CRUISE REPORT

***R/V Atlantic Explorer* Cruise AE-1833**

RAPID/MOCHA/WBTS Program
November 17 - Dec. 3, 2018
Ft. Pierce, FL to Ft. Pierce, FL

1. Introduction and Objectives

The RAPID/MOCHA/WBTS program is a joint research effort between the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML), and the U.K.'s National Oceanography Centre (Southampton, U.K.). 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-1833 were to:

1. Service (recover and redeploy) 3 tall current meter moorings and 1 short ("bottom-lander") mooring located off the eastern Bahamas along latitude 26.5°N.
2. Retrieve data from 6 pressure-equipped inverted echo sounders (PIES) by underwater acoustic telemetry, and recover and redeploy one C-PIES (a PIES with integrated deep current meter).
3. Conduct CTD (Conductivity-Temperature-Depth) and Lowered ADCP (Acoustic Doppler Current Profiler) sections across the Florida Current at 27ºN, the Northwest Providence Channel, and along the 26.5ºN RAPID-MOCHA western boundary line east of Abaco, Bahamas.
4. Perform two additional deep water CTD casts to calibrate moored instrumentation.
5. Recover a deep glider operated by the University of Washington along the Abaco 26.5ºN line.
6. Perform additional work including a shipboard ADCP survey of the Antilles Current and/or CTD/LADCP stations along the 26ºN Florida Current section as time permits.

2. Cruise Synopsis

The cruise departed from Ft. Pierce, FL on November 17 at 0930 local time. The ship transited across the Florida Current and into the Northwest Providence Channel where a

CTD test cast was performed for training purposes and to check the CTD sensors and lowered ADCP instruments on the CTD package. The test cast failed shortly after deployment due to up-wire communication problems and it was discovered that the CTD termination had failed due to water intrusion and had to be redone. After re-terminating and testing the package on deck, a second test cast was done outside of Hole-in-the-Wall which was successful. The ship arrived at the western end of the 26.5°N Abaco section at 1530 local time on Nov. 18 to begin the Abaco CTD line. CTDs 001-003 were performed successfully but during CTD004 the LADCP system experienced a large voltage drop causing multiple data files to be written and poor data quality for the last half of the upcast. Problems with adequate battery power for the LADCP system persisted until CTD010 when we began swapping out the battery cannister after each cast with a freshly charged cannister. The issues with battery charging for the LADCP system are detailed in the appendix on LADCP operations.

The Abaco CTD section was continued through Nov. 23rd when conditions became very rough and the CTD line had to be terminated after the completion of CTD022 near 72° 22' W, just one station short of the location of PIES E. A deep glider (SG037) operated by the University of Washington was also recovered on Nov. 21st in between CTDs 015 and 016 at the request of Dr. Charlie Eriksen, who coordinated the surfacing time of the glider with our progress along the section. CTD 019 also served as a calibration ("cal-dip") cast for the Seabird microcat instruments to be deployed on mooring WB3 later in the cruise. Following normal procedure for these casts, small airplane straps were put on the frame so that the microcats could be clamped on. Twelve bottle stops were then maintained for 5 minutes to obtain the needed calibration data. During the CTD section, communications were also attempted with all PIES sites located near the CTD stations (with the exception of PIES A), and it was determined that both PIES B ad PIES D were not functioning normally, which would require them to be recovered and redeployed on this cruise (in addition to the planned recovery and deployment of PIES C).

Telemetry at PIES E was performed on Nov. 23rd, and PIES D was successfully recovered and redeployed on Nov. 25th, followed by the recovery and redeployment of PIES C in the early hours of Nov. 26th.

Tall mooring operations began on Nov. 26th with the successful recovery of mooring WBC. Recovery and deployment of PIES B was also successfully accomplished on the night of Nov. 26th. Mooring WBC was redeployed on Nov. 27th followed by the recovery of mooring WB3. The recovery of WB3 was difficult due to the mooring coming up in a tight spiral and the only safe grappling point being a mid-water float cluster, meaning that the top part of the mooring had to be hauled in backwards before recovering the bottom part of the mooring. After a long recovery stretching into the evening hours, the mooring was all successfully recovered with only minor damage to two microcats on the mooring. By the time the mooring recovery was completed the winds and seas were building rapidly as a strong cold front moved into the area, and the ship steamed into the lee of Abaco for the remainder of the night and stayed there through most of the following day (Nov. 28th) to safely conduct respooling operations and deck preparations for the redeployment of mooring WB3. During this break it was also discovered that the CTD frame had a broken weld on its lower rung - probably caused by contact with the ships hull during the recovery of CTD022 - and therefore the entire CTD and LADCP system and cabling had to be swapped over to the spare AOML CTD frame. By the evening of Nov. 28th the mooring respooling and CTD change-over were completed and the winds and seas began to come down, and the ship headed offshore at 2000 local to resume science operations.

Acoustic telemetry was successfully performed at PIES A2 during the night of Nov. 28th. Mooring WB3 was redeployed on Nov. 29th, followed by the recovery and deployment of the nearby WBL3 bottom lander mooring. During the evening of Nov. 29th, a second cal-dip cast was performed (CTD023) to check the calibrations of the microcats that had been recovered from mooring WB3.

Telemetry at PIES A was successfully completed on the morning of Nov. 30th, followed by successful recovery and redeployment of mooring WB0, thereby completing all mooring and PIES operations. The ship then headed for Hole-in-the-Wall in transit to the Northwest Providence Channel (NWP) CTD section. The NWP section (CTDs 024-028) was completed on Dec. 1st. Because the Abaco CTD line had to be terminated early, there was extra time available for science operations, and the 26°N Florida Current section was added to the schedule in between the NWP and 27°N Florida Current sections. The 26°N Florida Current section (CTDs 029-039) was completed on Dec. 1st and 2nd, and the 27°N Florida Current section (CTDs 040-048) was completed on Dec. 2nd and into the morning hours of Dec. 3rd.

The ship arrived at the Ft. Pierce sea buoy at 0800 local Dec. 3rd and was berthed by 0905. All planned science operations were successfully completed, except for the last six stations on the Abaco line which had to be abandoned due to unworkable conditions at the offshore end of the line. In addition, extra science was accomplished, including the 26°N Florida Current section and two unplanned PIES recoveries and redeployments.

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
Manish Devana	Student	RSMAS/ U. Miami
Greg Koman	Student	RSMAS/ U. Miami
Tiago Bilo	Student	RSMAS/U. Miami
Andrew Stefanick	Technician	NOAA/ AOML
Pedro Pena	Technician	NOAA/ AOML
James Hooper	Technician	CIMAS/U. Miami
Diego Ugaz	Technician	CIMAS/U. Miami

Marion Kersale	Post-Doc	CIMAS/U. Miami
Cyril Germineaud	Post-Doc	CIMAS/U. Miami

4. Cruise Operations

4.1 Mooring Operations

Mooring Recoveries

Four 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/pressure recorders. Site WBL3 is a short "bottom lander" mooring containing only a high precision bottom pressure sensor and releases.

Table 1. Mooring Recoveries

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
WB0	M459	26° 30.66'	76° 50.46'	1004	11/30/2018
WB3	M460	26° 29.69'	76° 29.66'	4840	11/27/2018
WBC	M462	26° 30.73'	76° 06.26'	4814	11/26/2018
WBL3	M461	26° 28.97'	76° 28.84'	4846	11/29/2018

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 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	M477	26° 30.54'	76° 50.52'	1006	11/30/2018
WB3	M478	26° 29.72'	76° 30.07'	4840	11/29/2018
WBC	M480	26° 30.70'	76° 06.44'	4819	11/27/2018
WBL3	M479	26° 29.50'	76° 29.20'	4846	11/29/2018

4.2 PIES Operations

In addition to the tall mooring and hydrographic operations completed on this cruise, regular maintenance of an array of NOAA-funded pressure-equipped inverted echo sounders (PIES) was also completed. This maintenance consisted primarily of acoustic download of the last ~15 months of daily-averaged data collected by the PIES moorings. The PIES units at Site A, Site A2, Site E had only telemetry sessions scheduled for the duration of the trip which ran successfully. With respect to Site E, there were also issues with thruster noise due to constant ship repositioning during its telemetry session. One PIES (Site C) was scheduled for recovery (4 years in the water). The telemetry was attempted twice; the first session only lasting the duration of the CTD station cast for the PIES training of Diego Ugaz, which ended up being an incomplete download. Upon the 2nd attempt, the telemetry download was fully completed. This PIES unit (Site C) was successfully recovered and a replacement PIES was deployed at the same site. Another PIES unit (Site D) was recovered because it failed to respond to any commands during its schedule telemetry session. The PIES unit at Site B was able to reply to telemetry commands during its scheduled telemetry session but was unable to send data or sample at all. This resulted in the successful deployment of another replacement PIES unit at both sites B and D upon successful recoveries of the compromised PIES units.

Table 3. PIES Operations

Site	Latitude	Longitude	Date	Operation	Result	PIES S/N
A	26° 30.945 **N**	76° 50.044 **W**	11/30/2018	Telemetry	Success	324
A2	26° 30.084 **N**	76° 44.779 **W**	11/29/2018	Telemetry	Success	159
B	26° 29.467 **N**	76° 28.187 **W**	11/19/2018	Telemetry	Failure	400
B	26° 29.467 **N**	76° 28.187 **W**	11/26/2018	Telemetry	Failure	400
B	26° 29.467 **N**	76° 28.187 **W**	11/26/2018	Recovery	Success	400
B	26° 29.467 **N**	76° 28.187 **W**	11/27/2018	Deployment	Success	322
C	26° 30.000 **N**	76° 05.600 **W**	11/20/2018	Telemetry	Failure	325
C	26° 30.000 **N**	76° 05.600 **W**	11/25/2018	Telemetry	Success	325
C	26° 30.000 **N**	76° 05.600 **W**	11/26/2018	Recovery	Success	325
C	26° 30.000 **N**	76° 05.600 **W**	11/26/2018	Deployment	Success	413
D	26° 30.112 **N**	75° 42.318 **W**	11/20/2018	Telemetry	Failure	281
D	26° 30.112 **N**	75° 42.318 **W**	11/25/2018	Recovery	Success	281
D	26° 30.112 **N**	75° 42.318 **W**	11/25/2018	Deployment	Success	323
E	26° 30.067 **N**	72° 00.000 **W**	11/24/2018	Telemetry	Success	335

4.3 CTD/LADCP Stations

A total of 48 CTD stations were conducted during the cruise (Table 4, Figure 3a,b). At each station, profiles of temperature, salinity (conductivity), and dissolved oxygen concentration were collected from the surface to within approximately 10 m of the bottom, using a dual Sea-Bird SBE-911plus CTD system. Two of these stations were performed to provide calibration data for SBE microcat instruments to be deployed on (or recovered from) the moorings (Stations 19 and 23). During these casts, the mooring instruments and the CTD package was lowered to its target depth, with 5 minute bottle stops during the upcast at the 12 selected dip cast depths and regular bottle stops at the other 12 depths. The outer Niskin bottles did not need to be removed from the frame to attach the microcasts. This allowed the first dip cast to be done at station 19 with the regular CTD cast. The second was done after recovery of the moorings as a standalone cast. These casts 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 12 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. A high-precision, slow-response thermistor (SBE-35RT, sampling at the bottle stops) was also used on the CTD package for all the stations on this cruise to enable more accurate calibration of the CTD temperature sensors.

Water velocity profiles were also measured at the stations using a paired downward looking 150 kHz and upward-looking 300 kHz Workhorse Acoustic Doppler Current Profiling 'hybrid" system (LADCP). Details on setup and operation of the dual LADCP system are contained in Appendix 1 of this report.

Table 4. CTD /LADCP Stations

Station	Date	Time (UTC)	Latitude (N)	Longitude (W)	Bottom Depth (m)	Max. CTD Depth (m)
1	11/18/20	2026	26 31.865	76 52.988	381	355
2	11/18/20	2148	26 31.231	76 50.059	1117	1094
3	11/18/20	2340	26 30.065	76 44.654	3945	3935
4	11/19/20	358	26 29.942	76 39.477	4697	4686
5	11/19/20	1039	26 30.011	76 33.820	4922	4909
6	11/19/20	1626	26 29.993	76 28.579	4933	4915
7	11/19/20	2207	26 29.995	76 20.816	4940	4919
8	11/20/20	334	26 29.964	76 13.035	4903	4894
9	11/20/20	927	26 29.999	76 05.178	4891	4883
10	11/20/20	1502	26 30.086	75 53.957	4830	4819
11	11/20/20	2051	26 30.014	75 42.203	4776	4756
12	11/21/20	152	26 30.103	75 30.068	4769	4749
13	11/21/20	718	26 30.039	75 17.839	4720	4713
14	11/21/20	1415	26 29.992	75 04.963	4695	4682
15	11/21/20	1949	26 29.975	74 48.081	4625	4606
16	11/22/20	109	26 29.965	74 31.055	4572	4554
17	11/22/20	647	26 30.029	74 14.009	4625	4619
18	11/22/20	1317	26 29.982	73 51.992	4831	4820
19*	11/22/20	1933	26 30.086	73 30.039	5020	5010
20	11/23/20	229	26 30.042	73 07.948	5142	5123
21	11/23/20	1018	26 30.119	72 45.791	5232	5222
22	11/23/20	2324	26 31.556	72 23.353	5285	5272
23*	11/30/20	208	26 30.071	76 28.186	4933	4922

24	12/1/20	954	26 25.886	78 40.011	776	766
25	12/1/20	1148	26 19.980	78 42.873	703	700
26	12/1/20	1319	26 15.102	78 45.957	527	521
27	12/1/20	1441	26 10.195	78 47.930	463	455
28	12/1/20	1620	26 04.132	78 51.022	309	299
29	12/1/20	1930	26 02.933	79 13.961	325	307
30	12/1/20	2051	26 03.007	79 18.623	491	470
31	12/1/20	2222	26 03.043	79 23.899	595	579
32	12/1/20	2358	26 03.124	79 28.793	681	668
33	12/2/20	146	26 02.922	79 33.991	772	752
34	12/2/20	350	26 02.941	79 39.946	708	688
35	12/2/20	544	26 03.155	79 45.886	610	599
36	12/2/20	728	26 03.107	79 50.882	336	325
37	12/2/20	849	26 03.235	79 55.879	277	266
38	12/2/20	1006	26 03.146	79 59.946	254	244
39	12/2/20	1112	26 02.800	80 03.928	135	126
40	12/2/20	1821	27 00.002	79 12.081	489	472
41	12/2/20	1948	27 00.010	79 16.994	619	607
42	12/2/20	2123	27 00.076	79 22.904	668	650
43	12/2/20	2312	27 00.070	79 29.982	768	749
44	12/3/20	118	26 59.790	79 37.057	651	629
45	12/3/20	252	26 59.703	79 41.093	542	528
46	12/3/20	433	26 59.726	79 47.115	390	379
47	12/3/20	555	27 00.212	79 51.916	271	262
48	12/3/20	706	27 00.139	79 55.964	150	140

* Instrument calibration casts

5. Underway Measurements

Thermosalinograph

Values of surface temperature and salinity were continuously monitored using a Sea-Bird SBE-45 temperature-conductivity recorder installed in the ship's seawater intake line, and logged by the vessel's underway recording system.

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 typically extended to 600 m below the vessel and as much as 800 m in calm sea state conditions. In rougher conditions a ship speed of 6 kts or less was necessary to obtain good data. Data were processed onboard in real time using the UHDAS acquisition system. Gyrocompass data were continuously corrected by an ADU-800 inertial navigation system.

6. Preliminary Results

The upper ocean velocity structure off Abaco during the cruise was dominated by a very large anticyclonic eddy extending from Abaco to about 73°W, with another center of anticyclonic circulation indicated in sea surface height imagery to the north of Abaco (Fig. 6). The LADCP (Fig. 4) and shipboard ADCP data (Fig. 5) were very consistent with this description, showing a center of circulation near 75°W across the south side of the eddy and a corresponding westward flow along most of the Abaco line. Within about 20 km of Abaco a surface intensified northward flow was observed, which could indicate the presence of a weak Antilles Current or possibly (and perhaps more likely) a northward boundary jet forced by the impingement of the eddy on the Bahamas. Interestingly, just a little farther south - off southern Abaco - the near boundary flow reversed abruptly to southward and appeared to flow into Northwest Providence Channel (Fig. 5), suggestive of the formation of a "wall jet" that is characteristic of the interaction of an anticyclonic eddy with a western boundary.

Below 1000 m the Deep Western Boundary Current (DWBC) was observed flowing strongly southward between the Bahamas escarpment and approximately 130 km offshore. Rather atypically, the strongest flow was observed in the lower part of the DWBC below 3000 m instead of in the upper part of the DWBC near 2000 m where it usually occurs. Offshore of the DWBC was a band of northward and then southward flow that were aligned more or less with the circulation of the upper ocean anticyclonic eddy, suggesting that these flows could be associated with a deep extension of the eddy. On the other hand a band of northward recirculation in is often present just offshore of the DWBC, with alternating bands farther offshore, so this apparent connection could be coincidental.

The Florida Straits and Northwest Providence Channel sections (not shown) revealed fairly typical flow conditions in both channels, with maximum speeds in the surface core of the Florida Current of about 1.8 m/s, and a subsurface-intensified westward flow in NW Providence Channel.

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 CTD/LADCP station data, will be provided within 1 year of the termination of the cruise (December, 2019).

Moored Instrumentation

Time series data records from the moored instruments will be provided within 2 years of recovery of the instruments (nominally December, 2020).

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.

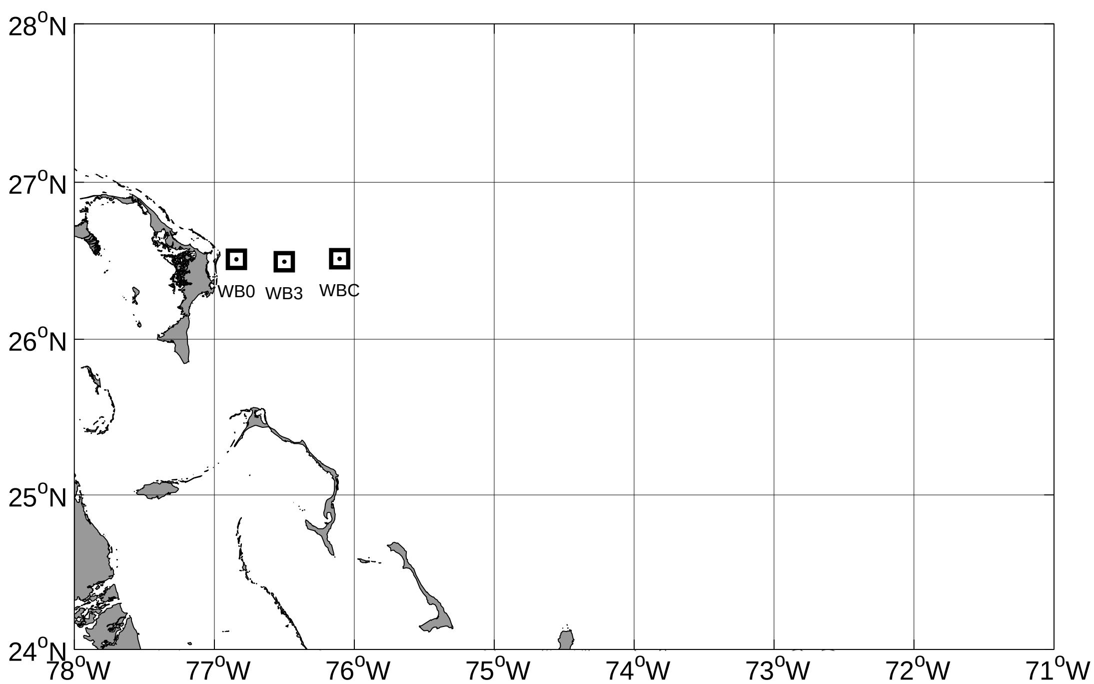


Figure 1. Current meter moorings recovered and deployed on AE-1833. An additional "bottom lander" mooring (WBL3, not shown on map) was deployed near mooring WB3.

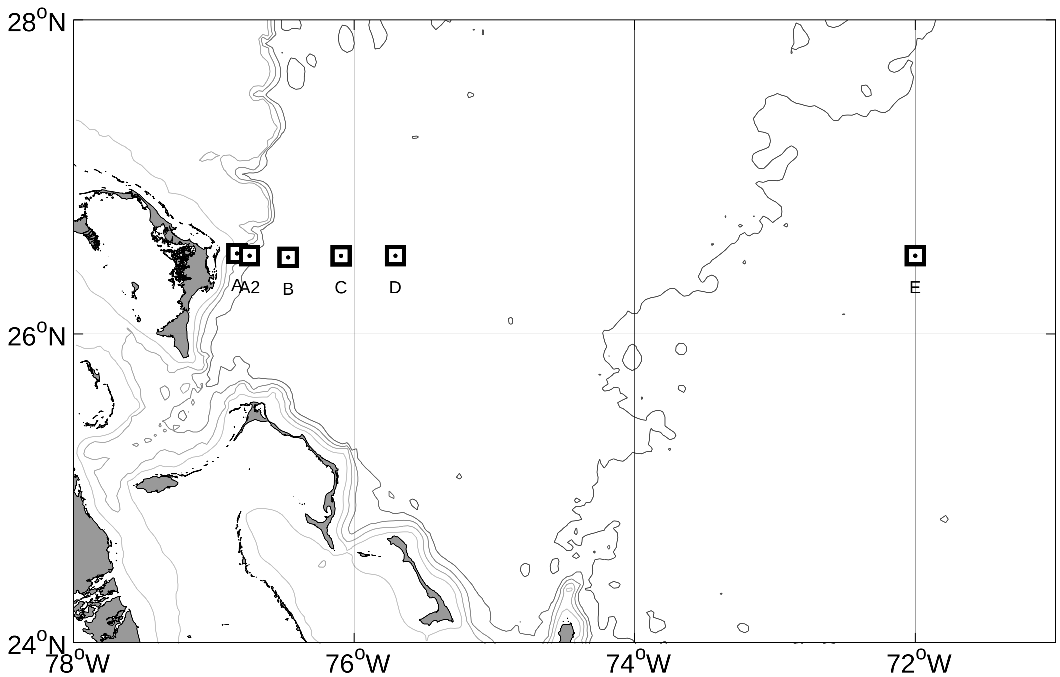


Figure 2. PIES locations along the 26.5°N Abaco line.

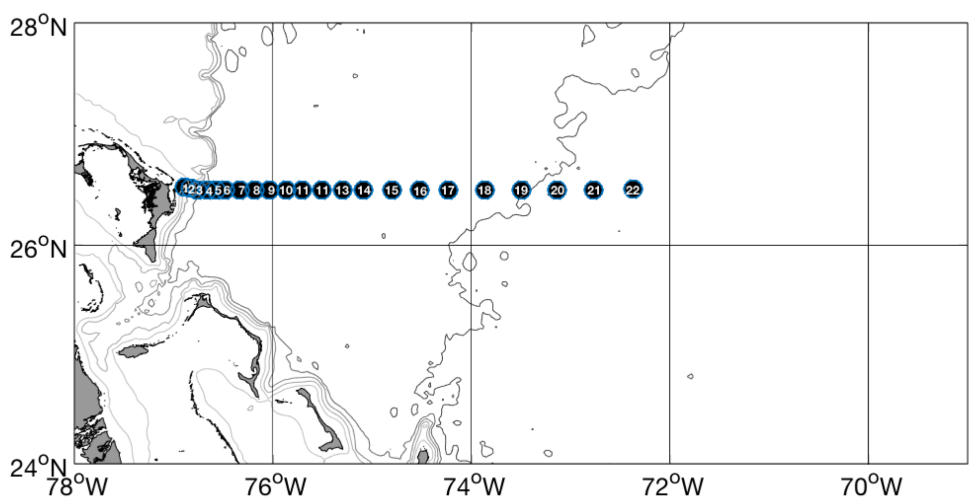


Figure 3a. CTD/LADCP stations occupied along the 26.5° N Abaco line.

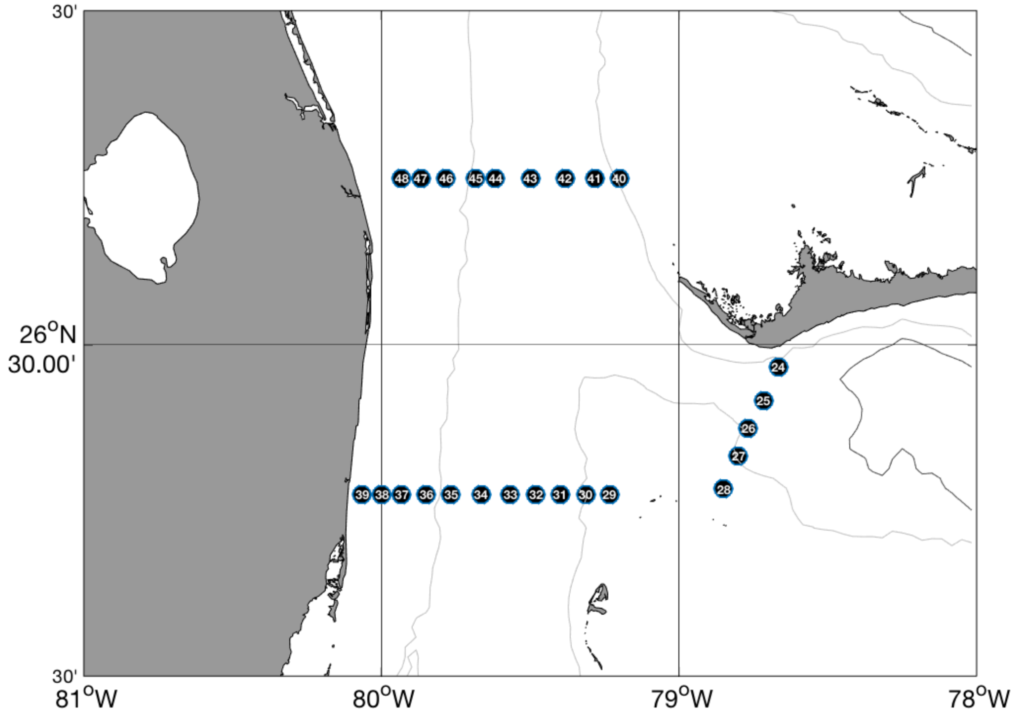
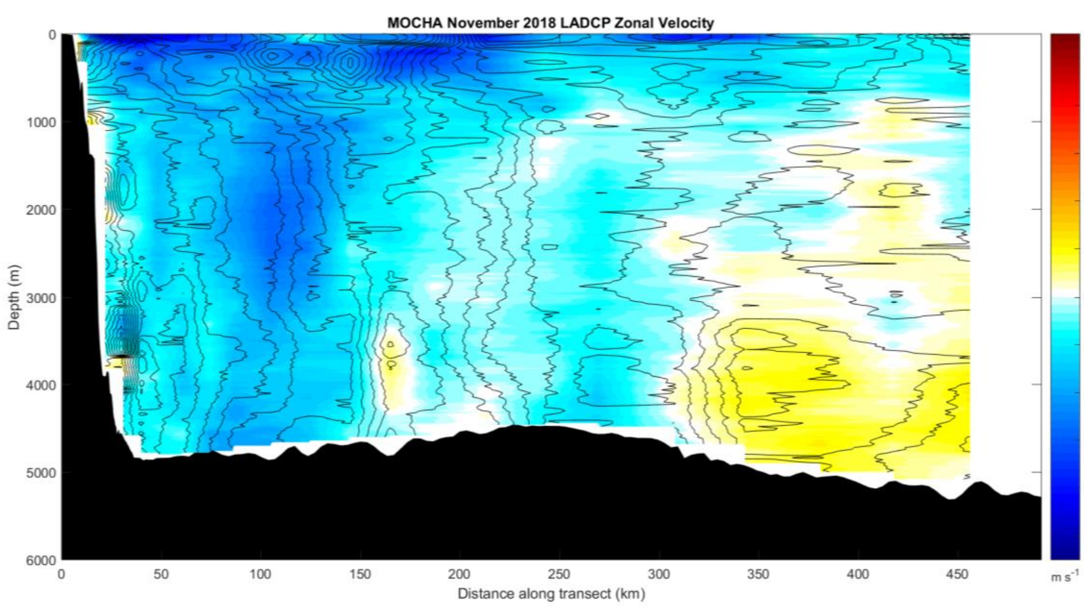


Figure 3b. CTD/LADCP stations occupied along the 26°N and 27°N Straits of Florida sections and across the Northwest Providence Channel.



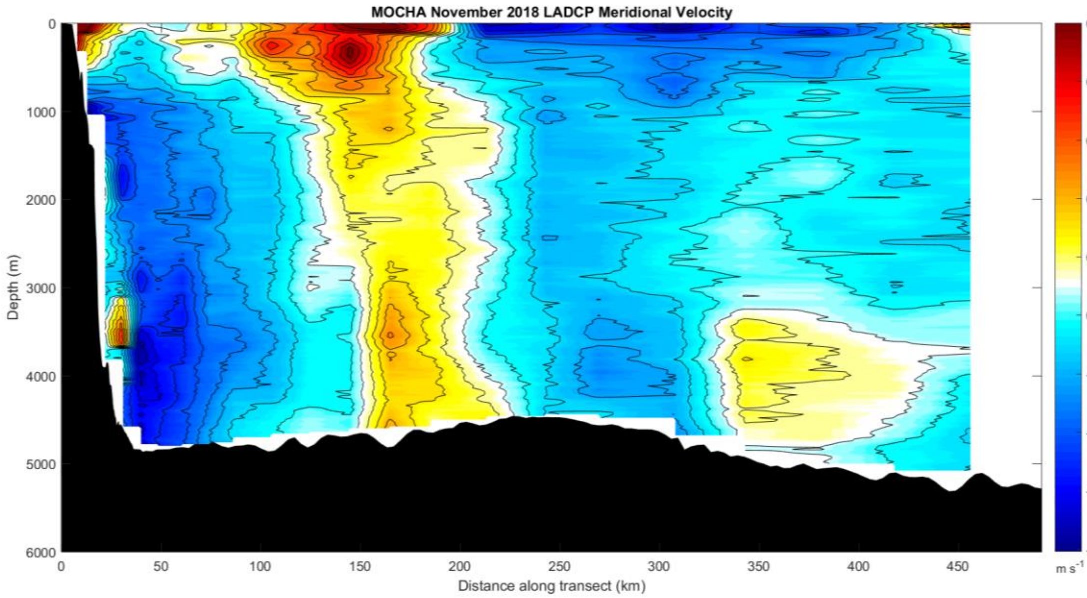


Figure 4. Zonal and meridional velocity sections for the Abaco line, from Lowered-ADCP profiles collected at the CTD stations.

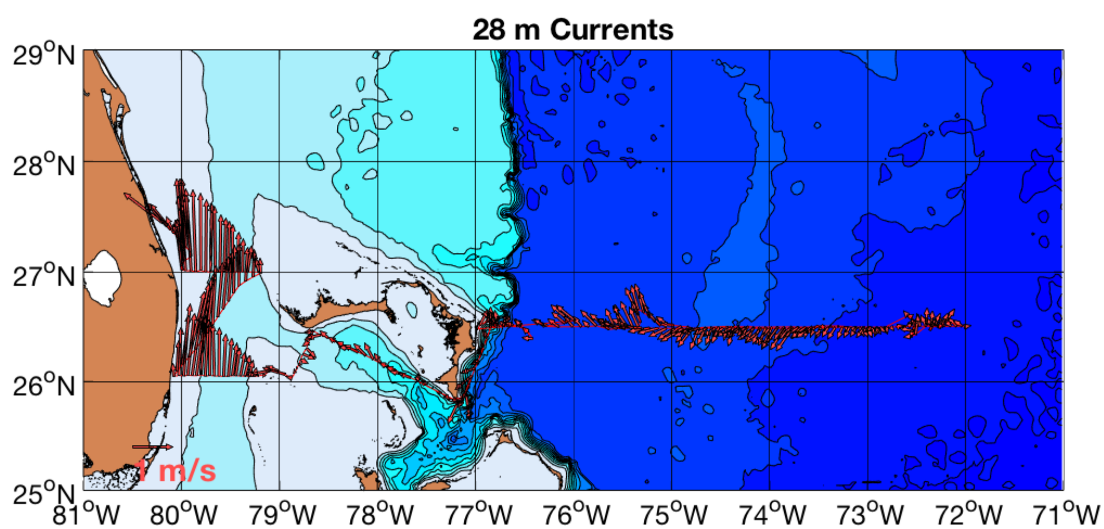


Figure 5. Near-surface currents along the cruise track, derived from the vessel-mounted ADCP.

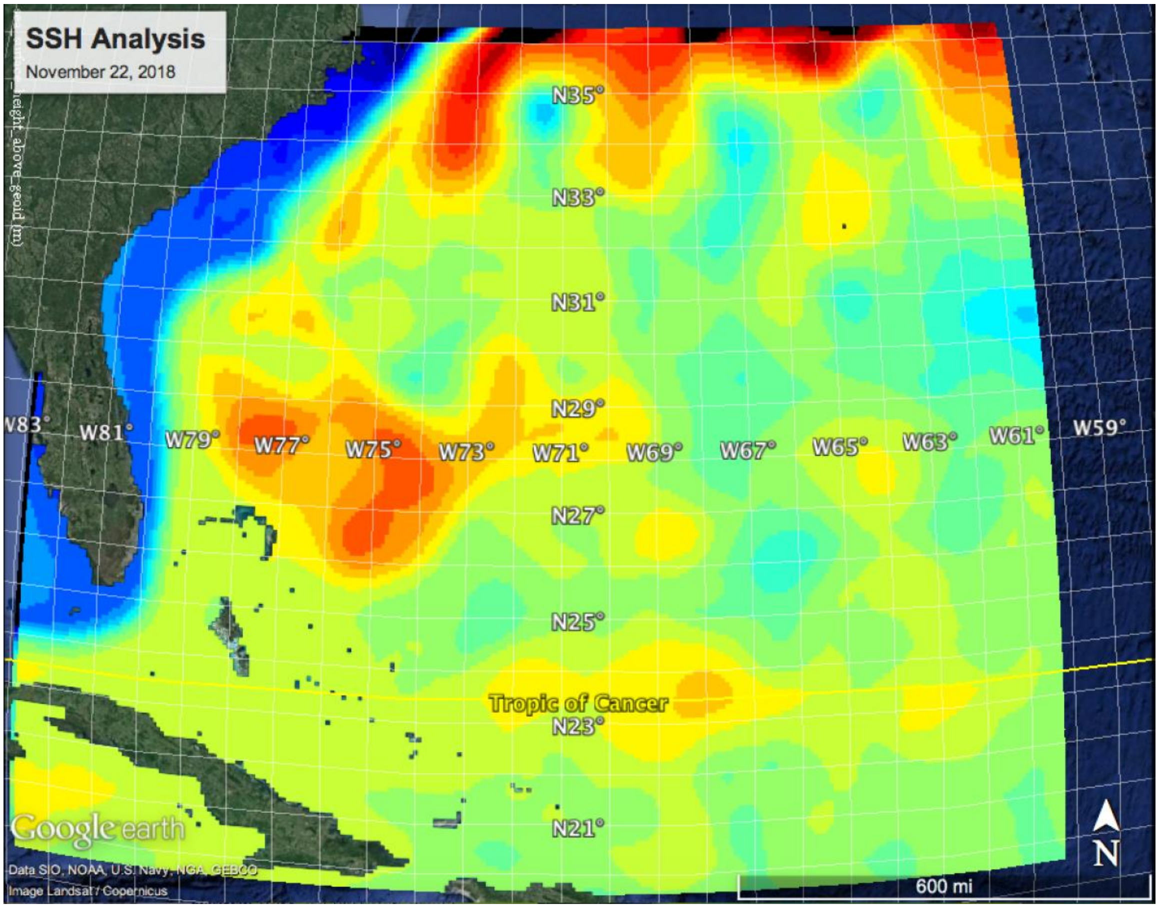


Figure 6. Altimetric sea surface height analysis of the study region for November 22, 2018, during the occupation of the 26.5°N CTD/LADCP line.

Appendix 1. Lowered ADCP Operations

Pedro Pena
3 Dec 2018

LADCP Setup:

Full water column velocity profiles for the MOCHA November 2018 cruise were collected using a hybrid 150/300kHz Workhorse configuration. The instruments, cables, and related equipment were supplied by NOAA's AOML physical oceanography group. The primary downward-looking 150 kHz ADCP was S/N 18144 for the first 5 casts and 18145 for the remaining casts. The upward-looking 300 kHz ADCP was S/N 15329 for the first 8 casts and S/N 1856 for the remaining casts. Custom-made 48-volt lead-acid battery packs were supplied by AOML. The two Workhorse ADCPs were mounted on AOML's 24-bottle CTD rosette. The upward-looking ADCP was mounted near the outer edge of the rosette, situated above the upper rim of the frame. The downward-looking 150 kHz ADCP was mounted in the center of the frame adjacent to the SBE9 CTD, with the transducer face about 10cm above the bottom of the frame. The battery pack was secured adjacent to the downward-looking ADCP using brackets bolted to the bottom of the rosette frame. Both ADCP's were wired to run off a single battery pack and communicate with each other using a standard star-cable.

Data Acquisition Setup:
The 150 kHz ADCP was configured for 16 16-meter bins, 16 meter blanking distance, and an ambiguity velocity of 350 cm s^{-1}. The 300 kHz ADCP was configured for 20 8-meter bins, zero blanking distance, and an ambiguity velocity of 250 cm s^{-1}. The units were configured for staggered single-ping ensembles; the upward-looking ADCP was set to 1 sec ensembles, and the downward-looking ADCP was set to burst-sample every 2 seconds with 0.8 seconds between pings. Measurements were saved in beam coordinates, with 3-beam solutions and bin-mapping disabled. ADCP S/N 18144 was running firmware version 51.40 and the other ADCP's were running firmware version 50.40.

Inside the main lab of the Atlantic Explorer, a dedicated PC laptop running a custom Linux distribution with a two-port USB-serial hub was set up as the primary data acquisition platform. A dual-terminal program written in Python ('ladcp2.py' which is included in the UH-DAS ADCP software package) was used to communicate with the instruments. Data files downloaded to the acquisition PC were transferred to the ship's public network drive for processing and archiving. A Soneil 4808SR automatic battery charger was used to charge the battery pack. A single cable with dual serial port lines, along with power leads connected to the battery charger, was run outside to the CTD rosette where it plugged into the star-cable wiring.

The two raw ADCP data files were processed on the acquisition computer and a second computer with uncorrected one-second time-series CTD data provided by the CTD operator. The initial processing of the raw ADCP data was done using a compiled version of M. Visbeck version 10.20 & A. Thurnherr MATLAB toolbox, modified by G. Krahmann running with in Matlab.

Operational Issues:

Processing issues

Lowered ADCP operations began on November 18th on the east side of Abaco. Initially the Visbeck version of the processing script did not work but the Thurnherr version of the script did.
The failure to process correctly was later discovered to be a time difference of 1 minute and 50 seconds between the ship's time server and the ship's NMEA source. The previous stations were later reprocessed using the time correction and the results were comparable to the results obtained from the Thurnherr version.

Charging issues

The battery pack was swapped for the first time when charging problems were discovered after station 004 and as a result the LADCP data for that station was of poor quality. Station 005 processed correctly but an unacceptable downward trend in the battery voltage meant that there was still an issue.
To isolate the the problem, after station 005, the 150kHz ADCP was swapped and after station 008, the 300kHz ADCP and the star cable were swapped. This did not fix the problem and it was later found that the resistance in the deck lead was too high causing an increase in charge time. For future cruises the charging wire pair in the deck lead should be of a lower gauge to reduce wire resistance and decrease charge time. The battery pack was swapped with a charged one when needed.

Command files for the WH300 and WH150:

```
Workhorse 150 kHz Downward-looking ADCP (MASTER) Command File
Filename: AB1811_150kHz_master.cmd
PS0
OL
rnMASTR
CR1
WM15
TC2
TB 00:00:02.00
TE 00:00:00.80
TP 00:00.00
WP1
WN016
WS1600
WF1600
WV350
EZ0011101
EX00100
CF11101
SM1
SA011
SW05000
T?
L?
TS?
CS
```

```
Workhorse 300 kHz Upward-looking ADCP (SLAVE) Command file
Filename: AB1811_300khz_slave.cmd
PS0
OL
CR1
rnSLAVE
WM15
CF11101
EX00100
EZ0011101
WP1
TE00:00:01.0
TP00:00.01
```

```
SM2
SA011
WN020
WS0800
WF0000
WV250
LZ30,220
CK
T?
L?
CS
```