CRUISE REPORT

***R/V Endeavor* Cruise EN-517**

RAPID/MOCHA Program
September 24 – October 10, 2012
Port Everglades, FL to Port Everglades, FL

1. Introduction and Objectives

The RAPID/MOCHA program is a joint research effort between the National Oceanography Centre (Southampton, U.K.), the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), and NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). The objective of this program is to continuously observe the strength and structure of the Atlantic meridional overturning circulation at 26.5º N using a trans-basin observing system. The U.K. program is referred to as "RAPID-WATCH" and is a part of the U.K. Rapid Climate Change Program (RAPID) funded by the National Environmental Research Council (NERC). The U.S. program is referred to as "MOCHA" (Meridional Overturning Circulation and Heat-flux Array) and is funded by the National Science Foundation (NSF). NOAA contributes significantly to the effort through its Western Boundary Time Series (WBTS) Program.

The goals of cruise EN-517 were to:

1. Service 5 deep-sea moorings located off the eastern Bahamas along latitude 26.5°N.
2. Service 3 pressure-inverted echo sounders (PIES) and recover data from 3 other PIES by underwater acoustic telemetry.
3. Conduct CTD (Conductivity-Temperature-Depth) and Lowered ADCP (Acoustic Doppler Current Profiler) sections across the Florida Current at 27ºN, Northwest Providence Channel, and along the 26.5ºN RAPID-MOCHA western boundary line east of Abaco, Bahamas.
4. Perform several additional deep water CTD casts to calibrate moored instrumentation, and
5. Deploy 10 satellite tracked surface drifters at chosen locations along the cruise track.

2. Cruise Synopsis

The cruise departed from Port Everglades (Ft. Lauderdale), FL on September 24 at 1100 local time. The ship arrived off Bimini at 1600 local and a small boat was sent in to complete Bahamian clearance check in, which was finished by 1800 local. Two surface drifters were launched on Sept. 24th, one about midway across the Florida Current and another on the east side off the Florida Current shortly after leaving Bimini. The CTD/LADCP section across Northwest Providence Channel (stations 1 to 5) was

accomplished with few problems, with both CTD and LADCP systems functioning well. The NOAA/AOML CTD/LADCP system was used, with a hybrid 150/300 kHz LADCP system using a 300 kHz Workhorse ADCP looking upward from the CTD frame and a 150 kHz ADCP looking downward. On this cruise we tested the new 150 kHz ADCPs recently purchased from Teledyne-RDI for LADCP operations, one belonging to NOAA/AOML and one belonging to the RSMAS OTECH group. This cruise was also the first test of a new CTD frame designed by AOML that allows easier removal of the downward looking 150 kHz ADCP for trouble-shooting or change out. It proved to work very well and is a great improvement.

Once in deep water east of Abaco, 2 deep "cal-dip" CTD stations (Stations 6 and 7) were done to obtain in-situ calibration data for all the Seabird microcat instruments to be deployed on the moorings. As usual for these casts, the outer ring of Niskin bottles was removed and small airplane straps were put on the frame so that the microcats could be clamped onto.

Following this, the Abaco 26.5º N $CTDO_2$/LADCP section was commenced on September 26th, and completed on October 1st (stations 8 to 34). Eight surface drifters were launched along the section, in pairs of two, near longitudes 76°W, 74°W, 72°W, and 70°W. The Abaco section was stopped one station short, at 70°W, in order to be on station at the first mooring site at first light on Oct. 2, to begin the mooring operations.

During the NW Providence Channel section, the secondary conductivity sensor was changed after station 1 because it was giving bad readings. Later, during the Abaco section, the secondary temperature and conductivity sensors were both changed out after station 34 because the temperature sensor was offset by about 0.002°C from the primary sensor, as well as from climatological deep Abaco hydrography, and the conductivity sensor was having occasional data dropouts and spikes. Otherwise the CTD operations went very smoothly.

All planned mooring operations (Tables 1 and 2) were successfully completed between Oct. 2 – Oct. 8, working from east to west across the array. For the tall moorings (WB3 and WB5), the approach used was to recover the old mooring on one day, and deploy the replacement mooring the next day, with bottom lander recoveries and deployments fit in between. The mooring operations all went relatively smoothly with the exception of the recovery of WB3 (M403), which was not sighted after surfacing and had to be chased down using sporadic transpond replies from the acoustic releases. It was eventually found 1.7 nm to the south of the mooring site, a full 2.5 hours after release from the bottom. ARGO transmissions later confirmed that it had surfaced more than a mile to the south of the bottom location. It was also determined from the mooring instruments, after recovery, that the mooring was in an extreme blow-over state at the time of release, and the surface components could have been displaced almost a mile south of the anchor location when released. A significant, and continuing, problem with regard to all mooring recoveries is the failure of the radio beacons on the mooring top floats. Not a single radio beacon was heard on any of the tall mooring or bottom landers. For the tall moorings the main failure mode is the pressure switch in the end cap on the Novatech radio beacons,

which fails to activate after long submersions, and this has been a frequent problem in the past. Even the new Novatech combo radio/strobe units had the same failure mode. For the bottom landers, which use a RSMAS-designed radio/strobe inside a 10" glass sphere, both of these failed, one by flooding and the other by an apparent implosion, since the sphere was missing but shredded remnants of steel bands and webbing around the float were still attached to the recovery line. Hopefully these problems will be solved with the new style Novatech radios and strobes that are activated by a seawater contact (resistance) switch when surfacing. Two sets of these new units were tried out on this cruise on the redeployed bottom landers.

On mooring WB3, two individual glass spheres on different chains had imploded, and on WB5 the microcat at 600m had clearly been the victim of shark bite (its sensor guard had been ripped off and numerous teeth scrapes were visible on the titanium housing). Otherwise the moorings came up in good shape.

During the breaks in the mooring work, several PIES operations were conducted, including 3 attempted PIES recoveries, 2 redeployments, and acoustic data telemetry at several sites (Table 5). Additional CTD casts (stations 35 and 36) were also conducted to provide post-deployment CTD data for the PIES sites and post-recovery cal-dip data for the microcats retrieved from the two tall moorings. The new RSMAS 150 kHz LADCP was also swapped in for these casts to evaluate its deep water performance.

The final CTD/LADCP section across the Straits of Florida at 27°N was completed at 1950 local time on Oct 9th. The ship arrived at the Port Everglades sea buoy at approximately 0400 local Oct 10th. Berthed by 0900. The cruise was very successful and all planned operations were accomplished except for the final offshore CTD station on the Abaco line, and the unsuccessful recovery of two PIES that either did not surface after their attempted release or could not be found on the surface.

3. Scientific Personnel

Name	Position	Organization
Bill Johns	Ch. Scientist	RSMAS/ U. Miami
Adam Houk	Scientist	RSMAS/ U. Miami
Mark Graham	Technician	RSMAS/ U. Miami
Robert Jones	Technician	RSMAS/ U. Miami
Athanasia Papapostolou	Student	RSMAS/ U. Miami
Jian Zhao	Student	RSMAS/ U. Miami
Christopher Meinen	Scientist	NOAA/ AOML
Renellys Perez	Scientist	CIMAS/ U. Miami
Andrew Stefanick	Technician	NOAA/ AOML
Pedro Pena	Technician	NOAA/ AOML
Kyle Seaton	Technician	NOAA/ AOML
James Hooper	Technician	NOAA/ AOML

3. Cruise Operations

3.1 Mooring Operations

Mooring Recoveries

Five subsurface moorings were successfully recovered from the locations listed in Table 1 and shown in Figure 1. These moorings contained a mixture of current meters, Acoustic Doppler Current Profilers (ADCPs), and temperature/salinity recorders. Sites with an "L" in their name represent bottom lander moorings which contained only high precision bottom pressure sensors.

Table 1. Mooring Recoveries

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
WB0	M402	26° 30.39'	76° 50.47'	1005	10/07/2012
WB3	M403	26° 29.40'	76° 29.87'	4840	10/05/2012
WB5	M405	26° 29.48'	71° 59.07'	5298	10/02/2012
WBL3	M404	26° 29.09'	76° 29.72'	4843	10/06/2012
WBL5	M306	26° 30.06'	71° 59.18'	5295	10/02/2012

Mooring Deployments

Five moorings (3 taut-wire moorings and 2 bottom landers) were deployed at the locations listed in Table 3 and shown in Figure 1. Acoustic surveying of the on-bottom position of all moorings was successfully completed after each mooring deployment.

Table 2. Mooring Deployments

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
WB0	M414	26° 30.49'	76° 50.50'	1005	10/08/2012
WB3	M415	26° 29.50'	76° 29.75'	4840	10/06/2012
WB5	M417	26° 30.01'	71° 58.59'	5298	10/03/2012
WBL3	M416	26° 29.27'	76° 29.39'	4843	10/07/2012
WBL5	M418	26° 29.68'	71° 58.71'	5295	10/04/2012

3.2 PIES Operations

NOAA/AOML maintains a line of pressure-equipped inverted echo sounders (PIES) along 26° 30' N as part of its Western Boundary Time Series program. Regular

maintenance the PIES array was also performed on the cruise. This maintenance consisted of acoustic download of the last 8 months of data as well as recovery and deployment of selected instruments that have either developed problems or have reached the end of their battery life. The operations involving PIES during the cruise are summarized in Table 3.

Table 3. PIES Operations

Site Name	Latitude	Longitude	Date	Planned operation	Operation results
A	26° 30.938' N	76° 50.036' W	Oct. 7-8, 2012	Recovery & Deployment	100% success
A2	26° 30.078' N	76° 44.663' W	Oct. 6, 2012	Telemetry	100% success
B	26° 29.480' N	76° 28.160' W	Oct. 6, 2012	Telemetry	100% success
C	26° 30.020' N	76° 05.550' W	Oct. 5, 2012	Recovery & Deployment	Deployment successful, recovery unsuccessful
D	26° 30.160' N	75° 42.330' W	Oct. 4, 2012	Telemetry	100% success
E	26° 30.000' N	71° 59.953' W	Oct. 2, 2012	Recovery & Deployment	Deployment canceled, recovery unsuccessful

4. $CTDO_2$/LADCP Stations

A total of 45 $CTDO_2$ stations were conducted during the cruise (Table 4, Figure 2). At each station, profiles of temperature, salinity (conductivity), and dissolved oxygen concentration were collected from the surface to within approximately 20 m of the bottom, using a Sea-Bird SBE-911plus CTD system. Some additional stations were performed to provide calibration data for SBE microcat instruments to be deployed on (or recovered from) the moorings. During these casts, the outer rack of Niskin bottles was removed from the Rosette to accommodate the mooring instruments and the CTD package was lowered to its target depth, with 5 minute bottle stops during the package retrieval. These casts were not part of the regular $CTDO_2$/LADCP hydrographic sampling performed on the cruise and are indicated by an asterisk (*) in Table 4.

Water samples for calibration of the salinity and dissolved oxygen profiles were collected using a 24-bottle Rosette system containing 10 liter Niskin bottles. Salinity samples were

analyzed on a Guildline Auto-Sal salinometer, while dissolved oxygen samples were titrated using a modified Winkler technique with automated electrical endpoint determination.

Current profiles were also measured at the stations using a paired downward-looking 150 kHz Broadband and upward-looking 300 kHz Workhorse Acoustic Doppler Current Profiling 'hybrid" system (LADCP). Both of the new 150 kHz ADCP's recently acquired by AOML and RSMAS for dedicated LADCP operations appeared to work well and reliably during the cruise.

Table 4. CTDO$_2$ Station Locations

Station	Date	Time (UTC)	Latitude (^{o}N)	Longitude (^{o}W)	Depth (m)
1	9/25/2012	0227	26^o 04.262'	78^o 51.074'	303
2	9/25/2012	0433	26^o 10.056'	78^o 48.134'	447
3	9/25/2012	0627	26^o 14.989'	78^o 46.002'	514
4	9/25/2012	0817	26^o 19.086'	78^o 42.901'	656
5	9/25/2012	1027	26^o 25.813'	78^o 40.057'	759
6*	9/25/2012	2203	25^o 57.275'	76^o 53.645'	4374
7*	9/26/2012	0256	25^o 56.968'	76^o 53.212'	4283
8	9/26/2012	1058	26^o 31.528'	76^o 52.946'	457
9	9/26/2012	1235	26^o 30.997'	76^o 49.770'	1128
10	9/26/2012	1500	26^o 29.960'	76^o 44.689'	3827
11	9/26/2012	1925	26^o 30.120'	76^o 39.317'	4520
12	9/27/2012	0002	26^o 29.962'	76^o 34.007'	4803
13	9/27/2012	0455	26^o 30.023'	76^o 28.604'	4813
14	9/27/2012	0955	26^o 29.954'	76^o 20.829'	4810
15	9/27/2012	1441	26^o 30.040'	76^o 13.166'	4782
16	9/27/2012	1930	26^o 30.065'	76^o 05.214'	4770
17	9/28/2012	0044	26^o 29.845'	75^o 54.018'	4713
18	9/28/2012	0542	26^o 30.022'	75^o 42.143'	4659
19	9/28/2012	1020	26^o 30.070'	75^o 30.008'	4654
20	9/28/2012	1512	26^o 30.013'	75^o 17.911'	4606
21	9/28/2012	1959	26^o 30.070'	75^o 04.758'	4583
22	9/29/2012	0052	26^o 30.047'	74^o 47.917'	4511
23	9/29/2012	0543	26^o 30.114'	75^o 30.977'	4471
24	9/29/2012	1040	26^o 30.010'	74^o 13.991'	4517
25	9/29/2012	1619	26^o 30.062'	73^o 51.985'	4707
26	9/29/2012	2128	26^o 30.055'	73^o 30.036'	4920
27	9/30/2012	0251	26^o 30.082'	73^o 07.949'	5028
28	9/30/2012	0838	26^o 30.100'	72^o 45.910 '	5095
29	9/30/2012	1428	26^o 30.071'	72^o 23.044'	5144
30	9/30/2012	2022	26^o 30.072'	71^o 59.317'	5241
31	10/01/2012	0237	26^o 30.050'	71^o 29.959'	5371

32	10/01/2012	0924	26° 30.173'	71° 00.135'	5433
33	10/01/2012	1554	26° 30.104'	71° 29.971 '	5437
34	10/01/2012	2224	26° 30.103'	70° 00.163'	5438
35*	10/05/2012	0402	26° 29.251'	76° 06.588'	4770
36*	10/05/2012	0302	26° 29.352'	76° 28.427	4811
37	10/09/2012	1108	27° 00.162'	70° 11.956'	476
38	10/09/2012	1222	27° 00.126'	79° 16.961'	607
39	10/09/2012	1347	27° 00.309'	79° 22.991'	698
40	10/09/2012	1522	27° 00.522'	79° 30.030'	760
41	10/09/2012	1713	27° 00.262'	79° 36.984'	642
42	10/09/2012	1830	27° 00.157'	79° 40.919'	537
43	10/09/2012	2037	27° 00.128'	79° 47.026'	389
44	10/09/2012	2226	27° 00.176'	79° 52.016'	264
45	10/09/2012	2351	26° 59.920'	79° 55.964'	149

* Instrument calibration casts

5. Underway Measurements

Thermosalinograph

Values of surface temperature and salinity were continuously monitored using a Sea-Bird temperature-conductivity recorder installed in the ship's seawater intake line, and logged by the vessels's underway recording system.

Shipboard Acoustic Doppler Current Profiler

Upper ocean currents were continuously measured with a dual vessel-mounted Acoustic Doppler Current Profiler (ADCP) system consisting of 300 kHz and 75 kHz Ocean Surveyor systems. The depth range of good velocity data from the 300 kHz system typically extended to 80 m below the vessel, and to approximately 800 m for the 75 kHz system, depending on sea state conditions. Data were processed onboard in real time using the UHDAS acquisition system. Gyrocompass data were continuously corrected by an ASHTEK multi-receiver GPS system.

6. Preliminary Results

The Abaco section showed a relatively strong Deep Western Boundary Current with speeds in excess of 0.4 m/s flowing just offshore of the Bahamas escarpment (Fig. 3). Immediately offshore of this there was a large band of deep northward flow or recirculation. The temperature section showed these features clearly in the pronounced vertical deflections of the deep temperature surfaces between 1000 m and the bottom (Fig. 4). In the upper water column, there was only a weak northward Antilles Current in the thermocline off Abaco, with otherwise a dominant southward flow in the offshore region overlying the DWBC. Farther offshore there were alternating bands of northward

and southward flow in both the near surface and deep ocean, typical of wave or eddy features seen in previous sections.

The Florida Current was found to be very strong at the time the CTD/LADCP section was taken across it, on Oct. 9. Surface core speeds were in excess of 5 kts, which made for challenging ship handling while on station to maintain acceptable wire angles.

7. Release of Project Data

In accordance with the provisions specified in the cruise prospectus and application for Bahamian clearance, the full data results from this experiment will be provided to the Commonwealth of the Bahamas according to the following schedule:

Shipboard Measurements

All shipboard measurements, including underway data records and $CTDO_2$/LADCP station data, will be provided within 1 year of the termination of the cruise (October, 2013).

Moored Instrumentation

Time series data records from the moored instruments will be provided within 2 years of recovery of the instruments (nominally October, 2014).

7. Acknowledgements

The support and able assistance provided by the Captain and crew of the *R/V Endeavor* is gratefully acknowledged. Support for the scientific research was provided by the U.S. National Science Foundation and the NOAA Climate Program Office. The Commonwealth of the Bahamas graciously granted privileges to conduct scientific research in their territorial waters.

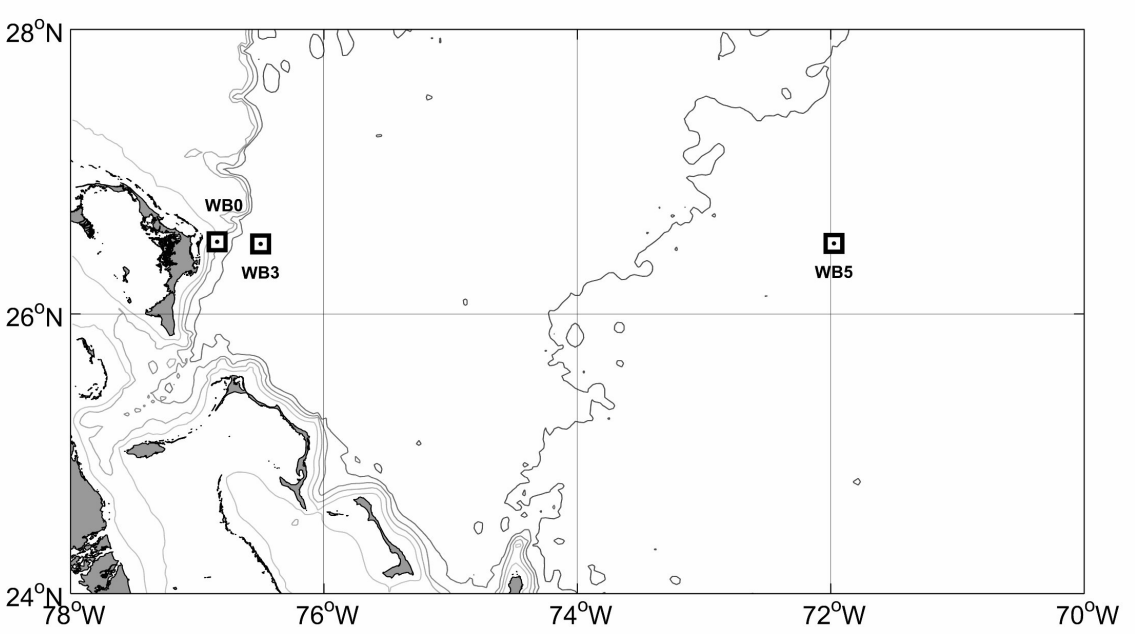

Figure 1. Current meter moorings recovered and deployed on EN-517. Additional "bottom lander" moorings (not shown on map) were deployed near mooring sites WB3, and WB5.

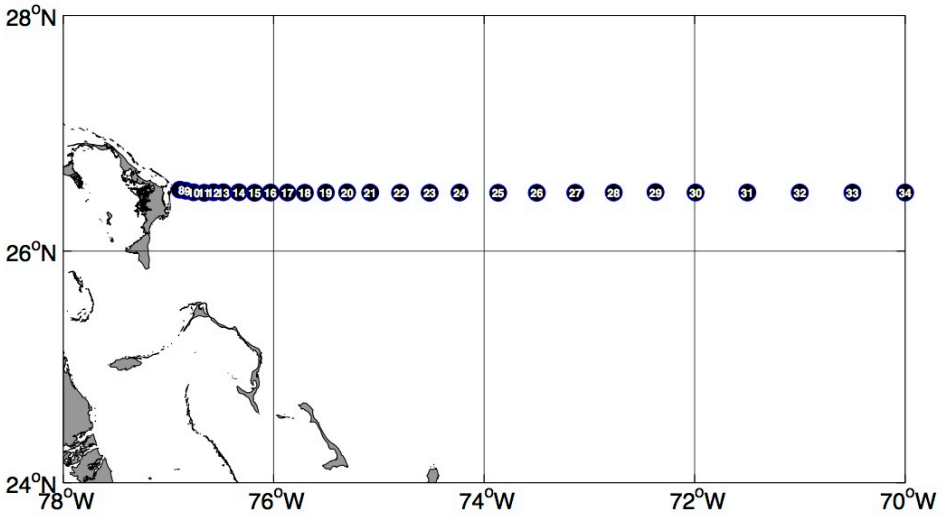

Figure 2a. $CTDO_2$/LADCP stations occupied along the 26.5° N Abaco line.

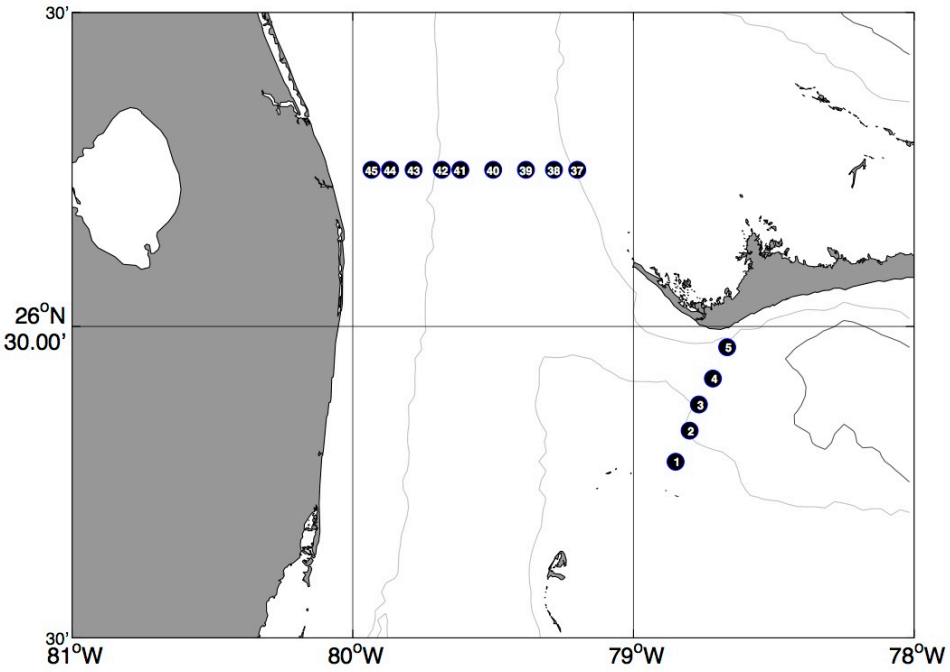

Figure 2b. CTDO$_2$/LADCP stations occupied along the 27° N Straits of Florida section and across the Northwest Providence Channel.

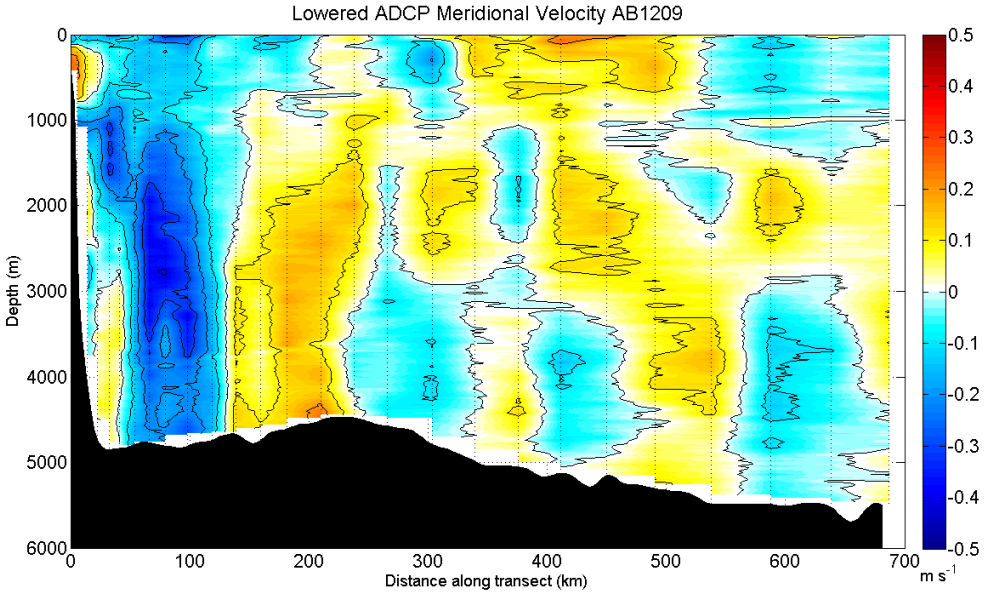

Figure 3. Absolute velocity section from LADCP off Abaco, along 26.5°N, Sept. 26 - Oct. 1, 2012.

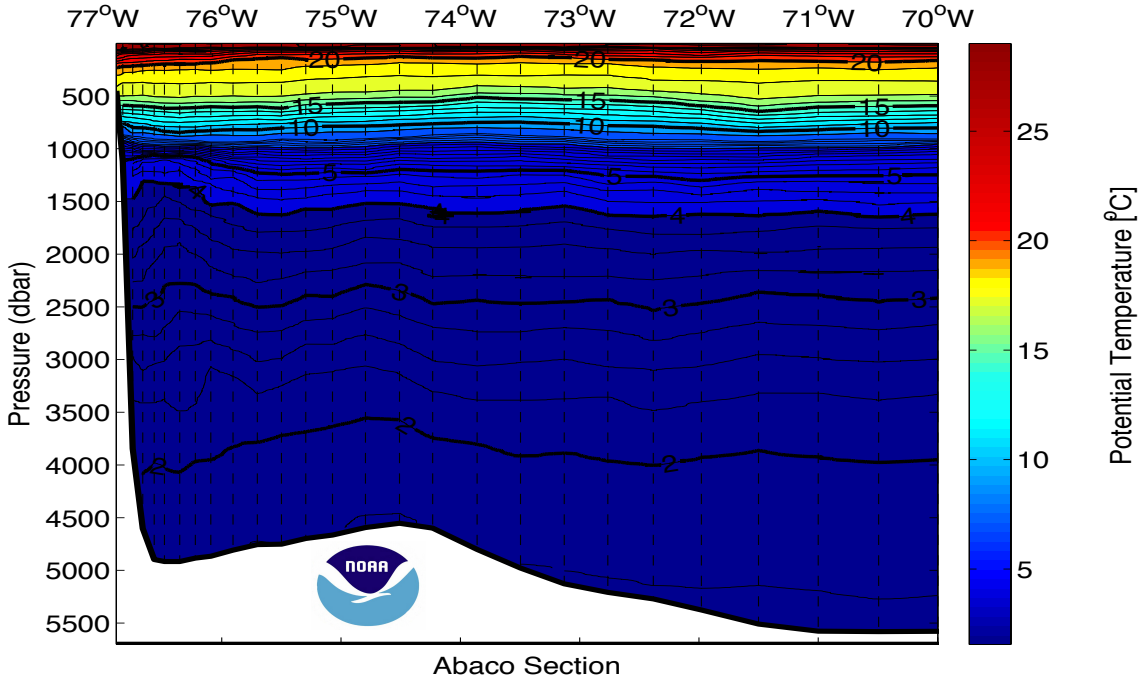

Figure 4. CTD potential temperature section off Abaco, along 26.5°N. Sept. 26 - Oct. 1, 2012.

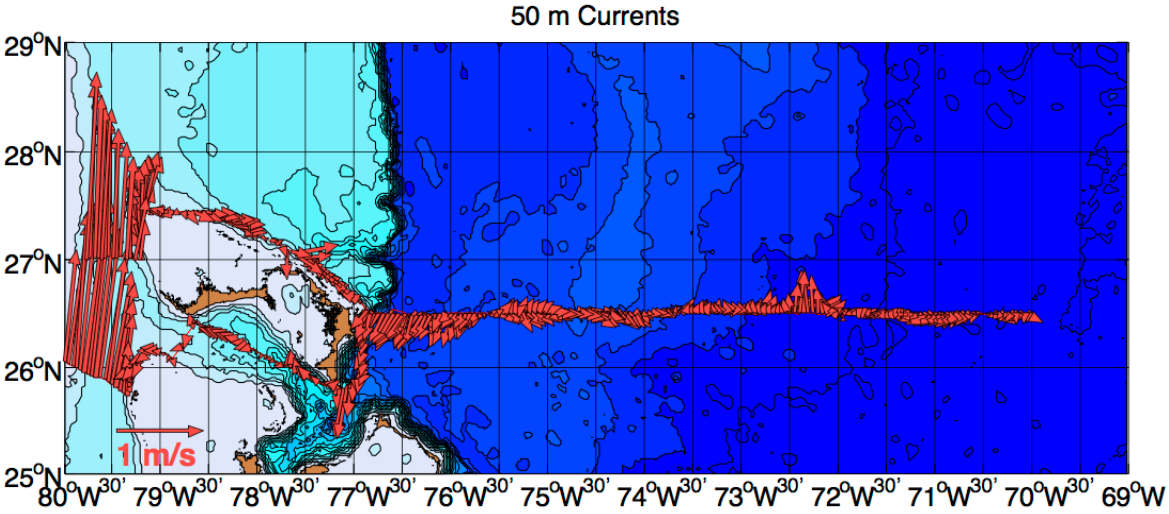

Figure 5. Currents at 50 m along the cruise track, derived from the vessel-mounted ADCP.