Cruise report: *R/V Oceanus* cruise no. 446

Woods Hole to Woods Hole
May 10 – 23, 2008

Line W: Continuing the measurement program

Background

R/V Oceanus cruise number 446 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 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 of our first 5 mooring sites (plus a shallower site) and along an additional measurement line to the north.. 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 these moorings 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. Oc446 represented the start of 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 is 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, is planned to be in place for a full 4 years. However, at 6-month interval, a data capsule will be released that will telemeter a subset of the observations to shore. Moorings 2 and 4 (counting offshore) are planned to support Moored Profilers. In order to achieve the planned 2-year endurance, Mooring 2 was designed with 2 Profilers on it while Mooring 4 will have 3 instruments, each profiling a ~1000 m depth interval. Fixed sensors are planned above and below each profile interval. Between profiling operations, a new Profiler feature will used for the first time: the Profilers will park mid-span and sample hourly, mimicking a fixed-depth sensor. The result, we hope, will be data sets with 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.

It turned out that the weight of all 6 moorings we hoped to deploy, the associated deployment gear and the hydrographic sampling equipment exceeded the carrying capacity of *R/V Oceanus.* Thus a cruise plan was constructed in which four of the moorings would be deployed, followed by a mid-cruise port stop to pick up the balance of the mooring equipment. A companion research program supported by the NSF and WHOI funded a series of sediment trap moorings within the Line W array. A final mooring of this program was also planned to be recovered during Oc446 if time permitted. As detailed below, strong winds and the associated waves significantly limited the mooring work that we were able to complete and we were not able to recover the sediment trap mooring.

Under the Line W program, continuous profiles of temperature, salinity and dissolved oxygen (obtained from the CTD system), velocity (from a shipboard and Lowered Acoustic Doppler Current Profiler systems) are acquired on each cruise along with discrete water samples that are analyzed for salinity and oxygen (used to calibrate the CTD sensor data), CFC's (F11, F12 and F113), SF6, and underway surface ocean and atmosphere parameters. In addition, water samples are collected and stored for subsequent shipment to Dr. John Smith (BIO, Canada) for analysis of I^{129} concentration. All of these parameters were sampled during Oc446.

Mooring and station positions are displayed in Figure 1 with details provided in Tables 1 and 2.

Science party:

Chief scientist: J. Toole (WHOI)

Hydrographic/LADCP sampling: J. Dunworth-Baker (leg 1), D. Torres, D. Wellwood (WHOI); B. Pena-Molino, Y. Kaspi (leg 2) (MIT/WHOI Joint Program); E. Gorman, S. Rab-Green (LDEO);

Mooring operations: S. Worrilow, B. Hogue, D. Bogorff, P. Koski (leg 1), D. Montlucon (leg 2)

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

Cruise narrative:

R/V Oceanus was loaded with Line W scientific equipment on May 7-9 and departed Woods Hole at 10 AM on May 10. [Note: all events in this section are reported in local Eastern Daylight Time.] Sea surface temperature imagery for the week prior to the cruise revealed a large northward meander in the Gulf Stream with the axis of the warm core roughly at mooring site 4, Figure 1. This structure persisted through the cruise. Sampling was initiated just after dinner with the first set of CTD stations (numbers 1-6) that extended from the 90-m isobath across the shelf break to approximately 2000 m water depth. Around dawn on May 11, the station work was terminated and the vessel was positioned for recovery of the bottom pressure gauge (BPR) at site W0. Foden and Mack successfully communicated acoustically with the instrument and initiated its anchor release procedure. It surfaced, was quickly sighted and brought aboard. *R/V Oceanus* was then directed to mooring site W1 for recovery of the Moored Profiler mooring at that site and a BPR, both of which were accomplished before lunch. A new BPR at W1 was then deployed while the mooring team prepared to deploy Ultramoor. That deployment operation proceeded smoothly with anchor launch at 8:40 PM.

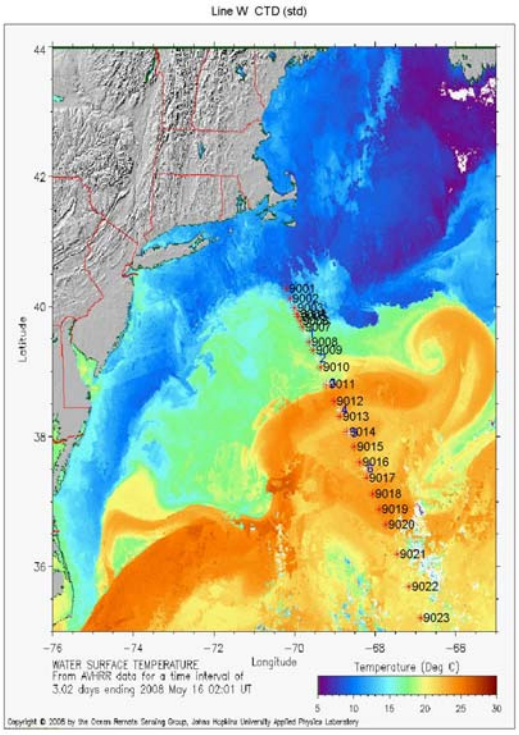
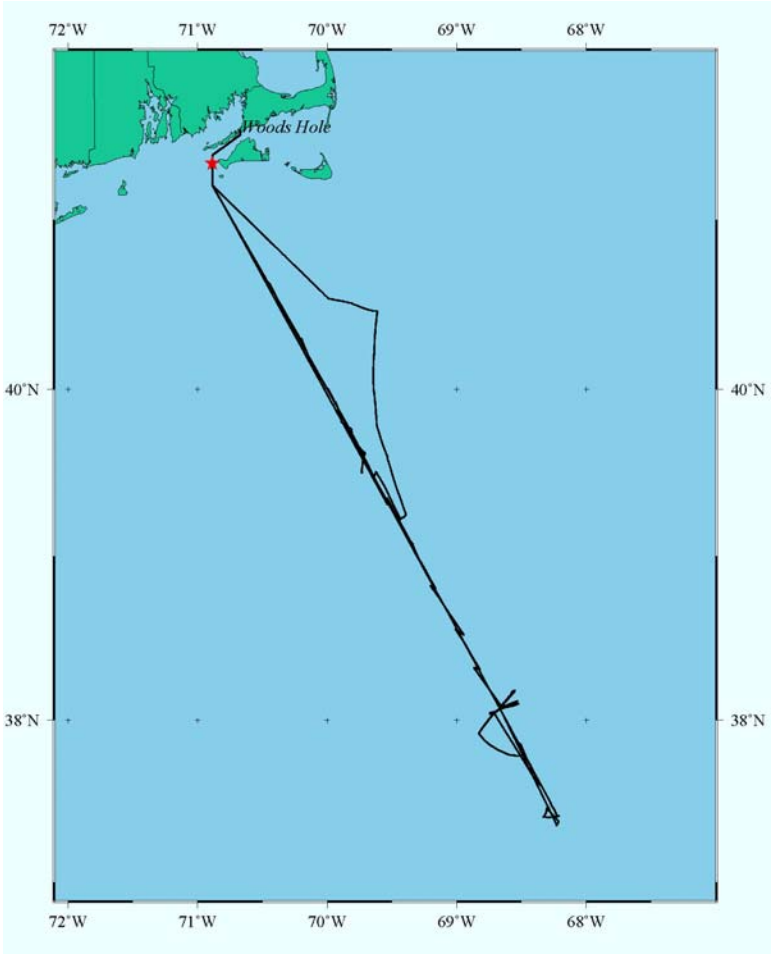


Figure 1. Sea surface temperature distribution for the period of Oc446 with mooring sites (blue numbers) and nominal hydrographic stations marked.

Hydrographic casts at sites 7 and 8 were occupied at night and then the ship was directed to the site of Mooing #2 at first light to attempt additional mooring work. However, winds and associated seas increased significantly over night due the approach of a major low pressure system that caused major wind and rain damage farther south; mooring and hydrographic work on May 12 was not possible. Since we could not work, it was decided to head back to Woods Hole early to pick up the remaining mooring components. A direct course would have put the vessel abeam of the building seas, so an angled course was taken, figure 2. Woods Hole arrival was at 8AM on May 13. Most of the day was spent loading and securing the new mooring gear and winding the wire for Mooring #6 on the deployment winch. Given that the winds were

Figure 2. Cruise track of Oc446. The departure from the linet to the northeast was the return to port after leg 1 work was interrupted by weather.



still strong and knowing how long it takes seas to relax after a blow, it was decided to delay leg 2 departure until 8AM on May 14.

Leg 2 departed at 8AM on the 14th with initial task the deployment of a new BPR at site W0. *R/V Oceanus* arrived on site at 6:30 PM and the BPR was efficiently launched and tracked to the bottom. The vessel then proceeded to mooring site #6 which, at this time, lay south of the Gulf Stream. Arrival at M6 occurred at 9AM. A test lowering of 8 acoustic releases was conducted using the CTD cable while the mooring components were prepared for deployment. The surface buoy was overboarded at 3:45 PM and 4 hours later, the anchor was launched.

Given the time lost to the May 12-13 storm and return to port to pick up more mooring gear, and with an eye ahead to another storm forecast, it was decided not to extend the CTD line farther to the south. Our southernmost station at site 17 was occupied in the evening of May 15 while the mooring team wound wire for Mooring #5. After completing the station, *R/V Oceanus* was directed north to the Mooring #5 site, arriving at 6AM on the 16th. First up, the UK contingent recovered their BPR despite it suffering a leak. Then the 2006-7 mooring at M5 was recovered and the old wire off-spooled. While so engaged, the hydrographic team did a CTD station at nominal site 14. The balance of the day was spent preparing to redeploy the mooring and BPR, and then positioning the ship to start the wire payout. At 7:30 PM the mooring deployment team was poised to overboard the main floatation sphere when the mate on watch determined that the starting position he selected was not appropriate. With winds building to 30 knots from the SE due to the approach of another low pressure system (figure 3) and given the time of day, it was decided to postpone the deployment.

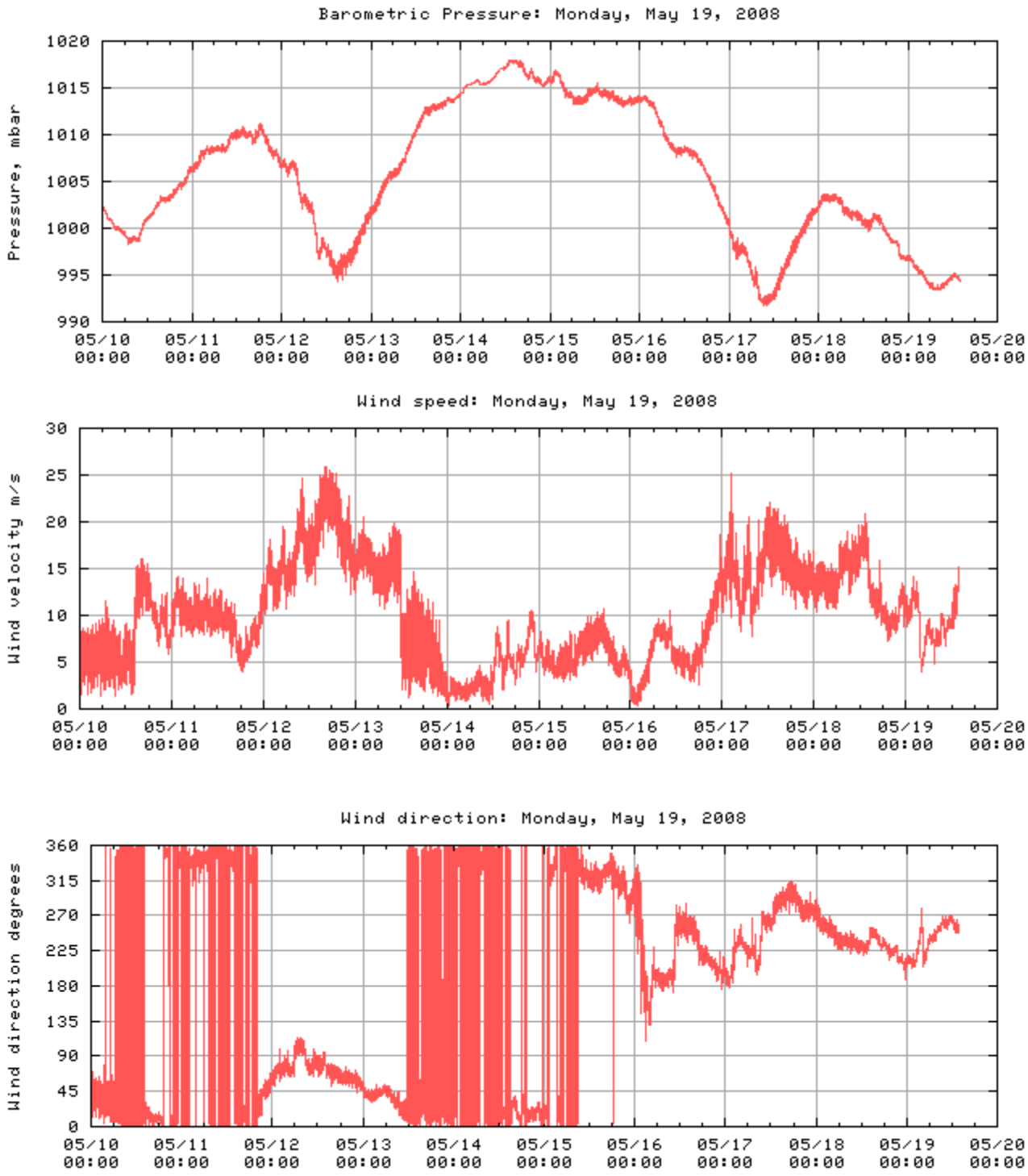


Figure 3. Time series of barometric pressure, wind speed and wind direction measured by R/V Oceanus during Oc446.

After securing the equipment on deck (bringing inside the bulk of the moored instrumentation), we transited back south to pick up the hydrographic stations between mooring sites 5 and 6. Stations at sites 16 and 15 were occupied during the night,

returning to Mooring Site #5 mid-morning on May 17. Seas were still too large to allow safe mooring operations, but a BPR was successfully deployed.

Strong winds were forecast to persist for at least the next 24 hours and yet another low pressure system was predicted to spin up over Line W after that. It became apparent that we would not have sufficient periods of good working conditions to complete the remaining mooring work. Our choices of action were to either hove to and do what work we could accomplish in the available time or return to port early and petition to apply the ship time saved against an emergency cruise at a later date (when weather conditions would hopefully be much better). We chose the latter, directing *R/V Oceanus* to return to Woods Hole, picking up the hydrographic stations not yet occupied enroute. Stations at sites 13-9 were done as planned; arrival in Woods Hole occurred midday on May 19.

As detailed in Table 1 below, 3 complete moorings remain to be recovered and redeployed with a 4th mooring at site 5 to be deployed. (This count does not include the sediment trap mooring.) Most of the instrumentation on these existing moorings will be exhausting their batteries in the coming weeks. We hope these moorings can be serviced sometime this summer to minimize the gap in the measurement time series.

Acknowledgements

The Line W program is supported by the National Science Foundation through grant nos. OCE-0241354 and 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, planned for Spring 2008 – Spring 2010

Mooring 0: BPR only: successfully recovered and redeployed

Lat: 38 44.3 N
Lon: 69 48.8 W
Bottom Depth: 1800 m

Mooring 1: Fixed sensors & BPR : both successfully recovered and redeployed
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Lat: 39 35.821 N
Lon: 69 41.710 W
Bottom Depth: 2227 m

Mooring 2: MMPs & BPR: not serviced on Oc446

Lat: 39 12.962 N
Lon: 69 26.564 W
Bottom Depth: 2740 m

Mooring 3: Fixed sensors & BPR : not serviced on Oc446

Lat: 38 50.690 N
Lon: 69 10.224 W
Bottom Depth: 3245 m

Mooring 4: MMPs & BPR: not serviced on Oc446

Lat: 38 26.843 N
Lon: 68 54.508 W
Bottom Depth: 3644 m

Mooring 5: Fixed sensors & BPR: BPR recovered and redeployed. Mooring recovered.

Lat: 38 10.696 N
Lon: 68 34.001 W
Bottom Depth: 4102 m

Mooring 6: Fixed sensors GUSTO-08: Mooring successfully deployed.

Lat: 37 31.159
Lon: 68 16.998
Bottom Depth: 4676

* bottom depths are uncorrected.

MMP denotes a mooring supporting a McLane Moored Profiler instrument
Fixed sensors denotes a mooring fitted with multiple fixed-depth current meters and T/S sensors
BPR denotes a bottom pressure gauge deployed separately at the site

Table 2: List of hydrographic stations occupied on Oc446