Woods Hole Oceanographic Institution

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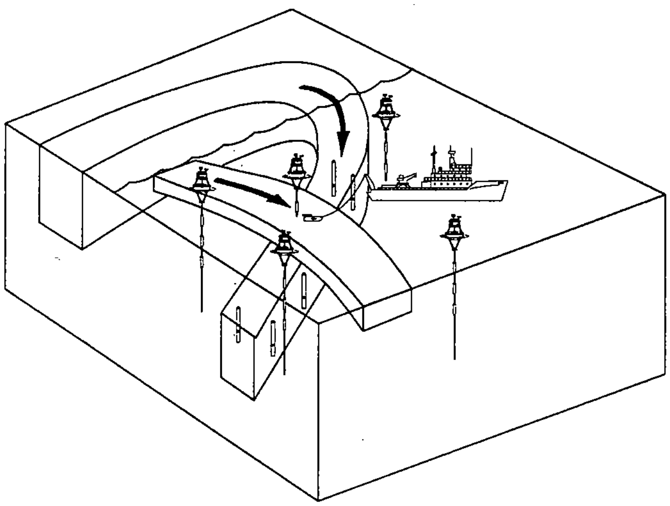
Technical Report

December 1993

The Subduction Experiment



Cruise Report
R/V *Knorr*
Cruise Number 138 Leg XV
Subduction 3 Mooring Recovery Cruise
13 – 30 June 1993

by

Richard P. Trask
Nancy Galbraith
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Woods Hole Oceanographic Institution
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UOP Technical Report 93-8

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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.

This report describes the work that took place during R/V Knorr cruise number 138 leg XV which was the fourth scheduled Subduction mooring cruise. During this cruise the moorings previously deployed for a third and final eight month period were recovered. This report includes a description of the moorings and instrumentation that were recovered, has information about the underway measurements (XBT and meteorological observations) that were made including plots of the data, and presents a chronology of the cruise events.

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Section 1: Introduction

R/V Knorr cruise number 138 (KN138) Leg XV departed Ponta Delgada, Azores, at 0855 UTC on Sunday, 13 June 1993, to recover an array of five surface moorings as part of the Office of Naval Research (ONR) funded Subduction experiment. This cruise was the fourth of four scheduled mooring cruises planned for this experiment (figure 1). Hourly XBTs and meteorological observations were made while in transit between mooring locations.

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 moored array was originally deployed in June 1991 and recovered and redeployed in both February and October 1992. The moorings recovered during this cruise were from the third setting of the array and were known as Subduction 3. Table 1 lists the Subduction 3 mooring positions and the dates they were deployed and recovered. For completeness, the Subduction 1 and 2 (the first and second settings of the moored array) mooring positions and deployment dates are included in tables 2 and 3 respectively.

This report has, in addition to this introduction, two other sections. The second section provides a description of the moorings, buoys, and instrumentation that were recovered, as well as the underway measurements that were made, including XBT profiles and meteorological observations. The third section is a chronology of the entire cruise.

Figure 1. Mooring Cruise Schedule

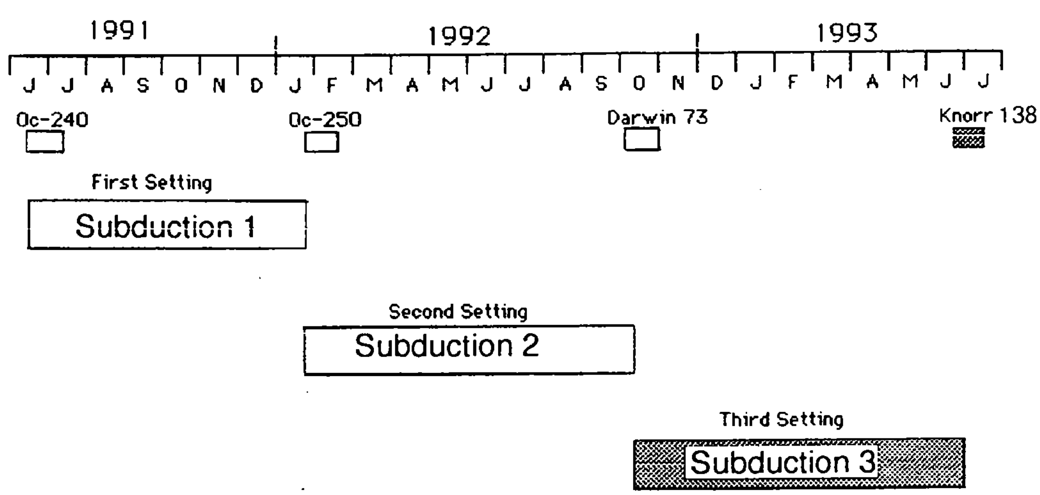


Figure 2. KN138 Leg XV cruise track and mooring positions

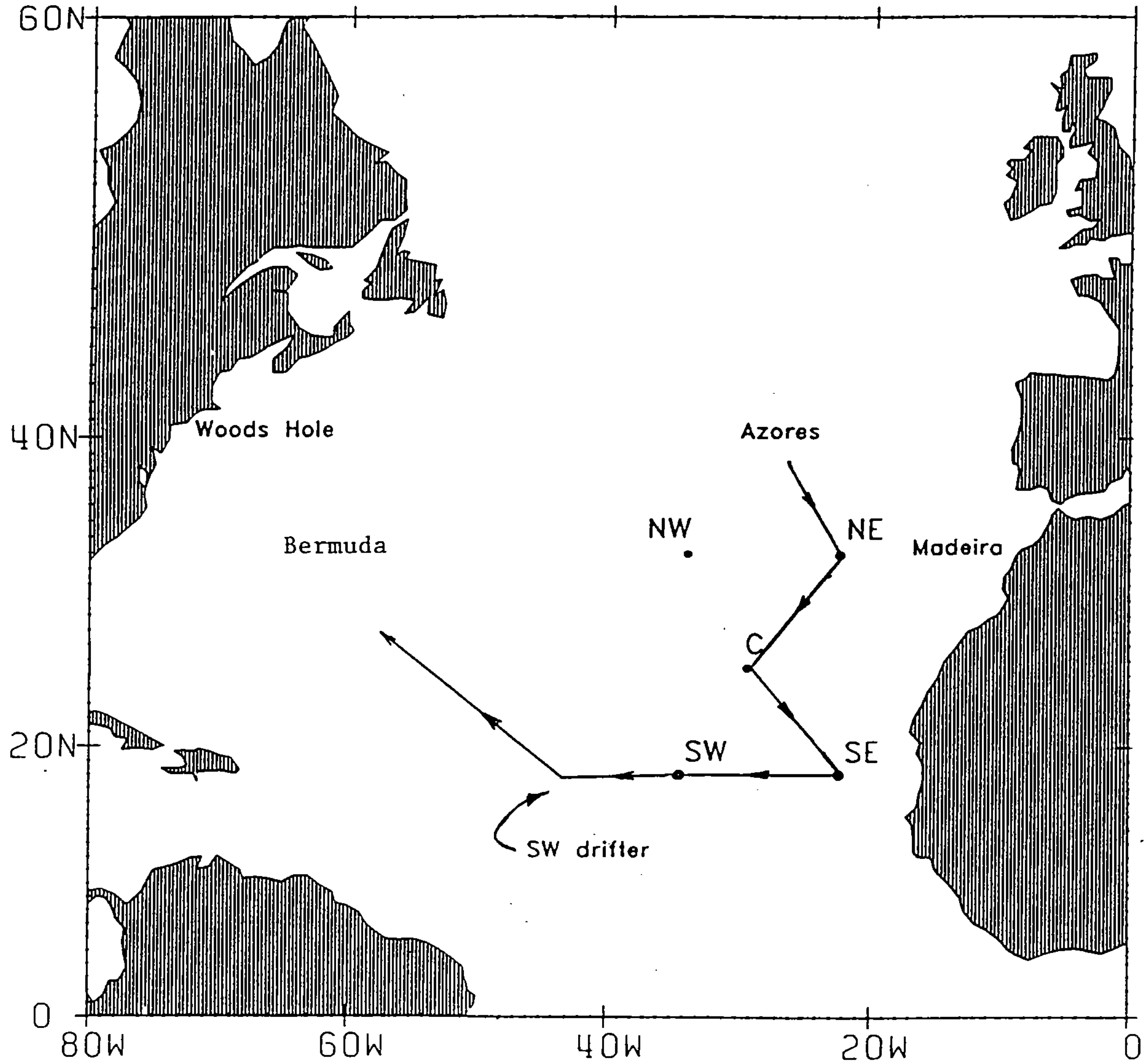


Table 1
Subduction 3 Mooring Deployments and Positions

Buoy	Mooring #	Deployment Date Time (UTC)	Recovery Date Time (UTC)	Position(GPS)
SW**	954	11 Oct1992 @ 1846	21 Jun 1993 @ 1506	18° 05.57'N 33° 53.97'W
SE	953	7 Oct 1992 @ 1157	19 Jun 1993 @ 0526	17° 57.71'W 22° 02.77'W
C	955	15 Oct 1992 @ 1023	16 Jun 1993 @ 2009	25° 31.93'N 28° 56.52'W
NE	952	2 Oct 1992 @ 1449	14 Jun 1993 @ 1528	33° 01.80'N 21° 59.39'W
NW*	956	24 Oct 1992 @ 0017	15 Jun 1993 @ 0300	32° 54.38'N 33° 53.58'W

* NW parted13 March 1993, Discus with upper instruments recovered 11April 1993.
Remainder recovered 15 June 1993.
** SW parted 22 May 1993. Top 10 meters recovered 25 June 1993.
Remainder recovered 21 June 1993.

Table 2
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

Table 3
Subduction 2 Mooring Deployment Dates and Positions

Buoy	Mooring Number	Deployment	Recovery	Position (GPS)
		Date and Time (UTC)		
SW*	924	5 Feb 92 @1318	23 June 93	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.
A second attempt to drag for the mooring during Kn 138 was successful. Bottom recovered 23 June 1993.

Section 2: The Mooring Program

A. Mooring and Buoys

The mooring work carried out during KN138 Leg XV consisted of recovering five moorings that were deployed during earlier Subduction cruises. Five surface moorings were deployed for a third time in October 1992 during RRS Charles Darwin cruise number 73. The surface moorings included two WHOI moorings designated Central and Northeast and three SIO moorings designated Southeast, Southwest and Northwest. Figure 3 schematically shows all five moorings and the distribution of the Subduction 3 subsurface instrumentation. For details about the buoys and their tower configurations deployed during Subduction 3, see Trask et al. 1993a. Appendix 2 has a complete discussion on the surface mooring recovery operations that took place during KN138 Leg XV.

Two moorings failed during the third setting of the Subduction array. The first to fail was the Northwest mooring followed soon thereafter by the Southwest mooring. On 13 March 1993, the Northwest mooring parted and the discus buoy went adrift. The buoy was tracked via satellite and was recovered by the Canadian research vessel Hudson on 11 April 1993. Recovered with the buoy was the upper 104 meters of the mooring. Figure 4 is a mooring schematic of the Subduction 3 Northwest mooring. The deepest component recovered by the CSS Hudson was a pear ring. The shackle and everything below was missing.

Figure 3. Subduction 3 Moored Instrument Positions

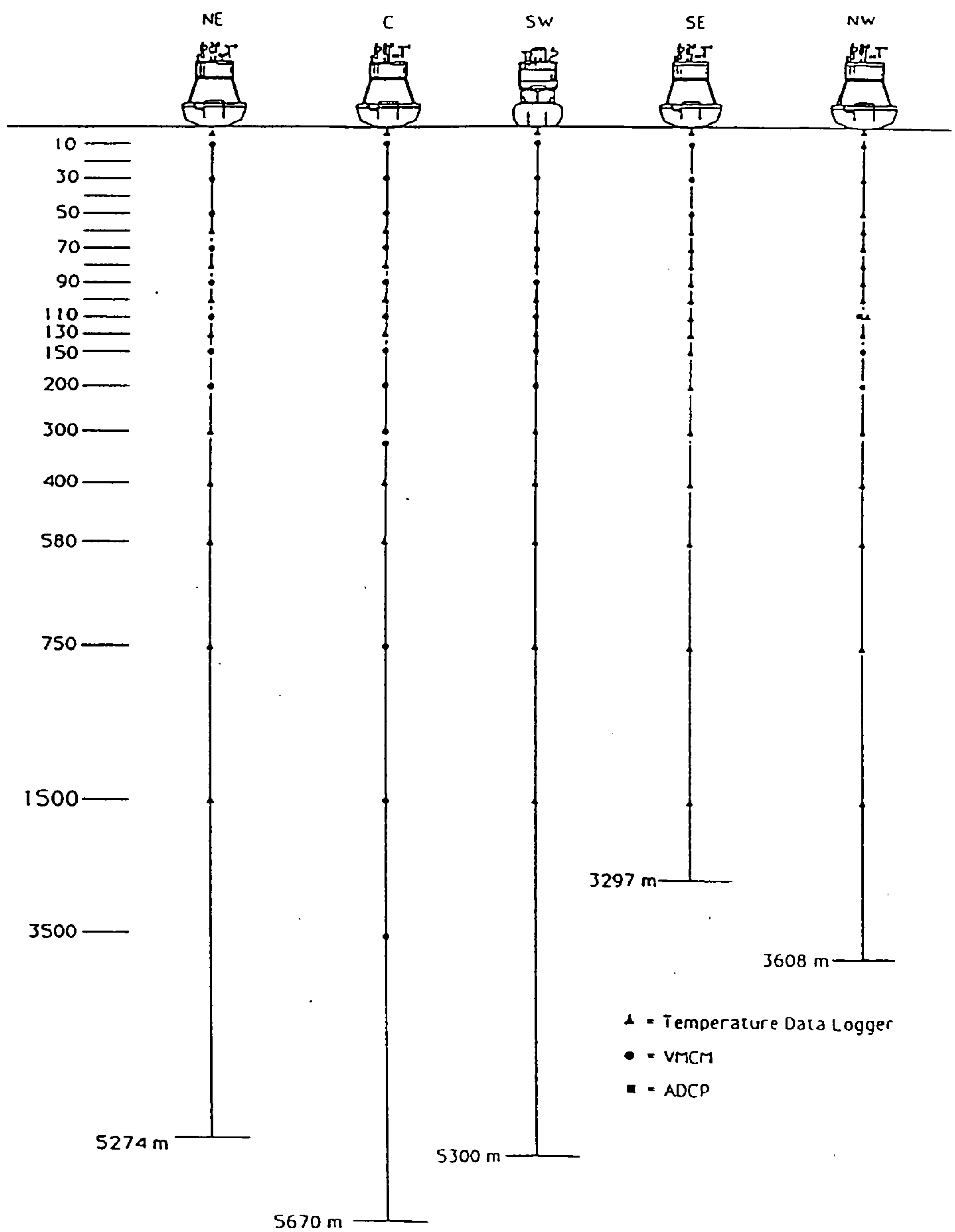
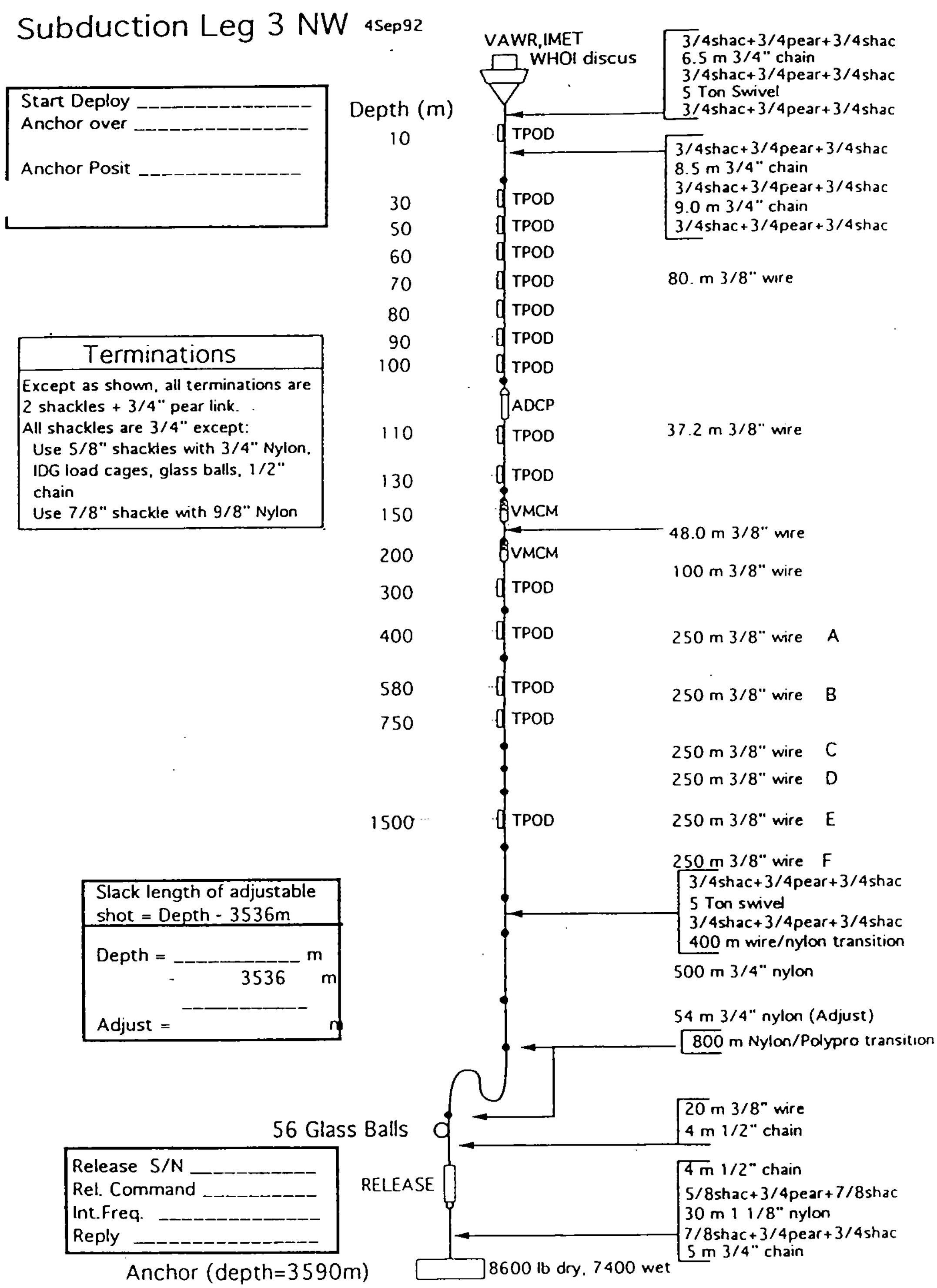


Figure 4. Subduction 3 Northwest Mooring Schematic



Dr. James Luyten (WHOI), chief scientist during R/V Oceanus cruise number 258 Leg 3 agreed to try to recover the lower part of the Northwest mooring if time permitted during his cruise. Two days after the Knorr had left Ponta Delgada the Oceanus reported that they had successfully recovered the bottom portion of the failed Northwest mooring. The upper most part of the mooring recovered by the Oceanus consisted of the lower bail of the ADCP cage. Somehow the ADCP cage failed, and the shackle in the top bail either failed on its own, rattled loose or was removed. It remains a mystery as to the sequence of events that led to the loss of the Acoustic Doppler Current Profiler (ADCP).

Since the Oceanus was able to recover the bottom of the Northwest mooring, there was no need for the Knorr to transit to that site. The shiptime saved by not having to transit to the Northwest site was used to drag for a previously lost mooring at the Southwest site.

On 22 May 1993, the Subduction 3 Southwest mooring parted and its toroid surface buoy went adrift. The lower portion of the Southwest mooring was successfully recovered during KN138 Leg XV (see Section 3). The surface buoy was tracked via satellite and recovered during the same cruise on 25 June 1993, at 0924 UTC.

On 4 June 1992, the Southwest mooring from the second setting of the Subduction array parted. The top of the mooring was recovered on 17 July 1992, by the NOAA vessel Malcolm Baldridge. Attempts to recover the lower portion of the mooring during Darwin cruise 73 were unsuccessful (see Trask et al. 1993a). A dragging operation conducted during KN138 resulted in the successful recovery of all mooring components from the Subduction 2 Southwest mooring. For details about the dragging operation see Section 3 and Appendix 3.

Hardware and wire rope samples were collected from the Northeast and Central moorings. The shackles and pear rings that were deployed together were kept together and labelled. The label included the mooring number and the numbers of the two items that the hardware had connected. The item numbers were taken from the mooring logs. For example, on the Northeast mooring the label on the hardware that connected the buoy to the upper shot of chain would read "952 Item 1-2". The wire rope samples were labelled with the mooring number, their item number from the mooring log and either the word "top" or "bottom" depending upon the end of the wire shot (as oriented on the mooring) from which the sample was taken. For example, the tag on a wire sample from the top of the first shot of wire on the Northeast mooring would read "952 Item 4 TOP". The swaged ends of the wire plus approximately 5 feet of wire were saved as a sample. This will permit re-swaging on the cut end so that the samples can be tested. To inhibit further corrosion, the samples were submerged in seawater for the transit back to Woods Hole. Both the hardware and wire rope samples will be used in future cyclic fatique tests.

B. Instrumentation

A total of 102 recording instruments were deployed on the five Subduction 3 moorings. There were nine meteorological packages, 34 current meters, 58 temperature data loggers, and one ADCP. 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. 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. Both the VAWR and IMET systems individually recorded all data internally as well as telemetered 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.

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. During the third Subduction setting the Southwest toroid did not have an IMET system. The IMET sensors on all the discus buoys are configured the same and mounted on the tower top. The IMET electronics and rechargeable batteries are housed in the discus buoy watertight instrument well.

Since there was no capability to read the IMET optical disk on board ship, it was impossible to back-up the moored IMET data. The VAWR data was read on a model 12B Sea Data reader and transcribed to floppy disk. An exabyte tar tape was also made of the VAWR data. Appendix 4 lists for each VAWR the number of data records, and parity, long and tape errors encountered during the initial tape reading. Appendix 5 describes the condition of each of the IMET systems at the time of recovery.

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 majority of the SIO VMCMs it was 15 minutes. Two SIO instruments (numbers 23 and 24 at 70 and 150 meters respectively on the Southwest mooring) had flash card memory and new electronics which permitted them to store 4 minute averages.

The WHOI VMCMs incorporate several changes to the standard EG&G Sea Link product. These include 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 pods are described in Trask et al (1989) as is some historical information on propeller bearings and blade materials.

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

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-3278	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	V-704WR	V-722WR	V-720WR	V-721WR	V-121WR
IMET					
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	V-380WR	V-712WR	V-713WR	V-707WR	V-717WR
IMET					
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-3296
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 the Subduction experiment the WHOI VMCMs in the upper 100 meters were outfitted with cages that have 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 is 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, 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 8-month Subduction deployments would be 30% longer than most previous deployments. The VMCM propellers used in the Subduction experiment are made of an unpigmented Delrin 100 ST which is impact modified.

The Subduction 3 WHOI VMCMs that were recovered during KN138 were, for the most part, 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 (at 30 and 50 meters depth) on the Northeast mooring had commercial fishing line entangling the propellers. Once removed both rotors on both instruments spun freely. The one WHOI instrument on the Southeast mooring had a sluggish top rotor, and the propeller shaft appeared bent. Two instruments (VM009 and VM011) that were recovered from the Central mooring had been in the water during Subduction 1, 2 and 3 with their original stings (propeller sensor assemblies). These instruments had a total deployment time of 24 months and were found to still be in excellent mechanical condition. See Appendix 6 for specific details noted as both the WHOI and SIO instruments were recovered. Appendix 7 contains more detailed information about the SIO instruments and other notes pertaining to the cruise.

The original data cassettes were read using a Sea Data reader model 12 B, and the data were transcribed to floppy disks. In addition the data were transferred to the ship's SUN computer and stored on an exabyte tar tape. VMCM number 009 (Central mooring at 150 meters depth) was the only instrument that had a noticeably shorter record than the others. Appendix 4 lists for each WHOI current meter the number of data records, parity, long and tape errors encountered during the initial tape reading.

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 were 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 were sampling at 15-minute intervals. 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 installed. The sampling interval for the 4000-series instruments was the same as the 3000-series units.

The Subduction 1 deployment of the Brancker temperature loggers had 15 instruments that leaked a small quantity of water, and, as a result, their data could not be read. See Trask et al 1993a and 1993b for details about the flooding Brancker temperature loggers. In preparation for the third setting of instruments several changes were made to the temperature loggers. In addition to the procedures that were adopted from SIO during the second setting, which included extreme tightening of 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.

Two temperature loggers (at 80 and 580 meters) recovered from the failed Subduction 3 Southwest mooring had pressure cases that were rated for 1000-meters depth. When the mooring failed the instrumentation went to the bottom (5300 meters) where the pressure exceeded the instruments' operating pressure and crushed their pressure cases.

Other than the two crushed instruments none of the WHOI Subduction 3 temperature loggers recovered during KN138 had any indication of leaking, and all instruments recorded data for the entire deployment. The five WHOI temperature instruments recovered from the failed Subduction 2 Southwest mooring showed no signs of leaking and all recorded data. For a complete listing of all Brancker temperature recorders and their previous deployments during the three Subduction settings, see Trask et al 1993a.

The temperature logger data was read from the instruments and stored on floppy disks. Copies of those floppies were made and a copy of the data was also stored on an exabyte tar tape.

C. Underway Measurements

Expendable Bathythermographs (XBT)

Two hundred and three XBTs were deployed during KN138 Leg XV. The T-7 probes were purchased from Spartan of Canada. The XBT data were logged on a personal computer outfitted with the Sippican MK-12 Oceanographic Data Acquisition System (version 1.3). With this system the digitized XBT data were plotted in real time on the PC monitor, and at the conclusion of the profile the data was stored on disk.

Hourly XBTs were taken on the hour while the ship was underway. When the ship was within 10 miles of a surface mooring site, XBTs were temporarily suspended. XBT positions and overplots of the XBT data, as well as contoured sections, can be found in Appendix 8.

The original XBT data was stored on floppy disks. Copies of those floppies were made, as well as an exabyte tar tape.

Meteorological Measurements

IMET sensors shipped from Woods Hole were installed on the bow mast and connected to the shipboard logging system prior to departure from Ponta Delgada. The meteorological parameters measured by the IMET system included wind speed and direction (oceanographic convention relative to the ship), air temperature, relative humidity, short wave radiation, barometric pressure, sea surface temperature and precipitation The IMET sea surface temperature module was installed some time prior to KN138 Leg XV.

IMET data aboard Knorr were exported to a data base management system called Minotaur, which runs on a PC. Minotaur uses Network File System to export data to the shipboard SunSparc 1, named Mike. Once on the Sun, data are available across the network. Minotaur includes a user selectable export list which allowed us to tailor the data storage on the Sun. On KN138, we chose to store all IMET variables and all GPS data to the Sun. The system was easy to use, although an unknown password on the Sun prevented data logging at the start of the cruise.

Using PCDC Telnet, we were able to access the data on the Sun from the PCs in the main lab. Using shell scripts, we could locate the most recent Minotaur data file and extract the fields of interest for the watch's meteorological log. We were also able to access the data directly on the Sun for plotting and archiving.

The instantaneous access to the IMET and GPS data was valuable because it saved time and provided constant verification of successful data storage. Data were extracted from Minotaur data files and tarred to exabyte tape to be brought home for later use. See Appendix 9 for a sample Minotaur log file from KN138. Appendix 9 also includes the shell scripts used to access the Minotaur files in order to print out the most recent IMET data at the terminal.

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 in the main lab using an AIR hand-held sensor; and from the bridge's barometer, air temperature and relative humidity using a hand-held Vaisala sensor; sea surface temperature from a bucket thermometer, and cloud type and cloud coverage in octas. These observations, plus the corresponding IMET data, were manually recorded in the underway meteorological log.

The manual observations of barometric pressure by the AIR hand-held sensor, Vaisala relative humidity and air temperature and bucket temperature were entered and stored on floppy disk. A copy of the data was made on the exabyte tar tape.

Another meteorological data recording system utilizing a Tattletale 7 and IMET modules as sensors was undergoing testing during KN138 Leg XV. Four parameters were being recorded by the TT-7 system. They included barometric pressure, relative humidity, air temperature and shortwave radiation. The data from these sensors were also recorded by hand in the underway meteorological log. A partial record of the data was stored on floppy disk, and a complete record exists on the instrument's hard disk and was read in Woods Hole.

Appendix 10 contains time series plots of meteorological data collected during a two-week period of the cruise. The plots are a comparison of the shipboard IMET system, the TT-7 system, and the hand-held data. The variables plotted are barometric pressure, relative humidity, air temperature and shortwave radiation.

Wind speed and direction from an RM Young anemometer mounted on a 10-foot mast above the flying bridge were also recorded. Since this sensor was mounted 20 feet in front of the ship's mast, there were certain directions relative to the ship that yielded questionable results.

Three independent measurements of sea surface temperature (SST) were collected during the cruise. They included IMET shipboard SST at 4-meters depth, XBT temperature and bucket temperature. IMET SST, and bucket temperature were recorded hourly on the hour in conjunction with the XBTs. Appendix 11 has a comparison of the data collected during the cruise.

Intensive Meteorological Observations

As the ship arrived at each buoy, four hours of intense meteorological observations (IMO) were carried out while the ship maintained a position approximately 1/4 mile downwind of the buoy. During this period, shipboard IMET data were logged by hand every 5 minutes. Every half hour, sea surface temperature readings were taken with a bucket thermometer, and air temperature and relative humidity readings were taken with the Vaisala. Anemometer, gyro, speed log and barometer readings were also taken on the bridge every half hour.

During the IMO periods, VAWR and IMET Argos data telemetered from the buoys were logged using a Telonics receiver and laptop computer for comparison with the shipboard observations. VAWR Argos data were processed on the PC using a suite of programs including picktel and vawrtel. Data were then transferred to the shipboard Sun for plotting. Comparison plots of VAWR and shipboard IMET data were done with Matlab. Table 7 shows the IMO periods for the four buoys recovered during Kn 138 Leg XV.

Table 7
Intense Meteorological Observation Periods KN138 Leg XV.

BUOY	VAWR	DATE	Yr DAY	I.M.O.TIMES. (UTC)
NE	721	14 June	165	1050 - 1450
C	121	16 June	167	1600 - 2000
SE	704	19 June	170	0130 - 0530
SW	720	25 June	176	0400 - 0800

Section 3: Cruise Chronology

The R/V Knorr left Ponta Delgada, Azores, on 13 June 1993, at 0855 UTC. While enroute to the Northeast mooring, hourly XBTs and meteorological observations were taken starting at 1200 UTC on 13 June.

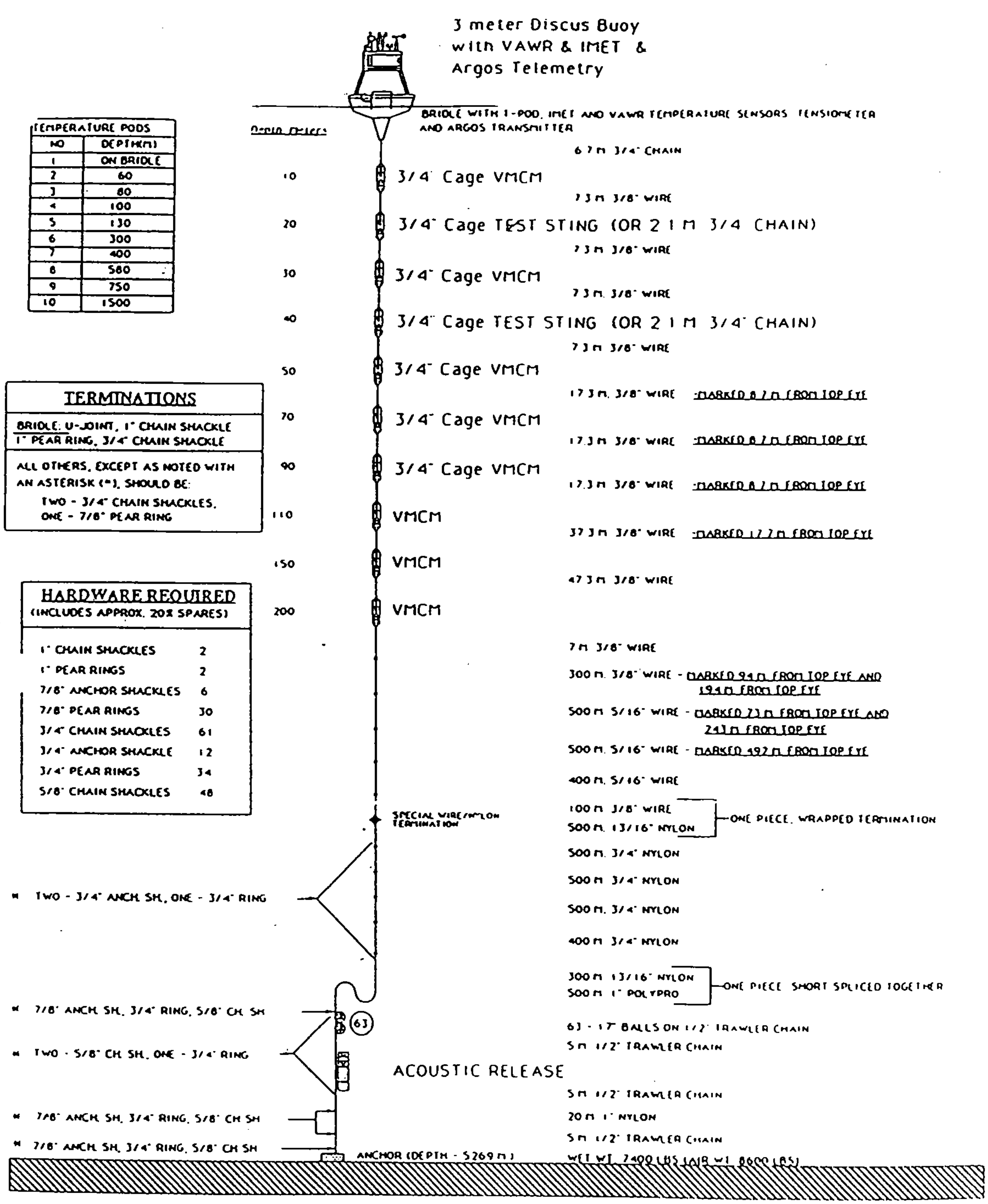
Northeast Mooring

The Knorr arrived at the Northeast buoy at 1050 UTC on Monday, 14 June 1993 at position 33°01.46'N, 21°59.74'W. Figure 5 is a schematic of the Northeast Subduction 3 mooring (WHOI mooring number 952) as deployed in October 1992. As the ship passed by the buoy, it appeared in good condition. 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 5 minutes. With the meteorological observations completed, several attempts were made to talk to the acoustic release. After sending a number of enable commands, a faint response was finally heard. The ship deassigned all engines to try to make things as acoustically quiet as possible. Unable to range on the release, a decision was made to send a release command. An appropriate response to the release command was detected and slant ranges were checked for a short period in order to ascertain that the mooring was coming to the surface. The ship then moved into position for recovery. The discus buoy was alongside and hooked into at 1615 UTC.

While the buoy was alongside, one of the pickup hooks became caught on the VAWR air temperature sensor cable at the base of the sensor. It was freed relatively soon with no visible damage to the wiring. The multiplate shield suffered a small dent. During a short delay in getting a pickup hook in the primary lifting bale, the buoy came in contact with the ship on several occassions. As the buoy was brought on board a tag line caught the R.M. Young wind speed and direction sensor and pulled it from its IMET module. The sensor landed on deck and was retrieved.

The buoy was recovered and secured to the deck. The recovery of the mooring commenced using the WHOI Lebus double barrel capstan winch. The entire mooring was on board by 2118 UTC, 14 June 1993.

Figure 5. Subduction 3 Northeast Mooring Schematic



SUBDUCTION NORTHEAST - THIRD SETTING