The High Wind Gas Exchange Project (HiWinGS): Cruise Report for R/V Knorr KN213-03, 10 Oct to 14 Nov 2013

Byron Blomquist[1], Barry Huebert[2], Jeff Hare[2], Ian Brooks[3], Robin Pascal[4], Mingxi Yang[5], Helen Czerski[6], Tim Bertram[7], Christopher Fairall[8], and Chris Zappa[9]

[1] CIRES, University of Colorado (formerly Dept. of Oceanography, University of Hawaii)
[2] Dept. of Oceanography, University of Hawaii
[3] School of Earth and Environment, University of Leeds, UK
[4] National Oceanography Centre, Southampton, UK
[5] Plymouth Marine Laboratory, Plymouth, UK
[6] Dept. of Mechanical Engineering, University College London, UK (formerly Univ. Southampton, UK)
[7] Dept. of Chemistry, University of Wisconsin, Madison (formerly Univ. of California, San Diego)
[8] NOAA Earth Systems Research Laboratory, Physical Sciences Division, Boulder CO
[8] Lamont-Doherty Earth Observatory, Columbia University

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Abstract

This report summarizes the activities and raw results from the 2013 High Wind Gas Exchange (HiWinGS) cruise on R/V Knorr. Scientific analyses of these results are ongoing at the time of this report (Nov 2015). The principal HiWinGS objective was to deploy direct measurements of trace gas and physical fluxes together with a suite of wave physics and sea state observations. Flux and sea state observations were conducted successfully at a series of seven stations along a cruise track from Nuuk, Greenland to Woods Hole, MA from October 9 to November 12, with the greatest amount of time spent in the central Labrador Sea.

Results from basic processing of raw measurements are presented as figures in this report. The final section provides instructions for access to these results via the project ftp site. We strongly encourage interested parties to contact the original investigators with specific questions regarding measurement systems and for guidance on data quality issues. Contact information for each dataset is provided in the final section and on the ftp site. Information on the ftp site will be updated when necessary as scientific analysis proceeds.

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Project Objective

The HiWinGS project was conceived to address important questions relating to air/sea interaction at high wind speeds with large waves and significant whitecap coverage. The physical mechanisms for gas transfer, momentum transfer and sensible/latent heat flux evolve as wind speeds increase and the wind sea develops. A variety of theoretical frameworks and/or parameterizations exist to describe the physical mechanisms, but very few field observations exist to validate these approaches. Thus the primary HiWinGS objective was to deploy direct measurements trace gas and physical fluxes together with an extensive suite of wave physics and sea state observations. To this end we organized an international collaboration between groups specializing in state-of-the-art trace gas flux, physical flux, and wave physics measurements.

Operational Plan

The field operational plan to address the program objective had to meet several constraints: 1) a location with a high frequency of extra-tropical cyclones and high wind speeds; 2) a region and time of year with sufficient sea surface trace gas concentrations to yield measurable air/sea fluxes; 3) a location logistically feasible for deployment of a UNOLS research vessel; and 4) a deployment strategy maximizing the time dedicated to simultaneous flux and wave physics observations. The Labrador Sea in October-November was selected as the best compromise location. At this time of year the area is subject to frequent storms and is a well-known sink for atmospheric CO_2, with air/sea ΔpCO_2 magnitudes greater than 30 μAtm (a requirement for useful CO_2 flux measurements). Additionally, while sea surface DMS concentrations are declining from the Spring-Summer maximum, levels at this time of year are still sufficient for precise DMS flux measurements.

Wave physics observations required deploying drifting buoys, and the best flux measurements require the ship to sit on-station, bow-to-wind. Ship operations therefore centered around identifying an approaching weather system and a location of maximum wind speeds, positioning the ship ahead of the storm, deploying the observational buoys, and riding through the storm, hove-to and drifting with the buoys. In calm periods between storms buoys were recovered and the ship was able to transit to the next location of a forecast wind event. A secondary but nevertheless important consideration was seawater CO_2 concentration and when possible we chose a location within the area of forecast high winds with the largest ΔpCO_2 air/sea gradient.

Convenient temporal spacing between storms contributed to the success of this approach and we were able to occupy a series of seven stations for high wind observations, following a SW course toward our final destination of Woods Hole, MA. Periods of transit between stations were during calm weather, maximizing the quantity and quality of high wind observations and providing comfortable cruising conditions for preparations between stations.

Cruise Participants

Science Party

Byron Blomquist	Chief Scientist	Univ. of Hawaii, Oceanography (now Univ. Colorado)
Ludovic Bariteau	Scientist	NOAA ESRL, Physical Sciences Division
Michelle Kim	Student	UC San Diego (now Calif. Inst. Tech.)
Sophia Brumer	Student	Columbia Univ., LDEO
Ian Brooks	Scientist	Univ. of Leeds, UK
Matt Amison	Student	Univ. of Leeds, UK
Sam Peppe	Technician	Univ. of Leeds, UK
Robin Pascal	Scientist	National Oceanography Centre, UK
Helen Czerski	Scientist	Univ. of Southampton, UK (now Univ. College London)
Adrian Matei	Student	Univ. of Southampton, UK (now Univ. College London)
Mingxi Yang	Scientist	Plymouth Marine Laboratory, UK
Amy Simoneau	SSSG Tech	Woods Hole Oceanographic Institution
David Sims	SSSG Tech	Woods Hole Oceanographic Institution
Claudia Bagge-Peterson	Observer	Aalborg Univ., Denmark

R/V Knorr Crew

Kent Sheasley	Master	Woods Hole Oceanographic Institution
Paul Carty	Chief Mate	Woods Hole Oceanographic Institution
Jennifer Hickey	2nd Mate	Woods Hole Oceanographic Institution
Samantha Cibelli	3rd Mate	Woods Hole Oceanographic Institution
Jerry Beard	Comm ET	Woods Hole Oceanographic Institution
Peter Liarikos	Bosun	Woods Hole Oceanographic Institution
Paul St Onge	AB	Woods Hole Oceanographic Institution
Jose Andrade	AB	Woods Hole Oceanographic Institution
- Fitz	AB	Woods Hole Oceanographic Institution
- Cacho	OS	Woods Hole Oceanographic Institution
Scott Loweth	OS	Woods Hole Oceanographic Institution
Stephen Walsh	Chief Engineer	Woods Hole Oceanographic Institution
Piotr Marczak	1st Asst. Engineer	Woods Hole Oceanographic Institution
Wayne Sylvia	2nd Asst. Engineer	Woods Hole Oceanographic Institution
Vasile Tudoran	3rd Asst. Engineer	Woods Hole Oceanographic Institution
Russell Adams	Electrician	Woods Hole Oceanographic Institution
- Covert	Oiler	Woods Hole Oceanographic Institution
- Bronson	Oiler	Woods Hole Oceanographic Institution
Rogelio Fong	Oiler	Woods Hole Oceanographic Institution
Bobbie Bixler	Steward	Woods Hole Oceanographic Institution
Erskine Goddard	Cook	Woods Hole Oceanographic Institution
Anthony Reveira	Mess Attendant	Woods Hole Oceanographic Institution

Measurements

Various instruments deployed for HiWinGS are summarized in Table 1. Measurement types fall into 3 categories: meteorological, physical oceanographic, and chemical (air and seawater). Meteorological measurements encompass 1-minute average bulk properties (such as air temperature, humidity, barometric pressure, wind speed, down-welling solar radiation, down-welling IR radiation, and rain rate) and turbulent flux parameters (wind components and temperature, aerosol size distributions, and water vapor all at 10Hz). Oceanographic measurements include CTD profiles (on-station) and underway measurements of temperature and salinity, ocean current profiles (ADCP), and various properties related to waves and whitecaps from both underway and buoy-mounted systems. High rate (10 Hz) atmospheric chemical measurements for DMS, CO_2, acetone, methanol were used to measure the air/sea flux of these gases. Underway and CTD surface water samples were analyzed to assess the air/sea concentration gradients of trace gases (DMS, CO_2, acetone, methanol) and compute transfer coefficients from the measured fluxes.

Cruise Narrative

R/V Knorr departed the pier at Nuuk, Greenland at approximately 2300 UTC on Oct 9 and stood off in the fjord for approximately 6 hours durting a deployment and recovery test of the large spar. At 0500 Oct 10 the ship began a transit leg from Nuuk south along the Greenland coast in moderately rough seas and declining westerly winds in the wake of a strong low pressure system.

Station 1: A forecast for strong northerly winds led to the decision to set Station 1 at 59N 50W, commencing 1000 Oct 11. The WaveRider buoy (hereafter WR) and large spar were deployed. Sea surface temperature (SST) was ~6.5°C. The ship's underway seawater system air-locked from 1830 to 2130. The WR was recovered later that night when it's tether became fouled in the ship's props and was redeployed Oct 12. Wind speed remained above 15 m/s for ~12 hours, declining on Oct 13. The large spar buoy was damaged on recovery and subsequently repaired with assistance from the ship's engineers over the next few days. We noted a large bias in DMS concentration between the underway seawater line and discrete grab samples of surface seawater from the CTD rosette. We therefore conducted a chlorination of the ship's seawater lines on departure from Station 1 and underway seawater measurements were suspended for the duration of the cleaning. Strong winds were forecast near the S tip of Greenland within 24 hours and we began a transit to 59N 43W at 1630 on Oct 13.

Station 2: Facing strong winds and rough seas, we halt the transit leg at 1200 Oct 14 and set station 2 at 58.47N 44.95W. Seawater line chlorination stopped at 0815. ΔpCO_2 measurements resumed at 0900. The small spar buoy and WR were deployed between 1200 and 1300. This station was characterized by very strong winds from the NE with large wind sea. Wind speed exceeded 20 m/s for ~16 hours on Oct 14-15. ΔpCO_2 was marginal at the start (–30 μAtm) but improved as we drifted west with the buoys. SST was ~7°C. The small spar followed drifted with ocean current to the W while the WR drifted faster with the current and wind to the WSW.

We recovered the WR Oct 17 at 1130 and small spar at 1320. We then transited south along 46W over Oct 17-18 with calm seas and easterly winds less than 10 m/s.

Station 3: We set Station 3 at 54.1N 46W on Oct 18 1800 following a forecast of strong winds in this area. This station is characterized by a gradual, steady increase in NE wind over Oct 19 with coincident development of wind sea, peaking at about 0000 Oct 20 with ~9 hours of wind speeds in excess of 15 m/s, followed by a gradual reduction in wind and seas into Oct 21. The buoys drifted in a large cyclonic (CCW) eddy. ΔpCO_2 started at approximately –60 µAtm and finished at about –50 µAtm. At the start we appeared to be in an area of enhanced biological productivity and upwelling, but we drifted away from that over the first day. SST was ~8.7°C. The WR was recovered Oct 21 1130 and large spar about 20 nm to the NE at 1415. The forecast shows calm conditions for the next 2 days with a significant low-pressure system arriving on Oct 24. Over Oct 22-23 we conduct a survey of seawater pCO_2 and DMS in calm conditions via the following waypoints: 54.3N 46.5W; 53.5N 49.4W; 53.0N 49.5W; 53.0N 47.7W; 54.0N 46.0W; and 53.5N 46W.

Station 4: On the basis of observed pCO2 and wind forecasts, Station 4 is established at 53.5N 45.4W at 0900 Oct 24. This station characterized by the passage of a very strong low-pressure system, with a minimum pressure of ~960 hPa at 0400 Oct 25. From 1200 Oct 23 through Oct 24, as the low approached, wind veered from southerly to easterly, increasing gradually to 20 m/s. As the eye of the low passed over our location pressure reached a minimum and winds decreased to ~6 m/s with fog. Then very rapidly, from 0700 to 0800 on Oct 25, westerly wind grew to >25 m/s. This transition led to an initially chaotic sea state, subsequently developing into a full wind sea with ~10 m waves under westerly wind. Wind dropped below 20 m/s just after 0000 Oct 26 and declined further over the course of the day, but waves remained large. We recovered the WR at 1200 on Oct 27 and the large spar at 1400. SST was ~10.4°C. ΔpCO_2 was –55 µAtm early on Oct 25 but drifted up to ~ –35 µAtm during the height of the storm and remained at that level to the end of the station.

Station 5: With a forecast showing continued high winds in the area we remain at the Station 4 location and begin Station 5. Buoys were deployed at ~1500 Oct 28. Westerly winds increased quickly during Oct 28 and remained > 15 m/s over the next two days. ΔpCO_2 was marginal at this station, ranging from –40 to –30 µAtm for most of the time, drifting to –20 µAtm toward the end. Sea state at this station was chaotic and mixed, with strong swell from the NE (coming from the N lobe of the Oct 25 low pressure system) mixed with wind seas from strong westerly winds. Ship motion was characterized by strong roll. Wind, motion, rain, T/RH and laser altimeter sensors from the NOAA flux system failed at this station due to a power short and we made plans for subsequent repairs in a few days in calmer conditions near Newfoundland. SST was ~8.6°C. Forecasts for the following 2 days were for moderate winds with some indication of stronger winds developing just E of Newfoundland. Oct 31 1200 we begin a transit leg to the west for a station on or near the Newfoundland shelf, influenced by flow from the Labrador Current.

Station 6: We arrived at a location just short of the continental shelf at 1900 Nov 01, in cooler, fresher water just east of the core of the Labrador Current. The large spar, WR and small spar were all deployed at this site, with the small spar tethered to ship. Winds grew to >15 m/s for most of Nov 02. ΔpCO_2 was –40 to –50 μAtm for the entire period. The WR and small spar were recovered 1220 Nov 03 and large spar at 1340. With a forecast for calm weather over the next several days we depart for the Strait of Belle Isle at 1500 Nov 03. On Nov 04 we make a short stop in the Strait to examine NOAA met sensors and on Nov 05 we stop again to complete repairs and bring wind, rain and T/RH sensors back on-line. The transit continues south along the W coast of Newfoundland in very calm seas with light headwinds toward the final station in the Atlantic south of Nova Scotia.

Station 7: This station was sited just off the continental shelf, avoiding currents and clear of shipping lanes and other restricted areas. At 0900 Nov 07 we arrive at 41.45N 64W in very calm, warm conditions. SST and air temperature were ~20°C with high humidity. The WR, large and small spar buoys were deployed again. All buoys were drifting, with the ship following the small spar. The small spar was recovered each evening. We recovered the WR each morning and relocate to the location of the large spar, redeploying the WR and small spar. Strong southerly winds develop over Nov 07. At 0600 Nov 08 a cold front passes and winds die quickly, veering northerly. Temperature and humidity drop and northerly winds strengthen over the course of the day. This station is notable for atmospheric instability behind the front when SST was ~20°C and air temp ~10°C, resulting in numerous squalls with hail and rain over the course of Nov 08 and 09. The large spar was recovered 0900 Nov 10 and we repositioned to the point of origin at 41.45N 64W. The small spar and WR were redeployed. Over Nov 10-11 another cold front passes and winds grow to ~15 m/s and decline gradually. Both buoys were recovered and we depart the Station 7 at 1500 Nov 12, beginning the final transit leg to WHOI.

Tables

Table 1: Measurement Systems

Institution	Instrumentation	Description
Ship:		
NOAA/ESRL/PSD	Wind, motion, Licor CO_2 & H_2O	Heat, momentum & CO_2 fluxes
	Laser altitude wave height	1D Wave spectra
	T/RH/P, rain, radiation, SST	Bulk meteorological parameters
Univ. Hawaii	Wind, motion, DMS & CO_2	Heat, momentum, DMS & CO_2 fluxes
	Chilled mirror hygrometer	Bulk humidity
	Seawater DMS	Underway & CTD seawater DMS conc.
Univ. Cal San Diego	CI-TOFMS	Volatile organic carbon compounds
Plymouth Marine Lab	Wind, Motion, PTRMS	Heat, stress, methanol & acetone fluxes
NOAA/PMEL	pCO_2 equilibrator system	Underway sea surface ΔpCO_2
Univ. Leeds	CLASP aerosol spectrometer	Aerosol size spectra and flux
	Whitecap camera	Whitecap fraction
	WaveRider buoy (WR)	2D wave spectra (Hs >1m)
Columbia Univ./LDEO	High speed whitecap video	Wave crest velocity distribution & Whitecap fraction
Large Spar Buoy:		
NOC Southampton	Wave wires & video	High frequency wave spectra & whitecaps
Univ. Southampton	Bubble camera	Large bubble size distribution
	Bubble resonators	Small bubble size distribution
	Sonar	Bubble plume evolution
	Foam camera	Sea surface foam coverage
Univ. Leeds	ADV Current– turbulence probe	Sub-surface turbulence & current @ 3m
Small Spar Buoy:		
NOC Southampton	Wave wires & video	High frequency wave spectra & whitecaps
Univ. Leeds	ADV Current– turbulence probe	Buoy-relative current
R/V Knorr Systems:		
WHOI SSSG	Wind, T, P, RH, rain, radiation	Bulk meteorological parameters
	Lat, Lon, COG, SOG, Gyro	Navigation parameters
	SST, salinity, fluorometer, depth	Oceanographic parameters
	Underway ADCP	Currents: near surface and depth profiles
	CTD: SST, Sal, fluoro, depth	Depth profiles on station
	Multibeam	Bottom mapping / topography

Table 2: CTD Stations (with surface water collected for DMS, acetone & methanol analysis)

CTD No.	Date (UTC)	Latitude	Longitude	Depth (m)
1	Oct 11 2013 14:52:21	58° 59.92’ N	049° 59.84’ W	3250
2	Oct 12 2013 15:09:07	58° 52.57’ N	049° 50.94’ W	500
3	Oct 12 2013 20:05:54	58° 51.44’ N	049° 47.15’ W	500
4	Oct 13 2013 10:35:53	58° 50.73’ N	049° 46.93’ W	985
5	Oct 14 2013 20:10:06	58° 22.40’ N	045° 11.14’ W	500
6	Oct 15 2013 11:11:59	58° 14.25’ N	045° 35.22’ W	500
7	Oct 15 2013 20:12:20	58° 13.82’ N	045° 51.87’ W	500
8	Oct 16 2013 11:15:03	58° 11.52’ N	046° 09.13’ W	500
9	Oct 16 2013 20:08:54	58° 12.02’ N	046° 19.15’ W	500
10	Oct 17 2013 11:09:18	58° 16.04’ N	046° 18.87’ W	500
11	Oct 18 2013 21:20:39	54° 09.39’ N	046° 04.90’ W	500
12	Oct 19 2013 11:02:32	54° 13.75’ N	046° 14.90’ W	500
13	Oct 19 2013 20:02:48	54° 15.27’ N	046° 20.08’ W	500
14	Oct 20 2013 11:00:13	54° 10.42’ N	046° 37.32’ W	500
15	Oct 20 2013 20:05:03	54° 06.13’ N	046° 41.44’ W	500
16	Oct 21 2013 10:58:41	53° 57.71’ N	046° 45.60’ W	1000
17	Oct 23 2013 21:05:19	53° 31.05’ N	046° 00.41’ W	500
18	Oct 24 2013 11:03:55	53° 30.01’ N	045° 26.04’ W	500
19	Oct 24 2013 20:06:59	53° 29.51’ N	045° 26.87’ W	500
20	Oct 26 2013 11:08:32	53° 16.65’ N	045° 22.13’ W	500
21	Oct 26 2013 20:06:54	53° 16.17’ N	045° 28.96’ W	500
22	Oct 27 2013 11:25:00	53° 14.45’ N	045° 23.71’ W	500
23	Oct 27 2013 21:00:39	53° 26.18’ N	045° 09.63’ W	500
24	Oct 28 2013 12:01:31	53° 26.58’ N	045° 08.63’ W	500
25	Oct 28 2013 21:02:44	53° 30.67’ N	045° 02.78’ W	500
26	Oct 30 2013 12:05:06	53° 10.76’ N	043° 55.50’ W	500
27	Oct 30 2013 20:57:06	53° 03.56’ N	043° 39.65’ W	500
28	Oct 31 2013 11:27:53	52° 57.65’ N	043° 26.28’ W	500
29	Nov 01 2013 20:59:26	52° 01.29’ N	050° 08.20’ W	500
30	Nov 02 2013 11:58:42	52° 07.89’ N	049° 57.20’ W	500
31	Nov 02 2013 21:09:48	51° 58.15’ N	049° 54.13’ W	500
32	Nov 03 2013 13:20:48	51° 56.26’ N	049° 49.02’ W	500
33	Nov 07 2013 13:01:06	41° 44.93’ N	063° 59.77’ W	500
34	Nov 07 2013 21:57:38	41° 43.55’ N	063° 50.75’ W	500

Table 2 (continued): CTD Stations

CTD No.	Date (UTC)	Latitude	Longitude	Depth (m)
35	Nov 08 2013 12:17:29	41° 38.48’ N	063° 30.03’ W	500
36	Nov 08 2013 21:59:09	41° 27.88’ N	063° 32.53’ W	500
37	Nov 09 2013 12:24:14	41° 09.29’ N	063° 30.79’ W	500
38	Nov 09 2013 21:57:35	41° 05.17’ N	063° 37.39’ W	500
39	Nov 10 2013 12:17:22	40° 58.66’ N	063° 40.40’ W	500
40	Nov 10 2013 22:03:44	41° 45.72’ N	063° 56.39’ W	500
41	Nov 11 2013 14:01:09	41° 27.16’ N	063° 37.58’ W	500
42	Nov 11 2013 22:58:19	41° 17.63’ N	063° 35.45’ W	500
43	Nov 12 2013 14:07:54	41° 06.91’ N	063° 37.57’ W	1000

Table 3: Flux Stations and Wave Buoy Deployments

Station No.	Start Date / Time (UTC)	End Date / Time (UTC)	Nominal Location
1	Oct 11 2013 03:00	Oct 13 2013 17:00	58°N, 048°W
2	Oct 14 2013 12:00	Oct 17 2013 12:00	58°N, 046°W
3	Oct 18 2013 18:00	Oct 21 2013 16:00	54°N, 046°W
4	Oct 23 2013 21:00	Oct 27 2013 18:00	53.5°N, 045.5°W
5	Oct 27 2013 20:00	Oct 31 2013 12:00	53.5°N, 045°W
6	Nov 01 2013 19:00	Nov 03 2013 15:00	52°N, 050°W
7	Nov 07 2013 09:00	Nov 12 2013 12:00	41°N, 064°W

Table 4: Large Spar Buoy Deployments and System Status

Deployment	Wave Wires	IMU	GoPro1 Video	GoPro2 Video	Nortek ADV	Bubble systems	Comments
LB Dep1	09/10/13	17:35:15					
	Wire 1 OK Wire 2 OK Wire 3 OK	IMU data good GPS fixes	none	none	Working	Foam Cam NO Bubble Cam OK Sonar NO Resonators NO	Test deployment in Nuuk. All systems working as expected.
LB Dep2	11/10/13	12:35:00	1100–1800 hrs 2 days each	1100 & 1800 2 days each			
	NO wave wire data	No IMU	16 files , 25 min each	5 files, 25 min each	Working	Foam Cam NO Bubble Cam OK Sonar OK Resonators NO	Buoy broken on recovery. Logger hung and failed to record data. GoPro's worked through out as expected. GoPro 2 dead after flooding . Foam camera data lost after flooding.
LB Dep3	18/10/13	12:19:04	1100–1800 hrs 4 days each	camera dead			
	Wire 1 bad Wire 2 bad Wire 3 bad	IMU Rate broken Bad pitch roll, heave No GPS	3 files, 25 min each Last file lost due to power down		Working ADV bracket rotated by 90° portside (wires fwd)	Foam Cam NO Bubble Cam OK Sonar OK Resonators OK	2 hr TEST deployment. Large spikes in wire data and drifting. Wire 1 worst, Wire 3 best. Foam camera not installed.
LB Dep4	18/10/13	14:49:10	1100–1800 hrs 4 days each	camera dead			
	Wire 1 bad Wire 2 bad Wire 3 bad	IMU Rate broken Bad pitch roll, heave No GPS	No files		Working ADV moved again by 180° to avoid strop (stdbside)	Foam Cam NO Bubble Cam OK Sonar OK Resonators NO	Short 30 min TEST deployment to calibrate resonators. Large spikes in wire data and drifting. Wire 1 worst, Wire 3 best. Foam camera not installed.
LB Dep5	18/10/13	18:08:00	1100–1800 hrs 4 days each	camera dead			
	Wire 1 bad Wire 2 bad Wire 3 OK	IMU Rate broken Bad pitch roll, heave No GPS	16 files, 25 min each		Working	Foam Cam NO Bubble cam OK Sonar OK Resonators OK	GPS Aerial disconnected for Dep 5 as possibly causing major spikes in wire data and no fixes so appears not to be working. Wire 1 & 2 duff. Wire 3 data OK. Foam camera not installed.

Table 4 (continued): Large Spar Buoy Deployments and System Status

Deployment	Wave Wires	IMU	GoPro1 Video	GoPro2 Video	Nortek ADV	Bubble systems	Comments
LB Dep6	24/10/13	14:39:52	1100–1800 hrs 4 days each	camera dead			
	Wire 1 OK Wire 2 OK Wire 3 OK	IMU Rate broken Bad pitch roll, heave GPS fix on deck None during dep	10 files, 20 min each		Working	Foam Cam NO Bubble cam OK Sonar Ok Resonators NO	All system working OK. Logger stopped after 26 hrs. So no wire, IMU or camera data after this. Replaced GOPS aerial with one given by ship side, works on deck but fails to get fix when buoy deployed. Nortek ADV stem was bent by a few degrees.
LB Dep7	1/11/13	19:56:21	1100–1800 hrs 4 days each	camera dead			
	Wire 1 OK Wire 2 OK Wire 3 OK	IMU Rate broken Bad pitch roll, heave. GPS fix on deck None during dep	7 files, 20 min each		Working	Foam Cam OK Bubble cam Ok Sonar OK Resonators OK	All system working OK but logger failed to activate GoPro after day 1. Turns out need to reset daily flag, by saving setting even after power down. This probably the cause.
LB Dep8	7/11/13	14:54:42	1200–1900 hrs 4 days each	camera dead			
	Wire 1 OK Wire 2 bad Wire 3 OK	IMU Rate broken Bad pitch roll, heave.	31 files, 20 min each		Working	Foam Cam OK Bubble cam OK Sonar Ok Resonators OK	All systems working OK, Logger continued until stopped, Wire 2 died after about 12 hrs. Wires 1 & 3 worked throughout. GoPro has the full amount expected.

Table 5: Small Spar Buoy Deployments and System Status

Deployment	Wave Wires	Compass	GoPro1	Nortek ADV	Comments
SB Dep1	14/10/13 Wire 1 OK Wire 2 OK Wire 3 bad Wire 4 bad	12:42:10 Heading , pitch & roll OK	Continuous 7 files (23.9Gb) Ran until batt died. 4.5hrs	working	Deployed free drifting with Iridium unit TRI222060. Wires 3&4 initially OK but go bad quite early on. 72 hrs of data.
SB Dep2	01/11/13 Wire 1 OK Wire 2 OK Wire 3 OK Wire 4 OK	16:17:30 Heading , pitch & roll OK	Continuous 6 files (23.1Gb) Ran until batt died. 4.5hrs	working	Tethered deployment as no Iridium available. All system worked OK. Buoy re wired prior to dep and new calibration made. Approx. 7hrs data.
SB Dep3	07/11/13 Wire 1 OK Wire 2 OK Wire 3 OK Wire 4 OK	16:00:04 No Compass data	Continuous 7 files (24.9Gb) Ran until batt died. 4.5hrs	working	Free drifting but watched by bridge as no available Iridium. Approx 8 hrs data. All wires worked through out dep. Compass failed to start on power up, so no compass data at all.
SB Dep4	08/11/13 Wire 1 OK Wire 2 OK Wire 3 OK Wire 4 OK	13:40:37 Heading , pitch & roll OK	Continuous 7 files (24.9Gb) Ran until batt died. 4.5hrs	working	Free drifting but watched by bridge as no available Iridium. Aprox. 10 hrs data. All wires worked throughout. Compass worked throughout.
SB Dep5	09/11/13 Wire 1 OK Wire 2 OK Wire 3 OK Wire 4 OK	13:51:26 Heading , pitch & roll OK	Continuous 3 files (8.2Gb) Ran until batt died. 90 mins	working	Free drifting but watched by bridge as no available Iridium. Battery for GoPro must not have been fully charge as finished early. Approx. 10 hrs data. All wires worked throughout. Compass worked throughout.
SB Dep6	10/11/13 Wire 1 OK Wire 2 OK Wire 3 bad Wire 4 OK	18:43:05 Heading , pitch & roll OK	Continuous 7 files (24.9Gb) Ran until batt died. 4.5hrs	working	Free drifting Large Spar iridium used: 3021490. Approx. 44 hrs data. Wire 3 fails part way through the deployment , other 3 worked throughout. Should be noted large amount of weed floating on surface. Compass worked through out.

Figures

Figure 1: Bow tower installation for flux and bulk meteorological measurements.

Figure 2: A third sonic anemometer and inlets for the trace organic analyzers were mounted above the yardarms on the foremast. Two container labs housed instrumentation for meteorological data acquisition systems and DMS, CO_2 and VOC flux measurements.

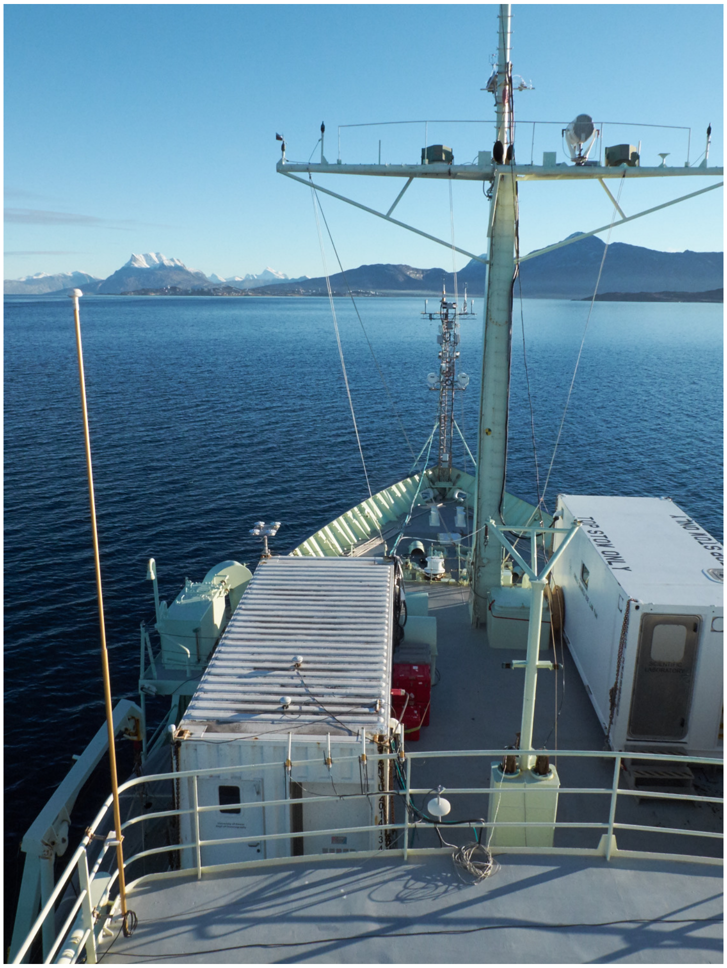


Figure 3: The large spar buoy with whitecap cameras, data acquisition and communication electronics at the top, wave wires and bubble-sizing instruments mounted along the length of the column, and batteries and sonar (upward looking) at the base.

Figure 4: Large spar buoy, deployed orientation showing wave wires.

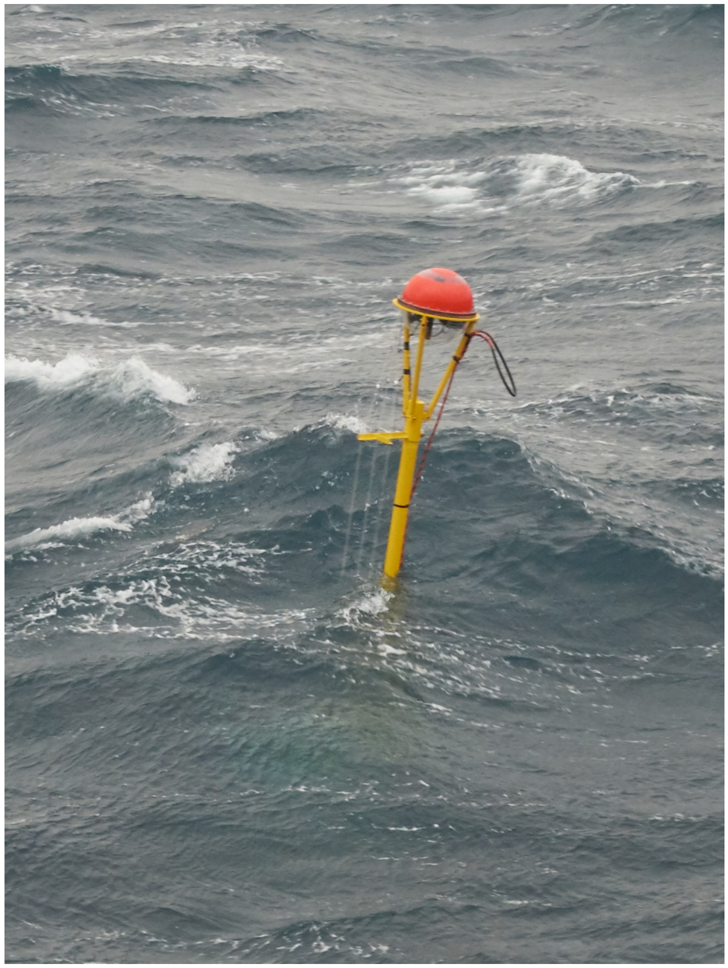


Figure 5: Small spar buoy with wave wires only.

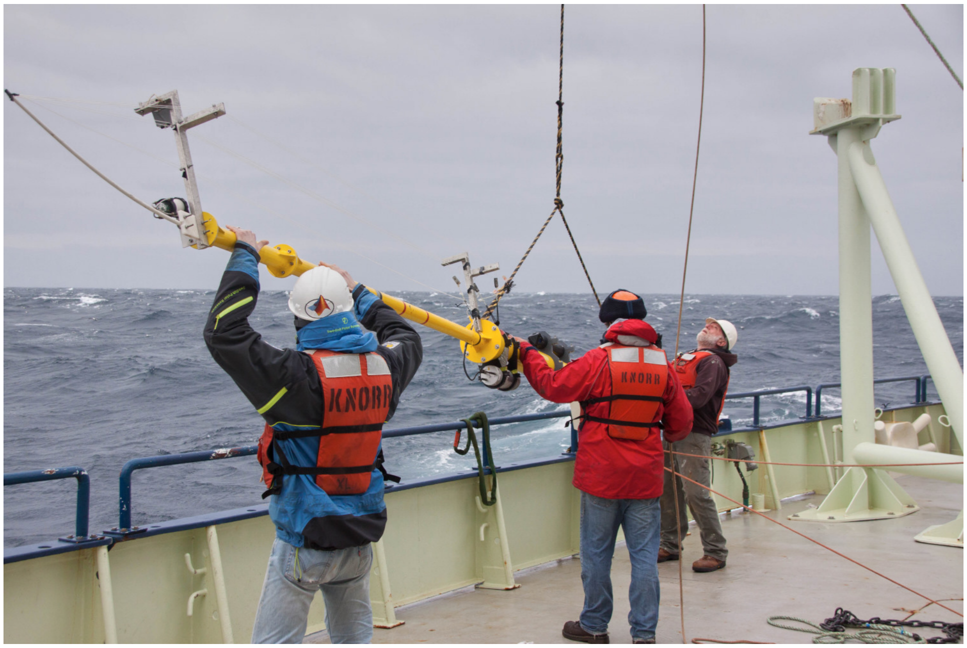


Figure 6: Cruise track and stations for intensive observations.

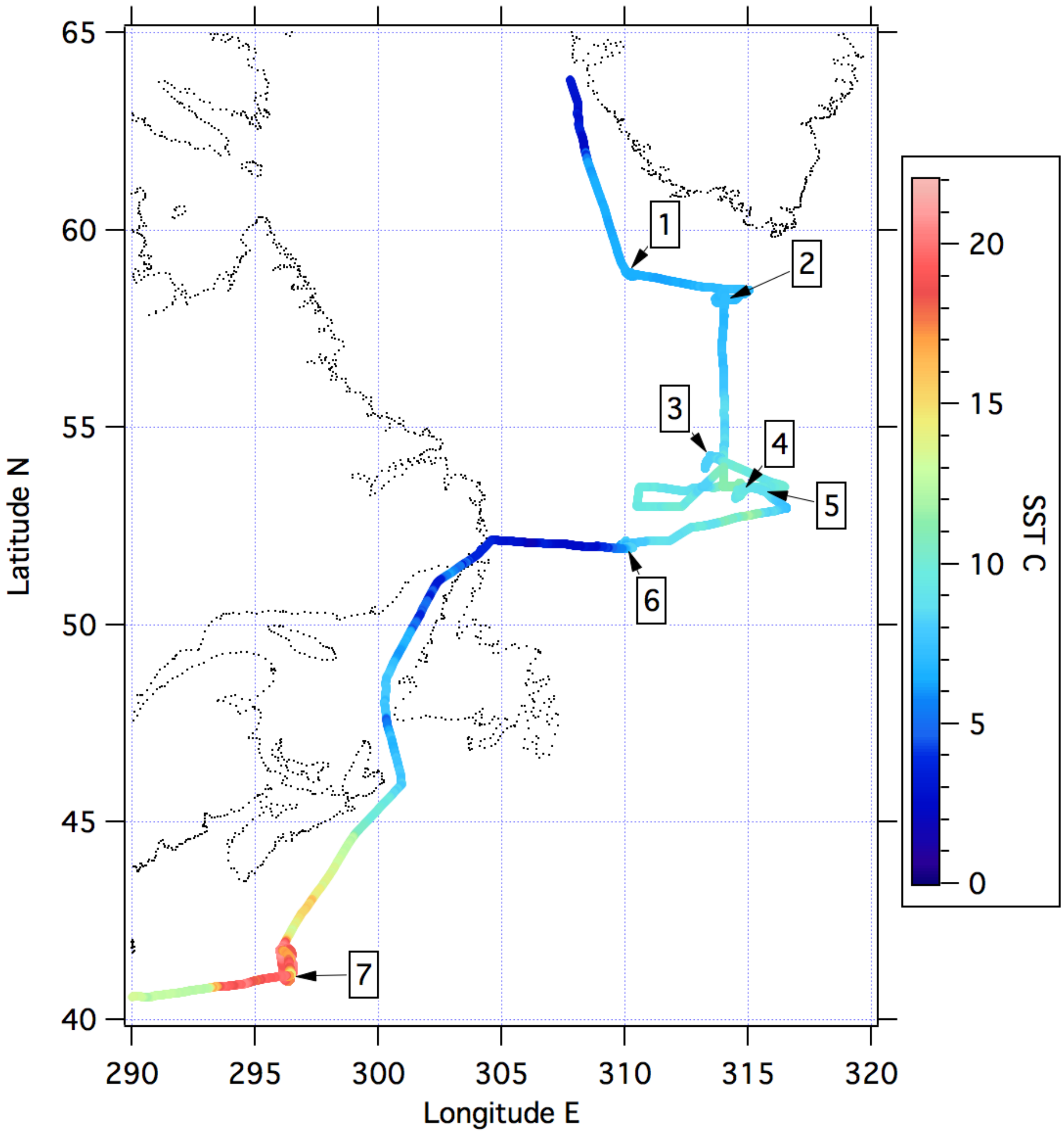


Figure 7: Station 1 CTD Profiles

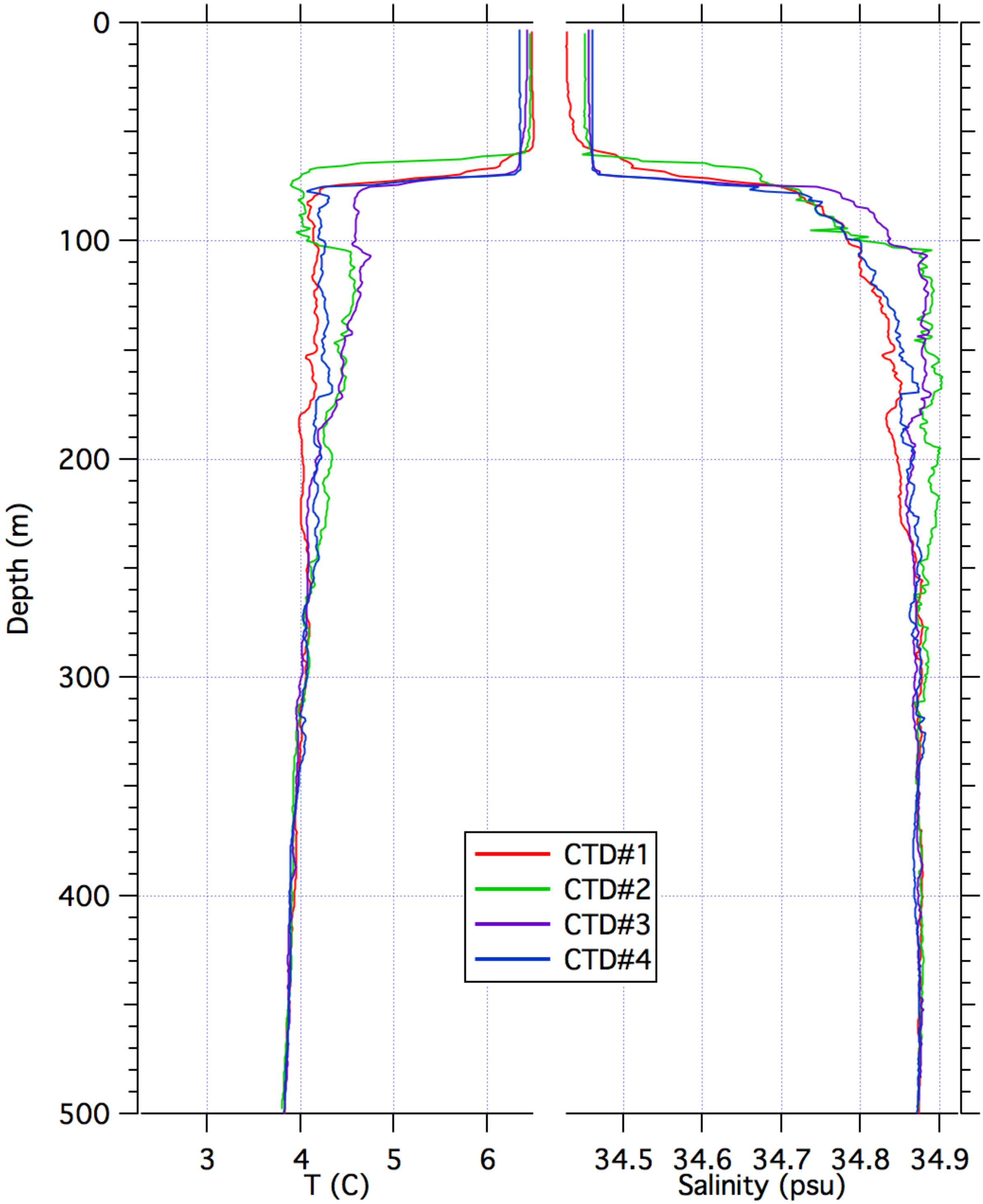


Figure 8: Station 2 CTD Profiles

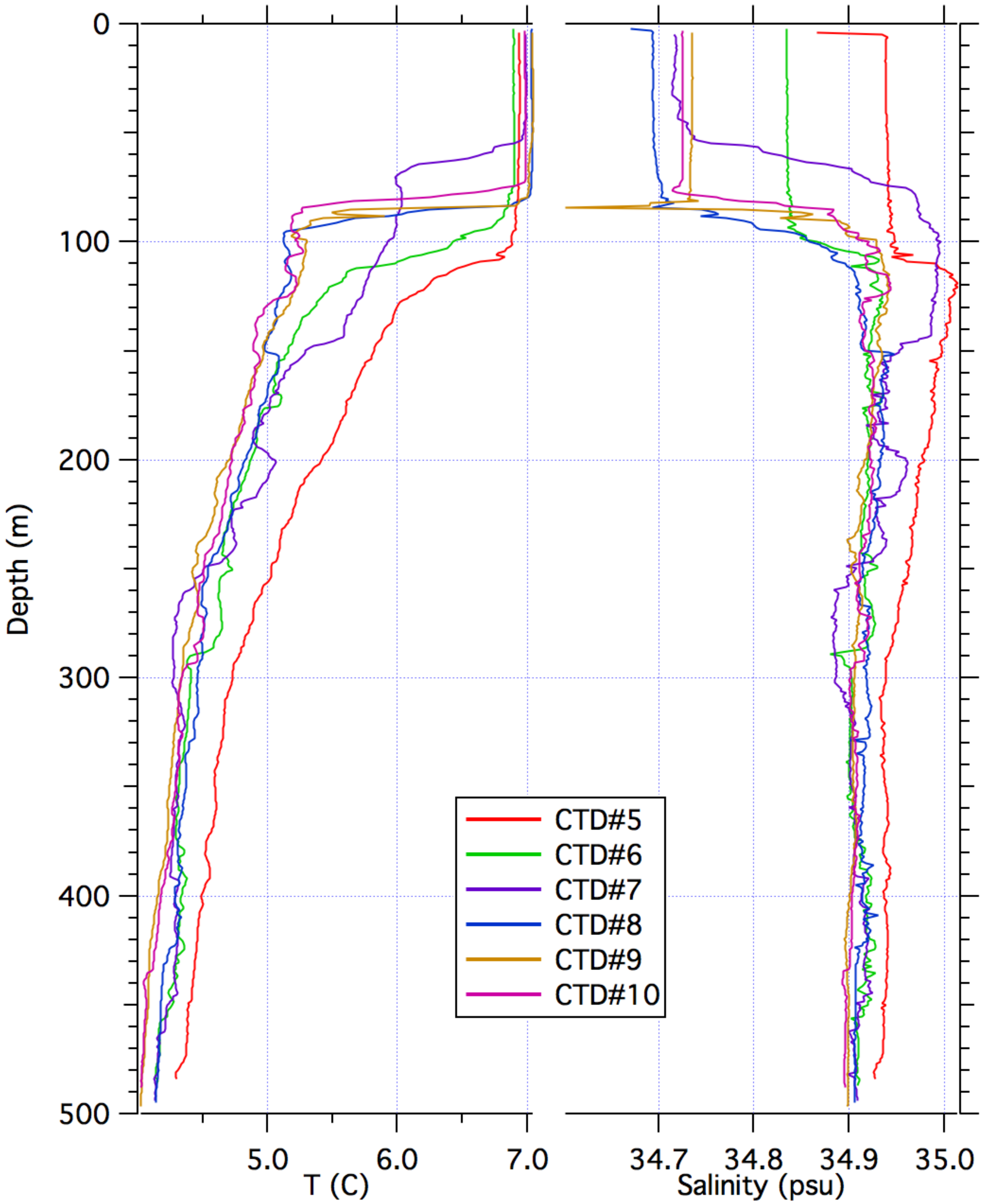


Figure 9: Station 3 CTD Profiles

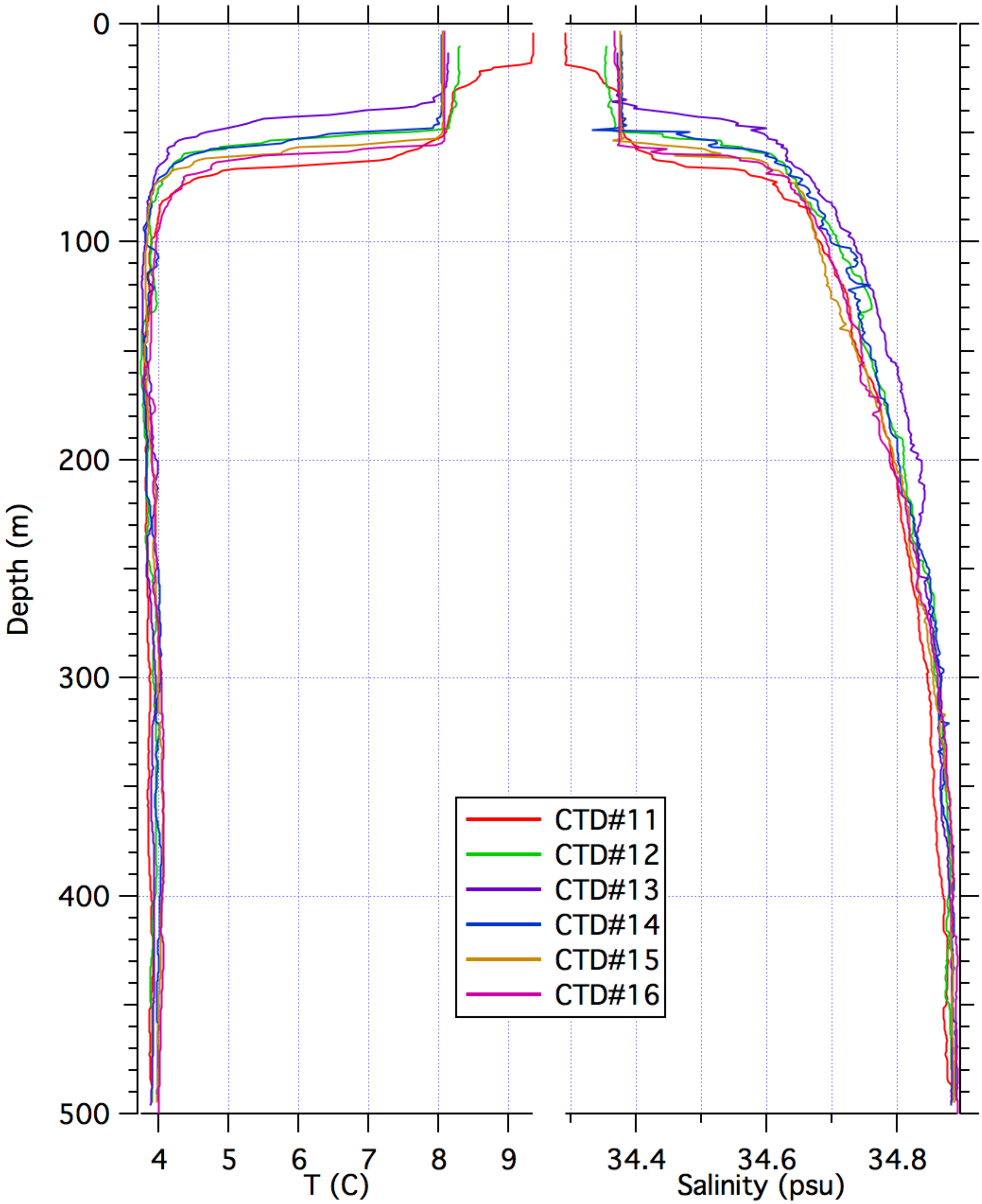


Figure 10: Station 4 CTD Profiles

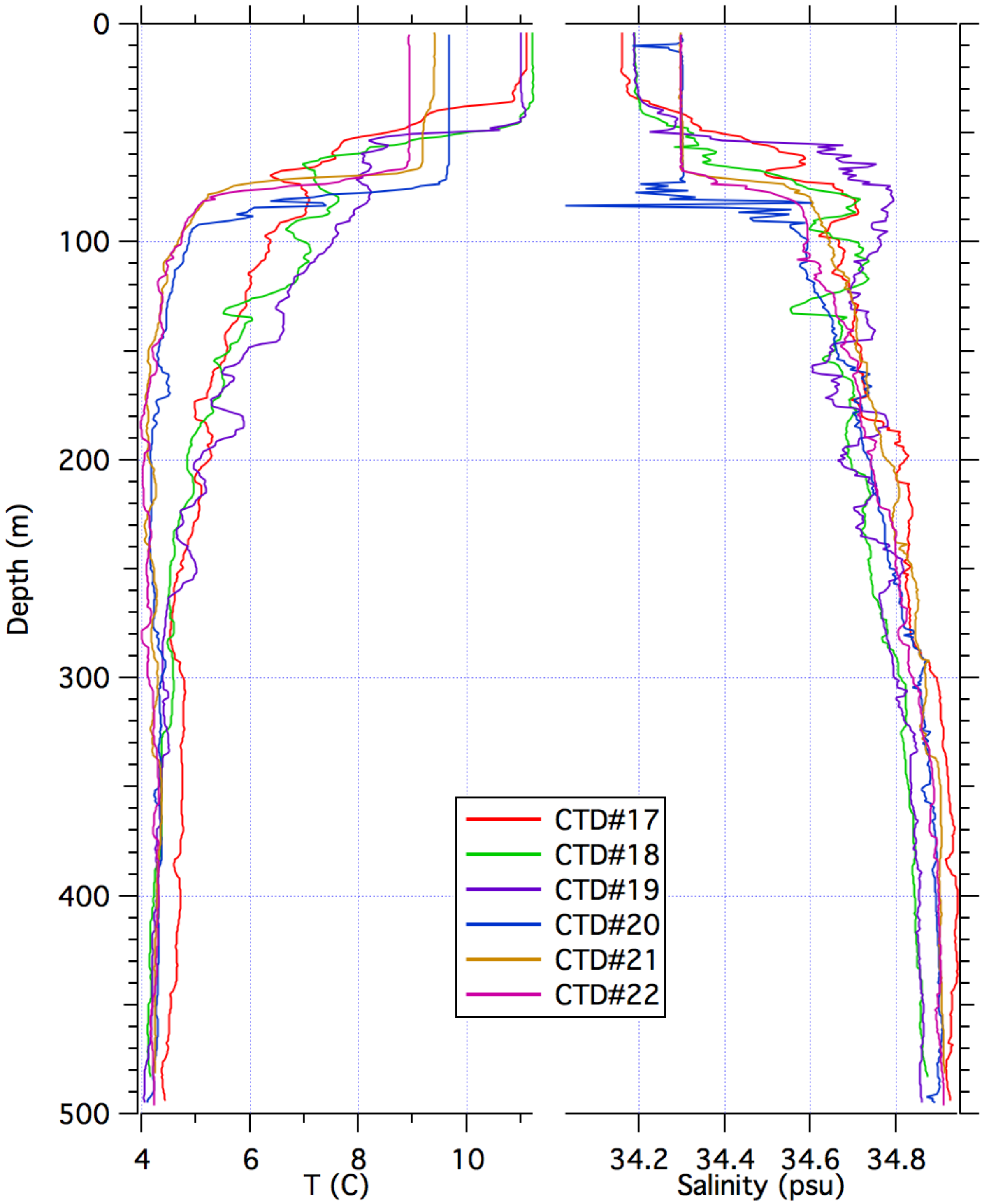


Figure 11: Station 5 CTD Profiles

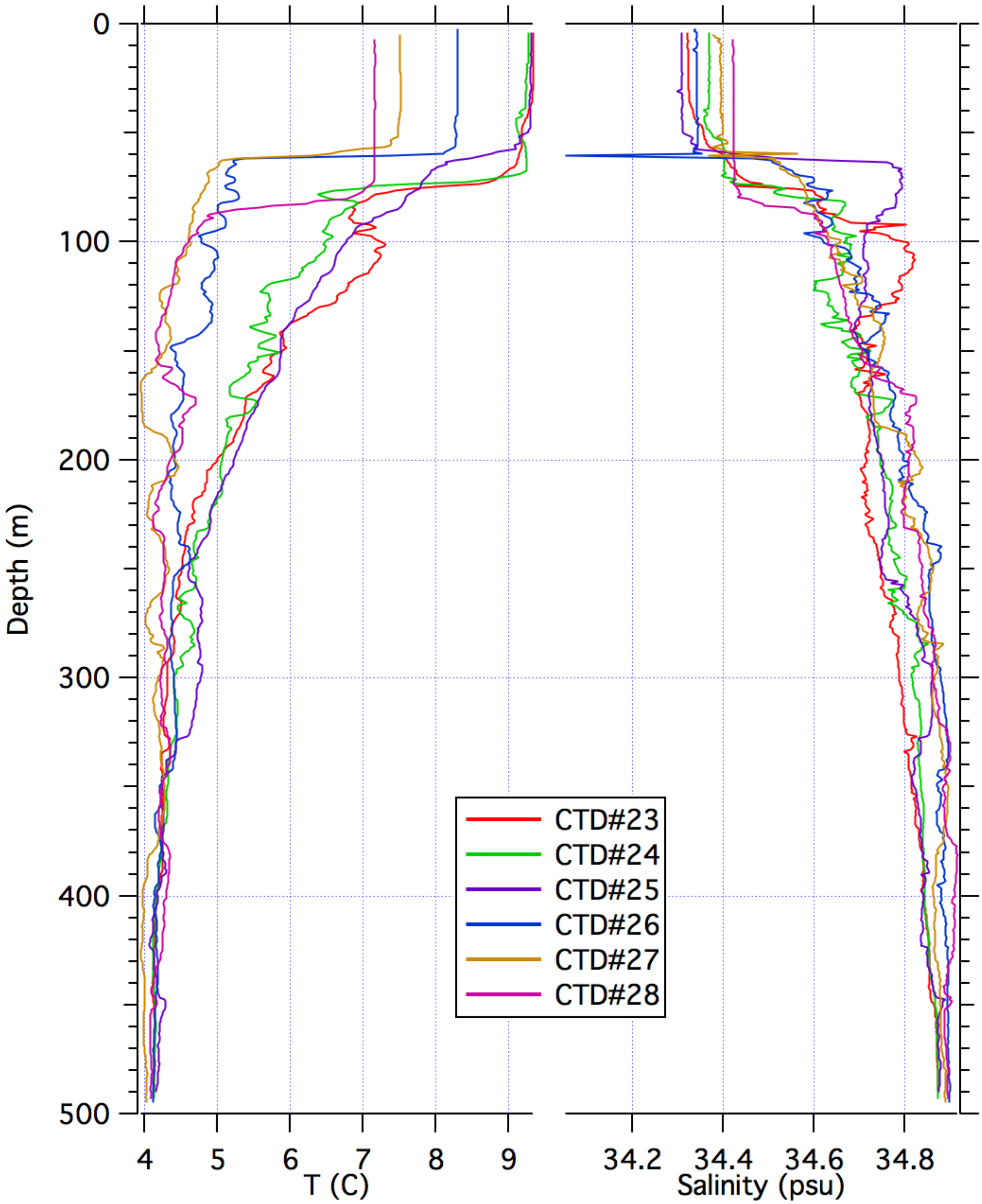


Figure 12: Station 6 CTD Profiles

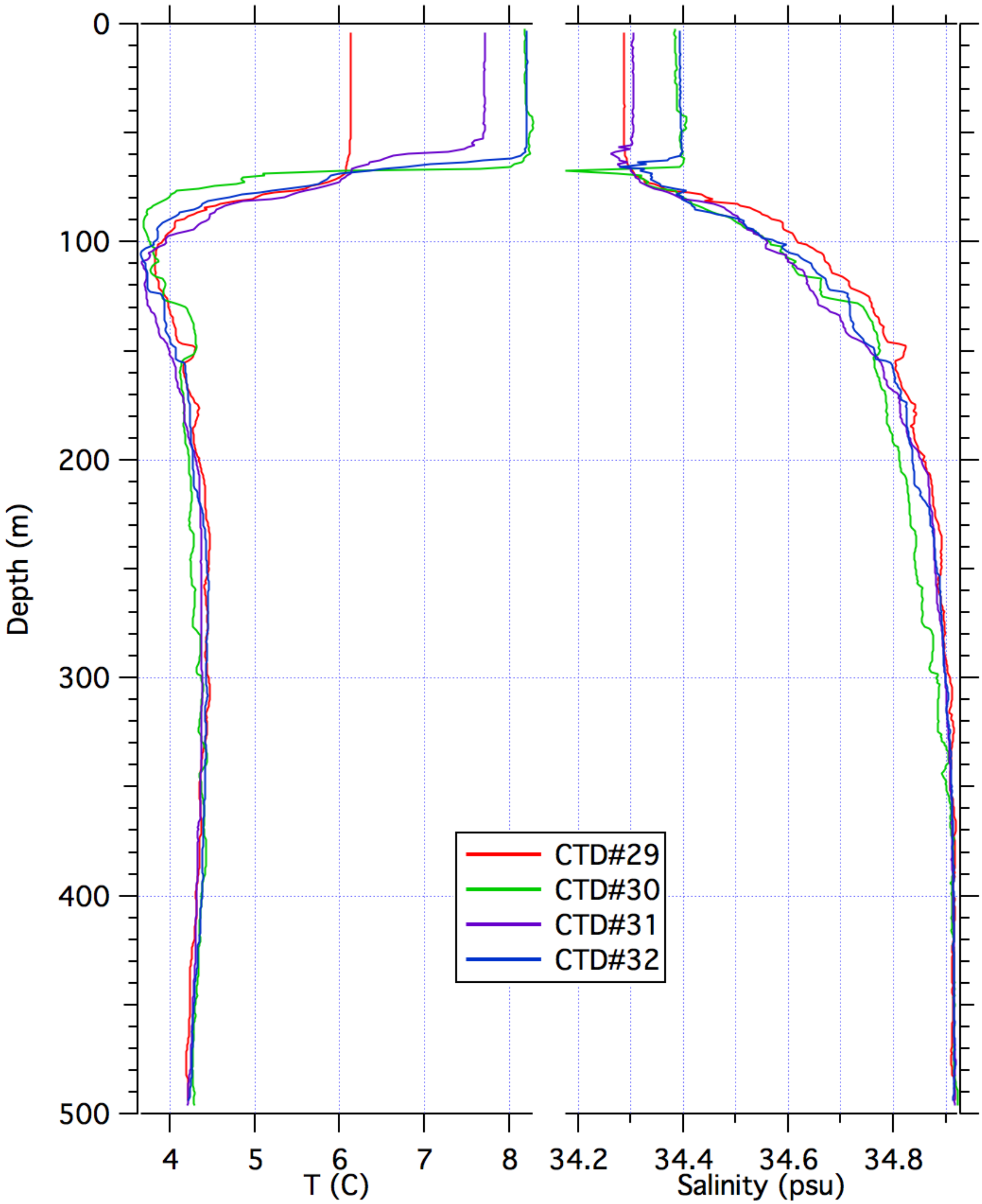


Figure 13: Station 7 CTD Profiles

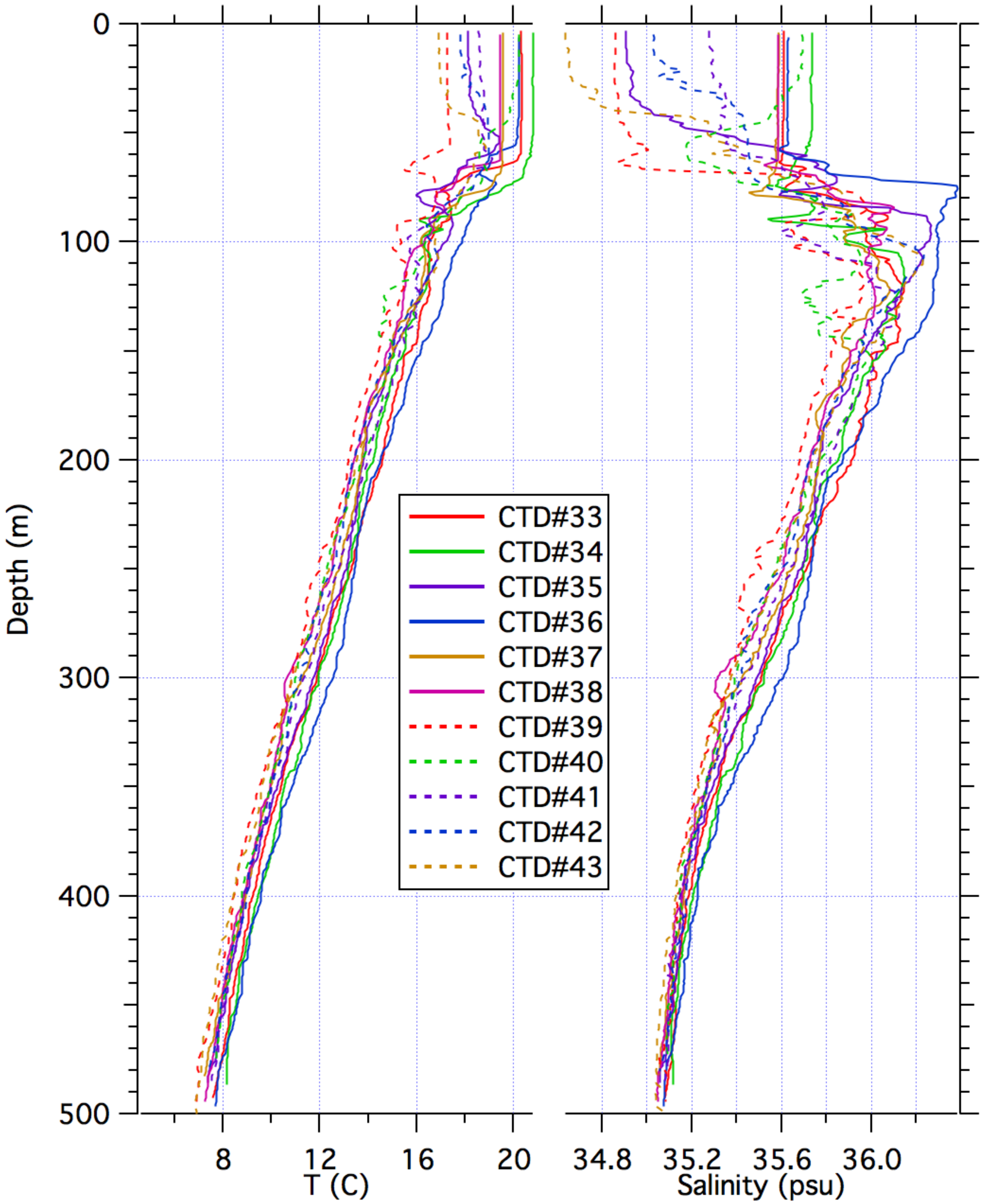


Figure 14: Bulk Meteorological Measurements

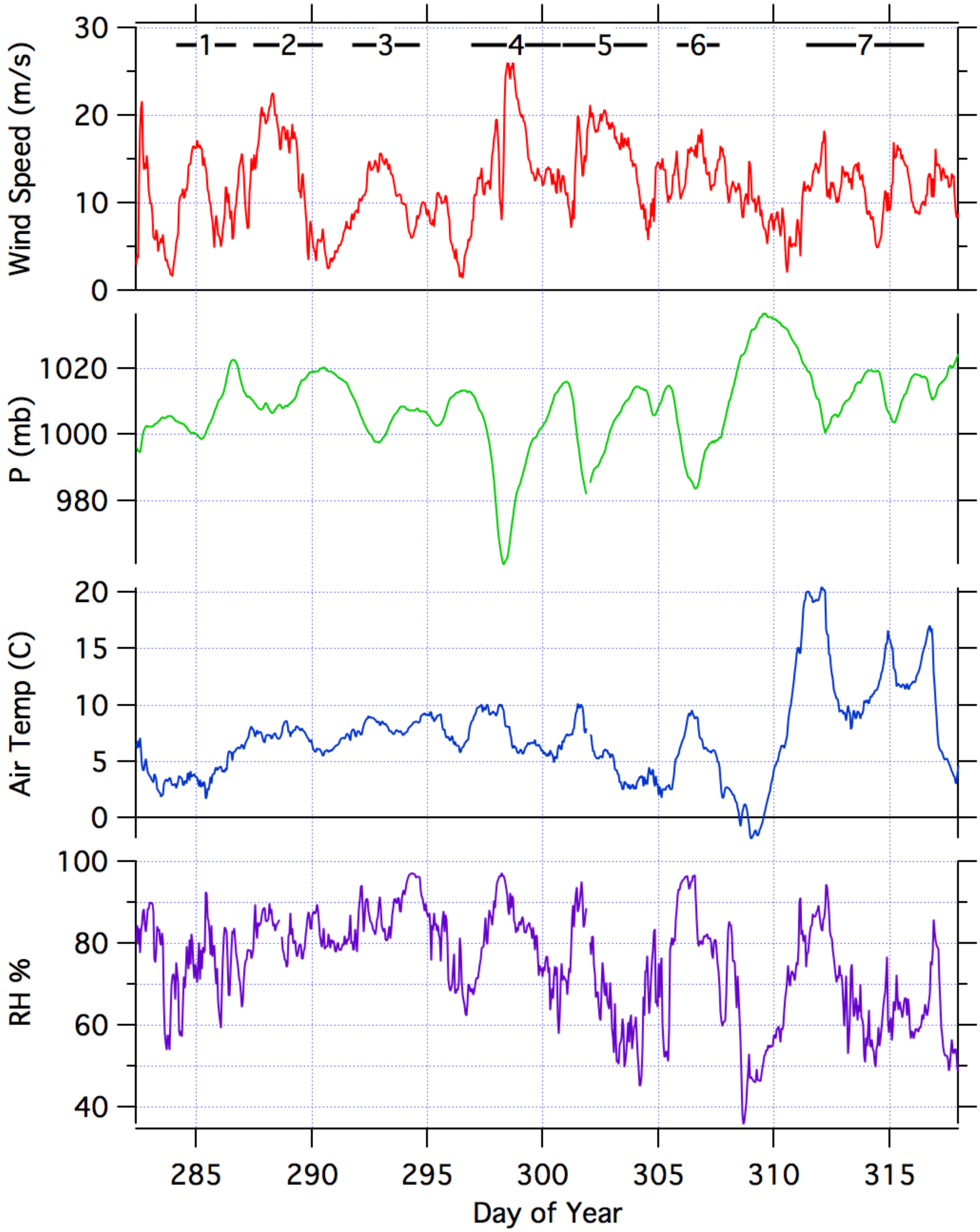


Figure 15: Bulk Seawater Measurements

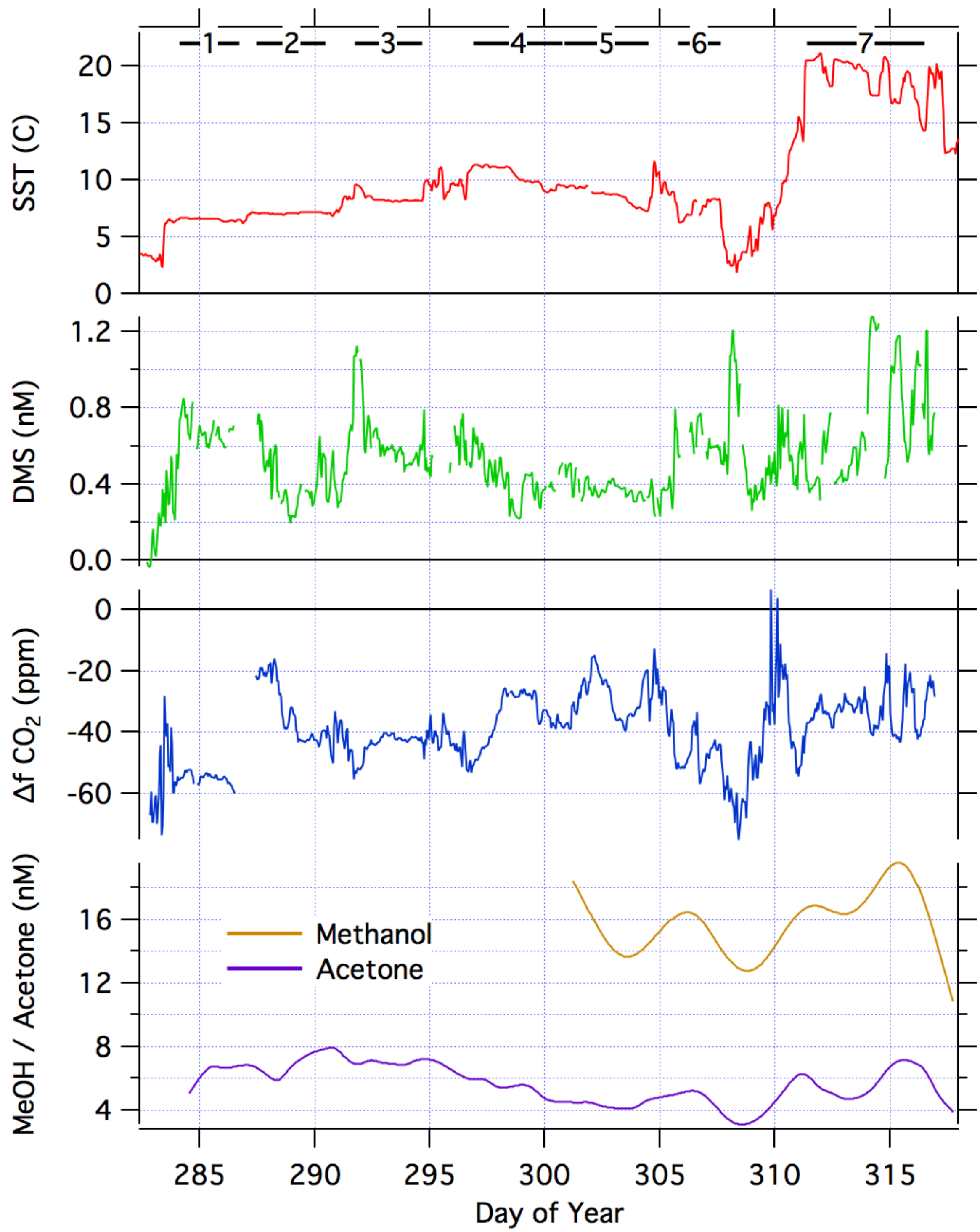


Figure 16: Physical fluxes from COARE 3.5 Bulk Model

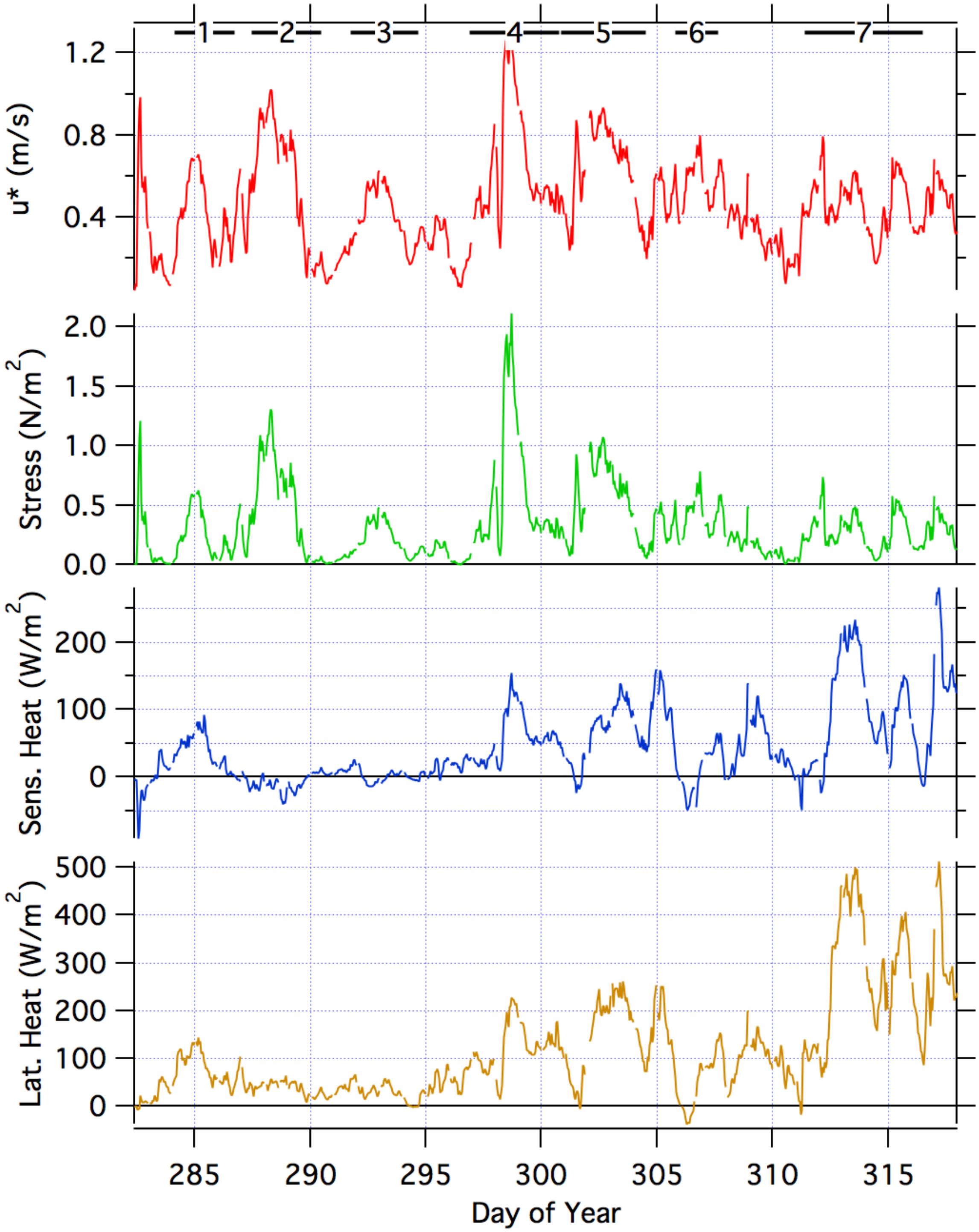


Figure 17: Trace Gas Air-Sea Fluxes

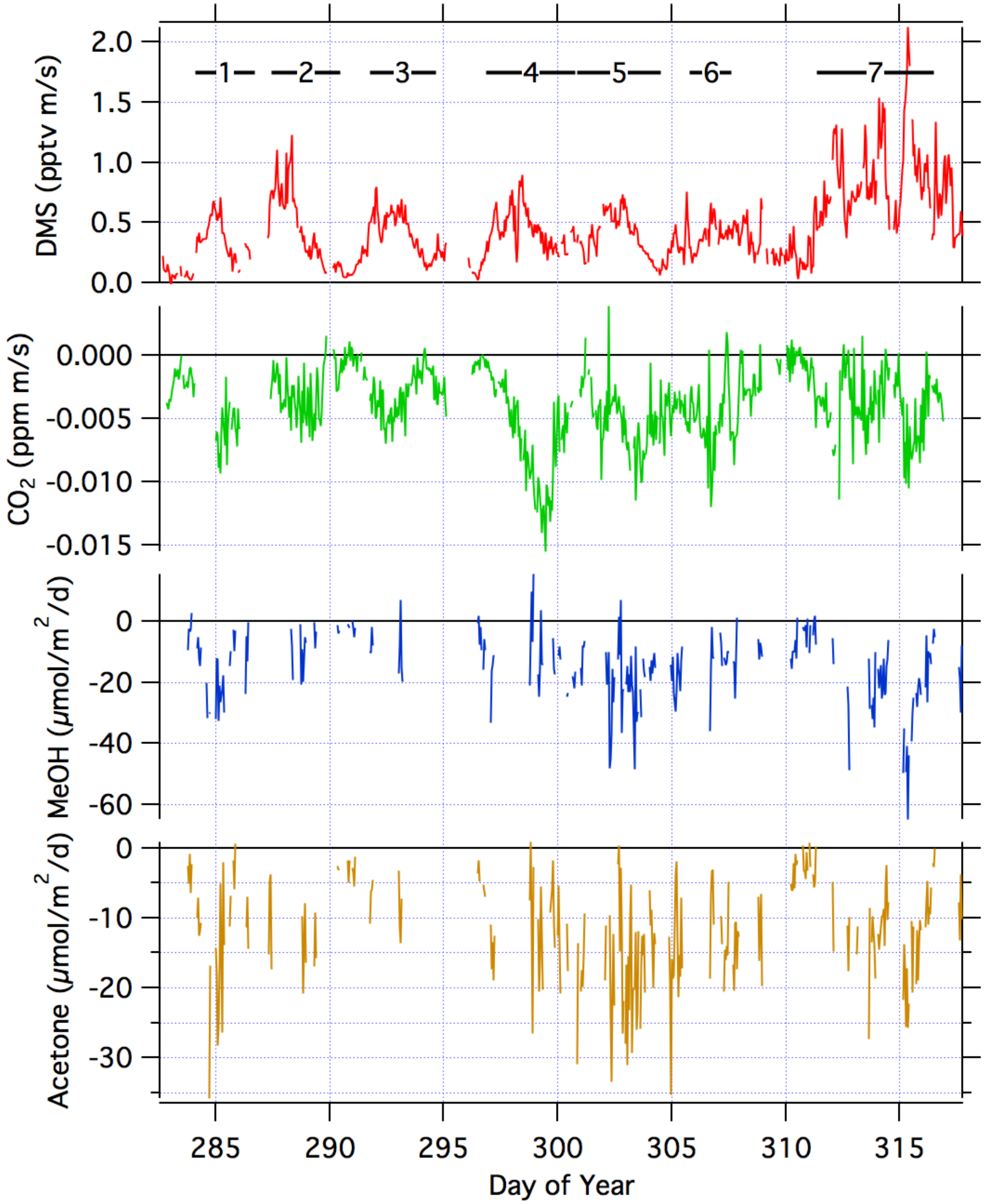


Figure 18: Whitecap fraction (Wf) from image analysis (blue: LDEO video analysis, red: Leeds still image analysis); significant wave height (Hs) and peak period (Tp) from the WaveRider buoy.

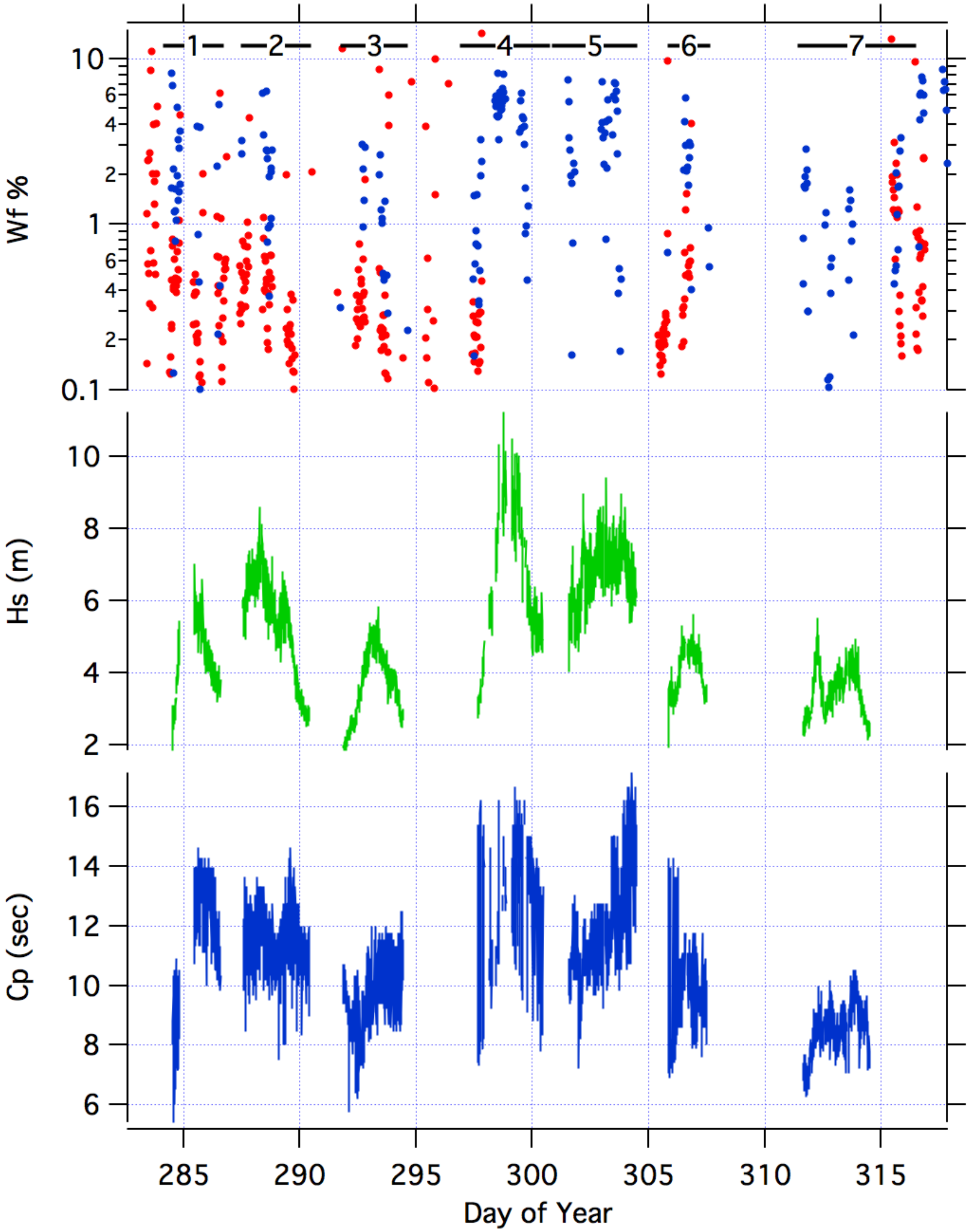


Figure 19: Sample sonar image of bubble plumes at the sea surface from the large spar buoy.

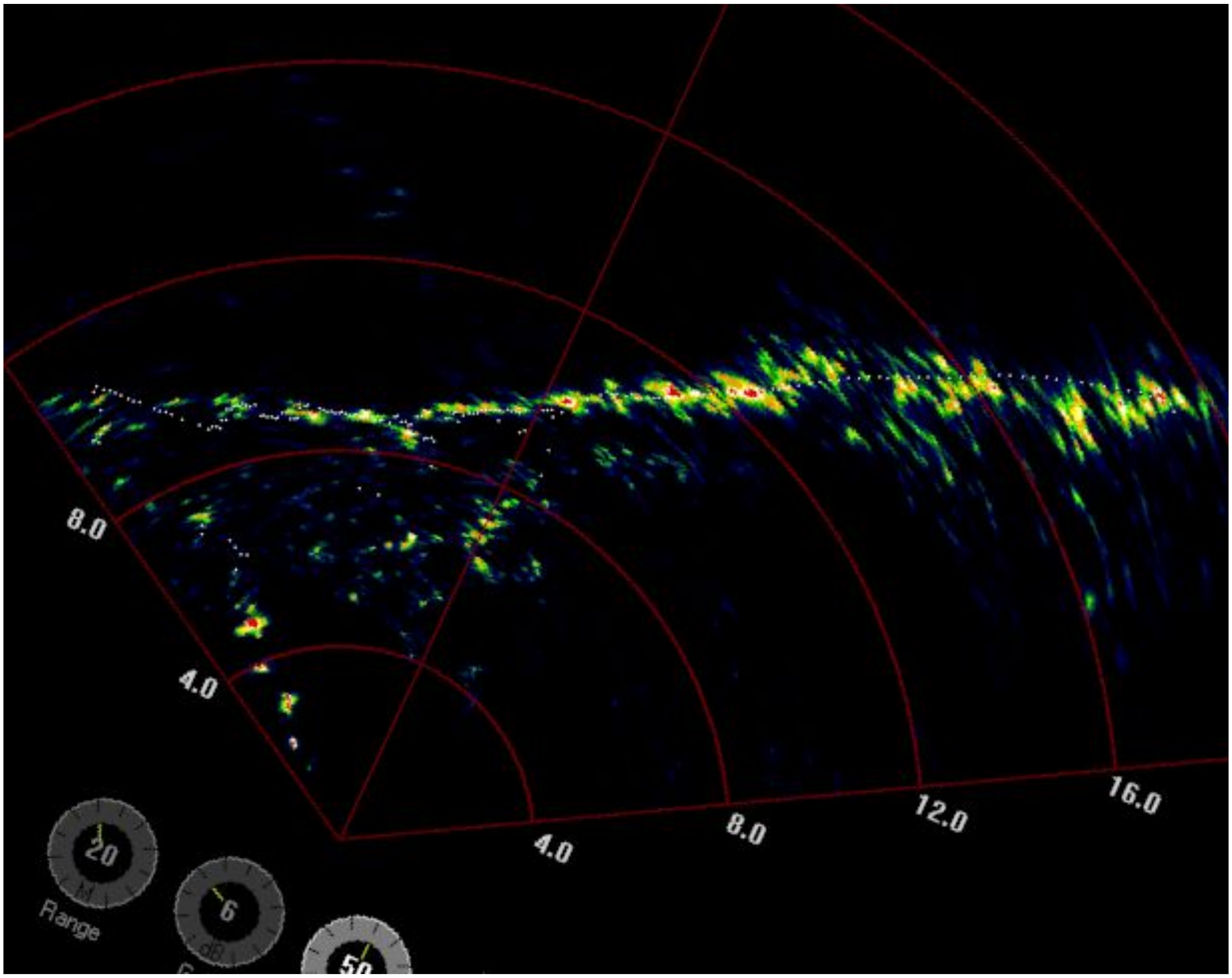


Figure 20: OS75 ADCP current components time series example (Oct 25).

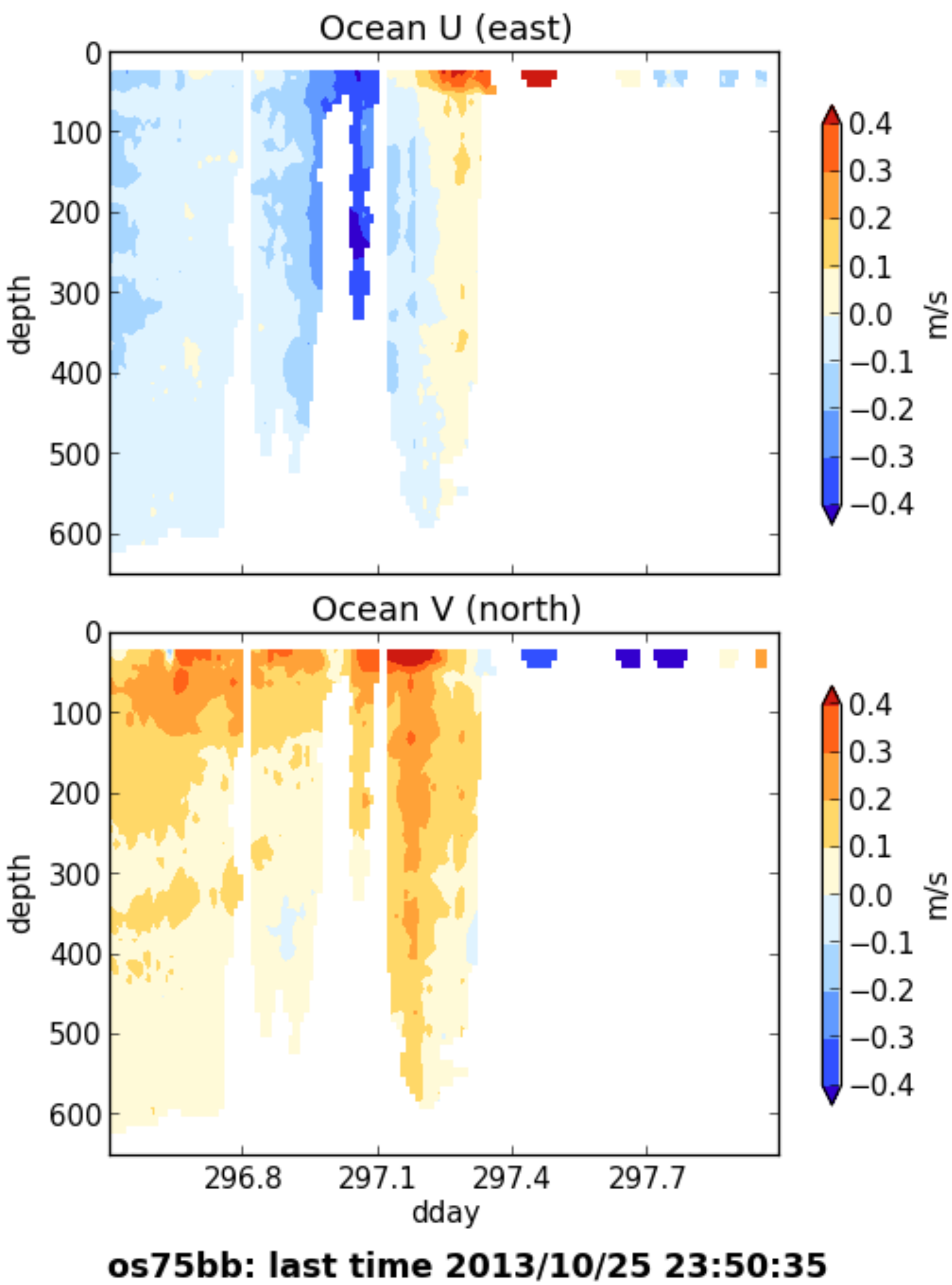


Figure 21: OS75 ADCP surface current vector plot example (Oct 25).

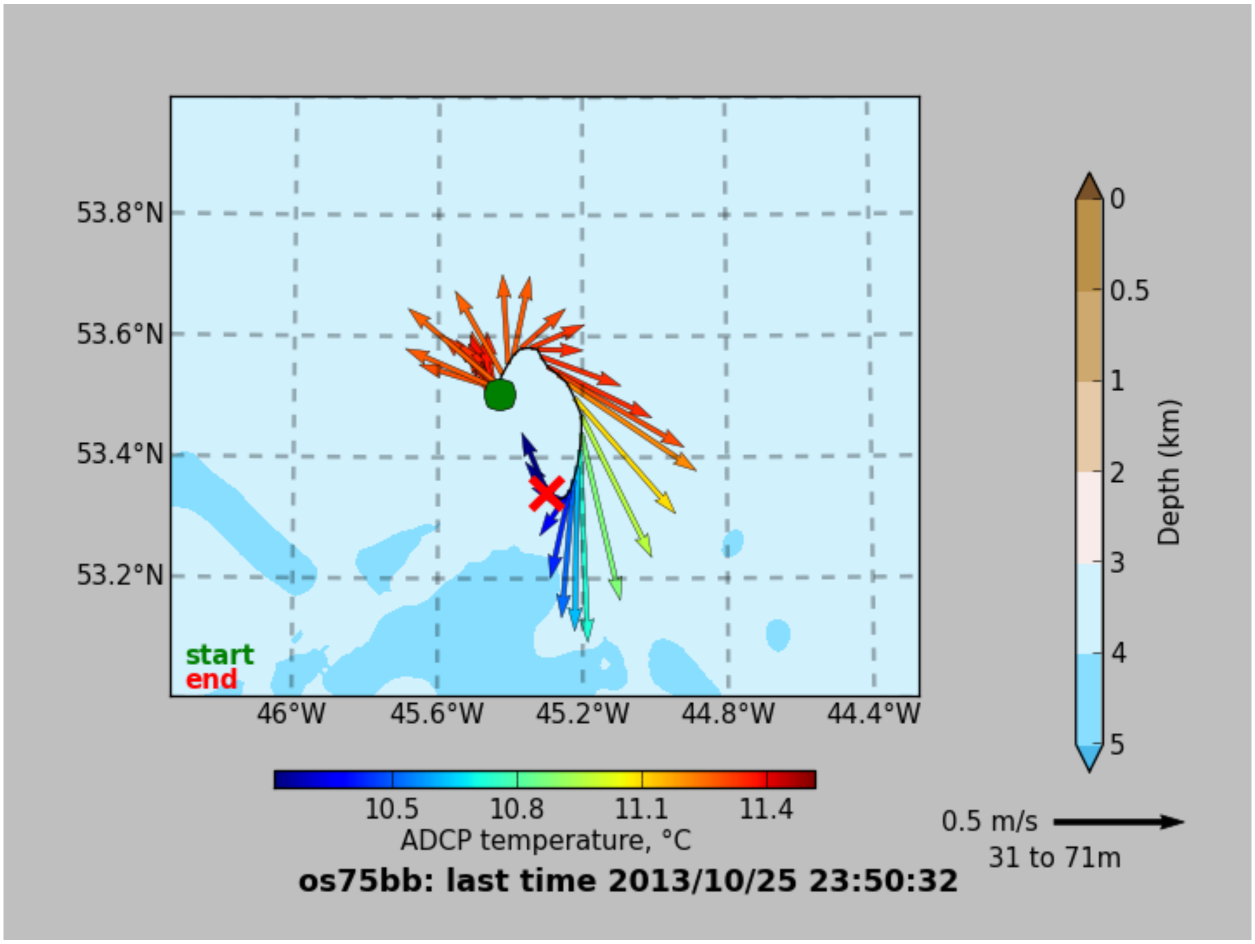


Figure 22: WH300 ADCP current components time series example (Oct 25).

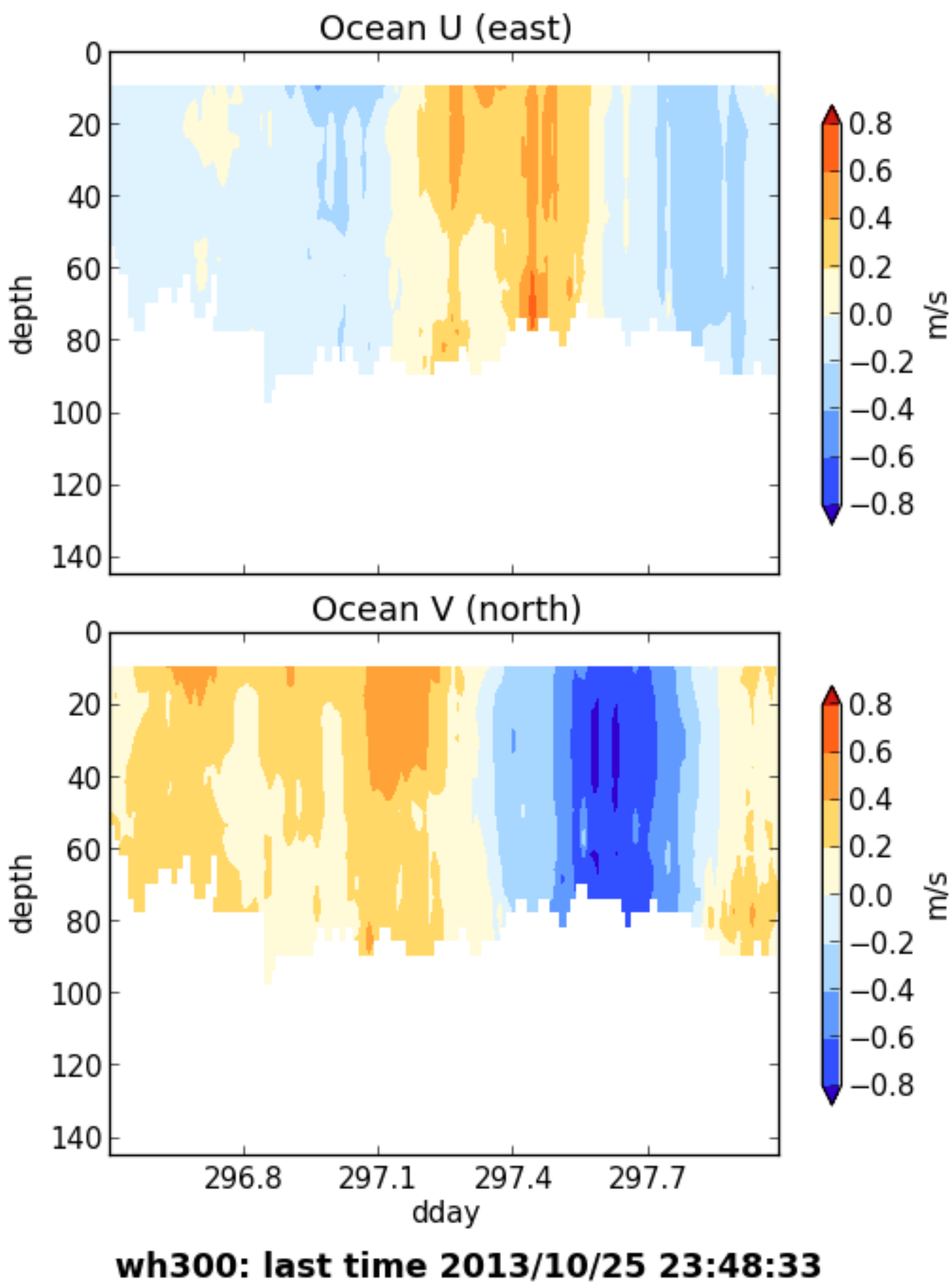


Figure 23: WH300 ADCP surface current vector plot example (Oct 25).

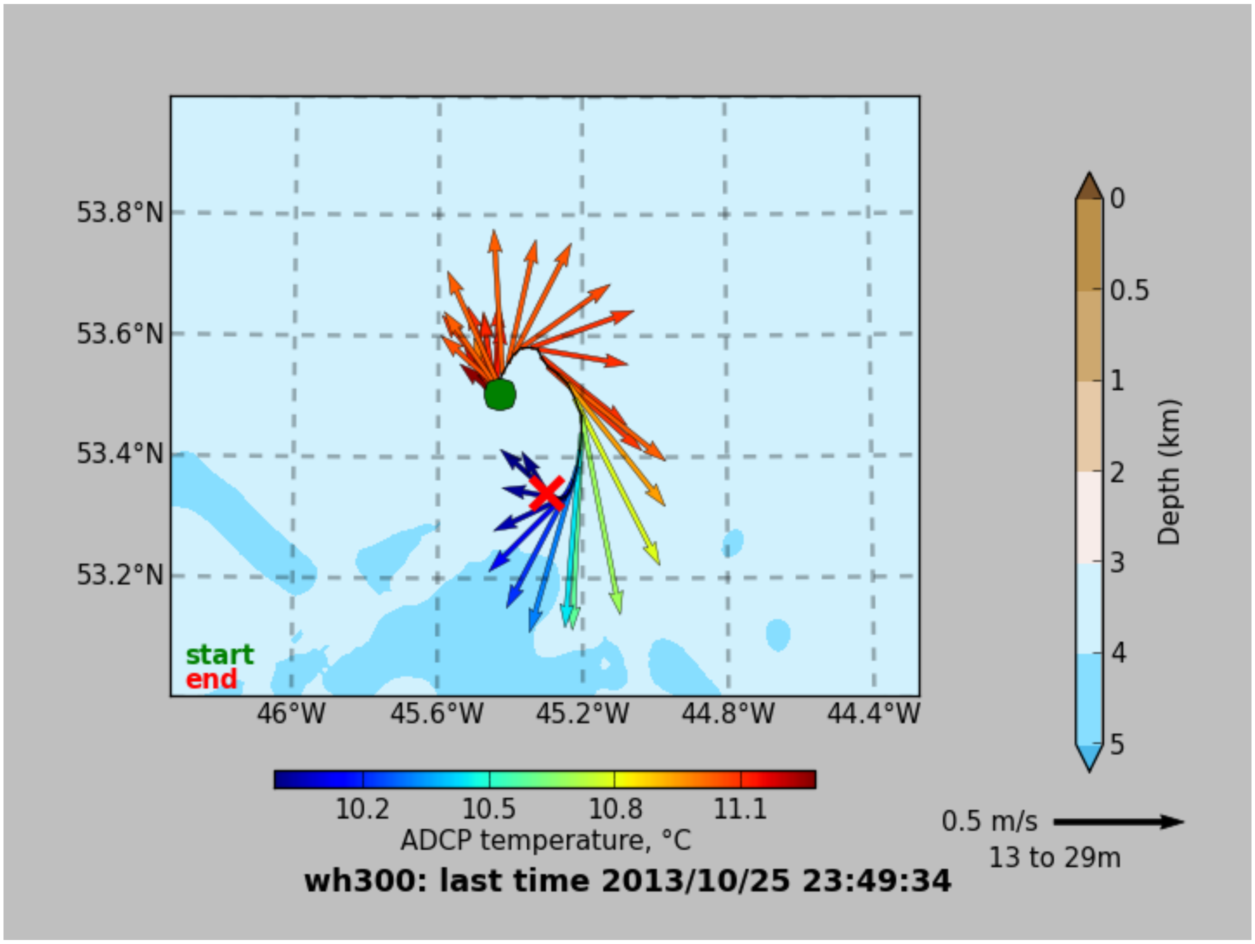
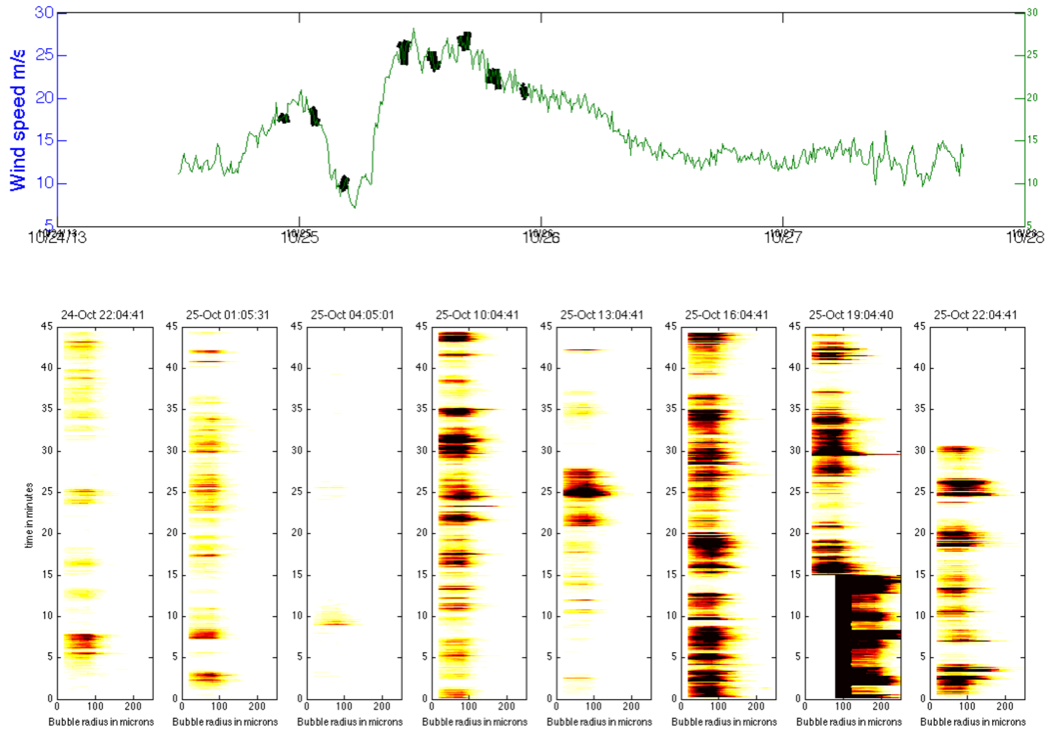


Figure 24: Illustration of bubble spectra obtained from the large spar buoy (Oct 25).

Dark green segments in the upper plot indicate wind speed for the eight measurement periods shown in the lower graph.



Data Access

Data files may be obtained by anonymous ftp at ftp1.esrl.noaa.gov in the root directory /psd3/cruises/HIWINGS_2013/Collective_Archive. This directory contains the following subdirectories:

NOAA_MET_COARE: hourly bulk meteorological data, covariance heat fluxes and stress, and output from the COARE 3.5 bulk flux model. Meteorological data is also provided as 10-minute averages. Contacts: Byron Blomquist and Chris Fairall, byron.blomquist@colorado.edu, chris.fairall@noaa.gov

PMEL_pCO2: processed output from the NOAA/PMEL underway pCO_2 analyzer. Contact: Byron Blomquist, byron.blomquist@colorado.edu

PML_ACETONE_METHANOL: Plymouth Marine Laboratory processed hourly methanol and acetone fluxes and seawater concentrations, processed hourly stress and sensible heat fluxes, and modeled wave statistics from ECMWF. Contact: Mingxi Yang, miya@pml.ac.uk

RV_KNORR_UNDERWAY: processed underway meteorological and oceanographic data, ADCP current data, CTD data, and Multibeam mapping data from RV Knorr. Contact: Woods Hole Oceanographic Institution, Shipboard Scientific Services Group (SSSG), sssg@whoi.edu

UH_NOAA_DMS_CO2: hourly processed DMS and CO_2 flux data from University of Hawaii and NOAA/ESRL/PSD systems. Contact: Byron Blomquist, byron.blomquist@colorado.edu

LEEDS_NOC_WAVES: processed whitecap fraction, significant wave height and wave period from buoys and image analysis. Contact: Ian Brooks, i.brooks@see.leeds.ac.uk

LDEO_WAVES: processed whitecap fraction from video image analysis. Contact: Chris Zappa, zappa@ldeo.columbia.edu

UCL_BUBBLES: processed bubble spectra and void fraction from the large spar buoy. Contact: Helen Czerski, h.czerski@ucl.ac.uk