WHOI-2012-04

Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-8 2011 Mooring Turnaround Cruise Report

by

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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

April 2012

Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration under Grant No. NA09OAR4320129 and the Cooperative Institute for the North Atlantic Region (CINAR).

Upper Ocean Processes Group
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UOP Technical Report 2012-02

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Approved for Distribution:

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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 part of the NOAA Climate Observation Program. The WHOTS mooring also serves as a coordinated part of the HOT program, contributing 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.

This report documents recovery of the seventh WHOTS mooring (WHOTS-7) and deployment of the eighth mooring (WHOTS-8). Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity in a cooperative effort with R. Lukas of the University of Hawaii. A pCO_2 system was installed on the WHOTS-8 buoy in a cooperative effort with Chris Sabine at the Pacific Marine Environmental Laboratory. A set of radiometers were installed in cooperation with Sam Laney at WHOI.

The WHOTS mooring turnaround was done on the NOAA ship *Hi'ialakai* by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 5 July and 13 July 2011. Operations began with deployment of the WHOTS-8 mooring on 6 July. This was followed by meteorological intercomparisons and CTDs. Recovery of WHOTS-7 took place on 11 July 2011. This report describes these cruise operations, as well as some of the in-port operations and pre-cruise buoy preparations.

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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). The present HOT program includes comprehensive, interdisciplinary upper ocean observations, but does not include continuous surface forcing measurements. Thus, a primary driver for the WHOTS mooring is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and to contribute to the program goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The WHOTS mooring also serves as an Ocean Reference Station – a part of NOAA's Ocean Observing System for Climate – providing time-series of accurate surface meteorology, air-sea fluxes, and upper ocean variability to quantify air-sea exchanges of heat, freshwater, and momentum, to describe the local oceanic response to atmospheric forcing, to motivate and guide improvement to atmospheric, oceanic, and coupled models, to calibrate and guide improvement to remote sensing products, and to provide anchor point for the development of new, basin scale air-sea flux fields.

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°45′N, 158°00′W by means of annual "turnarounds" (recovery of one mooring and deployment of a new mooring near 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.

Subsurface observations have been made on all WHOTS deployments in cooperation with Roger Lukas at the University of Hawaii (UH). The upper 155 m of the mooring line is outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity. For WHOTS-8, a pCO_2 system for investigation of the air-sea exchange of CO2 at the ocean surface was mounted in the buoy well in cooperation with Chris Sabine at the Pacific Marine Environmental Laboratory (PMEL). The pCO_2 system was augmented with conductivity, temperature, dissolved oxygen and pH measurements utilizing instruments mounted on the buoy base. In addition, 5 radiometers were deployed on the surface buoy tower as part of a cooperative effort with Sam Laney of the Woods Hole Oceanographic Institution.

The mooring turnaround was done on the NOAA Ship *Hi'ialakai* by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI) with assistance from the UH personnel. The cruise originated from, and returned to, Honolulu, HI (Fig. 1-1). The facilities of the NOAA operations center at Ford Island were used for pre-cruise staging.

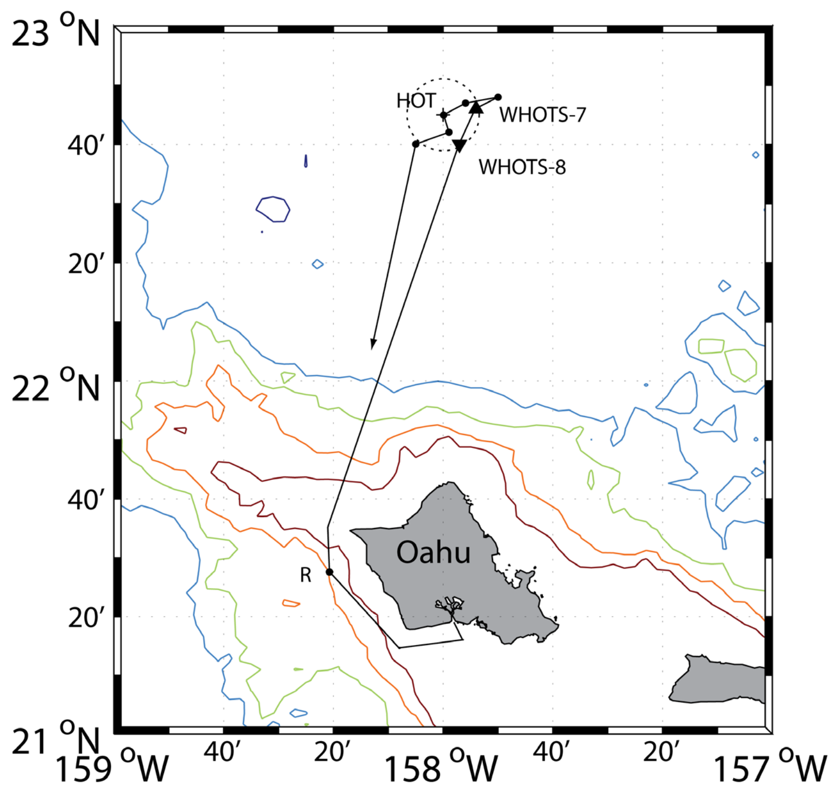


Figure 1-1: WHOTS-8 cruise track showing location of release and CTD tests (R), WHOTS-7 and WHOTS-8 mooring locations (triangles), the center (+) and radius (dashed line) of the HOT site, and the location of 5 CTD stations (dots) occupied prior to the transit back to Honolulu.

2. Pre-Cruise and Post-Cruise Operations

a. Staging and Loading

The pre-cruise workload for the WHOTS 8 project was anything but typical. We worked on an unfamiliar vessel out of an unknown facility; all heavy equipment had to be welded to the ship's deck; the buoy hull, glass balls, and other support equipment had to be transported from the UH facility at Sand Island to the NOAA facility; the buoy hull needed many modifications and assembly. Added to the standard ORS buoy were the following: PMEL pCO_2 system, PMEL SAMI (pH), PMEL SBE 16, WHOI (Sam Laney) radiometer array and a remote line deployment system developed by UOP. Only the pCO_2 system had been mounted on the buoy before. All modifications were made during the preparation period in Honolulu.

On June 21, a team from UH gave the project a head start by moving all the essential gear from Sand Island to Ford Island. Island Movers provided a 40-foot box truck and driver to make two trips between the facilities. Two 40-foot containers arrived from WHOI the next day, containing mooring components, deck gear, buoy well and tower, and instrumentation, arrived at Ford Island. Pre-cruise preparation for the WHOI group began on June 26 when an advance party arrived in Honolulu buoy assembly and modifications, and ship preparations. A group from ESRL had arrived a day earlier to begin preparing their shipboard atmospheric sampling systems.

WHOI rented a 5,000 pound capacity forklift to use for the week (Servco Forklift &Industrial Equipment, 94-729 Farrington Highway, Waipahu, HI 96797, (808)564-1603 Direct, (808)564-2219 Fax). The Navy (Fleet Industrial Supply Center) heavy lift forklift was hired on 27 June to remove the mooring winch from a container and drop it near the ship. The Navy (FISC) crane was hired on June 28 to load the winch and anchor aboard the ship.

Shaka Engineering (Shaka1@hawaii.rr.com, Cell. 808-228-8614, Ph: 808 735-9323) was hired to weld the deck gear and ESRL tower base on the ship, and to restore the deck to original condition after the cruise. This work was performed on 28-29 June.

Final buoy assembly and ship loading was finished on July 5, just prior to departure.

b. Buoy Spins

The buoy spin begins by selecting an area with favorable conditions and then orienting the buoy tower's forward face to true north determined by a GPS azimuth pointing system. The lubber lines on individual wind modules are oriented forward. The mechanical wind vane on the RM Young is also locked with tail pointing towards true north; this involves the encoder in the test. The modules and buoy remain static for 15 minutes to present a clear record in the logger. A laptop is plugged into each respective wind module and it is queried for a compass measurement, allowing the primary loggers to continue to sample without interruption. Furthermore, the encoder value is also recorded for the mechanical wind modules. The module compass value is magnetic and the measurement is converted to a true wind direction with the local variation provided at: http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination. The buoy is then rotated, 45 degrees using a pallet jack, verified by the azimuth pointing system and the procedure is repeated at all 8 stations.

The first buoy spin was conducted on the outside of the Clark South Laboratory high bay in Woods Hole. Both the primary WND modules on the buoy (SN 210 and 219) and the spare system (SN 344) were spun. The deviation of wind direction (compass+vane) from the expected direction is reported in Fig. 2-1.

The second buoy spin was conducted at the Ford Island NOAA facility in Hawaii on an area of parking lot near water. A surveyor's compass and a GPS azimuth pointing system were used to determine that the magnetic field in the area was constant within a few degrees. Clean locations were limited and the selected location at the NOAA facility may have had some magnetic anomalies from possible piping under the nearby street. A point across the harbor was sighted approximately 2 miles away at a bearing of true north. The two primary WND modules, as well as the Vaisala WXT, were included in the test. Reporting the compass readings allowed the WXT results to be compared to the WND modules prior to computing wind direction. The results are plotted in Fig 2-2.

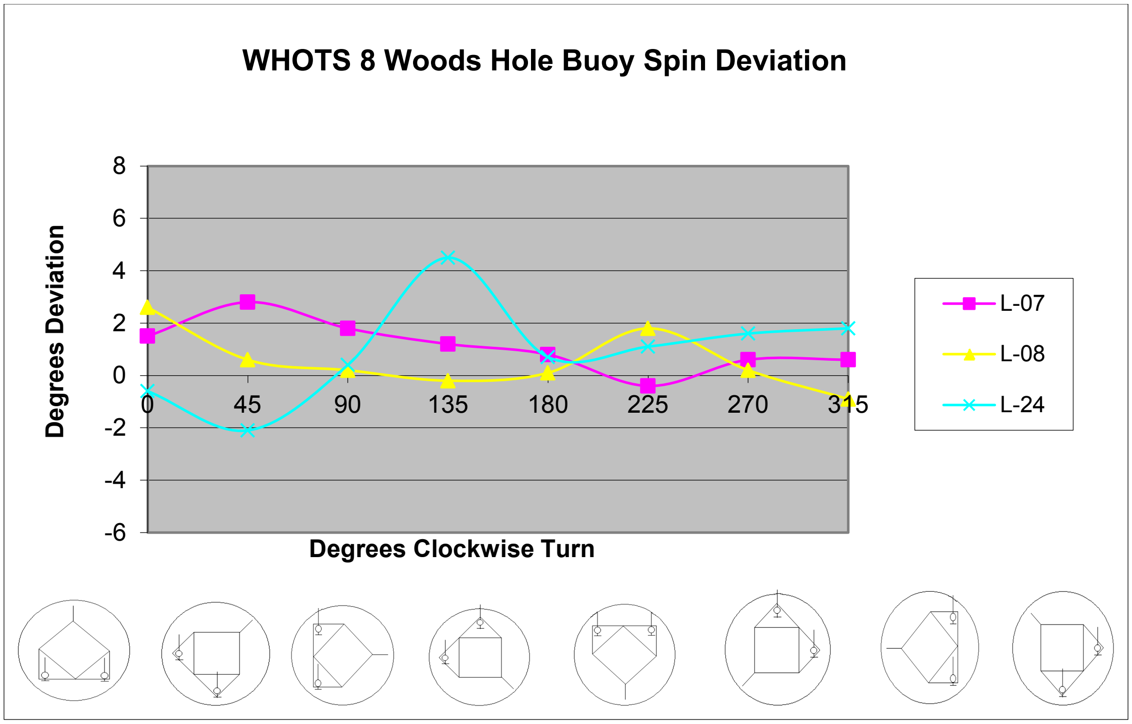


Fig 2-1: Buoy spin results, Woods Hole. Two primary WND modules (SN 210 on Logger L-07 and SN 219 on Logger L-08) and a spare (SN 344 on Logger L-24) were tested.

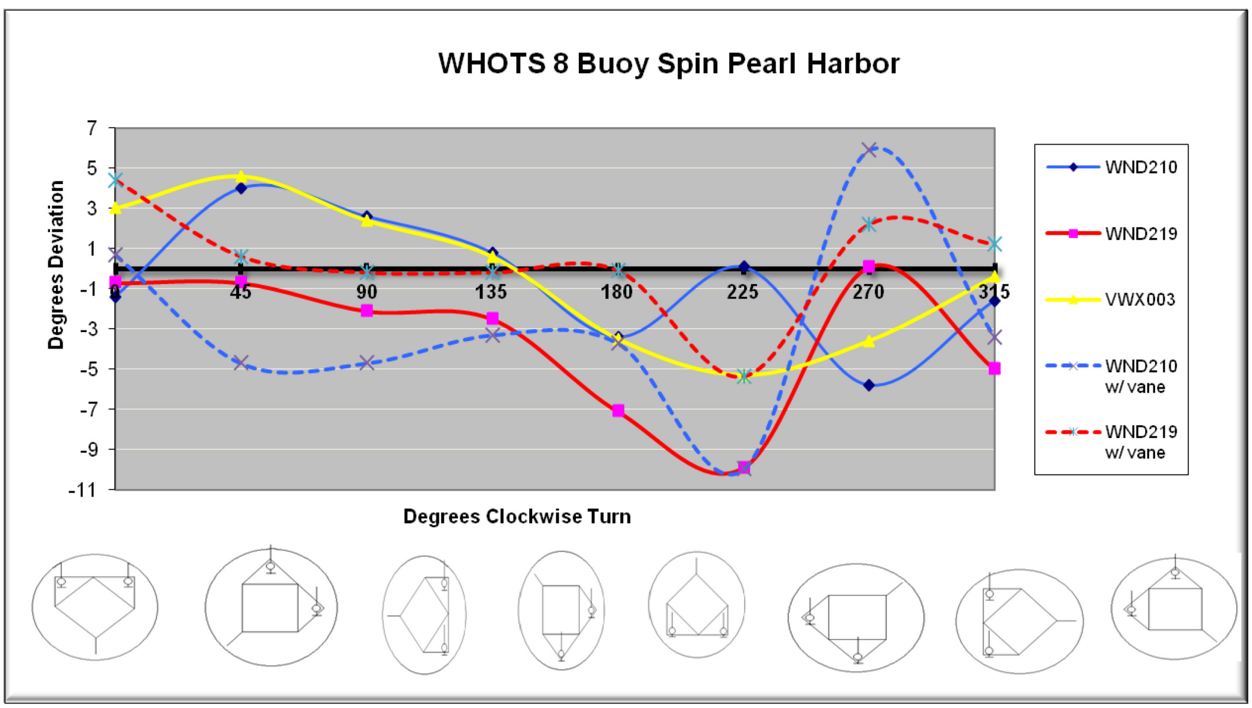


Fig 2-2: Buoy spin results, Hawaii. Two primary WND modules (SN 210 SN 219) were tested along with the Vaisala WXT. Both the compass readings (solid lines) and computed wind direction (dashed lines) were evaluated.

During the Hawaii buoy spin, there was confusion about the Vaisala WXT module orientation relative to the lubber-line. For the buoy spin, the module was aligned to point the compass at 0^o when the front face of the buoy was pointed North (Fig. 2.3a). However, this orientation resulted in possible flow distortion by the “fingers” of the sonic anemometer for winds perpendicular to the tower face. Thus, after the buoy spin, the module case was re-aligned so that the WXT sensing volume was not obstructed for winds perpendicular to the tower face. The rotation angle, obtained by polling the module before and after the rotation, was 29 deg CCW.

Fig 2-3: Orientation of Vaisala WXT-520 before (left) and after (right) rotation.

c. 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.

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 in-port evaluation period. The results of these checks, and a final in-port evaluation of hourly Argos data, showed all modules to be functioning as expected with the exception of wind speed. With the buoy tower on the dock prior to deployment, a discrepancy in wind speed of 0.2-0.4 m/s was seen (Fig. 2-4, left). Since the site was very near the ship, this difference was attributed to partial blocking by the ship and no action was taken. However, wind speed differences persisted after deployment, indicating that the discrepancy was not due to the test location. Persistent wind speed differences of 0.7-0.8 m/s were seen (Fig. 2.4, right). There is some evidence that the discrepancy is wind speed dependent, increasing from about 0.2 m/s at 2 m/s winds to 0.8 at 10 m/s winds.

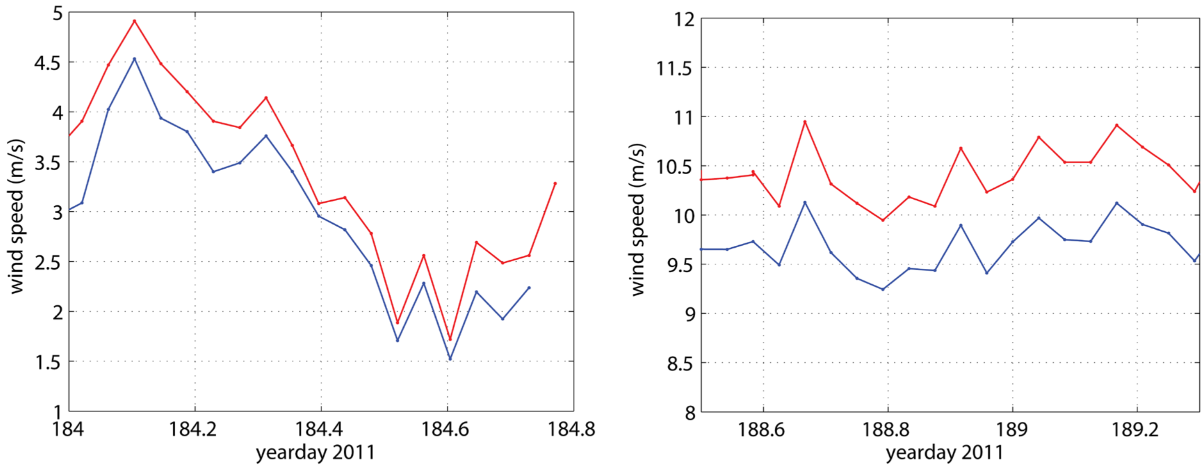


Fig 2-4: Wind speed comparison for WHOTS-8 ASIMET L07 (blue) and L08 (red) with buoy on the Ford Island pier next to the *Hi'ialakai* (left) and after deployment (right).

d. Destaging

Discussions with the *Hi'ialakai* Operations Officer resulted in agreement that the ship would make a stop at the UH facility on Sand Island to unload all of the mooring and CTD equipment that would remain in Hawaii. This took place on the morning of July 13 and eliminated the need to truck all the equipment from Ford Island to Sand Island at the end of the cruise. The Hi'ialakai then continued to Ford Island, arriving at ~ 1300 on July 13. This left enough time to offload almost all of the cargo remaining on board. By the end of the day, just the mooring winch was on the deck, and a few small items remained in the labs.

On July 14, the FISC crane removed the mooring winch from the main deck. The crane repositioned and made four picks to remove ESRL equipment and the AutoIMET boxes from the bow. Work began to organize gear for loading into the two 40-foot containers that had been dropped off earlier in the morning. Most of the equipment was loaded into the containers by the end of the day.

On July 15, the remaining gear was loaded into the containers. The FISC forklift moved the winch from the dock and into the container. The NOAA facility was cleaned up, and residual gear was delivered back to Sand Island. Shaka Engineering began the work of deck restoration.

3. WHOTS-8 Mooring Description

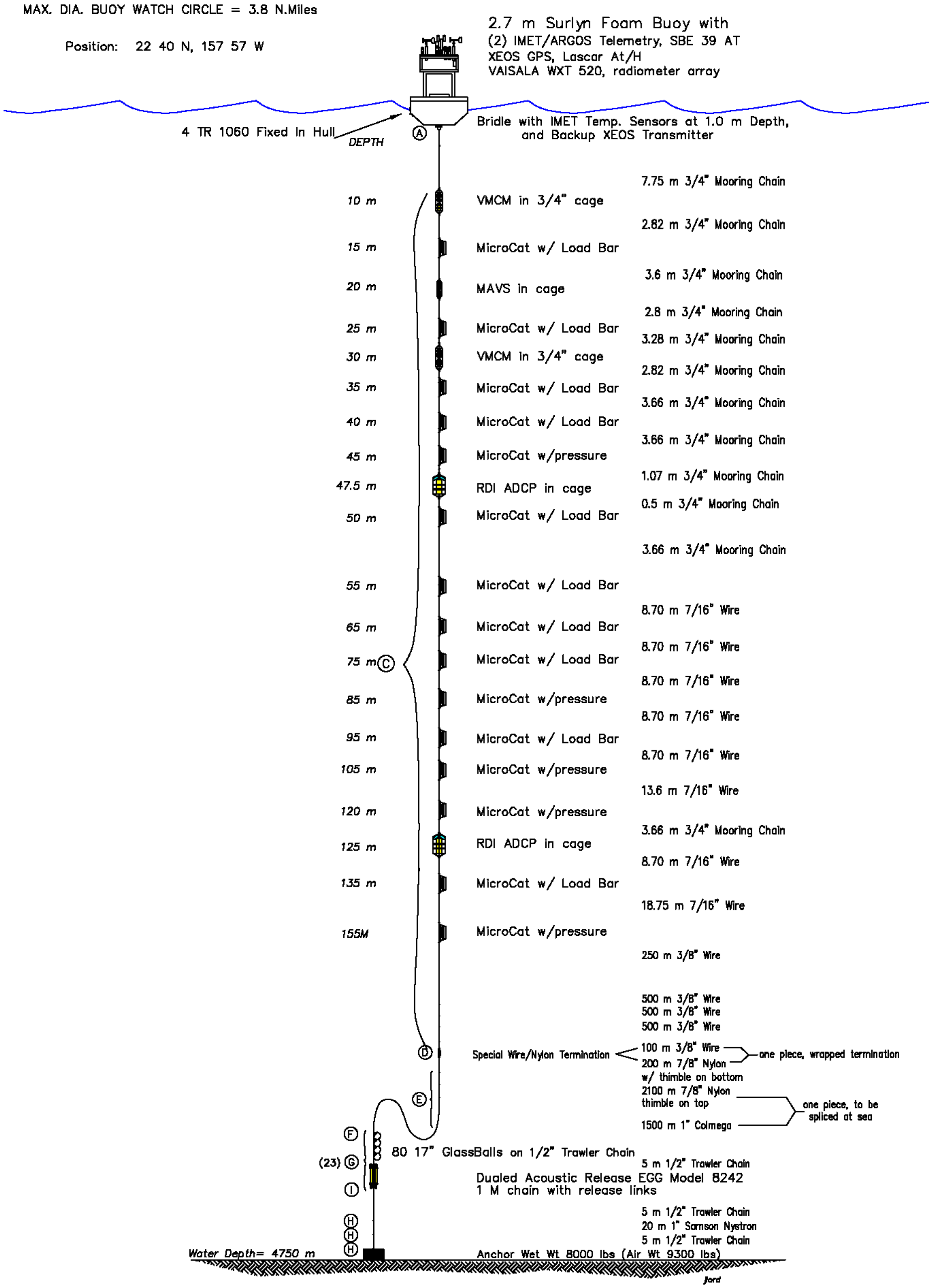


Figure 3-1: WHOTS-8 mooring diagram.

a. Mooring Design

The mooring is an inverse catenary design utilizing wire rope, chain, nylon line and Colmega synthetic line. The mooring scope (ratio of total mooring length to water depth) is about 1.25. The watch circle has a radius of approximately 1.9 nm (3.5 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. WHOTS-8 used a “deep well” design that provides increased stability and allows more equipment and batteries to be included.

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. Two ASIMET data loggers and batteries sufficient to power the loggers and tower sensors for one year are mounted in the buoy well. The tower also contains a radar reflector, a marine lantern, and two independent Argos satellite transmission systems that provide continuous monitoring of buoy position. For WHOTS-8, a self-contained Global Positioning System (GPS) receiver, a SBE-39 temperature sensor adapted to measure air temperature, a Lascar temperature/humidity sensor, and a Vaisala WXT-520 multi-variable sensor (temperature, humidity, pressure, wind and precipitation) were also mounted on the tower. A fourth positioning system was mounted beneath the hull. This is a backup system, and would only be activated if the buoy capsized. Sea surface temperature and salinity are measured by sensors bolted to the underside of the buoy hull and cabled to the ASIMET loggers through an access tube through the buoy foam.

Several other instruments were mounted on the buoy. Sam Laney (WHOI) provided a set of 5 radiometers (four looking down towards the sea surface and one looking up) on the tower and a chlorophyll fluorometer mounted in one of the buoy access tubes. These six instruments were wired in to a controller/logger mounted in the aft corner of the tower. The original plan had two more fluorometers in-line along the mooring, but these were not deployed. Chris Sabine (PMEL) provided a pCO_2 system, mounted in the buoy well with sensors in air and in the water. A SBE-16 CTD with oxygen and a SAMI-2 pH sensor were mounted to the underside of the buoy and wired in to the pCO_2 controller/logger.

Temperature-conductivity sensors, Vector Measuring Current Meters (VMCMs), Acoustic Doppler Current Meters (ADCP) and a Modular Acoustic Velocity Sensor (MAVS) current meter were attached along the mooring line 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. Dual acoustic releases, attached to a central load-bar, were placed approximately 33 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.

b. Bird Barrier

WHOTS-8 incorporates *Nixalite Premium Bird Barrier Strips Model S* as a physical deterrence for pest birds and their accompanying guano deposition. The anti-bird wire is constructed of grade 316 stainless steel and is 4 inches high and 4 inches wide and has no less than 120 wire points per foot with full 180-degree coverage (order information: S Kit 6 - 4 ft strips 24 ft and S Kit 10 - 4 ft strips 40 ft). The wire strips were installed fully around the crash bar, the flat top portion, inside lip, and carefully around the solar radiometers. Individual strips were 4 foot long and secured with cable ties and correctly sized hose clamps.. The wires are sharp so it is recommended that gloves and eye protection be used for installation. It is important to note that the bird wire contains magnetic characteristics and should not be mounted near modules with compasses. Furthermore, transparent monofilament fishing line was installed in a simple X pattern inside the tower to also serve as a bird deterrent.

c. Anti-foul Treatment

E-Paint's products have been refined to best suit WHOI's need for effective products that remain relatively safe to apply. Treatment of the WHOTS-8 mooring was straightforward. One gallon of grey E-Primer provided two coats on the Surlyn foam buoy hull, and aluminum bottom plate. Two gallons of grey E-Paint Sunwave was applied in the same areas. Pasco PVC tape was wrapped around the housing of the SSTs mounted to the bottom base plate of the buoy. Sea surface temperature probes were inserted into the hull and Green Aqua Lube was applied to the heads of the probes. The VMCMs, propellers were treated with gray E-Paint and the hubs were sprayed with gray transducer paint prior to deployment.

d. Remote Line Deployment System

Buoy recovery requires attaching a hauling line to the forward bale (lifting bale) of the buoy hull. This is typically done by hand, either by attaching a line from the deck using a snap hook as the ship passes in close proximity to the buoy, or by launching a work boat to approach the buoy and attach the line, which is then passed to the ship. Ship characteristics, availability of a work boat, and weather conditions can make these methods difficult. As a result, a method of stowing the hauling line on the buoy itself and deploying it remotely on command was developed. This remote line deployment system consists of two cylinders and an actuating device (Fig. 3-2). The first cylinder contains 2 small floats attached to 60 feet of 5/16" Amsteel Blue buoyant synthetic line (9,000 break strength) that serves as a "leader" for the hauling line. The actuator is connected to this cylinder. Upon receiving a radio signal, the actuator opens a hinged door allowing the leader line to drop into the sea where it will trail behind the buoy. The second cylinder contains 50 feet of 5/8" Amsteel Blue (53,000 lb break strength) hauling line. When the leader is grappled form the ship and hauled in, sufficient tension is generated to pull open the door of the second cylinder and release the hauling line, which is connected to the lifting bale of the buoy. Note that the foam hull is notched at the location of the line deployment system (Fig. 3-2) in order to accommodate the two cylinders and produce an orientation that will allow the line to readily fall into the water.

e. Buoy Instrumentation

i. Buoy Tower Instruments

The full ASIMET installation for WHOTS-8 is summarized in Table 3-1.

WHOTS 8 Serials/Heights			
	System 1		
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	7	LOGR53 v4.11cf	
HRH	246	VOSHRH53 v4.29cF	230
BPR	218	VOSBPR53 v4.03cf (Heise)	238
WND	210	VOSWND53 v4.02cf	270
PRC	215	VOSPRC53 v4.03cf	245
LWR	208	VOSLWR53 v4.02cf	283
SWR	213	VOSSWR53 v4.01cf	283
SST	1835	SBE37-SM 485 V 2.3b	-151
PTT	14637	ID's = 07563, 07581, 07582	
	System 2		
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	8	LOGR53 v4.11cf	
HRH	236	VOSHRH53 v4.29cf	230
BPR	207	VOSBPR53 v4.03cf (Heise)	238
WND	219	VOSWND53 v4.02cf	270
PRC	219	VOSPRC53 v4.03cf	245
LWR	502	VOSLWR53 v4.02cf	283
SWR	221	VOSSWR53 v4.01cf	283
SST	1727	SBE37-SM 485 V 2.3b	-151
PTT	12790	ID's = 06930, 07387, 14708	
	Stand-Alone Modules		
Module	**Serial**		**HeightCm**
VWX	3	VOSWXT520 v4.04cf	259
SBE39	1446	V 2.2	230
XEOS	1500	300034012611500	248
MINIMET	264		188
PC02	102		83
SIS	4230	ID: 300034012194230	

Table 3-1. Serial numbers and heights for WHOTS-8 buoy mounted instrumentation.

ii. Surface Temperature Array

The sea surface temperature array installation for WHOTS-8 is summarized in Table 3-2.

	Serial	Depth Cm	Sample	Start Date	Start Time
TR-1060	20565	-80 120 degrees	1 minute	6/28/11	22:00
TR-1060	20566	-80 180 degrees	1 minute	6/28/11	22:00
TR-1060	20567	-95 180 degrees	1 minute	6/28/11	22:00
TR-1060	20568	-80 240 degrees	1 minute	6/28/11	22:00
SBE37	1727	Bridle	5 minute	6/28/11	21:00
SBE37	1835	Bridle	5 minute	6/28/11	21:00

Table 3-2. Sea Surface Temperature Array

Fig. 3-2. Remote line deployment system on the WHOTS-8 buoy.

iii. Position Monitoring Beacon

WHOTS 8 deployed a Xeos Melo surface buoy monitoring beacon on the tower, a self-contained GPS receiver/logger and Iridium satellite transmitter. The Melo system settings were for a 5 min burst of GPS fixes at 20 sec intervals repeated every half hour. These data are logged internally and available upon recovery of the buoy. The Melo was also programmed to broadcast GPS position via an Iridium Short Burst Data (SBD) message every 4 h.

iv. Emergency Positioning Beacon

The buoy hull also contained an emergency positioning beacon in the form of a Xeos Sable GPS receiver with Iridium telemetry. The beacon is mounted in a buoy hull access tube. In the event of catastrophic failure where the buoy hill flips upside down, the beacon would activate and relay position information to facilitate recovery.

v. Argos Telemetry

The meteorological system controller, the ASIMet logger, is designed to communicate directly with an Argos Platform Transmitter Terminal (PTT). The logger sends 32-byte messages to the PTT, the maximum length that Argos can currently handle. We can count on a minimum of seven Argos satellite passes per day at our buoy site, though pass frequency varies with latitude. To minimize data gaps, we use three Argos ids per ASIMet logger, with a rolling buffer that handles six records at a time. Because of the throughput constraints, we transmit hourly averages, and data values are encoded at a lower resolution than the instruments internally recorded data. Data messages received by the Argos satellites are collected at their processing center in Maryland and delivered every six hours via ftp to a workstation at Woods Hole, where they are processed by a set of automated scripts and Matlab programs, with data displayed on our website in near-real-time.

The Argos system also provides Doppler buoy positions, which we monitor via the web with Matlab-generated maps. Although the position information is accurate to only about 1000 m, it is sufficient for determining if a buoy has broken anchor and for tracking moving buoys.

For data transmissions, we use Seimac Wildcat or Smartcat PTTs, which fit inside the cases of our ASIMet loggers. Flat patch antennae are mounted on the buoy towers. The PTTs are programmed to broadcast nearly continuously, retransmitting the same messages for a full hour between data updates from the loggers, as there is no verification of receipt of messages from the Argos satellites.

WHOTS 8 deployed 2 Argos Satellite data transmission systems connected to the ASIMET logger.

PTT	14637	ID's = 07563, 07581, 07582
PTT	12790	ID's = 06930, 07387, 14708

Table 3-3. Argos PTT IDs.

vi. pCO_2

Adding a pCO_2 system to the WHOTS mooring expanded the OceanSITES moored pCO_2 network. The current pCO_2 network is developing throughout the global ocean and currently has approximately 30 sites. This location provides key CO2 measurements every three hours in marine boundary layer air and air equilibrated with surface seawater using an infra-red detector.

The detector is calibrated prior to each reading using a zero gas derived by chemically stripping CO2 from a closed loop of air and a span gas (440 ppm CO2) produced and calibrated by NOAA's Earth System Research Laboratory (ESRL). For this deployment PMEL added a SAMI-2 pH system and a SBE16 package with dissolved oxygen, chlorophyll and turbidity instruments. These measurements were added to upgrade WHOTS from a carbon flux monitoring site to a full ocean acidification (OA) site as part of the growing OA network. For an overview of the PMEL carbon network visit: http://pmel.noaa.gov/co2/story/Buoys+and+Autonomous+Systems.

A summary file of the measurements is transmitted once per day and plots of the data are posted in near real-time to the web. To view the daily data visit the NOAA PMEL Moored CO2 Website: http://www.pmel.noaa.gov/co2/story/WHOTS. Within a year of system recovery, the final processed data are submitted to the Carbon Dioxide Information Analysis Center (CDIAC) for release to the public.

vii. Hyperspectral Radiometers

In cooperation with Dr. Sam Laney (WHOI), an above-water hyperspectral radiometry system was integrated into the WHOTS-8 mooring to provide yearlong, finely resolved measurements of changes in ocean-leaving radiances in the visible and near-infrared radiation at this site. Four downlooking Trios RAMSES hyperspectral radiometers observe water-leaving radiance at four orthogonal directions relative to the mooring (plan view) at 45° down angles. Three are mounted on the port, starboard and forward and faces of the buoy tower, and one is mounted on the buoy vane (Fig. 3-3a). A single complementary hyperspectral sensor is mounted facing upward near the near the ASIMET radiometer modules as a reference for the incoming spectral irradiance (Fig. 3-3b). An active chlorophyll fluorometer (SeaPoint SCF) is mounted to the hull of the buoy and is polled every four hours, to provide in-water measurements of phytoplankton biomass for comparison with the satellite-retrieved ocean color proxies. A wiper is incorporated into this subsurface system to minimize biofouling of the fluorometer over its deployment.

Ocean color is sampled frequently over the day and stored locally in memory for later download at the end of the deployment. Daily, at solar noon, a subset of the ocean color data most relevant to satellite retrievals of chlorophyll and sun-stimulated fluorescence is transmitted to shore over an Iridium SBD link, for near-real time monitoring of ocean color at this site. Sampling and data storage is provided by a custom micrologger designed specifically for this study. Sampling parameters of the entire system can be reconfigured remotely via the Iridium link, to provide adaptive sampling of intermittent or aperiodic events in ocean color known to occur in this region. This system currently represents the only moored, long-term but frequent sampling, hyperspectral ocean color monitoring program in an open ocean region.

The sensors and interfaces making up the hyperspectral radiometer system are described below:

4 Radiometers – Model: RAMSES-ARC-VIS-Ti, manufacturer TriOS, Germany
Serial #: 835A- mounted on wind vane (aft)
Serial #: 835B- mounted on starboard side
Serial #: 835D- mounted on bow
Serial #: 835F- mounted on port side

1 Radiometer – model: RAMSES-ACC-VIS-Ti, manufacturer TriOS, Germany, Serial #: 835E- mounted looking upwards, near met radiometers

1 Chlorophyll Fluorometer – model SCF, manufacturer Seapoint Sensors, USA, Serial #: SCF3257- mounted underneath buoy, with: *Mechanical Wiper – model : Hydro-Wiper, manufacturer Zebra-Tech, New Zealand*

1 Interface Unit – model: Smart Cable, manufacturer Martin Cooper Consulting, Canada, Serial #: 048- mounted with fluorometer

1 Logger Unit – model: Mooring Logger, manufacturer Martin Cooper Consulting, Canada, Serial #: 053- mounted on plate next to wind vane, Iridium antenna immediately above

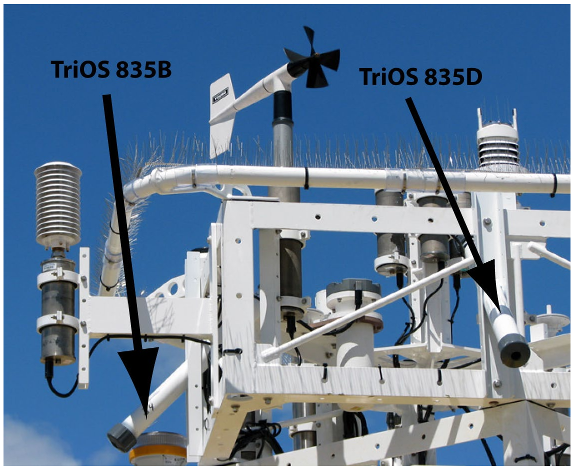


Fig 3-3a: Location of downlooking hyperspectral radiometers on forward and starboard faces of the buoy tower.

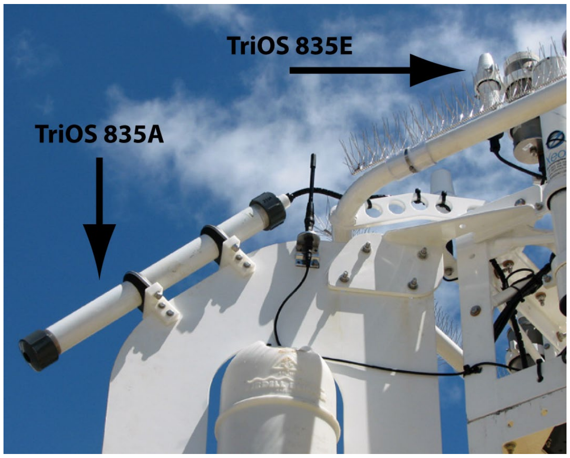


Fig 3-3b: Location of downlooking hyperspectral radiometer on buoy vane and upward facing radiometer attached to ASIMET radiometer module.

f. Subsuface Instrumentation

UH provided 15 SBE-37 Microcats, a RDI 300 kHz Workhorse acoustic Doppler current profiler (ADCP), and a Nobska MAVS acoustic velocity sensor. WHOI provided 2 Vector Measuring Current Meters (VMCMs) and a RDI 600 kHz Workhorse ADCP (SN 1825). The Microcats measure temperature and conductivity; five Microcats also measure pressure. Tables 3-4 and 3-5 provide deployment information for the subsurface instrumentation on the WHOTS-8 mooring. The ADCPs were deployed in the upward-looking configuration. The MAVS was deployed in a vertical downward orientation. The ACDPs and MAVS instruments were programmed as described in Table 3-6.

SN:	Instrument	Depth	Pressure SN	Sample Interval (sec)	Start Logging Data (UTC)	
6893	Microcat	15	N/A	150	06/30/11	0:00:00
10260	MAVS	20	N/A	1800	07/06/11	0:00:00
6894	Microcat	25	N/A	150	06/30/11	0:00:00
6895	Microcat	35	N/A	150	06/30/11	0:00:00
6896	Microcat	40	N/A	150	06/30/11	0:00:00
6887	Microcat	45	2651319	180	06/30/11	0:00:00
1825	600 kHz ADCP	47.5	N/A	600	7/6/2011	0:00:00
6897	Microcat	50	N/A	150	06/30/11	0:00:00
6898	Microcat	55	N/A	150	06/30/11	0:00:00
6899	Microcat	65	N/A	150	06/30/11	0:00:00
3618	Microcat	75	N/A	150	06/30/11	0:00:00
6888	Microcat	85	2651320	180	06/30/11	0:00:00
3617	Microcat	95	N/A	150	06/30/11	0:00:00
6889	Microcat	105	2651321	180	06/30/11	0:00:00
6890	Microcat	120	2651322	180	06/30/11	0:00:00
4891	300 kHz ADCP	125	N/A	600	07/06/11	0:00:00
3634	Microcat	135	N/A	150	06/30/11	0:00:00
6891	Microcat	155	2651323	180	06/30/11	0:00:00

Table 3-4. WHOTS-8 subsurface instrument deployment information (excluding VMCMs).

Instrument	Serial	Depth m	Sample	Start Date	Start Time
VMCM	16	10	1 minute	7/5/11	20:01
VMCM	19	30	1 minute	7/511	20:01

Table 3-5. WHOTS-8 VMCM configuration and deployment information.

	ADCP S/N 4891	ADCP S/N 1825	MAVS S/N 10260
Frequency (kHz)	300	600	N/A
Number of Depth Cells	30	25	1
Pings per Ensemble	40	80	80
Depth Cell Size	4 m	2 m	N/A
Time per Ensemble	10 min	10 min	30 min
Time per Ping	4 sec	2 sec	2 sec
Time of First Ping	07/06/11, 00:00	07/06/11, 00:00	07/06/11, 00:00
Cold Spike Time	07/06/11, 00:55	07/06/11, 01:26	07/06/11, 02:15
Time in water	07/06/11, 19:50	07/06/11, 19:17	07/06/11, 18:27
Depth	125 m	47.5 m	20

Table 3-6. WHOTS-8 ADCP and MAVS deployment information.

4. WHOTS-8 Mooring Deployment

a. Deployment Approach

Mooring deployment operations were conducted on the *Hi'ialakai* using techniques developed from previous cruises. The nominal WHOTS mooring site is at 22° 45' N, 157°54' W, about 6 nm E of the HOT central site at 22° 45' N, 158° 00' W. Starting with WHOTS-4, a southern site was used alternately so that both the newly deployed mooring and the mooring to be recovered were in the water during the intercomparison period. Thus, the WHOTS-8 mooring was slated for the southern site at a nominal location of 22° 40.2' N, 157° 57.0' W. Due to erroneous positions provided to the ship, the bridge used an anchor target of 22° 40.0' N, 157° 57.0' for WHOTS-8.

Winds were from nearly due E (80°) at 13-15 kt. The shipboard ADCP was not functioning at the time, but the drift of the ship as well as the location of the WHOTS-7 buoy relative to its anchor indicated currents were to the NW. Data obtained later in the day from the shipboard ADCP confirmed this (Fig. 4-1). It appeared that the nominal approach for the WHOTS-8 mooring deployment would be from the W-SW. Estimation of set and drift by the bridge showed that a course of 70° at about 1.5 kt was sustainable. It was decided to steam to a starting point approximately 6 nm from the drop site at a course of 250° (approach course 70°). Deployment operations began at about 0800 h (local) on 6 July with the *Hi'ialakai* at a distance of 6.0 nm from the drop site (Fig. 4-2).

b. Deployment Operations

The mooring was deployed in several stages. The first stage was the lowering of the upper 45 meters of the mooring over the starboard side of the ship. Instruments and chain shots from 45 meters to the surface were deployed off the starboard side using the crane to lift them into the water. A hauling line, payed out from the mooring winch and passed through the A-frame and around the starboard quarter, was connected to the first instrument to be deployed. Instruments and chain were lifted over the side with the crane. As each instrument was added to the line and lowered to the water, the hauling line followed it. Once the upper 45 m of the mooring was in the water, the upper chain shot was secured with a slip line until the buoy went over the side.

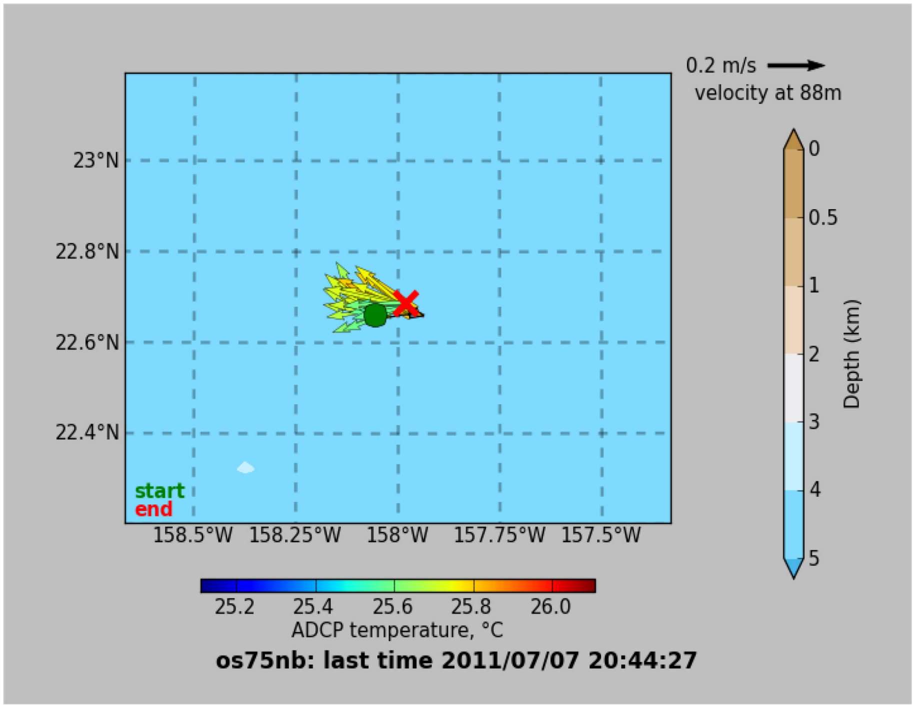


Fig 4-1: Currents at 85 m depth near the WHOTS-8 anchor target on the day of deployment.

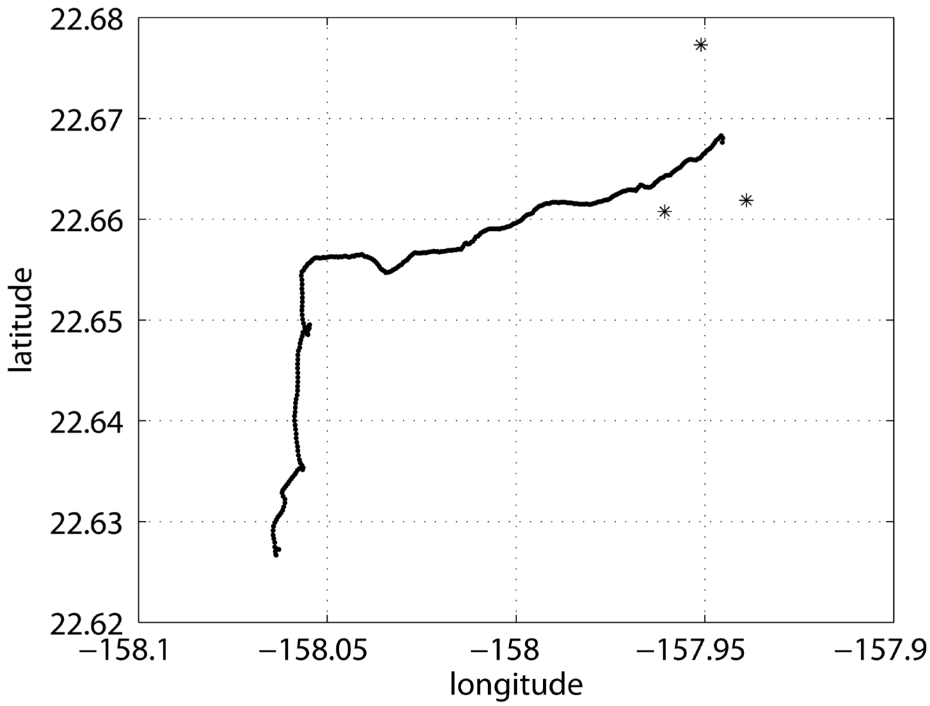


Figure 4-2: WHOTS-8 deployment approach and three triangulation sites used for the anchor survey.

The next stage of the operation was the launching of the surface buoy. Slip lines were rigged on the buoy and the ship's crane was attached to the quick release hook. The slack chain from the upper section of mooring line was connected to the buoy bridle. The buoy was lifted off the deck and outboard, and the slip line holding the 45 meters of instrumented mooring was eased off to transfer the load to the buoy. The buoy was then swung outboard and lowered to the water. Once the buoy settled into the water (approximately 15 ft. from the side of the ship), and the crane line went slack, the quick-release hook was tripped. The ship then maneuvered slowly ahead to allow the buoy to pass around the stern. The 90-meter length of payed out mooring wire and instrumentation provided adequate scope for the buoy to clear the stern.

The remainder of the mooring was deployed over the stern. Once the buoy was behind the ship, speed was increased to about 1 knot and the hauling wire was pulled up on the winch. Instruments and mooring components were added to the 45 meters previously deployed. The winch, and stopper lines on cleats, was used to parcel out shots of wire, chain, and instruments. The long lengths of wire and nylon were then payed out. When the winch drum was empty, the end of the nylon was stopped off to a deck cleat and connected to the first shot of nylon in the wire baskets. An H-bit, positioned in front of the winch, was used to slip the 3500-meter shot of nylon/Colmega line stowed in three wire baskets. While the nylon/Colmega line was being payed out, the 80 glass balls were staged on the main deck for deployment.

With approximately 30 meters of Colmega line behind the H-bit, payout was stopped and the termination was connected to the winch leader. The mooring was stopped off using a Yale Grip. The slack line was removed from the H-bit and wound onto the winch, taking tension of the Yale grip. The remaining line was payed out until it was at the transom. The glass balls were then shackled into the mooring line and eased over the transom with the winch, followed by the releases, trawler chain, 20 m Samson anchor pendant, and 5m anchor chain. The anchor chain was stopped off using a link shackled into the chain and the two stopper lines.

The loose end of the anchor chain was shackled to the anchor. A second sling link was shackled into the anchor chain. A slip-line was passed through the link and secured to the winch leader. The winch took enough tension to balance the load between the stoppers and the slip line. A tie back was secured from the eyebolt on the anchor to a deck eye. At this point, the ship was still approximately one hour from the anchor drop position. The mooring was towed to the final drop site in this configuration.

The ship gave the deck crew a five-minute warning for the anchor drop. The chain binders were removed from the anchor, the stopper lines were made slack and removed, and 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.

As the ship approached the launch site, the slip line was eased out and the mooring load was transferred to the anchor. At the signal from the bridge, the backstay was cut, the crane wire was raised, and the tip plate raised enough to let the anchor slip into the water.

Fig 4-3: Examples of deck welding necessary to accommodate mooring deployment gear on the deck of the *Hi'ialakai*. Square plates with bolts extending vertically were used for the TSE winch (upper left) while threaded disks were used for the H-bit, cleats and air tuggers (clockwise from upper right).

c. Anchor Survey

The anchor survey was done by acoustic ranging on one of the releases to determine the exact anchor position and allow estimation of the anchor fall-back from the drop site. Three positions about 1.5 nm away from the drop site were occupied in a triangular pattern (Fig. 4-5). The WHOI over-the-side transducer and deck box were used to obtain slant range (or travel time) to the release at each station. The Edgetech Model 8242XS Dualed Release and Transponder is rated to 6000 Meter Depth, 5500 kg load, and 2 years of battery life using alkaline batteries. This unit also includes status reply which indicates a tilted angle or an upright condition and release status. The anchor survey was conducted sounding on the release. Ranges from the first two stations at 1.5 nm were inconsistent, and no contact with the release was obtained from the third site. As a result, it was decided to move closer to the anchor drop location. Three more stations were occupied at about 0.75 nm distance. All three stations provided reliable ranges, and these were used to estimate anchor position.

Triangulation using ranges from the three 0.75 nm sites was done with Art Newhall's acoustic survey program. Two ranges from each site were used (6 range circles). The position (lat, lon) of the anchor drop, a corrected depth of 4750 m, a soundspeed of 1505 m/s and transducer depth of

10 m gave an anchor position of 22° 40.1527' N, 157° 57.0225' W. The estimated fall-back from the drop site was about 370 m, or 5.7% of the water depth.

Fig 4-4: WHOTS-8 buoy being lifted over the starboard rail of the *Hi'ialakai*.

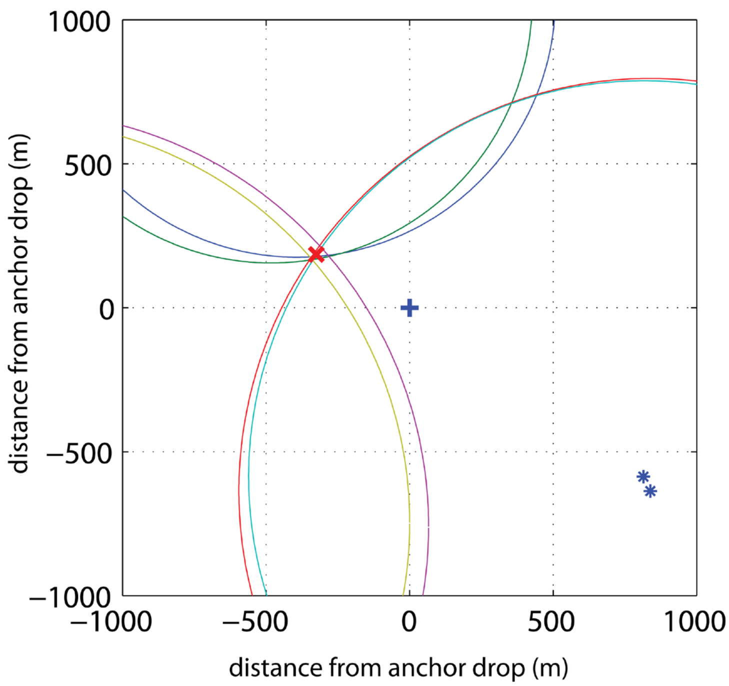


Figure 4-5: WHOTS-8 anchor survey. The anchor drop position (+) is shown along with 2 survey locations (*) and the estimated anchor location (x) near the intersection of the range arcs.

5. WHOTS-7 Mooring Recovery

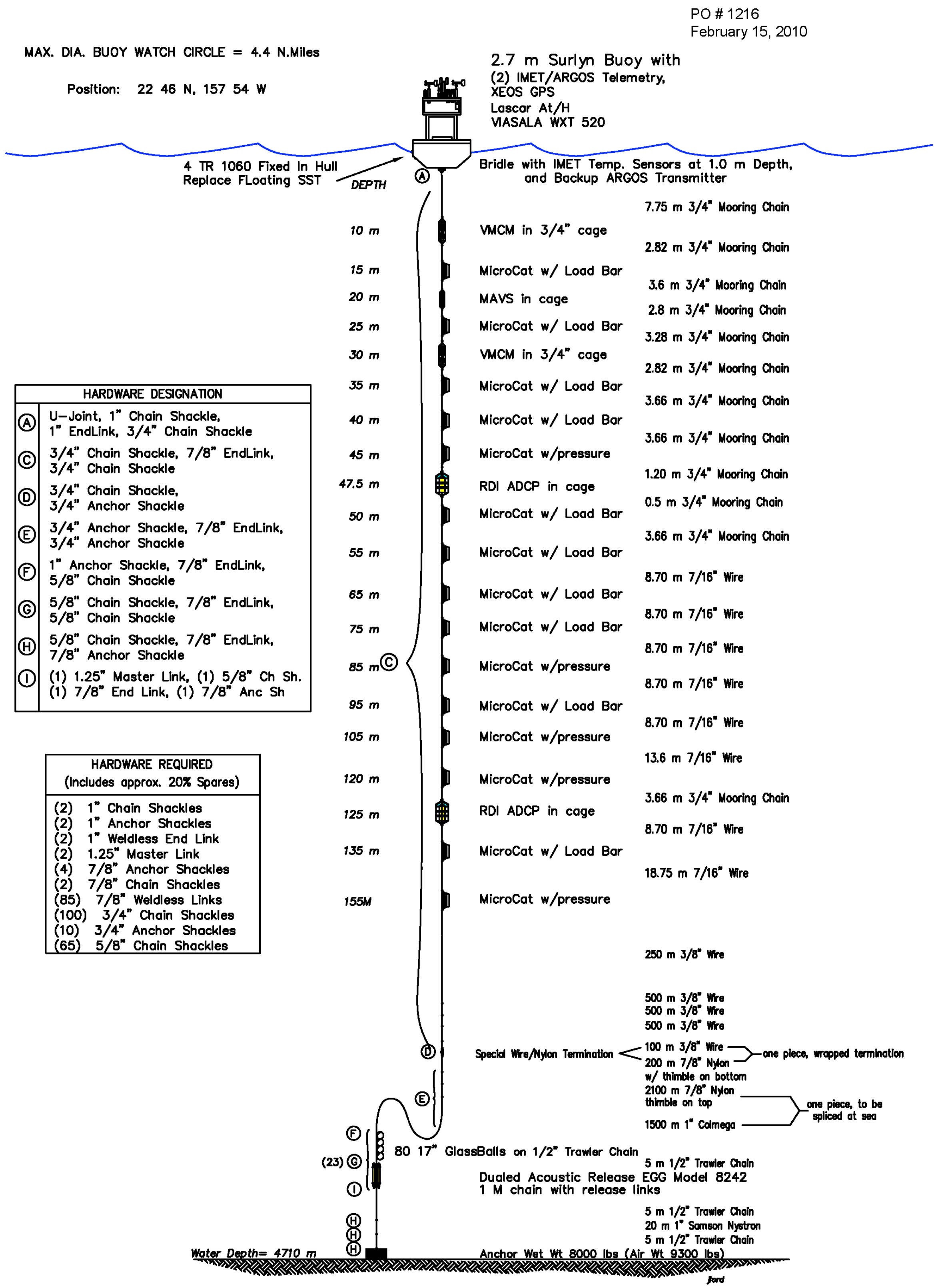


Figure 5-1: WHOTS-7 mooring diagram.

a. Recovery Operations

Recovery was initiated with the ship positioned approximately ¼ mile up wind of the anchor position while the acoustic release was fired. When the glass-ball floatation surfaced, the ship launched its work boat and began its approach. The small boat attached a lifting sling securely to the glass ball cluster. A working line was passed to the small boat and attached to the lifting sling. When the flotation cluster was secured to the mooring winch line, the ship steamed upwind of the cluster, and the small boat was recovered.

The winch hauled in on the working line until the glass balls were at the transom. At this point, the crane was stationed over the transom and the glass ball cluster was transferred to the crane hook and released from the winch. The winch leader was removed, the A-frame was deployed aft, and the crane lifted the entire cluster of balls up and onto the deck. One air tugger was used to stabilize the cluster and help bring it forward. A stopper line was used on the last section of balls connected to the Colmega line, and another on the 5m section of chain leading to the acoustic releases. The crane was disconnected from the balls and stowed.

The terminations at the Colmega line, and the release chain were separated to free the glass ball cluster from the mooring line and releases. The a-frame was brought up and the winch leader was used to haul the releases up and on board. A second stopper was attached to the mooring line while the glass ball cluster was separated into 4-meter segments of chain and balls. These balls were craned up to the wire baskets on the winch deck.

Once the glass balls were secured, the mooring line was hauled up with the capstan and recovery of line began. The ship steamed ahead at approximately 1.5 knots while the capstan hauled in the mooring. The line was pulled directly into wire baskets. After 1500 meters of Colmega line and 2100 meters of nylon line had been recovered, the mooring was stopped off at a shackle termination. The termination was separated, and the mooring line was transferred to the winch.

The winch continued the recovery of the remaining 200 meters of nylon and 1900 meters of wire rope. The hauling operation was stopped periodically to removes instruments shackled between segments of the mooring wire. As instruments surface and were pulled up through the a-frame, loads were transferred to stopper lines and the instruments are removed from the mooring line.

When there was only about 40 meters remaining in the mooring line, the buoy was cast adrift for recovery over the side. It was necessary to spend approximately 20 minutes rearranging the deck equipment for the buoy recovery prior to launching the small boat. The small boat was deployed to attach a lifting pendant to the buoy's lifting eye. This pendant is attached to a working line and passed to the ship to gain control of the buoy. With minimal weight and drag under the hull, the buoy was lifted over the starboard side of the ship using the crane. Air tuggers were used to steady the buoy as it was brought on deck. The capstan was used to pull the mooring line, providing slack to lower the buoy to the deck and disconnect. Once the buoy has been secured on the deck, the remaining instruments are recovered using short picks with the crane. Stopper lines were used to transfer the load as instruments are pulled from the mooring line.

b. Surface Instrumentation and Data Return

Recovery information for the WHOTS-7 buoy sensors are listed in Table 5-1

WHOTS 7 RECOVERY

Module	Serial	UTC Time	UTC Date	Internal Time	Internal Date	Stop Samp	Records
		[-----------------TIME CHECK	-------------]			[--------------DATA	-----------------]
Logger	**L-09**	4:11:00	7/13/15	4:18:02	7/14/15	4:10:30	32914560
HRH	506	21:11:00	7/13/15	21:18:19	7/13/15	18:56:00	4373504
BPR	505	21:39:00	7/13/15	21:43:26	7/13/15	18:56:00	2193152
WND	207	22:30:15	7/13/15	22:38:37	7/13/15	18:56:00	6339580
PRC	209	23:47:00	7/13/15	23:58:23	7/13/15	18:56:00	2193152
LWR	218	0:54:00	7/14/15	1:01:22	7/14/15	18:56:00	5242392
SWR	201	1:20:00	7/14/15	1:19:53	7/14/15	18:56:00	2192640
SST	1419	5:02:00	7/13/15	5:01:52	7/13/15	5:02:30	102853
Logger	**L-10**	4:07:00	7/14/15	4:05:02	7/14/15	4:06:30	32913920
HRH	216	20:19:00	7/13/15	20:30:48	7/13/15	18:54:00	4373504
BPR	216	21:50:00	7/13/15	21:57:54	7/13/15	19:15:00	2192640
WND	221	22:43:00	7/13/15	22:49:29	7/13/15	19:15:00	6338100
PRC	502	23:26:00	7/13/15	23:37:25	7/13/15	19:15:00	2192640
LWR	212	0:43:00	7/14/15	0:44:06	7/14/15	19:15:00	5241168
SWR	505	1:10:00	7/14/15	1:17:52	7/14/15	19:15:00	2192384
SST	1306	4:32:00	7/13/15	4:32:10	7/13/15	4:33:30	102847
Stand Alone							
VWX	1	20:03:00	7/13/15	1:04:36	7/9/15	19:19:00	571660
XEOS	1980					7/13/2015 17:15	86.49%
Lascar	11609					7/13/2015 20:00	8564
PC02	108						
	VOLTAGES						
	Logger P-13	**Module P-14**	**PTT P-19**				
L-09	13.28	13.32	12.72				
L-10	13.66	13.24	12.56				
XEOS	15						
VWX	3.16						

Table 5-1: WHOTS 7 Surface Instruments Recovered

c. Subsurface Instrumentation and Data Return

For the seventh WHOTS mooring deployment that took place on 27 July 2010, UH provided 15 SBE-37 Microcats, a RDI 300 kKHz Workhorse ADCP, a RDI 600 kHz Workhorse ADCP and a Nobska MAVS acoustic velocity sensor. The Microcats all measured temperature and conductivity, with 6 also measuring pressure. WHOI provided 2 VMCMs and all required subsurface mooring hardware.

All instruments on the mooring were successfully recovered. Most of the instruments had some degree of biofouling, with the heaviest fouling near the surface. Fouling extended down to the ADCP at 125 m, although it was minor at that level.

Table 5-2 provides deployment information WHOTS-7 Microcat instruments. Table 5-3 provides the ADCP and MAVS deployment configuration and recovery information.

SN:	Depth m	Pressure SN	Sample Interval (sec)	Start Logging (UTC)		Cold Spike In (UTC)		Cold Spike Out (UTC)		Time in Water (UTC)	
3382	15	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:00:20
4663	25	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	18:52:45
3633	35	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	18:48:30
3381	40	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	18:44:20
3668	45	5579	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	18:40:45
3619	50	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	18:38:40
3620	55	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:40:20
3621	65	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:45:40
3632	75	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:48:45
4699	85	10209	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:51:37
3791	95	N/A	150	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:54:05
2769	105	2949	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	19:56:55
4700	120	2479944	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	20:04:55
3669	135	5700	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:33:00	07/28/10	20:07:45
4701	155	10211	180	07/22/10	0:00:00	07/22/10	23:21:00	07/23/10	0:21:00	07/28/10	20:11:16

Table 5-2. WHOTS-7 Microcat deployment information. All times are in UTC.

	ADCP S/N 7637	ADCP S/N 3917	MAVS S/N 10261
Frequency (kHz)	300	600	N/A
Number of Depth Cells	30	25	1
Pings per Ensemble	40	80	80
Depth Cell Size	4 m	2 m	N/A
Time per Ensemble	10 min	10 min	30 min
Time per Ping	4 sec	2 sec	2 sec
Time of First Ping	07/28/10, 02:00	07/28/10, 02:00	07/26/10, 00:00
Time of Last Ensemble	N / A	N / A	07/13/11, 01:00
Number of Ensembles	38,015	38,432	16,898
Time in water	07/28/10, 20:05	07/28/10, 18:39	07/28/10, 18:54
Time out of the water	07/11/11, 22:40	07/11/11, 23:21	07/12/11, 01:36
Time of spike	07/12/11, 05:40:00	07/12/11, 04:55:00	07/12/11, 06:35
Depth	125	47.5	20

Table 5-3. WHOTS-7 ADCP and MAVS deployment and recovery information.

Table 5-4 gives the post-deployment information for the C-T instruments. All instruments returned full data records. The data recovered from the Microcats appear to be of high quality, although post-deployment calibrations are required. The nominally calibrated temperature, conductivity and salinity records from each instrument, and pressure for those instruments that were equipped with pressure sensors, are shown in Appendix A (Fig.A1-A15).

Depth (meters)	Seabird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality	File Name raw data
15	37SM31486 -3382	07/12/2011 01:32	07/12/2011 04:15:00	07/12/2011 05:44:30	204,618	good	mc_3382_data.cap
25	37SM31486 -4663	07/12/2011 01:36	07/12/2011 04:15:00	07/12/2011 08:45:00	204,690	good	mc_4663_data.cap
35	37SM31486 -3633	07/12/2011 01:41	07/12/2011 04:15:00	07/12/2011 05:18:30	204,607	good	mc_3633_data_b.cap
40	37SM31486 -3381	07/12/2011 01:43	07/12/2011 04:15:00	07/12/2011 05:22:00	204,609	good	mc_3381_data_b.cap
45	37SM31486 -3668	07/11/2011 23:24	07/12/2011 04:15:00	07/12/2011 05:54:30	170,518	good	mc_3668_data_p.cap
50	37SM31486 -3619	07/11/2011 23:19	07/12/2011 04:15:00	07/12/2011 05:58:00	204,623	good	mc_3619_data.cap
55	37SM31486 -3620	07/11/2011 23:16	07/12/2011 04:15:00	07/12/2011 05:13:00	204,605	good	mc_3620_data.cap
65	37SM31486 -3621	07/11/2011 23:11	07/12/2011 04:35:00	07/12/2011 08:43:00	204,689	good	mc_3621_data.cap
75	37SM31486 -3632	07/11/2011 23:07	07/12/2011 04:35:00	07/12/2011 08:47:00	204,691	good	mc_3632_data.cap
85	37SM31486 -4699	07/11/2011 23:03	07/12/2011 04:35:00	07/12/2011 08:56:00	170,579	good	mc_4699_data_p.cap
95	37SM31486 -3791	07/11/2011 22:59	07/12/2011 04:35:00	07/12/2011 17:52:00	204,908	good	mc_3791_data.cap
105	37SM31486 -2769	07/11/2011 22:54	07/12/2011 04:35:00	07/12/2011 08:54:00	170,578	good	mc_2769_data_p.cap
120	37SM31486 -4700	07/11/2011 22:50	07/12/2011 04:35:00	07/12/2011 08:50:00	170,577	good	mc_4700_data_p.cap
135	37SM31486 -3669	07/11/2011 22:36	07/12/2011 04:35:00	07/12/2011 08:52:00	170,577	good	mc_3669_data_p.cap
155	37SM31486 -4701	07/11/2011 22:31	07/12/2011 04:15:00	07/12/2011 05:48:00	170,516	good	mc_4701_data_p.cap

Table 5-4. WHOTS-7 mooring Microcat recovery information. All times are in UTC.

Post recovery inspection showed that the fouling on the 300 kHz ADCP transducer faces (Fig. 5-2) was minimal most likely due to the depth of deployment (125 m) as well as E-Paint anti-foulant grease used on the faces. The transducer faces for the 47.5 m ADCP were also treated with anti-foulant grease and despite significant algae growth near the faces, the faces themselves did not show the same level of growth (Fig. 5-3).

Data from the upward-looking 300 kHz ADCP at 125 m ends in April 2011. The instrument was not pinging upon recovery. The cause of this malfunction is still being investigated. The data file had to be repaired, as it was not closed properly when the instrument stopped recording. The repaired data file for the 300 kHz ADCP needs further work before standard plots can be made. A sample, however, of u and v velocities are shown in Fig. 5-4 and 5-5.

Data from the upward-looking 600 kHz ADCP at 47.5 m ends in April 2011. The instrument was not pinging upon recovery. Examination of the connectors on both the transducer and battery units showed corrosion (Fig. 5-6). It appears that water may have leaked through those connectors and possibly caused the ADCP to stop recording data.

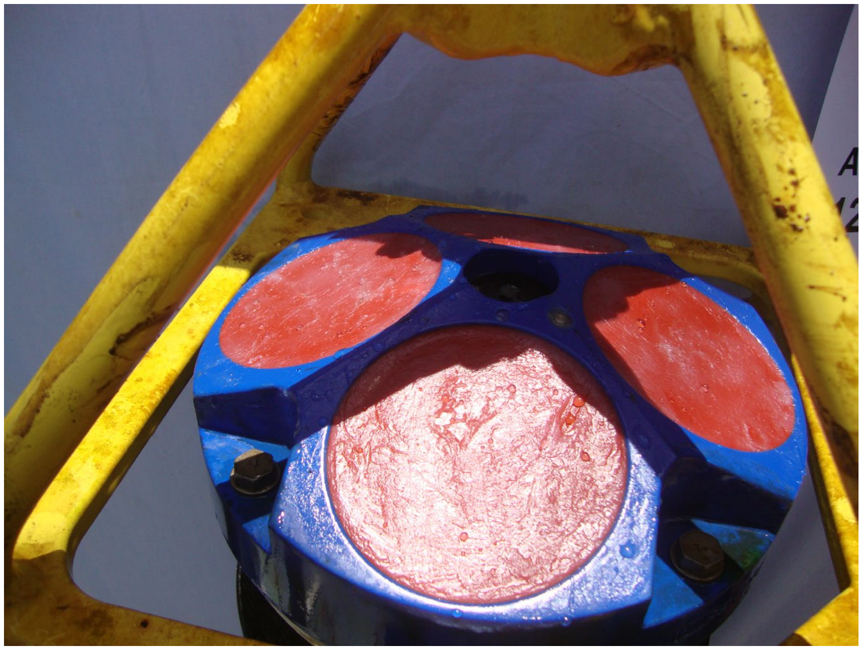


Figure 5-2. WHOTS-7 300 kHz ADCP deployed at 125 m after recovery.

Figure 5-3. WHOTS-7 600 kHz ADCP deployed at 47.5 m after recovery.

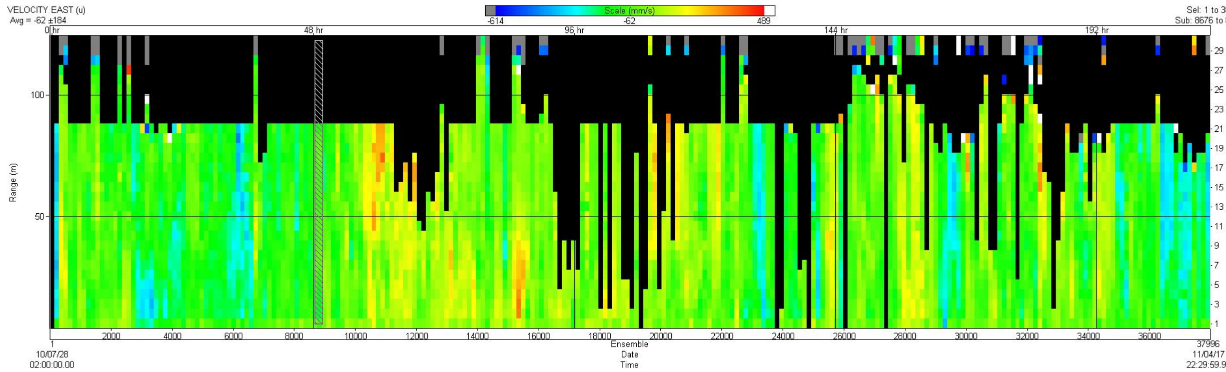


Figure 5-4. Sample of u velocity from the ADCP at 125 m depth on the WHOTS-7 mooring.

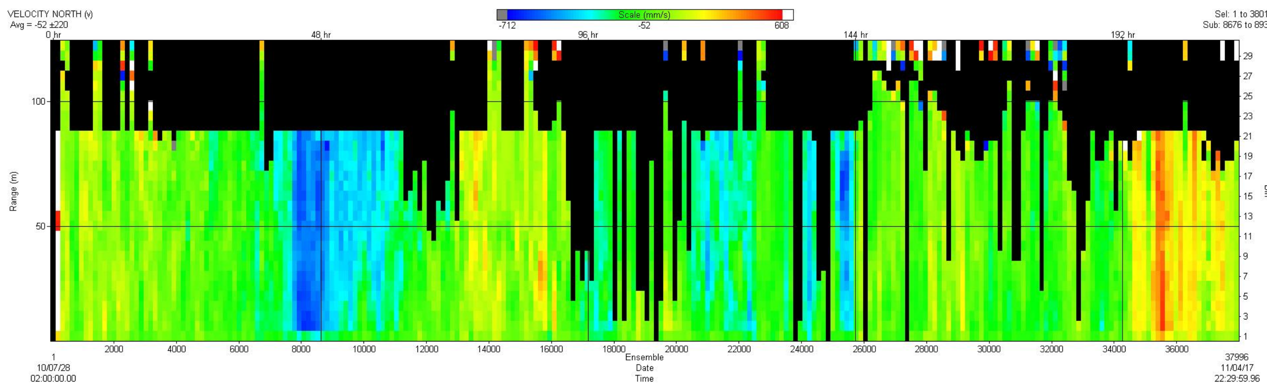


Figure 5-5. Sample of v velocity from the ADCP at 125 m depth on the WHOTS-7 mooring.

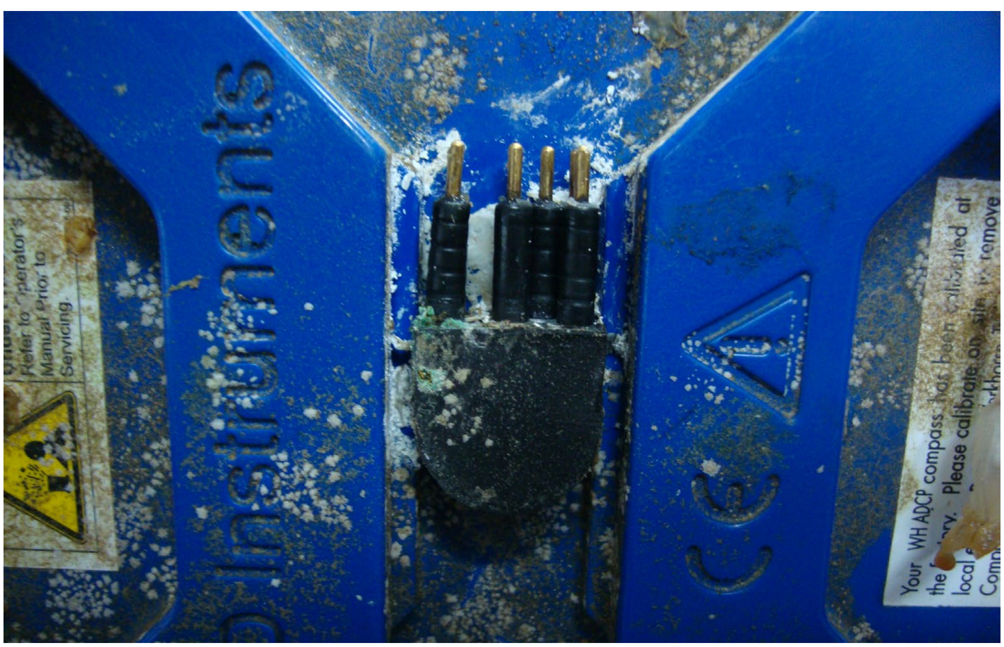


Figure 5-6: Connector corrosion on the 600 kHz ADCP.

Figure 5-7 shows the heading, pitch and roll information from the 600 kHz ADCP at 47.5 m before the instrument failed. Figure 5-8 shows the variations of the horizontal and vertical components of velocity in depth and time before the instrument failed. The height in meters above the transducer is approximately 2 times the bin number.

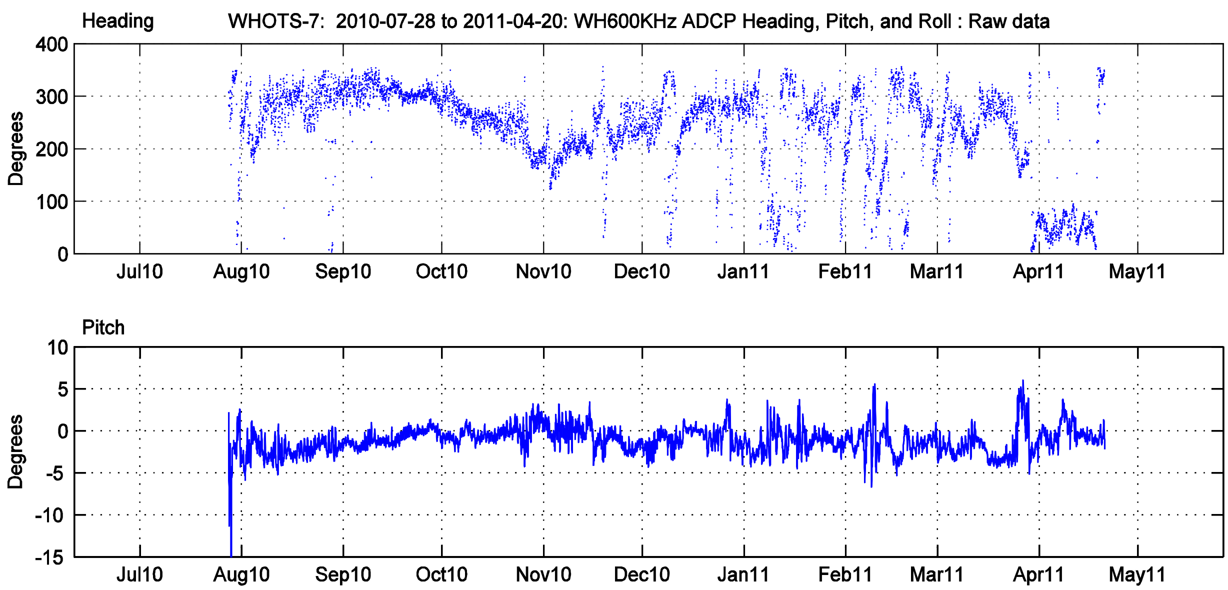


Figure 5-7. Heading, pitch and roll variations measured by the ADCP at 47.5 m depth on the WHOTS-7 mooring.

The MAVS at 20 m was downloaded via Flash memory. Figure 5-9 shows the pitch, roll, and temperature information from the MAVS. Computed u, v and w velocities appeared suspect after download. Figure 5-10 shows the raw velocities from each of the four acoustic transducers and it appears that two of the transducers (B and D) failed at the beginning of the record. This issue will have to be investigated further.

Table 5-5 summarizes the post-recovery information for the WHOTS-7 VMCMs as well as the instruments on the buoy hull – SBE-37 T-C sensors and a SST array consisting of four TR-1060 temperature sensors and two prototype SBE-56 temperature sensors from Seabird Electronics. The SST instruments, set to a 5 sec sample rate, and were not expected to run for the full deployment duration. Indeed all six SST instruments were found to have full memory and dead batteries upon recovery.

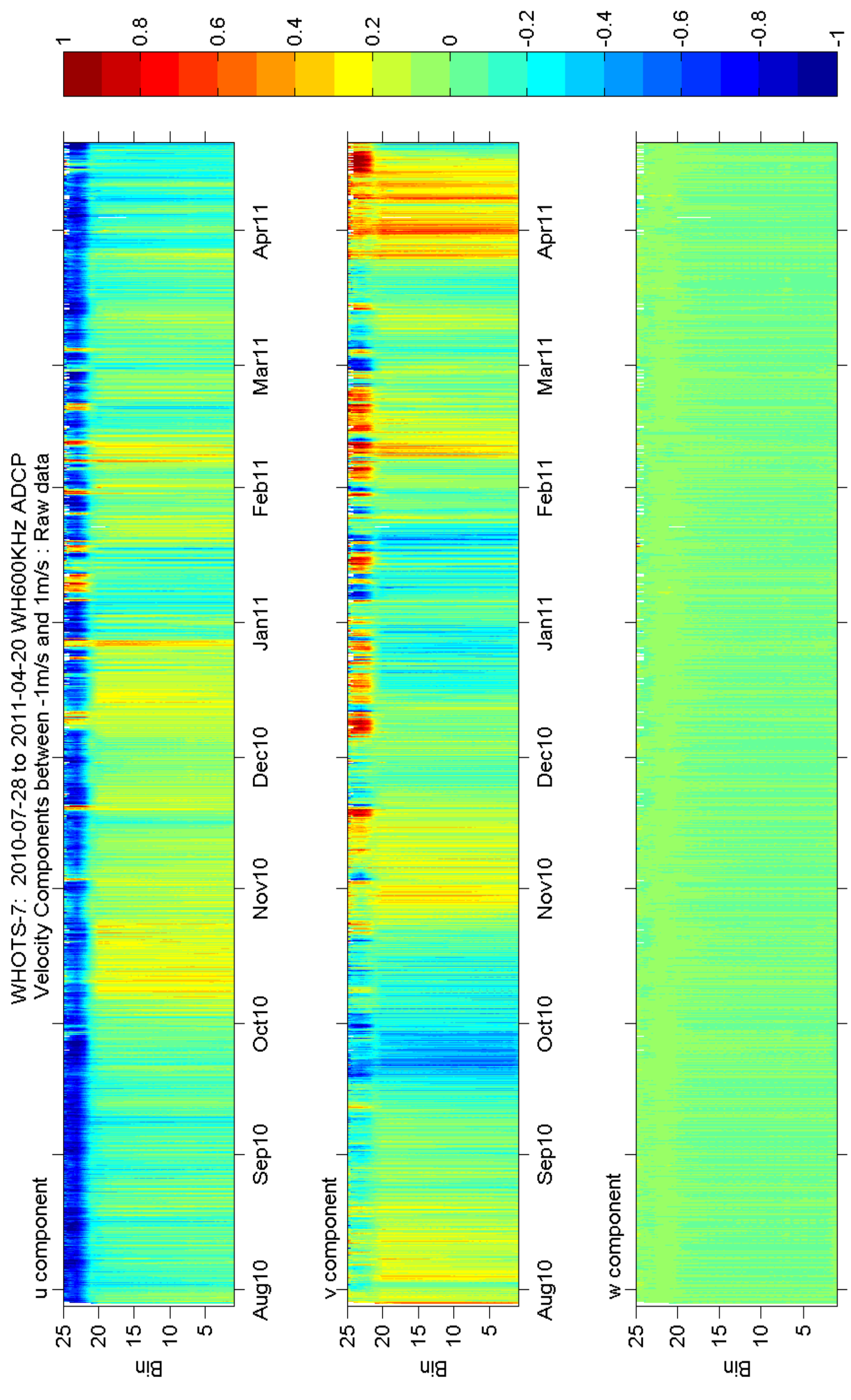


Figure 5-8. Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 47.5 m depth on the WHOTS-7 mooring.

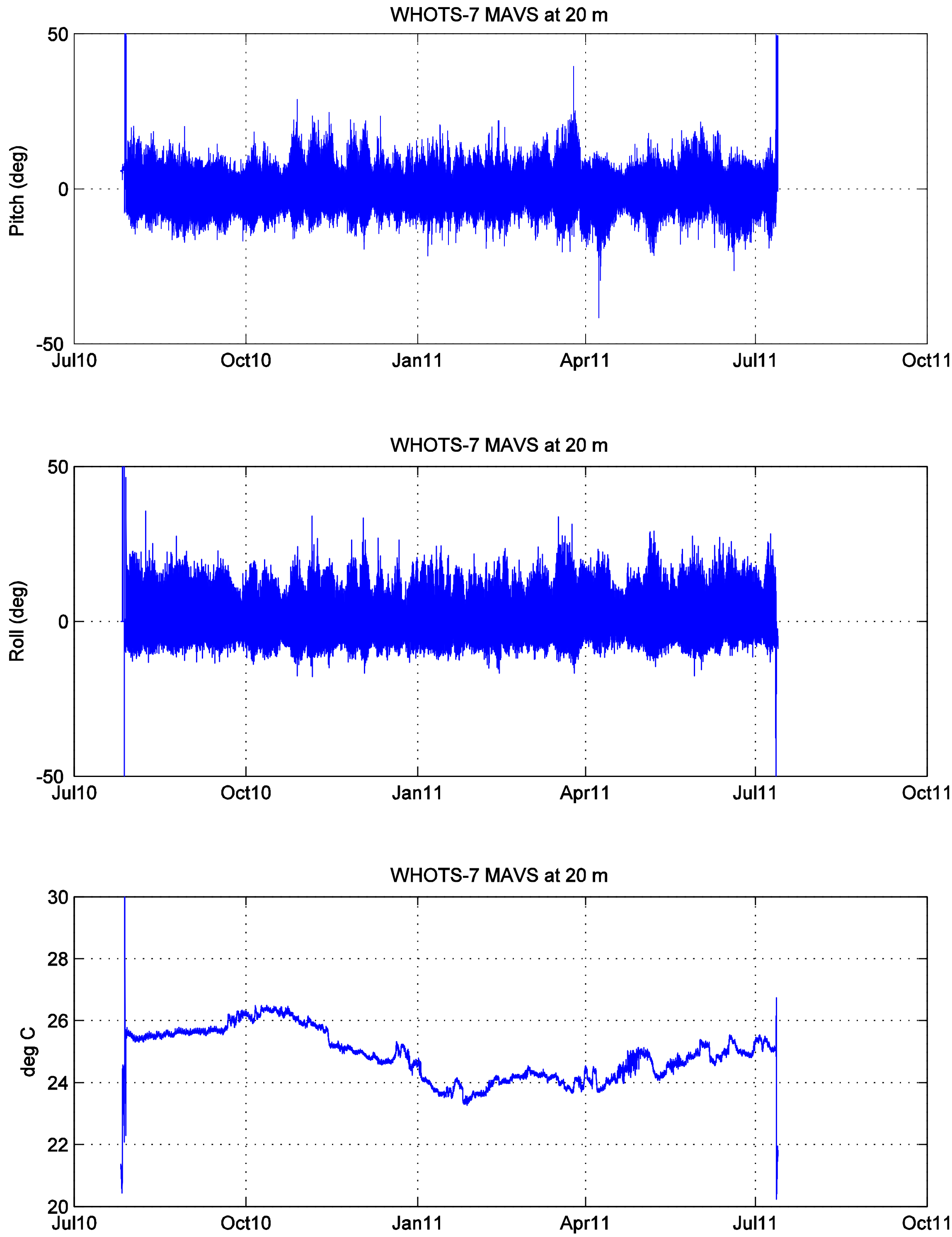


Figure 5-9. Pitch, roll and temperature variations measured by the MAVS at 20 m depth on the WHOTS-7 mooring.

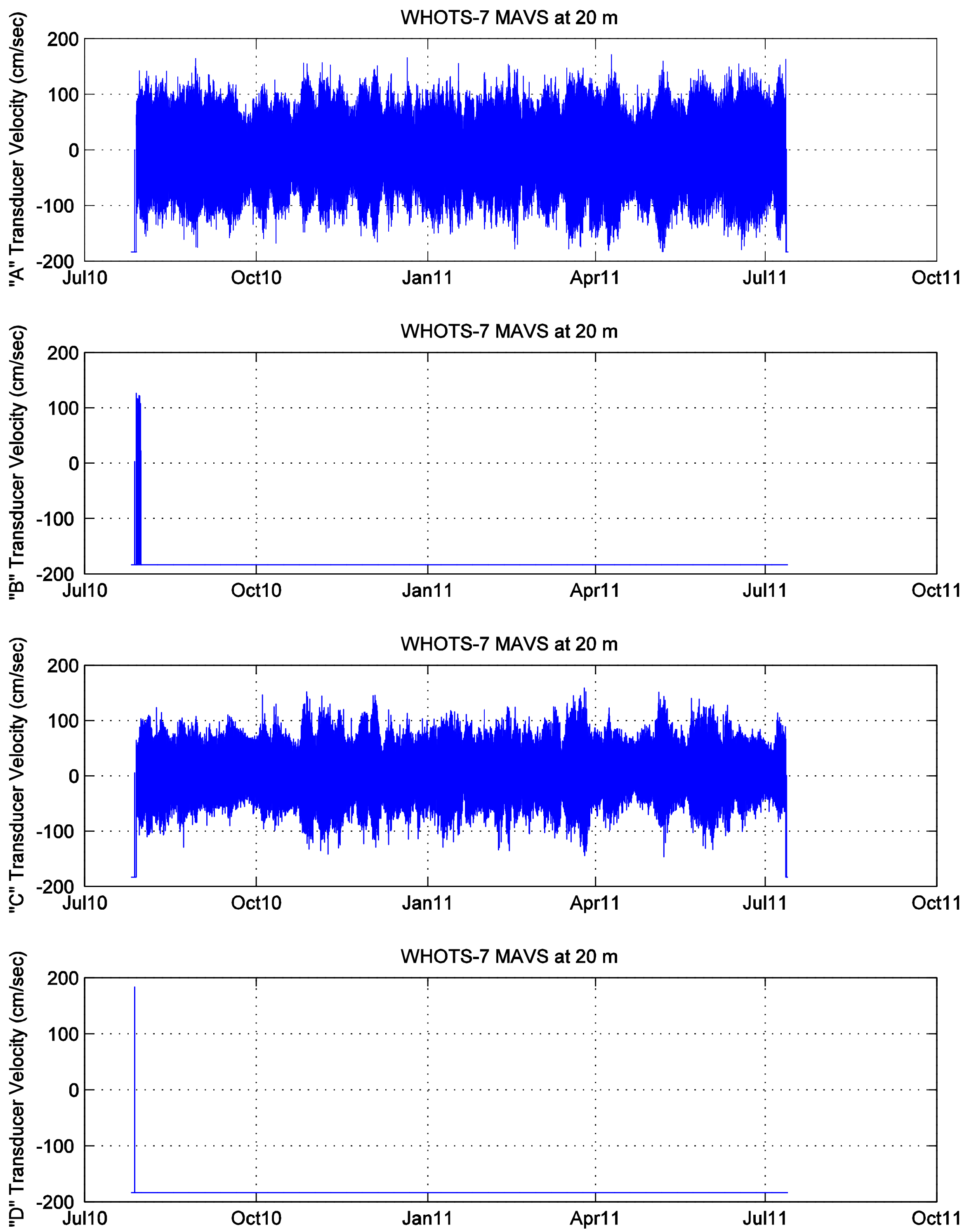


Figure 5-10. Time-series of the raw acoustic velocity measured by each transducer from the MAVS at 20 m depth on the WHOTS-7 mooring.

WHOTS 7 RECOVERY								
		[-----------------TIME CHECK-------------]				-------------DATA----------------		
Instrument	serial	UTC Time	UTC Date	Internal Time	Internal Date	Stop Sampling	Records	Rate
NGVM	35	3:38:00	07/14/15	3:58:02	14-Jul-15	3:39:00	510292	1 min
NGVM	38	3:43:00	07/14/15	3:44:05	14-Jul-15	3:43:30	510251	1 min
sbe37	1306	4:32:00	07/13/15	4:32:10	13-Jul-15	4:33:30		5 min
sbe37	1419	5:02:00	07/13/15	5:01:52	13-Jul-15	5:02:30		5 min
SBE56	22	sending back to seabird					full	
SBE56	23	sending back to seabird					full	
TR-1060	20182	Dead Battery					full	5 sec
TR1060	20186	Dead Battery					full	5 sec
TR1060	14813	Dead Battery					full	5 sec
TR1060	14812	Dead Battery					full	5 sec

Table 5-5. WHOTS-7 VMCM and Sea Surface Temeprature Array recovery information.

6. Meteorological Intercomparison

a. Overview

In order to assess the performance of the buoy meteorological systems, two periods of about 48 h were dedicated to buoy vs. ship intercomparisons. The first inter-comparison period followed deployment of the WHOTS-8 mooring, and the second was prior to recovery of the WHOTS-7 mooring. Hourly ASIMET data were obtained by intercepting the Argos PTT transmissions from the buoy with an Alpha-Omega satellite uplink receiver and a whip antenna mounted on a forward deck rail. Consistent receptions were obtained with the ship standing-off at a distance of about 0.2 nm from the buoy. CTD casts to 200 m were performed during the intercomparison period while holding station near the buoy. Due to substantial drift (2-3 nm) during CTD operations, and subsequent maneuvering to re-acquire a station near the buoy, the ship orientation was not always favorable for the meteorological systems. Although the quality of the comparison suffered during these periods, no buoy data were lost since 6 h of buffered data are transmitted by the ASIMET logger PTTs each hour.

Three other sets of meteorological sensors were available for comparison with the buoys: (1) The ship's meteorological measurements, obtained via the Scientific Computer System (SCS) and described in Sec. 6.b, (2) An AutoIMET system, installed by WHOI and described in Sec. 6.c, and (3) The ESRL/PSD system installed on a bow mast and described in Appendix C. The comparisons presented here use only the first two systems.

b. Shipboard Instruments

The *Hi'ialakai* was outfitted with sensors for air temperature (AT), relative humidity (RH), barometric pressure (BP), sea surface temperature (SST) and sea surface salinity (SSS), wind speed (WSPD), and wind direction (WDIR). AT and RH were measured by a RM Young 4137V sensor mounted on the flying bridge. BP was measured by a RM Young 6120V also mounted on the flying bridge. These sensors were estimated to be 14 m above the waterline. Wind speed and direction was measured by a RM Young propeller and vane anemometer mounted on the bow jackstaff at 14 m height. The anemometer measured relative wind speed and direction, which was corrected to absolute speed and direction by the SCS system. There were two sources for SST, a SBE-38 and a SBE-21. Both measured water from the bow intake estimated to be at 1.5 m depth. The SBE-38 probe was located near the intake, whereas the SBE-21 thermosalinograph measured water that had been pumped from the forward intake to the Wet Lab at the aft of the ship. The SBE-38 was the preferred sensor for SST. Still, a consistent positive bias (warming) was seen in the SBE-38 SST compared to the buoys. Sea surface salinity (SSS) was measured by the SBE-21. SCS data were streamed over the ship's network (telnet port 23) at 1 Hz, recorded at 30 sec intervals, and averaged to 1 h for comparison with the telemetered buoy data.

Readings of AT, SST and BP from the SCS differed dramatically from the same parameters obtained from the AutoIMET and buoy sensors. The extent of these anomalies are shown in Fig. 6-1 through 6-3. In part (a) of the figures, the box and whisker plots graphically display the location and variability of each data set. The 'box' encloses 50% of the data (the interquartile range) and the 'whiskers' indicate the outlier limits of the data (1.5 times the interquartile range). Values outside the outlier limits are indicated by red crosses. SCS indicates the ship's sensors, AI indicates the UOP AutoIMET system mounted on the pilot house top, W8a and W8b refer to readings from the two sets of sensors on the WHOTS-8 buoy, and W7a and W7b refer to the results from the WHOTS-7 buoy. In part (b), the time series of each data type collected is shown. The blue line indicates ship's data; the green line is the AutoIMET data; red and cyan lines are WHOTS-7 data; and yellow and magenta lines are WHOTS-8 data. Part (c) of the figures shows a least squares regression line of the mean of the buoy and AutoIMET (where available) data against the corresponding ship's data. The solid line shows the regression line and the dashed lines indicate the 1-standard deviation error in the regression.

For sea surface temperature, Fig. 6-1a indicates the range and variability of the SCS data are different than the buoy data, which have very similar medians and interquartile ranges. In part (b) this is very clearly demonstrated. The differences between the buoy readings early in the record are attributed to the separation between the two buoy sites. Data from sensors on the same buoy are almost indistinguishable. The regression line in part (c) is $y = 0.60248x + 9.882$.

For air temperature, Fig. 6-2a indicates the SCS data are different than the buoy and AutoIMET data. Part (b) suggests the offset is nearly 1.5 C. The regression line in part (c) is $y = 0.7549x + 4.8791$.

For barometric pressure, the AutoIMET data were adjusted to the height of the buoys by the addition of 1.2 millibar to the raw pressures. The same correction was applied to the ship's data (SCS). This comparison is rendered less accurate than the others by the telemetered buoy data being rounded to the nearest unit of barometric pressure (millibar), while SCS and AutoIMET data are rounded to the first decimal place. Despite this degradation in accuracy introduced in reporting, the greater range of the SCS data shown in Fig. 6-3a clearly suggests that the ship's data differ from the other instruments. The nature of this difference is evident in the time series shown in part (b). Some scaling factor appears to be skewing the SCS data. This is quantified in the regression in part (c) which also shows the effect of the greater rounding of the buoy data in increasing the error range shown. The regression is $y = 0.37474x + 636.0988$.

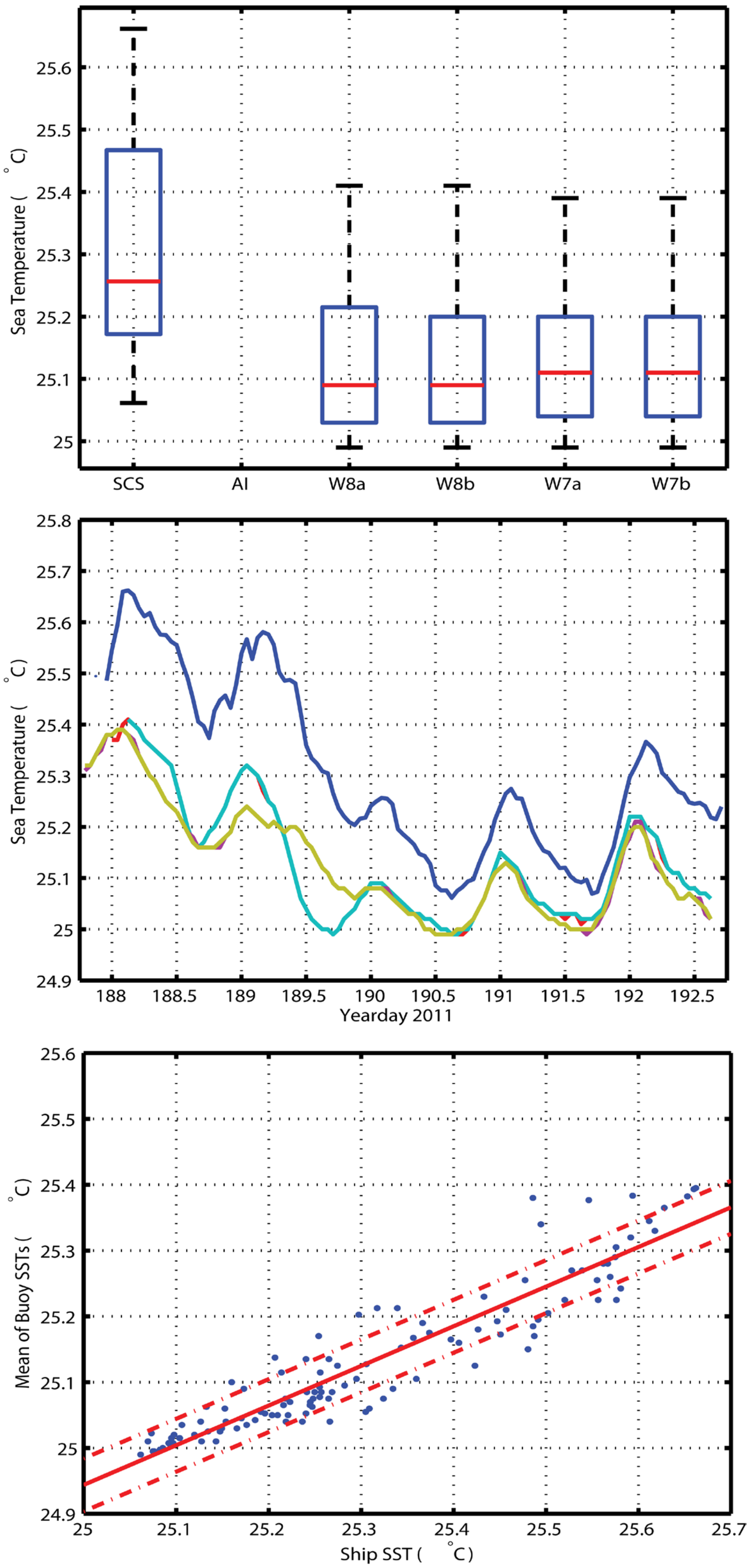


Fig. 6-1. Sea Surface temperature comparison for *Hi'ialakai* shipboard sensors (SCS) vs. UOP AutoIMET and WHOTS buoys. See text for description.

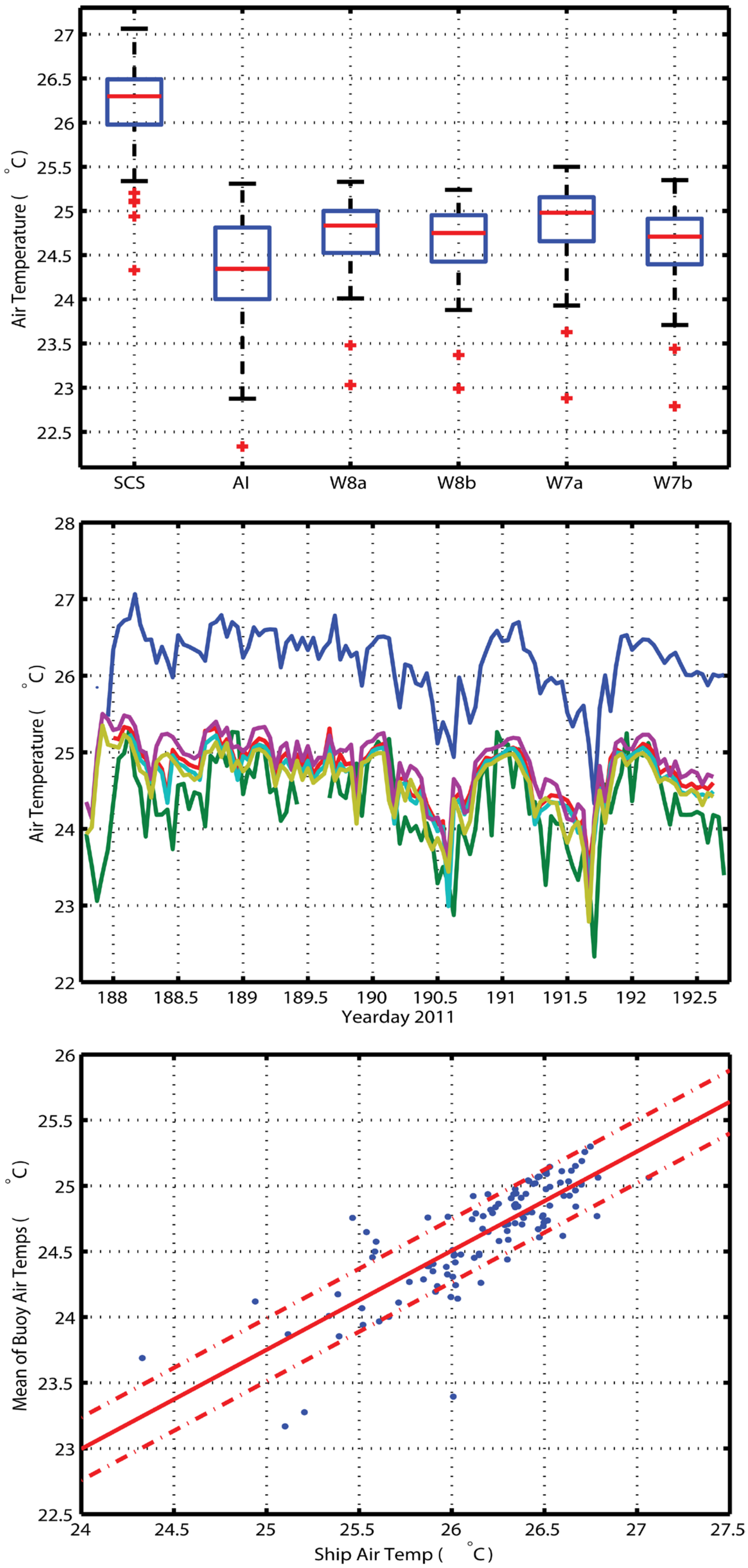


Fig. 6-2. Air temperature comparison for *Hi'ialakai* shipboard sensors (SCS) vs. UOP AutoIMET and WHOTS buoys. See text for description.

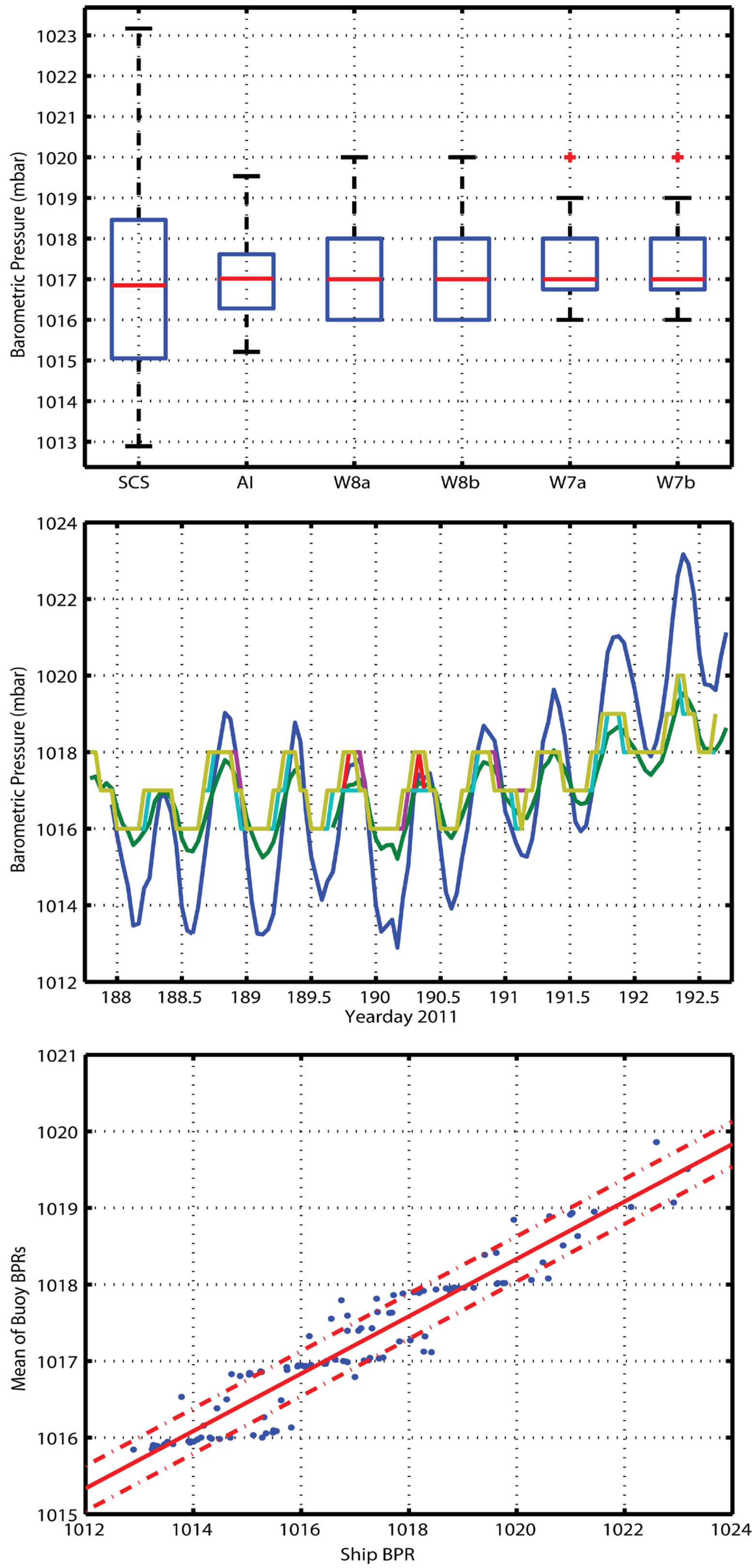


Fig. 6-3. Barometric pressure comparison for *Hiialakai* shipboard sensors (SCS) vs. UOP AutoIMET and WHOTS buoys. See text for description.

c. AutoIMET

The AutoIMET system was developed at WHOI to meet the need for improved marine meteorological observations from volunteer observing ships (VOS). AutoIMET is based on the ASIMET sensor suite and electronics, with the principal differences being a more compact physical configuration and the ability to interface with the NOAA shipboard environmental data acquisition system (SCS). For WHOTS-8, an AutoIMET system was installed on the *Hi'ialakai* to supplement the shipboard meteorological system. This differed from the typical VOS installation in that

- Sea surface temperature was not included. For the WHOTS-8 cruise, SST was obtained from the ship's bow intake temperature sensor (SBE-38);
- Data were not relayed via INMARSAT; instead, a cable was run from the terminal output connector on the logger to a computer in the *Hi'ialakai*, science lab and recorded at two minute intervals for use in inter-comparisons and monitoring the system functions. One minute interval data were stored internally by the AutoIMET logger.

The AutoIMET configuration on *Hi'ialakai* included five main components mounted on the flying bridge (pilot house top; Fig. 6-4). This area was not ideal but was the only appropriate space available. This area was also shared with the NOAA/ESRL gas analysis station and some of the ship's weather instruments. The proximity of the *Hi'ialakai's* radar systems also limited the choice of positions available. The ship's science mast at the aft rail of the pilot house top had no rail and was not suitable for mounting instruments.

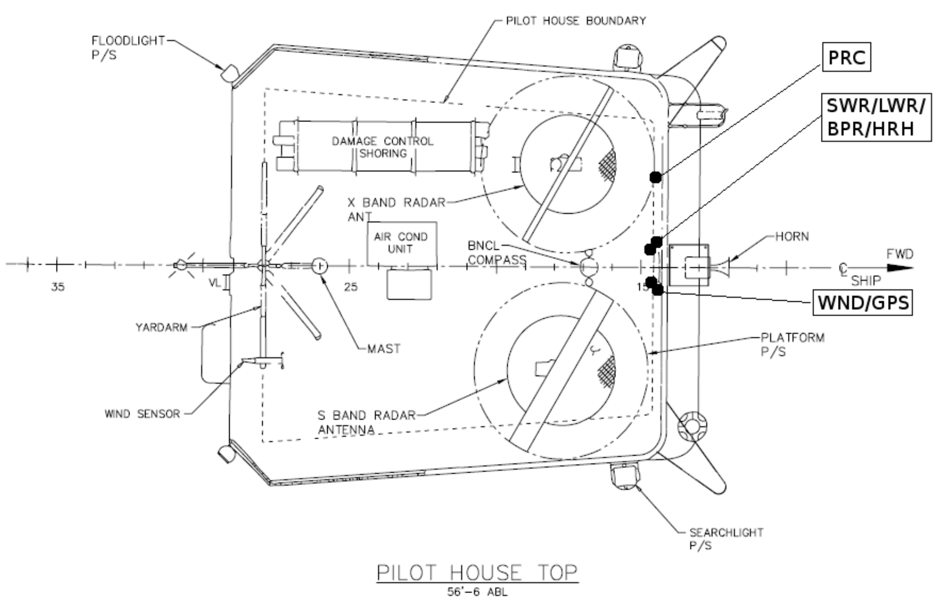


Fig. 6-4: Plan view of the pilot house top indicating approximate mounting positions of the AutoIMET sensors (PRC:precipitation; SWR/LWR: radiometers; BPR: pressure; HRH: humidity; WND: wind; and GPS: global positioning system logger.)

The five components of AutoIME the system were:

- a splash-proof housing with sensors for AT/RH, SWR and LWR;
- a second housing with a BP sensor and central data logger;
- a rain gauge;
- a wind sensor; and
- a GPS logger.

The best available location for mounting the radiometers and wind sensors was a small platform amidships on the forward rail of the pilot house top. The two housings were mounted on the same side of parallel pipe sections with the radiometers and the AT/RH sensor above the logger/BP sensor on the port side of the platform, a location that minimized shadowing (Figs.6-5 and 6-6). The wind sensor and GPS logger were mounted back to back on a pipe alongside the radiometer/BP position, on the starboard side of the platform, the distance separating the positions being limited by the proximity of the vessel's S-band radar antenna, and available securing positions. Care was taken to minimize shadowing of or by the radiometer sensors. The rain gauge was mounted on the forward rail approximately midway between the midships platform and the port side of the flying bridge. The rain gauge electronics system is less sensitive to radar interference and the height of the ship's X-band radar antenna above the position meant the rain gauge could be mounted here. According to the *Hi'ialakai* General Plan, the deck of the pilot house top is 12.6 m above the ship's DWL (sea level) and positions of the AutoIMET components relative to this level were measured after installation. The calculated heights of the sensors above DWL are shown in Table 6-1.

Further constraints on the installation were the lack of points to secure the AutoIMET mounting poles. The platform structure for the ship's met system provided some convenient places to secure poles. The forward rail, however, had no such points, and C-clamps attached to supporting stanchions were used to secure the rain gauge. These clamps can be seen in Fig. 6-5.

AutoIMET Serial numbers		
Instrument	Serial Number	Height above DWL (m)
GPS	N/A	14.50
Wind vane	WND706	14.88
SWR/LWR	PRC706	14.79
HRH	PRC706	14.24
PRC	942	14.72
BPR	703	14.13

Table 6-1. AutoIMET serial numbers and mounting heights.

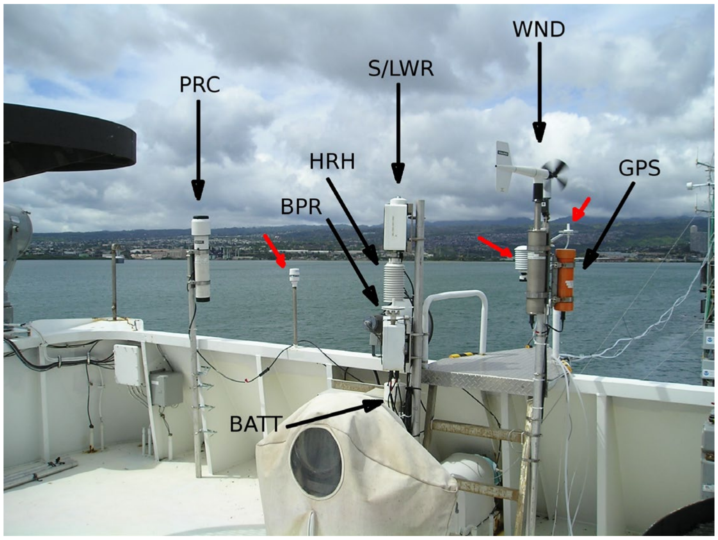


Fig. 6-5. AutoIMET sensors mounted on the flying bridge. Indicated and labelled are: PRC-- precipitation; BPR -- barometric pressure; HRH -- humidity; S/LWR -- radiometers; WND -- wind vane and rotor; GPS -- global positioning system; BATT -- battery pack (partly obscured). Indicated in red are elements of the ship's meteorological system. The black structure intruding from the left is the platform of the ship's X-band radar antenna.

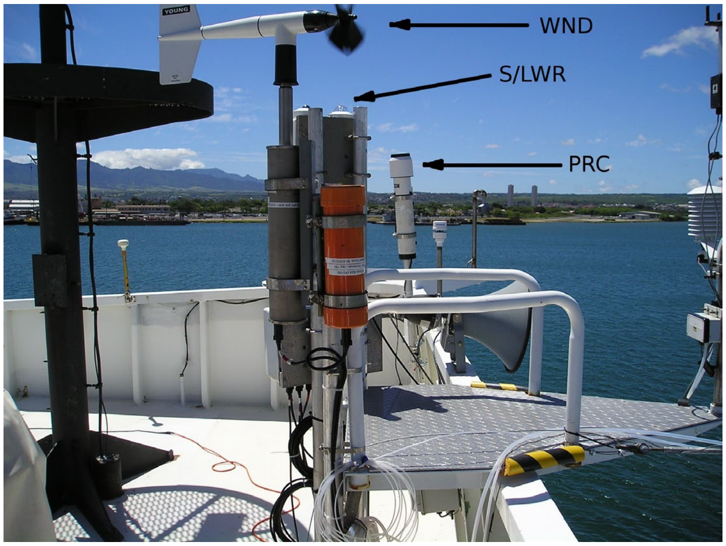


Fig 6-6. View of the AutoIMET system from the starboard side of the flying bridge. Some sensors are indicated: WND -- wind vane and rotor; S/LWR -- radiometers; PRC -- rain gauge. Also visible are: GPS -- global positioning system logger (orange canister) and the ship's met system sensors (extreme right edge of the picture). The black structure on the left of the picture is the mounting platform for the X-band radar antenna.

The AutoIMET system provided barometric pressure (BP), air temperature (AT), relative humidity (RH), shortwave radiation (SWR), longwave radiation (LWR), precipitation (PRC), and winds(WNDU and WNDV) relative to the ship. GPS position data were recorded, but the wind data were not corrected in real-time. For the buoy comparisons, the AutoIMET wind speed and direction were corrected to true (WNDN and WNDE, and WSPD and WDIR) using ship's heading and course and speed over ground recorded from the *Hi'ialakai* shipboard scientific data system (SCS). The AutoIMET data, collected at 2 min intervals, were averaged to 1 hr for comparison with the buoy systems.

The AutoIMET AT, RH, PRC, SWR and LWR sensors were at approximately 14.5 m above the waterline (Table 6-1), but were not corrected for height, with the exception of BP and WND. AutoIMET BP (14.1 m) was corrected to 3 m height to correspond to the buoy. AutoIMET WSPD (14.9 m) and buoy WSPD (3 m) were adjusted to 10 m using a neutral drag coefficient. Since the AutoIMET system did not include sensors for sea surface temperature (SST) and sea surface salinity (SSS), the *Hi'ialakai* shipboard systems were used. As noted in Sec. 6b, there were two sources of SST data. The SBE-38, physically located near the bow intake, was the preferred sensor for SST. S surface salinity came from the TSG. Both SST and SSS data, available from the shipboard computer system at 10 sec intervals, were averaged to 1 h. A correction of -0.2°C was applied to SST for comparison with the buoy (see Fig. 6-1).

Data from the AutoIMET system were made available in real-time in the science lab, using multiple laptop computers and the ships network, in order to assess performance of the WHOTS buoys relative to the ship (the GPS system logged internally, providing position data for post-cruise correction of the relative winds). AutoIMET data recorded by the central logger were captured by a data acquisition computer in the science dry lab. This computer, a Linux PC running Ubuntu, stored two-minute data records in hourly files, and also wrote out a cumulative data file that included all the data. These data were displayed graphically using a matlab script plotwhots.m which called three functions plot_complete_record.m, plot_day_record.m, and plot_hour_record.m to plot the complete record, the last twenty-four hours and the last two hours of the AutoIMET record in real-time. For comparison with other instruments, the ship's SCS data acquisition system was set up to output a text stream of data on the telnet port 23. This data stream (at 1 Hz) was then logged on a windows laptop and stored at thirty second intervals.

d. WHOTS-8 Intercomparison

The WHOTS-8 intercomparison period started at 0600 h UTC on 7 July (year day 188.25) when the anchor survey was complete. The comparison continued until 1000 h UTC on 9 July (year day 190.42), when the ship transitioned to the WHOTS-7 buoy. The total duration was 52 h. The *Hi'ialakai* drifted away from the site five times for CTD casts (0600, 1000, 1400, 1800 and 2200 local on 7 July) and had to maneuver back to a location near the buoy.

The results of the comparison are shown in Figures 6-7 through 6-12. The buoy systems are identified in the plots by their logger numbers (L07=WHOTS-8 System 1, L08=WHOTS-8 System 2). The AutoIMET system is designated "AIMET" and the *Hi'ialakai* shipboard sensors are designated "SCS". Although the principal comparison is intended to be the WHOTS-8 buoy vs. sensors aboard the ship, the WHOTS-7 telemetered data (obtained over the internet from the UOP website) are also included (L09=WHOTS-7 System 1, L10 =WHOTS-7 System 2). The WHOTS-8 buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy) for all variables except WSPD and WDIR.

Examination of the buoy data in conjunction with the shipboard meteorology and the WHOTS-7 data provided further understanding of these discrepancies, and resulted in other useful observations about system performance, as described below.

The WHOTS-8 buoy AT pair agreed to within about 0.1°C. The AutoIMET AT showed a different pattern of variability than the buoy AT pair, sometimes in good agreement and other times reading low relative to the buoy by up to 0.6°C. Shipboard AT offsets of about -0.2°C relative to the buoys have been seen in previous comparisons, and attributed to vertical gradients. Contributing factors to the larger discrepancies in this case may be the AutoIMET mounting location and the fact that the ship was at a variety of distances from the buoy and at a variety of headings while maneuvering for CTD casts. The buoy AT values were closer to those from WHOTS-7 than to the AutoIMET. In addition, the buoy AT values were found to be within about 0.1°C of the SBE-39 AT in dock tests. Considering these factors, it was concluded that the WHOTS-8 AT sensors were within expected accuracy. Note that the SCS AT was about 1.5 °C higher than the buoy AT and considered unreliable.

The WHOTS-8 buoy RH pair typically agreed to within 1%, which is the resolution of the Argos telemetry data. The AutoIMET and SCS RH were within about 2%, and were consistently lower than the buoy values. Considering the increased height of the SCS and AutoIMET sensors, it was concluded that the buoy RH sensors were within expected accuracy.

The WHOTS-8 buoy BP pair agreed within the 1.0 mb resolution of the telemetered data. Adjusting the AutoIMET BP by +1.2 mb, to account for the buoy at 3 m vs. the AutoIMET at 14 m, resulted in good agreement with the buoy BP (within 0.5 mb). The adjusted SCS BP was lower on average than the buoy and AutoIMET BP, and also showed significantly larger semidiurnal fluctuations. It was concluded that buoy and AutoIMET BP were operating as expected while the ship's BP was not reliable.

None of the three PRC sensors indicated rain during the intercomparison period. The buoy fill levels were near zero while the AutoIMET fill level was near 17 mm. The fill levels of the WHOTS-7 PRC sensors were between 40 and 50 mm.

The buoy SST pair agreed to within the 0.01°C resolution of the telemetered data. Differences of order 0.1°C between WHOTS-8 and WHOTS-7 SST were attributed to horizontal gradients. The SCS (bow intake) SST was about 0.2°C higher than the buoy pair and was assumed to have a bias error. The buoy conductivity pair agreed to within the 0.01 S/m resolution of the telemetered data, the analogous salinity pair was within about 0.05 PSU. The SCS salinity agreed reasonably well (0.02-0.04 PSU) with the buoy salinity, but showed "drop-outs", perhaps due to bubbles, to as much as 0.4 PSU below the buoy values. It was concluded that the buoy SSS sensors were within expected accuracy. The SCS salinity must be used with caution due to drop-outs.

The buoy SWR pair agreed to within 10-20 W/m^2 at mid-day, or < 2% of the 1020 W/m^2 mid-day peak. The AutoIMET SWR was within 10-20 W/m^2 of the buoy pair at mid day. The buoy LWR pair typically agreed to within 4 W/m^2. The AutoIMET LWR was intermittent for reasons that were not diagnosed during the cruise. When available, the AutoIMET LWR was within a few W/m^2 of the buoy pair. It was concluded that both SWR and LWR on the WHOTS-8 buoy were within expected accuracy.

The buoy WND pair showed a consistent speed difference of 0.6-0.8 m/s 6-8% for 10 m/s winds), far larger than the expected errors of ~0.1 m/s or 2%. AutoIMET and SCS winds were similar to each other and about 1 m/s higher than the mean of the buoy pair (note that no correction was made for the ~10 m ht difference). In this case, comparison with WHOTS-7 values was useful. Both WHOTS-7 buoy wind speed values were within about 0.2 m/s of WHOTS-8 Logger 8. It was also notable that the dock test results indicated a speed-dependent error (Fig.2-4), with WHOTS-8 L07 underspeeding relative to L08. It was concluded that WHOTS-8 L07 WND was operating as expected, but the L08 WND (SN 210) was reading low by as much as 8%.

The WHOTS-8 buoy WND showed a consistent direction difference of about 8°, larger than expected errors. The AutoIMET and SCS directions agreed within 2°- 3° during the second half of the comparison period (when the ship was not maneuvering for CTD casts), and were closer to L08 than to L07. The WHOTS-7 buoy wind directions were similar to each other and within a few degrees of WHOTS-8 L08. It was concluded that WHOTS-8 L07 WND was operating as expected, but the L08 WND (SN 210) had a direction bias of about 8° clockwise.

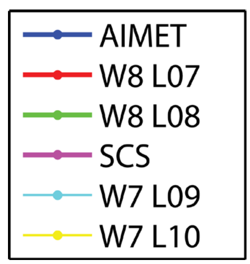


Fig. 6-7: Legend for WHOTS-8 intercomparison plots.

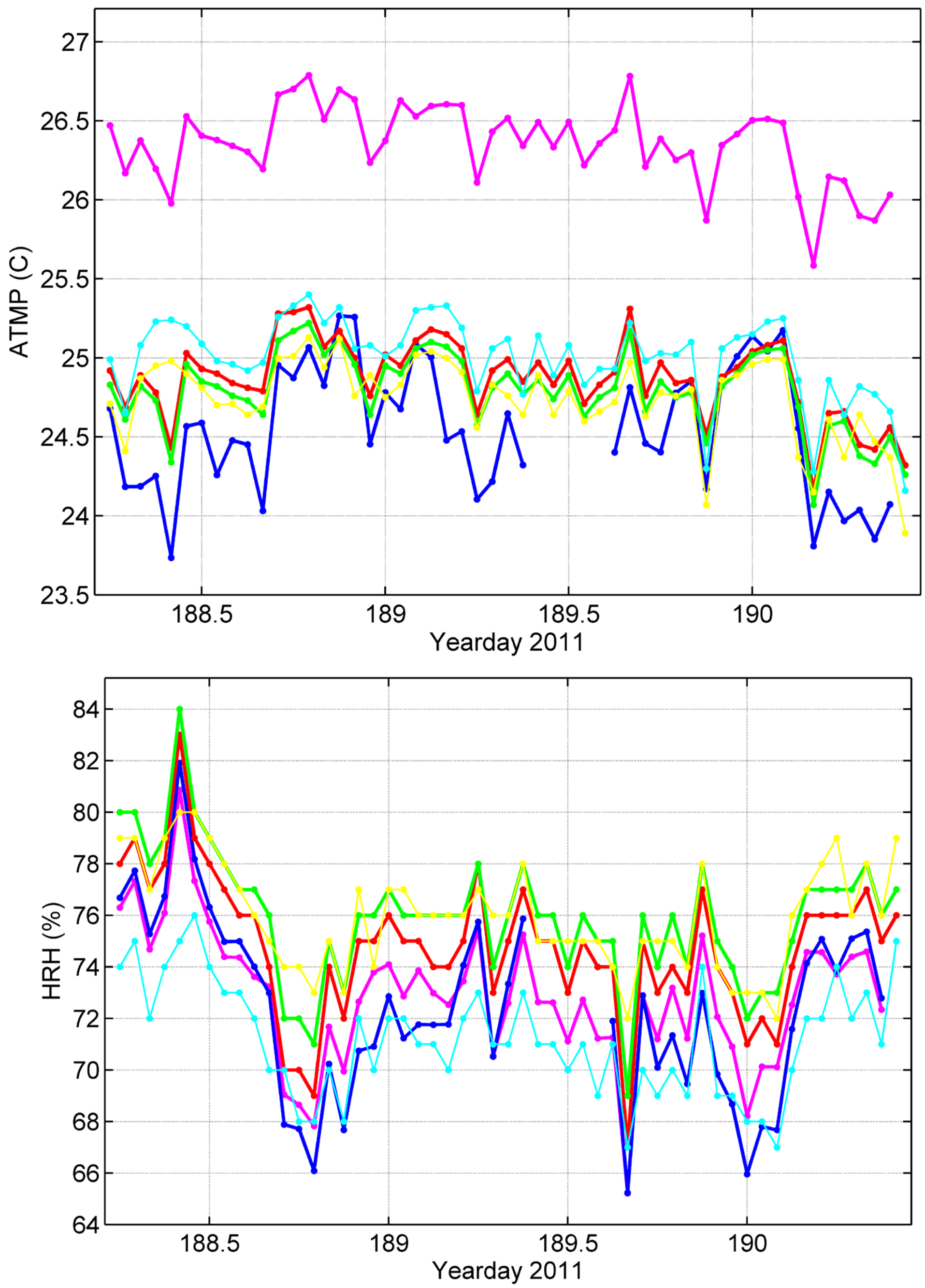


Fig. 6-8. Air temperature (ATMP, upper) and relative humidity (HRH, lower) for the WHOTS-8 buoy systems (L07 and L08), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-8 intercomparison period. Data from the WHOTS-7 buoy (L09, L10) are also shown (thin lines).

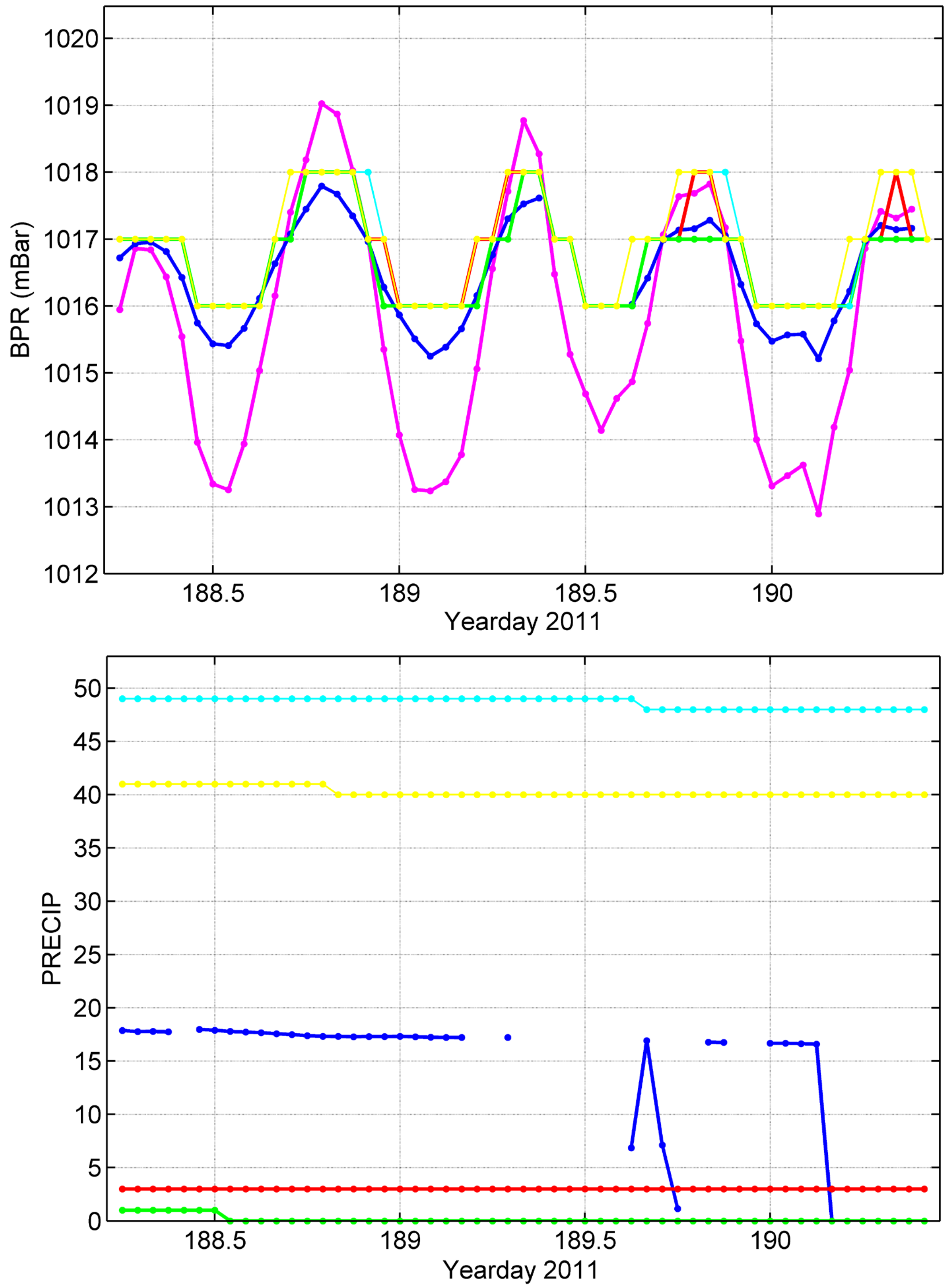


Fig. 6-9. Barometric pressure (BP, upper) and precipitation level (PRECIP, lower) for the WHOTS-8 buoy systems (L07 and L08), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-8 intercomparison period. Data from the WHOTS-7 buoy (L09, L10) are also shown (thin lines).

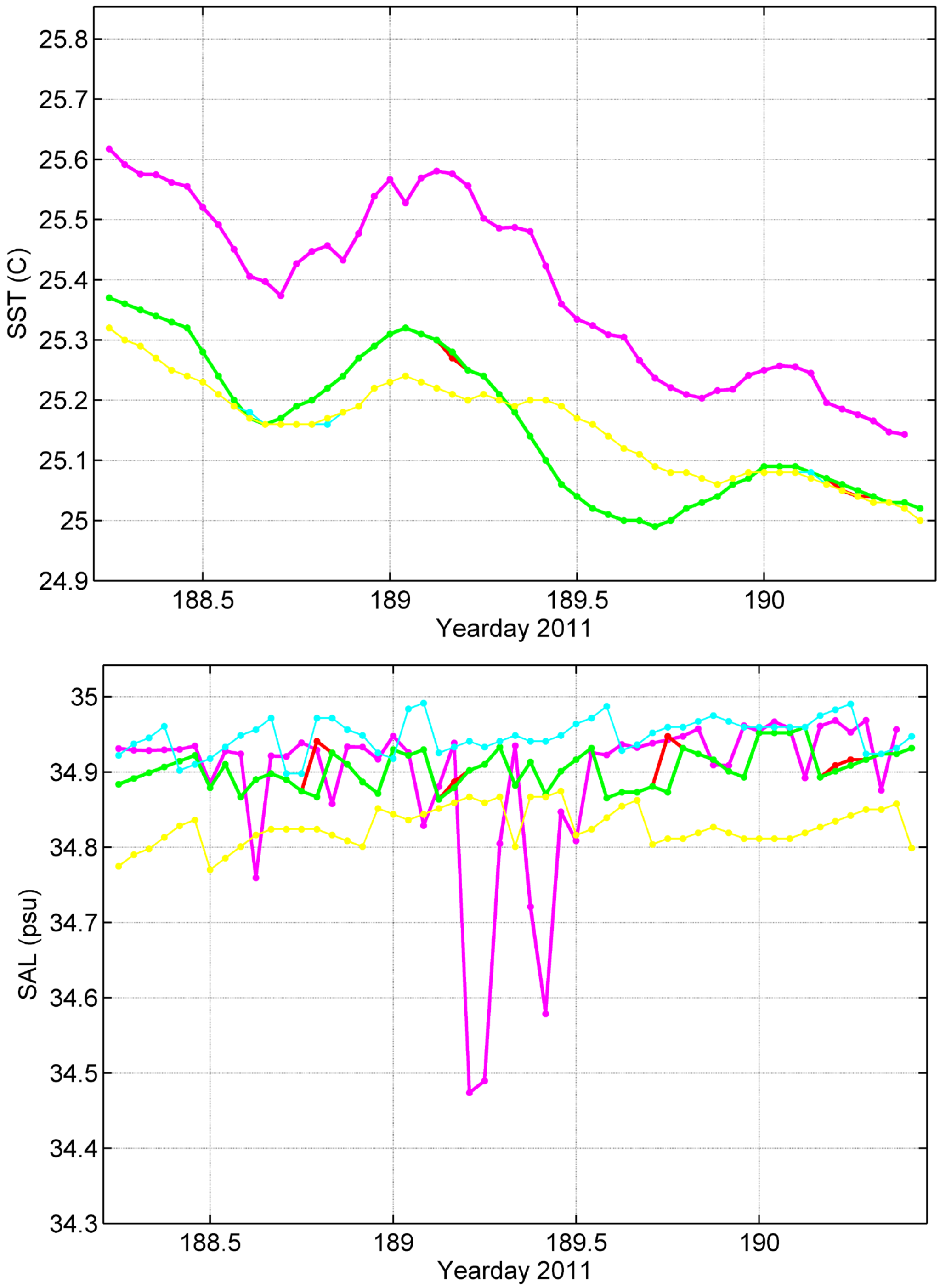


Fig. 6-10. Sea surface temperature (SST, upper) and sea surface salinity (SAL, lower) for the WHOTS-8 buoy systems (L07 and L08), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-8 intercomparison period. Data from the WHOTS-7 buoy (L09, L10) are also shown (thin lines).

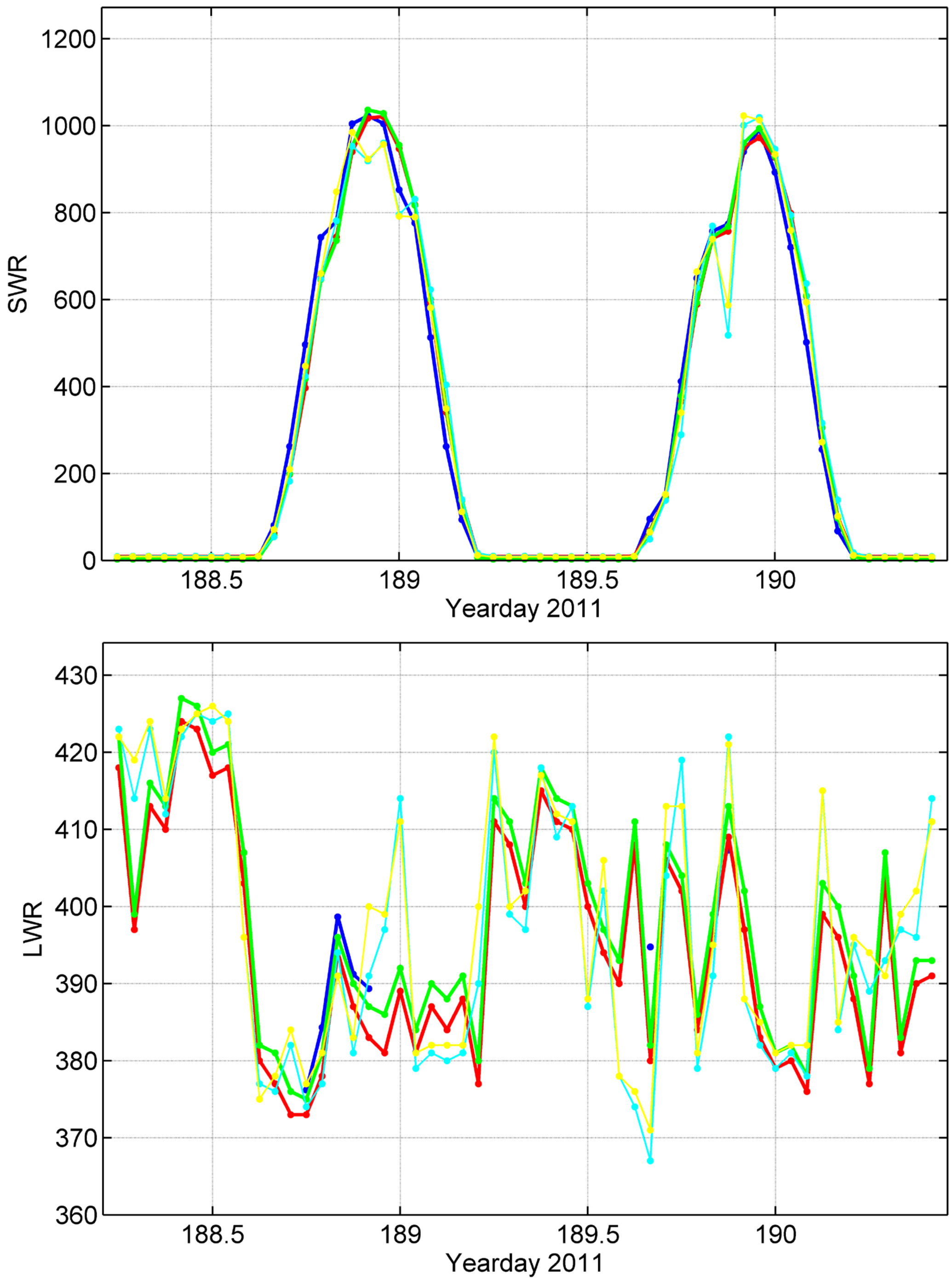


Fig. 6-11. Shortwave radiation (SWR, upper) and longwave radiation (LWR, lower) for the WHOTS-8 buoy systems (L07 and L08) and the UOP AutoIMET system (AIMET) during the WHOTS-8 intercomparison period. Data from the WHOTS-7 buoy (L09, L10) are also shown (thin lines).

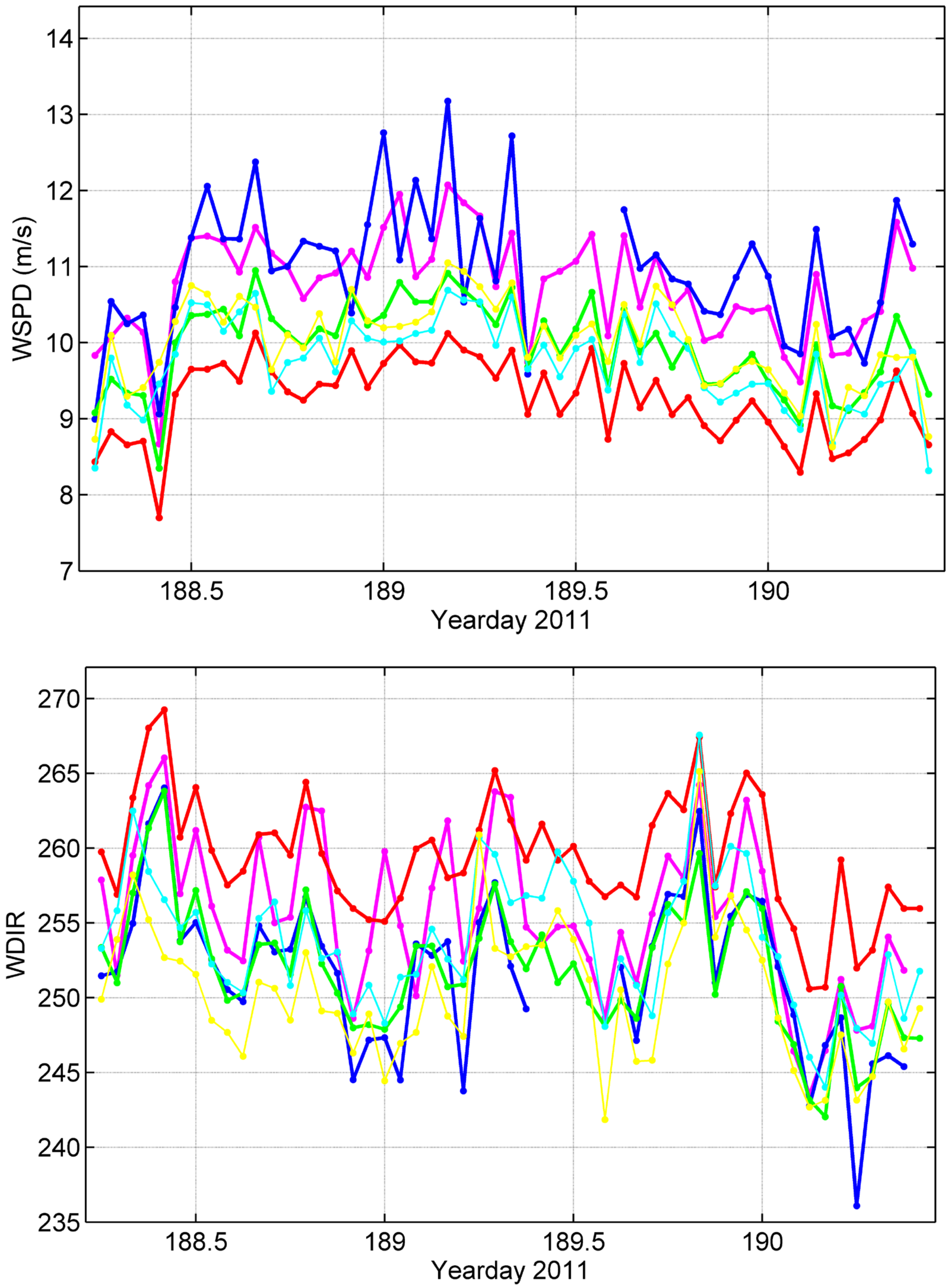


Fig. 6-12. Wind speed (WSPD, upper) and wind direction (WDIR, lower) for the WHOTS-8 buoy systems (L07 and L08), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-8 intercomparison period. Data from the WHOTS-7 buoy (L09, L10) are also shown (thin lines).

e. WHOTS-7 Intercomparison

The WHOTS-7 intercomparison period started at 1000 h UTC on 9 July (year day 190.42) when the ship established position near the WHOTS-7 buoy. The comparison continued until 1600 h UTC on 11 July (year day 192.67), when the WHOTS-7 release was fired. The total duration was 54 h. The *Hi'ialakai* drifted away from the site five times for CTD casts (0600, 1000, 1400, 1800 and 2200 local on 9 July) and had to maneuver back to a location near the buoy.

The results of the comparison are shown in Figs. 6-13 through 6-18. The buoy systems are identified in the plots by their logger numbers (L09=WHOTS-7 System 1, L10 =WHOTS-7 System 2). The AutoIMET system is designated "AIMET" and the *Hi'ialakai* shipboard sensors are designated "SCS". Although the principal comparison is intended to be the WHOTS-7 buoy vs. sensors aboard the ship, the WHOTS-8 telemetered data (obtained over the internet from the UOP website) are also included (L07=WHOTS-8 System 1, L08=WHOTS-8 System 2). The WHOTS-7 buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy) for all variables except RH and SSS. Examination of the buoy data in conjunction with the shipboard meteorology and the WHOTS-8 data provided further understanding of these discrepancies, and resulted in other useful observations about system performance, as described below.

The WHOTS-7 buoy AT pair showed a persistent difference of about 0.3°C. The AutoIMET AT showed a different pattern of variability than the buoy AT pair, sometimes in good agreement and other times reading low relative to the buoy by up to 0.6°C. Shipboard AT offsets of about -0.2°C relative to the buoys have been seen in previous comparisons, and attributed to vertical gradients. Contributing factors to the larger discrepancies in this case may be the AutoIMET mounting location and the fact that the ship was at a variety of distances from the buoy and at a variety of headings while maneuvering for CTD casts. The buoy AT values were closer to those from WHOTS-8 than to the AutoIMET, and L10 was closer to the WHOTS-8 values than L09. Considering these factors, it was concluded that WHOTS-7 L10 AT was within expected accuracy while L09 had a high bias of about 0.23°C. Note that the SCS AT was about 1.5 °C higher than the buoy AT and considered unreliable.

The WHOTS-7 buoy RH pair showed persistent differences of about 5%, with L09 reading low relative to L10. The AutoIMET and SCS RH were within about 2%, and were consistently lower than the buoy values. WHOTS-7 L09 was close to the AIMET and SCS values, while L10 was close to the WHOTS-8 buoy values. Considering the increased height of the SCS and AIMET sensors, it was concluded that WHOTS-7 L10 RH was within expected accuracy while L09 had a low bias of about 5%.

The WHOTS-7 buoy BP pair agreed within the 1.0 mb resolution of the telemetered data. Adjusting the AutoIMET BP by +1.2 mb, to account for the buoy at 3 m vs. the AutoIMET at 14 m, resulted in good agreement with the buoy BP (within 0.5 mb). The adjusted SCS BP disagreed with buoy and AutoIMET BP, and also showed significantly larger semidiurnal fluctuations. It was concluded that buoy and AutoIMET BP were operating as expected while the ship's BP was not reliable.

None of the three PRC sensors indicated rain during the intercomparison period. The buoy fill levels were between 40 and 50 mm while the AutoIMET fill level was near 17 mm. The fill levels of the WHOTS-8 PRC sensors were near zero.

The buoy SST pair agreed to within the 0.01°C resolution of the telemetered data. Differences of order 0.05°C between WHOTS-7 and WHOTS-8 SST were attributed to horizontal gradients. The SCS (bow intake) SST was about 0.15°C higher than the buoy pair and was assumed to have a bias error. The buoy salinity showed a persistent difference of about 0.08 PSU, with L10 reading low relative to L09. The SCS salinity agreed reasonably well (0.02-0.04 PSU) with the buoy salinity, but showed less variability. The L09 salinity was close to that of the WHOTS-8 buoy pair, whereas L10 was significantly lower. It was concluded that WHOTS-7 L09 salinity was within expected accuracy while L10 had a low bias of about 0.08 PSU. Note that the SCS salinity showed a few "drop-outs", presumably due to bubbles.

The buoy SWR pair agreed to within 10-20 W/m^2 at mid-day, or < 2% of the 1020 W/m^2 mid-day peak. The AutoIMET SWR was within 10-20 W/m^2 of the buoy pair at mid day, but showed an offset indicative of a timing error. The buoy LWR pair typically agreed to within 5 W/m^2. The AutoIMET LWR was intermittent for reasons that were not diagnosed during the cruise. When available, the AutoIMET LWR was within a few W/m^2 of the buoy pair. It was concluded that both SWR and LWR on the WHOTS-7 buoy were within expected accuracy.

The buoy WND pair agreed to within 0.2 m/s, or 3% for 7.5 m/s winds, near the expected errors of ~0.1 m/s or 2%. AutoIMET and SCS winds were similar to each other and about 0.5 m/s higher than the buoy pair (note that no correction was made for the ~10 m ht difference). It was concluded that WHOTS-7 wind speeds were within expected accuracy.

The WHOTS-7 buoy WND agreed to within about 4°. The AutoIMET and SCS directions were within within 2°- 3° of the buoy directions during the second half of the comparison period (when the ship was not maneuvering for CTD casts). It was concluded that WHOTS-7 wind directions were within expected accuracy.

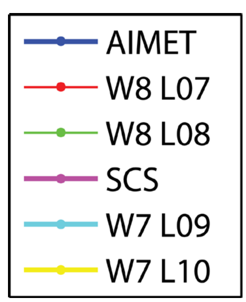
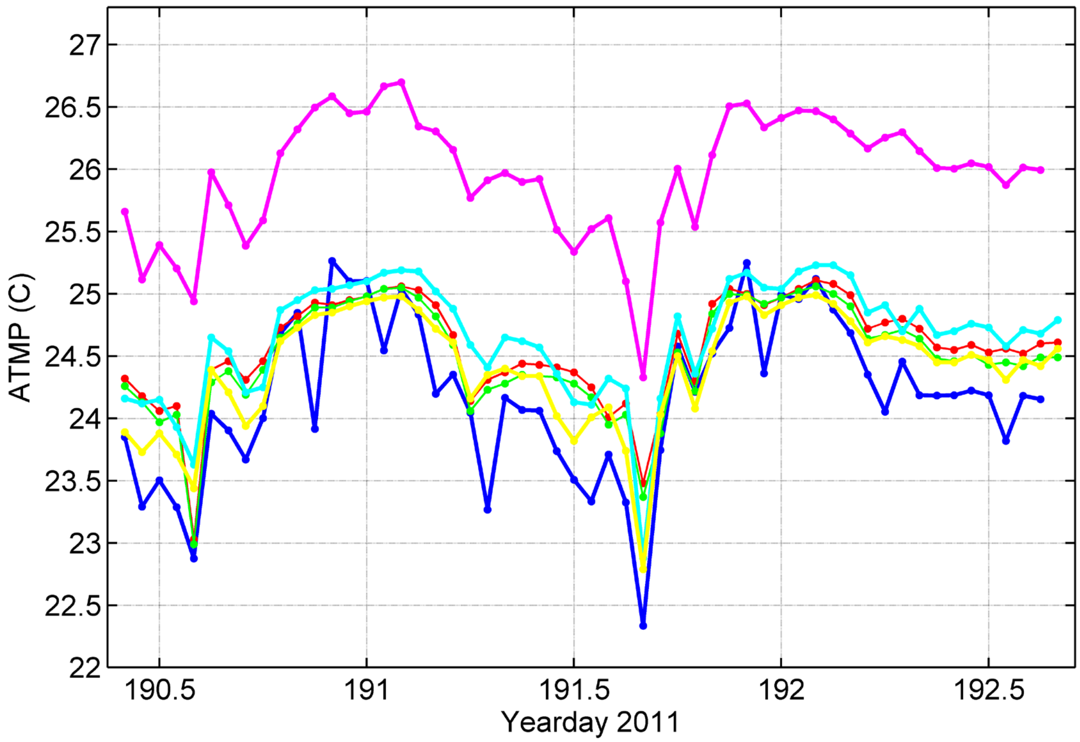


Fig. 6-13: Legend for WHOTS-7 intercomparison plots.



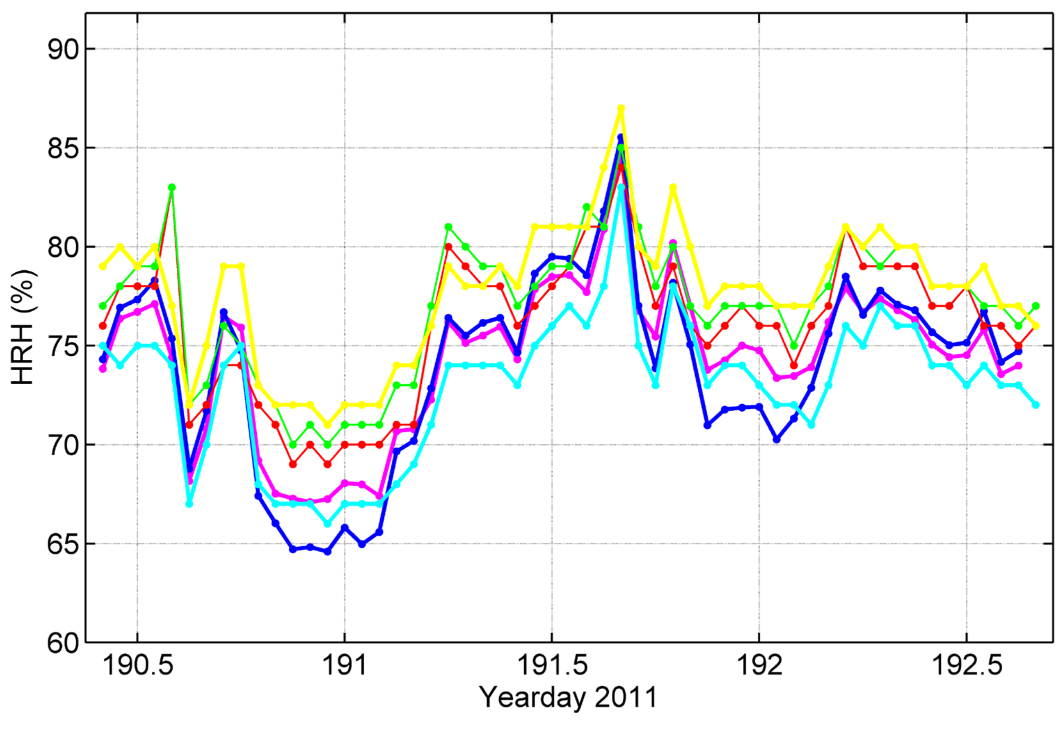


Fig. 6-14. Air temperature (ATMP, upper) and relative humidity (HRH, lower) for the WHOTS-7 buoy systems (L09 and L10), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-7 intercomparison period. Data from the WHOTS-8 buoy (L07, L08) are also shown (thin lines).

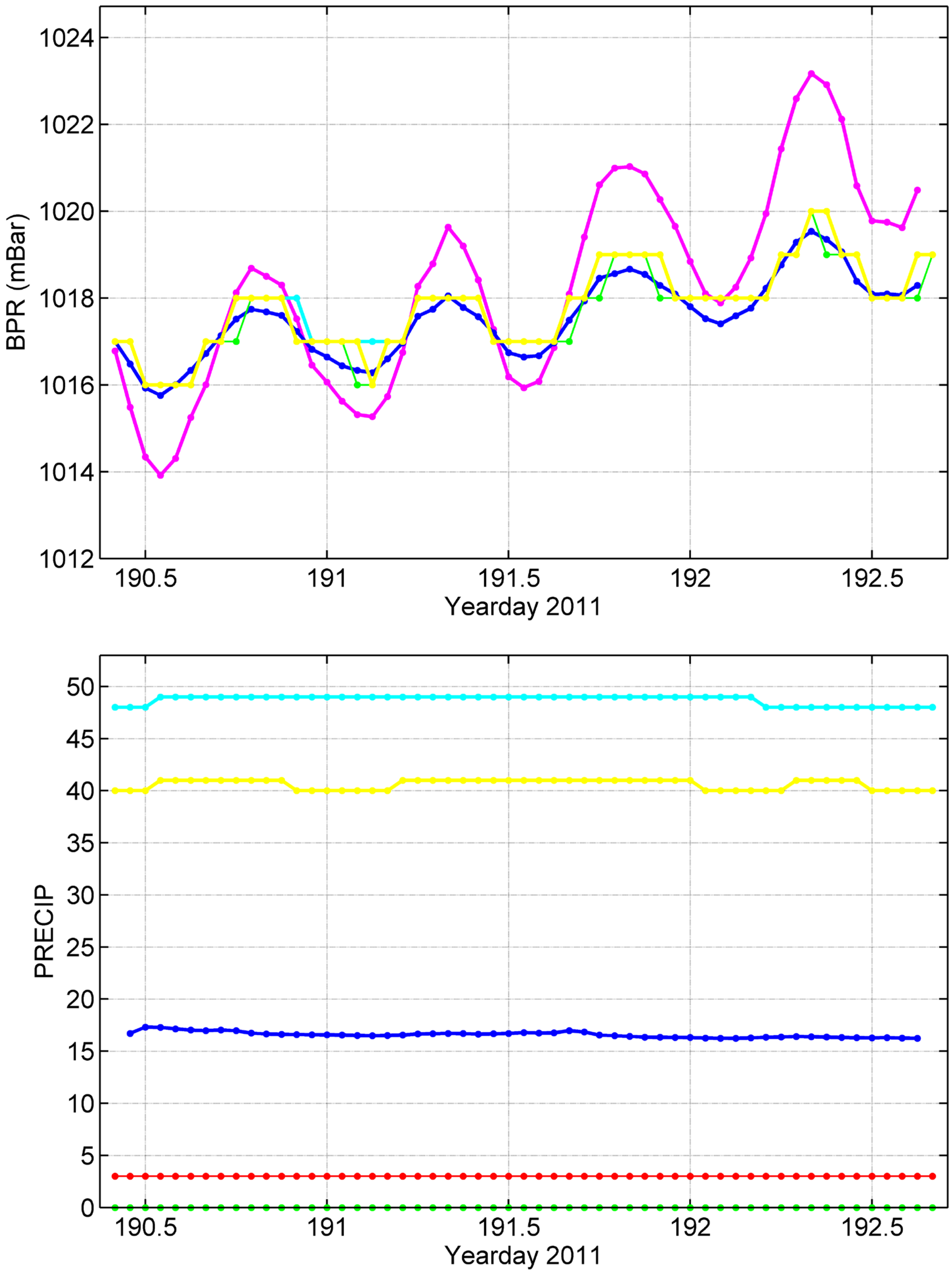


Fig. 6-15. Barometric pressure (BP, upper) and precipitation level (PRECIP, lower) for the WHOTS-7 buoy systems (L09 and L10), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-7 intercomparison period. Data from the WHOTS-8 buoy (L07, L08) are also shown (thin lines).

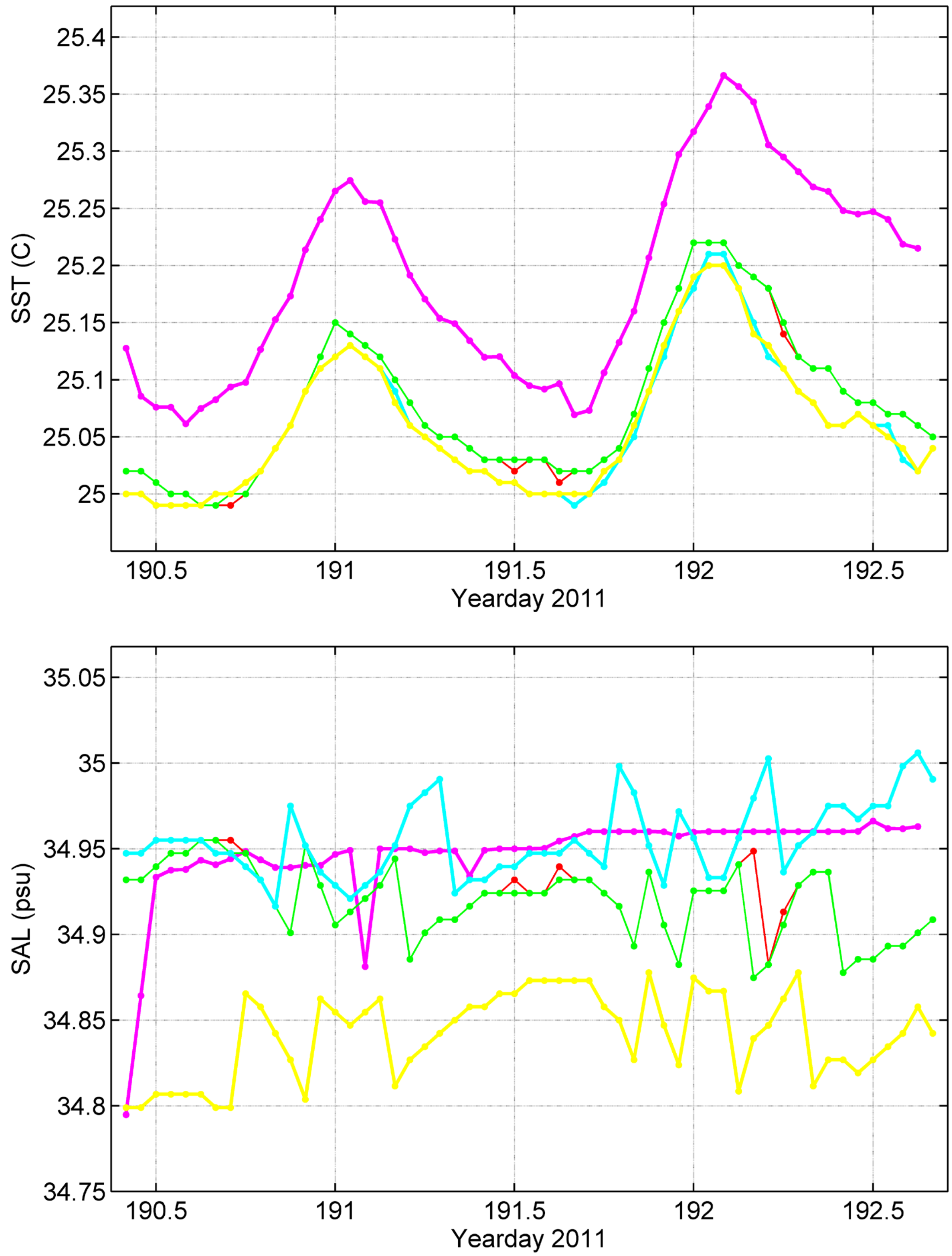


Fig. 6-16. Sea surface temperature (SST, upper) and sea surface salinity (SAL, lower) for the WHOTS-7 buoy systems (L09 and L10), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-7 intercomparison period. Data from the WHOTS-8 buoy (L07, L08) are also shown (thin lines).

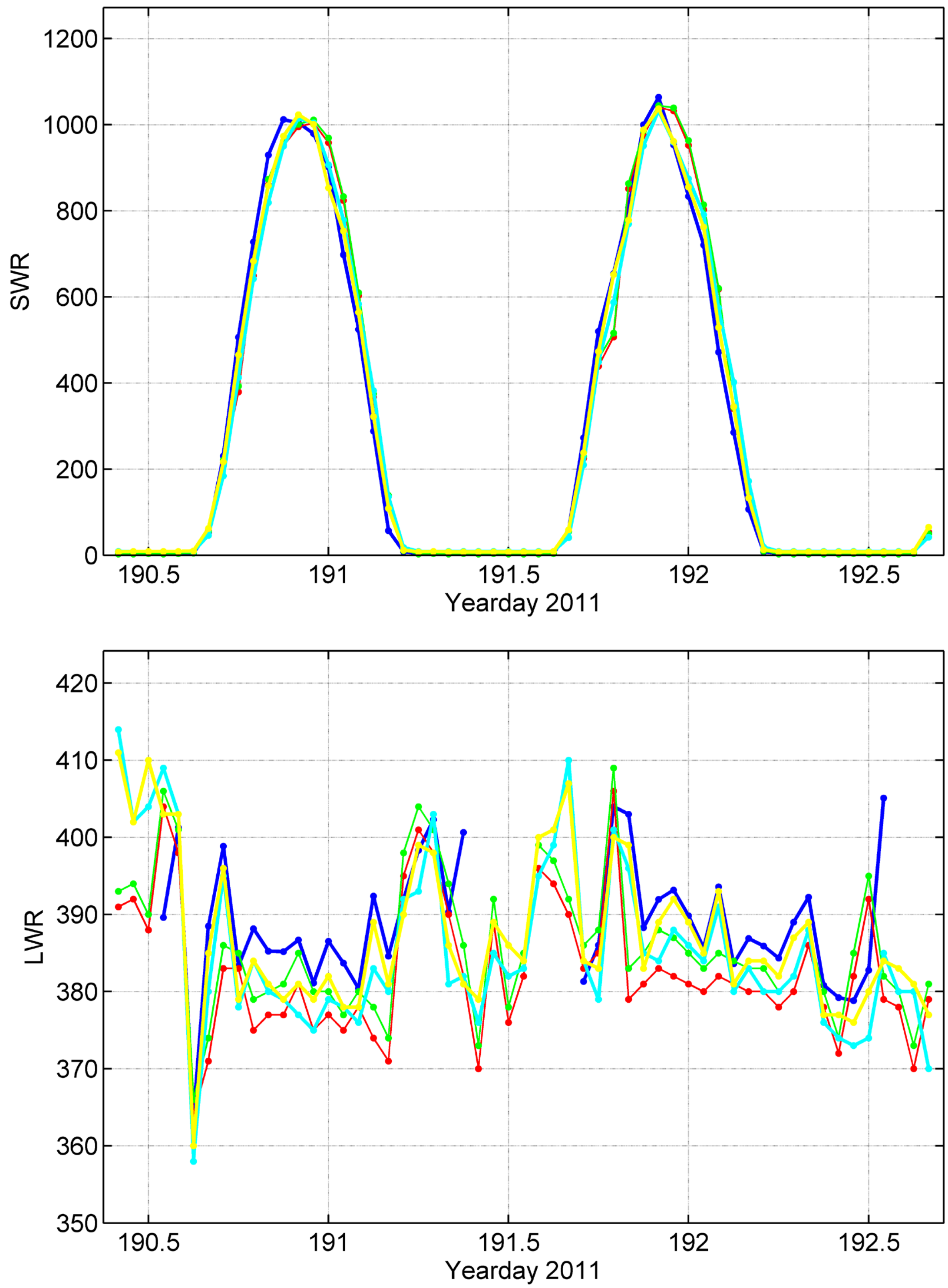


Fig. 6-17. Shortwave radiation (SWR, upper) and longwave radiation (LWR, lower) for the WHOTS-7 buoy systems (L09 and L10) and the UOP AutoIMET system (AIMET) during the WHOTS-7 intercomparison period. Data from the WHOTS-8 buoy (L07, L08) are also shown (thin lines).

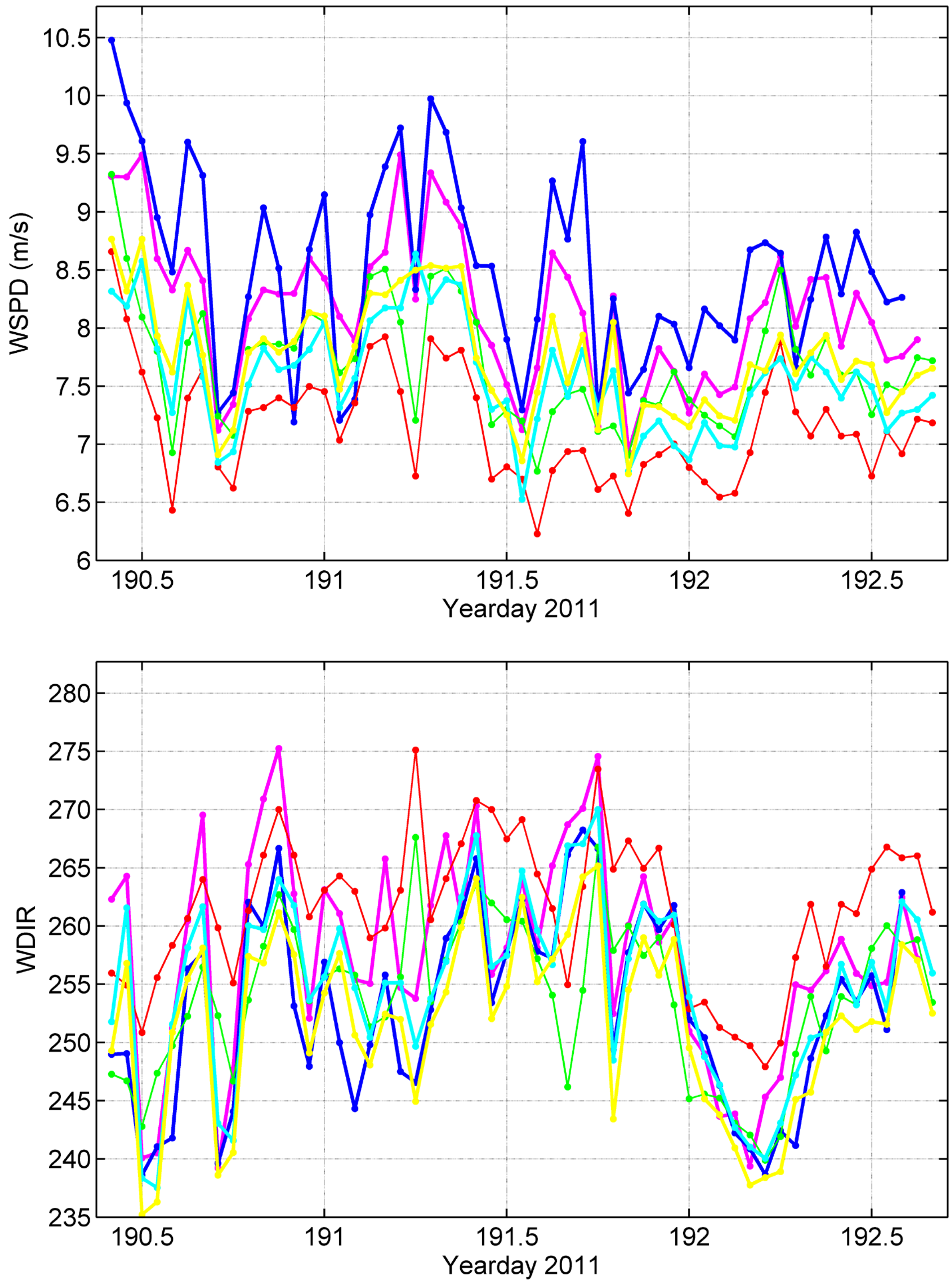


Fig. 6-18. Wind speed (WSPD, upper) and wind direction (WDIR, lower) for the WHOTS-7 buoy systems (L09 and L10), the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the WHOTS-7 intercomparison period. Data from the WHOTS-8 buoy (L07, L08) are also shown (thin lines).

7. Shipboard Sampling

a. CTD Casts

UH provided CTD and water sampling equipment, including a Seabird 9/11+ CTD sampling pressure, dual temperature, dual conductivity and dual oxygen sensors at 24 Hz. Seabird sensors used by UH routinely as part of the Hawaii Ocean Time-series were used to more easily tie the WHOTS cruise data into the HOT CTD dataset. The CTD was installed inside a twelve-place General Oceanics rosette with six 5-liter Niskin sampling bottles controlled by a Seabird carousel.

Eleven CTD casts were conducted from July 6 – 10 at station 50 (near the WHOTS-7 buoy), station 52 (near the WHOTS-8 buoy) and at a test station. CTD summary data, including the date, time, location and maximum depth of each cast, are shown in Table 7-1. Profiles of CTD data for each cast are presented in Appendix A.

Station/cast	Date	Time (UTC)	Location	Maximum pressure (dbar)
Test	7/6/11	06:05	21° 27.98′ N, 158° 20.70′ W	1020
52 / 1	7/7/11	16:07	22° 40.57′ N, 157° 58.97′ W	500
52 / 2	7/7/11	19:36	22° 40.65′ N, 157° 59.03′ W	500
52 / 3	7/7/11	23:45	22° 40.88′ N, 157° 59.14′ W	500
52 / 4	7/8/11	03:50	22° 40.93′ N, 157° 59.14′ W	500
52 / 5	7/8/11	07:31	22° 40.49′ N, 157° 59.66′ W	500
50 / 1	7/9/11	15:43	22° 46.56′ N, 157° 55.95′ W	500
50 / 2	7/9/11	19:37	22° 46.57′ N, 157° 56.01′ W	500
50 / 3	7/9/11	23:36	22° 47.00′ N, 157° 55.87′ W	500
50 / 4	7/10/11	03:42	22° 47.00′ N, 157° 55.66′ W	500
50 / 5	7/10/11	07:32	22° 46.84′ N, 157° 55.90′ W	1020
51 / 1	7/12/11	16:15	22° 47.85′ N, 157° 49.96′ W	1020
50 / 6	7/12/11	18:06	22° 46.90′ N, 157° 56.09′ W	1020
2 / 1	7/12/11	19:47	22° 44.95′ N, 158° 00.00′ W	1020
52 / 6	7/12/11	21:46	22° 40.97′ N, 157° 59.02′ W	1020
53 / 1	7/12/11	23:53	22° 40.02′ N, 158° 05.04′ W	1020

Table 7-1. CTD stations occupied during the WHOTS-8 cruise.

Ten CTD casts were conducted to obtain profiles for comparison with WHOTS mooring data. Five casts were conducted near the WHOTS-7 mooring before recovery, and five casts were conducted near the WHOTS-8 mooring after deployment. These were sited approximately 200 to 500 m from the buoys. The comparison casts consisted of 4 yo-yo cycles between 10 dbar and 200 dbar and then to 500 dbar (5th yo-yo cycle of each cast) except for the last cast at station 50 which went to 1000 dbar. Station numbers were assigned following the convention used during HOT cruises.

Five additional CTD casts were conducted on July 12th as part of a survey through an anti-cyclonic eddy that had been monitored during the cruise while on station. The survey utilized five stations (Fig. 7-1). Station 51 was located northeast of the WHOTS mooring sites in an attempt to assess the center of the eddy. Station 53 was located southwest of the WHOTS mooring sites to assess the area outside of the eddy. Station 2 is the center of Station ALOHA; the primary site for HOT cruise work and will be reoccupied by a HOT cruise on July 19th. Stations 50 and 52 were the same sites used for the comparison work conducted July 7-10 and provided an opportunity for a temporal comparison of both the eddy and subsurface instruments on the WHOTS-8 mooring. All CTD casts conducted as part of the eddy survey were to 1000 meters.

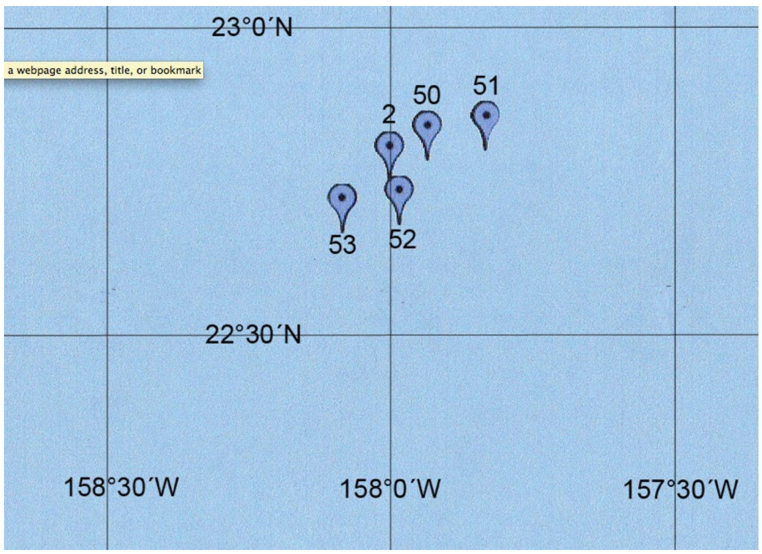


Figure 7-1. General map of hydrographic survey on 12 July 2011.

Water samples were taken from all casts; 4-5 samples for both the 500 dbar and 1000 dbar casts. These samples will be analyzed for salinity and used to calibrate the CTD conductivity sensors.

b. Thermosalinograph

R/V *Hi'ialakai* has an underway seawater system that includes an internal Seabird Seacat thermosalinograph (TSG) model SBE-21, with an SBE-38 external temperature sensor. Thermosalinograph data and calibration information will be received from the Survey Technician following the cruise.

c. Shipboard ADCPs

R/V *Hi'ialakai* ADCP data will be received from the Survey Technician following the cruise.

Acknowledgments

The Captain and crew of the Hi'ialakai were flexible in accommodating the science mission, and exhibited a high degree of professionalism throughout the cruise. Nan Galbraith and Frank Bahr provided shore support for real-time Argos and AutoIMET logging. 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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Whelan, S.P., R.A. Weller, R. Lukas, F. Bradley, J. Lord, J. Smith, F. Bahr and P. Lethaby and J. Snyder, 2007. WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-3 Mooring Turnaround Cruise Report. *Woods Hole Oceanogr. Inst. Tech. Rep.,* WHOI-2007-03, 103 pp.

Whelan, S. P., A. Plueddemann, R. Lukas, J. Lord, P. Lethaby, J. Snyder, J. Smith, F. Bahr, N. Galbraith, and C. Sabine, 2008. WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-4 2007 Mooring Turnaround Cruise Report. *Woods Hole Oceanogr. Inst. Tech. Rep.*, WHOI-2008-04, 112 pp.

Whelan, S.P., J. Lord, R. Weller, R. Lukas, F. Santiago-Mandujano, J. Snyder, P. Lethaby, F. Bahr, C. Sabine, J. Smith, P. Bouchard and N. Galbraith, 2009. WHOI Hawaii Ocean Timeseries Stations (WHOTS): WHOTS-5 2008 Mooring Turnaround Cruise Report, *Woods Hole Oceanogr. Inst. Tech. Rep.*, WHOI-2009-04, 86 pp.

Whelan, S.P., F. Santiago-Mandujano, F. Bradley, A. Plueddemann, L. Barista, J. Ryder, R. Lukas, P. Lethaby, J. Snyder, C. Sabine, D. Stanitski, A. Rapp, C. Fairall, S. Pezoa, N. Galbraith, J. Lord, and F. Bahr, 2010. WHOI Hawaii Ocean Timeseries Station (WHOTS) : WHOTS-6 2009 Mooring Turnaround Cruise Report, *Woods Hole Oceanogr. Inst. Tech. Rep*., WHOI-2010-02, 107 pp.

Whelan, S.P., C. Nosse, P. Lethaby, J. Snyder, R. Lukas, R.A. Weller, W.M. Ostrom, and J.C. Smith, 2011. WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-7 2010 Mooring Turnaround Cruise Report, *Woods Hole Oceanogr. Inst. Tech. Rep*., WHOI-2011-01, 146 pp.

Appendix A: Moored C-T Time Series

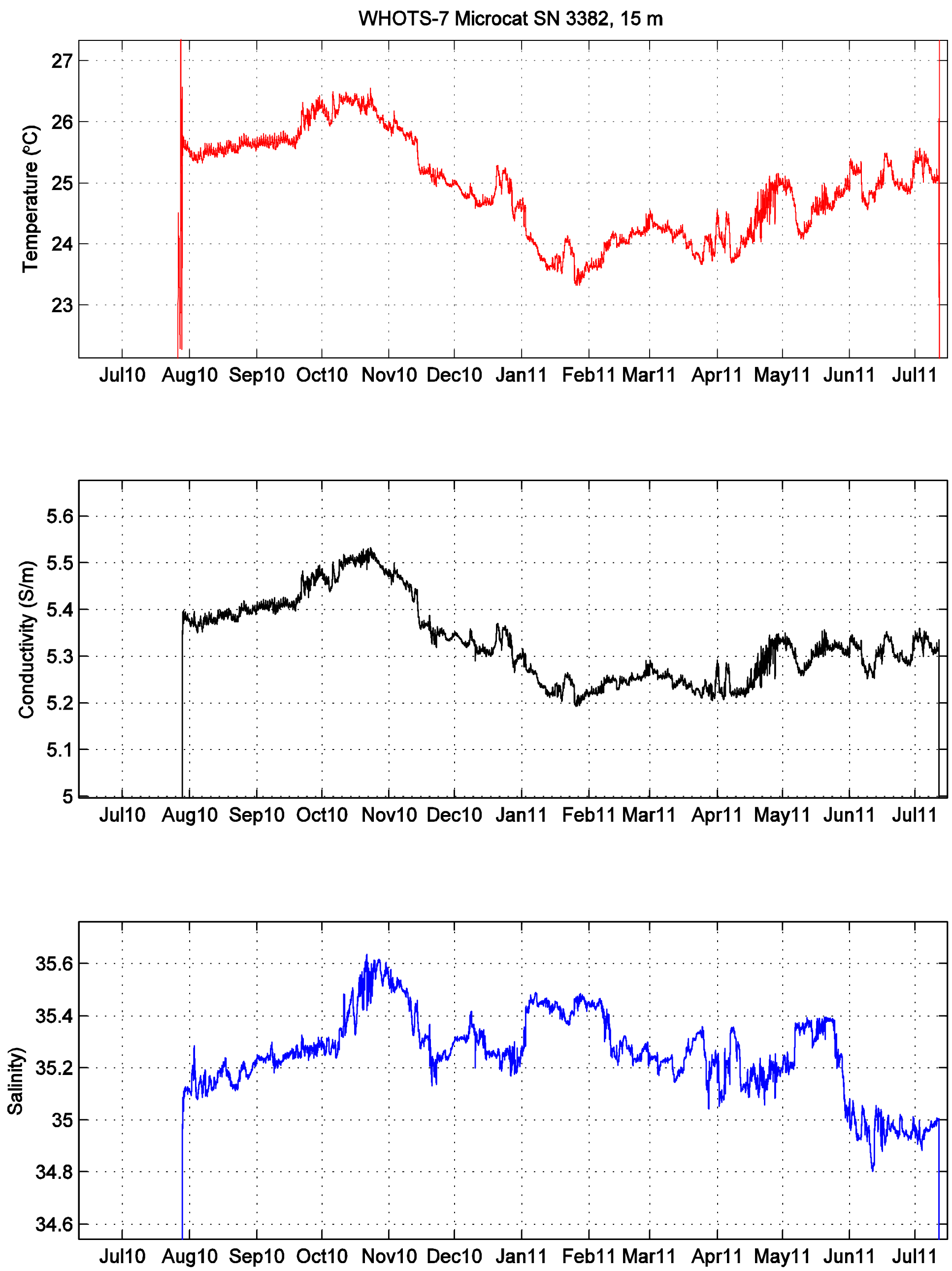


Figure A-1. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3382 deployed at 15 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

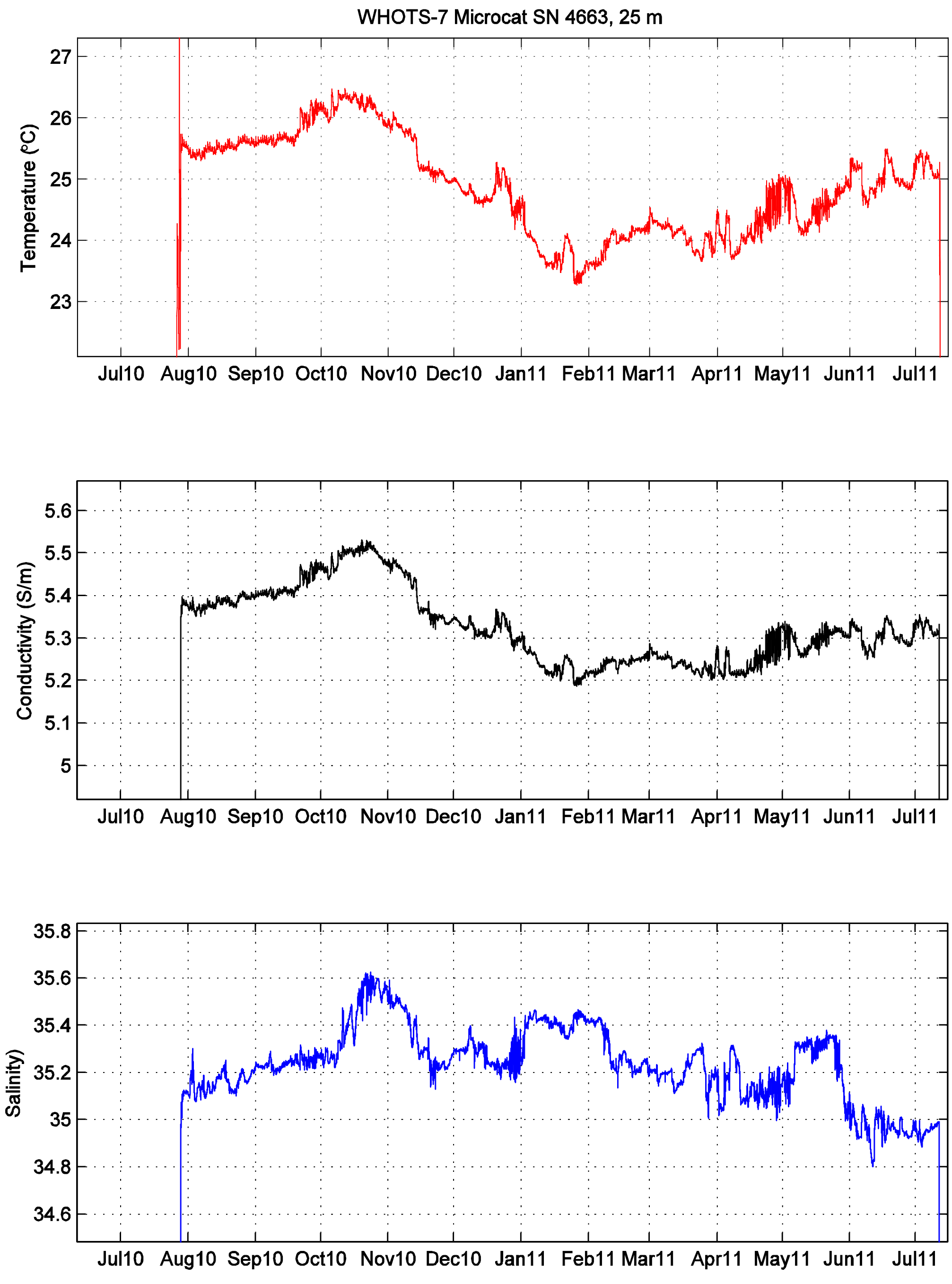


Figure A-2. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 4663 deployed at 25 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

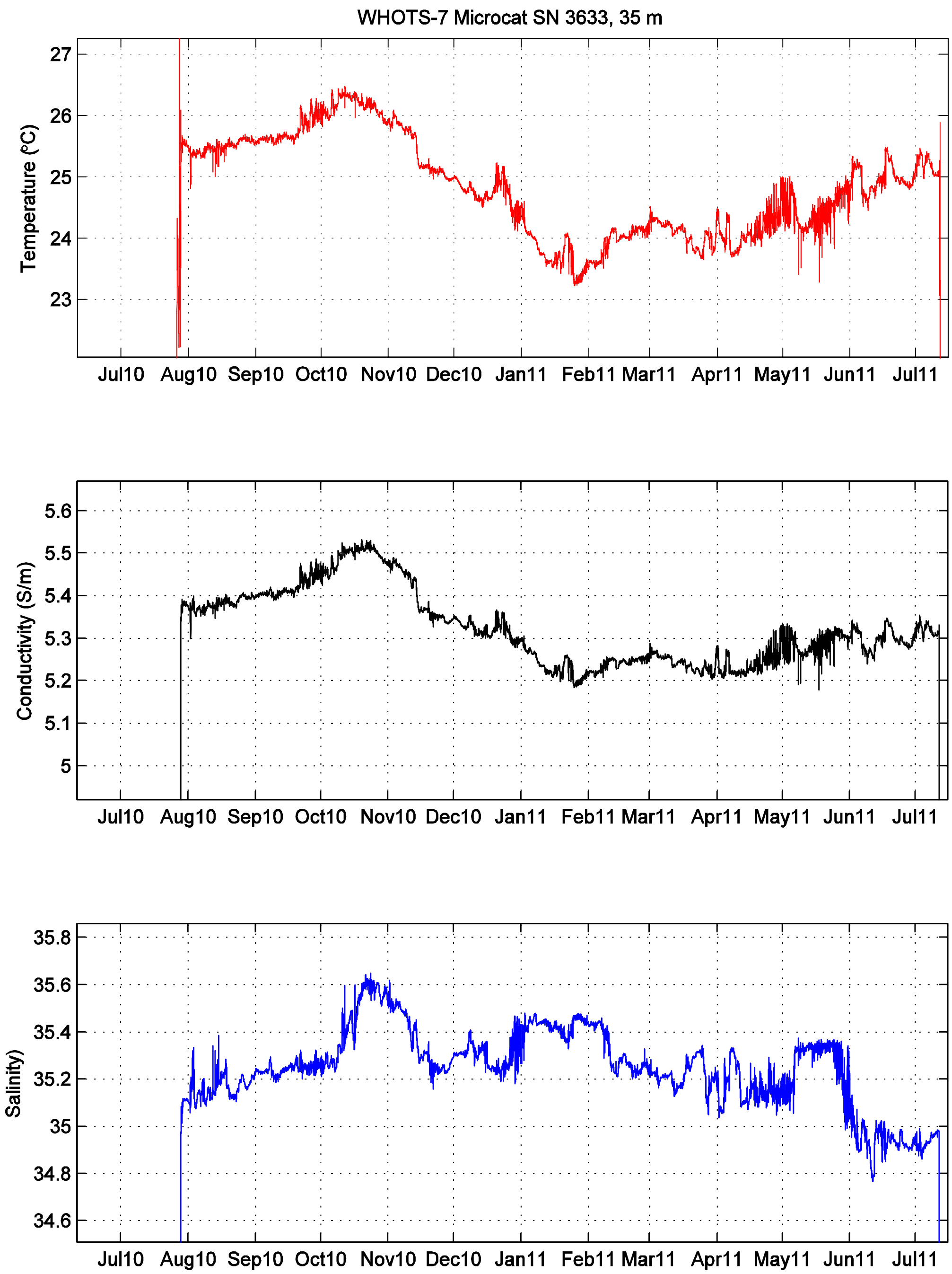


Figure A-3. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3633 deployed at 35 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

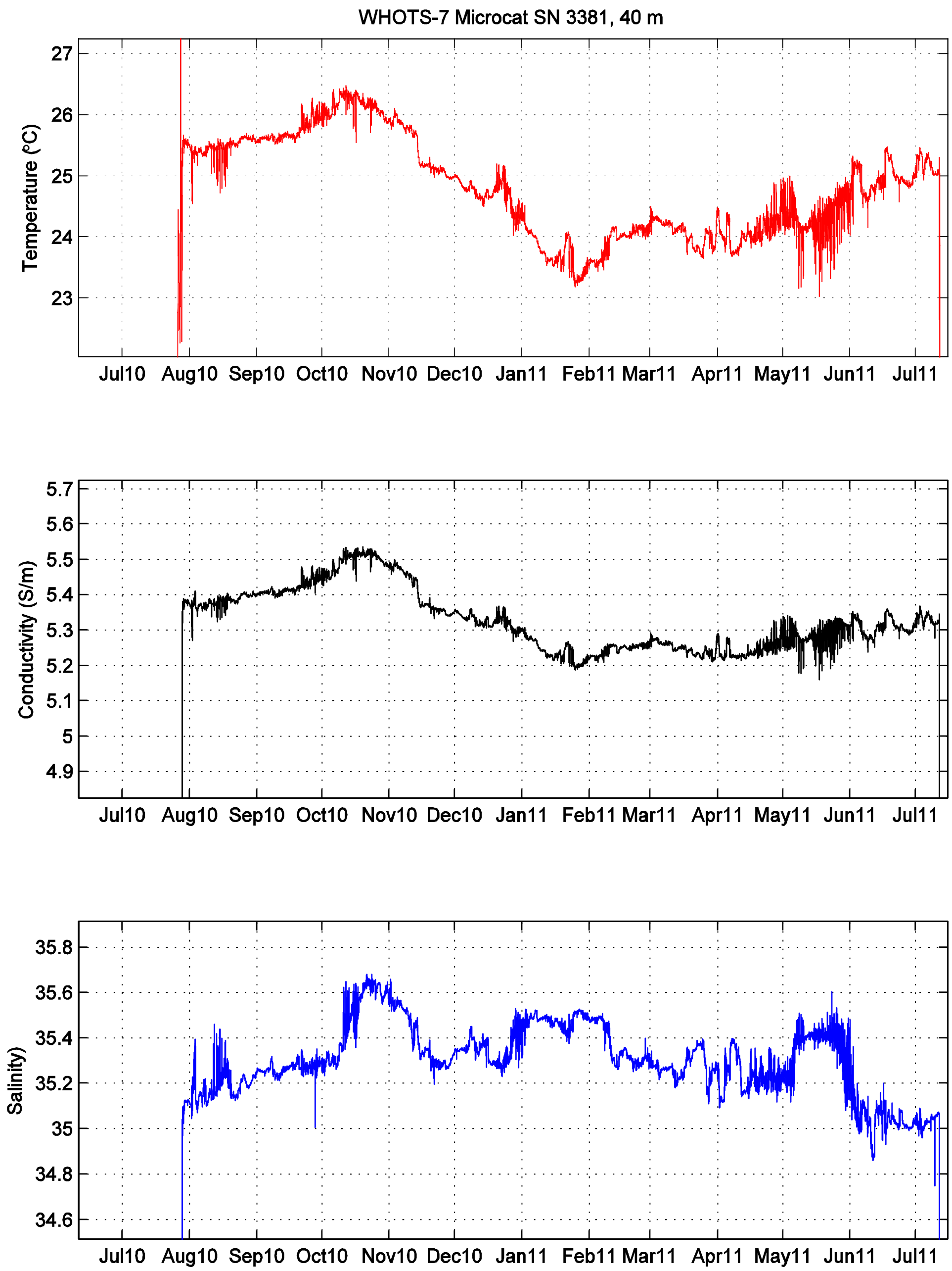


Figure A-4. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3381 deployed at 40 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

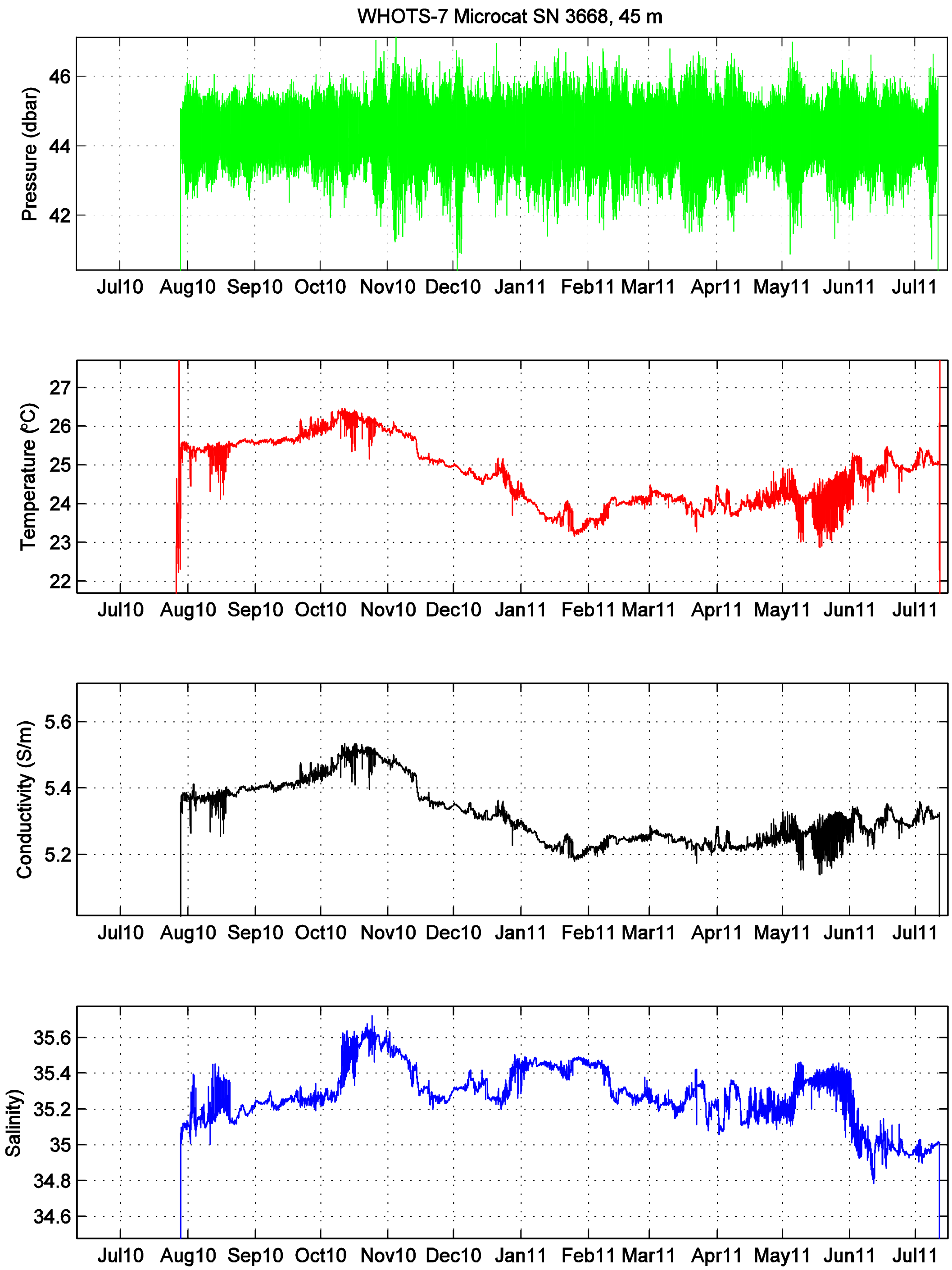


Figure A-5. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 3668 deployed at 45 m on the WHOTS-7 mooring.

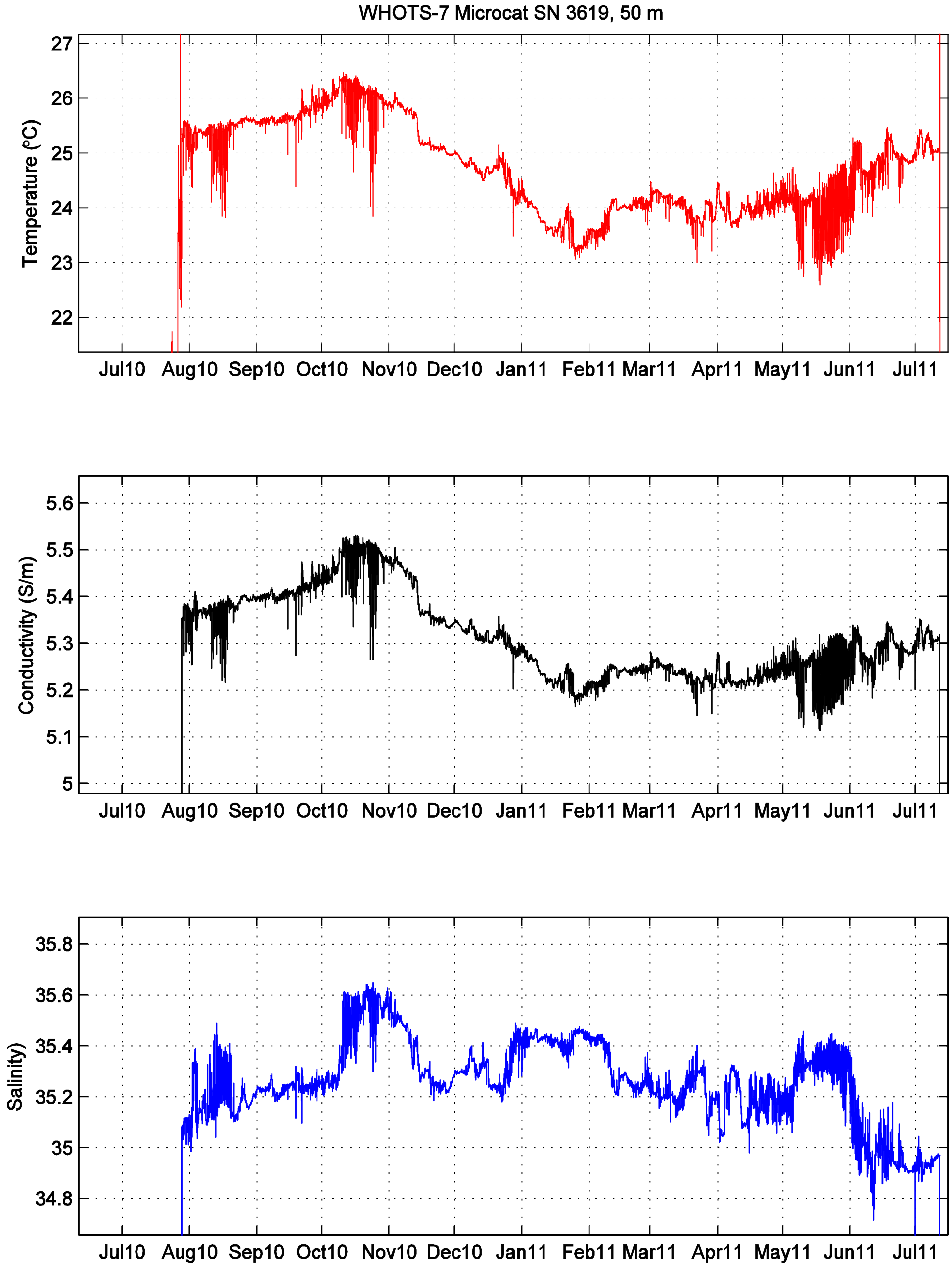


Figure A-6. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3619 deployed at 50 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

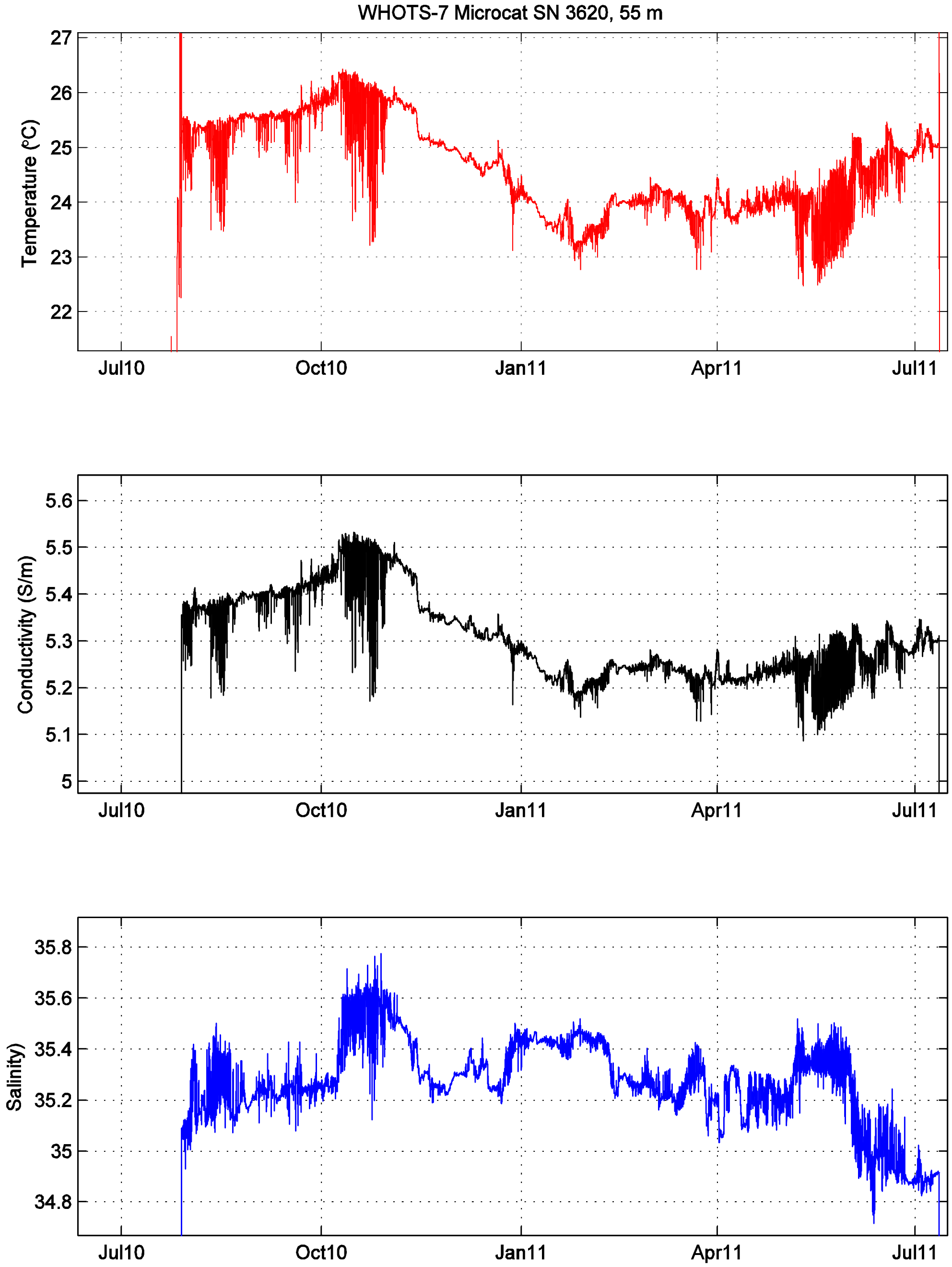


Figure A-7. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3620 deployed at 55 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

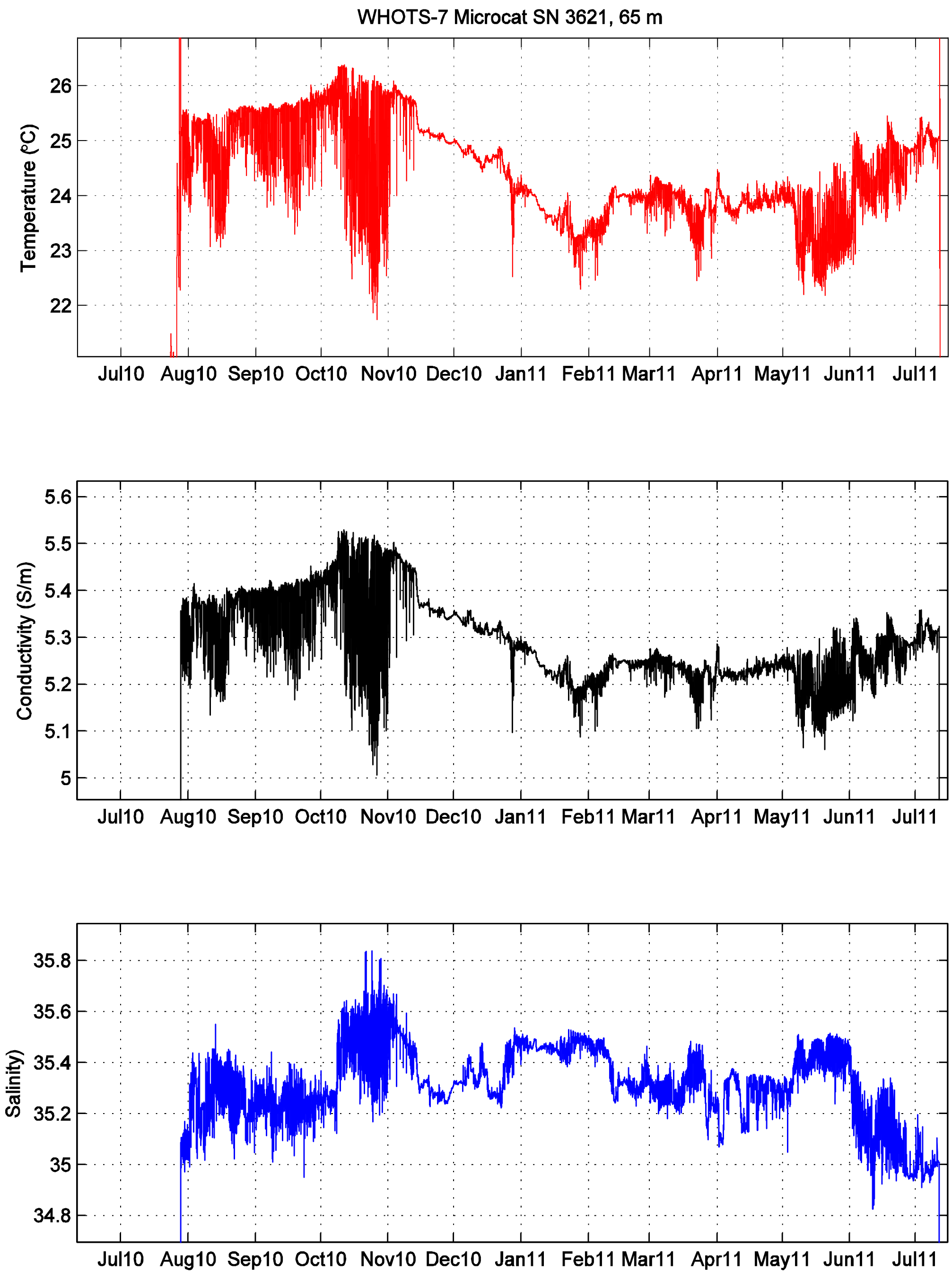


Figure A-8. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3621 deployed at 65 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

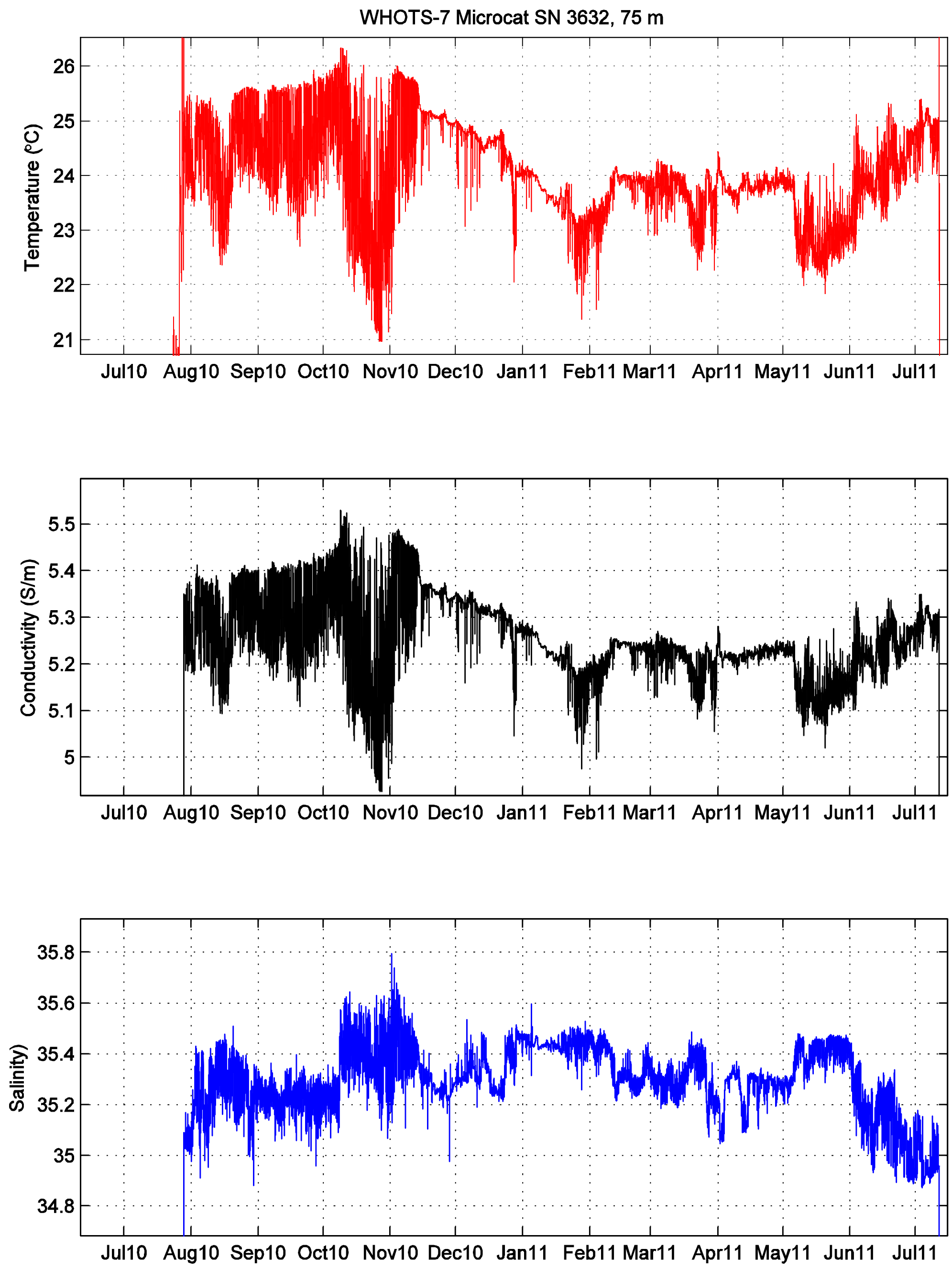


Figure A-9. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3632 deployed at 75 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

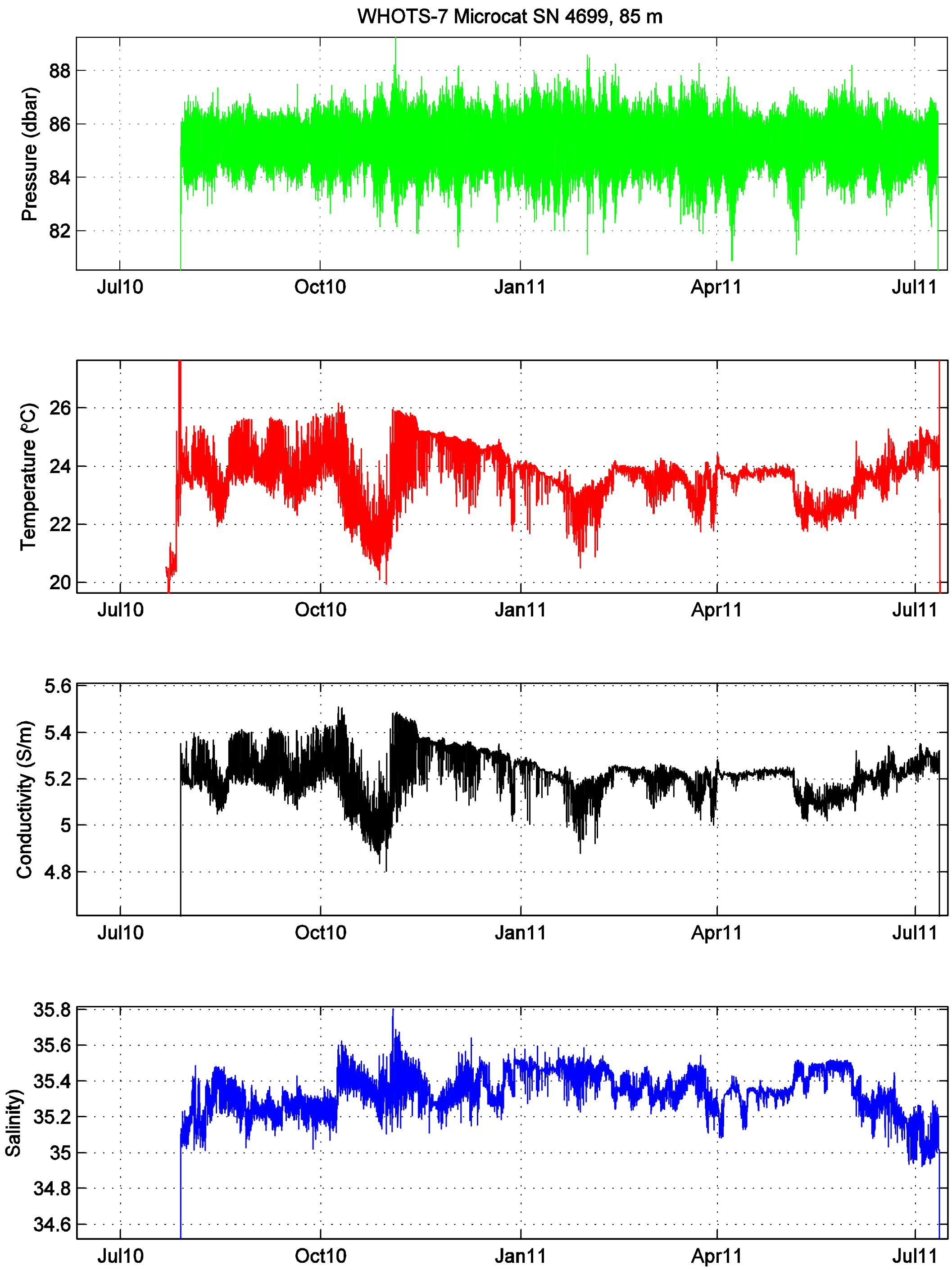


Figure A-10. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4699 deployed at 85 m on the WHOTS-7 mooring.

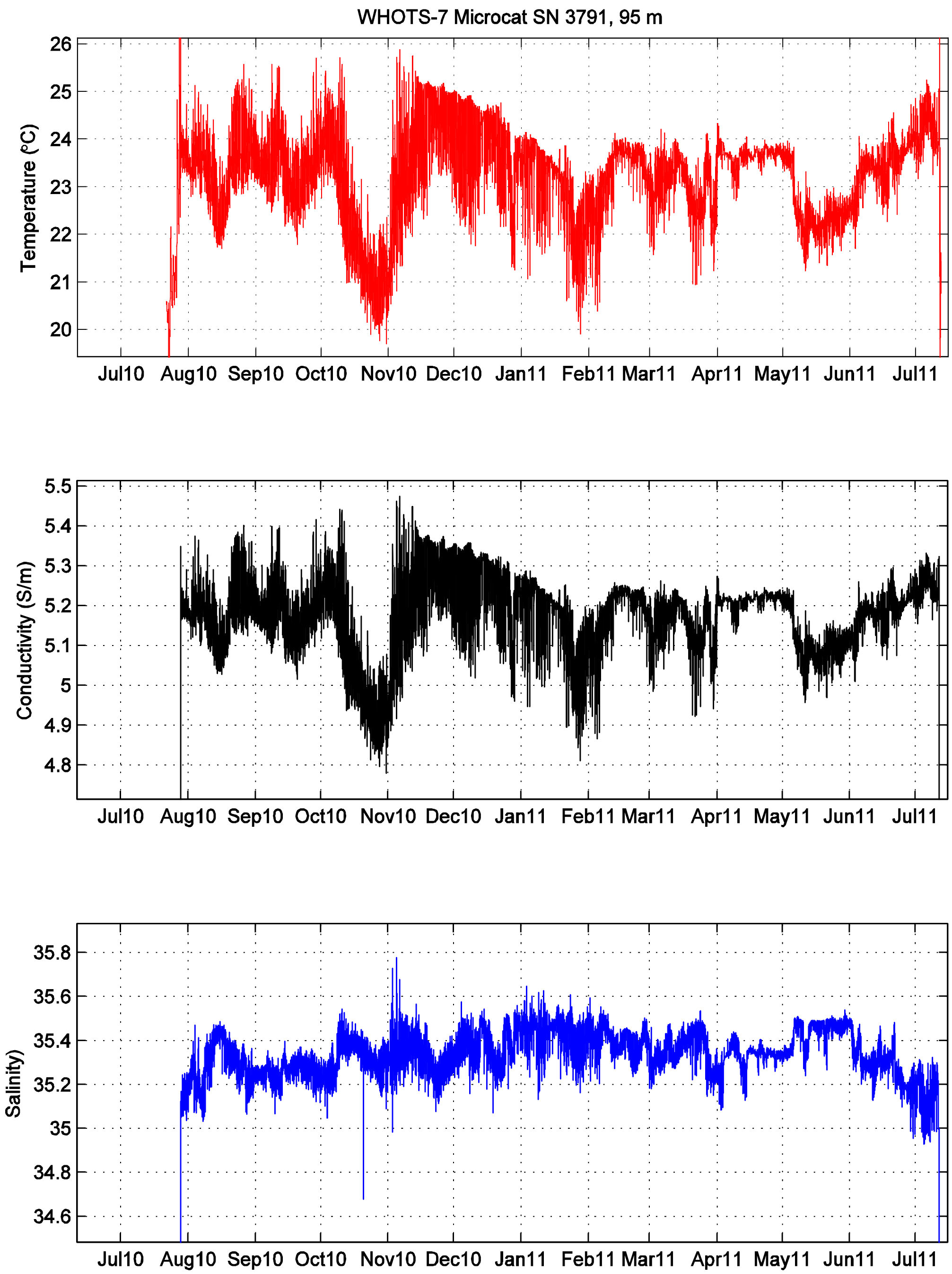


Figure A-11. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3791 deployed at 95 m on the WHOTS-7 mooring. Nominal pressure was used to calculate salinity.

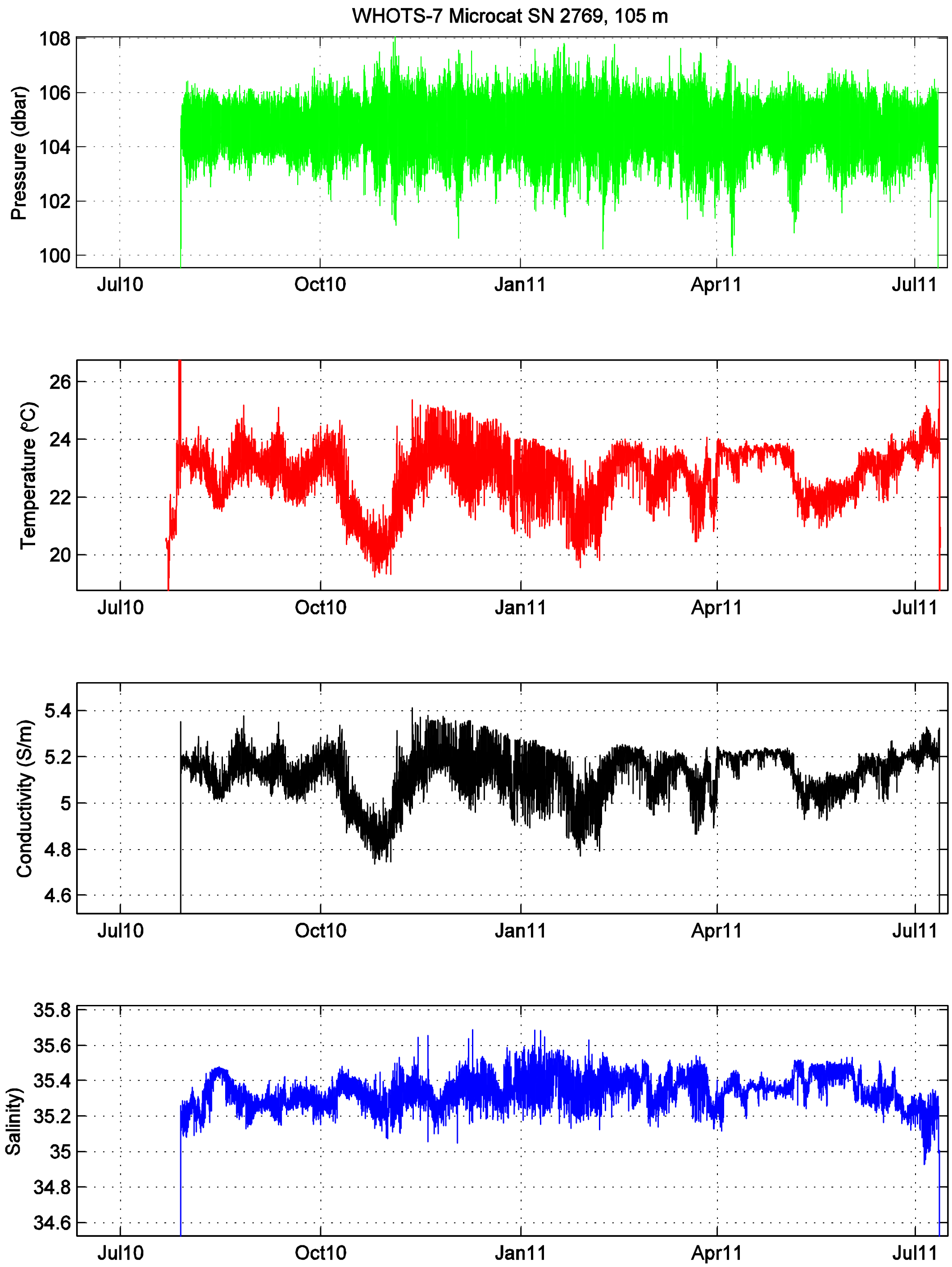


Figure A-12. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 2769 deployed at 105 m on the WHOTS-7 mooring.

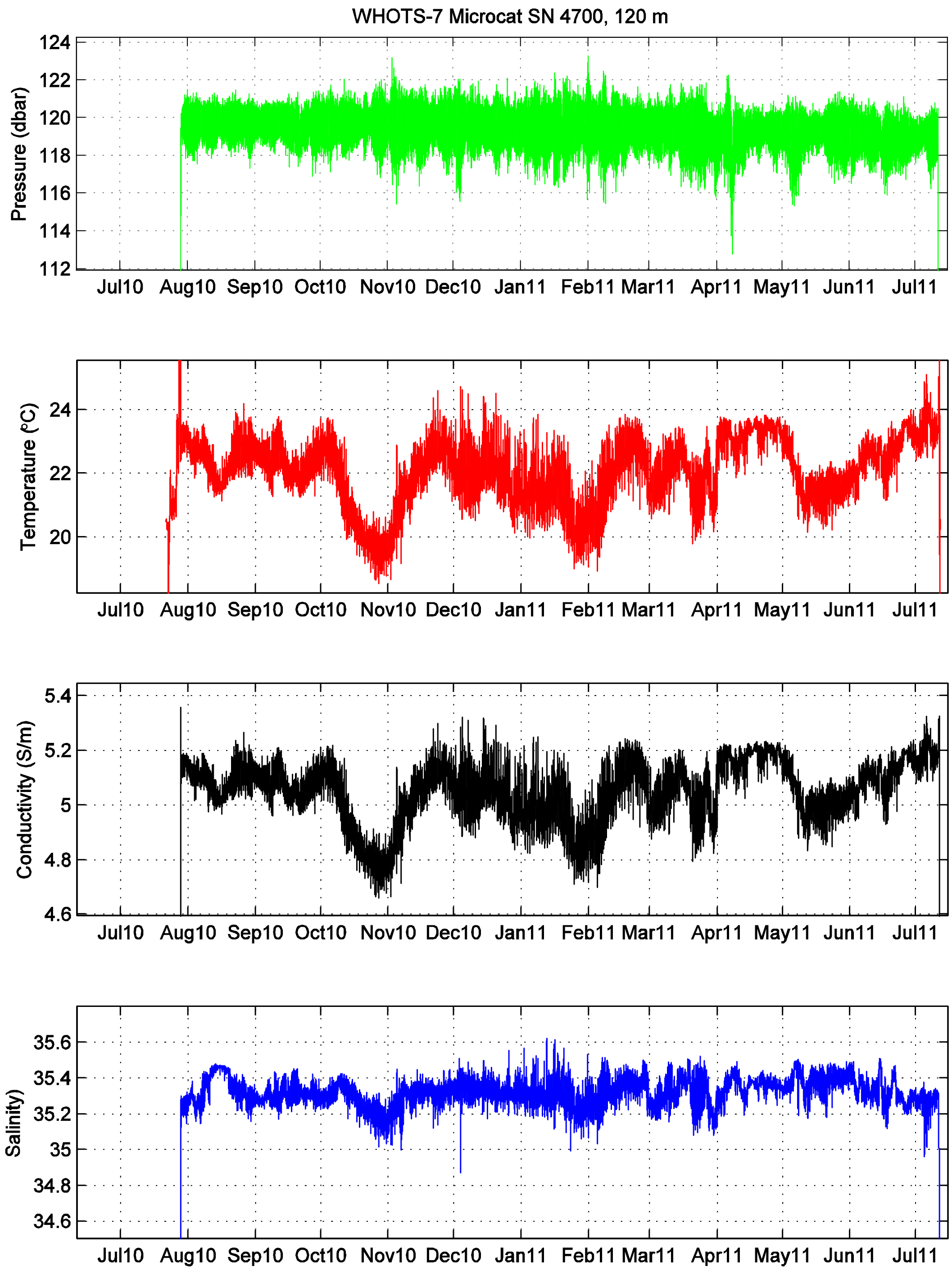


Figure A-13. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4700 deployed at 120 m on the WHOTS-7 mooring**.**

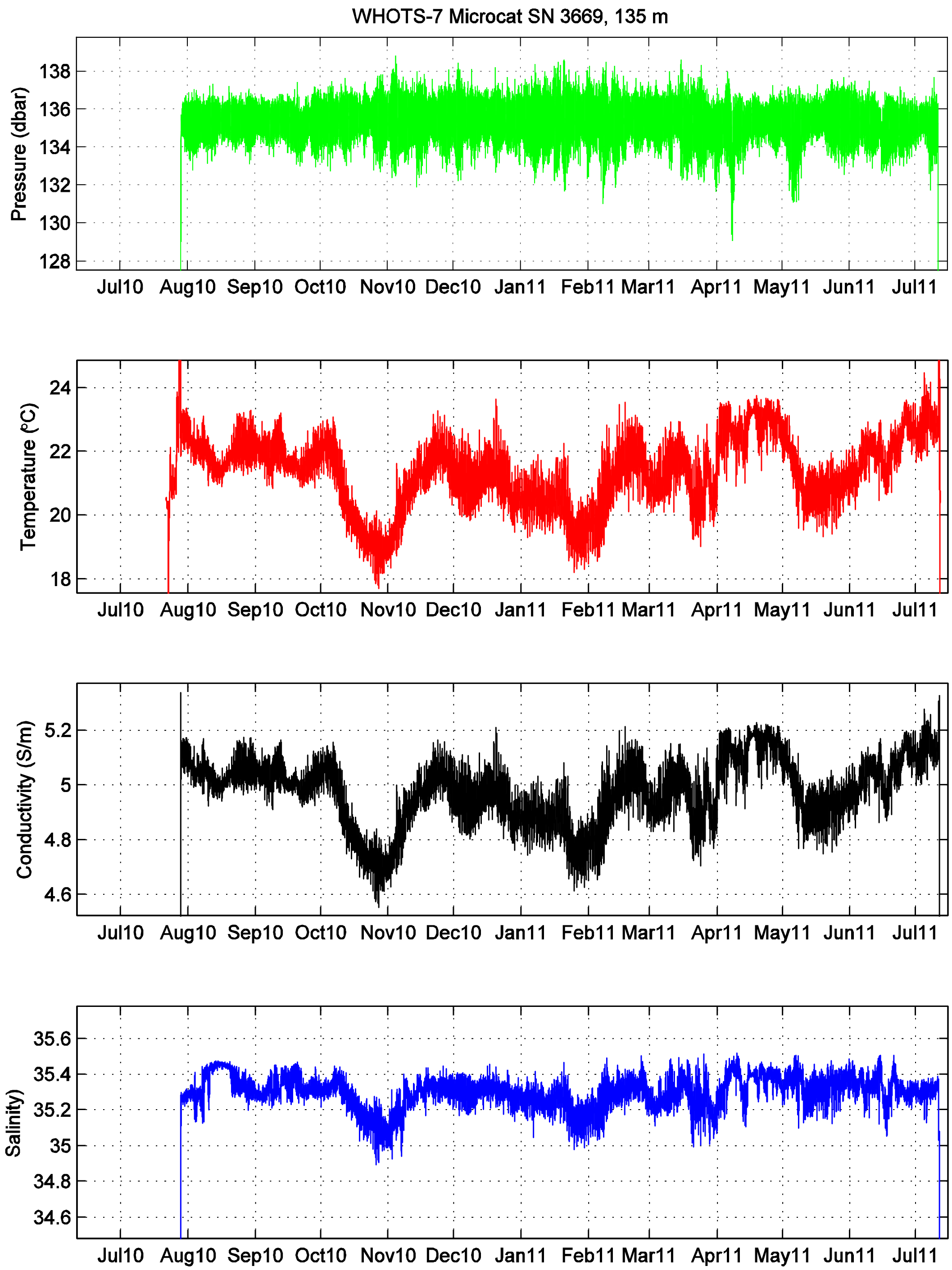


Figure A-14. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 3669 deployed at 135 m on the WHOTS-7 mooring.

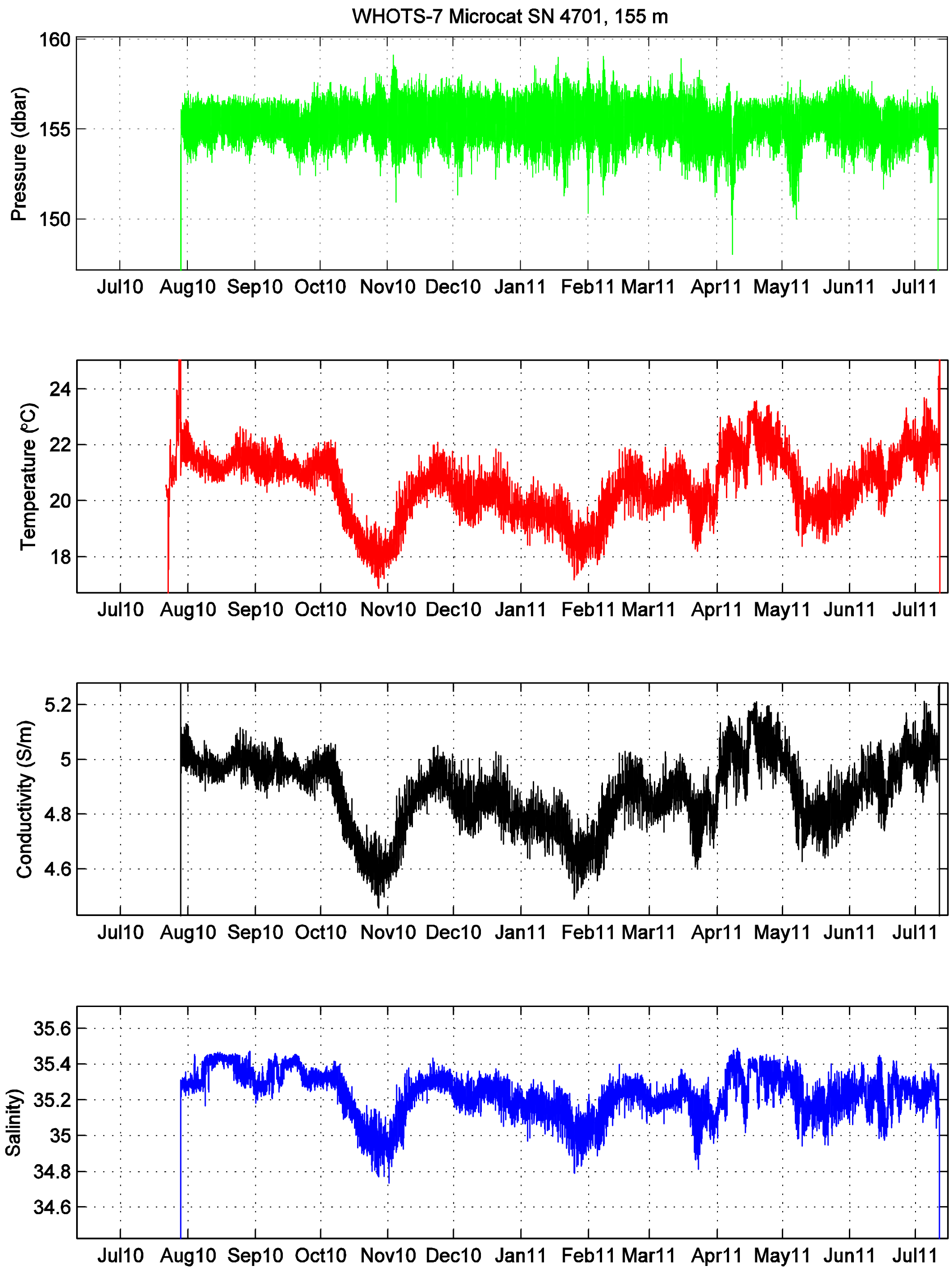


Figure A-15. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4701 deployed at 155 m on the WHOTS-7 mooring.

Appendix B: CTD Profiles

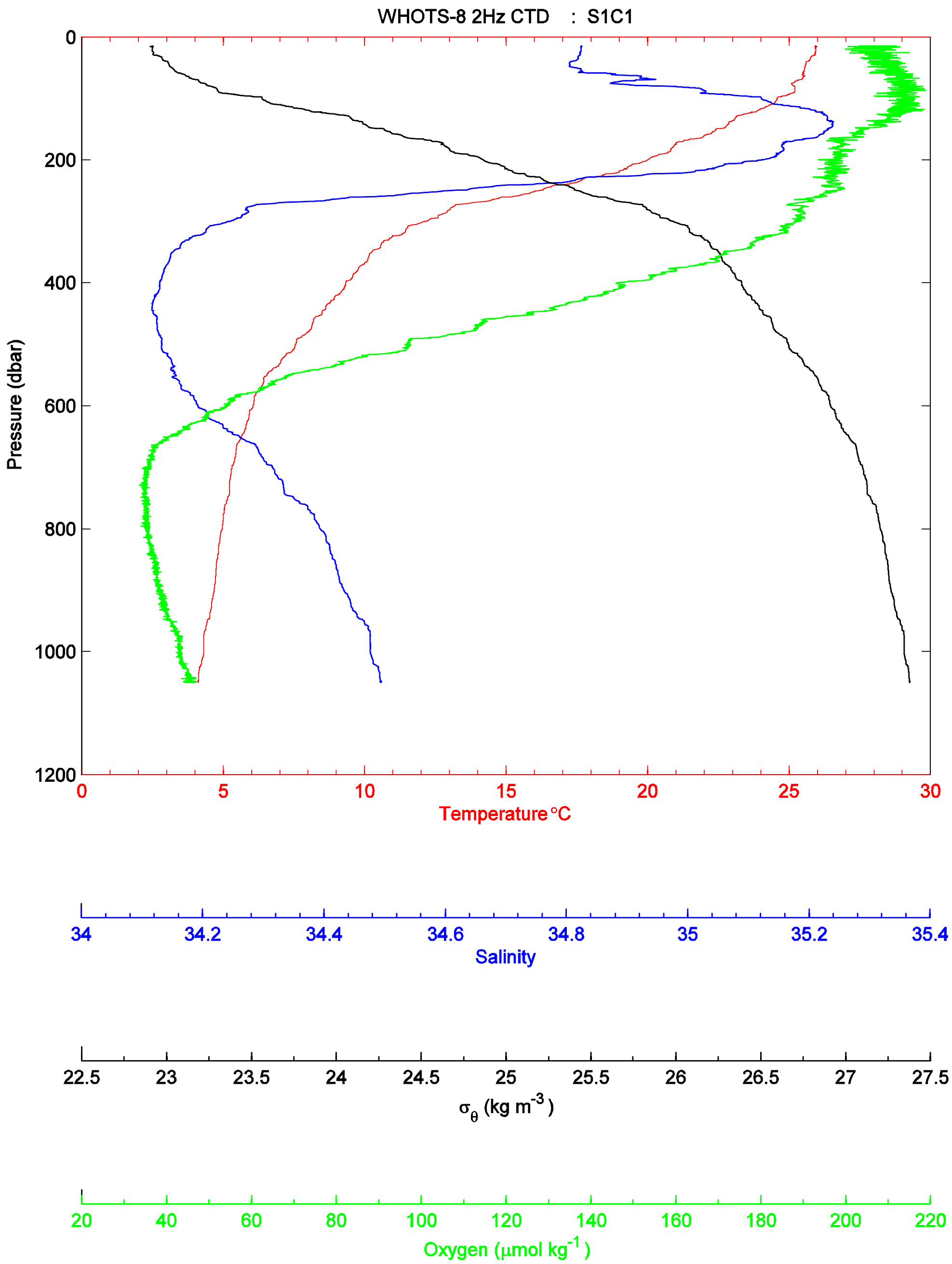
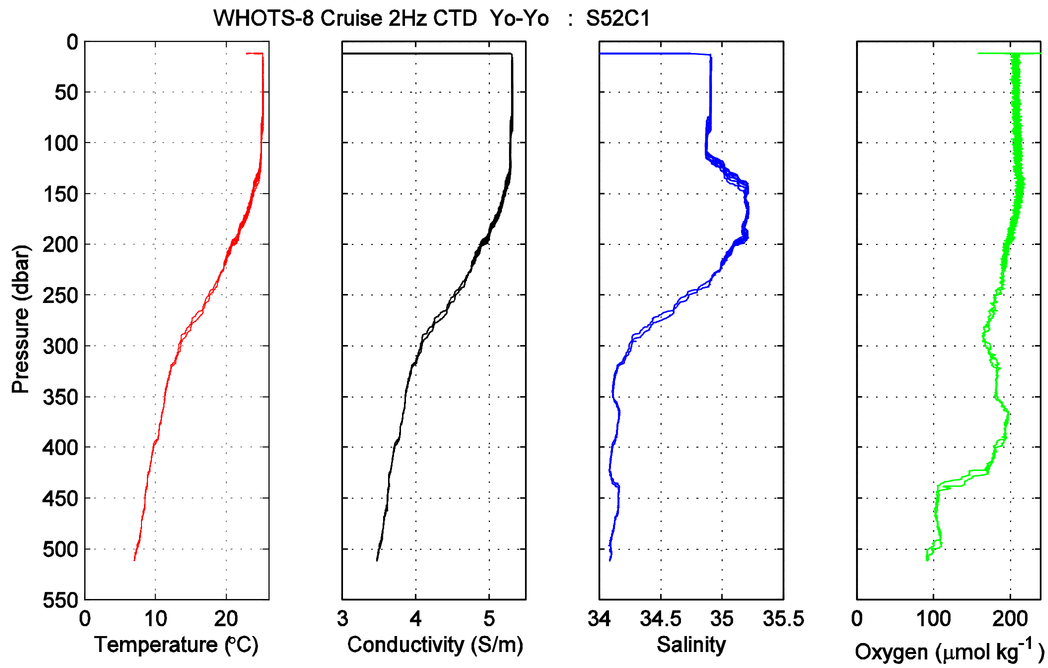


Figure B-1. Profiles of 2 Hz temperature, salinity, potential density and oxygen data during test CTD station.



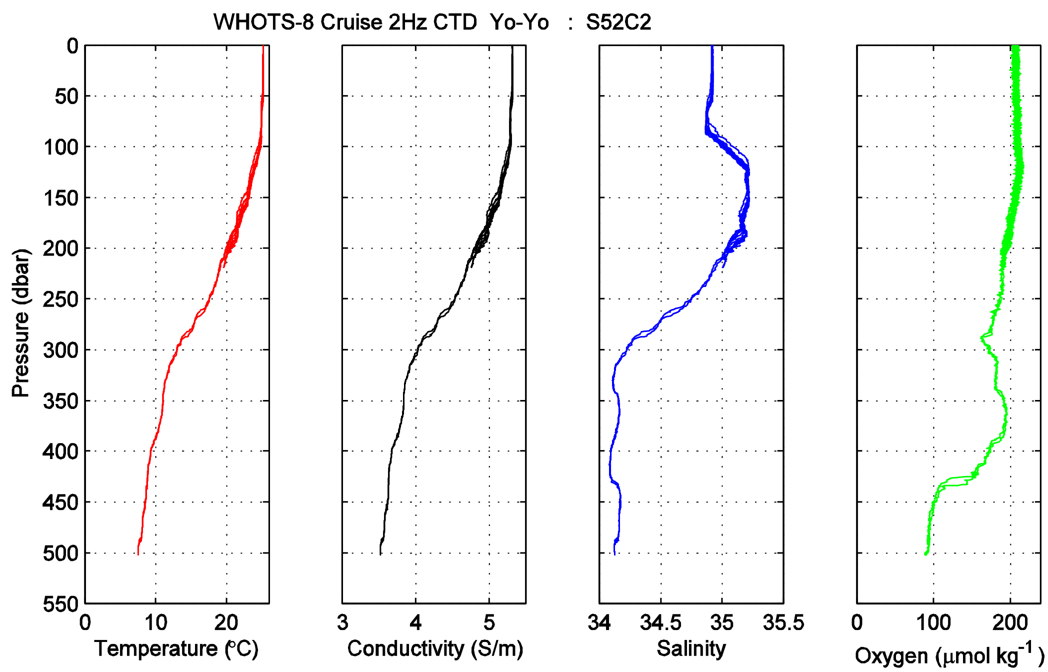


Figure B-2. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S52C1 and S52C2.

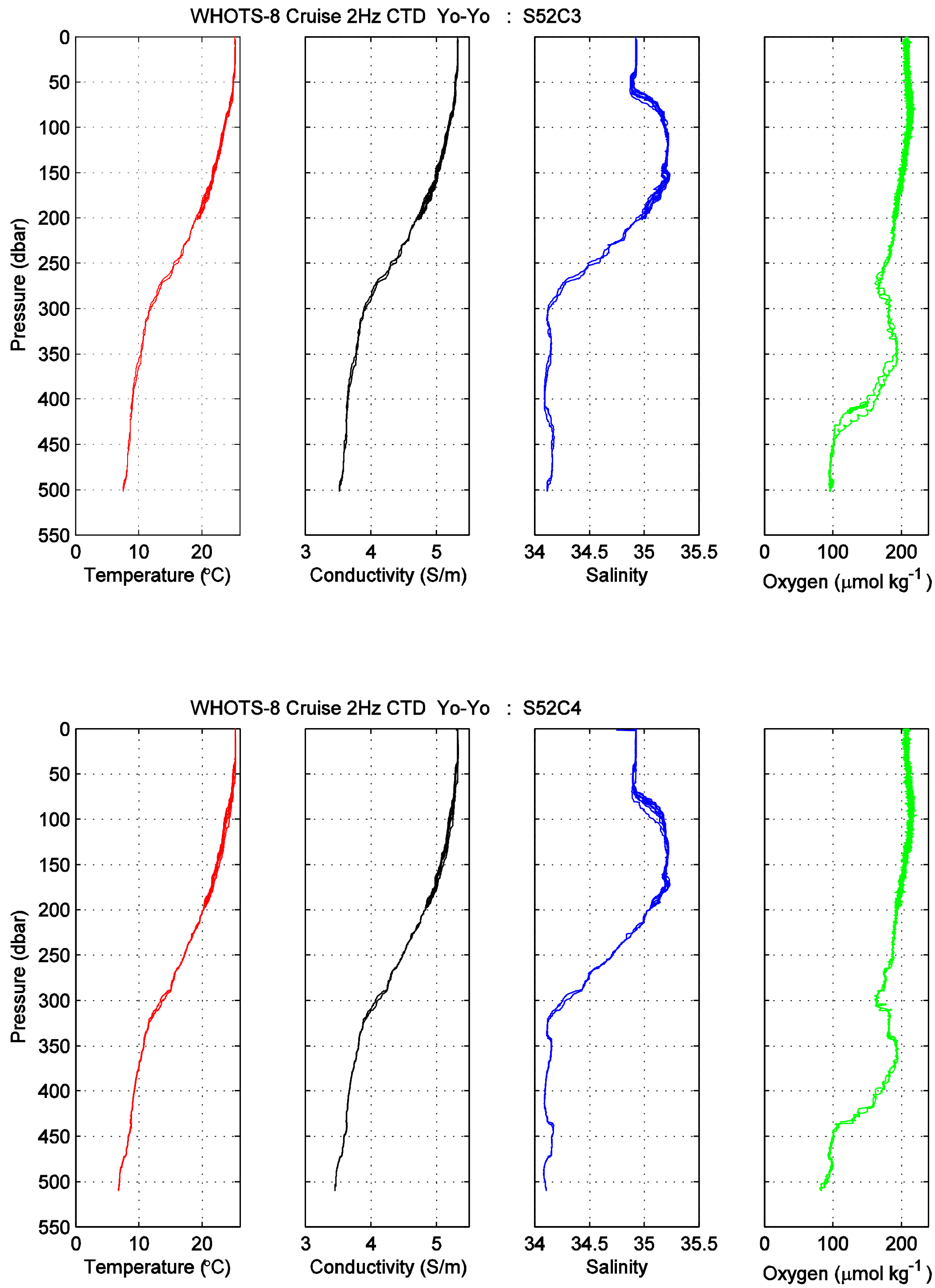


Figure B-3. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S52C3 and S52C4.

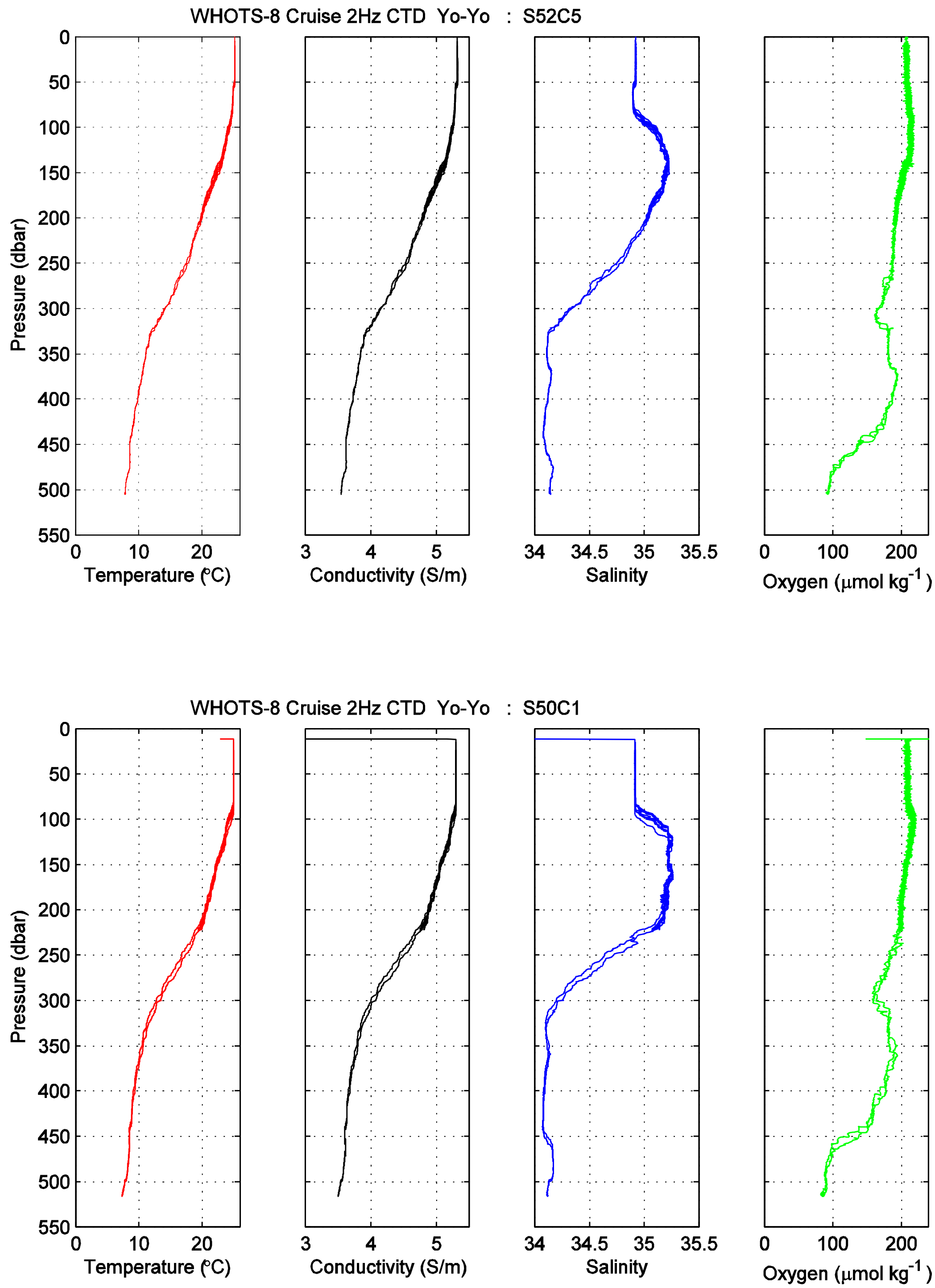
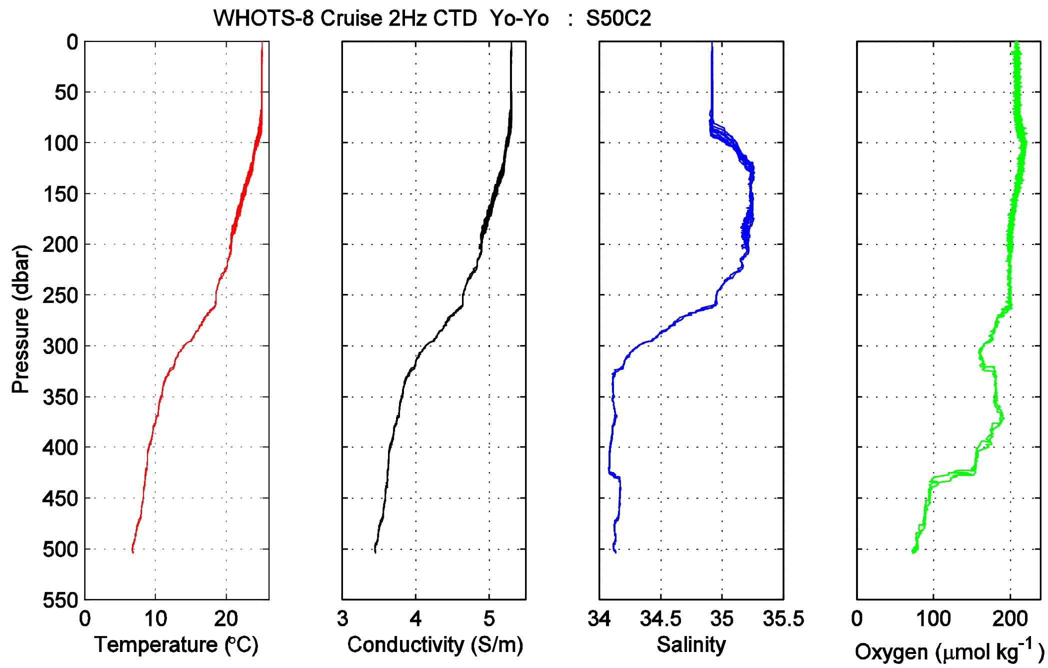


Figure B-4. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S52C5 and S50C1.



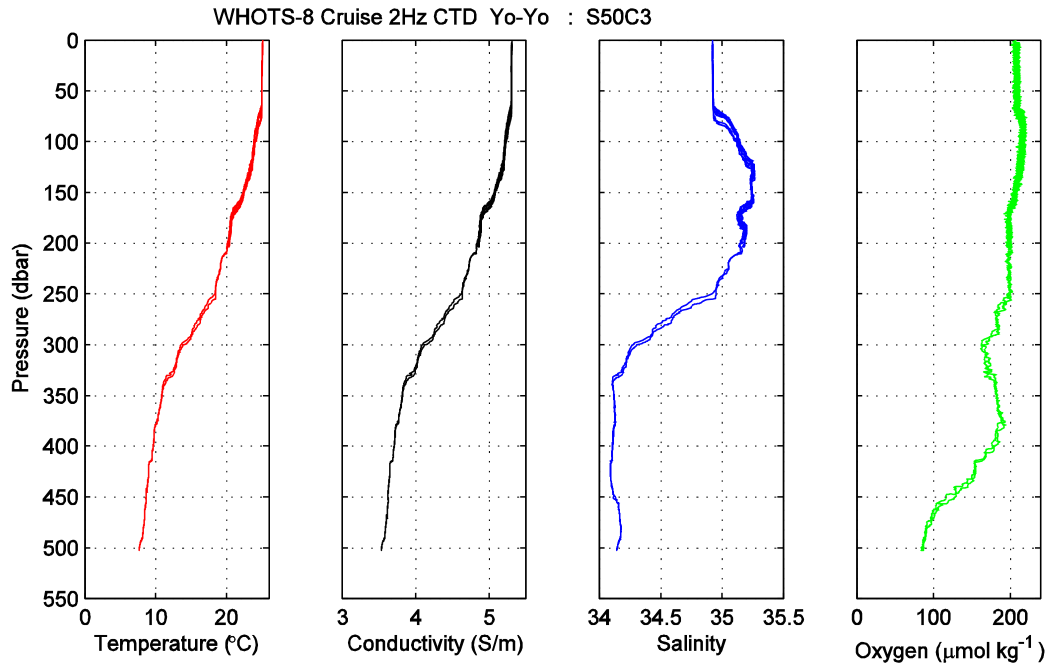
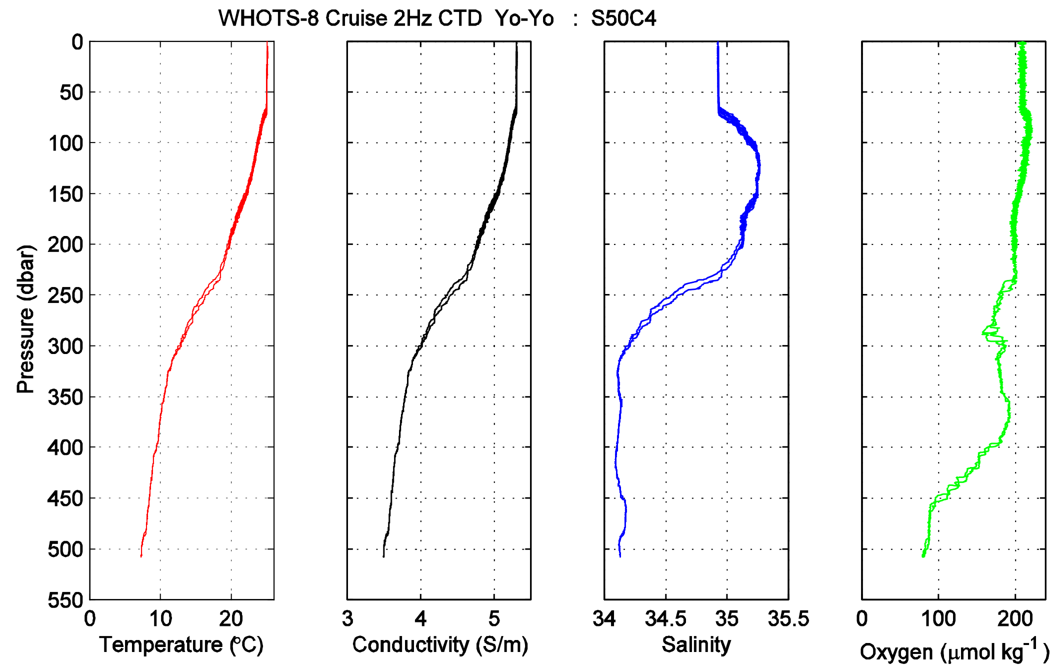


Figure B-5. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S50C2 and S50C3.



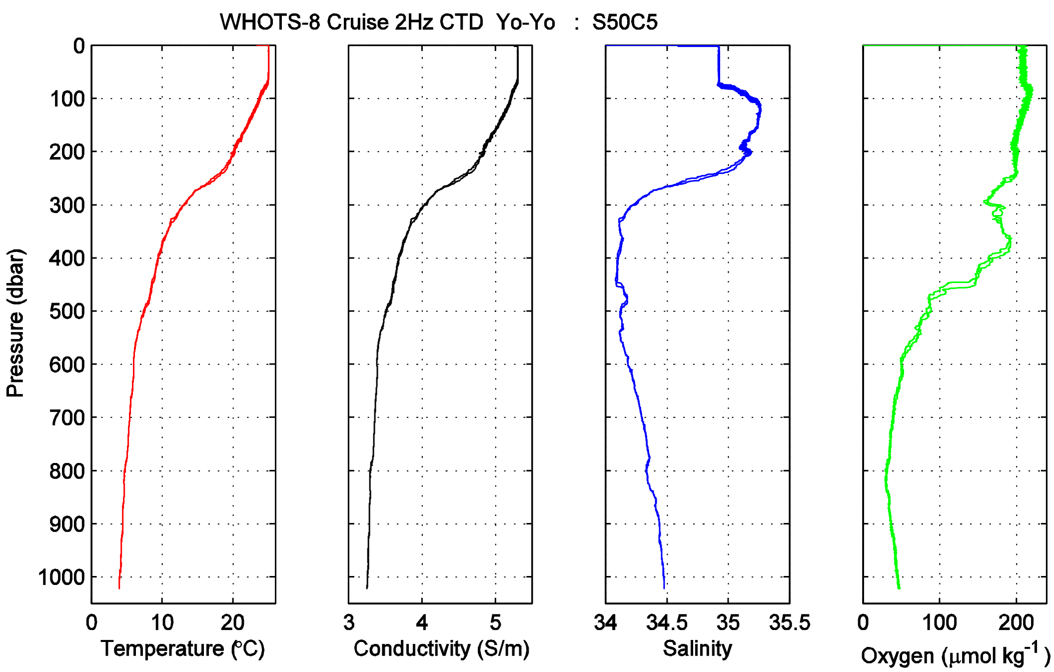
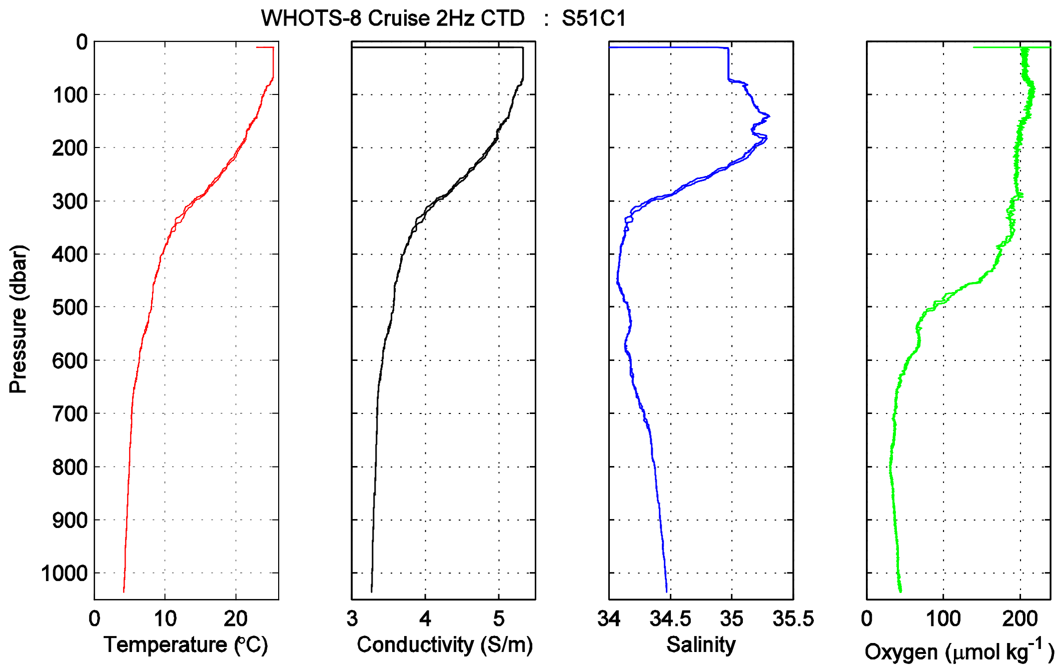


Figure B-6. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S50C4 and S50C5.



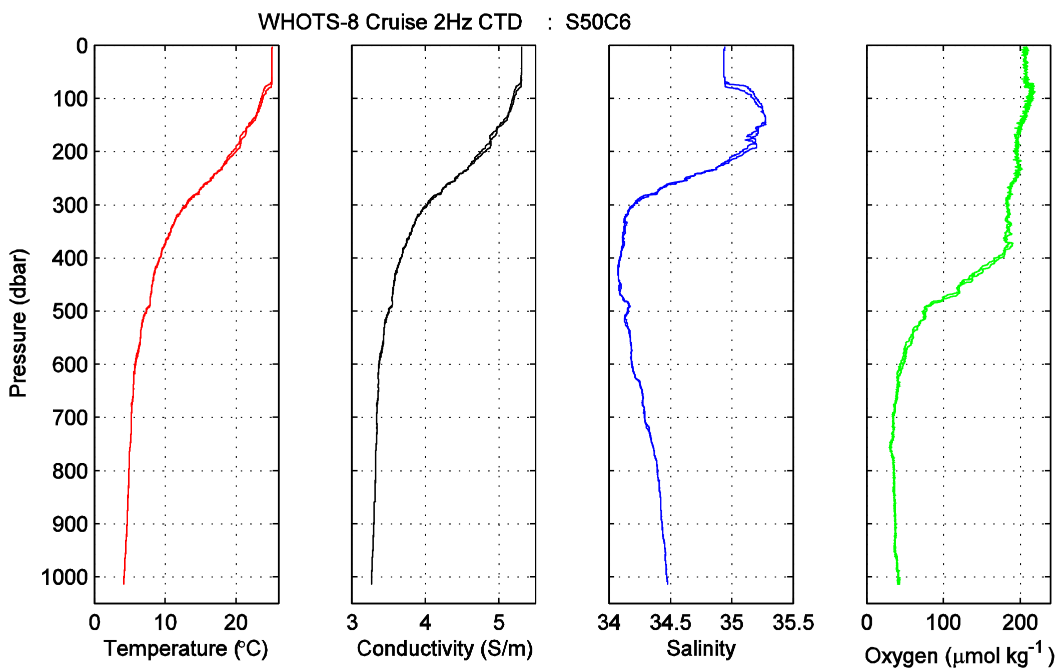
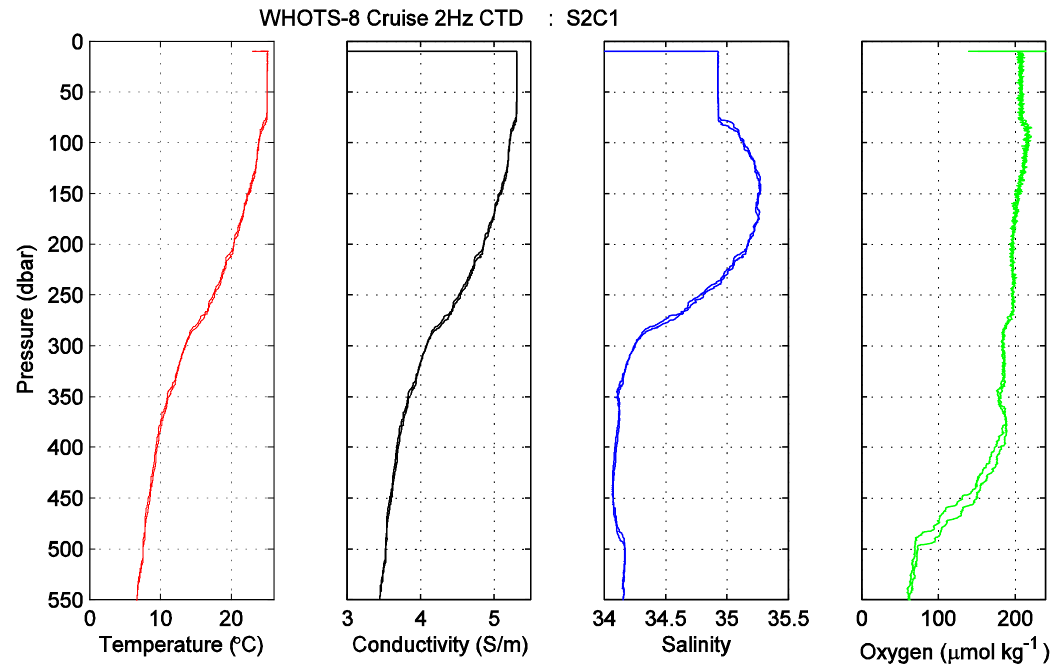


Figure B-7. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S51C1 and S50C6.



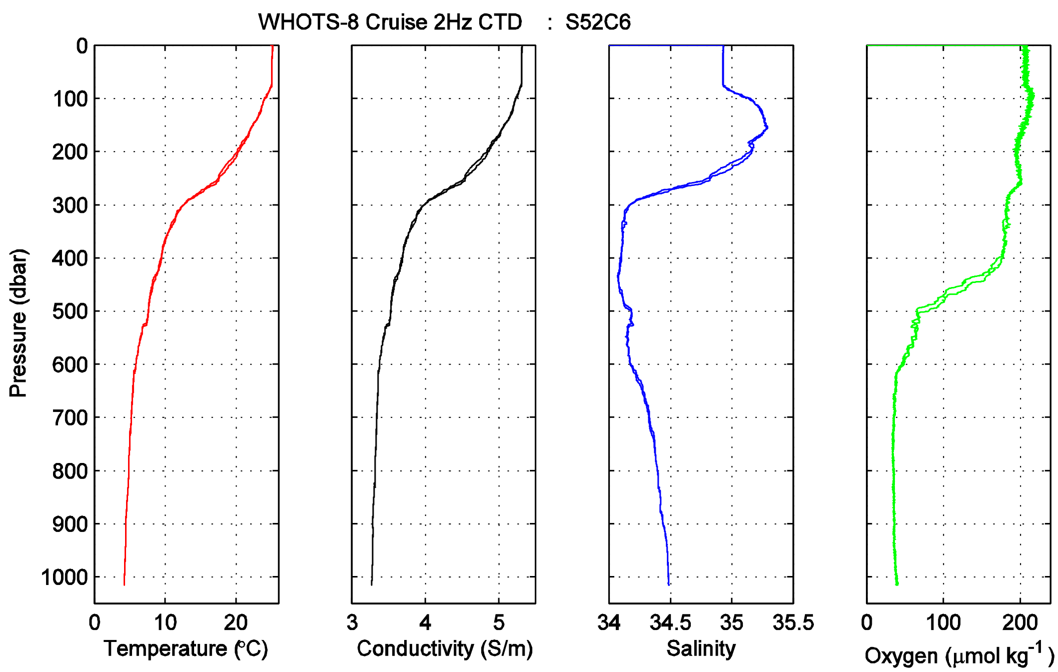


Figure B-8. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S2C1 and S52C6.

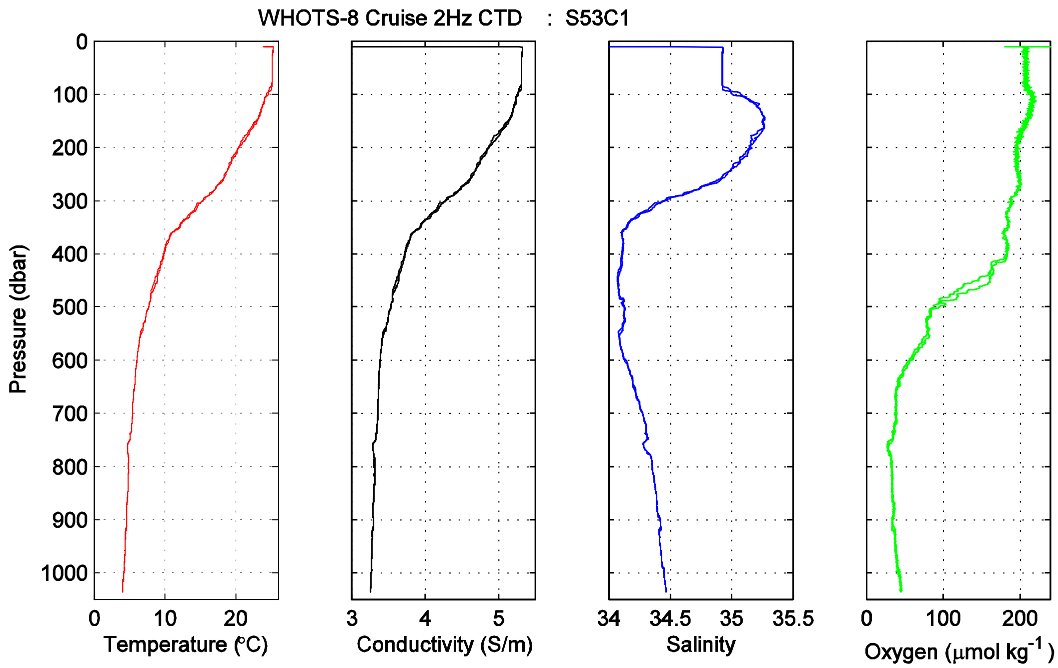


Figure B-9. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during CTD S53C1.

Appendix C: ESRL/PSD Meteorological Measurements

The Earth System Research Laboratory (ESRL) Physical Science Division (PSD) air-sea flux group collected surface meteorology, cloud, and rawinsonde observations during the Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Time-series Station (WHOTS) research cruise on board the NOAA Research Vessel *Hi'ialakai*. Instruments were deployed on the ship a few days prior the departure date.

a. Flux System

A 30' tower was setup on the 02 deck at the bow of the ship (Fig. C-1). The fast turbulence system installed on the bow tower is composed of a GILL Sonic anemometer, a Li-Cor LI-7500 fast CO_2/hygrometer, and a Systron-Donner motion-pak. A mean T/RH sensor in an aspirator and an optical rain gauge were also mounted on the bow tower. To complete the PSD air-sea flux system, pyranometers and pyrgeometers (Eppley and Kipp&Zonen) were mounted on top of pole on the flying bridge (above the pilot house). Finally, a near surface sea surface temperature sensor ('sea snake') consisting of a floating thermistor was deployed from the portside rail (Fig. C-1).

Slow mean data (T/RH, PIR/PSP, etc) are digitized on two Campbell dataloggers and transmitted via wireless as 1-minute averages. Inside the dry lab on the 01 deck, a central data acquisition computer logs continuously all sources of data via RS-232 digital transmission and wireless radio modem network.

1. Sonic Anemometers
2. Licor 7500, CO2/H2O
3. Slow means (two Campbell dataloggers)
4. Systron-Donner Motion-Pak
5. GPS
6. Heading and pitch systems (two Crescent VS100)

The 10 data sources are archived at full time resolution. At sea, a set of programs are run in order to read the sonic anemometers (acquired at 10 Hz) and the mean measurement systems (sampled at 0.1 Hz and averaged to 1 min), and write daily text files at 1 min time resolution. The 1-min daily ASCII files are named as *proc_nam_DDD.txt* (nam='pc', or 'son'; DDD = yearday where 000 GMT January 1, 2011 =1.00). File structure is described in the readme accompanying these files. Further data analysis will include time matching the PSD met data with the ship's various systems in order to create 5 and 30-min daily flux files.

b. CL31 Cloud Base Ceilometers

The ceilometer is a vertically pointing lidar that determines the height of cloud bases from time-of-flight of the backscatter return from the cloud. The instrument was setup on the 02 deck (Fig. C-2). The time resolution of the unit used during the WHOTS cruise is 30 seconds and the vertical resolution is 30 m. The raw backscatter profile and cloud base height information deduced from the instrument's internal algorithm are stored in daily files.

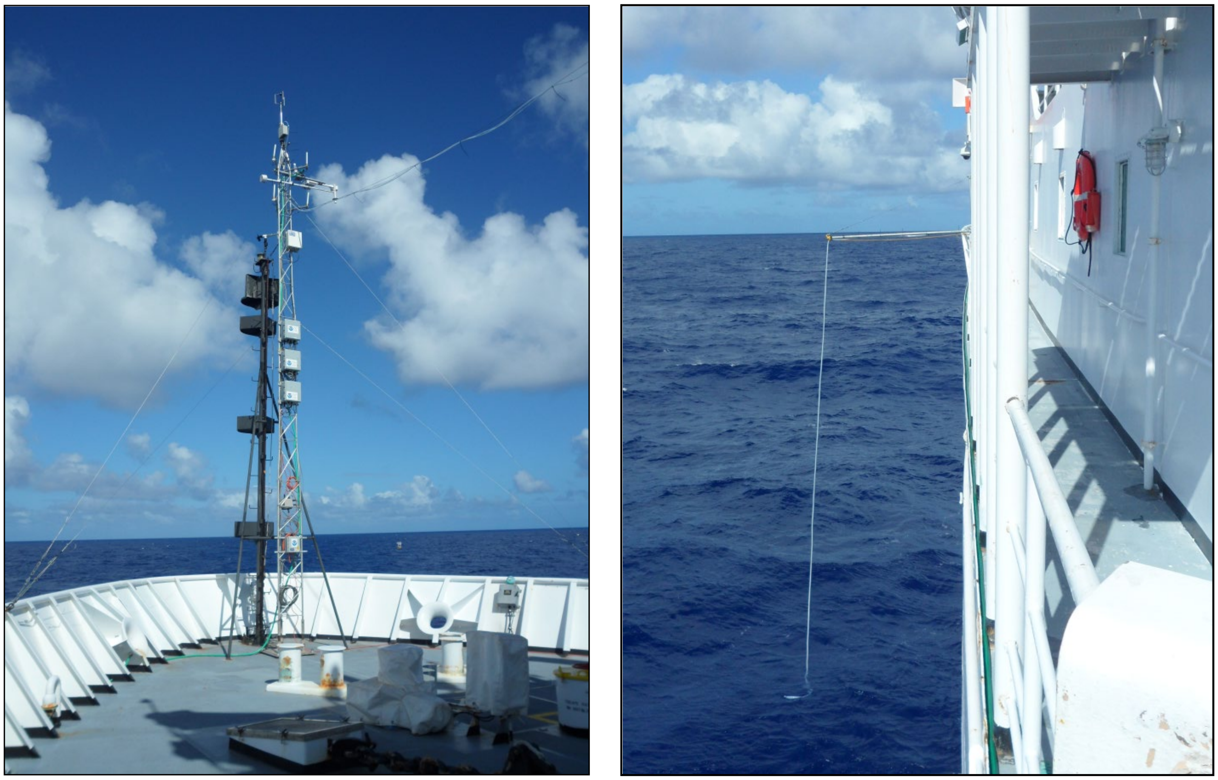


Figure C-1: Left: Flux tower deployed at the bow directly behind the ship's jackstaff. Right: The sea surface thermistor, i.e. "sea snake", can be seen on port side of the ship.

Figure C-2: View of ceilometer on the 02 deck.

c. Radiosondes

Thirty-one Vaisala RS92-SGP radiosondes were launched on the WHOTS 2011 cruise between July 5th and July 12th. 2 radiosondes were launched the evening of the 5th, coinciding with CTD casts. Starting on July 7, 16:00 UTC, radiosondes were launched every 4 hours until July 11, 12:00 UTC. Radiosondes sample the atmosphere every 1 s and transmit observations to a Vaisala MW21 ground receiver unit (setup in the dry lab on the 01 deck, Fig. C-3). Helium gas was used to inflate the radiosonde balloons on the fantail of the main deck (Fig. C-3). The radiosondes collect vertical profiles of temperature, relative humidity, pressure, and winds (calculated from GPS) (Fig. C-4).

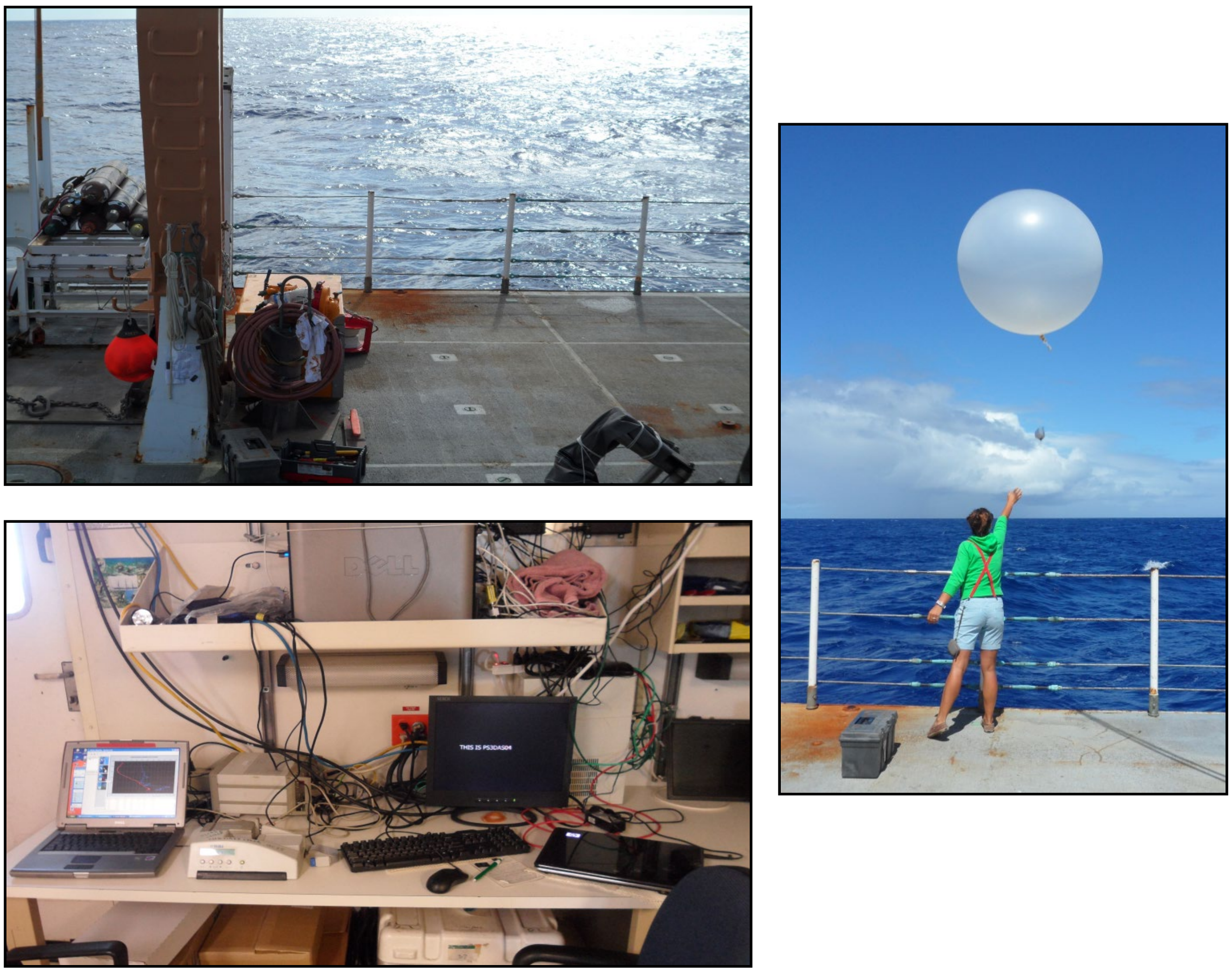


Figure C-3: Upper Left: view of helium bottles and the inflation site on the main deck. Bottom Left: Vaisala radiosonde system deployed in the dry lab of the O1 deck. Right: Scientist releasing radiosonde package.

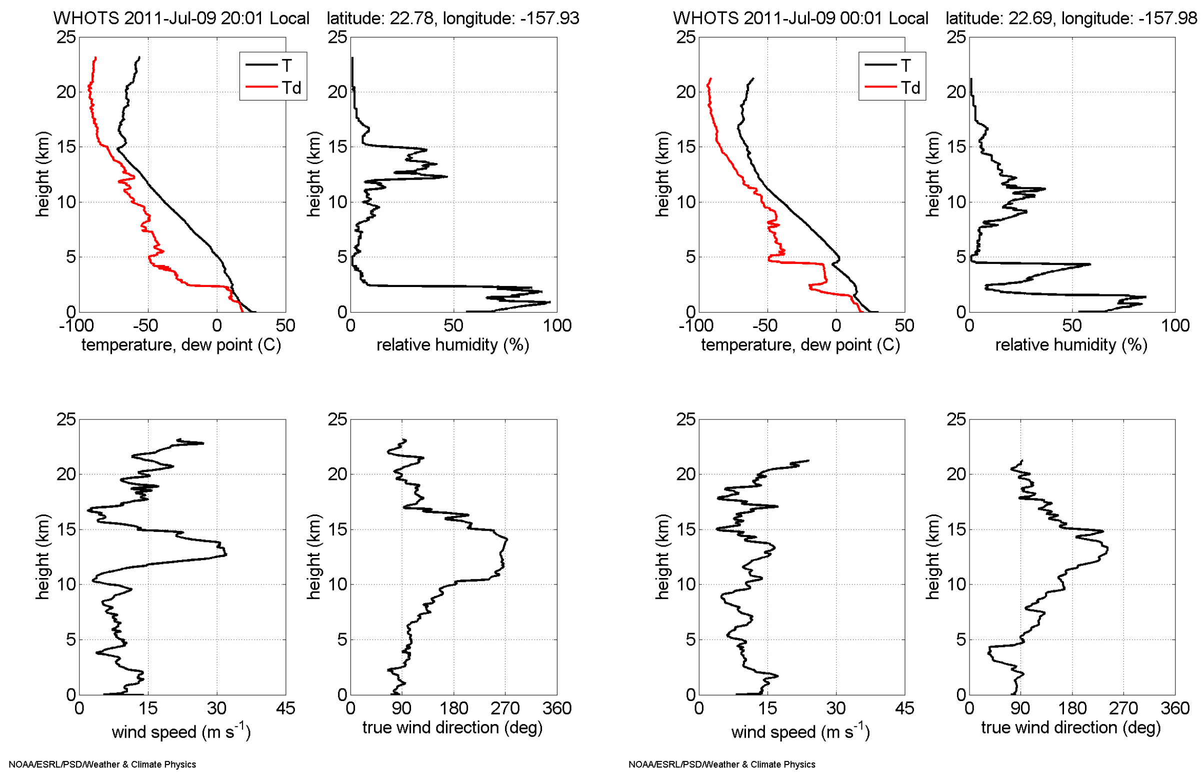


Figure C-4: Left: Sonde profile from July 9, 00:01 Local. Right: Sonde profile from July 9, 20:01.

d. Data Archive

Selected data products were made available at the end of the cruise for the joint cruise archive. Further analysis will be done in order create the 5-min and 30-min daily flux files. After post processing, direct covariance, inertial-dissipation and bulk turbulent flux will be produced at 10 min and hourly average. This will include mainly momentum, sensible and latent heat fluxes. All data for this project will be put on an ftp site back in Boulder.

For access to the FTP site:
ftp://ftp1.esrl.noaa.gov/psd3/cruises/WHOTS_2011/
username anonymous, password (email address)

Contacts:
Ludovic Bariteau / Patrick Boylan / C. W. Fairall / Sergio Pezoa
NOAA Earth System Research Laboratory
325 Broadway, Boulder, CO USA 80305
303-497-4482 Ludovic.Bariteau@noaa.gov
303-869-6265 Patrick.Boylan@noaa.gov
303-497-3253 Chris.Fairall@noaa.gov
303-497-6441 Sergio.Pezoa@noaa.gov

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

Launch (anchor over)

Date (day-mon-yr) 29-07-2010 Time 02:37 UTC

Deployed by Ostrom | Whelan Recorder/Observer Signell

Ship and Cruise No. Kilo Moana KM-10-14 Intended Duration 12 months

Depth Recorder Reading 4703.8 m Correction Source historical CTD

Depth Correction ______ m data, 750 m XBT

Corrected Water Depth 4703.8 SOUND SPEED PROFILE m Magnetic Variation (E/W) ______

Anchor Drop Lat. (N/S) 22° 45.776 Lon. (E/W) -157° 53.745

Surveyed Pos. Lat. (N/S) 22° 46.0052' Lon. (E/W) 157° 53.9897

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

Acoustic Release Model EG+G 8242, dual Tested to 1500 m

Release No. 1 (sn) 32478 Release No. 2 (sn) 32482

Interrogate Freq. 11 KHz Interrogate Freq. 11 kHz

Reply Freq. 12 kHz Reply Freq. 12 kHz

Enable 114442 Enable 114651

Disable 114461 Disable 114672

Release 132043 Release 132157

Recovery (release fired)

Date (day-mon-yr) 11-07-2011 Time 16:28 UTC

Latitude (N/S) 22 45.87 Longitude (E/W) 157 53.89

Recovered by Lord Recorder/Observer Plueddemann

Ship and Cruise No. HA-11-02 Hi'ialakai Actual duration ______ days

Distance from waterline to buoy deck 75cm

1

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

Surface Components

Buoy Type ~~MSB~~ Foam hull Color(s) Hull Tower yellow/white Tower White

Buoy Markings 'B' If found adrift contact U. Hawaii 808 956 7896

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET	LØ9	logger	System 1
HRH	~~221~~ 506	239	
BPR	505	237	
WND	207	264.5	
PRC	209	235	
LWR	218	279	
SWR	201	278	
PTT	63878	wildcat in well	27356, 27364, 27413
SST	1419	-150.5	
ASIMET	L1Ø	logger	System 2
HRH	216	240	
BPR	216	238.5	
WND	221	266.5	
PRC	502	238.5	
LWR	212	279	
SWR	505	278	
SST	1306	-150.5	
PTT	63879	wildcat in well	Ø7561, 27415, 27416
SIS ARGOS	09207	buoy hull	
YEOS GPS	1980	182.5	pwr con height
pCO2	108	~~225~~ 84.5	air intake
Lascar	11609	231	
Vaisala	VWX001	281 (wind finger)	260cm RH sensor

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

Subsurface Instrumentation on Buoy and Bridle			
Item	ID #	Depth†	Comments
Fixed SST	20182	-80	RBR TR-1060 mounted Aft/port side
Fixed SST	023	-80	SBE 56 mounted Aft/Starboard side
Fixed SST	20186	-80	RBR TR-1060 mounted Port side
Fixed SST	14813	-80	RBR TR-1060 mounted Forward/starboard side *
Fixed SST	022	-80	SBE 56 mounted Forward/port side *
Fixed SST	14812	-80	RBR TR-1060 mounted Starboard side
		*	Removed 14813 from fwd PORT side
			Removed 022 from fwd STBD side

†Depth below buoy deck in centimeters

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

Item No.	Length (m)	Item	Depth m	Inst No.	Time Over	Time Back	Notes
1		buoy		19:20:34		0101	/
2	7.75	3/4" chain				7/12/11	props free
3		VMCM	10	035	19:03:10	0129	60 SPIN TIME 18:53:45 07/28/2010
4	2.82	3/4" chain					
5		MCAT	15	3382	19:00:20	0132	
6	3.6	3/4" chain					
7		MAVS	20	10261	18:54:15	0136	
8	2.8	3/4" chain					
9		MCAT	25	4663	18:52:45	0136	
10	3.28	3/4" chain					
11		VMCM	30	038	18:51:10	0139	60 SPIN TIME 18:42:45 props fouled and blades broken
12	2.82	3/4" chain					
13		MCAT	35	3633	18:48:30	0141	
14	3.66	3/4" chain					
15		MCAT	40	3381	18:44:20	0143	
16	3.66	3/4" chain				7/11/11	
17		w/ PRESSURE MCAT	45	3668	18:40:45	2324	
18	1.2	3/4" chain					
19		RDI ADCP 600	47.5	13917	18:39.10	2321	did not come out of water after deployment
20	0.5	3/4" chain					
21		MCAT	50	3619	18:38:40	2319	out of water 19:25:10 back in water 19:40:01
22	3.66	3/4" chain					
23		MCAT	55	3620	19:40:20	2316	hit transom on recovery
24	8.7	7/16" wire					
25		MCAT	65	3621	19:45:40	2311	rough handling

4

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
26	8.7	7/16" wire					
27		MCAT	75	3632	19:48:45	2307	
28	8.7	7/16" wire					
29		w/ pressure MCAT	85	4699	19:51:37	2303	
30	8.7	7/16" wire		10037-11			
31		MCAT	95	3791	19:54:05	2259	
32	8.7	7/16" wire		10037-12			
33		w/ pressure MCAT	105	2769	19:56:55	2254	
34	13.6	7/16" wire		10037-8		.	
35		w/ pressure MCAT	120	4700	20:04:55	2250	
36	3.66	3/4" chain					
37		300 RDI ADCP	125	7637	20:05:20	2240	
38	8.7	7/16" wire		10037-9		2236	
39		MCAT	135	3669	20:07:45	2236	fishing line on recovery
40	18.75	7/16" wire		10037-5		2231	
41		w/ pressure MCAT	155	4701	20:11:16	2231	
42	250	3/8" wire		10037-4	20:11:16 20:23	2222	water time to start block time to end ship 45s
43	500	3/8" wire		10037-2	20:24 20:55	2208	block times ↓ significant chafing on recovery, looks like fishing gear
44	500	3/8" wire		10037-1	20:57 21:20	2154	
45	500	3/8" wire		10037-3	21:22 21:40	2139	
46	100	3/8" wire		7221-13	21:41 21:43	2135	one piece w/ wrapped termination
47	200	7/8" nylon			21:43 21:50	2122	w/ thimble on bottom
48	2100	7/8" nylon			21:53 22:54	2000	thimble on top
49	1500	1" colmega			22:54 23:38	1910	one piece to be spliced at sea
50		glass balls			00:03 00:43	1824	80, 17" balls on 1/2" trawler chain

5

11 July 2011

estimate 9 broken on recovery

ARRAY NAME AND NO. WHOTS-7 MOORED STATION NO. 1216

11 Jul 11

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
51	5	½" chain					trawler chain
52		release		32478	00:44 OTS	1834	dual, 1m chain w/ release links
53		release		32482	00:44 OTS	1834	
54	5	½" chain					trawler chain
55	20	1" Nystron					
56	5	½" chain					trawler chain
57		anchor			02:37		
58					07/29/2010		
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							
70							
71							
72							
73							
74							
75							

OTS = over the side

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-8 MOORED STATION NO. 1244

Launch (anchor over)

Date (day-mon-yr) 7-Jul-2011 Time 0108 UTC

Latitude (N/S, deg-min) 22° 40.057 Longitude (E/W, deg-min) 157° 56.837

Deployed by Lord/Pietro Recorder/Observer Plueddemann

Ship and Cruise No. Hi'ialakai HA-11-02 Intended Duration 12 mo

Depth Recorder Reading 4734 m Correction Source +5m hull driver depth, +0.23% sound spd corr. =11m

Depth Correction 16 m

Corrected Water Depth 4750 m Magnetic Variation (E/W)

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

Surveyed Anchor Position

Lat (N/S) 22° 40.1572 N. Long. (E/W) 157° 57.0225 W

Acoustic Release Model EGG 8242 (dual)

Release No. ~~127476/131266~~ SN 35319 / 35469 Tested to 1000 m

Receiver No. Release Command 127476/131266

Enable 111446/114442 Disable 111465/114461

Interrogate Freq. 11kHz Reply Freq. 12kHz

Recovery (release fired)

Date (day-mon-yr) Time UTC

Latitude (N/S, deg-min) Longitude (E/W, deg-min)

Recovered by Recorder/Observer

Ship and Cruise No. Actual duration days

Distance from actual waterline to buoy deck 75 cm

1

Surface Components

Buoy Type MOB foam Hull Color(s) Hull gray/yellow Tower white

Buoy Markings 'B' If found adrift contact U Hawaii 808-956-7896

Surface Instrumentation

Item	ID #	Height* (cm)	Comments
ASIMET	L07	well ~~230~~	system 1 logger
HRH	246	230 ~~238~~	
BPR	218	238 ~~270~~	
WND	210	270	
PRC	215	245	
LWR	208	283	
SWR	213	283	
SST	1835	-151	
PTT	14637	buoy well	ID's: 7563, 7581, 7582
ASIMET	L08	buoy well	system 2 logger
HRH	236	230	
BPR	207	238	
WND	219	270	
PRC	219	245	
LWR	502	283	
SWR	221	283	
SST	1727	-151	
PTT	12790	buoy well	ID's: 6930, 7387, 14708
~~Xeos Sable~~			
Xeos GPS	1500	248 ~~259~~	surface beacon (melo) IMEI 300034012611150
Vaisala WXT	003	259	
SBE-39 AT	1446	230	
Lascar	264	188	
pCO_2	0102	83	
Radiometers	various	various	see pg 3 for description

*Height above buoy deck in centimeters

2

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SST	20565	-80	RBR 1060, 120° cw from vane
SST	20566	-80	RBR 1060 180°
SST	20567	-95	RBR 1060 180°
SST	20568	-80	RBR 1060 240°
Xeos Sable		bottom of hull	subsurface GPS/Iridium beacon
CTD	6568	"	PMEL SBE-16 w/ fluoro + O_2
pH	P0031	"	PMEL SAMI-2
Fluoro.	3257	"	Laney's SCF Chl fluorometer
	IMEI 300034012194230		
Radiometers on surface buoy tower			
TriOS	835A	178	aft (on wind vane) } angled toward sea surface
TriOS	835B	176	starboard
TriOS	835C	176	~~port~~ bow
TriOS	835D	176	port
TriOS	?	283	on radiometer stalk, uplooking

†Depth below buoy deck in centimeters

July 6
UTC

Moored Station Number ____________

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		buoy	—	1855			0		
2	7.75	3/4 chain	—						
3		VMCM	016	1834	SN 008 under paint on press case		10		bands off 1828
4	2.82	3/4 chain	—						
5		μCAT	6893	1829			15		
6	3.66	3/4 chain	—						
7		MAVS	10260	1827			20		sensor down
8	2.8	3/4 chain	—						
9		μCAT	6894	1824			25		
10	3.28	3/4 chain	—						
11		VMCM	019	1821			30		bands off 1817
12	2.82	3/4 chain	—						
13		μCAT	6895	1818			35		
14	3.66	3/4 chain	—						
15		μCAT	6896	1815			40		
16	3.66	3/4 chain	—		↑ ↑				
17		μCAT	6887	1812	time over for 45 m + shallower is over transom on stbd side, not in water		45		w/pressure
18	1.07	3/4 chain	—						
19		ADCP	1825	1917			47.5		heads up, 600 kHz
20	0.5	3/4 chain	—						
21		μCAT	6897	1922			50		
22	3.66	3/4 chain	—						

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		μCAT	6898	~~1922~~	redeployed 1927		55		
24	8.7	7/16 wire	11061-10						
25		μCAT	6899	1930			65		
26	8.7	7/16 wire	11061-12						
27		μCAT	3618	1936			75		
28	8.7	7/16 wire	11061-11						
29		μCAT	6888	1939			85		w/pressure
30	8.7	7/16 wire	11061-9						
31		μCAT	3617	1941			95		
32	8.7	7/16 wire	11061-13						
33		μCAT	6889	1944			105		w/pressure
34	13.6	7/16 wire	10037-7						
35		μCAT	6890	1947			120		w/pressure
36	3.66	3/4 chain	—						
37		ADCP	4891	1950			125		heads up
38	8.7	7/16 wire	—						
39		μCAT	3634	1953			135		
40	18.75	7/16 wire	11061-6						
41		μCAT	6891	1959			155		w/pressure
42	250	3/8 wire	9014-12	1959					
43	500	3/8 wire	11061-2	2008					
44	500	3/8 wire	11061-3	2020					
45	500	3/8 wire	9014-10	2033					

5

Moored Station Number ____________

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	100	3/8 wire	10037-16	2045	} one piece w/				
47	200	7/8 nylon	—	2050	} wrapped termination				
48	2100	7/8 nylon	—	2105					
49	1500	1" colmega	-	2144					
50		glass balls		2243	80 balls on chain				
51	5	1/2 chain	—						
52		release	35319	July 7	} dual releases				
53		release	35469	0018	} on strongback				
54	5	1/2 chain	—	0020					
55	20	nystron	—	0024					
56	5	1/2 chain	—						
57		anchor	—	0108					
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-2012-04	2.	3. Recipient's Accession No.

4. Title and Subtitle
WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-8 2011 Mooring Turnaround Cruise Report

5. Report Date
April 2012

6.

7. Author(s)
Sean Whelan, et.al.

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) NA09OAR4320129
(G)

12. Sponsoring Organization Name and Address
NOAA

13. Type of Report & Period Covered
Technical Report

14.

15. Supplementary Notes
This report should be cited as: Woods Hole Oceanographic Institution Tech. Report., WHOI-2012-04.

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 part of the NOAA Climate Observation Program. The WHOTS mooring also serves as a coordinated part of the HOT program, contributing 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.

This report documents recovery of the seventh WHOTS mooring (WHOTS-7) and deployment of the eighth mooring (WHOTS -8). Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity in a cooperative effort with R. Lukas of the University of Hawaii. A pCO2 system was installed on the WHOTS-8 buoy in a cooperative effort with Chris Sabine at the Pacific Marine Environmental Laboratory. A set of radiometers were installed in cooperation with Sam Laney at WHOI.

The WHOTS mooring turnaround was done on the NOAA ship Hi'i*alakai by t*he Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 5 July and 13 July 2011. Operations began with deployment of the WHOTS-8 mooring on 6 July. This was followed by meteorological intercomparisons and CTDs. Recovery of WHOTS-7 took place on 11 July 2011. This report describes these cruise operations, as well as some of the in-port operations and pre-cruise buoy preparations.

17. Document Analysis a. Descriptors
Ocean Reference Station
Cruise Report
Hawaiian Ocean

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	109
	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