R/V Falkor Cruise Report
FK150728

30 July – 17 August, 2015
Majuro, Marshall Islands to Honolulu, Hawaii

1. Overview

The cruise extends measurements aimed at determining and quantifying the processes in the tropical ocean that generate turbulence and associated mixing of properties in the upper ocean. Mixing of heat, salt and momentum plays a large role in shaping the upper ocean structure and the way the ocean interacts with the atmosphere. Previous measurements in the western equatorial Pacific identified small vertical scale flow features (SVSs) as major contributors to shear-generated turbulence within and above the thermocline. The SVSs themselves are generated through a combination of wind forcing and flow instabilities. A primary aim of the present cruise was to determine if similar flow features dominate the vertical shear in the central equatorial Pacific and to determine the levels of turbulence generated by them.

The cruise took place during a developing El Niño. This had consequences for the conditions encountered. Figure 1.1 shows the time history of anomalies in the eastward wind, sea surface temperature (SST) and the depth of the thermocline (given by the depth of the 20^{o}C isotherm) along the equator in the Pacific Ocean. El Niño conditions are seen in the slackening or reversal of the easterly trade winds, increasing SST in the central and eastern Pacific, and the deepening of the thermocline in the east.

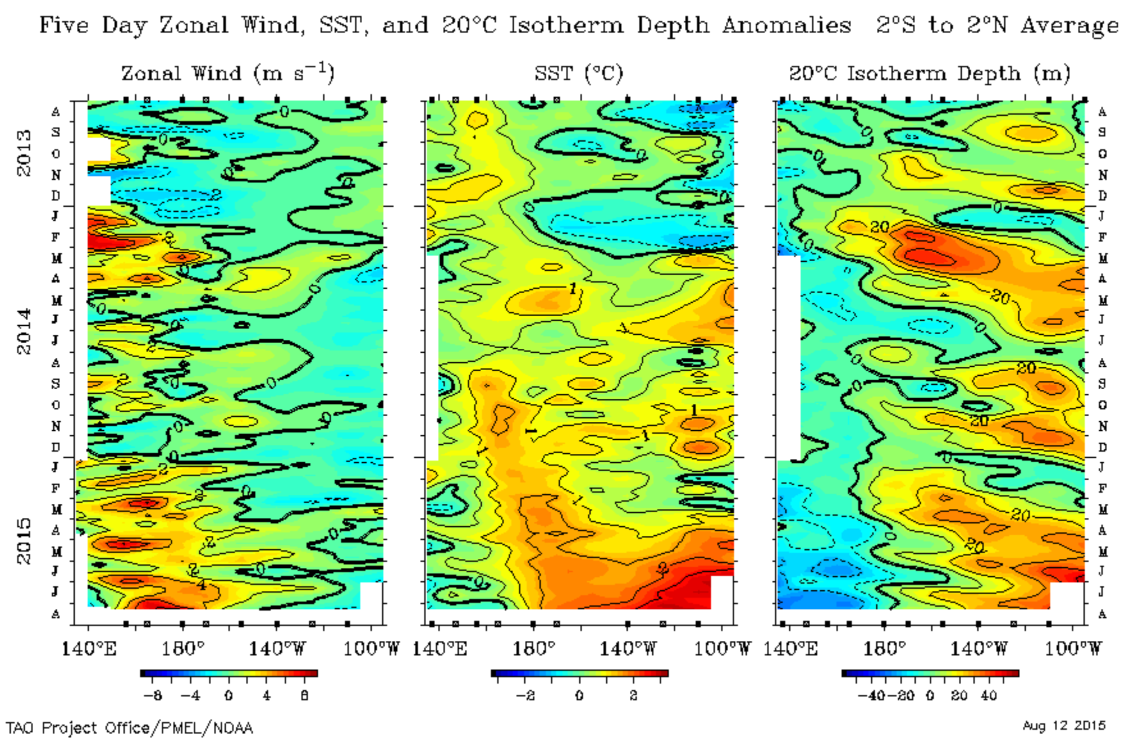


Figure 1.1 Time history of anomalies in the eastward wind, sea surface temperature (SST) and the depth of the 20^{o}C isotherm) along the equator in the Pacific Ocean. (from PMEL TAO web site)

In addition a number of strong westerly wind events occurred in the western equatorial Pacific, starting in February 2015, continuing through to the time of the cruise, August 2015. The eastward limit of these wind events increases with time. Along 170W (the location of the measurements taken on the present cruise) two strong westerly wind events occurred in July, extending from the equator to several degrees north (Figure 1.2). The change in winds led to surface currents being directed towards the east. The expectation is the strength of the Equatorial Under Current had been reduced (although not adequately measured during the cruise), and the variable winds may have generated strong inertia-gravity waves leading to strong SVSs.

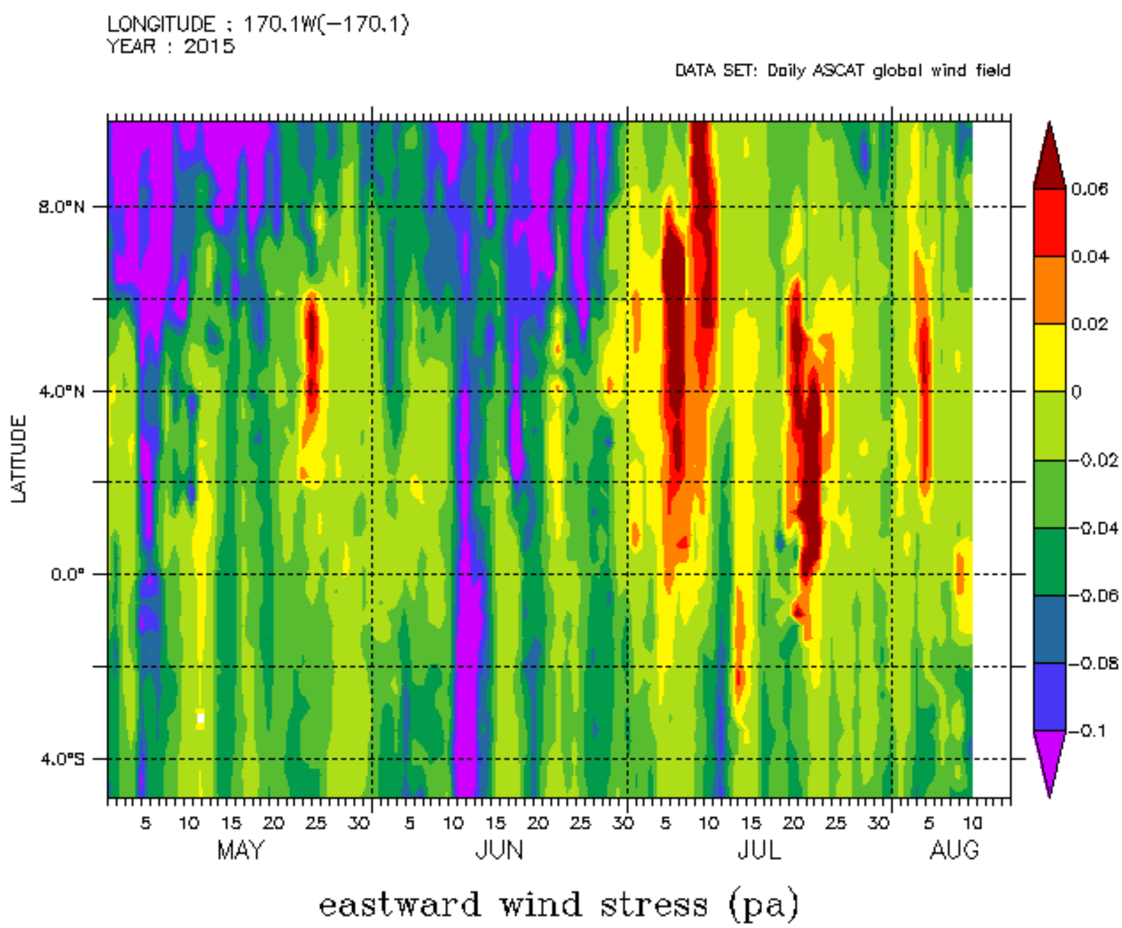


Figure 1.2. Eastward component of the surface wind stress along 170W, May to August, 2015

2 Summary of observations

All *in situ* measurements, apart from underway meteorological and ocean sampling, were taken along 170W (see cruise track, Figure 2.1). Primary instrumentation was a CTD and a 600kHz ADCP attached to the CTD frame operated in lowered mode (LADCP). Casts were typically taken to 500m. Water samples were taken on 6 of the CTD casts for nutrient analysis. A combination of meridional sections, time series and tow-yo's were made: see Figure 2.2 for the time history along 170W. When on station or tow-yo'ing at slow speed a 300kHz ADCP was deployed on the USBL spar to sample currents in the top 50-80m of the water column. It was planned to take turbulence measurements with a VMP500. The instrument had problems throughout the cruise with only a couple of usable profiles produced. Both of the ship's ADCPs, a OS75 and 300, did not function throughout the cruise. A more detailed description of the measurements from the instrumentation is given in Section 5.

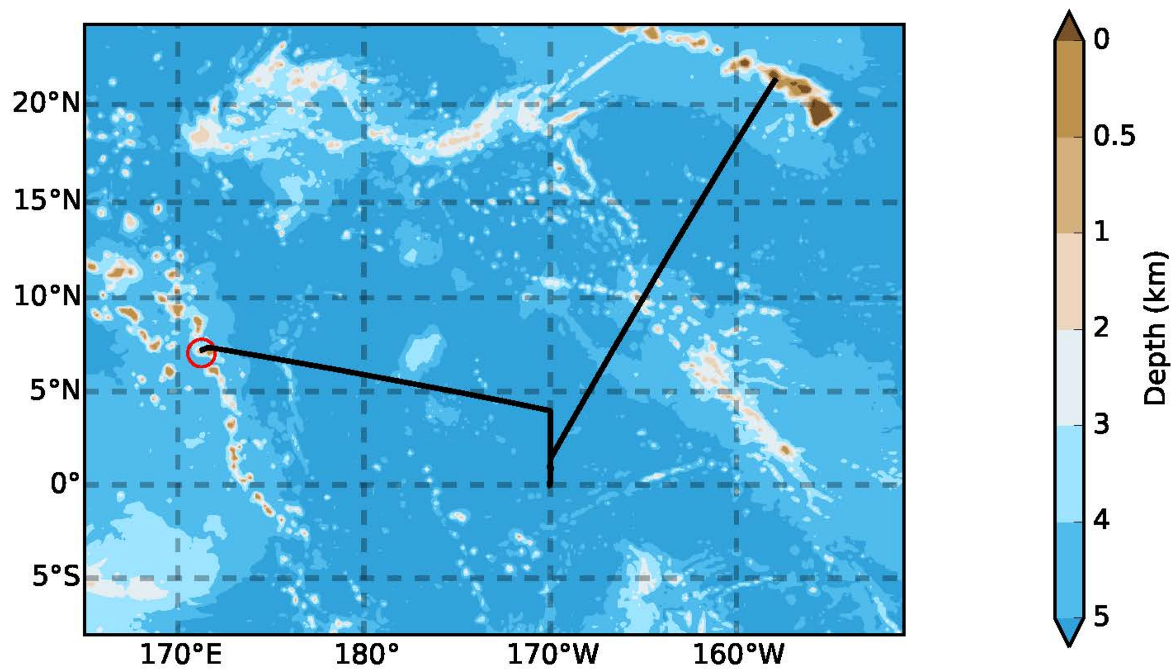


Figure 2.1. Cruise track

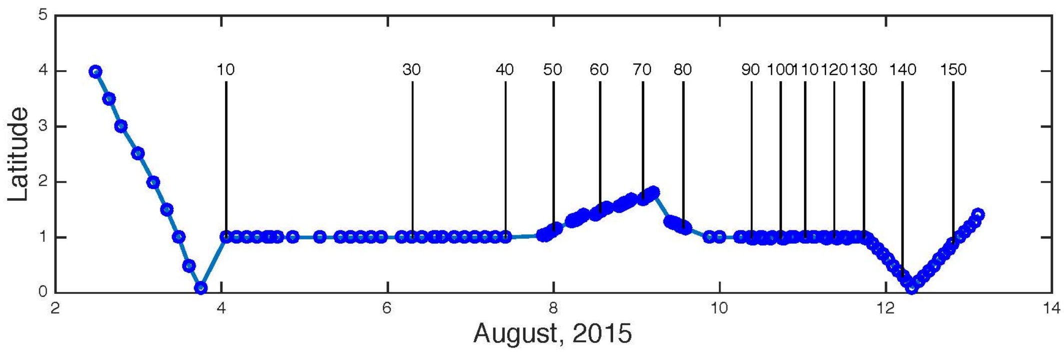


Figure 2.2. Ship's position along 170W as a function of time. Circles indicate casts. Numbers indicate cast numbers.

3 Narrative

All times are GMT unless otherwise noted.

The R/V *Falkor* set sail from Majuro, Marshall Islands on **30 July 2015** at 11:09 local time (+ 12 hours GMT)

The ship steamed to the first station at 4N, 170W. A test cast of the VMP was conducted enroute.

Aug 2, 12:00. Arrived 4N 170W and performed first station (cast 001)

Proceeded south along 170W taking CTD casts every 0.5 degree. Enroute inspected TAO buoy at 2N 170W using small boat. No visible damage.

Aug 3, 17:30. Arrived 0.08N 170W (slightly north of the equator to be outside the EEZ of Kiribati). Cast 009.

Steamed south to inspect TAO buoy at 0N, 170W using small boat. No visible damage. Returned to 1N 170W.

Aug 4, 01:00. Arrived 1N 170W. Started time series of CTD casts every 3 hours. Casts 010 to 044.

Aug 7, 20:30. Ended time series.

Started tow-yo'ing towards the north at 2kts, stopping periodically to download LADCP data (tow-yo's 1-5). Casts 045 to 074.

Aug 9, 05:17. Stopped northward tow-yo at 1.8N.

Aug 9, 09:39. Returned to 1.3N. Started tow-yo 6 to fill in missing section. Casts 75-81.

Aug 9, 14:51. Ended tow-yo 6 at 1.16N. Returned to 1N.

Aug 9, 17:31. Resumed time series at 1N. Casts 82-85 every 3 hours. Casts 86-133 done as a yo-yo with periodic stops to download LADCP data.

Aug 11, 19:00. End time series. Start transect south along 170W taking CTD casts every 0.1 degree.

Aug 12, 07:30. Arrived 0.1N. Cast 142. Returned north along 170W taking CTD casts every 0.1 degree.

Aug 13, 02:37. Arrived 1.4N. Last cast 155.

Aug 13, 03:30. End of CTD sampling. A problem with one of the ship's generators forced and early stop to work and return to Honolulu. Transit to Honolulu

The R/V *Falkor* arrived in Honolulu, Hawaii on **17 August 2015** at 14:00 local time (-10 hours GMT)

The weather throughout the cruise was in general set fair and did not affect operations. Winds were in general less than 10 ms^{-1}. Precipitation was limited to a small number of short showers.

4. Participant List

Scientists

Name	Affiliation	Position
Kelvin Richards	University of Hawai\`i	Chief Scientist
Eric Firing	University of Hawai\`i	Co-Investigator
Glenn Carter	University of Hawai\`i	Co-Investigator
Andrei Natarov	University of Hawai\`i	Ass. Researcher
Saulo Soares	University of Hawai\`i	Postdoc
Øyvind Lundesgaard	University of Hawai\`i	Student
Andrew Cookson	University of Washington	Technician
Albert J. Noh	Seoul National University	Student
Suyun Noh	Seoul National University	Student
Chang-Su Hong	KIOST	Technician
Jennifer Killinger		Student Intern
Julianna Diehl	University of Maine	Student Intern

R/V Falkor Crew Members

Name	Position
Heiko Voltz	Captain
Jason Garwood	Chief Officer
Oliver Hurdwell	Safety (2nd) Officer
Erik Suits	Navigation (3rd) Officer
Michael Utley	Bosun
Wendel Virrey	Lead Deckhand
Archel Benitez	Deckhand
Kaarel Räis	Deckhand
Luke MacNut	Deckhand
Allen Watt	Chief Engineer
Rass Tolstrup	2nd Engineer
Ramon Tabaque	3rd Engineer
Karl Rogers	3rd Engineer
Todor Gerasimov	Electro-Technical Officer
Edwin Pabustan	Fitter
Albert Barcelo	Fitter
Adriana Zamudio	Purser
Arkadiusz Ochocki	Chef
Carlos Pereira Waihrich	Chef
Mildred Dadis	Stewardess
Joyce Young	Stewardess
Colleen Peters	Lead Marine Technician
Paul Duncan	Marine Technician
Brandon D'Andrea	Marine Technician
Amanda Umbrasas	Procurement Specialist
Carlie Wiener	Communication Manager

5. Observations

5.1 Underway measurements

The following instrument packages recorded data throughout the cruise. Data were logged by the Scientific Computing System (SCS).

Package	Measurements
Vaisala WXT520	Wind speed and direction Air temperature Relative humidity Pressure
Gill MetPak PWS	Wind speed and direction Air temperature Relative humidity Pressure
SBE 38 remote temperature probe	Near sea surface temperature
SBE 45 Micro thermosalinograph	Temperature and conductivity

5.2 CTD

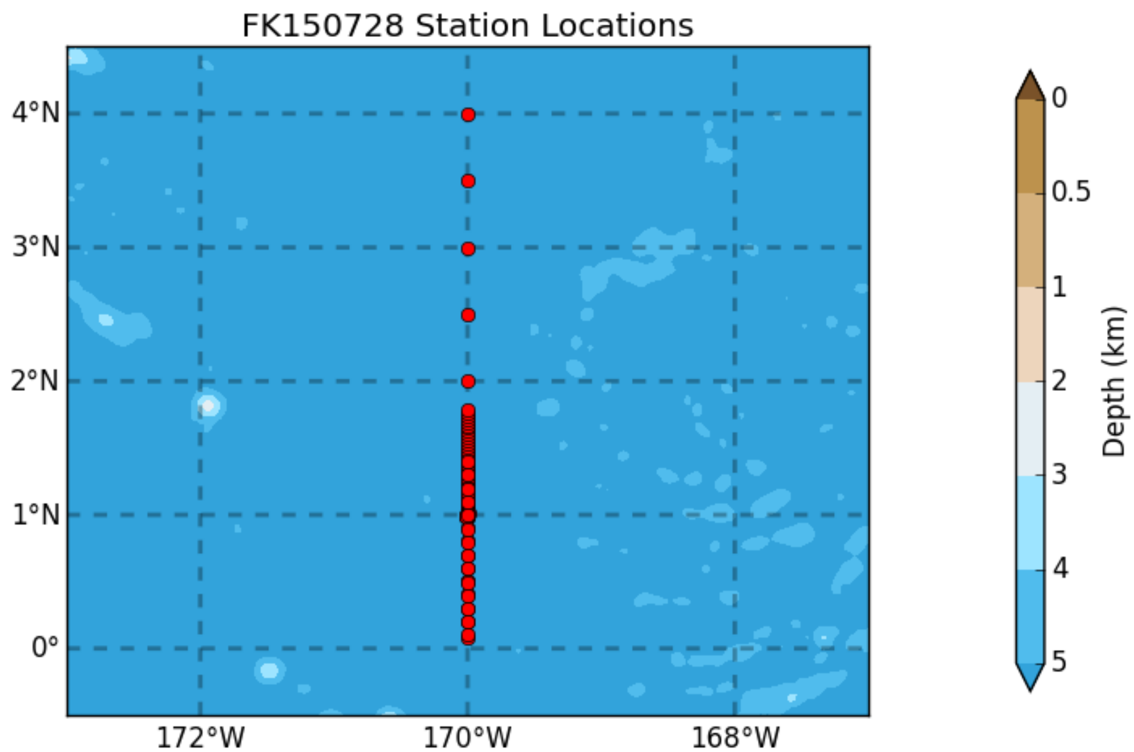
5.2.1 CTD Data Collection

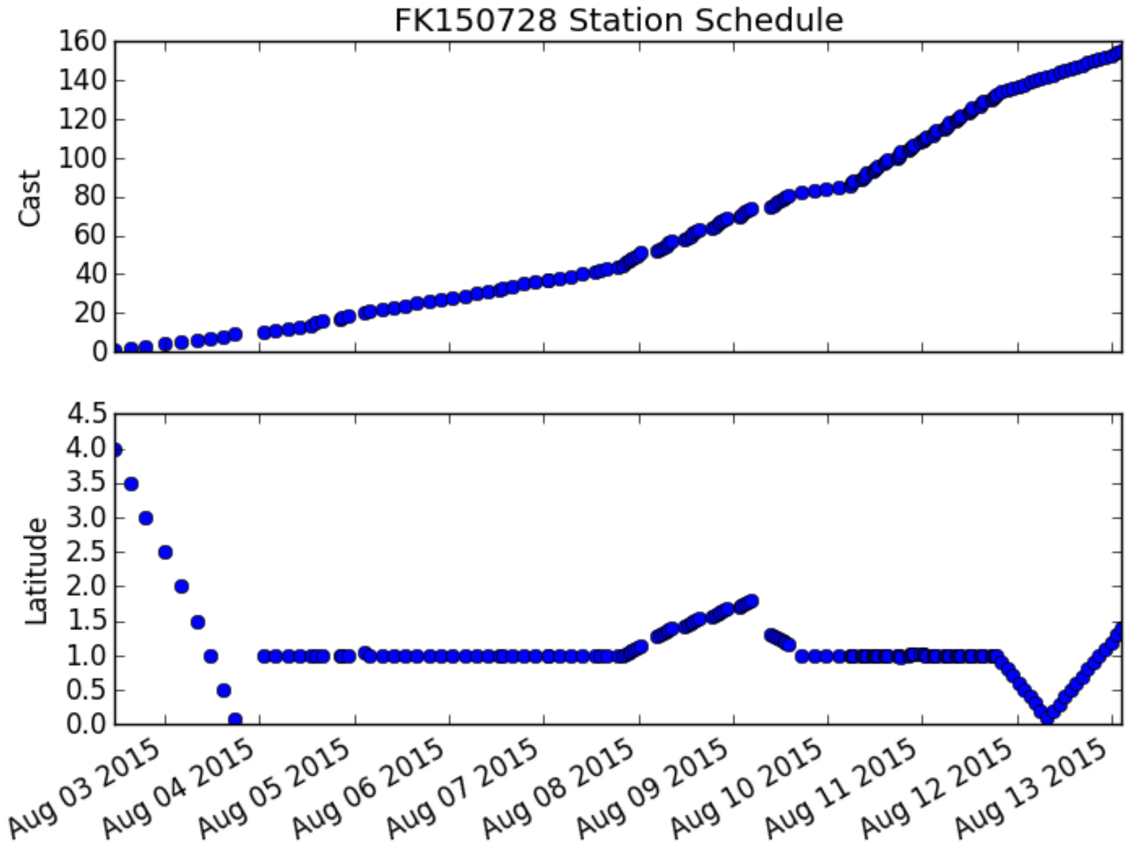
The Falkor's CTD was used throughout, configured with dual temperature, conductivity, and oxygen sensors, plus a fluorometer, turbidity sensor, and a PAR sensor. Twenty bottles were mounted on the frame during some of the casts.

The CTD system generally worked well, with good agreement between the sensors, but there were periods when large anomalies were common. Although some "loops" in the profile were expected, given the ship-induced package heave, we found surprisingly large temperature excursions with relatively small pressure excursions. Evidently the package was carrying water with it, and/or projecting it downward, so that on the downcast there could be glitches in which the temperature matched that of water from many meters above—more than one might have expected based on the actual range of pressures during a heave cycle. We found that the problem could be reduced by steaming at 0.7-1 kt, particularly when bottles were not mounted on the package.

A few data transmission errors occurred early in the cruise. The sea cable was re-terminated between casts 16 and 17, and the cable to the winch was replaced prior to cast 20. No errors occurred subsequently.

Apart from a few tests, CTD casts were usually made to 500 m or, in some yo-yo sequences, to 300 m. In most cases each cycle of a yo-yo was treated as a new cast by restarting the data acquisition with a new cast number and a new file. We completed 155 casts for 166 cycles, where each cycle is a single down/up pair. Details are given in the following figures, table and notes.





cycle	cast	date	time	longitude	latitude	min. press.	max. press.	Bot.
1	001	2015-08-02	11:27	170.00°W	4.00°N	1	505	
2	002	2015-08-02	15:31	170.00°W	3.50°N	2	506	
3	003	2015-08-02	18:58	170.00°W	3.00°N	1	507	
4	004	2015-08-02	23:57	170.00°W	2.50°N	2	502	
5	005	2015-08-03	04:17	170.00°W	2.00°N	12	504	
6	006	2015-08-03	08:02	170.00°W	1.50°N	1	504	
7	007	2015-08-03	11:29	170.00°W	1.00°N	1	503	
8	008	2015-08-03	14:53	170.00°W	0.50°N	1	507	
9	009	2015-08-03	17:46	170.00°W	0.08°N	1	507	
10	010	2015-08-04	01:12	170.00°W	1.00°N	2	506	12
11	011	2015-08-04	04:10	170.00°W	1.00°N	2	504	
12	012	2015-08-04	07:08	170.00°W	1.00°N	2	504	
13	013	2015-08-04	10:00	170.00°W	1.00°N	2	505	
14	014	2015-08-04	13:03	170.00°W	1.00°N	2	507	
15	015	2015-08-04	14:09	170.00°W	1.00°N	2	310	
16	016	2015-08-04	16:01	170.00°W	1.00°N	2	506	
17	017	2015-08-04	20:17	170.00°W	1.00°N	2	505	
18	018	2015-08-04	20:58	170.00°W	1.00°N	3	267	

19	019	2015-08-04	22:39	170.00°W	1.00°N	2	300
20	020	2015-08-05	02:28	170.00°W	1.05°N	3	326
21	021	2015-08-05	04:04	170.00°W	1.00°N	3	503
22	022	2015-08-05	07:02	170.00°W	1.00°N	2	507
23	023	2015-08-05	10:02	170.00°W	1.00°N	3	506
24	024	2015-08-05	13:03	170.00°W	1.00°N	4	507
25	025	2015-08-05	16:00	170.00°W	1.00°N	4	506
26	026	2015-08-05	19:07	170.00°W	1.00°N	2	507
27	027	2015-08-05	22:01	170.00°W	1.00°N	2	505
28	028	2015-08-06	01:05	170.00°W	1.00°N	3	504
29	029	2015-08-06	04:03	170.00°W	1.00°N	3	504
30	030	2015-08-06	07:03	170.00°W	1.00°N	3	505
31	031	2015-08-06	10:00	170.00°W	1.00°N	3	505
32	032	2015-08-06	13:01	170.00°W	1.00°N	3	503
33	033	2015-08-06	13:30	170.00°W	1.00°N	2	508
34	034	2015-08-06	15:57	170.00°W	1.00°N	3	508
35	035	2015-08-06	19:01	170.00°W	1.00°N	3	504
36	036	2015-08-06	21:59	170.00°W	1.00°N	2	506
37	037	2015-08-07	01:04	170.00°W	1.00°N	2	504
38	038	2015-08-07	04:03	170.00°W	1.00°N	1	504
39	039	2015-08-07	06:59	170.00°W	1.00°N	3	505
40	040	2015-08-07	09:58	170.00°W	1.00°N	3	504
41	041	2015-08-07	13:01	170.00°W	1.00°N	3	503
43	042a	2015-08-07	14:22	170.00°W	1.00°N	3	311
44	042b	2015-08-07	14:43	170.00°W	1.00°N	50	306
45	042c	2015-08-07	15:00	170.00°W	1.00°N	50	303
46	042d	2015-08-07	15:15	170.00°W	1.00°N	50	246
47	042e	2015-08-07	15:25	170.00°W	1.00°N	165	235
48	042f	2015-08-07	15:31	170.00°W	1.00°N	170	235
49	042g	2015-08-07	15:35	170.00°W	1.00°N	169	235
50	042h	2015-08-07	15:40	170.00°W	1.00°N	169	234
51	042i	2015-08-07	15:45	170.00°W	1.00°N	170	235
52	043	2015-08-07	15:59	170.00°W	1.00°N	3	505
54	044a	2015-08-07	19:04	170.00°W	1.00°N	2	505
55	044b	2015-08-07	19:36	170.00°W	1.00°N	9	504
56	045	2015-08-07	20:08	170.00°W	1.00°N	48	503
57	046	2015-08-07	20:50	170.00°W	1.03°N	12	504
58	047	2015-08-07	21:35	170.00°W	1.05°N	9	506
59	048	2015-08-07	22:18	170.00°W	1.07°N	11	506
60	049	2015-08-07	22:59	170.00°W	1.09°N	12	503
61	050	2015-08-07	23:49	170.00°W	1.12°N	11	505
62	051	2015-08-08	00:36	170.00°W	1.15°N	11	502
63	052	2015-08-08	04:48	170.00°W	1.28°N	3	505

64	053	2015-08-08	05:32	170.00°W	1.30°N	12	502	
65	054	2015-08-08	06:15	170.00°W	1.33°N	12	502	
66	055	2015-08-08	07:00	170.00°W	1.35°N	12	503	
67	056	2015-08-08	07:43	170.00°W	1.37°N	15	503	
68	057	2015-08-08	08:33	170.00°W	1.40°N	10	504	
69	058	2015-08-08	11:50	170.00°W	1.42°N	2	506	
70	059	2015-08-08	12:34	170.00°W	1.44°N	12	506	
71	060	2015-08-08	13:16	170.00°W	1.46°N	11	504	
72	061	2015-08-08	13:58	170.00°W	1.49°N	12	506	
73	062	2015-08-08	14:43	170.00°W	1.51°N	13	503	
74	063	2015-08-08	15:27	170.00°W	1.54°N	12	503	
75	064	2015-08-08	18:44	170.00°W	1.56°N	3	504	
76	065	2015-08-08	19:33	170.00°W	1.58°N	7	506	
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81	070	2015-08-09	01:36	170.00°W	1.70°N	3	505	
82	071	2015-08-09	02:21	170.00°W	1.72°N	12	506	
83	072	2015-08-09	03:05	170.00°W	1.74°N	11	502	
84	073	2015-08-09	03:48	170.00°W	1.77°N	12	502	
85	074	2015-08-09	04:32	170.00°W	1.79°N	11	503	
86	075	2015-08-09	09:39	170.00°W	1.30°N	3	502	
87	076	2015-08-09	10:26	170.00°W	1.28°N	10	504	
88	077	2015-08-09	11:11	170.00°W	1.25°N	12	504	
89	078	2015-08-09	11:58	170.00°W	1.22°N	12	508	
90	079	2015-08-09	12:40	170.00°W	1.21°N	12	506	
91	080	2015-08-09	13:21	170.00°W	1.19°N	12	506	
92	081	2015-08-09	14:01	170.00°W	1.17°N	12	505	
93	082	2015-08-09	17:32	170.00°W	1.00°N	3	507	
94	083	2015-08-09	20:41	170.00°W	1.00°N	2	506	
95	084	2015-08-09	23:37	170.00°W	1.00°N	3	505	
96	085	2015-08-10	02:40	170.00°W	1.00°N	2	505	20
97	086	2015-08-10	05:38	170.00°W	1.00°N	3	505	
98	087	2015-08-10	06:05	170.00°W	1.00°N	12	303	
99	088	2015-08-10	06:27	170.01°W	1.00°N	12	302	20
100	089	2015-08-10	08:34	170.00°W	1.01°N	3	504	
101	090	2015-08-10	09:07	170.00°W	1.00°N	10	303	
102	091	2015-08-10	09:26	170.00°W	1.00°N	11	303	
103	092	2015-08-10	09:47	170.00°W	0.99°N	10	303	
104	093	2015-08-10	11:29	170.00°W	1.01°N	4	505	
105	094	2015-08-10	11:58	170.00°W	1.00°N	13	304	
106	095	2015-08-10	12:16	170.00°W	0.99°N	13	304	

107	096	2015-08-10	12:34	170.00°W	0.99°N	12	303	
108	097	2015-08-10	14:29	170.00°W	0.99°N	3	504	
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111	100	2015-08-10	17:29	170.00°W	1.00°N	3	507	
112	101	2015-08-10	17:58	170.00°W	0.99°N	9	303	
113	102	2015-08-10	18:16	170.00°W	0.99°N	9	303	
114	103	2015-08-10	18:37	170.00°W	0.98°N	11	305	
115	104	2015-08-10	20:33	170.00°W	1.00°N	2	505	
116	105	2015-08-10	21:02	170.00°W	1.01°N	9	303	
117	106	2015-08-10	21:22	170.00°W	1.01°N	9	303	
118	107	2015-08-10	21:41	169.99°W	1.02°N	10	303	
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120	109	2015-08-11	00:15	170.00°W	1.01°N	12	303	
121	110	2015-08-11	00:35	170.00°W	1.01°N	13	301	
122	111	2015-08-11	00:55	170.00°W	1.00°N	13	302	
123	112	2015-08-11	02:39	169.99°W	1.01°N	12	504	
124	113	2015-08-11	03:08	170.00°W	1.00°N	13	421	
125	114	2015-08-11	03:31	170.00°W	1.00°N	12	309	20
126	115	2015-08-11	05:34	170.00°W	1.00°N	3	508	
127	116	2015-08-11	06:03	170.00°W	1.00°N	13	303	
128	117	2015-08-11	06:21	170.00°W	1.00°N	13	302	
129	118	2015-08-11	06:39	170.01°W	0.99°N	13	304	
130	119	2015-08-11	08:31	169.99°W	1.01°N	3	506	
131	120	2015-08-11	09:00	170.00°W	1.00°N	10	304	
132	121	2015-08-11	09:20	170.00°W	1.00°N	9	302	
133	122	2015-08-11	09:42	170.00°W	0.99°N	10	304	
134	123	2015-08-11	11:36	170.00°W	1.00°N	3	506	
135	124	2015-08-11	12:06	170.00°W	1.00°N	13	303	
136	125	2015-08-11	12:28	170.01°W	0.99°N	12	304	
137	126	2015-08-11	12:46	170.01°W	0.99°N	13	305	
138	127	2015-08-11	14:36	170.01°W	0.99°N	4	506	
139	128	2015-08-11	15:08	170.00°W	1.00°N	13	305	
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141	130	2015-08-11	17:32	170.00°W	1.00°N	3	502	
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144	133	2015-08-11	18:37	170.01°W	0.99°N	13	304	
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153	142	2015-08-12	07:28	170.00°W	0.11°N	3	508	20
154	143	2015-08-12	09:08	170.00°W	0.20°N	3	503	
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157	146	2015-08-12	13:31	170.00°W	0.50°N	3	504	10
158	147	2015-08-12	15:07	170.00°W	0.60°N	3	505	
159	148	2015-08-12	16:34	170.00°W	0.70°N	3	504	
160	149	2015-08-12	17:56	170.00°W	0.80°N	3	506	
161	150	2015-08-12	19:23	170.00°W	0.90°N	3	508	
162	151	2015-08-12	20:54	170.00°W	1.00°N	3	504	10
163	152	2015-08-12	22:28	170.00°W	1.10°N	3	504	
164	153	2015-08-12	23:52	170.00°W	1.20°N	2	504	
165	154	2015-08-13	01:18	170.00°W	1.30°N	2	505	
166	155	2015-08-13	02:41	170.00°W	1.40°N	3	503	

Notes

1. Cast 15 was truncated at 300 m because of data spikes.
2. Cast 16 had 6 modulo count errors. The wire was reterminated.
3. Cast 17 was followed by cast 18 without bringing the CTD on deck. Cast 18 was a test with lower winch speeds, ended at about 270 m.
4. Additional testing was conducted on shallow casts 19 and 20. The LADCP was not operated on these casts. The cable run from the winch to the lab was changed. The eventual conclusion was that we had encountered two or three problems: the termination, and noise input on the cable from the winch, probably both contributed to modulo errors; and at the same time, increased ship motion was causing puzzlingly large anomalies in temperature and salinity as the CTD sampled its own wake on the downcast.
5. Cast 42 was a yo-yo to resample the region of large vertical displacement between downcast and upcast seen on cast 41. The cast includes 3 cycles from the surface to 300 m, then 6 cycles over a small range near 200 m. The cycles are designated as 42a, 42b, etc., ending with 42i.
6. Cast 43 followed 42 without bringing the CTD on deck; it was a full 500-m cycle.
7. Cast 44 began a yo-yo with two cycles, designated 44a and 44b; on the 3rd and subsequent cycles, a new cast was started.
8. On cast 108 the CTD acquisition computer froze at 70 m on the upcast. The computer was rebooted, the CTD brought to the surface, and cast 109 was started without bringing the CTD on deck.

Yo-yos and tow-yos: cast ranges

1. 42-43.
2. 44-51.
3. 52-57.
4. 58-63.
5. 64-69.
6. 70-74.
7. 75-81.
8. 86-88.
9. 89-92.
10. 93-96.
11. 97-99.
12. 100-103.
13. 104-107.
14. 108-111.
15. 112-115.
16. 115-118.
17. 119-122.
18. 123-126.
19. 127-129.
20. 130-133.

5.2.2 CTD processing and storage

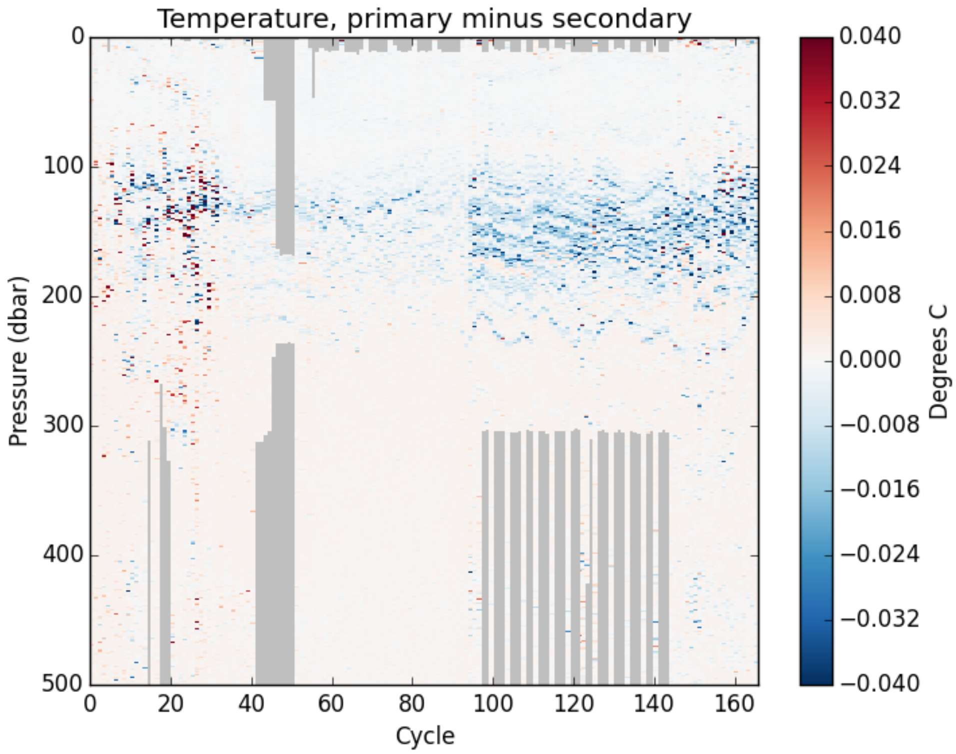
The original files (*.hex, *.XMLCON, *.hdr, and *.bl) were processed by Saulo Soares using the SeaSoft software installed on the ship's computers. One intermediate stage is saved: the minimal conversion of the *.hex files to *.cnv, with the original variables scaled to their physical units using the sensor calibration values. The final processing yields two reduced-resolution sets of files: a one-Hz time series for the entire cast, and a one-decibar pressure-gridded file for each downcast.

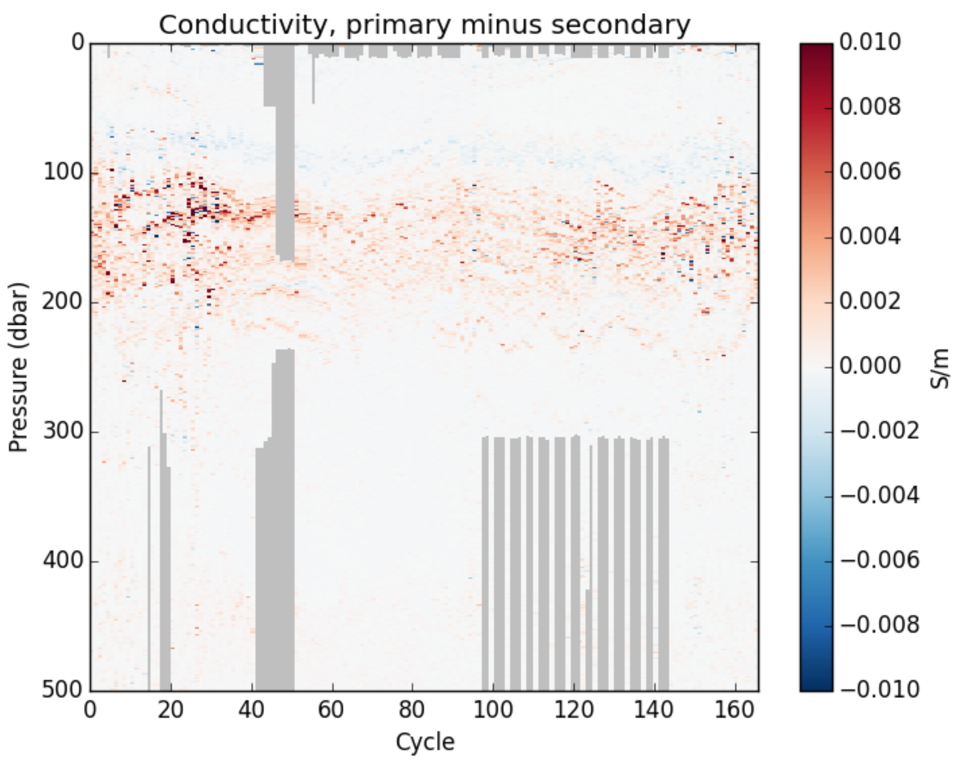
5.2.3 CTD diagnostics

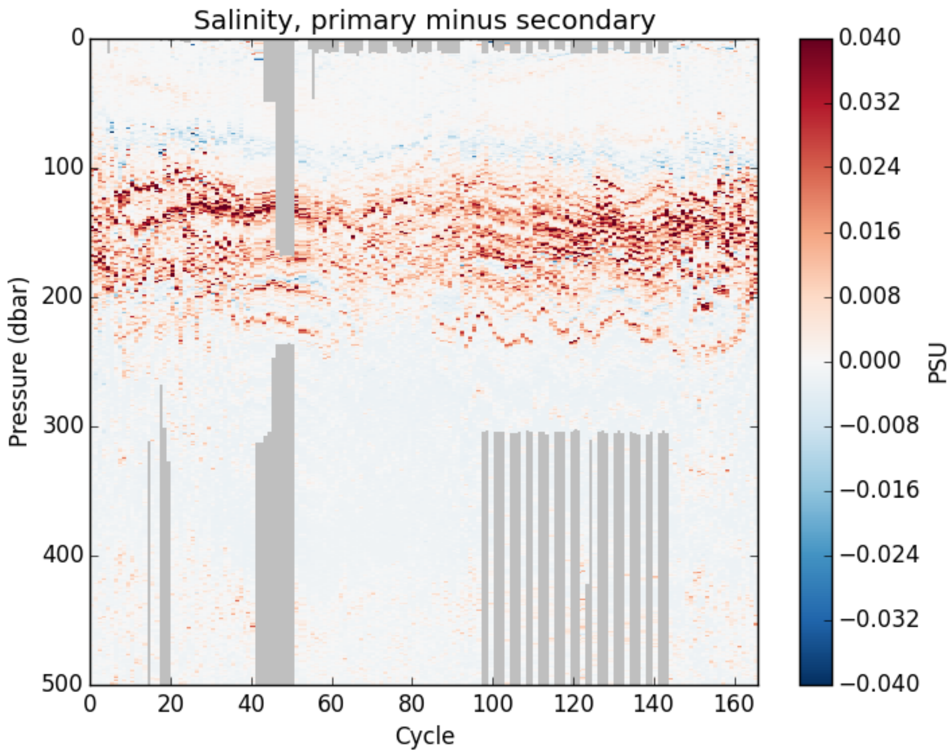
There were systematic differences between sensors, resulting in a difference in salinity derived from the primary sensors versus the secondary sensors. Temperature and conductivity differences were associated with property gradients, but the oxygen difference indicated a relative drift in calibration between the two sensors; the primary oxygen was always higher than the secondary, and more so at higher values than at lower values, but the ratio decreased during the cruise.

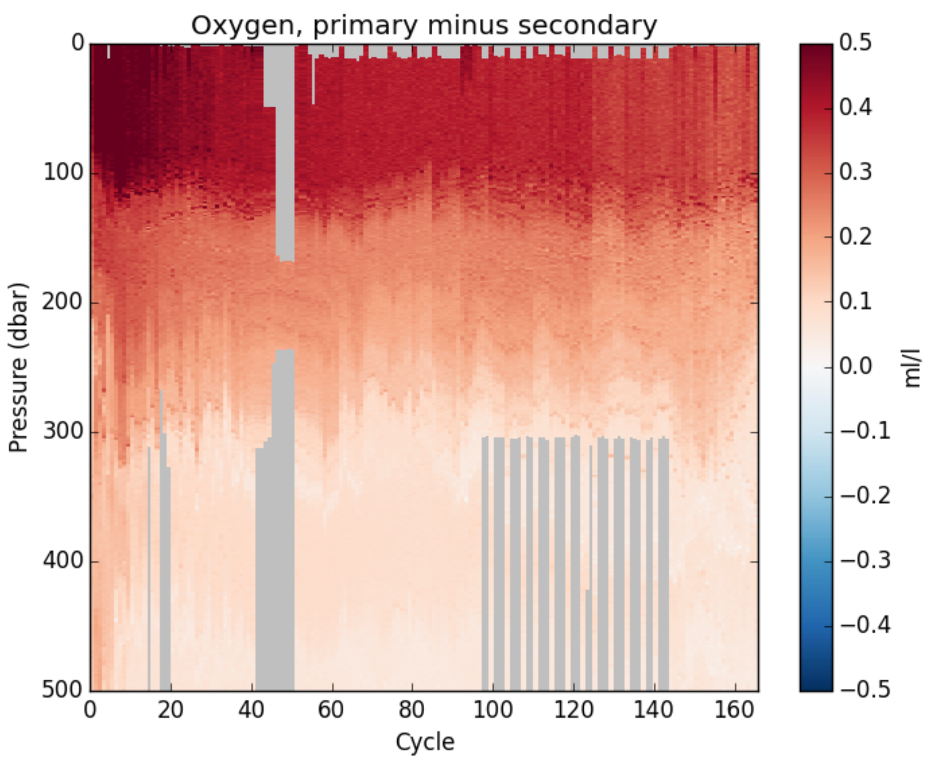
As the plots below show, the differences between sensors varied depending on the package configuration and the ship's motion. Bottles were mounted early in the cruise, removed for the middle part, and re-mounted for occasional water sampling (nutrients only) starting with cast 85 (cycle 96). The change in the sensor difference is particularly marked at cast 85. Despite such clues, the exact explanation for these sensor differences has not yet been determined.

In addition to the systematic differences at high gradients, there were scattered differences, particularly in the first 20 casts, and then increasing again towards the end of the cruise. These presumably result from package motion, in which the effects of pressure-loops, in which the sensors occasionally sample water that was entrained by the package, were not completely removed by editing


Temperature, primary minus secondary
Pressure (dbar)
Cycle
Degrees C
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
0.040
0.032
0.024
0.016
0.008
0.000
−0.008
−0.016
−0.024
−0.032
−0.040


Conductivity, primary minus secondary
Pressure (dbar)
Cycle
S/m
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
0.010
0.008
0.006
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
−0.010

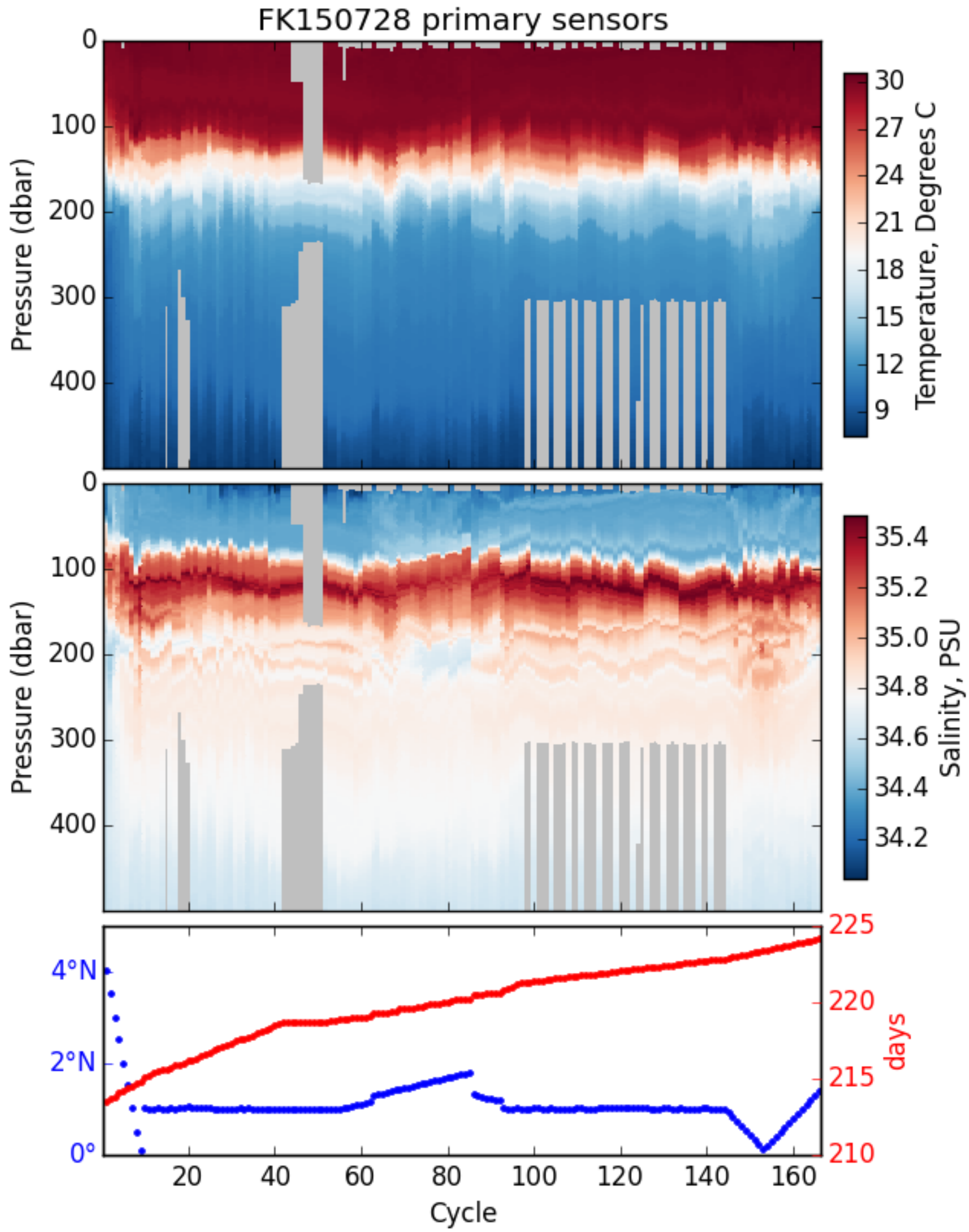

Salinity, primary minus secondary
Pressure (dbar)
Cycle
PSU
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
0.040
0.032
0.024
0.016
0.008
0.000
−0.008
−0.016
−0.024
−0.032
−0.040

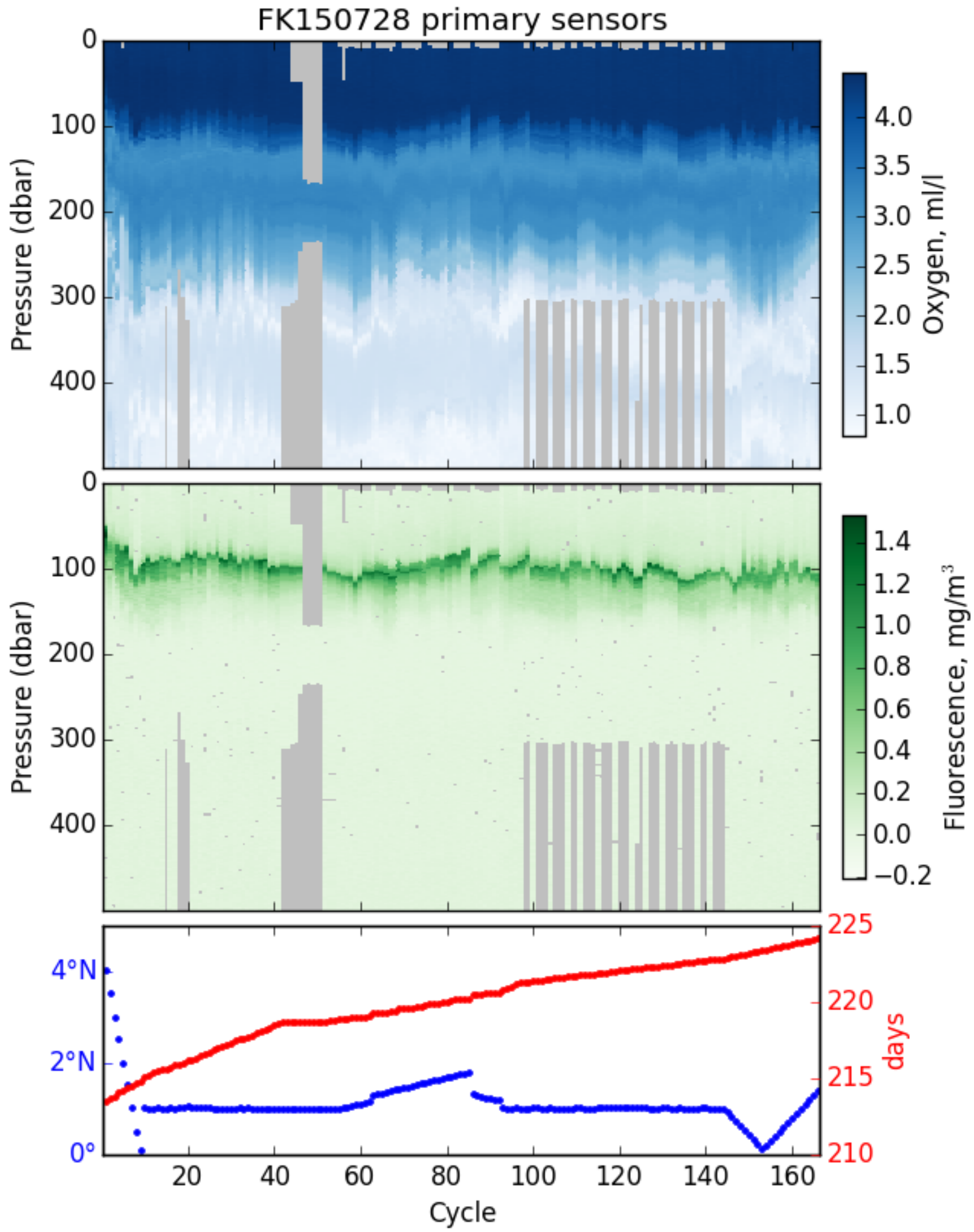

Oxygen, primary minus secondary
Pressure (dbar)
Cycle
ml/l
0
100
200
300
400
500
0
20
40
60
80
100
120
140
160
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5

5.2.4 CTD Data: water properties

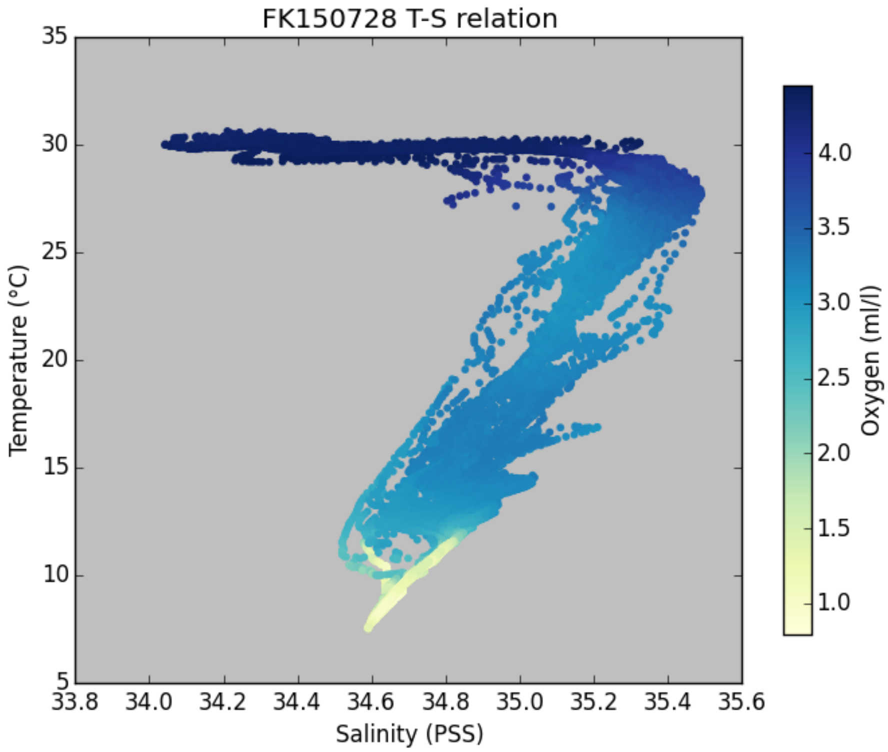
The CTD profiles consistently showed water properties and structure similar to what would be expected farther west in a non-El Nino year. There was a nearly isothermal surface layer 100-m thick, but only the top few meters were actually mixed. Salinity in the top few meters was variable. Salinity increased sharply with depth as temperature dropped at the base of the 100-m surface layer. A thin high-chlorophyll layer coincided with these high temperature and salinity gradients.

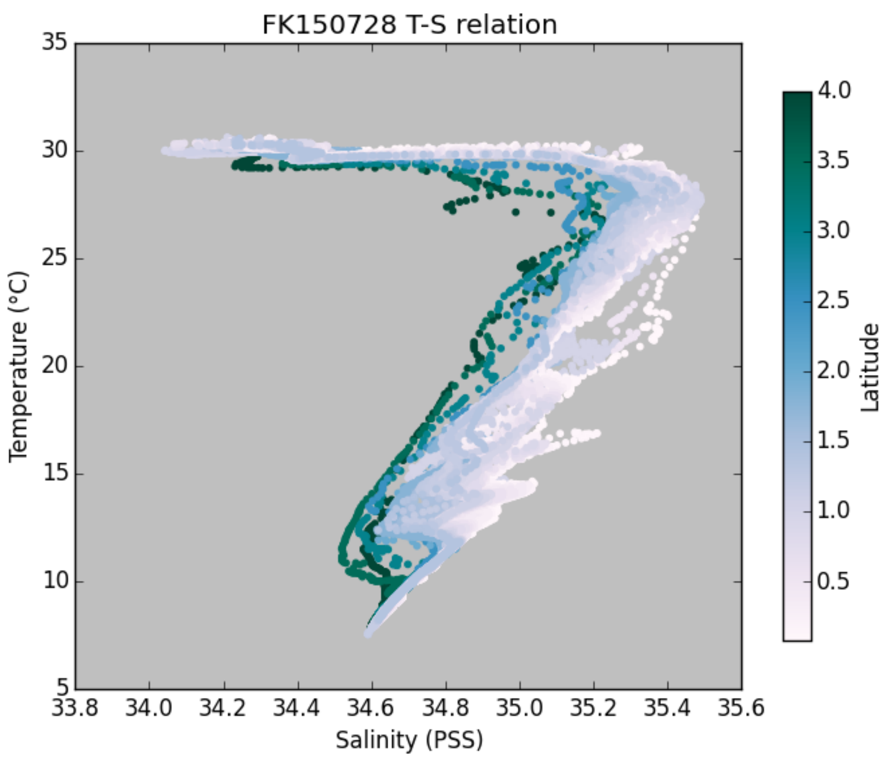
The thermocline was concentrated between 100 and 200 m, and contained a salinity maximum at about 120 m. Salinity generally decreased with increasing latitude. Small-scale salinity features were consistent over the sampling time scale of a few days. Local oxygen maxima at about 200 m and 400 m interrupted the general oxygen decrease with depth.


FK150728 primary sensors
Pressure (dbar)
0
100
200
300
400
30
27
24
21
18
15
12
9
Temperature, Degrees C
Pressure (dbar)
0
100
200
300
400
35.4
35.2
35.0
34.8
34.6
34.4
34.2
Salinity, PSU
4°N
2°N
0°
225
220
215
210
days
20
40
60
80
100
120
140
160
Cycle


FK150728 primary sensors
Pressure (dbar)
0
100
200
300
400
Oxygen, ml/l
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Fluorescence, mg/m3
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
4°N
2°N
0°
225
220
215
210
days
20
40
60
80
100
120
140
160
Cycle

T-S relation


FK150728 T-S relation
Temperature (°C)
Salinity (PSS)
Oxygen (ml/l)
35
30
25
20
15
10
5
33.8
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.4
35.6
4.0
3.5
3.0
2.5
2.0
1.5
1.0


FK150728 T-S relation
Temperature (°C)
Salinity (PSS)
Latitude
35
30
25
20
15
10
5
33.8
34.0
34.2
34.4
34.6
34.8
35.0
35.2
35.4
35.6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

5.3 Lowered ADCP

5.3.1 Objective

The instrument was used to produce high (2m) vertical resolution measurements of zonal (u) and meridional (v) velocity components in the upper 500 meters of the ocean.

5.3.2 Overview of instrument and operation

The instrument, a Teledyne RDI Workhorse Sentinel 600kHz ADCP rated for 1000m depth, was used in lowered mode, attached to the CTD frame using a collar made of two plastic halves joined by a number of bolts as shown in Figure 5.3.1. The instrument was deployed on CTD casts 1 through 155 and performed well throughout its use.

The instrument is self-contained with an internal battery pack. The health of the battery is monitored by the recorded voltage count. The relationship between the actual battery voltage and the recorded voltage count is obscure and appears to vary with the instrument and environmental conditions. Taking a direct measurement of the state of the battery requires opening up the instrument. One battery was used in the course of the FK150728 cruise. Direct measurements of the battery voltage were taken at the start and end of the cruise and compared to the recorded voltage count. The results, summarized in Table 5.3.1, show an almost constant relationship of V~=0.29VC. RDI recommend the battery is changed when V gets below 30V.

5.3.3 Setup and parameter settings

At all casts, the LADCP was controlled at deploy and recover stages by a Linux PC (henceforth referred to as the LADCP laptop) using the python script **ladcp600.py** (written by Eric Firing, University of Hawai`i). The commands sent to the instrument at setup were contained in **ladcp600.cmd**. The instrument was set up to have a relatively small bin depth (2m) and a fast ping rate (every 0.25 sec). The full list of commands sent to the instrument is

```
CR1              # Retrieve parameter (default)
TC2              # Ensemble per burst
WP1              # Pings per ensemble
TE 00:00:00.00   # Time per ensemble (time between data collection
                   cycles)
TP 00:00.25      # Time between pings in mm:ss
WN25             # Number of Depth cells
WS0200           # Depth cell size (in cms)
```

```
WF0088        # Blank after transit (recommended setting for 600kHz)
WB0           # Mode 1 bandwidth control (default - wide)
WV250         # Ambiguity velocity (in cm/s)
EZ0111101     # Sensor source (speed of sound excluded)
EX00000       # Beam coordinates
CF11101       # Data flow control parameters
```

(see the RDI Workhorse "Commands and Data Output Format" document for details.)

Figure 5.3.1. Teledyne RDI Workhorse Sentinel 600kHz ADCP attached to the CTD frame

	Battery Voltage (V)	**Voltage Count (VC)**	**Ratio (V/VC)**
Before	44.6	154	0.29
After	36.0	122	0.29

Table 5.3.1 Battery characteristics before and after the deployment

The data collected by the instrument were copied to the hard drive of the LADCP laptop and saved under filenames **dn<cast#>.dat**, e.g. **dn001.dat** … **dn155.dat**.

An initial sampling of the data was made using the script **adcp_rawplot.py** to check that the instrument was performing correctly. For files with multiple up and down profiles (yo-yo and tow-yo stations) an additional step was taken to split them into multiple files containing single-cast profiles. This step was accomplished using the script **ladcp_cut.py**.

The principal onboard data processing on single-cast files was performed using the script **shearcalc.py** which computes horizontal velocity components u and v (eastward and northward, respectively) profiles using the *shear* method separately for the downwcast and upcast. It also produces the average between the two solutions. The input data for the scripts are the LADCP raw data, CTD (for depth) and GPS data. Frequent CTD data are required. Files of 1 second averaged CTD data were prepared for each cast. Accurate time keeping is essential, particularly between the CTD and GPS data. To ensure this the CTD data records also included the GPS position.

5.3.4 Preliminary results

All data were collected at 170W longitude. To ensure high temporal and meridional resolution, we selected the pattern shown in Figure 1.2 in time and latitude. The shipboard ADCP is a 300 kHz Teledyne RDI Workhorse mounted on a pole and was deployed just before every LADCP cast. It provides useful data only for the upper 80 meters of the ocean.

Figures 5.3.2 and 5.3.3 show the vertical shear of the zonal (eastward) and meridional (northward) velocity components in the upper 300 meters for the entire cruise as a function of time, erspectively. A time series was performed at 1N, Aug 4-7 (casts 010-044, see Figure 2.2). We can clearly see upward phase propagation at around 150m depth which is consistent with the dynamics of the inertia-gravity waves (IGWs) radiated from the mixed layer into the ocean interior. Further evidence for the downward energy propagation was gathered by the high horizontal resolution northward section (Aug. 7-9, casts 045-074) in which the phase lines between 100 and 200m depths slope upward at a steeper angle suggestive of phase lines sloping up towards the north. The phase lines during a second time series (Aug 9-11) and northward section (Aug 12-13) have similar characteristics. The remaining portions of the plot provide further data that will be used in post cruise analysis of the flow field.

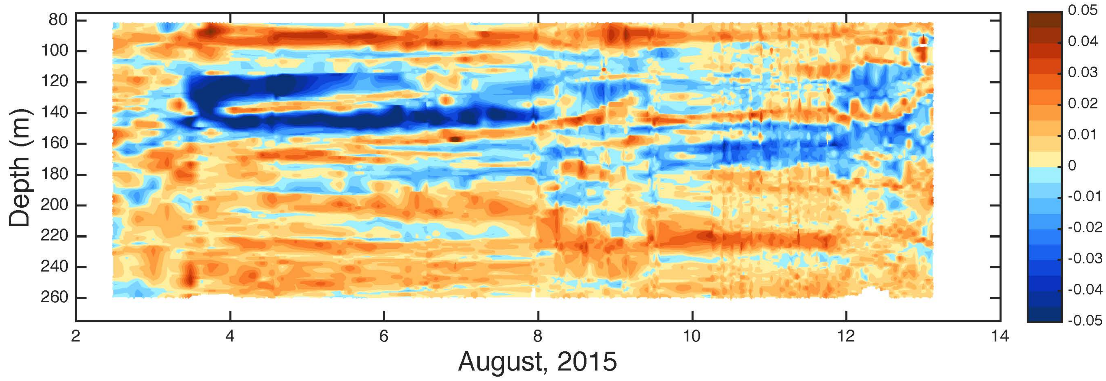


Figure 5.3.2 Vertical shear of the zonal (eastward) component of velocity, du/dz, as function of time. Vertical profiles have been aligned with respect to density.

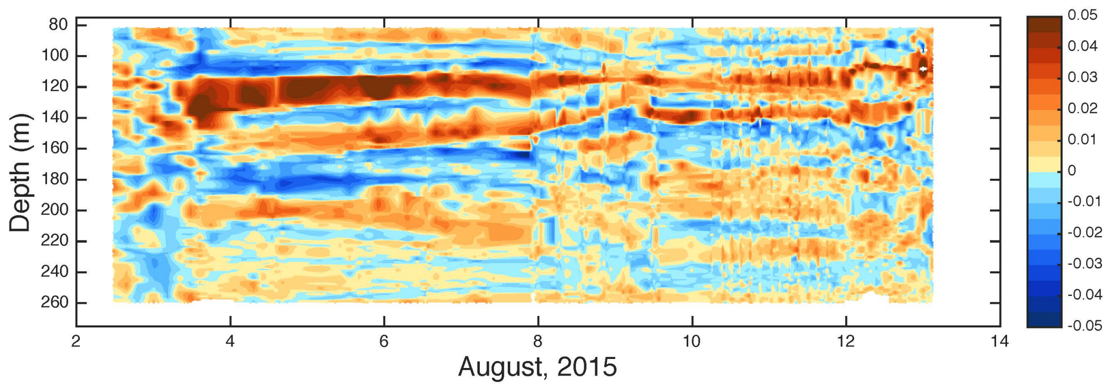


Figure 5.3.3 Vertical shear of the meridional (northward) component of velocity, dv/dz, as function of time. Vertical profiles have been aligned with respect to density.

5.4 Shipboard ADCP

Observation of the regional current field was severely hampered by instrument failures beyond the control of SOI or ourselves. Prior to the cruise we knew that the RD Instruments Workhorse 300 kHz (WH300) instrument mounted in the gondola was not functional, and that the 75 kHz Ocean Surveyor (OS75) had suffered a temperature sensor failure several months ago. Once underway and beyond the 12-mile limit, we found that that OS75 was completely nonfunctional. The only remaining shipboard ADCP system was a WH300 mounted on the USBL probe, which could be lowered and operated when the ship speed was under about 4 kts. This was used during most such opportunities beginning with the initial southbound section on 170°W, August 2, and continuing until departure from the operating area on August 13. An overview of the zonal (U) and meridional (V) current components from the WH300 is given in Figure 5.4.1.

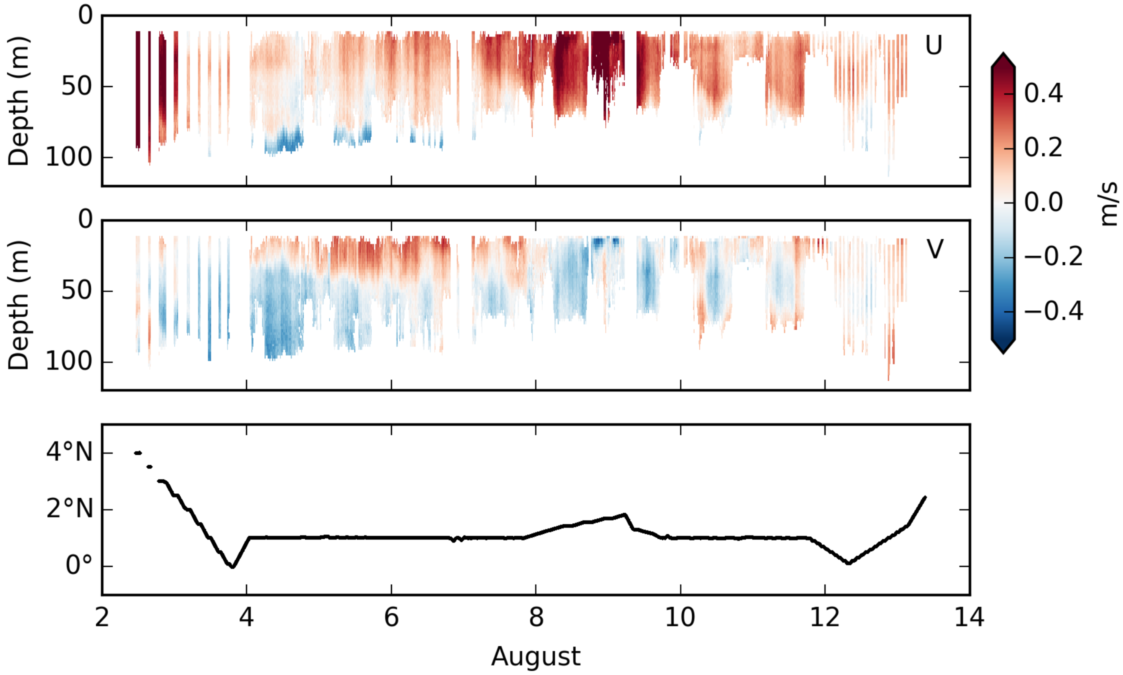


Figure 5.4.1 Upper and middle panels: Zonal (U) and mridioanal (V) components of velocity as measured by the WH300. Lower panel: Latitude along 170W.

It will be noted that in addition to the time gaps when the ship was underway, coverage was severely limited by poor depth range during the day, a problem that became progressively worse at the primary station (1°N) during the observation period. The extraordinarily low scattering affected the 600 kHz lowered ADCP as well; our impression is that this is the weakest backscattering environment we have ever seen in the upper 100 m.

Until very near the end of the cruise, the WH300 was operated with the default UH configuration, optimized for vertical resolution: 2-m depth cells, and the broad bandwidth option (WB0 command). At 19:35Z on August 12 we tried switching to 4-m depth cells and noted a larger improvement in depth range than expected. Ten minutes later we also switched to the narrower bandwidth option (WB1), and saw additional improvement in range. In retrospect, these configuration options would have been better suited to our situation from the start; with extremely low daytime scattering and with no OS75, it makes sense to configure the WH300 maximize range rather than resolution.

5.4.1 Calibration

Because the WH300 could be operated only intermittently and only at low speeds, there is much less calibration information available than we would normally have for a shipboard system; but because of the low speeds, the estimates ocean currents are also less sensitive to calibration errors than for a normal installation. Nevertheless, by loosening our criteria for the ship accelerations that can contribute calibration information, and then editing heavily, we were left with 59 calibration points consistent with the 30.5° transducer orientation estimate that had been made early in the cruise.

5.5 Vertical Microstructure Profiles (VMP)

The VMP component of FK150728 was very disappointing, to say the least, (read failure) due to data transfer problems that were traced to circuit board level issues. Despite Andrew working many consecutive 17 or 18 hour days and email support from the manufacturer (Rockland Scientific) we were not about to find a work-around solution. We ended the cruise having only managed to do six casts (plus 2 test casts), some of which had to be terminated early.

5.5.1 Instrument description

The VMP-500 is a loosely tethered microstructure profiler designed to measure centimeter scale fluctuations of velocity and temperature. From these measurements the dissipation rate of turbulent kinetic energy and dissipation rate of thermal variance can be calculated, both of which are measures of ocean mixing. It also carries SeaBird temperature and conductivity sensors. It is approximately 1.5m long and weighs about 20kg. The VMP-500 sends data back up the cable in real time.

The instrument is designed to be decoupled from the ship on the descent, effectively free-falling with tether being paid out faster than the instrument fall rate. The tether is used to haul the VMP back to the surface. In order to maintain a steady fall rate as the density increases, the instrument is more negatively buoyant than needed for the desired fall rate. Drag elements are used to control the descent rate.

5.5.2 Deck operations

After discussions with Jimbo (MT) and Mick (Bosun), the winch was positioned 12 feet back from the transom in line with a block hanging from the A-frame (second mount point from starboard side). When on deck the VMP sat in a cradle close to the starboard crane where it was out of the way of CTD operations. During launches the A-frame was vertical and the instrument was lifted by the VMP winch to just above the top life line. As the A-frame went out the instrument was kept level until it was about 4 m aft of the transom, at which point it was lowered into the water. The A-frame was then brought back over head so that the line could be pulled through the block by hand. As the instrument needs to be free falling, there must be loose line in the water and consequently the weight of the instrument can not be used to pull the line through the block (like the CTD does). Recoveries were essentially the reverse.

This layout meant that the cable was not subject to any very tight bending radii. This launch and recovery technique was successful.

5.5.3 Description of problems

The original drag element consisted of two 36 x 6 inch high density brushes. On the previous cruise one of the drag brushes was lost. We decided to try a new disk shaped design. Weed whacker string was stretched between four pieces of perforated plastic sheet (Fig. x.1). This new design had less surface area than the original resulting in a fall rate of 70 cm/s rather than 65 cm/s. However, we felt the new design had some advantages over the original. It did not stick out as far from the instrument and it made the instrument more manageable during launch and recovery operations. The bright yellow weed whacker string made the instrument much easier to see as it approached the surface. We will continue the development of these more symmetrical drag elements. We have also concluded that the VMP-500 is more negatively buoyant than needed, and will be looking in to options to add buoyancy.

Starting on FK150728_VMP_003 (the fifth cast overall) the files contained bad buffers. A bad buffer flag is set when a write record (one second) contains a check field with the wrong value. At the beginning of each data “matrix” is a channel with requests a null response from the instrument, if it receives a null then this channel is given a value of 32752. If it receives any other response then that value is returned and the bad buffer flag is set. Each “matrix” is sampled at 64Hz, so a bad buffer flag could represent between 1 and 64 scrambled data blocks. The data transfer was so bad on casts FK150728_VMP_005 and FK150728_VMP_006 that communication with the instrument was lost.

After hours and hours and hours of troubleshooting what seemed to be multiple problems we have concluded that they were mostly symptoms of two boards being damaged. The damage was almost certainly caused when a slip-ring replaced under warranty was returned with incorrect wiring. This put 200VDC down the data lines. This was discovered in February and the slip-rings, power board, RSTrans board (in the instrument), and a DC-to-DC step down convertor were returned to Rockland. In early April Rockland returned a new slip-ring and the checked out boards, there is no indication that anything had been found. When the instrument was reassembled it ran on the bench, however, after about 10 minutes we started to notice the connector heating up. Regardless of whether the deck cable or the tether cable was used there was a drop from 200VDC to ~85VDC over the bulkhead connector. Rockland sent a new bulkhead connector, and once installed we ran a number of bench test files with no problems.

Initially, we believed this to be a cable problem. We did not have a spare 4 pin connector. There was a voltage drop over the cable end connector. The cable was re-terminated three times. Before the final time, Todor (ETO) gave the connector a deep clean and noticed two grooves between the pins, indicating that they had been arcing at some point. Once thoroughly cleaned, the connector was megaohm'ed at 1000VDC and returned 2.2 GigaOhm (open) between all the pin combinations. The resulting assembled cable had 200VDC out of the power pins and no cross talk between any of the pins. However, this did not fix the problem, even when running the instrument on the bench.

The ship lent us a oscilloscope to look at the signals between the Utrans board at the ship side and the RStrans board on the instrument. We sent a representative set of these oscilloscope traces to Rockland. They responded within four hours starting an email conversation that amount to about 40 emails. Initially, it was thought that the Utrans board was the problem as the RStrans board should have been protected by two slow-blo fuses and a transformer. The final conclusion was that both boards were damaged and unable to use the differential voltages on the cable to develop a common ground.

Although the instrument is outside the official one year warranty period, Rockland has sent a Utrans and RStrans board to UH as a warranty repair (no cost). We will install these and test once we are in Honolulu. The Falkor has allowed us to stay onboard for a couple of days to conduct the repairs and testing.

On cast 006 the winch lost power on the downcast with about 200m of cable out. This was traced to the winch controller and not to the motor. They were able to get it working again to haul the instrument in, but it again lost power during the recovery. There was no obvious damage to the winch controller. Todor (ETO) cobbled together a temporary controller that just had on/off fwd/back capability and a lower top speed. We did three casts with this arrangement: pulling the line off the cable by hand and using the winch for recovery. On the transit back Andrew was able to get the controller working, but didn't find anything obviously wrong.

5.5.4 Preliminary data

We only managed to get six casts with varying depths plus two test casts during the transit. We attempted three more, hoping there was a software solution that would allow us to descramble the data, this turned out not to be the case. The target depth for the non test casts (_VMP_) was 400db. At that point we stopped paying out on the winch and the instrument continued falling until it either stopped, having reached the end of the loose cable, or had passed 450db, when we would start to haul in on the winch.

Cast FK150728_test_001: Test cast using the probe guard supplied by Rockland. This has a wire ring, which we were concern could be disturbing the flow ahead of the sensors. Unfortunately, the instrument appeared to not be decoupled from the ship. Maximum depth: 420db, no bad buffers.

Cast FK150728_test_002: Test cast using a straight probe guard fabricated at UH. Maximum depth: 490db, no bad buffers.

Cast FK150728_VMP_001: 4^o 00.065'N; 169^o 59.635W. Maximum depth 417 db.

Cast FK150728_VMP_002: 3^o 00.006'N; 169^o 59.934'W. Maximum depth 464 db.

Cast FK150728_VMP_003: 2^o 29.990'N; 169^o 59.992'W. Maximum depth 470 db.

Cast FK150728_VMP_004: 1^o 59.960'N; 169^o 59.965'W. Maximum depth 359 db. Maximum usable depth is 180db.

Cast FK150728_VMP_005: 1^o 00.004'N; 169^o 59,997'W. Maximum usable depth 180db.

Cast FK150728_VMP_006: 1^o 00.005'N; 169^o 59.988'W. Maximum usable depth 250 db.

Casts FK150728_VMP_007 to FK150728_VMP_009 were conducted in case a software solution to salvage any data could be found. This turned out to be impossible.

We are currently trying to transition from processing code written in Matlab to one written in Python (the python code should be faster to run and easier to maintain). At the moment the python code is not complete. However, the matlab code does not handle the large number of bad buffers found in the later files. I decided to spend my time on continuing to develop the python code, rather than pursue major debugging of the matlab code.

Unfortunately, the python code does not yet have the algorithm to remove signals coherent between the shear probes and the accelerometers. This algorithm makes a significant difference on the VMP-500 profile as the noise floor is higher than expected seemingly due to vibration. FK150728_VMP_002 is a cast that can be processed with both codes. Figure x.2 plots the dissipation profile from one of the shear probes for cast FK150728_VMP_002 using the Matlab routines (green) and the python code (blue). The vibration reduction algorithm has a larger affect on smaller dissipation values and those deeper than 200db pressure.

Dissipations from cast FK150728_VMP_006 are plotted in Figure x.3. This is the only cast from the 1^{o}N time series that goes deep enough to encompass the shear layer. Based on Figure x.2, the vibration reduction algorithm will reduce the noise floor (shift most of the profile to the left).

Figure x.1: Andrew making final preparations to the VMP prior to the first cast. The new drag disk is visible at the rear of the instrument. [Photo credit: Carlie Wiener.]

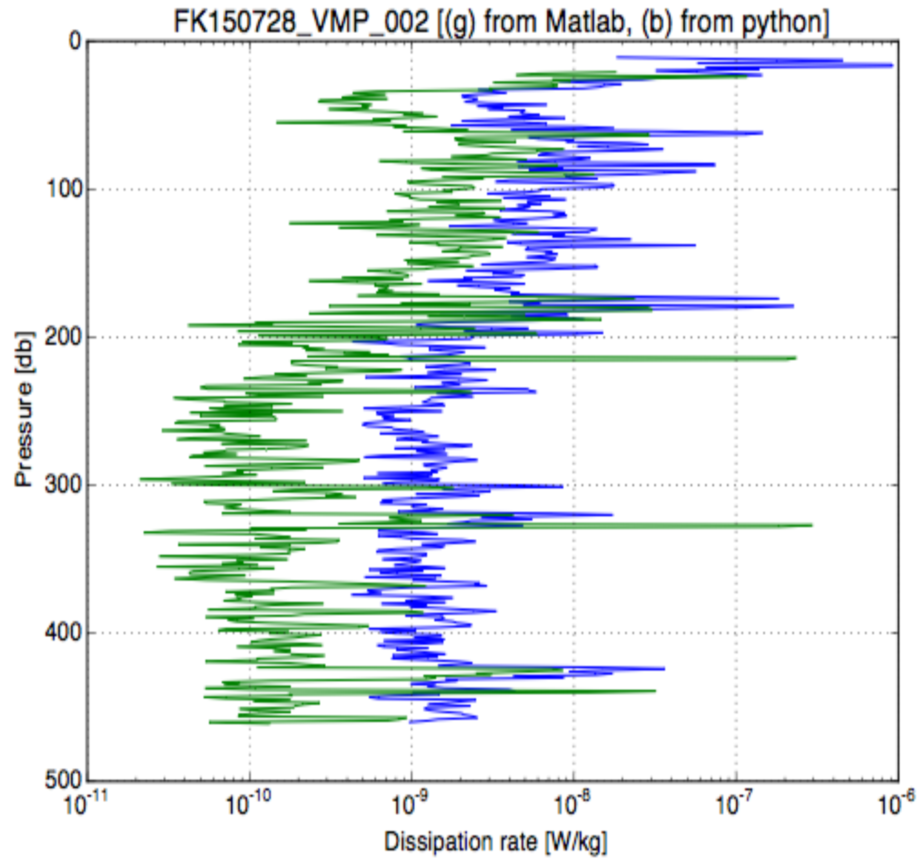


Figure x.2: Comparing the dissipation rate calculated with the vibration reduction algorithm, that removes signals that are correlated between the accelerometers and the shear probes. The profile calculated in Matlab (green line) has this implemented, whereas the python code (blue line) does not at this stage.

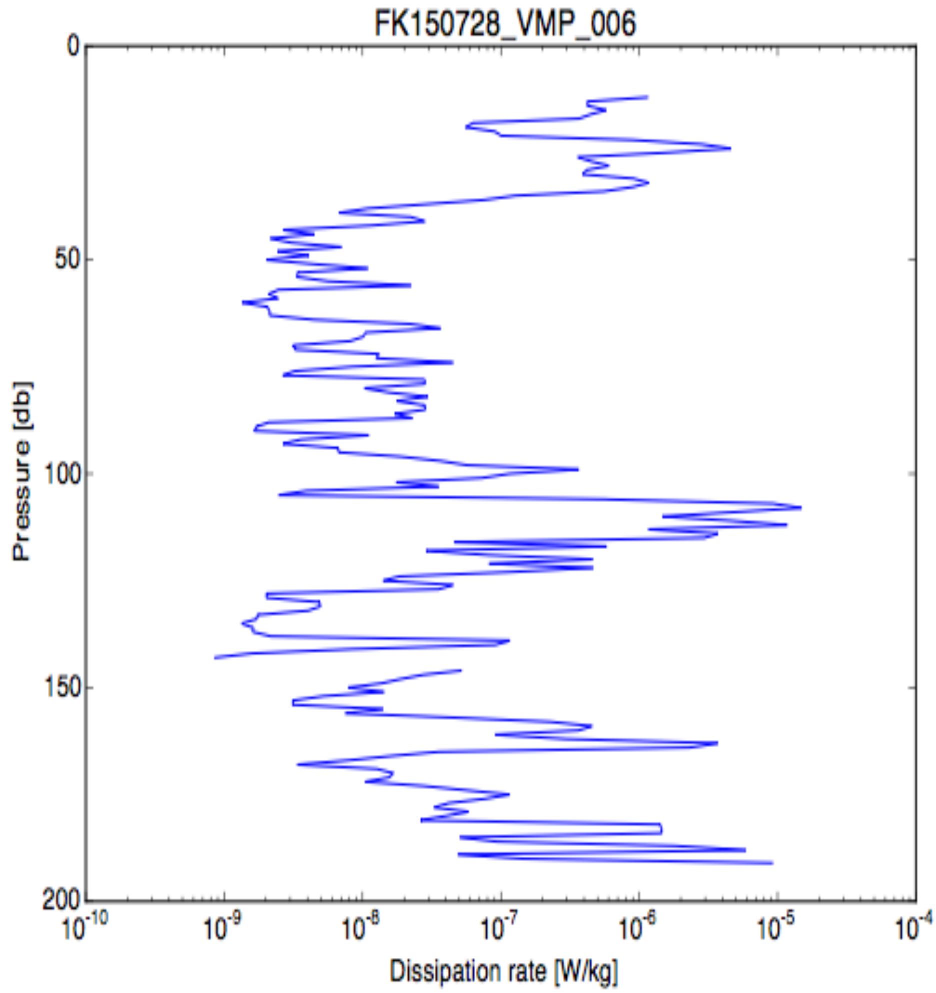


Figure x.3: Dissipation profile from FK150728_VMP_006 during the timeseries at 1°N. Corresponding CTD casts are 017 and 018.