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Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS):

WHOTS-11 2014 Mooring Turnaround Cruise Report

by

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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

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Technical Report

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UOP Technical Report 2015-01

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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 tenth WHOTS mooring (WHOTS-10) and deployment of the eleventh mooring (WHOTS-11). 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 and ancillary sensors were 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 15 and 23 July 2014. Operations began with deployment of the WHOTS-11 mooring on 16 July. This was followed by meteorological intercomparisons and CTDs. Recovery of the WHOTS-10 mooring took place on 20 July. 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, chlorophyll fluorescence, turbidity, dissolved oxygen and pH measurements utilizing instruments mounted on the buoy base. In addition, 4 radiometers were deployed on the surface buoy tower and one chlorophyll fluorometer was mounted on the buoy base 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-14-03, 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.

The HA departed Ford Island at 1000 local on 15 July. The cruise was completed in 9 days, between 15 July and 23 July, 2014. A schematic cruise track is shown in Fig. 1.

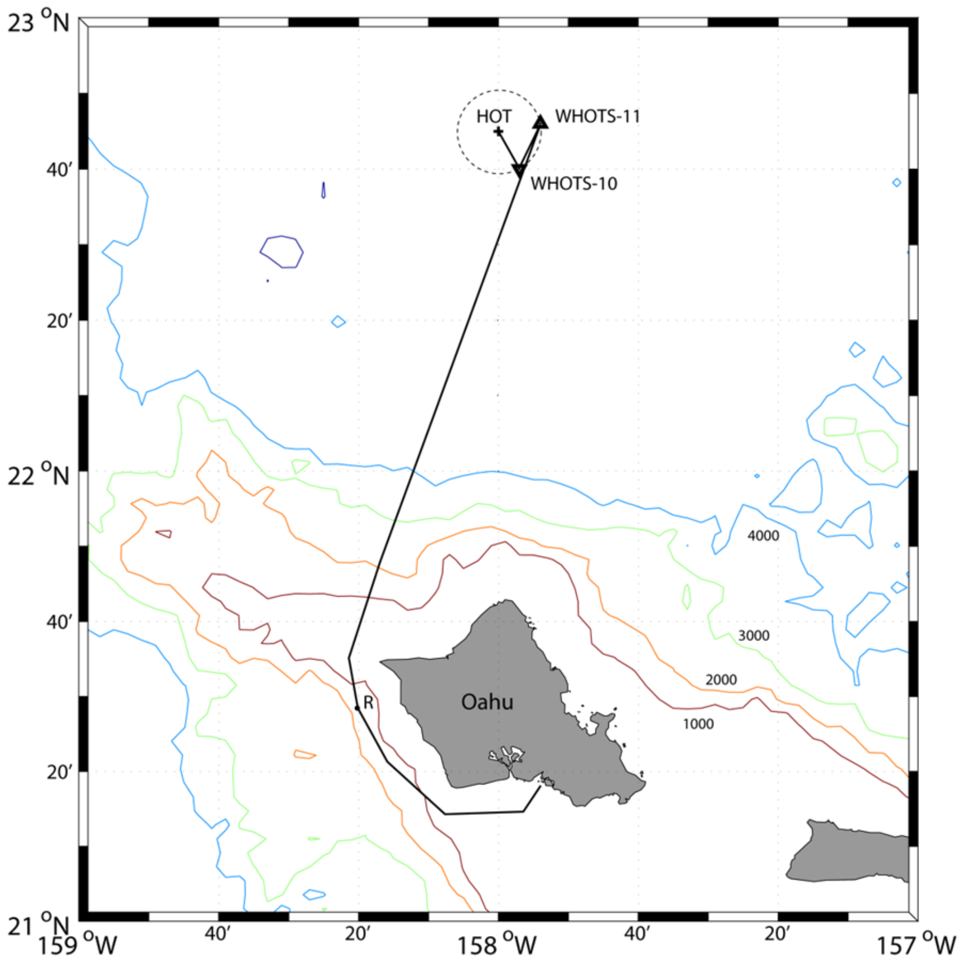

Figure 1. WHOTS-11 cruise track showing location of release and CTD tests (R), WHOTS-10 and WHOTS-11 mooring locations (triangles), and the center (+) and radius (dashed line) of the Station ALOHA circle.

This report consists of five main sections, describing pre-cruise operations (Sec. 2), the WHOTS-11 mooring (Sec. 3), the WHOTS-11 mooring deployment (Sec. 4), the WHOTS-10 mooring recovery (Sec. 5), and meteorological intercomparisons (Sec. 6). Seven 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 June 2014. 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.

Al Plueddemann, Ben Pietro and Sean Whelan traveled to Hawaii on 6 July, unloaded the containers, and set up an operation area on the port grounds. Pre-cruise operations took place from 7 July to 14 July; the *Hi'ialakai* arrived in port on the morning of July 10th. Pre-cruise operations included assembly of the buoy tower top and well, painting the foam hull, evaluation of ASIMET data, loading, deck arrangement, lab setup, a buoy spin, and insertion of the tower assembly into the hull. During the set up and evaluation an Alpha-Omega Argos receiver was available to collect real-time data, in conjunction with data access via the UOP web site.

During the load of the TSE winch onto the ship, it was discovered that the winch feet did not align with the adapter plates as expected. A review of photos from prior cruises showed that the plates had been fit to TSE #2 (WHOTS-9) and TSE #4 (WHOTS-10). For WHOTS-11 we obtained TSE #1, which apparently has a different footprint that of #2 and #4. To fit TSE #1 to the deck, oversized holes were cut in the starboard adapter plates using a plasma torch. The winch was then able to pick up 2 of the 4 studs on each of the port adapter plates (Fig. 2).

Figure 2. TSE winch #1 fit to the deck of the Hi'ialakai. These photos shows the port side aft corner with two of the four adapter plate studs mated to the foot of the winch.

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 0°. Fig. 3 shows the WND module directional error relative to 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 0° was established with a distant object as a reference point. The technique used was the same as for the WHOI buoy spins. Fig. 4 shows the WND module directional error relative to the sighting angle for the Ford Island spin.

c. Sensor Evaluation

The UOP science party started work at Ford Island on 7 July 2014. 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 8 July 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-minute ASIMET logger data were offloaded for evaluation on 11 July. All buoy sensor pairs agreed well. At night, the buoy HRH module ATs agreed to about 0.15°C and compared well with the SBE-39 AT (Fig 5). The Vaisala WXT AT was low by about 0.1°C compared to the SBE-39 AT. HRH module AT differences were only slightly larger during the day (~0.2°C), while the Vaisala AT was up to 0.5°C high at midday. Comparison of the Vaisala RH with the buoy pair indicated that the WXT was biased low by as much as 4%. The buoy wind speeds compared well (within 0.2 m/s) during an overnight test on the pier prior to arrival of the HA. The Vaisala wind speed was typically 0.5 m/s lower than the buoy pair. The buoy wind directions agreed to within about 5°.

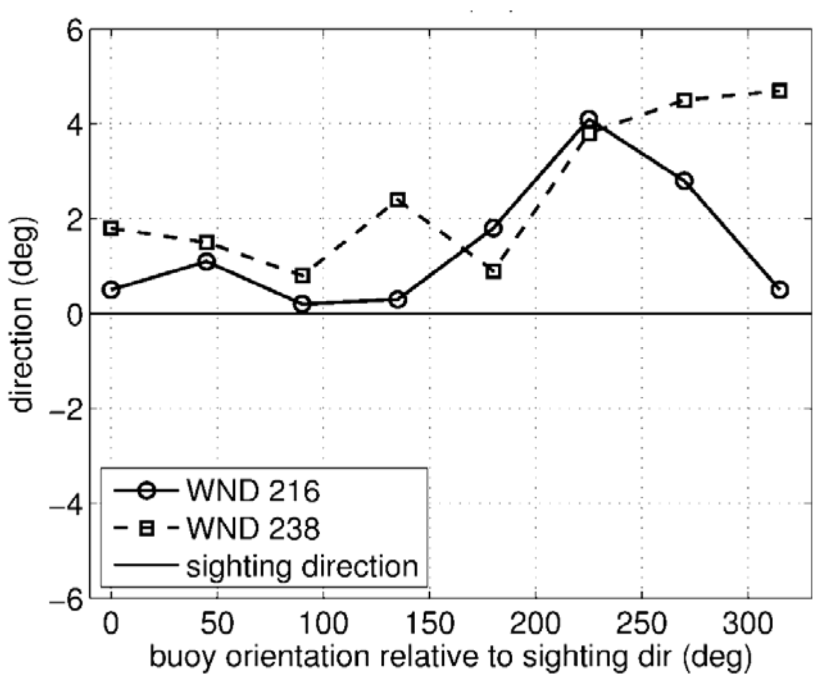

Figure 3. WHOI buoy spin results.

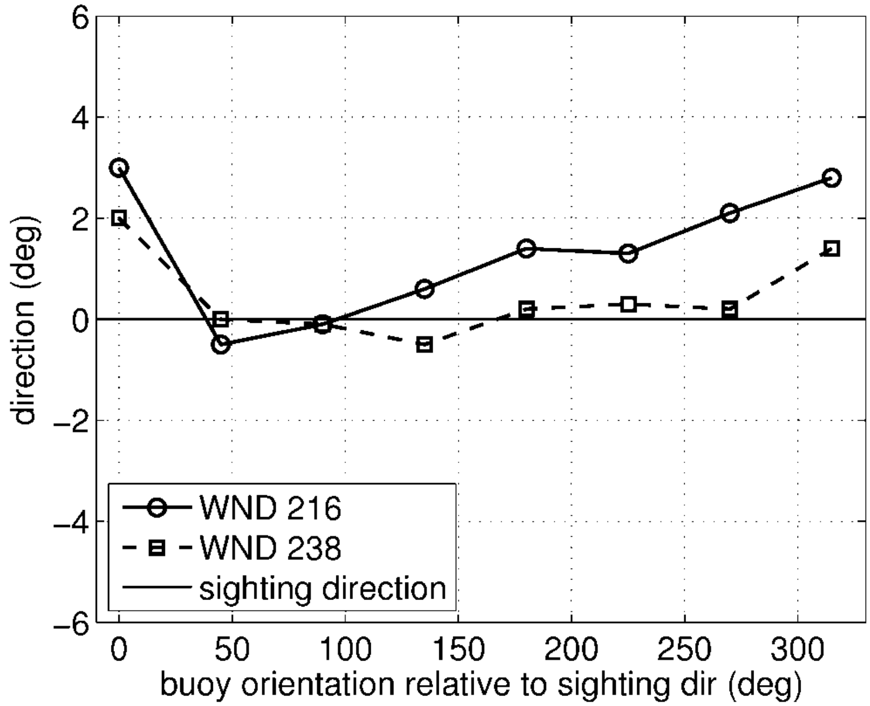

Figure 4. Ford Island, Hawaii buoy spin results.

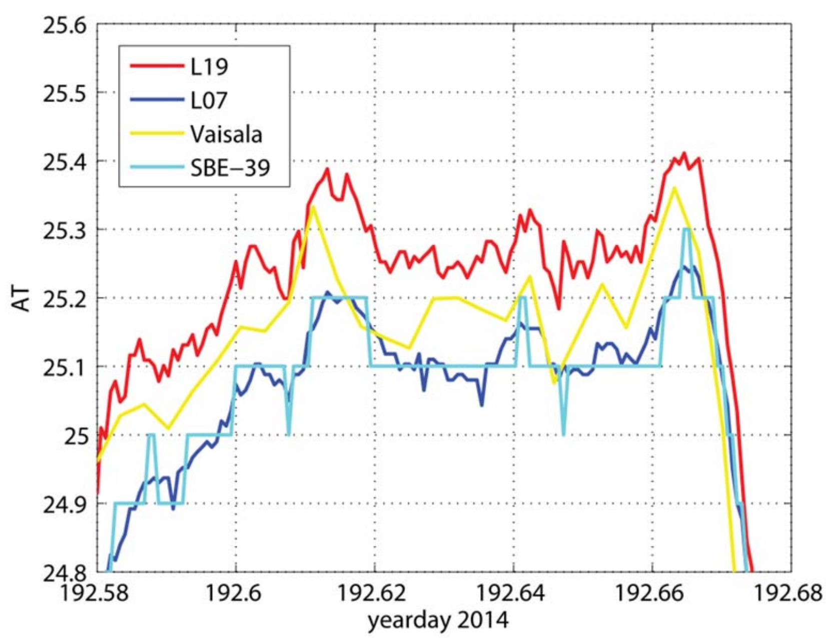

Figure 5. Nighttime air temperature sensor check at Ford Island on 11 July. The buoy tower was in open air on the pier prior to arrival of the Hi'ialakai.

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 prior to the cruise departure. The function checks showed proper operation. The buoy tower was loaded into the foam buoy hull on 12 July and moved from the warehouse area to the pier next to the ship. Evaluation of hourly Argos data during 12-14 July showed all modules continued to function as expected (differences between like sensors within accuracy tolerances).

3. WHOTS-11 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.

Instruments were attached along the mooring line using a combination of load cages (attached in-line between chain sections), load bars and clamps (Fig. 6). The design was consistent with that of WHOTS-10, with the transition from chain to jacketed wire at 47.5 m.

The wire to synthetic transition was a urethane-encapsulated termination with 100 m of 3/8” wire and 200 m of 7/8” nylon. The termination was stored in a box large enough for the urethane section to lay flat. Split plastic tubing was used to cover the urethane coated 8-strand nylon line immediately below the wire to nylon junction during storage and while on the winch drum. The tubing was removed as the termination was spooled off the winch during deployment.

Dual acoustic releases, attached to a central load-bar, were placed approximately 30 m above the anchor. Above the release were 68 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-11 incorporated *Nixalite Premium Bird Barrier Strips* as a physical deterrence for pest birds and their accompanying guano deposition. Individual 4 foot strips were secured to the tower crash bar with cable ties and hose clamps. The wire has magnetic characteristics and should not be mounted near modules with compasses. Short strips were also placed around the solar radiometers and other potential roosting sites.

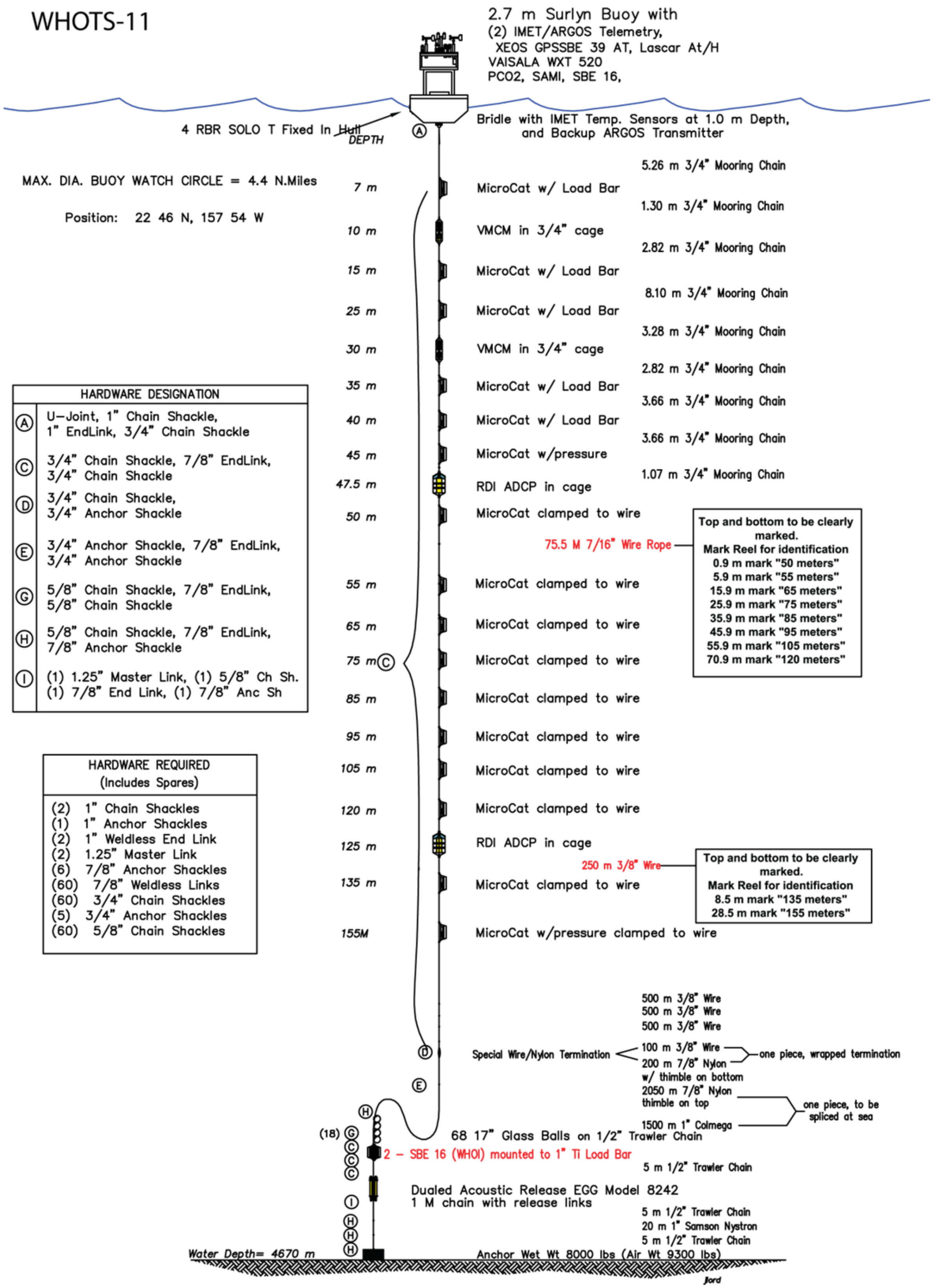

Figure 6. WHOTS-11 mooring diagram. Note that the "SAMI" pCO2 was replaced with a "SEAFET".

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-11 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 1 small float attached to 50 feet of 3/8” Amsteel Blue buoyant synthetic line 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.

Figure 7. Remote line deployment system on the WHOTS-11 buoy.

b. Buoy Instrumentation

Two independent sets of ASIMET sensor modules were 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 about 18 months were mounted in the buoy well. The two independent systems provide redundancy in the event of component failures. 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-11, 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-11 tower top, showing the location of ASIMET modules and a variety of auxiliary sensors.

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 Table 2.

Table 1. WHOTS-11 ASIMET system serial numbers and sampling

System	Module	Type	Serial No.	Firmware Version [1]	Sample Rate [2]
ASIMET-1	BPR	ASIMET-Heise	212	VOS53 4.03cf	1 min
	HRH	ASIMET-Rotronic	219	VOS53 4.29cf	1 min
	LWR	ASIMET-Eppley	224	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-19	LGR53 4.11cf	1 min
	PTT	WildCAT	99595	ID#1 14663	90 sec
				ID#2 14677	90 sec
				ID#3 14697	90 sec
ASIMET-2	BPR	ASIMET-Heise	503	VOS53 4.03cf	1 min
	HRH	ASIMET-Rotronic	256	VOS53 4.29cf	1 min
	LWR	ASIMET-Eppley	206	VOS53 4.02cf	1 min
	PRC	ASIMET-Young	216	VOS53 4.03cf	1 min
	STC	Seabird SBE-37	1727	SBE 3.1	5 min
	SWR	ASIMET-Eppley	223	VOS53 4.01cf	1 min
	WND	ASIMET-Young	238	VOS53 4.02cf	1 min
	Logger	C530	L-07	LGR53 4.11cf	1 min
	PTT	WildCAT	99596	ID#1 27356	90 sec
				ID#2 27364	90 sec
				ID#3 27413	90 sec
Stand-Alone	AT	SBE-39	5276	3.1b	5 min
Stand-Alone	VWX	Vaisala WXT-520	6	VOS 4.04cf	1 min
Stand-Alone	AT/RH	Lascar	20074	v1.1	1 hr
Stand-Alone	GPS	Xeos	1980	300034013701980	4 hr
Buoy hull	PTT	SiS	3	ID#1 009209	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-11 ASIMET heights			
Module	Relative [1] Height (cm)	Absolute [2] Height (cm)	Measurement Location
SWR	283	353	base of dome
LWR	283	353	base of dome
WND	270	340	prop axis
HRH	222	292	top of case
BPR	235	305	center of port
PRC	247	317	top of cup
STC	-151	-81	center of port
Vaisala	250	320	top of shield
Lascar	225	295	base of shield
SBE-39	217	287	base of shield

[1] Relative to buoy deck, positive upwards

[2] Relative to buoy water line, positive upwards,
WHOTS-10 WL= -65 cm from deck

The water line was determined to be approximately 70 cm below the buoy deck by visual inspection after launch.

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 the CF 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. The Argos transmissions also include location data that can be used to monitor buoy position.

A wind vane on the tower top keeps the “bow” of the buoy oriented towards the wind. For WHOTS-11, a bolt-on vane extension was added to the standard vane. Trials with the NTAS buoy indicated that the increased area improved the effectiveness of the vane and reduced the relatively large angle (~30°) of the buoy face relative to the wind that is characteristic of the UOP 2.7 m modular buoys with a standard vane.

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.

Three additional sensors serve as back-ups to the ASIMET modules: a SBE-39 temperature sensor, a Lascar temperature/humidity sensor and a Vaisala WXT 520 mult-parameter instrument. The SBE-39 was configured with a radiation shield to serve as a backup air temperature sensor and mounted inboard of the ASIMET HRH module on the port side (Fig. 8). The Lascar was mounted behind the SBE-39. 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, behind the starboard side BPR, (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-minute burst of 20 second samples, repeated every 30 minutes, 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 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.

A pCO_2 system was added to the WHOTS buoy by Chris Sabine of the Pacific Marine Environmental Laboratory (PMEL) in 2007, and continues to be deployed. The electronics, batteries and gas cylinder are mounted in the buoy well, with sensors in the air and in the water. 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 (480 ppm CO_2) produced and calibrated by NOAA's Earth System Research Laboratory (ESRL). Starting in 2011 PMEL added a pH sensor and a SBE16 package with dissolved oxygen, chlorophyll and turbidity instruments. For this deployment, the SBE-16 package and SEAFET pH sensor were mounted on the base of the buoy hull and wired to the controller through pass-through tubes in the foam hull. 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. Table 3 describes the system configuration as deployed for WHOTS-11.

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.

Table 3. WHOTS-11 pCO2 System		
SN	**Make/Model**	**Measurement**
144	Batelle	pCO2, air/water
95	SEAFET	pH
7409	Seabird SBE-16	temp/cond
630480	Seabird SBE-63	dissolved oxygen
3012	WET Labs ECO	chlorophyll & turbidity

In cooperation with Dr. Sam Laney (WHOI), an above-water hyperspectral radiometry system was integrated into the WHOTS-11 mooring to provide yearlong, finely resolved measurements of changes in ocean-leaving radiances in the visible and near-infrared radiation at this site. Three downlooking Trios RAMSES hyperspectral radiometers observe water-leaving radiance at semi-orthogonal directions relative to the mooring (plan view) at 45° down angles. 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 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. The five instruments are wired in to a controller/logger mounted in the aft corner of the tower. The ocean color instruments and locations are described in Table 4.

Sampling and data storage is provided by a custom micrologger designed specifically for this study. Ocean color is sampled frequently over the day and stored locally in memory for later download at the end of the deployment. The fluorometer is polled every four hours. 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 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.

Table 4. WHOTS-11 Ocean Color Instrumentation				
SN	**Instrument**	**Manufacturer**	**Model**	**Mounting Location**
8394	Radiometer	TriOS	RAMSES-ARC-VIS-Ti	stbd quarter
839B	Radiometer	TriOS	RAMSES-ARC-VIS-Ti	port beam
8393	Radiometer	TriOS	RAMSES-ARC-VIS-Ti	port quarter
8396	Radiometer	TriOS	RAMSES-ACC-VIS-Ti	radiometer tower
3256	Fluorometer	Seapoint	SCF	buoy base
49	Interface	Martin Cooper Consulting	Smart Cable	buoy base
62	Logger	Martin Cooper Consulting	Mooring Logger	buoy tower

c. Subsurface Instrumentation

Four RBR Solo-T temperature sensors were installed in the buoy hull to provide a SST measurement within about 10 cm of the mean water line. These small (25 mm diameter x 210 mm long) sensors are recessed directly into the buoy hull by drilling a hole in the foam and inserting the sensor. For WHOTS-11, two sensors were inserted at the "bow" of the buoy (180^0 from the vane) at depths of about 80 and 98 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 buoy hull SST configuration is summarized in Table 5.

Table 5. WHOTS-10 Buoy Hull SST Configuration

Rel depth (cm) [1]	Abs depth (cm)	Angle (deg) [2]	Instrument	SN	Sample rate
80	10	120	RBR Solo-T	76105	1 min
80	10	180	RBR Solo-T	76107	1 min
98	28	180	RBR Solo-T	76112	1 min
80	10	240	RBR Solo-T	76113	1 min

[1] depth = below buoy deck, WHOTS-11 WL = 70 cm
[2] angle = clockwise from buoy vane

Along the mooring line, WHOI provided 2 Vector Measuring Current Meters (VMCMs), configured as shown in Table 6.

Table 6. WHOTS-11 VMCM configuration

SN	Instrument	Depth (m)	Sample Interval (sec)	Start Logging Date, Time (UTC)	
62	VMCM	10	60	07/09/14	19:06:00
83	VMCM	30	60	07/09/14	19:06:00

Deep temperature/conductivity (T/C) sensors, introduced on WHOTS-9, were also deployed on WHOTS-11. A pair of SBE-16 Seacat sensors were placed just below the glass balls at 36 m above the bottom. The SBE-16s were configured as shown in Table 7.

Table 7. WHOTS-11 deep SBE-16 configuration

SN	Instrument	above bottom (m)	Sample Interval (sec)	Start Logging Date, Time (UTC)	
1880	SBE-16	36	1800	07/09/14	21:00:00
1881	SBE-16	36	1800	07/09/14	21:00:00

The university of Hawaii group provided 16 SBE-37 Microcats, and two RDI Workhorse Acoustic Doppler Current Profilers (ADCPs; 300 kHz and 600 kHz) for the WHOTS-11 mooring. This instrumentation was mounted along the upper 155 m of the mooring line. All of the Microcats measure temperature and conductivity; six Microcats also measure pressure. Table 8 summarizes deployment information for the UH instrumentation.

The ADCPs were deployed with transducers facing upward. The ACDPs were programmed as described in Table 9. Each instrument was rubbed gently by hand for 20 seconds to produce a spike in the data as a reference point to check the instrument's clock.

Table 8. WHOTS-11 UH Instrumentation

SN	Instrument	Depth	Pressure SN	Sample Interval (sec)	Start Logging Date, Time (UTC)	
6892	Microcat	7	2651324	75	07/14/14	0:00:00
3382	Microcat	15	N/A	180	07/14/14	0:00:00
4663	Microcat	25	N/A	180	07/14/14	0:00:00
3638	Microcat	35	N/A	180	07/14/14	0:00:00
3381	Microcat	40	N/A	180	07/14/14	0:00:00
3668	Microcat	45	2651319	240	07/14/14	0:00:00
13917	600 kHz ADCP	47.5	N/A	600 [1]	07/14/14	0:00:00
3619	Microcat	50	N/A	180	07/14/14	0:00:00
3620	Microcat	55	N/A	180	07/14/14	0:00:00
3621	Microcat	65	N/A	180	07/14/14	0:00:00
3632	Microcat	75	N/A	180	07/14/14	0:00:00
4699	Microcat	85	3418742	240	07/14/14	2:00:00
3791	Microcat	95	N/A	180	07/14/14	0:00:00
2769	Microcat	105	2651321	240	07/14/14	0:00:00
4700	Microcat	120	2651322	240	07/14/14	0:00:00
7637	300 kHz ADCP	125	N/A	600 [1]	07/14/14	0:00:00
3669	Microcat	135	N/A	240	07/14/14	0:00:00
4701	Microcat	155	2651323	240	07/14/14	0:00:00

[1] see Table 9 for details of sampling programs for these instruments

Table 9. WHOTS-11 ADCP configuration details		
	ADCP S/N 7637	**ADCP S/N 13917**
Frequency (kHz)	300	600
Number Depth Cells	30	25
Pings per Ensemble	40	80
Depth Cell Size	4 m	2 m
Time per Ensemble	10 min	10 min
Time per Ping	4 sec	2 sec
Time of First Ping	07/14/14, 00:00:00	07/14/14, 00:00:00
Transducer 1 Spike Time	07/15/14, 22:20:10	07/15/14, 22:29:40
Transducer 2 Spike Time	07/15/14, 22:20:30	07/15/14, 22:30:00
Transducer 3 Spike Time	07/15/14, 22:20:50	07/15/14, 22:30:20
Transducer 4 Spike Time	07/15/14, 22:21:10	07/15/14, 22:30:40
Time in water	07/16/14, 19:45	07/16/14, 19:30
Depth	125 m	47.5 m

4. WHOTS-11 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-11 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 20 kt from E-NE (75^{o}), and currents were about 0.4 m/s to the W-NW. It appeared that the best approach would be from slightly south of west. The ship maneuvered to a starting point approximately 6.0 nm from the drop point with an inbound course of 75^{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 16 July with the *Hi'ialakai* at a distance of 6.0 nm from the drop site (Fig. 9).

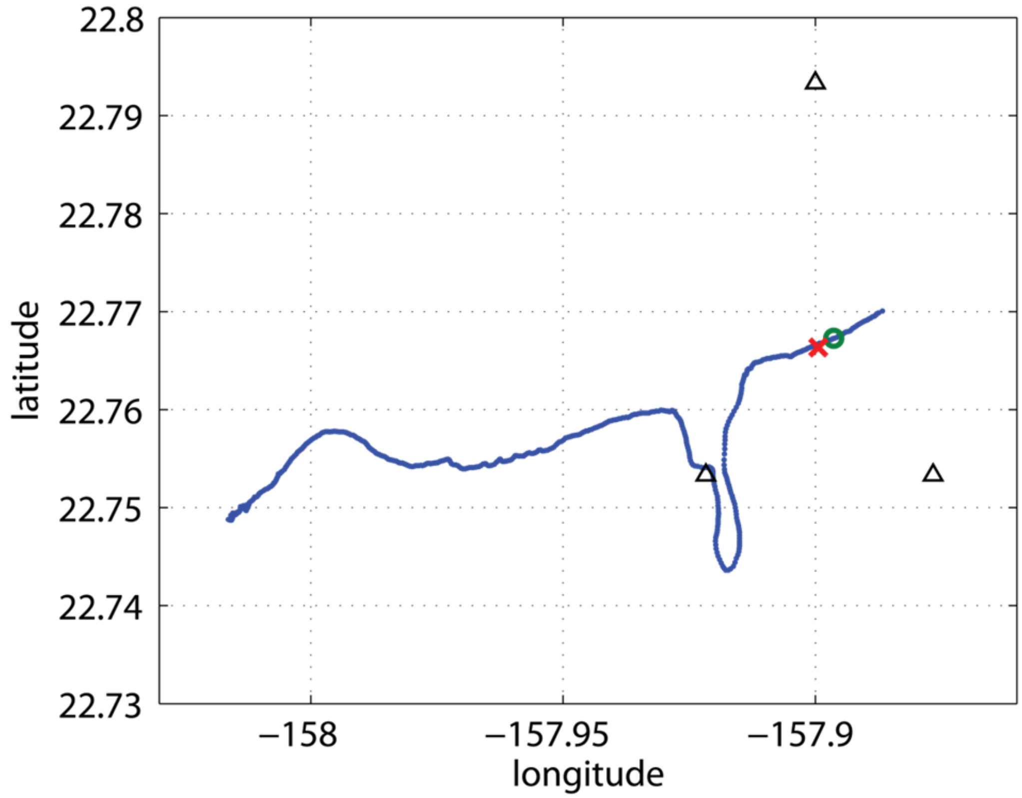

Figure 9. Ship track during WHTOS-11 deployment. The ship's position at 1-minute intervals is shown as blue dots. The anchor drop location is marked with a "o" and the surveyed anchor location is marked with "x". The three survey stations are marked with triangles.

Two deviations from the desired approach track are evident from Fig. 9. The deviation to the north near 158.0° W was a result of drift during initial deployment operations (upper 45 m instruments and buoy) when the ship attempts to maintain heading with minimal forward motion. The excursion to the south at about 158.92° W was the result of slowing down (to about 0.75 kt) during glass ball deployment. The mooring was stopped off partway through the glass ball deployment and under tow until the desired course was re-established. After completing the mooring deployment and rigging the anchor, the mooring was again under tow. The final approach to the anchor drop point took about 20 minutes at a speed of about 1.25 kt.

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 chain sections immediately above them had been assembled and laid out on deck prior to the start of operations (Fig. 10). The 45 m Microcat was selected as the first instrument to be deployed. Instruments up to the 7 m Microcat were deployed from deepest to shallowest, using the crane to lift them into the water over the starboard rail.

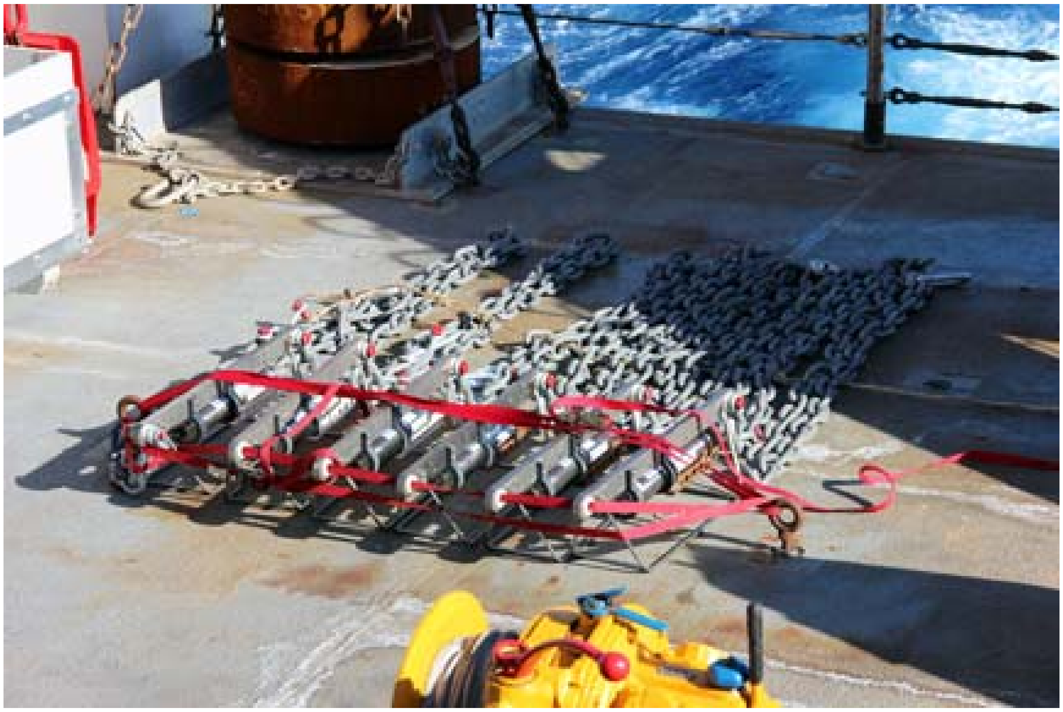

Figure 10. Subsurface instrumentation assembled and laid out in sequence on deck prior to deployment. The deepest instrument is at the far left.

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 connected to the buoy universal and then slipped out using a slip line attached to the cleat on the rail.

The next stage of the operation was the launching of the surface buoy. Slip lines were rigged on the buoy tower D-ring, the port-side deck D-ring and the 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 buoy was lifted off the deck 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 as the tag lines were slipped out (Fig. 11). 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 11. WHOTS-11 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 bolted on vane extension can also be seen in this photo.

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 using the cleated stopper lines and the 47.5 m ADCP was shackled into the chain. The ½" spectra leader was off-spooled from the winch, exposing the 75.5 m section of wire rope. The 75.5 m section of wire rope was attached to the lower end of the ADCP cage. Tension was taken up by the winch and the ADCP was eased over the transom. The Microcats from 50 m to 120 m were clamped to the 7/16" wire as it was spooled off the winch drum. As the wire was payed out, the ship's speed was increased to about 1.25 kt. The mooring was stopped off at the end of the 75.5 m wire section using the cleated stopper lines. The 125 m ADCP was shackled into the 75.5 m wire section above and the 250 m wire section below. The final two Microcats were clamped to the 250 m 3/8" wire as it was spooled off the winch.

When all the instruments were deployed, the remaining 1600 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 out the 2050 m of nylon and 1500 m of Colmega line stowed in three wire baskets. The entire 3550 m of synthetic line had been previously spliced into a continuous piece. While the synthetic line was being payed out, the 68 glass balls were staged on the main deck for deployment.

With approximately 20 m 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 off 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 and stopper lines. The distance from winch drum to transom was just enough to allow two four-ball strings to be deployed at once.

Part way through the glass ball deployment, approximately 1.4 nm away from the drop point, the ship fell off course and was losing ground relative to the drop site (see Fig. 9). Deployment operations were paused with a set of glass balls at the transom and a stopper line shackled to the 7/8 end link below the glass balls. The ship then maneuvered for approximately 25 min to re-acquire the desired course towards the drop point. Glass ball deployment commenced when the ship was back on course.

With the last glass ball at the transom, two stopper lines were shackled to the chain and to the 7/8 end link below the glass balls. Two SBE 16s on a 1” load bar were shackled into the mooring. 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. The 20 meter of Nystron line was wound on the winch and the 5 m chain section at the bottom of the releases was shackled to the Nystron. A ½” chain hook was shackled into the spectra 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 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 load was then transferred from the winch to a stopper line.

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. An expendable back stay was rigged from the eye of the anchor to a deck eye to secure it. With approximately 1/2 h still to go until the anchor drop, a screw pin shackle and pear link were connected to the middle of the 5 m 1⁄2” chain from the anchor. A 3⁄4” nylon line was attached to the winch leader using a bowline and fed through the pearl link on the 5m chain and brought back to the winch leader and tied off with a bowline.

With about 10 minutes to the drop site, the chain binders holding the anchor in place were removed and the 3⁄4” slip line took the load from the stopper line. 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 winch payed out slowly and put the load to the anchor and the nylon backstay. The backstay was removed in the last minute, the crane hook was raised, and the tip plate raised enough to let the anchor slip into the water. The anchor was dropped at 0240 UTC on 17 July at 22° 46.035′ N, 157° 53.784′ W in (corrected) water of depth 4707 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. 9). WHOI's Edgetech 8011M deck gear was used to range on the release. The anchor survey began at about 1830 local on 16 July and took about 1.5 hours to complete. Triangulation using the horizontal range to the anchor from the three sites gave an anchor position of 22° 45.981′ N, 157° 53.964′ W (Fig. 12). Fallback from the drop site was about 324 m, or ~7 % 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.

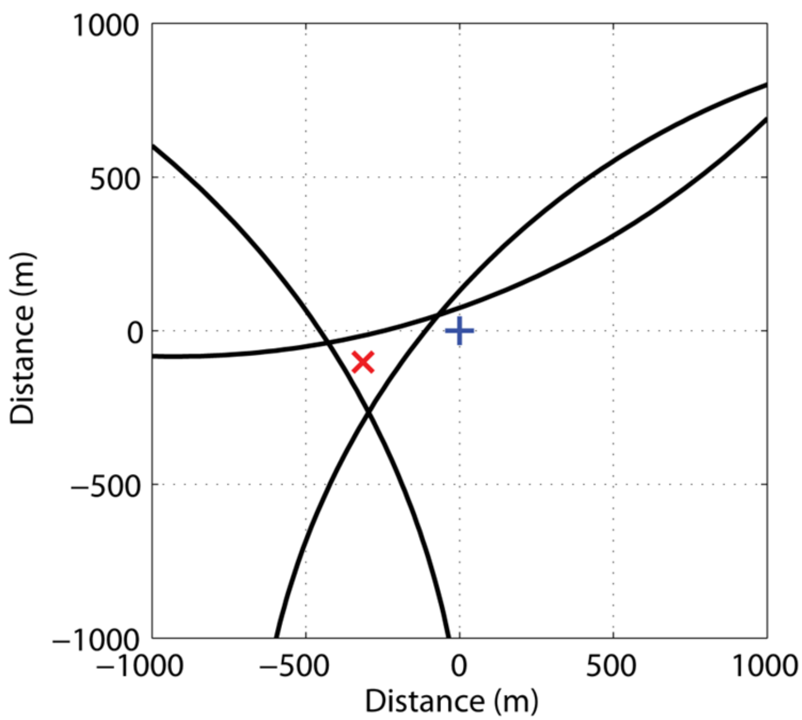

Figure 12. WHOTS-11 post-deployment anchor position survey. Arcs from the three survey sites are shown along with the anchor drop location (+) and surveyed anchor position (x).

5. WHOTS-10 Mooring Recovery

Recovery operations for the WHOTS-10 mooring began at 0530 (local) on 20 July 2014. The *Hi'ialakai* was positioned at about 0.25 nm from the anchor site with the anchor downwind and to starboard. The forecast for recovery day called for moderate seas (5-7 ft) swell from the SE, and winds of 10-15 kt. The sea state in the morning was consistent with the forecast, but winds were 25-30 kt, much stronger than predicted.

WHOI deck gear and an over-the-side transducer were used to communicate with the release. The strong winds meant that the ship was steaming at ~1 kt to maintain heading, resulting in a steep wire angle with the transducer trailing astern. Before the release sequence was complete, the transducer was lost from the end of the cable, presumably sheared off by the propeller. The spare transducer was used thereafter. The release was fired at 0623 local on 20 July. The ship held position for another few minutes while repeated ranging was done to confirm release. After about 50 minutes, the glass balls were spotted on the surface.

Strong wind and swell precluded deployment of the work boat for making the attachment to the glass balls. Thus, the ship maneuvered to the ball cluster so that a connection could be made using a pick-up pole and snap hook from the starboard rail. A grappling hook made connection to the cluster on the first pass, but the ship's forward speed was too high to allow the cluster to be pulled alongside. Eventually, the grapple released from the cluster. On the second pass, a solid connection was made with the snap hook. The line had been passed through the A-frame block and connected to the TSE winch, and was hauled in as the ball cluster passed the starboard quarter. Unfortunately, the complete cluster did not pass the stern. Tension remained on a string of glass balls that passed beneath the transom on the starboard side. This string remained under tension while about 60 glass balls were hauled aboard and disconnected into four-ball strings. The deep Seacats and the releases were also recovered.

The assumption that some glass balls were caught on the prop or rudder meant that the main propulsion could not be used (the bow thruster was used to maintain heading into the wind). As a result, the ship drifted significantly downwind during the glass ball recovery. The ship's drift was faster than that of the buoy, and the ship eventually ended up dragging the buoy downwind with the Colmega line trailing forward.

A GoPro camera held underwater on a pick up pole allowed the situation to be diagnosed. It was determined that the Colmega line passed to starboard of the prop post. The lowermost set of glass balls was wedged between the top of the rudder and the ship's hull. No other tangling was evident. It was determined that there was a good chance of freeing the balls by turning the rudder hard to port and allowing the ship to fall off with the wind on the starboard side. This maneuver was completed and was successful, with the remaining glass balls and Colmega line appearing at the starboard quarter as the ship turned to port.

At this point, the mooring line was free and the ship was heading downwind. Conditions on the fantail were not conducive to instrument recovery, and tension on the line was very high. A stopper line was secured to the uppermost string of glass balls, which remained connected to the Colmega line. The chain section was over the transom while the ship turned slowly to starboard to get the bow into the weather and relieve tension on the line. While under tow, the previously broken down glass ball strings were craned up to the wire baskets on the 01deck for storage. After about 90 min of towing the ship was in position to begin hauling the synthetic line through the capstan.

The remainder of the recovery operation preceded a more conventional manner. A nylon leader was passed through the UOP block hanging from the A-frame. An air tugger was used to raise the block off the deck just enough for the line to clear the transom. The TSE winch was used to haul in on the last string of glass balls until the nylon leader could be attached to the eye on the bottom of the Colmega. The nylon was fed through the capstan until it took up the tension of the mooring. The glass ball string was then disconnected. The Colmega and nylon were hauled through the capstan and tended by hand directly into wood-lined wire baskets. Canvas bags were placed inside the baskets for easy removal of the line.

After the 1500 m of Colmega and 2100 m of nylon were hauled through the capstan, the final section of nylon was transferred over to the winch. The remaining 200 meters of nylon, the wire/nylon termination, 1850 meters of 3/8” wire rope, and 75.5 m of 7/16” wire rope were collected on the winch. The hauling operation was stopped periodically to remove instruments clamped on the wire or in-line between wire sections. As each instrument was removed from the mooring, it was inspected and photographed.

With 45 meters remaining in the mooring line (i.e. just below the 45 m Microcat), the buoy was cast adrift for recovery over the starboard side. Just after slipping out the mooring line, with the buoy clearly visible about 50 feet off the transom, the remote line deployment system was activated. The actuating device did not function and the cylinder door did not open. Thus, the leader and hauling line were not available for grappling, and the buoy had to be approached along the starboard rail.

The deck was arranged for recovery of the buoy, including moving one air tugger from port to starboard, rigging the lifting line for the crane, and preparing multiple tag lines to be attached using snap hooks and pick-up poles. The first approach was unsuccessful because the buoy was too far from the ship to be hooked. The buoy was successfully hooked on the second pass, held outboard with the crane until stable, then lifted over the starboard bulwarks and maneuvered into position to be set on the deck. During recovery, the port-side HRH module hit on the ships rail. The HRH radiation shield was bent and the sensor was damaged. In addition, a tag line was caught beneath the vane-mounted radiometer, which was broken off of its mounting bracket. The radiometer fell to the deck and was retrieved.

Once the buoy was secured on the deck, the remaining instruments were recovered from the chain section of the mooring using short picks with the crane. Stopper lines were used to transfer the load as instruments were disconnected from the chain. As each instrument was removed from the mooring, it was inspected and photographed.

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-11 mooring and prior to recovery of the WHOTS-10 mooring. Due to the approach of tropical storm “Wali” and the threat of bad weather on the WHOTS-10 recovery day, it was decided to recover the WHOTS-10 mooring one day early. To accommodate this change, the intercomparison sequence was modified. The modified plan broke the intercomparison into three phases: 24 h at WHOTS-11 immediately after deployment, 48 h at WHOTS-10 prior to recovery, and another 24 h at

WHOTS-11 after the WHOTS-10 recovery. The actual time spent on the three phases was 27 h, 52, h, and 31 h.

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 0.15 nm from the buoy. Due to substantial drift (up to 3 nm) during CTD operations, and subsequent maneuvering, Argos data acquisition suffered some drop outs. In addition, the ~6 nm separation of the buoys meant that only one buoy could be monitored at a time. The resulting gaps in the directly received Argos data were supplemented by telemetered data served from the WHOI UOP web site.

Two other sets of meteorological sensors were available for comparison with the buoys: The ship's meteorological measurements obtained via the Scientific Computer System (SCS) as described in Sec. 6.b, and the ESRL system installed on a bow mast as described in Sec. 6.c.

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). An effort was made to document the data sources and instrument locations for the variables being collected. AT and RH were measured by a RM Young model 41372 sensor mounted along the ship centerline on a short mast above the pilot house. The AT/RH sensor height was estimated to be about 15 m. BP was measured by a Vaisala model PTB330 mounted in the aft section of the bridge on the 03 deck. The BP sensor was estimated to be 12 m above the waterline. Wind speed and direction were measured by a RM Young sonic anemometer mounted above the pilot house at about 15 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 potential sources for SST, a SBE-38 digital thermometer and a SBE-21 thermosalinograph. Both measured water from the bow intake estimated to be at 4 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 averaged to 1 minute and recorded to ASCII text files on the ship's SCS computer. Security firewalls between the ship's servers and the network available to the science party made it difficult to obtain the SCS Event files onboard. Since the *Hi'ialakai* routinely transmits underway data to the Shipboard Automated Meteorological and Oceanographic System (SAMOS), a work-around was to download the 1 min average SCS data files from the SAMOS web site (http://samos.coaps.fsu.edu). Note that the only SST variable reported to SAMOS was the SBE-38, not the SBE-21 TSG, despite the "TSGWT" variable name. Due to an issue with TSG processing, the SAMOS data up to 19 July did not contain SST data, and salinity data were not available at all via SAMOS. SST and salinity data should be available from post-cruise processing of the ship's raw data files.

c. ESRL/PSD flux system

The ESRL Physical Science Division (PSD) air-sea flux group collected surface meteorology and sea surface temperature data during the cruise. The flux measurement system consists of six components:

1. A turbulent wind measurement system with motion correction.
2. Solar and infrared radiation sensors measuring downward radiative fluxes.
3. Bulk meteorology sensors (air temperature, relative humidity and precipitation)
4. A CO2/H2O gas analyzer (installed but did not function during the cruise)
5. A differential GPS unit measuring heading, pitch and roll information.
6. A sea surface temperature measurement made with a floating thermistor.

The turbulent wind system, AT/RH sensor and gas analyzer were mounted on a portable 10 m tall meteorological tower at the bow of the HA. The radiometers were mounted above the pilot house. The pressure sensor was mounted on the starboard side midship at a height of ~8 m. An outrigger was used to deploy the floating thermistor ("sea snake"), a water temperature sensor that drags near the surface, off the port bow. These sensors were logged in the ship's lab using equipment supplied by ESRL. The sensor configuration details are summarized in Table 10. The systems were run continuously through the cruise. The ship's SCS system with a set of navigation and meteorological data was archived along with the ESRL data. Note that the best situation for obtaining flux data is with the ship going slow ahead and the wind within 45 degrees of the bow.

Table 10. WHOTS-11 ESRL Sensor Description

Description	Make	Model	Data Rate	Location	Ht above WL (m)
Wind	Gill	WindMaster Pro	10 Hz	Bow Tower	17.6
Motion	Systron-Donner	MotionPak	10 Hz	Bow Tower	N/A
Rain	OSI	ORG 815	1 min	Bow Tower	15.8
CO2 / H2O	LI-COR	7500	10Hz	Bow Tower	16.3
T / RH	Vaisala	HMP 230	1 min	Bow Tower	14.2
Pressure	Vaisala	PTB 220	1 min	Port Side Railing	7.9
Solar Radiation	Eppley	PSP	1 min	Top of Pilot House	N/A
IR Radiation	Eppley	PIR	1min	Top of Pilot House	N/A
Heading, Pitch	Hemisphere GPS	VS 110	10 Hz	Port Side Railing	N/A

d. WHOTS-11 Intercomparison

The WHOTS-11 comparison occurred in two phases: from 0700 UTC on 17 July to 1000 UTC on 18 July and from 0800 UTC on 21 July to 1500 UTC on 22 July. Results obtained during the first phase of the WHOTS-11 comparison (17 July) are presented. Comparisons for AT, RH, BP, SST, SWR, LWR, WSPD and WDIR are shown in Figs. 13 through 20. The ESRL/PSD and ship's data are averaged to 1 hour intervals and compared to the 1 hour averaged buoy data obtained from Argos telemetry. SST was not available in the SAMOS SCS data during this period. SSS and PRC were not available from either the ESRL/PSD or SCS.

The HA drifted away from the WHOTS-11 buoy several times for CTD casts and occasionally steamed away for sewage discharge. These excursions can cause short-term discrepancies in the sensor comparisons. To identify excursions, the distance from the ship to the WHOTS-11 anchor is shown in each figure. The buoy was about 2 nm from the anchor. Excursions to > 3 nm indicate CTD casts or sewage discharge runs. For the 17 July period evaluated here, it is notable that the ship was completing the anchor triangulation survey until about 0700 UTC and drifted about 7 nm from the anchor near 1800 UTC.

The WHOTS-11 buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy) for all variables. Examination of the buoy data in conjunction with the ESRL meteorology sensors provided further understanding of discrepancies, and resulted in other useful observations about system performance, as described below.

The WHOTS-11 buoy AT pair agreed to within about 0.15°C at night, and the difference did not increase at midday. The ERSL AT was within 0.2°C of the buoy pair, although consistently lower. Offsets of about -0.2°C for shipboard AT sensors (mounted at ~10 m height) relative to the buoys have been seen in previous comparisons, and attributed to vertical gradients. So the ESRL AT offset is plausible. The SCS AT was biased high by about 1°C, as had been observed on previous cruises on the *Hi'ialakai* (Whelan et al., 2012; Plueddemann et al., 2013; Plueddemann et al., 2014).

The WHOTS-11 buoy RH pair typically agreed to within 1%, which is the resolution of the Argos telemetry data. The ERSL RH was 2-3% lower than the buoy pair. Shipboard RH sensors (mounted at ~10 m height) reading a few percent lower than the buoys has been seen in previous comparisons, and attributed to vertical gradients. Therefore, the offset of the buoy RH from ESRL is plausible.

The WHOTS-11 buoy BP pair agreed within the 1.0 mb resolution of the Argos telemetry data. None of the pressures were adjusted to sea level. The height difference between buoy and ESRL sensors was estimated to be about 5 m. The relatively good agreement (+/- 0.5 mb) between the buoy and ESRL pressures was plausible, particularly given the limited precision of the telemetered buoy BP data. The SCS BP was consistently lower than the buoy BP, as expected with the ship's sensor higher than the buoy sensor. However, the offset of <0.5 mb was less than expected given the ~10 m height difference.

The WHOTS-11 buoy SSTs were indistinguishable within the 0.01°C resolution of the Argos telemetry data. The best comparison with ESRL SST was at night when the ship held a stable position near the buoy (0700-1400 UTC). Differences of 0.1°C to 0.2°C during the day may be due to a combination of vertical gradients (buoy thermistor at ~1 m depth vs. ESRL thermistor floating at the sea surface) and horizontal gradients as the distance between the ship and the buoy varied.

The WHOTS-11 buoy SWR pair agreed to within 10-20 W/m^2 during the day, or 1-2% of the maximum insolation of 1000 W/m^2. The buoy pair agreed well with ESRL PSP-1, but not as well with ESRL PSP-2. Comparison of values at midday was compromised by missing data.

The WHOTS-11 buoy LWR pair agreed to within 2-4 W/m^2. The buoy pair agreed well with ESRL PIR-1throughout the day. All four systems were within a few W/m^2 from 0700-1500 UTC when the ship held a stable position near the buoy. The two ESRL PIRs, mounted on the same platform, diverged from each other before 0700 and after 1800. This was attributed to calibration problems with ESRL PIR-2.

The WHOTS-11 buoy WND pair showed speed differences of about 0.3 m/s. The ESRL wind speeds were about 1 m/s higher than the buoy values, but such a difference would be expected given the ~14 m height difference between the two measurements. An adjustment of ESRL wind speed to 3 m improved the comparison significantly. The SCS winds were consistently higher than the ESRL winds despite being measured at a lower height. It was suspected that flow distortion at the leading edge of the bridge contributed to acceleration along the flow streamlines, leading to increased speed readings at the SCS sensor.

The WHOTS-11 buoy WND pair showed direction differences of a few degrees. The buoy, ESRL and SCS directions all agreed well except for a brief period when the ship was over 5 nm away from the anchor (so several nm away from the buoy).

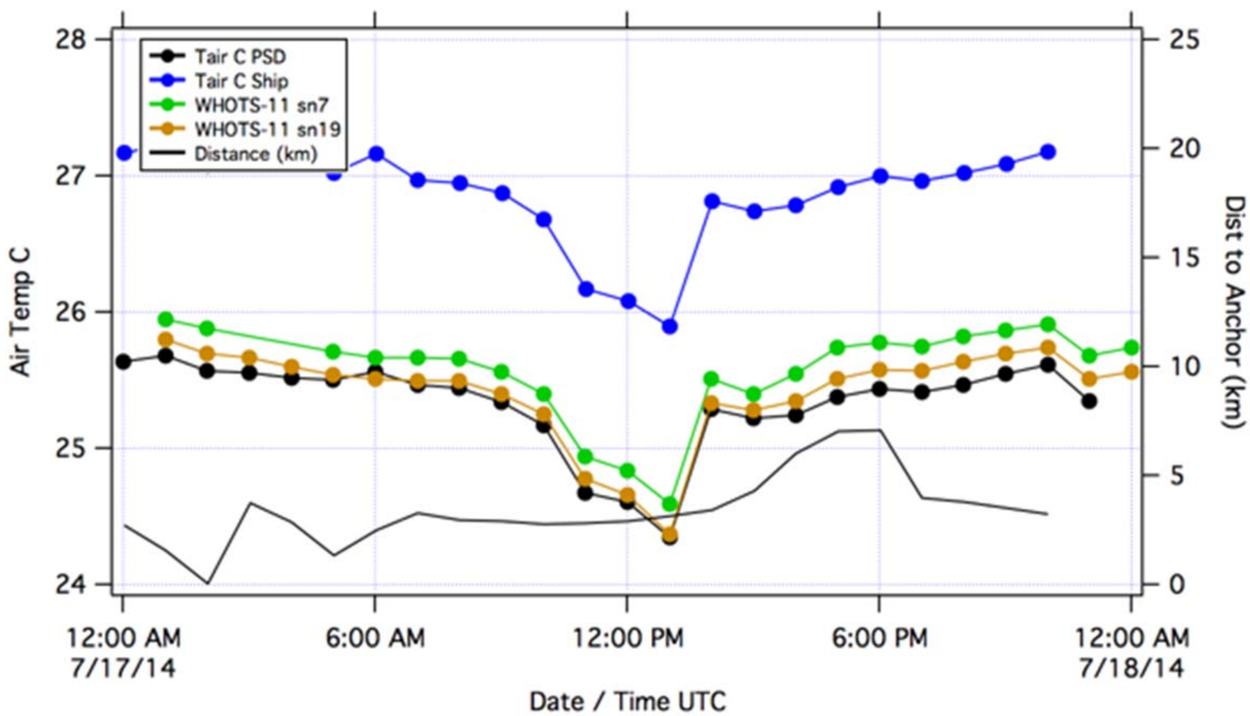

Figure 13. Air temperature for the WHOTS-11 buoy systems (SN 7 and SN 19), the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period. The thin black line in this and subsequent plots indicates the distance from the ship to the WHOTS-11 anchor.

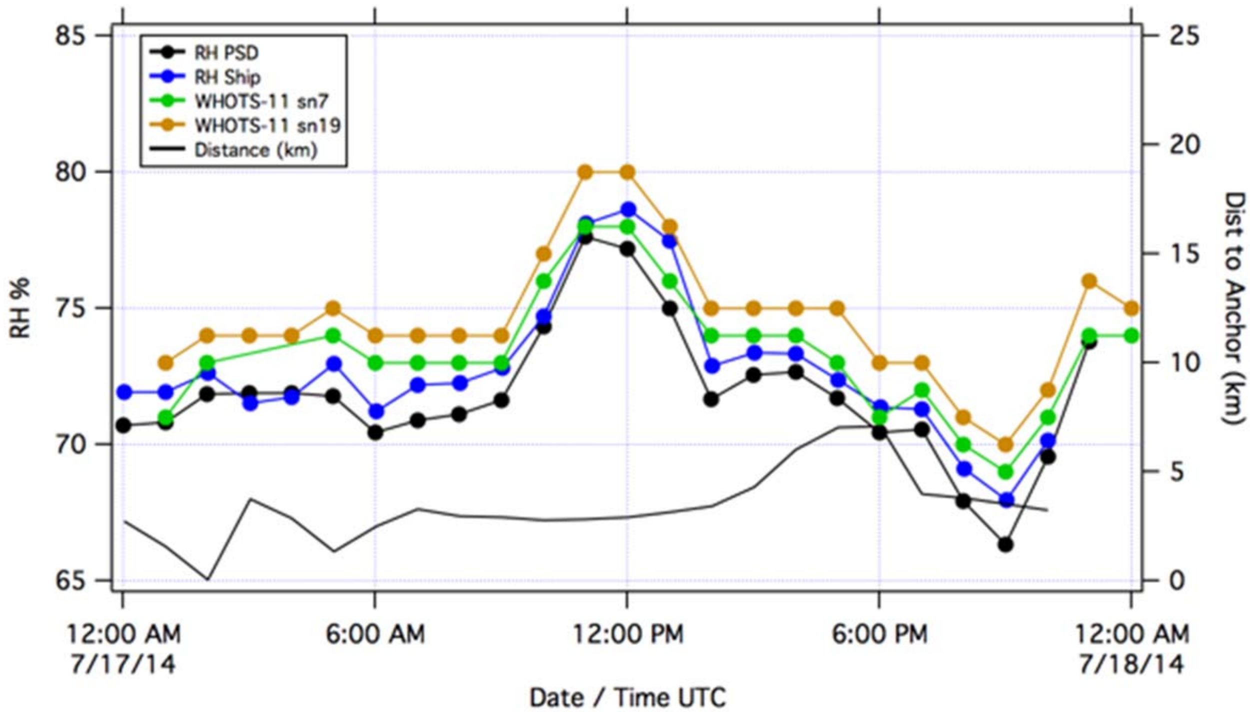

Figure 14. Relative humidity for the WHOTS-11 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

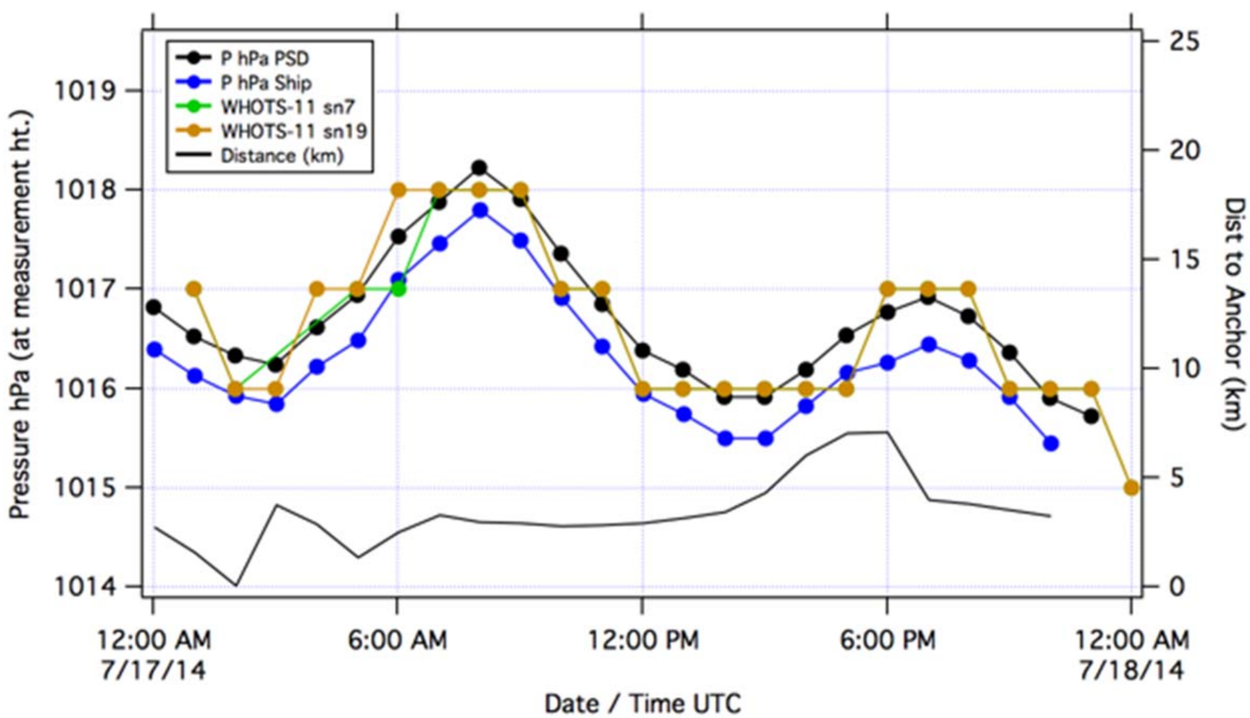

Figure 15. Barometric pressure for the WHOTS-11 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

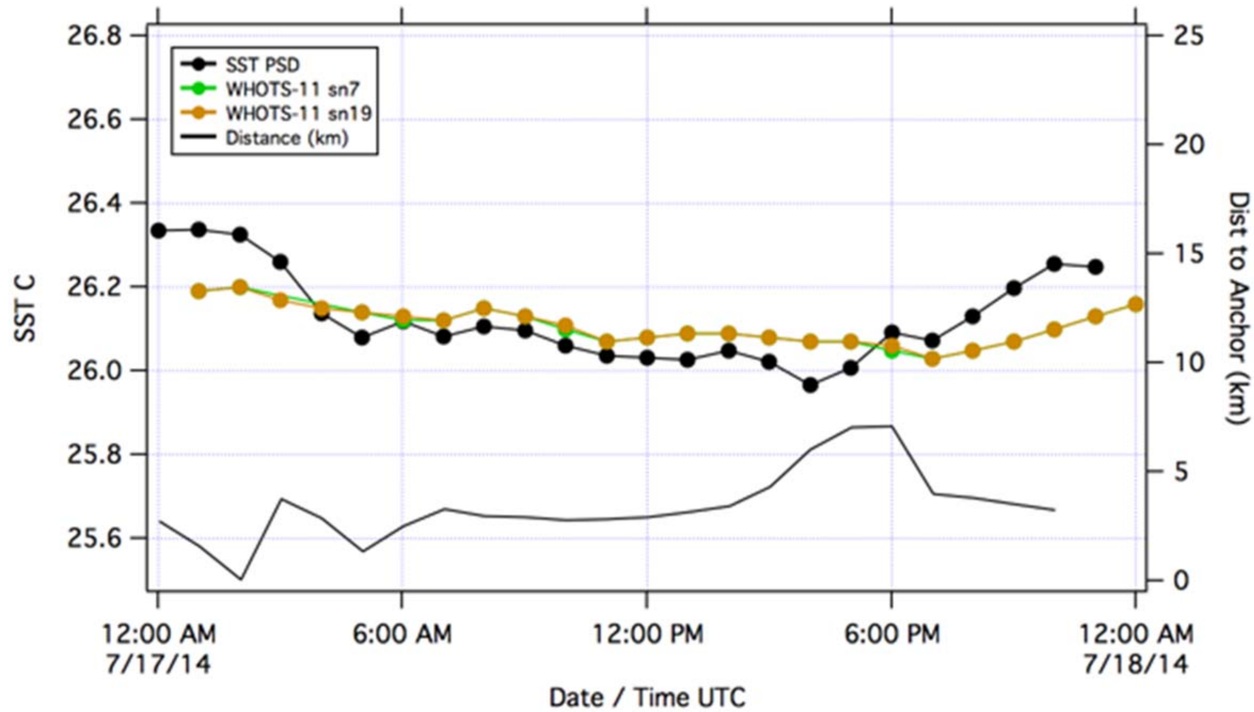

Figure 16. Sea Surface Temperature for the WHOTS-11 buoy systems (SN 7 and SN 19) and ESRL/PSD system (black) during the intercomparison period. SCS SST was not available.

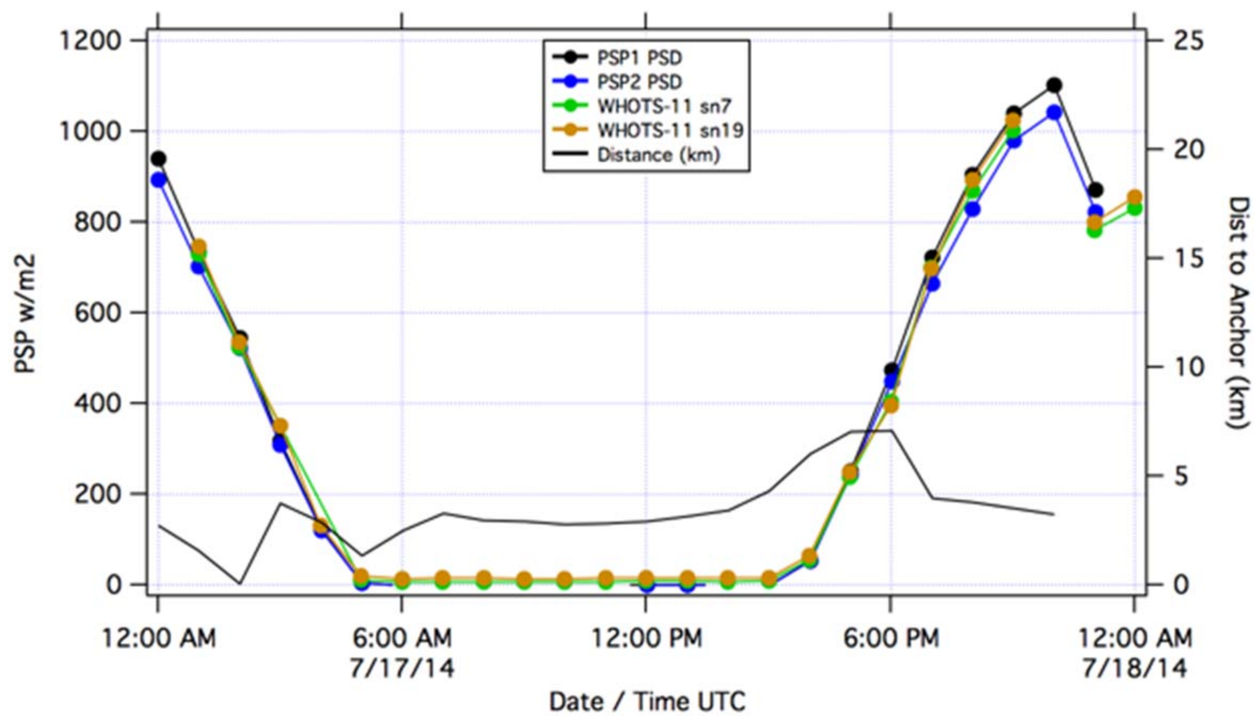

Figure 17. Shortwave radiation for the WHOTS-11 buoy systems (SN 7 and SN 19) and ESRL/PSD systems (black, blue) during the intercomparison period. SCS SWR was not available.

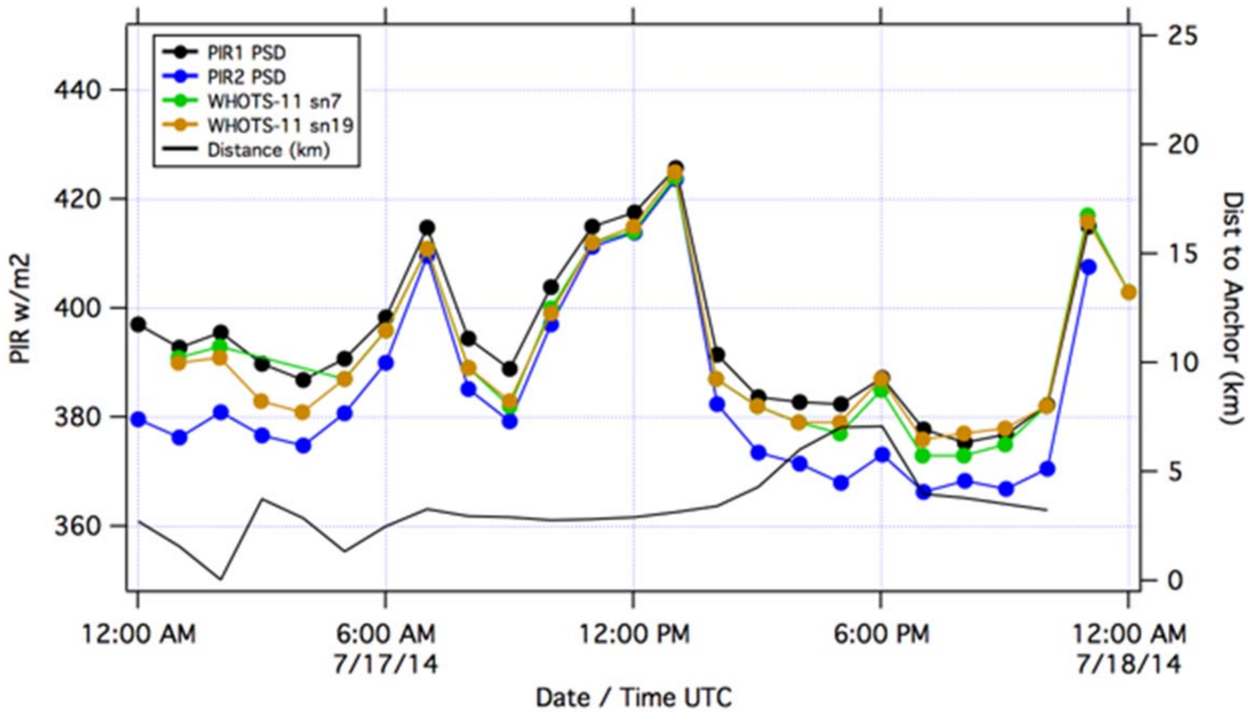

Figure 18. Longwave radiation for the WHOTS-11 buoy systems (SN 7 and SN 19) and ESRL/PSD systems (black, blue) during the intercomparison period. SCS LWR was not available.

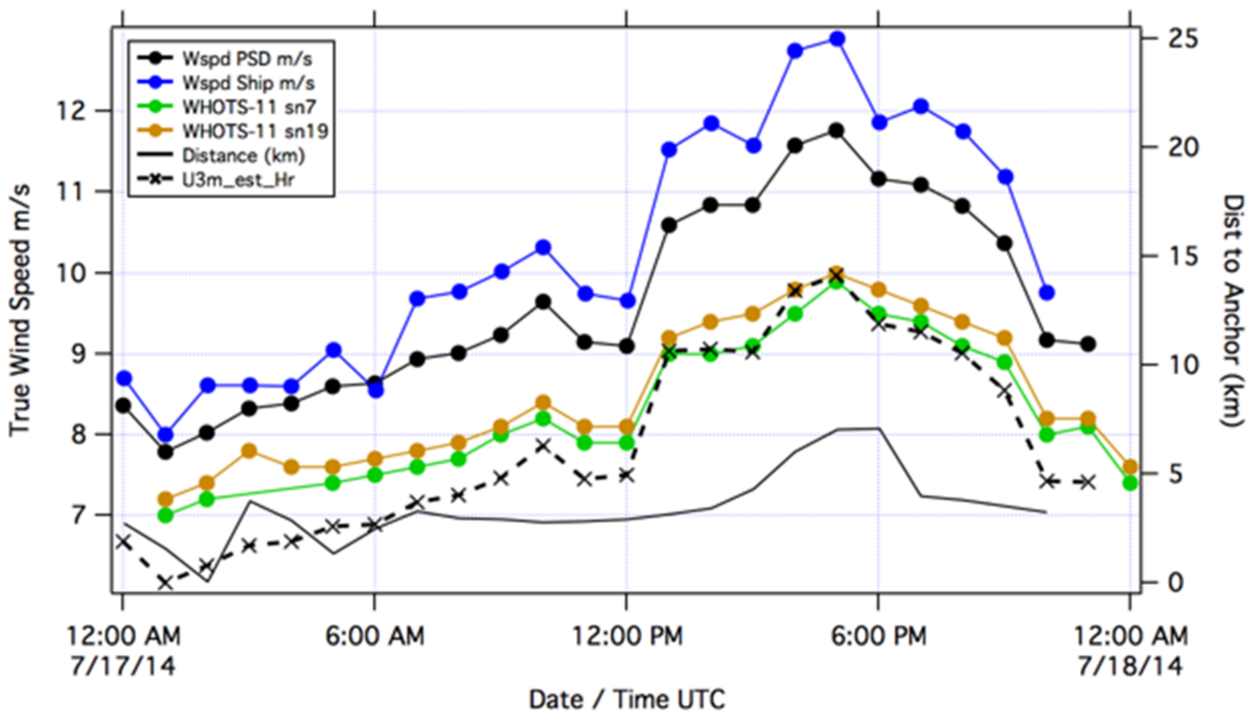

Figure 19. Wind speed for the WHOTS-11 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period. An estimate of the ESRL wind speed adjusted to 3 m height is shown as a dashed line.

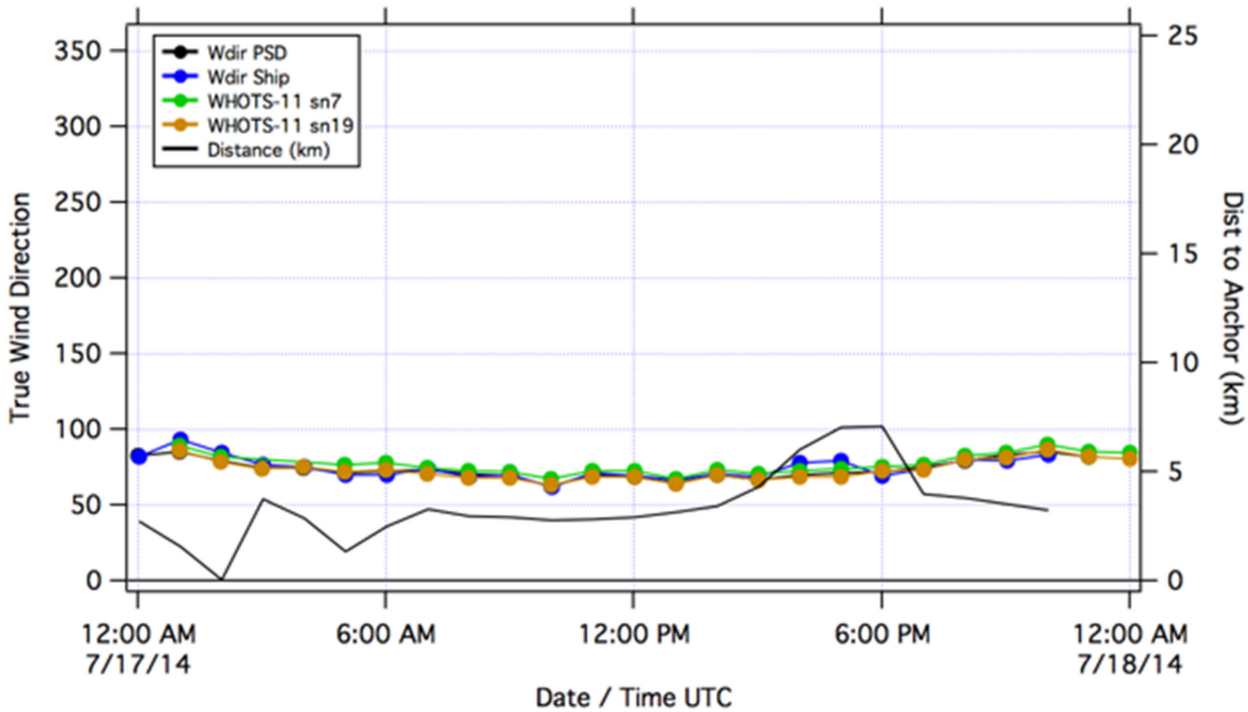

Figure 20. Wind direction for the WHOTS-11 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

e. WHOTS-10 Intercomparison

The WHOTS-10 comparison took place from 1100 UTC on 18 July to 1500 UTC on 20 July. Results obtained during the middle of the WHOTS-10 comparison period (19 July) are presented. Comparisons for AT, RH, BP, SST, SWR, LWR, WSPD and WDIR are shown in Figs. 21 through 28. The ESRL/PSD and ship's data are averaged to 1 hour intervals and compared to the 1 hour averaged buoy data obtained from Argos telemetry. SSS and PRC were not available from either the ESRL/PSD or SCS.

The HA drifted away from the WHOTS-10 buoy several times for CTD casts and occasionally steamed away for sewage discharge. These excursions can cause short-term discrepancies in the sensor comparisons. To identify excursions, the distance from the ship to the WHOTS-11 anchor is shown in each figure. The buoy was about 2 nm from the anchor. Excursions to > 3 nm indicate CTD casts or sewage discharge runs.

The WHOTS-10 buoy sensor pairs showed good agreement (differences between like sensors were within the expected short-term accuracy) for all variables except wind direction. Examination of the buoy data in conjunction with the ESRL meteorology sensors provided further understanding of discrepancies, and resulted in other useful observations about system performance, as described below.

The WHOTS-10 buoy AT pair agreed to within 0.1°C at night. The magnitude of the difference did not increase significantly during the day, but a change in sign suggested differences in self-heating. The ERSL AT was about 0.1°C lower than the buoy pair at night. Offsets of about -0.2°C for shipboard AT sensors (mounted at ~10 m height) relative to the buoys have been seen in previous comparisons, and attributed to vertical gradients. So the ESRL AT offset is plausible. Increasing differences (0.2-0.3°C) between buoy and ESRL AT during the day are consistent with self heating of the buoy sensors. It was concluded that the WHOTS-10 AT sensors were operating as expected, with evidence of self heating. The SCS AT was biased high by about 1°C, as had been observed on previous cruises on the *Hi'ialakai*.

The WHOTS-10 buoy RH pair typically agreed to within 1%, which is the resolution of the Argos telemetry data. The ERSL RH was very close (+/-2%) to the buoy pair. Shipboard RH sensors (mounted at ~10 m height) typically read a few percent lower than the buoys due to vertical gradients. Thus, these results indicate that the WHOTS-10 RH may be biased low. A more careful comparison, including the WHOTS-11 buoy RH during the period of overlap, would be warranted.

The WHOTS-10 buoy BP pair agreed within the 1.0 mb resolution of the Argos telemetry data. None of the pressures were adjusted to sea level. The height difference between buoy and ESRL sensors was estimated to be about 5 m. The relatively good agreement (+/- 0.5 mb) between the buoy and ESRL pressures was plausible, particularly given the limited precision of the telemetered buoy BP data. The SCS BP was consistently lower than the buoy BP, as expected with the ship's sensor higher than the buoy sensor. However, the offset of <0.5 mb was less than expected given the ~10 m height difference.

The WHOTS-10 buoy SSTs were indistinguishable within the 0.01°C resolution of the Argos telemetry data. The best comparison with ESRL SST was at night (0500-1500 UTC). Differences of 0.1-0.2°C during the day were assumed to result from vertical gradients given the different measurement depths (buoy thermistor at ~1 m depth and ESRL thermistor floating at the sea surface). The SCS SST appears to be biased high by about 0.2°C.

The WHOTS-10 buoy SWR pair agreed to within 10-20 W/m^2, through the diurnal cycle or 1-2% of the maximum insolation of 1000 W/m^2. The buoy pair showed reasonable agreement (+/- 30 W/m^2) with the ESRL PSP values.

The WHOTS-10 buoy LWR pair agreed to within 3-5 W/m^2. The buoy pair agreed well with ESRL PIR-1throughout the day. ESRL PIR-2, mounted on the same platform as PIR-1, was consistently low by about 10 W/m^2. This was attributed to a calibration problem with PIR-2.

The WHOTS-10 buoy WND pair showed a persistent speed difference of about 0.5 m/s. The ESRL wind speeds were about 1 m/s higher than the buoy values, but such a difference would be expected given the ~14 m height difference between the two measurements. An adjustment of ESRL wind speed to 3 m improved the comparison, but did not completely resolve the disagreement. The SCS winds were consistently higher than the ESRL winds despite being measured at a lower height. It was suspected that flow distortion at the leading edge of the bridge contributed to flow acceleration and increased speed readings at the SCS sensor.

The WHOTS-10 buoy WND pair showed a direction difference of about 10°. The buoy L15, ESRL and SCS directions all agreed well. It was concluded that the WHOTS-10 L08 wind direction was biased high by about 10°.

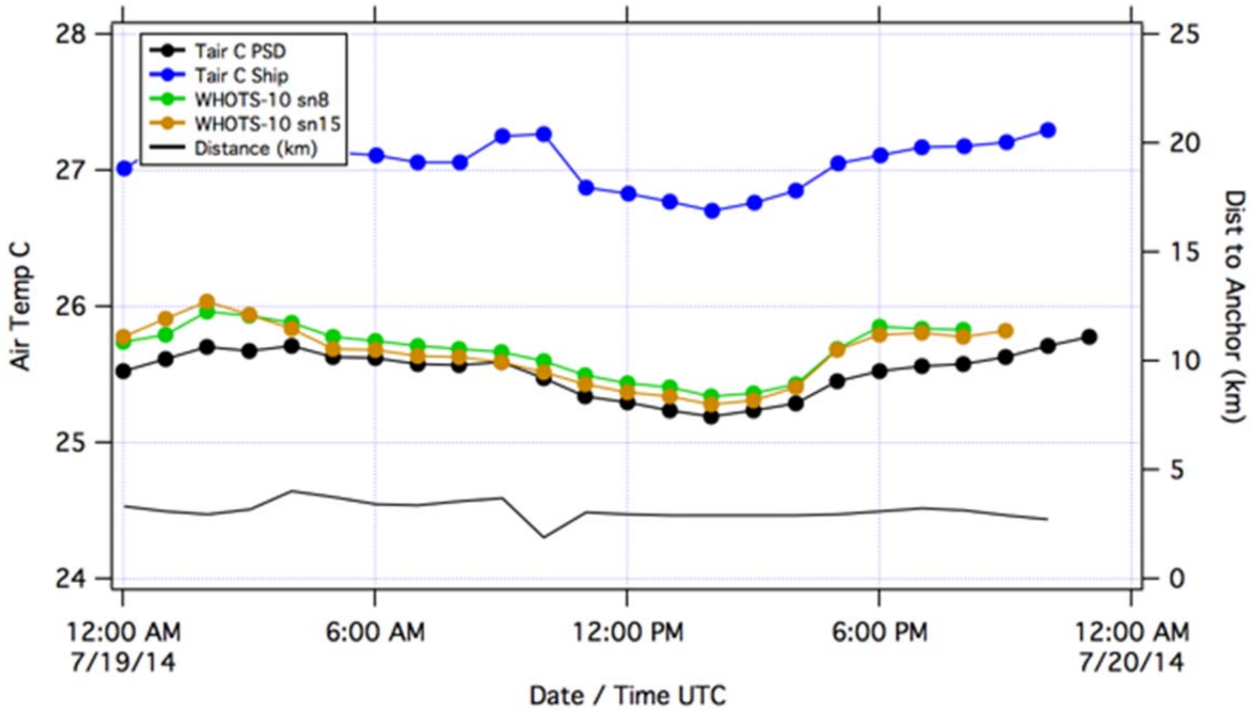

Figure 21. Air temperature for the WHOTS-10 buoy systems (SN 8 and SN 15), the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period. The thin black line in this and subsequent plots indicates the distance from the ship to the WHOTS-11 anchor.

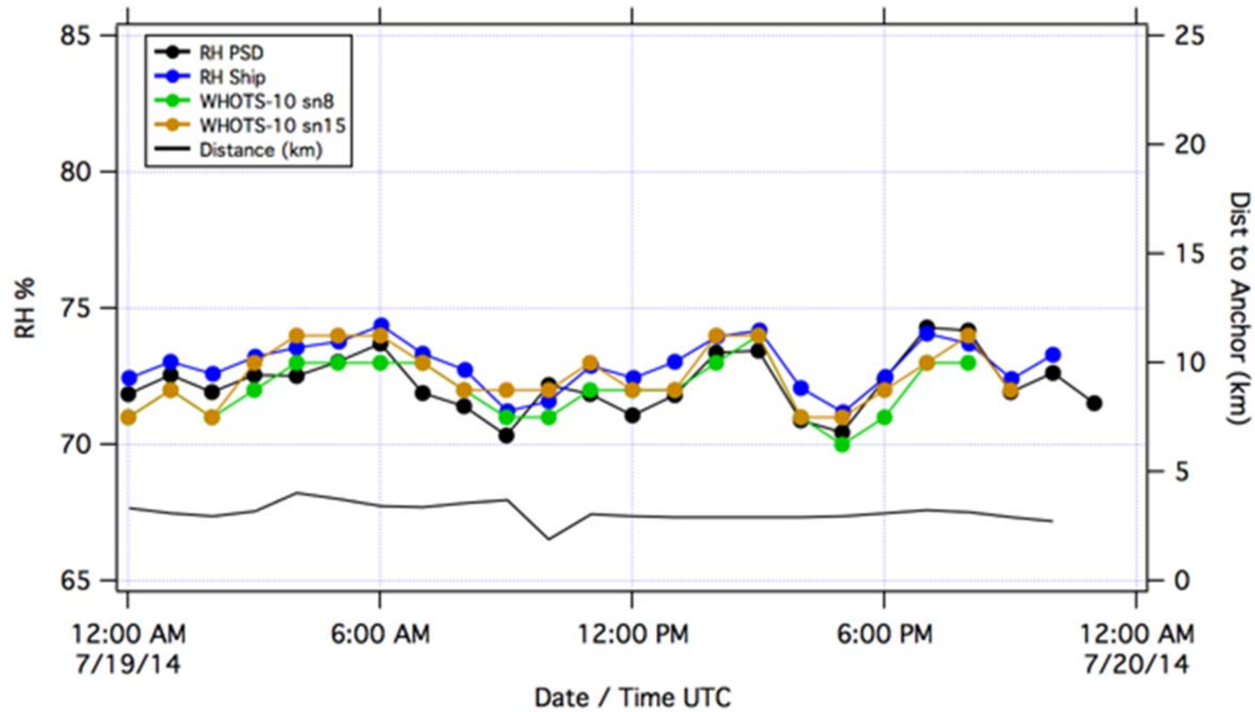

Figure 22. Relative humidity for the WHOTS-10 buoy systems (SN 8 and SN 15), the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

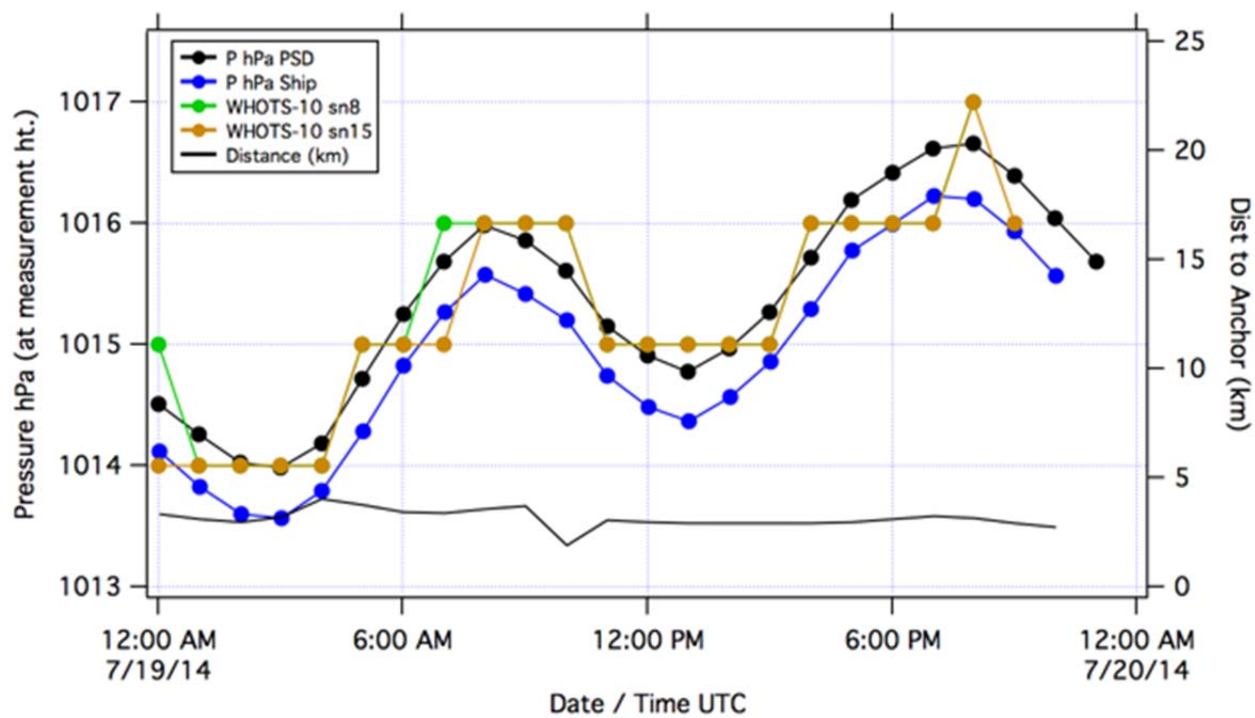

Figure 23. Barometric pressure for the WHOTS-10 buoy systems (SN 8 and SN 15), the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

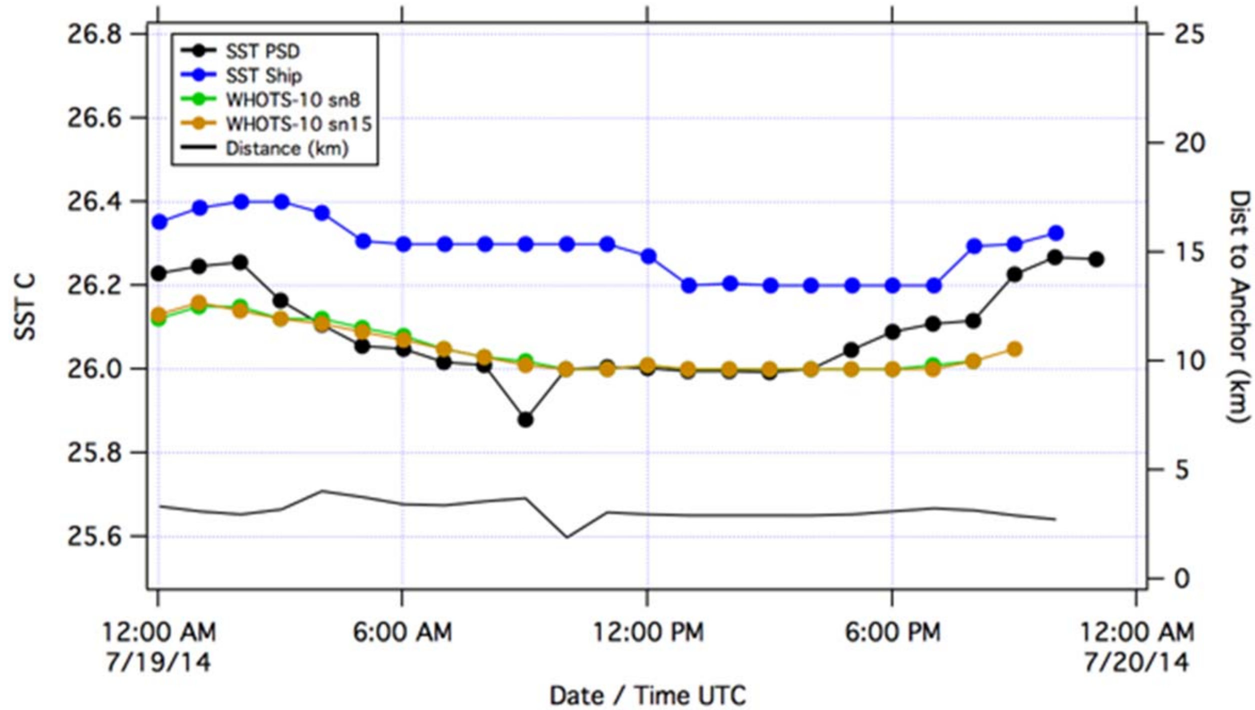

Figure 24. Sea surface temperature for the WHOTS-10 buoy systems (SN 8 and SN 15), the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

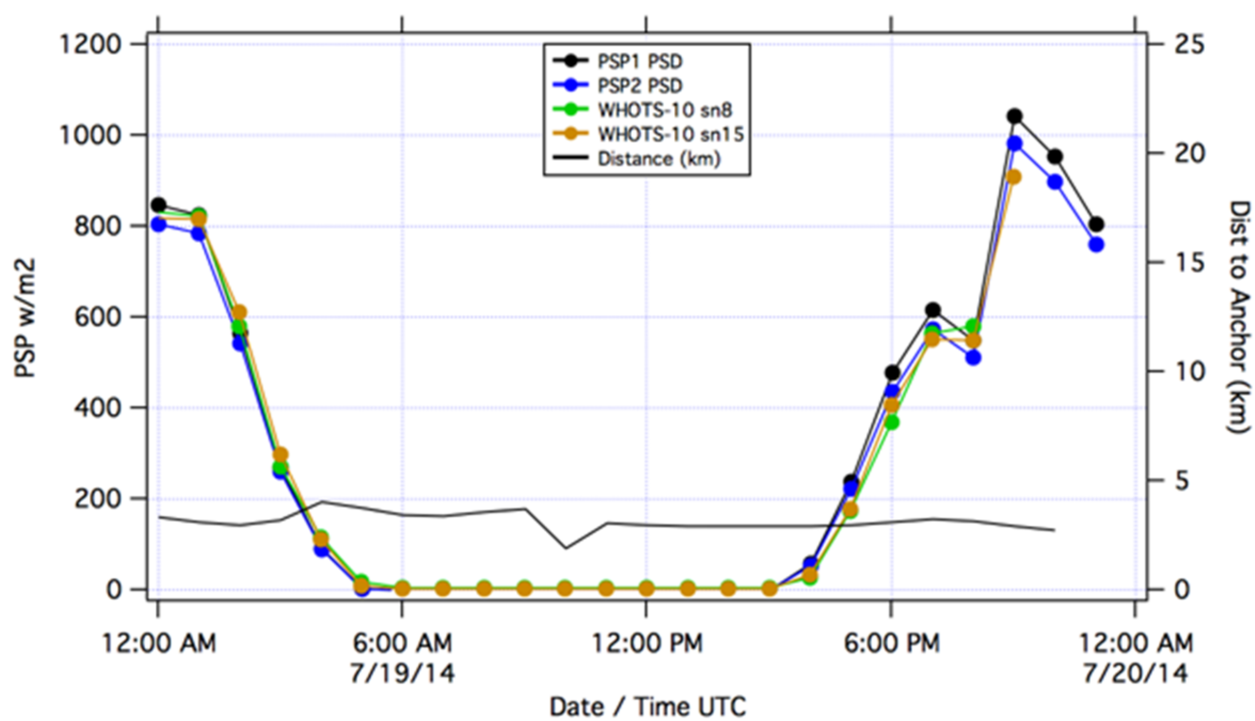

Figure 25. Shortwave radiation for the WHOTS-10 buoy systems (SN 7 and SN 19) and ESRL/PSD systems (black, blue) during the intercomparison period. SCS SWR was not available.

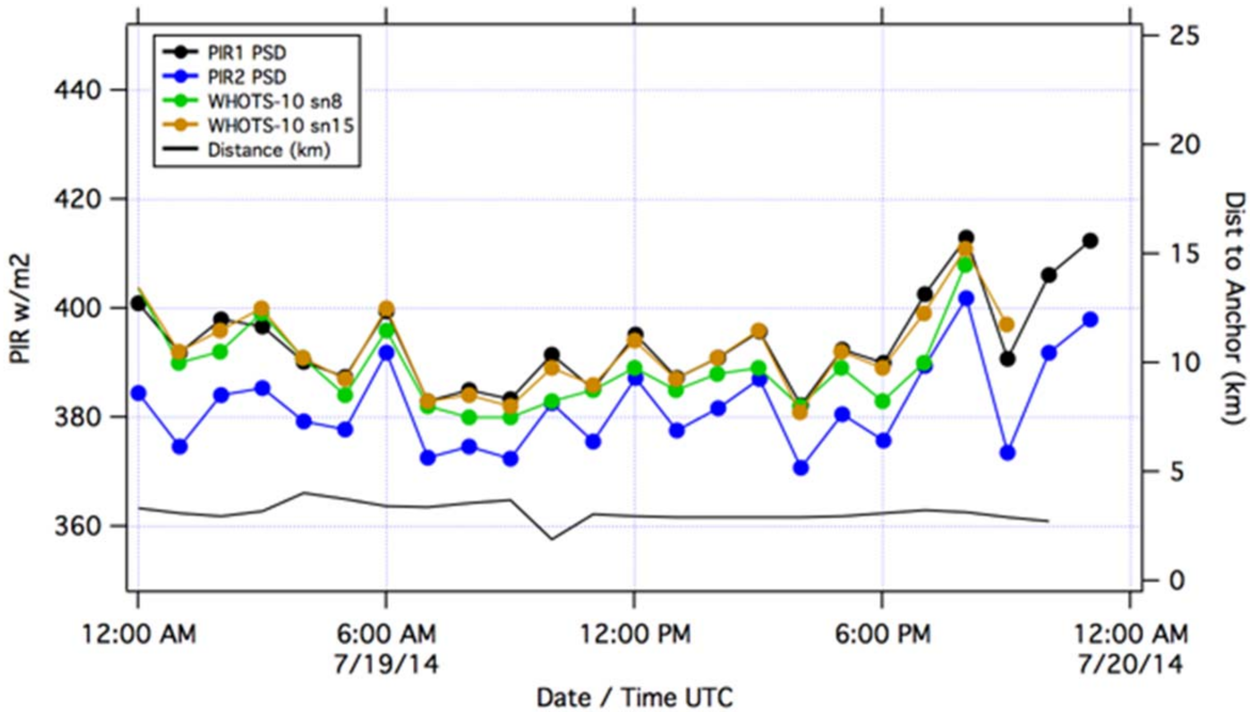

Figure 26. Longwave radiation for the WHOTS-10 buoy systems (SN 7 and SN 19) and ESRL/PSD systems (black, blue) during the intercomparison period. SCS SWR was not available.

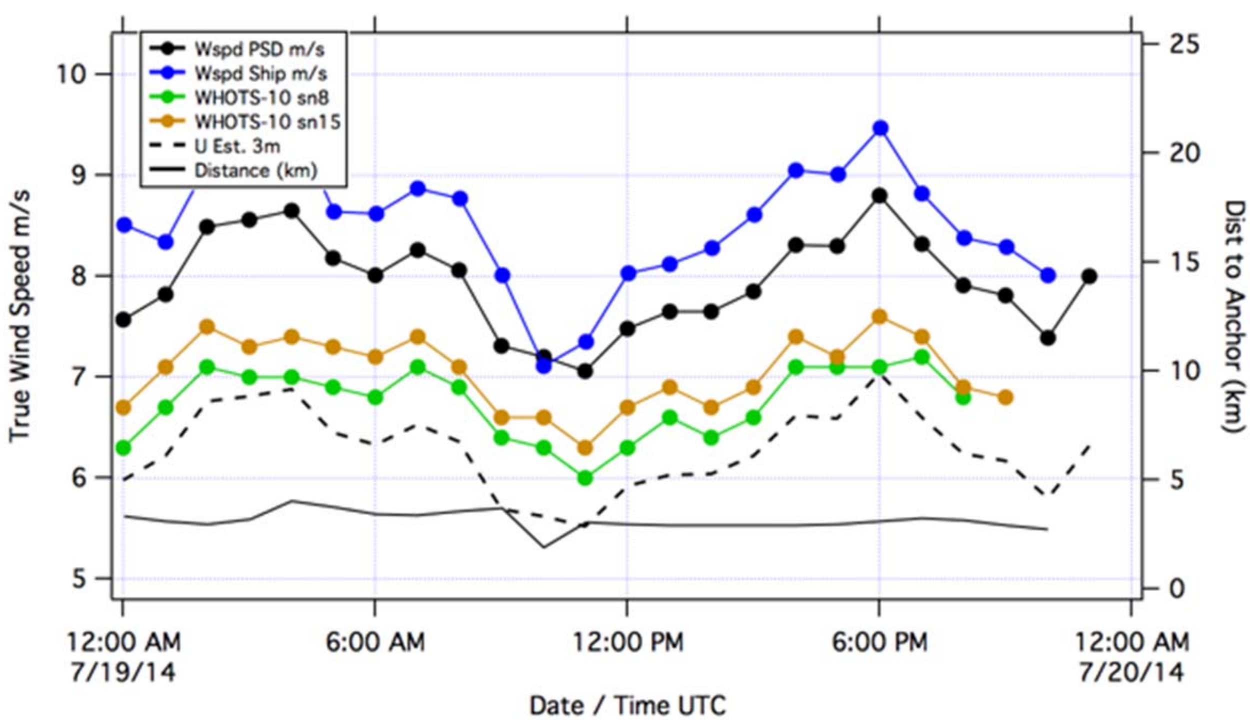

Figure 27. Wind speed for the WHOTS-10 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period. An estimate of the ESRL wind speed adjusted to 3 m height is shown as a dashed line.

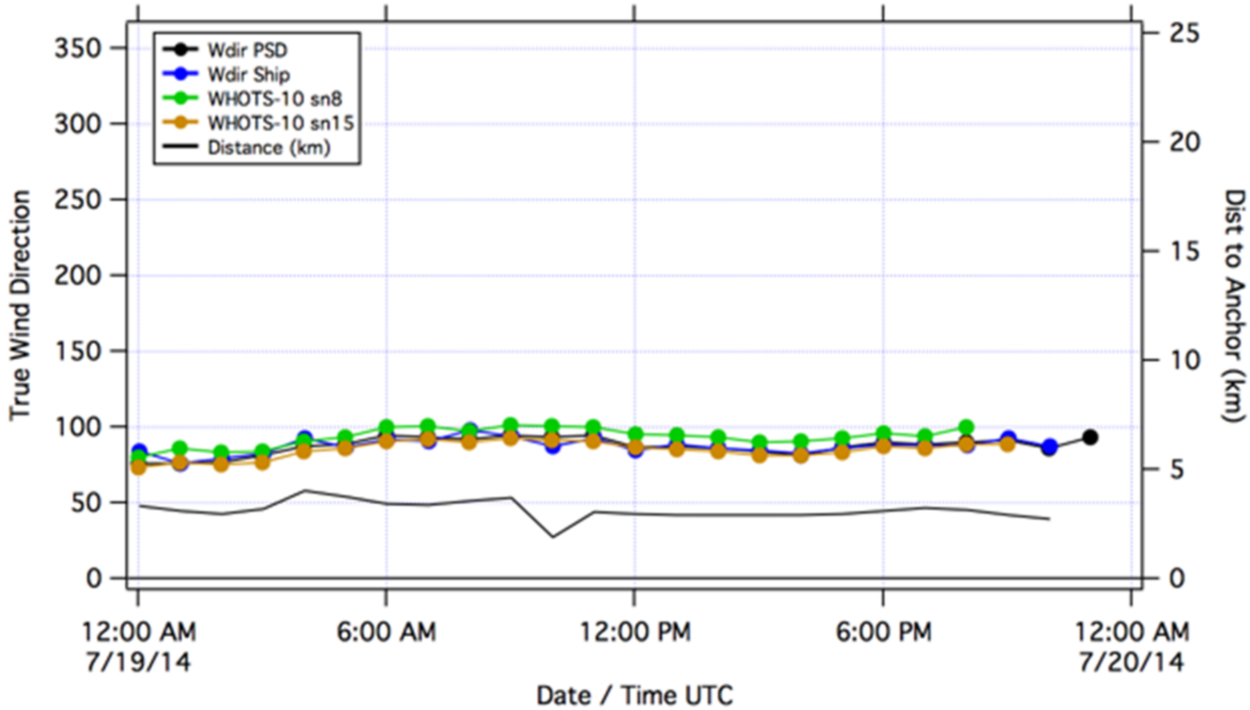

Figure 28. Wind direction for the WHOTS-10 buoy systems (SN 7 and SN 19) the SCS system (blue) and the ESRL/PSD system (black) during the intercomparison period.

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.

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Appendix A: Cruise Participants

Captain: Dan Simon (CDR)

Officers

Don Beaucage (LCDR, Executive Officer)
Faith Knighton (LT, Operations Officer)
Andrew Reynaga (ENS)
Steven Solari (ENS)
Amanda Goeller (LCDR)
Jimbo Donovan (3M)

Deck Department

Mark O'Connor (CB)
Rich Hinostroza (SS)
Mike Murphy (AB)
Tim Crumley (AB)
Ryan Harris (AB)
Kelson Bracey (AB)
Jared Thurber (AB)
Pat Kreigh (AB)
Frank Poloniak (GVA)

Survey Department: Tonya Watson (SST)

Electronics Department: Charlie Weintraub (ET)

Science Party

Albert Plueddemann (Chief Scientist, WHOI)
Ben Pietro (WHOI)
Sean Whelan (WHOI)
Fernando Santiago-Mandujano (UH)
Jefrey Snyder (UH)
Branden Nakahara (UH)
Danny McCoy (UH)
Ryan Tabata (UH)
Kelly Lance (UH)
Thanh-van Tran (UH)
Byron Blomquist (CIRES)

Appendix B: WHOTS-11 Weather and Currents

During the WHOTS-11 cruise, Station ALOHA was under the influence of the eastern North Pacific high pressure system, and the associated east-northeasterly trade winds (Fig. B1). Conditions were favorable during the WHOTS-11 deployment on 16 July, with 15-18 kt ENE winds.

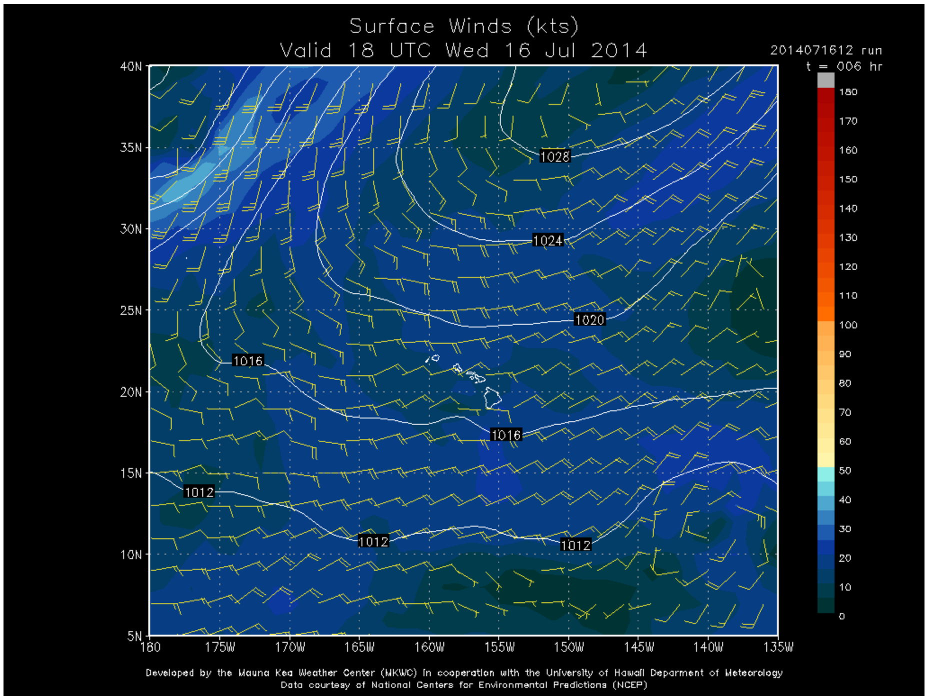


Figure B1. NOAA/NCEP GFS surface wind and sea level pressure analysis for the central-eastern North Pacific, valid for 18Z on 16 July 2014.

Weather conditions remained favorable during 17-19 July, with ENE wind speeds of 17 kts with occasional higher gusts. Tropical storm Wali started developing SE of Hilo (Fig. B2), but weakened to below tropical storm status before reaching the islands. However Wali did cause overcast conditions and a few showers during the WHOTS-10 recovery. Winds intensified to 20-25 kts, with swells in the 8-10 ft range in the morning of the mooring recovery on 20 July, only to decrease to less than 10 kts soon after, and for the rest of the day.

Winds were from the east in the 18-20 kt range on the morning of 22 July, but intensified to 25-40 kts with occasional higher gusts (up to 45 kts) for the rest of the day, causing the cancellation of additional CTD casts that were planned for that day.

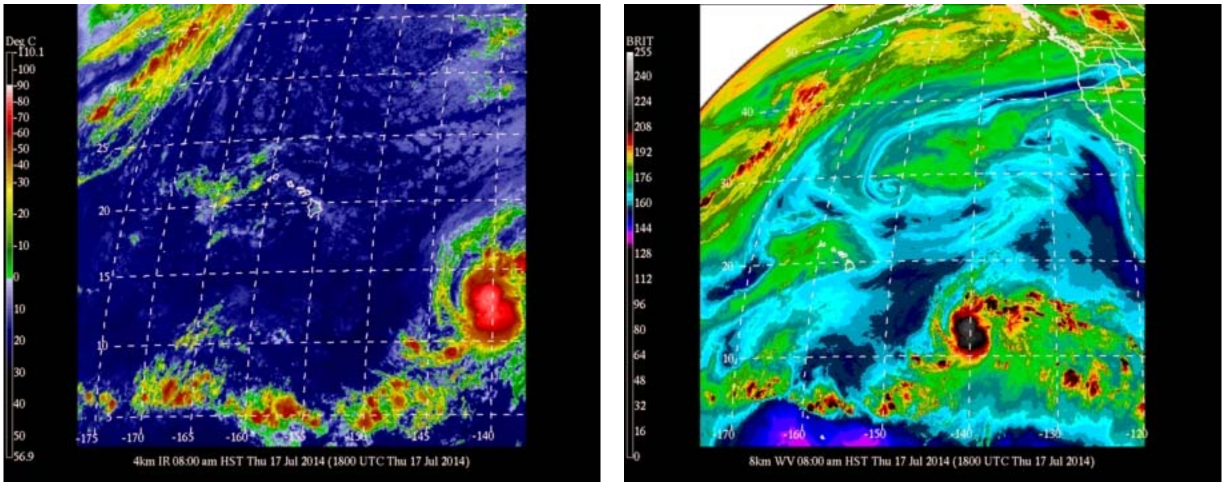


Figure B2. Water vapor channel image (left) and infrared channel image (right) from the NOAA geostationary satellite on 17 July, 18Z.

Near-surface currents were slightly westward during transit near Station ALOHA, turning NNEward at about 0.2 m/s during the WHOTS-11 deployment, and fluctuating from NEward to NWward the rest of the cruise (Fig. B3). There were no obvious cyclonic or anti-cyclonic eddies present (Fig. B4), although a combination of internal semidiurnal and diurnal tides, along with near-inertial oscillations, were noticeable especially in vertical shear (Fig. B5).

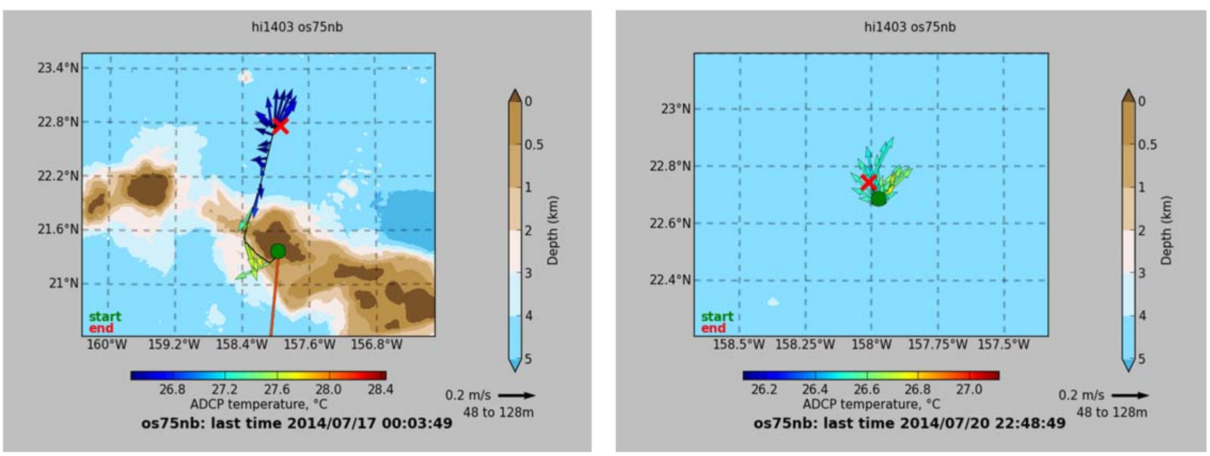


Figure B3. Shipboard 300 kHz ADCP current measurements from 17 July (left) and 20 July (right) 2014 averaged over depths from 48 to 128 m. Water temperature at the hull transducer depth is indicated by vector color.

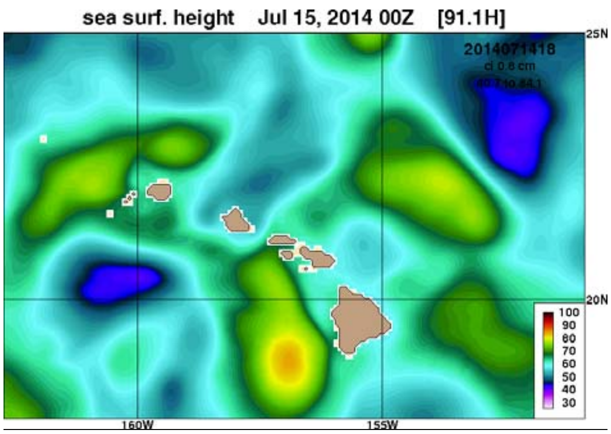


Figure B4. Sea surface height from the NRL 1/12th degree HYCOM analysis for 00Z on 15 July 2014 (left) and 20 July (right).

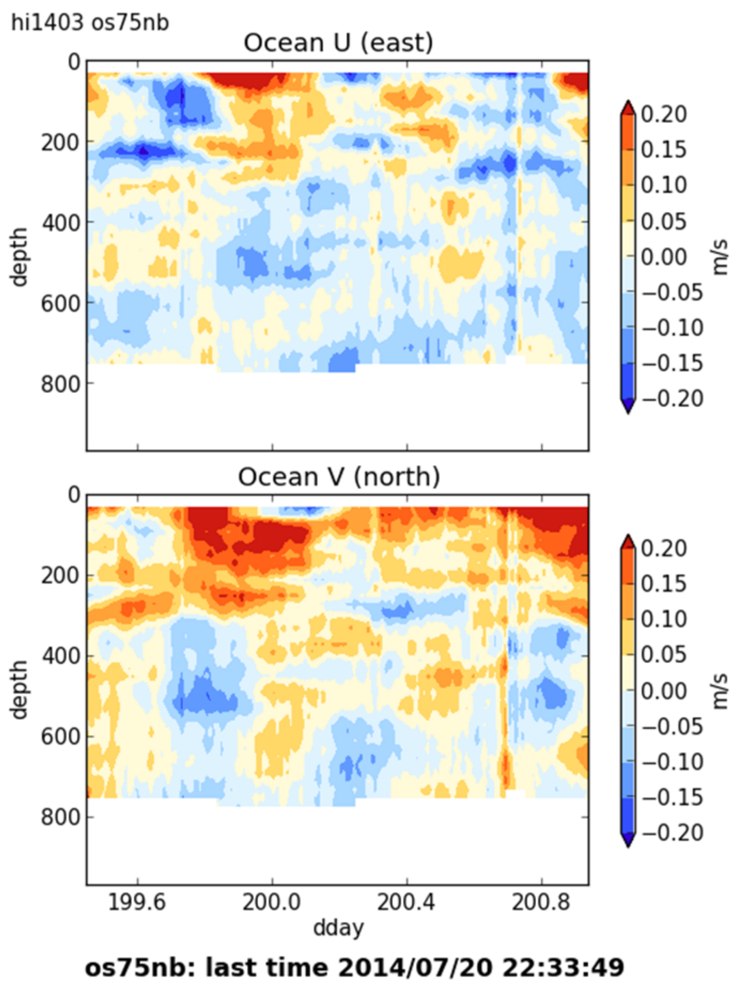


Figure B5. Shipboard 75 kHz ADCP currents from 19-20 July as a function of depth and time.

Appendix C: WHOTS-10 Subsurface Instrumentation and Data Return

For the tenth WHOTS mooring deployment 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 6 also measuring pressure.

MicroCATs and SeaCATs

Table C1 provides the deployment information for all of the UH temperature-conductivity instruments on the WHOTS-10 mooring.

Table C1. WHOTS-10 Microcat deployment information.

SN:	Depth	Pressure SN	Sample Interval (sec)	Cold Spike begin (UTC)		Cold Spike end (UTC)		Time in Water (UTC)	
6893	15	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	18:33
6894	25	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	18:14
6895	35	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	18:07
6896	40	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	18:03
6887	45	2651319	75	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	17:58
6897	50	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:22
6898	55	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:23
6899	65	N/A	60	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:24
3618	75	N/A	180	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:25
6888	85	3418742	75	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:27
3617	95	N/A	180	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:27
6889	105	2651321	75	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:28
6890	120	2651322	75	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:29
3634	135	N/A	180	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:35
6891	155	2651323	75	07/08/13	19:30:30	07/08/13	20:00:30	07/10/13	19:36

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.

All MicroCATs were in good condition after recovery. Table C2 gives the post-deployment information for the UH C-T instruments. The WHOI SBE-16 SeaCAT temperature-conductivity instruments are also included. The data were downloaded on board ship, and all instruments returned full data records, except for SN 3634 which had a 20 minute gap on October 20, 2013, 21:21Z. The data from this instrument were downloaded again in the shore lab after the cruise and the missing data were recovered. Both SeaCATs were missing their anti-foulant plugs on recovery.

Table C2. WHOTS-10 C-T instrument recovery information. All times are in UTC.

Depth (m)	Sea-Bird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality
15	37SM31486-6893	07/21/2014 05:14	07/21/2014 07:41:00	07/22/2014 05:51:30	548,992	good
25	37SM31486-6894	07/21/2014 05:21	07/21/2014 07:41:00	07/21/2014 08:48:30	547,729	good
35	37SM31486-6895	07/21/2014 05:25	07/21/2014 07:41:00	07/21/2014 08:33:00	547,714	good
40	37SM31486-6896	07/21/2014 05:28	07/21/2014 07:41:00	07/21/2014 08:44:30	547,725	good
45	37SM31486-6887	07/21/2014 05:28	07/21/2014 07:41:00	07/21/2014 08:41:00	438,177	good
50	37SM31486-6897	07/21/2014 03:22	07/21/2014 07:41:00	07/21/2014 08:07:00	547,687	good
55	37SM31486-6898	07/21/2014 03:21	07/21/2014 07:41:00	07/21/2014 08:11:30	547,693	good
65	37SM31486-6899	07/21/2014 03:20	07/21/2014 07:41:00	07/21/2014 08:15:00	547,696	good
75	37SM31486-3618	07/21/2014 03:19	07/21/2014 07:41:00	07/22/2014 05:29:30	182,990	good
85	37SM31486-6888	07/21/2014 03:18	07/21/2014 07:41:00	07/21/2014 08:19:00	438,160	good
95	37SM31486-3617	07/21/2014 03:17	07/21/2014 07:41:00	07/22/2014 05:36:00	182,992	good
105	37SM31486-6889	07/21/2014 03:16	07/21/2014 07:41:00	07/22/2014 05:43:00	439,187	good
120	37SM31486-6890	07/21/2014 03:15	07/21/2014 07:41:00	07/22/2014 05:47:00	439,190	good
135	37SM31486-3634	07/21/2014 03:11	07/21/2014 07:41:00	07/22/2014 05:33:00	182,991	20 min gap (recovered after a second data download)
155	37SM31486-6891	07/21/2014 03:08	07/21/2014 07:41:00	07/22/2014 05:26:00	439,173	good
36 mab	SBE-16-04-1882	07/20/2014 20:53	07/21/2014 22:40:00	07/22/2014 02:04:00	18,401	Antifoulant plug missing. Conductivity offset lasting one month
36 mab	SBE-16-04-2325	07/20/2014 20:53	07/21/2014 22:40:00	07/22/2014 02:04:00	18,401	Antifoulant plug missing. Conductivity drift

ADCPs and MAVS

The fouling on the 300 kHz ADCP transducer faces (Fig. C1) was minimal, most likely due to the depth of deployment (125 m) as well as Destin rash paste (which contains 40% Zinc oxide) used as anti-foulant on the faces. The transducer faces for the 47.5 m ADCP were also treated with anti-foulant paste, and despite significant algae growth near the faces, the faces themselves did not show the same level of growth, although a barnacle was found attached near the face edge of transducer #1 (Fig. C1).

Figure C1. WHOTS-10 ADCPs deployed at 125 m (left) and 47.5 m (right) after recovery.

Table C3 provides the ADCP and MAVS deployment configuration and recovery information.

Table C3. WHOTS-10 ADCP and MAVS deployment 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	07/06/13, 00:00:00	07/06/13, 00:00:00	07/06/13, 00:00:00
Time of Last Ensemble	07/21/14, 18:51:33	07/21/14, 20:06:45	07/23/14, 01:06:00
Number of Ensembles	54,892	54,893	18,338
Time in water	07/10/13, 19:34	07/10/13, 19:22	07/10/13, 18:27
Time out of the water	07/21/14, 03:12	07/21/14, 03:22	07/21/14, 05:18
Transducer 1 spike	07/21/14, 19:02:00	07/21/14, 20:17:00	N/A (sensor broken)
Transducer 2 spike	07/21/14 19:02:30	07/21/14, 22:17:30	N/A (sensor broken)
Transducer 3 spike	07/21/14, 19:03:00	07/21/14, 22:18:00	N/A (sensor broken)
Transducer 4 spike	07/21/14, 19:03:30	07/21/14, 22:18:30	N/A (sensor broken)
Depth	125 m	47.5 m	20 m

The MAVS was found to have its two transducers damaged on recovery (Fig. C2).

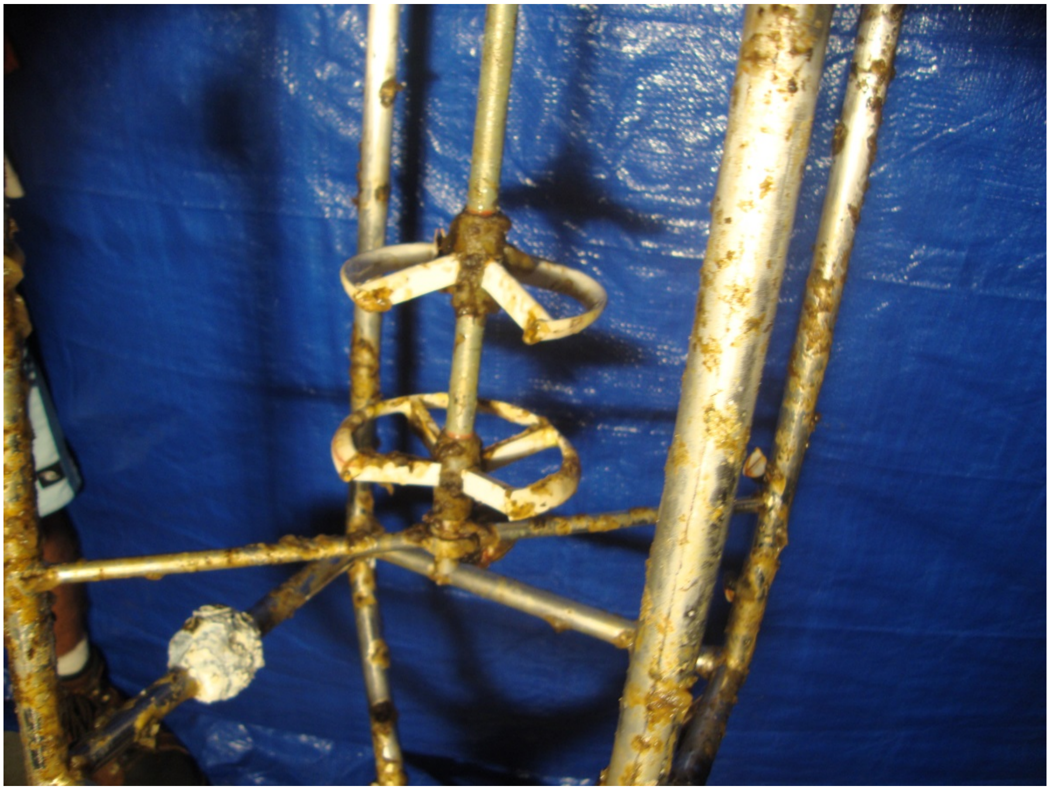


Figure C2. WHOTS-10 MAVS deployed at 20 m, after recovery.

Data Return

The data recovered from the MicroCATs appear to be mostly of high quality, although post-deployment calibrations are required. Figures C3-C19 show the nominally calibrated temperature, conductivity and salinity records from each instrument, and pressure for those instruments that were equipped with pressure sensors. The WHOI SBE-16 SeaCAT temperature -conductivity instruments are also included.

The data recovered from SeaCAT SN 1882 showed a conductivity drift throughout the duration of the deployment (Fig. C18). The data from SeaCAT SN 2325 showed a large conductivity offset early in the record that recovered to values similar to those before the offset, and comparable to the conductivities measured by SN 1882 after about one month (Fig. C19).

The data from the upward-looking 300 kHz ADCP at 125 m were good; the instrument was pinging upon recovery. There appears to be no obviously questionable data from this ADCP at this time, apart from near-surface artifacts. Figure C20 shows the variations of the horizontal and vertical components of velocity in depth and time. Figure C21 shows the heading, pitch and roll information from the 300 kHz ADCP.

The data from the upward-looking 600 kHz ADCP at 47.5 m were good; the instrument was pinging upon recovery. There appears to be no initial questionable data from this ADCP at this time, apart from near-surface artifacts. Figure C22 shows the variations of the horizontal and vertical components of velocity in depth and time. Figure C23 shows the heading, pitch and roll information from the 600 kHz ADCP.

Figure C24 shows the computed u, v and w velocity components at 20 m from the MAVS. The velocity data show about a month of off-scale readings in January 2014, apparently recovering before the sensors failed in April 2014. Figure C25 shows the raw velocities from each of the four acoustic transducers. Transducer “A” and “B” appeared to function the whole time, but “A” shows an offset in January as in Figure C24. It appears that transducers “C” and “D” failed in April 2014.

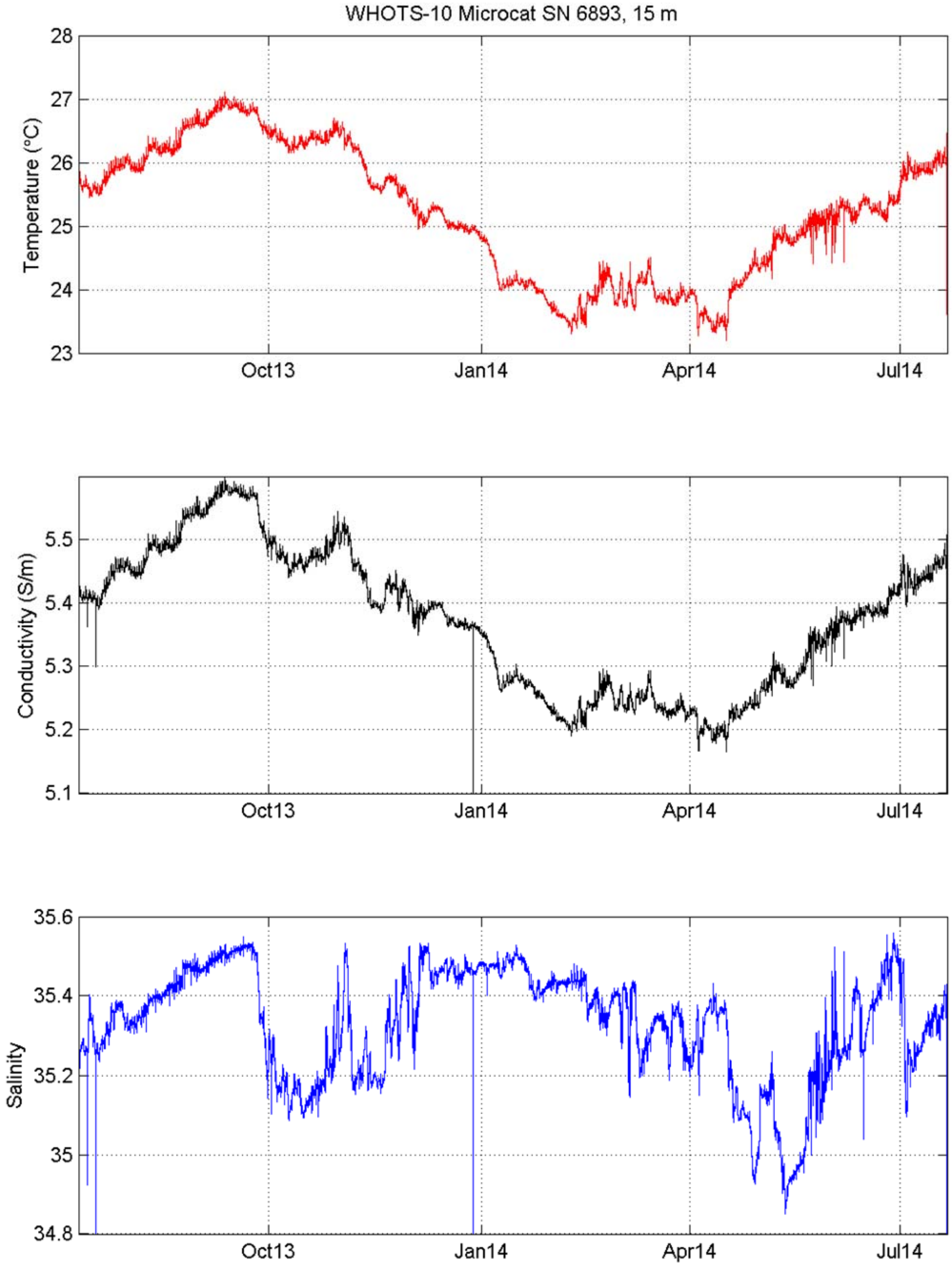


Figure C3. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6893 deployed at 15 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

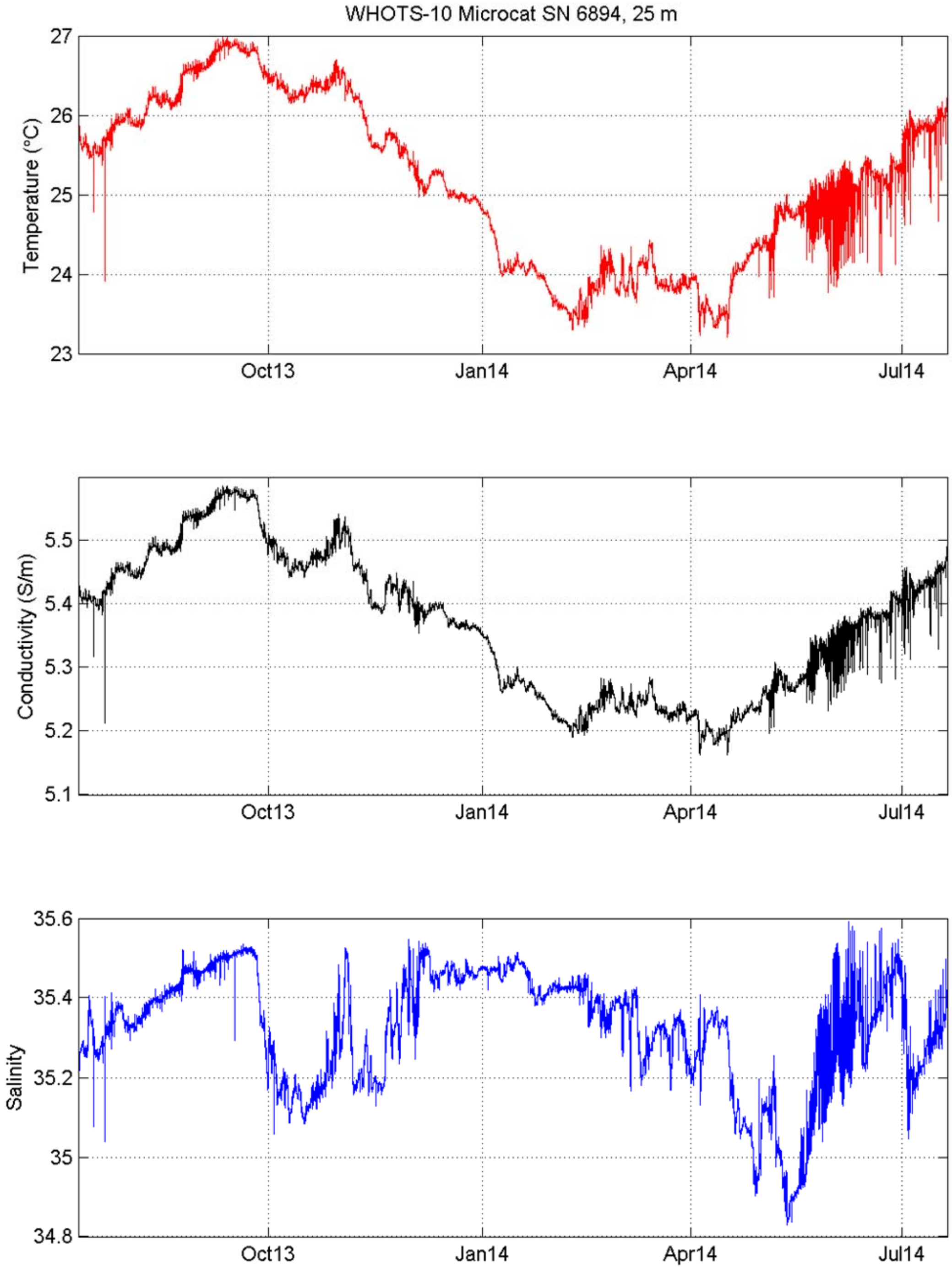


Figure C4. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6894 deployed at 25 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

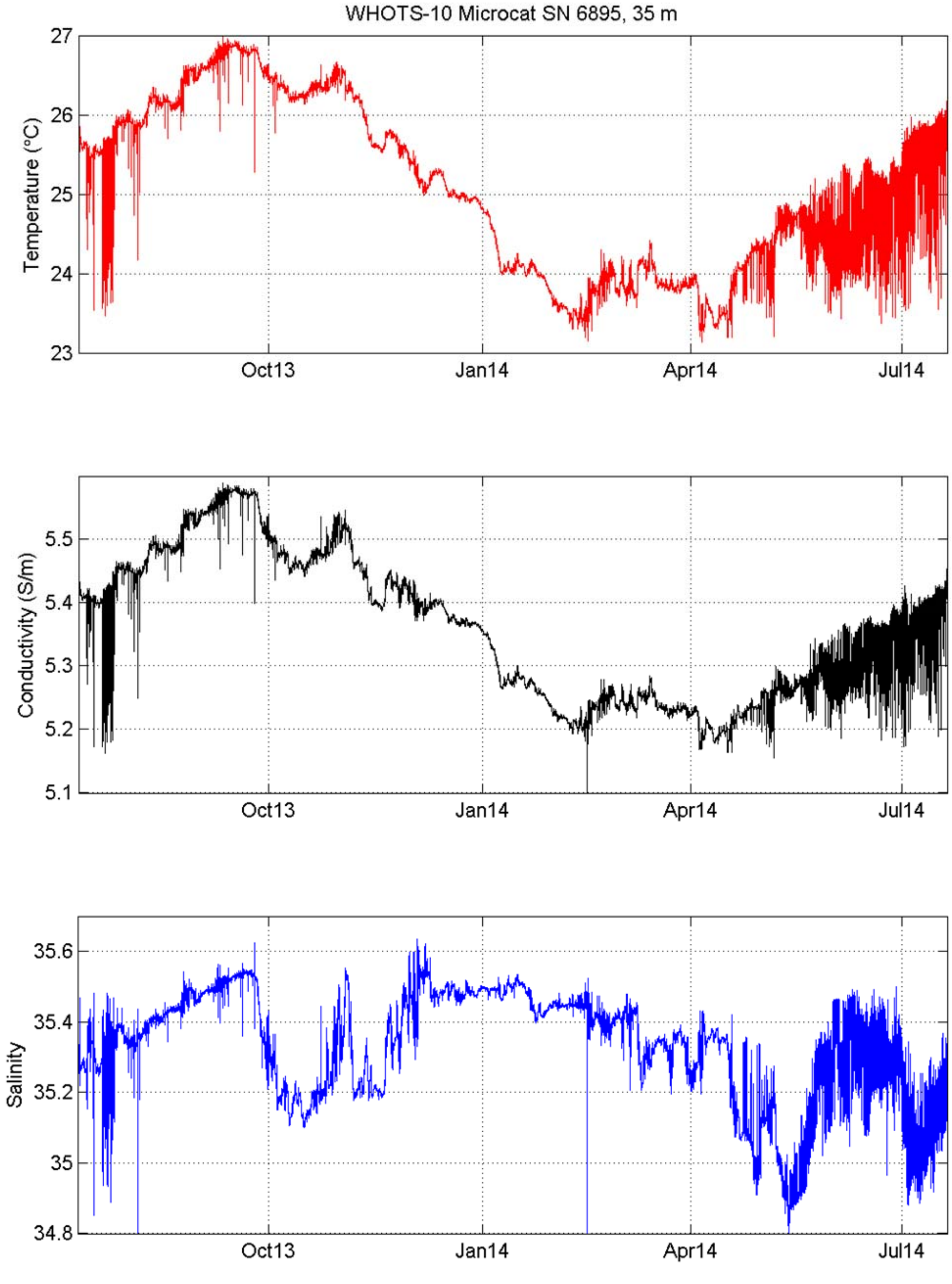


Figure C5. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6895 deployed at 35 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

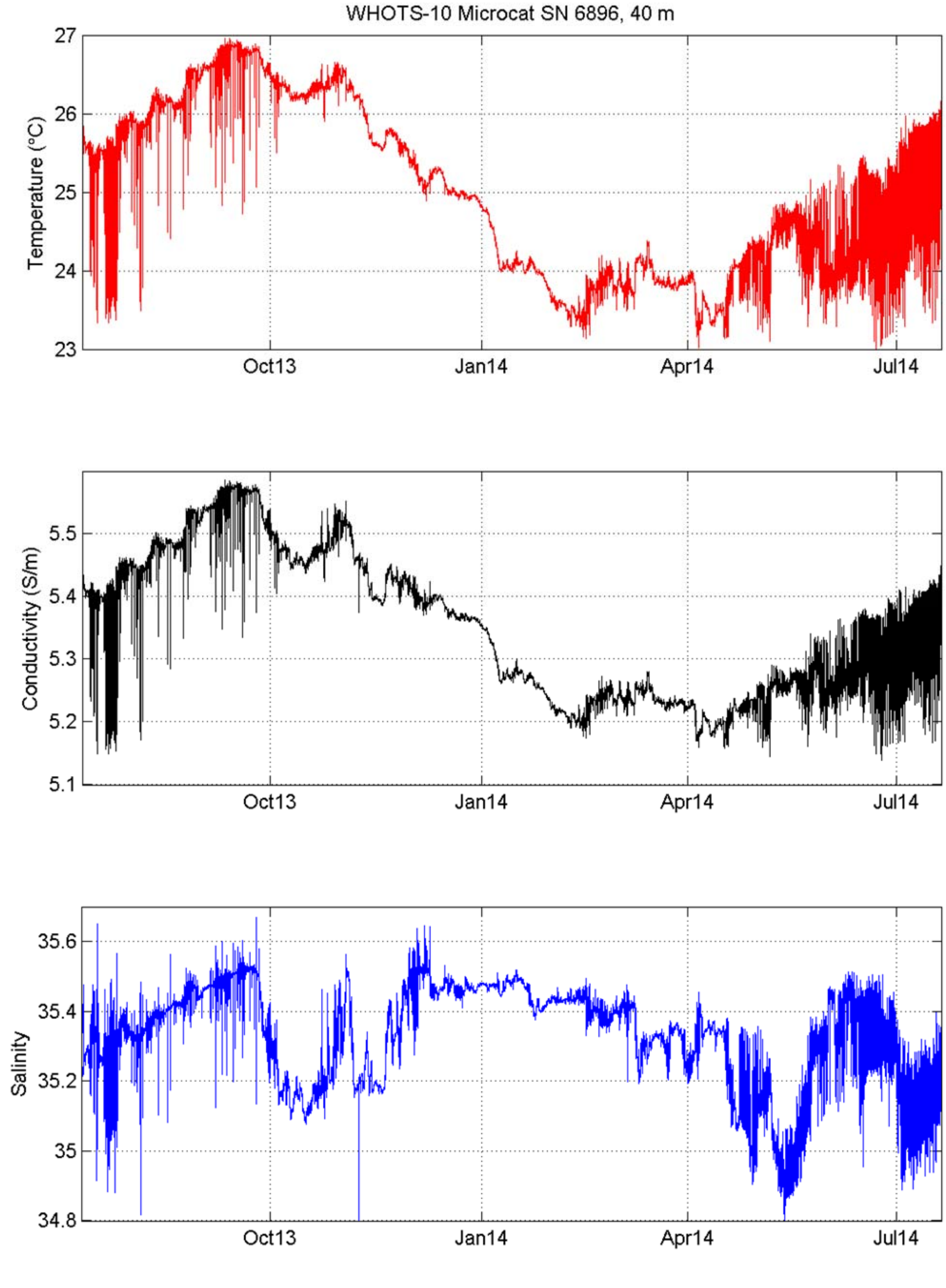


Figure C6. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6896 deployed at 40 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

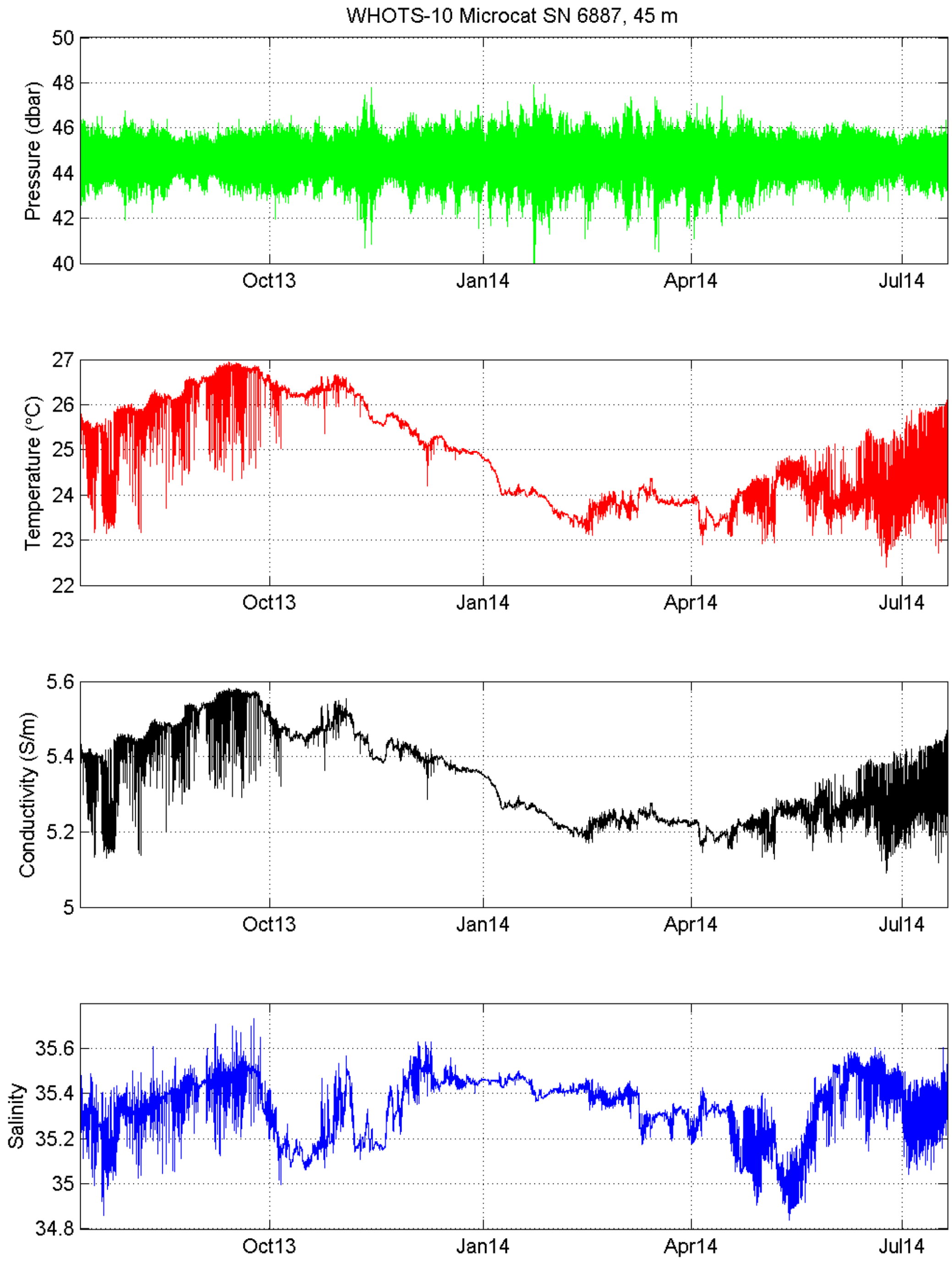


Figure C7. Pressure, temperature, conductivity and salinity from MicroCAT SBE-37 SN 6887 deployed at 45 m on the WHOTS-10 mooring. Pre-deployment calibration information was used.

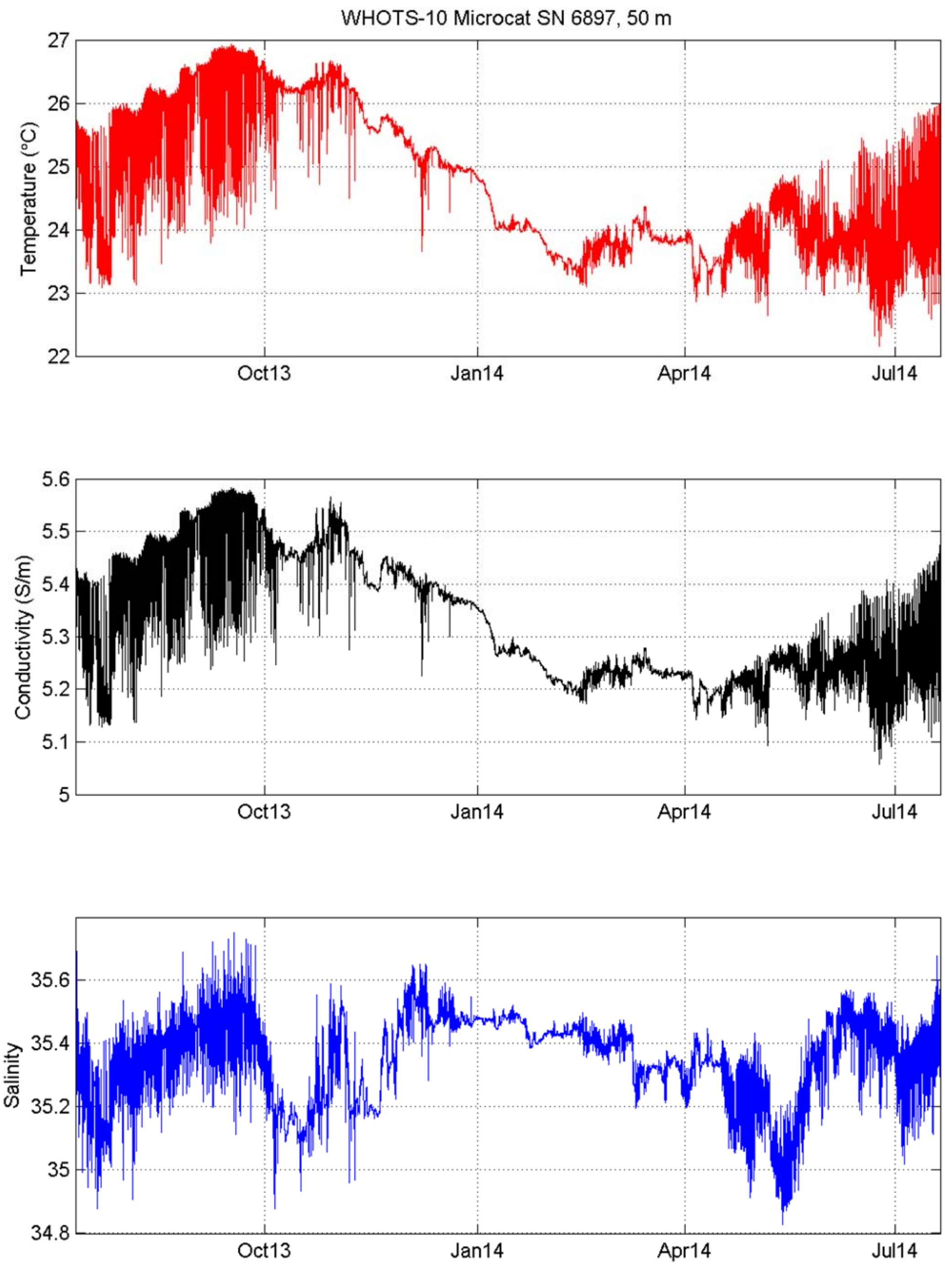


Figure C8. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6897 deployed at 50 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

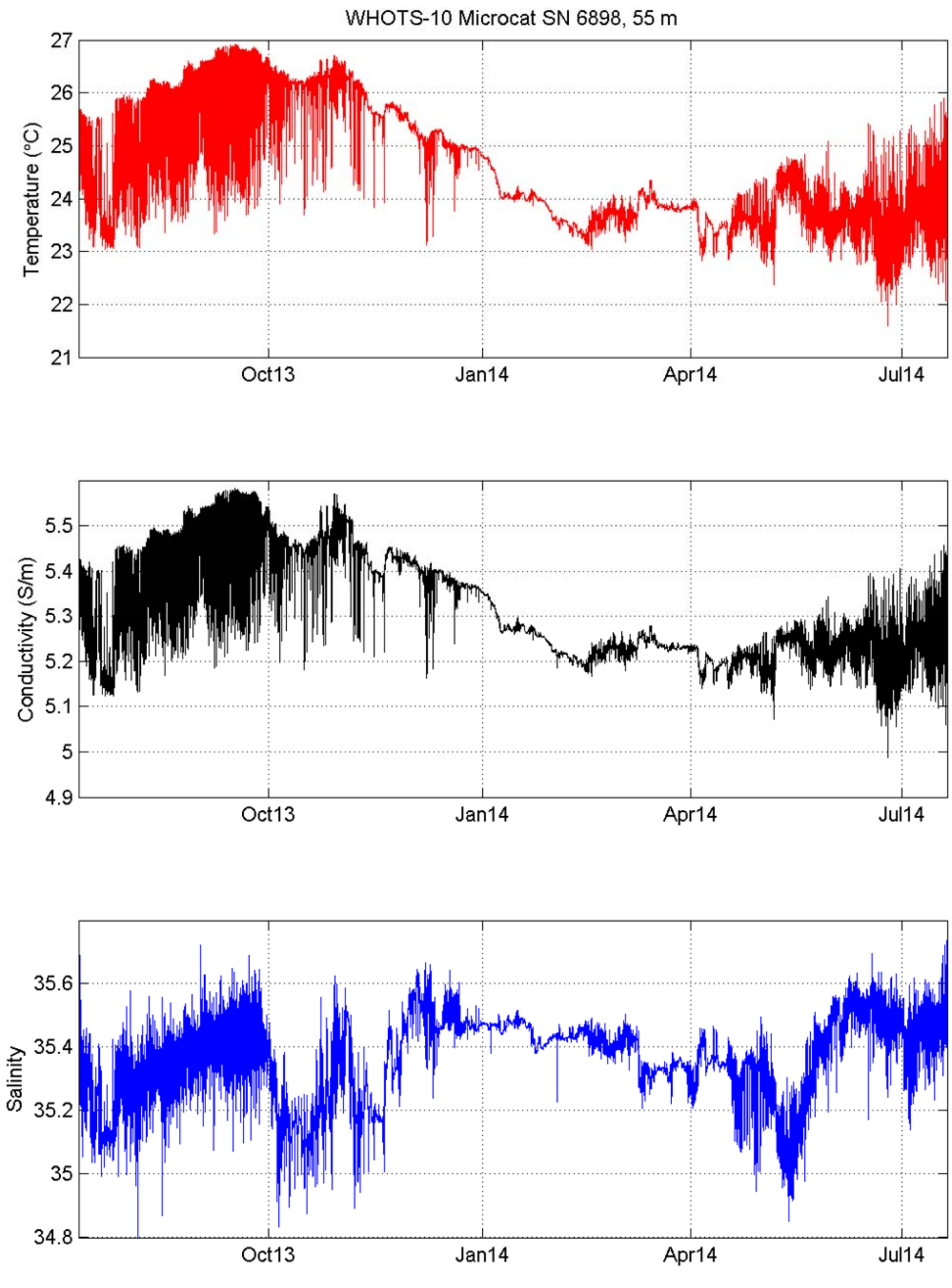


Figure C9. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6898 deployed at 55 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

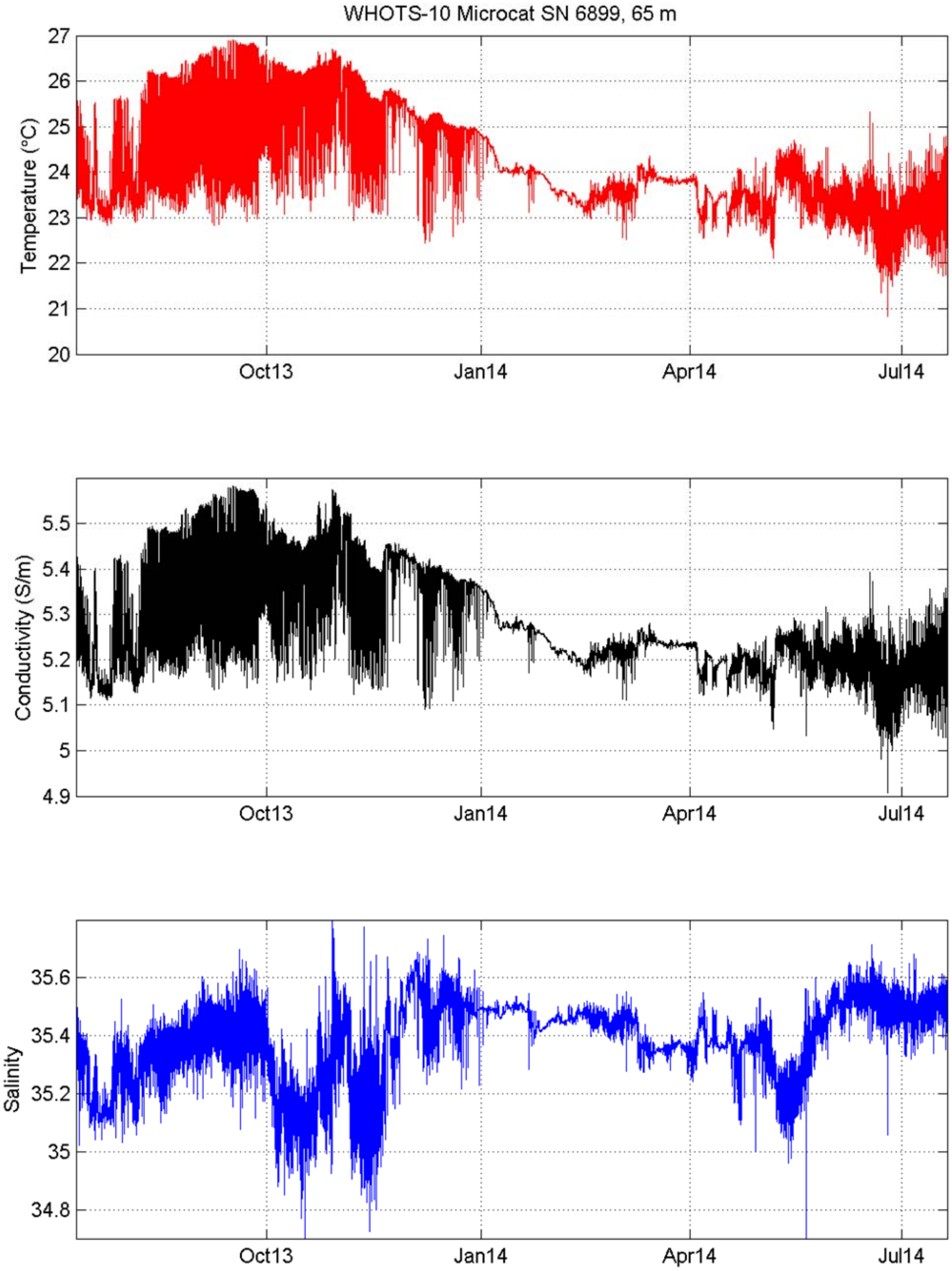


Figure C10. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 6899 deployed at 65 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

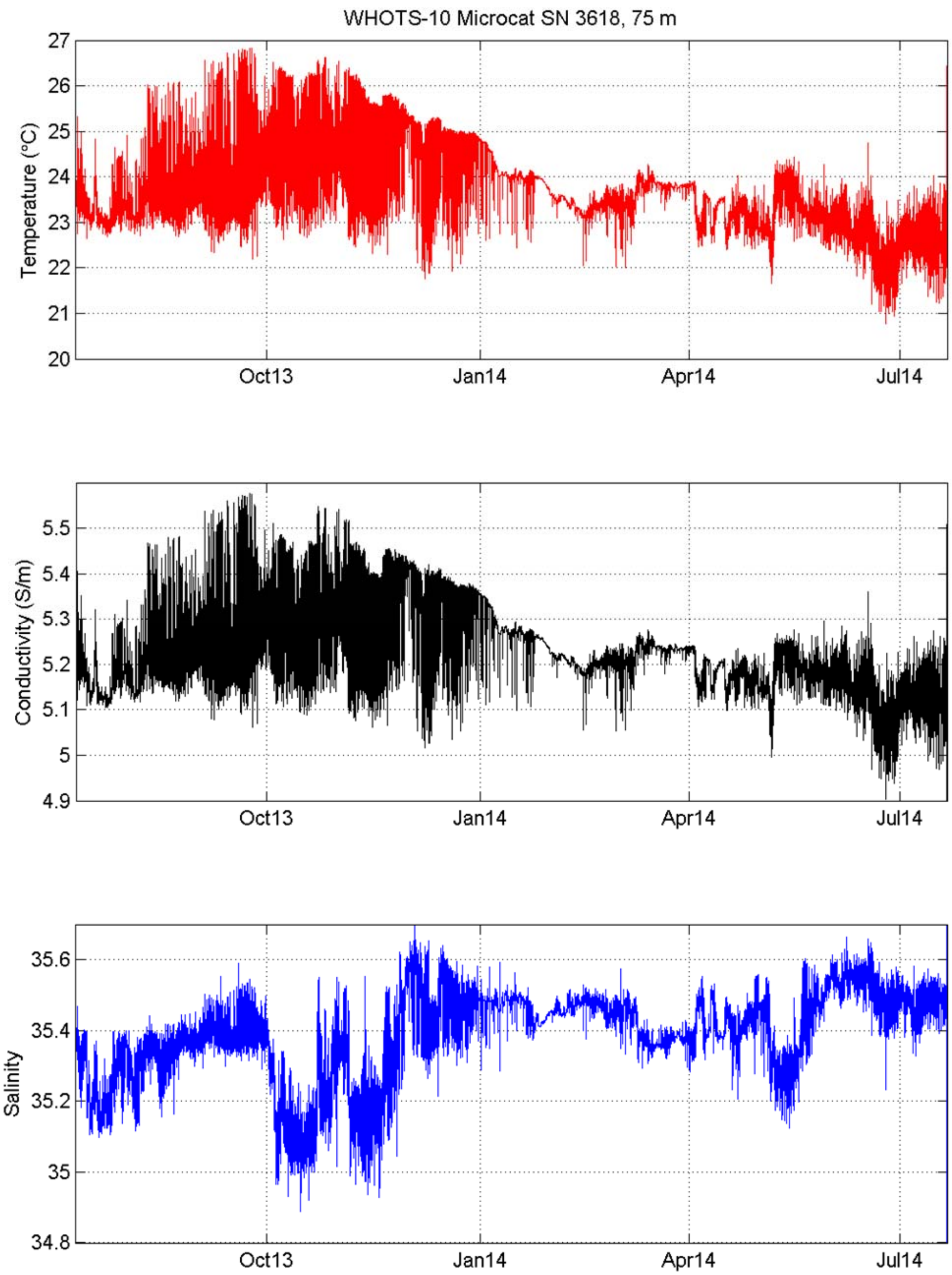


Figure C11. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 3618 deployed at 75 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

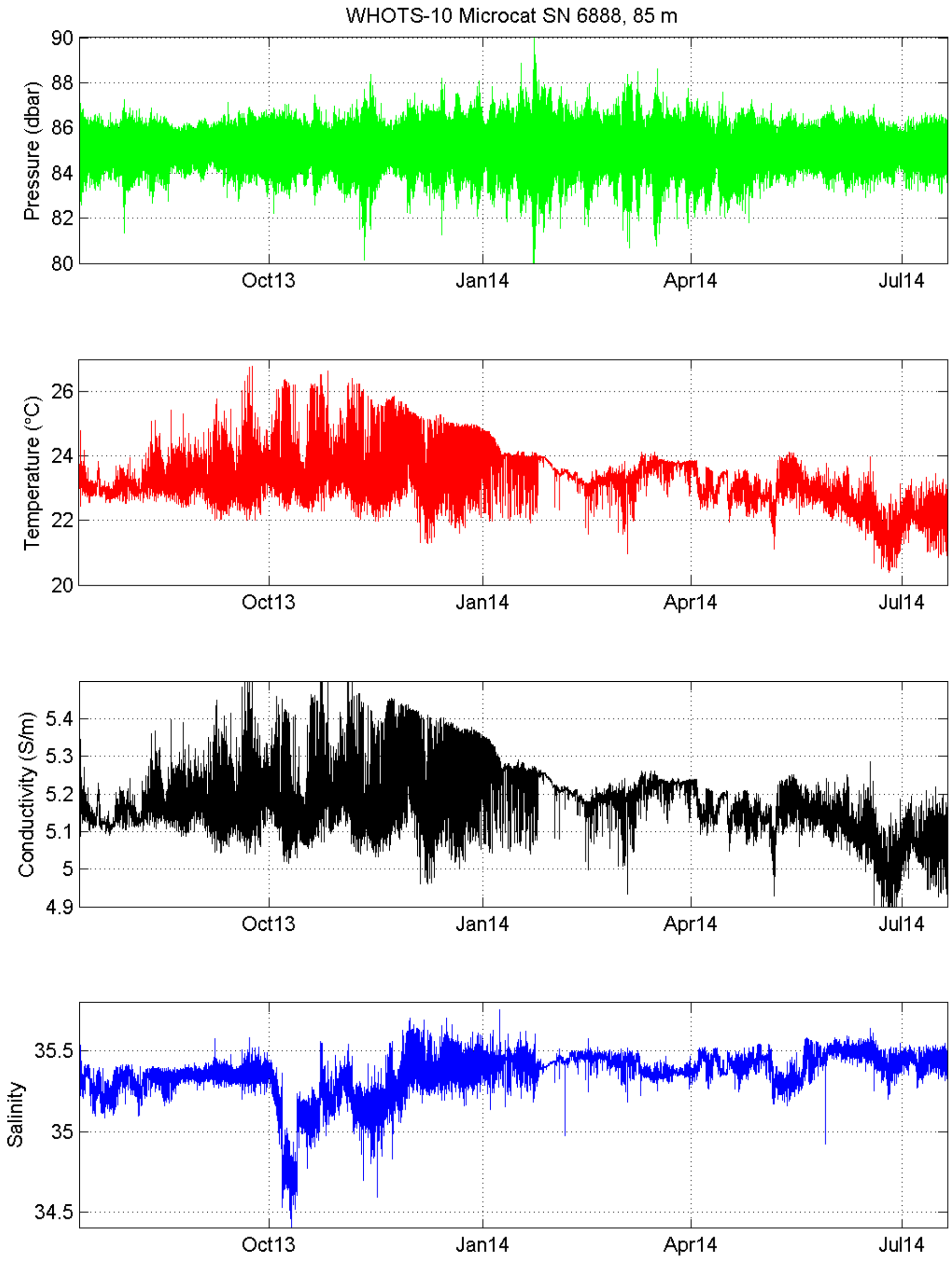


Figure C12. Pressure, temperature, conductivity and salinity from MicroCAT SBE-37 SN 6888 deployed at 85 m on the WHOTS-10 mooring. Pre-deployment calibration information was used.

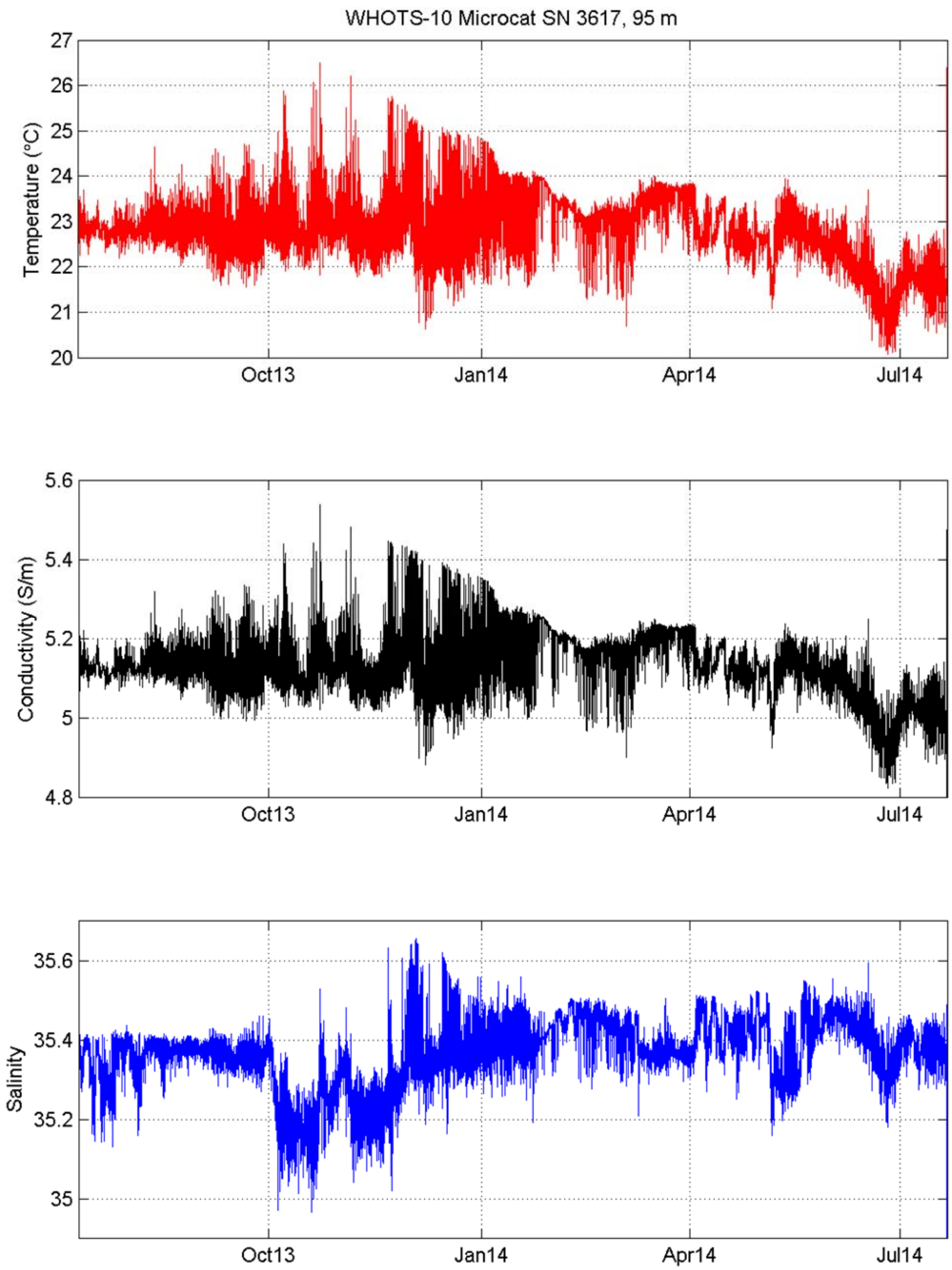


Figure C13. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 3617 deployed at 95 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

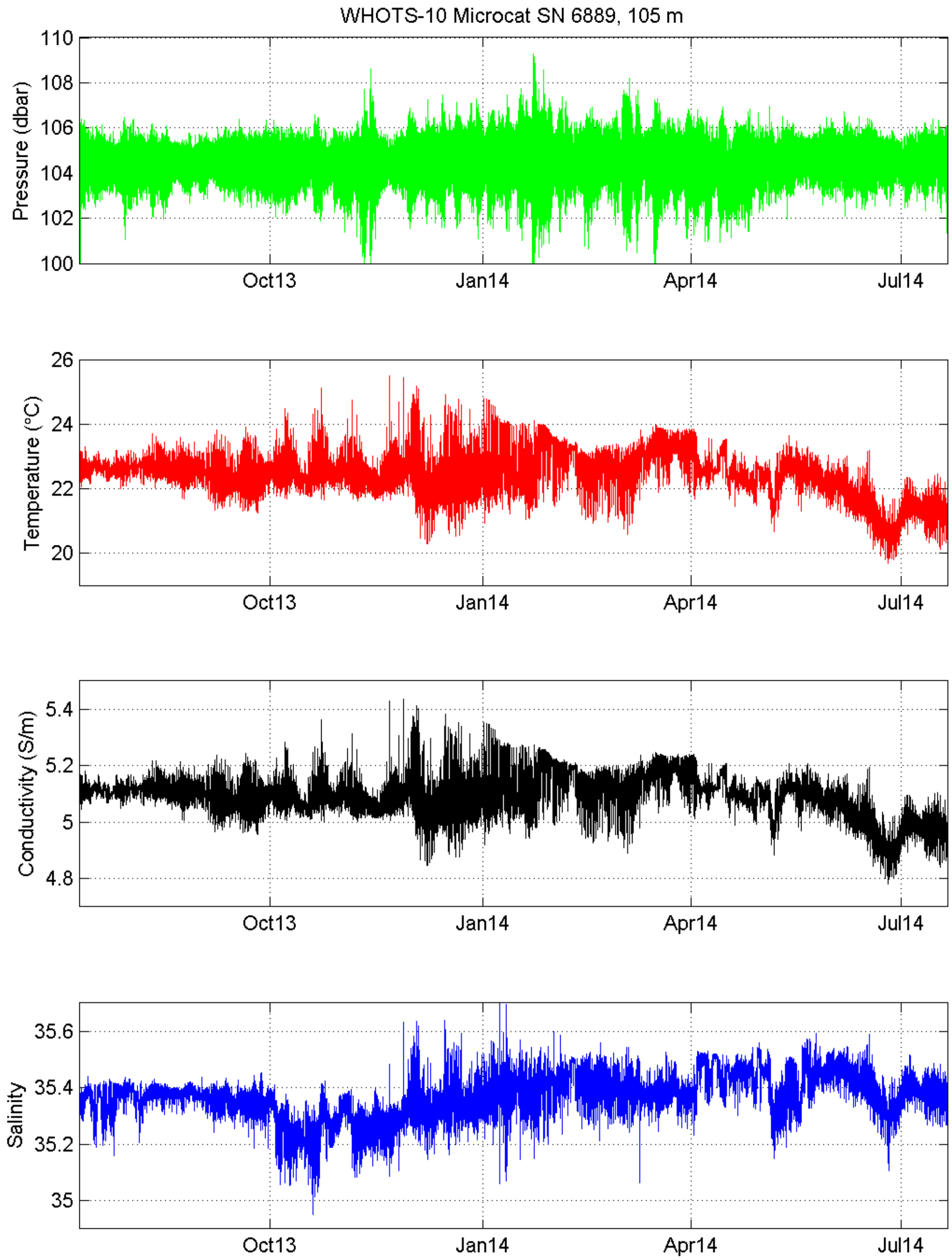


Figure C14. Pressure, temperature, conductivity and salinity from MicroCAT SBE-37 SN 6889 deployed at 105 m on the WHOTS-10 mooring. Pre-deployment calibration information was used.

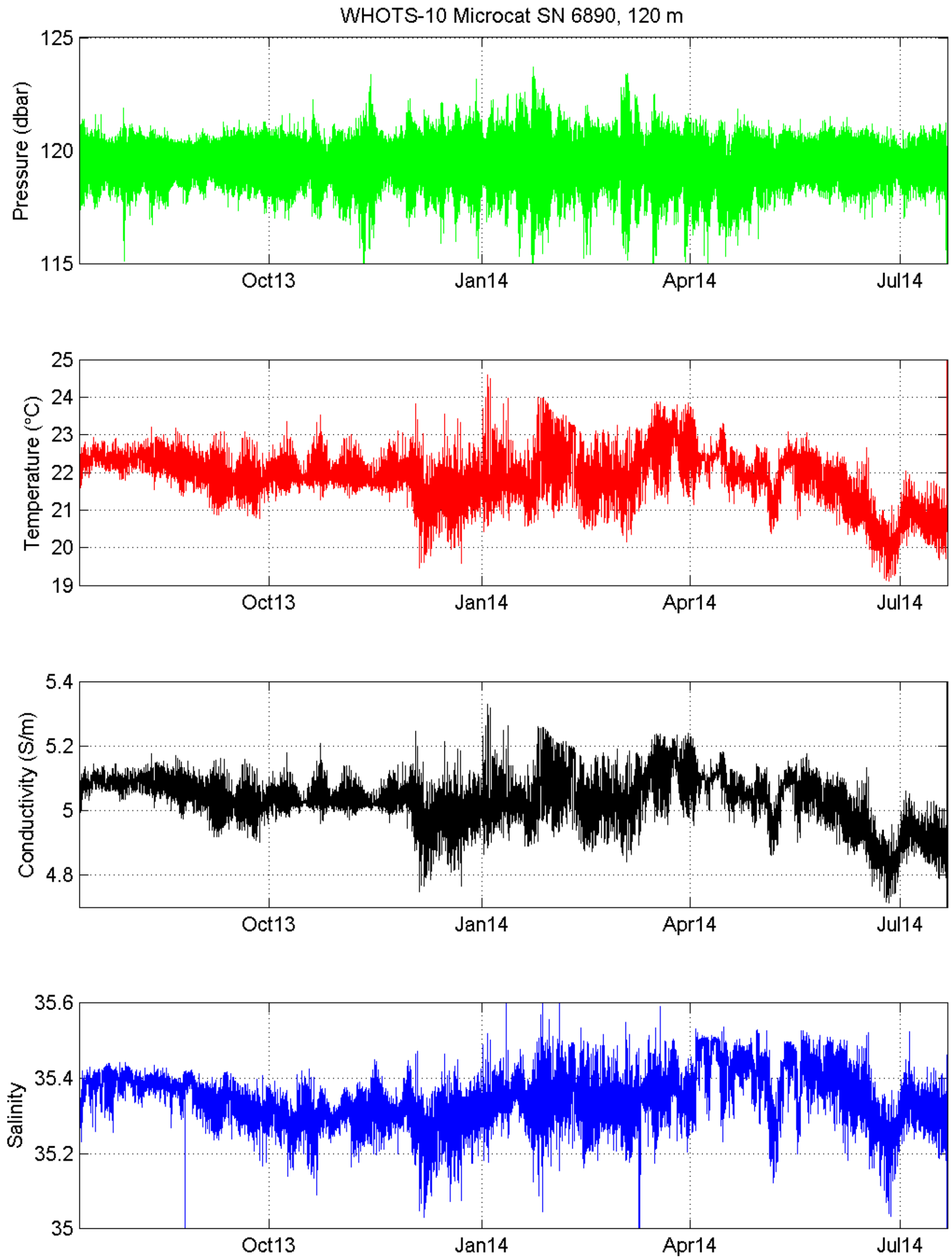


Figure C15. Pressure, temperature, conductivity and salinity from MicroCAT SBE-37 SN 6890 deployed at 120 m on the WHOTS-10 mooring. Pre-deployment calibration information was used.

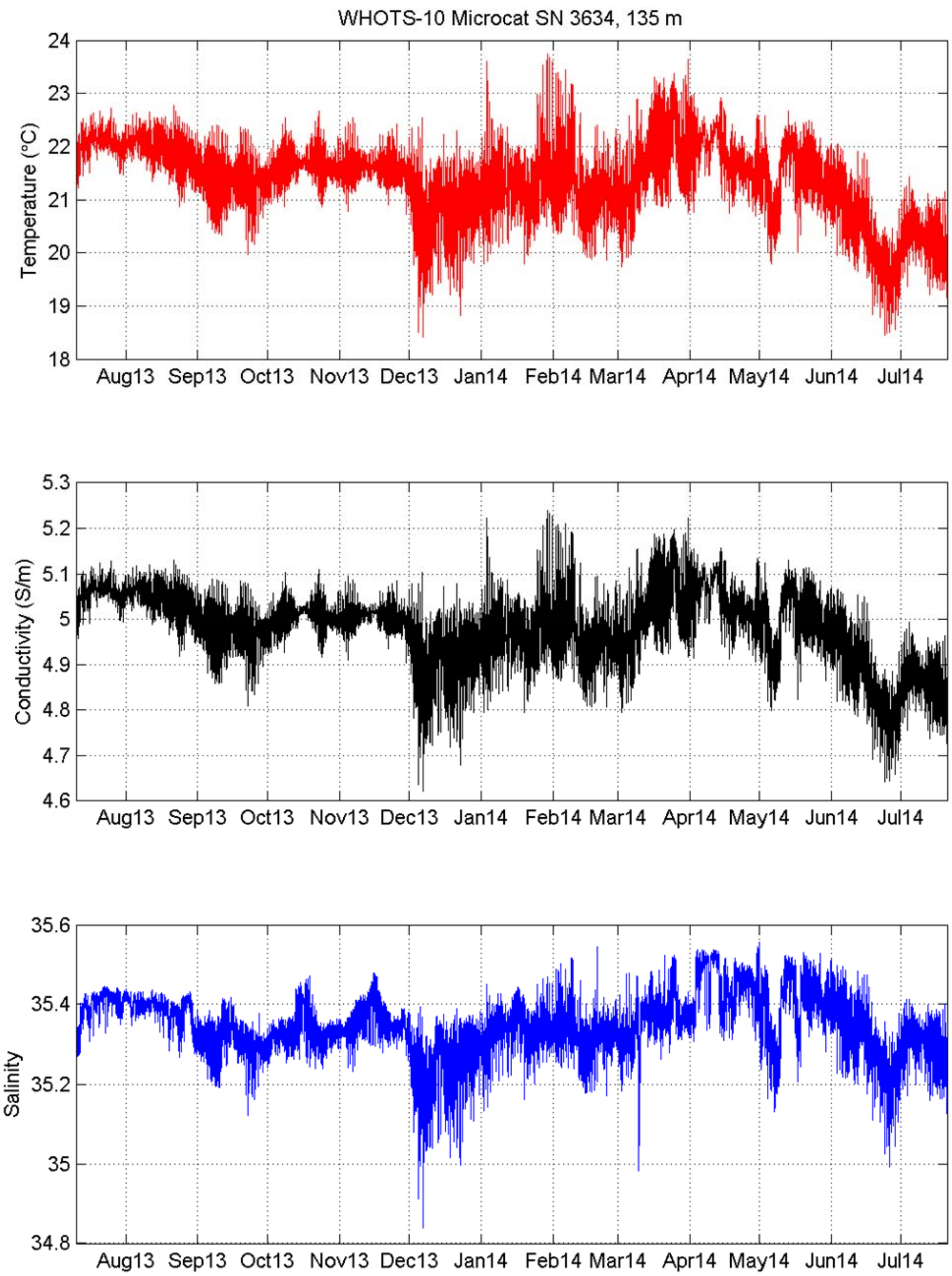


Figure C16. Temperature, conductivity and salinity from MicroCAT SBE-37 SN 3634 deployed at 135 m on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure to calculate salinity.

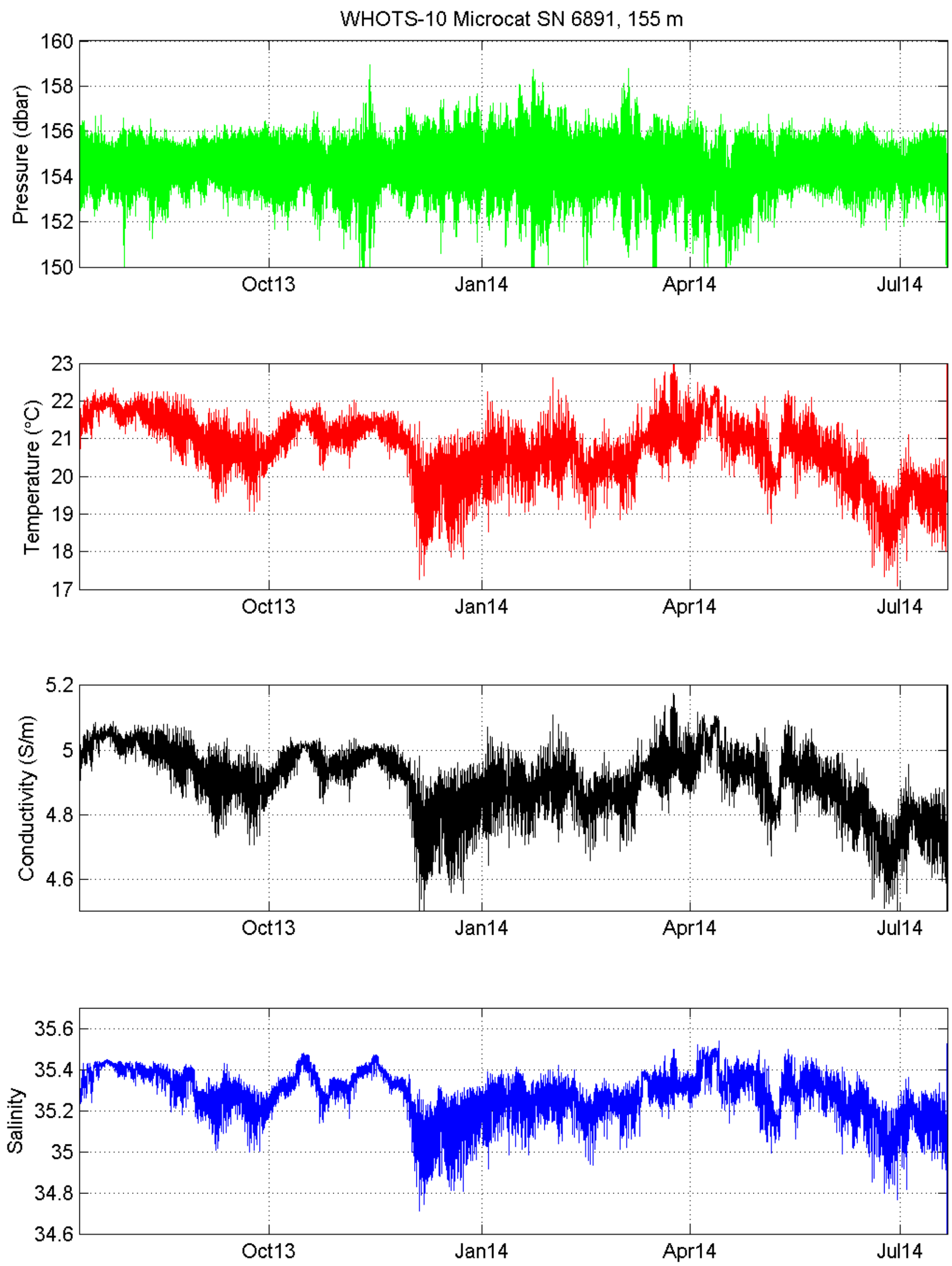


Figure C17. Pressure, temperature, conductivity and salinity from MicroCAT SBE-37 SN 6891 deployed at 155 m on the WHOTS-10 mooring. Pre-deployment calibration information was used.

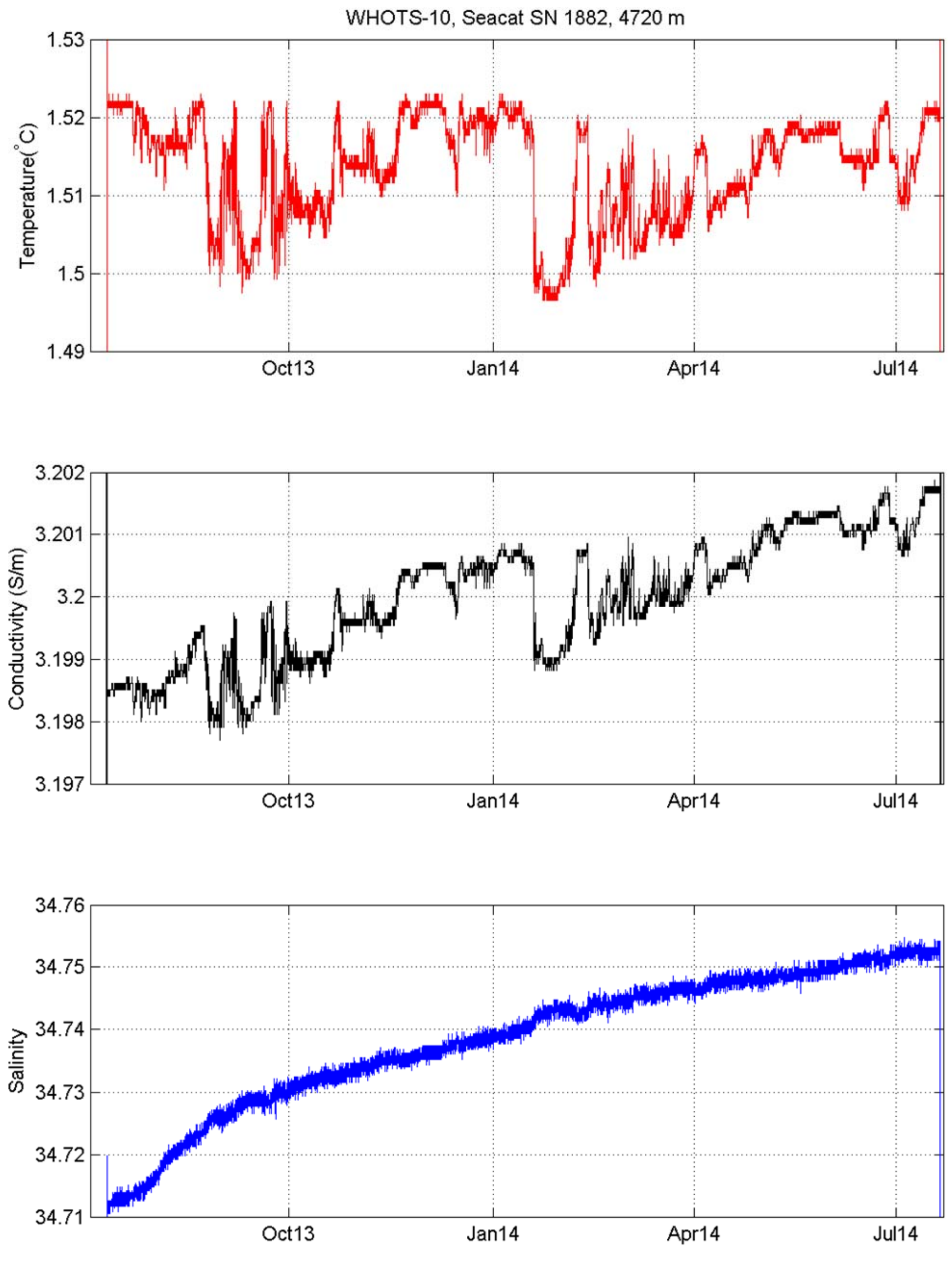


Figure C18. Temperature, conductivity and salinity from SeaCAT SBE-16 SN 1882 deployed 36 m above the bottom on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure was used to calculate salinity.

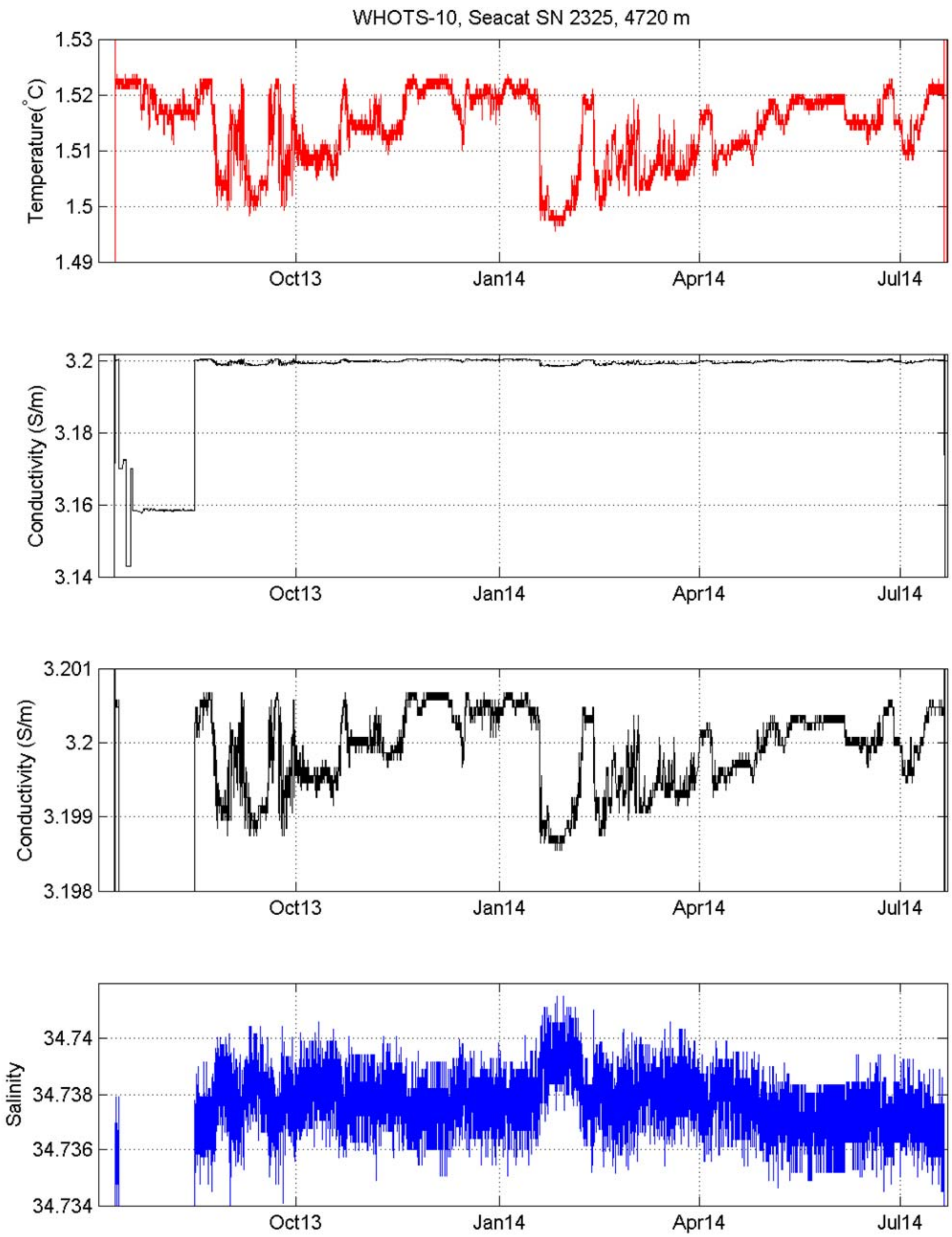


Figure C19. Temperature, conductivity and salinity from SeaCAT SBE-16 SN 2325 deployed 36 m above the bottom on the WHOTS-10 mooring. Pre-deployment calibration information was used. Nominal pressure was used to calculate salinity.

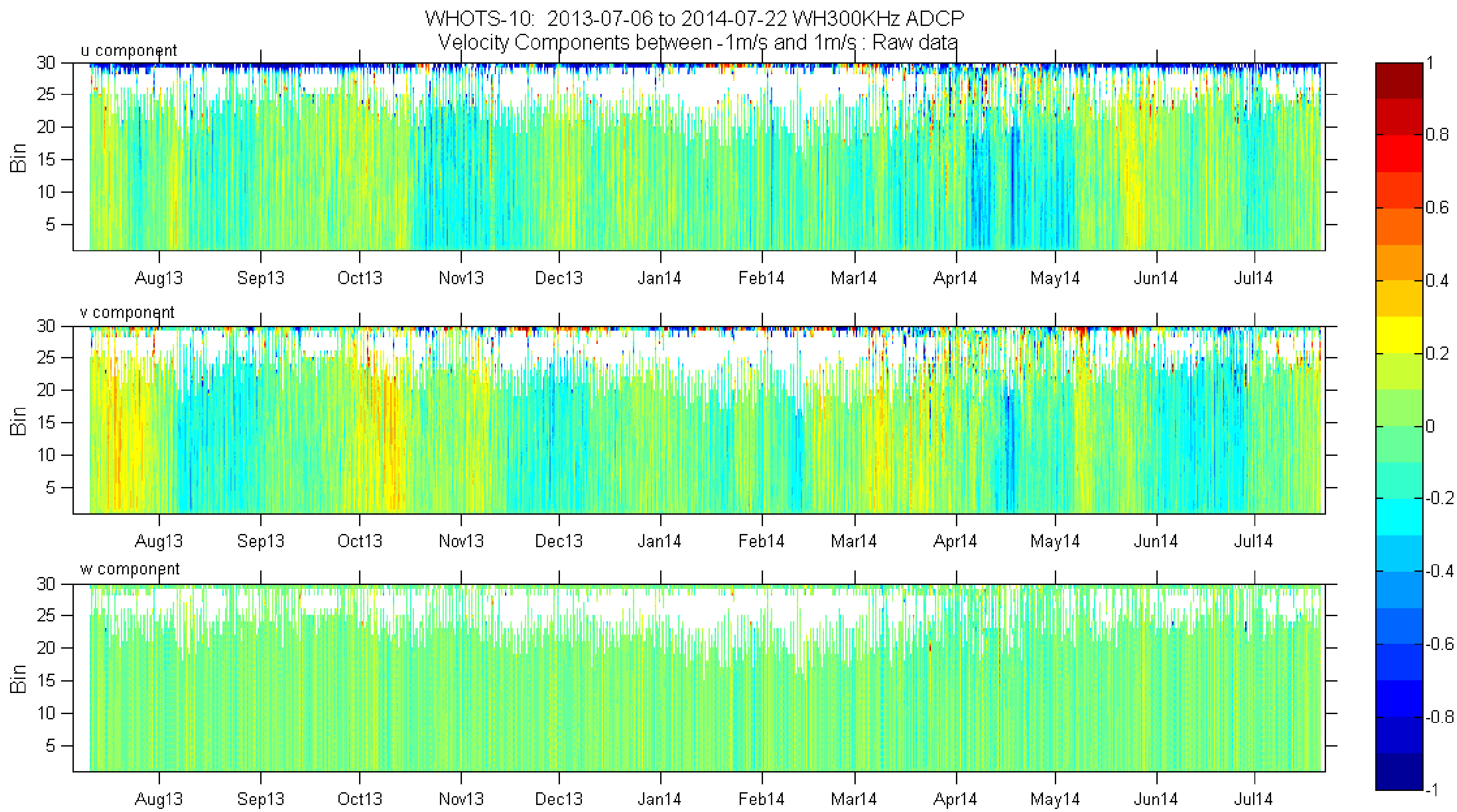


Figure C20. Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 125 m depth on the WHOTS-10 mooring. Height in meters above the transducer is approximately 4 times the bin number. Current speeds greater than 1 m/s are not included. Color bar gives current speed in m/s.

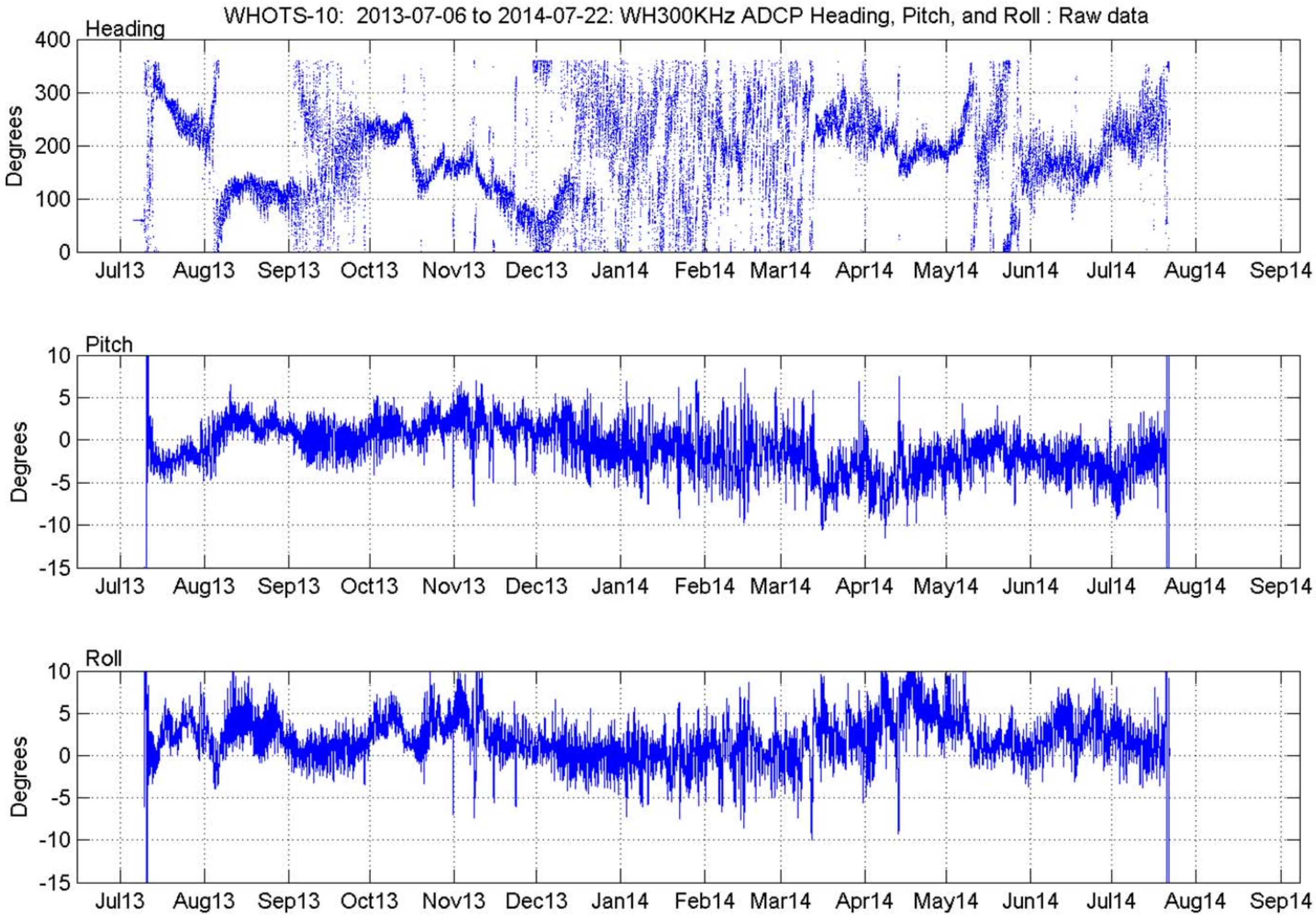


Figure C21. Heading, pitch and roll variations measured by the ADCP at 125 m depth on the WHOTS-10 mooring.

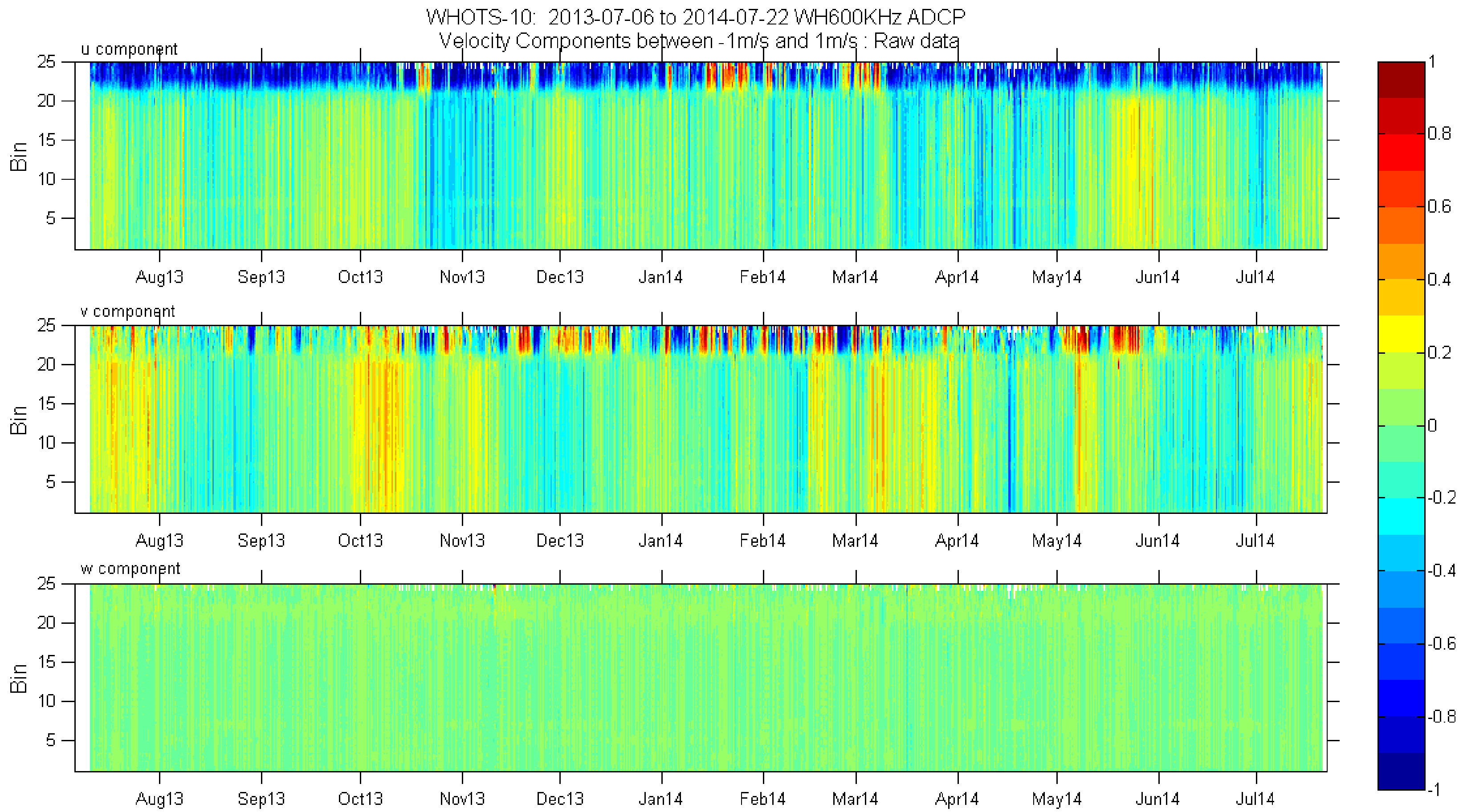


Figure C22. Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 47.5 m depth on the WHOTS-10 mooring. Height in meters above the transducer is approximately 2 times the bin number. Current speeds greater than 1 m/s are not included. Color bar gives current speed in m/s.

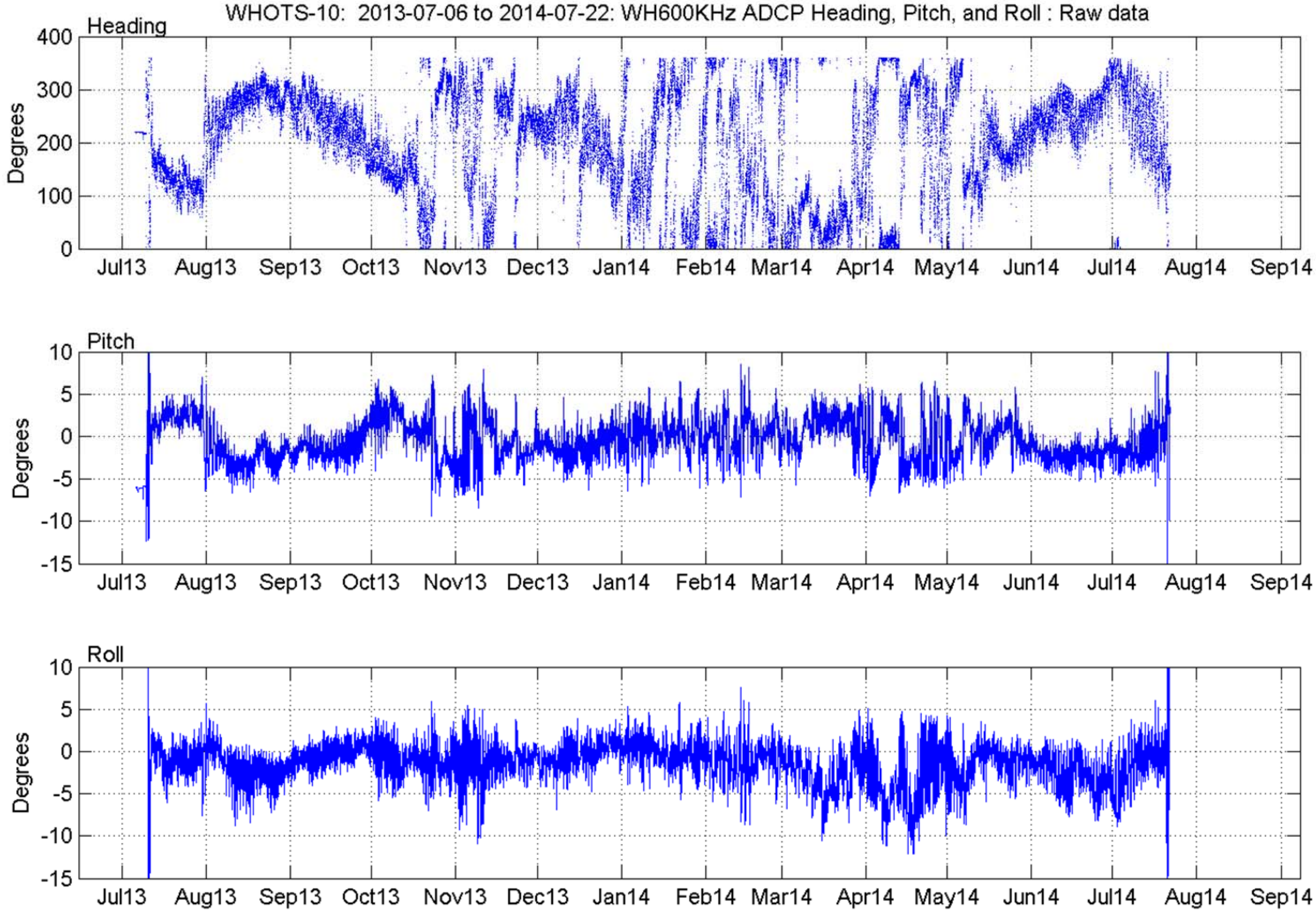


Figure C23. Heading, pitch and roll variations measured by the ADCP at 47.5 m depth on the WHOTS-10 mooring.

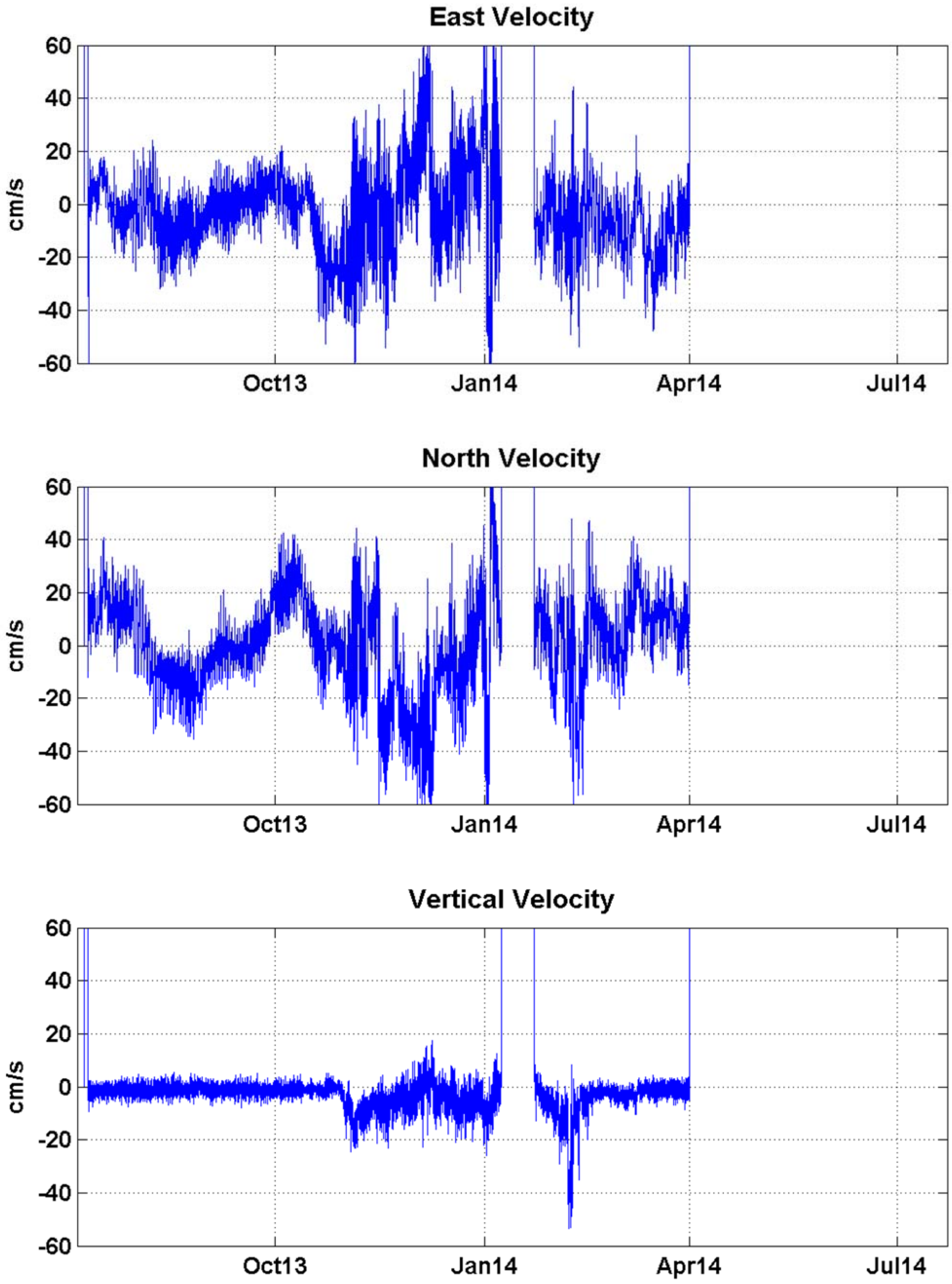


Figure C24. Computed u, v and w velocities from the MAVS at 20 m depth on the WHOTS-10 mooring.

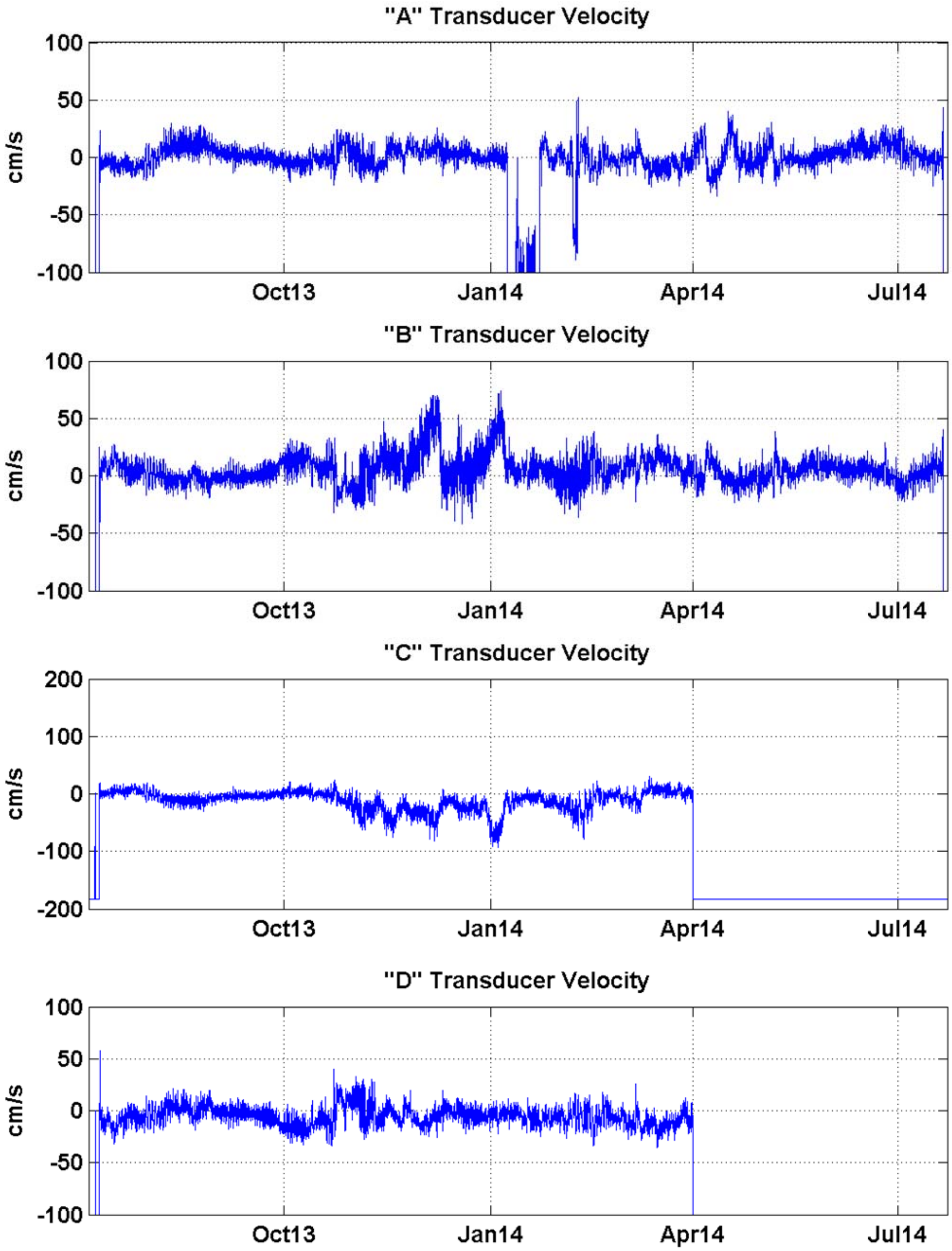


Figure C25. Time-series of the raw acoustic velocity measured by each transducer from the MAVS at 20 m depth on the WHOTS-10 mooring.

Appendix D: CTD Stations and Data Summary

UH provided CTD and water sampling equipment, including a Sea-Bird 9/11+ CTD sampling pressure, dual temperature, dual conductivity and dual oxygen sensors at 24 Hz. Sea-Bird sensors used routinely as part of the Hawaii Ocean Time-series were employed to tie the WHOTS cruise data into the HOT CTD dataset. The CTD was installed inside a twelve-place Sea-Bird SBE-32 rosette with six 5-liter Niskin sampling bottles controlled by a Sea-Bird carousel. Table D1 provides summary information for all CTD casts, and Figures D1-D9 show the water column profile information that were obtained.

Table D1. WHOTS-10 ADCP and MAVS deployment and recovery information.

Station/cast	Date	In-water Time (UTC)	Location *(using NMEA data)*	Maximum pressure (dbar)
1 / 1	7/16/14	00:41	21° 28.04´ N, 158° 21.07´ W	1024
50 / 1	7/17/14	16:10	22° 46.38´ N, 157° 57.37´ W	945
50 / 2	7/17/14	19:54	22° 45.79´ N, 157° 56.15´ W	206
50 / 3	7/18/14	00:05	22° 46.77´ N, 157° 55.64´ W	206
50 / 4	7/18/14	04:28	22° 46.40´ N, 157° 55.86´ W	201
50 / 5	7/18/14	08:11	22° 46.50´ N, 157° 55.87´ W	203
52 / 1	7/18/14	16:09	22° 40.42´ N, 157° 58.79´ W	205
52 / 2	7/18/14	19:57	22° 40.72´ N, 157° 58.78´ W	206
52 / 3	7/18/14	23:49	22° 40.89´ N, 157° 58.56´ W	204
52 / 4	7/19/14	03:53	22° 41.04´ N, 157° 58.74´ W	205
52 / 5	7/19/14	07:45	22° 40.99´ N, 157° 58.74´ W	208
50 / 6	7/22/14	16:02	22° 47.07´ N, 157° 55.65´ W	204
2 / 1	7/23/14	01:59	22° 44.93´ N, 157° 59.55´ W	1001

Thirteen CTD casts were conducted during the WHOTS-11 cruise, from July 16 – 23. CTD profile data were collected at a deep test site (Station 1 south of Kaena Ridge and offshore of Makaha), at Station 50 (near the WHOTS-11 buoy), Station 52 (near the WHOTS-10 buoy), and at Station ALOHA (Station 2). The test cast was 1000 m deep, and the acoustic releases for the WHOTS-11 mooring were attached to the rosette frame for function testing. Six CTD yo-yo casts were conducted to obtain profiles for comparison with subsurface instruments on the WHOTS-11 mooring after deployment, and five yo-yo casts were conducted for comparison with the WHOTS-10 mooring before recovery. These were started approximately 200 to 500 m from the buoys with varying drift during each cast. The comparison casts consisted of 5 up-down cycles between 5 dbar and 200 dbar, except during the first cast at Station 50. The first cycle of this cast was to 945 dbar to correct overlapping wraps of cable that had developed on the winch at about 360 m due to incorrect level winding during the previous CTD cast (Station 1). After correcting for this, the rest of the yo-yo casts were conducted to a maximum of 210 m of wire out, except for the last cast of the cruise, which was conducted near the center of Station ALOHA to 1000 dbar.

Water samples were taken from all casts; 4 samples for each of the yo-yo casts, and 6 from the test cast and the cast at Station ALOHA. These samples will be analyzed for salinity at UH and used to calibrate the CTD conductivity sensors.

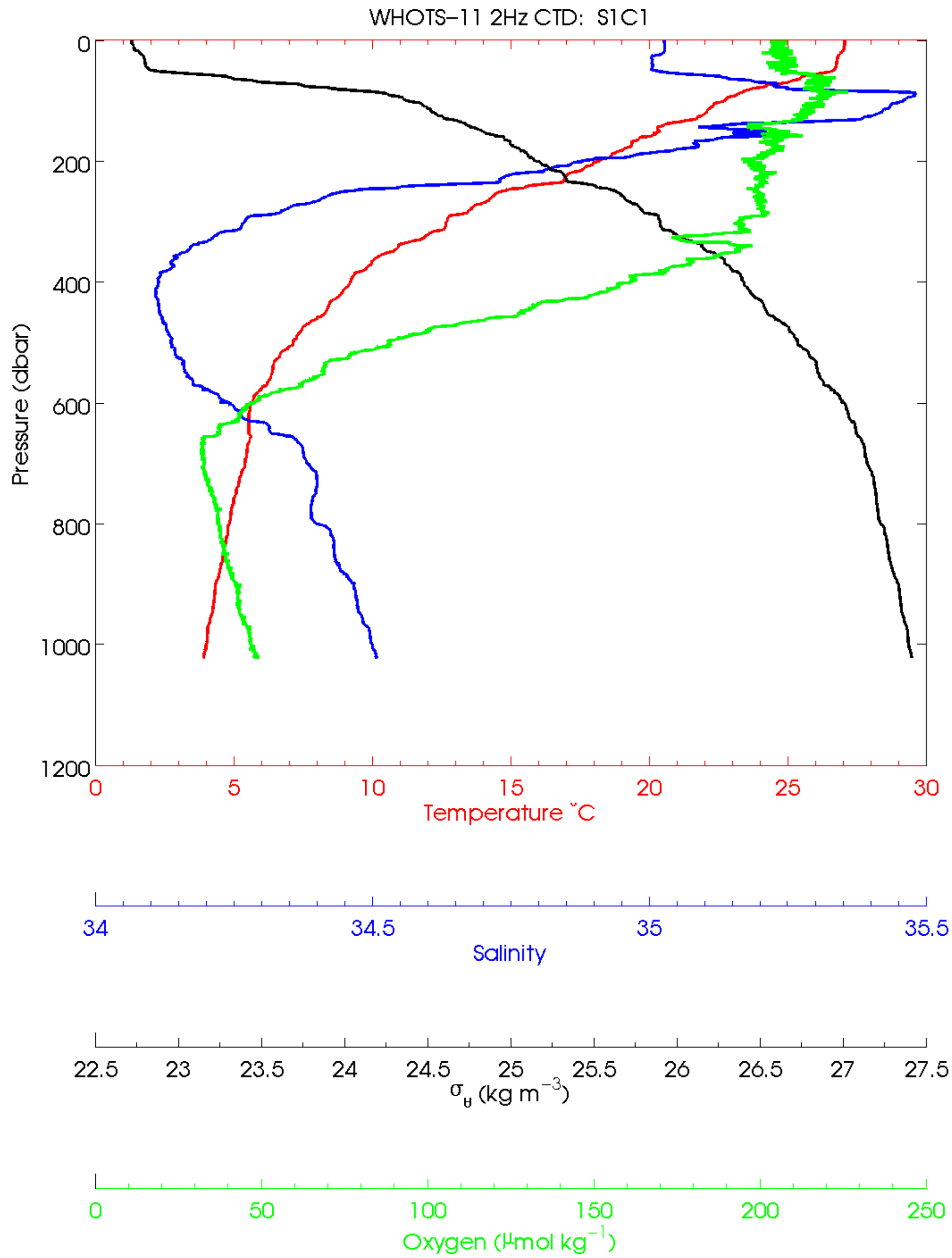


Figure D1. Profiles of temperature, salinity, potential density and oxygen data from the CTD test cast.

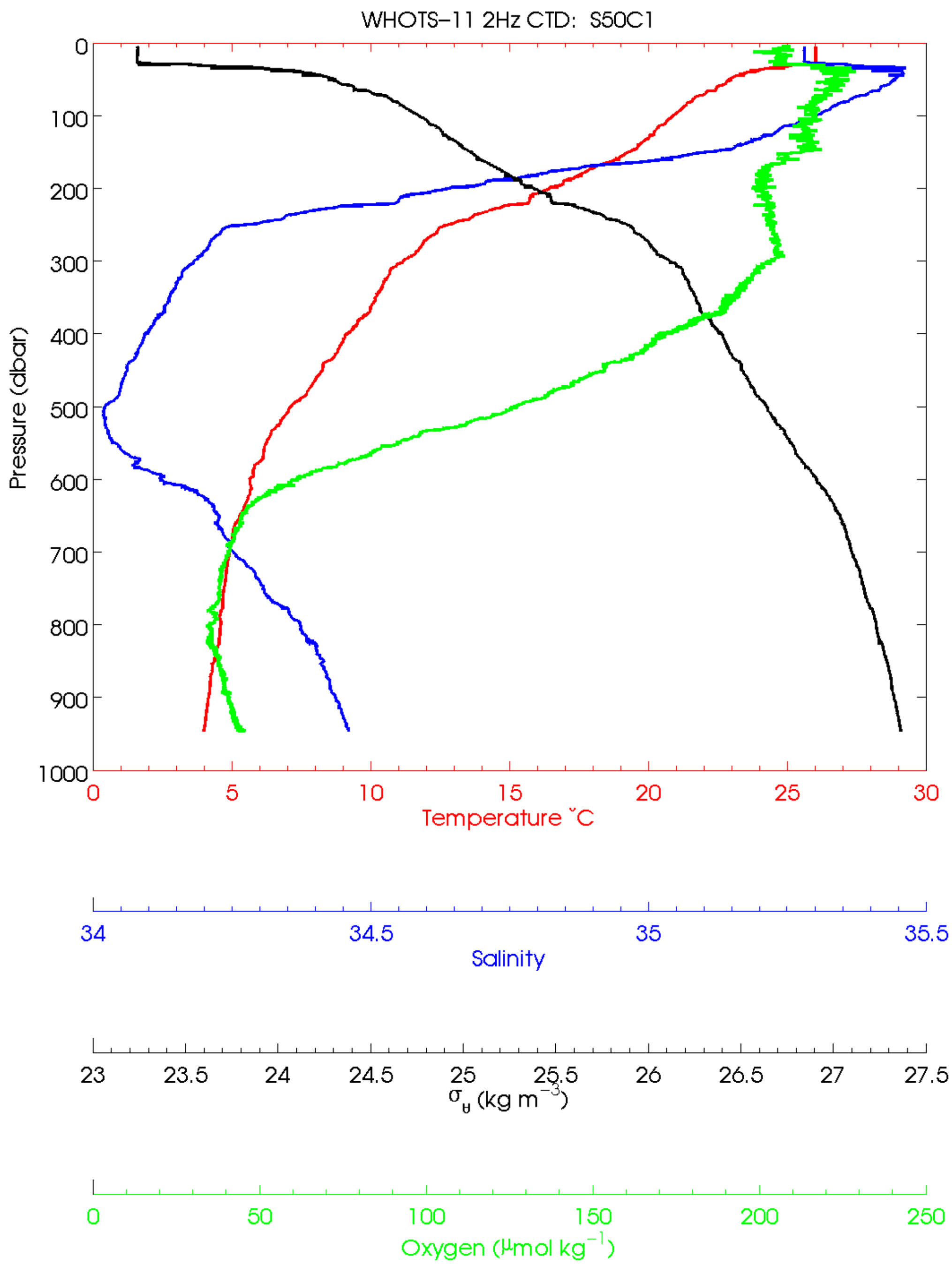


Figure D2. Profiles of 2 Hz temperature, salinity, potential density and oxygen data near the WHOTS-11 mooring during CTD Station 50 Cast 1.

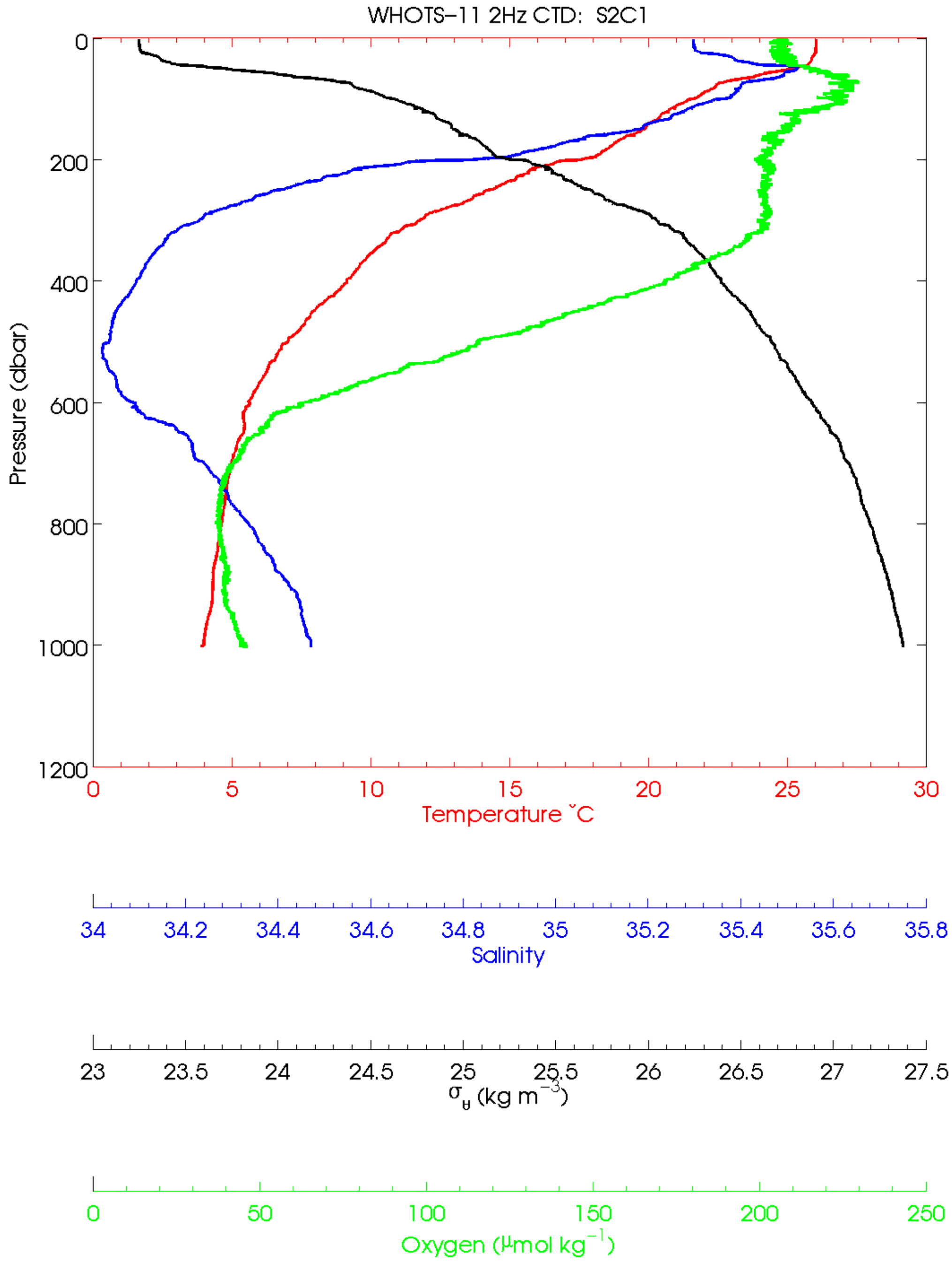


Figure D3. Profiles of 2 Hz temperature, salinity, potential density and oxygen data at ALOHA Station during CTD Station 2 Cast 1.

WHOTS-11 CTD Casts at Station 50 (WHOTS-11 Mooring)

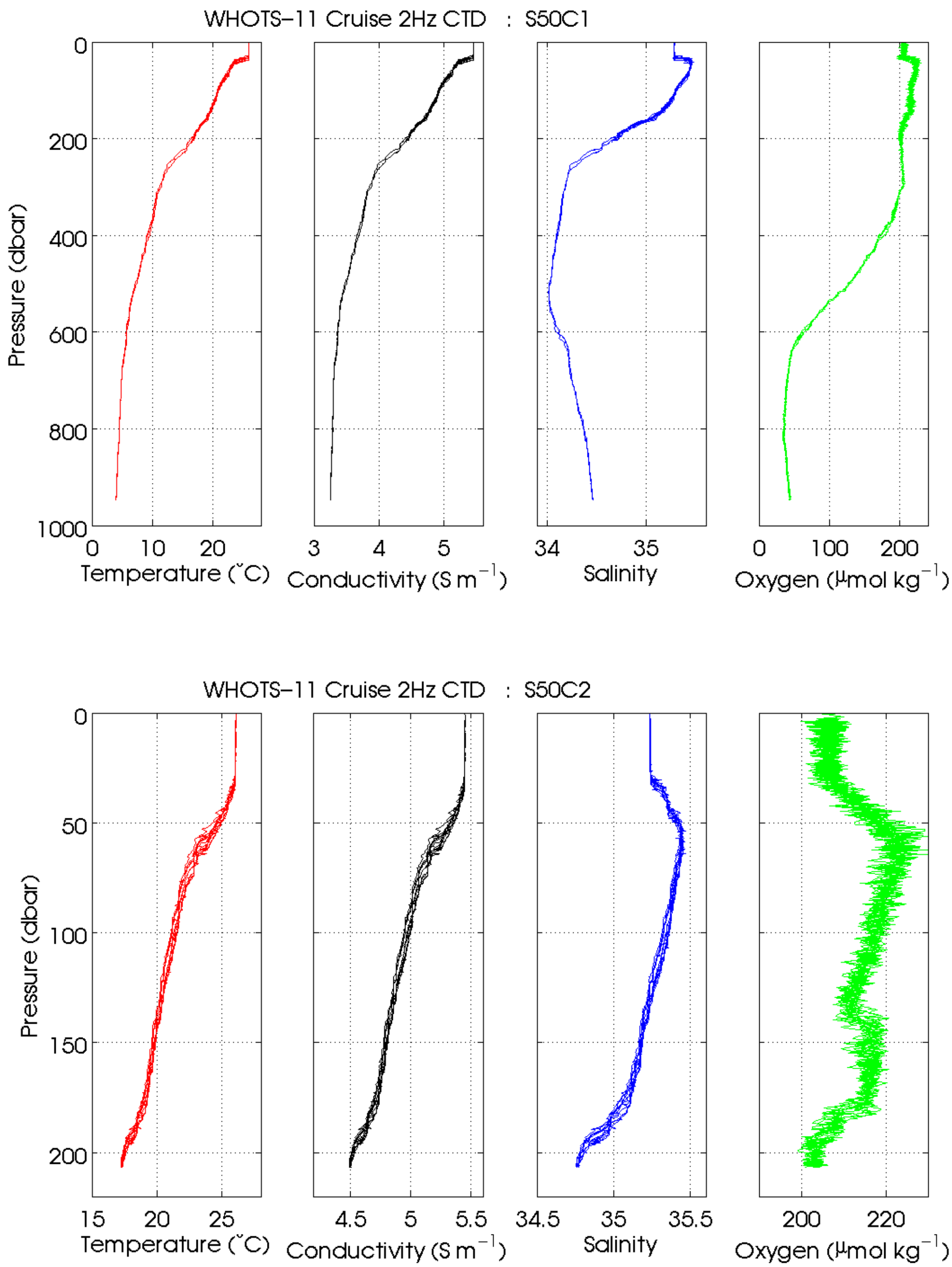
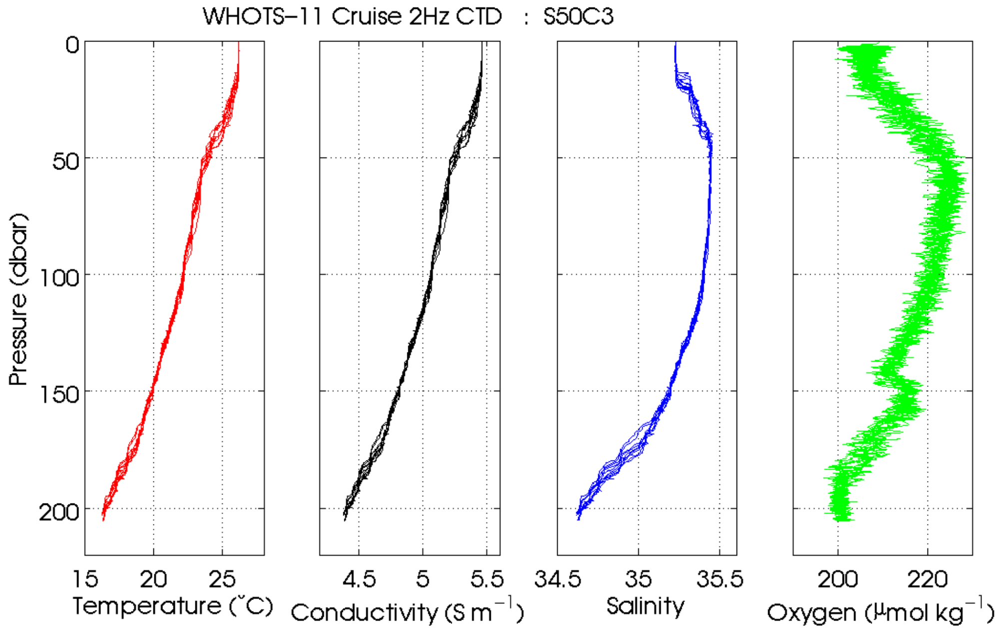


Figure D4. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S50C1 and S50C2.



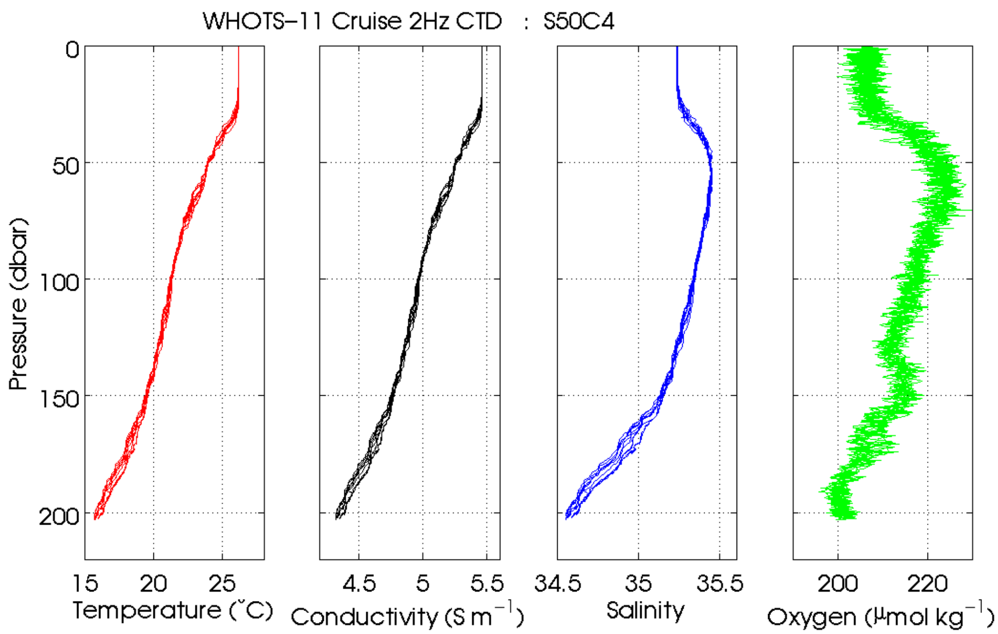


Figure D5. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S50C3 and S50C4.

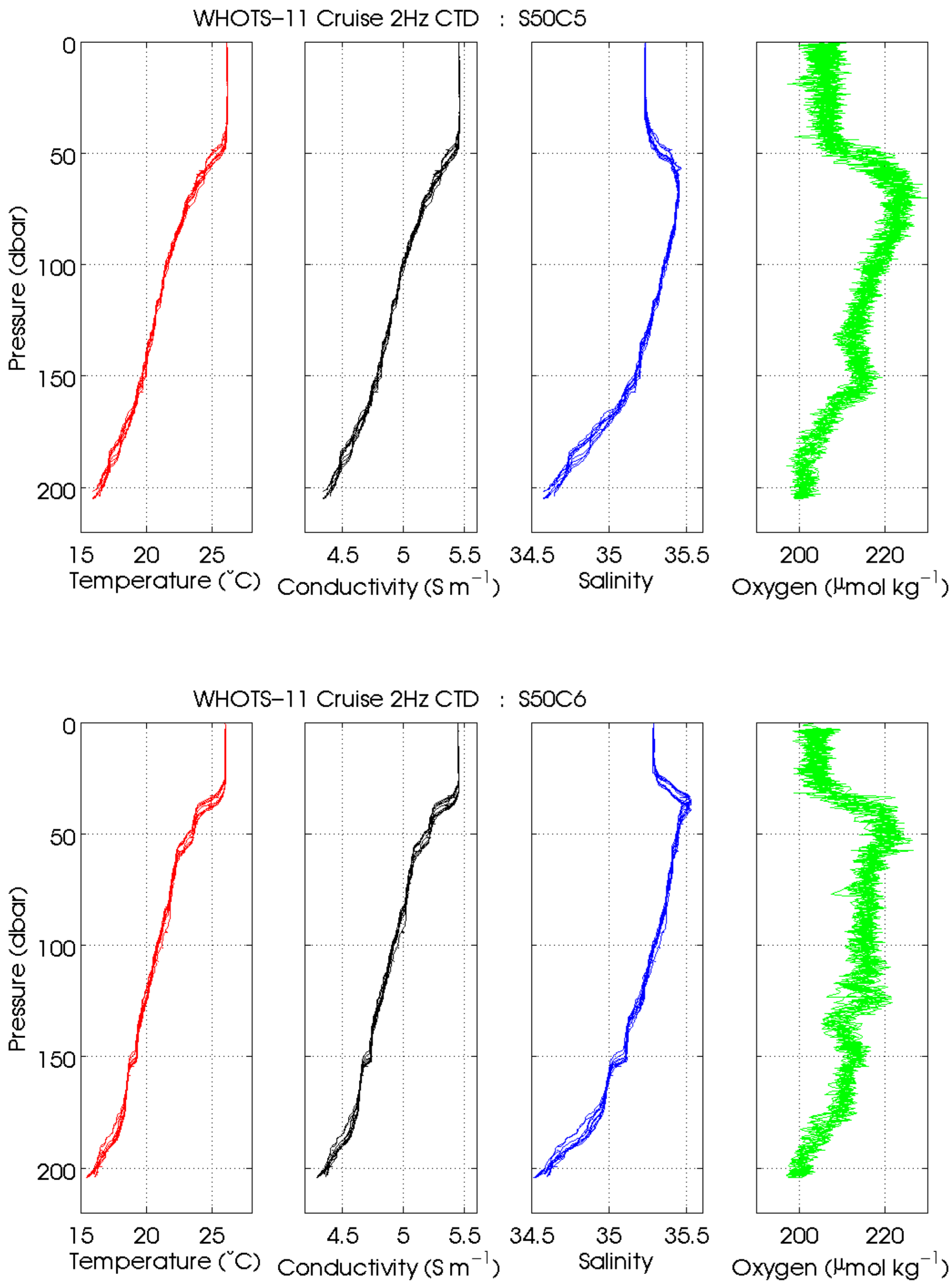


Figure D6. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S50C5 and S50C6.

WHOTS-11 CTD Casts at Station 52 (WHOTS-10 Mooring)

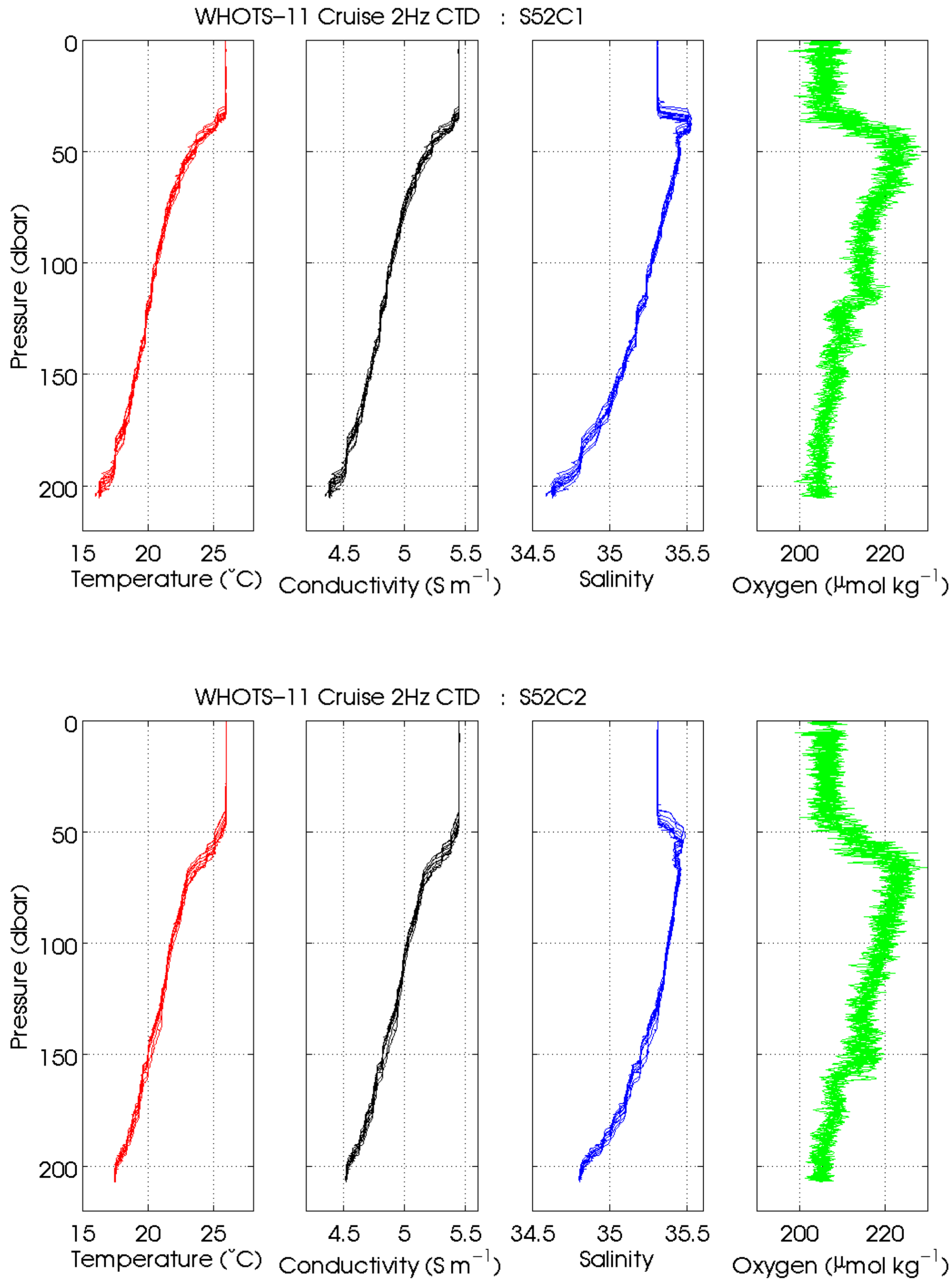


Figure D7. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S52C1 and S52C2.

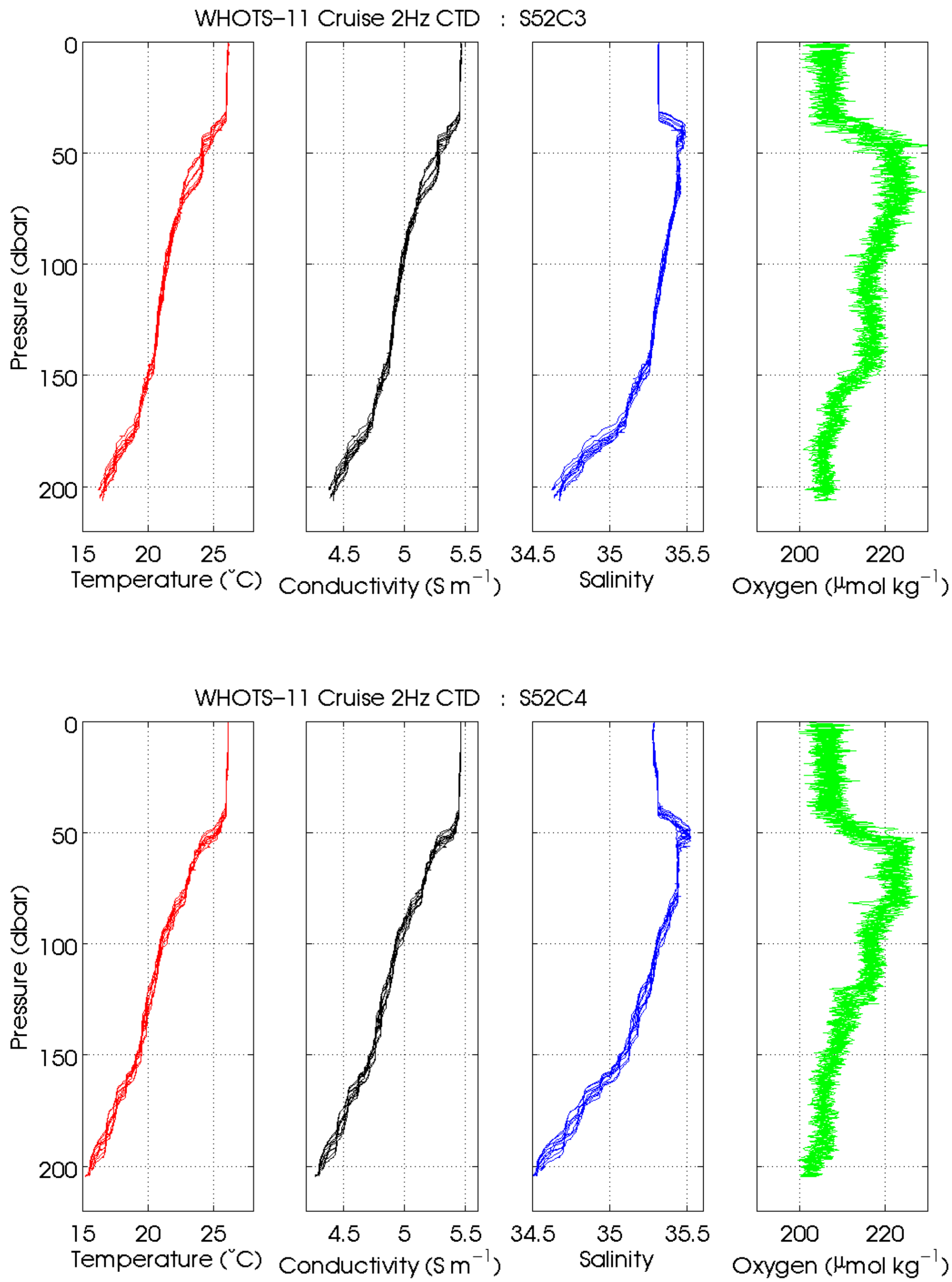


Figure D8. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S52C3 and S52C4.

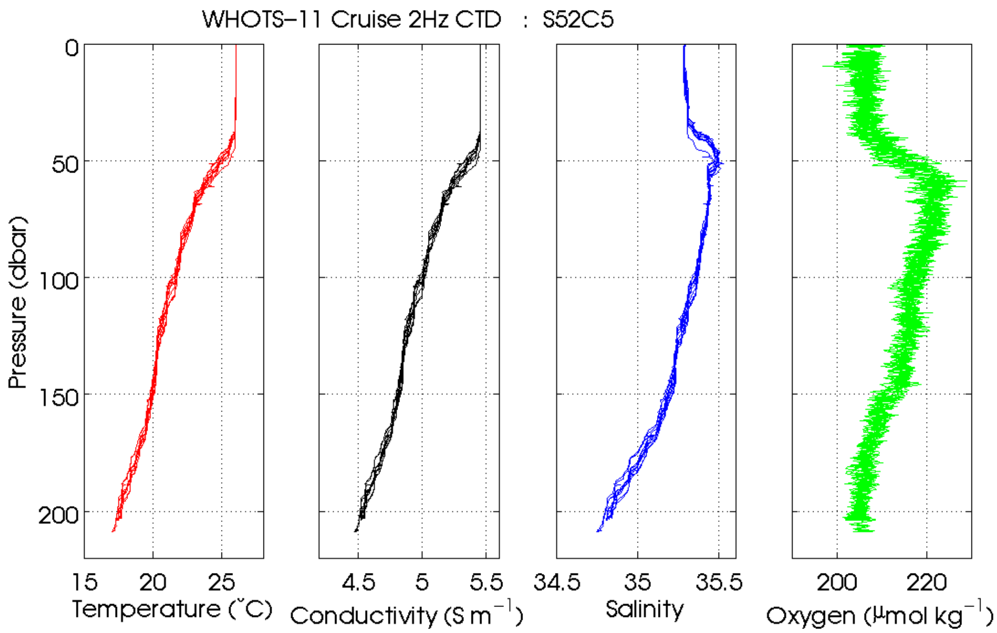


Figure D9. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during S52C5.

Appendix E: Thermosalinograph Data

Near-surface temperature and salinity data during the WHOTS-11 cruise were acquired from the thermosalinograph (TSG) system installed on the NOAA Ship *Hi'ialakai*. The sensors were sampling water from the continuous seawater system running through the ship, and were comprised of a thermosalinograph model SBE-21 (SN 3233) with (internal) temperature and conductivity sensors located in the ship's wet lab, about 67 m from the intake, and an SBE-38 (SN 227) external temperature sensor located at the water intake. The ship's system running SeaSave (Sea-Bird) recorded data from these sensors every 10 seconds. The *Hi'ialaki* has a water intake depth of 2 m located at the bow of the ship, next to the starboard side bow thruster. The water pressure at the thermosalinograph is between 5 and 7 psi.

Thermosalinograph data exhibited large spikes in conductivity, which often occur due to bubble entrainment from the surface, especially during bad weather or while the ship is pitching in transit (Fig. E1). The rest of the conductivity data and the calculated salinity seem to be of good quality (Fig. E2). The records from the external and internal temperature sensors are also of good quality, the internal temperature is 0.04 °C lower on average than the external temperature, probably due to cooling from the ship's A/C system while the water travels from the intake to the thermosalinograph. The ship's position data were not incorporated into the thermosalinograph logging system until July 16th due to wiring problems with the GPS system Fig. E3). Navigation data recorded elsewhere will be used during processing to complete this record.

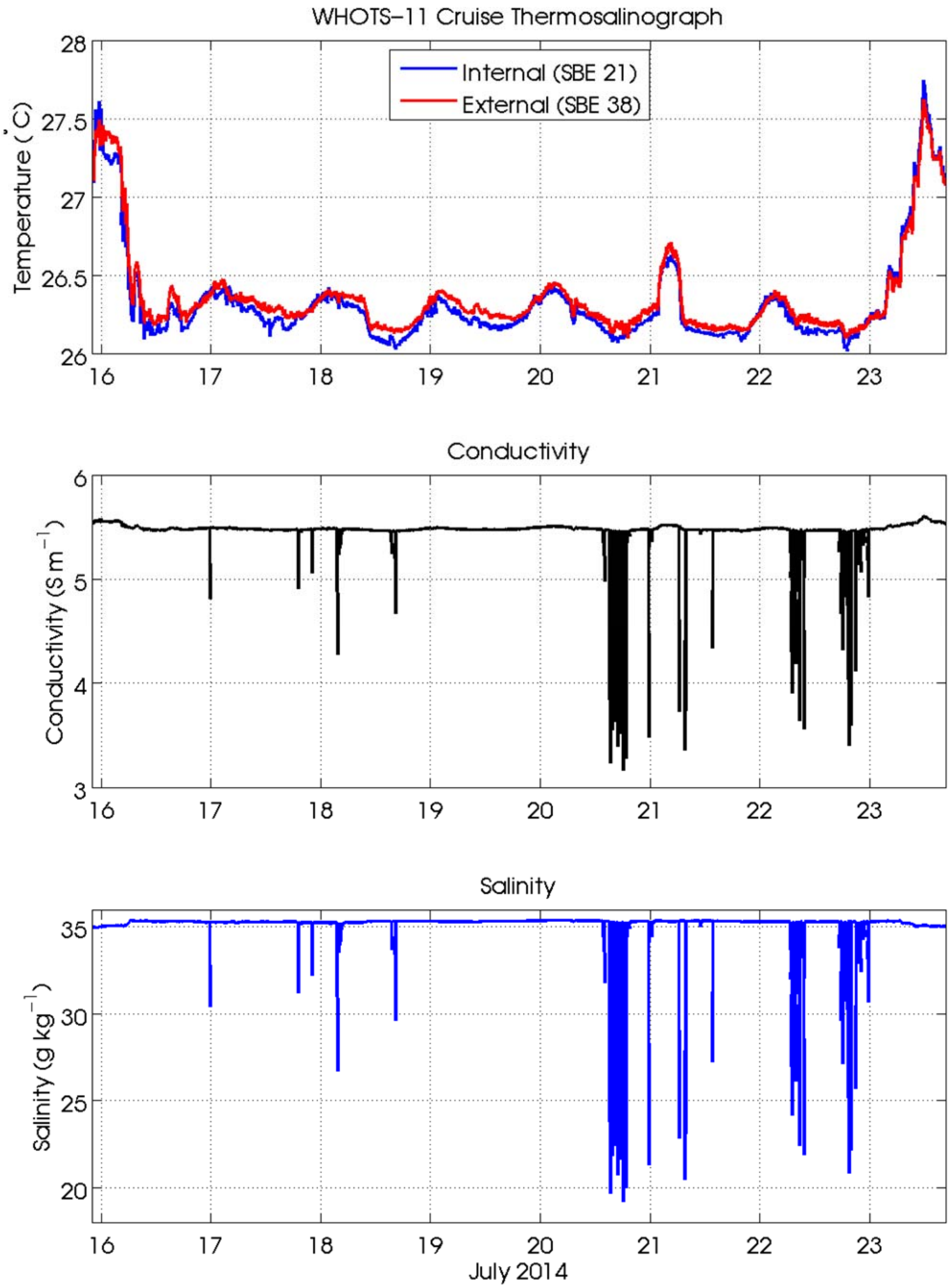


Figure E1. Time-series of Ship *Hi'ialakai* thermosalinograph data from the WHOTS-11 deployment cruise. Times are UTC.

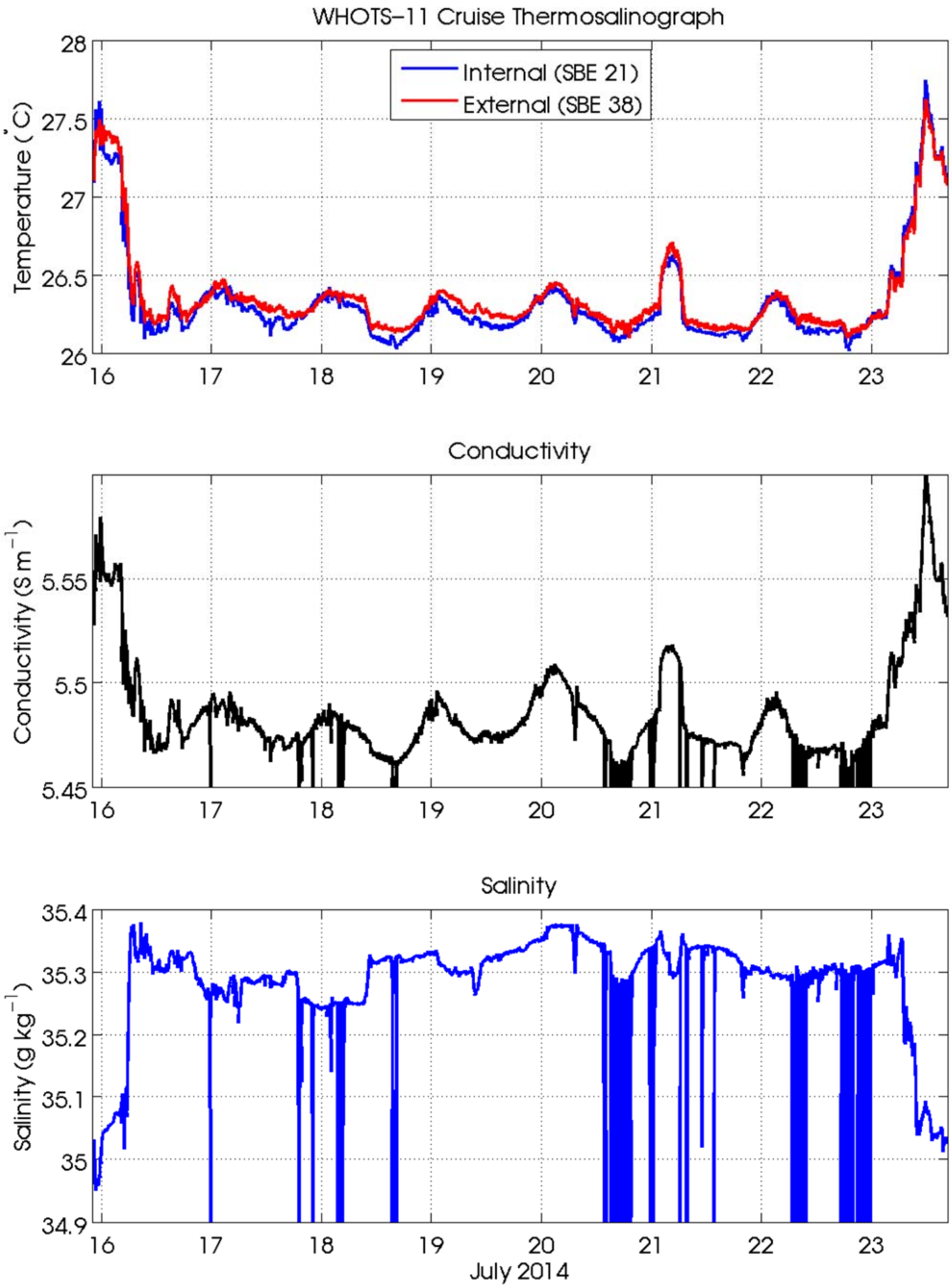


Figure E2. Same as in Figure 10a, but with different scales in the middle and bottom plots.

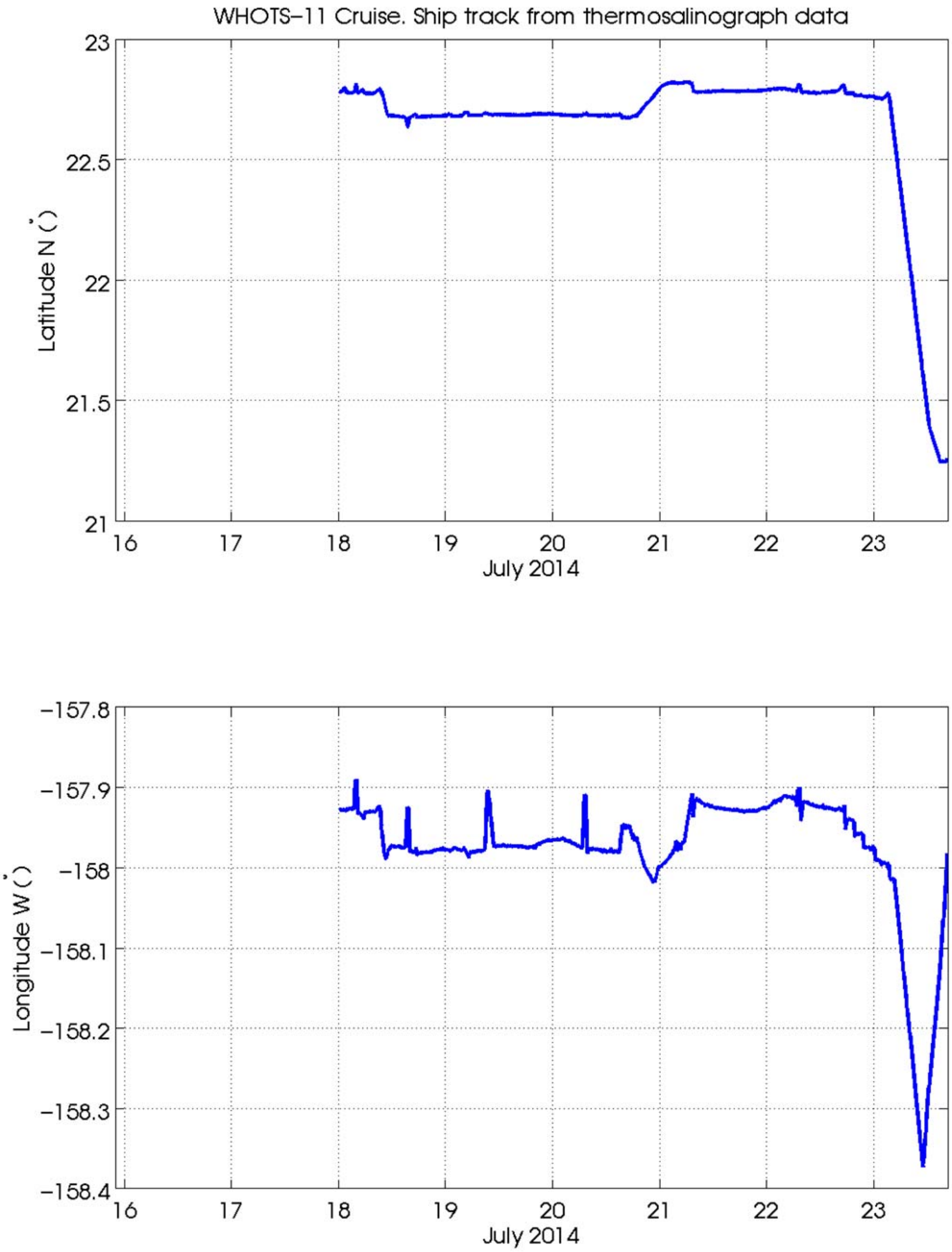


Figure E3. Time-series of Ship *Hi'ialakai* navigation data from the WHOTS-11 cruise.

Appendix F: WHOTS-10 Recovered Buoy Hull Instrumentation

Figure F1. WHOTS-10 buoy hull overview.

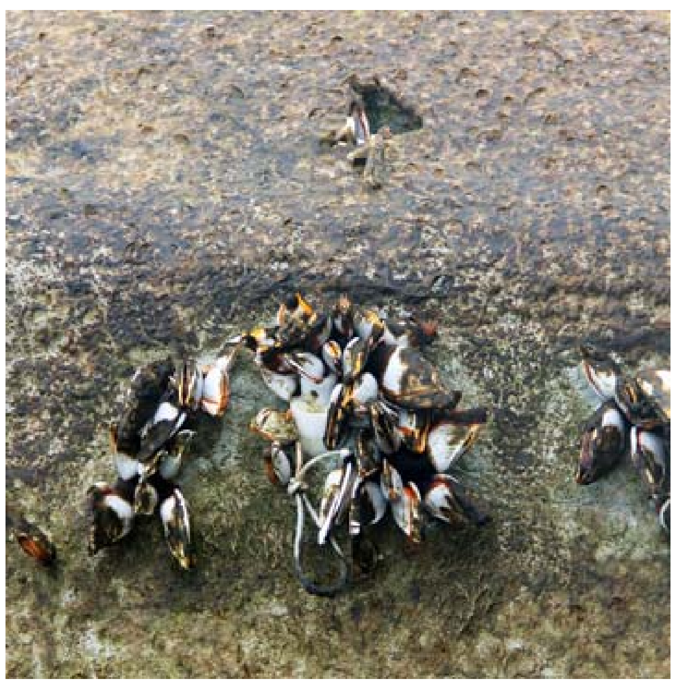


Figure F2. WHOTS-10 buoy hull SST instruments.

Figure F3. WHOTS-10 buoy hull SBE-37 instruments.

Figure F4. WHOTS-10 PMEL SBE-16 instrument.

Figure F5. WHOTS-10 PMEL SAMI-2 pH sensor.

Figure F6. WHOTS-10 chlorophyll fluorometer from below (left) and from the side (right).

Appendix G: Moored Station Logs

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-10 MOORED STATION NO. 1264

Launch (anchor over)

Date (day-mon-yr) 11 Jul 2013 | Time 04:26:53 UTC

Deployed by Pietro/Whelan | Recorder/Observer Plueddemann

Ship and Cruise No. Hi'ialakai HA-13-03 | Intended Duration 12 mo

Depth Recorder Reading 4737 m | Correction Source ducer depth + 5m, climatol. HOT site sound spd = 1505 = 0.3% = 14 m

Depth Correction 19 m

Corrected Water Depth 4756 m | Magnetic Variation (E/W)

Anchor Drop Lat. (N/S) 22°40.115 N | Lon. (E/W) 157° 56.830 W

Surveyed Pos. Lat. (N/S) 22° 40.118 N | Lon. (E/W) 157° 57.010 W

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

Acoustic Release Model BACS 8242 | Tested to 1000/500 m

Release No. 1 (sn) 32481	Release No. 2 (sn) 32483
Interrogate Freq. 11 kHz	Interrogate Freq. 11 kHz
Reply Freq. 12 kHz	Reply Freq. 12 kHz
Enable 114617	Enable 114703
Disable 114634	Disable 114720
Release 132132	Release 132174

Recovery (release fired)

Date (day-mon-yr) 20-07-2014 | Time 1623 UTC

Latitude (N/S) 22° 40.341 N | Longitude (E/W) 157° 56.977 W

Recovered by Pietro/Whelan | Recorder/Observer Plueddemann

Ship and Cruise No. HA-14-03 | Actual duration 375 days

Distance from waterline to buoy deck 65 cm

1

ARRAY NAME AND NO. WHOTS-10 MOORED STATION NO. 1264

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

Surface Instrumentation

Item	ID #	Height*	Comments
~~Logger~~ ASIMET	L15	buoy well	sys 1
HRH	221	235	
BPR	218	237	
WND	206	266	
PRC	219	248	
LWR	212	279	
SWR	502	279	
SST	1834	-151	
PTT	14637	—	IDs 7563, 7581, 7582
Logger	L08	buoy well	sys2
HRH	246	235	radiation shield smashed on recovery
BPR	234	237	
WND	344	266	
PRC	210	248	
LWR	214	279	
SWR	218	279	
SST	1841	-151	
PTT	12790	—	IDs 6930, 7387, 14708
Xeos Melo	7580	243	IMEI 300034013707580
SBE-39 AT	1446	224	
Vaisala WXT	002	258	
Lascar	12104	200	
pCO_2	0132		
radiom. (Laney)	(see pg 3)		

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. WHOTS-10 MOORED STATION NO. 1264

Subsurface Instrumentation on Buoy and Bridle			
Item	ID #	Depth†	Comments
SST	14813	82	RBR 1060, 180° cw fr. vane
SST	14879	96	RBR 1060, 180°
SST	14875	82	RBR 1060, 240°
SST	19714	82	RBR 1060, 120°
SiS	14	buoy base	Argos beacon ID 24576
CTD	6883	151	PMEL SBE-16, optode + fluoro
pH	P0032	151	PMEL SAMI pH
Fluoro	SCF3257	151	Laney fluoro.
Laney	radiometers on tower		
Irrad.	835E	280	uplooking on tower
Rad	835A	176	downlooking, on vane. ← broken off mount + fell to deck on recovery
Rad	835B	176	" , stbd
Rad	835D	176	" , bow
Rad	835F	176	" , port

†Depth below buoy deck in centimeters

3

ARRAY NAME AND NO. WHOTS-10 MOORED STATION NO. 1264

Item No.	Length (m)	Item	Depth	Inst No.	Time Over (10 July, UTC)	Time Back (21 July)	Notes
1		buoy	0	—	1903	0504	
2	7.75	3/4 chain		—			
3		VMCM	10	016	1833	0512	bands off 1825
4	2.82	3/4 chain		—			
5		μCAT	15	6893	1833	0514	
6	3.6	3/4 chain		—			
7		MAVS	20	10260 ~~6894~~	1827	0518	
8	2.8	3/4 chain		—			
9		μCAT	25	6894	1814	0521	3 dunks while dealing w/ MAVS
10	3.28	3/4 chain		—	(1822) (1826)		
11		VMCM	30	019	1808	0524	bands off 1806 ← broken blade on both upper + lower props
12	2.82	3/4 chain		—			
13		μCAT	35	6895	1807	0525	
14	3.66	3/4 chain		—			
15		μCAT	40	6896	1803	0528	
16	3.66	3/4 chain		—			
17		μCAT	45	6887	1758	0528	broke mooring here for recovery + cast off buoy
18	1.07	~~ADCP~~ 3/4 chain		—			
19		ADCP	47.5	1825	1922	0322	600kHz
20	75.5	7/16 wire		13025-7		0322	
21		μCAT	50	6897	1922	0322	clamped to wire
22		μCAT	55	6898	1923	0321	"
23		μCAT	65	6899	1924	0320	"
24		μCAT	75	3618	1925	0319	"
25		μCAT	85	6888	1927	0318	"

4

ARRAY NAME AND NO. WHOTS-10 MOORED STATION NO. 1264

Item No.	Length (m)	Item	Depth	Inst No.	Time Over (10 July)	Time Back (21 July)	Notes
26		µCAT	95	3617	1927	0317	clamped to wire ← missing upper clamp recovery
27		µCAT	105	6889	1928	0316	"
28		µCAT	120	6890	1929	0315	"
29		ADCP	125	4891 ~~3169~~	1934	0312	300 kHz
30	250	3/8 wire		11257-4	~~1257~~	0312	
31		µCAT	135	3634	1935	0311	
32		µCAT	155	6891	1936	0308	
33	500	3/8 wire		13025-3		0303	
34	500	3/8 wire		1127-1	2021	0251	shackle/link hockled on recovery
35	500	3/8 wire		13025-1	2044	0239	
36	100	3/8 wire		13025-5	2108	0226	← Problem with air tugger brake
37	200	7/8 nylon		—	2112	0222	
38	2100	7/8 nylon		—	2134	0212	
39	1500	1" colmega		—	2240	21 July 0059	
40		glass balls		—	11 July 0002	20 July 2015	counted 9 strings of 8 = 72 10 broken on recovery
41		SBE-16	36 m above bottom	1882	0324	2053	no antifoul plugs on either instrument
42		SBE-16		2325	0324	2053	
43	5	1/2 chain		—			
44		Release		32481	0325	2054	
45		Release		32483	0325	2054	
46	5	1/2" chain		—			
47	20	1" nystron		—			
48	5	1/2 chain		—			
49		anchor		—	0426	—	9300 lb (air)
50							

5

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-11 MOORED STATION NO. 1267

Launch (anchor over)

Date (day-mon-yr) 17-07-2014	Time 0240 UTC
Deployed by Pietro/Whelan	Recorder/Observer Plueddemann
Ship and Cruise No. Hi'ialakai HA-14-03	Intended Duration 12 mo
Depth Recorder Reading 4689 m	Correction Source ducer depth +5m, HOT sspd =1504, 0.27% =+13 m
Depth Correction 18 m	
Corrected Water Depth 4707 m	Magnetic Variation (E/W)
Anchor Drop Lat. (N/S) 22° 46.035 N	Lon. (E/W) 157° 53.784' W
Surveyed Pos. Lat. (N/S) 22° 45.981	Lon. (E/W) 157° 53.964 W
Argos Platform ID No. see pg 2+3	Additional Argos Info on pages 2 and 3

Acoustic Release Model ~~EGG~~ 8242	Tested to ~~1500~~ 1000 m m

Release No. 1 (sn) 35316	Release No. 2 (sn) 35317
Interrogate Freq. 11kHz	Interrogate Freq. 11 kHz
Reply Freq. 12kHz	Reply Freq. 12kHz
Enable 111273	Enable ~~127~~ 111321
Disable 111302	Disable 111344
Release 127413	Release 127430

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-11 MOORED STATION NO. 1267

Surface Components

Buoy Type MOB Color(s) Hull Tower gray hull, white tower

Buoy Markings 'B', If found adrift: U. Hawaii 808-956-7896

Surface Instrumentation

Item	ID #	Height*	Comments
Logger	L19	—	
PTT	99595	—	IDs 14663, 14677, 14697
HRH	219	222	
BPR	212	235	
WND	216	270	
PRC	501	247	
LWR	224	283	
SWR	201	283	
SST	1306	-151	
Logger	L07	—	
PTT	~~L07~~ 99596	—	IDs 27356, 27364, 27413
HRH	256	~~256~~ 222	
BPR	503	235	
WND	238	~~238~~ 270	
PRC	216	~~216~~ 247	
LWR	206	283	
SWR	223	283	
SST	1727	-151	
Xeos Melo	1980	242	IMEI 3000 340 1370 198
SBE-39 AT	5276	217	
Vaisala WXT	6	225	
Lascar	10020074	250	
pCO_2	see pg 3	—	
Radiom.	see pg 3	—	

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. WHOTS-11 MOORED STATION NO. 1267

Subsurface Instrumentation on Buoy and Bridle			
Item	**ID #**	**Depth†**	**Comments**
SST	76107	80	RBR Solo-T, 180° CW from vane
SST	76112	98	RBR Solo-T, 180°
SST	76105	80	RBR Solo-T, 120°
SST	76113	80	RBR Solo T, 240°
SIS	3		ID 009209 Argos beacon
PMEL	pCO2 system		
pCO2	144	90 ht,	Battelle pCO2
CTD	7409	~150	Seabird SBE-16
pH	95	~150	SEAFET pH
fluoro	3012	~150	ECO-FLNTU
oxygen	630480	~150	Seabird SBE-63
Laney	radiometers + fluoro		
Irrad	8396	282 ht	uplooking on tower
Rad	8394	175 ht	downlooking, stbd quarter
Rad	839B	175 ht	downlooking, port beam
Rad	8393	175 ht	downlooking, port quarter
Fluoro	SCF3256	150	Seapoint SCF, buoy hull
†Depth below buoy deck in centimeters			

3

ARRAY NAME AND NO. WHOTS-11 MOORED STATION NO. 1267

16 July 2014

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
1		buoy	0	—	1907		
2	5.26	3/4 chain		—			
3		µCAT	7	6892	1905		out of water again during haul-back, ~ 1920
4	1.30	3/4 chain		—			
5		VMCM	10	62	1842		bands off 1823
6	2.82	3/4 chain		—			
7		µCAT	15	3382 ~~3882~~	1826		
8	8.10	3/4 chain		—			
9		µCAT	25	4663	1817		
10	3.28	3/4 chain		—			
11		VMCM	30	83	1816		bands off 18:09
12	2.82	3/4 chain		-			
13		µCAT	35	3633	1812		
14	3.66	3/4 chain		—			
15		µCAT	40	3381	1807		
16	3.66	3/4 chain		—			
17	.	µCAT	45	3668	1801		
18	1.07	3/4 chain					
19		ADCP	47.5	13917	1930		600kHz
20	75.5	7/16 wire rope		13025-8			
21		µCAT	50	3619	1930		
22		µCAT	55	3620	1931		
23		µCAT	65	3621	1933		
24		µCAT	75	3632	1934		
25		µCAT	85	4699	1936		

4

ARRAY NAME AND NO. WHOTS-11 MOORED STATION NO. 1267

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
26		μCAT	95	3791	1937		
27		μCAT	105	2769	1938		
28		μCAT	120	4700	1945		
29		ADCP	125	7637	1945		300kHz
30	250	3/8 wire		13025-4			
31		μCAT	135	3669	1947		
32		μCAT	155	4701	1949		
33	500	3/8 wire		13025-2			
34	500	3/8 wire		14024-3			
35	500	3/8 wire		14024-1			
36	100	3/8 wire		13025-6			} urethane termination
37	200	7/8 nylon		—	2103		
38	2050	7/8 nylon		—	2144		
39	1500	1" colmega		—	2334		
40		glass balls			2350 start		qty 68 balls
41		SBE-16	} 36m above bottom	1880	} 0208 7/17		} no poison plugs
42		SBE-16		1881			
43	5	1/2 chain					
44		release		35316	} 0210		
45		release		35317			
46	5	1/2 chain					
47	20	1" samson					
48	5	1/2 chain					
49		anchor			0240		
50							End

5

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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.

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