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Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS):
WHOTS-9 2012 Mooring Turnaround Cruise Report

by

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Woods Hole, MA 02543

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Technical Report

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Upper Ocean Processes Group
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Approved for Distribution:

John M. Toole, Chair

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Abstract

The Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Timeseries 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 Hawaii Ocean Timeseries (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 eighth WHOTS mooring (WHOTS-8) and deployment of the ninth mooring (WHOTS-9). 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 buoys in cooperation 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 12 and 19 June 2012. Operations began with deployment of the WHOTS-9 mooring on 13 June. This was followed by meteorological intercomparisons and CTDs. Recovery of the WHOTS-8 mooring took place on 16 June. 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 are made on the WHOTS mooring 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. 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, turbidity, 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* (HA; cruise HA-12-02, by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI) with assistance from UH participants. Personnel from the NOAA Earth Systems Research Lab (ESRL), Physical Sciences Division were also aboard. The goals of the ESRL group were to obtain high quality shipboard meteorology measurements. The cruise originated from, and returned to, Honolulu, HI (Fig. 1). The facilities of the NOAA operations center at Ford Island were used for pre-cruise staging.

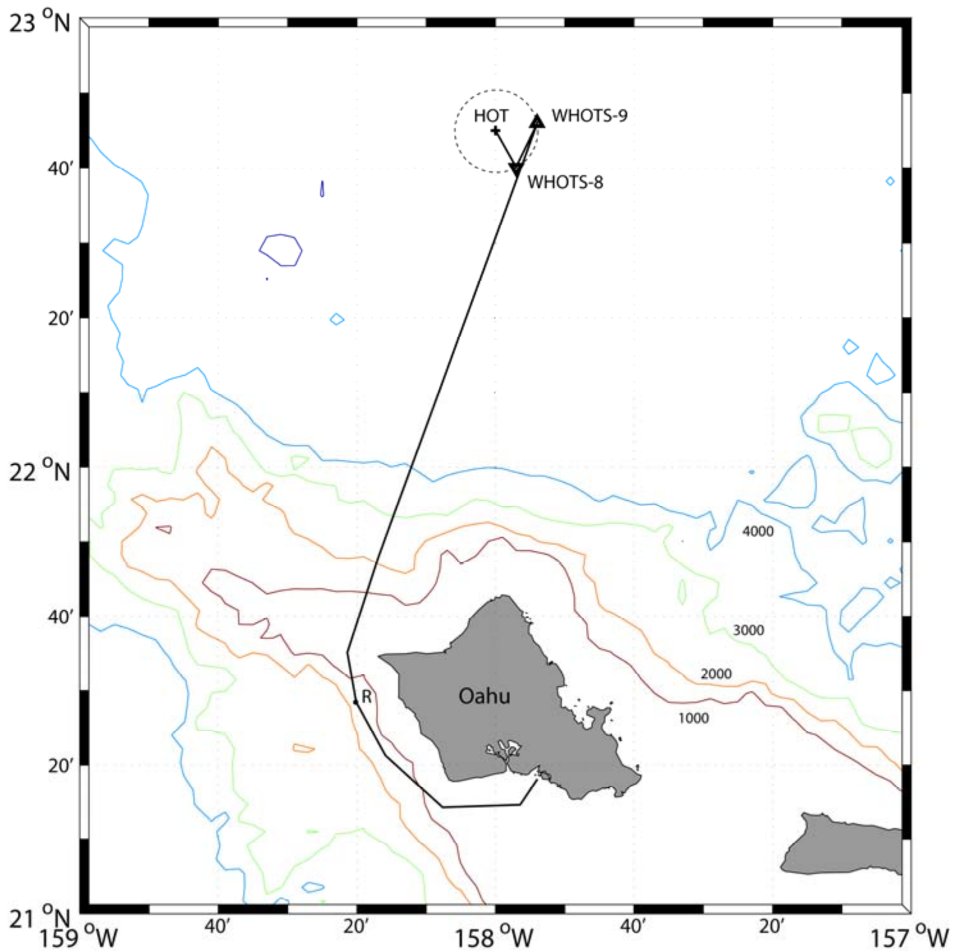


Figure 1. WHOTS-9 cruise track showing location of release and CTD tests (R), WHOTS-8 and WHOTS-9 mooring locations (triangles), and the center (+) and radius (dashed line) of the Station ALOHA circle.

The HA departed Ford Island at 0900 local on 12 June, stopped for fuel, and then departed for the WHOTS-9 site at about 1500. The cruise was completed in 8 days, between 12 June and 19 June, 2012. A schematic cruise track is shown in Fig. 1.

Bad weather during 18-19 June resulted in a decision to recovery the WHOTS-8 mooring early, precluded planned post-recovery CTD operations, and resulted in returning to port one day early relative to the 9 day cruise plan. Fig. 2 shows the steady increase in wind speed (11 to 24 kt) and significant wave height (1.1 to 3.2 m) beginning on 16 June and continuing through 19 June. Wind and wave conditions precluded all over-the-side operations during 18-19 June. Despite the deteriorating conditions, the primary mooring deployment and recovery operations, including a 59 h intercomparison period, were completed.

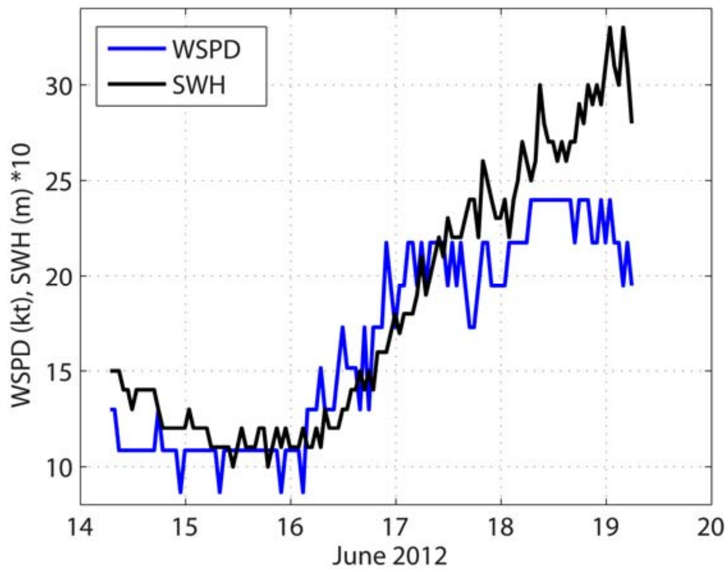


Figure 2. Wind speed (WSPD) from the WHOTS-9 mooring (obtained via Argos telemetry) and significant wave height (SWH) from NDBC station 51000 (Northern Hawaii, 23° 32.8' N, 154° 3.3' W) during 14-19 June 2012. Note that wave height has been multiplied by ten for presentation on the same axis as wind speed.

This report consists of five main sections, describing pre-cruise operations (Sec. 2), the WHOTS-9 mooring (Sec. 3), the WHOTS-9 mooring deployment (Sec. 4), the WHOTS-8 mooring recovery (Sec. 5), and meteorological intercomparisons (Sec. 6). Five appendices contain ancillary information.

2. Pre-Cruise Operations

a. Staging and Loading

Pre-cruise operations were conducted at the port facility on Ford Island, Oahu, Hawaii. A shipment consisting of two 40' containers left Woods Hole for Hawaii on 11 May 2012. Major items in the containers were the tower top and base, winding and tension carts, anchor, mooring instrumentation and miscellaneous deck and lab equipment, wire baskets with synthetic line, dragging gear, and a Tension Stringing Equipment (TSE) winch. Several pieces of mooring equipment, including the buoy hull, glass balls, spare anchor and anchor tip plate, were stored at the University of Hawaii Sand Island facility. The UH group moved this equipment from Sand Island to Ford Island prior to arrival of the UOP Group.

Jim Ryder, Ben Pietro and Jason Smith traveled to Hawaii on 3 June, located the containers, and set up an operation area on the port grounds . Al Plueddemann and Chris Duncombe Rae arrived in Hawaii on 4 June. Pre-cruise operations took place from 4-11 June while the *Hi'ialakai* was in port. Pre-cruise operations included assembly of the buoy tower top and well, evaluation of ASIMET data, loading, deck arrangement, lab setup, evaluation of subsurface sensor telemetry performance, a buoy spin, and insertion of the tower top assembly into the hull. During the set up and evaluation, an Alpha-Omega Argos receiver was used to collect real-time data.

b. Buoy Spins

A buoy spin begins by orienting the assembled buoy well and tower (without the foam hull attached) towards a distant point with a known (i.e. determined with a surveyor's compass) magnetic heading. The buoy is then rotated, using a fork truck or pallet jack, through eight positions in approximate 45-degree increments. At each position, the vanes of both wind sensors are oriented parallel with the sight line (vane towards the sighting point and propeller away) and held for several sample intervals. If the compass and vane are working properly, they should co-vary such that their sum (the wind direction) is equal to the sighting direction at each position (expected variability is plus or minus a few degrees).

The first buoy spin was done in the parking lot outside the WHOI Clark Laboratory high bay, with care taken to ensure that cars were not parked within about 30 ft of the buoy. The sighting angle was 89°. The last compass, last vane, and direction (compass+vane) from the buoy winds obtained in test mode are reported below. Fig. 3 shows the sensor directions and the sighting angle for the WHOI spin.

The second buoy spin was done in Hawaii, on an open area of pavement at the Ford Island facility parking lot near the pier. A sighting direction of 5° was established with a distant object as a reference point. The technique used was the same as for the WHOI buoy spins. The last compass, last vane, and compass+vane from test mode are reported below. Fig. 4 shows the sensor directions and the sighting angle for the Ford Island spin.

c. Sensor Evaluation

The UOP advance party started work at Ford Island on 4 June 2012. The buoy well and tower top were unpacked from the container and assembled (modules were shipped still attached to the tower top). By the end of the day on 5 June the buoy was operating and transmitting meteorological data. Evaluation of ASIMET Argos data showed all variables looking reasonable and comparisons within expected tolerances. Internally logged 1 min ASIMET logger data were offloaded for evaluation on 9 June. All buoy sensor pairs agreed well. The buoy HRH module AT compared well with the SBE-39 AT, within about 0.1°C, at night (Fig 5). The Vaisala WXT AT was high by 0.1 – 0.2°C. AT differences were quite a bit larger during the day (up to 1°C). Comparison of the Vaisala WXT RH with the buoy indicated that the WXT was biased low by about 4%. Evaluation of WND module performance was difficult due to generally low winds (<1 m/s). A step-fill test showed both PRCs functioning as expected.

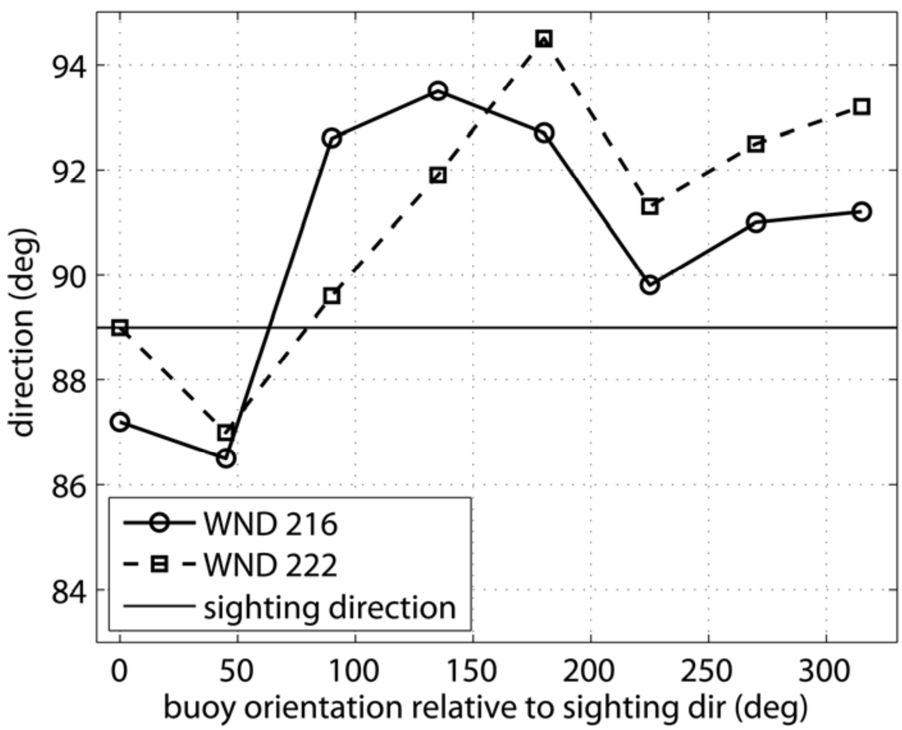


Figure 3. WHOI buoy spin results.

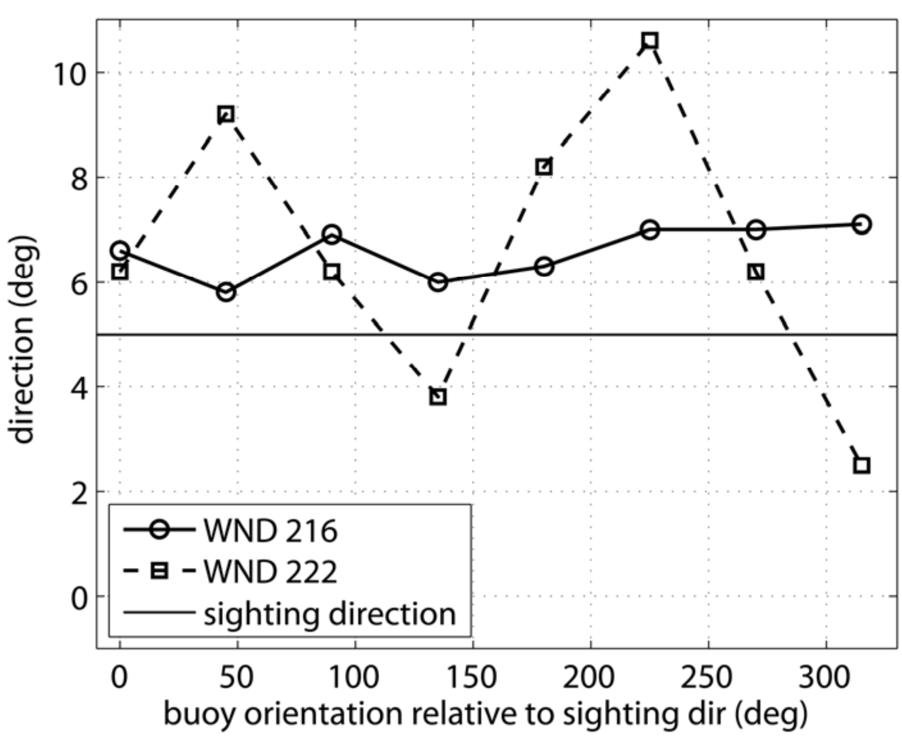


Figure 4. Ford Island, Hawaii buoy spin results.

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 on Ford Island during 5-9 June. The function checks showed proper operation. Evaluation of hourly Argos data and 1min data offloaded from the loggers on 9 June showed all modules to be functioning as expected (differences between like sensors within accuracy tolerances). The buoy tower was loaded into the foam buoy hull on 10 June and moved from the warehouse area to the pier next to the ship.

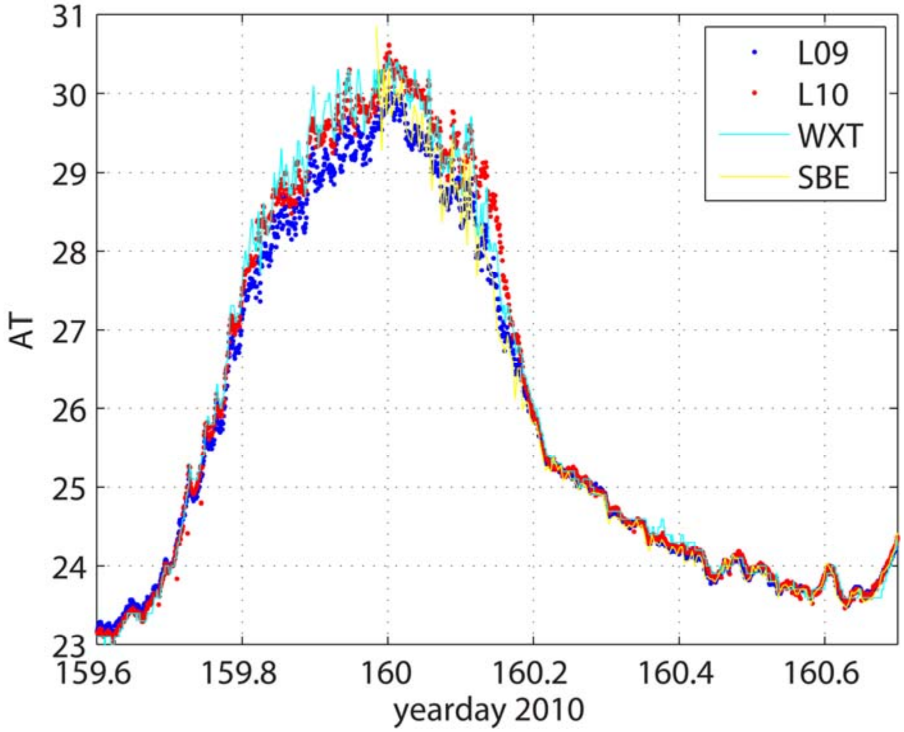


Figure 5. Air Temperature sensor check at Ford Island. Note the improved agreement at night (yearday 160.2 – 160.6) and increased scatter during the day.

3. WHOTS-9 Mooring, Systems, and Sensors

a. Mooring Design

The mooring is an inverse-catenary design of compound construction (Fig. 6), utilizing chain, wire rope, nylon and Colmega (buoyant 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 2.2 nm (4.1 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 15,000 pounds, with reserve buoyancy of approximately 12,000 lb when deployed in a typical configuration. A fully assembled buoy weighs about 4500 lb. 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. Data loggers, electronics for satellite telemetry, and batteries fit into the instrument well.

Two complete sets of ASIMET sensor modules are attached to the upper section of the two-part aluminum tower at a height of about 3 m above the water line. 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, two marine lanterns, and two independent Argos satellite transmission systems that provide continuous monitoring of buoy position. A Xeos Melo Global Positioning System (GPS) receiver, a SBE-39 temperature sensor adapted to measure air temperature and a Vaisala WXT-520 multi-variable sensor (temperature, humidity, pressure, wind and precipitation) were also mounted on the tower. A fourth positioning system (SiS Argos transmitter) 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 via an access tube through the buoy foam.

Several other instruments were mounted on the buoy. Chris Sabine (PMEL) provided a pCO_2 system, mounted in the buoy well with sensors in air and in the water. A pumped SBE-16 CTD and a SAMI-2 pH sensor were mounted to the underside of the buoy and wired in to the pCO_2 controller/logger. The SBE-16 hosted turbidity and dissolved oxygen sensors. 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.

Temperature-conductivity sensors (SBE-37), 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. This instrumentation was along the upper 155 m of the mooring line. For WHOTS-9, two deeper instruments were also deployed – a pair of SBE-16 T/C sensors was placed just below the glass balls at 35 m above the bottom. Dual acoustic releases, attached to a central load-bar, were placed approximately 30 m above the anchor. Above the release were eighty 17" glass balls meant to keep the release upright and ensure separation from the anchor after the release is fired. This flotation is sufficient for backup recovery, raising the lower end of the mooring to the surface in the event that surface buoyancy is lost.

WHOTS-9 incorporated *Nixalite Premium Bird Barrier Strips* 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. Individual strips were 4 feet long and secured with cable ties and hose clamps. The wire has magnetic characteristics and should not be mounted near modules with compasses.

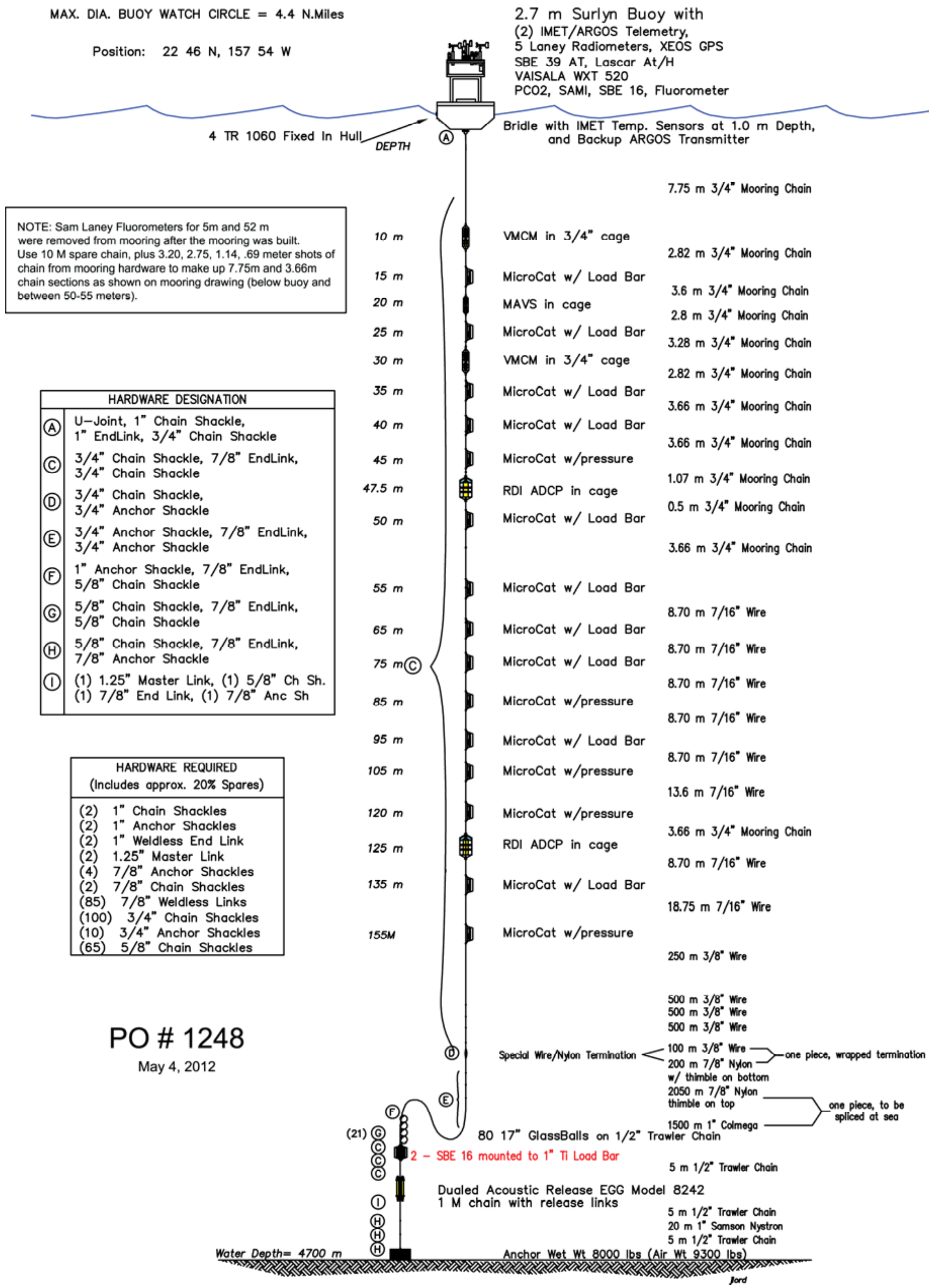


Figure 6. WHOTS-9 mooring diagram.

The anti-bird wire was installed fully around the crash bar and along the upper HRH extension arms. Wire was installed on the aft portion of the tower rail, but not the front portion to avoid magnetic disturbance of the wind module compasses. Short strips were also placed around the solar radiometers and other potential roosting sites. As a deterrent to birds settling on the buoy hatch, transparent monofilament fishing line was installed in an X pattern along the tower faces and inside the tower.

The WHOTS-9 buoy incorporated a remote line deployment system (Fig. 7) to enable a hauling line to be deployed from the buoy rather than attaching it by hand using a snap hook from the deck or a small boat. The system consists of two cylinders and an actuating device. 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 in order to accommodate the two cylinders at an angle that will allow the line to readily fall into the water.

Fig. 7. Remote line deployment system on the WHOTS-9 buoy.

b. Buoy Instrumentation

The buoy was outfitted with two independent ASIMET systems to provide redundancy. The ASIMET system is the second-generation of the Improved Meteoro-ogical (IMET) system described by Hosom et al. (1995). Performance of the second-generation sensors is described by Colbo and Weller (2009). Sensor modules are connected to a central data logger and addressed serially using the RS485 communication protocol. Modules also log internally using compact flash (CF) memory.

As configured for WHOTS-9, each system included six ASIMET modules mounted to the tower top (Fig. 8), one Sea-Bird SBE-37 "MicroCAT" mounted beneath the buoy hull, a data logger mounted in the buoy well, and an Argos Platform Transmit Terminal (PTT) mounted inside the logger electronics housing. The seven-module set measures ten meteorological and oceanographic variables: tower-top ASIMET modules measure wind speed and direction (WND), barometric pressure (BPR), relative humidity and air temperature (HRH), shortwave radiation (SWR), longwave radiation (LWR), and precipitation (PRC). The hull-mounted MicroCAT measures sea temperature and conductivity (STC). The MicroCATs were specified with an RS485 interface option, and thus could be addressed by the ASIMET logger in the same manner as the meteorological modules on the tower top.

Figure 8. WHOTS-9 tower top, showing the location of ASIMET modules. A SBE-39 (port side in front of PRC) supplemented the ASIMET HRH modules. A Vaisala WXT multi-parameter sensor was mounted between the two WND modules. A self-contained GPS module was mounted just forward of the starboard BPR.

Serial numbers of the sensors and loggers comprising the two ASIMET systems are given in Table 1, along with the various stand-alone sensors and telemetry system components. The sensor heights relative to the buoy deck, and relative to the water line, are given in Tables 2 and 3. The water line was determined to be approximately 70 cm below the buoy deck by visual inspection after launch.

Table 1. WHOTS-9 ASIMET system serial numbers and sampling

System	**Module**	**Type**	**Serial No.**	**Firmware Version** [1]	**Sample Rate** [2]
ASIMET-1	BPR	ASIMET-Heise	502	VOS53 4.03cf	1 min
	HRH	ASIMET-Rotronic	249	VOS53 4.29cf	1 min
	LWR	ASIMET-Eppley	205	VOS53 4.02cf	1 min
	PRC	ASIMET-Young	501	VOS53 4.03cf	1 min
	STC	Seabird SBE-37	1306	SBE 2.3b	5 min
	SWR	ASIMET-Eppley	201	VOS53 4.01cf	1 min
	WND	ASIMET-Young	216	VOS53 4.02cf	1 min
	Logger	C530	L-09	LGR53 4.11cf	1 min
	PTT	WildCAT	63878	ID#1 27356	90 sec
				ID#2 27364	90 sec
				ID#3 27413	90 sec
ASIMET-2	BPR	ASIMET-Heise	224	VOS53 4.03cf	1 min
	HRH	ASIMET-Rotronic	256	VOS53 4.29cf	1 min
	LWR	ASIMET-Eppley	218	VOS53 4.02cf	1 min
	PRC	ASIMET-Young	205	VOS53 4.03cf	1 min
	STC	Seabird SBE-37	1419	SBE 2.3b	5 min
	SWR	ASIMET-Eppley	226	VOS53 4.01cf	1 min
	WND	ASIMET-Young	222	VOS53 4.02cf	1 min
	Logger	C530/NTAS	L-10	LGR53 4.11cf	1 min
	PTT	WildCAT	63879	ID#1 7561	90 sec
				ID#2 27415	90 sec
				ID#3 27416	90 sec
Stand-Alone	AT	SBE-39	5276	3.1b	5 min
Stand-Alone	VWX	Vaisala WXT-520	1	VOS 4.03cf	1 min
Stand-Alone	GPS	Xeos	N/A	300034013701980	4 hr
Buoy hull	PTT	SiS	3	ID#1 9209	110 sec

[1] For Argos PTTs and Iridium, ID or IMEI are given rather than firmware version
[2] All modules sample internally. The logger samples all modules.
For PTTs and Iridium, "sample rate" is the transmission interval.

Table 2. WHOTS-9 ASIMET System 1 heights

Module	Relative [1] Height (cm)	Absolute [2] Height (cm)	Measurement Location
SWR	250	320	base of dome
LWR	250	320	base of dome
WND	258	328	prop axis
HRH	223	293	top of case
BPR	236	306	center of port
PRC	243	313	top of cup
STC	-155	-85	center of port
Vaisala	261	331	top of shield
SBE-39	222	292	base of shield

[1] Relative to buoy deck, positive upwards

[2] Relative to buoy water line, positive upwards,
WHOTS-9 WL= -70 cm

Table 3. WHOTS-9 ASIMET System 2 heights

Module	Relative [1] Height (cm)	Absolute [2] Height (cm)	Measurement Location
SWR	250	320	base of dome
LWR	250	320	base of dome
WND	260	330	prop axis
HRH	228	298	top of case
BPR	236	306	center of port
PRC	241	311	top of cup
STC	-155	-85	center of port

[1] Relative to buoy deck, positive upwards

[2] Relative to buoy water line, positive upwards,
WHOTS-9 WL= -70 cm

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

A wind vane on the tower top keeps the “bow” of the buoy oriented towards the wind. Flat-plate Argos PTT antennas are mounted on either side of the lower vane and a radar reflector is mounted in the upper vane. Wind modules are mounted in locations that minimize obstructions along the downwind path. Radiation sensors, mounted at the stern of the buoy, are at the highest elevation to eliminate shadowing. Two marine lanterns were mounted on either side of the tower, just outboard of the PRC modules. The two HRH modules were mounted on 18" extension arms off the port and starboard sides of the buoy to maximize aspiration and minimize self-heating.

Two additional sensors serve as back-ups to the ASIMET modules: a SBE-39 temperature sensor, and a Vaisala WXT 520 mult-parameter instrument. The SBE-39 was configured with a radiation shield to serve as a backup AT sensor and mounted inboard of the ASIMET HRH modules on the port side (Fig. 8). The Vaisala WXT 520 was configured as a stand-alone ASIMET module and deployed on the forward rail of the tower between the two RM Young wind modules (Fig. 8). The WXT measures pressure, temperature, relative humidity, wind speed and direction and precipitation. The WXT is powered by an independently wired set of batteries in the buoy well and serves as a backup for the ASIMET BPR, HRH, WND and PRC modules.

A stand-alone Xeos GPS module mounted to the tower (Fig. 8) served two purposes, first to record buoy position at higher precision than available from Argos and second to provide real-time positions as a backup in the event that the two primary Argos PTTs failed. For internal recording, a 5 min burst of 20 sec samples, repeated every 30 min, was specified. The real-time telemetry interval was set to 4 h. In addition to an internal battery, the GPS module was connected to batteries in the buoy well to provide power for approximately 700 days of operation.

A pCO_2 system was added to the WHOTS buoy by Pacific Marine Environmental Laboratory (PMEL). The WHOTS pCO_2 system provides measurements every three hours of CO_2 in marine boundary layer air and in 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 CO_2 from a closed loop of air and a span gas (440 ppm CO_2) 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. To view the daily data from WHOTS, visit the NOAA PMEL Moored CO_2 Website: http://www.pmel.noaa.gov/co2/story/WHOTS.

In cooperation with Dr. Sam Laney (WHOI), an above-water hyperspectral radiometry system was integrated into the WHOTS-9 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 (Fig. 9a), and one is mounted on the buoy vane (Fig. 9b). A single complementary hyperspectral sensor is mounted facing upward near the near the ASIMET radiometer modules as a reference for the incoming spectral irradiance. 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.

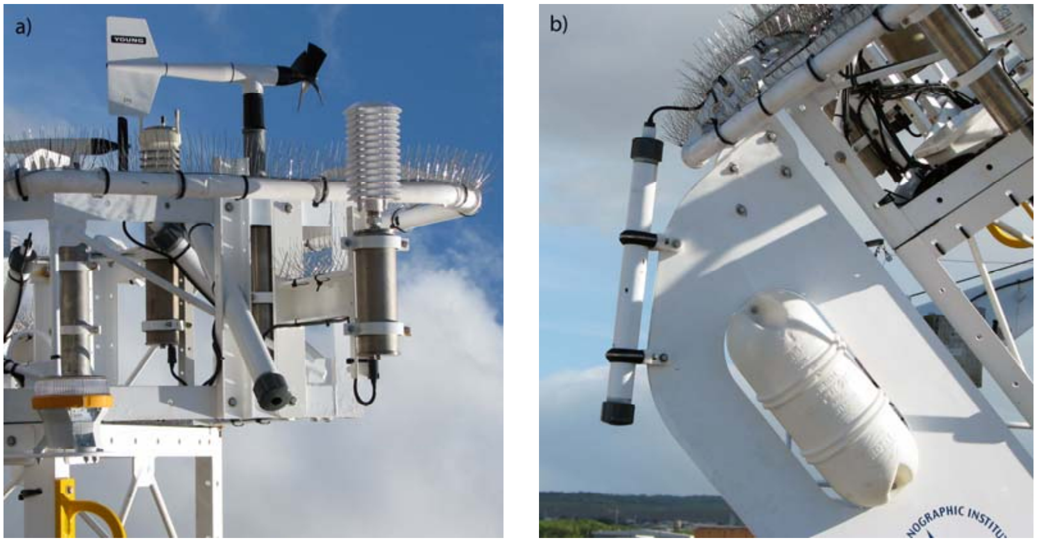


Figure 9. Radiometers mounted on a) the starboard face of the tower and b) the vane of the WHOTS-9 buoy.

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 ocean color instruments and locations were as follows:

4 Radiometers – model: RAMSES-ARC-VIS-Ti, manufacturer TriOS, Germany
Serial #: 010-11-8395 WHOI 114766 - mounted on wind vane (aft)
Serial #: 010-11-8394 WHOI 114765 - mounted on starboard side
Serial #: 010-11-839B WHOI 114767 - mounted on bow
Serial #: 010-11-8393 WHOI 114764 - mounted on port side

1 Radiometer – model: RAMSES-ACC-VIS-Ti, manufacturer TriOS, Germany
Serial #: 010-11-8396 WHOI 114768-mounted looking upward on radiometer tower

1 Chlorophyll Fluorometer – model SCF, manufacturer Seapoint Sensors, USA
Serial #: SCF3256- mounted underneath buoy

1 Mechanical Wiper – model: Hydro-Wiper, manufacturer Zebra-Tech
Serial # 410 - mounted with fluorometer.

1 Interface Unit – model: Smart Cable, manufacturer Martin Cooper Consulting
Serial #: 049 - mounted with fluorometer

1 Logger Unit – model: Mooring Logger, manufacturer Martin Cooper Consulting
Serial #: 062 - mounted on plate next to wind vane

c. Subsurface Instrumentation

Four RBR TR-1060 temperature sensors were installed in the buoy hull to provide a SST measurement within about 10 cm of the mean water line. The TR-1060s are relatively small and light, with a diameter of 25 mm. This allows them to be recessed directly into the buoy hull by drilling a hole in the foam and inserting the sensor. For WHOTS-9, two sensors were inserted at the "bow" of the buoy (180^0 from the fin) at depths of 80 and 95 cm below the buoy deck. Two more were inserted at approximately 120^0 and 240^0 at about 80 cm below the deck. The protruding ends were coated with anti-seize lubricant just prior to deployment as an antifouling measure. The configuration is summarized in Table 4. Visual inspection of the buoy after deployment indicated that the 80 cm sensors were seldom exposed, i.e. they remained submerged below the ~70 cm water line.

Table 4. WHOTS-9 Buoy Hull SST Configuration

Rel depth (cm) [1]	Abs depth (cm)	Angle (deg) [2]	Instrument	SN	Sample rate
80	10	120	TR-1060	14977	1 min
80	10	180	TR-1060	14878	1 min
95	25	180	TR-1060	14978	1 min
80	10	240	TR-1060	14882	1 min

[1] depth = below buoy deck, WHOTS-9 WL = 70 cm
[2] angle = clockwise from buoy vane

The university of Hawaii group provided 15 SBE-37 Microcats, a RDI 300 kHz Workhorse acoustic Doppler current profiler (ADCP), a RDI 600 kHz Workhorse ADCP and a Nobska MAVS acoustic velocity sensor for the WHOTS-9 mooring. All of the Microcats measure temperature and conductivity; six Microcats also measure pressure. Table 5 summarizes deployment information for the UH instrumentation. WHOI provided 2 Vector Measuring Current Meters (VMCMs), configured as shown in Table 6. 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 7.

Table 5. WHOTS-9 UH Instrumentation

SN	Instrument	Depth	Pressure SN	Sample Interval (sec)	Start Logging Date, Time (UTC)	
3382	Microcat	15	N/A	180	06/07/12	0:00:00
10261	MAVS	20	N/A	1800 [1]	06/07/12	0:00:00
4663	Microcat	25	N/A	180	06/07/12	0:00:00
3633	Microcat	35	N/A	180	06/07/12	0:00:00
3381	Microcat	40	N/A	180	06/07/12	0:00:00
3668	Microcat	45	5579	240	06/07/12	0:00:00
13917	600 kHz ADCP	47.5	N/A	600 [1]	06/07/12	0:00:00
3619	Microcat	50	N/A	180	06/07/12	0:00:00
3620	Microcat	55	N/A	180	06/07/12	0:00:00
3621	Microcat	65	N/A	180	06/07/12	0:00:00
3632	Microcat	75	N/A	180	06/07/12	0:00:00
4699	Microcat	85	10209	240	06/07/12	0:00:00
3791	Microcat	95	N/A	180	06/07/12	0:00:00
2769	Microcat	105	2949	240	06/07/12	0:00:00
4700	Microcat	120	9944	240	06/07/12	0:00:00
7637	300 kHz ADCP	125	N/A	600 [1]	06/07/12	0:00:00
3669	Microcat	135	5700	240	06/07/12	0:00:00
4701	Microcat	155	10211	240	06/07/12	0:00:00

[1] see Table 7 for details of sampling programs for these instruments

Table 6. WHOTS-9 VMCM configuration

SN	Instrument	Depth (m)	Sample Interval (sec)	Start Logging Date, Time (UTC)	
11	VMCM	10	60	06/10/12	20:35:30
61	VMCM	30	60	06/10/12	22:03:30

Table 7. WHOTS-9 ADCP and MAVS configuration details

	ADCP S/N 7637	ADCP S/N 13917	MAVS S/N 10261
Frequency (kHz)	300	600	N/A
Number 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	06/07/12, 00:00	06/07/12, 00:00	06/07/12, 00:00
Transducer 1 Spike Time	06/08/12, 19:30:05	06/08/12, 18:59:40	06/08/12, 20:05:00-21:20:00
Transducer 2 Spike Time	06/08/12, 19:30:25	06/08/12, 19:00:00	06/08/12, 20:05:00-21:20:00
Transducer 3 Spike Time	06/08/12, 19:30:45	06/08/12, 19:00:20	06/08/12, 20:05:00-21:20:00
Transducer 4 Spike Time	06/08/12, 19:31:05	06/08/12, 19:00:40	06/08/12, 20:05:00-21:20:00
Time in water	06/13/12, 20:19	06/13/11, 19:49	06/13/12, 18:26
Depth	125 m	47.5 m	20 m

4. WHOTS-9 Mooring Deployment

a. Deployment Approach

Mooring deployment operations were conducted on the *Hi'ialakai* using techniques developed from previous cruises. 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-9 mooring was slated for the northern site at a nominal location of 22° 46'N, 157°54'W, about 6 nm east of the HOT central site at 22° 45'N, 158°00'W.

Winds from the bridge and currents from the shipboard ADCP were noted while maneuvering to the deployment starting point. Winds were about 13 kt from just south of east (100^o), and currents were 0.2 m/s to the N/NE. It appeared that the best approach would be from the NW. It was decided to steam to a starting point approximately 6.0 nm from the drop point with an inbound course of 110^o. The waypoint for the bridge was the anchor drop point, 0.20 nm beyond the desired anchor position to allow for an expected fall-back of 350 – 400 m. Deployment operations began at about 0800 h (local) on 13 June with the *Hi'ialakai* at a distance of 6.0 nm from the drop site (Fig. 10).

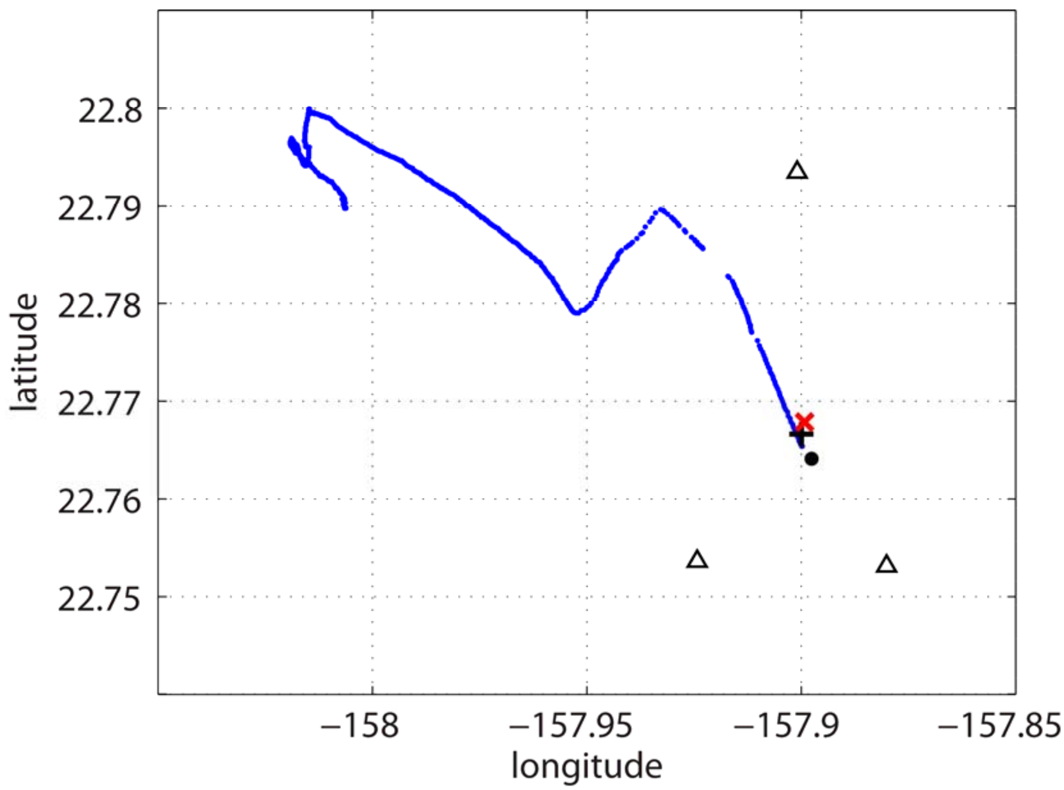


Figure 10. Ship track during WHTOS-9 deployment. The ship's position at 1 min intervals is shown as blue dots; gaps represent missing data. The anchor drop location is marked with a circle, the anchor target is marked with "+" and the surveyed anchor location is marked with a red "x". The three survey stations are marked with triangles.

Two aspects of deployment operations are evident from Fig. 10. First, the buoy deployment was delayed for about 1h due to problems with the pCO_2 system which were noticed and diagnosed between the time that the upper portion of the mooring was deployed and the buoy was launched. As a result, propulsion was secured for longer than normal at the start of the deployment, and the ship drifted about 1 nm to the NW. Second, forward speed was reduced for about 1 h during deployment of the glass balls. The ship drifted to the NE during this period. As a result, the final approach to the anchor drop site was along a course of about 130^o.

b. Deployment Operations

The mooring was deployed in multiple stages. The first stage was the lowering of the upper 45 meters of the mooring over the starboard side of the ship. Instruments and the wire or chain sections immediately above them had been assembled and laid out on deck prior to the start of operations (Fig. 11). The 45 m Microcat was selected as the first instrument to be deployed. Instruments up to the 10 m VMCM were deployed from deepest to shallowest, using the crane to lift them into the water over the starboard rail.

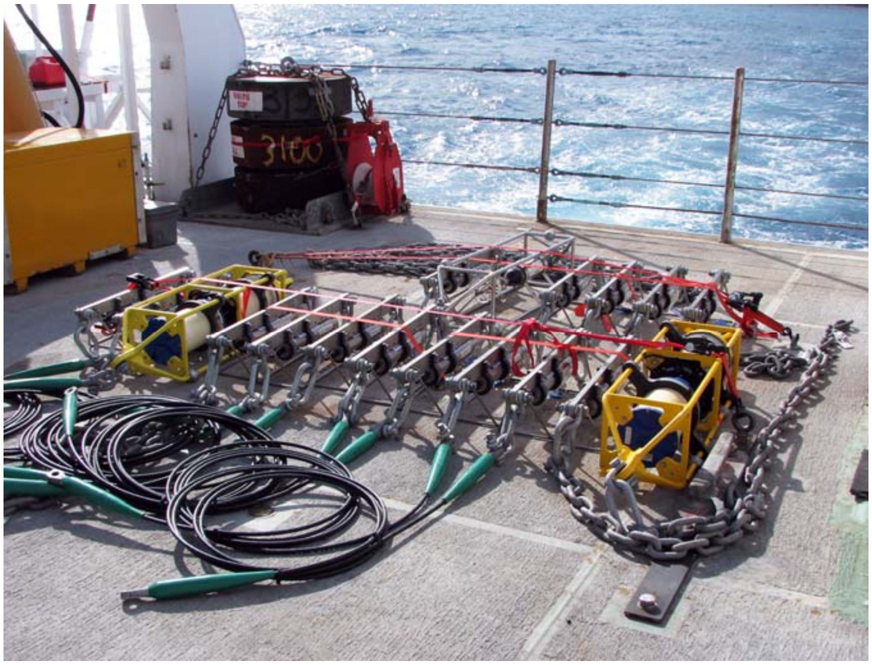


Figure 11. Subsurface instrumentation assembled and laid out in sequence on deck prior to deployment. The deepest instrument is at the far left.

A ½ inch spectra hauling line was payed out from the mooring winch and passed through the UOP block. The block was hauled up by using the large air tugger. The spectra line was passed around the A-frame, around the starboard quarter, and shackled to the chain below the first instrument to be deployed. Instruments and chain were lifted over the side with the crane. A stopper line was then hooked into a chain link and made fast to the deck cleat. The crane was removed and the next instrument was shackled to the stopped-off chain. Once connected, the crane lifted the chain and instrument off the deck. After the crane had the load, the stopper line was eased off and cleared. As each instrument was added and lowered into the water, the hauling line was payed out to follow the mooring down. Once the upper 45 m of the mooring was in the water, the upper chain section was secured with a slip line until the buoy was deployed.

The next stage of the operation was the launching of the surface buoy. Slip lines were rigged on the buoy tower top, deck D-ring and buoy base to maintain control during the lift. The ship's crane was attached to the Peck and Hale release hook on the buoy lifting bale and a tag line was attached just above the crane hook. The slack chain from the upper section of mooring line was connected to the buoy universal. 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 (Fig. 12). Once the buoy settled into the water, and the crane wire went slack, the release hook was tripped. The ship then maneuvered slowly ahead to allow the buoy to pass around the stern. The 45-meter length of mooring, along with the ½" spectra hauling line, provided adequate scope for the buoy to clear the stern.

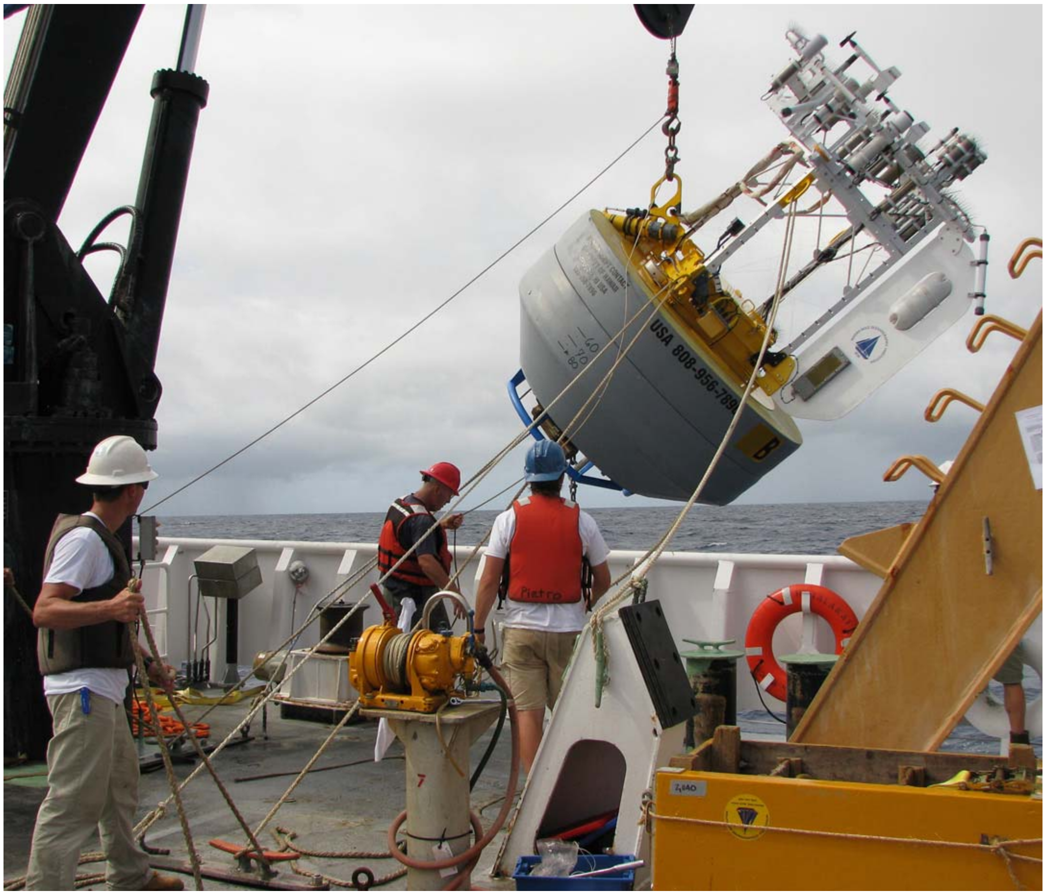


Figure 12. WHOTS-9 buoy deployment. The buoy is lifted over the (non-removable) gunwales with the ship's crane. Tag lines for the crane whip, quick release, buoy deck, and buoy tower can be seen.

The remainder of the mooring was deployed over the stern. Once the buoy was behind the ship, speed moved ahead slowly (~0.5 kt) and the spectra leader was hauled in on the winch bringing the chain below the 45 meter Microcat over the stern. The mooring was stopped off and the remaining instruments and mooring components were added to the 45 meters previously deployed. The winch and cleated stopper lines were used to parcel out sections of wire, chain, and instruments. When all the instruments were deployed the remaining 1900 meters of wire and 200 meters of nylon (previously wound on the winch drum) were 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 length of nylon in the wire baskets. An H-bit, positioned in front of the winch was used to slip the 3500-meter combined length of nylon/Colmega line stowed in three wire baskets. While the synthetic line was being payed out, the 80 glass balls were staged on the main deck for deployment.

With approximately 30 meters of Colmega line remaining, payout was stopped and the shackle-link 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 Yale grip was removed and the remaining line was payed out from the winch until it was at the transom. The glass balls were then shackled into the mooring line and eased over the transom using the winch.

At this point, the ship was approximately one hour from the drop position. With the last glass ball at the transom, two stopper lines were shackled to the chain and to the 7/8 end link. Just below the glass balls on a 1” load bar, 2 SBE 16’s were shackled into the mooring. The mooring was towed for roughly ½ hour. Approximately 0.5 nm from the site, the final sections of the mooring were prepared. The tandem-mounted acoustic releases were shackled into the mooring chain at the transom. Another 5-meter section of chain was attached to the bottom link of the release chain. A 50 foot ¾” Nystron slip line was placed through the 7/8” link which was shackled to the 20 meter of Nystron line. The two ends of the slip line were tied with a bowline to the winch leader. The slip line and the 20 meter section of Nystron were wound on the winch. The 5 meter ½” chain from the releases was shackled to the 20 meter section of Nystron.

A ½” chain hook was shackled into the working line hanging from the A-frame and hooked into the chain just below the acoustic releases. The working line was pulled up with the large air tugger, lifting the releases off the deck. The tugger payed out and the A-frame was boomed out until the releases were clear of the transom. The working line was lowered and the chain hook removed from the mooring. The winch continued to pay out until the end of the 20-meter Nystron line was near the transom. The anchor, positioned on the starboard side inboard of the A-frame, was rigged with a 5-meter section of ½” chain. The 5 meter chain section was shackled to the 20 meter Nystron line. The chain lashings on the anchor were removed, and an expendable back stay was rigged on the anchor to secure it. With 150 meters to the drop site, the winch payed out slowly until the anchor had the mooring load. The ¾” slip line was removed from the winch and was slowly slipped out through the 7/8” link.

The crane was positioned over the forward end of the tip plate and hooked into the tip plate bridle. As the ship approached the launch site, the backstay was removed, the crane hook was raised, and the tip plate raised enough to let the anchor slip into the water. The anchor was dropped at 0223 UTC on 14 June at 22° 45.845′ N, 157° 53.857′ W in water of depth 4668 m.

An anchor survey was done 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. 10). WHOI’s Edgetech 8011M deck gear was used to range on the release. The anchor survey began at about 1800 local on 13 June and took about 2 hours to complete. Triangulation using the horizontal range to the anchor from the three sites gave an anchor position of 22° 46.071′ N, 157° 53.956′ W (Fig. 13). Fallback from the drop site was about 447 m, or ~10 % of the water depth.

Visual observations from the bridge the day after deployment showed the tower top instrumentation intact and the buoy riding smoothly with a nominal waterline about 70 cm below the buoy deck.

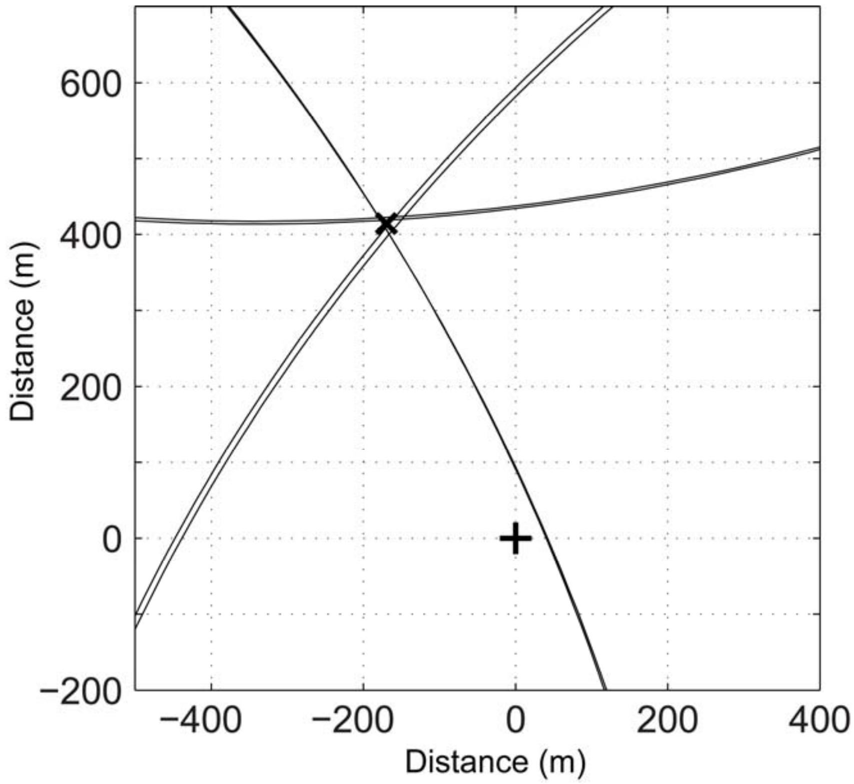


Figure 13. WHOTS-9post-deployment anchor position survey. Multiple arcs from the three survey sites are shown along with the anchor drop location (+) and surveyed anchor position (x).

5. WHOTS-9 Mooring Recovery

Recovery operations for the WHOTS-8 mooring began at 0730 (local) on 16 June 2012. The *Hi'ialakai* was positioned at about 0.25 nm from the anchor site with the anchor downwind and to port. An unsuccessful attempt was made to use the ship's through-hull transducer to communicate with the release. Instead, WHOI deck gear and an over-the-side transducer were used. The release was fired at 0745 local on 16 June. The ship held position for another few minutes while repeated ranging was done on the release. The mooring was considered released from the anchor when ranging indicated that the release had traveled about 400 m. After about 55 minutes, the glass balls were spotted on the surface.

The upper ocean flow during the WHOTS-8 recovery (and in fact during the majority of the cruise) was unusual, an anticyclonic feature developing to the east of ALOHA and pushing westward during the cruise (Fig. 14). Northward currents were seen on the 12th and evidenced further by the displacement of WHOTS-8 from its anchor. The currents turned to northeastward during the recovery of WHOTS-8, and eastward over the upper 200 m at more than 0.5 m/s by the 18th of June. During this period, the winds veered from southeasterly to northeasterly and strengthened.

The upwind flow became somewhat problematic during the recovery of WHOTS-8, as the buoy started off to port and moved upwind faster than the glass ball cluster. Hauling in the mooring line was thus slowed because of the extra forces as it was towed upwind through the water between the ship and buoy.

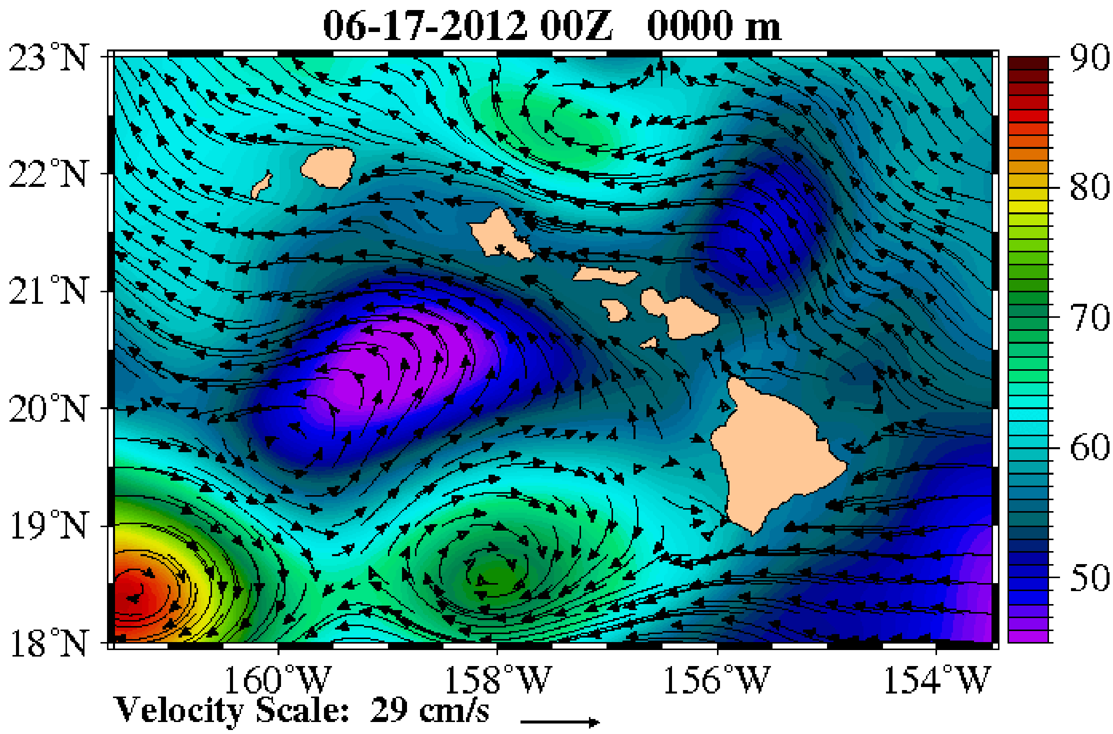


Figure 14. Surface currents (arrows) over sea surface height (colors) for the Hawaiian island region during the recovery of WHOTS-8. Analysis is from the Navy Coastal Ocean Model (NCOM).

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 to provide a secure connection to the glass ball cluster. The TSE winch was wound with ½" spectra line. The line was passed through the a-frame block and faked out on deck. The workboat came to the stern and the spectra line was lowered to them. The work boat maneuvered to the flotation cluster and snapped in a 3 ton snap hook to a 7/8" link. The ship steamed upwind of the cluster of balls and initiated recovery operations. The work boat continued on to the buoy to activate the remote line deployment system. The line deployment was a partial success, in that the actuating device functioned and the cylinder door opened. However, the 60 ft leader was not ejected from the cylinder as expected. The line was pulled out by hand to complete the operation. The work boat was recovered just after the glass balls were secured in the wire baskets.

The winch hauled in on the working line until the glass balls were at the transom. The A-frame was boomed out. The winch then hauled the cluster of balls onto the deck. Several picks with the winch were required to get all the balls on deck. One air tugger was used to stabilize the cluster and help bring the cluster 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 shackle-link 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 boomed out and the spectra 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 for storage.

Once the glass balls were secured, the winch leader was passed through the UOP block hanging from the A-frame. The large tugger was used to raise the block off the deck. The winch leader was shackled into the Colmega link, the winch hauled in to take the mooring tension, and the stopper line was eased and cleared. The Colmega and nylon were wound onto the winch. When the winch drum was full, the mooring was stopped off using a Yale Grip and a stopper line. When the stopper line had the load, the winch payed out enough line so that the H-Bit could be used as an additional stopper. The synthetic line from the winch drum was off spooled into large canvas bags. When the winch was empty, the bitter end of the nylon was tied with a bowline to the winch leader. The nylon was removed from the H-Bit and the winch took up the nylon slack. The stopper line was eased off and cleared. The Yale Grip was removed. This process took place multiple times to accommodate the 3550 m of synthetic line.

The winch was used to complete the recovery of the remaining 200 meters of nylon and 1900 meters of wire rope. The hauling operation was stopped periodically to remove instruments shackled between segments of the mooring wire. As instruments surfaced and were pulled up through the a-frame, loads were transferred to stopper lines and the instruments are removed from the mooring line. As each instrument was removed from the mooring, it was inspected and photographed.

With 45 meters remaining in the mooring line, the buoy was cast adrift for recovery over the starboard side. It was necessary to spend approximately 20 minutes rearranging the deck equipment for 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 ship's capstan was used to pull the mooring chain, providing slack to lower the buoy to the deck and disconnect. Once the buoy was secured on the deck, the remaining instruments were recovered using short picks with the crane. Stopper lines were used to transfer the load as instruments were pulled from the mooring line.

6. Meteorological Intercomparison

a. Overview

In order to assess the performance of the buoy meteorological systems, a 48 h period of observations at each buoy was planned following the deployment of the WHOTS-9 mooring and prior to recovery of the WHOTS-8 mooring. Due to forecasts of worsening weather conditions that would make recovery operations difficult, the WHOTS-8 mooring was recovered two days prior to the originally scheduled day. As a result the intercomparison period at each buoy was shorter than planned. The total duration was 59 h: 31 h at WHOTS-9 and 28 h at WHOTS-8.

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. Due to substantial drift (~1 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. Gaps in the directly received Argos data were supplemented by data obtained from the WHOI UOP web site.

Note that routine system monitoring at WHOI had shown that WHOTS-8 L07 Argos transmissions failed to update with new meteorological data as of 5/5/2012, although the SBE-37s on the buoy hull did update. Thus, at the time of the intercomparison only SST an SSS were available for L07.

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 system installed on a bow mast as described by Whelan et al, 2012. The comparisons presented here use available data from the WHOTS-8 and WHOTS-9 buoys, the ship's SCS and the AutoIMET system. ESRL data are included for assessment of selected variables.

b. Shipboard Instruments

The HA 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 above the pilot house. BP was measured by a RM Young 6120V also mounted above the pilot house. 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 mast 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 digital thermometer and a SBE-21 thermosalinograph. 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 measured water that had been pumped from the forward intake to the Wet Lab at the aft of the ship. Thus, the SBE-38 was the preferred sensor for SST. 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.

c. AutoIMET

An AutoIMET system, based on the ASIMET sensor suite (Colbo and Weller, 2009) and developed at WHOI for volunteer observing ships (VOS), was installed on the HA to supplement the shipboard systems.Comparison of the AutoIMET system installed above the pilot house on the WHOTS-8 cruise with ESRL measurements made from a bow-mounted meteorological tower showed that the AutoIMET sensors suffered from flow distortion and self heating. For

WHOTS-9, we were able to install some of the AutoIMET system in a more favorable location by sharing space on the ESRL meteorological tower.

The AutoIMET system provided barometric pressure (BP), air temperature (AT), relative humidity (RH), shortwave radiation (SWR), longwave radiation (LWR), and winds relative to the ship. A precipitation (PRC) sensor was also available, but because of limited space and load capacity of the ESRL met tower, the PRC was omitted from the instrument suite. GPS position data were recorded, but the wind data were not corrected in real-time. AutoIMET data recorded by the logger were also captured by a data acquisition computer in the science lab. The SCS was set up to output a text stream of data (on the telnet port 23 at 1 Hz) which was logged on a windows laptop and stored at thirty second intervals. AutoIMET wind speed and direction were corrected to true (WNDN and WNDE, and WSPD and WDIR) using ship's heading and speed over ground recorded from the SCS. The AutoIMET data, collected at 2 min intervals, were averaged to 1 hr for comparison with the buoy systems.

The WHOTS-9 AutoIMET installation on the HA included four main components: 1) a splash-proof housing with sensors for AT/RH, SWR and LWR, 2) a second housing with a BP sensor and central data logger, 3) a wind sensor, and 4) a GPS logger. Figure 15 shows the mounting configuration. Radiometers, AT/RH sensor, wind sensor and GPS logger were attached to an H-frame mounted on the ESRL tower. The logger housing with BPR and the battery pack were mounted at the base of the tower. The long cables connecting the sensors to the logger and the long cable from the logger to the data acquisition computer in the lab were a concern due to potential noise and signal loss. During the cruise data were consistently obtained from all sensors except LWR (and occasionally SWR) and the GPS unit.

Estimated heights above the ship’s design water line (DWL) for the AutoIMET sensors were: Wind, 15.2 m; SWR/LWR, 14.9 m; AT/RH 14.4 m; GPS, 14.2 m; BPR, 8 m.

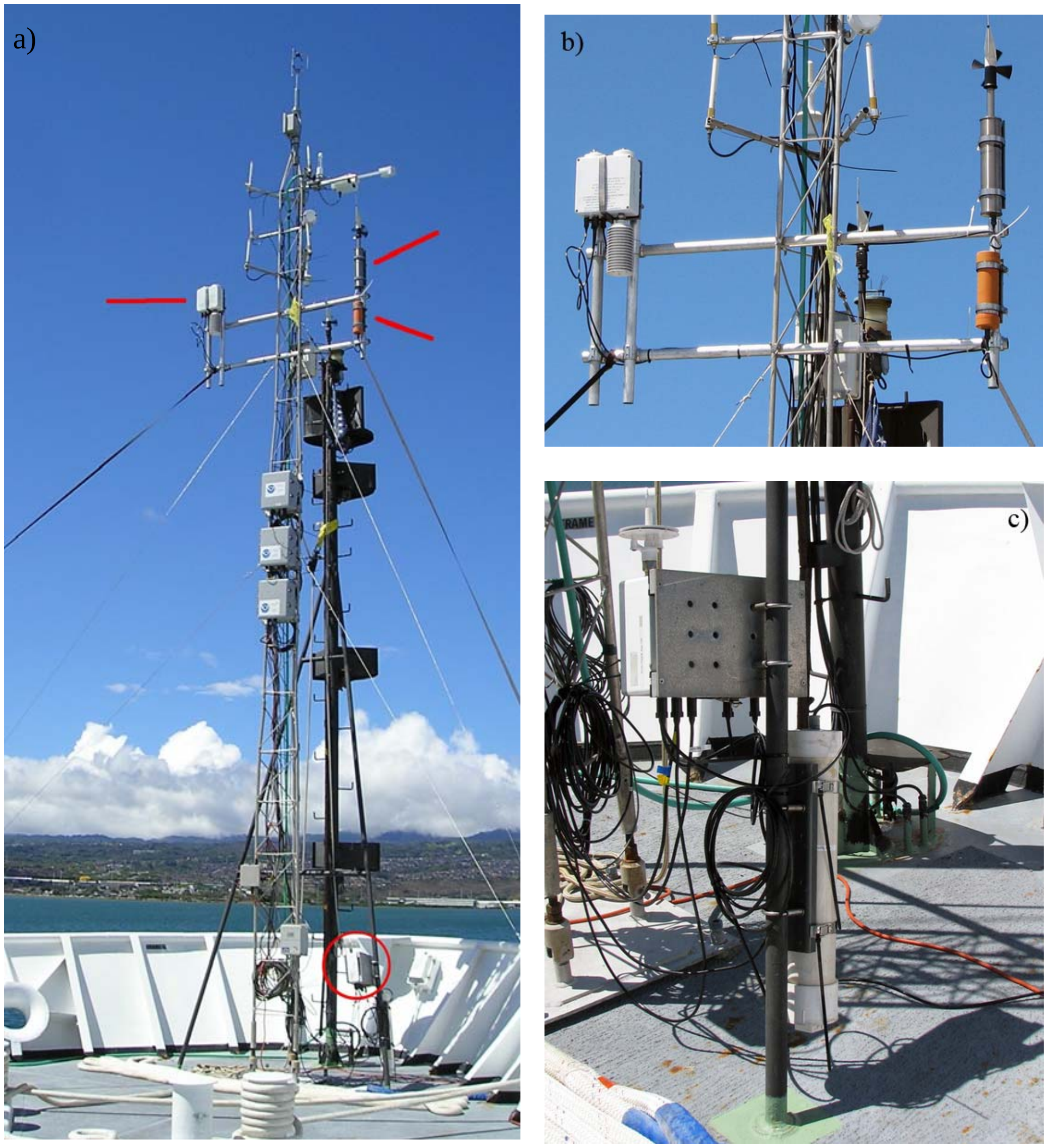


Figure 15. a) AutoIMET sensors mounted on the ESRL meteorological tower, indicated by the red lines. AT/RH and radiometers are to the left, wind sensor and GPS to the right. The BPR and logger are at the base of the ship's bow mast (circled). The battery pack is attached below the logger. b) Close-up of the AutoIMET installation on the tower. c) Close up of the bow mast base.

d. WHOTS-8 and WHOTS-9 Intercomparison

The WHOTS-9 comparison period started at 0600 h UTC on 14 June (year day 166.25), after the anchor survey, and ended at 1300 h UTC on 15 June (year day 167.54) when the ship transitioned to the WHOTS-8 buoy. The HA drifted away from the WHOTS-9 site five times for CTD casts, and had to maneuver back to a location near the buoy. These excursions are identifiable in Fig. 16. The WHOTS-8 comparison period began at 1300 h UTC on 15 June (year day 167.54) and ended at 1700 h UTC on 16 June (year day 168.71) when WHOTS-8 mooring recovery began. The HA drifted away from the WHOTS-8 site four times for CTD casts, and had to maneuver back to a location near the buoy. These excursions are identifiable in Fig. 16.

The results of the comparison are shown in Figs. 18 through 27, with Fig. 17 providing the legend. The buoy systems are identified in the plots by their logger numbers. Loggers L07 and L08 are associated with WHOTS-8. Loggers L09 and L10 are associated with WHOTS-9. The AutoIMET system is designated “AIMET” and the *Hi’ialakai* shipboard sensors are designated “SCS”. The WHOTS-9 buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy) for all variables except AT and SSS. The performance of most sensor pairs could not be evaluated for WHOTS-8 since only one system (L08) had all variables available. However, comparison with WHOTS-9 and AutoIMET data indicated that WHOTS-8 L08 was operating within expected tolerances with the exception of LWR. Examination of the buoy data in conjunction with the shipboard meteorology provided further understanding of discrepancies, and resulted in other useful observations about system performance, as described below.

The WHOTS-9 buoy AT pair agreed to within about 0.05°C at night, but the differenced increased to as much as 0.4°C at mid day. The WHOTS-8 L08 AT was within about 0.1°C of the WHOTS-9 buoy pair at night and closer to L09 at mid day. The AutoIMET and ESRL AT showed a pattern of variability similar to the buoys, but AutoIMET was about 0.4°C low and ESRL about 0.2°C low relative to the buoys. Shipboard AT offsets of about -0.2°C relative to the buoys have been seen in previous comparisons, and attributed to vertical gradients. So the AutoIMET and ESRL AT offsets are plausible. The SCS, however, appears to be unreliable, with a positive bias of as much as 1.3°C. Adjusting AutoIMET and ESRL to match the buoys at night results in mid day values close to L08 and L09, with L10 higher by 0.2-0.3°C. In addition, L10 AT was found to be about 0.5°C higher than the SBE-39 AT at mid day in pre-deployment dock tests. It was concluded that the WHOTS-8 L08 and WHOTS-9 L09 AT sensors were within expected accuracy, but that WHOTS-9 L10 was biased high at mid day.

The WHOTS-9 buoy RH pair typically agreed to within 1%, which is the resolution of the Argos telemetry data. The WHOTS-8, AutoIMET, ESRL and SCS RH were all within about 2%, of each other and the WHOTS-9 buoy values. It was concluded that the buoy RH sensors were within expected accuracy.

The WHOTS-9 buoy BP pair agreed within the 1.0 mb resolution of the telemetered data. The WHOTS-8 BP was typically within 1.0 mb of the WHOTS-9 pair. AutoIMET and SCS BP were adjusted to the buoy level of 3 m. This resulted in good agreement of the AutoIMET with the buoy BP (within 0.5 mb). However, the adjusted SCS BP did not match the trend shown by the other sensors and had 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 available PRC sensors indicated rain during the intercomparison period. The WHOTS-9 buoy fill levels were between 40 and 44 mm. The WHOTS-8 buoy L08 fill level was 24-25 mm (the L07 value was flat-lined at 38 mm). The AutoIMET PRC was not connected, and PRC was not available from the ship.

Both the WHOTS-9 and WHOTS-8 buoy SST pairs agreed to within the 0.01°C resolution of the telemetered data. Differences of 0.1°C to 0.3°C between WHOTS-9 and WHOTS-8 SST were attributed to horizontal gradients. This is corroborated by the ESRL SST, which tends to follow the WHOTS-9 pair up to about yearday 167.4, but is closer to the WHOTS-8 pair after yearday 167.6 (the ship moved from WHOTS-9 to WHOTS-8 at yearday 167.5, see Fig. 16). The SCS (bow intake) SST was about 0.2°C higher than the nearest buoy (i.e. 0.2°C higher than WHOTS-9 before yearday 167.5 and 0.2°C higher than WHOTS-8 afterwards). It was concluded that the buoy SSTs were operating as expected, but the SCS SST had a significant warm bias.

The WHOTS-9 buoy salinity pair disagreed by about 0.2 PSU, which was puzzling since they agreed to 0.05 PSU in a salt water bath during burnin. L09 was presumed to be correct since it was much closer to the WHOTS-8 buoy pair. The WHOTS-8 buoy pair agreed to within 0.05 PSU. It was concluded that the WHOTS-9 L10 SSS was biased low by about 0.2 PSU. The SCS salinity was consistently 0.5 PSU higher than the buoy salinities and did not appear reliable.

The WHOTS-9 buoy SWR pair agreed to within 7 W/m^2 at mid-day, or < 1% of the 1030 W/m^2 mid-day peak. The AutoIMET and ESRL SWR tracked well with the WHOTS-9 diurnal cycle during the first day, and were within 15 W/m^2 and 15 W/m^2, respectively, of the buoy pair at mid day. The WHOTS-8 SWR agreed reasonably well with AutoIMET and ESRL SWR on the second day if a time delay of about 20 min was considered (e.g. due to clock drift). It was concluded that all of the SWR instruments were operating as expected.

The WHOTS-9 buoy LWR pair typically agreed to within 2 W/m^2. The AutoIMET LWR was higher than the WHOTS-9 buoy pair by about 6 W/m^2 on the first day, but the close agreement with the ESRL LWR indicated that the WHOTS-9 results were accurate. The WHOTS-8 LWR was about 7 W/m^2 higher than the AutoIMET and ESRL LWR on the second day. Considering the ESLR LWR as the transfer standard indicates that WHOTS-8 L08 LWR was biased high by about 10 W/m^2.

The WHOTS-9 WND pair showed a consistent speed difference of about 0.2 m/s. The WHOTS-8 L08 WND speed fell roughly between the two WHOTS-9 values. The AutoIMET, ESRL and SCS wind speeds were similar to each other and about 0.6 m/s higher than the mean of the buoy values (note that no correction was made for the ~10 m ht difference). A tentative conclusion is that the WHOTS-9 L09 wind speed is low by about 0.1 m/s.

The WHOTS-9 buoy WND pair showed a direction difference of about 3°. The ESRL direction was within a few degrees of the buoy directions. Both SCS and AutoIMET showed relatively large directional variability, perhaps due to to problems with the correction for ship's orientation. Eliminating the noisy SCS and AutoIMET winds shows the three buoy directions and the ESRL direction agree to within about 5°. It was concluded that the buoy wind directions were within expected accuracy.

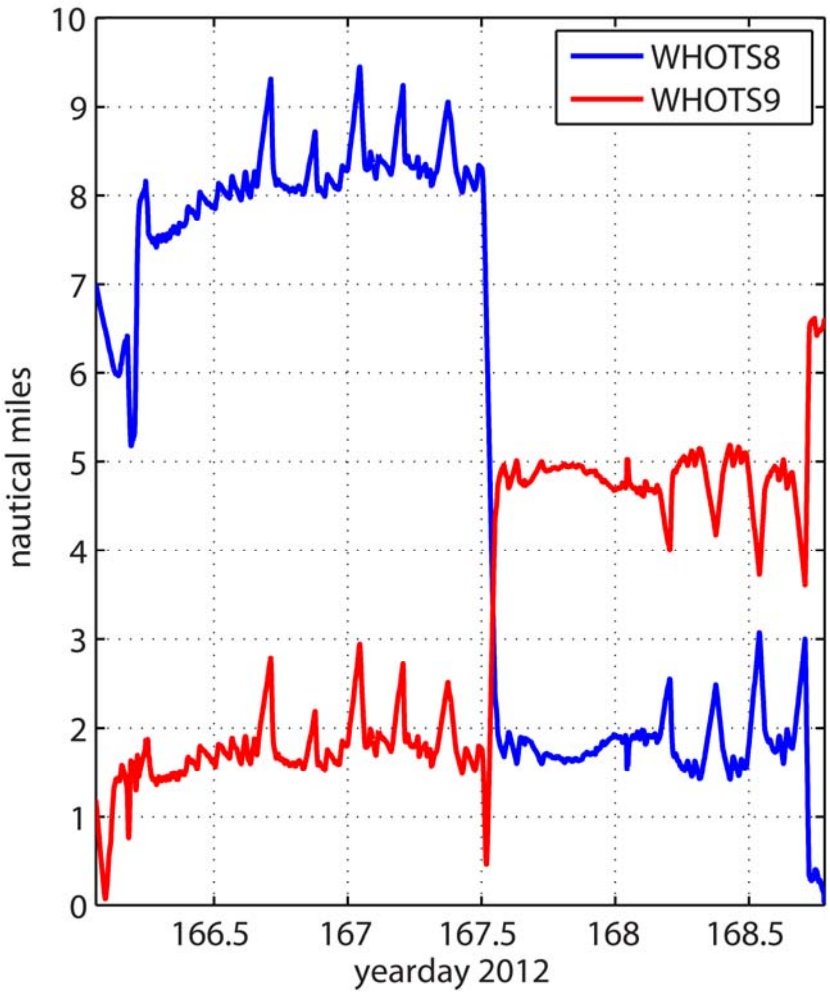


Figure 16. Distance between the *Hi'ialakai* and the WHOTS-8 and WHOTS-9 anchor positions during the intercomparison period. The buoys were about 2 nm from their anchors. Excursions to ~3 nm indicate CTD casts.

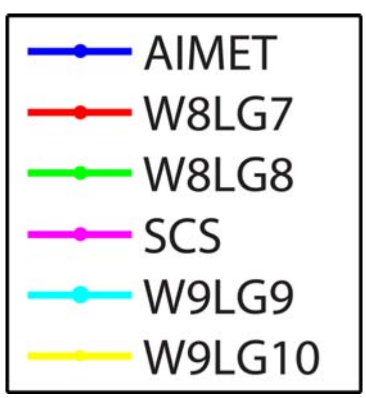


Figure 17. Legend for WHOTS intercomparison plots.

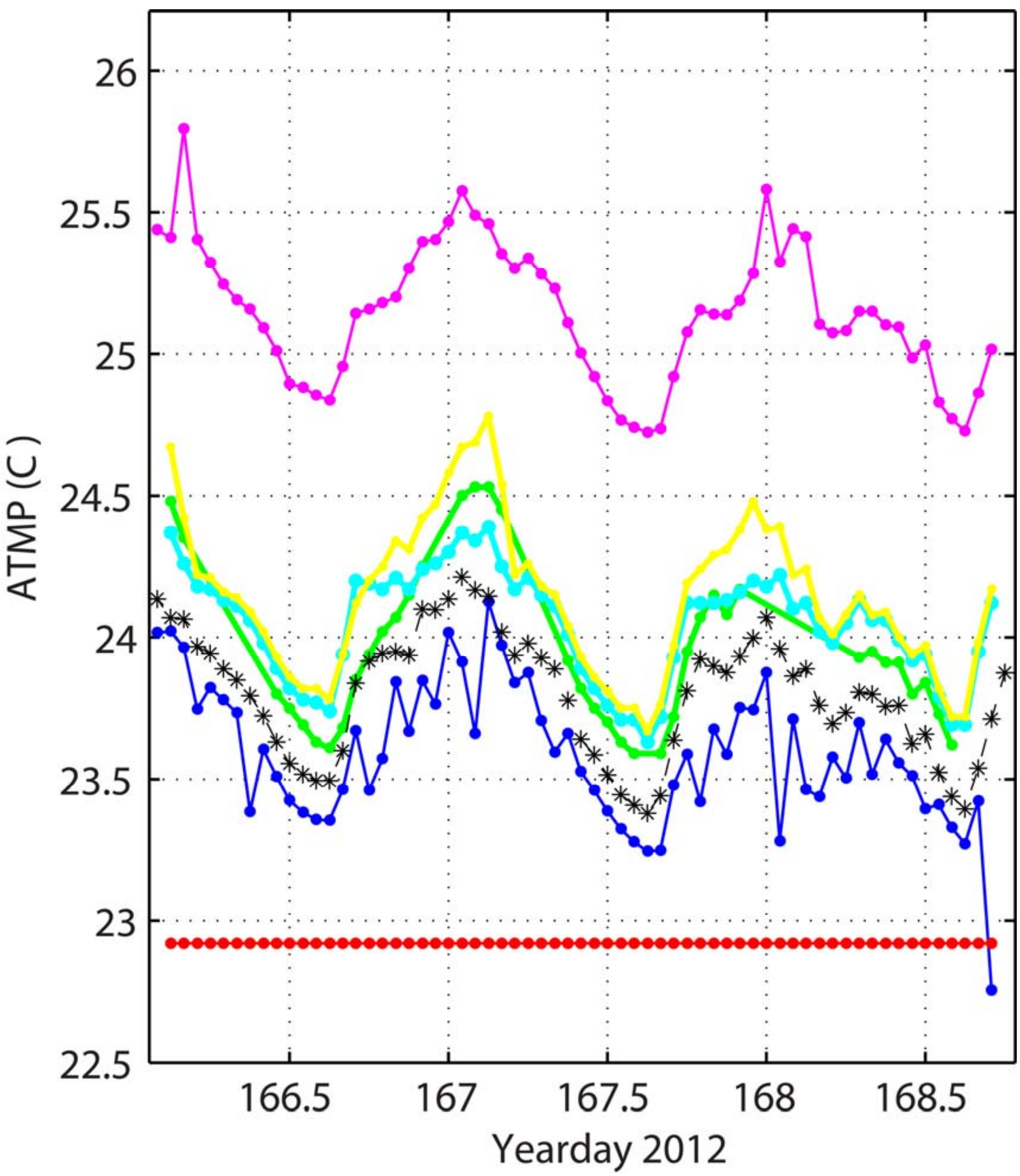


Figure 18. Air temperature (ATMP) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems, the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the intercomparison period. Data from the buoys are shown as thick lines. ESRL data are also included (*).

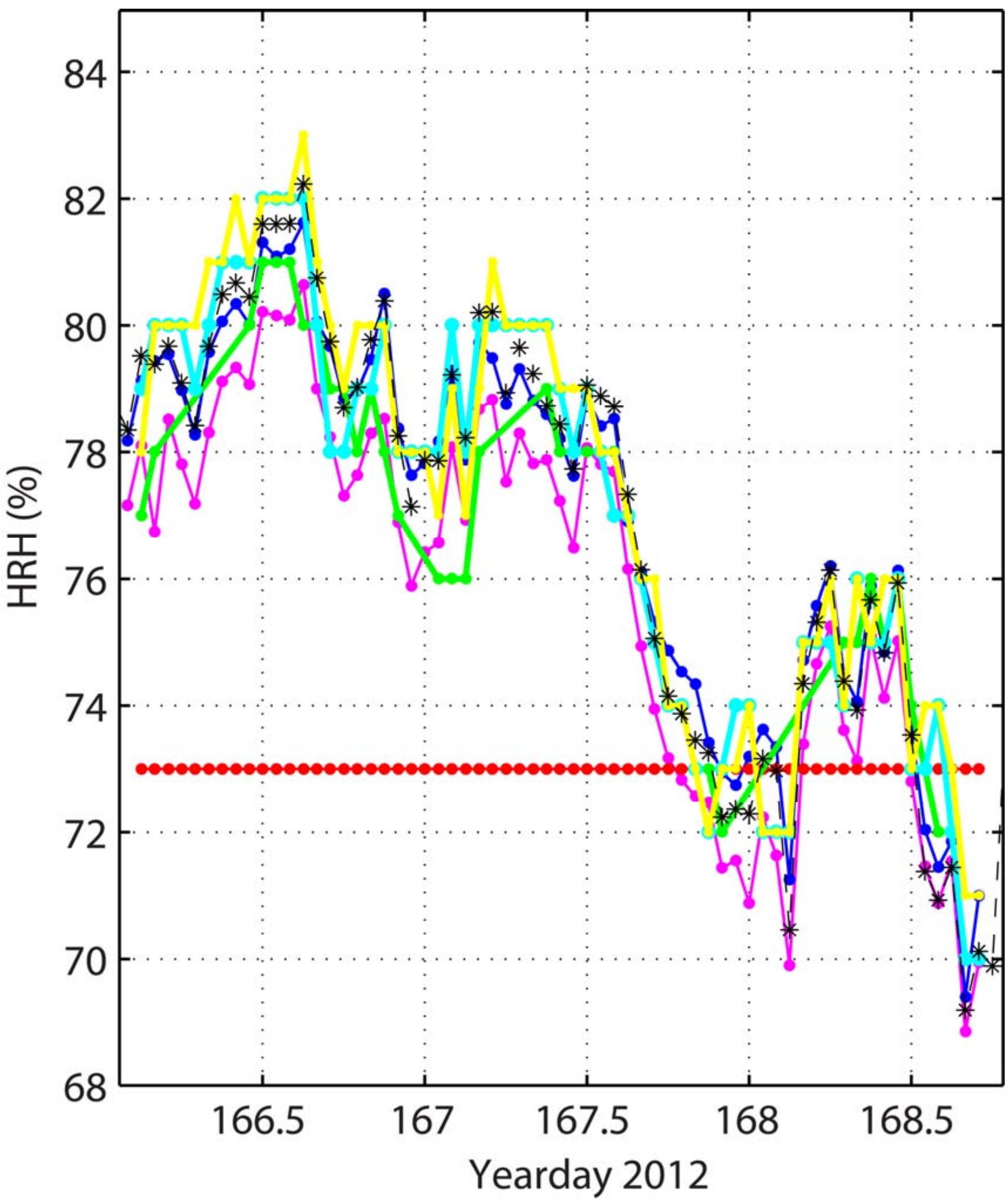


Figure 19. Relative humidity (HRH) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems, the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the intercomparison period. Data from the buoys are shown as thick lines. ESRL data are also included (*).

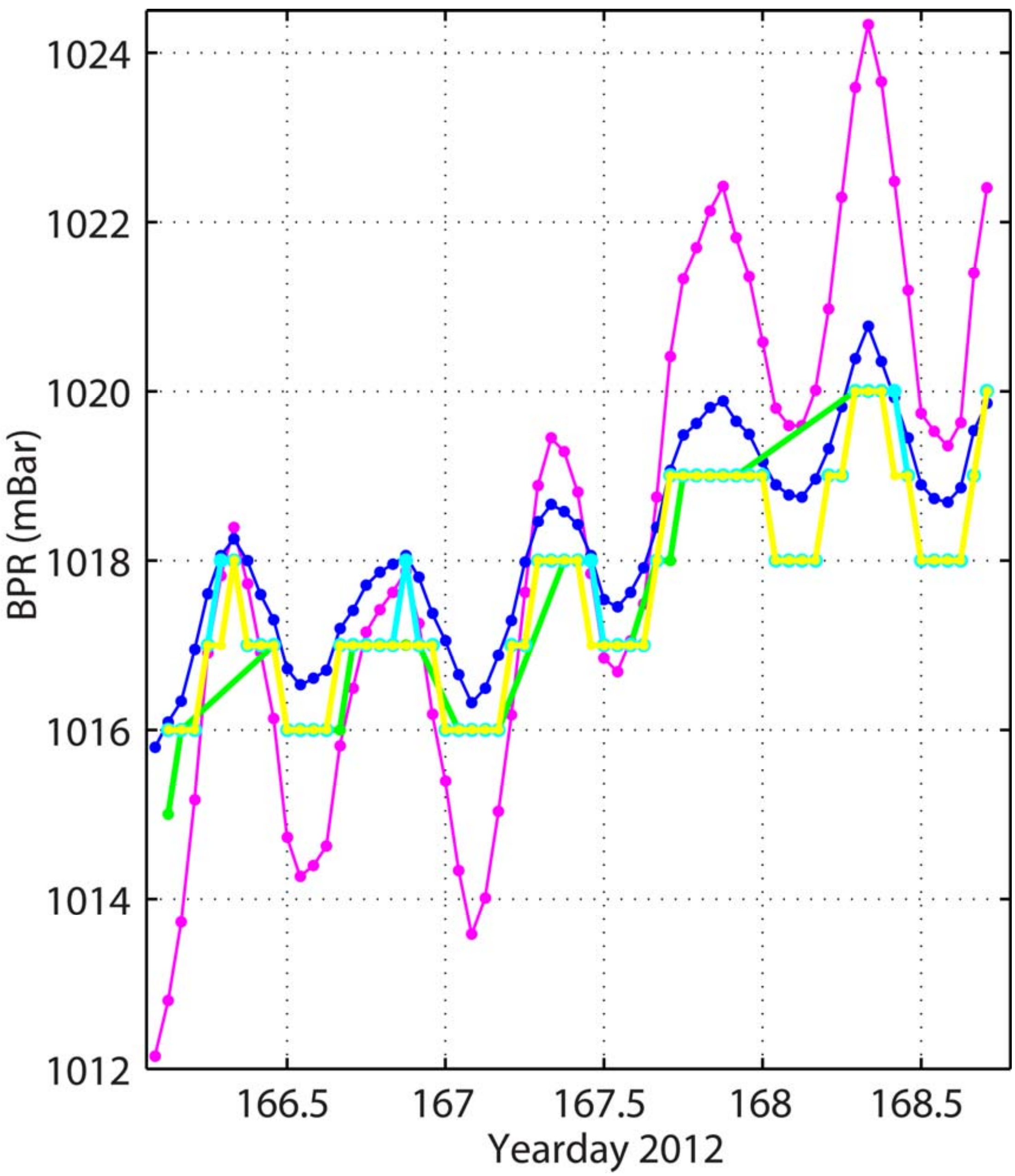


Figure 20. Barometric pressure (BPR) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems, the *Hiialakai* shipboard sensors (SCS), and the UOP AutoIMET system (AIMET) during the intercomparison period. Data from the buoys are shown as thick lines.

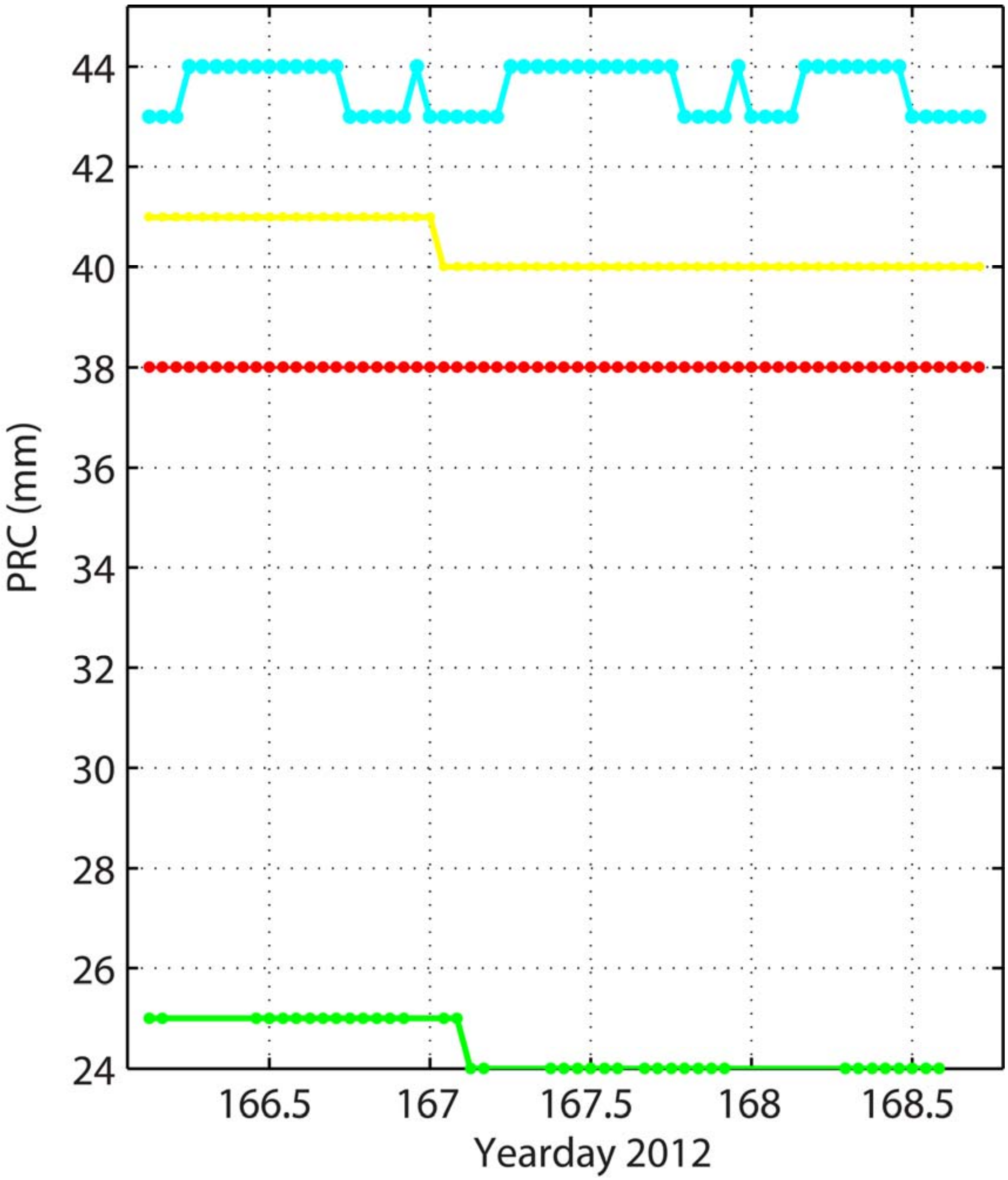


Figure 21. Precipitation (PRC) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems during the intercomparison period. Precipitation was not available from the *Hiialakai* shipboard sensors (SCS)l or the UOP AutoIMET system (AIMET).

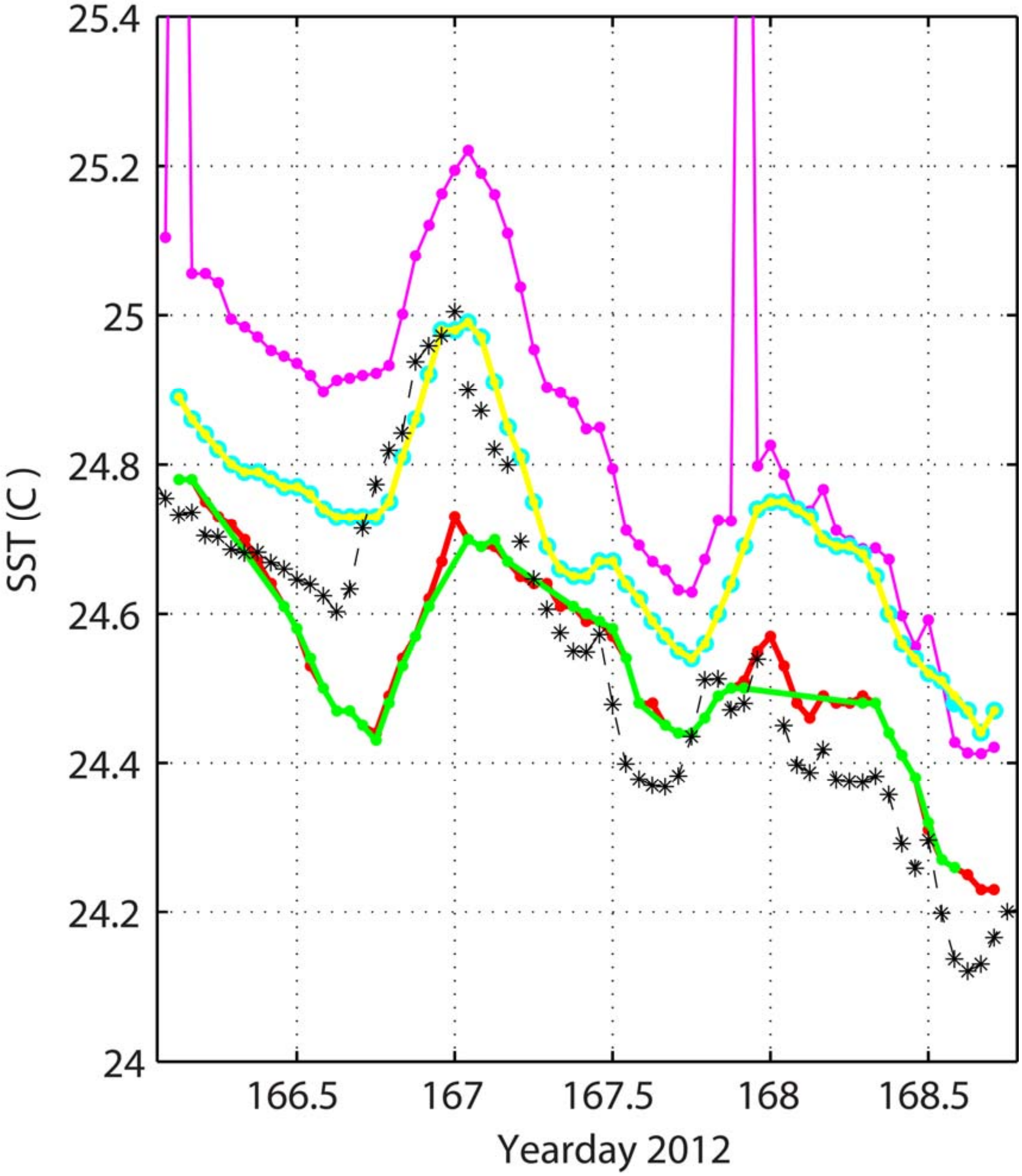


Figure 22. Sea surface temperature (SST) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the *Hiialakai* shipboard sensors (SCS) during the intercomparison period. SST was not available from the UOP AutoIMET system (AIMET). Data from the buoys are shown as thick lines. ESRL data are also included (*).

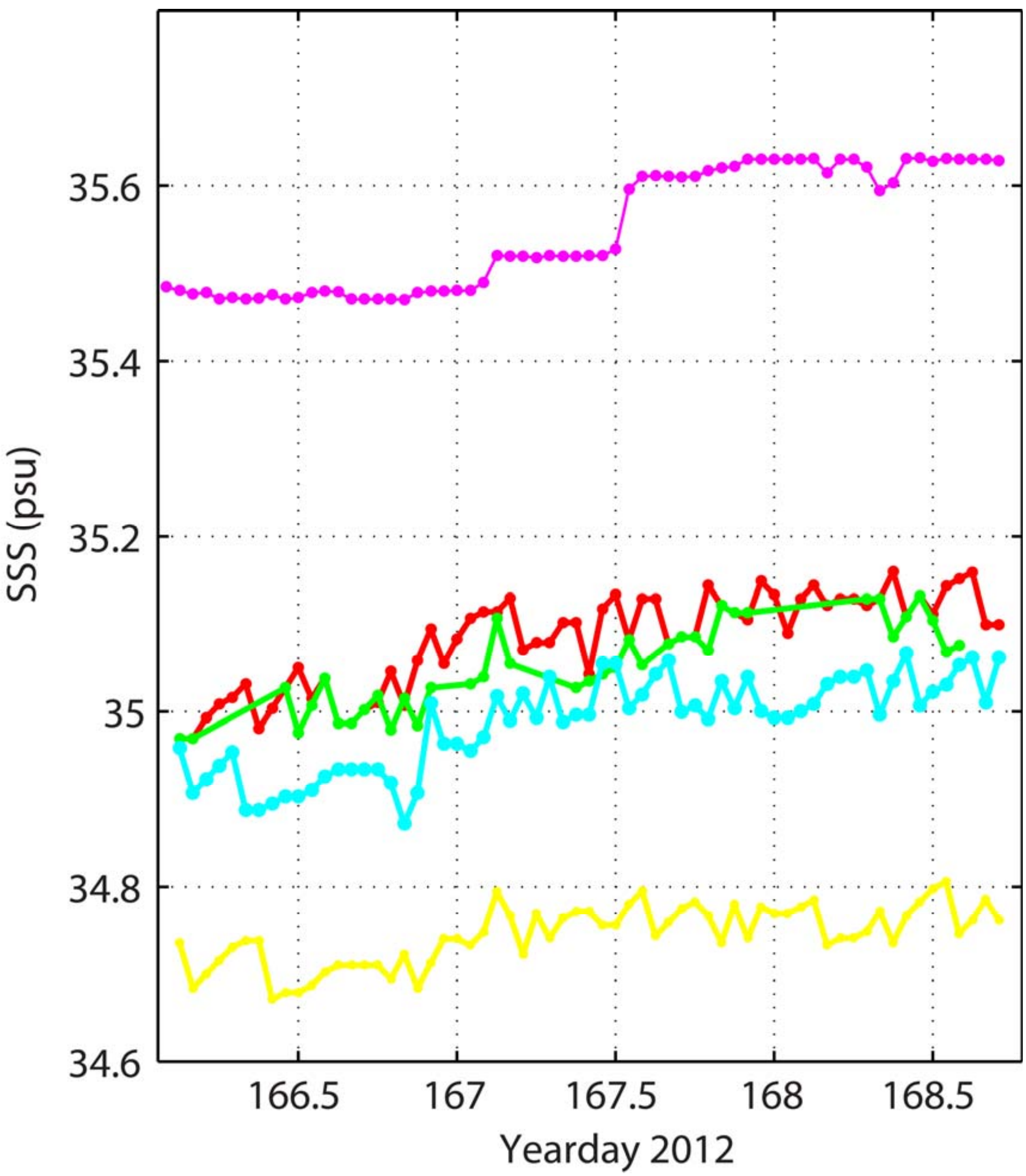


Figure 23. Sea surface salinity (SSS) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the *Hiialakai* shipboard sensors (SCS) during the intercomparison period. SSS was not available from the UOP AutoIMET system (AIMET). Data from the buoys are shown as thick lines.

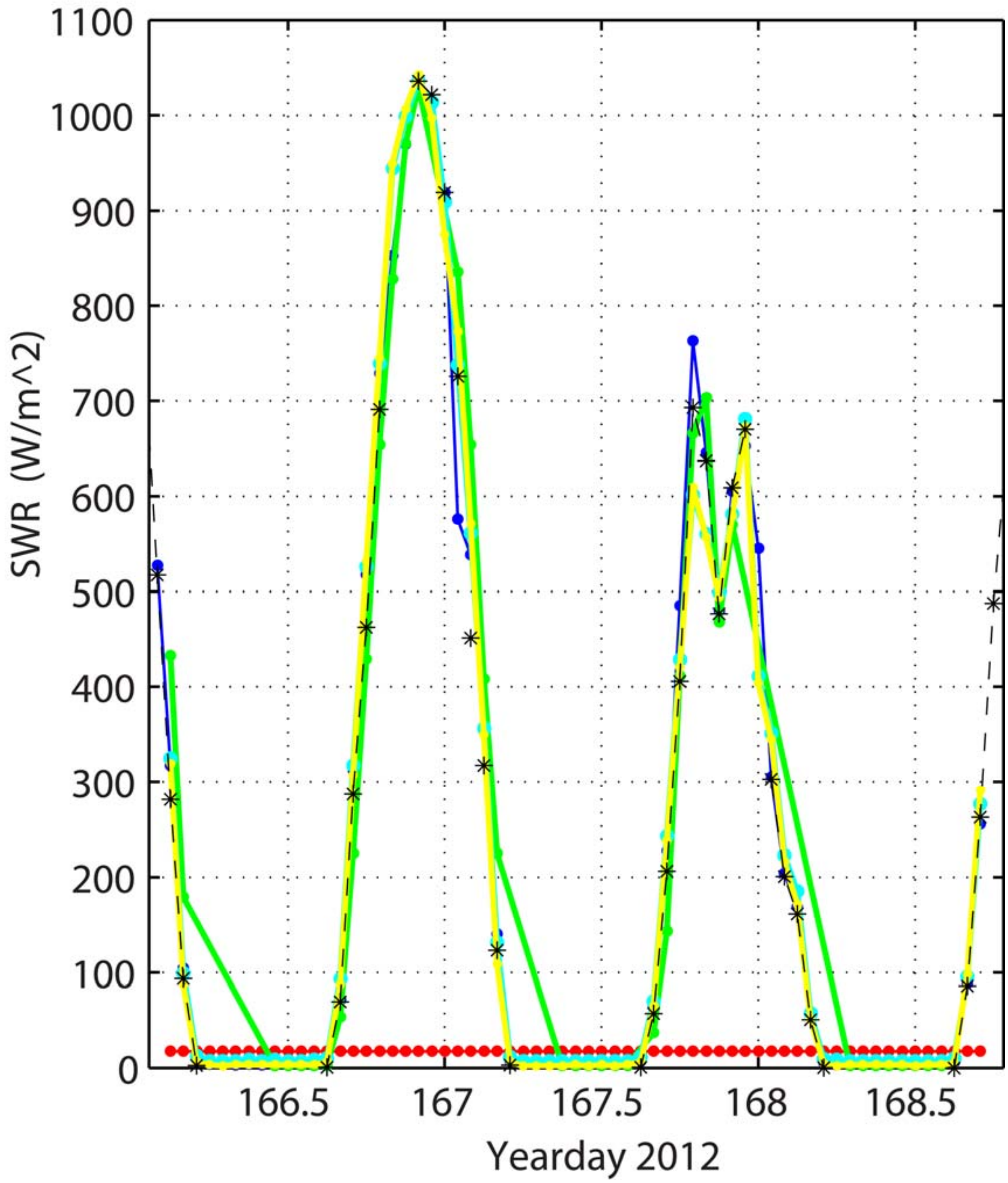


Figure 24. Shortwave radiation (SWR) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the UOP AutoIMET system (AIMET) during the intercomparison period. SWR was not available from the *Hiialakai* shipboard sensors (SCS). Data from the buoys are shown as thick lines. ESRL data are also included (*).

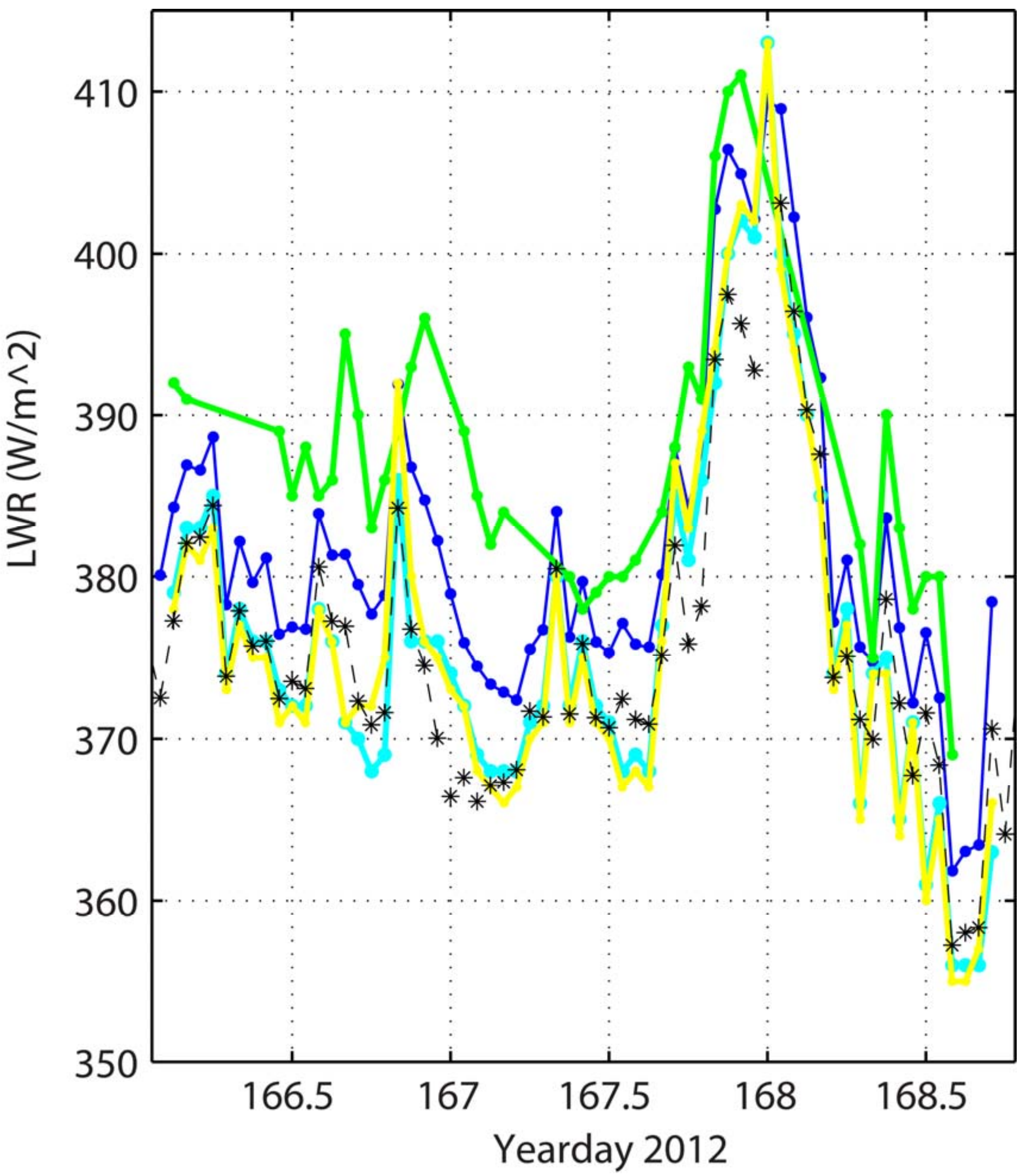


Figure 25. Longwave radiation (LWR) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the UOP AutoIMET system (AIMET) during the intercomparison period. LWR was not available from the *Hiialakai* shipboard sensors (SCS). Data from the buoys are shown as thick lines. ESRL data are also included (*).

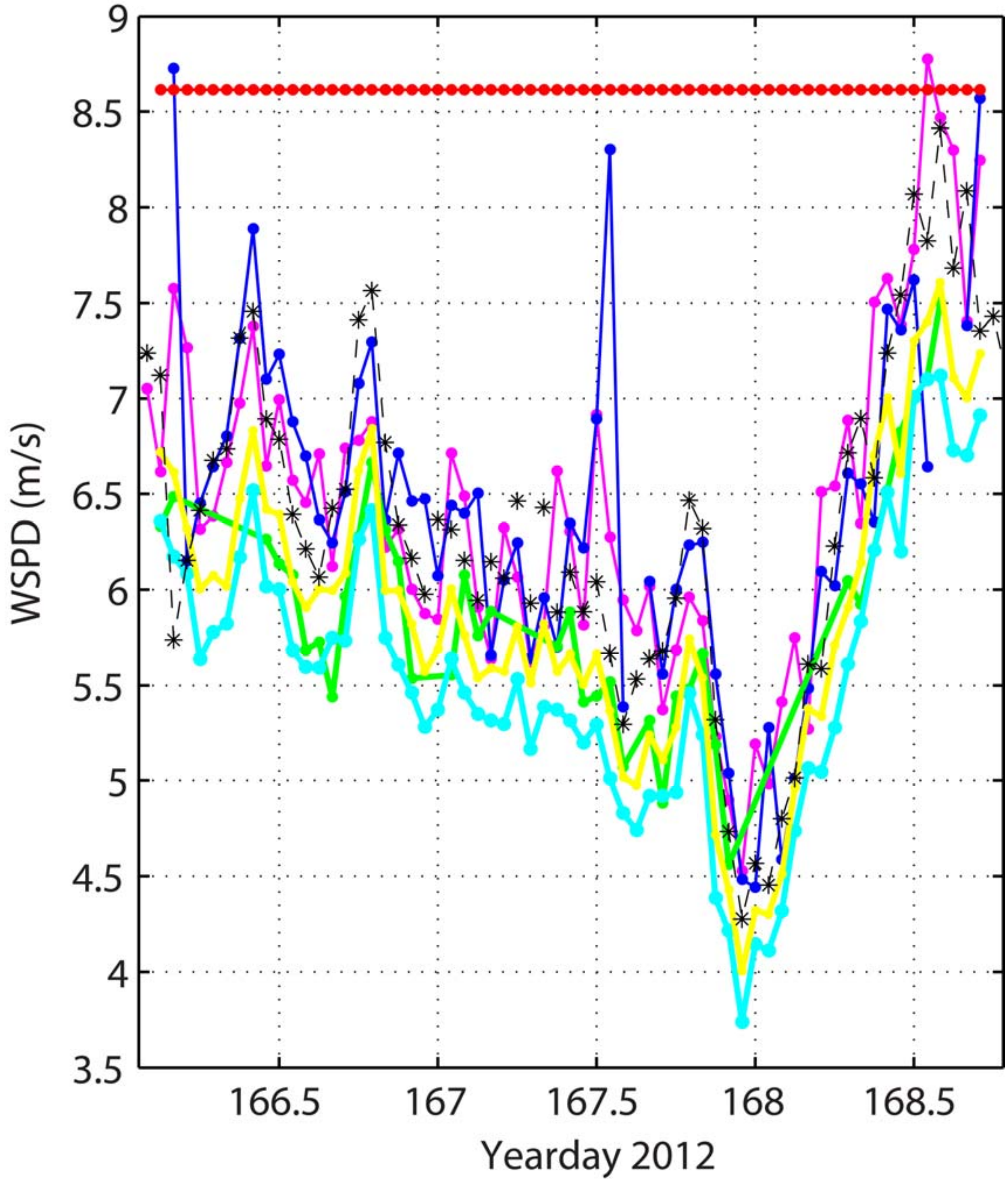


Figure 26. Wind speed (WSPD) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the UOP AutoIMET system (AIMET) during the intercomparison period. LWR was not available from the *Hiialakai* shipboard sensors (SCS). Data from the buoys are shown as thick lines. ESRL data are also included (*).

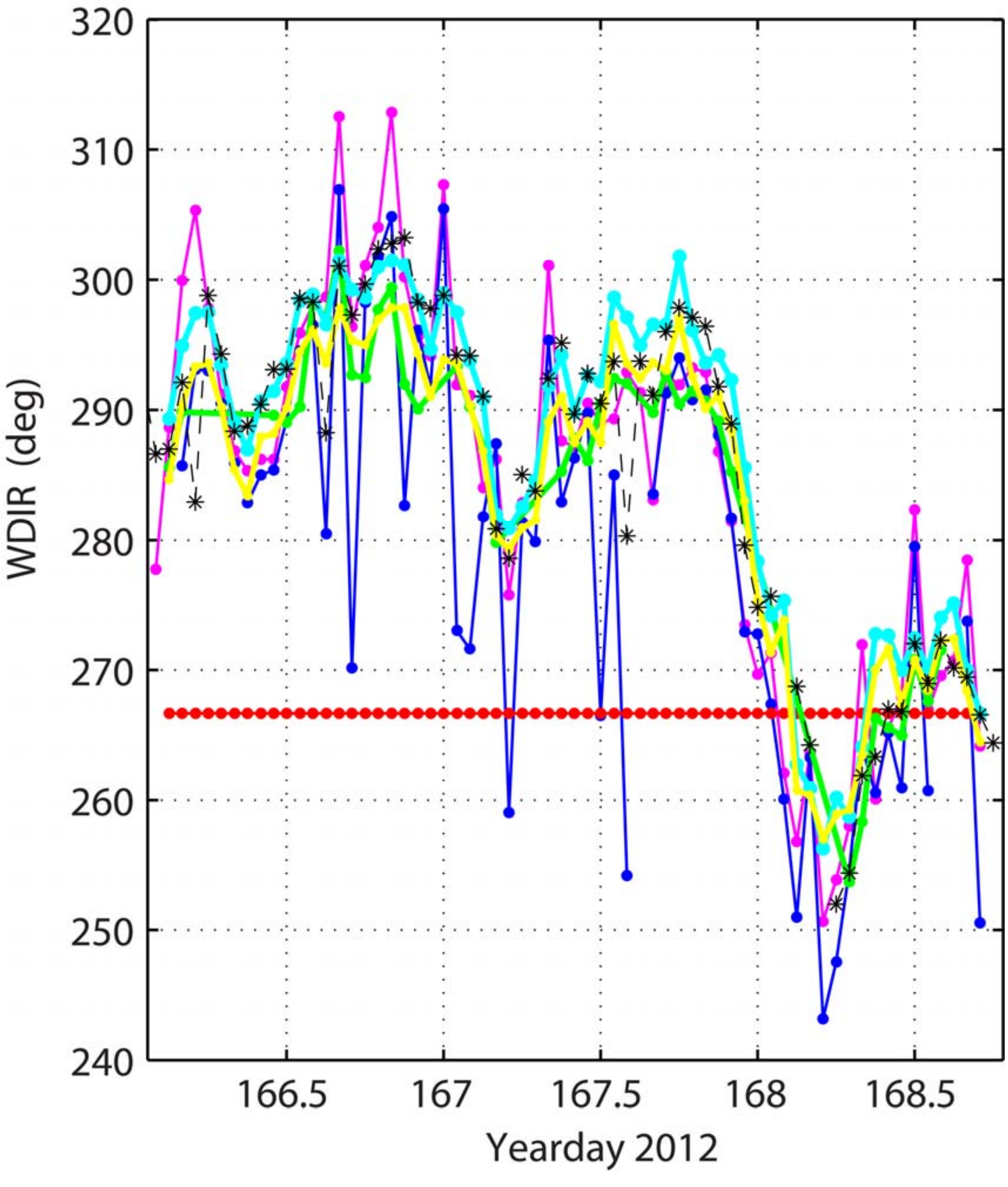


Figure 27. Wind direction (WDIR) for the WHOTS-8 (L07 and L08) and WHOTS-9 (L09 and L10) buoy systems and the UOP AutoIMET system (AIMET) during the intercomparison period. LWR was not available from the *Hiialakai* shipboard sensors (SCS). Data from the buoys are shown as thick lines. ESRL data are also included (*).

Acknowledgments

The captain, officers and crew of the NOAA Ship *Hi'ialakai* were flexible in accommodating the science mission, and exhibited a high degree of professionalism throughout the cruise. The capabilities of the ship and crew were critical to the success of the mooring operations. WHOTS is funded by the National Oceanic and Atmospheric Administration (NOAA) Climate Observation Division of the Climate Program Office through grant NA09OAR4320129 to the Cooperative Institute for the North Atlantic Region (CINAR) at the Woods Hole Oceanographic Institution.

References

Colbo, K. and R. Weller, 2009. Accuracy of the IMET Sensor Package, *J. Atmosph. Ocean. Technol*,. **26**(9), 1867-1890.

Hosom, D.S., R. Weller, R. Payne, K. Prada, 1995. The IMET (Improved Meteorology) Ship and Buoy Systems, *J. Atmosph. Ocean. Technol*, **12** (3), 527-540.

Whelan, S., J. Lord, C. Duncombe Rae, A. Plueddemann, J. Snyder, C. Nosse, R. Lukas, P. Boylan, B. Pietro, L. Bariteau, C. Sabine, and S. Pezoa, 2012. WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-8 2011 Mooring Turnaround Cruise Report, *WHOI Tech. Rept.*, WHOI-2012-04, 98 pp.

Appendix A: Cruise Participants

Captain: Mike Ellis (CDR)

Officers

Paul Kemp (LCDR, Executive Officer)
Tony Perry (LT, Operations Officer)
Brian Elliot (ENS)
Jared Holonen (ENS)

Deck Department

Mark O'Connor (CB)
Gaetano Maurizio (SS)
Scott Jones (AB)
Carmen Greto (AB)
Rich Hinostroza (AB)

Survey Department: Lauren Fuqua (SST)

Electronics Department: Mike Crumley (ET)

Science Party

Albert Plueddemann (Chief Scientist, WHOI)
James Ryder (WHOI)
Ben Pietro (WHOI)
Jason Smith (WHOI)
Chris Duncombe Rae (WHOI)
Roger Lukas (UH)
Craig Nosse (UH)
Jefrey Snyder (UH)
Cameron Fumar (UH)
Alison Andrews (UH)
David Hashisaka (UH)
Ethan Roth (UH)
Nicholas Seymour (UH)
Ludovic Barteau (CIRES)
Sang-Jong Park (KOPRI)

Appendix B. WHOTS-8 Subsurface Instrumentation and Data Return

For the eighth WHOTS mooring deployment that took place on 7 July 2011, UH provided 15 SBE-37 Microcats, a RDI 300 kKHz Workhorse ADCP and a Nobska MAVS acoustic velocity sensor. The Microcats all measured temperature and conductivity, with 5 also measuring pressure. WHOI provided 2 VMCMs, a RDI 600 kHz Workhorse ADCP and all required hardware for attaching the instruments to the mooring.

Table B1 provides the deployment information for each C-T instrument on the WHOTS-8 mooring. Table B 2 provides the VMCM deployment information.

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. The fouling on the 125 m ADCP transducer faces was minimal (Fig. B1) most likely due to the depth of deployment 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 showed minimal growth (Figure B1).

Table B3 provides the ADCP and MAVS deployment configuration and recovery information.

Table B1. WHOTS-8 Microcat deployment information.

SN:	Depth	Pressure SN	Sample Interval (sec)	Start Logging 06/30/2011 (UTC)	Cold Spike In (UTC)	Cold Spike Out (UTC)	In Water 07/06/2011 (UTC
6893	15	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	18:29
6894	25	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	18:24
6895	35	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	18:18
6896	40	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	18:15
6887	45	2651319	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	18:12
6897	50	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	19:22
6898	55	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	19:27
6899	65	N/A	90	0:00:00	7/1/2011 23:30:00	7/2/2011 0:00:00	19:30
3618	75	N/A	150	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:36
6888	85	2651320	90	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:39
3617	95	N/A	150	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:41
6889	105	2651321	90	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:44
6890	120	2651322	90	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:47
3634	135	N/A	150	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:53
6891	155	2651323	90	0:00:00	7/2/2011 0:05:00	7/2/2011 0:35:00	19:59

Table B2. WHOTS-8 VMCM deployment information.

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 B3. WHOTS-8 ADCP and MAVS configuration and recovery 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
Time of Last Ensemble	N / A	N / A	06/18/12, 19:30
Number of Ensembles	5,445	4,895	16,744
Time in water	07/06/11, 19:50	07/06/11, 19:17	07/06/11, 18:27
Time out of the water	06/17/12, 03:04	06/17/12, 03:31	06/17/12, 04:59
Time of spike	N / A	N / A	06/18/12, 04:15
Depth	125	47.5	20

Figure B1. WHOTS-8 ADCPs deployed at 125 m (left) and 47.5 m (right) after recovery.

The data from the upward-looking 300 kHz ADCP at 125 m ends in January 2012. The instrument was not pinging upon recovery. Examination of the connectors on both the transducer and battery units showed corrosion. Post-cruise diagnosis showed that water penetrated a faulty cable connector on the external battery pack. As the connector started to fail, intermittent data were recorded beginning on January 11, 2012. Complete failure occurred on February 1. Cable connector failures also affected the previous WHOTS-7 deployment. Fig. B2 shows the heading, pitch and roll information from the ADCP before the instrument failed. Fig. B3 shows the variations of the horizontal and vertical components of velocity in depth and time before the instrument failed.

The data from the upward-looking 600 kHz ADCP at 47.5 m ends in December 2011. The instrument was not pinging upon recovery. The same cable connector failure described for the battery pack of the 300 kHz ADCP also occurred for the 600 kHz ADCP. Intermittent data were recorded beginning on December 22, 2011 until a complete failure on December 28. Fig. B4 shows the heading, pitch and roll information from the ADCP before the instrument failed. Fig. B5 shows the variations of the horizontal and vertical components of velocity in depth and time before the instrument failed.

The MAVS at 20 m was downloaded via Flash memory. Fig. B6 shows the computed u, v and w velocities from the MAVS. These velocities begin to show off scale readings in September 2011. Fig. B7 shows the raw velocities from each of the four acoustic transducers and it appears that transducer “C” failed before deployment, transducer “B” failed in September 2011, transducer “A” failed in October 2011 and transducer “D” failed in April 2012. Post-cruise diagnosis showed that water intruded into the velocity sensor. The intrusion was attributed to faulty sensors from the manufacturer which have also affected previous WHOTS deployments.

Table B4 gives the recovery 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. Pressure data for the 155 m instrument (#6891) suggest a deployment about 2 meters deeper than intended. Figures B8-B22 show the nominally calibrated temperature, conductivity and salinity records from each instrument, and pressure for those instruments that were equipped with pressure sensors.

Table B4. WHOTS-8 Microcat recovery information. All times are in UTC.

Depth (m)	Seabird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality	File Name raw data
15	37SM31486-6893	06/17/2012 04:55	06/17/2012 19:37:00	06/17/2012 22:22:00	369,536	good	6893_recovery.cap
25	37SM31486-6894	06/17/2012 05:02	06/17/2012 19:37:00	06/17/2012 22:11:15	369,529	good	6894_recovery.cap
35	37SM31486-6895	06/17/2012 05:08	06/17/2012 19:37:00	06/17/2012 22:19:15	369,534	good	6895_recovery.cap
40	37SM31486-6896	06/17/2012 05:13	06/17/2012 19:37:00	06/18/2012 16:26:00	370,259	good	6896_recovery.cap
45	37SM31486-6887	06/17/2012 05:19	06/17/2012 19:37:00	06/18/2012 16:34:00	370,264	good	6887_recovery.cap
50	37SM31486-6897	06/17/2012 03:31	06/17/2012 19:37:00	06/18/2012 16:44:00	370,271	good	6897_recovery.cap
55	37SM31486-6898	06/17/2012 03:28	06/17/2012 19:37:00	06/17/2012 22:15:10	369,532	good	6898_recovery.cap
65	37SM31486-6899	06/17/2012 03:24	06/17/2012 19:37:00	06/17/2012 22:50:00	369,555	good	6899_recovery.cap
75	37SM31486-3618	06/17/2012 03:21	06/17/2012 19:37:00	06/17/2012 22:55:15	203,878	one bad time stamp	3618_recovery.cap
85	37SM31486-6888	06/17/2012 03:17	06/17/2012 19:37:00	06/17/2012 21:06:00	369,486	good	6888_recovery.cap
95	37SM31486-3617	06/17/2012 03:14	06/17/2012 19:37:00	06/17/2012 23:21:15	203,888	good	3617_recovery.cap
105	37SM31486-6889	06/17/2012 03:11	06/17/2012 19:37:00	06/17/2012 21:02:15	369,483	good	6889_recovery.cap
120	37SM31486-6890	06/17/2012 03:07	06/17/2012 19:37:00	06/17/2012 20:57:30	369,480	good	6890_recovery.cap
135	37SM31486-3634	06/17/2012 03:01	06/17/2012 19:37:00	06/17/2012 23:24:30	203,890	good	3634_recovery.cap
155	37SM31486-6891	06/17/2012 02:56	06/17/2012 19:37:00	06/17/2012 21:09:05	369,487	good	6891_recovery.cap

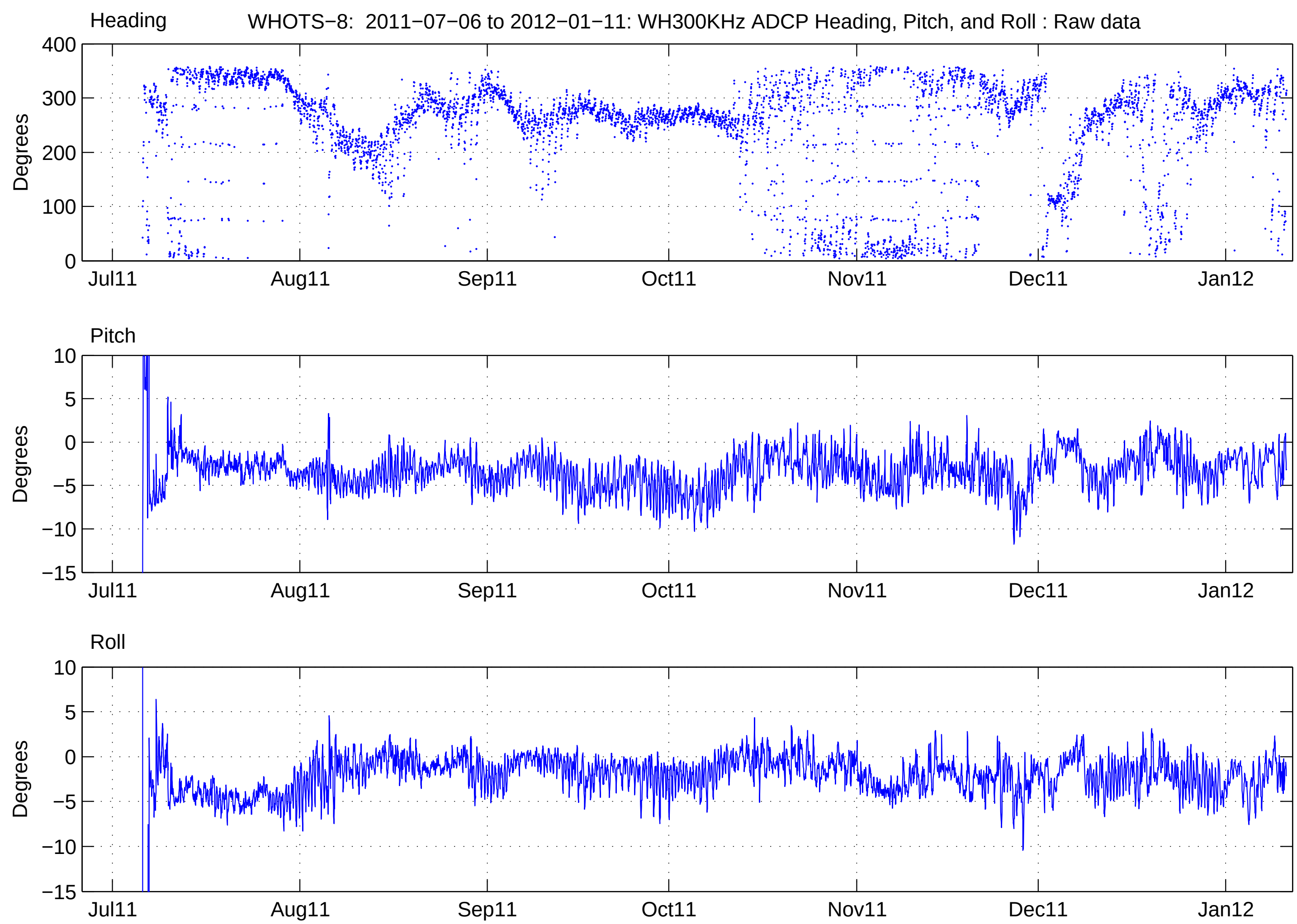


Figure B2. Heading, pitch and roll variations measured by the ADCP at 125 m depth on the WHOTS-8 mooring.

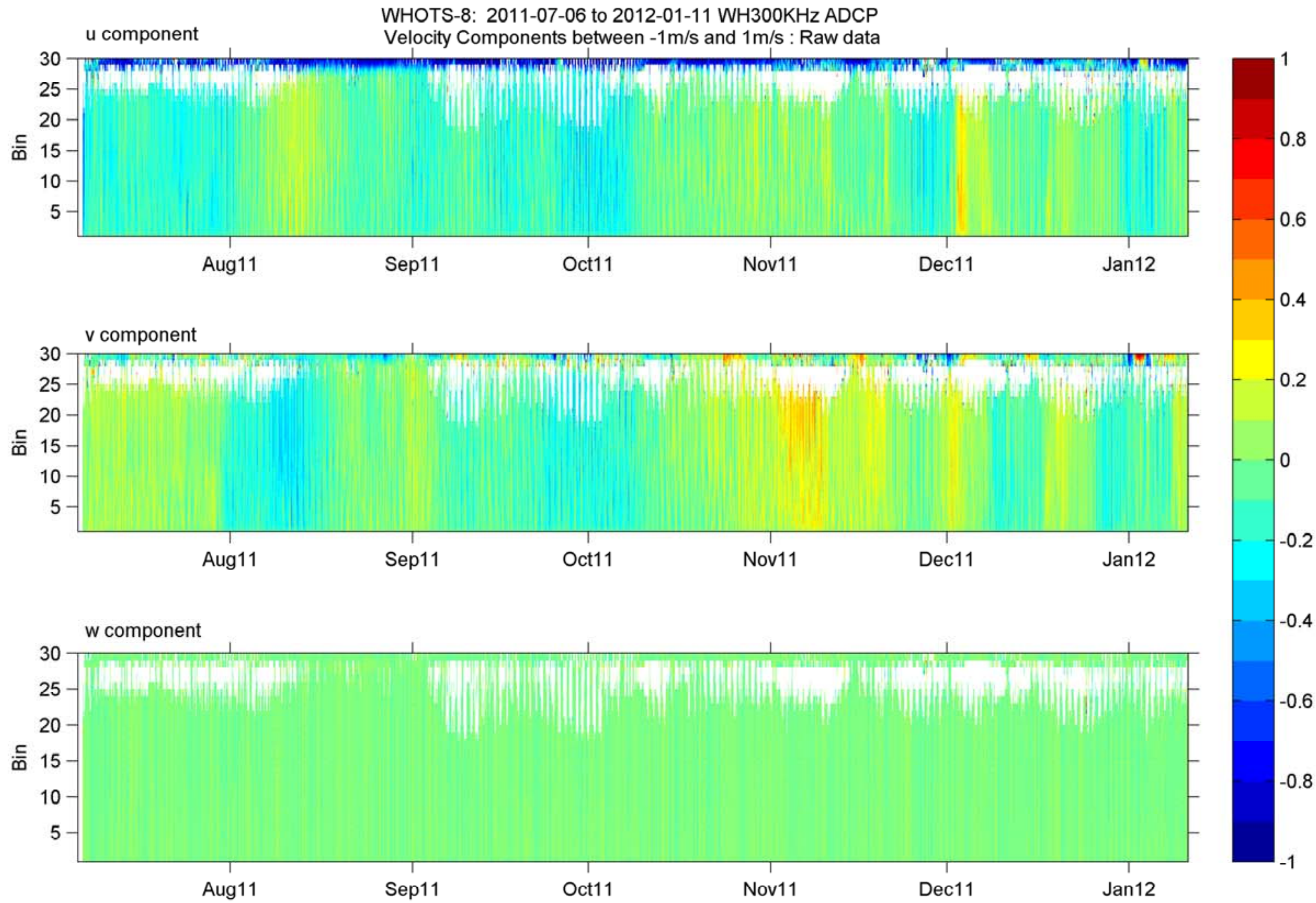


Figure B3. Time-series of eastward, northward and upward velocity versus bin number measured by the ADCP at 125 m depth on the WHOTS-8 mooring. Height in meters above the transducer is approximately 4 times the bin number.

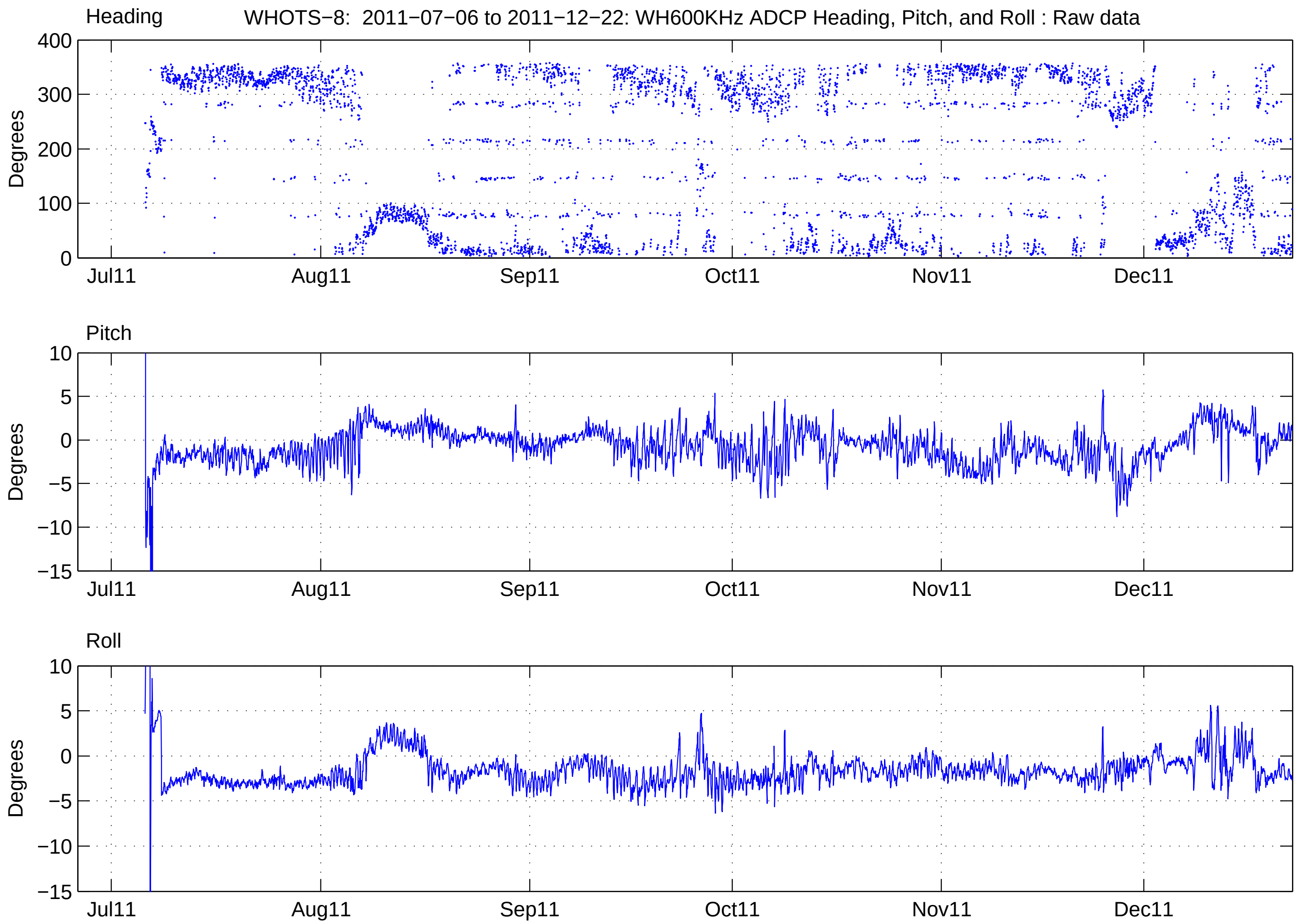


Figure B4. Heading, pitch and roll variations measured by the ADCP at 47.5 m depth on the WHOTS-8 mooring.

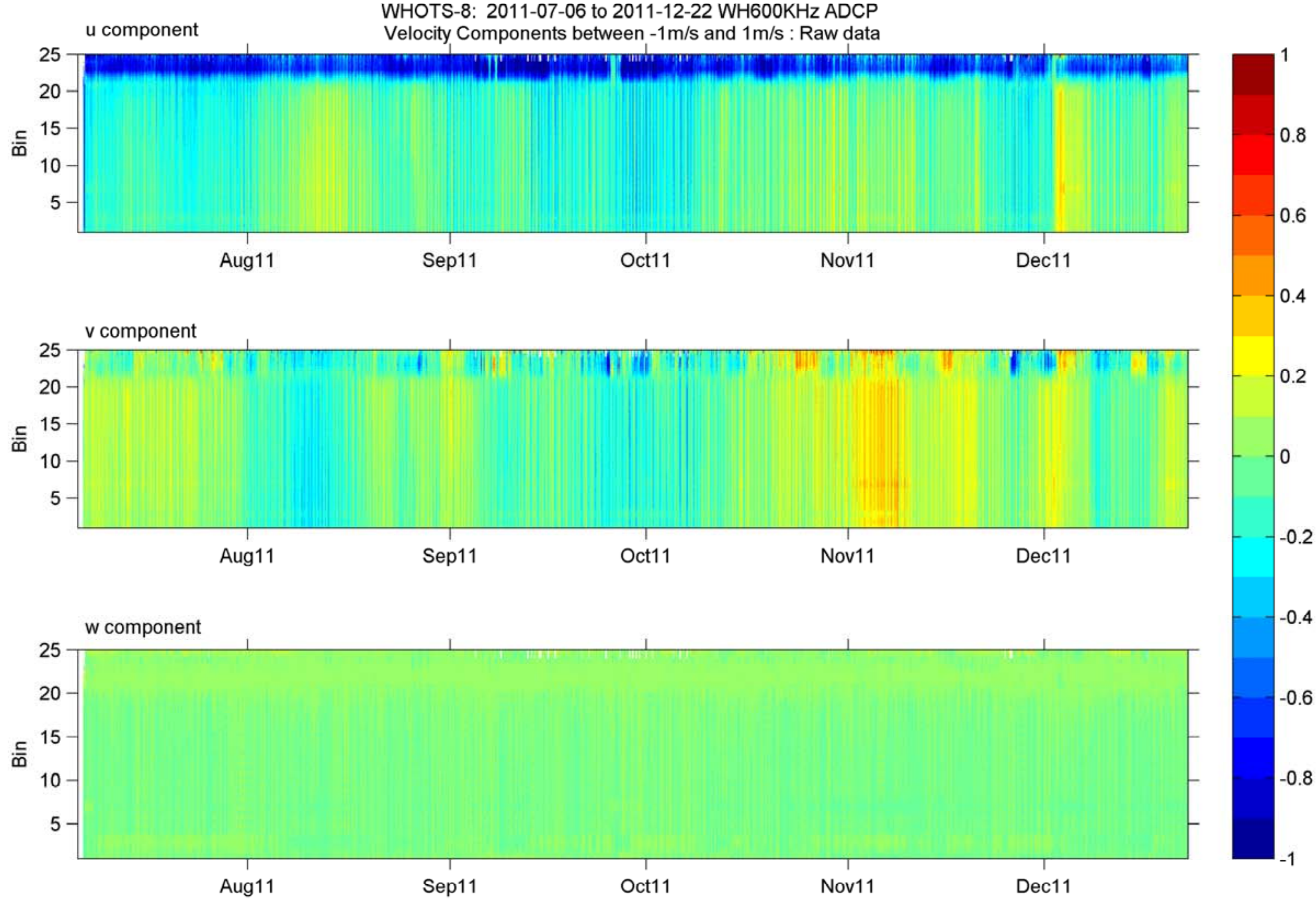


Figure B5. Time-series of eastward, northward and upward velocity versus bin number measured by the ADCP at 47.5 m depth on the WHOTS-8 mooring. Height in meters above the transducer is approximately 2 times the bin number.

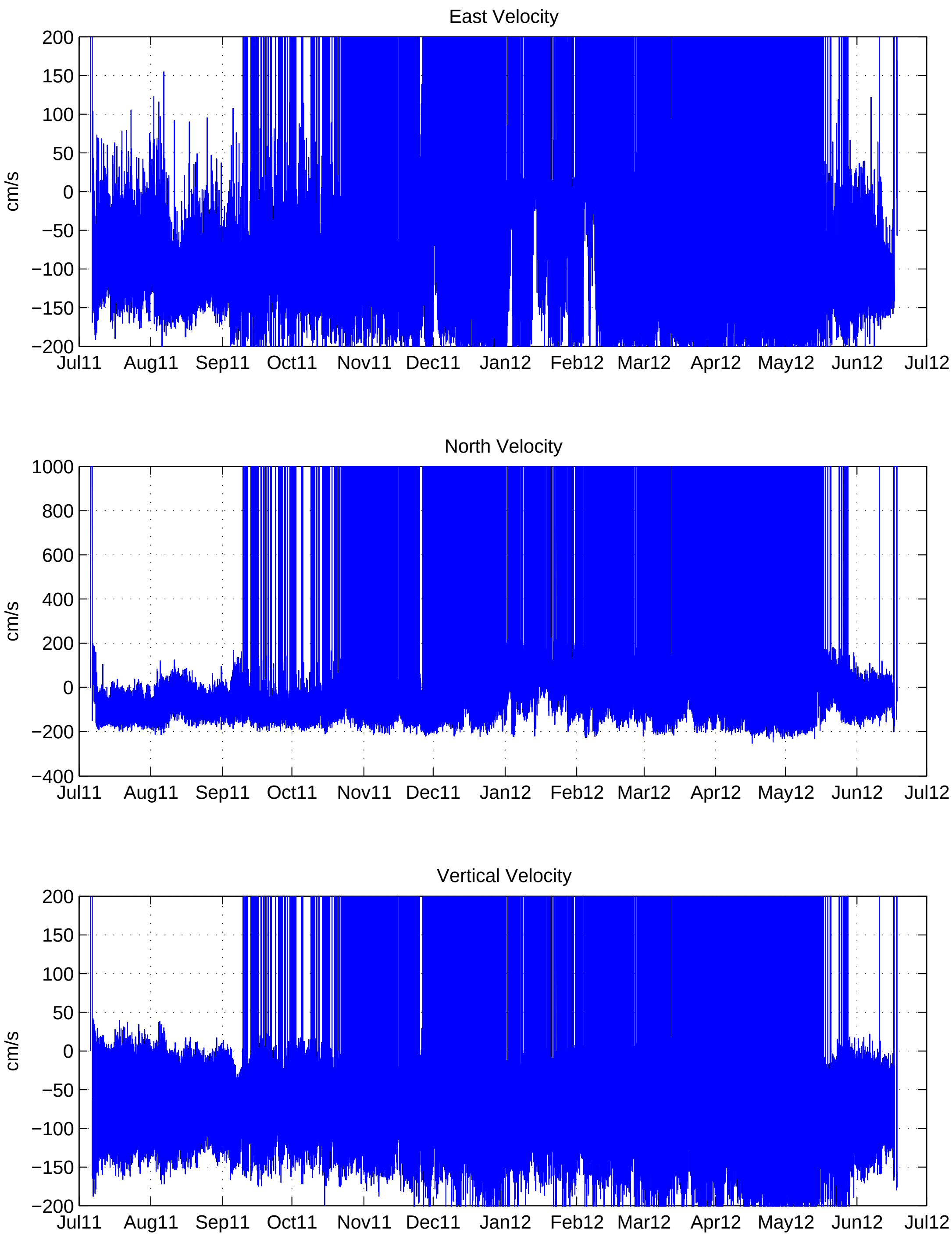


Figure B6. Computed u, v and w velocities from the MAVS at 20 m depth on the WHOTS-8 mooring.

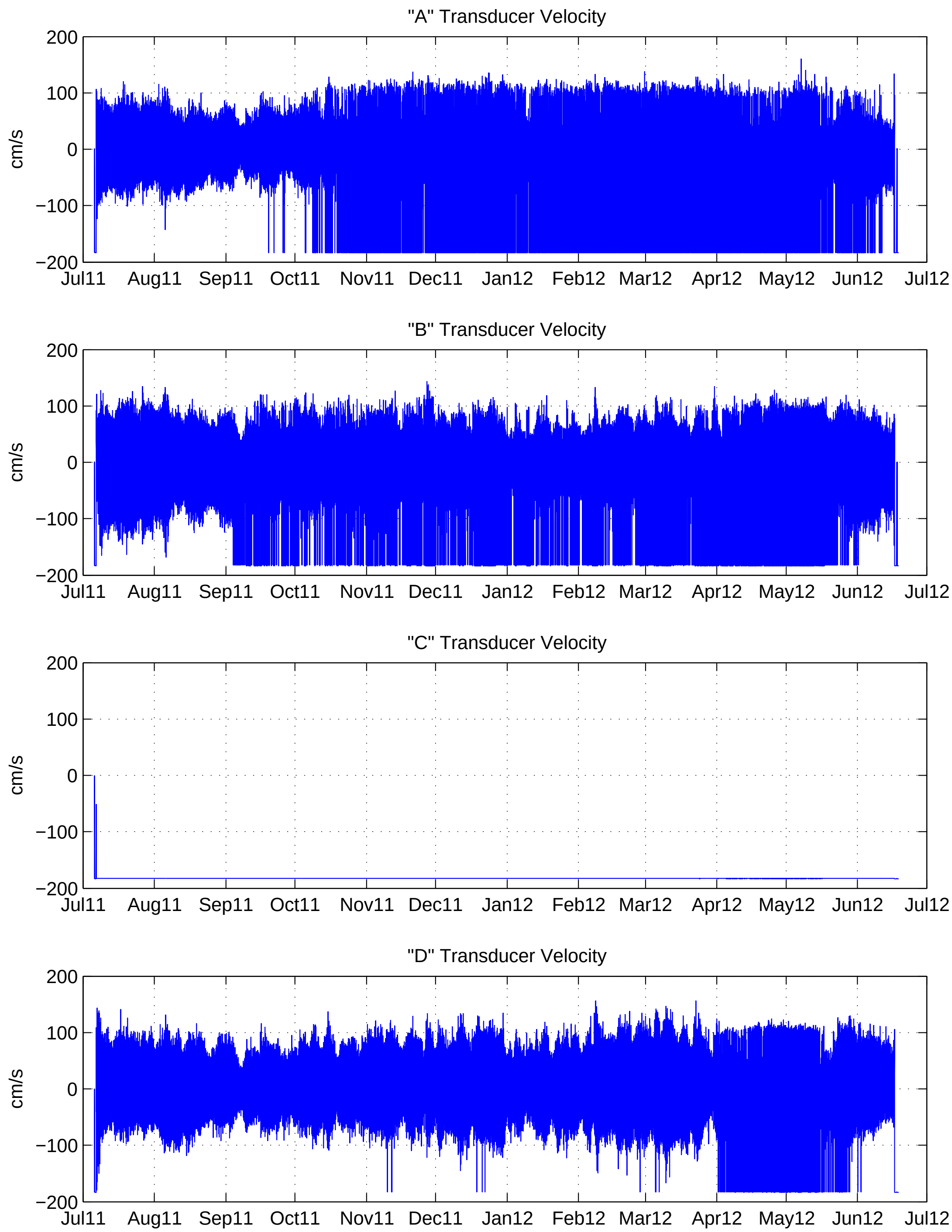


Figure B7. Time-series of the raw acoustic velocity measured by each transducer from the MAVS at 20 m depth on the WHOTS-8 mooring.

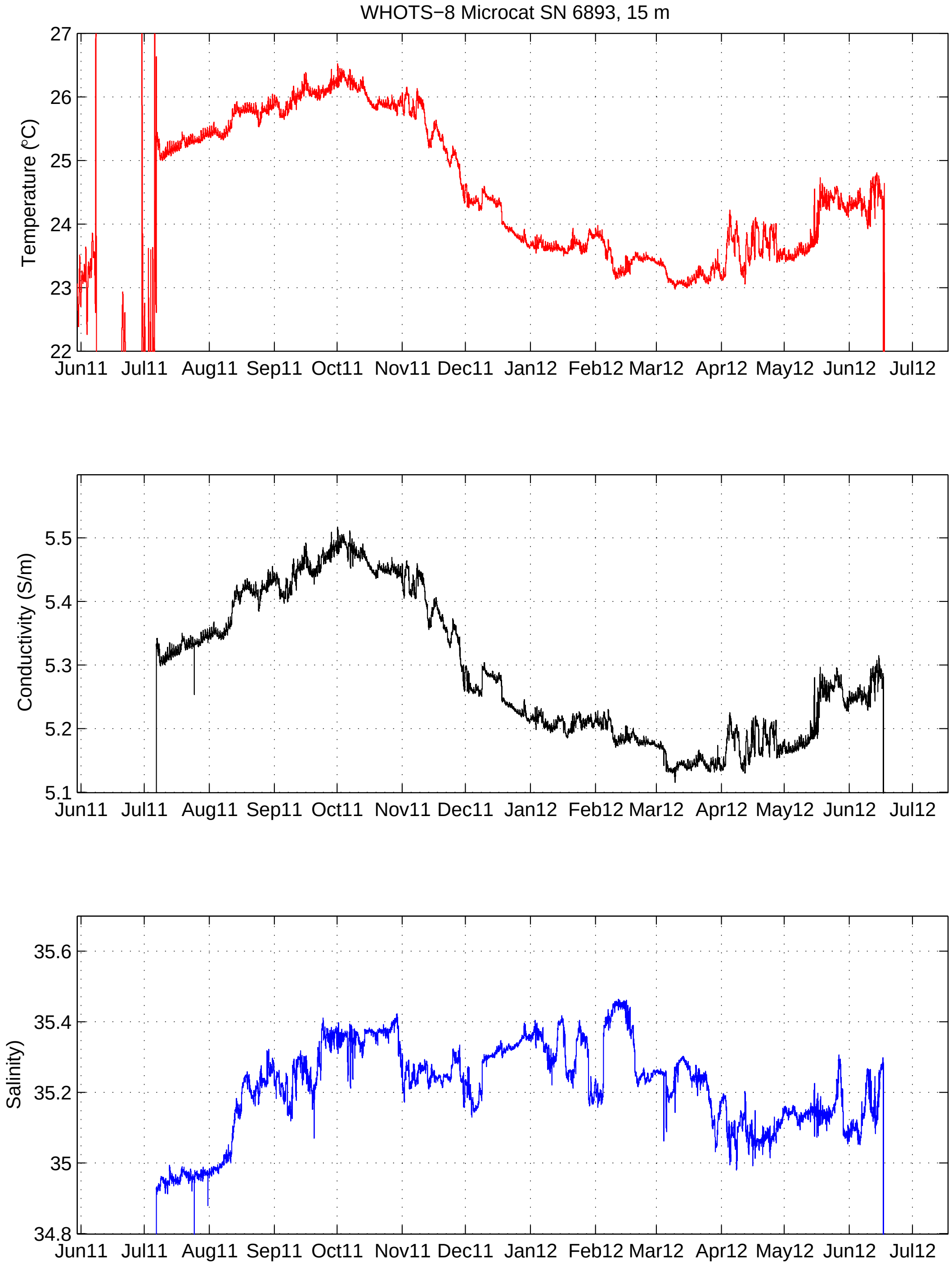


Figure B8. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6893 deployed at 15 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

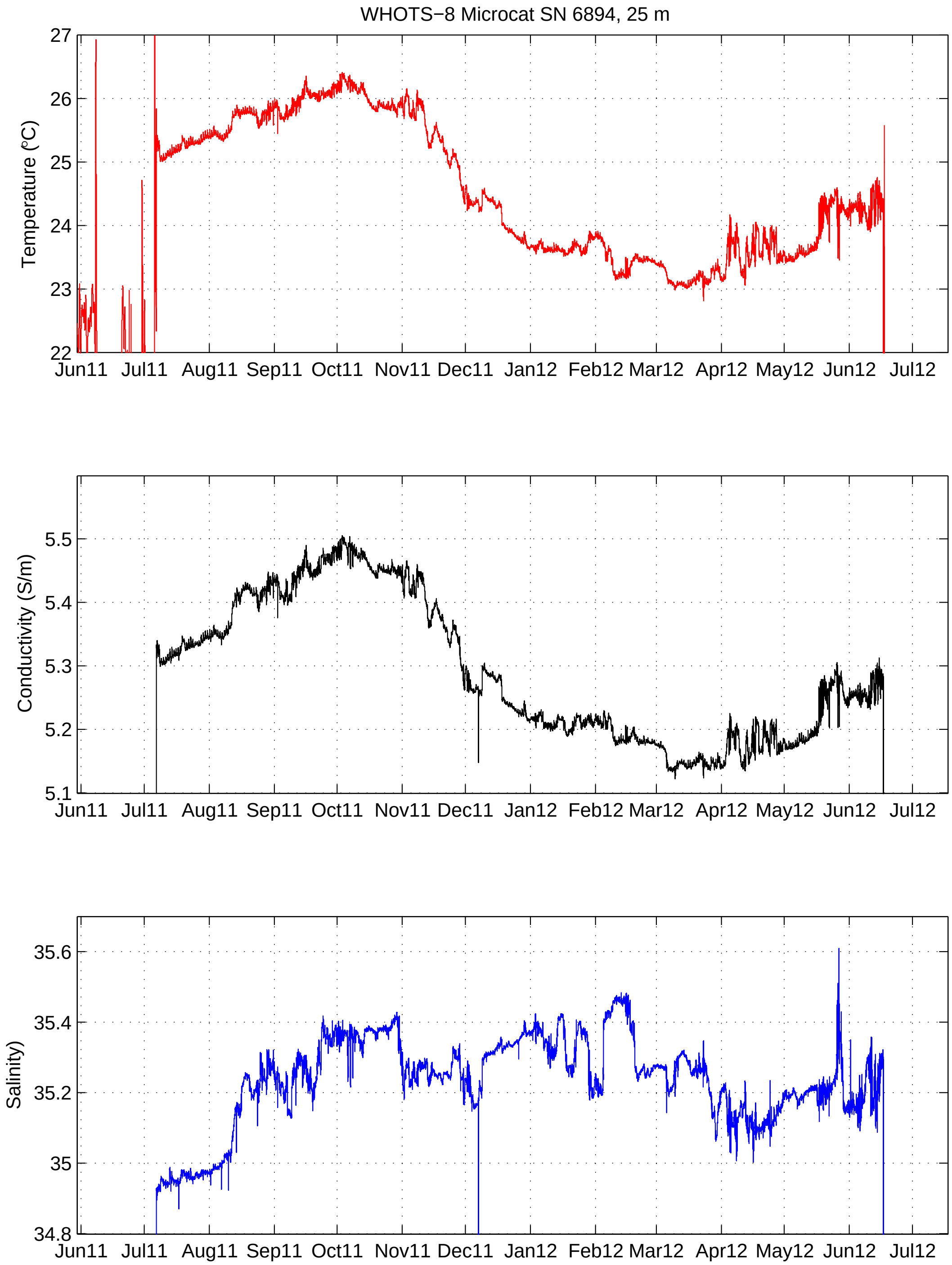


Figure B9. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6894 deployed at 25 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

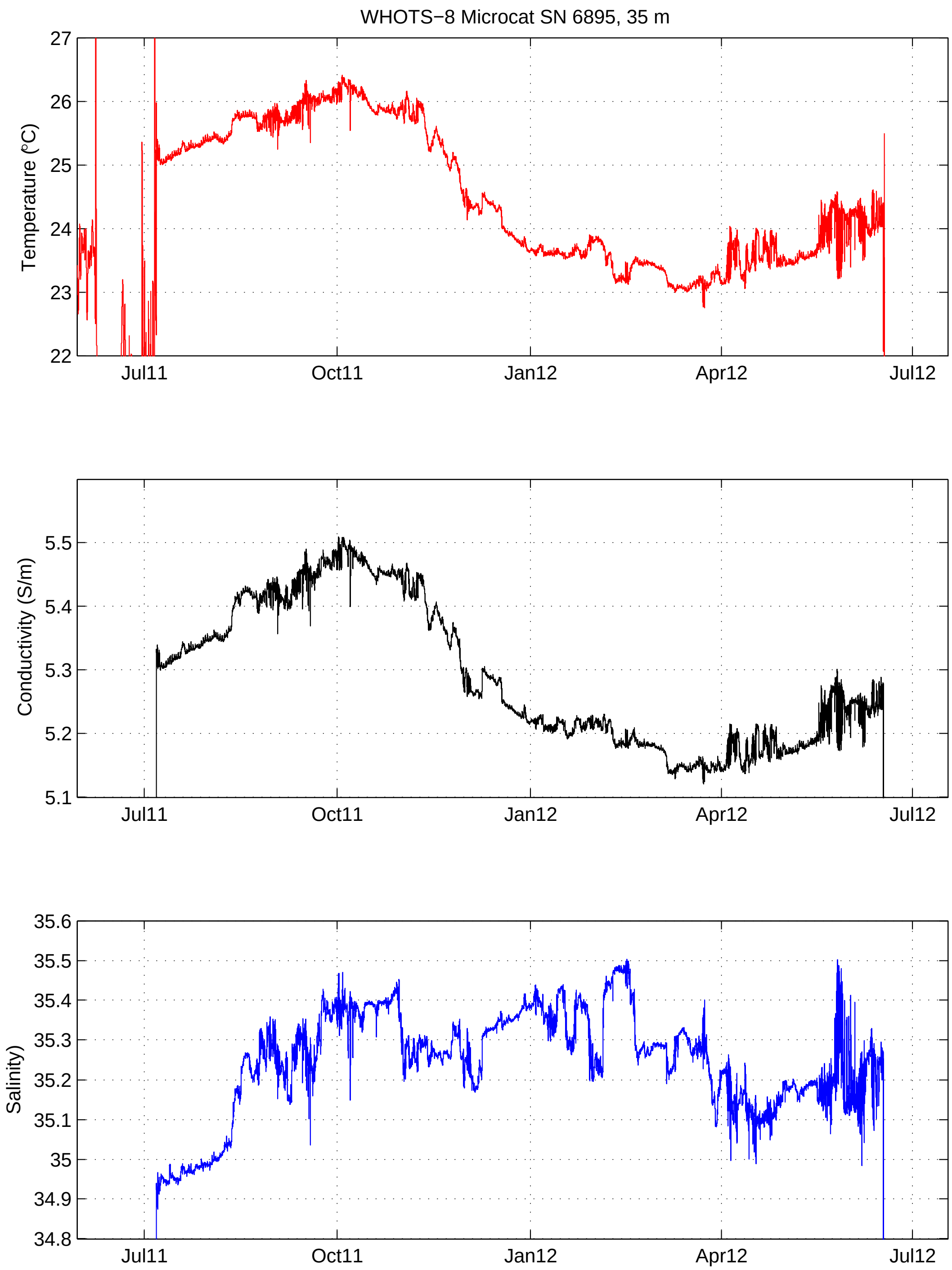


Figure B10. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6895 deployed at 35 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

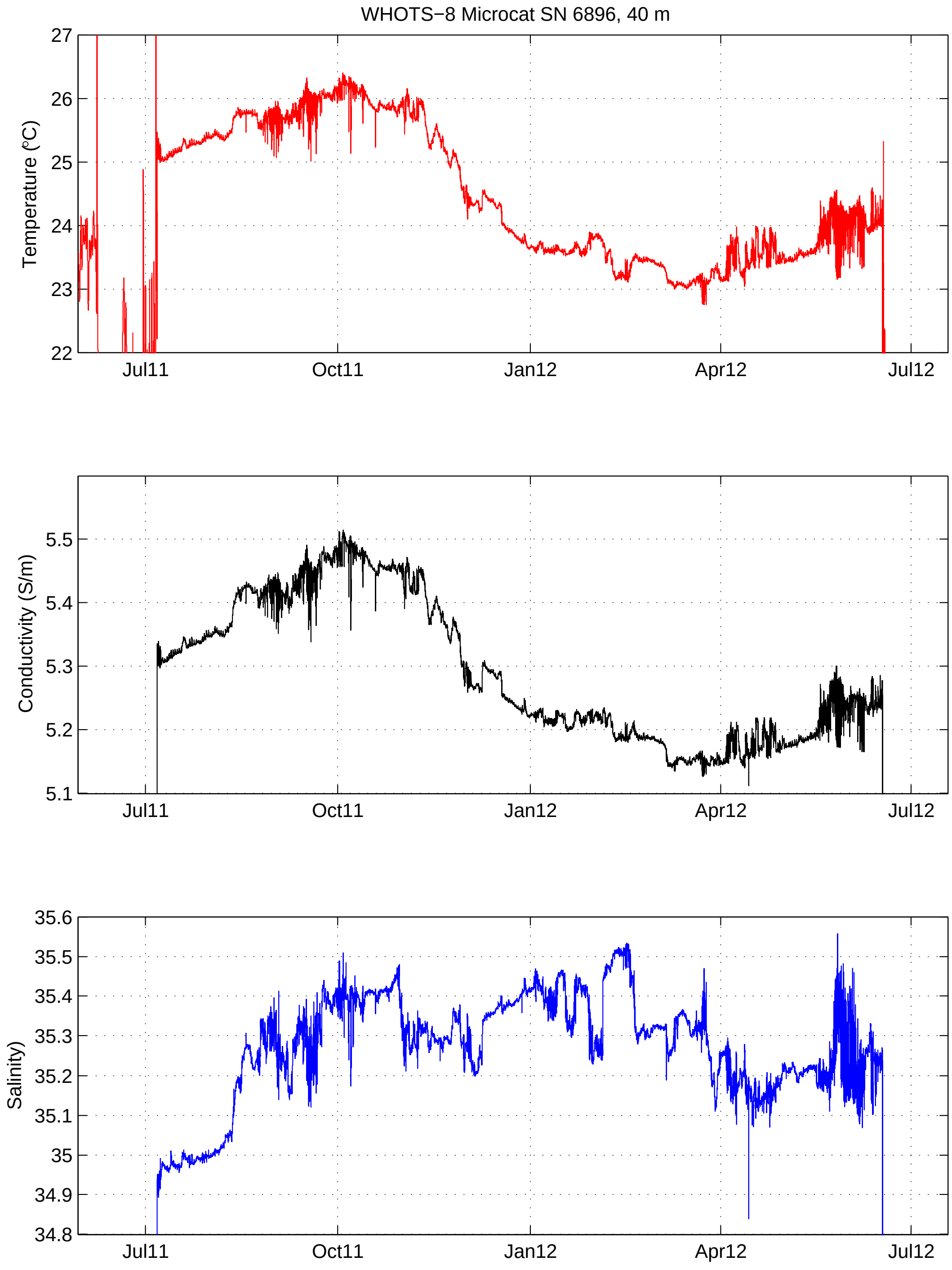


Figure B11. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6896 deployed at 40 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

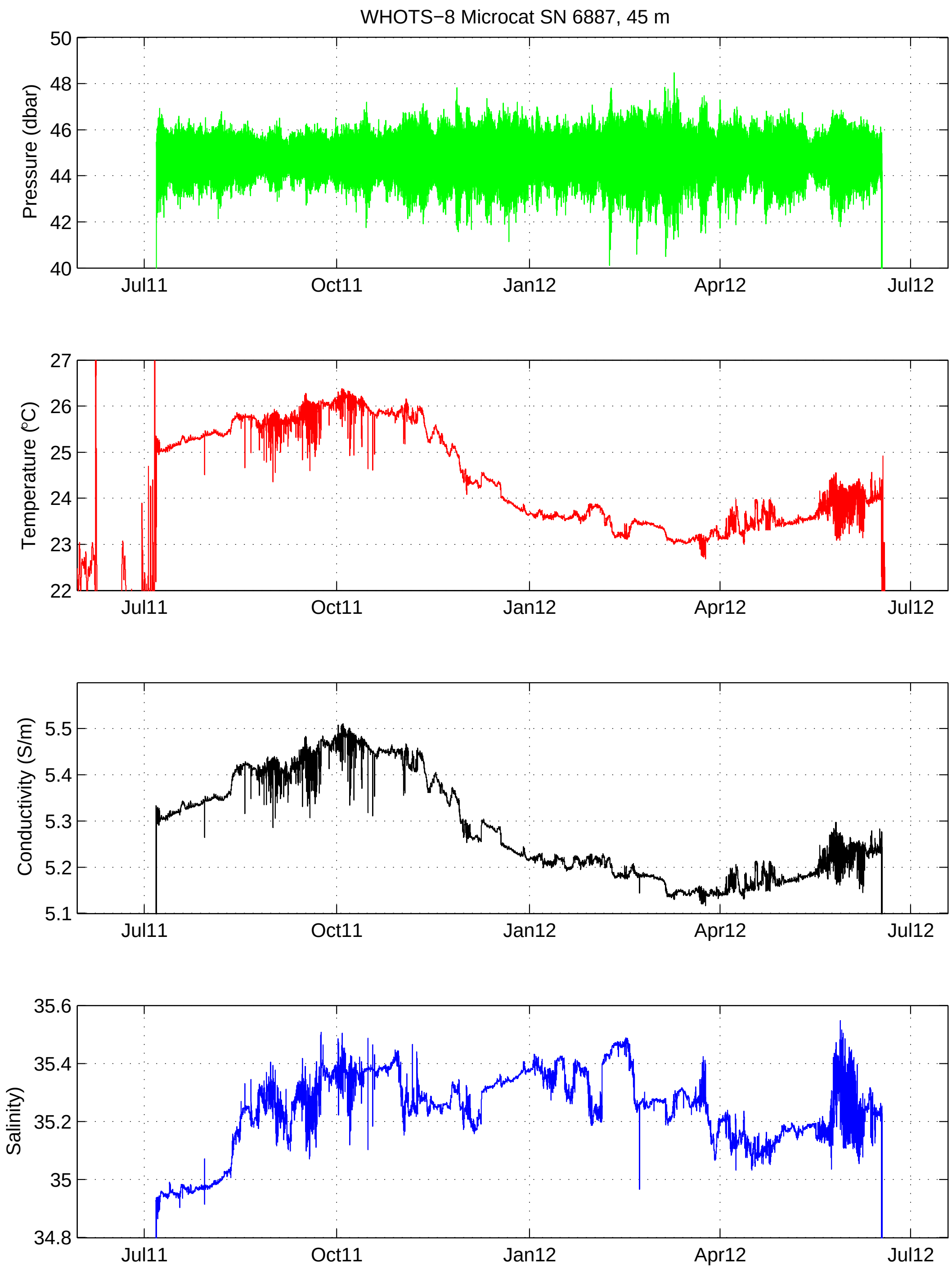


Figure B12. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 6887 deployed at 45 m on the WHOTS-8 mooring.

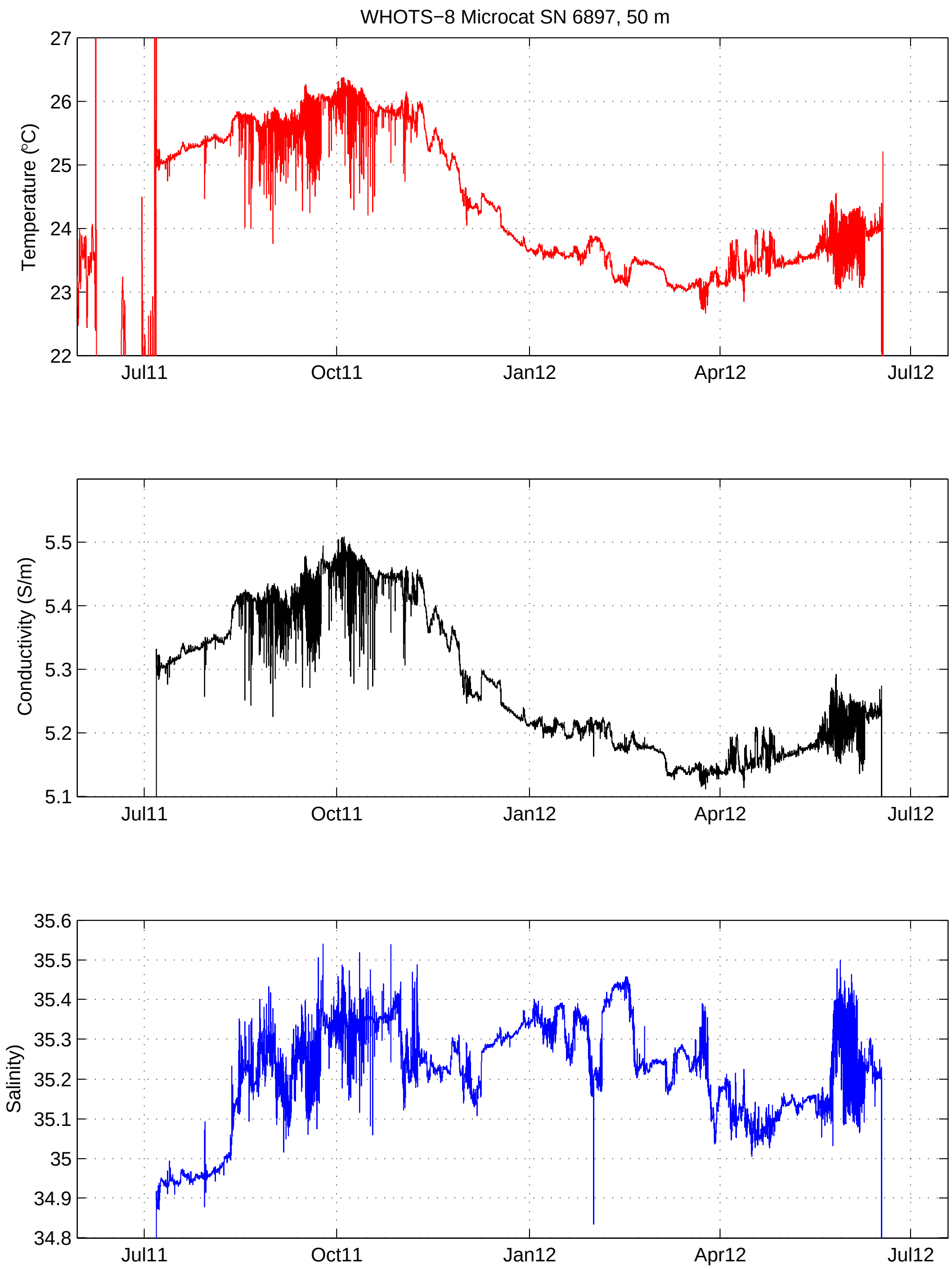


Figure B13. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6897 deployed at 50 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

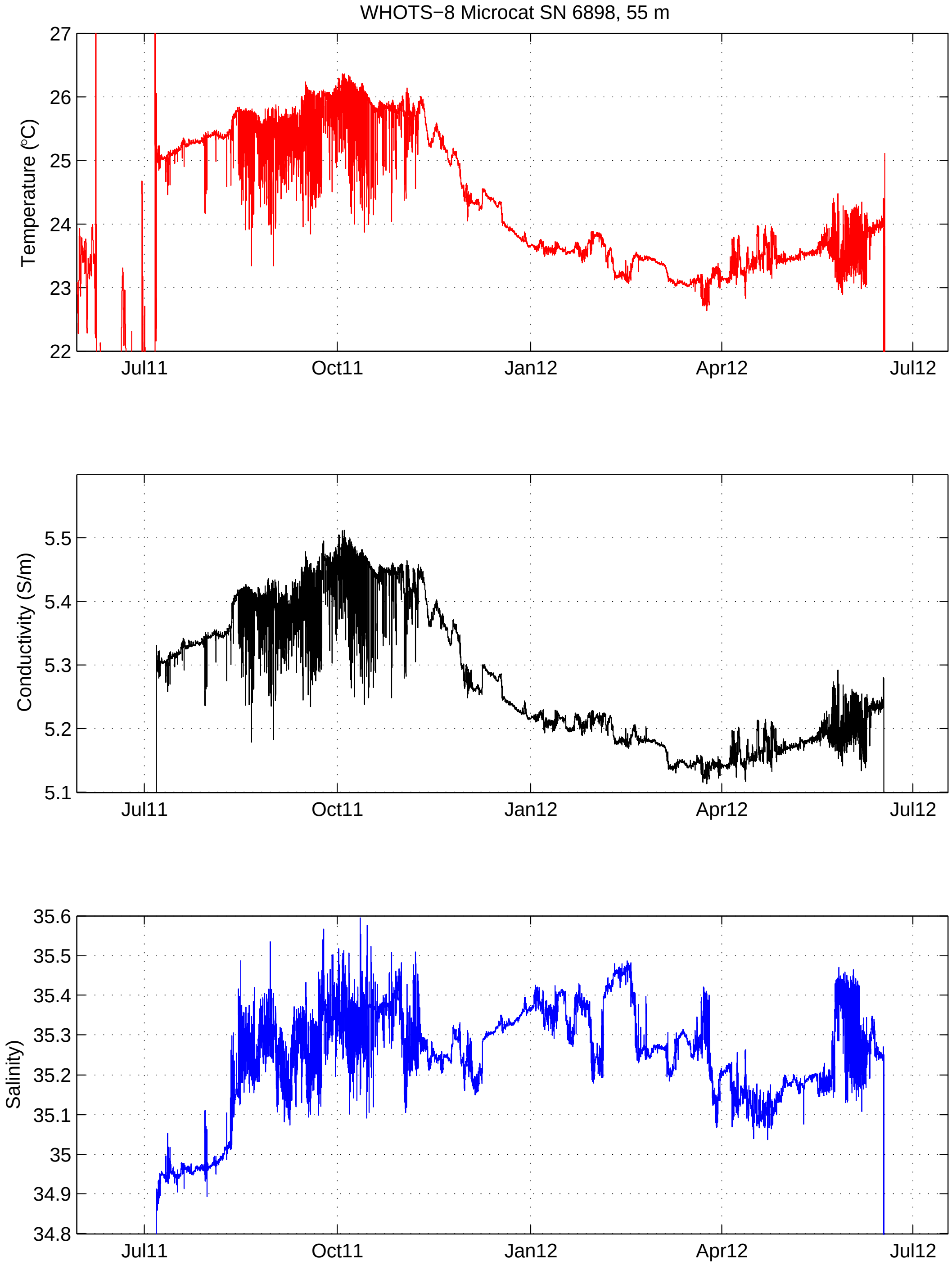


Figure B14. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6898 deployed at 55 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

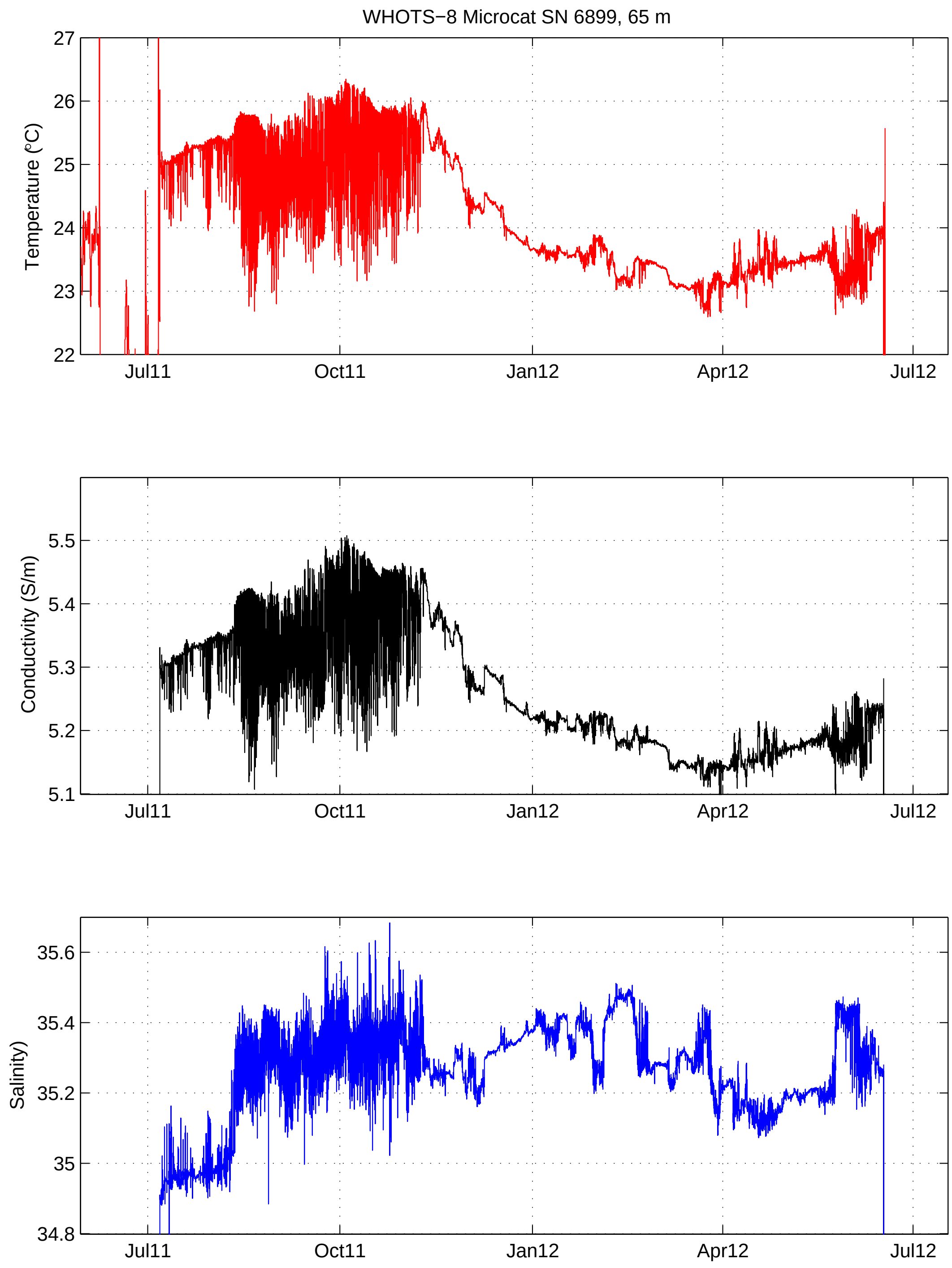


Figure B15. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 6899 deployed at 65 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

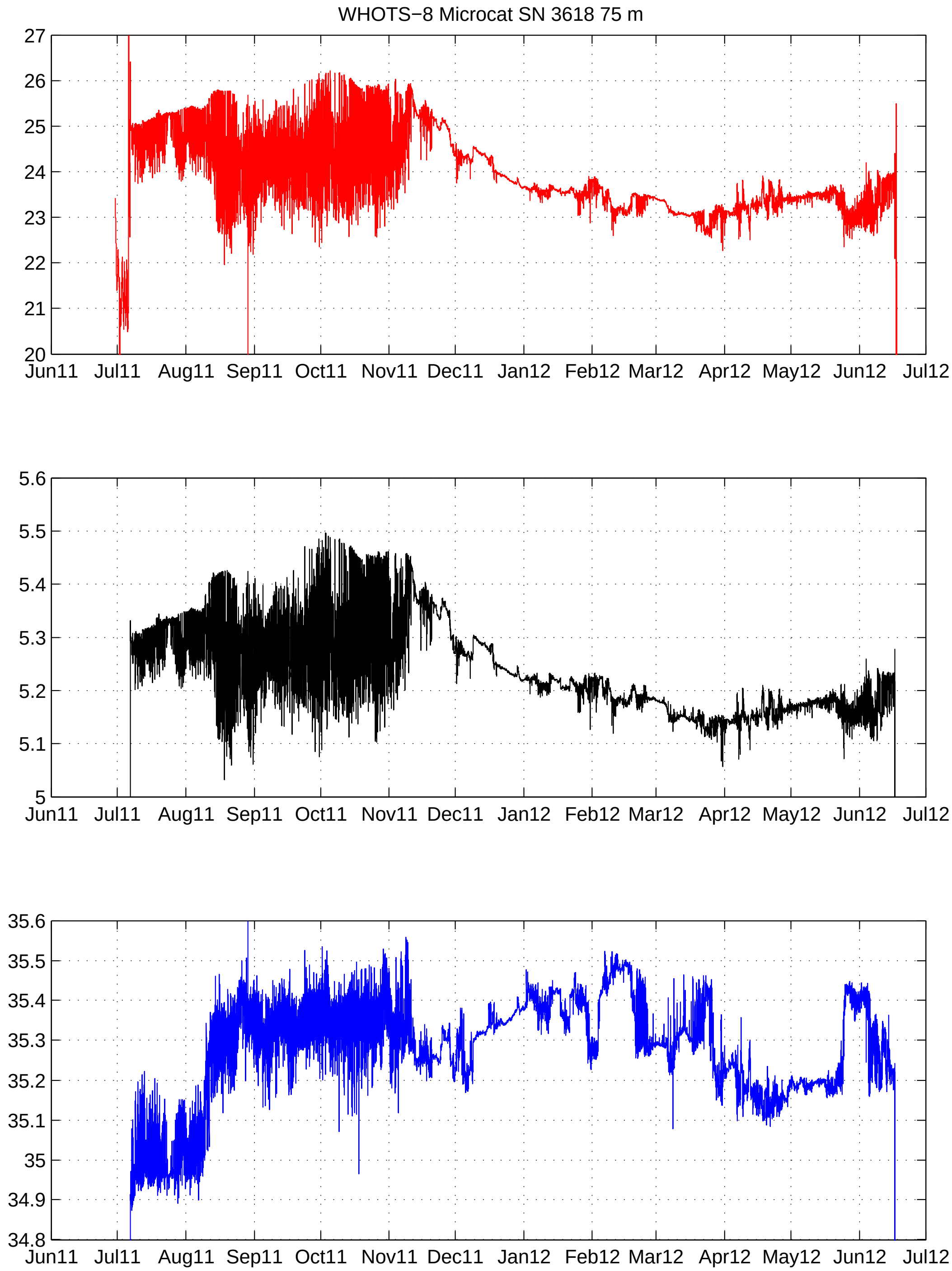


Figure B16. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3618 deployed at 75 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

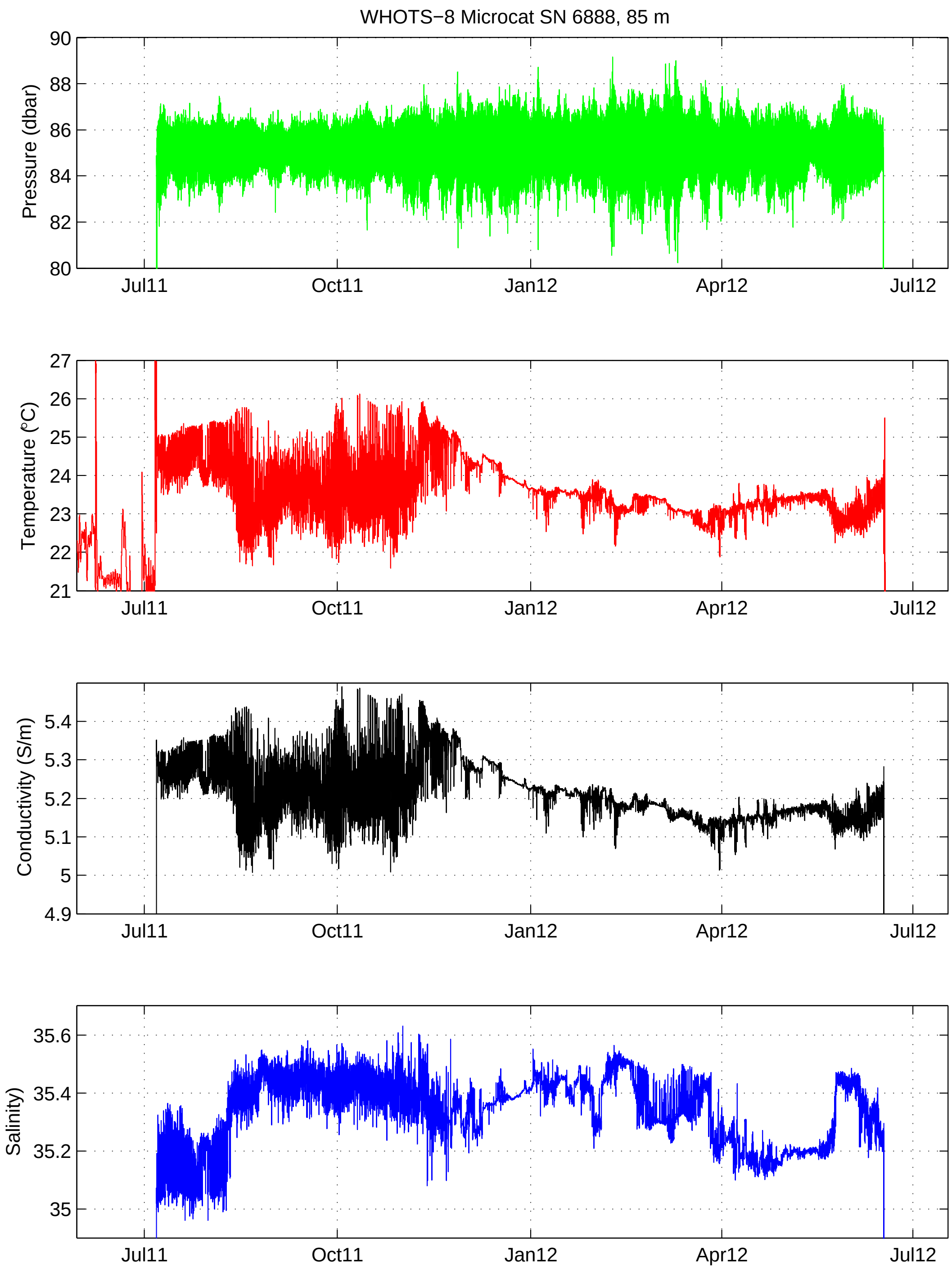


Figure B17. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 6888 deployed at 85 m on the WHOTS-8 mooring.

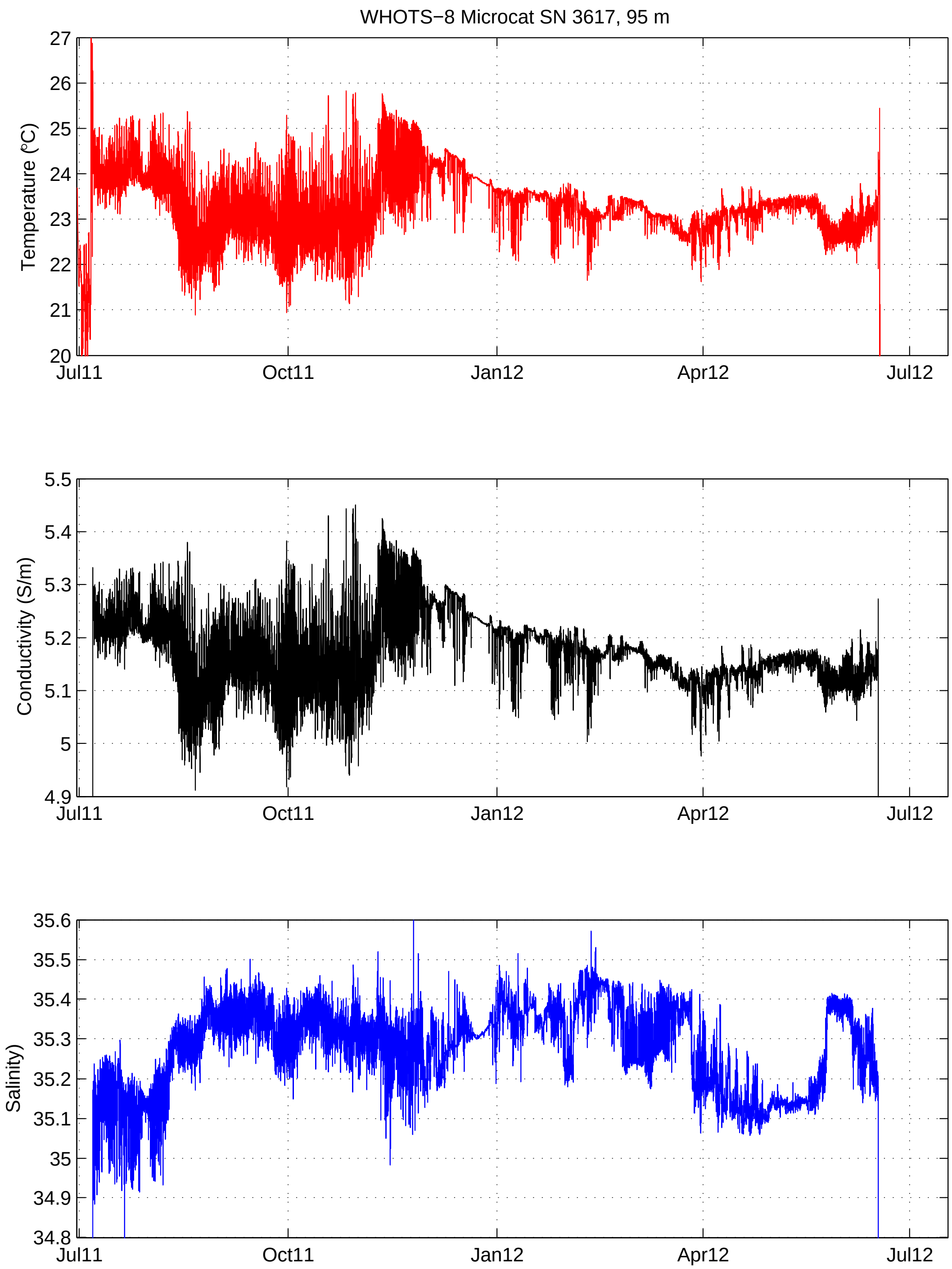


Figure B18. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3617 deployed at 95 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

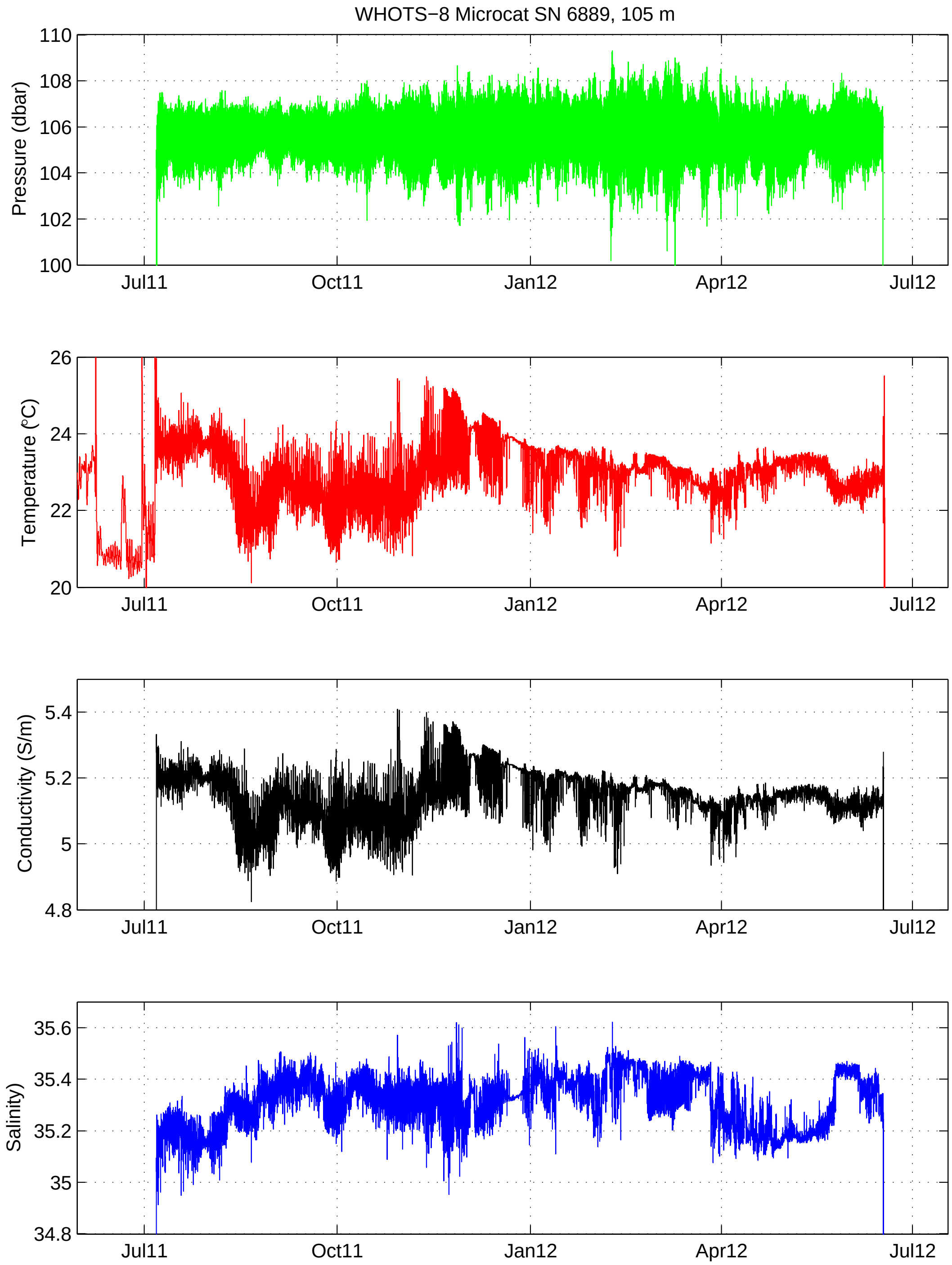


Figure B19. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 6889 deployed at 105 m on the WHOTS-8 mooring.

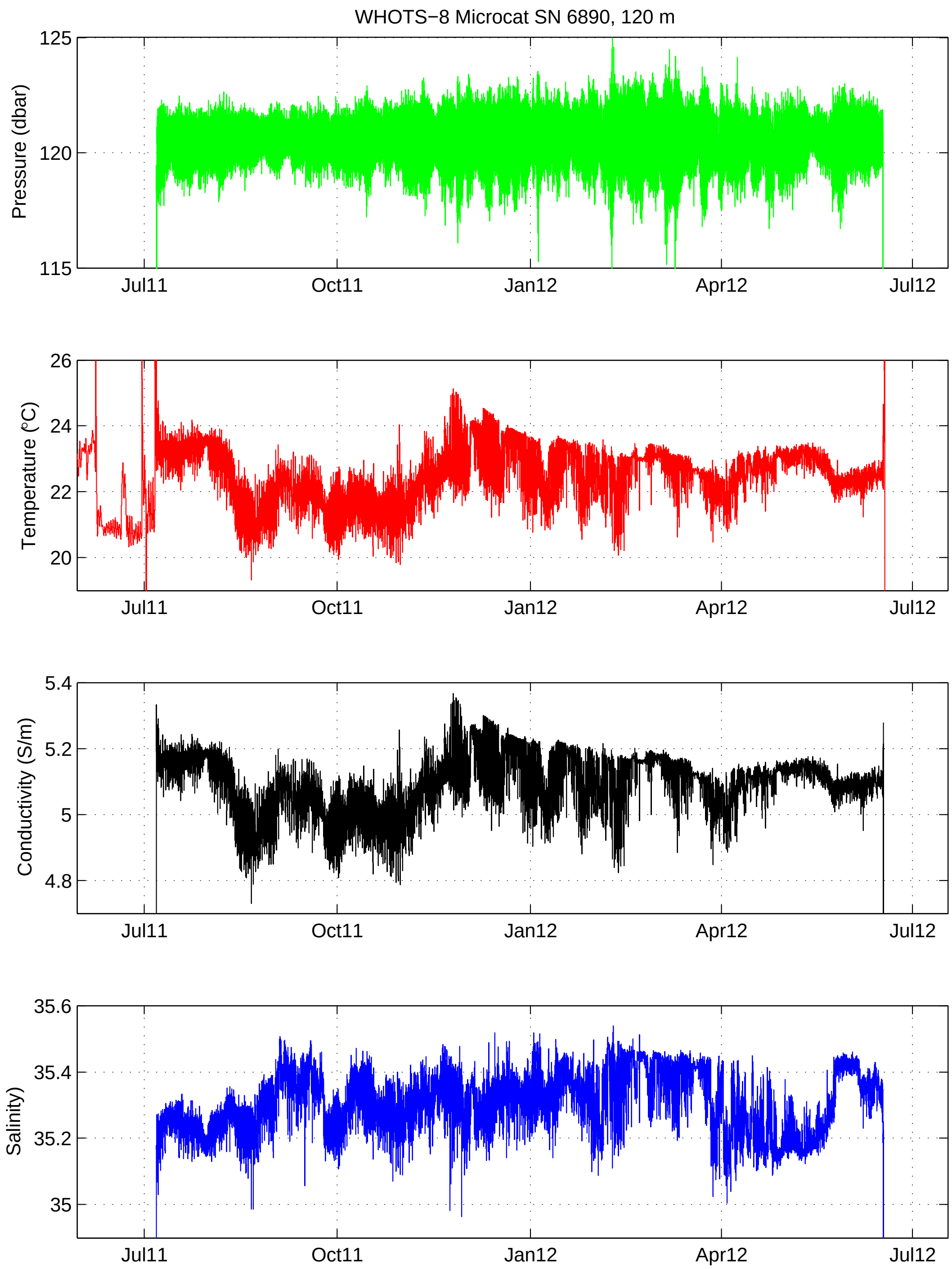


Figure B20. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 6890 deployed at 120 m on the WHOTS-8 mooring.

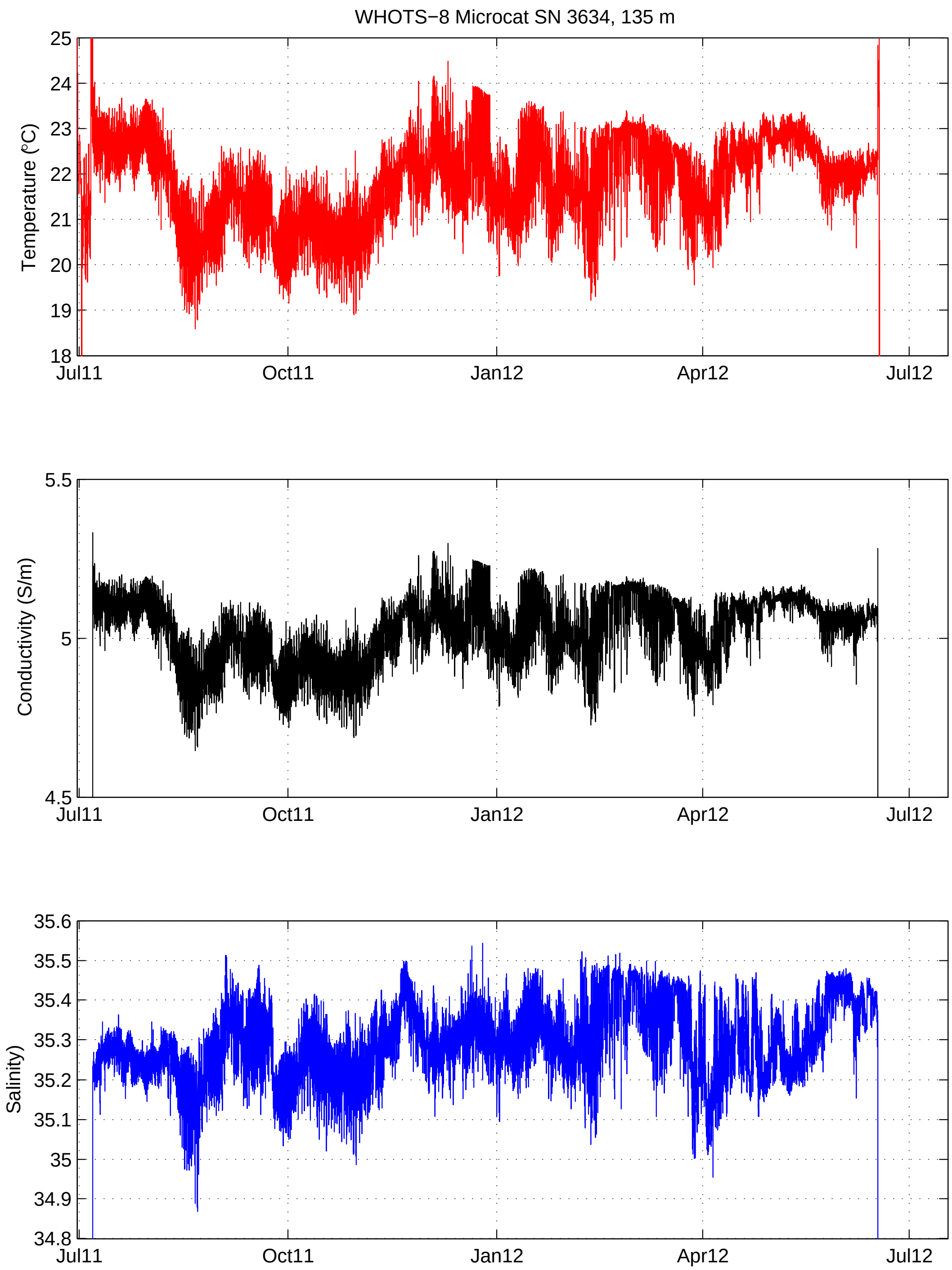


Figure B21. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3634 deployed at 135 m on the WHOTS-8 mooring. Nominal pressure was used to calculate salinity.

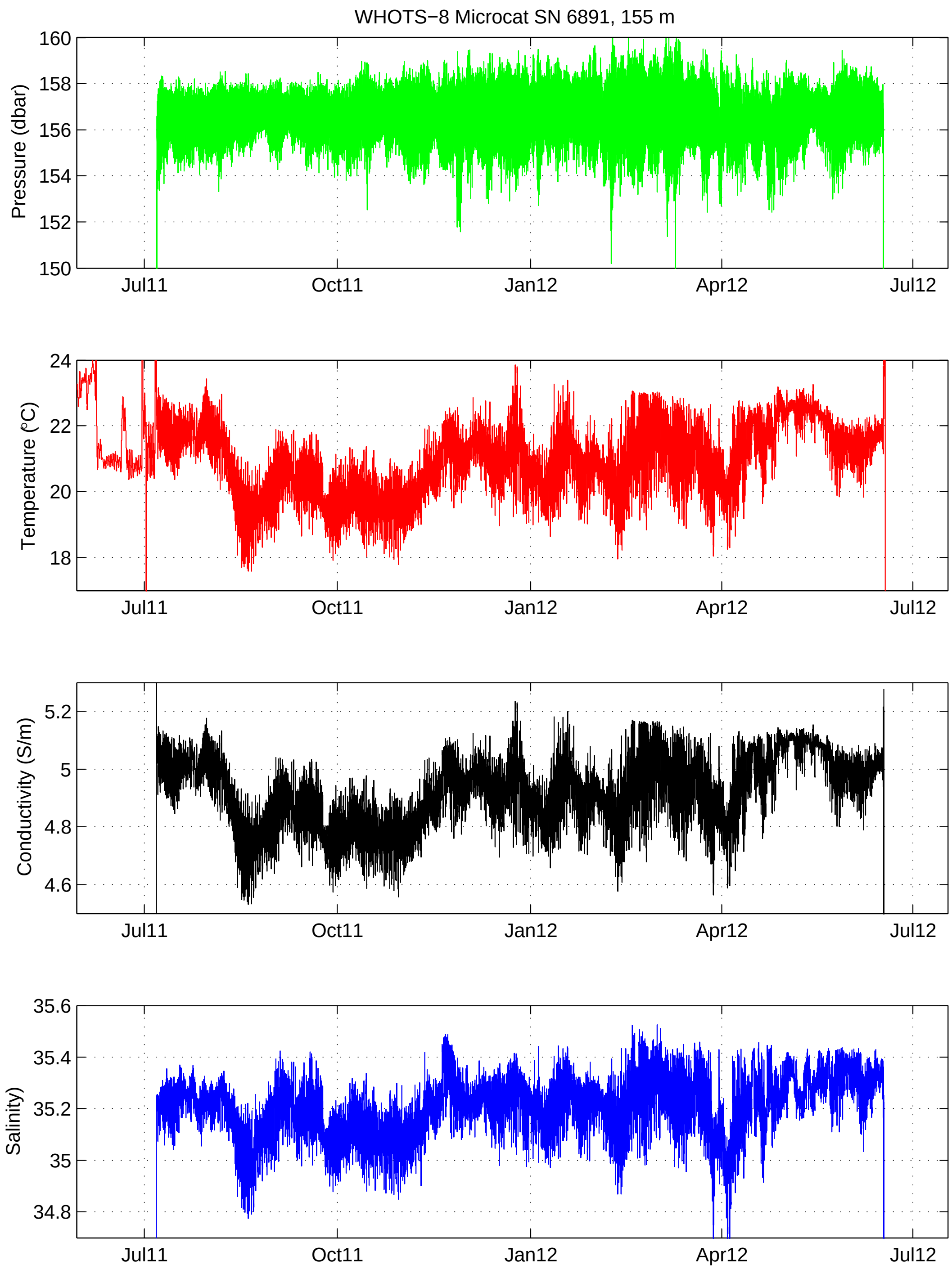


Figure B22. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 6891 deployed at 155 m on the WHOTS-8 mooring.

Appendix C: CTD Stations

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.

Ten CTD casts were conducted from June 13 – 16 (Table C1). A test cast was done in conjunction with release testing. Five casts were conducted at station 50 (near the WHOTS-9 buoy) for comparison with the WHOTS-9 mooring after deployment. Four casts at station 52 (near the WHOTS-8 buoy) were conducted to obtain profiles for comparison with subsurface instruments on the WHOTS-8 mooring before recovery. The casts at stations 50 and 52 were sited approximately 200 to 500 m from the buoys. The comparison casts consisted of 4 yo-yo cycles between 5 dbar and 200 dbar and then to 500 dbar (5th yo-yo cycle of each cast). A fifth cast was intended for Station 52 (near the WHOTS-8 mooring) but the schedule was changed due to poor weather conditions. Additional casts were planned for a regional survey on June 18 but could not be completed due to the poor weather conditions. Station numbers were assigned following the convention used during HOT cruises. Water samples were taken from all casts; 4 samples for each 500 dbar cast. These samples will be analyzed for salinity and used to calibrate the CTD conductivity sensors.

Table C1 provides summary information for all CTD casts, and Figs. C1 through C6 show the water column profile information that was obtained.

Table C1. CTD stations occupied during the WHOTS-9 cruise.

Station/ cast	Date	Time (UTC)	Location	Maximum press (dbar)
Test	6/13/12	06:03	21° 28.06´ N, 158° 21.13´ W	1020
50 / 1	6/14/12	15:49	22° 47.78´ N, 157° 54.04´ W	500
50 / 2	6/14/12	19:47	22° 47.66´ N, 157° 53.81´ W	500
50 / 3	6/14/12	23:52	22° 47.86´ N, 157° 53.72´ W	500
50 / 4	6/15/12	03:50	22° 47.80´ N, 157° 53.66´ W	500
50 / 5	6/15/12	07:50	22° 47.73´ N, 157° 53.50´ W	500
52 / 1	6/16/12	03:51	22° 41.96´ N, 157° 56.38´ W	500
52 / 2	6/16/12	07:51	22° 41.66´ N, 157° 56.65´ W	500
52 / 3	616/12	11:50	22° 41.75´ N, 157° 56.79´ W	500
52 / 4	6/16/12	15:51	22° 41.92´ N, 157° 56.74´ W	500

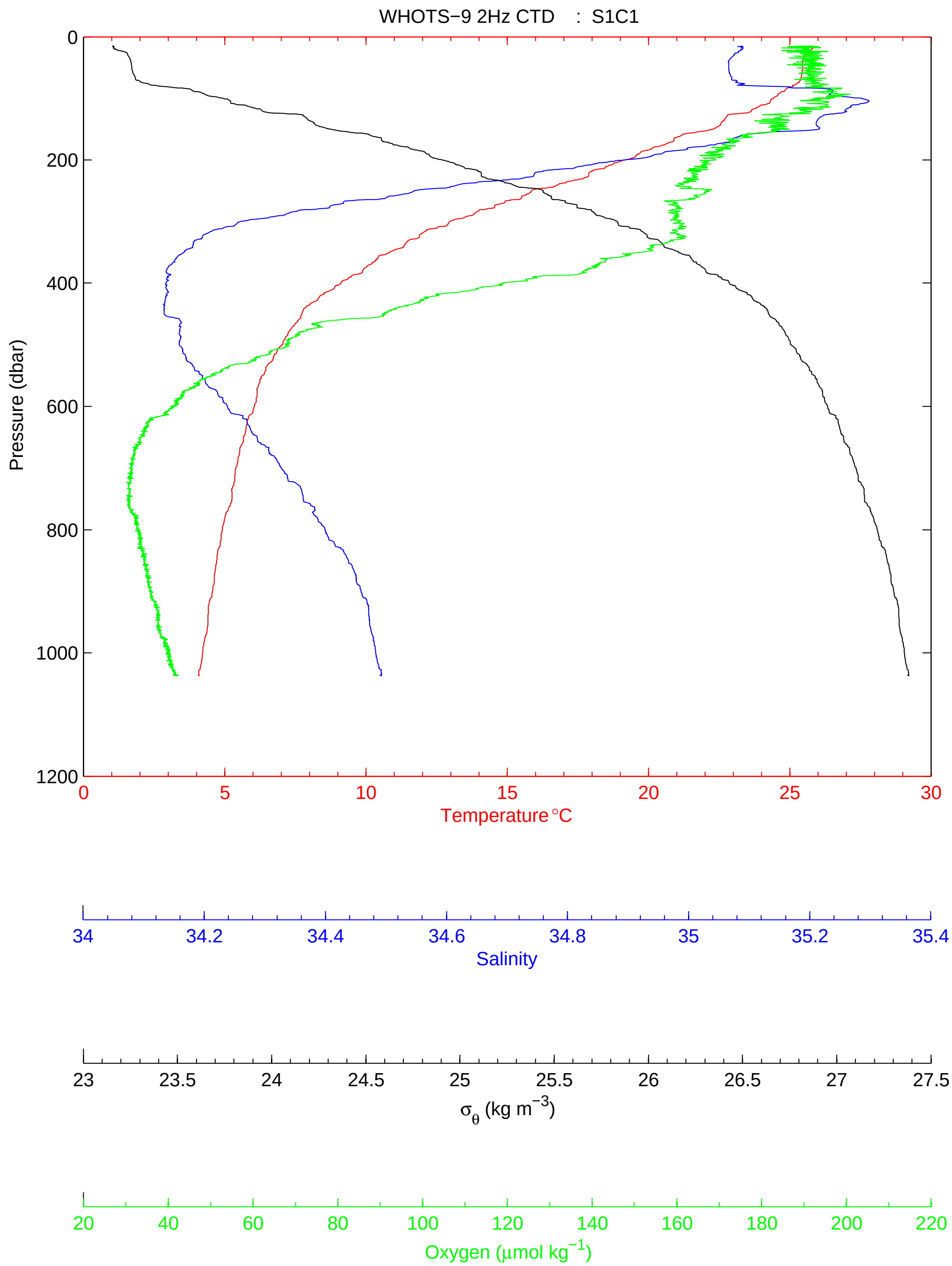
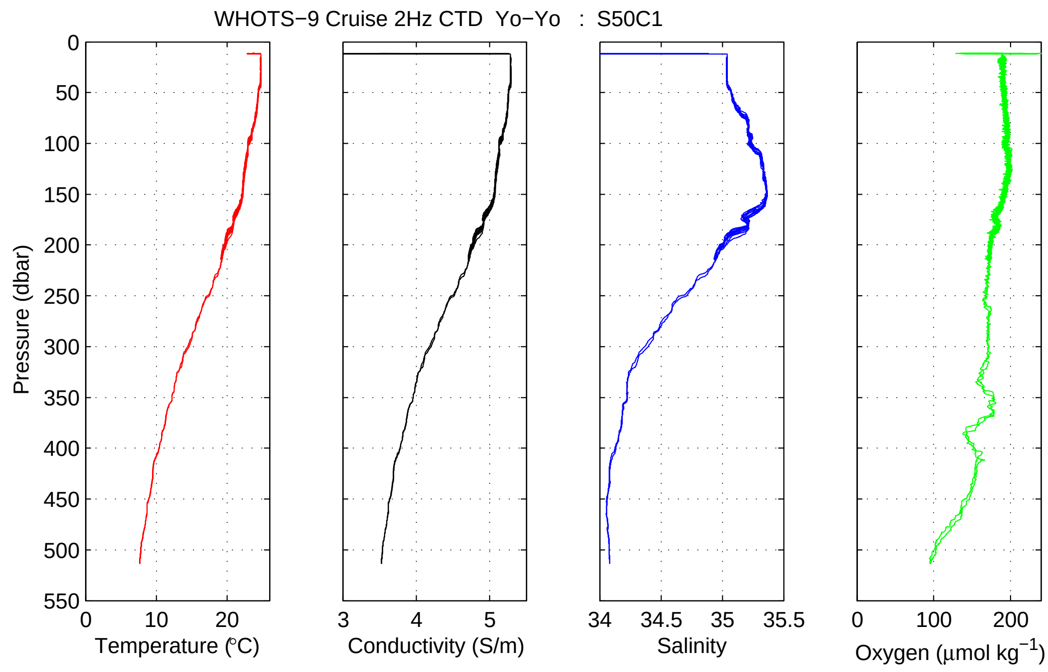


Figure C1. Profiles of 2 Hz temperature, salinity, potential density and oxygen data during test CTD station.



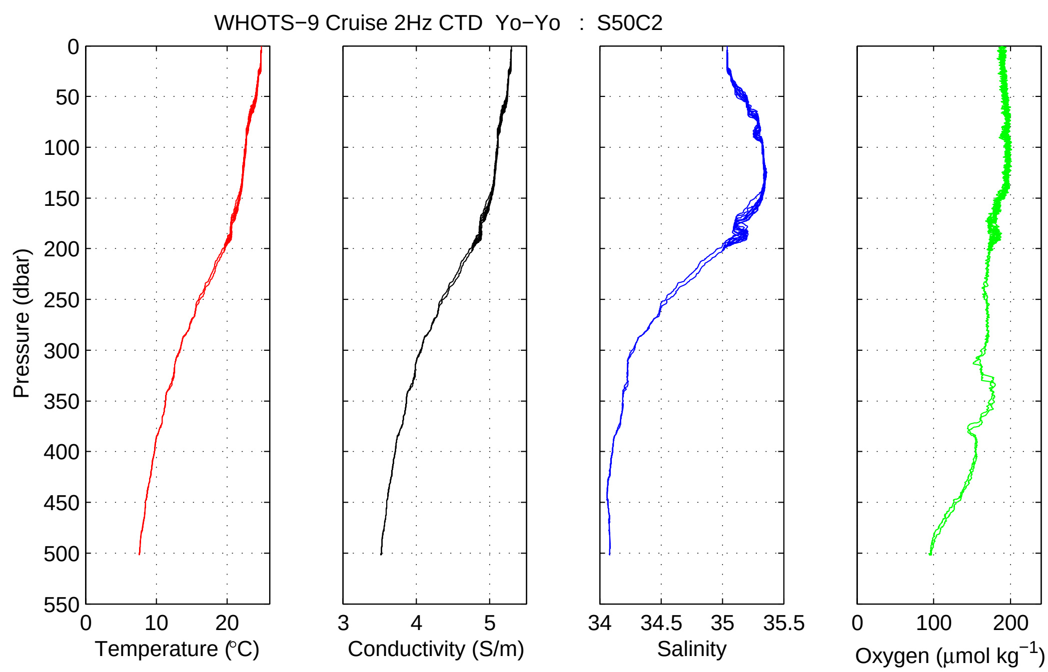


Figure C2. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S50C1 and S50C2.

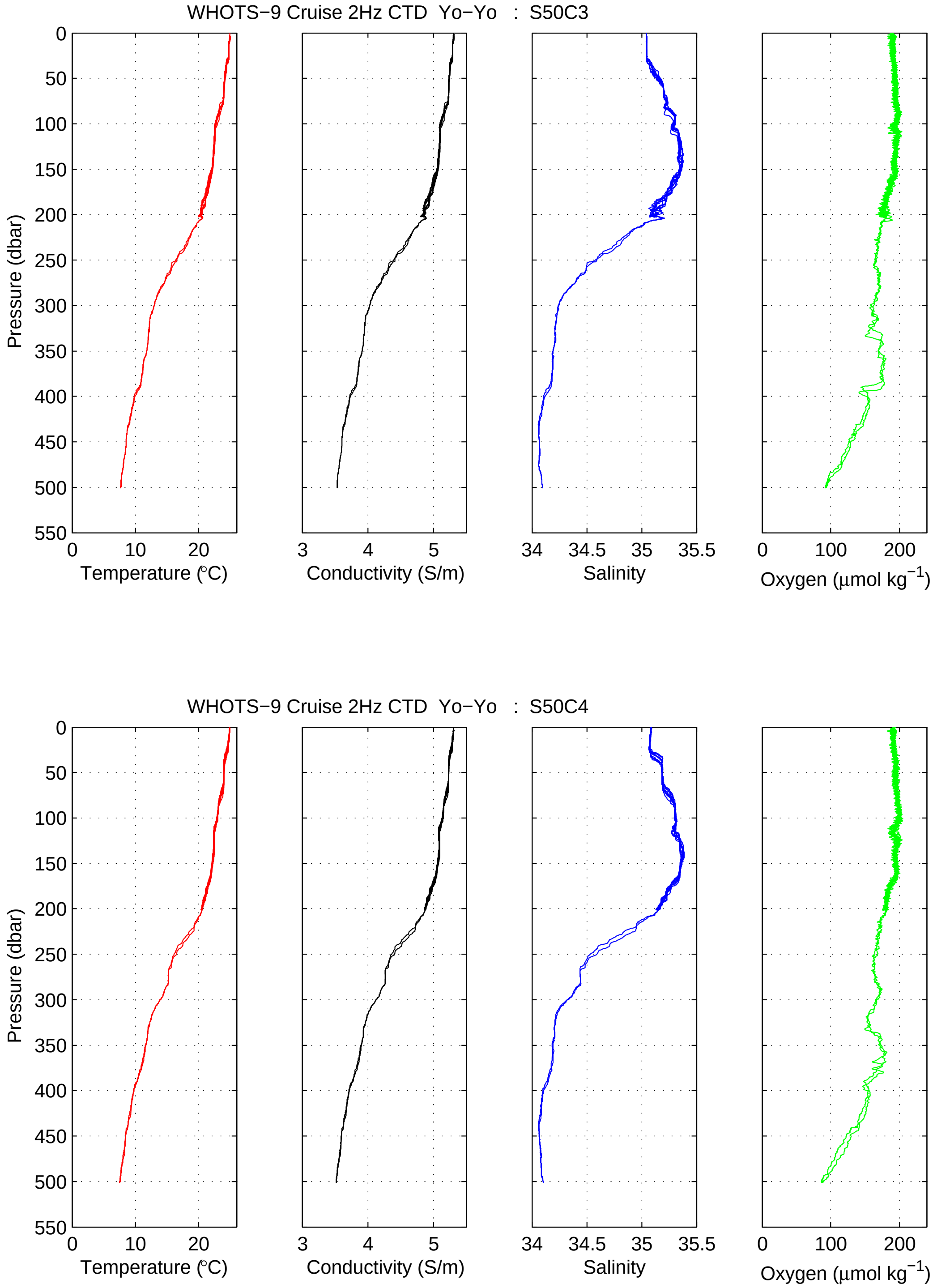
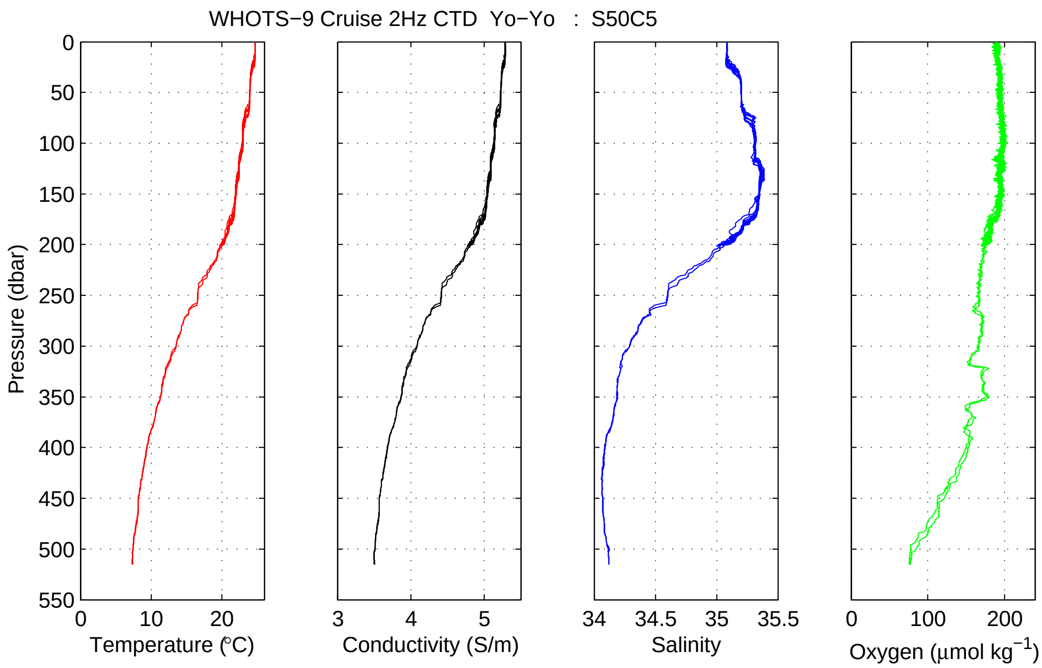


Figure C3. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S50C3 and S50C4.



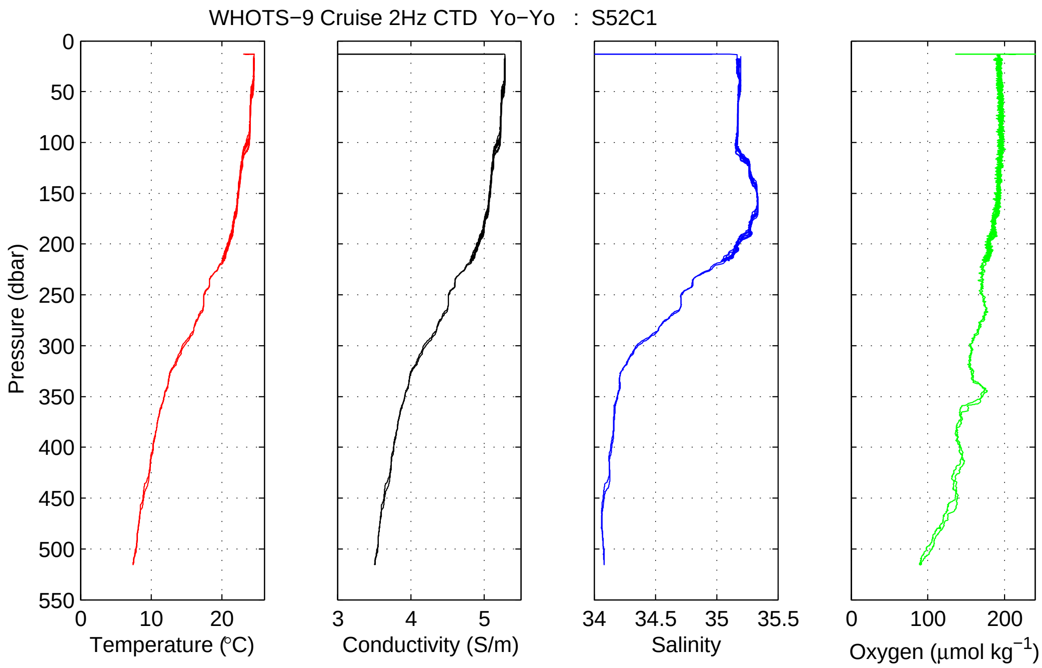
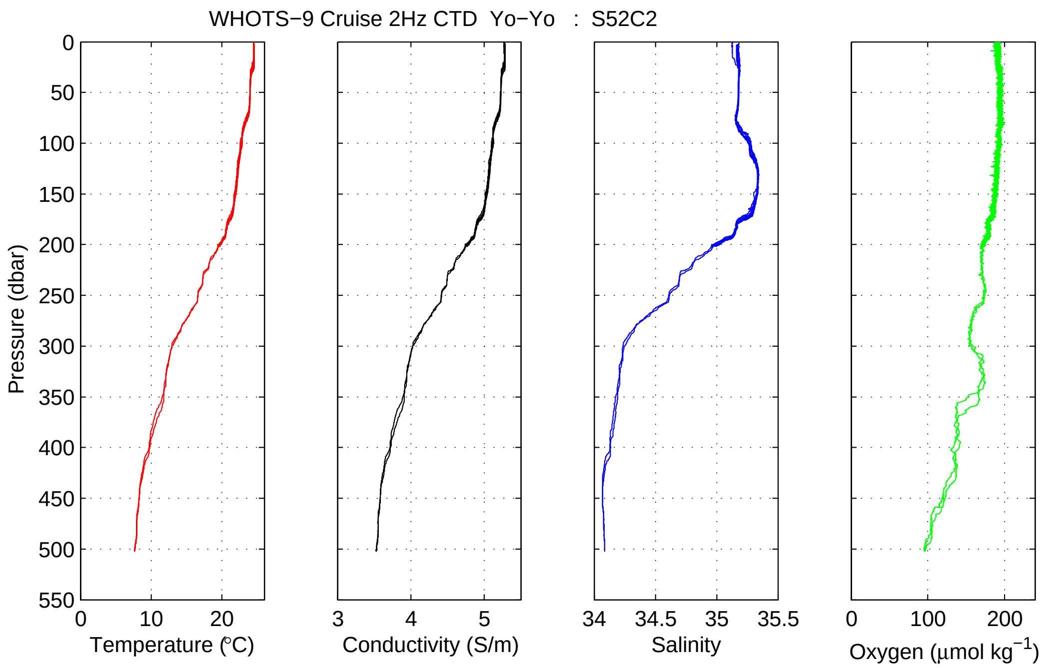


Figure C4. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S50C5 and S52C1.



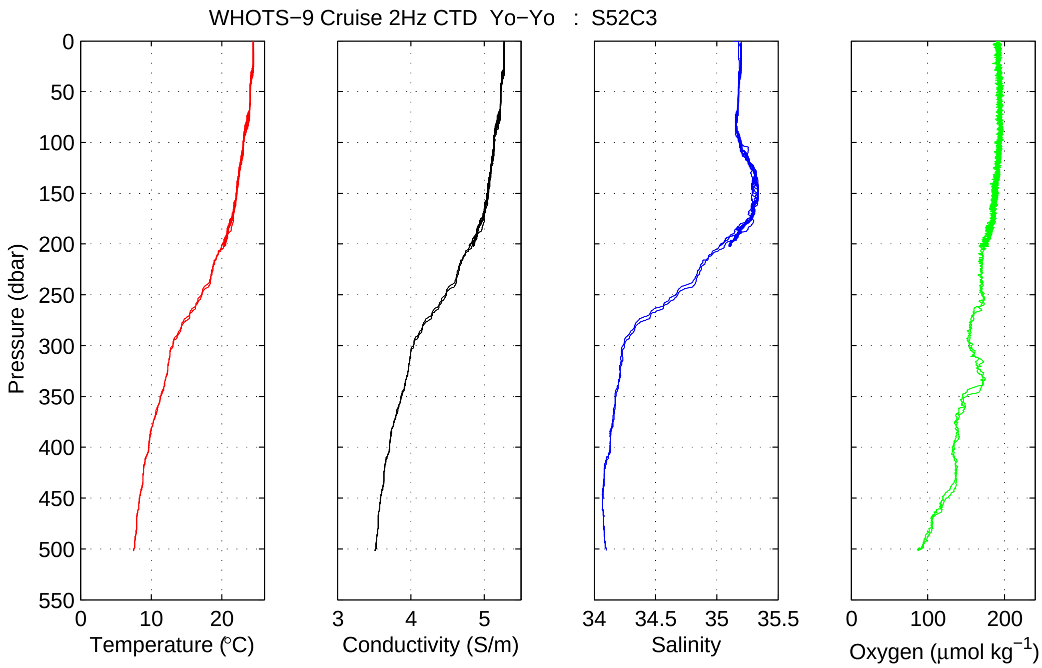


Figure C5. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S52C2 and S52C3.

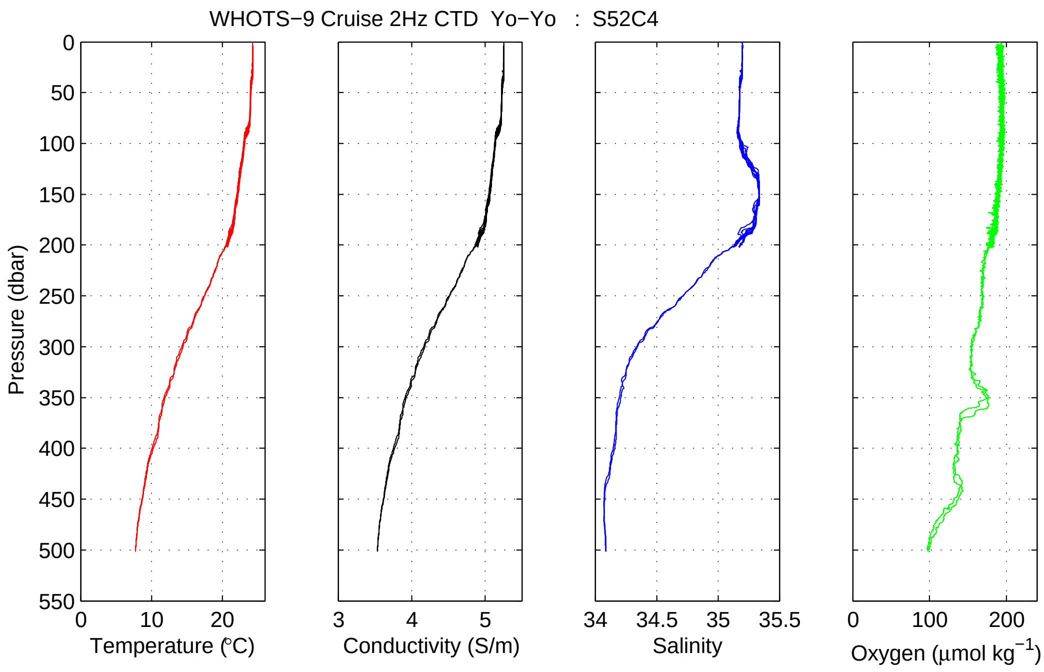


Figure C6. Profiles of 2 Hz temperature, conductivity, salinity and oxygen data during S52C.

Appendix D: WHOTS-8 Recovered Buoy Hull Instrumentation

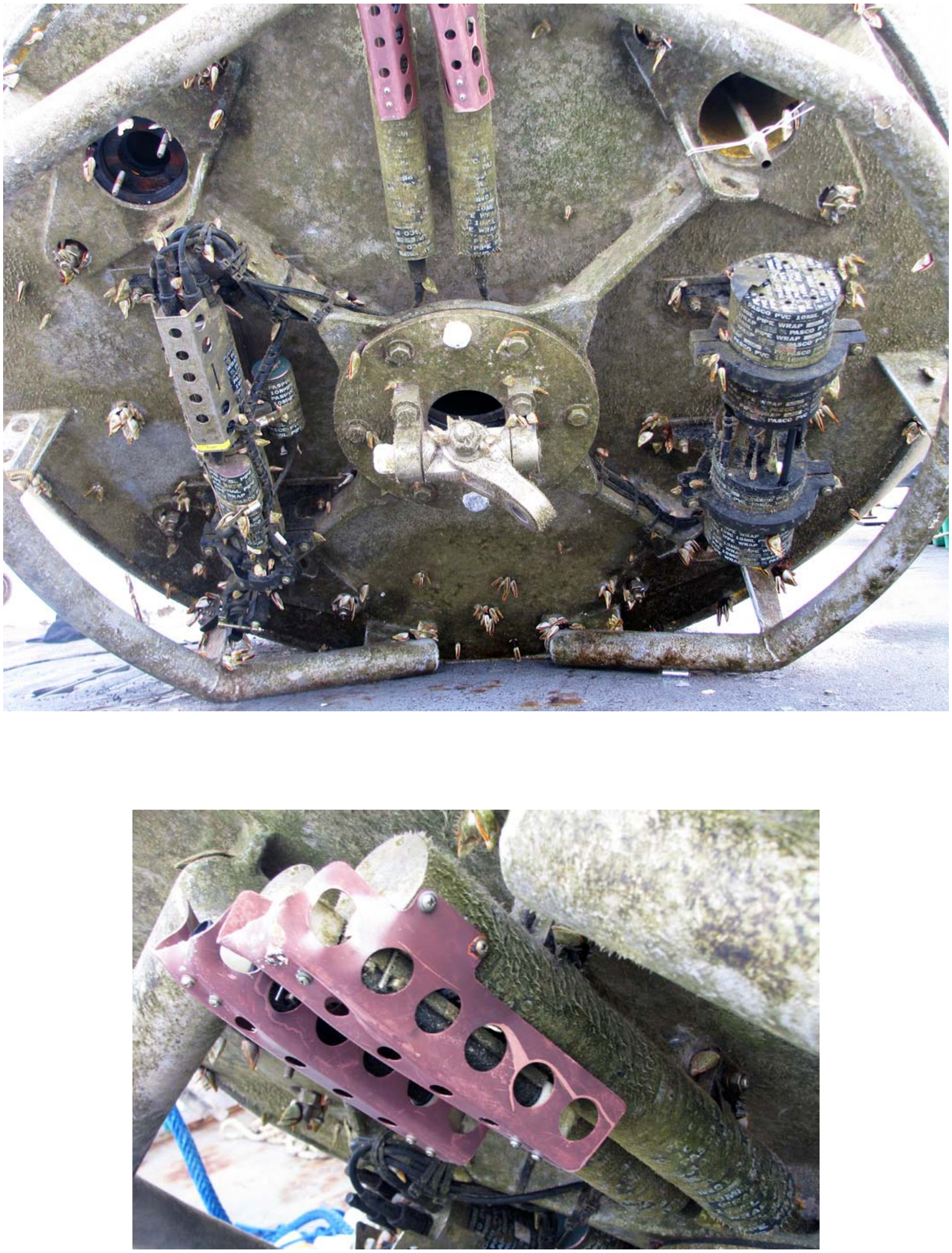


Figure D1. WHOTS-8 buoy hull and SBE-37 instruments.

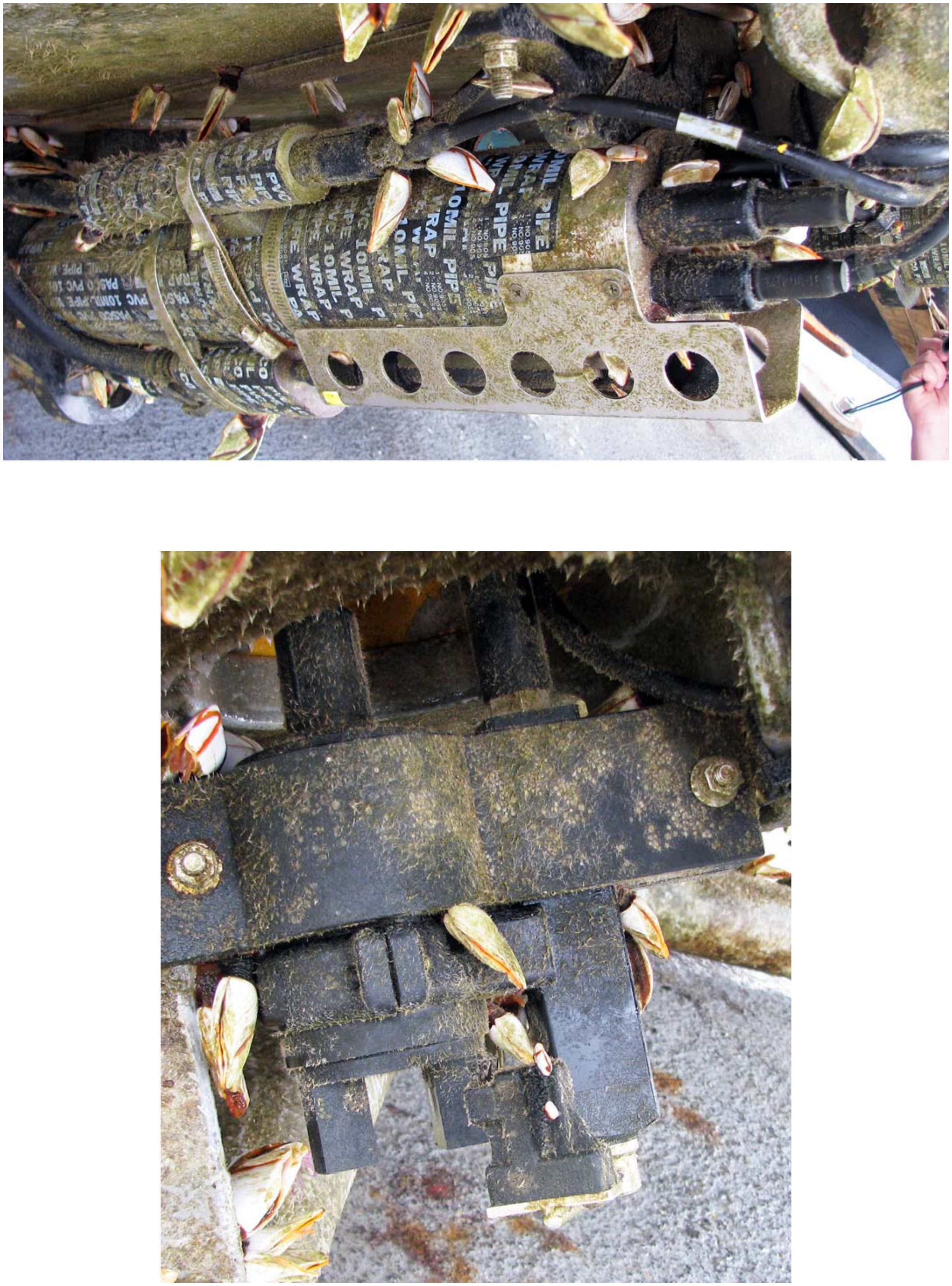


Figure D2. WHOTS-8 PMEL SBE-16 and Laney fluorometer.

Figure D3. WHOTS-8 PMEL SAMI-2 pH sensor.

Appendix E: Moored Station Logs

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° 56.832
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 diver depth, +0.23% sound spd corr. = 11 m
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 EG&G 8242 (dual)

Release No. SN ~~127 476/131 266~~ 35319/35469	Tested to 1000 m
Receiver No.	Release Command 127476/131266
Enable 111446/114442	Disable 111465/114461
Interrogate Freq. 11 kHz	Reply Freq. 12 kHz

Recovery (release fired)

Date (day-mon-yr) 16-06-2012	Time 17:47 UTC
Latitude (N/S, deg-min) 22° 40.267 N	Longitude (E/W, deg-min) 157° 57.369 W
Recovered by Ryder/Pietro	Recorder/Observer Plueddemann
Ship and Cruise No. HA-12-02	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 300034010261150
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 — angled toward sea surface
TriOS	835C	176	~~port~~ bow — angled toward sea surface
TriOS	835D	176	port — angled toward sea surface
TriOS	?	283	on radiometer stalk, uplooking

†Depth below buoy deck in centimeters

3

July 6
UTC

Moored Station Number WHOTS-8 1244

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		buoy	—	1855			0	0440	
2	7.75	3/4 chain	—					0440	
3		VMCM	016	1834	SN 008 under paint on press case		10	0453	bands off 1828
4	2.82	3/4 chain	—						props spinning on recovery
5		μCAT	6893	1829			15	0455	
6	3.6	3/4 chain	—						
7		MAVS	10260	1827			20	0459	sensor down
8	2.8	3/4 chain	—						
9		μCAT	6894	1824			25	0502	
10	3.28	3/4 chain	—						
11		VMCM	019	1821	one broken prop on each hub on recovery		30	0507	bands off 1817
12	2.82	3/4 chain	—						props spinning on recovery
13		μCAT	6895	1818			35	0508	
14	3.66	3/4 chain	—						
15		μCAT	6896	1815			40	0513	
16	3.66	3/4 chain	—						
17		μCAT	6887	1812	time over for 45m + shallower is over transom on stbd side, not in water		45	0519	w/pressure
18	1.07	3/4 chain	—		← cast off the buoy at this point on recovery				
19		ADCP	1825	1917			47.5	0331	heads up, 600 kHz
20	0.5	3/4 chain	—					0331	
21		μCAT	6897	1922			50	0331	
22	3.66	3/4 chain	—					0331	

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		μCAT	6898	~~1922~~	redeployed 1927		55	0328	
24	8.7	7/16 wire	11061-10					0327	
25		μCAT	6899	1930			65	0324	
26	8.7	7/16 wire	11061-12					0324	
27		μCAT	3618	1936			75	0321	
28	8.7	7/16 wire	11061-11					0321	
29		μCAT	6888	1939			85	0317	w/pressure
30	8.7	7/16 wire	11061-9					0317	
31		μCAT	3617	1941			95	0314	
32	8.7	7/16 wire	11061-13					0314	
33		μCAT	6889	1944			105	0311	w/pressure
34	13.6	7/16 wire	10037-7					0310	
35		μCAT	6890	1947			120	0307	w/pressure
36	3.66	3/4 chain	—					0307	
37		ADCP	4891	1950			125	0304	heads up
38	8.7	7/16 wire	—					0303	
39		μCAT	3634	1953			135	0301	
40	18.75	7/16 wire	11061-6					0301	
41		μCAT	6891	1959			155	0256	w/pressure
42	250	3/8 wire	9014-12	1959				0241	
43	500	3/8 wire	11061-2	2008				0222	
44	500	3/8 wire	11061-3	2020				0200	
45	500	3/8 wire	9014-10	2033				0134	

6/17/2012

Moored Station Number WHOTS-8 1244

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/			0130 6/~~1~~/2012 ~~1218~~	~~broken ~~
47	200	7/8 nylon	—	2050	wrapped termination			0040	2126 stopped off to take off winch
48	2100	7/8 nylon	—	2105				~~2117~~	
49	1500	1" colmega	-	2144				2013	
50		glass balls		2243	80 balls on chain			1918	broken = 13
51	5	1/2 chain	—						
52		release	35319	July 7	dual releases			1934	
53		release	35469	0018	on strongback			1934	
54	5	1/2 chain	—	0020				6/16/12	
55	20	nystron	—	0024					
56	5	1/2 chain	—						
57		anchor	—	0108					
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-9 **MOORED STATION NO.** 1248

Launch (anchor over)

Date (day-mon-yr) 14-06-2012 Time 0223 UTC

Deployed by Ryder / Pietro Recorder/Observer Plueddemann

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

Depth Recorder Reading — m Correction Source —

Depth Correction — m

Corrected Water Depth 4668 m Magnetic Variation (E/W) ____

Anchor Drop Lat. (N/S) 22° 45.845 N Lon. (E/W) 157° 53.857 W

Surveyed Pos. Lat. (N/S) 22° 46.071 N Lon. (E/W) 157° 53.956 W

Argos Platform ID No. see pg 2 for IDs Additional Argos Info on pages 2 and 3

Acoustic Release Model ORE Tested to 1000 m

Release No. 1 (sn) 33408 Release No. 2 (sn) 35318

Interrogate Freq. 11 K Interrogate Freq. 11 k

Reply Freq. 12 K Reply Freq. 12 k

Enable 361035 Enable 111367

Disable 361050 Disable 111400

Release 346341 Release 127455

Recovery (release fired)

Date (day-mon-yr) ____ Time ____ UTC

Latitude (N/S) ____ Longitude (E/W) ____

Recovered by ____ Recorder/Observer ____

Ship and Cruise No. ____ Actual duration ____ days

Distance from waterline to buoy deck 70 cm

1

ARRAY NAME AND NO. WHOTS-9 MOORED STATION NO. 1248

Surface Components			
Buoy Type MOB Color(s) Hull Tower gray hull, white tower, yellow deck			
Buoy Markings 'B' Contact: U. Hawaii, 808-956-7896			

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET	L09	buoy well	system 1 logger
HRH	249	~~249~~ 223	
BPR	502	235.6	
WND	216	258	
PRC	501	242.5	
LWR	205	249.5	
SWR	201	249.5	
SST	1306	-155	
PTT	63878	—	IDs 27356, 27364, 27413
ASIMET	L10	buoy well	system 2 logger
HRH	256	227.5	
BPR	224	235.5	
WND	222	260.0	
PRC	205	~~205~~ 241	
LWR	218	249.5	
SWR	226	249.5	
SST	1419	-155	
PTT	63879	—	IDs 7561, 27415, 27416
Xeos GPS	–	—	IMEI 300034013701980
SBE-39 AT	5276	222	
Viasala WXT	001	261	to center of fingers
pCO2	22		
radiometers	various	various	see pg 3

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. WHOTS-9 MOORED STATION NO. 1248

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SST	14977	-80	RBR 1060, 120° CW from vane
SST	14878	-80	RBR 1060, 180°
SST	14978	-95	RBR 1060, 180°
SST	14882	-80	RBR 1060, 240°
~~[illegible]~~ SiS	3	bottom of hull	subsurf beacon, Argos ID 9209
CTD	6885	"	PMEL SBE-16 w/ fluoro + O_2 Optode
pH	35	"	PMEL SAMI SN1332 SN2400
Fluoro	SCF3256	"	Laney SCF chl fluorometer
Laney	Radiometers on tower		
TriOS	114766	178	aft, on wind vane
TriOS	114765	176	stbd
TriOS	114767	176	bow
TriOS	114764	176	port
TriOS	114768	249	on radiometer stalk, uplooking

†Depth below buoy deck in centimeters

ARRAY NAME AND NO. WHOTS-9 MOORED STATION NO. 1248

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
1		buoy	0		1930		
2	7.75	3/4" chain					
3		VMCM	10	011	1832		~~bands off~~ spin ~~off~~ 1827
4	2.82	3/4 chain					
5		μCAT	15	3382	1831		CT
6	3.[illegible]6	3/4 chain					
7		MAVS	20	10261	1826		head down
8	2.8	3/4 chain					
9		μCAT	25	4663	1823		CT
10	3.28	3/4 chain					
11		VMCM	30	061	1818		spin ~~bands off~~ 1811
12	2.82	3/4 chain					
13		μCAT	35	3633	1814		CT
14	3.66	3/4 chain					
15		μCAT	40	3381	1808		CT
16	3.66	3/4 chain					
17		μCAT	45	3668	6/13 1803		CTP
18	1.07	3/4 chain					
19		ADCP	47.5	13917	1949		
20	0.5	3/4 chain					
21		μCAT	50	3619	1949		CT
22	3.66	3/4 chain					
23		μCAT	55	3620	1952		CT
24	8.7	7/16 wire		11-257-10			
25		μCAT	65	3621	1957		CT

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ARRAY NAME AND NO. WHOTS-9 **MOORED STATION NO.** 1248

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
26	8.7	7/16 wire		11257-13			
27		µCAT	75	3632	2000		CT
28	8.7	7/16 wire		11237-9			
29		µCAT	85	4699	2003		CTP
30	8.7	7/16 wire		11257-8			
31		µCAT	95	3791	2006		CTP
32	8.7	7/16 wire		11257-12			
33		µCAT	105	2769	2013		CTP
34	13.6	7/16 wire		11257-7			
35		µCAT	120	4700	2015		CTP
36	3.66	3/4 chain		~~11257-11~~			
37		ADCP	125	7637	2019		
38	8.7	7/16 wire		11257-11			
39		µCAT	135	3669	2023		CTP
40	18.75	7/16 wire		11257-6			
41		µCAT	155	4701	2034		CTP
42	250	3/8 wire		11064-4			
43	500	3/8 wire		11257 3	2044		
44	500	3/8 wire		~~11257~~ →	2102 11061-1		
45	500	3/8 wire		11257-2	2117		
46	100	3/8 wire		11061-5	2130		
47	200	7/8 nylon			2133		
48	2050	7/8 nylon			2156		
49	1500	1" colmega			2250		
50		Glass Balls		start end	2356 0100	14 June	counted 80 balls

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ARRAY NAME AND NO. WHOTS-9 MOORED STATION NO. 1248

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
51		SBE-16	*	1880	14 Jun 0200		* approx 37m above the bottom, side by side on load bar
52		SBE-16	*	1881	0200		
53	5	½ chain			0201		
54		Release			0202		
55		Release			0202		
56	5	½ chain			0215		
57	20	1" Nystron			0216		
58	5	½ chain		0224	~~1624~~		
59		anchor		0224	~~1624~~		
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16. Abstract (Limit: 200 words)

The Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Timeseries 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 Hawaii Ocean Timeseries (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 eighth WHOTS mooring (WHOTS-8) and deployment of the ninth mooring (WHOTS-9). 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 buoys in cooperation 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 12 and 19 June 2012. Operations began with deployment of the WHOTS-9 mooring on 13 June. This was followed by meteorological intercomparisons and CTDs. Recovery of the WHOTS-8 mooring took place on 16 June. 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

UOP - Upper Ocean Processes Group
Cruise On Board the NOAA Ship Hi'ialakai
Hawaiian Island Region

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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