SCICEX-96

Hydrographic Data Report
USS POGY SSN 647
Polar Cruise
27 August - 12 November 1996

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INTRODUCTION

The Submarine Arctic Science Cruise (SCICEX-96) was conducted on the USS POGY (SSN 647) within the Arctic US Navy operating area leaving San Diego on 27 August and returning to Honolulu on 12 November 1996. The Office of Naval Research (ONR) in collaboration with the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS) sponsored the cruise. This cruise constituted the third in a series of five SCICEX Cruises designed to provide nuclear submarine services to the civilian scientific community. The USS POGY entered the data collection area through the Bering Strait and commenced operations on September 13. Sampling ended 45 days later on October 28. The scientific experiments of SCICEX-96 were divided into five phases: P1) an initial ice survey in the Chukchi Borderland area; P2) a surfacing water-property transect across the Canadian Basin; P3) a water-property survey of the Chukchi Borderland; P4) a high speed geophysical survey of the Arctic Mid-Ocean Ridge and Russian portion of Lomonosov Ridge; and P5) a repeat ice survey in the Chukchi Borderland.

This hydrographic data report summarizes the physical oceanographic data taken during all phases of the SCICEX-96 cruise. The chemical sampling associated with these casts and online sampling is reported separately (Gossett and Sambrotto, 1996). A detailed chronology of sampling during the cruise is available from the Arctic Submarine Laboratory and can be found in the *SCICEX-96 Technical Advisor's Log* and in the *Ship's Operations Log* prepared by cruise coordinator Jeff Gossett and chief scientist Ray Sambrotto of LDEO (Lamont Doherty Earth Observatory).

A total of nine surface stations (18 casts) were taken using self-recording Sea-Bird Equipment (SBE) CTDs and Niskin bottles (Fig. 1). This form of sampling was aborted early in the cruise due to instrument loss and hazardous working conditions. The sampling strategy intended to provide accurate vertical casts of the water-mass distributions, to provide concurrent data needed to calibrate the Sub-Surface Expendable CTD probe (SSXCTD or XCTD) casts, and to support the chemical sampling of collaborating scientists. A total of 115 Sippican XCTD probes were launched during SCICEX-96. These XCTDs provided the primary means of acquiring data on the vertical and horizontal water-mass structure. These data were augmented by an underway, online system utilizing two SBE-19 SeaCat CTDs mounted in the submarine's sail.

METHODS

1. Data Acquisition.

1.1. Surface CTD Casts. The surface casts involved rigorous maneuvers and preparations so that the Submarine could break through the ice and a working party could make an ice hole for the cast and maintain the sampling gear (winch, shelter, etc.) necessary to conduct the station. During its first deployment the primary CTD (SBE-25) flooded; it was a self-recording instrument equipped with pressure, temperature, conductivity and oxygen sensors. All remaining surface casts were conducted with a secondary CTD SBE-19, which was also self-recording and similarly equipped except without the oxygen sensor. The temperature, conductivity and oxygen sensors were configured within Sea-Bird's pumped TC Duct system.

The normal sampling procedure involved first a shallow (~300 m) CTD cast. This was followed by a deep-water sampling cast in which Niskin bottles were hung on the CTD wire (and tripped with a messenger) at depths based on the vertical structure as displayed by the SeaSoft plots of the first cast. The replay was done on the ice in the Station shelter and consulted with respect to the vertical placement of the bottles. Frequently an additional cast was deployed. The surface casts ceased on Calendar Day (CD) 276 due to hazardous ice conditions. The surface sampling scheme is listed in Table 1. A total of 138 water samples for on-board salinity analysis were drawn from nearly all the sampled depths.

1.2. Expendable CTD Casts. During the first phase of the cruise XCTD probes were launched approximately every 46 km (25 nm) over the Chukchi Plateau and again during the Chukchi Borderland survey (Phase 3). Similarly, these probes were deployed approximately every 46 km along the transarctic section, which ran from just north of Greenland (88° 0.3’N and 36° 18.6’W) to off the northeast coast of Alaska (71° 8.5’N and -147° 8.5’W) during Phase 2. During the Lomonosov Ridge survey (Phase 4) and the second ice survey (Phase 5), XCTD probes were deployed more infrequently at approximately a diurnal rate (Fig. 2). In instances where the probe failed or a bad trace was recorded, an XCTD launch was typically repeated. A single submarine-launched bathythermograph (BT) was deployed during SCICEX-96, but a totally erratic trace was recorded.

Sippican's under ice XCTD probe is specifically designed for under ice operations and is deployed solely by the U.S. Navy for sampling in Arctic environments. The design of this probe is only a few years old and the exact physics of its launch and fall through the water column are still uncertain. In general, the positively buoyant XCTD probe is launched in a canister from a submarine where it ascends to a prescribed depth which activates a pressure switch that causes the probe to release from its housing, and the probe to flip downward near 12.2 m depth. During this flip operation, another switch, activated by flooding, causes the probe's batteries to turn on and data collection to begin. After flooding, the first good data point is obtained typically 0.4 seconds after the first signal sent by the probe. A fine tether wire attached from the probe to Sippican's MK-12 recording and display unit on the submarine transmits measured conductivity and temperature between approximately 12.2 m and 1000 m depth sampling every 0.25 seconds.

Overall, the performance of Sippican's XCTD was much improved from previous years due to modifications to the tail fin of the probe. This modification was designed to alleviate stability problems encountered as the probe falls through the water column. XCTD depth is inferred from elapsed time by the non-linear, second order, fall rate equation; *Depth (m) = bt + a (txt) + c* where depth is in meters, *t* is time in seconds commencing from the first measurement, and manufacturer coefficients are *a* = -0.000533 m s-2 , *b* = 3.254 m s -1, and *c* = 12.2 m; the depth at which the CTD first sends a signal. Analysis to determine the depth and the sensor corrections for the XCTD probes used the calibrated SBE-19 CTD measurements as a standard. Analysis of SCICEX-96 data resulted in slightly revised fall-rate coefficients (Sect.. 3.2).

1.3. Underway SeaCat Sampling. Two pumped SeaCats (SBE-19) were used to measure the underway properties. Both were hull mounted in the ship's sail. The first underway unit (S/N 1827) was logging every half second and was equipped with Sea-Bird pressure, temperature, conductivity and oxygen sensors, and a WET LABS fluorometer. The oxygen sensor failed due to freezing temperatures upon surfacing on CD 265 and was replaced on CD 281. The second oxygen sensor similarly failed on CD 288. The second underway SeaCat (S/N 2040) was initially set up to log every half second but on the second day (CD 259) the sampling rate was changed to every two seconds. This unit was equipped with Sea-Bird pressure, temperature and conductivity sensors, a WET LABS beam transmissometer, and a LDEO oxygen sensor. The conductivity sensor was replaced on CD 281 (S/N 1939). The pressure sensor showed signs of failure on CD 286 but settled down during periods of constant depth by CD 289. A total of 287 salinity samples were taken via the torpedo room water sampling line.

2. CTD Data Processing

2.1. Surface CTD Data. The initial portions of the data processing for the SCICEX-96 SBE-19 surface casts were done using the Sea-Bird Software Version 4.219 routines. DATCNV converted the raw data to pressure, temperature and conductivity in engineering units. The FILTER routine was then run to force conductivity to have the same response as temperature (to minimize the difference in sensor response times). Conductivity was filtered with a time constant of 0.5 seconds. ALIGNCTD was used to advance temperature relative to pressure 0.6 seconds. Next, LOOPEDIT was run to mark scans where the CTD was moving less than 0.00 m/s (due to ship roll). BINAVG was used to averaged the data into 1-dbar pressure bins. Finally, the TRANS routine produced an ASCII version of the averaged data for transferring them to a PC system.

As was previously mentioned, the deep cast on St. 28 employed a SBE-25 which flooded during its descent and was not used again. Its data were processed independently. The SeaSoft routines, WILDEDIT and WFILTER, were used to edit out much of the noise and data spikes on St. 28 and smooth the data. For this cast, the oxygen values below the depth of 1100 m were deleted but temperature and conductivity channels were unharmed.

At NCSU, a PC was used to convert the 1-dbar averaged ascii files to binary. A Fortran routine was used to extrapolate the values to the surface (0 dbars). Next, salinity was corrected based on a linear regression of the CTD values to the water samples. Only Sts. 35-38 needed correction. After salinity was corrected, additional parameters including density, potential temperature, Brunt-Våisålå frequency, integrated density, steric height and depth were derived. Lastly, the data were transposed to ASCII format again and depth-averaged into 1-meter averages (see Sect. 4.1).

2.2. Expendable CTD Data. Post-test, all XCTD data were reprocessed and converted to ASCII format utilizing Sippican's MK-12 Data Acquisition software (Version 3.03). Once converted, editing and analysis were performed using the System for At-Sea Environmental Analysis (SASEA), Version 7.2, oceanographic analysis and profile editing software developed by JHU/APL and SAIC (Hanson, 1990). Raw XCTD profiles were edited to:

1) omit outlier/uncorrectable profiles,
2) verify and correct header information,
3) eliminate bad or noisy data, and
4) create decimated profiles at 1-m standard depths without changing the profile's characteristics.

As discussed in Sect. 3.2, XCTD data were corrected for a slight fall rate offset based upon comparison of XCTD profiles with concurrent CTD profile data. The editing of each XCTD profile included the following procedures:

1) correction of raw data using revised fall rate equation,
2) editing and verification of the header record,
3) automated gross spike editing to remove erroneous spikes,
4) on-screen fine scale editing,
5) decimation of profiles to 1-m standard depths,
6) on-screen verification to ensure that the decimation retained profile features, and
7) evaluation of the legitimacy of profiles based upon a comparison of profile structure with neighboring data.

Sound speeds were generated from temperature and salinity profiles and a decimated version of these profiles were created for acoustic modeling purposes.

An extended version of the SCICEX library was created by merging SCICEX profiles with historical, modeled profiles representative of the Arctic basin during the fall season. The sound speed and extended/bottom corrected T/S libraries are available from Science Applications International Corp. (SAIC) upon request.

2.3. Underway SeaCat Data. The Sea-Bird software routines (Version 4.219) were used to DATCNV, FILTER (0.5), and ALIGN (0.5) both underway units. The data were then bin-averaged by time into 15-second bins using the module BINAVG. Using DERIVE, salinity, density, oxygen (ml/l), oxygen % saturation, and chlorophyll concentration were calculated for S/N 1827. The fluorometer data were kept in voltage units (full scale 5 V). Salinity, density, beam attenuation, beam transmission and transmissometer volts were derived for S/N 2040/1939. The TRANS routine produced ASCII versions of the time-averaged data.

Using a text editor on the PC, the start time of the underway files were corrected to ship's time. All data collected during the vertical movements of the ship were deleted, based on approximately a 2-dbar envelope about 118 dbar. This was to produce a time series data file having a constant pressure. Latitude and longitude positions were affixed at the start of each file and every time a break in the time sequence occurred in the data, i.e. where the pressure changes had occurred. Data users should note that both the pressure and oxygen data are subject to error due to occasional sensor failure. *None of the underway data have been corrected or deleted during these time periods.* An attempt was made to create daily underway files with the start and end of each file created shortly after midnight. However, due to ship operations and other at-sea variables, there are often multiple files for each calendar day. These file listings are given in Table 2a,b.

3. CTD Calibration.

3.1. Surface CTD Data. As a first approach, the deepest salinities were used to calibrate the CTD because the deepest bottle was the only water sample taken at precisely the same time as the CTD. A simple regression between the deepest CTD values and the deepest bottle salinity values on the SBE-19 surface casts was made; and the results indicated two distinct groups, with the break occurring before and after St. 34 (Fig. 3). This regression was limited to the number of bottle samples (9 total). To obtain a larger sample size, the bottle depths for the rest of the water column were estimated by adjusting the depths proportionately. An iterative regression was then performed for each of the two groups, Sts. 30-34 and 35-38.

The average difference between the deepest bottle and the deepest CTD value for the first group of stations was less than .001 ppt, which is less than the stated accuracy of either the Portasal, Guildline Instruments Inc., or the SBE CTD conductivity sensor (+/- .003 ppt). Therefore, for Sts. 30-34, a calibration of the CTD to the water sample salinities from all depths was not statistically warranted. However for the second group of stations (Sts. 35-38), a linear correction was needed as follows: *Corrected Salinity = 1.012257 x CTD Salinity - 0.42209* with a standard deviation of + 0.0012 ppt (Fig. 4).

Since there were no water samples available for St. 7, or the shallow cast of St. 28, no correction was applied to either of these two stations. Similarly, no correction was applied to the deep cast of St. 28 (SBE-25 cast). Because of the limited number of bottle salinity samples for this deep cast, 7 total, and because the difference between the deepest bottle salinity and deepest CTD value was 0.003 ppt, a regression was not statistically warranted.

No observations were available to calibrate the in-situ temperature and pressure values. The manufacturer's calibration values were used.

3.2. Expendable CTD Data. Comparison of XCTD profiles to nearly simultaneously surface launched Sea-Bird SBE-19 profiles during SCICEX-96 indicated slight differences between the depths of temperature and salinity features. Profiles were evaluated against concurrent SBE-19 profiles that derive depth from pressure. In nine instances during SCICEX-96, Sippican XCTD probes were launched concurrent to Sea-Bird deployments. Measurement comparisons among these matched pairs showed that the XCTD fall rate algorithm consistently overestimated temperature and salinity features observed in concurrent CTD casts by an average of 10 m, which exceeds the XCTD depth accuracy specification of 0.2% stated by the manufacturer. Depth differences are largest in the upper 300 m of the water column (Fig. 5a).

To improve the fit, the manufacturer's depth coefficients used as input to the quadratic fall rate equation, Depth (m) = bt + a (txt) + c, were revised by conducting a least squares fit of concurrent CTD depth and XCTD time pairs taken from matching profile features (Moustafa and Boyd, 1998). Residuals and estimates of XCTD depths were calculated to determine the quality of the fit and an "average best-fit", least squares estimate. Original XCTD profiles were recalculated based upon best-fit analysis results. Fall rate equation coefficients were modified by setting a =-0.001, b = 3.438, and c = 12.2, thus minimizing temperature, salinity, and depth errors between CTD and XCTD match drop data (Fig. 5b). These revised best-fit parameters were used to compute fall rates for all the SCICEX-96 XCTD T-S profiles.

To illustrate the magnitude of the XCTD sensor and depth error, scatter plots of T and S from XCTD vs CTD casts are shown for uncorrected data created using Sippican's default fall-rate coefficients, and again after applying our newly determined best-fit depth coefficients (Fig. 6). The observed bias and standard deviation in the uncorrected T and S were reduced significantly after applying the best-fit fall-rate parameters. As the best-fit parameters reflect the fit of nine different profile pairs, collected at different locations and with different time and space separation, small depth errors still remain (Table 3).

On a few occasions multiple XCTDs were launched closely in time and space (Fig. 7). In these instances, good agreement between T and S profiles was observed, providing a measure of the probe-to-probe variability. Discrepancies in XCTD T and S values at specific depths were within the manufacturer’s accuracy specifications (0.035°C and 0.05 ppt). Fig. 8 indicates a measure of the overall performance of Sippican’s XCTD probes during SCICEX-96. During SCICEX-96 a total of 115 XCTD probes were deployed with an 83% success rate.

Of these deployments, 96 XCTDs resulted in valid / acceptable T-S profile measurements, eleven probes recorded unsalvageable / offset data; seven failed to record data, and one did not deploy properly.

3.3. Comparison of CTD and XCTD Data below the Halocline. Smethie, et. al., 1998, compared potential temperature / salinity CTD and XCTD profiles from overlapping and adjacent stations collected during SCICEX-96. They examined 1) the scatter in the plots, 2) the trends in the plots at each station that result from the vertical distribution of temperature and salinity, and 3) the trends in the lateral variability of the potential temperature / salinity in the plots. Scatter in the potential temperature / salinity plots can be caused by variability in both temperature and salinity.

The general trends at each station were the same for CTD and XCTD data, however, there was a systematic offset in salinity between the CTD and XCTD data that varied from station pair to station pair. The XCTD data always was higher in salinity and the offset ranged from 0.012 to 0.045 ppt. For water beneath the halocline (about 150 m depth) there was a clear trend in the CTD data (Figures *A and *B). Salinity increased monotonically from the central Canadian Basin to a maximum at the southern flank of the Alpha Ridge and then decreased monotonically to the Lomonosov Ridge. This trend was not observed in the XCTD data (Figure *C and D) due to a combination of the scatter in the XCTD salinity data and the variable offset in salinity between the XCTD and CTD data. The conclusion of this comparison was that the salinity data obtained with 1996 XCTD probes should not be used in an analysis where an accuracy of better than 0.05 ppt is required.

3.4. Underway SeaCat Data. The underway salinities and oxygen data of this report have not been calibrated to the bottle values.

4. CTD Data Formatting.

4.1. Surface CTD Data. The surface SBE-19 casts were archived into the following formats. The raw data files (containing pressure, temperature and conductivity) as acquired on board are archived on ZIP diskettes, available from NCSU on request.

The sampling rate of the SBE-19 was 2 Hz which necessitated bin averaging the data every decibar. An extrapolation routine was run on the files of pressure, temperature and conductivity to complete the casts in the vertical, i.e. from the first sample (1 to 2 dbar) to the surface. This was done to permit complete water-column integrations. Calibrations were performed on the 1-dbar center-averaged files. The secondary parameters were derived from the calibrated 1-dbar files. The algorithms for the computation of salinity, density, potential temperature and freezing point were obtained from Fofonoff and Millard (1983). Depth was computed from pressure and the density profiles by inverting the hydrostatic equation i.e. instead of that of the standard ocean (i.e. Saunders and Fofonoff, 1976). The Brunt-Våisålå frequency was also computed from the density profiles (as a function of the calculated depth), as well as integrated density, defined as:

´

Finally, using integrated density, steric height

´

was computed, where ´ is the surface density and ´ is a reference density of 1.0282 taken to be slightly greater than the maximum for the Arctic Ocean, so as to insure positive values for the steric heights.

The processed and calibrated 1-dbar averaged files were converted to 1-meter averages. The edited, calibrated, 1-dbar and 1-m average files are archived on ZIP, available from NCSU on request or via the SCICEX-96 FTP site.

4.2. Expendable CTD Data. The processed XCTD data were converted to 1-meter standard depths through decimation and by applying a low pass filter to the edited profiles. The processed/edited XCTD data files have been placed in a single data file. The format of the final edited data is presented in column format with each profile proceeded by a header record. A blank line separates each profile. The header record contains cast number, year, Julian day, time, latitude, longitude, and number of data points in the profile. This ascii file can be easily imported into a spreadsheet or text editor for data manipulation.

The algorithms used to compute pressure, potential temperature, salinity, and density were obtained using the SASEA analysis software. More specifically, pressure was derived from Saunders (1981), potential temperature and density from NODC User's Guide (1984) and salinity from Fofonoff and Millard (1983). The XCTD combined data file and a file containing location and time information for each individual file have been compressed into a ZIP file, currently available from SAIC to test participants via the SCICEX-96 FTP site, or on floppy disc by request from SAIC or NCSU.

4.3. Underway SeaCat Data. The processed underway data were archived into the following formats. The raw data files as acquired on board are archived on ZIP diskettes; similarly the processed and edited 15-sec time-averaged files are archived on ZIP. Both are available from NCSU on request. The processed and edited files can also be downloaded from the SCICEX-96 FTP site. The format for the final edited files is identical to the SeaSoft converted engineering unit data file (.CNV), with latitude and longitude appearing in the last two columns when a break in the time sequence occurred. If the .UND extension is renamed to .CNV, the SeaSoft module SEAPLOT can still be used to display the measured and derived parameters.

5. CTD Data Presentation

5.1. Surface CTD Casts. CTD Downcast Tables. The downcast values shown on pages X-X are from the 1-m average file.   These list numeric values of parameters as function of depth. The values are spaced every 2 m from 0 to 40 m, every 5 m from 40 to 125 m, every 25 m from 125 to 400 m and every 100 m thereafter. Finally, the last 1-m record is also listed.

CTD Downcast Plots. The vertical structure is presented on pages X-X in a 2-panel format for each cast: salinity and potential temperature (Q); potential density (Sigma-Q) and steric height. The parameters are plotted against depth from the 1-m average files. Potential temperature-salinity diagrams are presented on pages X-X with isopleths of potential density.

5.2. Expendable CTD Casts. The SCICEX-96 XCTD Sample Log distributed by ASL at the culmination of the cruise was revised and is presented in Table 4. This table contains specifics as to XCTD probe ID / sequence number, date, time, location, maximum probe depth, and approximate bottom depth derived from the ship's log. The variability of the vertical structure of the water column is illustrated in composite plots of all XCTD profiles on pages X-X: potential temperature, salinity, and sigma-Q versus depth; and a potential temperature-salinity diagram. Individual vertical plots of potential temperature and salinity versus depth of the XCTD library are shown on pages X -X. These plots indicate depth in meters, potential temperature in degrees C, and salinity in psu.

5.3. Underway SeaCat Files. Example from S / N 1827, CD 283. On pages X-X are examples of the time-series output from the underway SeaCat files. The first shows the complete pressure file with the vertical excursions of the submarine included. The second shows the edited file at constant pressure with the excursions removed. Variables of temperature, salinity and oxygen are also presented for the edited file.

References

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Saunders, P.M. and N.P. Fofonoff (1976) Conversion of pressure to depth in the ocean. Deep-Sea Res., 23, 109-11.

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Table 1
CTD Surface Stations

Notes:
C day is calendar day from 1 January.
Date, time and position are taken from the deepest point of the cast.
File Name: N/A means no CTD cast was taken; SH means shallow and MD means medium and DP or DP1 means deepest.

Table 2
Underway SeaCat Data

Notes:
Multiple daily files are noted by the letters A, B & C.
Positions: Reference for start of file; written in decimal degrees; longitude west is converted to longitude east.

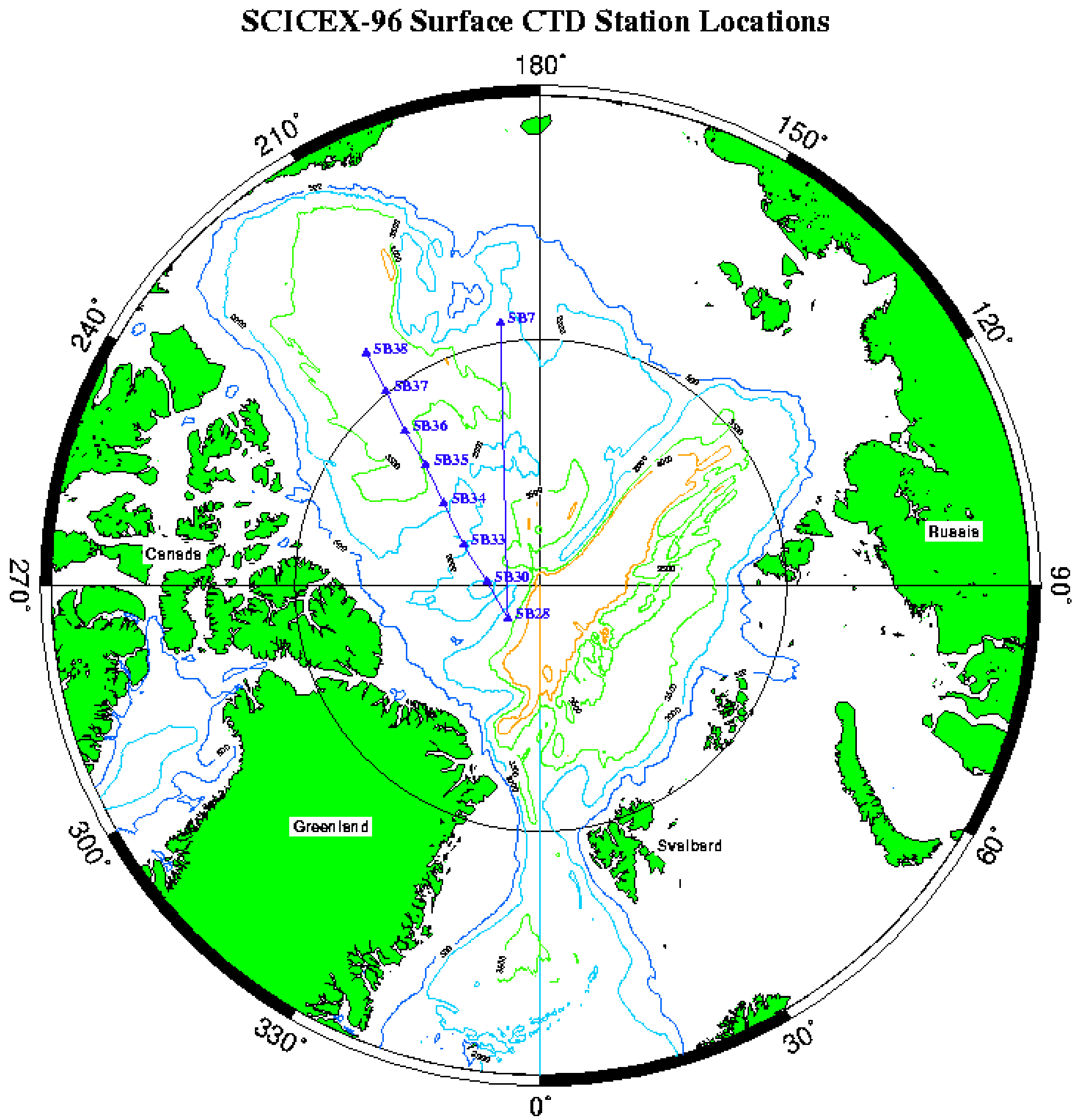


Fig. 1 Locations for Surface CTD Stations of the SCICEX-96 Cruise.

SCICEX-96 SSXCTD Station Locations

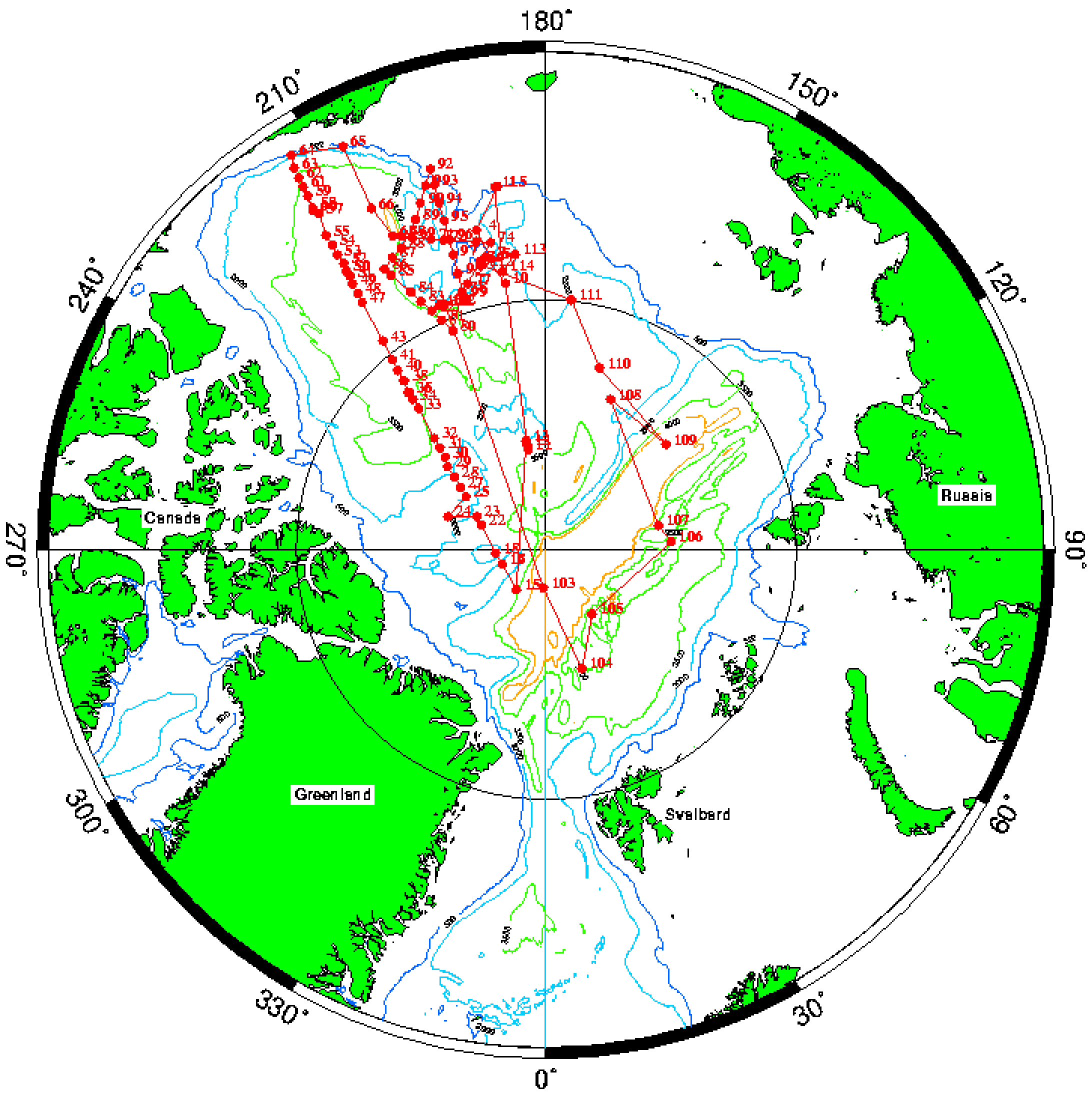


Fig. 2 XCTD station locations for SCICEX-96 Cruise. Stations are numbered in a chronological order.

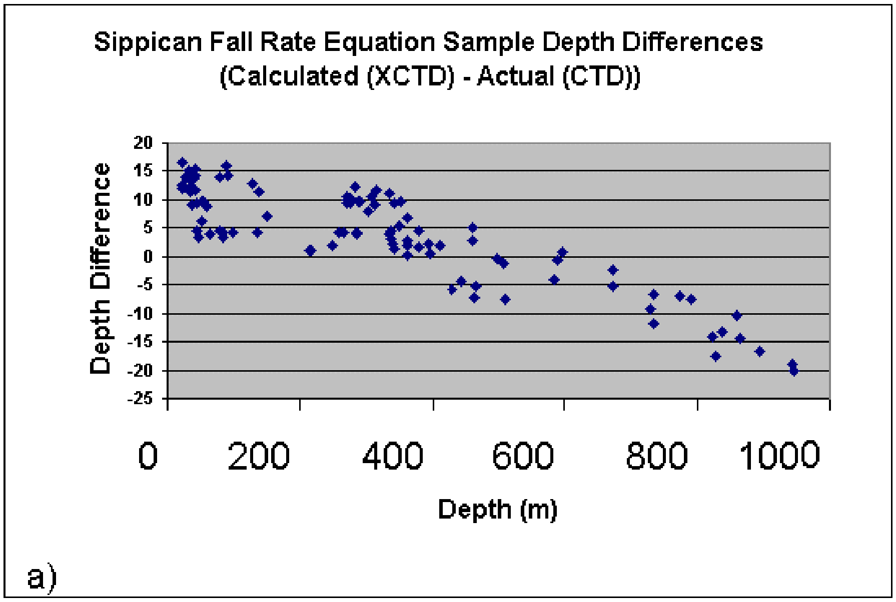
Table 3 . Best-fit of SSXCTD/CTD profile pairs. Temperature and salinity errors are derived from 1 m linearly interpolated data binned by depth. Depth errors are based on actual temperature and salinity feature depths.

XCTD Depth Range (M)		Temperature Error (C)		Salinity Error		Depth Error (m)	
Min	Max	Bias	Std Dev	Bias	Std Dev	Bias	Std Dev
20	100	-0.005	0.033	0.004	0.103	0.342	4.182
100	200	0	0.042	0.049	0.058	-1.035	4.161
200	300	-0.035	0.039	0.13	0.059	-2.402	4.333
300	400	-0.015	0.015	0.014	0.022	-3.777	3.342
400	500	-0.011	0.021	0.026	0.036	0.455	4.807
500	600	0.008	0.034	0.055	0.058	-1.554	4.259
600	700	-0.012	0.065	0.061	1.055	-3.551	2.054
700	800	-0.031	0.037	0.001	0.068	-0.275	2.822
800	900	-0.016	0.024	0.003	0.016	2.556	2.741
all data (20 to 1000 m)		-0.016	0.041	0.026	0.351	-1.038	4.298

* Temperature and salinity statistics are based upon 792 data points for each depth bin

Depth measurements are based on approximately 20 measurements per depth bin

Fig. 4 Group 2 salinity comparison using bottle salinities from all depths with corresponding CTD salinities. Final regression was Corrected Salinity = 1.012257 x CTD Salinity - 0.42209 with a r2 = 0.999, average = 0.0055 ppt, standard deviation = + 0.0012 ppt.



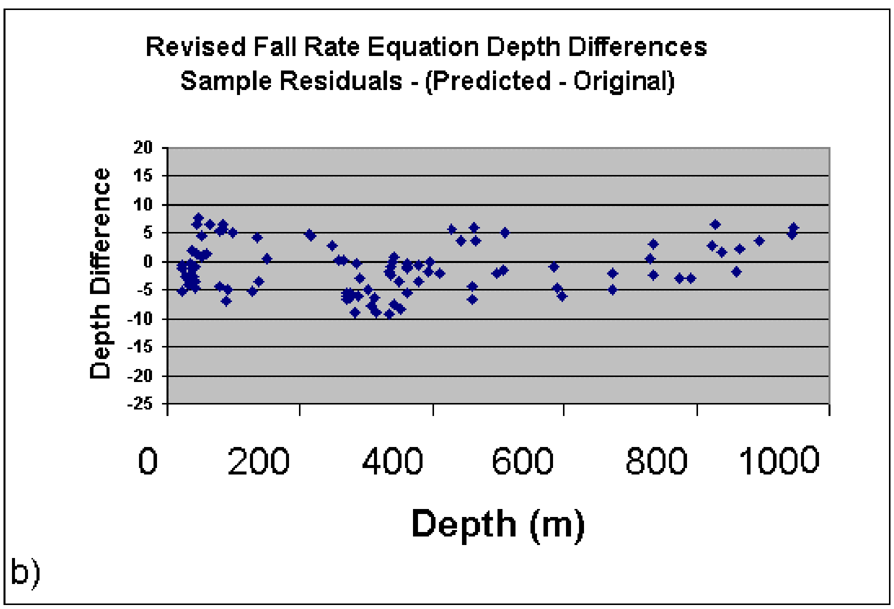


Figure 5a,b a) Depth errors derived from matching the depths of CTD and SSXCTD features and noting the differences. b) The same difference calculated after adjusting the SSXCTD data with revised "best-fit" fall-rate coefficients.

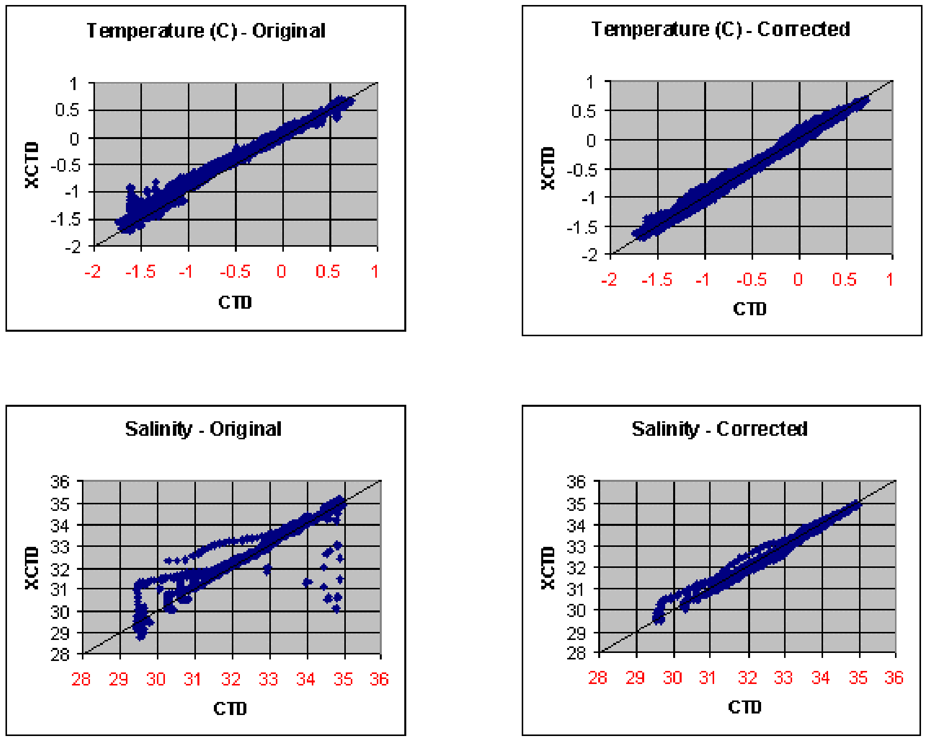


Figure 6 . Scatter plots of 1m linearly interpolated temperature and salinity data for original SSXCTD vs CTD pairs at similar depths between 20 and 100m depth. Corrected temperature and salinity data plotted after revising the fall rate parameters based on goodness-of fit results.

Fig. 6 Scatter plots of 1 m linearly interpolated temperature and salinity data for original SSXCTD vs CTD pairs at similar depths between 20 and 100 m depth. Corrected temperature and salinity data plotted after revising the fall rate parameters based on goodness-of-fit results.

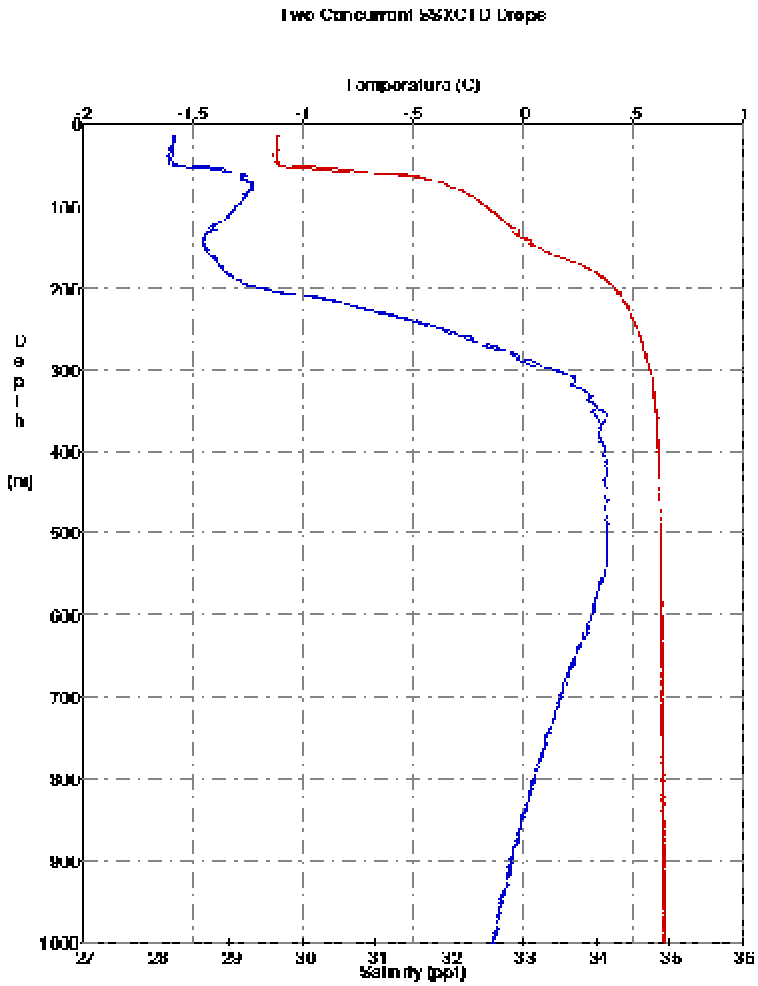


Figure 7 . Exemplifies SSXCTD probe-to-probe variability. SSXCTD's 35 and 36 were launched close in time and space. These two traces indicate that probe-to-probe variability is small. Differences in temperature and salinity between these profiles are within the instruments stated accuracy.

Fig. 7 Exemplifies SSXCTD probe-to-probe variability. SSXCTD's 35 and 36 were launched close in time and space. These two traces indicate that probe-to-probe variability is small. Differences in temperature and salinity between these profiles are within the instruments stated accuracy.

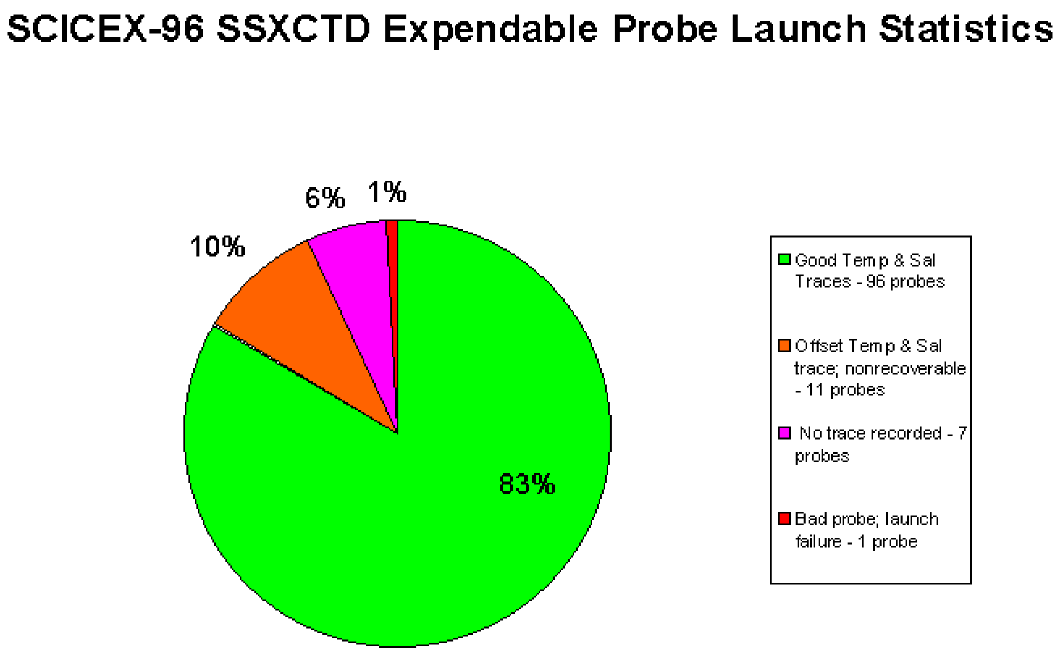


Figure 8. Launch statistics for Sippican's under- ice, expendable, submarine launched CTD probes during the SCICEX-96 exercise. Results include offset traces that could not be properly edited or realigned.

Fig. 8 Launch statistics for Sippican's under-ice, expendable, submarine launched CTD probes during the SCICEX-96 exercise. Results include offset traces that could not be properly edited or realigned.