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NOAA Technical Memorandum ERL AOML-76



**WINDWARD ISLANDS PASSAGES MONITORING PROGRAM:
PHYSICAL OCEANOGRAPHIC DATA COLLECTED ON CRUISE
WI-91-01, *HMBS TRIDENT*, 15-21 DECEMBER 1991**

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William E. Johns
Malcolm D. Hendry
J. Allison Routt

Atlantic Oceanographic and Meteorological Laboratory
Miami, Florida
November 1993

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NATIONAL OCEANIC AND
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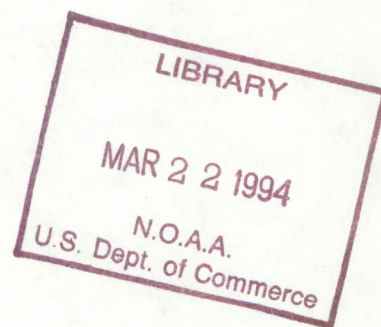
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November 1993



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ABSTRACT

During 1991 a collaborative program between the U.S. and Barbados was established with NOAA / CGC / ACCP support to conduct regular measurements of the transport and water mass characteristics in the major southern passages to the Caribbean. This program involves the use of a Barbados Coast Guard vessel (the *HMBS TRIDENT*) that makes routine (monthly) patrols in this area, which has been equipped to collect standard hydrographic measurements (CTD and water samples) and velocity profile measurements using a downward-looking ADCP. The purpose of the program is to determine the quantity and time-variability of South Atlantic surface, thermocline, and intermediate waters flowing into the North Atlantic in compensation for southward cross-equatorial transport of North Atlantic Deep Water, and to establish an economical means for future monitoring of this return flow. This report contains data from cruise WI - 91 - 01 conducted 15 - 21 December 1991.

INTRODUCTION

The Windward Islands Passages Monitoring Program is an experiment designed to monitor water mass properties and transport between the Atlantic Ocean and the Caribbean Sea through the Windward Island Passages. The project is supported by the United States National Oceanic and Atmospheric Administration's Climate and Global Change Atlantic Climate Change Program.

Quantity and time variability of the flow of water of southern hemisphere origin into the Caribbean Sea and through the Straits of Florida is an unknown factor of significant importance to any attempts to estimate Atlantic interhemispheric heat flux. Analyses of historical data suggest that the amount of South Atlantic thermocline and intermediate water flowing northward through the Caribbean and Straits of Florida may be enough to balance the deep southward transport of cold waters in the Atlantic thermohaline circulation. The most likely location for South Atlantic inflow into the Caribbean Sea is through the Windward Island passages south of Dominica. This is also the easiest place to measure, since flow is geographically constrained by the islands, the passages are relatively shallow with sill depths of about 1000 m, and proximity to the equator makes identification of the South Atlantic water masses easier. There are few recent measurements in this region, and no repeated coverage. The latter is especially important since studies to the southeast of this region, along the South American coast, show an energetic eddy regime suggesting that South Atlantic throughflow might be highly episodic.

The goal of this project is to utilize regional resources to maintain an oceanographic measurement program in an area of importance to Atlantic Ocean circulation and climate studies. Data collection consists of regular CTDO₂ (Conductivity-Temperature-Depth-dissolved Oxygen) profiles, water samples, and acoustic Doppler current measurements in the passages, taken during cruises of the *HMBS TRIDENT*. The data will also be of importance to understanding local ocean circulation and its relationship to regional environmental issues and fisheries ecology.

This report contains data collected on the first cruise of this project, 15-21 December 1991. The general area of operations is shown in Figure 1, and the specific locations of oceanographic stations occupied during this cruise are shown in Figure 2.

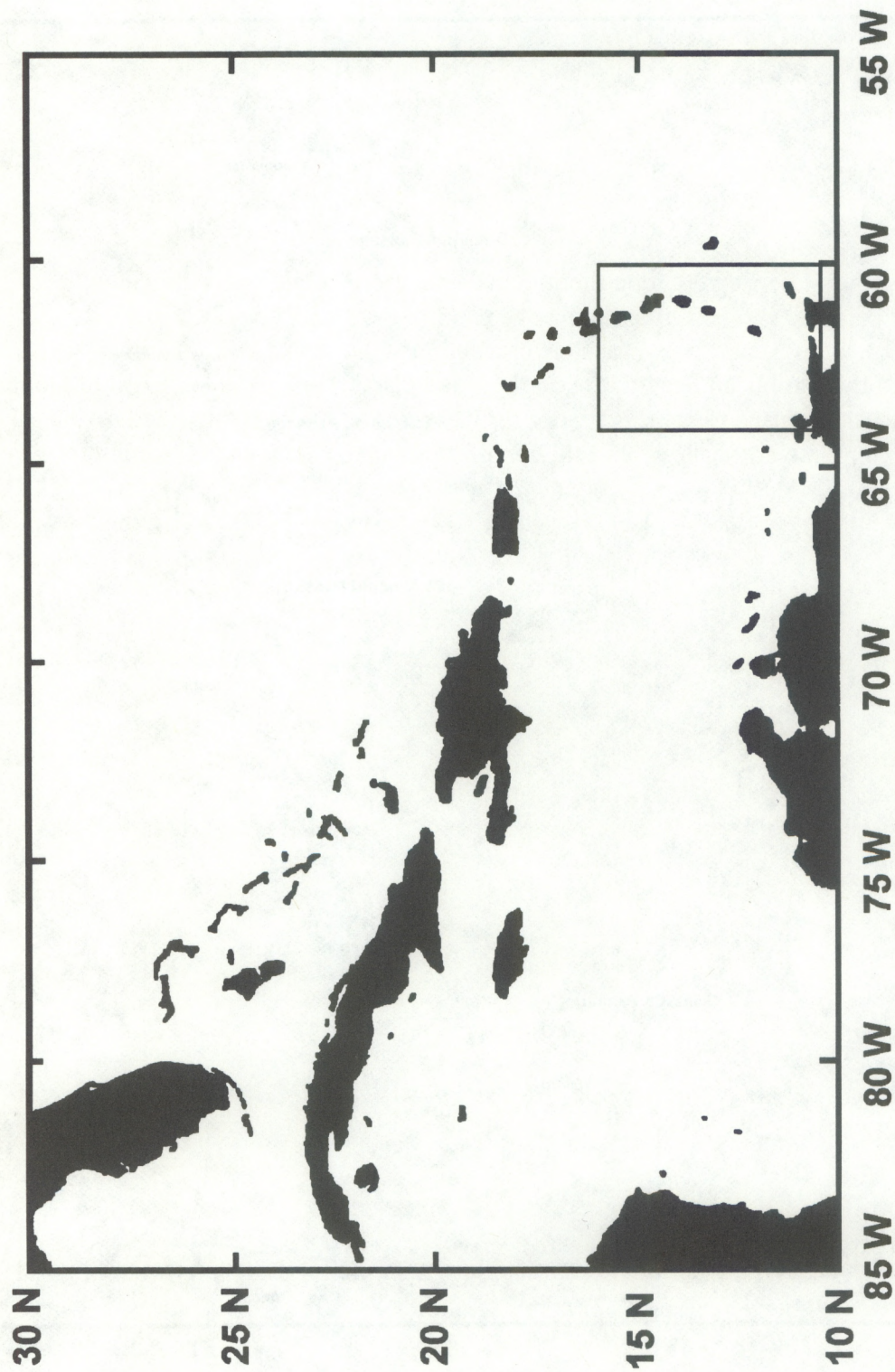


Figure 1. Location of Windward Islands Passages Monitoring Program region within the Greater Caribbean Basin

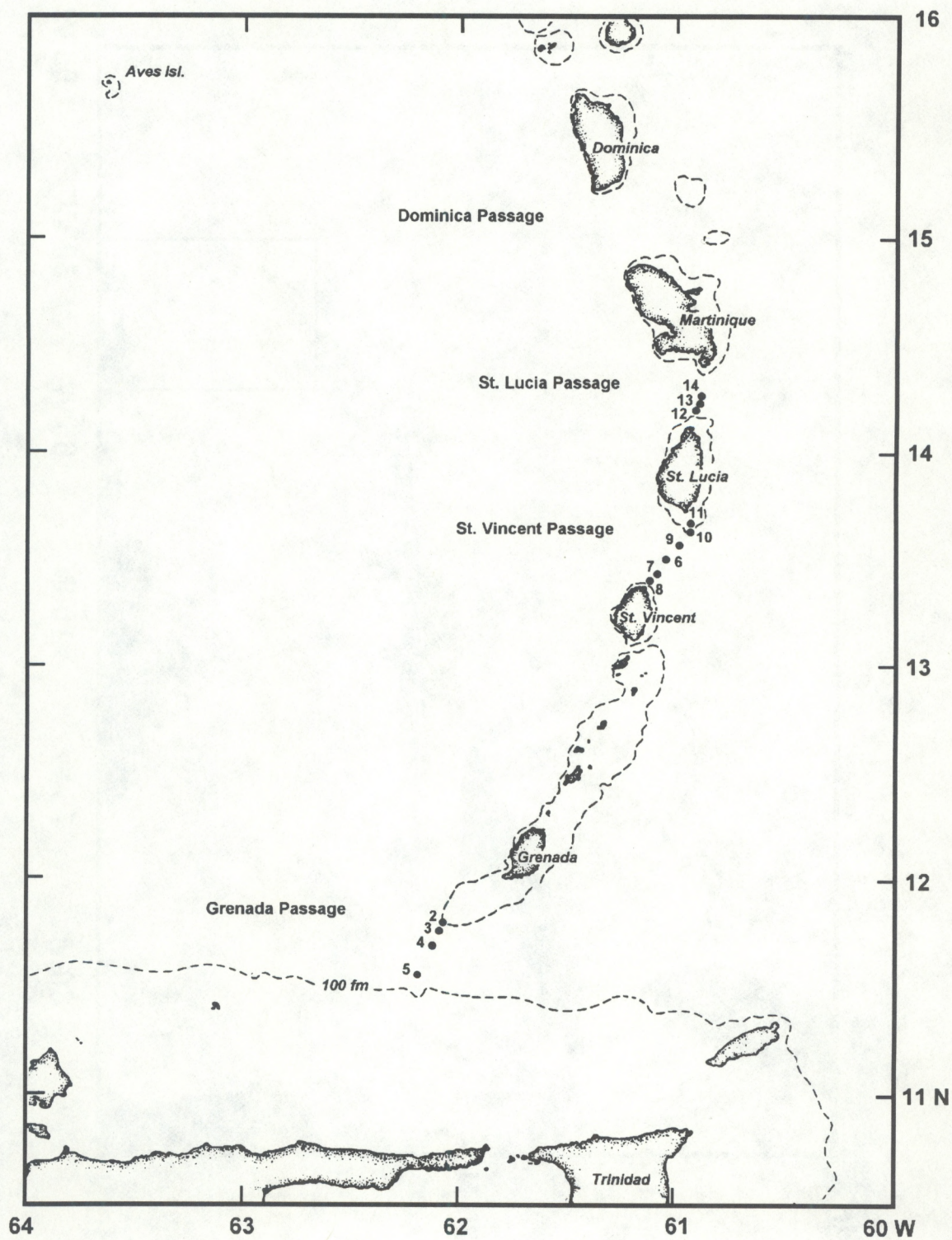


Figure 1. Windward Islands Passages Monitoring Program region showing WI - 91 - 01 station locations.

STATION INFORMATION

Cruise WI - 91 - 01 was carried out on the *HMBS TRIDENT* over the period 15 to 21 December 1991. The following table lists stations occupied and summarizes operations. Individual stations will be numbered consecutively throughout the project and referred to as **W###**, with **###** the station number. Standard station names are designated within each passage with numbers increasing northward. Times and positions correspond approximately to the CTD at maximum depth.

Operations: A = ADCP Current Profile
 B = Bottle Samples for Salinity and Dissolved Oxygen
 C = CTDO₂ Profile

Station Name	Station Number	Date	Time	Latitude	Longitude	Depth	Operations
--------------	----------------	------	------	----------	-----------	-------	------------

Barbados

B-01	W001	12/16/91	2139 Z	13 10.38 N	59 44.49 W	570m	A, C
------	------	----------	--------	------------	------------	------	------

Grenada Passage

GR-01							
GR-02							
GR-03	W005	12/17/91	1840Z	11 32.93 N	62 11.59 W	510m	A, C
GR-04							
GR-05	W004	12/17/91	1657Z	11 41.13 N	62 07.45 W	850m	A,B,C
GR-06	W003	12/17/91	1545Z	11 45.24 N	62 05.69 W	460m	A, C
GR-07	W002	12/17/91	1450Z	11 47.49 N	62 04.49 W	310m	A,B,C

St. Vincent Passage

SV-01	W008	12/19/91	2118Z	13 22.66 N	61 07.36 W	400m	A,B,C
SV-02	W007	12/19/91	2012Z	13 24.54 N	61 05.36 W	550m	A, C
SV-03	W006	12/19/91	1843Z	13 28.61 N	61 02.93 W	850m	A,B,C
SV-04	W009	12/20/91	0324Z	13 32.63 N	60 59.37 W	300m	A,B,C
SV-05	W010	12/20/91	0417Z	13 36.19 N	60 56.24 W	370m	A,B,C
SV-06	W011	12/20/91	0539Z	13 38.42 N	60 56.00 W	200m	A,B,C

St. Lucia Passage

SL-01	W012	12/20/91	1530Z	14 10.42 N	60 54.48 W	300m	B,C
SL-01	W012A	12/20/91	1929Z	14 10.59 N	60 54.89 W	300m	A
SL-02	W013	12/20/91	1658Z	14 12.43 N	60 53.76 W	750m	A,B,C
SL-03	W014	12/20/91	1814Z	14 14.57 N	60 53.47 W	800m	A,B,C
SL-04							
SL-05							
SL-06							

HYDROGRAPHIC DATA

CTDO₂ DATA

CTDO₂ profile data were collected using a SEABIRD SBE Model 19 CTD with pumped conductivity and dissolved oxygen sensors, sampling at 2 Hz. Relevant information on the CTDO₂ instrument is summarized below. Profiles of temperature, salinity, and dissolved oxygen concentration for each station, along with a listing of values at standard depths, are shown in Appendix A. Corrected CTD salinity values, based on post-cruise instrument calibrations and comparison with bottle samples, are estimated to be accurate to better than .01 PSU. CTD and bottle oxygen's were similarly compared and CTD dissolved oxygen's are estimated to be accurate to .05 ml/l.

CTDO₂ Instrument Information

Model SBE 19-01	S/N 195075-0822		
Instrument type	SEACAT PROFILER		
Firmware Version	2.1		
Pressure Sensor	3000 psi S/N 145868	Calibrated	5 September 1991
DO Sensor	S/N 230297	Calibrated	26 February 1992
Conductivity Sensor	S/N 0822	Calibrated	27 February 1992
Temperature Sensor	S/N 0822	Calibrated	27 February 1992
Pump	S/N 050457		

BOTTLE DATA

Salinity Calibration

Water samples for CTDO₂ calibration were collected using 1.7 liter Niskin bottles attached to the instrument cable and tripped by messenger when the instrument was at maximum depth. Two protected reversing thermometers were placed on each bottle (except for the surface bottle) to measure the temperature at the time of the sample for correlation with the CTDO₂ data. Bottle salinity values were determined using a Guildline 8400 Autosol with an accuracy of .002 PSU. Bottle data used for salinity calibration are shown in the following table. NOM PRS is the target pressure in decibars, estimated at the time of bottle placement; TEMP is the temperature in degrees Celsius based on reversing thermometer readings; PRS is the approximate CTD pressure in decibars at which that temperature was found; CTD SAL is the uncorrected CTD salinity (PSU) at that temperature/pressure; and BOT SAL is the salinometer salinity (PSU) for the water sample. For surface samples, values at 5 db were used. X's represent no reversing thermometer or water sample values. The location of the deep bottle at station 14 was estimated.

CAST	NOM PRS	TEMP	PRS	CTD SAL	BOT SAL
2	285.	15.36	229.	35.987	36.004
2	200.	18.66	150.	36.518	36.482
2	120.	xxxx	xxx	xxxxx	35.811
2	50.	26.95	36.	35.812	36.833
2	5.	26.98	5.	35.792	35.810
4	830.	5.73	804.	34.695	34.694
4	500.	8.58	425.	34.838	36.859
4	120.	21.33	104.	36.828	36.858
4	50.	26.69	40.	36.220	36.236
4	5.	27.28	5.	35.988	36.008
6	400.	13.40	297.	35.629	xxxxxx
6	120.	23.22	102.	36.732	xxxxxx
6	50.	27.21	23.	35.808	35.824
6	5.	27.23	5.	35.807	35.827
8	280.	15.27	245.	35.968	35.983
8	200.	16.86	162.	36.200	36.218
8	120.	20.73	110.	36.500	36.612
8	50.	27.17	56.	36.589	36.624
8	5.	27.00	5.	35.794	35.813
9	280.	12.46	240.	35.526	35.547
9	200.	19.64	137.	36.620	36.655
9	120.	23.25	105.	36.750	36.778
9	50.	27.10	55.	36.251	36.266
9	5.	27.22	5.	35.832	35.852
12	300.	14.50	268.	35.834	35.858
12	200.	19.61	156.	36.538	36.551
12	120.	25.67	84.	36.728	36.779
12	5.	26.80	5.	36.632	36.653
14	900.	xxxxx	782.	34.849	34.856
14	400.	11.08	397.	35.263	35.286
14	5.	26.90	5.	35.656	35.681

After discarding two outliers (2/200 and 8/120), the mean difference between bottle sample and CTD salinities was 0.022 with a standard deviation of 0.009. There was no significant depth dependence to the differences. Accordingly, 0.022 was added to all CTD salinity values. The mean difference using only surface and bottom values (those with the best known trip depths) was 0.020, with a standard deviation of only 0.003. Much of the variance appears to arise from inaccuracy of the trip depths estimated from the reversing thermometers in the presence of strong vertical temperature gradients. The final accuracy of the calibrated salinity profile data is therefore estimated to be better than 0.01 PSU.

Oxygen Sensor Calibration

Based on the results of the salinity calibration, it appeared that comparing corrected salinity to bottle salinity would be a better estimator of bottle trip depth than reversing thermometer temperature. Using corrected salinity to estimate bottle trip locations, the following data were obtained and used for calibrating the dissolved oxygen sensor. PRS represents the estimated pressure in decibars at the appropriate bottle salinity; TEMP is the CTD temperature in degrees Celsius at that pressure; SAL is the bottle salinity (PSU) ; CTD OX is the CTD dissolved oxygen value in ml/l, based on the calibration coefficients described below; and BOT OX is the titrated dissolved oxygen value in ml/l from the water sample. Bottles marked with a * had no valid

salinity bottle values, so firing depth was estimated from reversing thermometer temperatures as described above. Water sample oxygen values were determined using Carpenter's modification of the Winkler method with a computer-controlled titrator with photometric endpoint determination.

CAST	PRS	TEMP	SAL	CTD OX	BOT OX
2	231.	15.22	36.004	2.97	3.02
2	167.	18.38	36.482	3.28	3.22
2	30.	26.94	35.833	4.28	4.32
2	5.	26.98	35.815	4.21	4.35
4	793.	5.69	34.694	2.85	2.97
4	425.	8.58	34.859	2.67	2.65
4	103.	21.55	36.858	3.22	3.24
4	41.	26.56	36.236	4.08	3.96
4	3.	27.31	36.008	4.21	4.29
6	297.	XXXXX	XXXXXX	XXXX	3.35 *
6	102.	XXXXX	36.732	XXXX	3.34 *
6	6.	27.28	35.827	4.32	4.35
8	245.	15.07	35.983	3.01	3.05
8	164.	15.55	36.218	3.06	3.04
8	105.	21.61	36.612	3.25	3.22
8	6.	27.00	35.818	4.39	4.36
9	239.	12.66	35.547	2.82	2.82
9	138.	19.93	36.656	3.22	3.17
9	106.	23.32	36.778	3.33	3.34
9	53.	27.11	36.266	4.17	4.16
9	4.	27.22	35.855	4.30	4.36
12	266.	14.52	35.858	3.01	2.92
12	153.	19.57	36.551	3.01	2.96
12	86.	25.63	36.720	4.18	4.18
12	5.	26.79	35.653	4.36	4.37
14	762.	5.28	34.859	3.61	3.59
14	398.	11.06	35.286	2.77	2.64
14	4.	26.90	35.681	4.48	4.36

CTD oxygen sensor calibration coefficients were determined by a least square fit to the Owens and Millard (1985)¹ algorithm:

$$OX = [SOC * (oc + tau * doc/dt) + BOC] * OXSAT(T,S) * \exp(TCOR * [T + WT * (To - T)] + PCOR * P)$$

where

OX	CTD dissolved oxygen value in ml/l
T	CTD salinity (PSU)
P	CTD pressure in decibars
C	oxygen sensor current in microamps
To	oxygen sensor temperature in degrees Celsius
OXSAT(T,S)	oxygen saturation value

Empirically determined coefficients were :

SOC	2.52	oxygen current slope
BOC	-0.045	oxygen current bias
TCOR	-0.032	temperature correction factor for membrane permeability
PCOR	0.00015	pressure correction factor for membrane permeability
TAU	0.	oxygen sensor response time (not used)
WT	0.96	weighting fraction of oxygen sensor internal temperature

The standard deviation of the fit, after discarding four of the 26 values as outliers, was 0.04. The accuracy of the final dissolved oxygen profile data is therefore estimated to be 0.05 ml./l.

¹ Owens, W.B., and R.C. Millard Jr., 1985. A new algorithm for CTD oxygen calibration. **J. Physical Oceanography**, 15, 621-631.

ACOUSTIC DOPPLER CURRENT PROFILER DATA

Data were collected while on station using a 150kHz RD Instruments self-contained acoustic Doppler current profiler (ADCP) suspended over the side at approximately 5 meters depth. Two minute ensembles of data were collected, edited, averaged, and referenced with ship drift information to yield absolute velocity profiles. Ensemble-to-ensemble standard deviations, relative to the depth averaged velocity, ranged from 3 to 10 cm/s in the upper 250 meters. The profiling technique gave quite stable results, with much of the variability appearing to be attributable to actual time dependent changes in current velocity while on station. Ship drift estimates made using Global Positioning System (GPS) data during ADCP casts agreed well with bottom track-based ship drift estimates. Based on GPS data collected with the ship at rest, RMS position errors were 20-30 meters during times of good coverage. This translates to a 3 cm/s RMS error when differencing the endpoints of a 30 minute ADCP station. In the following table, ENSEM is the number of two-minute ensembles averaged into the final value; DATE, TIME, LATITUDE, and LONGITUDE are at the approximate midpoint of the average; U_B and V_B are mean eastward and northward ship drift velocities based on ADCP bottom tracking; and U_G and V_G are mean eastward and northward ship drift velocities based on GPS navigation. All velocity values are in cm/s.

ADCP STATION AND REFERENCING DATA

STN	ENSEM	DATE	TIME	LATITUDE	LONGITUDE	U_B	V_B	U_G	V_G
001	32	15/12/91	1057 Z	13 10.37 N	59 44.47 W			-14	-25
002	12	16/12/91	1451 Z	13 10.50 N	62 04.50 W	-74	4	-71	3
003	14	16/12/91	1543 Z	11 45.24 N	62 05.64 W	-92	11	-91	6
004	29	16/12/91	1655 Z	11 41.13 N	62 07.44 W	-	-	-57	15
005	7	16/12/91	1848 Z	11 32.76 N	62 11.94 W	-	-	-81	10
006	32	18/12/91	1835 Z	13 28.49 N	61 02.80 W	-	-	-38	62
007	21	18/12/91	2010 Z	13 24.49 N	61 05.31 W	-	-	-57	74
008	16	18/12/91	2114 Z	13 22.55 N	61 07.34 W	-43	83	-36	83
009	24	19/12/91	0310 Z	13 32.51 N	60 59.24 W	-17	28	-20	28
010	14	19/12/91	0416 Z	13 36.23 N	60 56.25 W	-16	27	-17	29
011	12	19/12/91	0543 Z	13 38.42 N	60 56.03 W	-45	13	-42	18
12A	11	19/12/91	1927 Z	14 10.57 N	60 54.88 W	-49	36	-53	34
013	18	19/12/91	1657 Z	14 12.43 N	60 53.75 W	-	-	-6	-6
014	24	19/12/91	1812 Z	14 14.59 N	60 53.44 W	-	-	-25	10

Appendix B contains plots of the absolute velocity profiles at each ADCP station.

Appendix A

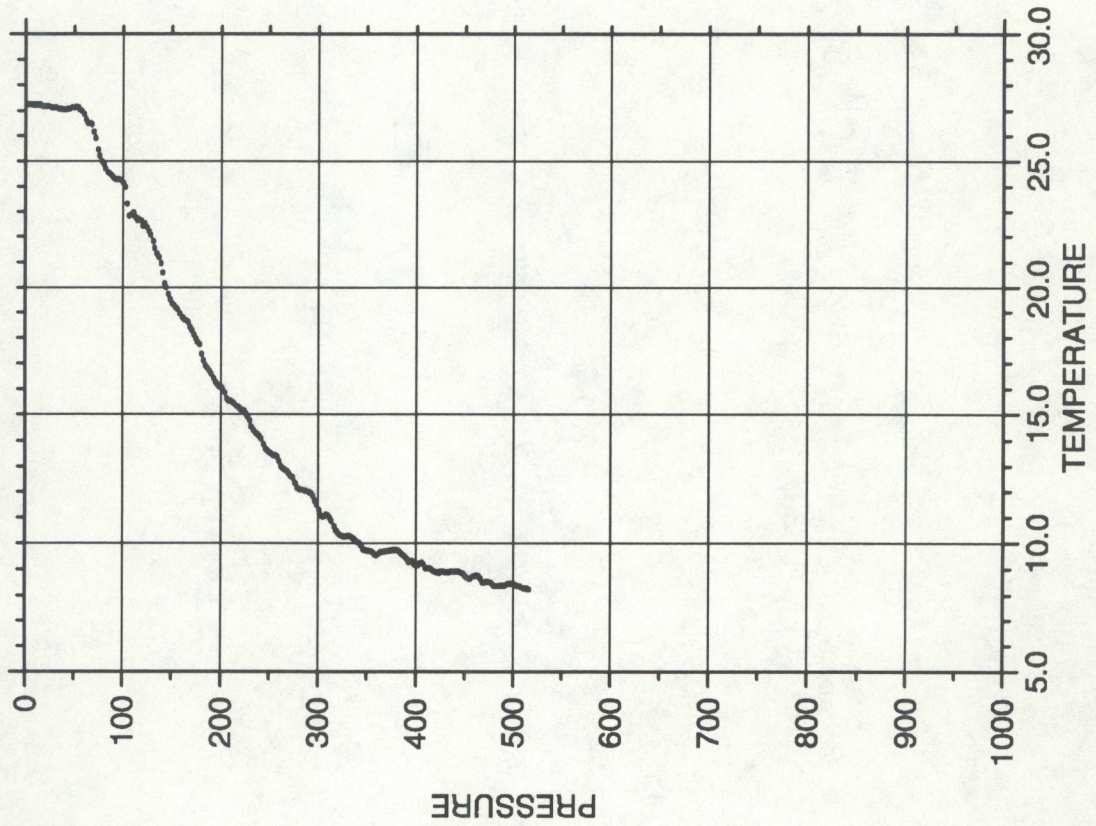
CTDO₂ Station Profiles

The following plots are based on calibrated downcast CTD values averaged into 2 decibar vertical bins. Pressure values are in decibars; Temperature values are in degrees Celsius; Salinity values are in Practical Salinity Units (PSS-78); and dissolved oxygen values are in milliliters/liter (ml/l).

WIPP-1 HMBS TRIDENT

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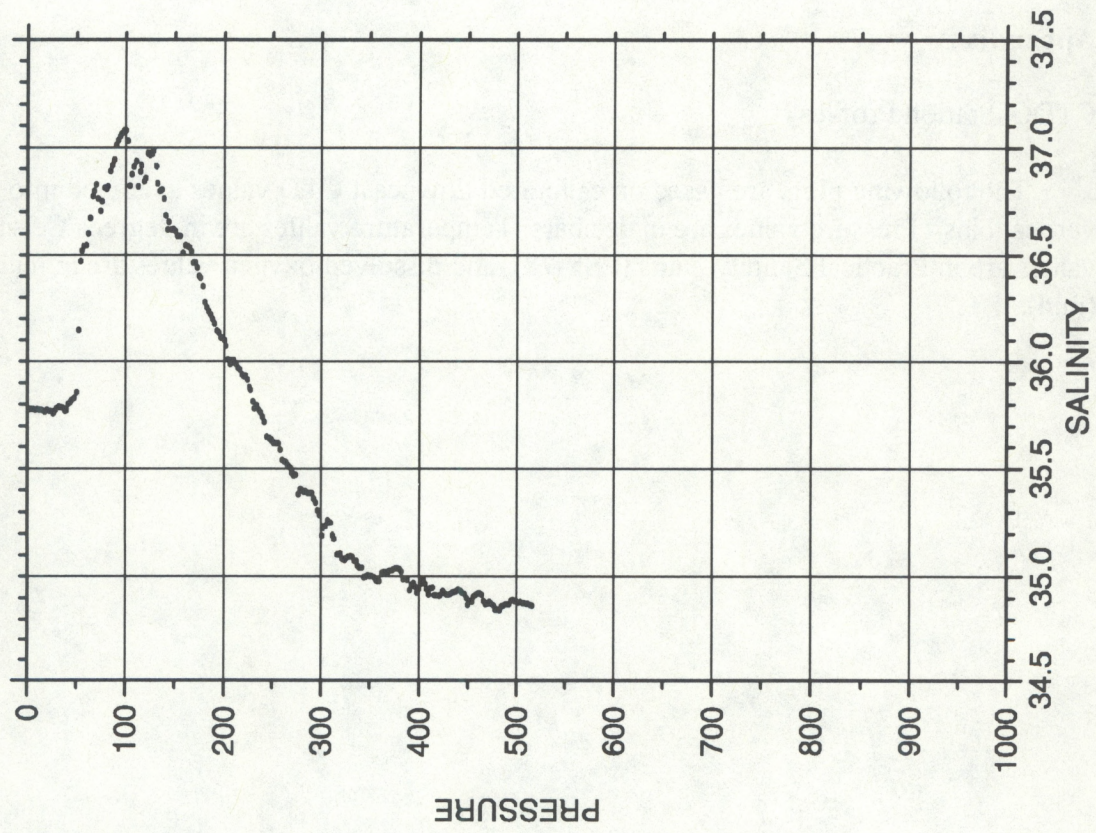
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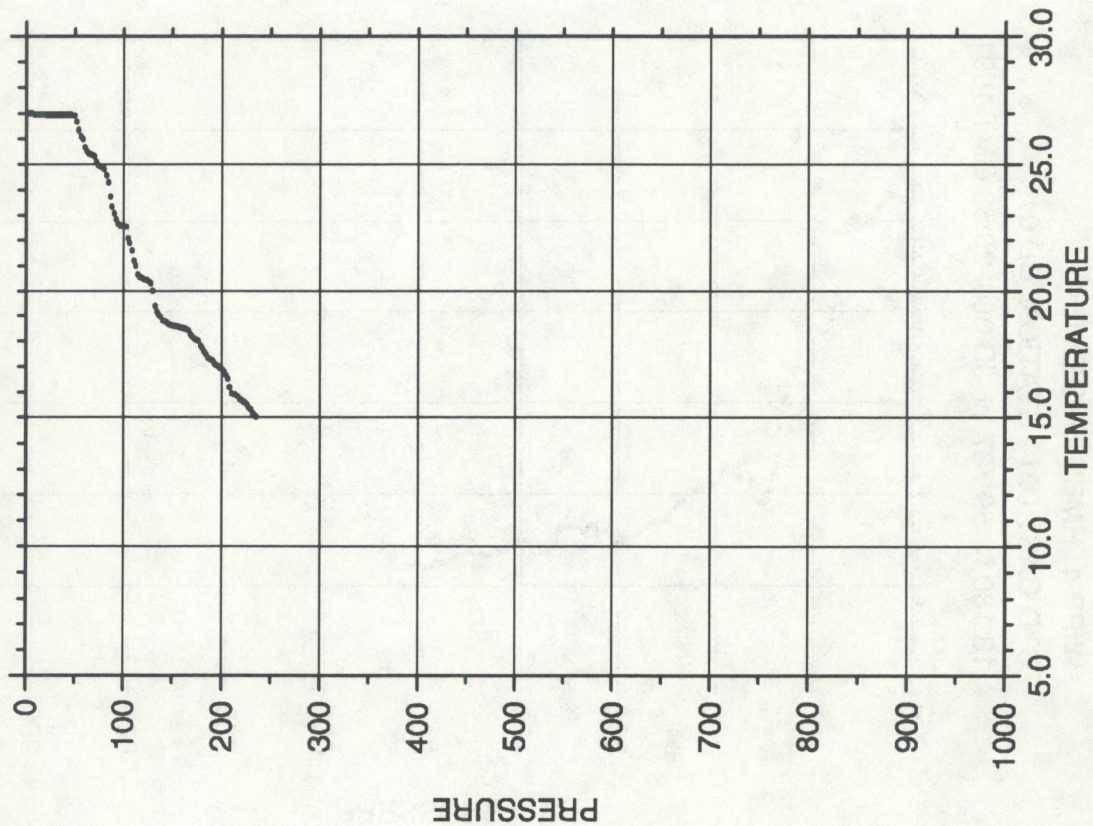
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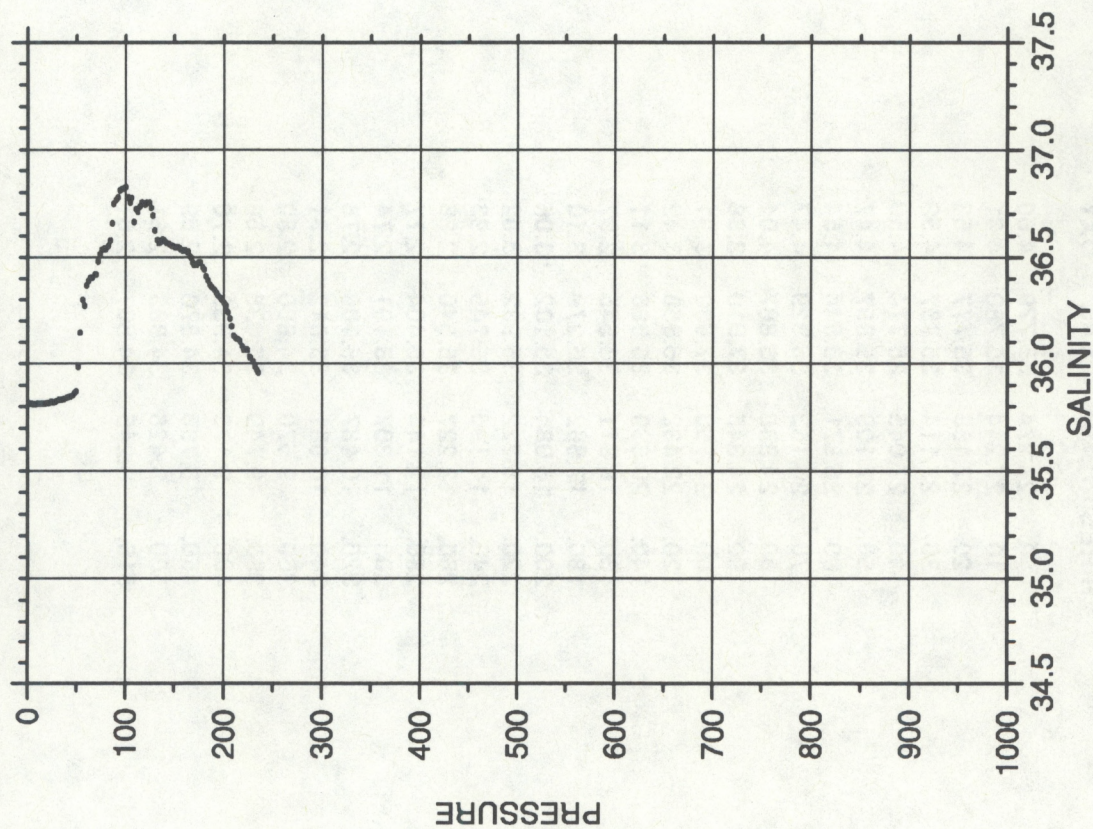


PRES	TEMP	SAL	OXY
4.	27.274	35.779	4.60
10.	27.244	35.780	4.61
20.	27.188	35.777	4.63
30.	27.114	35.787	4.59
40.	27.045	35.774	4.50
50.	27.109	35.857	4.47
60.	26.871	36.544	4.54
70.	26.163	36.829	4.47
80.	24.885	36.807	4.04
90.	24.345	37.010	3.88
100.	24.150	37.080	3.91
120.	22.432	36.858	3.42
140.	20.599	36.686	3.11
160.	18.811	36.545	2.97
180.	17.382	36.279	3.10
200.	16.084	36.102	3.06
220.	15.222	35.932	3.02
240.	14.196	35.745	2.93
260.	13.227	35.540	2.86
280.	12.144	35.404	2.77
300.	11.307	35.191	2.74
320.	10.437	35.109	2.78
340.	10.081	35.042	2.81
360.	9.570	34.980	2.80
380.	9.749	35.035	2.68
400.	9.173	34.939	2.76
450.	8.788	34.870	2.69
500.	8.426	34.883	2.61
516.	8.245	34.867	2.61

WIPP-1 HMBS TRIDENT
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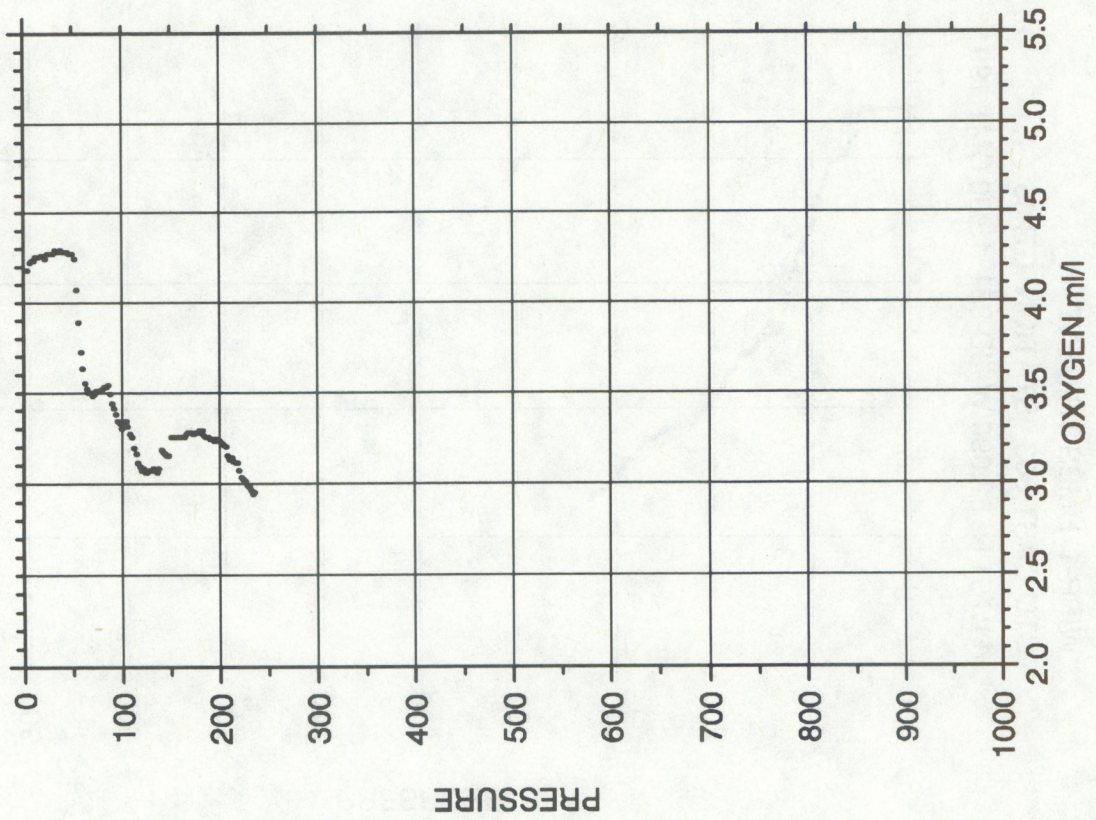
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WIPP-1 HMBS TRIDENT

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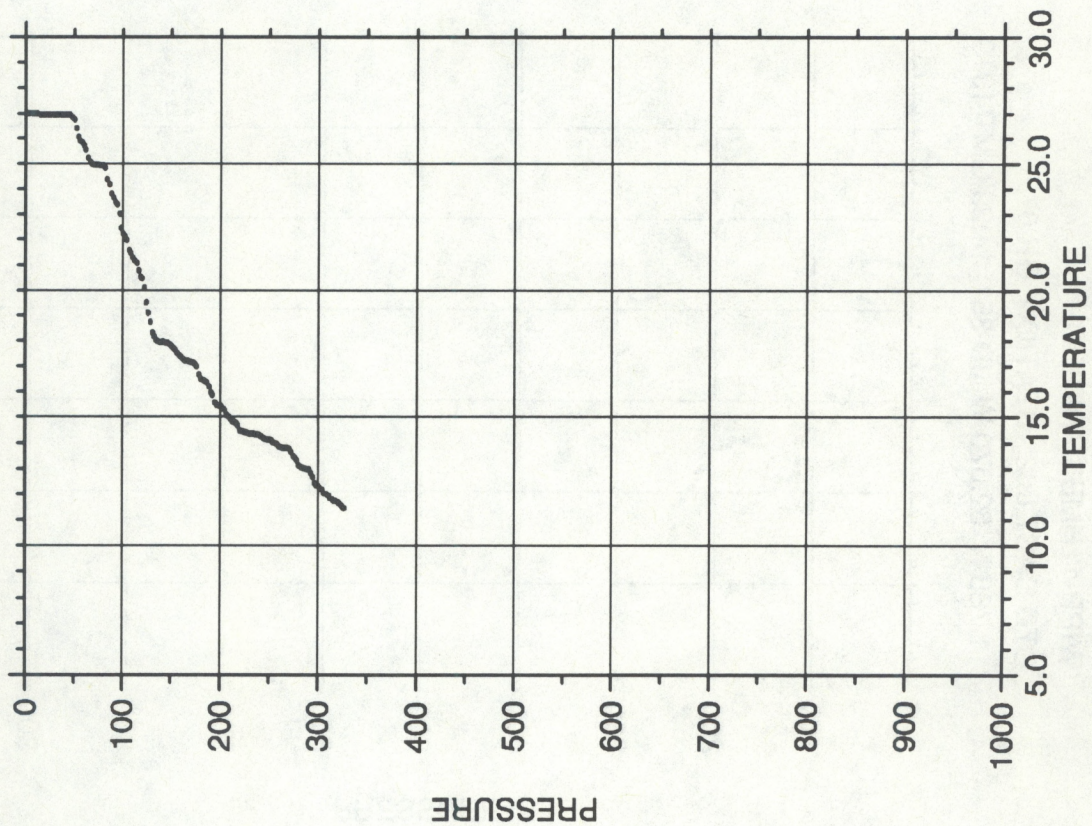


PRES	TEMP	SAL	OXY
4.	26.986	35.816	4.18
10.	26.968	35.815	4.23
20.	26.952	35.819	4.26
30.	26.942	35.829	4.27
40.	26.934	35.843	4.28
50.	26.913	35.874	4.27
60.	25.667	36.370	3.63
70.	25.333	36.421	3.48
80.	24.827	36.538	3.52
90.	23.080	36.765	3.44
100.	22.575	36.825	3.30
120.	20.491	36.744	3.07
140.	18.823	36.574	3.18
160.	18.522	36.533	3.25
180.	17.752	36.443	3.29
200.	16.893	36.285	3.23
220.	15.705	36.070	3.07
236.	15.037	35.960	2.95

WIPP-1 HMBS TRIDENT

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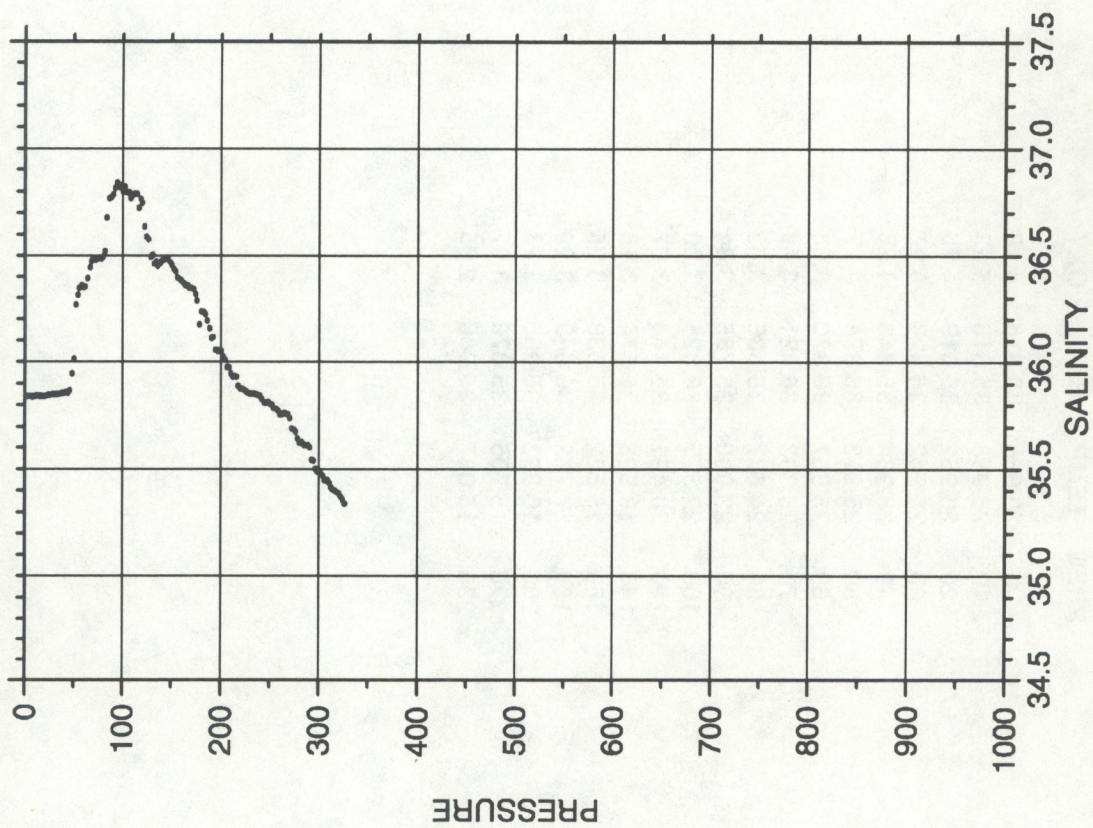
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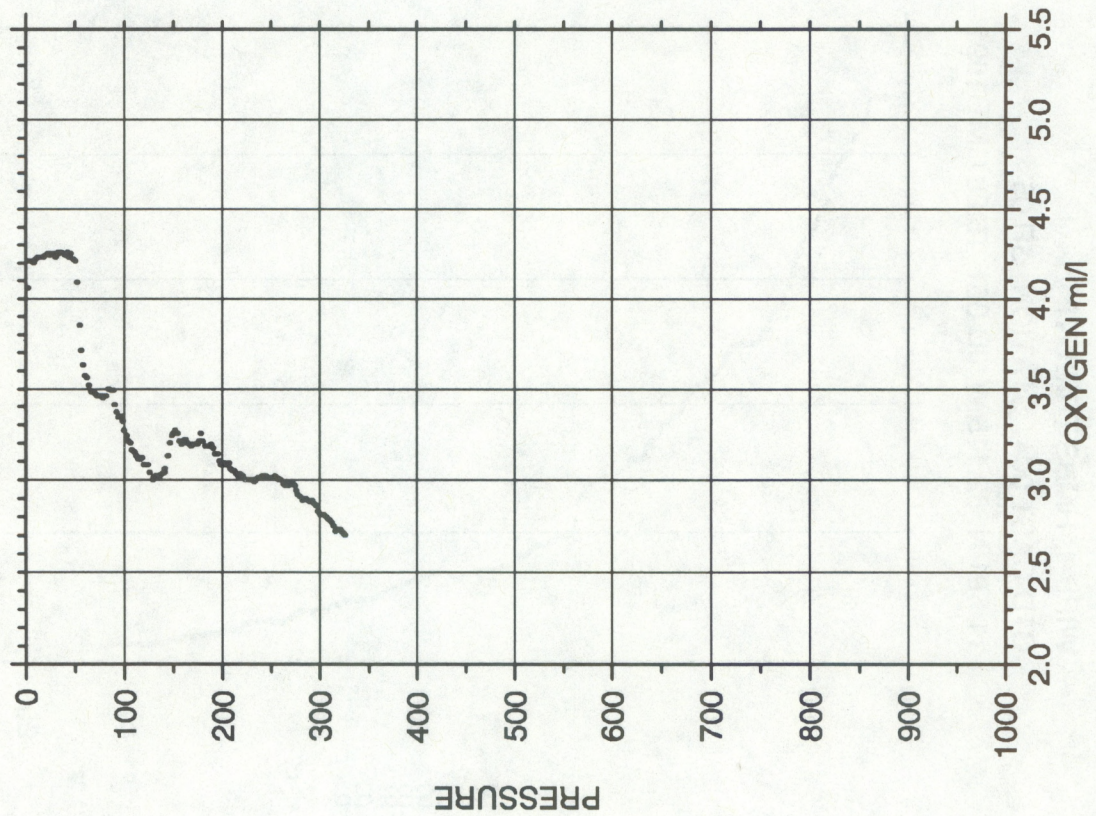
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WIPP-1 HMBS TRIDENT

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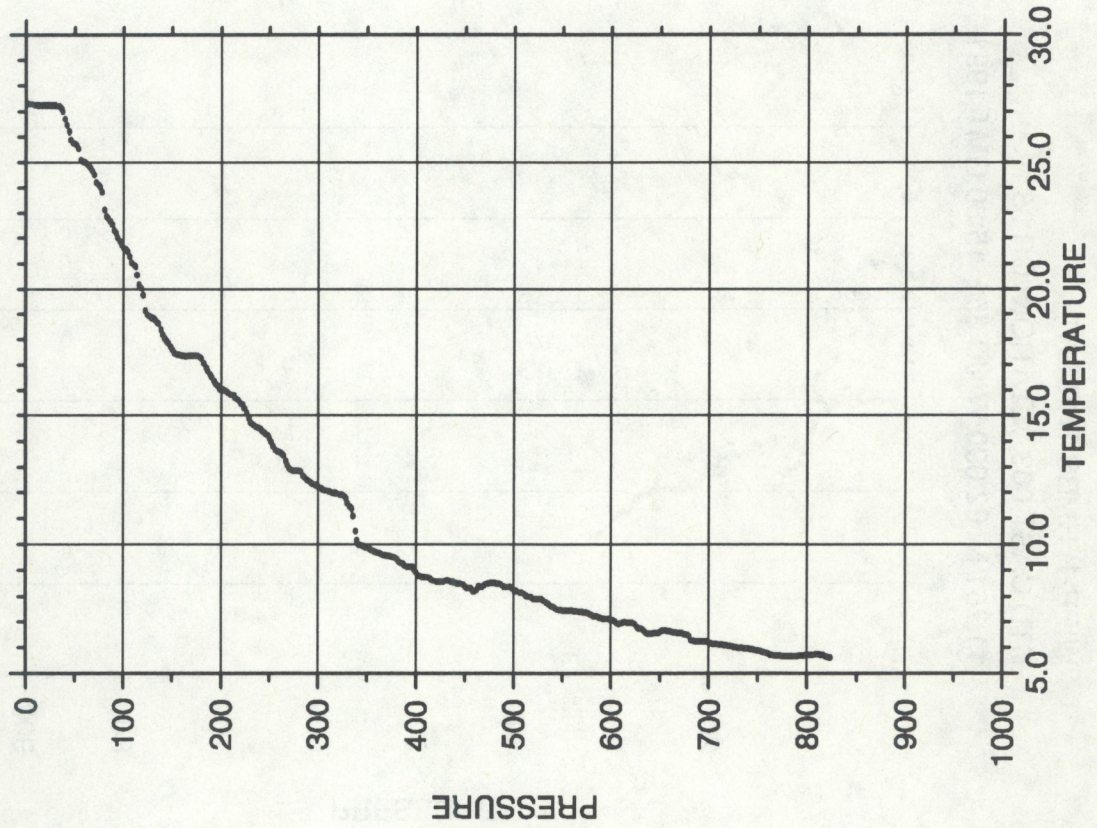


PRES	TEMP	SAL	OXY
4.	27.009	35.843	4.21
10.	26.987	35.844	4.22
20.	26.967	35.844	4.24
30.	26.964	35.851	4.23
40.	26.974	35.857	4.24
50.	26.767	36.017	4.21
60.	25.715	36.351	3.57
70.	24.975	36.484	3.47
80.	24.954	36.494	3.46
90.	23.669	36.787	3.41
100.	22.234	36.799	3.27
120.	20.498	36.749	3.08
140.	17.960	36.477	3.04
160.	17.390	36.382	3.21
180.	16.501	36.236	3.21
200.	15.454	36.053	3.08
220.	14.493	35.880	3.02
240.	14.325	35.846	3.02
260.	13.864	35.760	3.00
280.	13.145	35.625	2.91
300.	12.288	35.487	2.81
320.	11.704	35.389	2.73
326.	11.481	35.342	2.70

WIPP-1 HMBS TRIDENT

CTD CAST 004 STATION GR 05

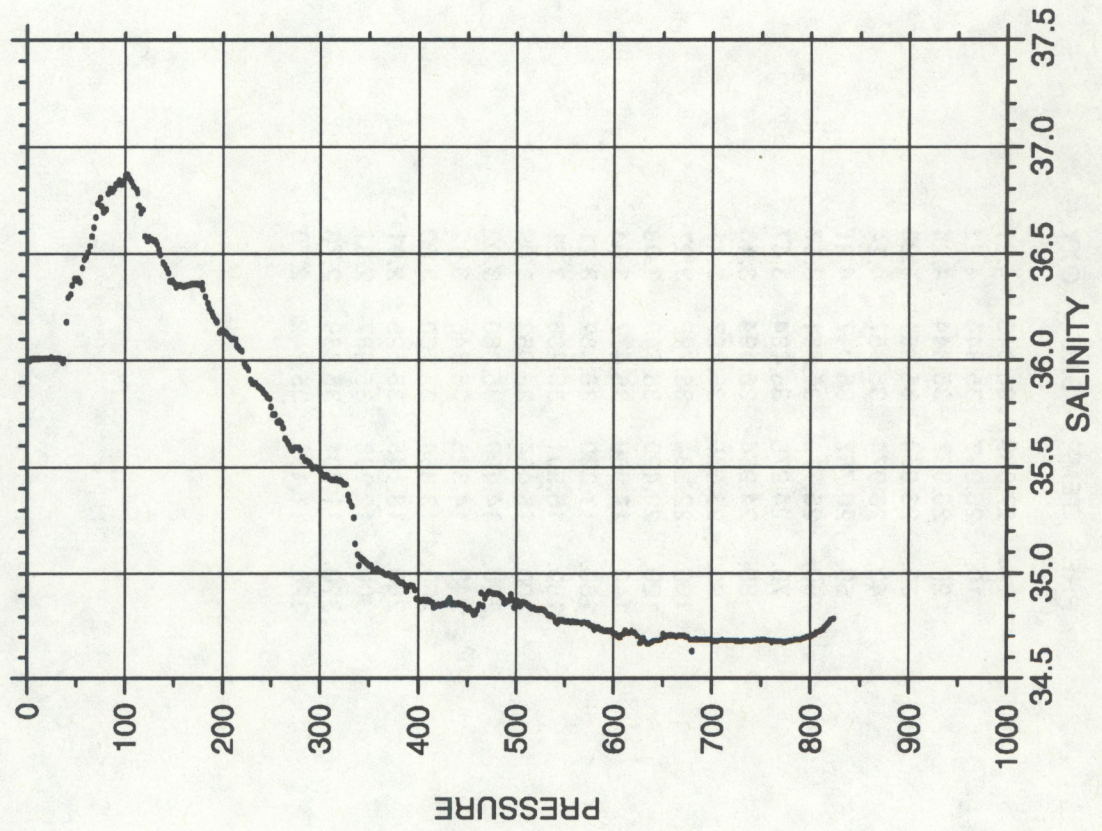
11.681 N 62.115 W JD 351 16:28 GMT 1991



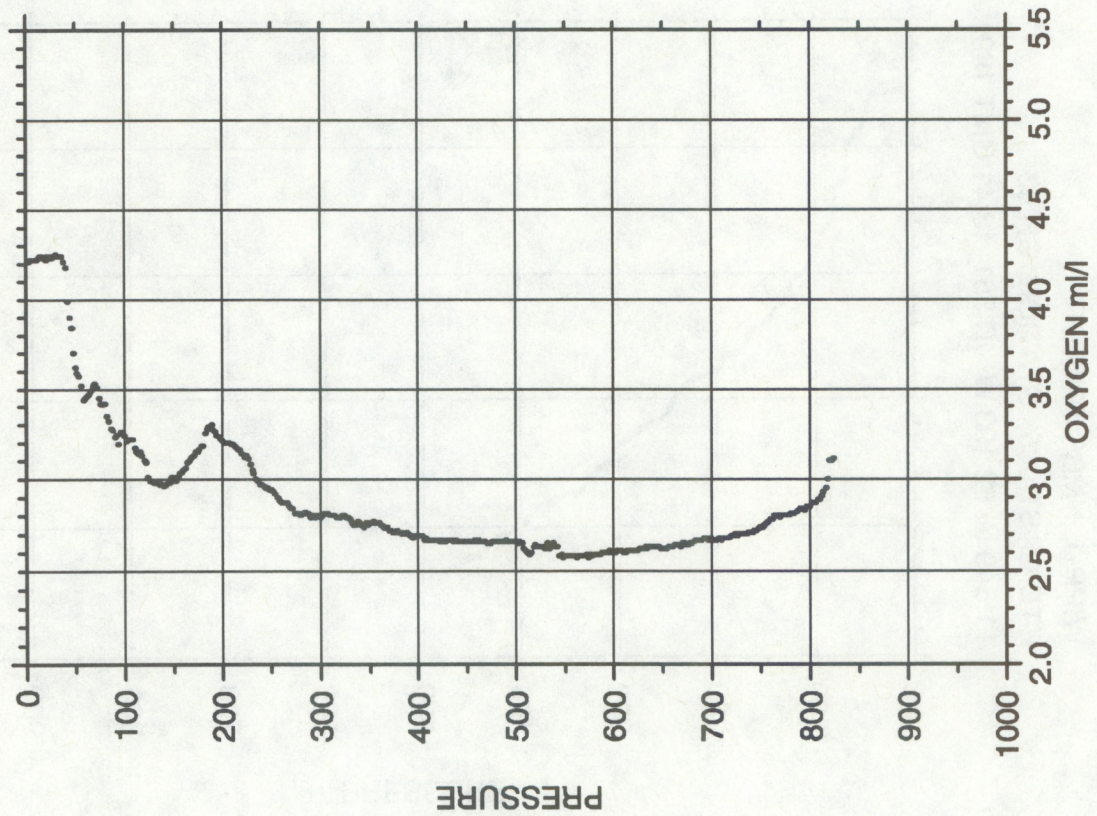
WIPP-1 HMBS TRIDENT

CTD CAST 004 STATION GR 05

11.681 N 62.115 W JD 351 16:28 GMT 1991



WIPP-1 HMBS TRIDENT
CTD CAST 004 STATION GR 05
11.681 N 62.115 W JD 351 16:28 GMT 1991

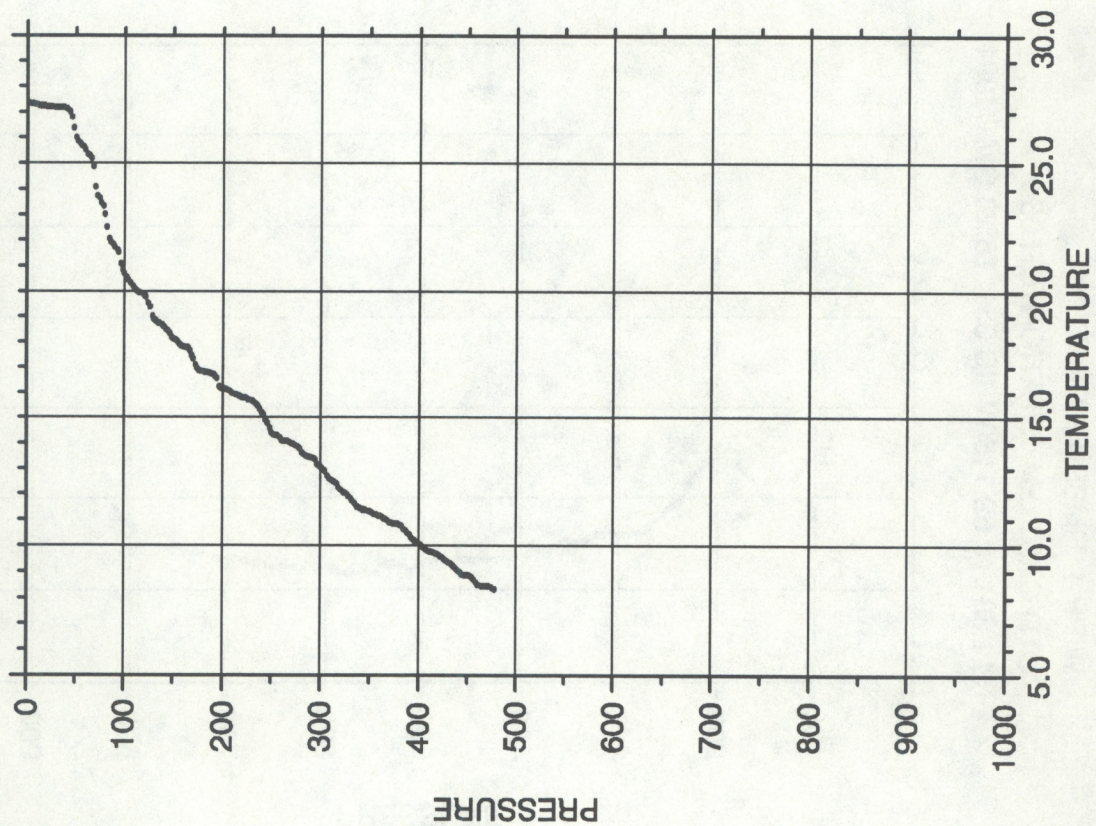


PRES	TEMP	SAL	OXY
4.	27.285	36.010	4.22
10.	27.261	36.011	4.22
20.	27.240	36.014	4.22
30.	27.227	36.014	4.25
40.	26.688	36.183	4.18
50.	25.745	36.378	3.62
60.	25.015	36.486	3.45
70.	24.514	36.672	3.53
80.	23.139	36.705	3.42
90.	22.310	36.823	3.23
100.	21.607	36.866	3.24
120.	19.770	36.581	3.10
140.	18.197	36.449	2.96
160.	17.384	36.347	3.05
180.	17.287	36.337	3.18
200.	16.055	36.146	3.21
220.	15.499	36.047	3.14
240.	14.500	35.863	2.97
260.	13.587	35.710	2.87
280.	12.864	35.583	2.80
300.	12.248	35.482	2.79
320.	11.976	35.438	2.79
340.	10.191	35.039	2.76
360.	9.719	35.015	2.76
380.	9.447	34.963	2.71
400.	8.932	34.881	2.69
450.	8.383	34.835	2.66
500.	8.234	34.876	2.66
550.	7.452	34.779	2.58
600.	7.087	34.720	2.60
650.	6.623	34.716	2.62
700.	6.213	34.685	2.68
750.	5.892	34.687	2.74
800.	5.715	34.705	2.85
824.	5.622	34.791	3.11

WIPP-1 HMBS TRIDENT

CTD CAST 005 STATION GR 03

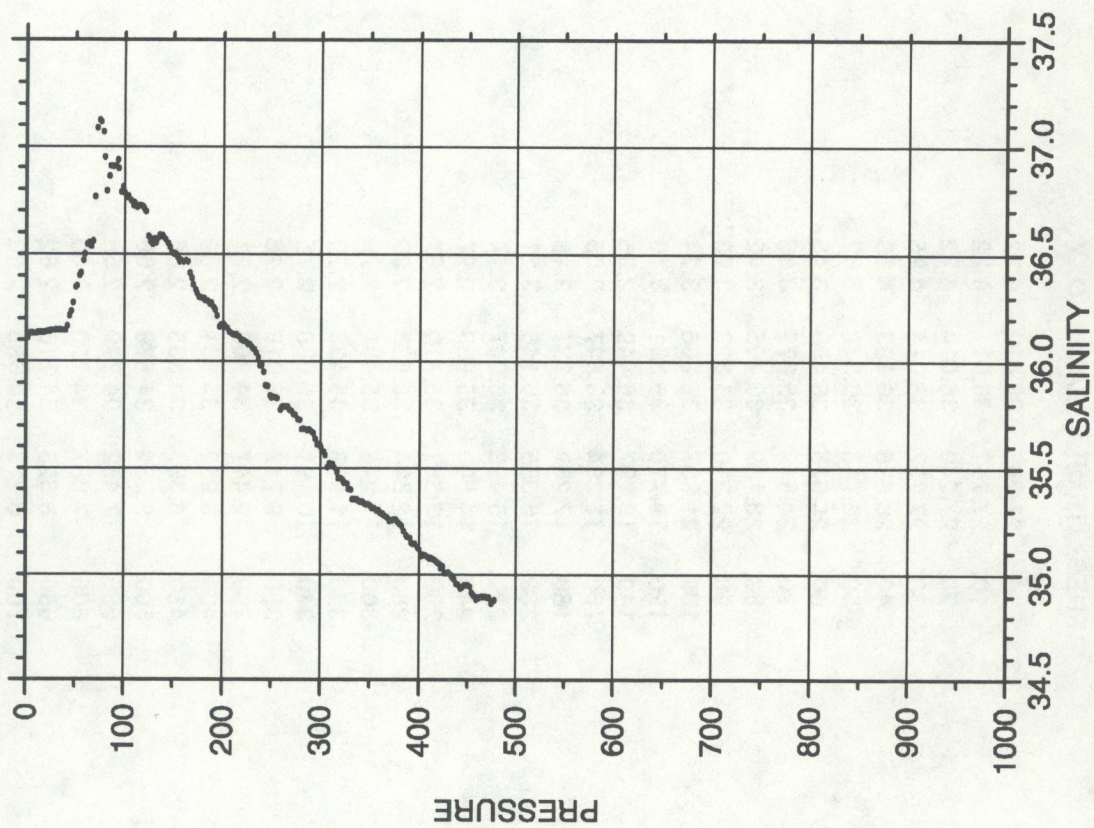
11.549 N 62.193 W JD 351 18:41 GMT 1991



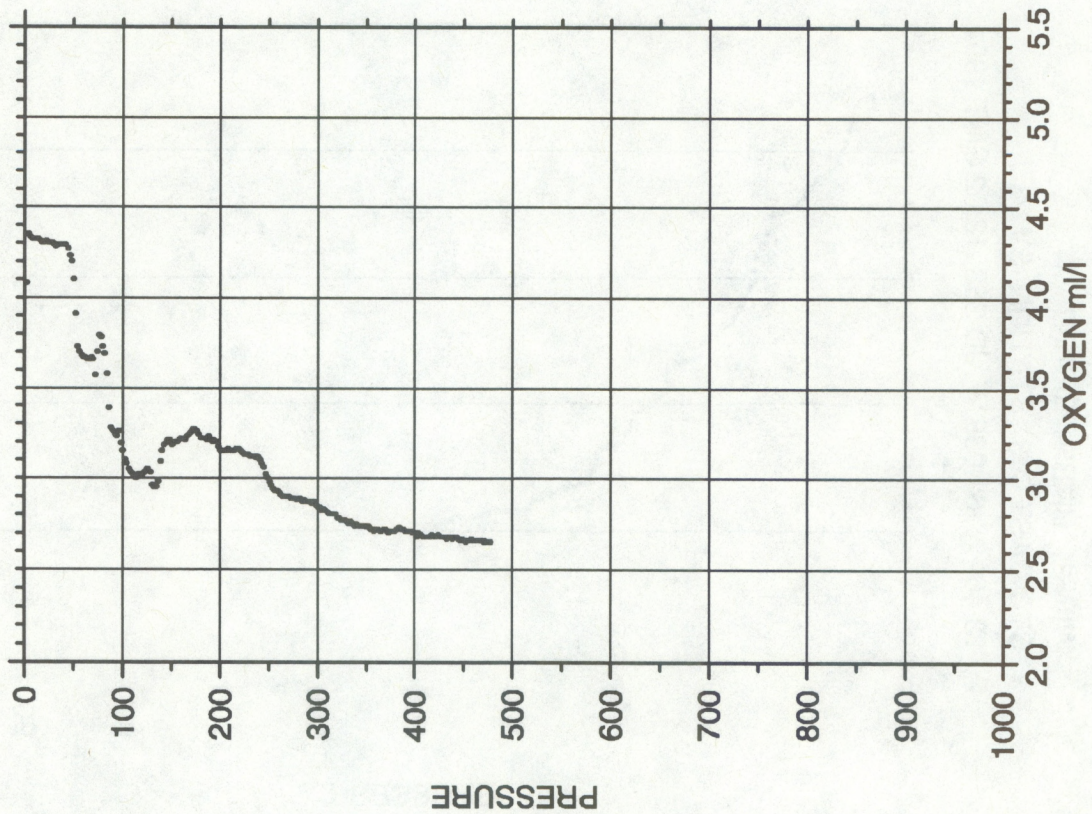
WIPP-1 HMBS TRIDENT

CTD CAST 005 STATION GR 03

11.549 N 62.193 W JD 351 18:41 GMT 1991



WIPP-1 HMBS TRIDENT
 CTD CAST 005 STATION GR 03
 11.549 N 62.193 W JD 351 18:41 GMT 1991

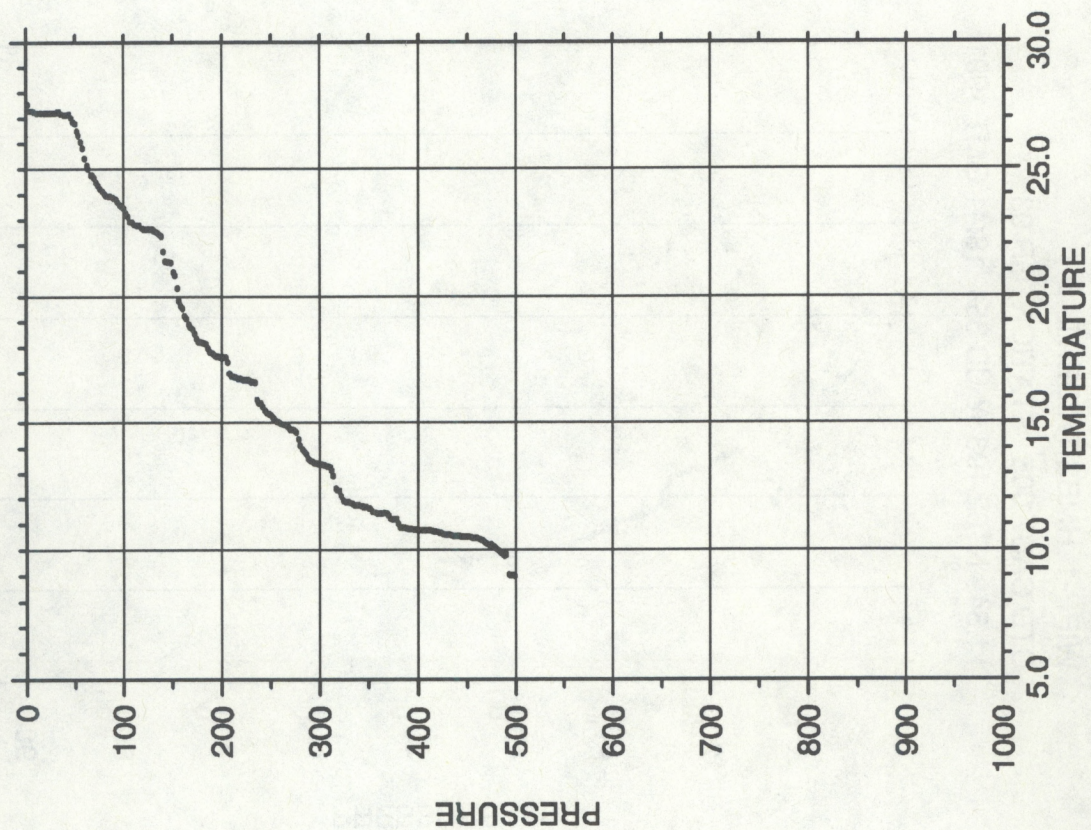


PRES	TEMP	SAL	OXY
4.	27.338	36.135	4.35
10.	27.277	36.136	4.32
20.	27.226	36.143	4.30
30.	27.198	36.151	4.29
40.	27.143	36.148	4.29
50.	25.987	36.348	4.10
60.	25.522	36.500	3.67
70.	24.109	36.765	3.66
80.	23.030	36.952	3.73
90.	21.736	36.909	3.26
100.	20.721	36.784	3.15
120.	19.885	36.710	3.02
140.	18.603	36.576	3.15
160.	17.830	36.468	3.22
180.	16.831	36.297	3.22
200.	16.181	36.176	3.15
220.	15.817	36.103	3.15
240.	15.244	35.985	3.10
260.	14.114	35.790	2.92
280.	13.633	35.683	2.89
300.	13.063	35.601	2.84
320.	12.180	35.453	2.78
340.	11.442	35.343	2.75
360.	11.156	35.289	2.72
380.	10.804	35.240	2.71
400.	10.071	35.121	2.70
450.	8.880	34.952	2.66
478.	8.343	34.883	2.65

WIPP-1 HMBS TRIDENT

CTD CAST 006 STATION SV 03

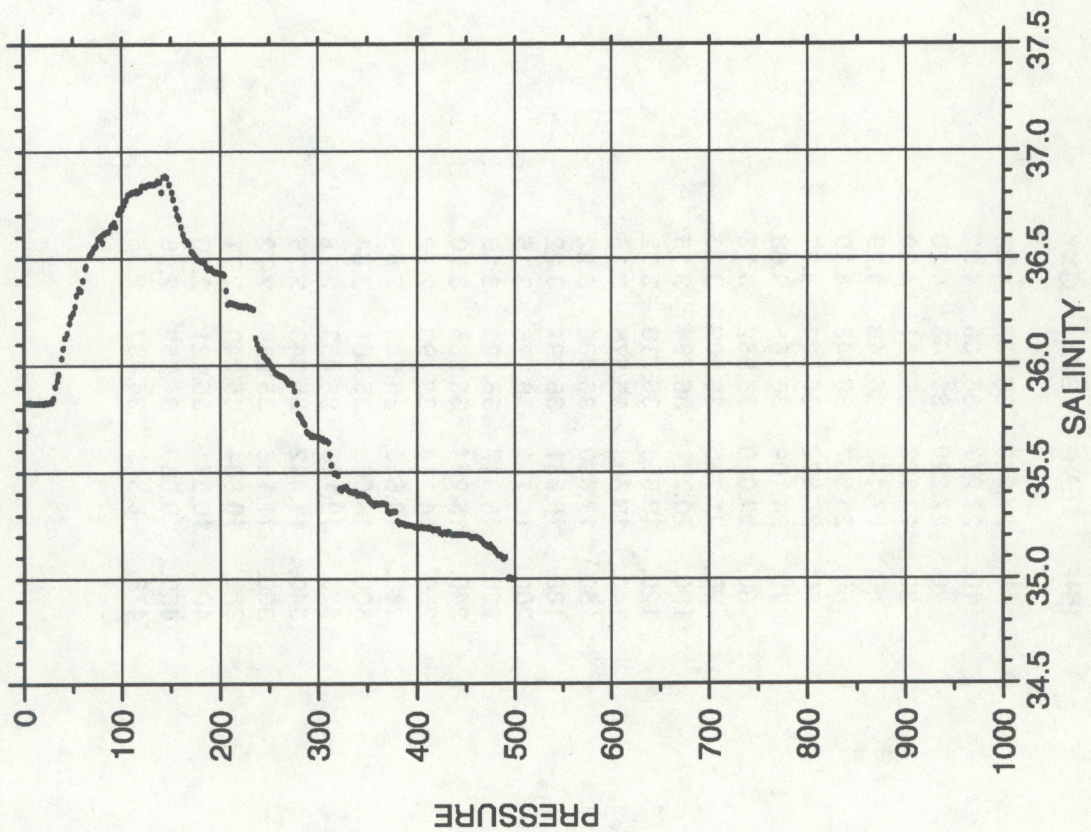
13.469 N 61.038 W JD 353 18:02 GMT 1991



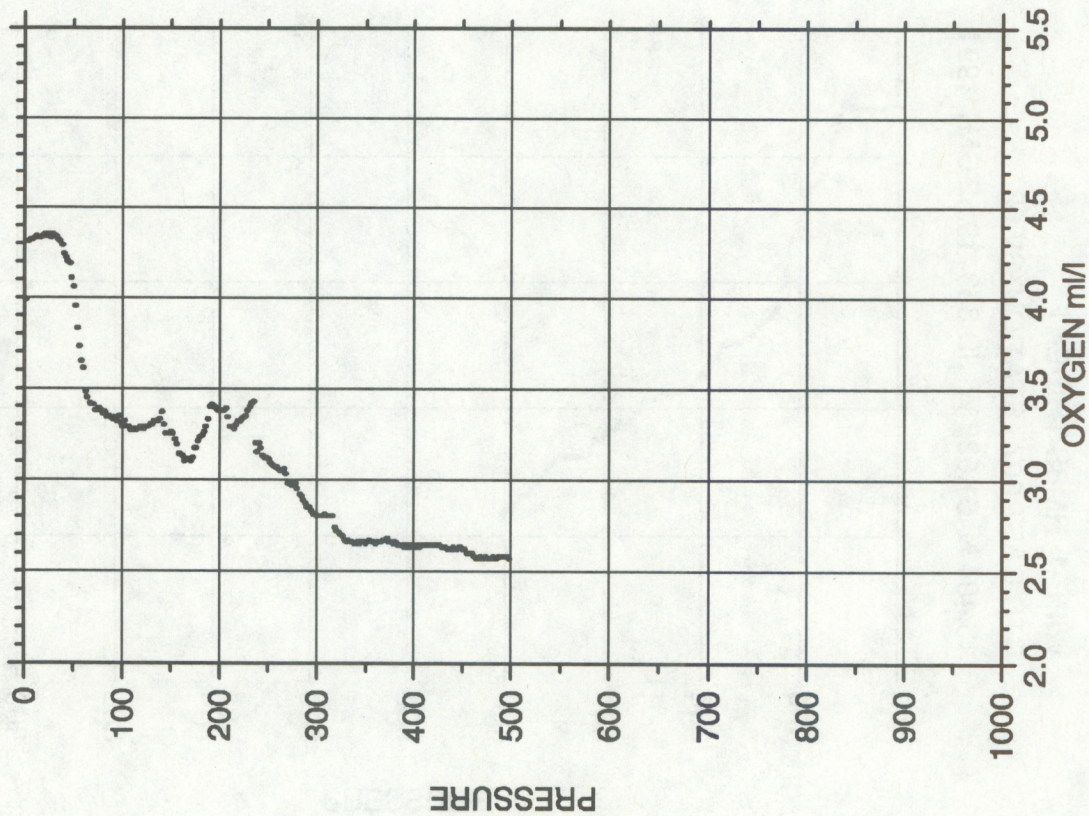
WIPP-1 HMBS TRIDENT

CTD CAST 006 STATION SV 03

13.469 N 61.038 W JD 353 18:02 GMT 1991



WIPP-1 HMBS TRIDENT
 CTD CAST 006 STATION SV 03
 13.469 N 61.038 W JD 353 18:02 GMT 1991

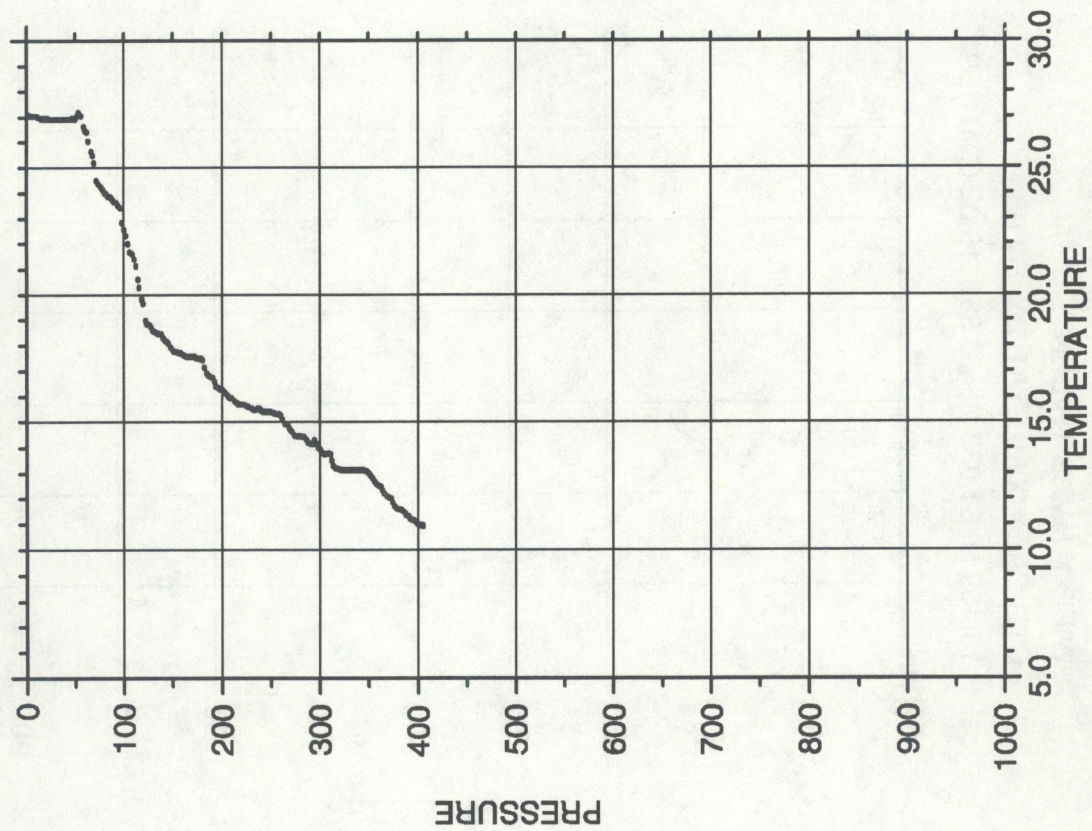


PRES	TEMP	SAL	OXY
4.	27.284	35.831	4.31
10.	27.225	35.827	4.33
20.	27.212	35.829	4.35
30.	27.216	35.853	4.34
40.	27.114	36.084	4.24
50.	26.786	36.249	4.06
60.	25.422	36.399	3.61
70.	24.663	36.534	3.41
80.	24.059	36.576	3.36
90.	23.885	36.656	3.33
100.	23.484	36.730	3.29
120.	22.642	36.835	3.28
140.	21.756	36.808	3.37
160.	19.544	36.646	3.14
180.	18.199	36.489	3.23
200.	17.636	36.430	3.38
220.	16.745	36.278	3.32
240.	15.800	36.079	3.20
260.	14.988	35.955	3.06
280.	14.112	35.778	2.95
300.	13.374	35.665	2.80
320.	12.317	35.486	2.72
340.	11.746	35.395	2.65
360.	11.425	35.354	2.65
380.	11.032	35.272	2.66
400.	10.794	35.245	2.64
450.	10.532	35.206	2.62
498.	9.019	35.001	2.57

WIPP-1 HMBS TRIDENT

CTD CAST 007 STATION SV 02

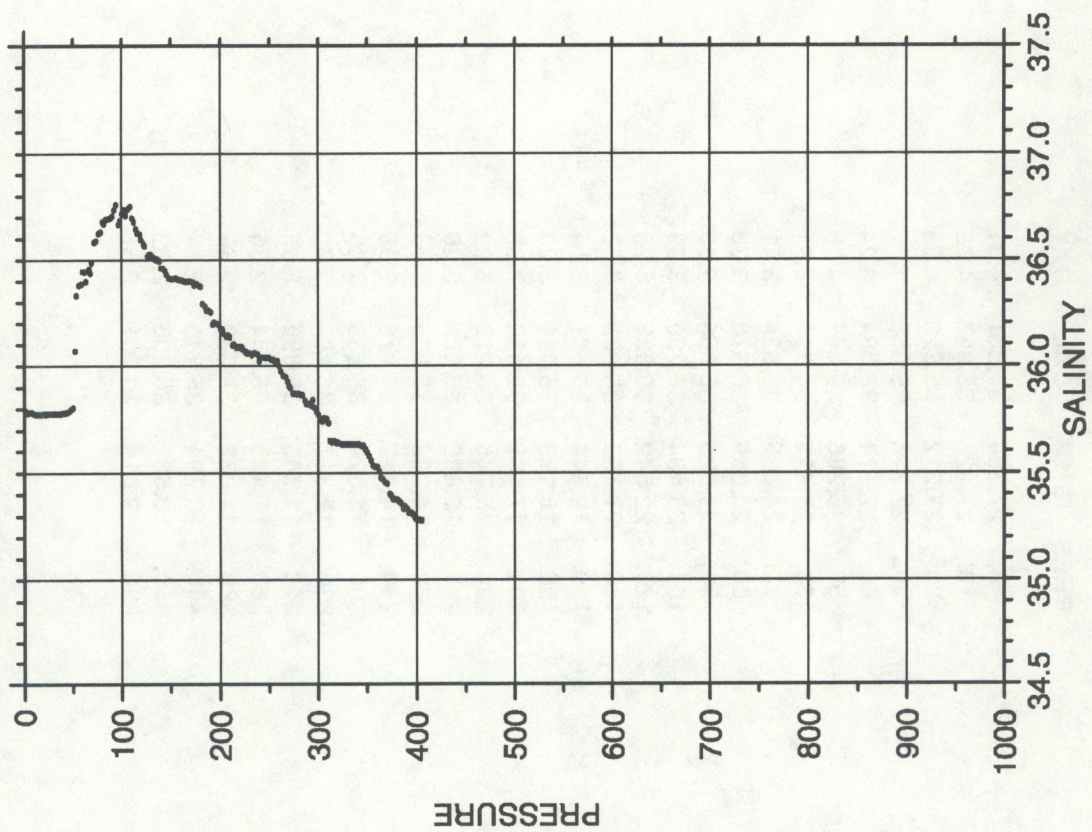
13.404 N 61.088 W JD 353 19:52 GMT 1991



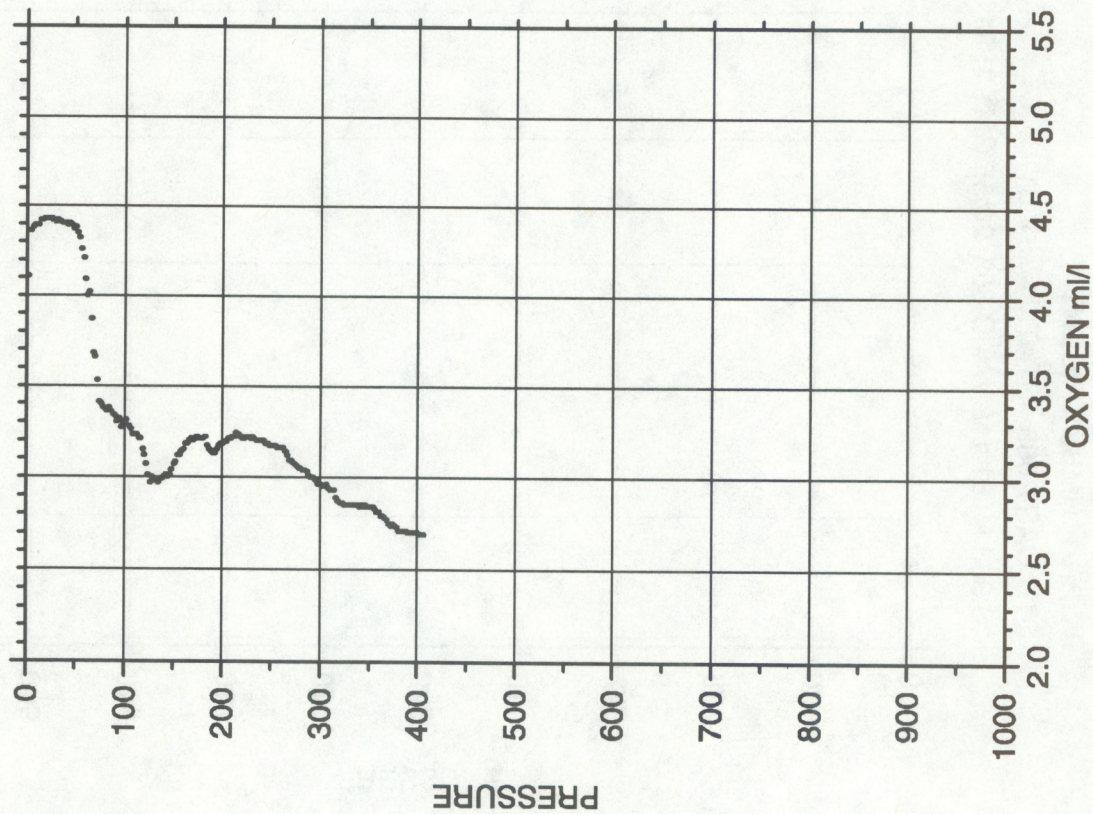
WIPP-1 HMBS TRIDENT

CTD CAST 007 STATION SV 02

13.404 N 61.088 W JD 353 19:52 GMT 1991

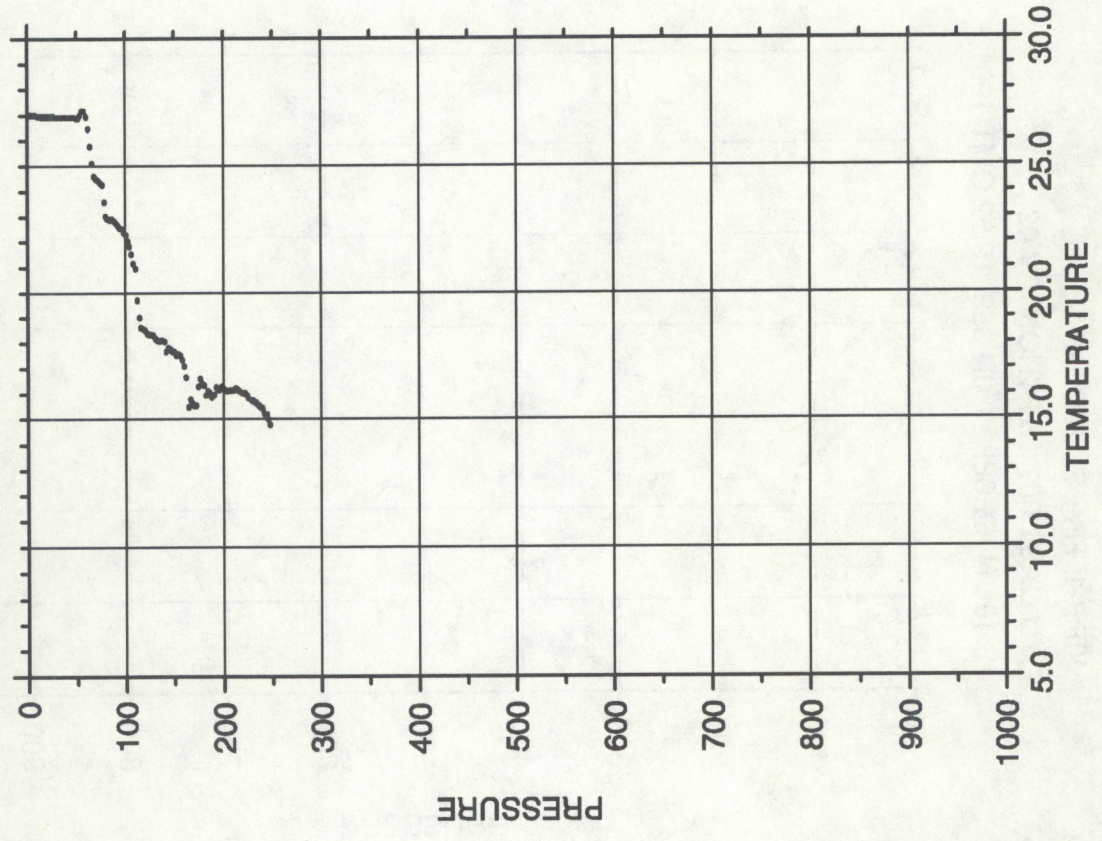


WIPP-1 HMBS TRIDENT
 CTD CAST 007 STATION SV 02
 13.404 N 61.088 W JD 353 19:52 GMT 1991

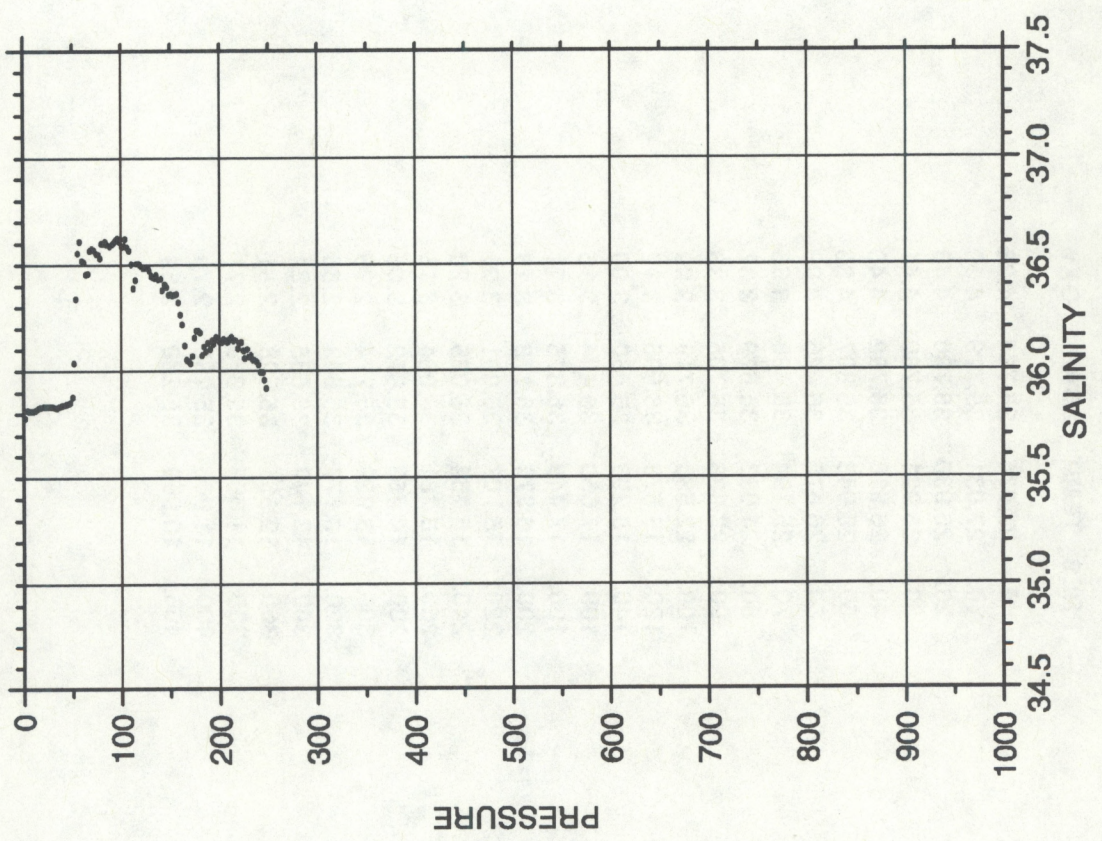


PRES	TEMP	SAL	OXY
4.	27.074	35.784	4.36
10.	27.031	35.779	4.39
20.	26.930	35.780	4.43
30.	26.921	35.780	4.41
40.	26.918	35.782	4.40
50.	26.943	35.807	4.38
60.	26.476	36.446	4.09
70.	25.194	36.488	3.66
80.	24.033	36.679	3.37
90.	23.688	36.706	3.33
100.	22.586	36.718	3.29
120.	19.673	36.596	3.12
140.	18.293	36.460	3.00
160.	17.660	36.404	3.15
180.	17.449	36.375	3.21
200.	16.276	36.178	3.18
220.	15.707	36.091	3.21
240.	15.464	36.025	3.20
260.	15.281	36.004	3.16
280.	14.453	35.872	3.05
300.	13.929	35.774	2.96
320.	13.177	35.643	2.86
340.	13.142	35.635	2.84
360.	12.531	35.528	2.81
380.	11.603	35.378	2.71
400.	11.005	35.285	2.70
406.	10.960	35.280	2.69

WIPP-1 HMBS TRIDENT
 CTD CAST 008 STATION SV 01
 13.368 N 61.118 W JD 353 20:55 GMT 1991



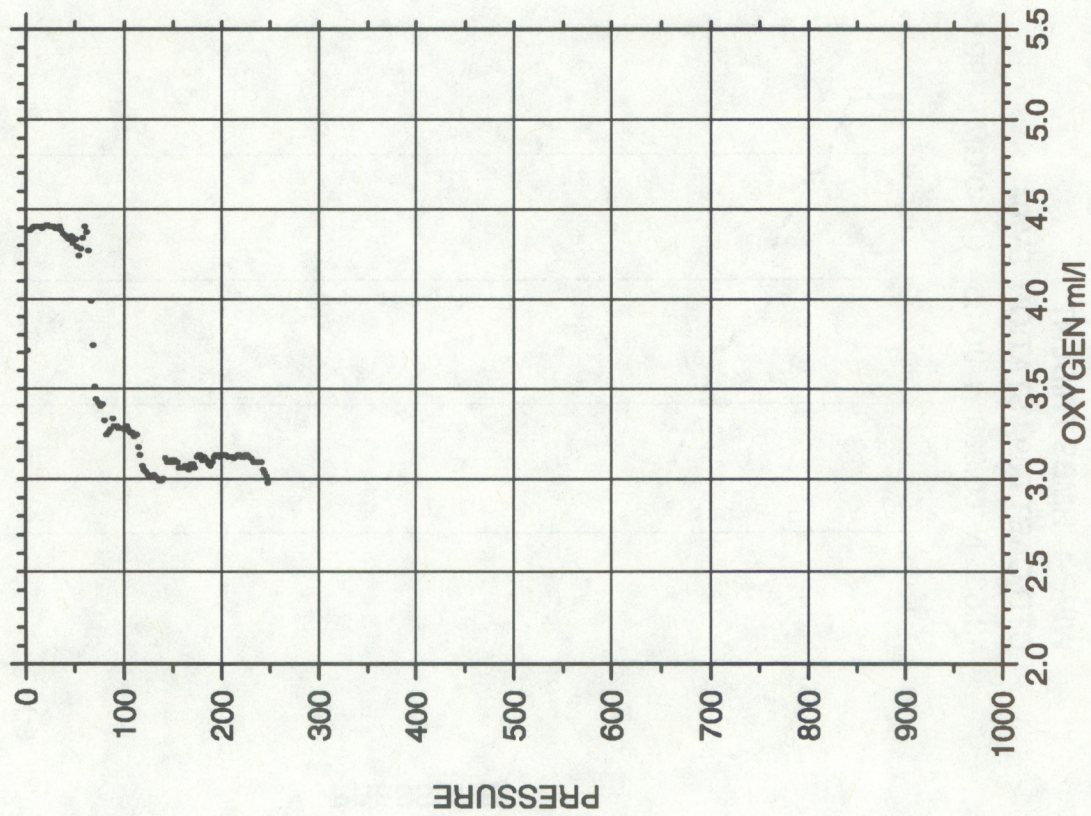
WIPP-1 HMBS TRIDENT
 CTD CAST 008 STATION SV 01
 13.368 N 61.118 W JD 353 20:55 GMT 1991



WIPP-1 HMBS TRIDENT

CTD CAST 008 STATION SV 01

13.368 N 61.118 W JD 353 20:55 GMT 1991

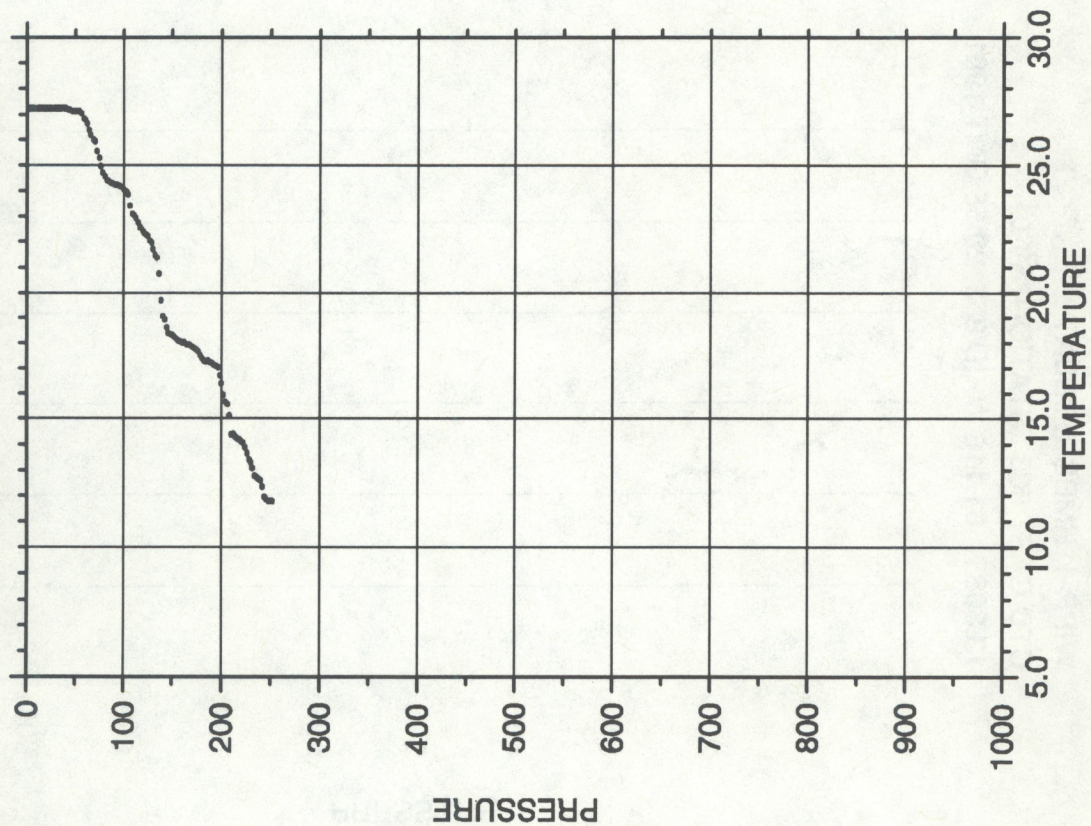


PRES	TEMP	SAL	OXY
4.	26.998	35.818	4.38
10.	26.972	35.815	4.40
20.	26.938	35.836	4.41
30.	26.926	35.837	4.39
40.	26.909	35.842	4.35
50.	26.875	35.882	4.33
60.	26.931	36.522	4.40
70.	24.504	36.576	3.51
80.	23.021	36.601	3.32
90.	22.751	36.595	3.29
100.	22.276	36.588	3.27
120.	18.524	36.495	3.05
140.	18.071	36.434	3.00
160.	17.099	36.267	3.06
180.	16.353	36.184	3.10
200.	16.204	36.138	3.13
220.	16.049	36.136	3.12
240.	15.432	36.032	3.09
248.	14.795	35.921	2.98

WIPP-1 HMBS TRIDENT

CTD CAST 009 STATION SV 04

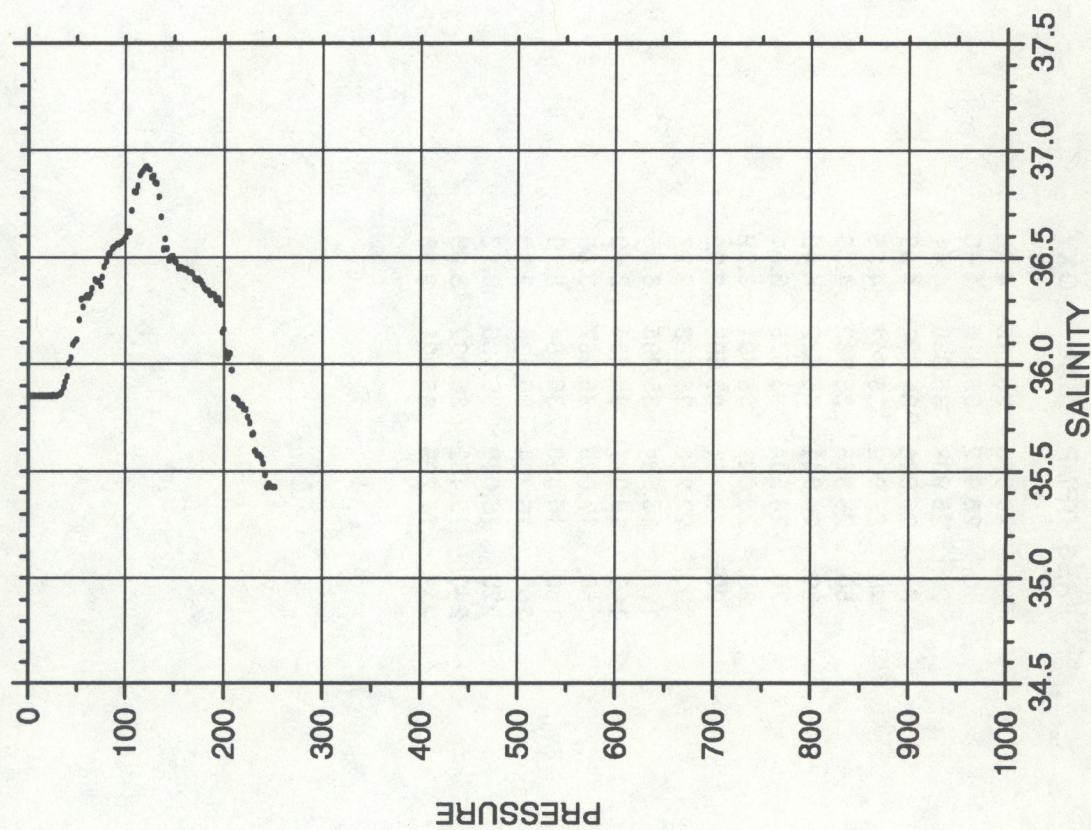
13.535 N 60.985 W JD 354 02:40 GMT 1991



WIPP-1 HMBS TRIDENT

CTD CAST 009 STATION SV 04

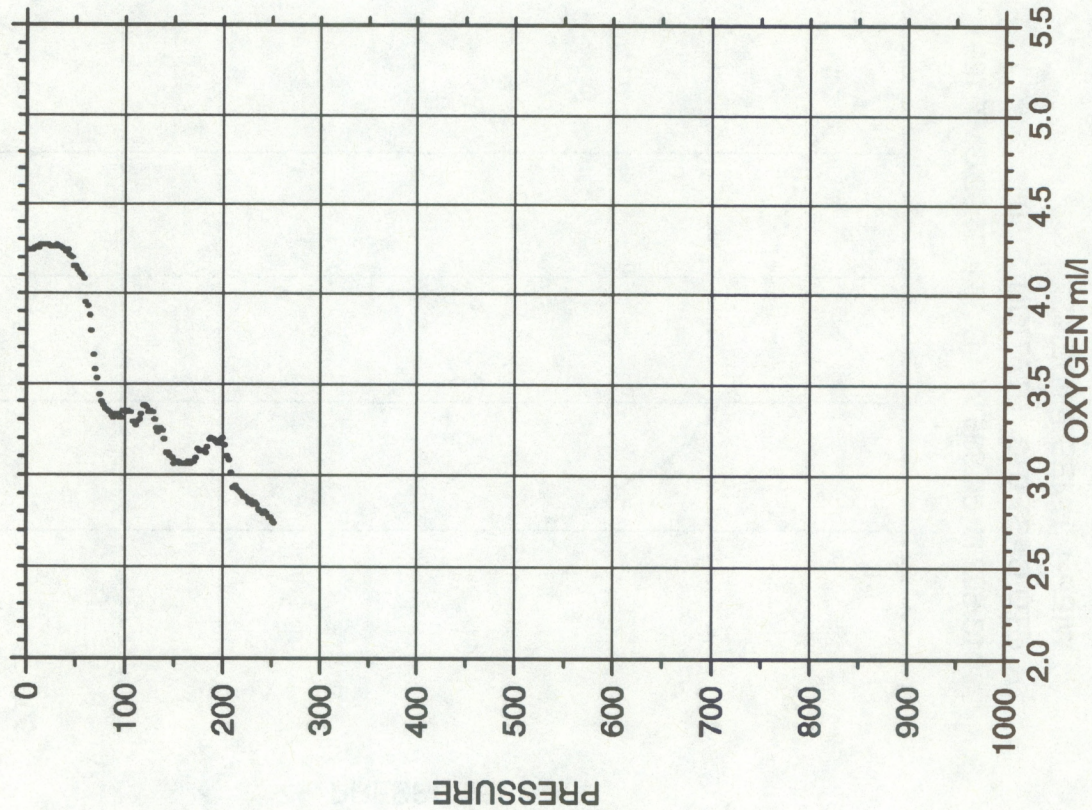
13.535 N 60.985 W JD 354 02:40 GMT 1991



WIPP-1 HMBS TRIDENT

CTD CAST 009 STATION SV 04

13.535 N 60.985 W JD 354 02:40 GMT 1991

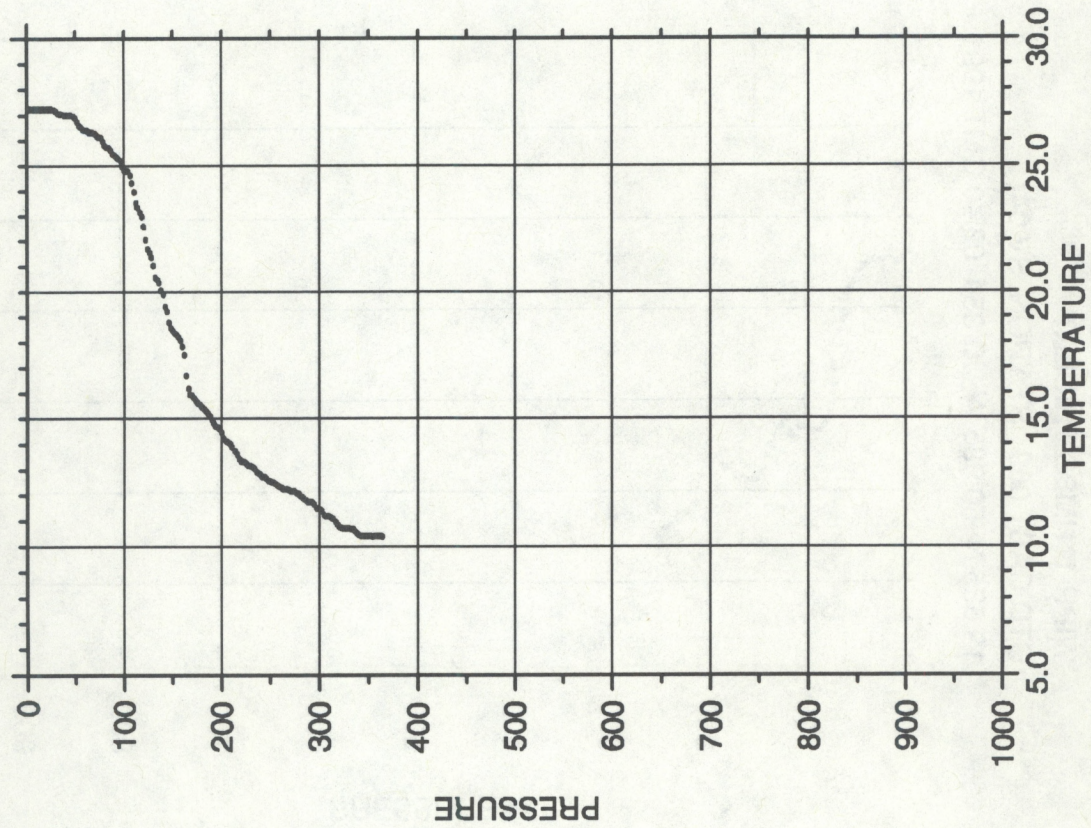


PRES	TEMP	SAL	OXY
4.	27.229	35.855	4.24
10.	27.240	35.854	4.26
20.	27.241	35.855	4.27
30.	27.244	35.859	4.27
40.	27.240	35.943	4.23
50.	27.127	36.118	4.15
60.	26.789	36.323	3.95
70.	25.932	36.389	3.58
80.	24.585	36.482	3.36
90.	24.258	36.559	3.33
100.	24.059	36.597	3.35
120.	22.372	36.918	3.38
140.	19.069	36.586	3.19
160.	18.027	36.444	3.06
180.	17.405	36.357	3.13
200.	16.400	36.166	3.20
220.	14.131	35.795	2.88
240.	12.630	35.538	2.79
252.	11.811	35.427	2.74

WIPP-1 HMBS TRIDENT

CTD CAST 010 STATION SV 05

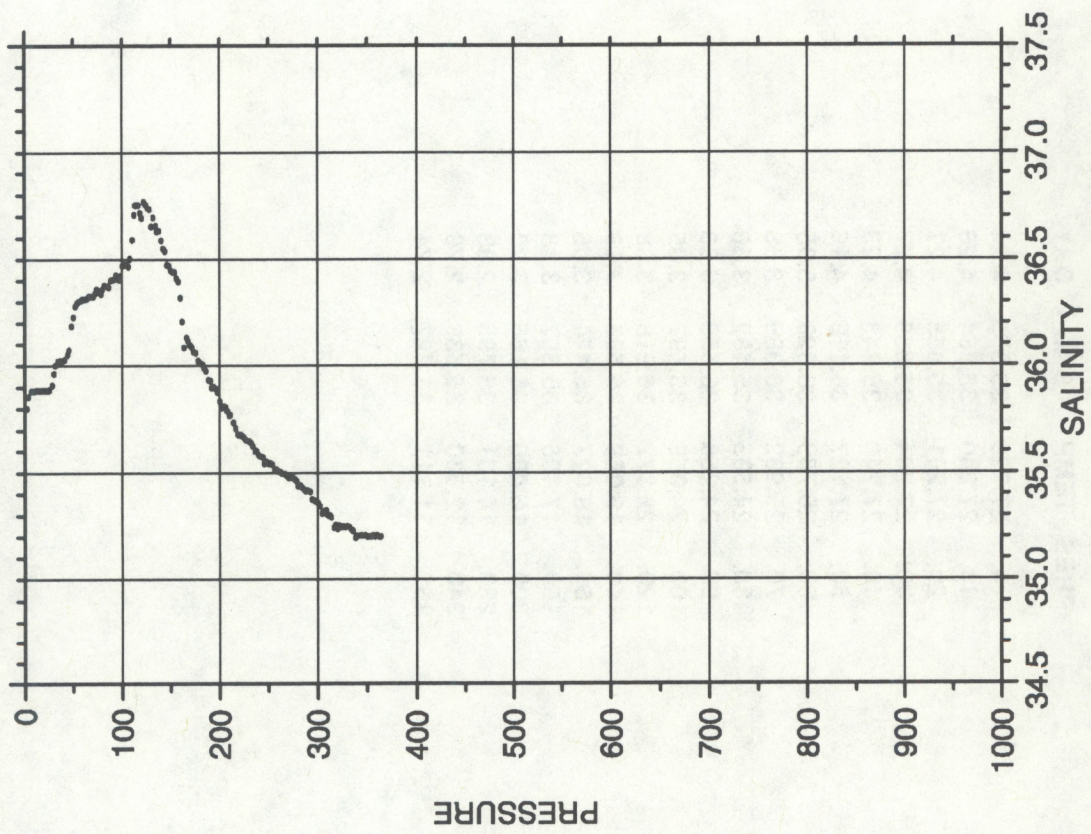
13.602 N 60.935 W JD 354 04:02 GMT 1991



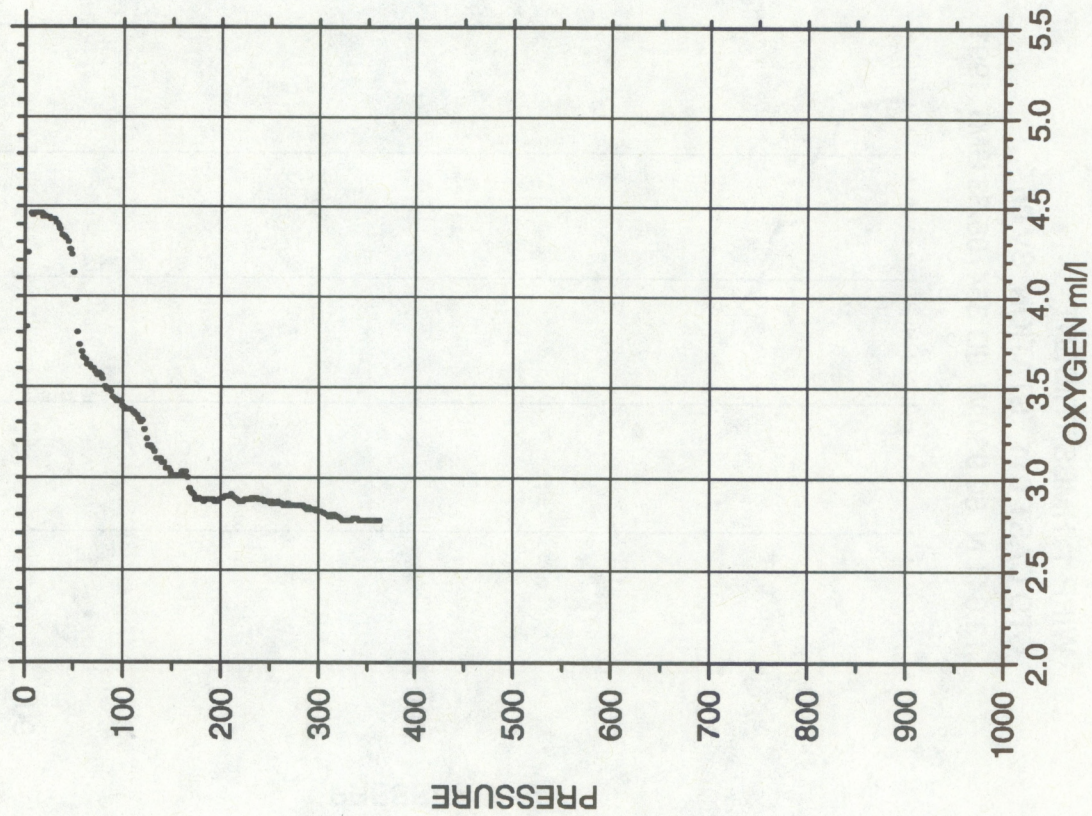
WIPP-1 HMBS TRIDENT

CTD CAST 010 STATION SV 05

13.602 N 60.935 W JD 354 04:02 GMT 1991



WIPP-1 HMBS TRIDENT
 CTD CAST 010 STATION SV 05
 13.602 N 60.935 W JD 354 04:02 GMT 1991

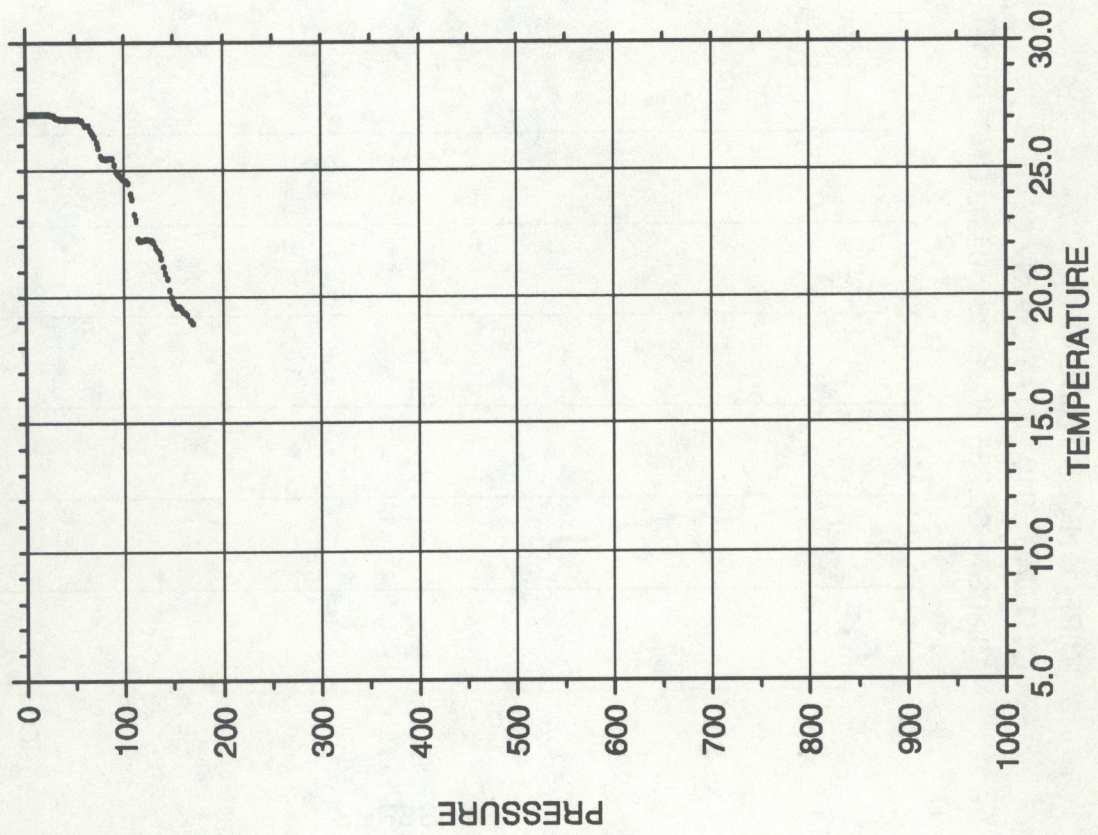


PRES	TEMP	SAL	OXY
4.	27.238	35.858	4.24
10.	27.244	35.886	4.46
20.	27.243	35.888	4.45
30.	27.135	35.965	4.43
40.	27.005	36.027	4.33
50.	26.885	36.232	4.13
60.	26.419	36.316	3.66
70.	26.270	36.328	3.60
80.	25.817	36.361	3.54
90.	25.420	36.405	3.44
100.	24.832	36.469	3.39
120.	22.590	36.693	3.31
140.	19.894	36.590	3.08
160.	17.840	36.321	3.03
180.	15.457	36.017	2.88
200.	14.459	35.838	2.89
220.	13.355	35.682	2.87
240.	12.857	35.587	2.88
260.	12.336	35.507	2.86
280.	12.035	35.440	2.85
300.	11.484	35.362	2.82
320.	10.773	35.239	2.79
340.	10.469	35.207	2.78
360.	10.430	35.209	2.77
364.	10.399	35.202	2.77

WIPP-1 HMBS TRIDENT

CTD CAST 011 STATION SV 06

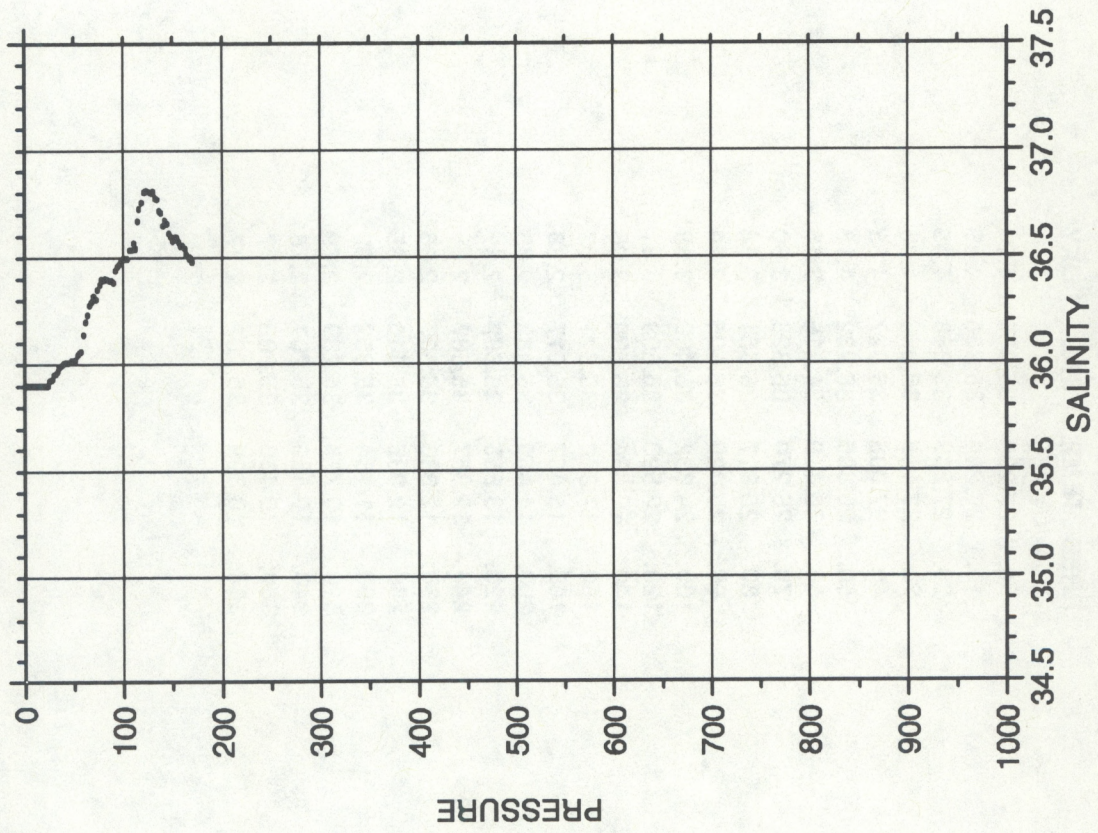
13.641 N 60.930 W JD 354 05:33 GMT 1991

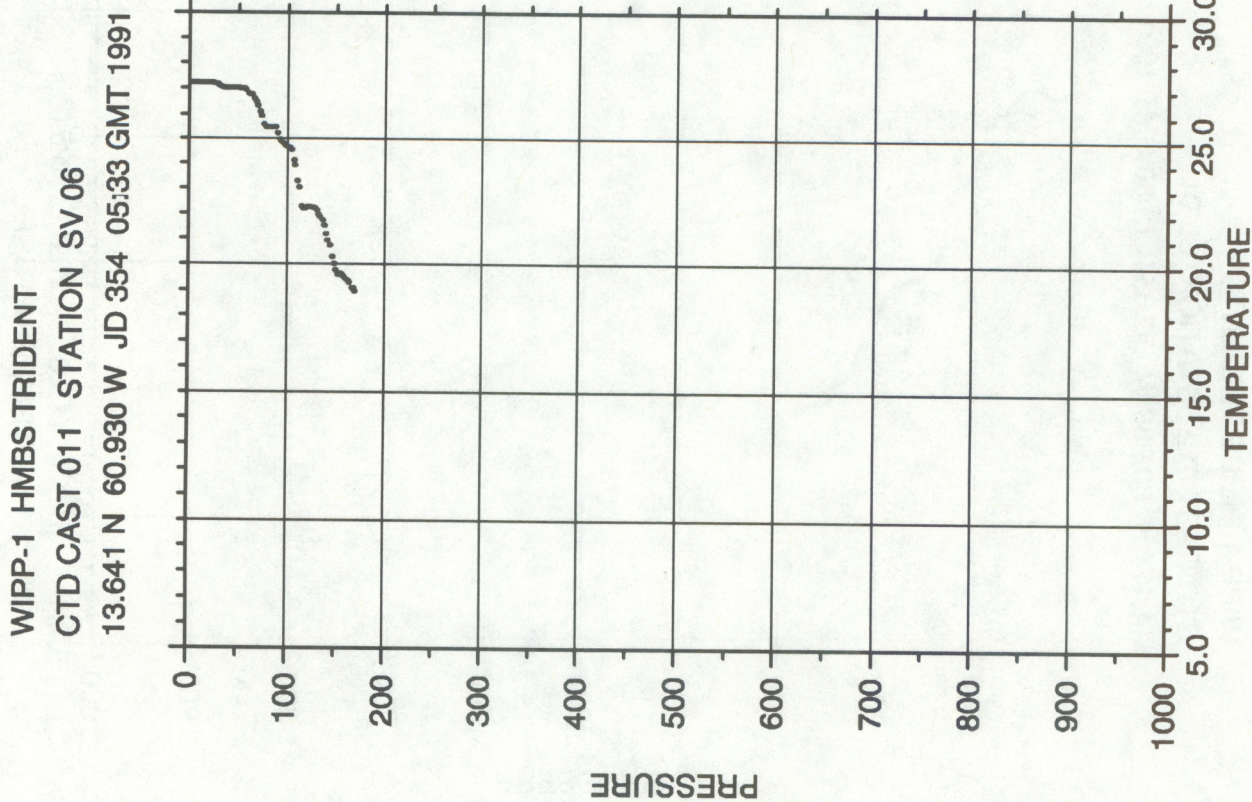


WIPP-1 HMBS TRIDENT

CTD CAST 011 STATION SV 06

13.641 N 60.930 W JD 354 05:33 GMT 1991



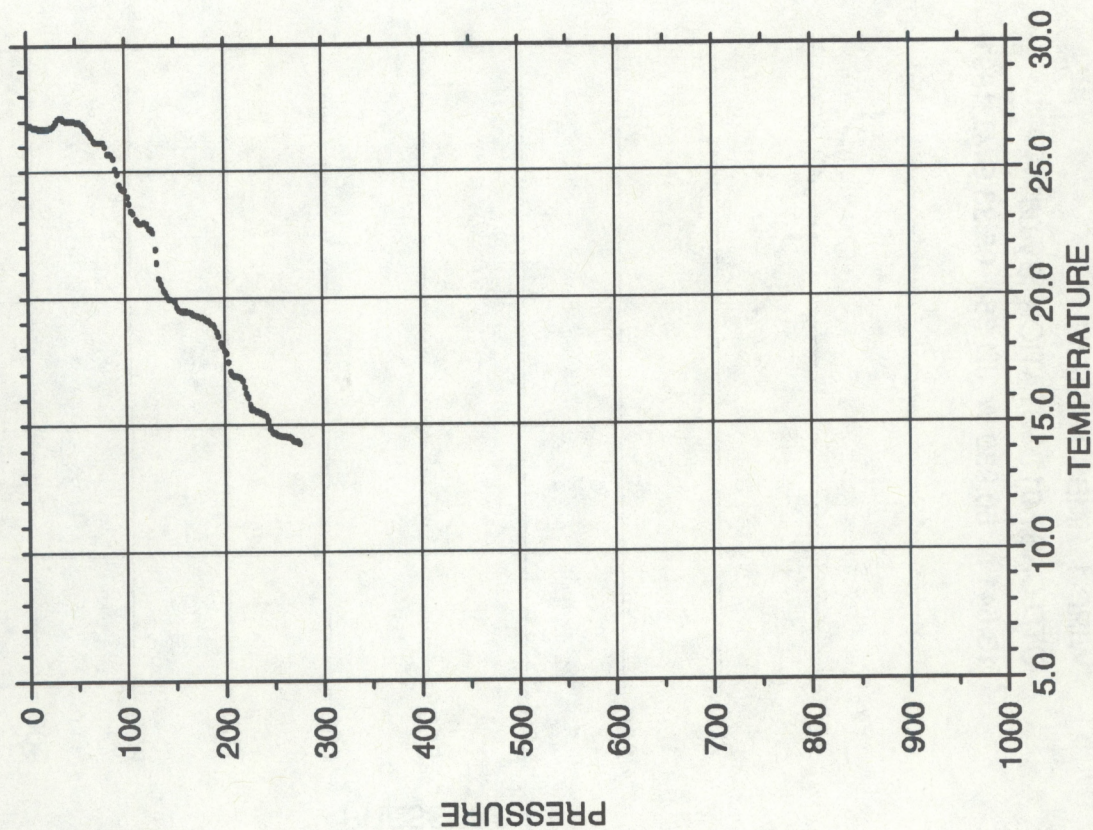


PRES	TEMP	SAL	OXY
4.	27.205	35.902	4.36
10.	27.204	35.902	4.37
20.	27.206	35.902	4.37
30.	27.100	35.952	4.36
40.	27.002	36.006	4.30
50.	26.997	36.019	4.26
60.	26.773	36.142	4.09
70.	26.324	36.320	3.67
80.	25.465	36.397	3.46
90.	25.220	36.384	3.44
100.	24.621	36.496	3.35
120.	22.243	36.804	3.20
140.	21.194	36.650	3.15
160.	19.406	36.558	2.93
170.	18.943	36.479	2.97

WIPP-1 HMBS TRIDENT

CTD CAST 012 STATION SL 01

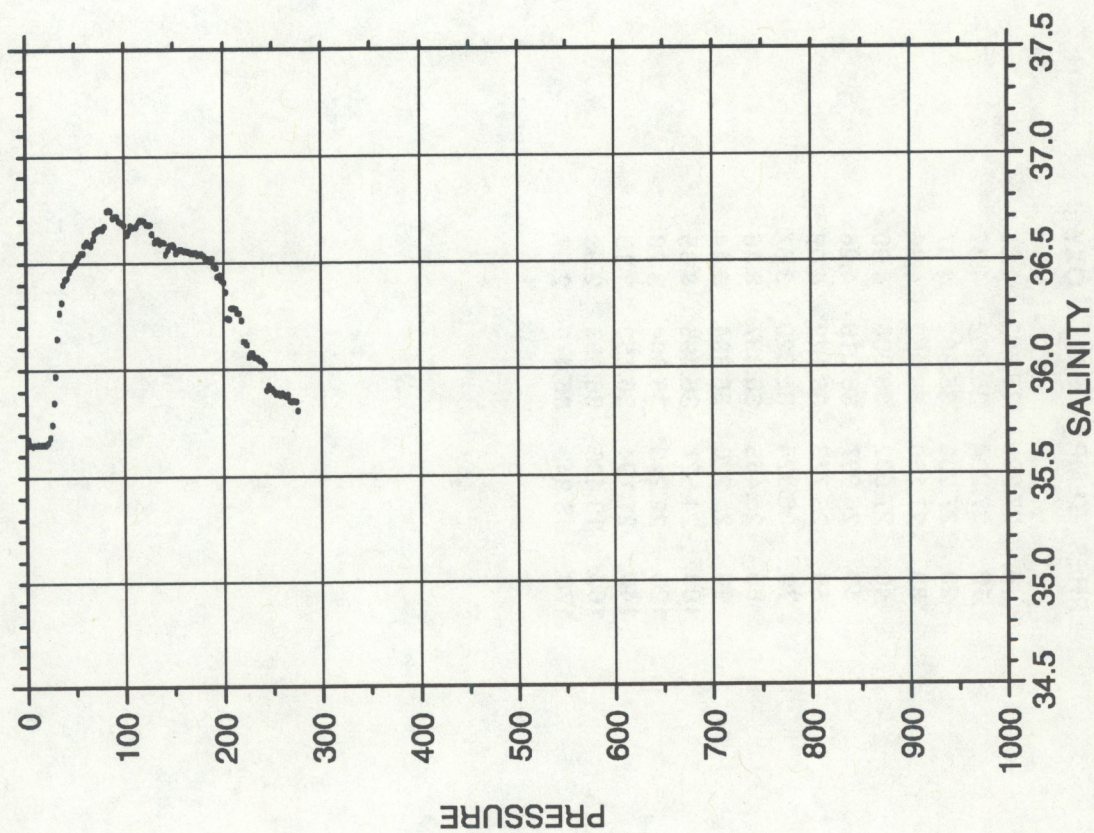
14.174 N 60.908 W JD 354 15:30 GMT 1991



WIPP-1 HMBS TRIDENT

CTD CAST 012 STATION SL 01

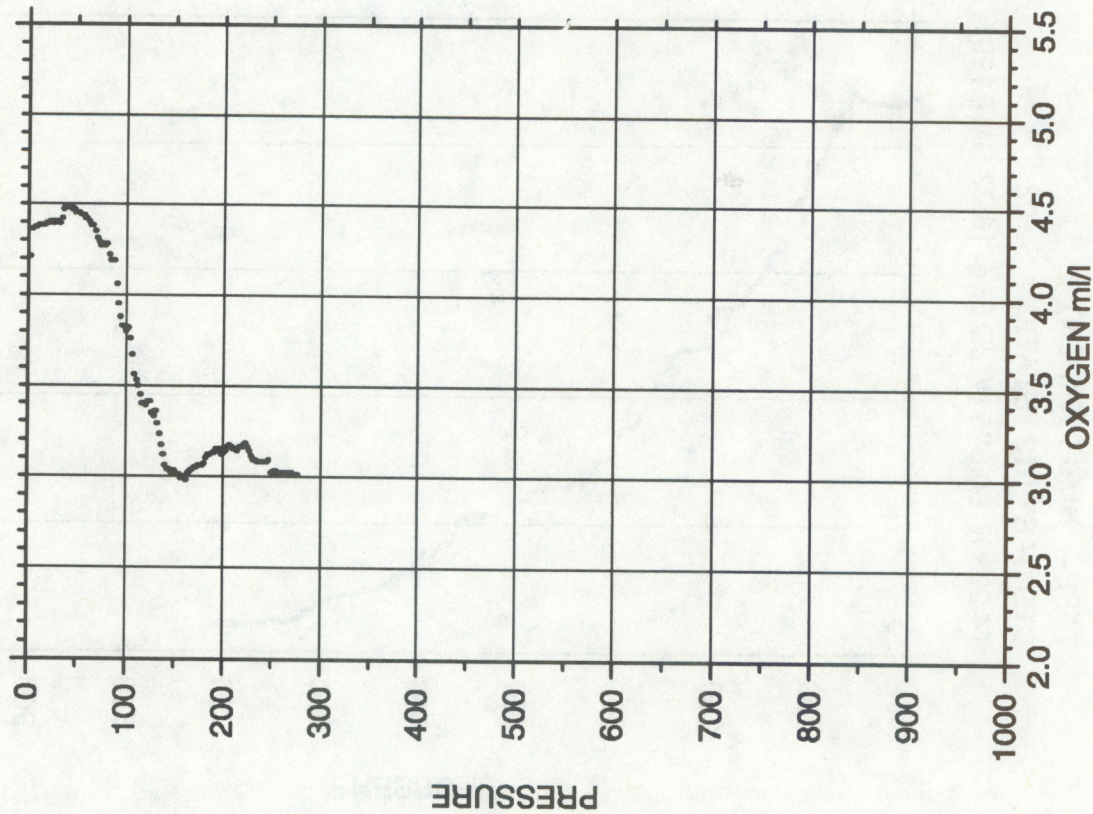
14.174 N 60.908 W JD 354 15:30 GMT 1991



WIPP-1 HMBS TRIDENT

CTD CAST 012 STATION SL 01

14.174 N 60.908 W JD 354 15:30 GMT 1991

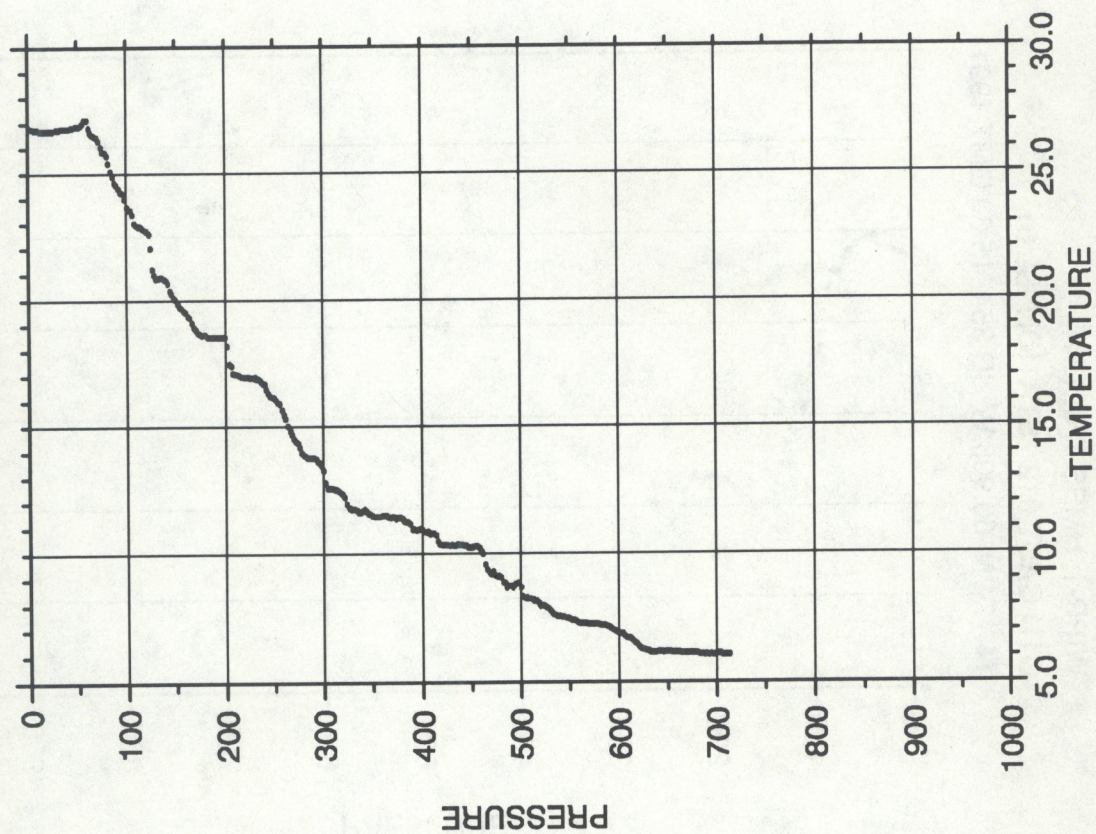


PRES	TEMP	SAL	OXY
4.	26.812	35.655	4.36
10.	26.729	35.656	4.38
20.	26.722	35.657	4.39
30.	26.962	35.974	4.40
40.	27.021	36.424	4.48
50.	26.974	36.500	4.45
60.	26.699	36.588	4.42
70.	26.177	36.644	4.31
80.	25.995	36.675	4.28
90.	25.105	36.719	4.06
100.	24.273	36.680	3.80
120.	22.954	36.698	3.39
140.	20.247	36.595	3.06
160.	19.463	36.557	3.00
180.	19.169	36.533	3.07
200.	17.925	36.408	3.13
220.	16.507	36.134	3.17
240.	15.440	36.040	3.08
260.	14.567	35.892	3.02
276.	14.293	35.811	3.01

WIPP-1 HMBS TRIDENT

CTD CAST 013 STATION SL 02

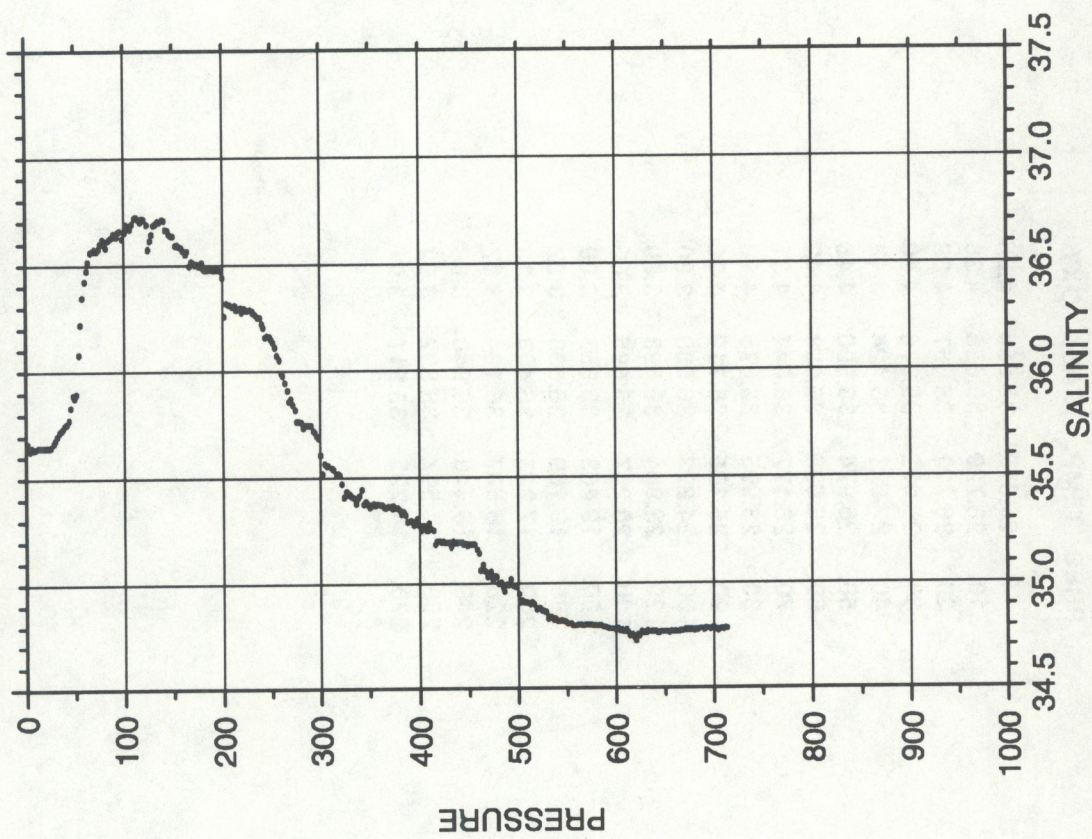
14.208 N 60.895 W JD 354 16:27 GMT 1991



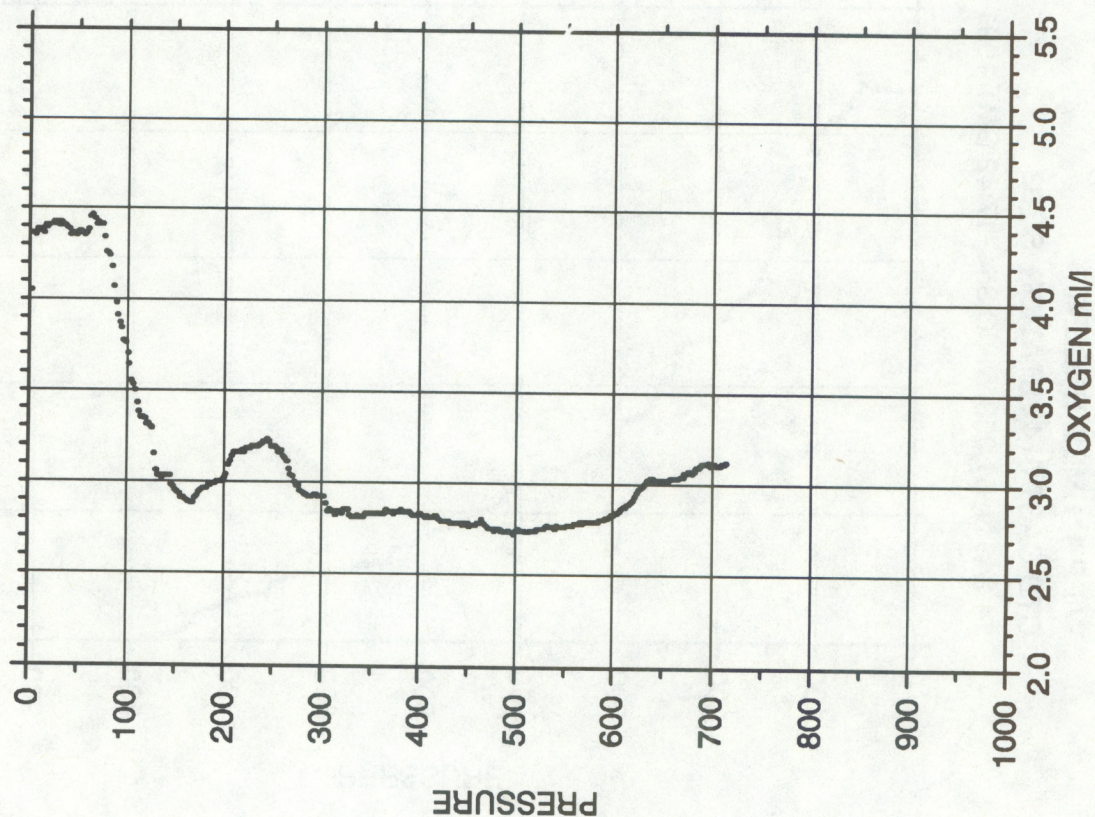
WIPP-1 HMBS TRIDENT

CTD CAST 013 STATION SL 02

14.208 N 60.895 W JD 354 16:27 GMT 1991



WIPP-1 HMBS TRIDENT
 CTD CAST 013 STATION SL 02
 14.208 N 60.895 W JD 354 16:27 GMT 1991

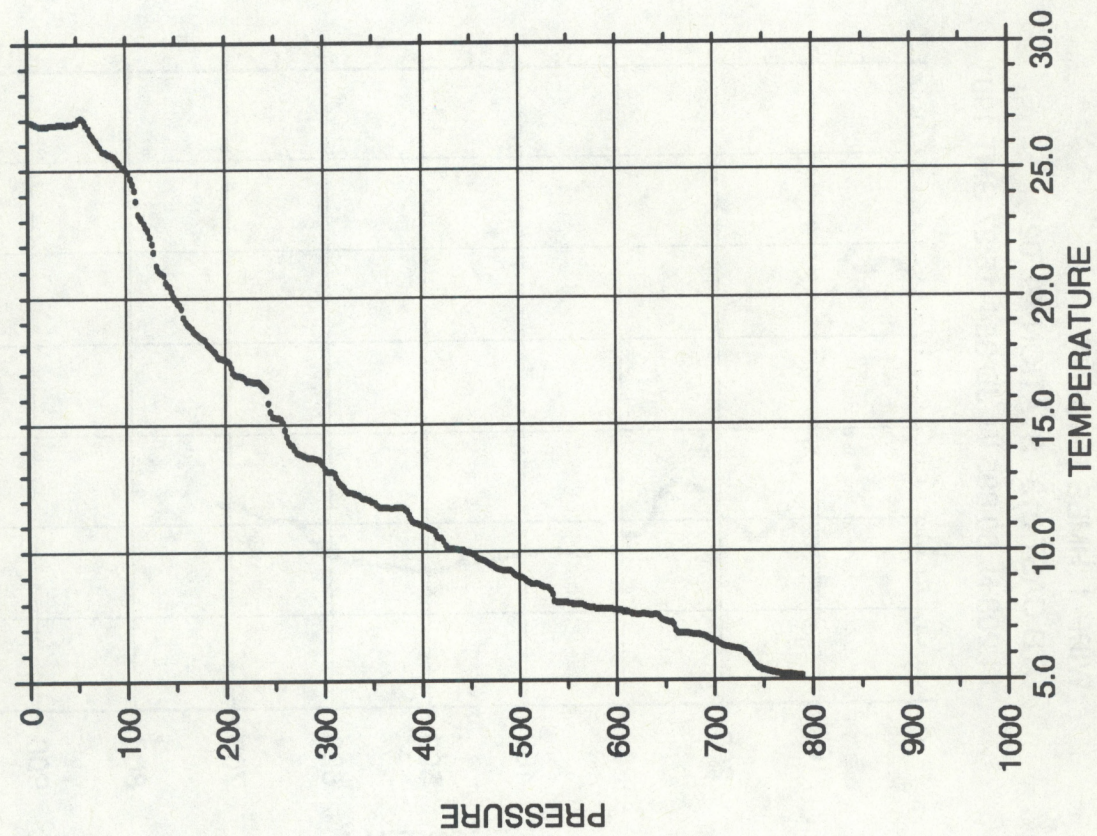


PRES	TEMP	SAL	OXY
4.	26.783	35.637	4.36
10.	26.729	35.647	4.37
20.	26.717	35.651	4.40
30.	26.750	35.686	4.40
40.	26.797	35.756	4.38
50.	26.874	35.883	4.37
60.	27.137	36.425	4.38
70.	26.459	36.574	4.42
80.	25.724	36.599	4.25
90.	24.585	36.651	3.91
100.	23.668	36.657	3.70
120.	22.735	36.715	3.31
140.	20.762	36.709	3.03
160.	19.516	36.569	2.90
180.	18.647	36.488	2.96
200.	18.560	36.440	3.02
220.	16.981	36.280	3.16
240.	16.711	36.226	3.22
260.	15.474	35.993	3.14
280.	13.897	35.766	2.94
300.	13.294	35.610	2.92
320.	12.354	35.510	2.83
340.	11.665	35.415	2.81
360.	11.525	35.375	2.83
380.	11.380	35.346	2.84
400.	10.973	35.278	2.83
450.	10.258	35.187	2.78
500.	8.692	34.951	2.74
550.	7.439	34.815	2.76
600.	6.883	34.785	2.83
650.	6.172	34.773	3.02
700.	6.079	34.795	3.11
714.	6.038	34.788	3.12

WIPP-1 HMBS TRIDENT

CTD CAST 014 STATION SL 03

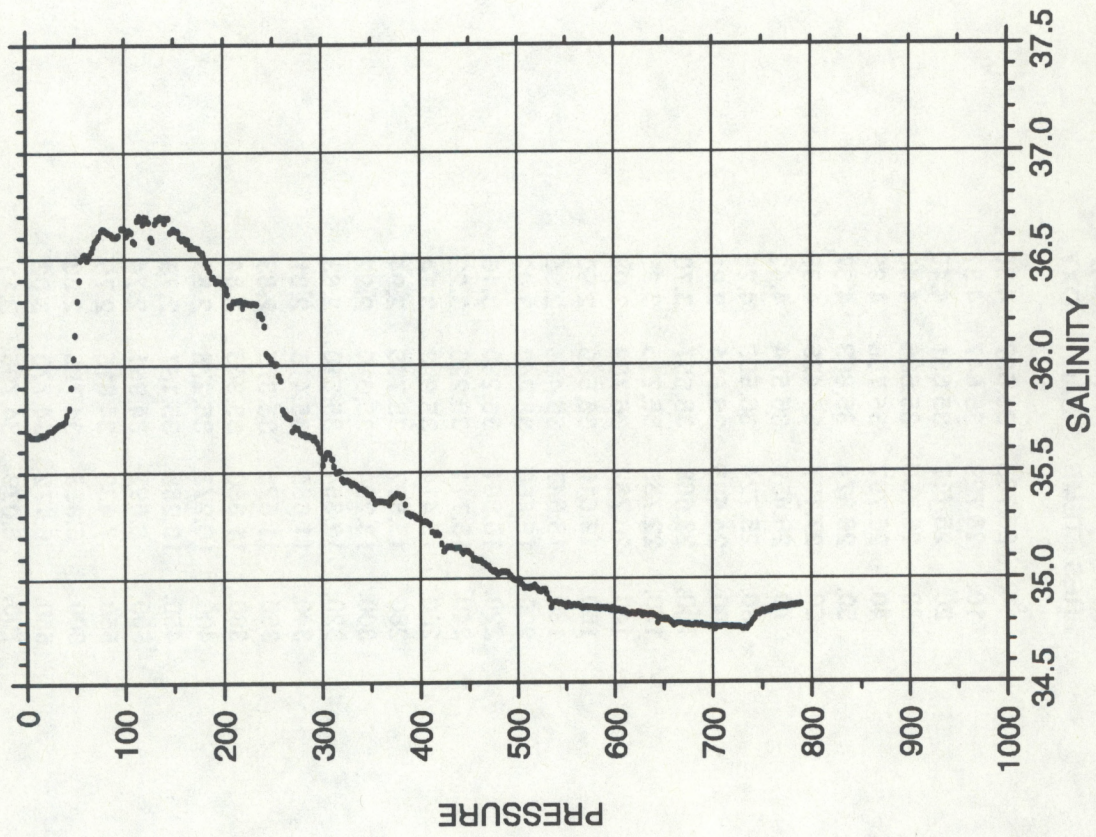
14.243 N 61.053 W JD 354 17:42 GMT 1991



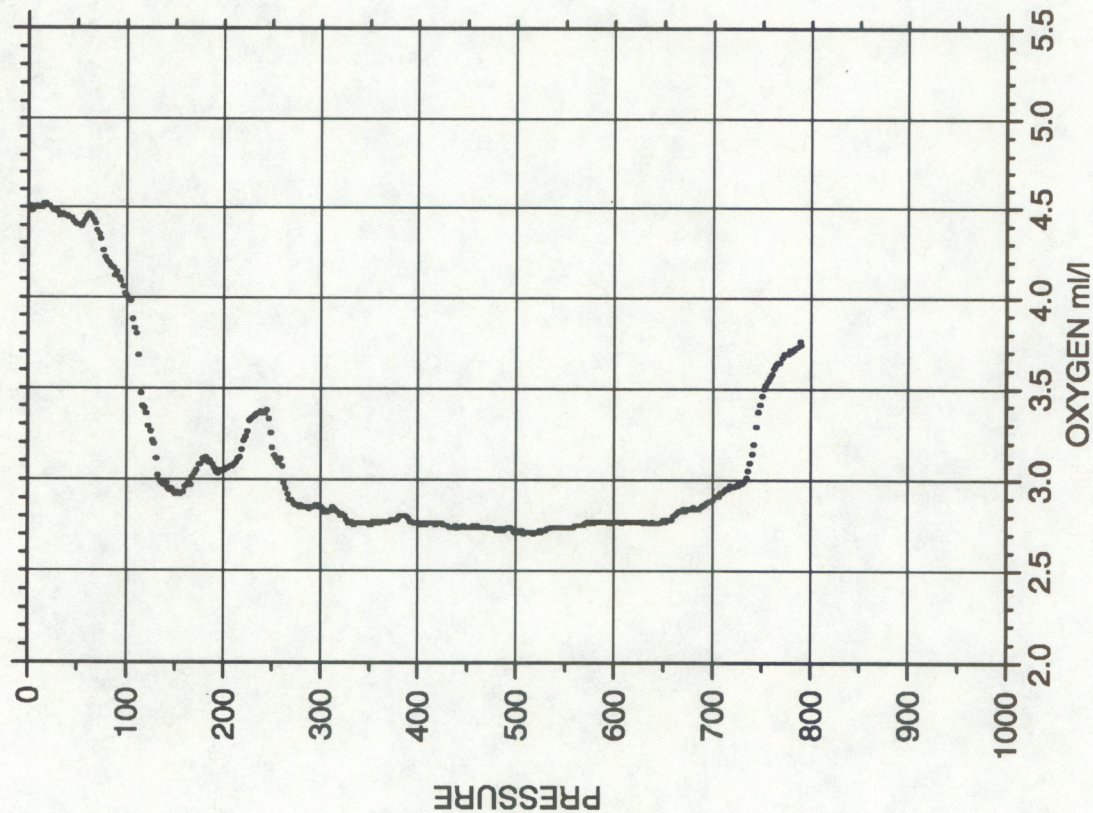
WIPP-1 HMBS TRIDENT

CTD CAST 014 STATION SL 03

14.243 N 61.053 W JD 354 17:42 GMT 1991



WIPP-1 HMBS TRIDENT
 CTD CAST 014 STATION SL 03
 14.243 N 61.053 W JD 354 17:42 GMT 1991



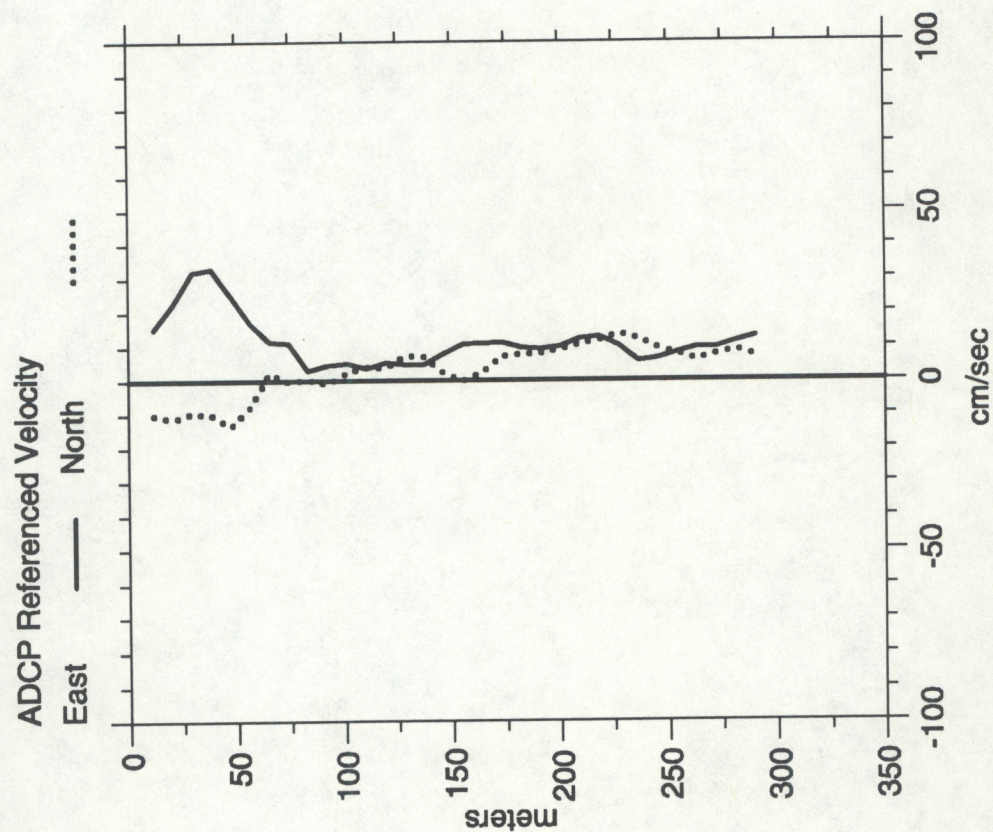
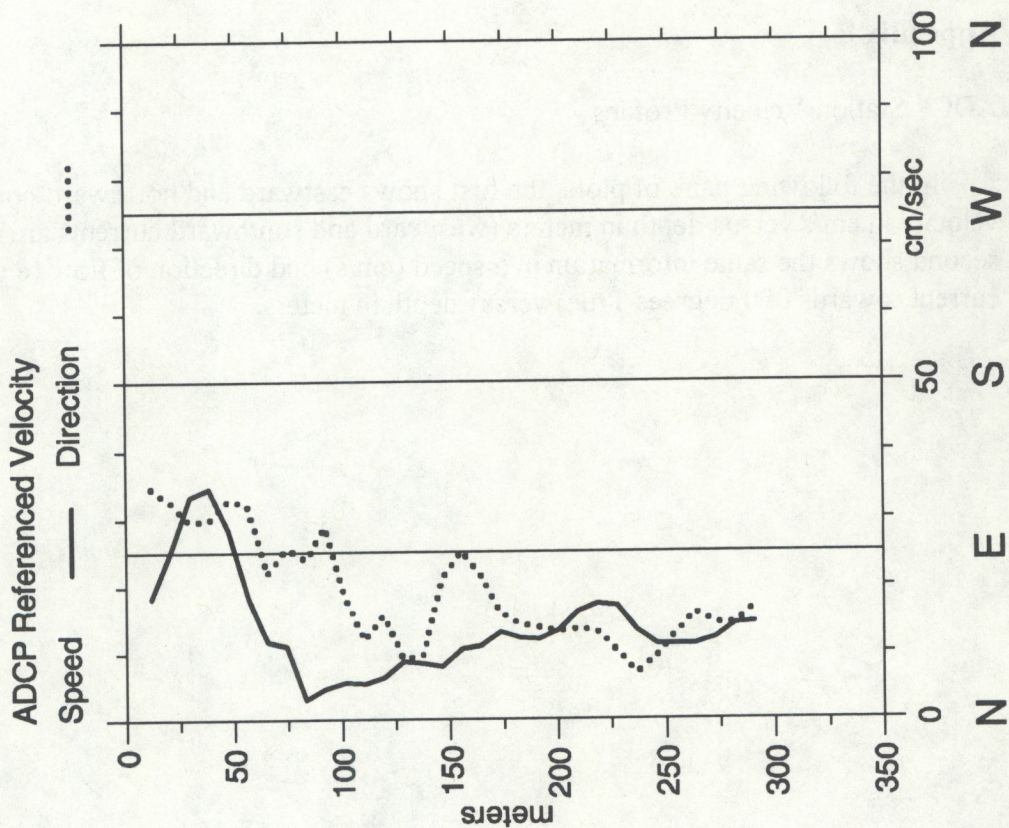
PRES	TEMP	SAL	OXY
4.	26.904	35.678	4.48
10.	26.795	35.670	4.50
20.	26.772	35.688	4.51
30.	26.811	35.721	4.47
40.	26.799	35.746	4.45
50.	26.894	36.145	4.40
60.	26.794	36.520	4.45
70.	26.156	36.583	4.37
80.	25.715	36.637	4.20
90.	25.459	36.605	4.14
100.	25.037	36.645	4.01
120.	22.751	36.696	3.36
140.	20.612	36.670	2.98
160.	19.047	36.596	2.96
180.	18.349	36.511	3.10
200.	17.588	36.379	3.05
220.	16.845	36.270	3.21
240.	16.483	36.221	3.36
260.	14.823	35.795	3.07
280.	13.789	35.681	2.86
300.	13.285	35.536	2.85
320.	12.584	35.468	2.80
340.	12.128	35.425	2.76
360.	11.768	35.365	2.76
380.	11.754	35.386	2.79
400.	11.040	35.283	2.76
450.	9.948	35.125	2.74
500.	9.020	34.994	2.72
550.	8.002	34.868	2.74
600.	7.732	34.856	2.77
650.	7.280	34.811	2.78
700.	6.528	34.776	2.89
750.	5.388	34.846	3.46
790.	5.165	34.878	3.74

Appendix B

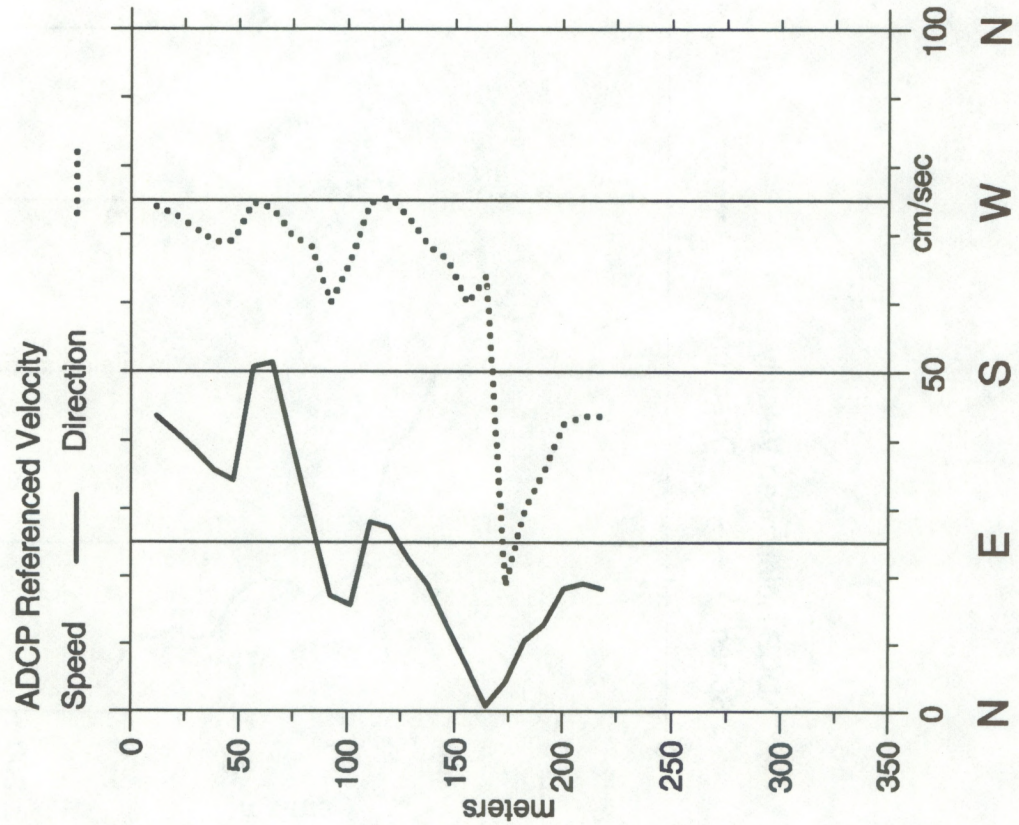
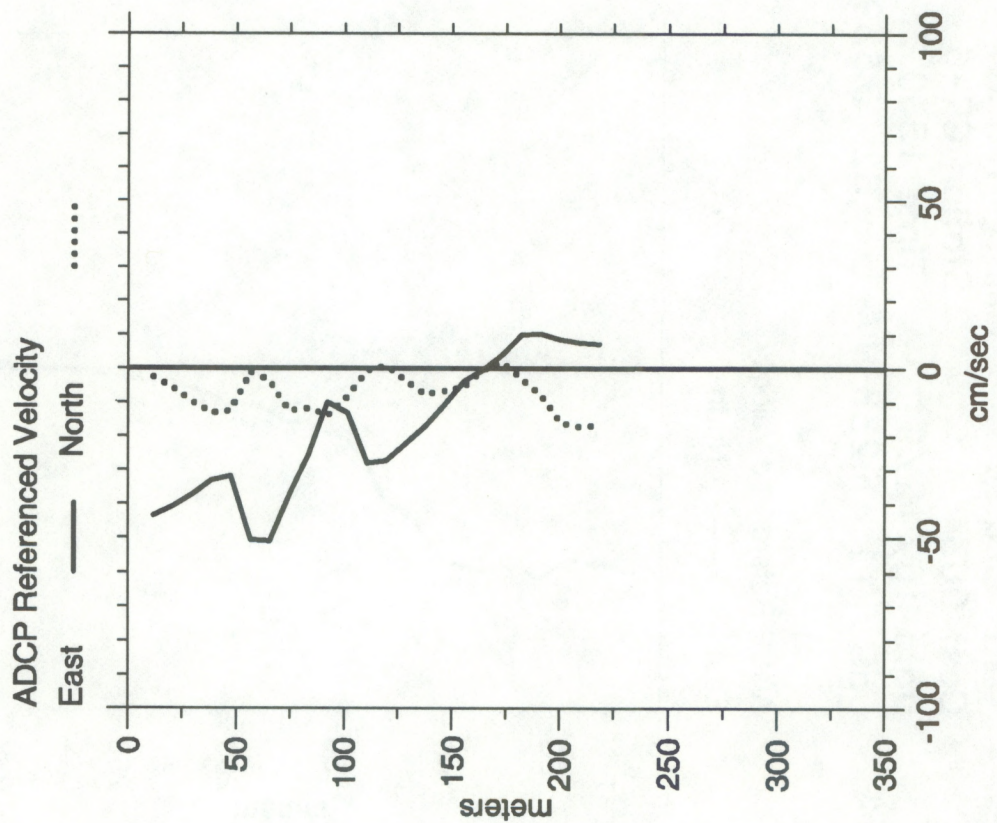
ADCP Station Velocity Profiles

In the following pairs of plots, the first shows eastward and northward components of current velocity in cm/s versus depth in meters (westward and southward currents are negative), and the second shows the same information in a speed (cm/s) and direction of flow (e.g., E represents current towards 090 degrees True) versus depth in meters.

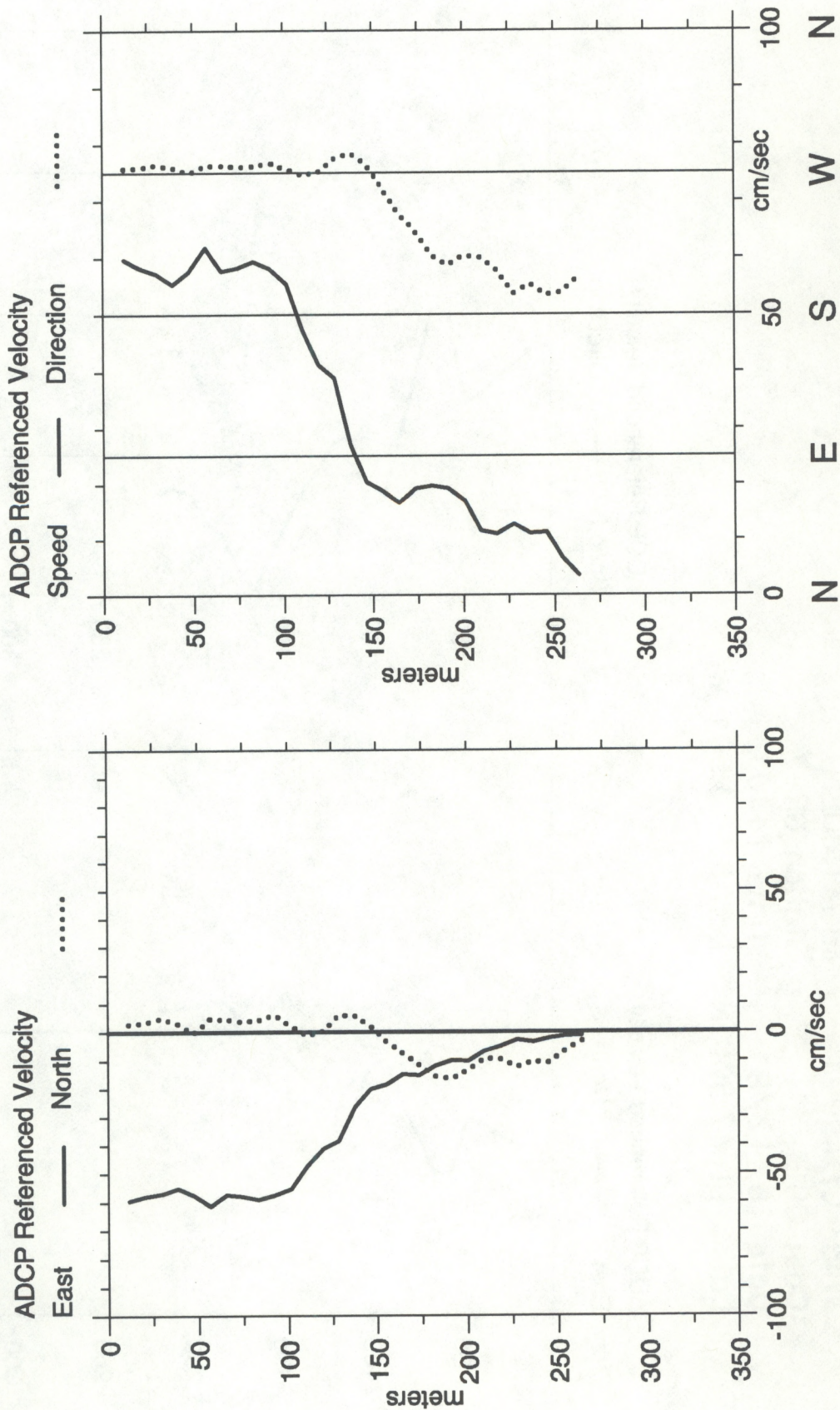
WIPP Cruise 1 HMBS TRIDENT
 Cast 001 Station BD-1
 Date 15/12/91 Time 2126 Z
 Lat 13 10.367 N Lon 59 44.474 W



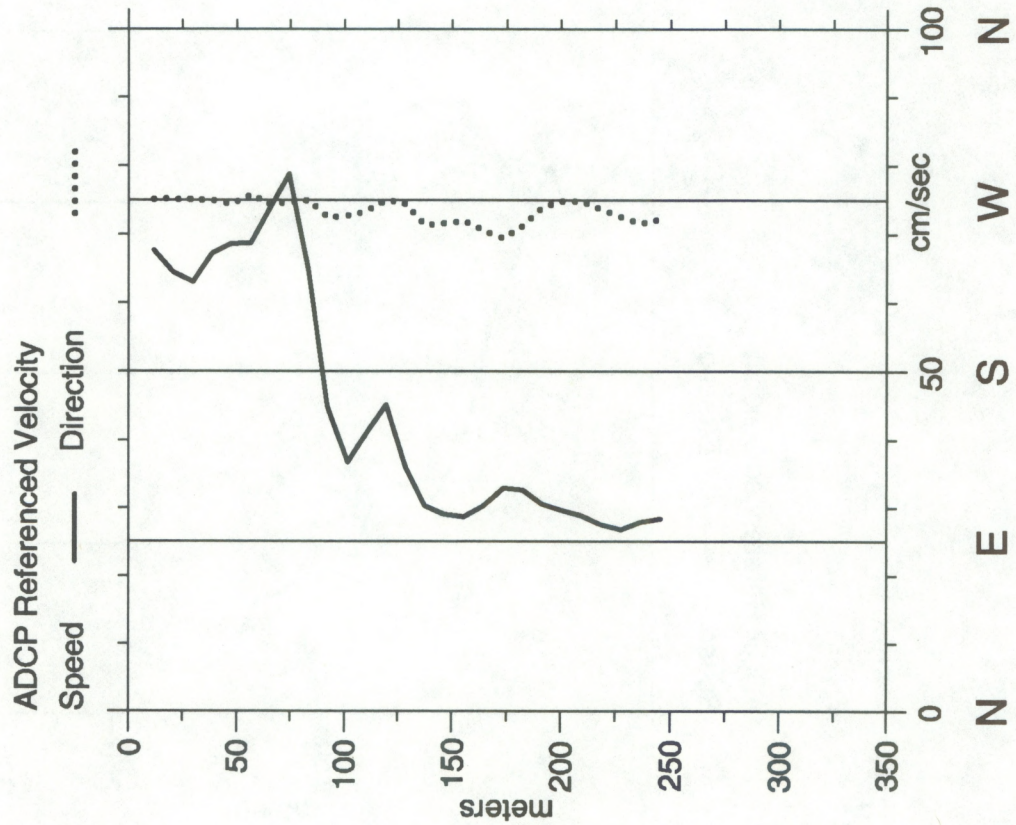
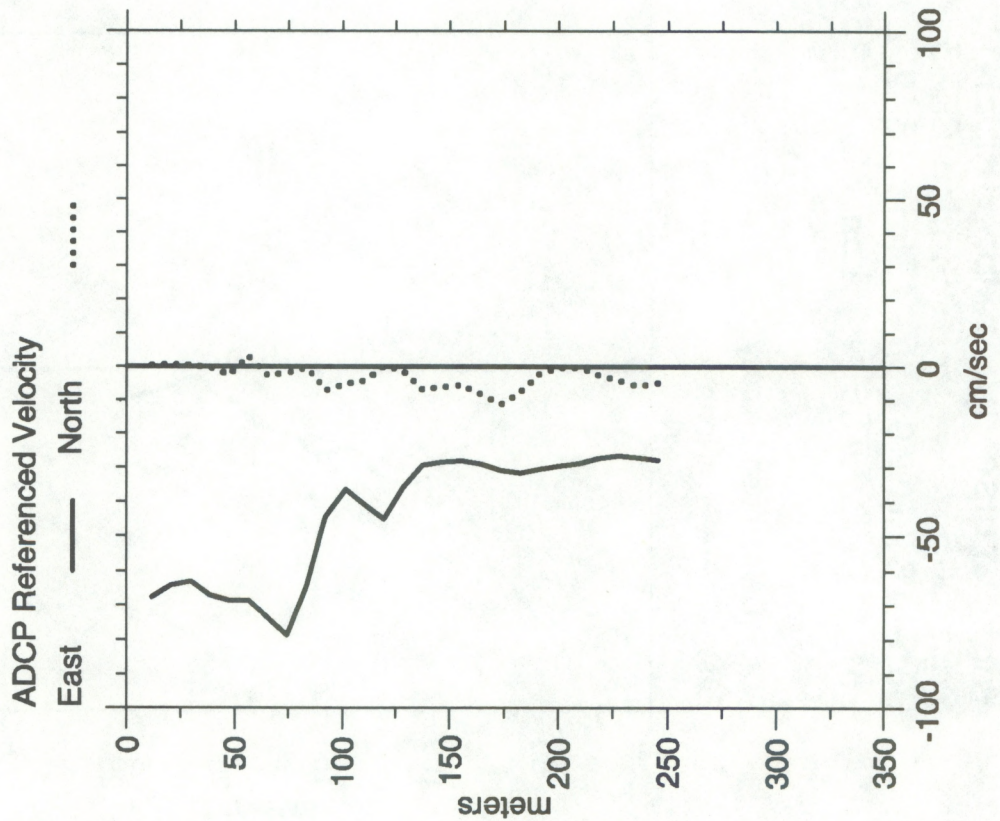
WIPP Cruise 1 HMBS TRIDENT
 Cast 002
 Date 16/12/91
 Lat 11 47.500 N Lon 62 4.501 W



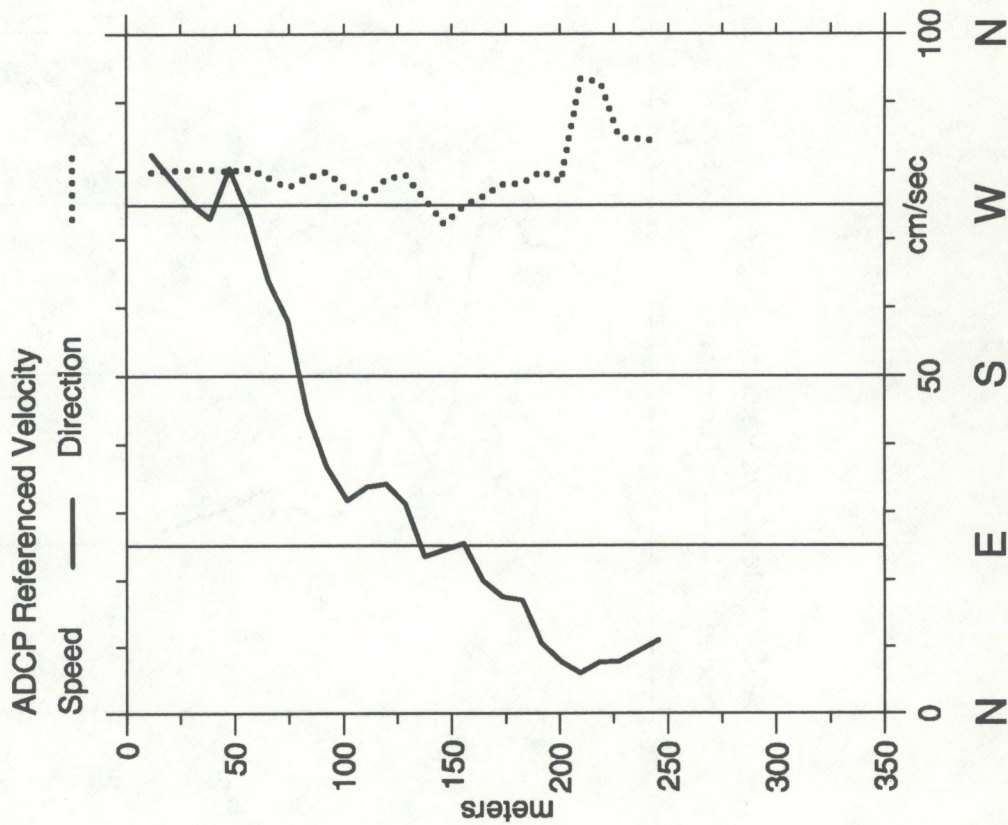
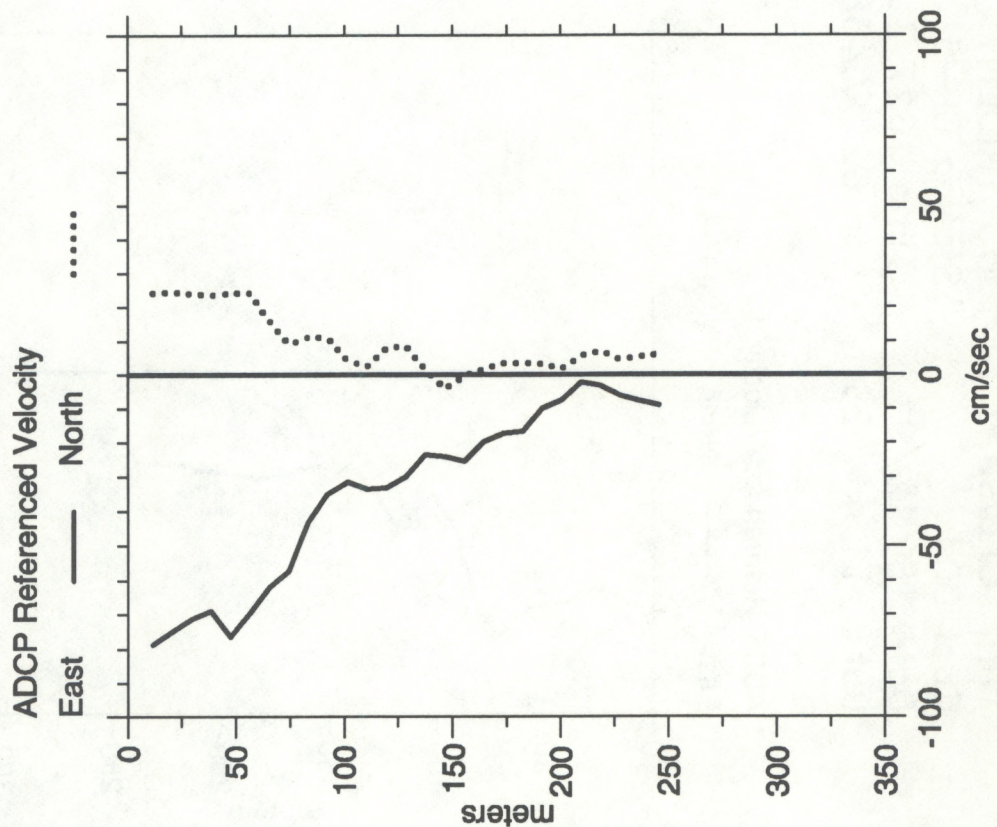
WIPP Cruise 1 HMBS TRIDENT
 Cast 003 Station GR-6
 Date 16/12/91 Time 1530 Z
 Lat 11 45.238 N Lon 62 5.639 W



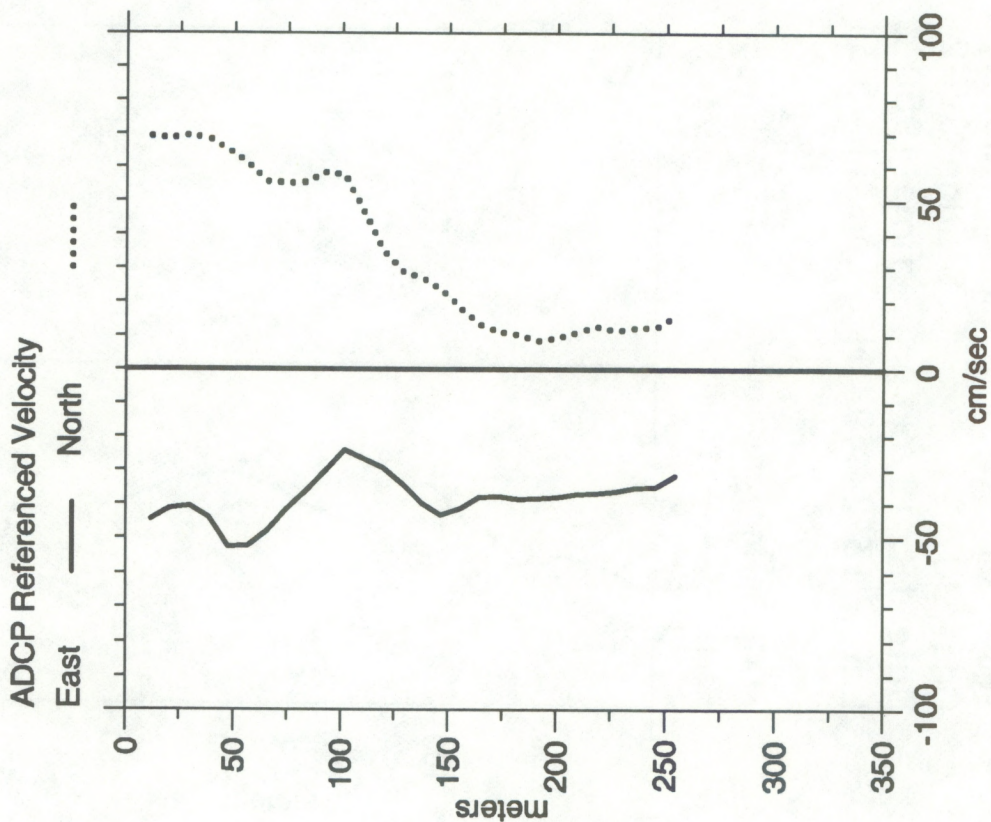
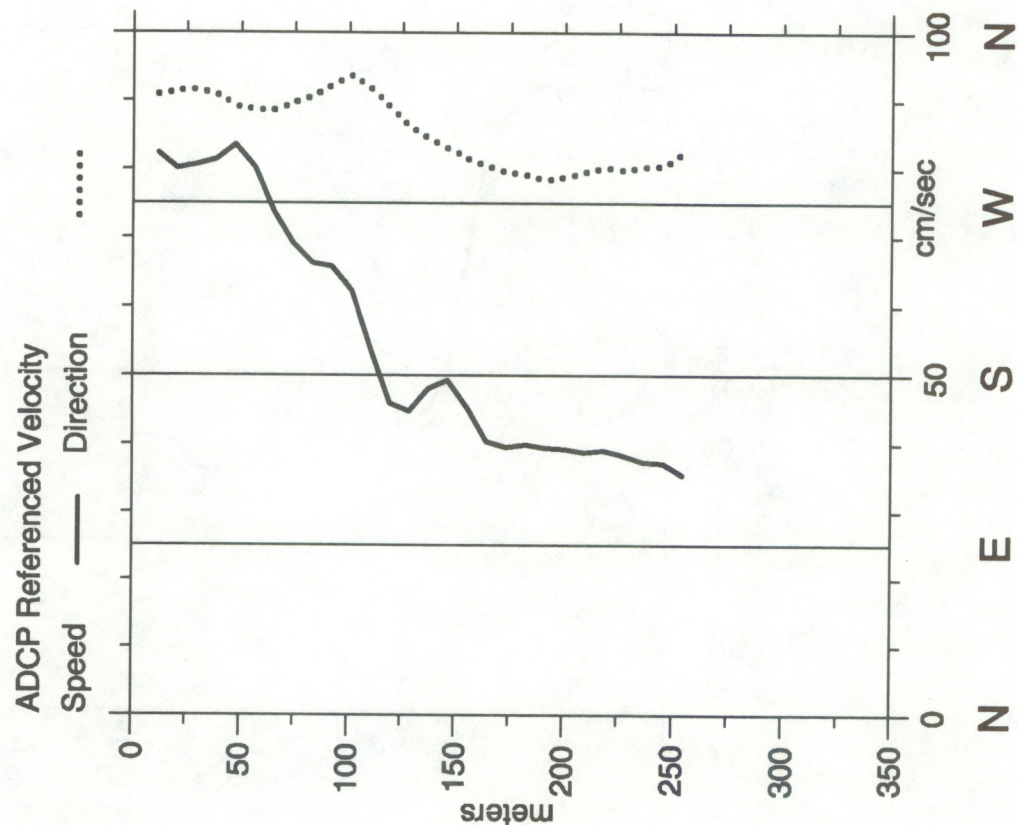
WIPP Cruise 1 HMBS TRIDENT
 Cast 004
 Date 16/12/91
 Lat 11 41.126 N Lon 62 7.438 W



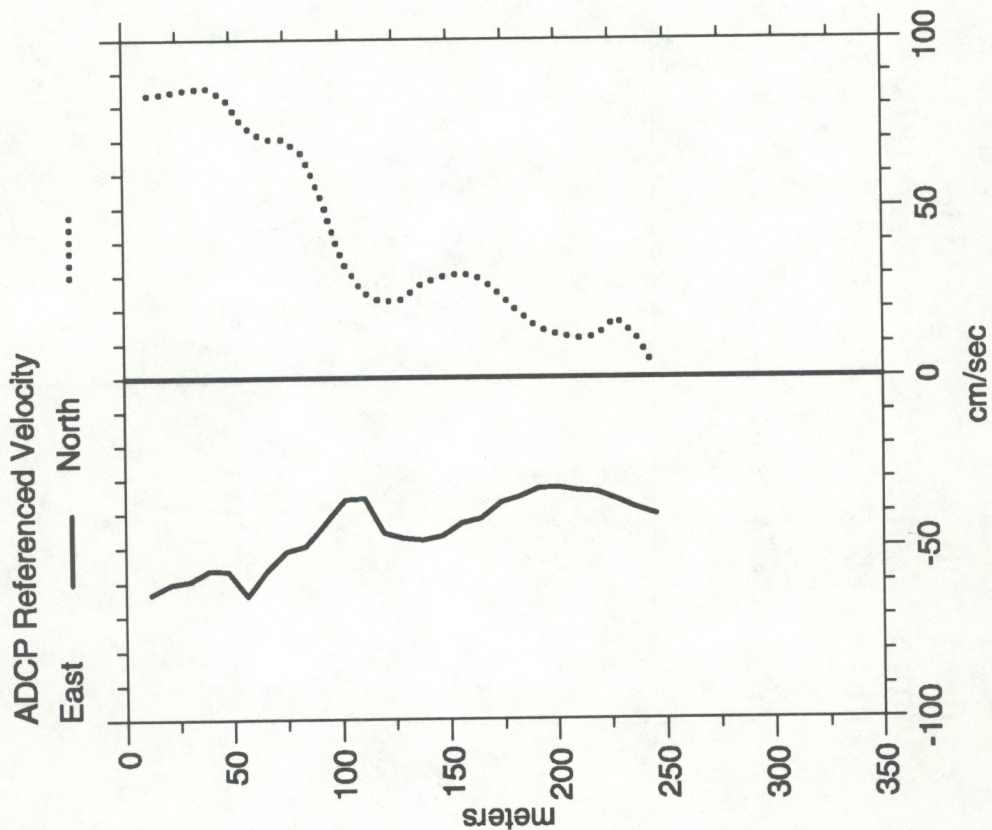
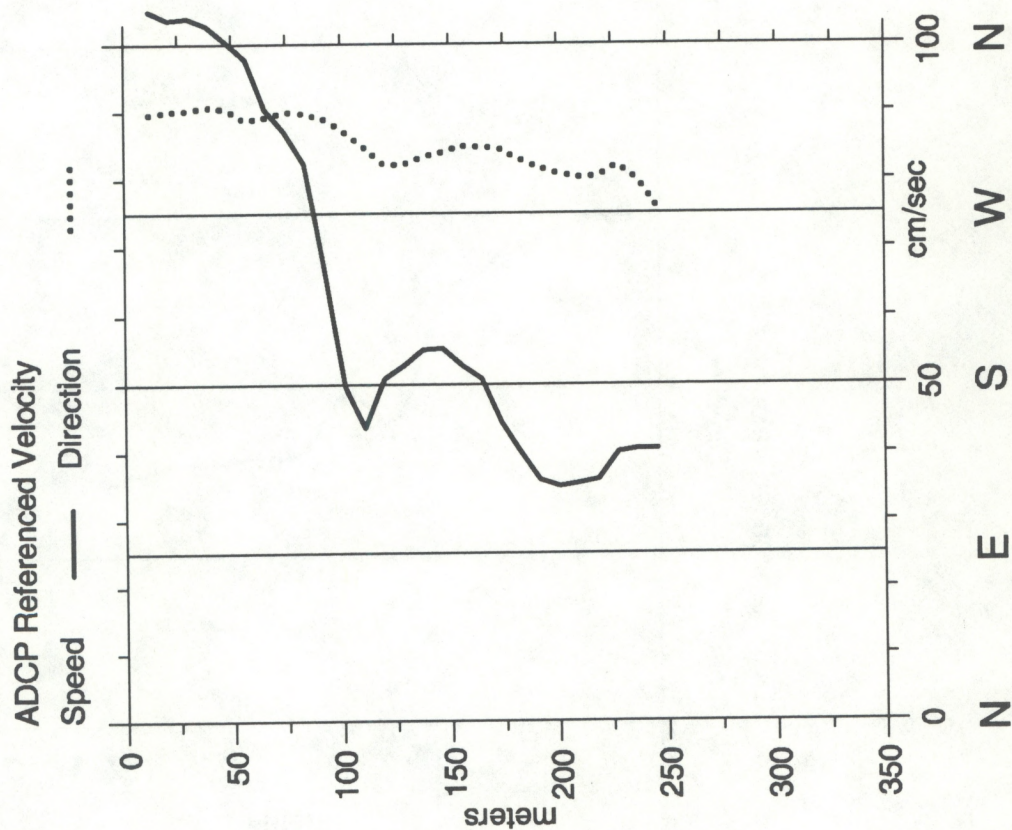
WIPP Cruise 1 HMBS TRIDENT
 Cast 005 Station GR-3
 Date 16/12/91 Time 1842 Z
 Lat 11 32.756 N Lon 62 11.938 W



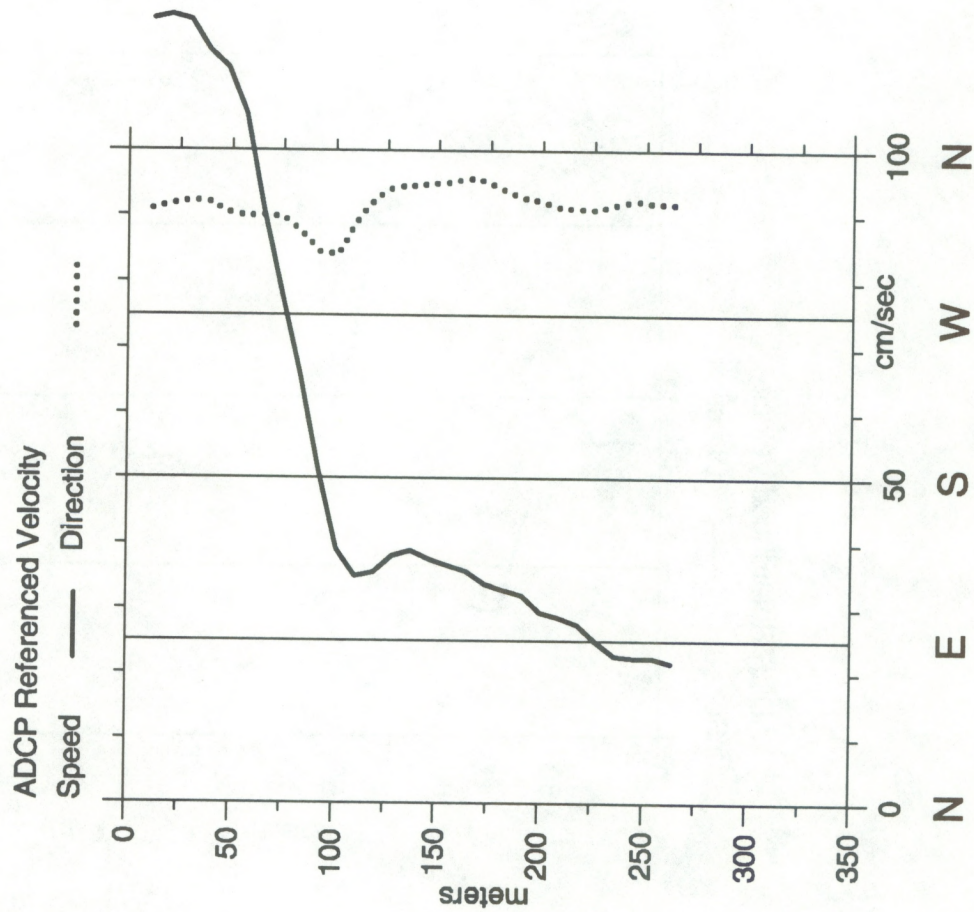
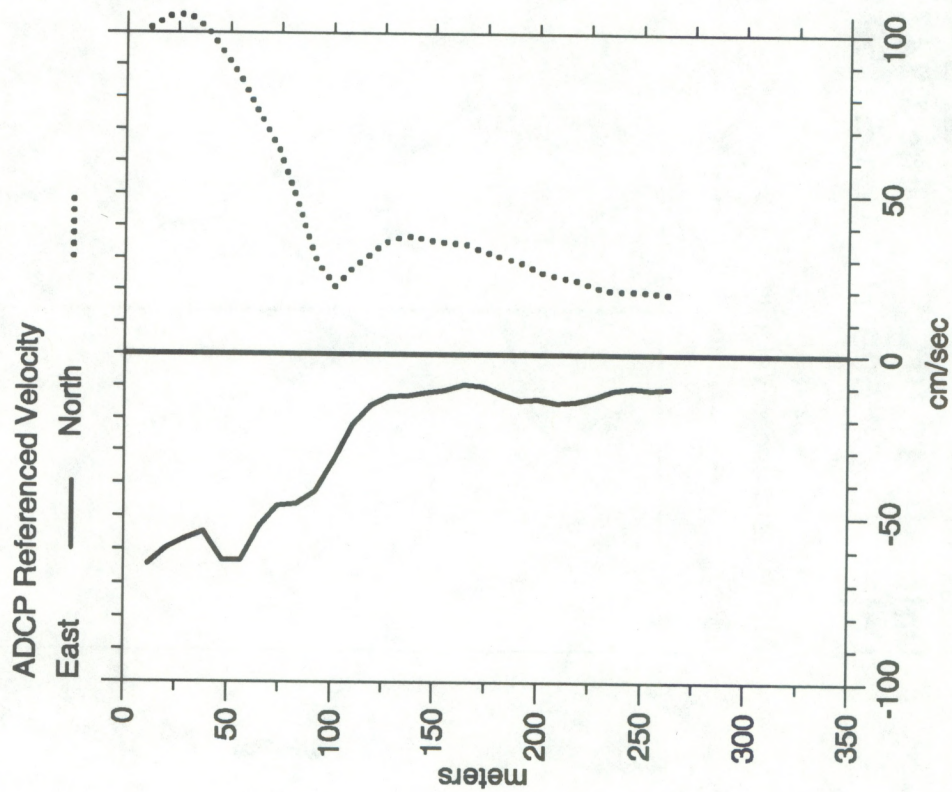
WIPP Cruise 1 HMBS TRIDENT
 Cast 006 Station SV-3
 Date 18/12/91 Time 1804 Z
 Lat 13 28.489 N Lon 61 2.802 W



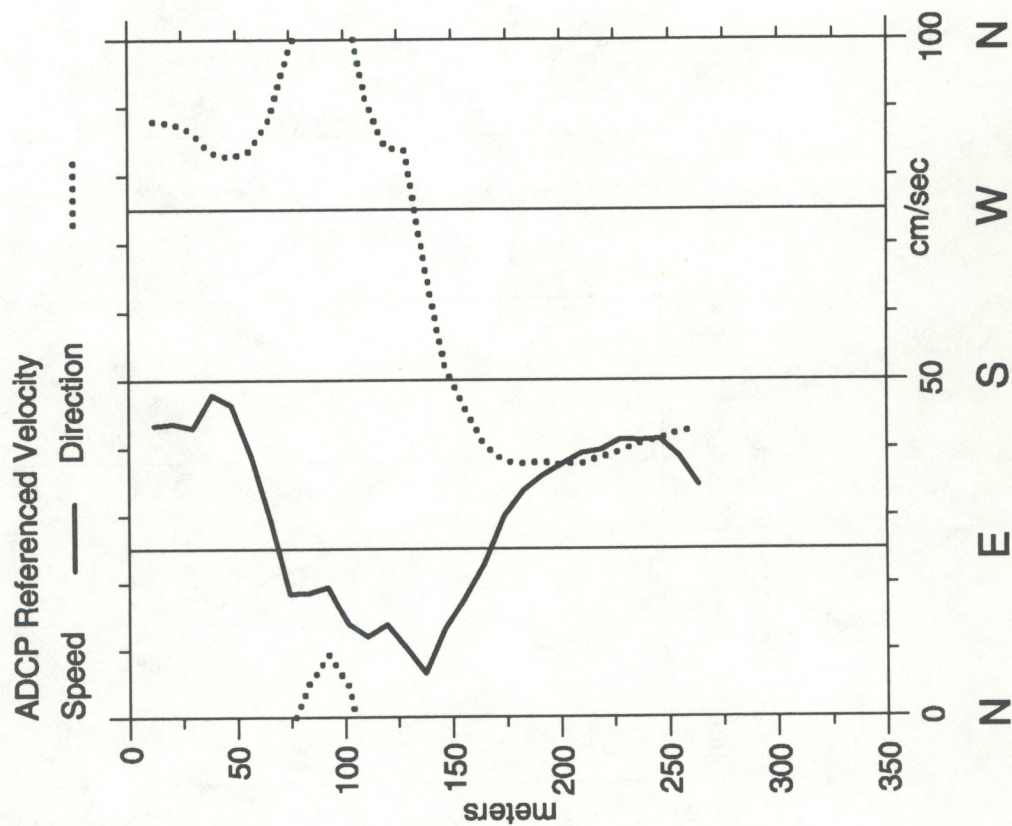
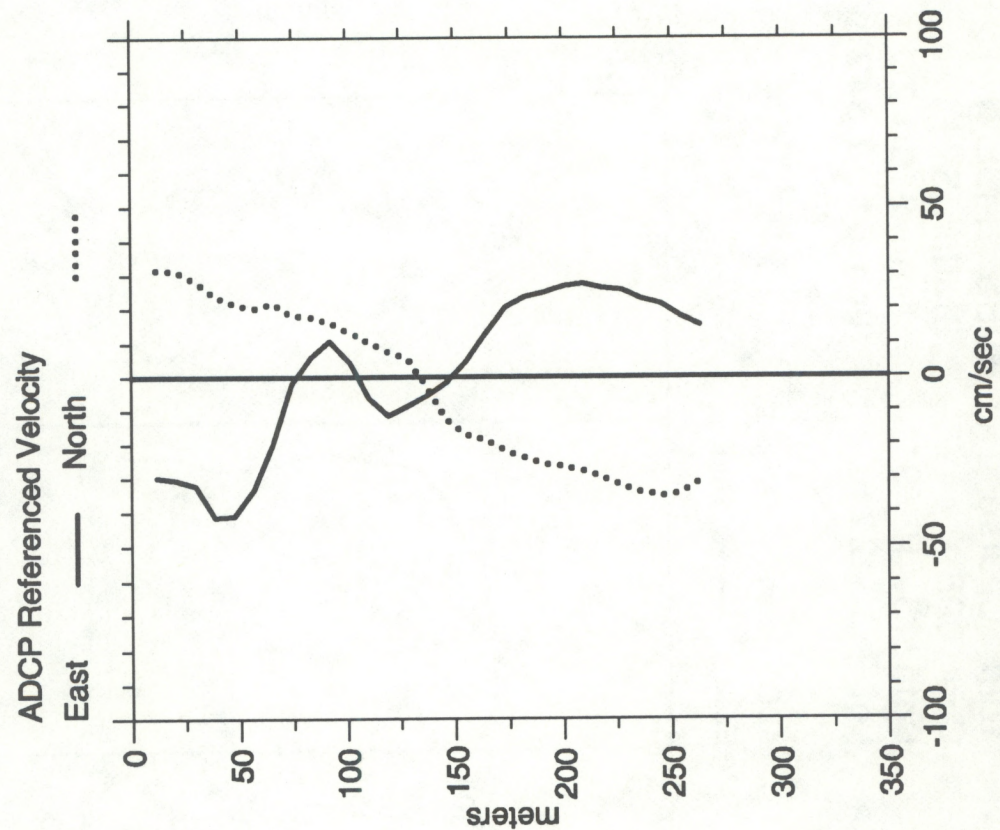
WIPP Cruise 1 HMBS TRIDENT
 Cast 007 Station SV-2
 Date 18/12/91 Time 1950 Z
 Lat 13 24.494 N Lon 61 5.311 W



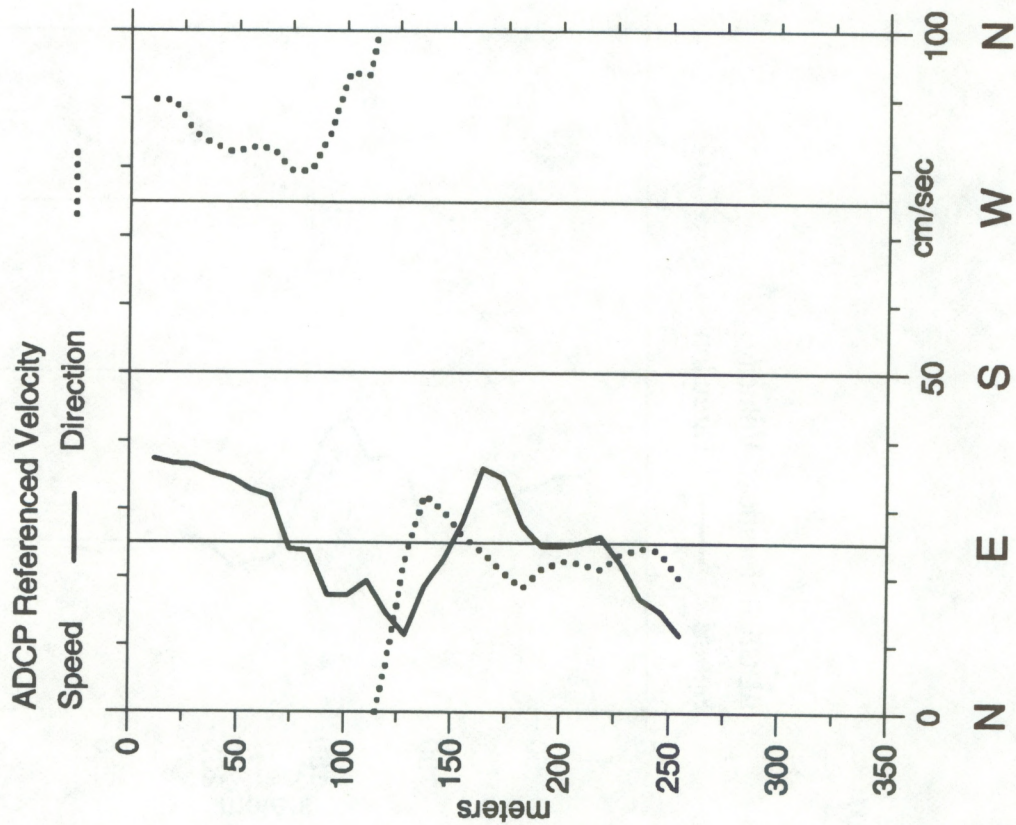
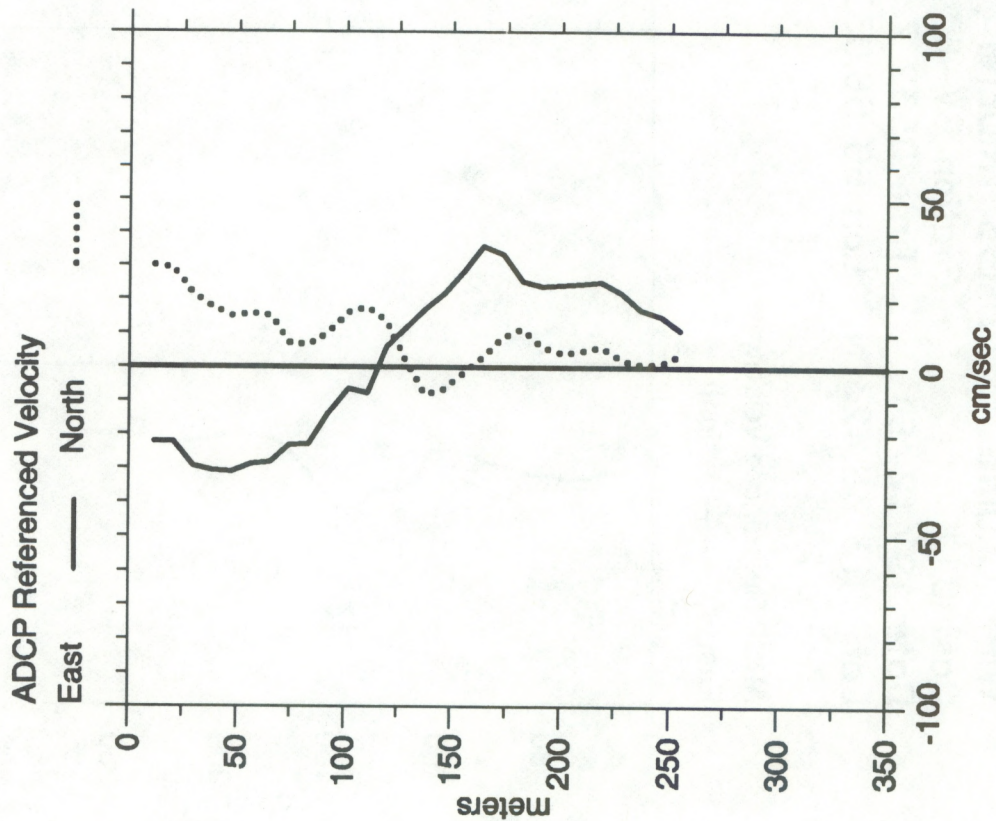
WIPP Cruise 1 HMBS TRIDENT
 Cast 008 Station SV-1
 Date 18/12/91 Time 2100 Z
 Lat 13 22.552 N Lon 61 7.342 W



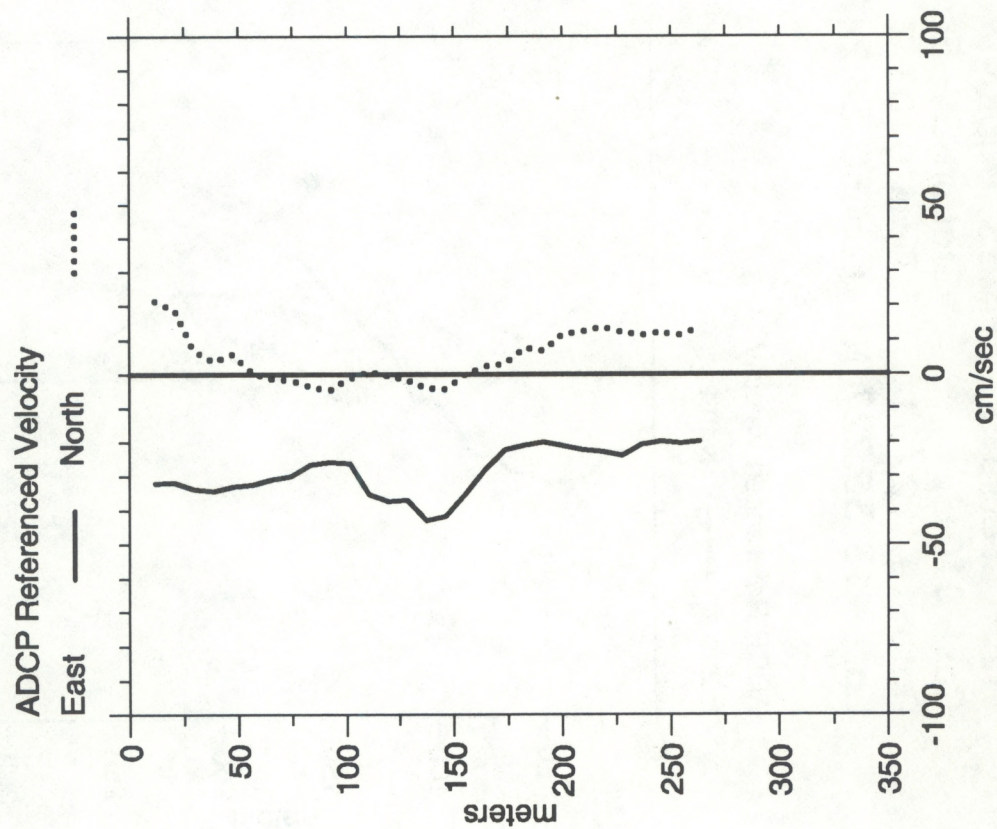
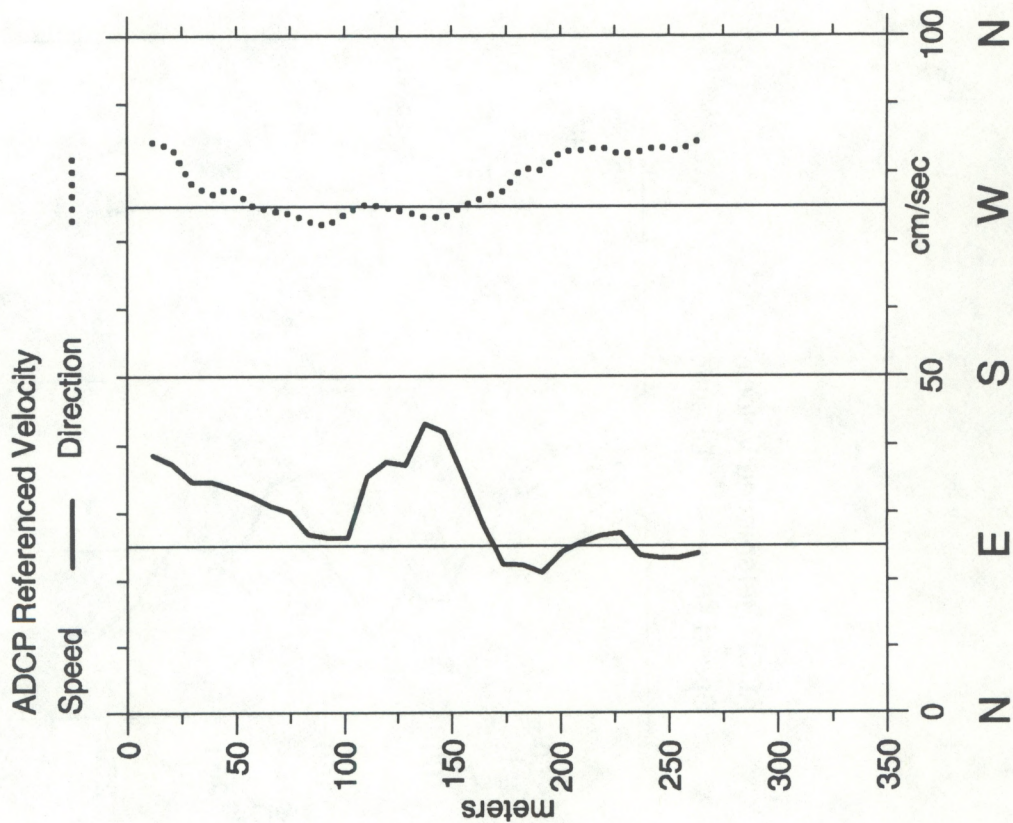
WIPP Cruise 1 HMBS TRIDENT
 Cast 009 Station SV-4
 Date 19/12/91 Time 0247 Z
 Lat 13 32.509 N Lon 60 59.236 W



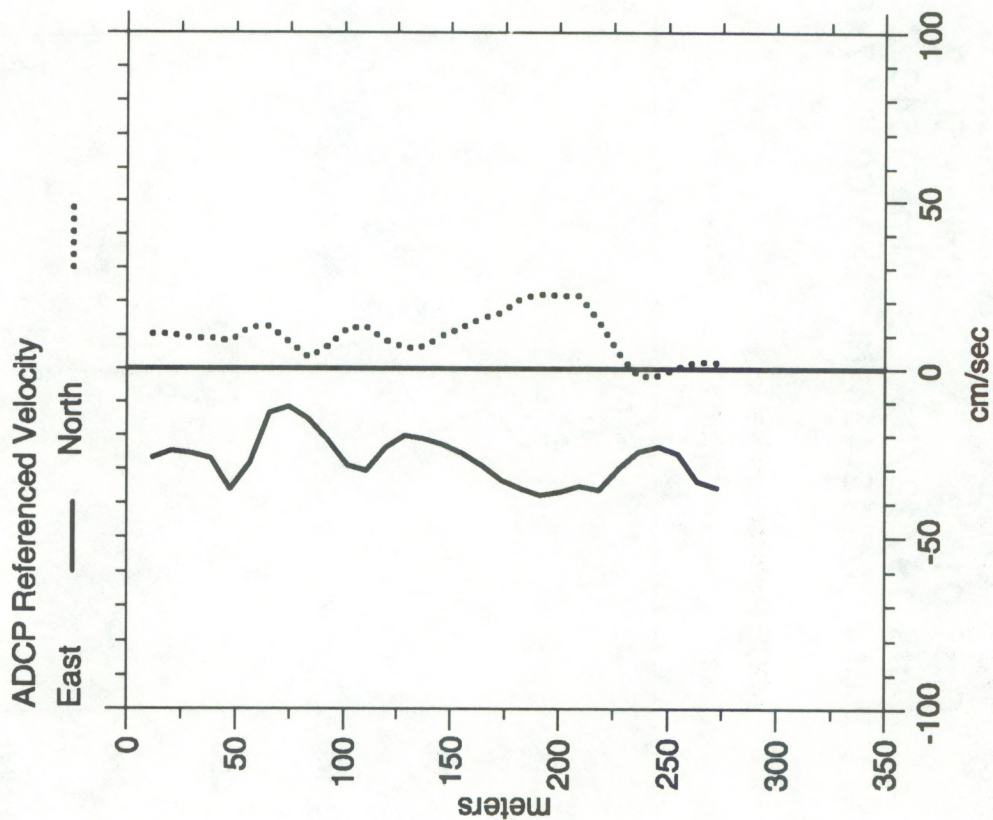
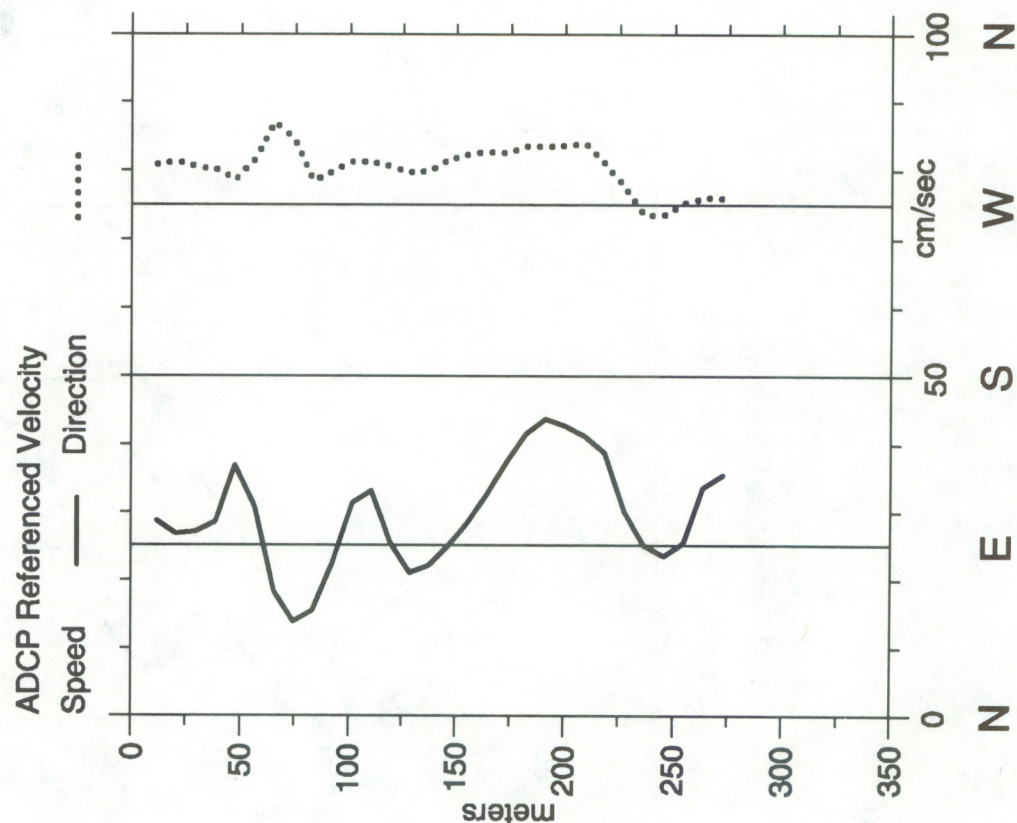
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 Cast 010 Station SV-5
 Date 19/12/91 Time 0403 Z
 Lat 13 36.227 N Lon 60 56.249 W



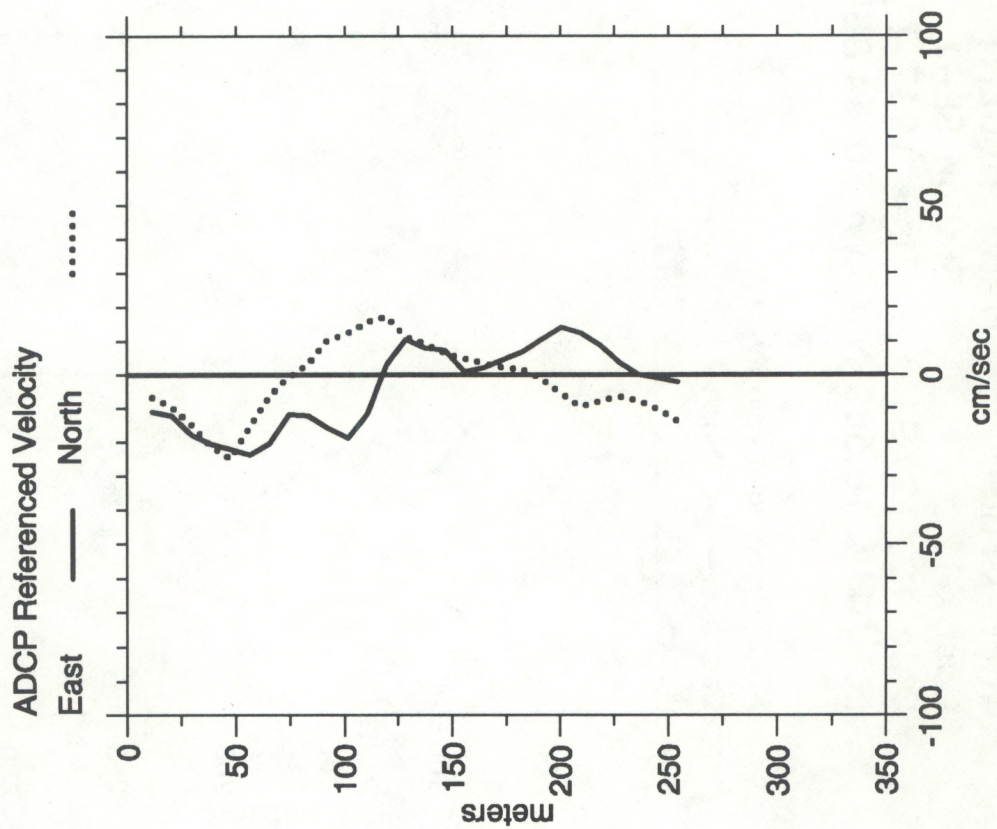
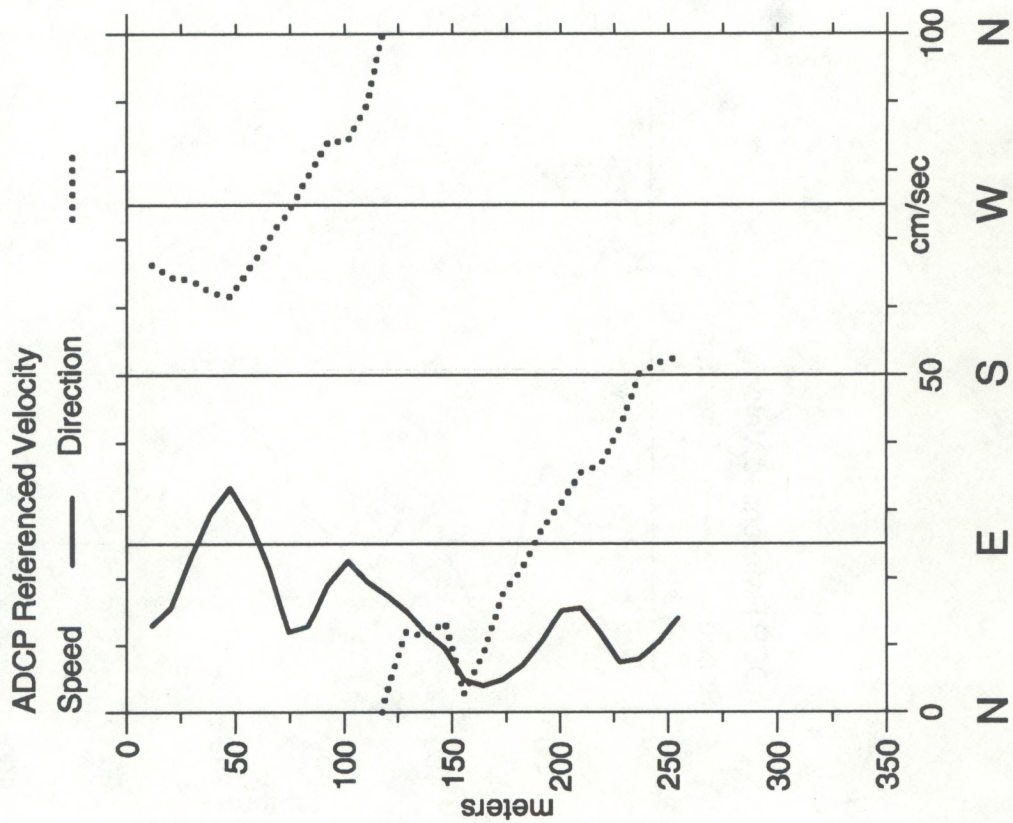
WIPP Cruise 1 HMBS TRIDENT
 Cast 011 Station SV-6
 Date 19/12/91 Time 0532 Z
 Lat 13 38.423 N Lon 60 56.033 W



WIPP Cruise 1 HMBS TRIDENT
 Cast 012 Station SL-1
 Date 19/12/91 Time 1917 Z
 Lat 14 10.569 N Lon 60 54.880 W



WIPP Cruise 1 HMBS TRIDENT
 Cast 013 Station SL-2
 Date 19/12/91 Time 1640 Z
 Lat 14 12.434 N Lon 60 53.746 W



WIPP Cruise 1 HMBS TRIDENT
 Cast 014 Station SL-3
 Date 19/12/91 Time 1749 Z
 Lat 14 14.587 N Lon 60 53.441 W

