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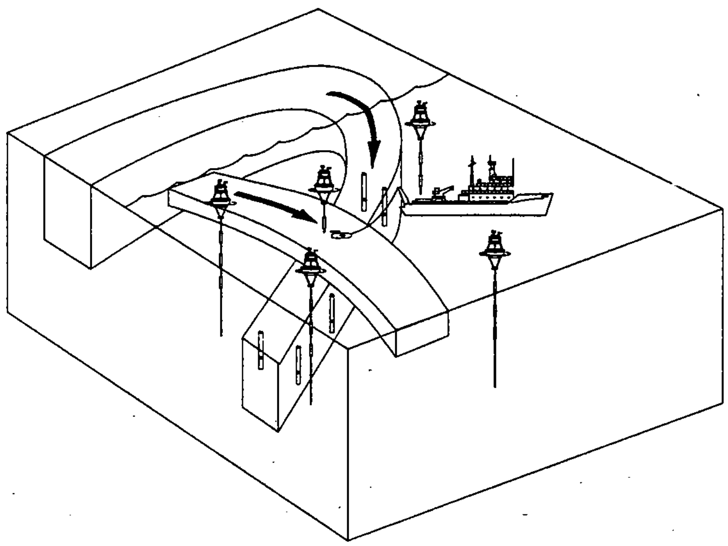
Technical Report

March 1993

The Subduction Experiment



Cruise Report
RRS *Charles Darwin*
Cruise Number 73
Subduction 3 Mooring Deployment and Recovery Cruise
30 September – 26 October 1992

by

Richard P. Trask
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Approved for Distribution:

James Luyten, Chair
Department of Physical Oceanography

Abstract

Subduction is the mechanism by which water masses formed in the mixed layer and near the surface of the ocean find their way into the upper thermocline. The subduction process and its underlying mechanisms were studied through a combination of Eulerian and Langrangian measurements of velocity, measurements of tracer distributions and hydrographic properties and modeling.

An array of five surface moorings carrying meteorological and oceanographic instrumentation were deployed for a period of two years beginning in June 1991 as part of an Office of Naval Research (ONR) funded Subduction experiment. Three eight month deployments were planned. The moorings were deployed at 18°N 34°W, 18°N 22°W, 25.5°N 29°W, 33°N 22°W and 33°N 34°W.

A Vector Averaging Wind Recorder (VAWR) and an Improved Meteorological Recorder (IMET) collected wind speed and wind direction, sea surface temperature, air temperature, short wave radiation, barometric pressure and relative humidity. The IMET also measured precipitation. The moorings were heavily instrumented below the surface with Vector Measuring Current Meters (VMCM) and single point temperature recorders.

Expendable bathythermograph (XBT) data were collected and meteorological observations were made while transitting between mooring locations. In addition a series of 59 CTD stations were made and water samples taken to be analyzed for tritium levels, salinity and dissolved oxygen content.

This report describes the work that took place during RRS Charles Darwin cruise number 73 which was the third scheduled Subduction mooring cruise. During this cruise the second setting of the moorings were recovered and redeployed for a third eight month period. This report includes a description of the instrumentation that was deployed and recovered, has information about the underway measurements (XBT and meteorological observations) that were made including plots of the data, includes a description of the work conducted in conjunction with the tracer/hydrography program and presents a chronology of the cruise events.

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Section 1: Introduction

The RRS Charles Darwin departed Funchal, Madeira at 0910 UTC on Wednesday, 30 September, 1992 for a joint Physical Oceanography and Chemistry cruise. This was the third of four scheduled mooring cruises planned for this experiment (figure 1). The purpose of this cruise was to recover and redeploy five surface moorings deployed in February 1992 as part of the ONR funded ASTEX and Subduction experiments. In conjunction with the mooring work a series of 59 CTD stations were made and water samples taken to be analyzed for tritium levels, salinity and dissolved oxygen content. Hourly XBTs and meteorological observations were also made.

The cruise involved personnel and equipment from both the Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography (SIO). Appendix 1 lists the cruise participants. Figure 2 shows the cruise track and the mooring locations. The moorings recovered during this cruise were the second setting of the array and were known as Subduction 2. Table 1 lists the Subduction 2 mooring positions and the dates they were deployed and recovered. Table 2 lists the deployment positions and dates for the moorings deployed during this cruise which is the third setting, known as Subduction 3. For completeness the Subduction 1 mooring positions and deployment dates are included in Table 3. Figure 1 shows the mooring cruise schedule for the entire Subduction experiment. (See Trask and Brink, 1993 and Trask et al., 1993 for information about the first and second Subduction mooring cruises, respectively.)

This report has in addition to this introduction three sections. The second section describes the mooring program including the instrumentation that was deployed and recovered, as well as the underway measurements that were made including XBT profiles and meteorological observations. The third section describes the tracer/ hydrography program and the fourth section is a chronology of the entire cruise.

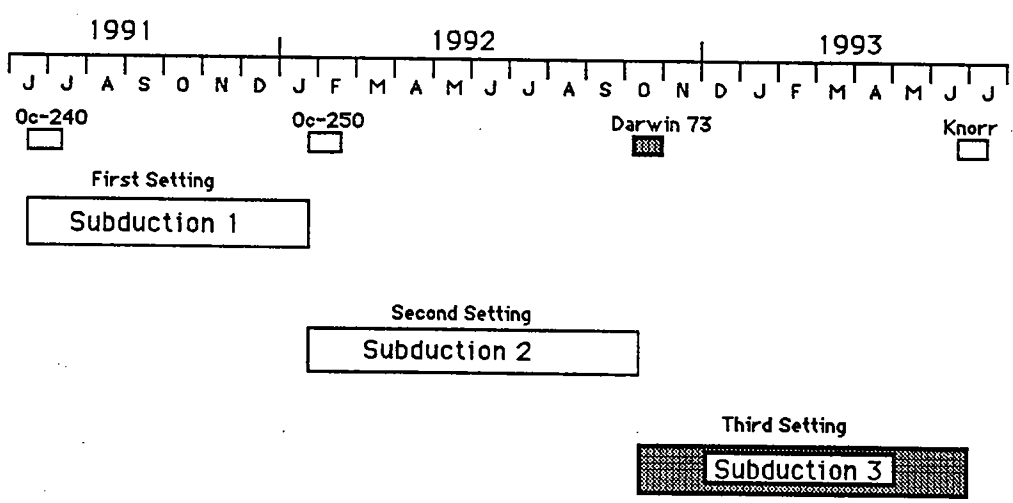


Figure 1. Mooring Cruise Schedule

Figure 2. Darwin 73 Cruise track and mooring positions.

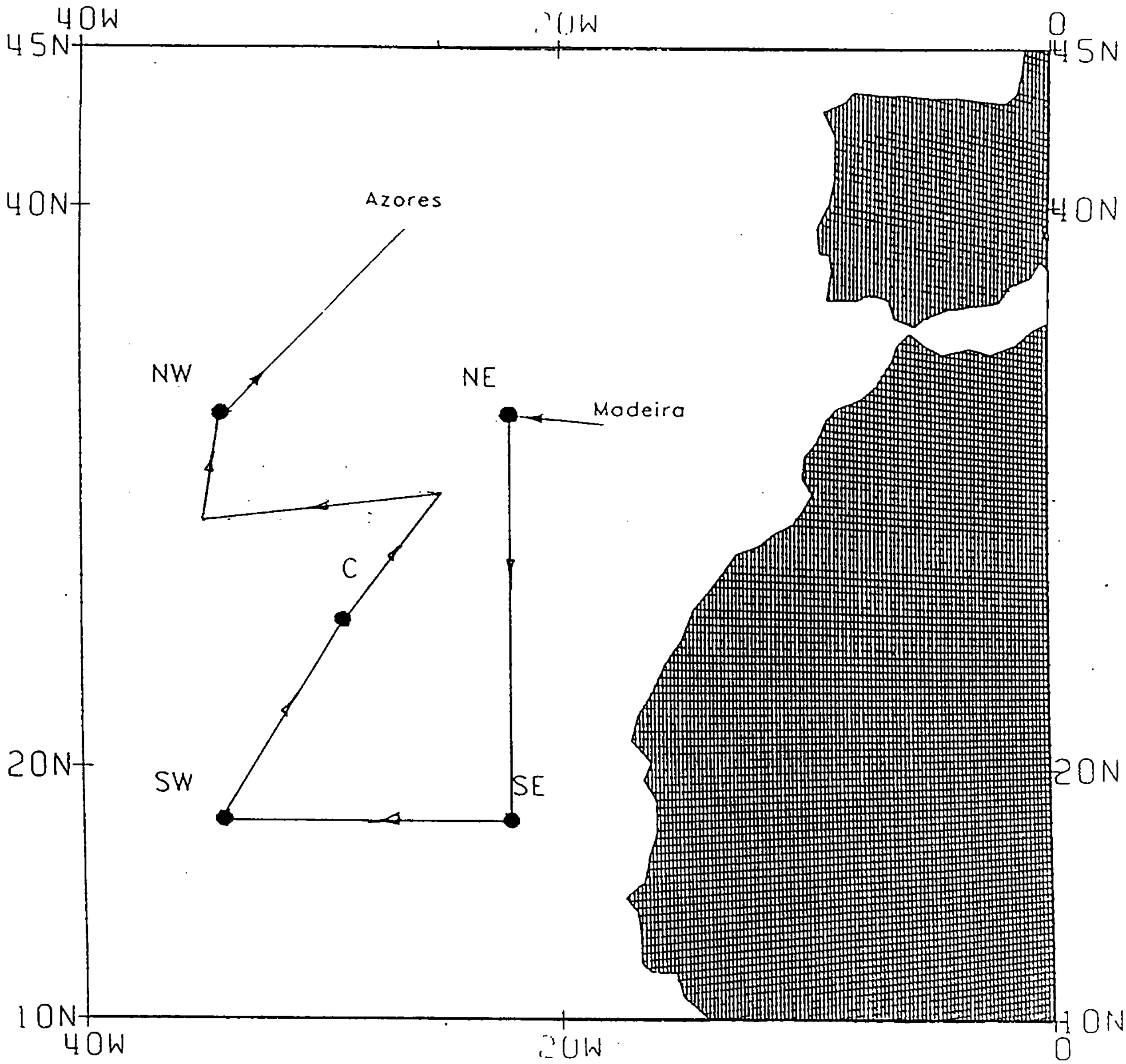


Table 1
Subduction 2 Mooring Deployment Dates and Positions

Buoy	Mooring Number	Deployment	Recovery	Position (GPS)
		Date and Time (UTC)		
SW*	924	5 Feb 92 @1318		17°59.93'N 34°00.65'W
SE	925	9 Feb 92 @ 0244	6 Oct 92 @1759	17°59.72'W 22°00.29'W
C	926	12 Feb 92 @ 1915	14 Oct 92 @1203	25°31.95'N 28°57.23'W
NE	927	20 Feb 92 @ 1547	1 Oct 92 @ 1857	33°01.98'N 22°00.27'W
NW	928	23 Feb92 @ 2328	23 Oct 92 @ 0912	32°54.42'N 33°53.35'W

*SW Parted 4 June 92, Toroid with upper instrument cage recovered 17 July 92
Unsuccessful dragging attempt during DARWIN cruise 73.

Table 2
Subduction 3 Mooring Deployment Dates and Positions

Buoy	Mooring Number	Deployment Date and Time (UTC)	Position (GPS)
SW	954	11 October1992 @ 1846	18° 05.57'N 33° 53.97'W
SE	953	7 October 1992 @ 1157	17° 57.71'W 22° 02.77'W
C	955	15 October 1992 @ 1023	25° 31.93'N 28° 56.52'W
NE	952	2 October 1992 @ 1449	33° 01.80'N 21° 59.39'W
NW	956	24 October 1992 @ 0017	32° 54.38'N 33° 53.58'W

Table 3
Subduction 1 Mooring Deployments and Positions

Buoy	Mooring #	Deployment Time (UTC)	Recovery Time (UTC)	Position(GPS)
NE	914	18 Jun1991 1642	14 Feb 1992 2315	33° 00.07'N 21° 59.75'W
C	915	23 Jun 1991 0026	11 Feb 1992 1120	25° 31.90'N 28° 57.17'W
SW	916	25 Jun 1991 1312	2 Feb 1992 0727 4 Feb 1992 1844 *	18° 00.03'N 33° 59.96'W
SE	917	29 Jun 1991 0137	30 Oct 1991 0000 8 Feb 1992 0843**	18° 00.13'N 22° 00.00'W
NW	918	3 Jul 1991 1323	15 Sept 1991 2035 23 Feb 1992 1022***	32° 54.61'N 33° 53.50'W

* SW Mooring broke free on 3 November 1991. Top 110m recovered 2 February 1992 remainder of mooring recovered 4 February 1992.

** SE Mooring broke free on 10 October 1991. Top 50m recovered on 30 October 1991 remainder of mooring recovered 8 February 1992

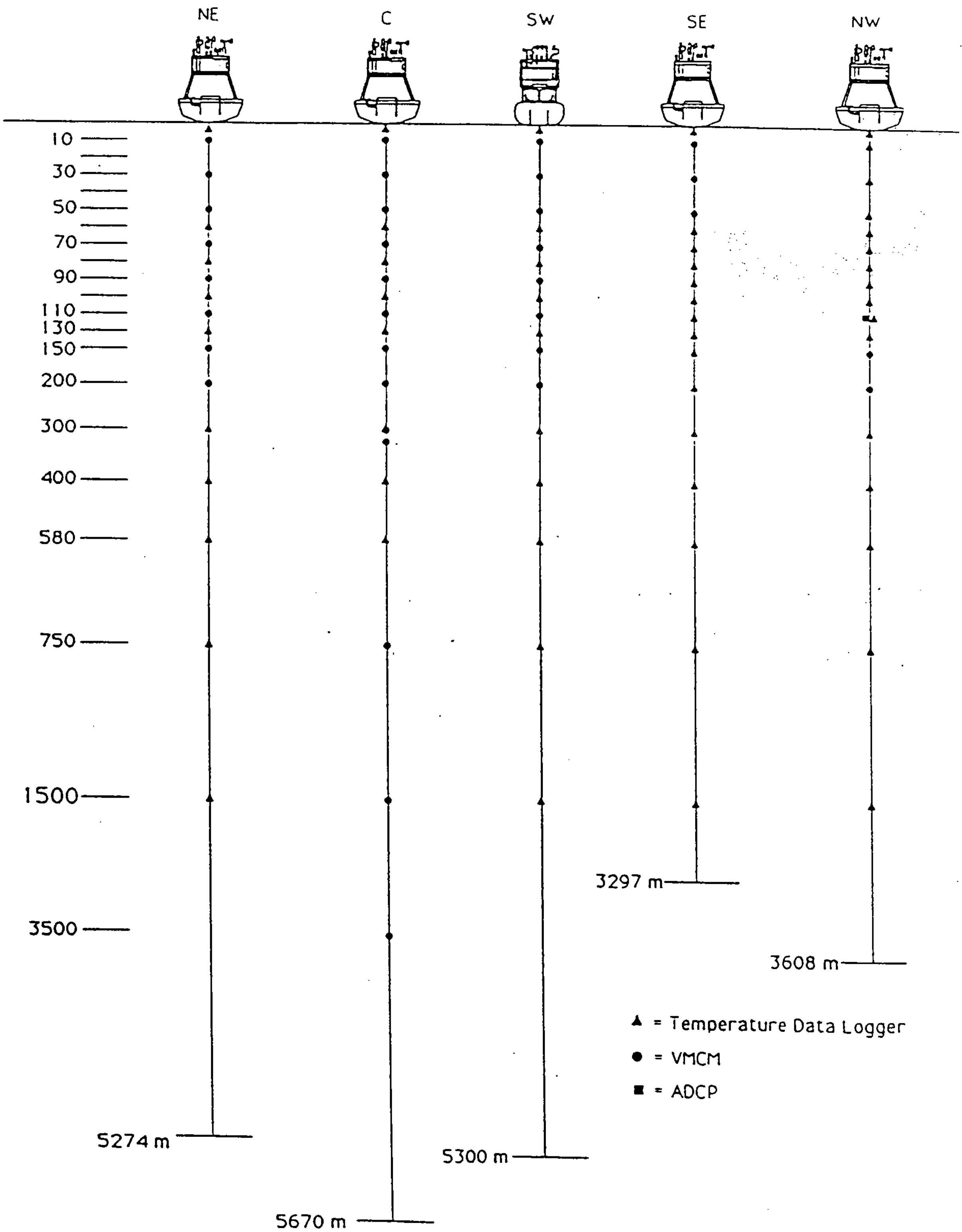
*** NW Mooring broke free on 3 August 1991. Top 400m recovered 15 September 1991 remainder of mooring recovered 23 February 1992

Section 2: The Mooring Program

A. Mooring and Buoys

The goal of the mooring program conducted during Darwin cruise number 73 was to recover five moorings that were deployed during R/V Oceanus cruise number 250 in February 1992 and deploy replacement moorings. The five surface moorings deployed in February included two WHOI moorings designated Central and Northeast and 3 SIO moorings designated Southeast, Southwest and Northwest. The Central, Northeast, Southeast and Northwest moorings were deployed with WHOI 10' diameter discus buoys and the Southwest mooring had a SIO 7'6" diameter toroid buoy. Additional buoyancy was provided to the toroid by means of a large boat fender that was inserted in the center hole of the toroid and inflated. Figure 3 schematically shows all five moorings and the distribution of the Subduction 2 and 3 subsurface instrumentation.

Figure 3. Subduction 2 and 3 Mooring Instrument Placements



Meteorological instrumentation was mounted on both toroid and discus buoys. A two part aluminum tower was attached to both buoy types. The top half, which has the meteorological sensors, marine lantern and satellite antennae was the same for both buoy types so as to minimize the differences between buoys and to facilitate assembly. The lower half was specific to the buoy type and acted as an interface between the buoy hull and tower top. The tower tops were separate assemblies so that they could easily be replaced with new units containing freshly calibrated sensors when the moorings were recovered and redeployed.

On 4 June, 1992 the Southwest mooring parted and the toroid buoy went adrift. The buoy was tracked via satellite and eventually recovered by NOAA vessel Malcolm Baldridge on 12 July 1992. The only component suspended below the buoy at the time of recovery was a damaged load cage from the uppermost current meter. The cage had apparently failed causing the toroid buoy to go adrift. The cause of the cage failure is unknown. Since cage failures are uncommon one can speculate that the mooring may have been tampered with or inadvertantly became entangled with fishing gear and pulled beyond its load capability.

Attempts to recover the portion of the failed Southwest mooring still on station were unsuccessful during Darwin cruise 73. The acoustic release on the mooring would not release when commanded. The release could be interogated without difficulty; however, when a release command was sent it would not release the mooring nor return confirmation of release. A dragging attempt was made but without success. The location of the mooring was surveyed carefully in the event that a future attempt at dragging is possible. Details of the dragging attempt during Darwin cruise 73 can be found in the cruise chronology section of this report.

B. Instrumentation

A total of 102 recording instruments were deployed on the five Subduction 3 moorings. There were 9 meteorological packages, 34 current meters, 58 temperature data loggers, and one Acoustic Doppler Current Profiler. The specific instrumentation deployed during the third setting of the Subduction array is shown in table 4. For reference purposes the instrumentation on the first and second settings are shown in tables 5 and 6 respectively.

Meteorological Instrumentation

Each discus buoy was outfitted with two separate meteorological instruments. One system was a Vector Averaging Wind Recorder (VAWR) which recorded measurements of wind speed and direction, air temperature, relative humidity, barometric pressure, sea surface temperature, short wave radiation, and long wave radiation. Additional information about the VAWR can be found in Trask et al. (1989). The other meteorological package was an IMET system which made measurements of the same variables as the VAWR plus precipitation. The IMET systems on the second Subduction deployment did not measure longwave radiation but it was included on the third deployment. Both the VAWR and IMET systems individually recorded all data internally as well as telemeter their data via Argos . The VAWR stored its data on cassette tape every 15 minutes, and the IMET system recorded on optical disk every minute.

Table 4.
Subduction 3 Instrumentation

Depth	NE	C	SW	SE	NW
VAWR IMET	V-721WR	V-121WR	V-720WR	V-704WR	V-722WR
1	W-3283	W-3279	W-3297	W-3305	W-3262
10	VM-038	VM-032	SVM-02	SVM-06	S-3306
30	VM-021	VM-018	SVM-22	VM-022	W-3341
50	VM-012	VM-024	SVM-07	SVM-20	W-4492
60	W-4488	W-3303	S-2432	W-4481	W-2541
70	VM-033	VM-030	SVM-23	S-2418	W-2537
80	W-3259	W-4489	W-2539	S-2436	W-3665
90	VM-037	VM-028	SVM-13	S-2428	W-2533
100	W-4485	W-3265	W-4487	S-2422	W-3274
110	VM-041	VM-039	SVM-4	S-2420	ADCP-185 W-3309
130	W-4482	W-3280	S-2421	S-2424	S-3710
150	VM-015	VM-009	SVM-24	S-2437	VM-014
200	VM-016	VM-034	SVM-19	S-2433	SVM-03
300	W-4493	VM-035	S-2435	S-2425	S-3270
310		VM-027			
400	S-3302	W-4491	S-3295	S-3312	S-3314
580	S-3311	W-3662	W-2542	W-4490	S-3307
750	S-3378	VM-036	S-3292	S-3275	S-3708
1500	S-3281	VM-011	W-4483	W-3271	S-3304
3500		VM-045			

W-# = WHOI Brancker Temperature Recorder
S-#= SIO Brancker Temperature Recorder
VM-# = WHOI Vector Measuring Current Meter
SVM-#= SIO Vector Measuring Current Meter

Table 5
Subduction 1 Instrumentation

Depth	NE	C	SW	SE	NW
VAWR IMET	V-704WR	V-722WR	V-720WR	V-721WR	V-121WR
10	VM-041	VM-035	SVM-04	SVM-12	S-3285
20	TEST STING1				TEST STING2
30	VM-021	VM-033	SVM-07	VM-007	S-3315
40	TEST STING3				
50	VM-039	VM-024	SVM-06	SVM-16	S-3294
60	W-3274	W-3309	S-3314	W-3297	W-3262
70	VM-032	VM-012	SVM-22	S-3282	S-3313
80	W-3265	W-3308	W-3279	S-3270	S-3260
90	VM-022	VM-038	SVM-02	S-3298	S-3261
100	W-3288	W-3296	W-3303	S-3284	W-3258
110	VM-030	VM-009	SVM-05	S-2425	ADCP S-3277
130	W-3269	W-3280	S-2427	S-2432	S-2434
150	VM-028	VM-037	SVM-20	S-2418	SVM-11
200	VM-018	VM-016	SVM-13	S-2424	SVM-10
206	COND				
300	W-3300	W-3289	S-2435	S-2433	S-2421
400	W-3305	W-3283	S-2437	S-2422	S-2431
580	W-3268	W-3271	W-3341	W-3290	W-3272
750	W-3286	VM-015	S-2436	S-2426	S-2420
1500	W-3293	VM-034	W-3287	W-3259	W-3273
3490		TENS 1029			
3500		VM-011			

W-# = WHOI Brancker Temperature Recorder
S-#= SIO Brancker Temperature Recorder
VM-# = WHOI Vector Measuring Current Meter
SVM-#= SIO Vector Measuring Current Meter

Table 6
Subduction 2 Instrumentation

Depth	NE	C	SW	SE	NW
VAWR IMET	V-380WR	V-712WR	V-713WR	V-707WR	V-717WR
1	W-3507	W-3506	W-3665	W-3704	W-3508
10	VM-034	VM-002	SVM-01	SVM-03	S-3709
30	VM-027	VM-023	SVM-16	VM-010	W-3274
50	VM-036	VM-020	SVM-08	SVM-17	W-3288
60	W-2539	W-2541	S-3285	W-3279	W-3296
70	VM-014	VM-013	SVM-15	S-3707	W-3309
80	W-2542	W-2534	W-3263	S-3261	W-3269
90	VM-045	VM-019	SVM-14	S-3706	W-2536
100	W-3280	W-2537	W-3291	S-3714	W-2540
110	VM-035	VM-008	SVM-12	S-3710	ADCP-195 W-2535
130	W-3265	W-2538	S-3310	S-3294	S-3313
150	VM-009	VM-026	SVM-11	S-3715	SVM-09
200	VM-011	VM-025	SVM-18	S-3708	SVM-21
300	S-3260	VM-017	S-3713	S-3712	S-3276
310		VM-031			
400	S-3711	W-2533	S-2430	S-2423	S-3277
580	S-3298	W-3262	W-3299	W-3303	S-3316
750	S-2426	VM-029	S-2429	S-2434	S-3282
1500	S-2427	VM-001	W-3258	W-3341	S-3284
3500		VM-003			

W-# = WHOI Brancker Temperature Recorder
S-#= SIO Brancker Temperature Recorder
VM-# = WHOI Vector Measuring Current Meter
SVM-#= SIO Vector Measuring Current Meter

For both the discus and toroid buoys the VAWR sensors (except sea temperature) and electronics with battery pack were attached to the tower top. The sea surface temperature sensors for both the VAWR and IMET systems were attached to the buoy bridle approximately 1 meter below the surface. All the other meteorological sensors were placed at the same heights on the tower tops as in Subduction 1 and 2 (Trask and Brink, 1993). During the second and third Subduction settings the Southwest toroid did not have an IMET system. The IMET sensors on all the discus buoys were configured the same and mounted on the tower top. The IMET electronics and rechargeable batteries were housed in the discus buoy water tight instrument well. Details regarding the IMET performance during the second setting can be found in Appendix 2.

Current Meters

A total of 34 Vector Measuring Current Meters (VMCM) provided by both WHOI and SIO were deployed on the five Subduction 3 surface moorings. The 23 WHOI VMCMs were a modified version of the EG&G Sea Link instrument whereas the 11 SIO VMCMs were built by Scripps personnel. The sampling interval for the WHOI VMCMs was 7.5 minutes, and for the SIO VMCMs it was 15 minutes

The WHOI VMCMs incorporated several changes to the standard EG&G Sea Link product. These included different propeller bearings, a different plastic for the propeller blades, an external temperature pod for faster temperature response, and a redesign of the instrument cage. The cage redesign and external temperature pod is described in Trask et al. (1989) as is some historical information on propeller bearings and blade materials.

For the Subduction experiment the WHOI VMCMs in the upper 100 meters were outfitted with cages that had 3/4" diameter cage rods. The deeper instruments had cages with 1/2" cage rods. All cages had a single cross brace to support the sting between the two sets of propellers.

An alternative propeller bearing chosen for use in the Subduction experiment was an all silicon nitride ball bearing (SiNi balls and races with a Duroid ball retainer) available from Miniature Precision Bearing (MPB), of Keene, New Hampshire as part number J0001-809. This was selected over the typical stainless steel bearing based on previous test results, actual deployments and the fact that the eight month Subduction deployment would be 30% longer than most previous deployments.

The VMCM propellers used in the Subduction experiment were made of an unpigmented Delrin 100 ST which is impact modified.

The Subduction 2 VMCMs that were recovered during Darwin cruise number 73 were in excellent condition with respect to propeller bearings and blades. None of the propellers had broken blades and the silicon nitride bearings were like new. Two instruments (VM009 and VM011) that were recovered during this cruise had been in the water during both Subduction 1 and Subduction 2 with their original stings (propeller sensor assemblies). These instruments had a total deployment time of 16 months and were found to still be in excellent condition. VM009 and VM011 were both redeployed on the Central mooring at 150 and 1500 meters depth respectively for an additional eight months.

Appendix 3 has a complete listing of all the VMCMs used during the three Subduction settings. The listing shows the mooring and depth where each instrument was deployed for each of the three settings.

Temperature Loggers

A total of 58 temperature data loggers manufactured by Richard Brancker Research Ltd. were provided by both WHOI and SIO for the five Subduction moorings. The locations of the loggers are shown in figure 3 and table 4. The loggers provided by WHOI were attached to the mooring line using a hinge type clamp that was tightened around the wire. The SIO clamping arrangement consisted of two 2-piece monel blocks which have been machined to accept the mooring wire. The two pieces were clamped around the wire with .25" hardware.

Several different temperature recorder models were deployed. The SIO 2000 series instruments sampled at 30 minute intervals. The WHOI 2000 series instruments which were modified for extra memory sampled at 15 minutes, and both the SIO and WHOI 3000 series instruments sampled at 15 minutes. The SIO 2000 series instruments had SIO fabricated pressure cases and endcaps. The WHOI 4000 series instruments were rebuilt XX-105 units that flooded during Subduction 1 and had new EPROMS. The sampling interval for the 4000 series instruments was the same as the 3000 series units.

A total of 15 temperature loggers recovered from the first Subduction setting during Oc-250 leaked a small quantity of water, and their data could not be read. In response to this problem while at sea the instruments that were deployed for the second setting had a vacuum drawn during assembly to better seat the O-rings. This procedure was adopted from SIO whose nearly identical temperature loggers did not display the problem as severely. In addition, the endcaps were tightened considerably more than previously deployed using a large adjustable wrench. The procedures adopted during Oc-250 proved worthwhile since none of the 25 WHOI instruments recovered during Darwin cruise 73 showed any signs of leaking.

In preparation for the third setting of instruments several changes were made to the Brancker temperature loggers. In addition to tightening the endcaps and drawing a vacuum, a new flexible nut assembly was incorporated into all the temperature loggers prepared in Woods Hole. The intent of the flexible nut was to correct for an out-of-square condition between the removable endcap and its threaded rod used to secure the endcap to the pressure case. The preparation of instruments also included spray coating all electronic boards with DOW Corning 1-2577 conformal coating to offer some resistance to moisture should the instruments leak a small quantity of water. The following Brancker serial numbers were modified to have the flexible nut assembly, and coated electronics boards: 3662, 4491, 4489, 3283, 4488, 3259, 4485, 4487, 3297, 3305, 4481, 4482, 4493, 4490, 4483, 3271, 4492, 3665.

Appendix 4 has a complete listing of all Brancker temperature recorders used during the three Subduction settings. The listing shows the mooring and depth where each instrument was deployed for each of the three settings.

ALACE Float

One SIO <u>A</u>utonomous <u>LA</u>grangian <u>C</u>irculation <u>E</u>xplorers was deployed during Darwin cruise 73. It was deployed at position 25°19.36'N, 29°05.79'W on 14 October 1992 at 0508 UTC. A description of that instrument can be found in Appendix 5 of this report.

C. Underway Measurements

Expendable Bathythermographs (XBT)

Two hundred XBTs were deployed during Darwin cruise 73. The T-7 probes were purchased from Spartan of Canada. XBT data was logged on a NEC APC IV with a Spartan data aquisition microprocessor card. The digital data was simultaneously logged in memory and plotted on the screen. Problems with a drifting calibration were encountered early on resulting in XBT surface temperatures which differed from those taken by the bucket thermometer. After numerous attempts to find the cause of this problem the cable on the ship's hand held launcher was replaced with a new shielded cable. With this change the calibration became stable and the surface temperatures agreed with the surface bucket temperatures. Once the cable was replaced there were very few probes that failed to produce reasonable data. Unfortunately the first 48 probes were used prior to correcting the calibration problem. The last XBT drop occurred at 1100 UTC on 19 October 1992 at position 29° 06.36'N, 33° 56.17'W.

Hourly XBTs were taken on the hour while the ship was underway. If a scheduled XBT occured within a half hour of a CTD station then the XBT was not taken. XBTs were also suspended when the ship was within 10 miles of a surface mooring. XBT positions and overplots of the XBT data can be found in Appendix 6.

Meteorological Measurements

The primary source of high quality meteorological data on Darwin 73 was a Multimet system installed by Peter Taylor's group from Rennell Centre, Southampton. The Multimet sensors were installed on a foremast about 4 meters aft of the peak of the bow with most of the sensors located at a height of about 15 meters above the water line. Sensors on the foremast included an R.M.Young AQ anemometer, an Eppley pyrgeometer, two aspirated wet/dry bulb aspirated temperature units, and two Kipp and Zonen short wave pyranometers. All three radiation measuring sensors were mounted on gimbals. The pyrgeometer was near the top of the mast where it was unaffected by neighboring objects. The two pyranometers were located about 2 meters to port and starboard from the mast. The larger value was selected in the processing with the assumption that the larger had not been affected by the mast's shadow. The barometric pressure sensor was in the top lab with the processing and recording electronics package. The output of the ship's gyro was also recorded.

All parameters were averaged over the first 50 seconds of each minute. The time assigned to these values was that of the beginning of the minute. These one minute values of undecoded data were recorded on EPROM within the electronics package and on the ship's Sun-based data logging system.

All appropriate sensors were calibrated before and after the cruise. The calibrations were applied to the raw data in off line processing using a set of programs developed by the Taylor group. The processing used the navigation data recorded by the ship's logging system to correct the measured wind speed and direction for ship movement. The logged outputs of the ship's thermosalinograph were added to the final data files.

Manual meteorological observations were taken hourly on the half hour. The manual observations consisted of recording the time, position, ship's speed, ship's heading, wind speed and wind direction from the bridge readout, barometric pressure using an AIR hand held barometer, air temperature and relative humidity using a hand held Vaisala sensor, sea surface temperature and salinity as measured by the thermosalinograph (pumped from 5 meters depth), cloud type and cloud coverage in octas and bucket temperature. In addition the corresponding Multimet data was also recorded by hand.

Hourly on the hour in conjunction with XBTs the time, position, sea surface temperature and salinity from the thermosalinograph and bucket temperature were recorded.

Section 3: The Tracer/Hydrography Program

A. Introduction and Purpose

The purpose of this part of the cruise was to obtain a large scale mapping of the distribution of tritium-helium age, oxygen, salinity and temperature over the area of study. The tritium-helium age, deduced from the distributions of both tritium (the heaviest isotope of hydrogen) and its stable daughter product helium-3, can be regarded as a measure of elapsed time since water was at the ocean surface, and hence is a direct measure of the subduction rates of different water masses. By subduction, we mean the process by which water resident at the ocean surface enters the subsurface circulation of the great, subtropical ocean gyres. Subduction apparently takes place in several ways. The first is called Ekman Pumping, whereby water is forced downward by wind driven convergence of surface waters. The second is a form of "thermodynamic underthrusting", where southward flowing water at the base of the previous winter's mixing layer is buried under warmer, less deeply convecting surface layers. The third, associated with secondary vertical processes and mixing at current fronts (in particular, the Azores Front), we refer to as "frontal subduction". The first is computable from the large scale wind fields, coupled with more-or-less well understood upper ocean physics. The limitation of this calculation is the quality and availability of good wind observations over the ocean (hence the need for the meteorological moorings in the Subduction Experiment). The second has only recently been recognized as an important process, and has been estimated by a combination of upper ocean circulation fields and the topography of the winter mixed layer depths. The third is by far the most difficult to assess and predict, and is probably only addressable from tracer and tritium-helium age measurements. We suspect that all three processes play an important role in subduction. Indeed, this is supported by observations of tracer distributions and the tritium-helium age fields. The goal of the Tracer/Hydrography component of the Subduction Experiment is evaluate the relative contributions of these mechanisms, and to characterize the subsurface circulation and mixing.

B. Sampling Scheme

The stations sampled are shown in figure 4. A total of 59 stations were taken. Logistically, we were constrained to sample largely on the cruise tracks between the mooring sites, but a central "Z" shaped excursion was included to obtain mapping across important tritium-helium age gradients and flow lines. Because the overall goals and subject study of the mooring programme are the same as the tracer/hydrography programme, the cruise track is close to optimal for our purposes. The track may be divided into four major sections:

- a meridional section along 22 W (stations 4-17) cutting through the large scale flow stagnation point and penetrating into the confluence between southward flowing subtropical and northward flowing tropical waters

- diagonal section (stations 23-34) extending "upstream" into the tongue of subducting waters

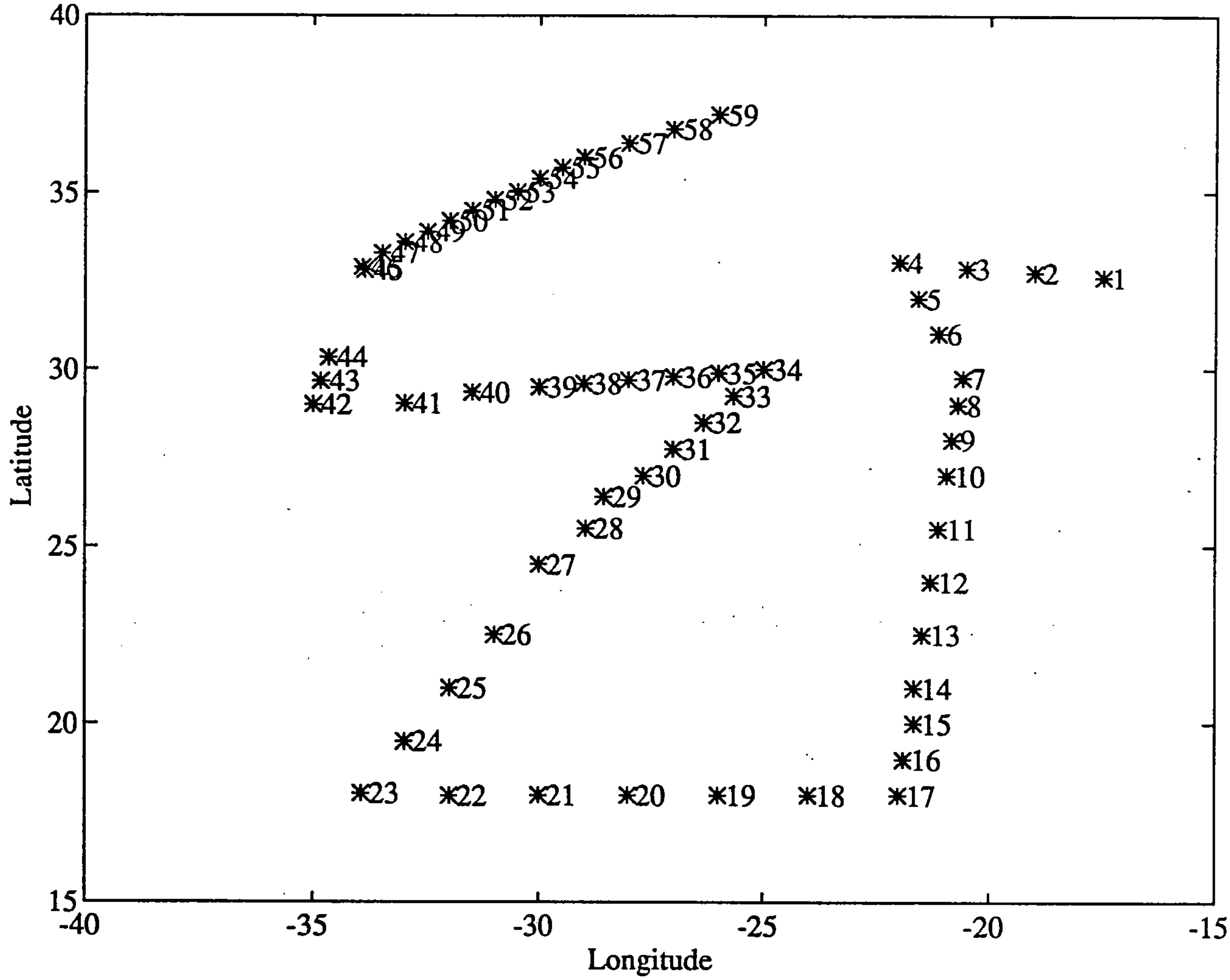
- two sections (stations 34-42, and stations 45-59) transecting the southward veering subtropical gyre circulation

The last of these sections is perhaps the most critical, in that it provides the only means or directly assessing the frontal subduction component. The means by which this can be done is by determining the directional rotation of tritium-helium age isochrons relative to the mean streamlines.

C. Sampling Procedures and Techniques

Water samples were obtained from a 12 place, 10 litre Niskin Bottle rosette sampler with a Neil Brown CTD. Typical stations were to 500 metres depth, with occasional sampling to 1000 or 2000 metres. Sampling was primarily done over the potential density anomaly range of 26.0 to 26.9 kg/m3, with "supporting sampling" done above and below these levels. Salinity, oxygen, helium and tritium samples were drawn from the Niskins on deck. Salinity samples were measured using a Guildline AutoSalinometer bridge calibrated with IAPSO standard water ampoules. Oxygen measurements were by high precision Modified Winklet Titrations using an automated dosimat with electrode end point determination. The helium and tritium samples were drawn into 90 cc stainless steel sample cylinders with O-ring sealed plug valves on either end. The helium was extracted into 25 cc glass ampoules (Corning type 1724, low He-permeability aluminosilicate glass) using a hot-extraction technique in an all metal UHV vacuum system. Tritium samples were degassed in 200 cc glass flasks (again Corning type 1724 glass) on a separate UHV system. Both UHV systems were cryo- and diffusion pumped, instrumented with convectron and ion vacuum gauges, and operated with computer controlled solenoid/pneumatic valves. The subsequently obtained samples are being returned to WHOI for shore-based mass spectrometric analysis of helium and tritium. The tritium will be determined by helium-3 regrowth techniques, after an incubation period of one year.

Figure 4. Tracer/Hydrography Station Plan



D. Preliminary Hydrographic Results

Since they require shore-based analytical procedures, the tritium-helium data are currently unavailable. We do, however, have some preliminary hydrographic (temperature, salinity and dissolved oxygen) data. Figure 5, for example, is a contour plot of temperature vs depth along the central (diagonal) section, with north on the right. The isotherms, particularly warmer than 18 degrees, show the dominant southward deepening associated with subduction. Surface waters show a banded structure, with front-like southward increases in temperature at about the 1600 and 200 km positions. At the extreme southward end, the deep isotherms turn upward, characterizing the westward flowing limb of the subtropical gyre circulation.

The zonal banding is even more evident in the salinity distribution shown in figure 6, which is a surface plot of salinity vs depth and distance along the same section. Aside from the 100-200 km oscillation, the shallow salinity is domes upward in the middle of the section due to the high salinity cell created by the high E-V trade winds. A subtle subsurface bulge in the salinity surface (most evident at about 100-150 metres in the southern end of the section) is an imprint of the subducting waters, known further west as the Subtropical Underwater. Deeper down, the influence of Antarctic Intermediate water can be seen in the southern end of the section at 500 metres (note how the surface dips downward).

The southern water influence is also seen in the oxygen surface (figure 7) for this section, where the deep oxygen concentrations dip to about 2 ml/l. This is an artifact of the large tongues of low oxygen water protruding from the coast of Africa. A striking feature of the oxygen distribution shown here is the subsurface photosynthetic oxygen maximum at about 60-100 metres. This feature attenuates southward and eastward, reflecting geographic variations in new primary production, which result from changing patterns of nutrient recycling.

Section 4: Cruise Chronology

The RRS Charles Darwin left Funchal Madeira on 30 September 1992 at 0910 UTC. While enroute to the Northeast mooring, one deep (3000 meter) and 2 shallow (500 meter) CTD stations were taken.

Northeast Mooring

The Darwin arrived at the Northeast buoy at 1420 UTC on Thursday 1 October 1992 at position 33°01.81'N, 21° 59.52'W. Figure 8 is a schematic of the Northeast Subduction 2 mooring (WHOI mooring number 927) as deployed in February 1992. As the ship passed by the buoy it appeared in good condition and photographs were taken. The ship then moved to a position .25 miles downwind of the surface buoy and remained there for four hours while meteorological observations were recorded every five minutes. With the meteorological observations completed the ship moved into position for recovery. The discus buoy was alongside and hooked into at 1912 UTC. At this point the buoy had to be led aft around to the stern gantry. The ship took too long to pass by the buoy and as a result the buoy got caught under a shelf on the starboard quarter outboard of the rail. Repeated contact with the ship as it slowly passed aft caused excessive damage to the buoy

Figure 5. Temperature along the Central Section

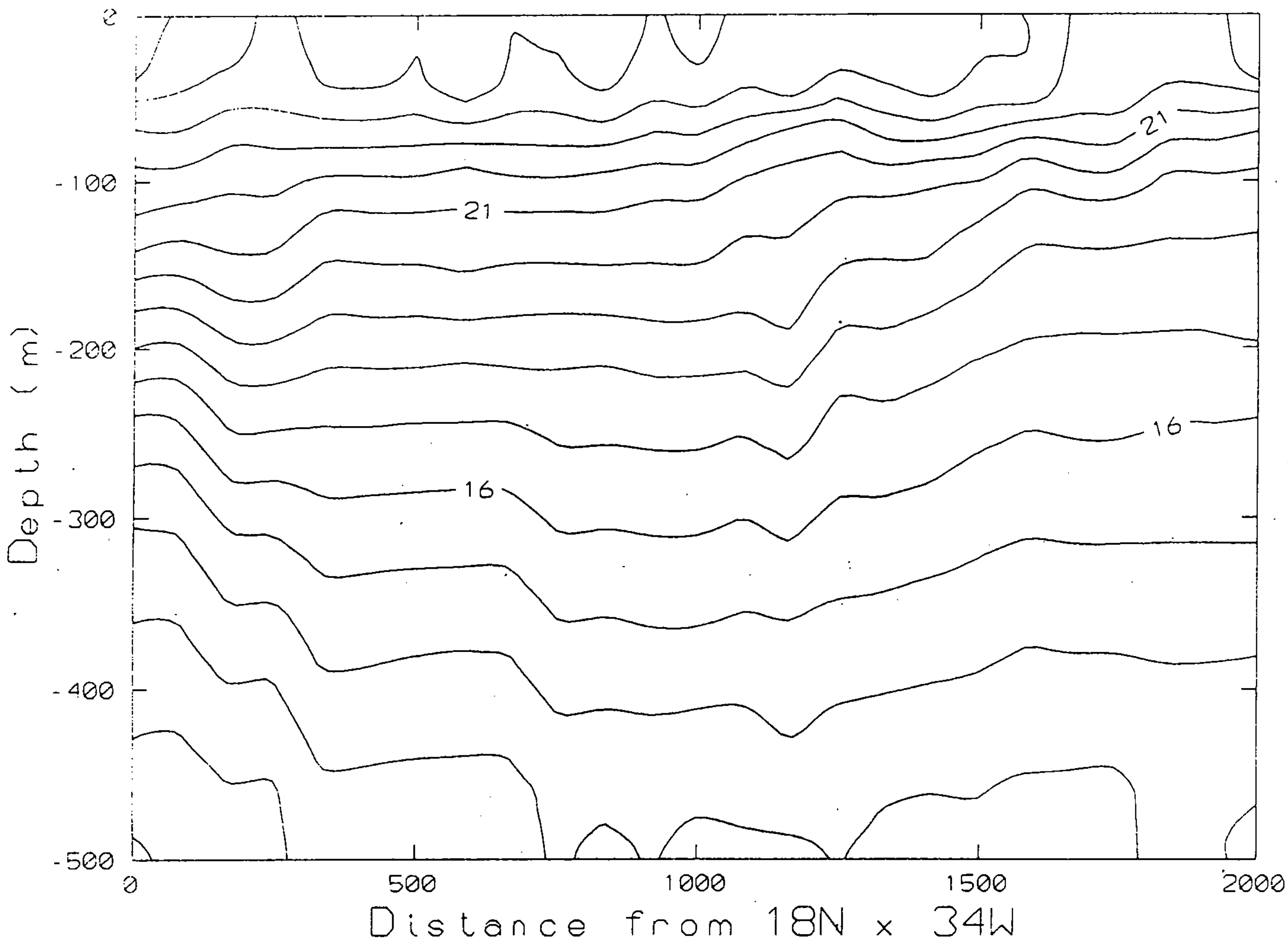


Figure 6. Salinity along the Central Section

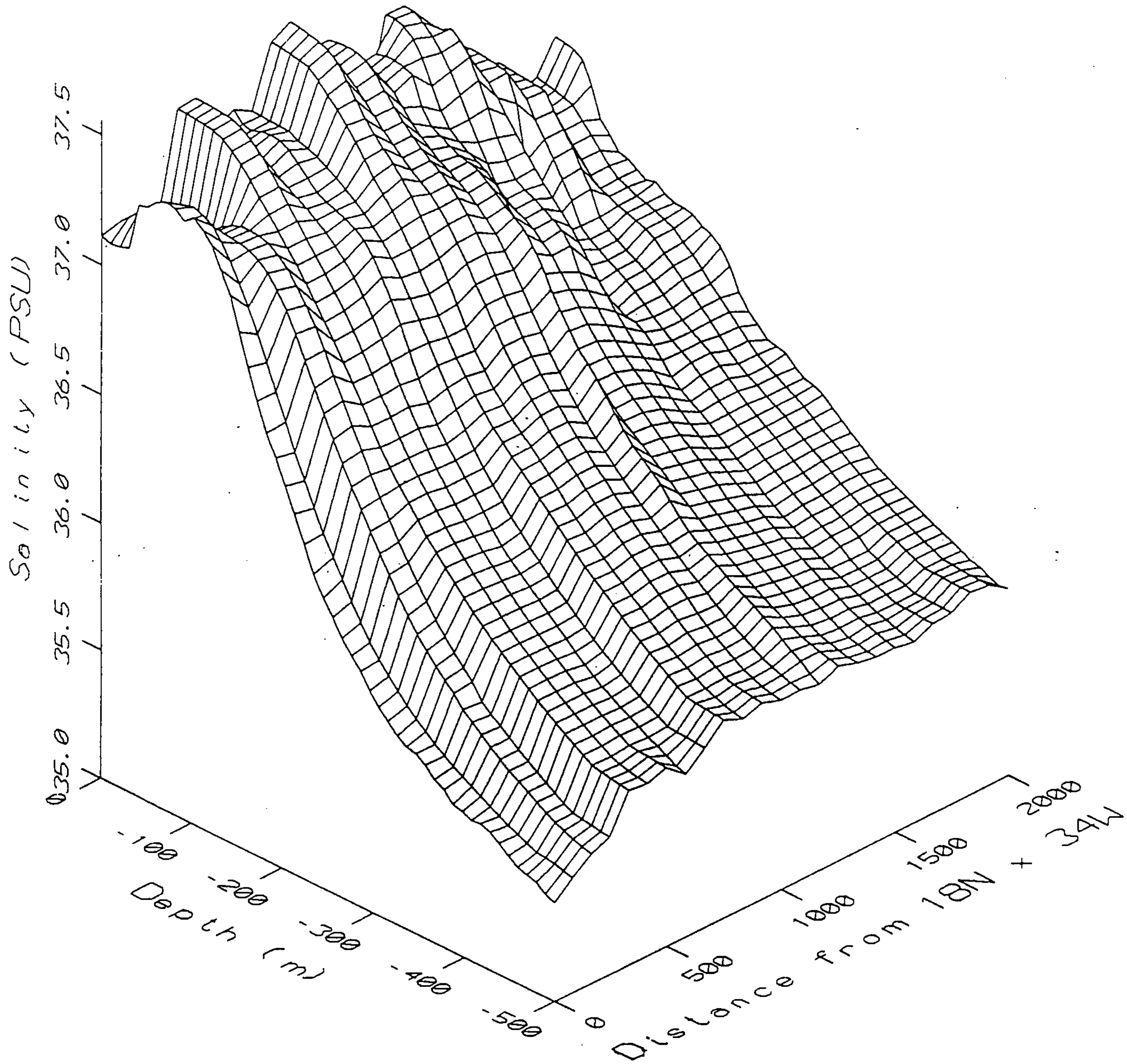


Figure 7. Oxygen Along the Central Section

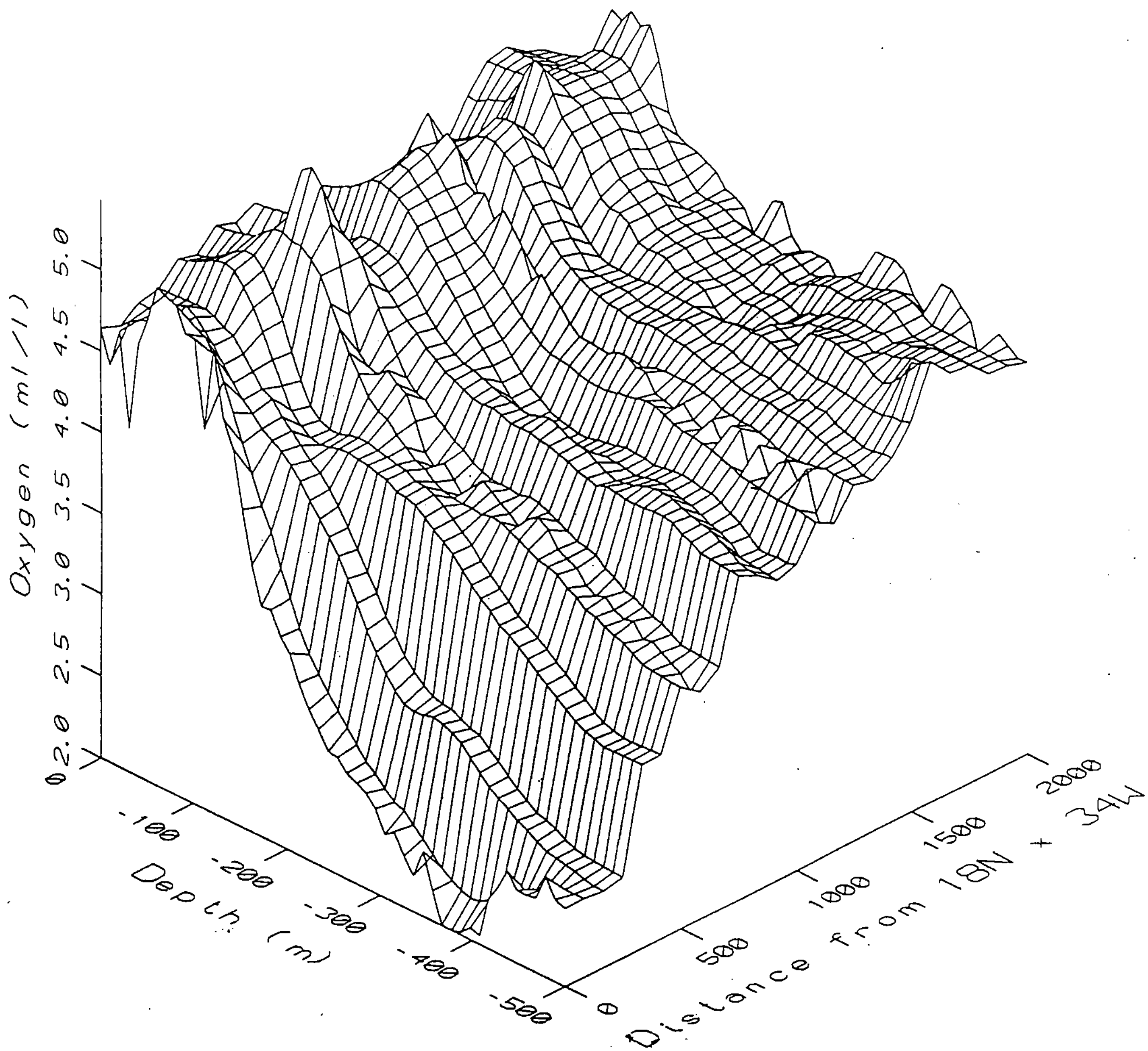
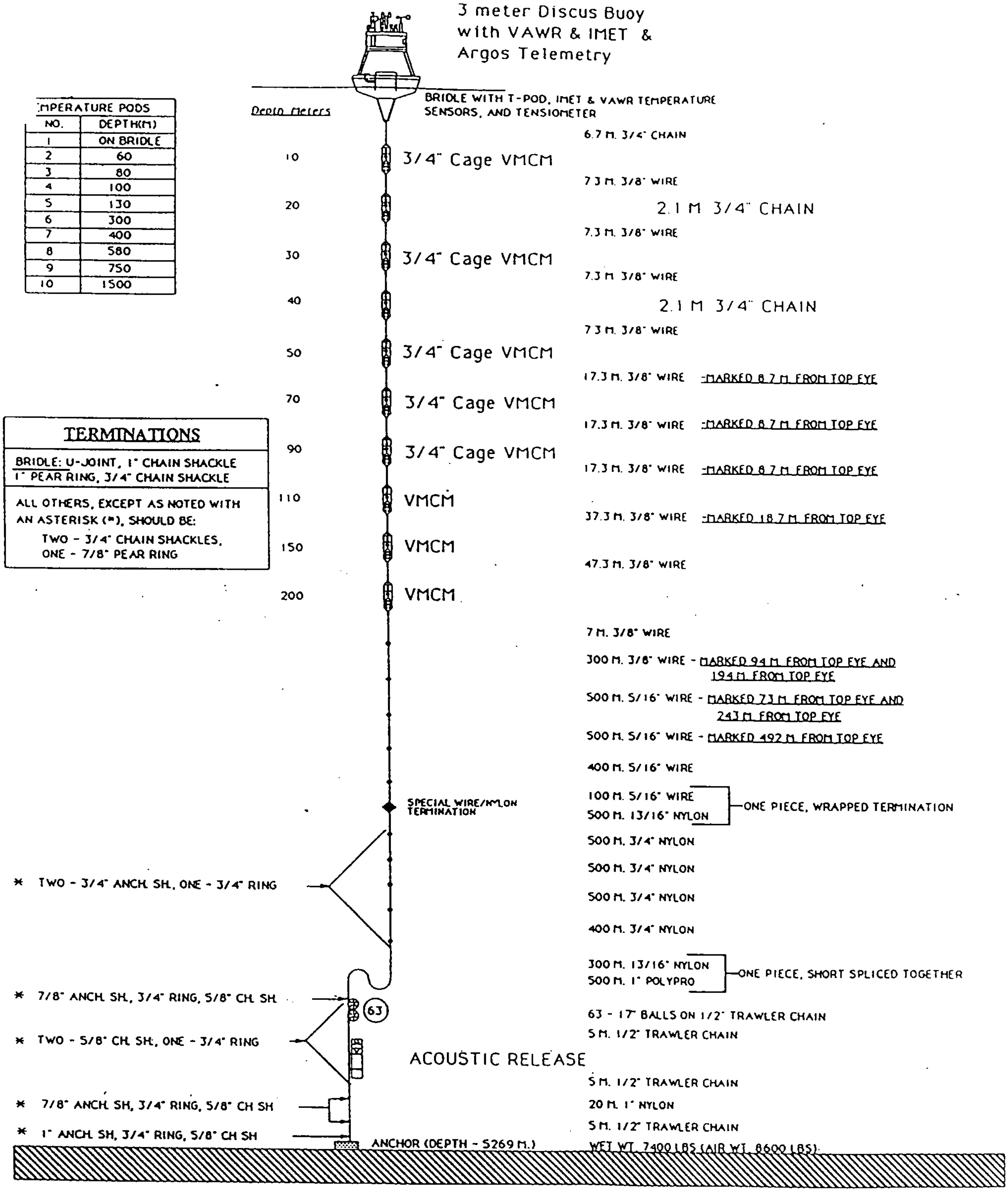


Figure 8. Subduction 2 Northeast Mooring Schematic



SUBDUCTION NORTHEAST - SECOND SETTING

PER 20 NOV 91
1st REV. 25 NOV 91
2ND REV. 5 DEC 91

FINAL

** NOTE TO RIGGING SHOP: THIS MOORING TO BE LAUNCHED WITH LEBUS WINCH. THEREFORE, ON SHOTS WHICH HAVE A DEFINITE TOP AND BOTTOM (MARKED WIRE FOR T-PODS, FOR EXAMPLE), THE TOP OF SHOT SHOULD BE ON THE OUTSIDE OF THE WOODEN REEL.

tower top. A crash bar with solar panel was torn from the tower top and fell into the ocean. The solar radiation sensor bracket also took multiple hits and was bent. The IMET longwave radiation sensor was torn from its bracket and left dangling by connecting wires but was recovered. The IMET wind monitor bracket was bent and the junctions between the two modules that make up the wind monitor were slightly separated. The tower top sustained considerable structural damage with channel pieces being bent and welds broken. Once the buoy got aft of the ship the recovery of the buoy through the stern gantry went quite well. With the buoy on deck and the mooring stopped off the buoy was moved to the starboard rail. The recovery of the mooring commenced using the WHOI Lebus double barrel capstan winch. This was the first at sea use of the winch. The entire mooring was on board by 0112 UTC 3 October 92.

Mooring number 927 had five WHOI Brancker temperature recorders. All five instruments collected data for the full deployment. There were also five SIO Brancker temperature recorders on the Northeast mooring. Two SIO temperature recorders (numbers 2427 at 1500m and 2426 at 750m) did not record any data because the temperature was out of the measurement range of those instruments. The SIO temperature logger at 400 meters (number 3711) appeared to have leaked early in the deployment and still had a few drops of water when opened after recovery. Its data were, however, readable. An interesting difference between the one instrument that leaked and the other four SIO temperature loggers is that the instrument that leaked had aluminum purge plugs and the others had plastic purge plugs.

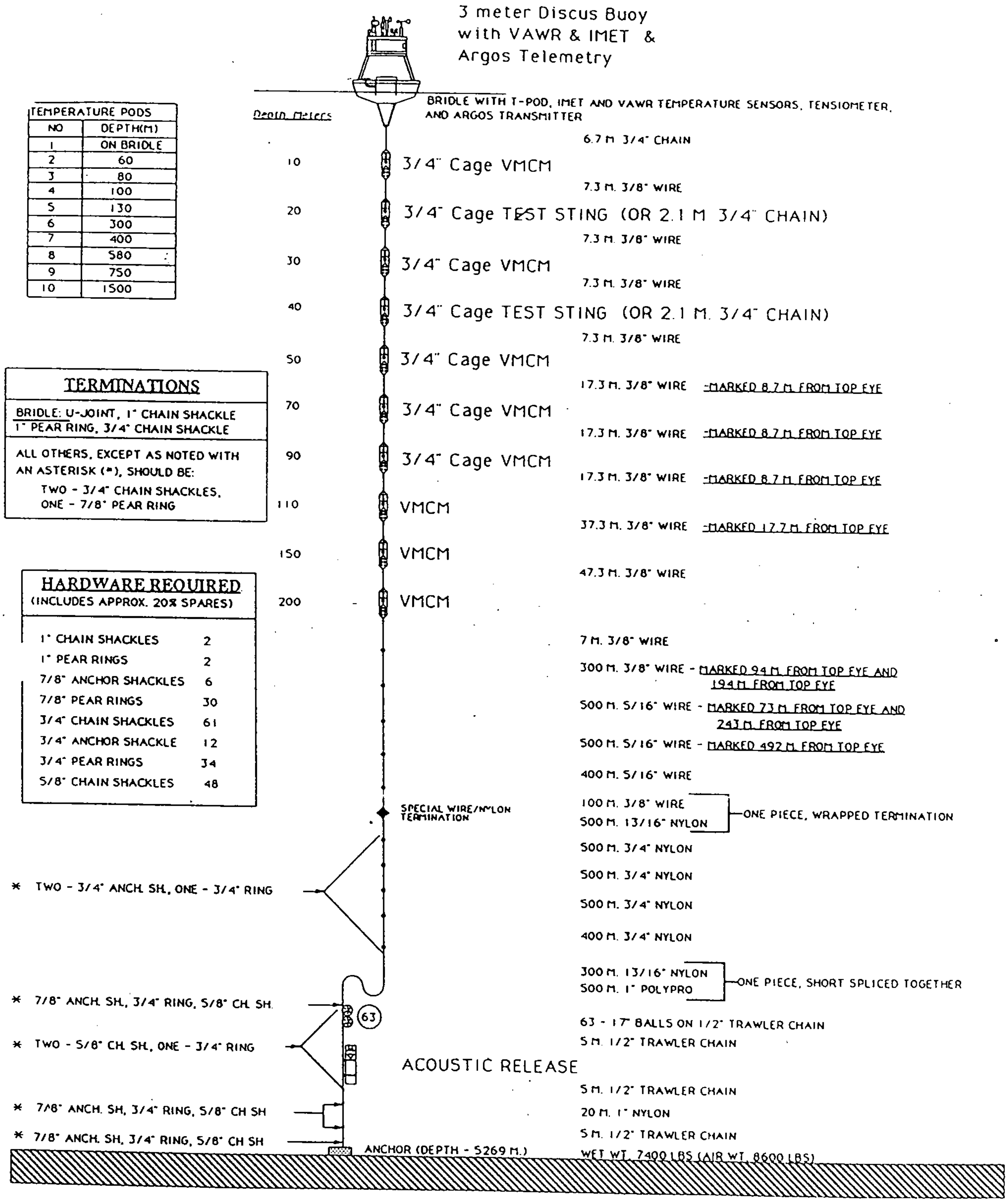
Eight WHOI VMCMs were also recovered from this mooring. The instruments appeared in good mechanical condition as they came on board. Propeller bearings spun freely and all propeller blades were intact. See Appendix 7 for specific details noted as the instruments were recovered. There was minimal growth on the instruments and very few goose barnacles. The buoy hull was also clean upon recovery. Some sections of the hull no longer had any antifouling paint presumably because it had worn off during the eight month deployment. Even in these bare spots there was no growth. The IMET and VAWR sea surface temperature cable showed evidence of fish bite and photographs of this were taken.

The VAWR on the Northeast buoy had a full data record collecting data from all sensors. The IMET system worked for approximately four months.

With the mooring on board glass balls were transferred to the ball container and the mooring reels for the next mooring were broken out and staged for deployment. An acoustic release test lowering to 1000 meters was also conducted. Following the release test a shallow (500 meter) CTD station was made. Upon completion of the CTD station the ship was positioned one mile downwind of the mooring target position and instructed to steam a steady course upwind at one knot. This was to determine the ships set and drift that we might expect during deployment. The exercise indicated that there was a current directly opposing the wind because the ship traveled about 1.4 miles in the one hour time frame. It was unclear as to whether this was due to a current or variablility in the ships speed. (It has since been learned that the ship's speed through the water indicator was unreliable at slow speeds).

To be safe we positioned the ship seven miles downwind and prepared to deploy the mooring. Figure 9 shows the Northeast mooring deployed during Darwin cruise 73. The upper instrumentation and buoy were deployed without incident starting at 0758 UTC 2 October 1992. The anchor was dropped at 1449 UTC on 2 October 1992.

Figure 9. Subduction 3 Northeast Mooring Schematic



SUBDUCTION NORTHEAST - THIRD SETTING

G. TUPPER 23 JUN 92

An acoustic release survey was conducted following the deployment. The results of that survey are shown in figure 10. **The anchor position for the third setting of the Northeast mooring (WHOI mooring number 952) was 33° 01.80'N, 21° 59.39'W.** The mooring anchor fell back 365 meters or 6.9% of the water depth. The corrected water depth at the Northeast site was 5280 meters. The uncorrected reading from the ship's Simrad depth recorder was 5222 meters and the correction for the site taken from the "Echo Sounding Correction Tables" was +58 meters. The uncorrected reading already took into consideration the depth of the transducer which was towed alongside the ship.

Following the release survey meteorological observations were made every five minutes for four hours while the ship was within a quarter mile of the surface buoy. At the conclusion of the intense meteorological observation period the ship got underway for the Southeast Subduction mooring. While enroute to that site 10 shallow CTD stations down to 500 meters and two intermediate depth stations (one to 1000 meters and one to 2000 meters) were made. The ship's track south had a slight dog leg to the east in order to conduct a CTD station (CTD station number 7) in close proximity to a predicted location of an ALACE float that had been deployed in February 1992. Hourly XBTs were resumed at 1000 UTC on 6 October 1992. Problems with a drifting calibration were eliminated after replacing the cable on the hand held XBT launcher. XBT number 48 was the first XBT taken with the new cable. XBTs taken prior to number 48 are suspect.

Southeast Mooring

The Darwin arrived at the Southeast buoy at 1400 UTC on Tuesday 6 October 1992. Figure 11 is a schematic of the Southeast mooring as deployed in February 1992. After a brief inspection of the surface buoy the ship was positioned .25 miles downwind of the buoy so that meteorological observations could be made every five minutes for four hours. Following the meteorological observations the mooring's acoustic release was fired at 1759 UTC . The ship cautiously approached the buoy trying not to get too close so as to prevent the damage that had occurred during the Northeast recovery. Three passes were made before the buoy was close enough to get a hook into the lifting bale. The recovery scenario had been altered slightly so that the buoy could be kept away from the starboard quarter where all the damage occurred. To do this the ship's starboard HIAB crane was used to guide the buoy out away from the ship after it had been connected to the primary lifting line. Recovery of the buoy was accomplished without any damage to the buoy or meteorological instrumentation. The subsurface instrumentation was recovered without any problems and the glass balls and release were on board by 2334 UTC.

The surface buoy that was recovered from the Southeast mooring had a considerable quantity of gooseneck barnacles on the underside of the hull. A small section of fish net was found wrapped around one of the bridle legs. The deck of the buoy was covered by a dark brown growth that looked like a kind of algae. The tower top with meteorological instrumentation was covered by a light brown very fine clay like material. Sensors were covered with the same material. Solar radiation sensors and solar panels had a very fine coating that presumably would impair the passage of radiation. Wind instruments had their leading faces covered as did the radiation shields. The whole tower top took on a light brown color rather than the usual white.

Figure 10. Subduction 3 Northeast Acoustic Release Survey

Subduction 3
Northeast Mooring
Mooring Number 952
Acoustic Release Survey
2 October 1992

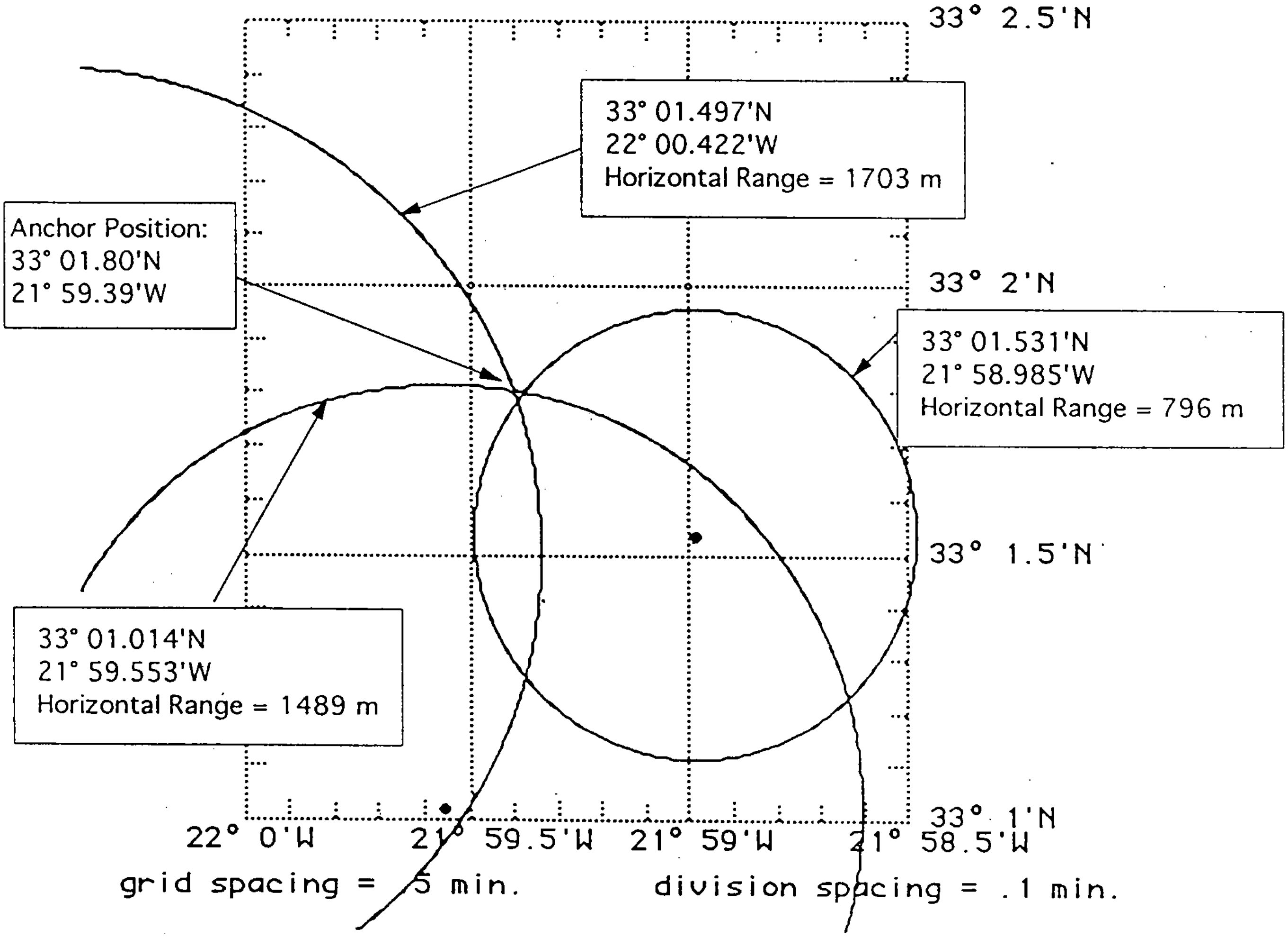
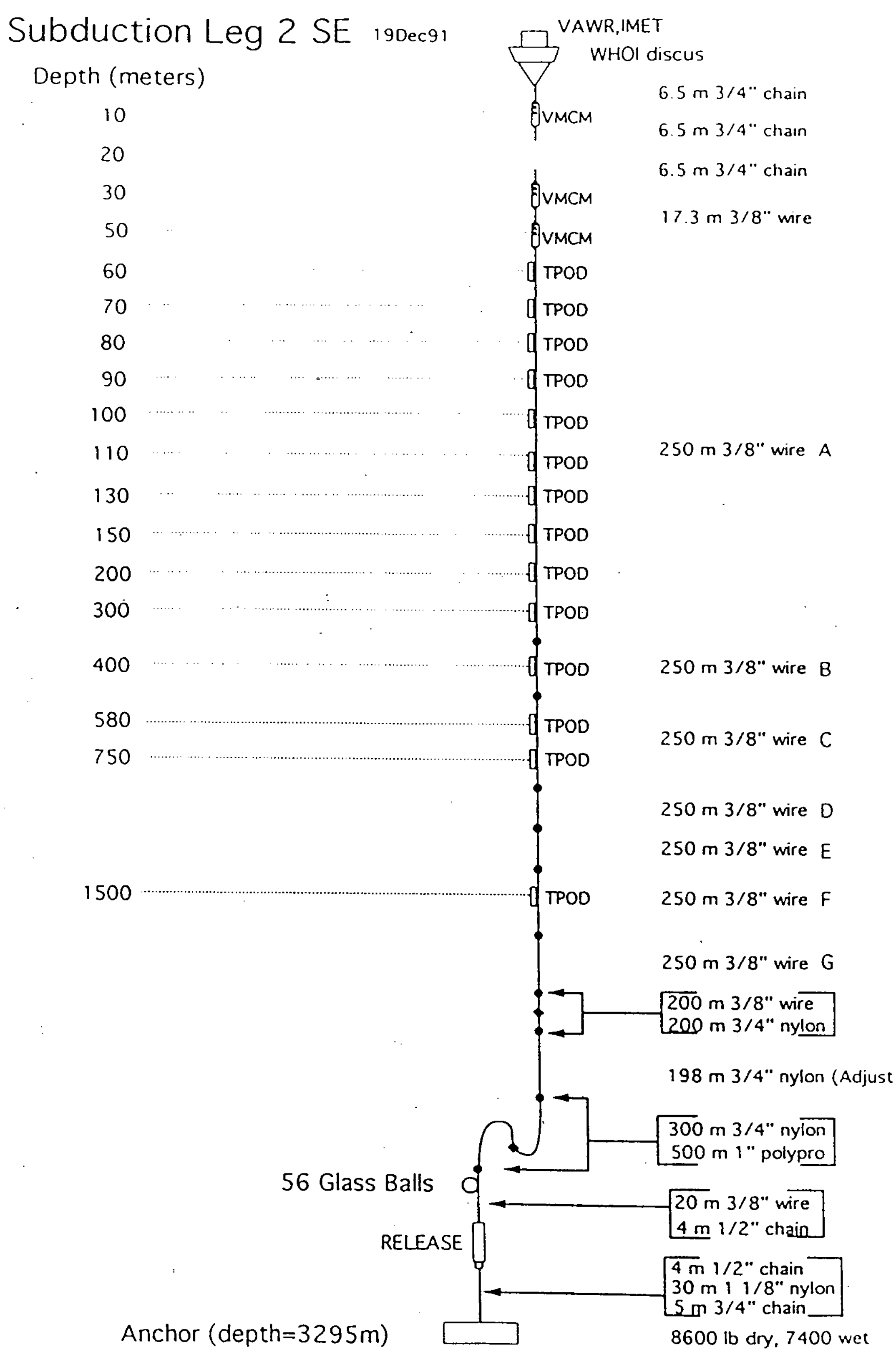


Figure 11. Subduction 2 Southeast Mooring Schematic



One WHOI VMCM was recovered from the Southeast mooring. Upon recovery the instrument was in good mechanical condition. The propeller bearings did not have any excess endplay and none of the propeller blades were broken. The data recorded by this instrument was processed and all variables looked reasonable except temperature. Temperature failed soon after the anchor was launched on 9 February, 1992. Inspection of the instrument revealed a broken wire as the cause of the temperature failure. Two Scripps VMCMs were also recovered from the Southeast mooring. The propeller bearings on these instruments exhibited slightly more radial and axial endplay than when deployed. One of the two SIO VMCMs worked for five months. The other instrument recorded data for the full deployment.

The VAWR on the Southeast mooring collected data for the entire deployment. The IMET system had filled its optical disk by 15 September 1992 and therefore was missing the last month of data.

Four WHOI-owned and eleven Scripps-owned Brancker temperature recorders were recovered from this mooring. All four WHOI instruments recorded data for the entire deployment. Eight Scripps units had full data records. The Scripps unit at 300 meters depth (Serial Number 3712) leaked a small quantity of water and would not respond to any control commands. Scripps temperature loggers at 400 and 750 meters depth (Numbers 2423 and 2434 respectively) failed to record any temperature data because of limitations in the temperature range of those particular instruments.

It should be noted that there was at least one shackle recovered from the nylon section of the Southeast mooring that was missing a cotter pin due to an enlarged hole and at least one shackle recovered that was missing a nut all together. Several shackles had severely corroded nuts. The corrosion problems were evident only in the nylon which had bronze thimbles. Also worthy of note is that the thimble of the nylon end of the wire-to-nylon shot was found to be reversed, ie., the shackle was found in the end opposite the greater radius.

A deep CTD station down to 2000 meters was started following the recovery of the mooring. Simultaneously the glass balls recovered from the mooring were untangled and laid out for redeployment. All of the glass balls recovered from the second setting of the Southeast mooring were redeployed. Once the CTD was completed an acoustic release test lowering was made down to 1000 meters. Three releases were tested; two Scripps releases and one WHOI release. The one WHOI release could not be interrogated at the 1000 meter depth even though it could be heard at 200 meters. Both Scripps releases functioned properly. With the releases back on board the ship was positioned a mile downwind of the target mooring position. The ship then steamed a steady course at approximately one knot. The resulting speed and course indicated an easterly current. To compensate for its effects the ship was positioned approximately 8.5 miles downwind of the target position. (This, however, was too far. The error was presumably caused by the inaccuracy of the ship's speed through the water indicator. It would have been necessary to tow the mooring for a considerable length of time in order to reach the target. Since the bottom was flat the anchor was dropped when the mooring was completely paid out.)

The upper instrumentation and buoy for the third setting of the Southeast mooring were deployed without any problems beginning at 0631 UTC on 7 October 1992. Figure 12 is the mooring drawing of the Southeast mooring. The deployment proceeded very smoothly and the anchor was dropped at 1157 UTC 7 October 1992. An acoustic release survey was conducted immediately following the mooring deployment. The results of that anchor survey are shown in figure 13 . **The anchor position for the third setting of the Southeast mooring (WHOI mooring number 953) was 17°57.71'N, 22° 02.77'W.** The anchor apparently fell back approximately 369 meters (11.2% of the water depth) from its original drop position.

The ship was then positioned .25 miles downwind of the surface buoy and meteorological observations were made every five minutes for four hours. Following this intense period of observations the ship got underway for the Southwest mooring site. Hourly XBTs were resumed once the ship was approximately 10 miles from the mooring While enroute to the next mooring four shallow (500 meter) and one intermediate (1000 meter) depth CTD stations were taken.

Southwest Mooring

The ship arrived at the Southwest site at 0814 UTC on 10 October 1992. This mooring is shown schematically in figure 14. It had parted on or about 4 June 1992. The surface buoy and top current meter cage at 10 meters depth was recovered by a NOAA ship in early July. Since we did not know whether the anchor had dragged since deployment in February 1992 an acoustic release survey was conducted to ascertain the anchor position. Based on the survey results it did not appear to have moved. There were no problems interrogating the release and all horizontal ranges obtained were consistent with the earlier surveys. The ship was then positioned .3 miles downwind of the anchor position and a release command was sent. The mooring release responded with a 16 one pulse per second response instead of the usual 32 two pulse per second response for release confirmation. Slant ranges to the release remained unchanged. Numerous release commands were sent. In the event that the problem was a low battery no commands were sent for an hour thinking the battery might be able to recover. After an hour, more release commands were sent and the proper confirmation was not obtained. Despite our efforts the release would not activate.

Several alternate recovery options were discussed. The trawl wire on board the ship was 10,500 meters in length but the condition of it was suspect. The RVS technicians felt that the working load of the wire given that there were 6 broken strands was reduced to 3.5 tons. The concern was that if a dragging attempt was made and the mooring was snagged there was a good chance that the ship's trawl wire would part. If the mooring was hooked above the glass balls it would require approximately 14,000 pounds pull to part the mooring wire/nylon. The trawl wire would see the 14,000 pounds tension plus its own weight which together would far exceed its reduced working limit.

A second option was to use the coring warp which was in good condition however there was only 5000 meters on board. Since this would not have been able to reach the bottom this option was dismissed early on.

Another option was to attempt to cut the mooring below the balls and therefore let the mooring come up on its own. The chances of being able to cut the mooring that low were very small. If at the same time we snagged the mooring line we would be in the same situation as in an earlier option and risk parting the trawl wire.

Figure 12. Subduction 3 Southeast Mooring Schematic

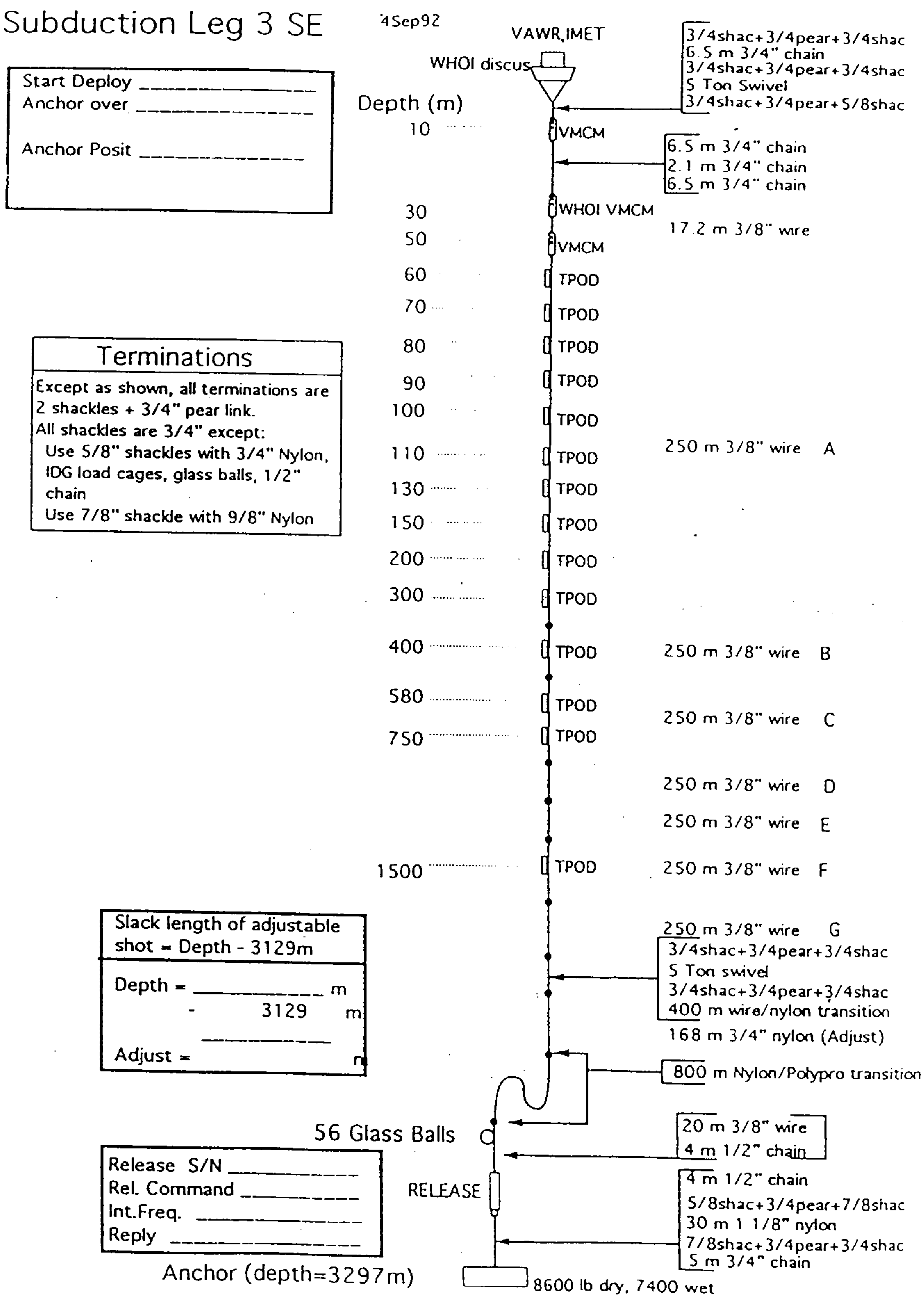


Figure 13. Subduction 3 Southeast Acoustic Release Survey

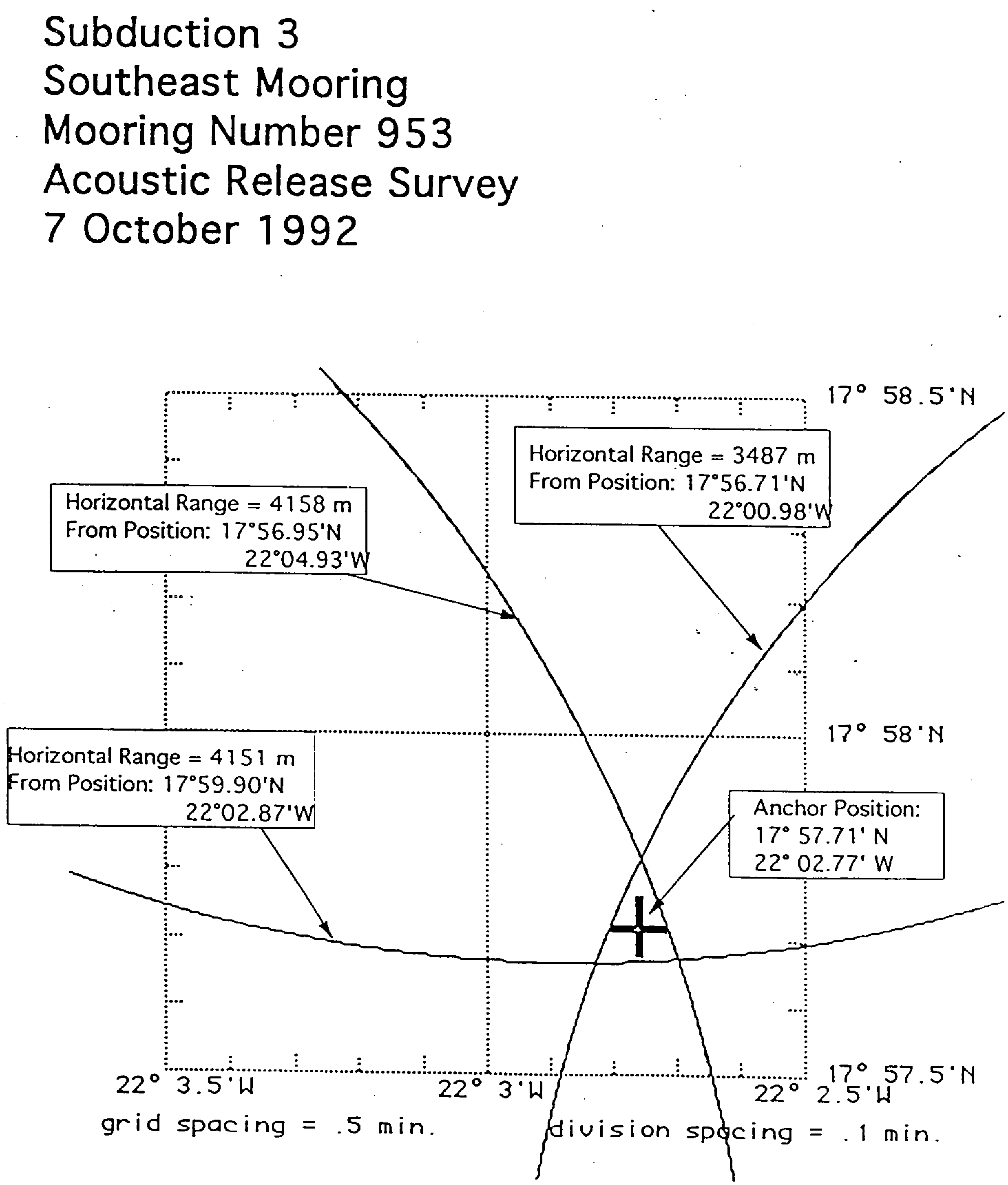
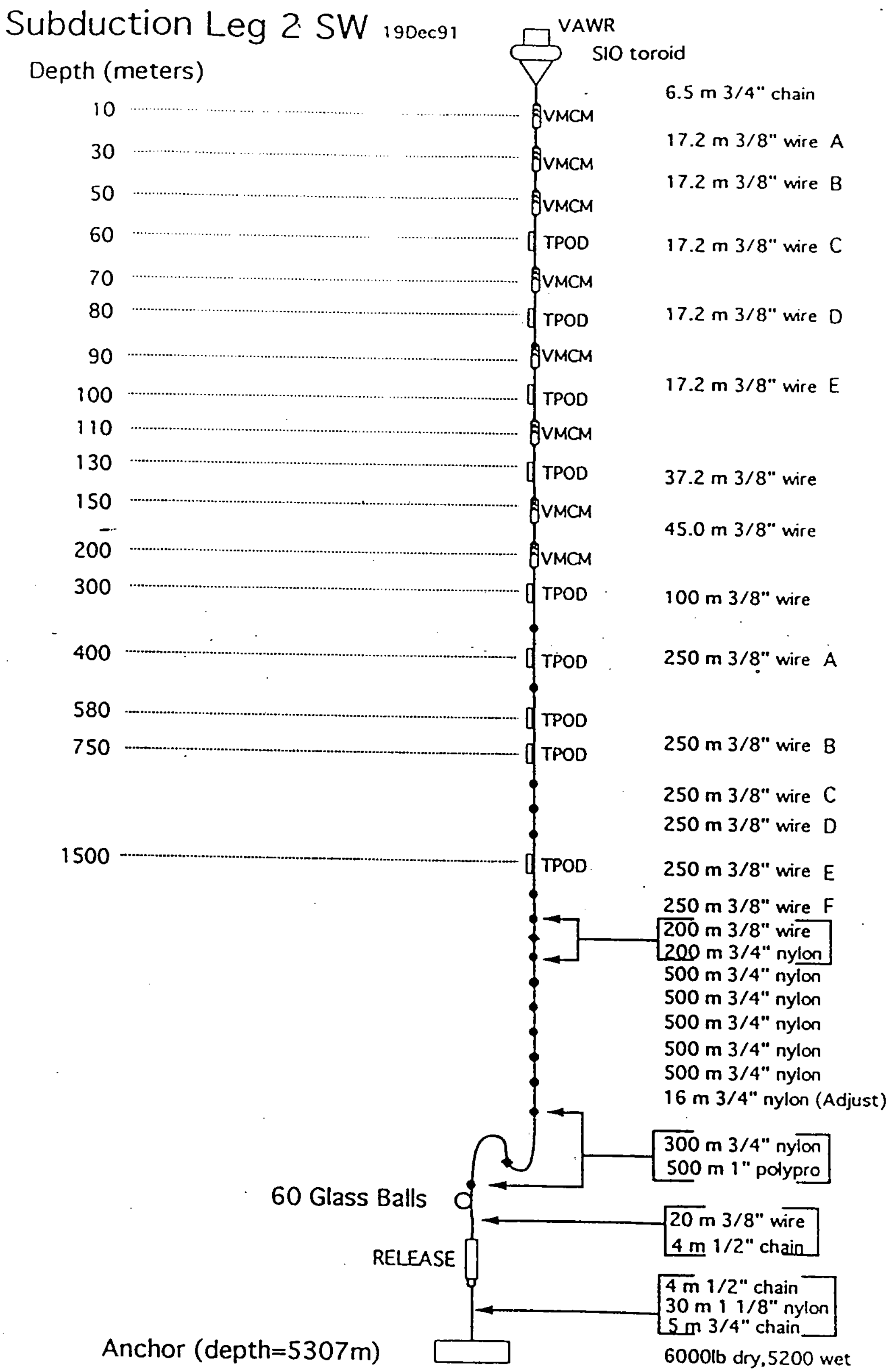


Figure 14. Subduction 2 Southwest Mooring Schematic



A third option was to wait till the final recovery cruise in June 93 and come out with better equipment and make an attempt to recover the mooring at that time.

In all these options there was the risk of sawing through the mooring line. Since all the buoyancy was located at the bottom of the mooring there was a good chance that dragging would cut the instrumentation from the buoyancy. If cut, the only way to recover the upper part would be by dragging over the mooring line and snagging the instrumentation section.

The various scenarios were discussed with ship's personnel, WHOI and SIO mooring people as well as with Dr. Weller in Woods Hole. A decision was made to attempt to lay enough wire around the anchor position and try to cut the mooring below the balls. The deck was rigged and deployment of the sacrificial shot of WHOI trawl wire was started at 1527 UTC 10 October 1992. Problems with the ship's wire out indicator delayed deployment of the ship's trawl wire until 1711 UTC. The configuration of the trawl wire is shown in figure 15. A Benthos pinger was placed 520 meters up the ship's trawl wire as an indicator of how much wire was actually laying on the bottom. It is believed that the bottom depressor weight touched down on the bottom at approximately 1911 UTC. The ship then steamed into the wind at 1 knot while the ship paid out trawl wire at 25 meters per min. The pinger was at 20 meters off the bottom at 2000 UTC at which time the payout of trawl wire was stopped. Since the pinger started to rise up off the bottom the payout continued at a slow rate so as to keep the pinger approximately 20 meters off the bottom. The ship steamed east past the anchor position about .25 miles to the north and went past the anchor by 1.25 miles. The ship then turned and steamed a reciprocal course passing .25 miles to the south of the anchor position. During the turn and while passing the anchor position the trawl wire was paid out at 25 meters per minute trying not to pull the cable. At 2317 UTC the ship stopped paying out wire and turned to the north encircling the anchor. A total of 9202 meters of wire were paid out.

Rehaul was started at 0005 UTC 11 October 1992. While hauling in the trawl wire ranges to the release and numerous release commands were sent. The release position did not change during rehaul and trawl wire tensions did not peak at any particular time. The hooks were recovered at 0457 UTC with no indication of contact with the mooring.

Upon completion of the dragging attempt deep CTD station number 23 was taken. A bottom depth survey was conducted to the northeast inorder to find a new location for the Suduction 3 Southwest mooring. A relatively flat area was selected two water depths to the northeast of the original site in 5206 meters of water. The ship was then positioned five miles downwind of the new site and an acoustic release test lowering was done to test two SIO releases. With the release work completed the ship was repositioned and the mooring deployment started at 1210 UTC 11 October 1992. Figure 16 is a drawing of the Subduction 3 Southwest mooring. The upper instrumentation and buoy were deployed by 1300 UTC. The remainder of the mooring was deployed without incident. The anchor was dropped at 1846 UTC 11 October 1992.

Immediately following the anchor drop the ship repositioned and watched the toroid buoy skip across the water as the anchor went to the bottom. After the anchor settled out an anchor survey was conducted. The results of that survey are shown in figure 17. **The anchor position of the third setting of the Southwest Subduction mooring (WHOI mooring number 954) was 18°05.57'N, 33°53.97'W.** The water depth at the mooring site was 5206 meters corrected. The sound speed used in range calculations was 1514 m/sec. The anchor fallback was calculated to be 400 meters or 7.7% of the water depth.

Figure 15. Trawl Wire Configuration for Dragging

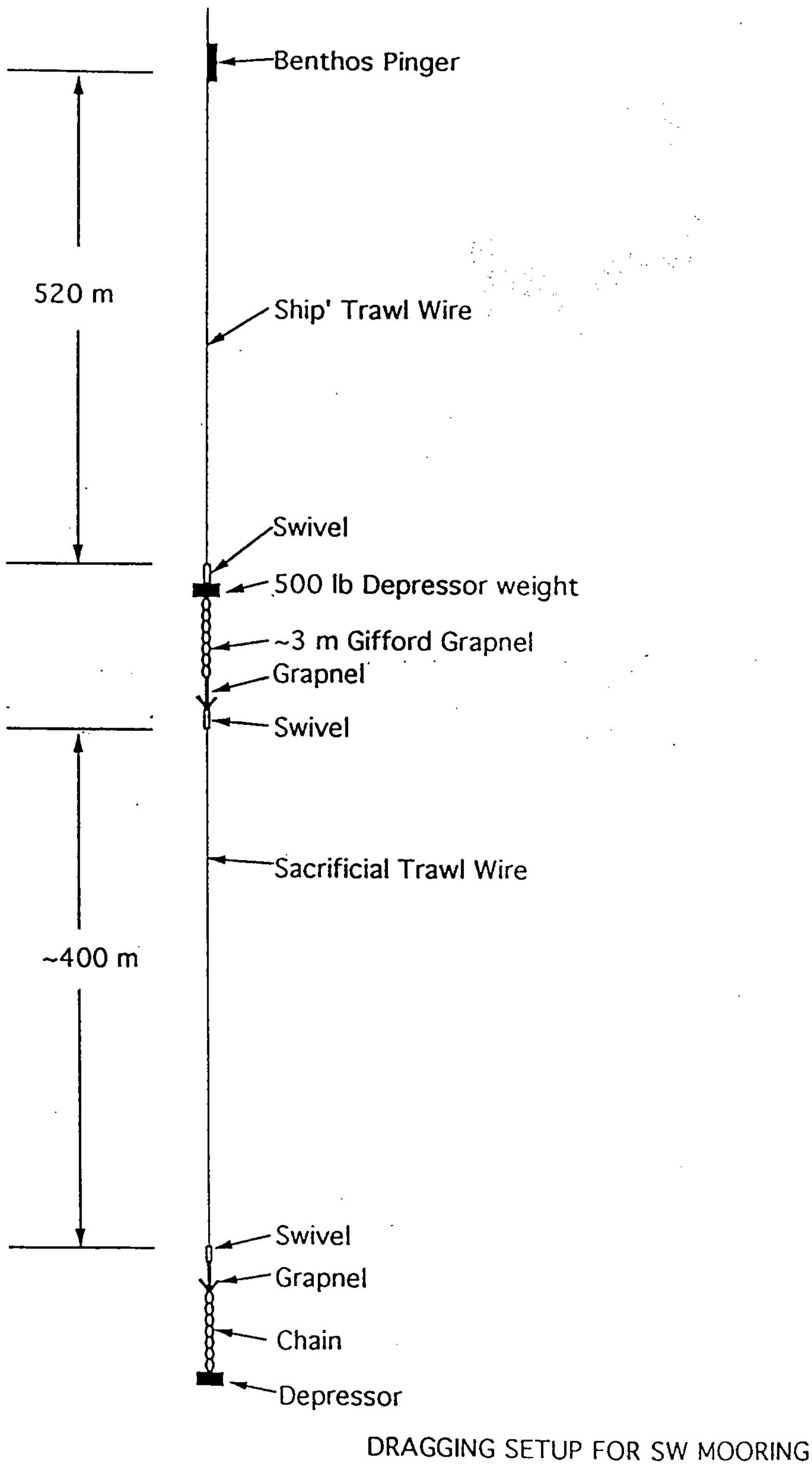


Figure 16. Subduction 3 Southwest Mooring Schematic

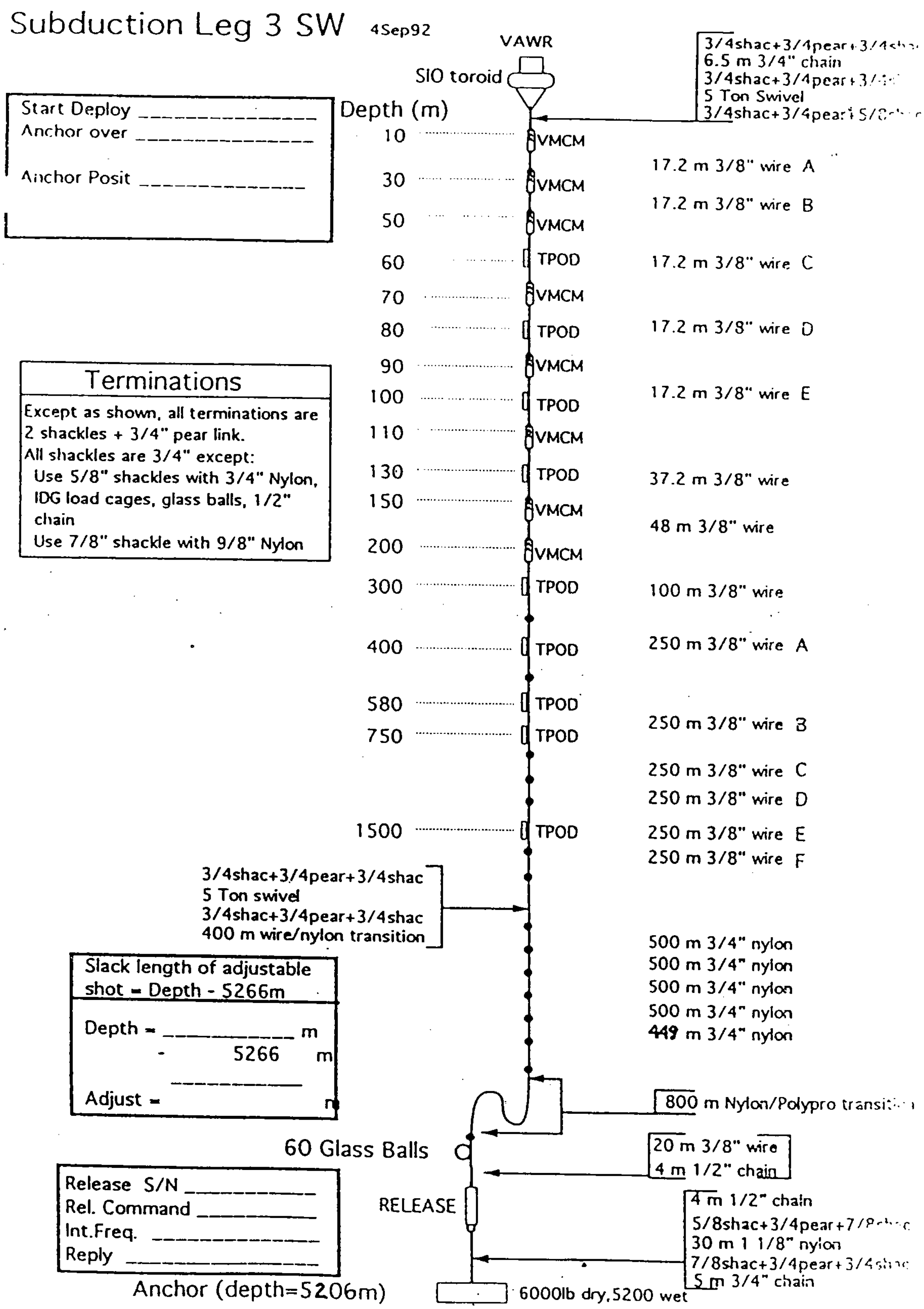
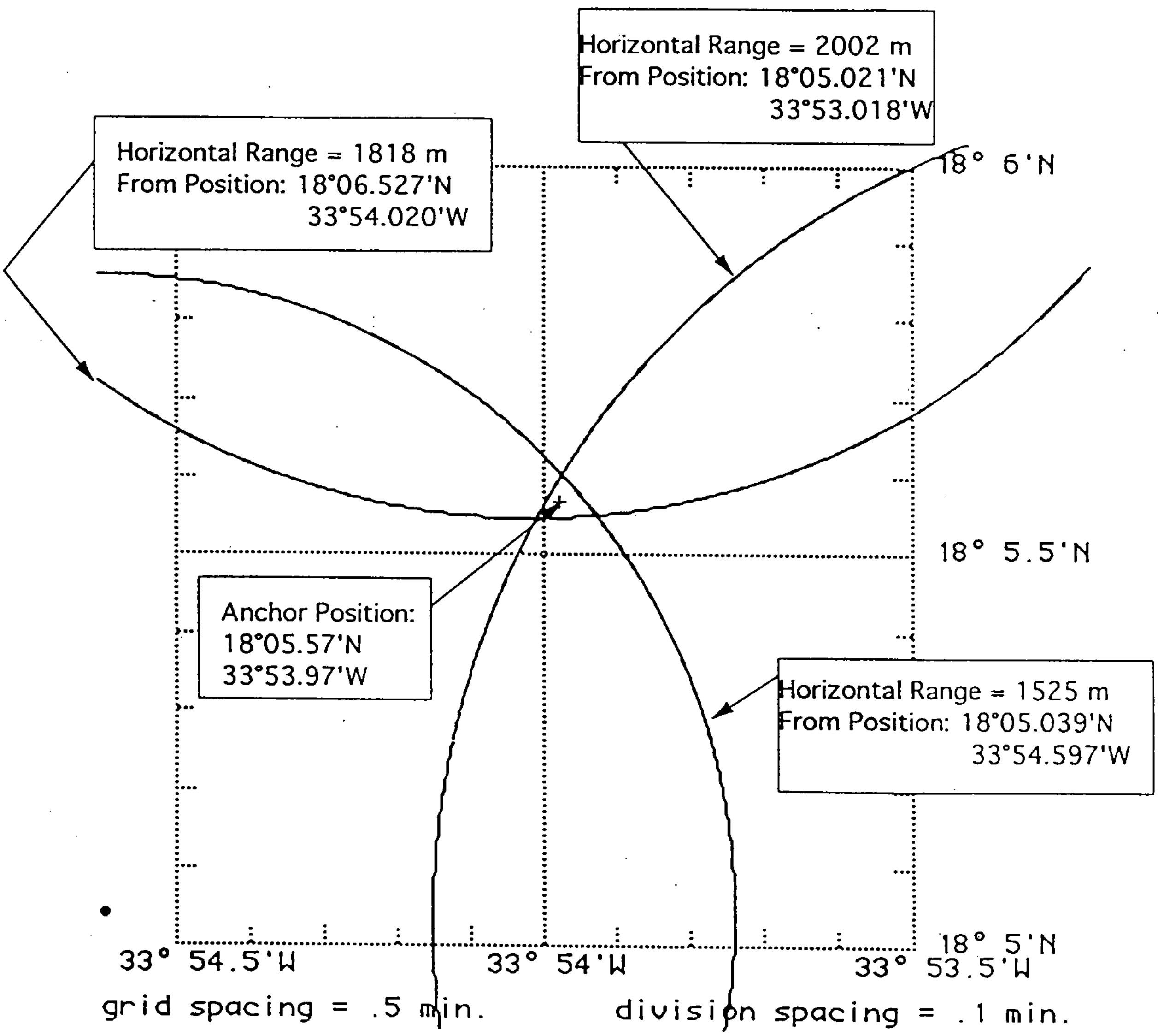


Figure 17. Subduction 3 Southwest Acoustic Release Survey

Subduction 3
Southwest Mooring
Mooring Number 954
Acoustic Release Survey
11 October 1992



Following the anchor survey at mooring 954 the ship returned to the original Southwest site (mooring 924) and conducted an anchor survey to do a final check on the anchor location. At the first survey point the acoustic release deck gear transducer drifted aft and was severed by the ship's propeller. A spare transducer was installed and the survey was continued. The release location determined by this final survey was 18°00.49'N, 34°01.89'W. The release on mooring 924 and on mooring 954 were both disabled. The ship then returned to the Southwest buoy where meteorological observations were made every five minutes for four hours. The ship then got underway for the Central mooring. While enroute to the central mooring site five shallow CTD stations were made. Two of the five stations were conducted at the same location.

Central Mooring

The ship arrived at the Central mooring buoy at 0635 UTC on 14 October 1992 at which time meteorological observations were made every five minutes for four hours. Figure 18 shows the Central mooring deployed in February 1992.The acoustic release was fired at 1203 UTC and the ship moved to recover the buoy. Some difficulty was experienced in getting the buoy connected to the primary lifting line. This was in part due to the thickness of the bales on the buoy. The line that went to the HIAB crane to be used to direct the buoy out away from the stern quarter was connected to the tower top ladder. The buoy came up hard on this line and broke the rail of the ladder and as a result became free of that tag line. Fortunately the buoy was far enough aft at that point that it continued to travel around behind the ship. The only damage that occurred was to the ladder. The intermediate set of glass balls were reported on the surface 42 minutes after firing the release. The bottom set of glass balls were sighted as they came to the surface 54 minutes after the release was fired. The remainder of the recovery proceeded without any problems. Recovery of the acoustic release occurred at 1834 UTC 14 October 1992. Two glass balls recovered from the lower cluster had imploded. Hardware recovered from the Central mooring was labelled and put aside for possible future dynamic testing.

The upper VMCM at 10 meters depth (VM002) was recovered with the remnants of plastic attached to the upper horizontal cross member of the cage. The upper rotor was stiff and had pieces of plastic wound in around the hub of the propeller. The propeller was sluggish. Plastic was also wound around the lower rotor of the 30 meter instrument (VM023). All propeller bearings were in excellent condition and there were no broken propeller blades. The VMCM at 750 meters (VM029) flooded during deployment and did not collect any data. All the other VMCMs appeared in good condition.

The Brancker temperature loggers recovered from the Central mooring recorded data for the full deployment. All VAWR sensors with the exception of relative humidity recorded data for the full deployment. Relative humidity failed prematurely on 28 May 1992. The IMET system operated from the time of deployment to 16 April 1992.

Following the mooring recovery a 2000 meter depth CTD station was conducted along with a 3000 meter depth station in an attempt to sort out a discrepancy between water sample salinity and CTD readings. The ship was then positioned 5 miles to the east of the target position. The deployment began at 0301 UTC. Figure 19 is a mooring drawing of the Central mooring deployed during Darwin cruise 73. The upper instrumentation and surface buoy were deployed without any problems. The anchor was dropped at 1023 UTC 15 October 1992. Following the deployment an acoustic release survey was conducted. The results of that survey are shown in figure 20. **The anchor position for the third setting of the Central Subduction mooring (WHOI mooring number 955) was 25°31.93'N, 28°56.52'W.** The water depth at the site is 5670 meters corrected (+65 meters correction as per the Echo Sounding Correction Tables area 18). The sound speed for the area is 1517 meters per second. The anchor of the Central mooring fell back approximately 370 meters or 6.5% of the water depth.

Figure 18. Subduction 2 Central Mooring Schematic

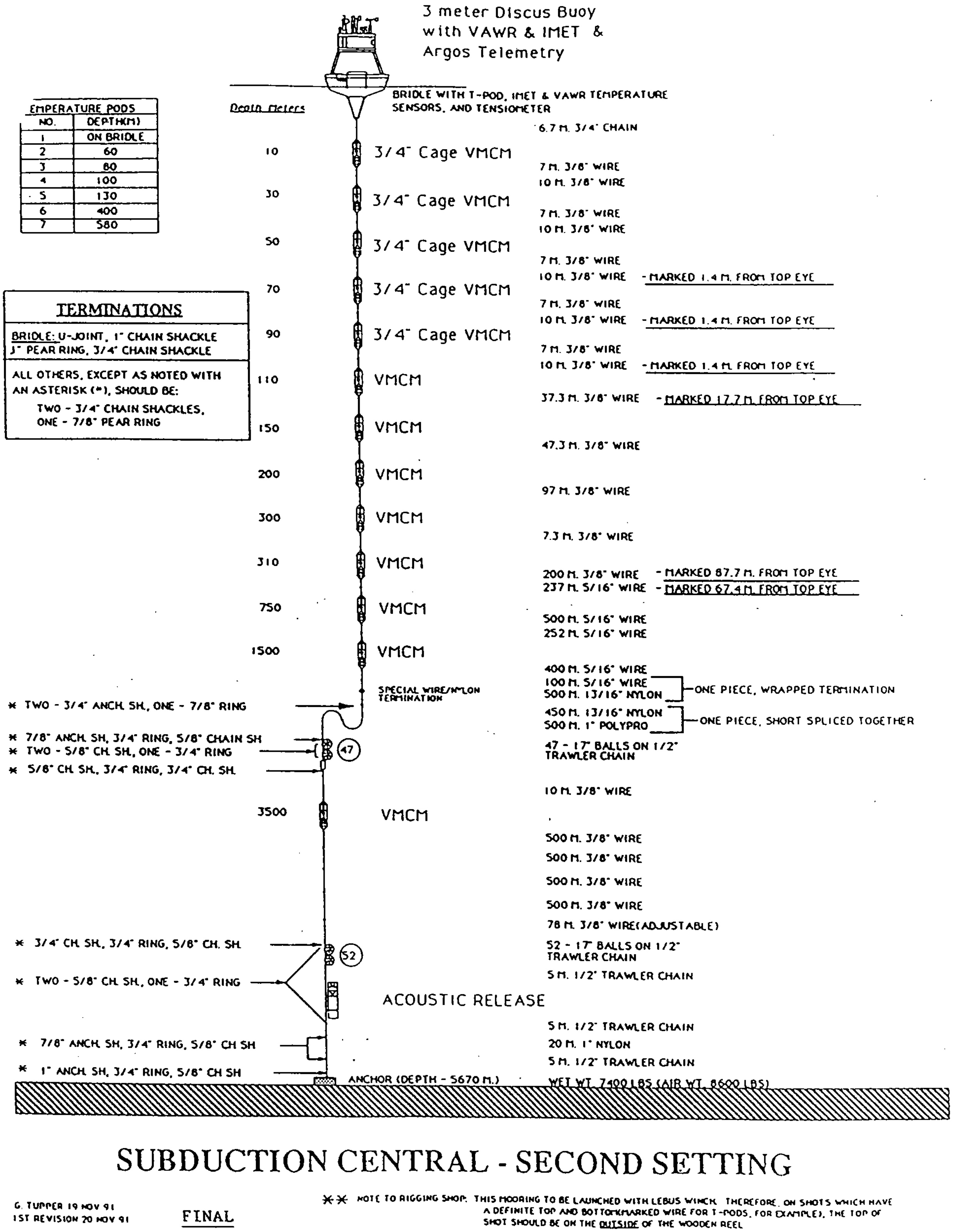
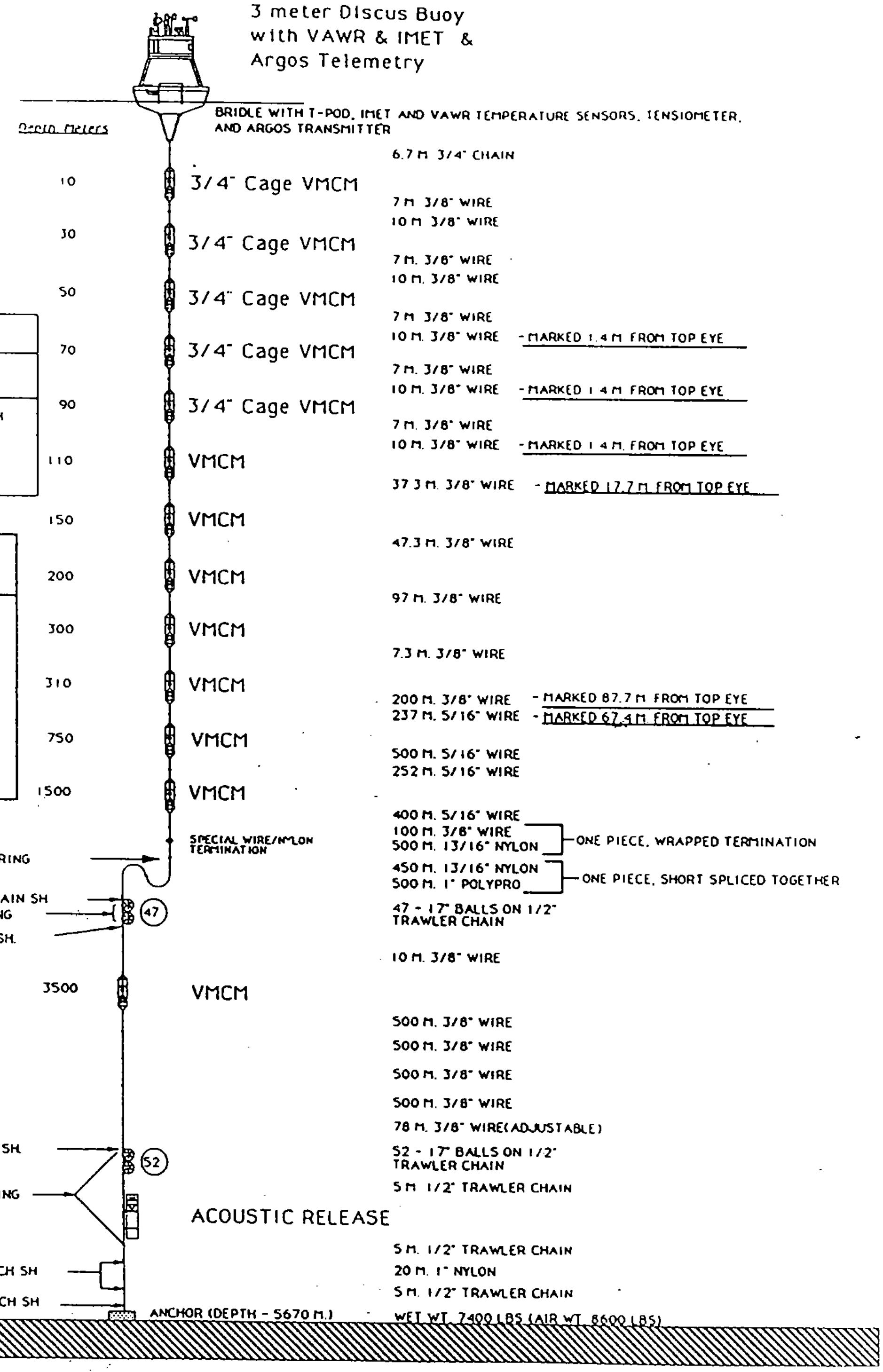


Figure 19. Subduction 3 Central Mooring Schematic



TEMPERATURE PODS	
NO	DEPTH(M)
1	ON BRIDLE
2	60
3	80
4	100
5	130
6	400
7	580

TERMINATIONS

BRIDLE: U-JOINT, 1" CHAIN SHACKLE
1" PEAR RING, 3/4" CHAIN SHACKLE

ALL OTHERS, EXCEPT AS NOTED WITH AN ASTERISK (*), SHOULD BE:
TWO - 3/4" CHAIN SHACKLES,
ONE - 7/8" PEAR RING

HARDWARE REQUIRED
(INCLUDES APPROX. 20% SPARES)

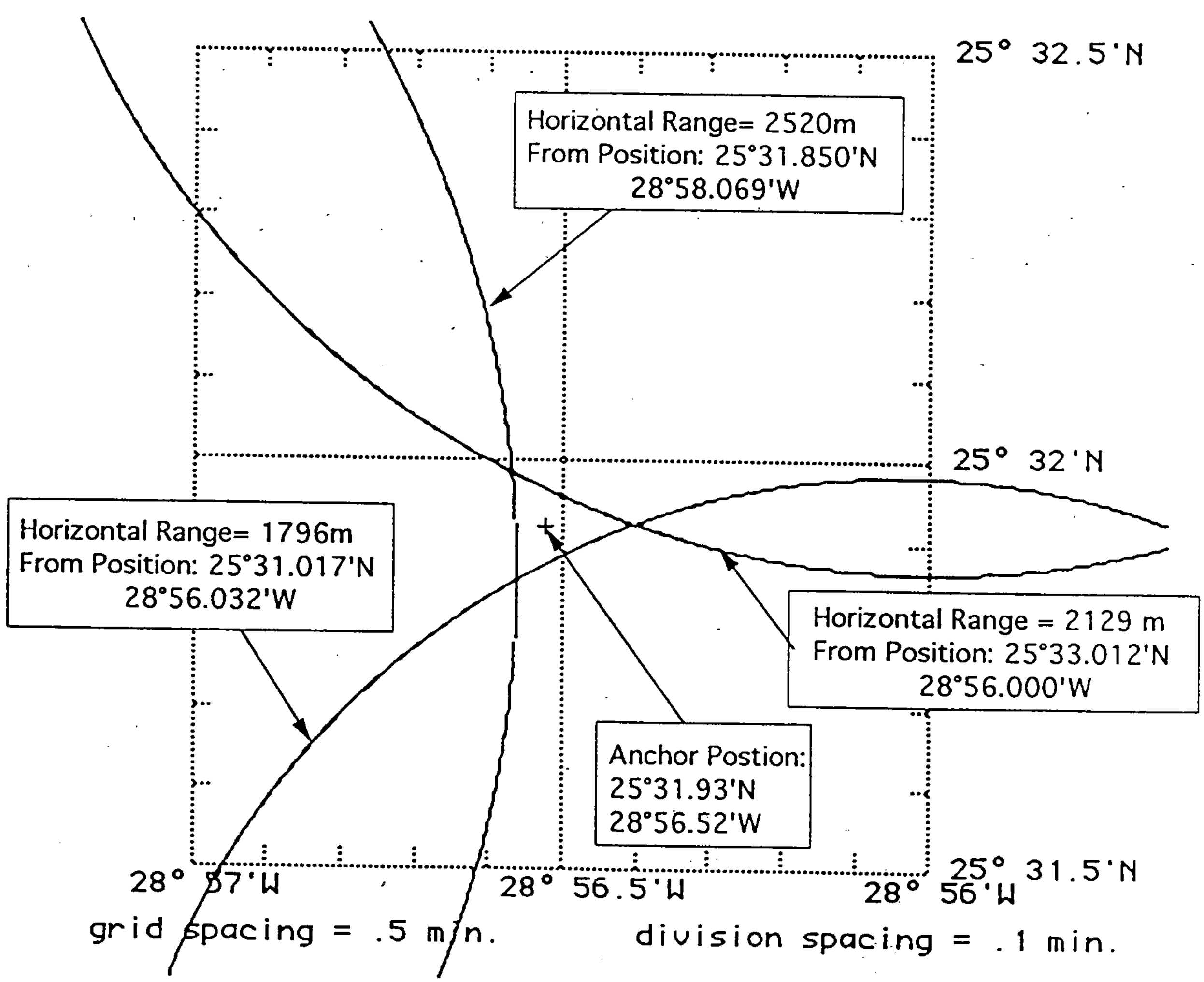
1" CHAIN SHACKLES	2
1" PEAR RINGS	2
7/8" ANCHOR SHACKLES	6
7/8" PEAR RINGS	47
3/4" CHAIN SHACKLES	95
3/4" ANCHOR SHACKLE	3
3/4" PEAR RINGS	42
5/8" CHAIN SHACKLES	72

SUBDUCTION CENTRAL - THIRD SETTING

G TUPPER 23 JUN 92

Figure 20. Subduction 3 Central Acoustic Release Survey

Subduction 3
Central Mooring
Mooring Number 955
Acoustic Release Survey
15 October 1992



Following the anchor survey the ship was positioned .25 miles from the buoy and meterological observations were made every five minutes for four hours. The ship then got underway for the next CTD station to the northeast. A total of 14 shallow (500 meter) CTD stations, 2 intermediate depth (1000 meter) and 1 deep (2000 meter) CTD station were conducted while transiting to the Northwest mooring site.

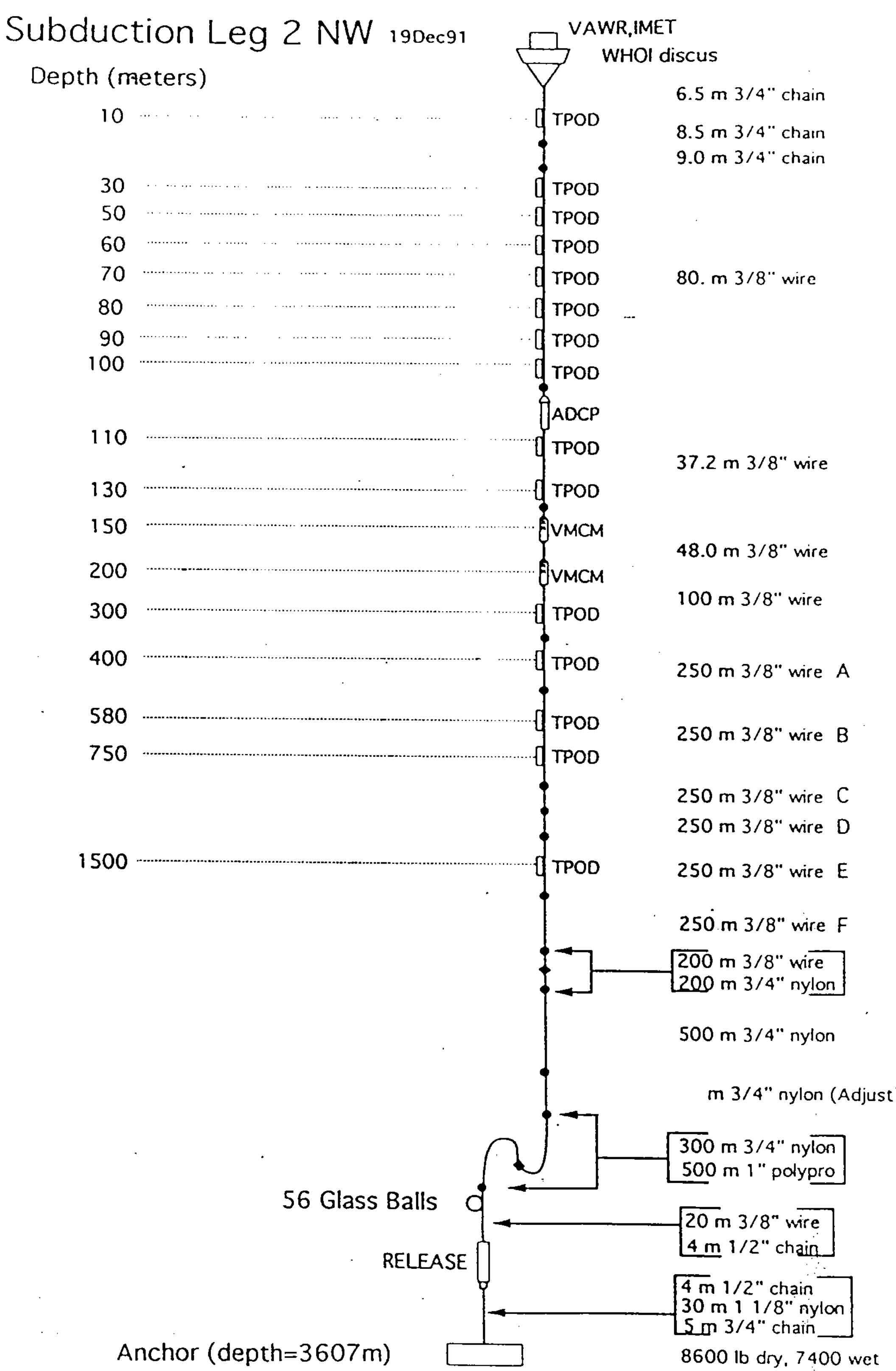
The weather deteriorated on Tuesday 20 October 1992 while enroute to the Northwest Mooring and the ship slowed to only 2 to 3 knots for a period of 48 hours. Winds were typically 35 to 40 knots with gusts to 45 knots during this time. The last three shallow CTD stations scheduled just prior to arriving at the Northwest mooring could not be done. While waiting for the weather to improve a deep (3000 meter) CTD station was done near the mooring site. The intense four-hour long meteorological observations were also made while waiting for the weather to improve. The first opportunity to recover the Northwest mooring came on the morning of 23 October 92. Figure 21 is a mooring schematic of the Northwest mooring. With winds still gusting to 30 knots and a moderate sea the ship was maneuvered to recover the discus buoy. The release was fired at 0902 UTC and the ship moved in to pick up the buoy. Given the sea state it was difficult to get the lifting lines into the bales but after several attempts all lines were in place. Despite revised plans for the buoy recovery it still sustained moderate damage. As the buoy passed aft the solar panel crash bar got caught under the starboard quarter shelf and the welds were broken. Fortunately the solar panel did not break free completely and was able to be recovered. As the buoy was brought through the stern gantry the Argos antenna was struck against the gantry and the 18" PVC extension was broken mid span. The VAWR wind direction cage was also hit and broken. The glass balls and release came aboard at 1352 UTC.

During deployment in February 1992 there was a question as to whether the 80 meter shot of wire with temperature recorders was deployed right side up or upside down. The top of the shot was marked "80 m TOP" on recovery with hopes of being able to distinguish where the recorders were located from their marks. It would have been very easy to identify whether the shot had been deployed correctly since the 30 meter temperature recorder was to be only one meter from the upper termination. However on recovery it was found that that 30 meter instrument had slid down to the 50 meter instrument on that shot, which made the determination more difficult. This shot will be laid out and inspected after the cruise.

Nine WHOI Brancker temperature recorders were recovered from the Northwest mooring. All nine recorded reasonable data for the entire deployment. There were seven SIO temperature recorders on the Northwest mooring and all wrote data. None of the temperature recorders had any evidence of leakage. One of the two SIO VMCMs failed just before the anchor was deployed in February 1992. The other VMCM worked for approximately four months up until the middle of June 1992. The ADCP wrote data to memory but the quality of the data could not be determined at the time of this writing. The IMET system on the buoy recorded files up until 17 October 1992. The optical disk was found ejected from the LOPACS when the buoy instrument well was opened. The VAWR failed to record data past the beginning of April 92.

There was evidence of water in the buoy instrument well when opened following recovery. It appeared to have entered the well through the top access plate. Corrosion products appeared below the top access pipe in the well. No more than half an inch of water was found on the bottom of the well after the well insert was removed for shipping. Evidence of fishbite was seen in the sea surface temperature cables.

Figure 21. Subduction 2 Northwest Mooring Schematic



Due to a shortage of temperature recorders resulting from not recovering the Southwest mooring it was necessary to use two instruments that were recovered from the Northwest mooring and redeploy them for the third setting. Those instruments had to be selected on the basis of their performance during the previous deployment and based on the results of a calibration check done on board ship. The data processing and instrument preparation were started soon after the instruments were brought on board.

While the temperature recorders were prepared and the majority of the mooring crew rested a deep CTD station was conducted. Following the CTD the ship was positioned 4 miles downwind of the target position in preparation for deployment. The deployment of the upper instrumentation and the discus buoy began at 1904 UTC 23 October 92. A mooring schematic for the third setting of the Northwest mooring is shown in figure 22. One problem encountered during deployment involved the wire-to-nylon shot. At the bottom of the reel on which the wire-to-nylon shot was wound the end of the nylon was not terminated with a thimble. Not knowing whether the length of the shot was correct it was recovered and a spare wire-to-nylon shot was substituted in its place. The spare shot had been prepared by SIO and was therefore slightly different from the standard WHOI product. This unexpected delay resulted in getting to the target position sooner than planned so the deployment proceeded right through to anchor drop without the need for towing the mooring into place. The anchor was dropped at 0017 UTC 24 October 1992.

During the first two hours following the deployment of the upper instrumentation and buoy, intense meteorological observations were made every five minutes. This was done as a time saving measure to make up time lost during the inclement weather. Following the anchor deployment and allowing time for the anchor to reach the bottom an additional one hour of intense meteorological observations were taken. The anchor survey shown in figure 23 followed. **The anchor position of the Subduction 3 Northwest mooring (WHOI mooring number 956) was 32°54.38'N, 33°53.58'W.** The water depth at the time of anchor drop was 3621 meters. The correction applied to the depth recorder reading was +14 meters (area 16/18 "Echo Sounding Correction Tables").

Following the anchor survey the release on the Northwest mooring was disabled. The ship then got underway toward the Azores. While enroute to the Azores 12 shallow (500 meter), and one deep (2000 meter) CTD station were taken. The meteorological watch was terminated at 1600 UTC on 24 October 1992. The ship arrived in Ponta Delgada on Monday 26 October 92 at 0900 UTC.

Figure 22. Subduction 3 Northwest Mooring Schematic

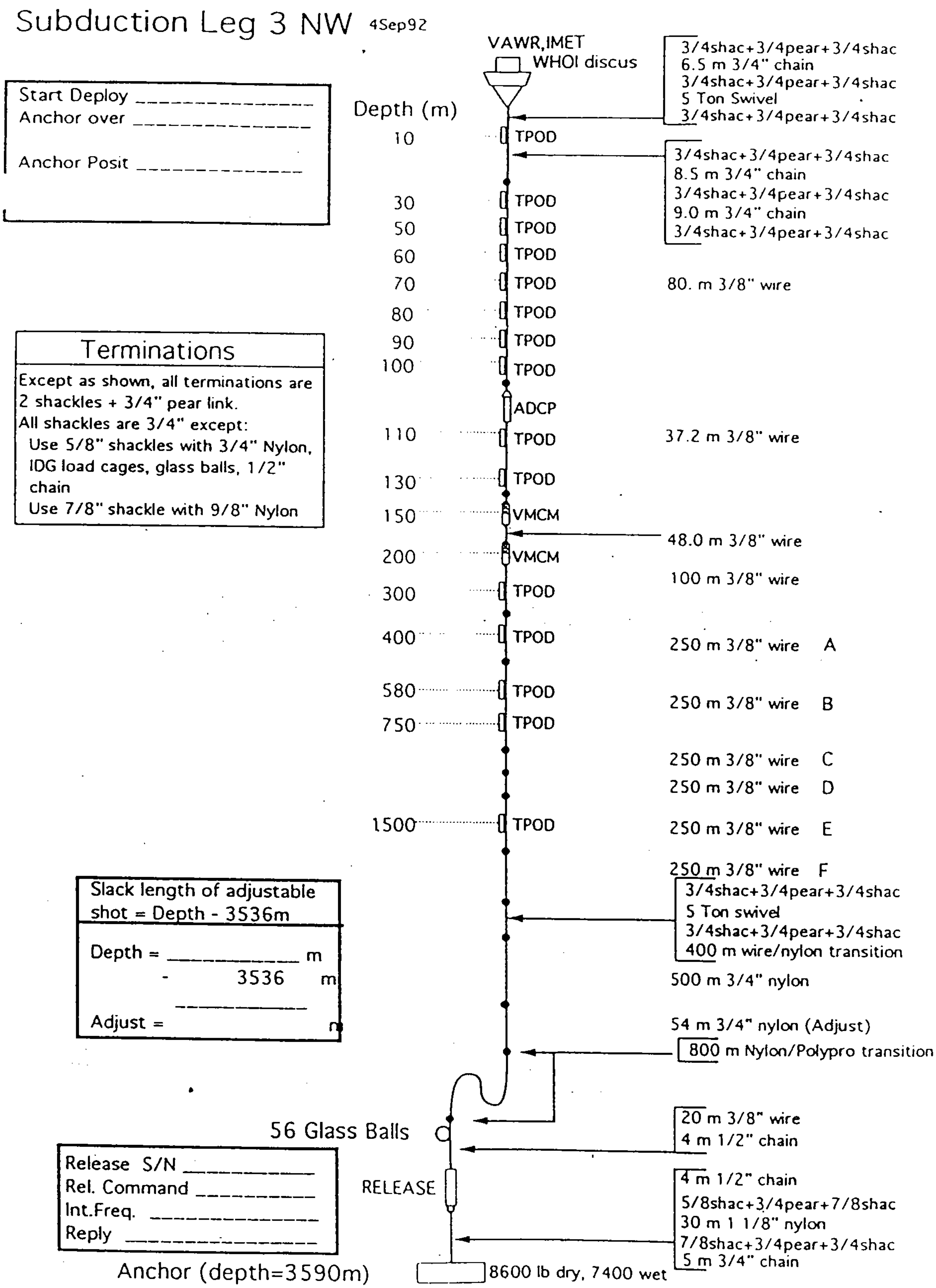
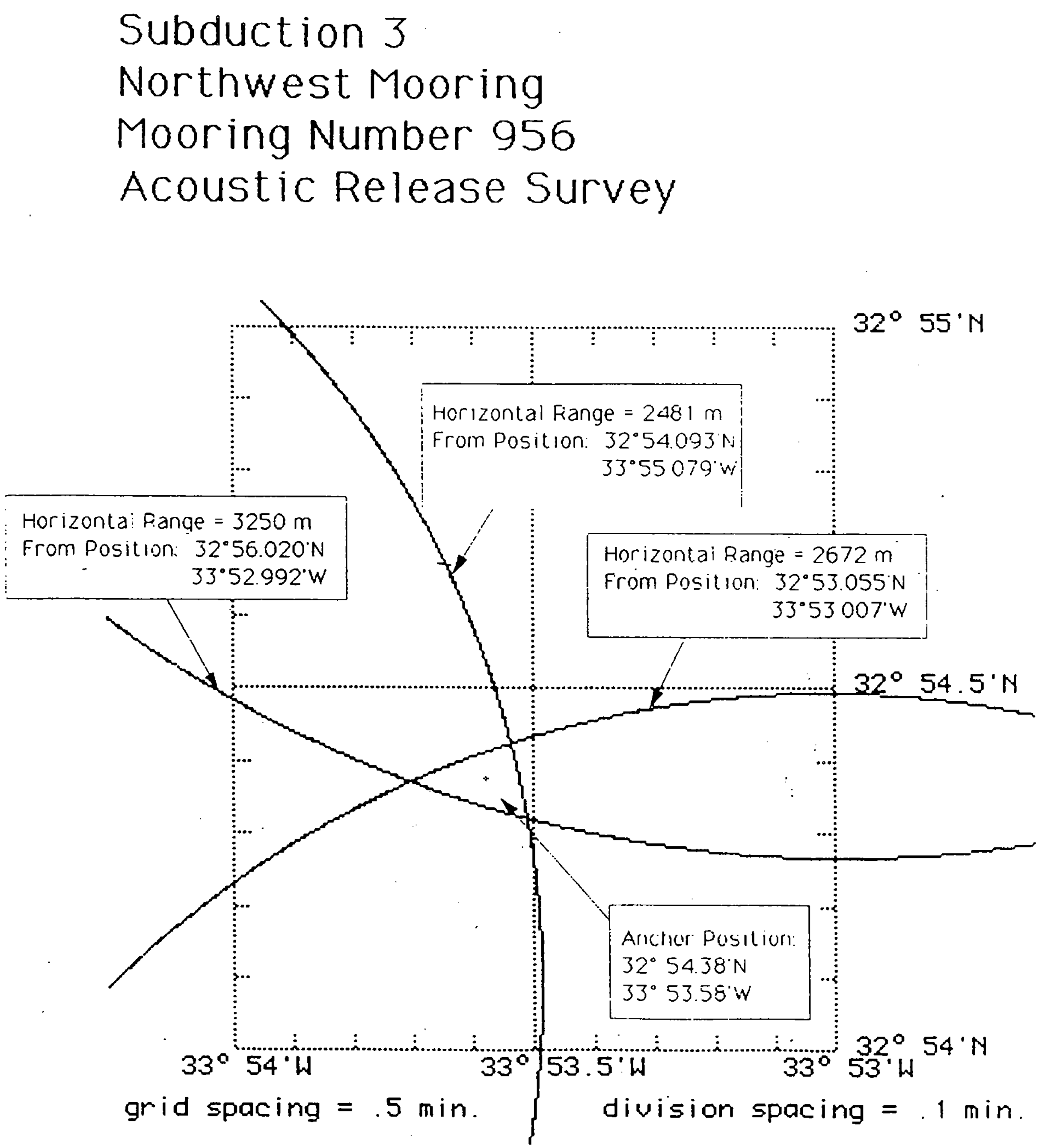


Figure 23. Subduction 3 Northwest Acoustic Release Survey



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Trask, Richard P., Nancy J. Brink, Lloyd Regier and Neil McPhee, 1993. The Subduction Experiment, Cruise Report, R/V Oceanus Cruise Number 250, Woods Hole Oceanographic Institution Technical Report, WHOI-93-13, 102 pp.

Acknowledgements

The WHOI moorings deployed during RRS Charles Darwin cruise number 73 were designed by George Tupper and carefully prepared by the WHOI Rigging Shop under the direction of David Simoneau. The instrumentation that was deployed on these moorings was carefully prepared by Bryan Way, who also provided invaluable assistance through the entire cruise both on deck and in turning around instrumentation for deployment.

We are grateful for the skill of Captain McDermott and the assistance provided by all the crew members of the RRS Charles Darwin. Glenn Pezzolli and Steve Abbott from Scripps Institution of Oceanography were extremely helpful as usual during all of the mooring operations. The redeployment of the best operating instrumentation would not have been possible without the efforts of Nan Galbraith and Melora Samelson who processed the recovered data quickly to permit an evaluation of instrument performance. Several new faces to the complement of people that usually participate on the Subduction mooring cruises were a pleasant addition. Those people included Marshall Swartz, Peter Landry and Dave Wellwood who were involved with the tracer/hydrography part of the Subduction experiment. We sincerely thank Bob Weller and Nancy Brink for their help in preparing this report.

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Appendix 1 Cruise Personnel

Richard Trask	WHOI	Chief Scientist
William Ostrom	WHOI	
Bryan Way	WHOI	
Neil McPhee	WHOI	
Nancy Galbraith	WHOI	
Richard Payne	WHOI	
Melora Samelson	WHOI	
Steve Abbott	SIO	
Glenn Pezzolli	SIO	
Jeff Sherman	SIO	
Marshall Swartz	WHOI	
Peter Landry	WHOI	
William Jenkins	WHOI	
Dave Wellwood	WHOI	
Mike Davies	NERC RVS	
Colin (Berni) Woodley	NERC RVS	
Adrian (Triff) Fern	NERC RVS	

Appendix 2

SUBDUCTION 3
IMET SUMMARY

Arrived Funchal, Madeira, 17 Sept. 1992. The first few days were spent unpacking, rearranging the containers and setting up the lab van. When this was completed the tower tops were uncased and inspected. There were no signs of damage and all the clamps were secure. The wind modules' top cap, stem and encoder which had been removed and shipped separately were now reinstalled.

A cable was connected to each junction box in turn and the modules checked for proper response using the standard RS 485 test assembly. All modules responded and returned reasonable values. The Northeast tower top was connected to the Northeast LOPACS and run for a few hours with no problems.

A relatively "clean" area was found, headings established and the tower tops "spun" to establish compass and wind direction integrity. Again no problems were found.

The Northeast tower top was installed on the buoy hull, cabling connected and the LOPACS installed. Wiring was completed and secured and the buoy made ready for loading aboard ship.

CRUISE PLAN

(For more specific information please refer to the cruise report)

There were five buoys involved in this trip, four discus and one torroid. The discus were instrumented with both IMET and VAWR while the torroid only had a VAWR. The torroid mooring at the SW had previously failed and the torroid recovered, so only the remainder of the mooring needed to be retrieved.

The buoys were visited in the following order:

NE - SE - SW - C - NW

About 50 CTD stations were planned between the buoys and on added legs.

NORTHEAST 2 RECOVERY

We arrived on scene 1 October 1992. All ARGOS ID's were received via Telonics and the buoy appeared in good physical shape.

The buoy tower top was damaged while alongside during the initial part of the recovery. The wind module was banged up, the bracket bent, and the tubes slightly separated at the connecting section. The SWR module was ripped from its bracket and only saved from being lost by its cable. A complete solar panel/crash bar assembly was torn off and lost.

After the buoy was recovered, set on deck and secured, the external coms cable was connected and the following noted:

Subduction acquisition program still running.

WND:	0, with prop spinning
BPR:	Good readings
HRH:	Stuck at 5%
TMP:	Good readings
SST:	Good readings
SWR:	Removed due to damage
PRC:	0
Battery:	12.45

Observed an attempted file write but error message indicated disk was full. Checked disk directory and found last file written on 3 Sept. 1992. Due to media incompatibility found during last cruise and a shortage of the correct disks, the disk installed at the time was one which had been previously used.

Date/Time check: Actual- 11:04:00
LOPACS- 11:02:17

Ran buoycomm diagnostic program, WND, HRH, and PRC timed out.

No further diagnostics were performed at this time and the cable to the sensor j-box disconnected in preparation for the tower top replacement.

Note: There were signs of fish bite on all bridle cables. No conductors were exposed but the outer insulation was damaged in quite a few spots. More tygon tubing and tie wraps will be used on turned around buoy.

N.E. DATA ANALYSIS
(from optical disk)

Buoy was deployed 20 Feb. 1992, year day 51. ARGOS transmissions soon indicated that there were problems with quite a few of the sensors. Extensive drop-outs for TMP, SST, and BPR. RH, PRC, and SWR seemed to have failed completely. A review of the optical disk data confirmed these problems.

SWR:	Good, data until 27 Feb. when it quit.
TMP:	Good and clean until 29 Feb. but drop-outs increased after that. It did track with the VAWR very well until the end.
SST:	Same as TMP, good comparison with VAWR, drop-outs not considered.
BPR:	Good, some noise (drop-outs) after 10 March. Drop-outs increased dramatically after 31 May, but still tracking with VAWR.
PRC:	Appears N.G. from start.
HRH:	Same as above.
WND:	No drop-outs until 31 May when it failed completely. Until then it worked well with a wind speed slightly lower than VAWR. WD was also lower by about 10 deg.
Tension:	Good data throughout. Showed launch tensions well.

NORTHEAST 3 DEPLOYMENT

After a problem free burn-in at WHOI, this buoy was assembled and tested on the dock in Madeira with no problems noted. Pre-deployment checks included a review of the disk files written since the start to insure a file of the proper length was written each hour, a date\time check, and tension cell response. VAWR and IMET ARGOS data were also compared and found in agreement.

The Optical disk installed is SN:000101657

The buoy was deployed 2 Oct. 1992. The 4 hour intensive met period following the deployment showed good agreement between the hand obs, VAWR and IMET. Tension also was responding well. (See Telonics files IMETNE3.276 and GTSNE3.276)

BUOY TURNAROUND

The minimum requirements for buoy turnaround were the same for all three buoys with additional procedures as noted.

ARGOS PTTs were removed from the recovered tower tops, checked for power output, reprogrammed with the SUB3 ID's, and cases prepared for redeployment.

New SST modules were installed using the new style bracket.

The Tension cells were removed, cleaned, checked for proper operation and reinstalled.

All bridle cables were checked for fish bite.

IMET system gel cells were checked for proper voltage and solar panels and regulators for proper operation.

The LOPACS was inspected for any signs of corrosion or physical damage. The MEMIO board was removed and the acquisition program EPROMS replaced with the new version. The memory back-up batteries were also checked. A new optical disk was inserted into the LOPACS.

BUOY TURNAROUND: N.E. to S.E.

Inserted new optical disk (sn:000101282). New program booted OK, all modules responding with believable numbers. All new ARGOS ID's being received.

Connected tension cell simulator at connector to cell.
Set to 1.0v., ARGOS output via Telonics was 27hex = 39dec = 1.0v.
Set to 2.0v., 4fhex = 79dec = 2.02v
Removed simulator and connected to load cell (sn:43844), used crowbar and C clamp to apply load, good response.

Connected to ext. comms cable and observed disk write. Just prior to deployment checked files written since start-up. All written and of proper length.

RECOVERY OF SUB2 SOUTHEAST

Arrived on scene for recovery 6 Oct. 1992

No ARGOS transmissions from IMET were received while near buoy prior to recovery.

Drive by of buoy showed it to be filthy. Deck was black with slime/ooze, hull very thick with growth, and the tower top coated with red dust, especially on the windward surfaces.

Buoy was recovered without damage and when secured on deck and the external comms cable attached there was no response. The well was opened and the main LOPACS fuse was found to be blown. Replaced fuse and program began running with all modules responding. Disk check showed last file was written 15 Sept. All ARGOS ID's also began transmitting at this time.

Date\time check: Actual- 09:27:00
LOPACS- 09:25:40

No modules were damaged, the wind speed propeller and vane turned freely, despite the covering of dust, and there was no indication of fishbite on any bridle cables.

S.E. DATA ANALYSIS

(from optical disk)

SST:	Slightly higher than VAWR but matched Brancker temp pod on bridle.
SWR:	Excellent overlay with VAWR.
TMP:	Same as VAWR
BPR:	Higher than VAWR by ?
HRH:	Slightly lower than VAWR, spread increased with time.
WND:	Direction was higher than VAWR from the start but took a sudden jump even higher on 1 April. This occurred concurrently with a weather anomaly seen on both IMET and VAWR. The wind speed tracked VAWR speed exactly.
PRC:	Level showed changes over course of deployment, no noise or dropouts Data appears good.
Tension:	Was working well until 13 July when the tension cell failed.

The three modules which need to be investigated further are humidity, barometer and wind. With the exception of the wind it is not clear if the problem is with the IMET or VAWR.

The LOPACS failure due to a blown fuse is at this time not explained. Voltage and current checks, especially of the Optical disk system, did not show any abnormalities. The system had run perfectly for 7 months, and had run without glitch on deck since turnaround.

The LOPACS failure due to a blown fuse is at this time not explained. Voltage and current checks, especially of the Optical disk system, did not show any abnormalities. The system had run perfectly for 7 months, and had run without glitch on deck since turnaround.

DEPLOYED AT S.E. 7 October 1992.
(Y.D. 281)

4 hr post deployment check showed buoy was working properly.

Met data output via ARGOS is good and compares well with VAWR and hand obs. (See Telonics files IMETSE3.281 and GTSSE3.281)

TURNAROUND: S.E. TO CENTRAL

Checked LOPACS internal voltages and current draws. Inspected connectors and components on power supply boards. No problems found which would explain the blown fuse.

Inserted optical disk (SN 000102950) and observed disk write. All new modules responded well and ARGOS data looked good.

Installed tension cell simulator at cable connector to cell:
Set to 1.0v   ARGOS output via Telonics: 1.0v
Set to 3.0v   "   : 3.02v
Removed simulator and connected to new tension cell. No load output is 0.15v. Output increased when load was applied.

RECOVERY OF SUB 2 CENTRAL

Arrived on scene for recovery 14 Oct. 1992. ARGOS data from this buoy was good until the end of day 106 (15 April 1992) at which point all values went off scale. ARGOS from the buoy when in sight, using the TSUR involved all 4 ID's, the first ID sending the default values, the other 3, 0's. This seemed to vary during the pre-recovery time, occasionally only the first ID was being received with bad values. This may have been due to it's getting stepped on by other transmissions.

With the buoy recovered and secured on deck, the external comms cable was connected. There was no indication the acquisition program was still running or any response when reset. Opening the well and observing the Telebyte showed the RD light constantly lit but the RTS and TD lights did flash on the minute as if attempting to communicate.

Since there was no access to the logger via the external comm port it was not possible to check the date/time or disk operation.

CENTRAL 2 DATA ANALYSIS
(from optical disk)

The Central discus buoy was deployed 12 Feb. 1992. The last file written to optical disk was on 13 Aug. 1992 but the last file containing good data was on 16 April 1992. Until then all the modules were responding and the data comparison with the VAWR is good. All the modules ceased responding at the same time which along with the other symptoms noted seems to indicate a LOPACS failure.

Even though this LOPACS is not going to be redeployed for this experiment the reason for its' failure was investigated. The symptoms exhibited, no module response, no external comms, seemed to indicate a failure in the input/output section of the MEMIO board. The HCT04 hex inverter used to drive the RS 232 output being the prime suspect. When this was replaced, the subduction program ran and the modules responded. This failure has been observed before but only when very long or mis-wired cables had been connected to the external comms port of the LOPACS.

Since the Telebyte 232/485 converter is an effective buffer preventing module failure from affecting the LOPACS the exact reason for the failure is at this time unknown.

Tension readings were bad from the start and a post recovery check showed the cell itself to be bad.

A clock check gave the following results:

Actual:	08:52:00
LOPACS:	08:49:10

DEPLOYED AT CENTRAL 15 OCT. 1992

Post deployment met ops indicated all modules working well. (See Telonics files IMETC3.289 and GTSC3.289). Tension also appeared to be functioning properly.

TURNAROUND: CENTRAL TO N.W.

The primary concern with this buoy was the failure of the LOPACS. A spare LOPACS, having been assembled and burnt in during the summer, was available and installed. Optical disk SN: 000104335 was inserted. All modules responded and all ID's were transmitting.

A new tension cell was installed, SN:? The tension cell simulator was installed with the following result

Set: 1.0v ARGOS output via Telonics was 27hex=39dec=1.0v
Set: 3.0v " 77hex= =3.05v
Connected to tension cell. No load was 0.202v and stable. Values increased when a load was applied.

RECOVERY OF SUB3 N.W.

Arrived on scene for recovery 23 Oct. 1992. ARGOS transmissions were received and checked good during the pre-recovery met-obs. Seas were running 6 to 10 ft with 25 kt winds, even so the pickup and recovery went well. The only damage being a broken crash bar weld, a broken ARGOS antenna PVC extension base, and minor damage to the VAWR wind cage.

When on deck, secured and the external comms cable attached the acquisition program was running and all the modules were responding properly. The battery voltage did seem low at 11.81 vdc.

Date/time check:

Actual:	08:54:00
LOPACS:	08:51:49

When a disk file check was attempted an error message indicating the disk cartridge was not present (ejected) was returned. The well was opened at this time and the disk was found to have been ejected. The disk was reinstalled without problem and a file check indicated the last file written was 17 Oct. 1992 or just 6 days before recovery.

The low battery voltage leads to the suspicion it may be to blame for the ejection. A review of the SWR readings prior to the failure however don't indicate any prolonged periods of attenuated sunlight which would have affected the battery charging solar panels.

It did appear that water had recently entered the buoy well since all surfaces were moist and some signs of early corrosion were visible.

SUB 2 N.W. DATA ANALYSIS

All IMET modules appeared to function well. Data recorded until the disk ejection appears good, without drop-outs or noise. The VAWR had failed earlier so data intercomparison is not possible for this buoy.

Appendix 3 Subduction VMCMs

Instrument No.	Sub 1	Sub 2	Sub 3
1		C-1500	
2		C-10	
3		C-3500	
7	SE-30		
8		C-110	
9	C-110	NE-150*	C-150*
10		SE-30	
11	C-3500	NE-200*	C-1500*
12	C-70		NE-50
13		C-70	
14		NE-70	NW-150
15	C-750		NE-150
16	C-200		NE-200
17		C-300	
18	NE-200		C-30
19		C-90	
20		C-50	
21	NE-30		NE-30
22	NE-90		SE-30
23		C-30	
24	C-50		C-50
25		C-200	
26		C-150	
27		NE-30	C-310
28	NE-150		C-90
29		C-750	
30	NE-110		C-70
31		C-310	
32	NE-70		C-10
33	C-30		NE-70
34	C-1500	NE-10	C-200
35	C-10	NE-110	C-300
36		NE-50	C-750
37	C-150		NE-90
38	C-90		NE-10
39	NE-50		C-110
41	NE-10		NE-110
45		NE-90	C-3500
SVM-01		SW-10	
SVM-02	SW-90		SW-10
SVM-03		SE-10	NW-200
SVM-04	SW-10		SW-110
SVM-05	SW-110		
SVM-06	SW-50		SE-10
SVM-07	SW-30		SW-50
SVM-08		SW-50	
SVM-09		NW-150	
SVM-10	NW-200		
SVM-11	NW-150	SW-150	

Instrument No.	Sub 1	Sub 2	Sub 3
SVM-13	SW-200		SW-90
SVM-14		SW-90	
SVM-15		SW-70	
SVM-16	SE-50	SW-30	
SVM-17		SE-50	
SVM-18		SW-200	
SVM-19			SW-200
SVM-20	SW-150		SE-50
SVM-21		NW-200	
SVM-22	SW-70		SW-30
SVM-23			SW-70
SVM-24			SW-150

* = Reused sting from previous deployment

Appendix 4 Subduction Brancker Temperature Recorders

Instrument No.	Sub 1	Sub 2	Sub 3
S-2418	SE-150		SE-70
S-2420	NW-750		SE-110
S-2421	NW-300		SW-130
S-2422	SE-400		SE-100
S-2423		SE-400	
S-2424	SE-200		SE-130
S-2425	SE-110		SE-300
S-2426	SE-750	NE-750	
S-2427	SW-130	NE-1500	
S-2428			SE-90
S-2429		SW-750	
S-2430		SW-400	
S-2431	NW-400		
S-2432	SE-130		SW-60
S-2433	SE-300		SE-200
S-2434	NW-130	SE-750	
S-2435	SW-300		SW-300
S-2436	SW-750		SE-80
S-2437	SW-400		SE-150
2533		C-400	NW-90
2534		C-80	
2535		NW-110	
2536		NW-90	
2537		C-100	NW-70
2538		C-130	
2539		NE-60	SW-80
2540		NW-100	
2541		C-60	NW-59
2542		NE-80	SW-580
3258	NW-100	SW-1500	
3259	SE-1500		NE-80
S-3260	NW-80	NE-300	NW-300
S-3261	NW-90	SE-80	
3262	NW-60	C-580	NW-1
3263		SW-80	
3265	NE-80	NE-130	C-100
3268	NE-580		
3269	NE-130	NW-80	
S-3270	SE-80		
3271	C-580		SE-1500
3272	NW-580		
3273	NW-1500		
3274	NE-60	NW-30	NW-100
S-3275			SE-750
S-3276		NW-300	
S-3277	NW-110	NW-400	
3279	SW-80	SE-60	C-1
3280	C-130	NE-100	C-130
S-3281			NE-1500
S-3282	SE-70	NW-750	

Instrument No.	Sub 1	Sub 2	Sub 3
3283	C-400		NE-1
S-3284	SE-100	NW-1500	
S-3285	NW-10	SW-60	
3286	NE-750		
3287	SW-1500		
3288	NE-100	NW-50	
3289	C-300		
3290	SE-580		
3291		SW-100	
S-3292			SW-750
3293	NE-1500		
S-3294	NW-50	SE-130	
S-3295			SW-400
3296	C-100	NW-60	
3297	SE-60		SW-1
S-3298	SE-90	NE-580	
3299		SW-580	
3300	NE-300		
S-3302			NE-400
3303	SW-100	SE-580	C-60
S-3304			NW-1500
3305	NE-400		SE-1
S-3306			NW-10
S-3307			NW-580
3308	C-80		
3309	C-60	NW-70	NW-111
S-3310		SW-130	
S-3311			NE-580
S-3312			SE-400
S-3313	NW-70	NW-130	
S-3314	SW-60		NW-400
S-3315	NW-30		
S-3316		NW-580	
3341	SW-580	SE-1500	NW-30
S-3378			NE-750
3506		C-1	
3507		NE-1	
3508		NW-1	
3662			C-580
3665		SW-1	NW-80
3704		SE-1	
S-3706		SE-90	
S-3707		SE-70	
S-3708		SE-200	NW-750
S-3709		NW-10	
S-3710		SE-110	NW-130
S-3711		NE-400	
S-3712		SE-300	
S-3713		SW-300	
S-3714		SW-100	
S-3715		SE-150	

Instrument No.	Sub 1	Sub 2	Sub 3
4481			SE-60
4482			NE-130
4483			SW-1500
4485			NE-100
4487			SW-100
4488			NE-60
4489			C-80
4490			SE-580
4491			C-400
4492			NW-50
4493			NE-300

Appendix 5

Description of ALACE micro-temperature profiler

Time duration of microstructure data sets have generally been confined by the scientist's tolerance for staying at sea and by the funding agent's ability to pay for ship time. By perhaps mutual agreement (??) this seems to reach a maximum period of about 1 month. Microstructure data sets spanning a long time period have been lacking. This leaves a void in understanding the climatic variability of dissipation. The ALACE micro-temperature profiler (ALACE-mT) is an effort to alleviate this problem.

Based on the standard ALACE design, the ALACE-mT has been modified by adding two micro-temperature probes and a 200 mb hard disk. By using two probes, a cross-check can be performed on sensor health, along with some analysis of horizontal correlation of microstructure. It also increases the odds of having at least one probe survive a long deployment. The instrument profiles once every programmed time period. The cycle consists of the following steps: Oil is pumped into the external bladder, causing ALACE to rise. Enough time is alloted to ensure ALACE is at the surface. The bladder is then emptied. Micro-temperature data is recorded on descent and recorded to hard disk. The bladder is then partially filled, such that ALACE's neutral depth is approximately 300m. The instrument remains at this depth until it is time to perform the next profile. After a set number of cycles, ALACE-mT remains on the surface, transmitting to the Argos satellite system. The instrument is recovered by using the rough location provided from Argos, followed by a direction finder tuned to the Argos frequency.

For Subduction 3, ALACE-mT has been programmed to perform 200 profiles, one every 1.22 days, yielding a 244 day total deployment. Given that it was deployed 14 Oct. 92, it should start transmitting to Argos on 15 June 93. For each profile, data is recorded for 130 min. Descent rate should vary between 5-9 cm/s, corresponding to a profile depth in excess of 500m. Data from both probes are recorded at 30 Hz rate. Pressure is also sampled at 30 Hz, with 1 second averages recorded.

Instrument Description

The temperature probes and front-end electronics are manufactured by Sea-Bird Electronics (SBE). The temperature probe consists of a fast time-response thermistor (FP07). Its output is high-pass filtered on the SBE analog board, and then sampled by a 16-bit a/d. The a/d board is controlled by a TattleTale 6 computer with 1 Mb memory. At the end of each profile the data is written to hard disk. To supply the extra power required, three lithium 30 A-h battery packs are used in parallel. In case of a malfunction causing low battery voltage, the instrument will go into a low-power state for the remainder of the deployment, and then switch in a spare battery pack for final pumping of the bladder plus Argos transmission. Batteries should allow for 90 days of Argos transmission at the end of the deployment. To accomodate the added electronics and batteries, the standard ALACE pressure case has been stretched 30 cm, for a total length of 113 cm and in-air weight of 33 Kg.

Appendix 6

XBT Data

Two hundred and one XBTs were deployed during Darwin-73. The T-7 probes were purchased from Sippican Inc. of Marion,Massachusetts. The XBT data were logged on a NEC APC IV which had a Spartan of Canada Ltd. data acquisition microprocessor card installed. The digital data was simultaneously logged in memory and plotted on the screen.

Figure A6-1(a through aa) shows the XBT profiles in groups of ten. Table A6-1 contains the positions and time of the XBTs. Figure A6-2 shows the positions of the XBTs.

Figure A6-2a Overplot of XBT Profiles 48-49
Successive Profiles are offset by 1° C

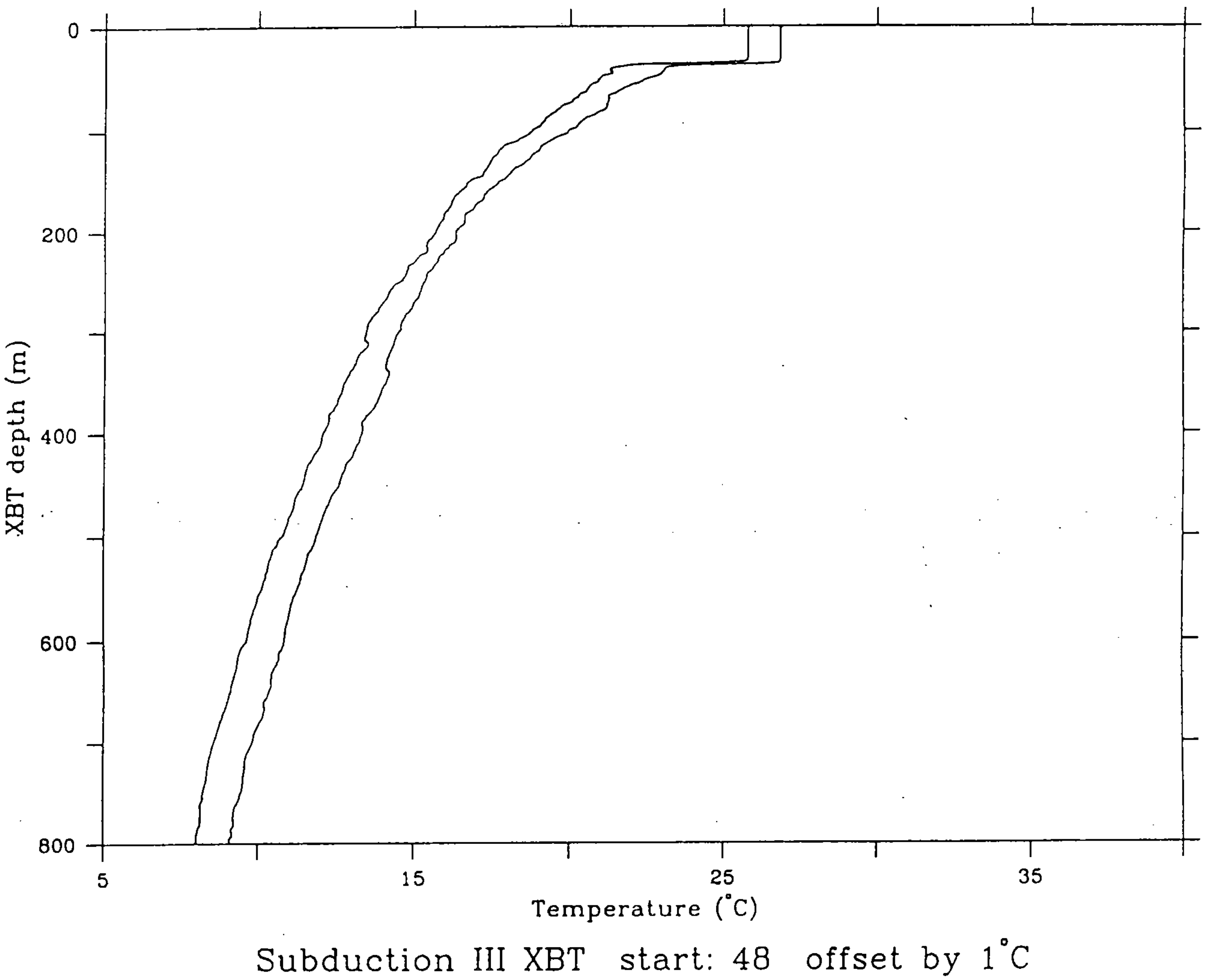


Figure A6-2b Overplot of XBT Profiles 50-59
Successive Profiles are offset by 1° C

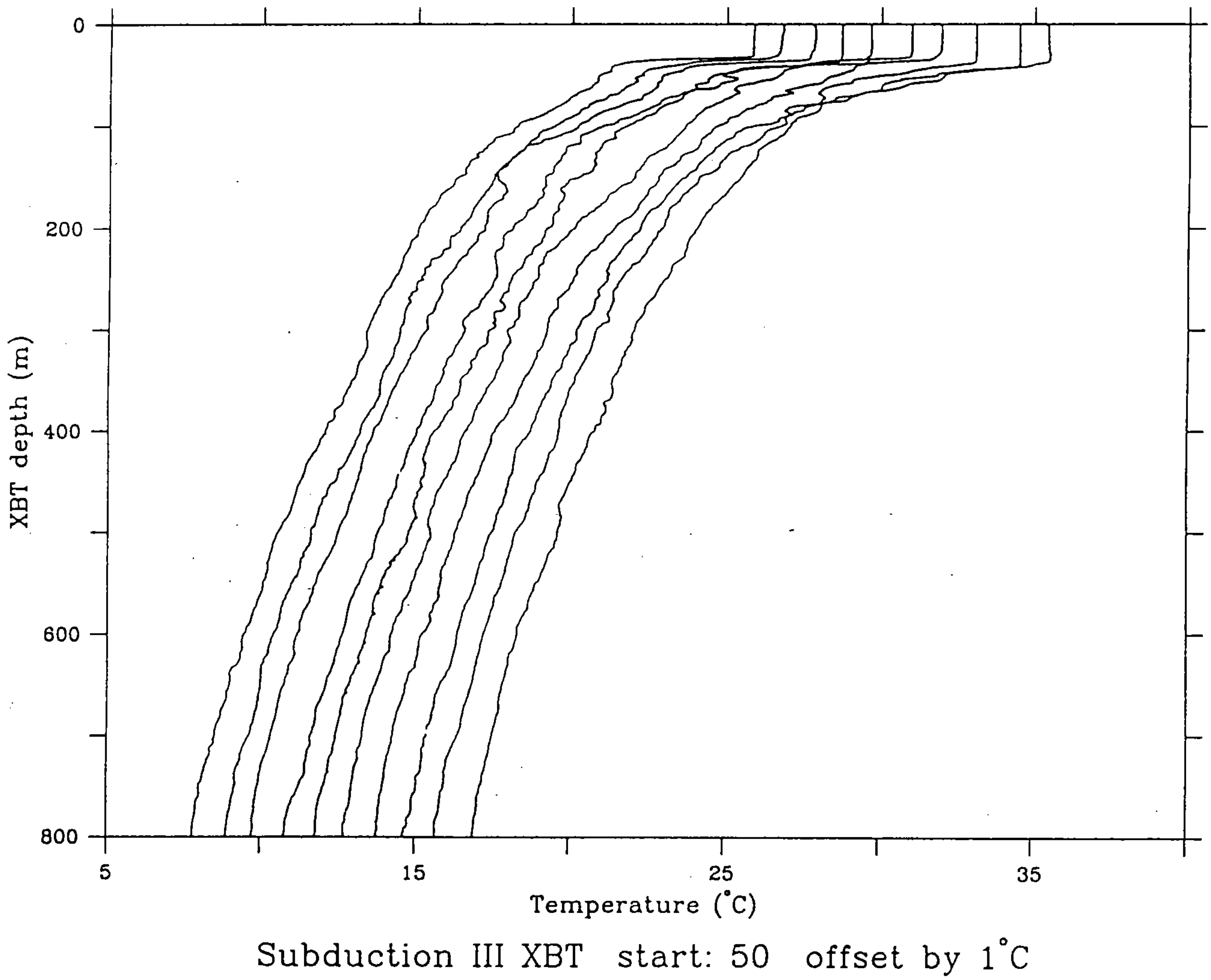


Figure A6-2c Overplot of XBT Profiles 60-69
Successive Profiles are offset by 1° C

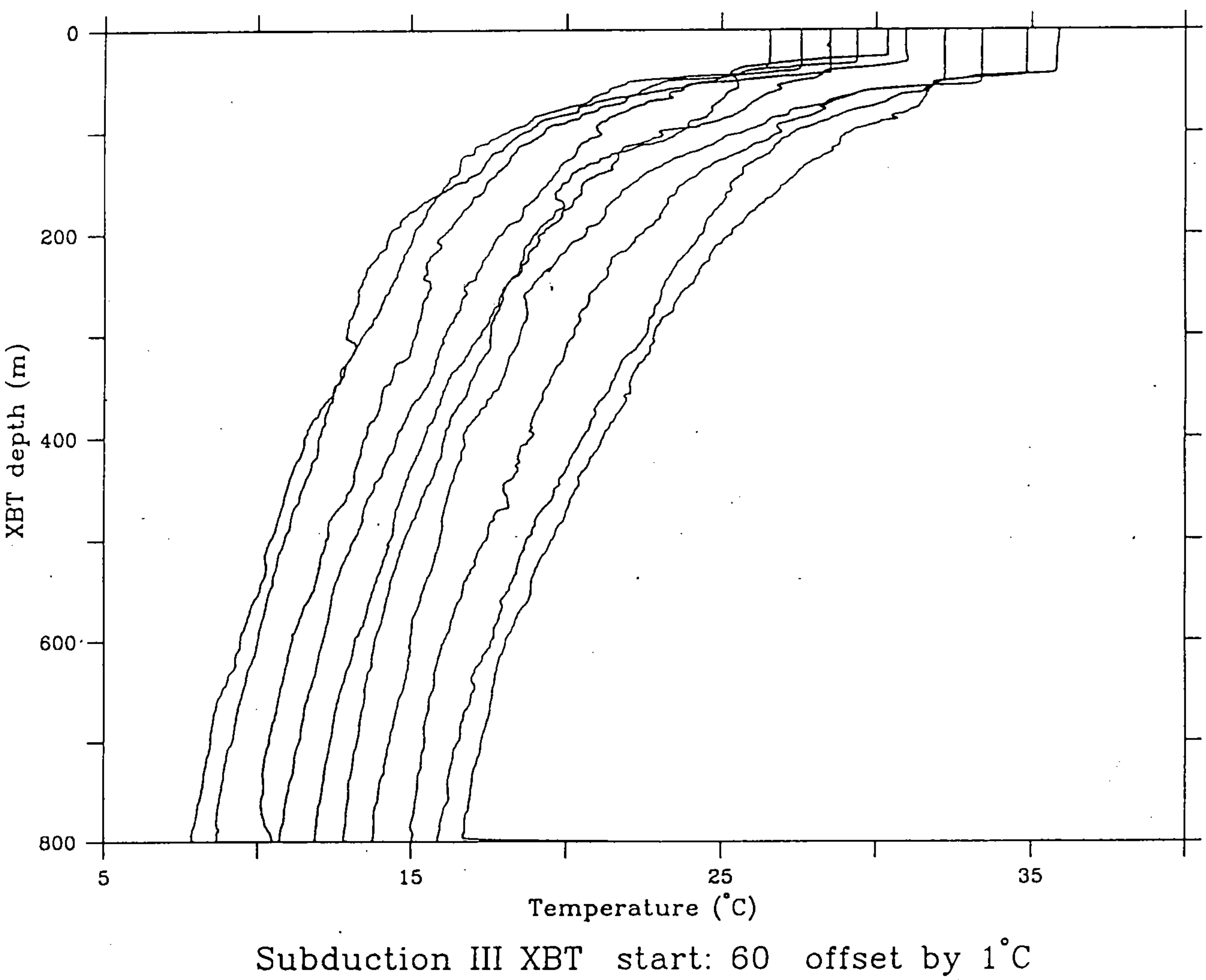


Figure A6-2d Overplot of XBT Profiles 70-79
Successive Profiles are offset by 1° C

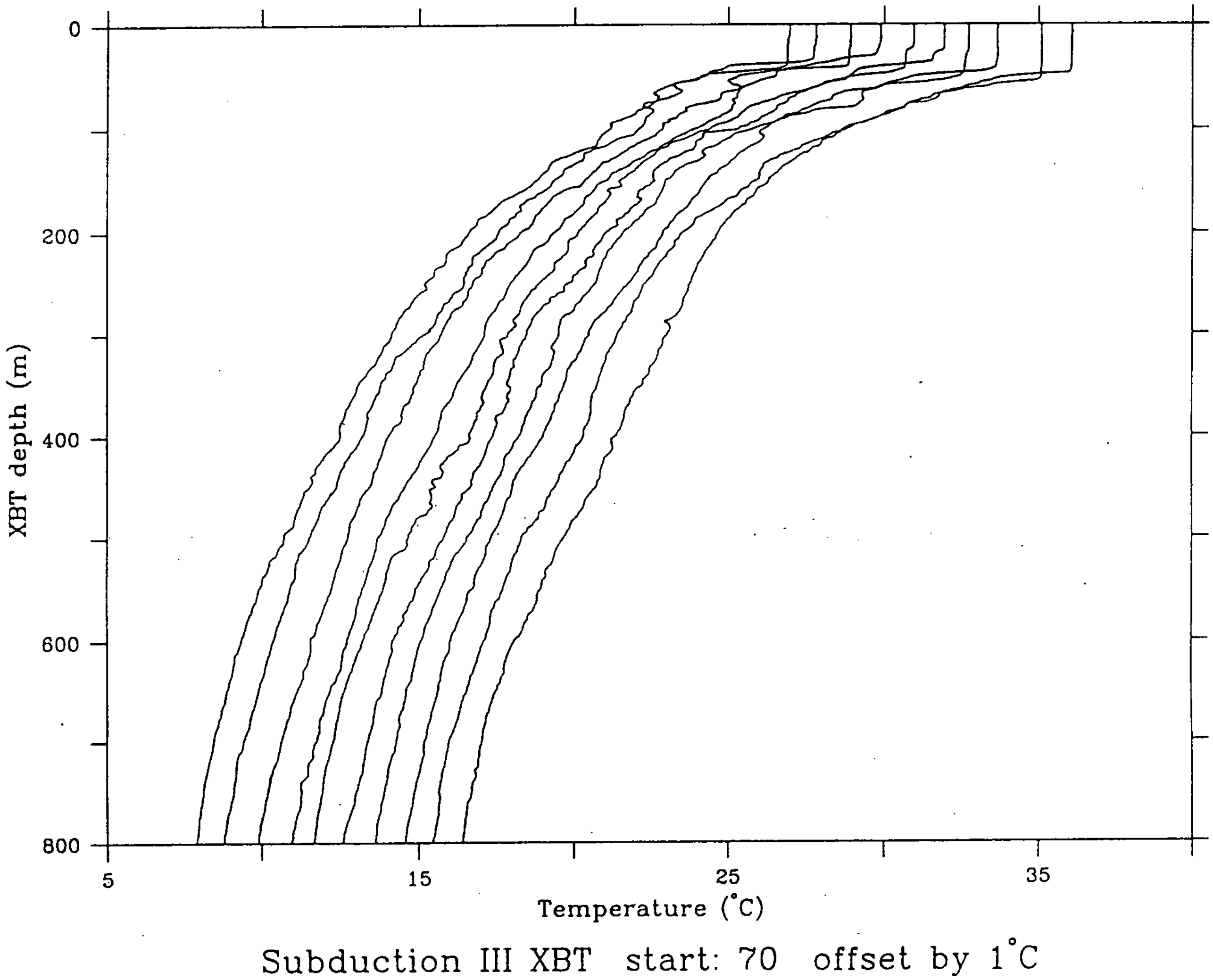


Figure A6-2e Overplot of XBT Profiles 80-89
Successive Profiles are offset by 1° C

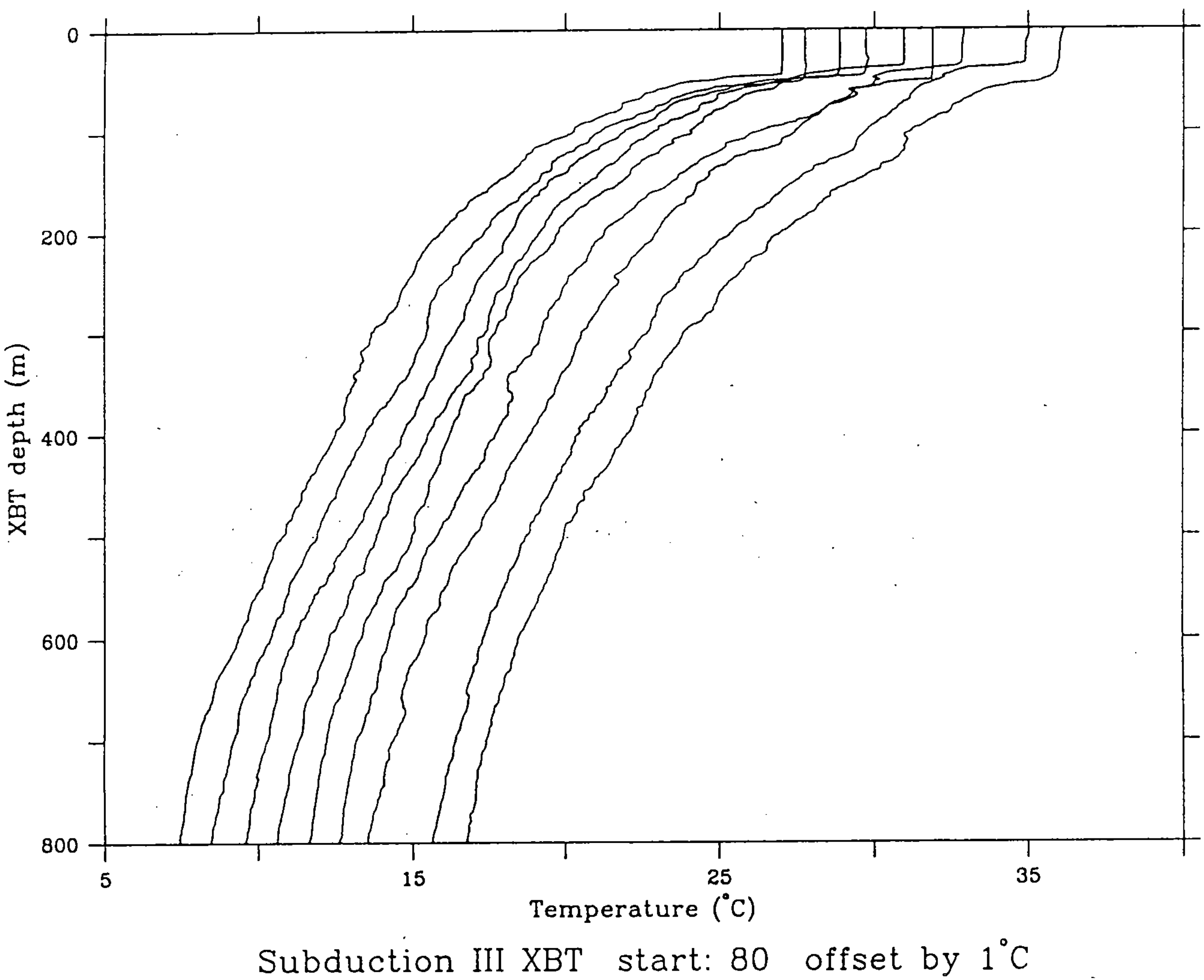


Figure A6-2f Overplot of XBT Profiles 90-99
Successive Profiles are offset by 1° C

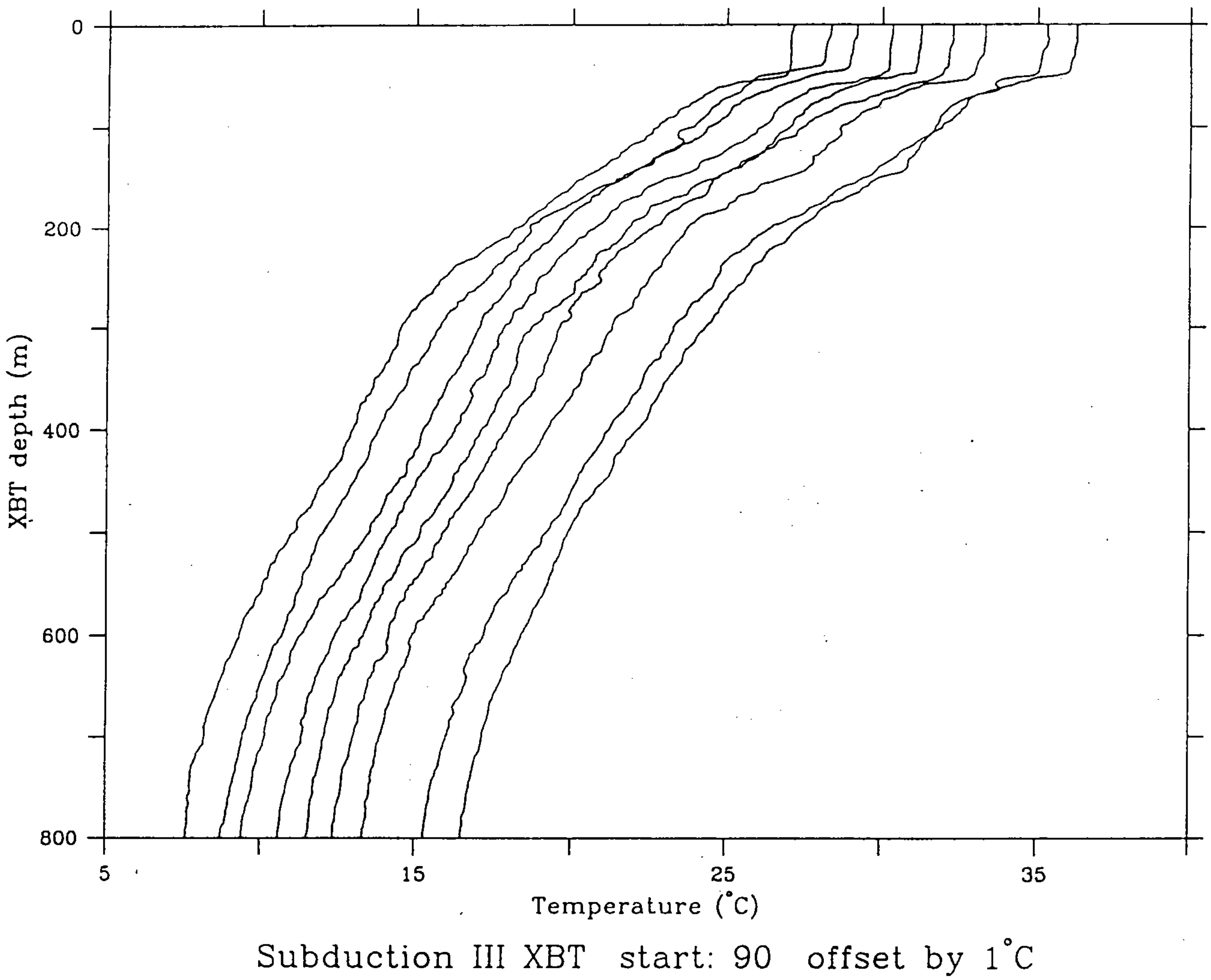


Figure A6-2g Overplot of XBT Profiles 100-109
Successive Profiles are offset by 1° C

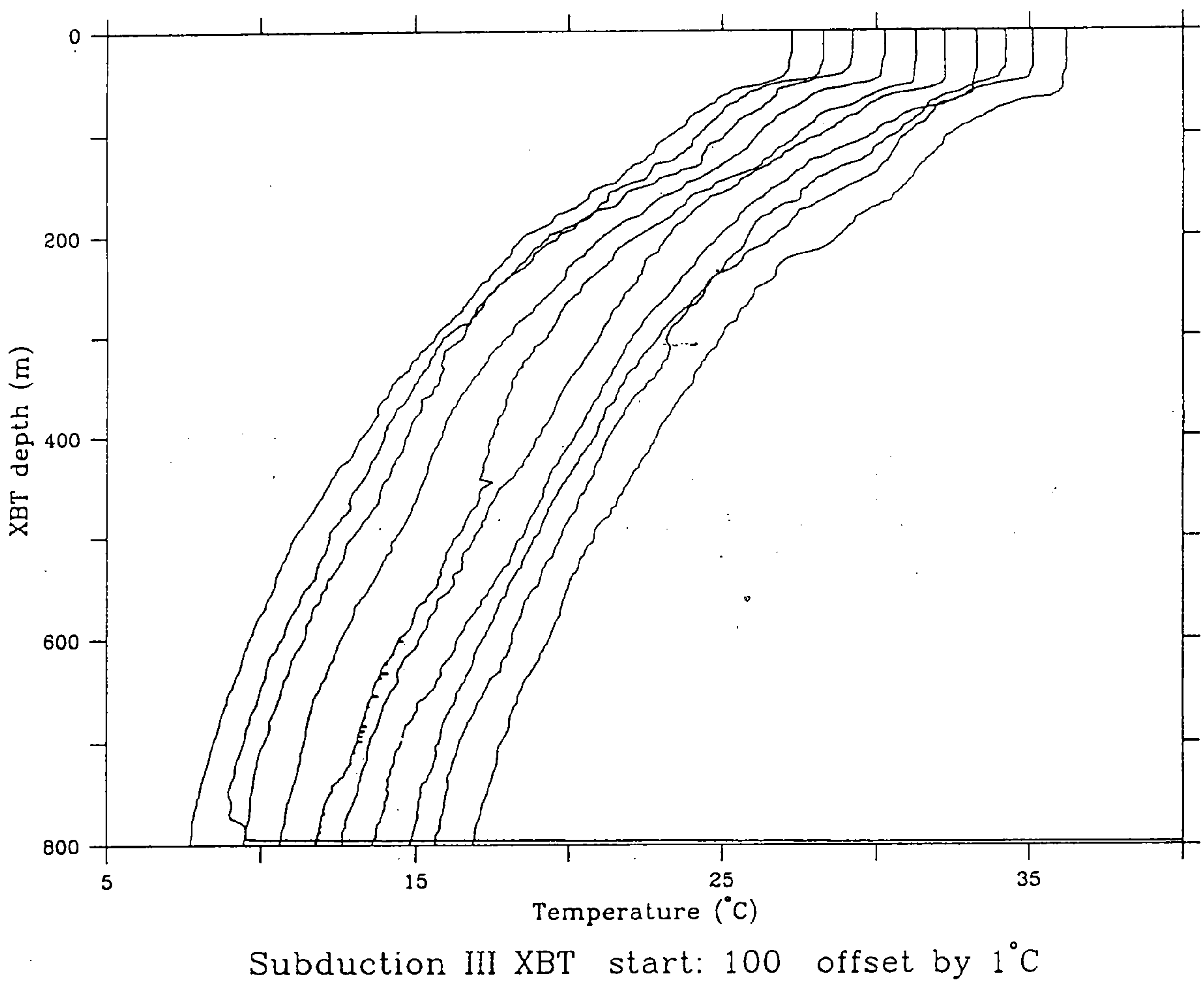


Figure A6-2h Overplot of XBT Profiles 110-119
Successive Profiles are offset by 1° C

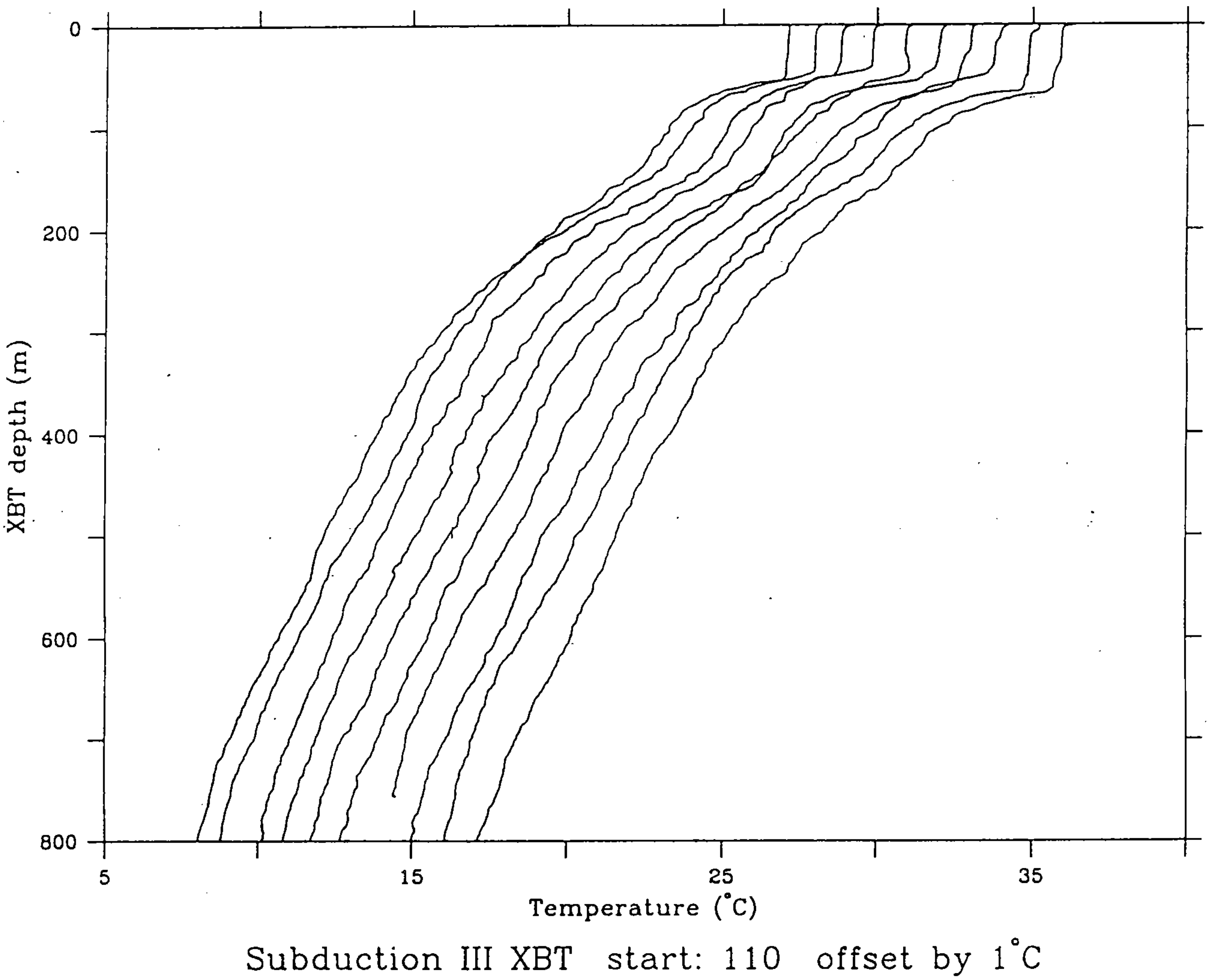
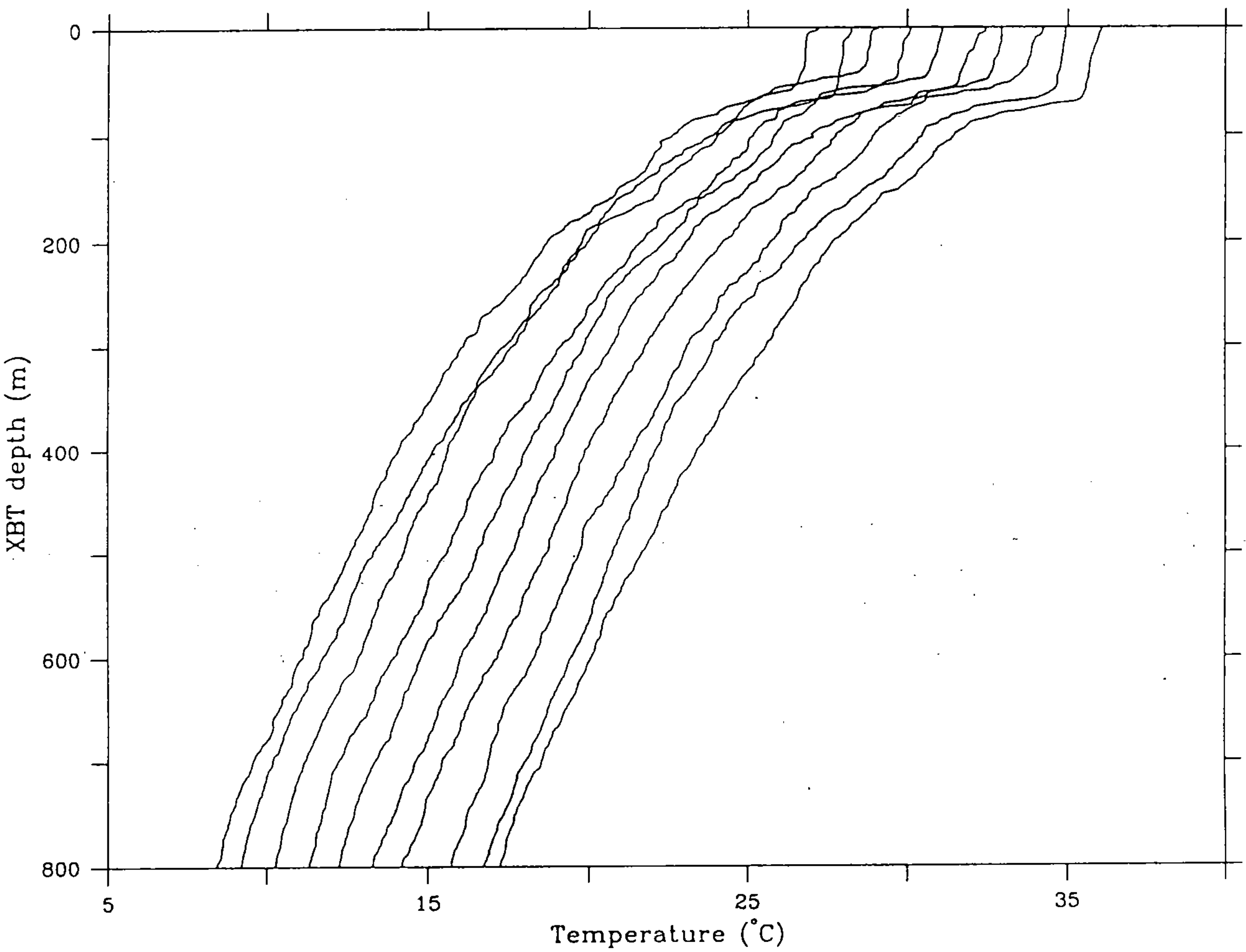


Figure A6-2i Overplot of XBT Profiles 120-129
Successive Porfiles are offset by 1° C



Subduction III XBT start: 120 offset by 1°C

Figure A6-2j Overplot of XBT Profiles 130-139
Successive Profiles are offset by 1° C

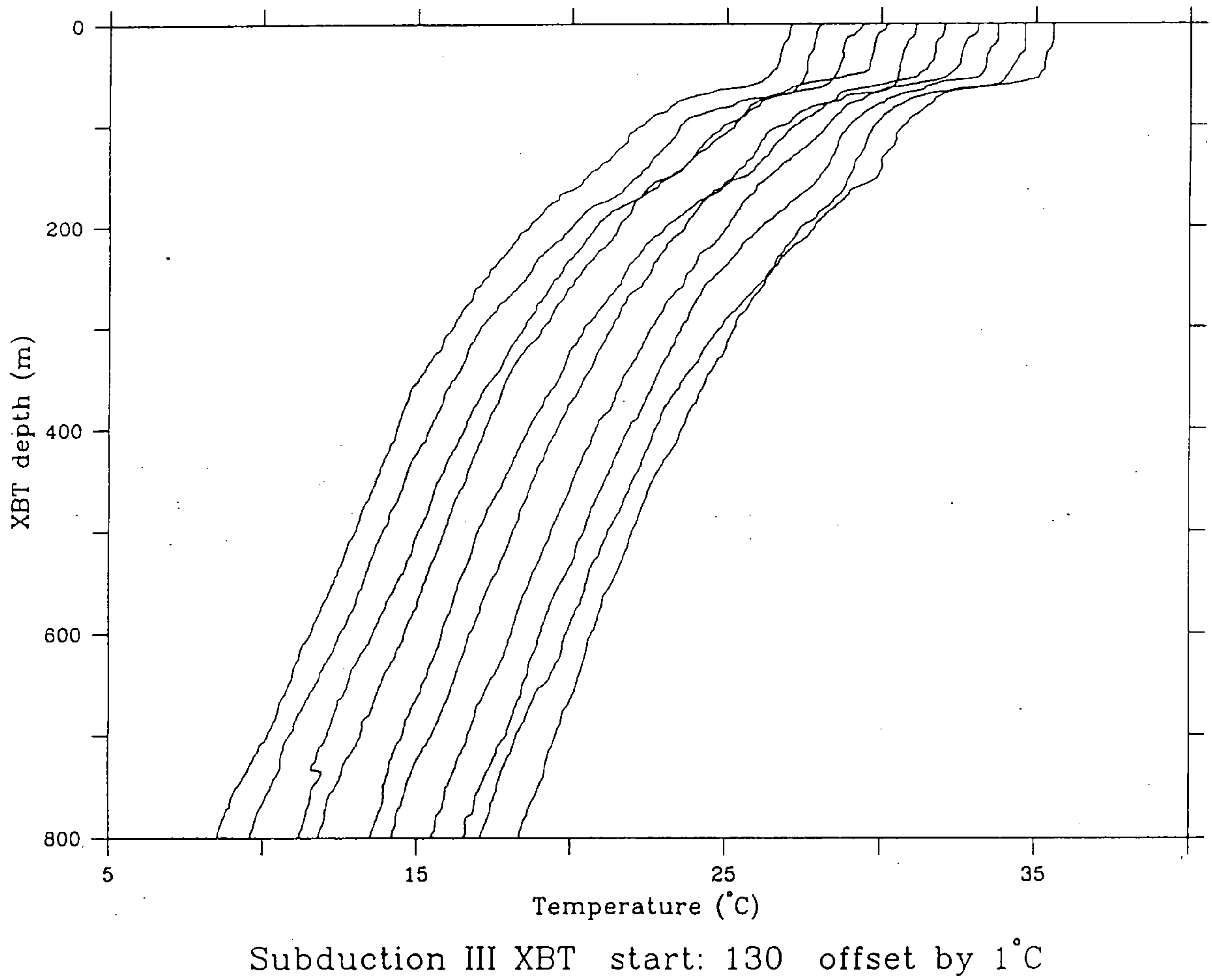
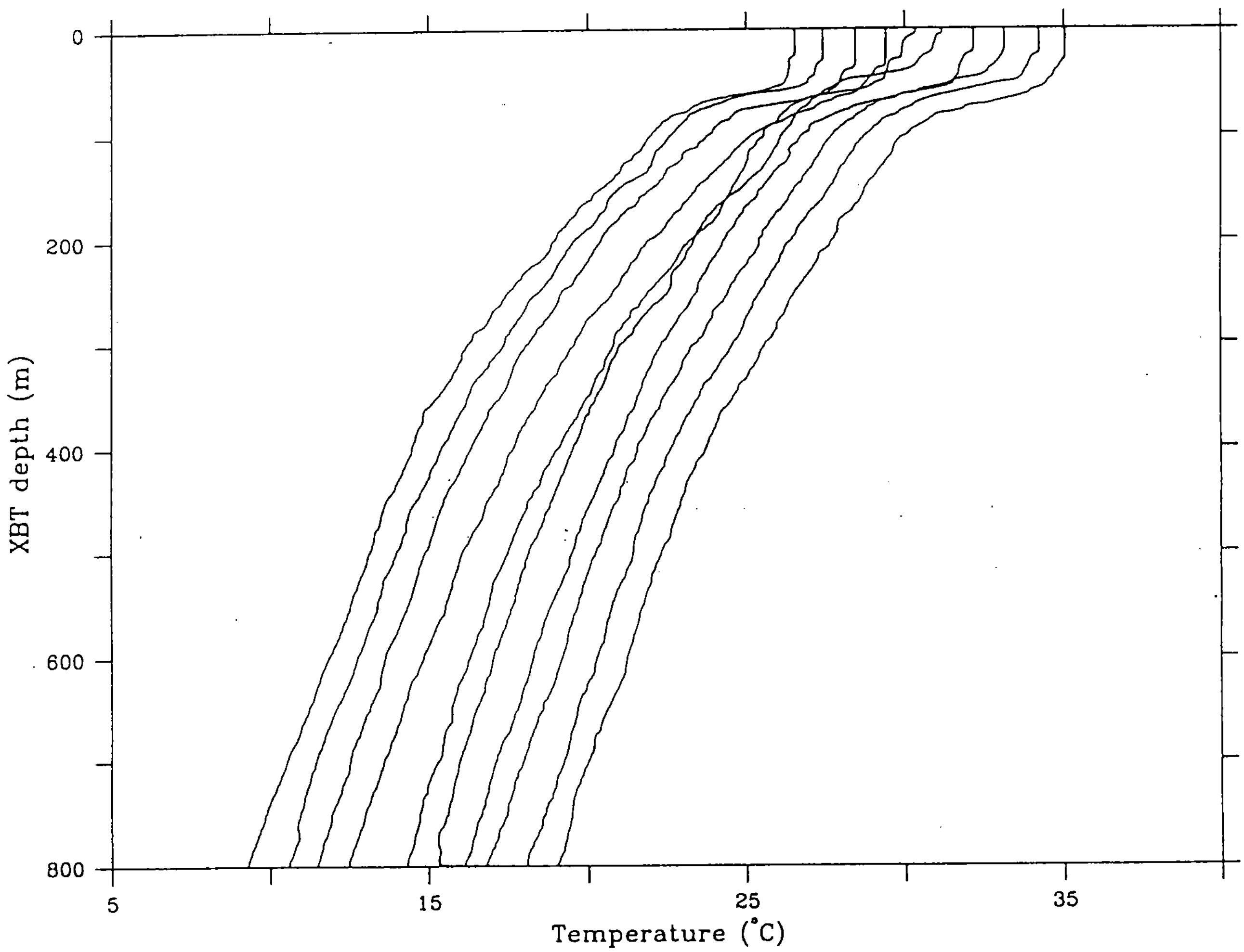


Figure A6-2k Overplot of XBT Profiles 140-149
Successive Profiles are offset by 1° C



Subduction III XBT start: 140 offset by 1°C

**Figure A6-21 Overplot of XBT Profiles 150-159
Successive Profiles are offset by 1° C**

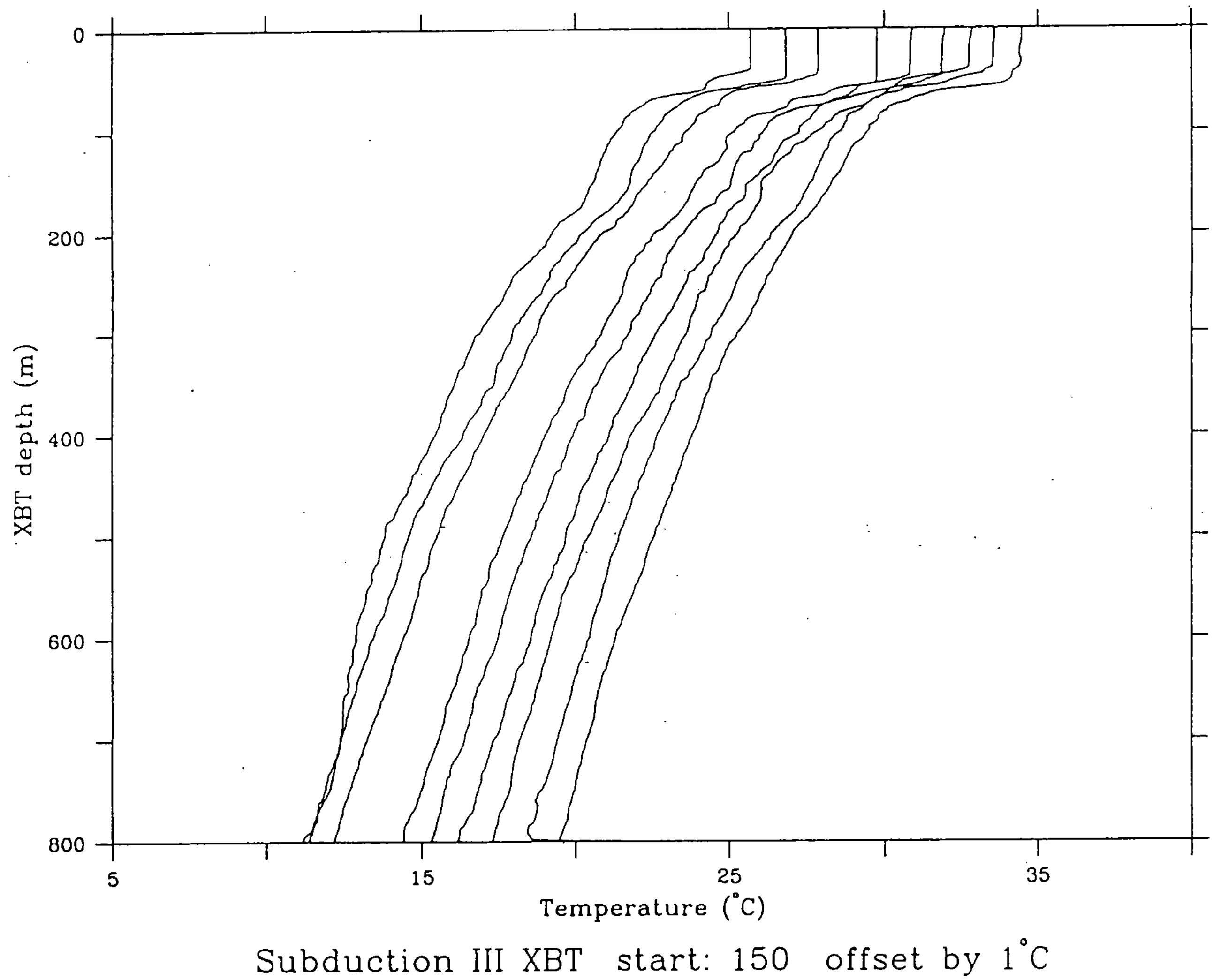


Figure A6-2m Overplot of XBT Profiles 160-169
Successive Profiles are offset by 1° C

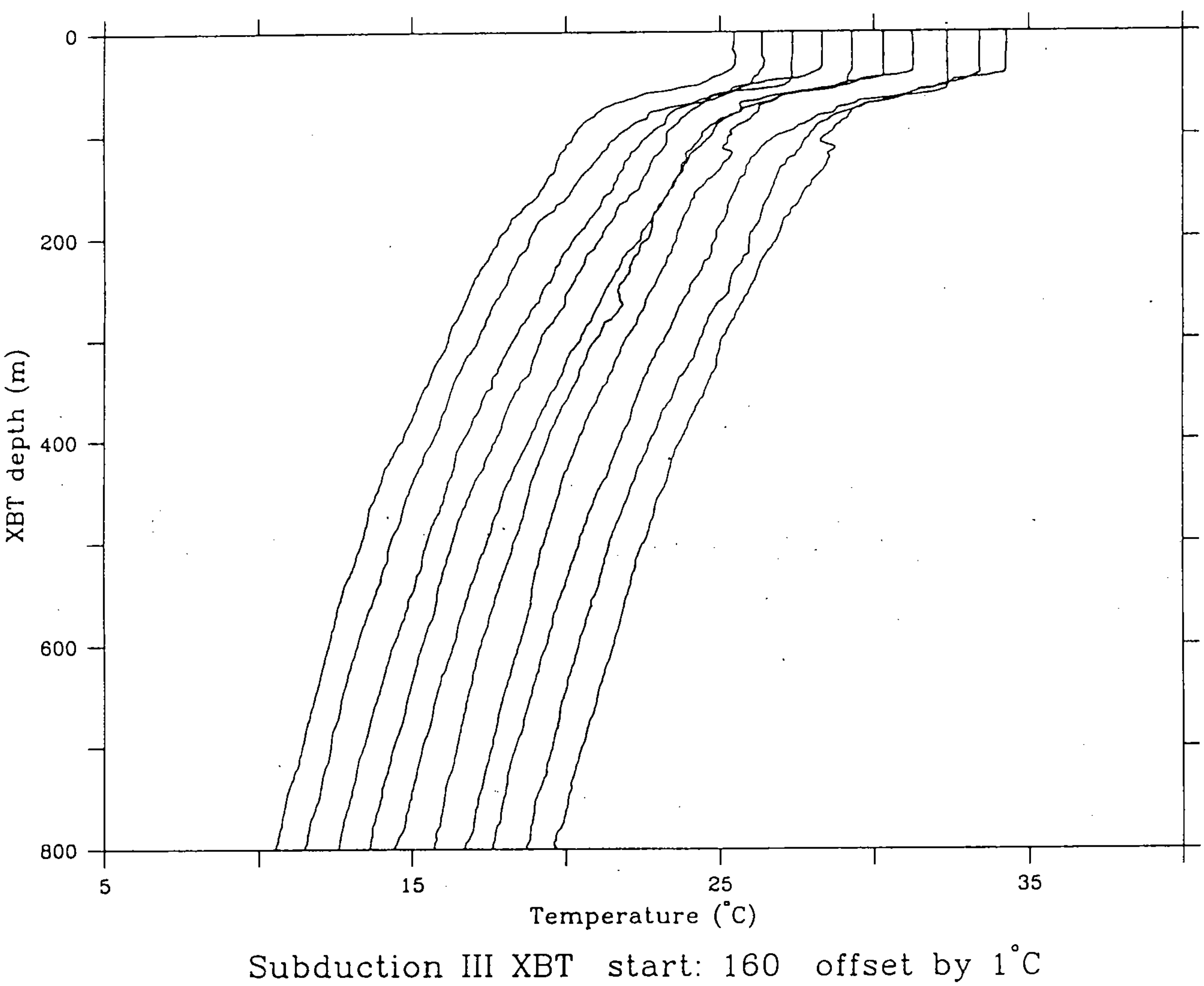


Figure A6-2n Overplot of XBT Profiles 170-179
Successive Profiles are offset by 1° C

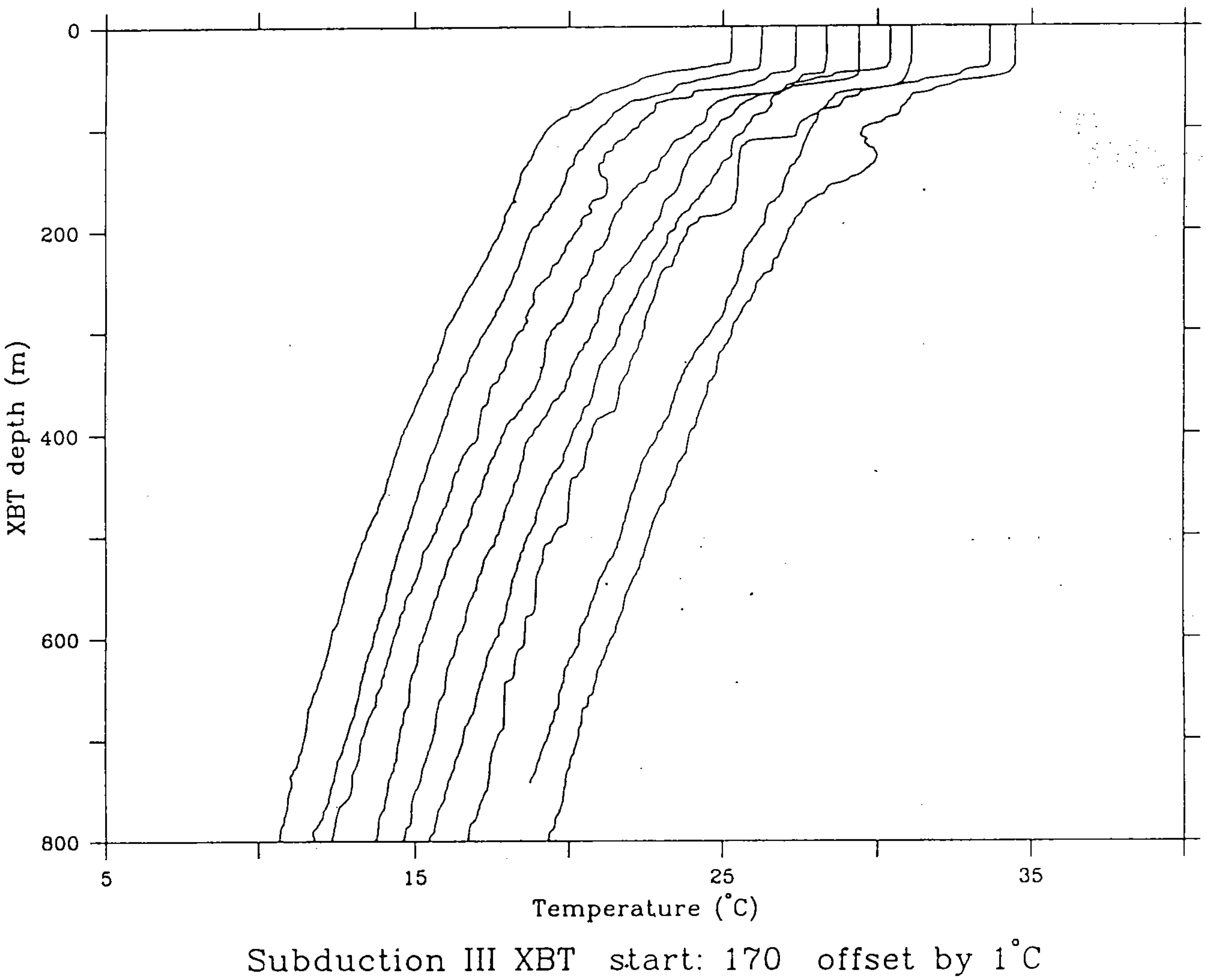


Figure A6-2o Overplot of XBT Profiles 180-189
Successive Profiles are offset by 1° C

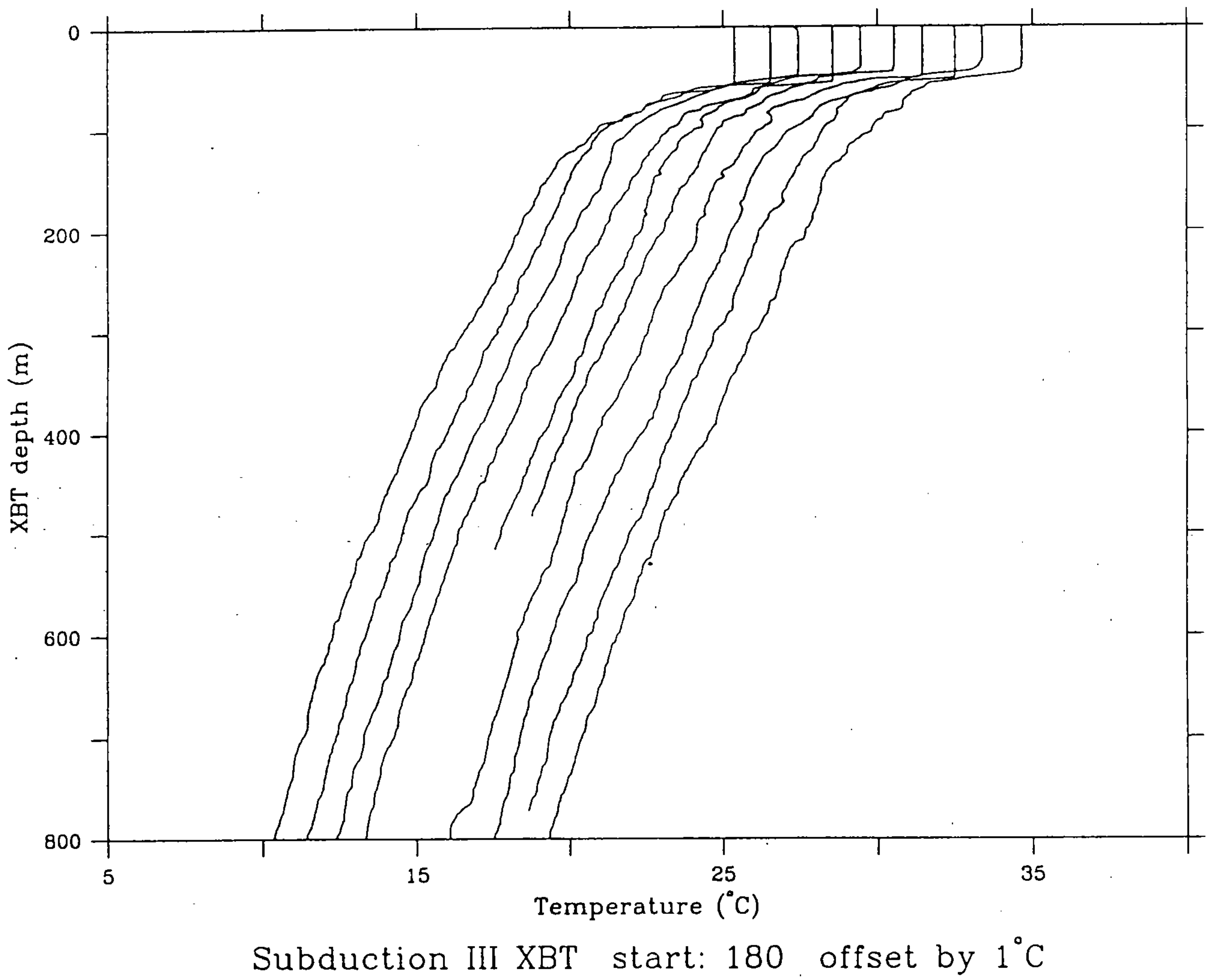


Figure A6-2p Overplot of XBT Profiles 190-199
Successive Profiles are offset by 1° C

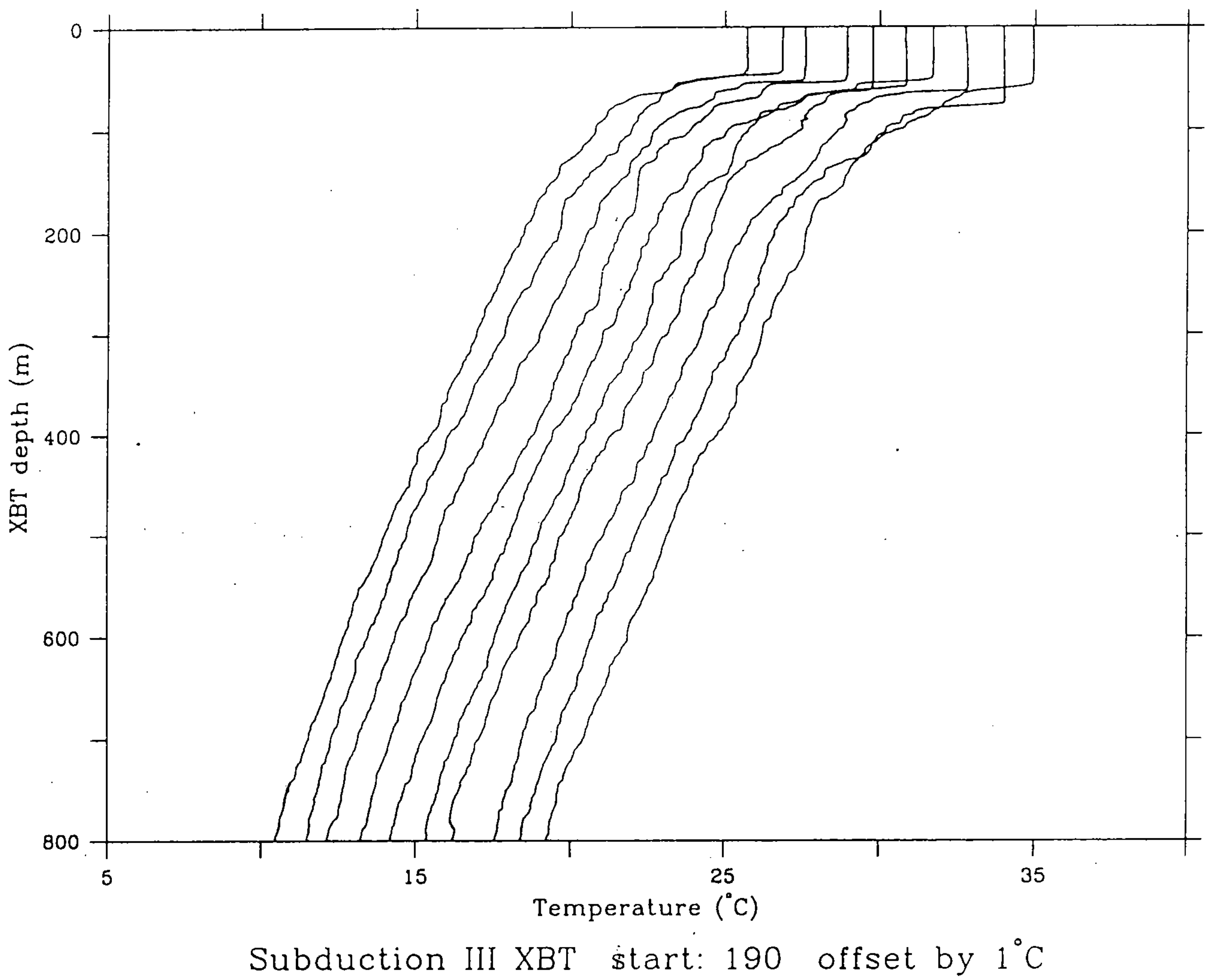


Figure A6-2q Overplot of XBT Profiles 200-201
Successive Profiles are offset by 1° C

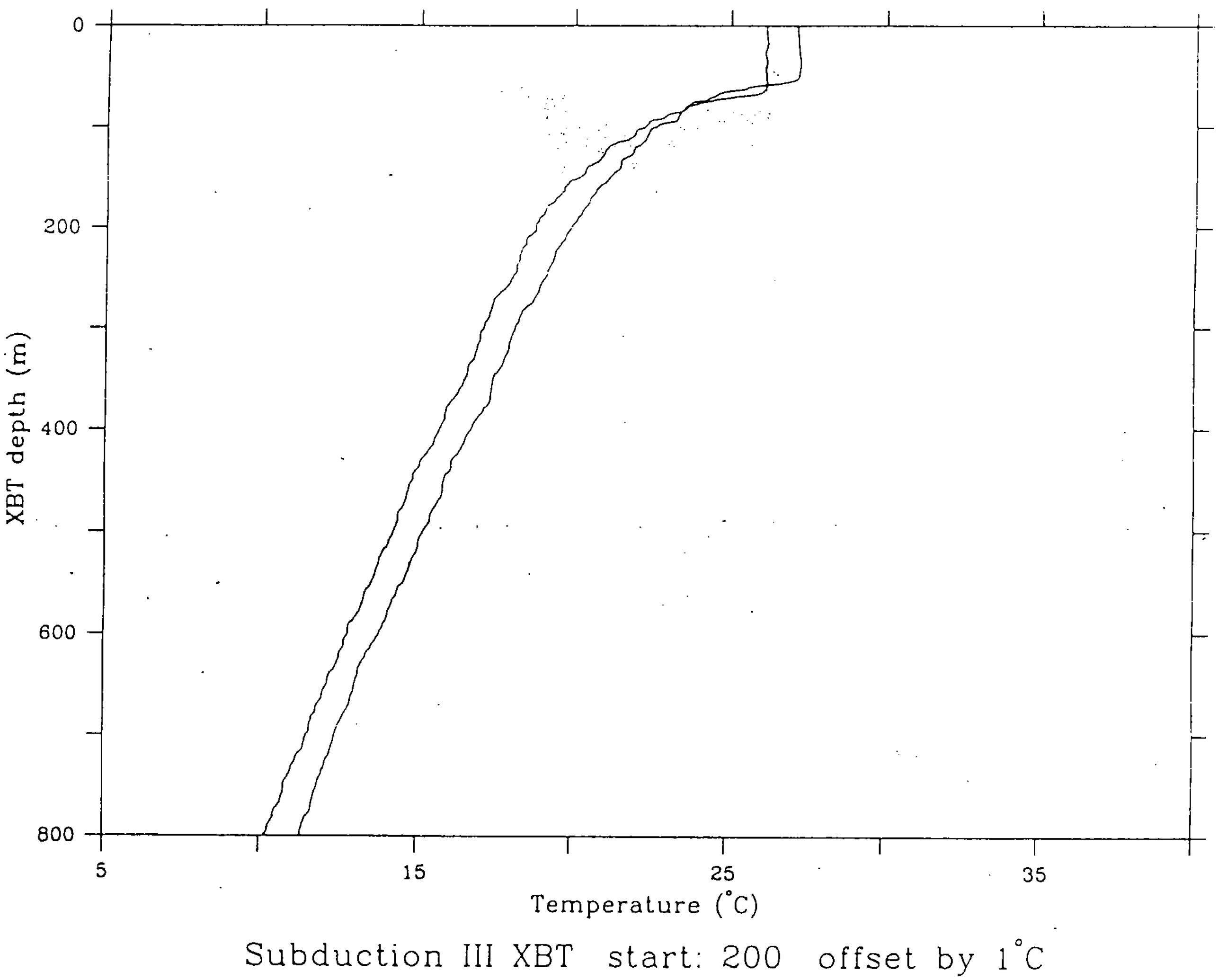


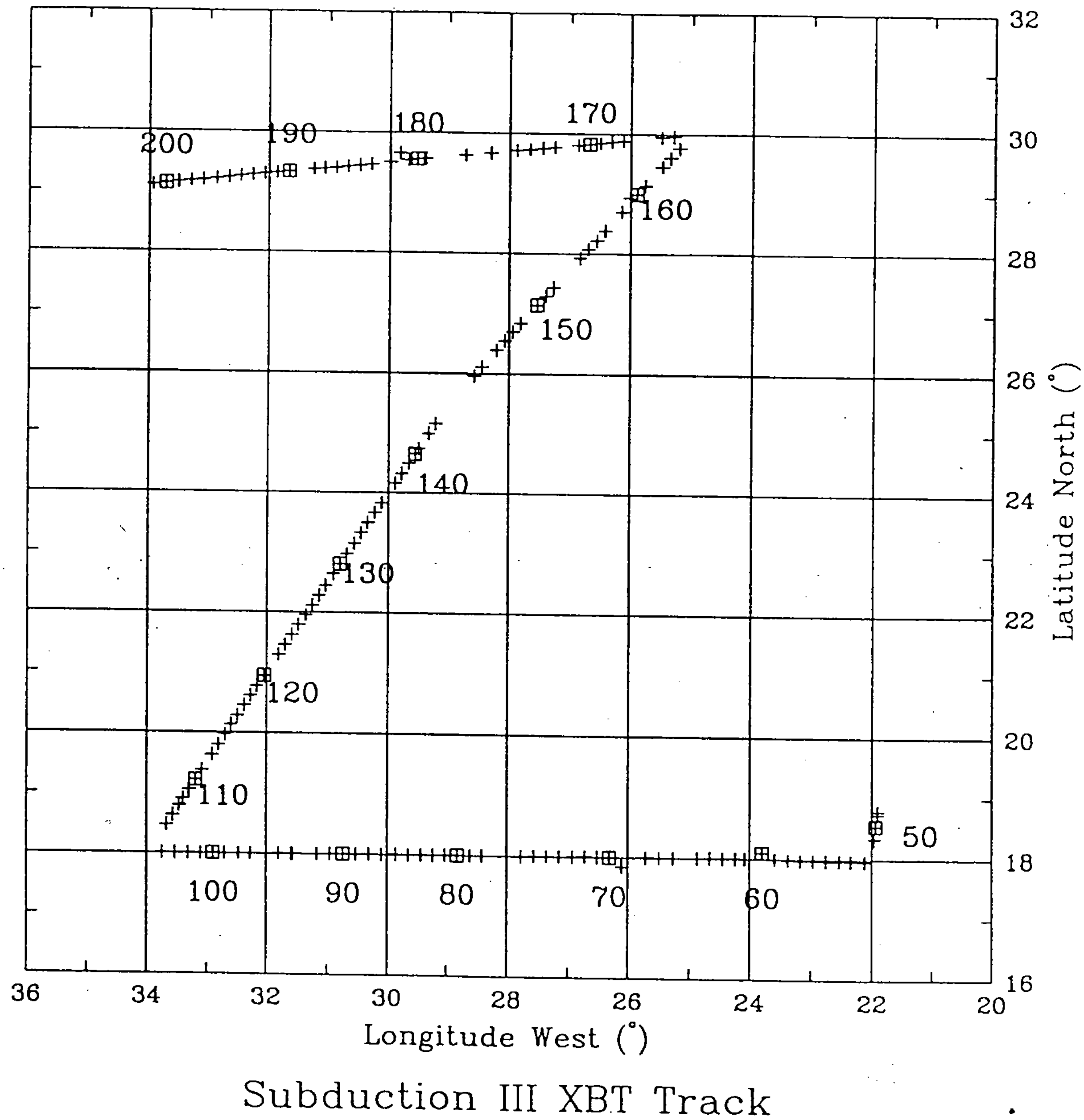
Table A6-1 Darwin 73 XBT positions

No.	Date day/mo/yr	Time (UTC)	Latitude (N)	Longitude (W)
48	06/10/92	09:45	18 47.58	21 54.57
49	06/10/92	10:01	18 44.47	21 54.75
50	06/10/92	11:00	18 32.89	21 56.44
51	06/10/92	12:05	18 20.09	21 57.87
52	08/10/92	19:05	17 57.73	22 07.23
53	08/10/92	20:01	17 57.92	22 20.94
54	08/10/92	21:00	17 58.05	22 32.16
55	08/10/92	22:02	17 58.25	22 45.02
56	08/10/92	23:02	17 58.54	22 57.67
57	08/10/92	00:04	17 58.83	23 10.31
58	08/10/92	01:03	17 59.20	23 22.55
59	08/10/92	02:12	17 59.77	23 35.73
61	08/10/92	06:04	18 00.17	24 13.82
62	08/10/92	07:03	18 00.11	24 26.56
63	08/10/92	08:01	18 00.17	24 39.33
64	08/10/92	09:02	17 59.91	24 51.79
65	08/10/92	10:04	18 00.00	24 04.75
66	08/10/92	11:04	17 59.89	25 15.73
67	08/10/92	12:04	17 59.90	25 29.71
68	08/10/92	13:05	18 00.12	25 42.40
69	08/10/92	16:04	17 50.72	26 06.35
70	09/10/92	17:03	17 59.87	26 18.80
71	09/10/92	18:03	18 00:00	26 31.10
72	09/10/92	19:03	18 00:56	26 43.44
73	09/10/92	20:01	18 00.07	26 55.70
74	09/10/92	21:04	17 59.95	27 08.41
75	09/10/92	22:03	18 00.15	27 21.04
76	09/10/92	22:59	18 00.10	27 33.51
77	09/10/92	00:00	17 59.88	27 45.83
78	09/10/92	04:04	17 59.99	28 24.95
79	09/10/92	05:00	17 59.81	28 36.66
80	09/10/92	06:01	18 00.16	28 49.39
81	09/10/92	07:02	18 00.09	29 01.81
82	09/10/92	08:01	17 59.98	29 14.02
83	09/10/92	09:00	18 00.05	29 26.20
84	09/10/92	10:02	17 59.85	29 39.04
85	09/10/92	11:00	18 00.04	29 51.54
86	09/10/92	13:02	17 59.83	30 05.80
87	09/10/92	14:02	18 00.18	30 18.41
88	09/10/92	14:06	18 00.18	30 18.41
89	09/10/92	15:05	17 59.87	30 31.20
90	09/10/92	16:01	18 00.09	30 44.03
91	10/10/92	17:01	18 00.10	30 56.99
92	10/10/92	18:00	18 00.00	31 09.93
93	10/10/92	19:03	17 59.92	31 33.50
94	10/10/92	20:01	18 00.05	31 35.21
95	10/10/92	21:00	18 00.10	31 48.09
96	10/10/92	00:02	18 00.00	32 15.60

97	10/10/92	01:01	17 59.99	32 27.54
98	10/10/92	01:06	17 59.99	32 27.54
99	10/10/92	02:07	17 59.91	32 41.76
100	10/10/92	03:03	18 00.10	32 53.67
101	10/10/92	04:02	17 59.90	33 06.09
102	10/10/92	05:01	18 00.04	33 18.82
103	10/10/92	06:01	17 59.99	33 31.75
104	10/10/92	07:02	18 00.10	33 44.74
105	12/10/92	07:02	18 27.81	33 40.45
106	12/10/92	08:01	18 37.47	33 34.16
107	12/10/92	09:00	18 47.35	33 27.62
108	12/10/92	10:03	18 53.92	33 23.83
109	12/10/92	11:01	19 02.85	33 17.70
110	12/10/92	12:03	19 12.74	33 11.26
111	12/10/92	13:03	19 22.52	33 04.79
112	12/10/92	16:02	19 37.67	32 54.88
113	13/10/92	17:04	19 47.64	32 48.18
114	13/10/92	18:04	19 57.64	32 41.73
115	13/10/92	19:04	20 07.86	32 35.50
116	13/10/92	20:00	20 16.57	32 28.79
117	13/10/92	21:02	20 26.80	32 22.10
118	13/10/92	22:03	20 36.50	32 15.78
119	13/10/92	23:02	20 46.05	32 09.51
120	13/10/92	00:04	20 56.29	32 02.42
121	13/10/92	03:05	21 17.07	31 48.54
122	13/10/92	04:03	21 27.20	31 41.89
123	13/10/92	05:05	21 37.36	31 35.34
124	13/10/92	06:04	21 47.31	31 28.83
125	13/10/92	07:05	21 57.21	31 21.56
126	13/10/92	08:01	22 06.82	31 15.19
127	13/10/92	09:01	22 16.81	31 08.62
128	13/10/92	10:01	22 26.88	31 02.10
129	13/10/92	12:04	22 38.54	30 54.35
130	13/10/92	13:02	22 48.36	30 47.66
131	13/10/92	14:03	22 58.43	30 41.07
132	13/10/92	15:05	23 09.02	30 33.77
133	13/10/92	16:04	23 19.74	30 27.10
134	14/10/92	17:04	23 29.77	30 20.33
135	14/10/92	18:04	23 39.90	30 13.40
137	14/10/92	19:04	23 49.53	30 06.53
137	14/10/92	22:02	24 09.35	29 53.49
138	14/10/92	23:00	24 18.98	29 47.01
139	14/10/92	00:07	24 29.59	29 39.63
140	14/10/92	01:06	24 39.13	29 33.30
141	14/10/92	02:03	24 44.40	29 29.90
142	14/10/92	03:05	24 59.56	29 19.62
143	14/10/92	04:04	25 09.37	29 12.75
144	16/10/92	20:04	25 57.37	28 34.51
145	16/10/92	21:03	26 06.59	28 26.91
146	16/10/92	00:04	26 23.58	28 12.19
147	16/10/92	01:06	26 33.03	28 04.11
148	16/10/92	02:06	26 41.90	27 56.03
149	16/10/92	03:04	26 50.52	27 48.57
150	16/10/92	06:05	27 08.84	27 32.15

151	16/10/92	07:05	27 17.68	27 23.80
152	16/10/92	08:02	27 26.66	27 16.42
154	16/10/92	12:07	27 55.80	26 50.74
155	16/10/92	13:05	28 04.77	26 42.62
156	16/10/92	14:08	28 13.18	26 33.91
157	16/10/92	15:06	28 22.99	26 25.65
158	17/10/92	18:06	28 42.08	26 08.92
159	17/10/92	19:07	28 56.06	26 01.10
160	17/10/92	20:04	28 59.80	25 53.60
161	17/10/92	21:03	29 08.36	25 45.55
162	17/10/92	00:04	29 27.32	25 29.26
163	17/10/92	01:04	29 36.41	25 21.24
164	17/10/92	02:06	29 46.05	25 12.39
165	17/10/92	07:05	29 57.80	25 18.03
166	17/10/92	08:04	29 56.92	25 30.15
167	17/10/92	12:05	29 53.16	26 07.95
168	17/10/92	13:05	29 52.05	26 19.55
169	17/10/92	14:04	29 50.91	26 30.83
170	17/10/92	15:04	29 49.49	26 41.59
171	17/10/92	16:05	29 48.60	26 52.97
172	18/10/92	19:05	29 46.33	27 15.63
173	18/10/92	20:04	29 45.29	27 27.33
174	18/10/92	21:04	29 44.06	27 39.93
175	18/10/92	22:04	29 42.97	27 52.77
176	18/10/92	01:04	29 40.19	28 18.71
178	18/10/92	03:07	29 37.63	28 43.87
179	18/10/92	08:04	29 34.12	29 23.58
180	18/10/92	09:04	29 33.63	29 32.31
181	18/10/92	10:04	29 32.45	29 41.16
182	18/10/92	11:04	29 39.29	29 49.96
183	18/10/92	12:04	29 30.24	29 59.52
184	18/10/92	15:06	29 27.96	30 18.26
186	18/10/92	16:10	29 26.87	30 29.88
187	19/10/92	17:07	29 25.72	30 41.56
187	19/10/92	18:05	29 24.14	30 53.36
188	19/10/92	19:06	29 23.58	31 04.73
189	19/10/92	20:02	29 22.43	31 15.63
190	19/10/92	23:05	29 20.11	31 39.91
191	19/10/92	00:09	29 18.79	31 52.06
192	19/10/92	01:06	29 17.71	32 03.88
193	19/10/92	02:06	29 16.54	32 15.74
194	19/10/92	03:05	29 15.23	32 27.85
195	19/10/92	04:06	29 14.00	32 39.85
196	19/10/92	05:07	29 12.67	32 52.18
197	19/10/92	07:06	29 11.20	33 05.95
198	19/10/92	08:05	29 10.28	33 18.24
199	19/10/92	09:05	29 09.02	33 31.01
200	19/10/92	10:05	29 07.72	33 43.43
201	19/10/92	11:05	29 06.36	33 56.17

Figure A6-2 XBT Positions



Appendix 7:

VMCM condition immediately following recovery.

Subduction 2
WHOI VMCMs
Northeast (Mooring 927)
VMCM 034
both props spinning,
a little more play in upper propeller than in lower propeller,
one or two goose barnacles on propeller hub of both lower and upper prop,
no blades broken,
aqua lube washed away from upper end cap
antifouling around hubs washed away

VMCM 027
both props spinning
antifouling looks good
lower propeller bearings feels good
upper propeller bearings feel good
no broken blades
no goose barnacles evident
Some evidence of blade nicking the sting

VMCM 036
both hubs spinning
upper and lower bearings feel good
upper bearing has a little more play than lower bearing but not excessive
Some evidence of blade nicking the sting

VMCM 014
both rotors spinning
antifouling paint looks ok
bearings of both upper and lower props feel fine
antifouling paint on the blade near the hub is in most cases gone. Possibly due to blade flexing and then antifouling paint chipping away
Sting shows slight evidence of nicking by the propeller blade
No goose barnacles

VMCM 045
both hubs spinning
antifouling looks good
no broken blades
Some evidence of blades nicking sting
antifouling paint on blade near hub not as worn away as on shallower instruments

VMCM 035
both hubs spinning
antifouling looks good
missing paint near hub of propeller blade more evident than on VM 045
propeller bearing in good condition
No evidence of nicking of sting

VMCM 009
both rotors spinning
antifouling paint looks good
paint in hub area still present on blade

VMCM 011
both rotors spinning
antifouling looks good

Southeast (Mooring 925)

Net on Bridle leg
VM010
Upper rotor spinnning
Lower rotor spinning
At root of blade see evidence of flexing since no antifouling paint
Dead goose barnacle on upper rotor , not blocking anything
goose barnacle on lower rotor
goose barnacle on hub
Antifouling paint worn away in patches
Both cage anodes completely gone
Aqua lube on top endcap nearly completely gone
Sting antifouling paint gone
No broken blades
Bearings feel good

SIO instruments (see SIO notes that follow)
bearings wobbley
no broken blades
anti fouling paint worn off case
marked difference in bearing quality
antifouling paint worn off blades near the hub
propellers a little sluggish

Southwest (Mooring 924)
Not recovered

Central (Mooring 926)

VMCM 002
Props not spinning initially on recovery
Plastic material hanging from top horizontal member of cage
Lower prop spun in wind
Upper rotor stiff, has pieces of plastic imbedded in behing propeller
Lower rotor a little stiff but free to spin
Propeller bearings feel good
Antifouling paint missing from root of blade near hub
Gooseneck barnacles on endcap of instrument
Slime on cage rods and sting
Three gooseneck barnacles on inside of lower rotor propeller
One gooseneck barnacle on upper rotor
Anodes on cage 50% gone
Photos taken

VMCM 023
Top rotor spinning in wind
Bearings in good condition
No broken blades
Lower rotor has shredded plastic material in behind hub
Antifouling intact
Not much antifouling on sting
Upper rotor free to spin
Lower rotor will spin but stiff
Anode at top of cage 50% gone anode on bottom of cage 70 -80% gone Photos taken

VMCM 020
Upper and lower rotors spinning in wind
no broken blades
bearings in good condition
Antifouling paint missing from root of blade near hub
No goose barnacles
Antifouling paint missing from sting
Top anode 30% gone and 60% gone on bottom
Slime on cage rods and sting

VMCM 013
Upper and lower rotors spinning freely
Considerably less slime on this instrument
Bearings feel good on both upper and lower rotor
Antifouling paint not gone near root of propeller
Anode 20% gone at top, 50% gone at bottom
No broken blades
No gooseneck barnacles
No nicking evidence

VMCM 019
Upper and lower rotors spinning
Antifouling paint looks good
Bearings feel in good condition
No broken blades
No nicking on sting from blades
Antifouling paint missing from root of blade near hub of both upper and lower rotor
Anodes in good condition

VMCM 008
Upper and lower rotor spinning freely
Bearing in good condition
No broken blades
Lower rotor does not show the flexing as much as the upper rotor
Antifouling paint looks ok
Anodes pretty well shot
Slight evidence of nicking on sting, mostly on lower part of sting

VMCM 026
Upper and lower rotors spiinning
Bearings feel good
Root of blade missing antifouling paint
No obvious evidence of nicking
antifouling paint intact
anodes on cage bottom is 50% gone

VMCM 025
Upper and lower rotor spinning
antifouling paint intact
No broken blades
Bearings feel good
Antifouling paint missing from root of blade near hub
No obvious signs of nicking
Anodes at bottom is 50% gone

VMCM 017
Upper and lower rotor spinning
antifouling paint looks good
bearing in good condition
no broken blades
Signs of nicking on lower parts of sting

VMCM 031
Upper and lower rotors spinning
No broken blades
Bearings in good condition
Cage has slight bend in one of the longitudal members

VMCM 029
Bearings in good condition
No broken blades
Paint missing from the top hub
Little bit of antifouling paint missing from root of blades near hub
Anode on top of cage completely gone and bottom anode also pretty well gone

VMCM 001
Upper and lower rotor spinning freely
No broken blades
Bearings feel good
No evidence of nicking
Antifouling paint looks good
Antifouling paint near root of blade somewhat gone.
Anode on bottom of cage is black and nearly gone, top anode completely gone.
Anodes on instrument itself are in fine shape

VMCM 003
Upper and lower rotors spinning
Noo growth
No broken blades
Bearings feel good
No missing antifouling paint
Anode at top of cage is nearly completely gone one at bottom is about 50% gone

Northwest (Mooring 928)

No WHOI VMCMs

Appendix 8

Discus buoy recovery and deployment on RRS. Darwin.

W.Ostrom
11/9/92

Recovery operations

Personnel required:
1- deck supervisor
1- pickup pole person
2 - airtugger person
3 - line handlers
1 - trawl winch operator

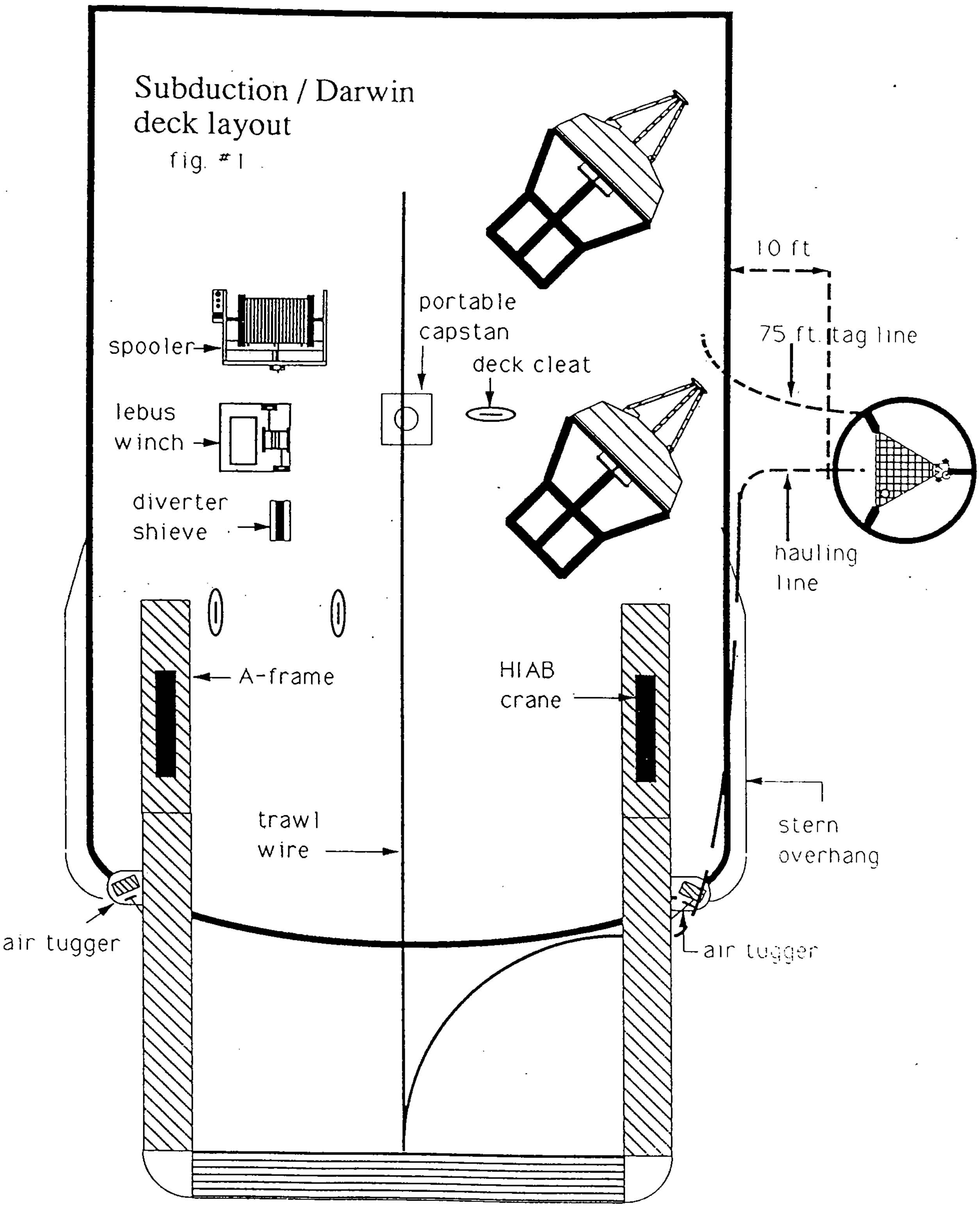
Special Deck Gear and Lines:
1 - 35 ft. x 1 1/2" dia. nylon pennant with hard eyes on both ends
2 - 13 ft. "Lift All" pickup hooks
2 - 13 ft. aluminum pickup poles
2 - Ingersall Rand 1200 lb. line pull airtuggers with 100 ft. x 1/4" cable
2 - 75 ft. x 1" dia. 2 and 1 Samson deck lines
1 - 75 ft. 1 1/2" dacron bull rope
2 - 3/4" chain grabs
3 - 1 1/2 ton Renfro snap hooks
1 - W.H.O.I. 5000 lb. line pull - portable capstan
1 - trawl winch with minimum lifting caps. of 10000 lbs.
1 - ship's A-frame
4 - voice actuated radios
2 - large throuted trawl blocks

Standard UOP discus buoy recoveries usually involve the ship's crane to lift the buoy up and over the port or starboard rail. Since the RRS Darwin's crane did not having the lifting capacity needed to raise the discus and attached mooring components out of the water, the ship's A-frame was used instead in conjunction with the ship's trawl winch and cable.

Following the mooring's release from the sea bottom the discus buoy was initially hooked a-midships under the starboard gantry. Two lines were used, first a Lift All pennant with a 75 ft. tag line attached was hooked into a bail of opportunity on the discus tower. This line was used to hold and orient the discus hull so that a second Lift All pennant could be hooked into the main lifting bail on the discus deck. The second Lift All pennant or hauling line was shackled to a 35 ft. x 1 1/2" nylon line, and finally to the ship's trawl wire. This 35 ft. nylon line gave the pickup pole man greater maneuverability while hooking the buoy than if the trawl wire was shackled directly into the Lift All pennant. Prior to hooking the buoy the hauling line was reeved up through the ship's trawl block located in the center of the stern A-frame and passed outboard along the starboard rail. Three line handlers positioned down along the starboard rail had the responsibility of tending the hauling line and its 75 ft. tag line as the buoy drifted aft (figure A-8-1).

The mooring supervisor, trawl winch operator and the 2 air tugger operators used voice activated radios (VAC) to communicate to one another during the discus lift. These radios proved to be valuable in directing small adjustments in the buoy's position as it was raised on board.

Figure A8-1. Darwin deck layout during buoy recovery with initial connections to the buoy.



Positioning the ship while the discus was being hooked and tended around the stern of the ship was critical in preventing the discus from being crushed under the Darwin's overhanging transom. The initial approach required the ship to steam forward with the wind slightly on the port bow, to allow the ship's windage to shift to starboard towards the buoy. Once the discus was hooked and stopped off the ship used its bow thruster to port to allow the windage to shift to the starboard side causing the ship to drift downwind away from the discus. The tag line and hauling line were eased off allowing the discus to drift 10 to 15 ft. outboard from the rail. The ship at this time steamed slowly forward. The hauling line and 75 ft. tag line were handled aft as the discus moved down around to the stern only to keep the buoy hull from rotating. The mooring supervisor, using his VAC, instructed the trawl winch operator to set the take up the hauling line as the discus tended aft.

With the A- frame fully extended outboard and discus clear around the stern the hauling wire was taken in raising the buoy so that its bridle was clear of the water. The A-frame was than brought inboard to allow the 2 air tugger's cables, located on the port and starboard stern cap rail to be hooked into the discus tower bails on either side of the main lifting bail and tension taken up. W.H.O.I. pickup poles were used in hooking these bails. These tugger lines were used to center the buoy in the A-frame and prevent any swing as the buoy was brought inboard (figure A8-2). The discus was lifted so that 1 meter of 3/4" chain was exposed above the deck. The A-frame was then brought inboard bringing the 3/4" chain up against the transom. A 3/4" chain grab shackled to a 1 1/2" dia. bull rope was than hooked .5 meter from the apex of the buoy's bridle into the chain. This line was then passed around the portable capstan and tension was taken up. The mooring tension was then transfered to the capstan and the buoy pulled inboard allowing the buoy bridle to tend inboard and the tower outboard. The buoy and mooring chain were hauled inboard far enough to allow the buoy hull to be lowered just inboard of the deck transom. Once the buoy had been lowered to the deck and wooden wedges put in place, the capstan line was hauled up until the shackle connection between the bridle and the 3/4" chain went slack. The capstan line was then cleated to the deck (figure A8-3). The shackle connection at the bridle was than removed. The discus, now free from the mooring, was shifted out of the mooring recovery area using the starboard HIAB crane. The buoy was then secured to the deck.

The Lebus winch tag line was than reeved thru the port side inboard A-frame block and shackled to the bitter end of the 3/4" chain. The Lebus then began to take up tension on the chain and the capstan line was slowly paid out. The capstan line was removed once the full mooring tension came onto the Lebus tag line. The remainder of the mooring was than recovered using the standard Buoy Group recovery techniques (Heinmiller 1976).

Deployment Operations

Deployment operations on the Darwin involved a 2 phase operation; Phase 1, instrumentation lowering and phase 2, discus deployment.

Phase 1 began by first, lowering the 40 meter VMCM over the stern of the ship using the trawl wire rigged thru the A-frame central block. Attached to the VMCM's cage bottom was the next lower shot of mooring wire rope. This section of wire rope ran back to the Lebus mooring winch. A line handler positioned on the aft port quarter tended this shot of wire to keep the catenary from the VMCM up to the ship as small as possible so as to prevent any twisting or fouling of the wire. Connected to the top of the 40 meter VMCM was the next upper shot of wire rope. This shot of wire was than shackled to the trawl wire. The trawl winch hauled up the upper shot of wire shackled to the instrument so that it hung vertically, just clear of the deck. The A-frame was positioned slightly outboard and the trawl winch paid out slowly in conjunction with the Lebus so that the VMCM was lowered over the transom. The trawl winch stopped paying out when the wire shot's

Figure A8-2. Darwin deck layout while preparing to lift the buoy out of the water. Positioning under the A-Frame and tag line placement.

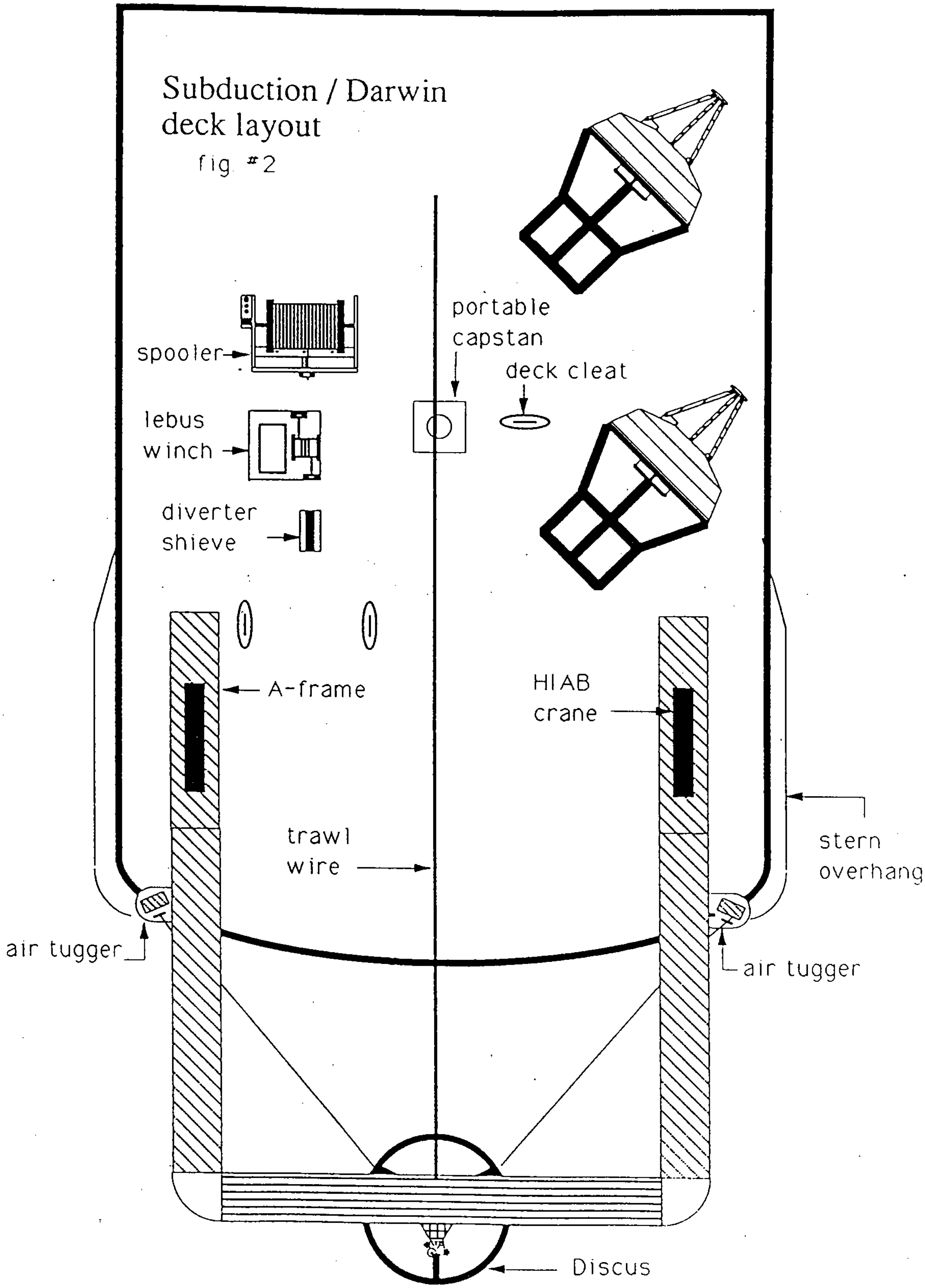
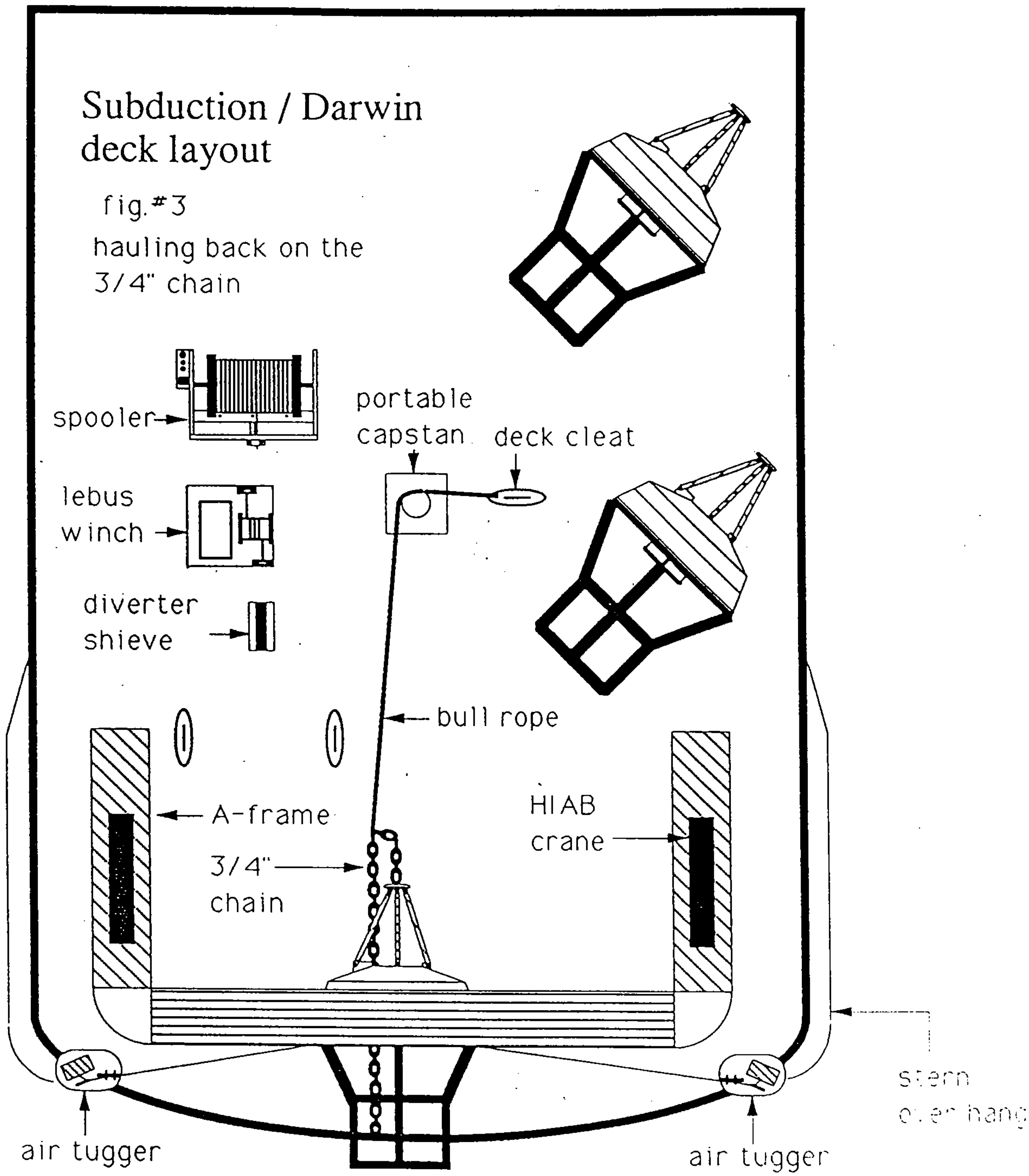


Figure A8-3. Darwin deck layout with buoy on deck and hauling back on the mooring.



upper termination was approximately 2 meters above the deck. The upper wire shot was than stopped off to the deck, and the trawl winch wire removed. The next shallow VMCM was then shackled to the stopped off end of wire rope. The wire shot above this instrument was then shackled to its top and the bitter end of the wire shackled to the trawl winch cable. The trawl winch hauled up the mooring wire and VMCM until vertical and then payed out lowering the assembly over the stern. This procedure was repeated up to the last upper shot before the buoy. The last shot, a 6.5 meters of 3/4" chain, was hooked 1 meter from its top end, using a 3/4" chain grab connected to a bull line run back to the portable capstan. The capstan applied tension to the bull rope / 3/4" chain and the trawl wire was removed. The capstan then hauled the mooring string hung over the stern inboard across the deck 13 ft. and was stopped off. The 13 ft. distance from the transom inboard was the minimum length needed to position the buoy hull in the A-frame and keep the first VMCM from coming up over the stern. Phase 2 involved the shifting of the discus hull into the center of the A-frame and deployment into the water. The discus was raised from it's stowage area along the starboard rail using the starboard HIAB crane, and positioned so that the apex of the buoy bridle could be shackled to the loose end of the stopped off 3/4" chain.

The discus was then rigged with three mooring slip lines. These included one 30 ft. and two 75 ft. 3/4" nylon lines. The 30 ft. slip line was rigged thru a bridle pear ring and stopped off to a deck cleat, positioned forward 2 meters from the end of the bridle. This line was used to control the forward to aft swing of the buoy. The 75 ft. slip lines were passed thru the buoy deck bails, located on either side of the main lifting bail and back to cleats on the port and starboard aft. cap rail. These lines were used to keep the buoy's port to starboard roll in check.

The trawl wire was at this time passed up thru the center A-frame block and its bitter end shackled to a 4 ton quick release hook. The quick release hook was then attached to the main lifting bail. Once tension was taken up by the trawl winch the HIAB crane was unhooked from the discus. Approximately 3 meters above the quick release hook, a 45 ft. tag line was tied to the trawl wire to be used to assist in pulling the wire away from the buoy tower when the discus was finally deployed.

The deck stopper holding the mooring was then paid out transferring the mooring tension to the buoy bridle. With the A-frame positioned slightly outboard, the trawl winch lifted the buoy .5 meter off the deck. The A-frame swung outboard with the three slip lines keeping check on the buoy. Once the buoy's bridle had passed over the transom and lowered 1 meter over the stern of the ship, the bridle slip line was removed. The port and starboard slip lines were paid out slowly keeping the buoy hull centered over the A-frame block as the A-frame shifted outboard. The mooring wire, which had been handled on the aft port quarter, was than cast off over the transom to allow the mooring wire to run unobstructed back to the Lebus. With the A-frame extended outboard the buoy was lowered into the sea. The moment the quick release hook/trawl wire went slack the release hook man pulled the trip line tied to the hook, releasing the buoy. The release hook and tag line tied to the trawl wire were pulled forward, clear of the buoy. The port and starboard slip lines were paid out and cleared last. These lines maintained the proper orientation for the quick release hook, to be released from the main lifting bail. As soon as the buoy was released the ship was instructed to put a minimal amount of weigh on so as to get the buoy away from the stern of the ship. The buoy then moved aft with approximately 80 meters of wire out. After the ship's speed had stabilized the mooring wire running back up to the Lebus was then hauled in slowly up to the next instrument location below the 40 meter VMCM. The mooring deployment from this point continued in the standard Buoy Group technique, (Heinmiller 1976), to the anchor launch.

Appendix 9

CTD Station Summary
RRS Charles Darwin Cruise #73

STA	CTD	DA MO YR	STRT	END	LAT	LONG	DEEP CAL
1	10	30 9 92	1239	1440	32 35.75	17 29.58	3000 .C05
2	10	30 9 92	2153	2239	32 43.81	19 00.32	500 .C05
3	10	1 10 92	0608	0650	32 50.94	20 30.00	500 .C05
4	10	2 10 92	0339	0421	33 02.22	21 58.79	500 .C05
5	10	3 10 92	0228	0308	31 59.97	21 33.89	500 .C05
6	10	3 10 92	0850	0927	30 59.99	21 07.08	500 .C05
7	10	3 10 92	1634	1705	29 45.03	20 35.01	500 .C05
8	10	3 10 92	2104	2145	28 59.98	20 41.07	500 .C05
9	10	4 10 92	0252	0343	28 00.01	20 49.09	1000 .C05
10	10	4 10 92	0904	0937	27 00.07	20 56.15	500 .C05
11	10	4 10 92	1731	1809	25 30.07	21 07.00	500 .C05
12	10	5 10 92	0204	0238	24 00.04	21 16.98	500 .C05
13	10	5 10 92	1036	1203	22 30.02	21 27.89	2000 .C05
14	10	5 10 92	2005	2045	21 00.00	21 39.00	500 .C05
15	10	6 10 92	0208	-9	20 00.02	21 46.05	500 .C05
16	10	6 10 92	0801	0835	19 00.00	21 52.96	500 .C05
17	10	7 10 92	0000	0117	18 01.09	21 57.95	2000 .C05
18	10	8 10 92	0406	0444	18 00.12	23 59.94	500 .C05
19	10	8 10 92	1440	1517	18 00.12	25 59.93	500 .C05
20	10	9 10 92	0116	0159	17 59.96	28 00.07	1000 .C05
21	10	9 10 92	1146	1225	18 00.01	30 00.06	500 .C05
22	10	9 10 92	2158	2238	17 59.01	32 00.00	500 .C05
23	10	10 10 92	0543	0721	18 02.88	33 56.92	2000 .C05
124	10	10 10 92	-9	-9	19 30.02	33 00.04	300 .C05
24	10	12 10 92	1357	1506	19 30.02	33 00.04	500 .C05
25	10	13 10 92	0033	0111	20 59.98	32 00.02	500 .C05
26	10	13 10 92	1026	1106	22 29.96	31 00.21	500 .C05
27	10	13 10 92	2009	2054	24 00.02	29 59.91	500 .C05
28	10	14 10 92	1922	2112	25 30.85	28 56.94	2000 .C05
228	10	14 10 92	2222	-9	25 29.88	28 55.55	3000 .C05
29	10	15 10 92	2204	2253	26 14.93	28 19.78	500 .C05
30	10	16 10 92	0415	0453	26 59.94	27 40.33	500 .C05
31	10	16 10 92	1007	1048	27 45.02	26 59.90	500 .C05
32	10	16 10 92	1542	1638	28 30.01	26 19.70	500 .C05
33	10	16 10 92	2149	2231	29 14.91	25 40.13	500 .C05
34	10	17 10 92	0345	0529	29 59.97	25 00.02	2000 .C05
35	10	17 10 92	1029	1112	29 54.08	25 59.84	500 .C05
36	10	17 10 92	1645	1736	29 48.08	27 00.04	500 .C05
37	10	17 10 92	2233	2327	21 41.98	27 59.10	500 .C05
38	10	18 10 92	0534	0638	29 35.11	29 11.35	1000 .C05
39	10	18 10 92	1310	1359	29 28.74	30 11.30	500 .C05
40	10	18 10 92	2117	2201	29 21.00	31 29.90	500 .C05
41	10	19 10 92	0550	0626	29 11.98	33 00.05	500 .C05
42	10	19 10 92	1558	1706	29 00.01	34 59.99	1000 .C05
43	10	19 10 92	2056	2139	29 40.18	34 49.72	500 .C05

STA	CTD	DA MO YR	STRT	END	LAT	LONG	DEEP CAL
44	10	20 10 92	0135	0213	30 19.90	34 40.14	500 .C05
45	10	22 10 92	0822	0901	32 48.58	33 53.10	500 .C05
46	10	23 10 92	1420	1603	32 54.08	33 56.20	3000 .C05
47	10	24 10 92	0625	0701	33 18.02	33 30.05	500 .C05
48	10	24 10 92	1007	1041	33 35.90	32 59.97	500 .C05
49	10	24 10 92	1334	1409	33 54.05	32 29.93	500 .C05
50	10	24 10 92	1657	1729	34 12.00	32 00.08	500 .C05
51	10	24 10 92	2025	2059	34 29.93	31 30.00	500 .C05
52	10	24 10 92	2344	0018	34 48.04	31 00.02	500 .C05
53	10	25 10 92	0309	0340	35 06.00	30 30.06	500 .C05
54	10	25 10 92	0629	0700	35 24.08	30 00.04	500 .C05
55	10	25 10 92	0947	1015	35 42.11	29 29.59	500 .C05
56	10	25 10 92	1246	1327	36 00.04	29 00.01	500 .C05
57	10	25 10 92	1801	1836	36 24.01	27 59.99	500 .C05
58	10	25 10 92	2320	-9	36 47.90	26 59.92	500 .C05
59	10	26 10 92	0430	0558	37 11.99	25 59.99	2000 .C05

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16. Abstract (Limit: 200 words)

Subduction is the mechanism by which water masses formed in the mixed layer and near the surface of the ocean find their way into the upper thermocline. The subduction process and its underlying mechanisms were studied through a combination of Eulerian and Langrangian measurements of velocity, measurements of tracer distributions and hydrographic properties and modeling.

An array of five surface moorings carrying meteorological and oceanographic instrumentation were deployed for a period of two years beginning in June 1991 as part of an Office of Naval Research (ONR) funded Subduction experiment. Three eight month deployments were planned. The moorings were deployed at 18°N 34°W, 18°N 22°W, 25.5°N 29°W, 33°N 22°W and 33°N 34°W.

A Vector Averaging Wind Recorder (VAWR) and an Improved Meteorological Recorder (IMET) collected wind speed and wind direction, sea surface temperature, air temperature, short wave radiation, barometric pressure and relative humidity. The IMET also measured precipitation. The moorings were heavily instrumented below the surface with Vector Measuring Current Meters (VMCM), and single point temperature recorders.

Expendable bathythermograph (XBT) data were collected and meteorological observations were made while transitting between mooring locations. In addition a series of 59 CTD stations were made and water samples taken to be analyzed for tritium levels, salinity and dissolved oxygen content.

This report describes the work that took place during RRS *Charles Darwin* cruise number 73 which was the third scheduled Subduction mooring cruise. During this cruise the second setting of the moorings were recovered and redeployed for a third eight month period. This report includes a description of the instrumentation that was deployed and recovered, has information about the underway measurements (XBT and meteorological observations) that were made including plots of the data, includes a description of the work conducted in conjunction with the tracer/hydrography program and presents a chronology of the cruise events.

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3. subduction

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