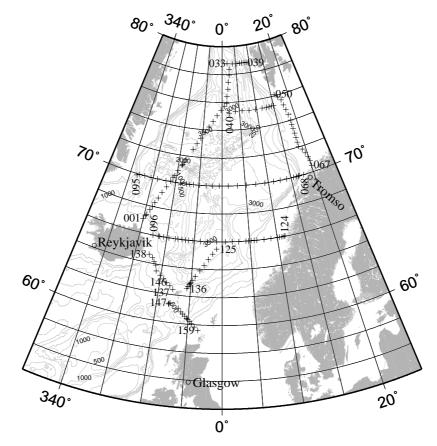# Nordic Seas

R/V Knorr Voyage 166-11
30 May 2002 - 1 July 2002
Reykjavik, Iceland - Glasgow, Scotland

Chief Scientist: Dr. William M. Smethie, Jr.
Lamont-Doherty Earth Observatory
Columbia University

Nordic Seas Cruise Track

ODF Preliminary Cruise Report
rev. 1 April 2004

Data Submitted by:

1. Summary

A hydrographic survey consisting of CTD/rosette sections in the North Atlantic was carried out May to July 2002. The R/V Knorr departed Reykjavik, Iceland on 30 May 2002. 159 CTD/Rosette stations were occupied from 1-30 June. 3282 bottles were tripped resulting in 3255 usable bottles. Water samples (up to 36) and CTDO data were collected in most cases to within 10 meters of the bottom. Salinity, dissolved oxygen and nutrient samples were analyzed from every bottle sampled on the rosette. The cruise ended in Glasgow, Scotland on 1 July 2002.

2. Personnel

Name	Affiliation	Duties
Alfimov, Vassili	Ion Physics Div.,Uppsala Univ.	I129/SF6
Anderson, George C.	SIO/MPL	Nutrients/Rosette
Bahr, Frank	WHOI	LADCP/Rosette
Bellerby, Richard G.J.	*BCCR	TCO2/PCO2/Alkalinity/pH
Calderwood, John K.	SIO/STS/SEG	ET/O2/Rosette
Dachille, Anthony	LDEO	Helium/Tritium/O18
Ghan, Ryan	LDEO	CFCs
Gorman, Eugene	LDEO	CFCs
Gorodetskaia, Irina	LDEO	CTD Console/LADCP/Sample Cop
Harris, Grant B.	WHOI	SSSG Technician
Hiller, Scott M.	SIO/STS/SEG	Watch Leader/ET/Salts
Johnson, Mary Carol	SIO/STS/ODF	CTD Data Processing
Laird, Robert S.	WHOI	SSSG Technician
Mathieu, Guy	LDEO/Retired	CFCs
Mattson, Carl W.	SIO/STS/SEG	TIC/Watch Leader/ET/Salts
Messias, Marie-Jose	Univ.of East Anglia,UK	SF6
Mignon, Benoit	*BCCR	TCO2/PCO2/Alkalinity/pH
Muus, David A.	SIO/PORD	Bottle Data Processing
Nondal, Gisle	Univ.of Bergen	TCO2/PCO2/Alkalinity/pH
Patrick, Ronald G.	SIO/STS/ODF	O2/Rosette
Quiroz, Erik W.	Univ.of So.Miss.	Nutrients
Searson, Sarah	LDEO	CFCs
Sequeira, Sandra	*LODYC	I129/SF6
Smethie, William M.,Jr.	LDEO	Chief Scientist
Smith, Helen B.	Univ.of East Anglia,UK	SF6
Swift, James H.	SIO/STS/ODF	co-Chief Scientist
*BCCR Bjerknes Centre for Climate Research		
*LODYC Laboratoire d'Océanographie Dynamique et de Climatologie		

Table 2.0 Scientific Personnel Nordic Seas

3. Scientific Programs

Analysis	Institution	Principal Investigator
Basic Hydrography (Salinity,O2,Nutrients,CTD)	SIO	J.Swift
CFCs	LDEO	W.Smethie
I129/SF6	LDEO	W.Smethie
He/Tr/O18	LDEO	P.Schlosser
pCO2/TCO2/Alkalinity/PH	BCCR	R.Bellerby
ADCP and LADCP	WHOI	F.Bahr
UW Meteorology	WHOI	

Table 3.0 Principal Programs of Nordic Seas

The SIO ODF hydrographic measurements program is described in detail in this report.

4. Description of Measurement Techniques

4.1. Hydrographic Measurements Program

The basic hydrography program consisted of salinity, dissolved oxygen and nutrient (nitrite, nitrate, phosphate and silicate) measurements made from bottles taken on CTD/rosette casts, plus pressure, temperature, salinity and dissolved oxygen from CTD profiles. 159 CTD/rosette casts were made, usually to within 10 meters of the bottom. The distribution of samples is illustrated in figures 4.1.0-4.1.4.
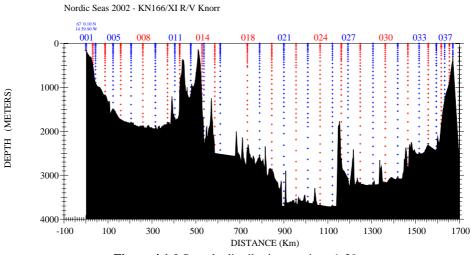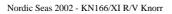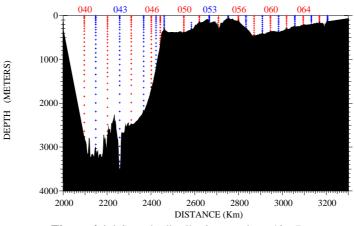

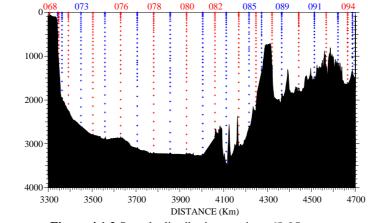**Figure 4.1.0** Sample distribution, stations 1-39.

Figure 4.1.1 Sample distribution, stations 40-67.

Nordic Seas 2002 - KN166/XI R/V Knorr

Figure 4.1.2 Sample distribution, stations 68-95.
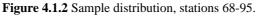
Nordic Seas 2002 - KN166/XI R/V Knorr

Figure 4.1.3 Sample distribution, stations 96-124.

Nordic Seas 2002 - KN166/XI R/V Knorr

Figure 4.1.4 Sample distribution, stations 125-159.

4.2. Water Sampling Package

CTD/rosette casts were performed with a system consisting of a 36-bottle rosette frame (ODF), a 36-place pylon (SBE32) and 36 10-liter PVC bottles (ODF). Underwater electronic components consisted of an ODF-modified NBIS MKIII CTD (ODF #5) with dual conductivity and temperature sensors, Sea-Bird SBE43 oxygen sensor with pump, RDI LADCP and Simrad altimeter.

Equipment used on stations 1-159:		
36-bottle rosette frame	ODF	s/n RSS1-94
Bullister 10-liter bottles	ODF	1-36
36-place Water Sampler	Sea-Bird SBE32	s/n 3213290-0113
Digital Reversing Temperature Sensor	Sea-Bird SBE35	s/n 3516590-0011
ODF CTD #5	NBIS MKIIIB	s/n 01-1070
Pressure	Paine	s/n 77017
Temperature#1	Rosemount 171BJ	s/n 13407
Temperature#2	Rosemount 171BJ	s/n 17534
Conductivity#1	GO 09035-00151	s/n P41
Conductivity#2	GO 09035-00151	s/n O24
Oxygen Sensor	Sea-Bird SBE43	s/n 430072
Pump for Oxygen Sensor	Sea-Bird SBE5T	s/n 052146
Altimeter	Simrad 1007	s/n 0201074
Battery Pack for Pump and Altimeter	ODF	
LADCP	RDI CS-150KHZ BB	s/n 2644
XTC Firmware	v2.04	
CPU Firmware	v5.59	
LADCP Battery Pack	WHOI	
Additional equipment used only on Stations 138-146:		
Data Logger/Controller (for ODF CTD #5)	ODF	
CTD	Sea-Bird 9*plus*	s/n 09P19275-0576
Pressure	Paroscientific Digiquartz	s/n 75639
Temperature	SBE3P	s/n 4035
Conductivity	SBE4C	s/n 2178

Table 4.2.0 Underwater sampling package.

CTD #5 was mounted horizontally along the bottom of the rosette frame, with the SBE43 dissolved oxygen and SBE35 PRT sensors deployed next to the CTD. The altimeter reported distance-above-bottom. The dissolved oxygen sensor and altimeter were interfaced with the CTD, and their data were incorporated into the CTD data stream. The LADCP was vertically mounted to the frame inside the bottle rings. The rosette system was suspended from a three-conductor 0.322" electro-mechanical cable. Power to the CTD and pylon was provided through the cable from the ship. The R/V Knorr's port-side Markey CTD winch was used throughout the leg.

The deck watch prepared the rosette approximately 45 minutes prior to each cast. All valves, vents and lanyards were checked for proper orientation. The bottles were cocked and all hardware and connections rechecked. Time, position and bottom depth were logged by the console operator at arrival on station. The rosette was moved into position under a projecting boom from the starboard ("forward") hangar using an air-powered cart on tracks. Two stabilizing tag lines were threaded through rings on the frame, and CTD sensor covers were removed. As directed by the watch leader, the winch operator raised the package, extended the boom over the side of the ship and quickly lowered the package into the water; then the tag lines were removed.

Each rosette cast was lowered to within 6-20 meters of the bottom. Bottles on the rosette were identified with unique serial numbers. These numbers corresponded to the pylon tripping sequence 1-36, the first trip closing bottle #1. No bottles were changed out during the leg, although parts of bottles may have been replaced or repaired.

Averages of CTD data corresponding to the time of bottle closure were associated with the bottle data during a cast. Pressure, depth, temperature, salinity and density were immediately available to facilitate examination and quality control of the bottle data as the sampling and laboratory analyses progressed.

Recovering the package at the end of deployment was essentially the reverse of launching, with the additional use of air-tuggers for added stabilization. The rosette was moved into the starboard hangar for sampling. The bottles and rosette were examined before samples were taken, and anything unusual was noted on a sample log for each cast.

Routine CTD maintenance included soaking the conductivity and CTD O_2 sensors in distilled water between casts to maintain sensor stability. The rosette was stored in the starboard side hangar between casts to insure the CTD was not exposed to direct sunlight or wind, in order to maintain the internal CTD temperature near ambient air temperature.

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

4.3. Underwater Electronics Packages

CTD data were collected with a modified NBIS MKIII CTD (ODF CTD #5). This instrument provided pressure, temperature, conductivity and dissolved O_2 channels, and additionally measured a second PRT temperature and conductivity as a calibration check and backup. Other data channels included elapsed-time, altimeter, accelerometer, water-leak detector and several power supply voltages. CTD #5 supplied a non-standard 17-byte (NBIS-format + 2 bytes) data stream at a data rate of 20 frames/second (fps). Modifications to the instrument included a revised pressure sensor mounting, a four-channel 14-bit A/D converter, 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 CTD sensor configuration is provided in Table 4.2.0 in the previous section.

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 secondary CTD temperature and conductivity sensors, mounted in a single turret, could have been used to calculate coherent salinities if the primary sensors failed. However, they were only used as a secondary temperature calibration reference or to occasionally verify unusual T/S structures observed in the primary sensors.

An SBE35 laboratory-grade reference PRT was employed as an additional temperature calibration check. This is an internally recording device triggered by the SBE32 pylon confirmation signal, providing a calibration point for each bottle trip. The SBE35 was used on stations 1-136.

An SBE43 dissolved O_2 sensor was located near the primary CTD temperature sensor. The sensor was pumped using an SBE5T running at ~3000rpm with a flow rate of ~25ml/s. The SBE43 signal was interfaced directly to the MKIII CTD and digitized using one of the 4 channels of the 14-bit A/D converter.

An SBE32 36-place carousel was the water sampler control unit on the rosette. The SBE32 has the advantage of requiring a single sea cable conductor for power and signals, and providing for the use of the SBE35 reference PRT.

The CTD system was configured for single-conductor operation by combining together the 3 sea cable conductors. An SBE33 deck box located in the Knorr's Main Lab supplied power and telemetry control for the rosette water sampler and MKIII CTD. Data from the MKIII CTD were routed to the SBE32 underwater unit and sent up the wire to the ship. The SBE33 deck box decoupled the signal and sent it to the ODF CTD demodulator unit, which converted it to an RS232 9600-baud binary data stream. The binary data were fed into the main CTD acquisition computer. Bottle-trip commands were sent from this computer to the SBE33 deck box, which transmitted the commands down the cable to the SBE32 water sampler unit.

Both SBE33 deck boxes failed after station 137. An ODF data logger unit was installed on the rosette so that CTD #5 data could continue to be collected for data consistency. The logger internally stored CTD #5 data at the full-stream data rate during stations 138-146. The Knorr's SBE9*plus* CTD was also installed on the rosette, then used with an SBE11*plus* deck unit and a Sea-Bird DOS-based acquisition system to control the SBE32 water sampler and to allow the operator to select and trip bottles. The altimeter was connected to the SBE9*plus* to allow detection of bottom depth during the cast. The digitized CTD #5 data from the ODF data logger were dumped onto the data processing computer after each cast and processed as usual. The SBE9*plus* CTD data were retained for bottle trip information only. The SBE33 deck boxes were repaired and reinstalled prior to station 147, and CTD operations continued as they were for the first 137 stations. The SBE9*plus* and data logger remained on the rosette but were not

used after station 146.

4.4. Navigation and Bathymetry Data Acquisition

P-code navigation data were acquired from the ship's Trimble Tasman GPS receiver via RS-232. Data were logged automatically at 12-second intervals by the Linux computer. Underway bathymetry was logged every 2 seconds by the ship's computer system, recording a corrected SeaBeam 2112 center-beam depth. Unedited depth data were merged with the navigation data to provide a time-series of underway position, course, speed and bathymetry data. These data were used for station positions, cast bottom depths and bathymetry on vertical sections.

4.5. CTD Data Acquisition and Real-Time Control System

The CTD data acquisition and real-time control system consisted of a generic PC workstation running RedHat 7.2 Linux, ODF-built CTD and pylon deck units, CTD and pylon power supplies, and a VCR recorder for real-time analog backup recording of the sea-cable signal. The Linux system consisted of a color display with 3-button mouse and keyboard (the CTD console), 4 RS-232 ports, 40-GB disk and CD-R drive. Two other Linux systems were networked to the data acquisition system, as well as to the rest of the networked computers aboard the Knorr. These systems were available for real-time CTD data display and provided for CTD and hydrographic data management and backup. One HP 1600C color inkjet printer and various postscript printers on the Knorr provided hardcopy from any of the workstations.

The CTD FSK signal 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 CTD acquisition computer. The pylon deck unit was connected to the CTD acquisition computer through a bi-directional 300 baud serial line, allowing bottle trips to be initiated and confirmed by 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 CTD data, navigation, and rosette trip displays.

The CTD data acquisition, processing and control system was prepared by the console watch a few minutes before each 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 initiated by pointing and clicking a mouse cursor on the display at icons representing functions to perform. The system then presented the operator with short dialog prompts with automatically-generated choices that could either be accepted as defaults or overridden. The operator was instructed to turn on the CTD and pylon power supplies, 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 were begun and a time and position were automatically logged for the beginning of the cast. A backup analog recording of the CTD signal on a VCR tape was started at the same time as the data acquisition. 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 and informed the console operator that the rosette was at the surface (also confirmed by the computer displays), the console operator or watch leader provided the winch operator with a target depth (wire-out) and maximum lowering rate, normally 60 meters/minute for this package. The package then began its descent, building up to the maximum rate during the first few hundred meters, then optimally continuing at a steady rate without any stops during the down cast.

The console operator examined the processed CTD data during descent via interactive plot windows on the display, which could also be run at other workstations on the network. Additionally, the operator decided where to trip bottles on the up cast, noting this on the console log. The altimeter signal was also monitored for bottom proximity.

Around 100-200 meters above the bottom, depending on bottom conditions, the altimeter typically began signaling a bottom return on the console. The winch speed was usually slowed to ~30 meters/minute during the final approach. The winch and altimeter displays allowed the watch leader to refine the target depth relayed to the winch operator and safely approach to within 10-20 meters of the bottom.

Bottles were closed on the up cast by pointing the console mouse cursor at a graphic firing control and clicking a button. The data acquisition system responded 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 then instructed the winch operator to bring the rosette up to the next bottle depth. The console operator was also responsible for generating the sample log for the cast.

After the last bottle was tripped, the console operator directed the deck watch to bring the rosette on deck. Once the rosette was on deck, the console operator terminated the data acquisition and turned off the CTD, pylon and VCR recording. The VCR tape was filed. Usually the console operator also brought the sample log to the rosette room and served as the *sample cop*.

4.6. CTD Data Processing

ODF CTD processing software consists of over 30 programs running under the Linux 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 various 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
- Store the output time-series in a CTD-independent format

Once the CTD data are reduced to a standard-format time-series, they can be manipulated in various ways. Channels can be additionally filtered. The time-series can be split up into shorter time-series or pasted together to form longer time-series. A time-series can be transformed into a pressure-series, or into a larger-interval time-series. The pressure calibration corrections are applied during the creation of the initial time-series. Temperature, conductivity and oxygen 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 half-second time-series data, as well as the 20 fps raw data, were stored on disk 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-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 daily for potential problems. The two PRT temperature sensors were inter-calibrated and checked for sensor drift. The CTD conductivity sensor was monitored by comparing CTD values to check-sample conductivities, and by deep theta-salinity comparisons between down and up casts as well as adjacent stations. The CTD O_2 sensor was calibrated to check-sample data.

A few casts exhibited conductivity offsets or noise due to biological or particulate artifacts. Many casts were subject to noise in the data stream caused by sea cable, slip-ring or deck box problems (especially stations 40-137); or by moisture in interconnect cables between the CTD and external sensors (i.e. O_2). Intermittent noisy data were filtered out of the half-second time-series data using a spike-removal filter. A least-squares polynomial of specified order was fit to fixed-length segments of data. Points exceeding a specified multiple of the residual standard deviation were replaced by the polynomial value.

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 occurring in these areas because of "ship roll". In order to minimize density inversions, a ship-roll filter was applied to all casts during pressure-sequencing to disallow pressure reversals. The first few seconds of in-water data were excluded from the pressure-series data, since the sensors were still adjusting to the going-in-water transition.

Pressure intervals with no time-series data can optionally be filled by double-quadratic interpolation/extrapolation. The only pressure intervals missing/filled during this leg were at 0-2 db, caused by chopping off going-in-water transition data during pressure-sequencing.

When the down-cast CTD data have excessive noise, gaps or offsets, the up-cast data are used instead. CTD data from down and up casts are not mixed together in the pressure-series data because they do not represent identical water columns (due to ship movement, wire angles, etc.). It was not necessary to use any up casts for Nordic Seas CTD data.

4.7. CTD Laboratory Calibration Procedures

Laboratory calibrations of the CTD pressure and temperature sensors were used to generate tables of corrections 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 March 2002, prior to Nordic Seas.

The CTD pressure transducer (Paine 211-35-440-05 8850 psi, s/n #77017) was calibrated in a temperature-controlled water bath to a Ruska Model 2400 Piston Gauge pressure reference. Calibration curves were measured at 5 temperatures from -1.31 to 25.65°C to three maximum loading pressures (1191, 4152 and 6080 db). Figure 4.7.0 summarizes the laboratory pressure calibration performed in March 2002.
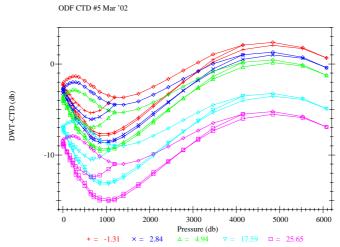

Figure 4.7.0 Pressure Calibration for ODF CTD #5, March 2002.

CTD PRT temperatures were calibrated to a NBIS ATB-1250 resistance bridge and Rosemount standard PRT. The primary (Rosemount 171BJ, s/n #13407) and secondary (Rosemount 171BJ, s/n #17534) CTD temperatures were offset by 1.5°C to avoid the 0-point discontinuity inherent in the internal digitizing circuitry. Figure 4.7.1 summarizes the laboratory temperature calibration performed on the primary PRT March 2002.
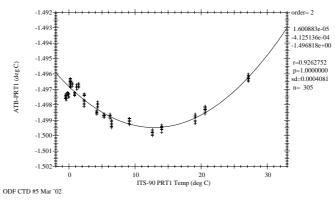

Figure 4.7.1 Primary PRT Temperature Calibration for ODF CTD #5, March 2002.

These calibration procedures are being repeated post-cruise at ODF.

4.8. CTD Shipboard Calibration Procedures

ODF CTD #5 was used for all Nordic Seas casts. A redundant PRT sensor was used on CTD #5 as a calibration check while at sea. An SBE35 laboratory-grade reference PRT was deployed on the rosette as an additional check of

the primary and secondary PRT temperatures at bottle trip levels. CTD conductivity and dissolved O_2 were calibrated to *in-situ* check samples collected during each rosette cast.

4.8.1. CTD #5 Pressure

Pre-cruise pressure calibration data were applied to CTD #5 raw pressures during each cast. Down-cast surface offsets were automatically adjusted to 0 as the CTD entered the water; any difference between this value and the calibration value was automatically adjusted during the top 50 decibars.

Residual offsets at the end of each up-cast (the difference between the last pressure in-water and 0) were monitored during the cruise to check for shifts in the pressure calibration. Most residual differences were less than 1.2 decibar. Preliminary checks of the post-cruise calibrations indicate a maximum 0.5 decibar shift at any pressure/temperature combination, indicating there was likely no signifi cant shift in pressure calibration during the cruise. CTD pressure data will not be considered fi nal until after the post-cruise laboratory calibrations have been completed and analyzed.

4.8.2. CTD #5 Temperature

Pre-cruise laboratory calibrations for the CTD #5 primary temperature sensor (PRT1) were applied to all shipboard CTD data.

A second Rosemount PRT sensor was deployed as the secondary temperature channel and compared with the primary PRT channel on all casts to monitor for drift. The response times of the sensors were fi rst matched, then preliminary corrected temperatures were compared for a series of standard depths from each CTD down-cast.

Comparison of the two CTD #5 PRTs at intermittent down-cast pressures deeper than 500 decibars showed the difference increasing by about +0.001°C during the cruise. Figure 4.8.2.0 summarizes the shipboard comparison between the primary and secondary PRT channels for CTD #5.
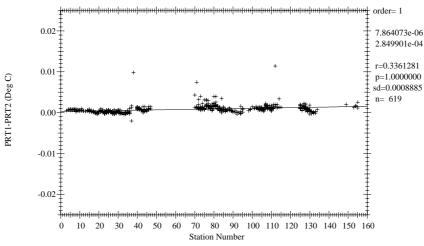

Figure 4.8.2.0 Shipboard comparison of CTD #5 dual PRTs, PRT1-PRT2, pressure>500db.

The comparison of CTD #5 PRT1 with the SBE35 reference PRT at up-cast bottle trips showed the difference decreasing by about -0.001°C at pressures deeper than 500 decibars during the cruise. Figure 4.8.2.1 summarizes the comparison between the CTD #5 primary PRT and the SBE35 reference PRT temperatures.
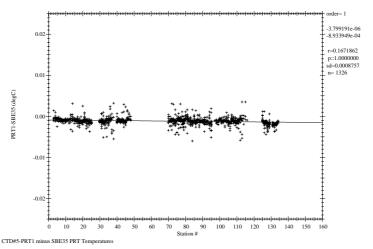
Figure 4.8.2.1 Comparison between CTD #5 primary and SBE35 PRTs, PRT1-SBE35, pressure>500db.

A preliminary check of the post-cruise calibration indicates PRT1 shifted up to 0.001°C between calibrations at temperature ranges applicable to this cruise. CTD temperature data will not be considered final until after the post-cruise laboratory calibrations have been completed and analyzed.

4.8.3. CTD #5 Conductivity

Corrected CTD rosette trip pressures and temperatures were used with bottle salinities to calculate bottle conductivities. Differences between the bottle and CTD conductivities were then used to derive a conductivity correction. This correction is normally linear for the 3-cm conductivity cell used in the Mark III CTD.

Conductivity differences above and below the thermocline were fit to CTD conductivity for stations 1-111 to determine a conductivity slope. A first-order fit was calculated, with outlying values (4,2 standard deviations) rejected. Figure 4.8.3.0 shows the data used to determine the Nordic Seas preliminary conductivity slope.

Figure 4.8.3.0 Nordic Seas CTD #5 preliminary conductivity slope, using stations 1-111.

Once the preliminary conductivity slope was applied, residual CTD conductivity offset values were calculated for stations 1-111 using bottle conductivities deeper than 700 db. Data from all pressure levels were used to determine the offsets for stations 46-67, which were all shallower than 700 db. Figure 4.8.3.1 illustrates the Nordic Seas preliminary conductivity offset residual values.

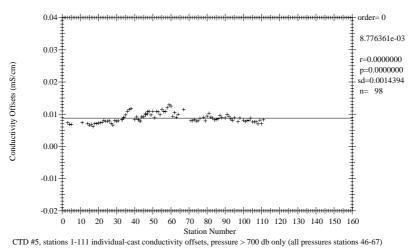Figure 4.8.3.1 Nordic Seas CTD #5 preliminary conductivity offsets by station number, stations 1-111.

Bottle data from over half of the first 15 casts were eliminated from the offset determinations because they were as much as 0.002 PSU low compared to nearby casts when the CTD deep theta-S data were consistent. A possible cause of this was inadequate equilibration of the extremely cold bottle samples to the fairly warm lab and Autosal bath temperatures. The bath temperature was lowered by 3°C starting with station 32 samples, and later sample bottles were better equilibrated in a tub of room-temperature water prior to analysis.

Smoothed offsets were applied to each cast. Some offsets were manually adjusted to account for discontinuous shifts in the conductivity transducer response or bottle salinities, or to maintain deep theta-salinity consistency from cast to cast. The stations 1-111 preliminary slope and stations 68-111 mean offset were applied through station 159. Cast-by-cast comparisons showed intermittent drifts up to 0.007 mS/cm, probably attributable to organic fouling of the sensor. These larger drifts were reversed during long transits between track lines, when sensors soaked in distilled water for longer periods than usual. There was an overall drift of 0.003 mS/cm in the conductivity sensor offset and no apparent slope changes over the entire leg.

The final shipboard Nordic Seas conductivity slopes are summarized in Figure 4.8.3.2. Figure 4.8.3.3 summarizes the final shipboard conductivity offsets.
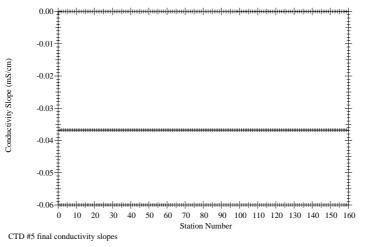

Figure 4.8.3.2 Nordic Seas CTD #5 conductivity slope corrections by station number.

CTD #5 final conductivity offsets

Figure 4.8.3.3 Nordic Seas CTD #5 conductivity offsets by station number.

Summary of Residual Salinity Differences

Figures 4.8.3.4, 4.8.3.5 and 4.8.3.6 summarize the Nordic Seas residual differences between bottle and CTD salinities after applying the conductivity corrections. Only CTD and bottle salinities with quality code 2 (acceptable) were used to generate these figures and statistics. Residual differences exceeding ±0.025 PSU are included in the calculations for averages and standard deviations, even though they are not plotted.

CTD #5, residual salt diffs, after correction, all pressures

Figure 4.8.3.4 Salinity residual differences vs pressure (after correction).

order= 0

2.077649e-01

r=0.0000000
p=0.0000000
sd=6.4909139
n= 3168
cl= 68.27%

CTD #5, residual salt diffs, after correction, all pressures

Figure 4.8.3.5 Salinity residual differences vs station # (after correction).
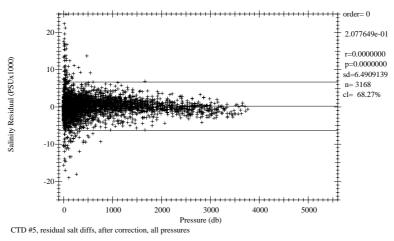

order= 0

1.959242e-01

r=0.0000000
p=0.0000000
sd=2.5813378
n= 1443
cl= 68.27%

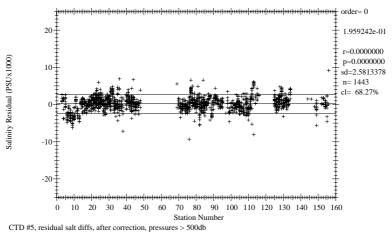CTD #5, residual salt diffs, after correction, pressures > 500db

Figure 4.8.3.6 Deep salinity residual differences vs station # (after correction).

The CTD conductivity calibration represents a best estimate of the conductivity field throughout the water column. 3σ from the mean residual in Figures 4.8.3.5 and 4.8.3.6, or ±0.0098 PSU for all salinities and ±0.0039 PSU for deep salinities, represents the limit of repeatability of the bottle salinities (Autosal, rosette, operators and samplers). This limit agrees with station overlays of deep theta-salinity. Within most casts (a single salinometer run), the precision of bottle salinities appears to be better than 0.001 PSU. The precision of the CTD salinities appears to be better than 0.0005 PSU.

Historical data comparisons and tabulation of temperature and conductivity correction coefficients will be included in the final Nordic Seas report, after corrections are finalized.

4.8.4. CTD Dissolved Oxygen

A single pumped SBE43 dissolved O_2 sensor was used for the entire cruise. This was the first time an SBE43 sensor was used by ODF with the NBIS MKIII. There were numerous problems with oxygen pump power during the first 39 casts. These were resolved by re-wiring one of the 3 conductors in the sea cable to use for power to the altimeter and oxygen pump; there were only two more casts with oxygen pump problems the rest of the cruise. Due to pump problems, the CTD O_2 data for stations 9 and 46 are extremely noisy; the data for stations 18 and 21 are noisier than most casts, but usable. A free-flow/no-pump experiment was conducted during station 108, which also resulted in noisier-than-usual CTD dissolved O_2 data.

There were a number of problems with the response characteristics of the typical SensorMedics O_2 sensor used with the NBIS MKIII CTD, the major ones being a secondary thermal response and a sensitivity to profiling velocity.

Stopping the rosette for as little as half a minute, or slowing down for a bottom approach, could cause shifts in the CTD O_2 profile as oxygen became depleted in water near the sensor. This apparently was still a problem on Nordic Seas, despite using the new Sea-Bird SBE43 pumped sensor.

Because of these problems, up-cast CTD rosette trip data cannot be optimally 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. Only station 154 had an up-cast processed, in addition to processing its down-cast: the chief scientist requested this because of extreme differences between down- and up-cast CTD profiles for all parameters. The differences between CTD O_2 data modeled from these derived values and check samples are then minimized using a non-linear least-squares fitting procedure.

There were no usable bottle O_2 data for stations 40-67 due to reagent problems, as documented later in the Oxygen Analysis section of this report. Station 40 began a new line 3.5 degrees south and 7 degrees west of station 39. The closest cast was at station 25, but it fell on the opposite/west side of a deep ridge from station 40. Stations 26 and 27 were on the east side of this ridge and were similar in depth to stations 40 and 41, respectively. Their bottle O_2 data were matched along isopycnals to stations 40 and 41 CTD data and used to approximate CTD O_2 fits. The corrections for each of these casts were temporarily applied to station 69, the next deeper cast with good bottle O_2 data, and the resulting CTD O_2 profile was compared to station 69 bottle O_2 data. The two corrections gave very different results; as an experiment, the two sets of CTD O_2 correction coefficients were averaged, and the result was an offset and slightly sloped station 69 CTD profile compared to bottle data. The c_1, c_1 and c_1 terms of the 40+41 averaged correction were shifted around until the station 69 CTD O_2 profile matched its own bottles. The stations 40+41 averaged CTD O_2 corrections were then applied to stations 42-67, with these three coefficients changed in equal increments between the 40+41 values and those determined as above for station 69. Ultimately, station 69 was fit to its own bottle data.

Figures 4.8.4.0 and 4.8.4.1 show the residual differences between the corrected CTD O_2 and the bottle O_2 (ml/l) for each station. Only CTD and bottle oxygens with quality code 2 (acceptable) were used to generate these figures and statistics. Residual differences exceeding ±0.5 ml/l are included in the calculations for averages and standard deviations, even though they are not plotted.
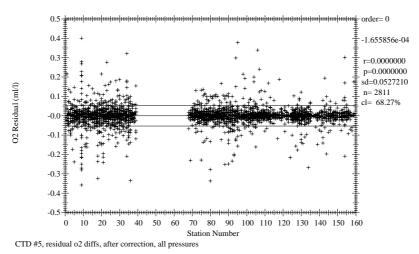

CTD #5, residual o2 diffs, after correction, all pressures

Figure 4.8.4.0 Nordic Seas O_2 residual differences vs station # (after prelim. correction).
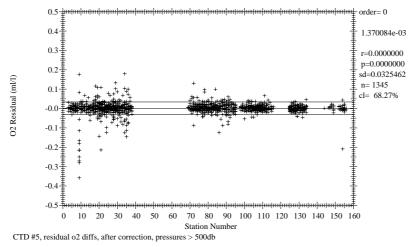
Figure 4.8.4.1 Nordic Seas Deep O_2 residual differences vs station # (after prelim. correction).

The standard deviations of 0.053 ml/l for all oxygens and 0.033 ml/l for deep oxygens are only intended as indicators of how well the up-cast bottle and down-cast CTD O_2 values match up. ODF makes no claims regarding the precision or accuracy of CTD dissolved O_2 data, especially for stations 40-67 where no bottle oxygen data were available for fitting the CTD O_2 sensor. As with other CTD properties, the CTD dissolved O_2 data are not considered final until after post-cruise pressure and temperature calibrations have been completed and analyzed.

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 O_c gradient, dO_c/dt, is approximated by low-pass filtering 1st-order O_c differences. This gradient 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:

$$O_{pp} = [c_1 O_c + c_2] \cdot f_{sat}(S, T, P) \cdot e^{(c_3 P_l + c_4 T_f + c_5 T_s + c_6 \frac{dO_c}{dt})} \tag{4.8.4.0}$$

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);
$\dfrac{dO_c}{dt}$	= Sensor current gradient (μamps/secs).

4.9. Bottle Sampling

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

- CFCs
- ^3He
- O_2
- SF_6
- pH
- Total CO_2
- Alkalinity
- Tritium
- ^{18}O
- Nutrients
- ^{129}I
- Salinity

Note that some properties were subsampled by cast or by station, so the actual sequence of samples drawn was modified accordingly. Five stations also had 3-5 bottles tripped just for noble gas sampling.

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 the proper drawing order.

Normal sampling practice included opening the drain valve and then the air vent on the bottle, indicating an air leak if water escaped. This observation together with other diagnostic comments (e.g., "lanyard caught in lid", "valve left open") that might later prove useful in determining sample integrity were routinely noted on the sample log.

Once individual samples had been drawn and properly prepared, they were distributed to their respective laboratories for analysis. Oxygen, nutrients and salinity analyses were performed on computer-assisted (PC) analytical equipment networked to the data processing computer for centralized data analysis. The analysts for each specific property were responsible for insuring that their results were updated into the cruise database.

5. Bottle Data Processing

Bottle data processing began with sample drawing, and continued until the data were considered to be final. One of the most important pieces of information, the sample log sheet, was filled out during the drawing of the many different samples. It was useful both as a sample inventory and as a guide for the technicians in carrying out their analyses. Any problems observed with the rosette before or during the sample drawing were noted on this form, including indications of bottle leaks, out-of-order drawing, etc. Additional clues regarding bottle tripping or leak problems were found by individual analysts as the samples were analyzed and the resulting data were processed and checked by those personnel.

The next stage of processing was accomplished after the individual parameter files were merged into a common station file, along with CTD-derived parameters (pressure, temperature, conductivity, etc.). The rosette cast and bottle numbers were the primary identification for all ODF-analyzed samples taken from the bottle, and were used to merge the analytical results with the CTD data associated with the bottle. At this stage, bottle tripping problems were usually resolved, sometimes resulting in changes to the pressure, temperature and other CTD properties associated with the bottle. All CTD information from each bottle trip (confirmed or not) was retained in a file, so resolving bottle tripping problems consisted of correlating CTD trip data with the rosette bottles.

Diagnostic comments from the sample log, and notes from analysts and/or bottle data processors were entered into a computer file associated with each station (the "quality" file) as part of the quality control procedure. Sample data from 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. Various property-property plots and vertical sections were examined for both consistency within a cast and consistency with adjacent stations by data processors, who advised analysts of possible errors or irregularities. The analysts reviewed and sometimes revised their data as additional calibration or diagnostic results became available.

Quality coding of CTD and water samples was done using a coding scheme developed for the World Ocean Circulation Experiment (WOCE) Hydrographic Programme (WHP) [Joyc94] Based on the outcome of investigations of the various comments in the quality files, WHP water sample codes were selected to indicate the reliability of the individual parameters affected by the comments. WHP bottle codes were assigned where evidence showed the entire bottle was affected, as in the case of a leak, or a bottle trip at other than the intended depth.

WHP water bottle quality codes were assigned as defined in the WOCE Operations Manual [Joyc94] with the following additional interpretations:

2	No problems noted.
3	Leaking. *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	Did not trip correctly. *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	Not reported. *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.*
9	The samples were not drawn from this bottle.

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

1	The sample for this measurement was drawn from the water 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 acceptable, but are open to interpretation.*
4	Bad measurement. *The data did 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 up-cast.*
4	Bad measurement. *The CTD up-cast data were determined to be unusable for calculating a salinity.*
7	Despiked. *The CTD data have been filtered to eliminate a spike or offset.*

Table 5.0 shows the number of samples drawn and the number of times each WHP sample quality flag was assigned for each basic hydrographic property. Nutrient data are temporarily omitted from this chart until they can be incorporated into the ODF bottle data files. CTD Oxygen statistics will also be included when preliminary fitting has been completed.

Rosette Samples Stations 001-159								
	Reported	WHP Quality Codes						
	Levels	1	2	3	4	5	7	9
Bottle	3282	0	3235	18	2	0	0	27
CTD Salt	3282	0	3141	0	0	0	141	0
Salinity	3216	0	3168	44	4	0	0	66
Oxygen	3180	0	2811	10	359	3	0	99
Silicate	3225	0	3208	14	3	0	0	57
Nitrate	3225	0	3212	10	3	0	0	57
Nitrite	3225	0	3217	6	2	0	0	57
Phosphate	3225	0	3213	9	3	0	0	57

Table 5.0 Frequency of WHP quality flag assignments for Nordic Seas.

5.1. Bottle Pressure and Temperature

All pressures and temperatures for the bottle data tabulations on the rosette casts were obtained by averaging CTD data for a brief interval at the time the bottle was closed on the rosette, then correcting the data based on CTD laboratory calibrations.

The temperatures are reported using the International Temperature Scale of 1990.

5.2. Salinity Analysis

Equipment and Techniques

A single Guildline Autosal Model 8400A salinometer (s/n 55-654) was used for measuring salinity on all stations. Salinometer 46-992 was the backup salinometer and was not used. The salinometers were modified by ODF and contained interfaces for computer-aided measurement. The water bath temperature was set and maintained at a value near the laboratory air temperature. It was set at 24°C for stations 1-31 and stations 109-159, and at 21°C for stations 32-108.

The salinity analyses were performed when samples had equilibrated to laboratory temperature, usually within 8-30 hours after collection. Equilibration time was sometimes accelerated by immersing sample bottles in a tub of room temperature water because of the extreme differences between *in situ* sample temperatures and the lab temperature. The salinometer was standardized for each group of analyses (usually one or two casts, up to ~50 samples) using at least one fresh vial of standard seawater per group. Some groups included up to 80 samples and 8 casts between standardizations, usually for a series of shallow stations. A computer (PC) prompted the analyst for control functions such as changing sample, flushing, or switching to "read" mode. The salinometer cell was flushed and results were logged by the computer until two successive measurements met software criteria for consistency. These values were then averaged for a final result.

Sampling and Data Processing

Salinity samples were drawn into 200 ml Kimax high-alumina borosilicate bottles, which were rinsed three times with sample prior to filling. The bottles were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Prior to collecting each sample, inserts were inspected for proper fit and loose inserts were replaced to insure an airtight seal. The draw time and equilibration time were logged for all casts. Laboratory temperatures were logged at the beginning and end of each run.

PSS-78 salinity [UNES81] was calculated for each sample from the measured conductivity ratios. The difference (if any) between the initial vial of standard water and one run at the end as an unknown was applied linearly to the data

to account for any drift. The data were added to the cruise database. 3216 salinity measurements were made and 170 vials of standard water were used. The estimated accuracy of bottle salinities run at sea is usually better than 0.002 PSU relative to the particular standard seawater batch used.

Laboratory Temperature

The temperature in the salinometer laboratory varied from 19 to 25°C during the cruise. The air temperature change during a run of samples ranged from less than 0.5°C to more than 4°C. The laboratory temperature was 4°C lower to 3°C higher than the Autosal bath temperature.

Standards

IAPSO Standard Seawater (SSW) Batch P-140 was used to standardize the salinometer.

5.3. Oxygen Analysis

Equipment and Techniques

Dissolved oxygen analyses were performed with an ODF-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365nm wavelength ultra-violet light. The titration of the samples and the data logging were controlled by PC software. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 ml buret. ODF used a whole-bottle modified-Winkler titration following the technique of Carpenter [Carp65] with modifications by Culberson *et al.* [Culb91], but with higher concentrations of potassium iodate standard (~0.012N) and thiosulfate solution (~65 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. Pre-made ODF liquid potassium iodate standards were also used. 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 or dilution error. Reagent/distilled water blanks were determined, to account for presence of oxidizing or reducing materials. The auto-titrator generally performed very well.

Sampling and Data Processing

Samples were collected for dissolved oxygen analyses soon after the rosette sampler was brought on board. Using a Tygon drawing tube, nominal 125ml volume-calibrated iodine flasks were rinsed 2-3 times with minimal agitation, then filled and allowed to overflow for at least 3 flask volumes. Reagents were added to fix the oxygen before stoppering. The flasks were shaken twice to assure thorough dispersion of the precipitate, once immediately after drawing, and then again after about 20 minutes.

Drawing oxygen samples usually included taking the sample draw temperature from a small platinum-resistance thermometer embedded in the drawing tube. However, the thermometers normally used were in a shipment that never arrived. Sampling the temperatures with substitute equipment was deemed too awkward, and the practice was abandoned after 9 stations.

The samples were analyzed within 1-15 hours of collection, and then the data were merged into the cruise database.

Thiosulfate normalities were calculated from each standardization and corrected to 20°C. The 20°C normalities and the blanks were plotted versus time and were reviewed for possible problems. New thiosulfate normalities will be recalculated after the blanks have been smoothed as a function of time, if warranted. These new normalities will then be smoothed, and the oxygen data recalculated.

As samples warmed up to room temperature they would often degas which would cause an occasional noisy endpoint due to gas bubbles in the light path. 3180 oxygen measurements were made. In addition, 14 replicate samples were analyzed to compare reagent batches, and 57 oxygen samples (3 per rosette bottle) were analyzed from noble gas sampling.

Volumetric Calibration

Oxygen flask volumes were determined gravimetrically with degassed deionized water 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. The volumetric flasks used in preparing standards were volume-calibrated by the same method, as was the 10 ml Dosimat buret used to dispense standard iodate solution.

Standards

Potassium iodate standards, nominally 0.44 gram, were pre-weighed in ODF's chemistry laboratory to ±0.0001 grams. The exact normality was calculated at sea after the volumetric flask volume and dilution temperature were known. Liquid potassium iodate standards were also used on the cruise. The normality of the liquid standard was determined at ODF by calculation from weight and by comparison to other iodate standards. Potassium iodate was obtained from GFS Chemical Co. and was reported by the supplier to be >99.4% pure. All other reagents were "reagent grade" and were tested for levels of oxidizing and reducing impurities prior to use.

One lot number of NaI reagent gave a high negative blank which was not measurable with normal methods. It was necessary to use this "bad" reagent for stations 40 to 67 since this was the only NaI remaining on board. After station 67, the ship ran in north of Tromsø, Norway to get shipments of good reagents from Swedish and ODF sources, delivered by a pilot boat. Comparisons were done between "good" and "bad" reagents to calculate a correction to apply to stations run with the "bad" reagents. No other reagent problems occured during the remainder of the cruise.

5.4. Nutrient Analysis

Equipment and Techniques

Nutrient analyses (phosphate, silicate, nitrate and nitrite) were performed on an ODF-modified 4-channel Technicon AutoAnalyzer II, generally within one hour after sample collection. Occasionally samples were refrigerated up to 4 hours at ~4°C. All samples were brought to room temperature prior to analysis.

The methods used are described by Gordon *et al.* [Gord92]. The analog outputs from each of the four colorimeter channels were digitized and logged automatically by computer (PC) at 2-second intervals.

Silicate was analyzed using the technique of Armstrong *et al.* [Arms67]. An acidic solution of ammonium molybdate was added to a seawater sample to produce silicomolybdic acid which was then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. Tartaric acid was also added to impede PO_4 color development. The sample was passed through a 15mm flowcell and the absorbance measured at 660nm.

A modification of the Armstrong *et al.* [Arms67] procedure was used for the analysis of nitrate and nitrite. For the nitrate analysis, the seawater sample was passed through a cadmium reduction column where nitrate was quantitatively reduced to nitrite. Sulfanilamide was introduced to the sample stream followed by N-(1-naphthyl)ethylenediamine dihydrochloride which coupled to form a red azo dye. The stream was then passed through a 15mm flowcell and the absorbance measured at 540nm. The same technique was employed for nitrite analysis, except the cadmium column was bypassed, and a 50mm flowcell was used for measurement.

Phosphate was analyzed using a modification of the Bernhardt and Wilhelms [Bern67] technique. An acidic solution of ammonium molybdate was 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 was heated to ~55°C to enhance color development, then passed through a 50mm flowcell and the absorbance measured at 820nm.

Sampling and Data Processing

Nutrient samples were drawn into 45 ml polypropylene, screw-capped "oak-ridge type" centrifuge tubes. The tubes were cleaned with 10% HCl and rinsed with sample 2-3 times before filling. Standardizations were performed at the beginning and end of each group of analyses (typically one cast, up to 36 samples) with an intermediate concentration mixed nutrient standard prepared prior to each run from a secondary standard in a low-nutrient seawater matrix. The secondary standards were prepared aboard ship by dilution from primary standard solutions. Dry standards were pre-weighed at the laboratory at ODF, and transported to the vessel for dilution to the primary standard. Sets of 6-7 different standard concentrations were analyzed periodically to determine any deviation from linearity as a function of concentration for each nutrient analysis. A correction for non-linearity was applied to the final nutrient concentrations when necessary. In addition, a "deep seawater" high nutrient concentration check sample was run with each station as an additional check on data quality.

After each group of samples was analyzed, the raw data file was processed to produce another file of response factors, baseline values, and absorbances. Computer-produced absorbance readings were checked for accuracy

against values taken from a strip chart recording. The data were then added to the cruise database.

Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at 1 atm pressure (0 db), *in situ* salinity, and an assumed laboratory temperature of 25°C.

3225 nutrient samples were analyzed. The pump tubing was changed 3 times.

Standards

Na_2SiF_6, the silicate primary standard, was obtained from Aesar Chemical Company and was reported by the suppliers to be >98% pure. Primary standards for nitrate (KNO_3), nitrite ($NaNO_2$), and phosphate (KH_2PO_4) were obtained from Johnson Matthey Chemical Co.; the supplier reported purities of 99.999%, 97%, and 99.999%, respectively. The efficiency of the cadmium column used for nitrate was monitored throughout the cruise and ranged from 99-100%.

No major problems were encountered with the measurements. The temperature of the laboratory used for the analyses ranged from 21°C to 28°C, but was relatively constant during any one station (±1.5°C).

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