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Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-3 Mooring Turnaround Cruise Report

by

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May 2007

Technical Report

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Woods Hole, MA 02543
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Approved for Distribution:

Robert A Weller

Robert A. Weller, Chair

Department of Physical Oceanography

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Abstract

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

The first WHOTS mooring (WHOTS-1) was deployed in August 2004. WHOTS-1 was recovered and WHOTS-2 deployed in July 2005. This report documents recovery of the WHOTS-2 mooring and deployment of the third mooring (WHOTS-3) at the same site. Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite, the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. WHOTS-2 was equipped with one Iridium data transmitter, and WHOTS-3 had two Iridium data transmitters. In cooperation with R. Lukas of the University of Hawaii, the upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity.

The WHOTS mooring turnaround was done on the Scripps Institution of Oceanography Ship *Revelle*, Cruise AMAT-07, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution and Roger Lukas' group at the University of Hawaii. The cruise took place between 22 and 29 June 2006. Operations on site were initiated with an intercomparison of shipboard meteorological observations with the WHOTS-2 buoy. Dr. Frank Bradley, CSIRO, Australia, assisted with these comparisons. This was followed by recovery of the WHOTS-2 mooring on 24 June. A number of recovered instruments were calibrated by attaching them to the rosette frame of the CTD. Shallow CTD profiles were taken every two hours for 12 hours on the 25th of June. A fish trap was deployed on June 25th by John Yeh, a University of Hawaii graduate student. The WHOTS-3 mooring was deployed on 26 June at approximately 22°46′N, 157°54′W in 4703 m of water. A ship-buoy intercomparison period and series of shallow CTDs followed along with a second deployment of the fishtrap.

A NOAA Teacher-At-Sea, Diana Griffiths, and a NOAA Hollings Scholar, Terry Smith, participated in the cruise. This report describes the mooring operations, some of the pre-cruise buoy preparations and CTD casts taken during the cruise, the fish trap deployments, and the experiences of the Teacher-At-Sea and Hollings Scholar.

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1. Introduction

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

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

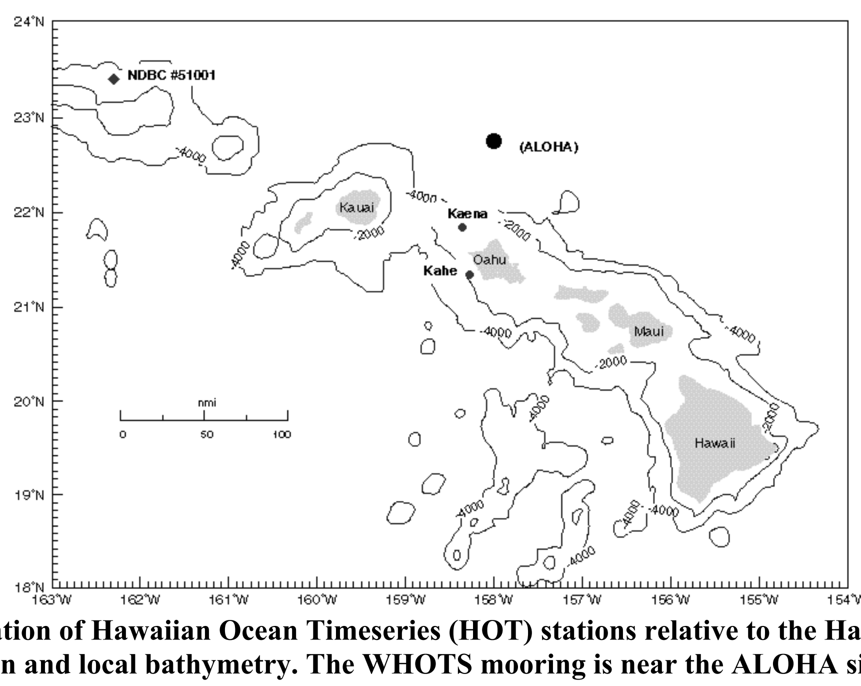


Figure 1. Location of Hawaiian Ocean Timeseries (HOT) stations relative to the Hawaiian Island chain and local bathymetry. The WHOTS mooring is near the ALOHA site.

The mooring turnaround in June 2006 was done on the Scripps Institution of Oceanography (SIO) Ship *Revelle*, Cruise AMAT-07, by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI) and by Dr. Roger Lukas and his group from the University of Hawaii. The cruise was completed in 8 days, between 22 and 29 June 2006, and consisted of approximately 1 day of steaming, 7 days of operations near the WHOTS site. The cruise originated from, and returned to, Honolulu, HI (Fig. 2). There were six principal operations during the cruise. First, an intercomparison was done between shipboard meteorological sensors and buoy meteorological sensors with the *Revelle* standing off the WHOTS-2 buoy, collecting shipboard meteorological data, and intercepting the Argos satellite transmissions from the buoy with receivers aboard ship. Second, the WHOTS-2 mooring was recovered. Third, temperature/salinity recorders recovered from WHOTS2 were post-calibrated by mounting them on the *Revelle's* CTD rosette, and a series of shallow CTDs were taken every 2 hours for 12 hours. Fourth, a bottom fish trap was deployed twice. Fifth, the WHOTS-3 mooring was deployed at 22°45.9938′N, 157°53.992′W. Finally, a data intercomparison period was completed with *Revelle* standing off from the WHOTS-2 buoy while at the same time a second 12-hour series of shallow CTD profiles were obtained.

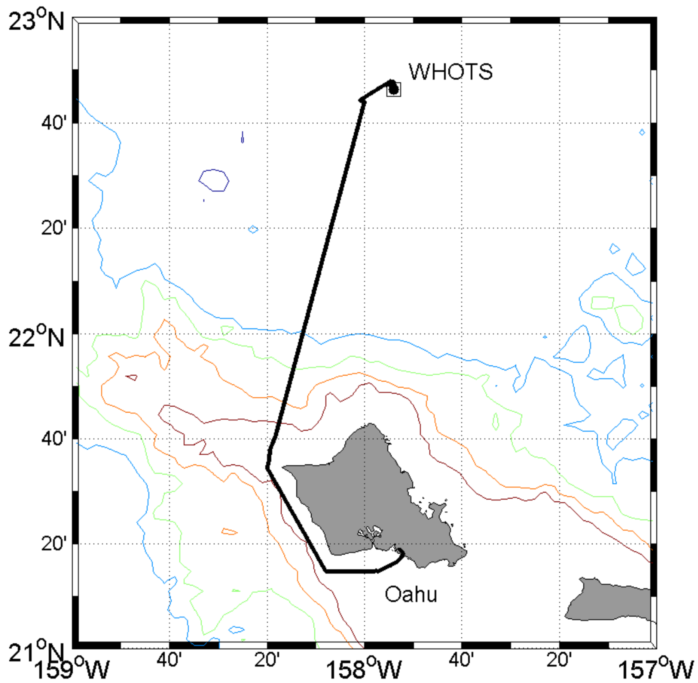


Figure 2. WHOTS-3 outbound cruise track, departing from Honolulu, HI for the WHOTS mooring site. Bathymetry is shown at 1, 2, 3, 4, and 5 km.

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

The WHOI part of the WHOTS effort is funded by the NOAA Office of Climate Observations, NOAA sponsored Diana Griffiths as a NOAA Teacher-at-Sea and Terry Smith as a Hollings Scholar to participate in the cruise. In addition, University of Hawaii graduate student, John Yeh, was offered the opportunity to deploy a bottom fish trap twice as part of his graduate studies and Scott Burman, an incoming student at Florida Institute of Technology, participated as a volunteer. Dr. Frank Bradley from CSIRO, Australia, was invited to participate to carry out a detailed comparison of shipboard and buoy meteorological observations in support of our efforts to quantify the accuracy of the meteorological and surface flux observations made from the Ocean Reference Stations.

This report contains ten sections following this introduction: pre-cruise operations (Sec. 2), recovery of the WHOTS-2 mooring (Sec. 3), deployment of the WHOTS-3 mooring (Sec. 4), the meteorological intercomparison results (Sec. 5), shipboard ADCP (Sec. 6), CTD surveys (Sec. 7), fish trap deployments (Sec. 8), the Teacher-at-Sea report (Sec. 9), and the Hollings' scholar report (Sec. 10).

2. Pre-Cruise Operations

Pre-cruise operations were conducted on the grounds of the UH Marine Center in Honolulu, HI. A shipment consisting of (1) 40' container left Woods Hole for Honolulu on 09 June 2006. The container held the buoy well, tower mid-section, tower top with modules, spare modules, VMCMs, acoustic releases and deck gear, instrument brackets and load bars, primary mooring components, deck boxes, lab boxes, anchor modules.

A second 40' container left WHOI on 16 June, 2006 and was delivered directly to the Revelle at Pier 31. This container held most of the spare mooring components, winding cart, tension cart, and dragging gear. We used the ship's TSE winch. Many of the spares and support gear were already in Hawaii and we moved them to the ship with the rest of the gear, including the foam hull.

Three UOP representatives arrived in Honolulu on June 13, and began offloading the gear to a staging area near the dock. One additional UOP person arrived in Honolulu on June 18. UH personnel also assisted with in-port preparations. The UOP group was grateful for access to the Hawaii Undersea Research Laboratory (HURL) tent to house gear not suitable for outside storage and for use as a staging for electronics. Pre-cruise operations took place from June 13, prior to departure of the *Revelle* on 22 June. In addition to loading the ship, pre-cruise operations included: assembly of primary and spare anchor, assembly of glass balls onto 4 m chain sections, painting of the buoy hull, assembly of the buoy tower top, insertion of the tower top assembly into the foam buoy hull, a buoy spin, evaluation of ASIMET data, and preparation of the oceanographic instruments.

Because continued pre-cruise work in Hawaii is anticipated, space is rented in containers on the UH Marine Center site; therefore, not all recovered gear was shipped back to WHOI. Items left at the Marine Center included the assembled buoy hull, a spare anchor, approximately 80 glass balls, and spare wire, nylon, and polypropylene.

a. Buoy Spins

A buoy spin begins by orienting the buoy tower section towards a distant point with a known (i.e. determined with a surveyor's compass) magnetic heading. The buoy is then rotated, using a fork-truck, through 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 spins were done in the parking lot outside the WHOI Clark Laboratory high bay, with care taken to ensure that cars were not parked within about 30 ft of the buoy. The sighting angle to "the big tree" was about 309°, WHOI buoy spin. Figure 3 shows Woods Hole deviation results graphically.

The second buoy spin was done in Honolulu, on an open area of dirt near the pier. A surveyor's compass was used to determine that the magnetic field in the area was constant within a few degrees. A building with tall antennae on top was sighted approximately 4 miles away at a bearing of 87.5° and was used as a sighting point. The technique used was the same as for the Woods Hole buoy spins. Figure 4 shows the Honolulu deviation results graphically.

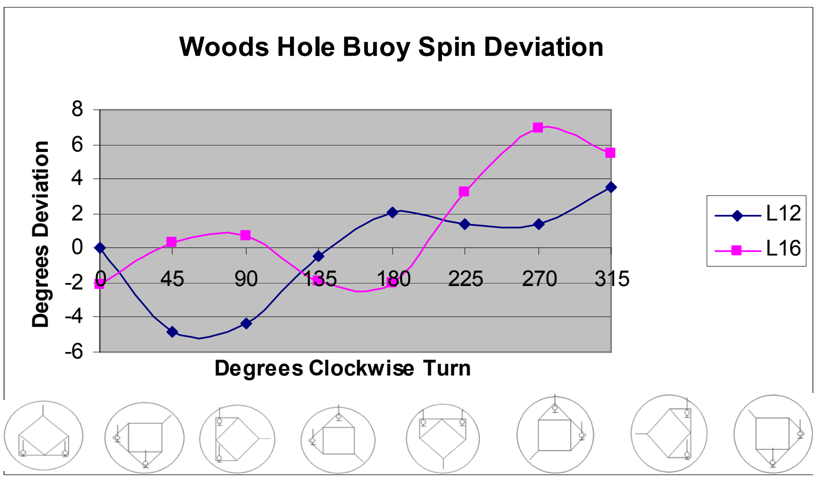


Figure 3. Woods Hole buoy spin deviation results.

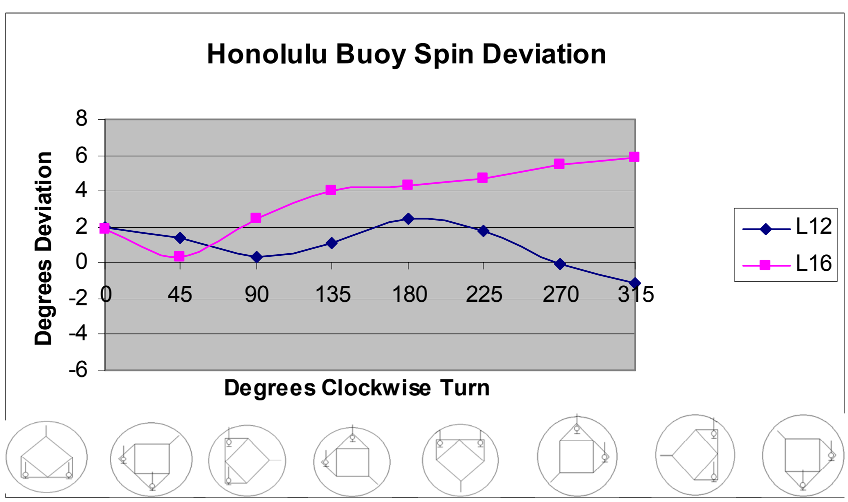


Figure 4. Honolulu buoy spin deviation results

b. Sensor Evaluation

Once the buoy well and tower top were assembled, the ASIMET modules were initialized and connected to the loggers. When mechanical assembly was complete, power was applied, the loggers were started, and data acquisition began. Evaluation of the primary sensor suite took place through a series of overnight tests. Hourly Argos transmissions were evaluated. This evaluation indicated that the ASIMET sensors were performing as expected with one exception. HRH223 performed poorly and was replaced with HRH215.

A series of "sensor function checks," including filling and draining the PRC modules, covering and uncovering the solar modules, and immersing the bridle SST modules in a salt-water bucket, were completed during in-port testing. The results of these checks, and a final in-port evaluation of hourly Argos data, showed both systems to be functioning as expected.

c. Mini-Mets

The WHOTS-3 instrument tower debuted (2) Mini-Met relative humidity/air temperature standalone modules. Both Lascar EL-USB-2 Easy Log temperature and humidity sensors, with direct USB interface and enhanced USB flash drive, were set up with one hour sample rates enabling them to last the entirety of deployment period. Although pre-deployment tests conducted in the Thunder Scientific chamber at WHOI were not overly encouraging, we hope to evaluate their accuracy and effectiveness further upon recovery.

d. Global Positioning System

Also installed, was SEIMAC GPS III standalone receiver/logger. The GPS unit was powered up, initialized and found to be functioning as expected.

e. Floating Sea Surface Bracket

Furthermore, the floating SST was modified to incorporate a redundant sensor. The WHOTS-3 floating SST consists of a Brancker TR-1050 appendage in addition to the standard Seabird SBE39.

f. Telemetry

With regards to telemetry, WHOTS3 was equipped with (2) ARGOS transmitting systems and (2) Iridium transmitting systems. Argos functioned as expected, but with Iridium, a malfunction was encountered with one of the two transmitters. After diagnostics, it was determined that the "power control cable" lacked continuity, due to an uninstalled wood-head and lack of strain relief. After remediation, the iridium functioned properly.

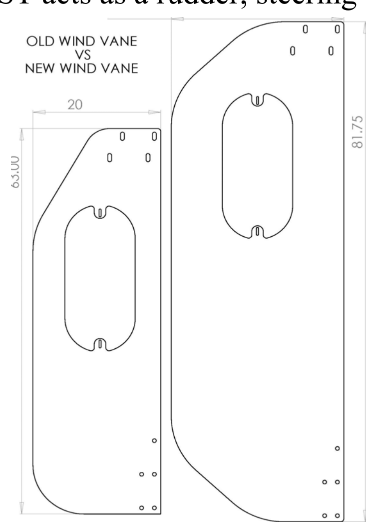
The composition of the ASIMET instrument suite for the WHOTS3 deployment is detailed in Table 1.

g. Wind Vane Modification

Observations prior to the recovery of the WHOTS-1 buoy showed that ocean currents acting on the floating sea surface temperature (SST) bracket could overpower the wind vane and rotate the buoy so it was not oriented into the wind. The floating SST acts as a rudder, steering the buoy by several degrees. As it was too late to modify the WHOTS-2 buoy prior to deployment in July 2005, a modification was made to the WHOTS-3 buoy.

The wind vane surface area was increased approximately 30 percent, and the channel used on the floating SST bracket was shortened by 6 inches.

Initial observations after the deployment of the WHOT-3 buoy showed the buoy orientation improved over the WHOT-2 buoy, although not perfect. The current acting on the buoy during the deployment was ~ 50 cm sec. It is no surprise there was a rudder effect on the floating SST bracket.



WHOTS 3 Serials/Heights

System 1

Module	Serial	Firmware Version	Height Cm
Logger	L-12	LOGR53 V3.10	
HRH	211	3.2/1.6	231.5
BPR	505	3.3	234
WND	219	3.5/1.5	265
PRC	204	3.4/1.7	235
LWR	504	3.5/1.6	285
SWR	209	3.3/1.6	287
SST	3603		-150
PTT	63878	IDs 27356, 27364, 27413	
IRIDIUM	8370		

System 2

Module	Serial	Firmware Version	Height Cm
Logger	L-16	LOGR53 V3.10	
HRH	215	3.2/1.6	233
BPR	506	3.3	234.5
WND	218	3.5/1.5	266
PRC	215	3.4/1.7	234
LWR	205	3.5/1.6	285
SWR	504	3.3/1.6	287
SST	3605		-150
PTT	63879	IDs 07561, 27415, 27416	
IRIDIUM	16710		

Stand-Alone Module(s)

Module	Serial	Firmware Version	HeightCm
GPS	69975		245
BEACON	24338		
LASCAR RHAT #1			193
LASCAR RHAT #2			193

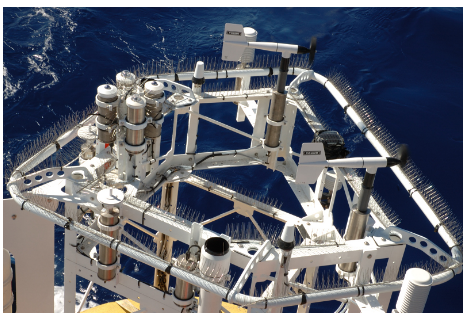
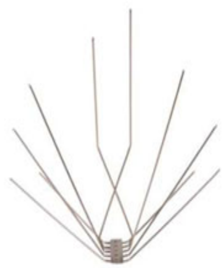
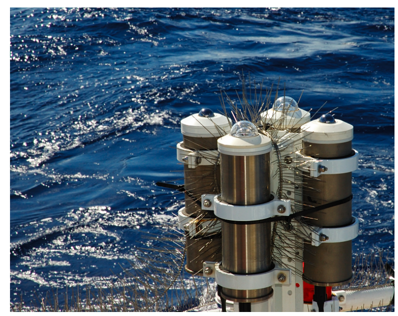
Horizontal Distances

System 1	Cm	System 2
HRH 211	244	HRH 215
BPR 505	59	BPR 506
WND 219	123	WND 218
PRC 204	148	PRC 215
LWR 504	23.5	LWR 205
SWR 209	23.5	SWR 504
SST 3603	9	SST 3605
RHAT #1	47	RHAT #2

Table 1: WHOTS-3 ASIMET System Composition

h. Bird Barrier

WHOTS-3 incorporates *Nixalite Premium Bird Barrier Strips Model S* as a physical deterrence for pest birds and their accompanying guano deposition. The anti-bird wire is constructed of 316 stainless steel and is 4 inches high and 4 inches wide and has no less than 120 wire points per foot with full 180-degree coverage. Forty eight feet of wire strip was installed fully around the crash bar, the flat top portion, inside lip, and carefully around the solars. Individual strips were 2 foot long and secured with cable ties. The wires are sharp so it is recommended that gloves and eye protection be used for all future installation. Furthermore, transparent monofilament fishing line was installed in a simple X pattern inside the tower to also serve as a deterrent. Initial observations prove the installation to be very effective but the birds' resourcefulness will be the ultimate test throughout the year long deployment.

i. Anti-foul Treatment

E-Paint's research of anti-fouling treatments for oceanographic buoys and mooring components has been winding down. Their products have been refined to best suit the wishes of WHOI. Effective products that remain relatively safe to apply, including water based (vs solvent based) coatings, are now being produced commercially. Treatment of the WHOTS-3 mooring was straightforward.

The Surlyn foam buoy hull and bottom plate were treated with E-Paint Sunwave +. Six coats (2.5 gallons) of paint were applied to the foam hull, and two coats were applied to the bottom plate and universal joint.

E-Paint ZO was used to coat the two SBE 37s mounted to the bottom of the buoy, and on the floating SST and SST bracket. Two coats of ZO were used on these components.

E-Paint ZO was also used to treat the instruments mounted on the mooring line down to 50 meters. The shield over the conductivity cell on SBE 37s and SBE 16s was coated on both sides. The conductivity cell was coated as well. On the VMCMs, propellers were treated with E-Paint. VMCM stings were painted with E-Paint ZO prior to deployment.

3. WHOTS-2 Mooring Recovery

a. Recovery Operations

The WHOTS-2 mooring was recovered buoy-first rather than release-first in an effort to make instruments available for data recovery as soon as possible. A mooring drawing, specifying the mooring components and location of the attached instrumentation, is provided in Appendix 3.

The TSE winch, ship's trawl winch, capstan and assorted WHOI deck lines and hooks were used during the recovery. The trawl winch leader was led through the ship's mooring block, hung in the center of the A-frame, and led forward on the starboard side. Two air tuggers were positioned inboard on either side of the A-frame. A third tugger was near the center of the deck, approximately 30 feet forward of the transom. The air tugger lines were led so that as the buoy transitioned onto the fantail, there was adequate forward and side loading on the buoy. This prevented buoy swing, as the hull transitioned in board.

The R/V Revelle was positioned downwind from the buoy. The acoustic release was ranged and fired, releasing the mooring. The ship held position near the buoy while continued acoustic ranging confirmed that the release was free of the anchor. The ship's work boat was launched with a crew to attach a pickup line to the buoy. The line was tossed to the ship and shackled to the trawl wire.

Once the winch leader was connected to the buoy, the ship steamed ahead slowly, and the slack line was taken up on the trawl winch. The A-frame was shifted outboard. The winch was hauled in, lifting the buoy hull approximately 2m above the water. The buoy rotated so the tower was facing forward. The A-frame was shifted inboard close enough to attach air tugger lines to the two side bales on the buoy well. The A-frame was then shifted inboard as the winch hauled in, raising the buoy hull up to a height approximately 1 m above the fantail.

Once the A-frame had swung to the full inboard position, the buoy was lowered to the deck and temporarily lashed. A 5/8" pear link was shackled into a link of the ¾" chain 1 meter below the buoy. Two stopper lines with snap hooks were connected to the pear link and took the mooring load. The TSE mooring winch was attached to the chain under the buoy and hauled in slightly to create some slack in the chain. The shackle below the buoy was removed; this completed the separation of the buoy from the rest of the mooring. Tugger lines and tag lines were rigged in preparation to move the buoy out of the working area. The starboard crane lifted the buoy out of the way, where it was lashed to the deck near the Hiab crane on the port rail.

The trawl winch leader was removed from the block on the A-frame. The TSE mooring winch leader was led through the block and connected to the stopped off 3/4" chain on the mooring. The stopper lines were eased off, transferring tension to the winch. The winch was used to systematically recover all subsurface instruments through the A-frame. The recovery continued, with all of the wire rope, and 200 meters of nylon line wound onto the winch. The remainder of the mooring was recovered using the capstan, dumping line into wire baskets. The final mooring components; 80 glass balls, 5 meters of ½" chain, and the acoustic release were pulled aboard using the mooring winch and the large air tugger.

b. Surface Instruments and Data Return

The WHOTS-2 mooring, deployed on 28 July 2005 from the R/V *Melville*, was outfitted with a full suite of ASIMET sensors on the buoy and subsurface instruments from 10 to 155 m depth. Data return from the two ASIMET systems was excellent; with no significant failures. The remaining sensors recorded 1 min data for the full deployment period.

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

An internally logging Seimac GPS unit was also deployed to monitor buoy position at 10 min intervals. Unfortunately, this sensor did not perform well. Data gaps were found, occasional "wild points" were evident, and data logging stopped completely. The SEIMAC III GPS unit was set to collect and internally record GPS fixes at10-minute intervals. The unit had been burned-in at WHOI for about a month prior to shipment to Hawaii, and had worked fine. Unfortunately, it failed after about two weeks in the field. It had been turned on in port (Honolulu) on July 16, 18:00 GMT, and stopped recording on July 30, 7:00 GMT. We have since learned from the manufacturer, that a bug in the software makes the units fail, at somewhat random intervals when any of the power savings options have been selected, which was the case for this deployment.

Tables 2, 3, and 4 illustrate sensor specifications, serial numbers/sample rate, and module heights, respectively.

Table 2. WHOTS-2 ASIMET sensor specifications

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

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

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

Table 3. WHOTS-2 ASIMET system serial numbers and sampling

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

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

Table 4. WHOTS-2 ASIMET module heights and separations

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

[1] Relative to buoy deck, positive upwards

[2] Relative to buoy water line, positive upwards

c. Subsurface Instruments and Data Return

For the second WHOTS mooring deployment that took place in July 2005, UH provided fifteen SBE-37 Microcats and an RDI 300 KHz acoustic Doppler current profiler (ADCP). The Microcats all measured temperature and conductivity; three of the Microcats also measured pressure. WHOI provided two Vector Measuring Current Meters (VMCMs) and all required subsurface mooring hardware via a subcontract with UH. Table 5 provides the instrument types and serial numbers at each nominal depth on the mooring, along with sampling rates and other pertinent information. All instruments were successfully recovered as shown in Table 6. All instruments provided full data return.

Table 5. WHOTS-2 Mooring - Microcat Deployment Information

All times stated are in GMT
Deployment Date: 7/27/2005

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

Table 6. WHOTS-2 Mooring - Microcat Recovery Information.

All times stated are in GMT

Depth (meters)	Seabird Serial #	Time out of water	Time of cold spike	Time Logging Stopped	Samples Logged	Data Quality	File Name - raw data
15	37SM31486-3382	6/24/2006 19:56	6/24/2006 22:13:00	6/24/2006 23:50:30	191660	good	whots2_m_3382.asc
25	37SM31486-3621	6/24/2006 20:02	6/24/2006 22:13:00	6/24/2006 23:54:15	191660	good	whots2_m_3621.asc
35	37SM31486-3620	6/24/2006 20:05	6/24/2006 22:13:00	6/24/2006 23:55:00	191663	good	whots2_m_3620.asc
40	37SM31486-3632	6/24/2006 20:10	6/24/2006 22:53:00	6/25/2006 04:03:30	191761	good	whots2_m_3632.asc
45	37SM31486-2965	6/24/2006 20:14	6/24/2006 22:53:00	6/25/2006 03:57:30	159799	good	whots2_p_2965. asc
50	37SM31486-3633	6/24/2006 20:17	6/24/2006 22:53:00	6/25/2006 03:55:00	191758	good	whots2_m_3633.asc
55	37SM31486-3619	6/24/2006 20:19	6/24/2006 22:53:00	6/25/2006 04:08:00	191763	good	whots2_m_3619.asc
65	37SM31486-3791	6/24/2006 20:26	6/24/2006 22:13:00	6/24/2006 23:52:15	191661	good	whots2_m_3791.asc
75	37SM31486-3618	6/24/2006 20:31	6/24/2006 22:13:00	6/24/2006 23:52:30	191662	good	whots2_m_3618.asc
85	37SM31486-3670	6/24/2006 20:35	6/24/2006 22:53:00	6/25/2006 07:30:15	159870	good	whots2_p_3670. asc
95	37SM31486-3617	6/24/2006 20:40	6/24/2006 22:53:00	6/25/2006 04:02:00	191761	good	whots2_m_3617.asc
105	37SM31486-3669	6/24/2006 20:43	6/24/2006 22:53:00	6/25/2006 04:00:00	159800	good	whots2_p_3669.asc
120	37SM31486-2451	6/24/2006 20:50	6/24/2006 22:13:00	6/24/2006 23:54:15	159718	good	whots2_p_2451.asc
135	37SM31486-3634	6/24/2006 20:59	6/24/2006 22:13:00	6/25/2006 07:29:30	191844	good	whots2_m_3634.asc
155	37SM31486-3668	6/24/2006 21:04	6/24/2006 22:53:00	6/25/2006 03:53:12	159191	good	whots2_p_3668. asc

The data from the Microcats appear to be of high quality, though post-deployment calibrations are required to assess instrument stability. Appendix A shows the nominally calibrated temperature, salinity and pressure records from each instrument. The upper ocean thermal structure was dominated by the annual cycle, with a maximum temperature in late summer. Below the mixed layer, intraseasonal and internal tidal variability dominate. Upper ocean salinity showed relatively slow trends with rapid changes occurring at various times. Notable are the 0.2-0.3 decreases around day 225 (of 2005), day 305, and day 475. A 0.4 increase was observed near day 480. These events can be seen in all of the records down to 65 m. Below that depth, intraseasonal and internal wave motions dominate. During the spring of 2006, surface mixing appears to have penetrated to the 155 m microcat.

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

d. Biofouling and Guano

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

Preparation- WHOTS-2 Buoy Hull

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

Coat Product Description

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

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

Preparation- WHOTS-2 Buoy Base

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

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

Coat Product Description

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

Preparation- WHOTS-2 Subsurface Instrumentation E Paint coatings used to protect WHOTS-2 instrumentation are detailed in Table 7.

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

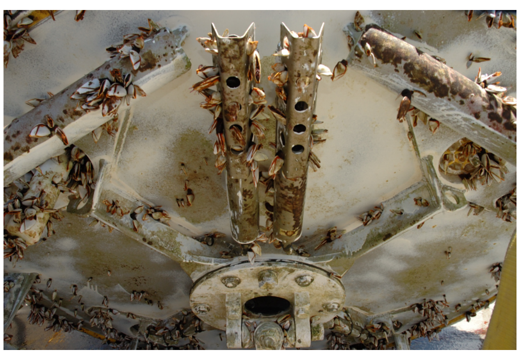
Table 7. Antifouling coatings on WHOTS-2 instrumentation

Assessment after WHOTS-2 Recovery

Most of the antifouling paint applied to the buoy hull and base had eroded after 12 months exposure. Very little SUNWAVE+ was visible on the buoy hull when recovered. Only a narrow strip of paint was visible behind the SST bracket. This is a shaded area protected from full sun exposure. Given the photoactive nature of SUNWAVE+, photochemical degradation of the paint is assumed the primary mode of failure that resulted in complete erosion of the product on the majority of the buoy hull. Additional coats of SUNWAVE+ did not appear to extend the service life of this product at WHOTS. Like the SUNWAVE+, much of the E Paint ZO had eroded from the buoy base.

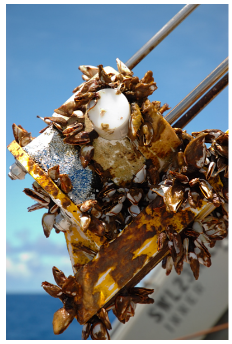
Very little biofouling was observed on the Surlyn buoy hull. Low densities of juvenile gooseneck barnacles (10 /m_2) were reported on the side of the buoy. The gooseneck barnacles appeared to larger than the barnacles observed after the recovery of the WHOTS-1 buoy. Variability in environmental conditions is likely the reason for the difference in biofouling between the WHOTS-1 and WHOTS-2 buoys. Filimentous bryozoa was also observed forming a brown fuzzy film on the sides of the buoy. Adult goose-neck barnacles were localized in regions that were not coated with antifouling, such as on the tie-rod bolts and plugs. This observation suggests that the antifouling paint, even if eroded, effectively controlled biofouling for most of the exposure period.

Assessment- WHOTS-2 Buoy Base



Assessment- WHOTS-2 Subsurface Instrumentation

Biofouling was most prolific near the surface down to 70 meters. Gooseneck barnacles, organisms that can affect the proper operation of instrumentation, accounted for most of the biomass observed. Mature goosenecks were observed down to 70 meters. However, the density of gooseneck barnacles was very light from the surface down to 70 meters. Filimentous bryozoans and algae were also observed, but their growth was easily removed and poses little threat to the proper operation of instrumentation.



The SBE-37P positioned at 155m came up virtually clean. Biofouling increased with closer proximity to the surface. Filimentous bryozoans and algae coated instruments and load bars down to 70 meters. The instruments at 85 and 95 meters were clean, and brown fibrous film was observed on the instruments between 105 and 135 meters. This organism was thought to be a bryozoan.

The VMCMs and frames were fouled with gooseneck barnacles. Fouling on the device positioned at 10m was more severe that on the device positioned at 30m. No gooseneck barnacles were observed on the propellers of the VMCMs, which were coated at E-Paint's Falmouth headquarters. Filamentous bryozoans and algae were present on the propellers.

Guano

Heavy guano was found on buoy deck, tower, and J-Boxes. Fortunately, the solars were clear. Most of the Guano was removed through power spraying.

4. WHOTS-3 Mooring Deployment

a. Mooring Design

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

Fifteen temperature-conductivity sensors, two Vector Measuring Current Meters (VMCMs) and an Acoustic Doppler Current Meter (ADCP) were attached along the mooring using a combination of load cages (attached in-line between chain sections) and load bars. All instrumentation was along the upper 155 m of the mooring line (Fig. 5). Dual acoustic releases attached to a central load-bar were placed approximately 30 m above the anchor. Above the release were eighty 17" glass balls meant to keep the release upright and ensure separation from the anchor, after the release is fired. This flotation is sufficient for backup recovery, raising the lower end of the mooring to the surface, in the event that surface buoyancy is lost.

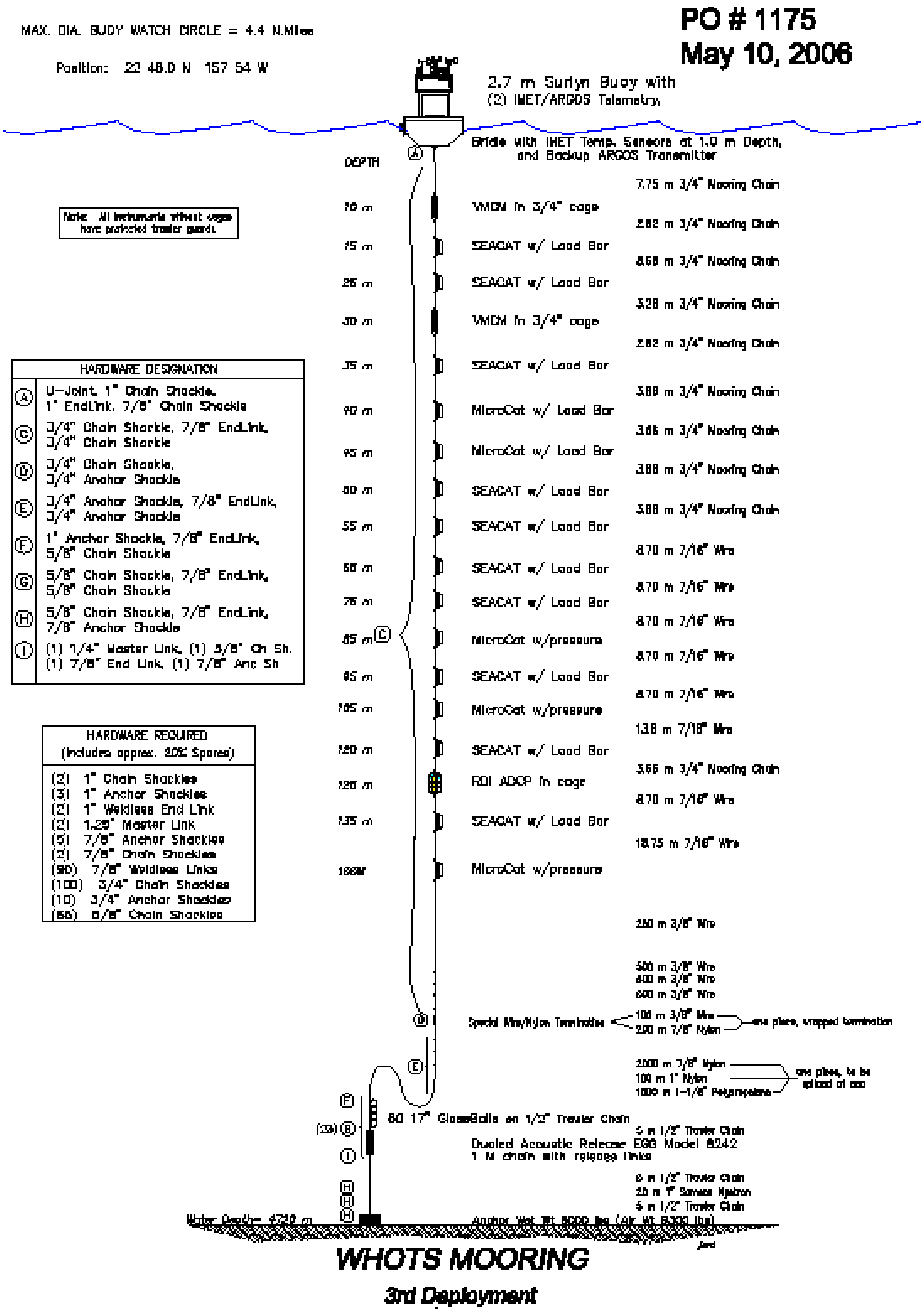


Figure 5. WHOTS-3 mooring diagram.

b. WHOTS-3 Instrumentation

UH provided five new SBE-37 Microcats, ten SBE-16 Seacats, and a new RDI 300KHz Workhorse ADCP for the WHOTS-3 mooring deployment. WHOI provided two refurbished VMCMs for WHOTS-3. Table 8 gives summary information on the subsurface instrumentation on WHOTS-3.

Table 8. WHOTS-3 Mooring - Microcat /Seacat Deployment Information

All times stated are in GMT

Deployment Date: 6/26/2006

Depth (meters)	Seabird Serial #	Para-meters	Sample Interval (seconds)	Navg	Time Logging Started	Cold Spike Time	Time in the water
15	163452-801	C, T	600	1	6/19/2006 12:00:00	6/19/2006 23:47:00	6/26/2006 18:28
25	165807-1085	C, T	600	1	6/19/2006 12:00:00	6/19/2006 23:47:00	6/26/2006 18:25
35	165807-1087	C, T	600	1	6/19/2006 12:00:00	6/19/2006 23:47:00	6/26/2006 18:16
40	37SM31486-3381	C, T	150	2	6/20/2006 04:00:00	6/20/2006 04:08:00	6/26/2006 18:14
45	37SM31486-4663	C, T	150	2	6/20/2006 04:00:00	6/20/2006 04:08:00	6/26/2006 18:59
50	165807-1088	C, T	600	1	6/19/2006 12:00:00	6/19/2006 23:47:00	6/26/2006 19:02
55	165807-1090	C, T	600	1	6/19/2006 12:00:00	6/20/2006 00:37:00	6/26/2006 19:09
65	165807-1092	C, T	600	1	6/19/2006 12:00:00	6/19/2006 23:47:00	6/26/2006 19:13
75	165807-1095	C, T	600	1	6/19/2006 12:00:00	6/20/2006 00:37:00	6/26/2006 19:16
85	37SM31486-4699	C, T, P	180	1	6/20/2006 04:00:00	6/20/2006 04:08:00	6/26/2006 19:18
95	165807-1097	C, T	600	1	6/19/2006 12:00:00	6/20/2006 00:37:00	6/26/2006 19:21
105	37SM31486-2769	C, T, P	180	1	6/20/2006 04:00:00	6/20/2006 04:08:00	6/26/2006 19:24
120	165807-1099	C, T	600	1	6/19/2006 12:00:00	6/20/2006 00:37:00	6/26/2006 19:27
135	165807-1100	C, T	600	1	6/19/2006 12:00:00	6/20/2006 00:37:00	6/26/2006 19:33
155	37SM31486-4700	C, T, P	180	1	6/20/2006 04:00:00	6/20/2006 04:08:00	6/26/2006 19:38

c. Deployment Operations

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

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

Prior to the deployment of buoy, 50 meters of 3/8" diameter wire rope was payed out to allow its bitter end to be passed through the center of the A-frame and around the aft port quarter, and forward along the port rail to the instrument lowering area. This working wire was connected to the bottom of the shot of chain, rigged to the 40-meter MicroCAT. Four wire handlers were stationed around the aft port rail. The wire handler's job was to keep the hauling wire from fouling in the ship's propellers and pass the wire around the stern to the line handlers on the port rail.

To begin the mooring deployment, the crane was positioned over the instrument lowering area with about 6 meters of vertical lift available to the boom. A lifting sling, passed through the end link, connected to the shot of chain on the 40 meter MicroCAT, was attached to the crane hook. The crane wire was raised so the chain and instrument were lifted off the deck. The crane swung outboard to clear the ship's side, and slowly lowered the wire and attached mooring components down into the water. The wire handlers, positioned around the stern, eased wire over the port side, paying out enough wire to keep the mooring segment vertical in the water. The crane wire was lowered until there was about 2 feet of chain suspended above the deck. A chain hook connected to an air tugger was used to stop off the mooring at this point and a safety stopper was clipped to the end link. The next instrument was brought in and shackled to the link at the end of the suspended chain.

The operation of lowering the upper mooring components was repeated until the 7.75 meter shot of 3/4" chain shackled to the 10 meter VMCM was reached. The crane lifted the chain and suspended instruments from a sling link shackled into the ¾" chain about 7 feet from the top end. The crane wire was lowered until it was even with the deck. The slack end of the 7.75 meter chain was shackled into the universal joint at the bottom of the buoy. A slip line was passed through the link and the crane wire was lowered until the load was transferred to slip line on a cleat. The crane and sling were then removed from the mooring line.

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

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

The winch operator slowly hauled in the slack wire, once the buoy had drifted behind the ship. The ship's speed was increased to ~1/2 knot through the water to maintain a safe distance between the buoy and the ship. The 50-meter working wire was hauled in. The bottom end of the shot of ¾" chain shackled to the working wire was pulled in and stopped off at the transom. The 45 meter MicroCAT and pre-attached chain shot were shackled to the end of the stopped off chain. The free end of chain was attached to the working wire on the winch. The winch was pulled tight and the stopper lines were removed from the chain.

The large air tugger line was passed through the mooring block on the A-frame. A ¾" chain hook on the tugger line was used to lift the instrument off the deck as the winch payed out. This kept the instrument from dragging off the transom. Once the instrument was clear, the tugger was lowered and the chain hook removed. This method was used for the next two instruments. When the 65 meter SeaCat was installed, a Gifford block was hung from the large mooring block, so its height could be adjusted with the large air tugger.

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

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

While wire was being payed out, the Hiab crane was used to lift the 80 glass balls out of wire baskets. These balls were staged fore and aft, in four ball segments, just forward of the wire baskets.

The end of the 2000 meters of nylon and 1500 meters polypropylene, coiled in 3 wire baskets, was shackled into the mooring. The slack part of the nylon was dressed over a heavy duty H-bit bolted to the deck as illustrated in Figure 6. The stopper lines were slacked off and the load transferred to the nylon on the H-bit. With one person tending the line in the baskets, one person tending the H-bit, and another person spraying cooling wire onto the H-bit, deployment of the synthetic lines resumed.

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

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

At this point, the ship was still approximately 1 nm from the target drop position. As we continued toward the site, the final sections of the mooring were prepared. A 5-meter shot of chain was attached to the last string of glass balls and to the tandem-mounted acoustic releases. Another 5-meter shot of chain was attached to the bottom link on the dual release chain. This chain was then shackled into the 20-meter nylon anchor pennant, which was shackled into the final 5 meters of ½" chain. The chain, anchor pennant, and next shot of chain were wound onto the winch, and took the mooring load. The stopper lines were removed. The air tugger line, passed through the A-frame, lifted the releases to prevent them from dragging down the deck. The winch payed out until the releases, 5 meter chain, 20 meter nylon, and 2 meters of the final 5 meter shot of chain had been deployed.

A sling link was shackled into the ½" chain about 2 meters up from the Sampson anchor pennant. With the two stopper lines and a slip line rigged in the final 5 meter shot of chain, the ship towed the mooring for about 45 minutes. As we approached the anchor drop site, the slack end of the chain was shackled to the anchor. The bolts holding the anchor tip plate to the deck, and chain binders on the anchor were removed. The crane was positioned with the boom slightly aft of the lifting bridle on the tip plate. The crane was then attached to the tip plate bridle and slight tension was taken on the crane wire.

At 85 meters from the launch site, the slip line on the final shot of chain was eased out and the mooring load was transferred to the anchor. At the signal from the Chief Scientist, the crane wire was raised and the tip plate raised enough to let the anchor slip into the water.

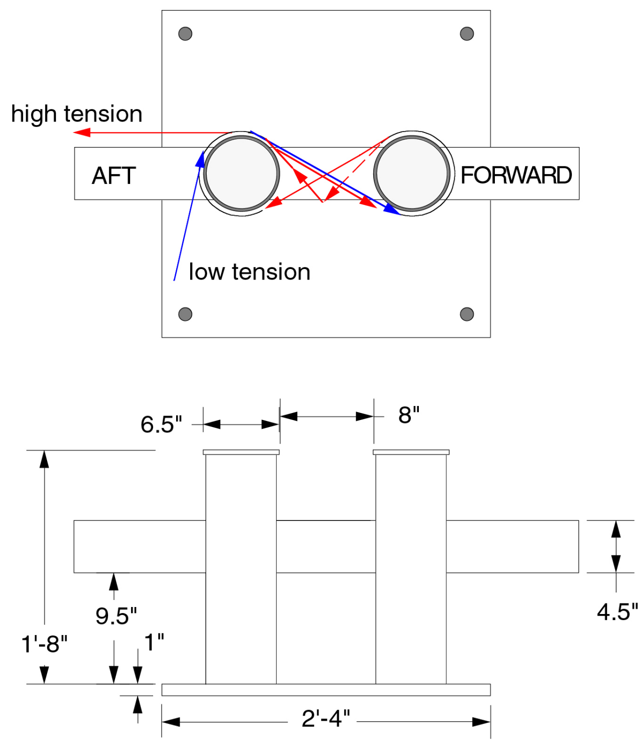


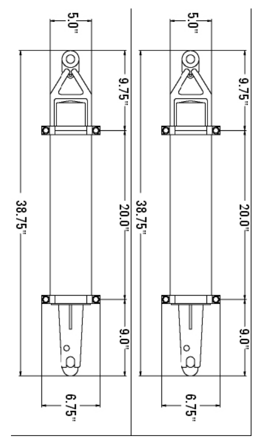
Figure 6. H-Bit dimensions and fair lead detail.

d. WHOTS-3 Anchor Survey

	Lat/lon	Slant range (m)	Lat/lon	Horiz range (m)	Lat/Lon	Travel time (ms)
Point 1	22° 46.717	4826	22° 46.727	1237	22° 46.721	3219
	157° 54.023	4826	157° 54.023	1232	157° 54.026	
		4827				
Point 2	22° 45.517	4965	22° 45.523	1681	22° 45.525	3306
	157° 53.098	4964	157° 53.104	1676	157° 53.106	3306
Point 3	22° 45.545	4972	22° 45.543	1708	22° 45.535	3314
	157° 54.909	4972	157° 54.907	1708	157° 54.901	3313

Table 9 WHOTS-3 Anchor Survey

The Edgetech Model 8242XS Dualed Release and Transponder is rated to 6000 Meter Depth, 5500 kg load, and 2 years of battery life using alkaline batteries. This unit also includes status reply which indicates a tilted angle or an upright condition and release status.



3 point acoustic survey of anchor of WHOTS-3
3 points chosen, roughly 1 nm away from target
1) 22° 47'N, 157° 54'W
2) 22° 45.5'N, 157° 53.1'W
3) 22° 45.5'N, 157° 54.9'W

Release is 32 meters off the bottom
5 m correction for transducer depth for Seabeam
4694.5 m read from Seabeam at start of survey
Actual ranging, locations recorded as ship drifted close to survey points
Anchor Location: LAT 22 45.994N LON 157 53.992W

5. Meteorological Intercomparisons 22-29 June 2006

In order to assess the performance of the buoy meteorological sensors, two periods of intercomparisons between the ship and the buoys were scheduled. The first (I/C1), of duration slightly more than one day, took place before WHOTS-2 was recovered, and the second (I/C2) of almost two days, was performed after WHOTS-3 was in position. In each case, the ship was stationed about 500 meters downwind from the buoy, head into wind.

There were two components to each intercomparison; direct comparison between equivalent sensors on the ship and the buoy, and regular observations of air temperature and humidity using a hand-held Assman psychrometer.

Ship equipment

The R/V Revelle is equipped with a full set of IMET sensors mounted high on the ship's foremast, and well exposed. Two pairs of Eppley shortwave (PSP, SW) and longwave (PIR, LW) radiometers are mounted on the very top of the mast at a height above the water of 20.7m. Wind speed and direction (WS and WD) are measured with a two-dimensional ultra-sonic anemometer (VaisalaWS425) at a height of 18m, and air temperature (AT) and relative humidity (RH) at 17.4m using a Vaisala HMP45A unit in a naturally ventilated Gill radiation shield. A barometric pressure (BP) probe (Air Inc DB-2a or Vaisala PTB101C) is also mounted at 17.4m. On Revelle, the data from these instruments is logged without any correction to standard height or, in the case of BP, to surface level. Sea surface temperature (SST) and salinity (SAL) are measured with a thermosalinograph (Seabird SBE-45) at the bow, via an inlet port at 5m below the waterline. The distance from the port to the thermosalinograph is about 2m.

These measurements (together with about 60 other parameters of no relevance in the present context) are logged at 30-second intervals, and available on the ship's network in a data file which is continuously updated, and closed daily (GMT).

Buoy equipment

The buoys are each equipped with two identical meteorological systems, comprising sensors for SW, LW, AT, RH, WS, WD, BP and precipitation, at a height of about 3m above the water. The sensors are well exposed, providing the wind is strong enough so that its vane keeps the buoy turned into the wind. This was the case throughout both intercomparisons. SST sensors were mounted at a depth of 1m below the waterline.

Data are logged on the ASIMET system at 1-minute intervals, but hourly average values are transmitted to base via the Argos system. For the intercomparisons, these transmissions were intercepted and recorded.

Assman psychrometer

The Assman is a traditional hand-held instrument for measurement of air temperature and humidity. It consists of a pair of high-quality mercury-in-glass thermometers with 0.2°C graduations, which can be interpolated to 0.1°C. One mercury bulb is surrounded with a cotton wick which is moistened (but not soaked) with distilled water. The thermometers are mounted together and ventilated with a clockwork fan. The thermodynamic response of a well-ventilated wet bulb is well understood, and the difference in temperature between the wet and dry bulbs is a known function of atmospheric water vapour pressure.

Before wetting the wick, the thermometers were compared and found to agree. Then, throughout the intercomparisons, psychrometer readings were taken every half-hour through one of the forward chocks on the bow, port or starboard, depending on the relative wind direction. The purpose was to introduce a method of measurement which would not be subject to uncertainties of calibration, signal bias or exposure problems. The only measure of uncertainty is that, particularly in light wind and convective conditions, both wet and dry bulb may fluctuate slowly, so that the observer must perform some visual averaging.

Data processing

A line of data from the ship IMET system was written every 30 seconds. The daily files covering each intercomparison were concatenated and edited to contain only the parameters of relevance, which were then averaged over 5 minutes to produce filtered time series. Relative humidity values were converted to specific humidity using the simultaneous measurements of air temperature and barometric pressure. The appropriate basic variables were used as input to the COARE3.0 bulk flux algorithm (Fairall et al., 2003) to obtain time series of the fluxes of momentum, sensible and latent heat, the interface values of SST and specific humidity, and the Monin-Obukhov diabatic flux/gradient parameters (including the roughness lengths for velocity and the scalar quantities). These fluxes and other parameters are needed to adjust the ship observations made near the top of the foremast, to the heights of the Assman (6.8m) and the buoy instruments (3.22m for wind and 2.88m for T/RH), to enable proper comparisons.

All of the above measurements and calculated parameters were averaged to obtain hourly values, from which vertical profiles of wind speed, potential temperature and specific humidity were obtained each hour during the two intercomparison periods. For the time being, we regard the ship instruments as the reference for systems on the two buoys. In the following graphs, data points are plotted halfway through each hour.

The two systems on each buoy were already in the form of hourly averages. After some format manipulation and conversion of RH to specific humidity, the buoy data were time-matched to the ship data in an Excel spreadsheet.

Assman psychrometer readings were taken on the hour and half-hour (within a few minutes) throughout each intercomparison period. In a highly variable environment, such a "spot" reading does not sit well with an hourly average. In fact, throughout this exercise we are attempting to compare three systems with widely different time constants, sampling strategies, and sensor heights. Fortunately, both intercomparisons took place in fine, relatively steady conditions. Short-term fluctuations are filtered to some extent by the thermal inertia of the mercury thermometers, and through visual averaging by the observer. Otherwise, we rely upon a long enough time series to obtain a statistically valid dataset to identify biases in the automatically logged data. To make the Assman values more representative, we averaged together the three readings from the beginning, middle and end of each hour.

Intercomparison 1 (I/C1)

I/C1 took place from 1400GMT on June 23 (Year day 174.583) to 1700GMT on June 24 (Year day 175.708). Meteorological parameters measured continuously near the top of the ship's foremast are shown in Figure 7. The solar radiation signal is included to relate the observations to local time. For about an hour, from 1800/174, ship maneuvers affected the wind and temperature signals; these have been removed from the analysis, as have the data after 1700/175 when the buoy retrieval began.

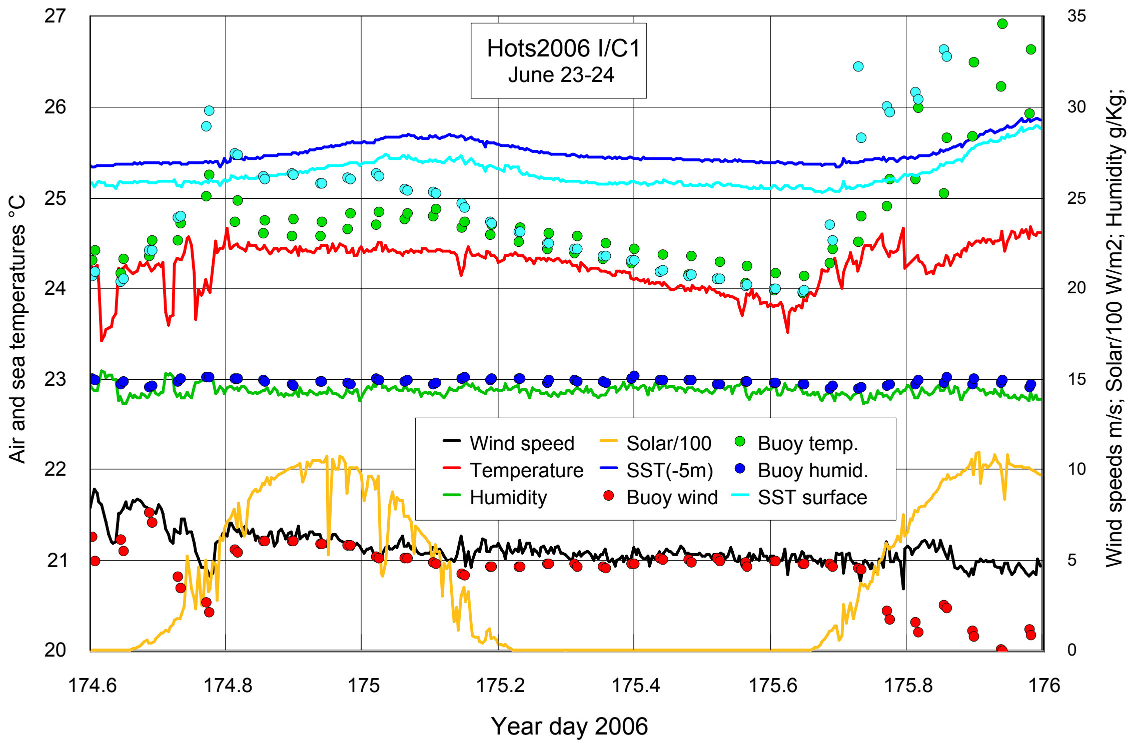


Figure 7. Meteorological variables measured by the ship's IMET system near the top of the foremast. Circular symbols are from the two WHOTS-2 buoy systems. The dark blue line is the ship's thermo-salinograph measurement at 5m depth, and the light blue line is the same data extrapolated to the surface, using models of diurnal warming and cool skin in COARE3.0.

Displacement of the hourly averaged measurements of the two systems on the buoy, from the continuous time series on the foremast, is due to different heights of the sensors above the water. Wind mixing of the surface layer produces a diurnal heating signal at 5m depth, although the upper ocean model built into COARE3.0 does not indicate a significant vertical temperature gradient. It does, however, indicate a persistent surface cool skin, with an average value of 0.25ºC (the difference between the dark and light blue lines) which is typical of this phenomenon. It is the light blue line which we take as the surface SST, and from which the humidity at the surface is derived, in the height adjustment calculations which follow.

The light blue circles are from the buoy sea temperature sensors at 1m depth. They can't seem to decide whether to measure water or air temperature and will not be discussed further.

Height adjustment

The variation with height of wind speed, temperature, and water vapour content in the atmospheric surface layer (their profiles), depend on surface conditions and thermal stability.

Without going into details, which can be found in many reference texts, the profiles take a "log-linear" form described by Monin-Obhukov similarity theory. The critical assumption is that the fluxes, or equivalently the M-O scaling parameters (u_*, t_*, q_*), are constant with height within the surface layer. In neutral conditions, the logarithmic profiles are specified completely by their slope (u_* etc.) and intercept on the height axis, the roughness lengths (z_0 etc.). With increasing thermal instability (or stability) the linear term produces a departure from the logarithmic form, requiring a third parameter, the M-O stability length. It is important to realize that, under diabatic conditions, the shapes of the three profiles (wind speed, temperature, humidity) are interdependent; but they can be constructed when all the fluxes, roughness parameters and the stability length are known. The COARE3.0 bulk flux algorithm calculates these quantities iteratively and simultaneously, using the time series' of ship observations shown in Figure 7 as input. Figure 8 illustrates the resulting time series of the fluxes during I/C1.

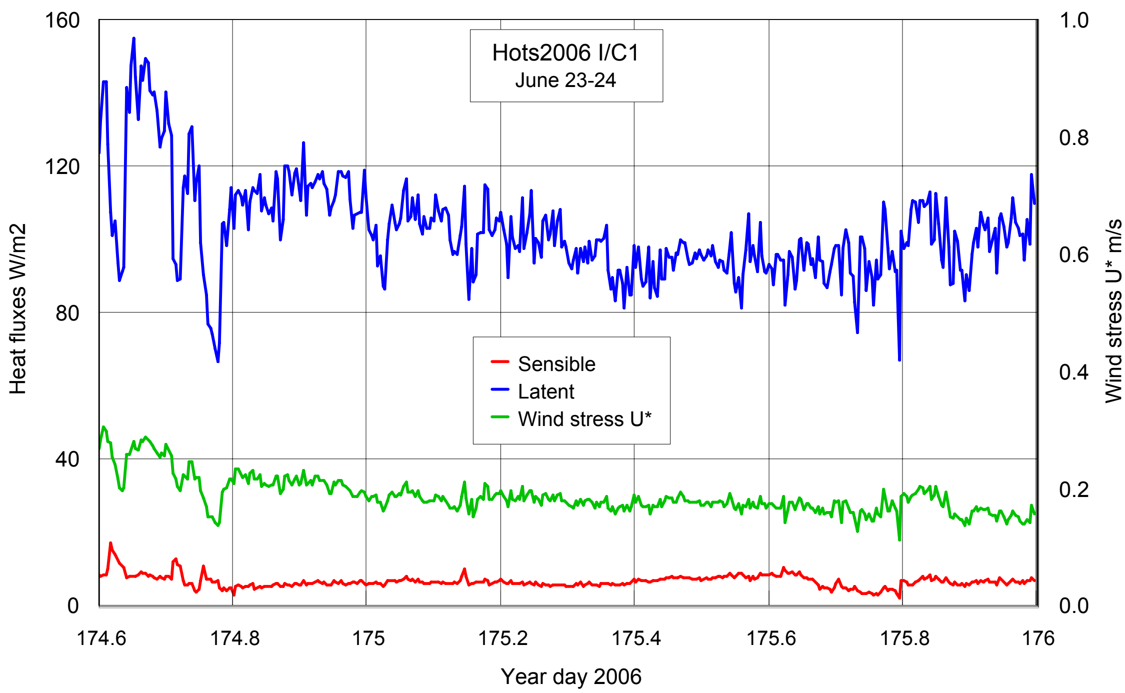


Figure 8. Sensible and latent heat fluxes, and wind stress (momentum flux) during I/C1

The fluxes and profile parameters have been averaged over each hour, and used to determine the values of the three atmospheric variables on the profile at the height of the buoy instruments and the Assman psychrometer (temperature and humidity only). Figure 9 illustrates this process for the hour beginning 0600GMT on June 24 (Year day 175.25), a very steady period. For this hour, the M-O stability parameter z/L=-0.4, which is moderately unstable, but not in the realm of convective conditions. The temperature values have been converted to potential temperature by addition of the adiabatic lapse rate (0.0098ºCm^{-1}), and the surface values calculated from the bulk algorithm. No surface currents were available, so the surface velocity is taken as zero.

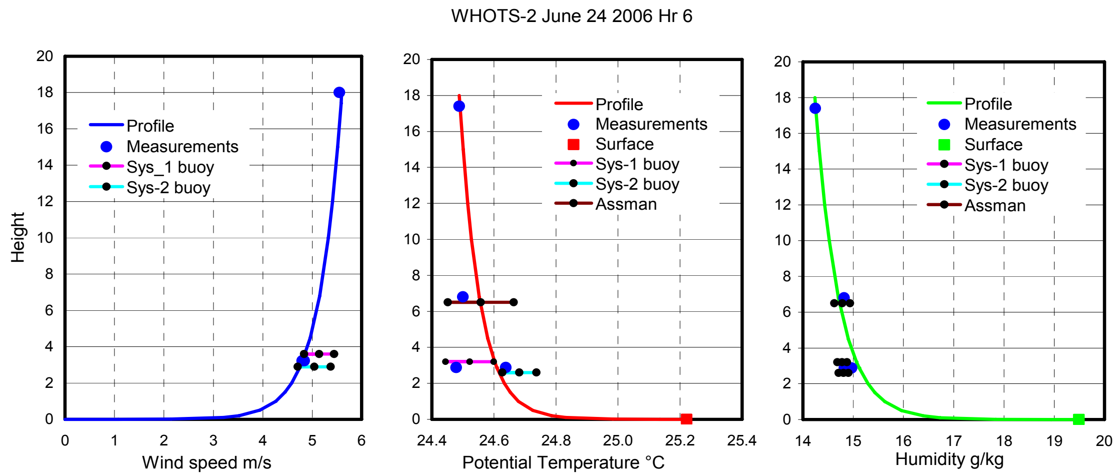


Figure 9. Example of profiles used for height adjustment of the various measurements during I/C1. The ship's anemometer was at 18m on the foremast, and the temperature/humidity (T/RH) sensor at 17.4 m. Temperature and humidity were measured with an Assman psychrometer through a forward chock at 6.8 m height. The ship was standing about 0.25 nm downwind of the WHOI buoy, which had two wind sensors at 3.22 m above the sea surface and two T/RH sensors at 2.88 m. The ship and buoy data points are hourly averages; the Assman values are spot readings. The profiles were constructed from flux/gradient parameters calculated using version 3.0 of the COARE bulk flux algorithm. A linear height scale is used to illustrate more clearly the characteristics of near-surface profiles over the ocean. Because the sea is very "smooth" compared with land surfaces (typically, z_0 over grassland is 0.01 m), most of the sea-air difference occurs in the lowest 1-2 meters.

For this particular hour, average wind speeds from the two buoy sensors are almost identical with each other, and with the profile. Without allowing for the height difference, they would have seemed almost 1ms^{-1} too low compared with the ship's ultrasonic anemometer. The profiles show that at buoy height (2.88m) the potential temperature is 0.15ºC higher, and the specific humidity 0.73gkg^{-1} higher, than at the top of the foremast (17.4m). For this hour, Sys-1 is -0.13ºC and +0.29gkg^{-1} relative to the profiles and Sys-2 +0.03ºC and -0.15gkg^{-1}. The Assman measurements are also very close to the profile values.

However, some variability in the comparisons is expected, due mainly to the separation between the ship and buoy, and also the different sampling strategies of the ship and Assman. The performance of the systems is best judged by averaging the 27 hours of I/C1. The results are given by the horizontal bars, which for clarity are displaced vertically from their true heights. They represent the average and ±1 standard deviation of the differences between measurements and the height adjusted ship value, referenced to the profile shown. The actual values are given in the following table:

	Sys-1			Sys-2			Assman	
	u	θ	q	u	θ	q	θ	q
	ms^{-1}	ºC	gkg^{-1}	ms^{-1}	ºC	gkg^{-1}	ºC	gkg^{-1}
Average	0.337	-0.087	-0.340	0.238	0.073	-0.314	0.005	0.074
Std. Dev.	0.303	0.078	0.095	0.333	0.055	0.097	0.106	0.157

The very good, overall agreement between the Assman and the height adjusted ship sensors indicate that the latter provide a reliable reference for temperature and humidity. Both buoy temperature sensors are well within what could be reasonably expected after a year of unattended operation at sea. The humidity results are just outside the ±1% RH (=0.2gkg^{-1} at 25ºC and 75%) specification of the sensors. But note both buoy humidity sensors are low compared with the ship, by about the same amount and with the same variability. Such a situation could arise if they were both calibrated against the same (incorrect) standard, or had deteriorated identically over the year of deployment. The same is also true of the wind sensors, although in this case we have no independent sensor against which to compare.

Barometric pressure

As we understand it, the *Revelle's* barometric pressure measurement, made at 17.4m above the water, is not corrected to the surface. We have therefore adjusted the ship measurements to nominal buoy height of 3m, on the basis of +0.12 mbm^{-1}, and taken hourly averages to make the comparisons. The buoy barometers are reported to a resolution of 1mb, and are identical excepting for one hour (17/175). The comparison with the height-corrected ship was made as the average and standard deviation of the difference Sys-1 minus ship, -1.3±0.3mb, with a maximum difference of 0.5mb.

Wind direction

The ship's meteorological data processing includes conversion of relative wind speed and direction to their true values, using the ship's navigational data. With the ship stationary, only the heading is needed which is presumably obtained from the gyro-compass. The true wind values are included in the meteorological data stream, and as before, have been converted to hourly averages for comparison with the two buoy wind direction systems. Errors in calculation of true wind direction can occur during ship maneuvers, so we limit this comparison to the period between year-day 174.8 and 175.7 to avoid the hiatus apparent in the wind signal in Figure 7.

The wind was fairly steady from the north-east during this period, the average direction from the ship data being 67.0±11.5 degrees. The two buoy systems recorded wind direction using the "oceanographic" convention – "towards". For these hourly comparisons the buoy data have been converted to the "meteorological" convention. The differences between the three systems were very consistent;

Sys1-Sys2	Ship-Sys1	Ship-Sys2
8.1±1.9°	3.6±4.5°	11.2±5.5°

Thus compared with the ship, Sys1 measured average wind direction as 63.4 degrees and Sys2 as 55.8 degrees.

Radiation

Shortwave radiation and latent heat flux are usually the dominant components of the air-sea energy balance. Usually it is the pyrgeometer (longwave sensor) which gives the most trouble, but an error in the pyranometer calibration can lead to more serious errors. We identify the *Revelle*'s two longwave instruments as LW and LW1, and the shortwave as SW and SW1. The buoy instruments will be lower case, lw1 and sw1, lw2 and sw2 corresponding to Sys-1 and Sys-2.

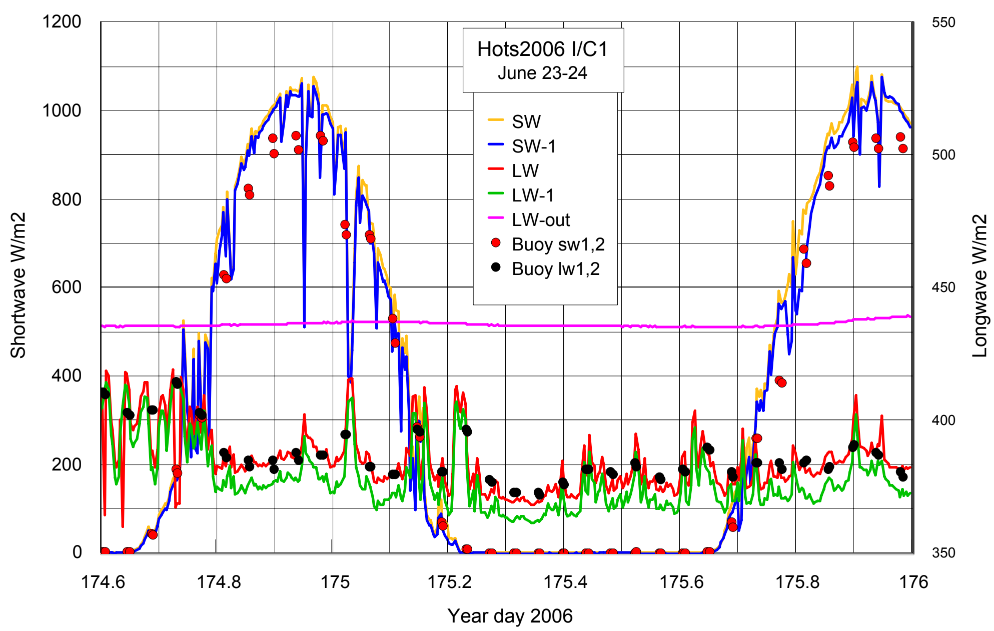


Figure 10. Longwave and shortwave intercomparisons between the two sets of instruments on the ship and those on the buoy LW-out is calculated from sea surface temperature, and shown here for completeness; net longwave is about 60 Wm^{-2}.

The comparison between the two pairs of ship radiometers and those on the buoy are given in Figure 10. Agreement between the two pyrgeometers on the buoy was remarkable during I/C1. The average difference for the hourly data was 0.82±0.98 Wm^{-2} and the maximum hourly difference was 3.0 Wm^{-2}. The graph also suggests good agreement between the buoy instruments and the ship's LW. This instrument showed a few anomalous spikes at the beginning of I/C1, but remained spike-free for the rest of the intercomparison (during I/C2, the spiking of LW became more frequent). Omitting the spikes, the average difference between lw1 and LW was 1.8±2.0 Wm^{-2}. The ship pyregeometers showed a consistent difference with LW-LW1= 7.24±1.35 Wm^{-2}.

Figure 10 indicates that the two pyranometers on the ship agree quite well, while those on the buoy have lower sensitivity and disagree with one another at the peak of radiation by some 30 Wm^{-2}. Although the shortwave radiation patterns appear similar during the solar peaks in Figure 10, according to the T/RH and wind data in Figure 7, recovery of the buoy may have begun immediately after 1700GMT (Year day 175.708). If so, the data in the second peak will be invalid, and until the situation is known, we will just analyze the first peak.

Looking just at the nighttime data from the four instruments, we find the following average values in Wm^{-2} :

SW SW1 sw1 sw2
0.06±0.69-2.8±0.622.20±0.602.50±1.02

These are relatively small biases, within the manufacturer's accuracy specification.

To compare the daytime responses, we first examine the ship data using 5-minute averages. The average difference SW-SW1= 19.05±13.59 Wm^{-2}. The 3 Wm^{-2} of this can be ascribed to the nighttime bias; the remaining 16 Wm^{-2} is probably due to different exposure and shadowing. Calibration error does not appear to be a factor, because the difference is not dependent on radiation intensity.

To quantify the comparison with the buoy, we produce hourly averages of the ship instruments as previously. For daylight hours of the first day only, we find:

sw1-SW1sw2-SW1

Average-35.83-54.29 Wm^{-2}
Std. dev. 26.4730.85 Wm^{-2}

However, these differences are clearly dependent on radiation intensity. At the peak, the differences are -77.4 Wm^{-2} and -92.4 Wm^{-2} respectively. Since the problem seems to be a difference in calibration factor, we calculate the average ratio between ship and buoy for the hourly data, with the result:
sw1/SW1sw2/SW1
Average0.95 0.90
Std. dev.0.05 0.04

The reasons for this rather large discrepancy are not known at this time.

Intercomparison 2 (I/C2)

I/C2 took place from 0400GMT on June 27 (Year day 178.167) to 0500GMT on June 29 (Year day 180.208). Instrumentation and analysis procedures are identical to those of I/C1, so much of the description will not be repeated here. Comparisons of the variables will be taken in the same order, beginning with the illustration of the basic meteorological time series in Figure 11.

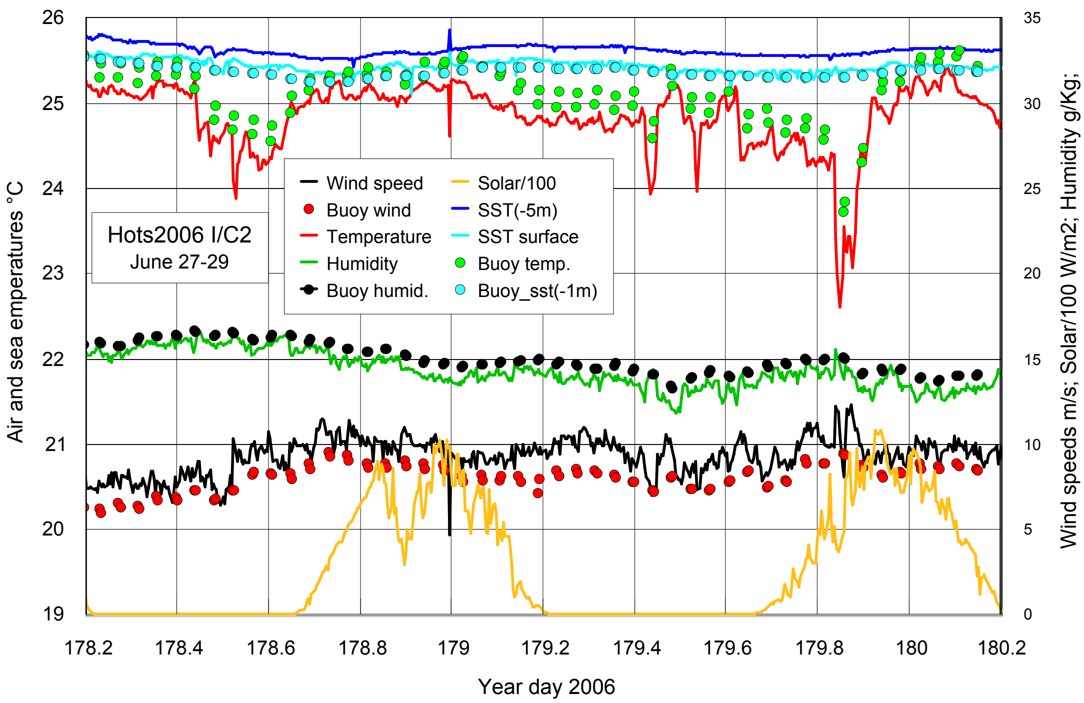


Figure 11. Meteorological variables measured by the ship's IMET system near the top of the foremast. Circular symbols are from the two WHOTS-3 buoy systems. The dark blue line is the ship's thermo-salinograph measurement at 5m depth, and the light blue line is the same data extrapolated to the surface using models of diurnal warming and cool skin in COARE3.0.

Winds were stronger than in I/C1, consistently near 10 ms^{-1} and more easterly. There was also more cloud cover. The air temperature signal indicates the passage of two cooling events, but neither the ship nor the buoy registered any associated rainfall. All the buoy sensors tracked the ship measurements consistently, again with the clear need for height adjustment. This time, the buoy sea temperatures at 1m depth were both very close to the surface SST value produced by the COARE3.0 upper ocean models. The average difference of 0.19ºC between this and the ship's thermo-salinograph measurement at 5m depth, on which it was based, must again be attributed to the cool skin phenomenon. One would have expected the buoy values to be closer to the bulk value.

The two buoy systems seem to agree well with one another, with the exception of the air temperature sensors. As shown below, Sys-2 temperatures average about 0.13ºC higher than Sys-1, which is still well within the specification of the sensors.

Height adjustment

As in I/C1, the ship time series has been run through the COARE3.0 bulk flux algorithm to obtain the fluxes and profile parameters. Figure 12 shows the time series of fluxes. Latent heat and momentum fluxes are considerably higher than in I/C1, driven by the stronger winds, while sensible heat fluxes are less because of a much smaller air-sea temperature difference. The average *z/L*= -0.11±0.05, which is approaching neutral conditions.

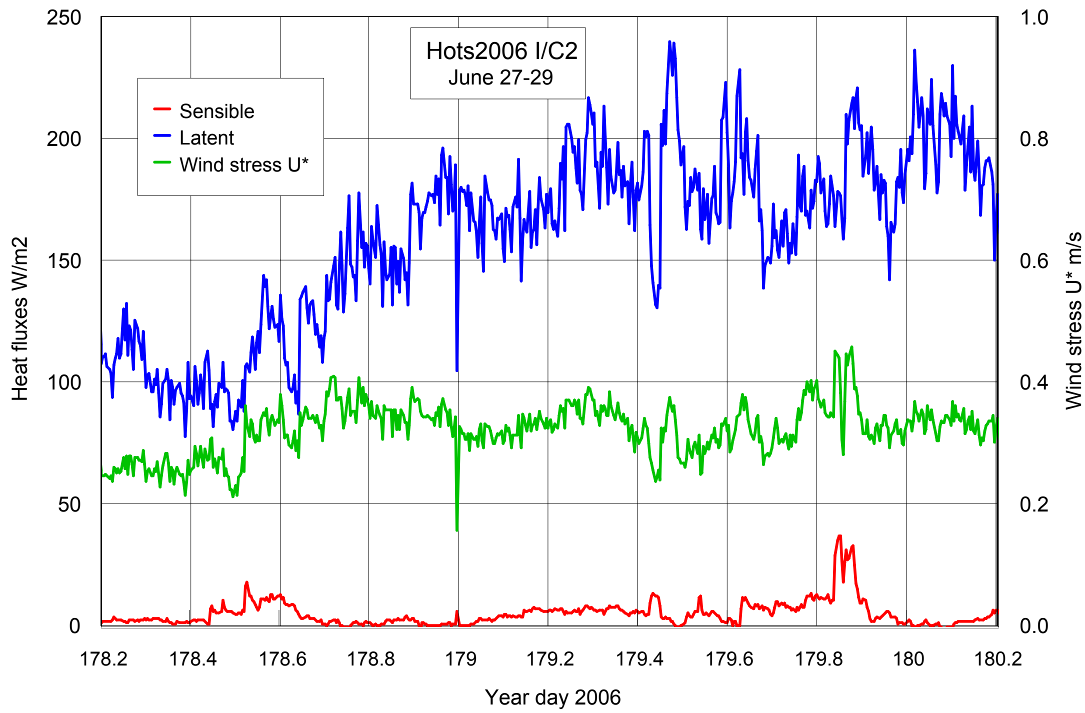


Figure 12. Sensible and latent heat fluxes, and wind stress (momentum flux) during I/C2.

As before, the profile parameters from COARE3.0 have been used to calculate the values of wind speed, potential temperature and specific humidity at Assman and buoy sensor heights, displayed in Figure 13 with reference to sample profiles from hour 14 on June 28 (Year day 179.604). For this example, the ship wind speeds and specific humidity are extremely close to the profile values. The difference between the temperature sensors noted consistently in Figure 11 is evident, but the very small air-sea temperature difference and the fine temperature scale put this in context. The Assman values are also very close to the profiles at 6.8m height.

However, the horizontal bars showing averages and standard deviations give the overall picture for the 49 hours of I/C2. The average hourly differences between sensors and the height adjusted ship profiles are given below as in I/C1.

	Sys-1			Sys-2			Assman	
	u	θ	q	u	θ	q	θ	q
	ms^{-1}	^{o}C	gkg^{-1}	ms^{-1}	^{o}C	gkg^{-1}	^{o}C	gkg^{-1}
Average	0.192	0.019	-0.081	0.072	0.130	-0.054	0.048	0.060
Std. Dev.	0.303	0.084	0.090	0.259	0.053	0.094	0.142	0.325

The Assman averages again confirm the reliability of the ship meteorological system as a reference, while their variability signals the human challenge of maintaining half-hourly observations day and night for 49 hours. All buoy sensors match the ship measurements within the desired target accuracy. Even the Sys-1 wind speed and Sys-2 temperature, which serve to highlight the excellent agreement of the other measurements. It tends to rule out calibration error in the case of the I/C1 humidities.

Barometric pressure

We have again adjusted the ship measurements to nominal buoy height of 3m, on the basis of +0.12 mbm^{-1}, and taken hourly averages to make the comparisons. The buoy barometers are reported to a resolution of 1mb, and are identical except for two hours. The comparison with the height-corrected ship was made as the average and standard deviation of the difference Sys-1 minus ship, -1.1±0.3mb, with a maximum difference of 0.5mb. These figures are very similar to I/C1.

Wind direction

The wind was fairly steady from the east during I/C2, the average direction from the ship data being 80.9.0±9.4 degrees. For the hourly comparisons, the buoy systems have been converted to the "meteorological" convention. The differences between the three systems were very consistent. However, unlike I/C1, the two buoy systems gave virtually identical measurements. But they were almost 10 degrees different from the ship:

Sys1-Sys2	Ship-Sys1	Ship-Sys2
0.9±1.6°	9.0±2.7°	9.8±3.5°

Thus, compared with the ship, the buoy systems measured average wind direction during I/C2 at about 72 degrees.

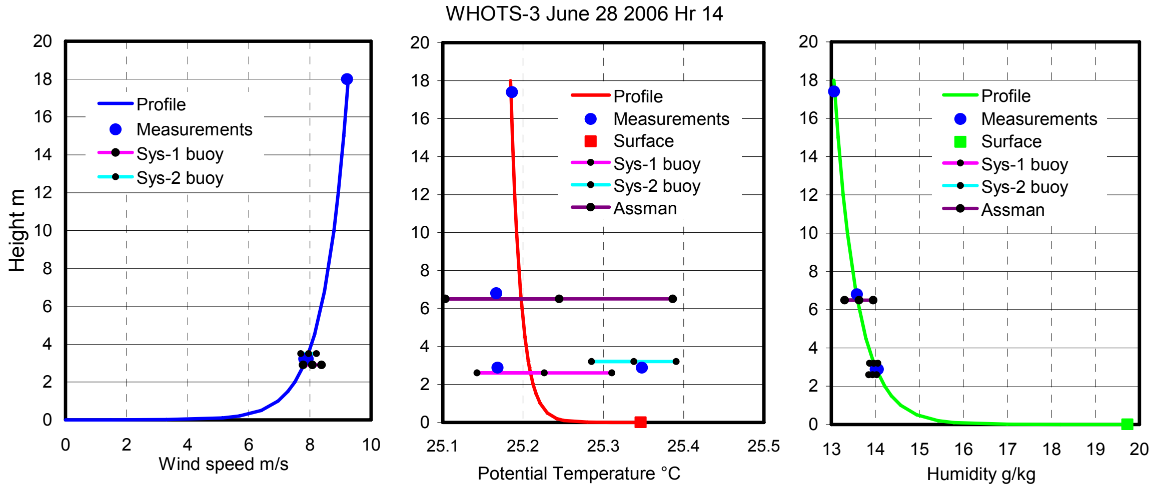


Figure 13. Example of profiles used for height adjustment of the various measurements during I/C1. The ship's anemometer was at 18m on the foremast, and the temperature/humidity sensor at 17.4 m. Temperature and humidity were measured with an Assman psychrometer through a forward chock at 6.8 m height. The ship was standing about 0.25 nm downwind of the WHOI buoy, which had two wind sensors at 3.22 m above the sea surface and two temperature/humidity sensors at 2.88 m. The ship and buoy data points are hourly averages; the Assman values are spot readings. The profiles were constructed from flux/gradient parameters calculated using version 3.0 of the COARE bulk flux algorithm.

Radiation

As before, the *Revelle*'s two longwave instruments are called LW and LW1, and the shortwave SW and SW1. The buoy instruments are lower case, lw1 and sw1, lw2 and sw2 corresponding to Sys-1 and Sys-2.

Agreement between the two pyrgeometers was even closer than during I/C1. The average difference for the hourly data was 0.13±0.86 Wm^{-2} with the maximum hourly difference just 1.0 Wm^{-2}. Sys-2 was higher. The ship's LW pyrgeometer produced spikes intermittently, but we discovered that the spike signal was very specific, and could be removed. From a total of 588 5-minute values during the intercomparison, only 50 were affected. The resulting average difference LW-LW1 was 6.94±1.08 Wm^{-2}, virtually identical to that found in I/C1. Nevertheless, we have plotted only LW1 in Figure 14, and find the hourly average lw1-LW1 to be 4.4± 1.2 Wm^{-2}, so agreement between the ship and buoy systems is close as in I/C1.

In the case of shortwave radiation, the cloudiness makes it difficult to compare the instruments qualitatively as we did with I/C1. However, we will follow the same procedure, by first determining the average nighttime signal from the four instruments:

SW	SW1	sw1	sw2	
-0.17±0.56	-2.47±0.63	2.06±0.23	2.17±0.37	Wm^{-2} :

The ship instruments are virtually unchanged, while the new pair of buoy radiometers have similar bias as before, but are less noisy.

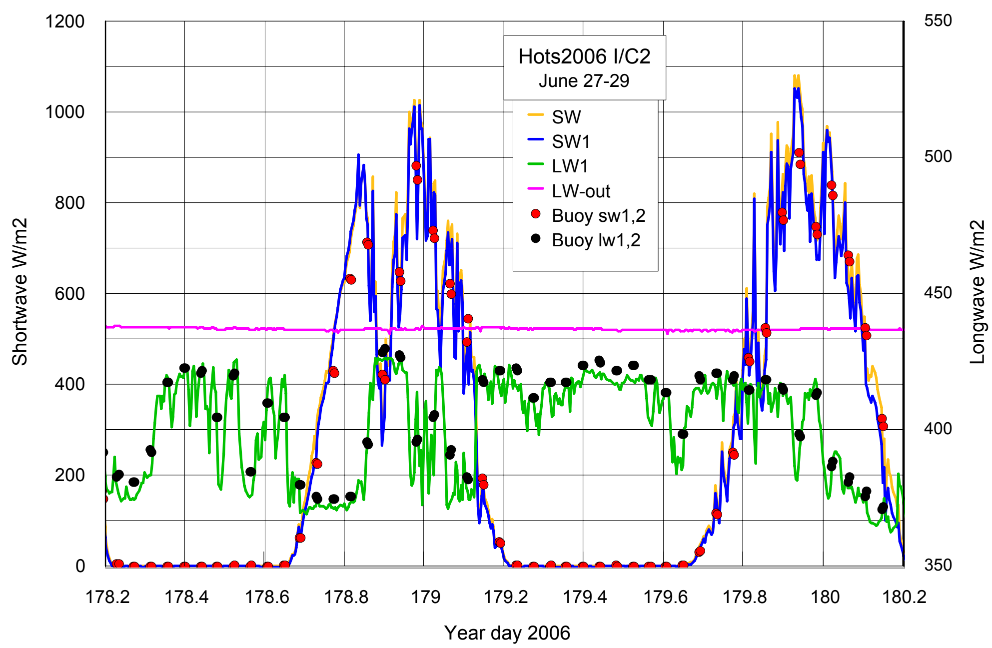


Figure 14. Longwave and shortwave intercomparisons between the two sets of instruments on the ship and those on the buoy. LW-out is calculated from sea surface temperature. Unlike during I/C1, intermittent cloudiness makes downwelling, and hence net, longwave very variable.

For the daytime signals, we find the 5-minute average difference SW-SW1= 22.09±18.14 Wm^{-2}, very similar to I/C1 (19.05±13.59 Wm^{-2}).

To quantify the comparison with the buoy, we produce hourly averages of the ship instruments and for daylight hours during both days, we find, again similar to I/C1 and dependent on radiation intensity:

	sw1-SW1	sw2-SW1	
Average	-29.68	-39.89	Wm^{-2}
Std. dev.	23.11	26.60	Wm^{-2}

At the peak, the differences are -69.3 (in I/C1 -77.4) Wm^{-2} and -97.3 (-92.4) Wm^{-2} respectively. The average ratio between ship and buoy for the hourly data:

	I/C1		I/C2	
	sw1/SW1	sw2/SW1	sw1/SW1	sw2/SW1
Average	0.95	0.90	0.94	0.92
Std. dev.	0.05	0.04	0.05	0.06

The discrepancy persists, and can seriously affect the determination of net air-sea heat transfer. Since the WHOTS location is not too remote, it would be worth sending out a ship equipped with a set of Fairall radiation sensors to stand off for a carefully forecast few days. Figure 15 plots R/V *Revelle*'s shipboard meteorological data.

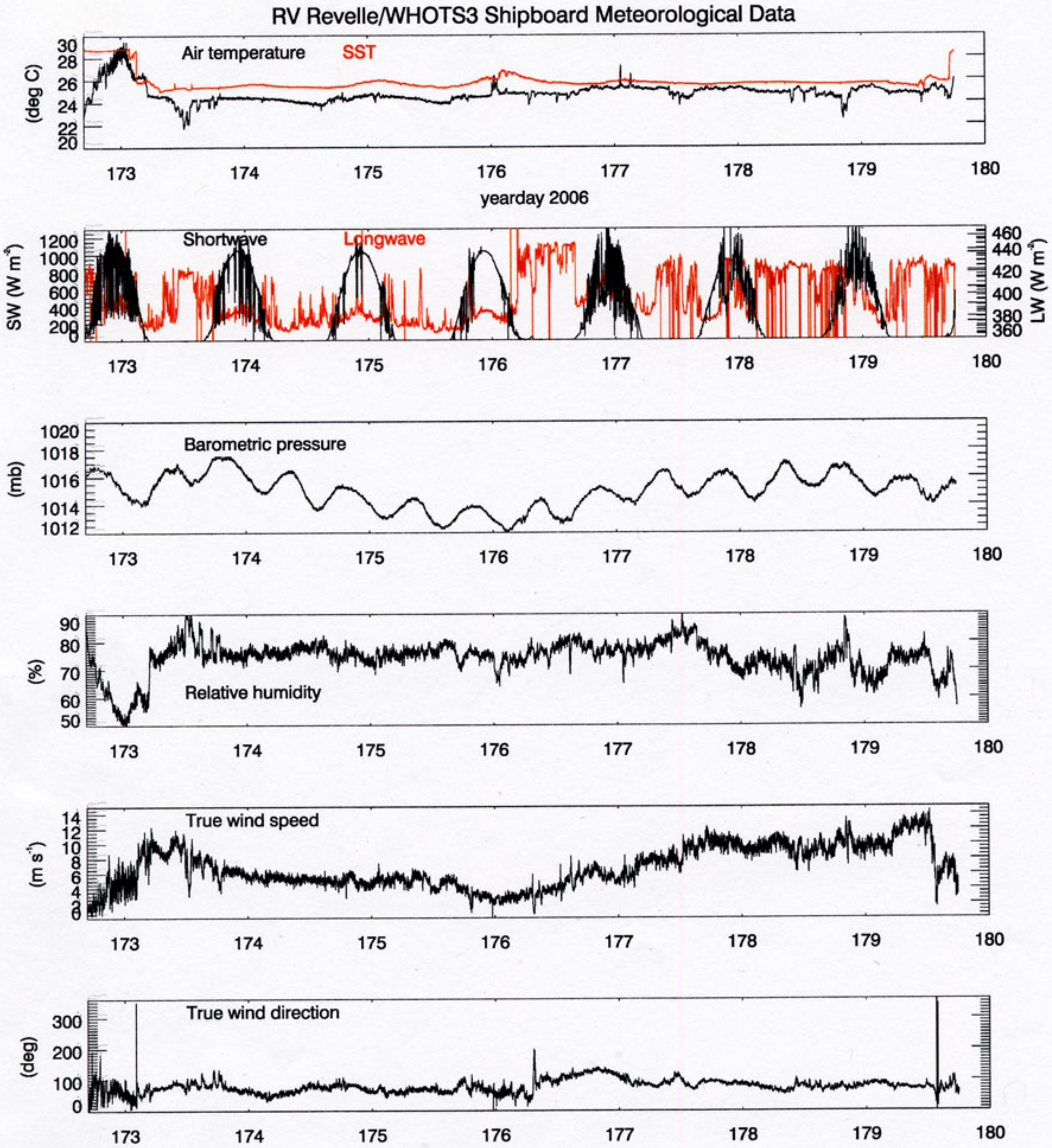


Fig 15. RV *Revelle* WHOTS 3 Shipboard Meteorological Data

Summary

During changeover of the WHOTS mooring, two periods of instrument intercomparisons were performed. Before the existing mooring (WHOTS-2) was recovered its instruments were compared with those on the R/V *Revelle* over the course of one day (I/C1). Those on the replacement mooring (WHOTS-3) were similarly compared for two days after deployment (I/C2). During both periods, half-hourly readings of air temperature and humidity were made with a hand-held Assman psychrometer to check the automatic systems. Because of the difference in height above sea level of the three sets of instruments (*Revelle* ~17m; Assman 6.8m, Buoy ~3m) boundary-layer flux/gradient parameters were calculated using the COARE3.0 bulk flux algorithm to adjust the *Revelle* observations to the level of the others.

The comparisons were based on hourly-averaged data to match those transmitted from the moorings, each of which supports two independent sets of meteorological instruments, identified as Sys-1 and Sys-2. The ship carries two sets of radiation instruments, LW and LW1 for longwave, and SW and SW1 for shortwave. The following summarizes the results of comparing corresponding sensors, averaged over each period. Differences are given as buoy (or Assman) minus *Revelle*, after the latter had been adjusted to the height of the lower sensor. The adjusted values were calculated individually for each set of hourly data; the *average* adjustment is quoted here. The ship pressure sensor reading was reduced to buoy level for the comparison.

I/C1

This period of 27 hours had fairly clear sky, with a very steady wind of about 5 ms^{-1} from the northeast. The average measured sea-air temperature difference was 1.04ºC, and both sensible and latent heat fluxes were fairly steady around 6Wm^{-2} and 100Wm^{-2} respectively. The average height adjustment of wind speed, potential temperature, and specific humidity from foremast to buoy was -0.75ms^{-1}, 0.31ºC, and 0.86gkg^{-1} respectively. Average sensor differences were:

	θ ºC	q gkg^{-1}	ms^{-1}	Dir.ºp mb
Assman-ship	0.005	0.074	—	—
Sys-1 – ship	-0.087	-0.340	0.337	-3.6-1.3
Sys-2 – ship	0.073	-0.314	0.238	-11.2-1.3

The good agreement between the Assman and the height-adjusted ship sensors indicate that the latter provide a reliable reference for temperature and humidity. Both buoy temperature sensors matched the ship reference to better than 0.1ºC which is remarkable after a year of unattended operation at sea. The humidity comparisons are just outside the ±1%RH specification of the sensors. Both buoy humidity sensors are low compared with the ship by about the same amount, which may indicate a common calibration error or identical deterioration during the year-long deployment. Both wind sensors read high by about 0.3ms^{-1} compared with the ship sensor; the latter is an ultrasonic anemometer with no moving parts, whereas rotating systems, such as the propellers used on the buoys, are prone to overestimation errors. Other possible sources of discrepancy in wind speed and direction measurements, are different flow distortion over ship and buoy, and errors in the ship's heading.

For most of I/C1 the two SST sensors at 1m depth on the buoy gave values which were clearly influenced by air temperature. The reason for this is not known.

The average difference between the two buoy pyrgeometers was less than 1Wm^{-2} averaged over the 27 hourly values of I/C1. The ship pyrgeometers showed a consistent difference of 7.2Wm^{-2}, with LW averaging just 1.8Wm^{-2} less than the buoy instruments. Before I/C1 began, LW was seen to exhibit a few spikes but these were absent during the intercomparison.

The ship pyranometers agreed well with one another, but gave higher values than those on the buoy. This appears to be a difference in calibration rather than a bias, because all 4 pyranometers give nighttime values less than ±3Wm^{-2}. At the diurnal peak the buoy instruments differed from one another by some 30Wm^{-2}. Averaged over the daytime observations, we find sw1/SW1=0.95 and sw2/SW1=0.90. The reasons for this serious discrepancy are a matter for further investigation.

I/C2

This 49-hour period was cloudier, with winds consistently stronger (near 10 ms^{-1}) and more easterly than in I/C1. The higher winds took atmospheric stability closer to neutral so that profiles and fluxes were markedly different from I/C1. The average sea-air temperature difference was 0.41ºC, and average height adjustments to buoy level were 1.35 ms^{-1}, 0.23ºC and 0.78 gkg^{-1}. Sensible heat flux remained less than 6Wm^{-2}, the effect of higher wind being countered by the reduced air-sea temperature difference, but latent heat flux increased to values exceeding 200Wm^{-2}.

	θ ºC	q gkg^{-1}	ms^{-1}	Dir.ºp mb
Assman-ship	0.048	0.060	—	——
Sys-1 – ship	0.019	-0.081	0.192	-9.0-1.1
Sys-2 – ship	0.130	-0.054	0.072	-9.8-1.1

The Assman averages again confirmed the reliability of the ship T/RH system as a reference. All the freshly calibrated buoy meteorological sensors matched the height-adjusted ship values within the target accuracies. In particular, the humidity comparisons suggest deterioration rather than calibration error in the case of I/C1.

The two sea temperature sensors at 1m depth on the buoy agreed with one another to 0.01ºC. They were consistently 0.25ºC lower than the ship's thermo-salinograph which takes water from 5m depth. Although this value approximates the cool skin effect (the COARE3.0 cool skin model predicts 0.19ºC), this cannot be the explanation because the cool skin is confined to the top 1mm or less of the ocean. A more likely explanation is local heating of the water around the stationary ship.

As with I/C1, the two buoy pyrgeometers agreed closely; the average difference for the hourly data was 0.13Wm^{-2}. The ship's LW pyrgeometer spiked more frequently through I/C2 than before, but when the spikes were removed the average difference LW-LW1 was 6.9Wm^{-2} virtually identical to I/C1. The buoy instruments averaged 2.4Wm^{-2} less than LW and 4.4Wm^{-2} greater than LW1.

There was broken cloud cover on both days of I/C2 so the comparison between the buoy and ship pyranometers was not so clear graphically. However the same data analysis to that of I/C1 produced similar results. The nighttime signals of both ship and buoy radiometers was of order ±2Wm^{-2} and the two ship instruments agreed well, but gave higher values than their buoy counterparts. The latter agreed better with one another than before; the average daytime ratios were sw1/SW1=0.94 and sw2/SW1=0.92.

6. Shipboard ADCP

The R/V *Revelle* is equipped with an RDI OS150 Acoustic Doppler Current Profiler. The University of Hawaii processing system is installed, producing real-time profiles and other products. In addition to providing an intercomparison with the upward-looking ADCP on the WHOTS mooring, the shipboard ADCP system revealed interesting regional current features.

During WHOTS-3, we observed the northwestward flow of the North Hawaiian Ridge Current during our transit from Oahu to Station ALOHA (Figure 16). While working around the WHOTS mooring site, we experienced relatively strong and persistent northward to north-northeastward flow (Figure 17). This was roughly consistent with the NCOM analysis of 6/24/06 showing an anticyclonic eddy to our east (Figure 18).

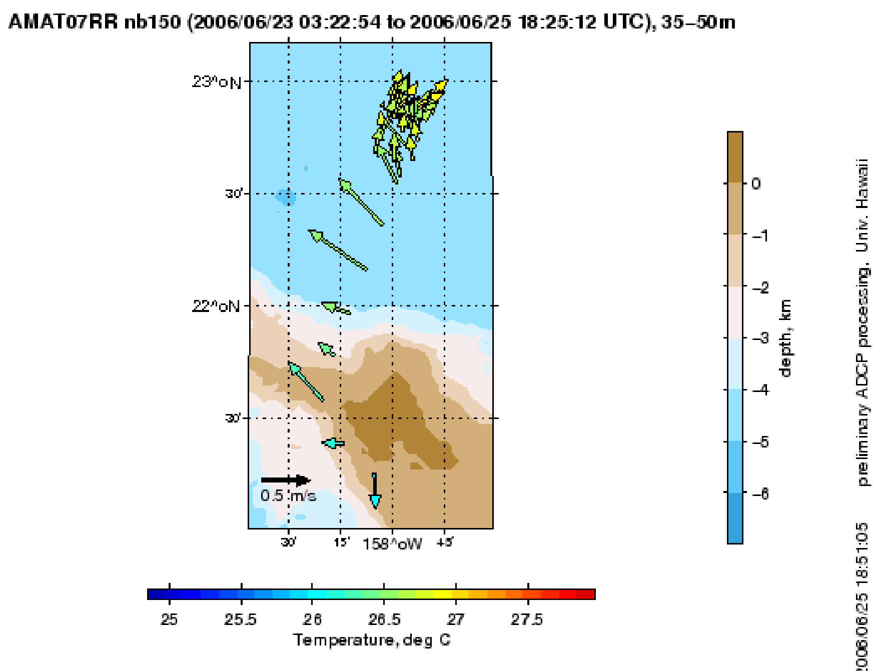


Figure 16. Current vectors for the 35-50 m layer measured by the R/V *Revelle* from Honolulu to the WHOTS site during the dates indicated.

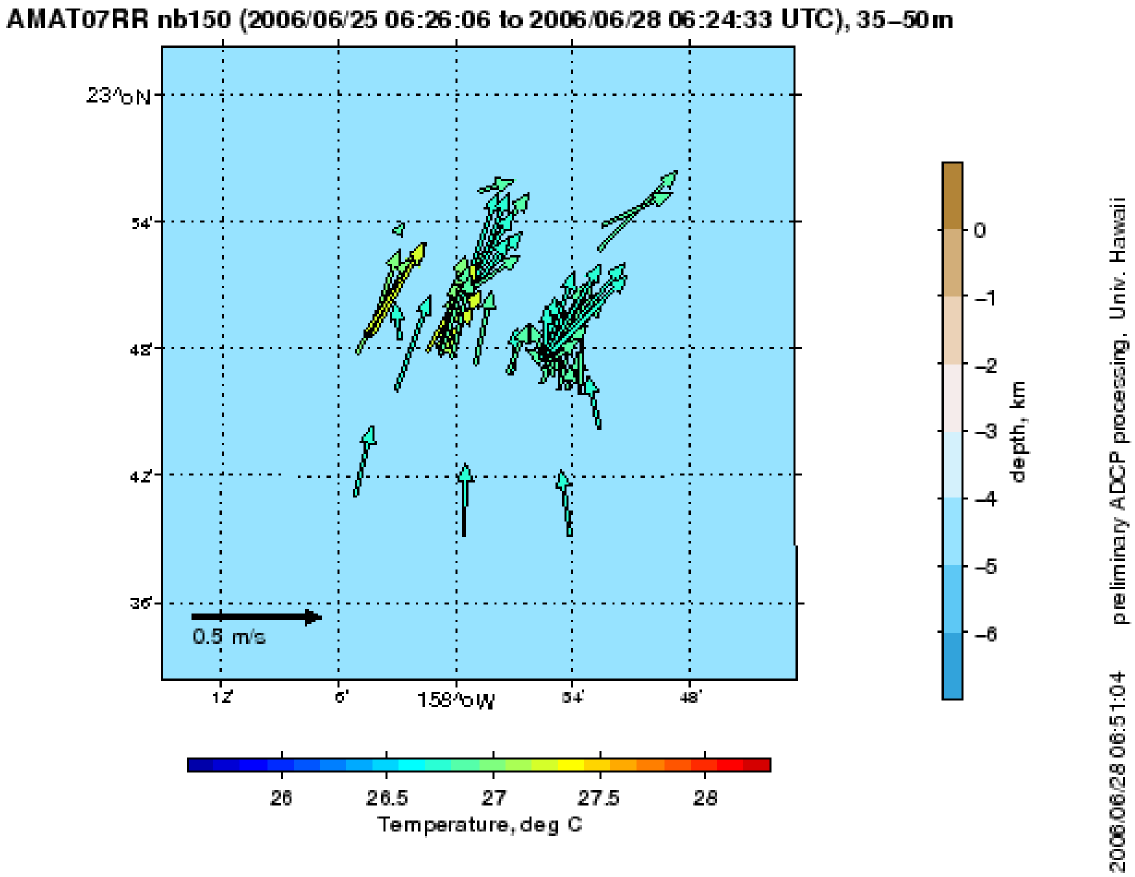


Figure 17. Current vectors for the 35-50 m layer measured by the R/V *Revelle* while working around the WHOTS site during the dates indicated.

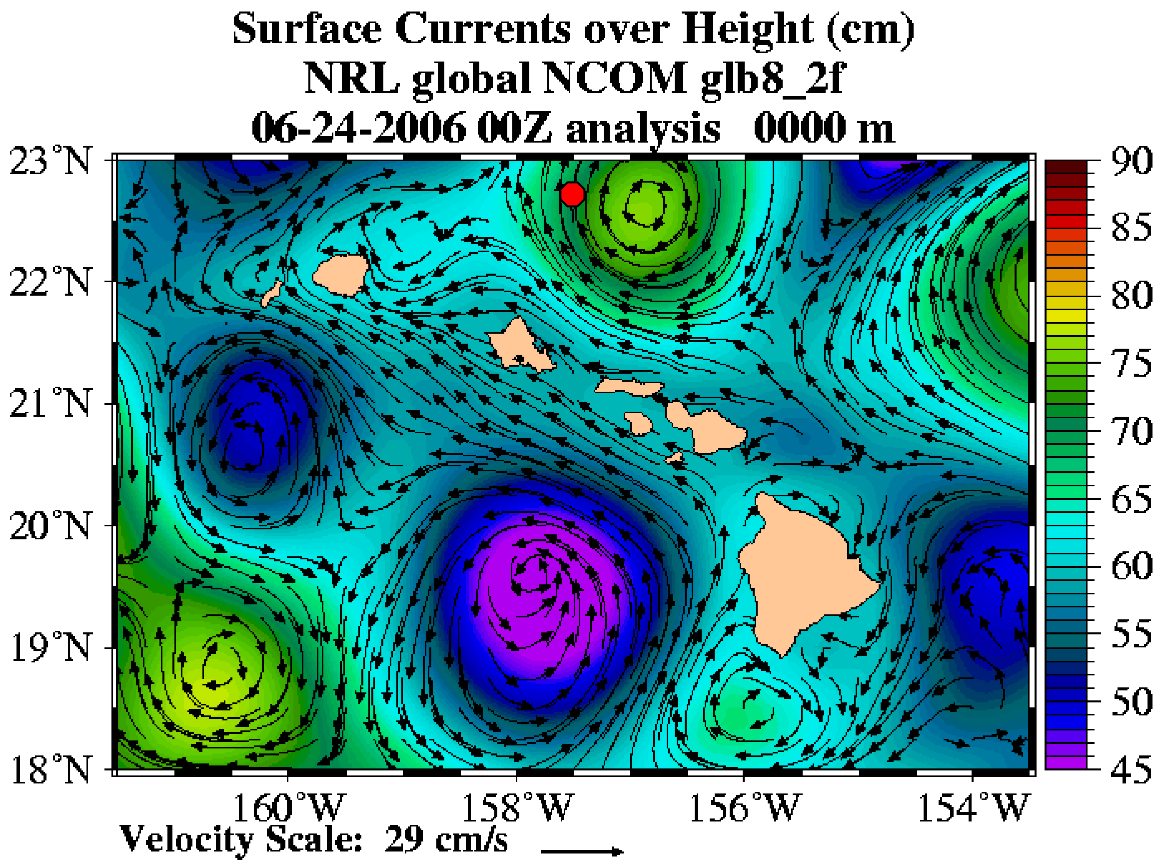


Figure 18. Hawaii region sea level and surface current analysis from the Navy NCOM system for 6/24/06. Note the anticyclonic eddy feature to the east of Station ALOHA (indicated by red dot.)

File Size 35,981,087 bytes
BB/WH Ensemble Length 748 bytes
System Frequency: 307.2 kHz
1st Bin 6.23 m, Bin Size 4.00 m
No. Bins 30, Pings/Ens 40, Time/Ping 00:15.00
First Ensemble 00000001 05/07/27 03:50:00.00
Last Ensemble 00048092 06/06/26 03:00:00.00 NVRAM Data in File
Average Ensemble Interval 00:02:20.43
Orientation UP
Beam Angle 20 Degrees
Transducer 4 Beam Janus
Convex

7. CTD Operations

The R/V *Revelle* provided CTD and water sampling equipment, including a Sea-Bird 9/1+ CTD sampling at 24 Hz, with pressure, dual temperature and dual conductivity sensors. However, Seabird temperature and conductivity sensors used by UH routinely as part of the Hawaii Ocean Time-series were used instead of those provided by the ship. This was to allow the data to be more easily tied into the HOT CTD dataset. The CTD was installed inside a twelve-place rosette with 12 liter Bullister sampling bottles.

A total of 16 CTD profiles were obtained. Two series of CTD casts were made to obtain profiles for comparison with subsurface instruments on the WHOTS-2 mooring before recovery, and with those on the WHOTS-3 mooring after deployment. The comparison series consisted of casts to at least 200 m every two hours for twelve hours (roughly one semidiurnal tidal cycle). In addition, three 1000 m CTD profiles were made to provide a cross-calibration between the CTD and the SBE-37s that were recovered from the WHOTS-2 mooring. These casts included approximately ten-minute long stops at four selected depths to provide stable conditions for the calibration. Appendix B provides summary information for the CTD stations.

Water samples were taken from all casts; four samples for 1000 m casts and two samples for the 200 m casts. These samples will be analyzed for salinity and used to calibrate the conductivity sensors used for the CTD profiling. Water samples were also drawn from the shipboard Seabird thermosalinograph system for post-calibration of that dataset.

Station numbers were assigned the standard HOT notation. Station 2 refers to profiles taken within a six-mile radius of 22°45'N, 158°W. Station 50 is used to refer to profiles taken close to the WHOTS mooring (within a km) for comparison.

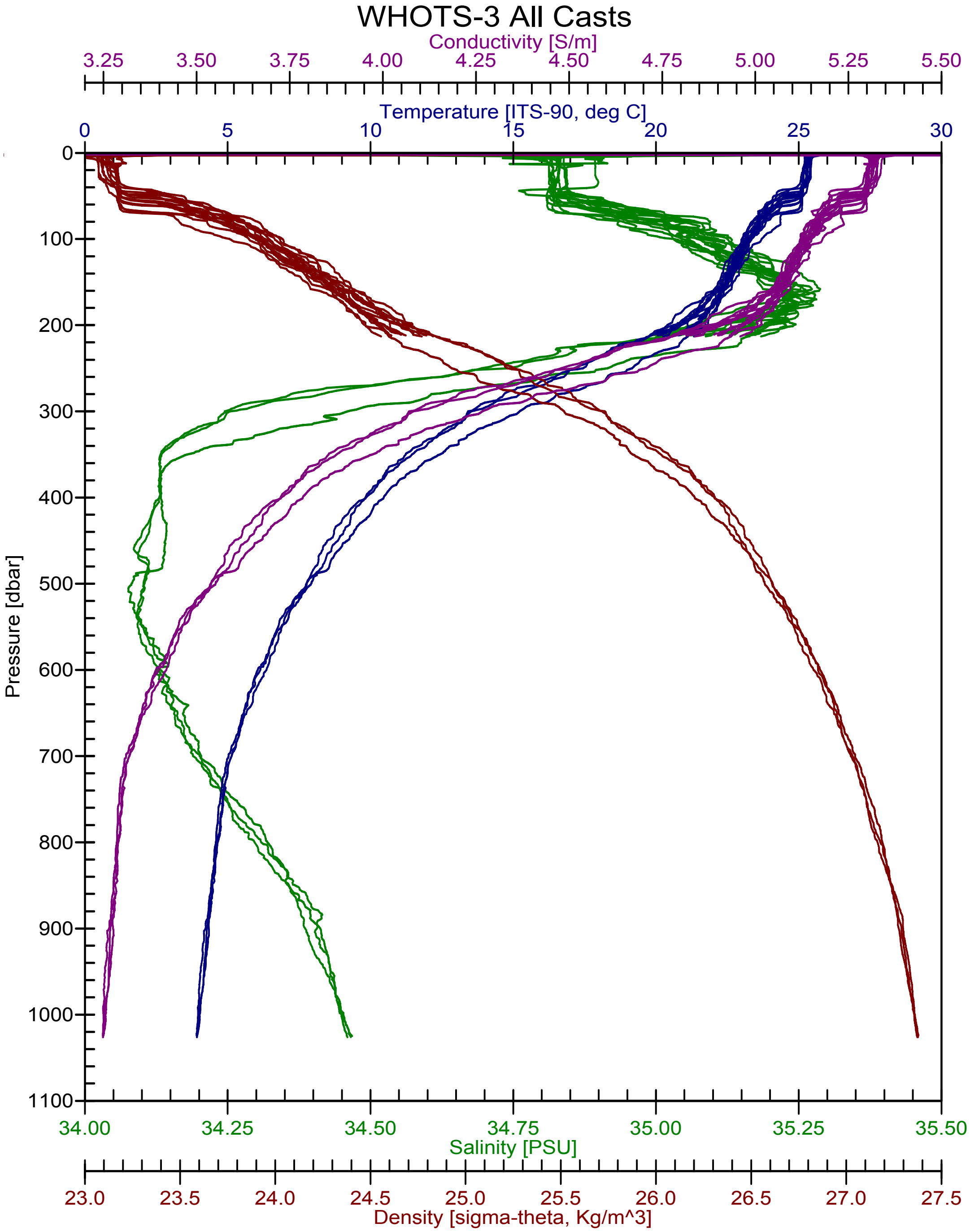


Figure 19: CTD All Casts.

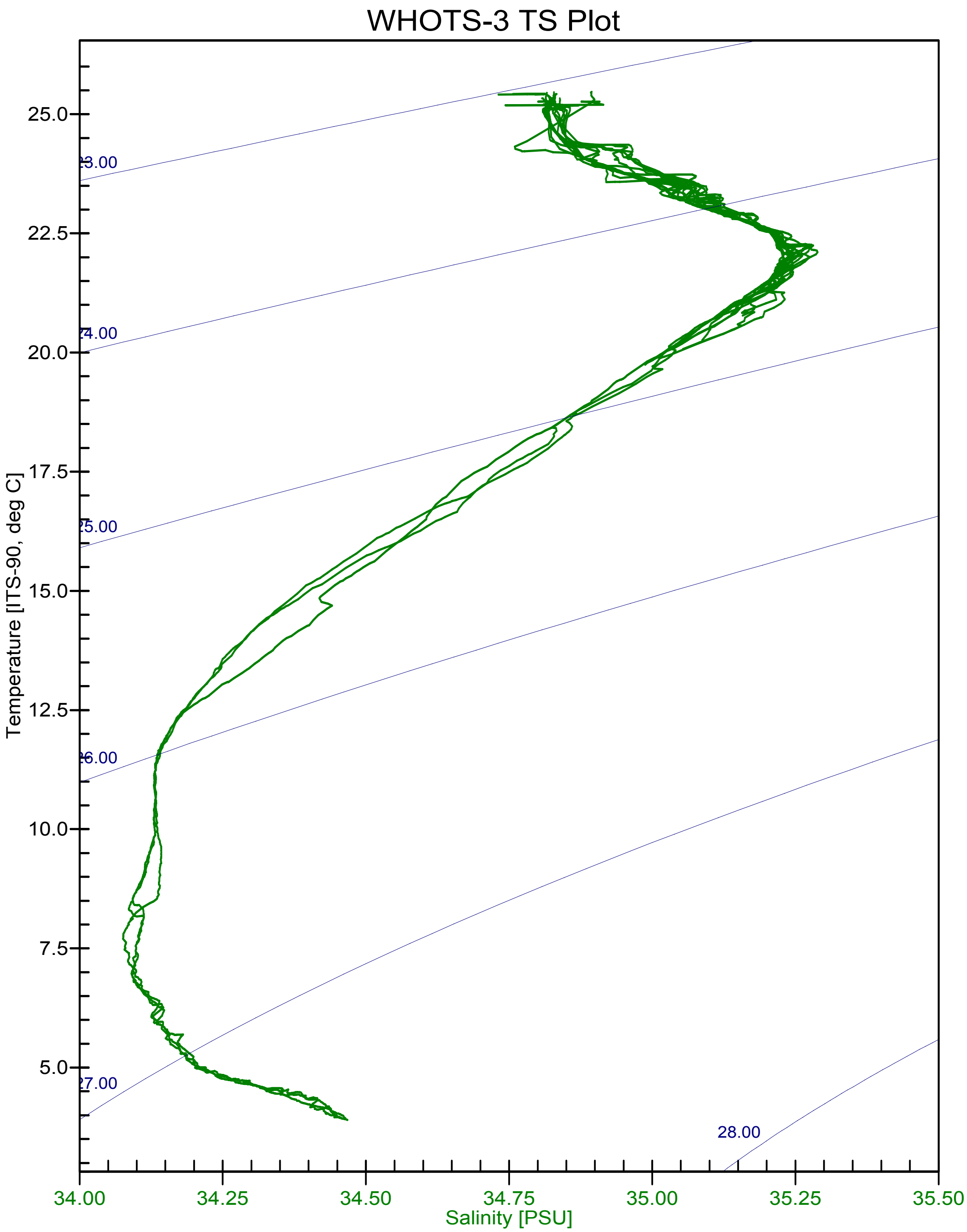
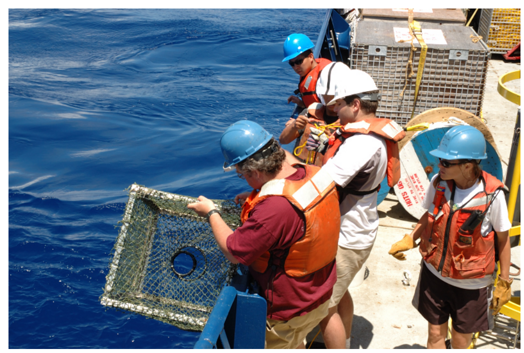


Figure 20: TS Plot.

8. Fish Trap

John Yeh, a graduate student at the University of Hawaii, gathered data for his thesis. It focuses on the deep sea ecology of scavengers on the Hawaiian slope. Specifically, in how patterns of community structure such as biodiversity, abundance, and size of benthopelagic scavenging fauna change along a depth gradient. To facilitate his research, he designed and built a free vehicle longline/fish trap system. The longline/trap deployed on the cruise served to capture voucher specimens and was equipped with a baited rectangular trap with a conical opening in addition to 10 long line hooks. It was deployed completely untethered to the ship and freefell until it landed on the seafloor (4690m). A galvanic timed release made of magnesium and steel corroded 15 hours after deployment. The buoyant system returned to the surface. Upon surfacing, a spar buoy equipped with a radio beacon transmitted a signal to the ship and the trap was recovered.



9. NOAA Teacher At Sea

A NOAA Teacher-at-Sea was onboard the ship during the WHOTS-3 mooring cruise. The purpose of the Teacher-at-Sea program is to help to fulfill NOAA's mission to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to help to meet economic, social, and environmental needs. The program seeks to allow teachers to experience current research being carried out on a research vessel so that they, in turn, can foster an interest and understanding of oceanography within their own classrooms and among their colleagues. The responsibilities of the Teacher-at-Sea included: writing and submitting logs and digital photos of her experiences to the NOAA Teacher-at-Sea website, interviewing scientists and crew, and responding to e-mail from students and other interested parties. Post cruise, the Teacher-at-Sea will develop 8-10 lessons that correspond with the science and research being conducted on the R/V *Revelle*. In addition, she will submit an article for publication or conduct a presentation to her colleagues.

10. Ernest F. Hollings Undergraduate Scholarship Program

Overview of NOAA Hollings Scholarship

The NOAA Ernest F. Hollings Scholarship program is (1) designed to increase undergraduate training in oceanic and atmospheric science research and technology and education, and to foster multidisciplinary training opportunities, (2) to increase public understanding of the ocean and atmosphere and improve environmental literacy, (3) to recruit and prepare students for public service careers with NOAA and other natural resource and science agencies at the Federal, State and local levels of government, and (4) to recruit and prepare students for careers as teachers and educators in oceanic and atmospheric science, and to improve scientific and environmental education in the United States. A ten week internship with NOAA or a NOAA cooperative institute such as CICOR (Cooperative Institute for Climate and Ocean Research) is required. The UOP internship was arranged by CICOR Administrator Patricia White and was designed to include WHOTS 2006 cruise. Dr. Robert Weller is the principal supervisor of the Hollings Scholar, Theresa L. Smith.

Preparation for the cruise

Duties for Ms. Smith before R/V *Roger Revelle* was underway, were helping to pack instruments into containers, loading equipment from the ship deck into the science lab, using carts and a palate jack for transporting heavy objects, organizing the lab and tying down equipment. Training was provided on the use of all machinery during the cruise. Hard hats, closed toe shoes and work vests (PFD's) were required while working onsite.

CTD deployment

The Scholar assisted in the deployment and recovery of the CTD at 12:00 A.M.

Intercomparison of data

To check the accuracy of data being transmitted from WHOTS 2005, a comparison of data from the ship and manual readings was conducted. Dr. Frank Bradley of Commonwealth Scientific and Industrial Research Organization (CSIRO) in Canberra, Australia, provided manually obtained data for the intercomparison. An Assman Psychrometer was used to record dry air temperature and wet air temperature at the bow of the ship. This data was calculated by Dr. Bradley into several parameters, two of which, relative humidity (HRH) and air temperature, were used in the intercomparison exercise. These measurements were taken every 30 minutes on each intercomparison day of the cruise at the bow of the ship. Ms. Smith was trained to operate the psychrometer to serve as a back up person.

Data files were obtained from each source and were processed in CYGWN to be read in MatLab. Nan Galbraith programmed MatLab files to concatenate the data and plot them. Ms. Galbraith also included a complete 'read-me' file explaining the details of this procedure. The scholar ran MatLab and relayed messages to Ms. Galbraith, trying to work out kinks in the programming. This took three days. Finally, the intercomparison was plotted and sent to Dr. Weller.

Recovery and Deployment of WHOTS buoys

Throughout the cruise, the Recovery of WHOTS 2005 buoy and the deployment of WHOTS 2006 buoy and final preparation for the trip back to port, Ms. Smith performed a variety of duties which included the operation of heavy machinery such as the winch and A-frame. Ms. Smith also took photographs and was available to help when needed.

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Acknowledgments

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

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Colbo, K. and R. Weller, Accuracy of the IMET sensor package, *J. Atmosph. Ocean. Technol,.* submitted.

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, 2003. Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm. *J. Climate*, **16**, 571–591.

Hosom, D. S., R. A. Weller, R. E. Payne, and K. E. Prada, 1995. The IMET (Improved Meteorology) ship and buoy systems. *J. Atmosph. Ocean. Technol.*, **12**(3), 527–540.

Appendix A: WHOTS-2 Subsurface Recovery

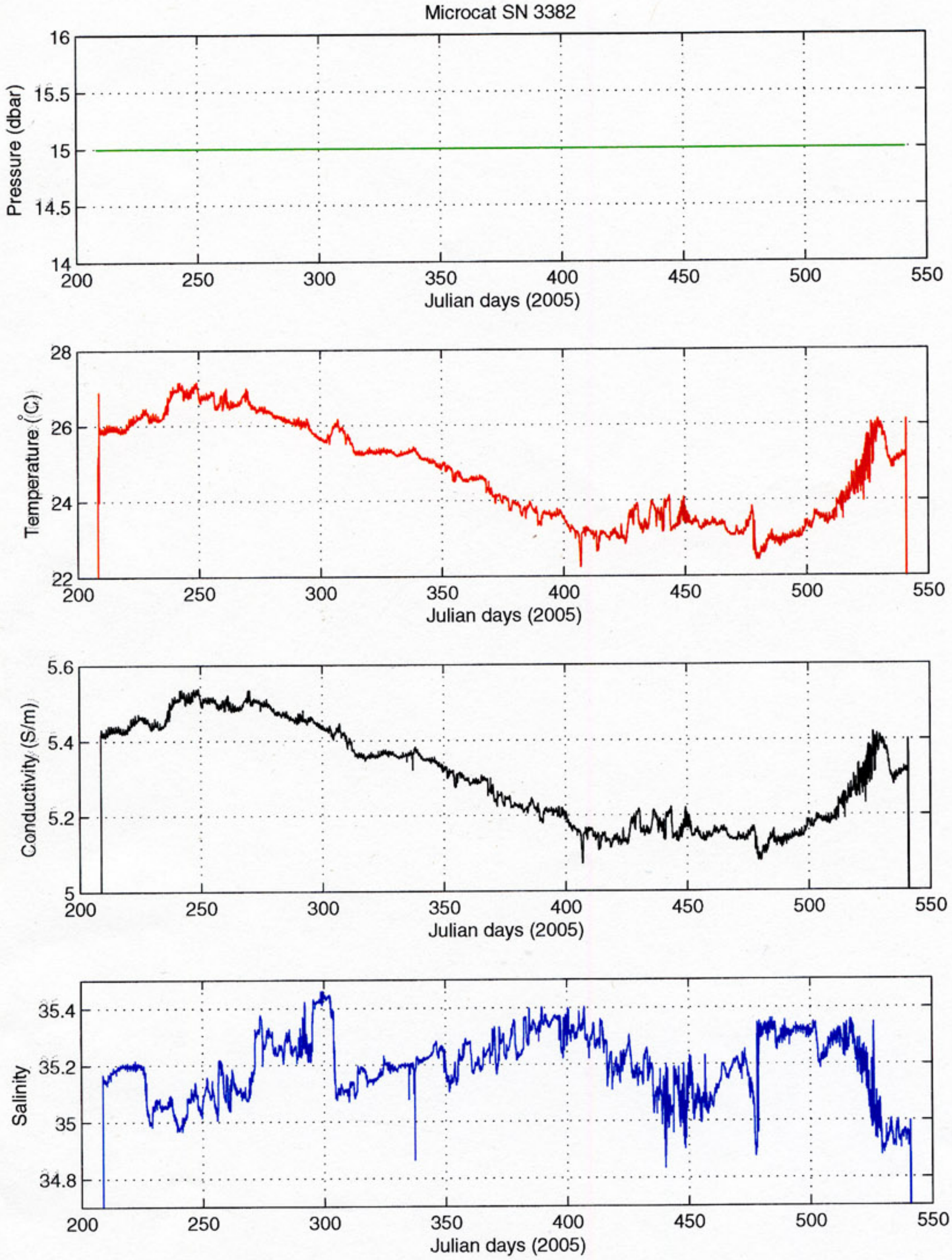

Figure A1: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3382 Microcat instrument deployed at 15m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

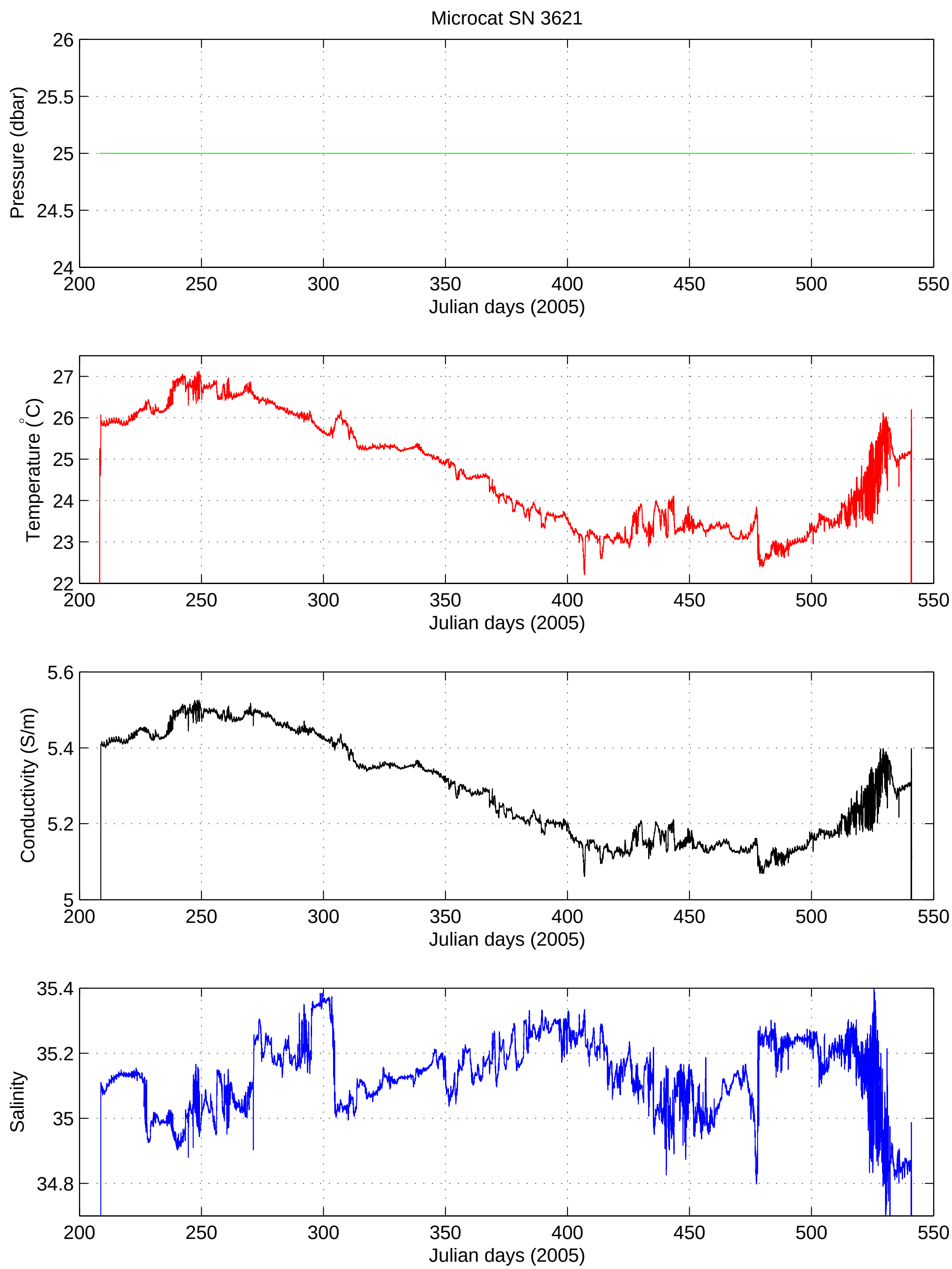

Figure A2: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3621 Microcat instrument deployed at 25m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

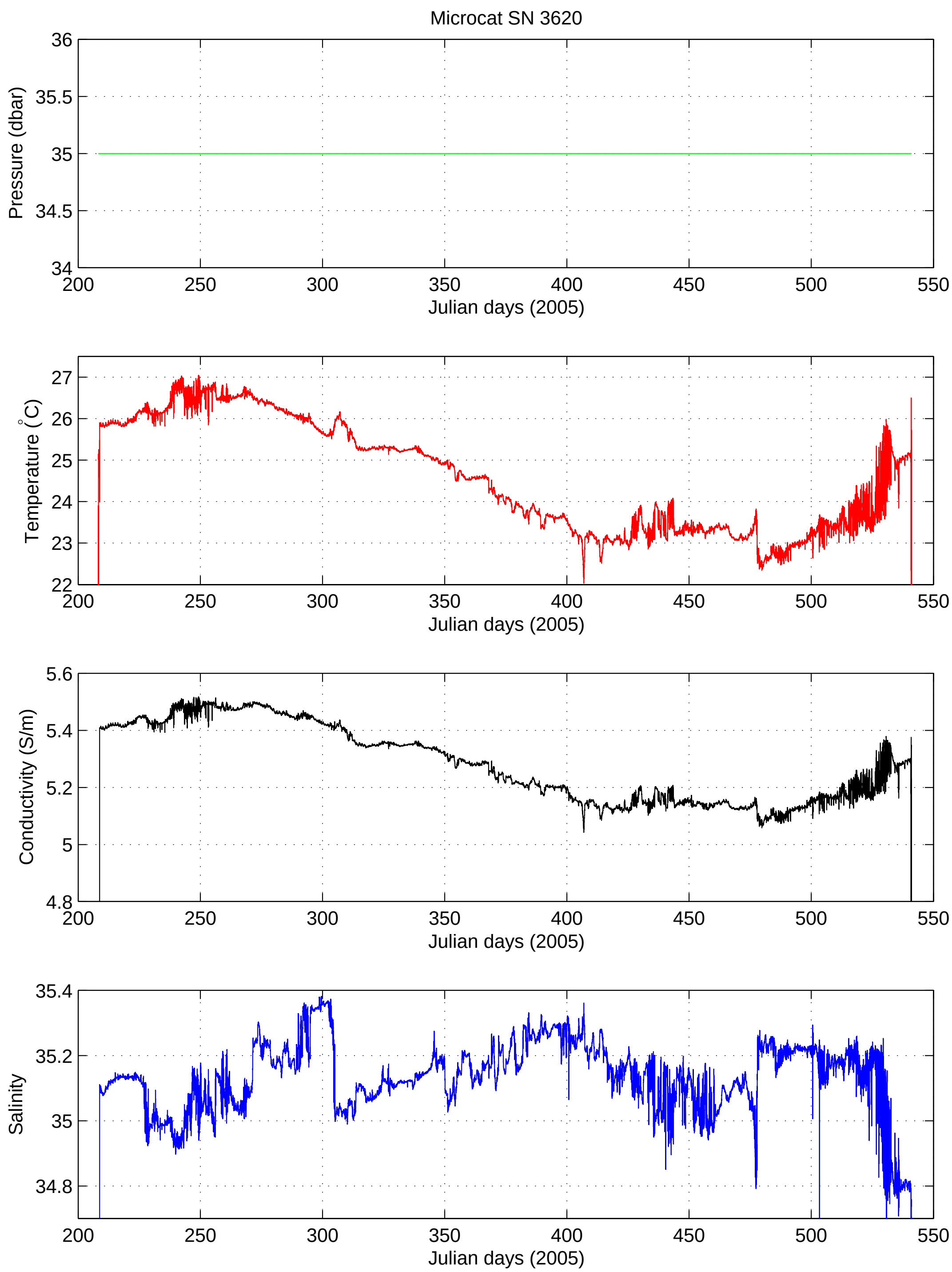

Figure A3: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3620 Microcat instrument deployed at 35m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

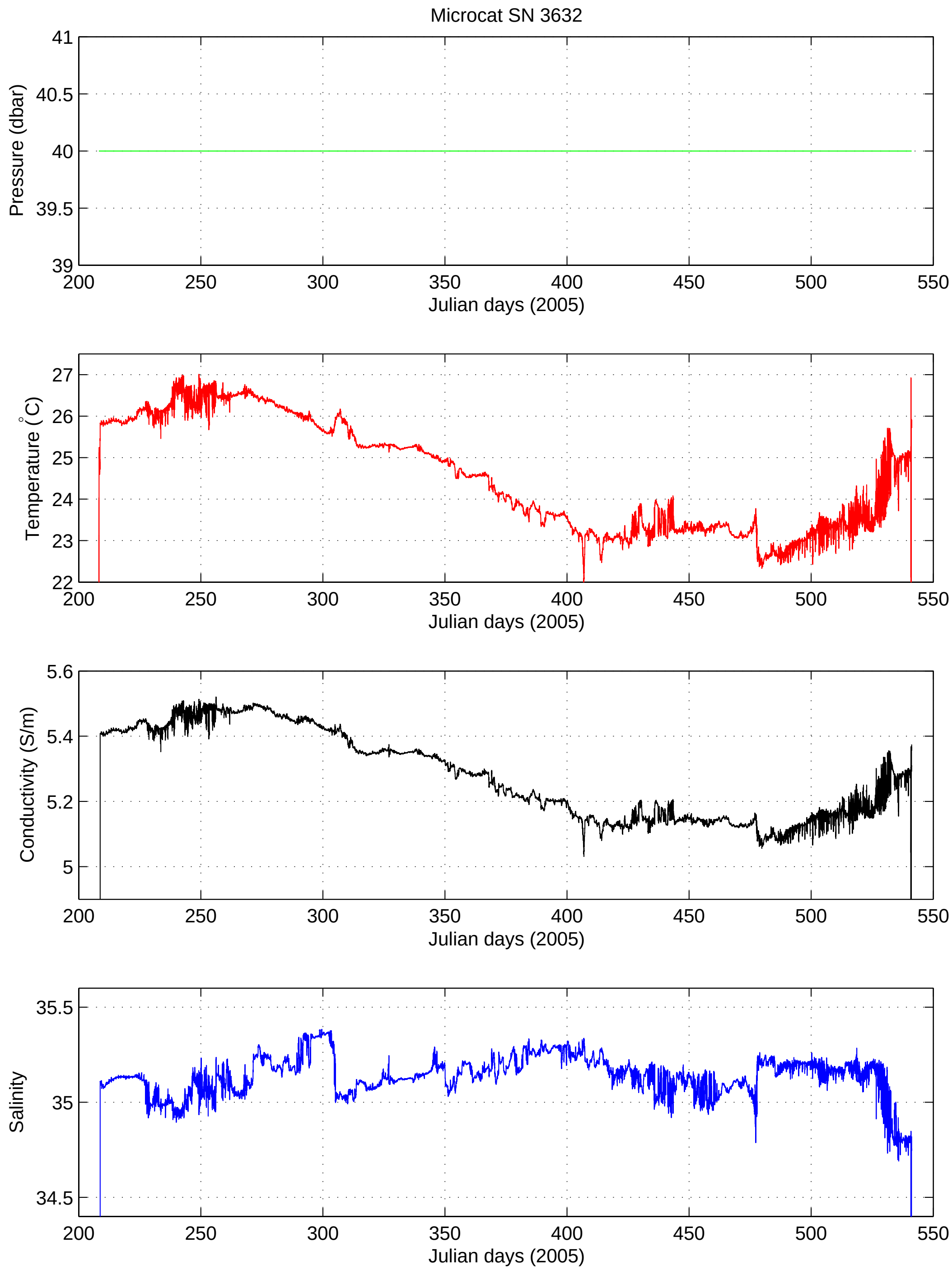

Figure A4: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3632 Microcat instrument deployed at 40m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

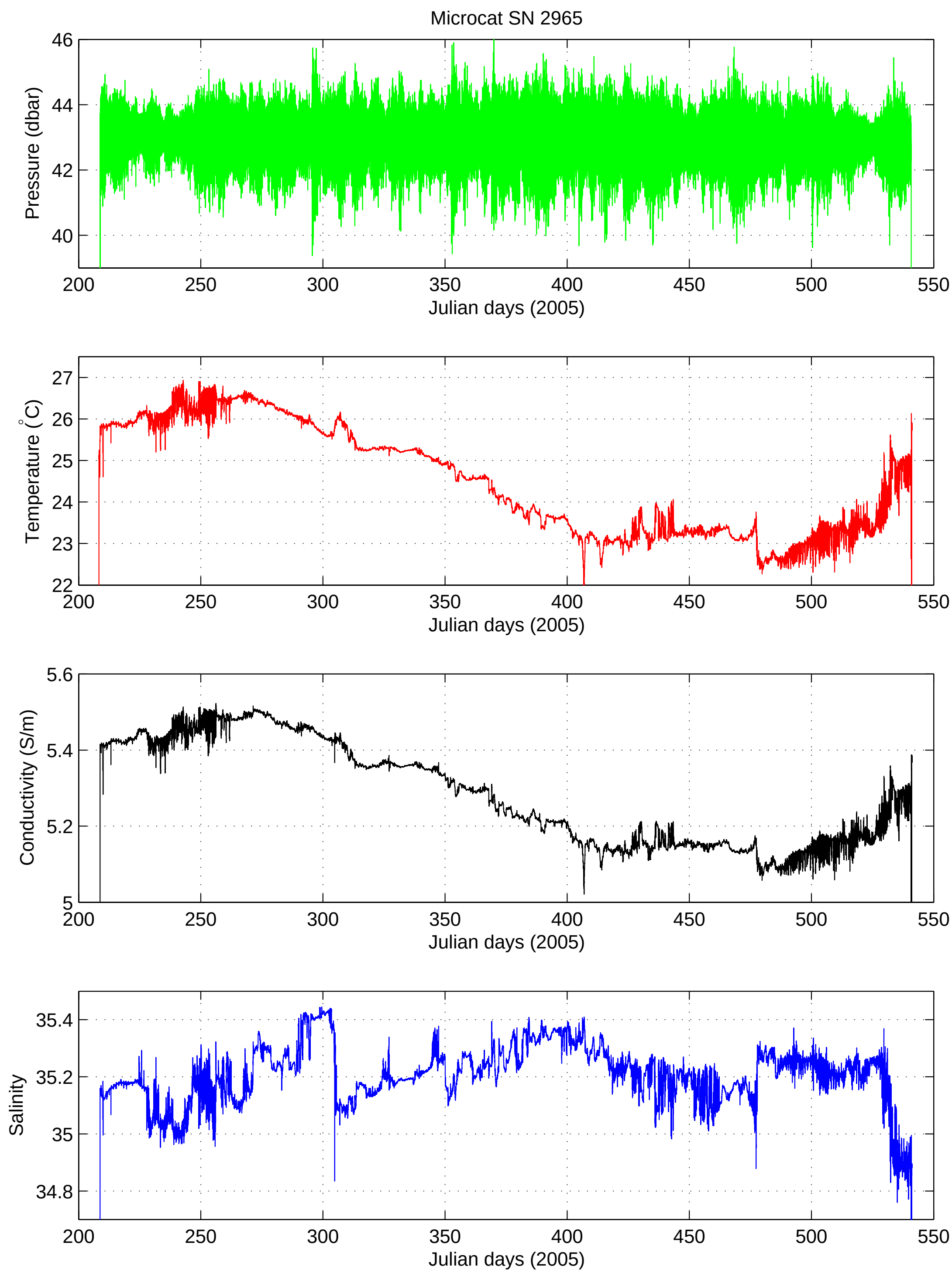

Figure A5: Preliminary Pressure, Temperature, Conductivity and Salinity from SBE 37 SN2965 Microcat instruments deployed at 45m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise.

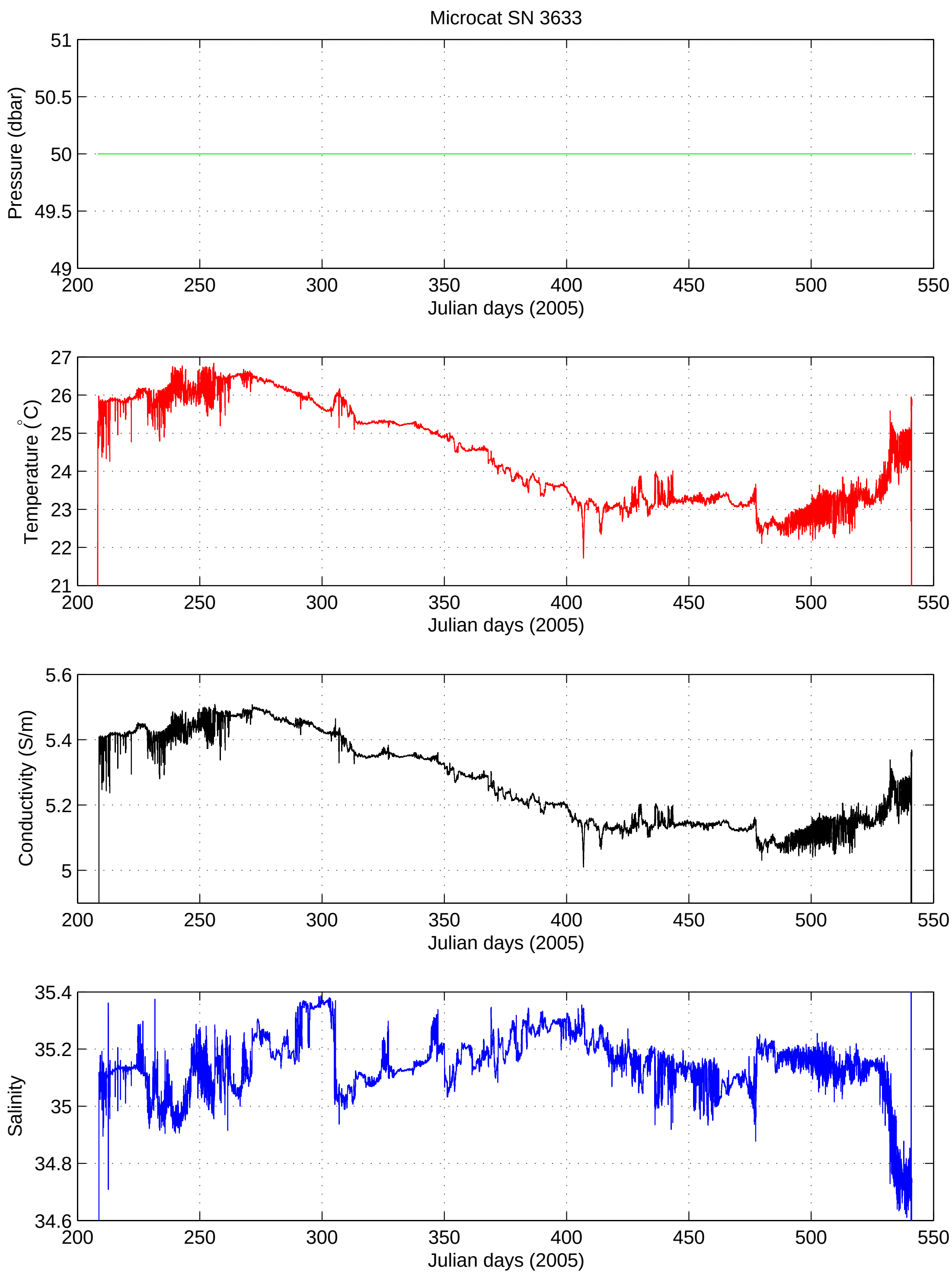

Figure A6: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3633 Microcat instrument deployed at 50m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

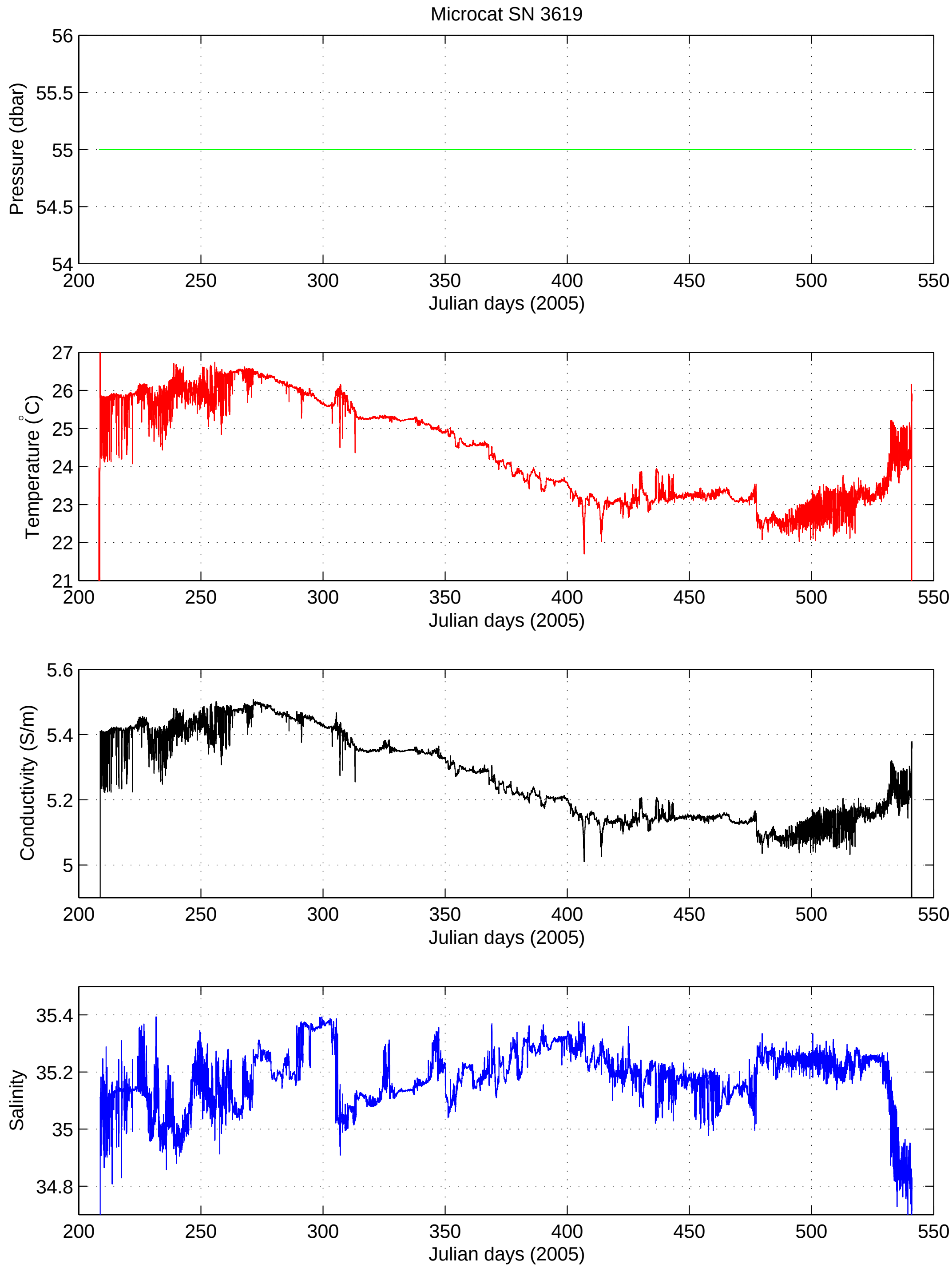

Figure A7: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3619 Microcat instrument deployed at 55m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

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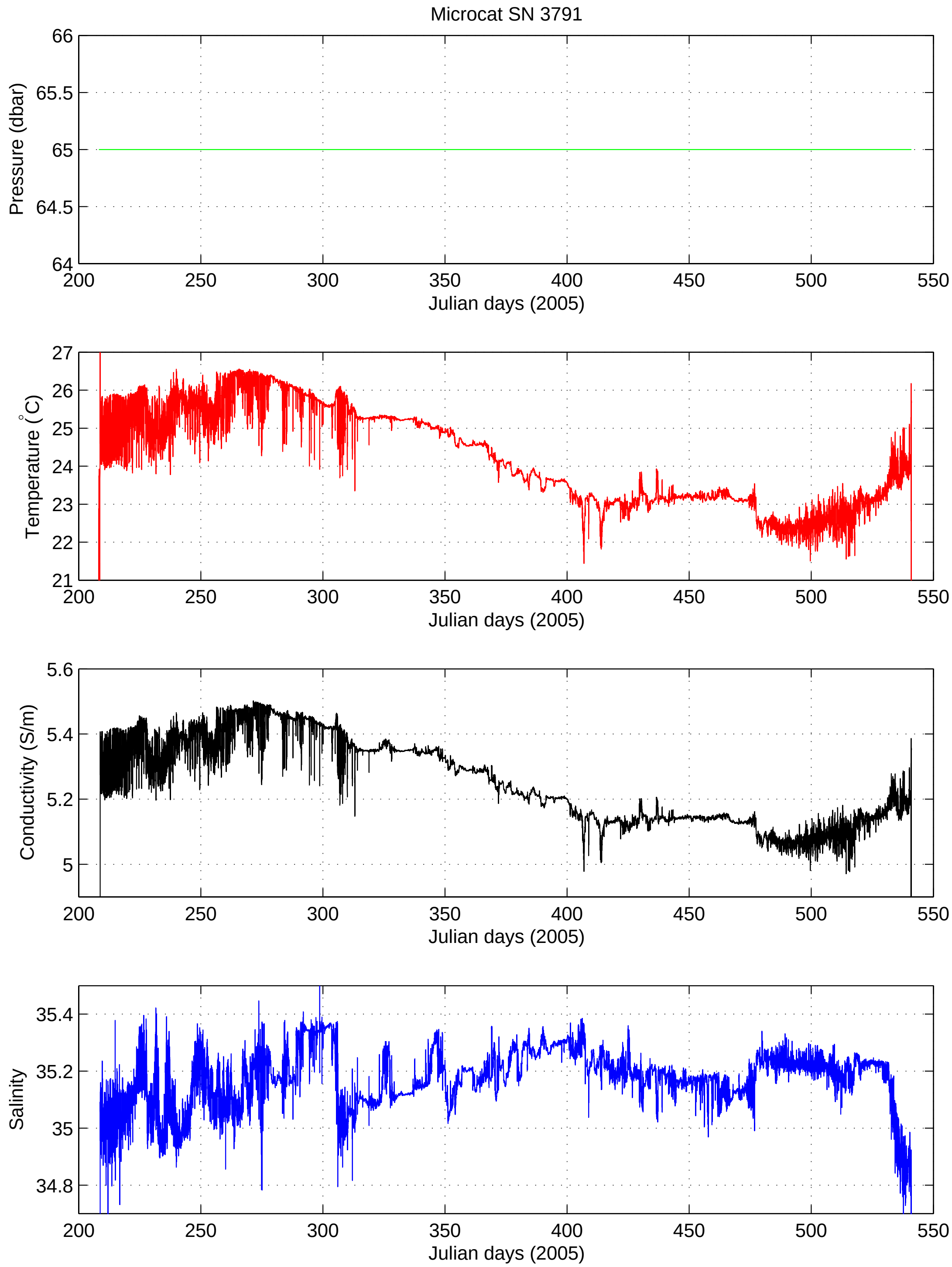


Figure A8: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3791 Microcat instrument deployed at 65m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

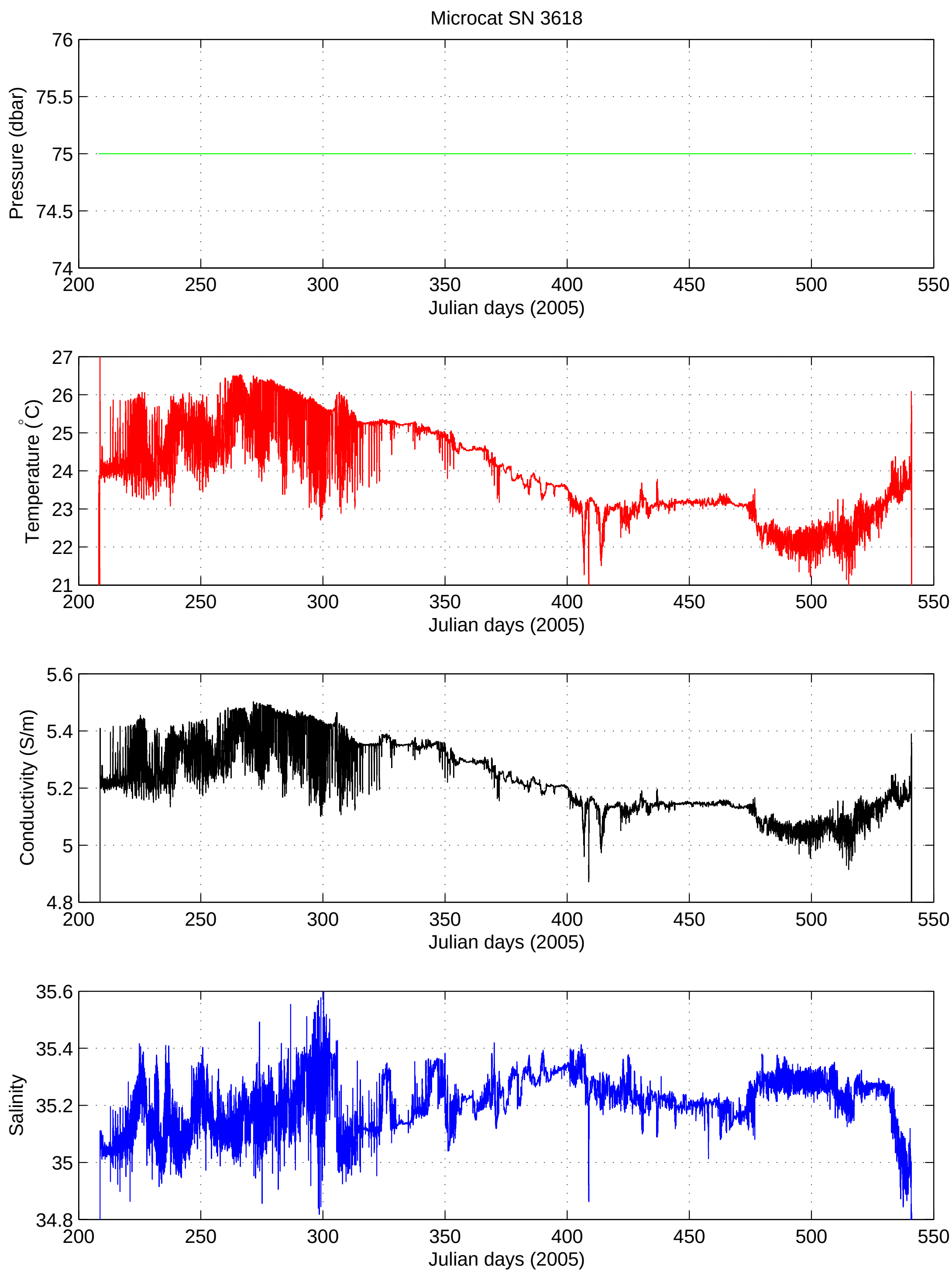


Figure A9: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3618 Microcat instrument deployed at 75m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

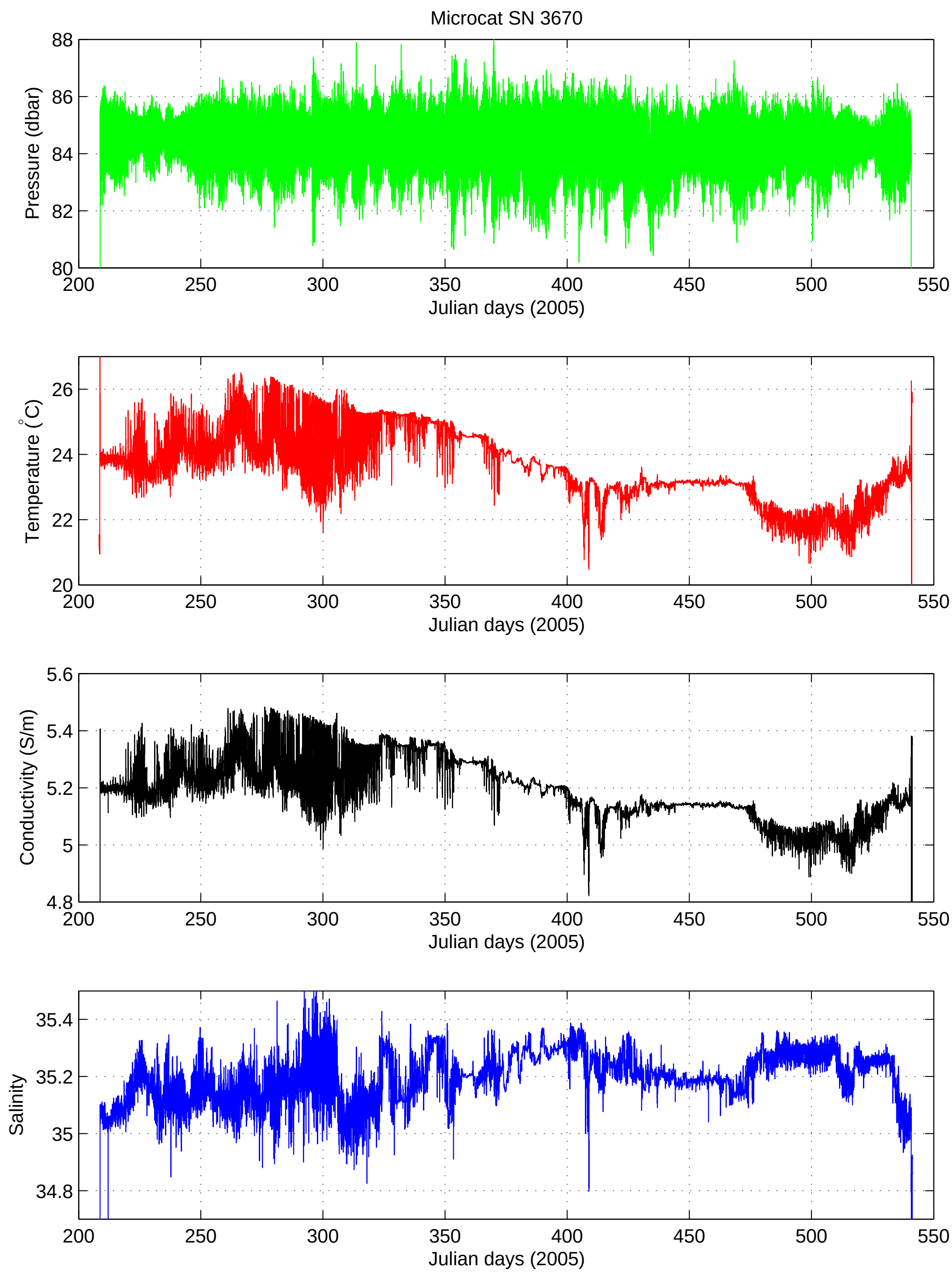


Figure A10: Preliminary Pressure, Temperature, Conductivity and Salinity from SBE 37 SN3670 Microcat instruments deployed at 75m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise.

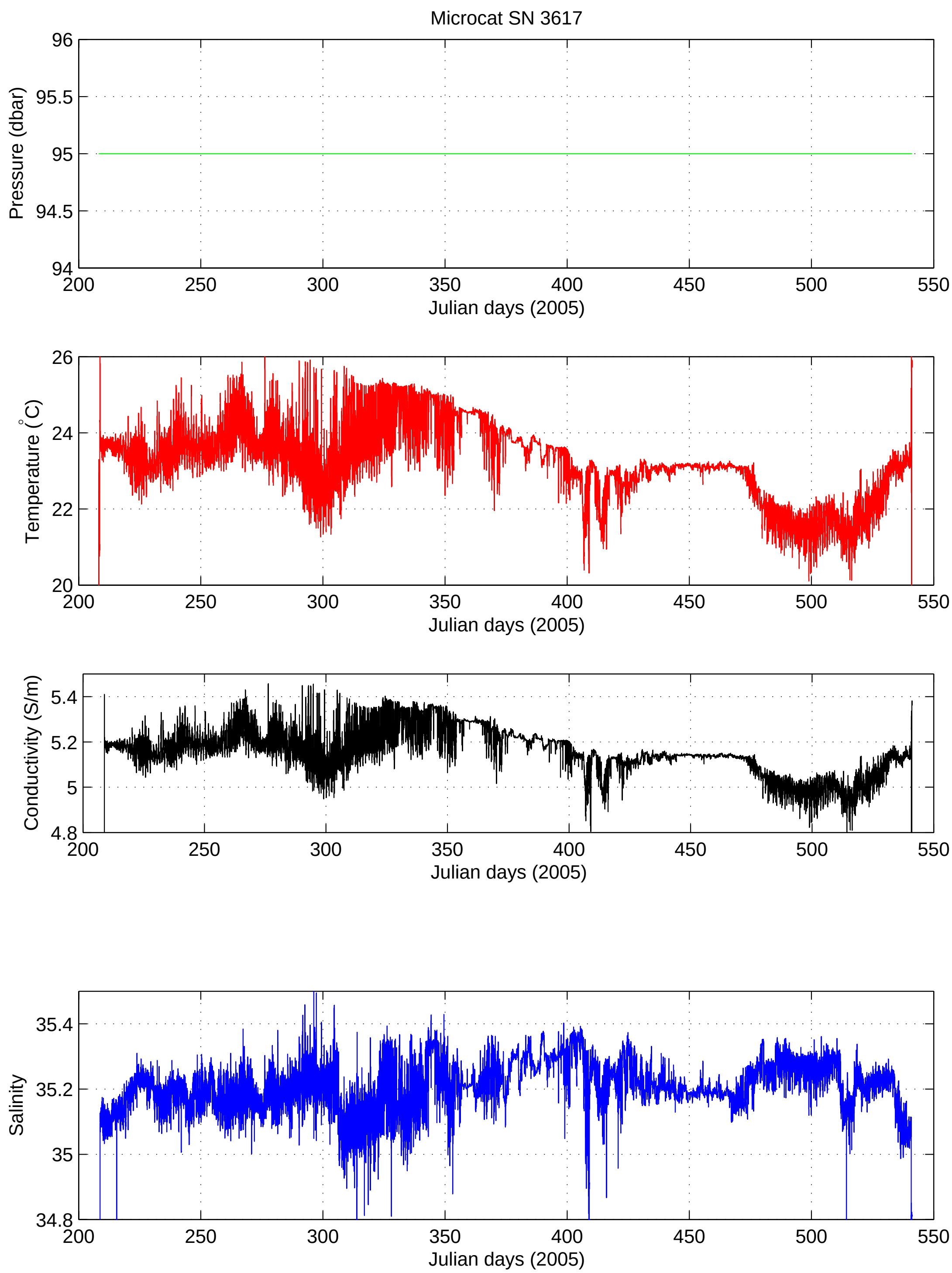


Figure A11: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3617 Microcat instrument deployed at 95m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

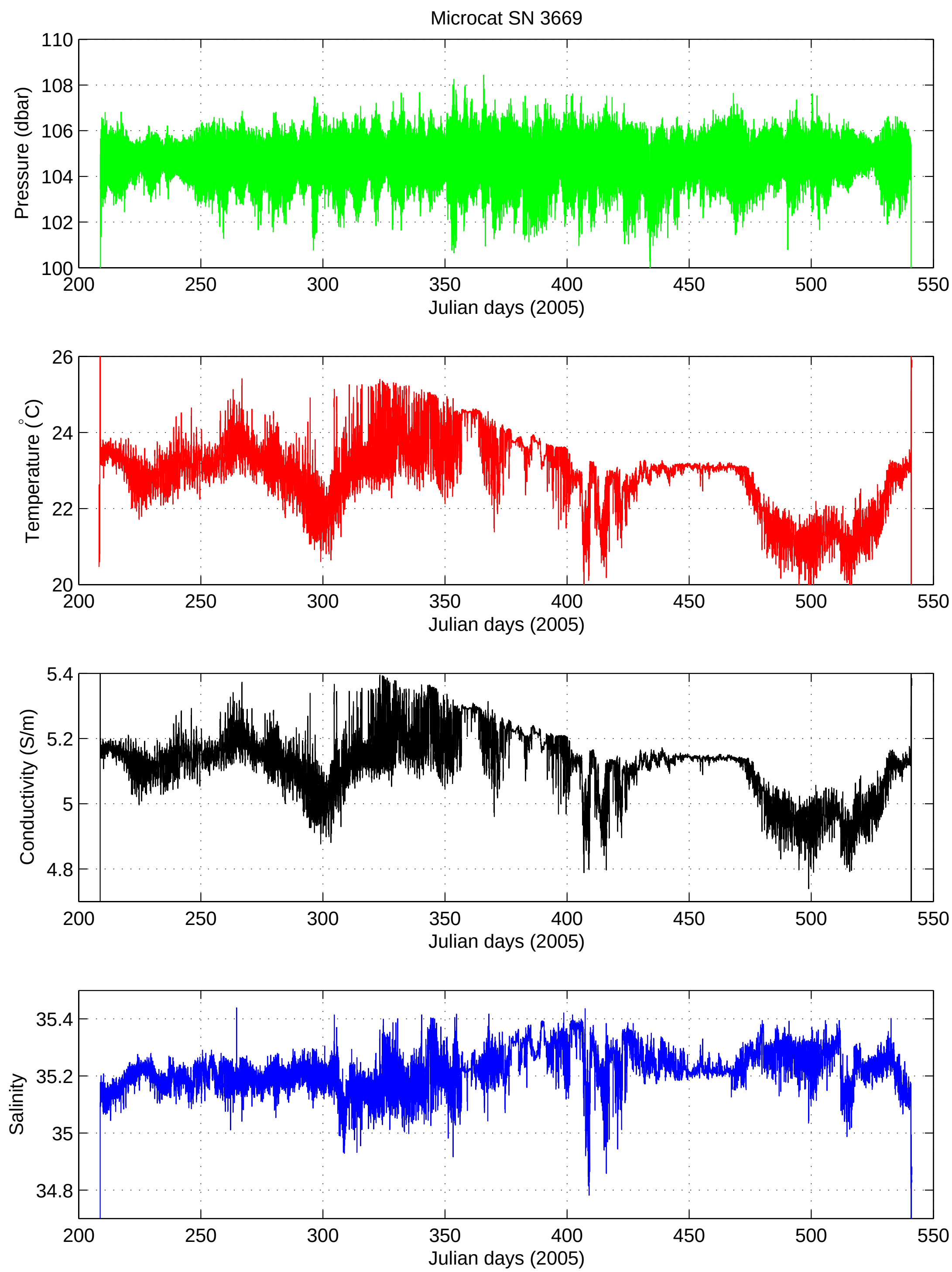


Figure A12: Preliminary Pressure, Temperature, Conductivity and Salinity from SBE 37 SN3669 Microcat instruments deployed at 105m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise.

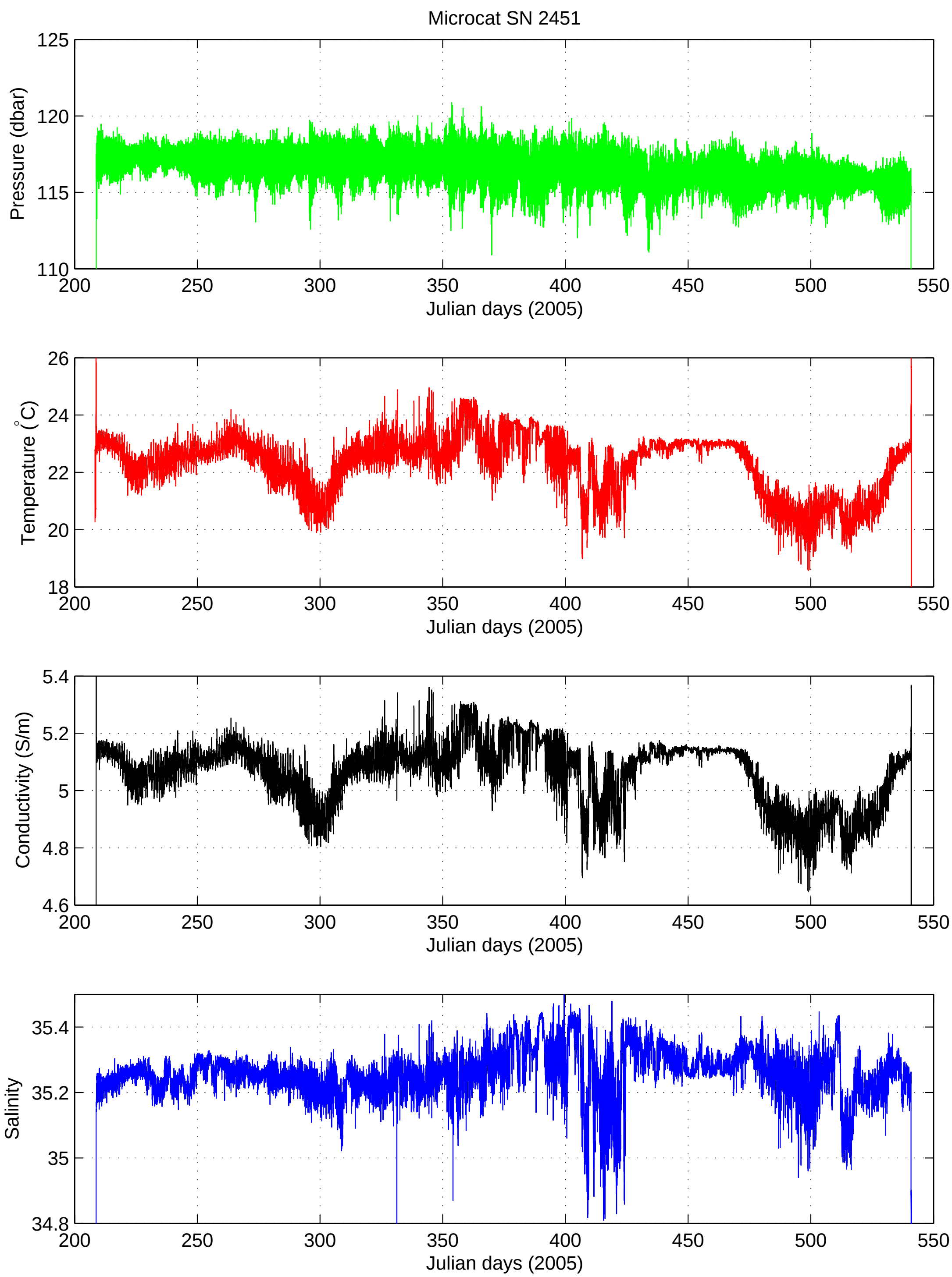


Figure A13: Preliminary Pressure, Temperature, Conductivity and Salinity from SBE 37 SN2451 Microcat instruments deployed at 115m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise.

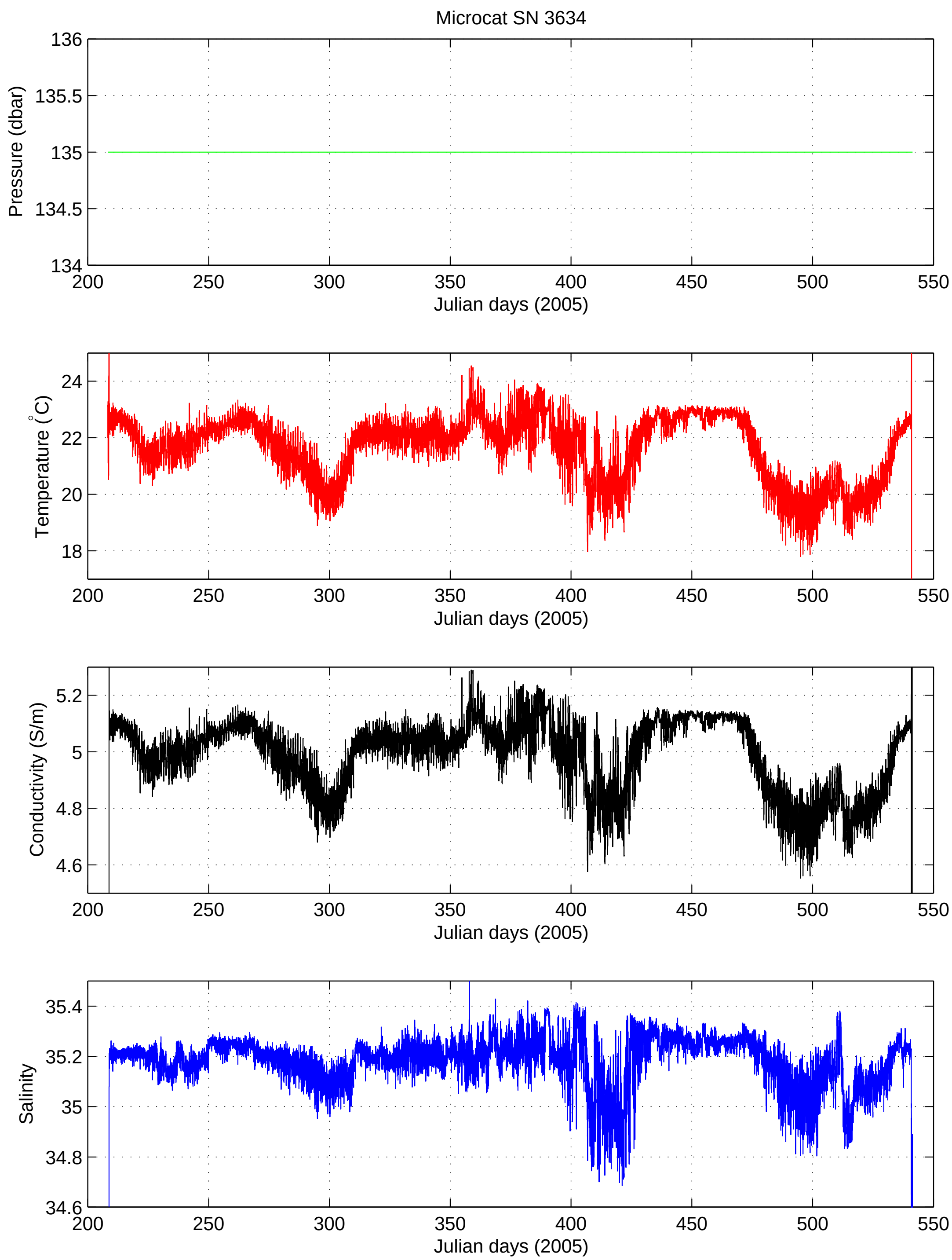


Figure A14: Preliminary Temperature, Conductivity and Salinity from SBE 37 SN3634 Microcat instrument deployed at 135m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise. Nominal pressure is also included to calculate salinity where pressure data was not available.

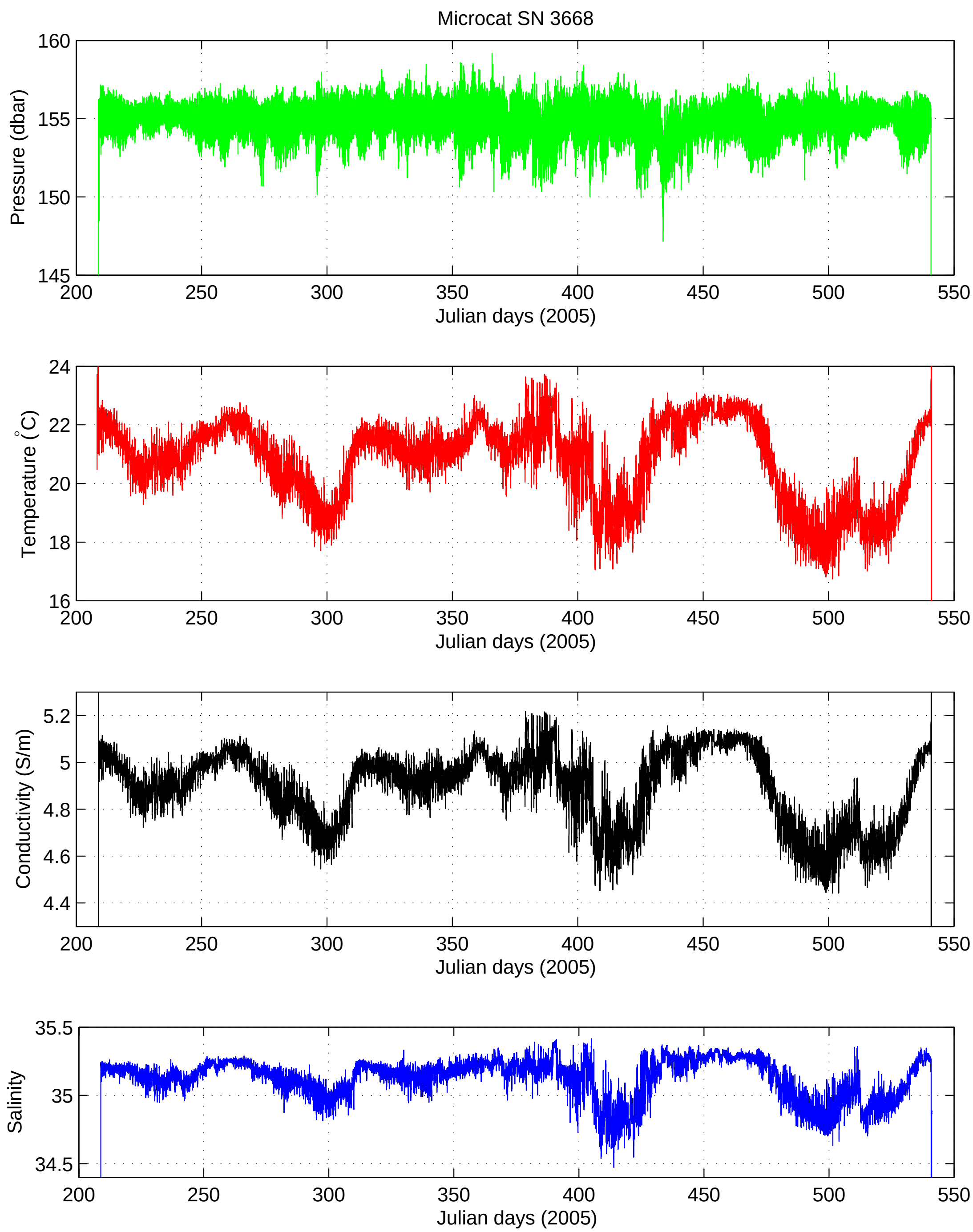
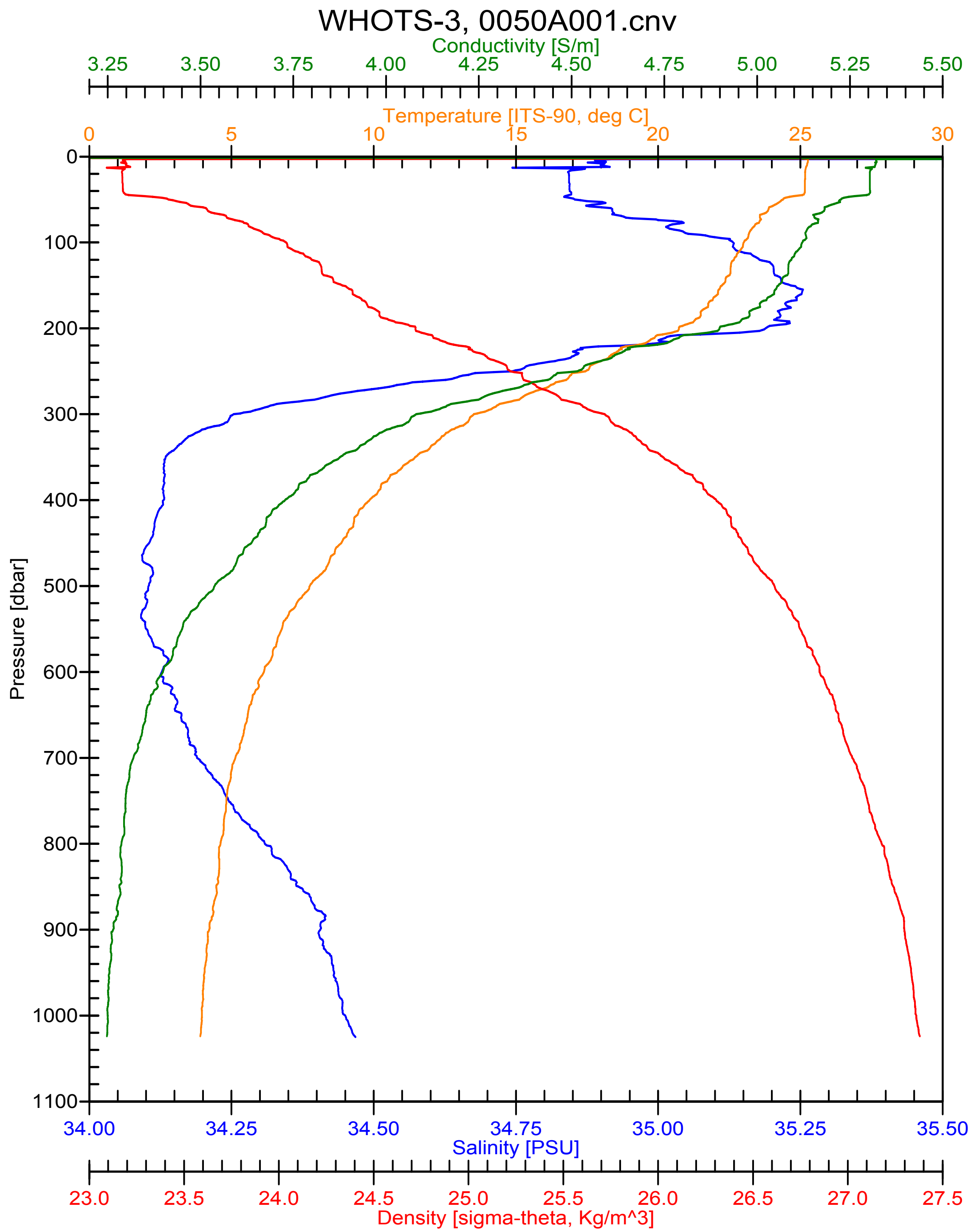


Figure A15: Preliminary Pressure, Temperature, Conductivity and Salinity from SBE 37 SN3668 Microcat instruments deployed at 155m during the 2005 WHOTS-2 cruise and recovered during the 2006 WHOTS-3 cruise.

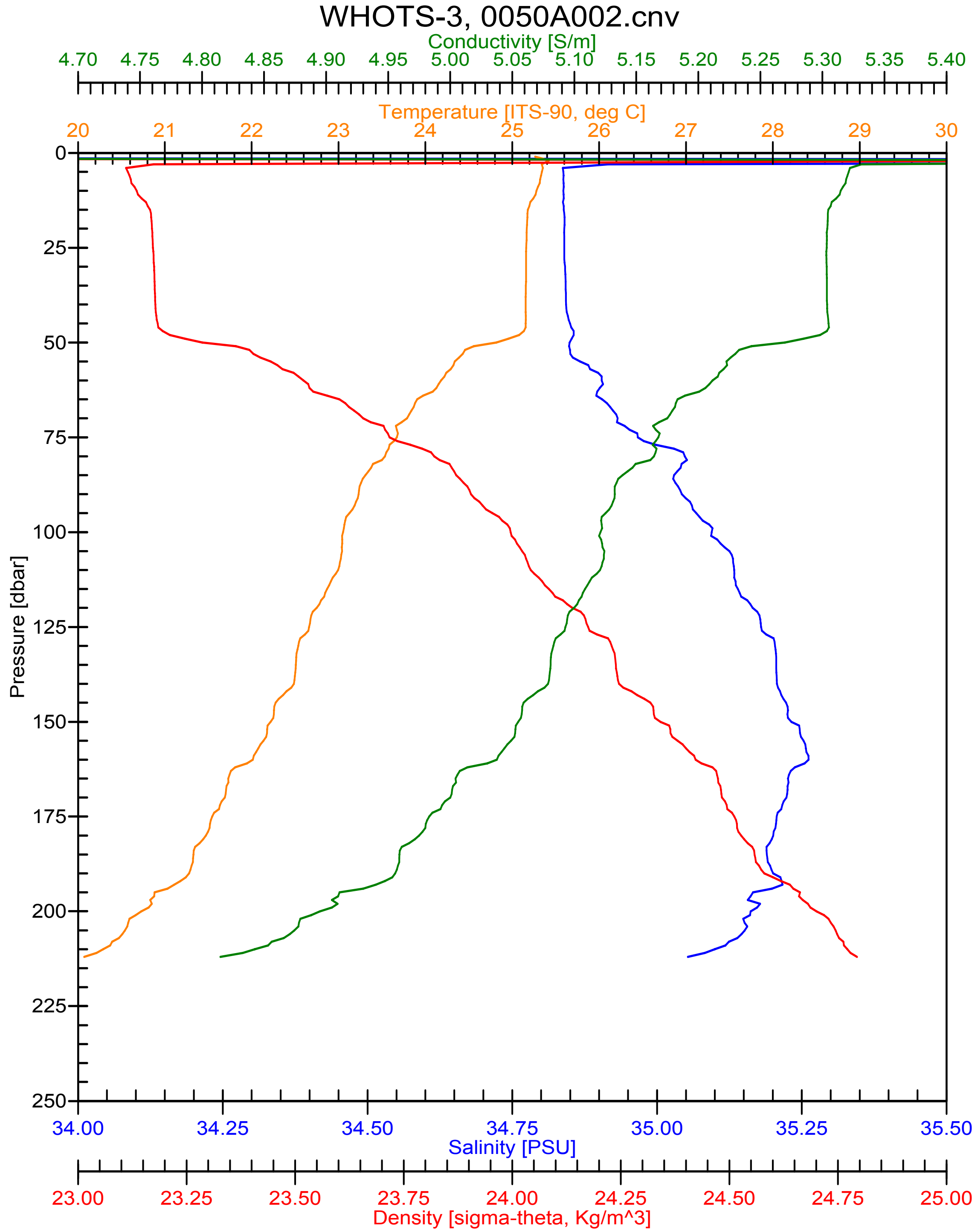
Appendix B: CTD Casts

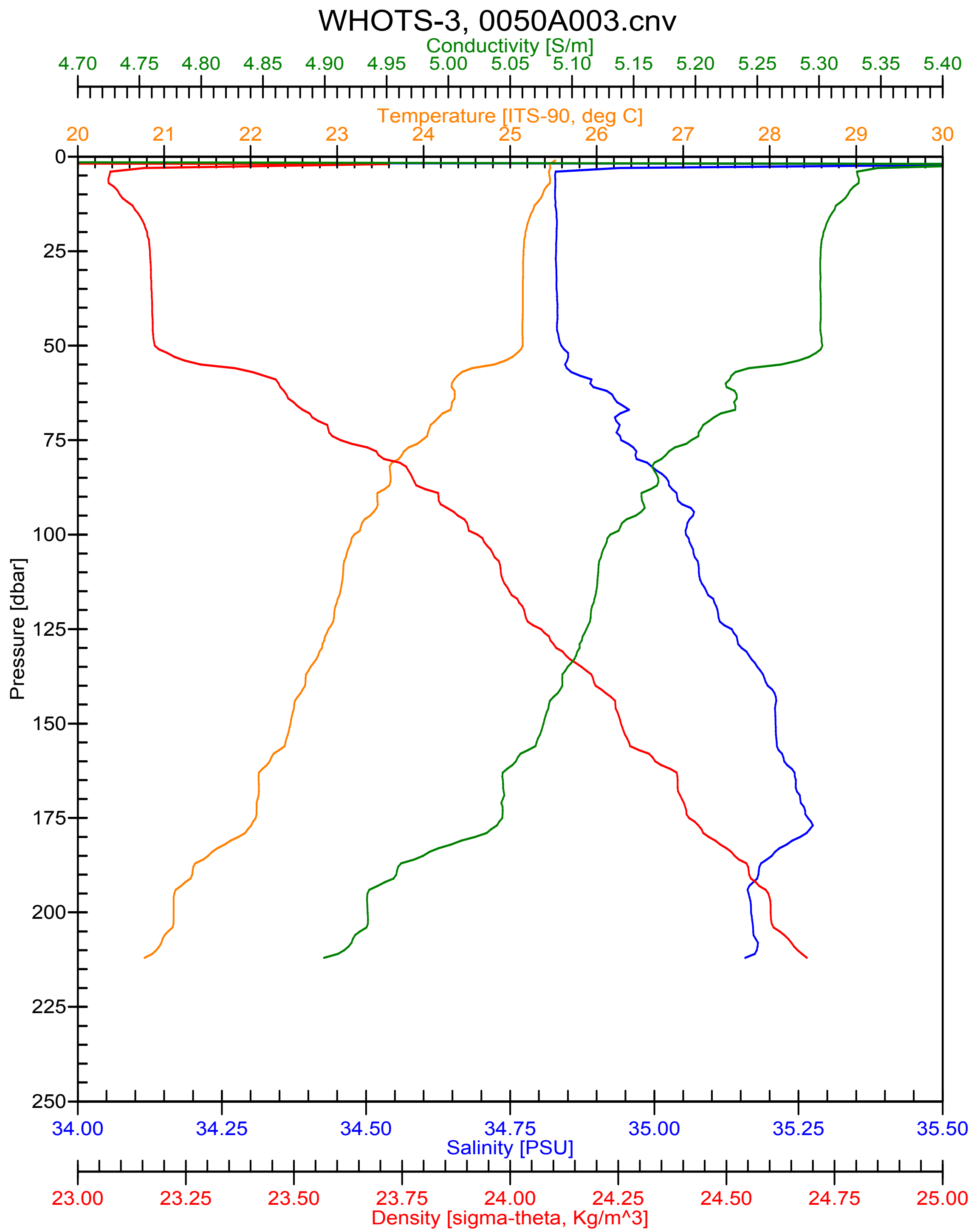
Table B1. CTD stations occupied during WHOTS-3 cruise. Note that numbering of stations follow the HOT conventions.

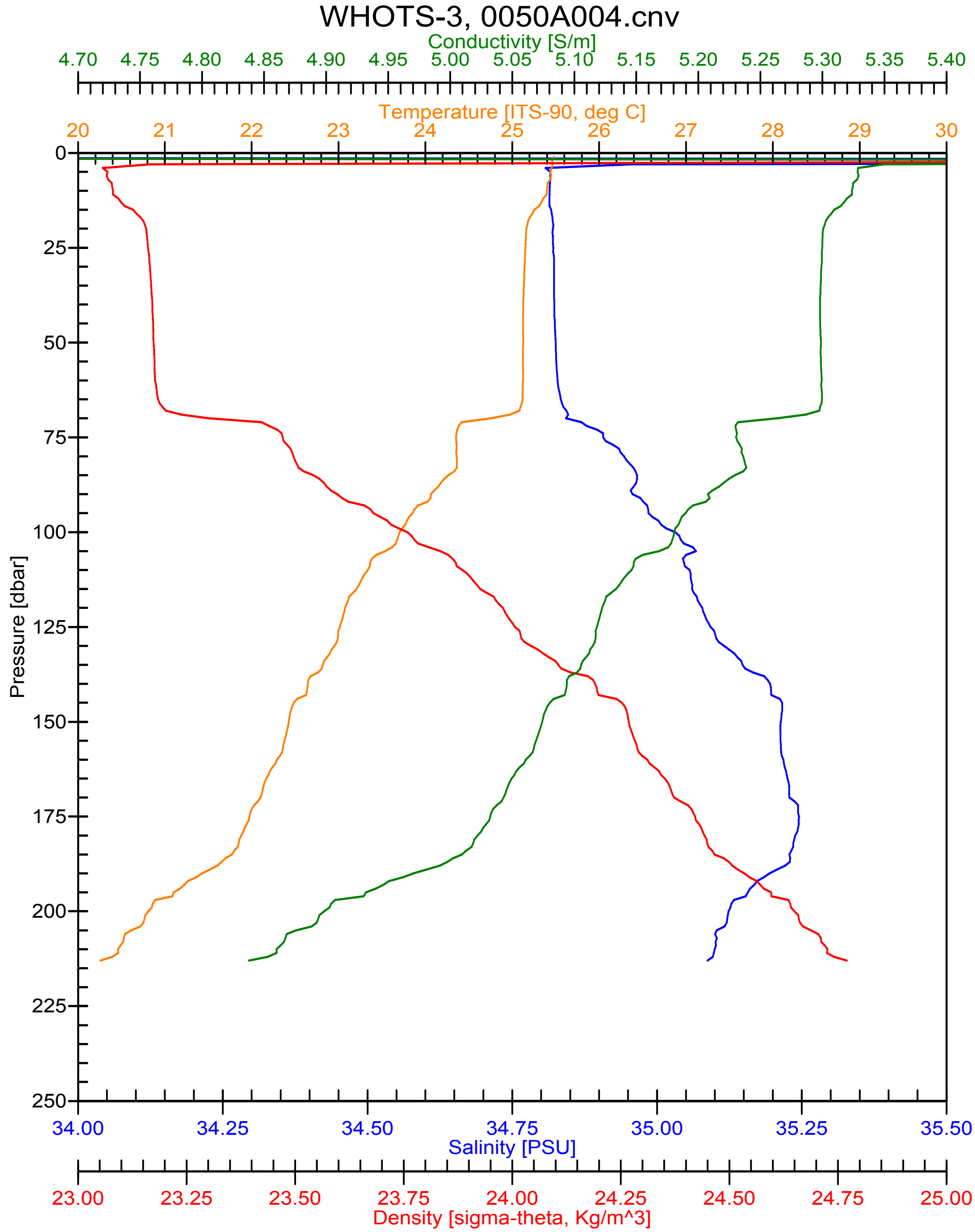
Station/cast	Date	Time (GMT)	Location	Maximum pressure (dbar)
50/1	6/23/06	21:21	22 47.875N, 157 55.057W	1020
50/2	6/23/06	23:07	22 47.875N, 157 55.055W	210
50/3	6/24/06	00:59	22 47.802N, 157 54.678W	210
50/4	6/24/06	03:03	22 47.820N, 157 54.630W	210
50/5	6/24/06	05:00	22 47.842N, 157 54.439W	210
50/6	6/24/06	06:58	22 47.824N, 157 54.339W	210
50/7	6/24/06	08:57	22 47.791N, 157 54.220W	210
2/1	6/25/06	19:30	22 50.498N, 157 58.994W	1020
2/2	6/25/06	22:30	22 50.972N, 157 58.939W	1020
50/8	6/27/06	18:31	22 47.514N, 157 55.617W	1020
50/9	6/27/06	20:32	22 47.516N, 157 55.664W	210
50/10	6/27/06	22:29	22 47.512N, 157 55.385W	210
50/11	6/28/06	00:31	22 47.544N, 157 55.368W	210
50/12	6/28/06	02:30	22 47.575N, 157 55.671W	210
50/13	6/28/06	04:30	22 47.661N, 157 55.388W	210
50/14	6/28/06	06:29	22 47.870N, 157 55.028W	210



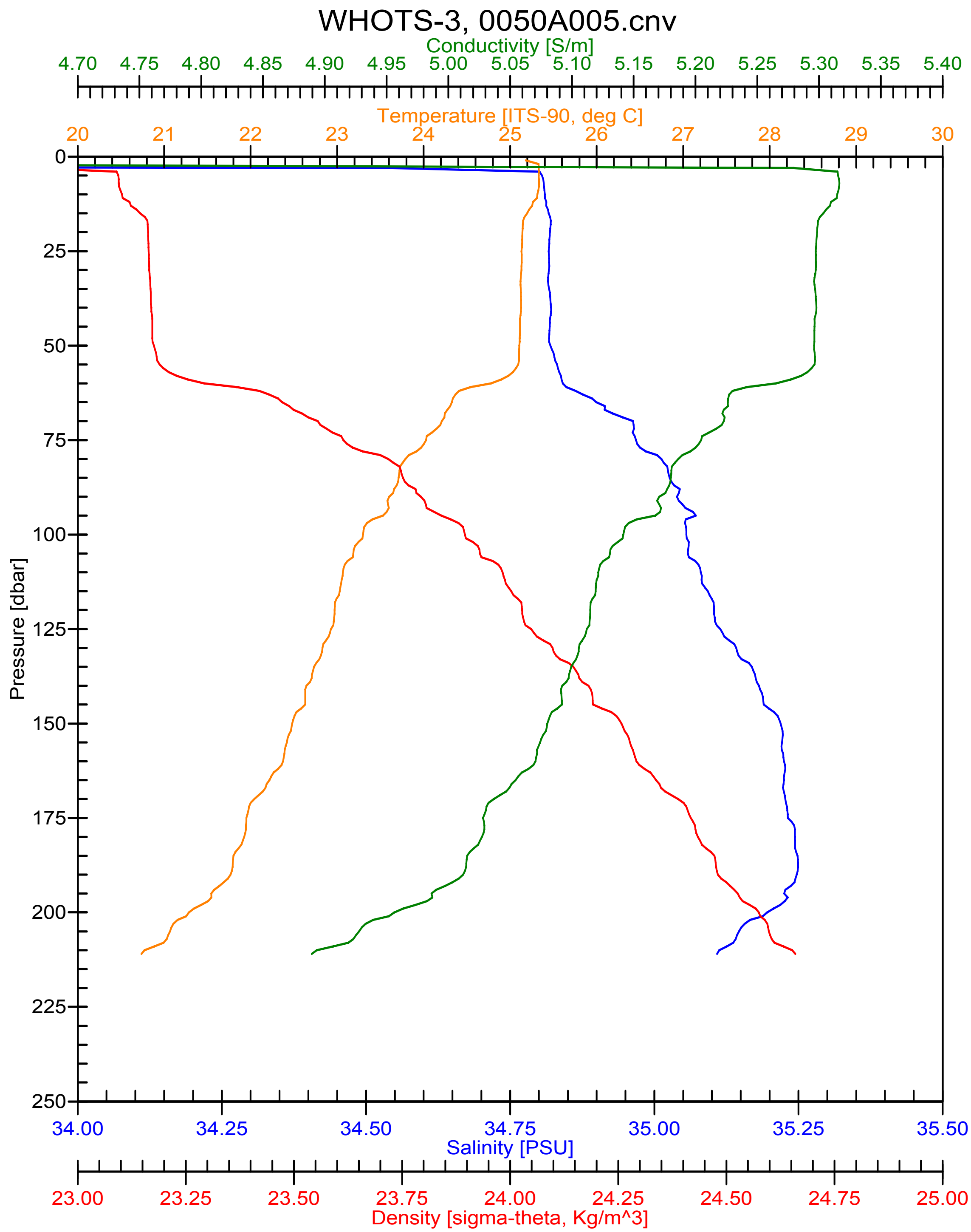
WHOTS-3, 0050A001.cnv
Conductivity [S/m]
3.25 3.50 3.75 4.00 4.25 4.50 4.75 5.00 5.25 5.50
Temperature [ITS-90, deg C]
0 5 10 15 20 25 30
Pressure [dbar]
0 100 200 300 400 500 600 700 800 900 1000 1100
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5 27.0 27.5
Density [sigma-theta, Kg/m^3]

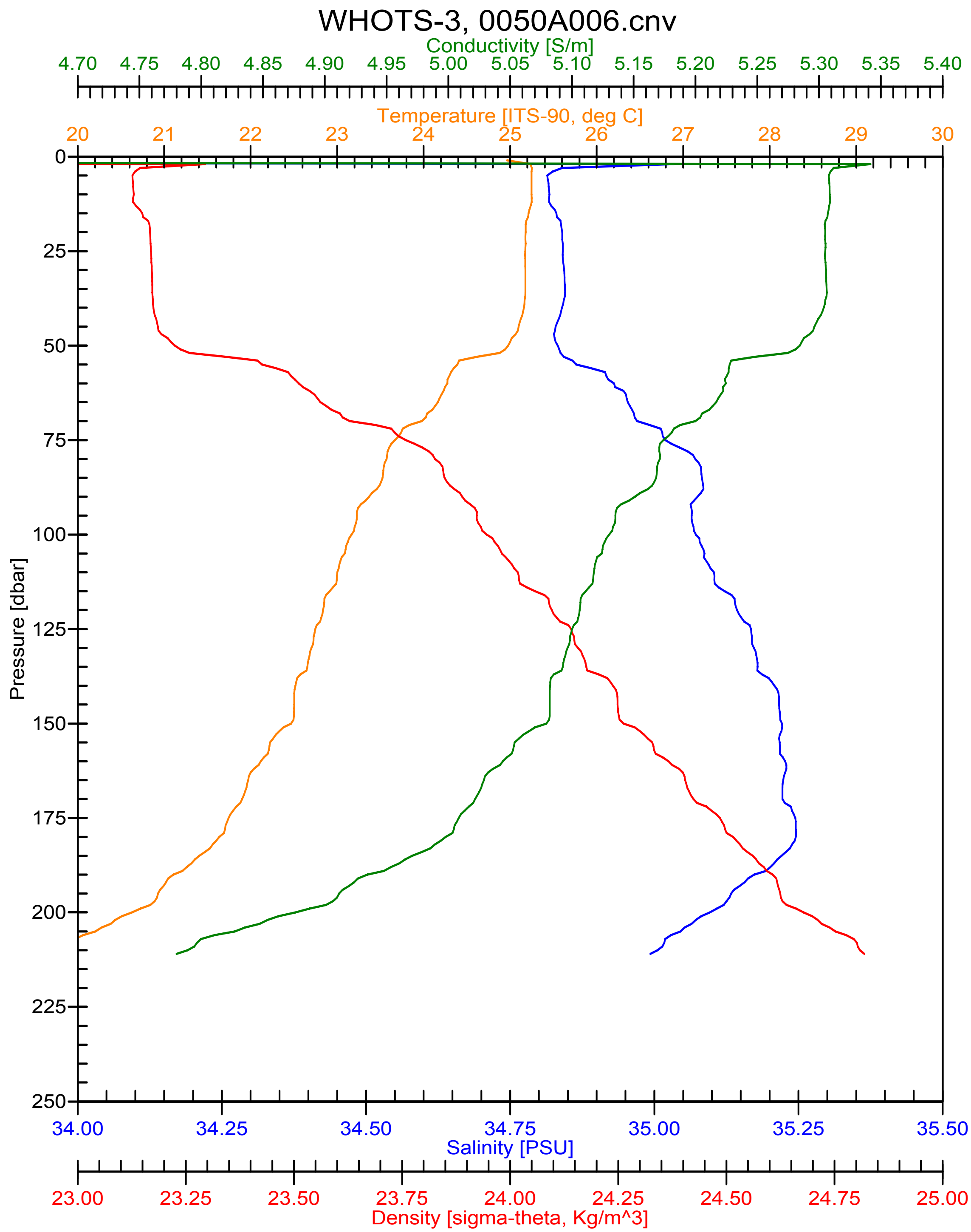

WHOTS-3, 0050A002.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]

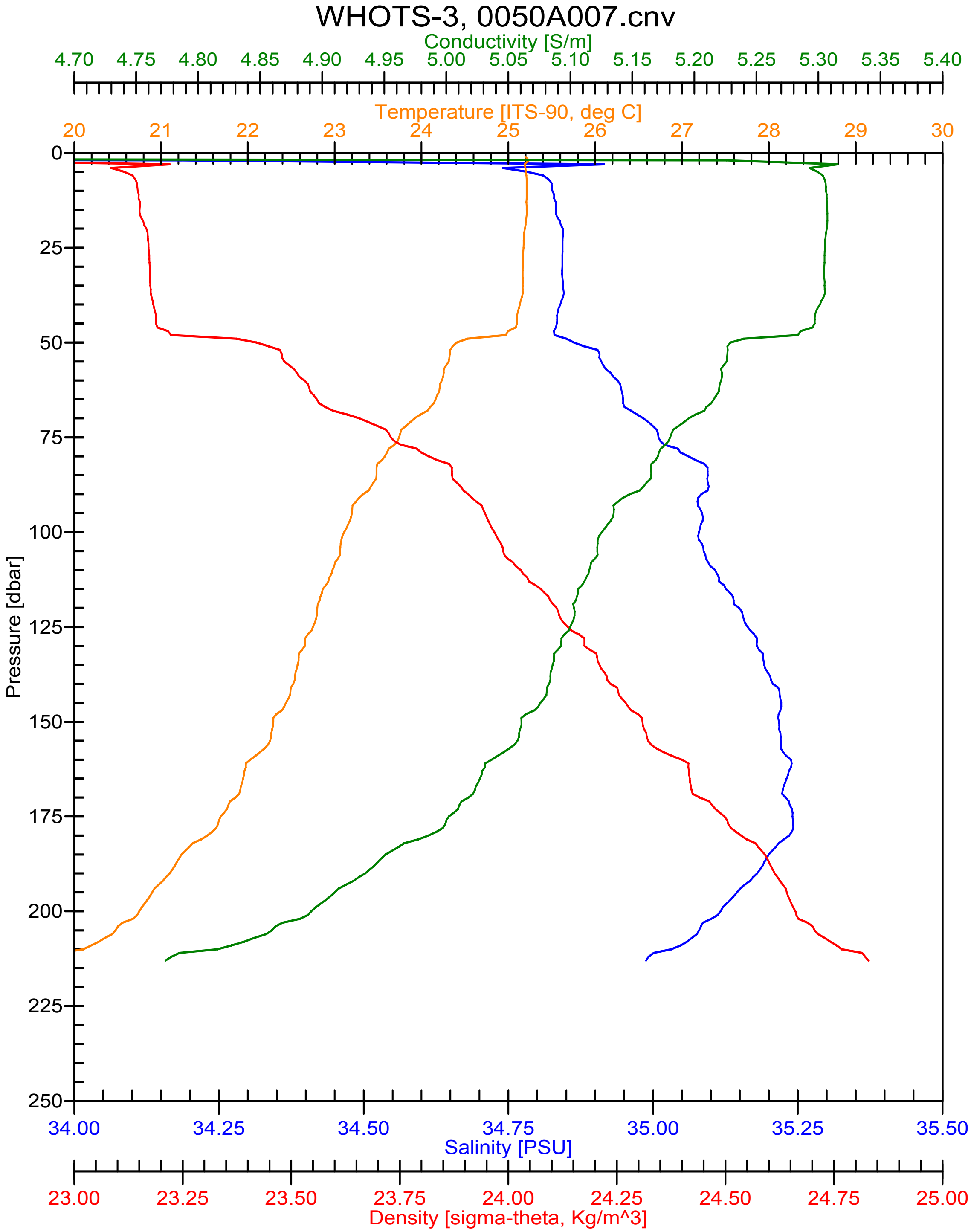

WHOTS-3, 0050A003.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]

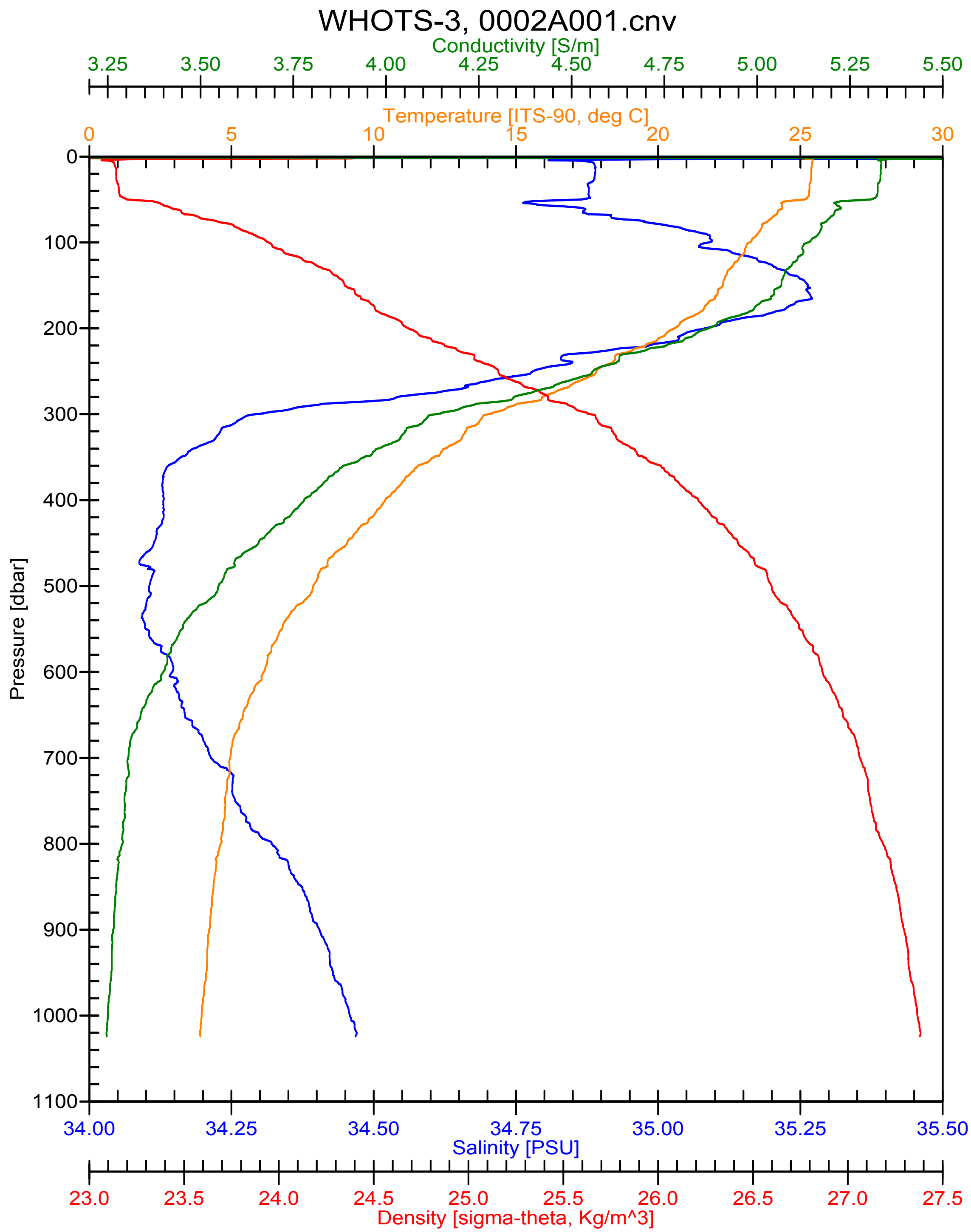


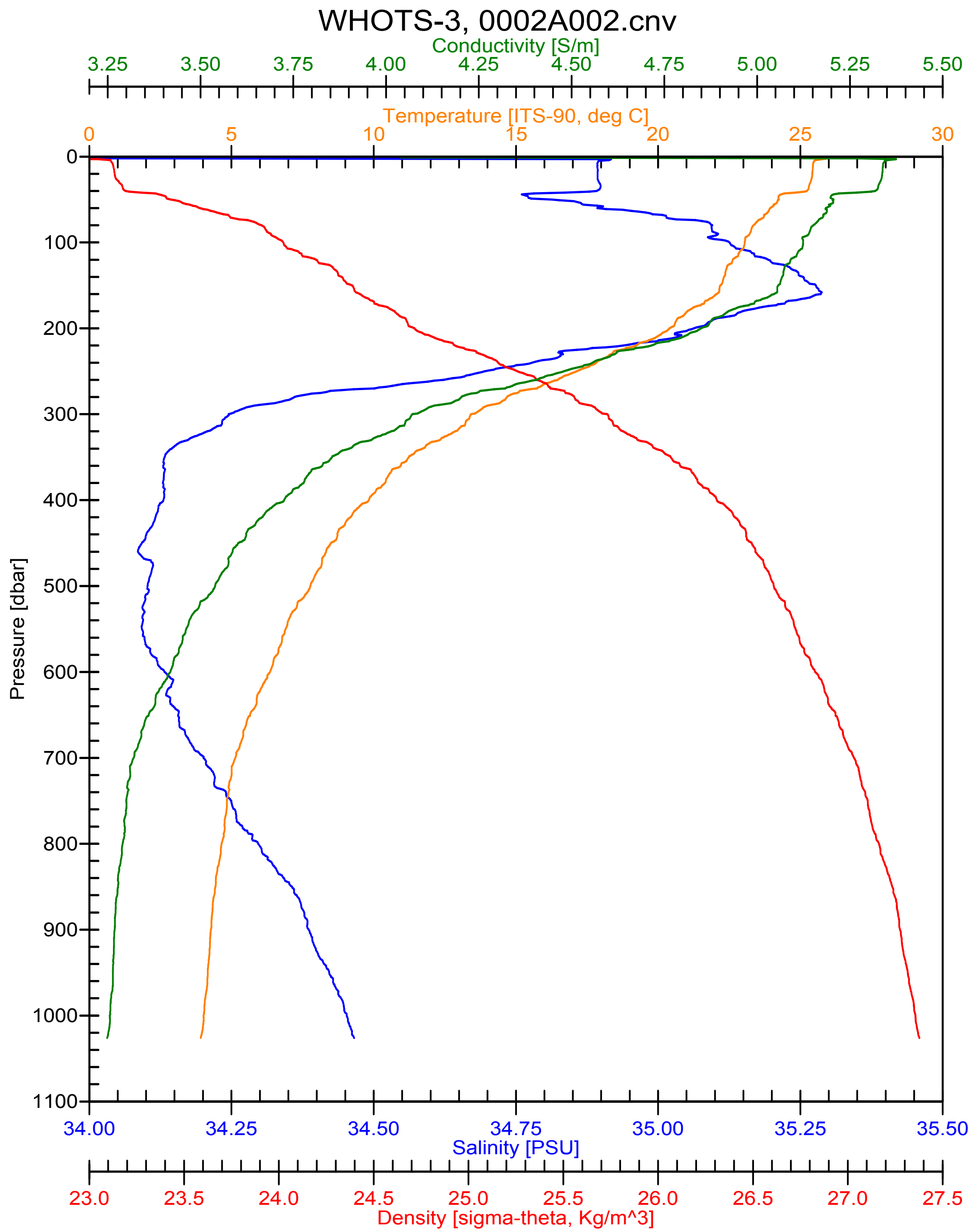
WHOTS-3, 0050A004.cnv
Conductivity [S/m]
4.70
4.75
4.80
4.85
4.90
4.95
5.00
5.05
5.10
5.15
5.20
5.25
5.30
5.35
5.40
Temperature [ITS-90, deg C]
20
21
22
23
24
25
26
27
28
29
30
Pressure [dbar]
0
25
50
75
100
125
150
175
200
225
250
34.00
34.25
34.50
34.75
35.00
35.25
35.50
Salinity [PSU]
23.00
23.25
23.50
23.75
24.00
24.25
24.50
24.75
25.00
Density [sigma-theta, Kg/m^3]

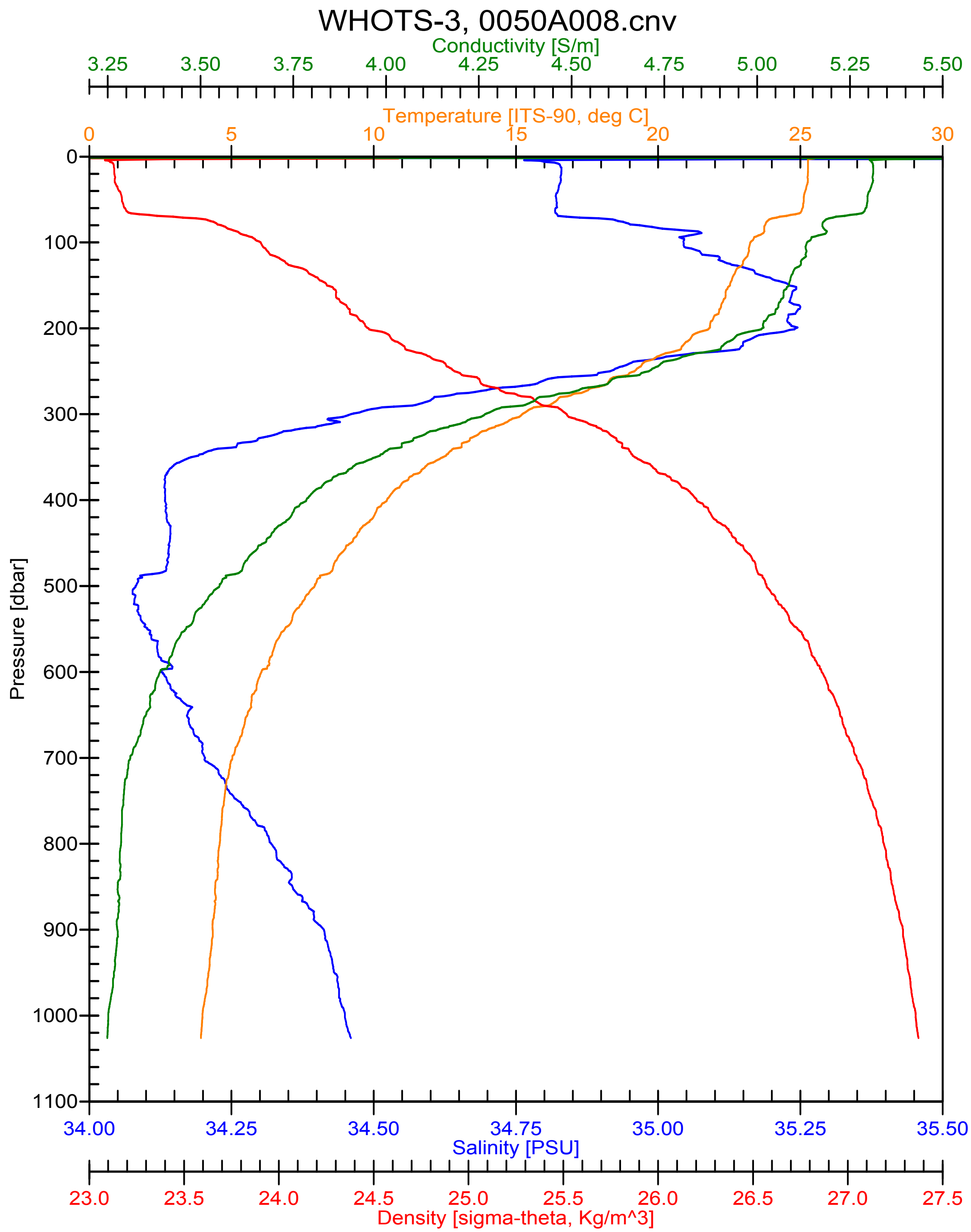

WHOTS-3, 0050A005.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]


WHOTS-3, 0050A006.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]

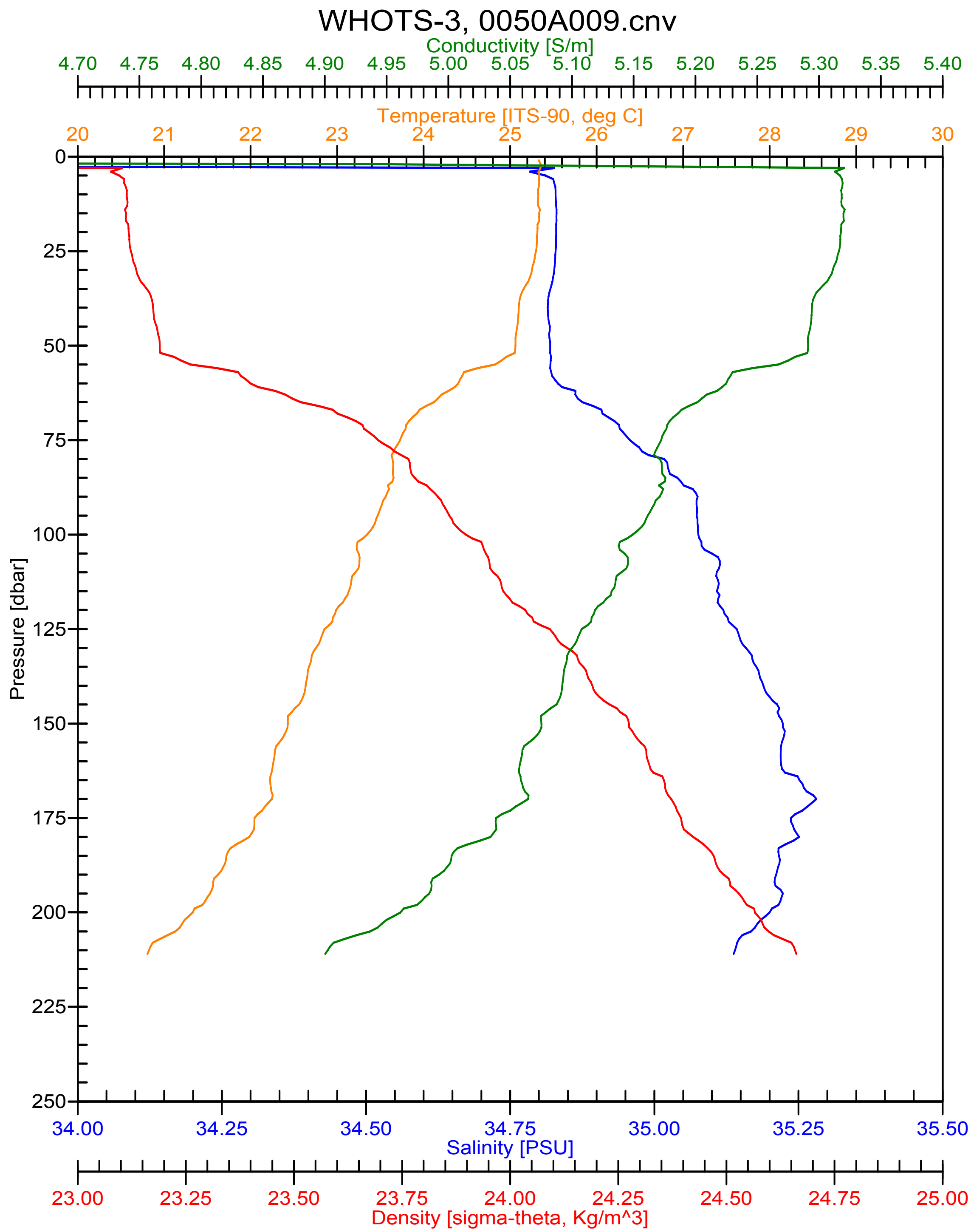

WHOTS-3, 0050A007.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]


WHOTS-3, 0002A001.cnv
Conductivity [S/m]
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
Temperature [ITS-90, deg C]
0
5
10
15
20
25
30
Pressure [dbar]
0
100
200
300
400
500
600
700
800
900
1000
1100
34.00
34.25
34.50
34.75
35.00
35.25
35.50
Salinity [PSU]
23.0
23.5
24.0
24.5
25.0
25.5
26.0
26.5
27.0
27.5
Density [sigma-theta, Kg/m^3]

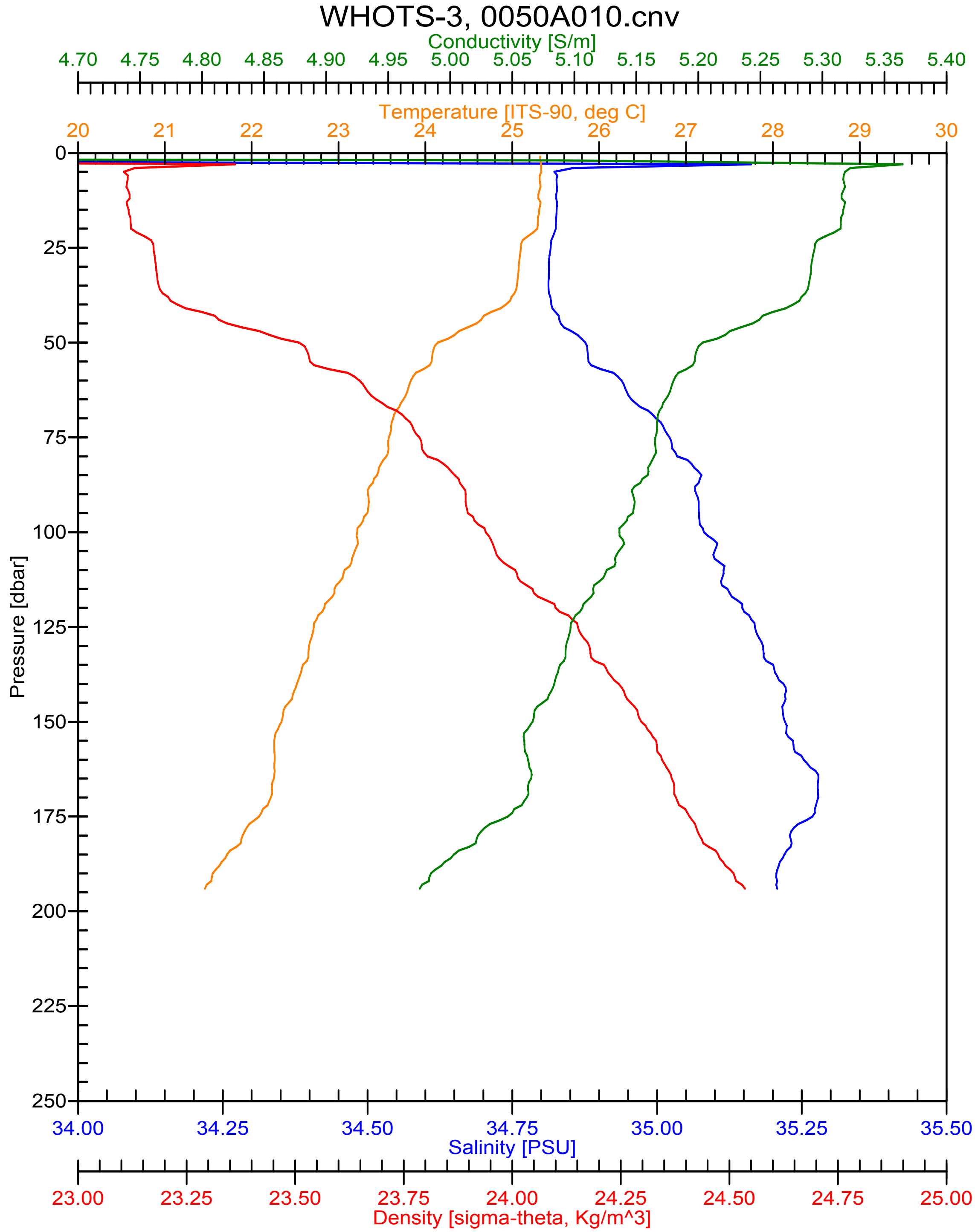

WHOTS-3, 0002A002.cnv
Conductivity [S/m]
3.25 3.50 3.75 4.00 4.25 4.50 4.75 5.00 5.25 5.50
Temperature [ITS-90, deg C]
0 5 10 15 20 25 30
Pressure [dbar]
0 100 200 300 400 500 600 700 800 900 1000 1100
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5 27.0 27.5
Density [sigma-theta, Kg/m^3]



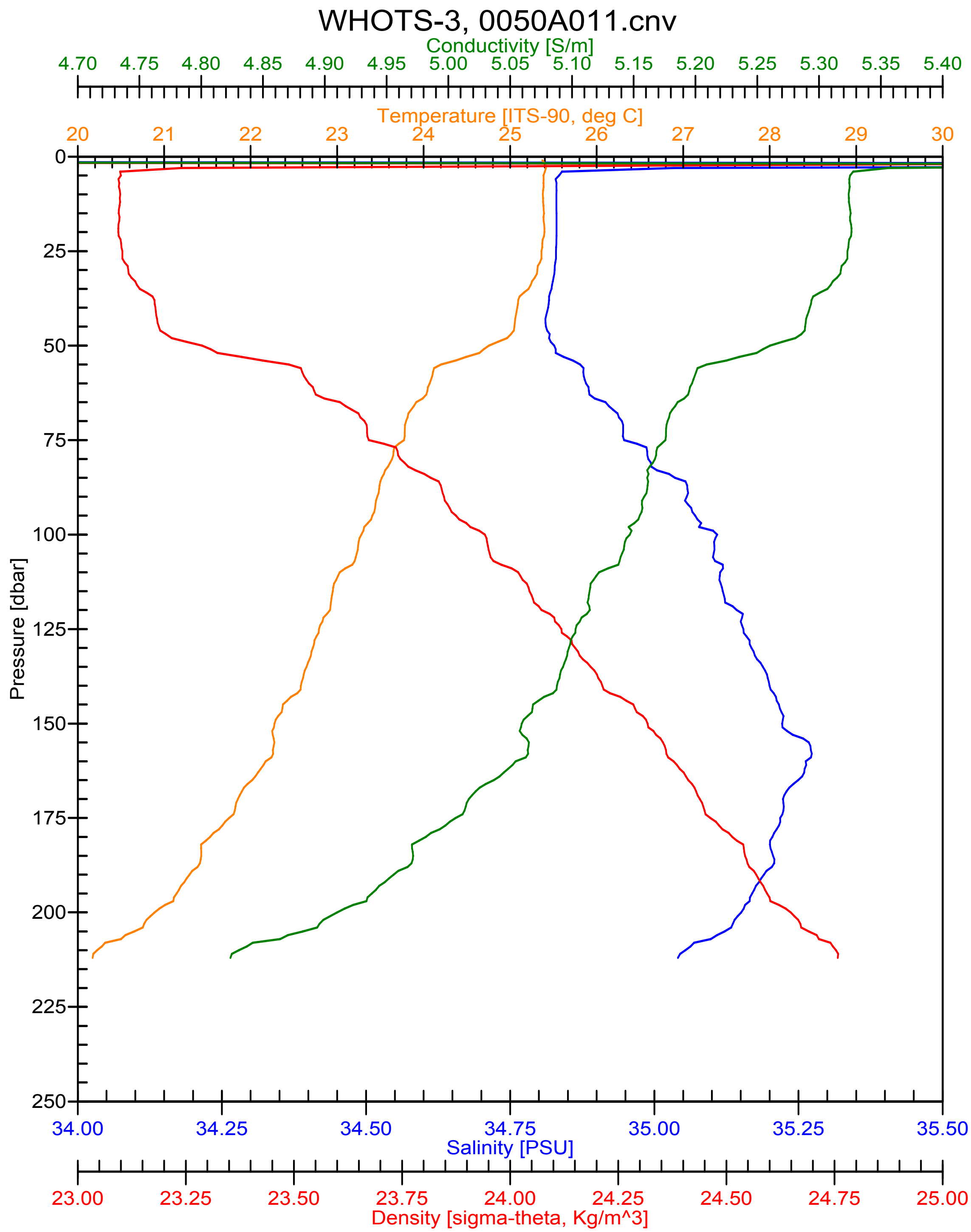
WHOTS-3, 0050A008.cnv
Conductivity [S/m]
3.25 3.50 3.75 4.00 4.25 4.50 4.75 5.00 5.25 5.50
Temperature [ITS-90, deg C]
0 5 10 15 20 25 30
Pressure [dbar]
0 100 200 300 400 500 600 700 800 900 1000 1100
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5 27.0 27.5
Density [sigma-theta, Kg/m^3]



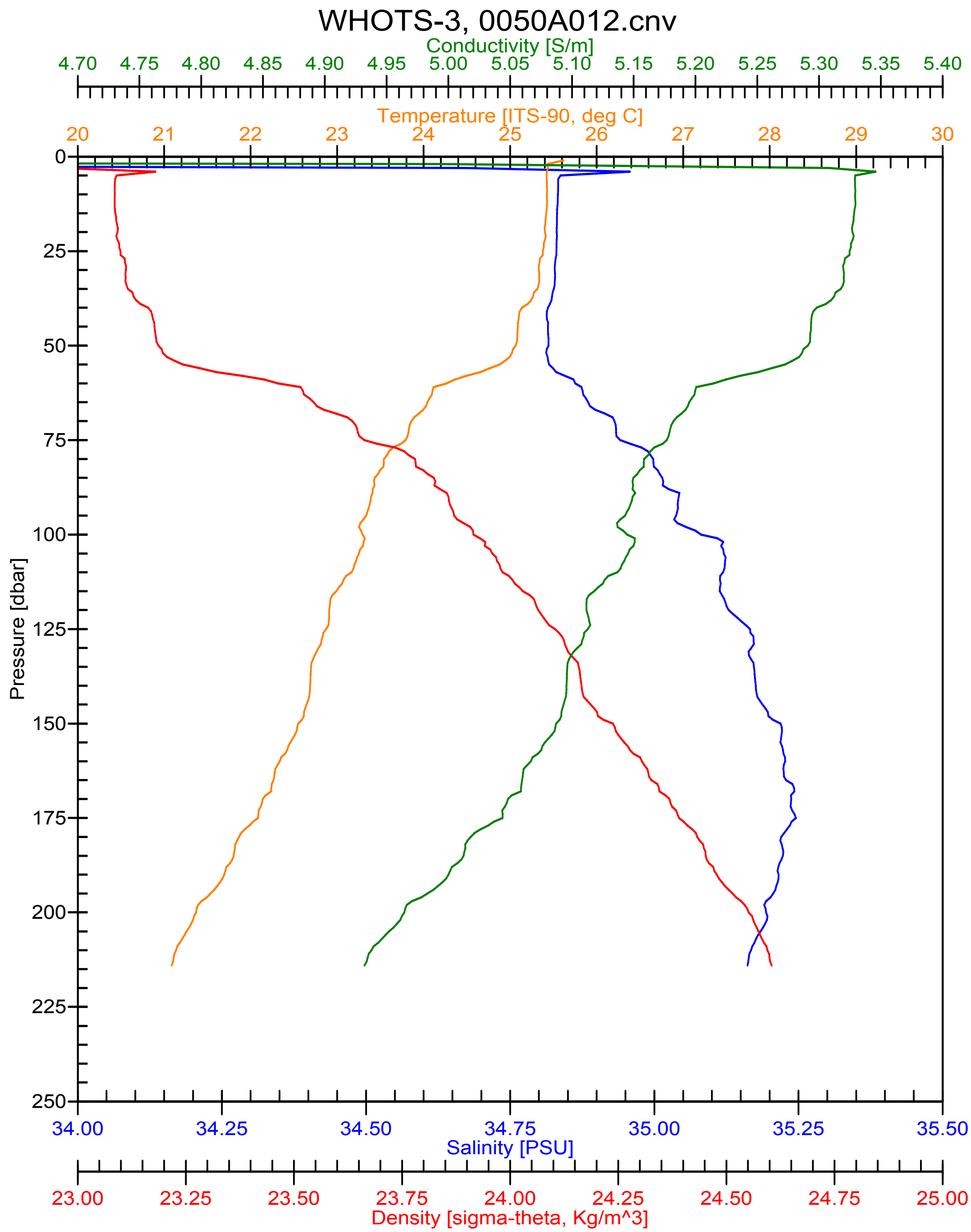
WHOTS-3, 0050A009.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]



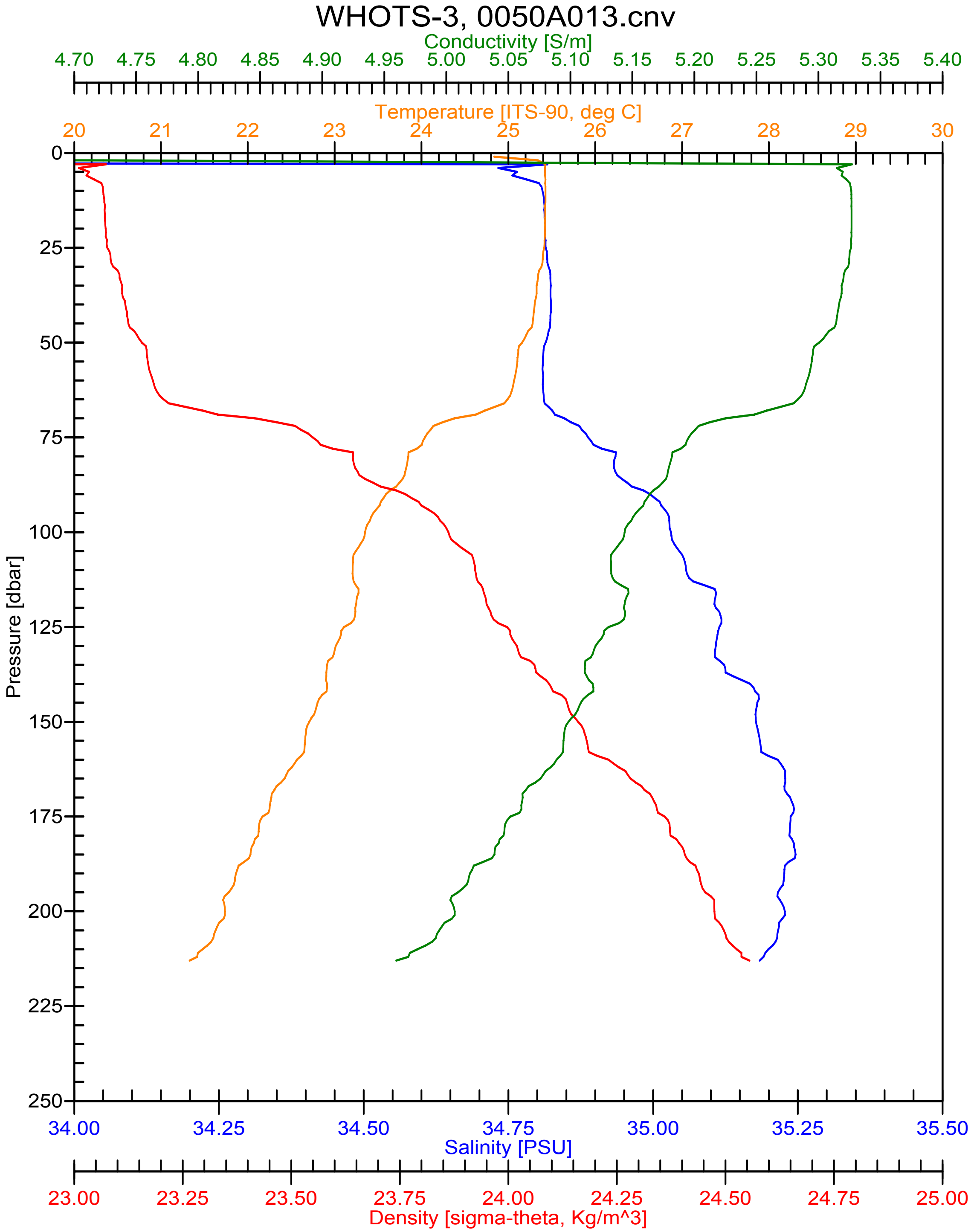
WHOTS-3, 0050A010.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]

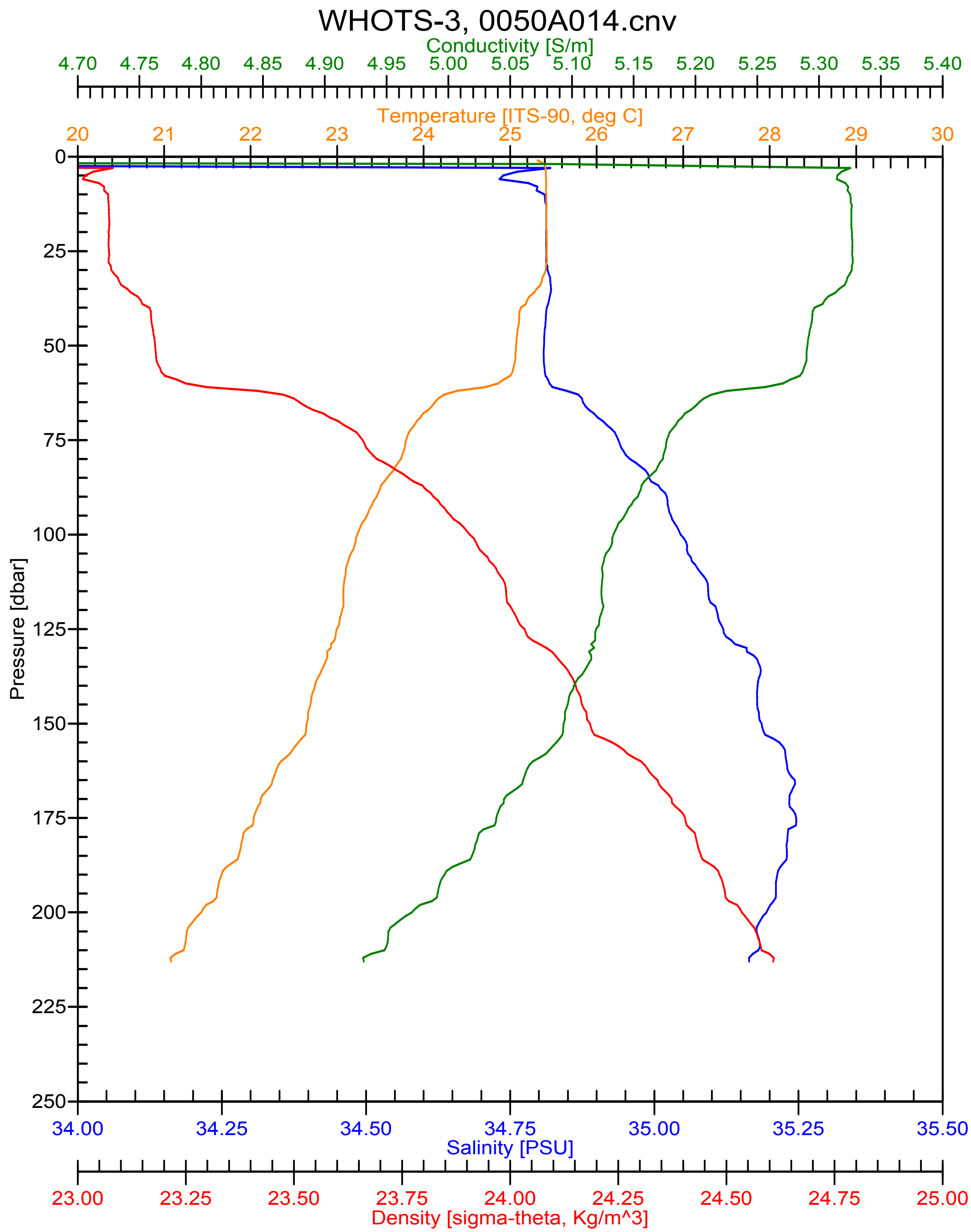


WHOTS-3, 0050A011.cnv
Conductivity [S/m]
4.70
4.75
4.80
4.85
4.90
4.95
5.00
5.05
5.10
5.15
5.20
5.25
5.30
5.35
5.40
Temperature [ITS-90, deg C]
20
21
22
23
24
25
26
27
28
29
30
Pressure [dbar]
0
25
50
75
100
125
150
175
200
225
250
34.00
34.25
34.50
34.75
35.00
35.25
35.50
Salinity [PSU]
23.00
23.25
23.50
23.75
24.00
24.25
24.50
24.75
25.00
Density [sigma-theta, Kg/m^3]



WHOTS-3, 0050A012.cnv
Conductivity [S/m]
4.70
4.75
4.80
4.85
4.90
4.95
5.00
5.05
5.10
5.15
5.20
5.25
5.30
5.35
5.40
Temperature [ITS-90, deg C]
20
21
22
23
24
25
26
27
28
29
30
Pressure [dbar]
0
25
50
75
100
125
150
175
200
225
250
34.00
34.25
34.50
34.75
35.00
35.25
35.50
Salinity [PSU]
23.00
23.25
23.50
23.75
24.00
24.25
24.50
24.75
25.00
Density [sigma-theta, Kg/m^3]


WHOTS-3, 0050A013.cnv
Conductivity [S/m]
4.70
4.75
4.80
4.85
4.90
4.95
5.00
5.05
5.10
5.15
5.20
5.25
5.30
5.35
5.40
Temperature [ITS-90, deg C]
20
21
22
23
24
25
26
27
28
29
30
Pressure [dbar]
0
25
50
75
100
125
150
175
200
225
250
34.00
34.25
34.50
34.75
35.00
35.25
35.50
Salinity [PSU]
23.00
23.25
23.50
23.75
24.00
24.25
24.50
24.75
25.00
Density [sigma-theta, Kg/m^3]



WHOTS-3, 0050A014.cnv
Conductivity [S/m]
4.70 4.75 4.80 4.85 4.90 4.95 5.00 5.05 5.10 5.15 5.20 5.25 5.30 5.35 5.40
Temperature [ITS-90, deg C]
20 21 22 23 24 25 26 27 28 29 30
Pressure [dbar]
0 25 50 75 100 125 150 175 200 225 250
34.00 34.25 34.50 34.75 35.00 35.25 35.50
Salinity [PSU]
23.00 23.25 23.50 23.75 24.00 24.25 24.50 24.75 25.00
Density [sigma-theta, Kg/m^3]

Appendix C: WHOTS-2 Moored Station

Moored Station Log

PAGE 1

(fill out log with black ball point pen only)

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

Launch (anchor over)

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

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

Position Source: GPS, LORAN, SAT. NAV., OTHER

Deployed by: J. Lord Recorder/Observer: Plueddemann

Ship and Cruise No Melville TUIM10MV Intended duration: 365 days

Depth Recorder Reading 4695 m Correction Source: XBT

Depth Correction already corrected m

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

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

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

Acoustic Release Information

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

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

Interrogate Freq. 11kHz Reply Freq. 12 kHz

Recovery (release fired)

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

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

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

Recovered by: ____ Recorder/Observer: ____

Ship and Cruise No. ____ Actual duration: ____ days

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

Surface Components

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

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

Surface Instrumentation

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

* Height above buoy deck

visual inspec. indicates WL at 75 cm below deck

Sub-Surface Instrumentation on Buoy and Bridle

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

† Depth below buoy deck

Sub-Surface Components

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

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

No. of Flotation Clusters ________

Anchor Dry Weight 9300 lbs

MOORED STATION NUMBER 1160

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

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

MOORED STATION NUMBER 1160

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

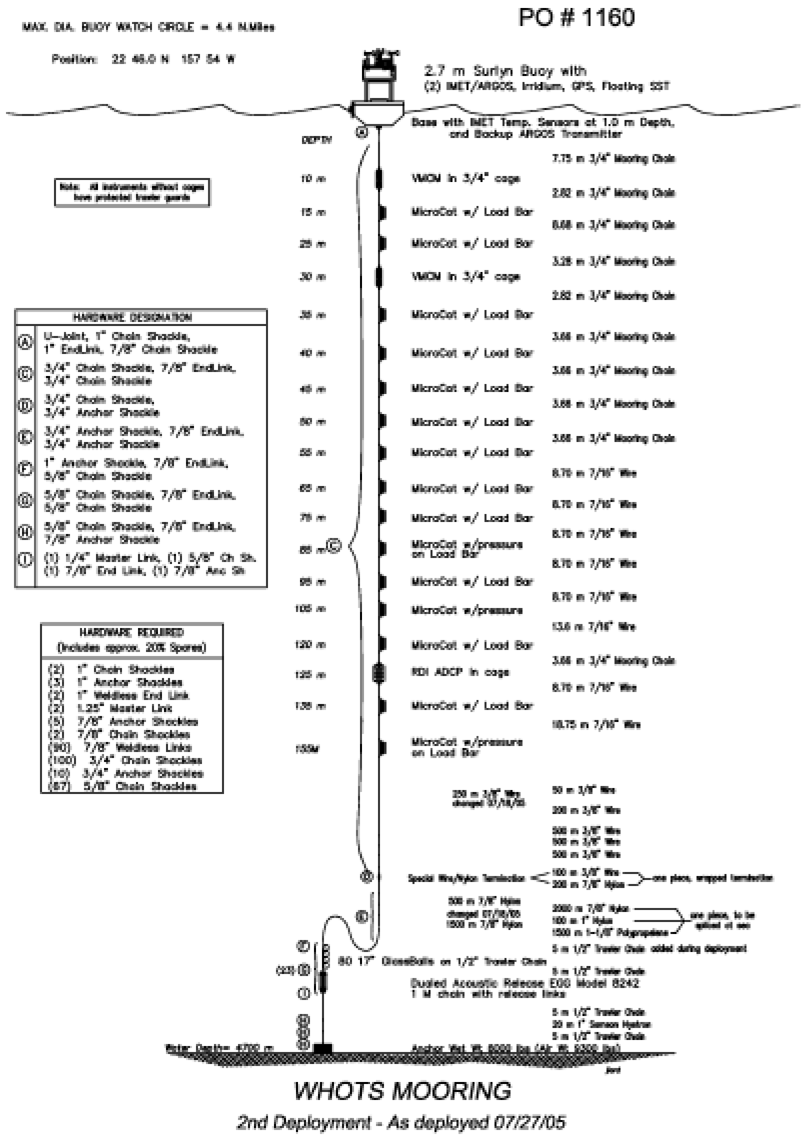
Date/Time	Comments
1946 27 Jul	* 50 m (4041-14) + 200 m (4042-4)

MOORED STATION NUMBER 1160

Item No.	Lgth [m]	Item	Inst No.	Time Over	Notes	Data No.	Calc Dpth	Time Back	Notes
41	500	3/8 wire		2021	5030-112 5002-113				
42	100	3/8 wire	one piece, spliced	2040	4042-6				
43	200	7/8 nylon		2045					
44	500	7/8 nylon	*						
45	1500	7/8 nylon	one piece, spliced						
46	100	1" nylon		2059					
47	1500	1 1/8 poly		end 2300					
48	5	1/2" chain		start					
49		80 glass balls on 1/2 chain		2312					
50				end 2349					
51	5	1/2" chain		‡					
52		release	32480	0124					
53		release	30555						
54	5	1/2 chain							
55	20	1" Samson							
56	5	1/2 chain							
57		anchor		0143					
58									
59									
60									

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

Figure C1: WHOTS mooring diagram 2nd deployment.



Appendix D: WHOTS-3 Moored Station Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-3 MOORED STATION NO. 1175

Launch (anchor over)

Date (day-mon-yr) 26-6-2006 Time 2347 UTC

Latitude (N/S, deg-min) 22°45.961 N Longitude (E/W, deg-min) 157°53.823 W

Deployed by Lord, Weller Recorder/Observer Griffiths

Ship and Cruise No. Revelle AMAT 07 Intended Duration 365 days

Depth Recorder Reading 4698.5 m Correction Source This already has sound speed cor (1000 m XBT, Carter table deeper than 1000 m)

Depth Correction 5m (transducer depth)

Corrected Water Depth 4703.5 m Magnetic Variation (E/W) ____

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

Surveyed Anchor Position 32 m - release off bottom

Lat (N/S) 22° 45.9938' Long. (E/W) 157° 53.992'

Acoustic Release Model Model 8242 XS Tandem in frame

Release No. SN 30846 #1 SN 31272 #2 Tested to 1500 m m

Receiver No. ~~151376~~ ~~166561 #1~~, ~~444237 #2~~ Release Command #1 151376 #2 444237

Enable #1 166561 #2 460422 Disable #1 166603 #2 460447

Interrogate Freq. 11 KHz Reply Freq. 12 KHz

Recovery (release fired)

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

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

Recovered by ____ Recorder/Observer ____

Ship and Cruise No. ____ Actual duration ____ days

Distance from actual waterline to buoy deck ____ m

1

Surface Components

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

Buoy Markings

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET lgr	L-12	-	System 1
HRH	211	231.5	above deck
BPR	505	234.0	"
WND	219	265.0	"
PRC	204	235.0	
LWR	504	285.0	
SWR	209	287.0	
SST	3603	-150.0	below deck
PTT	63878		IDs: 27356, 27364, 27413
ASIMET lgr	L-16		
HRH	215	233.0	
BPR	506	234.5	
WND	218	266.0	
PRC	215	234.0	
LWR	205	285.0	
SWR	504	287.0	
SST	3605	-150.0	
PTT	63879		IDs: 07561, 27415, 27416
standalone RH #1		193.0	
standalone RH #2		193.0	
GPS	69975	245.0	
Iridium	8370		system 1
Iridium	16710		system 2
Floating SST			
SS-Argos	8		~~24438~~ ID 24338

*Height above buoy deck in centimeters

2

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SST	3603		L12 / Sys 1
SST	3605		L16 / Sys 2
floating SST			

†Depth below buoy deck in centimeters

Moored Station Number 1175

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		Buoy Hull		1847					
2	7.75	3/4 chain							
3		NGVM	035	1829	bands off		10 m		
4	2.82	3/4 chain							
5		Seacat	801	1828	SBE 16		15 m		
6	8.68	3/4 chain							
7		Seacat	1085	1825	SBE 16		25 m		
8	3.28	3/4 chain							
9		NGVM	059	1818	bands off		30 m		
10	2.82	3/4 chain							
11		Seacat	1087	1816	SBE 16		35 m		
12	3.66	3/4 chain							
13		Microcat	3381	1814	SBE 37		40 m		
14	3.66	3/4 chain							
15		Microcat	4663	1859	SBE 37		45 m		
16	3.66	3/4 chain							
17		Seacat	1088	1902	SBE 16		50 m		
18	3.66	3/4 chain							
19		Seacat	1090	1909	SBE 16		55 m		
20	8.70	7/16 wire							
21		Seacat	1092	1913	SBE 16		65 m		
22	8.70	7/16 wire							

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		Seacat	1095	1916	SBE 16		75 m		
24	8.70	7/16 wire							
25		Microcat	4699	1918	SBE37 with pressure		85 m		
26	8.70	7/16 wire							
27		Seacat	1097	1921	SBE16		95 m		
28	8.70	7/16 wire							
29		Microcat	2769	1924	SBE37 with pressure		105 m		
30	13.6	7/16 wire							
31		Seacat	1099	1927	SBE16		120 m		
32	3.66	3/4 chain							
33		RDI ADCP	4891	1929	upward looking		125 m		
34	8.70	7/16 wire							
35		SEACAT	1160	1933	SBE 16		135 m		
36	18.75	7/16 wire							
37		Microcat	4700	1938	SBE37 with pressure		155 m		
38	250m	3/8 wire		1938	5030-10 (start time)				
39	500m	3/8 wire		1946	5030-13				
40	500m	3/8 wire		2001	5234-12				
41	500m	3/8 wire		2019	5234-11				
42	100	3/8 wire	5030-14 one piece	2038	wire/nylon term.				
43	200	7/8 nylon		2042	wrapped				
44	2000	7/8 nylon		2057	one piece 44-46				
45	100	1" nylon		2140 ~~2131~~					

*ADCP serial number 4891 incorrect. It should be 7637.

Moored Station Number 1175

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	1500	1 1/8 poly		2143	one piece c̄ 44,45				
47		80 balls	start end	2223 2254	on 1/2" trawler chain				
48	5	1/2 trawler chain							
49		dual release	both	2307	EGG				
50		dual rel			EGG				
51	1	chain w/ rel. links							
52	5	1/2 trawler chain							
53	20	1" Samson Nystron		2308					
54	5	1/2" trawler chain							
55		anchor		2347					
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
68									
69									
70									
71									
72									
73									
74									
75									
76									
77									
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88									
89									
90									

Appendix E: WHOTS-3 Science Party

	Science Party	Sex	Nationality	Affiliation
1.	Robert Weller	M	USA	WHOI
2.	Jeff Lord	M	USA	WHOI
3.	Sean Whelan	M	USA	WHOI
4.	Edward Bradley	M	Australia	CSIRO
5.	Theresa Smith	F	USA	NOAA
6.	Scott Burman	M	USA	Volunteer
7.	Diana Griffiths	F	USA	NOAA Teacher At Sea
8.	Roger Lukas	M	USA	U. Hawaii
9.	Paul Lethaby	M	British	U. Hawaii
10.	Brandon Shima	M	USA	U. Hawaii
11.	John Yeh	M	USA	U. Hawaii
12.	Jerome Aucan	M	USA	U. Hawaii
13.	Jefrey Snyder	M	USA	U. Hawaii

Appendix F: WHOTS-3 Timeline

WHOTS-3 Timeline

Start Date, Time	End Date, Time	Operation
22 June, 1600		Depart Honolulu for WHOTS operations area (approx 120 nmi at 10 kt = 12 hr transit)
23 June, 0400		Arrive at WHOTS site, prepare for intercomparison Deploy bottom camera
23 June, 0500	24 June 0500	WHOTS-2 Ship/Buoy intercomparison and CTDs
24 June 0500	24 June 0700	Maneuver to recovery start position, begin deck prep
24 June 0700	24 June 1600	WHOTS-2 mooring recovery
24 June 1600	24 June 2000	Deck, buoy and instrument clean up
25 June, 0600	26 June, 0500	Prepare mooring gear and instruments for deployment
26 June 0500		Maneuver to deployment start position
26 June 0600	26 June 1400	WHOTS-3 mooring deployment
26 June 1400	26 June 1800	Anchor tracking and survey
26 June 1800	26 June 2000	Clean up and stow deck gear
27 June, 0500	28 June, 1800	WHOTS-3 Ship/Buoy intercomparison and CTDs
28 June, 1800		Depart WHOTS site for Honolulu (approx 120 nmi at 10 kt = 12 hr transit)
29 June, 0800		Arrive Honolulu

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5. Report Date May 2007

6.

7. Author(s) Sean P. Whelan, Robert A. Weller, Roger Lukas, Frank Bradley, Jeffrey Lord, Jason Smith. Frank Bahr. Paul Lethabv. Jeffrev Snvder

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
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Woods Hole, Massachusetts 02543

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16. Abstract (Limit: 200 words)

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

The first WHOTS mooring (WHOTS-1) was deployed in August 2004. WHOTS-1 was recovered and WHOTS-2 deployed in July 2005. This report documents recovery of the WHOTS-2 mooring and deployment of the third mooring (WHOTS-3) at the same site. Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air-Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite, the surface meteorological variables necessary to compute air-sea fluxes of heat, moisture, and momentum. WHOTS-2 was equipped with one Iridium data transmitter, and WHOTS-3 had two Iridium data transmitters. In cooperation with R. Lukas of the University of Hawaii, the upper 155 m of the morrings were outfitted with oceanographic sensors for the measurement of temperature, conductivity, and velocity.

The WHOTS mooring turnaround was done on the Scripps Institution of Oceanography ship *Revelle*, Cruise AMAT-07, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution and Roger Lukas'group at the University of Hawaii. The cruise took place between 22 and 29 June 2006. Operations on site were initiated with an intercomparison of shipboard meteorological observations with the WHOTS-2 buoy. Dr. Frank Bradley, CSIRO, Australia, assisted with these comparisons. This was followed by recovery of the WHOTS-2 mooring on 24 June. A number of recovered instruments were calibrated by attaching them to the rosette frame of the CTD. Shallow CTD profiles were taken every two hours for 12 hours on the 25th of June. A fish trap was deployed on June 25th by John Yeh, a University of Hawaii graduate student. The WHOTS-3 mooring was deployed on 26 June at approximately 22°46'N, 157°54'W in 4703 m of water. A ship-buoy intercomparison period and series of shallow CTDs followed along with a second deployment of the fishtrap.

A NOAA Teacher-At-Sea, Diana Griffiths, and a NOAA Hollings Scholar, Terry Smith, participated in the cruise. This report describes the mooring operations, some of the pre-cruise buoy preparations and CTD casts taken during the cruise, the fish trap deployments, and the experiences of the Teacher-at-Sea and Hollings Scholar.

17. Document Analysis a. Descriptors

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ocean
climate

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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