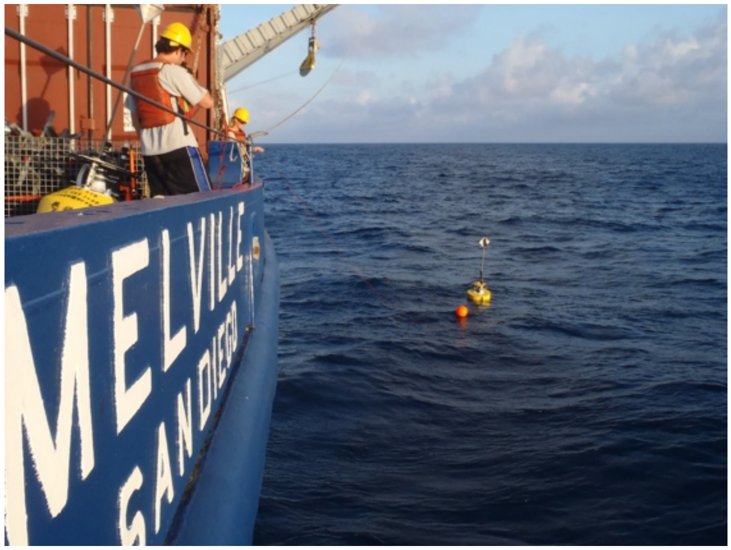
GalapaMix Cruise Report

Tycho Huussen, San Nguyen, Stephanie Snyder,
Caitlin Whalen, and Breck Owens



Cruise ID	MV1208
Experiment name	GalapaMix
Chief Scientist	Tycho Huussen / SIO
Dates	2012 JUNE 05 - 2012 JUNE 21
Ship	R/V MELVILLE
Ports of call	Puerto Ayora, Galapagos, Ecuador to San Diego, California
Station geographic boundaries	0° 00” N 95° 00” W 93° 00” W 0° 40” S
Stations	17 CTD / 69 water samples
Sections	4 ADCP / 1 echosounder
Floats deployed	11 Argo floats
Wirewalker buoys deployed	4

Dr Tycho N. Huussen
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla, CA 92093, USA
T: 858 822 4312 E: thuussen@ucsd.edu

Contents

Itinerary 3

Background and objectives 3

Personnel 4

Met and sea-surface data from ship 5

CTD stations 7

Water samples 10

Wirewalkers 14

Mini-wirewalkers 15

Macro-wirewalker 20

Shipboard ADCP sections 24

Argo floats 27

Echosounder 28

Ship’s event log 29

Itinerary

Cruise MV1208 left Puerto Ayora, Galapagos, Ecuador on June 4 at 1600 local time (LT). Before arriving at our wirewalker deployment site (0°, 95°W), we conducted two meridional sections with the shipboard ADCP (SADCP), one ~80 nm section beginning at the northern tip of Isabela Island and another section at 93°W. We arrived at 0° ,95° W around 0700 (LT) on June 7. After deployment of the gear we drifted east with our free floating gear at a rate of approximately 0.6 m/s. We concluded our equatorial survey with a SADCP section across the equatorial undercurrent (EUC) from 1° 20' S to 1° 20' N at about 93° 25" W. During the transit to San Diego we deployed 11 Argo floats and conducted an acoustics backscatter survey off Baja-California, Mexico.

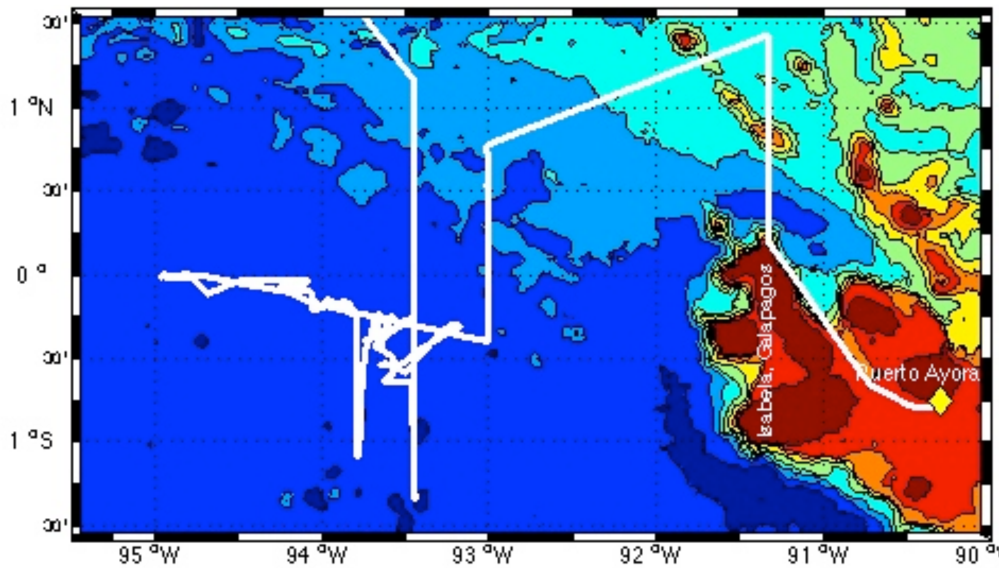


Figure 1. Ship track during the first week of the cruise. The R/V Melville left from Puerto Ayora, Galapagos on June 5 at 1600 local time.

Background and objectives

The science on cruise MV1208 was funded by UC ship funds, the UC Senate and NSF as an add-on project during the planned transit of R/V Melville from Galapagos, Ecuador to San Diego, California. The main objective of the experiment is to observe the development and breakdown of the diurnal surface layer (DSL) near the eqautor. For this pupose we have deployed six mini-wirewalkers on three free-floating surface moorings that repeatedly sample the top 30 m of the water column. A larger wirewalker, called the "Macro", was equipped to simultaneously measure chlorophyll concentrations, ocean currents, temperature, pressure and conductivity. The aim of this component of the project is to sample diurnal variability in phytoplankton concentrations in relation to changes in the physical environment.

Personnel

Scientific personnel

Name	Role	Affiliation
Tycho Huussen	Chief scientist	SIO/UCSD
San Nguyen	Instrumentation wirewalkers	SIO/UCSD
Caitlin Whalen	Ship CTD / Argo floats	SIO/UCSD
Stephanie Snyder	Water sampling / echosounder	SIO/UCSD
Breck Owens	Shipboard ADCP	WHOI
Drew Cole	Restech	SIO/UCSD
Bud Hale	Computer tech	SIO/UCSD

SIO: Scripps Institution of Oceanography
UCSD: University of California, San Diego
WHOI: Woods Hole Oceanographic Institution

Ship's personnel

1 Dave Murline Master
2 Joseph Ferris 1st Officer
3 Don Jack 2nd Officer
4 Eugene Chae 3rd Officer
5 Ed Keenan Boatswain
6 Sandor Vinkovits Able Seaman
7 Kevin Gillette Able Seaman
8 Rob Ball Able Seaman
9 Joe Martino OS
10 Bob Seeley Sr. Cook
11 Mark Smith Cook
12 Alex Rodriguez Chief Eng.
13 Pat Fitzgerald 1st Asst Eng
14 Elizabeth Mack 2nd Asst Eng
15 Cory Googins 3rd Asst Eng
16 Antje Wienke Electrician
17 Phil Hogan Oiler
18 William Brown Oiler
19 Bob Juhasz Oiler
20 Eddie Bautista Oiler
21 Tony Porcioncula Wiper

Met and sea-surface data from ship

The heat flux across the equatorial thermocline is ultimately controlled by the heat and momentum forcing at the surface. Solar irradiance and winds as recorded by standard onboard meteological instruments are shown in Fig. 2, as well as surface seawater temperature (SST) and salinity.

Most days of the experiment we had partial cloud cover, which shows as high frequency fluctuations in the observed short-wave energy flux. The net long wave radiation is small because of the small temperature difference between the sea surface and the air on top of it (back radiation Q_b from the sea surface was calculated using the black body radiation law, $Q_b=\sigma*T^4$, with $\sigma=5.6704*10^{-8}$ $Js^{-1}m^{-2}K^{-4}$ the Stefan-Boltzmann constant and T=SST+273.15 the absolute temperature).

The air temperature at ~20 m above the sea surface and the SST are diurnally modulated. The difference between the afternoon maximum and early morning minimum is about 0.1 ^oC for SST and up to 0.5 ^oC for T_{air}. The winds were consitently northerly (southward) in contrast to the predominant south-easterly trade winds. The wind speed was weak to moderate between 2 to 15 m/s. The diurnal surface layer can only fully develop when wind is absent or very light (<5 m/s). Typical winds were around 8 m/s throughout the experiment. The wind speed rarely dropped below 5 m/s except for the early morning of June 10th.

On two occasions, we observed transitions between water masses. On June 6, during the transit from Puerto Ayora to 0,95W we crossed a warmer and fresher (less saline) watermass north of Isabela Island. Then in the afternoon of June 8, we observed a clear, almost instantaneous jump in SST and a drop in surface salinity. This interesting frontal feature was also apparent in the Macro wirewalker data. The crossing of the front could be detected in the ship's air temperature measurements as well..

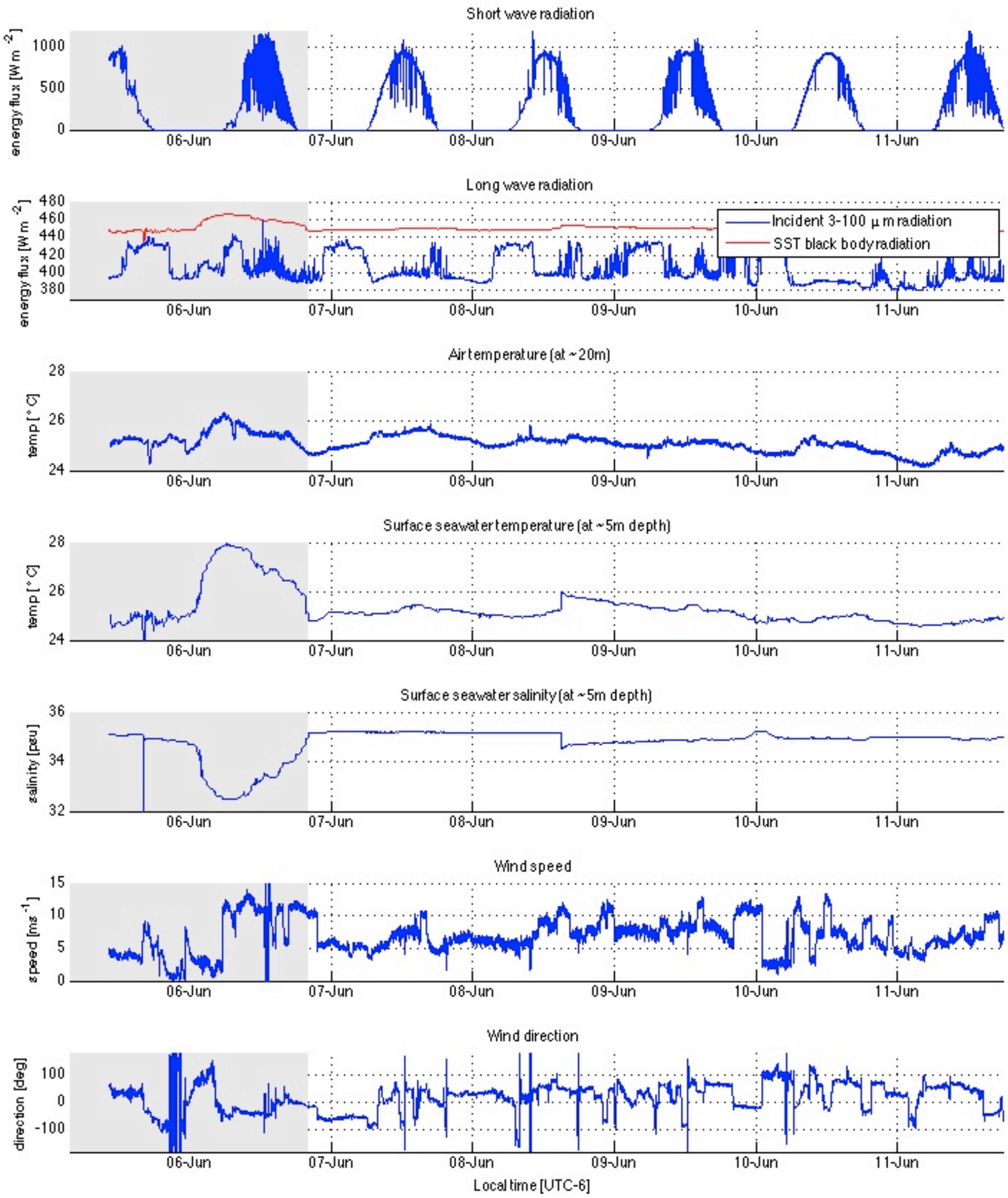


Figure 2. Met data and surface seawater temperature and salinity from shipboard instruments on R/V Melville. The gray shaded area indicates the transit from Puerto Ayora, Galapagos to the deployment site of the Wirewalkers near 0^{o} ,95^{o}W.

CTD stations

We used the ship's CTD for 17 casts, 3 shallow casts to 250 m, 8 casts to 500 m, and 6 full depth casts (Fig. 3). On cast 10 we yoyo-ed the CTD for about 125 minutes between 270-340 m across a deep thermocline step. The measured variables were: pressure, temperature, salinity, fluorescence, and oxygen (Figs. 4-8). The plots show data from downcasts binned in 2 m vertical bins.

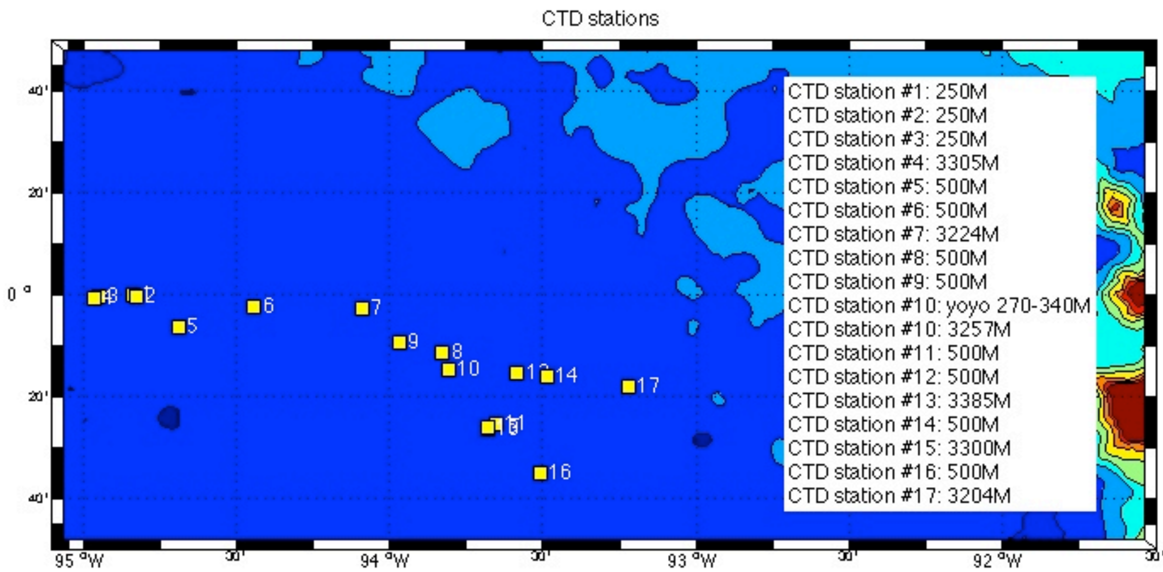


Figure 3. Locations of CTD cats with the ship's CTD. Water samples were collected on all casts except cast 2, 13, and 15.

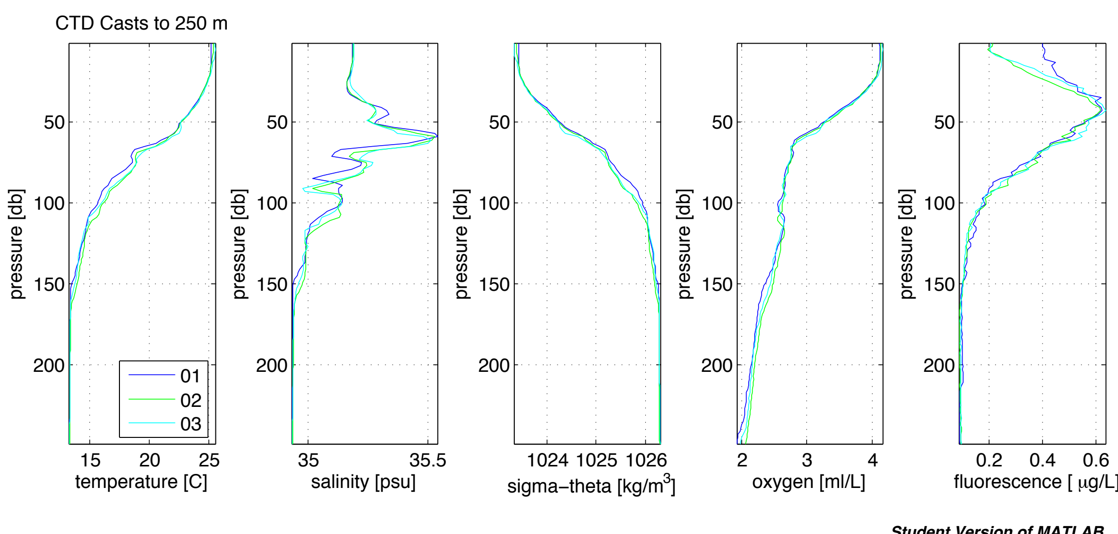


Figure 4. CTD casts to 250 m depth.

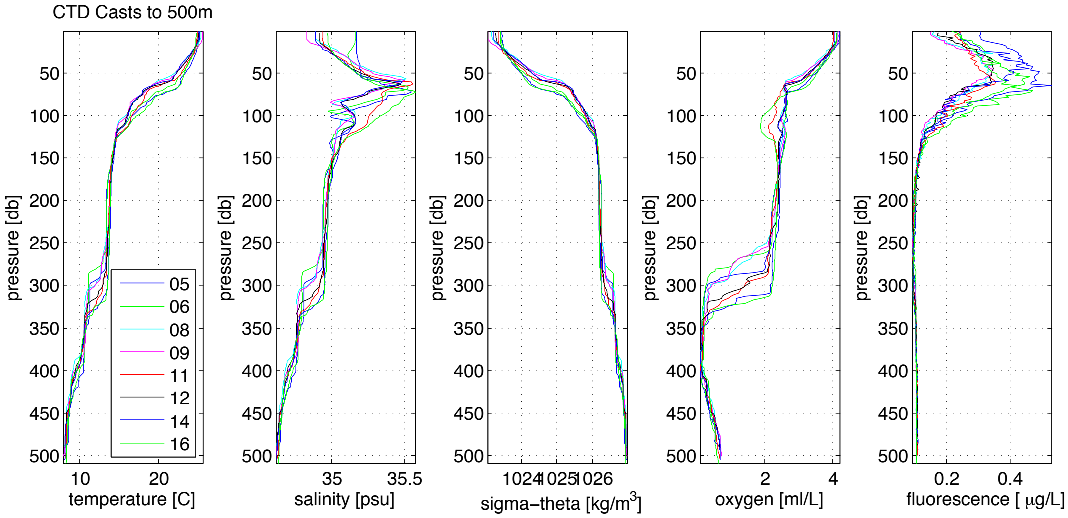


Figure 5. CTD casts to 500 m depth.

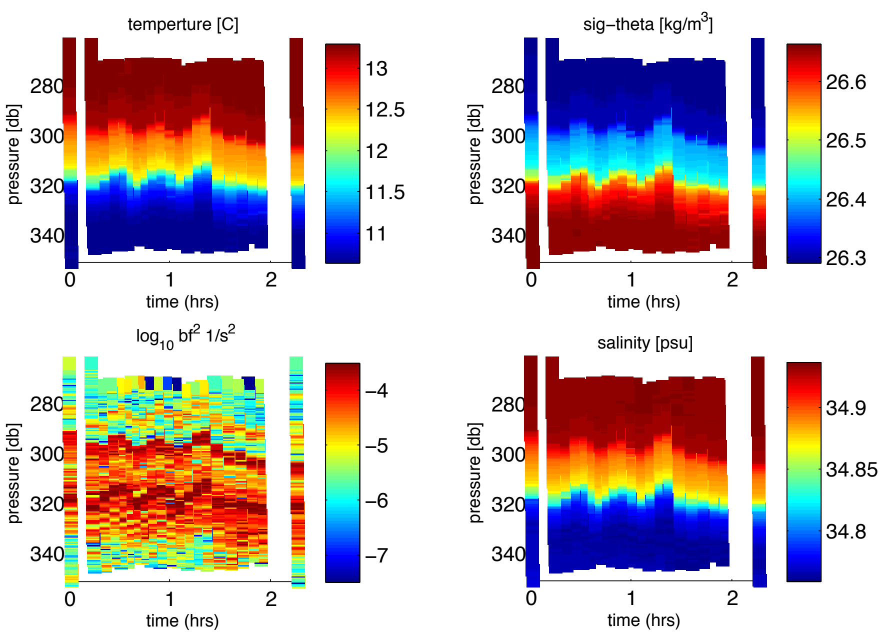


Figure 6. CTD yoyo casts between 270 and 340 m.

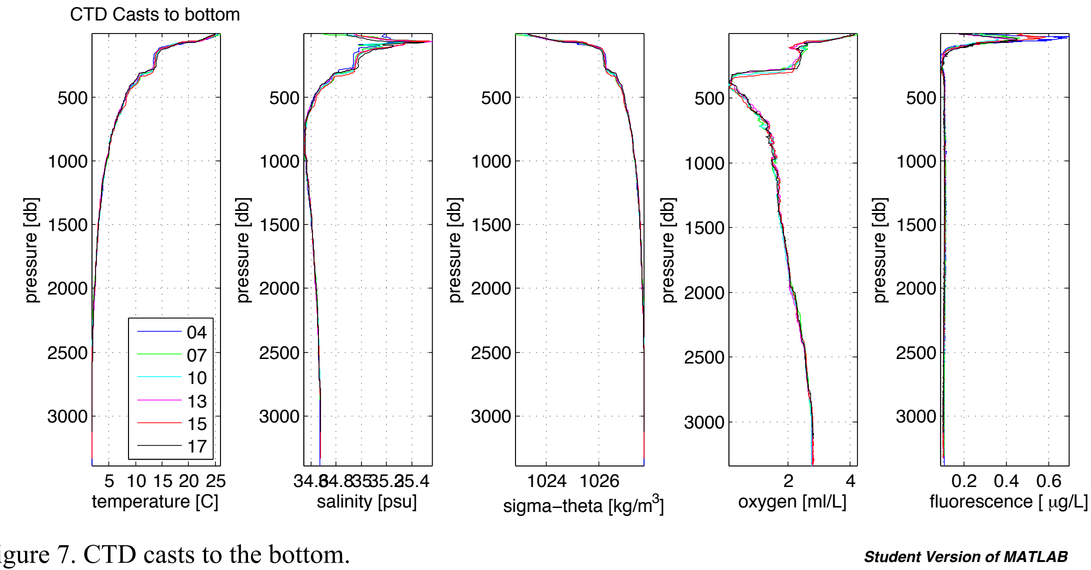


Figure 7. CTD casts to the bottom.

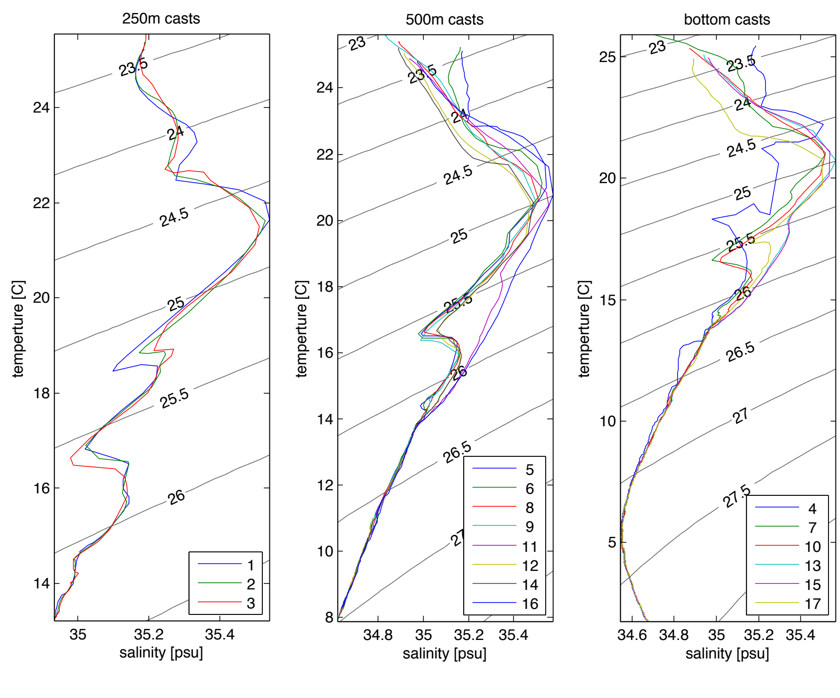


Figure 8. Temperature-Salinity plots.

Water samples

Water samples were collected from all CTD casts (with the exception of casts 2,13, and 15) from 5 depth levels: the depth extremes of the CTD cast (i.e. shallowest and deepest depths sampled by the CTD), the chlorophyll maximum and two bottles dispersed in between. From each depth, we collected approximately 30 ml of seawater which we kept frozen at -80°C. Refer to Table 1 for a complete list of the samples taken.

Table 1. Times and locations of water samples where (*) denotes a cast near the macro-wirewalker with all other casts near the mini-wirewalkers. Depths in **bold** indicate the depths of the chlorophyll maximum. (Salinity failed on cast 004.)

Cast #	Latitude	Longitude	Bottle #	Date & Time (UTC)	Depth (m)
001			1-1	7 June 2012 14:19	250
001			1-2	7 June 2012 14:22	150
001			1-3	7 June 2012 14:25	100
001			1-4	7 June 2012 14:29	**45**
001			1-5	7 June 2012 14:32	0.8
003*	0	94° 56 W	3-1	7 June 2012 18:57	250
003*	0	94° 56 W	3-2	7 June 2012 19:01	150
003*	0	94° 56 W	3-3	7 June 2012 19:04	100
003*	0	94° 56 W	3-4	7 June 2012 19:06	**45**
003*	0	94° 56 W	3-5	7 June 2012 19:09	0.5
004	0	94° 47 W	4-1	8 June 2012 00:23	250
004	0	94° 47 W	4-2	8 June 2012 00:32	150
004	0	94° 47 W	4-3	8 June 2012 00:33	100
004	0	94° 47 W	4-4	8 June 2012 00:36	**40**
004	0	94° 47 W	4-5	8 June 2012 00:39	2.1
005	0° 6 S	94° 41.4 W	5-1	8 June 2012 16:31	255
005	0° 6 S	94° 41.4 W	5-2	8 June 2012 16:36	154

Cast #	Latitude	Longitude	Bottle #	Date & Time (UTC)	Depth (m)
005	0^o 6 S	94^o 41.4 W	5-3	8 June 2012 16:43	101
005	0^o 6 S	94^o 56 W	5-4	8 June 2012 16:48	**51**
005	0^o 6 S	94^o 41.4 W	5-5	8 June 2012 16:52	1
006*	0	94^o 26 W	6-1	8 June 2012 19:41	249
006*	0	94^o 26 W	6-2	8 June 2012 19:48	152
006*	0	94^o 26 W	6-3	8 June 2012 19:52	102
006*	0	94^o 26 W	6-4	8 June 2012 19:55	**53**
006*	0	94^o 26 W	6-5	8 June 2012 19:59	3
007	0	94^o 5 W	7-1	9 June 2012 02:07	260
007	0	94^o 5 W	7-2	9 June 2012 02:16	160
007	0	94^o 5 W	7-3	9 June 2012 02:18	110
007	0	94^o 5 W	7-4	9 June 2012 02:22	**49**
007	0	94^o 5 W	7-5	9 June 2012 02:28	0
008	0	93^o 49 W	8-1	9 June 2012 16:56	233
008	0	93^o 49 W	8-2	9 June 2012 17:00	150
008	0	93^o 49 W	8-3	9 June 2012 17:03	102
008	0	93^o 49 W	8-4	9 June 2012 17:06	**52**
008	0	93^o 49 W	8-5	9 June 2012 17:10	3
009*	0	93^o 49 W	9-1	9 June 2012 19:27	251
009*	0	93^o 58 W	9-2	9 June 2012 19:31	152
009*	0	93^o 58 W	9-3	9 June 2012 19:33	100
009*	0	93^o 58 W	9-4	9 June 2012 19:36	**46**
009*	0	93^o 58 W	9-5	9 June 2012 19:39	3
010	0^o 14 S	93^o 48 W	10-1	10 June 2012 01:43	254
010	0^o 14 S	93^o 48 W	10-2	10 June 2012 01:45	156

Cast #	Latitude	Longitude	Bottle #	Date & Time (UTC)	Depth (m)
010	0^{o} 14 S	93^{o} 48 W	10-3	10 June 2012 01:48	100
010	0^{o} 14 S	93^{o} 48 W	10-4	10 June 2012 01:51	**47**
010	0^{o} 14 S	93^{o} 48 W	10-5	10 June 2012 01:53	2
011	0^{o} 25 S	93^{o} 39 W	11-1	10 June 2012 14:31	250
011	0^{o} 25 S	93^{o} 39 W	11-2	10 June 2012 14:34	150
011	0^{o} 25 S	93^{o} 39 W	11-3	10 June 2012 14:38	102
011	0^{o} 25 S	93^{o} 39 W	11-4	10 June 2012 14:41	**51**
011	0^{o} 25 S	93^{o} 39 W	11-5	10 June 2012 14:44	4
012*	0^{o} 25 S	93^{o} 35 W	12-1	10 June 2012 16:54	241
012*	0^{o} 25 S	93^{o} 35 W	12-2	10 June 2012 16:58	153
012*	0^{o} 25 S	93^{o} 35 W	12-3	10 June 2012 17:01	104
012*	0^{o} 25 S	93` 35 W	12-4	10 June 2012 17:05	**43**
012*	0^{o} 25 S	93^{o} 35 W	12-5	10 June 2012 17:09	3
014*	0^{o} 16 S	93^{o} 29 W	14-1	10 June 2012 23:30	252
014*	0^{o} 16 S	93^{o} 29 W	14-2	10 June 2012 23:34	152
014*	0^{o} 16 S	93^{o} 29 W	14-3	10 June 2012 23:36	103
014*	0^{o} 16 S	93^{o} 29 W	14-4	10 June 2012 23:39	**41**
014*	0^{o} 16 S	93^{o} 29 W	14-5	10 June 2012 23:42	2
016	0^{o} 34 S	93^{o} 30 W	16-1	11 June 2012 14:20	251
016	0^{o} 34 S	93^{o} 30 W	16-2	11 June 2012 14:24	152
016	0^{o} 34 S	93^{o} 30 W	16-3	11 June 2012 14:27	103
016	0^{o} 34 S	93^{o} 30 W	16-4	11 June 2012 14:30	**72**
016	0^{o} 34 S	93^{o} 30 W	16-5	11 June 2012 14:35	3
017*	0^{o} 18 S	93^{o} 13 W	17-1	11 June 2012 19:25	249
017*	0^{o} 18 S	93^{o} 13 W	17-3	11 June 2012 19:33	103

Cast #	**Latitude**	**Longitude**	**Bottle #**	**Date & Time (UTC)**	**Depth (m)**
017*	0^o 18 S	93^o 13 W	17-4	11 June 2012 19:39	**63**
017*	0^o 18 S	93^o 13 W	17-5	11 June 2012 19:43	2

Wirewalkers

Wirewalkers are wave-powered vertically profiling platforms that rachet down a wire and float up freely. the vertical wire or line was suspended from a free-floating buoy with a 40 or 200 lb bottom weight, depending on the size of the wirewalker. The wirewalker reverses its profiling direction (up/down) when it reaches the bottom weight, hits an intermediate stopper, or the surface buoy.

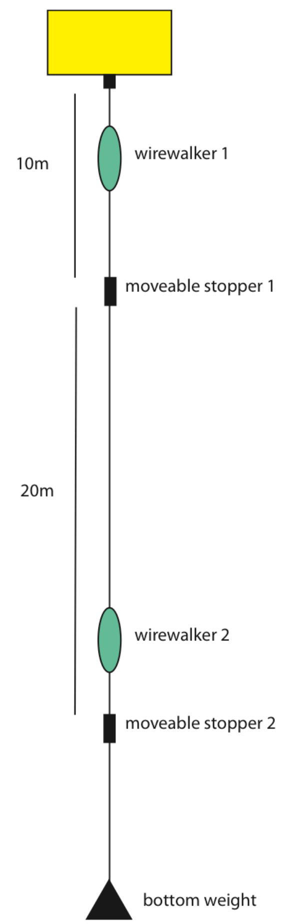


Figure 9. Schematic of setup with two Mini-Wirewalkers.

In this experiment we deployed two types of wirewalkers: a bigger version equipped with a CTD, a fluorometer and an acoustical current meter, called 'The Macro', and six smaller wirewalkers with temperature and pressure recorders, which we call 'Minis'. We deployed the Minis in two different configurations. In one configuration, two wirewalkers were deployed on the same vertical wire or line with a stopper acting to separate the shallow (0-10 m) and deeper (10-20 m) wirewalker (Fig. 9). This double-wirewalker configuration allowed for an increased sampling rate of the water column for even greater temporal resolution. The second configuration contained only one wirewalker which sampled to a depth of 30 m.. The setup with two wirewalkers on one line is novel and had only been tested once before during a short time deployment off the Scripps pier.

The buoys floated freely with the (sub)surface currents and wind depending on the depth of the setup and the drag on the various elements (buoy, wirewalker, wire, weight). The tracks of the buoys are shown in Fig. 10 (each buoy had a GPS and sent its postion over the Iridium satellite network). The Macro drifted predominantly eastward at a rate of about half a degree longtude (~55km) per day. The Minis drifted to the SE at a slightly slower rate. The different drift is consistent with the equatorial current system: the Macro profiled to a depth of about 125 m and was mostly dragged eastward by the EUC (core depth ~70 m), and the shallower Minis (weight at ~45 m) moved predominantly with the surface currents that diverge from the equator and with the (untypical) northerly winds (Fig. 2).

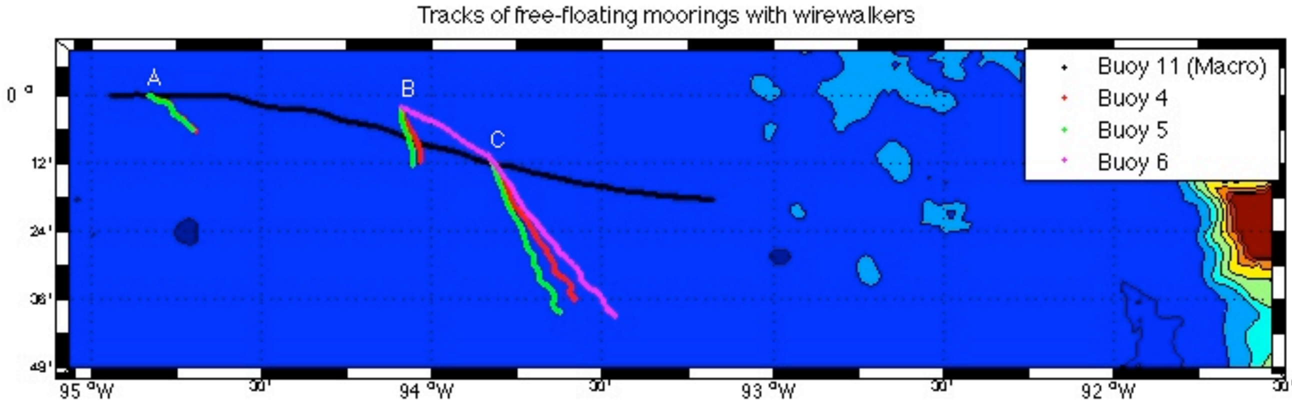


Figure 10. Tracks of wirewalker buoys. The Minis were first deployed at site A on June 7, around 0900 LT. The Macro was deployed about 10 nm west at 1358 LT on the same day. The Minis were recovered twice during the experiment and redeployed at sites B and C.

Mini-wirewalkers

The Minis were deployed a triangle configuration (about 250 m apart) on the morning of June 7 in calm conditions (wind speed ~5 m/s) near 0° 0.02' S and 94° 49.99' W. After deployment they drifted towards the SE and stayed within a couple of nm of each other (Fig. 10). The next morning we noticed that buoy #6's trajectory diverged from those of buoys #4 and #5. When appraoching buoy #6 we discovered that the line was broken (Fig. 11) and we recovered the buoy around 0730 LT (without the two Minis). The other Mini-buoys were recovered shortly after to inspect the ropes.

Figure 11. Pictures of the shredded line on buoy #6 as recovered at 0730, June 7 LT. The line might have been damaged by a fish/shark bite. A school of Mahis was seen around the buoy in the evening and early moring. The Mahis are similar in size and coloring to the Minis which might have confused a bigger fish preying on them. The line will wear down once the jacket is damaged due to the repeated action of the cam on the weak spot when the line does not feed through the cam anymore. This could also happen when the jacket had a manufacturing defect (which we deem unlikely).

The lines on the other buoys had no sings of damage or wear. We outfitted buoy #6 with a pre-terminated 100 m long line and re-deployed the Minis around 1600 LT the same day near 0º 1.70' S and 94º 5.70' W (almost a degree east of the first deployment site and about 20 nm ahead of the eastward drifting Macro). The next morning we noticed that buoy #6 had drifted about 15" more east compared to #4 and #5 (Fig. 9) which we attributed to the deeper bottom weight (at ~100 m instead of ~46 m). We recovered buoys #4 and #5 around 0630 LT and #6 around 0940 LT. Buoy #6 was re-terminated to 46 m and re-deployed at 0959 LT and the other buoys were re-deployed shortly after. Refer to Table 2 for an overview of the Mini deployments.

Table 2. Mini deployments.

Deployment 1: June 7 ~0900	**Mini**	**bottom weight depth/weight**
Buoy #4	#2 (0-10m), #1 (10-30m)	45.5 m / 40 lbs
Buoy #5	#4 (0-10m), #3 (10-30m)	45.5 m / 42.5 lbs
Buoy #6	#6 (0-10m), #5 (10-30m)	46.3 m / 40 lbs
Deployment 2: June 8 ~1630	**Mini**	**bottom weight depth/weight**
Buoy #4	#2 (0-30m)	45.5 m / 40 lbs
Buoy #5	#4 (0-10m), #3 (10-30m)	45.5 m / 42.5 lbs
Buoy #6	#1 (0-30m)	100 m / ~60 lbs
Deployment 3: June 9 ~1000	**Mini**	**bottom weight depth/weight**
Buoy #4	#2 (0-30m)	45.5 m / 40 lbs
Buoy #5	#4 (0-10m), #3 (10-30m)	45.5 m / 42.5 lbs
Buoy #6	#1 (0-30m)	46 m / ~60 lbs

The full record of all Mini measurements is shown in Fig. 12. The data from buoys #4 and #5 is of good to excellent quality throughout the experiment. Due to the loss of the instruments on buoy #6 there is no data from the first deployment and the data from subsequent deployments shows that the Mini 1 on buoy #6 did not profile with the 100 m line, which we ascribe to the drag of the EUC on the line and weight. Shortening the line to 46 m in the morning of June 9 improved the profiling although there were some remaining issues in the night from June 9 to June 10 when the wirewalker only profiled between 12-22 m. It is not clear what caused this problem. The setup and Mini on buoy 6 were identical to the other buoys, except for a 20 lb heavier weight (Table 2) and a slight difference in the magnetic latch on the Wirewalker cam (latch magnet was not screwed in as far and the white ring on the stopper rod was slightly tighter to the cam).

The temperature record from the first deployment is shown in Fig. 13 and the second deployment in

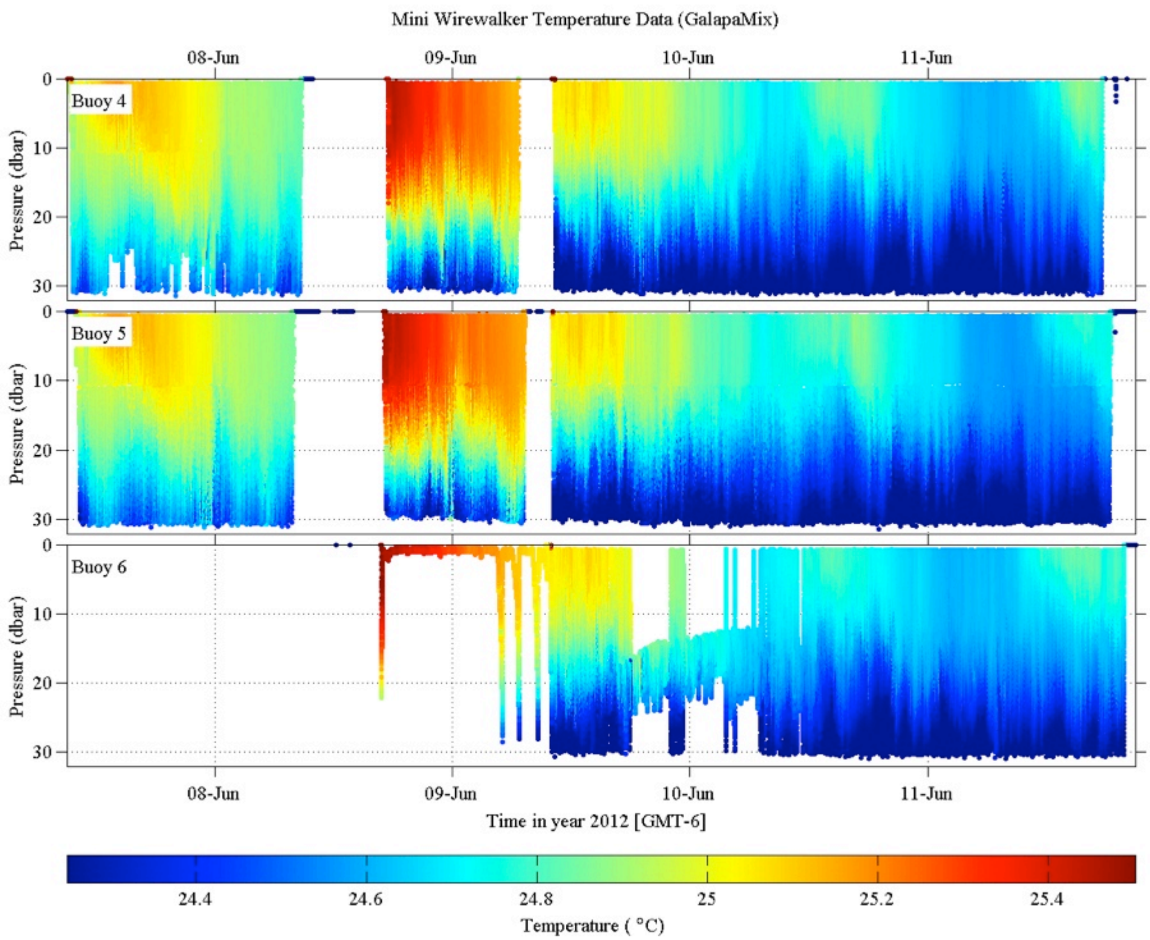


Figure 12. Full record of all temperature and pressure data collected by the Mini-Wirewalkers.

Fig. 14. The wirewalkers on buoy 4 had some trouble walking down during the first deployment. In an attempt to address this issue we added 5 ballasting washers to the Mini-wirewalkers to decrease their buoyancy. The record from the second deployment shows that the profiling improved for the Minis on buoy 4 (Fig. 14).

The cycle periods of the Minis is 1.7-1.9 minutes in the top 10 m, 1.7-4.3 minutes in the 10-20 m range and 5.0-7.5 minutes when profiling over 0-30 m (Table 3). Profiling speeds are lower in the top 10 m because the vertical movement of the line with respect to the ambient fluid is less near the surface and because it takes some time for the wirewalker to accelerate to terminal velocity when floating up. Cycle periods in deployments II and III are slightly longer than during deployment I which we attribute to the different ballasting of the wirewalkers (we added 5 washers after deployment I). Mini #1 profiled slower than the other Minis, which may be related to the above discussed cam issue.

Isotherm oscillations with a 1-3 m amplitude and a period of 18-25 minutes (Figs. 13 and 14) are well resolved by the Mini data set. These oscillations extend to within the upper couple of meters from the surface when the surface layer is stratified (see June 7-9) and they are visible below 10 m when the top layer is well mixed (June 10-11).

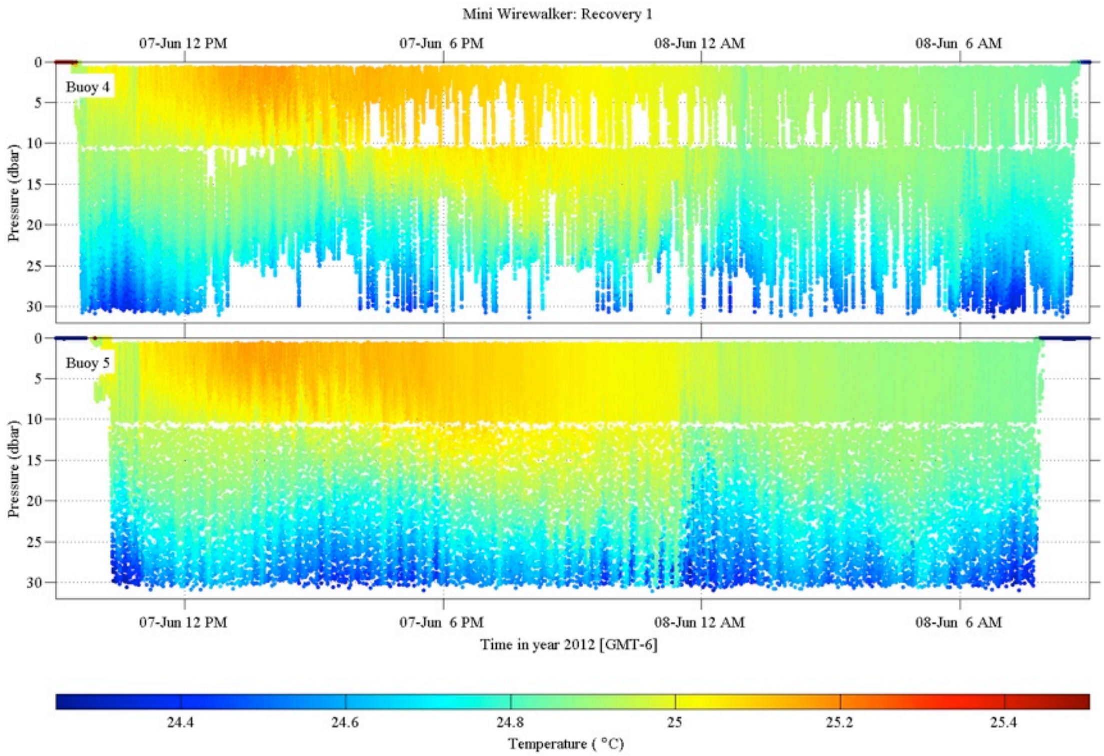


Figure 13. Scatter plot of data from first deployment of buoys 4 and 5.

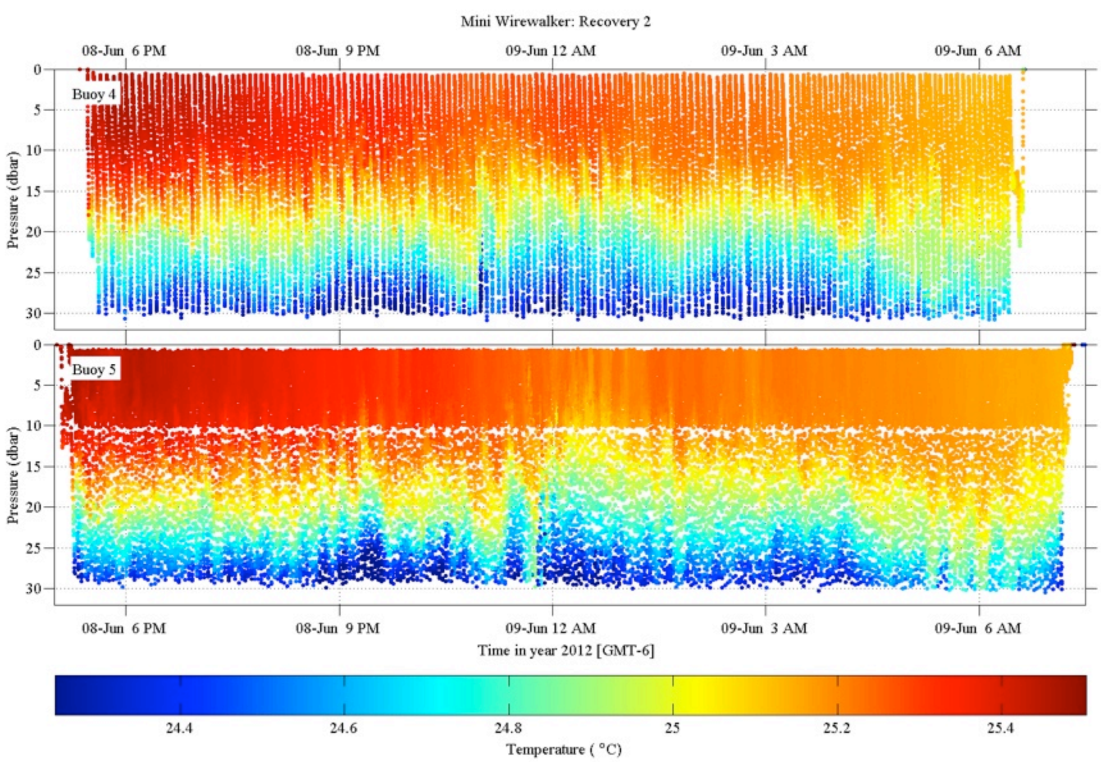


Figure 14. Scatter data from second deployment of buoys 4 and 5. The Mini-wirewalkers were ballasted with 5 more washers compared to the first deployment

A diurnal surface layer (DSL) developed during the first day of the experiment (June 7) when the winds were weak 5-6 m/s. This feature deepened to about 20 m during the afternoon and evening and quickly dissappeared after midnight. The next day we passed the front discussed in the Met section when the Minis were on deck. By the time they were redeployed the water temperature had increased by about 0.5 ^oC. Heating of the surface layer was weak in the subsequent days. It is not obvious how this relates to the wind stress because variations in wind speed were small (Fig. 2). Mixing in the surface layer might be related to Langmuir circulation which needs winds speeds of at least 5-8 m/s.

Table 3. Cycle periods of Minis. We added 5 ballasting washers to all the Minis after deployment I.

Deployment	Buoy #	Mini #	Range [m]	Period [min.]
I	4	2	0-10	1.7
	4	1	10-20	2.3
	5	4	0-10	1.7
	5	3	10-20	1.7
II	4	2	0-30	5.0
	5	4	0-10	1.9
	5	3	10-20	2.5
III	4	2	0-30	5.0
	5	4	0-10	1.9
	5	3	10-20	4.3
	6	1	0-30	7.5

Macro-wirewalker

The Macro-wirewaker sampled continuously throughout the experiment between about 1 and 125 m collecting CTD and fluorometer data at 16 Hz and horizontal velocity at 1 Hz. The simultaneous aquisition of these variables provides a unique, high resolution (Δz=1-2 m, Δt=14 min) data set of vertical shear, density, and fluorescence in the top 125 m of the equatorial ocean.

The profiling performance of the Macro was remarkably good considering that it profiled through a ~1 m/s strong EUC. In a previous experiment (DYNAMO, Indian Ocean Dec 2011), the profiling of similar Macro-Wirewalkers was often hampered by the shear between the westward South Equatorial Current (SEC) and the eastward EUC. Causes for better performace in this experiment may include: (i) the virtual absence of a SEC during our deployment, (ii) the use of a heavier bottom weight (~200 lbs), (iii) and potentially more buoyancy of the wirewalker (this is not confirmed).

Table 4. Instruments on the Macro-wirewalker.

Variable	Instrument
C, T, P	SBE 49 sampling at 16 Hz
F (chl a)	Turner designs Cyclops 7 analog fluorometer sampled at 16 Hz
u, v	Nortek Aquadopp sampling at 1 Hz

Upcast data from the CTD and the fluorometer are shown in Fig. 15. The main features in the data are the typical salinity maximum at the core of the EUC and the passage of the previously discussed front in the afternoon of June 8. This front is more clear in Fig. 16 which shows the temperature profile in the top 30 m. Chlorophyll fluorescence has a clear diurnal cycle with maxima at night and minima around noon (we think that the low chlorophyll values during the day are indicative of a saturation response in the phytoplankton due to solar irradiance).

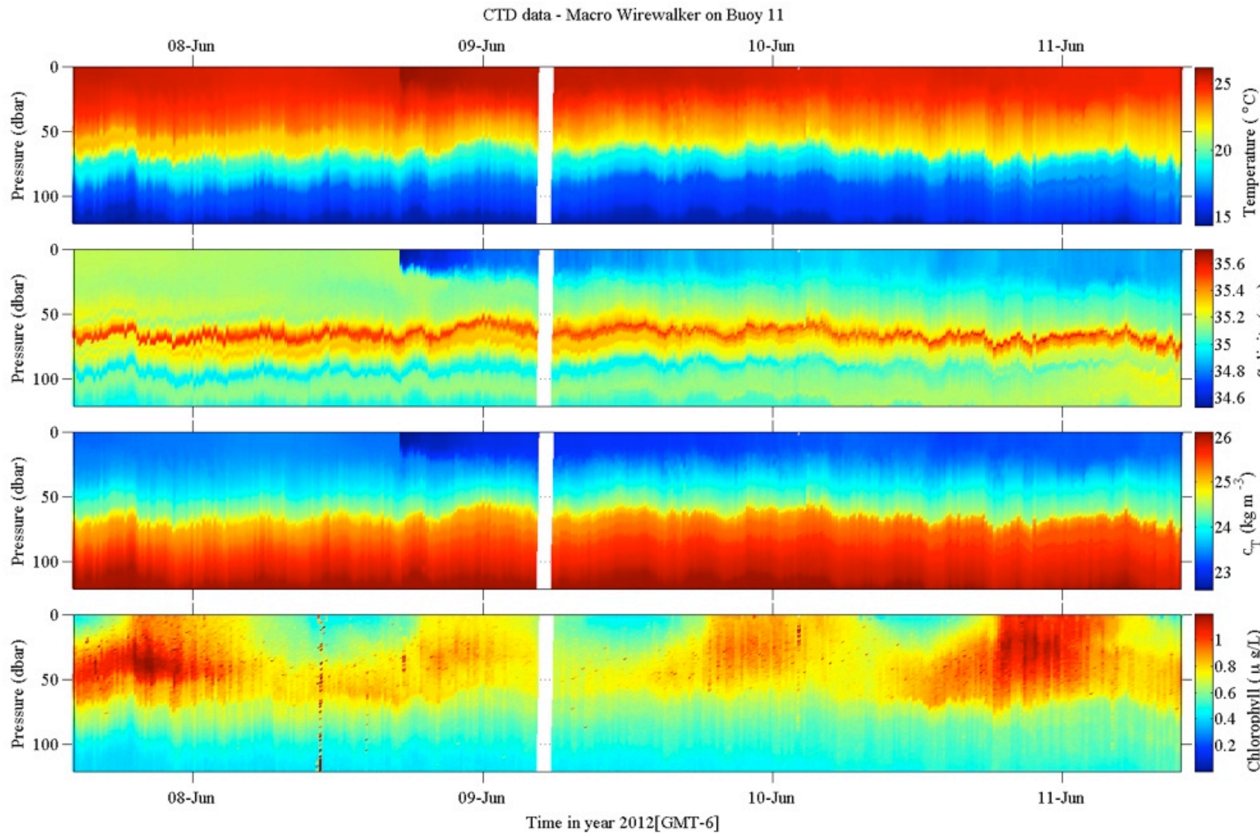


Figure 15. Temperature, salinity, potential density, chlorophyll concentration from the CTD and fluorometer on the Macro-wirewalker.

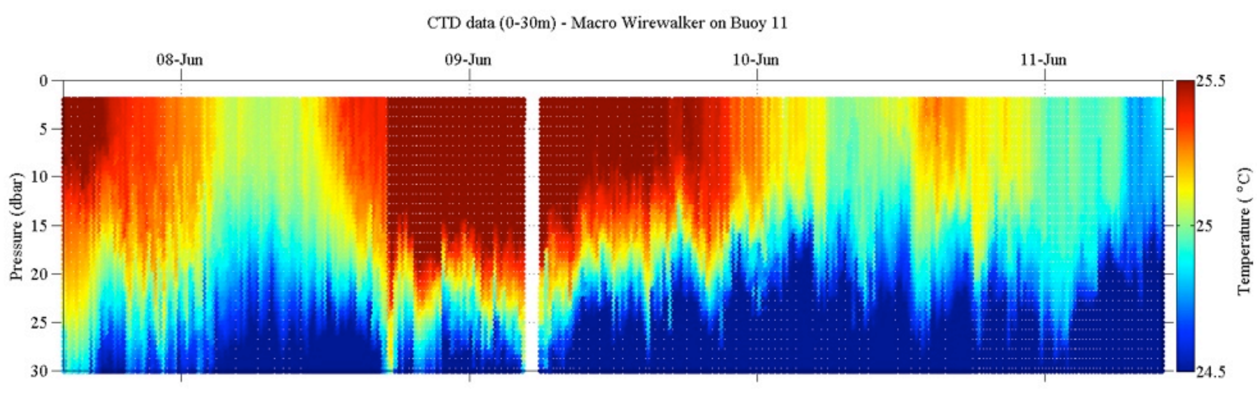


Figure 16. Temperature in the top 30 m from the CTD on the Macro-wirewalker.

Current Profiler

The Aquadopp acoustic current profiler measured u,v, and w velocity components every second in a 0.75^3 m^3 volume above the Macro wirewalker. The data shown in Fig. 17 has been binned in 2 dbar vertical bins and includes data from the upcast only. Downcast data was disregarded because the walk down is 'jerky' and produces lesser quality data compared to the smooth upcast when the wirewalker floats freely to the surface. (Jerky downward motion is caused by the abrupt engagement of the wirewalker cam when the wire is pulled down by the bottom weight.) The typical round trip time of the wirewalker was 14 minutes and the profiling depth is ~125 m. The average profiling speed is thus ~0.3 m/s and the average number of samples per 2 m vertical bin is 2.8.

The horizontal velocity components with respect to the Macro are shown in Fig. 17. The zonal velocity at the core of the EUC is larger than 1 m/s at times during the first days of the deployment, while the Macro itself is drifting eastward at an average speed of aout 0.6 m/s. The negative zonal velocity above the EUC is mostly due to the eastward propagation of the Macro (there is almost no westward SEC). The Aquadopp data record is shorter than the deployment period because the battery pack petered out in the afternoon of June 10 (Fig. 18).

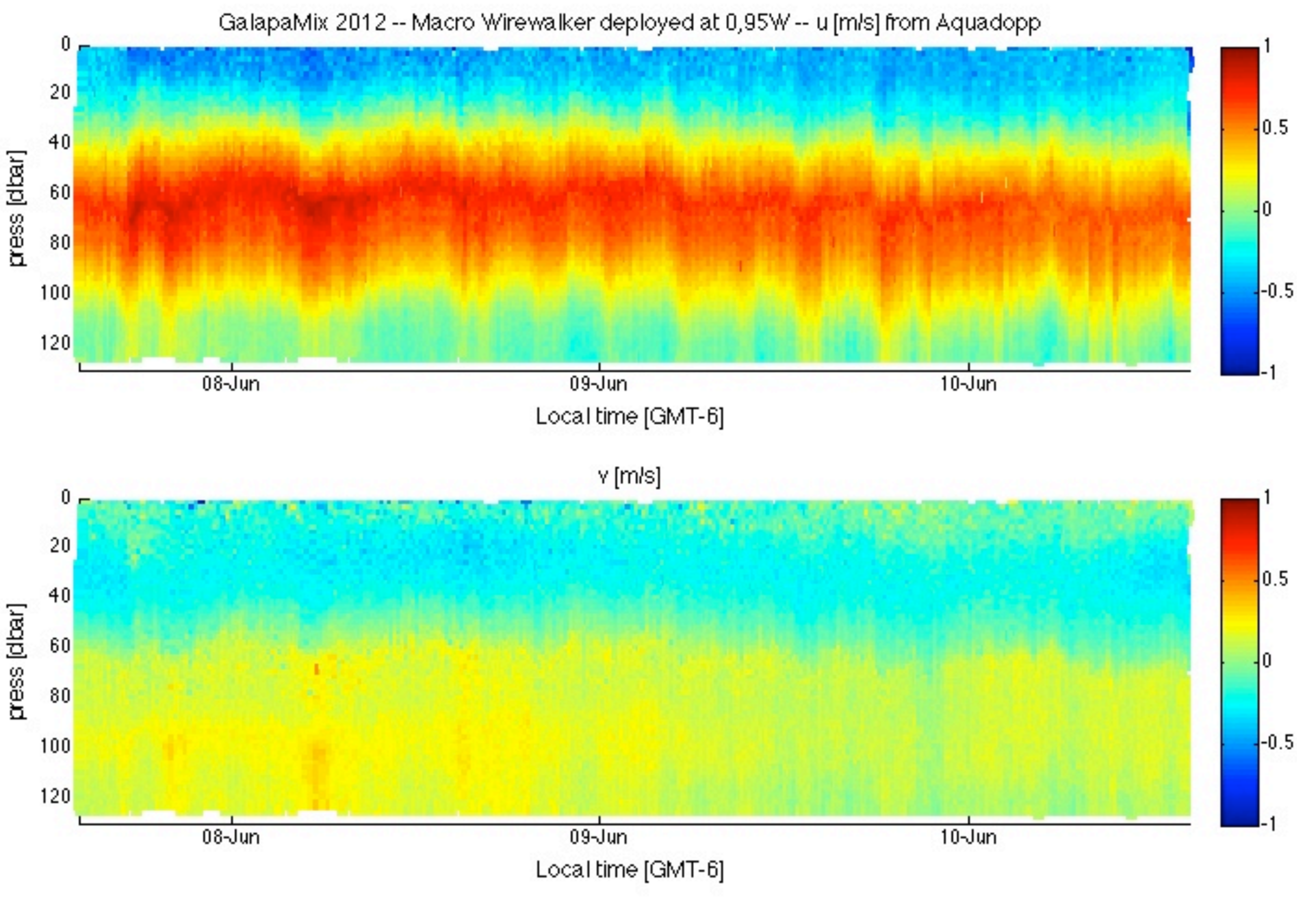


Figure 17. Horzontal velocity components (u positive east, v positive north) as measured by the Aquadopp current profiler on the Macro Wirewalker.

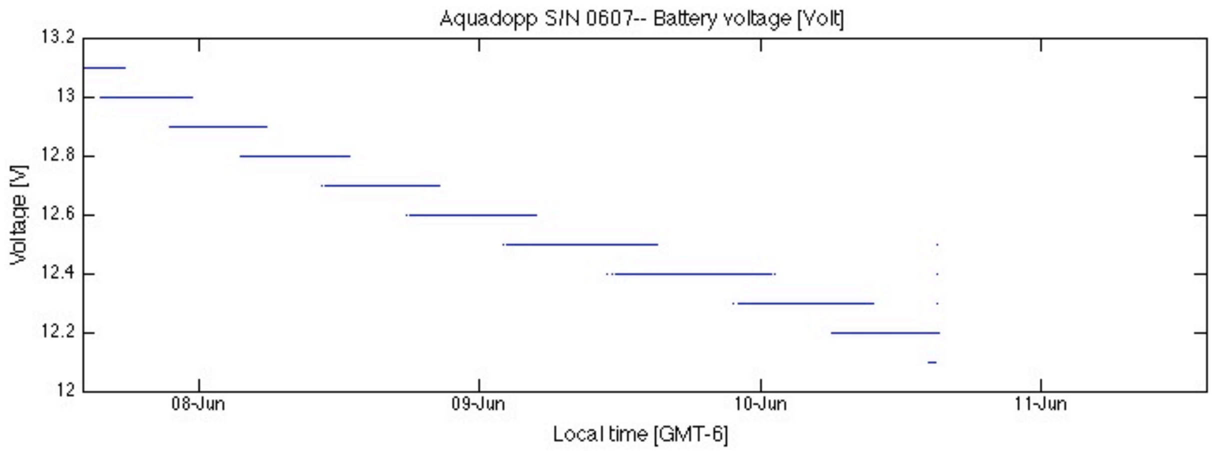


Figure 18. Battery voltage of the Aquadopp current meter.

Shipboard ADCP sections

Keywords: Equatorial Undercurrent (EUC), Galapagos, climate system, El Nino Southern Oscillation (ENSO)

The EUC is a critical part of the climate system and in part of the El Nino Southern Oscillation (ENSO) system. There have been surprisingly few measurements of the EUC near the Galapagos. People are still relying on measurements made by John Knaus when he was at Scripps around 1960. Kris Karnauskas wrote a recent paper (Karnauskas, etal, 2010, Journal of Physical Oceanography, 40, 2768-2777) combining all the ADCP measurements near the Galapagos and there is no data north of Isabela Island. These measurements will also help plan a proposed collaborative effort with INOCAR to use Spray gliders to study the EUC in the vicinity of the Galapagos.

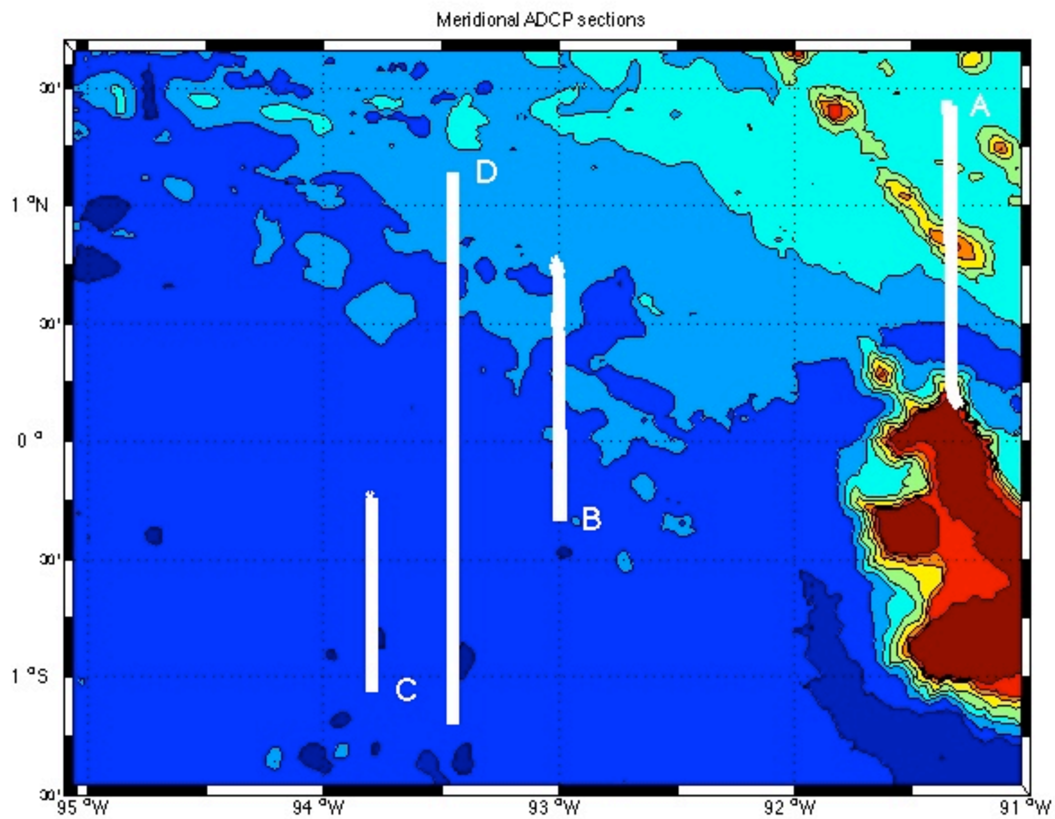


Figure 19. Map of the meridional ADCP sections.

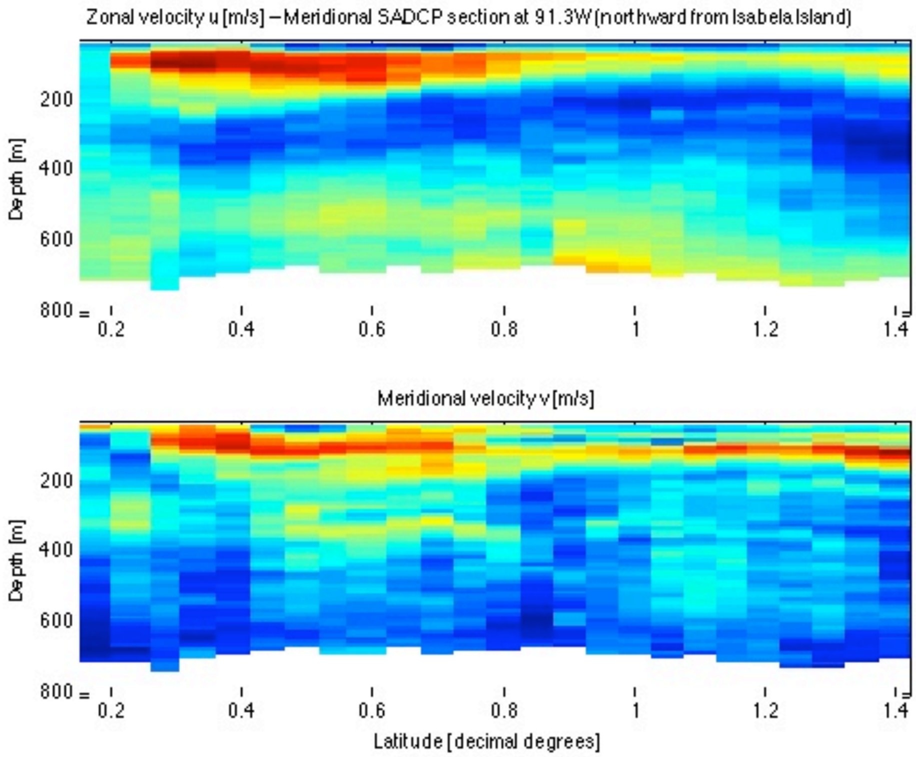


Figure 20. ADCP section A.

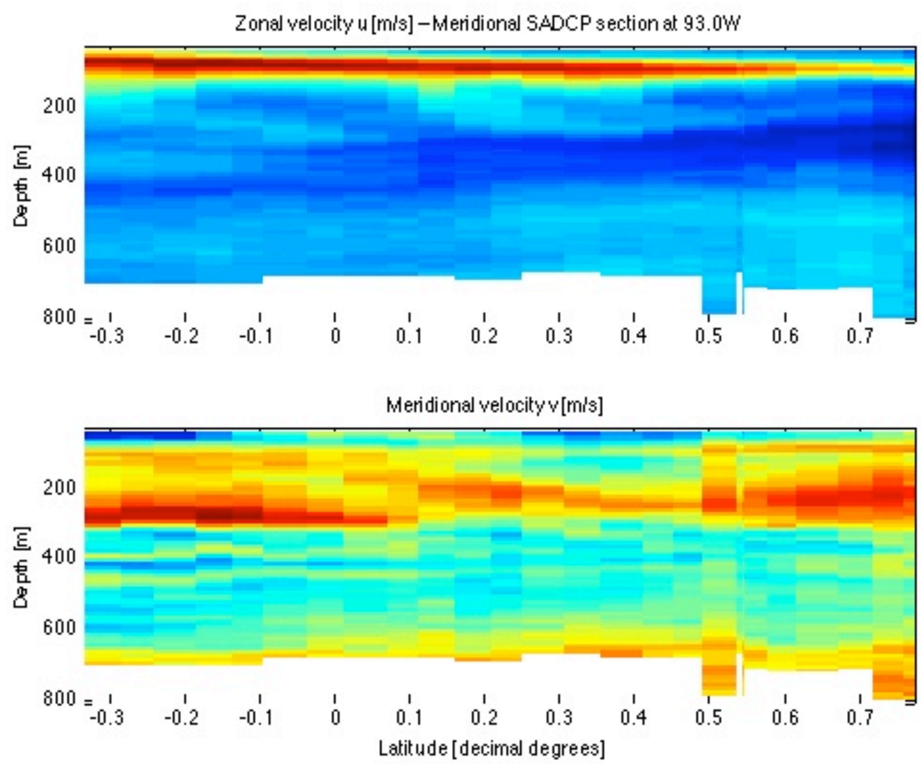


Figure 21. ADCP section B.

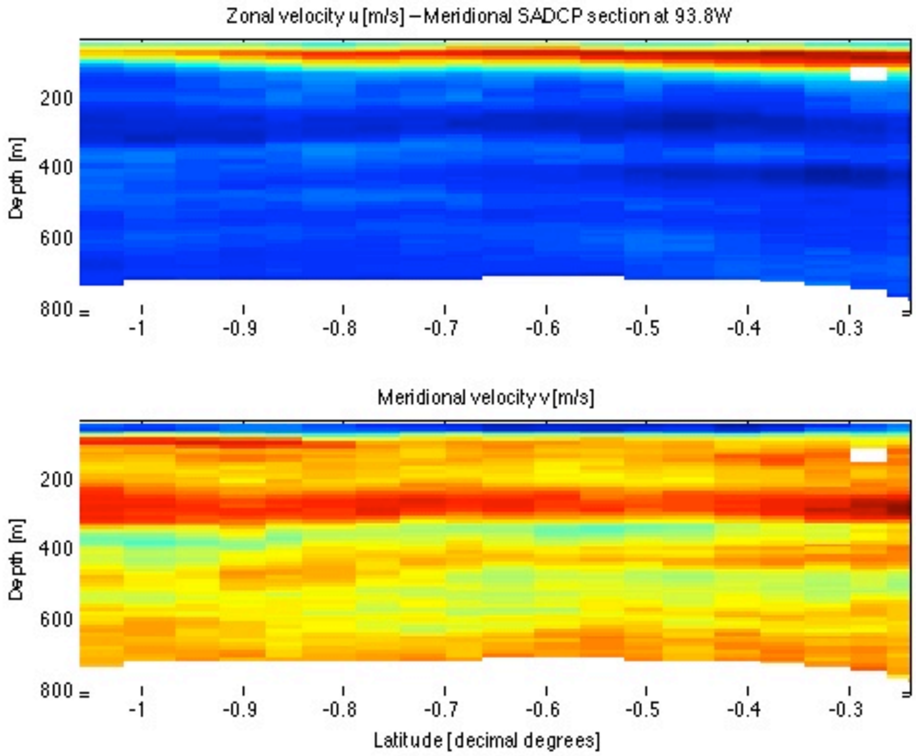


Figure 22. ADCP section C.

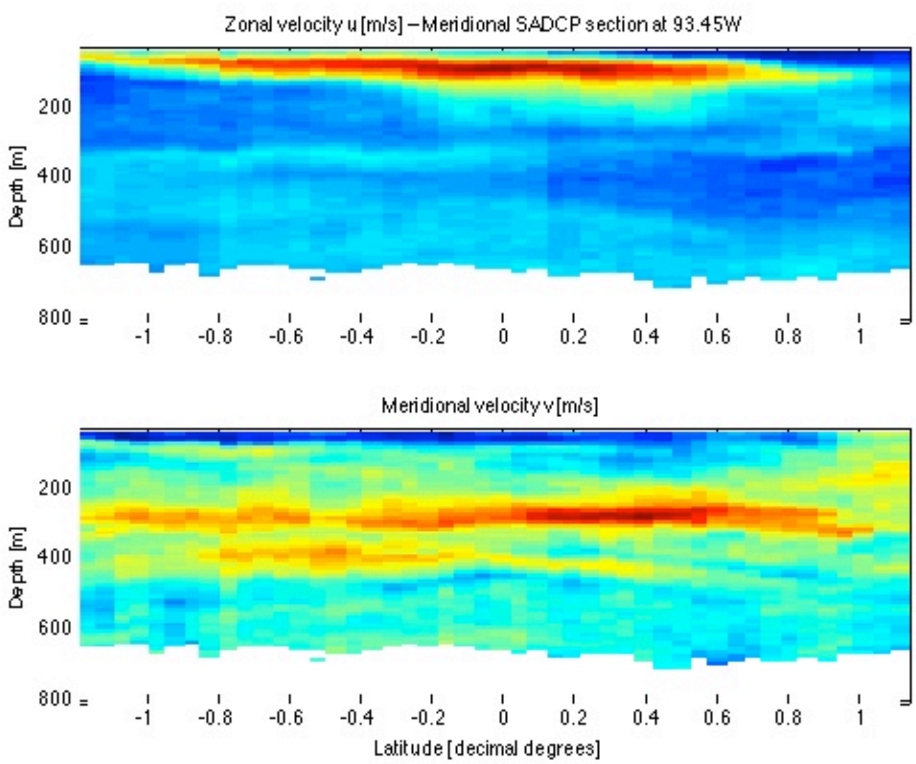


Figure 23. ADCP section D.

Argo floats

We deployed 11 SOLO II floats for Dean Roemmich at SIO (Table 5). All floats have succesfully reported data to SIO.

Table 5. Excerpt from the ship's event log with date, time, latitude, longitude, deployment number and serial number of the deployed floats.

20120613 1734 5 00.072N. 96 28.054W.ARGO #1 #8065 DEPLOYED EC
20120614 0032 5 59.808N. 97 15.217W.ARGO #2 #8086 Deployed JF
20120614 0729 7 00.025N. 98 02.836W.ARGO #3 #8088 Deployed DJ
20120614 1424 8 00.074N. 98 50.439W.ARGO #4 #8089 deployed DM
20120614 2052 8 59.913N. 99 37.975W.ARGO #5 #8090 Deployed DJ
20120615 0257 10 00.101N. 100 25.927W.ARGO #6 #8091 DEPLOYED EC
20120615 0912 11 00.109N. 101 13.892W.ARGO #7 #8092 Deployed DJ
20120615 1545 12 00.023N. 102 01.943W.ARGO #8 #8093 DEPLOYED EC
20120615 2037 12 45.088N. 102 38.202W.ARGO #9 #8094 Deployed DJ
20120616 0128 13 30.029N. 103 14.470W.ARGO #10 #8095 Deployed JF
20120616 0625 14 14.969N. 103 50.856W.ARGO #11 #8096 DEPLOYED EC

Echosounder

Amanda: For my dissertation I am building a habitat model that predicts the vertical extent of deep scattering layer (DSL) organisms. The key hypotheses are that bottom up forces (e.g., oxygen in the Northeastern Pacific) set the lower boundary, and top down forces (e.g., predation) set the upper boundary. My lab is preparing a proposal to NSF to test these hypotheses on a cruise track from San Diego to waters off of southern Baja, Mexico, where oxygen concentrations are much lower and the hypoxic boundary layer much shallower. We will use a Simrad EK-60 four-frequency echo sounder to sample DSL layers, accompanied by trawl catches and metabolic measurements. The data collected on the Galapagos cruise will contribute significantly to the proposal by providing preliminary data on the vertical extent of deep scattering layers in the region of interest.

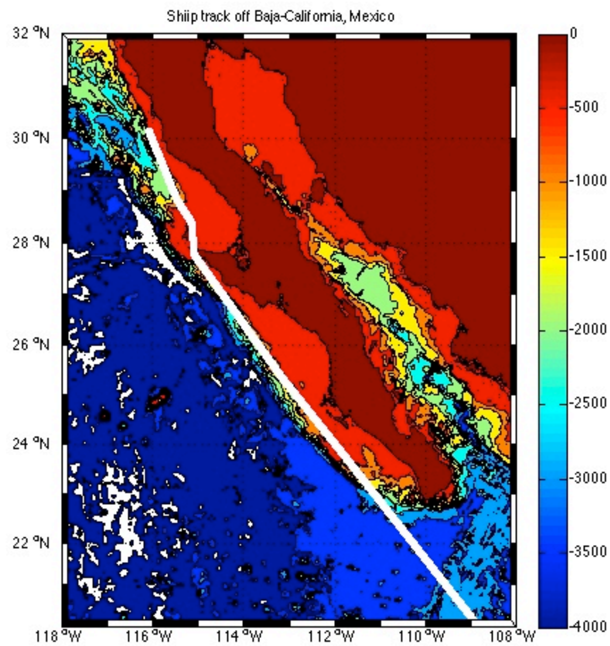


Figure 24. Track of the deep scattering layer survey with the 12 kHz Knudsen echosounder (the last position is at 1520, June 20 (LT).

Ship's event log

20120605 2200 0 45.204S. 90 18.051W.Departure Puerto Ayora
20120607 1405 0 00.026S. 94 50.315W.CTD #1 DEPLOYED EC
20120607 1415 0 00.005N. 94 50.224W.CTD #1 @ 250M EC
20120607 1437 0 00.191N. 94 49.894W.CTD #1 ON DECK EC
20120607 1535 0 00.003S. 94 49.995W.MINI BUOY #4 DEPLOYED,RDF 154.585 Mhz EC
20120607 1615 0 00.067S. 94 49.718W.MINI BUOY #5 DEPLOYED EC
20120607 1642 0 00.128S. 94 49.378W.MINI BUOY #6 DEPLOYED EC
20120607 1706 0 00.224S. 94 49.552W.CTD #2 DEPLOYED EC
20120607 1716 0 00.219S. 94 49.391W.CTD #2 @ 250M EC
20120607 1726 0 00.221S. 94 49.302W.CTD #2 ON DECK EC
20120607 1848 0 00.242S. 94 57.004W.CTD #3 Deployed DJ
20120607 1900 0 00.122S. 94 56.844W.CTD #3 @ 250 DJ
20120607 1915 0 00.018N. 94 56.647W.CTD #3 ON DECK DJ
20120607 1956 0 00.019N. 94 56.446W.MACRO Deployed DJ RDF Freq.160.785 MHz
20120607 2026 0 00.615S. 94 57.842W.CTD #4 Deployed JF
20120607 2230 0 00.905S. 94 47.208W.CTD #4 at 3305M JF
20120608 0004 0 00.872S. 94 46.974W.CTD #4 on deck JF
20120608 1320 0 06.095S. 94 41.674W.MINI BUOY #6(GREEN) ON DECK, MISSING WALKER EC
20120608 1357 0 06.045S. 94 42.134W.MINI BUOY #5(PINK) ON DECK
20120608 1450 0 06.474S. 94 41.392W.MINI BUOY #4(BLUE) ON DECK
20120608 1600 0 06.292S. 94 41.400W.CTD #5 DEPLOYED EC
20120608 1619 0 06.302S. 94 41.150W.CTD #5 @ 500M EC
20120608 1655 0 06.345S. 94 40.666W.CTD #5 ON DECK EC
20120608 1914 0 02.258S. 94 26.495W.CTD #6 Deployed DJ
20120608 1930 0 02.174S. 94 26.326W.CTD #6 @ 500M DJ
20120608 2006 0 01.800S. 94 25.678W.CTD #6 On Deck DJ
20120608 2256 0 01.865S. 94 05.485W.MINI #6 deployed JF
20120608 2314 0 02.074S. 94 05.233W.MINI #5 deployed JF
20120608 2332 0 02.374S. 94 05.029W.MINI #4 deployed JF
20120609 0003 0 02.498S. 94 05.471W.CTD #7 deployed JF
20120609 0112 0 02.473S. 94 05.296W.CTD #7 at 3224M JF
20120609 0230 0 02.528S. 94 04.955W.CTD #7 ON DECK EC
20120609 1224 0 11.290S. 94 02.025W.MINI #4 along side KG
20120609 1310 0 12.378S. 94 03.452W.MINI #5 along side KG
20120609 1536 0 10.456S. 93 50.350W.MINI BUOY #6 ON DECK EC
20120609 1558 0 10.682S. 93 50.040W.MINI BUOY #6 DEPLOYED EC
20120609 1612 0 10.909S. 93 49.866W.MINI BUOY #5 DEPLOYED EC
20120609 1620 0 11.023S. 93 49.794W.MINI BUOY #4 DEPLOYED EC
20120609 1634 0 11.403S. 93 49.635W.CTD #8 DEPLOYED EC
20120609 1648 0 11.452S. 93 49.434W.CTD #8 @ 500M EC
20120609 1713 0 11.512S. 93 48.996W.CTD #8 ON DECK EC
20120609 1908 0 09.289S. 93 58.124W.CTD #9 Deployed DJ
20120609 1924 0 09.206S. 93 58.044W.CTD #9 AT 500M DJ
20120609 1942 0 09.126S. 93 57.822W.CTD #9 On Deck DJ

20120609 2124 0 14.535S. 93 48.429W.CTD #10 Deployed DJ
20120609 2139 0 14.497S. 93 48.319W.CTD #10 @ 500m DJ
20120609 2146 0 14.467S. 93 48.325W.CTD #10 @ 250M commence yo-yo JF
20120609 2344 0 14.386S. 93 48.078W.CTD #10 at surface commence deep cast JF
20120610 0045 0 14.367S. 93 47.990W.CTD #10 at 3257M JF
20120610 0157 0 14.367S. 93 47.817W.CTD #10 ON DECK EC
20120610 1410 0 25.353S. 93 39.088W.CTD #11 DEPLOYED EC
20120610 1424 0 25.295S. 93 38.959W.CTD #11 @ 500M EC
20120610 1447 0 25.253S. 93 38.682W.CTD #11 ON DECK EC
20120610 1635 0 15.204S. 93 34.972W.CTD #12 DEPLOYED EC
20120610 1648 0 15.156S. 93 34.750W.CTD #12 @ 500M EC
20120610 1712 0 15.099S. 93 34.447W.CTD #12 ON DECK EC
20120610 1857 0 26.101S. 93 40.789W.CTD #13 Deployed DJ
20120610 2005 0 25.377S. 93 40.616W.CTD #13 @ 3385M DJ
20120610 2118 0 25.097S. 93 40.455W.CTD #13 ON DECK DJ
20120610 2309 0 16.097S. 93 29.173W.CTD #14 DEPLOYED EC
20120610 2323 0 16.065S. 93 28.964W.CTD #14 @ 500M EC
20120610 2304 0 16.083S. 93 29.280W.CTD #14 on deck JF
20120611 0147 0 26.007S. 93 40.822W.CTD #15 DEPLOYED EC
20120611 0249 0 25.922S. 93 40.439W.CTD #15 @ 3300M EC
20120611 0348 0 25.898S. 93 40.116W.CTD #15 ON DECK EC
20120611 1400 0 34.911S. 93 30.504W.CTD #16 DEPLOYED EC
20120611 1414 0 34.874S. 93 30.406W.CTD #16 @ 500M EC
20120611 1438 0 34.855S. 93 30.145W.CTD #16 ON DECK EC
20120611 1725 0 17.958S. 93 13.227W.CTD #17 DEPLOYED EC
20120611 1830 0 17.961S. 93 12.449W.CTD #17 @ 3204m DJ
20120611 1945 0 17.898S. 93 11.171W.CTD #17 ON DECK DJ
20120611 2012 0 18.405S. 93 10.469W.MACRO WIRE WALKER #11 HOOKED DJ
20120611 2345 0 36.058S. 93 34.972W.MINI #4 ON DECK JF
20120612 0030 0 38.499S. 93 37.466W.MINI #5 ON DECK JF
20120612 0200 0 39.252S. 93 27.539W.MINI #6 ON DECK EC
20120613 1734 5 00.072N. 96 28.054W.ARGO #1 #8065 DEPLOYED EC
20120614 0032 5 59.808N. 97 15.217W.ARGO #2 #8086 Deployed JF
20120614 0729 7 00.025N. 98 02.836W.ARGO #3 #8088 Deployed DJ
20120614 1424 8 00.074N. 98 50.439W.ARGO #4 #8089 deployed DM
20120614 2052 8 59.913N. 99 37.975W.ARGO #5 #8090 Deployed DJ
20120614 2100 9 01.225N. 99 39.019W.
20120615 0257 10 00.101N. 100 25.927W.ARGO #6 #8091 DEPLOYED EC
20120615 0912 11 00.109N. 101 13.892W.ARGO #7 #8092 Deployed DJ
20120615 1545 12 00.023N. 102 01.943W.ARGO #8 #8093 DEPLOYED EC
20120615 2037 12 45.088N. 102 38.202W.ARGO #9 #8094 Deployed DJ
20120616 0128 13 30.029N. 103 14.470W.ARGO #10 #8095 Deployed JF
20120616 0625 14 14.969N. 103 50.856W.ARGO #11 #8096 DEPLOYED EC