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Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-5 2008 Mooring Turnaround Cruise Report

by

Sean P. Whelan, Jeffrey Lord, Robert Weller, Roger Lukas, Fernando Santiago-Mandujano, Jefrey Snyder, Paul Lethaby, Frank Bahr, Chris Sabine, Jason Smith, Paul Bouchard, and Nan Galbraith

Woods Hole Oceanographic Institution,
Woods Hole, Massachusetts

April 2009

Technical Report

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

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
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Approved for Distribution:

Robert Weller

Department of Physical Oceanography

Abstract

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

The first four WHOTS moorings (WHOTS-1 through 4) were deployed in August 2004, July 2005, June 2006, and June 2007, respectively. This report documents recovery of the WHOTS-4 mooring and deployment of the fifth mooring (WHOTS-5). Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity in a cooperative effort with R. Lukas of the University of Hawaii. A pCO2 system was installed on the WHOTS-5 buoy in a cooperative effort with Chris Sabine at the Pacific Marine Environmental Laboratory.

The WHOTS mooring turnaround was done on the University of Hawaii research vessel *Kilo Moana*, Cruise KM-08-08, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 3 and 11 June 2008. Operations began with deployment of the WHOTS-5 mooring on 5 June at approximately 22°46.1′N, 157°54.1′W in 4702 m of water. This was followed by meteorological intercomparisons and CTDs at the WHOTS-4 site. A period of calmer weather was taken advantage of to recover WHOTS-4 on 6 June 2008. The *Kilo Moana* then returned to the WHOTS-5 mooring for CTD operations and meteorological intercomparisons. This report describes these cruise operations, as well as some of the in-port operations and pre-cruise buoy preparations.

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1. Introduction

The Hawaii Ocean Timeseries (HOT) site, 100 km north of Oahu, Hawaii, has been occupied since 1988 as a part of the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). The present HOT program includes comprehensive, interdisciplinary upper ocean observations, but does not include continuous surface forcing measurements. Thus, a primary driver for the WHOTS mooring is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and to contribute to the program goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The WHOTS mooring also serves as an Ocean Reference Station – a part of NOAA's Ocean Observing System for Climate – providing time-series of accurate surface meteorology, air-sea fluxes, and upper ocean variability to quantify air-sea exchanges of heat, freshwater, and momentum, to describe the local oceanic response to atmospheric forcing, to motivate and guide improvement to atmospheric, oceanic, and coupled models, to calibrate and guide improvement to remote sensing products, and to provide anchor point for the development of new, basin scale air-sea flux fields.

To accomplish these objectives, a surface mooring with sensors suitable for the determination of air–sea fluxes and upper ocean properties is being maintained at a site near 22°45′N, 158°00′W (Fig. 1-1) by means of annual "turnarounds" (recovery of one mooring and deployment of a new mooring near the same site). The moorings use Surlyn foam buoys as the surface element, outfitted with two complete Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum.

Subsurface observations have been made on all WHOTS deployments in cooperation with Roger Lukas at the University of Hawaii (UH). The upper 155 m of the mooring line is outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity. For WHOTS-5, a pCO2 system for investigation of the air-sea exchange of CO2 at the ocean surface was mounted in the buoy well in cooperation with Chris Sabine at the Pacific Marine Environmental Laboratory (PMEL).

The mooring turnaround was done on the UH Research Vessel *Kilo Moana* by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI) with assistance from the UH personnel. The cruise was completed in 8 days, between 3 June and 11 June 2008. The cruise originated from, and returned to, Honolulu, HI (Fig. 1-1). The facilities of the UH Marine Center at Sand Island, and a tent maintained by the Hawaii Undersea Research Lab, were used for pre-cruise staging.

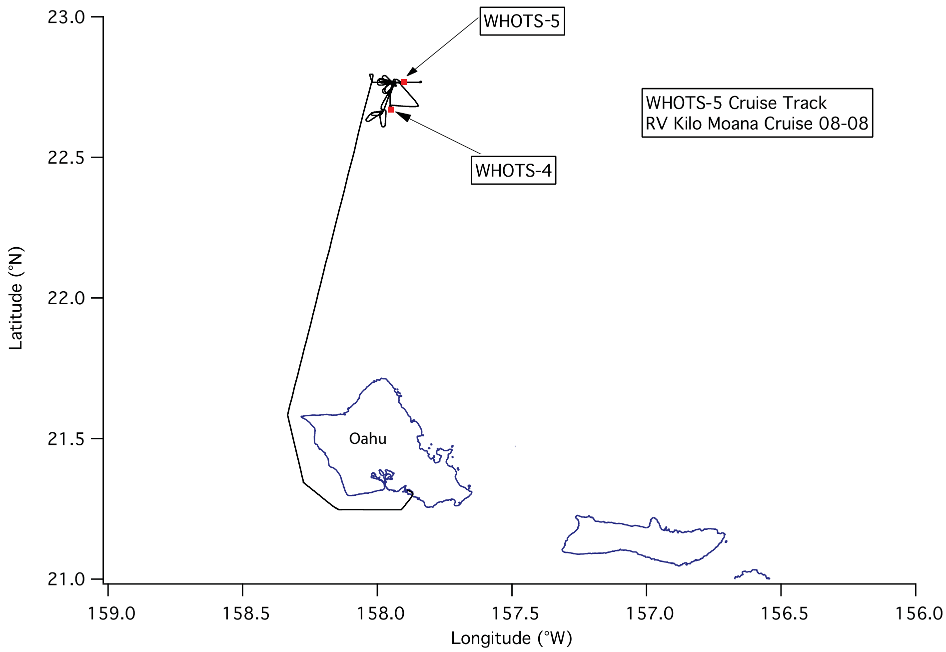


Figure 1-1. WHOTS-5 site map and cruise track. The WHOTS moorings are at the perimeter of the Station Aloha circle (dashed) with the Hawaii Ocean Timeseries (HOT) site at its center.

2. Pre-Cruise Operations

a. Staging and Loading

Pre-cruise operations were conducted on the grounds of the UH Marine Center in Honolulu, HI. A 40' 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.

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 and began offloading the gear to a staging area near the dock. 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. 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.

b. 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 conducted 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 310°, WHOI buoy spin.

The second buoy spin was conducted in Honolulu Fig 2-1, 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 90.5° and was used as a sighting point.

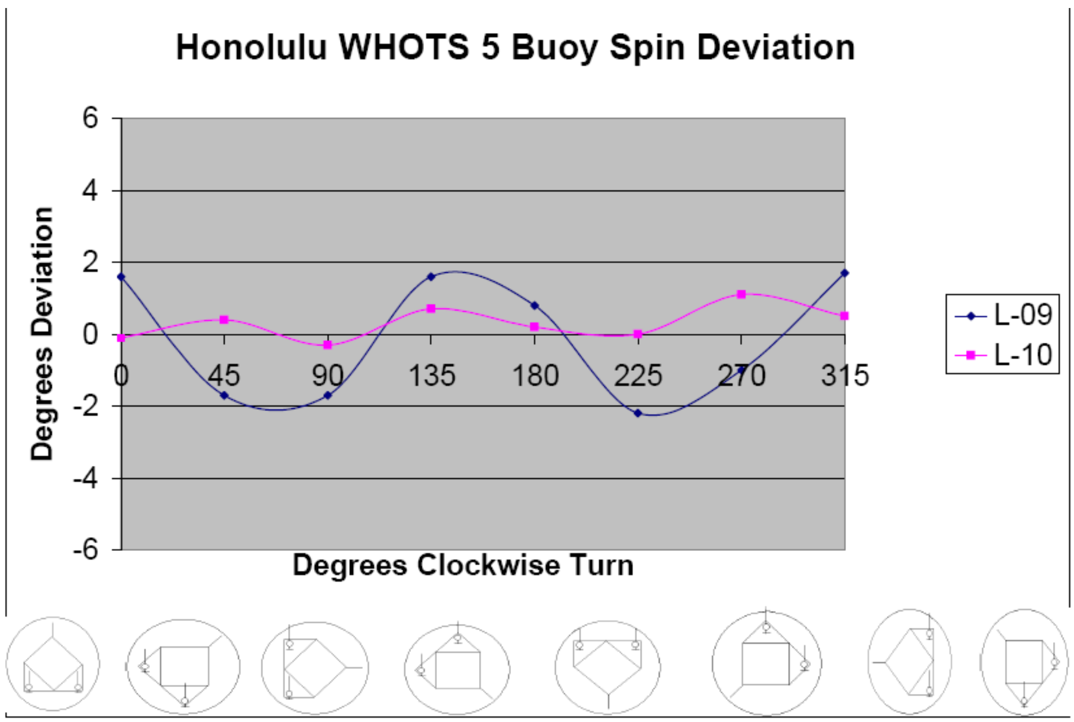
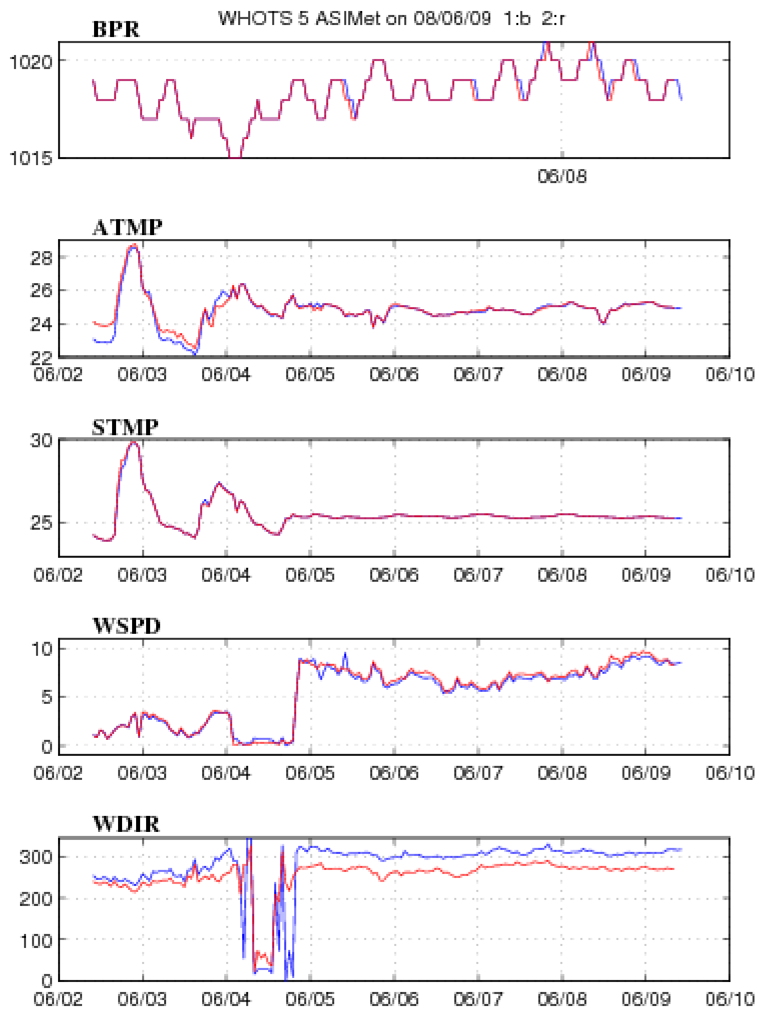


Fig 2-1: Buoy spin data.

c. Sensor Evaluation

Once the buoy well and tower top were assembled, the ASIMET modules were initialized and connected to the loggers. When mechanical assembly was complete, power was applied, the loggers were started, and data acquisition began. Evaluation of the primary sensor suite was done through a series of overnight tests. Both hourly Argos transmissions and 1 min logger data were evaluated.

A series of "sensor function checks," including filling and draining the PRC modules, covering and uncovering the solar modules, and dunking the STC modules in a salt-water bucket, were done during the in-port evaluation period. The results of these checks, and a final in-port evaluation of hourly Argos data, showed all modules to be functioning as expected as seen in Fig. 2-2.



WHOTS 5

Fig 2-2: Sensor evaluation data.

3. WHOTS-5 Mooring Description

a. Mooring Design

The mooring is an inverse catenary design utilizing wire rope, chain, nylon line and polypropylene line. The mooring scope (ratio of total mooring length to water depth) is about 1.25. The watch circle has a radius of approximately 2.2 nm (4.2 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 was mounted within an access tube in the foam hull. This is a backup system, and would only be activated if the buoy capsized. For WHOTS-4, a self-contained Global Positioning System (GPS) receiver and a PCO_2 sampling system were also mounted on the buoy. Sea surface temperature and salinity are measured by sensors bolted to the underside of the buoy hull and cabled to the loggers through an access tube through the buoy foam.

Fifteen temperature-conductivity sensors, two Vector Measuring Current Meters (VMCMs) and two Acoustic Doppler Current Meters (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. Dual acoustic releases, attached to a central load-bar, were placed approximately 33 m above the anchor. Above the release were eighty 17" glass balls meant to keep the release upright and ensure separation from the anchor after the release is fired. This flotation is sufficient for backup recovery, raising the lower end of the mooring to the surface in the event that surface buoyancy is lost.

b. Bird Barrier

WHOTS-4 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. The wire strips were installed fully around the crash bar, the flat top portion, inside lip, and carefully around the solars. Individual strips were 4 foot long and secured with cable ties. Order: S Kit 6 - 4 ft strips 24ft and S Kit 10 - 4ft strips 40ft Kit. The wires are sharp so it is recommended that gloves and eye protection be used for installation. Furthermore, transparent monofilament fishing line was installed in a simple X pattern inside the tower to also serve as a deterrent.

c. Anti-foul Treatment

E-Paint's products have been refined to best suit the wishes of WHOI- effective products that remain relatively safe to apply. Treatment of the WHOTS-4 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.

d. Buoy Instrumentation

i. ASIMET

Table 3-1: WHOTS 5 Serials/Heights

System 1

Module	Serial	Firmware Version	Height Cm
Logger	L-09	LOGR53 V3.21	
HRH	227	VOS HRH53 V3.2	223.5
BPR	505	VOS BPR53 V3.3 (Heise)	233
WND	~~228~~ 219	VOS WND53 ~~V3.0~~ V3.5	260.5
PRC	214	VOS PRC53 V3.4	246
LWR	205	VOS LWR53 V3.5	285
SWR	208	VOS SWR53 V3.3	285
SST	1419		-156
PTT		27356, 27364, 27413	

System 2

Module	Serial	Firmware Version	Height Cm
Logger	L-10	LOGR53 V3.21	
HRH	216	VOS HRH53 V3.2	223.5
BPR	506	VOS BPR53 V3.3 (Heise)	233
WND	205	VOS WND53 V3.5	260.5
PRC	210	VOS PRC53 V3.4	246
LWR	210	VOS LWR53 V3.5	285
SWR	207	VOS SWR53 V3.3	285
SST	1306		-156
PTT		7561, 27415, 27416	

Stand-Alone Module(s)

Module	Serial	Firmware Version	Height Cm
HRH	231	VOS HRH53 V3.2	211
MINI-MET	#1		214
XEOS GPS	9060		248
SEIMAC GPS	67699		245
SIS	??		

ii.Floating SST

A floating SST bracket was incorporated on to the buoy hull, using 1 SBE39 temperature recorder and 1 Brancker temperature recorder.

iii.SIS Argos

The buoy hull also contained an emergency beacon. In the event of catastrophic failure where the buoy hill flips up side down, an Argos beacon would activate and relay position information to facilitate recovery.

iv. Global Positioning System

WHOTS 5 deployed a Xeos unit along side a SEIMAC internally logging GPS unit.

v. Telemetry

WHOTS 5 deployed using 2 Argos Satellite data transmission systems.

vi. PCO$_2$

The WHOI Hawaii Ocean Time-series Station (WHOTS) is located near the HOT shipboard time series site (22.75°N, 158°W) in order to maximize the utility of both data sets. There are several advantages of this site. These include: (1) A rich historical database is available for the site; this is useful for setting up new moored instruments, as well as facilitating intercomparisons and interpretations; (2) The HOT site is well away from sources of anthropogenic influence, which is especially important for trace metal, dissolved CO_2, oligotrophic biological and optical, and aerosol studies; (3) The ongoing JGOFS time-series sampling program (approximately monthly frequency) collects a relatively complete suite of physical, chemical (including nutrients and CO_2), and biological data. There are analogous advantages for comparisons and calibrations of present and emerging sensors; (4) Remote sensing data (SeaWiFS, AVHRR, TOPEX/Poseidon and ERS-series altimetry, QuikScat, MODIS, and weather images) are collected, thus providing complementary measurements for our study and *vice versa*; (5) there is a documented need for high temporal resolution/mooring data at the site because of undersampling and aliasing as described above; (6) there is a reasonably high probability of passage of intense storms and occasionally hurricanes; (7) other testing is either ongoing or planned from other platforms near the HOT site (e.g., AUVs); and (8) the region is often used for other scientific studies that can be used to enhance the HOT and WHOTS data sets and *vice versa*.

Adding a pCO_2 system to the WHOTS mooring expands the OceanSITES moored pCO_2 network. The current network is developing in the North Pacific. This site provides the next logical step for an expansion.

CO_2 measurements are made every three hours in marine boundary layer air and air equilibrated with surface seawater using an infra-red detector. The detector is calibrated prior to each reading using a zero gas derived by chemically stripping CO_2 from a closed loop of air and a span gas (470 ppm CO_2) produced and calibrated by NOAA's Earth System Research Laboratory (ESRL). For an overview of the system visit:

http://www.pmel.noaa.gov/co2/moorings/eq_pco2/pmelsys.htm. PMEL pCO_2 system was used for this deployment.

A summary file of the measurements is transmitted once per day and plots of the data are posted in near real-time to the web. To view the daily data visit the NOAA PMEL Moored CO_2 Website: http://www.pmel.noaa.gov/co2/moorings/hot/hot_main.htm. Within a year of system recovery, the final processed data are submitted to the Carbon Dioxide Information Analysis Center (CDIAC) for release to the public.

e. Subsurface Instrumentation

Instrument	Serial	Depth	Sample	Start Date	Start Time	Start Spike Spike Start		End Spike Spike Stop	
VMCM	003	10	60sec	28-May-08	19:53:30	19:54:30	1-Jun	19:55:30	1-Jun
VMCM	037	30	60 sec	28-May-08	19:46:30	19:54:30	1-Jun	19:55:30	1-Jun
SBE39	1447	FSST	300 sec	31-May-08	19:45:00	20:07:00	31-May	20:40:00	31-May
Branker TR1050	10986	FSST	300 sec	31-May-08	20:00:00	20:07:00	31-May	20:40:00	31-May
SBE37 SST	1419	SST	300 sec	29-May-08	01:00:00	21:00:00	30-May	22:16:00	30-May
SBE37 SST	1306	SST	300 sec	29-May-08	01:00:00	21:00:00	30-May	22:16:00	30-May

Table 3-2: WHOTS 5 Subsurface

UH provided 6 SBE-37 Microcats, 9 SBE-16 Seacats, an RDI 300 kHz Workhorse ADCP, and a 1.2 MHz RDI Workhorse ADCP. WHOI provided 2 Vector Measuring Current Meters (VMCMs). The Microcats and Seacats measure temperature and conductivity; four Microcats also measure pressure. Table 3-3 provides deployment information for the C-T instrumentation on the WHOTS-5 mooring.

SN:	Instrument	Depth	Pressure SN	Sample Interval (sec)	Start Logging Data(GMT)		Ice Bath In (GMT)		Ice Bath Out (GMT)		Time in Water (GMT)	
1099	Seacat	15	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	19:02:00
1085	Seacat	25	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	18:58:00
1087	Seacat	35	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	18:49:00
3381	Microcat	40	N/A	150	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	18:45:00
4663	Microcat	45	N/A	150	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	18:41:00
2530	1200 kHz ADCP	47.5	N/A	600	5/31/2008	0:00:00	N/A		N/A		06/04/08	18:41:00
1088	Seacat	50	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	18:36:00
1090	Seacat	55	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	20:04:00
1092	Seacat	65	N/A	600	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	20:09:00
1095	Seacat	75	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	20:13:00
4699	Microcat	85	10209	180	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	20:16:00
1097	Seacat	95	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	20:19:00
2769	Microcat	105	2949	180	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	20:24:00
4701	Microcat	120	10211	180	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	20:27:00
7637	300 kHz ADCP	125	N/A	600	5/31/2008	0:00:00	N/A		N/A		06/04/08	20:31:00
1100	Seacat	135	N/A	600	05/19/08	0:00:00	05/19/08	23:59:00	05/20/08	0:34:00	06/04/08	20:35:00
4700	Microcat	155	2479944	180	05/19/08	0:00:00	05/20/08	0:39:00	05/20/08	1:19:00	06/04/08	20:38:00

Table 3-3: WHOTS-5 mooring subsurface C-T instrument deployment information. All times are in GMT.

The ADCPs were deployed in the upward-looking configuration. The instruments were programmed as described in Table 3-4.

=	S/N 7637 300 kHz	S/N 2530 1200 kHz
Number of Depth Cells	30	17
Depth Cell Size	4 m	1 m
Time per Ensemble	10 min	10 min
Pings per Ensemble	40	120
Time per Ping	4 sec	2 sec
Time of First Ping	05/31/08, 00:00	05/31/08, 00:00
Time in water	06/04/08, 20:31	06/04/08, 18:41
Depth	125 m	47.5 m

Table 3-4: WHOTS-5 mooring ADCP deployment information.

4. WHOTS-5 Mooring Deployment

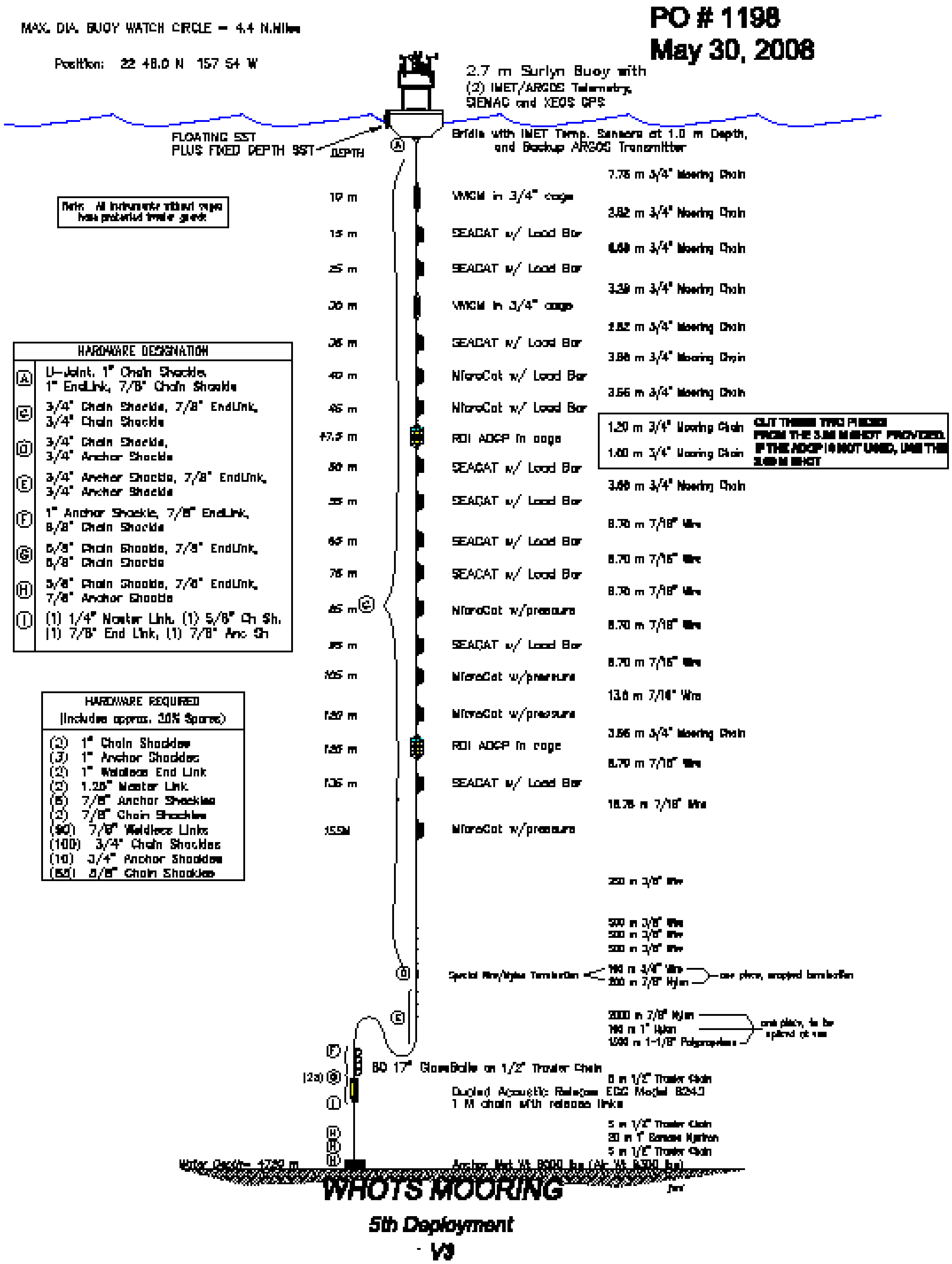
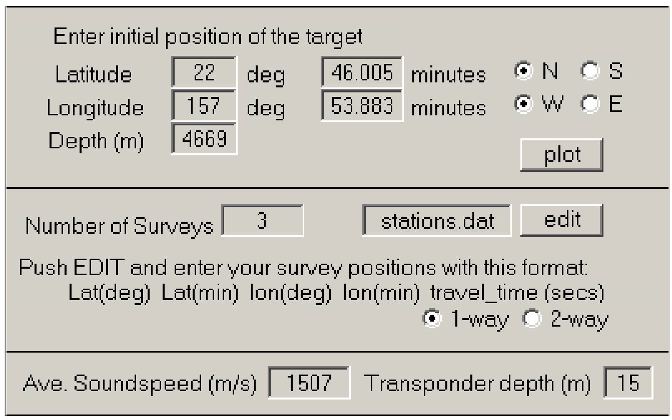


Figure 4-1: WHOTS 5 mooring design.

a. Anchor Survey

The anchor survey was done by acoustic ranging on one of the releases to determine the exact anchor position and allow estimation of the anchor fall-back from the drop site. Three positions about 2.5 nm away from the drop site were occupied in a triangular pattern (Fig. 4-2). The WHOI over-the-side transducer and deck box were used to obtain slant range (or travel time) to the release at each station. The anchor survey began at 1515 h local and took about 2 hours to complete. Triangulation from the three sites using Art Newhall's acoustic survey program gave an anchor position of



lat N: 22 deg 46.064 min
lon E: -157 deg -54.0845

Anchor Position

22 46.467	157 54.009	3.131
22 45.596	157 53.630	3.184
22 45.678	157 54.518	3.164

Survey Points and milliseconds

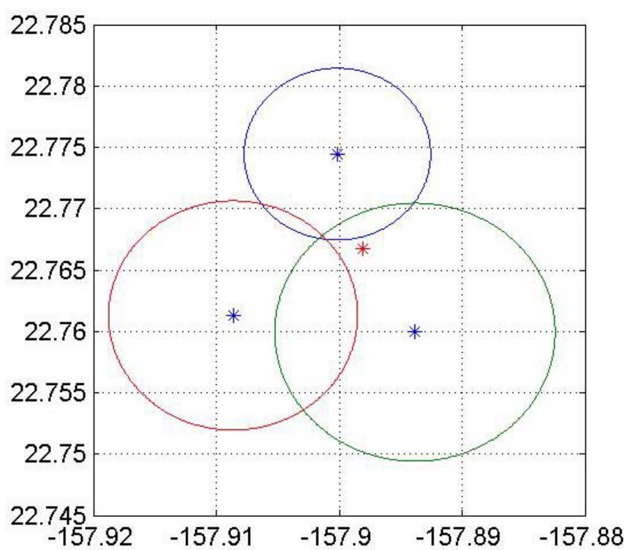


Figure 4-2: WHOTS-4 anchor survey. The anchor drop position (+) is shown along with the three acoustic ranging sites (*), the range circles, and the calculated anchor position (x).

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

b. Deployment Operations

Mooring operations on the *Kilo Moana* (KM) would require techniques new to the UOP group. The back deck of the KM, and limitations of crane operations would require that all work be done under the stern A-frame (see Fig. 4-3). The length of the deck on the port and starboard sides is 18 feet, and the central portion of the main deck is only about 34 feet square. All operations must take place in the central portion of the main deck. The buoy, mooring winch, and two capstans must also fit in this area.

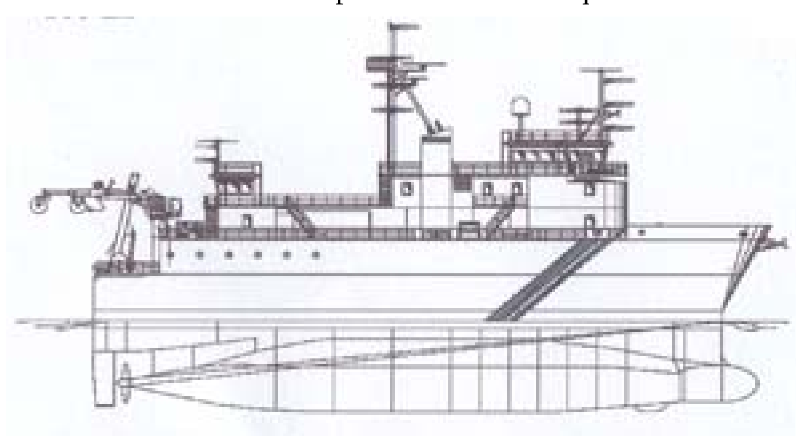


Figure 4-3: R/V *Kilo Moana* diagram.

Setup for the mooring deployment included running a Spectra working line through the turning blocks on the A-frame, and over the flag block in the center of the A-frame. A Gifford block was shackled to the working line under the A-frame, and the ship's capstan was used to haul the block up and suspend it just below the flag block. The A-frame was positioned so the block hung slightly aft of the transom. The working end of the Spectra was stopped off on a cleat. An air tugger was positioned about 15 feet forward of the stern on the port side of the A-frame. The end of the tugger line was fitted with a ¾" chain hook.

Instruments from the surface to 50 meters were pre-rigged with chain and hardware at the top of the load bar or instrument cage. Instruments below 50 meters were pre rigged with wire rope or chain shots shackled to the bottom of the load bar or cage. Doing this work in advance saved time during the actual deployment process.

To begin the mooring deployment a shot of wire rope was passed from the mooring winch through the Gifford block and lowered to the deck. A 150-meter Spectra working line was shackled to the bottom of the 50-meter MicroCat load bar. The top of the 50-meter MicroCat load bar was shackled directly into the cage of the 48.5-meter ADCP. The working wire from the winch was shackled into a link at the top of a 2.13 meter shot of 3/4" chain connected to the top of the ADCP cage. To begin the deployment the winch hauled in wire to suspend the chain, ADCP, and MicroCat from the A-Frame. Next, the winch payed out wire to lower the instruments and chain to the water. A person tending the 150-meter working line on a cleat payed out line approximately equal to what was being lowered into the water.

When the top of the chain above the ADCP was about .5 meters above the transom, the tugger line with chain hook was attached to the chain and the tugger pulled the chain in to the deck. The winch lowered the chain to the deck and a backup stopper line was attached to the link on the chain before disconnecting from the winch line. The procedure for inserting the 45 meter MicroCat and the rest of the instruments above 50-meters included: shackling the bottom of the instrument cage or load bar into the link at the top of the instrument array suspended in the water, lifting the instrument and attached chain shot off the deck with the winch, paying out with the winch and Spectra working line, stopping off the chain, and repeating this process.

The 7.75 meter shot of chain above the 10 meter depth VMCM was stopped off using a pear link shackled into the chain about 2 meters from the top. A slip line was passed through the link and secured to a cleat. The port side crane was used to move the buoy from its position under the A-frame on the starboard side to a position generally centered under the A-frame. A 1" shackle was used to attach the top section of mooring chain to the buoy.

To prepare for the buoy deployment cleats were set up on each side of the buoy hull. Slip lines were passed through the handling rings on the buoy hull and secured. A "west coast" quick release was rigged to the buoy's lifting bale, and attached to the working line on the A-frame. The ship was instructed to move ahead slowly. When all preparations for the deployment were complete, lines and straps securing the buoy were removed. The slip line holding the mooring tension was slowly removed and the mooring load was transferred to the buoy.

The buoy was lifted off the deck with the capstan and working line rigged to the A-frame. The A-frame was moved back, and slip lines kept the buoy in check as it moved out beyond the transom of the ship. When the A-frame was fully extended, the port slip line was removed. This allowed the buoy to spin 90 degrees and provide a better angle for the quick release line. The buoy was slowly lowered into the water, and once it settled in the quick release was tripped. The starboard slip line was slowly pulled free of the buoy as the ship moved away from it.

As the ship moved away from the buoy, more of the Spectra working line attached to the bottom of the mooring chain was payed out to keep the tension down. As the buoy settled in behind the ship and everything appeared stable, this working line was slackened and removed from the cleat. The end of this working line had been previously shackled to the mooring winch wire. The ship speed was reduced to just enough to provide steerage, and the winch was used to pull in the working line coming from the deployed mooring chain.

When the end of the working line and the bottom of the chain below the 50-meter MicroCat was pulled over the transom, stopper lines were attached to the link at the bottom of the chain. The working line was removed. The 55-meter MicroCat was moved into position and the bottom of the MicroCat load bar was shackled into the mooring chain. The bottom of the wire rope section was shackled into the wire on the winch. The winch hauled in on the wire until it had the load from the mooring. Stopper lines were slacked off and removed.

The winch payed out wire until the bottom end of end of the short shot of wire was about 1 meter above the deck, the winch stopped and stopper lines were attached to the link in the termination. The winch wire was lowered to the deck and 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. Before the wire to nylon transition, the block was lowered to hang about 3 feet over the deck. A heavy duty H-bit was moved into position about 15 feet from the transom and about 4 feet off center on the port side. The end of the nylon was stopped off and the winch leader removed.

The end of the 2000 meters of nylon and 1500 meters polypropylene, coiled in three wire baskets, was shackled into the mooring. The slack part of the nylon was dressed over the H-bit bolted to the deck. 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 water 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 four ball (4 meter) increments. The port crane was used to lift each string of glass balls out of the wire baskets and lower them to the deck. The first string of balls was dragged aft and connected to the end of the polypropylene line. The winch leader was then connected to the string of balls. The winch leader was pulled tight, and the stopper lines were eased out and disconnected. The winch payed out until 3 balls were beyond the transom. The two stopper lines were then attached to the link at the end of the string of balls. Another set 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. A five meter shot of ½" chain was shackled into the mooring and stopped off with approximately 2 meters of chain remaining on the deck.

At this point, the ship was still approximately 1.2 nm from the target drop position. The ship towed the mooring toward the drop position in this configuration. Approximately 0.2 nm from the site, the final sections of the mooring were prepared. The tandem-mounted acoustic releases were shackled into the mooring chain at the transom. Another 5-meter 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 another four meters of ½" chain. The chain, anchor pennant, and next shot of chain were wound onto the winch. The stopper lines were removed.

The anchor, positioned on the port side, just outboard of the A-frame was rigged with a 4-meter shot of ½" chain. The bolts holding the anchor tip plate to the deck were removed. The chain lashings on the anchor were removed, and a expendable back stay was rigged on the anchor to secure it.

A ½" chain hook was shackled into the working line hanging from the A-frame and hooked into the chain just below the acoustic releases. The working line was pulled up with the capstan, lifting the releases off the deck. The winch payed out and the A-frame was moved out until the releases were clear of the transom. The working line was lowered and the chain hook removed from the mooring. The winch continued to pay out until the 5-meter chain, 20-meter nylon, and 2 meters of the final 4-meter shot of chain had been deployed.

A sling link was shackled into the ½" chain about two meters up from the Sampson anchor pennant. A slip line was passed through the link and secured to a cleat on the A-frame and another cleat on the deck. The section of chain from the anchor was shackled to the end of the chain on the mooring. The crane was positioned with the boom slightly aft of the lifting bridle on the tip plate. The crane was then attached to the tip plate bridle and slight tension was taken on the crane wire.

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

5. WHOTS-4 Mooring Recovery

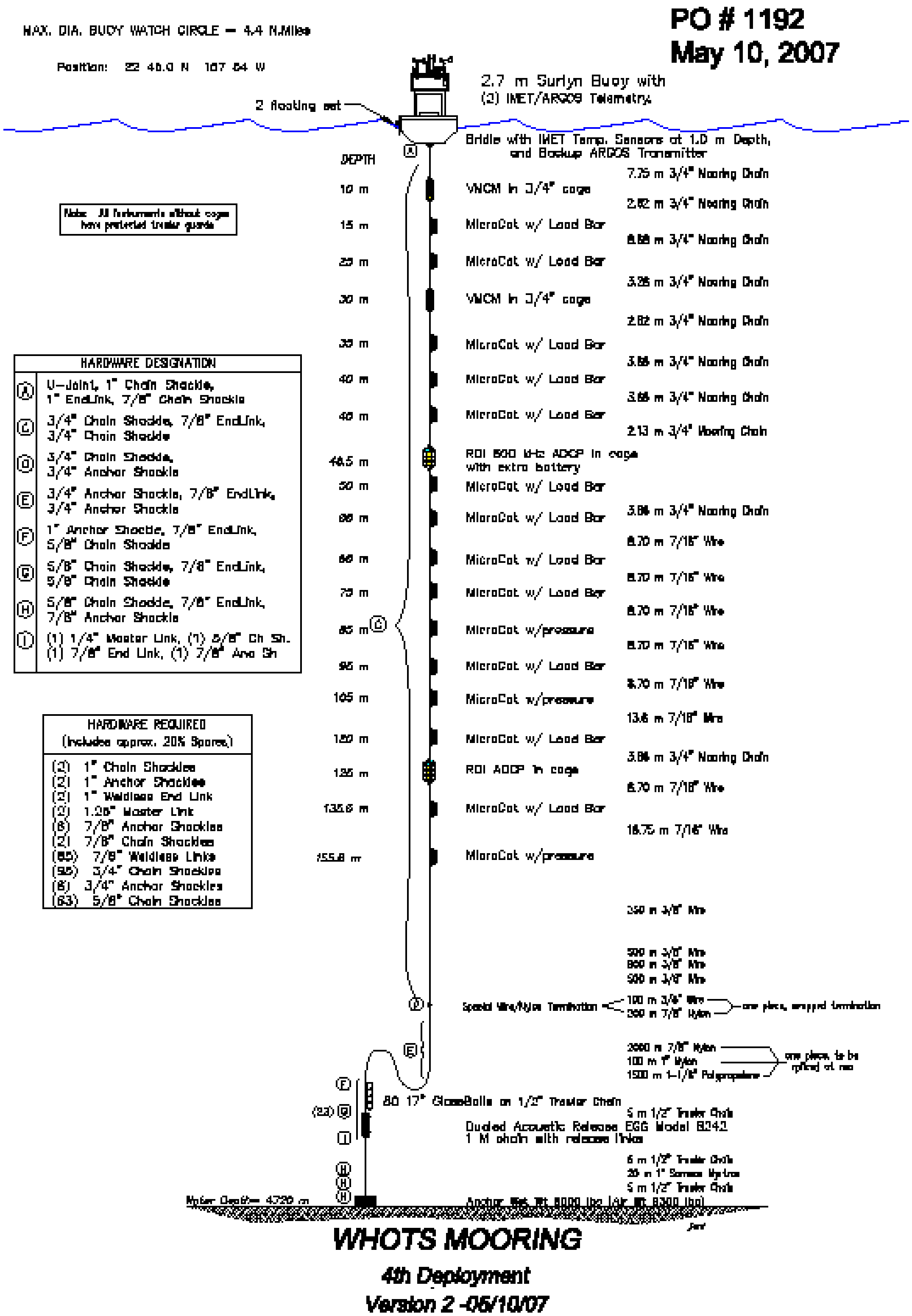


Figure 5-1: WHOTS-4 mooring diagram.

a. Recovery Operations

The WHOTS-4 Fig 5-1 mooring was recovered buoy-first rather than release-first in an effort to make instruments available for data recovery as soon as possible, and to minimize the use of the workboat.

The TSE winch, ship's capstan, UH capstan and assorted WHOI deck lines and hooks were used during the recovery. A ¾" Spectra working line was led through the ship's flag block in the center of the A-frame, and through the turning blocks on the A-frame. This line was dressed onto the ship's capstan. Two air tuggers were positioned inboard on either side of the A-frame. The air tugger lines were led to provide control of the buoy as it was lifted out of the water and onto the deck.

The R/V *Kilo Moana* 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 maneuvered closer to the buoy, and the ship's workboat was launched with a crew to attach the Spectra working line to the buoy. The workboat drove to the stern of the ship, and the Spectra working line was lowered to it. Once the crew on the workboat had the working line, drove to the buoy. The Spectra line was payed out from the ship as the workboat made its way to the buoy. The Spectra working line was attached to the buoy's lifting bale with a heavy duty snap hook.

As soon as the working line was connected to the buoy, the slack line was taken up on the capstan. The A-frame was shifted outboard. The capstan hauled in, pulling the buoy to the stern and lifting the buoy out of 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 shifted inboard until the buoy was completely over the deck. While the buoy was suspended, the winch leader was attached to the mooring chain below the buoy. The winch hauled in to take the mooring tension from the buoy. The buoy was lowered to the deck

Once the buoy was on the deck, a pear link was shackled into the mooring chain and two stopper lines were attached to the link. The winch 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 working line was removed from the lifting bale on the buoy, and the port crane lifted it out of the way, where it was lashed to the deck on the starboard side of the main deck.

The Gifford block was hung from the Spectra working line on the A-frame. The capstan hauled in to raise the block to the top of the A-frame. The 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, and a vertical stopper line rigged on the A-frame trawl block, was used to recover all subsurface instruments and mooring components through the A-frame. The recovery continued, with all of the wire rope, and 200 meters of nylon line wound onto the winch.

Approximately 30 meters of the 2000 meters of nylon line was wound up onto the winch. A Yale grip was attached to the nylon line, and stoppers were used to take the winch tension. The winch payed out 30 meters of nylon, and the termination was broken. The slack end of the nylon line was wrapped around the UH capstan.

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 UH capstan, TSE mooring winch and the two air tuggers.

b. Surface Instrumentation and Data Return

The WHOTS-4 mooring was outfitted with a full suite of ASIMET sensors on the buoy and subsurface instrumentation from 10 to 155 m depth.

Table 5-1: WHOTS 4 Serials/Heights

System 1

Module	Serial	Firmware Version	Height Cm
Logger	L-07	LOGR53 V2.7	
HRH	218	VOS HRH53 V3.2	228
BPR	503	VOS BPR53 V3.3 (Heise)	242
WND	221	VOS WND53 V3.5	313.5
PRC	209	VOS PRC53 V3.4	249
LWR	209	VOS LWR53 V3.5	282.5
SWR	221	VOS SWR53 V3.3	283.5
SST	1839		
PTT	14637	7563, 7581, 7582	

System 2

Module	Serial	Firmware Version	Height Cm
Logger	L-19	LOGR53 V3.10	
HRH	219	VOS HRH53 V3.2	229
BPR	504	VOS BPR53 V3.3 (Heise)	242
WND	212	VOS WND53 V3.5	317.5
PRC	211	VOS PRC53 V3.4	249
LWR	219	VOS LWR53 V3.5	282.5
SWR	210	VOS SWR53 V3.3	283.5
SST	1837		
PTT	18136	14633, 14677, 14697	

Stand-Alone Module(s)

Module	Serial	Firmware Version	Height Cm
GPS	67700 6/19/2007 19:06	L-19 Power UHMC 21 19.005N 157 53.182W	238
PCo2	0021	PMEL	85
SIS	268	PTT ID= 25702	

Horizontal Distances

	Cm	
WND	122	WND
LWR	24	LWR
SWR	24	SWR
PRC	116	PRC
BPR	119	BPR
HRH	246	HRH

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 (accepted) except conductivity, which is from Plueddemann (unpublished results).

Table 5-2 WHOTS-4 ASIMET sensor specifications

FSST

Internally logging Sea-Bird SBE-39 and RBR 1050 temperature sensors were mounted beneath a foam flotation cylinder 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.

GPS

The WHOTS 4 buoy deployed again a SEIMAC III internally recording GPS receiver. As an improvement over previous deployment, we added a power cycling feature of the SEIMAC unit to the buoy logger code. Under this scheme, power to the SEIMAC receiver would be toggled off and on once per day. Tests at WHOI had previously shown that power cycling could revive the receiver when it had stopped recording. A burn-in period on the Clark South roof with a modified logger collected about 230 days of SEIMAC data before the unit was sent out to Hawaii. Unfortunately, the receiver stopped recording 9 days after being turned on in Hawaii, or 3 days after the buoy was deployed.

WHOTS mooring subsurface instrumentationWHOTS-4 recovery

For the fourth WHOTS mooring deployment that took place on 25 June 2007, UH provided 15 SBE-37 Microcats and an RDI 300 kHz Workhorse acoustic Doppler current profiler (ADCP). The Microcats all measured temperature and conductivity, with 5 also measuring pressure. WHOI provided 2 VMCMs, an RDI 600 kHz Workhorse ADCP, and all required subsurface mooring hardware via a subcontract with UH.

Table 5-3 provides the deployment information for each C-T instrument on the WHOTS-4 mooring.

Depth (meters)	Seabird Model/Serial #	Variables	Sample Interval (seconds)	Navg	Time Logging Started	Cold Spike Time	Time in the water
15	37SM31486-3382	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 17:10
25	37SM31486-3621	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 17:04
35	37SM31486-3620	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 17:01
40	37SM31486-3632	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 16:59
45	37SM31486-2965	C, T, P	180	1	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 16:56
50	37SM31486-3633	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 16:54
55	37SM31486-3619	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 18:17
65	37SM31486-3791	C, T	150	2	06/19/07 12:00:00	06/19/07 21:30:00	06/25/07 18:20
75	37SM31486-3618	C, T	150	2	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:22
85	37SM31486-3670	C, T, P	180	1	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:25
95	37SM31486-3617	C, T	150	2	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:27
105	37SM31486-3669	C, T, P	180	1	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:30
120	37SM31486-2451	C, T, P	180	1	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:33
135	37SM31486-3634	C, T	150	2	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:38
155	37SM31486-3668	C, T, P	180	1	06/19/07 12:00:00	06/19/07 20:40:00	06/25/07 18:41

Table 5-3: WHOTS-4 mooring Microcat deployment information. All times are GMT.

	S/N 4891 300 kHz	S/N 1825 600 kHz
Number of Depth Cells	30	25
Depth Cell Size	4 m	2 m
Time per Ensemble	10 min	15 min
Pings per Ensemble	40	120
Time per Ping	4 sec	1 sec
Time of First Ping	06/25/07, 00:00	06/18/07, 01:00
Time of Last Ensemble	06/08/08, 04:30	06/08/08, 06:15
Number of Ensembles	50284	34198
Time in water	06/25/07, 18:35	6/25/07, 16:54
Time out of the water	06/06/08, 23:50	6/07/08, 00:22
Depth	125 m	48.5 m

Table 5-4: WHOTS-4 mooring ADCP deployment.

All instruments on the mooring were successfully recovered. Most of the instruments had some degree of biofouling, with the heaviest fouling near the surface. Fouling extended down to the ADCP at 125 m, although it was minor at that level. The fouling appeared to be much less than in the previous WHOTS deployments.

Table 5-5 gives the post-deployment information for the C-T instruments. All instruments returned full data records. Microcat SN 2451 pressure sensor drifted about 10 m during most of the deployment, and it failed a couple of months before recovery. Microcat SN 3668 conductivity sensor had an offset early in the record, and returned to apparently normal values near the middle of the record.

With the exceptions noted above, the data recovered from the Microcats appear to be of high quality, although post-deployment calibrations are required. Figures A3-1 to A3-15 show the nominally calibrated temperature, conductivity and salinity records from each instrument, and pressure for those instruments that were equipped with pressure sensors.

Depth (meters)	Seabird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality	File Name raw data
15	37SM31486-3382	6/7/2008 01:13	06/7/2008 05:46:30	06/7/2008 21:30:00	204,131	good	whots4_m_3382.asc
25	37SM31486-3621	6/7/2008 01:18	06/7/2008 05:11:30	06/7/2008 21:26:00	204,130	good	whots4_m_3621.asc
35	37SM31486-3620	6/7/2008 01:24	06/7/2008 05:11:30	06/7/2008 06:30:30	203,770	good	whots4_m_3620.asc
40	37SM31486-3632	6/7/2008 01:26	06/7/2008 05:46:30	06/8/2008 00:34:00	204,205	good	whots4_m_3632.asc
45	37SM31486-2965	6/7/2008 01:28	06/7/2008 05:11:30	06/7/2008 07:39:00	169,833	good	whots4_p_2965.asc
50	37SM31486-3633	6/7/2008 00:22	06/7/2008 05:46:30	06/8/2008 00:38:00	204,207	good	whots4_m_3633.asc
55	37SM31486-3619	6/7/2008 00:18	06/7/2008 05:11:30	06/7/2008 21:21:00	204,128	good	whots4_m_3619.asc
65	37SM31486-3791	6/7/2008 00:15	06/7/2008 05:11:30	06/7/2008 06:57:00	203,782	good	whots4_m_3791.asc
75	37SM31486-3618	6/7/2008 00:10	06/7/2008 05:11:30	06/7/2008 07:45:00	203,802	good	whots4_m_3618.asc
85	37SM31486-3670	6/7/2008 00:06	06/7/2008 05:46:30	06/7/2008 21:42:00	170,114	good	whots4_p_3670.asc
95	37SM31486-3617	6/7/2008 00:03	06/7/2008 05:11:30	06/7/2008 06:50:10	203,779	good	whots4_m_3617.asc
105	37SM31486-3669	6/6/2008 23:59	06/7/2008 05:11:30	06/7/2008 07:35:00	169,831	good	whots4_p_3669.asc
120	37SM31486-2451	6/6/2008 23:55	06/7/2008 05:46:30	06/8/2008 00:41:00	170,174	P sensor drifted	whots4_p_2451.asc
135.5	37SM31486-3634	6/6/2008 23:46	06/7/2008 05:46:30	06/7/2008 21:39:00	204,135	good	whots4_m_3634.asc
155.6	37SM31486-3668	6/6/2008 23:40	06/7/2008 05:46:30	06/7/2008 21:35:00	170,112	C offset half of record	whots4_p_3668.asc

Table 5-5: WHOTS-4 mooring Microcat recovery information. All times are GMT.

		[-------TIME CHECK---------]				[----------DATA--------]		[----------Post Recovery Spike--------]			
Instrument	**Depth**	**UTC Time**	**UTC Date**	**Internal Time**	**Internal Date**	**Stop Sampling**	**Records**	**Start Time**	**Start Date**	**Stop Time**	**Stop Date**
NGVM 34	10	0:52:00	9-Jun	0:53:37	9-Jun-08	dead battery	417912	0:29:00	9-Jun	0:30:00	9-Jun-08
NGVM 40	30	0	9-Jun	0:34:20	9-Jun-08	0:34:00	508552	0:31:00	9-Jun	0:32:00	9-Jun-08

Table 5-6: The WHOTS-4 VMCM recovery information.

The fouling on the ADCP transducer head (Fig 5-2) was much less than during the previous WHOTS ADCP deployment at 125 m. The transducer faces for the 48.5 m ADCP were treated with an appropriate antifouling compound and consequently did not show any significant fouling (Fig 5-3).

Figure 5-2: WHOTS-4 ADCP deployed at 125 m after recovery.

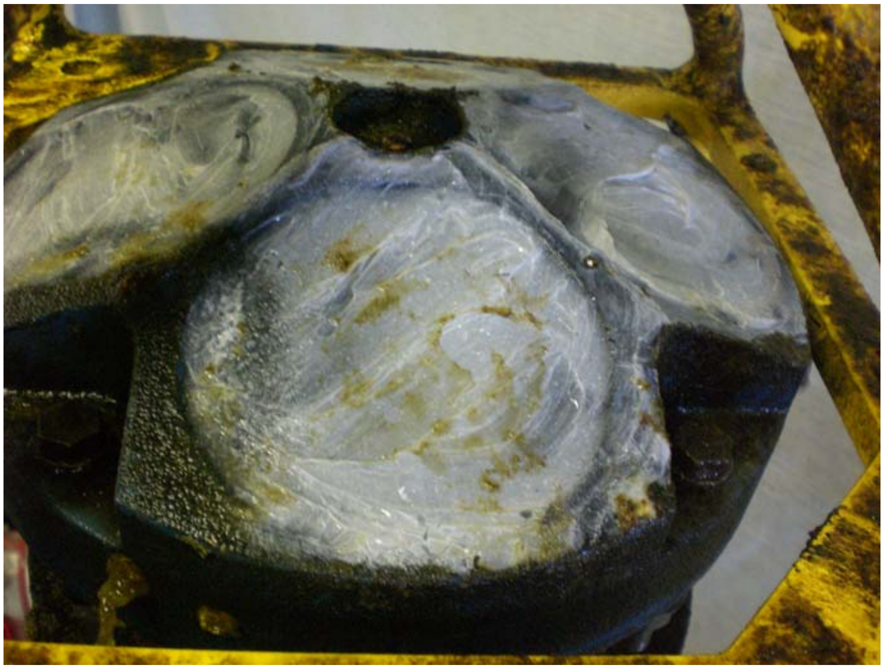


Figure 5-3: WHOTS-4 ADCP deployed at 48.5 m after recovery.

The data from the upward-looking 300 kHz ADCP at 125 m appears to be of high quality, however the instrument's clock on retrieval was offset by 9 minutes and 5 seconds ahead of GMT. The heading, pitch and roll information from the ADCP (Fig 5-4) provide useful information about the overall behavior of the mooring during its deployment. An example is that the buoy apparently was twisted one turn between May and June 2008. Pitch and roll are generally less than 5 degrees from the vertical, but there are some periods with deviations from the vertical of as much as 10 degrees.

Figure 5-5 shows the variations of the horizontal and vertical components of velocity in depth and time. The acoustic returns from the upper 40 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. The high spurious speeds due to sideband reflections near the surface are apparent. A very strong (~0.8 m/s) northward flow was seen briefly in December 2007, followed by a strong southward flow in January 2008.

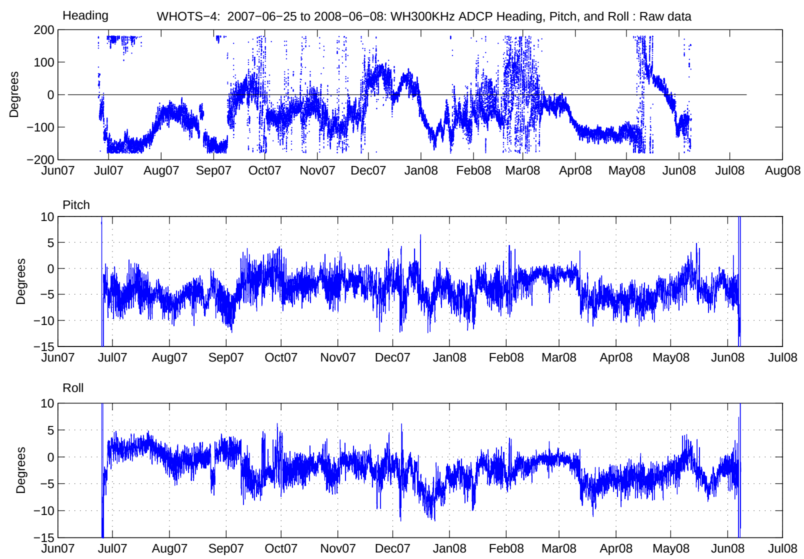


Figure 5-4: Heading, pitch and roll variations measured by the ADCP at 125 m depth on the WHOTS-4 mooring.

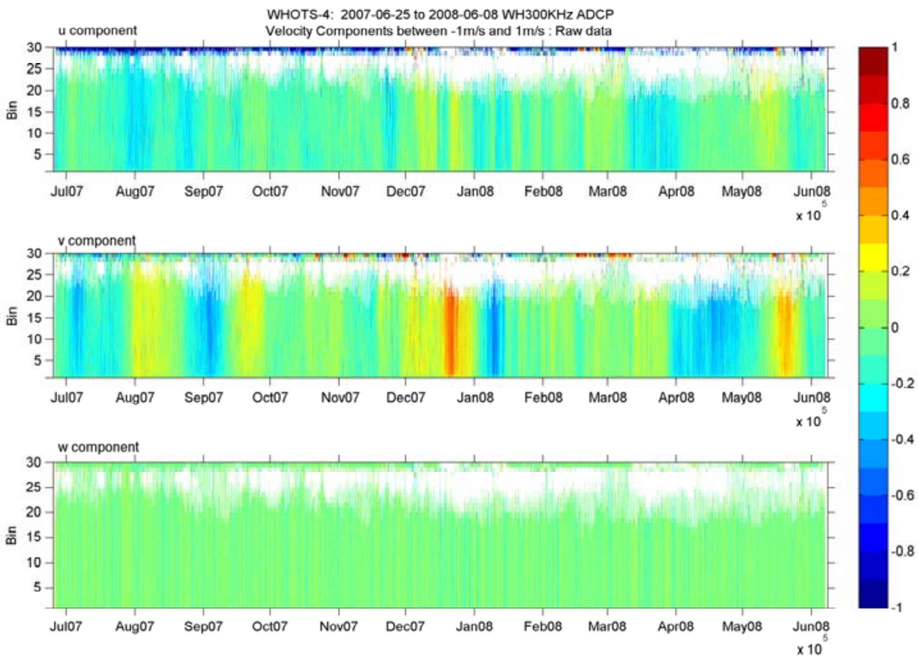


Figure 5-5. Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 125 m depth on the WHOTS-4 mooring. Height in meters above the transducer is approximately 4 times the bin number.

The data from the upward-looking 600 kHz ADCP at 48.5 m appears to be of high quality, however the instrument's clock on retrieval was offset by 3 minutes and 3 seconds ahead of GMT. Figure 5-6 shows the heading, pitch and roll information from the ADCP. The apparent twisting of the buoy during May-June 2008 observed in the 125 ADCP data (Fig 5-4) is not obvious in this ADCP heading record. Pitch and roll are generally less than 5 degrees from the vertical, but there are some periods with deviations from the vertical of as much as 10 degrees.

Figure 5-7 shows the variations of the horizontal and vertical components of velocity in depth and time. Evidence of reflection from the surface can be seen in the upper three to four bins. The three bins closest to the transducer exhibit contamination possibly from ringing from the transducer or reflection from the nearby instruments; this will be examined closely during data processing. The strong northward flow in December 2007 seen in the 300 kHz ADCP record was also observed in the 600 kHz record.

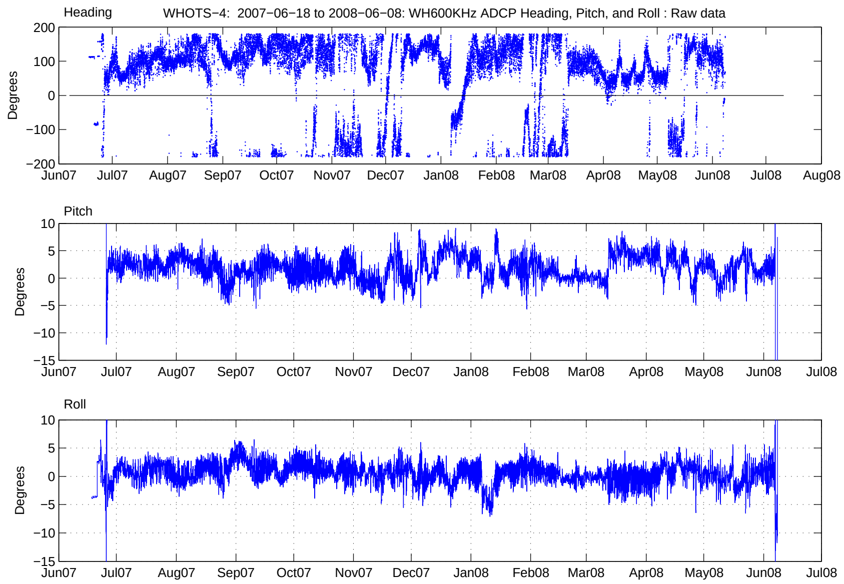


Figure 5-6: Heading, pitch and roll variations measured by the ADCP at 48.5 m depth on the WHOTS-4 mooring.

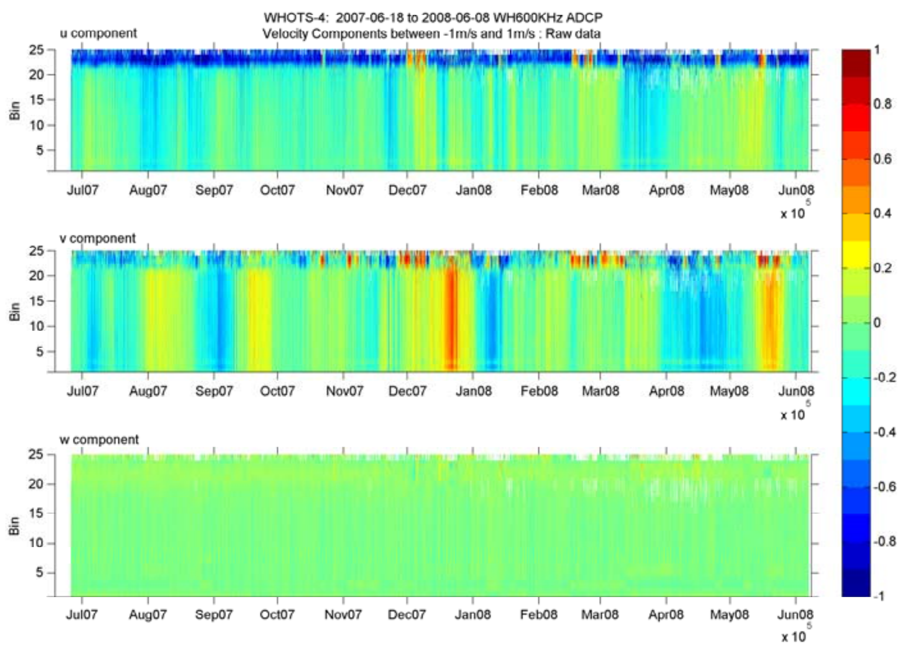


Figure 5-7: Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 48.5 m depth on the WHOTS-4 mooring. Height in meters above the transducer is approximately 2 times the bin number.

6. Meteorological Intercomparisons

a. Overview

In order to assess the performance of the buoy meteorological systems, two periods of about 24 h were dedicated to buoy vs. ship intercomparisons. The first intercomparison period followed deployment of the WHOTS-5 mooring, and the second was prior to recovery of the WHOTS-4 mooring. Hourly ASIMET data were obtained by intercepting the Argos PTT transmissions from the buoy with an Alpha-Omega satellite uplink receiver and a whip antenna mounted on the forward deck rail. Consistent receptions from both PTTs were obtained with the ship standing-off at a distance of about 0.15 nm from the buoy. CTD casts were performed during the intercomparison period while holding station near the buoy. However, the *Kilo Moana* departed the area twice during each period for sewage and trash disposal. Although the quality of the comparison suffered during these periods, no buoy data were lost since 6 h of buffered data are transmitted by the ASIMET logger PTTs each hour. Further, analysis of the intercomparison data will be conducted and will be available.

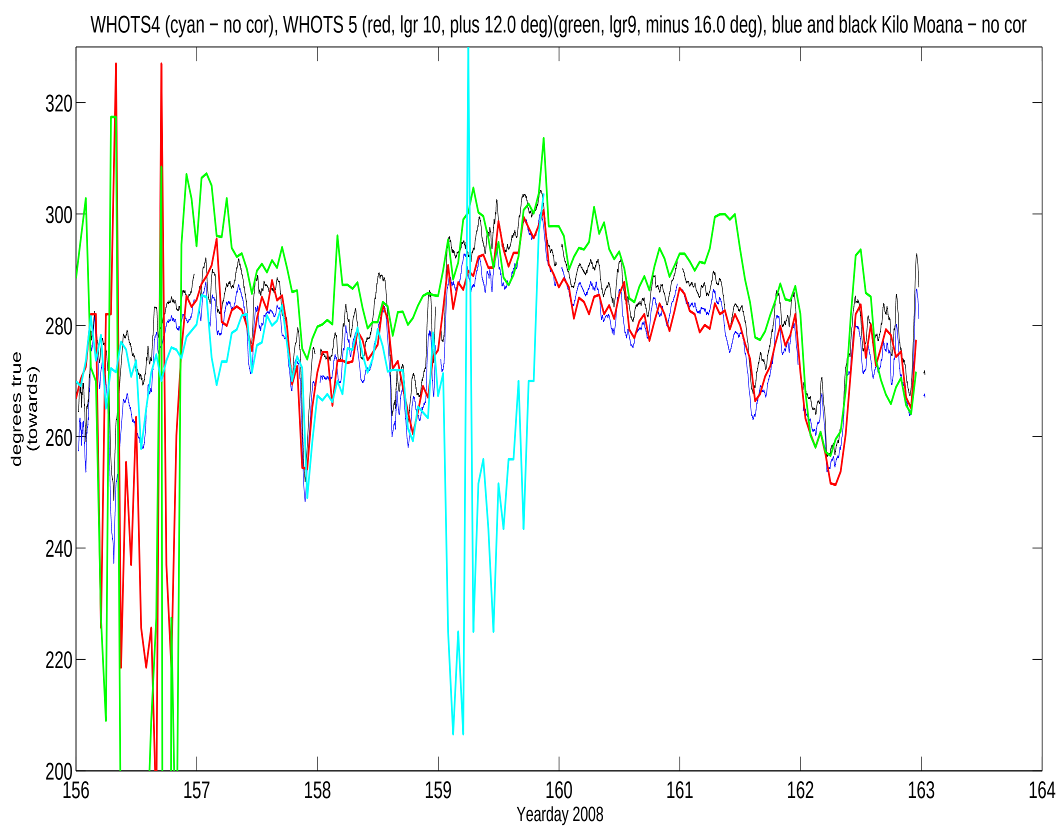


Figure 6-1: WHOTS 5 vs WHOTS 4 Meteorological Intercomparison

7. CTD Operations

a. CTD Stations

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

Table 7-1: CTD stations occupied during the WHOTS-5 cruise.

Station/cast	Date	Time (GMT)	Location	Maximum pressure (dbar)
52 / 1	6/5/08	09:56	22° 40.25´ N, 157° 59.14´ W	1020
52 / 2	6/5/08	13:52	22° 39.70´ N, 157° 59.10´ W	200
52 / 3	6/5/08	17:52	22° 39.67´ N, 157° 58.84´ W	200
52 / 4	6/5/08	21:56	22° 39.61´ N, 157° 58.92´ W	200
52 / 5	6/6/08	01:51	22° 39.57´ N, 157° 58.88´ W	200
52 / 6	6/6/08	05:54	22° 39.92´ N, 157° 58.84´ W	200
52 / 7	6/6/08	09:55	22° 39.79´ N, 157° 58.87´ W	200
50 / 1	6/7/08	21:52	22° 45.94´ N, 157° 56.05´ W	500
50 / 2	6/8/08	01:56	22° 45.94´ N, 157° 56.07´ W	500
50 / 3	6/8/08	05:59	22° 45.95´ N, 157° 56.07´ W	500
50 / 4	6/8/08	09:52	22° 46.06´ N, 157° 55.94´ W	500
50 / 5	6/8/08	13:52	22° 45.69´ N, 157° 56.13´ W	500
50 / 6	6/8/08	17:56	22° 45.66´ N, 157° 56.13´ W	500
50 / 7	6/8/08	21:52	22° 45.85´ N, 157° 56.19´ W	500
50 / 8	6/9/08	1:53	22° 46.11´ N, 157° 56.61´ W	1020

A total of 15 CTD casts were conducted at stations 52 (near the WHOTS-4 buoy), and station 50 (near the WHOTS-5 buoy). The first and last casts were to a depth of 1000 m for the purpose of calibrating the CTD conductivity cells. Six CTD casts were conducted to obtain profiles for comparison with subsurface instruments on the WHOTS-4 mooring before recovery, and 7 more casts were conducted for comparison with the WHOTS-5 mooring after deployment. These were sited approximately 200 to 500 m downstream from the buoys. The comparison casts each consisted of 6 yo-yo cycles between 5 dbar and 200 and 500 dbar. Station numbers were assigned following the convention used during HOT cruises. Table 7-1 provides summary information for all CTD casts, and Figures A4-1 to A4-14 show the water column profile information that was obtained.

Water samples were taken from all casts; 6 samples for 1000 dbar casts and 2 samples each for the 200 and 500 dbar casts. These samples will be analyzed for salinity and used to calibrate the CTD conductivity sensors.

b. Thermosalinograph

The *Kilo Moana* has an Uncontaminated Scientific Sea Water (USSW) system that includes an internal Seabird Seacat thermosalinograph (TSG) model SBE-21, with an SBE-38 external temperature sensor installed in the bow thruster chamber close to the seawater intake. The intake is located on the starboard hull, 20’ 8” from the bow, at a mean depth of 8 m. Sensor information for the TSG system during WHOTS-5 is as follows:

Temperature: SBE-38 Sensor SN0169 was used to measure temperature near the seawater intake, and was last calibrated on May 10, 2007, and installed on May 23, 2008. The SBE-21 thermosalinograph used temperature sensor SN3292, which was last calibrated on November 11, 2007, and installed on January 25, 2008.

Conductivity: The SBE-21 thermosalinograph used conductivity sensor SN3392, which was most recently calibrated on November 11, 2007, and installed on January 25, 2008.

c. Shipboard ADCPs

The R/V *Kilo Moana* is equipped with an RDI 300 kHz Workhorse Mariner ADCP and an RDI OS38 ADCP. The University of Hawaii ADCP 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 moorings, the shipboard ADCP systems revealed interesting regional current features.

During the WHOTS-5 cruise, the northwestward flow of the North Hawaiian Ridge Current was not observed during our transit from Oahu to Station ALOHA (Fig 7-1). Instead, a southeastward flow was seen. Approaching ALOHA, the upper ocean flow intensified and veered from southward to southwestward. The 4 June 2008 NRL 1/12° HyCOM sea surface height analysis showed a cyclonic eddy centered just to the east of ALOHA (Fig 7-2**)**, which was consistent with our shipboard ADCP measurements. Inspection of the NRL NCOM analysis for the same time revealed that it was inconsistent with our observations, which was unusual in our experience.

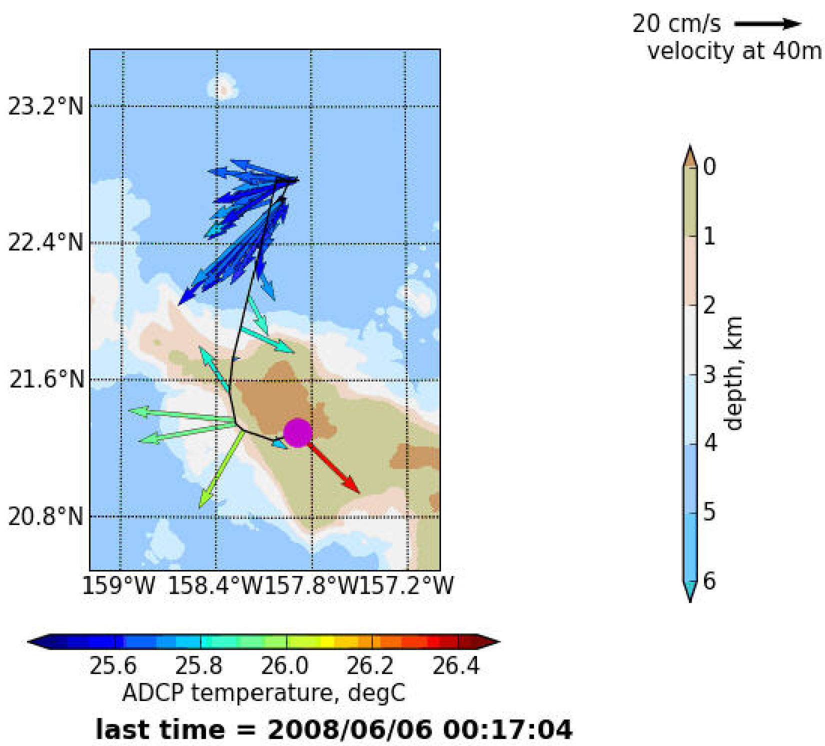


Figure 7-1: Current vectors to 40 m measured by the R/V *Kilo Moana's* 300 kHz Workhorse ADCP from Honolulu to the WHOTS-4 site from 4 June through 6 June 2008.

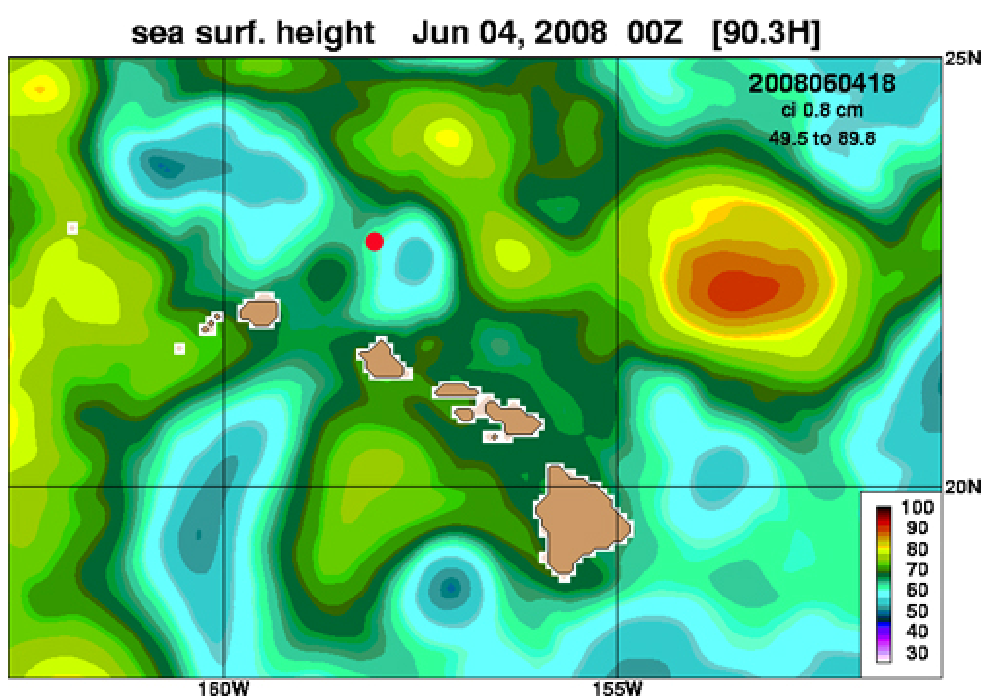


Figure 7-2: Hawaii region sea level analysis from the Navy Research Laboratory HyCOM analysis system for 6/4/08. The position of Station ALOHA is indicated by the red dot.

Acknowledgments

Shore-side support from the University of Hawaii (UH) Marine Center, including facilities provided by the Hawaii Undersea Research Laboratory, was critical to successful cruise preparation. The Captain and crew of the *Kilo Moana*, and the UH Marine Technicians, were flexible in accommodating the science mission, and exhibited a high degree of professionalism throughout the cruise. Nan Galbraith and Frank Bahr provided shore support for real-time Argos and AutoIMET logging. This project was funded by the National Oceanic and Atmospheric Administration (NOAA) through the Cooperative Institute for Climate and Ocean Research (CICOR) under Grant No. NA17RJ1223 to the Woods Hole Oceanographic Institution.

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Hosom, D. S., R. A. Weller, R. E. Payne, and K. E. Prada, 1995. The IMET (Improved Meteorology) ship and buoy systems. *Journal of Atmospheric and Oceanic Technology*, **12**(3), 527–540.

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Serra, Y.L., P. A'Hearn, H.P. Freitag and M. McPhaden, 2001. ATLAS self-siphoning rain gauge error estimates. *Journal of Atmospheric and Oceanic Technology*, **18**(12), 1989 – 2002.

Whelan, S.P., R.A. Weller, R. Lukas, F. Bradley, J. Lord, J. Smith, F. Bahr and P. Lethaby and J. Snyder, 2007, WHOI Hawaii Ocean Timeseries Station (WHOTS): WHOTS-3 Mooring Turnaround Cruise Report. *Woods Hole Oceanogr. Inst. Tech. Rep.*, WHOI-2007-03, 103 pp.

Appendix 1: WHOTS 2008 Science Party

Name	Nationality	Affiliation
Robert A. Weller	USA	WHOI
James Ryder	USA	WHOI
Sean Whelan	USA	WHOI
Frank Bradley	Australian	CSIRO
Tenley Fullington	USA	USNA/WHOI
Roger Lukas	USA	University of Hawaii
Paul Lethaby	British	University of Hawaii
Jefrey Snyder	USA	University of Hawaii
Christin Shacat	German	University of Hawaii
Fernando Santiago-Mandujano	Mexico	University of Hawaii
Kristen Fogaren	USA	University of Hawaii
Guy Bennallack	USA	University of Hawaii
Damion Rosbrugh	USA	University of Hawaii
Patrica Kassis	USA	Parker School
Shandy Buckley	New Zealand	University of Hawaii
Bradley Simmons	USA	University of Hawaii
Jim Christman	USA	Cons. Ocean Leadership

Appendix 2: Sand Island Port Contacts

University of Hawaii Marine Center
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Phone (808) 842-9813, Fax (808) 842-9833 Toll Free 1-888-800-0460
email snug@soest.hawaii.edu

Stan Winslow, Marine Superintendent (808) 842-9814
Gen Pickering, Administrative Assistant (808) 842-9810
Grey Drewry , Port Operations Manager (808) 842-9815
John Nikola, Port Engineer (808) 842-9816
Keith Adams, Purchasing Agent (808) 842-9811
Alton Goo, Section Head (808) 842-9812
Keith Yamasaki, Superstructure Design/Fabrication Supervisor (808) 842-9812

Phone numbers for ships while in port
R/V *KILO MOANA* (808) 842-9817 / 842-9834

Appendix 3. Moored C-T Time Series

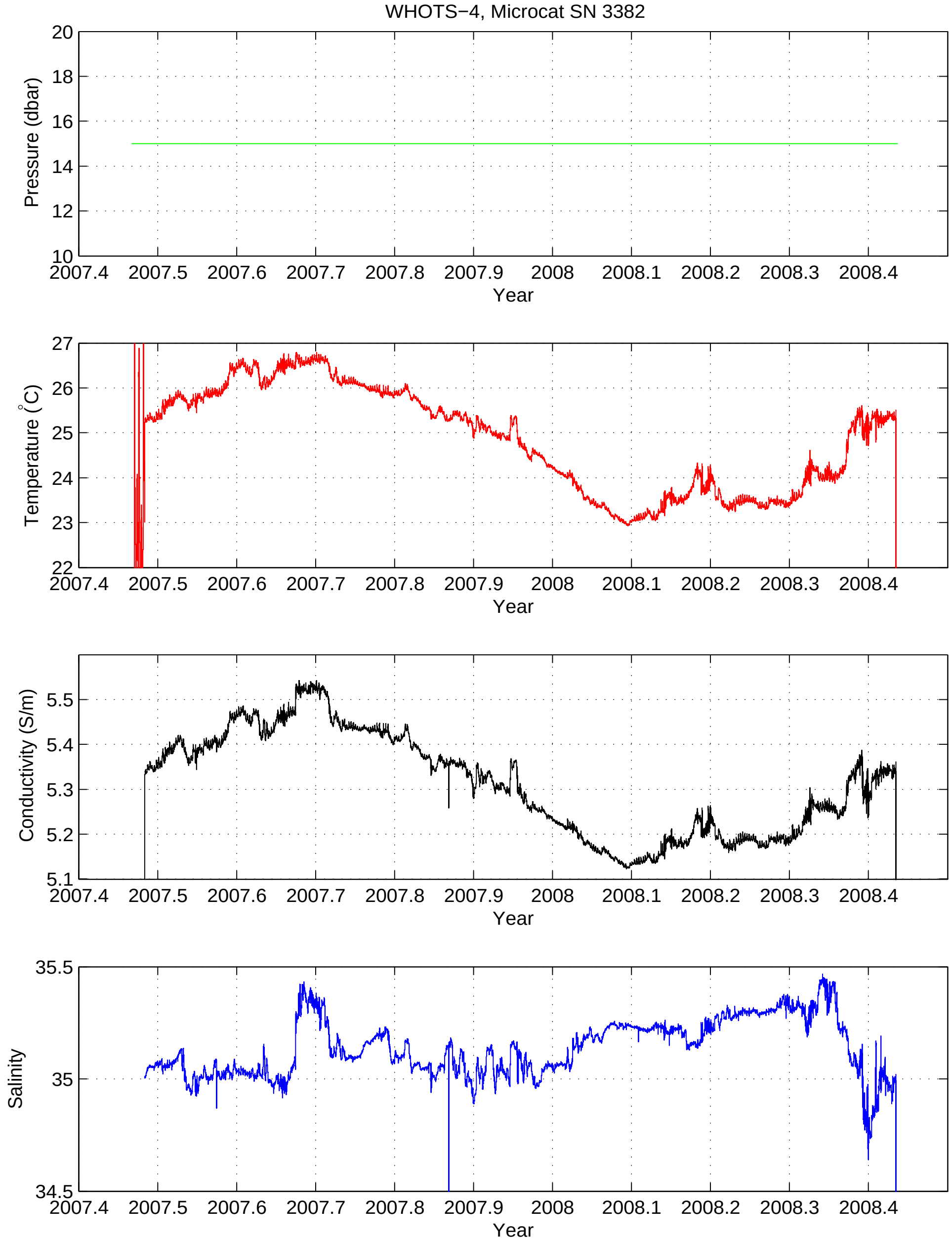

Figure A3-1. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3382 deployed at 15 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

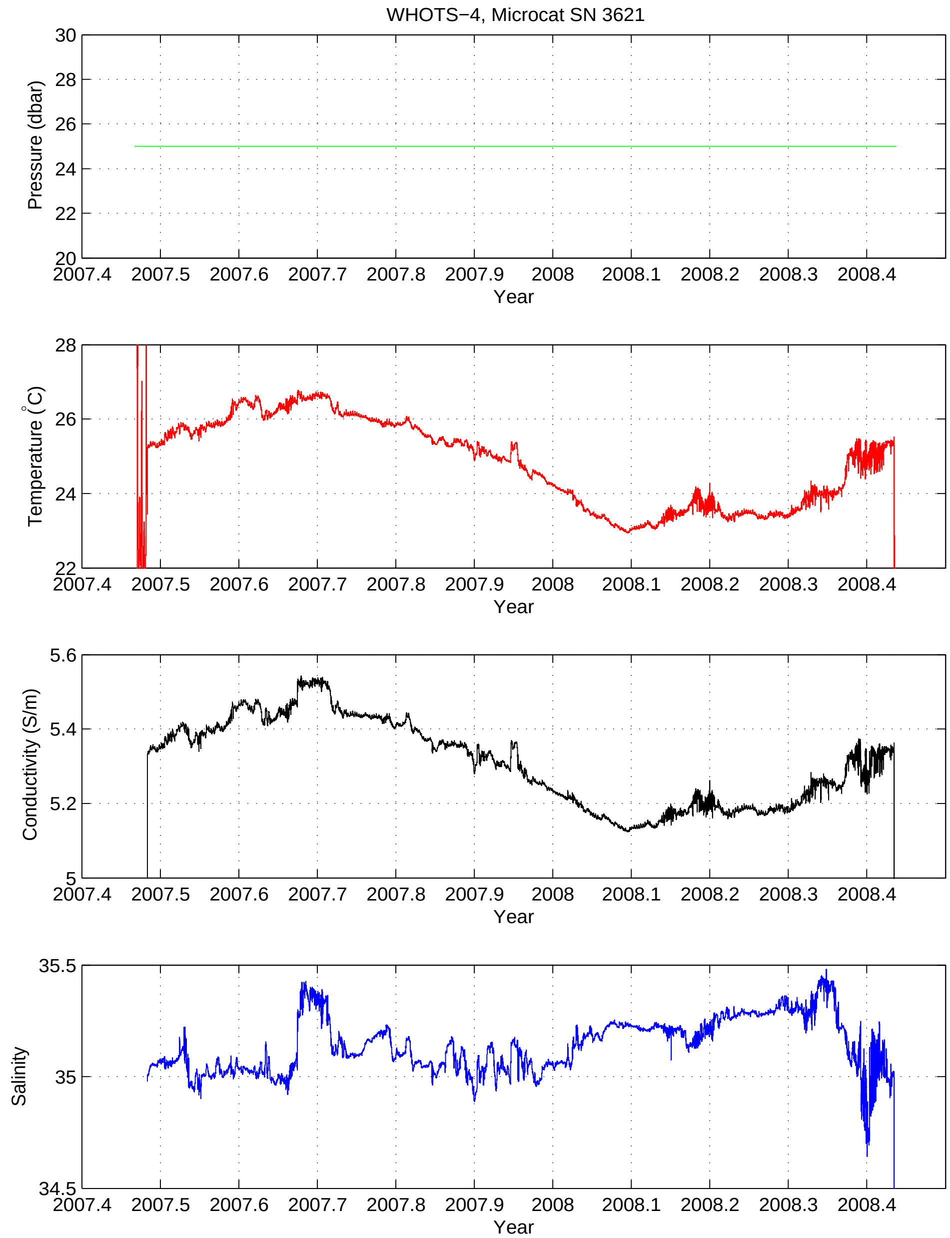

Figure A3-2. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3621 deployed at 25 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

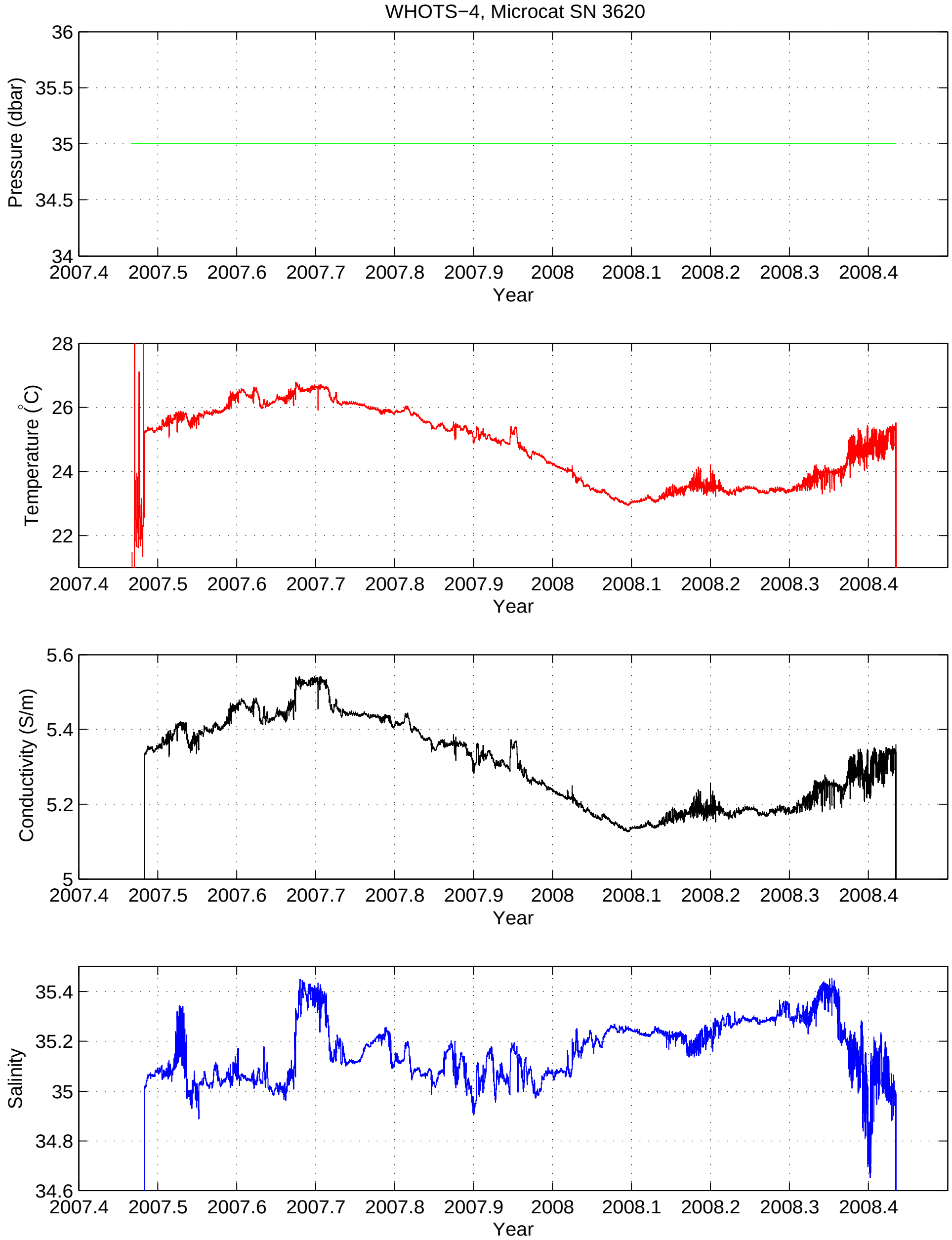

Figure A3-3. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3620 deployed at 35 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

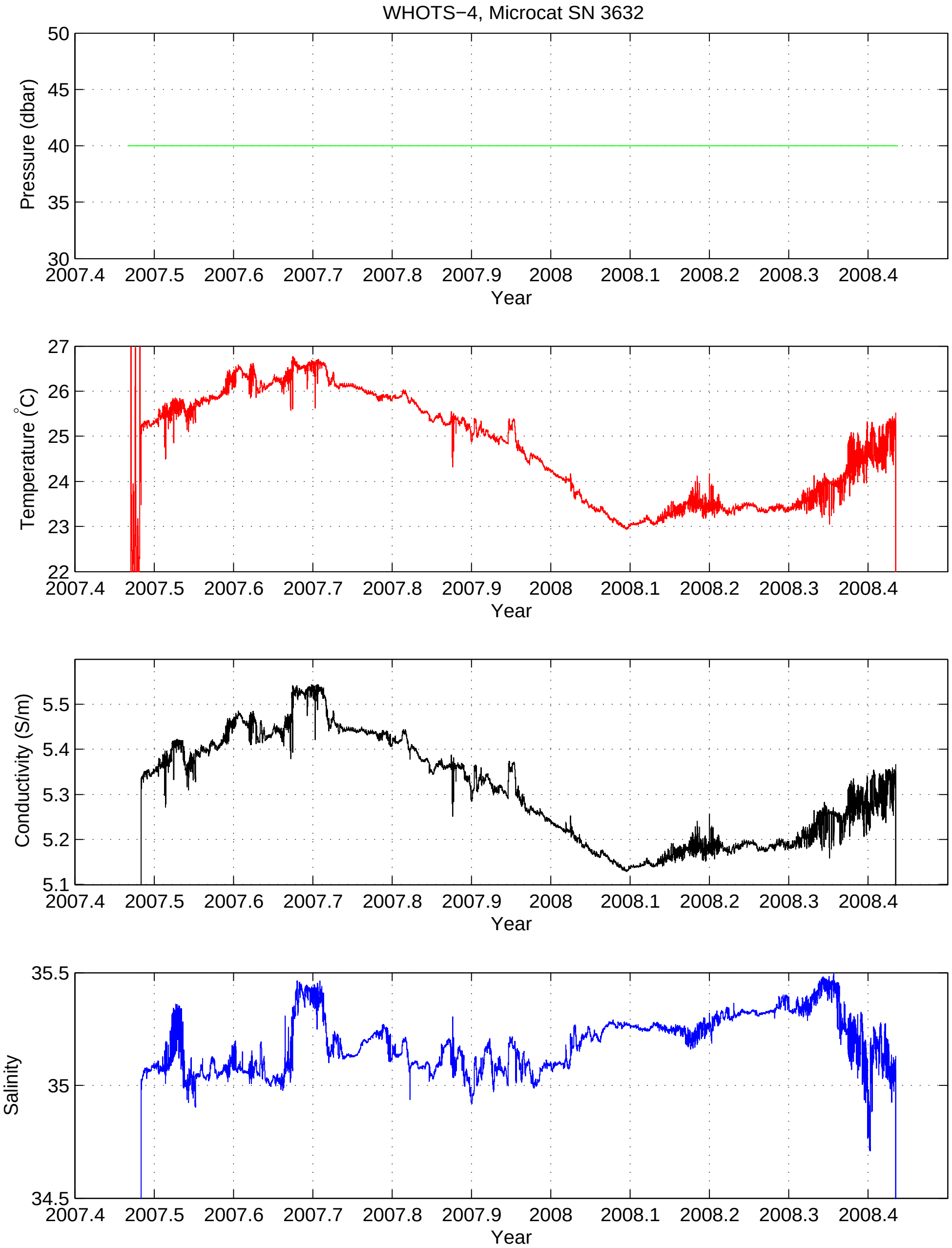

Figure A3-4. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3632 deployed at 40 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

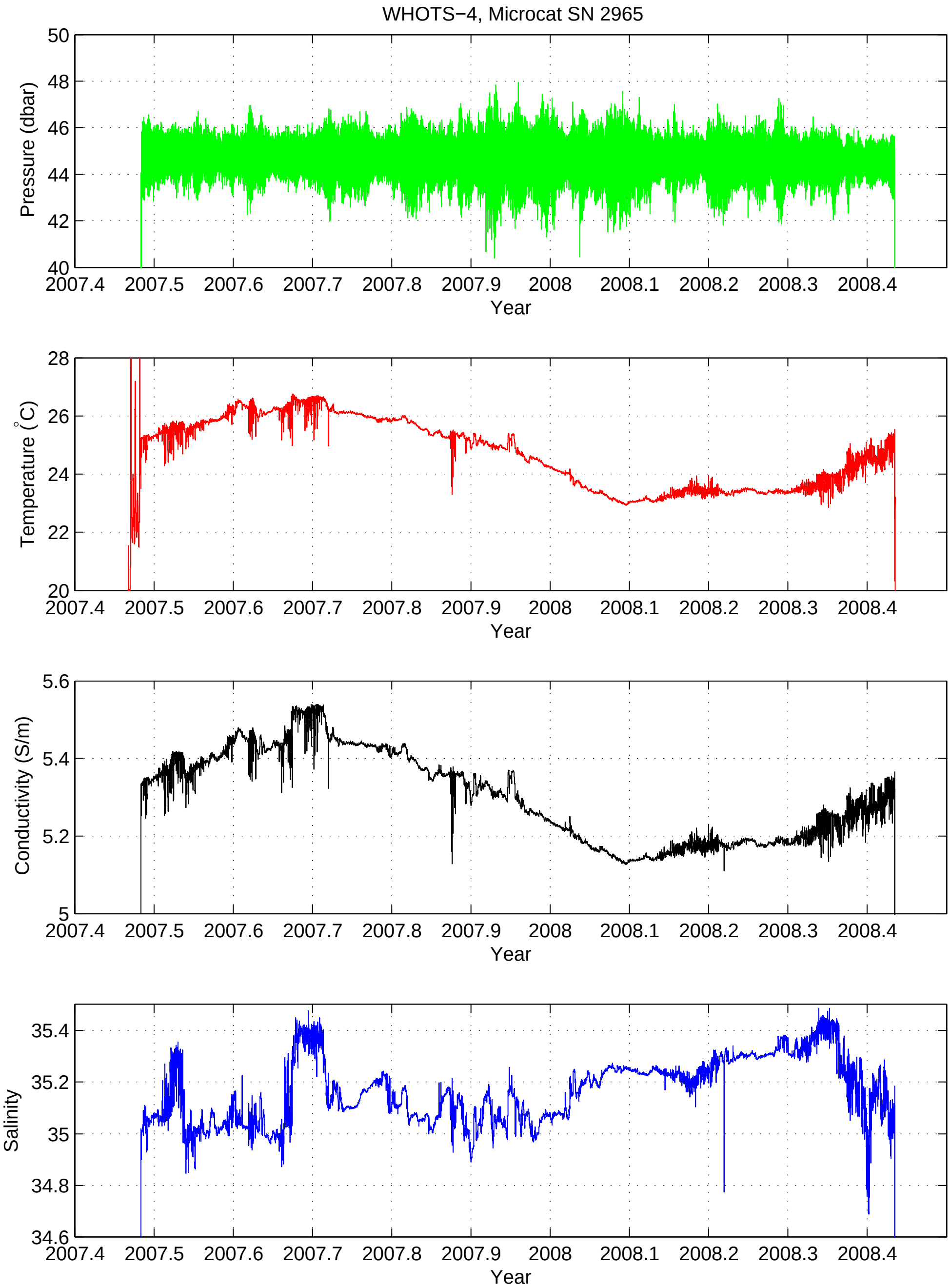

Figure A3-5. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 2965 deployed at 45 m on the WHOTS-4 mooring.

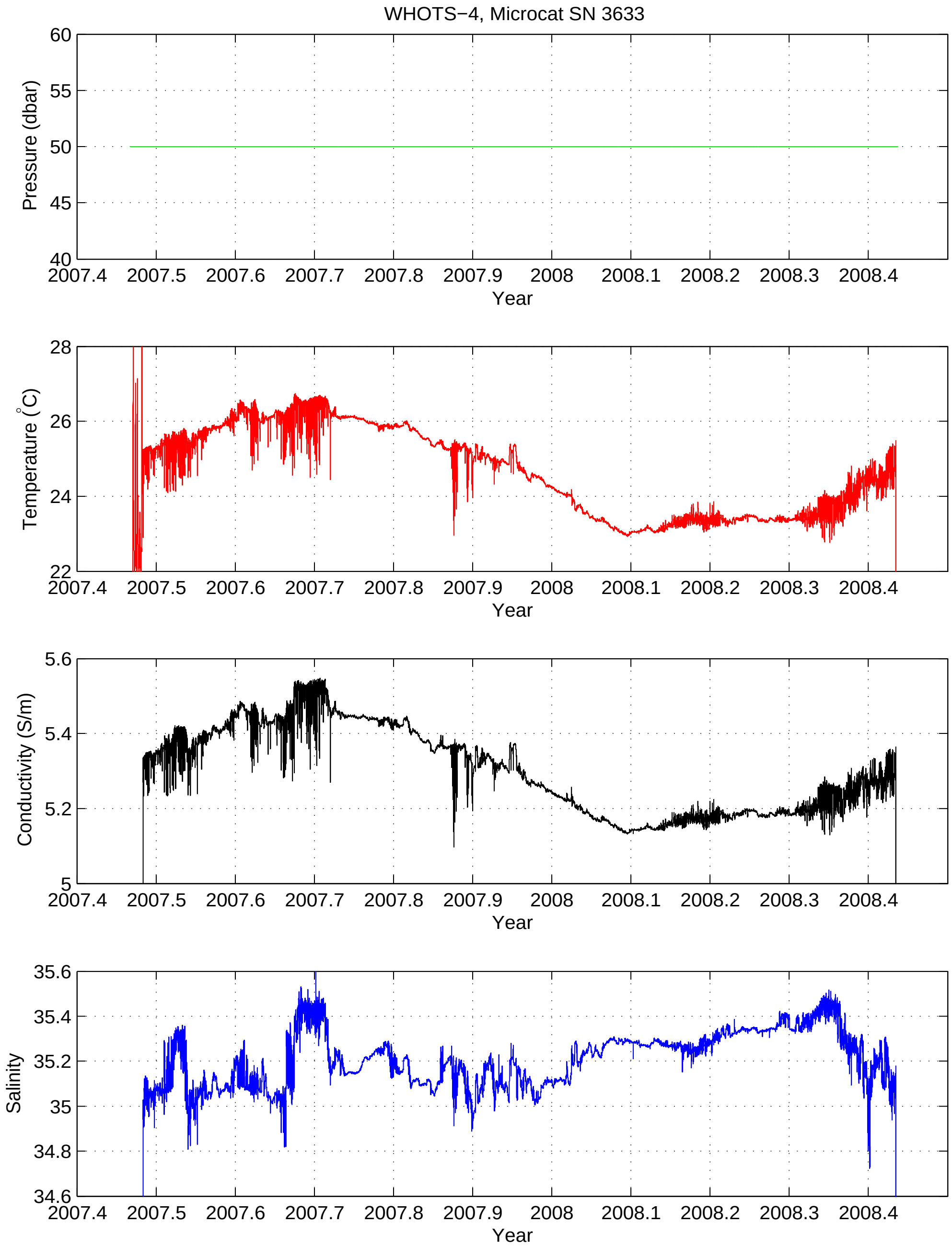

Figure A3-6. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3633 deployed at 50 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

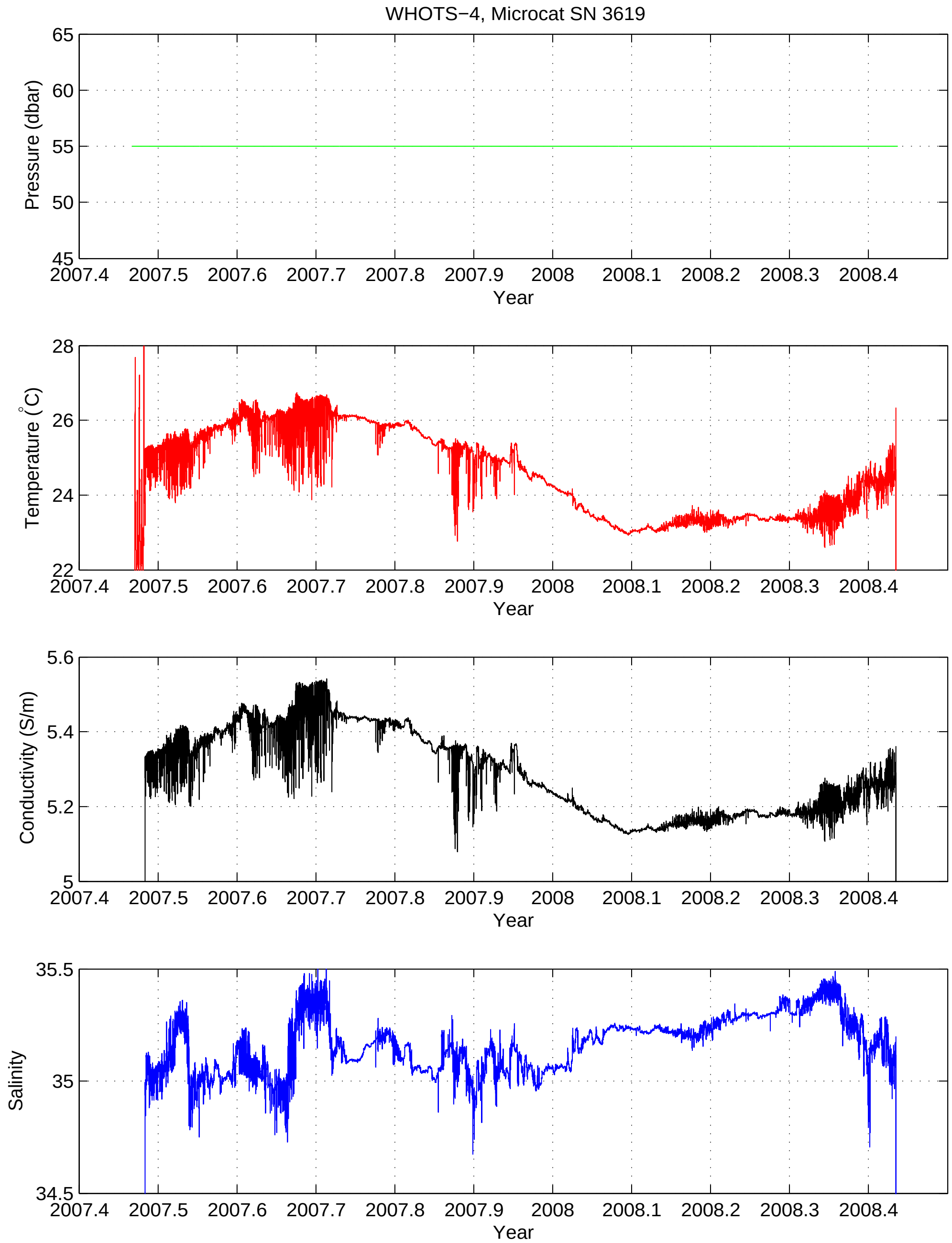

Figure A3-7. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3619 deployed at 55 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

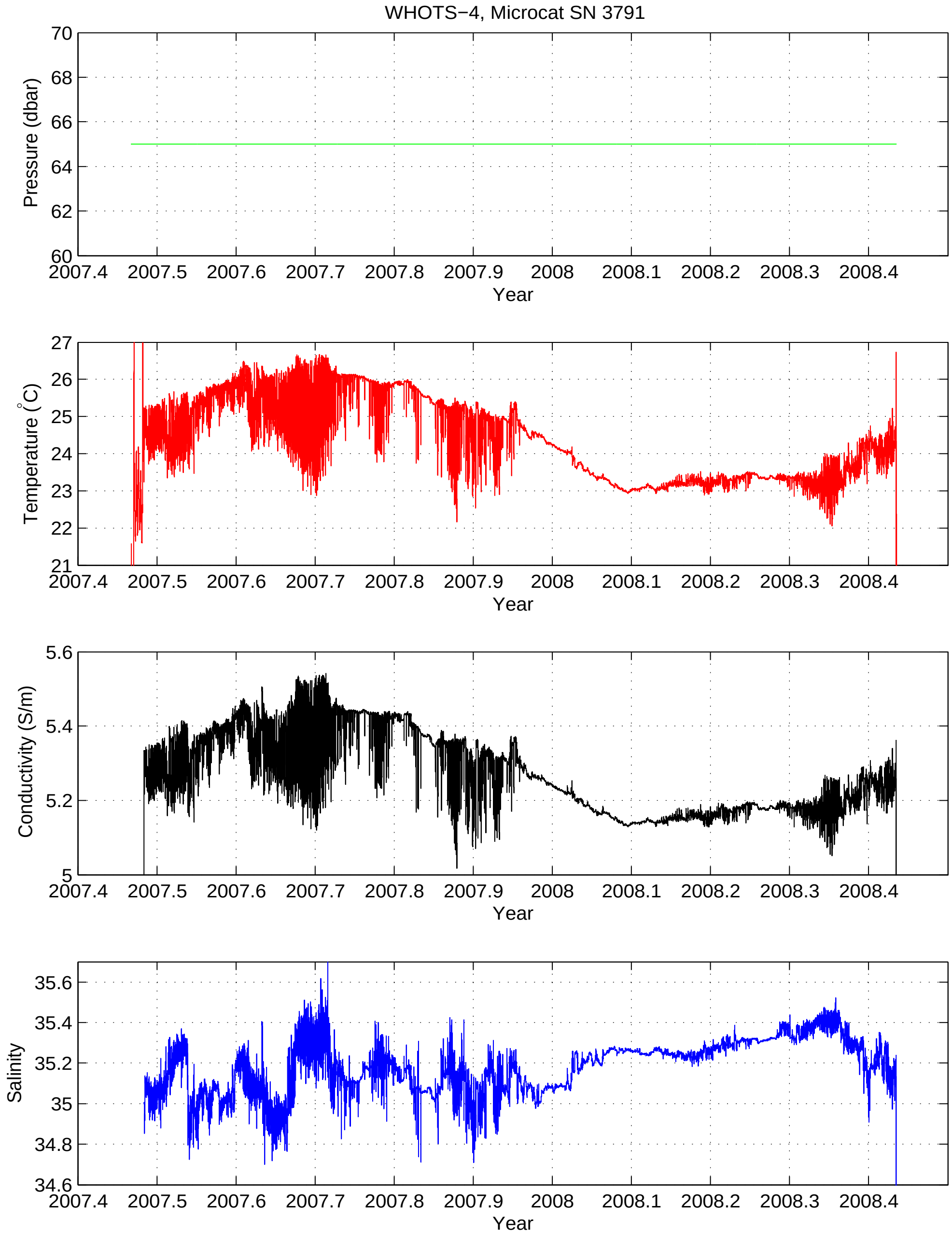

Figure A3-8. Preliminary temperature, conductivity and salinity from Seacat SBE-37 SN 3791 deployed at 65 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

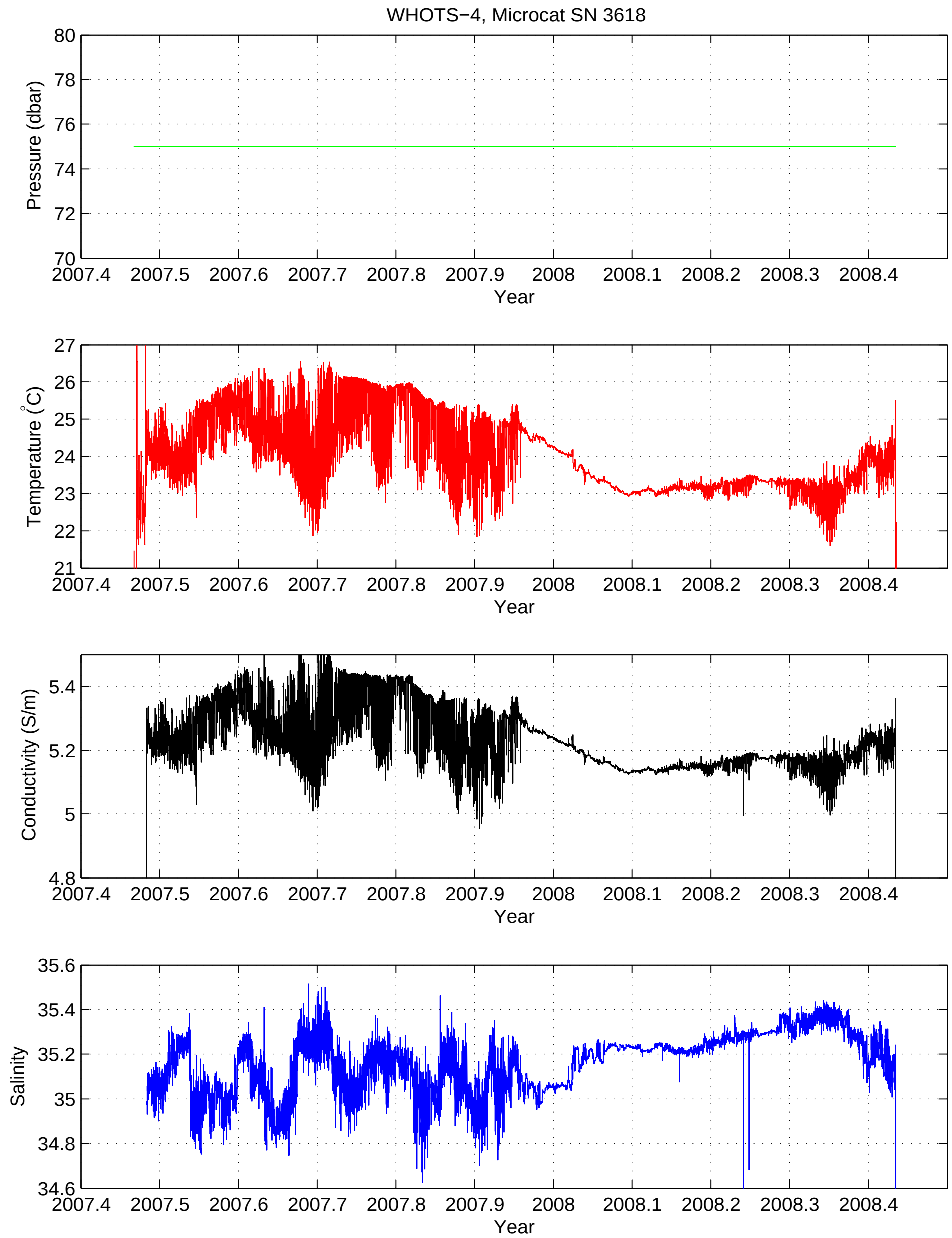

Figure A3-9. Preliminary temperature, conductivity and salinity from Seacat SBE-37 SN 3618 deployed at 75 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

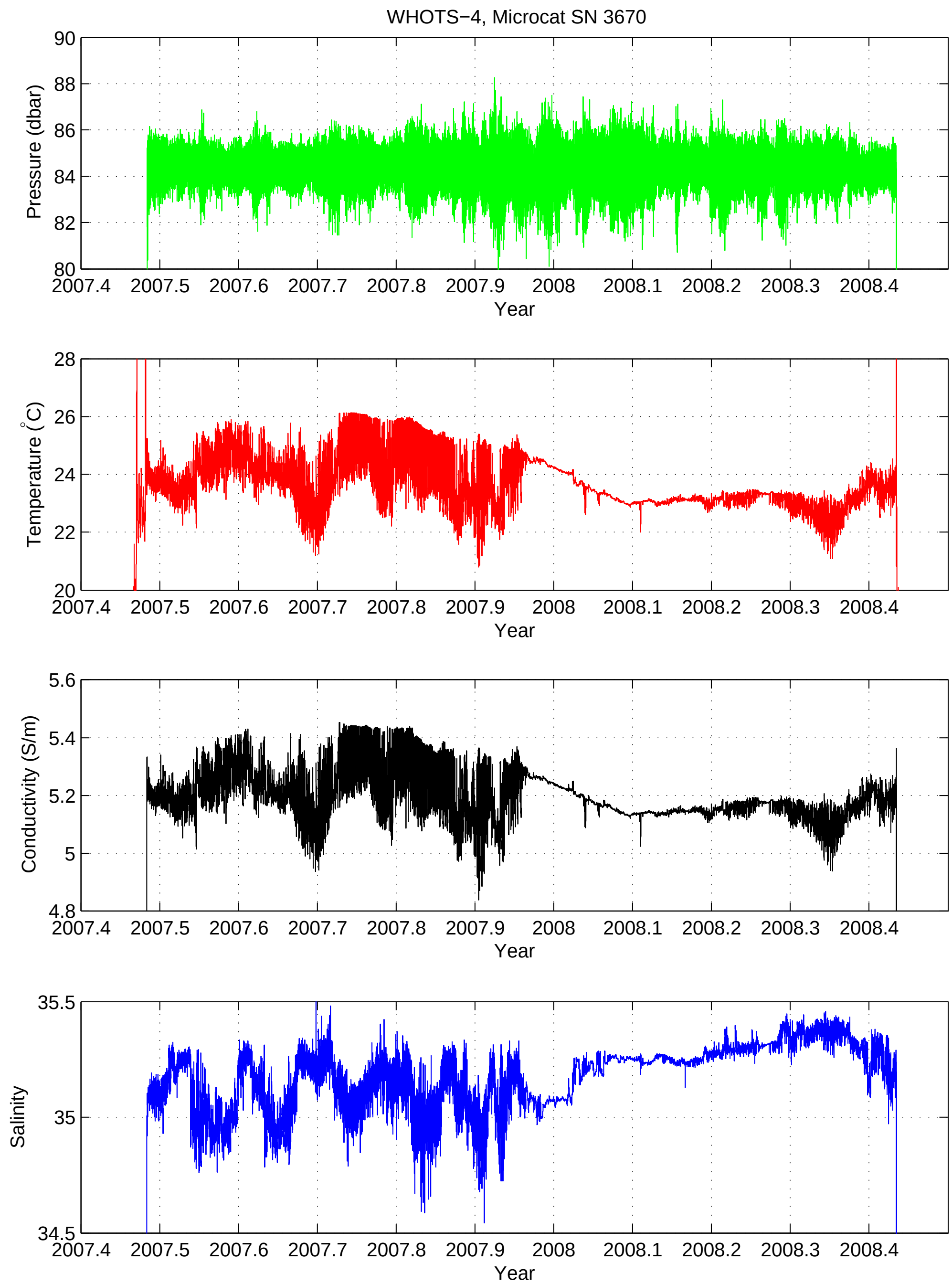

Figure A3-10. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 3670 deployed at 85 m on the WHOTS-4 mooring.

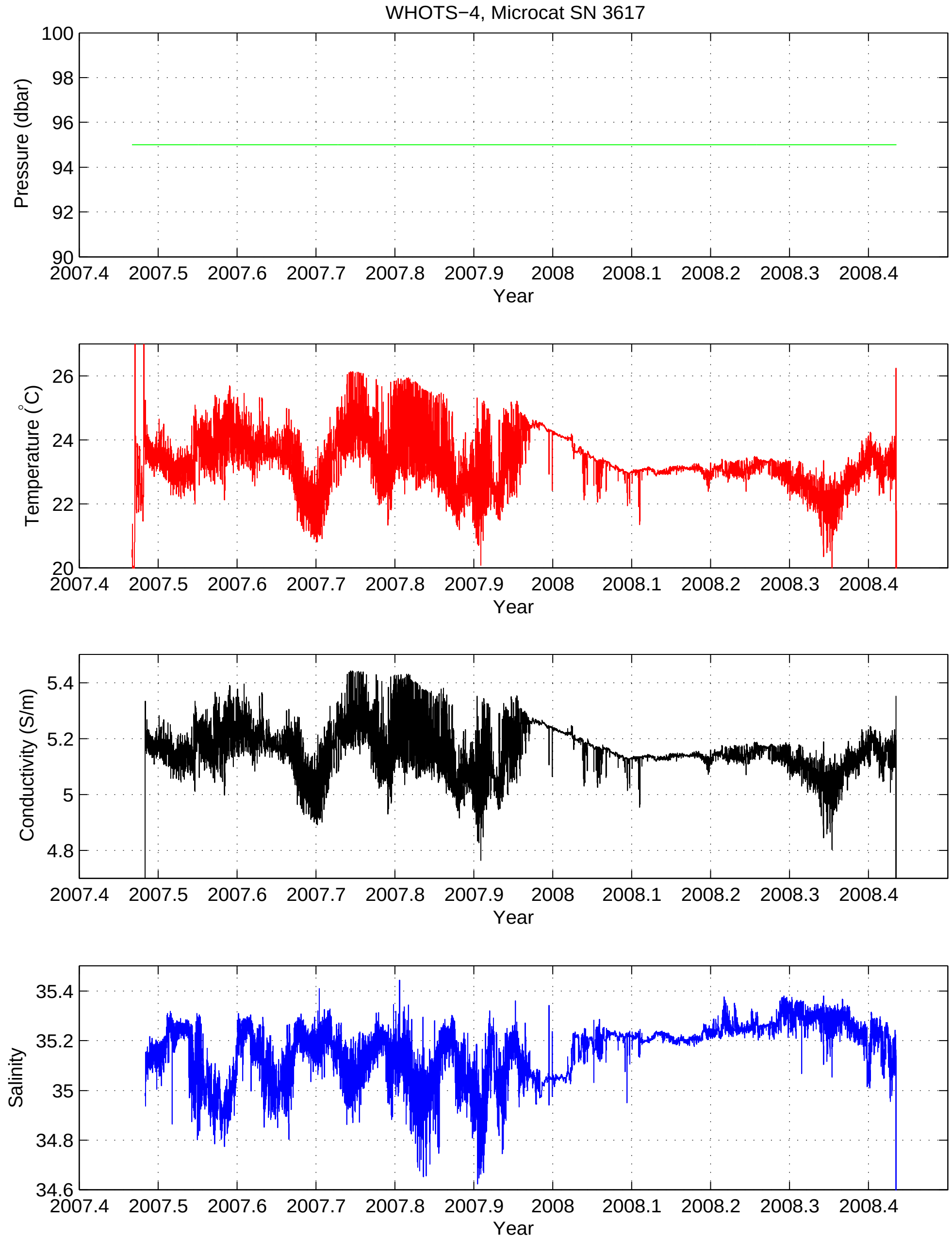

Figure A3-11. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3617 deployed at 95 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

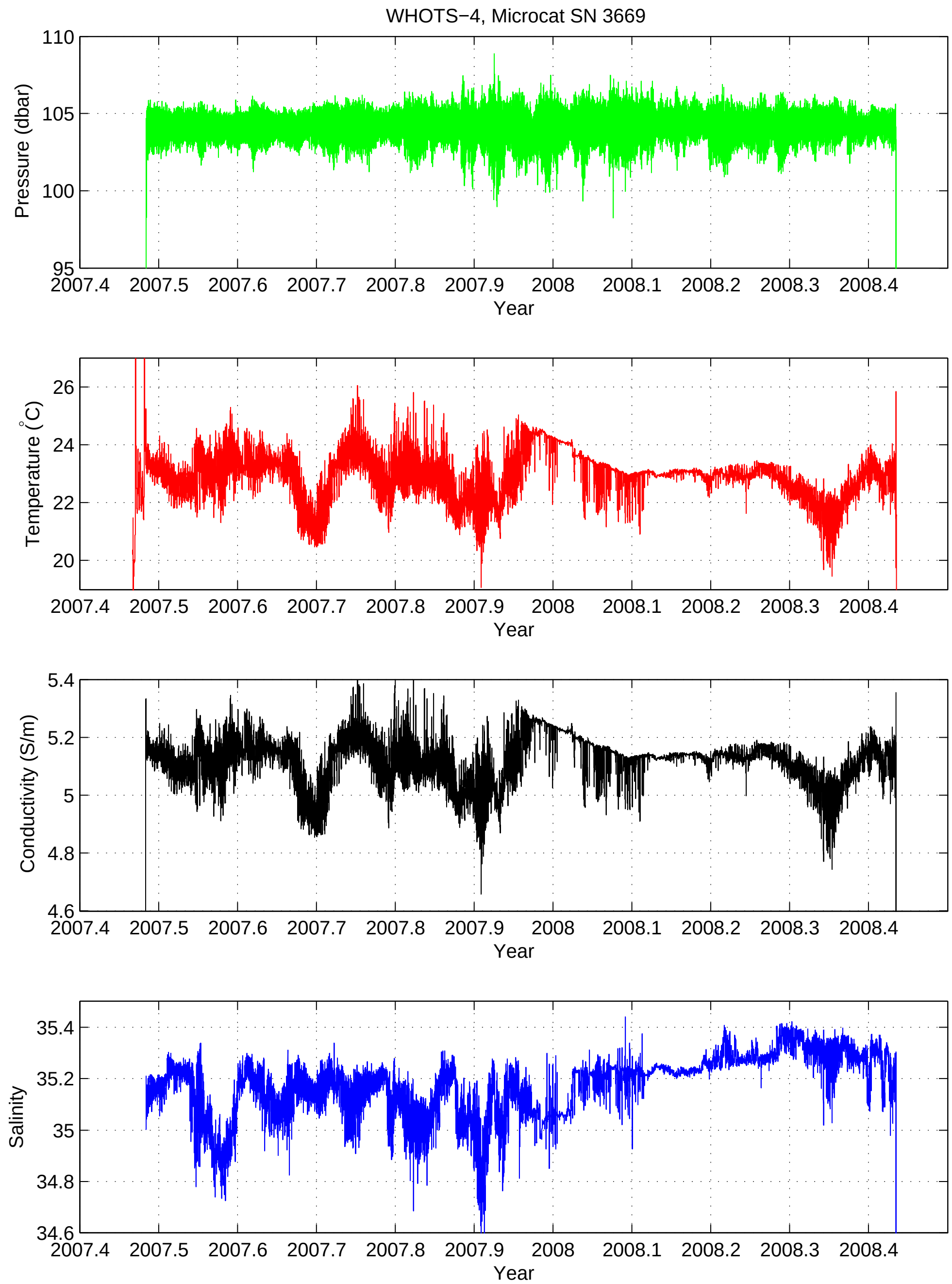

Figure A3-12. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 3669 deployed at 105 m on the WHOTS-4 mooring.

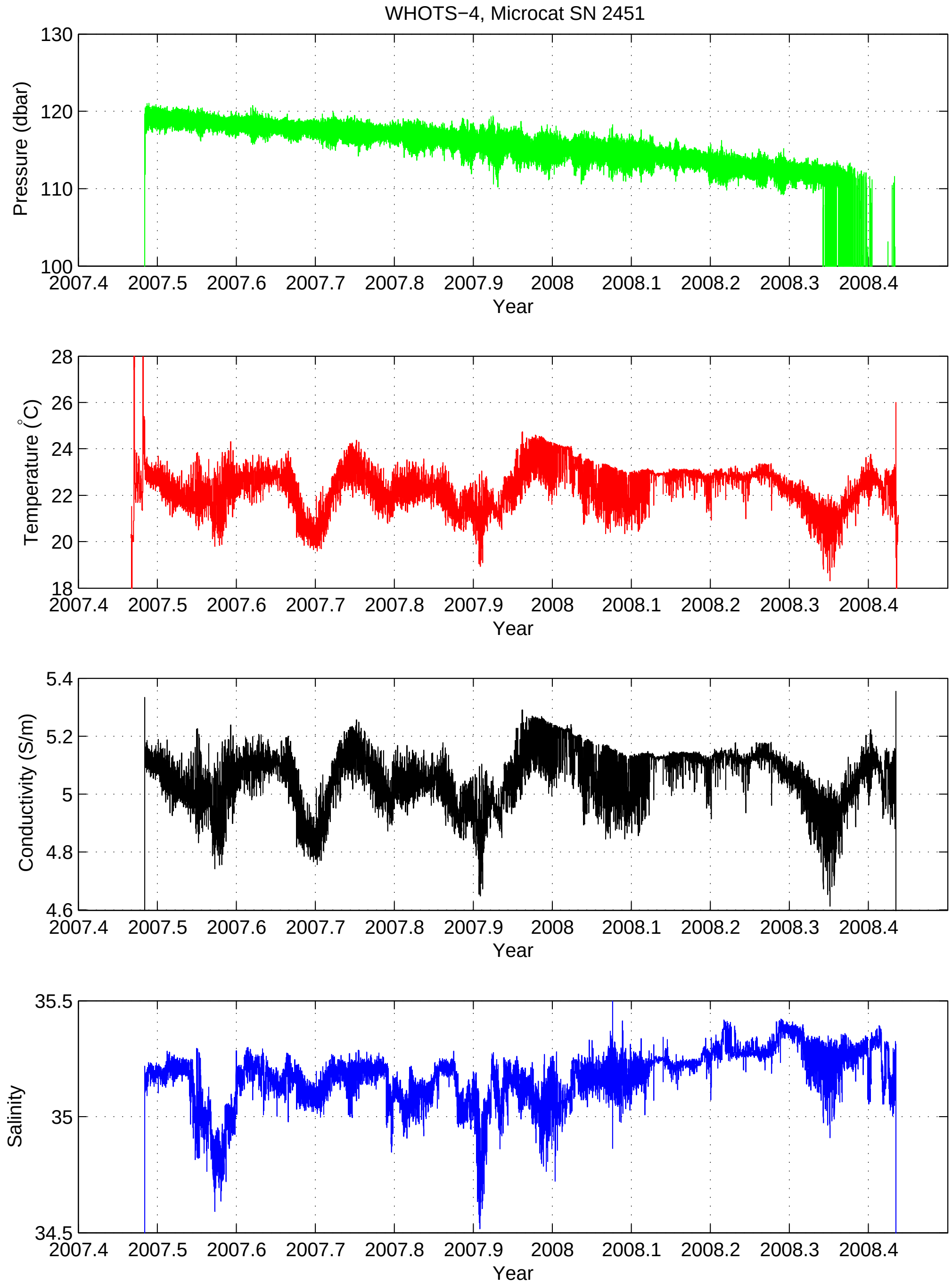

Figure A3-13. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 2451 deployed at 120 m on the WHOTS-4 mooring.

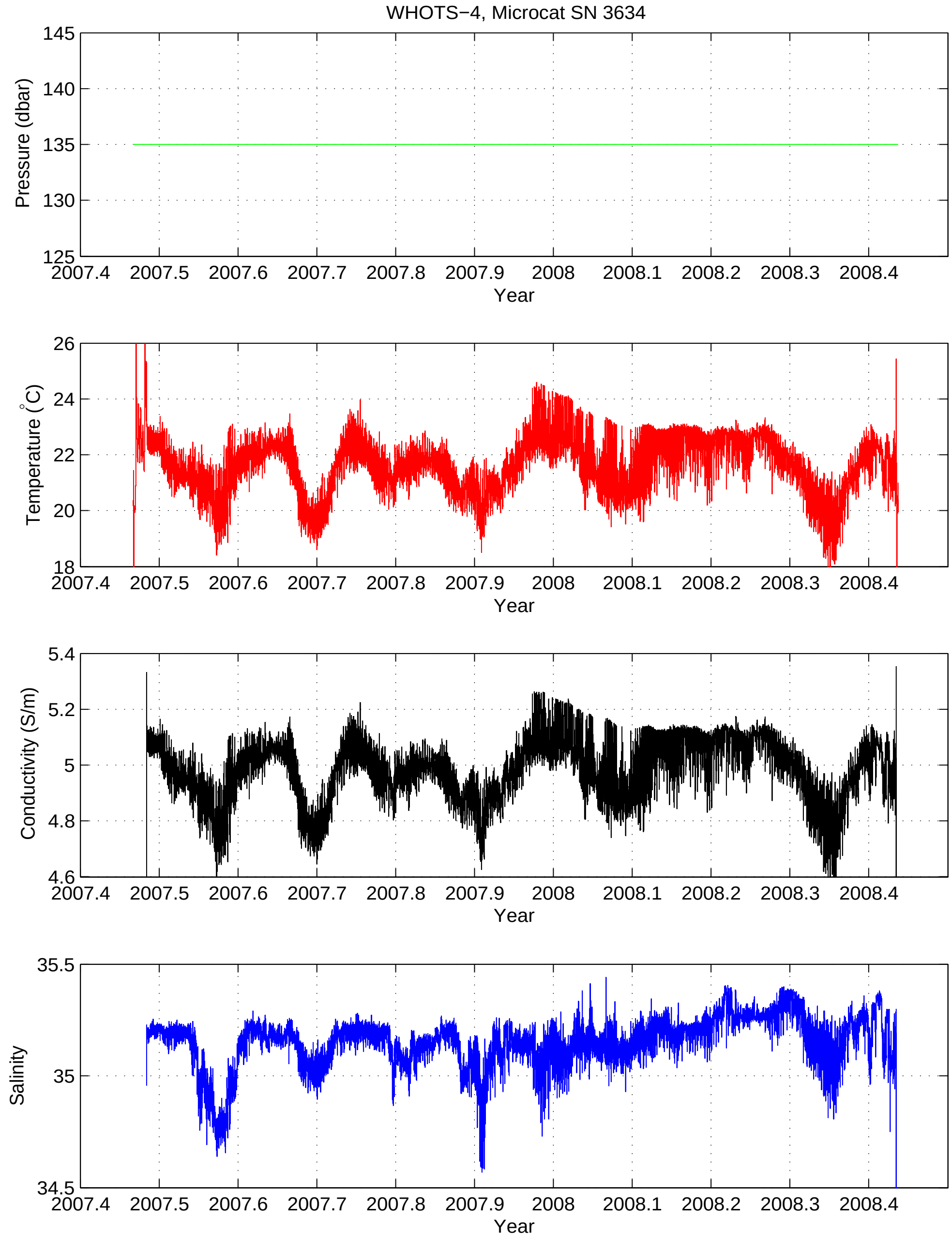

Figure A3-14. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3634 deployed at 135 m on the WHOTS-4 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

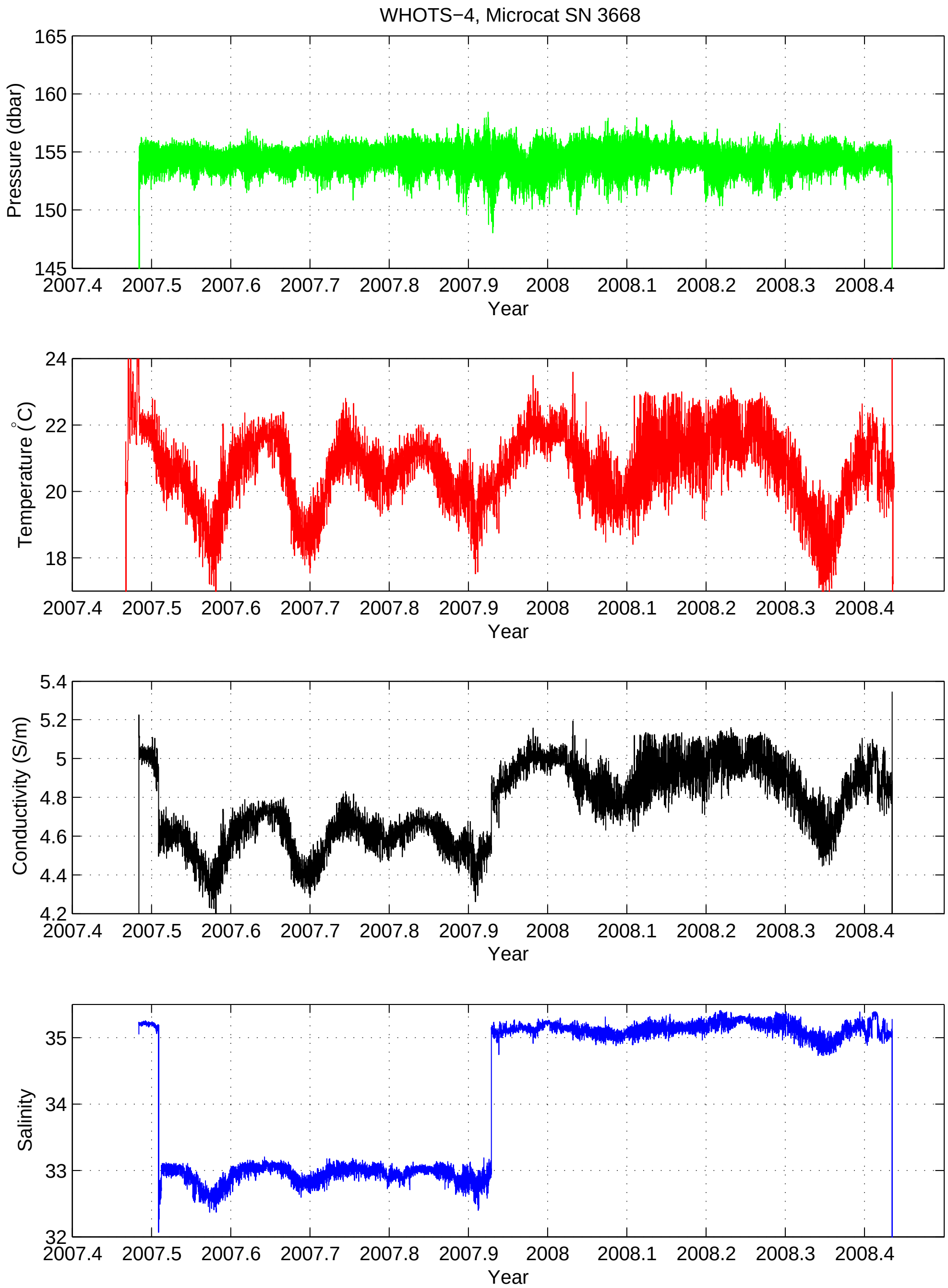

Figure A3-15. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 3668 deployed at 155 m on the WHOTS-4 mooring.

Appendix 4. CTD Casts

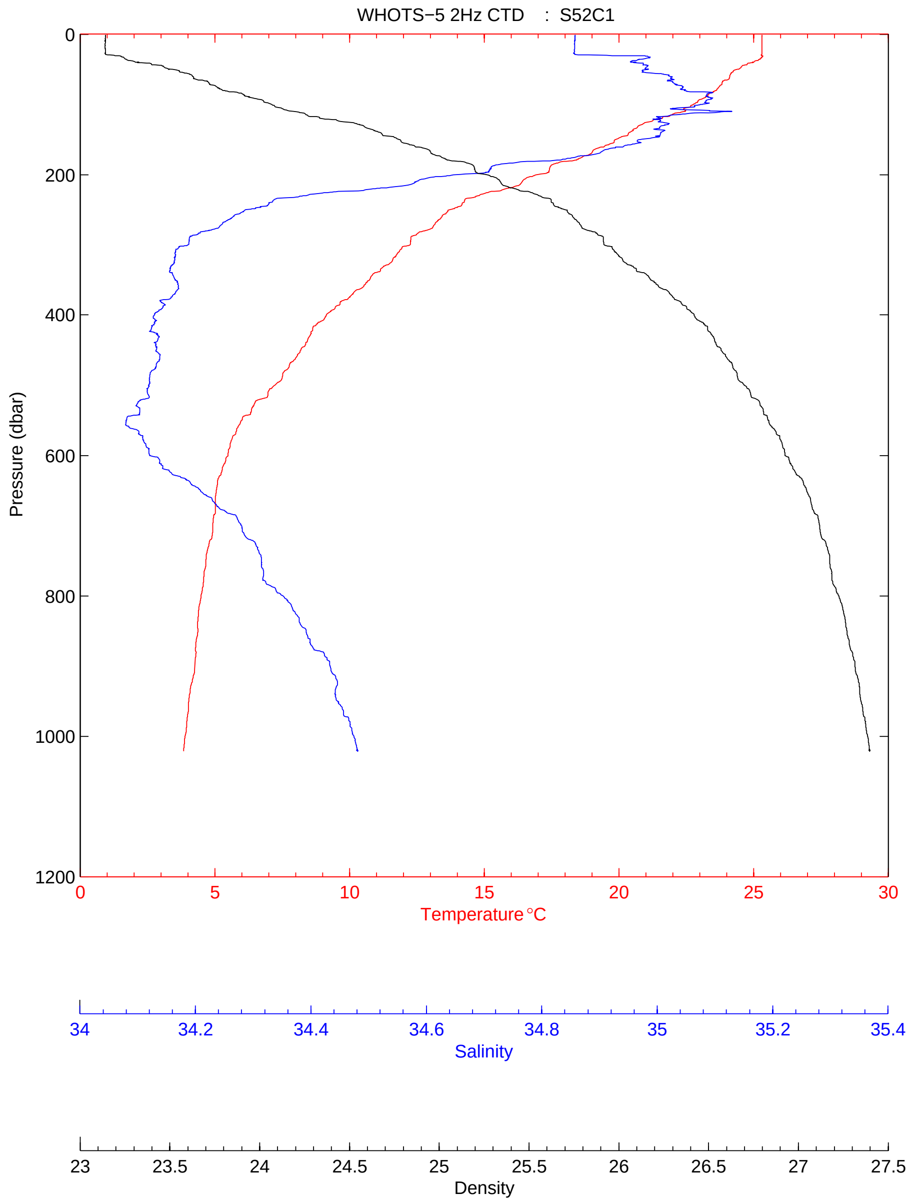

Figure A4-1. Profiles of 2 Hz temperature, salinity and potential density data during CTD S52C1.

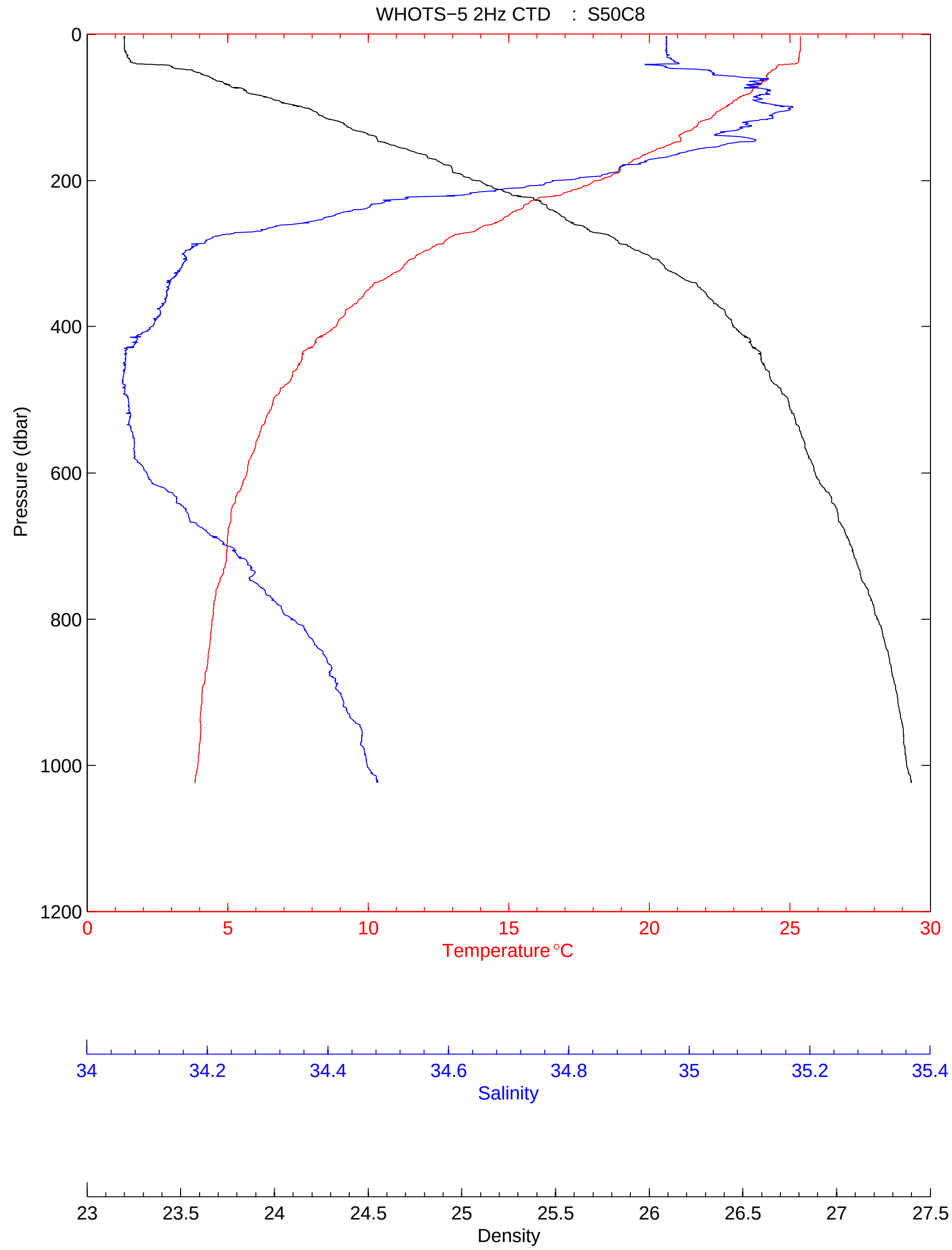

Figure A4-2. Profiles of 2 Hz temperature, salinity and potential density data during CTD S50C8.

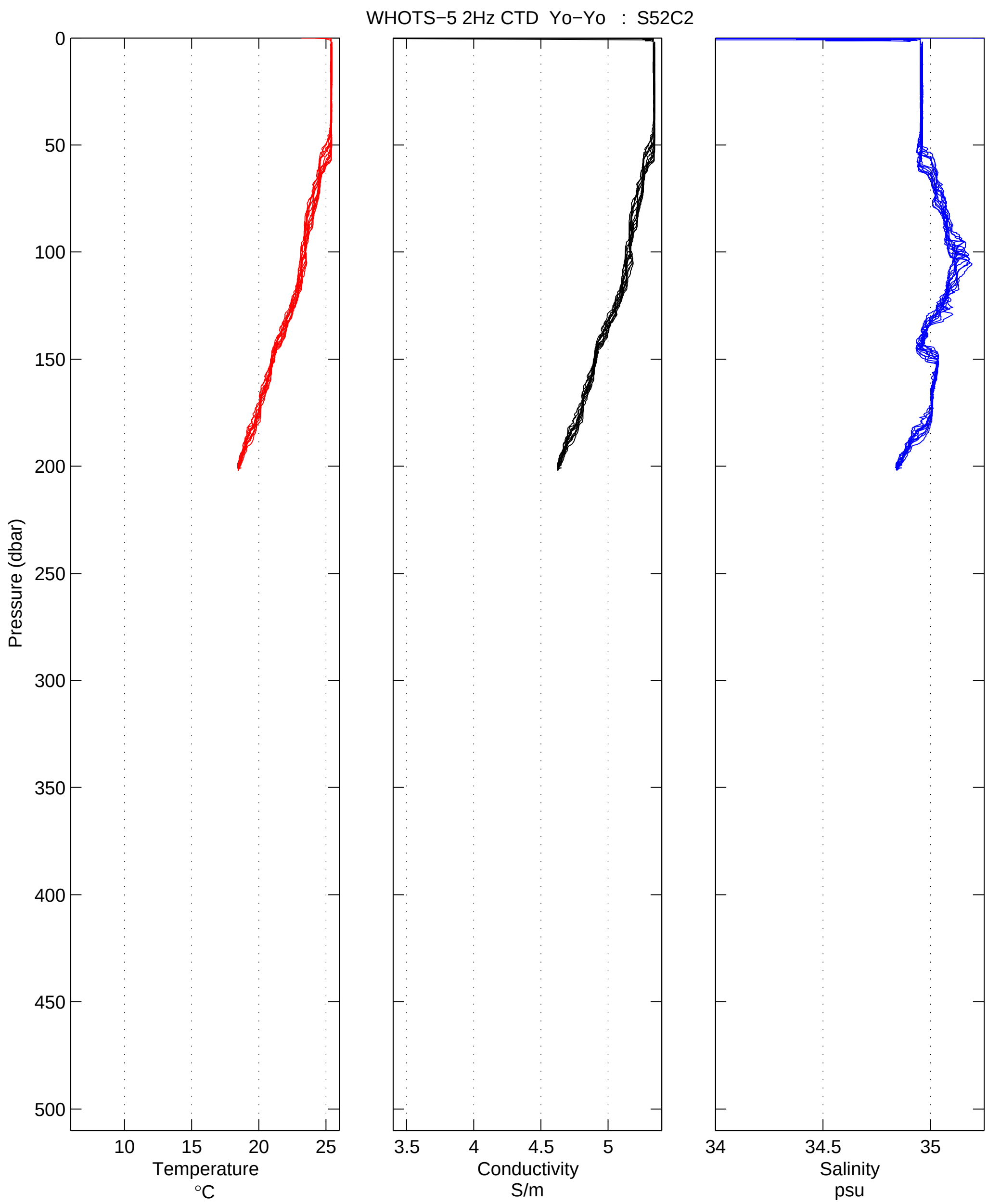

Figure A4-3. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C2.

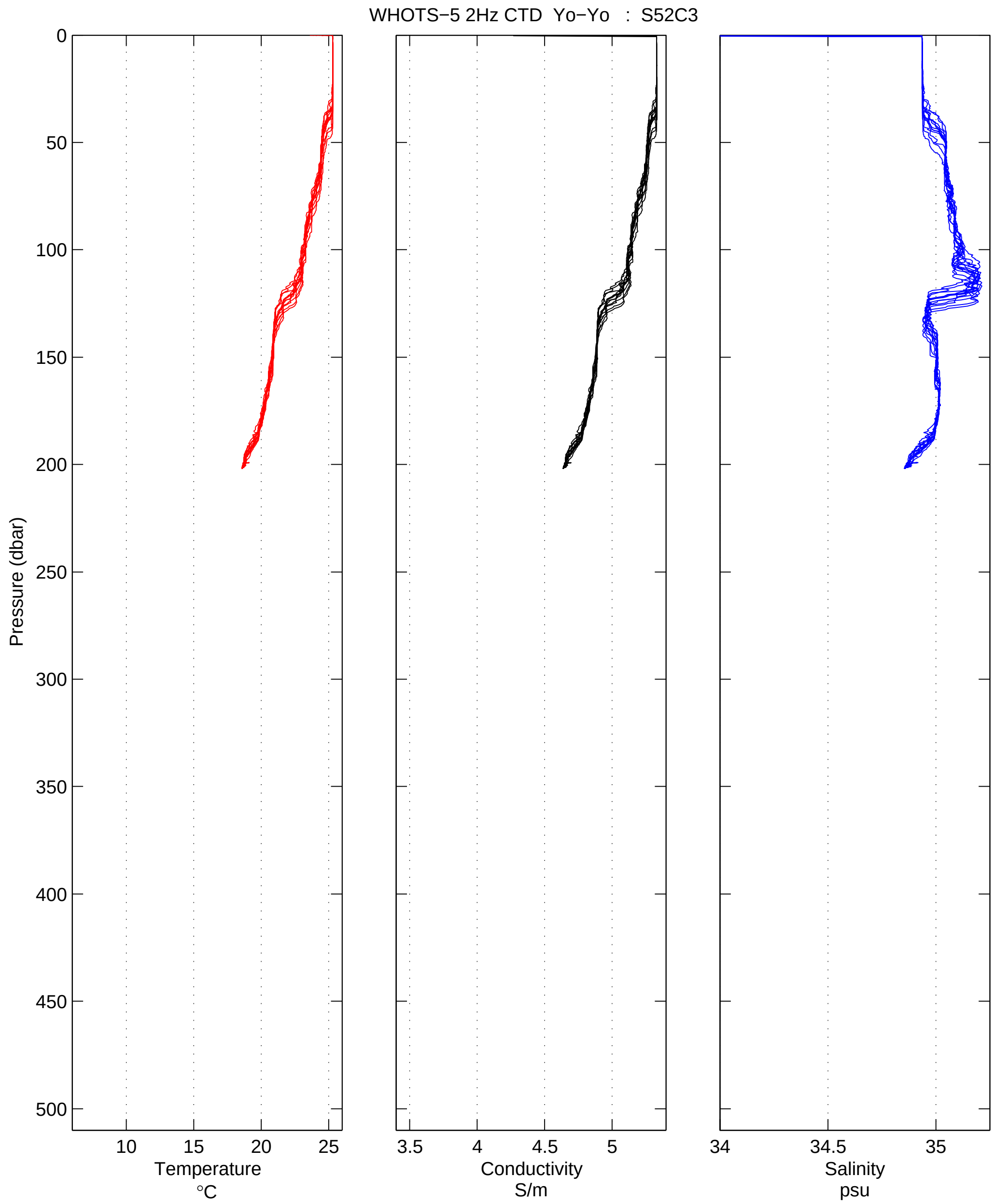

Figure A4-4. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C3.

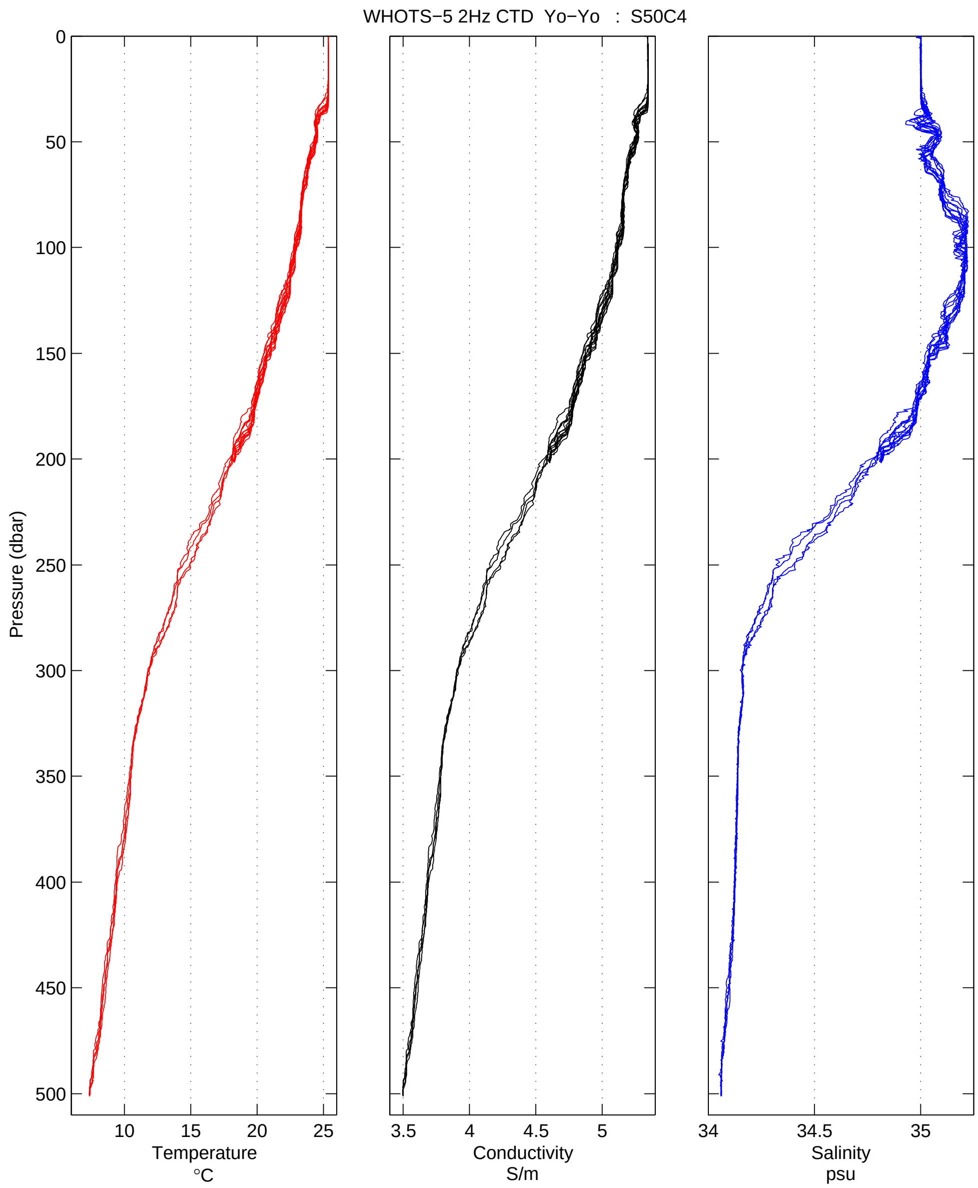

Figure A4-5. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C4.

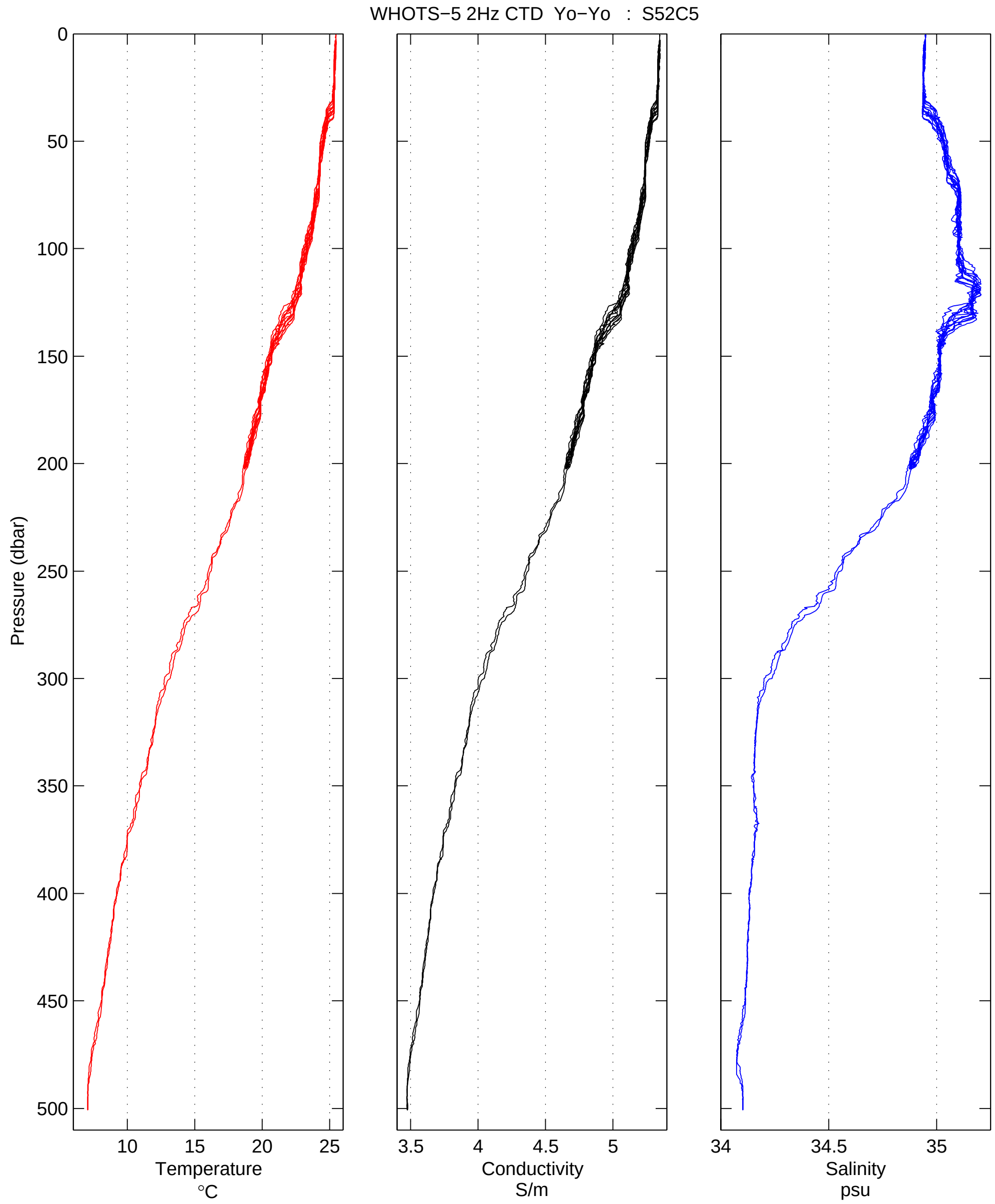

Figure A4-6. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C5.

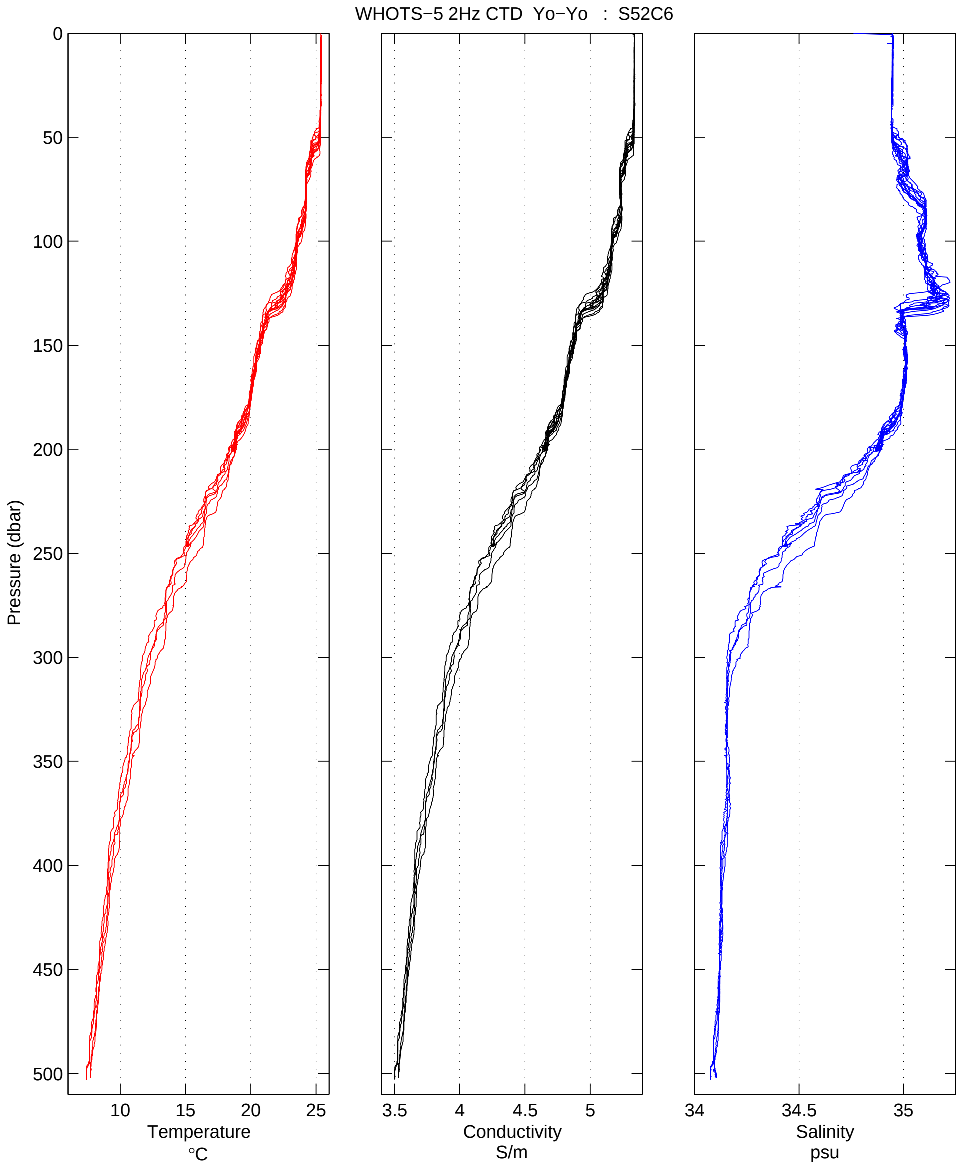

Figure A4-7. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C6.

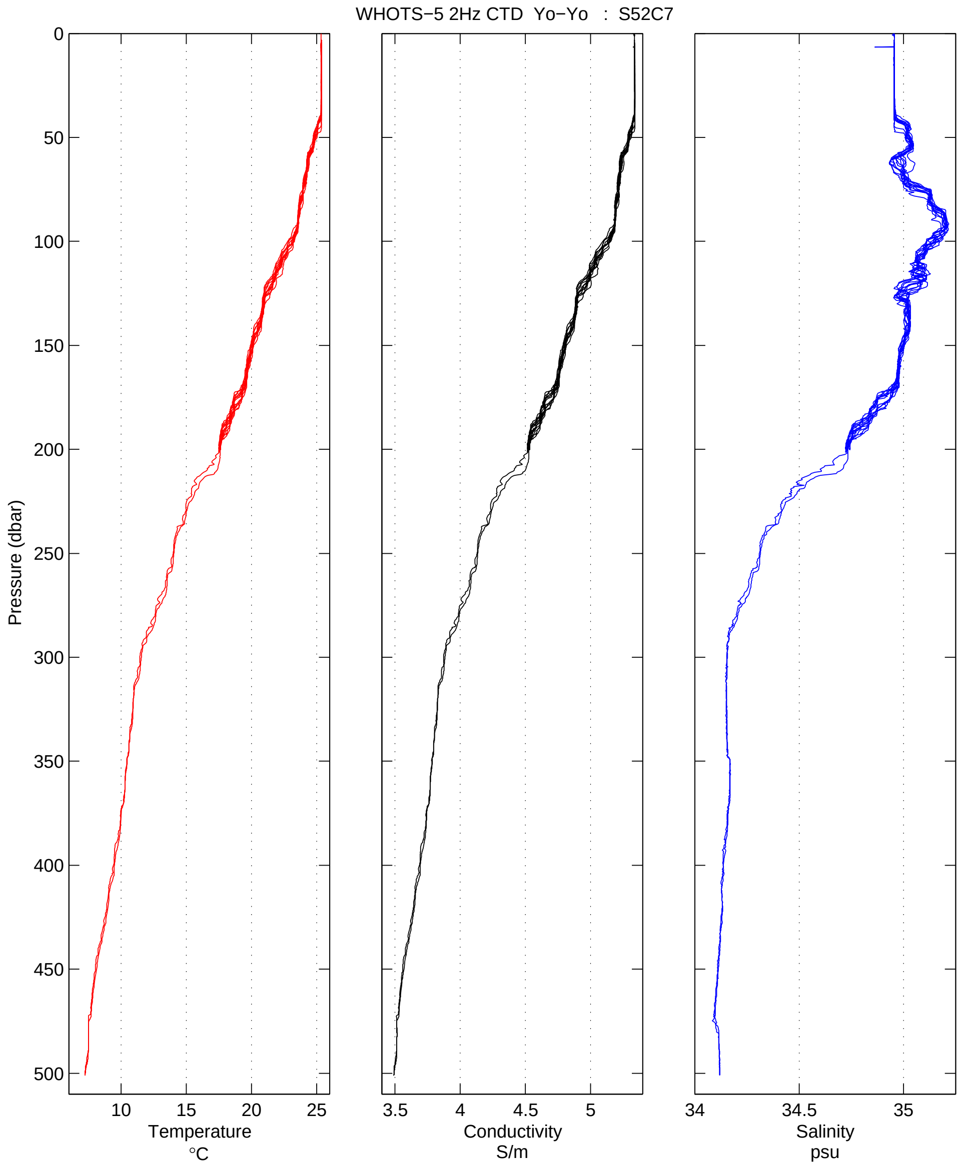

Figure A4-8. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C7.

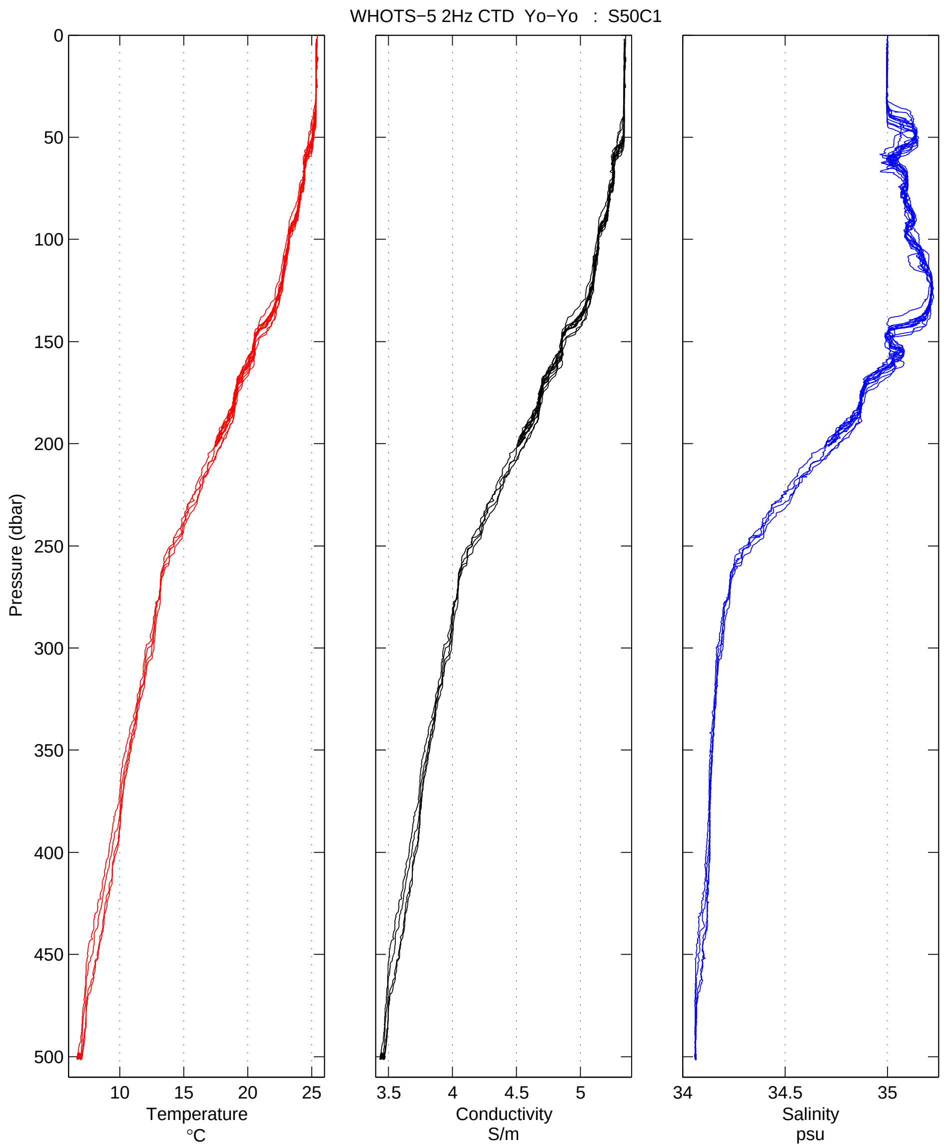

Figure A4-9. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C1.

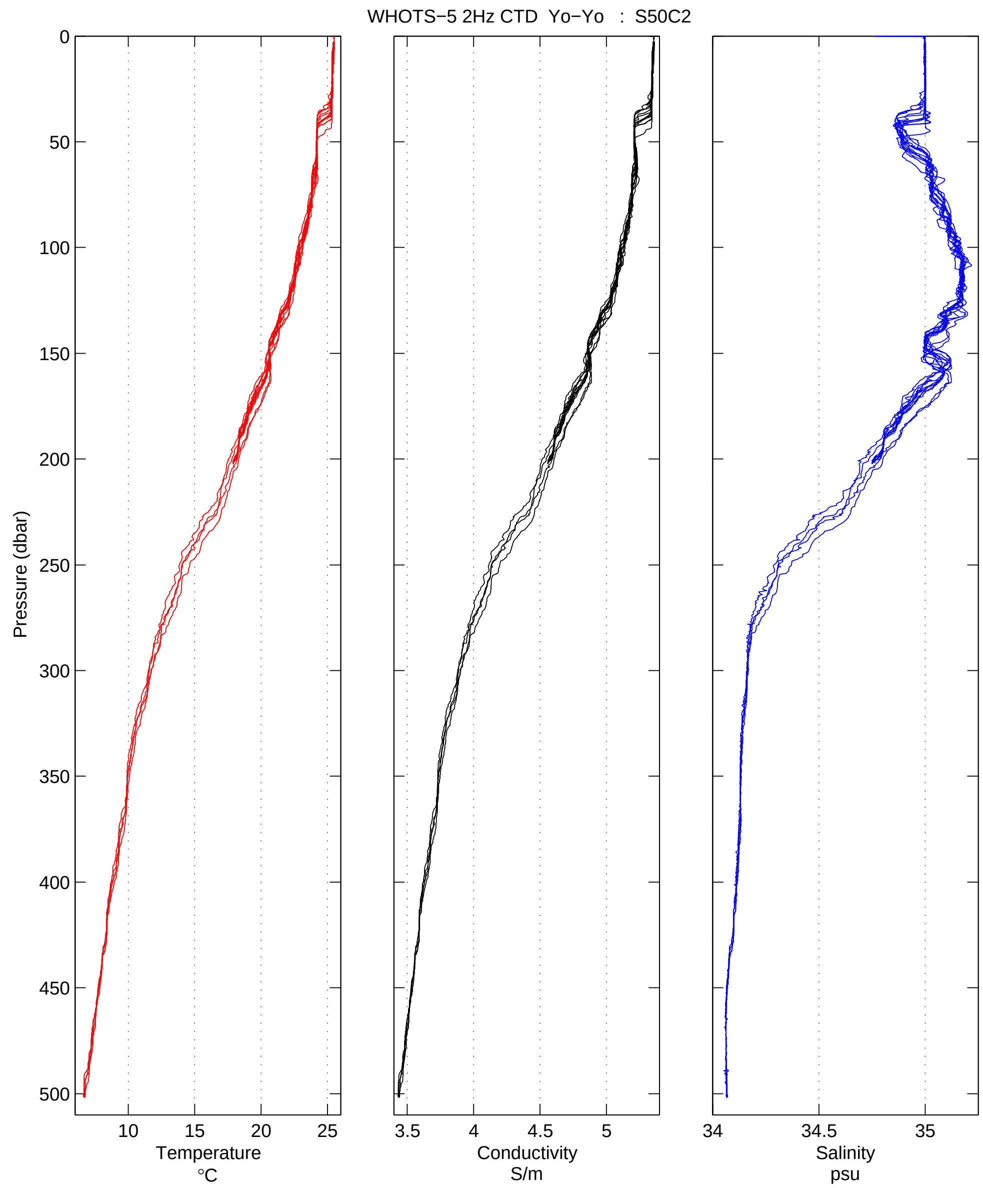

Figure A4-10. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C2.

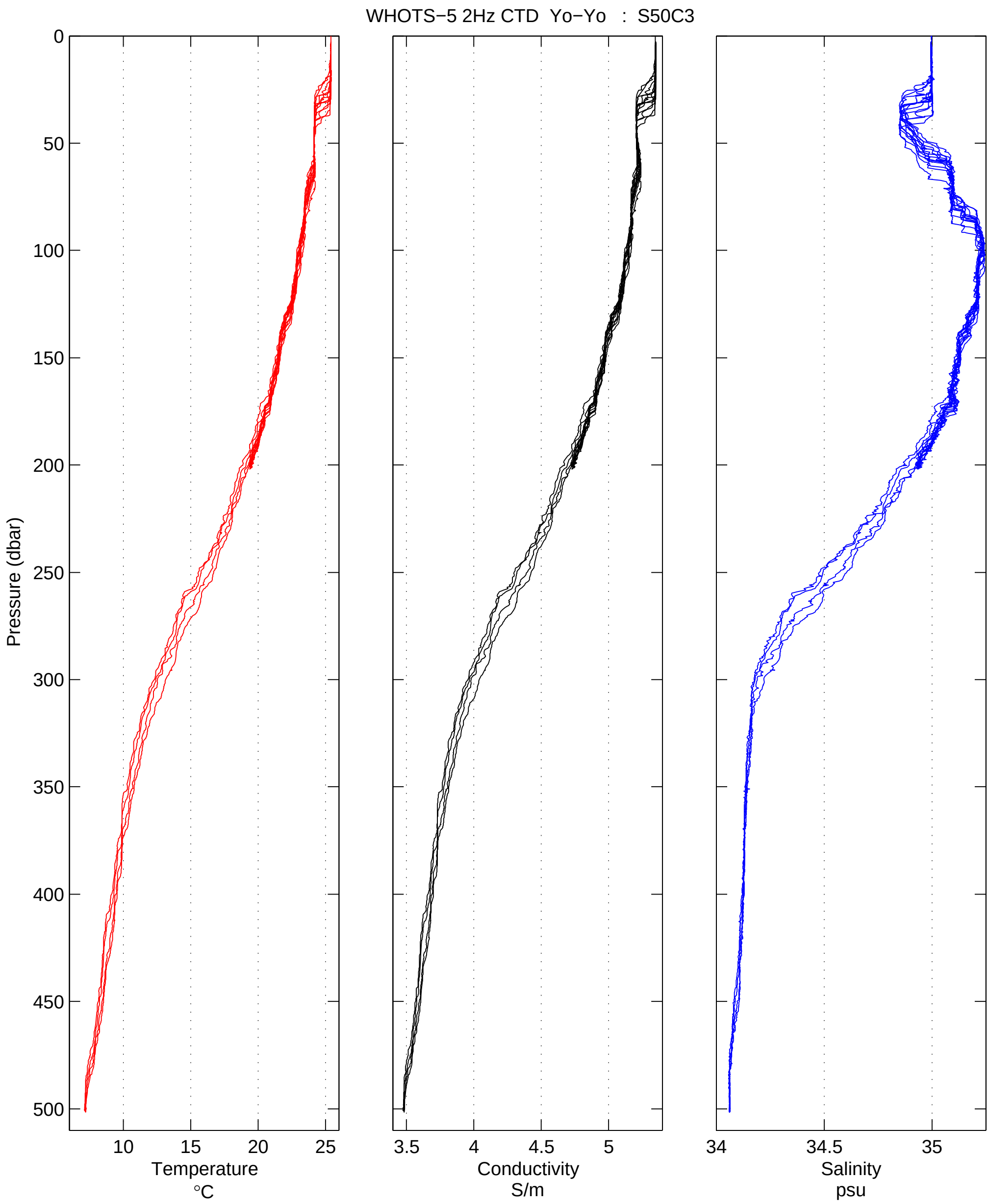

Figure A4-11. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C3.

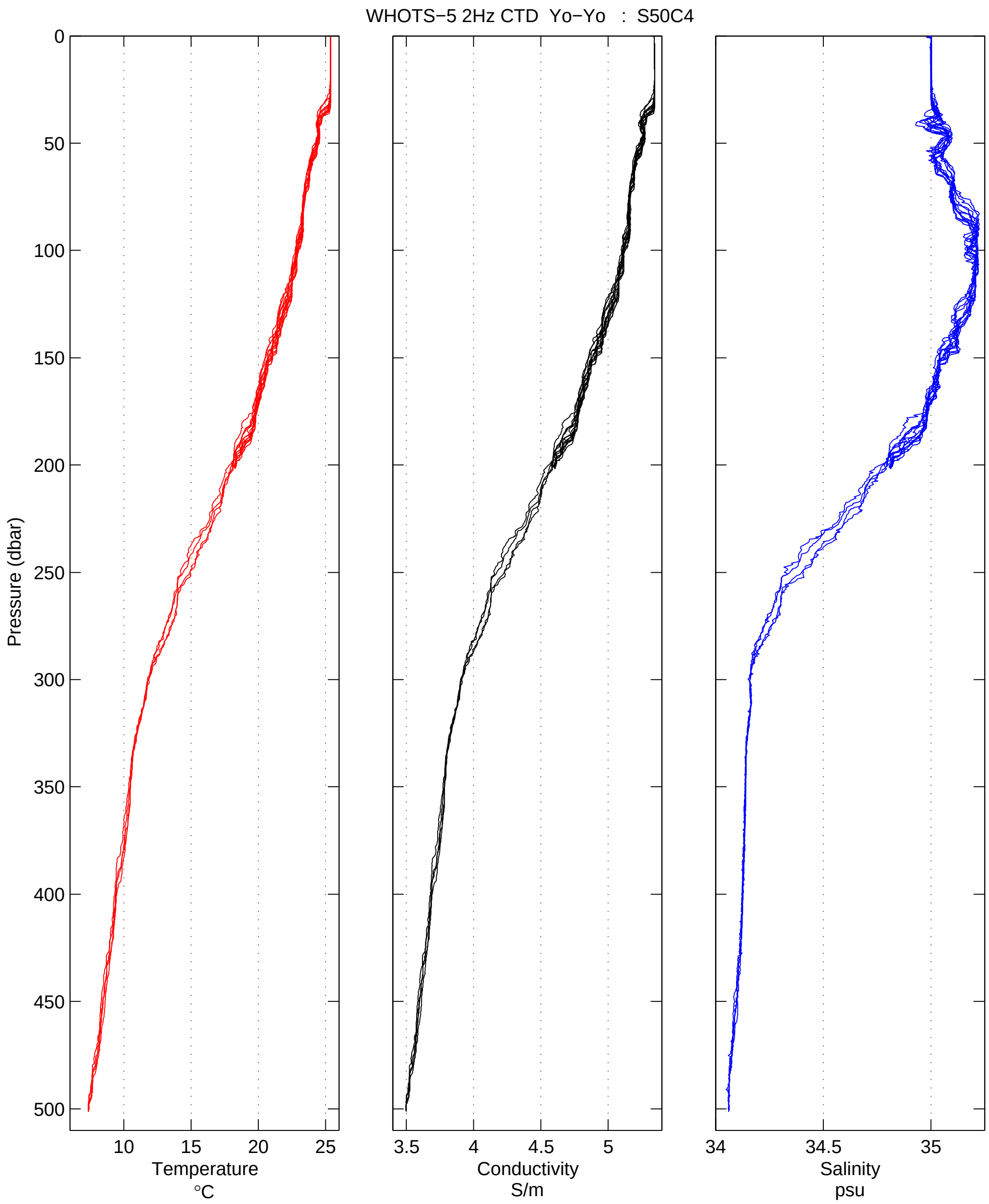

Figure A4-12. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C4.

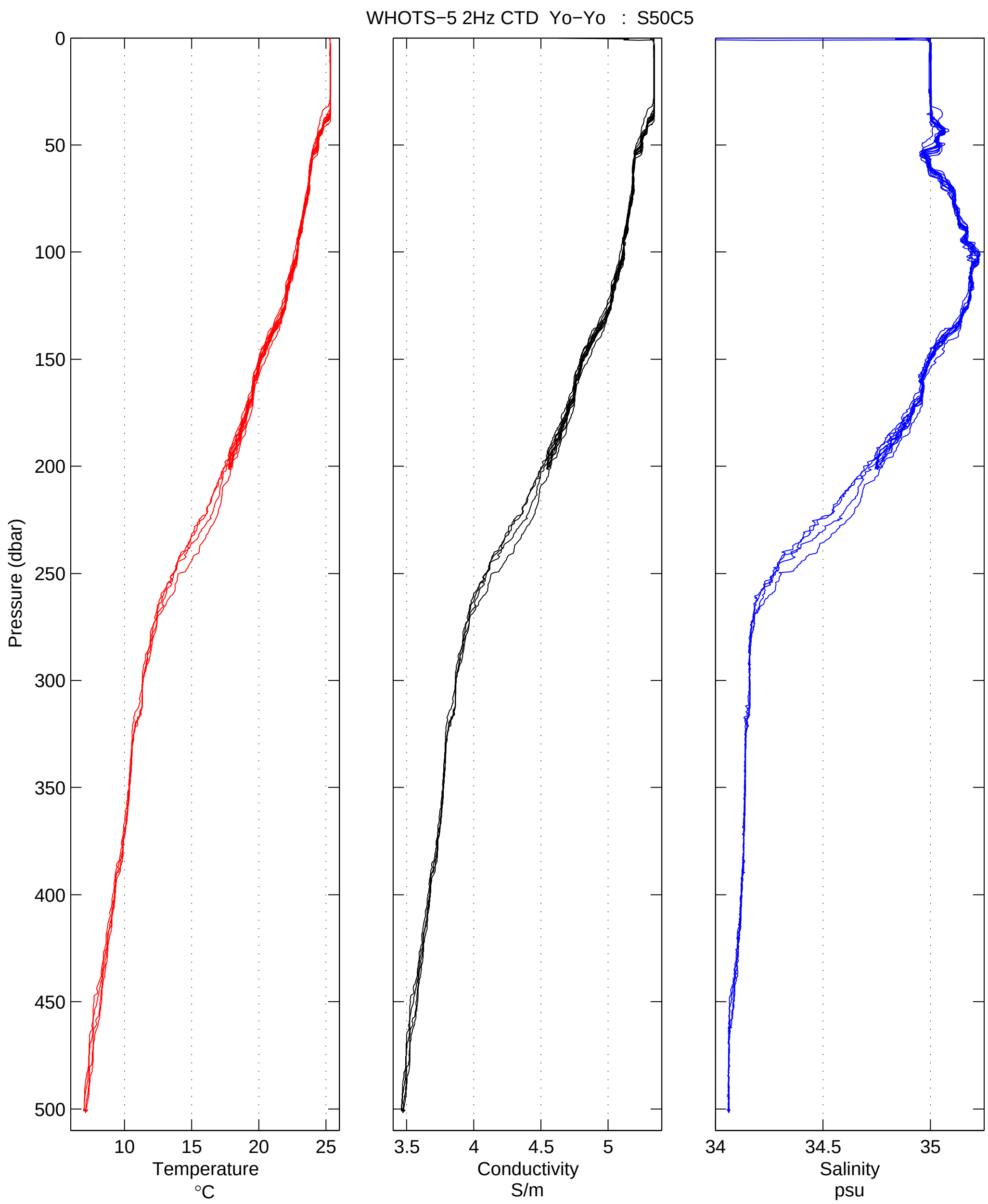

Figure A4-13. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C5.

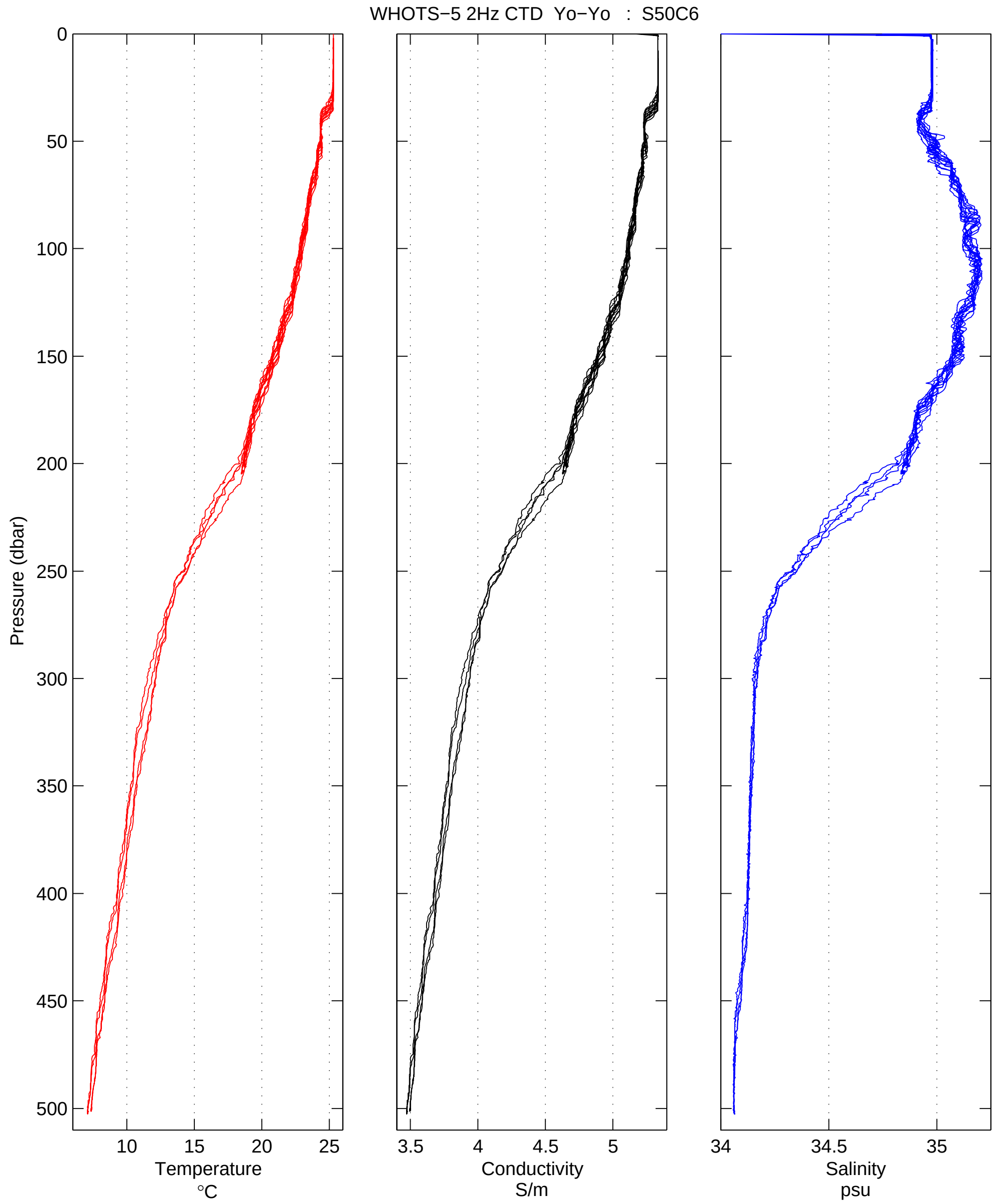

Figure A4-14. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C6.

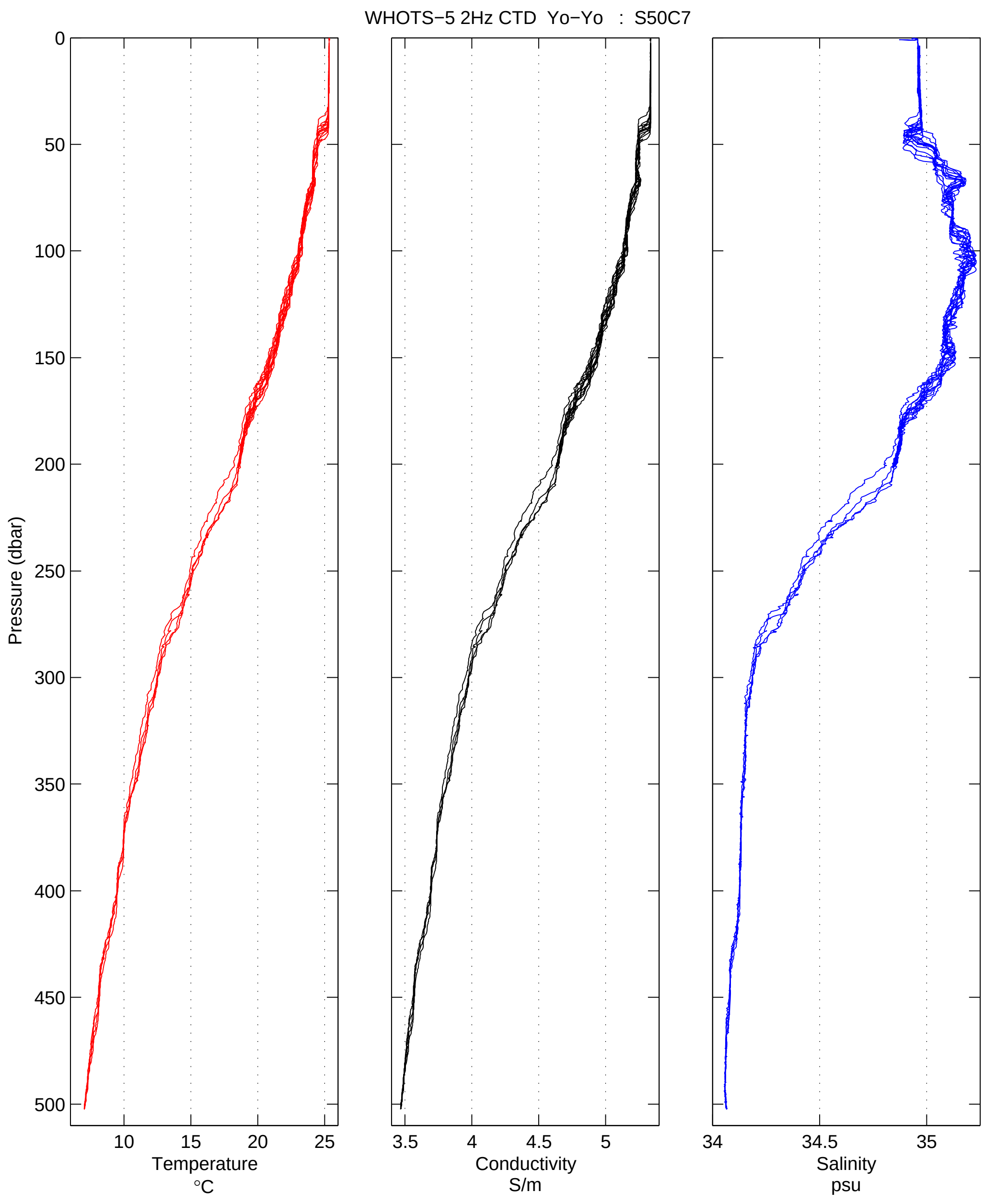

Figure A4-15. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S50C7.

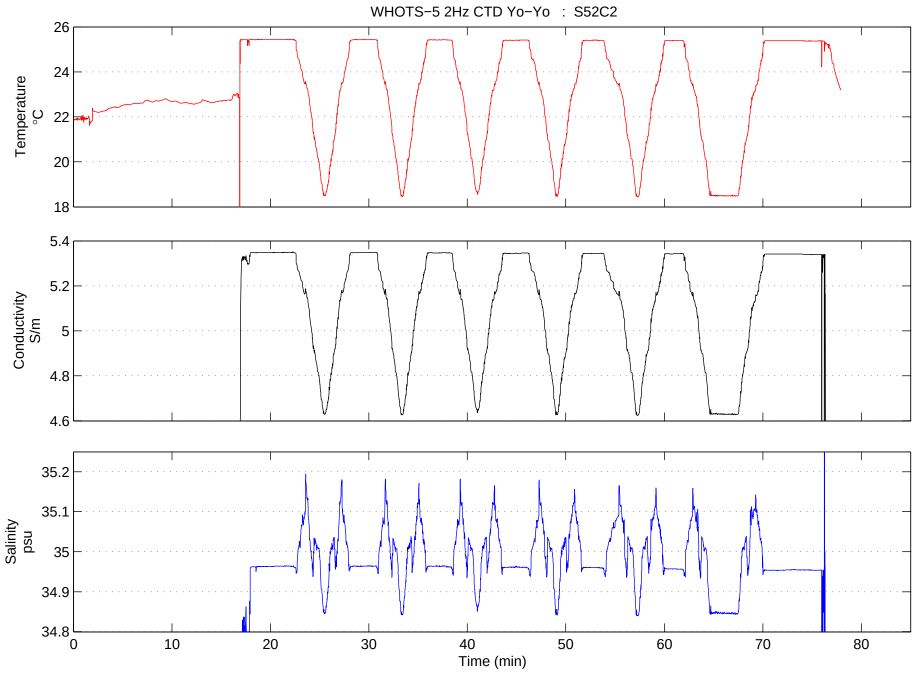

Figure A4-16. Profiles of 2 Hz temperature, conductivity and salinity data during CTD S52C2.

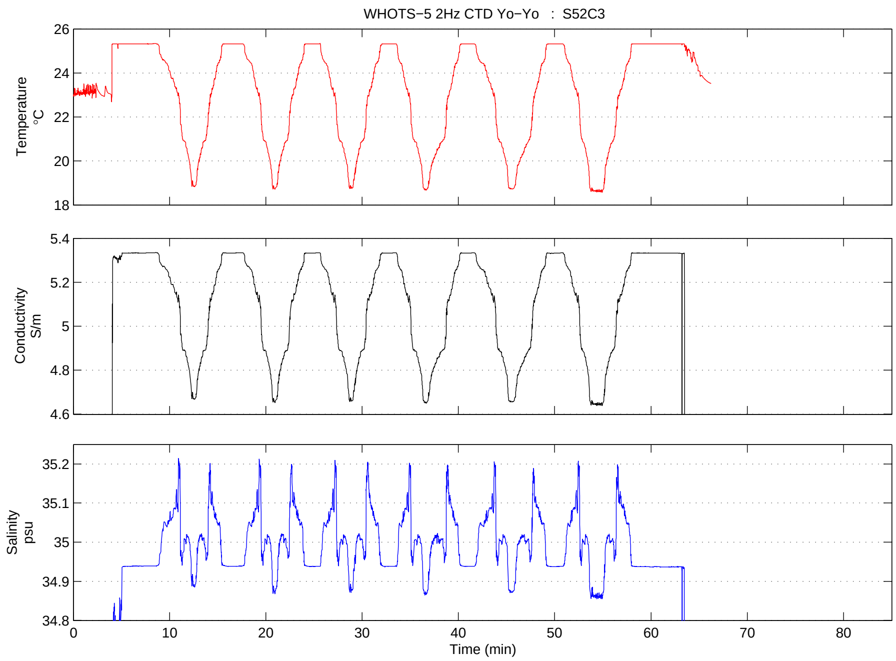

Figure A4-17. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S52C3.

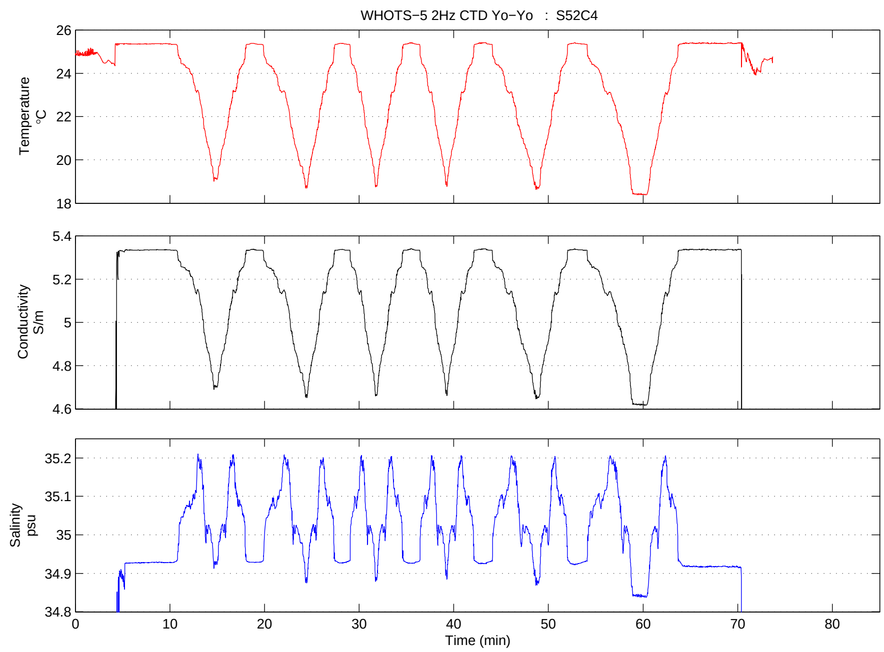

Figure A4-18. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S52C4.

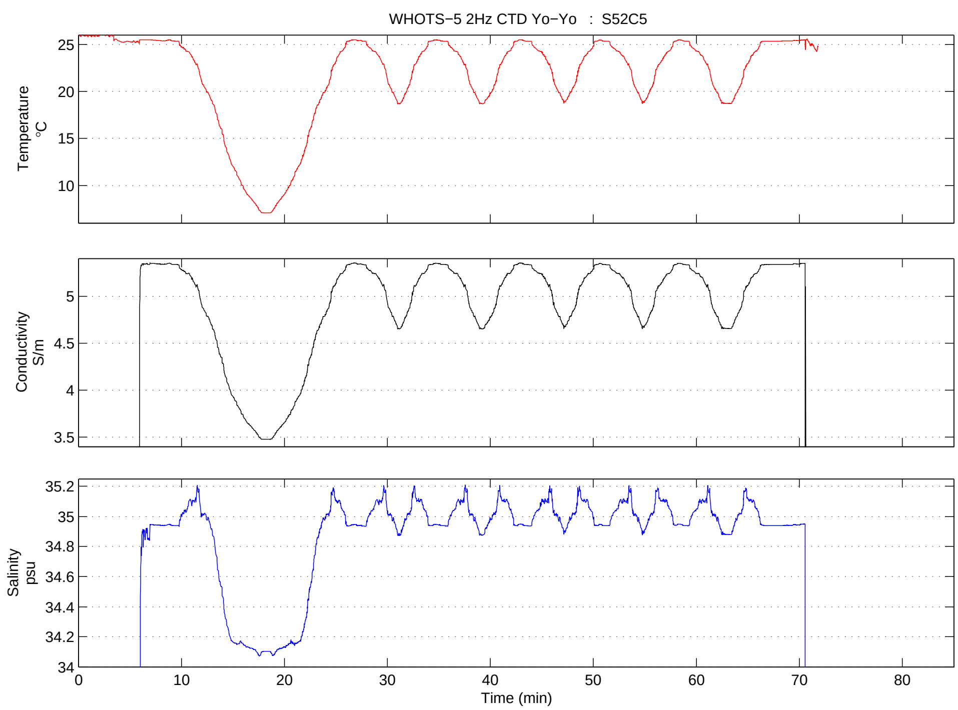

Figure A4-19. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S52C5.

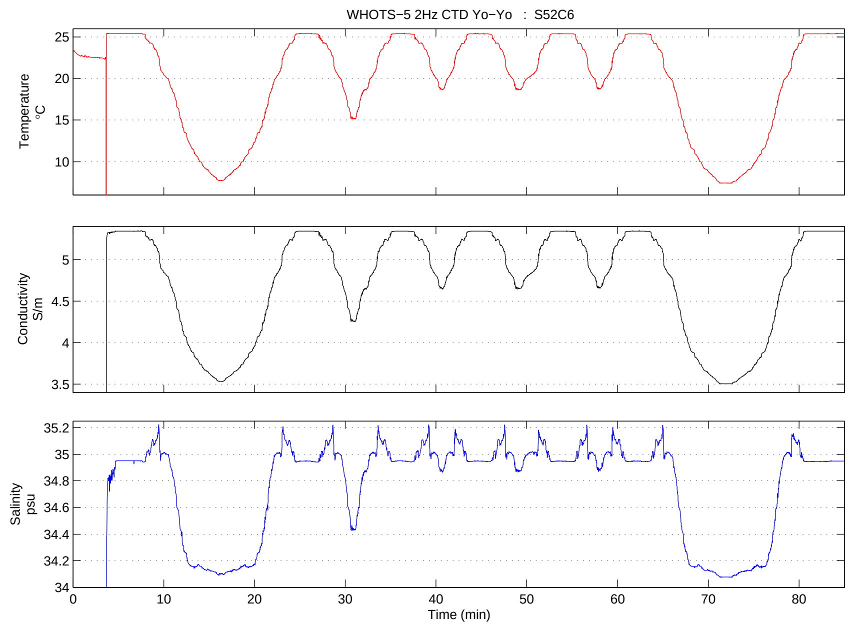

Figure A4-20. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S52C6.

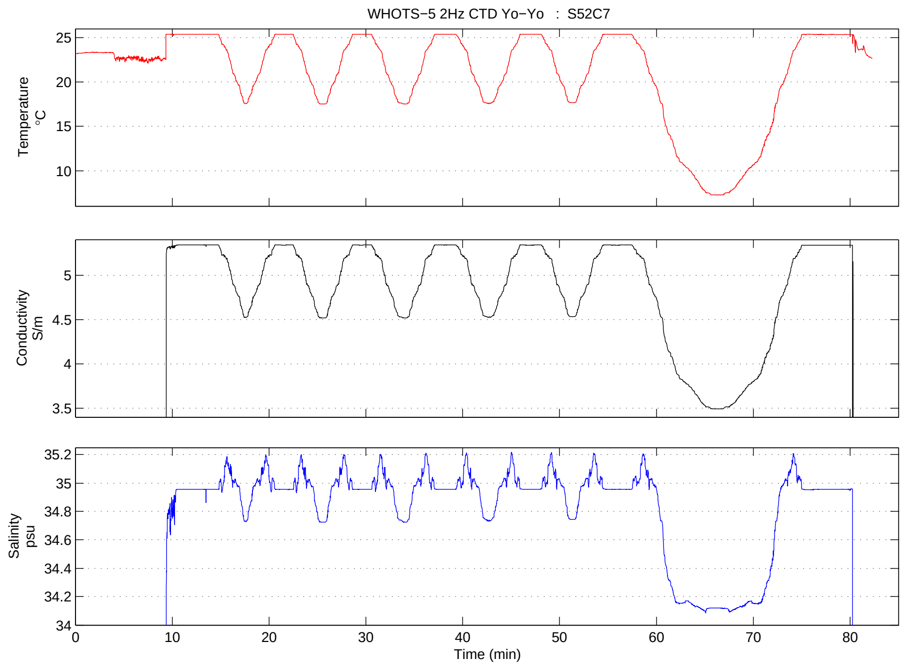

Figure A4-21. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S52C7.

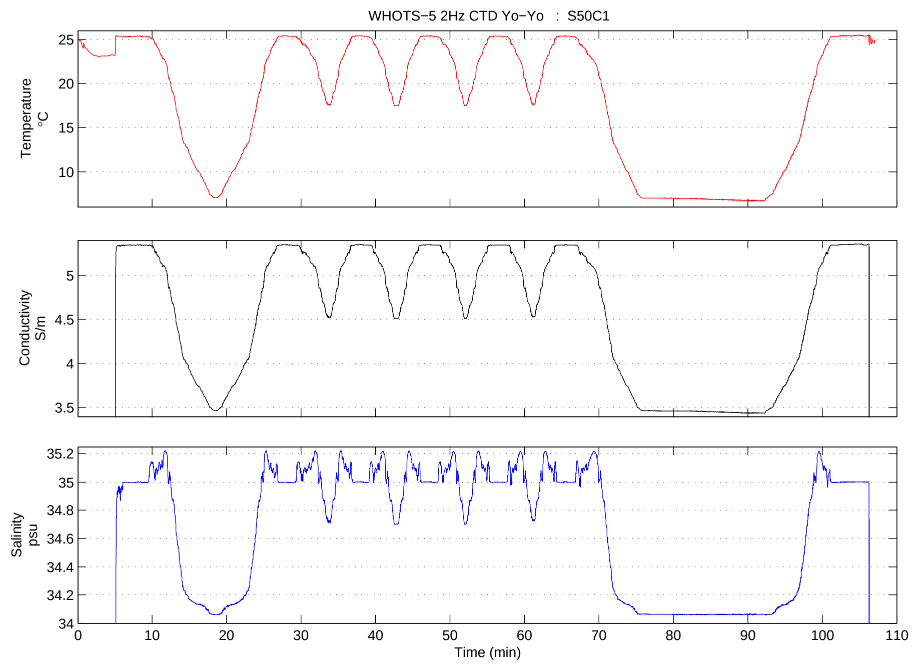

Figure A4-22. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C1.

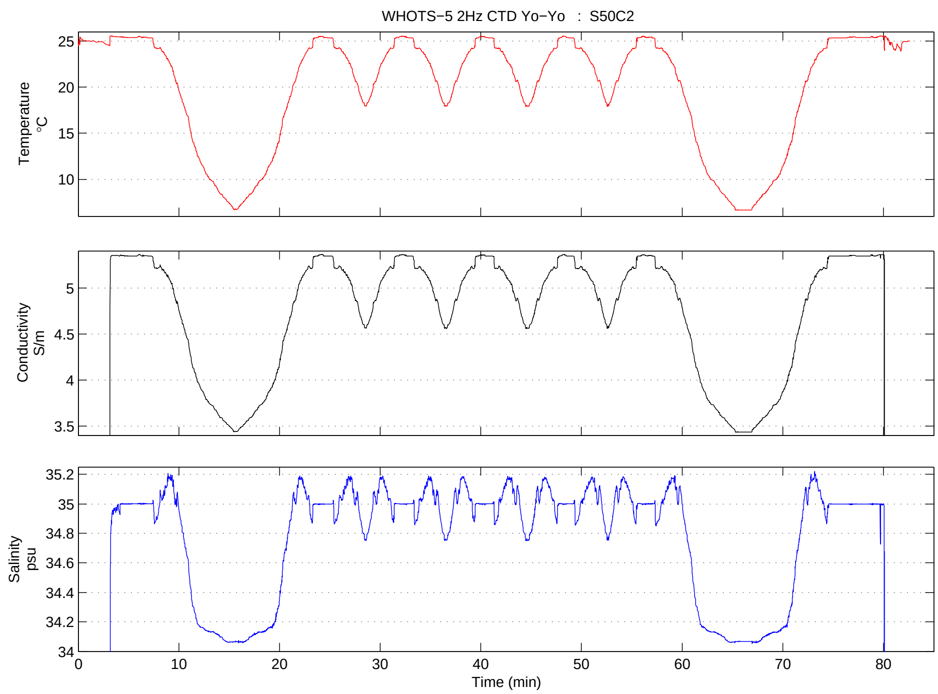

Figure A4-23. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C2.

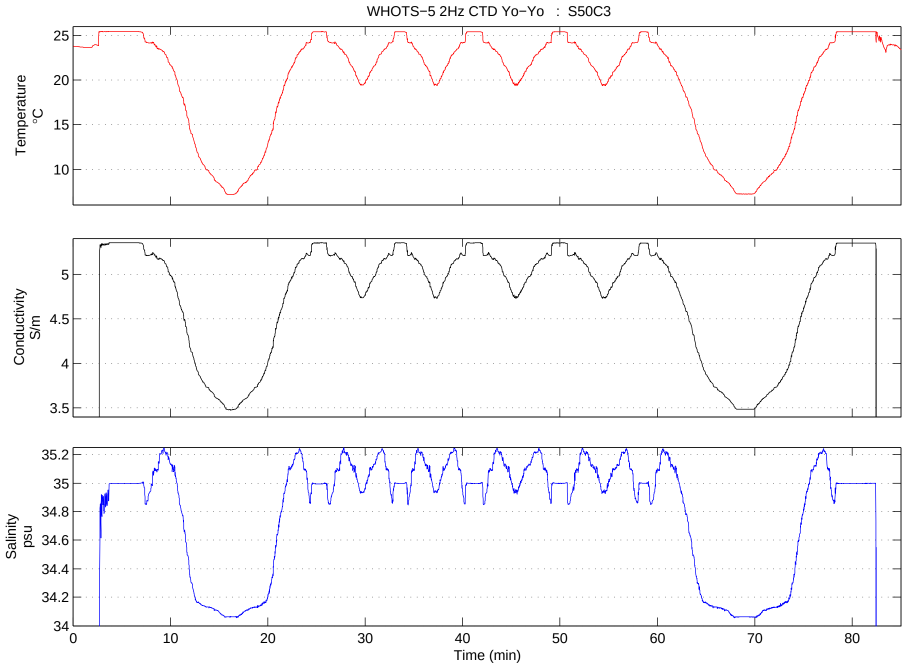

Figure A4-24. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C3.

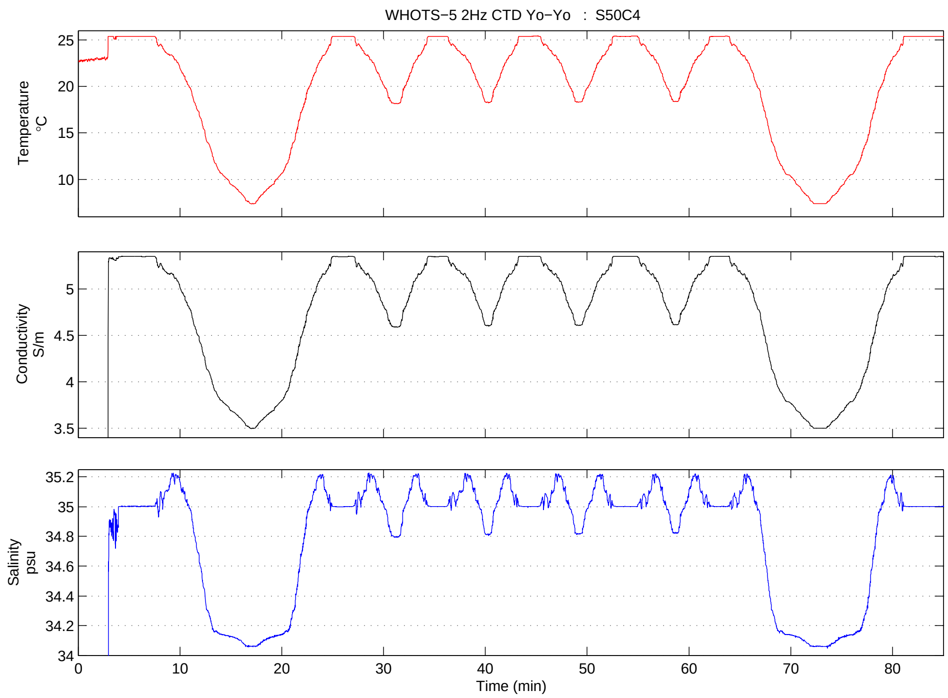

Figure A4-25. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C4.

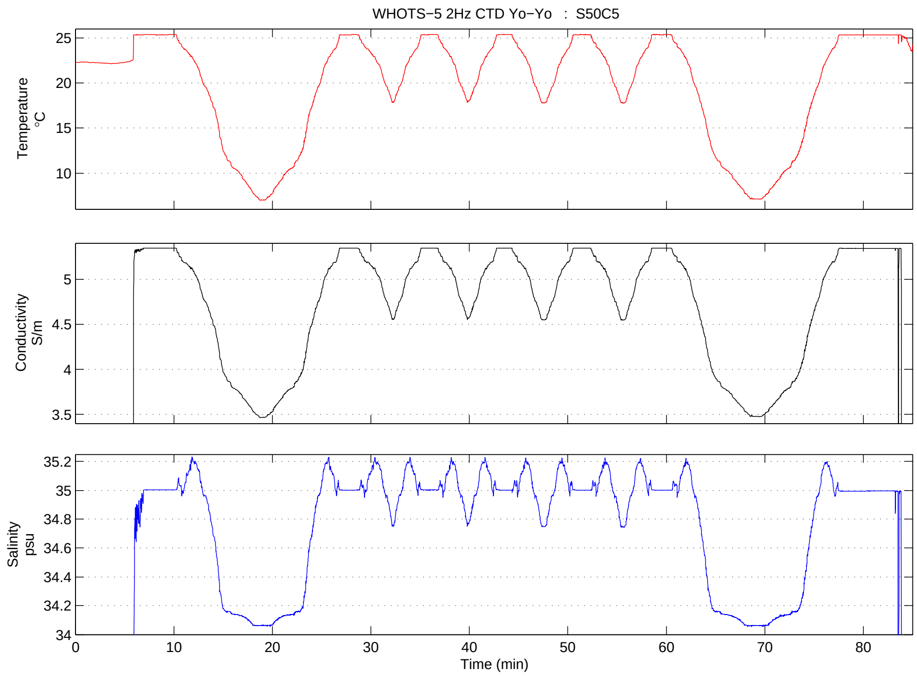

Figure A4-26. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C5.

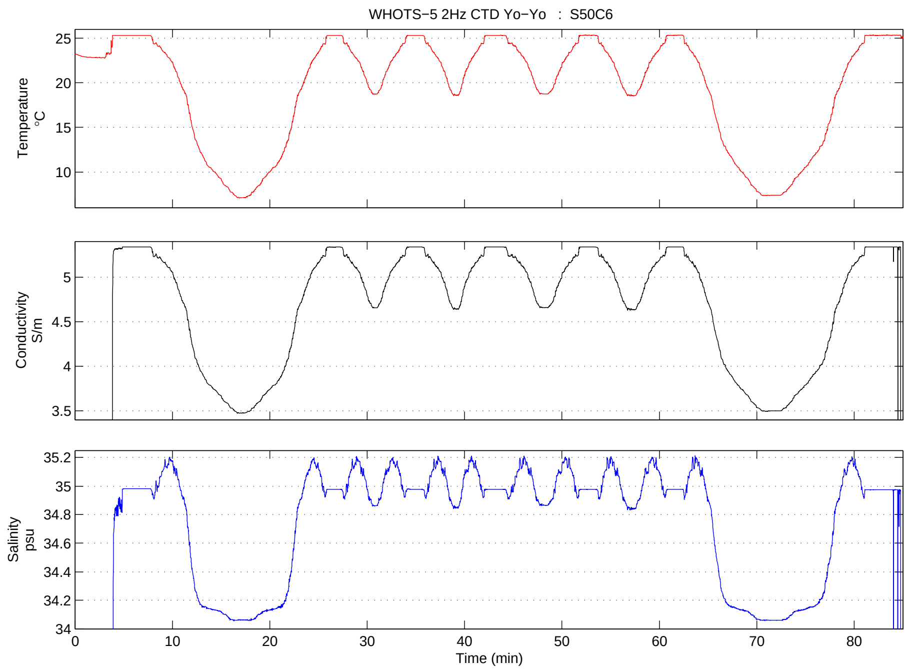

Figure A4-27. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C6.

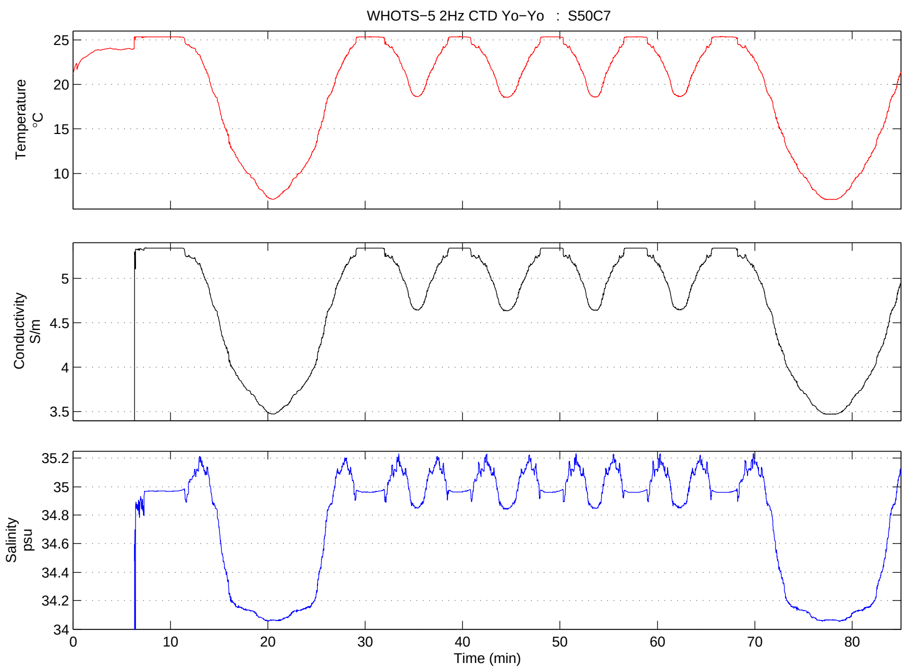

Figure A4-28. Time-series of 2 Hz temperature, conductivity and salinity data during CTD S50C7.

Appendix 5. Thermosalinograph

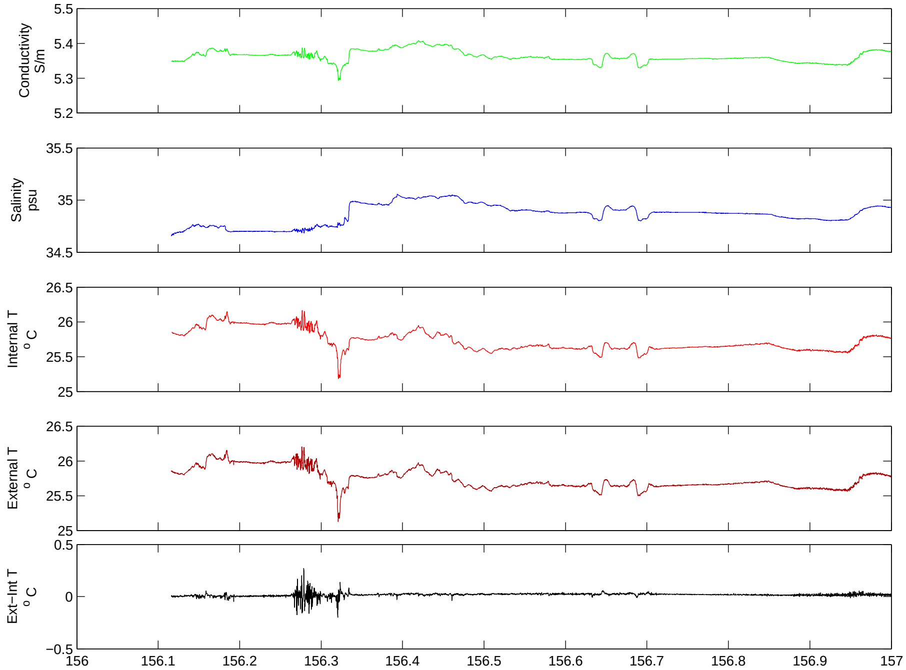

Figure A5-1. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 4 June 2008. The time axis is in Julian days.

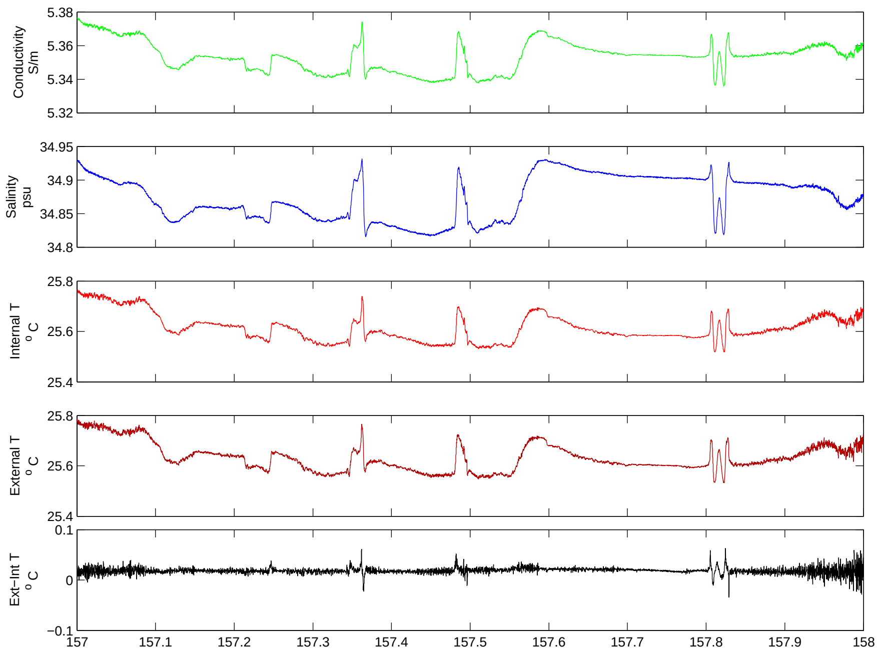

Figure A5-2. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 5 June 2008. The time axis is in Julian days.

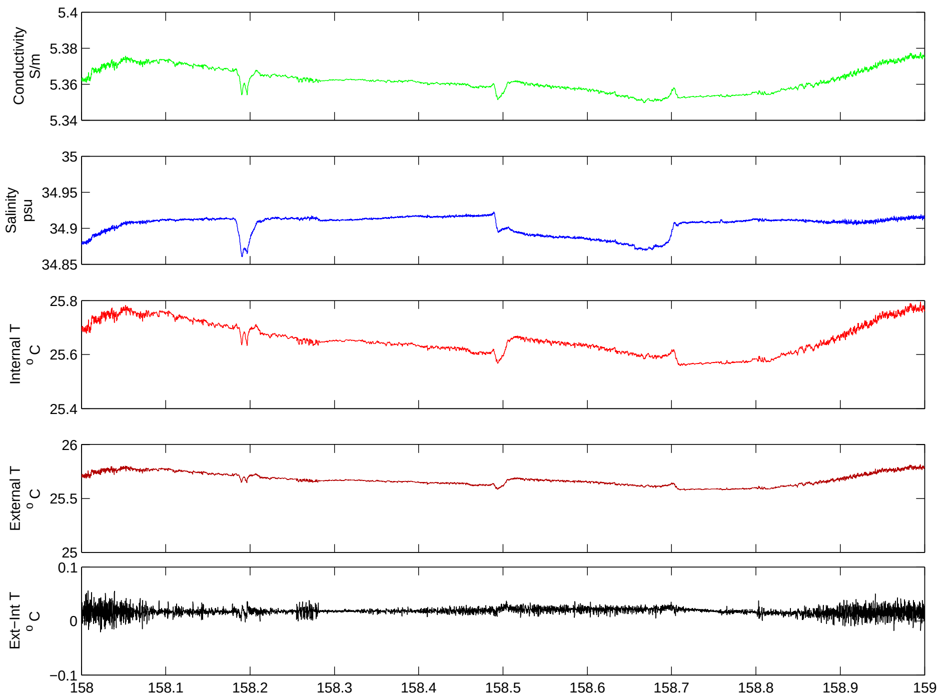

Figure A5-3. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 6 June 2008. The time axis is in Julian days.

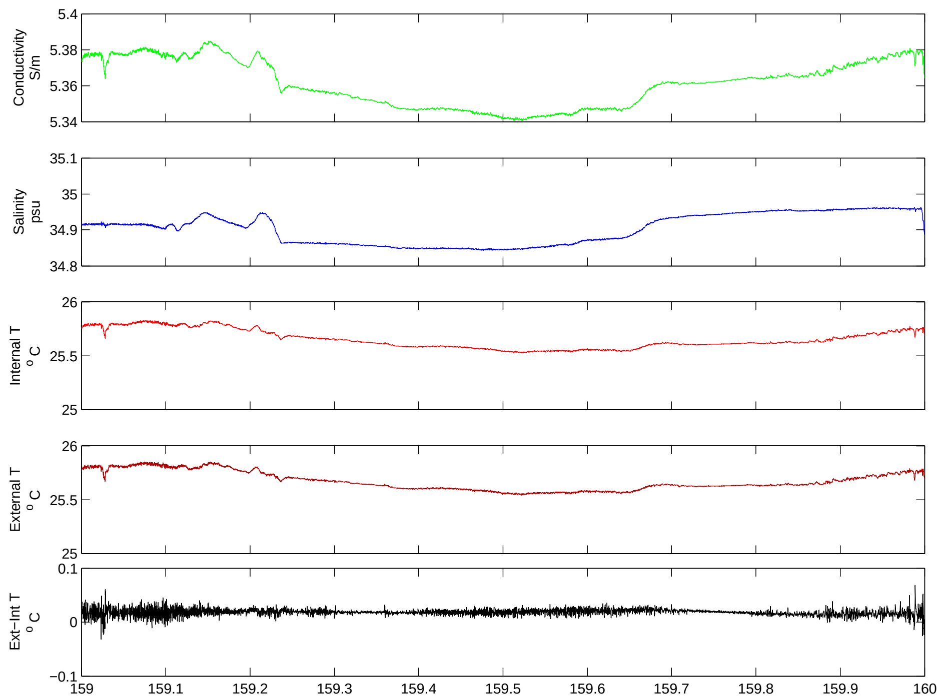

Figure A5-4. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 7 June 2008. The time axis is in Julian days.

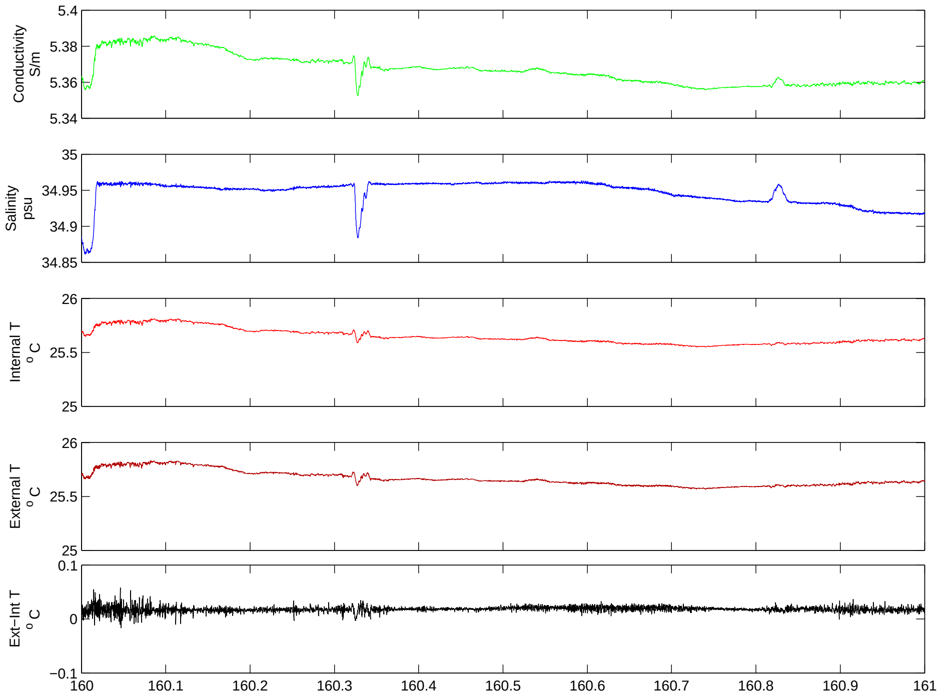

Figure A5-5. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 8 June 2008. The time axis is in Julian days.

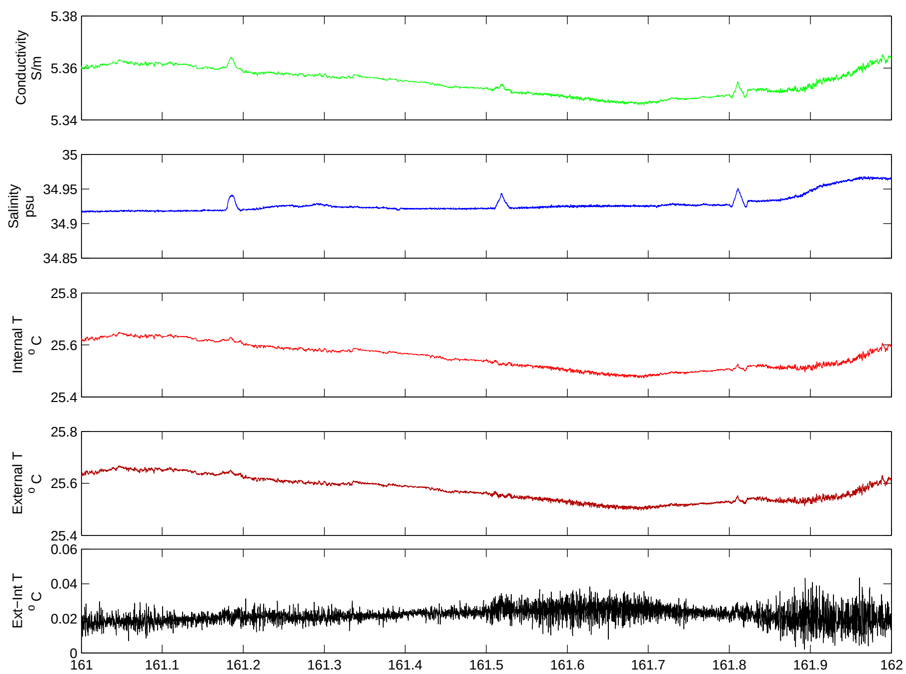

Figure A5-6. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 9 June 2008. The time axis is in Julian days.

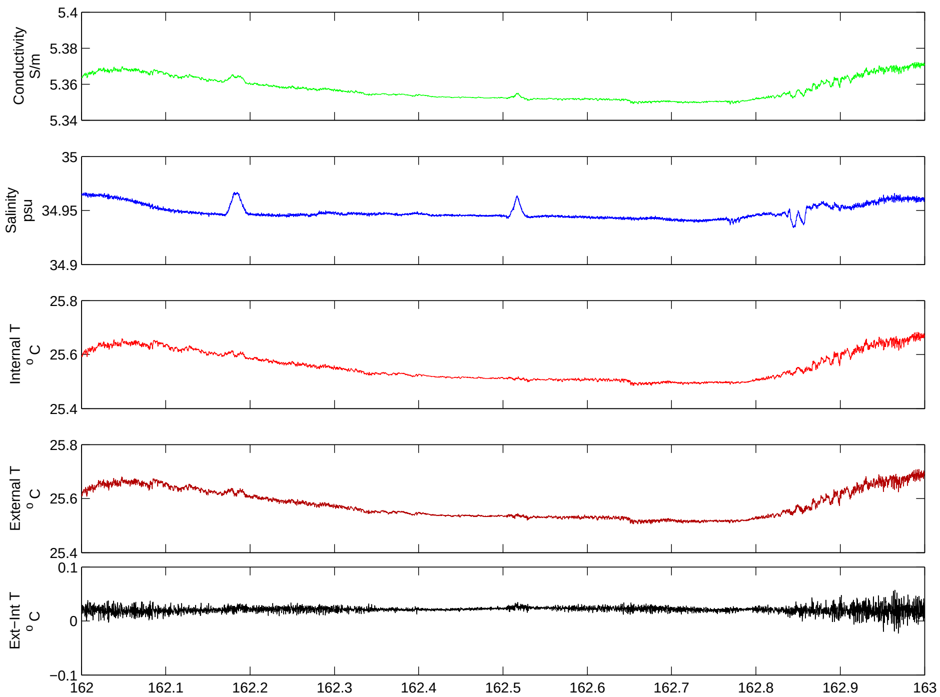

Figure A5-7. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 10 June 2008. The time axis is in Julian days.

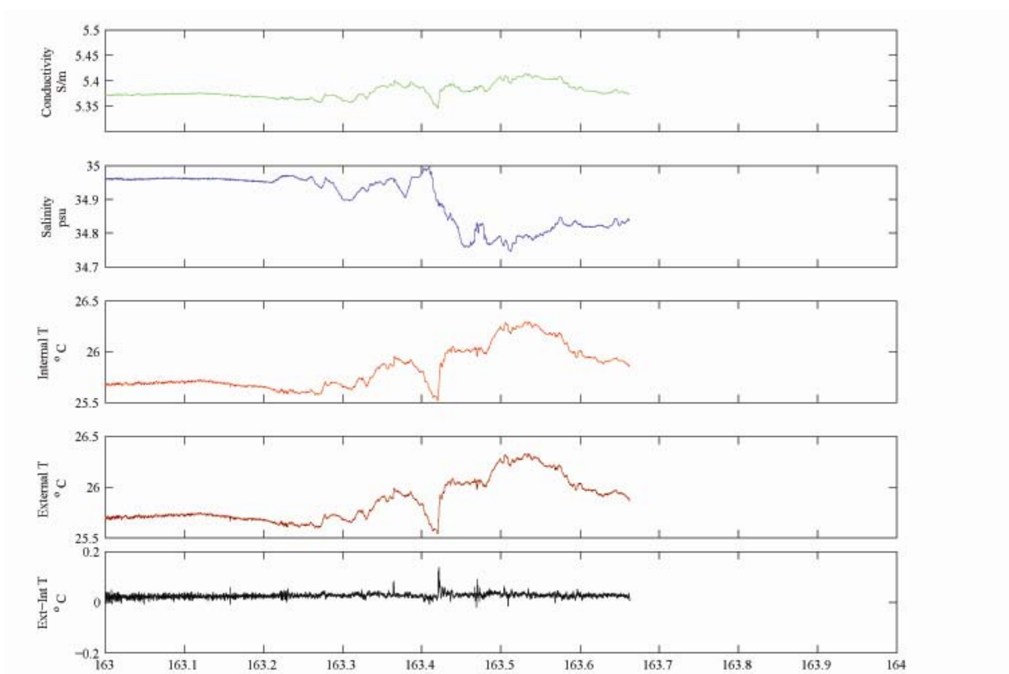

Figure A5-8. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 11 June 2008. The time axis is in Julian days

Appendix 6: WHOTS 4 Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS 4 MOORED STATION NO. 1192

Launch (anchor over)

Date (day-mon-yr) 25 Jun 2007 Time 23:48:30 UTC

Latitude (N/S, deg-min) 20° 40.221 N Longitude (E/W, deg-min) 157 56.838 W

Deployed by Lord/Whelan Recorder/Observer Plueddemann

Ship and Cruise No. KM 07-08 Intended Duration 365 d.

Depth Recorder Reading 4756 m Correction Source XBT for soundspeed plus transducer offset from EM 120 multibeam

Depth Correction already corrected m

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

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

Surveyed Anchor Position

Lat (N/S) 22° 40.208 N Long. (E/W) 157° 57.001 W

Acoustic Release Model ORE/Edgetech 8242XS (tandem)

Release No. 32479 / 32482 Tested to 2000 m

Receiver No. N/A Release Command 132060 / 132157

Enable 114510 / 114651 Disable 114533 / 114672

Interrogate Freq. 11 KHZ Reply Freq. 12 KHZ

Recovery (release fired)

Date (day-mon-yr) 6 June 2008 Time 17:20:15 UTC

Latitude (N/S, deg-min) 22° 46.436' N Longitude (E/W, deg-min) 157° 57.065' W

Recovered by Ryder/Whelan/Weller Recorder/Observer Lukas

Ship and Cruise No. KM 08-08 Actual duration ______ days

Distance from actual waterline to buoy deck 70 cm

1

Surface Components

Buoy Type Foam hull MOB Color(s) Hull Yellow/White Tower white

Buoy Markings 'B' U. Hawaii 808-956-7896

Surface Instrumentation

Item	ID #	Height* (cm)	Comments
ASIMET	LØ7		
HRH	218	228	
BPR	503	242	
WND	221	314	
PRC	209	249	
LWR	209	283	
SWR	221	284	
SST	1839	-150	
PTT	14637	—	ID's 7563, 7581, 7582
ASIMET	L19		
HRH	219	229	
BPR	504	242	
WND	212	318 ~~275~~	
PRC	211	249	
LWR	219	283	
SWR	210	284	
SST	1837	-150	
PTT	18136	—	ID's 14633, 14677, 14697
SIS Argos	268		ID 25702
Floater SSTs			
L SBE-39	716		
L RBR 1050	12710		
GPS	67700		power cycled by L19
pCO_2	Sys# 0021		Systems check by PMEL prior to deployment

*Height above buoy deck in centimeters

Buoy WL = 70cm below deck

2

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SBE-37	1839	150	ASIMET L07
SBE-37	1837	150	ASIMET L19

†Depth below buoy deck in centimeters   Buoy WL = 70 cm below deck

3

Moored Station Number WHOTS-4 1192

Item No.	Length (m)	Item	Inst No.	Time Over (UTC)	Notes	Data No.	Depth (m)	Time Back	Notes
1	7.75	chain ✓	3/4"		~~see pg 8 for buoy~~			0108	Buoy released at 1753 UTC
2		VMCM ✓	034	1712	bands off 1707	0124:30 rotor spin	10	0108	Buoy W/LON DECK AT 00410
3	2.82	chain ✓	3/4					0113	Some sensors on tower hit under stern
4		μCAT ✓	3382 ✓	1710	SBE-37		15	0113	wind vane knocked off by a line
5	8.68	chain ✓	3/4					0118	
6		μCAT ✓	3621 ✓	1704	SBE-37		25	0118	
7	3.28	chain ✓	3/4					0121	
8		VMCM ✓	040	1704	bands off 1659	0136 rotor spin	30	0121	
9	2.82	chain ✓	3/4					0124	
10		μCAT ✓	3620 ✓	1701	SBE-37		35	0124	
11	3.66	chain ✓	3/4					0126	
12		μCAT ✓	3632 ✓	1659	SBE-37		40	0126	
13	3.66	chain ✓	3/4					0128	
14		μCAT ✓	2965 ✓	1656	SBE-37		45	0128	
15	2.13	chain ✓	3/4					0128	
16		ADCP ✓	1825 ✓	1654	WHOI 600 kHz		48.5	0022	grease on heads
17		μCAT ✓	3633 ✓	1634	SBE-37		50	0022	
18	3.66	chain ✓	3/4	6/25/04				0022	
19		μCAT ✓	3619 ✓	1817	SBE-37		55	0018	
20	8.7	wire ✓	7045-7	1817				0018	
21		μCAT ✓	3791 ✓	1820	SBE-37		65	0015	
22	8.7	wire ✓	7045-8	1820				0015	

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		µCAT ✓	3618 ✓	1822	SBE-37		75	0010	
24	8.7	wire ✓	7045-6	1822				0010	
25		µCAT ✓	3670 ✓	1825	SBE-37 w/press		85	0006	
26	8.7	wire ✓	7045-3	1825				0006	
27		µCAT ✓	3617 ✓	1827	SBE-37		95	0003	
28	8.7	wire ✓	7045-4	1827				0003	
29		µCAT ✓	3669 ✓	1830	SBE-37 w/press		105	2359	
30	13.6	wire ✓	7045-2	1830				2359	
31		µCAT ✓	2451 ✓	1833	SBE-37 w/press		120	2355	
32	3.66	chain ✓	3/4	1835				2355	
33		ADCP ✓	4891 ✓	1835	UH 300 kHz no grease on heads		125	2350	
34	8.7	wire ✓	7045-5	1835				2350	
35		µCAT ✓	3634 ~~155~~ ✓	1838	SBE-37		135.5	2346	
36	18.75	wire ✓	7045-1	1838				2346	
37		µCAT ✓	3668 ✓	1841	SBE-37 w/press		155.6	2340	
38	250	wire ✓	5234-9	1841				2340	
39	500	wire ✓	7045-10	1851				2331	
40	500	wire ✓	5234-10	1909				2316	
41	500	wire ✓	7045-9	1922				2302	jacket damaged, repaired at sea
42	100	wire ✓	5227-13	1950				2246	} spliced + wrapped
43	200	nylon	7/8"	1956				2241	}
44	2000	nylon	7/8"	2009				2224	
45	100	nylon	1"	2052					

Moored Station Number WHOTS-4 1192

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	1500	poly	1 1/8"	2055				2049	
47		glass balls		2150	4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 80				1930 balls in baskets
48	5	chain	1/2	2338					
49		release	32479✓	2338				1848	
50		release	32482✓	2338				1848	
51	5	chain	1/2	2339					balls on deck 1840
52	20	Nystron	1"	2340	change from drawing				balls on surface
53	8	chain	1/2	2348	due to extra distance to anchor				18:07 UTC
54		anchor		2348					
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

6

Appendix 7: WHOTS 5 Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS 5 MOORED STATION NO. 1198

Launch (anchor over)

Date (day-mon-yr) 5 June 08 Time 03:24:39 UTC

Latitude (N/S, deg-min) 22° 46.085' N Longitude (E/W, deg-min) 157° 53.833 W

Deployed by Ryder / Whelan / Weller Recorder/Observer Lukas

Ship and Cruise No. Kilo Moana 08-08 Intended Duration 365 days

Depth Recorder Reading ~~[illegible]~~ 4702 m Correction Source XBT correction for sound spd plus transducer depth included

Depth Correction — m

Corrected Water Depth 4702 m Magnetic Variation (E/W) ______

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

Surveyed Anchor Position

Lat (N/S) ~~[illegible]~~ 22° 46.0640' N Long. (E/W) 157° 54.0845' W

Acoustic Release Model ORE / Edgetech tandem

Release No.	~~31396~~ 32478	~~30841~~ 30841	
Receiver No.		~~32478~~	
Enable	~~[illegible]~~ 114442	~~114442~~ ~~166312~~ 166312	
Interrogate Freq.	11 kHz (both)		
Tested to	1500	1500	m
Release Command	~~[illegible]~~ 132043	151241	
Disable	~~[illegible]~~ 114461	166331	
Reply Freq.	12 kHz (both)		

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 65 cm m

1

Surface Components

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

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

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET	Logger 09		System 1
HRH	227	223.5	
BPR	505	233	
WND	228	260.5	
PRC	214	246	
LWR	205	285	
SWR	208	285	
SST	1419	-156	
PTT	27356, 27364, 27413		
ASIMET	Logger-10		System 2
HRH	216	223.5	
BPR	506	233	Horizontal
WND	205	260.5	wnd wnd 123
PRC	210	246	lwr lwr 24
LWR	210	285	swr swr 24
SWR	207	285	prc prc 150
SST	1306	-156	bpr bpr 59
PTT	[illegible], 27415, 27416		hrh hrh 256
SIS Argos			
Floater SST	39 5?E	0	SN 1447
Fixed hull SST	[illegible]1450	-115	SN 10986
PCO2		-100	
GPS	67699		

*Height above buoy deck in centimeters

2 Xeos —9060

Subsurface Instrumentation on Buoy and Bridle			
Item	**ID #**	**Depth†**	**Comments**
SBE37	1419	156	logger 9
SBE37	1306	156	logger 10
			initial deployment –
			Argos overplots look
			good with WHOTS 4
			and ship except one
			WHOTS 5 wind looks
			~30° out
		buoy	waterline – 68 cm
		~ 0100 UTC	6/10/08
			small boat ride –
			replace WHOTS 5 lgr 9
			wind SN 228 with
			wind SN 219

†Depth below buoy deck in centimeters

3

Moored Station Number

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		buoy hull		1950	quick release + strap right side slipped through past wind vane				1924 PCO2 floater free
2	7.75	chain	3/4						SST float appears
3		VMCM	03 ✓	1905	spin@1903		10		stuck@ bottom
4	2.82	chain	3/4						
5		seacat	1699 ✓	1902			15		
6	8.68	chain	3/4						
7		seacat	1085 ✓	1858			25		
8	3.28	chain	3/4						
9		VMCM	037 ✓	1853	spin@ 1850		30		
10	2.82	chain	3/4						
11		seacat	1087 ✓	1849			35		
12	3.66	chain	3/4						
13		microcat	338 ✓	1845			40		
14	3.66	chain	3/4						
15		microcat	4663 ✓	1841			45		
16	1.20	chain	3/4						
17		RDI 1.2 MHz	2530 ✓	1841			47.5		
18	1.00	chain	3/4						
✓ 19		seacat	1088 ✓	1836	slightly banged stern		50		
20	3.66	chain	3/4						
21		seacat	1090 ✓	2004			55		
22	8.70	wire	7/16						

Item No.	Length (m)	Item	Inst No. (1092)	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		Seacat	1092 ✓	2009			65		
24	8.70	wire	7/16						
25		Seacat	1095 ✓	2013			75		
26	8.70	wire	7/16						
27		microcat	4699 ✓	2016			85		
28	8.70	wire	7/16						
29		Seacat	1097 ✓	2019			95		
30	8.70	wire	7/16						
31		microcat	2769 ✓	2024			105		
32	13.6	wire	7/16						
33		microcat	4701 ✓	2027			120		
34	3.66	chain	3/4						
35		RDI 300 kHz	7637 ✓	2031			125		
36	8.70	wire	7/16						
37		Seacat	1100 ✓	2035			135		
38	18.75	wire	7/16						
39		microcat	4700 ✓	2038			155		
40	250	wire	3/8 ✓	2047					
41	500	wire	3/8 ✓	2108					
42	500	wire	3/8	2141					
43	500	wire	3/8	2204					
44	100m	wire	3/8	2209	) one piece,				
45	200m	nylon	7/8	2229	) wrapped termination				

5

Moored Station Number ____________

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	2000	7/8 nylon	7/8						
47	100	nylon	1"	2340	end of nylon				
48	1500	poly prop.	1 1/8"	0052					
49		glass balls	80 balls	0128	on 1/2" trawler chain				𝍸 𝍸 𝍸 𝍸
50	5	chain	1/2"	0251	✓				
51	1	~~[illegible]~~ dual acoustic releases		0251	32478/30841 ✓				
52	1	chain	1/2	0251	release links				
53	5	chain	1/2"						
54	20	samson	1"						
55	5	chain	1/2"						
56		anchor	9300 lb	0324:39	22° 46.005N 157°53.833°W				
57									
58		0400, 0403,	0405,	0420	balls implode				
59		4100, 4300,	4500,	bottom	estimated depths of implosion				
60									
61									
62									
63									
64									
65									
66									
67									

50272-101

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7. Author(s) Sean Whelan et al.

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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 part of the NOAA Climate Observation Program. The WHOTS mooring also serves as a coordinated part of the HOT program, contributing to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near 22.75°N, 158°W by successive mooring turnarounds. These observations will be used to investigate air–sea interaction processes related to climate variability.

The first four WHOTS moorings (WHOTS-1 through 4) were deployed in August 2004, July 2005, June 2006, and June 2007, respectively. This report documents recovery of the WHOTS-4 mooring and deployment of the fifth mooring (WHOTS-5). Both moorings used Surlyn foam buoys as the surface element and were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 155 m of the moorings were outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity in a cooperative effort with R. Lukas of the University of Hawaii. A pCO_2 system was installed on the WHOTS-5 buoy in a cooperative effort with Chris Sabine at the Pacific Marine Environmental Laboratory.

The WHOTS mooring turnaround was done on the University of Hawaii research vessel *Kilo Moana*, Cruise KM-08-08, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 3 and 11 June 2008. Operations began with deployment of the WHOTS-5 mooring on 5 June at approximately 22°46.1′N, 157°54.1′W in 4702 m of water. This was followed by meteorological intercomparisons and CTDs at the WHOTS-4 site. A period of calmer weather was taken advantage of to recover WHOTS-4 on 6 June 2008. The *Kilo Moana* then returned to the WHOTS-5 mooring for CTD operations and meteorological intercomparisons. This report describes these cruise operations, as well as some of the in-port operations and pre-cruise buoy preparations.

17. Document Analysis a. Descriptors

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b. Identifiers/Open-Ended Terms

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