliers passengers plus Louis crew transferred ashore via helicopter. Heading to Northwind Ridge at 16 knots. Captain refused JAMSTEC request to slow to 12 knots for XCTD casts.

10/15 The Louis made good progress overnight and was coming on to the intended mooring area, based on bathymetric charts, at 0800 ship time. The air chilled from -5°C to -9°C during the day, and winds were 25-30 knots, though did not overly disrupt operations. The Louis encountered no ice en route, although there was grease ice in the mooring area. The science party began a bathymetric watch at 0630, looking for the 3000 (± 20) meter isobath for the JAMSTEC mooring. The slope must have been very steep because this became an impossible operation. The bottom trace on the depth sounder was lost approaching the mooring site, with the last reading of ≈3800 meters. A CTD cast at the site showed that the Louis was in only 1470 meters of water, instead of the ca. 3000 expected from the chart. On trying to do a bathymetric survey towards deeper water, the sounder trace was lost again at 2000 meters, and never regained in deep water. Koji Shimada decided to deploy the mooring at the 1500 meter isobath instead (not a problem), and Doug Sieberg and JAMSTEC were convinced to go for anchor-last instead of anchor first deployment. This lost some time initially but the mooring deployment itself went OK. The sounder's bottom trace returned when the vessel crossed into water shallower than 2000 meters. At 0058 UT the JAMSTEC Northwind Ridge mooring was launched at the prime location near 74° 30' N, 158°W, in 1500 meters water depth. After launch, one acoustic release did not respond to interrogation, but the other release did respond. An important deep CTD cast 7 miles to the SE had been planned to establish lateral gradients across the current, and to get the CTD wire level wound better for storage, but the Captain summarily cancelled it, ordered the ship east, but then held speed down overnight in good weather. The speed decrease alone more than covered the time needed earlier for the lost station, further upsetting the JAMSTEC and Section groups.

Sixteen CTD stations were completed, with total of 24.4 hours wire time used, out of 72 hours allotted in the science plan. The Captain's peremptory cuts deleted >20% from the Section program (in terms of wire time), in addition to the large cut-backs that were made with science team approval to fit within the reduced science time available. The JAMSTEC and Section groups noted to each other that science missions are best carried out using vessels with science - supportive captains.

10/16 Steamed to the east in -12°C, 25-30 knot winds. A wintry day with leaden skies, grease and pancake ice all about, and bitter cold winds. Found the messengers for the SHEBA hydro bottles today. (!)

1. HYDROGRAPHIC MEASUREMENTS PROGRAM

Careful CTD work is the hallmark of reference-quality hydrographic measurements partly because the interpretation of other data, such as those from oxygen, nutrients other tracers, is much enhanced when combined with sufficient background information, especially for the parameters needed to calculate density, to enable accurate comparisons with other regions and times. Density is closely tied to salinity at the extremely cold temperatures typical of the Canada Basin domain.

Scientists and technicians from the Bedford Institute of Oceanography, Lamont-Doherty Earth Observatory, Institute of Oceanographic Science Patricia Bay, and the Scripps Institution of Oceanography participated in Cruise JOIS Leg 4 of the Canadian icebreaker CCGS Louis S. St-Laurent during 18 September - 19 October 1997, in the waters of the Canada Basin of the Arctic Ocean. The primary goal of this program was to determine the surface-to-bottom distributions of the physical and chemical characteristics of Canada Basin waters along a closely-spaced section of measurements extending from the Beaufort shelf to the deep Canada Basin, specifically to, and if possible beyond, the site selected for the year-long ice camp for the SHEBA (Surface Heat Budget of the Arctic) program. It was hoped that the measurements would identify the structure and spatial limits of the boundary regime, and relate that to the hydrographic structure of the interior of the Canada Basin. The measurements completed at sea for this program include CTDO, salinity, oxygen, nutrients (nitrate, nitrite, phosphate, and silicate), chlorofluoromethanes (CFC-11, CFC-12, CFC-113, and CCl4), total alkalinity, and total carbonate. Samples taken to be analyzed ashore included helium, tritium, oxygen-18, barium, iodine-129, cesium-137, total organic carbon ("TOC"), total organic nitrogen ("TON"), and the organic pesticide "HCH". Other measurement programs on JOIS Leg 4 included bongo net tows and XCTD casts. No reference-quality data of similar scope and completeness existed from this domain prior to this expedition. All rosette casts were made to within 10 meters of the bottom, with the exception of a second shallow cast for HCH on station 13. No major problems were encountered during the operation. The distribution of samples is illustrated in figure 1.0

Here are reported preliminary results of the shipboard measurements from the rosette water sampler deployed at each station. Preliminary pressures and temperatures during rosette bottle trips are reported from the accompanying CTD profiles. These data represent a rare shelf-to-deep-basin section into the Canada Basin by a oceanographic expedition equipped for a broad range of reference-quality measurements, and we expect considerable interest to be generated by these data.

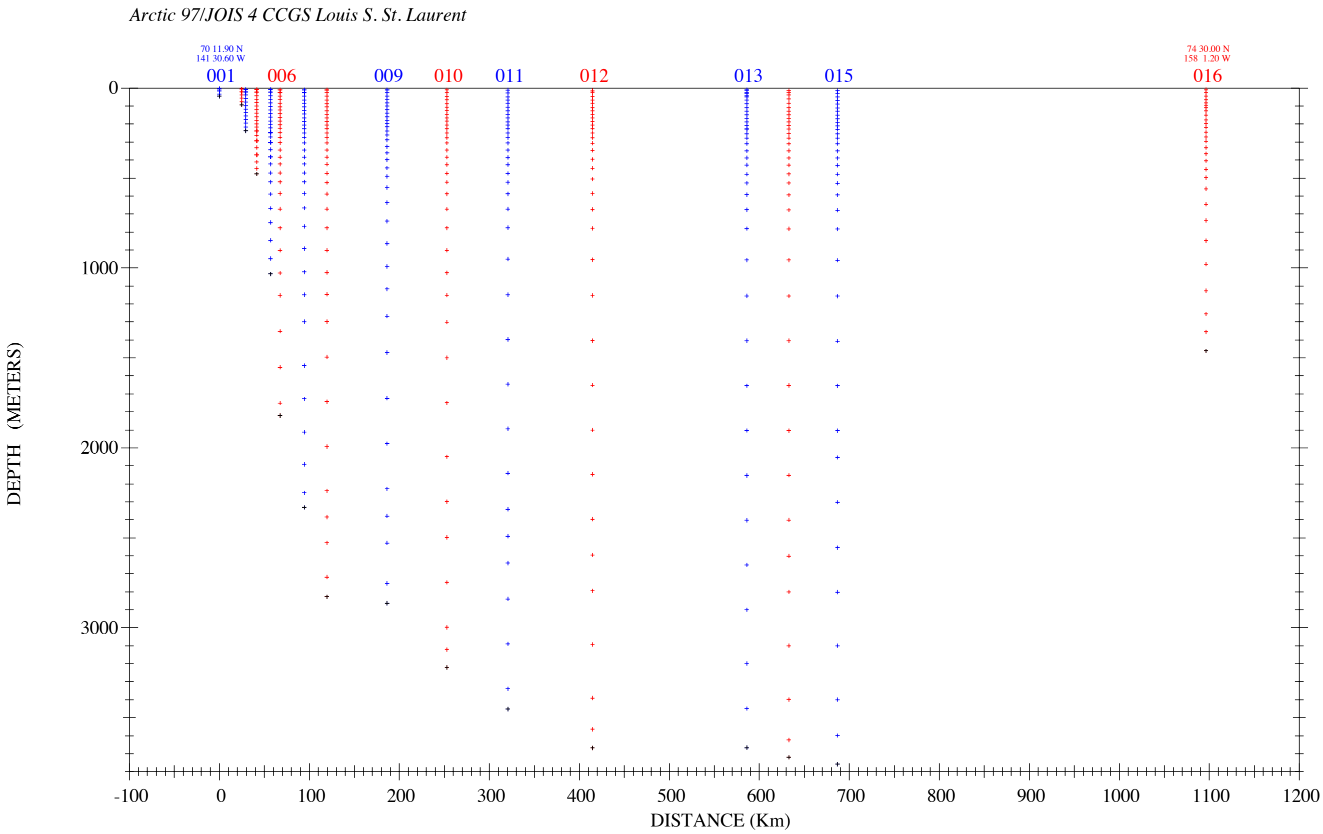


Figure 1.0 Sample distribution, stations 1-16.

Description of Measurement Techniques

1.1. Water Sampling Package

Hydrographic (rosette) casts were performed with a 36-place 10-liter rosette system consisting of a 36-bottle rosette frame (ODF) and 36 10-liter PVC bottles (ODF). Underwater electronic components included:

- SeaBird SBE 32 36-place pylon;
- ODF-modified NBIS Mark III CTD with dual conductivity and temperature sensors and a dissolved oxygen sensor;
- SeaBird SBE 35 reference temperature sensor;
- Simrad altimeter;
- Benthos pinger; and
- FSI ICTD connected to an ODF-built data logger.

The Mark III CTD was mounted horizontally along the bottom of the rosette frame, with the dissolved oxygen and SBE 35 temperature sensors deployed alongside. The SBE 35 was connected to the SBE 32 pylon, internally recording a temperature for each rosette trip. The Simrad altimeter provided distance above the bottom in the CTD data stream. The Benthos pinger was not used, as the Ship’s 12KHz PDR system was not reliable. The FSI ICTD data were collected for evaluation purposes.

The rosette system was suspended from a three-conductor 0.322" electro-mechanical (EM) cable. A single conductor in this cable was used to communicate with the CTD and pylon from the ship.

The rosette system was deployed from the midship starboard side boat deck. A wheeled cart was used to move the rosette into the sampling van.

The deck watch prepared the rosette 45 minutes prior to a cast. All valves, vents and lanyards were checked for proper orientation. The bottles were cocked and all hardware and connections rechecked. Upon arrival on station, time, position and bottom depth were logged and the deployment begun. The rosette was moved into position under an A-frame from the sampling van using the wheeled cart. Stablizing tag lines were threaded through rings on the frame. CTD sensor covers were removed. Once the CTD acquisition and control system in the ship's laboratory had been initiated by the console operator and the CTD and pylon had passed their diagnostics, the watch leader would verify with the bridge that deployment could begin. The winch operator would raise the package and move the A-frame over the side of the ship. The package was then quickly lowered into the water, the tag lines removed and the console and winch operators notified by radio of the target depth (wire-out).

During each cast, the rosette was lowered to 5-10 meters above the bottom. Each bottle on the rosette had a unique identification number. These numbers were initially assigned to correspond to the pylon tripping sequence 1-36, the first trip closing bottle #1. No bottles were changed during the leg. Averages of CTD data corresponding to the time of bottle closure were associated with each bottle during a cast.

At the end of the cast, the deck watch snagged the rosette frame with tag lines. The package was then lifted out of the water, the A-frame moved inboard, and the rosette lowered onto the cart. Sensor covers were replaced and the cart and rosette moved into the sampling van for sampling. A detailed examination of the bottles and rosette would occur before samples were taken, and any extraordinary situations or circumstances noted on the sample log for the cast.

Rosette maintenance was performed on a regular basis. O-rings were changed as necessary and bottle maintenance performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced.

A broken armor strand on the seacable (2070 MWO) was discovered on cast 14/1 and was taped-up. Subsequently, the winch was stopped on both down and upcasts to examine the wire.

1.2. Underwater Electronics Packages

CTD data were collected with a modified NBIS Mark III CTD (ODF CTD #5). This instrument provided pressure, temperature, conductivity and dissolved O_2 channels, and additionally provided redundant PRT temperature and conductivity channels. Other data channels included elapsed-time, an altimeter, and several power supply voltages. The instrument supplied a standard 17-byte NBIS-format data stream at a data rate of 20 FPS. Modifications to the instrument included revised pressure and dissolved O_2 sensor mountings; an ODF-designed sensor interface for O_2; implementation of 8-bit and 16-bit multiplexer channels; an elapsed-time channel; instrument id in the polarity byte and power supply voltages channels. The instrument sensor configuration is provided in Table 1.2.0.

Sensor	Manufacturer	Serial	Notes
Pressure	Paine 211-35-440-05	77017	Primary
Temperature	Rosemount 171BJ	15407	Primary
Conductivity	GO 09035-00151	E197	Primary casts 1/01-14/01
Conductivity	GO 09035-00151	O16	Primary casts 15/01-16/01
Temperature	Rosemount 171BJ	17534	Secondary
Conductivity	GO 09035-00151	E184	Secondary casts 1/01-14/01
Conductivity	GO 09035-00151	O24	Secondary casts 15/01-16/01
Dissolved O_2	SensorMedics	6-02-07	Primary

Table 1.2.0 CTD #5 sensor configuration data.

The CTD pressure sensor mounting had been modified to reduce the dynamic thermal effects on pressure. The sensor was attached to a length of coiled, oil-filled stainless-steel tubing threaded into the end-cap pressure port. The transducer was also insulated. The NBIS temperature compensation circuit on the pressure interface was disabled. All thermal response characteristics were modeled and corrected in software.

The SensorMedics O_2 sensor was deployed in a pressure-compensated holder assembly mounted separately on the rosette frame and connected to the CTD by an underwater cable. The O_2 sensor interface was designed and built by ODF.

A Sea-Bird Electronics SBE 35 (#350006) reference temperature sensor was employed as an additional temperature calibration check. Based on ultrastable thermistors and reference resistances, this device is internally-recording and triggered by the SBE 32 pylon confirmation signal, providing a calibration point for each bottle trip. [SBE97]

Standard CTD maintenance procedures included soaking the conductivity and O_2 sensors in distilled water between casts to maintain sensor stability, and protecting the CTD from exposure to weather to maintain an equilibrated internal temperature. In spite of these precautions, both conductivity sensors were damaged by freezing during the transit to station 15 and were replaced.

A Sea-Bird SBE 32 36-place pylon and SBE 33 deck unit were employed throughout the cruise. The SBE 32 has the advantage of using a single sea cable conductor for power and signals to both CTD and pylon. It also directly supports the use of the SBE 35 temperature reference. The pylon provided very reliable operation and positive confirmation of all bottle trip attempts. There were no mistripped bottles.

1.3. Navigation and Bathymetric Data

GPS position and bottom depth were logged manually at three times for each CTD/rosette deployment: at the beginning of the cast, at the bottom of the cast and at the end of the cast. An ELAC 12KHz PDR (provided by IOS) was used to determine bottom depth. It proved to be not very reliable in the ice, and not usable with the Benthos pinger on the rosette.

1.4. CTD Laboratory Calibration Procedures

Laboratory calibrations of the CTD pressure and temperature sensors were used to generate tables of corrections for sensor calibration models applied by the CTD data acquisition and processing software at sea.

Pressure and temperature calibrations were last performed on CTD #5 at the ODF Calibration Facility (La Jolla) in August, 1997, prior to Arctic 97/JOIS Leg 4.

The CTD pressure transducer (Paine 211-35-440-05 8850 psi, Serial #77017) was calibrated in a temperature-controlled water bath to a Ruska Model 2400 Piston Gauge pressure reference. Calibration curves were measured at 0.33 and 31.49°C to two maximum loading pressures (1194 and 6079 db, figure 1.4.0).

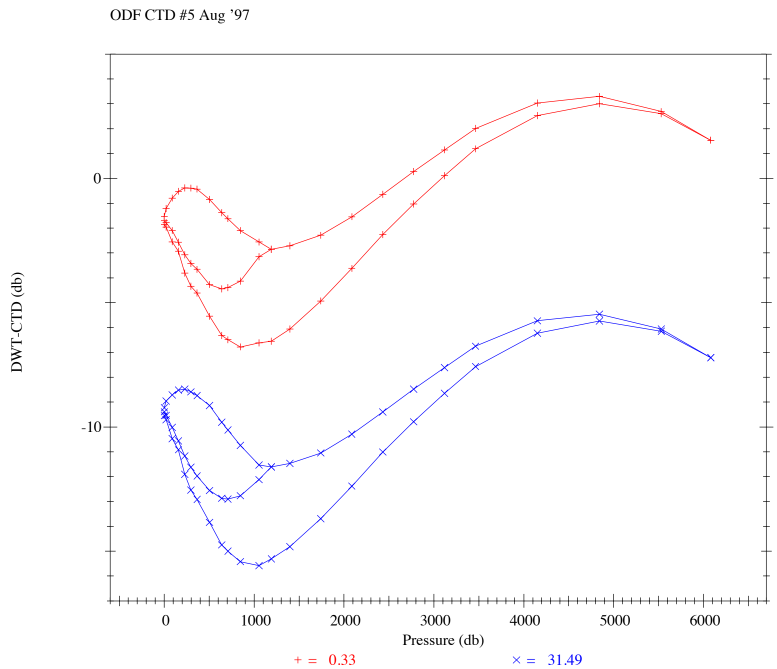


Figure 1.4.0 Pressure calibration for ODF CTD #5 (Payne #77017), August 1997.

CTD PRT temperatures and the SBE 35 temperature reference were calibrated to a NBIS ATB-1250 resistance bridge and Rosemount standard PRT. The primary (Rosemount 171BJ, Serial #15407) and secondary (Rosemount 171BJ, Serial #17534) CTD temperatures were offset by 1.5°C to avoid the 0-point discontinuity inherent in the Mark III internal digitizing circuitry. Figures 1.4.1, 1.4.2 and 1.4.3 summarize the laboratory temperature calibrations performed on the primary, secondary and reference sensors in August, 1997. These calibration procedures will be repeated when the instrument is returned to ODF.

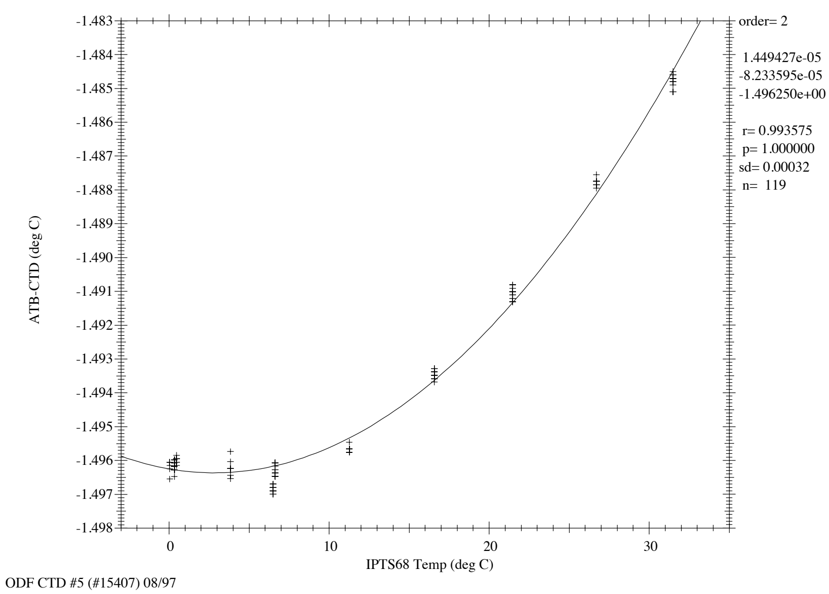


Figure 1.4.1 Temperature calibration for ODF CTD #5, August 1997.
Primary PRT #15407.

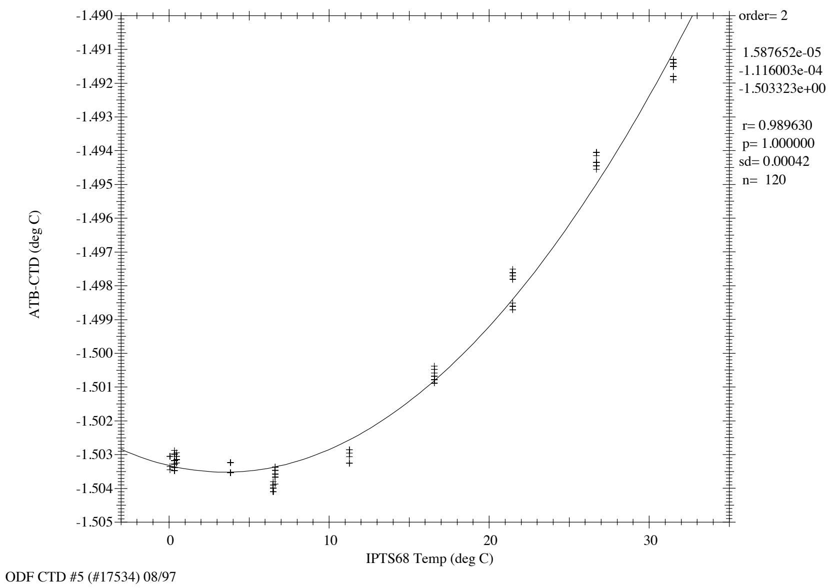


Figure 1.4.2 Temperature calibration for ODF CTD #5, August 1997.
Secondary PRT #17534.

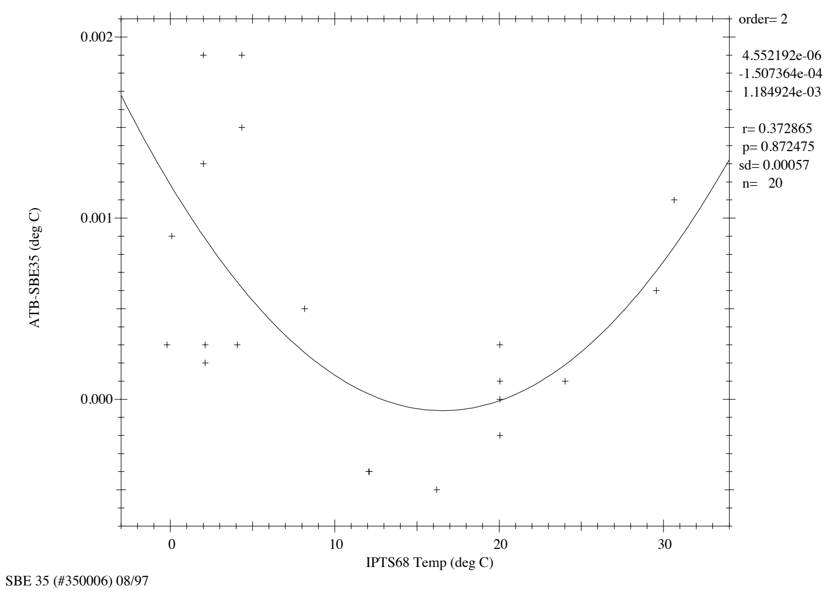


Figure 1.4.3 Temperature calibration for reference sensor, August 1997.
SBE 35 temperature sensor #350006.

1.5. CTD Data Acquisition, Processing and Control System

The CTD data acquisition, processing and control system consisted of a Sun SPARCstation LX computer workstation, ODF-built CTD deck unit, SBE 33 pylon deck unit and power supply and a VCR recorder for real-time analog backup recording of the seacable signal. The Sun system consisted of a color display with trackball and keyboard (the CTD console), 2 RS-232 ports, 1.05GB and 1.6 GB disks and 8-mm cartridge tape. Two other Sun systems (one Sparc LX, one SparcStation 2) were networked to the data acquisition system, as well as to other data acquisition and processing computers used for the hydrographic section program. These systems were available for real-time CTD data display as well as providing hydrographic data management, storage and backup. Two HP 1200C color inkjet printers provided hardcopy from any of the workstations.

The CTD FSK signal from the sea cable was demodulated and converted to a 9600 baud RS-232C binary data stream by the CTD deck unit. This data stream was fed to the Sun SPARCstation. The pylon deck unit was also connected to the Sun through a bi-directional 300 baud serial line, allowing rosette trips to be initiated and confirmed through the data acquisition software. A bitmapped color display provided interactive graphical display and control of the CTD rosette sampling system, including real-time raw and processed data displays, navigation, winch and rosette trip displays.

The CTD data acquisition, processing and control system was prepared by the console watch a few minutes before a deployment. A console operations log was maintained for each deployment, containing a record of every attempt to trip a bottle as well as any pertinent comments. Most CTD console control functions, including starting the data acquisition, were performed by pointing and clicking a trackball cursor on the display at pictures representing functions to perform. The system would then present the operator with a short dialog prompting with automatically-generated choices that could either be accepted as default or overridden. The operator was instructed to turn on the CTD and pylon power, then to examine a real-time CTD data display on the screen for stable voltages from the underwater unit. Once this was accomplished, the data acquisition and processing was begun and a time and position automatically associated with the beginning of the cast. The backup analog recording of the CTD signal on a VCR tape was started. A rosette trip display and pylon control window popped up, giving visual confirmation that the pylon was initializing properly. Various plots and displays were initiated. When all was ready, the console operator informed the deck watch by radio.

Once the deck watch had deployed the rosette, the deck watch leader provided the winch operator with a target depth (wire-out) and lowering rate (normally 30 meters/minute to 120 meters and then increasing to 60 meters/minute).

The console operator would examine the processed CTD data during descent via interactive plot windows on the display, which could also be initiated from other workstations on the network. Additionally, the operator would decide where to trip bottles on the up cast, noting this on the console log. The PDR and CTD altimeter channel were monitored to insure the bottom depth was known at all times.

The rosette distance above the bottom was monitored by the deck watch leader using the altimeter, which (together with the lack of ship motion in the ice) allowed bottom approaches to within 10 meters.

Bottles would be closed on the up cast by pointing the console trackball cursor at a graphic firing control and clicking a button. The data acquisition system would respond with the CTD rosette trip data and a pylon confirmation message in a window. All tripping attempts were noted on the console log. The console operator would then direct the winch operator to the next bottle stop. The console operator was also responsible for generating the sample log for the cast.

After the last bottle was tripped, the console operator would inform the deck watch and the rosette would be brought on deck. Once on deck, the console operator would terminate the data acquisition and turn-off the CTD, pylon and VCR recording. The VCR tape was filed.

1.6. CTD Data Processing

ODF CTD processing software consists of some 35-odd programs running under the Unix operating system. The initial CTD processing program (ctdba) is used either in real-time or with existing raw data sets to:

- Convert raw CTD scans into scaled engineering units, and assign the data to logical channels;
- Filter data channels according to specified filtering criteria;
- Apply sensor or instrument-specific response-correction models;
- Provide periodic averages of the channels corresponding to the output time-series interval; and
- 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 a number of 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 a different interval time-series. Calibration corrections to the series are maintained in separate files and are applied whenever the data are accessed.

ODF data acquisition software acquired and processed the CTD data in real-time, providing calibrated, processed data for interactive plotting and reporting during a cast. The 20 FPS data from the CTD were filtered, response-corrected and averaged to a 0.5 second time-series. Sensor correction and calibration models were applied to pressure, temperature, conductivity and O_2. Rosette trip data were extracted from this time-series in response to trip initiation and confirmation signals. The calibrated 0.5 second time-series data were stored on disk (as were the 20 FPS raw data) and were available in real-time for reporting and graphical display. At the end of the cast, various consistency and calibration checks were performed, and a 2.0 db pressure-series of the down-cast was generated and subsequently used for reports and plots.

CTD plots generated automatically at the completion of deployment were checked for potential problems. The two PRT temperature sensors were compared with the SBE 35 temperature reference and checked for sensor drift. The CTD conductivity sensor was monitored by comparing CTD values to check-sample conductivities and by deep TS comparisons with adjacent stations. The CTD dissolved O_2 sensor was calibrated to check-sample data.

The primary conductivity sensor developed a non-linear pressure hysteresis on cast 12/01. For this reason, the secondary PRT and conductivity sensors were processed and used for casts 1/01 through 14/01. While on transit to station 15, both conductivity sensors were damaged by freezing and had to be replaced. The secondary PRT and (new) secondary conductivity sensors were used for casts 15/01 and 16/01. On some casts, noise in the O_2 channel was evident. In these cases additional filtering was applied to the O_2 channel in the 0.5 second time-series, using a spike-removal filter that replaced points exceeding (by a specified multiple of the standard deviation) the least-squares polynomial fit of specified order of segments of the data. The filtered points were replaced by the filtering polynomial value.

Freezing conductivity sensors during deployment were a problem on two casts (13/01, 14/01). This was anticipated and was diagnosed immediately. The cast was lowered to about 50 meters (until the sensor responded normally), then raised to just-below the surface. The cast was then lowered normally. The initial yo-yo to 50 meters was removed from the data set, and the pressure calibration model re-applied to the pressure channel.

Operating in ice provided an additional complication to CTD data processing due to the lack of package motion initiated by ship-roll (figures 1.6.0 and 1.6.1). The 36-bottle rosette is a large (2 meter diameter, 2 meter height) package that has considerable drag and a noticeable wake. At bottle stops, the wake catches up with the package, resulting in anomalous CTD temperatures and conductivities in high gradient regions (figure 1.6.2).

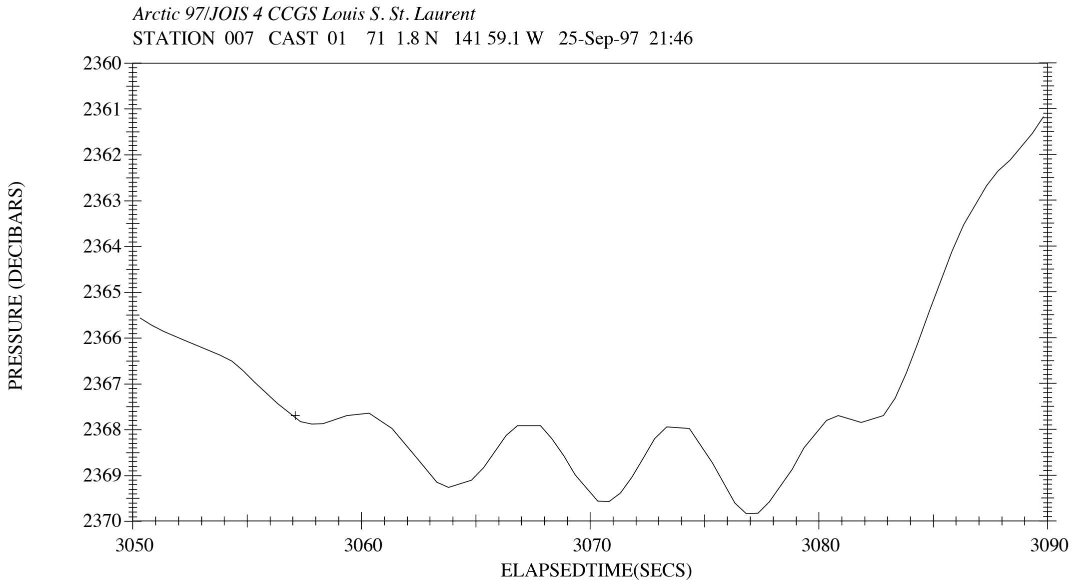


Figure 1.6.0 Bottom of cast 7/01. Ship-roll is evident.

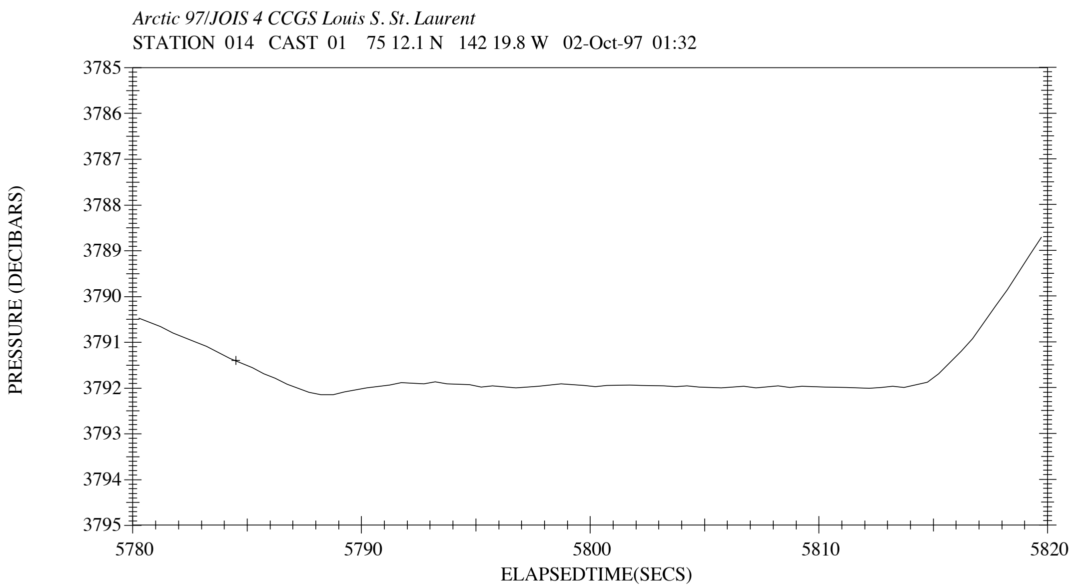


Figure 1.6.1 Bottom of cast 14/01. No ship-roll is evident.

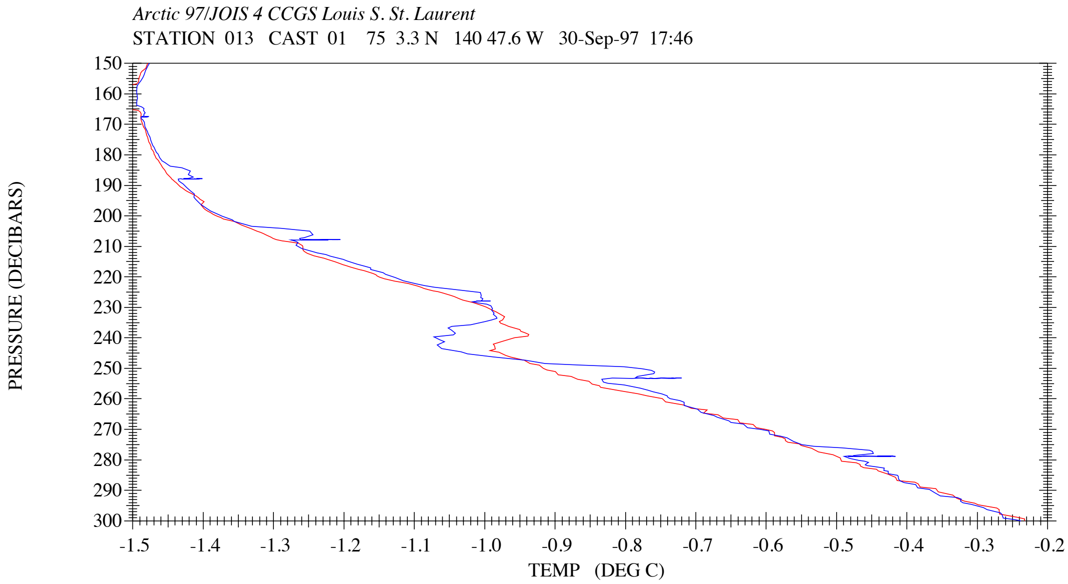


Figure 1.6.2 The effect of package wake on downcast and upcast CTD temperature.

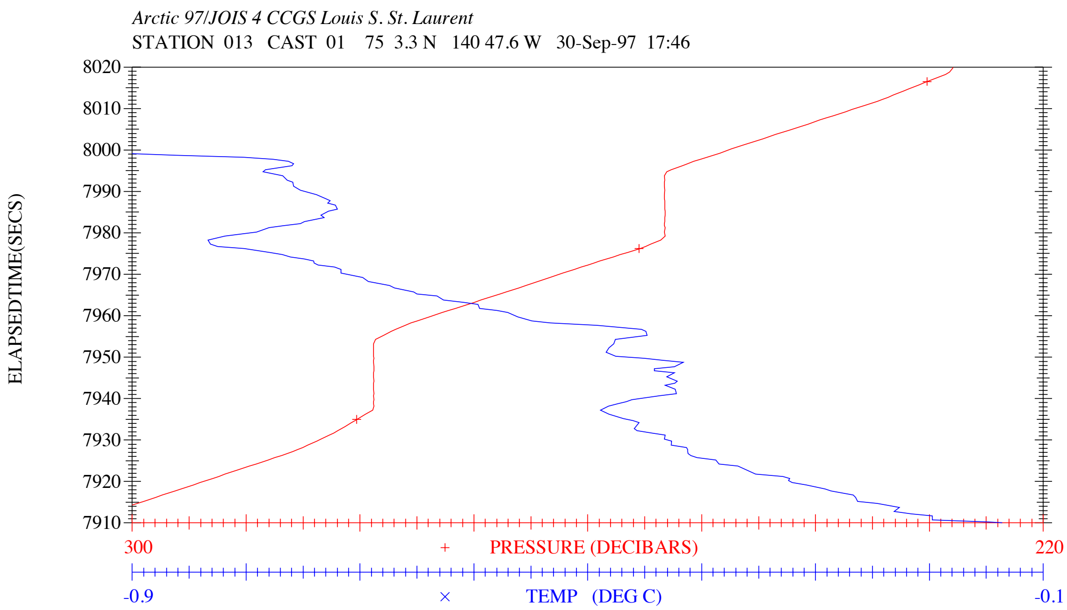


Figure 1.6.3 The bottom two rosette trips from figure 1.6.2, as a function of elapsed time.

Figures 1.6.2 and 1.6.3 show pronounced spikes at each bottle stop on the upcast temperature trace. This effect biased comparisons made between the CTD and check samples used to calibrate CTD conductivity. A more realistic comparison was obtained by extracting CTD data corresponding to a rosette trip five seconds before the actual trip. On casts 15/01 and 16/01 the CTD temperature was carefully monitored for stability at each bottle stop before tripping the bottle.

Another interesting effect was noted on several casts (10/01 through 15/01) while descending through the deep isothermal layer of the Canada Basin. When the descent rate was decreased to less than 10 M/min, a rise of up to 0.001°C was observed (figure 1.6.4), proof that this was an artifact.

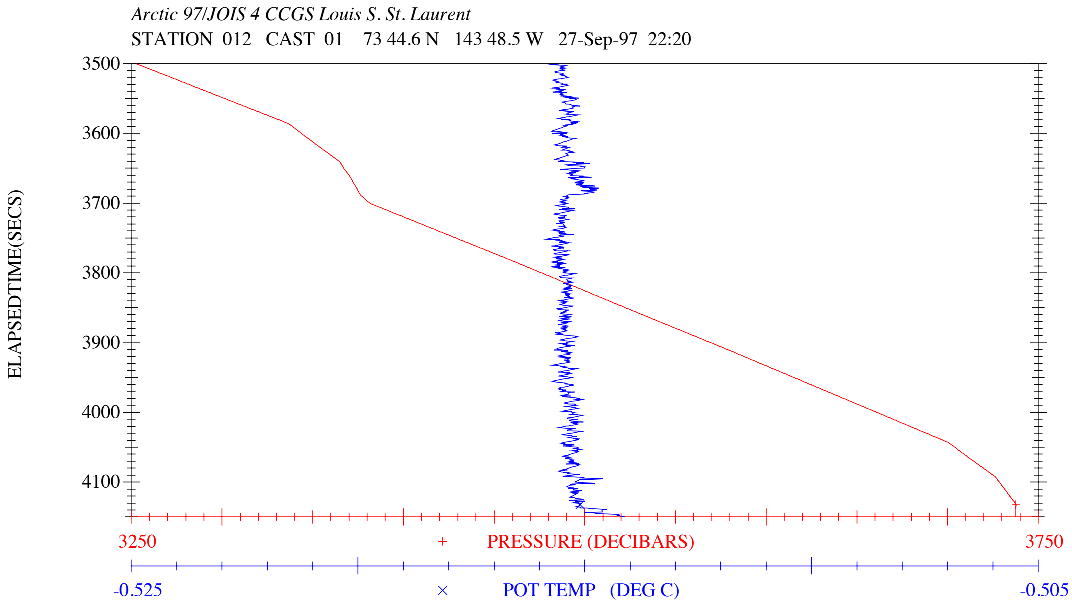


Figure 1.6.4 Thermal artifact on cast 12/01 produced by slowing the rosette in the deep isothermal layer.

Table 1.6.0 provides a list of all CTD casts requiring special attention.

Cast	Problems	Solutions
008/01	Winch stop @1566M d/c, O_2 offset.	Filtered.
012/01	T,C (T2,C2) noise@700-1800 secs	Filtered.
013/01	Frozen conductivity sensors	Filtered, pressure calibration model reapplied.
014/01	Frozen conductivity sensors	Filtered, pressure calibration model reapplied.
001/01-014/01	Package wake on up-cast, bad CTD trip values	Trip time offset -5.0 seconds.
014/01-015/01	Winch stop @ 2065M (seacable)	O_2 filtered.
015/01-016/01	New conductivity sensors	New conductivity calibration used.

Table 1.6.0 Tabulation of problem CTD casts.

1.7. CTD Shipboard Calibration Procedures

- ODF CTD #5 was used for all casts.
- A SBE 35 Laboratory-grade reference temperature sensor (#350006) was deployed on the rosette as a cross calibration check for the primary and secondary PRT temperatures.
- Due to the appearance of a non-linear pressure hysteresis in the primary conductivity channel on cast 12/01, the secondary PRT and conductivity sensors were used from all casts.
- CTD conductivity and dissolved O_2 were calibrated to *in-situ* check samples collected during each rosette cast.
- Due to the effects of the rosette package wake at bottle stops, rosette trip data were offset -5.0 seconds for casts 1/01-14/01.

- Both conductivity sensors were replaced prior to cast 015/01 because of damage to the original sensors caused by freezing.

CTD Pressure and Temperature

The final pressure and temperature calibrations will be determined when CTD #5 is returned to ODF. Based on the SBE 35 comparisons and the conductivity calibration, there were no significant shifts in the CTD pressure or temperature.

The primary (serial #15407) and secondary (serial #17534) PRTs both appeared to hold their calibration relative to the SBE 35 to within 0.0005 °C. Figures 1.7.0 and 1.7.1 summarize the comparisons between the SBE 35 temperature reference and the primary and secondary PRT temperatures.

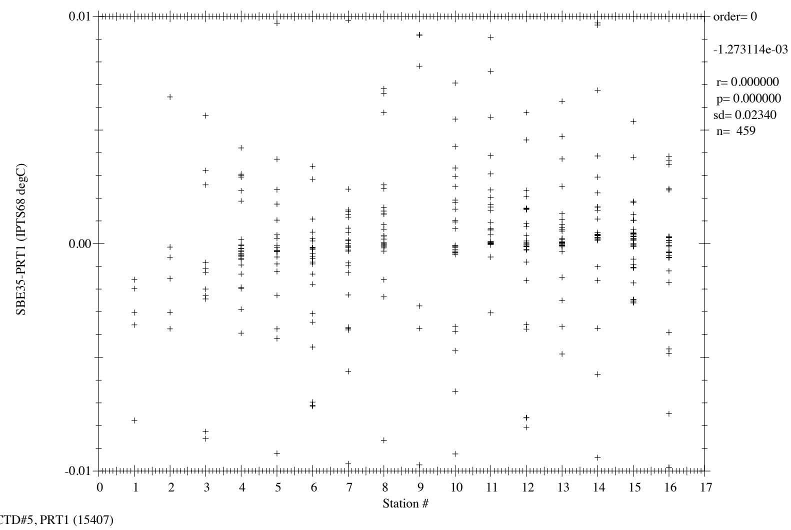


Figure 1.7.0 Comparison between SBE 35 reference and primary PRT temperatures.

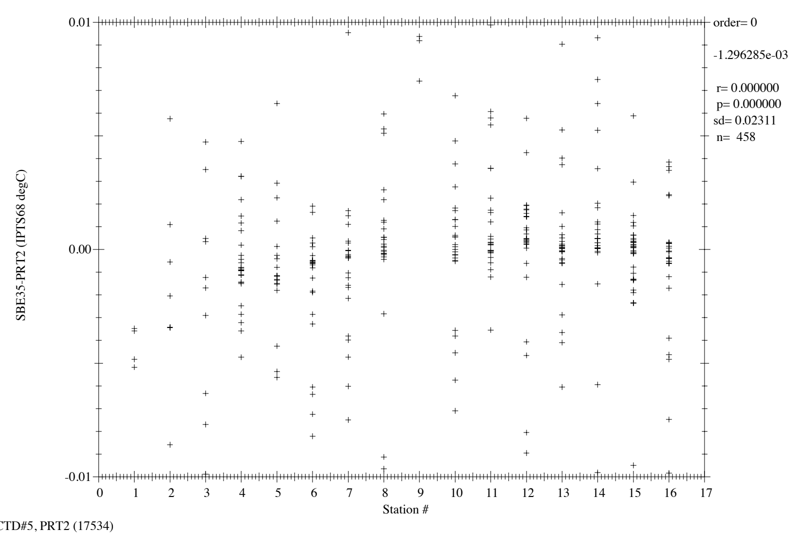


Figure 1.7.1 Comparison between SBE 35 reference and secondary PRT temperatures.

Conductivity

The CTD rosette trip pressure and temperature and the bottle salinity were used to calculate a bottle conductivity. Differences between the bottle and CTD conductivities were then used to derive a conductivity correction. This correction is normally linear for the 3cm conductivity cell employed in the Mark III.

Casts 1/01 through 14/01 were calibrated as a group. Since the conductivity sensors were replaced prior to cast 15/01, 15/01 and 16/01 were calibrated as a second group.

For casts 1/01 through 14/01 conductivity differences were fit to CTD conductivity for each cast, and the mean of the conductivity correction slopes examined (figure 1.7.2):

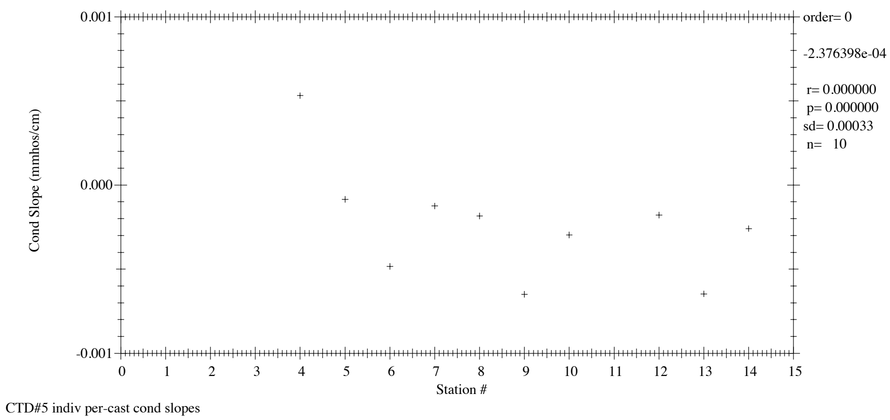


Figure 1.7.2 Conductivity correction slopes, per station.

No statistically significant change in the conductivity correction slope occurred through cast 14/01. Conductivity differences were then fit to CTD conductivity for all bottles to determine a mean conductivity correction slope (figure 1.7.3):

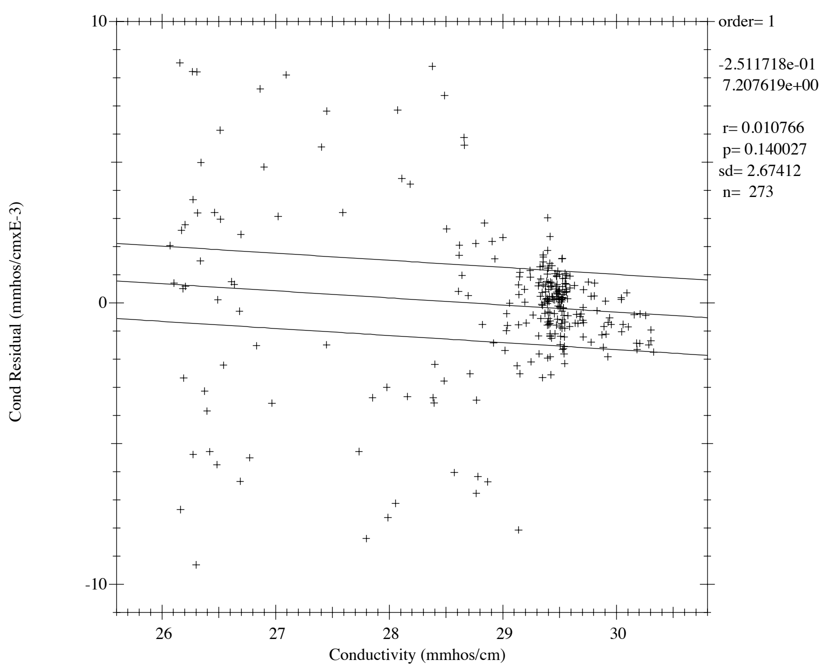


Figure 1.7.3 Mean conductivity correction slope, stations 1-14.

Since the mean correction slope did not significantly differ from the mean of individual slopes, the mean correction slope was applied and individual correction offsets fit for each cast. The resulting correction was adjusted for minor non-linearities in pressure. Figure 1.7.4 illustrates the correction offsets by station after applying the correction slope:

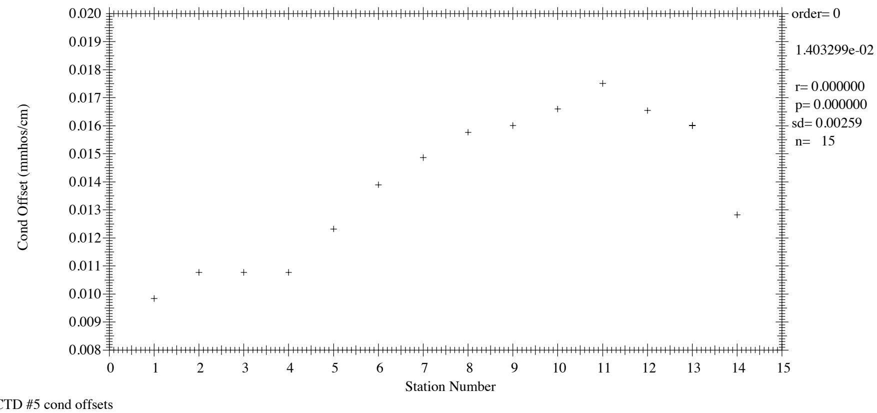


Figure 1.7.4 Conductivity correction offsets, casts 1/01-14/01.

The final form of the conductivity correction for casts 1/01-14/01 is:

$$G_{corr} = G_{raw} - 2.25278e-10P^2 + 6.7119e-07P - 0.000251172G_{raw} + c_{offset} \quad (1.7.0)$$

where:

G_{corr} = Corrected conductivity (mmhos/cm);
G_{raw} = Raw sensor conductivity;
P = Corrected CTD pressure (db); and
c_{offset} = Coefficient derived from the fit to bottle conductivity.

Casts 15/01 and 16/01 were determined in the same fashion. The final form of the conductivity correction for casts 15/01 and 16/01 is:

$$G_{corr} = G_{raw} + 1.31955e-09P^2 + -4.1843e-06P - 0.0298943G_{raw} + c_{offset} \quad (1.7.1)$$

Deep potential temperature-salinity overlays of successive CTD casts were then examined for consistency and the corrections fine-tuned.

Figures 1.7.5, 1.7.6 and 1.7.7 summarize the residual differences between bottle and CTD salinities after applying the conductivity correction.

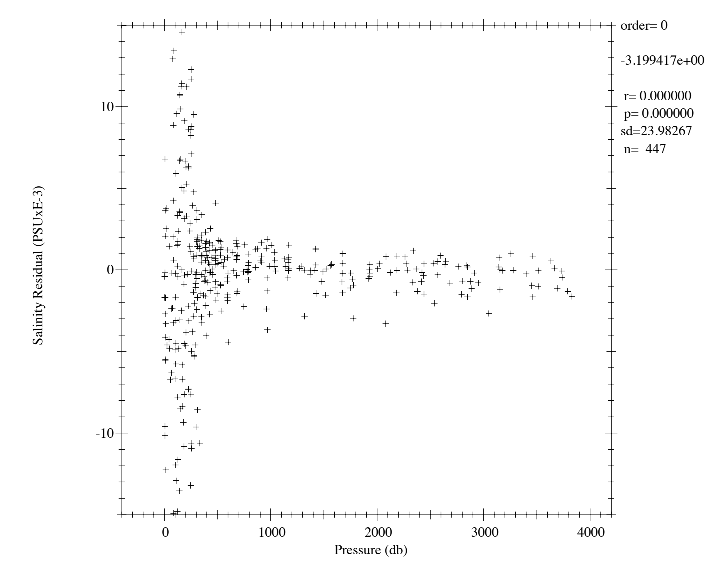


Figure 1.7.5 Salinity residual differences after correction, by pressure.

Note that because of extreme temperature and conductivity gradients, and rosette package wake effects, there are some large (> 0.5 PSU) differences between the CTD and bottle salinities. These large gradients typically occurred between 50 and 250 meters, and were excluded from the calibration.

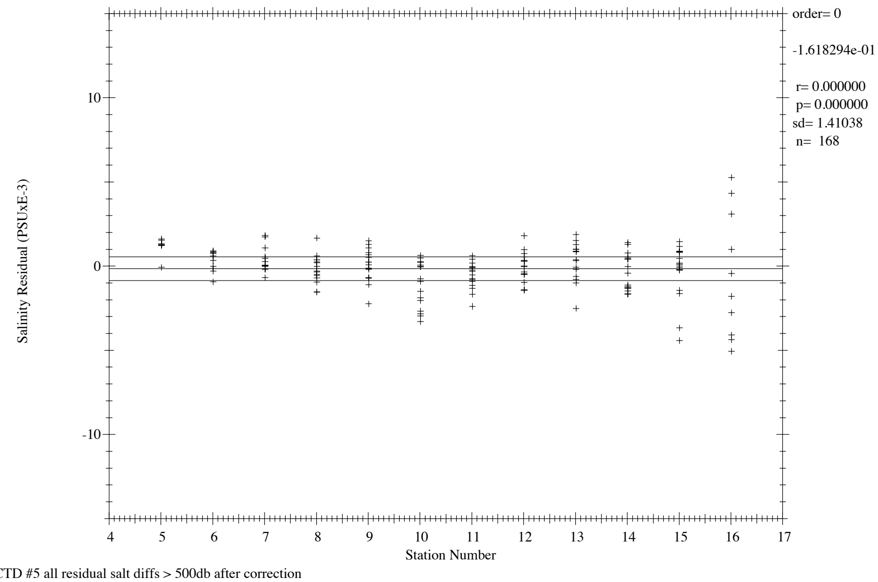


Figure 1.7.6 Salinity residual differences after correction, by station.

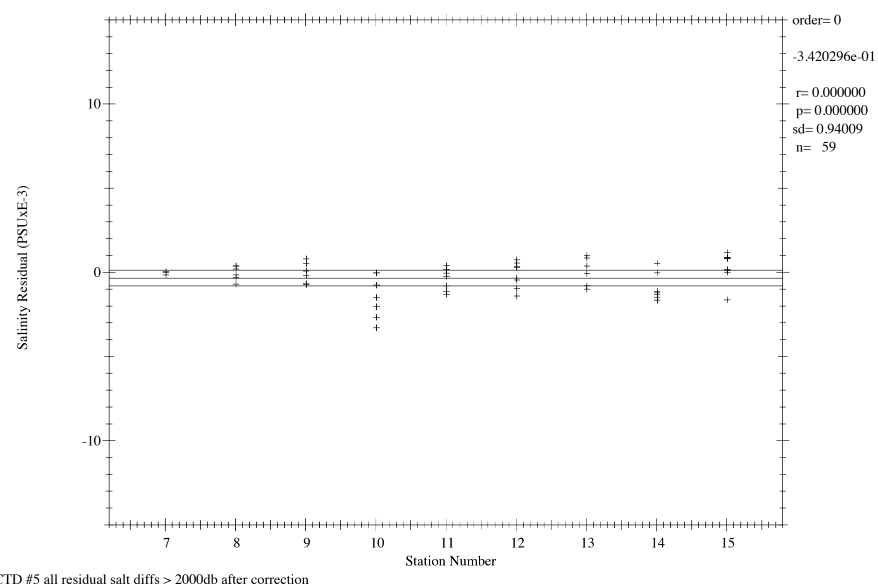


Figure 1.7.7 Deep salinity residual differences after correction, by station.

3σ from the mean residual in Figures 1.7.6 and 1.7.7, or ±0.0021 PSU for all salinities and ±0.0014 PSU for deep salinities represents the limit of repeatability of the bottle salinities with all sources of variation (e.g., Autosal, rosette, operators and samplers) included. This limit agrees with station overlays of deep TS. Within a cast (a single salinometer run), the precision of bottle salinities appears to exceed 0.001 PSU. The precision of the CTD salinities appears to exceed 0.0005 PSU.

CTD Dissolved Oxygen

The CTD dissolved O_2 sensor (serial #6-02-07) worked without major problems the entire cruise. There were problems fitting the CTD data to check samples because of rosette package wake, high gradients and cold temperatures. Additionally, the winch was stopped during the downcasts of 14/01 and 15/01 to examine the wire, which subsequently required filtering the CTD O_2 channel.

There are a number of problems with the response characteristics of the Sensormedics O_2 sensor used in the NBIS Mark III CTD, the major ones being a secondary thermal response and a sensitivity to profiling velocity. Because of these problems, CTD rosette trip data cannot be directly calibrated to O_2 check samples. Instead, down-cast CTD O_2 data are derived by matching the up-cast rosette trips along isopycnal surfaces. The differences between CTD O_2 modeled from these derived values and check samples are then minimized using a non-linear least-squares fitting procedure. Figures 1.7.8 and 1.7.9 show the residual differences between the corrected CTD O_2 and the bottle O_2 (ml/l) for each station.

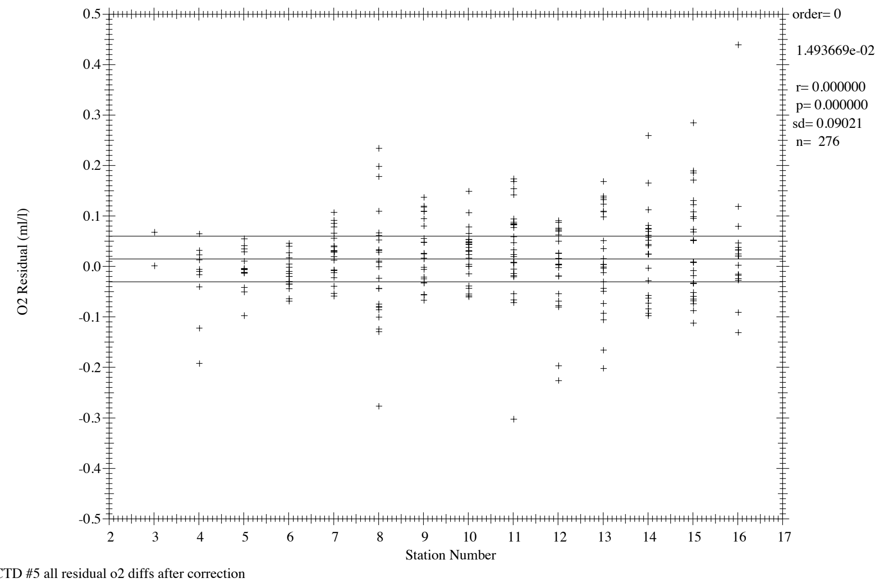


Figure 1.7.8 O_2 residual differences after correction, by station.

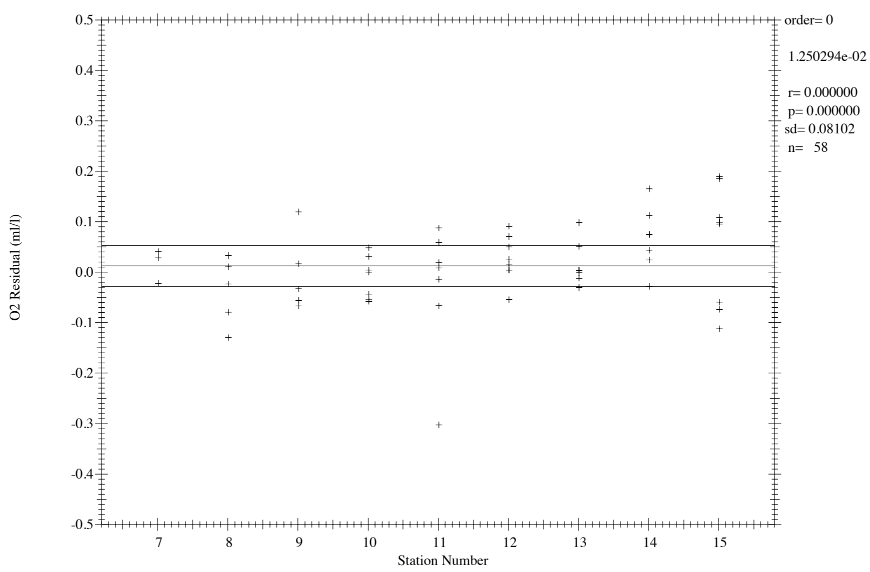


Figure 1.7.9 O_2 residual differences (>2000db).

Note that the mean of the differences is not zero, because the O_2 values are weighted by pressure before fitting. The standard deviations of 0.090 ml/l for all oxygens and 0.081 ml/l for deep oxygens are only intended as metrics of the goodness of the fits. ODF makes no claims regarding the precision or accuracy of CTD dissolved O_2 data.

The general form of the ODF O_2 conversion equation follows Brown and Morrison [Brow78] and Millard [Mill82], [Owen85]. ODF does not use a digitized O_2 sensor temperature to model the secondary thermal response but instead models membrane and sensor temperatures by low-pass filtering the PRT temperature. *In-situ* pressure and temperature are filtered to match the sensor response. Time-constants for the pressure response τ_p, and two temperature responses τ_{Ts} and τ_{Tf} are fitting parameters. The sensor current, or O_c, gradient is approximated by low-pass filtering 1° O_c differences. This term attempts to correct for reduction of species other than O_2 at the cathode. The time-constant for this filter, τ_{og}, is a fitting parameter. Oxygen partial-pressure is then calculated:

$$O_{pp} = [c_1 O_c + c_2] \cdot f_{sat}(S,T,P) \cdot e^{(c_3 P_l + c_4 T_f + c_5 T_s + c_6 \frac{dO_c}{dt})} \qquad (1.7.1)$$

where:

O_{pp}	= Dissolved O_2 partial-pressure in atmospheres (atm);
O_c	= Sensor current (μamps);
$f_{sat}(S,T,P)$	= O_2 saturation partial-pressure at S,T,P (atm);
S	= Salinity at O_2 response-time (PSUs);
T	= Temperature at O_2 response-time (°C);
P	= Pressure at O_2 response-time (decibars);
P_l	= Low-pass filtered pressure (decibars);
T_f	= Fast low-pass filtered temperature (°C);
T_s	= Slow low-pass filtered temperature (°C);
$\frac{dO_c}{dt}$	= Sensor current gradient (μamps/secs).

1.8. Bottle Sampling

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

- CFCs;
- ^{3}He;
- O_2;
- Total CO_2;
- Alkalinity;
- HCH;
- TOC, TON,

The following samples were drawn in the following approximate order:

- Nutrients;
- Tritium;
- ^{129}I;
- Salinity;
- ^{18}O;
- Ba;
- ^{137}Cs.

Note that some properties were subsampled by cast or by station, so the actual sequence of samples drawn was modified accordingly.

The correspondence between individual sample containers and the rosette bottle 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 insure that sampling progressed in proper drawing order.

Normal sampling practice included opening the drain valve before opening 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 can sometimes be useful in determining leaking or mis-tripped bottles.

Once individual samples had been drawn and properly prepared, they were distributed for analysis.

1.9. Bottle Data Processing

The first stage of bottle data processing consisted of verifying and validating individual samples, and checking the sample log (the sample inventory) for consistency. Oxygen flask numbers were verified, as each flask is individually calibrated. At this stage, bottle tripping problems would have been resolved, had there been any. The rosette bottle number was the primary identification for all samples taken from the bottle, as well as for the CTD data associated with the bottle. All CTD trips were retained whether confirmed or not so that they could be used to help resolve bottle tripping problems. Additionally, BIO (Bedford) numbers were assigned uniquely to each bottle tripped on the cruise. The BIO number was used by the tracer groups.

Diagnostic comments from the sample log were then translated into preliminary WOCE quality codes, together with appropriate comments. Each code indicating a potential problem would be investigated.

The next stage of processing would begin after all the samples for a cast had been accounted for. All samples for bottles suspected of leaking were checked to see if the properties were consistent with the profile for the cast, with adjacent stations and where applicable, with the CTD data. All comments from the analysts were examined and turned into appropriate water sample codes.

The third stage of processing continued throughout the cruise and later until the data set was judged "final". Various property-property plots and vertical sections were examined for both consistency within a cast and consistency with adjacent stations. In conjunction with this process the analysts would review (and sometimes revise) their data as additional calibration or diagnostic results became available. Assignment of a WHP water sample quality code to an anomalous sample value was typically achieved through consensus.

WHP water bottle quality flags were assigned with the following additional interpretations:

3	An air leak large enough to produce an observable effect on a sample is identified by a code of 3 on the bottle and a code of 4 on the oxygen. (Small air leaks may have no observable effect, or may only affect gas samples.)
4	Bottles tripped at other than the intended depth were assigned a code of 4. There may be no problems with the associated water sample data.
5	No water sample data reported. This is a representative level derived from the CTD data for reporting purposes. The sample number should be in the range of 80-99.

WHP water sample quality flags were assigned using the following criteria:

1	The sample for this measurement was drawn from a bottle, but the results of the analysis were not (yet) received.
2	Acceptable measurement.
3	Questionable measurement. The data did not fit the station profile or adjacent station comparisons (or possibly CTD data comparisons). No notes from the analyst indicated a problem. The data could be correct, but are open to interpretation.

4	Bad measurement. Does not fit the station profile, adjacent stations or CTD data. There were analytical notes indicating a problem, but data values were reported. Sampling and analytical errors were also coded as 4.
5	Not reported. There should always be a reason associated with a code of 5, usually that the sample was lost, contaminated or rendered unusable.
9	The sample for this measurement was not drawn.

WHP water sample quality flags were assigned to the CTDSAL (CTD salinity) parameter as follows:

2	Acceptable measurement.
3	Questionable measurement. The data did not fit the bottle data, or there was a CTD conductivity calibration shift during the cast.
4	Bad measurement. The CTD data were determined to be unusable for calculating a salinity.
8	The CTD salinity was derived from the CTD down cast, matched on an isopycnal surface.

WHP water sample quality flags were assigned to the CTDOXY (CTD oxygen) parameter as follows:

2	Acceptable measurement.
4	Bad measurement. The CTD data were determined to be unusable for calculating a dissolved oxygen concentration.
5	Not reported. The CTD data could not be reported.
9	Not sampled. No operational dissolved oxygen sensor was present on this cast.

Note that all CTDOXY values were derived from the down cast data, matched to the upcast along isopycnal surfaces.

Table 1.9.0 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 001-016								
	Reported Levels	WHP Quality Flag 1	2	3	4	5	8	9
Bottle	481	0	480	1	0	0	0	0
CTD Salt	481	0	481	0	0	0	0	0
CTD O2	481	0	481	0	0	0	0	0
Nitrite	450	0	449	1	0	0	0	31
Nitrate	450	0	449	1	0	0	0	31
Oxygen	442	0	426	13	3	4	0	35
Phosphate	450	0	447	3	0	0	0	31
Silicate	450	0	449	1	0	0	0	31
Salinity	479	0	476	3	0	0	0	2

Table 1.9.0 Frequency of WHP quality flag assignments.

Additionally, all WHP quality code comments are presented in Appendix A.

1.10. Salinity Analysis

Salinity samples were drawn into 200 ml Kimax high alumina borosilicate bottles after 3 rinses, and were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Salinity was determined after a box of samples had equilibrated to laboratory temperature, usually within 8-12 hours of collection. The draw time and equilibration time, as well as per-sample analysis time and temperature were logged.

A Guildline Autosal Model 8400A salinometer (55-654) located in a temperature-controlled laboratory was used to measure salinities. The salinometer was modified by ODF and contained interfaces for computer-aided measurement. A computer (PC) prompted the analyst for control functions (changing sample, flushing) while it made continuous measurements and logged results.

The salinometer was standardized for each cast with IAPSO Standard Seawater (SSW) Batch P-125, using at least one fresh vial per cast. The estimated accuracy of bottle salinities run at sea is usually better than 0.002 PSU relative to the particular Standard Seawater batch used. PSS-78 salinity [UNES81] was then calculated for each sample from the measured conductivity ratios, and the results merged with the hydrographic database.

479 salinity measurements were made and 35 vials of standard water were used. Various statistics pertaining to each run are summarized in Table 1.10.0. The temperature stability of the laboratory used to make the measurements was very good, ranging from 22.6 to 24.8°C. The salinometer bath temperature was maintained at 24°C. The salinities were used to calibrate the CTD conductivity sensor.

Autosal log starting 25/09/1997
Expedition: JOIS LEG 4
Ship: CCGS LOUIS S. ST. LAURENT
Salinometer serial number 55-654

St	Cs	Box Nbr	Nbr Smp	Equ Hrs	Date	Start Time	End Time	Start Air	End Air	Bath Temp	Worm Batch	Start Sby	End Sby	Std Dial	Drift	OPR
1	1	J	6	18.9	2509	2042	2112	23.4	23.5	24	P125	6507	6508	569	-9.00000	CM
2	1	J	8	18.1	2509	2113	2138	23.5	23.8	24	P125	6507	6508	569	-9.00000	CM
3	1	J	15	17.3	2509	2200	2331	23.7	24.2	24	P125	6508	6544	569	+0.00006	SR
4	1	C	27	17.4	2609	0108	0246	23.5	24.0	24	P125	6502	6501	563	+0.00006	SR
5	1	R	34	21.1	2609	1426	1622	23.3	24.2	24	P125	6501	6491	563	-0.00000	SR
6	1	E	32	20.6	2609	1809	1915	23.6	24.3	24	P125	6502	6503	563	+0.00000	CM
7	1	J	35	42.9	2609	1917	2043	24.3	24.7	24	P125	6502	6502	563	-0.00002	SR
8	1	C	36	19.5	2709	0031	0206	23.6	24.0	24	P125	6502	6502	563	+0.00003	SR
9	1	R	36	20.8	2709	1545	1711	22.7	23.8	24	P125	6503	6503	563	+0.00000	SR
10	1	J	36	18.8	2709	1809	1937	23.3	23.8	24	P125	6503	6502	563	+0.00001	SR
11	1	E	36	14.9	2709	1938	2102	23.8	24.3	24	P125	6502	6502	563	+0.00008	SR
12	1	J	36	12.5	2809	1436	1615	22.6	24.0	24	P125	6497	6496	554	-0.00003	SR
13	1	E	36	24.8	0110	2127	2249	23.8	24.4	24	P125	6500	6500	558	-9.00000	SR
13	2	C	5	999.0	0110	2250	2314	24.4	24.7	24	P125	6500	6499	558	+0.00004	SR
14	1	C	36	16.2	0210	2011	2230	23.4	24.3	24	P125	6501	6501	558	-9.00000	SR
11	91	A	7	137.8	0210	2230	2257	24.3	24.8	24	P125	6501	6500	558	+0.00007	SR
15	1	C	36	38.2	1410	1825	2002	23.1	22.6	24	P125	6497	6497	547	-9.00000	SR
112	1	A	3	104.1	1410	2004	2020	22.6	22.1	24	P125	6497	6496	547	+0.00001	SR
16	1	E	29	25.0	1610	2014	2125	22.2	22.5	24	P125	6497	6497	547	+0.00001	SR

Table 1.10.0 Arctic 97/JOIS Leg 4 per-box salinometer log.

1.11. Oxygen Analysis

Samples were collected for dissolved oxygen analyses soon after the rosette sampler was brought on board and after CFC and helium were drawn. Nominal 125 ml volume-calibrated iodine flasks were rinsed twice with minimal agitation, then filled via a drawing tube and allowed to overflow for at least 3 flask volumes. The sample temperature was measured with a small platinum resistance thermometer embedded in the drawing tube. Draw temperatures are useful in detecting possible bad trips even as samples are being drawn. Reagents were added to fix the oxygen before stoppering. The flasks were shaken twice; immediately after drawing, and then again after 20 minutes, to assure thorough dispersion of the $MnO(OH)_2$

precipitate. The samples were analyzed within 4 hours of collection.

Dissolved oxygen analyses were performed with an SIO-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365 nm wavelength ultra-violet light. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 ml buret. The apparatus is controlled by a PC running ODF software. ODF uses a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et. al* [Culb91], but with higher concentrations of potassium iodate standard (approximately 0.012N) and thiosulfate solution (50 gm/l). Standard solutions prepared from pre-weighed potassium iodate crystals were run at the beginning of each session of analyses, which typically included from 1 to 3 stations. Several standards were made up during the cruise and compared to assure that the results were reproducible, and to preclude the possibility of a weighing error. Reagent/distilled water blanks were determined to account for oxidizing or reducing materials in the reagents. No preservative was added to the thiosulfate.

The auto-titrator generally performed well, although titrator computer-related glitches caused 7 samples to be lost. The titrator computer also did not maintain the proper date.

Blanks, and thiosulfate normalities corrected to 20°C, calculated from each standardization, were plotted versus time, and were reviewed for possible problems. New thiosulfate normalities were recalculated after the blanks had been smoothed. These normalities were then smoothed, and the oxygen data were recalculated.

Oxygens were converted from milliliters per liter to micromoles per kilogram using the *in-situ* temperature. Ideally, for whole-bottle titrations, the conversion temperature should be the temperature of the water issuing from the bottle spigot. The sample temperatures were measured at the time the samples were drawn from the bottle, but were not used by the reporting software in the conversion from milliliters per liter to micromoles per kilogram.

Oxygen flasks were calibrated gravimetrically with degassed deionized water (DIW) to determine flask volumes at ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect bottle volume is detected. All volumetric glassware used in preparing standards is calibrated as well as the 10 ml Dosimat buret used to dispense standard Iodate solution.

Iodate standards are pre-weighed in ODF's chemistry laboratory to a nominal weight of 0.44xx grams and the exact normality is calculated at sea. Potassium Iodate (KIO_3) is obtained from Johnson Matthey Chemical Co. and is reported by the suppliers to be > 99.4% pure. All other reagents are "reagent grade" and are tested for levels of oxidizing and reducing impurities prior to use.

442 oxygen measurements were made. The temperature of the laboratory used for the analyses ranged from 26° to 29°C, and temperature stability was generally poor.

1.12. Nutrient Analysis

Nutrient samples were drawn into dual 8 ml high density polyethylene, narrow mouth, screw-capped centrifuge tubes which were rinsed three times before filling. The tubes were rinsed with 1.2N HCL before each filling. Standardizations were performed at the beginning and end of each group of analyses (one cast, up to 36 samples) with a set of an intermediate concentration standard prepared in low-nutrient seawater for each run from secondary standards. The secondary standards were prepared aboard ship by dilution from dry, pre-weighed primary standards. Sets of 6-7 different concentrations of shipboard standards were analyzed periodically to determine the deviation from linearity as a function of concentration for each nutrient. All nutrient concentrations encountered on this cruise were in their respective linear ranges.

Nutrient analyses (phosphate, silicate, nitrate and nitrite) were performed on a 4 channel Technicon AutoAnalyzer II borrowed from IOS, generally within one hour of the cast. Occasionally some samples were refrigerated at 4°C for a maximum of 4 hours. The methods used are described by Gordon *et al*. [Atla71], [Hage72], [Gord92]. The colorimeter output from each of the four channels were recorded on a strip-chart recorder and logged manually.

Silicate is analyzed using the technique of Armstrong *et al*. [Arms67]. Ammonium molybdate is added to a seawater sample to produce silicomolybdic acid which is then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. Tartaric acid is added to impede PO_4 color interference. The sample is passed through a 50 mm flowcell and the absorbence measured at 660nm.

Modifications of the Armstrong *et al.* [Arms67] techniques for nitrate and nitrite analysis are also used. The seawater sample for nitrate analysis is passed through a cadmium column where the nitrate is reduced to nitrite. Sulfanilamide is introduced, reacting with the nitrite, then N-(1-naphthyl)ethylenediamine dihydrochloride which couples to form a red azo dye. The reaction product is then passed through a 50 mm flowcell and the absorbence measured at 550 nm. The same technique is employed for nitrite analysis, except the cadmium column is not present.

Phosphate is analyzed using a modification of the Bernhardt and Wilhelms [Bern67] technique. An acidic solution of ammonium molybdate is added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The reaction product is heated to 50°C to enhance color development, then passed through a 50 mm flowcell and the absorbence measured at 820 nm.

Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at zero pressure, *in-situ* salinity, and an assumed laboratory temperature of 25°C.

Na_2SiF_6, the silicate primary standard, is obtained from Aesar, a division of Johnson Matthey Chemical Co., and is reported by the supplier to be >98% pure. Primary standards for nitrate (KNO_3), nitrite ($NaNO_2$), and phosphate (KH_2PO_4) are also obtained from Johnson Matthey Chemical Co. and the supplier reports purities of 99.999%, 97%, and 99.999%, respectively.

450 nutrient analyses were performed. No major problems were encountered with the measurements. The efficiency of the cadmium column used for nitrate was monitored throughout the cruise and ranged from 99.5-100.0%. The temperature of the laboratory used for the analyses ranged from 26° to 29°C, and temperature stability was generally poor. Attempts to improve the stability using oscillating fans met with little success. The laboratory temperature was monitored and recorded.

TABULATED DATA

The following data are tabulated:

A WOCE Hydrographic Program format (Joyce et al., 1994) summary ("*.SUM") file was produced for the expedition. In it, station positions were taken from a GPS receiver in a small van near the CTD winch. Times (all in Universal Time) are accurate within about one minute. Due to problems with the ship's depth sounder, the reported depths are calculated from corrected maximum CTD pressure and calculated CTD density profiles, plus the altimeter height above bottom.

CTD and bottle data for each station are tabulated in WOCE Hydrographic Program formats (Joyce et al., 1994): hydrographic data in a "*SEA" file and CTD data in ".CTD" files. The single exception to the format and content rules for the bottle data is that two data indices appear in the report. The WOCE recommendations, followed by the lead group on the bottle data, are for indexing of samples via a hierarchy of expedition/station/cast/bottle, where the bottle number refers to the Niskin bottle number for the sample. The second index is known as a "Bedford number" and is a unique, one-time-only identifier assigned to each bottle closed during an expedition, and also attached to any samples drawn from it. These are included in the "*.SEA" file to assist co-investigators' registration of their sample data.

Depths, in meters, are calculated using the Saunders-Mantyla step-wise application of the hydrostatic equation.

Temperatures reported are ITS90.

Practical salinities (PSS78) are used throughout. Neither the symbol ‰ nor "psu" are used for PSS78 salinities.

Dissolved oxygen concentrations, all from bottle samples, are listed in units of µmol/kg, as per WOCE Hydrographic Program practice. Although for the oxygen titration methodology employed here the correct temperature to use for conversion from the original units of ml/L to µmol/kg is the temperature of the water as it issues from the Niskin bottle spigot, and although that temperature was measured for every water sample, software limitations make it necessary to use in situ water temperature for the conversions. This introduces only a very small error.

Nutrient values are reported in µmol/kg, as per WOCE Hydrographic Program recommendations.

Potential temperatures are calculated from Fofonoff's (1977) computational method, based upon Bryden's (1973) results. Densities, expressed in sigma- notation (sigma-p = rho-p - 1000 kg/m3), are calculated at the sea surface, and 1000, 2000, and 3000 decibars, from the International Equation of State (EOS80; see UNESCO, 1981). For example, rho-3 is the in situ density in kg/m3 that the water would have if moved adiabatically to the depth where the pressure is 3000 db (= 30 MPa), and sigma-3 is this value less 1000 Kg/m3.

OUTCOME OF THIS PROGRAM

The Canada Basin section was a central focus of the JOIS Leg 4 science plan but an ancillary program from the perspective of SHEBA. Planning letters indicated that 72 hours of dedicated wire time were tentatively allocated to the Section. With much time lost to logistics difficulties at the beginning of the expedition (see narrative), it was expected that the Section would of necessity be carried out at an at-least reduced level. This reduction took place, as measured by the final count of 15 stations along track, reduced from ca. 23 in the original plan over this distance, with ≈23 hours of wire time used. A different and more encouraging perspective is afforded by the data. The shelf-slope-basin transition was well measured, with the principal reduction in stations there caused more by the combination of problems with the depth sounder with a steep slope than any limitations placed by the ship or SHEBA. Station spacing over the basin was to have been 18-20 miles, but section plots and other data representations suggest that lateral variability in the deep basin domain was low, and that the section program suffered little as a result of the reduced lateral coverage. The primary objective of linking boundary and interior measurements from a single expedition aimed at producing reference-quality measurements was well-realized. New and occasionally subtle features were seen that could not be gleaned easily from comparing boundary and interior data from two expeditions. The JOIS Leg 4 Canada Basin section will also help to set the tone for future work. The expedition can be regarded as a success, with much owed to the departments and agencies which supported this work on short notice.

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2. Helium, Tritium and ^{18}O

Sample Collection

Samples for the analysis of helium, tritium and ^{18}O were collected from the 10 L Niskin bottles. The strategy was to sample the entire water column. 216 samples for combined helium and tritium analysis, 207 samples for combined tritium and ^{18}O analysis, and 362 samples for ^{18}O analysis were collected. Water samples for helium and tritium analysis were collected in 40 ml copper tubes sealed by pinch off tools. Water samples for tritium and ^{18}O analysis were collected in 1 L glass bottles. Water samples for ^{18}O analysis were collected in 30 ml glass bottles.

Sample Analysis

Samples for helium and tritium analysis from the copper tubes and the 1 L glass bottles will be measured in the Noble Gas Laboratory of the Lamont-Doherty Earth Observatory of Columbia University according to the procedure described in detail by Ludin et al. (submitted). ^{18}O samples from the 1 L glass bottles will be analyzed mass spectrometrically in the Stable Isotope Laboratory of the Lamont-Doherty Earth Observatory of Columbia University, and from the 30 ml glass bottles by K. Falkner of Oregon State University.

References

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Data Processing Notes

Date	Contact	Data Type	Summary
2010-09-01	*Fields, J*	BTL	Copied from CARINA collection This bottle file was part of the CARINA collection compiled by Bob Key.
2010-11-19	*Muus, D*	CTD/BTL	data online Notes on Louis St-Laurent cruise JOIS 97 Leg IV Expocode 18SN19970924 101119/dm 1. CARINA bottle data file posted Sept 1, 2010. (Date Stamp 20081215PRINUNIVRMK) 2. Header notes modified Sept 15, 2010: Chief Scientist: "Jim Swift" vs "F. McLaughlin, K. Faulkner" Faulkner misspelling corrected to Falkner. 3. CARINA bottle file missing TIME, CTDSAL, CTDOXY. Some SALNTY appear to be CTDSAL. Changed bottle numbers on CARINA file Station 13 Casts 1 & 2 to match ODF bottle numbers. (e.g. Cast 1 changed from 5-40 to 1-36, bottom-top.) 4. ODF bottle file(dated Dec 16, 1997) has slightly different nutrients, CFCs, TCARBN and ALKALI. No TCARBN or ALKALI flags. 5. Assume ODF file has best CTD, oxygen and nutrient data and CARINA has best CFCs, TCARBN and ALKALI. 6. Merged CARINA CFCs, TCARBN and ALKALI into ODF bottle file. 7. ODF/TIC (C. Mattson) Preliminary Cruise Report says departure Tuktoyaktuk 18 Sep 1997. ODF unsigned 25 page Preliminary Cruise Report says departure Tuktoyaktuk 20 Sep 1997. CARINA file used EXPOCODE 18SN19970924. (Date of first station) Used Expocode 18SN19970924 since it has been previously used. 8. Made WOCE and Exchange format CTD files from ODF files dated Oct 17, 1997 9. New WOCE and Exchange format bottle and CTD files posted on website Nov 19, 2010.
2010-11-24	*Kappa, J*	CrsRpt	Website Updated New PDF version online I just put a preliminary pdf cruise report for jois97 in the JOIS97_18SN19970924 directory.
2010-12-10	*Muus, D*	CTD/SUM	Website Update CTD Exchange & sum files online Notes on Louis St-Laurent cruise JOIS 97 Leg IV Expocode 18SN19970924 101119/dm 1. CARINA bottle data file posted Sept 1, 2010. (Date Stamp 20081215PRINUNIVRMK) 2. Header notes modified Sept 15, 2010: Chief Scientist: "Jim Swift" vs "F. McLaughlin, K. Faulkner" Faulkner misspelling corrected to Falkner. 3. CARINA bottle file missing TIME, CTDSAL, CTDOXY. Some SALNTY appear to be CTDSAL. Changed bottle numbers on CARINA file Station 13 Casts 1 & 2 to match ODF bottle numbers. (e.g. Cast 1 changed from 5-40 to 1-36, bottom-top.) 4. ODF bottle file(dated Dec 16, 1997) has slightly different nutrients, CFCs, TCARBN and ALKALI. No TCARBN or ALKALI flags. 5. Assume ODF file has best CTD, oxygen and nutrient data and CARINA has best CFCs, TCARBN and ALKALI. 6. Merged CARINA CFCs, TCARBN and ALKALI into ODF bottle file. 7. ODF/TIC (C. Mattson) Preliminary Cruise Report says departure Tuktoyaktuk 18 Sep 1997. ODF unsigned 25 page Preliminary Cruise Report says departure Tuktoyaktuk 20 Sep 1997. CARINA file used EXPOCODE 18SN19970924. (Date of first station) Used Expocode 18SN19970924 since it has been previously used. 8. Made WOCE and Exchange format CTD files from ODF files dated Oct 17, 1997. 9. New WOCE and Exchange format bottle and CTD files posted on website Nov 19, 2010.

2014-03-12	*Kappa, J* CrsRpt Website Updated Final TXT version online I've placed a final TXT version of the cruise report: JOIS97_18SN19970924do.txt into the directory: http://cchdo.ucsd.edu/data/co2clivar/arctic/JOIS97/JOIS97_18SN19970924/ . It includes all the reports provided by the cruise PIs, summary pages and CCHDO data processing notes.
2014-03-12	*Kappa, J* CrsRpt Website Updated Final PDF version online I've placed a final pdf version of the cruise report: JOIS97_18SN19970924do.pdf into the directory: http://cchdo.ucsd.edu/data/co2clivar/arctic/JOIS97/JOIS97_18SN19970924/ . It includes all the reports provided by the cruise PIs, summary pages, CCHDO data processing notes and internal links to figures, tables and appendices.