Cruise report: *R/V Atlantis* cruise no. 17

Woods Hole to Woods Hole
October 9 – 24, 2010

Line W: Continuing the measurement program

Background

R/V Atlantis cruise number 17 contributed to a joint Woods Hole Oceanographic Institution and Lamont Doherty Earth Observatory research program funded by the U.S. National Science Foundation that is investigating the characteristics, causes and consequences of interannual variations in the Northwest Atlantic's Deep Western Boundary Current (DWBC). The study is documenting temperature, salinity, tracer, and velocity variations of the DWBC by maintaining a 6-element moored array spanning the continental slope southeast of Woods Hole, and repeatedly occupying a hydrographic section along this line (Figure 1). A companion research program by U.K. investigators from the Proudman Oceanographic Laboratory is sampling bottom pressure variability (their instruments are called Bottom Pressure Recorders - BPRs) at several of our mooring sites (plus a shallower site) and along an additional measurement line to the north. Cruise AT17 was designed to service the moored array (recover and redeploy the 6 moorings) and to occupy the hydrographic section along the array and extending southwest to 66°W. In addition, time permitting, we agreed to deploy an ocean glider, launch an Argo float, do test lowerings on a cable of a new BPR sensor and perform test deployments of the High Resolution Profiler instrument for WHOI colleagues.

The array south of New England (named Line W in memory of L. Valentine Worthington) is quantifying changes in DWBC water properties, stratification (potential vorticity), and transport. The high-spatial-resolution sampling possible from the ship is helping to verify that the moored array resolves the structure of the boundary current as well as returning water samples for at-sea and shoreside tracer analyses. We are furthermore encouraging other researchers to build on the Station W infrastructure to augment the fields being sampled. One such effort focusing on biogeochemistry questions is being led by T. Eglinton.

The moored array was initially deployed during *R/V Oceanus* cruise 401 in April-May, 2004. Three of the moorings in the initial array supported Moored Profiler instruments that were subsequently serviced annually in spring 2005, 2006 and 2007; fixed-depth sensors were deployed for two year periods on the other two moorings. Later, a 6th offshore mooring using fixed sensors was deployed under funding from the WHOI Climate Institute. A cruise aboard *R/V Oceanus* in spring 2008 initiated a second phase of observations at Line W with the goal of extending the observations through a full 10-year time period. The array was redesigned slightly with all moorings planned for a 2-year (or longer) service schedule. Mooring #1, the shallowest in the array at the 2200 m isobath was the first operational deployment of the *Ultramoor* mooring developed by Nelson Hogg and Dan Frye at WHOI. The *Ultramoor* mooring, that utilizes a series of fixed-depth sensors spanning the water column, was planned to be in place for 4 years,

with the release of telemetering data capsules at 6-month interval. Moorings 2 and 4 (counting offshore) support Moored Profilers. In order to achieve the planned 2-year endurance, Mooring 2 was designed with 2 Profilers on it while Mooring 4 holds 3 instruments, each profiling a ~1000 m depth interval. Fixed sensors are located above and below each profile interval. Between profiling operations, the Profilers are programmed to park mid-span and sample hourly, mimicking a fixed-depth sensor. The resulting data sets have high temporal resolution at multiple depths spanning the water column, in addition to high-vertical-resolution profile data collected at regular interval throughout the deployment. Moorings 3, 5 and 6 are designed with conventional fixed sensors.

Weather seriously disrupted the renewal of the array in 2008. In the end, a total of three cruises (spring and fall 2008, spring 2009) were required to renew all 6 of the Line W moorings. Given the mass of all 6 moorings and scientific gear that was required on the vessel (in excess of the maximum deck load of the *R/V Oceanus*), we petitioned for a global-class vessel for the 2010 cruise and were put on *R/V Atlantis*, but several months later than we had hoped. The delay meant that most of the moored instruments will have exhausted their battery power prior to our servicing the array, resulting in more gaps in the time series.

Owing to a cruise schedule conflict, the LDEO tracer sampling team was unable to participate on this year's Line W cruise. Arrangements were made for a group from the University of Miami to join the cruise and analyze the water samples.

Despite some bad weather at times during the cruise, we accomplished all of our goals for the cruise.

Science party:

Chief scientist: J. Toole (WHOI)

Hydrographic/LADCP sampling: R. Curry, J. Dunworth-Baker, D. Torres, M. Swartz, D. Wellwood, G. Tupper (WHOI); J. Happell and Y. Mendoza (RSMAS)

Mooring operations: B. Hogue, B. Guest, D. Bogorff, B. Pietro, M. Jegliski (WHOI)

Bottom pressure gauge operations: S. Mack, (POL)

High Resolution Profiler test team: K Polzin and E. Hobart (WHOI)

Cruise narrative:

AT17 departed Woods Hole at high slack tide at noon on October 9. Our plan was to recover the 6 moorings as the hydrographic section was worked north-to-south, then redeploy moorings while returning back north. Stations over the shelf were initiated after dinner on the 9th carrying into the next morning. The BPR just offshore from the shelf break was successfully recovered before breakfast, whereupon the vessel was directed to Mooring 1. Although the *Ultramoor* installation was designed to last for

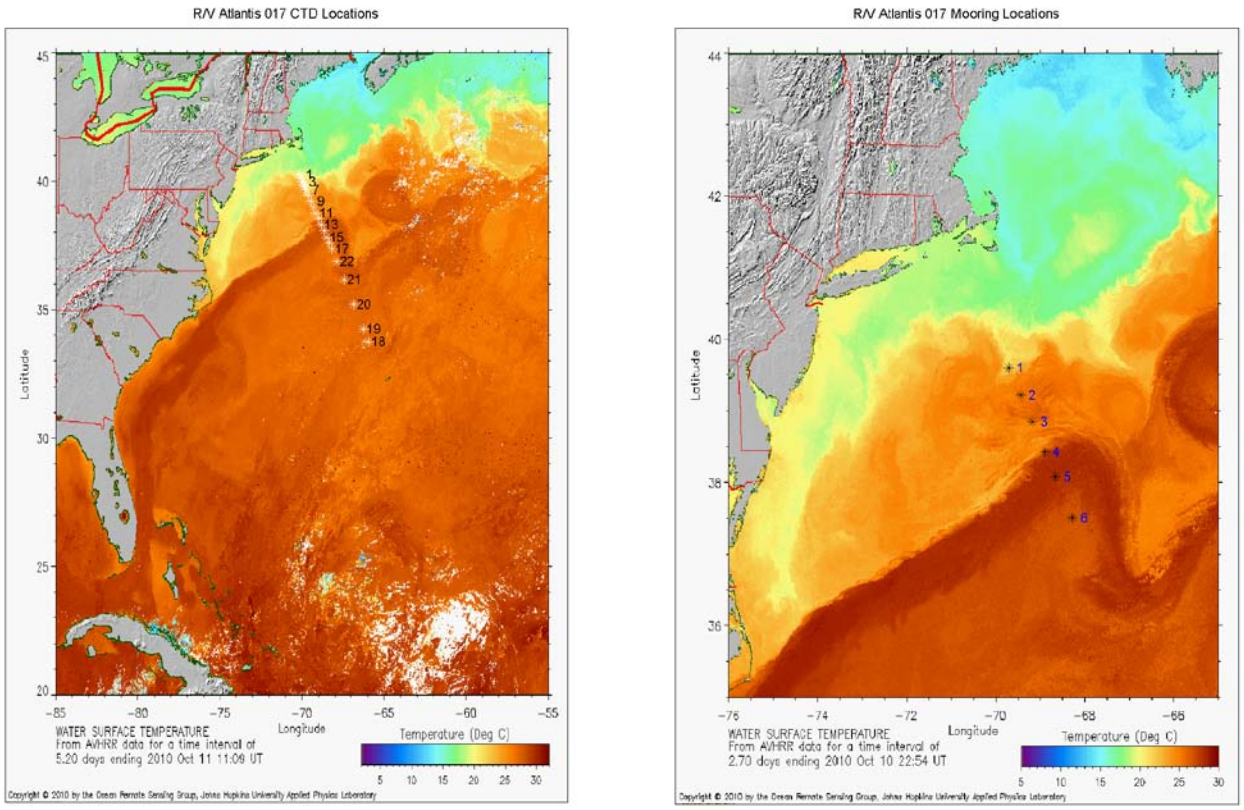

Figure 1. Map of CTD/LADCP stations (left) and mooring locations (right) occupied during *R/V Atlantis* cruise 17 Oct 9-24, 2010. The locations are displayed superimposed on maps of satellite-derived sea surface temperature at the start of the cruise obtained from the Johns Hopkins/Applied Physics Laboratory web site.

4 years, no data capsule had been heard from for about 1 year. So it was decided to recover the *Ultramoor* replace it with a conventional mooring. The system was successfully recovered by that afternoon but unfortunately, the BPR at this site was not. That instrument communicated acoustically but its burn-wire release system evidently failed as it did not lift off the bottom.

After securing from mooring operations, the Spray glider was launched. Spray 10 was delivered to the ship along with all of the necessary support gear by John Ahern on Oct. 9th just prior to departure. It was suggested that once *R/V Atlantis* had steamed beyond the shelf break, the glider should be deployed. On the evening of the 9th prelaunch checks were made to insure that the glider was operating properly. On the morning of the 10th the glider was taken outside to complete the prelaunch checks, including acquiring a GPS position. At 1833 z on Oct. 10th the glider was deployed at 39° 36.23 N 69° 43.06 W. A phone call was made to Breck Owens to inform him of the deployment and the glider was observed, while in the water, rolling to acquire a GPS position then beginning its 100-m test dive. Owens reported that everything looked good and that the mission had begun properly.

CTD stations 7-9 were occupied overnight; on the morning of Oct 11, the BPR at mooring site 2 was recovered, followed by Mooring 2. With half the day remaining, we opted to proceed to mooring site 3 and its recovery. Mooring 3 came aboard reasonably well, though each current meter/glass ball grouping came aboard as a wire wuzzle. Notably, the BPR that had been deployed atop Mooring 3's anchor with a tether to the mooring cable attached above the acoustic releases, was brought aboard as designed.

CTD stations 10-12 were completed overnight with the ship arriving at Mooring site 4 around 10AM on October 12. That mooring was brought aboard by 3PM. As with the previous mooring, there were many wire wuzzles to deal with during haul back. One of the Moored Profiler current meters was recovered with two broken transducer arms.

After recovering Mooring 4, we occupied CTD stations 13 and 14, then stood by Mooring site 5 until daytime. The BPR at this site was successfully recovered, followed by the mooring. CTDs 15-17 were done the following night.

Recovery of Mooring 6 on Oct 14 was more stressful. Back in May of this year, the main buoyancy sphere of this mooring came loose when one of the terminations of the top segment of wire rope failed. The sphere, an acoustic Doppler current profiler instrument mounted on the sphere and a temperature/conductivity sensor mounted just below were recovered during a rescue trip aboard *R/V Atlantic Explorer*. The majority of the mooring (instruments, glass ball spheres and wire rope) were still on site, likely fallen to the bottom. The mooring had been designed with sufficient backup buoyancy in glass balls to lift the mooring to the surface after firing the releases, but if the wire snagged on something on the bottom, or several of the spheres had imploded, recovery could be jeopardized. The acoustic release on the mooring was triggered at 0651 local and initially, ranging to the releases indicated reasonable rise rate to the surface. By 0900 however, the rise rate had fallen to near zero, while maneuvering to close range on the releases suggested the mooring was drifting east with the Gulf Stream. By noon we had achieved close approach range of less than 100 m, but there was no sighting made of the backup buoyancy spheres. Just as we were starting to prepare to drag for the drifting mooring, the spheres were sighted, just barely above the surface. By 2PM we had grappled the spheres and were hauling the mooring aboard; eventually the whole mooring was recovered. Two glass balls were found to have imploded at depth, and several of the

current meters showed trapped mud, indicating that they had lain on the bottom. Despite this, we are not sure why it took 7 hours for this mooring to surface.

With the weather forecast for the next few days indicting winds above 25 knots in the area of the Gulf Stream where we were located, it was decided to transit south to the end of the CTD line and work the remaining stations S-to-N. After completing the southernmost two stations, schedule projections (adjusted to account for a 30 knot headwind while steaming north and somewhat longer station time due to the seas) suggested that we did not have sufficient time to occupy all the remaining sites. Thus a reduced sampling plan was devised that in total deleted 4 stations from the original scheme. The result was somewhat coarser resolution for the CTD section than designed, but in a region of the line without much horizontal structure (Sargasso Sea south of the Gulf Stream), see Table 2 and Figure1. During the steam back north, the wire for Moorings 5 and 6 were wound on the TSE winch and the other components for these two moorings were made ready.

By the morning of Oct 18 we had returned to Mooring site 6 ready to redeploy. The weather by this time had calmed significantly, facilitating the mooring operations. Mooring 6 anchor over occurred at 11:23 PM local (see Table 1). We then proceeded to mooring site 5 and hove to until morning. Mooring 5 deployment went equally smoothly; its anchor was dropped at 12:46 PM on Oct 19. After securing from mooring operations, two deployments of the High Resolution Profiler were completed while the mooring team wound wire for moorings 3 & 4. Overnight, a test lowering of the CTD package fitted with a new gyro package was completed.

While monitoring the glider's progress via its web site, it was apparent that the conductivity cell was not performing properly. A request was made by Owens to recover the glider during our transit back to Woods Hole. On Oct 19th the glider stopped reporting data to the web site. This fact was relayed back to Owens and John Ahern on the 20th to see if there was a problem with the instrument or possibly the web site. Ahern replied stating that Owens had requested that a group from Blue Fin Technologies, who were in the general area, recover the glider.

Mooring 4 was deployed in the morning of Oct 20, followed by the launch of a Solo Argo float. Paul Robbins requested that Solo float #1018 be deployed at Line W station #9018. The request stated that the instrument would be delivered to the ship already running and no further attention would be required except to lower the float into the water. On Oct 11th, word was received from Connor Ahearn by email that it was very likely that the float was not started as promised. The start up procedure is simple. Open the flap on the cardboard box that contains the float, swipe a magnet over the "Reset" mark on the pressure case and observe that the air bladder inflates to indicate that instrument is running. This was done on Oct 14th but the air bladder never inflated. Attempts were made multiple times using a variety of magnets. An email was sent to Owens and Ahern informing them that the float failed to start its mission. The word came back to return the float to WHOI. On Oct 19th, Robert Tavares sent an email stating that a recent batch of Solo floats were not inflating the air bladder at start up and that as long as the oil bladder

on the bottom of the float had emptied, indicating the piston pump had run all the way in, then it was safe to deploy the float. This was checked and the oil bladder did appear to be empty. At this point the desired launch location had passed but Paul Robbins indicated that if the float had appeared to have started its mission then to proceed with the deployment. Solo #1018 was launched at 1802 Z at 38° 25.48 N, 68° 54.44 W.

R/V Atlantis was then directed to mooring site 3. That mooring deployment was completed by 9:30 PM. With the long range weather forecast suggesting high winds and seas later in the week, we opted to wind moorings 1 & 2 on the TSE winch that evening and attempt to deploy both the following day. Wire winding was completed by 01:30 AM on Oct 21 despite several severe lightning storms and intense rain. Also during the night, another CTD/LADCP cast was done to collect additional gyro data. Mooring 2 was successfully deployed by noon on Oct 21 and Mooring 1 anchor over occurred at 6PM in building winds and seas as forecast. While Oct 20-21 were busy tiring days for the mooring team, their efforts paid off as all moorings were able to be deployed in very reasonable working conditions.

R/V Atlantis hove to overnight. In the morning of Oct 22, test lowerings of a new BPR instrument being evaluated by POL investigators were carried out. Afterwards, two HRP dives were completed to test the on-board acoustic altimeter. By the time of the second recovery (after dark), winds had increased to 30+ knots and the seas were building. Recovery took a very long time, but was eventually accomplished with no damage to the instrument. It was decided to defer additional HRP test deployments to the morning.

Oct 23 dawned clear but very windy (30+ knots) with substantial seas, and it was decided conditions were too rough to risk HRP deployment. Thus we began the return leg to Woods Hole, arriving at the WHOI pier at 12:30 AM on Oct 24 at slack high tide.

Despite two weather interruptions, the fall 2010 Line W cruise achieved all of its goals and supported some additional instrument deployments and testing for colleagues. The officers and crew of *R/V Atlantis* and the entire scientific party are to be commended for their hard work during the cruise.

Acknowledgements

The Line W program is supported by the National Science Foundation through grant no. OCE-0726720 to the Woods Hole Oceanographic Institution. The study contributes to the U.S. Atlantic Meridional Overturning Circulation activity and the U.K. RAPID-WATCH programme.

Table 1: The Line W moored array as deployed, October 2010

Mooring 1: Fixed sensors

Lat: 39 36.0203 N
Lon: 69 41.4812 W
Bottom Depth: 2176 m

Mooring 2: MMPs & fixed sensors

Lat: 39 12.8308 N
Lon: 69 26.9170 W
Bottom Depth: 2646 m

Mooring 3: Fixed sensors

Lat: 38 50.3235 N
Lon: 69 10.8450 W
Bottom Depth: 3269 m

Mooring 4: MMPs & fixed sensors

Lat: 38 25.5023 N
Lon: 68 54.4465 W
Bottom Depth: 3681 m

Mooring 5: Fixed sensors

Lat: 38 4.456 N
Lon: 68 40.8867 W
Bottom Depth: 4108 m

Mooring 6: Fixed sensors

Lat: 37 30.3017
Lon: 68 20.1172
Bottom Depth: 4642 m

* bottom depths are uncorrected.

MMP denotes a mooring supporting McLane Moored Profiler instruments
Fixed sensors denotes a mooring fitted with multiple fixed-depth current meters and T/S sensors

Table 2: List of hydrographic stations occupied on AT17

R/V Atlantis 017 Oct 9-24, 2010

STNNBR	DATE	TIME	LATITUDE	LONGITUDE	DEPTH	P-MAX
1	101010	0030	40 17.11 N	70 12.40 W	91	83
2	101010	0209	40 8.49 N	70 6.19 W	121	111
3	101010	0335	40 0.68 N	70 0.34 W	164	153
4	101010	0501	39 53.94 N	69 55.80 W	769	771
5	101010	0639	39 51.49 N	69 54.01 W	1031	987
6	101010	0838	39 47.43 N	69 51.18 W	1464	1455
7	101010	2055	39 42.08 N	69 48.05 W	2104	2087
8	101110	0041	39 28.49 N	69 38.49 W	2425	2423
9	101110	0455	39 15.53 N	69 29.42 W	2664	2660
10	101110	2352	39 1.01 N	69 19.98 W	3085	3089
11	101210	0550	38 47.46 N	69 11.03 W	3250	3290
12	101210	1030	38 33.51 N	69 1.53 W	3449	3494
13	101210	2200	38 19.75 N	68 51.61 W	3795	3852
14	101310	0250	38 5.51 N	68 41.37 W	4107	4168
15	101310	1918	37 51.00 N	68 32.24 W	4367	4437
16	101410	0047	37 37.18 N	68 22.55 W	4599	4676
17	101410	0623	37 23.00 N	68 12.94 W	4743	4823
18	101510	2207	33 46.64 N	65 59.95 W	5104	5192
19	101610	0640	34 15.45 N	66 17.27 W	5138	5290
20	101710	1229	35 13.70 N	66 52.78 W	5090	5177
21	101810	0053	36 11.86 N	67 27.43 W	4964	5049
22	101810	1120	36 53.85 N	67 53.90 W	4929	5016