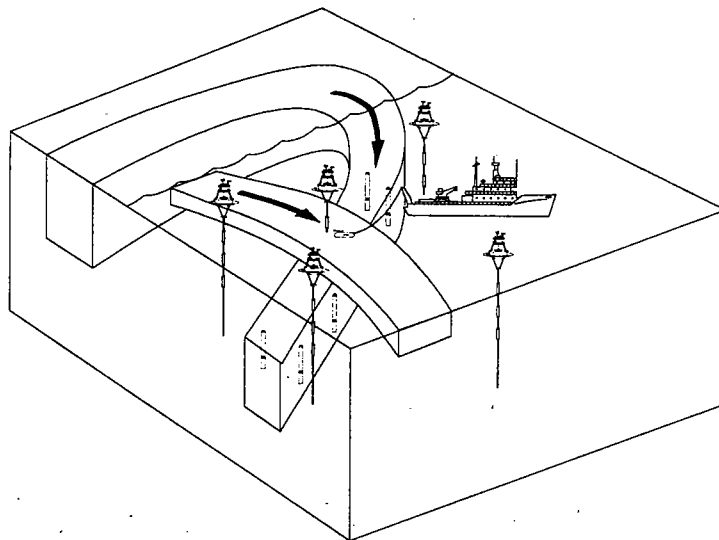




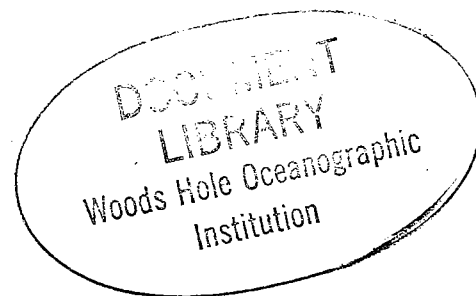
The Subduction Experiment



Cruise Report
R/V *Oceanus*
Cruise Number 240 Leg 3
Subduction 1 Mooring Deployment Cruise
17 June – 5 July 1991

by

Richard P. Trask
Nancy J. Brink



Upper Ocean Processes Group
UOP Technical Report 93-1

**WHOI-93-12
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March 1993

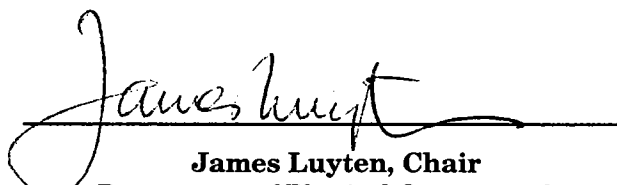
Technical Report

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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 Lagrangian 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 initial deployment of five surface moorings took place during the third leg of R/V Oceanus cruise number 240. 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 transiting between mooring locations.

This report describes the work that took place during R/V Oceanus cruise 240 leg 3. It includes a description of the instrumentation that was deployed, information about the XBT data collected and plots of the data as well as a chronology of the cruise events.

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Section 1: Introduction

R/V Oceanus cruise number 240, Leg 3 departed Funchal, Madeira on 17 June 1991 to deploy five surface moorings as part of the Office of Naval Research (ONR) funded ASTEX and Subduction Experiments. This cruise involved both personnel and equipment from the Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography (SIO). Appendix 1 lists the members of the scientific party. Table 1 lists the deployment positions and dates for the moorings deployed during the cruise. In addition to the mooring work hourly XBTs and half hourly meteorological observations were taken while transiting between mooring sites.

The mooring deployment schedule for the Subduction experiment is shown in Figure 1. The moored array deployed during R/V Oceanus cruise 240 was the first of three settings for the Subduction experiment and is therefore referred to as Subduction 1. Three eight-month deployments were planned so as to collect a two year data set. Moorings were recovered and redeployed in February and October 1992. The final recovery of the array will take place in June 1993.

This report describes the work that took place during R/V Oceanus cruise number 240. It includes a description of the instrumentation that was deployed, information about the XBT data collected, and a chronology of the cruise events.

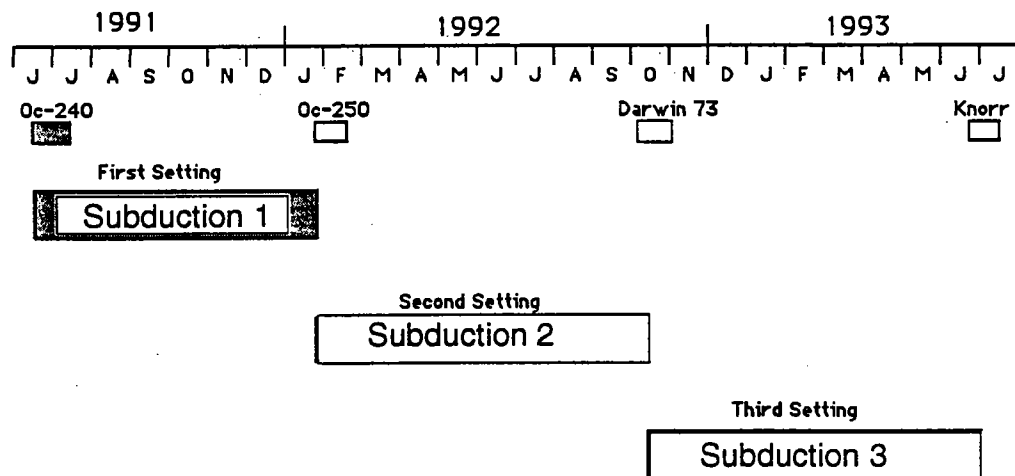


Figure 1. Mooring Cruise Schedule

Table 1. Subduction 1 Deployment Information

Buoy	Mooring #	Deployment Time (UTC)	Position (GPS)
NE	914	18 Jun 1991 1642	33° 00.07'N 21° 59.75'W
C	915	23 Jun 1991 0026	25° 31.90'N 28° 57.17'W
SW	916	25 Jun 1991 1312*	18° 00.03'N 33° 59.96'W
SE	917	29 Jun 1991 0137**	18° 00.13'N 22° 00.00'W
NW	918	3 Jul 1991 1323***	32° 54.61'N 33° 53.50'W

* SW Mooring broke free on 3 November 1991.

** SE Mooring broke free on 10 October 1991.

*** NW Mooring broke free on 3 August 1991.

Section 2: The Mooring Program

A. Moorings and Buoys

Two of the five surface moorings deployed in conjunction with the Subduction experiment were prepared by WHOI. These moorings had a 10' diameter discus buoy as their primary flotation at the surface. The WHOI moorings were deployed at the Northeast (NE) and Central (C) sites of the array. The other three moorings were prepared by SIO and had 7'6" diameter toroid shaped buoys for their primary flotation. The SIO moorings occupied the Southeast (SE), Southwest (SW) and Northwest (NW) sites of the array. Figure 3 shows a line drawing of the discus and toroid buoys with their instrumented tower tops. Figure 4 schematically shows all five moorings and the location of the subsurface instrumentation.

Meteorological instrumentation was mounted to both the discus and toroid buoys. A two part aluminum tower was attached to both buoy types. The top half, which had all the meteorological sensors, marine lantern and satellite antennae is 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 acts as an interface between the buoy hull and the 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 in February and October 1992.

Figure 2. Oceanus 240 ship track and mooring positions

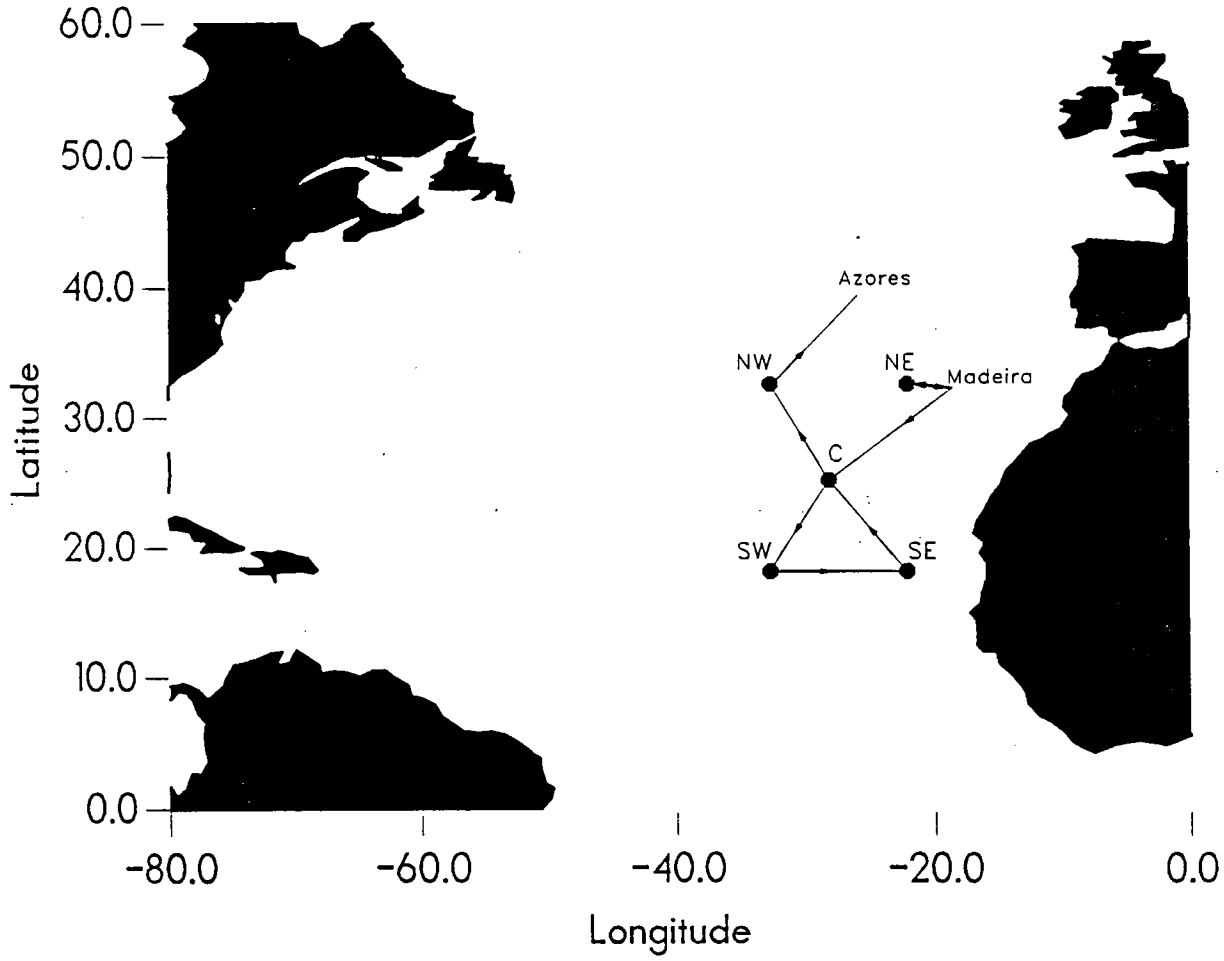


Figure 3. Disc and toroid buoys with instrumented tower tops.

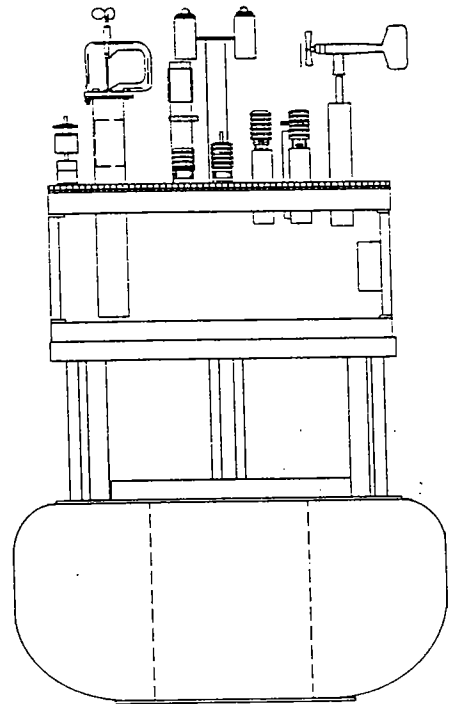
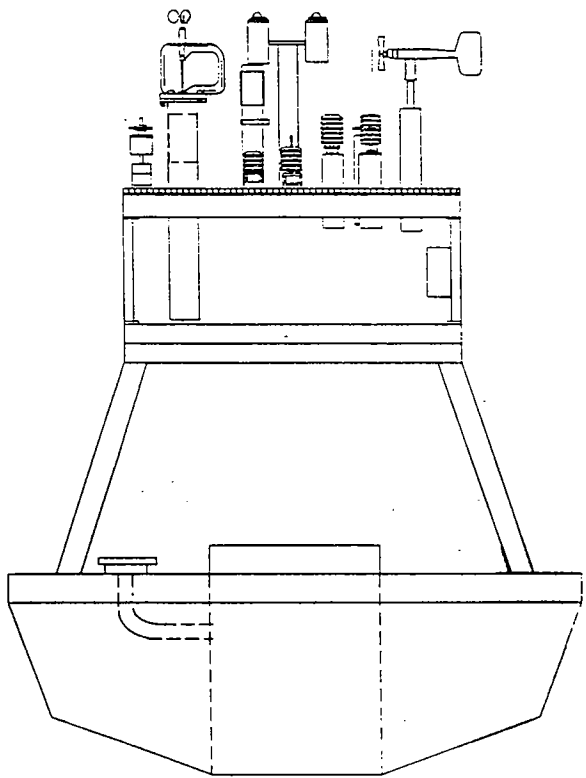
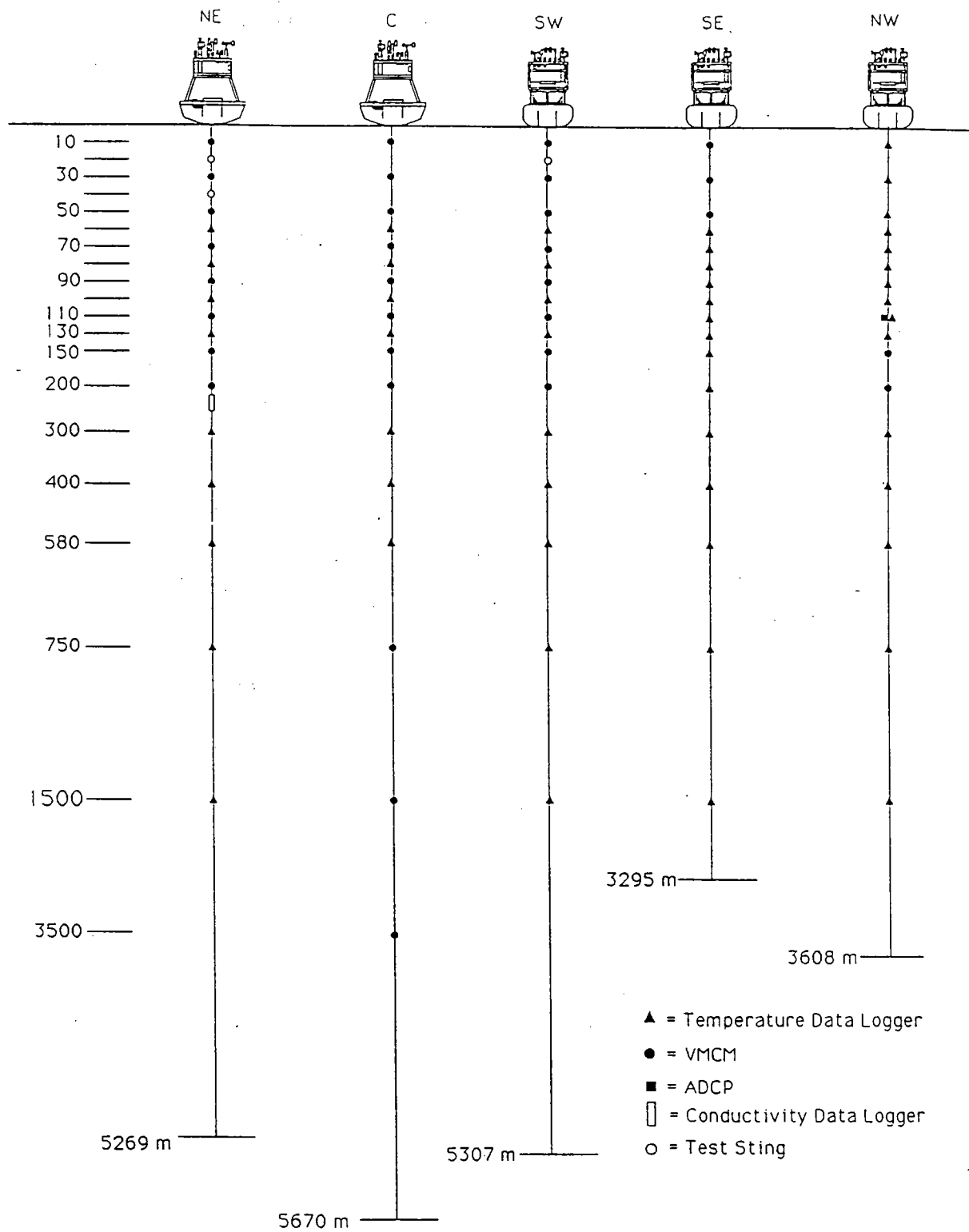


Figure 4. Instrument locations on the Subduction 1 moorings.



B. Instrumentation

A total of 97 recording instruments were deployed on the five Subduction surface moorings. There were 9 meteorological packages, 32 current meters, 53 temperature data loggers, one acoustic Doppler profiler, one conductivity recording instrument and one tension recorder. The specific instrumentation deployed during this cruise is shown in Table 2 .

Meteorological Instrumentation

Four of the five buoys (NE, C, SE and SW) were 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 (Improved METeorological measurements) system which made measurements of the same variables as the VAWR plus precipitation. Tables 3 and 4 provide details about the individual sensors on the VAWR and IMET systems respectively. 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. The Northwest toroid was outfitted with a single VAWR.

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. The IMET sensors on the discus and toroid buoys were configured the same and mounted on the tower top. Sensor heights with respect to the waterline are listed in table 5. In the case the discus buoys the IMET electronics and rechargeable batteries were housed in the discus buoy water tight instrument well. The toroids however had no instrument well and the electronics were fitted in a fiberglass weatherproof enclosure which was secured to the deck of the toroid. The batteries used to power the IMET system on the toroids were Deep Sea Power and Light (San Diego, CA) underwater batteries. These batteries were housed in a stainless frame that was clamped to the inside of the buoy bridle. This configuration provided additional stability for the toroid buoy.

Prior to deployment the air and sea temperature sensors as well as the relative humidity sensors were calibrated at WHOI. The calibrations of the barometric pressure sensors were checked and if found out of specification were returned to the manufacturer for recalibration. The short wave and long wave radiation sensors were calibrated by the manufacturer. The wind direction sensor readings were compared with a known bearing to a fixed target. Details of the direction comparison tests can be found in Appendix 2.

Current Meters

A total of 32 Vector Measuring Current Meters (VMCM) provided by both WHOI and SIO were deployed on the five Subduction surface moorings. The 20 WHOI VMCMs were a modified version of the EG&G Sea Link instrument whereas the 12 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

Table 2. 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
130	W-3269	W-3280	S-2427	S-2432	S-3277 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 3490 3500	W-3293	VM-034 TENS 1029 VM-011	W-3287	W-3259	W-3273

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

Table 3. VAWR Sensor Specifications

Parameter	Sensor	Range	Comments
Wind Speed	Gill 3-cup Anemometer R.M. Young Model 12170C 100 cm/rev	0.2-50 m/s	Vector-averaging
Wind Direction	Integral Vane w/ Vane follower WHOI / EG&G	0-360°	Vector-averaging
Short wave Radiation	Pyranometer Eppley Model: 8-48	0-1400 watts/m ²	Average system
Long wave Radiation	Pyrgeometer Model: PIR	0-700 watts/m ²	Average system
Relative Humidity	Variable Dielectric Conductor Vaisala Humicap	0-100%	3.5 sec sample
Barometric Pressure	Quartz Crystal Digiquartz Paroscientific Model: 215	0-1034 mb	2.5 sec sample (Burst taken midway through avg. period)
Sea Temperature	Thermistor Thermometrics 4K @ 25° C	-5 to +30°C	1/2 time average Measured during first half of avg. period.
Air Temperature	Thermistor Yellow Springs #44034 5K @ 25°C	-10 to +35° C	1/2 time average Measured during 2nd half of avg. period.

Table 4. IMET Sensor Specifications

Parameter	Sensor	Range	Comments
Wind Speed and Wind Direction	R.M. Young Model 5103 w/9 bit Gray Code encoder and KVH Industries Model MC202 compass	0-60 m/sec	Vector-averaging
Short wave Radiation	Eppley Precision Spectral Pyranometer (PSP)	0-1400 watts/m ²	1 minute average
Long wave Radiation	Eppley Precision Infrared Pyrgeometer (PIR)	0-600 watts/m ²	1 minute average
Relative Humidity	Rotronic MP-100F	0-100%	1 minute average
Barometric Pressure	AIR Inc Model: DB-1A	850-1050 mb	1 minute average
Sea Temperature	Platinum Resistance Thermometer	-5° to +45° C	1 minute average
Air Temperature	Platinum Resistance Thermometer	-40° to +45° C	1 minute average
Precipitation	R.M. Young Model: 50201 Siphon Rain Gauge	0-50 mm	

Table 5. Height of Meteorological Sensors above a Nominal Waterline.

	Discus*	Toroid**
VAWR		
Air Temperature†	2.73	2.39
Relative Humidity†	2.74	2.40
Barometric Pressure	2.79	2.45
Short wave Radiation	3.45	3.11
Long wave Radiation	3.45	3.11
Wind Speed	3.40	3.06
Wind Direction	3.12	2.78
IMET		
Air Temperature†	2.79	2.45
Relative Humidity†	2.79	2.45
Barometric Pressure	2.76	2.41
Short wave Radiation	3.45	3.11
Long wave Radiation	3.45	3.11
Wind Speed and Direction	3.17	2.83
Precipitation	3.15	2.81

* Waterline approximately .41 m from buoy deck

** Waterline approximately .43m from buoy deck

† Measurement to midpoint of shield

Units = Meters above the waterline

blades and a redesign of the instrument cage. The cage redesign is described in Trask *et al.* (1989) as is some historical information on propeller bearings and blade materials.

For the first deployment of the Subduction experiment the WHOI VMCMs in the upper 100 meters were outfitted with cages that had 3/4" 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.

VMCM Bearings

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 8 month Subduction deployment would be 30% longer than most previous deployments.

The 3/8" diameter propeller shaft ball bearings typically used on VMCMs had stainless steel races and balls. Both type 316 and 440 stainless steel bearings had been used with variable results. The type 316 bearings offered greater corrosion resistance but were a softer material and showed excessive wear when used on near surface VMCMs. The type 440 stainless bearings were harder and could tolerate the near surface conditions but were less resistive to corrosion than were the type 316 bearings. The upper instruments required a bearing material with greater wear resistance due to the considerable relative motion they experienced introduced not only by the ocean currents and orbital wave velocities but also by the motion of the buoy as it tended to slide down the slope of the waves seeking the trough. Corrosion was still a factor but to a lesser degree. The deeper instruments experienced less wave action and did not experience as much buoy motion as did the near surface instruments. These bearings were not being flushed as readily as those near the surface and corrosion by products could build up in the bearing and cause it to bind. A bearing material more resistant to corrosion was therefore needed in the deeper environment. In the past the Upper Ocean Processes Group (UOP) group had outfitted the upper VMCMs with the type 440 stainless bearings and the deeper instruments have had type 316 stainless bearings. This configuration of bearings seemed to just survive a 5 to 6 month deployment however the individual surface mooring deployments for the Subduction experiment were planned for 8 months so an alternative bearing material was needed.

Previous test results indicated that silicone nitride bearings might be a promising alternative. The first tests of silicon nitride bearings were conducted in an accelerated wear test fixture. During those tests it was found that the SiNi balls displayed considerably less wear than did their stainless steel counterparts for the same operating period. One of the original bearings with SiNi balls had been used on three separate surface mooring deployments for a total of 19 months. (Since the spin characteristics of these bearings continued to be satisfactory they were deployed for a fourth time on one of the Subduction moorings). VMCMs with MPB SiNi bearings had been deployed on several different surface moorings but none had the opportunity to be reused. The longest deployment being 17 months. This however was not a typical deployment since the mooring parted after 66 days on station. The current meters with the SiNi bearings fell to the bottom (2845 m) and remained there for 15 months with little to no propeller motion. Upon recovery of these instruments the inspection of their bearings showed no detectable wear in either the balls or the races. The longest deployment in which the MPB SiNi bearings had continual use was off Bermuda for 9 months. Following recovery these bearings were inspected and appeared to be smooth and shiny with no visual wear. The races and balls were measured and there were no differences between similar parts. The Duroid ball retainer also showed little to no wear.

VMCM Propellers

The propellers for VMCMs which are commercially available from EG&G Ocean Products are manufactured by injection molding Delrin 577, a glass filled, ultraviolet stabilized acetal plastic. Individual blades of these propellers frequently returned from a deployment broken close to where the blade is dovetailed into the hub. Some propellers returned completely intact, while others were missing one or several blades and still others had no blades at all. Given the unpredictable nature of the problem a UOP group policy was established to not reuse the Delrin 577 propellers. New propellers were used every time the instrument was deployed.

The failure mode was first thought to be due to fatigue. It was hypothesized that the blades were constantly being flexed a finite amount until they failed. To test this hypothesis a fixture was set up in the laboratory to flex the propeller blade at an accelerated rate until it failed. The signature of the break caused by fatigue in the laboratory did not, however, resemble that which was always seen on the recovered propeller hubs. The signature of the at-sea break more closely resembled the type of break that occurs when the blade is quickly broken by hand when sharply bending it toward the front of the hub. Given the similarity of the breaks it was felt that the failure may be due to a more rapid process such as impact possibly by fish rather than fatigue.

Blade breakage however had not been a problem for SIO VMCM propellers. The SIO blades were reused many times without any evidence of a breakage problem. The SIO blades were machined rather than injection molded and were made from Delrin 500 which is not glass reinforced. A sample of the SIO blades along with both used and new Delrin 577 blades as well as an unreinforced Delrin blade were tested by the Comtex Development Corporation formerly of Bridgewater, MA. Three mechanical tests namely a flexure strength test (ASTM D790) and notched and unnotched IZOD Impact tests (ASTM D256) were completed on each blade type to assess the toughness and notch sensitivity of the materials.

Test results from the new and used Delrin 577 indicate that there was no detectable degradation in properties either with exposure to sea water or due to the stresses and fatigue of operation. In comparing the glass reinforced material with that which was not reinforced it was seen that the reinforcing fibers increased the flexure modulus by 45% but decreased the strength by 6.5%. Both of the factors are unfavorable because the reinforced blade cannot bend nearly as much before it reaches its failure stress. This indicates that the unreinforced material will bend farther and absorb more energy before cracking. This conclusion was confirmed by the IZOD impact tests. The notched impact strength of the unreinforced blade was 77% higher than the notched reinforced blade. In addition the unreinforced material had unnotched impact strengths 3 times greater than those for the reinforced blades.

Based on these results a decision was made to change to a unreinforced Delrin for the VMCM propeller blades. The material chosen was unpigmented Delrin 100 ST which is impact modified. The 100 ST has an Izod impact strength nearly 20 times greater than the Delrin 577 material. Since the flexural modulus of the 100ST is 180 kpsi vs 730 kpsi for the 577 material the 100 ST blades are considerably more flexible. Concern that the propeller blade might flex to the point of interfering with the VMCM sting led to several flow tests conducted by SIO personnel in their hydraulics laboratory stratified flow channel. The Delrin 100 ST propellers were checked at 5, 53, 76, 85, 91, 97, 107, 122, and 125 cm/sec flow. The sting was then rotated 180 degrees and tested at 125 cm/sec thus checking the deflection of the propellers for forward and aft currents. Throughout these tests there was no visible deflection of the propellers blades and therefore no interference with the sting. The clearance between the blades and sting remained constant at approximately .4" for the entire range of flows.

VMCM Bearing and Propeller Test Stings

In order to continue to gain experience with various bearing materials several test stings were deployed. The test sting consisted of a standard VMCM sting with two orthogonal hubs.

Since there are no electronics wired to the sting the pressure case was replaced by a short PVC housing at the base of the sting to provide a watertight seal and as a means of attachment to the cage.

Three test stings were deployed on the Subduction 1 moorings. Test sting number one (TS-1) was deployed at 20 meters depth on the Northeast discus mooring. Both hubs of the sting were fitted with previously used MPB silicone nitride bearings from the first Marine Light in the Mixed Layer deployment in 1989 (MLML-89). The 3/8" bearings (i.e. they have a .875" outside diameter (O.D.) and .375" (3/8") bore) were glued to the 3/8" diameter type 316 stainless steel propeller shafts using Loctite 271 and Primer T. Type 316 stainless steel C-rings were used on the shafts. The upper hub had propellers injection molded with Delrin 577 and the lower hub had WHOI assembled propellers with Delrin 100 blades and Delrin 577 propeller hubs.

Also on the Northeast discus mooring but at 40 meters depth was another test sting (TS-3). Both hubs on this test sting had used 3/8" bore bearings that consisted of silicone nitride balls and tungsten carbide races. These bearings were used in instruments that were deployed in three previous experiments. They were at 50 meters depth for 5 months during the Frontal Air Sea Interaction Experiment (FASINEX), followed by 8 months at 30 meters on a pilot mooring for the Subduction experiment called the PreSubduction Experiment and then at 15 meters depth for 6 months as part of the second deployment of the Engineering Surface Oceanographic Mooring (ESOM II) for a total of 19 months of operation at sea. The propeller shafts were 3/8" in diameter and were type 316 stainless steel. Type 316 stainless steel C-rings were used on both shafts. The propellers on the upper hub had Delrin 100ST blades with Delrin 577 hubs and the lower hub had propellers with Delrin 577 blades and hubs.

Another test sting, labeled TS-2 was deployed on the Southeast toroid mooring at 20 meters depth. The upper hub of this test sting was outfitted with a pair of used MPB silicon nitride bearings (part no. J0001-809) previously used in the MLML-89 deployment described earlier. The lower hub had a pair of new 440 stainless steel bearings (MPB part no. SR6MCKHH 5). Both upper and lower hubs had 3/8" diameter type 316 stainless propeller shafts with 3/8" C-rings of unknown type stainless. The upper hub had Delrin 100ST propeller blades and a Delrin 577 propeller hub. The propellers on the lower hub had Delrin 577 blades and hubs.

Temperature Loggers

A total of 53 temperature data loggers manufactured by Richard Brancker Research Ltd. were provided by both WHOI and SIO for the 5 Subduction moorings. The location of the loggers are shown in figure 4 and table 2. 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 had been machined to accept the mooring wire. The two pieces were clamped around the wire with .25" hardware.

Several different Brancker temperature recorder models were deployed. The SIO 2000 series instruments which had SIO fabricated pressure cases and endcaps sampled at 30 minute intervals. The WHOI and SIO 3000 series instruments sampled at 15 minute intervals.

C. Underway Measurements

Expendable Bathythermographs (XBT)

Two hundred and sixty-eight XBTs were deployed during OC-240. The T-7 probes were purchased from Sippican Inc. of Marion, MA. XBT data was logged on a NEC APC IV which had a Spartan of Canada data acquisition microprocessor card installed. The digital data was simultaneously logged in memory and plotted on the screen.

Hourly XBTs were taken on the hour while the ship was underway. XBTs were suspended when the ship was within 10 miles of a surface mooring. XBT positions and overplots of the XBT data as well as several horizontal contour plots of temperature at various depths and vertical sections of temperature are included in Appendix 3.

Meteorological Measurements

In addition to collecting hourly XBT data, meteorological observations of air temperature, relative humidity, relative wind speed and direction, (along with the ship's speed and direction), barometric pressure and sea surface (bucket) temperature were recorded every 30 minutes on the hour and half hour.

Section 3: Cruise Chronology

Leg 3 of Oceanus cruise number 240 departed Funchal, Madeira on June 17th, 1991 at 0714 UTC. The purpose of Leg 3 was to deploy a total of five surface moorings for the ONR funded ASTEX and Subduction Experiments. The nominal mooring locations are shown in Figure 2.

Northeast Mooring

The first mooring to be deployed was the Northeast mooring shown schematically in figure 5. Upon arrival at the site a depth survey was conducted. The bottom was found to be relatively flat with the mooring site having a corrected water depth of 5264 meters. Throughout the depth survey, mooring deployment, and subsequent acoustic release/anchor survey GPS was used during all navigation.

Following the depth survey two acoustic releases were wire tested down to 1000 meters using the trawl winch. The CTD/hydro winch was not used because the wire was removed to lessen the ship's load which was at its maximum when the ship left Madeira. No problems were encountered during the release tests.

The mooring deployment began 7 nautical miles downwind (southeast) of the target. The near-surface instrumentation were deployed first followed by the surface buoy and the remainder of the mooring. Careful attention was paid to the target site so as to get the anchor as close to it as possible. The anchor was deployed at 1642 UTC on 19 June 1991. Following the deployment an acoustic release/anchor survey (figure 6) was conducted. **Based on the anchor survey the GPS anchor position for the Northeast Subduction mooring (WHOI mooring number 914) was 33°00.07'N, 21°59.75'W.**

During the anchor survey the ship was positioned 1/4 mile downwind of the surface buoy and measurements of sea surface temperature, air temperature, relative humidity, barometric pressure, wind speed and direction were made every 5 minutes for 30 minutes. The ship's position at the start of the meteorological observations was 32°59.362'N, 22°00.151'W.

Following the anchor survey the ship returned to Madeira to load equipment that could not fit during the first part of the cruise. One toroid surface buoy and three anchors with flip plates and seven wire baskets were loaded in Madeira. During the loading of the wire baskets the shoreside crane lost control of the load and dropped it between the ship and the quay. In so doing it damaged the VAWR and one solar panel on the Southeast toroid surface buoy. The wind speed and direction head on the VAWR and solar panel were replaced with spares. Upon completion of loading and fueling in Madeira the ship departed at 2000 on 19 June 1991 enroute to the Central mooring site.

Figure 5. Subduction 1 Northeast Mooring Schematic

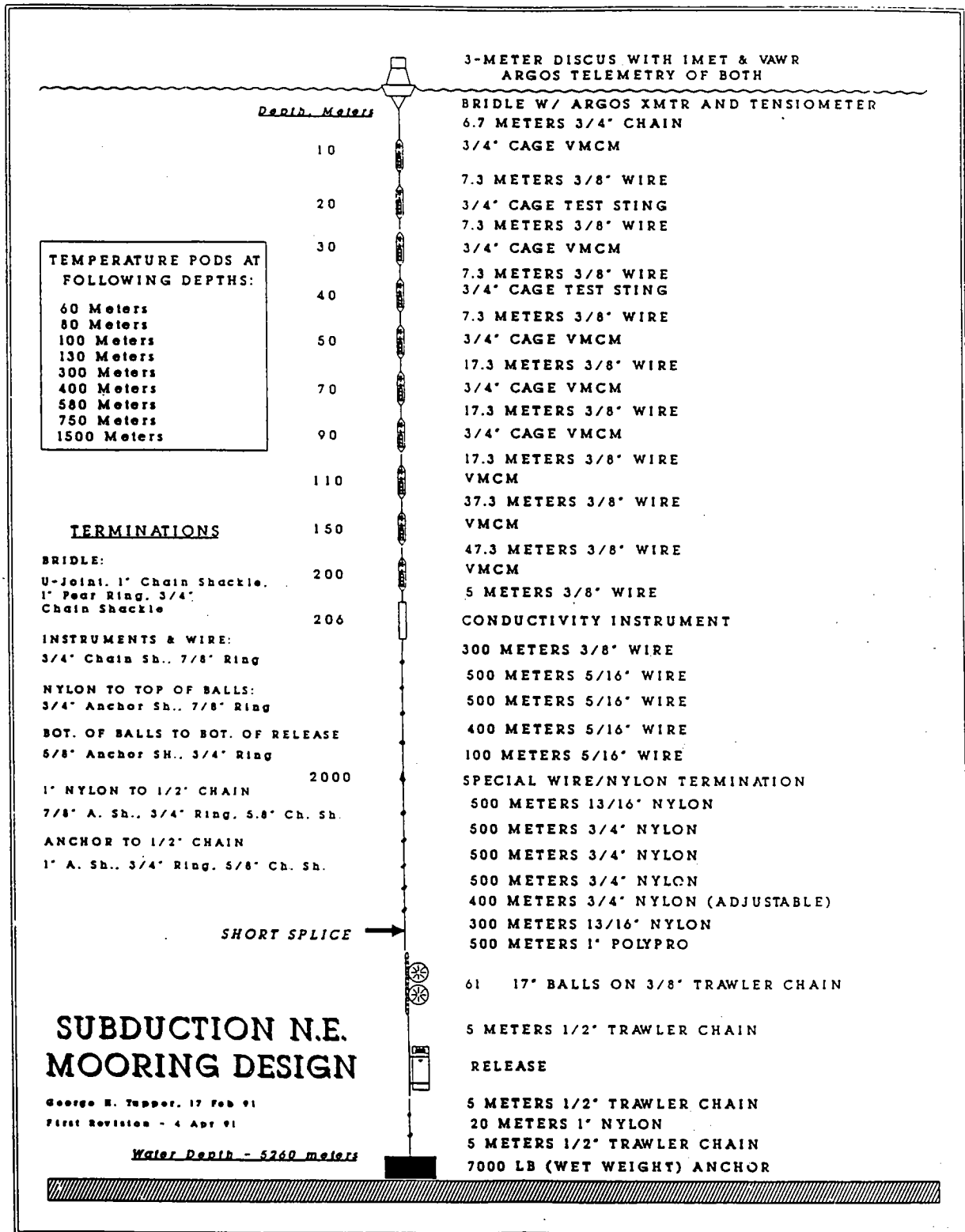
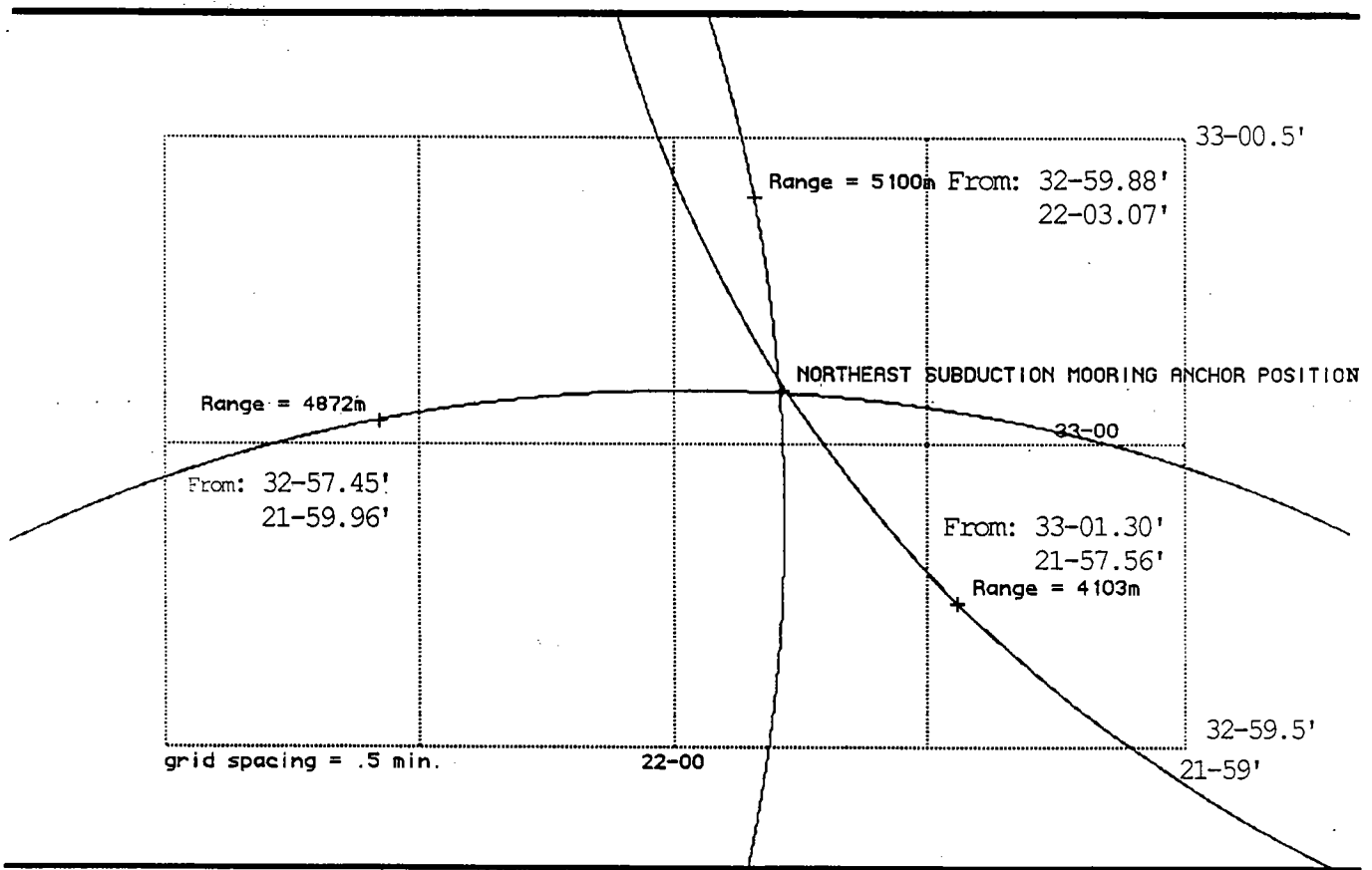


Figure 6. Subduction 1 Northeast Acoustic Release Survey



While enroute to the Central mooring site and throughout the remainder of the cruise (except as noted below) hourly XBTs were taken starting at position $31^{\circ}17.67'N$, $19^{\circ}16.37'W$.

Central Mooring

The second mooring to be deployed was the Central Subduction mooring shown schematically in figure 7. This mooring was unique in that it had two large clusters of glass ball flotation separated by 2000 meters of wire rope. It was a combination of a surface mooring and a taught subsurface mooring.

Deep current measurements from typical WHOI surface moorings have been difficult to make because the mooring inclination at depth can exceed the recommended 15 degrees needed for accurate current measurements. In addition the compliance of the nylon below 2000 meters results in uncertainty as to the depth of the measurements. The Central mooring design was a new design intended to keep the 3500 meter deep VMCM a known distance off the bottom and at an acceptable angle of inclination (<15 degrees).

The R/V Oceanus arrived at the Central Subduction mooring site at 1030 UTC on June 22, 1991. The depth survey was started upon arrival. The original proposed mooring site ($25^{\circ}30'N$, $29^{\circ}W$) had an irregular sloping bottom and it was decided to move the site to the northeast about 3 nautical miles where the bottom was flat and uniform. Following the depth survey one WHOI acoustic release and one SIO release were wire tested down to 1000 meters.

Upon completion of the acoustic release wire tests the Oceanus moved to a position 7 miles downwind (southwest) of the new mooring site in preparation for starting the mooring deployment. The buoy and upper instrumentation were deployed without incident starting at 1445 UTC. The deployment continued through to the wire-to-nylon shot which had all been pre-wound on the winch. At this point the mooring was stopped off and towed while the remaining shots were wound. Once the remainder of the mooring was on the winch, payout was resumed. The ship's speed over the ground during the deployment of the first half of the mooring (up to the first cluster of glass balls) was approximately 1 knot. After the glass balls were deployed the ship's speed was slowed to between .5 and .7 knots in anticipation of the increased drag due to the glass balls. The anchor was deployed at 0027 UTC on June 23, 1991. Following the deployment an anchor survey (figure 8) was conducted. **The GPS anchor position for the Central mooring (WHOI mooring number 915) was $25^{\circ}31.90'N$, $28^{\circ}57.17'W$.** The water depth at the site was 5670 meters.

Following the deployment of the Central mooring, water samples were collected for Jim Ledwell (WHOI). Since there was no hydro wire on board the ship, a reel of 1/4" kevlar was wound on the TSE mooring winch. Nine depths had previously been marked on the kevlar where Niskin bottles were to be placed. The Kevlar was deployed with a weight off the stern and Niskin bottles were attached at the appropriate depths (50, 100, 150, 200, 250, 300, 350, 400 and 450 meters). The Niskin bottles were tripped at 0135 UTC on 23 June 1991 at position $25^{\circ}32.817'N$, $28^{\circ}55.498'W$. The surface wire angle at the time the samples were collected was measured to be approximately 30 degrees.

Prior to leaving the Central mooring site the Oceanus was positioned 1/4 mile downwind of the surface buoy. Shipboard meteorological observations were logged every 5 minutes for

Figure 7. Subduction 1 Central Mooring Schematic

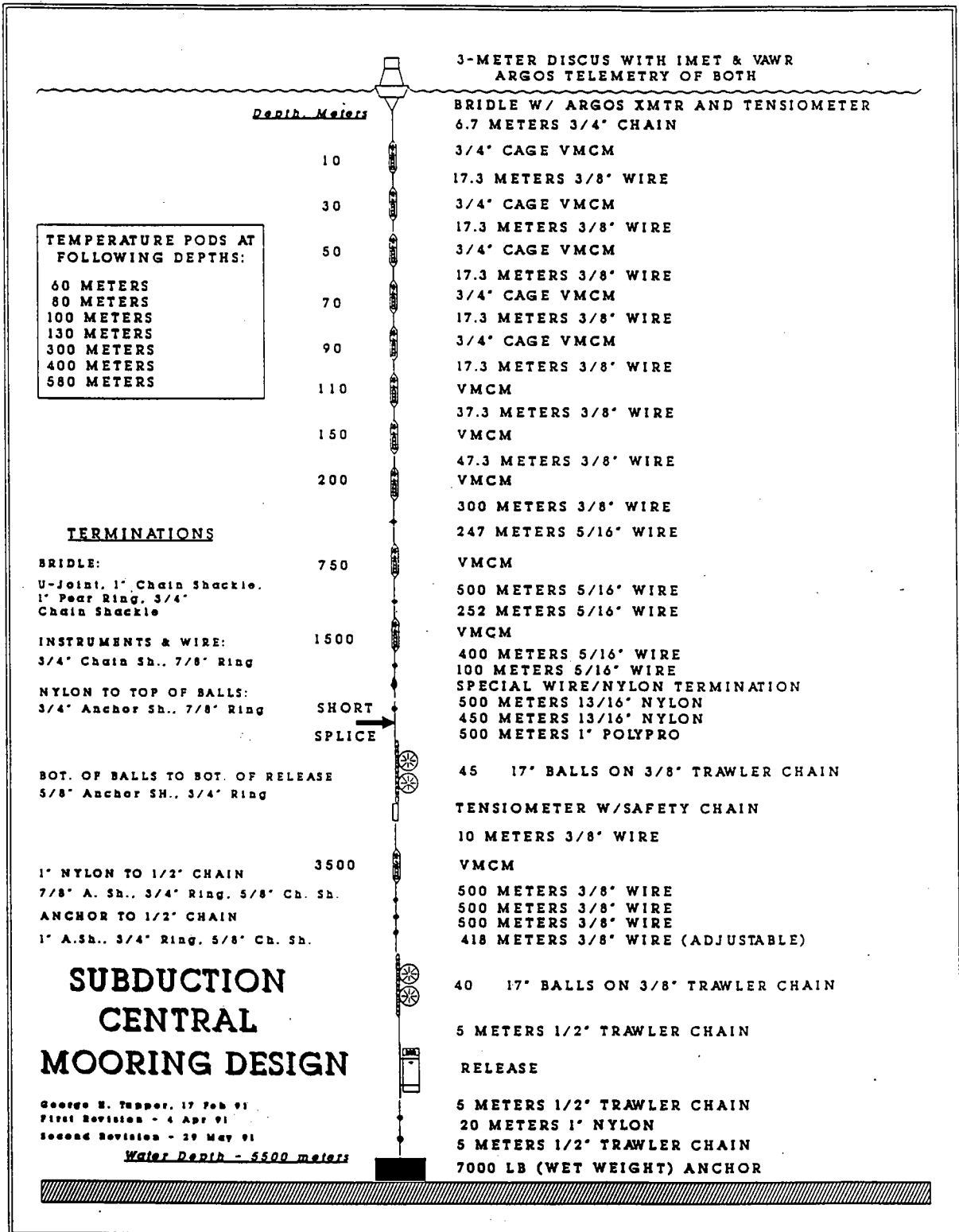


Figure 8. Subduction 1 Central Mooring Acoustic Release Survey

Central Mooring Release Survey

