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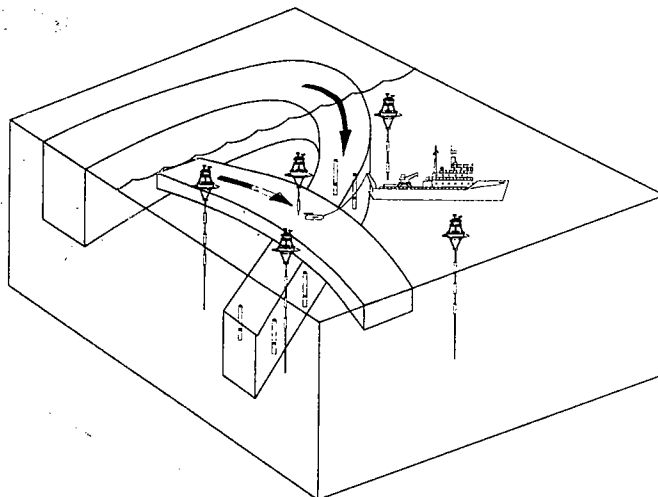
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Technical Report

June 1995



The Subduction Experiment



Mooring Field Program and Data Summary

Sub1 June 1991 – February 1992
Sub2 – February 1992 – October 1992
Sub 3 October 1992 – June 1993

by

Nancy J. Brink
Kerry A. Moyer
Richard P. Trask
Robert A. Weller



Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543-1541
UOP Technical Report 95-2

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Funding provided by the Office of Naval Research under
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Abstract

An array of five surface moorings carrying meteorological and oceanographic instrumentation was 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 carried out. The five mooring locations were 18°N 34°W, 18°N 22°W, 25.5°N 29°W, 33°N 22°W and 33°N 34°W.

Two Woods Hole Oceanographic Institution (WHOI) and three Scripps Institution of Oceanography (SIO) moorings collected oceanographic and meteorological data, using a 3-meter discus or 2-meter toroid buoy and multiple Vector Measuring Current Meters (VMCMs), an Acoustic Doppler Current Profiler (ADCP) and Brancker temperature recorders (tpods). The surface buoys carried a Vector Averaging Wind Recorder (VAWR) and, on four of the five moorings, an Improved Meteorological Recorder (IMET) which measured wind speed and wind direction, sea surface temperature, air temperature, short wave radiation, barometric pressure and relative humidity. The IMET also measured precipitation. The VMCMs, ADCP and tpods, placed at depths 1 m to 3500 m, measured oceanic velocities and temperatures.

This report presents meteorological and oceanographic data from the WHOI Upper Ocean Processes Group (UOP) and the SIO Instrument and Development Group (IDG) instruments and contains summaries of the instruments used, their depths, mooring positions, mooring deployment and recovery times, and data return. Appendices contain information on supplementary Subduction data sets.

Table of Contents

| | Page |
|------------------------------------|------|
| Abstract..... | 2 |
| List of Figures..... | 4 |
| List of Tables..... | 5 |
| Section 1. Introduction..... | 6 |
| Section 2. Instrumentation..... | 14 |
| A. Meteorological..... | 14 |
| B. Subsurface..... | 20 |
| Section 3. Data Processing..... | 22 |
| A. UOP Software Package..... | 22 |
| B. Meteorological Processing..... | 22 |
| Section 4. Data Display..... | 30 |
| Acknowledgments..... | 102 |
| References..... | 102 |
| Appendix A. VAWR and IMET IDs..... | 105 |
| Appendix B. VMCM IDs..... | 106 |
| Appendix C. TPod IDs..... | 108 |
| Supplemental Datasets | |
| Appendix D. XBT Information..... | 111 |
| Appendix E. Underway Data..... | 112 |
| Appendix F. ALACEs..... | 113 |

List of Figures

| | Page |
|--|-------|
| Figure 1. Subduction mooring locations. | 7 |
| Figure 2. Subduction mooring time line..... | 11 |
| Figure 3. VAWR sensor averaging periods..... | 17 |
| Figure 4. Discus buoy with fully instrumented tower top..... | 18 |
| Figure 5. Instrumental configuration of the subsurface moorings deployed during Subduction 2. | 21 |
| Figure 6. Four day running mean time series of the basic meteorological variables by mooring..... | 32–36 |
| Figure 7. Four day running mean time series of the computed wind stress and heat and radiation fluxes by mooring..... | 37–41 |
| Figure 8. Observed rainfall at each of the Subduction moorings. | 42 |
| Figure 9. Monthly averaged wind and wind-driven current vectors. | 43–51 |
| Figure 10. Composite temperature plot for moorings. | 52–56 |
| Figure 11. Calculated mixed layer depth plot..... | 57 |
| Figure 12. Stacked velocity stick plots..... | 58–62 |
| Figure 13. Composite progressive vector diagrams. | 63–65 |
| Figure 14. Meteorological variable spectra. | 66–67 |
| Figure 15. Stacked rotary spectra..... | 68–70 |
| Figure 16. 10 m spectra from each Subduction deployment..... | 71 |

List of Tables

| | Page |
|---|--------|
| Table 1. Subduction 1 deployment, recovery and position information..... | 8 |
| Table 2. Subduction 2 deployment, recovery and position information..... | 9 |
| Table 3. Subduction 3 deployment, recovery and position information..... | 10 |
| Table 4. Subduction data return. | 12 |
| Table 5. VAWR sensor specifications..... | 15 |
| Table 6. IMET sensor specifications..... | 16 |
| Table 7. Height of meteorological sensors above a nominal waterline. | 19 |
| Table 8. Subduction 1 instrument ID's..... | 23 |
| Table 9. Subduction 2 instrument ID's..... | 24 |
| Table 10. Subduction 3 instrument ID's..... | 25 |
| Table 11. Monthly meteorological statistics | 72–81 |
| Table 12. Monthly oceanic velocities and temperature statistics | 82–101 |

Section 1: Introduction

A clockwise atmospheric circulation around the Bermuda/ Azores High makes the Subtropical North Atlantic a preferred region for Ekman layer convergence and subduction. Subduction is a process by which mixed layer water is injected into the main thermocline (Stommel, 1979; Luyten *et al.*, 1983; Cushman-Roisin, 1987). In an effort to more fully understand the sequence of events leading to subduction, an ambitious two year field experiment was undertaken in the eastern North Atlantic.

One of the primary components of the Subduction experiment was the maintenance of a large-scale mooring array from which both atmospheric and oceanographic data were collected. The five-mooring array straddled the eastern flank of the Bermuda/Azores High from June 1991 through June 1993. As shown in Figure 1, the moorings were located at 33°N 34°W, 33°N 22°W, 18°N 34°W, 18°N 22°W, and 25.5°N 29°W and are referred to by their relative positions (NW, NE, SW, SE, and C) within the framework of the array. Each mooring was outfitted with a full compliment of meteorological and oceanographic instrumentation. The meteorological instruments collected dynamic, thermodynamic, and radiometric data just above the sea surface, while their oceanographic counterparts measured temperature and velocity at fixed depths below the surface.

The two-year mooring component of Subduction was separated into three distinct eight month settings in order to reduce the deleterious effect that a prolonged exposure to the harsh oceanic environment would have upon the moorings. Thus, at eight month intervals, the moorings were systematically retrieved, refurbished, and redeployed (Trask *et al.*, 1993a, b, c, d). Precise deployment and recovery dates for each of the moorings are provided in Tables 1, 2, and 3. Despite this careful attention, several moorings did not survive their respective eight month settings. This was especially true on the first deployment, as three of the five moorings parted at one time or another during their initial deployment. However, as illustrated in Figure 2, subsequent deployments were not as susceptible to mooring failure and the overall scope and quality of the Subduction mooring data is exceptionally good. Percentages of the data return from both the meteorological and oceanographic instrumentation are found in Table 4.

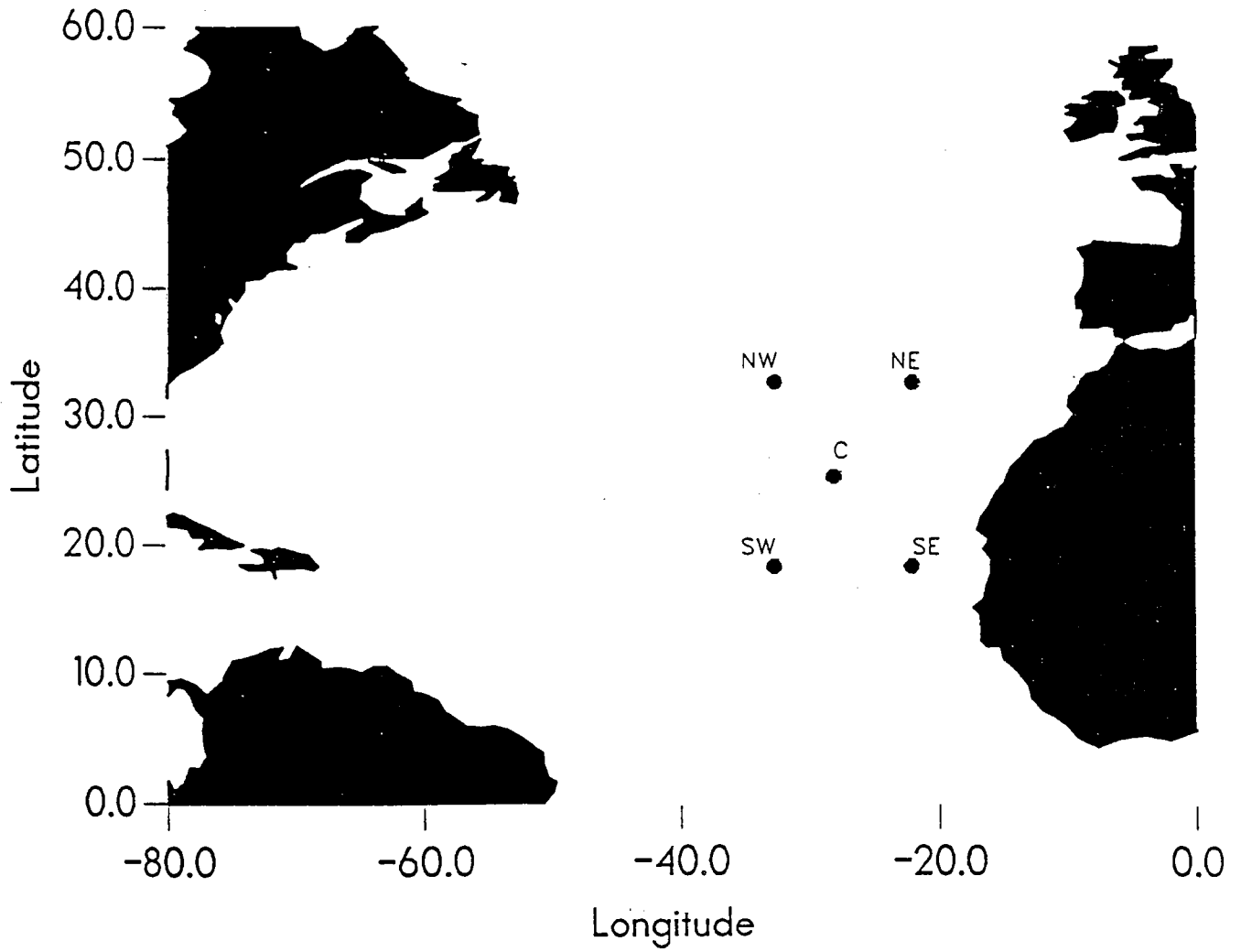


Figure 1. Subduction mooring locations.

Table 1
Subduction 1 Mooring Deployment Dates and Positions

| Buoy | Mooring # | Deployment Date Time (UTC) | Recovery Date Time (UTC) | Position (GPS) |
|-------|-----------|-------------------------------|-----------------------------|----------------------------|
| NE | 914 | 18 Jun 1991 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 | 4 Feb 1992 1844 | 18° 00.03'N 33° 59.96'W |
| SE** | 917 | 29 Jun 1991 0137 | 8 Feb 1992 0843 | 18° 00.13'N 22° 00.00'W |
| NW*** | 918 | 3 Jul 1991 1323 | 23 Feb 1992 1022 | 32° 54.61'N 33° 53.50'W |

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

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

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

Table 2
Subduction 2 Mooring Deployment and Recovery Dates and Positions

| Buoy | Mooring # | Deployment Date Time (UTC) | Recover Date Time (UTC) | Position (GPS) |
|------|-----------|-------------------------------|----------------------------|--------------------------|
| SW* | 924 | 5 Feb 1992 1318 | 23 Jun 1993 1840 | 17°59.93'N 34°00.65'W |
| SE | 925 | 9 Feb 1992 0244 | 6 Oct 1992 1759 | 17°59.72'N 22°00.29'W |
| C | 926 | 12 Feb 1992 1915 | 14 Oct 1992 1203 | 25°31.95'N 28°57.23'W |
| NE | 927 | 20 Feb 1992 1547 | 1 Oct 1992 1857 | 33°01.98'N 22°00.27'W |
| NW | 928 | 23 Feb 1992 2328 | 23 Oct 1992 0912 | 32°54.42'N 33°53.35'W |

* SW Parted 4 June 1992, Toroid with upper instrument cage recovered 17 July 1992.
 Unsuccessful dragging attempt during DARWIN cruise 73. Final recovery was on
 KNORR 138 on 23 June 1993.

Table 3
Subduction 3 Mooring Deployment and Recovery Dates and Positions

| Buoy | Mooring # | Deployment Date Time (UTC) | Recovery Date Time (UTC) | Position (GPS) |
|------|-----------|-------------------------------|-----------------------------|----------------------------|
| SW** | 954 | 11 Oct 1992 1846 | 21 Jun 1993 1506 | 18° 05.57'N 33° 53.97'W |
| SE | 953 | 7 October 1992 1157 | 19 Jun 1993 0526 | 17° 57.71'N 22° 02.77'W |
| C | 955 | 15 October 1992 1023 | 16 Jun 1993 2009 | 25° 31.93'N 28° 56.52'W |
| NE | 952 | 2 October 1992 1449 | 14 Jun 1993 1528 | 33° 01.80'N 21° 59.39'W |
| NW* | 956 | 24 October 1992 0017 | 15 Jun 1993 0142 | 32° 54.38'N 33° 53.58'W |

* NW parted 13 March 1993. Upper section recovered 11 April 1993. Bottom section recovered 15 June 1993.

** SW parted 22 May 1992. Upper section recovered 25 June 1993. Bottom section recovered 21 June 1993.

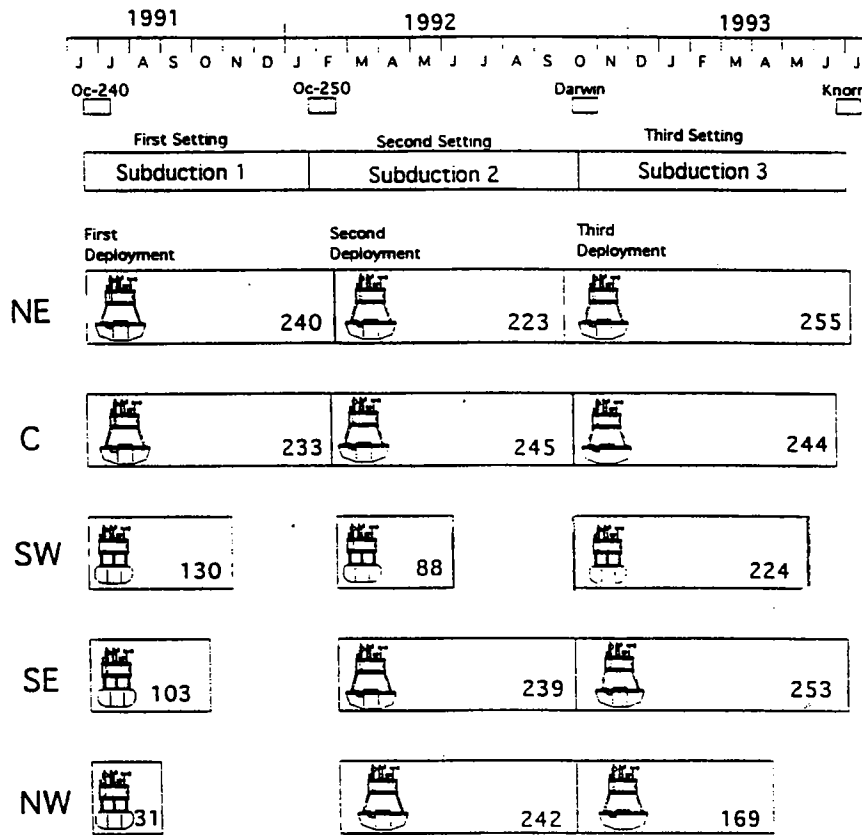


Figure 2. Subduction mooring time line.

Table 4. Subduction Data Return

| SUB 1 | NE | C | SW | SE | NW |
|--------------|-----------|----------|-----------|-----------|-----------|
| met | 100 | 100 | 100 | 95 | 100 |
| 1 | ----- | ----- | ----- | ----- | ----- |
| 10 | 100 | 100 | 100 | 95 | 100 |
| 30 | 100 | 25* | 100 | 0 | 100 |
| 50 | 100 | 100 | 100 | 10 | 60 |
| 60 | 10* | 100 | 100 | 0 | 0 |
| 70 | 100 | 100 | 100 | 100 | 100 |
| 80 | 100 | 100 | 100 | 100 | 100 |
| 90 | 100 | 7* | 100 | 100 | 100 |
| 100 | 2* | 100 | 100 | 100 | 0 |
| 110 | 35* | 100 | 0 | 100 | 100/100 |
| 130 | 100 | 100 | 100 | 100 | 100 |
| 150 | 100 | 20* | 100 | 100 | 100 |
| 200 | 100 | 35* | 100 | 100 | 100 |
| 300 | 0 | 0 | 100 | 100 | 100 |
| 310 | ----- | ----- | ----- | ----- | ----- |
| 400 | 0 | 0 | 100 | 100 | 100 |
| 580 | 0 | 0 | 100 | 0 | 0 |
| 750 | 0 | 0 | 0 | 100 | 100 |
| 1500 | 0 | 100 | 0 | 0 | 0 |
| 3500 | ----- | 100 | ----- | ----- | ----- |
| SUB 2 | NE | C | SW | SE | NW |
| met | 100 | 95 | 94 | 100 | 88 |
| 1 | 100 | 100 | 100 | 100 | 100 |
| 10 | 100 | 100 | 100 | 100 | 100 |
| 30 | 100 | 100 | 100 | 100 | 100 |
| 50 | 100 | 72 | 100 | 64 | 100 |
| 60 | 100 | 100 | 100 | 100 | 100 |
| 70 | 100 | 100 | 100 | 100 | 100 |
| 80 | 100 | 100 | 100 | 100 | 100 |
| 90 | 100 | 100 | 0 | 100 | 100 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 110 | 100 | 100 | 100 | 100 | 100/100 |
| 130 | 100 | 100 | 100 | 100 | 100 |
| 150 | 100 | 100 | 100 | 100 | 46 |
| 200 | 100 | 100 | 100 | 100 | 0 |
| 300 | 100 | 100 | 25 | 0 | 100 |
| 310 | ----- | 100 | ----- | ----- | ----- |
| 400 | 93 | 100 | 0 | 0 | 100 |
| 580 | 100 | 100 | 100 | 100 | 100 |
| 750 | 0 | 0 | 0 | 0 | 100 |
| 1500 | 0 | 100 | 100 | 100 | 100 |
| 3500 | ----- | 100 | ----- | ----- | ----- |

* bad cassette tape — additional processing required

Table 4. Subduction Data Return (cont.)

| SUB3 | NE | C | SW | SE | NW |
|-------------|-----------|----------|-----------|-----------|-----------|
| met | 100 | 100 | 100 | 100 | 100 |
| 1 | 100 | 100 | 100 | 100 | 100 |
| 10 | 100 | 100 | 100 | 66 | 100 |
| 30 | 100 | 100 | 100 | 100 | 100 |
| 50 | 100 | 100 | 100 | 70 | 100 |
| 60 | 100 | 100 | 100 | 100 | 100 |
| 70 | 100 | 95 | 100 | 0 | 100 |
| 80 | 100 | 100 | 0 | 100 | 100 |
| 90 | 100 | 100 | 100 | 100 | 100 |
| 100 | 100 | 100 | 100 | 100 | 100 |
| 110 | 100 | 100 | 100 | 100 | 0/100 |
| 130 | 100 | 100 | 100 | 100 | 100 |
| 150 | 100 | 0 | 100 | 100 | 100 |
| 200 | 100 | 100 | 100 | 100 | 100 |
| 300 | 100 | 100 | 100 | 100 | 100 |
| 310 | ---- | 100 | ---- | ---- | ---- |
| 400 | 100 | 100 | 100 | 100 | 100 |
| 580 | 100 | 100 | 0 | 100 | 100 |
| 750 | 100 | 100 | 100 | 100 | 100 |
| 1500 | 100 | 100 | 100 | 100 | 100 |
| 3500 | ---- | 100 | ---- | ---- | ---- |

Data return is the percent of good data collected by the individual instruments. If the instrument recorded good data for the total time period it remained on-station, it shows 100(%). If one or more of the variables died during the moored station time, it receives less than 100. This table is used for a quick look at the instruments that worked 100%, or 0%. Values in the middle tend to flag a missing variable or a short file.

Section 2: Instrumentation

A. Meteorological

Four of the five surface moorings carried two independent meteorological instrument systems. One of the systems was a Vector Averaging Wind Recorder (VAWR) which recorded barometric pressure, wind speed and direction, air temperature, sea temperature, relative humidity, and incoming shortwave and longwave radiation (Trask *et al.*, 1989). The other instrument system was an Improved Meteorological Recorder (IMET) which measured the same variables measured by the VAWR and rainfall as well (Hosom *et al.*, 1995). A summary of the individual sensors comprising the VAWR and IMET instrument systems including a general statement of their accuracy is provided in Tables 5 and 6, respectively.

The IMET recorded data every 1 min, while the VAWR recorded data every 15 min. While all of the IMET observables are representative of 1 min averages, the averaging intervals of the VAWR observables are variable dependent. Unlike the wind and radiation measurements which represent true 15 min averages, the remaining VAWR observables were averaged over a subset of the recording interval. For example, sea surface temperature was averaged over the initial 7.5 min, while air temperature was averaged over the final 7.5 min. Barometric pressure and relative humidity were sampled for 2.5 s and 3.5 s, respectively, midway through the 15 min period. The averaging intervals for all of the VAWR sensors are schematically depicted in Figure 3.

The two meteorological instrument systems were mounted on the deck of a 2 m high white aluminum tower which, in turn, was secured to the upper face of either a 3 m diameter discus or 2.4 m diameter toroid buoy. A vane was attached to one side of the tower in order to maintain the buoy's orientation relative to the wind. Special care was taken to ensure that the meteorological instrumentation was configured in an optimal manner. As shown in Figure 4, the radiometers, which require an unobstructed hemispheric view of the sky, occupied the uppermost position on the downwind side of the buoy, while the temperature, humidity, and wind instrumentation were mounted at slightly lower levels on the buoy's upwind side. The upwind positioning of these latter sensors was designed to reduce any inadvertent temperature modification or flow distortion associated with the surface mooring, itself. The precise heights at which each of these sensors were mounted are listed in Table 7 as a function of instrument system and buoy type.

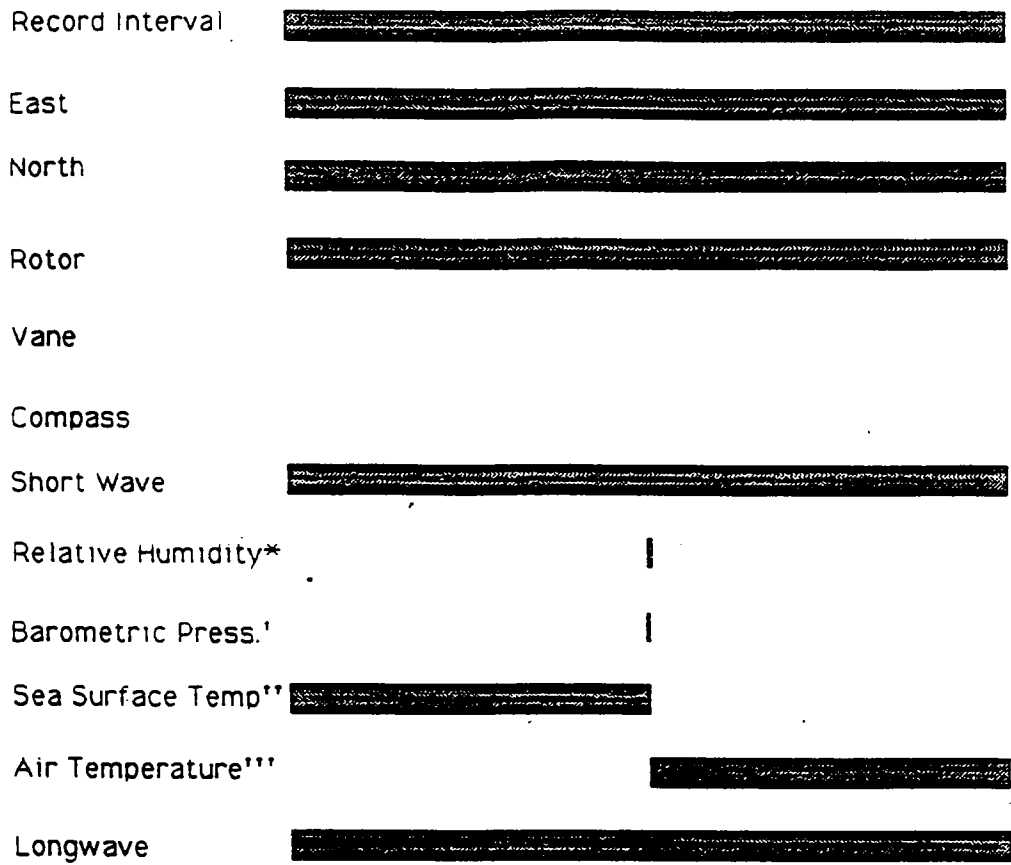
Table 5. VAWR Sensor Specifications

| Parameter | Sensor | Range | Accuracy | Comments |
|-------------------------|--|--------------------------------|--------------------------------|--|
| Wind speed | Gill 3-cup Anemometer R.M. Young Model 12170C 100 cm/rev | 0.2–50 m/s | +/-2% above 0.7 m/s | Vector averaging |
| Wind direction | Integral Vane w/ Vane follower WHOI / EG&G | 0–360° | +/- 1 bit 5.6 deg | Vector averaging |
| Short wave radiation | Pyranometer Eppley Model: 8-48 | 0–1400 watts/m ² | +/-3% of reading | Average system |
| Long wave radiation | Pyrgeometer Model: PIR | 0–700 watts/m ² | +/-10% | Average system |
| Relative humidity | Variable Dielectric Conductor Vaisala Humicap | 0–100% | +/-2%RH | 3.5 sec sample |
| Barometric pressure | Quartz Crystal Digiquartz Paroscientific Model: 215 | 0–1034 mb | +/-0.2mbar wind>20m/s | 2.5 sec sample (burst taken midway) |
| Sea temperature | Thermistor Thermometrics 4K @ 25° C | -5 to + 30°C | +/-0.005 deg C | 1/2 time ave Measured in 1st half of avg. period. |
| Air temperature | Thermistor Yellow Springs #44034 5K @ 25°C | -10 to + 35° C | +/-0.2 deg C wind > 5m/s | 1/2 time ave Measured in 2nd half of avg.period |

Table 6. IMET Sensor Specifications

| Parameter | Sensor | Range | Accuracy | 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 | +/-2% > 0.7m/s +/- 2 bit 0.7 degrees | Vector averaging Scalar ave over 1 min |
| Short wave radiation | Eppley Precision Spectral Pyranometer (PSP) | 0-1400 watts/m ² | +/-3% of reading | 1 min ave |
| Long wave radiation | Eppley Precision Infrared Pyrgeometer (PIR) | 0-600 watts/m ² | +/- 10% | 1 min ave |
| Relative humidity | Rotronic MP-100F | 0-100% | +/- 2%RH | 1 min ave |
| Barometric pressure | AIR Inc Model: DB-1A | 850-1050 mb | +/-0.2 mbar wind >20m/s | 1 min ave |
| Sea temperature | Platinum Resistance Thermometer | -5 to +45 deg C | +/-0.005 deg C | 1 min ave |
| Air temperature | Platinum Resistance Thermometer | -40 to +45 deg C | +/-0.005 deg C wind >5m/s | 1 min ave |
| Precipitation | R.M. Young Model: 50201 Siphon Rain Gauge | 0-50 mm | | |

VAWR sensor averaging periods



- * Relative humidity sensor is on for 7 seconds and counted for 3.515 seconds
 - ' Barometric Pressure sensor is on for 4.39 seconds and counts for 2.636 seconds
 - '' Sea surface temperature is averaged during the first half of the record rate Actual averaging interval is half the record rate minus 1.7578125 seconds (delay and settle time from SST to AT)
 - ''' Air temperature is counted for the second half of the averaging interval. The air temp average interval is half the record rate minus 1.7578125.
- Recorded compass and vane information is the last sample taken in the record interval.

Figure 3. VAWR sensor averaging periods.

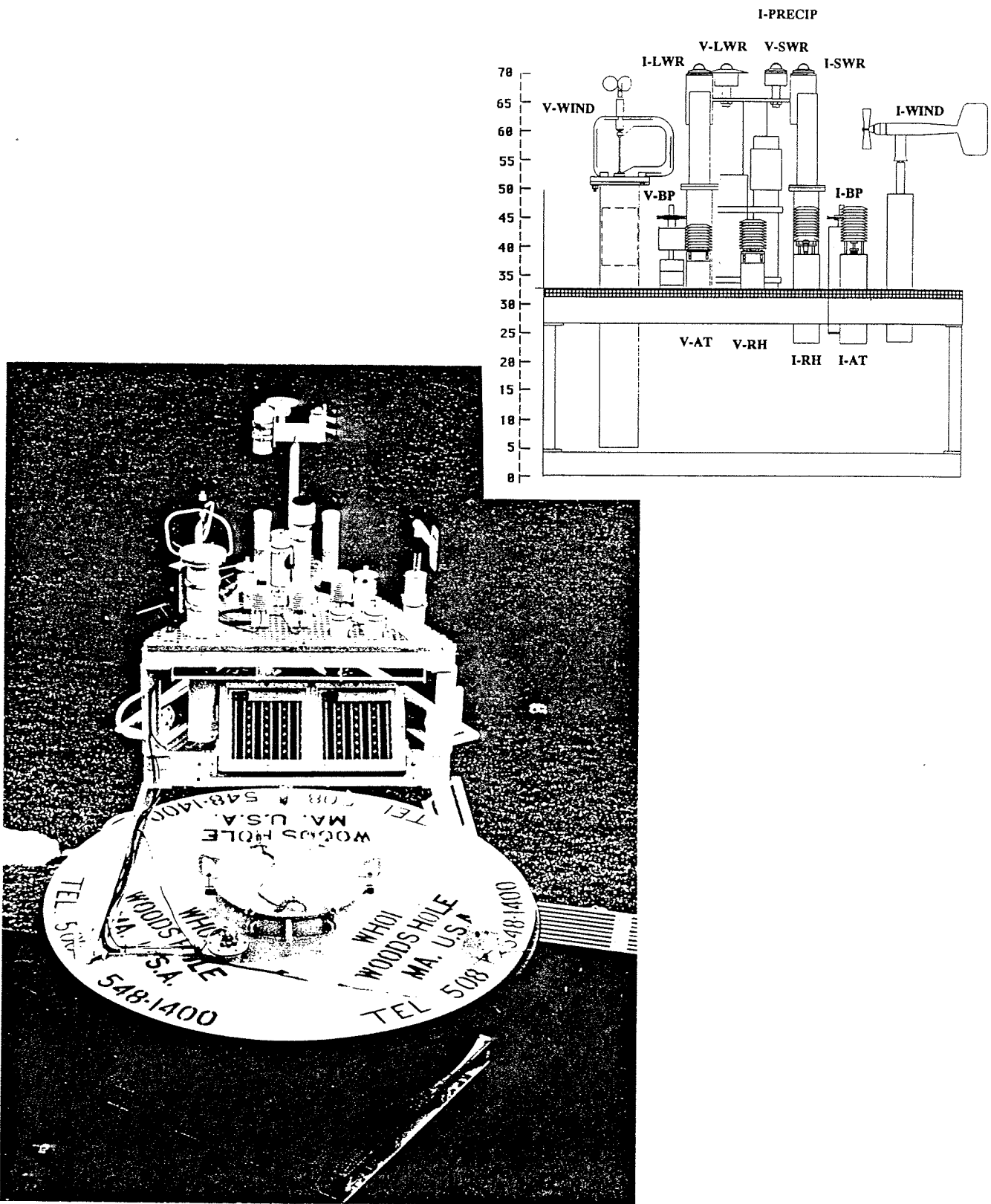


Figure 4. Disc buoy with fully instrumented tower top.

Table 7. 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 .43 m from buoy deck.

† Measurement to midpoint of shield.

Units = Meters above the waterline.

B. Subsurface

The five moorings were also outfitted with a full compliment of subsurface instrumentation. This subsurface hardware included multiple current meters and temperature loggers, and one Acoustic Doppler Current Profiler (ADCP).

The current meters deployed during Subduction were Vector Measuring Current Meters (VMCM's) (Weller and Davis, 1980). These current meters provided both velocity and temperature data at fixed depths. The VMCM's employ two propeller sensors and a compass to measure the east and north components of horizontal velocity and a pressure protected external thermistor to measure sea temperature. Most of the current meters utilized during Subduction were modified EG&G Sea Link instruments refitted with more durable bearings and blades by personnel from the Woods Hole Oceanographic Institution (WHOI). The remaining current meters were built and supplied by the Scripps Institution of Oceanography (SIO). The current meters supplied by WHOI possessed a sampling rate of 7.5 min, while those contributed by SIO recorded data every 15 min.

Fixed depth temperature measurements were also collected by temperature loggers. Several different Brancker temperature loggers were deployed during Subduction, as once again both WHOI and SIO contributed to the total logger pool. Although a majority of these temperature loggers possessed a sampling rate of 15 min, a few of the SIO models collected data at 30 min increments.

In addition to a number of VMCM's and temperature loggers, the NW mooring also carried an ADCP. Affixed to the mooring at a depth of 100 m, the upward looking ADCP measured the backscattered response generated by periodic pulses of acoustic energy. The backscattered energy possesses a distinctive Doppler shift from which a velocity profile of the water resident above the ADCP was derived. Further details regarding the ADCP, VMCM's and temperature loggers deployed during Subduction can be found in Trask *et al.* (1993a, b, c, d).

The precise positioning of the instrumentation along the length of the subsurface moorings varied not only between moorings, but also between deployments. However, the four moorings located on the perimeter of the array were typically outfitted to a depth of 1500 m, while instrumentation on the central mooring extended down through the main thermocline to 3500 m. A schematic representation of the positioning of the subsurface instrumentation on the second Subduction setting is provided in Figure 5. Complete listings of the specific instrumentation

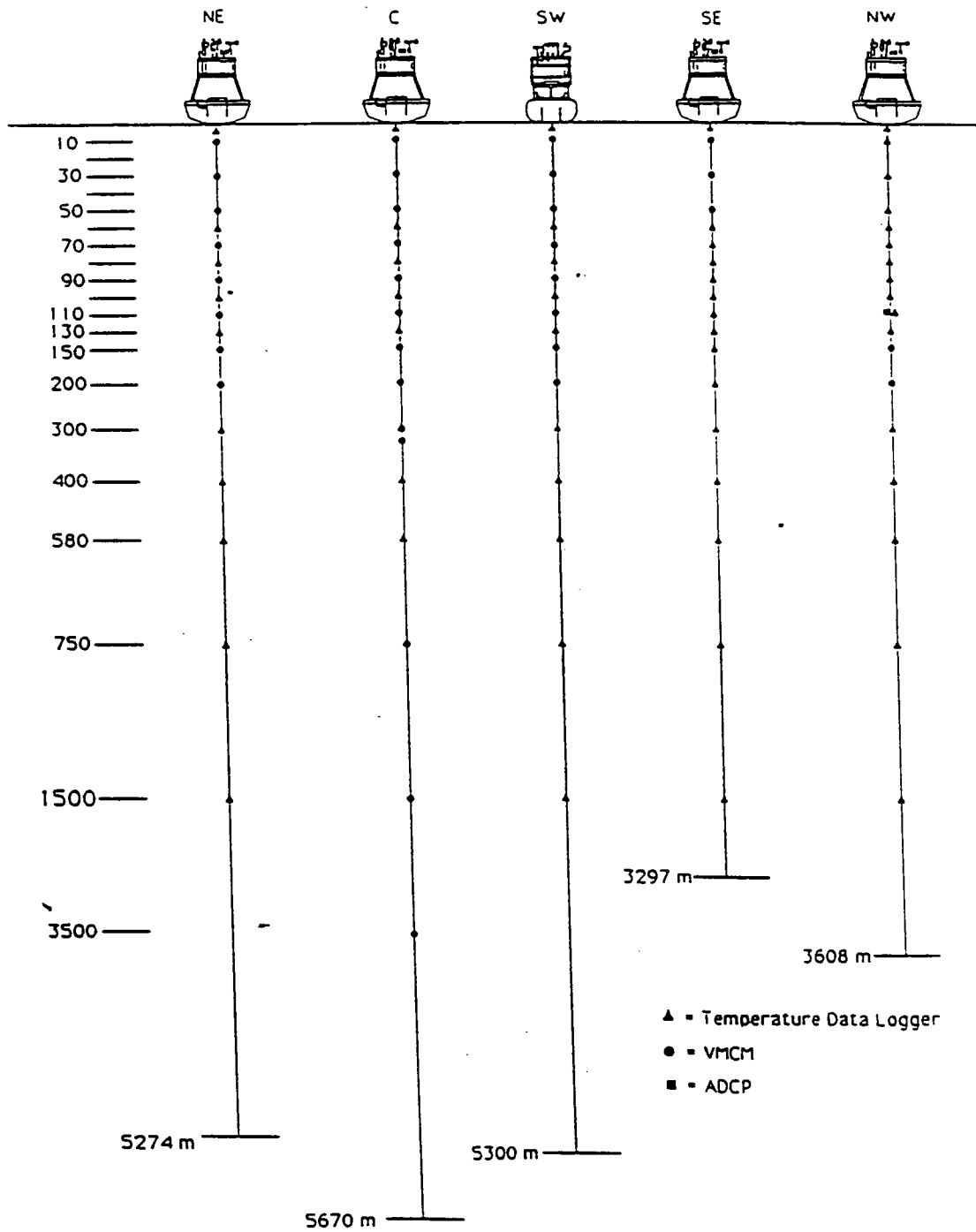


Figure 5: Instrumental configuration of the subsurface moorings deployed during Subduction 2.

affixed to each of the moorings during all three of the Subduction settings are found in Tables 8, 9, and 10.

Section 3: Subduction Data Processing

A. UOP Software Package

All the WHOI instruments, both meteorological and oceanographic, recorded data internally. The VAWRs and VMCMs wrote to Seadata cassette tape. The tpoDs stored data on a micro-chip. The IMETs wrote to an optical disk in the logger. The stored WHOI data files were read from their different sources and transferred to a SUN IPC workstation. All the meteorological and subsurface instruments were pre- and post-calibrated. All these datasets were processed on the SUN, using a software package written by K. Prada (1992), which was a conversion of the VAX processing system used by the WHOI Buoy Group for many years. The data were stored in netCDF format (Rew *et al.*, 1993) for the basic processing, then converted to EPIC (Denbo and Zhu, 1993) for additional processing. The SIO data files were processed by Lloyd Regier, IDG. These files were transferred back to WHOI and incorporated into the final Subduction moored data array. Most of the plots displayed in this report were generated by Plot Plus, (Denbo, 1993).

One final meteorological time series per buoy per deployment was chosen, from the VAWR and IMET datasets. See the next section for a complete description of the meteorological files advanced processing.

The majority of the subsurface instruments required only the basic processing. The temperatures were calculated using the pre-cal information, unless the post-cal showed better agreement. Data files were concatenated over the recovery and redeployment times to create a linearly interpolated two-year time series whenever the gap was considered minimal.

B. Meteorological Data Processing

Redundant meteorological measurements from the VAWR and IMET systems often allowed for gross deficiencies in the data collected by either system to be readily exposed in the field. In addition, several hours of shipboard meteorological observations were collected by hand-held and bridge-mounted sensors both prior to the retrieval of the moorings and immediately after their redeployment. These periods of intensive meteorological observations were utilized as yet another field check on the accuracy of the surface mooring data. However, gross malfunctions of

Table 8. Subduction 1 Instrumentation ID's

| Depth | NE | C | SW | SE | NW |
|----------------------|-------------|-------------------------------|-------------|---------|------------------|
| VAWR | 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 9. Subduction 2 Instrumentation

| Depth | NE | C | SW | SE | NW |
|--------------|-----------|----------|-----------|-----------|------------------|
| VAWR | 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 |
| 130 | W-3265 | W-2538 | S-3310 | S-3294 | W-2535 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 | | | |

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Table 10. Subduction 3 Instrumentation

| Depth | NE | C | SW | SE | NW |
|--------------|-----------|----------|-----------|-----------|------------------|
| VAWR | 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 |
| 130 | W-4482 | W-3280 | S-2421 | S-2424 | W-3309 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 | | | |

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either system were rare. More often, subtle deficiencies in the data were brought to light and corrected during the post-deployment calibration of the instrumentation.

Although the Subduction surface moorings were typically outfitted with both a VAWR and an IMET system, there were several occasions when a VAWR was singly deployed. Given that the VAWR systems were utilized more frequently and the quality of their data were comparable to that of the IMET systems, the VAWR was selected as the primary supplier of meteorological data from Subduction. However, data from the IMET system were utilized on those occasions when the VAWR data were either unavailable or deemed unreliable. For example, the IMET system supplied all of the basic observables on the northeast (6/18/91–2/14/92) and northwest (2/24/92–10/16/92) moorings, relative humidity (2/9/92–9/12/92) and barometric pressure (11/10/92–6/19/93) on the southeast mooring, barometric pressure (6/23/91–2/11/92) and incoming longwave (9/23/91–2/11/92) on the central mooring, and incoming longwave (8/24/91–11/2/91) on the southwest mooring. In order to account for the different sampling rates of the two instrument systems, the 1 min IMET data were subsequently averaged over 15 min to match the VAWR sampling rate.

The specific times when each of the five moorings were on station are illustrated in Figure 2. The moorings were necessarily off station for several hours between settings. During these brief intervals, a simple linear interpolation was employed to fill the void in the basic meteorological data. The one basic observable that was not subject to such a linear interpolation on account of its strong diurnal variation was incoming shortwave radiation. The estimation of incoming shortwave radiation during those periods when it was not measured in situ will be addressed shortly.

There were several occasions when the moorings experienced a structural failure and thus, were off station for an extended period of time. During these extended intervals, the lapse in the basic observables was filled by meteorological data generated by the European Centre for Medium Range Weather Forecasts (ECMWF) global operational numerical weather prediction analyses system (ECMWF Technical Attachment, 1994). The ECMWF analyses are produced four times daily at 0, 6, 12, and 18Z. The 6hr ECMWF data were linearly interpolated to match the desired 15min sampling rate of the Subduction observables. Since relative humidity was not directly available from the ECMWF analysis, it was computed using the temperature, dew point temperature, and barometric pressure analyses that were available from ECMWF (Bolton, 1980).

The 2 m height at which many of the ECMWF near surface variables are analyzed compares favorably with the 2.4 m–2.8 m height at which these basic observables were measured

on the moorings. However, it should be noted that the mooring winds were measured at heights ranging between 2.8 m and 3.4 m, while the ECMWF winds are analyzed at a height of 10 m. Although the ECMWF winds appearing in the time series of basic observables were not altered to correct for this height difference, the discrepancy in height was taken into account prior to the estimation of heat flux and wind stress.

ECMWF analyses were not only used during those periods when the moorings were off station for an extended time, but were also used on several occasions when the moorings were on station, but neither the VAWR nor the IMET systems provided an accurate measure of a specific variable. Such instances relate to relative humidity on the southeast (9/12/92–10/6/92) and central (5/28/92–10/14/92) moorings, barometric pressure on the southwest mooring (3/28/92–6/3/92), and winds on the southeast (6/29/91–10/9/91) and northwest (7/3/91–8/3/91) moorings.

As previously mentioned, the strong diurnal variation in shortwave radiation prohibits the use of linear interpolation even on time scales as small as six hours. Thus, when the moorings were not on station, incoming shortwave radiation was estimated using both clear sky and model forecasting of incoming shortwave radiation. The former were calculated as a function of true solar time using formulae from the Smithsonian Meteorological Tables (List, 1984) along with an empirically determined atmospheric transmission coefficient of 0.8. The latter are simply forecasts of the average incoming shortwave radiation over successive 6 hr periods from the ECMWF global operational numerical weather prediction analysis/forecast system (ECMWF Technical Attachment, 1994). In order to construct a time series with the desired temporal resolution, the 15 min values of clear sky incoming shortwave were multiplied by the ratio of the sum of four successive ECMWF 6 hr forecasts of incoming shortwave to the average value of clear sky incoming shortwave over similar 24 hr periods beginning and ending at midnight.

It has been demonstrated that the incoming longwave radiation measured by a stock Eppley Model PIR pyrometer contains an additional output equivalent to 3.6% of incoming solar radiation (Alados-Arboledas *et al.*, 1988). For some time now, investigators have attributed the inflated measurements to a heating of the pyrometer's dome (Albrecht and Cox, 1977). It has been suggested that some of this heating may be caused by the inadvertent transmission of shortwave radiation through the dome (Dickey *et al.*, 1994). However, Olivieri (1991) found that the transmission of shortwave radiation was too small to explain the magnitude of the observed error. Further investigation has revealed that the predominant cause of dome heating is a previously unaccounted for emittance from a cover resident beneath the dome (personal communication S. Anderson). This removable cover shields the upper face of the pyrometer's case. The cover on the VAWR pyrometer is constructed of stainless steel, while the IMET cover