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ANALYSIS OF CTD AND XBT DATA FROM MOANA WAVE CRUISE 1992

R. J. Wilkes, 10/18/92

To properly analyse acoustical data on transponder positions, it is necessary to know the detailed sound speed profile of the waters over the DUMAND site at the time of the acoustical observations. For this purpose, two measurements were made during the Moana Wave DUMAND cruise (9/28--10/5/92): an XBT (eXpendable Bathy-Thermograph) drop, providing temperature vs depth to approximately 460m, and a CTD (Conductivity, Temperature Depth meter) cast to 4500m. We used the UW Sea-Bird SBE-16 "SEACAT" CTD which will eventually be installed on the JBEM string. While the CTD is an inherently higher-precision instrument and provides the conductivity data needed for accurate sound speed estimates, our unit turned out to have a broken pressure sensor, so we have only T (temperature) and C (conductivity) data without directly correlated D (depth) measurements. Depth values must be inferred from a log of winch cable lengths versus time. Reduction of the data to a plot of V (sound speed) vs D and further analysis in terms of a depth-weighted <V> must involve some inference and calculation, described here.

The CTD data file consists of a series of "scans" (records) logged internally by the unit at 15 sec intervals during the drop. Appendix 1 describes the features of the instrument used. Dropping the meaningless depth values, the raw data thus consists of a series of C and T values. This data file was subjected to the following analysis:

1. Insert time values and correlate with winch log.
The raw data were rewritten to a file CTDDROP.DAT with time information (hours, minutes and decimal) inserted, assuming 15 sec scan intervals. Comparing with the winch log provided by Hans Berns (Appendix 1), we find good correlations between the stated times of pauses and plateaus in the T vs t plot (Fig. 1), with some minor exceptions. The 100m pause appears to have come a bit later than the log suggests and the 500m pause appears to have been less than 2 minutes rather than 5 minutes long. Pause interval data were identified as sequences of scans with non-decreasing T. Identification of the exact start and stop scans for pauses became more difficult for deeper points, where the rate of temperature drop vs depth was smaller. In general, I took a pause to begin with the first non-decreasing scan near a logged time point, and to end with the first subsequent scan to be followed by a monotone decrease. One should note that the 100m pause appears to begin late, possibly an indication of lagging temperature readings due to the finite settling time of the T sensor and the rapid dT/dD near the surface.

2. Average data from pause intervals to find known-depth points.
Data representing readings during winch drop pauses were edited out and separately averaged. Table I below shows the means and standard deviations for T and C for each pause, plotted vs depth in Fig. 2. One should remember that the "depths" shown are actually winch

cable lengths, which are really lower limits for the depth. The standard deviations for these time series at fixed depth give an indication of the practical precision of the CTD sensors. As noted above, the 100m series is clearly affected by the finite settling time of the sensor and the rapid dT/dD in shallow waters. Points below 500m are close to the specified precisions of the sensors.

Table I: results of averaging data from winch pause intervals.

Depth	Npts	<Temp>(C)	sigma-T	<Cond>(S/m)	sigma-C
100	60	23.4587	0.0915	5.1253	0.0119
500	6	6.2009	0.0307	3.4026	0.0074
1000	42	4.2438	0.0033	3.2715	0.0002
1500	25	2.8981	0.0013	3.1805	0.0002
2000	44	2.1404	0.0014	3.1384	0.0002
2500	24	1.7576	0.0020	3.1270	0.0004
3000	45	1.5782	0.0020	3.1319	0.0004
3500	26	1.4800	0.0012	3.1427	0.0002
4000	47	1.4609	0.0015	3.1592	0.0003
4500	66	1.4837	0.0023	3.1787	0.0004

3. Interpolate depth estimates for intervening scans.
The averaged values shown in Table I were put back into the data file to represent their corresponding depths. The remaining data points were then supplied with interpolated depth values, i.e., I assumed constant winch drop rate between the marked points.

4. Insert calculated pressure and salinity values.
The standard parameters for sound speed calculation are salinity, temperature and pressure (S,T,P) rather than the CTD values we have thus far. I used a simple expression for pressure vs depth from the "Handbook of Ocean and Underwater Engineering", 1969 edition, p. 2-9: p=0.444D+0.3*(D/1000)**2, where D is expressed in feet and p in psi. This is a rough approximation to the compressibility factor, and might be replaced with a more elaborate calculation, but I believe the errors introduced are no larger than appropriate given the rough depth values. For salinity, I used the formula for S(P,T,C) given in the PSS-78 standard (IEEE J.Oc.Eng. OE-5:1 (1978)). This provides the salinity in terms of the ratio C/C_c, where C_c represents the conductivity of Copenhagen water, C(35,15,0)=4.2914 Siemens/meter. Results are shown in Fig. 3.

5. Insert sound velocity values.
The next step is to use the measured T, calculated S and estimated P values to calculate the sound velocity vs D using one of the standard formulae. I used the Wilson (J.Ac.Soc.Am. 32:641 (1960)) formula which appears to be a common choice. Results are shown in Fig. 4.

6. Calculate mean sound speed for a vertical ray.
For first-stage analysis, we want to use a single speed representing the mean sound speed over a vertical path. For this we must average the V vs D profile, weighting points by the depth range they span (delta-D). This is equivalent to dividing the total depth by the numerically integrated transit time for a vertical

ray, using the calculated speed profile. The result is:
<V> = 1504.33 m/sec.

COMMENTS

The XBT data are reasonably consistent with the CTD data, but tend to lead them, as expected if the winch cable length (the "depth" parameter used for CTD data) is only an upper limit of the true depth, as expected.

The analyzed data are consistent with the only previous data set I could find, presented in raw form in HDC-DIR-14-83. These data end at 1500m and the only information for lower depths are notes pencilled onto the data sheet, giving T(3950)=1.49 and S(4000)=34.8. For this reason, the CTD cast during the 10/92 cruise provides essential information for DUMAND acoustics.

Once the CTD has been repaired, we can use it in future cruises (before array deployment) with much less analysis effort: software supplied with the unit by Sea-Bird will produce the desired results directly.

Appendix I: Details of CTD and winch operation, programs used.

The UW Sea-Bird SEACAT SBE-16 logging CTD is designed to be self contained and battery powered. It is normally started by connecting a PC terminal, then runs autonomously, sampling C, T and D at specified intervals, until the terminal is reconnected and the data in its internal memory are downloaded. Thus normal operation requires only a mechanical winch, with no electrical connections.

However, we ordered our unit without batteries, since it was intended for permanent mounting on the JBEM string. Therefore to use it from a ship, as on the Moana Wave cruise, we had to draw power from the winch cable. This in turn required a modification to the power control board in the unit, since voltage drop in the winch cable required a wider input voltage range than the standard battery powered unit can tolerate. The unit was modified, tested and recalibrated by Sea-Bird in mid-September 1992. However, upon testing aboard the Wave, it was found to have a defective pressure sensor. Engineers at Sea-Bird examined a data file downloaded from the ship, and told me that the C and T data appear to be OK.

Therefore we cannot directly correlate T and C measurements with depth, but must use the winch lengths as depth estimators.

Factory specifications on sensors are as follows:

Parameter	Accuracy	Resolution
C	0.001 S/m	0.0001
T	0.01 C	0.001
D	0.02 %	0.004

Accuracy is based on comparison to absolute standards at the US NOAA standards lab in the Seattle area.

Winch operation log (notes by Hans-Gerd Berns):

start data logging:	19:00	CTD on board, prepared for dive.
splash into water:	19:24	winch speed 50 m/min after accel.
100 m, first stop:	19:26	first check.
continue drop:	19:38	winch speed 50 m/min
500 m, 5 min. stop:	19:46	drop continued at 19:52
1000 m, 10 min.	20:02	" " " 20:12:20
1500 m, 5 min.	20:22:40	" " " 20:28:30
2000 m, 10 min.	20:38:30	" " " 20:49:00
2500 m	20:59:30	" " " 21:04:30
3000 m	21:14:50	" " " 21:25:15
3500 m	21:35:20	" " " 21:41:50
4000 m	21:51:50	" " " 22:03:00
4500 m	22:12:40	kept there for 16 min., then return started at 22:28:50
at 4419 m stop	22:31:30	cable had to be greased
at 4000 m	22:38:50	
at 3500 m	22:47:05	
at 3000 m	22:55:25	
at 2500 m	23:03:50	
at 2000 m	23:12:14	

at 1500 m	23:20:28	
at 1000 m	23:28:50	
at 500 m	23:37:05	
at 100 m	23:43:37	
at 10 m	23:45:15	halted for some last checks, then pulled out of water.

Analysis programs and files:
Program names listed represent Turbo C or Pascal programs which I have copied into DUMAND::/home/wilkes/cruise. The programs run on PCs using data files which have also been copied to DUMAND::.

Program	Function	Input/Output
DATACNV (Seabird)	Get C,T from binary file	T_1004.HEX T_1004.CNV
(Hand editing)	Remove pause data from file	T_1004.CNV CTDDROP.DAT
CTDAVG.PAS	Average pause data	CTDDROP.DAT CTDAVG.DAT
(Hand editing)	Insert averaged data pts back into file	CTDDROP.DAT CTDDROP.DAT
LINFITS.PAS	Fit to data 4300-4500m and extrapolate to get values for 4600-4800m	CTDEXTRP.DAT (no file)
(Hand editing)	Insert extrapolated data at end of data	(hand entry) CTDDROP.DAT
CTDINTRP.PAS	Interpolate to get D values; file now has D,T,C for 0--4800m	CTDDROP.DAT CTDDROP.OUT
CTDINSPS.PAS	Insert S, P and V values	CTDDROP.OUT CTDDROP.VEL
AVGSPD2.PAS	Find weighted avg sound speed	CTDDROP.VEL (no file out)

File contents:

T_1004.HEX =	raw seabird file downloaded from unit (binary data).
T_1004.CNV =	data containing C,T; processed using seabird software.
CTDDROP.DAT =	time (hour, decimal minutes), T, C; final version has averaged values for pauses typed in along with depths.
CTDDROP.OUT =	D, T, C (D is interpolated between pause values)
CTDDROP.VEL =	D, T, C, P, S, V
XBT.LOG =	XBT data file

Figures:
1. Raw CTD data file (T vs time), showing pauses.
2. Averaged data points for pause intervals.
3. CTD data with interpolated depths (CTDDROP.VEL): T, S vs D.
4. Velocity vs depth (CTDDROP.VEL).
5. XBT data, for comparison (XBT.LOG).

CTD Drop 10/4/92: Raw Data

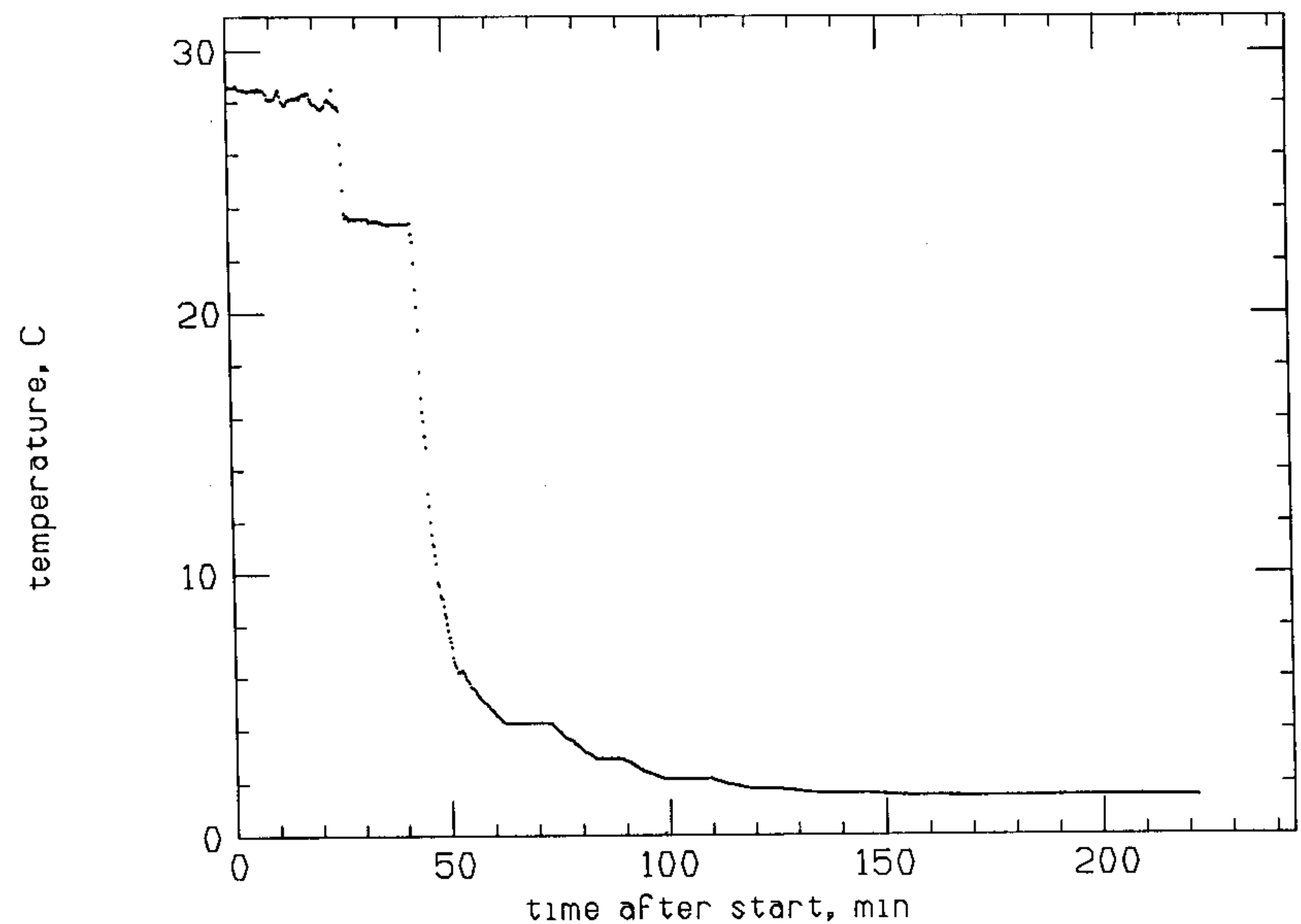


FIG. 1

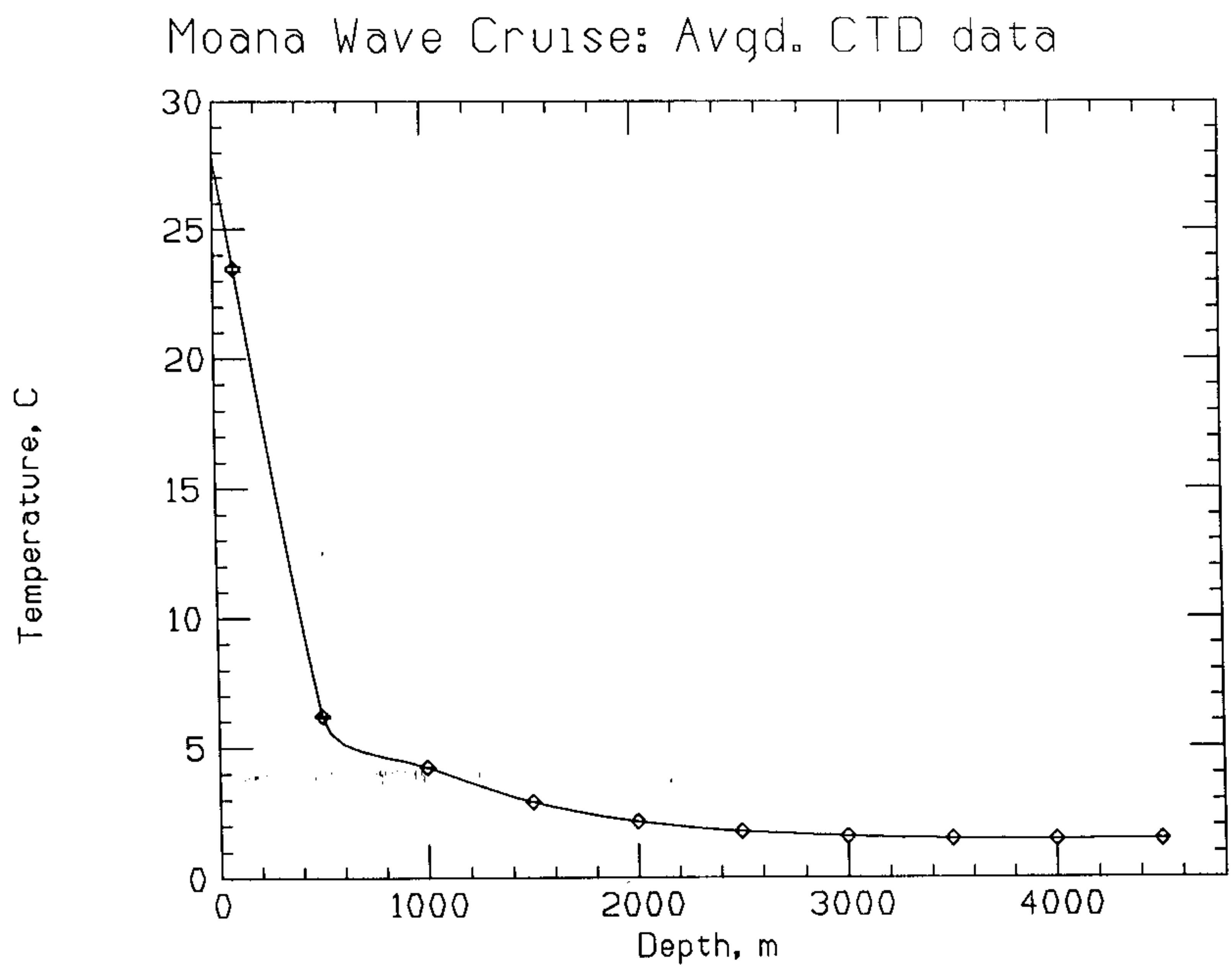

Moana Wave Cruise: Avgd. CTD data
30
25
20
15
10
5
0
Temperature, C
0
1000
2000
3000
4000
Depth, m

Fig. 2

Oceanographic parameters for DUMAND site

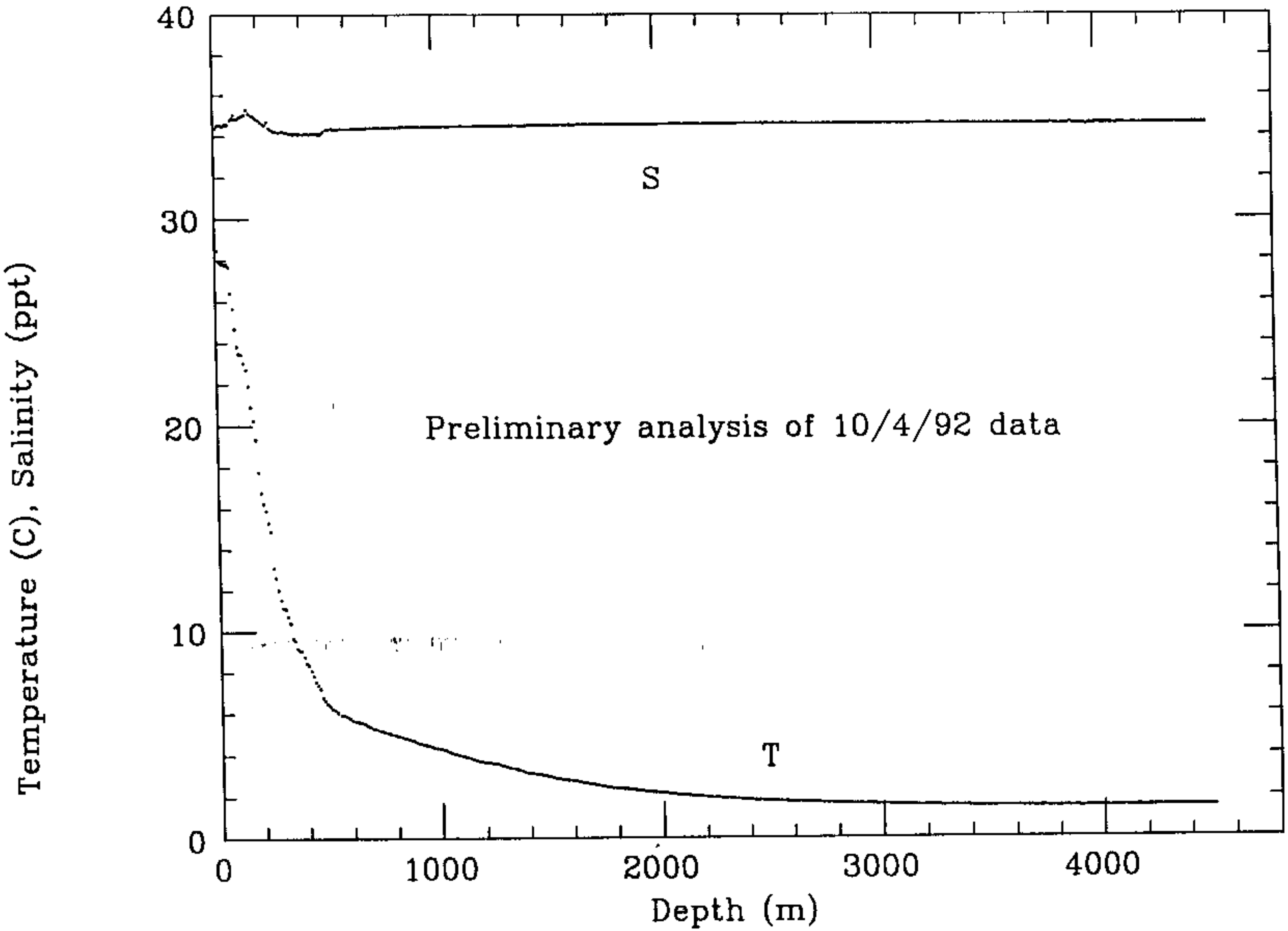


Fig. 3

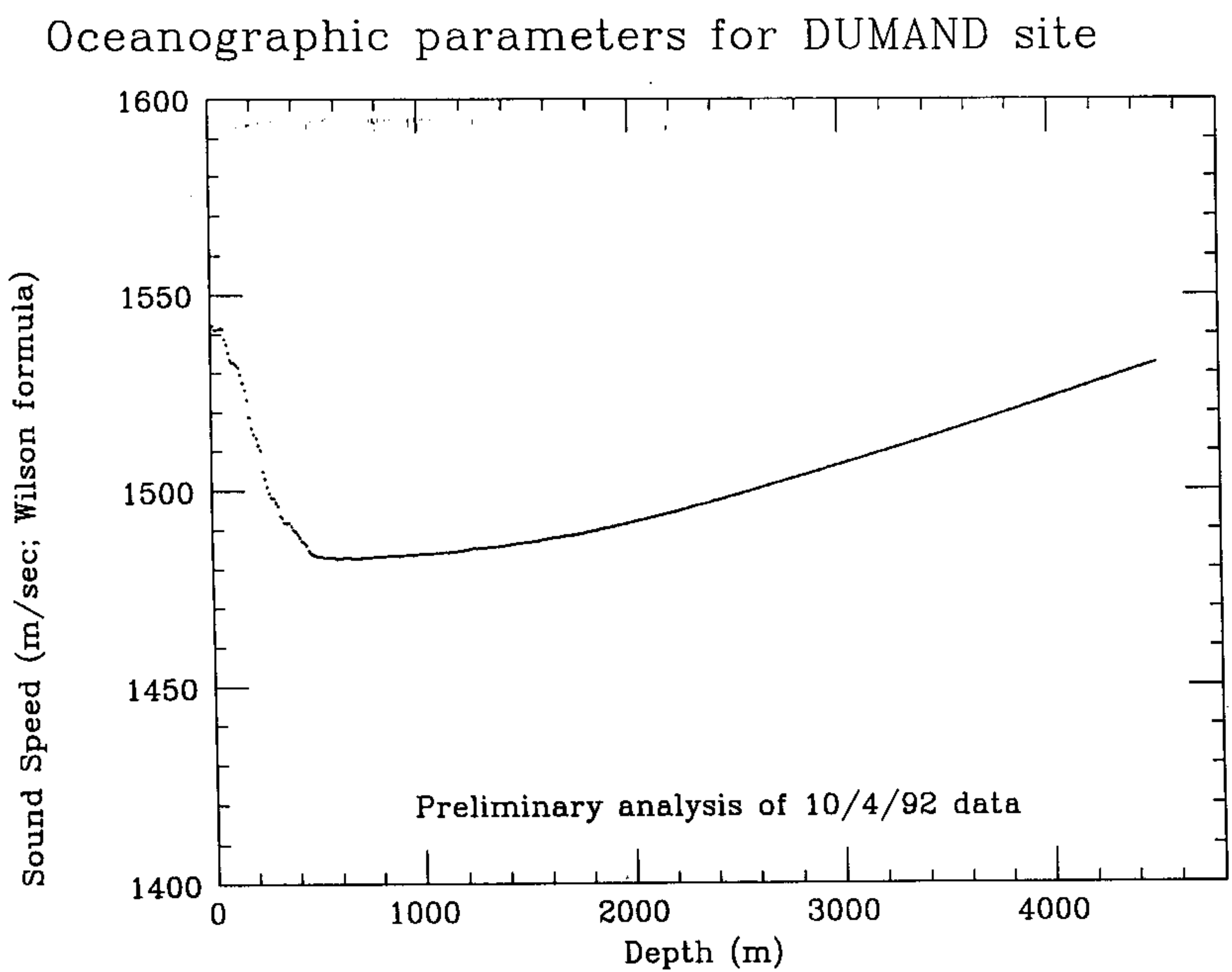
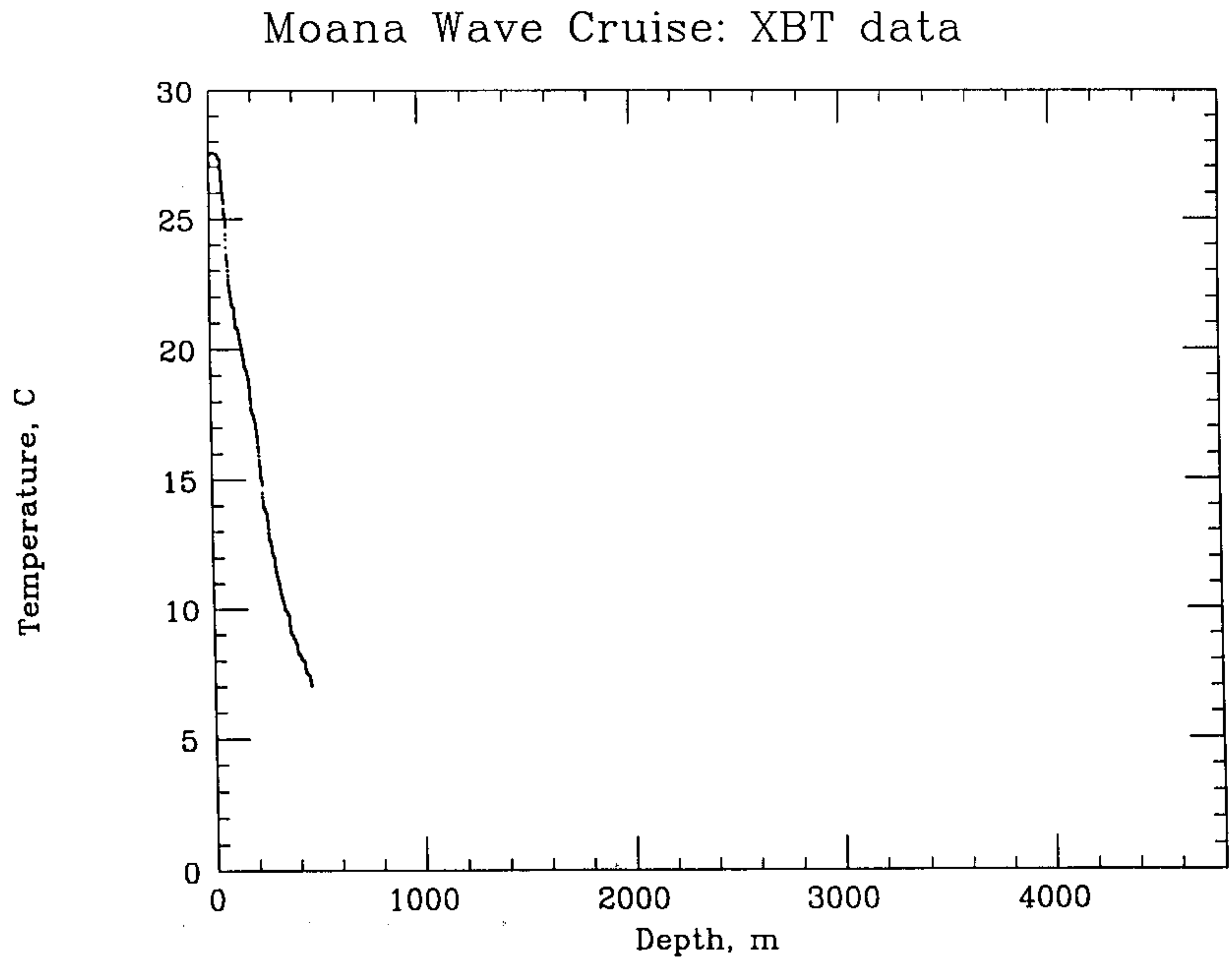

Oceanographic parameters for DUMAND site
1600
1550
1500
1450
1400
Sound Speed (m/sec; Wilson formula)
0
1000
2000
3000
4000
Depth (m)
Preliminary analysis of 10/4/92 data

Fig. 4


Moana Wave Cruise: XBT data
Temperature, C
30
25
20
15
10
5
0
0
1000
2000
3000
4000
Depth, m