CRUISE REPORT

***R/V Seward Johnson* Cruise No. SJ-08-03**

RAPID/MOCHA Program
April 4-30, 2008
Ft. Pierce to Ft. Pierce, Florida, USA

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 establish a pre-operational measurement system to continuously observe the strength and structure of the Atlantic meridional overturning circulation across the basin at 26º N. The U.K. program is referred to as "RAPID-MOC" 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 Program.

The goals of cruise SJ-08-03 were to:

1) Service the "western boundary array" of the RAPID/MOCHA transbasin observing system, consisting of 8 sites with current meter/CTD moorings, several including co-located bottom-pressure moorings;
2) Conduct hydrographic ($CTDO_2$) and direct current profiling (lowered-ADCP, "LADCP") stations along the 26.5º N mooring section off Abaco, Bahamas; and along sections in the Northwest Providence Channel and Florida Current at 27º N, including continuous shipboard ADCP observations; and
3) Retrieve data from 5 bottom pressure/inverted echo sounder (PIES) sites via acoustic telemetry

2. Cruise Synopsis

The cruise was split into two legs to accommodate the large amount of mooring gear that had to be carried on the ship. Leg 1 was from Ft. Pierce, FL to Freeport, Bahamas, from Apr. 4-20. During this leg the CTD work was completed (except the NW Providence section, which had to be skipped due to lack of time), and the U.S moorings were serviced. Leg 2 was from Freeport to Ft. Pierce, from Apr. 22-30, during which the U.K. moorings were serviced. During the intermediate port stop in Freeport, Apr. 20-21, the U.K mooring gear was loaded and the recovered U.S mooring gear was offloaded for temporary storage. On leg 2, before returning to Ft. Pierce, the ship again stopped in

Freeport to offload the U.K. gear for transshipment and reload the U.S. gear for transit to Ft. Pierce.

Leg 1 began with occupation of the Florida Current $CTDO_2$/LADCP section at 27º N enroute to Freeport, Bahamas to clear in for research in Bahamian waters. This section measures the outflow through the Straits of Florida where AOML monitors the Florida Current volume transport via submarine electromagnetic cable.

After departing Freeport, the ship proceeded to deep water offshore of Abaco where the 26.5º N section was occupied, consisting of 23 $CTDO_2$/LADCP stations extending from Abaco to 72º W. This section sampled the Deep Western Boundary Current and Antilles Current region east of the Bahamas and is part of an ongoing time series of these currents collected since 1984 by the AOML group. The $CTDO_2$/LADCP stations collected on this section are also important for calibration of results from the western boundary moored array.

Following completion of the Abaco section, U.S. mooring servicing operations were commenced from east to west across the RAPID/MOCHA array. U.S. mooring sites WB3 and WB5 were successfully serviced, but at site WB0 the mooring had to be recovered after deployment due to a malfunctioning acoustic release, and this was later redeployed on Leg 2. Acoustic telemetry from the AOML PIES sites A, B, and C was also accomplished. Due to rough weather the PIES telemetry at PIES site "D" had to be postponed to Leg 2, and the PIES at site "E" had to be recovered because it could not be communicated with (and had also stopped its normal pinging cycle).

The ship returned to Freeport on April 20th to load mooring equipment from the U.K. mooring team, and departed Freeport again on April 22nd. U.K. mooring sites WBA, WB1, WB2, and WB4 were successfully serviced, and an additional mooring was deployed at site WBH2. U.S. mooring WB0 was also redeployed on this leg, and data telemetry from PIES site "D" was successfully accomplished. A number of "cal-dip" CTD casts were also performed on this leg (as well as on leg 1) to provide high –quality calibrations for the moored T-S recorders (SeaBird micro-cats) used on the moorings. The ship returned to Freeport on April 29th to offload all U.K. gear and reload U.S. gear for the return transit to Ft. Pierce, and clear out of the Bahamas. On the return trip to Florida the ship steamed across the 27º N Florida Current section while sampling the current with shipboard ADCP and XBT profiles. Cruise disembarked in Ft. Pierce April 30th.

3. Scientific Personnel

Leg 1 (April 4-20, 2008):

Name	Position	Organization
Bill Johns	Ch. Sci.	RSMAS/ U. Miami
Lisa Beal	Scientist	RSMAS/ U. Miami
Jonathan Molina	Scientist	RSMAS/ U. Miami
Robert Jones	Technician	RSMAS/ U. Miami
Mark Graham	Technician	RSMAS/ U. Miami
Ben Shaw	Student	RSMAS/ U. Miami
Rafael Schiller	Student	RSMAS/ U. Miami
Wilson Mendoza	Student	RSMAS/ U.Miami
Chris Meinen	Scientist	NOAA/ AOML
Carlos Fonseca	Scientist	NOAA/ AOML
Ulises Rivero	Technician	NOAA/ AOML
Andy Stefanick	Technician	NOAA/ AOML

Leg 2 (April 22-30, 2008):

Name	Position	Organization
Bill Johns	Ch. Sci.	RSMAS/ U. Miami
Jonathan Molina	Scientist	RSMAS/ U. Miami
Mark Graham	Technician	RSMAS/ U. Miami
Carlos Fonseca	Scientist	NOAA/ AOML
Andy Stefanick	Technician	NOAA/ AOML
Stuart Cunningham	Scientist	NOC Southampton
Torsten Kanzow	Scientist	NOC Southampton
Craig Wallace	Scientist	NOC Southampton
Daniel Klocke	Scientist	IFM Hamburg
Robert McLachlan	Technician	NOC Southampton
Christian Crowe	Technician	NOC Southampton
Dave Childs	Technician	NOC Southampton
Colin Hutton	Technician	NOC Southampton
Peter Lazarevich	Scientist	FSU
Eric Howarth	Technician	FSU

3. Cruise Operations

3.1 Mooring Operations

Mooring Recoveries

Seven taut-line 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. Additionally, two bottom lander moorings (UK sites WBL3 and WBL4), containing only high-precision bottom pressure sensors, were successfully recovered. The University of Miami moorings (sites WB0, WB3, and WB5 in Table 1) had been deployed previously in September 2006 aboard the R/V Seward Johnson, while the NOC moorings (sites WBA, WB1, WB2, and WB4) had been deployed previously on the NOAA R/V Ronald Brown in March 2007. All mooring recoveries went smoothly and without incident, except for WB4, which had lost its near-surface flotation during deployment period and took several hours to come to the surface with the remaining buoyancy. Also, there were more than usual difficulties in communicating with some of the acoustic releases on both the U.S. and U.K. moorings, but eventually all the taut-wire moorings were successfully released from the bottom. A bottom lander mooring previously deployed at U.S. site WB3 could not be released from the bottom, after many attempts, and is presumed lost.

Finally, a bottom lander at U.S. site WB5, that had been intended for recovery on this cruise, was left in the water to continue recording data, as the PIES at this site had stopped working and had to be recovered ahead of plan.

Table 1. Mooring Recoveries

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
WBA	2007/04	26° 31.48'	76° 52.17'	600	04/23/2008
WB0	M371	26° 30.48'	76° 50.52'	1015	04/19/2008
WB1	2007/01	26° 29.90'	76° 49.30'	1400	04/23/2008
WB2	2007/02	26° 30.62'	76° 44.66'	3892	04/24/2008
WB3	M372	26° 29.66'	76° 29.93'	4840	04/17/2008
WB4	2006/05	26° 32.26'	76° 08.89'	4824	04/27/2008
WB5	M373	26° 30.00'	71° 58.30'	5297	04/13/2008
WBL3	2006/08	26° 30.42'	76° 44.66'	3880	04/24/2008
WBL4	2006/05	26° 30.02'	76° 02.95'	4810	04/27/2008

Mooring Deployments

A total of 12 moorings (8 taut-wire moorings and 4 bottom landers) were deployed at the locations listed in Table 2 and shown in Figure 1b. All deployments operations went smoothly except for U.S. site WBA on the first leg, which had to be recovered shortly

after deployment due to a malfunctioning acoustic release. This mooring was successfully redeployed on the second leg.

Mooring WB5 contained an experimental surface telemetry buoy intended to provide near-real time data from all of the instruments on the mooring. The instrument data is relayed via inductive up-wire telemetry to a subsurface controller/logger in the main subsurface flotation unit at 50 m depth, which then relays the data via conducting S-tether cable to a surface telemetry buoy. The other moorings contain only internally recording instruments whose data is recovered after the moorings are retrieved.

WB5 had to be deployed in relatively rough sea conditions (winds 25-35 kts, seas 7-8 ft.) due to an approaching weather system with conditions expected to worsen over for the next 2 days. The surface telemetry buoy was apparently damaged during deployment, since no data telemetry messages were successfully received from the unit after deployment. Visual inspection of the surface buoy the following morning confirmed that the satellite antenna had been broken, and therefore the surface buoy was recovered from the top of the mooring and replaced with a dummy float. Surveying of the on-bottom position of all moorings (except for the bottom landers) was successfully completed after each mooring deployment.

Table 2. Mooring Deployments

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
WBA		26° 31.52'	76° 52.12'	598	04/23/2008
WB0	M381	26° 30.34'	76° 50.49'	1001	04/23/2008
WB1		26° 30.00'	76° 49.23'	1380	04/25/2008
WB2		26° 30.12'	76° 44.52'	3891	04/26/2008
WBH2		26° 27.90'	76° 39.03'	4737	04/26/2008
WB3	M382	26° 29.53'	76° 30.04'	4858	04/18/2008
WB4		26° 24.92'	75° 41.90'	4705	04/28/2008
WB5	M383	26° 30.33'	71° 58.23'	5293	04/14/2008
WBL3		26° 30.41'	76° 44.66'	3887	04/24/2008
WBLB		26° 29.93'	76° 29.64'	4887	04/24/2008
WBL4		26° 24.25'	75° 42.59'	4705	04/28/2008
WBL5	M384	26° 30.44'	71° 58.86'	5239	04/14/2008

3.2 Inverted Echo Sounders

NOAA maintains a line of inverted echo sounders (IES) along 26° 30’ N as part of its Western Boundary Time Series project. Some of the instruments are also equipped with bottom pressure sensors (PIES), and one has both a bottom pressure sensor and a single

point current meter 50 m above the bottom (C-PIES). No deployment or recovery operations were planned for this cruise, but one PIES (site E) had to be recovered after it was determined the instrument was no longer sampling, and could not be communicated with acoustically. Acoustic data telemetry was successfully conducted at four other PIES sites. The activities involving inverted echo sounders are summarized in Table 3.

Table 3. PIES Operations

Site	Instrument type	Latitude (ºN)	Longitude (ºW)	Depth (m)	Activity
A	PIES	26º 30.9'	76º 50.0'	1092	Telemetry
B	PIES	26º 29.5'	76º 28.2'	4804	Telemetry
C	PIES	26º 30.1'	76º 05.2'	4761	Telemetry
D	CPIES	26º 30.2'	75º 42.3'	4690	Telemetry
E	PIES	26º 29.9'	72º 00.3'	5233	Recovery

4. $CTDO_2$/LADCP Stations

A total of 45 $CTDO_2$ stations were conducted during the cruise (Table 4, Figure 2a and 2b). 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. Water samples for calibration of the salinity and dissolved oxygen profiles were collected using a 24-bottle Rosette system containing 10 liter Niskin bottles. Current profiles were also measured using a paired downward-looking 150 kHz Broadband and upward-looking 300 kHz Workhorse Acoustic Doppler Current Profiling 'hybrid" system (LADCP) for all stations on the Abaco line (stations 13-35), and at one of the instrument calibration stations (station 10, see below). A second LADCP system consisting of paired upward and downward looking 300 kHz ADCPs was used for most of the remaining stations, including the Straits of Florida section (stations 1-9) and calibration casts 36-43. No LADCP data was collected on calibration casts 11-12 and 44-45. First pass processing of LADCP data was done using Visbeck version IX.4 software with navigation data only, which requires manually clipping off the on-deck data using RDI's WINADCP to obtain sensible profiles. Second pass processing was completed with version IX.4, including processed CTD station data and on-station shipboard ADCP data.

Some of the $CTDO_2$ casts were used to perform calibration checks on the temperature, salinity, and pressure measurements obtained from various moored instruments (SBE Microcats and Aanderaa RCM current meters) after their recovery or prior to deployment. Acoustic releases were also attached to the frame and tested on several of these stations. During these casts, the outer rack of Niskin bottles was removed from the Rosette to accommodate the moored instruments and the CTD package was lowered to

3000-4000m 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.

Table 4. $CTDO_2$ Station Locations

Station	Date	Time (UTC)	Latitude (^{o}N)	Longitude (^{o}W)	Depth (m)
1	04/04/08	1833	27.005	79.933	153
2	04/04/08	2051	27.002	79.867	258
3	04/04/08	2241	27.002	79.784	382
4	04/05/08	0010	26.999	79.686	528
5	04/05/08	0152	27.004	79.618	634
6	04/05/08	0351	27.001	79.503	760
7	04/05/08	0557	27.000	79.380	655
8	04/05/08	0747	27.003	79.284	611
9	04/05/08	0910	27.002	79.200	478
10*	04/08/08	0234	25.952	76.896	3472
11*	04/08/08	0708	25.943	76.912	3473
12*	04/08/08	1135	25.933	76.927	1107
13	04/08/08	1719	26.523	76.88	511
14	04/08/08	1844	26.516	76.832	1120
15	04/08/08	2022	26.500	76.743	3832
16	04/09/08	0004	26.500	76.656	4578
17	04/09/08	0526	26.500	76.566	4835
18	04/09/08	1022	26.497	76.474	4847
19	04/09/08	1535	26.495	76.346	4838
20	04/09/08	2022	26.500	76.218	4817
21	04/10/08	0055	26.500	76.086	4804
22	04/10/08	0538	26.499	75.900	4747
23	04/10/08	1026	26.499	75.703	4693
24	04/10/08	1545	26.500	75.499	4689
25	04/10/08	2106	26.503	75.304	4644
26	04/11/08	0143	26.501	75.083	4613
27	04/11/08	0650	26.503	74.800	4542
28	04/11/08	1158	26.501	74.517	4490
29	04/11/08	1719	26.498	74.239	4535
30	04/11/08	2329	26.503	73.871	4731
31	04/12/08	0516	26.500	73.501	4970
32	04/12/08	1105	26.500	73.133	5048
33	04/12/08	1713	26.500	72.768	5140
34	04/12/08	2243	26.500	72.383	5191
35	04/13/08	0425	26.501	71.990	5291
36*	04/19/08	0008	26.473	76.508	3472

37*	04/19/08	0427	26.464	76.505	3475
38*	04/19/08	1722	26.490	76.808	1114
39*	04/22/08	2212	26.041	76.837	3966
40*	04/23/08	0329	26.212	76.740	3960
41*	04/25/08	0040	26.500	76.599	3974
42*	04/24/08	0541	26.482	76.598	3959
43*	04/25/08	0155	26.460	76.635	3962
44*	04/27/08	0304	26.499	76.579	3998
45*	04/28/08	1546	26.393	75.676	3471

* Instrument calibration casts

5. Underway Measurements

Thermosalinograph

Values of surface temperature and salinity were continuously monitored and logged on the ship's computer using a Sea-Bird temperature-conductivity recorder installed in the ship's seawater intake line.

Shipboard Acoustic Doppler Current Profiler

Upper ocean currents were continuously measured with two different Acoustic Doppler Current Profilers (ADCPs) mounted in the ship's transducer well. One was a 150 kHz Ocean Surveyor ADCP and the other was a 38 kHz Ocean Surveyor ADCP. The depth range of good velocity data typically extended to 220 m below the vessel for the 150 kHz ADCP, and 1000 m for the 38 kHz ADCP, depending on sea state conditions. One of the beams of the 150 kHz ADCP was malfunctioning during the entire cruise, but the 3-beam solutions obtained from the 3 functioning beams appeared otherwise good. The POSMV 3-D navigation system used for the ADCPS was improperly calibrated during the first part of leg 1 (for the outbound Florida Straits section along 27° N), but was properly calibrated for the remainder of the cruise after careful repositioning of one of the antennas and recalibration of the system. Details of the shipboard and lowered ADCP operations on the cruise are contained in a separate (internal) report prepared by Dr. Lisa Beal, which can be made available on request.

6. Preliminary Results

The LADCP data acquired across the Florida Current (Figure 3) show the typical surface intensified velocity core of the current with maximum speeds near 2.0 m/s. However in this section the flow appears atypically strong over the shallow part of the section near Florida. Evidence is also found for a weak (southward) countercurrent near the bottom along the Florida continental slope.

The LADCP section east of Abaco (Figure 4) shows evidence of the Deep Western Boundary Current (DWBC) at depths below about 1000 m between Abaco and 75.5° W, with a nearly uniform vertical structure and with maximum speeds near 30 cm/s. Atypical features of the section include the absence of an "Antilles" Current, which is normally found flowing northward just offshore of Abaco with a subsurface core near 400 m, and a small eddy-like circulation centered near 700 m depth just offshore of the Bahamas escarpment. Farther offshore, a banded structure of reversing currents is found suggestive of planetary waves or additional eddy features of larger zonal scale.

7. Release of Project Data

In accordance with the provisions specified in the cruise prospectus and application for foreign clearances, 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 (May, 2009).

Moored Instrumentation

Time series data records from the moored instruments will be provided within 2 years of recovery of the instruments (nominally May, 2010).

8. Acknowledgements

The support and able assistance provided by the Captain and crew of the *R/V Seward Johnson*, operated by the Harbor Branch Oceanographic Institution, is gratefully acknowledged. Support for the scientific research was provided by the U.S. National Science Foundation, the NOAA Office of Global Programs, and the U.K. National Environmental Research Council. The Commonwealth of the Bahamas graciously granted privileges to conduct scientific research in their territorial waters.

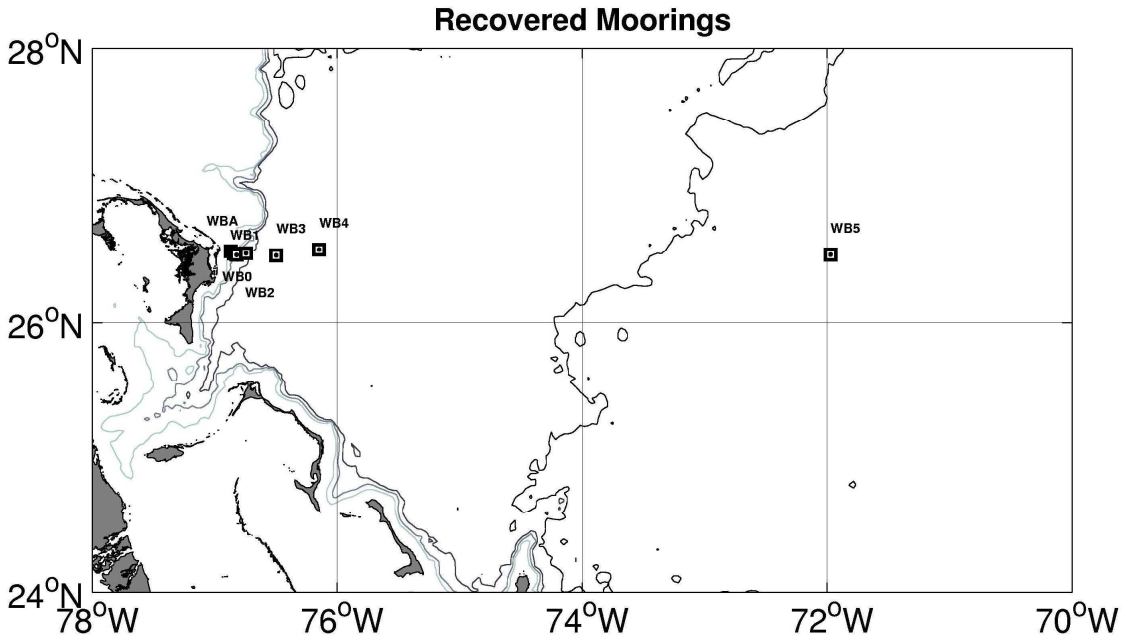

Figure 1a. Moorings recovered on cruise SJ-08-03. Additional "bottom lander" moorings were recovered at sites WB2 and WB4 (not shown).

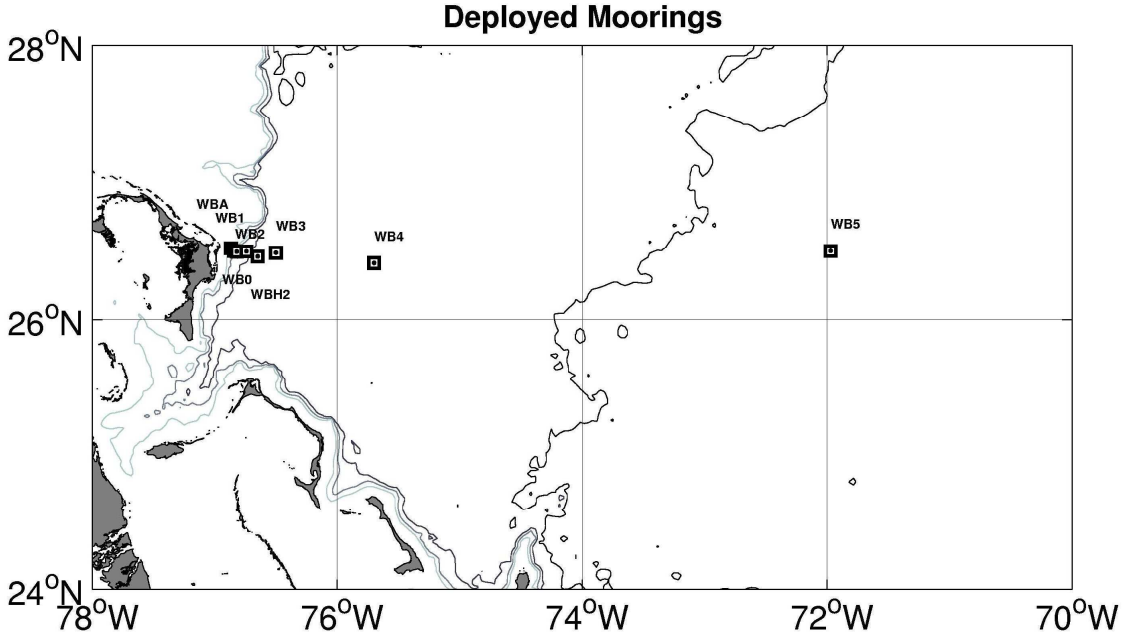

Figure 1b. Moorings deployed on cruise SJ-08-03. Additional "bottom lander" moorings were deployed at sites WB2, WB3, WB4 and WB5 (not shown).

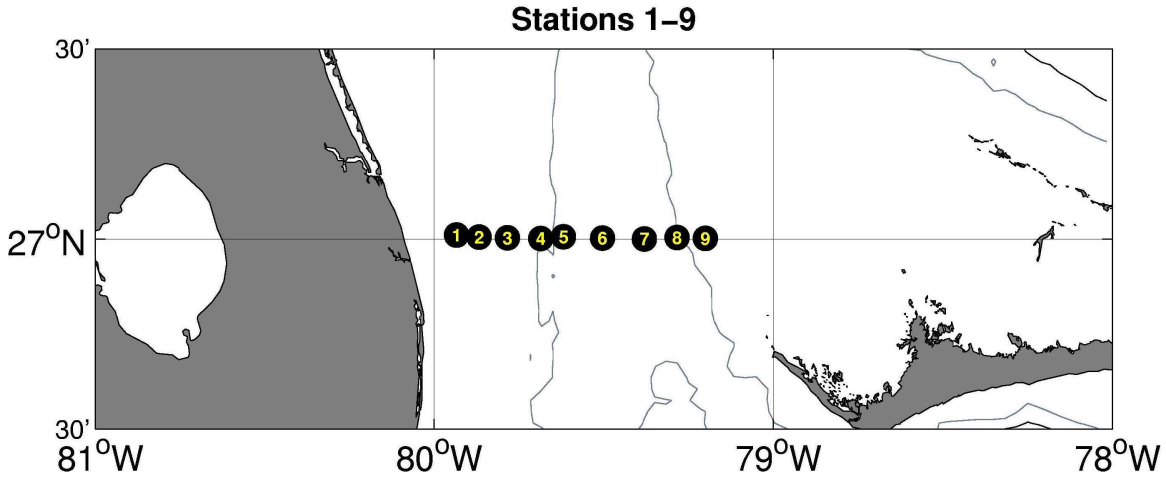

Figure 2a. CTDO2/LADCP stations 1-9, occupied on April 4-5, 2008.

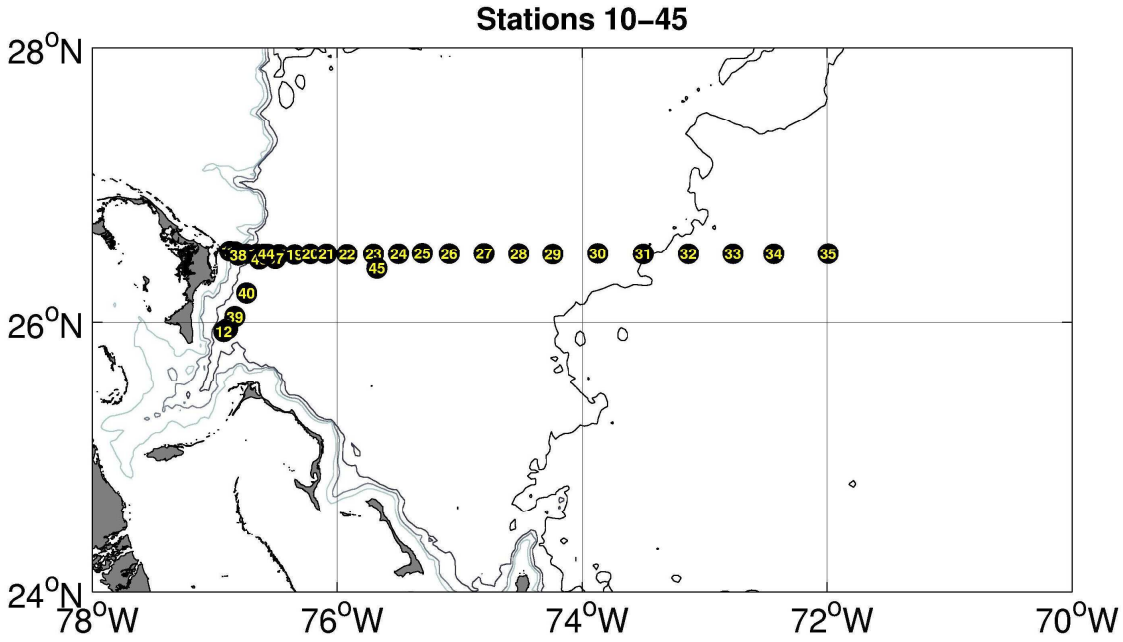

Figure 2b. CTDO2/LADCP stations 10-45, occupied on April 8-28, 2008.

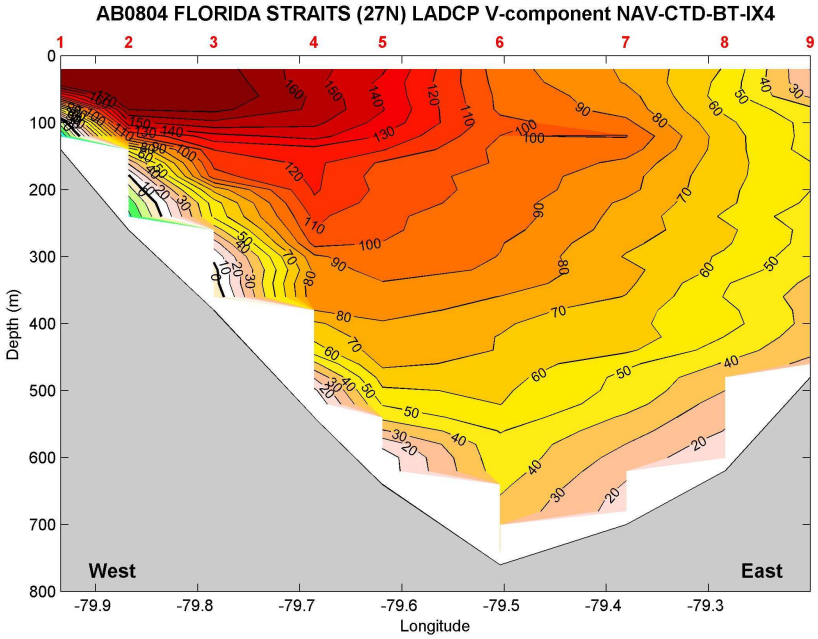

Figure 3. Gulf Stream at 27°N, stations 1-9, April 4-5, 2008.

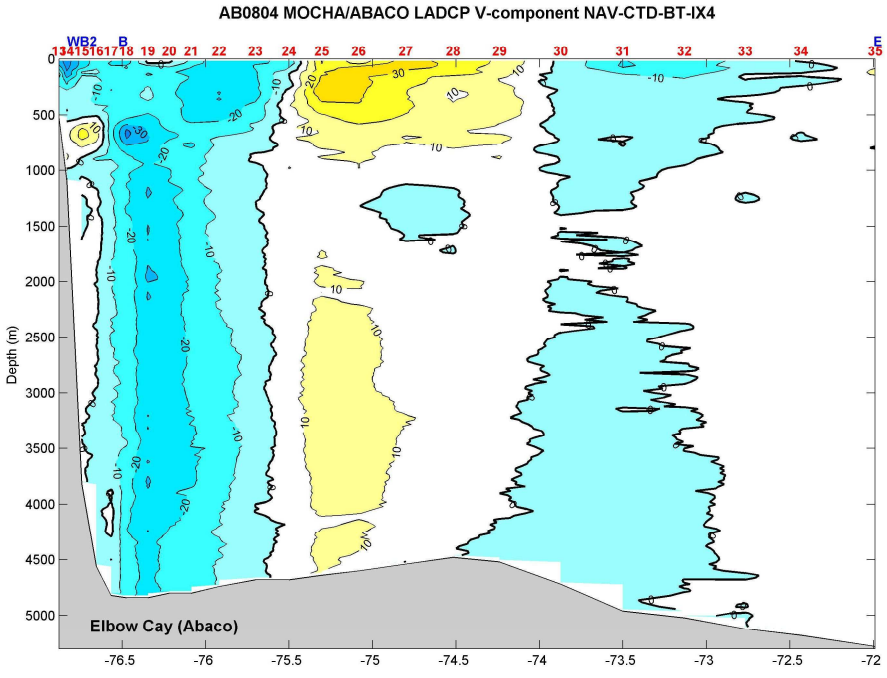

Figure 4. Meridional velocity section offshore of Abaco, contoured from LADCP velocity profiles at stations 13-35, April 8-13, 2008.