WHOI-2006-08

Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-2 Mooring Turnaround Cruise Report

by

Albert J. Plueddemann, Robert A. Weller, Roger Lukas, Jeffrey Lord,
Paul R. Bouchard, M. Alexander Walsh

Woods Hole Oceanographic Institution
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March 2006

Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration under Grant No. NA17RJ1223 and the Cooperative Institute for Climate and Ocean Research (CICOR).

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
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UOP Technical Report 2006-03

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Approved for Distribution:

Nelson G. Hogg, Chair

Department of Physical Oceanography

Abstract

The Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Timeseries (HOT) Site (WHOTS), 100 km north of Oahu, Hawaii, is intended to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near 22.75°N, 158°W by successive mooring turnarounds. These observations will be used to investigate air–sea interaction processes related to climate variability.

The first WHOTS mooring (WHOTS-1) was deployed in August 2004. This report documents recovery of the WHOTS-1 mooring and deployment of the second mooring (WHOTS-2) at the same site. Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. In cooperation with R. Lukas of the University of Hawaii, the upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity.

The WHOTS mooring turnaround was done on the Scripps Institution of Oceanography Ship *Melville*, Cruise TUIM-10MV, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 23 and 30 July 2005. Operations on site were initiated with a 30-hour meteorological intercomparison period, followed by recovery of the WHOTS-1 mooring on 25 July. After offloading data and preparing some subsurface instruments for re-deployment, the WHOTS-2 mooring was deployed on 28 July at approximately 22°46′N, 157°54′W in 4695 m of water. A 31-hour intercomparison period followed. This report describes these operations, as well as some of the pre-cruise buoy preparations and CTD casts taken during the cruise.

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1. Introduction

The Hawaii Ocean Timeseries (HOT) site, 100 km north of Oahu, Hawaii, has been occupied since 1988 as a part of the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). WOCE investigators sought to document and understand seasonal and interannual variability of water masses, relate water mass variations to gyre fluctuations, and develop a climatology of high-frequency physical variability. JGOFS investigators sought to use information about primary production, new production, and particle export from the surface ocean as part of an interdisciplinary research program. The present HOT program includes comprehensive, interdisciplinary upper ocean observations, but does not include continuous surface forcing measurements. Thus, the primary intent of the WHOTS mooring is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOTS program and contribute to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean.

To accomplish these objectives, a surface mooring with sensors suitable for the determination of air–sea fluxes and upper ocean properties is being maintained at a site near 22°46′N, 157°54′W (Fig. 1) by means of annual "turnarounds" (recovery of one mooring and deployment of a new mooring at the same site). The moorings use Surlyn foam buoys as the surface element, outfitted with two complete Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. In cooperation with the University of Hawaii (UH), the upper 155 m of the mooring line was outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity.

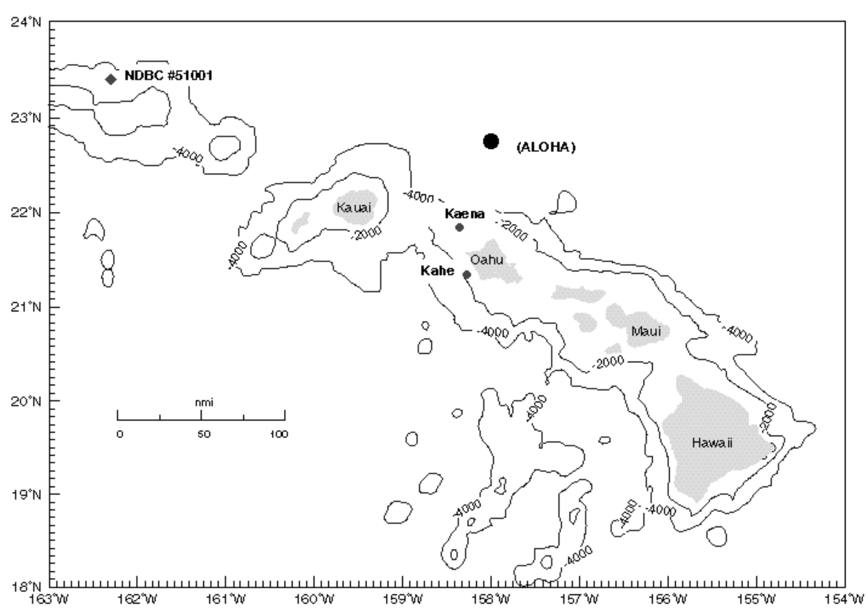

Figure 1. Location of Hawaiian Ocean Timseries (HOT) stations relative to the Hawaiian Island chain and local bathymetry. The WHOTS mooring is near the ALOHA site.

The mooring turnaround was done on the Scripps Institution of Oceanography (SIO) Ship *Melville*, Cruise TUIM-10MV, by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI). The cruise was completed in 8 days, between 23 and 30 July 2005, and consisted of approximately 1 day of steaming, 6 days of operations near the WHOTS site, and one offloading day. The cruise originated from, and returned to, Honolulu, HI (Fig. 2). There were five principal operations during the cruise. First, a 30-hour meteorological intercomparison was done with the *Melville* standing off the WHOTS-1 buoy, collecting shipboard meteorological data and intercepting the Argos satellite transmissions from the buoy with receivers aboard ship. Second, the WHOTS-1 mooring was recovered. Third, WHOTS-1 data were offloaded and some instruments were prepared for re-deployment. During this stage, a CTD survey of an eddy located near the site was completed. Fourth, the WHOTS-2 mooring was deployed at 22°45.997′N, 157°53.9054′W. Finally, a 31-hour data intercomparison period was completed with *Melville* standing off from the WHOTS-2 buoy. A further series of six CTD stations were occupied during the return trip to Honolulu.

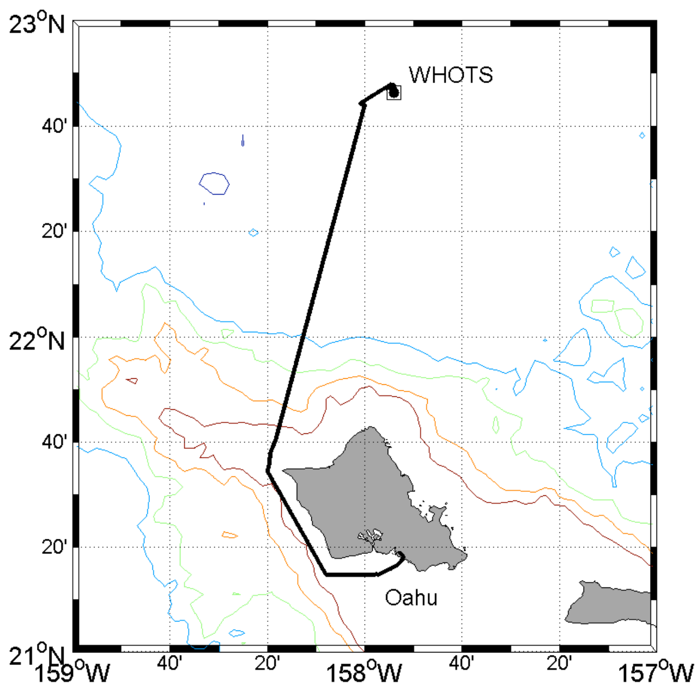

Figure 2. WHOTS-2 outbound cruise track, departing from Honolulu, HI for the WHOTS mooring site. Bathymetry is shown at 1, 2, 3, 4, and 5 km.

Equipment used during mooring operations included the WHOI TSE winch, UH continuous duty electric capstan, three pneumatic winches (air tuggers), an electric winding cart, a tension cart, and an assortment of blocks, hooks, lines, and working hardware. The ship's Allied and Pettibone cranes were also an essential part of the operations. Deck preparations on the *Melville* included the removal of 20 feet of bulwark on the port side of the ship, just aft of the rear equipment hangar and positioning of the winch, capstan, and air tuggers for use during instrument and buoy recovery. A Gifford block was hung from the A-frame to the port side of the large trawl block. Cleats for stopper lines were inserted on the fantail under the A-frame.

A seaglider operated by C. Eriksen of the University of Washington (http://www.apl.washington.edu/projects/seaglider) was operating near the HOT site during the WHOTS-2 cruise. This glider (SN SG020) was programmed to execute an "X" pattern with the center between the WHOTS buoy and the Multi-disciplinary Ocean Sensors for Environmental Analyses and Networks (MOSEAN) buoy (http://www.opl.ucsb.edu/mosean) deployed by the University of Santa Barbara Ocean Physics Lab (Fig. 3). Arrangements with Eriksen allowed glider position information to be forwarded to an email account on the ship, so that progress could be monitored during the cruise.

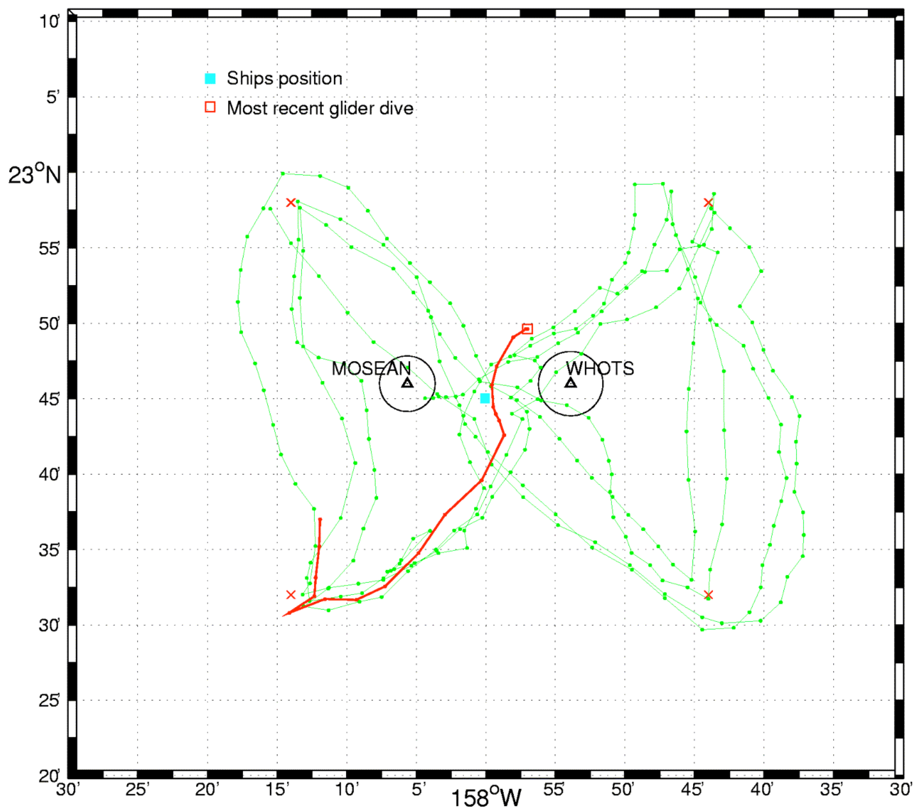

Figure 3. Two months of Seaglider SG020 tracks (green) along with the positions collected during the WHOTS-2 cruise (red). The nominal locations (triangles) and watch circles of the WHOTS and MOSEAN moorings are also shown.

This report consists of five main sections describing pre-cruise operations (Sec. 2), recovery of the WHOTS-1 mooring (Sec. 3), deployment of the WHOTS-2 mooring (Sec. 4), the meteorological intercomparison results (Sec. 5), and CTD surveys (Sec. 6). Four appendices contain ancillary information.

2. Pre-Cruise Operations

Pre-cruise operations were conducted on the grounds of the UH Marine Center in Honolulu, HI. A shipment consisting of two 40' containers and one 20' container left Woods Hole for Honolulu on 14 June 2005. The two 40' containers held the buoy hull (broken down into pieces), buoy well, tower mid-section, tower top with modules, spare modules, VMCMs, acoustic releases and deck gear, instrument brackets and load bars, mooring hardware, deck boxes, lab boxes, tension cart, winding cart, glass balls, and anchor. The 20' "rag-top" container held the Tension Stringing Equipment (TSE) mooring winch and most of the mooring materials (wire reels and wire baskets with nylon and polypropylene).

Four UOP representatives arrived in Honolulu between 13 and 14 July, and began offloading the gear to a staging area near the dock on 15 July. One additional UOP person arrived in Honolulu on 16 July. UH personnel also assisted with in-port preparations. The UOP group was grateful for access to the Hawaii Undersea Research Laboratory (HURL) tent to house gear not suitable for outside storage and for use as a staging for electronics. Pre-cruise operations took place from 15-22 July prior to departure of the *Melville* on 23 July. In addition to loading the ship, pre-cruise operations included: assembly of primary and spare anchor, assembly of glass balls onto 4 m chain sections, painting of the buoy hull, hull-mounted instruments, and VMCMs, assembly of the buoy tower top, insertion of the tower top assembly into the foam buoy hull, a buoy spin, evaluation of ASIMET data, and preparation of the oceanographic instruments.

Because continued pre-cruise work in Hawaii was anticipated, and space was available in rented containers on the UH Marine Center site, not all recovered gear was shipped back to WHOI. Items left at the Marine Center included the assembled buoy hull, a spare anchor, approximately 80 glass balls, and spare wire, nylon, and polypropylene. As a result, the return shipment was pared down to one 40' container and the 20' "rag-top" container.

a. Buoy Spins

A buoy spin begins by orienting the buoy tower section towards a distant point with a known (i.e. determined with a surveyor's compass) magnetic heading. The buoy is then rotated, using a fork-truck, through six positions in approximate 60-degree increments. At each position, the vanes of both wind sensors are oriented parallel with the sight line (vane towards the sighting point and propeller away) and held for several sample intervals. If the compass and vane are working properly, they should co-vary such that their sum (the wind direction) is equal to the sighting direction at each position (expected variability is plus or minus a few degrees).

The first buoy spins were done in the parking lot outside the WHOI Clark Laboratory high bay, with care taken to ensure that cars were not parked within about 30 ft of the buoy. The sighting angle to "the big tree" was about 309°. WND modules 205 and 348 were on the buoy during the first spin, but WND 348 showed relatively poor performance (consistently 4-5 deg from the sighting direction). The spin was repeated after adjustments to WND 348, but with similar results. For the third spin, WND 348 was replaced with the spare module, WND 207. The last compass, last vane, and direction (compass+vane) are reported below for the final

WHOI spin. Table 1 gives the sensor readings during the spins and Figure 4 shows the direction results graphically.

The second buoy spin was done in Honolulu, on an open area of pavement near the pier. A hand-held compass was used to determine that the magnetic field in the area was constant within a few degrees. A pole approximately 1/2 mile away at a bearing of 245° was used as a sighting point. The technique used was the same as for the WHOI buoy spins. The last compass, last vane, and compass+vane are reported below. Table 2 gives the sensor readings during the spin and Figure 5 shows the direction results graphically.

Table 1. WHOTS-2 WHOI buoy spin results

Position	Module SN	Last compass	Last vane	Compass + vane
1	205	103.3	205.4	308.7
	207	141.6	171.5	313.1
2	205	150.1	157.1	307.2
	207	187.4	122.3	309.7
3	205	197.4	113.6	307.3
	207	228.8	78.0	306.8
4	205	248.3	61.4	309.7
	207	282.2	25.5	307.3
5	205	286.4	23.8	310.2
	207	319.7	349.0	309.1
6	205	334.1	335.7	309.8
	207	7.1	301.4	308.5
7	205	18.2	292.9	311.1
	207	51.4	256.9	308.3
8	205	61.5	248.8	310.3
	207	97.0	215.7	312.7

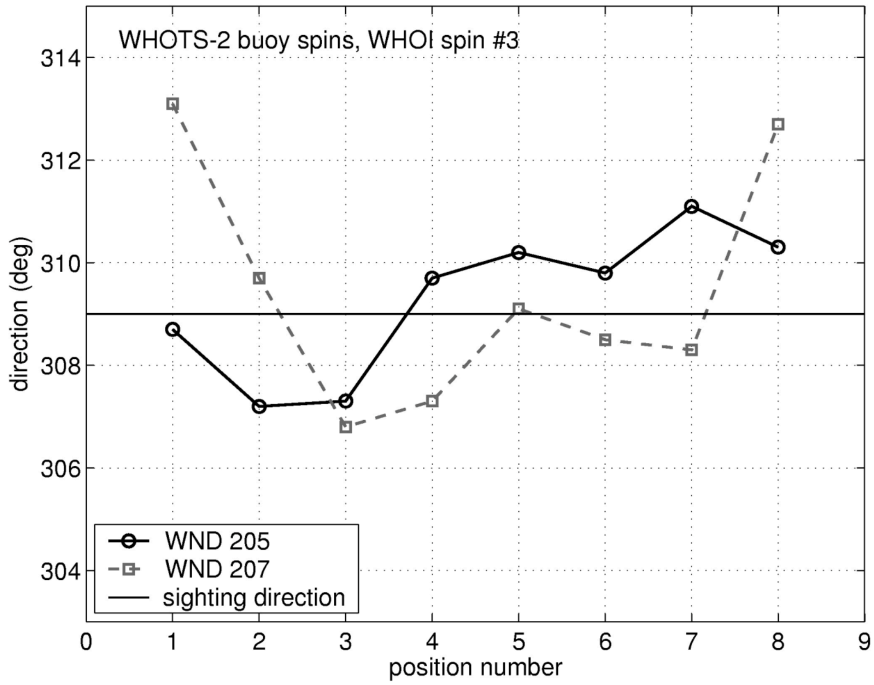

Figure 4. WHOI buoy spin results.

Table 2. WHOTS-2 Honolulu buoy spin results				
Position	Module SN	Last compass	Last vane	Compass + vane
1	205	223.7	21.9	245.6
	207	257.5	347.2	244.7
2	205	267.8	337.7	245.5
	207	302.2	304.1	246.3
3	205	317.1	290.9	247.0
	207	350.1	256.9	246.0
4	205	358.4	247.7	246.1
	207	30.4	215.6	246.0
5	205	43.5	203.9	247.4
	207	77.0	169.0	246.0
6	205	89.5	157.2	246.7
	207	126.2	123.3	249.5
7	205	133.8	113.1	246.9
	207	170.2	77.2	247.4
8	205	176.4	68.8	245.2
	207	210.7	33.3	244.0

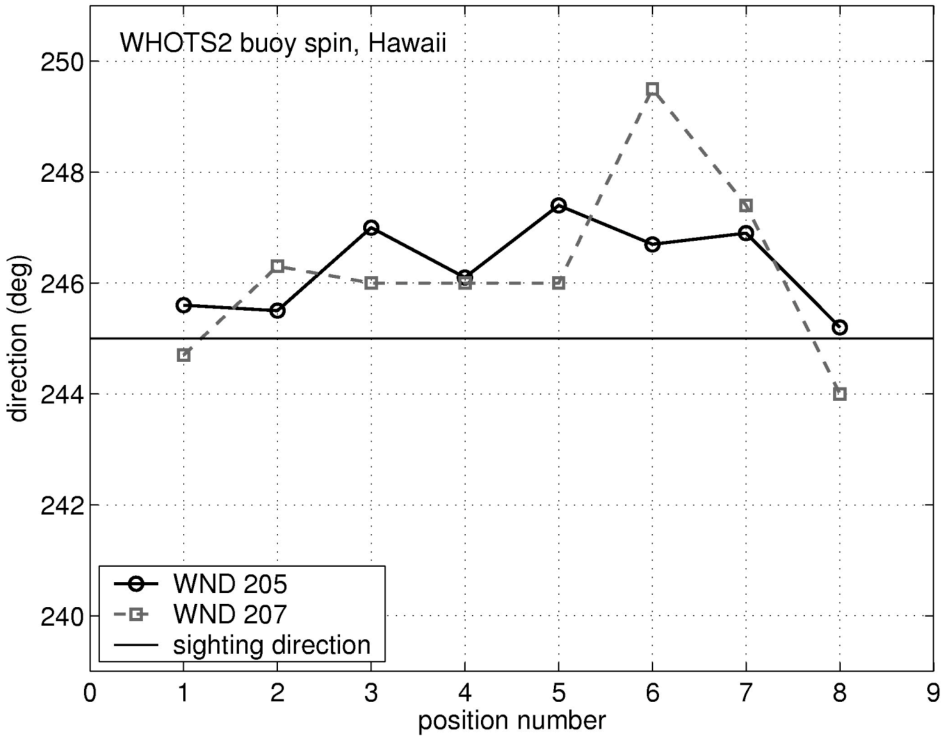

Figure 5. Hawaii buoy spin results.

b. Sensor Evaluation

Once the buoy well and tower top were assembled, the ASIMET modules were initialized and connected to the loggers. When mechanical assembly was complete, power was applied, the loggers were started, and data acquisition began. Evaluation of the primary sensor suite was done through a series of overnight tests. Both hourly Argos transmissions and 1 min logger data were evaluated. Attempts to evaluate 1 min module data from flash cards were frustrated due to problems with translating data from raw binary to Matlab.

Evaluation of Argos data on 17 July indicated that the ASIMET sensors were performing as expected (differences between like sensors within accuracy tolerances) with the exception of air temperature and longwave radiation. Air temperature differences of 0.2 to 0.3°C were noted during the daytime. After further evaluation, this was attributed to a combination of low winds and an unfavorable position for the buoy on the dock. Stronger winds and a different buoy position on subsequent days resulted in typical air temperature differences of 0.2°C or less.

It was found that values from LWR 212 and 505 disagreed by about 8 W/m^2. This was as expected relative to the WHOI burnin results, where it was found that SN 505 was greater then SN 212 by about 8 W/m^2. Because the LWR calibrations appeared "unstable" during the burnin (showing excellent agreement with each other and with the roof standard during the initial calibration phase, but relatively poor agreement when mounted on the buoy) another LWR sensor presumed to be stable (SN 221) was brought to Hawaii as a "transfer standard." Tests using LWR 221 in comparison with 212, 505 and the spare unit (504) are shown in Fig. 6. LWR 212 and 505 are both high relative to the transfer standard. LWR 504, which showed excellent agreement relative to the WHOI roof standard, has apparently suffered a calibration shift and showed poor performance. Post-cruise testing confirmed that LWR 221 had a stable calibration. Thus, the two primary sensors used on WHOTS-2 are both biased high, LWR 212 by about 5 W/m^2 and LWR 505 by about 10 W/m^2.

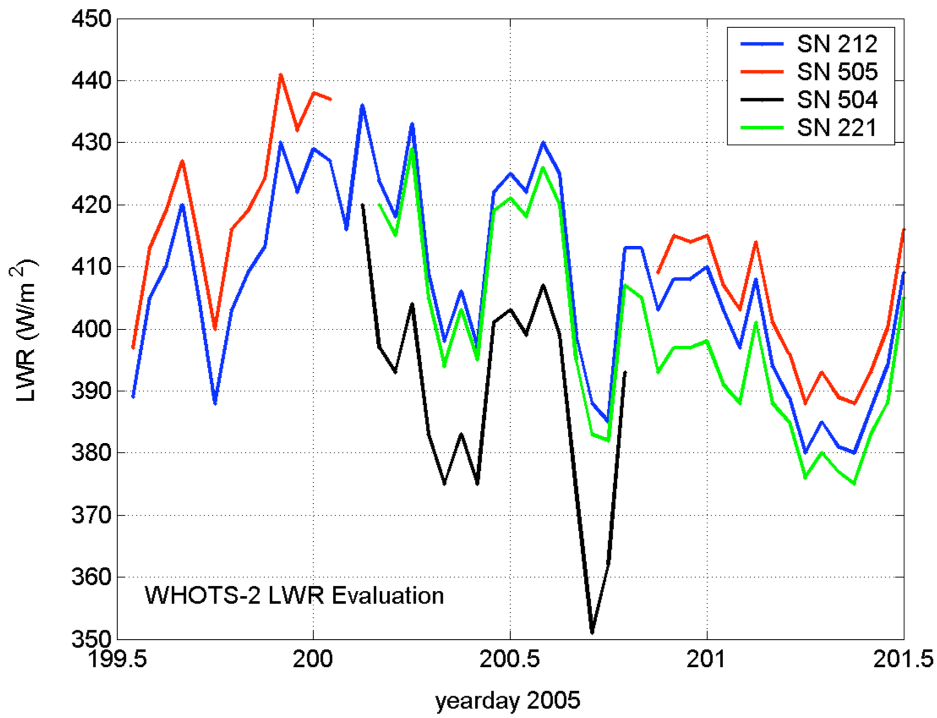

Figure 6. Evaluation of WHOTS-2 LWR module performance in Honolulu.

A series of "sensor function checks," including filling and draining the PRC modules, covering and uncovering the solar modules, and dunking the STC modules in a salt-water bucket, were done during the third day of in-port testing. The results of these checks, and a final in-port evaluation of hourly Argos data, showed all modules to be functioning as expected.

3. WHOTS-1 Mooring recovery

a. Recovery Operations

The recovery of the WHOTS-1 buoy and mooring began at 0700 on 25 July. With the ship positioned approximately ½ mile upwind of the anchor site, the acoustic release was acquired, enabled, and the release command sent. A sequence of range interrogations confirmed that the release had activated and subsurface floats were bringing the bottom of the mooring to the surface. At approximately 8:00 am, the cluster of 80 glass balls were spotted off the port quarter of the ship, and the ship began maneuvering into a position for recovery. Moderate winds and waves precluded the use of the small workboat for attachment into the mooring. Instead, the ship maneuvered to bring the cluster of glass balls along the port side. After failed attempts to hook the ball cluster with a grapnel, the floating polypropylene line leading from the balls was hooked and recovery began with a bight of line.

The bight of polypropylene was wound onto the winch until the cluster of glass balls was brought to the stern of the ship. A stopper line was attached to the chain between glass balls, and the poly line was disconnected from the mooring and stopped off on the cleat. In the meantime, personnel on the port quarter continued to pull slack poly line on board, and monitored the lead of the poly to be sure the ship did not foul in it. The ships trawl winch, led through the trawl block on the A-frame, was used to lift the cluster of glass balls onto the deck of the ship, with the assistance of two air tuggers. Once the balls were secured, the acoustic releases were pulled aboard using the trawl wire already hanging through a block. Recovery operations were stopped until glass balls were disconnected in four-meter segments and removed from the working area of the deck.

The recovery commenced by leading the slack poly line through a floating block and onto the large electric capstan. The lead from the capstan was directed into an empty wire basket just forward of the capstan. Recovery of 1500 meters of poly line and 2000 meters of nylon line continued in this fashion with personnel taking turns tailing the capstan and leading the line into wire baskets. While synthetic line was being recovered with the capstan, the recovered glass balls were moved to the 20 foot open-top container using three people and the Pettibone crane.

As the last of the nylon line was coming to the surface, recovery was stopped to transition from the capstan recovery to the recovery of wire and instruments using the TSE mooring winch. A Yale grip was attached to the nylon line and stopper lines held the mooring by the Yale grip. The nylon line was cut about 20 feet above the Yale grip. A bowline was tied into an end link on the end of the winch leader, which had been led through the large trawl block on the A-frame. Stopper lines were eased out as the load was transferred to the winch. Recovery continued with 1750 meters of wire spooled onto the winch.

While the wire was being spooled onto the winch, the deck was configured for the recovery of the instruments and the buoy. The first instrument recovered was a MicroCAT at 155 meters. As the MicroCAT was pulled out of the water and about 2 feet above the deck, stopper lines were attached to the link under the load bar. The lines were pulled tight and the winch lowered the instrument to the deck of the ship. The MicroCAT was removed from the mooring line and the two ends of wire were reconnected with shackles and links. The winch could continue to haul in the mooring at this point. As each instrument came to the surface it was recovered in much the same fashion. After several more instruments were recovered the lead from the block to the buoy became too much of an angle to grab the instruments. The mooring wire was then removed from the block and allowed to drag up the transom. Now, as instruments approached the transom, they were eased up and onto the deck by using an air tugger lead through the Gifford block on the A-frame. Ten instruments were recovered through the A-frame using this procedure. As each instrument was removed from the working area, serial numbers were verified. Photographs were taken to document the level of fouling on each instrument with its depth noted.

After the 10th instrument was recovered, a slip line was run through the link on the mooring attaching the final 55 meters to the buoy. The slip line was slowly released, setting the buoy and 55 meters of instruments and hardware adrift. In calm seas, a small workboat is typically deployed to assist with the hook-up of the drifting buoy to the lifting line. However, weather conditions precluded this technique. The ship maneuvered around the buoy in preparation for recovery on the port side. The Allied crane was brought out and positioned for recovery. As the ship maneuvered alongside the buoy, bringing it slowly down the port side, the recovery crew was standing by with hooks and lines to grab the buoy (Fig. 7). There is only one lifting point that can be used for the proper recovery of the buoy. As one person attempted to get the pickup hook and pennant attached to the lifting point on the buoy, another person hooked the protective halo around the buoy tower top. This line helped to keep the buoy from spinning while the hook was inserted into the lifting point.

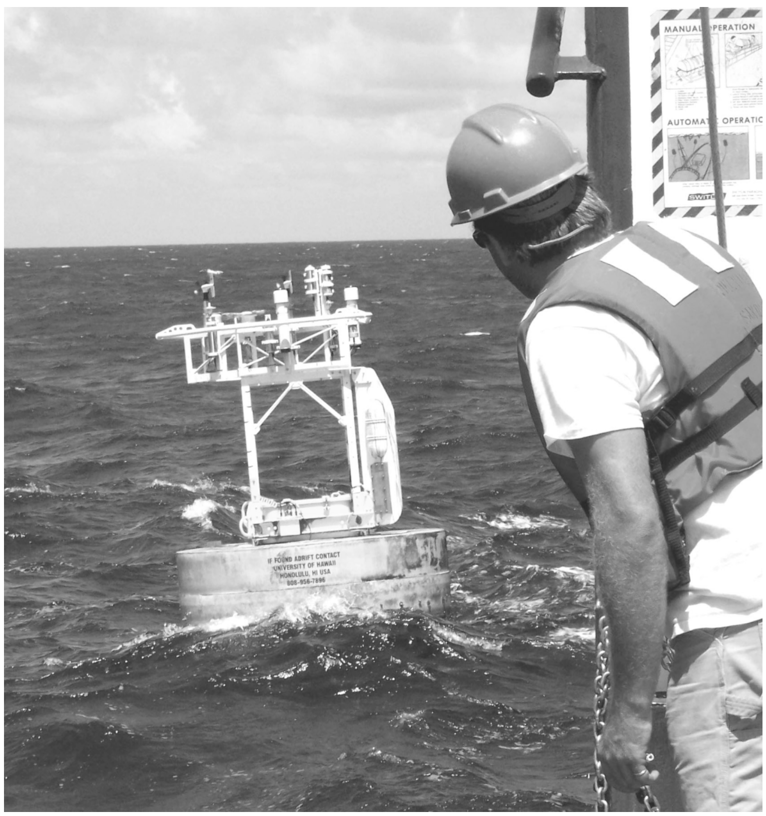

Figure 7. Preparing for recovery of the WHOTS-1 buoy.

Once the lifting hook and pennant were securely attached to the buoy, and the buoy hauled forward to the working area of the deck, the pennant was hooked into the crane. The crane then swung outboard to keep the buoy away from the ship as it was lifted from the water. Once the buoy was out of the water, the crane swung back in and allowed the foam hull to rest against the side of the ship as additional handling lines were attached to the buoy. Once lines were in place the crane lifted the buoy up and brought it onto the deck. The mooring line hanging below the buoy was stopped off securely, and the buoy was lifted again and brought slowly outboard to allow enough slack in the mooring chain to detach the buoy from the mooring. The buoy was then securely strapped to the deck. The crane was removed from its attachment to the buoy and the hook brought down to where the mooring line and instruments were stopped off.

To recover the instruments, a sling was passed through an end link at the end of the shot of chain at the top of the mooring. This sling went onto the crane hook, and the crane lifted the mooring string vertically in the air until an instrument was approximately two feet above the deck. At this point, an air tugger with a chain hook attached would pull in on the chain, about two feet below the instrument termination. The crane wire was then lowered until the chain and slack instrument were on the deck. The sling was removed from the end link on the slack chain, passed through the link just below the instrument on the deck, and again hooked onto the crane. The shackle attaching the bottom of the instrument to the mooring line was removed and the instrument was hauled away to be logged and photographed. This procedure continued until all eight remaining instruments were on the deck. After all instruments were cataloged and photographed, they were removed from load bars and cleaned. The buoy hull was scraped and washed.

b. Instrumentation and Data Return

The WHOTS-1 mooring, deployed on 13 August 2004 from the R/V *Ka'imikai-O-Kanoloa* (KOK), was outfitted with a full suite of ASIMET sensors on the buoy and subsurface instruments from 10 to 155 m depth (see Appendix 1). The mooring design was nearly identical to that of WHOTS-2 (Sec. 4a). Instrumentation was very similar to that of WHOTS-2 (Sec. 4b), the principal difference being the use of SeaCATs rather than MicroCATs for temperature-conductivity measurements. The WHOTS-1 recovery on 25 July 2005 resulted in 347 days on station.

Data return from the two ASIMET systems was excellent, with only one significant failure – the System-1 compass/vane follower failed on 09 Jan 2005, resulting in only wind speed information for the remainder of the deployment period. The remaining sensors recorded 1 min data for the full 347 days (Fig. 8-10). Minor data quality issues included an offset of about 8 W/m^2 between the two LWR sensors, occasional downward spikes of ~0.2 mS/m in conductivity, presumably due to air bubbles entrained in the sensing volume, and occasional "drop-outs" to 0.0 in the east and north winds. The consequence of the System-1 compass/vane failure is seen in Fig. 10, where east winds go to zero and the north component contains all of the wind variability.

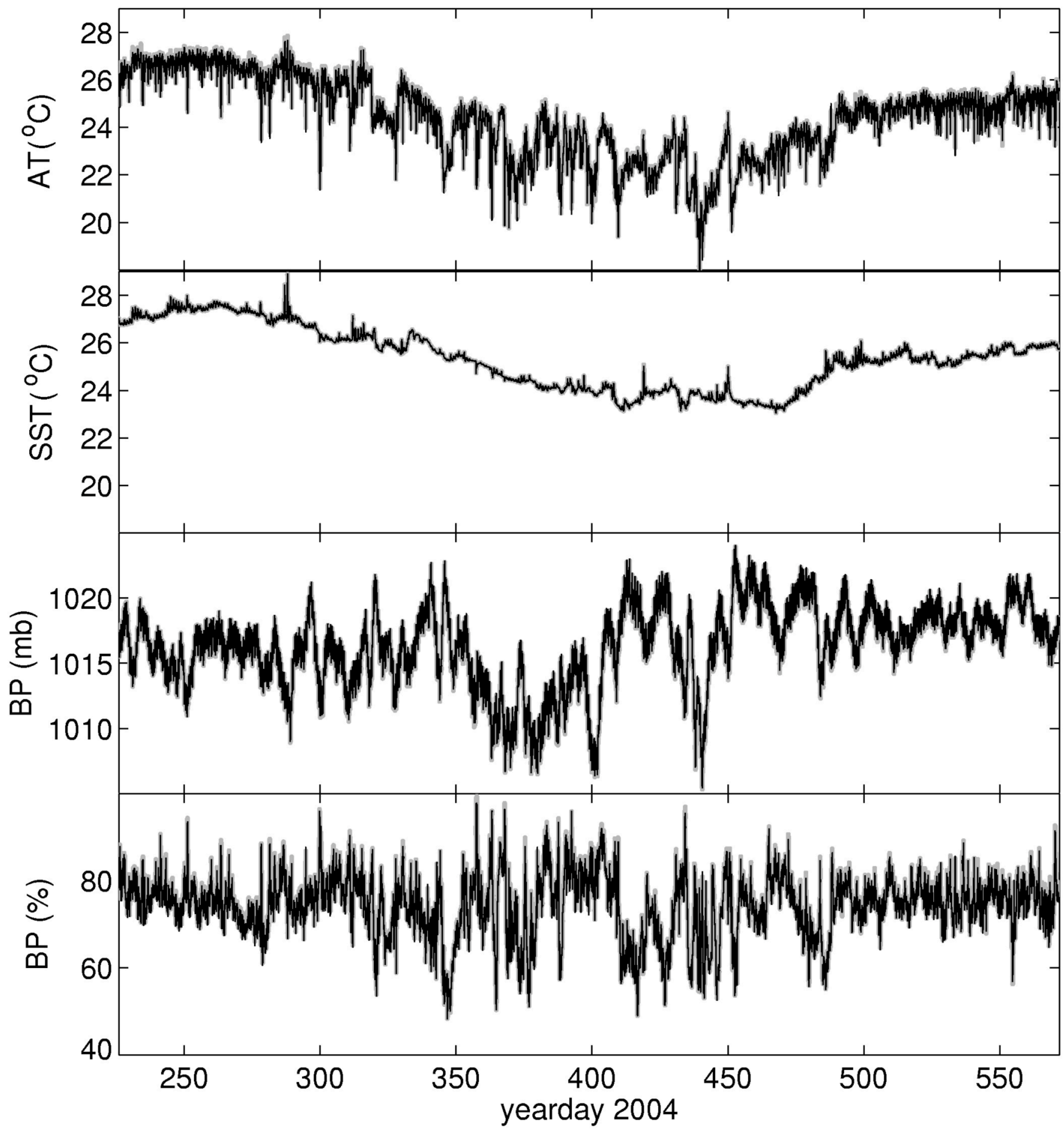

Figure 8. WHOTS-1 meteorological variables: Part 1. Raw data from ASIMET System 1 (black) and System 2 (gray) averaged to 1 hour are plotted. Variables shown from top to bottom are: Air temperature (AT, °C), sea surface temperature (SST, °C), barometric pressure (BP, mb) and relative humidity (RH, %).

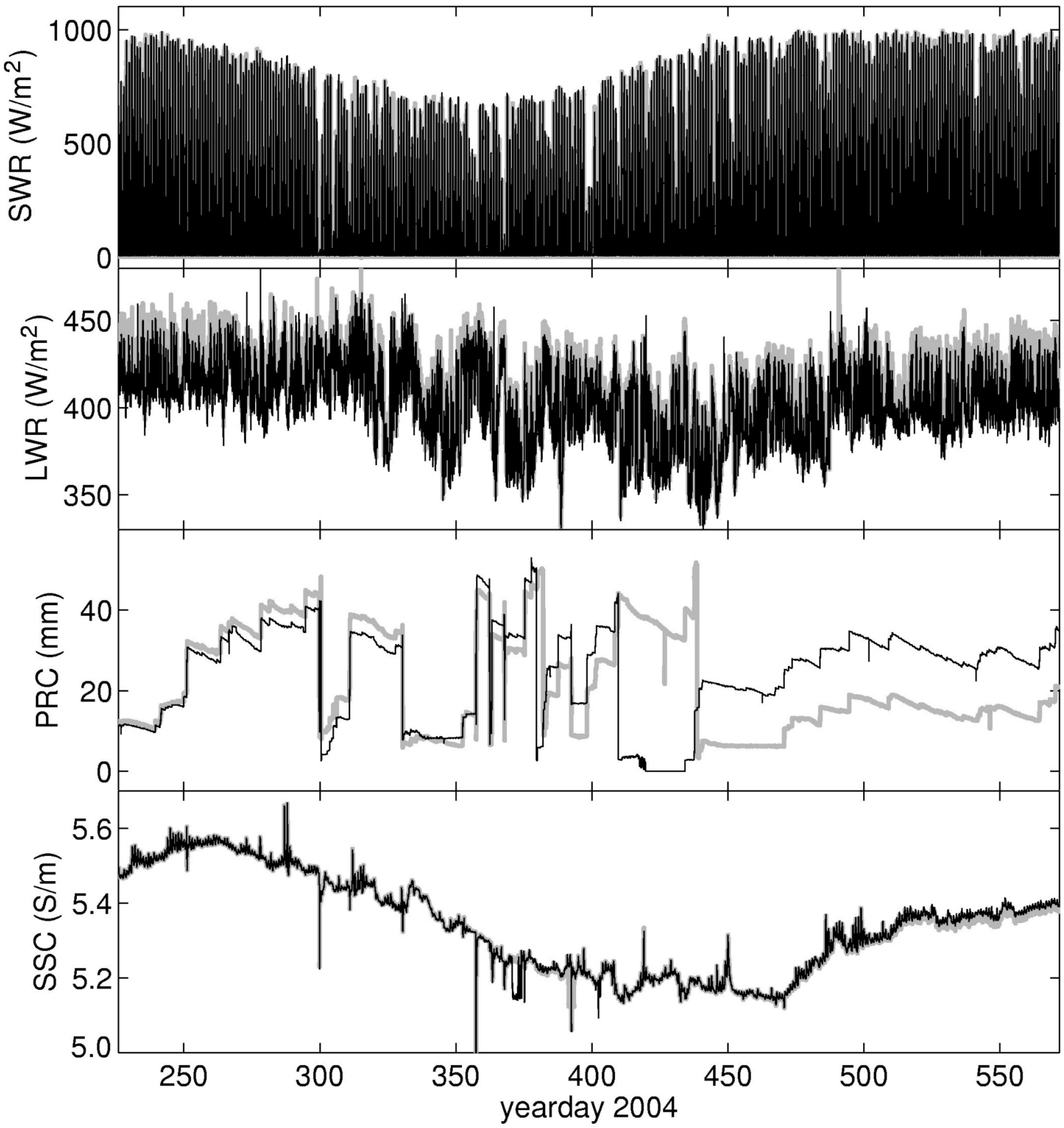

Figure 9. WHOTS-1 meteorological variables: Part 2. Raw data from ASIMET System 1 (black) and System 2 (gray) averaged to 1 hour are plotted. Variables shown from top to bottom are: shortwave radiation (SWR, W/m^2), longwave radiation (LWR, W/m^2), precipitation level (PRC, mm) and conductivity (COND, mS/m).

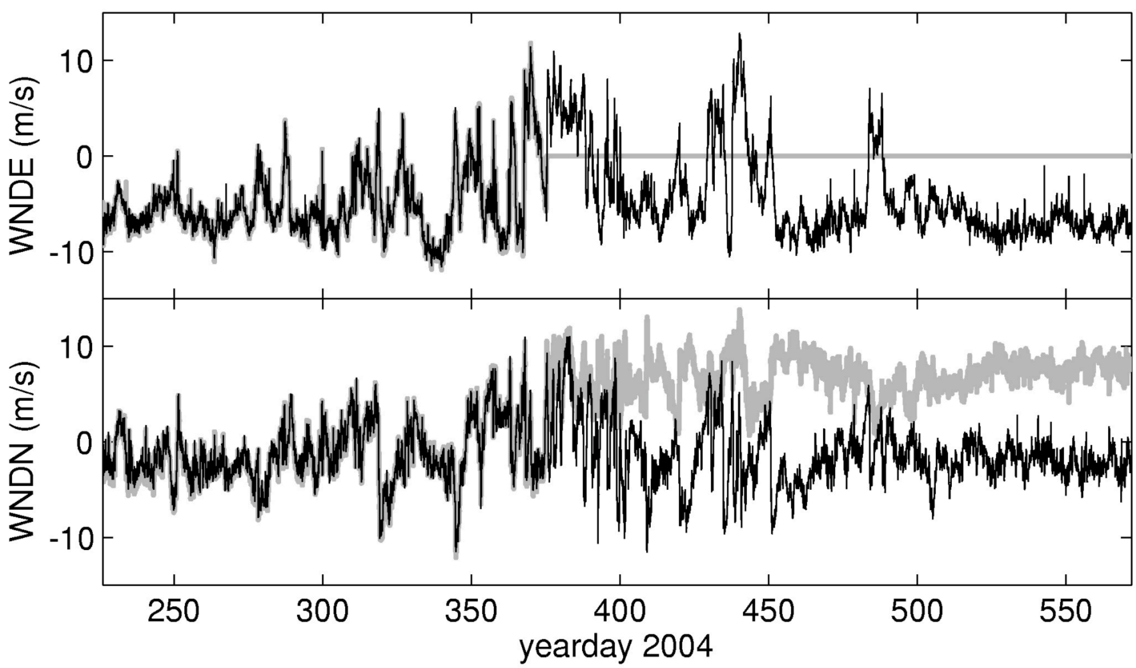

Figure 10. WHOTS-1 meteorological variables: Part 3. Raw data from ASIMET System 1 (gray) and System 2 (black) averaged to 1 hr intervals are plotted. Variables shown from top to bottom are: east wind component (WND-E, m/s), north wind component (WND-N, m/s). Directions are in "oceanographic" convention– direction towards.

An internally logging Sea-Bird SBE-39 temperature sensor was housed in a foam collar and mounted on the outside face of the buoy hull. Vertical rails allowed the foam to move up and down with the waves, so that the sensor measured the SST within the upper 10-20 cm of the water column. This "floating" SST sensor operated for the full deployment and showed temperatures that agreed well with the ASIMET SST measured beneath the buoy hull.

An internally logging Seimac GPS unit was deployed to monitor buoy position at 10 min intervals. Unfortunately, this sensor did not perform well. Data gaps of tens of minutes to several hours were found, occasional "wild points" were evident, and data logging stopped completely after only 32 days. Reasons for the failure are still being investigated.

Instrumentation provided by UH for the WHOTS-1 mooring included ten Sea-Bird SBE-16 SeaCATs (Fig. 11), five SBE-37 MicroCATs (Fig. 12) and an RD Instruments Acoustic Doppler Current Profiler (ADCP, Fig. 13). The SeaCATs and MicroCATs measured temperature and conductivity; three of the MicroCATs also measured pressure. WHOI provided two Vector Measuring Current Meters (VMCMs) and all required subsurface mooring hardware via a subcontract with UH. Table 3 provides a listing of the WHOTS-1 MicroCATs and SeaCATs at their nominal depths on the mooring, along with serial numbers sampling rates and other pertinent information.

The ADCP, SN 4891, was deployed at 125 m with beams facing upwards. The instrument is an RDI 300 KHz Workhorse Sentinel, with an external battery pack. The instrument was set to ping every 4 seconds for 160 seconds every 10 minutes. Bin size was set for 4 m. The total number of ensemble records was 50,414. The first ensemble was at 2004/08/10 00:00:00Z, and the last was at 2005/07/26 02:10:00Z.

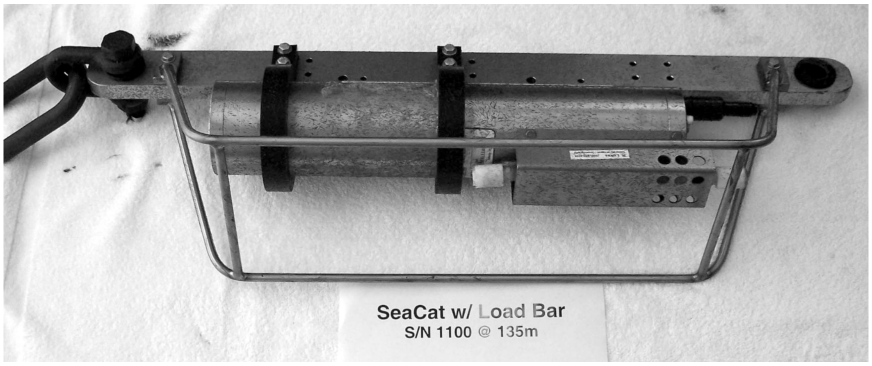

Figure 11. WHOTS-1 SeaCAT from 135 depth. The instrument is clamped to a load bar, which is shackled in-line with the mooring.

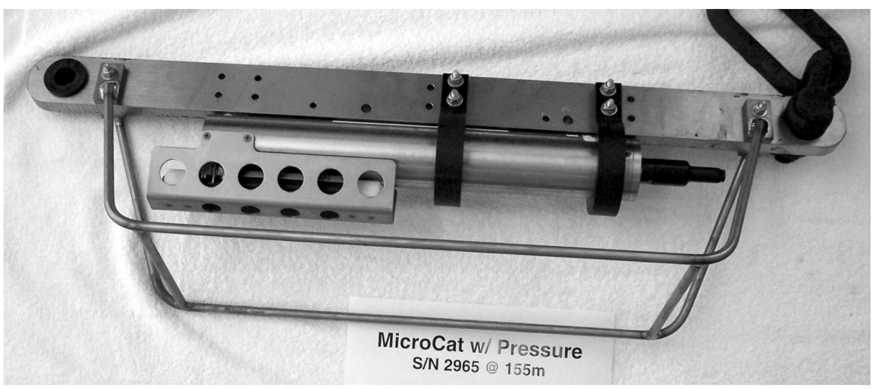

Figure 12. WHOTS-1 MicroCAT from 155 m depth.

Figure 13. WHOTS-1 ADCP from 125 m depth. The instrument (left) and external battery case (right) are housed in a titanium load cage.

Table 3. WHOTS-1 MicroCAT / SeaCAT Deployment Information.

Deployment Date: 8/13/2004 UTC, Time Logging Started: 8/8/2004 0:00:00
All times stated are in GMT

Depth (m)	Sea-Bird Serial #	Param-eters	Sample Int (seconds)	Navg	Time Logging Started	Time in the water
15	163452-0801	C, T	600	1	8/8/2004 00:00	8/13/2004 18:32
25	165807-1085	C, T	600	1	8/8/2004 00:00	8/13/2004 18:25
35	165807-1087	C, T	600	1	8/8/2004 00:00	8/13/2004 18:19
40	37SM31486-3381	C, T	150	2	8/8/2004 00:00	8/13/2004 18:14
45	37SM31486-3382	C, T	150	2	8/8/2004 00:00	8/13/2004 18:13
50	165807-1088	C, T	600	1	8/8/2004 00:00	8/13/2004 18:09
55	165807-1090	C, T	600	1	8/8/2004 00:00	8/13/2004 18:09
65	165807-1092	C, T	600	1	8/8/2004 00:00	8/13/2004 20:14
75	165807-1095	C, T	600	1	8/8/2004 00:00	8/13/2004 20:19
85	37SM31486-2451	C, T, P	180	2	8/8/2004 00:00	8/13/2004 20:22
95	165807-1097	C, T	600	1	8/8/2004 00:00	8/13/2004 20:27
105	37SM31486-2769	C, T, P	180	2	8/8/2004 00:00	8/13/2004 20:32
120	165807-1099	C, T	600	1	8/8/2004 00:00	8/13/2004 20:36
135	165807-1100	C, T	600	1	8/8/2004 00:00	8/13/2004 20:46
155	37SM31486-2695	C, T, P	180	2	8/8/2004 00:00	8/13/2004 20:51

Serial #s starting with 16 are Sea-Bird SeaCATs; those starting with 37 are MicroCATs

All WHOTS-1 instruments were successfully recovered as shown in Table 4. All instruments provided full data return except the shallow VMCM; the battery was depleted after about 8 months of sampling. The data from the SeaCATs and MicroCATs appear to be of high quality, though post-deployment calibrations are required to assess instrument stability. Figure 14 shows the time series from the shallowest SeaCAT (SN 0801, 15 m). Fig. 15 shows the time series from the deepest MicroCAT (SN 2695, 155 m), which also recorded pressure. These records use the nominal, pre-cruise calibrations and have not been adjusted for possible bias and drift. One annual cycle was observed in upper ocean thermal structure; below the mixed layer, intraseasonal variability dominates. Upper ocean salinity increased in a roughly linear trend from deployment through the first 2/3 of the record when a low salinity event on about a month's duration was observed. Peak salinities were observed in late June.

The data from the upward-looking ADCP at 125 m appears to be of high quality, except that acoustic returns from the upper 50 m of the water column are intermittent, apparently due to very low levels of scattering material near the surface. Diurnal migration of plankton often allowed good data returns to near the surface at night.

Table 4. WHOTS-1 MicroCAT / SeaCAT Recovery Information

All times stated are in GMT

Depth (m)	Sea-Bird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality
15	163452-0801	7/26/2005 00:44	7/26/2005 03:11:20	7/28/2005 00:58:00	50982	good
25	165807-1085	7/26/2005 00:50	7/26/2005 03:11:20	7/27/2005 22:50:00	50970	good
35	165807-1087	7/26/2005 00:58	7/26/2005 03:11:20	7/27/2005 23:20:00	50972	good
40	37SM31486-3381	7/26/2005 01:00	7/26/2005 01:35:58	7/26/2005 03:00:00	202872	good
45	37SM31486-3382	7/26/2005 01:05	7/26/2005 01:35:58	7/26/2005 03:03:00	202825	good
50	165807-1088	7/26/2005 01:09	7/26/2005 03:11:20	7/28/2005 00:27:00	50979	good
55	165807-1090	7/25/2005 23:28	7/26/2005 01:34:30	7/27/2005 18:27:00	50943	good
65	165807-1092	7/25/2005 23:24	7/26/2005 01:34:30	7/27/2005 21:22:00	50961	good
75	165807-1095	7/25/2005 23:21	7/26/2005 01:34:30	7/27/2005 22:18:00	50966	Good
85	37SM31486-2451	7/25/2005 23:17	7/26/2005 01:35:58	7/26/2005 02:46:00	169014	Good
95	165807-1097	7/25/2005 23:11	7/26/2005 01:34:30	7/27/2005 20:16:00	50954	Good
105	37SM31486-2769	7/25/2005 23:08	7/26/2005 01:35:58	7/26/2005 02:31:00	169010	Good
120	165807-1099	7/25/2005 22:59	7/26/2005 01:34:30	7/27/2005 23:50:00	50976	Good
135	165807-1100	7/25/2005 22:55	7/26/2005 01:34:30	7/27/2005 20:52:00	50958	Good
155	37SM31486-2695	7/25/2005 22:47	7/26/2005 01:35:58	7/26/2005 05:12:00	169062	Good

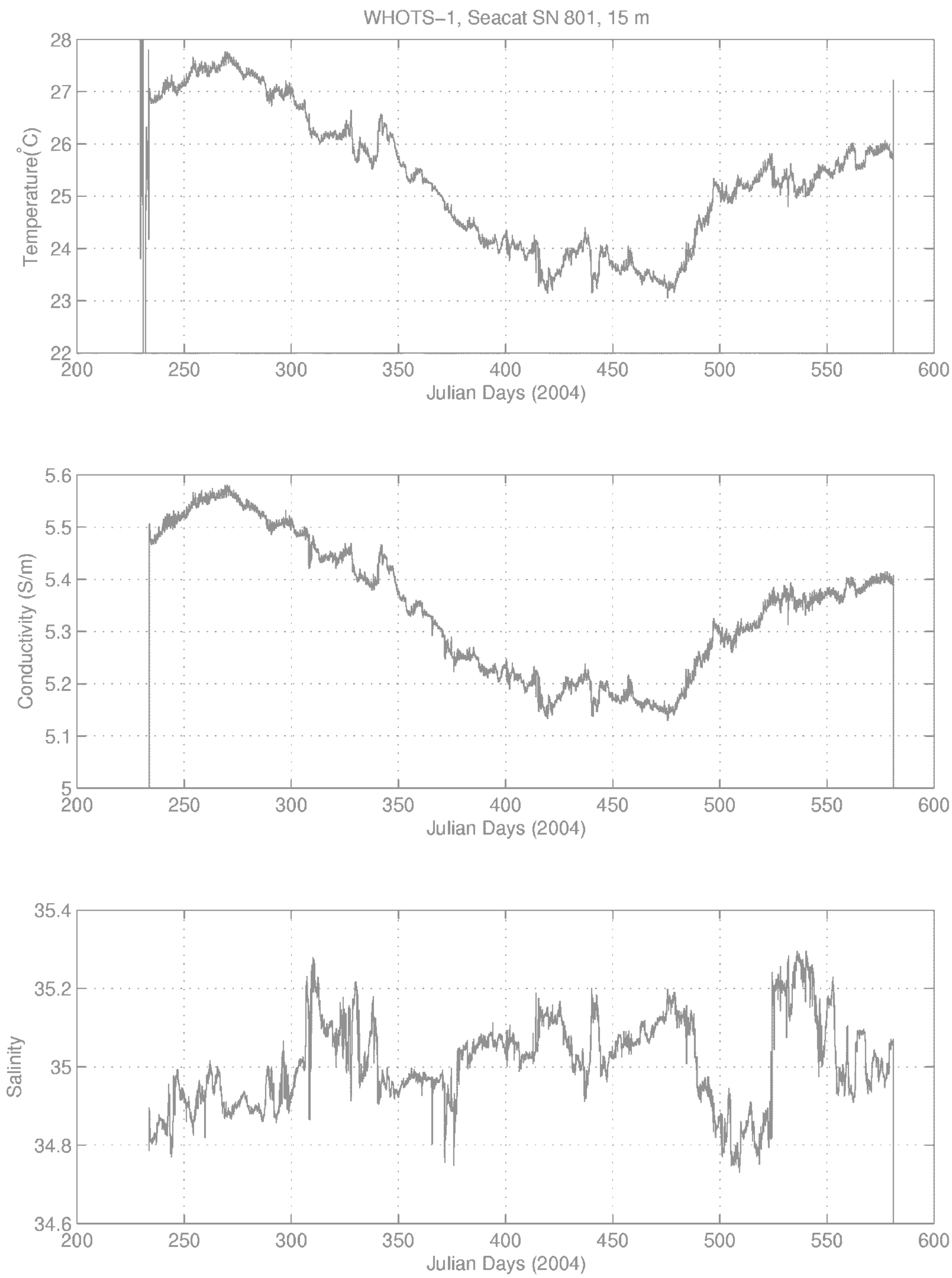

Figure 14. Temperature (upper panel), conductivity (middle) and salinity (lower) from WHOTS-1 SeaCAT SN 0801 deployed at 15 m.

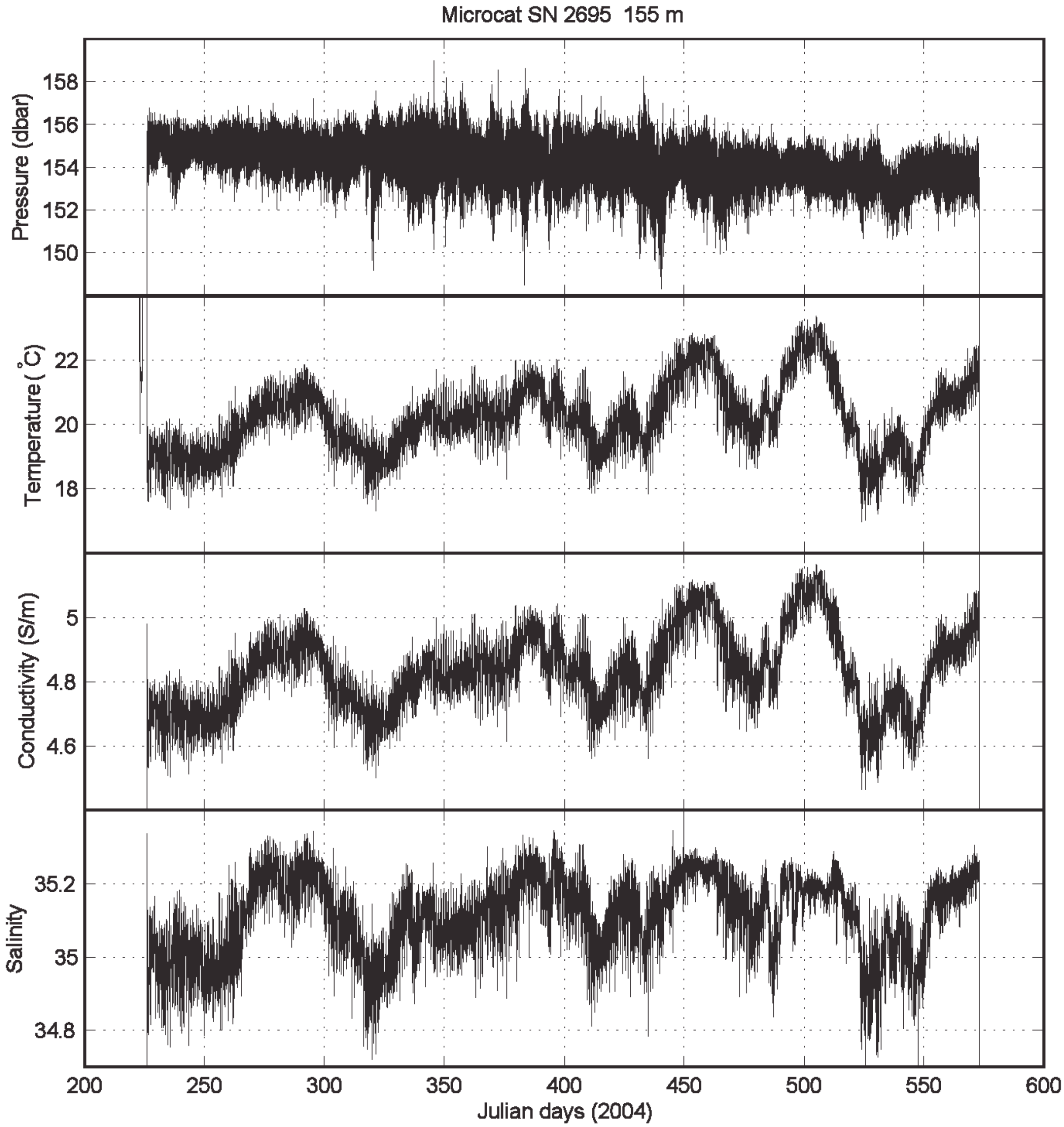

Figure 15. Pressure (upper panel), temperature, conductivity and salinity (lower panel) from WHOTS-1 MicroCAT SN 2695 deployed at 155 m.

4. WHOTS-2 Mooring Deployment

a. Mooring Design

The mooring is an inverse catenary design utilizing wire rope, chain, nylon and polypropylene (Fig. 16). The mooring scope (ratio of total mooring length to water depth) is about 1.25. The watch circle has a radius of approximately 2.2 nm (4.2 km). The surface element is a 2.7-meter diameter Surlyn foam buoy with a watertight electronics well and aluminum instrument tower. The two-layer foam buoy is “sandwiched” between aluminum top and bottom plates, and held together with eight 3/4" tie rods. The total buoy displacement is 16,000 pounds, with reserve buoyancy of approximately 12,000 lb when deployed in a typical configuration. The modular buoy design can be disassembled into components that will fit into a standard ISO container for shipment. A subassembly comprising the electronics well and meteorological instrument tower can be removed from the foam hull for ease of outfitting and testing of instrumentation. Two ASIMET data loggers and batteries sufficient to power the loggers and tower sensors for one year fit into the instrument well. Two complete sets of ASIMET sensor modules are attached to the upper section of the two-part aluminum tower at a height of about 3 m above the water line. The tower also contains a radar reflector, a marine lantern, and two independent Argos satellite transmission systems that provide continuous monitoring of buoy position. A third Argos positioning system, mounted within an access tube in the foam hull, is used as a backup and would be activated only if the buoy were to capsize. For WHOTS-2, a self-contained Global Positioning System (GPS) receiver was also deployed on the buoy tower. Sea surface temperature and salinity are measured by sensors bolted to the underside of the buoy hull and cabled to the loggers through an access tube through the buoy foam.

Fifteen temperature-conductivity sensors, two Vector Measuring Current Meters (VMCMs) and an Acoustic Doppler Current Meter (ADCP) were attached along the mooring using a combination of load cages (attached in-line between chain sections) and load bars. All instrumentation was along the upper 155 m of the mooring line (Fig. 16). Dual acoustic releases attached to a central load-bar were placed approximately 30 m above the anchor. Above the release were eighty 17” glass balls meant to keep the release upright and ensure separation from the anchor after the release is fired. This flotation is sufficient for backup recovery, raising the lower end of the mooring to the surface in the event that surface buoyancy is lost.

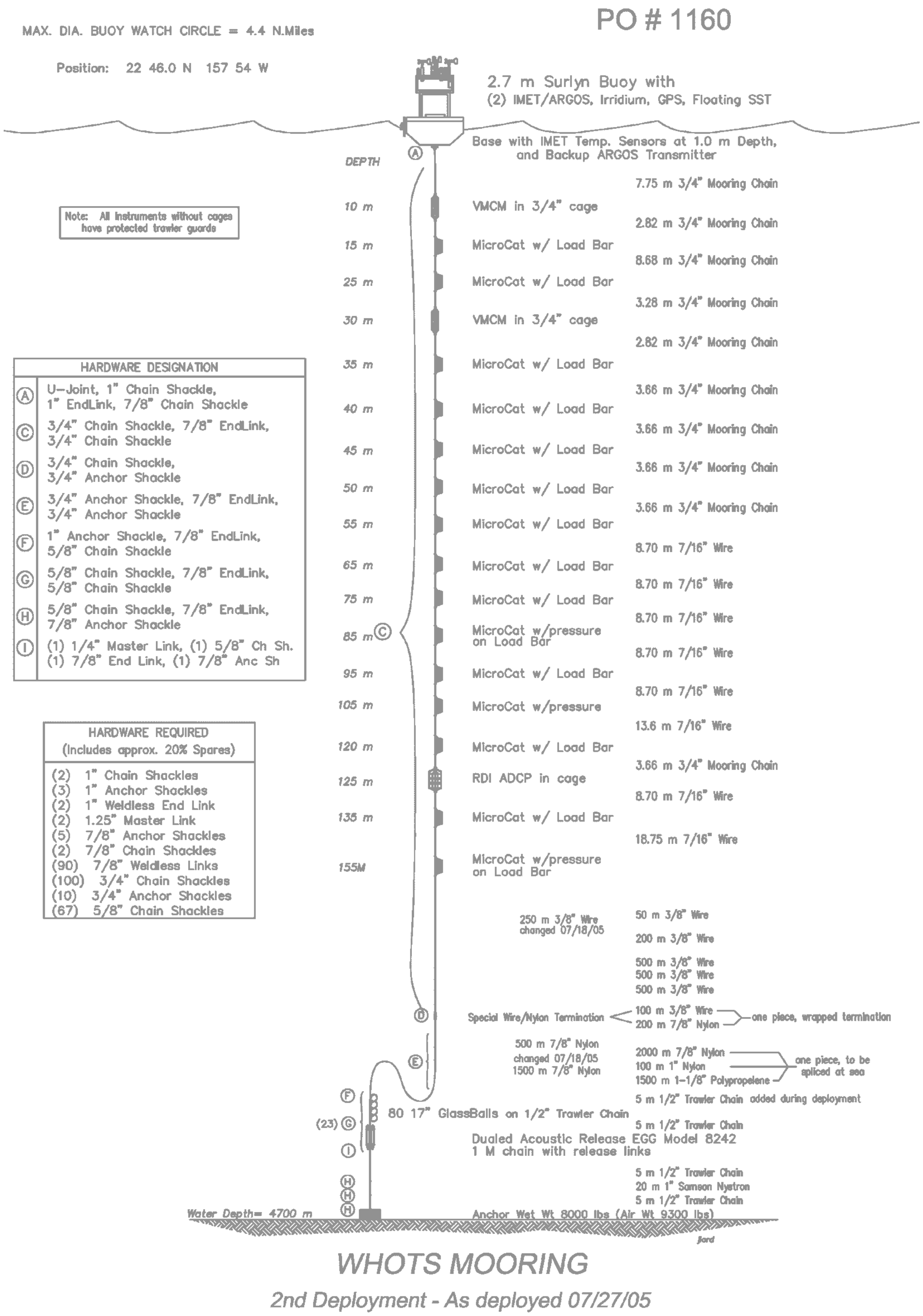

Figure 16. WHOTS-2 mooring diagram.

b. Instrumentation

The buoy was outfitted with two independent ASIMET systems to provide redundancy. The ASIMET system is the second-generation of the Improved Meteorological (IMET) system described by Hosom et al. (1995). Performance of the second-generation sensors is described by Colbo and Weller (submitted). The basic concept is a set of sensor modules that are connected to a central data logger and addressed serially using the RS485 communication protocol. As configured for WHOTS-2, each system included six ASIMET modules mounted to the tower top (Fig. 17), one Sea-Bird MicroCAT mounted on the buoy bridle leg, a data logger mounted in the buoy well, and an Argos Platform Transmit Terminal (PTT) mounted inside the logger electronics housing. The seven-module set measures ten meteorological and oceano-graphic variables (Table 5). Variables measured by the tower-top ASIMET modules are wind speed and direction (WND), barometric pressure (BPR), relative humidity and air temperature (HRH), shortwave radiation (SWR), longwave radiation (LWR), and precipitation (PRC). The MicroCAT measures sea temperature and conductivity (STC). The MicroCATs were specified with an RS485 interface option, and thus could be addressed by the ASIMET logger in the same manner as the meteorological modules on the tower top. A wind vane on the tower top keeps the "bow" of the buoy oriented towards the wind. A marine lantern is mounted above the vane and flat-plate Argos PTT antennas are mounted on either side of the lower vane. Wind modules are mounted in locations that minimize obstructions along the downwind path. Radiation sensors, mounted at the stern of the buoy, are at the highest elevation to eliminate shadowing.

Each tower-top module records one-minute data internally to a PCMCIA "flash" memory card at one-hour intervals. The STC module records internally at five-minute intervals. The logger polls the modules during the first few seconds of each minute, and then goes into low-power mode for the rest of the minute. The logger writes one-minute data to a flash memory card once per hour, and also assembles hourly averaged data for transmission through Argos PTTs. The Argos transmitter utilizes three PTT IDs to transmit the most recent six hours of one-hour averaged data.

For WHOTS-2, an Iridium modem subsystem was added to the ASIMET logger as a supplemental means of transmitting meteorological data. The Iridium controller obtained 1 min data from the logger once per four hours, averaged each variable to one hour, and sent the resulting hourly data as an email message to a shore-based workstation.

ASIMET sensor specifications are given in Table 5. Serial numbers of the sensors and loggers comprising the two systems (denoted ASIMET-1 and ASIMET-2) are given in Table 6. The sensor heights relative to the buoy deck, and relative to the water line, are given in Table 7. The water line was determined to be approximately 0.75 m below the buoy deck by visual inspection after launch.

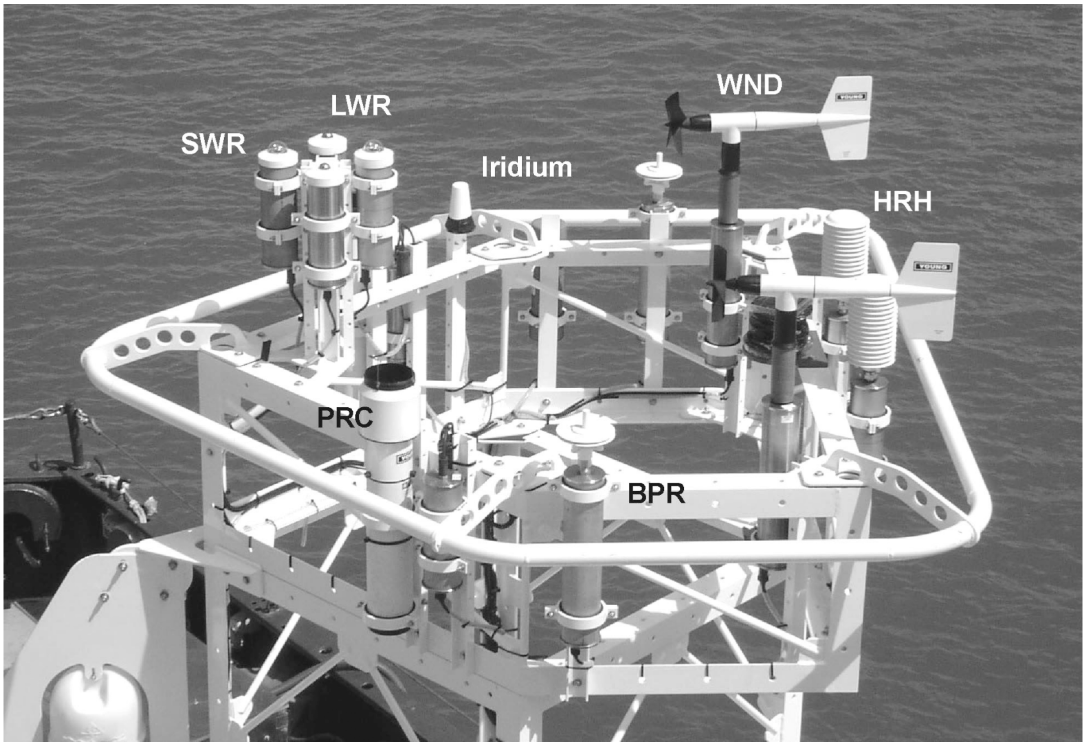

Figure 17. The WHOTS-2 tower top on the deck of the *Melville* with ASIMET modules labeled. When deployed, the windward side of the buoy is to the right and the wind vanes point in the opposite direction. The GPS module is to the right of the Iridium antenna on the far side of the tower. The sea surface temperature and conductivity (STC) modules, located on the underside of the buoy, are not visible in this view.

Table 5. ASIMET sensor specifications

Module	Variable(s)	Sensor	Precision	Short-term Accuracy [1]	Long-term Accuracy [2]
BPR	barometric pressure	AIR Inc.	0.01 mb	0.3 mb	0.2 mb
HRH	relative humidity	Rotronic	0.01 %RH	3 %RH	1 %RH
	air temperature	Rotronic	0.02 °C	0.2 °C	0.1 °C
LWR	longwave radiation	Eppley PIR	0.1 W/m^2	8 W/m^2	4 W/m^2
PRC	precipitation	RM Young	0.1 mm	[3]	[3]
STC	sea temperature	SeaBird	0.1 m°C	0.1 °C	0.04 °C
	sea conductivity	SeaBird	0.01 mS/m	10 mS/m	5 mS/m
SWR	shortwave radiation	Eppley PSP	0.1 W/m^2	20 W/m^2	5 W/m^2
WND	wind speed	RM Young	0.002 m/s	2%	1%
	wind direction	RM Young	0.1 ^{o}	6 ^{o}	5 ^{o}

[1] Expected accuracy for 1 min values.
[2] Expected accuracy for annual mean values after post calibration.
[3] Field accuracy is not well established due to the effects of wind speed on catchment efficiency. Serra et al. (2001) estimate sensor noise at about 1 mm/hr for 1 min data.

Accuracy estimates are from Colbo and Weller (submitted) except conductivity, which is from Plueddemann (unpublished results).

Table 6. WHOTS-2 ASIMET system serial numbers and sampling

System	Module	Type	Serial No.	Firmware Version [1]	Sample Rate [2]
ASIMET-1	BPR	ASIMET	219	VOS53 3.3	1 min
	HRH	ASIMET	220	VOS53 3.2	1 min
	LWR	ASIMET	212	VOS53 3.5	1 min
	PRC	ASIMET	503	VOS53 3.4	1 min
	STC	SBE-37	1836	SBE 2.2	5 min
	SWR	ASIMET	221	VOS53 3.3	1 min
	WND	ASIMET	205	VOS53 3.5	1 min
	Logger	C530/NTAS	L21	LGR53 3.1*	1 min
				* with Iridium	
	PTT	WildCAT	18231	ID#1 14663	90 sec
				ID#2 14677	90 sec
				ID#3 14697	90 sec
ASIMET-2	BPR	ASIMET	212	VOS53 3.3	1 min
	HRH	ASIMET	219	VOS53 3.2	1 min
	LWR	ASIMET	505	VOS53 3.5	1 min
	PRC	ASIMET	212	VOS53 3.4	1 min
	STC	SBE-37	3604	SBE 2.2	5 min
	SWR	ASIMET	503	VOS53 3.3	1 min
	WND	ASIMET	207	VOS53 3.5	1 min
	Logger	C530/NTAS	L19	LGR53 2.7	1 min
	PTT	WildCAT	14637	ID#1 07563	90 sec
				ID#2 07581	90 sec
				ID#3 07582	90 sec

[1] For PTTs, Argos PTT ID is given rather than firmware revision.
[2] All modules sample internally. The logger samples all modules.
For PTTs, "sample rate" is the transmission interval.

Table 7. WHOTS-2 ASIMET module heights and separations

Module	Relative [1] Height (cm)	Absolute [2] Height (cm)	Horizontal Sep. (cm)	Measurement Location
SWR	282	357	23	top of case
LWR	280	355	23	top of case
WND	268	343	120	middle of vane
PRC	234	309	116	top of cylinder
BPR	245	320	178	center of plate
HRH	248	323	45	center of shield
STC	-151	-76	9	center of shield

[1] Relative to buoy deck, positive upwards
[2] Relative to buoy water line, positive upwards

UH provided twelve MicroCATs for the WHOTS-2 mooring deployment. Three of the MicroCATs deployed on WHOTS-1 were turned around at sea and redeployed. This involved cleaning the instruments, downloading data, verifying data quality, calibrating against the CTD, and installing new batteries and anti-fouling. Table 8 gives summary information for the MicroCATs deployed on WHOTS-2. The ADCP was also turned around and redeployed. This involved cleaning the instrument, downloading data, verifying data quality, changing batteries, reprogramming and attaching new zincs. WHOI provided two refurbished VMCMs for WHOTS-2.

Table 8: WHOTS-2 MicroCAT Deployment Information

All times stated are in GMT

Deployment Date: 7/27/2005

Depth (m)	Sea-Bird Serial #	Param-eters	Sample Int (seconds)	Navg	Time Logging Started	Fresh Water Spike Time	Time in the water
15	37SM31486-3382	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:31
25	37SM31486-3621	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:27
35	37SM31486-3620	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:20
40	37SM31486-3632	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:18
45	37SM31486-2965	C, T, P	180	1	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:16
50	37SM31486-3633	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 18:13
55	37SM31486-3619	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:13
65	37SM31486-3791	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:17
75	37SM31486-3618	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:21
85	37SM31486-3670	C, T, P	180	1	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:24
95	37SM31486-3617	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:26
105	37SM31486-3669	C, T, P	180	1	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:29
120	37SM31486-2451	C, T, P	180	1	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:34
135	37SM31486-3634	C, T	150	2	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:42
155	3668	C, T, P	180	1	7/27/2005 6:00	06:31:00 - 07:03:30	7/28/2005 19:46

c. Deployment Operations

The nominal WHOTS deployment site is at 22°46′N, 157°54′W, about 6.5 nm E-NE of the HOT central site at 22°45’N, 158°00’W and about 12 nm due E of the MOSEAN mooring site (Fig. 3). Bathymetry database information indicated that the region surrounding the mooring site was relatively flat, which was confirmed during a SeaBeam and echosounder survey prior to the WHOTS-2 mooring deployment. The SeaBeam system included a transducer depth correction and incorporated XBT profiles to compute the local soundspeed profile. The corrected SeaBeam depths were found to be about 6 m greater than the 12 kHz Knudsen echo sounder, which did not include a transducer depth correction. The nominal mooring design was for a depth of 4700 m ±100 m. The survey indicated that depths within about 1 nm of the anchor site were 4700 ± 20 m, so no adjustment to the mooring design was necessary.

Winds from the *Melville* IMET system and currents from the shipboard ADCP were noted during the approach to the site. Winds were relatively steady at 15 kt from the E-NE, and currents were 10-15 cm/s to the N. It appeared that the best approach for the WHOTS-2 mooring deployment would be from the NW. However, estimation of set and drift by the bridge showed little influence from the surface currents, indicating that a direct upwind approach would be best. It was decided to steam to a starting point approximately 7 nm nearly due W of the drop site (approach course 80°). The target drop position was 22°46.00′N, 157°54.00′W.

The *Melville* began the approach at about 0800 h (local) on 27 July at a distance of 7.1 nm from the drop site (Fig. 18). The upper 40 m of the mooring (chain and instruments) were deployed between 0810 and 0835 h. The buoy was deployed about 15 min later, with the ship hove to. The remainder of the mooring was payed out as the ship made way at about 1.5 kt over the ground. The speed through the water, as estimated by the bridge, was consistently less than the speed over the ground, indicating a following current. At 1415 h local the mooring was completely in the water except for the anchor, and was under tow with the ship about 1.3 nm away from the drop site. The anchor was dropped at 1543 h local on 27 July (28 July 0143 UTC) at 22°46.030′N, 157°53.766′W in water of depth 4695 m. Following the anchor drop, the ship continued to steam along the approach course until it was determined that the anchor had settled to the bottom. At 1620 h the ship headed to the first acoustic survey station.

The acoustic ranging survey was done to determine the exact anchor position and allow estimation of the anchor fall-back from the drop site. Three positions about 2.5 nm away from the drop site were occupied in a triangular pattern (Fig. 18). The WHOI over-the-side transducer and deck box were used to obtain slant range (or travel time) to the release. The acoustic survey began at 1645 h local and took about 2 hours to complete. Triangulation from the three sites using Art Newhall’s acoustic survey program gave an anchor position of 22°45.999′N, 157°53.905′W (Fig. 19). The estimated fall-back from the drop site was about 250 m, or 5% of the water depth.

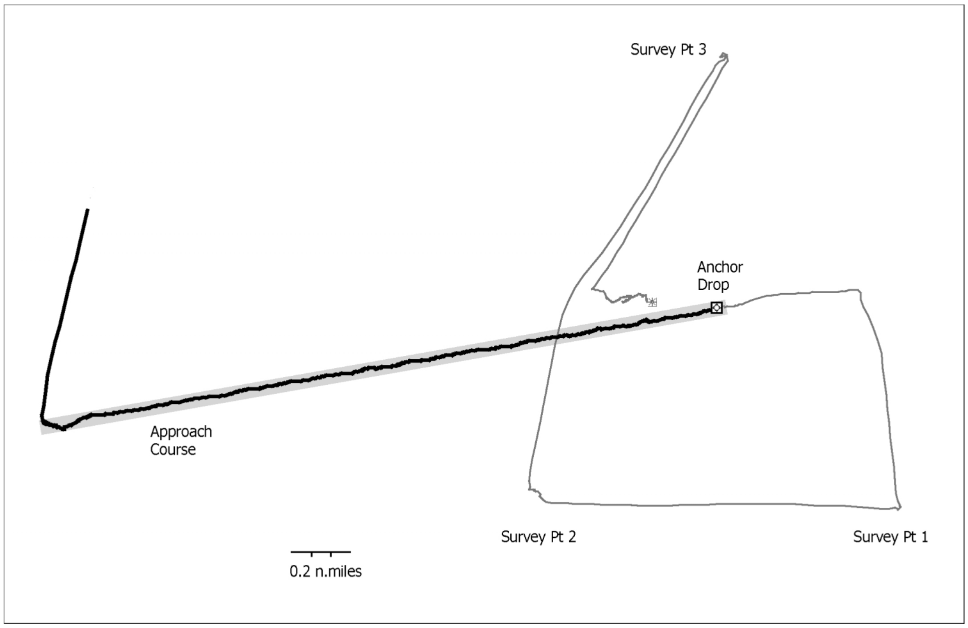

Figure 18. Ship track during WHOTS-2 deployment and acoustic survey. The anchor was dropped as the ship passed the drop target along the approach course (x). The ship returned to the surface buoy location (*) after the acoustic survey.

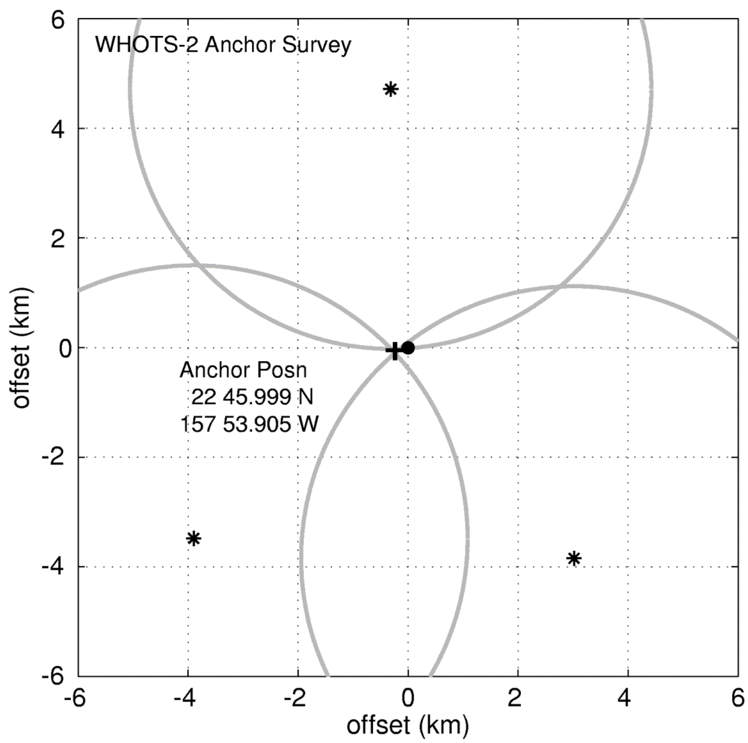

Figure 19. WHOTS-2 anchor survey. The estimated anchor position (+) is shown relative to the anchor drop location (o) and the three acoustic ranging sites (*).

During the intercomparison period, the ship maneuvered within a few hundred feet of the WHOTS-2 buoy. Visual observations showed the tower top instrumentation intact and the buoy riding smoothly with a nominal waterline about 75 cm below the buoy deck.

The WHOTS-2 surface mooring was deployed using the UOP two-phase mooring technique. Phase 1 involved the lowering of approximately 40 m of instrumentation over the starboard side of the ship. Phase 2 was the deployment of the buoy into the sea. The benefits of lowering the first 40 m of instrumentation are three fold: (1) it allows for the controlled lowering of the upper instrumentation; (2) the suspended load attached to the buoy's bridle acts as a sea anchor to stabilize the buoy during deployment; and (3) the 80 m length of payed-out mooring wire and instrumentation provides adequate scope for the buoy to clear the stern without capsizing or hitting the ship. The remainder of the mooring was deployed over the stern.

The deck was prepared for the WHOTS-2 deployment by shifting the WHOTS-1 buoy inboard and then shifting the WHOTS-2 buoy forward with the crane and tipping it on its side using the air tuggers. Once on its side, the buoy was shifted outboard to the deployment position. The 1750 meters of mooring wire from the recovery of the WHOTS-1 mooring was spooled off the winch using the WHOI winding cart and coiling attachment. All terminations were cut off the wire coils so the wire could be properly disposed of upon return to Hawaii. The new mooring wire for WHOTS-2, including the wire-to-nylon interface termination, was spooled onto the winch using the WHOI tension cart to apply 600 pounds tension to the wire as it was spooled onto the winch. Air tugger pedestals were moved on the deck to accommodate the mooring/buoy deployment. Deck cleats were positions around the buoy.

Instruments were prepared for deployment by pre-rigging the short shots of chain and wire onto the instrument cages and load bars. For the first 7 instruments (to 45 meters), the shots were rigged to the top of the load bar or cage. The 50-meter MicroCAT was rigged with shots of chain on the top and bottom of the load bar. The rest of the instruments, to be deployed from the stern, were rigged with the shots of chain or wire on the bottom of the load bar, or cage.

Prior to the deployment of the buoy, 50 meters of 3/8" diameter wire rope was payed out to allow its bitter end to be passed out through the center of the A-frame and around the aft port quarter and forward along the port rail to the instrument lowering area. This working wire was connected to the bottom of the shot of chain rigged to the 50-meter MicroCAT. Four wire handlers were stationed around the aft port rail. The wire handler's job was to keep the hauling wire from fouling in the ship's propellers and pass the wire around the stern to the line handlers on the port rail.

To begin the mooring deployment the crane was positioned over the instrument lowering area with about 4 meters of vertical lift available to the boom. A lifting sling passed through the end link connected to the shot of chain on the 50 meter MicroCAT was attached to the crane hook. The crane wire was raised so the chain and instrument were lifted off the deck. The crane swung outboard to clear the ship's side, and slowly lowered the wire and attached mooring components down into the water. The wire handlers positioned around the stern eased wire over the port side, paying out enough wire to keep the mooring segment vertical in the water. The crane wire was lowered until there was about 2 feet of chain suspended above the deck. A chain hook connected to an air tugger was used to stop off the mooring at this point. A safety stopper was clipped to the end link at the end of the chain, and the sling to the chain hook was removed. The next instrument was brought in and shackled to the link at the end of the suspended chain.

The operation of lowering the upper mooring components was repeated up to the 7.75 meter shot of 3/4" chain shackled to the 10 meter VMCM. The crane lifted the chain and suspended instruments from a sling link shackled into the ¾" chain about 6 feet from the top end. The crane wire was lower until it was even with the deck. The slack end of the 7.75 meter chain was shackled into the universal joint at the bottom of the buoy. Once the attachment was made, the crane wire was lowered until the load was transferred to the buoy. The crane and sling were then removed from the mooring line.

The second phase of the operation was to launch of the buoy. A total of five lines were attached to the buoy prior to lifting. Three slip lines were used to maintain control during the lift (Fig. 20). These lines were rigged on the bottom frame, tower halo and a buoy deck bail. A quick release hook was rigged on the lifting point of the buoy hull. An additional line was tied to the crane hook to help pull the crane block away from the tower's meteorological sensors once the quick release hook had been triggered and the buoy cast adrift.

With the crane positioned over the lifting bail, the quick release was attached. Slight tension was taken up on the crane to hold the buoy. The lashings holding the buoy to the deck were removed. The buoy was raised up and swung outboard as the slip lines kept the hull in check. The tower slip line was removed first, followed by the bridle slip line. Once the discus had settled into the water (approximately 20 ft. from the side of the ship), and the release hook had gone slack, the quick release was tripped. The crane swung forward to keep the block away from the buoy. The slip line to the buoy deck bail was cleared at about the same time. The ship then maneuvered slowly ahead to allow the buoy to come around to the stern.

The winch operator slowly hauled in the slack wire once the discus had drifted behind the ship. The ship's speed was increased to 1/2 knot through the water to maintain a safe distance between the buoy and the ship. The bottom end of the shot of ¾" chain shackled to the working wire was pulled in and stopped off at the transom. The working wire was removed from the winch. The 55 meter MicroCAT and pre-attached wire shot were shackled to the end of the stopped off chain. The free end of wire was passed through a trawl block suspended from the A-frame, and shackled to the wire on the winch. The winch was pulled tight and the stopper lines were removed from the chain.

Using the A-frame and the tugger to adjust the height of the trawl block, the winch payed out wire easing the instrument over the transom. At the end of the short shot of wire, the winch stopped and stopper lines were attached to the link in the termination. The winch wire was removed, and the next instrument and wire shot was inserted into the line. The procedure continued until all instruments had been deployed.

The remaining wire and nylon on the TSE winch was payed out through the hanging block on the A-frame. The end of the nylon was stopped off and the winch leader removed. The

Figure 20. Deployment of the WHOTS-2 buoy. The five lines visible are (clockwise from right) crane tag line, quick-release trip line, and the deck, base and tower slip lines.

end of the 2000 meters of nylon and 1500 meters polypropylene, coiled in 3 wire baskets, was shackled into the mooring. The slack part of the nylon was dressed over a heavy duty H-bit bolted to the deck (Fig. 21). The stopper lines were slacked off and the load transferred to the nylon on the H-bit. With one person tending the line in the baskets, and one person tending the H-bit, deployment of the synthetic lines resumed.

While the line was being payed out, the crane was used to lift the 80 glass balls out of the rag top container. These balls were staged fore and aft, in four ball segments, just aft of the container.

When the end of the polypropylene line was reached, payout was stopped and a Yale grip and stopper lines were used to take tension off the H-bit. The winch leader line was shackled to a 5 meter shot of ½" chain and into the end of the polypropylene line. The polypropylene line was removed from the H-bit. The winch line and mooring line were wound up taking the mooring tension away from the stopper line on the Yale grip. The Yale grip and stopper lines were removed. The TSE winch payed out the mooring line until the thimble was approximately 2 meters from the ship's transom. At this point the hanging block was lowered to the deck and removed. Payout continued until the ½" chain was over the transom. The chain was stopped off and the winch leader removed.

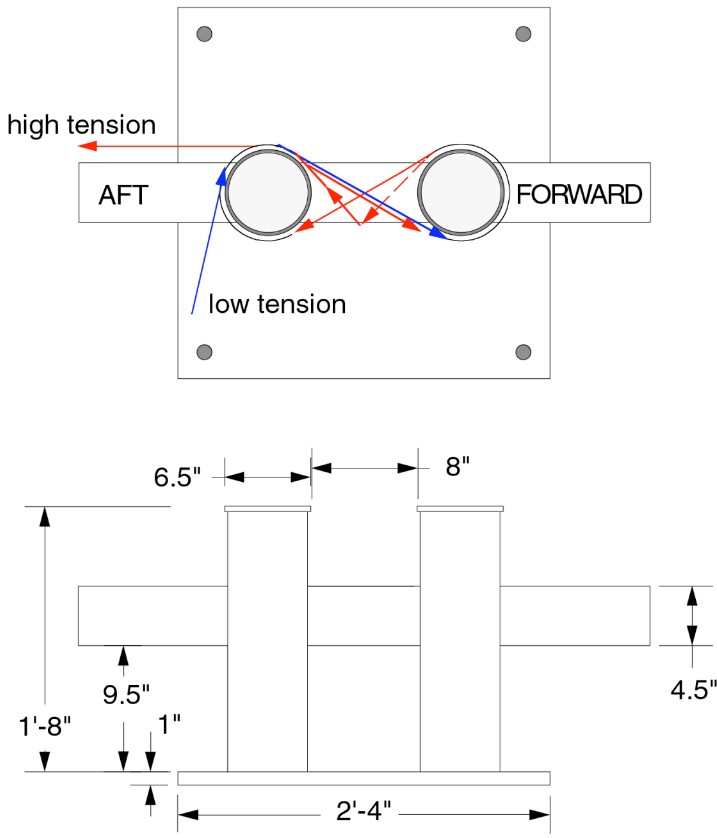

Figure 21. H-Bit dimensions and fair lead detail.

The next step was the deployment of 80 glass balls. The glass balls were bolted on 1/2" trawler chain in 4 ball (4 meter) increments. The 20 sections of chain and glass balls were laid out on the deck and pre-rigged with shackles and links. The first string of glass balls was dragged aft and connected to the stopped off chain. A second string of balls was shackled in, forward of the first. The winch leader was then connected to the string of 8 balls. The winch leader was pulled tight, and the stopper lines were eased out and disconnected. The winch payed out until 7 balls were beyond the transom. The two stopper lines were then attached to the link at the end of the string of balls. Another 2 sets of glass balls were then dragged into place and shackled into the mooring. This procedure continued until all 80 glass balls were attached to the mooring line.

At this point the ship was still more than 1 nm from the target drop position. As we continued toward the site, the final sections of the mooring were prepared. A 5-meter shot of chain was attached to the last string of glass balls and to the tandem-mounted acoustic releases. Another 5-meter shot of chain was attached to the bottom link on the dual release chain. This chain was then shackled into the 20-meter nylon anchor pennant, which was shackled into the final 5 meters of ½" chain. The chain, anchor pennant, and next shot of chain were wound onto the winch. The stopper lines were used to pass the load to the winch in increments. The air tugger line, passed through the A-frame, lifted the releases to prevent them from dragging down the deck.

With the two stopper lines and the winch leader attached to the mooring line, the ship towed the mooring for about one hour. As we approached the anchor drop site, final preparations were made. First, the releases and pennant were eased over the transom. Again, the air tugger lifted the releases to ease them over the transom. The final shot of chain was stopped as soon as 20-meter anchor pennant was clear of the transom. A sling link was shackled into the ½" chain about 1.5 meters up from the Sampson anchor pennant. A heavy-duty slip line was passed through this link and the mooring tension was transferred to the slip line. The slack end of the chain was removed from the winch leader and shackled to the anchor. The bolts holding the anchor tip plate to the deck and chain binders on the anchor were removed. A tie-back from the anchor to an eye bolt was tied in to prevent the anchor from slipping off as the load was passed to it. The crane was positioned with the boom slightly aft of the lifting bridle on the tip plate. The crane was then attached to the tip plate bridle and slight tension was taken on the crane wire.

At 100 meters from the launch site, the slip line on the final shot of chain was eased out and the mooring load was transferred to the anchor. The anchor was stable, and the tie back was removed. At the signal from the Chief Scientist, the crane wire was raised and the tip plate raised enough to let the anchor slip into the water.

5. Meteorological Intercomparisons

a. Overview

In order to assess the performance of the buoy meteorological systems, two periods of about 30 h were dedicated to ship-buoy intercomparisons. The first inter-comparison period was prior to recovery of the WHOTS-1 mooring and the second was following deployment of the WHOTS-2 mooring. Hourly ASIMET data were obtained by intercepting the Argos PTT transmissions from the buoy with Alpha-Omega satellite uplink receivers. Whip antennas were mounted on the forward deck rails to receive the transmissions. Consistent receptions from both PTTs required that the ship stand-off at a distance of 0.5–1.0 nm downwind of the buoy. CTD casts were performed in the vicinity of the buoys during the intercomparison period (see Sec. 6). Because 6 h of buffered data are transmitted by the ASIMET logger PTTs each hour, no meteorological data were lost if the ship was out of range of the uplink receivers for several hours.

The *Melville* was outfitted with an IMET system, with sensors for barometric pressure (BP), air temperature (AT), sea surface temperature (SST), sea surface conductivity (SSC), relative humidity (RH), wind speed (WSPD), wind direction (WDIR), shortwave radiation (SWR), longwave radiation (LWR), and precipitation (PRC). Standard navigation data (GPS position, course over ground, and speed over ground) and depth from the 12-kHz echo sounder were also available. These shipboard data were logged at 30-sec intervals by the shipboard Meteorological Acquisition System and saved as ASCII files. The data from daily log files were accessed over the network and archived on a laptop computer for processing. The *Melville* BP, AT, RH, WSPD WDIR SWR and LWR sensors were located on the forward met mast at a height of 55' (16.8 m) above the waterline. There were two sources of T/C data. Both systems took in water from the bow intake, located at a depth of about 5 m. The "bow" system was physically located in the bow chamber about 1.2 m from the seawater intake, whereas the "flow through" system measured seawater that had been pumped from the bow chamber to the Bio/Analytical Lab.

b. WHOTS-1 vs. *Melville*

The WHOTS-1 intercomparison period started at 1100 h UTC on 24 July (year day 205.46) when the first Argos transmissions were received upon approaching the WHOTS-1 buoy. Operations continued until 1700 h UTC on 25 July (year day 206.71), just before the release was fired. The total duration was 30 h, during which hourly data from the WHOTS-1 buoy were compared with 30 sec shipboard IMET data. The results of the comparison are shown in Figures 22-25. The buoy systems are identified as W1S1 (WHOTS-1 System 1) and W1S2 (WHOTS-1 System 2) in the plots. The buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy; Table 5) for all variables except SWR and LWR. Examination of the buoy data in conjunction with the shipboard meteorology provided further understanding of these discrepancies, and resulted in other useful observations about system performance, as described below.

The buoy BP was consistently higher than that of the ship by about 1 mb, consistent with the 14 m vertical offset between the buoy ship sensors. The buoy RH was lower than that of the ship by 3-4 %. Pending post-calibrations of the buoy modules, it was not clear whether this offset was attributable to calibration drift or to real vertical differences in RH. The buoy SST (measured at ~1 m depth) tracked the ship's flow-through system (5 m depth) within 0.1°C, but was 0.3-0.4°C higher than the bow SST. It was concluded that the bow SST was in error. The buoy AT was within 0.1°C of the ship at night, but showed a positive offset of about 0.3°C during the day. This positive bias was attributed to self-heating of the HRH module and/or a heat-island effect from the buoy. Since wind speed was relatively strong (8-10 m/s) throughout the intercomparison period, a module self-heating problem due to insufficient ventilation of the radiation shield seemed to be the most likely cause. SWR showed good agreement in general, but at times System 1 was below System 2 and the ship by more than 50 W/m^2. Since System 1 tended to be lower than System 2 before midday and higher after midday, the differences were attributed to timing errors in the buoy loggers (System 1 lagging). Both buoy LWR values showed consistent positive bias relative to the ship, with System 1 about 8 W/m^2 higher than System 2 and System 2 about 10 W/m^2 higher than the ship. Since this generation of buoy LWR sensors was known to suffer calibration shifts, these differences were attributed to buoy sensor error. Wind speed for both buoy systems was within 1 m/s of the ship, and wind direction for System 2 was within 10° (System 1 direction was not available due to the compass/vane failure). Considering the potential for flow distortion of the ship's winds, this was considered good agreement.

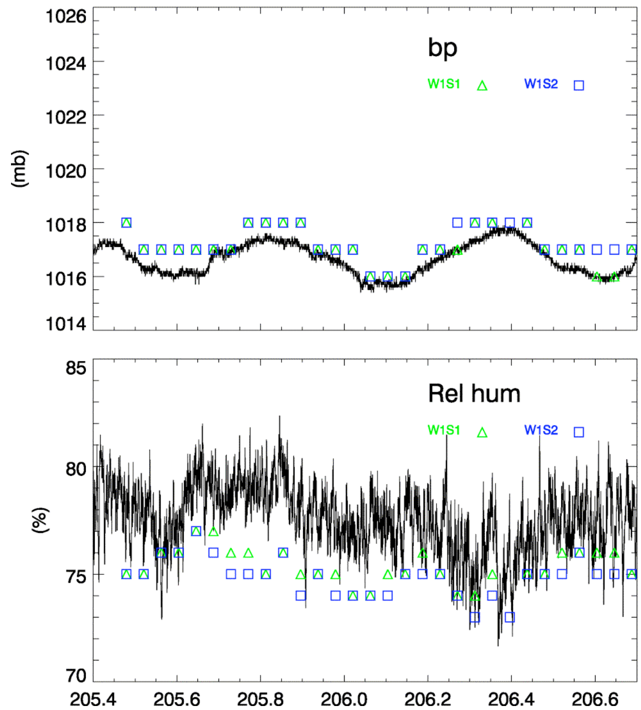

Figure 22. WHOTS-1 Barometric pressure (upper) and relative humidity (lower) compared with *Melville* shipboard data (black).

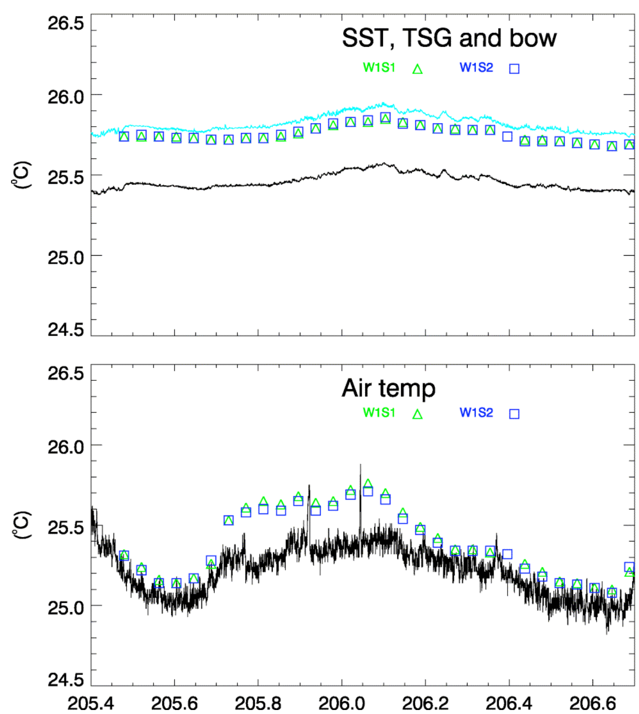

Figure 23. WHOTS-1 sea surface temperature (upper) and air temperature (lower) compared with *Melville* shipboard data.

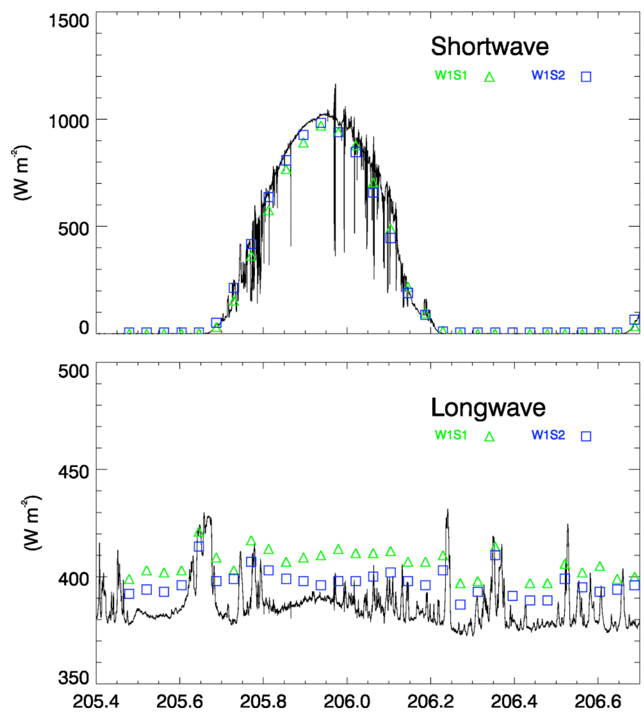

Figure 24. WHOTS-1 shortwave (upper) and longwave (lower) radiation compared with *Melville* shipboard data (black).

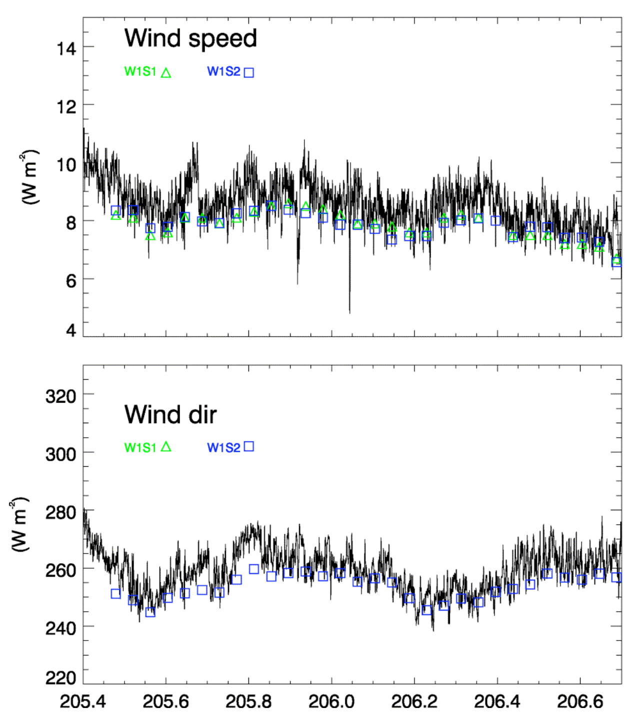

Figure 25. WHOTS- 1 wind speed (upper) and direction (lower) compared with *Melville* shipboard data (black).

c. WHOTS-2 vs. *Melville*

The WHOTS-2 intercomparison period started at 0300 h UTC on 28 July (year day 209.13) when the WHOTS-2 buoy had settled out from the anchor drop. Operations continued until 1000 h UTC on 29 July (year day 210.42), just prior to departing the station. The total duration was 31 h, during which hourly data from the WHOTS-2 buoy were compared with 30 sec shipboard IMET data. The results of the comparison are shown in Figures 26-29. The buoy systems were identified as WHOTS-2 System 1 (W2S1) and System 2 (W2S2). The WHOTS-2 sensor pairs showed good agreement (differences between like sensors within the expected short-term accuracy) for all variables except LWR. Examination of the buoy data in conjunction with the shipboard meteorology resulted in further observations about system performance, as described below. Since the WHOTS-2 sensors were freshly calibrated, considering the shipboard system as a "transfer standard" also allowed some inferences about WHOTS-1 performance.

The buoy BP was consistently higher than that of the ship by about 1 mb. This was attributed to the vertical offset of 14 m between the buoy sensors and the ship's bow mast sensors. The buoy RH showed good agreement with the ship (typically within 1%). Thus, the 3-4% low bias seen in the WHOTS-1 RH was likely due to drift in the buoy sensors rather than real environmental differences. The buoy SST tracked the ship's flow-through system within 0.1°C, but was 0.3-0.4°C higher than the bow SST. This was further confirmation that the bow SST was in error. The buoy AT was about 0.2°C higher than the ship at night, but this increased to about 0.3°C during the day. As with the WHOTS-1 buoy, the larger daytime offset was attributed to module self-heating. Buoy SWR values agreed well with the ship throughout the intercomparison period. Wind speed for both buoy systems was within about 1 m/s of the ship and wind direction was within 5°. Considering the potential for flow distortion of the ship's winds, this was considered good agreement.

Buoy LWR values showed consistent positive biases relative to the ship. The offset between sensors was similar to that seen during pre-deployment testing (Sec. 2b), with System 2 higher than System 1 by 8-10 W/m^2. The buoy sensors were 10-20 W/m^2 higher than the ship, also consistent with the pre-deployment results where both WHOTS-2 LWRs were higher than a third sensor confirmed to have no calibration shift. Considering that both WHOTS-1 LWRs also read high relative to the ship indicates that all four WHOTS LWR sensors had suffered positive calibration shifts.

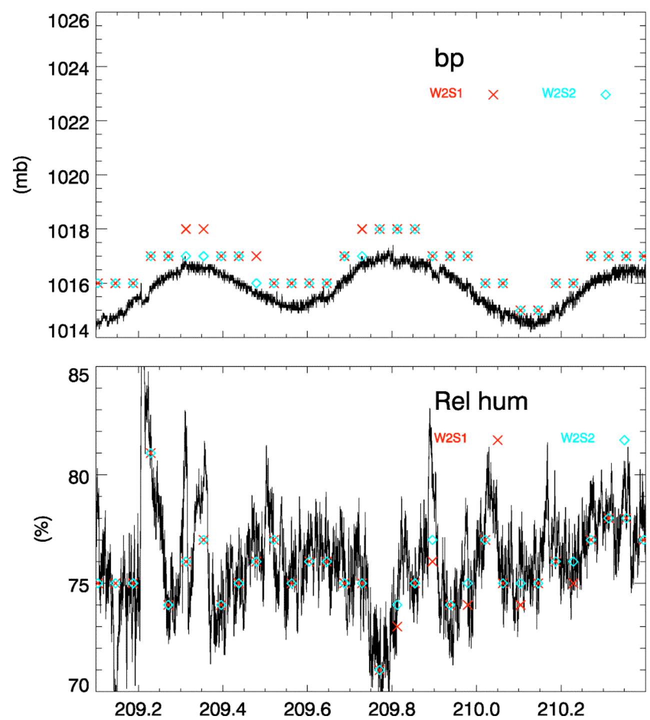

Figure 26. WHOTS-2 Barometric pressure (upper) and relative humidity (lower) compared with *Melville* shipboard data (black).

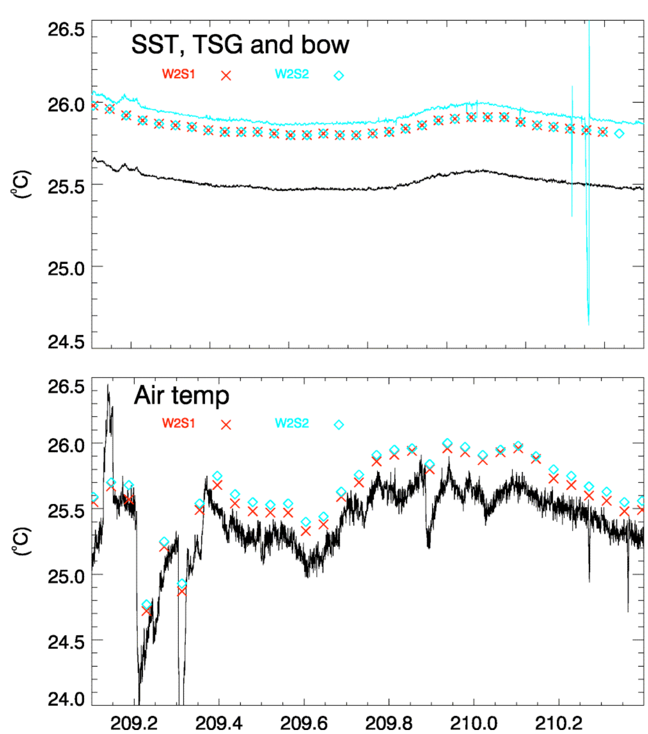

Figure 27. WHOTS-2 sea surface temperature (upper) and air temperature (lower) compared with *Melville* shipboard data.

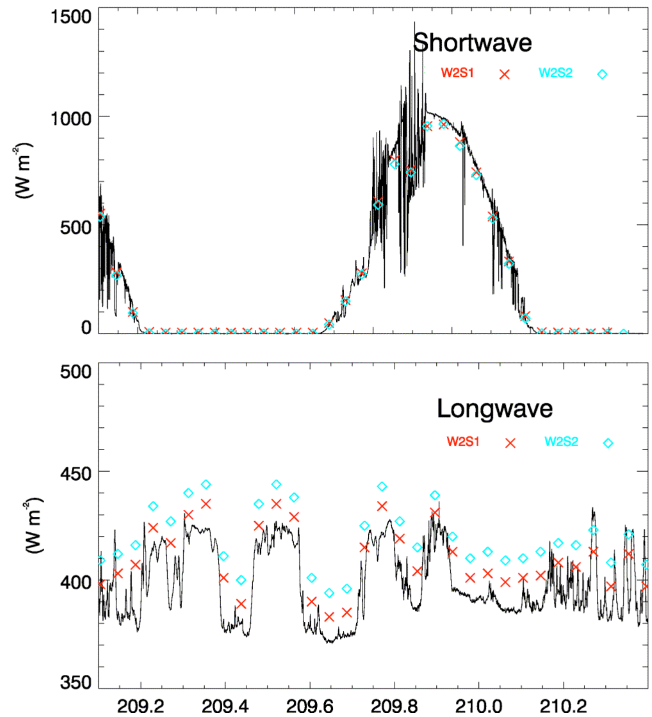

Figure 28. WHOTS-2 shortwave (upper) and longwave (lower) radiation compared with *Melville* shipboard data (black).

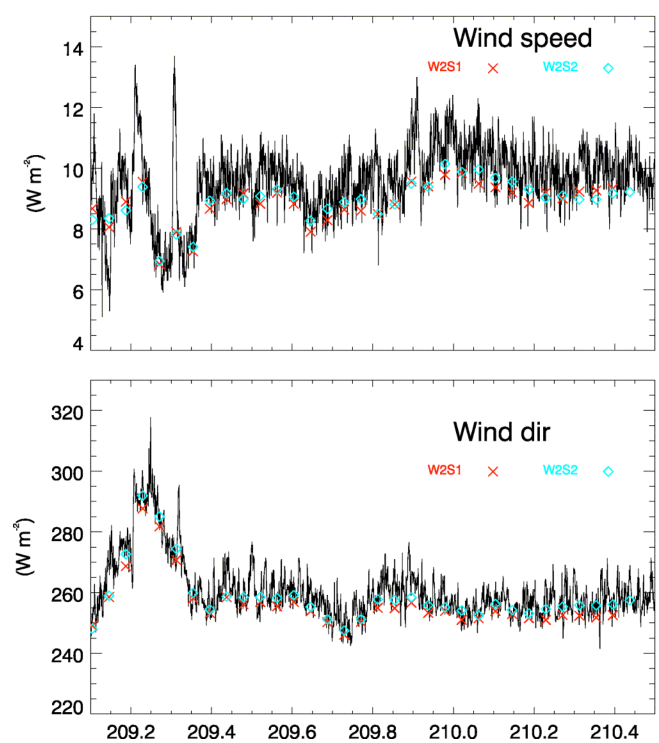

Figure 29. WHOTS- 2 wind speed (upper) and direction (lower) compared with *Melville* shipboard data (black).

6. CTD Operations

A Sea-Bird 911-Plus CTD and 24-place rosette with 121 sampling bottles were supplied by UH for the cruise and operated by UH personnel in cooperation with the *Melville* Res-Tech. In addition to a series of casts near the WHOTS mooring deployment site for sensor validation, additional CTD survey work was scheduled due to the presence of an anticyclonic eddy passing near the HOT area. This feature was evident in satellite altimetry as a sea surface height anomaly to the NNE of Oahu (Fig. 30) and was associated with a strong chlorophyll maximum (Fig. 31). Additional UH personnel were aboard to oversee the eddy CTD sampling.

The Sea-Bird 911 had sensors for pressure, temperature (2), conductivity (2), dissolved oxygen (2) and fluorescence, all sampled at 24 Hz. A self-contained Satlantic in-situ ultraviolet spectro-photometer (ISUS) sampling at 1 Hz was attached to the rosette frame. Table 9 shows the date, time, location, and max depth for each of the 19 CTD stations.

The following variables were sampled at CTD Stations 1,4,5,6,7,8,9,10,11, 12 and 16. Salinity samples were taken for all except Station 2.

- O2 - Oxygen
- DIC/TA – dissolved inorganic carbon and total alkalinity
- PC/PN – particulate carbon and particulate nitrogen
- PPO4 – particulate phosphorous
- HPLC pigments – high pressure liquid chromatography
- DNA/RNA – nucleic acids that indicate nitrogen fixers
- 15N/13C incubation to determine rates of nitrogen fixation
- Flow Cam - Preserved samples to determine particle size and image capture
- Live Samples – for microscopy
- Nutrients – the standard HOT mix – nitrate, silicate, phosphate...
- LLN – low level nitrogen
- LLP – low level phosphorous
- 15N – nitrogen isotope

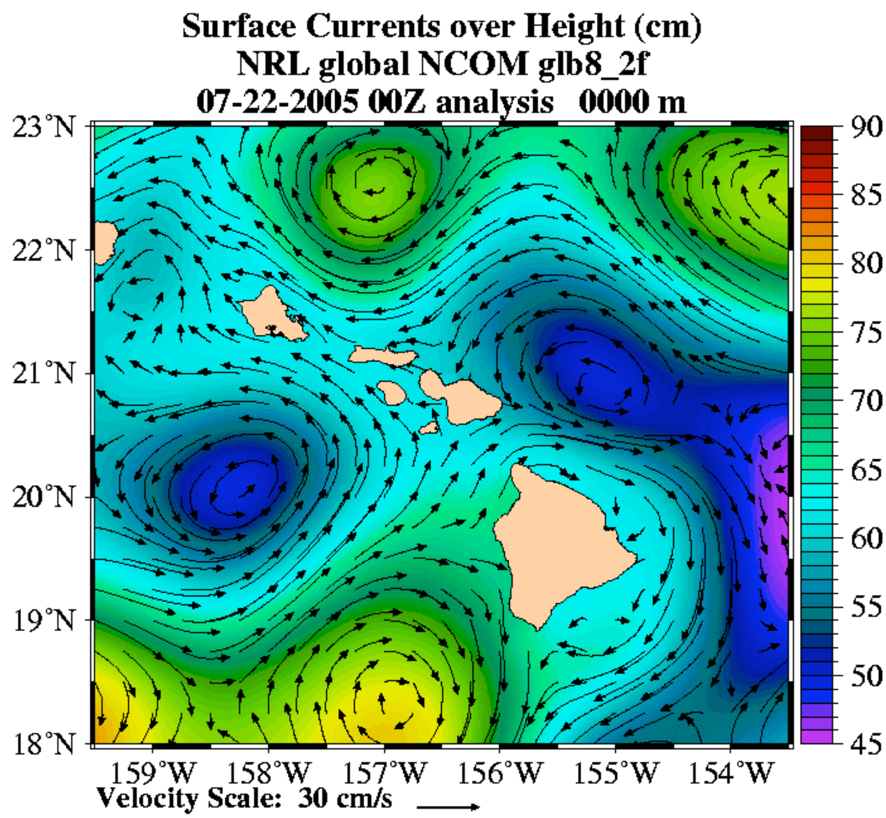

Figure 30. Sea surface height anomaly and surface currents for 22 July.

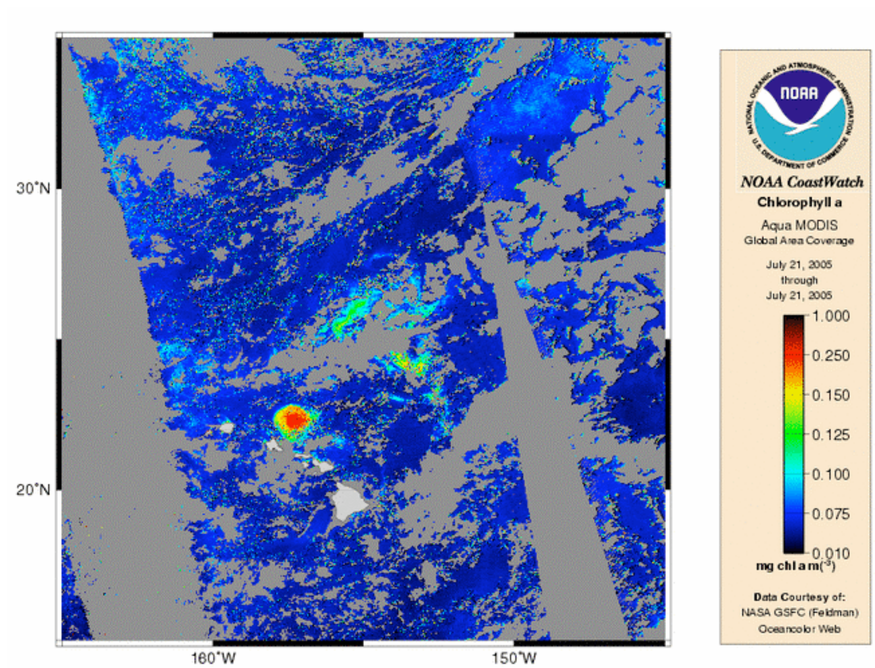

Figure 31. NOAA Aqua MODIS surface Chlorophyll for 21 July.

Table 9: CTD Stations

Station	Date	Time (GMT)	Location	Maximum pressure (dbar)
1	7/24/05	22:25	22 47.1N, 157 55.6W	1020
2	7/25/05	3:55	22 47.5N, 157 54.4W	200
4	7/26/05	7:20	22 22.5N, 157 30.0W	1020
5	7/26/05	10:55	22 27.3N, 157 39.3W	1020
6	7/26/05	14:23	22 33.04N, 157 48.6W	1020
7	7/26/05	17:56	22 35.7N, 157 53.1W	1020
8	7/26/05	21:45	22 38.4N, 157 57.9W	1020
9	7/27/05	00:54	22 41.6N, 158 3.6W	1020
10	7/27/05	4:25	22 45.0N, 158 9.56W	1020
11	7/27/05	7:48	22 50.2N, 158 18.7W	1020
12	7/28/05	21:57	22 47.1N, 157 55.6W	1020
13	7/29/05	3:53	22 46.01N, 157 54.62W	200
14	7/29/05	15:23	22 40.0N, 158 0.0W	1020
15	7/29/05	18:09	22 30.0N, 158 0.0W	1020
16	7/29/05	22:32	22 30.0N, 157 30.12W	1020
17	7/30/05	2:34	22 20.01N, 158 0.14W	1020
18	7/30/05	5:47	22 9.99N, 158 0.12W	1020
19	7/30/05	8:28	22 0.0N, 158 0.0W	1020

Figure 32 shows the geographic distribution of the 18 CTD stations. The first 2 CTD casts were done in near proximity to the WHOTS-1 buoy prior to recovery. Station 1 was a deep (1000 m) cast 1.5 nm downwind of the buoy anchor position. Station 2 was a shallow (200 m) cast about 0.5 nm downwind of the buoy. Due to a last-minute change in the operations plan, Station 3 was eliminated. Stations 4-11 were the primary eddy sampling stations, meant to produce a transect from near the eddy center (Station 4) to beyond its outer edge (Station 11). These stations were done during the period between WHOTS-1 recovery and WHOTS-2 deployment while instruments and mooring gear were being readied for the deployment. Stations 12-13 were deep and shallow casts, respectively, at the WHOTS site after deployment of the WHOTS-2 mooring. Stations 14-19 were occupied during the return trip to Honolulu to provide a more thorough regional survey in the vicinity of the eddy.

The two deep casts at the WHOTS site (Figs. 33-34) showed similar upper ocean structure: A relatively well-mixed region extending to about 60 m depth with increasing fluorescence, a fluorescence maximum near the mixed layer base, and a salinity maximum at about 150 m within a region of decreasing temperature and oxygen.

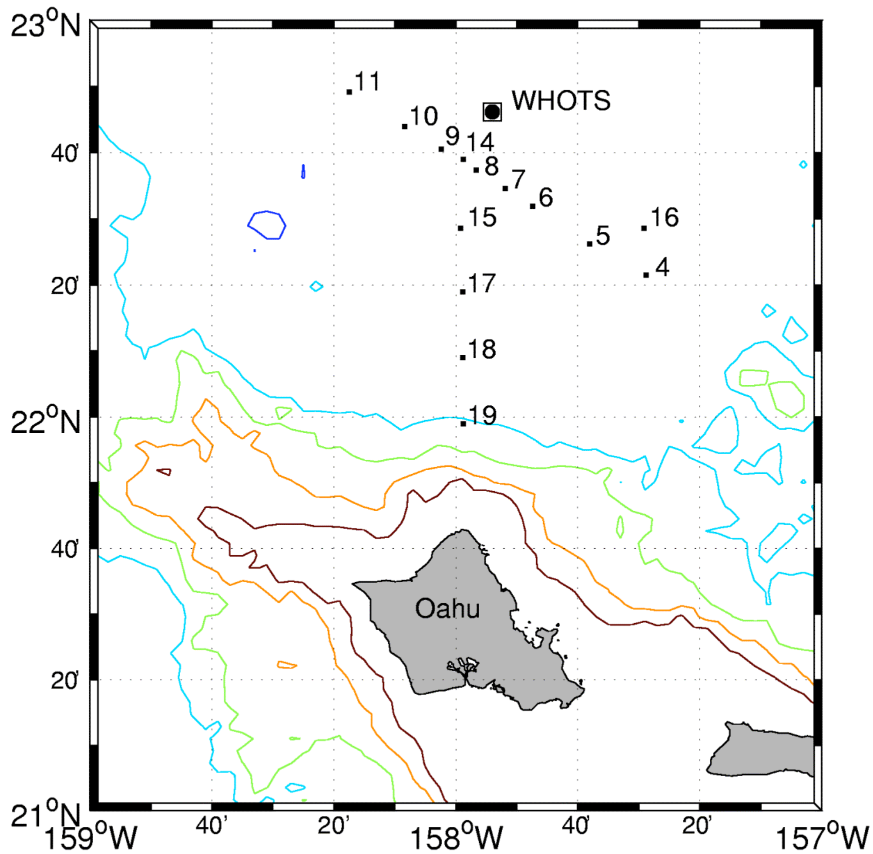

Figure 32. CTD station locations. Stations 1-2 and 12-13 were conducted at the WHOTS site. Station 3 was eliminated from the sampling plan. The remaining stations were in support of eddy sampling work.

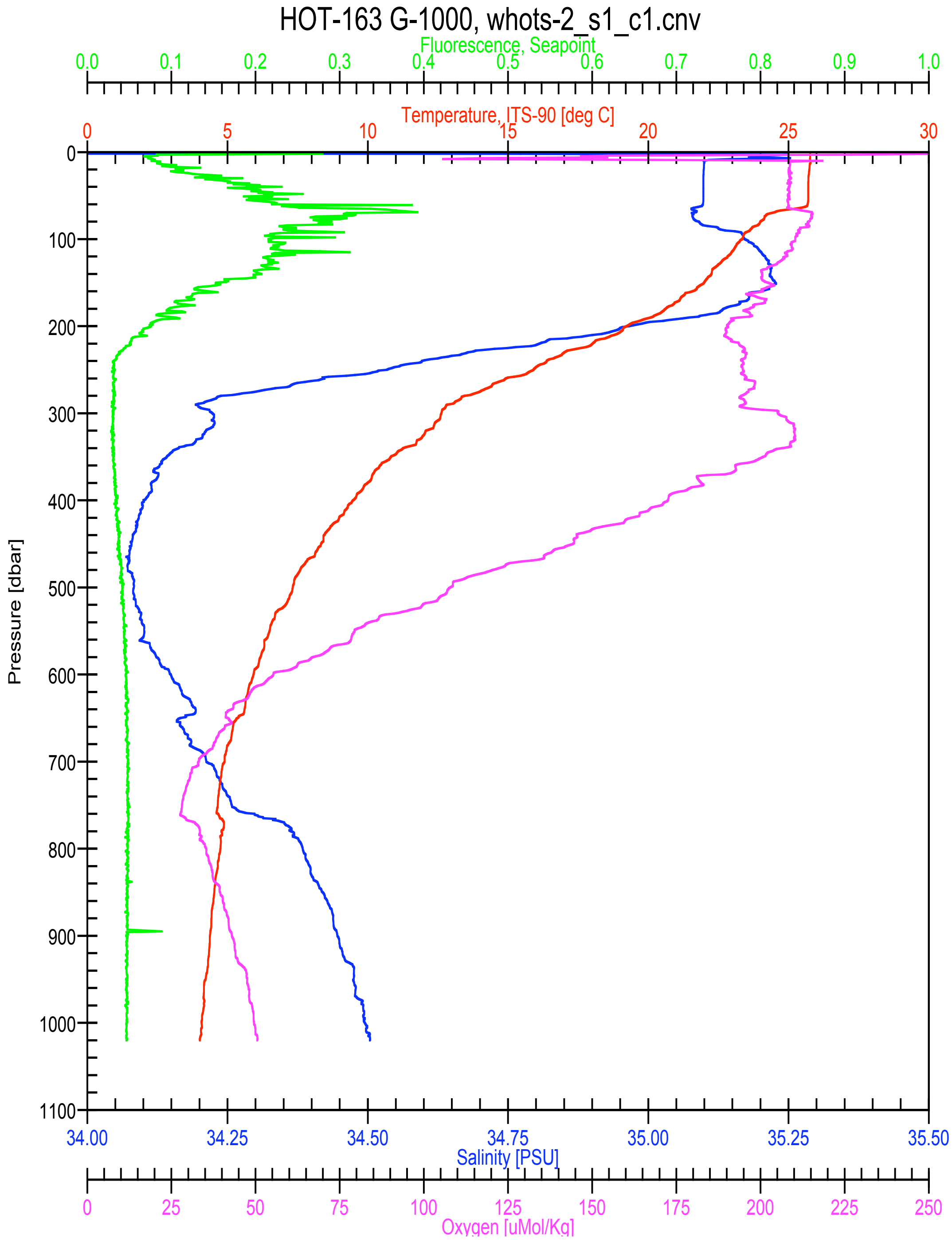

Figure 33. CTD Cast 1: Deep cast near the WHOTS-1 buoy.

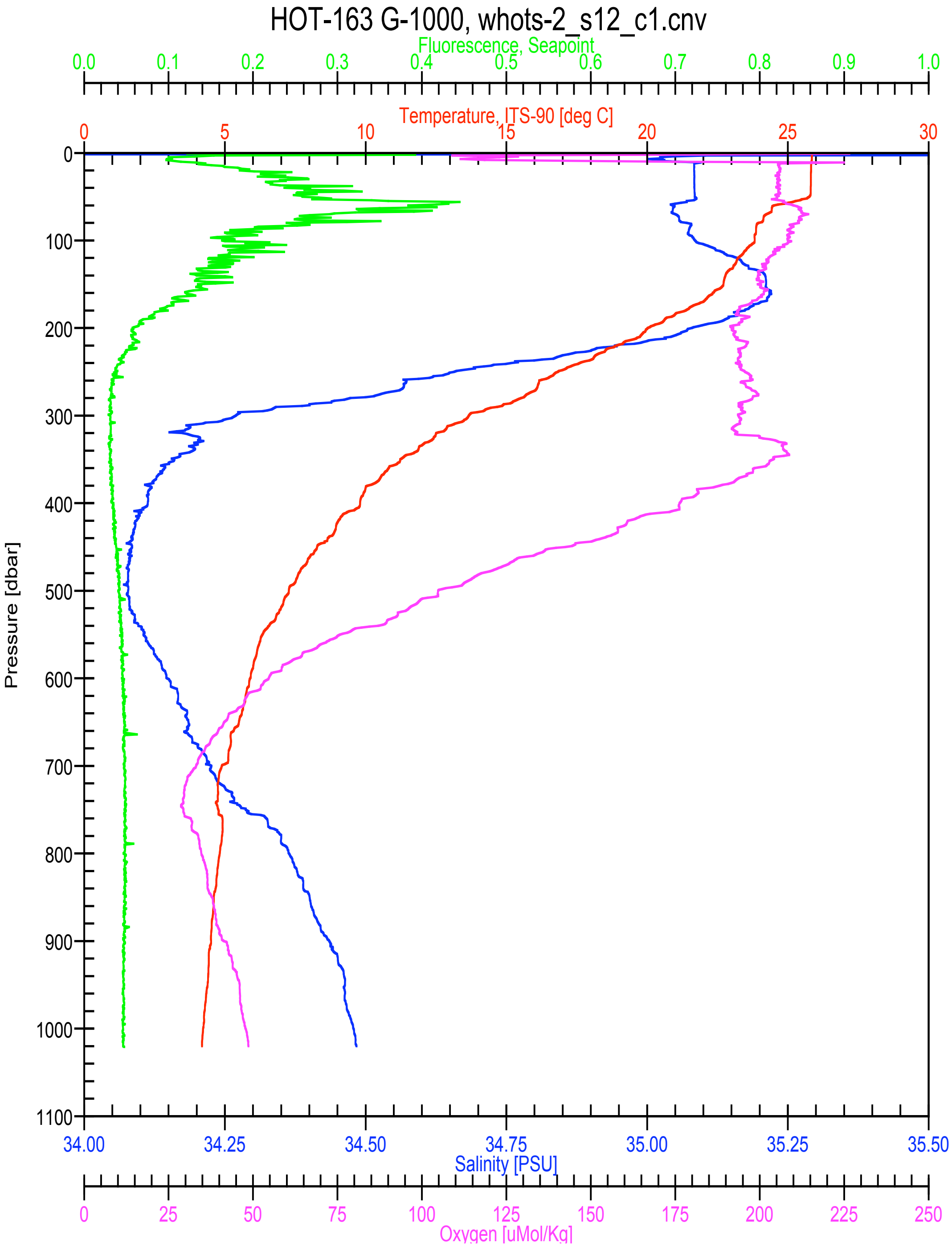

Figure 34. CTD Cast 12: Deep cast near the WHOTS-2 buoy.

Acknowledgments

The Captain and crew of the *Melville* were flexible in accommodating the science mission, and exhibited a high degree of professionalism throughout the cruise. The capabilities of the ship and crew were critical to the success of the mooring operations. Nan Galbriath provided shore support for monitoring Argos telemetry. This project was funded by the National Oceanic and Atmospheric Administration (NOAA) through the Cooperative Institute for Climate and Ocean Research (CICOR) under Grant No. NA17RJ1223 to the Woods Hole Oceanographic Institution.

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Appendix 1: WHOTS-1 Documentation

WHOTS-1 Mooring Deployment Notes
R. Weller, Aug. 31, 2004

On August 10-13, 2004 UOP and Roger Lukas joined with Tommy Dickey (UCSB) to use the RV *KOK* of the U. of Hawaii Undersea Research Laboratory (HURL) to deploy two surface moorings near the ALOHA site of the Hawaii Ocean Timeseries program. The Dickey mooring was an NSF-NOPP funded surface mooring also involving Dave Karl at U. Hawaii. This mooring is referred to a MOSEAN and carries a number of bio-optical and chemical sensors; it is planned to be serviced every 4 months. The WHOI UOP/Lukas mooring is referred to as WHOTS. UOP is funded by NOAA while Lukas is funded by NSF. UOP provides the surface mooring, two ASIMET systems, and instrumentation on the bridle. Lukas provides all subsurface instrumentation below the bridle including two UOP-prepared new generation VMCMs. The intent was to deploy the MOSEAN buoy to the west of the Aloha area and the WHOTS buoys to the east, with about 12 miles in between so that CTD work and deployment of drifting sediment traps could continue in between the two surface moorings.

MOSEAN was deployed 0236 UTC on August 12, 2004. WHOTS was deployed at 0240 UTC on August 13, 2004.

Anchor survey info for WHOTS, positions recovered from GPS position logged to Macintosh, giving position of start of ranging and position at end of ranging for each of three 'points' used to survey anchor. Anchor drop recovered from that logged file was 22.76610°N, 157.89285°W.

Position (initial/final)	Water depth	Horizontal Range
1. 22.73117°N, 157.86185°W 22.73432°N, 157.86607°W	4699 m	5027 m
2. 22.80285°N, 157.86217°W 22.80423°N, 157.86527°W	4656 m	5296 m
3. 22.76623°N, 157.95372°W 22.76328°N, 157.956°W	4698 m	5711 m

This ranging was done with transducer depth corrected but with an assumed 1490 m/s sound speed. Roger Lukas looked at sound speeds at the site and found the average sound speed between the surface and 4700 m from all deep CTD casts at ALOHA is 1503.3 m/s (Chen and Millero formulae). During the July cruise (HOT-161), the value was 1503.5. He recommended increasing the ranges above by 0.906%. The depths above were from the Seabeam system using 1500 m/s and need to be increased by 0.233%.

Factoring in these corrections, the table above becomes:

Position (initial/final)	Water depth	Horizontal Range
1. 22.73117°N, 157.86185°W 22.73432°N, 157.86607°W	4710 m	5073 m
2. 22.80285°N, 157.86217°W 22.80423°N, 157.86527°W	4667 m	5344 m
3. 22.76623°N, 157.95372°W 22.76328°N, 157.956°W	4709 m	5763 m

Using 'average' positions for the three points and running the CCOURS programs allows you to locate the anchor drop:

```
>> ccours
Input Latitude and Longitude in degrees
South and West locations are negative.
Input horizontal range in meters.
Latitude of Position 1 (deg): 22.733
Longitude of pos. 1 (deg): -157.864
Range of Position 1 (m):5073
Latitude of Position 2 (deg): 22.8032
Longitude of pos. 2 (deg): -157.8635
Range of Position 2 (m):5344
Latitude of Position 3 (deg): 22.764
Longitude of pos. 3 (deg): -157.955
Input range of Position 3 (m):5763
Latitude of Anchor drop (deg):  22.7661
Longitude of Anchor drop (deg):  -157.8929
Select the center of the region of interest.
Select the place to put the X.
Select the place where the anchor is.

xxloc = -157.8983
yyloc =    22.7667

fallback dist = 423.2096
```

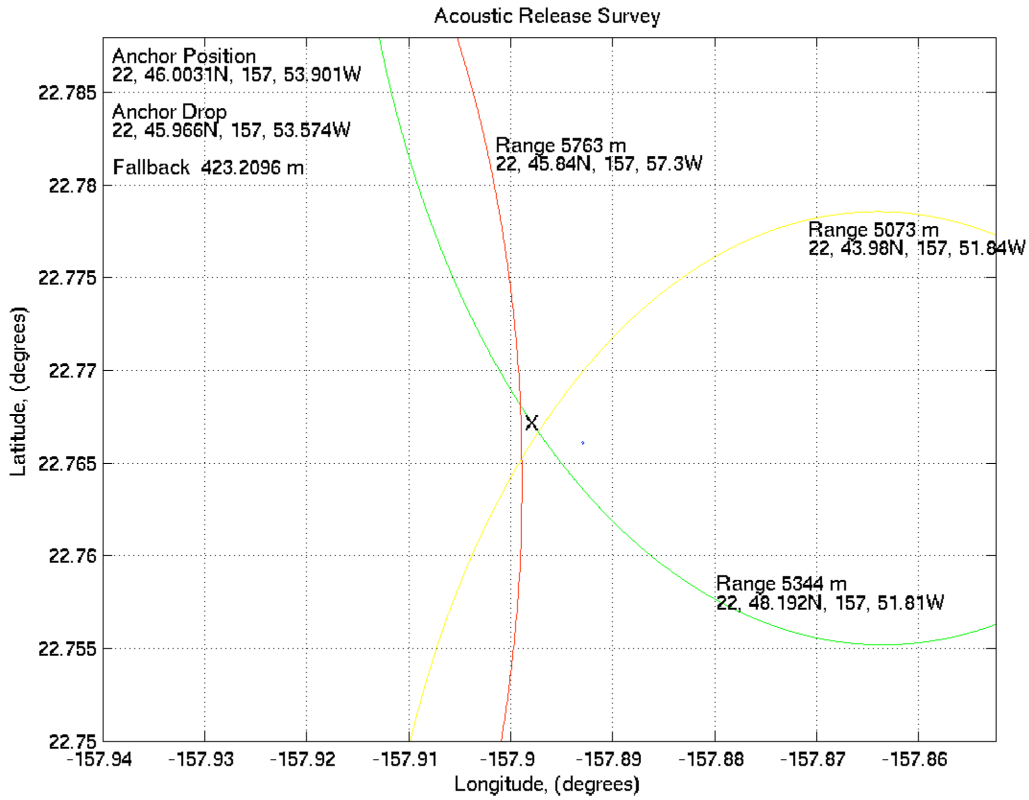

Figure 35. WHOTS-1 anchor survey.

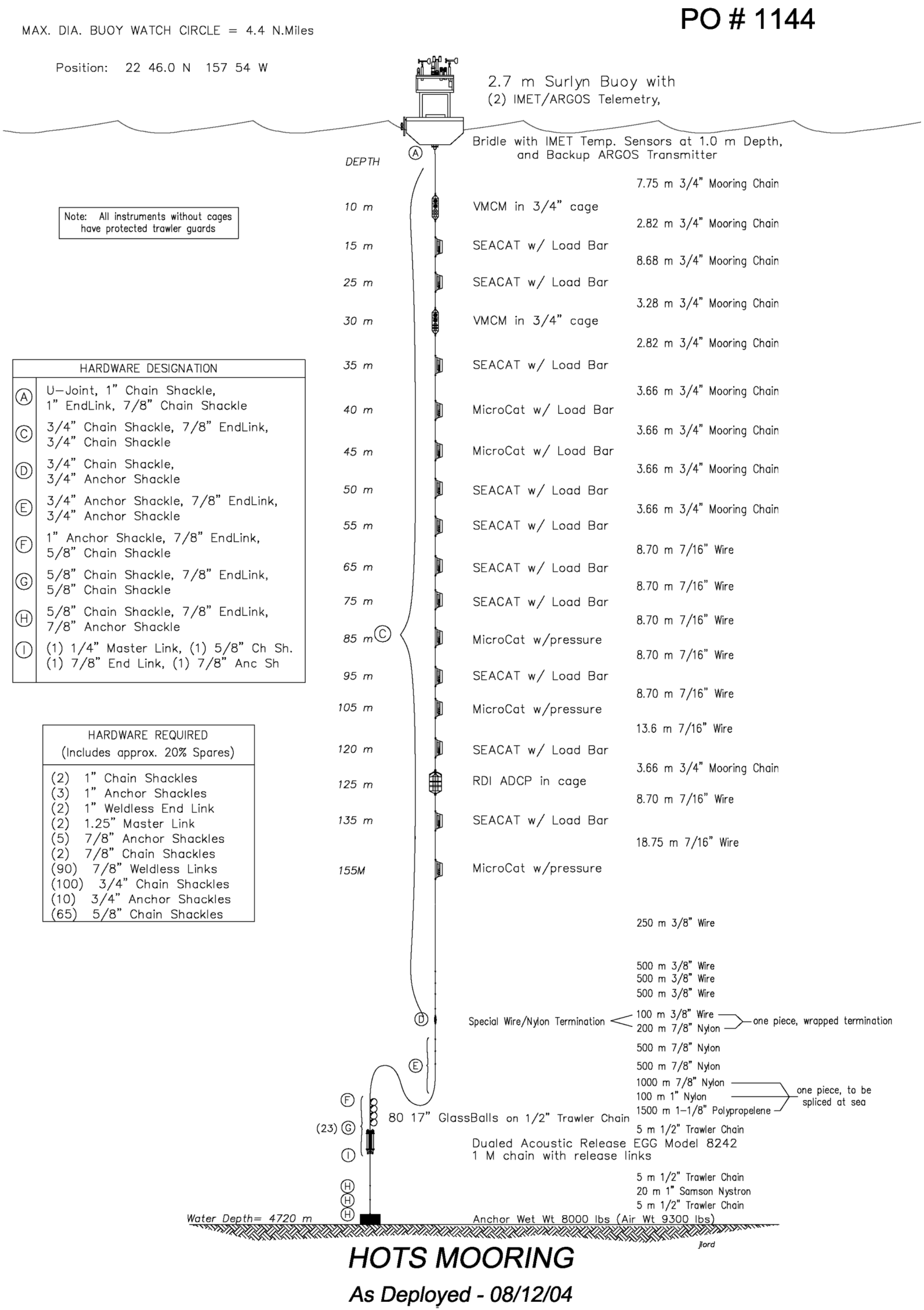

Figure 36: WHOTS-1 mooring diagram.

Appendix 2: WHOTS-1 Moored Station Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS 1 MOORED STATION NO. 1144

Launch (anchor over)

Date (day-mon-yr) ~~12~~ 13 Aug 2004 Time Ø24Ø UTC

Latitude (N/S, deg-min) 22° 45.966'N Longitude (E/W, deg-min) 157°53.571°W

Deployed by Lord/Dunn/Weller/Lukas Snyder Recorder/Observer Lukas

Ship and Cruise No. KOK Intended Duration 12 months

Sea Beam Depth Recorder Reading 4685 m Correction Source HOTS CTDS (Lukas)

Depth Correction .233% m

Corrected Water Depth 4693 m Magnetic Variation (E/W) 10.0667°

Argos Platform ID No. ______ Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 22°46.063'N Long. (E/W) 157° 53.901'W

Acoustic Release Model dual Edgetech 8242 on strongback

Release No. SN 905038 SN 016777 Tested to 500m, 1500m m

Receiver No. ______ Release Command 434071 542357

Enable 440437 561771 Disable ~~56~~ 440414 561752

Interrogate Freq. 11kHz (both) Reply Freq. 12 kHz (both)

Pulse Width 9.7Ø (both)

Recovery (release fired)

Date (day-mon-yr) 25 Jul 05 Time 1715 UTC

Latitude (N/S, deg-min) 22 45.443 Longitude (E/W, deg-min) 157 53.319

Recovered by Plued/Weller/Lukas Recorder/Observer Plueddemann

Ship and Cruise No. Melville TUIM1ØMV Actual duration ______ days

Distance from actual waterline to buoy deck ______ m

1

Surface Components

Buoy Type Gilman foam   Color(s) Hull yellow / white no foul   Tower white

Buoy Markings "B" on top; If found adrift contact Univ. of Hawaii, 808 956 7896

Surface Instrumentation

Item	ID #	Height*	Comments
DATA Logger	L-12	NA	
HRH	229	232 cm	Above Foam Deck
BPR	503	247.5 cm	
WND	222	271 cm	
PRC	216	246 cm	
LWR	219	283 cm	
SWR	216	283 cm	
PTT	63878	NA	ID's 06930, 07387, 07388
DATA logger	L-16	NA	
HRH	230	233 cm	
BPR	502	247.5 cm	
WND	218	272 cm	
PRC	215	246 cm	
LWR	215	282.5 cm	
SWR	215	283 cm	
PTT	63879	NA	ID's 07455, 07456, 07561
GPS	69024	238 cm	
Subsurface argos xmitter	102		ID 24337
light			installed 8/12/04 ~0600 local

Note: upon recovery, all bird wires are gone from PRCs except 1, which is bent horizontal.

*Height above buoy deck in centimeters

2

Subsurface Instrumentation on Buoy and Bridle			
Item	ID #	Depth†	Comments
1	1447	NEAR-SURFACE	FLOATING SST SBE-39
2	3601	1 M 150 cm	SBE-37 from Foam Deck
3	3602	1 M 150 cm	SBE-37 "
4	NGVM 012	10 M	VMCM
5	801	15 M	SBE-16
6	1085	25 M	SBE-16
7	NGVM 19	30 M	VMCM
8	1087	35 M	SBE-16
9	3381	40 M	SBE-37
10	3382	45 M	SBE-37
11	1088	50	SBE-16
12	1090	55	SBE-16
13	1092	65	SBE-16
14	1095	75	SBE-16
15	2451	85	SBE-37P
16	1097	95	SBE-16
17	2769	105	SBE-37P
18	1099	120	SBE-16
19	4891	125	RDI ADCP 300 KHz
20	1100	135	SBE-16
21	2965	155	SBE-37P
†Depth below buoy deck in centimeters			

3

Moored Station Number ________________

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		HULL		1956	1926 wind vanes back on			0015	(fight against hull, out of the water) on deck 0027
2		7.75M 3/4" Chain						0038	
3		VMCM	NGVM012	1956	rotor spin 1827:43			0038	bands on 0048
4		2.82m 3/4" Chain							
5		SBE-16	801	1832	15m			0044	✓0801
6		8.68M 3/4" Chain							
7		SBE-16	1085	1825	25M			0050	✓1085
8		3.28M 3/4" Chain							
9		VMCM	NGVM19	1823	rotor spin 1817:54			0053	bands on 0058
10		2.82m 3/4" chain							
11		SBE-16	1087	1819	35M			0058	✓1087
12		3.66m 3/4" Chain							
13		SBE-37	3381	1814	40M			0100	✓3381
14		3.66m 3/4" Chain							
15		SBE-37	3382	1813	45M			0105	✓3382
16		3.66m 3/4" Chain							
17		SBE-16	1088	1809	50M			0109	✓1088 instrument hit side of ship on
18		3.66m 3/4" chain							slipped off + set buoy recovery adrift at bottom of chain
19		SBE-16	1090	1809	55M			2328	✓1090
20		8.70m 7/16" wire						2327	
21		SBE-16	1092	2014	65M			2324	✓1092
22		8.70m 7/16" wire						2323	

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		SBE-16	1095	2019	75m			2321	√1095 (1st gooseneck)
24		8.70 7/16" wire						2320	
25		SBE-37P	2451	2022	85M			2317	√ 2451
26		8.70m 7/16 wire						2316	
27		SBE-16	1097	2027	95M			2311	√1097
28		8.70 7/16" wire						2310	
29		SBE-37P	2769	2032	105M			2308	√ 2769
30		13.6m 7/16" wire						2307	
31		SBE-16	1099	2036	120M			2259	√ 1099
32		3.66 3/4" chain						2259	
33		RDI ADCP	4891	2041	xducer cover off			2259	√ 4891
34		8.70m 7/16 wire						2258	
35		SBE-16	1100	2046	135M			2255	√1100
36		18.75 7/16" wire						2254	
37		SBE-37P	2965	2051	155M			2247	SN√2965
38		250m 3/8" wire						2246	
39		500M 3/8" wire		2057	started shot			2239	" "
40		500m 3/8" wire		2112	started shot			2226	" "
41		500m 3/8" wire		2127	started shot			2214	end of 500m shot
42	300	wire/nylon termination		2158	100m 3/8" wire + 200 M 7/8" nylon			2140	at splice, 2159 at end of wire
43		500m 7/8" nylon		2210	started shot		all one piece (spliced)		
44		500m 7/8" nylon						~~2052~~	
45		1000m 7/8" nylon				8		~~2040~~	2121 (upper end onboard)

Moored Station Number ____________

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46		100M 1" nylon						2030	
47		1500M 1-1/8" poly		2246	start shot			2010	
48		80 glass balls		2327 start	Note 5M trawl chain shot above balls per JL	2335 1st GB in water		1855	~~|||| |||| |||| ||||~~
49		5M 1/2" trawl chain		0031				1900	
50		dual release		0222				1900	
51		1M chain			acoustic release chain				
52		5M 1/2" trawl chain		0222					
53		20M 1" nystron		0223	started shot				working line spun free on winch drum
54		5m 1/2" trawl chain							
55		9300 16 anchor		0240 ~~0230~~	release stuck				nominal depth 4685
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

Appendix 3: WHOTS-2 Moored Station Log

Moored Station Log

PAGE 1

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-2 MOORED STATION NO. 1160

Launch (anchor over)

Date 28-07-2005 (day-mon-year) Time 01:43 UTC

Latitude 22° 46.03 (deg-min) (N) or S Longitude 157° 53.766 (deg-min) E or (W)

Position Source: (GPS), LORAN, SAT. NAV., OTHER ________

Deployed by: J. Lord Recorder/Observer: Plueddemann

Ship and Cruise No TUIM10MV Melville Intended duration: 365 days

Depth Recorder Reading 4695 m Correction Source: XBT

Depth Correction already corrected m

Corrected Water Depth 4695 m Magnetic Variation: ________ E or W

Anchor Position: Lat. 22° 45.9997 N or S Long. 157° 53.9054 E or W

Argos Platform ID No. see pg. 2 Additional Argos Info may be found on pages 2 and 3.

Acoustic Release Information

Release No. #1 32480 #2 30555 Tested to 1500 meters

~~Receiver No.~~ Enable Comm. #1 114556 #2 121062 Release Command #1 132111 #2 134224

Interrogate Freq. 11 kHz Reply Freq. 12 kHz

Recovery (release fired)

Date ________ (day-mon-year) Time ________ UTC

Latitude ________ (deg-min) N or S Longitude ________ (deg-min) E or W

Postion Source: GPS, LORAN, SAT. NAV., OTHER ________

Recovered by: ________ Recorder/Observer: ________

Ship and Cruise No. ________ Actual duration: ________ days

Distance from actual waterline to buoy deck 75 cm ~~meters~~

Surface Components

Buoy Type Gilman Foam Color(s) Hull yellow/white Tower white

Buoy Markings "B" Contact info: U. Hawaii 808 956-7896

Surface Instrumentation

Item	ID	Height *	Comments
ASIMET Lgr	L-21	—	
HRH	220	248 cm	above deck
BPR	219	246.5	"
WND	205	268.5	"
PRC	503	234.0	"
LWR	212	280.5	"
SWR	221	282.0	"
SST	1836	-151.5	(below deck)
PTT	18231	—	IDs: 14663, 14677, 14697
ASIMET Lgr	L-19	—	
HRH	219	248.0 cm	above deck
BPR	212	244.0	"
WND	207	267.5	"
PRC	212	234.0	"
LWR	505	280.0	"
SWR	503	281.0	"
SST	3604	-151.5	below deck
PTT	14637	—	IDs: ~~076~~ 07563, 07581 07582
GPS	73930	219.7	stand-alone
SS-Argos	3	—	ID = 9209
Floating SST	1446	—	SBE-39, on float attached to side of hull.
Light.			

* Height above buoy deck — visual inspec. indicates WL at 75 cm below deck

Sub-Surface Instrumentation on Buoy and Bridle

Item	ID	Depth†	Comments
SST	1836	151.5 cm	see logger L21, opposite
SST	3604	151.5	see logger L19, opposite
~~Floating~~ SST	1446		see opposite pg

† Depth below buoy deck

Sub-Surface Components

	Type	Size(s)	Manufacturer
Chain	3/4" mooring chain, 1/2" trawler chain		
Wire Rope	7/16" jacketed, to 155m		
	3/8" jacketed, below 155m		
Synthetics	7/8" nylon, 1" nylon, 1 1/8" poly		
Hardware	3/4 shackle, 7/8 end link, 3/4 shackle		
	5/8 shackle, 7/8 end link, 5/8 shackle		
	(other misc, see mooring drawing)		

Flotation	Type (G.B.s, Spheres, etc)	Size	Quantity	Color
above release	glass balls	17"	80	yellow

No. of Flotation Clusters ________

Anchor Dry Weight 9300 lbs

MOORED STATION NUMBER 1160

Item No.	Lgth [m]	Item	Inst No.	Time Over	Notes	Data No.	Calc Dpth	Time Back	Notes
1		Buoy Hull		1850					
2	7.75	3/4 chain					~~10m~~		
3		NGVM	066	1834	bands off 1832		10m		
4	2.82	3/4 chain					~~15m~~		
5		SBE-37	3382	1831			15m		
6	8.68	3/4 chain							
7		SBE-37	3621	1827			25m		
8	3.28	3/4 chain							
9		NGVM	068	1823 ~~068~~	bands off 1822		30m		
10	2.82	3/4 chain							
11		SBE-37	3620	1820			35m		
12	3.66	3/4 chain							
13		SBE-37	3632	1818			40m		
14	3.66	3/4 chain							
15		SBE-37	2965	1816			45m		
16	3.66	3/4 chain							
17		SBE-37	3633	1813			50m		
18	3.66	3/4 chain							
19		SBE-37	3619	1913			55m		
20	8.70	7/16 wire 5030-4							

Date/Time	Comments
1838 7/27	bird wires on both PRC's, domes cleaned,
	wmd "collars" on
1850	floating SST appears stuck in its lower pos'n
	at launch

MOORED STATION NUMBER 1160

Item No.	Lgth [m]	Item	Inst No.	Time Over	Notes	Data No.	Calc Dpth	Time Back	Notes
21		SBE-37	3791	1917			65m		
22	8.70m	7/16 wire	5030-2						
23		SBE-37	3618	1921			75 m		
24	8.70	7/16 wire	4014-21						
25		SBE-37P	3670	1924			85m		
26	8.70	7/16 wire	5030-6						
27		SBE-37	3617	1926			95 m		
28	8.70	7/16 wire	5030-5						
29		SBE-37P	3669	1929			105m		
30	13.6	7/16 wire	5030-8						
31		SBE-37	2451	1934			120m		
32	3.66	3/4 chain ~~wire~~							
33		ADCP	4891	1937			125m		
34	8.70	7/16 wire	5030-1						
35		SBE-37	3634	1942			135m		
36	18.75	7/16 wire	4041-29						
37		SBE-37P	3668	1946			155m		
38	250	3/8 wire*		1946					
39	500	3/8 wire		1953	5030-12				
40	500	3/8 wire		2007	4042-5				

Date/Time	Comments
1946 27 Jul	* 50m (4041-14) + 200m (4042-4)

MOORED STATION NUMBER 1160

Item No.	Lgth [m]	Item	Inst No.	Time Over	Notes	Data No.	Calc Dpth	Time Back	Notes
41	500	3/8 wire		2021	5030-11 ? 5002-11 ?				
42	100	3/8 wire	one	2040	4042-6				
43	200	7/8 nylon	piece, spliced	2045					
44	500	7/8 nylon	*						
45	1500	7/8 nylon							
46	100	1" nylon	one piece,	2059					
47	1500	1 1/8 poly	spliced	end 2300					
48	5	1/2" chain		start					
49		80 glass		2312					
50		balls on 1/2 chain		end 2349					
51	5	1/2" chain		‡					
52		release	32480	0124					
53		release	30555						
54	5	1/2 chain							
55	20	1" Samson							
56	5	1/2 chain							
57		anchor		0143					
58									
59									
60									

Date/Time	Comments
* 7/27 2053	transferring from winch to H-Bit to pay out nylon
‡ 7/27 0015	under tow on 5 m chain above release

Appendix 4: Biofouling assessment and treatment

M. Alex Walsh
E Paint Company/Cape Cod Research

1. Biofouling Assessment after the WHOTS-1 Recovery

a. Surface Buoy

The Suryln foam buoy was treated in 2004 with two coats of SUNWAVE+ (2.5% Zinc Omadine®), a total of two gallons. The buoy base was painted in Hawaii with E Paint ZO (white). At least two coats were applied.

Most of the antifouling paint applied to the buoy hull and base had eroded after 12 months exposure. Very little SUNWAVE+ was visible on the buoy hull when recovered. Only a narrow strip of paint was visible behind the SST bracket. This is a shaded area protected from full sun exposure. Given the photoactive nature of SUNWAVE+, photochemical degradation of the paint is assumed to be the primary mode of failure that resulted in complete erosion of the product on the majority of the buoy hull. Additional coats of SUNWAVE+ should extend the service life of this product at WHOTS. Like the SUNWAVE+, much of the E Paint ZO had eroded from the buoy base.

Very little biofouling was observed on the Surlyn buoy hull. Low densities of juvenile gooseneck barnacles (10 /m_2) were reported on the side of the buoy. Filimentous bryozoa was also observed forming a brown fuzzy film on the sides of the buoy. Adult goose-neck barnacles were localized in regions that were not coated with antifouling, such as on through hull bolts and plugs. This observation suggests that the antifouling paint, even if eroded, effectively controlled biofouling for most of the exposure period. The buoy hull and base are shown in Figure 37.

Figure 37. WHOTS-1 buoy hull after recovery.

b. Surface Buoy Instrumentation

Two antifouling coatings were applied to instrumentation mounted to the Surlyn buoy, Interlux Trilux 33 (Red) and E Paint ZO (White). The SST sensor and bracket and two MicroCATs were coated with Trilux 33. The backup ARGOS transmitter was coated with E Paint ZO.

Coating erosion was the primary mode of failure. Much of the Trilux 33 eroded from the SST and bracket as seen in the image below. Heavy gooseneck barnacle settlement was observed in and around these areas. The backup ARGOS transmitter was clean though no E Paint ZO was visible. Little Trilux 33 was visible on the two MicroCATs, which were each fouled with roughly 50-60 adult gooseneck barnacles as visible in the images of Figure 38.

Figure 38. WHOTS-1 buoy instrumentation: MicroCATs (left) and surface-following temperature sensor (right).

c. Subsurface Instrumentation

Biofouling was most prolific near the surface down to 30 meters. Gooseneck barnacles, organisms that can affect the proper operation of instrumentation, accounted for most of the biomass observed. Filimentous bryozoans and algae were also observed but their growth was easily removed and poses little threat to the proper operation of instrumentation.

The SBE-37P positioned at 155m came up virtually clean. Biofouling increased with closer proximity to the surface. A brown fibrous film was observed only on the SBE-16 positioned at 135m. This organism was thought to be a bryozoan. Organisms that look like gooseneck barnacles, but do not have hard calcareous shells, were observed from 125m to 75m.

The VMCMs and frames were heavily fouled with gooseneck barnacles. Fouling on the device positioned at 10m was more severe that on the device positioned at 30m. No antifouling coating was observed on the propellers of the VMCM, which were heavily fouled with gooseneck barnacles, filamentous bryozoans and algae. The Trilux 33 on the VMCM frame was eroded and bioactivity appeared to have decayed. Adult gooseneck barnacles were observed on surfaces painted with Trilux 33. Results are presented in the following Section.

2. Antifouling Treatment prior to WHOTS-2 deployment

Waters at the WHOTS site are not high fouling as compared to an estuarine environment, but there is enough activity to warrant use of antifouling measures. Gooseneck barnacles, the primary concern for increasing weight, drag and likelihood of instrument failures, are prolific down to 30 meters. For this reason it is critical to protect instrumentation, especially devices with moving parts (VMCM). Determining the proper antifouling treatment is the purpose of WHOTS-2 deployment. Because organotin-based antifouling coatings are no longer available and their use in the United States banned, viable alternatives are needed. This research effort evaluates four different E Paint coatings for use on oceanographic surface buoys, sensors and the like.

Antifouling coatings applied to the WHOTS-2 Buoy and instrumentation are detailed below:

a. SUNWAVE+ Bottom System Applied to the Buoy Hull

Maintaining adhesion of the antifouling coating to the Surlyn buoy hull is a technical challenge. The Surlyn foam is flexible, expands with temperature and compresses when impacted. Any antifouling coating used on this surface must chemically bond to the Surlyn and flex with the foam. Because of the nature of deployments of buoys and instrumentation, antifouling coatings for oceanographic use must be mar-resistant and offer excellent adhesion. Buoy hulls are often dragged across the decks of ships over non-skid. E Paint Company's answer to these demanding requirements is SUNWAVE+. SUNWAVE+ is an experimental 2-part, water-borne, epoxy-based antifouling paint. SUNWAVE+ adheres to all buoy hull materials including Surlyn. SUNWAVE+ is flexible and mar-resistant, fortified with Teflon® to impart a slippery foul-release surface. SUNWAVE+ contains Zinc Omadine®, an exceptional algaecide. SUNWAVE+ offers effective antifouling protection without harming the environment.

Coat	Product Description
1.	2 US Quarts Haze Gray - EP-PRIME 1000 / High Build Epoxy Primer
2.	2 US Quarts Gray – SUNWAVE+ (2.5% Zinc Omadine®)
3.	2 US Quarts White – SUNWAVE+ (2.5% Zinc Omadine®)
4.	2 US Quarts White – SUNWAVE+ (2.5% Zinc Omadine®)
5.	4 US Quarts White – SUNWAVE+ (4.7% Zinc Omadine®)

Table 10. Summary of WHOTS-1 biofouling observations

#	INSTRUMENT	MODEL	DEPTH	S/N	ANTIFOULING	Observations	BIOFOULING								
			(m)				GNB	#	Shell Length	Slime	ALGAE		SPONGE	BRYOZOANS	
2.7 m Suryln Surface Buoy with:									cm		Brown	Green		Encrusting	Filimentous
	Floating SST in Bracket	SBE-36	0		Tri-Lux 33/ Red	Much GN Barnacle fouling	Y	50-60	40-60	Y	Y				Y
	(2) IMET ARGOS Telemetry														
	IMET Temp. Sensors														
	MicroCat	SBE-37	1	3601	Tri-Lux 33/ Red	Much GN Barnacle fouling	Y	20-30		Y	Y	Y		Y	Y
	MicroCat	SBE-37	1	3602	Tri-Lux 33/ Red	Much GN Barnacle fouling	Y	20-30		Y	Y	Y		Y	Y
	Backup Argos Transmitter		1		Not Known		Y	n/d	n/d	Y	Y	Y			Y
1	VMCM in 3/4" Cage		10	O12	Tri-Lux 33 Cage/ Prop Unknown	Much GN Barnacle fouling	Y	100+	40-60	Y	Y	Y			Y
2	SEACAT w/ Load Bar	SBE-16	15	801			Y	46	40-60	Y	Y	Y			Y
3	SEACAT w/ Load Bar	SBE-16	25	1085			Y	18	30-50	Y	Y	Y			Y
4	VMCM in 3/4" Cage		30	O19	Tri-Lux 33 Cage/ Prop Unknown		Y	30-40	10-50	Y	Y	Y			Y
5	SEACAT w/ Load Bar	SBE-16	35	1087			Y	11	30-50	Y	Y	Y			Y
6	MicroCat w/ Load Bar	SBE-37	40	3381			Y	9	15-45	Y	Y	Y			Y
7	MicroCat w/ Load Bar	SBE-37	45	3382			Y	7	20-45	Y	Y	Y			Y
8	SEACAT w/ Load Bar	SBE-16	50	1088			Y	5	20-45	Y	Y	Y			Y
9	SEACAT w/ Load Bar	SBE-16	55	1090			Y	6	15-20	Y	Y	Y			Y
10	SEACAT w/ Load Bar	SBE-16	65	1092			Y	4	10-20	Y	Y	Y			Y
11	SEACAT w/ Load Bar	SBE-16	75	1095		2 GN Barnacle Species Observed	Y	7	n/d	Y	Y	Y			Y
12	MicroCat w/ Pressure	SBE-37P	85	2451		Barnacles are Deep Water Variety	Y	4	10-15	Y	Y	Y			
13	SEACAT w/ Load Bar	SBE-16	95	1097		Barnacles are Deep Water Variety	Y	3	n/d	Y	Y	Y			
14	MicroCat w/ Pressure	SBE-37P	105	2769		Barnacles are Deep Water Variety	Y	1	n/d	Y	Y	Y			
15	SEACAT w/ Load Bar	SBE-16	120	1099						Y					
16	RDI ADCP in Cage		125	4891		Barnacles are Deep Water Variety	Y	6	n/d	Y					
17	SEACAT w/ Load Bar	SBE-16	135	1100		Fiberous brown growths				Y				?	
18	MicroCat w/ Pressure	SBE-37P	155	2965		Clean									

A total of 2.5 US Gallons of SUNWAVE+ were applied to the hull of the WHOTS-2 2.7m Surlyn Buoy. This is 1 US gallon more product than was applied to the WHOTS-1 buoy. All coats were applied using a roller.

c. EP 2000 Bottom System Applied to the Buoy Base

EP 2000 is a hard, mar-resistant, urethane-based antifouling coating. The product is water-based and contains the algaecide biocide Zinc Omadine®, 4.7% by weight. EP 2000 was chosen for this application for its exceptional antifouling properties and mar-resistance.

EP 2000 was applied to the buoy base (powder coated aluminum) at E Paint Company's Falmouth facility. The base was bead blasted to abrade the powder-coated surface, degreased with acetone and primed with two coats of EP-Prime 2000. EP Prime contains ceramic particles for exceptional abrasion resistance and water barrier properties. All coats of the EP 2000 bottom system were applied using a HVLP spray gun.

Coat	Product Description
1.	1 US Quart Gray - EP-PRIME 2000 / Epoxy Barrier
2.	1 US Quart White - EP 2000
3.	1 US Quart White- EP 2000
4.	1 US Quart White- EP 2000

c. Antifouling Coatings Used on Instrumentation

E Paint coatings used to protect WHOTS-2 instrumentation are detailed in Table 11.

Table 11. Antifouling coatings on WHOTS-2 instrumentation

Instrument	Location	Coating	# Coats	Application Method
Universal Joint	Buoy Base/ 1m	SUNWAVE+/ White	3	Brush
Buoy Hardware	Buoy Base/ 1m	E Paint ZO/ White	1	Brush
SBE-37	Buoy Base/ 1m	E Paint ZO/ White	2	Brush
SBE-37	Buoy Base/ 1m	E Paint ZO/ White	2	Brush
Argos	Buoy Base/ 1m	E Paint ZO/ White	1	Brush
Floating SST and Bracket	Side of Buoy/ 0m	E Paint ZO/ White	3	Brush
VMCM Propellers	10 & 30m	E Paint ZO w/ 10% CuSCN	2	Spray
VMCM Stings and Hubs	10 & 30m	E Paint ZO/ White	1	Spray

d. Technical Questions to be Answered After One Year Exposure

- Did the additional two coats of SUNWAVE+ extend service life > 10 months? How much paint is left?
- What is the primary mode of failure with the SUNWAVE+ bottom system?
- What is the primary mode of failure with the EP 2000 bottom system?
- Is ZO still visible on the SST and bracket and are these surfaces free of biofouling?
- Is ZO with CuSCN still visible on the VMCM propellers and are these surfaces free of biofouling?
- How much erosion of ZO is observed on IMET temperature sensors (SBE-37) and backup ARGOS transmitter mounted to the buoy base (1m)? Are these surfaces free of biofouling?
- Is there variability of biofouling at the WHOTS site?

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-2006-08	2.	3. Recipient's Accession No.

4. Title and Subtitle WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-2 Mooring Turnaround Cruise Report	5. Report Date March 2006 6.
7. Author(s) Albert J. Plueddemann, Robert A. Weller, Roger Lukas, Jeffrey Lord, Paul R. Bouchard, M. Alexander Walsh	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) NA17RJ1223 (G)
12. Sponsoring Organization Name and Address National Oceanic and Atmospheric Administration and the Cooperative Institute for Climate and Ocean Research (CICOR)	13. Type of Report & Period Covered Technical Report 14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-2006-08.

16. Abstract (Limit: 200 words)

The Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Timeseries (HOT) Site (WHOTS), 100 km north of Oahu, Hawaii, is intended to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. This report documents recovery of the WHOTS-1 mooring, deployed in August 2004 near 22.75°N, 158°W, and deployment of the WHOTS-2 mooring at the same site. Both moorings were outfitted with Air-Sea Interaction Meteorology (ASIMET) systems to measure, record, and transmit the surface meteorological variables necessary to compute air-sea fluxes of heat, moisture and momentum. In cooperation with R. Lukas of the University of Hawaii, the upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity. The WHOTS mooring turnaround was done on the Scripps Institution of Oceanography Ship *Melville*, Cruise TUIM-10MV. The cruise took place between 23 and 30 July 2005.

17. Document Analysis a. Descriptors

air-sea interaction
tropical Atlantic
moored instrumentation

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for public release; distribution unlimited.	UNCLASSIFIED	76
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce