CRUISE REPORT

***R/V Seward Johnson* Cruise No. SJ-14-06**

RAPID/MOCHA Program
September 25 – October 12, 2006
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 prototype 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 provides significant support for the overall effort through its Western Boundary Time Series Program.

The purpose of cruise SJ-14-06 was fourfold:

1) to service 4 mooring sites that constitute part of the "western boundary array" of the RAPID/MOCHA transbasin moored array
2) to conduct hydrographic ($CTDO_2$) and direct current profiling (lowered-ADCP, "LADCP") stations along the 26.5 º N mooring section off Abaco, Bahamas; and along sections in the Northwest Providence Channel and Florida Current at 27º N,
3) to service 3 inverted echo sounder (IES) sites, deploy 4 new IESs, and recover data (via acoustic telemetry) from two IESs that had been deployed previously along the Abaco 26.5ºN line, and
4) to deploy a number of satellite-tracked surface drifters and ARGO profiling floats at locations in the Florida Current and the region offshore of Abaco.

The cruise began with occupation of the Florida Current $CTDO_2$/LADCP section at 27ºN 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 and cross-checking of results from the western boundary moored array.

Following completion of the Abaco section, mooring servicing operations were commenced from east to west across the RAPID/MOCHA array. Servicing of the IES sites, including acoustic telemetry, was also accomplished during this period, except for three IESs which were deployed during the Abaco CTD section. After the mooring operations were completed, the planned $CTDO_2$/LADCP section across Northwest Providence Channel had to be cancelled due to insufficient remaining time (owing to difficulties with some of the mooring deployments, see section 3.a). The ship cleared out via Freeport and finally steamed across the 27º N Florida Current section while sampling the current with shipboard ADCP and XBT profiles on the return to Harbor Branch for cruise disembarkation.

2. Scientific Personnel

1.	William Johns	RSMAS, U. Miami	Chief Scientist
2.	Jonathan Molina	RSMAS, U. Miami	Scientist
3.	Mark Graham	RSMAS, U. Miami	Technician
4.	Robert Jones	RSMAS, U. Miami	Technician
5.	Cedric Guigand	RSMAS, U. Miami	Technician
6.	Guilherme Castelao	RSMAS, U. Miami	Student
7.	Simona Simoncelli	RSMAS, U. Miami	Student
8.	Chris Meinen	NOAA/AOML	Scientist
9.	Carlos Fonseca	NOAA/AOML	Scientist
10.	Pedro Pena	NOAA/AOML	Technician
11.	Andrew Stefanick	NOAA/AOML	Technician
12.	Jeffrey Benson	NOC, Southampton	Technician

3. Cruise Operations

3.a) Mooring Operations

Mooring Recoveries

Four 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. The University of Miami moorings (sites A, B, and E in Table 1) had been deployed previously in May 2005 aboard the R/V Knorr, while the NOC mooring (site WB2) had been deployed previously on the NOAA R/V Ronald Brown in March 2006. All mooring recoveries went smoothly and without incident.

Table 1. Mooring Recoveries

Mooring Site	Mooring Number	Latitude (N)	Longitude (W)	Depth (m)	Date of Recovery
A	M366	26 30.55'	76° 50.52'	1015	10/09/2006
WB2	2006/06	26° 30.82'	76° 44.23'	3898	10/08/2006
B	M367	26° 29.73'	76° 29.98'	4840	10//06/2006
E	M368	26° 30.10'	71° 58.28'	5298	10/02/2006

Mooring Deployments

A total of 6 moorings were deployed at the locations listed in Table 2 and shown in Figure 1b. The moorings denoted A, WB2, B, and E were replacement moorings for the ones recovered at those same sites. Moorings B-L and E-L were short "bottom-lander" type moorings containing high-precision bottom pressure sensors deployed near the base of moorings B and E.

Mooring E 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.

Mooring E was deployed in relatively rough sea conditions (winds 25-30 kts, seas 7-8 ft.) after waiting on-site for 24 hours for weather conditions to improve, as had been forecast, but did not materialize. Conditions were too rough to do an acoustic survey of the on-bottom position of the mooring after deployment, as the continuous thrusting and maneuvering required to maintain a stable ship heading caused too much noise for good acoustic reception. However, both mooring E and mooring E-L were successfully confirmed on bottom before leaving the area. Unfortunately, the surface telemetry buoy was apparently damaged during deployment, since no data telemetry messages were successfully received from the unit after deployment. The cause of the failure is unknown but it is likely a broken Iridium antenna on the surface buoy. If the umbilical cable or any of the subsurface inductive components were damaged the surface buoy would still deliver messages containing its GPS position but without any subsurface data. The fact that no messages are being sent indicates it is a problem with the surface telemetry buoy itself.

The rest of the moorings were deployed in much better sea conditions. Deployment of moorings B/B-L and A went smoothly and without any incident. However, mooring WB2, which was initially deployed on October 9 GMT, resurfaced shortly after its anchor was launched due to a failed termination. The problem was first indicated when

the acoustic releases reached the bottom sooner than expected (based on continuous acoustic ranging), and was confirmed when the mooring strobe light was finally sighted on the surface about an hour after launch. Recovery operations immediately followed so that the mooring cable would not pose any danger to other ships in the area that night, and were completed the following morning, October 10 GMT, with all instruments on the mooring accounted for. The cause of the mooring failure was a failed termination in the 'parafil' cable segment closest to the anchor, which had pulled out of its termination socket. Fortunately, a length of spare ¼ inch steel-jacketed cable from the earlier recovery of Miami mooring 'B' was available that was used to replace the damaged parafil cable. Instruments were allowed to continue logging data and on October 11 GMT, mooring WB2 was successfully redeployed and its anchor was confirmed on bottom.

Surveying of the on-bottom position of all moorings (except E/E-L) were done using a new interactive Matlab script written by Jon Molina (RSMAS) that considerably streamlined the survey operations and provided more accurate bottom fixes.

Table 2. Mooring Deployments

Mooring Site	Mooring Number	Latitude (N)	Longitude (W)	Depth (m)	Date of Deployment
A	M366	26 30.52'	76° 50.51'	1015 m	10/10/2006
WB2	2005/28	26° 30.62'	76° 44.63'	3893 m	10/10/2006
B	M367	26° 29.45'	76° 29.90'	4840 m	10/07/2006
B-L	M369	26° 29.45'	76° 29.90'	4840 m	10/07/2006
E	M368	26° 30.00'	71° 58.30'	5297 m	10/05/2006
E-L	M370	26° 29.96'	71° 58.28'	5300 m	10/05/2006

3.b). 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). The activities involving inverted echo sounders are summarized in Table 3 and described below.

Deployment: Instruments were deployed at the following sites:
Site A2: PIES
Site B: PIES
Site C: PIES
Site D2: IES
Site D3: PIES
Site D4: IES

Site E: PIES

Recovery: Instruments were recovered at the following sites:
Site C: PIES
Site E: PIES

Failed Recovery: The PIES at Site B failed to leave the bottom and was not recovered.

Telemetry: Data was recovered at the following sites via acoustic telemetry
Site A: PIES
Site B: PIES
Site D: C-PIES

All operations with the IES/PIES/C-PIES instruments were successful except for the recovery at Site B. The instrument responded correctly to the release command but did not leave the bottom. Several attempts to release it again also failed. The instrument remained on the bottom in sampling mode upon departing the site.

Table 3

IES site	Instr. Type	Latitude	Longitude	Depth (m)	Activity
A	IES	26° 31.0' N	76° 50.0' W	1065	Telemetry
A2	IES	26° 30.0' N	76° 44.6' W	1065	Deploy
B	PIES	26° 29.5' N	76° 28.2' W	4843	Telemetry/Deploy
C	PIES	26° 30.1' N	76° 05.2' W	4843	Recover/Deploy
D	C-PIES	26° 30.2' N	75° 42.3' W	4690	Telemetry
D2	IES	26° 30.0' N	74° 48.0' W	4534	Deploy
D3	PIES	26° 30.0' N	73° 52.0' W	4717	Deploy
D4	IES	26° 29.9' N	72° 46.0' W	5118	Deploy
E	PIES	26° 29.9' N	72° 00.3' W	5294	Recover/Deploy

4. $CTDO_2$/LADCP Stations

A total of 42 $CTDO_2$/LADCP 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. 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). First pass processing of LADCP data was done using Visbeck version 8a software with navigation data only.

Version IX_2, which is supposedly a better version, was also utilized but only after clipping off on-deck data using RDI's WINADCP (as it has been observed that IX_2 does not automatically clip off on-deck data).

Some of the $CTDO_2$ casts were used to perform calibration checks on the temperature, salinity, and pressure measurements obtained from various types of moored instruments (including SBE Microcats, Interocean S4 and Aanderaa RCM current meters) after their recovery or prior to deployment. 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 typically 3000 m 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 a * in Table 4.

Table 4. $CTDO_2$ Station Locations

Station No.	Date	Time (UTC)	Latitude (N)	Longitude (W)	Depth (m)
1	09/25/06	2336	27º 0.17	79º 56.024	123
2	09/26/06	1137	27º 0.617	79º 51.968	244
3	09/26/06	0238	27º 0.337	79º 47.088	369
4	09/26/06	0442	27º 0.008	79º 40.909	517
5	09/26/06	0623	27º 0.347	79º 37.021	631
6	09/26/06	0809	27º 0.43	79º 29.990	722
7	09/26/06	1005	27º 0.238	79º 23.035	673
8	09/26/06	1141	27º 0.251	79º 16.885	598
9	09/26/06	1312	26º 59.995	79º 12.013	469
10*	09/27/06	0736	25º 57.216	76º 53.264	3504
11*	09/27/06	1153	25º 57.000	76º 53.609	3500
12*	09/27/06	1607	25º 57.377	76º 53.797	3512
13*	09/28/06	0046	26º 27.272	76º 52.646	1001
14	09/28/06	0328	26º 31.506	76º 53.495	290
15	09/28/06	0448	26º 30.964	76º 49.888	1087
16	09/28/06	0701	26º 30.15	76º 44.761	3919
17	09/28/06	1111	26º 30.034	76º 39.919	4604
18	09/28/06	1540	26º 29.898	76º 33.833	4897
19	09/28/06	2048	26º 30.136	76º 28.363	4922
20	09/29/06	0122	26º 29.800	76º 20.688	4932
21	09/29/06	0622	26º 29.974	76º 12.986	4879
22	09/29/06	1056	26º 29.994	76º 5.243	4864
23	09/29/06	1528	26º 29.664	75º 53.705	4810
24	09/29/06	2017	26º 29.996	75º 42.318	4674
25	09/30/06	0056	26º 30.019	75º 29.962	4667
26	09/30/06	0552	26º 29.977	75º 17.999	4699
27	09/30/06	1032	26º 30.049	75º 5.104	4593

28	09/30/06	1652	26º 30.102	74º 48.106	4507
29	09/30/06	2140	26º 29.994	74º 31.565	4475
30	10/01/06	0214	26º 30.002	74º 14.363	4520
31	10/01/06	0806	26º 30.029	73º 52.102	4710
32	10/01/06	1312	26º 30.012	73º 30.646	4929
33	10/01/06	1822	26º 30.022	73º 10.468	5024
34	10/01/06	2357	26º 29.872	72º 45.984	5115
35	10/02/06	0530	26º 29.962	72º 23.648	5175
36	10/02/06	1808	26º 30.084	71º 58.046	5271
37*	10/03/06	0148	26º 29.800	72º 0.370	3500
38	10/03/06	0526	26º 30.251	71º 59.879	5272
39	10/06/06	1824	26º 30.12	76º 5.287	4785
40*	10/06/06	2334	26º 30.09	76º 27.863	3500
41	10/08/06	0120	26º 30.403	76º 28.865	4814
42*	10/08/06	2320	26º 29.993	76º 44.624	3500

* Instrument calibration casts

5. Drifter Deployments

A total of 13 surface drifters were deployed during the cruise at the locations listed in Table 5. The drifters were of the "WOCE Standard" type including holey sock drogues at 15 m depth. The drifters are tracked by NOAA/AOML's Global Drifter Center in Miami via ARGOS. The drifter data includes drifter position and local sea surface temperature.

Table 5. Drifter Launches

Drifter ID	Launch Date	Time (UTC)	Latitude (N)	Longitude (W)
62225	09/26/2006	0320	27º 02.19	79º 47.06
62229	09/26/2006	0716	27º 02.18	79º 36.00
62233	09/26/2006	1051	27º 01.40	79º 22.60
62228	09/26/2006	1351	27º 00.27	79º 11.57
62234	09/29/2006	0021	26º 30.33	76º 26.20
62230	09/29/2006	1414	26º 30.04	76º 05.49
62226	09/30/2006	1349	26º 29.89	75º 05.48
621/64111	09/30/2006	1351	26º 29.91	75º 05.34
62227	10/01/2006	0146	26º 30.58	74º 14.34
62232	10/01/2006	2231	26º 30.04	73º 01.97
62231	10/02/2006	0516	26º 30.24	72º 22.36
631/64121	10/02/2006	0916	26º 29.90	72º 22.36
634/64124	10/05/2006	1112	26º 31.38	73º 33.29

6. 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 250 m below the vessel for the 150 kHz ADCP, and 1000 m for the 38 kHz ADCP, depending on sea state conditions.

7. Preliminary Results

The LADCP data acquired during the hydrographic section east of Abaco show typical flow features found close to the western boundary (Fig. 3): (1) a subsurface intensified northward flow on the upper continental slope with a core near 400 m (often referred to as the "Antilles" current), and (2) a southward deep flow below 1000 m, the Deep Western Boundary Current (DWBC). A thin layer of southward flow was found at the surface overlying the northward Antilles current.

An interesting feature of the DWBC seen during the cruise is the lateral offset of the upper and lower cores of the current, with the core of the upper DWBC (1000-3000 m) found at ~40 km offshore and the lower DWBC core at ~75 km offshore. This suggests that a meander or eddy has deflected the lower DWBC away from the boundary. Both cores were characterized by high speeds in excess of 40 cm/s. Offshore of the western boundary layer (>100 km), the flow consisted of alternating bands of northward and southward flow with a scale of ~100 km, which is also fairly typical of previous observations in the region.

8. 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 (November, 2007).

Moored Instrumentation

Time series data records from the moored instruments will be provided within 2 years of recovery of the instruments (nominally November, 2008).

9. 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.

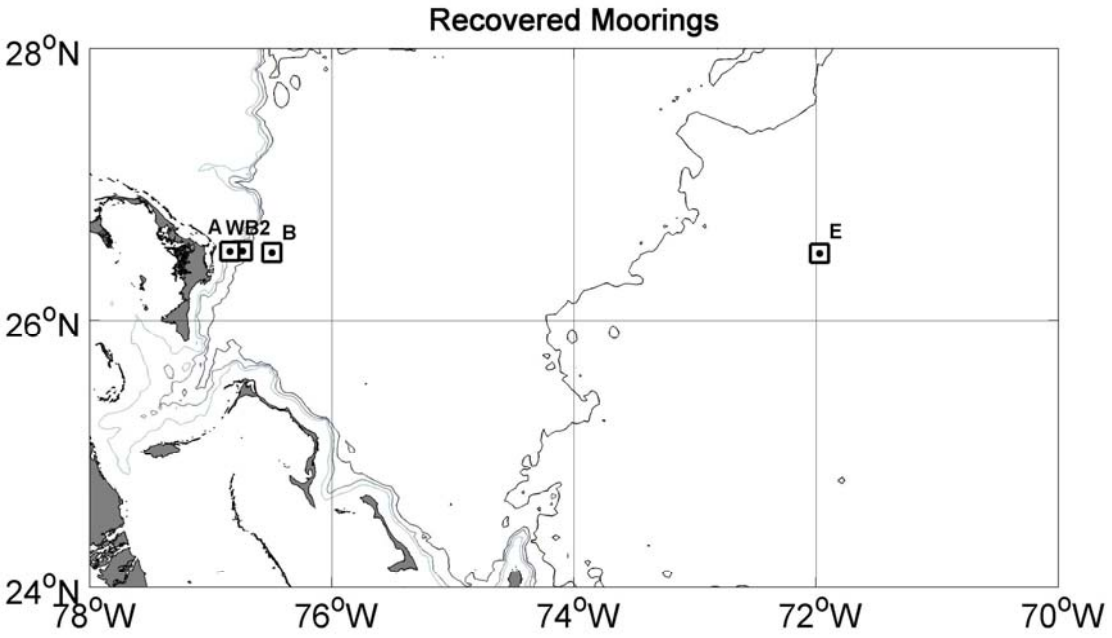

Figure 1111a. Moorings recovered on cruise SJ-14-06.

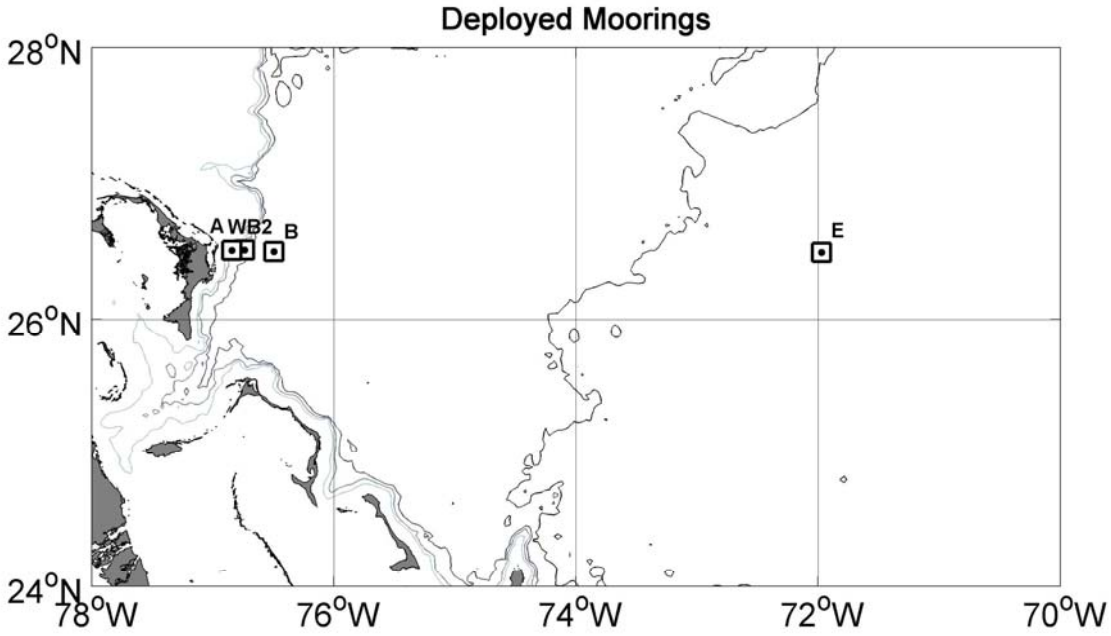

Figure 1b. Moorings deployed on cruise SJ-14-06. Additional "bottom lander" moorings were deployed at sites B and E (not shown).

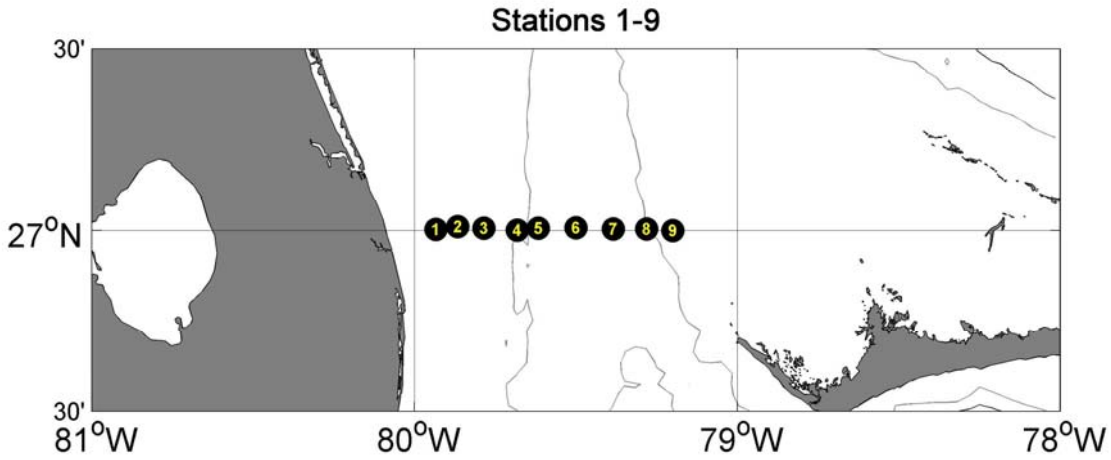

Figure 2222a. CTDO2/LADCP stations 1-9, occupied on September 25-26, 2006.

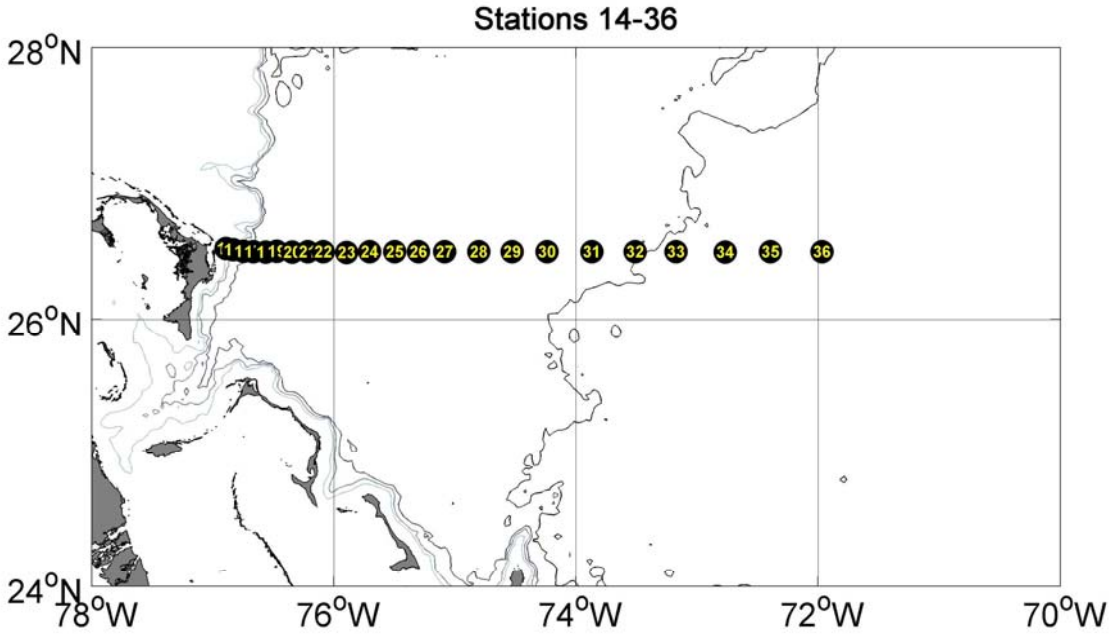

Figure 2b. CTDO2/LADCP stations 14-36, occupied on September 28 - October 2, 2006.

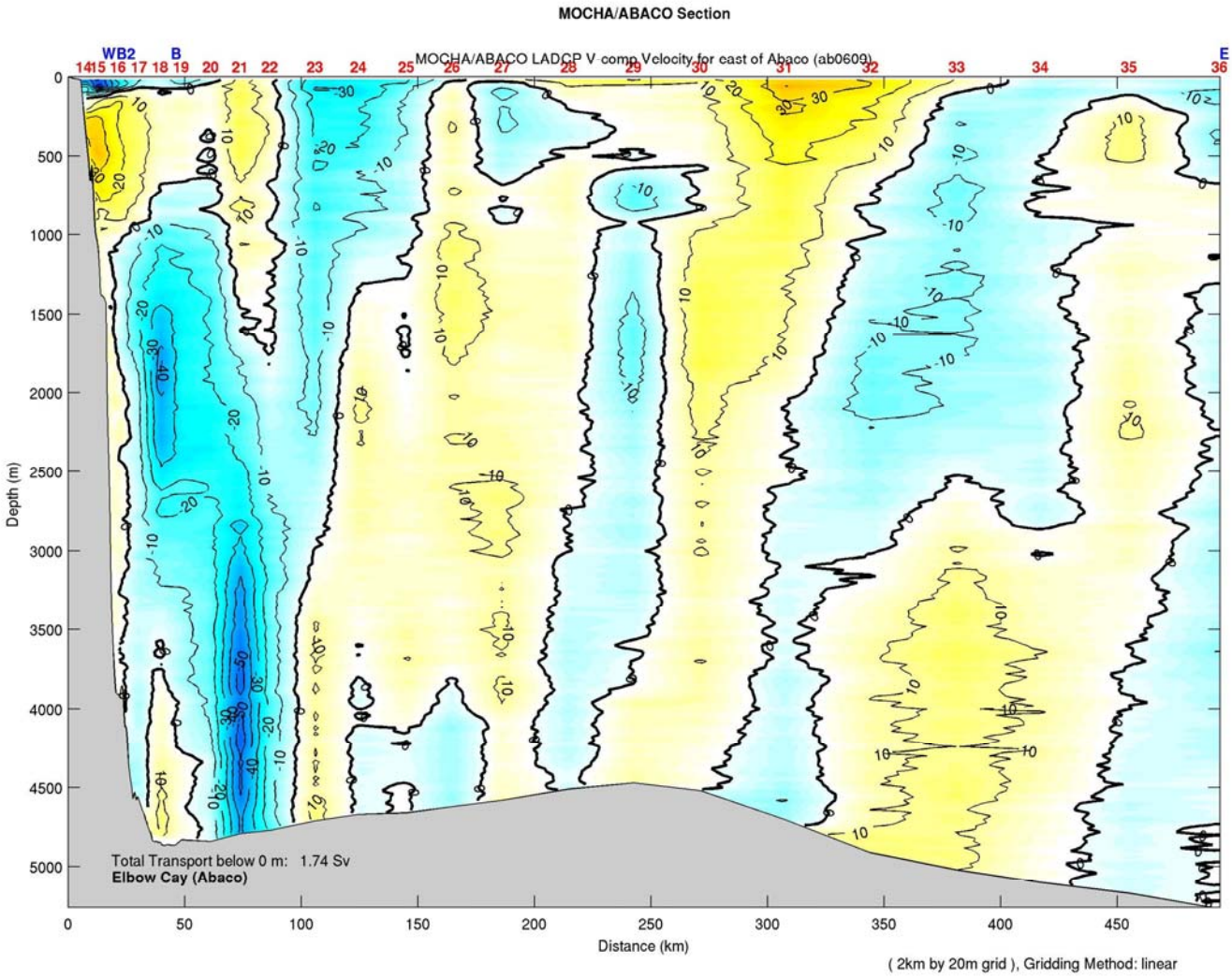

Figure 3. Meridional velocity section offshore of Abaco, contoured from LADCP velocity profiles at stations 14-36, September 28 - October 2. 2006.