Hydrographic Observations at the Woods Hole Oceanographic Institution Hawaii Ocean Time-series Site: 2009 – 2010 Data Report #6

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1. Introduction

In 2003, Robert Weller (Woods Hole Oceanographic Institution [WHOI]), Albert Plueddemann (WHOI) and Roger Lukas (University of Hawaii [UH]) proposed to establish a long-term surface mooring at the Hawaii Ocean Time-series (HOT) Station ALOHA (22°45'N, 158°W) to provide sustained, high-quality air-sea fluxes and the associated upper ocean response as a coordinated part of the HOT program, and as an element of the global array of ocean reference stations supported by the National Oceanic and Atmospheric Administration's (NOAA) Office of Climate Observation.

With support from NOAA and the National Science Foundation (NSF), the WHOI HOT Site (WHOTS) surface mooring has been maintained at Station ALOHA since August 2004. The objective of this project is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and contribute to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near Station ALOHA by successive mooring turnarounds. These observations are being used to investigate air-sea interaction processes related to climate variability and change.

The original mooring system is described in the mooring deployment/recovery cruise reports (Plueddemann et al., 2006; Whelan et al., 2007). Briefly, a Surlyn foam surface buoy is equipped with meteorological instrumentation including two complete Air-Sea Interaction Meteorological (ASIMET) systems (Hosom et al. (1995), Colbo and Weller (2009)), measuring air and sea surface temperatures, relative humidity, barometric pressure, wind speed and direction, incoming shortwave and longwave radiation, and precipitation. Complete surface meteorological measurements are recorded every minute, as required to compute air-sea fluxes of heat, freshwater and momentum. Each ASIMET system also transmits hourly averages of the surface meteorological variables via the Argos satellite system and via iridium. The mooring line is instrumented in order to collect time series of upper ocean temperatures, salinities and velocities with the surface forcing record. This includes vector measuring current meters, conductivity, salinity and temperature recorders, and two Acoustic Doppler current profilers (ADCPs). See the WHOTS-6 mooring diagram in Figure 1-1.

The subsurface instrumentation is located vertically to resolve the temporal variations of shear and stratification in the upper pycnocline to support study of mixed layer entrainment. Experience with moored profiler measurements near Hawaii suggests that Richardson number estimates over 10 m scales are adequate. Salinity is clearly important to the stratification, as salt-stratified barrier layers are observed at HOT and in the region (Kara et al., 2000), so we use Sea-Bird MicroCATs with vertical separation ranging from 5-20 m to measure temperature and salinity. We use an RDI ADCP to obtain current profiles across the entrainment zone and another in the mixed layer. Both ADCPs are in an upward-looking configuration, one is at 125 m, using 4 m bins, and the other is a 47.5 m using 2 m bins. To provide near-surface velocity (where the ADCP estimates are less reliable) we deploy two Vector Measuring Current Meters (VMCMs).

The nominal mooring design is a balance between resolving extremes versus typical annual cycling of the mixed layer (see WHOTS Data Report 1-2, Santiago-Mandujano et al., 2007

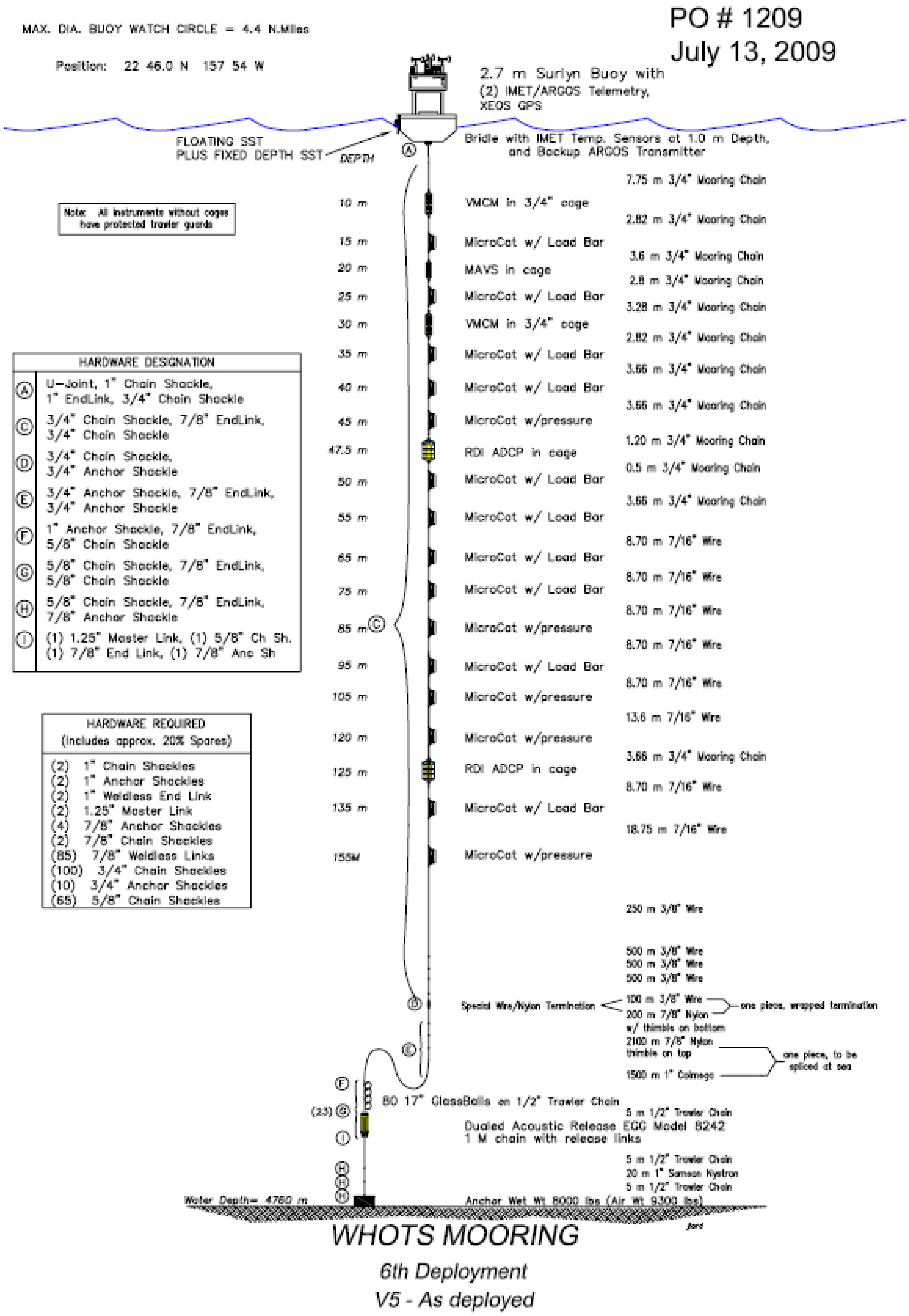


Figure 1-1. WHOTS-6 mooring design.

The sixth mooring (WHOTS-6 mooring) was deployed during the WHOTS-6 cruise, and it was recovered in July 2010 during a 9-day cruise (WHOTS-7 cruise) both aboard the UH R/V *Kilo Moana*. A seventh mooring (WHOTS-7 mooring) was deployed during the WHOTS-7 cruise; to be recovered in July 2011.

This report documents and describes the oceanographic observations made on the sixth WHOTS mooring during a period of nearly one year, and from shipboard during the two cruises when the mooring was deployed and recovered. Sections 2 and 3, respectively, include a detailed description of the cruises and the mooring. Sampling and processing procedures of the hydrographic casts, thermosalinograph, and shipboard ADCP data collected during cruises are in Section 4. Section 5 includes the processing procedures for the data collected by the moored instruments: SeaCATs, MicroCATs, VMCMs, and moored ADCP. Plots of the resulting data and a preliminary analysis are included in Section 6.

2. Description of the WHOTS-6 Mooring Cruises

A. WHOTS-6 Cruise: WHOTS-6 Mooring Deployment

The Woods Hole Oceanographic Institution Upper Ocean Processes Group (WHOI/UOP), with the assistance of the UH group conducted the sixth deployment of the WHOTS mooring at HOT Station 52 on board the R/V *Kilo Moana* during the WHOTS-6 cruise on 11 July 2009 at 01:18 UTC. The WHOTS-6 mooring was recovered during the WHOTS-7 cruise between July 9th and 17th, 2010. The scientific personnel that participated during the WHOTS-6 cruise are listed in Table 2-1.

Table 2-1. Scientific personnel on R/V Kilo Moana during the WHOTS-6 deployment cruise.

Cruise	**Name**	**Title or function**	**Affiliation**
WHOTS-6	Bariteau, Ludovic	Scientist	CIRES/UC
	Bradley, Frank	Scientist	CSIRO
	Dunn, Thomas	Student	UH
	Hawkins, Ian	Student	UH
	Kelly, Julie	Student	UH
	Lethaby, Paul	Research Associate	UH
	Lukas, Roger	Scientist	UH
	Plueddemann, Al	Chief Scientist	WHOI
	Quisenberry, Carly	Volunteer	UH
	Rapp, Anita	Student	CIRES/UC
	Ryder, James	Technician	WHOI
	Santiago-Mandujano, Fernando	Research Associate	UH
	Simmons, Bradley	Student	UH
	Snyder, Jefrey	Technician	UH
	Sperber, Scott	Outreach	Teacher
	Stanitski, Diane	Outreach	Teacher

Cruise	Name	Title or function	Affiliation
	Stein, Karl	Student	UH
	Whelan, Sean	Technician	WHOI

The shipboard oceanographic observations during the cruise were conducted by the UH group. A complete description of these operations is available in the WHOTS-6 cruise report (Whelan *et al.*, 2010a).

The WHOTS-6 mooring was deployed at approximately 22° 40' N, 157° 57' W in 4758 m of water. After a series of CTD and meteorological intercomparisons at the WHOTS-5 mooring site, the WHOTS-5 mooring was recovered on 15 July, 2009.

The ship provided CTD and water sampling equipment, including a Seabird 9/11+ CTD sampling at 24 Hz, with pressure, dual temperature and dual conductivity sensors. Sea-Bird temperature and conductivity sensors used by UH routinely as part of the Hawaii Ocean Time-series were used to allow the data to be more easily tied into the HOT CTD dataset. The CTD was installed inside a twelve-place rosette with 12-liter Bullister-type sampling bottles.

A total of 10 CTD profiles were obtained. Five CTD casts were conducted near the WHOTS-5 mooring (station 50) before recovery, four CTD casts were conducted at the WHOTS-6 mooring (station 52) after deployment, and one deep cast was conducted at station ALOHA (station 2). The casts were made to obtain profiles for comparison with subsurface instruments on the WHOTS-5 mooring before recovery (station 50, casts 1,3,4,5), and with those on the WHOTS-6 mooring after deployment (station 52, casts 1 through 4). The comparison casts each consisted of 5 yo-yo cycles between 5 dbar and 200 dbar, with the last cycle up to 200, 500 or 1020 dbar. Station 50 cast 2 had only one yo-yo cycle because the winch operator inadvertently took the CTD out of the water at the end of the first cycle and the cast was terminated. The time, location, and maximum CTD pressure for each of the profiles are listed in Table 2-2.

Water samples were taken from all casts except station 50 cast 2; 6 samples for 1020 dbar and 4808 dbar casts, and 2 to 3 samples each for the 500 dbar casts. These samples were analyzed for salinity and used to calibrate the CTD conductivity sensors.

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

Table 2-2 CTD Stations occupied during the WHOTS-6 deployment cruise. Note that numbering of stations follows the HOT conventions.

Station/cast	Date	Time (GMT)	Location	Maximum pressure (dbar)
52/1	7/11/09	16:02	22°40.62´N,157°59.32´W	1020
52/2	7/11/09	19:55	22°40.61´N,157°58.94´W	502
52/3	7/11/09	23:52	22°40.62´N,157°58.97´W	502
52/4	7/12/09	3:52	22°40.63´N,157°58.98´W	502
50/1	7/13/09	15:55	22°46.51´N,157°55.95´W	500

50/2	7/13/09	19:53	22°46.64´N,157°55.94´W	200
50/3	7/13/09	20:18	22°46.65´N,157°55.94´W	502
50/4	7/13/09	23:53	22°46.96´N,157°55.63´W	500
50/5	7/14/09	3:55	22°46.62´N,157°55.78´W	500
2/1	7/16/09	22:03	22°45.01´N,158°00.00´W	4808

In addition to CTD profiles, continuous ADCP and near-surface TSG data were obtained while underway.

The *R/V Kilo Moana* was equipped with an RD Instruments Ocean Surveyor 38 kHz ADCP and an RD Instruments Work Horse 300 kHz ADCP. Configurations for each system are shown in Table 2-3. The two systems used input from the gyro compass and corrected using a TSS POS/MV 320 (an integrated inertial and GPS system) to establish heading information. An Ashtech ADU5 is used as a heading correction device should there be a problem with the POS/MV. Position data are provided by the POS/MV system with the Ashtech ADU5 and a Trimble GPS as backups.

Table 2-3 Configuration of the RD Instruments Ocean Surveyor 38 kHz ADCP and the Work Horse 300 kHz ADCP on board the R/V Kilo Moana during the WHOTS-6 deployment cruise.

	OS38 - Narrow	**OS38 – Broad**	**WH300**
Sample interval (s)	300	300	120
Number of bins	70	75	32
Bin Length (m)	24	12	4
Pulse Length (m)	24	13	4
Transducer depth (m)	7	7	7
Blanking length (m)	16	16	4

The TSG observations were made by the ship's underway uncontaminated seawater system, drawing water from a nominal depth of 8 meters with a sampling interval of 10 seconds. The data were acquired continuously during the WHOTS-6 cruise, with salt calibration samples taken roughly twice per day from an outlet in the flow through system located less than 1.5 m from the TSG. In addition, the temperature and salinity records were checked against the CTD station data.

B. WHOTS-7 Cruise: WHOTS-6 Mooring Recovery

The WHOI/UOP Group conducted the mooring turnaround operations during the WHOTS-7 cruise between July 27th and August 4th, 2010 aboard the R/V *Kilo Moana*. The WHOTS-7 mooring was deployed at HOT Station 50 on 29 July 2010 at 02:37 UTC.

The scientific personnel that participated during the cruise are listed in Table 2-4.

Table 2-4. Scientific personnel during the WHOTS-7 cruise (WHOTS-6 mooring recovery).

Cruise	**Name**	**Title or function**	**Affiliation**
WHOTS-7	Weller, Robert	Senior Scientist/PI	WHOI
	Smith, Jason	Senior Engineering Assistant	WHOI
	Whelan, Sean	Engineering Assistant	WHOI
	Ostrom, Will	Senior Engineering Assistant	WHOI
	Signell, Elizabeth	Project Manager	WHOI
	McCarty, Amanda	NOAA Observer	NOAA
	Lukas, Roger	Senior Scientist/PI	UH
	Nosse, Craig	Research Associate	UH
	Lethaby, Paul	Technician	UH
	Snyder, Jefrey	Marine Electronics Technician	UH
	Fumar, Cameron	Research Associate	UH
	Keopaseut, Bo	Research Associate	UH
	Gum, Joseph	Student	UH
	Slotke, Danielle	Grad Student	UH
	Chou, Sherry	Grad Student	UH
	King, Steven	Teacher	Shepherd
	Polidoro, Vic	Marine Technician	UH/OTG
	Vellalos, Kuhio	Marine Technician	UH/OTG
	Goodman, Trevor	Marine Technician	UH/OTG
	Hashisaka, Dave	Marine Technician	UH/OTG

The shipboard oceanographic observations during the cruise were conducted by the UH group. A complete description of these operations is available in the WHOTS-7 cruise report (Whelan *et al.*, 2010b).

A Sea-Bird CTD (conductivity, temperature and depth) system was used to measure T, S, and O_2 profiles during eleven CTD casts. The time, location, and maximum CTD pressure for each of the profiles are listed in Table 2-5.

A total of 13 CTD casts were conducted at stations 52 (near the WHOTS-6 buoy), 50 (near the WHOTS-7 buoy), and a test station. The first cast at station 50 was 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-6 mooring before recovery, and six more casts were conducted for comparison with the WHOTS-7 mooring after deployment. These were sited approximately 200 to 500 m from the buoys. The comparison casts consisted of 5 yo-yo cycles between 5 dbar and 200 dbar and then to 500 dbar (6th yo-yo cycle of each cast) except for the first cast at station 50 which went to 1000 dbar and only had 5 cycles. Station numbers were assigned following the convention used during HOT cruises.

Water samples were taken from all casts; 6 samples for the 1000 dbar casts and 3 samples each for the 500 dbar casts. These samples were analyzed for salinity and used to calibrate the CTD conductivity sensors.

Table 2-5. CTD stations occupied during the WHOTS-7 cruise (WHOTS-6 mooring recovery).

Station	Date	Time (GMT)	Location	Maximum pressure (dbar)
Test	7/28/10	04:05	21° 47.09´ N, 158° 15.13´ W	1030
50/1	7/29/10	15:59	22° 47.98´ N, 157° 55.29´ W	1030
50/2	7/29/10	19:59	22° 48.14´ N, 157° 54.75´ W	502
50/3	7/29/10	23:57	22° 48.33´ N, 157° 55.05´ W	500
50/4	7/30/10	03:53	22° 48.00´ N, 157° 54.43´ W	500
50/5	7/30/10	07:56	22° 48.34´ N, 157° 54.86´ W	500
50/6	7/30/10	11:57	22° 48.11´ N, 157° 55.46´ W	500
52/1	7/30/10	15:56	22° 41.67´ N, 157° 58.55´ W	502
52/2	7/30/10	19:48	22° 41.78´ N, 157° 58.31´ W	500
52/3	7/30/10	23:57	22° 41.75´ N, 157° 58.79´ W	502
52/4	7/31/10	03:55	22° 41.60´ N, 157° 58.06´ W	500
52/5	7/31/10	07:50	22° 41.83´ N, 157° 58.63´ W	502
52/6	7/31/10	11:53	22° 41.31´ N, 157° 59.25´ W	500

In addition, continuous acoustic Doppler current profiler (ADCP) and near surface thermosalinograph (TSG) data were obtained while underway.

The *R/V Kilo Moana* was equipped with an RD Instruments Ocean Surveyor 38 kHz ADCP and an RD Instruments Work Horse 300 kHz ADCP. Configurations for each system are shown in Table 2-6. The two systems used input from the gyro compass and corrected using a TSS POS/MV 320 (an integrated inertial and GPS system) to establish heading information. An Ashtech ADU5 is used as a heading correction device should there be a problem with the POS/MV. Position data are provided by the POS/MV system with the Ashtech ADU5 and a Trimble GPS as backups.

Table 2-6. Configuration of the RD Instruments Ocean Surveyor 38 kHz ADCP and the Work Horse 300 kHz ADCP on board the R/V Kilo Moana during the WHOTS-7 cruise.

	OS38 - Narrow	**OS38 – Broad**	**WH300**
Sample interval (s)	300	300	120
Number of bins	70	75	32
Bin Length (m)	24	12	4
Pulse Length (m)	24	13	4
Transducer depth (m)	7	7	7
Blanking length (m)	16	16	4

The TSG observations were made by the ship's underway uncontaminated seawater system, drawing water from a nominal depth of 8 meters with a sampling interval of 10 seconds. The data were acquired continuously during the WHOTS-7 cruise, with salt calibration samples taken roughly twice per day from an outlet in the flowthrough system located less than 1.5 m from the TSG. In addition, the temperature and salinity records were checked against the CTD station data.

The scientific personnel that participated during the WHOTS-7 cruise are listed in Table 2-4.

3. Description of WHOTS-6 Mooring

The WHOTS-6 mooring deployed on 11 July 2009 from *R/V Kilo Moana* was outfitted with a full suite of ASIMET sensors on the buoy and subsurface instruments from 10 to 155 m of depth (Figure 1-1). The WHOTS-6 recovery on 02 August 2010 resulted in 388 days on station.

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.

The WHOTS-6 mooring deployed an XEOS GPS Melo Logger. The unit was configured to sample every 25 minutes, for five minutes, at 10 second intervals. The instrument functioned throughout the entire deployment, with the first record taken at 9 July 2009 19:47 and the last sample at 3 August 2010 01:29.

UH provided 15 SBE-37 Microcats, an RDI 300 kHz Workhorse acoustic Doppler current profiler (ADCP), and a Nobska MAVS acoustic velocity sensor. The Microcats all measure temperature and conductivity, with 5 also measuring pressure. WHOI provided 2 Vector Measuring Current Meters (VMCM), an RDI 600 kHz Workhorse ADCP, two MicroCATs installed underneath the buoy, and all required subsurface mooring hardware. Table 3-1 provides the deployment information for these instruments.

Before deployment, the MicroCATs were dunked in a cold freshwater bath to generate a spike in the data to be used for synchronization of their internal clocks (Table 3-2).

The RDI 300 kHz Workhorse ADCP, SN 4891, was deployed at 125 m with transducers facing upwards. The instrument was set to ping at 4-second intervals for 160 seconds every 10 minutes. This burst sampling was designed to minimize aliasing by occasional large ocean swell orbital motions. Bin size was set for 4 m. The total number of ensemble records was 56,352. The first ensemble was at 07/08/2009 00:00:00Z, and the last was at 08/03/2010 07:47:00Z. This instrument also measured temperature.

The RDI 600 kHz Workhorse ADCP, SN 1825, was deployed at 47.5 m with transducers facing upwards. The instrument was set to ping at 1-second intervals for 120 seconds every 15 minutes. Bin size was set for 2 m. The total number of ensemble records was 56,052. The first ensemble was at 7/10/2009 00:00:00Z, and the last was at 8/3/2010 06:00:00Z. This instrument also measured temperature.

The two VMCMs, SN 010 and 058 were deployed at 10 m and 30 m depth respectively. The instruments were prepared for deployment by the WHOI/UOP group and set to record at 1-minute intervals. These instruments also measured temperature.

Table 3-1. WHOTS-6 Mooring instruments, deployment Information. All times stated are in GMT.

Depth (meters)	**Sea-Bird Serial #**	**Parameters**	**Sample Interval (sec)**	**Time Logging Started**	**Cold Spike Time**	**Time in the water**
1.5	SBE-37 1835	C,T	60	7/7/09 06:35	NA	07/10/09 19:31
1.5	SBE-37 1727	U,V	60	7/3/09 20:00	NA	07/10/09 19:31
10	VMCM 010	C,T	60	7/8/09 16:59	NA	07/10/09 18:40
15	37SM31486-6893	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 18:35
20	MAVS 10260	U,V,W,T	2	7/9/09 0:00	NA	07/10/09 18:31
25	37SM31486-6894	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 18:30
30	VMCM 058	U,W	60	7/8/09 16:59	NA	07/10/09 18:25
35	37SM31486-6895	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 18:24
40	37SM31486-6896	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 18:19
45	37SM31486-6887	C,T,P	90	7/6/09 0:00	7/6/2009 1:41	07/10/09 18:17
47.5	ADCP-600 1825	U,V,W,T	600	7/11/09 09:10	NA	07/10/09 19:48
50	37SM31486-6897	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 19:4 9
55	37SM31486-6898	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 19:53
65	37SM31486-6899	C,T	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 19:59
75	37SM31486-3618	C,T	150	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:03
85	37SM31486-6888	C,T,P	90	7/6/09 0:00	7/6/2009 1:41	07/10/09 20:06
95	37SM31486-3617	C,T	150	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:09
105	37SM31486-6889	C,T,P	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:12
120	37SM31486-6890	C,T,P	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:16
125	ADCP-300 4891	U,V,W,T	600	7/11/09 05:10	NA	07/10/09 20:19
135.5	37SM31486-3634	C,T	150	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:23
155.6	37SM31486-6891	C,T,P	90	7/6/09 0:00	7/6/2009 0:51	07/10/09 20:27

All instruments on the mooring were successfully recovered. Microcat SN 3617 was recovered without a conductivity guard. Most of the instruments had some degree of biofouling, with the heaviest fouling near the surface. Fouling extended down to the ADCP at 125 m, although it was minor at that level.

Table 3-2 gives the post-deployment information for the C-T instruments. All instruments returned full data records. Microcat SN 6888 conductivity sensor showed suspect readings beginning in August 2009. The sensor readings rose dramatically, then slowly drifted to near normal levels.

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 10 minutes 6 seconds ahead of GMT. The heading, pitch and roll information from the ADCP provided useful information about the overall behavior of the mooring during its deployment.

The data from the upward-looking 600 kHz ADCP at 47.5 m appears to be of high quality, however the instrument's clock on retrieval was offset by 3 minutes 8 seconds ahead of GMT.

Table 3-2. WHOTS-6 Mooring - MicroCAT Recovery Information. All times stated are in GMT

Depth (meters)	**Seabird Serial #**	**Time out of water**	**Time of cold spike**	**Time Logging Stopped**	**Samples Logged**	**Data Quality**
15	37SM31486-6893	8/3/2010 1:36	8/3/2010 4:40	8/3/2010 6:25	377537	good
25	37SM31486-6894	8/3/2010 1:47	8/3/2010 4:40	8/3/2010 23:38	378226	good
35	37SM31486-6895	8/3/2010 1:50	8/3/2010 4:40	8/3/2010 6:03	377523	good
40	37SM31486-6896	8/3/2010 1:50	8/3/2010 4:40	8/4/2010 0:10	378247	good
45	37SM31486-6887	8/3/2010 1:53	8/3/2010 4:40	8/3/2010 6:31	377541	good
50	37SM31486-6897	8/3/2010 1:53	8/3/2010 4:40	8/3/2010 5:48	399513	good
55	37SM31486-6898	8/3/2010 1:55	8/3/2010 4:40	8/3/2010 23:59	378240	good
65	37SM31486-6899	8/3/2010 2:01	8/3/2010 4:40	8/4/2010 0:14	378250	good
75	37SM31486-3618	8/3/2010 2:04	8/3/2010 4:40	8/3/2010 19:26	226834	good
85	37SM31486-6888	8/3/2010 2:08	8/3/2010 4:40	8/3/2010 5:41	377508	C sensor suspect
95	37SM31486-3617	8/3/2010 2:11	8/3/2010 5:23	8/3/2010 19:38	226839	good
105	37SM31486-6889	8/3/2010 2:14	8/3/2010 4:40	8/3/2010 23:54	378236	good
120	37SM31486-6890	8/3/2010 2:18	8/3/2010 4:40	8/3/2010 5:55	377517	good
135	37SM31486-3634	8/2/2010 22:38	8/3/2010 4:40	8/3/2010 19:30	226835	good
155	37SM31486-6891	8/2/2010 22:33	8/3/2010 4:40	8/3/2010 5:59	377519	good

4. WHOTS-6 and -7 cruise shipboard observations

The profile observations made during WHOTS cruises were obtained with a Sea-Bird CTD (conductivity, temperature and depth) instrument with duplicate temperature, conductivity sensors and oxygen. Measurements were made to better than 0.01°C in temperature, 0.01 for salinity, and 1.5 µmol/kg in dissolved oxygen below 5 m. In addition, R/V *Kilo Moana* came equipped with a thermosalinograph which provided a continuous, high-resolution depiction of temperature and salinity of the near-surface layer. Horizontal currents over a depth range of 40-800 m by the 38 kHz ADCP with a vertical resolution of 16 m during WHOTS-6 and -7.

A. Conductivity, Temperature and Depth (CTD) profiling

Continuous measurements of temperature, conductivity and pressure were made with the UH SBE-911+ CTD (SN 91361) during WHOTS-6 and -7. Each CTD was equipped with an internal Digiquartz pressure sensor and two pairs of external temperature, conductivity, and oxygen sensors. Each of the temperature-conductivity sensor pairs used a Sea-Bird TC duct which circulated seawater through independent pump and plumbing installations. In all three cruises, the CTD was mounted in a vertical position in the lower part of a 12-place Rosette sampler, with the sensors' water intakes located at the bottom of the Rosette.

The package was deployed on a conducting cable, which allowed for real-time data acquisition and display. The deployment procedure consisted in lowering the package to 10-15 dbar and waiting until the CTD pumps started operating. The CTD was then raised until the sensors were close to the surface to begin the CTD cast. The time and position of each cast was obtained via a GPS connection to the CTD deck box. Sampling bottles were 12-liter Bullister type. Between two and six salinity samples were taken on each cast for calibration of the conductivity sensors.

1. Data acquisition and processing.

CTD data were acquired at the instrument's highest sampling rate of 24 samples per second. Digital data were stored on a laptop computer and, for redundancy, the analog signal was recorded on VHS video tapes. Backups of CTD data were made onto USB storage cards.

The raw CTD data were quality controlled and screened for spikes as described in the WHOTS Data Report 1 (Santiago-Mandujano et al., 2007). Data alignment, averaging, correction and reporting were done as described in Tupas *et al*. (1993). Spikes in the data occur when the CTD samples the disturbed water of its wake. Therefore, samples from the downcast were rejected when the CTD was moving upward or when its acceleration exceeded 0.5 m s^{-2} in magnitude. The data were subsequently averaged into 2-dbar pressure bins after calibrating the CTD conductivity with the bottle salinities.

The data were additionally screened by comparing the T-C sensor pairs. These differences permitted identification of problems with the sensors. The data from only one T-C pair, whichever was deemed most reliable, is reported here. Only data from the downcast are reported, as upcast data are contaminated by rosette wake effects.

Temperature is reported in the ITS-90 scale. Salinity and all derived units were calculated using the UNESCO (1981) routines; salinity is reported in the practical salinity scale (PSS-78). Oxygen is reported in μmol kg^{-1}.

2. CTD sensor calibration and corrections

Pressure

The pressure calibration strategy for CTD pressure transducer SN 101430 used during WHOTS-6 and WHOTS-7 cruises employed a high-quality quartz pressure transducer as a transfer standard. Periodic recalibrations of this lab standard were performed with a primary pressure standard. The only corrections applied to the CTD pressures were a constant offset determined at the time that the CTD first enters the water on each cast. In addition, a span correction determined from bench tests on the sensor against the transfer standard was applied. These procedures and corrections are thoroughly documented in HOT-2009 and 2010 data reports (Fujieki, et al. 2012, 2013)

Temperature

Two Sea-Bird SBE-3-Plus temperature transducers (#1416 and #2454) were used during WHOTS-6 and -7 cruises, and were calibrated at Sea-Bird before and after each cruise to an accuracy better than 0.5 x 10^{-3}°C. Calibration coefficients obtained at Sea-Bird are listed in HOT data reports 2009 and 2010 (Fujieki, et al. 2012, 2013. Table 4-1).

Temperature sensor #1416

This sensor was used during the WHOTS-6 and -7 cruises. The history and performance of this sensor has been monitored during HOT cruises (Fujieki, et al. 2012, 2013). Drift corrections were obtained using the 4 February 2010 calibration as a baseline. The resulting drift corrections for the cruises are in Table 4-1.

Temperature sensor #2454

This sensor was used during the WHOTS-6 and -7 cruises. The history and performance of this sensor has been monitored during HOT cruises (Fujieki, et al. 2012, 2013). Drift corrections were obtained using the 4 February 2009 and 20 August 2010 calibrations as a baseline for the respective cruises. The resulting drift corrections for the cruises are in Table 4-1.

Table 4-1. Temperature (T) and Conductivity (C) sensors used during the WHOTS cruises, including temperature drift correction and the thermal inertia parameter (alpha). Dual temperature and conductivity sensors were used during both cruises. The data reported here are from the sensors marked with (*).

Cruise	T-sensor #	T-correction (m°C)	C-sensor #	alpha
WHOTS-6	1416 (*)	-0.03	2218 (*)	0.028
WHOTS-6	2454	0.06	3162	0.020
WHOTS-7	1416 (*)	0.04	2218 (*)	0.028
WHOTS-7	2454	-0.004	3162	0.020

Conductivity

Two Sea-Bird SBE 4C conductivity sensors (#3162, and #2218) were used during the WHOTS cruises. Dual sensors were used during all the cruise casts. As mentioned earlier, only the data from the most reliable sensor (and its corresponding temperature sensor pair, as shown in Table 4-1) are reported here. The history of these sensor is documented in the HOT 2009 and 2010 data reports (Fujieki, et al. 2012, 2013).

The nominal conductivity calibrations were used for data acquisition. Final calibration was determined empirically from salinities of discrete water samples acquired during each cast. Prior to empirical calibration, conductivity was corrected for thermal inertia of the glass conductivity cell using the recursive filter given by Lueck (1990) and Lueck and Picklo (1990). Sensor parameters alpha and beta, which characterize the initial magnitude of the thermal effect and its relaxation time, are needed for this correction. As recommended by Lueck (personal communication, 1990), beta was set to 0.1 s^{-1}, but alpha was calculated for each sensor to close the spread between the down- and up-cast *T-S* curves (Table 4-1).

Salinity samples were collected at selected depths during each cast and measured with a salinometer (Sect. 4.B.1). The nominally calibrated CTD salinity trace was used to identify questionable samples. Salinity samples were later quality controlled and flagged by comparing them against the empirically calibrated CTD salinities.

Calibration of each conductivity sensor was performed empirically by comparing its nominally calibrated output against the calculated conductivity values obtained from the water sample salinities, using the pressure and temperature of the CTD at the time of bottle closure. The conductivity calibration coefficients (*b0*, *b1*, *b2*) derived from the least squares fit ($\Delta C = b0 + b1C + b2C^2$) to the CTD-bottle conductivity differences (ΔC) as a function of conductivity (C) are given in Table 4-2. This calibration was then used to identify suspect water samples. These samples were deleted from the analysis, and the calibration was repeated.

Table 4-2. CTD Conductivity calibration coefficients obtained from comparison against bottle salinities.

Cruise	Sensor #	b0	b1	b2
WHOTS-6	2218	0.000032	-0.000092	
WHOTS-6	3192	-0.000418	-0.0000489	
WHOTS-7	2218	0.002124	-0.000860	0.000770
WHOTS-7	3192	0.000366	0.0000983	

The final step of the calibration was to perform a profile-dependent bias correction, to allow for a drift of the conductivity cell with time during each cruise, or for sudden offsets due to fouling. This offset was determined by taking the median value of CTD-bottle salinity differences for each profile. No offset corrections were necessary for any of the WHOTS cruises casts.

The quality of the conductivity calibration is illustrated by Table 4-3 which gives the mean and standard deviations for the final calibrated CTD minus water sample salinities.

Table 4-3. CTD-Bottle salinity comparison for each sensor.

		0 to 1200 dbar		500 to 1200 dbar	
Cruise	Sensor #	Mean	Standard Deviation	Mean	Standard Deviation
WHOTS-6	2218	-0.0001	0.0015	0.0001	0.0006
WHOTS-6	3162	-0.0001	0.0015	-0.0002	0.0006
WHOTS-7	2218	0.0000	0.0015	0.0001	0.0008
WHOTS-7	3162	0.0000	0.0015	-0.0001	0.0008

Salinity differences between sensor sets were calculated the same way as for the temperature in order to identify problems with any of the sensors. These differences show a behavior similar to the temperature differences in the thermocline region. Maximum absolute salinity differences of about 9 x 10^{-3} were observed at 100 dbar, decreasing to less than 2 x 10^{-3} below 200 dbar. This behavior is due to a combination of the residual temperature effect on the temperature sensors described in the previous section, and an additional residual temperature effect on the conductivity sensors (N. Larson personal communication, 1999). The temperature effect on the conductivity sensors is similar to that described for the temperature sensors, and affects the conductivity measurements when the sensor passes through intense temperature gradients.

The largest variability in the salinity difference between sensors was observed in the halocline, with standard deviations of up to 1 x 10^{-2} between 50 and 100 dbar.

Dissolved Oxygen

Two Sea-Bird SBE-43 oxygen sensors were used during each of WHOTS-6 (#43918 and #431601) and -7 cruises (#43918 and #43982) (Table 4-4). The history of these sensor is documented in the HOT 2009 and 2010 data reports (Fujieki, et al. 2012, 2013). Oxygen data from the WHOTS-6 cruise were further calibrated using empirical calibrations coefficients obtained during the HOT-213 cruise conducted on 24-27 July 2009, conducted after WHOTS-6, which used the same oxygen sensors. Similarly, the WHOTS-7 oxygen data were calibrated using calibration coefficients obtained during the HOT-224 cruise conducted on 6-10 August 2010, after the WHOTS-7 cruise, which used the same oxygen sensors. The CTD empirical calibration was conducted using oxygen water samples and the procedure from Owens and Millard (1985). See Tupas et al. (1997) for details on these calibrations procedures.

Table 4-4 shows the mean and standard deviation for the calibrated CTD oxygen minus water sample residuals during HOT-213 and HOT-224, whose calibrations were used for the WHOTS-6 and WHOTS-7 cruises respectively. Dual sensors were used during each cruise, but only the sensor whose data were deemed more reliable are reported.

Table 4-4. CTD-Bottle dissolved oxygen comparison for each sensor during HOT-213cruise (calibration used for WHOTS-6 data) and HOT-224 (calibration used for WHOTS-7 data). The units are µmol kg^{-1}.

		0 to 1200 dbar		500 to 1200 dbar	
Cruise	Sensor #	Mean	Standard Deviation	Mean	Standard Deviation
WHOTS-6/HOT-213	43918	0.00	0.52	0.00	0.31
WHOTS-7/HOT-224	43918	0.01	0.53	0.03	0.52

B. Water samples

1. Salinity

Salinity samples were collected in 250 ml glass bottles during WHOTS-6 and -7. Samples from WHOTS were stored and measured after the cruise in the laboratory at the UH using a Guildline Autosal 8400B. International Association for Physical Sciences of the Ocean (IAPSO) standard seawater samples were measured to standardize the Autosal, and samples from a large batch of "secondary standard" (substandard) seawater were measured after every 24 bottle samples of each cruise to detect drift in the Autosal. Standard deviations of the secondary standard measurements were less than ± 0.001 for the WHOTS-6 and -7 cruises (Table 4-5).

The substandard water was collected during HOT cruises from 1000 m at station ALOHA and drained into a 50-liter Nalgene plastic carboy. In the laboratory, the water was then thoroughly mixed in a glass carboy for 20 minutes, after which a 2-inch protective layer of white oil was added on top to deter evaporation. The substandard water was allowed to stand for approximately three days before it was used, and was stored in the same temperature controlled room as the Autosal, protecting it from the light with black plastic bags to prevent algae growth. Substandard seawater batches #45 and #47 were prepared on 17 June 2009 and 17 June 2010 respectively and used for WHOTS-6 and -7 samples respectively.

The substandard statistics in Table 4-5 include all the substandard samples measured.

Table 4-5. Precision of salinity measurements using secondary lab standards.

Cruise	Mean Salinity +/- SD	# Samples	Substandard Batch #	IAPSO Batch #
WHOTS-6	34.4882 +/- 0.0001	38	45	P149
WHOTS-7	34.4937 +/- 0.0004	45	47	P151

C. Thermosalinograph data acquisition and processing

1. WHOTS-6 Cruise

Near-surface temperature and salinity data for the WHOTS-6 cruise were acquired through the use of a thermosalinograph system aboard the R/V *Kilo Moana*. The system was comprised of a SBE-38 remote temperature sensor (#0169) located at the seawater intake situated 8 meters below the sea surface in conjunction with a SBE-45 thermosalinograph sensor (#0267) situated in the IMET lab close to the port bow of the ship.

Data were acquired every second for the duration of the cruise and salinity samples were taken periodically throughout the cruise for calibration from an outlet in the flowthrough system located less than 1 m from the SBE-21.

Temperature Calibration

Data from the SBE-38 remote temperature sensor were used to measure temperature at the seawater intake, with an offset correction applied after comparing it with the 8 dbar CTD temperature data. This sensor was last calibrated at Sea-Bird on 12 December 2008.

Nominal Conductivity Calibration

Sea-Bird conductivity sensor #0267 was calibrated at Sea-Bird on 9 October 2008. All conductivity data from the thermosalinograph were converted with coefficients obtained from this calibration. However, all the final salinity data reported here were calibrated against bottle data as explained below.

Data Processing

Thermosalinograph data was merged with ship navigation data prior to processing. The thermosalinograph data were then screened for gross errors, with upper and lower bounds of 18 °C and 35 °C for temperature and 3 Siemens m^{-1} and 6 Siemens m^{-1} for conductivity. There were no points outside the valid temperature and conductivity ranges and no gross errors detected.

A 5-point running median filter was used to detect one or two point temperature and conductivity glitches in the thermosalinograph data. Glitches in temperature and conductivity detected by the 5-point median filter were immediately replaced by the median. Threshold values of 0.3 °C for temperature and 0.1 Siemens m^{-1} for conductivity were used for the median filter. One conductivity point was replaced after running the median filter. A 3-point triangular running mean filter was used to smooth the temperature and conductivity data after passing the glitch detection.

The thermosalinograph aboard the R/V *Kilo Moana* was set to record data every second, but occasionally, due to an error in the acquisition software rounding routine, a record is written at a longer interval. There were 297 timing errors in total, all 1-2 second gaps.

Bottle Salinity and CTD Salinity Comparisons

The thermosalinograph salinity was calibrated by comparing it to bottle salinity samples drawn from a water intake next to the thermosalinograph. Sixteen salinity samples were collected and analyzed as described in Section 4.B.1. The comparison was made in conductivity in order to eliminate the effects of temperature. The conductivity of the bottle was computed using the salinity of the bottle, thermosalinograph temperature and a pressure of 6 dbar, which includes the pressure of the pump.

Salinity samples were drawn from the flowthrough system, located less than 1 m from the SBE-21 and consequently there should be virtually no delay between when the water passes through the thermosalinograph and it being sampled. Thermosalinograph data were extracted within a 60 second window around the bottle sample time minus a 10 second delay (in order to try and incorporate the reading recorded just prior to bottle sampling). The 30 second mean, centered 10 seconds before the bottle sample time was chosen for processing purposes.

In order to make the comparison in conductivity units, the CTD conductivity was calculated using the 8 dbar downcast CTD salinity, the internal thermosalinograph temperature, and a pressure of 6 dbar. There were 10 casts conducted while the thermosalinograph was running.

A cubic spline was fit to the time series of the differences between the bottle and thermosalinograph conductivity and a correction was obtained for the thermosalinograph conductivities. Salinity was calculated using these corrected conductivities, the thermosalinograph temperatures, and 6-dbar pressure. After correction, the mean difference between the bottle and thermosalinograph salinities was 0.0000 with a standard deviation of 0.0001. The mean CTD - thermosalinograph difference was 0.0009 with a standard deviation of 0.0003.

CTD Temperature Comparisons

There were 10 CTD casts conducted during the WHOTS-6 cruise. The 8 dbar CTD temperature data were used to compare with the remote temperature sensor. The mean difference between the CTD and the remote temperature sensor was found to be approximately –0.2568 °C. Previous cruises aboard *R/V Kilo Moana* have shown similar temperature offsets as the seawater entering the ship's intake passes through a pump prior to the remote temperature sensor, which warms the water as it passes. An offset correction of -0.2568 °C was applied to all the remote temperature sensor data, which were then flagged as uncalibrated data.

2. WHOTS-7 Cruise

Near-surface temperature and salinity data for the WHOTS-7 cruise were acquired through the use of a thermosalinograph system aboard the R/V *Kilo Moana*. The system was comprised of a SBE-38 remote temperature sensor (#0150) located at the seawater intake situated 8 meters below the sea surface in conjunction with a SBE-21 thermosalinograph sensor (#0267) situated in the IMET lab close to the port bow of the ship.

Data were acquired every second for the duration of the cruise and salinity samples were taken periodically throughout the cruise for calibration from an outlet in the flowthrough system located less than 1 m from the SBE-21.

Temperature Calibration

Data from the SBE-38 remote temperature sensor were used to measure temperature at the seawater intake, with an offset correction applied after comparing it with the 8 dbar CTD temperature data. This sensor was last calibrated at Sea-Bird on 16 September 2009.

Nominal Conductivity Calibration

Sea-Bird conductivity sensor #0267 was calibrated at Sea-Bird on 3 November 2009. All conductivity data from the thermosalinograph were converted with coefficients obtained from this calibration. However, all the final salinity data reported here were calibrated against bottle data as explained below.

Data Processing

Navigation data (latitude, longitude and ship's speed) were recorded throughout the cruise every second and were merged with the thermosalinograph data stream. The thermosalinograph data were then screened for gross errors, with upper and lower bounds of 18 °C and 35 °C for temperature and 3 Siemens m^{-1} and 6 Siemens m^{-1} for conductivity. There were no points outside the valid temperature and conductivity ranges and no gross errors detected.

A 5-point running median filter was used to detect one or two point temperature and conductivity glitches in the thermosalinograph data. Glitches in temperature and conductivity detected by the 5-point median filter were immediately replaced by the median. Threshold values of 0.3 °C for temperature and 0.1 Siemens m^{-1} for conductivity were used for the median filter. There were no points replaced by the 5-point median filter. A 3-point triangular running mean filter was used to smooth the temperature and conductivity data after passing the glitch detection.

The thermosalinograph aboard the R/V *Kilo Moana* was set to record data every second. Previous cruises have occasionally shown errors in the acquisition software rounding routine, resulting in a record being written at a longer interval. There were 4596 such timing errors for WHOTS-7, all around 1-2 seconds.

Bottle Salinity and CTD Salinity Comparisons

The thermosalinograph salinity was calibrated by comparing it to bottle salinity samples drawn from a water intake next to the thermosalinograph. Twenty-four salinity samples were collected and analyzed as described in Section 4.B.1. The comparison was made in conductivity in order to eliminate the effects of temperature. The conductivity of the bottle was computed using the salinity of the bottle, thermosalinograph temperature and a pressure of 6 dbar, which includes the pressure of the pump.

Salinity samples were drawn from the flowthrough system, located less than 1 m from the SBE-21 and consequently there should be virtually no delay between when the water passes through the thermosalinograph and it being sampled. Thermosalinograph data were extracted within a 60 second window around the bottle sample time minus a 10 second delay (in order to try and incorporate the reading recorded just prior to bottle sampling). The 30 second mean, centered 10 seconds before the bottle sample time was chosen for processing purposes.

In order to make the comparison in conductivity units, the CTD conductivity was calculated using the 8 dbar downcast CTD salinity, the internal thermosalinograph temperature, and a pressure of 6 dbar. There were 10 casts conducted while the thermosalinograph was running.

A cubic spline was fit to the time series of the differences between the bottle and thermosalinograph conductivity and a correction was obtained for the thermosalinograph conductivities. Salinity was calculated using these corrected conductivities, the thermosalinograph temperatures, and 6-dbar pressure. After correction, the mean difference between the bottle and thermosalinograph salinities was 0.0000 with a standard deviation of 0.0003. The mean CTD - thermosalinograph difference was 0.0006 with a standard deviation of 0.0002.

CTD Temperature Comparisons

There were 10 CTD casts conducted during the WHOTS-7 cruise. The 8 dbar CTD temperature data were used to compare with the remote temperature sensor. The mean difference between the CTD and the remote temperature sensor was found to be approximately –0.435 °C. Previous cruises aboard *R/V Kilo Moana* have shown similar temperature offsets as the seawater entering the ship's intake passes through a pump prior to the remote temperature sensor, which warms the water as it passes. An offset correction of -0.435 °C was applied to all the remote temperature sensor data, which were then flagged as uncalibrated data.

D. Shipboard ADCP

1. WHOTS-6 Cruise

Currents measured by the R/V *Kilo Moana* Workhorse 300 kHz and Ocean Surveyor 38 kHz narrowband/broadband ADCP were processed using the CODAS ADCP processing suite. Horizontal velocity data, latitude and longitude were processed with 2 minute ensemble averages and 4 m depth resolution. The times of the datasets from the OS38 and WH300 are shown in Table 4-6.

Table 4-6. ADCP record times (UTC) for the R/V Kilo Moana ADCPs during the WHOTS-6 deployment cruise.

WHOTS-7	**OS38BB**	**OS38NB**	**WH300**
File beginning time	10-Jul-2009 00:05:55	10-Jul-2009 00:05:55	10-Jul-2009 00:04:43
File ending time	17-Jul-2009 17:36:07	17-Jul-2009 17:36:07	17-Jul-2009 17:43:42

2. WHOTS-7 Cruise

Currents measured by the R/V *Kilo Moana* Workhorse 300 kHz and Ocean Surveyor 38 kHz narrowband/broadband ADCP were processed using the CODAS ADCP processing suite. Data from the Ocean Surveyor was only available on the first day of the cruise; the Workhorse 300 kHz data was sampled throughout the entire cruise. Horizontal velocity data, latitude and longitude were processed with 2 minute ensemble averages and 4 m depth resolution. The times of the datasets from the OS38 and WH300 are shown in Table 4-7.

Table 4-7. ADCP record times (UTC) for the R/V Kilo Moana ADCPs during the WHOTS-7 cruise.

WHOTS-7	**OS38BB**	**OS38NB**
File beginning time	27-Jul-2010 19:33:22	27-Jul-2010 19:33:22
File ending time	27-Jul-2010 20:03:27	27-Jul-2010 20:03:45

5. Moored Instrument Observations

A. MicroCAT/SeaCAT data processing procedures

Each moored MicroCAT temperature, conductivity and pressure (when installed) was calibrated at Sea-Bird prior to their deployment and after their recovery (Table 5-1). The internally-recorded data from each instrument were downloaded on board the ship after the mooring recovery, and the nominally-calibrated data were plotted for a visual assessment of the data quality. The data processing included checking the internal clock data against external event times, pressure sensor drift correction, temperature sensor stability, and conductivity calibration against CTD data from casts conducted near the mooring during HOT and WHOTS cruises. The detailed processing procedures are described in this section.

Table 5-1. WHOTS-6 MicroCAT temperature sensor calibration dates, and sensor drift during deployments.

Sea-Bird Serial Number	Pre-deployment calibration	Post-recovery calibration	Total Temperature drift during WHOTS deployment (m°C)
37SM42760-3617	7/31/2008	9/26/2010	-0.31
37SM42760-3618	8/21/2008	9/22/2010	-0.19
37SM42760-3634	9/4/2008	9/22/2010	-0.32
37SM42760-6887	4/4/2009	9/22/2010	0.36
37SM42760-6888	4/3/2009	9/22/2010	0.27
37SM42760-6889	4/4/2009	9/22/2010	0.47
37SM42760-6890	4/3/2009	9/21/2010	0.55
37SM42760-6891	4/3/2009	9/21/2010	0.37
37SM42760-6893	4/4/2009	9/22/2010	0.19
37SM42760-6894	4/4/2009	9/22/2010	-0.12
37SM42760-6895	4/4/2009	9/22/2010	0.40
37SM42760-6896	4/1/2009	9/22/2010	0.92
37SM42760-6897	4/8/2009	9/22/2010	0.62
37SM42760-6898	4/3/2009	9/21/2010	0.65

37SM42760-6899	4/3/2009	9/21/2010	0.11

1. Internal Clock Check and Missing Samples

Before the WHOTS-6 mooring deployment and after its recovery (before the data logging was stopped), the MicroCATs temperature sensors were dunked in a cold fresh water bath to create a spike in the data, to check for any problems with their internal clocks, and for possible missing samples (Table 3-2). The cold spike was detected by a sudden decrease in temperature. For all the instruments, the clock time of this event matched correctly the time of the spike (within the sampling interval of each instrument). No missing samples were detected for any of the instruments.

2. Pressure Drift Correction and Pressure Variability

Some of the MicroCATs used in the moorings were outfitted with pressure sensors (Table 3-2). Biases were detected in the pressure sensors by comparing the on-deck pressure readings (which should be zero for standard atmospheric pressure at sea level of 1029 mbar) before deployment and after recovery (Table 5-2). To correct for this offset, a linear fit between the initial and final on-deck pressure offset as a function of time was obtained, and subtracted from each sensor. The biases were less than 0.25 dbar for all the sensors. Figure 5-1 shows the linearly corrected pressures measured by the MicroCATs during the WHOTS-6 deployment. For all the sensors, the mean difference from the nominal instrument pressure (based on the deployed depth) was less than 0.5 dbar. The standard deviation of the pressure for the duration of the record was less than 0.8 dbar for all sensors, with the deeper sensors showing a larger standard deviation. The range of variability for all sensors was about ± 3 dbar.

The causes of pressure variability can be several, including density variations in the water column above the instrument; horizontal dynamic pressure (not only due to the currents, but also due to the motion of the mooring); mooring position, etc. (see WHOTS Data Report 1, Santiago-Mandujano et al., 2007).

Table 5-2. Pressure bias of MicroCATs with pressure sensors.

Deployment	Depth (m)	Sea-Bird Serial #	Bias before deployment (dbar)	Bias after recovery (dbar)
WHOTS-6	45	37SM31486-6887	0.15	0.02
WHOTS-6	85	37SM31486-6888	0.17	0.14
WHOTS-6	105	37SM31486-6889	0.20	0.15
WHOTS-6	120	37SM31486-6890	0.15	0.08
WHOTS-6	155	37SM31486-6891	0.10	0.04

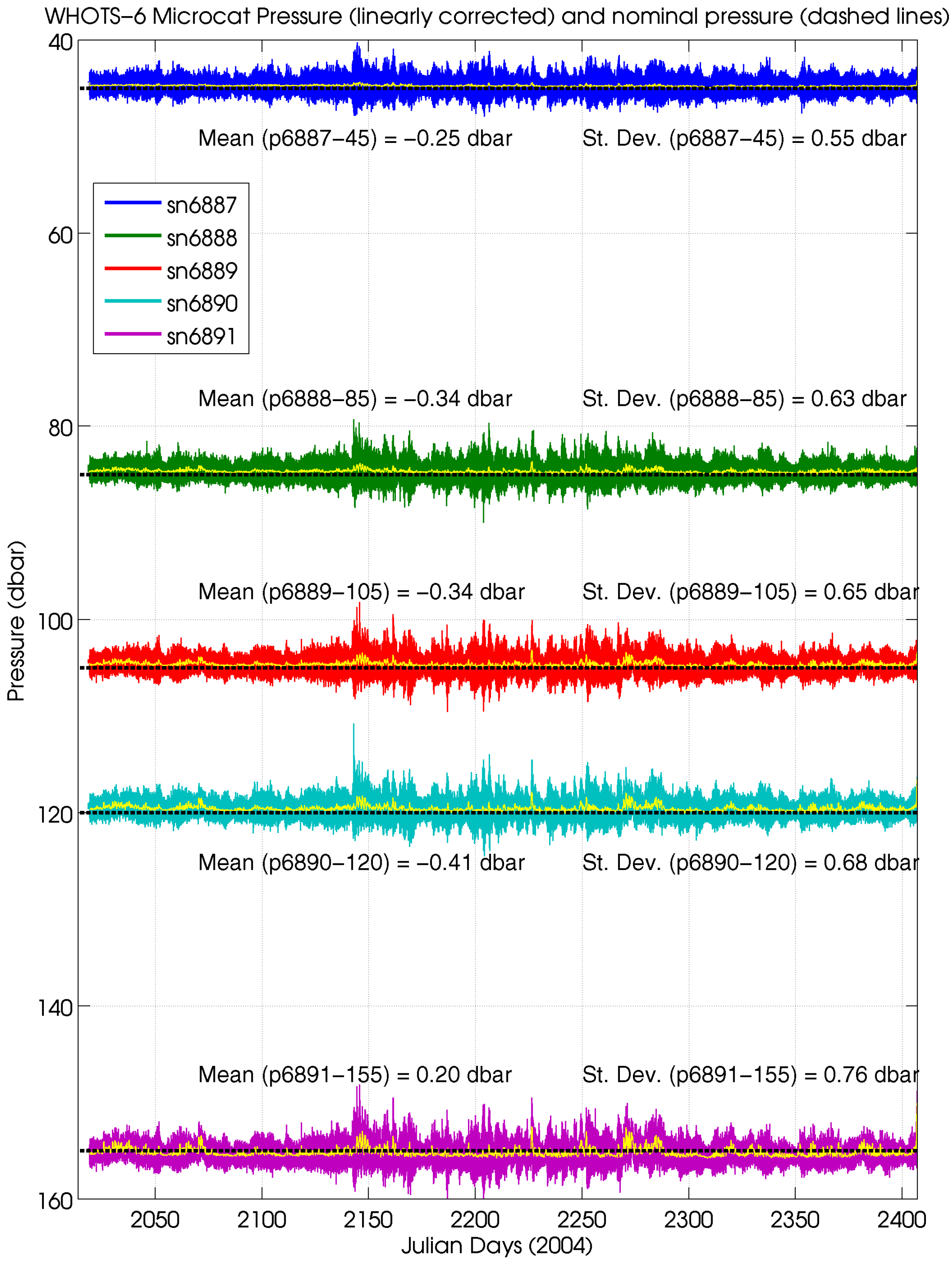


Figure 5-1. Linearly corrected pressures from MicroCATs during WHOTS-6 deployment. The yellow line is a 5-hour running mean. The horizontal dashed line is the sensor's nominal pressure, based on deployed depth.

3. Temperature Sensor Stability

The MicroCAT temperature sensors were calibrated at Sea-Bird before and after each deployment (see Table 5-1). Sea-Bird's evaluation of each sensor's drift was used to calculate the temperature offset for the duration of the deployment (Table 5-1). These values turned out to be insignificant (not higher than 1 milli °C) for all sensors deployed. Comparisons between the MicroCAT and CTD data from casts conducted near the mooring during HOT cruises confirmed that the temperature drift of the moored instruments was insignificant.

In addition to the temperature sensors in the Sea-Bird instruments, there were temperature sensors in the VMCMs (at 10 and 30 m), and in the ADCPs (at 47.5 m and 125 m). In order to evaluate the quality of the temperatures from these sensors, comparisons with the temperatures from adjacent MicroCATs were conducted.

Comparisons with VMCM and ADCP temperature sensors

The upper panel of Figure 5-2 shows the difference between the 10-m VMCM and the 15-m MicroCAT temperatures during WHOTS-6. The VMCM seem to have drifted from the MicroCAT some days after deployment. Also shown for comparison in the lower panel of the figure are the differences between MicroCAT temperatures at 15 and 25 m. The temperature fluctuations in the differences between the 15 and 25-m MicroCATs seem to be around zero.

The upper panel of Figure 5-3 shows the temperature differences between the 30-m VMCM and the temperatures from adjacent MicroCATs at 25 and 35-m during WHOTS-6. For comparison, the differences between the MicroCATs temperatures are also shown.

Temperature differences between the 47.5-m ADCP and the temperatures from adjacent MicroCATs at 45 and 50-m during WHOTS-6 are shown in Figure 5-4. For comparison, the differences between the MicroCATs temperatures are also shown. These plots indicate that there was no offset in the 47.5-m ADCP with respect to the adjacent MicroCATs (top and middle plots).

Temperature differences between the 125-m ADCP and the temperatures from adjacent MicroCATs at 120 and 135-m during WHOTS-6 are shown in Figure 5-5, Figure 5-6, and Figure 5-7. For comparison, the differences between the MicroCATs temperatures are also shown. It is difficult to assess the quality of the ADCP temperature from these comparisons, as these sensors were located at the top of the thermocline, where we expect to find large temperature differences between adjacent sensors.

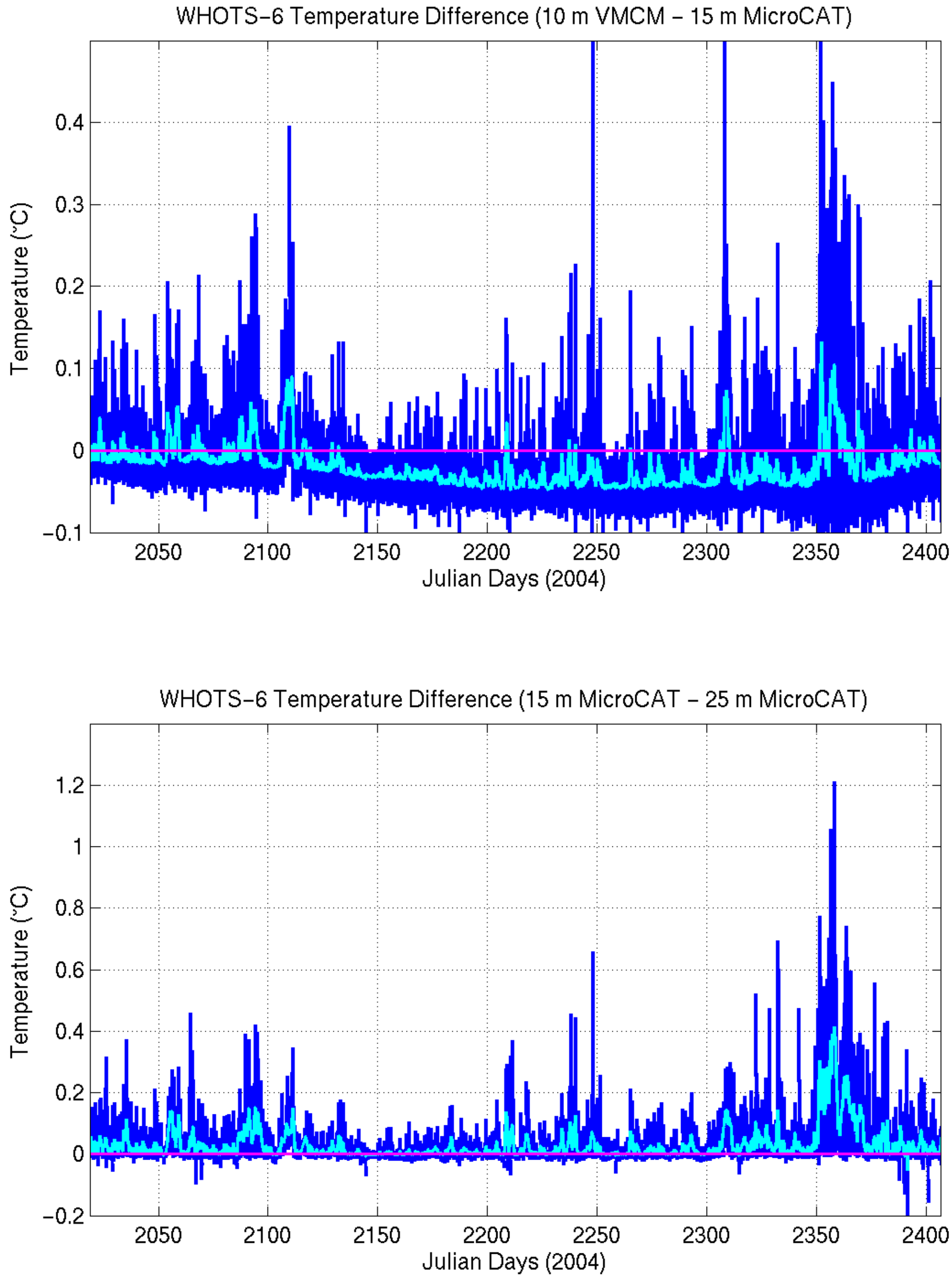


Figure 5-2. Temperature difference between the 10-m VMCM and the 15-m MicroCAT (upper panel) and between the 15-m MicroCAT and the 25-m MicroCAT during the WHOTS-6 deployment (lower panel). The light blue line is a 24-hour running mean of the differences.

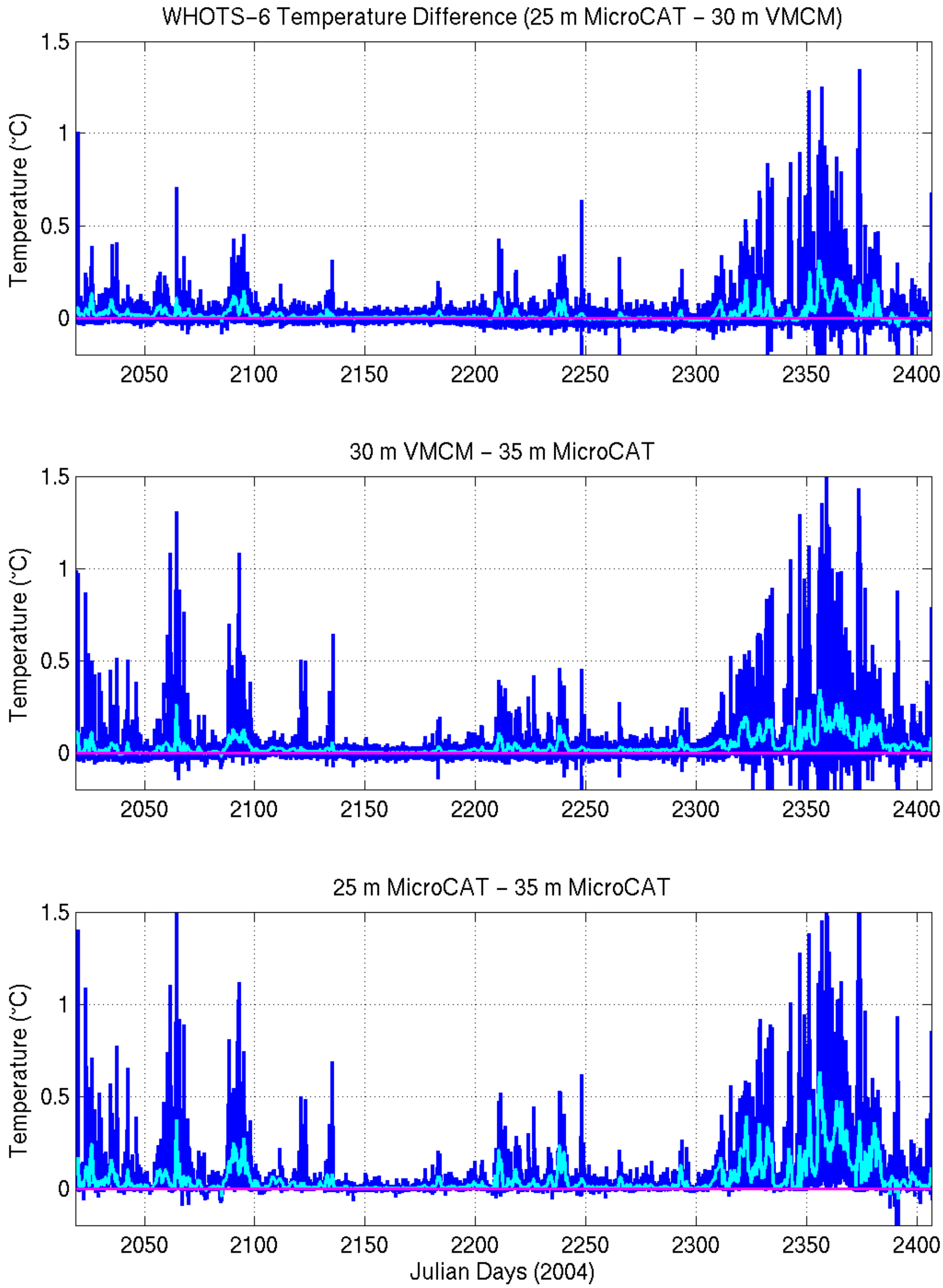


Figure 5-3. Temperature difference between the 30-m VMCM and the 25-m MicroCAT (upper panel); between the 30-m VMCM and the 35-m MicroCAT (middle panel); and between the 25-m and the 35-m MicroCATs (lower panel) during WHOTS-6. The light blue line is a 24-hour running mean of the differences.

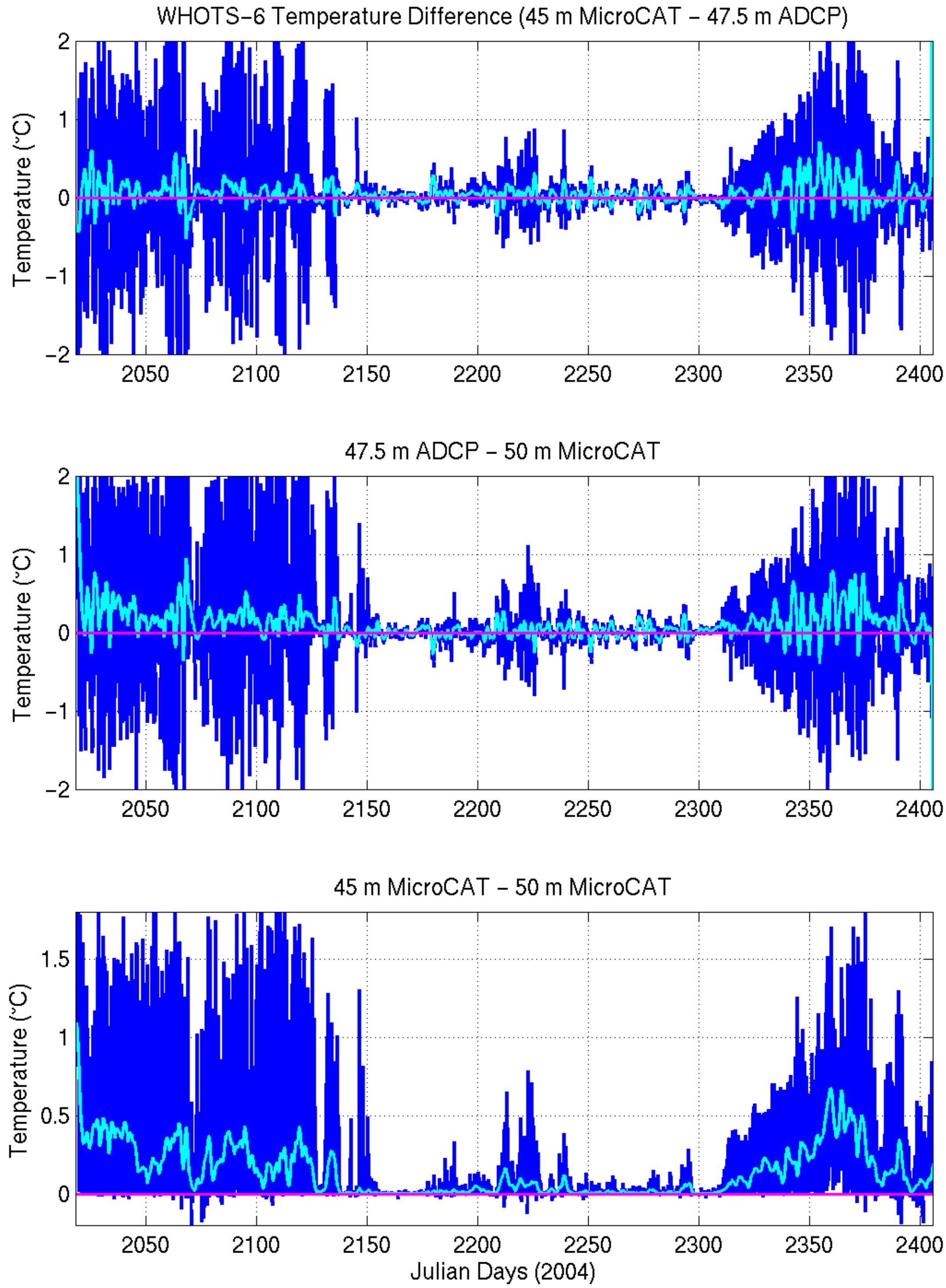


Figure 5-4. Temperature difference between the 47.5-m ADCP and the 45-m MicroCAT (upper panel); between the 47.5-m ADCP and the 50-m MicroCAT (middle panel); and between the 45-m and the 50-m MicroCATs (lower panel) during the WHOTS-6 deployment. The light blue line is a 24-hour running mean of the differences.

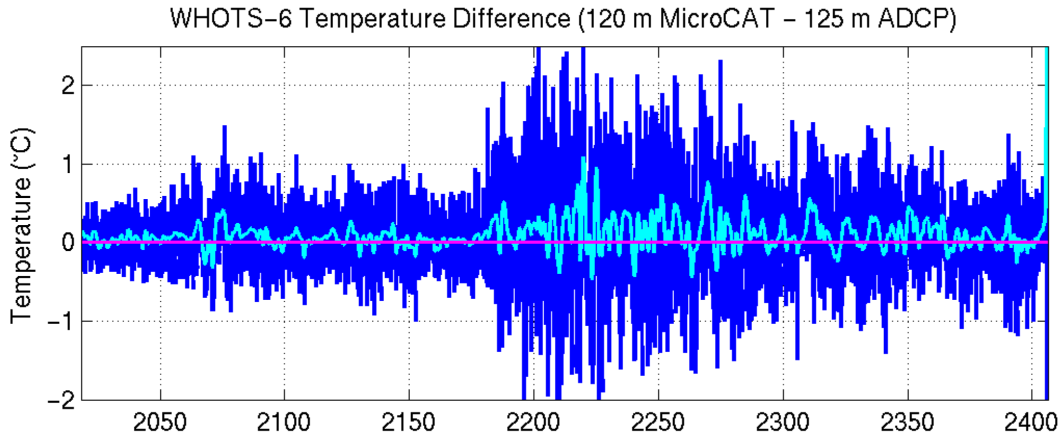


Figure 5-5. Temperature difference between the 125-m ADCP and the 120-m MicroCAT. The light blue line is a 24-hour running mean of the differences.

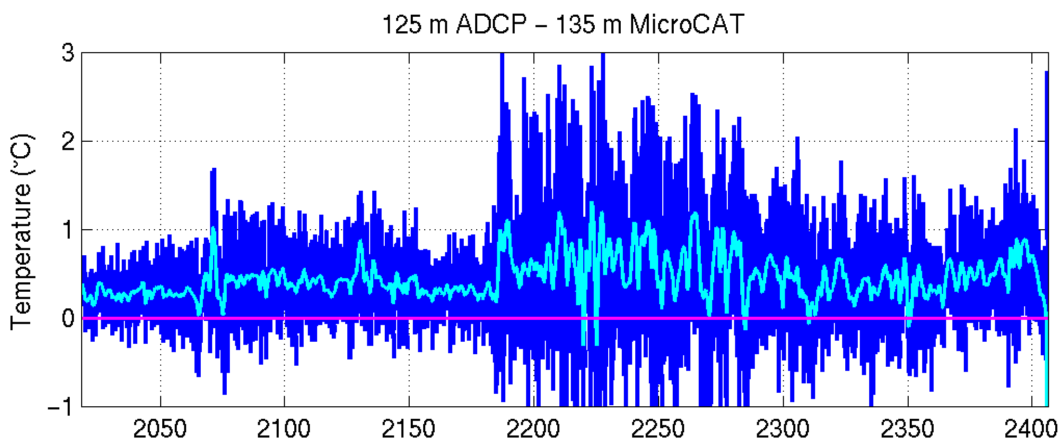


Figure 5-6. Temperature difference between the 125-m ADCP and the 135-m MicroCAT. The light blue line is a 24-hour running mean of the differences.

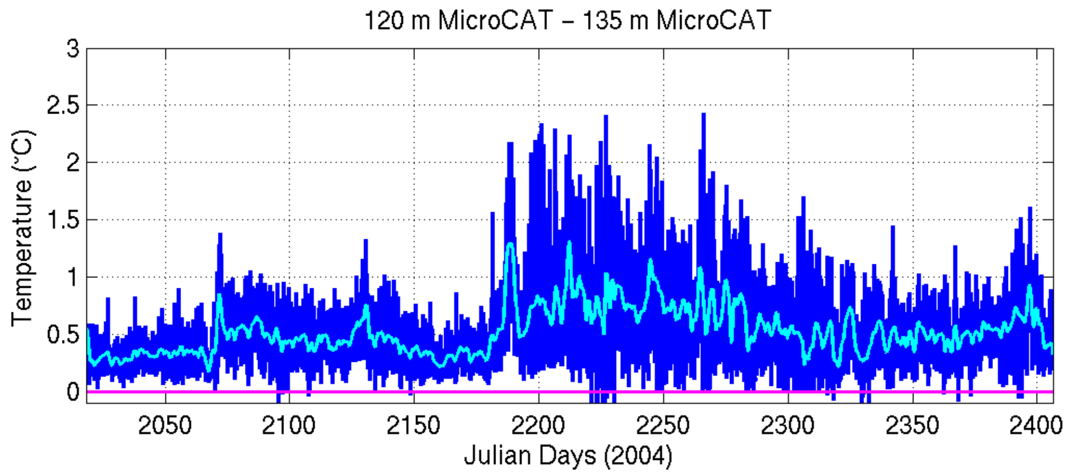


Figure 5-7. Temperature difference between the 120-m and the 135-m MicroCATs during the WHOTS-6 deployment. The light blue line is a 24-hour running mean of the differences.

4. Conductivity Calibration

The results of the Sea-Bird post-recovery conductivity calibrations indicated that some of the MicroCAT conductivity sensors experienced relatively large offsets from their pre-deployment calibration. These were qualitatively confirmed by comparing the mooring data against CTD data from casts conducted between 200 m and 5 km from the mooring during HOT cruises. The causes of the conductivity offsets are not clear, and there may have been multiple causes (see Freitag et. al, (1999) for a similar experience with conductivity cells during COARE). For some instruments the offset was negative, caused perhaps by biofouling of the conductivity cell while for others the offset was positive, caused possibly by scouring of the inside of the conductivity cell (possible by the continuous up and down motion of the instrument in an abundant field of diatoms). A visual inspection of the instruments after recovery did not show any obvious signs of biofouling, and there were no cell scourings reported in the post-recovery inspections at Sea-Bird.

Corrections of the MicroCATs conductivity data were conducted by comparing them against CTD data from profiles and yo-yo casts conducted near the mooring during HOT cruises, and during deployment/recovery cruises. Casts conducted between 200 and 1000 m from the mooring were given extra weight in the correction, as compared to those conducted between 1 and 5 km away. Casts more than 5 km away from the mooring were not used. Given that the CTD casts are conducted at least 200 m from the mooring, the alignment between CTD and MicroCAT data was done in density rather than in depth. For cases in which the alignment in density was not possible due to large conductivity offsets (causing unrealistic mooring density values), alignment in temperature space was done. A cubic least-squares fit (LSF) to the CTD-MicroCAT differences against time was applied as a first approximation, and the corresponding correction was applied.

Some of the sensors had large offsets and/or obvious variability that could not be explained by a cubic LSF. For these sensors, a stepwise correction was applied matching the data to the available CTD cast data, and then using the differences between consecutive sensors to determine when the sensor started to drift. For instance, during periods of weak stratification the conductivity difference between neighboring sensors A, B, and C could reach near-zero values, in particular for instruments near the surface, which are the ones most prone to suffer conductivity offsets. A sudden conductivity offset observed during this period between sensors A and B, but not between sensors A and C could indicate the beginning of an offset for sensor B.

Given that the deepest instruments on the mooring are less likely to be affected by biofouling and consequent sudden conductivity drift, the deep instruments served as a good reference to find any possible malfunction in the shallower ones. Therefore the deepest instruments' conductivity was corrected first, and the correction was continued sequentially upwards toward the shallower ones.

As a quality control to the conductivity corrections, the buoyancy frequency between neighboring instruments was calculated using finite differences. Over- or under-corrected conductivities yielded instabilities in the water column (negative buoyancy frequency) that were easy to detect and were obviously not real when lasting for several days. Based on this, the conductivity correction of the corresponding sensors was revised.

Another characteristic of the offsets in the conductivity sensors is that their development is not always linear in time, and their behavior can be highly variable (see WHOTS Data Report 1, Santiago-Mandujano et al., 2007).

The corrections applied to each of the conductivity sensors during WHOTS-6 can be seen in Figure 5-8. Most of the instruments had a drift of less than 0.015 Siemens/m for the duration of the deployment, which was corrected as explained above.

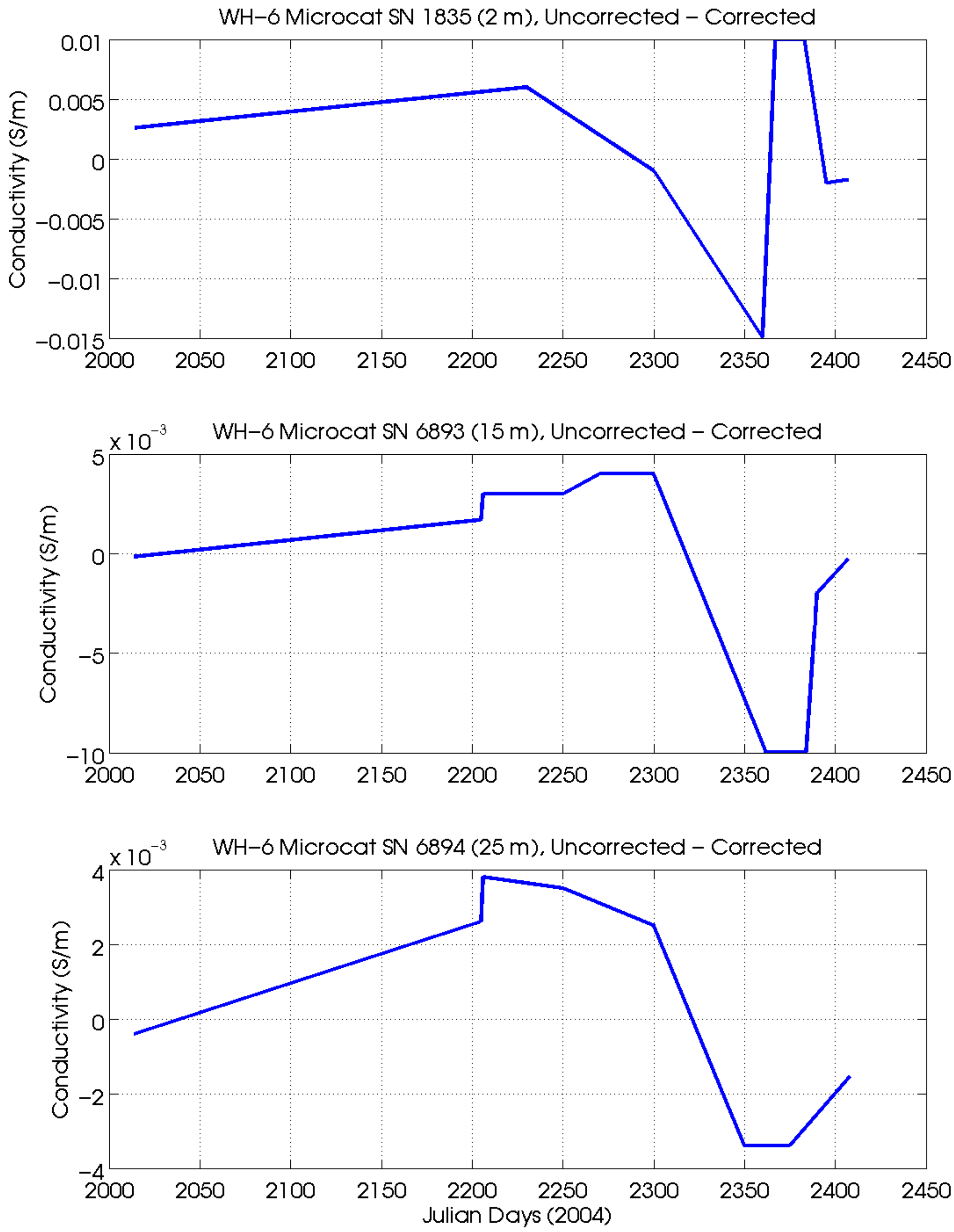


Figure 5-8. Conductivity sensor corrections for MicroCATs and SeaCATs during WHOTS-6

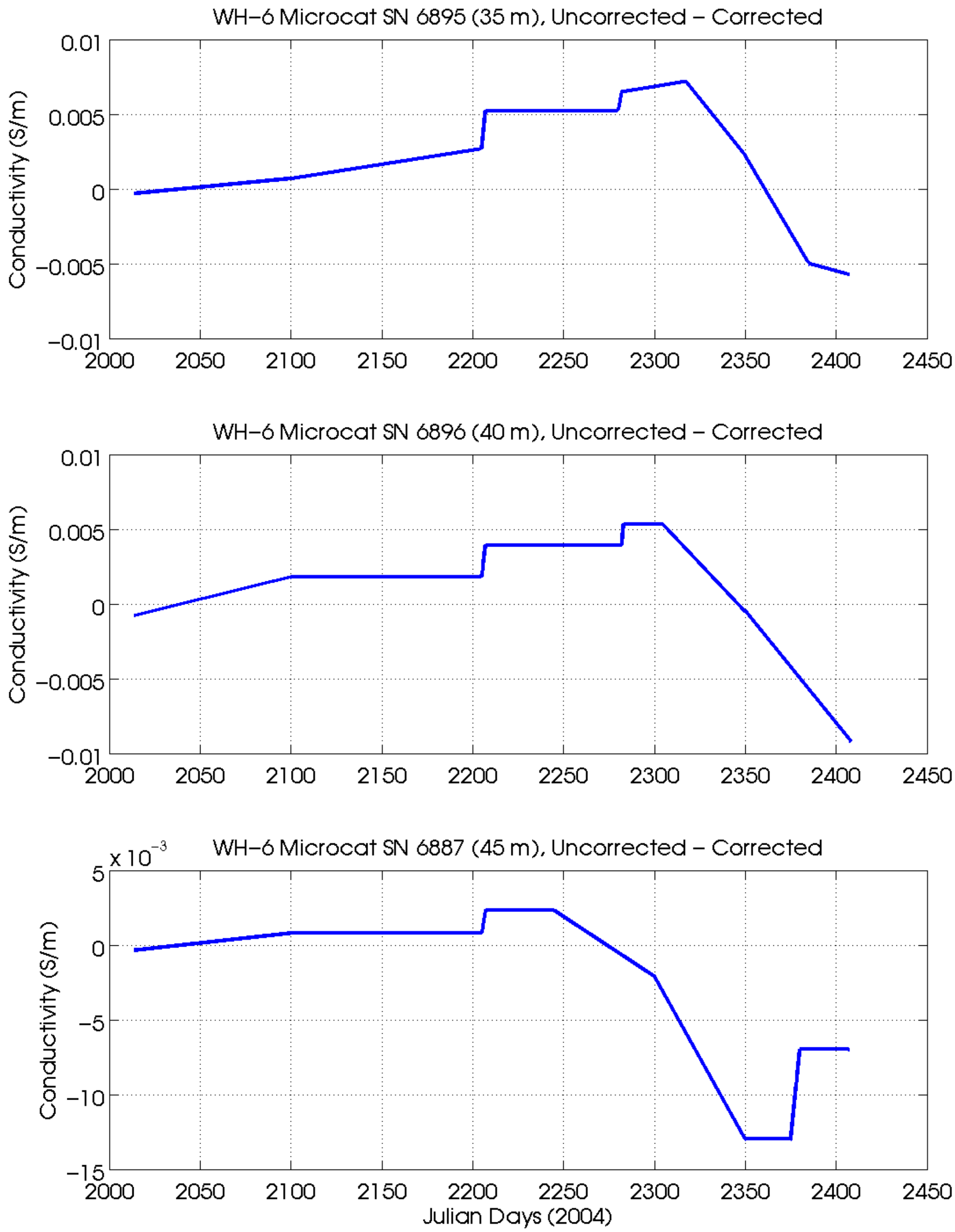


Figure 5-8. (Contd.)

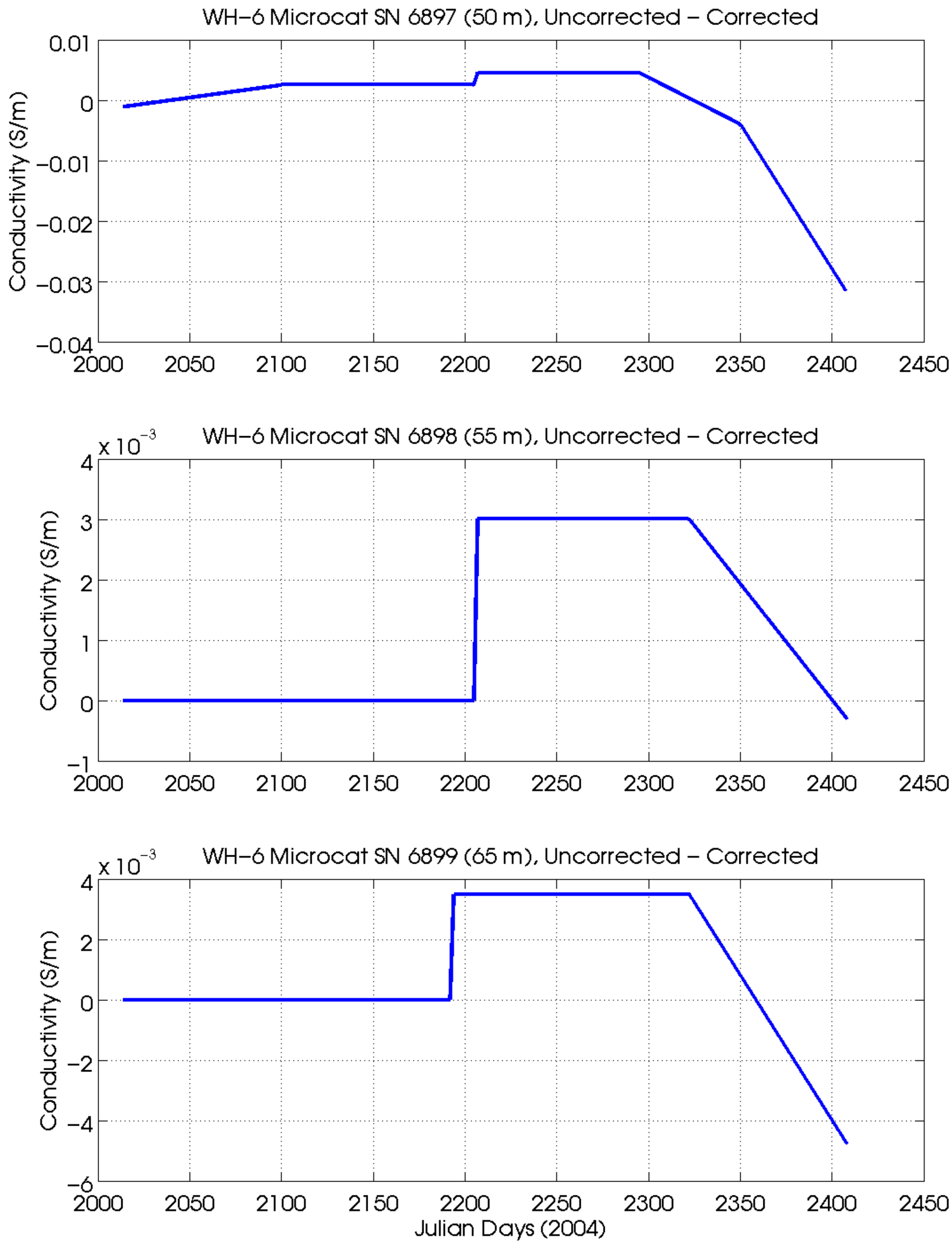


Figure 5-8. (Contd.)

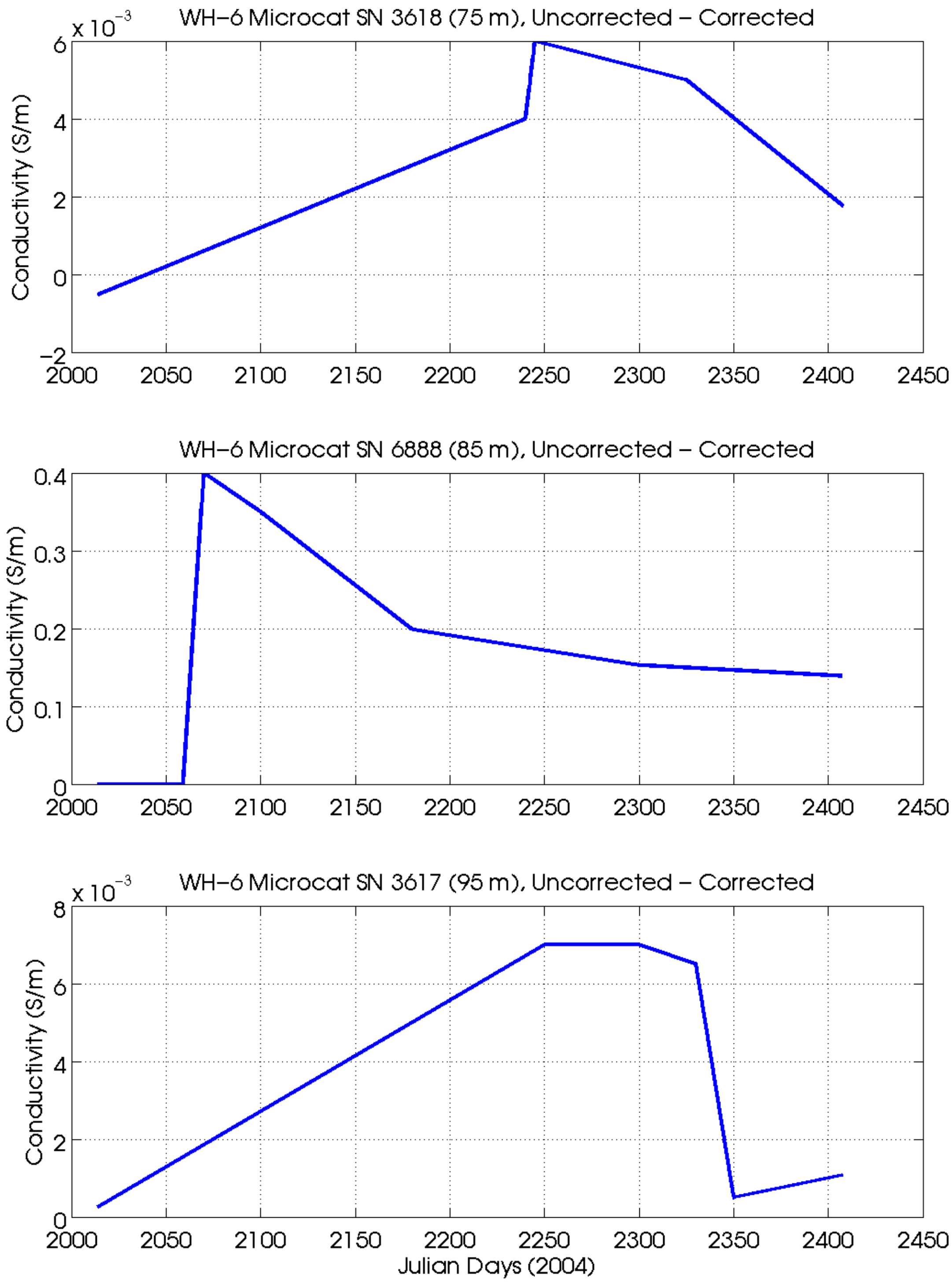


Figure 5-8. (Contd.)

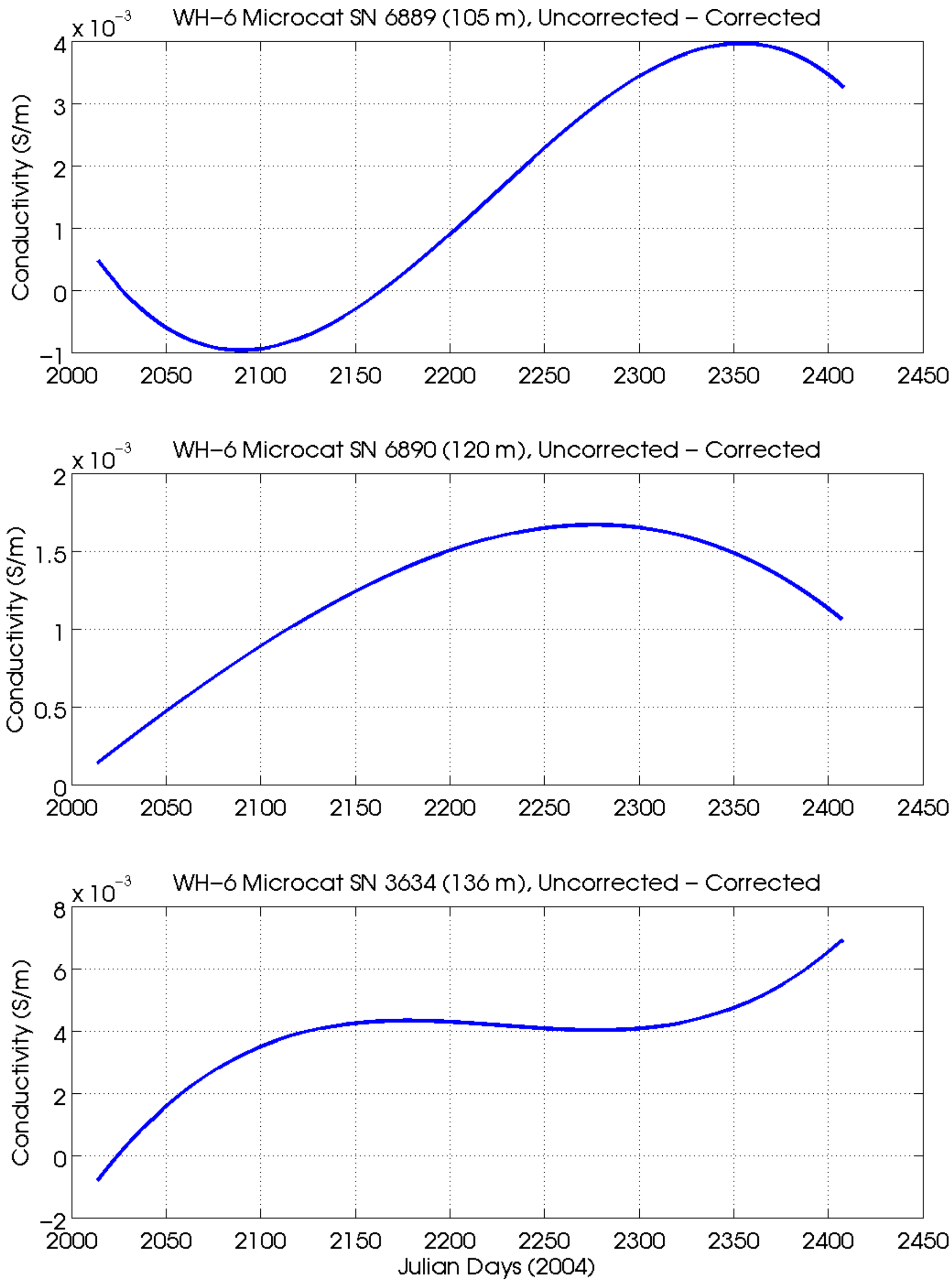


Figure 5-8. (Contd.)

B. Acoustic Doppler Current Profiler

Two Teledyne/RD Instruments broadband Workhorse Sentinel ADCP's were deployed on the WHOTS-6 mooring. The first ADCP, set to measure at 600 kHz, was deployed at 47.5 m depth in the upward looking configuration. The second was set to measure at 300 kHz and was deployed at 125 m, also in the upward looking configuration. The instruments were installed in aluminum frames along with an external battery module to provide sufficient power for the intended period of deployment. The four ADCP beams were angled at 20° from the vertical line of the instrument. The ADCP was set to profile across 30 range cells of 4 m with the first bin centered 6.2 m from the transducer. The maximum range of the instrument was just short of 125 m. The specifications of the instrument are shown in Table 5-3.

Table 5-3. Specifications of the ADCP's used for the WHOTS-6 mooring.

Instrument	Description
ADCP	*RDI Workhorse Sentinel, 300KHz* Model: WHS300-I-UG129; Serial Number: 4891 *RDI Workhorse Sentinel, 600KHz* Model: WHS600-I; Serial Number: 1825
Battery module	*300 kHz* Model: 717-3001-00; Serial Number: 3169 *600 kHz* Model: WH-EXT-BCL; Serial Number: 182

1. Compass Calibration

Pre-Deployment

Prior to the WHOTS-6 deployment, a field calibration of the internal compasses for two ADCPs (#1825 and #4891) was performed at Snug Harbor in Honolulu in June 2009. The instruments were mounted in their deployment cages along with their external battery modules and were located in an area though to be free of potential sources of magnetic field disturbances. The ADCP was mounted to the turntable, which was aligned with magnetic north using a surveyor's compass. Using the built-in calibration procedure, the instrument was tilted in one direction between 10 and 20 degrees and then rotated through 360 degrees at less than 5 ° /sec. The ADCP was then tilted in a different direction and a second rotation made. Based on the results from the first two rotations, calibration parameters are temporarily loaded and the instrument, tilted in a third direction is rotated once more to check the calibration. Results from each pre-deployment field calibration are shown in Table 5-4 (Figure 5-9).

Table 5-4. Results from the WHOTS-6 pre-deployment ADCP compass field calibration procedure.

	ADCP (Serial Number)	Single Cycle Error (°)	Double Cycle Error (°)	Largest Double + Single Cycle Error (°)	RMS of 3rd Order and Higher + Random Error (°)	**Overall Error** (°)	Pitch Mean and Standard Deviation (°)	Roll Mean and Standard Deviation (°)
Before Calibration	1825	4.50	0.96	5.46	0.30	**4.83**	11.27 ± 0.41	-0.35 ± 0.66
	4891	4.83	0.54	5.37	0.28	**4.84**	1.20 ± 0.60	16.84 ± 0.39
After Calibration	1825	0.18	0.93	1.11	0.76	**1.03**	1.78 ± 1.76	11.51 ± 0.66
	4891	0.24	0.61	3.24	0.23	**2.74**	-1.43 ± 0.50	-10.35 ± 0.44

Post-Deployment

After the WHOTS-6 mooring was recovered, the performance of the ADCP compasses was evaluated at the University of Hawaii Lower Campus with an identical compass calibration procedure as during the pre-deployment calibration. The new site on Lower Campus offered an area that showed very little magnetic field disturbances. Results from the WHOTS-6 post-deployment ADCP compass field calibration procedure are listed in Table 5-5 (Figure 5-10).

Table 5-5. Results from the WHOTS-6 post-deployment ADCP compass field calibration procedure

	ADCP (Serial Number)	Single Cycle Error (°)	Double Cycle Error (°)	Largest Double + Single Cycle Error (°)	RMS of 3rd Order and Higher + Random Error (°)	**Overall Error** (°)	Pitch Mean and Standard Deviation (°)	Roll Mean and Standard Deviation (°)
Post Deployment	1825	0.87	0.26	1.13	0.20	**0.99**	0.98 ± 0.56	4.47 ± 0.59
	4891	2.19	0.43	2.62	0.11	**2.28**	0.80 ± 0.487	2.09 ± 0.45

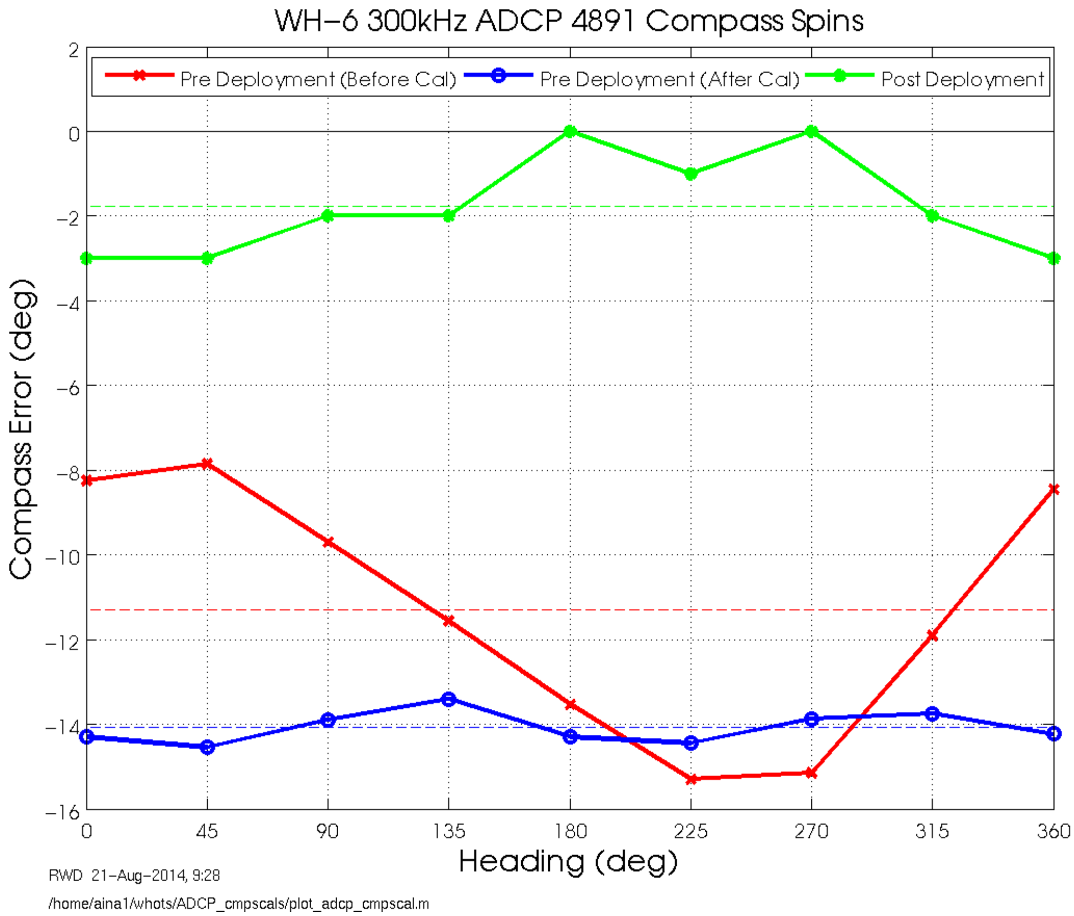


Figure 5-9. Results of the post-cruise compass calibration, conducted 25 June 2009 on ADCP SN4891 at SNUG Harbor.

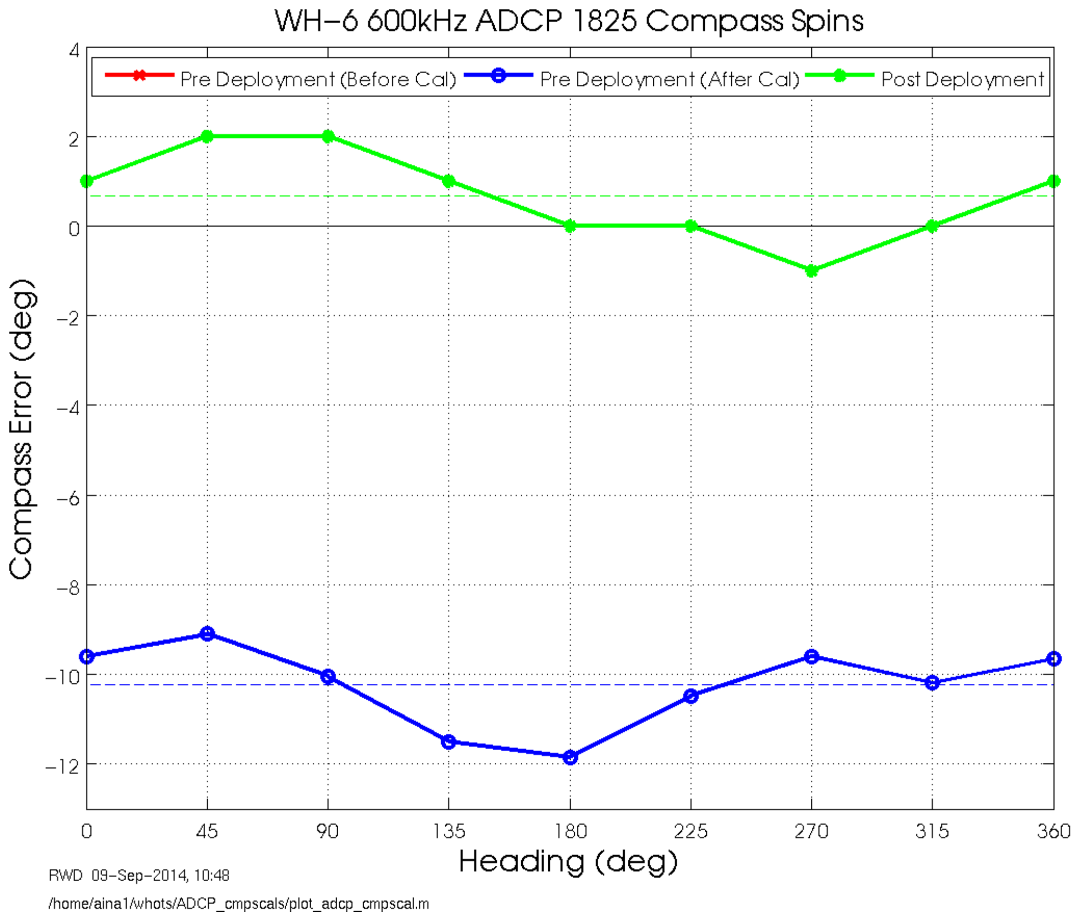


Figure 5-10. Results of the post-cruise compass calibration, conducted 25 June 2009 on ADCP SN1825 at the University of Hawai'i at Manoa soccer field.

2. ADCP Configurations

Individual configurations for the two ADCP's on the WHOTS-6 mooring are detailed in Appendices 1 and 2. The salient differences for each of the ADCP's are summarized below.

300 kHz (125m)

The ADCP, set to a beam frequency of 300 kHz, was configured in a burst sampling mode consisting of 40 pings per ensemble in order to resolve low-frequency wave orbital motions. The interval between each ping was 4 seconds so the ensemble length was 160 seconds. The interval between ensembles was 10 minutes. Data were recorded in earth coordinates with a heading bias of 10.06° E used. False targets, usually fish, were screened by setting the threshold maximum to 70 counts. Velocity data were rejected if the difference in echo intensity among the four beams exceeded this threshold.

600 kHz (47.5m)

The ADCP, set to a beam frequency of 600 kHz, was configured in a burst sampling mode consisting of 80 pings per ensemble. The interval between each ping was 2 seconds so the ensemble length was also 160 seconds. The interval between ensembles was 10 minutes. Data were recorded in earth coordinates with a heading bias of 10.06° E used. The threshold maximum was also set to 70 counts. Velocity data were rejected if the difference in echo intensity among the four beams exceeded this threshold.

3. ADCP data processing procedures

Binary files output from the ADCP were read and converted to MATLAB™ binary files using scripts developed by Eric Firing's ADCP lab (http://current.soest.hawaii.edu). The beginning of the raw data files were truncated to a time after the mooring anchor was released in order to allow time for the anchor to reach the seabed and for the mooring motions that follow the impact of the anchor on the sea floor to dissipate. The pitch, roll, and ADCP temperature were examined in order to pick reasonable times that ensured good data quality but without unnecessarily discarding too much data (see Figure 5-11 and Figure 5-12). Truncation at the end of the data files were chosen to be the ensemble prior to the time that the acoustic release signal was sent to avoid contamination due to the ascent of the instrument. The times of the first ensemble from the raw data, deployment and recovery time, along with the times of the truncated records of both deployments are shown in Table 5-6.

Table 5-6. ADCP record times (UTC) during WHOTS-6 deployment.

	300 kHz	600 kHz
Raw file beginning and end times	08-Jul-2009 00:00:00 03-Aug-2010 07:50:00	10-Jul-2009 00:00:00 03-Aug-2010 06:00:00
Deployment and recovery times	10-Jul-2009 20:19 in water 11-Jul-2009 01:18 anchor over 02-Aug-2010 17:11 release triggered 02-Aug-2010 22:43 on deck	10-Jul-2009 19:48 in water 11-Jul-2009 01:18 anchor over 02-Aug-2010 17:11 release triggered 03-Aug-2010 01:53 on deck
Processed data beginning and end times	11-Jul-2009 09:20:00 02-Aug-2010 17:00:00	11-Jul-2009 09:20:00 02-Aug-2010 17:00:00

ADCP Clock Drift

Upon recovery, the ADCP clocks were compared with the ship's time server and the difference between the two was recorded. A difference of 10 minutes and 6 seconds was observed with the 300 kHz (SN 7637) ADCP, while a difference of 3 minutes and 8 seconds was observed with the 600 kHz ADCP. Since the drift represents one ping from just one ensemble out of a total of over ~53,000, no corrections were made.

Heading Bias

As mentioned in the ADCP configuration section, the data were recorded in earth coordinates. A heading bias, the angle between magnetic north and true north, can be included in the setup to obtain output data in true earth coordinates. Magnetic variation was obtained from the National Geophysical Data Center 'Geomag' calculator. (http://www.ngdc.noaa.gov/seg/geomag). For a year-long deployment a constant value is acceptable because the change in declination is small, approximately -0.02° $year^{-1}$ at the WHOTS location. A heading bias of 10.06E° was entered in the setup of the WHOTS-6 ADCP's.

Speed of sound

Due to the constant of proportionality between the Doppler shift and water speed, the speed of sound needs only be measured at the transducer head (Firing, 1991). The sound speed used by the ADCP is calculated using a constant value of salinity (35) and the temperature recorded by the transducer temperature sensor of the ADCP. Using CTD profiles close to the mooring during HOT cruises, HOT-213 to HOT-223, and from the WHOTS deployment/recovery cruises, the mean salinity at 125 dbar was 35.30 while the mean salinity at 47.5 dbar was 35.22. Mean ADCP temperature at 125 dbar was 21.96 °C and 24.94 °C at 47.5 dbar (Figure 5-13).

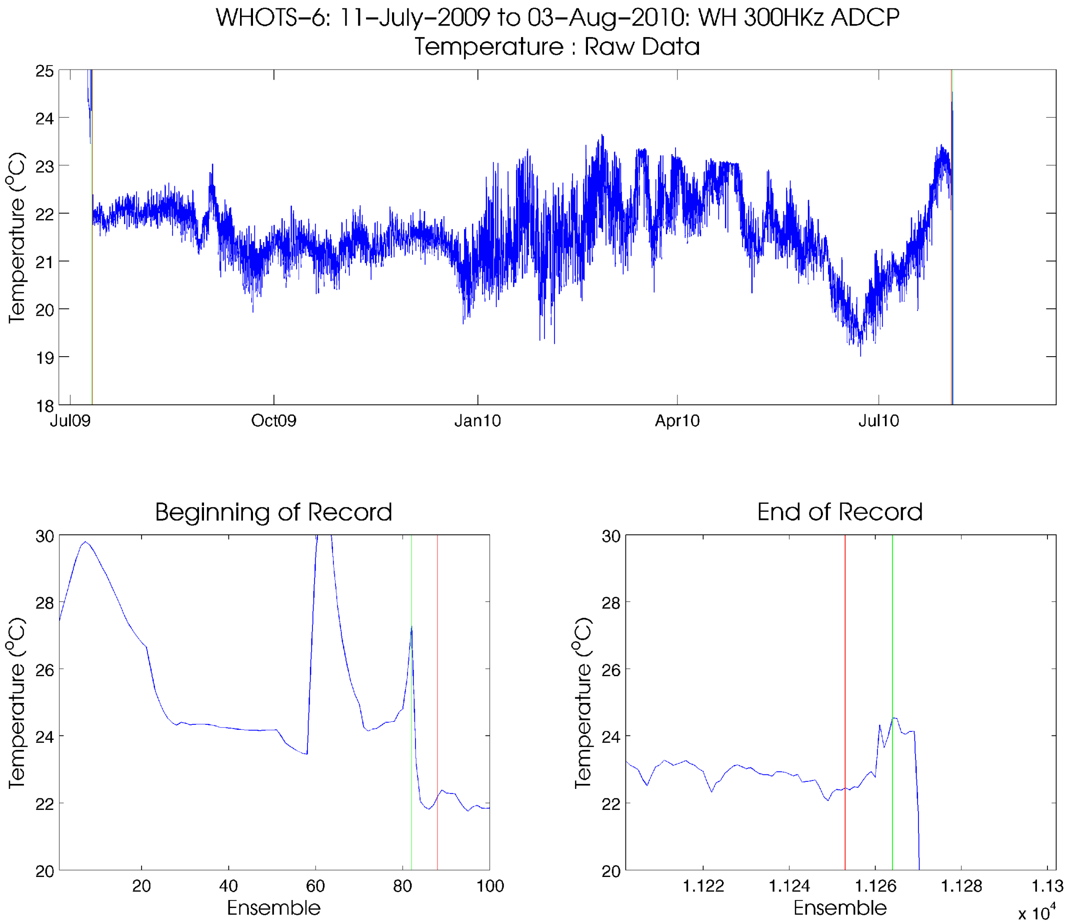


Figure 5-11. Temperature record from the 300 kHz ADCP during WHOTS-6 mooring (top panel). The bottom panel shows the beginning and end of the record with the green vertical line representing the in-water time during deployment and out-of-water time for recovery. The red line represents the anchor release and acoustic release trigger for deployment and recovery respectively.

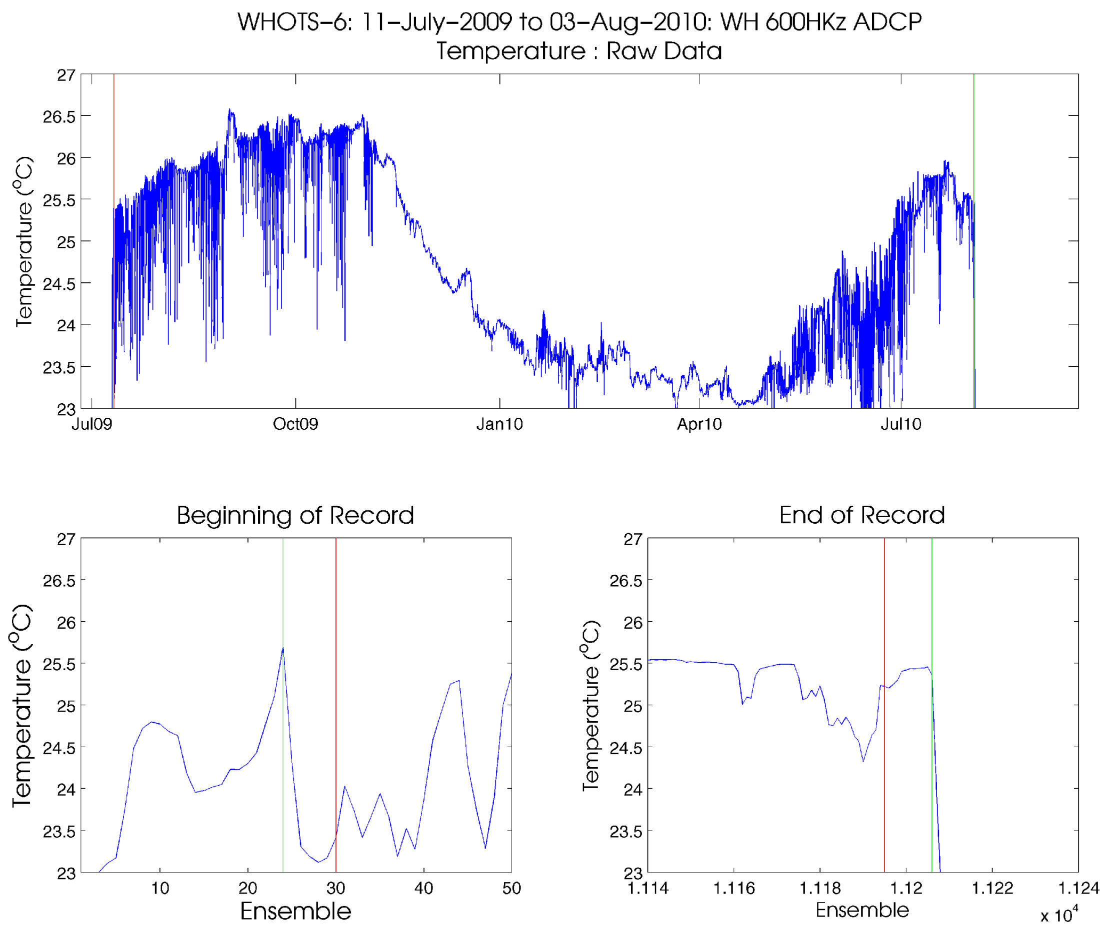


Figure 5-12. Same as Figure 5-11, but for the 600 kHz ADCP.

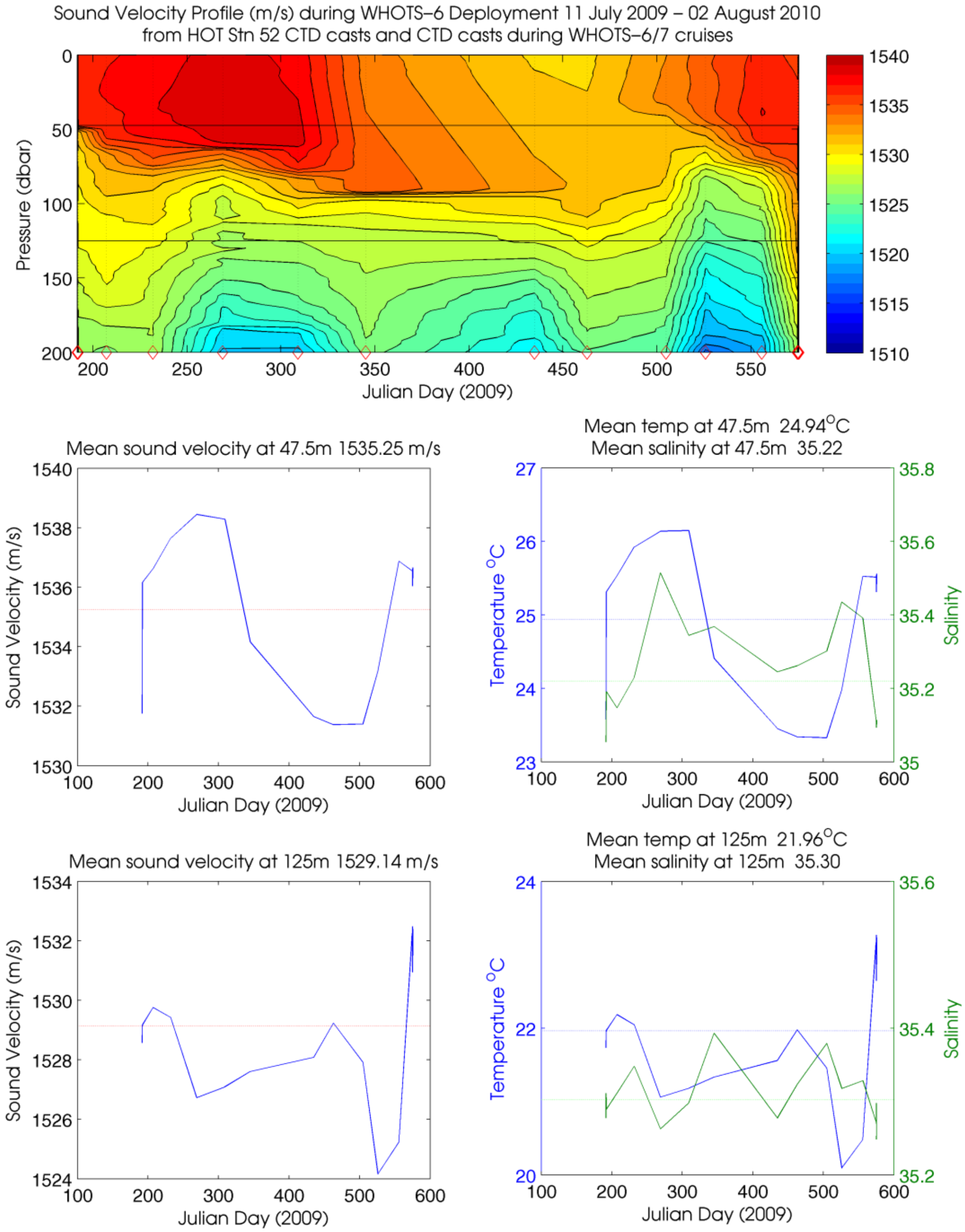


Figure 5-13. Sound speed profile (top panel) during the deployment of the WHOTS-6 mooring from 2 dbar CTD data taken during regular HOT cruises and CTD profiles taken during the WHOTS-7 recovery/deployment cruise (individual casts marked with a red diamond). The bottom left panels show the sound velocity at the depth of the ADCP's (47.5 m and 125 m), with the mean sound velocity indicated with a red line. The lower right panels show the temperature and salinity at each ADCP depth for the time series with the mean temperatures indicated with blue lines and mean salinity indicated with green lines.

Quality Control

Quality control of the ADCP data involved the thorough examination of the velocity, instrument orientation and diagnostic fields to develop the basis of the QC flagging procedures. Details of the methods used can be found in the WHOTS Data Report 1 (Santiago-Mandujano et al., 2007). The following QC procedures were applied to the WHOTS-6 deployment ADCP data.

1) The first bin (closest to the transducer) is sometimes corrupted due to what is known as ringing. A period of time is needed for the sound energy produced during a transmit pulse at the transducer to dissipate before the ADCP is able to properly receive the returned echoes. The blanking interval is used to prevent useless data from being recorded. If it is too short, signal returns can be contaminated from the lingering noise from the transducer. The default value for the blanking interval, (expressed as a distance) of 1.76 m was used for the 300 kHz ADCP, whereas an interval of 0.88 m was used for the 600 kHz ADCP. Thus bin 1 was flagged and replaced with Not a Number (NaN) in the quality controlled dataset (Figure 5-14).

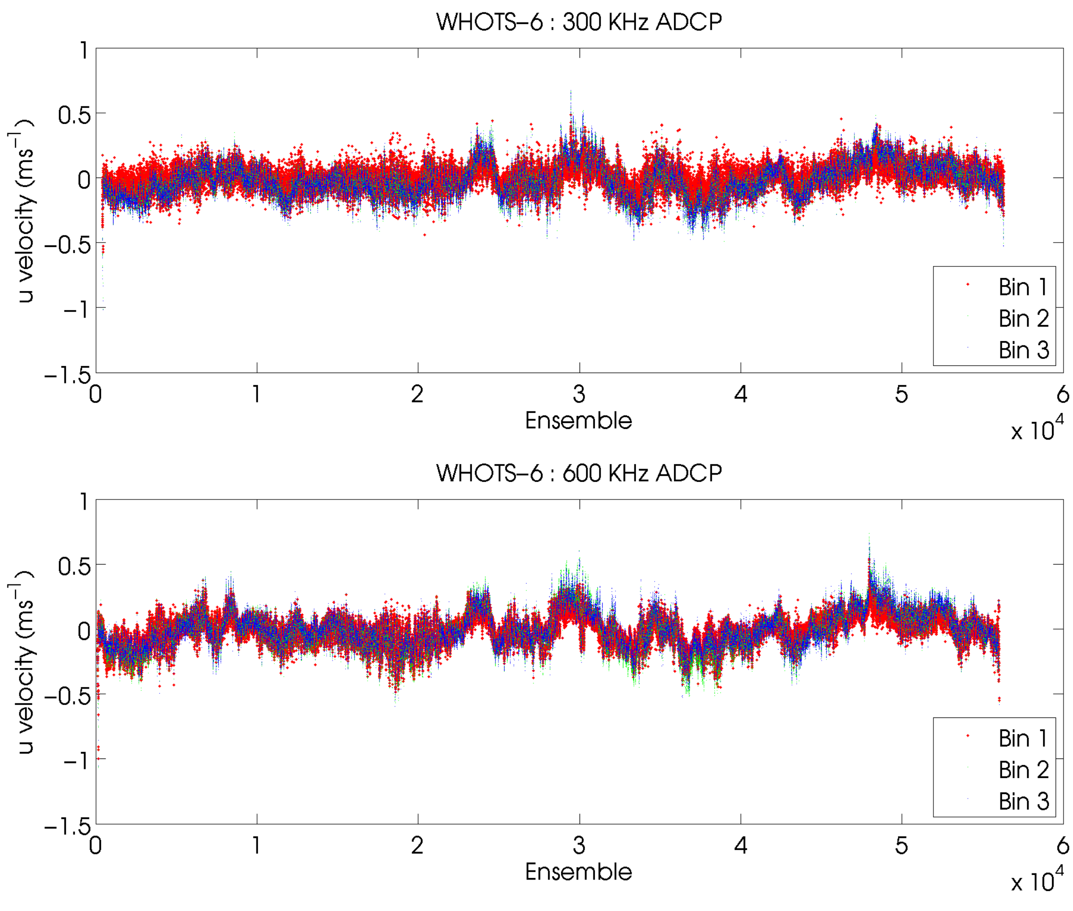


Figure 5-14. Eastward velocity component for the 300 kHz (top panel) and the 600 kHz (bottom panel) ADCPs showing the incoherence between depth 1 (red) and bins 2 (green) and 3 (blue).

2) For an upward-looking ADCP with a beam angle of 20° within range of the sea surface, the upper 6% of the depth range is contaminated with sidelobe interference (RDI, 1996). This is a result of stronger signal reflection from the sea surface (than from scatterers) overwhelming the sidelobe suppression of the transducer. Data are flagged using echo intensity (a measure of the strength of the return signal) from each beam to determine when the signal is contaminated with reflection from the sea surface. In practice, the majority of the data within the upper 4 bins (~14% of the vertical range) were flagged. These upper 4 bins range from about 15 m up to the sea surface.

3) The use of four beams (along with instrument orientation) to resolve currents into their component earth-referenced velocities provides us with a second estimate of the vertical velocity. The scaled difference between these estimates is defined as the error velocity and it is useful for assessing data quality. Error velocities with an absolute magnitude greater than 0.15 m s^{-1} (a value comparable to the standard deviation of observed horizontal velocities) were flagged and removed.

4) An indication of data quality for each ensemble is given by the “percent good” data indicator which accompanies each individual beam for each individual bin. The use of the percent good indicator is determined by the coordinate transformation mode used during the data collection. With profiles transformed into earth coordinates (as in the case of the WHOTS-6 deployment) the percent good fields show the percentage of data that was made using 4 and 3 beam solutions in each depth cell within an ensemble, and the percentage that was rejected as a result of failing one of the criteria set during the instrument setup (see Appendix 1: WHOTS-6 300 kHz ADCP Configuration). Data were flagged when data in each depth cell within an ensemble made from 3 or 4 beam solutions was 20% or less.

5) Data were rejected using correlation magnitude, which is the pulse-to-pulse correlation (in ping returns) for each depth cell. If anyone beam had a correlation magnitude of 20 counts or less, that data point was flagged.

6) Histograms of raw vertical velocity data and partially cleaned data from the ADCP [see Figure 5-15 and the WHOTS Data Report 1 (Santiago-Mandujano et al., 2007)] showed vertical velocities larger than expected, some exceeding 1 m s^{-1}. Recall that the instruments’ burst sampling (4-second intervals for the 300 kHz and 2-second intervals for the 600 kHz, for 160 seconds every 10 minutes) was designed to minimize aliasing by occasional large ocean swell orbital motions (Section 3), and therefore are not the source of these large speeds in the data. These large vertical speeds are possibly fish swimming in the beams based on the histograms of the partially cleaned data; depth cells with an absolute value of vertical velocity greater than 0.3 m s^{-1} were flagged.

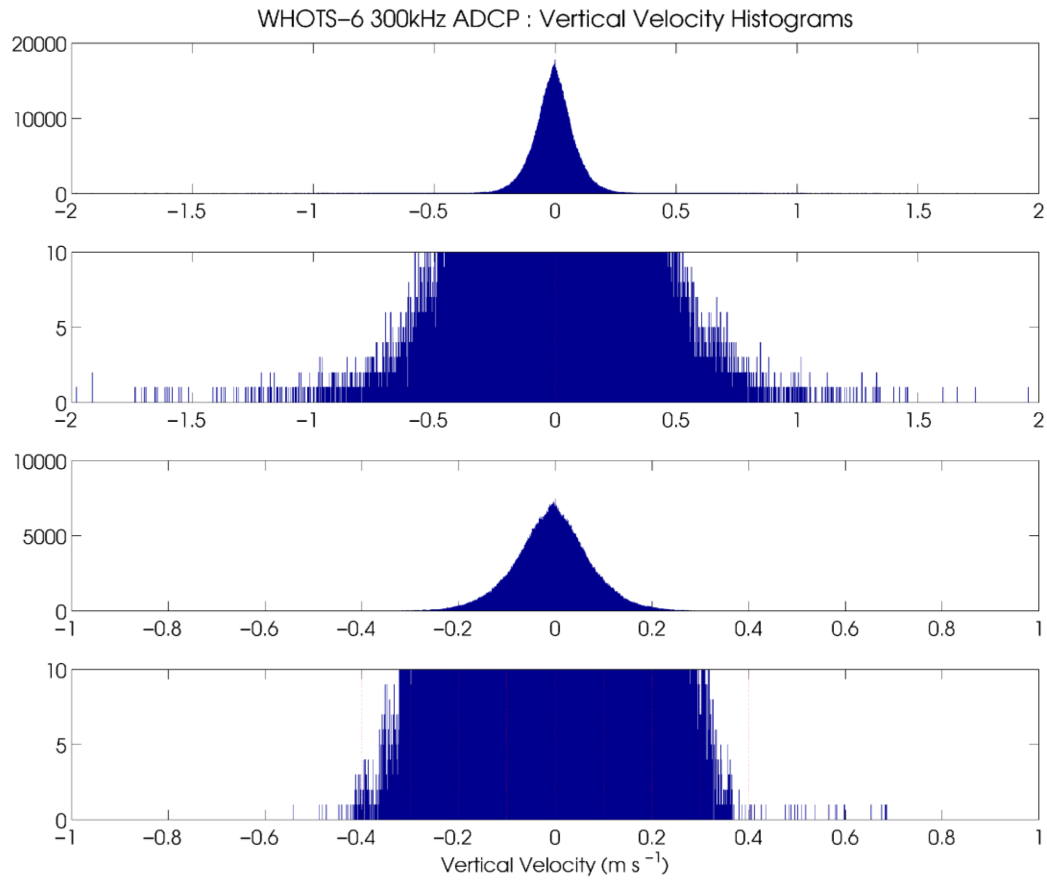


Figure 5-15. Histogram of vertical velocity of the 300 kHz ADCP for raw data (top panel) and enlarged for clarity (upper middle panel), and for partial quality controlled data (lower middle panel) and enlarged for clarity (bottom).

7) A quality control routine known as 'edgers' identifies outliers in surface bins using a five point median differencing method. The median velocity from surface bins was calculated for each ensemble, and then a five point running median of the surface bin median was calculated. This was then compared to individual velocity observations in the surface bins, and those differing by greater than 0.48 m/s were flagged.

8) A 5-pole low pass Butterworth filter with a cutoff frequency of 1/4 cycles/hour was used upon the length of the time-series to isolate low frequency flow for each bin independently. The low frequency flow is then subtracted giving a time series of high frequency velocity component fluctuations for each bin. Data points were considered outliers when their values exceeded four standard deviations from the mean (for each bin) and were removed.

9) A median residual filter used a 7-point (70 minute) median differencing method to define velocity fluctuations. A 7-point running median is calculated for each bin independently

and the result is subtracted out giving time series of fluctuations relative to the running median. Outliers greater than four standard deviations from the mean of the 7 points are flagged and removed for each bin.

10) Meticulous verification of all the quality control routines was performed through visual inspections of the quality controlled velocity data. Two methods were utilized; time-series of u and v components for multiple bins were evaluated as well as individual vertical profiles. The time-series methodology involved inspecting u and v components separately, five bins at a time, over 600 ensembles (100 hours). Any instance showing one bin behaving erratically from the other four bins was investigated further. If it seemed that there could be no reasonable rationale for the erratic points from the identified bin, the points were flagged [see Figure 5-16 and Figure 5-17 and the WHOTS Data Report 1 (Santiago-Mandujano et al., 2007)]. The intent of the vertical inspection of vertical profiles of the u and v components was to find entire profiles that were not aligned with neighboring profiles. Thirty u and v profiles were stacked at a time and were visually inspected for any anomalous data.

Figure 5-16. A sample of the horizontal inspection during WHOTS ADCP quality control

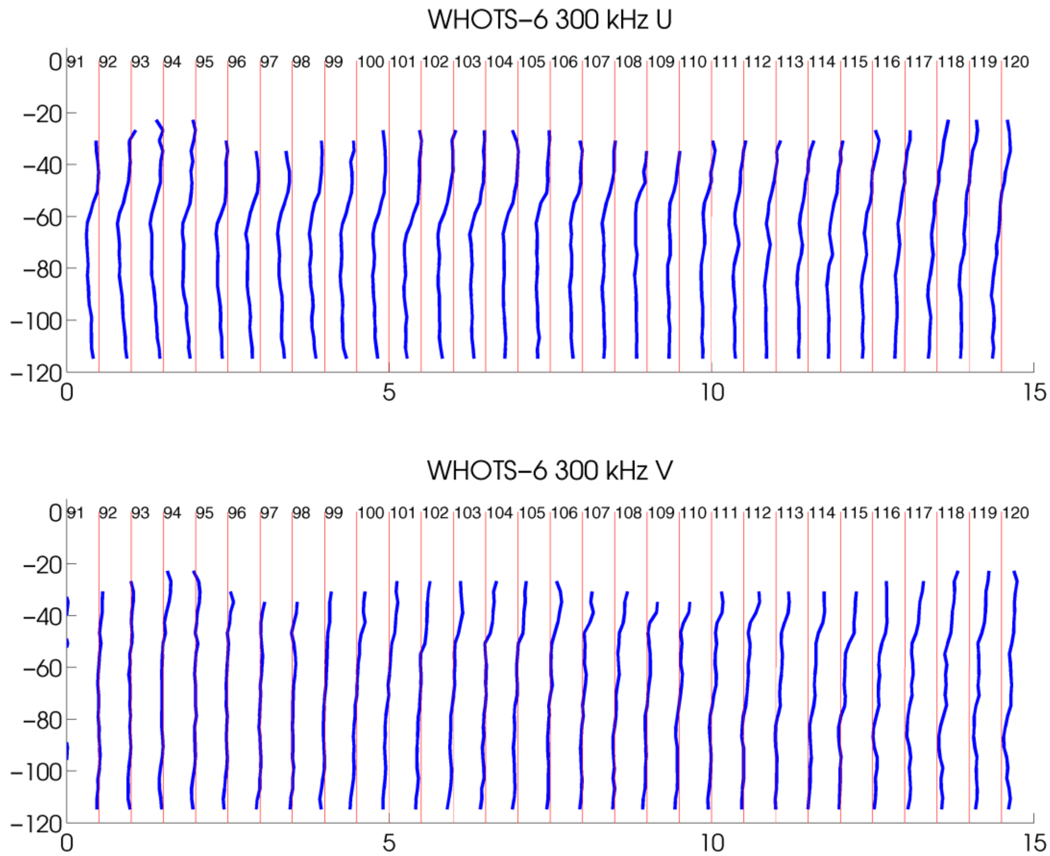


Figure 5-17. A sample of the profile consistency inspection from the WHOTS-6 ADCP quality control.

C. Vector Measuring Current Meter (VMCM)

Vector measuring current meters (VMCM) were deployed on the WHOTS-6 mooring at depths of 10 m and 30 m. VMCM data were processed by the WHOI/UOP group. VMCM record times are shown in Table 5-7.

Table 5-7. Record times (UTC) for the VMCMs at 10 m and 30 m during the WHOTS-6 deployment

	WHOTS-6	
	VMCM010	VMCM058
Deployment and recovery times	08-Jul-2009 16:59 04-Aug-2010 22:38	08-Jul-2009 16:59 04-Aug-2010 22:45
Processed file beginning and end times	11-Jul-2009 02:21 07-Apr-2010 21:09	11-Jul-2009 02:21 02-Aug-2010 17:08

Daily (24 hour) moving averages of quality controlled 600 kHz ADCP data are compared to VMCM data interpolated to the ADCP ensemble times in the top panels of Figure 5-18 through Figure 5-21, and the difference is shown in the middle panels. The absolute value of the mean difference plus or minus one standard deviation is shown at the top of the middle panel. Velocities are not compared if greater than 80% of the ADCP data within a 24 hour average was flagged. Velocity differences between the 10m VMCM and the 600 kHz ADCP were similar to the comparison with the 30m VMCM, although the 10m VMCM failed on April 7, 2010.

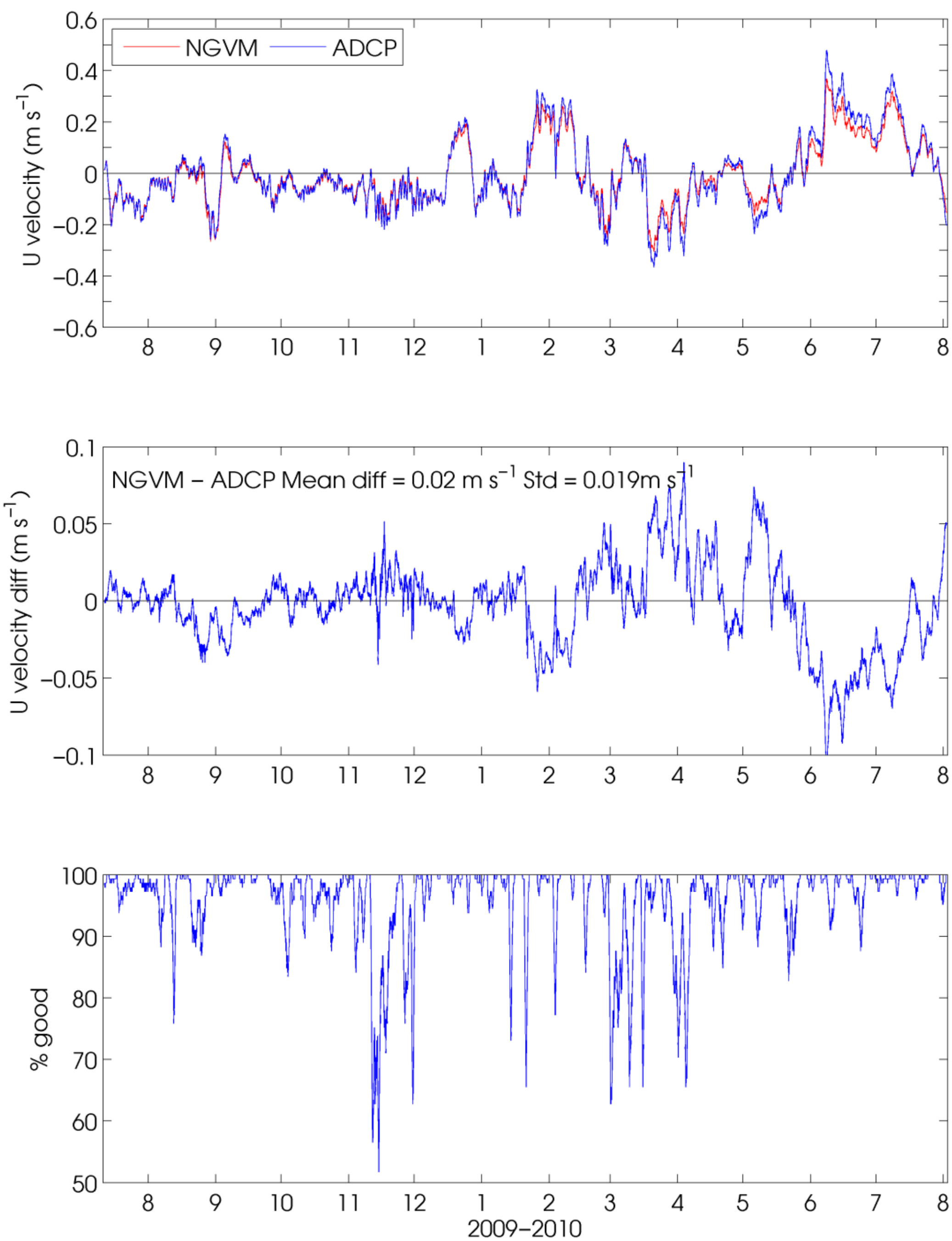


Figure 5-18. A comparison of 30 m VMCM and ADCP U velocity for WHOTS-6. The top panel shows 24 hour moving averages of VMCM zonal (U) velocity at 30 m depth (red) and ADCP U velocity from the nearest depth bin to 30 m (30.22 m). The middle panel shows the U velocity difference, and the bottom panel shows the percentage of ADCP data within the moving average not flagged by quality control methods. The dashed lines indicate a period of increased differences observed during spring months.

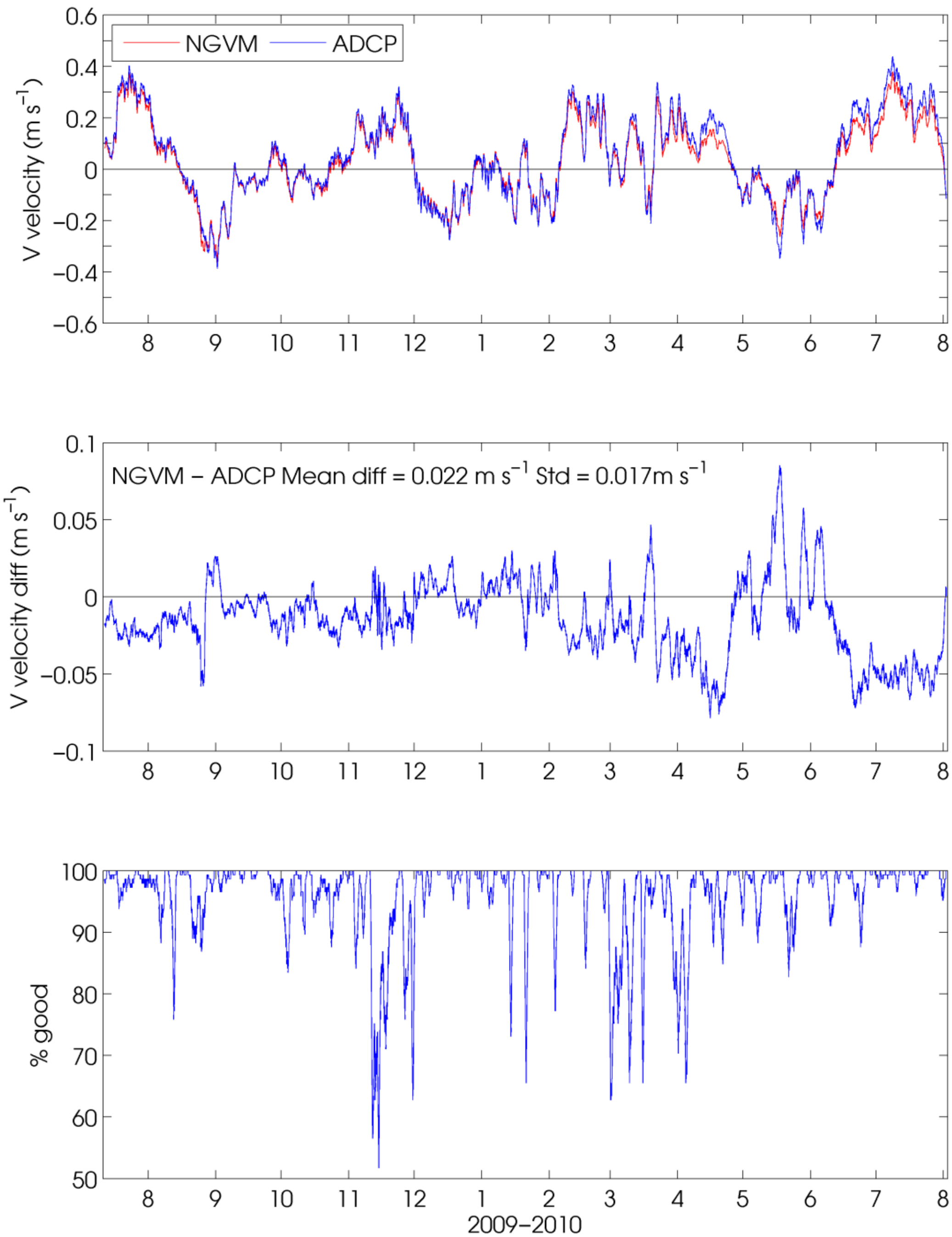


Figure 5-19. Same as in Figure 5 but for the meridional (V) velocity component.

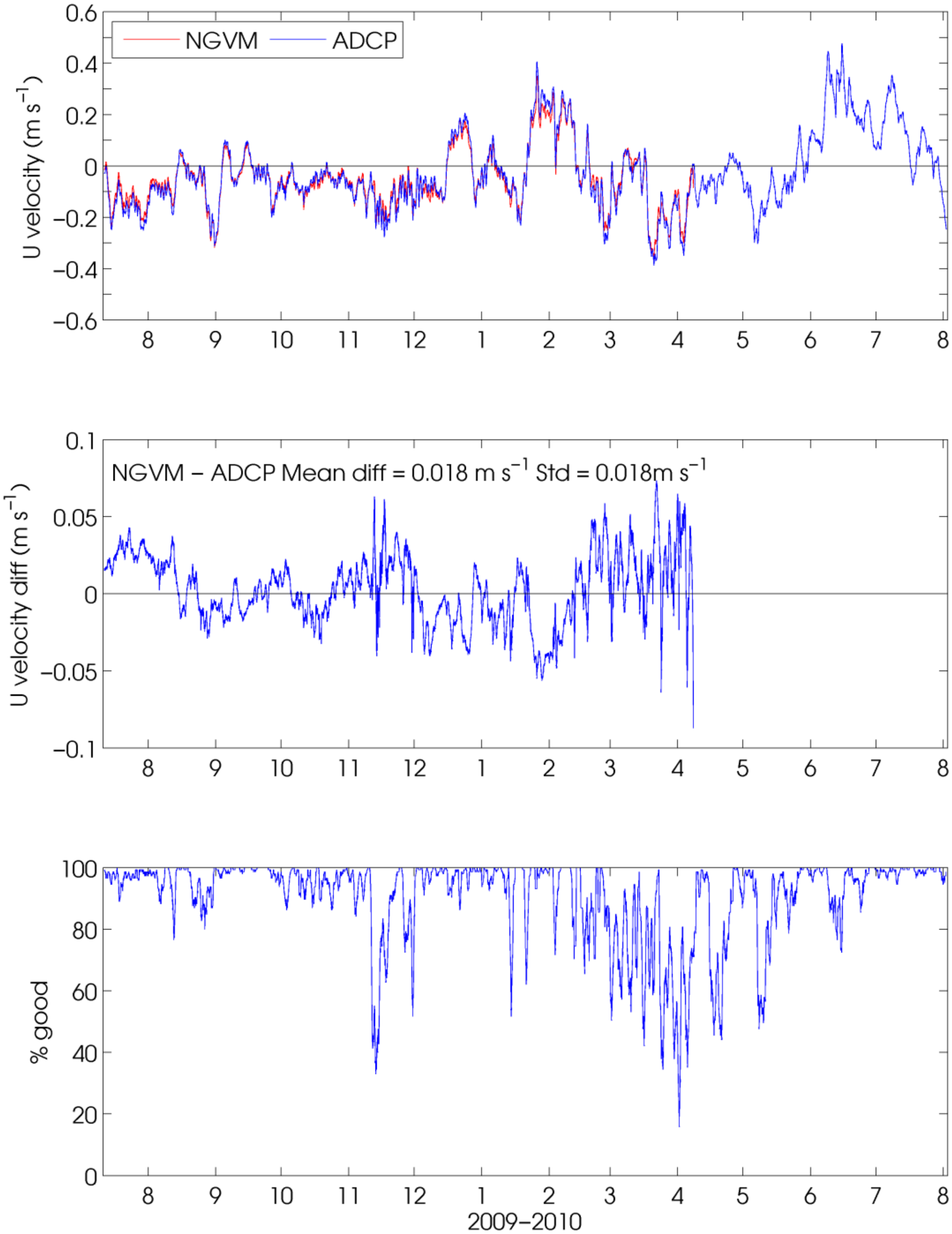


Figure 5-20. Same as in Figure 5 but for the 10 m VMCM.

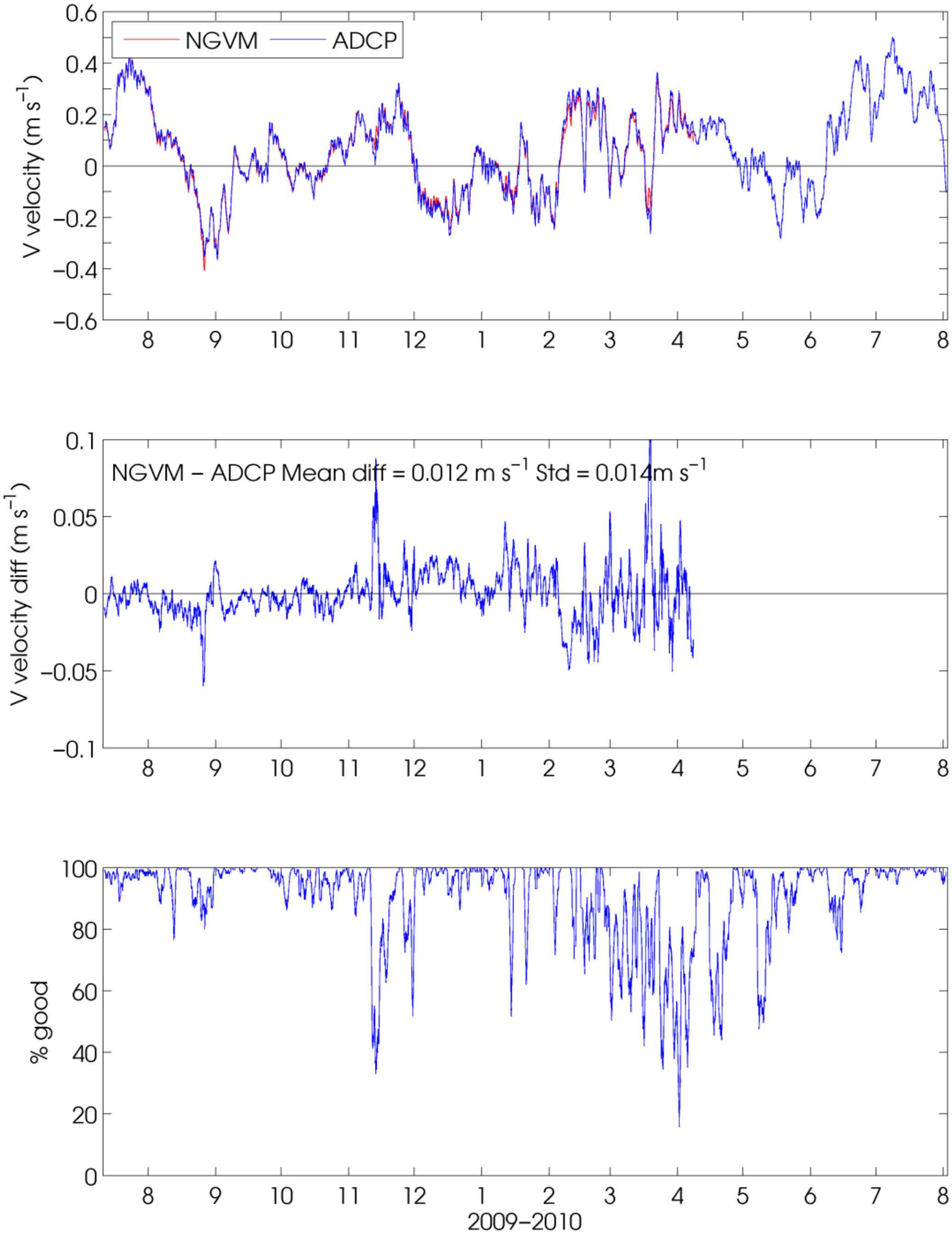


Figure 5-21. Same as in Figure 5- but for the V velocity component.

D. Global Positioning System Receiver and ARGOS Positions

Xeos Global Positioning System receiver (SN 611600) and ARGOS beacon (SN 25702) were attached to the tower top of the buoy during the WHOTS-6 deployment. Record times for both instruments are shown in Table 5-8.

Table 5-8. GPS and ARGOS record times (UTC) during WHOTS-6

WHOTS-6	Xeos GPS	ARGOS
Raw file beginning and end times	09-Jul-2009 19:47 03-Aug-2010 01:29	11-Jul-2009 03:26 02-Aug-2010 22:52

ARGOS positions were available during the WHOTS-6 deployment and they provided additional information on the buoy's motion. ARGOS data were recorded at 10 minutes intervals, although there are some small gaps at repeated times present in the records. Samples taken before mooring deployment were eliminated. Data were screened for points that were greater than 2.5 nautical miles from the surveyed anchor positions for each deployment which was considered to be the buoy watch circle radius. The velocity magnitude was calculated and positions that resulted in speeds greater than 1 m s^{-1} were removed. Data were interpolated onto a regular time grid in order to compute spectra.

For comparison, Figure 5-22 shows the ARGOS buoy's positions together with the GPS positions during the WHOTS-6 deployment. The standard deviation of the difference between these two records is about 350m.

The ARGOS positions of the WHOTS-6 buoy for the duration of the deployment are in Figure 5-23, and shows the color-coded positions according to their data quality. The data quality is determined by its distance from the satellite track. Data of a better quality have a higher flag number: 3 is for a distance less than 150 m, 2 is for a distance between 150 and 350 m, and 1 is for a distance between 350 and 1000 m. For the duration of the deployment, the buoy had a mean position of about 3 km from the anchor, with a standard deviation of about 600 m.

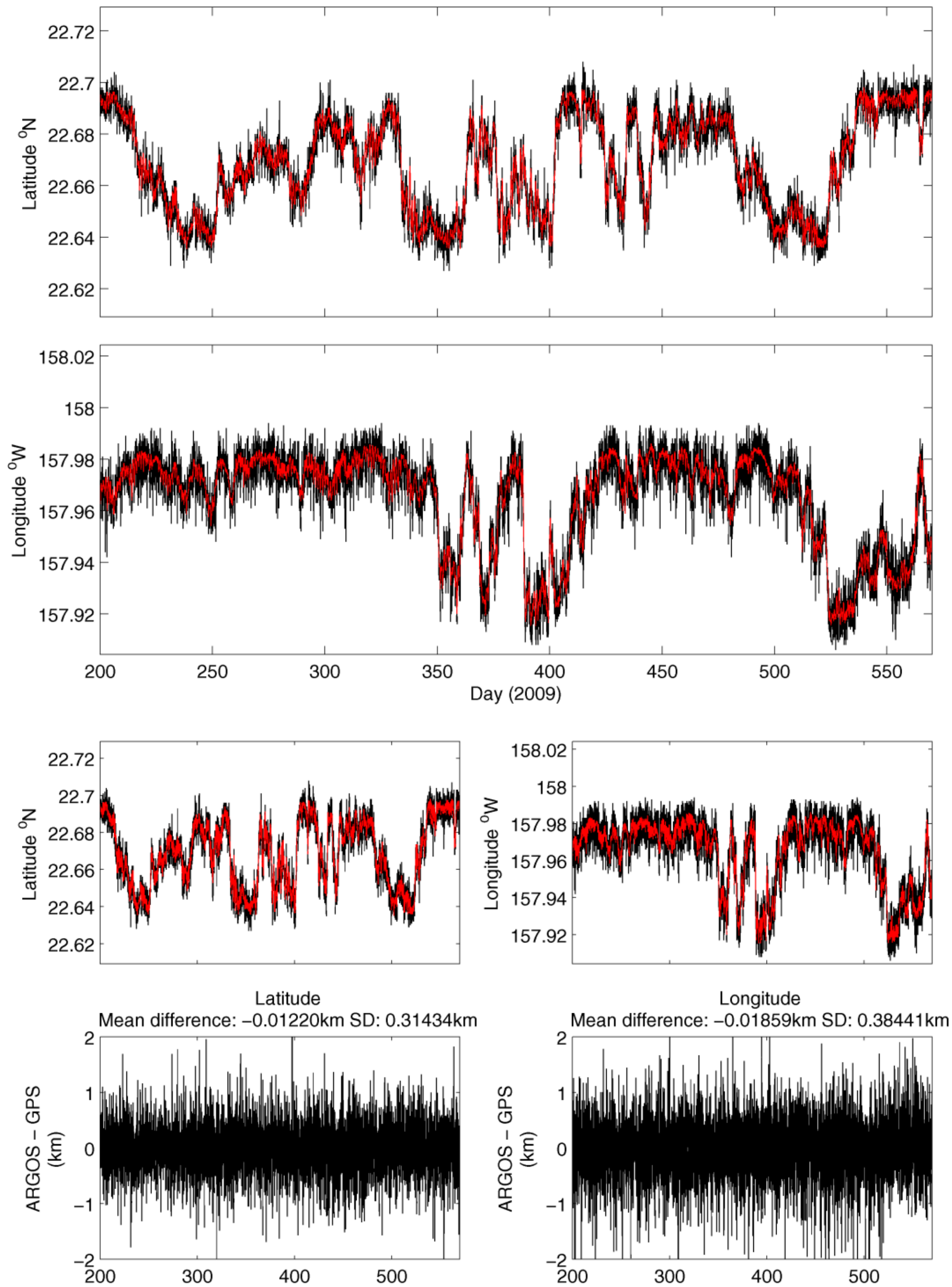


Figure 5-22. WHOTS-6 buoy position from ARGOS data (black line), and from GPS data (red line). The top and two middle panels show the latitude and longitude of the buoy. The bottom panel shows the difference between the GPS positions and the ARGOS positions interpolated to the GPS times.

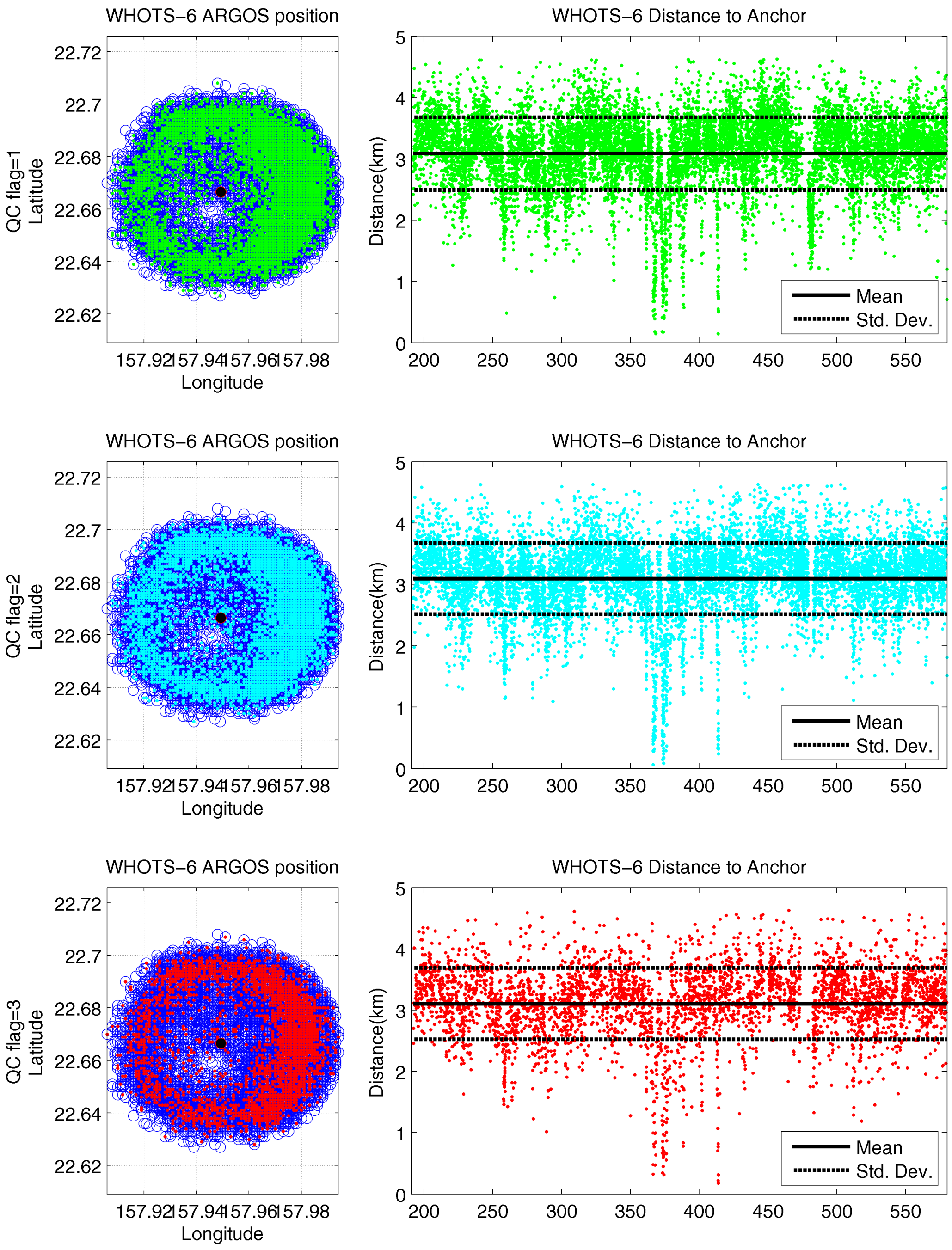


Figure 5-23. WHOTS-6 buoy ARGOS positions (circles, left panels), and distance from its anchor (dots, right panels). The data are colored according to their quality control flag, 1: green, 2: light blue, 3: red. The black circle in the center of the left side panels is the location of the mooring's anchor. The black line in the right panel plots is the mean distance between the buoy and its anchor, and the dashed line is the mean plus minus one standard deviation.

E. MAVS Acoustic Velocity Sensor

A Nobska MAVS acoustic velocity sensor (SN 10260) was deployed at 20 m on the WHOTS-6 mooring. Current velocities from this sensor were available until Feb 9, 2010 when the 'C' transducer failed, resulting in bad data (Figure 5-24).

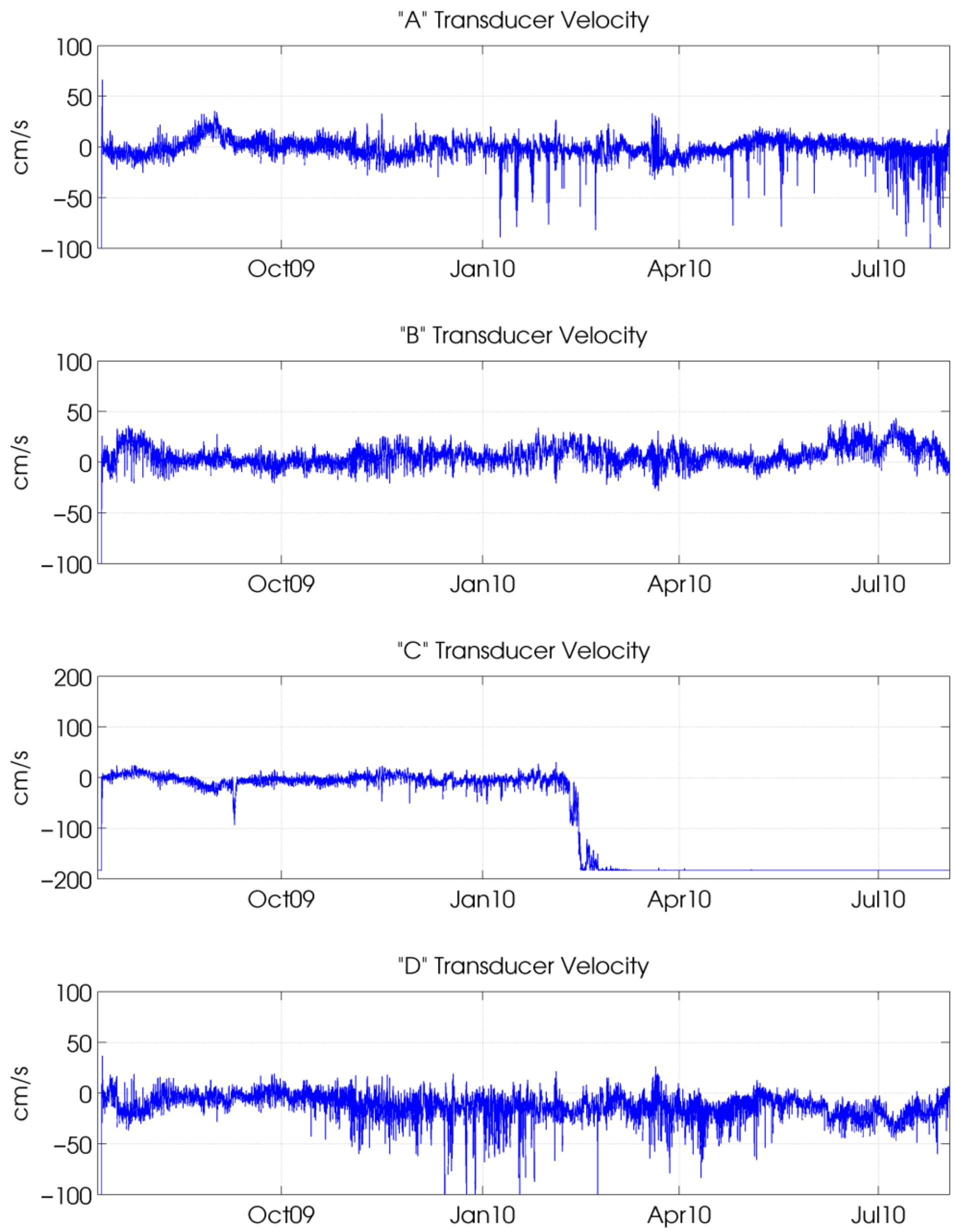


Figure 5-24. Time series of the raw acoustic velocity measured by each of the A, B, C and D transducers in cm s^{-1} *from the MAVS deployed at 20 m.*

6. Results

During the WHOTS-6 cruise (WHOTS-6 mooring deployment), Station ALOHA was under the influence of the eastern North Pacific high pressure system, and subject to moderate easterly trade winds. An upper level trough extended from the northeast of ALOHA towards the southwest, slightly destabilizing the lower atmosphere. This resulted in somewhat greater vertical development of trade wind cumulus, and occasional light rainfalls. The near surface (27 m) currents were eastward near Oahu. The Hawaiian Ridge Current was evident, with north-northwestward flow between Oahu and ALOHA. At Station ALOHA, the currents veered from northwest to northeast, as an anticyclonic eddy to the east of ALOHA drifted westward. The currents were also influenced by M2 internal tides and by inertial waves.

During the WHOTS-7 cruise (WHOTS-6 mooring recovery), Station ALOHA was under the influence of the eastern North Pacific high pressure system, and subject to moderate east-northeasterly trade winds. Winds were light (10-15 kts) during July 27-28th, 2010. Easterly waves were well developed, bringing the ITCZ northward, strengthening the surface pressure gradient near the wave crests. An upper level trough extended from the northeast of ALOHA towards the southwest, trailing a surface trough with a moist tropical air mass. This resulted in somewhat greater vertical development of trade wind cumulus, and occasional light rainfalls, resulting in showery, breezy weather for July 29th – August 3rd. This synoptic situation may have been enhanced by the onset of deep convection in the western equatorial Pacific, with enhanced trade wind inflows.

The temperature MicroCAT records during the WHOTS-6 deployment (Figure 6-14 through Figure 6-17) show obvious seasonal variability in the upper 100 m, and a temperature drop below 50 m during June-July 2010. The salinity records (Figure 6-18 through Figure 6-21) do not show an obvious seasonal cycle, but two instances of salinity increase were recorded between 25 and 70 m during September 2009 and during June-July 2010 by the instruments located between 50 and 90 m.

Figure 6-26 and Figure 6-27 show contours of the WHOTS-6 MicroCAT data in context with data from the previous deployments. The seasonal cycle is obvious in the temperature record, with record temperatures (higher than 26 °C) in the summer of 2004, and to a minor extent in the summer of 2005. Salinities in the subsurface salinity maximum were relatively low during the first 6 years of the record, only to increase drastically after 2008. The salinity maximum extended to near the surface during some instances in early 2010. When plotted in σ_θ coordinates (Figure 6-27), the salinity maximum seems to be centered roughly between 24 and 24.5 σ_{θ}.

Figure 6-31 through Figure 6-33 show time series of the zonal, meridional, and vertical currents recorded with the moored ADCPs during the WHOTS-6 deployment, and Figure 6-46 shows the vertical currents at 10 and 30 m collected by the VMCMs. Figure 6-28 through Figure 6-30 show contours of the ADCP current components in context with data from the previous deployments. In spite of the gaps in the data, an obvious variability is seen in the zonal and meridional currents, apparently caused by passing eddies. On top of this variability there have been periods of intermittent positive or negative zonal currents, for instance during 2007-2008. The contours of vertical current component (Figure 6-30) show a transition in the magnitude of the contours near 47 m, indicating that the 300 kHz ADCP located at 126 m moves more vertically than the 600 kHz ADCP located at 47.5 m.

Comparisons between the shipboard ADCP from HOT cruises and the mooring data are compiled in Table 6-1, and shown in Figure 6-34 through Figure 6-45. The correlation coefficient from these comparisons is higher than 0.8 for the majority of the cruises.

The motion of the WHOTS-7 buoy was registered by the Xeos-GPS receiver, and its positions are plotted in Figure 6-47. The buoy was located west of the anchor for the majority of the deployment, except during December 2009, January 2010, and May 2010 when it was east of it. Power spectrum of these data (Figure 6-48) shows extra energy at the inertial period (~31 hr). Combining the buoy motion with the tilt (a combination of pitch and roll) from the ADCP data (Figure 6-49), showed that the tilt increased as the buoy distance from the anchor increased. This was expected since the inclination of the cable increases as the buoy moves away from the anchor.

A. CTD Profiling Data

Profiles of temperature, salinity and potential density (σ_θ) from the casts obtained during the WHOTS-6 deployment cruise are presented in Figure 6-1 through Figure 6-5, together with the results of bottle determination of salinity. Figure 6-6 through Figure 6-11 are the results of the CTD profiles during the WHOTS-7 cruise.

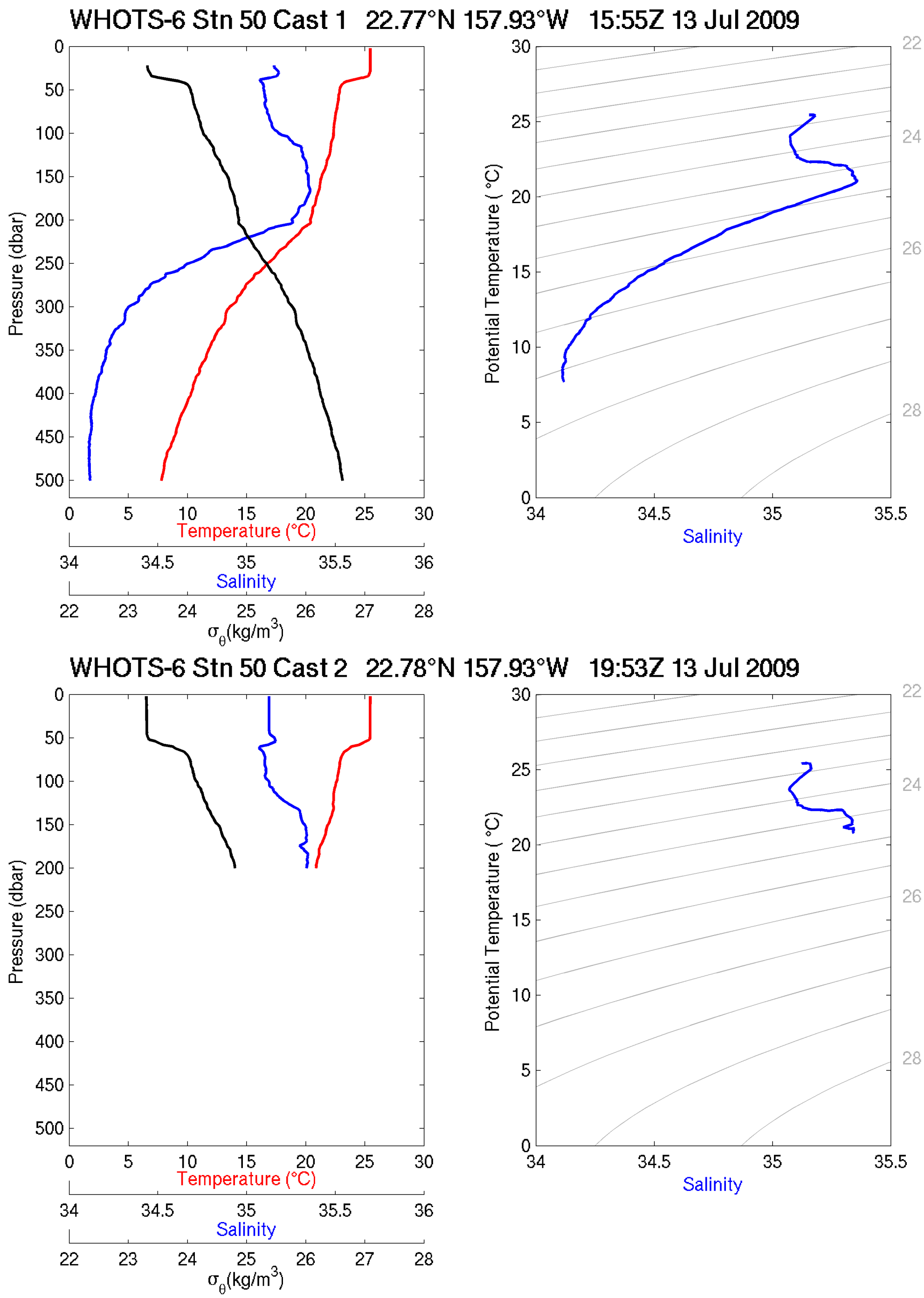


Figure 6-1. [Upper left panel] Profiles of CTD temperature, salinity, and potential density (σ_θ) as a function of pressure, including discrete bottle salinity samples (when available) for station 50 cast 1 during the WHOTS-6 cruise. [Upper right panel] Profiles of CTD salinity as a function of potential temperature, including discrete bottle salinity samples (when available) for station 50 cast 1 during the WHOTS-6 cruise. [Lower left panel] Same as in the upper left panel, but for station 50 cast 2. [Lower right panel] Same as in the upper right panel, but for station 50 cast 2.

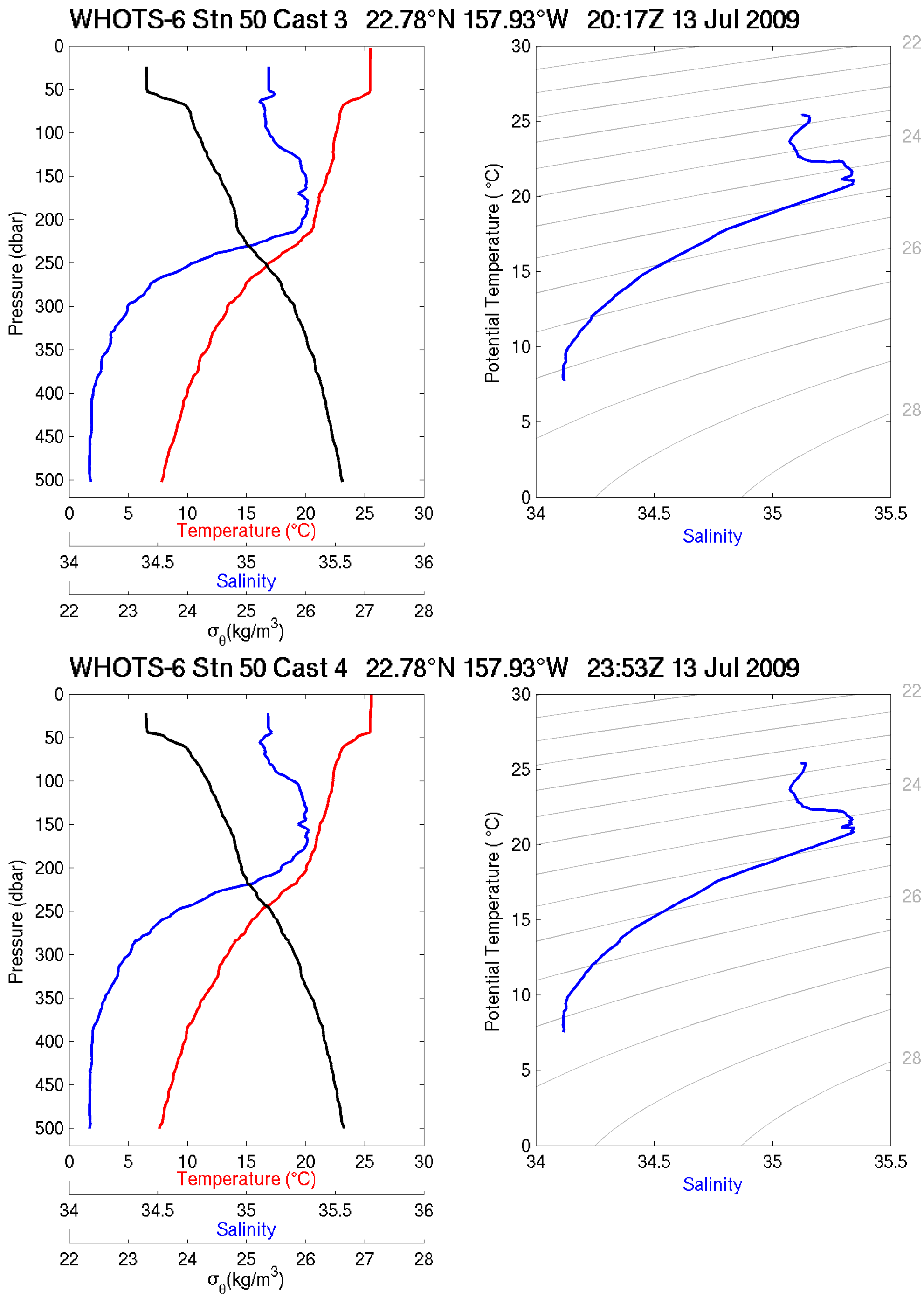


Figure 6-2. [Upper panels] Same as in Figure 6-1, but for station 50, cast 3. [Lower panels] Same as in Figure 6-1, but for station 50, cast 4.

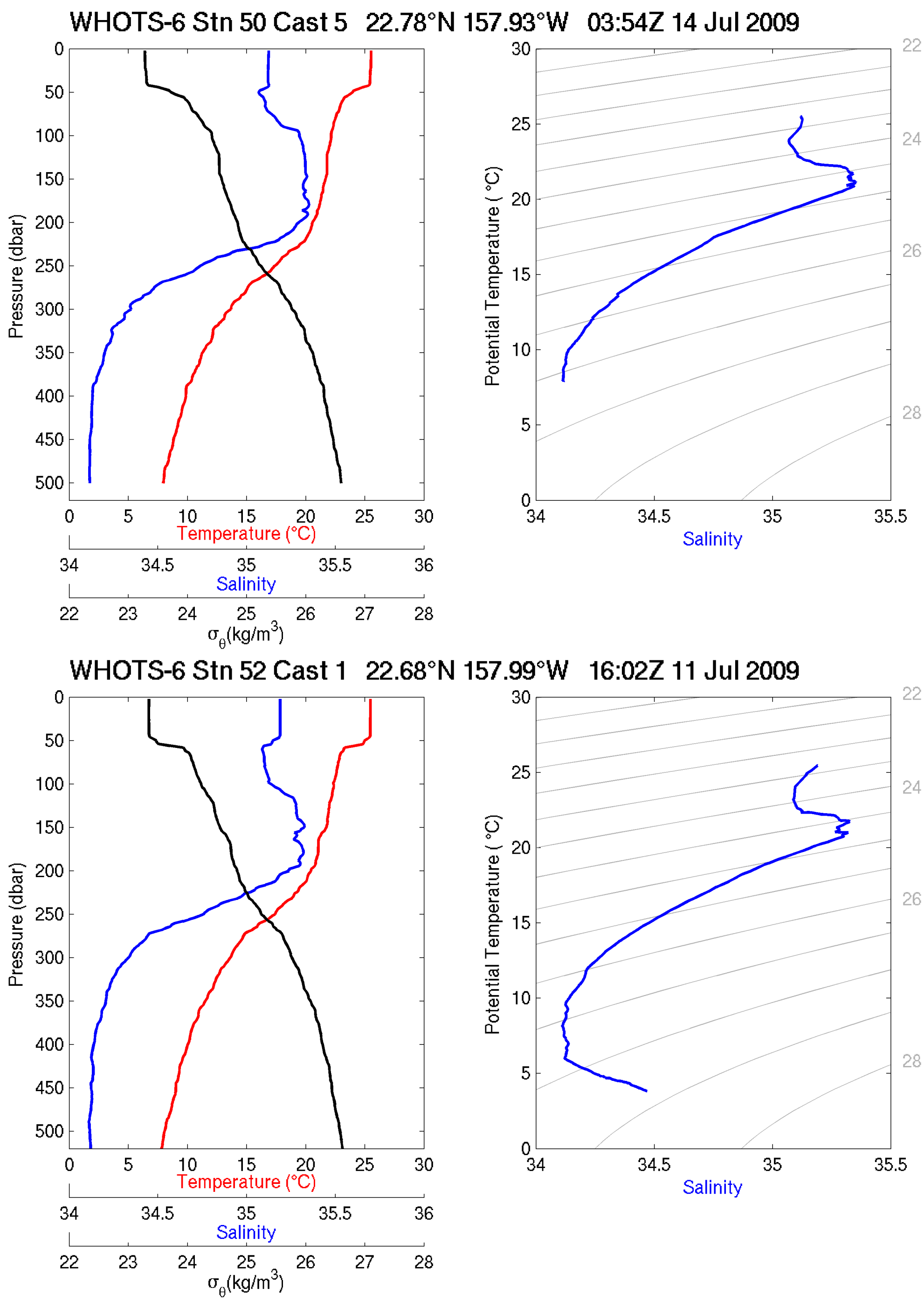


Figure 6-3. [Upper panels] Same as in Figure 6-1, but for station 50, cast 5. [Lower panels] Same as in Figure 6-1, but for station 52, cast 1.

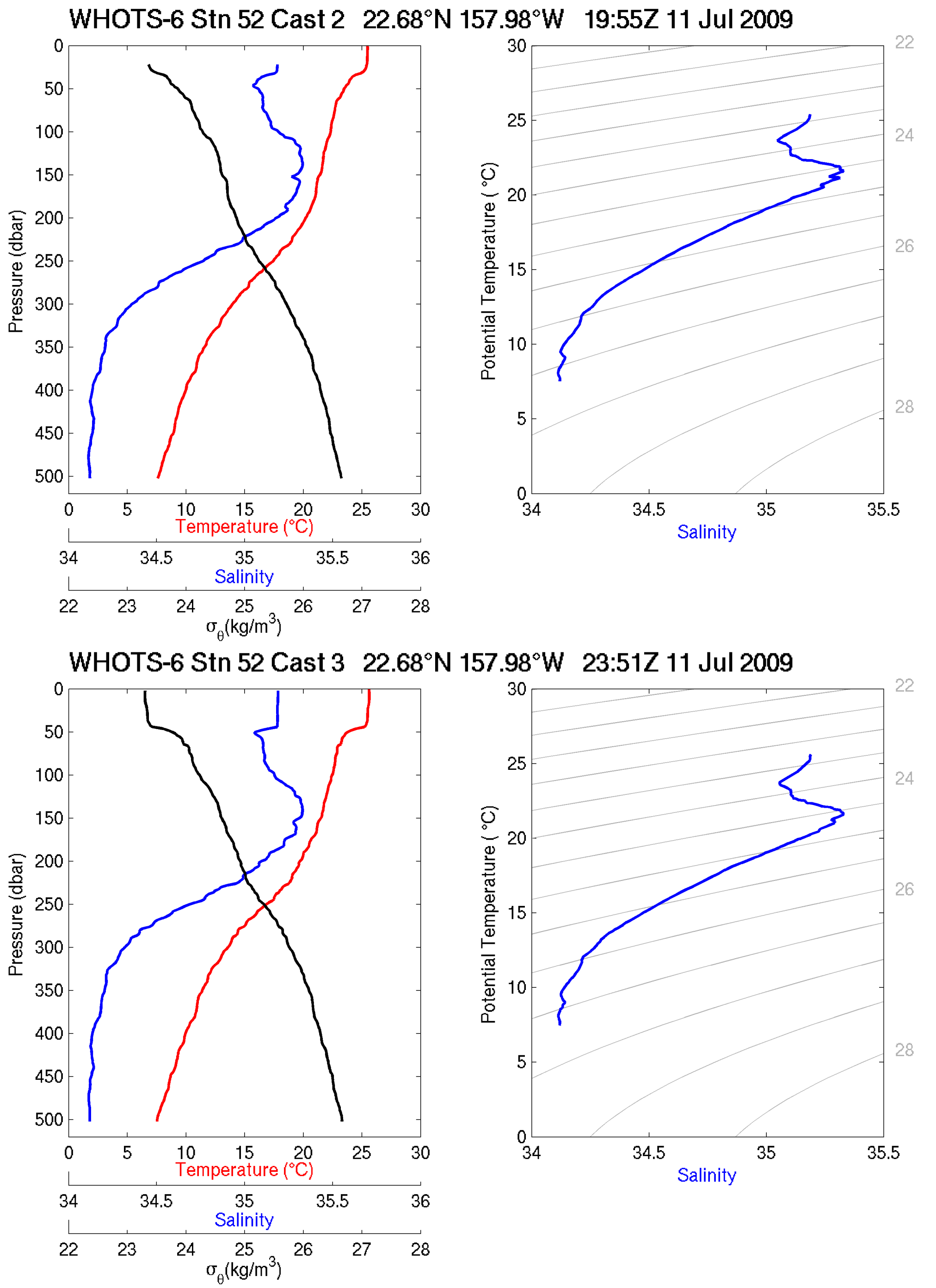


Figure 6-4. [Upper panels] Same as in Figure 6-1, but for station 52, cast 2. [Lower panels] Same as in Figure 6-1, but for station 52, cast 3.

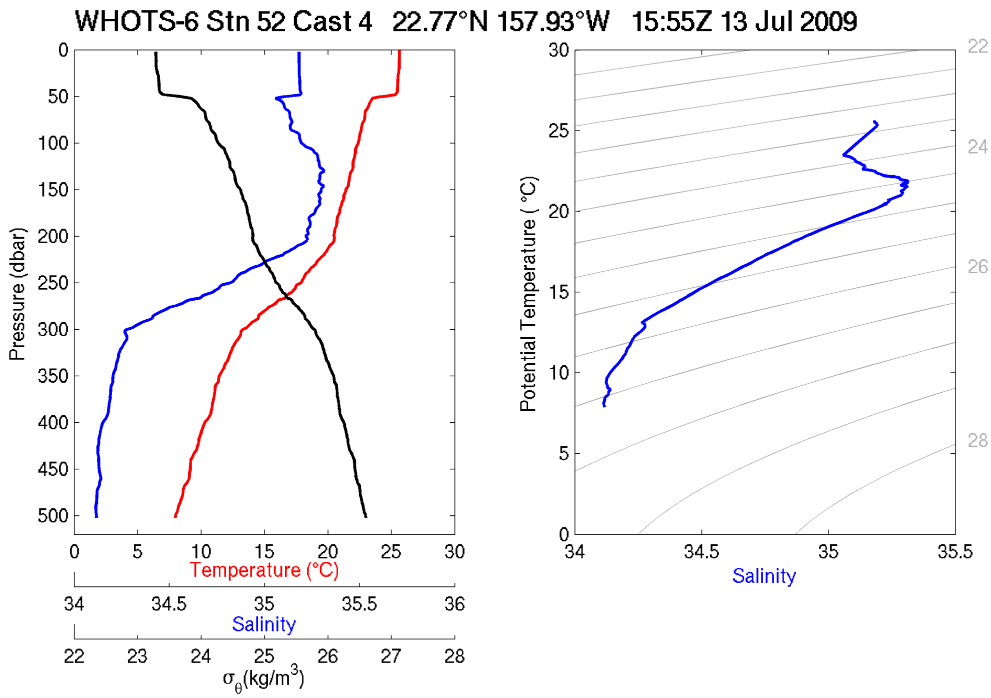


Figure 6-5. [Upper panels] Same as in Figure 6-1, but for station 52, cast 4 .

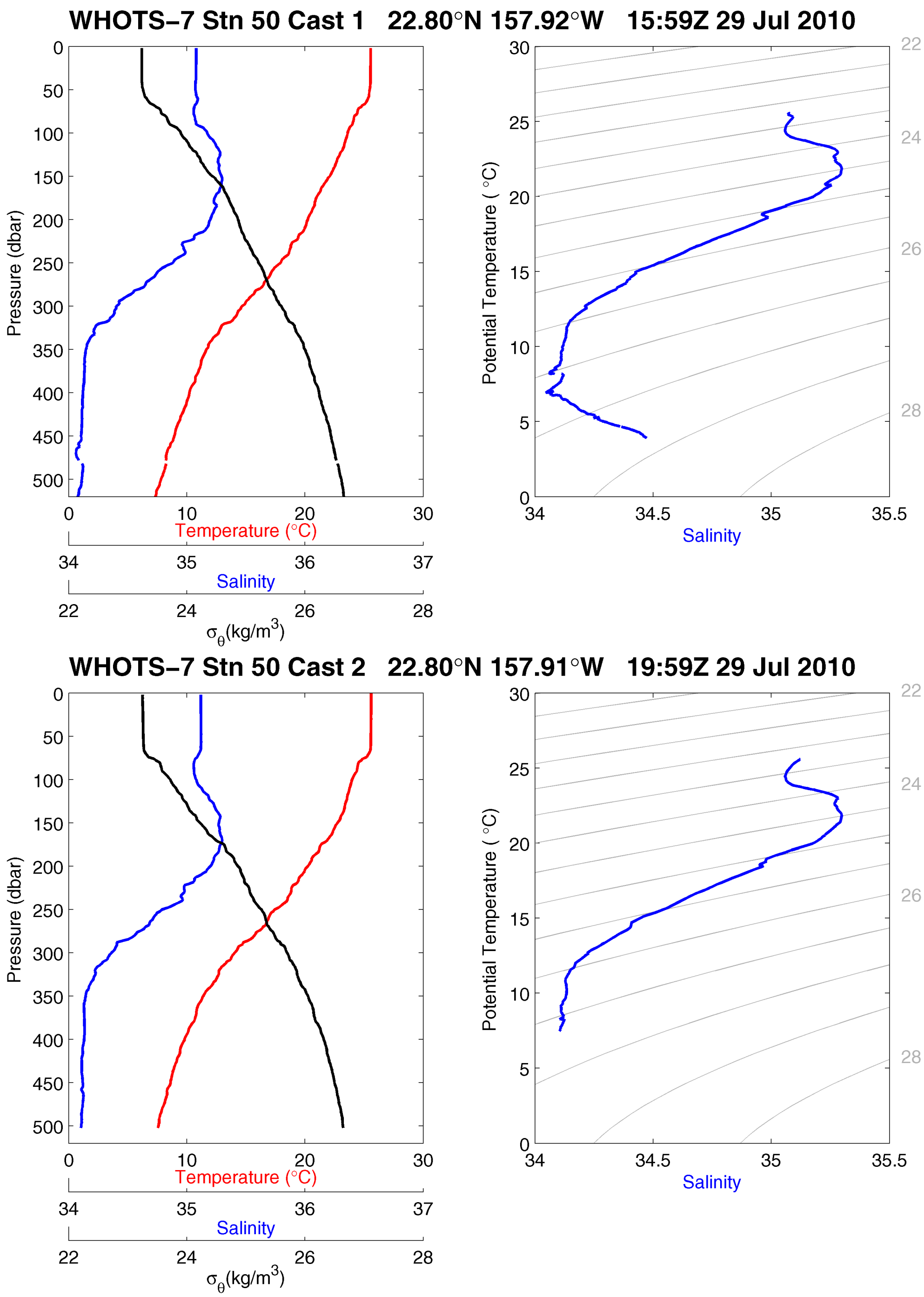


Figure 6-6.[Upper left panel] Profiles of CTD temperature, salinity, and potential density (σ_θ) as a function of pressure, including discrete bottle salinity samples (when available) for station 50 cast 1 during the WHOTS-7 cruise. [Upper right panel] Profiles of CTD salinity as a function of potential temperature, including discrete bottle salinity samples (when available) for station 50 cast 1 during the WHOTS-7 cruise. [Lower left panel] Same as in the upper left panel, but for station 50 cast 2. [Lower right panel] Same as in the upper right panel, but for station 50 cast 2.

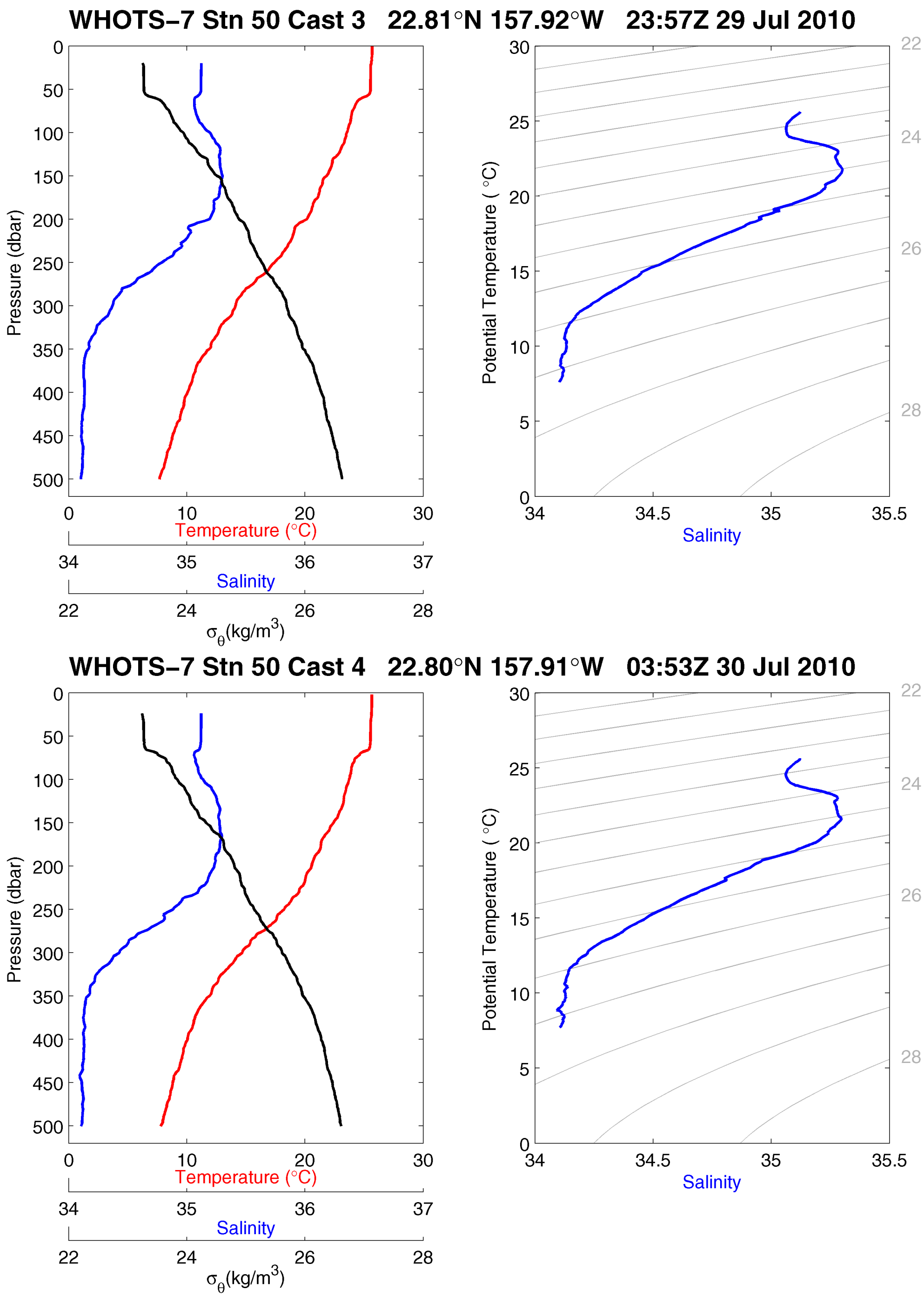


Figure 6-7. [Upper panels] Same as in Figure 6-7, but for station 50, cast 3. [Lower panels] Same as in Figure 6-7, but for station 50, cast 4.

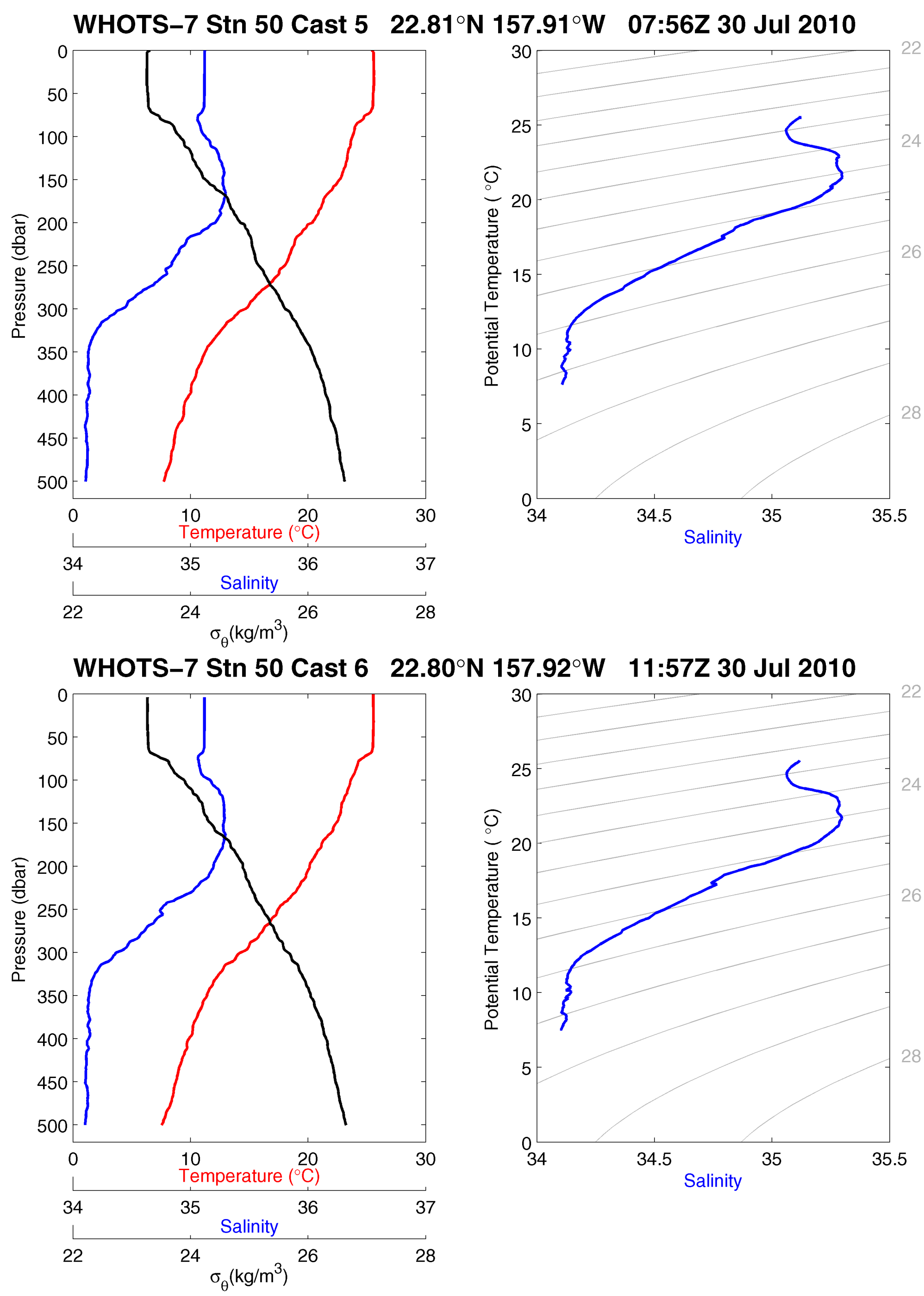


Figure 6-8. [Upper panels] Same as in Figure 6-7, but for station 50, cast 5. [Lower panels] Same as in Figure 6-7, but for station 50 cast 6.

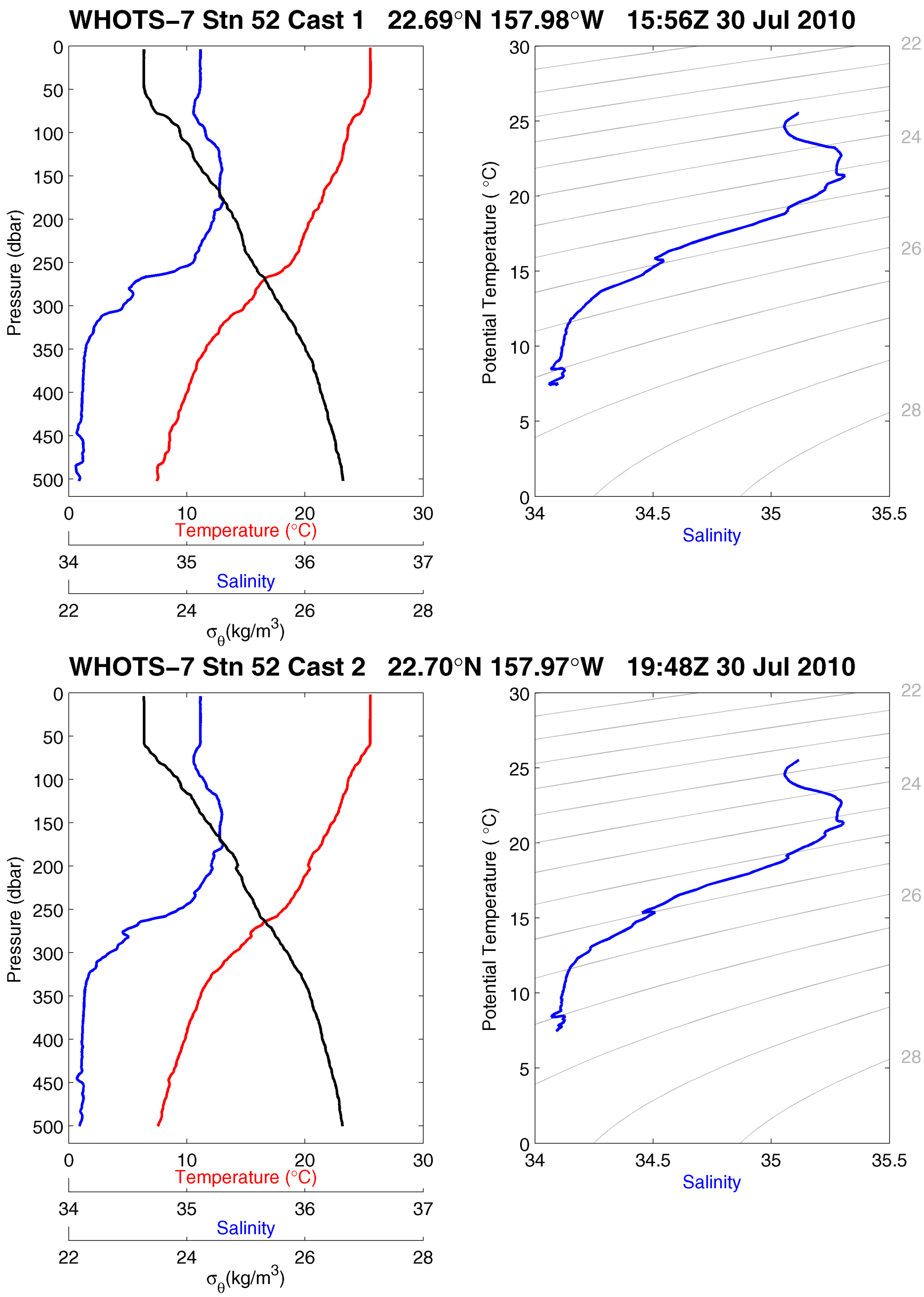


Figure 6-9. [Upper panels] Same as in Figure 6-7, but for station 52, cast 1. [Lower panels] Same as in Figure 6-7, but for station 52 cast 2.

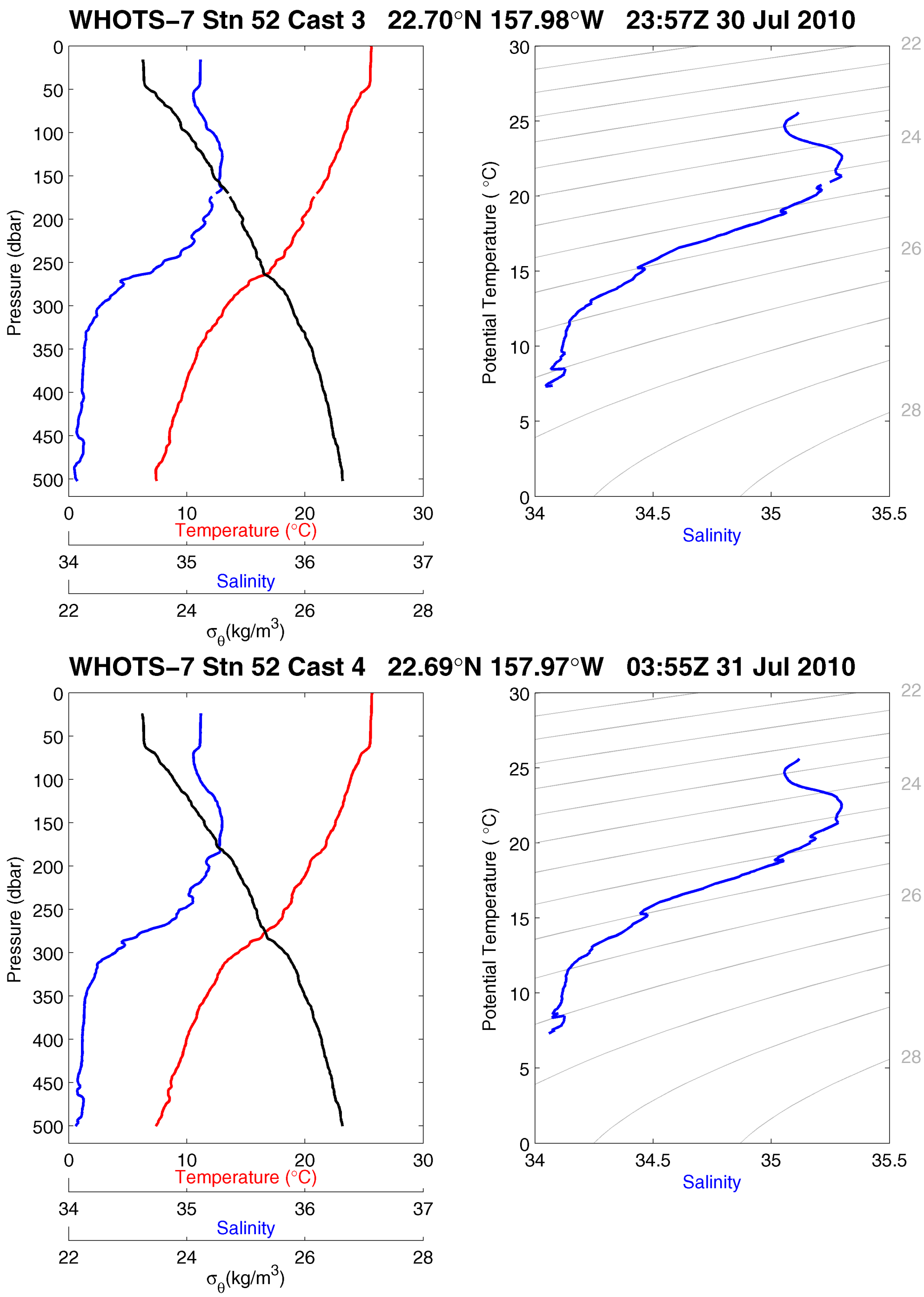


Figure 6-10. [Upper panels] Same as in Figure 6-7, but for station 52, cast 3. [Lower panels] Same as in Figure 6-7, but for station 52 cast 4.

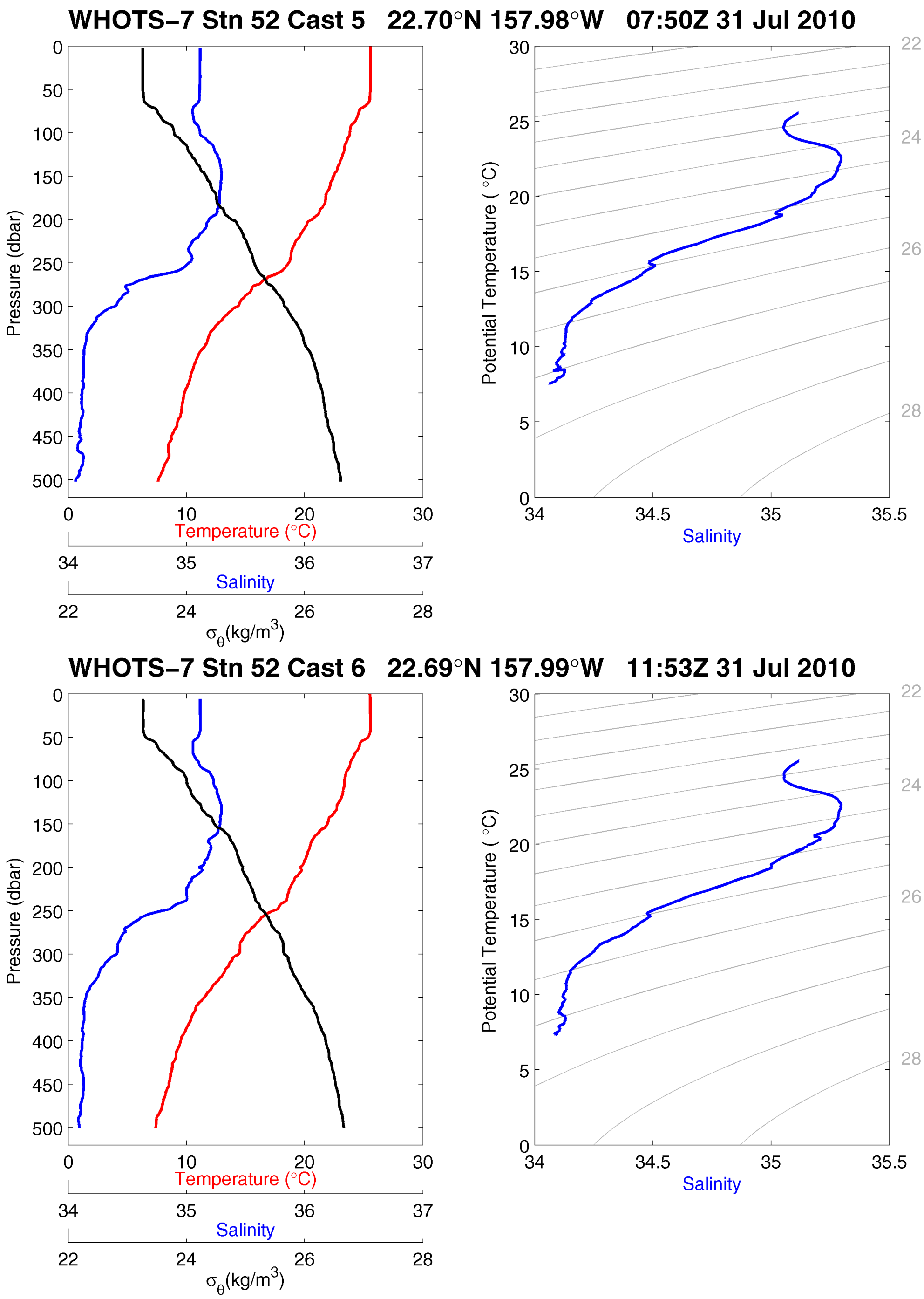


Figure 6-11. [Upper panels] Same as in Figure 6-7, but for station 52, cast 5. [Lower panels] Same as in Figure 6-7, but for station 52 cast 6.

B. Thermosalinograph data

Underway measurements of near surface temperature and near surface salinity from thermosalinograph as well as navigation for the WHOTS-6 cruise are presented in Figure 6-12 and Figure 6-13. Since external temperature data were available, temperatures from the internal sensor (where conductivity is measured) are corrected by an offset obtained from comparisons with the external sensor and CTD cast data; the internal sensor temperatures are affected by cooling and heating as the water traveled through the ship from the intake to the thermosalinograph (see Sect. 4.C.2), and therefore these data were flagged as uncalibrated.

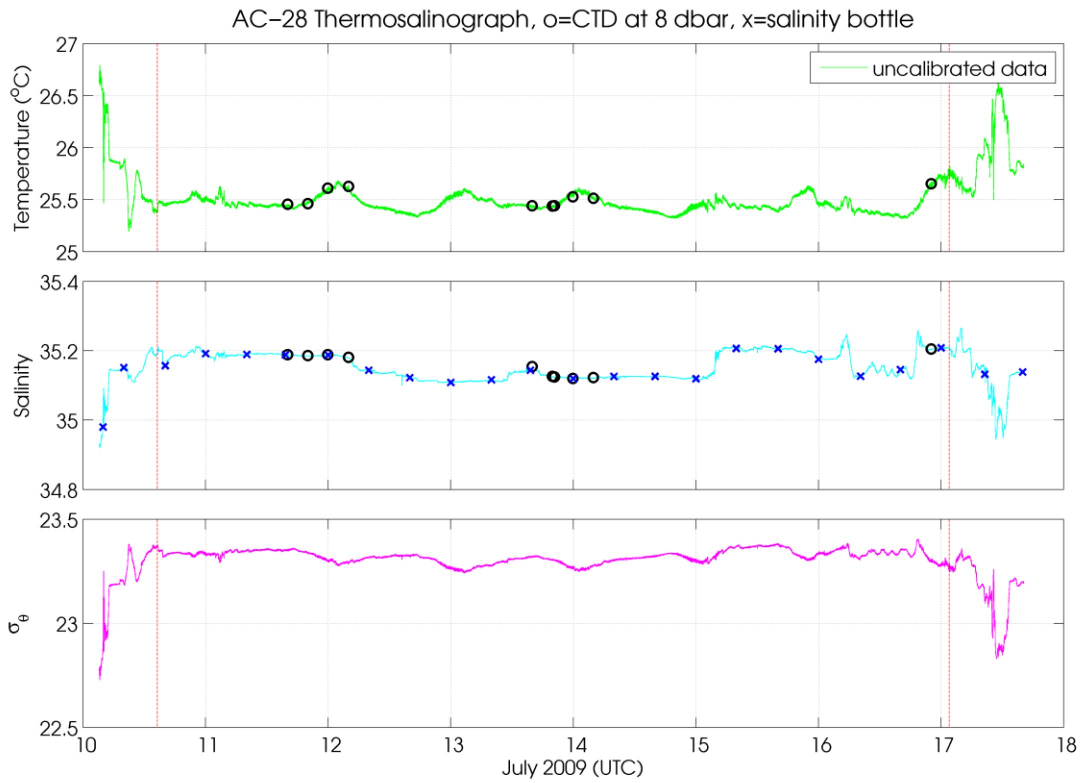


Figure 6-12. Final processed temperature (upper panel), salinity (middle panel) and potential density (σ_θ) (lower panel) data from the continuous underway system on board the RV Kilo Moana during the WHOTS-6 cruise (AC-28). Temperature and salinity taken from 6-dbar CTD data (circles) and salinity bottle sample data (crosses) are superimposed. The dashed vertical red line indicates the period of occupation of Station ALOHA and the WHOTS site.

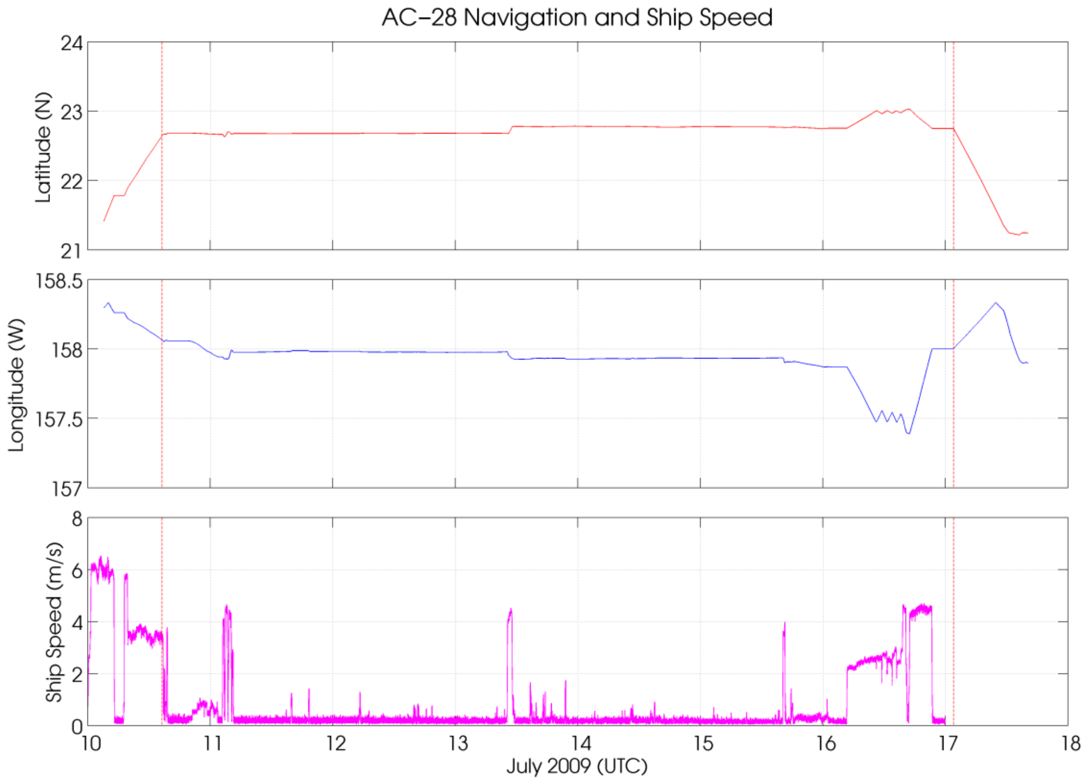


Figure 6-13. Timeseries of latitude (upper panel), longitude (middle panel), and ship's speed (lower panel) during the WHOTS-6 (AC-28) cruise.

C. MicroCAT/SeaCAT data

The temperature and salinity measured by MicroCATs during the mooring deployment are presented in Figure 6-14 to Figure 6-21 for each of the depths where the instruments were located. The potential density (σ_θ) is also plotted in Figure 6-22 to Figure 6-25.

Contoured plots of temperature and salinity as a function of depth are presented in Figure 6-26, and contoured plots of potential density (σ_θ) as a function of depth and of salinity as a function of σ_θ are in Figure 6-27.

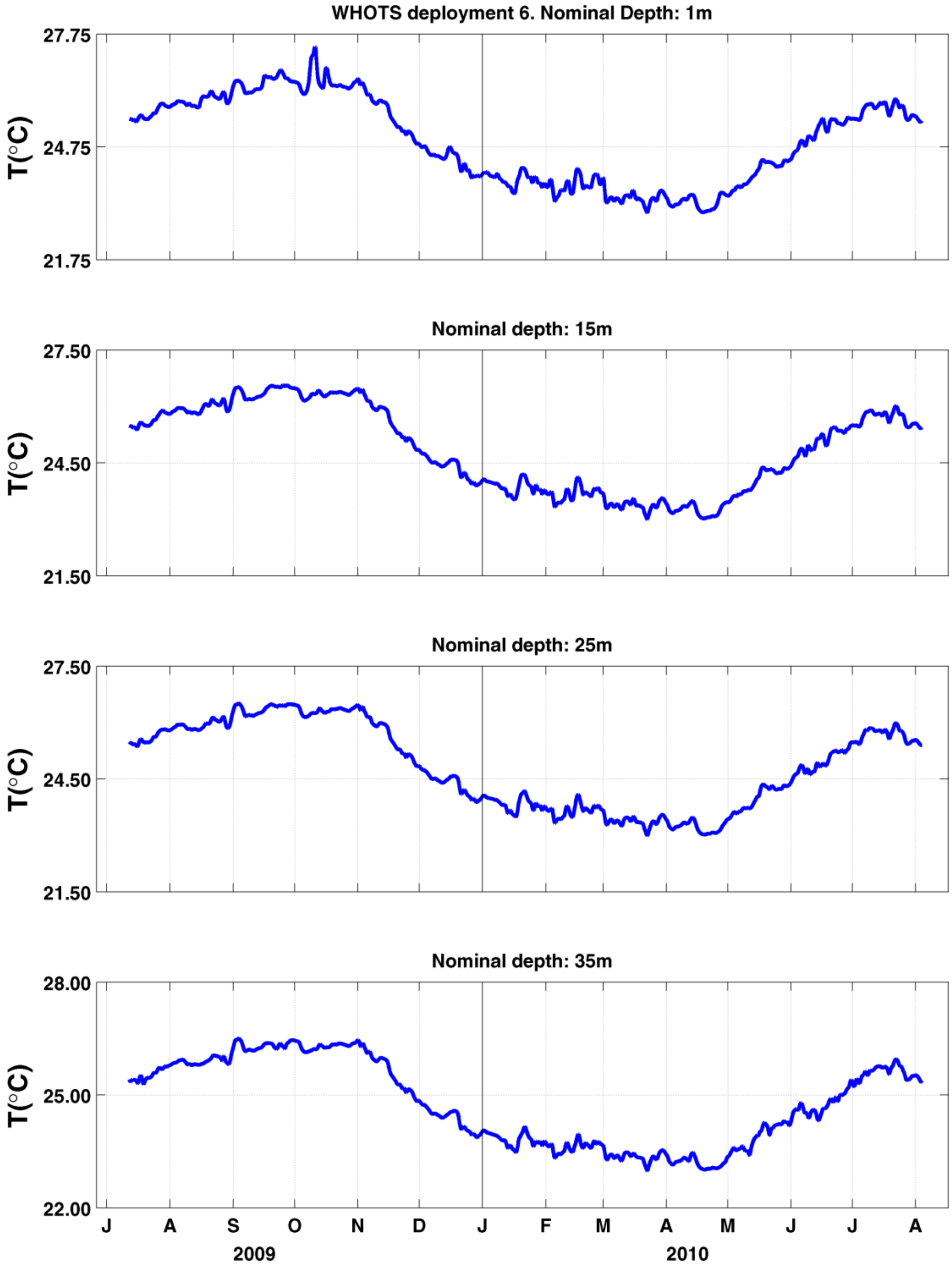


Figure 6-14. Temperatures from MicroCATs during WHOTS-6 deployment at 1, 15, 25, and 35 m.

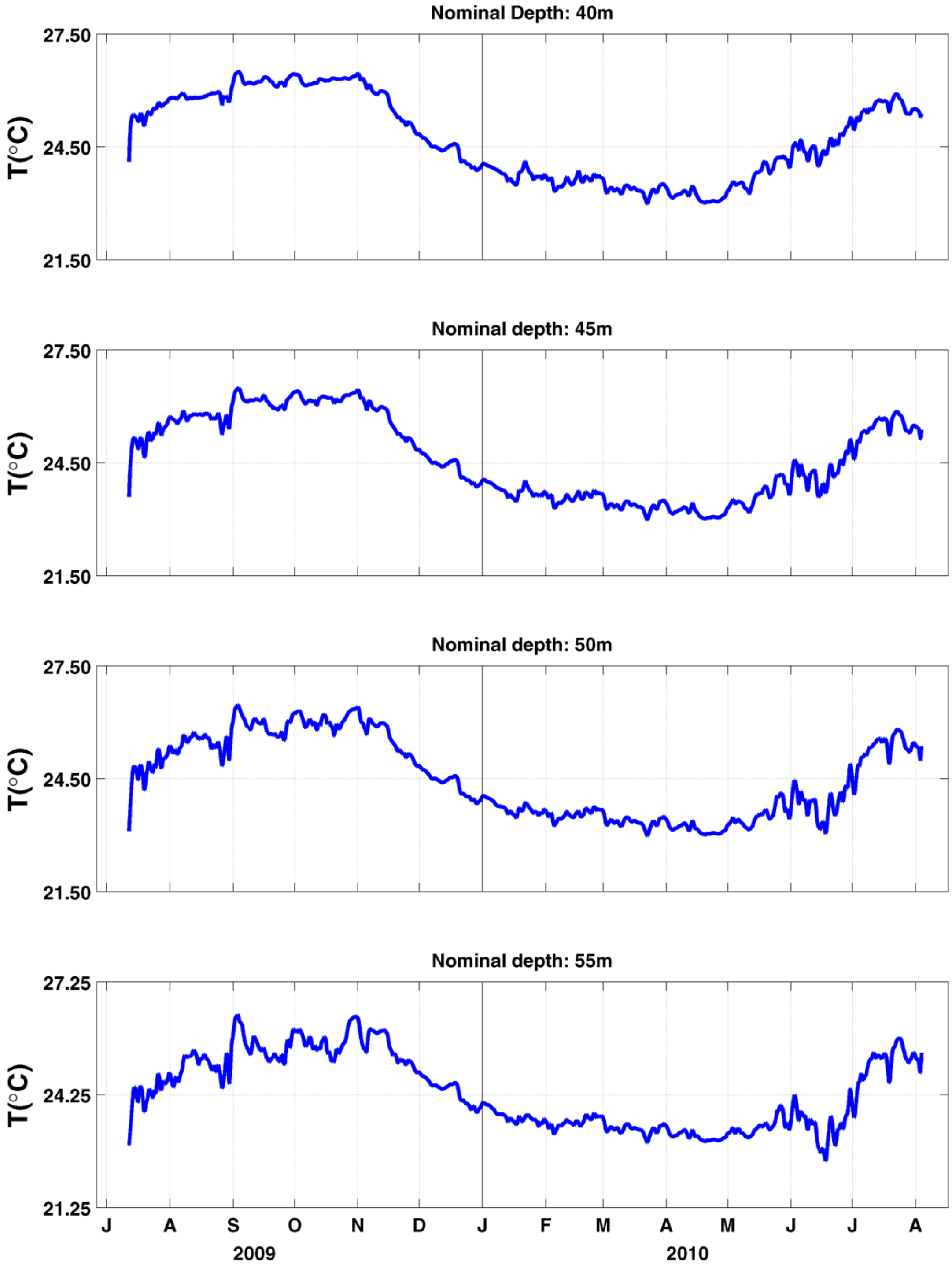


Figure 6-15. Same as in Figure 6-14, but at 40, 45, 50, and 55 m.

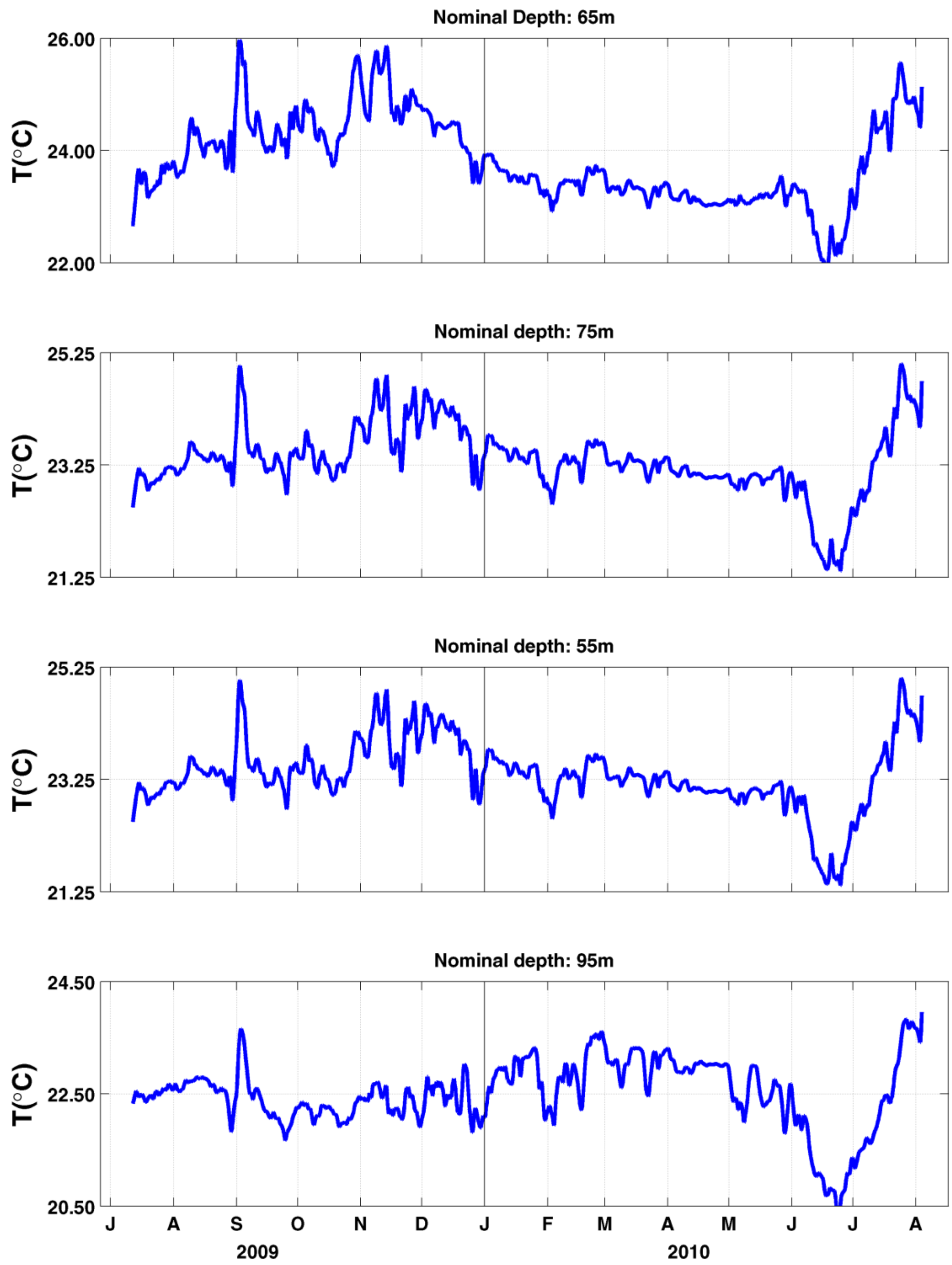


Figure 6-16. Same as in Figure 6-14, but at 65, 75, 85, and 95 m.

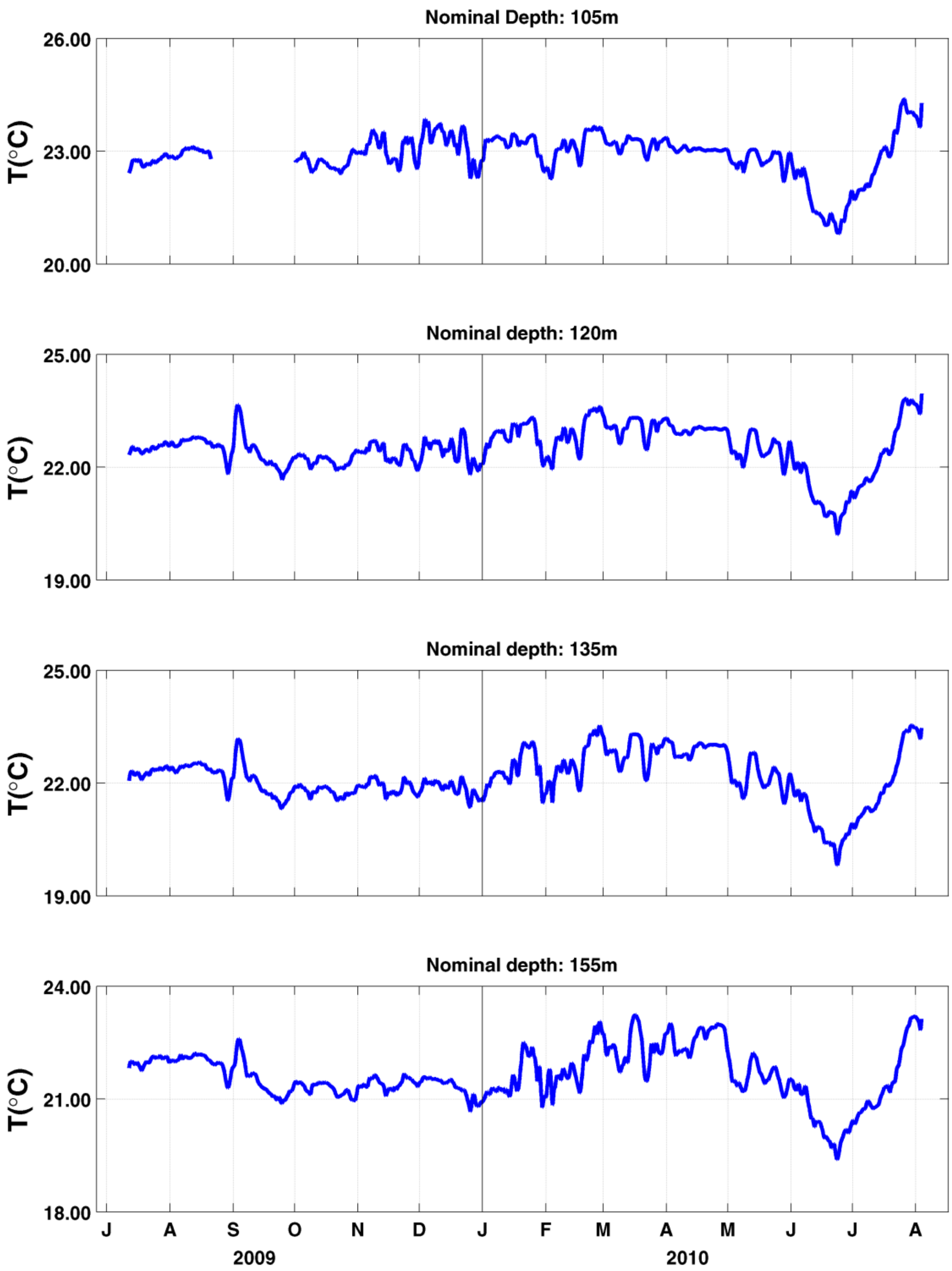


Figure 6-17. Same as in Figure 6-14, but at 105, 120, 135, and 155 m.

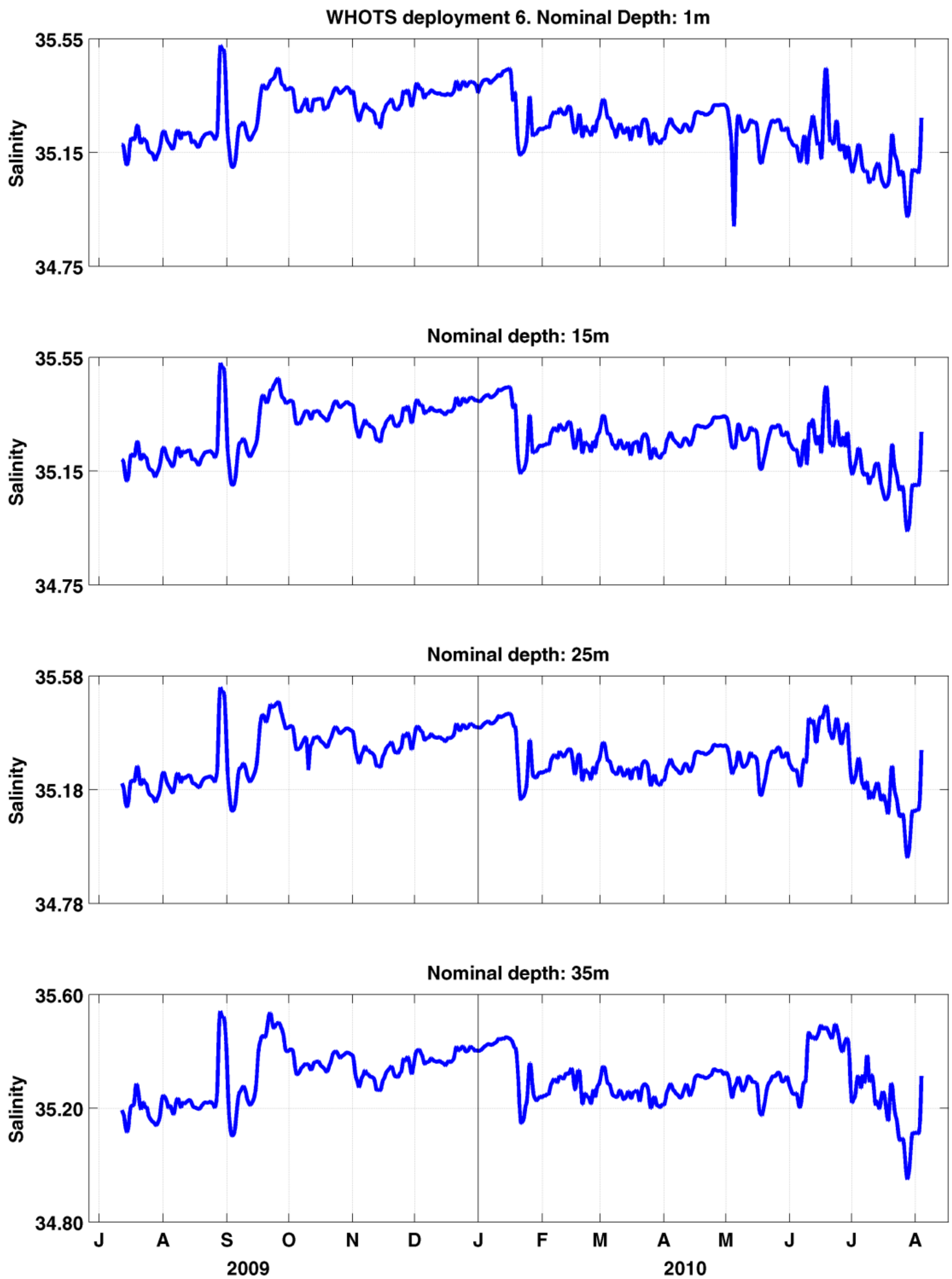


Figure 6-18. Salinities from MicroCATs during WHOTS-7 deployment at 1, 15, 25, and 35 m.

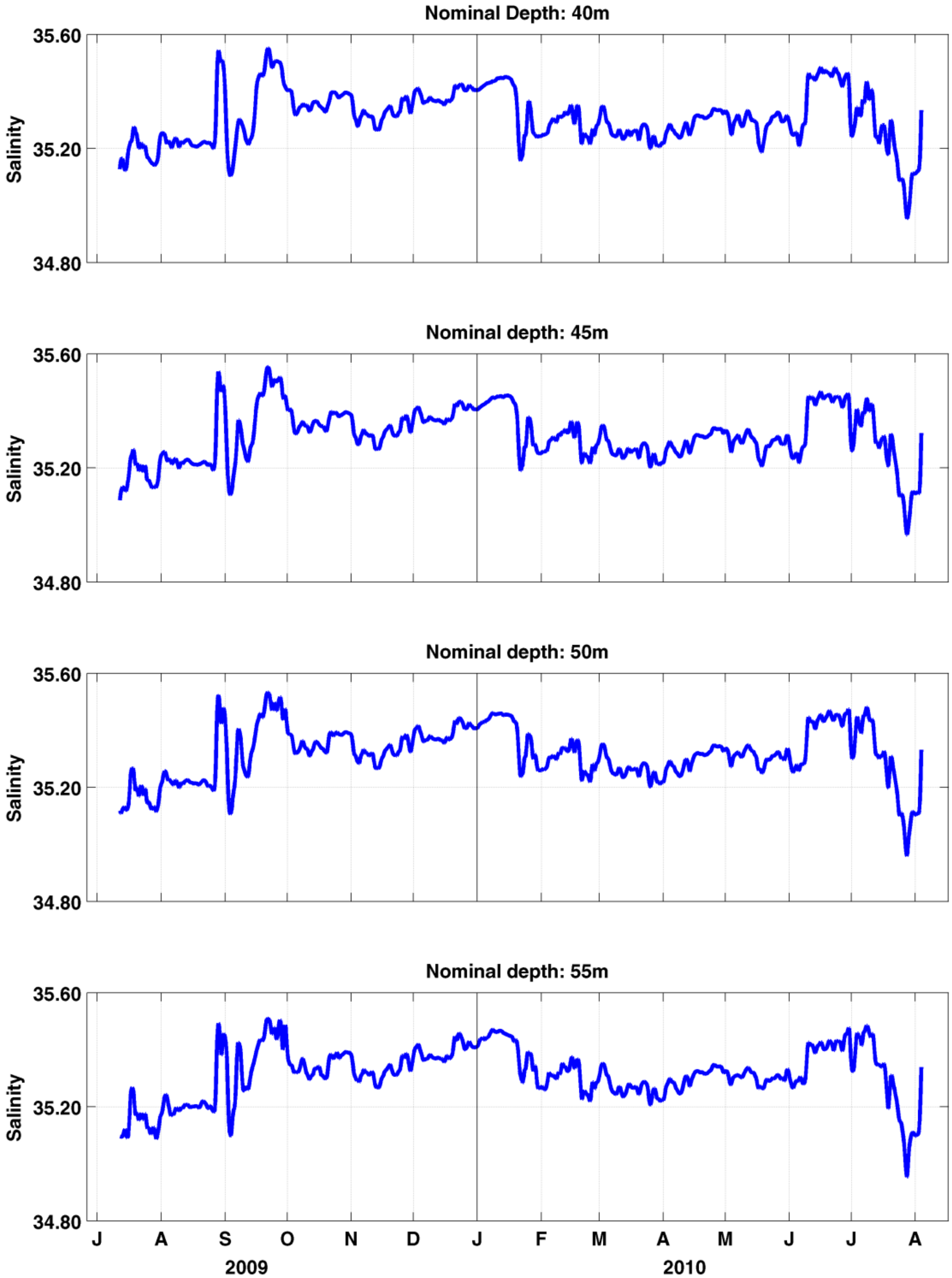


Figure 6-19. Same as in Figure 6-18, but at 40, 45, 50, and 55 m.

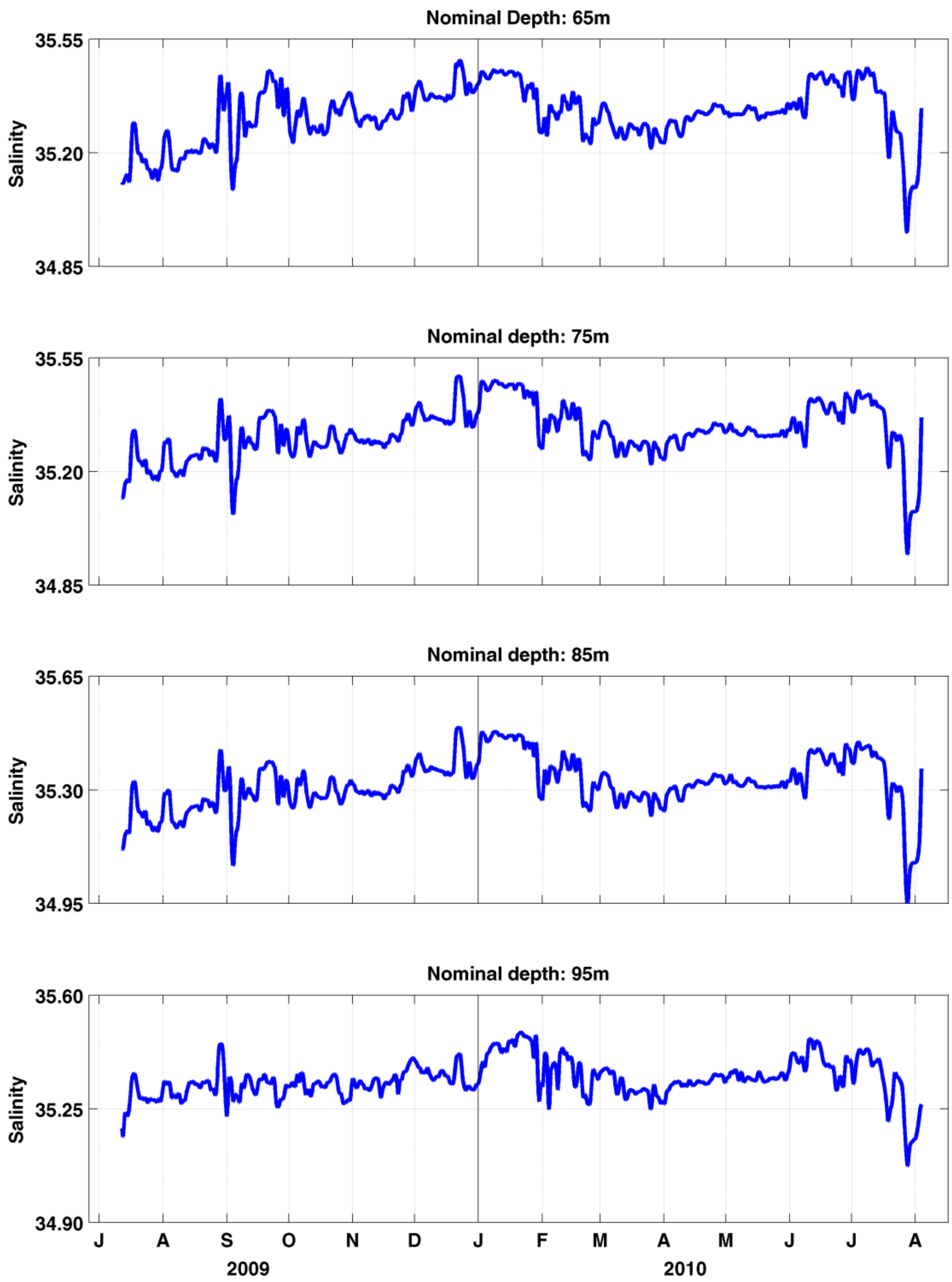


Figure 6-20. Same as in Figure 6-18, but at 65, 75, 85, and 95m.

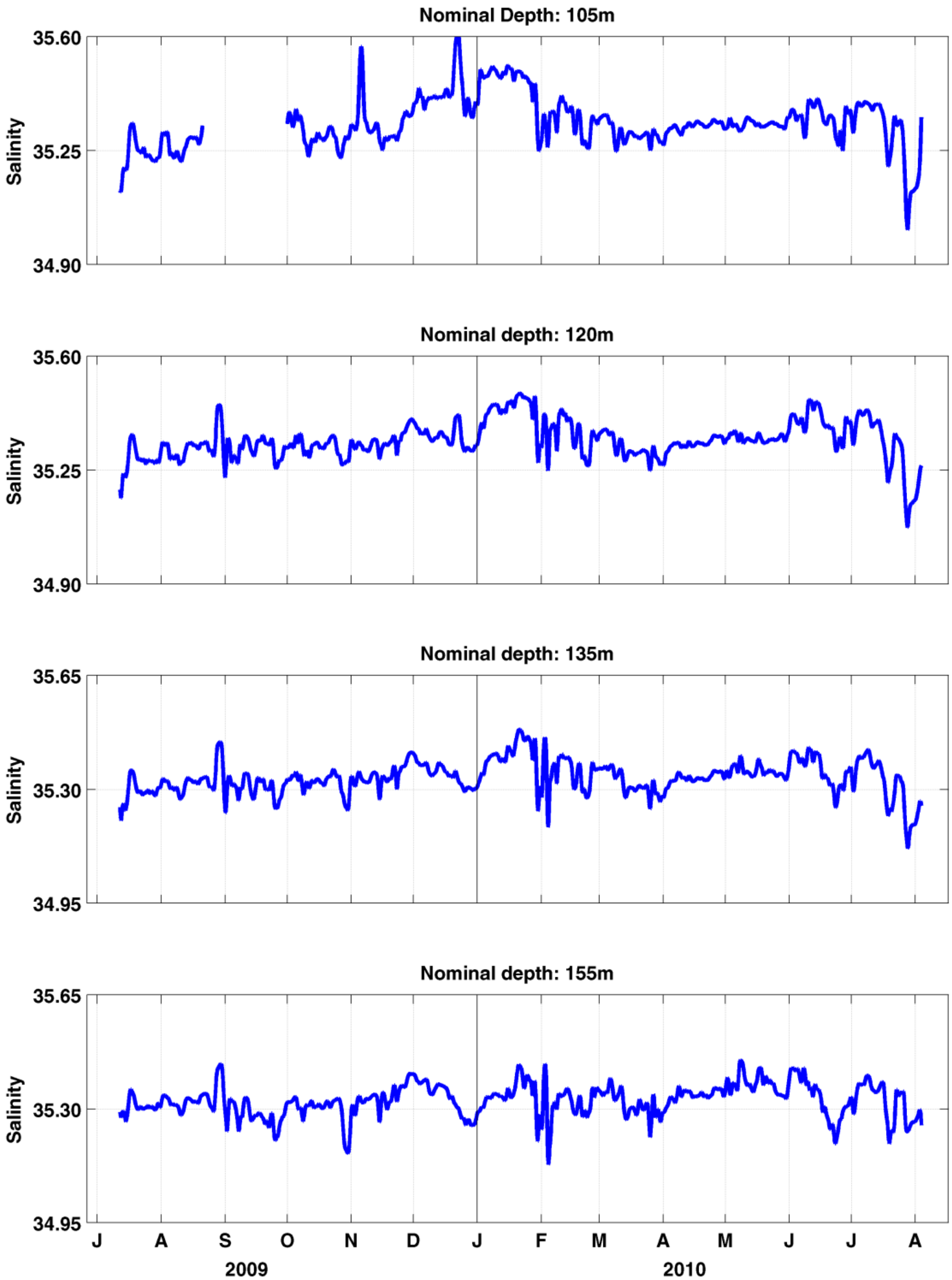


Figure 6-21. Same as in Figure 6-18, but at 105, 120, 135, and 155 m.

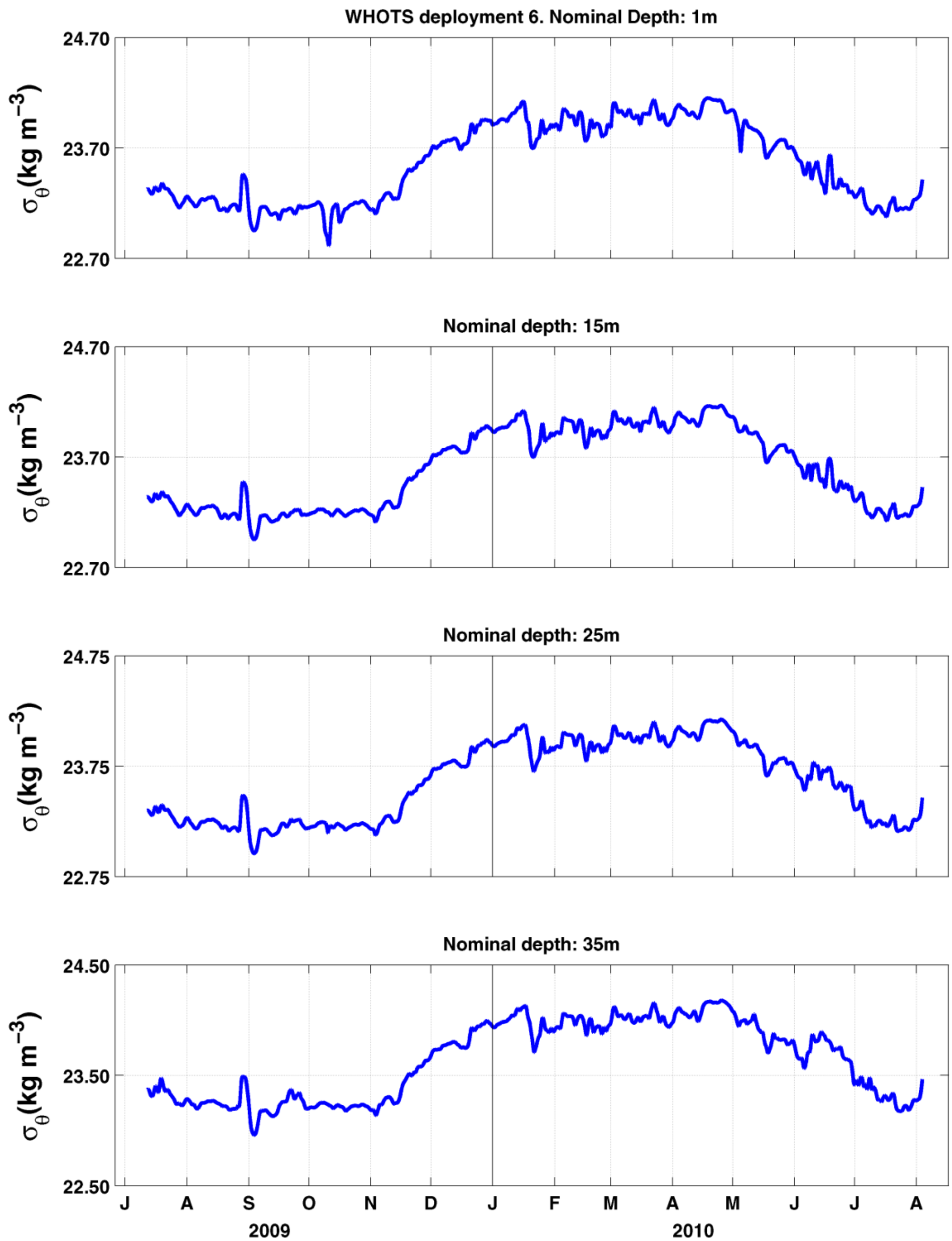


Figure 6-22. Potential density (σ_θ) from MicroCATs during WHOTS-7 deployment at 1, 15, 25, and 35 m.

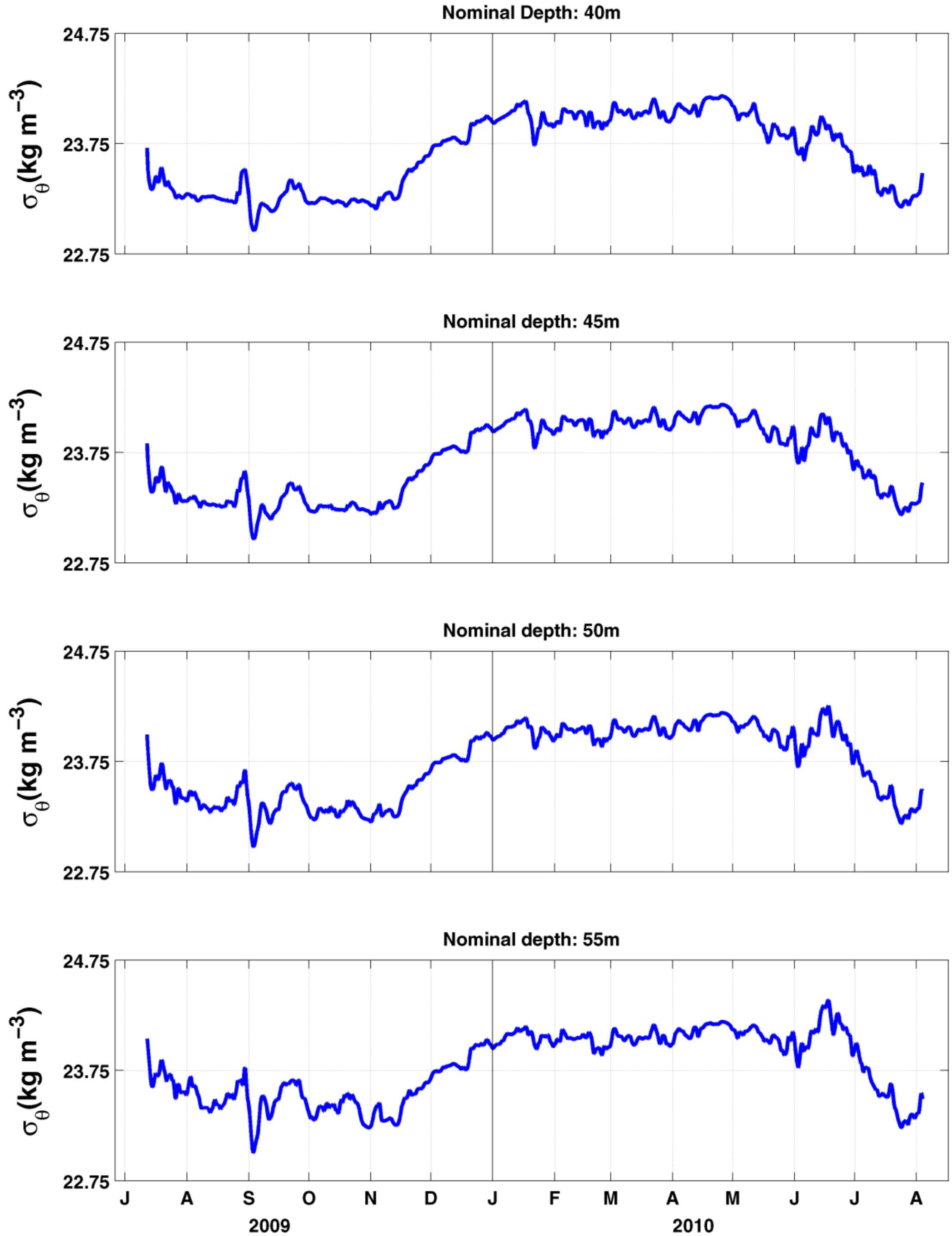


Figure 6-23. Same as in Figure 6-22, but at 40, 45, 50, and 55 m.

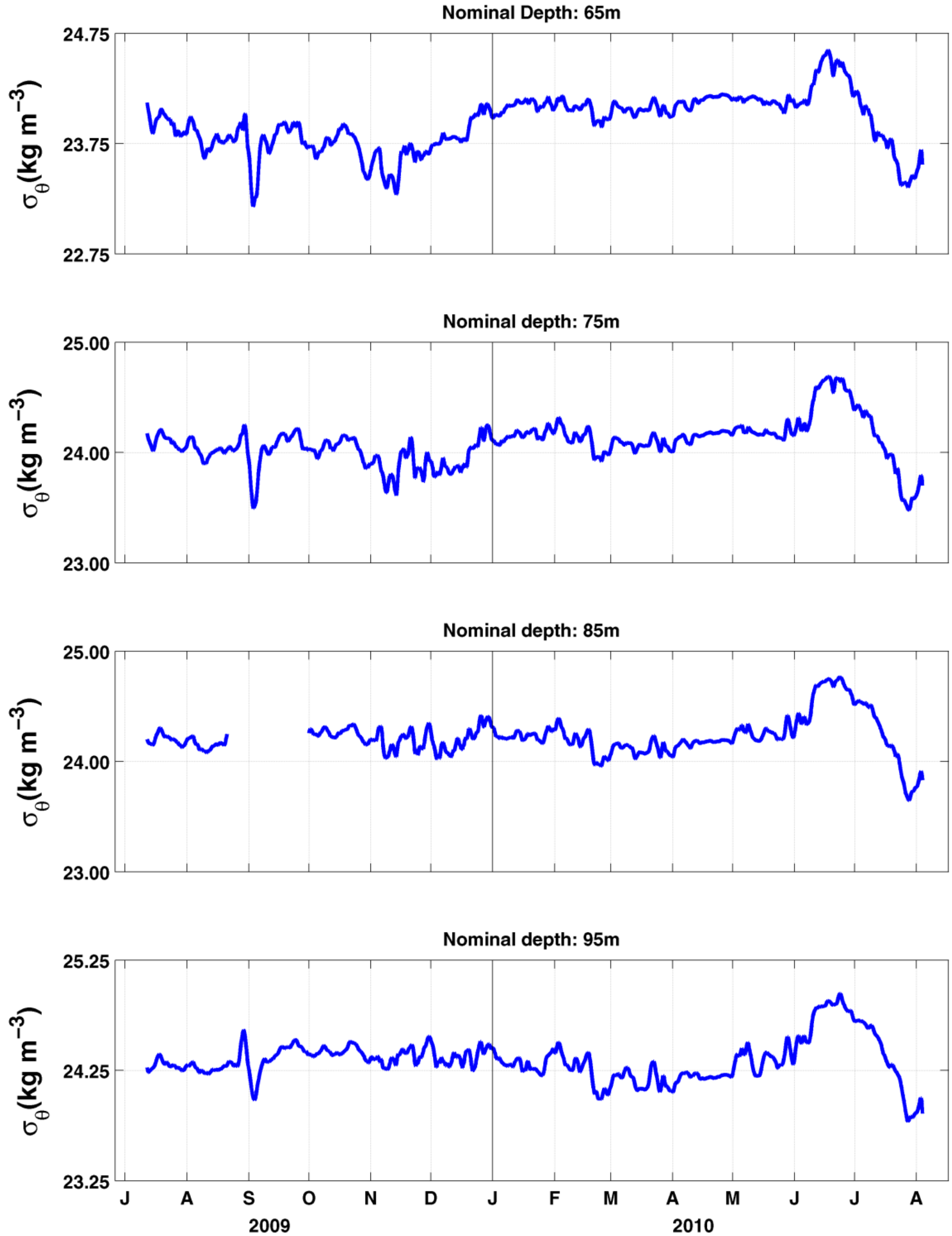


Figure 6-24. Same as in Figure 6-22, but at 65, 75, 85, and 95 m.

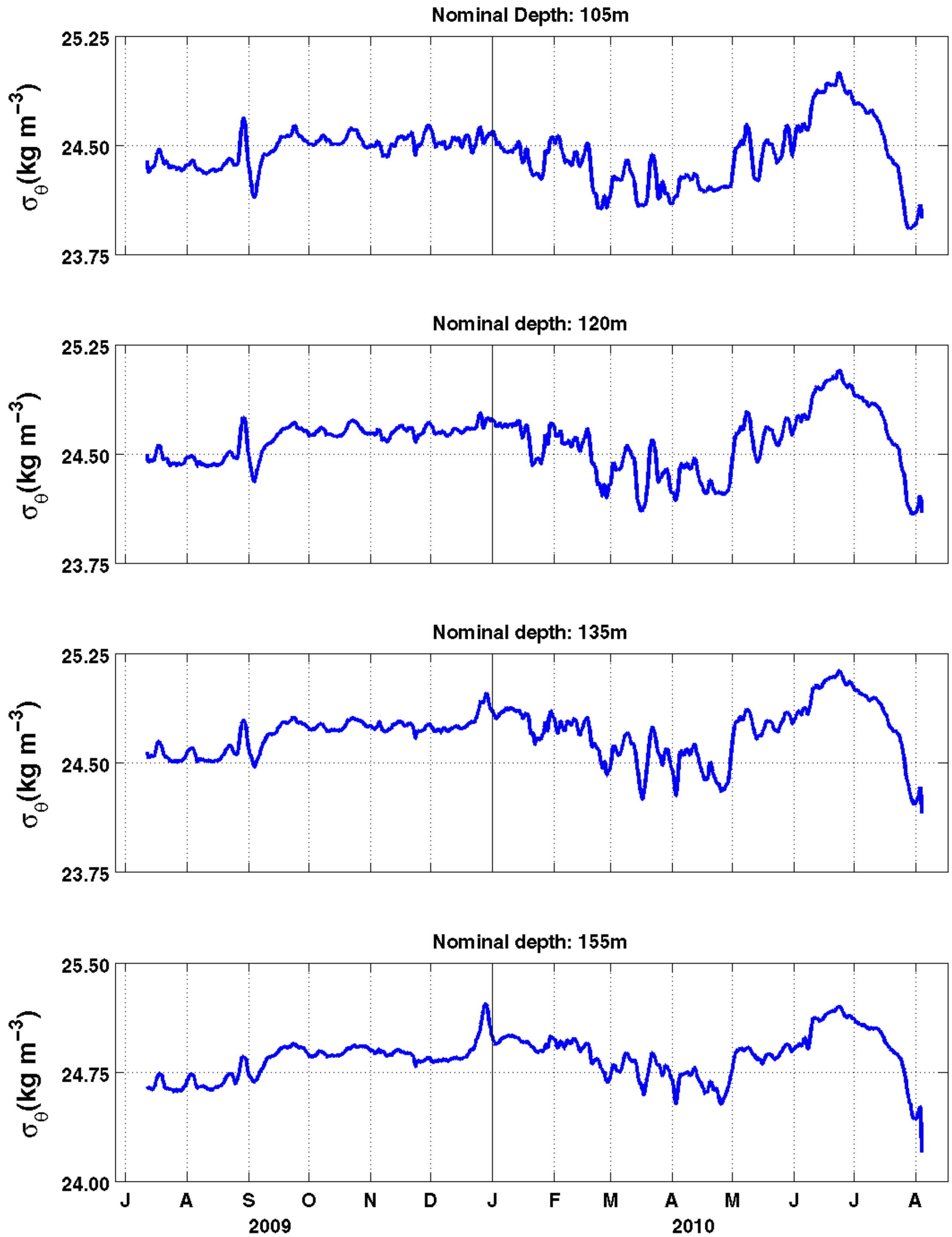


Figure 6-25. Same as in Figure 6-22, but at 105, 120, 135, and 155m.

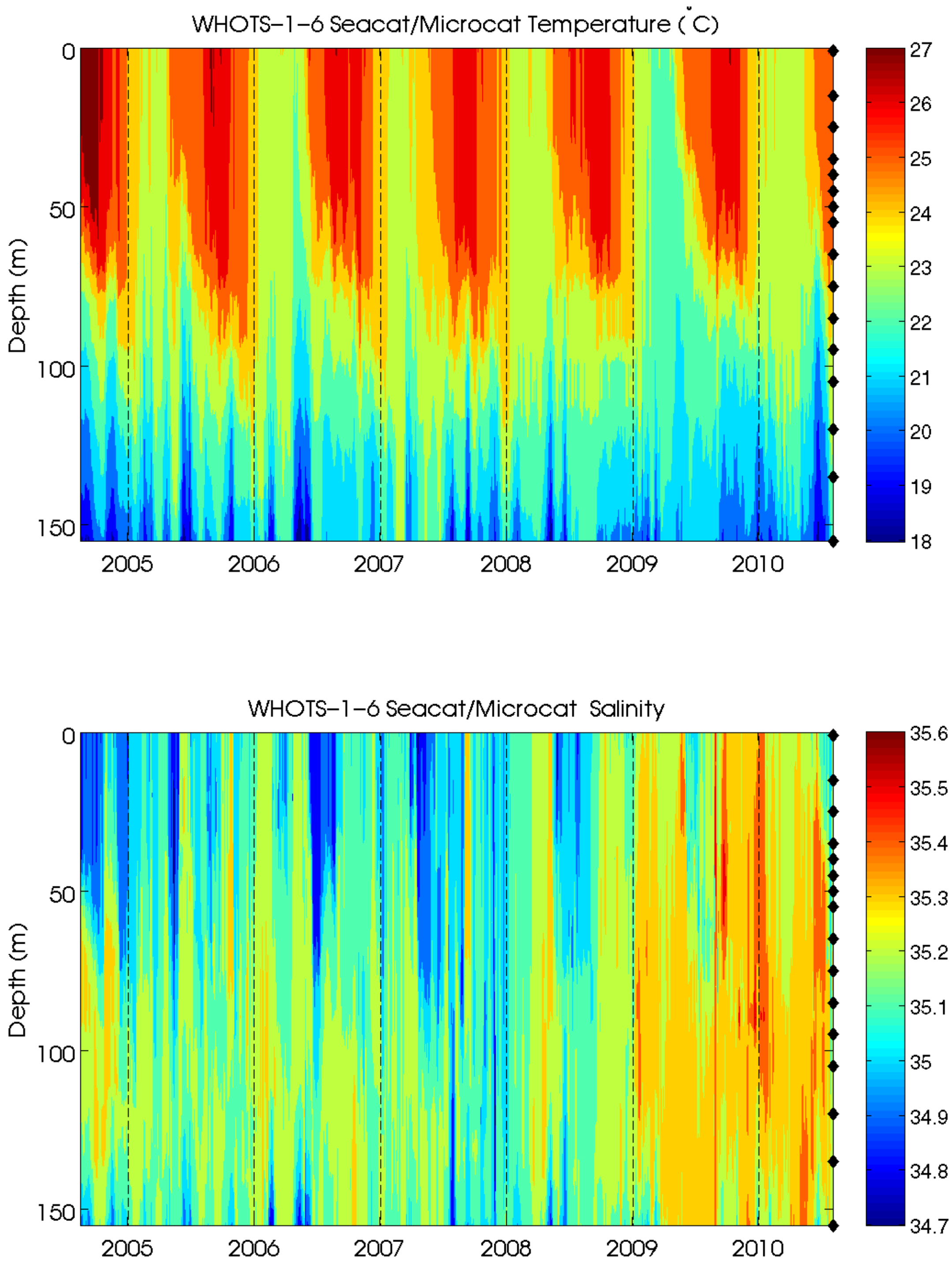


Figure 6-26. Contour plots of temperature (upper panel), and salinity (lower panel) versus depth from SeaCATs/ MicroCATs during WHOTS-1 through WHOTS-6 deployments. The diamonds along the right axis indicate the instruments depths.

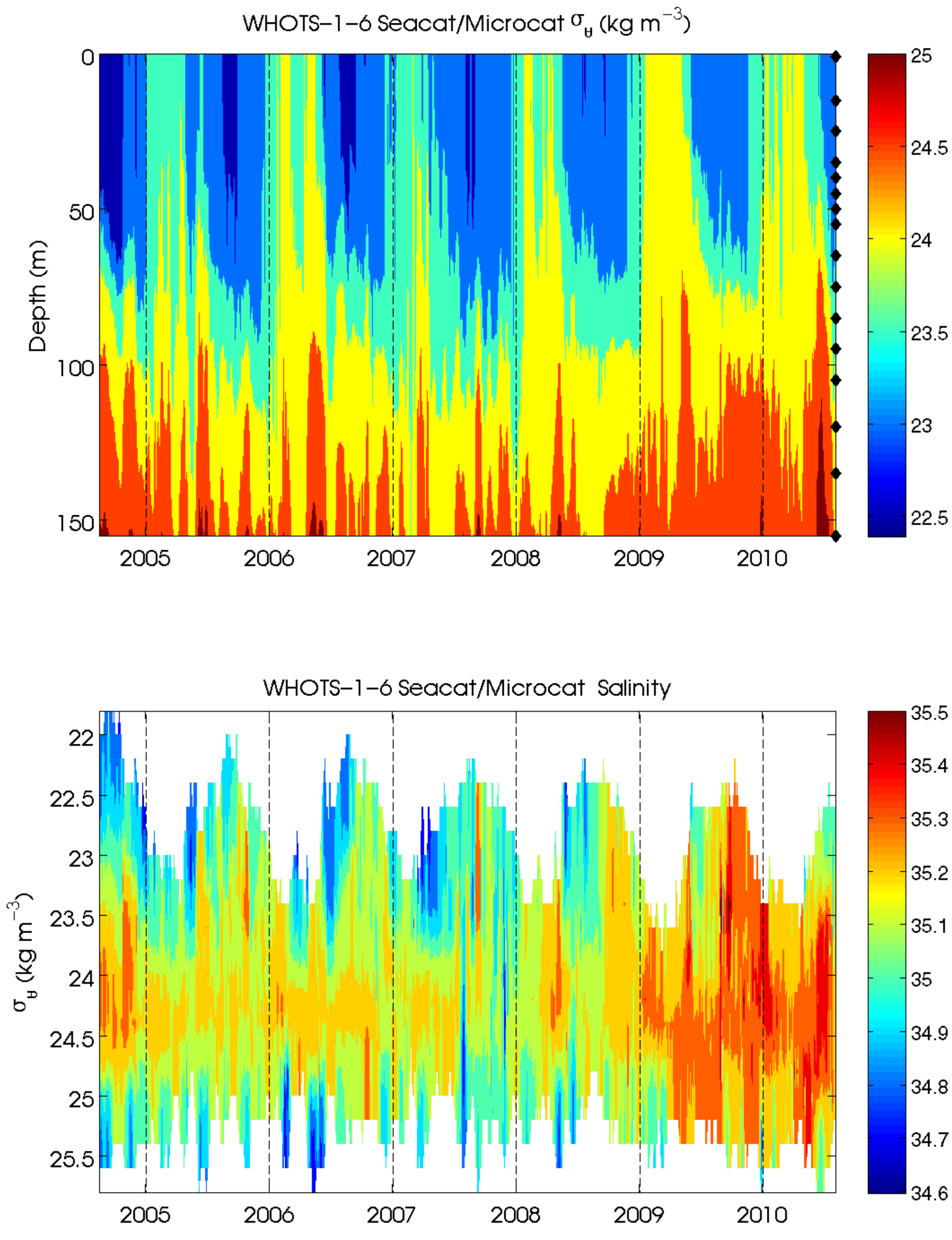


Figure 6-27. Contour plots of potential density (σ_θ), versus depth (upper panel), and salinity versus σ_θ (lower panel) from SeaCATs/MicroCATs during WHOTS-1 through WHOTS-6 deployments. The diamonds along the right axis in the upper figure indicate the instruments depths.

D. Moored ADCP data

Contoured plots of smoothed horizontal and vertical velocity as a function of depth during the mooring deployments 1 through 6 are presented in Figure 6-28 to

Figure 6-30. A staggered time-series of smoothed horizontal and vertical velocities are shown in Figure 6-31 to Figure 6-33. Smoothing was performed by applying a daily running mean to the data and then interpolating the data on to an hourly grid.

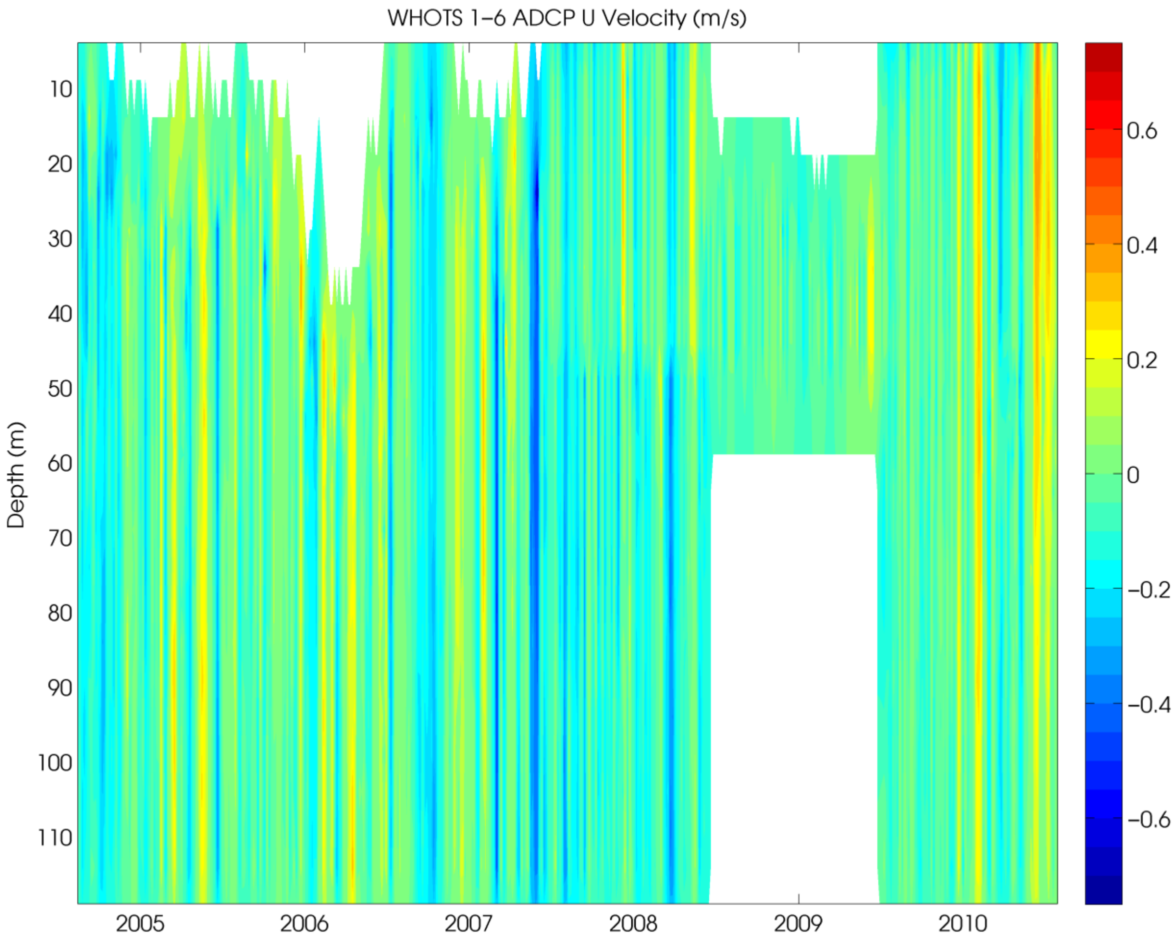


Figure 6-28. Contour plot of east velocity component (m s^{-1}) versus depth and time from the moored ADCPs from the WHOTS-1 through 6 deployments.

Figure 6-29. Contour plot of north velocity component (m s^{-1}) versus depth and time from the moored ADCPs from the WHOTS-1 through 6 deployments.

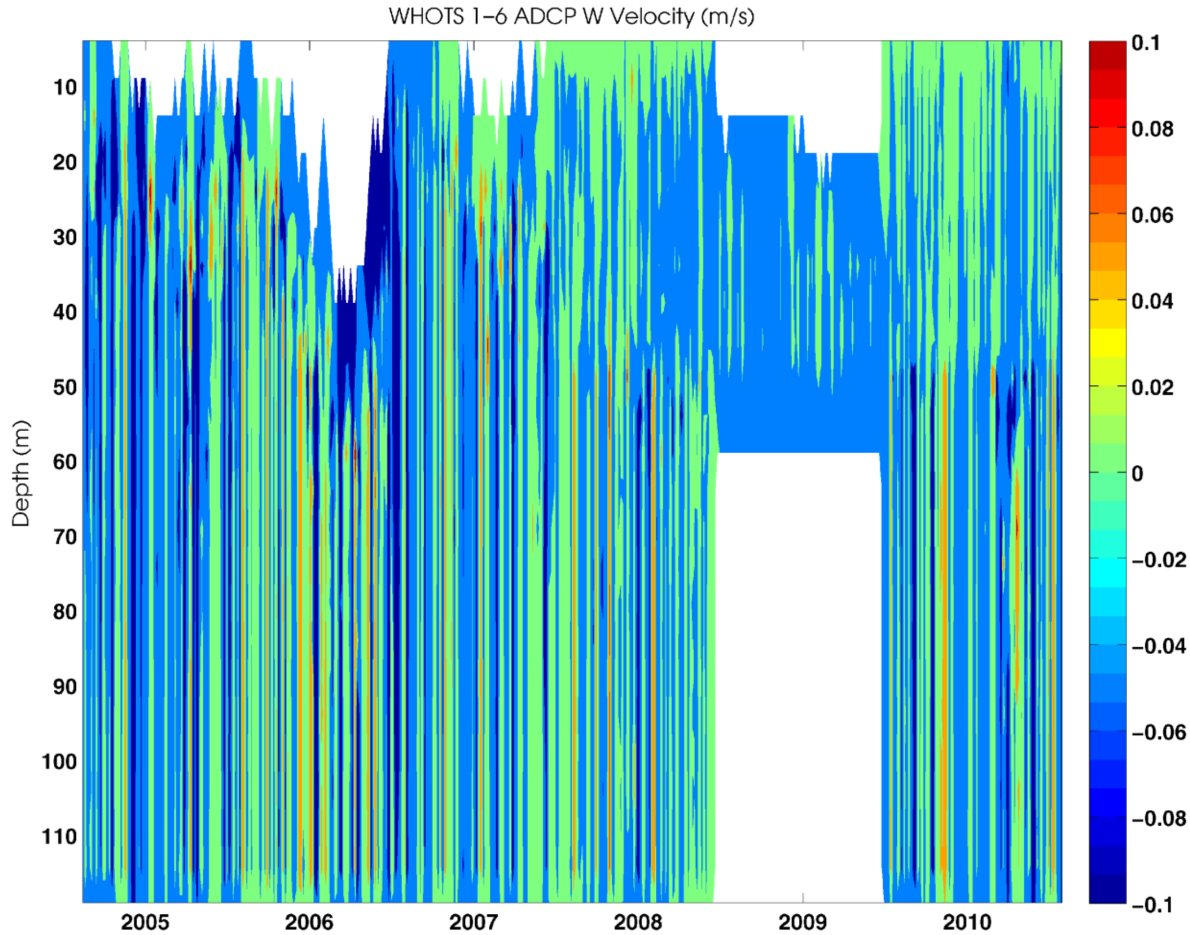


Figure 6-30.Contour plot of vertical velocity component (m s-1) versus depth and time from the moored ADCPs from the WHOTS-1through 6 deployments.

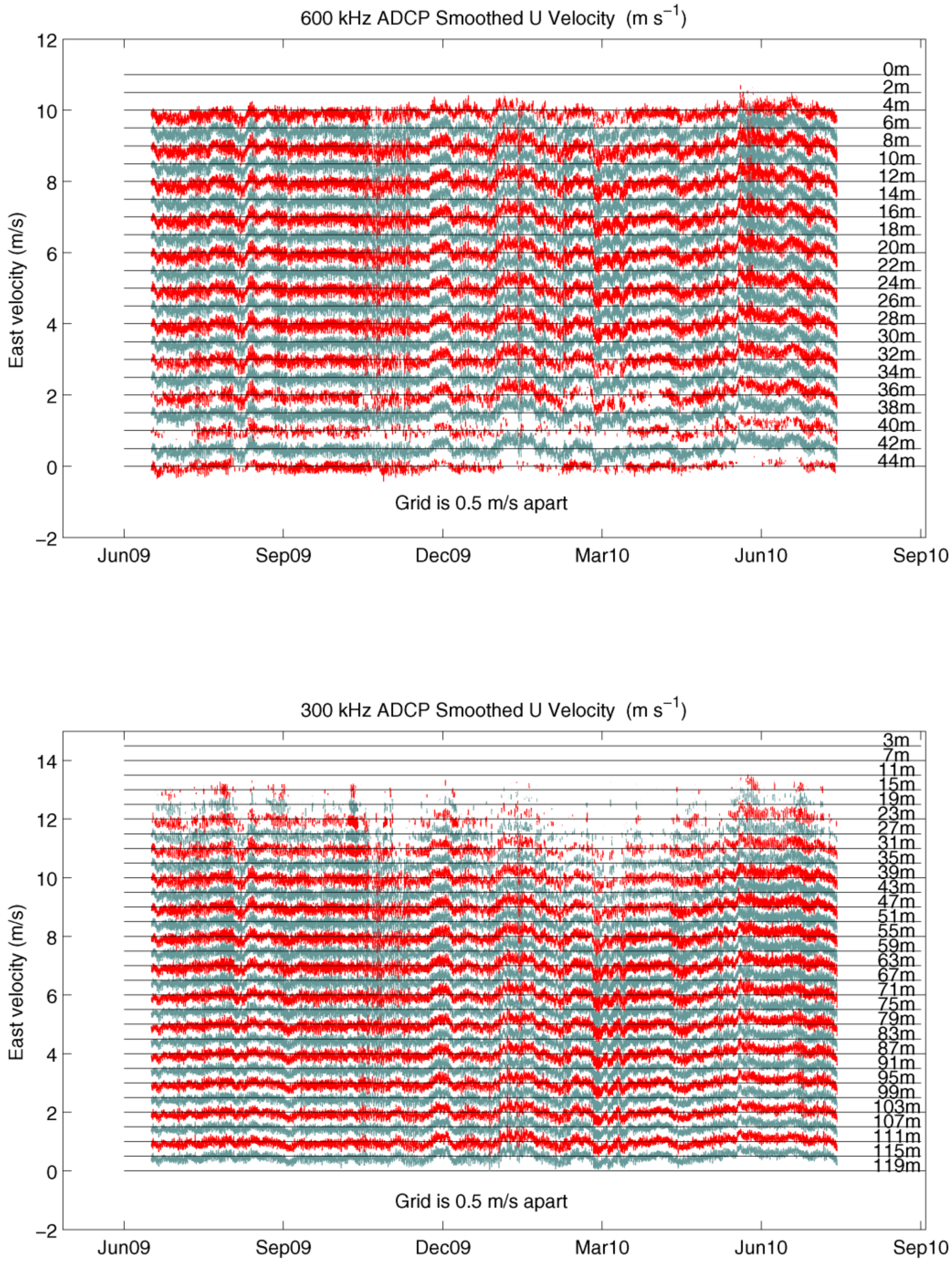
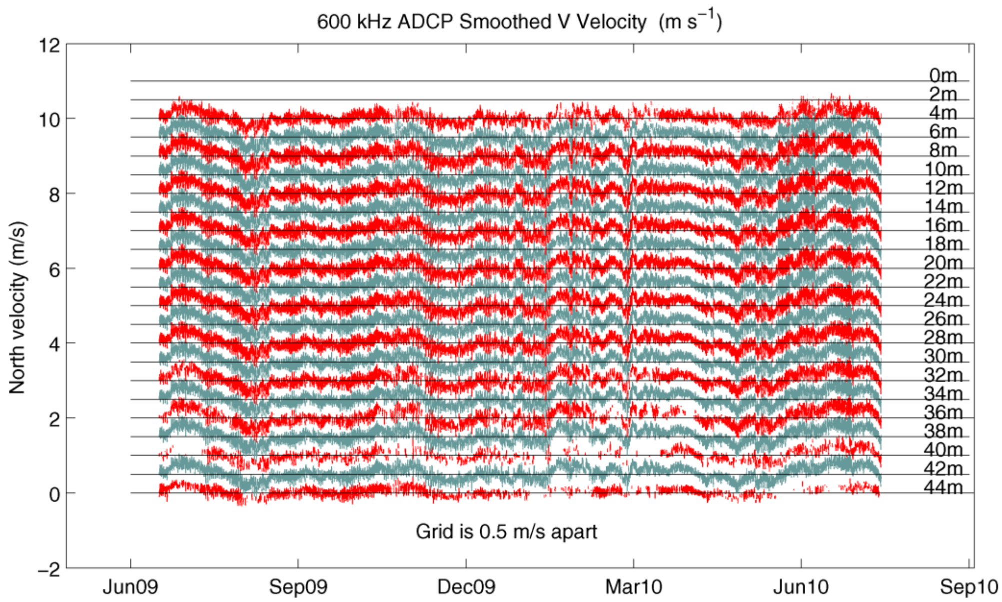


Figure 6-31. Staggered time-series of east velocity component (m s^{-1}) for each bin of the 600 kHz (upper panel), and 300 kHz (lower panel) moored ADCPs during WHOTS-6. The time-series are offset upwards by 0.5 m s^{-1}, the depth of each bin is on the right.



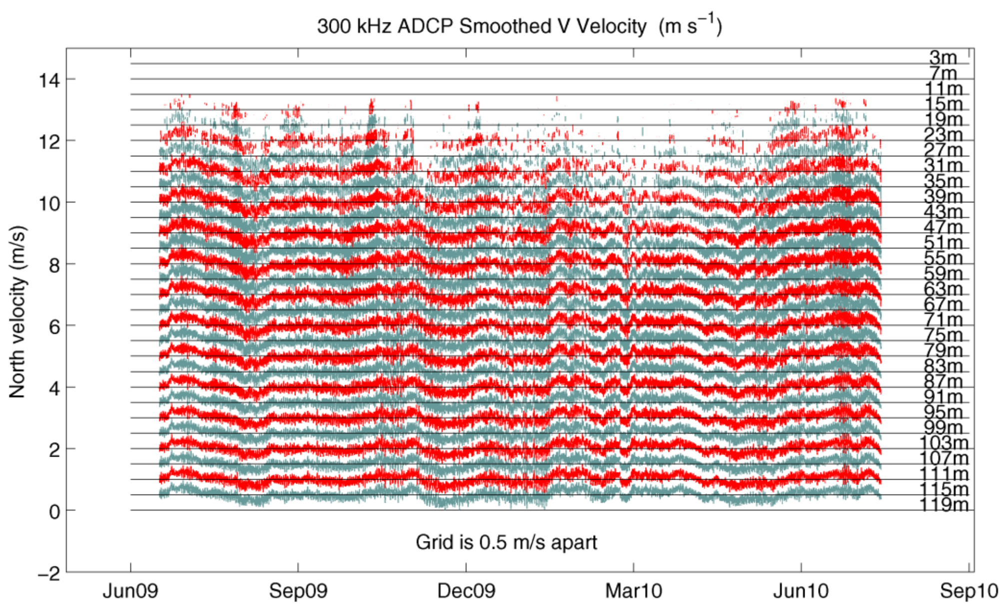


Figure 6-32. Staggered time-series of north velocity component (m s^{-1}) for each bin of the 600 kHz (upper panel), and 300 kHz (lower panel) moored ADCPs during WHOTS-6. The time-series are offset upwards by 0.5 m s^{-1}, the depth of each bin is on the right.

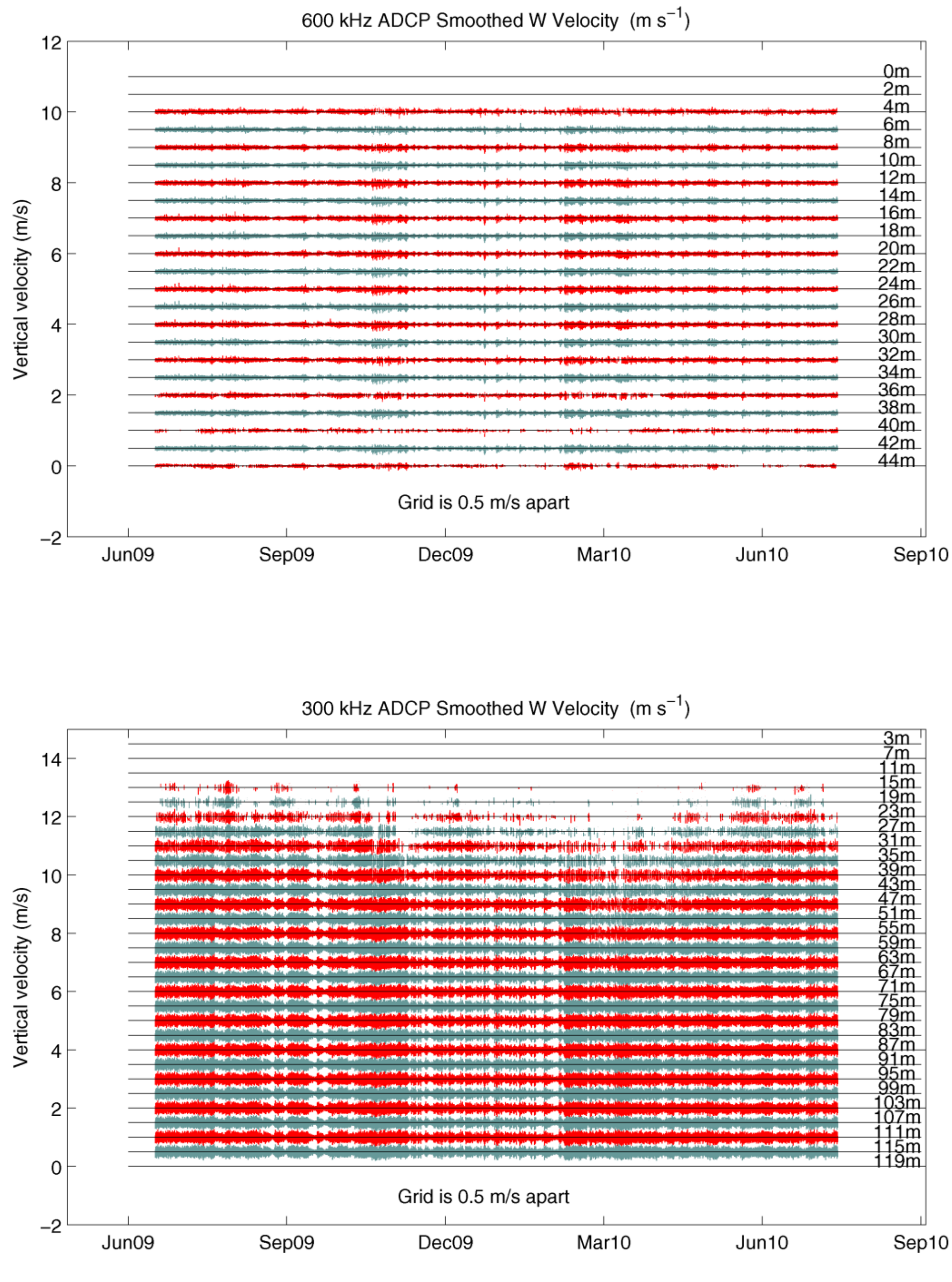


Figure 6-33. Staggered time-series of vertical velocity component (m s^{-1}) for each bin of the 600 kHz (upper panel), and 300 kHz (lower panel) moored ADCPs during WHOTS-6. The time-series are offset upwards by 0.5 m s^{-1}, the depth of each bin is on the right.

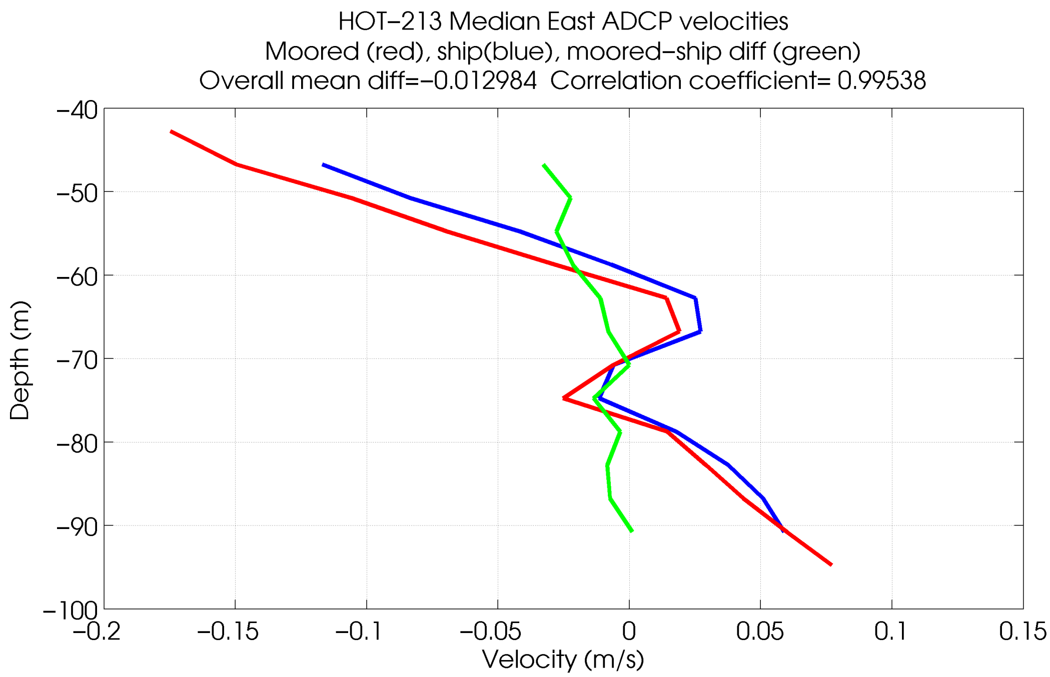
E. Moored and Shipboard ADCP comparisons

Comparisons between quality-controlled moored ADCPs during the WHOTS-6 deployment and available shipboard ADCP obtained during regular HOT cruises 213 – 217, 219, and 221 - 223 are shown in Figure 6-34 to Figure 6-42 for the 300 kHz ADCP, and Figure 6-43 to Figure 6-45 for the 600 kHz ADCP. Median and mean velocity profiles were computed during the time when HOT CTD casts were being conducted near the WHOTS mooring specifically intended to calibrate moored instrumentation (see 5.A.4). The shipboard profiles were taken when the ship was stationary, within 1 km of the mooring, and within 4 hours before the start and 4 hours after the end of the CTD cast conducted near the WHOTS mooring. All HOT cruises with comparable ADCP data were conducted on the R/V *Kilo Moana* which featured an RD Instruments Workhorse 300 kHz ADCP (wh300) with 4 m bin size, reaching 100 m, and averaging ensembles every 2 minutes; and from an RD Instruments Ocean Surveyor 38 kHz operating in broad band mode (os38bb) with 12 m bin size, reaching 1200 m, with 5 minute ensemble averages, and in narrow band mode (os38nb) with 24 m bin size, reaching 1500 m and also with 5 minute ensemble averages. Data from the wh300 were used for the comparisons with the moored ADCP data.

The moored ADCP data were collected from the upward facing 300 kHz ADCP located at 125 m and the upward facing 600 kHz ADCP located at 47.5 m over the same time period. Each of the zonal (U), and meridional (V) current components from the shipboard and moored vertical profiles were interpolated to the profile resolution of the shipboard ADCP, and ensemble mean and median profiles were obtained for each data set to compute differences and correlation coefficients between them (Table 6-1). Bins with less than 50% data were excluded. There were only 3 cruises which featured enough data for comparisons between the 600 kHz ADCP and shipboard ADCP. This was due to poor data return near the surface from the shipboard ADCP for these cruises. The correlations and the vertical mean of the differences between the ensemble median and mean for each of the U and V components are shown in Table 6-1.

Table 6-1. Correlations and differences of zonal (U), and meridional (V) ensemble median and mean currents (10 to 125 m) between WHOTS-6 moored ADCP (300 and 600 kHz) and shipboard ADCP during HOT cruises.

HOT Shipboard ADCP vs WHOTS Moored 300 kHz ADCP									
Cruise	**Ship ADCP Type**	**Ensemble Median U correlation**	**Vertical Mean of U median differences**	**Ensemble Median V correlation**	**Vertical Mean of V median differences**	**Ensemble Mean U correlation**	**Vertical Mean differences U**	**Ensemble Mean V correlation**	**Vertical Mean differences V**
HOT-213	wh300	0.9954	-0.0130	0.9559	-0.0007	0.9918	-0.0122	0.9679	-0.0040
HOT-214	wh300	0.9715	-0.0080	0.9150	0.0026	0.9879	0.0068	0.9757	-0.0137
HOT-215	wh300	0.6080	-0.0119	0.7854	0.0097	0.6640	-0.0092	0.8165	0.0013
HOT-216	wh300	0.9144	0.0494	0.9221	0.0327	0.9090	0.0492	0.8468	0.0229
HOT-217	wh300	0.9836	0.0173	0.8340	-0.0152	0.9850	0.0167	0.9260	-0.0090
HOT-219	wh300	0.9224	0.0268	0.7085	0.0083	0.8561	0.0314	0.5557	0.0102
HOT-221	wh300	0.6038	0.0092	0.9196	-0.0462	0.8770	0.0145	0.9243	-0.0490
HOT-222	wh300	0.9662	0.0036	0.9682	0.0685	0.9744	0.0098	0.9614	0.0599
HOT-223	wh300	0.9639	-0.0209	0.9529	-0.0091	0.9974	-0.0310	0.9642	-0.0127
HOT Shipboard ADCP vs WHOTS Moored 600 kHz ADCP									
HOT-213	wh300	0.0770	-0.0105	0.9626	-0.0155	0.1329	0.0090	0.9689	-0.0142
HOT-214	wh300	0.3942	0.0161	0.9033	0.0043	0.1203	0.0178	0.8572	0.0000
HOT-223	wh300	0.9776	0.0068	0.9641	0.02104	0.9704	0.0065	0.9665	0.0267



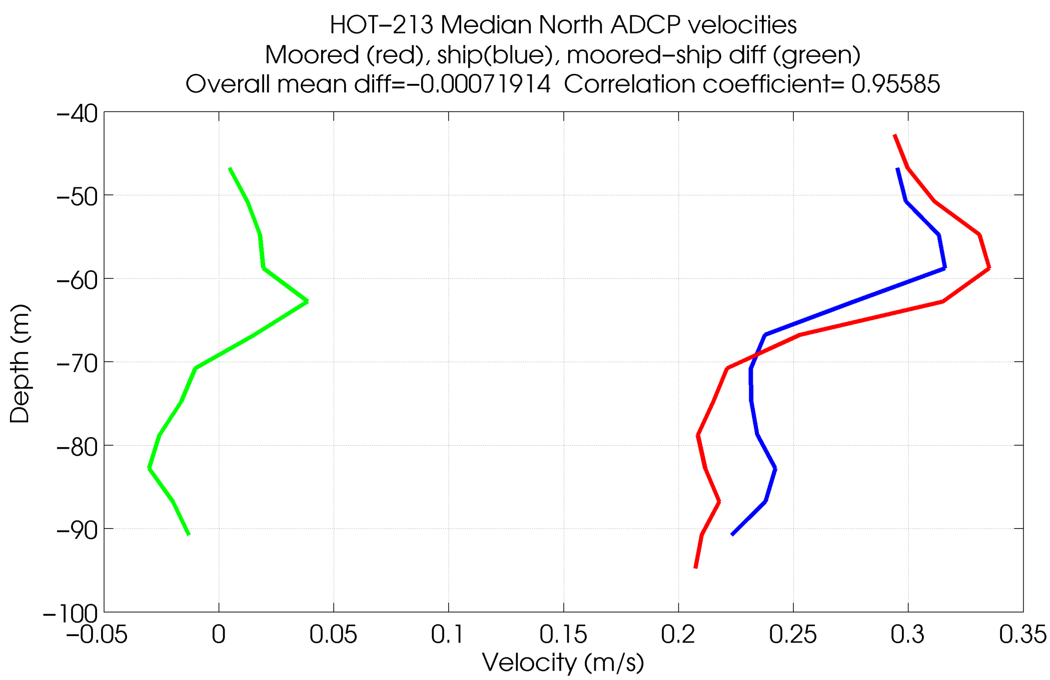


Figure 6-34. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-213. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

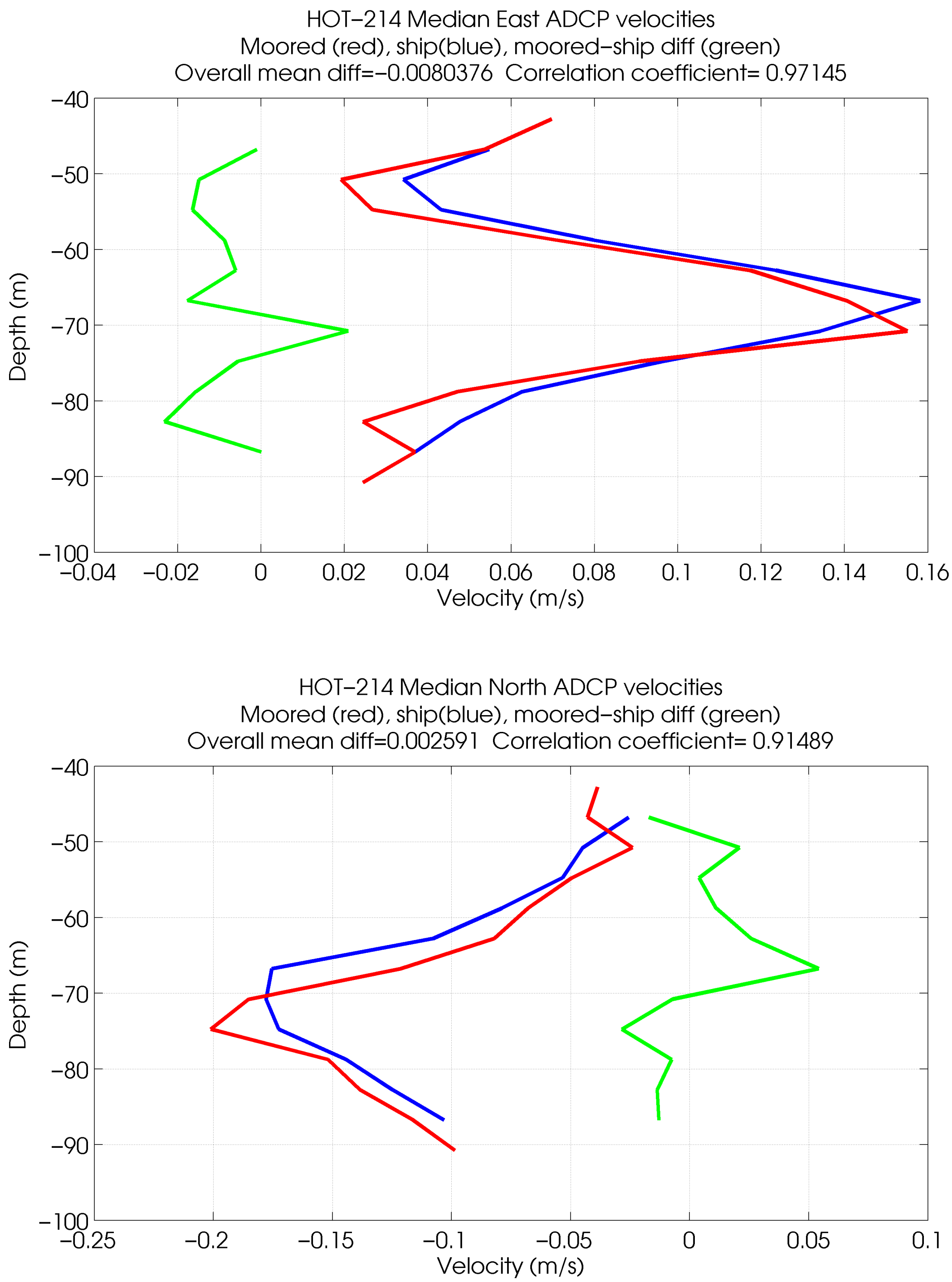


Figure 6-35. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-214. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

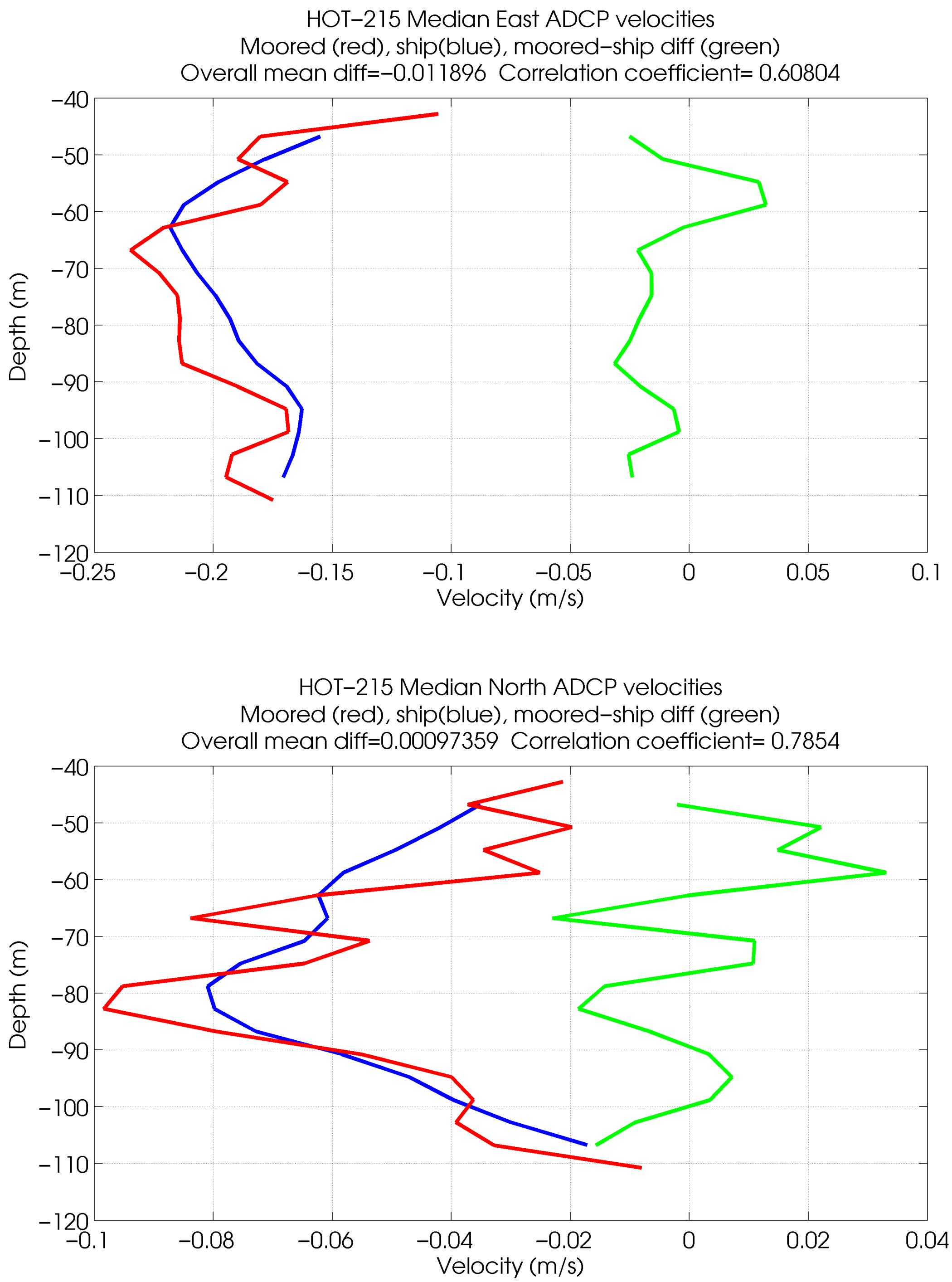
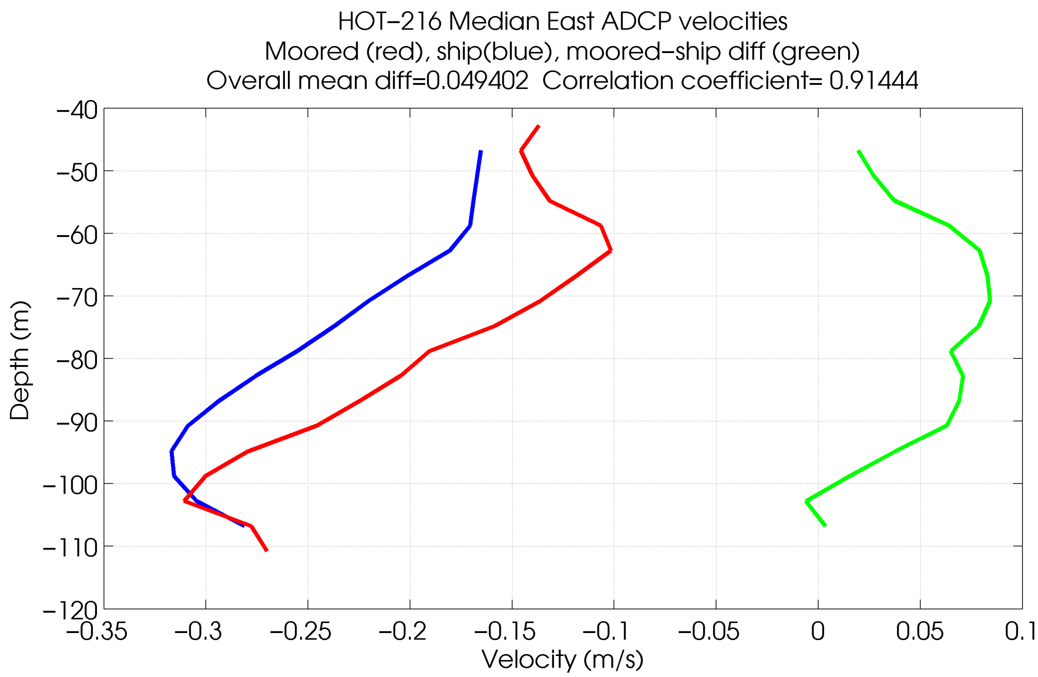


Figure 6-36. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-215. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.



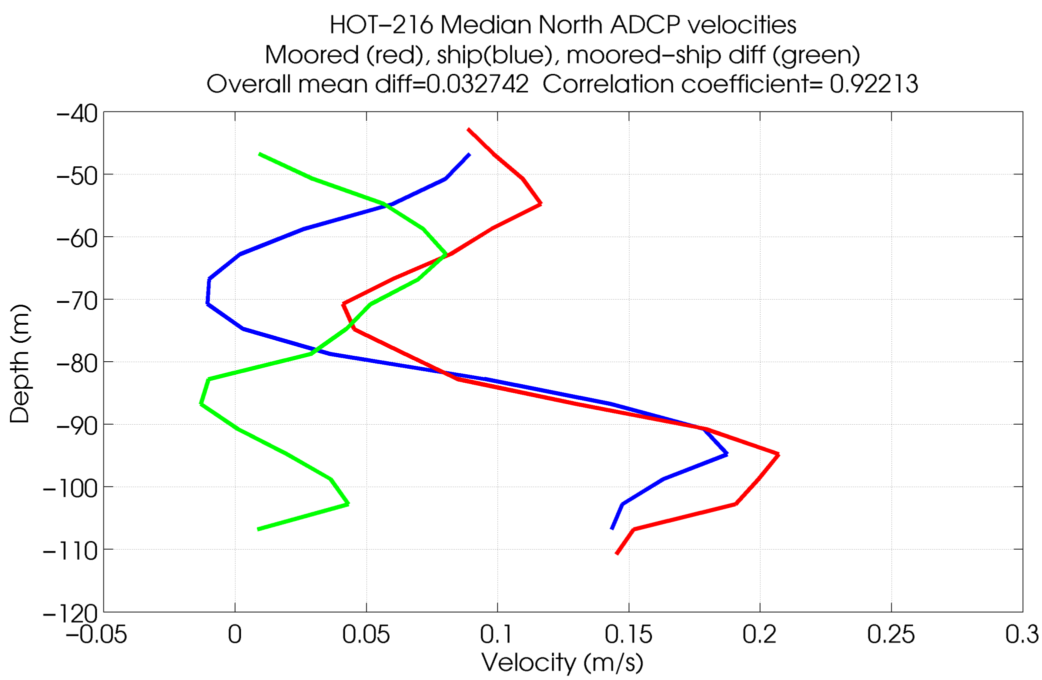


Figure 6-37. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-216. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

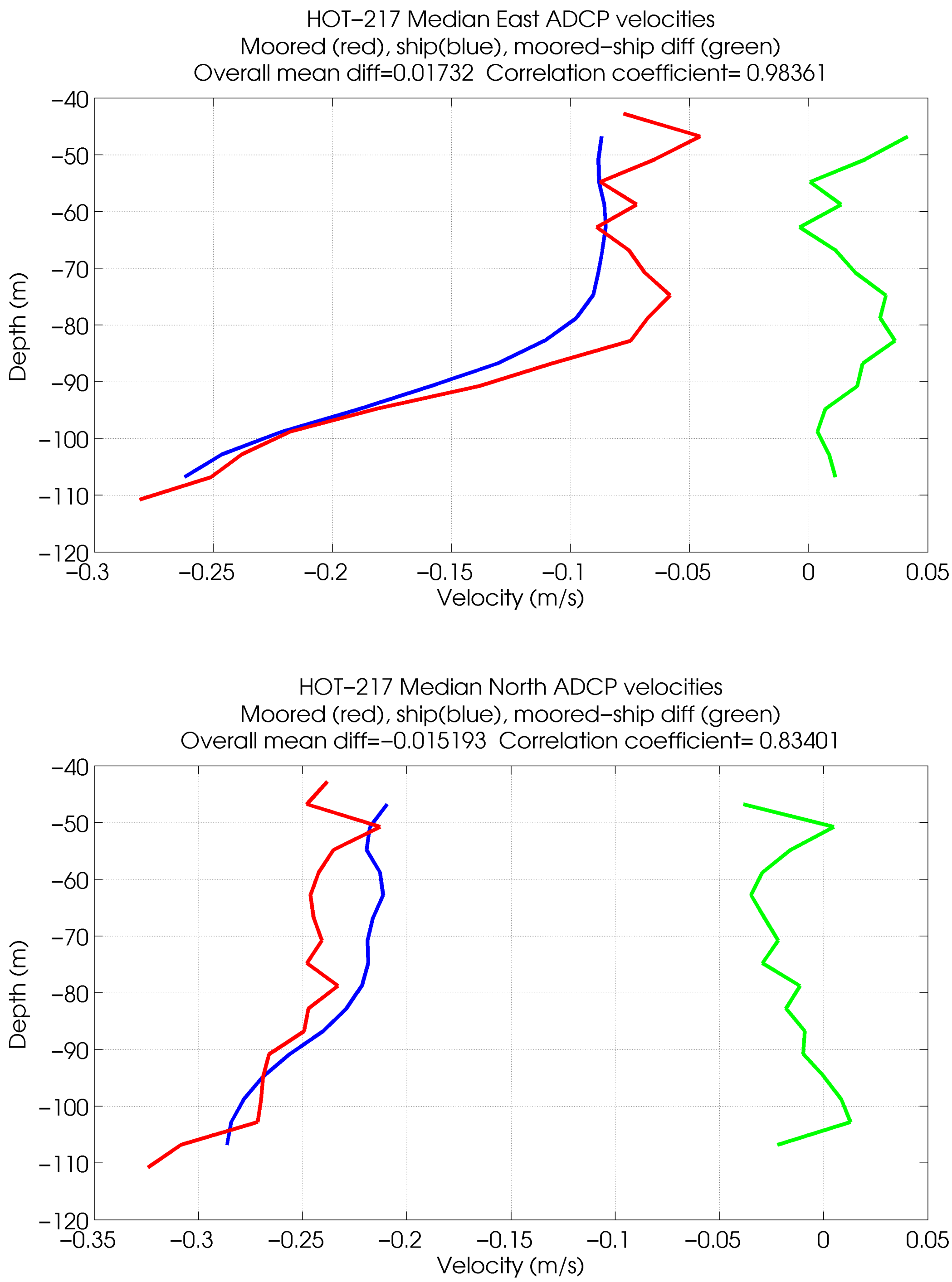


Figure 6-38. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-217. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

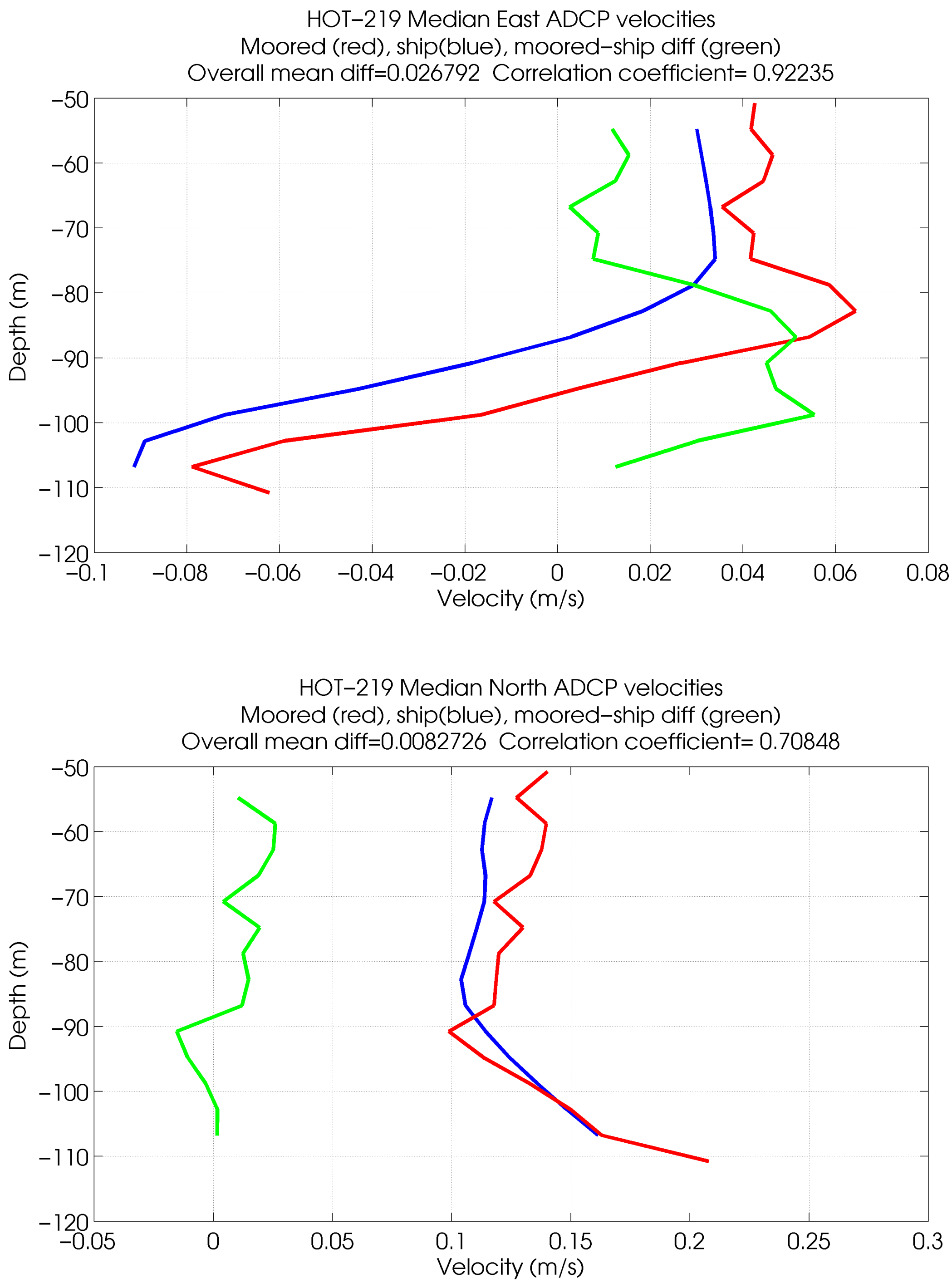


Figure 6-39. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-219. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

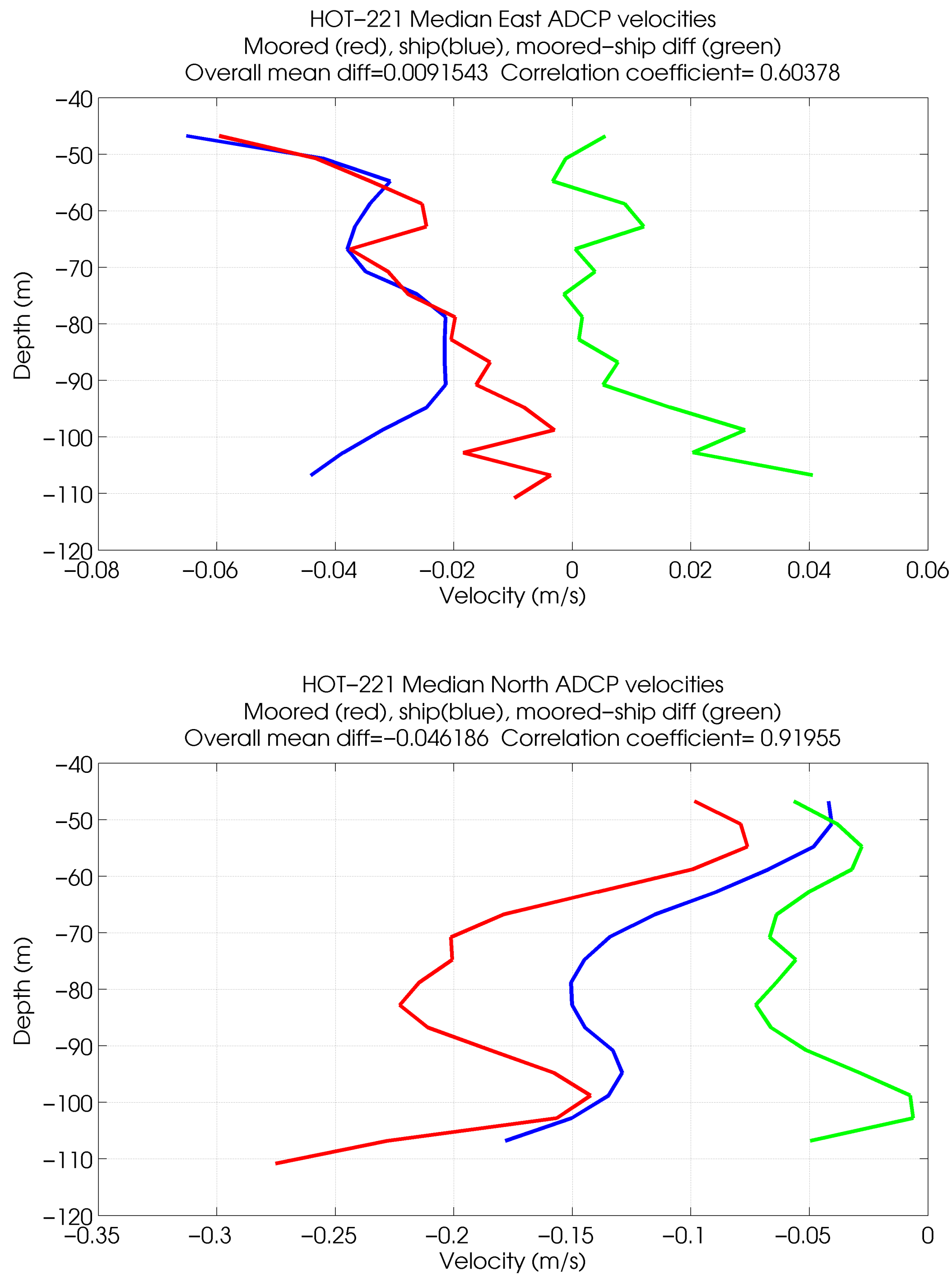


Figure 6-40. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-221. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

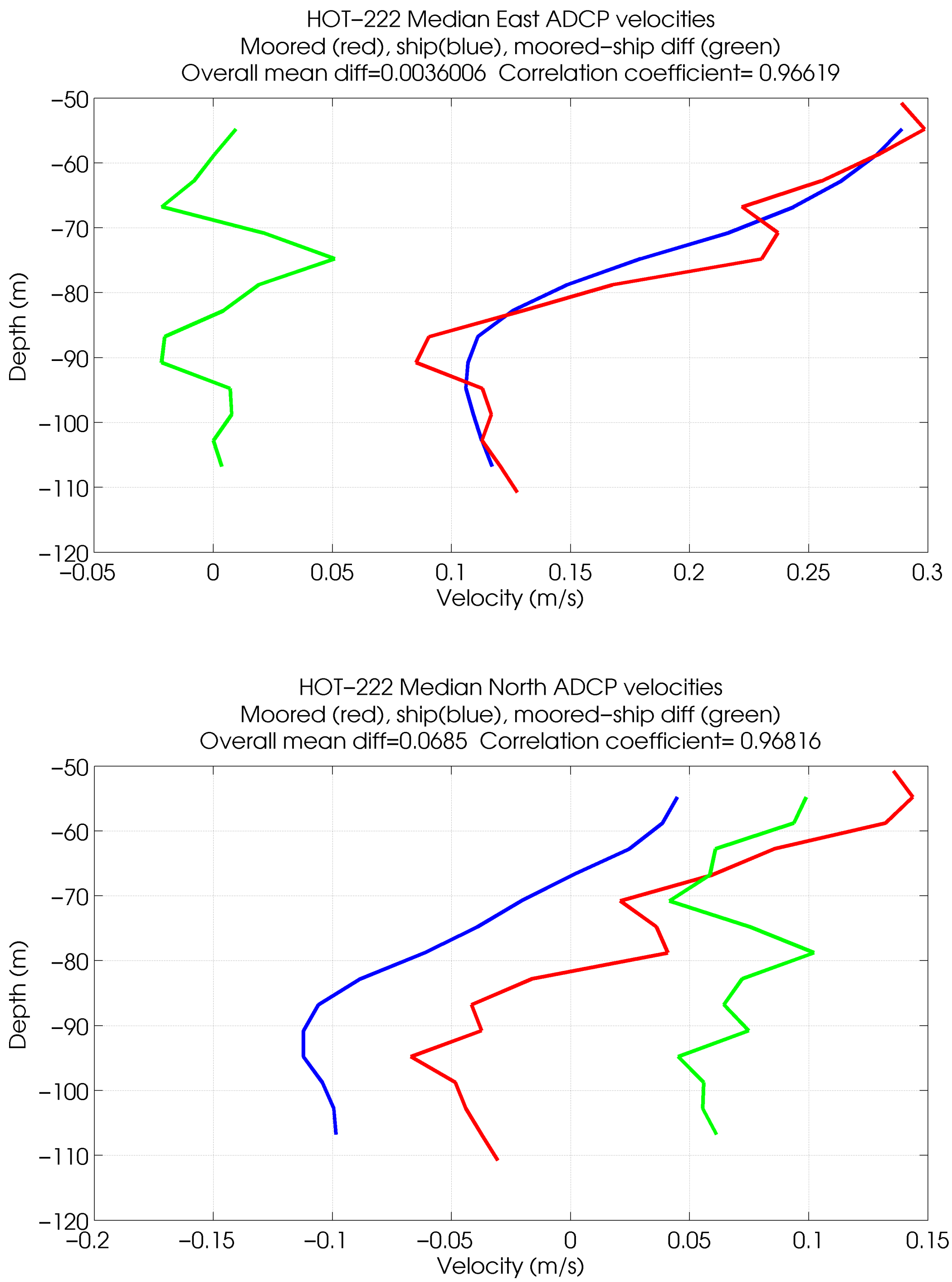


Figure 6-41. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-222. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

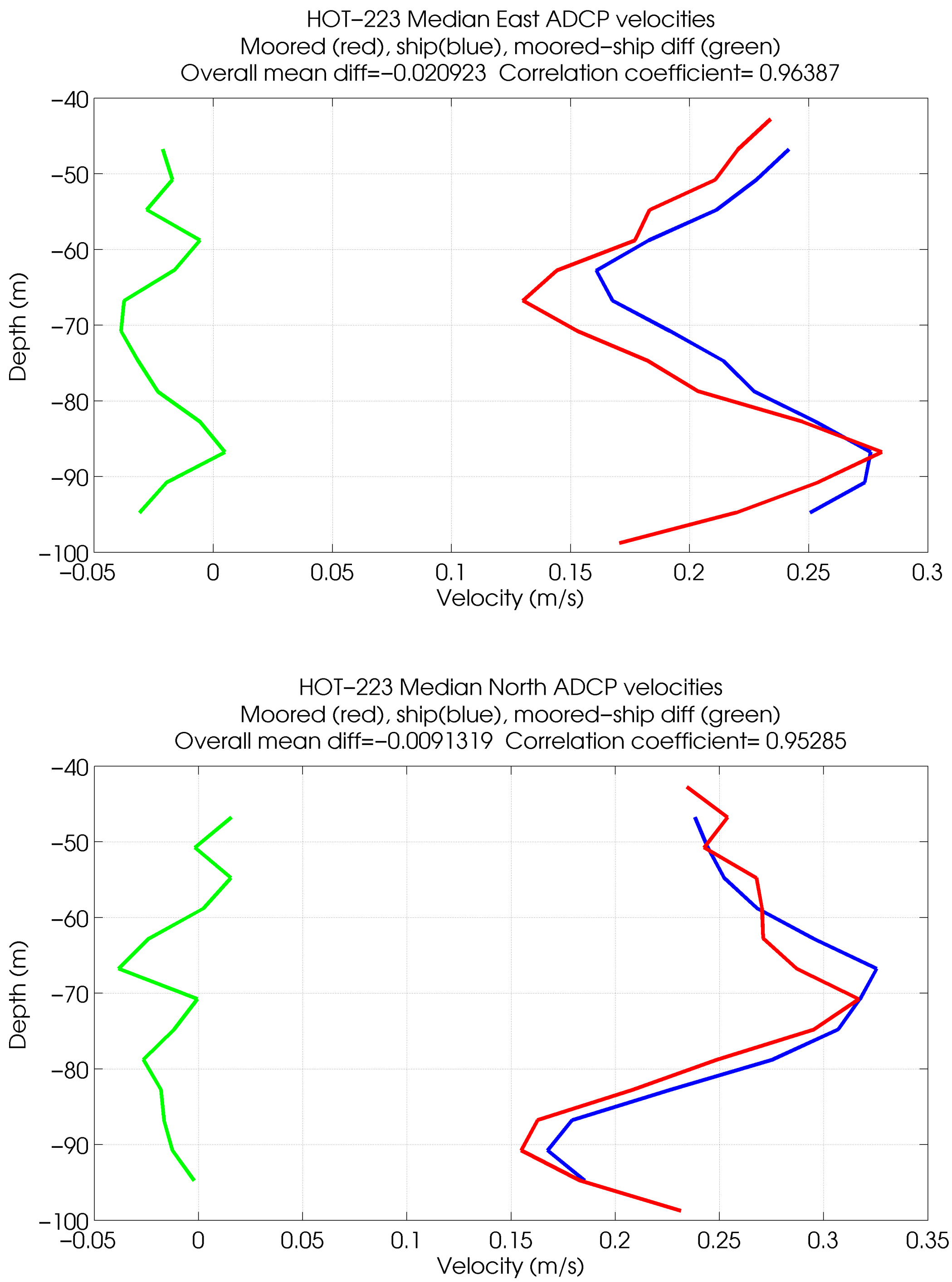
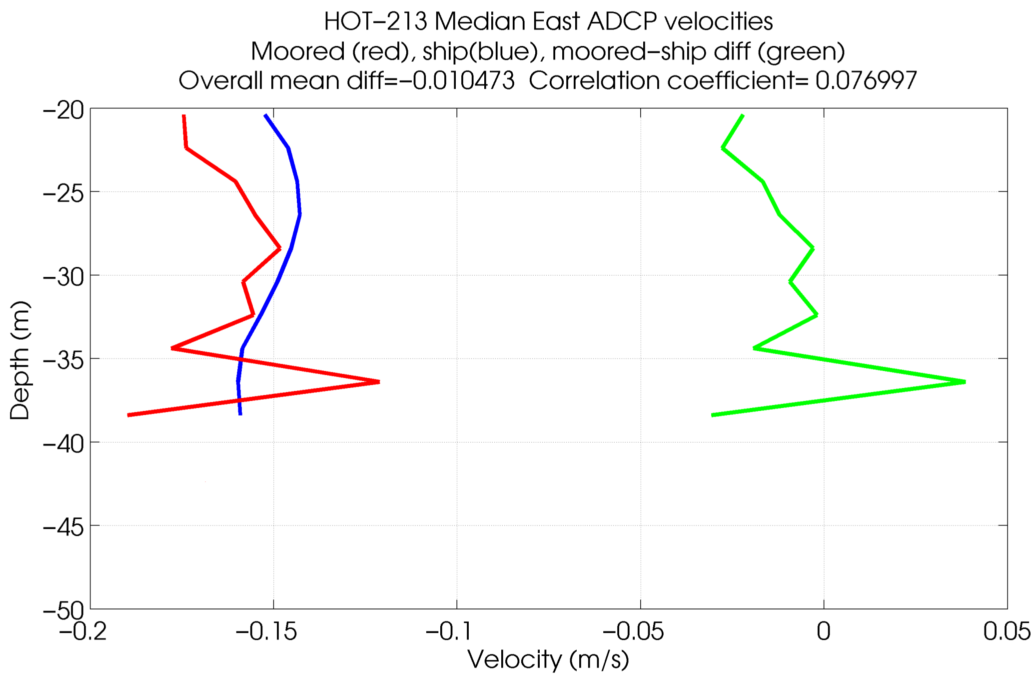


Figure 6-42. Median velocity profiles during shipboard ADCP (blue) versus moored 300 kHz ADCP (red) intercomparisons from HOT-223. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.



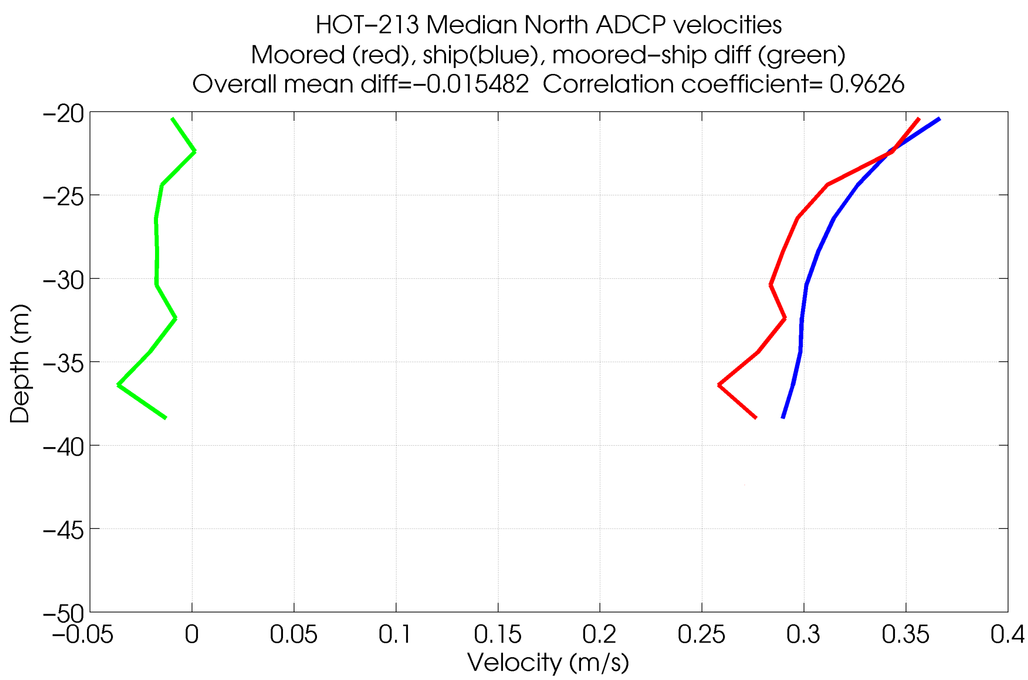


Figure 6-43. Median velocity profiles during shipboard ADCP (blue) versus moored 600 kHz ADCP (red) intercomparisons from HOT-213. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

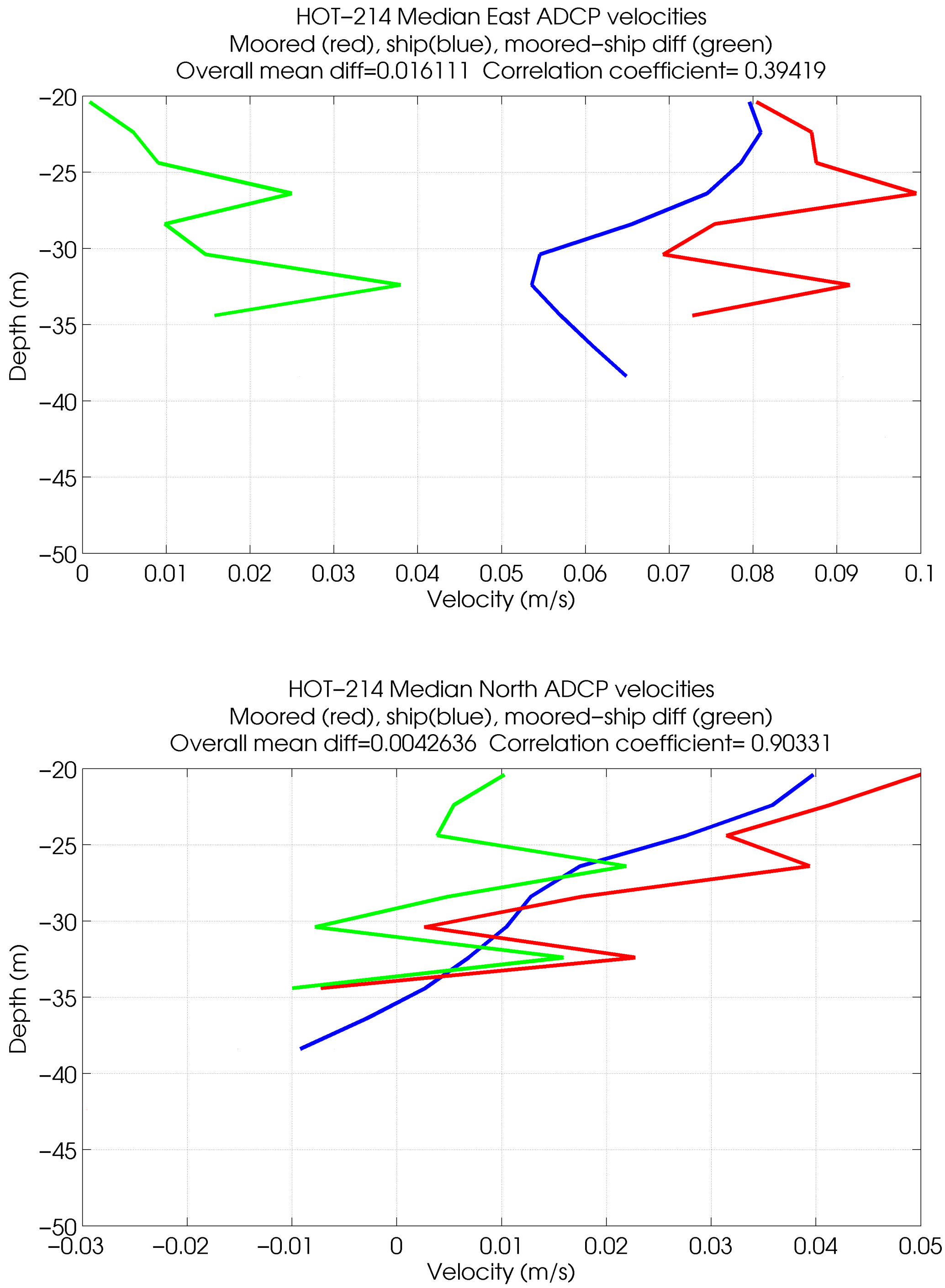
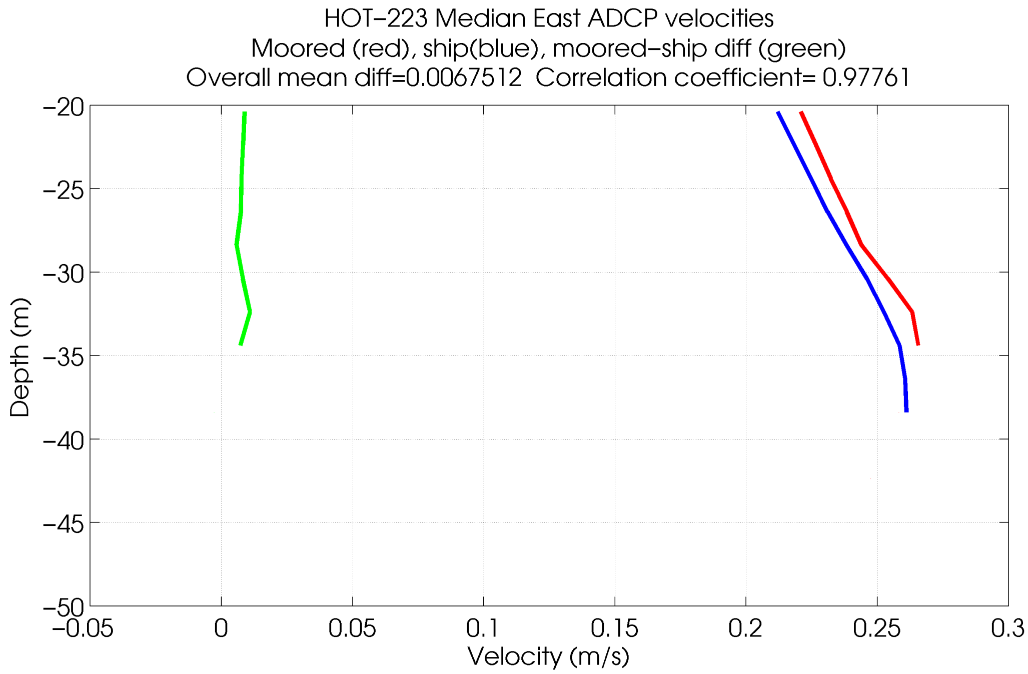


Figure 6-44. Median velocity profiles during shipboard ADCP (blue) versus moored 600 kHz ADCP (red) intercomparisons from HOT-231. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.



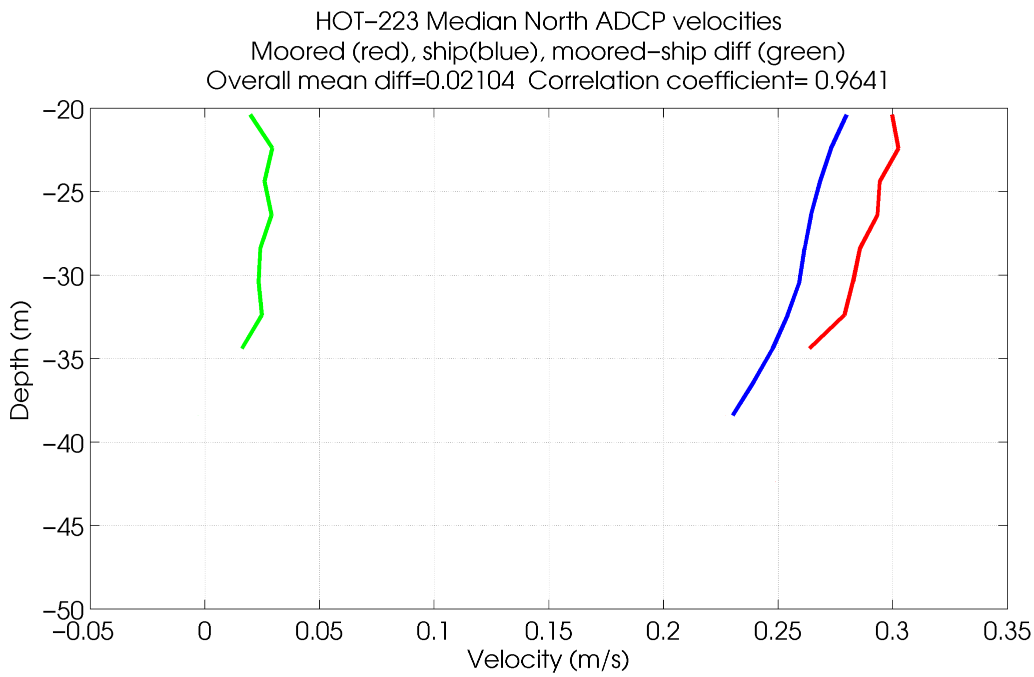


Figure 6-45. Median velocity profiles during shipboard ADCP (blue) versus moored 600 kHz ADCP (red) intercomparisons from HOT-231. Moored minus shipboard ADCP differences shown in green. Top panel shows east velocity components, bottom panel shows north velocity components.

F. Next Generation Vector Measuring Current Meter data (VMCM)

Time-series of daily mean horizontal velocity components for the VMCM current meters deployed during WHOTS-6 at 10 m and 30 m are presented in Figure 6-46.

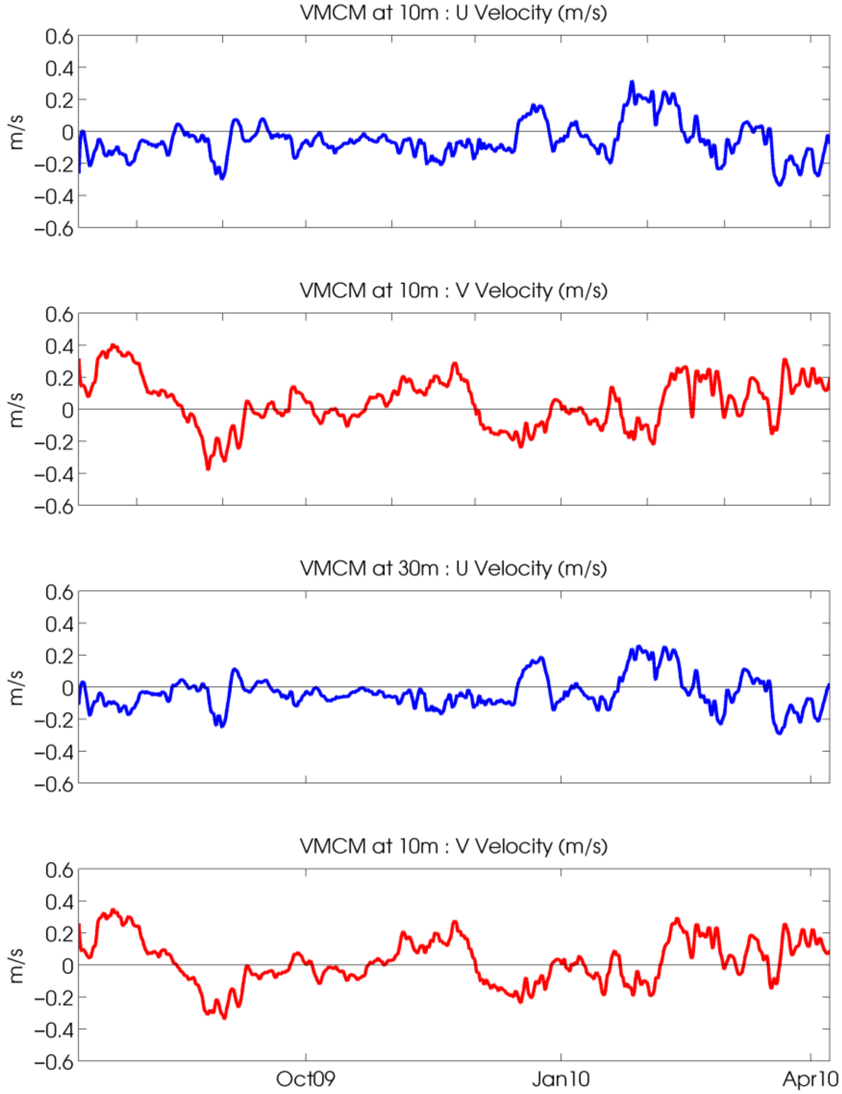


Figure 6-46. Horizontal velocity data (m/s) during WHOTS-6 from the VMCMs at 10 m depth (first and second panel) and at 30 m depth (third and fourth panel).

G. GPS data

Time-series of latitude and longitude of the WHOTS-6 buoy from GPS data are presented in Figure 6-47 and spectra of the time-series is shown in Figure 6-48.

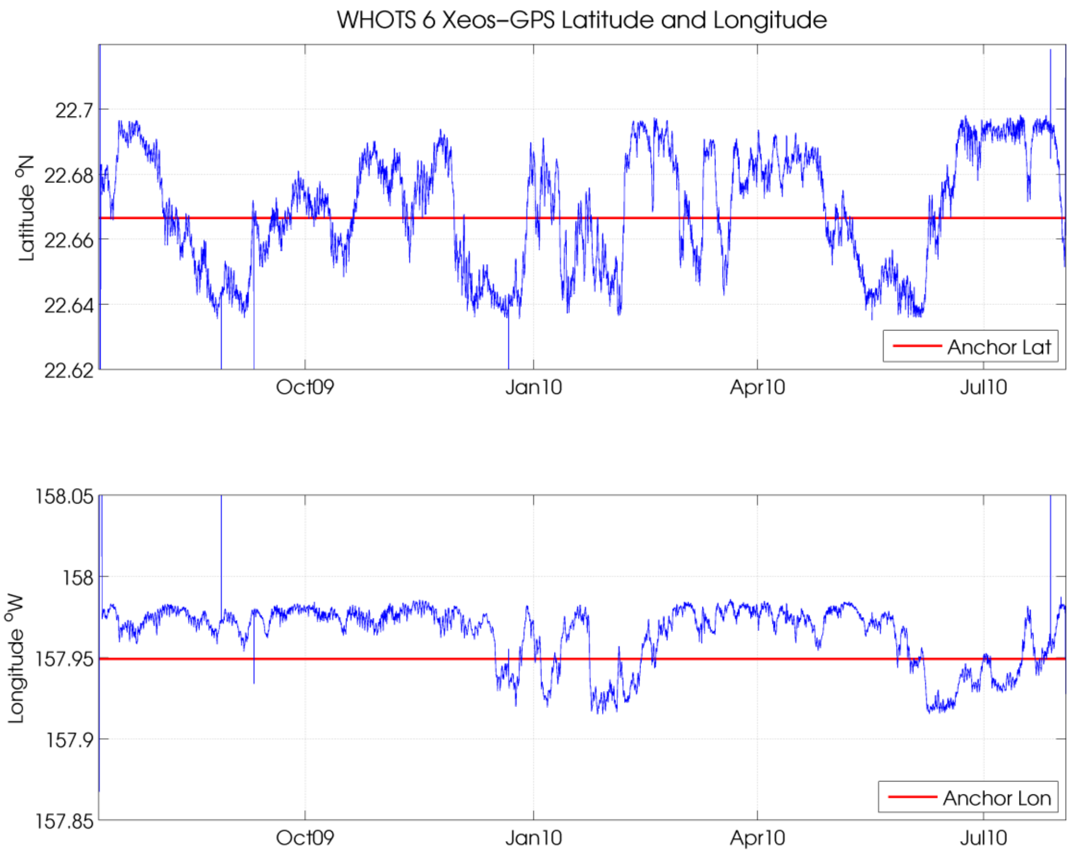


Figure 6-47. GPS Latitude (upper panel) and longitude (lower panel) time seris from the WHOTS-6 deployment.

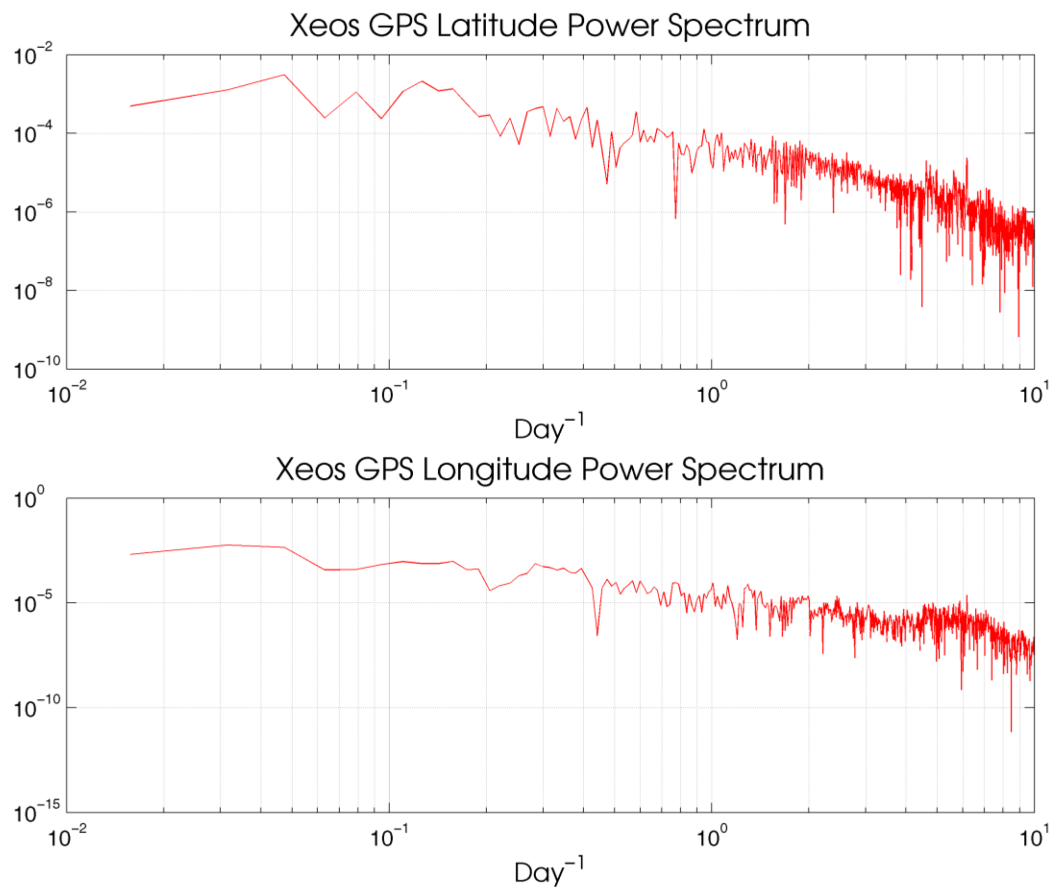


Figure 6-48. Power spectrum of latitude (upper panel) and longitude (lower panel) for the WHOTS-6 deployment.

H. Mooring Motion

The position of the mooring with respect to its anchor was determined from the ARGOS positions as shown in Section 5.D. Additional information of the mooring motion was provided by the ADCP data of pitch, roll and heading, shown in this section.

Figure 6-49 shows the ADCP data of the instrument's tilt (a combination of the pitch and roll), plotted against the buoy's distance from its anchor (derived from ARGOS positions), for both WHOTS ADCP's. The red line in the plot is a quadratic fit to the median tilt calculated every 0.2 km distance bins. The figure shows that during both deployments, the ADCP tilt increased as the distance from the anchor increased. This tilting was caused by the deviation of the mooring line from its vertical position as it was pulled by the anchor. The tilting of the line also caused the rising of the instruments attached to the line.

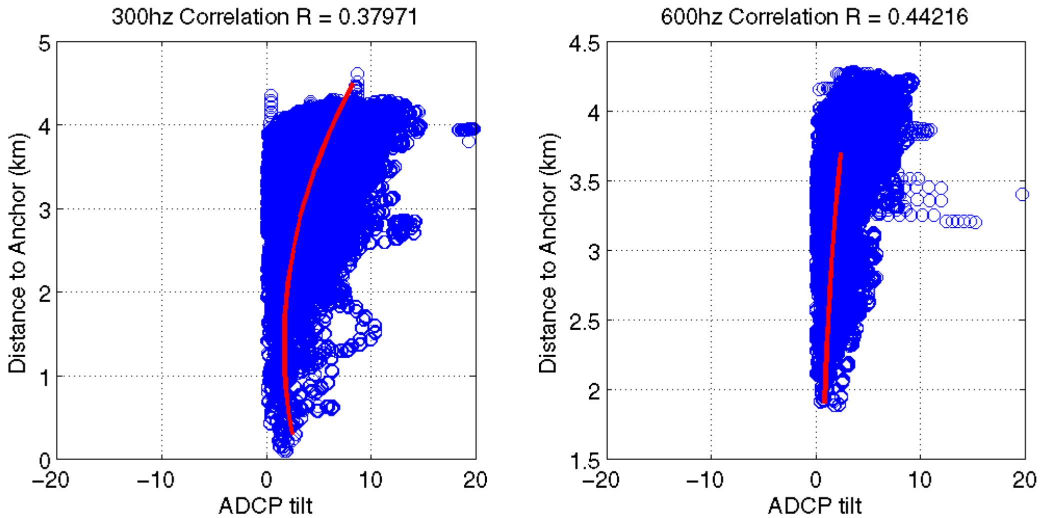


Figure 6-49. Scatter plots of ADCP tilt and distance of the buoy to its anchor for the 300 kHz (left panel), and the 600 kHz ADCP deployments (right panel, blue circles). The red line is a quadratic fit to the median tilt calculated every 0.2 km distance bins.

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8. Appendices

Appendix 1: WHOTS-6 300 kHz ADCP Configuration

File Size 42,159,567 bytes

Data Structure BB/WH/OS
Ensemble Length 752 bytes

Program Version 16.28

System Frequency 300 kHz
Convex
Sensor Configuration #1
Transducer Head Attached TRUE
Orientation UP
Beam Angle 20 Degrees
Transducer 4 Beam Janus

Real Data

CPU Serial Number: 71957

False Target(WA) 70 counts
Band Width (WB) 0
Cor. Thres. (WC) 64 counts
Err Thres. (WE) 2000 mm/s
Blank (WF) 1.76 m
Min PGood (WG) 0
Ref Layer (WL) 1, 5 first bin, last bin
Mode (WM) 1
Bins (WN) 30
Pings/Ens (WP) 40
Bin Size (WS) 4.00 m

Head Align (EA) 0.00 degrees
Head Bias (EB) 10.06 degrees
Coord Xform (EX) 00011111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping
Sens Source (EZ) 01111101 cdhprst
Sens Avail 00011101 cdhprst

Time/Ping (TP) 00:04.00

Hardware 4 Beams
Code Reps. 9
Lag Length 0.49 m
Xmt Length 4.42 m
1st Bin 6.22 m

BT Pings/Ens (BP) 0
BT Ens Delay (BD) 0
BT Cor.Thres. (BC) 0 counts
BT Eval. Thres. (BA) 0 counts

BT PG Thres.   (BG) 0
BT Mode   (BM) 0
BT Err Thres.   (BE) 0 mm/s
BT Max Range   (BX) 0 dm

First Ensemble 00000001 08-Jul-2009 00:00:00
Last Ensemble 00038015 03-Aug-2010 07:50:00

Appendix 2: WHOTS-6 600 kHz ADCP Configuration

File Size 36,659,200 bytes

Data Structure BB/WH/OS
Ensemble Length 652 bytes

Program Version 50.36

System Frequency 600 kHz
Convex
Sensor Configuration #1
Transducer Head Attached TRUE
Orientation UP
Beam Angle 20 Degrees
Transducer 4 Beam Janus

Real Data

CPU Serial Number: 70122

False Target(WA) 70 counts
Band Width (WB) 0
Cor. Thres. (WC) 64 counts
Err Thres. (WE) 2000 mm/s
Blank   (WF) 0.88 m
Min PGood   (WG) 0
Ref Layer   (WL) 1, 5 first bin, last bin
Mode   (WM) 1
Bins   (WN) 25
Pings/Ens   (WP) 80
Bin Size   (WS) 2.00 m

Head Align (EA) 0.00 degrees
Head Bias   (EB) 10.06 degrees
Coord Xform (EX) 00011111 Earth Coordinates Using Tilts, 3 Beam Solutions, and Bin Mapping
Sens Source (EZ) 01111101 cdhprst
Sens Avail   00011101 cdhprst

Time/Ping   (TP) 00:2.00

Hardware   4 Beams
Code Reps. 9
Lag Length 0.25 m

Xmt Length 2.22 m
1st Bin   3.11 m

BT Pings/Ens   (BP) 0
BT Ens Delay   (BD) 0
BT Cor.Thres.   (BC) 0 counts
BT Eval. Thres. (BA) 0 counts
BT PG Thres.   (BG) 0
BT Mode   (BM) 0
BT Err Thres.   (BE) 0 mm/s
BT Max Range   (BX) 0 dm

First Ensemble 00000001 10-Jul-2009 00:20:00
Last Ensemble 00056053 3-Aug-2010 06:00:00