CRUISE REPORT

***R/V Atlantic Explorer* Cruise AE-1404**

RAPID/MOCHA Program
March 15 – 31, 2014
Fort Pierce, FL to Fort Pierce, 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 AE-1404 were to:

1. Recover 5 deep-sea moorings located off the eastern Bahamas along latitude 26.5°N, and deploy 4 new moorings along the same line.
2. Recover and redeploy one pressure-inverted echo sounder (PIES), and recover data from 6 previously deployed 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 pre-selected locations along the cruise track.

2. Cruise Synopsis

The cruise departed from Fort Pierce, FL on March 15 at 0830 local time. After crossing the Florida Current, the ship arrived off West End, Bahamas at 1730 local and a small boat was sent in to complete Bahamian clearance check in, which was finished by 1930. After transiting through Northwest Providence Channel, a "cal-dip" CTD station was done in 4300 m depth east of Abaco to obtain in-situ calibration data for all the moored Seabird microcat instruments to be deployed during the cruise. The CTD system obtained

good temperature and salinity data on the cast but there was a problem with the dissolved oxygen channels and the altimeter data due to a system configuration error. This was immediately fixed and another short test cast was done before beginning the main Abaco section along 26.5°N, which showed all sensors working well. The LADCP system in use on the cruise consists of a downward looking 150 kHz ADCP and upward looking 300 kHz ADCP, both U. Miami instruments. It was discovered partway through the Abaco section that the U. Miami 150 kHz ADCP developed a problem with one of its beams and was giving poor results in the deep water casts. Thereafter it was swapped out for an identical 150 kHz ADCP from NOAA/AOML, which performed well for the remainder of the cruise. A more detailed account of CTD/LADCP package sensor issues and sensor replacements that took place during the cruise can be found in Appendix 1.

The Abaco CTD/LADCP section was completed from March 16-22, consisting of stations 2-24. An incident occurred during CTD004 when the CTD package got temporarily snagged on a nearby current meter mooring (mooring "WB2", maintained by the U.K. National Oceanography Centre), which we luckily got clear of after some great ship handling by the captain and bridge watch. The CTD package sustained only minor damage (some scrapes on the frame and damage to the Chinese finger tension grips), and was able to be redeployed again after a short delay. After CTD008 the ship had to transit to Marsh Harbor and send in a small boat to let off the Chief Engineer due to an illness, and pick up a replacement for him, which took place on Mar. 18, causing about a 17 hour delay including steaming time back and forth from the line. Near the end of the Abaco section, the deeper stations had to be terminated before reaching the bottom due to an insufficient amount of conducting cable on the CTD winch (wire payout was limited to 5100 m).

Mooring work commenced on March 22nd with the recovery of bottom lander WBL5 at the eastern end of the Abaco line. All planned mooring operations (Tables 1 and 2) were successfully completed between March 22–29, working from east to west across the array. Underwater communications with the acoustic releases were initially difficult, with replies from the releases being either being very faint or not detected at all by the deck unit, even though they could generally be heard on the ship's Knudsen echo-sounding system. After swapping out both the deck unit and transducers with backup units brought by AOML, it became apparent that the Benthos model UDB-9000 deck units, when paired with their cabled transducers, were not working well for communications with the EdgeTech acoustic releases used on the U. Miami moorings. Reasons for this are still to be determined. An older EG&G model 8011-A deck unit with cabled transducer was then used for mooring recovery and deployment operations, which showed more reliable communications. Later in the cruise, the Benthos deck units were interfaced with the ships 12 kHz transducer instead of their cabled transducers, and this combination worked much better and was used for all subsequent mooring operations.

All mooring recoveries went relatively smoothly except for M417 (site WB5) which had a bad tangle near the mid-depth float that took the mooring crew considerable time to unravel and recover safely. The mooring deployments also were generally smooth except for the end of M420 (site WB3), where the anchor fell over on deck as the tension was

transferred to the mooring line just before anchor launch. Quick action by the mooring team restored order on the deck and resulted in a normal and safe anchor launch.

During breaks in the mooring work, a number of PIES operations were conducted, including one PIES recovery and redeployment, and acoustic data telemetry at all 6 PIES sites on the Abaco line (Table 5 provides a summary of the PIES operations). Additional CTD casts (stations 25-27) were also conducted to provide post-deployment CTD data for PIES site A2 and post-recovery cal-dip data for the microcats retrieved from the two tall moorings WB3 and WB5.

After completing all work on the Abaco line, the ship transited Northwest Providence Channel and completed the CTD/LADCP section at the western end of the Channel (stations 28-32), on March 29-30. The ship stopped into West End on the morning of March 30 to clear out from the Bahamas and then proceeded northward to the 27°N line across the Straits of Florida. The final CTD/LADCP section across the Straits of Florida (stations 33-41) was completed at 0300 on March 31st. The ship arrived at Fort Pierce at dawn on March 31st and was docked by 0930. The cruise was very successful and all planned operations were accomplished.

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
Athanasia Papapostolou	Student	RSMAS/ U. Miami
Jian Zhao	Student	RSMAS/ U. Miami
Elizabeth Wong	Student	RSMAS/ U. Miami
Christopher Meinen	co-Ch. Scientist	NOAA/ AOML
Andrew Stefanick	Technician	NOAA/ AOML
Pedro Pena	Technician	NOAA/ AOML
Kyle Seaton	Technician	NOAA/ AOML
James Hooper	Technician	NOAA/ AOML

4. Cruise Operations

4.1 Mooring Operations

Mooring Recoveries

Five subsurface moorings were successfully recovered from the locations listed in Table 1 and shown in Figure 1a. 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 that 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	M414	26° 30.49'	76° 50.50'	1005	03/28/2014
WB3	M415	26° 29.50'	76° 29.75'	4840	03/25/2014
WB5	M416	26° 30.01'	71° 58.59'	5298	03/23/2014
WBL3	M417	26° 29.27'	76° 29.39'	4843	03/27/2014
WBL5	M418	26° 29.68'	71° 58.71'	5295	03/22/2014

Mooring Deployments

Four moorings (3 taut-wire moorings and 1 bottom lander) were deployed at the locations listed in Table 2 and shown in Figure 1b. 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	M419	26° 30.54'	76° 50.51'	1005	03/29/2014
WB3	M420	26° 29.93'	76° 29.79'	4840	03/28/2014
WBC	M422	26° 30.84'	76° 06.24'	4809	03/24/2014
WBL3	M421	26° 29.36'	76° 29.18'	4845	03/27/2014

4.2 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 ~15 months of data as well as recovery and redeployment of one instrument that had reached the end of its 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	Mar. 29, 2014	Telemetry	100% success
A2	26° 30.078' N	76° 44.663' W	Mar. 27-	Recovery &	100% success

			28, 2014	Deployment	
B	26° 29.480' N	76° 28.160' W	Mar. 27, 2014	Telemetry	100% success
C	26° 30.020' N	76° 05.550' W	Mar. 26, 2014	Telemetry	100% success
D	26° 30.160' N	75° 42.330' W	Mar. 25, 2014	Telemetry	100% success
E	26° 30.000' N	71° 59.953' W	Mar. 23, 2014	Telemetry	100% success

4.3 $CTDO_2$/LADCP Stations

A total of 41 $CTDO_2$ 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. On one cast, Station 27, no bottle samples were collected as this cast was used solely for calibrating the recently deployed PIES. 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).

Table 4. $CTDO_2$ Station Locations

Station	Date	Time (UTC)	Latitude (^oN)	Longitude (^oW)	Depth of Cast (m)
1*	03/16/2014	14:17	25.953	76.922	4351
2	03/16/2014	23:17	26.531	76.879	449
3	03/17/2014	00:53	26.521	76.820	1334
4	03/17/2014	03:20	26.515	76.742	3918
5	03/17/2014	15:36	26.505	76.649	4593
6	03/17/2014	20:25	26.499	76.551	4903
7	03/18/2014	01:45	26.496	76.470	4911

8	03/18/2014	07:13	26.497	76.336	4892
9	03/19/2014	05:04	26.497	76.222	4884
10	03/19/2014	10:26	26.496	76.087	4865
11	03/19/2014	16:02	26.502	75.901	4807
12	03/19/2014	21:09	26.500	75.703	4751
13	03/20/2014	03:08	26.504	75.498	4748
14	03/20/2014	08:39	26.500	75.301	4702
15	03/20/2014	14:49	26.508	75.078	4667
16	03/20/2014	19:48	26.501	74.798	4599
17	03/21/2014	01:07	26.512	74.518	4548
18	03/21/2014	06:22	26.502	74.231	4602
19	03/21/2014	12:19	26.504	73.871	4805
20	03/21/2014	18:18	26.496	73.501	5038
21	03/22/2014	00:12	26.500	73.133	5124
22	03/22/2014	06:23	26.498	72.769	5108
23	03/22/2014	12:36	26.504	72.373	5108
24	03/22/2014	22:21	26.505	71.983	5112
25*	03/26/2014	00:50	26.501	76.095	4869
26*	03/27/2014	03:53	26.496	76.473	4908
27*	03/30/2014	03:41	26.501	76.740	3006
28	03/30/2014	02:32	26.065	78.850	285
29	03/30/2014	03:41	26.166	78.800	441
30	03/30/2014	05:07	26.254	78.773	503
31	03/30/2014	06:25	26.336	78.718	679
32	03/30/2014	07:55	26.437	78.657	739
33	03/30/2014	15:57	26.998	79.201	468
34	03/30/2014	17:05	27.004	79.285	602
35	03/30/2014	18:26	27.005	79.372	660
36	03/30/2014	19:59	27.007	79.499	748
37	03/30/2014	21:40	27.007	79.614	639
38	03/31/2014	22:58	27.008	79.685	519
39	03/31/2014	00:21	27.005	79.786	369
40	03/31/2014	01:27	27.006	79.865	250
41	03/16/2014	02:23	27.010	79.931	130

* Instrument calibration casts

5. Underway Measurements

Shipboard Acoustic Doppler Current Profiler

Upper ocean currents were continuously measured with a 75 kHz Ocean Surveyor vessel-mounted Acoustic Doppler Current Profiler (ADCP) system. The depth range of good velocity data from the system typically extended to 600 m below the vessel during calm to moderate sea states, but degraded significantly in higher sea states and wind

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. A power outage midway through the cruise caused the shipboard ADCP system to go down for almost 1.5 days before the system was reset to acquire data. Fortunately this gap occurred during a period of mooring operations when the shipboard ADCP data were not critical to the cruise objectives, but it should have been detected and restarted much sooner. Partly this was due to a lack of a dedicated computer display on the ship for the shipboard ADCP system, but there were also failures in the UHDAS email alert system that are being investigated.

6. Preliminary Results

The Abaco section showed a relatively weak Deep Western Boundary Current, which was displaced almost 100 km east of the Bahamas escarpment (Fig. 3). Inshore of this there was a band of deep northward flow, suggesting that the DWBC was in an offshore meander state or that a deep anticyclonic eddy was located next to the escarpment. In the upper water column, there was a northward thermocline flow of about 0.2 m/s next to the Bahamas escarpment indicating the presence of a moderate but narrow Antilles Current. Farther offshore there was a signature of a strong anticyclonic eddy between 200 to 400 km from the escarpment, reaching to about 800 m depth. Temperature, salinity, and dissolved oxygen distributions along the 26.5°N Abaco line are shown in Figure 4.

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 (April, 2015).

Moored Instrumentation
Time series data records from the moored instruments will be provided within 2 years of recovery of the instruments (April, 2016).

7. Acknowledgements

The support and able assistance provided by the Captain and crew of the *R/V Atlantic Explorer* 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.

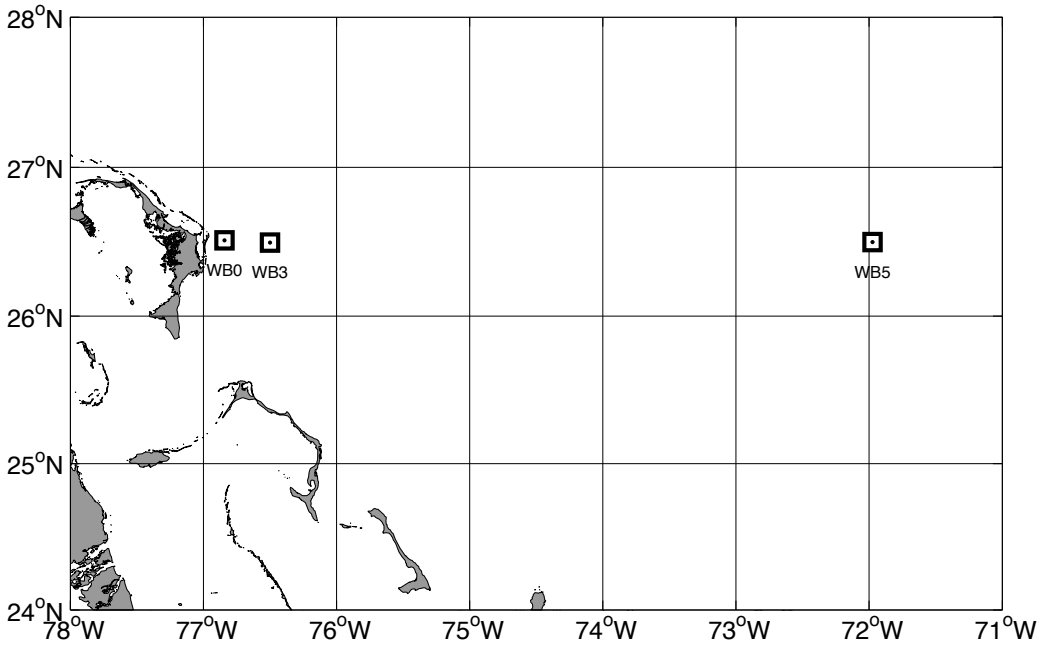

Figure 1a. Current meter moorings recovered on AE-1404. Additional "bottom lander" moorings (WBL3 and WBL5) not shown on map) were recovered near mooring sites WB3 and WB5.

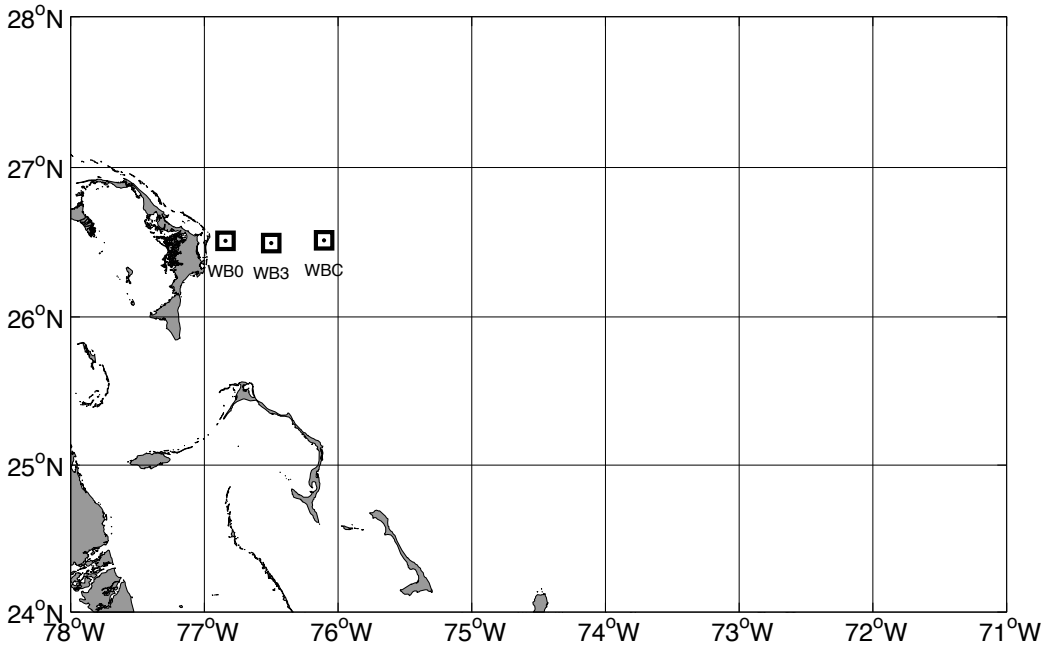

Figure 1b. Current meter moorings deployed on AE-1404. An additional "bottom lander" mooring (WBL3, not shown on map) was deployed near mooring site WB3.

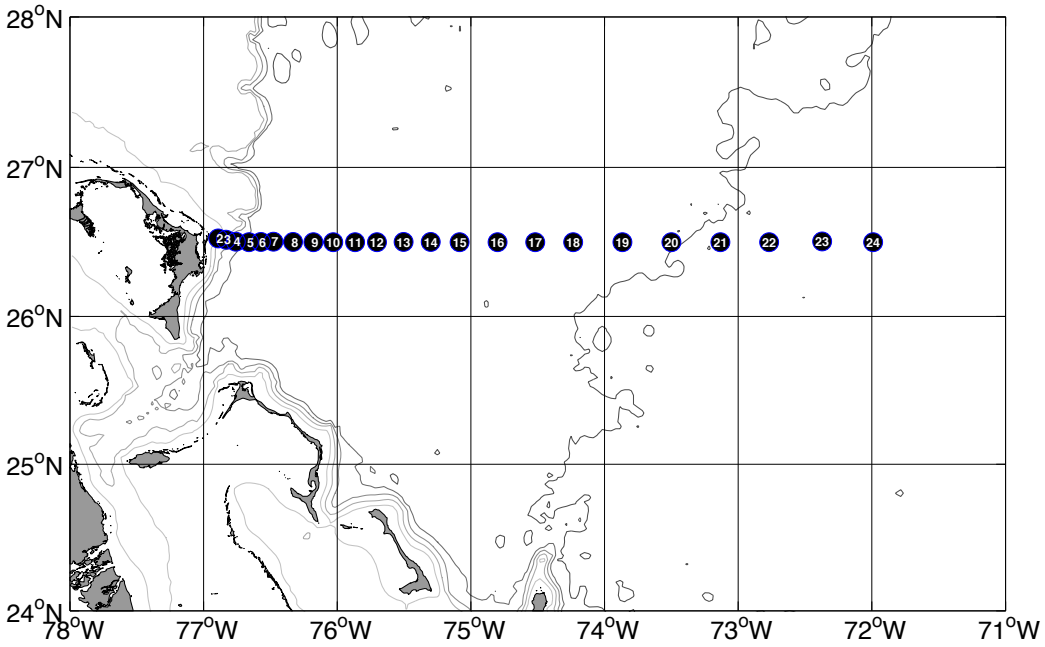

Figure 2a. CTDO$_2$/LADCP stations occupied along the 26.5° N Abaco line.

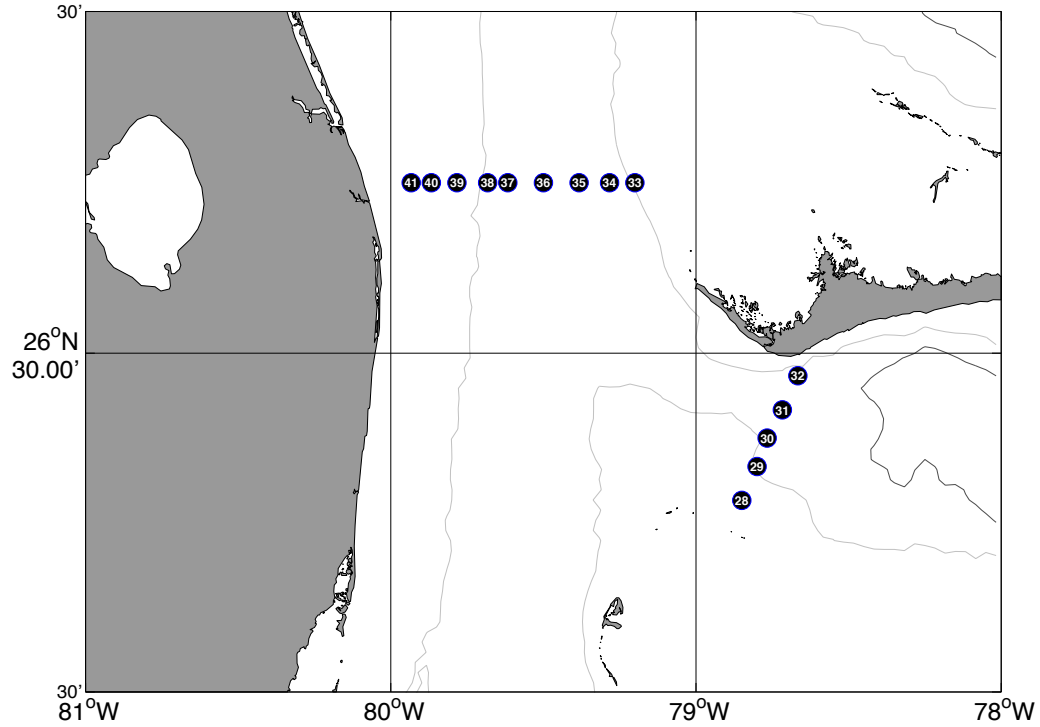

Figure 2b. CTDO$_2$/LADCP stations occupied along the 27° N Straits of Florida section and across the Northwest Providence Channel.

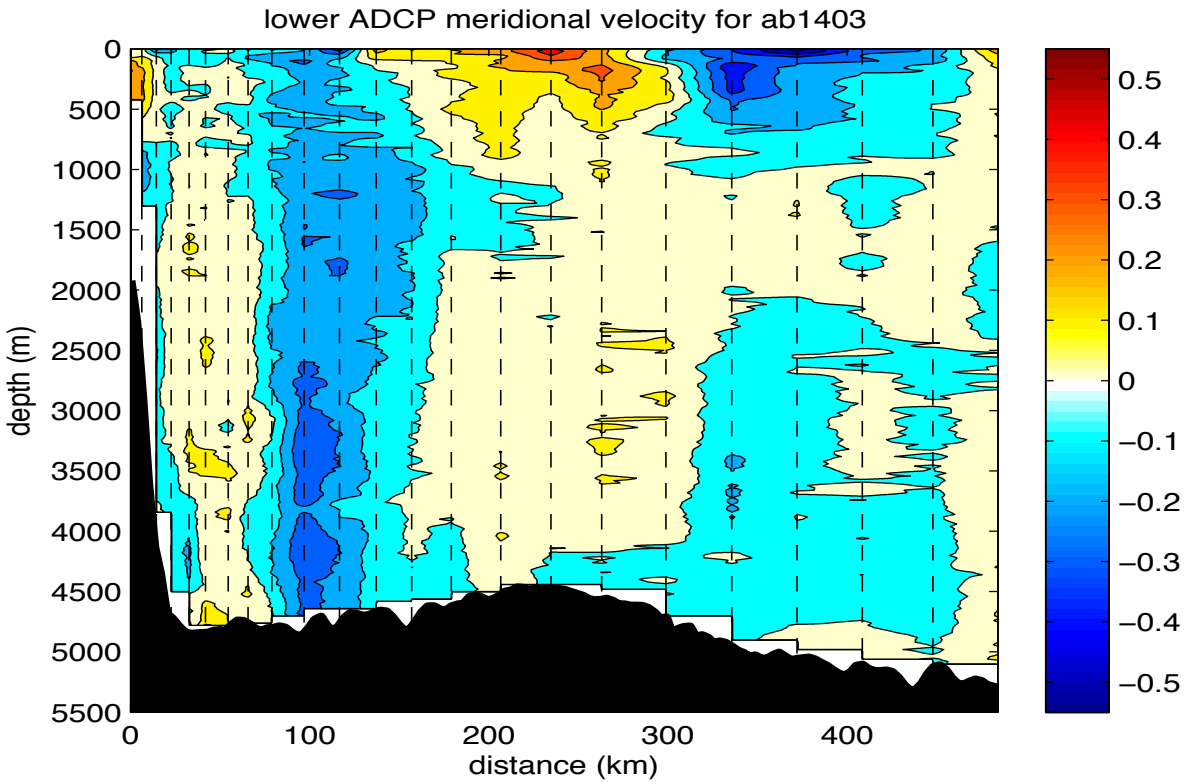

Figure 3. Absolute velocity section from LADCP off Abaco, along 26.5°N, acquired from March 16-22, 2014.

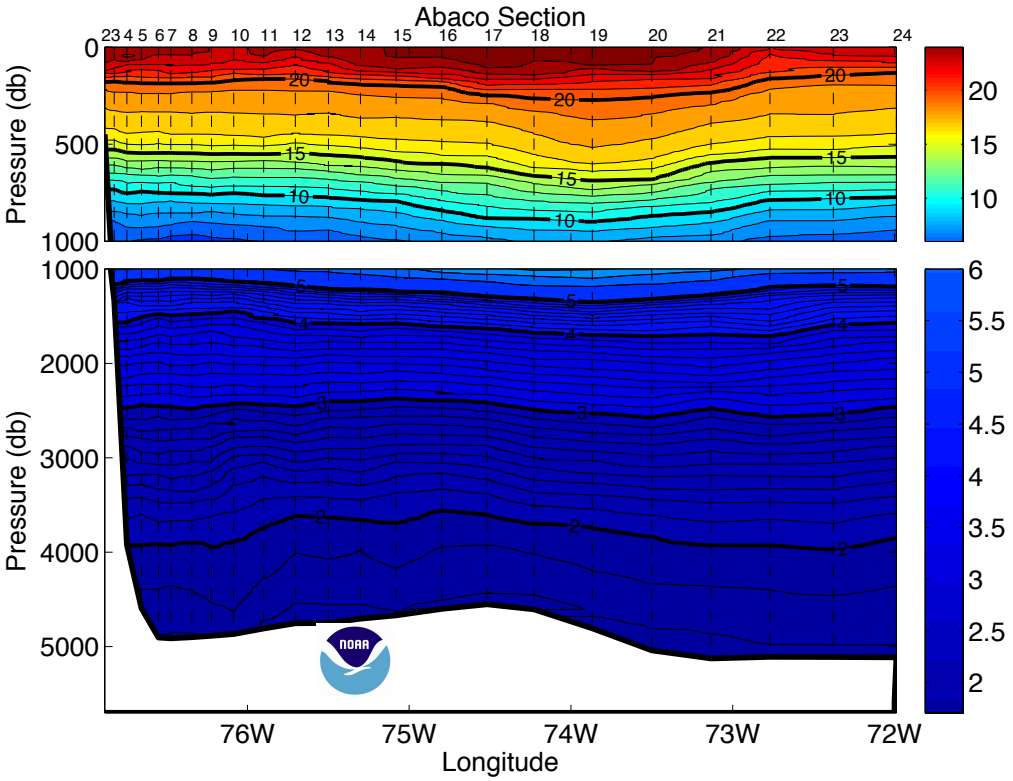

Figure 4a: Potential temperature along the Abaco section.

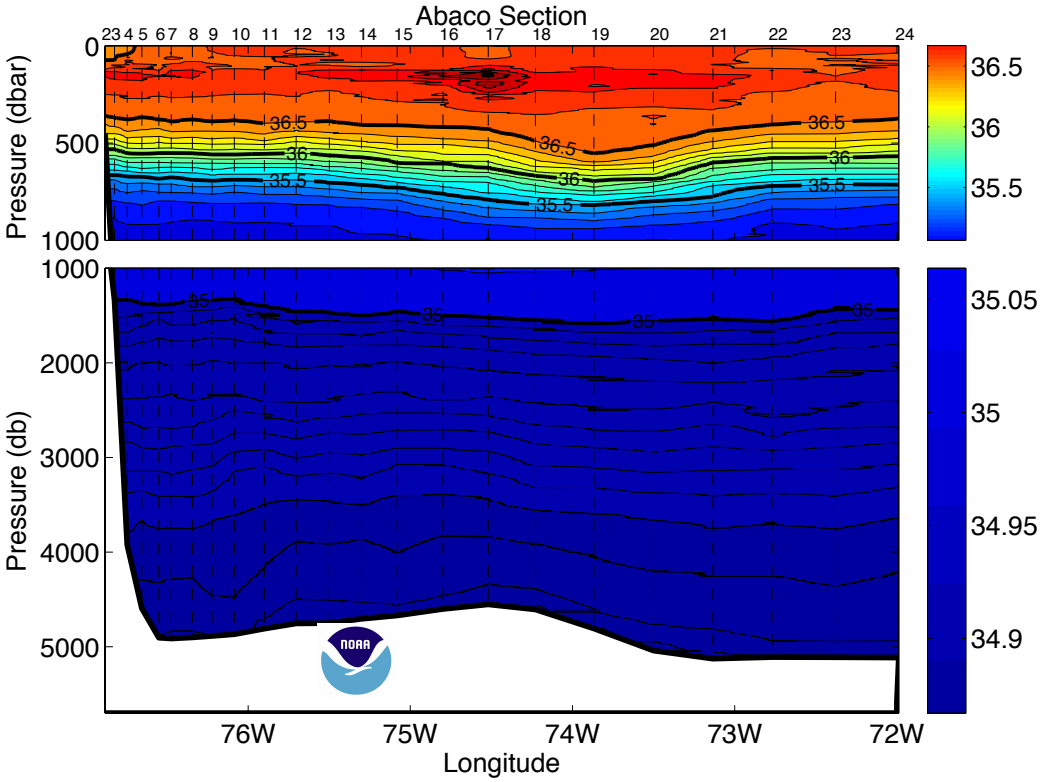

Figure 4b: Salinity along the Abaco section.

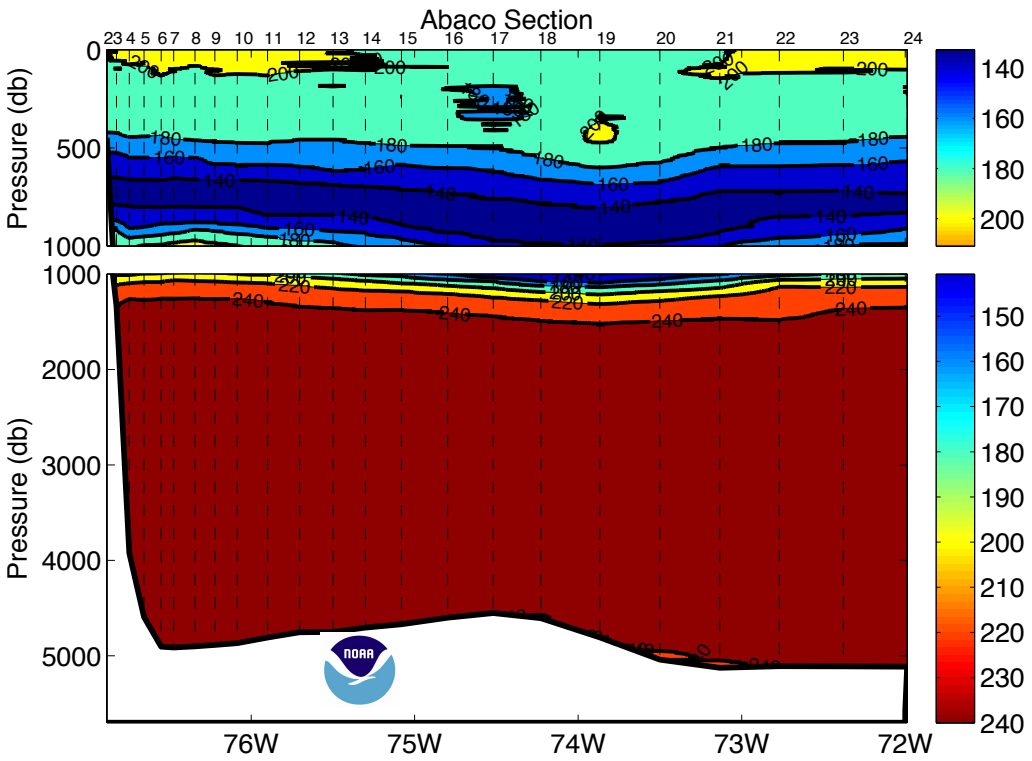

Figure 4c: Dissolved oxygen along the Abaco section.

Appendix 1: CTD Operations

1. CTD Electronics and Water Sampling Package

CTD/rosette casts were performed with a package consisting of a 24-place, 10-liter rosette frame (AOML's pink frame), a 24-place water sampler (SBE32) and 24, 10-liter Bullister-style bottles. This package was deployed on all stations/casts. Underwater electronic components consisted of a Sea-Bird Electronics (SBE) 9 plus CTD with dual pumps and the following sensors: dual temperature (SBE3), dual conductivity (SBE4), dual dissolved oxygen (SBE43), and a Simrad 807 altimeter. The other underwater electronic components consisted of two RDI LADCPs.

The CTD's supplied a standard Sea-Bird format data stream at a data rate of 24 frames/second. The SBE9 plus CTD was connected to the SBE32 24-place pylon providing for single-conductor sea cable operation. Power to the SBE 9 plus CTD, SBE32 pylon, auxiliary sensors, and altimeter was provided through the sea cable from the SBE 911plus deck unit in the computer lab. The rosette system was suspended from a UNOLS-standard three-conductor 0.322" electro-mechanical sea cable.

Routine CTD maintenance included soaking the conductivity and DO sensors in a solution of de-ionized water as recommended by Sea-Bird between casts to maintain sensor stability. Rosette maintenance was performed on a regular basis. O-rings were changed as necessary and bottle maintenance was performed each day to insure proper closure and sealing. Valves were inspected for leaks and repaired or replaced as needed.

2. Sensor Issues

Step-like profile features were seen during the cast at station 6 in the secondary oxygen profiles at depth. The secondary sensor, s/n 2082, was replaced with s/n1348. The problem persisted during stations 7 and 8. Replaced CTD, s/n 1165, with CTD, s/n 0363 along with a new cable for the secondary oxygen. This fixed the problem. It was determined it was most likely water intrusion in the cable. Secondary oxygen sensor, s/n 2082, was swapped back in place of s/n 1348. It was performing better with the primary oxygen sensor.

At station 12 the secondary conductivity sensor, s/n 3854, was swapped out for s/n 4229. A shift was seen in the T-S plot at depth for sensor s/n 3854.

At station 13 the UM 150 kHz ADCP was showing large error bars in the velocity profiles and replaced with AOML's 150 kHz ADCP.

At station 26 the CTD was re-terminated. Modulo errors were seen during several casts (Stations 13, 15, 25 and 26) and it was finally determined this was due to a bad sea-cable.

Table A1 (below) summarizes the equipment and sensors used on the CTD/LADCP package for all of the stations.

Table A1: Equipment and sensors used during the cruise

Instrument	Stations	S/N	Use	Pre-Cruise Cal
Sea-Bird SBE 32 24-palce Carousel Water Sampler	1-41	32 - 0980		
Sea-Bird SBE9plus CTD	1-8	1165		10/23/13
Paroscientific Digiquartz Pressure Sensor	1-8	128030		10/23/13
Sea-Bird SBE9plus CTD	9-41	360		9/7/10
Paroscientific Digiquartz Pressure Sensor	9-41	95798		9/7/10
Sea-Bird SBE3plus Temperature Sensor	1-41	5898	Primary	10/16/13
Sea-Bird SBE3plus Temperature Sensor	1-41	5237	Secondary	2/6/14
Sea-Bird SBE4C Conductivity Sensor	1-41	3861	Primary	2/6/14
Sea-Bird SBE4C Conductivity Sensor	1-11	3854	Secondary	2/6/14
Sea-Bird SBE4C Conductivity Sensor	12-41	4229	Secondary	10/1/13
Sea-Bird SBE43 Dissolved Oxygen Sensor	2-41	2691	Primary	10/23/13
Sea-Bird SBE43 Dissolved Oxygen Sensor	2-6,9-41	2082	Secondary	2/8/14
Sea-Bird SBE43 Dissolved Oxygen Sensor	7-8	1348	Secondary	3/4/14
Sea-Bird SBE5T Pump	1-41	7268	Primary	
Sea-Bird SBE5T Pump	1-7	7267	Secondary	
Sea-Bird SBE5T Pump	8-41	3953	Secondary	
Simrad 807 Altimeter	1-41	980	Range - 280 m	
RDI LADCP - 150 kHz Broad Band (UM)	1-12	18144	Downward	
RDI LADCP - 150 kHz Broad Band	13-41	18145	Downward	
RDI LADCP - 300 kHz Workhorse (UM)	1-41	6820	Upward	