R.V. MELVILLE CRUISE ME9706 - CTD DATA PROCESSING NOTES

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1. Field data collection methods

CTD data

A General Oceanics MarkIIIB (i.e. not WOCE upgraded) CTD in a short pressure housing was used for the entire cruise (CTD serial no. 1013 = CSIRO unit no. 2). Backup CTD's and deck units taken on board were not required. Base parameters measured were:

pressure (stainless steel tube type strain gauge bridge, no pressure temperature correction)
temperature
conductivity
altimetry (Benthos model 2110 altimeter)

An old dissolved oxygen sensor was mounted to seal the instrument at the oxygen sensor mounting, while the fast temperature thermistor was not connected. For station 28 onwards, an acoustic pinger was used in place of the altimeter to locate the bottom.

A 24 bottle rosette package was used, with a General Oceanics model 1015 24-position pylon, and a mix of 10 litre General Oceanics and CSIRO-manufactured Niskin bottles. Deep sea reversing thermometers (Gohla-Precision) were mounted at rosette position 2 for stations 3 to 16. An Antarctic Division "wind-on-barrel" type termination was used at the wet end of the sea cable. Note that sea cable gauge on the Melville is .322" (~8.2 mm).

The CTD raw data stream was logged simultaneously by two IBM-compatible PC's, using the General Oceanics software CTDACQ, version 5.2 revision 2. All data was ftp'd to a Sun Ultra workstation for calibration and processing. For a complete description of data calibration and processing methodology, see Appendix 2 in Rosenberg et al. (1995).

Bottle data

Salinity samples were drawn outdoors on the aft deck; the ship stayed on station during sampling to minimise contamination of samples from rain and flying spray. Bottle samples were analysed by Neale Johnston in the port lab aft of the main lab. Two Guildline Autosals (model 8400B) were used for anlysis of salinity bottle samples:

stations	salinometer serial no.	ISS batch	temperature bath setting
2	62549	P130	24°C
3 to 30	62549	P130	21°C
31 to 49	62548	P130	21°C

For salinometer 62549, the digital output jumped around by ~10 units, so the reading for each sample was averaged by watching the output display for a few seconds. Note that this output instability was a fluctuation about a stable mean, so there is no significant error in the data. For stations 31 and 32, salinometer 62549 became unstable. These 2 stations were re-analysed using salinometer 62548 (approximately half the samples were lost for these two stations). 62548 was then used for the remainder of the cruise - in contrast to salinometer 62549, the digital output of 62548 was very stable.

Overall, both salinometers were very stable over the entire cruise, showing no significant drift against seawater standards.

Salinometer conductivity ratio data was converted to salinities via an Excel-based program “HYDRO” (created by CSIRO) on an IBM-compatible PC. Note that thermometer data was also processed by the same program.

CTD laboratory calibrations

Pre cruise calibrations of CTD temperature and pressure were performed at the CSIRO Division of Marine Research calibration facility (Table 1). Note that the quadratic term for temperature is 0.

Table 1: Laboratory calibration coefficients for CTD 1013 (CSIRO unit 2).

coefficient	value of coefficient
pressure calibration coefficients (calibration for pressure increasing)	
CSIRO Calibration Facility - 14/10/1996	
pcal0	-2.468546
pcal1	9.983564e-02
pcal2	9.157603e-09
pcal3	8.213898e-14
pcal4	-2.401388e-18
platinum temperature calibration coefficients	
CSIRO Calibration Facility - 15/10/1996 to 16/10/1996	
Tcal0	6.90200e-03
Tcal1	4.99840e-04
Tcal2	0.0

2. CTD instrumentation problems

Several problems were encountered during the voyage, as follows.

Electrical connections

On two separate occasions (at stations 7 and 24), a clean CTD data stream could not be acquired. In both cases, there was a delay of ~14 hours fixing the problem. At station 7, the problem was traced to faulty slip rings at the sea cable winch drum; new slip rings were installed. At station 24, several faults were found: on the rosette package, a y-cable connector and the altimeter bulkhead connector both leaked (the latter was not discovered until station 26); at the slip rings, a connector was broken.

Following station 26, a bad leak was discovered in the altimeter bulkhead connector. One pin was completely corroded, and the altimeter could not be used for the remainder of the voyage.

Equipment damage/loss

During the instrument recovery at station 16, the package smashed against the side of the ship when the ship took a large roll. The mounting blocks on two Niskin bottles were broken off. A third Niskin with the reversing thermometers was lost from the package. No replacement thermometers were available, thus no more performance checks of the CTD temperature were possible.

3. Results

CTD station positions are shown in Figure 1. The final calibration results for conductivity/salinity, along with the performance check for temperature, are shown in Figures 2 to 4. Note that in Figure 2, Temp(DSRT) is the reversing thermometer temperature. Table 2 lists important data quality information relevant to the CTD 2dbar averaged data.

Temperature

For stations where reversing thermometer data were available, the CTD temperature performance appeared stable, and in agreement with the pre cruise laboratory calibration (Figure 2). Following loss of the thermometers at station 16, no further checks of CTD temperature could be made. At the time of writing, no post cruise temperature sensor calibration has been performed.

Conductivity/salinity

The conductivity calibration for CTD 1013 was of high quality (Figures 3 and 4), with salinity accurate to well within the WOCE specification of 0.002 (PSS78).

For stations 1 to 9, the conductivity cell was slightly fouled, resulting in a pressure dependant conductivity residual after initial calibration. This residual was removed by the following steps:

(a) CTD conductivity was initially calibrated to derive conductivity residuals (c_{btl} - c_{cal}), for in situ bottle conductivity c_{btl} (calculated from bottle salinity and in situ temperature and pressure) and c_{cal} equal to the conductivity value after the initial calibration only i.e. prior to any pressure dependent correction.

(b) Next, a fourth order pressure dependent fit was found for the conductivity residuals of station 4 to 9 (stations 1 to 3 were not used in the fit, as for these stations bottle samples were not available over the entire water column):

$$(c_{btl} - c_{cal})_n = \alpha_4 p_n^4 + \alpha_3 p_n^3 + \alpha_2 p_n^2 + \alpha_1 p_n^1 + \alpha_0$$

where the residuals $(c_{btl} - c_{cal})_n$ and corresponding pressures p_n (i.e. pressures where Niskin bottles fired) are all the values accepted for conductivity calibration in stations 4 to 9. The following values were obtained for the coefficients:

α_4 = -3.353000e-16
α_3 = 3.373000e-12
α_2 = -1.171327e-08
α_1 = 1.408843e-05

(c) Lastly, the conductivity calibration was repeated, this time fitting ($c_{ctd} + \alpha_4 p_n^4 + \alpha_3 p_n^3 + \alpha_2 p_n^2 + \alpha_1 p_n^1$) to the bottle values c_{btl} in order to remove the pressure dependence for stations 1 to 9 (for uncalibrated conductivity c_{ctd}; and note that the offset α_0 was not applied). Note that for previous cruises, any pressure dependant residuals have been adequately modelled by a linear pressure dependant correction. In this case however, significantly better results were obtained using the fourth order fit.

No bottle data was available for stations 1, 24, 25, 26 and 27 (for stations 24 to 27, the pylon was not connected). Conductivity calibrations from surrounding stations were applied to these stations.

The conductivity cell was fouled for station 37, resulting in a poorer conductivity calibration. The salinity accuracy for this station is ~0.003 (PSS78).

On Aurora Australis cruise au9601 along the SR3 transect (August to September 1996), a discrepancy was found between International Seawater Standard (ISS) batch numbers P128 and P130. The standards were compared by standardising a Guildline Autosal with one standard, measuring the other standard, and comparing the measurement with the second standard's nominal value. It was found that P128 read 0.0018 ± 0.0003 (PSS78) higher than P130. As a result, salinity samples standardised against P128 were lower by 0.0018 (PSS78) than samples standardised against P130. At the time of writing, it is not known which ISS batch is at fault (the supplier Ocean Scientific have been alerted to the problem). For Melville cruise me9706, ISS batch P130 was used for the entire cruise. If it turns out that P130 is a faulty batch, then all salinities for this cruise will need to be corrected by -0.0018 (PSS78).

Pressure

Pressure data is accurate to 6.5 dbar (manufacturer specified accuracy). Noise in the pressure signal increased slightly at station 28 and onwards, for unknown reasons. This noise however was less than 1 dbar in range, and did not effect pressure accuracy.

Altimeter/pinger elevations

Altimeter elevations (Table 3) were only available up to station 26. For station 27, no bottom location device was installed on the package, so elevation above the bed is unknown at the bottom of the cast. For stations 28 and onwards, a pinger (attached to the package) was used to locate the bottom. For stations 28 to 35, good bottom return was obtained (Table 3), although elevations are not as accurate as altimeter data, owing to inaccuracies in interpretation of pinger chart readings. For stations 36 to 49, no reliable elevations could be obtained from the pinger. Wire angles were very high during most of these casts, which may have contributed to poor pinger return. Elevations for stations 36 to 49 can be estimated by comparing the maximum pressure at the bottom of each cast with the ocean depth as measured by the sidescan sonar (no values are supplied in Table 3).

Table 2: Data quality information relevant to CTD 2dbar averaged files.

suspect 2dbar bins (refers to salinity only, plus derived quantities σ_T, specific volume anomaly, and geopotential anomaly):

station	pressure	flag	comment
1	88	suspect	salinity spike in steep gradient
9	1550-1570	deleted	fouling of conductivity cell
17	2	suspect	transient error when entering water
23	84	suspect	salinity spike in steep gradient
25	2	suspect	transient error when entering water
27	1252-1266	deleted	fouling of conductivity cell
32	2,4	suspect	transient error when entering water
36	466	deleted	fouling of conductivity cell
48	2	suspect	transient error when entering water

interpolated 2 dbar bins:

station	pressure
47	1312

additional missing 2 dbar bins:

station	pressure	comment
19	90	deleted, due to wake water at sensors during a pressure reversal

Table 3: Elevation above the ocean bed at the bottom of each CTD cast. An altimeter was used for stations 1 to 26. A pinger was installed for stations 28 to 49, though reliable pinger returns were only obtained for stations 28 to 35.

station	elevation above bottom (m)	station	elevation above bottom (m)
1	-	21	27.0
2	-	22	24.0
3	15.7	23	22.5
4	23.1	24	-
5	16.1	25	16.3
6	14.3	26	22.0
7	19.5	27	-
8	19.7	28	30
9	23.9	29	25
10	19.7	30	30
11	22.7	31	10
12	29.8	32	35
13	24.6	33	20
14	25.0	34	25
15	22.5	35	30
16	19.5	36 to 49	-
17	0.9		
18	25.6		
19	26.5		
20	23.8		

4. Data formats

2 dbar averaged CTD data file

The final format in which CTD data is distributed is as 2 dbar averaged data, contained in column formatted ascii files, named m9706ixxx.all (Table 4), for i=CTD unit number, and xxx=station number. Averaging bins are centered on even pressure values, starting at 2 dbar. A 15 line header is followed by the data, as follows:

column	parameter
1	pressure (dbar)
2	temperature (^{o}C) (ITS-90)
3	salinity (PSS78)
4	σ_T = density-1000 (kg.m^{-3})
5	specific volume anomaly x 10^{8}(m^{3}.kg^{-1})
6	geopotential anomaly (J.kg^{-1})
7	dissolved oxygen (μmol.l^{-1}) (blank for this cruise)
8	number of data points used in the 2 dbar averaging bin
9	standard deviation of temperature values in the 2 dbar bin
10	standard deviation of conductivity values in the 2 dbar bin

All files start at the 2 dbar pressure level, incrementing by 2 dbar for each new data line. Missing data are filled by blank characters (this most often applies to dissolved oxygen data).

Table 4: **Example 2 dbar averaged CTD data file (*.all file).**

```
SHIP                    : R.V. Aurora Australis
 STATION NUMBER     :    4
 DATE                    : 02-JAN-1994  (DAY NUMBER   2)
 START TIME            : 1020 UTC = Z
 BOTTOM TIME         : 1100 UTC = Z
 FINISH TIME           : 1222 UTC = Z
 CRUISE                 : Au94/07
 START POSITION     : 44:07.03S 146:13.35E
 BOTTOM POSITION  : 44:07.14S 146:13.71E
 FINISH POSITION    : 44:06.61S 146:13.95E
 MAXIMUM PRESSURE: 1038 DECIBARS
 BOTTOM DEPTH       :   1015    METRES

 PRESS TEMP SAL SIGMA-T S.V.A. G.A.    D.O.
        (T-90)
   2.0  11.899 34.773 26.432 158.69  0.032                  30 0.001 0.007
   4.0  11.899 34.778 26.436 158.41  0.063                  30 0.001 0.001
   6.0  11.903 34.779 26.436 158.46  0.095                  45 0.001 0.002
   8.0  11.903 34.778 26.435 158.55  0.127                  41 0.000 0.000
  10.0 11.903 34.778 26.435 158.60  0.159                  32 0.001 0.001
  12.0 11.904 34.778 26.435 158.66  0.190                  32 0.001 0.001
  14.0 11.905 34.778 26.435 158.72  0.222                  40 0.000 0.000
  16.0 11.907 34.779 26.435 158.76  0.254                  34 0.002 0.002
  18.0 11.908 34.780 26.435 158.77  0.286                  25 0.002 0.002
```

Bottle data file

The bottle data file, named m9706.bot, is a column formatted ascii files containing the hydrology data, together with CTD upcast burst data (Table 5). The columns contain the following values:

column	parameter
1	station number
2	CTD pressure (dbar)
3	CTD temperature (^{o}C) (ITS-90)
4	reversing thermometer temperature (^{o}C)
5	CTD conductivity (mS.cm^{-1})
6	CTD salinity (PSS78)
7	bottle salinity (PSS78)
8	ortho phosphate concentration (μmol.l^{-1}) (no data for this cruise)
9	nitrate + nitrite concentration (μmol.l^{-1}) (no data for this cruise)
10	reactive silicate concentration (μmol.l^{-1}) (no data for this cruise)
11	bottle dissolved oxygen concentration (μmol.l^{-1}) (no data for this cruise)
12	bottle quality flag (-1=rejected, 0=suspect, 1=good)
13	niskin bottle number

Missing data values are filled by a decimal point (surrounded by blank characters). Parameters 2,3,5 and 6 are mean values from the upcast CTD burst data at the time of bottle firing, where each burst contains the data 10 sec previous to the time of bottle firing. Parameters 7 to 11 are laboratory values for the hydrology analyses. Parameter 12, the bottle quality flag, is relevant to the calibration of CTD salinities - bottles flagged 1 and 0 are used for calibration, while those flagged -1 are rejected.

Parameter 13, the niskin bottle number, is a unique identifier for each bottle. Note that the bottle number does not always correspond with rosette position.

Table 5: Example hydrology data file (*.bot file).

2	148.516	11.904	.	40.025	35.052	35.067	.	.	.	.	-1	4
2	200.278	11.085	.	39.174	34.963	34.965	.	.	.	.	-1	3
2	247.807	10.678	10.691	38.758	34.914	34.914	.	.	.	.	0	2
2	289.188	9.625	.	37.640	34.769	34.794	.	.	.	.	-1	1
3	8.609	15.984	.	44.199	35.274	35.275	.	.	.	.	1	16
3	21.504	15.975	.	44.198	35.276	35.275	.	.	.	.	1	15
3	48.210	15.935	.	44.171	35.277	35.276	.	.	.	.	1	14

Station information file

The station information file, named m9706.sta (Table 6), contains position, time, bottom depth and maximum pressure of cast for CTD stations. The CTD instrument number is specified in the file header. Position and time (UTC) are specified at the start, bottom and end of the cast, while the bottom depth (Seabeam sidescan sonar) is for the start of the cast. Note that small inconsistencies may exist between bottom depth and maximum pressure, due to drift of the vessel between the start and bottom of the cast. XBT temperature profiles were used to calculate sound velocity profiles in echo sounder calculations (performed by SCRIPPS computer technician Ron Moe).

Table 6: Example CTD station information file (*.sta file).

RSV Aurora Australis   Cruise : Au93/09   CTD station list   (CTD unit 4)

stat	start				bottom	max P	bottom			end		
no.	time	date	latitude	longitude	depth(m)	(dbar)	time	latitude	longitude	time	latitude	longitude
1	2032	11-MAR-93	44:06.73S	146:14.35E	1000	956	2118	44:06.37S	146:14.35E	2154	44:06.19S	146:14.60E
2	0027	12-MAR-93	44:00.06S	146:18.61E	300	289	0042	44:00.03S	146:18.77E	0115	43:59.97S	146:18.64E
3	0513	12-MAR-93	44:07.51S	146:14.89E	1100	1115	0549	44:07.48S	146:15.06E	0632	44:07.39S	146:15.23E

Matlab files

The CTD and bottle files are available in matlab format, as follows:

(i) m9706.mat   This file contains the CTD 2 dbar averaged data from the *.all files, along with header information. Matrix column numbers correspond to CTD station number. All blanks are filled by NaN. Matrices are as follows:

ctd_press = ctd pressure
ctd_temp = ctd temperature
ctd_sal = ctd salinity
ctd_sigma_t = σ_T

ctd_sva	= specific volume anomaly
ctd_ga	= geopotential anomaly
ctd_npts	= no. of data points used in the 2 dbar averaging bin

botd	= bottom depth (i.e. ocean depth)
maxp	= maximum pressure of cast
day	
month	
year	

and the following header information at the start, bottom and end of each cast:

decimaltime	= decimat time from start of year e.g. midday on January 2nd is 1.500
lat	= latitude
lon	= longitude
time	

(ii) m9706bot.mat This file contains the bottle data information from the *.bot file. Matrix column numbers correspond to CTD station number. All blanks are filled by NaN. Matrices are as follows:

ctd_press, ctd_temp, ctd_sal, ctd_cond = CTD pressure, temperature, salinity and conductivity from upcast CTD burst data (see above)

hyd_sal	= bottle salinity
therm	= protected reversing thermometer temperature
flag	= bottle quality flag
niskin	= Niskin bottle number
station	

Table 7: CTD stations at mooring locations.

CTD station no.	mooring number
1	HEM 1
2	HEM 1
3	IES 1
4	IES 3
5	IES 5
6	IES 2
7	IES 4
8	IES 8
9	IES 6
10	IES 9
11	IES 10
12	IES 11
13	IES 7
14	IES 13
15	IES 12
16	IES 14
17	IES 15
18	IES 17
31	IES 18
32	IES 16

5. References

Rosenberg, M., Eriksen, R., Bell, S., Bindoff, N. and Rintoul, S., 1995. *Aurora Australis marine science cruise AU9407 - oceanographic field measurements and analysis*. Antarctic Cooperative Research Centre, Research Report No. 6, July 1995. 97 pp.

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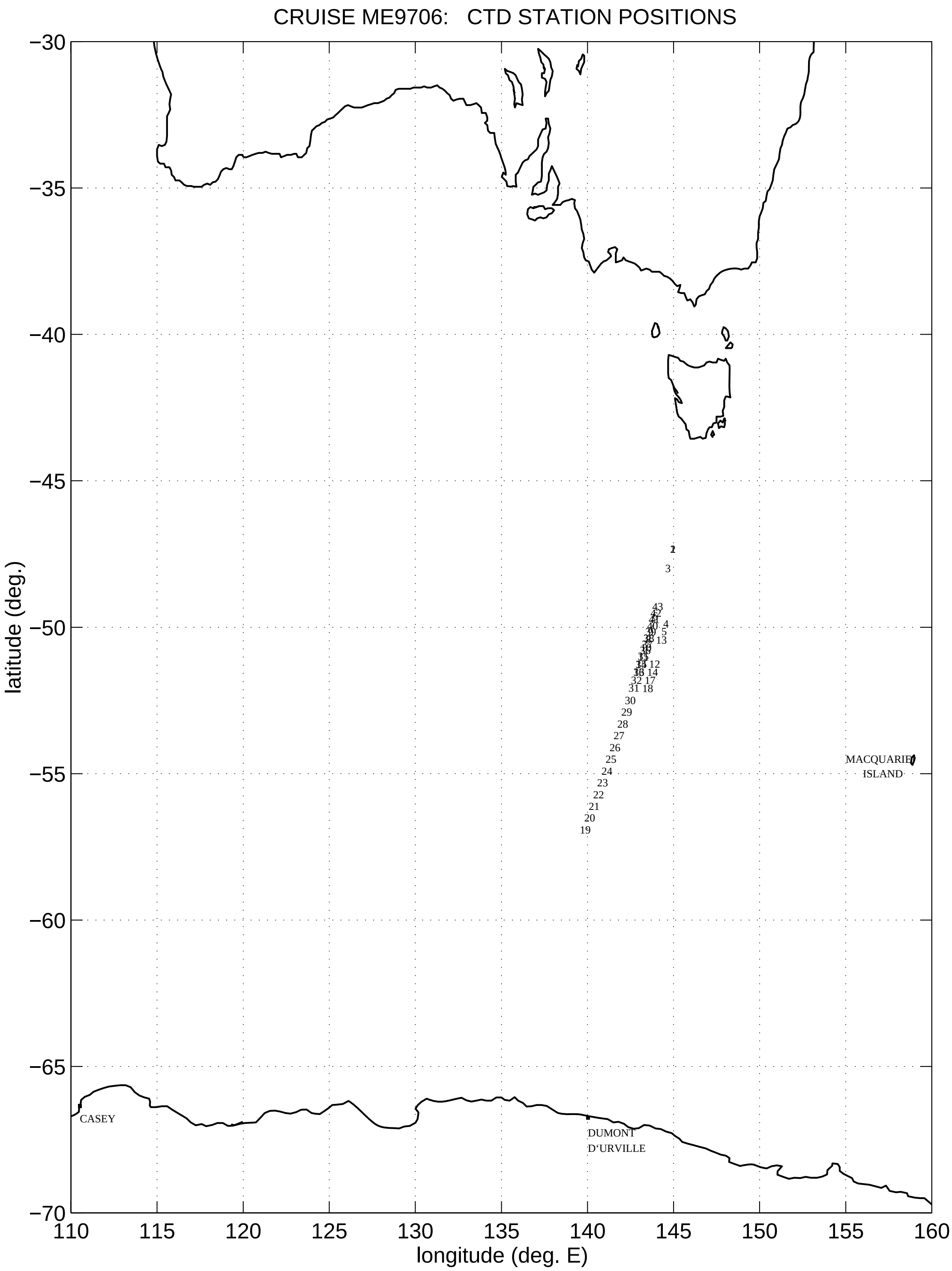
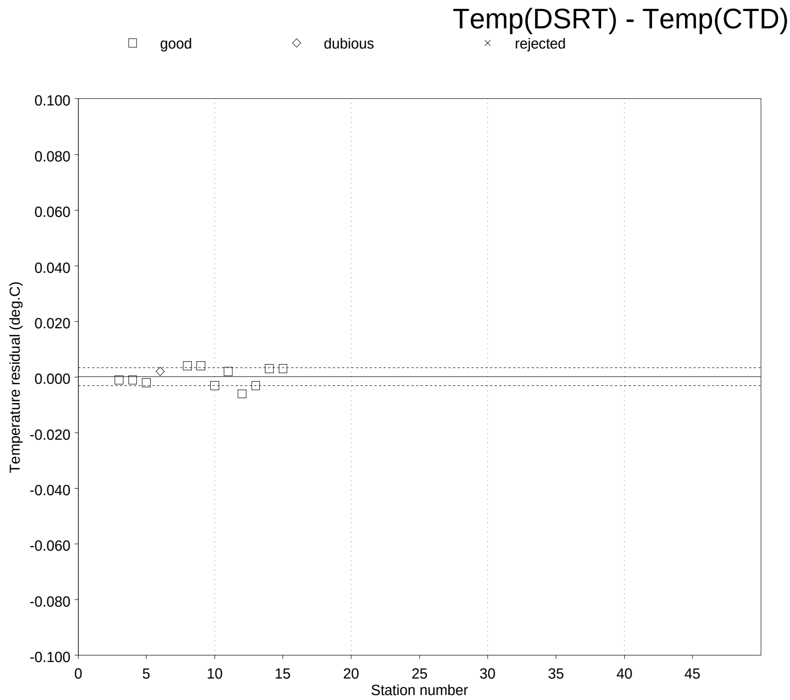


<u>Figure 1:</u> CTD station positions for RV Melville cruise me9706.



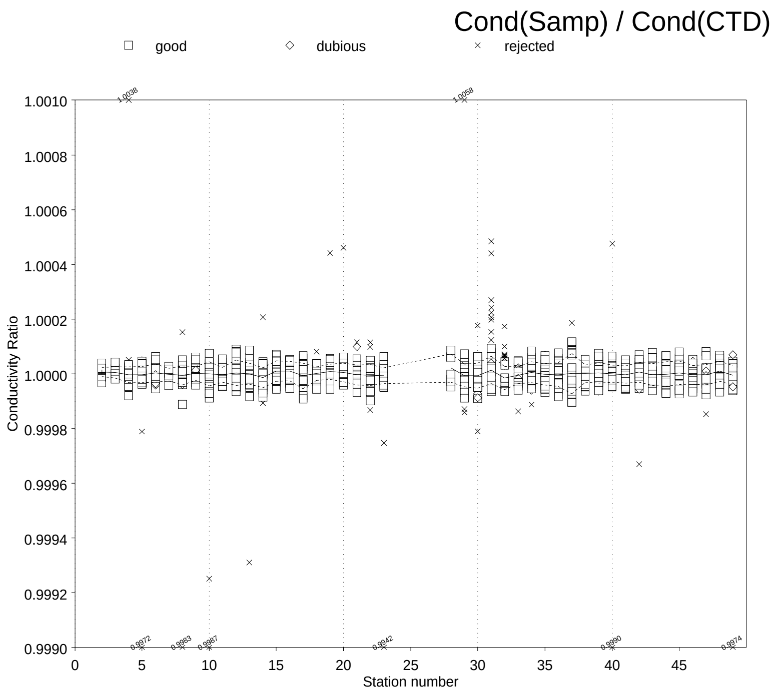
Calibration data for cruise : 9706

Calibration file : histcal.lis

Mean offset Temperature = 0.00017312c (s.d. = 0.0033 ˚c)

Number of samples used = 12 out of 12

<u>Figure 2:</u> Temperature residual (thermometer - CTD) versus station number.



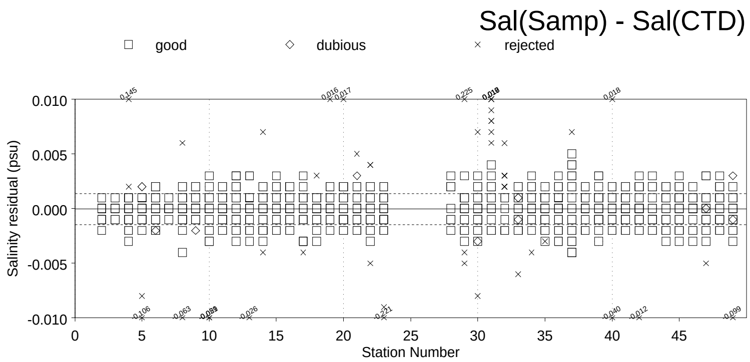
Calibration data for cruise : 9706

Calibration file : histcal.lis

Conductivity s.d. = 0.00004

Number of bottles used = 896 out of 960 Mean ratio for all bottles = 1.00000

<u>Figure 3:</u> Conductivity ratio versus station number.



Calibration data for cruise : 9706

Calibration file : histcal.lis

Mean offset salinity = -0.0001psu (s.d. = 0.0014 psu)

Number of bottles used = 896 out of 960

<u>Figure 4:</u> Salinity residual versus station number.