Cruise Report
PIRATA Northeast Extension 2013b &
AEROSE IX

NOAA Ship *Ronald H. Brown*
RB-13-06

November 11 – December 8, 2013
Bridgetown, Barbados – Recife, Brazil

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PIRATA Northeast Extension 2013b Scientific Party

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Moorings: J. Michael Strick (NOAA/PMEL).

AEROSE: Vernon Morris (Howard Univ.), Everette Joseph (Howard Univ.), Nicholas Nalli (NOAA/NESDIS/STAR), Mayra Oyola (Howard Univ.), Christopher Spells (Hampton Univ.), Ebony Roper (Howard Univ.), Jonathan Smith (NOAA/NESDIS/STAR), Elsa Castillo (Univ. Texas El Paso), Sarah Sammy (Univ. West Indies).

Surface Infrared Radiation and Ocean Skin Temperature: Malgorzata Szczodrak (Univ. Miami).

Note: This report provides detailed information about the hydrographic measurements and mooring operations carried out during the cruise. This work is in support of the PIRATA Northeast Extension project and is part of a collaborative agreement between AOML and PMEL and is funded by NOAA's Climate Program Office. Work performed by the AEROSE team and the Surface Radiation/Temperature team is described in detail in separate documents. All results reported in this document are subject to revision after post-cruise calibrations and other quality-control procedures have been completed.

OVERVIEW

The November-December 2013 PIRATA (Prediction and Research Moored Array in the Tropical Atlantic) Northeast Extension (PNE) and Aerosols and Ocean Science Expedition (AEROSE) cruise RB-13-06 was designed to (1) Collect oceanographic and meteorological observations in the northeastern tropical Atlantic, (2) Recover and redeploy the PIRATA Northeast Extensions' four Autonomous Temperature Line Acquisition (ATLAS) moorings, and (3) Recover and redeploy the TFlex mooring located near the 20°N, 38°W ATLAS mooring. The oceanographic component of (1) includes measurements of conductivity, temperature, pressure, oxygen concentration, and horizontal velocity from CTD casts and measurements of temperature and depth from XBT deployments. The majority of the measurements were acquired along the 23°W meridian, which samples the southeastern corner of the subtropical North Atlantic, a region of subduction that is important for the subtropical cell circulation; the Guinea Dome and oxygen minimum zone, where the subtropical and tropical gyres meet; and the tropical current system and equatorial waveguide. The meteorological component of (1) focused on measurements of atmospheric aerosols, temperature, water vapor, ozone, trace gases, winds, and other properties. All scientific goals of RB-13-06 were achieved.

We thank the crew and officers of the *Ronald H. Brown* for their work during the cruise and their help before, during, and after the cruise. Five surface moorings were successfully recovered and redeployed by Chief Bosun Bruce Cowden and the deck crew using a new method that eliminated the need for small boat operations. Thanks to the survey technicians, Jonathan Shannahof and Darcy Balcarce, and the Electronic Technician, Clay Norfleet, for their assistance during CTD casts and in assessing the state of the CTD wire. Thanks also to the rest of the crew, including the winch operators, engineers, galley crew, who kept operations running smoothly. Finally, we appreciate the efforts of the Field Operations Officer and Commanding Officer to ensure efficient operations and to provide information and advice on the physical state of the CTD wire and its usability. Because of the experience and helpfulness of the crew and officers, the cruise progressed very smoothly, and we were able to make six more CTD casts than were originally planned.

Introduction

1. PIRATA Northeast Extension

The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) is a three-party project involving Brazil, France and the United States that seeks to monitor the upper ocean and near-surface atmosphere of the Tropical Atlantic via the deployment and maintenance of an array of moored buoys with subsurface sensors and automatic meteorological stations. The array consists of a backbone of ten moorings that run along the equator and extend southward along 10ºW to 10ºS, and northward along 38ºW to 15ºN. Following the success of the backbone array, additional moorings were deployed as part of the Southeast Extension in 2005 and the Northeast Extension in 2006-2007 (Fig. 1).

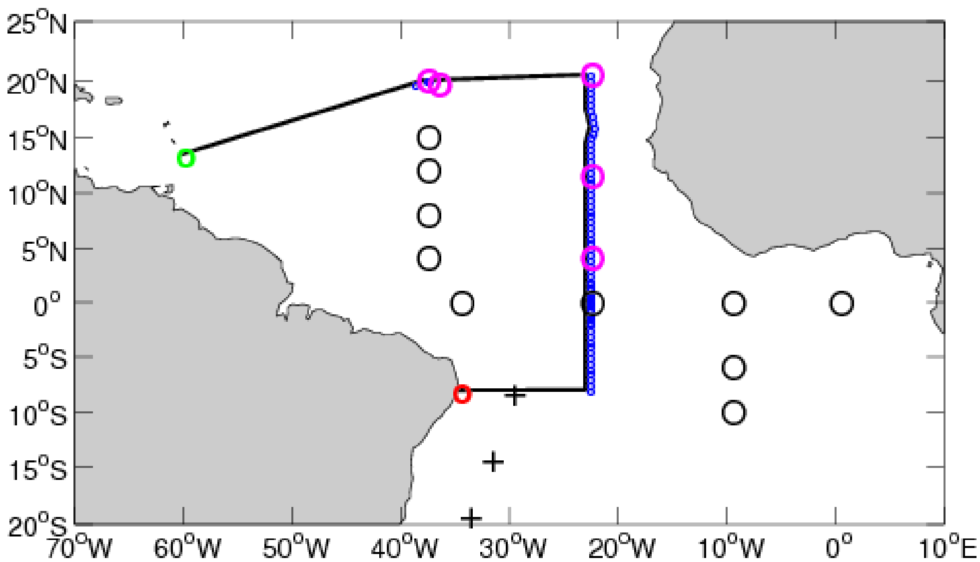

Figure 1 Locations of the PIRATA backbone array moorings (black circles), Southwest Extension moorings (black crosses), and Northeast Extension moorings (pink circles), including an experimental T-Flex mooring at 20°N, 38°W. Green and red circles indicate the beginning and end ports of Bridgetown, Barbados, and Recife, Brazil, respectively. Blue circles show the locations of 69 CTD casts performed during the cruise.

The Northeast Extension samples a region of strong climate variations on intraseasonal to decadal scales, with impacts on rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. The northeastern Tropical Atlantic includes the southern edge of the North Atlantic subtropical gyre, defined by the westward North Equatorial Current (NEC), and the northern edge of the clockwise tropical/equatorial gyre defined by the North Equatorial

Countercurrent (NECC). This area is the location of the North Atlantic's oxygen minimum zone, located at depths of 400—600m. The size and intensity of this zone is a potential integrator of long-term North Atlantic circulation changes, and the extremely low oxygen values have significant impacts on the biota of the region. The cyclonic Guinea Dome is centered near 10ºN, 24ºW, between the NECC and NEC in the eastern Tropical Atlantic. It is driven by trade wind-induced upwelling and may play an active role in modulating air-sea fluxes in this region.

The tropical North Atlantic includes the Main Development Region (MDR) of tropical cyclones. Many major hurricanes that ultimately threaten the eastern United States begin as atmospheric easterly waves propagating westward from the African continent. Once over the MDR in the 10ºN -20ºN band, these waves are exposed to convective instability driven by the upper ocean's high heat content. The resulting infusion of energy can result in closed cyclonic circulation and development from tropical depression to tropical storm and hurricane. These hurricanes are known as Cape Verde-type hurricanes, to distinguish them from storms forming further west, and they are often the most powerful storms to strike the US east coast. There is profound uncertainty regarding the specific atmospheric/oceanic conditions that determine which of the atmospheric waves will develop into tropical cyclones and then hurricanes. Specifically, the quantitative effects of the Saharan Aerosol Layer (SAL), anomalous sea surface temperatures (SST), upper-layer oceanic heat content, and atmospheric wind shear on the formation of tropical cyclones are poorly known.

Seasonal tropical storm and hurricane forecasts are generated annually and are based primarily on statistical analyses of historical data and the formulation of empirical predictors (e.g., ENSO index, Atlantic SST, Sahel rainfall, etc.). Recent empirical studies have demonstrated that tropical storm and hurricane activity in the Atlantic Ocean varies on decadal and multi-decadal time-scales and that this variability is correlated with SST anomalies in the MDR. There is hope that a better understanding of decadal-multidecadal SST variability in the tropical North Atlantic will lead to improved predictions of Atlantic hurricane activity and rainfall fluctuations over South America and Africa. There is currently great uncertainty regarding the roles of wind-induced evaporative cooling, cloudiness- and dust-induced changes in surface radiation, anthropogenic aerosol-induced surface cooling, and ocean mixed layer dynamics, in driving interannual-multidecadal SST variability in the tropical North Atlantic. Measurements from the moorings of the PIRATA Northeast Extension are valuable for conducting empirical heat budget analyses, which diagnose the causes of SST variability and are also useful for numerical model validation.

2. Aerosols and Ocean Science Expeditions (AEROSE)

The NOAA Aerosols and Ocean Science Expeditions (AEROSE) attempt to achieve a comprehensive measurement-based approach for gaining understanding of the weather and climate impacts of long-range transport of mineral dust and smoke aerosols over the tropical Atlantic (Morris et al., 2006; Nalli et al., 2011). The African continent is one of the world's major source regions of mineral dust and biomass burning smoke aerosols. These aerosols are transported over the tropical Atlantic as large-scale outflow plumes within the prevailing easterly winds, impacting phenomena ranging from cloud-seeding and precipitation, tropical cyclone development, net surface heat flux, tropospheric ozone and other trace gases, ocean fertilization, air quality and ecosystems in the Caribbean and along U.S. eastern seaboard, and NOAA infrared satellite data products. Red tides, increasing rates of asthma, and precipitation variability in the eastern Atlantic and Caribbean have been linked to increases in the quantity of Saharan dust transported across the Atlantic. The contribution of the Saharan air layer (SAL) to the development of the West African Monsoon (WAM) and its role in tropical cyclogenesis are only beginning to be understood. The interplay between thermodynamics, microphysics, and aerosol chemistry are currently unknown. Understanding of the mobilization, transport, and impacts of aerosols originating from natural and anthropogenic processes in Africa on the meteorology and climate of the tropical Atlantic is therefore a high priority. AEROSE has thus sought to address three central scientific questions (Morris et al., 2006):

1. How do Saharan dust, biomass burning aerosol, and/or the SAL affect atmospheric and oceanographic parameters during trans-Atlantic transport?
2. How do the Saharan dust aerosol distributions evolve physically and chemically during transport?
3. What are the capabilities of satellite remote sensing and numerical models for resolving and studying the above processes?

The AEROSE project hinges on multi-year, trans- Atlantic field campaigns conducted in collaboration with the PNE project. AEROSE is supported through collaborative efforts between NOAA's National Environmental Satellite Data and Information Service, Center for Satellite Applications and Research (NESDIS/STAR) and the National Weather Service (NWS), as well as NASA and several academic institutions linked through the NOAA Center for Atmospheric Sciences (NCAS) at Howard University.

AEROSE trans-Atlantic campaigns (including 4-5 week campaigns conducted 2004, 2006-2011, and 2013) have acquired a set of *in situ* measurements to characterize the impacts and microphysical evolution of continental African aerosol outflows (including both Saharan dust and sub-Saharan and biomass burning) across the Atlantic Ocean (Nalli et al., 2011).

Order of Operations

The R/V *Ronald H. Brown* (RHB) departed Bridgetown, Barbados on November 11 at 16:00 UTC and proceeded northeastward toward the first mooring site. Fig. 2 shows most of the members of the scientific parties from AOML, PMEL, and AEROSE. The RHB's departure was delayed several hours in order to wait for the arrival of one of the members of the crew. Before departure, the AOML team discovered that seven Argo floats were missing from Woods Hole's shipment. After communication between the AOML team, Woods Hole, the officers of the RHB, and the RHB's shipping agent, the missing floats were delivered to RHB's dock and were transferred to the RHB using the ship's small boat. The RHB's underway oceanic and atmospheric measurement system was turned off during the transit through Barbados' EEZ since research clearance had not been granted from the State Department.

Figure 2 Members of the scientific party of PNE2013b. Not included in the picture are Shaun Dolk, Elsa Castillo, and Malgorzata Szczodrak (a.k.a. Goshka).

Immediately prior to the start of the cruise, a total of approximately 800 m was cut from the end of the aft winch's CTD wire after surface corrosion was discovered by the RHB's crew and officers. Upon embarking the RHB before departure in Barbados, the AOML team performed a visual inspection of the aft CTD wire and discovered that significant amounts of corrosion were present on the surface of the remaining wire. The Chief Scientist communicated these concerns to the Chief Survey Technician (CST) and Electronic Technician (ET). During the All-hands briefing on the second day of the cruise, the Commanding Officer (CO) also communicated his concerns about the state of the CTD wire. After consultations between the Chief Scientist, Chief Survey Technician, and CO, the decision was made to perform a test CTD cast with a dummy weight on AOML's CTD frame prior to the planned test cast with all instruments attached. A weight of approximately 500 lb was attached to the CTD wire in preparation for the test cast.

On November 13 at 15:30 UTC, the test cast entered the water. The wire was taken out to approximately 2750 m with the dummy weight attached. Throughout the downcast, the AOML team, CST, ET, and CO carefully monitored the wire's external appearance. Corrosion was apparent on the outer 1800 m of the wire. After approximately 1800 m, the visible evidence of corrosion diminished significantly. The test cast was completed without any problems.

During the upcast of the test CTD, the AOML team and CST concluded that in order to minimize risk of loss, the top 1800 m of the CTD wire should be cut and the remaining wire re-terminated. Cutting 1800 m would leave about 3500 m on the spool, which would be more than enough to meet PNE's objective of 63 casts to 1500 m. Cutting the wire would eliminate the option to perform a bottom cast on the equator, but would allow an approach to within approximately 800 m of the bottom. The AOML team decided they would prefer to sacrifice the equatorial bottom cast for the reduction in the risk of loss that could be accomplished with the removal of the corroded portion of the wire. The decision to the cut wire was also based on examination of a previously cut segment of the wire, which showed evidence of corrosion on the inner strands. The was speculation among the CST, ET, and Chief Engineer that the CTD may have been improperly grounded, resulting in stray current through the wire and more rapid than normal corrosion of the wire over the past month.

After completion of the test CTD cast, the Chief Scientist explained his decision to cut the wire to the CO and Operations Officer. The CO objected, stating that his opinion was that the wire in its current state would most likely not fail and that he wanted to keep the full length of wire in case the following cruise (A16S) needed it as a backup for their CTD casts. After some discussion, it was decided to contact the Principle Investigators (PIs) of A16S and ask if they would object to cutting the wire. The PIs objected, preferring instead to wait for the results of lab analyses of a section of the wire and for confirmation that two new spools would be delivered to the RHB in time for the start of A16S. The Chief Scientist agreed to use the wire in its present condition until more information was available about the wire's condition and the arrival of the new spools.

After the dummy test cast and during the transit to the instrumented test cast, two Argo floats were deployed. The AOML team attached instruments (dual temperature, conductivity, oxygen sensors, and upward- and downward-looking 300 kHz ADCPs) and related gear to the CTD frame and planned a series of two casts to 100 m and two casts to 1500 m to test different ADCP settings. The goal was to increase the vertical resolution and decrease the noise level of the ADCP measurements in the upper 30 m by changing the upward-looking ADCP bin size from 8 m to 4 m and hanging the CTD frame at a depth of 100 m for several minutes during the upcast. A secondary goal of the test casts, in addition to testing the CTD bottle firing, electronics, and sensors, was to verify that the change in ADCP bin size did not significantly affect the quality of ADCP data at deeper levels (500-1500 m), where less sound-scattering material is present in the water.

On November 15, the results of a "pull test," using a section of wire from the aft winch, were made available to the Chief Scientist. The test was conducted at PMEL and overseen by Chris Meinig. The wire failed at 10,700 lb, which is in line with its manufacturing specifications. The positive results from the pull test made the Chief Scientist, CST, and Commanding Officer more comfortable using the wire for CTD casts. However, there was still uncertainty regarding the causes of the seemingly rapid deterioration of the wire and the extent to which the decay may affect the future strength of the wire.

At 16:00 UTC on November 16, the instrumented test casts began. All casts were completed as planned and all electronics and sensors worked well. After the casts, comparison of the ADCP data from the 1500 m cast with 8 m bins on the uplooker to the data from the 1500 m cast with 4 m bins on the uplooker did not reveal any significant differences. The Chief Scientist therefore decided to proceed with 4 m bins on the uplooker and 8 m bins on the downlooker for the remaining CTD casts. Although there was not a noticeable difference between the velocity profiles in the upper 100 m between the casts with and without a 5-minute hang at 100 m, the Chief Scientist decided to proceed with a 5-minute hang at 100 m during the upcasts at the remaining CTD stations with the hope of gaining more reliable data in the upper 30 m.

The RHB arrived at the first mooring site at 3:00 UTC on November 17. A CTD/ADCP cast was conducted between 3:35 and 5:00 UTC at the mooring location (20°00'N, 37°52'W). At 9:00 UTC the ATLAS mooring's release triggered. The release was on deck at 14:00 UTC, and the new ATLAS buoy was in the water at 16:00 UTC. The anchor was dropped at 19:00 UTC. A CTD/ADCP cast was performed at the TFlex mooring location (20°01'N, 37°48'W) starting at 22:30 UTC on November 17. The TFlex mooring's release was triggered at 8:30 UTC on November 18, and the release was on deck at 13:30 UTC. The new TFlex buoy was in the water at 15:50 UTC, and the anchor was dropped at 19:00 UTC. During the transit to the first two mooring sites and during the mooring recoveries and deployments, the AEROSE team launched 23 radiosondes and two ozonesondes and collected other atmospheric data. On the transit from the first ATLAS/TFlex sites to the start of the 23°W line, 12 more radiosondes and two more ozonesondes were launched. The sondes were launched to coincide with S-NPP (Suomi National Polar-orbiting Partnership) and MetOp satellite overpasses.

The RHB arrived at the northern end of the 23°W transect (20°27'N, 23°08'W) at 2:20 UTC on November 22. Between 2:30 and 3:10 UTC, eight pairs of XBTs were launched as part of an XBT comparison experiment. A CTD/ADCP cast was performed immediately following the XBT launches. After the standard cast to 1500 m, nine additional casts were conducted to depths of either 100 m or 200 m in order to test the impacts of different CTD/ADCP hang depths and durations on the ADCP data quality. After analyzing the data from the test casts, the Chief Scientist decided to continue hanging at 100 m for five minutes.

The acoustic release of second PNE mooring (third mooring overall, including the 20°N, 38°W TFlex mooring) was triggered at 20°27'N, 23°08'W at approximately 8:00 UTC on November 22 and was on deck at 13:00 UTC. The new ATLAS buoy was deployed at 15:00 UTC, and its anchor was dropped at 17:30 UTC. From the mooring site, the RHB proceeded southward along 23°W to the next ATLAS mooring located at 11.5°N. CTD/ADCP casts to 1500 m were performed every 0.5° of latitude along 23°W. The AEROSE team launched four radiosondes per day during the transit. Because of the combination of ADCP instrument failure and problems with the ADCPs' data recording and downloading, between 20.5°N and 14.5°N there were three casts for which no ADCP data are available, eight casts with only an uplooking ADCP (no downlooker), and one cast with only a downlooker. More details of the ADCP problems are provided later in this report. Both ADCPs were operational again starting at the 14°N CTD/ADCP station and continuing southward for the remainder of the casts.

On November 25, the Commanding Office and the Principle Investigators of the A16S project were confident that two new spools of CTD wire would arrive in Brazil in time for the A16S cruise following PNE. The Chief Scientist was therefore given permission to cut the wire as needed. After discussions between the CST, Chief Scientist, and Commanding Officer, it was decided to cut 1800 m from the CTD wire the following day.

The RHB arrived at the third PNE mooring (11°29'N, 23°00'W) site at 2:30 UTC on November 26. Eleven pairs of XBTs were launched between 2:45 and 3:20 UTC. A CTD cast to 1500 m was completed immediately following the XBT launches. The ATLAS moorings acoustic release was triggered at 8:15 UTC, and the release was on deck at 13:15 UTC. A SeaBeam survey was conducted before the new ATLAS buoy was deployed at 16:30 UTC and the anchor was dropped at 19:30 UTC. Upon arrival at the next CTD station (11°00'N, 23°00'W) and before the cast, the

CST and ET cut 1800 m from the CTD wire and re-terminated. During the CTD cast, numerous modulo errors were observed and the primary oxygen sensor appeared to be bad. At a depth of approximately 150 m, communication with the package was lost. The package was recovered and it was concluded that the deck unit was causing the problems, so it was swapped out for a new one. The CTD package was lowered into the water again, but the problems persisted. The package was recovered and the wire's termination was inspected and found to be faulty. The ET fixed the termination, and the CTD cast was performed without any further problems. The combination of cutting the wire, re-terminating, and diagnosing problems created approximately three hours of downtime.

After the cast at 11°00'N, 23°00'W, the RHB continued southward to the next mooring located at 4°N, 23°W. CTD/ADCP casts were performed to 1500 m every 0.5° of latitude during the transit, and the AEROSE team continued launching radiosondes and ozonesondes. Single surface drifters were deployed at 9°14'N, 23°00'W and 6°27'N, 23°00'W; pairs of surface drifters were deployed 4°59'N, 23°00'W and 4°02'N, 23°00'W.

Recovery of the fourth and final PNE mooring (4°03'N, 22°59'W) commenced with triggering of the acoustic release at 15:00 UTC on November 29. The release was on deck at approximately 19:00 UTC. After successful recovery of the ATLAS mooring, a 11 pairs of XBTs were dropped close to the mooring location. At 13:00 UTC on November 30, the ATLAS mooring was redeployed at 4°02'N, 23°00'W and the RHB continued its track southward along 23°W. CTDs were conducted every 0.5° of latitude between 4°N and 2°N, then every 0.25° of latitude between 2°N and 2°S, and every 0.5° of latitude between 2°S and 5°S. The original cruise plan included CTDs only to 5°S. However, because of the efficiency of operations during the cruise, additional time was available to extend the CTD line to 8°S with a spacing of 0.5°. A deep cast to 3500 dbar was conducted on the equator. Pairs of surface drifters were deployed every 0.5° of latitude between 3°N and the equator. The drifters were deployed at these locations after noticing that the RHB would be traveling into the leading edge of a tropical instability wave (TIW) between about 0.5°N and 3°N along 23°W. XBT comparison drops were conducted immediately following the CTDs at 0°15'N, 23°00'W and at 5°30'S, 23°00'W (9 pairs of XBTs at 0°15'N and eight pairs at 5°30'S).

On December 5, three days before arrival in Recife, results of a wire chemical analysis, based on a segment taken from the aft CTD wire, were released. The tests were initiated by Greg Johnson and Chris Meinig at PMEL, given the rapid deterioration of the wire. The results suggest that spurious current through the wire was the primary cause of the corrosion. If not corrected, it could cause rapid deterioration of the new wire that will be sent to the RHB for A16S. The recommendation in the report is: "The winch and all related components should be checked for proper electrical connections and grounding."

Summary of oceanographic and atmospheric work performed and data collected during the cruise:

1. Recovery and redeployment of four ATLAS moorings at 20°N, 38°W; 20.5°N, 23°W; 11.5°N, 23°W; and 4°N, 23°W.
2. Recovery and redeployment of one TFlex mooring at 20°N, 38°W.
3. CTD/O_2/ADCP profiles to 1500 dbar at 69 locations, including each ATLAS and TFlex mooring site.
4. CTD/O_2/ADCP profile to 3500 dbar on the equator.
5. Salinity of the CTD bottle samples collected with Niskin bottles.
6. Dissolved oxygen concentration of the CTD bottle samples collected with Niskin bottles.
7. Deployment of 20 surface drifting buoys.
8. Deployment of two Argo floats.
9. Launching of 96 XBTs as part of an XBT comparison experiment.
10. Continuous recording of shipboard ADCP data.
11. Continuous recording of Thermosalinograph (TSG) data.
12. Heading data from the Meridian Attitude and Heading Reference System (MAHRS) and the Position and Orientation Systems for Marine Vessels (POS MV).
13. Weatherpak meteorological sensors (Univ. Miami).
14. Microwave radiometer (Univ. Miami).
15. Marine Atmospheric Emitted Radiance Interferometer (M-AERI) (an infrared Fourier transform spectrometer (FTS)) to measure uplooking and downlooking spectral radiances, marine boundary layer profiles of temperature and water vapor, and skin SST (Univ. Miami).
16. Aerosol optical depth from Microtops handheld sun photometers (Howard Univ.).
17. Tropospheric profiles of pressure, temperature, humidity, and wind from launching of 97 Vaisala RS92 radiosondes during MetOp and S-NPP overpasses (NESDIS/STAR, Howard Univ.).
18. Ozone profiles from launching of 19 ozonesondes interfaced with RS92 launches (Howard Univ., NESDIS/STAR).
19. Laser particle counters (Howard Univ.).
20. Solar radiation from broadband pyranometer (Howard Univ.).
21. Downwelling infrared radiation from broadband pyrgeometers (Howard Univ.).
22. Trace gas monitors (Ozone, NOx, CO, VOC, and SO2) (Howard Univ.).
23. Sequential aerosol sampler (Howard Univ.).
24. Multi-stage aerosol impactors (Howard Univ.).
25. NOAA-unique satellite sounder sensor data records (SDRs) and environmental data records (EDRs) from the Suomi National Polar Partnership (S-NPP) Cross-track Infrared Microwave Sounder Suite (CrIMSS), and the MetOp-A and -B Infrared Atmospheric

Sounding Interferometer (IASI) matched to the radiosonde launch locations/times (NESDIS/STAR).

26. Hourly SEVIRI multichannel imager data for the entire AEROSE domain.

Oceanic Data (PNE)

1. ATLAS moorings and TFlex mooring (from Mike Strick, NOAA/PMEL)

Summary of Mooring Operations		
Site	**Mooring ID #**	**Operation**
20N_38W	PI 181A / PI 199	Rec / Depl
20N_38W	PT 002 / PT003	TFLEX Rec / Depl
20.5N_38W	PI 182 / PI 200	Rec / Depl
12N_38W	PI 183 / PI 201	Rec / Depl
4N_38W	PI 184 / PI 202	Rec / Depl

Lost or Damaged Instruments and Equipment *(from rec moorings)*				
Site	**Mooring ID**	**Sensor type**	**Serial No**	**Comments**
20N_38W	PI181	Sontek	D719	Broken fin
20N_38W	PT 002	SBE37-TC	9202	No shield
20N_38W	PT 002	SBE37-TC	9203	Pressure housing fell off at surface
20N_38W	PT 002	Nortek Aquadopp	9843	Broken fin
20.5N_23W	PI182	TC	14620	Flooded
20.5N_23W	PI 182	TC	12777	Dropped
11.5N_23W	PI 183	TV	15440	Missing/Lost
4N_23W	PI 184	TC	13990	No comms
4N_23W	PI 184	T	13838	Flooded

On-deck instrument or hardware failure *(pre-deployment)*		
Sensor type	**Serial No**	**Comments**
Sontek	D770	TV lockup?
TV	15596	TV lockup?
SSC	15047	Replaced with spare 15348

Fishing and Vandalism		
Site	**Mooring ID**	**Comments**
20.5N_38W	P I182	Small float attached to buoy. Some longline gear at 40M-80M

Shipping notes:

The Ron Brown (RHB) was tied up at the cruise ship terminal in Bridgetown, Barbados. Loading was scheduled for November 8, 2013 at 07:00. Containers (1-40'+1-20') arrived dockside at 08:00. An attentive and competent crew of Bajan dockworkers professionally offloaded the containers. The RHB used their starboard side crane to convey the PMEL mooring gear to the workdeck. The deck crew and myself made quick work of stowing the gear and the whole operation of offloading the containers was completed by 11:15. The German O2 sensors were already onboard and quickly located. There was some confusion as to the disposition of the Dalhousie University Ocean Tracking Network (OTN) sensors, were they to be delivered to ship or was I to pick them up at the airport or was I to facilitate their release from customs. Unfortunately this was all trying to be completed on a weekend in Barbados and my Canadian contacts were celebrating some obscure Canadian holiday and I was unable to get in contact with them. My search at Grayley International Airport Cargo Center was very unproductive as nothing was open until 12:00. I returned to the RHB expecting to not sail with OTN sensor. BGL Williams suggested we start an intensive search of the RHB science areas and with much relief BGL Williams discovered the wayward package behind several large shipping crates in the main lab. There was much rejoicing.

Prior to arriving in Recife, Brazil for the offload I began the often convoluted and laborious task of preparing the return shipment manifest. Suffice it to say 3 days later the manifest was completed to the satisfaction of Global Logistics and their Brazilian counterparts. Offload in

Recife went surprisingly well. The RHB was descended upon by approximately 20 dockworkers and we proceeded to offload the PMEL gear onto flatbeds which then transported our gear to the bonded customs facility where it would be inspected and eventually packed into containers. Offloading commenced at 14:00 and we completed the RHB offload at 16:30. In the original offload plans a forklift was reserved and supposed to be available to facilitate the offload process. No forklift appeared during the offload and quite honestly we did not need one.

Noteworthy Operational Details:

20N_38W

PI181 None

PI199 TV 15681 was inadvertently deployed on PI199 (20N_38W) instead of the prescribed 15596. TV 15596 was deployed on PI200 @ 21N_23W. Unfortunately no Dalhousie University Ocean Tracking Network (OTN) sensor was deployed at this site.

20N_38W - TFLEX

Retaining bolts holding the pressure housing on were missing. The electronics seemed to be OK as there was no obvious evidence of massive water intrusion. I may have been unable to download the data from this instrument.

PT003 I was totally confused by the nicely put together SBE deployment boxes. The cable connections necessary to make the inductive loop operational were just not intuitive to me. I should have paid more attention to the details and diagramed the correct setup when David was explaining it to me. My bad. I reverted to the simple inductive test loop we employ on ATLAS inductive systems. Unfortunately there were problems with the resistor wire breaking in the test loops. It took me some time to diagnose this problem, but in the end all was good and inductive comms with the TFLEX were established. The RF link worked flawlessly.

20.5N_23W

PI181 TC60 deployed on PI182 (PI13-12-RB) failed. Upon recover it was discovered to be flooded. I dropped the 20M TC (12777) overboard during recovery operations. It was not recovered.

PI200 Routine deployment. OTN sensor at 300M instead of 500M

11.5N_23W

PI183 Routine recovery

PI201 Routine deployment. 40M TC (14090) did not get inverted. OTN sensor at 300M. German O2 sensors at 300M and 500M.

4N_23W

PI184 T7 (S/N 13838) failed on deployment. When recovered it was recovered it was flooded and perhaps some kind of battery failure.

PI202 Routine deployment. Switched out SST/C before deploying. Original plan was to deploy SST/C 15047 but swapped in spare SST/C 15348. AOML Sonteks at 7M and

22M. OTN sensor at 500M and German O2 sensors at 300M and 500M. Mooring deployed without the 2 link _¾" LL chain.

Instrumentation and Hardware Notes:

Dalhousie University OTN sensors were deployed at 20.5N_23W (300M), 11.5N_23W (300M) and 4N_23W (500M).
German O2 sensors were deployed at 11.5N, 4N_23W (300M+500M).

Software Notes:

NONE

Ship Notes or issues:

The 'newish' EM 122 multi-beam system operated flawlessly. Per Steve Kunze (PI3-12-RB), *'The survey department is still climbing the learning curve with it but they were able to meet our needs without much headache. The system makes adjustments for the speed of sound through the water so the depths displayed are the actual corrected numbers'*. Two bathymetric maps generated from data collected on PI3-12-RB were supplied for PI3-13-RB (20.5N_23W and 4N_23W). The survey department collected data for two additional sites (20N_38W and 12N_23W). Data was returned to PMEL for processing. Unfortunately the EM 122 is not being utilized to its full extent, not even to 50% of its potential. The RHB Survey Department can utilize only the most rudimentary of the EM 122's functions. Some basic and necessary functions need to be learned for it to be truly useful (e.g. accurate lat and long information, depth, ruler function, setting flags or markers on the display). Unfortunately the EM 122 is not logging between stations. An opportunity to map the entire 23W line was missed. Perhaps some classroom training could be arranged for the Survey Department to ensure the EM 122 can be utilized to a greater extent.

The RHB's Deck Department was outstanding. Truly outstanding. On this cruise we did not launch the workboat at any time to recover buoys. Buoys were recovered from the starboard side utilizing a 'Happy Hooker' or some kind of hooking device resembling a shepard's hook that was fabricated by Chief Bosun Bruce Cowden. The ship's officers did an outstanding job of utilizing the RHB's dynamic positioning system to maneuver the ship into a position where we could 'capture' the buoys. No meteorological sensors were damaged during any of the five recoveries. The NOAA Corp officer's, ship's deck crew and myself were all extremely satisfied with not having to launch the workboat for recovery operations. It was felt by all that the increased safety factor and the time savings were significant. The Deck Department was extremely proactive and helpful in all mooring operations.

A hydraulic hose on the port side knuckle boom crane blew, as we were getting ready to deploy the 11.5N_23W buoy. The Engineering Department made short work of replacing the hose and cleaning up the resulting hydraulic fluid spill. We were ready to begin that deployment with only a two-hour delay.

I did not utilize the in hull mounted 12kHz transducer. I elected to dangle a transducer over the starboard side.

Per Steve Kunze from PI3-12-RB: *Internet connection speeds were noticeably slower than they had been in years past. It's probably due to an increase in bandwidth activity from the modern devices (e.g. smart phones, tablets) everyone carries around with them now. During the day it could be extremely slow but if you stayed up late or got up early enough it was okay.*

The above has not changed on PI3-13-RB, in fact, it's probably worse.

Ancillary Projects:

We continued deploying German O2 sensors. Current deployments were at 11.5N, 4N_23W at 300M and 500M.

OTN sensors were deployed at 20.5N_23W (300M), 11.5N_23W(300M), 4N_23W (500M).

Two Sontek current meters from AOML were deployed at depths of 5 m and 20 m on the 4°N ATLAS mooring to complement the existing current meter at a depth of 10 m. Fig. 3 shows preliminary daily-averaged data from the current meters.

Dalhousie University added instruments incorporating acoustic tracking technology to the moorings on PNE. Below is a brief description of the project as supplied by Dalhousie University Ocean Tracking Network:

Acoustic Mammal Receivers on 2013 PNE moorings

The Ocean Tracking Network (OTN) is a Canada Foundation for Innovation (CFI) - International Joint Ventures Fund global research and technology development project headquartered at Dalhousie University, Halifax, Nova Scotia. Starting in 2008, the OTN began deploying Canadian state-of-the-art acoustic receivers and oceanographic monitoring equipment in key global ocean locations. These are being used to document the movements and survival of marine animals carrying acoustic tags ("pingers"), and to document how both are influenced by oceanographic conditions. OTN deployments will occur in all of the world's five oceans, and span seven continents. The species tracked include marine mammals, sea turtles, squid, and fishes including sharks, sturgeon, eels, tuna, salmon, and cod. The Natural Sciences and Engineering Research Council of Canada (NSERC) supports OTN-Canada, a national network of researchers that works with the OTN infrastructure. The Social Sciences and Humanities

Research Council of Canada (SSHRC) funds the participation of social scientists in OTN work. Over 200 international researchers from 15 countries are currently participating in the global network. OTN hosts a Data Warehouse that serves as a repository for data collected by OTN researchers, and is working to develop interpretation and visualization tools for tracking data. OTN also operates a fleet of autonomous vehicles (Slocum gliders) in support of oceanographic and tracking research, and added a Liquid Robotics Wave Glider to its fleet in 2013.

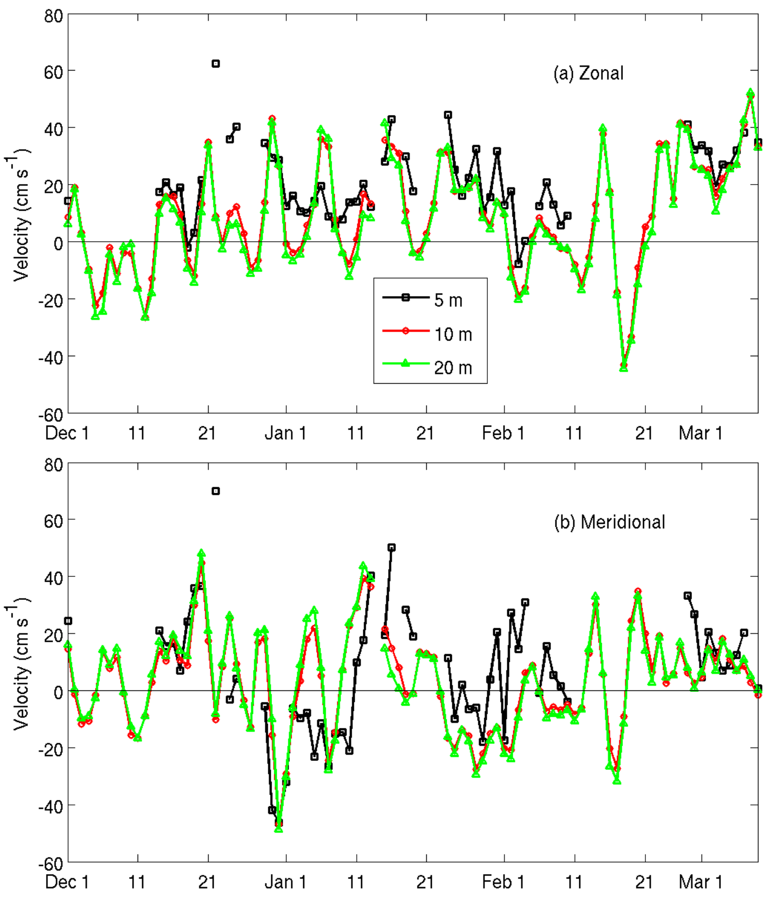

Figure 3 Daily-averaged real-time data during December 2013 – March 2014 from current meters deployed on the 4°N, 23°W PIRATA Northeast Extension mooring during the PNE2013b cruise. Current meters were attached to the mooring line at depths of 5 m, 10 m, and 20 m.

2. Conductivity-Temperature-Depth (CTD) and Acoustic Doppler Current Profiler (ADCP) casts

2.1 CTD casts

AOML's CTD package was initially configured with 24 Niskin bottles. For the PNE cruise, 10 bottles were removed in order to make room for the upward- and downward-looking ADCPs, leaving 12 bottles to be fired at various depths during the casts (to collect water samples for salinity and dissolved oxygen calibration) and two spare bottles. The sensors on the CTD frame consisted of primary and secondary temperature, conductivity, and oxygen (six total) and upward- and downward-looking 300 kHz ADCPs (Table 1).

Table 1 CTD sensors used during the cruise.

sensor name	serial #	date calibrated
Temperature – primary	1609	13 May 2013
Temperature – secondary	1652	22 Jun 2012
Conductivity – primary	3858	10 May 2013
Conductivity – secondary	1347	27 Jun 2013
Oxygen – primary (casts 1-22)	0703	13 Jul 2013
Oxygen – primary (casts 23-69)	0154	18 Jun 2013
Oxygen – secondary	2040	10 May 2013
Pressure	0957	22 Sep 2009

A total of 69 CTD/ADCP casts, including an instrumented test cast, was conducted by Greg Foltz, Grant Rawson, Renellys Perez, and Shaun Dolk with assistance from Survey Technicians Jonathan Shannahoff and Darcy Belcarce (Table 2). CTD processing was performed using Seabird software. After acclimating in the autosal room for at least two days, salinity samples were calibrated using the autosal "Dallas." Oxygen titration was performed by Rawson in order to calibrate dissolved oxygen concentration obtained from the CTD sensors.

Table 2 Date, start time, end time, latitude, and longitude of CTD casts.

station #	date (UTC)	time 1 (UTC)	time 2 (UTC)	latitude	longitude
1	Nov 16	17:40	19:10	19°39'N	39°10'W
2	Nov 17	03:30	05:00	20°01'N	37°52'W
3	Nov 17	22:20	23:50	20°01'N	37°49'W
4	Nov 22	03:15	04:40	20°27'N	23°10'W
5	Nov 22	22:15	23:30	20°00'N	23°00'W

6	Nov 23	02:35	03:55	19°30’N	23°00’W
7	Nov 23	07:05	08:30	19°00’N	23°00’W
8	Nov 23	11:35	12:55	18°30’N	23°00’W
9	Nov 23	16:00	17:20	18°00’N	23°00’W
10	Nov 23	20:30	21:50	17°30’N	23°00’W
11	Nov 24	01:30	02:35	17°00’N	22°49’W
12	Nov 24	05:45	07:10	16°30’N	22°44’W
13	Nov 24	11:00	11:50	16°00’N	22°36’W
14	Nov 24	14:30	16:00	15°30’N	22°44’W
15	Nov 24	18:35	20:00	15°00’N	22°52’W
16	Nov 24	23:15	00:35	14°30’N	23°00’W
17	Nov 25	04:00	05:15	14°00’N	23°00’W
18	Nov 25	08:20	09:50	13°30’N	23°00’W
19	Nov 25	13:00	14:15	13°00’N	23°00’W
20	Nov 25	17:25	18:45	12°30’N	23°00’W
21	Nov 25	21:55	23:10	12°00’N	23°00’W
22	Nov 26	03:30	04:45	11°28’N	23°00’W
23	Nov 27	03:45	05:05	11°00’N	23°00’W
24	Nov 27	08:05	09:20	10°30’N	23°00’W
25	Nov 27	12:10	13:30	10°00’N	23°00’W
26	Nov 27	16:30	18:00	09°30’N	23°00’W
27	Nov 27	20:45	22:00	09°00’N	23°00’W
28	Nov 28	01:00	02:20	08°30’N	23°00’W
29	Nov 28	05:20	06:35	08°00’N	23°00’W
30	Nov 28	09:25	10:40	07°30’N	23°00’W
31	Nov 28	13:30	14:45	07°00’N	23°00’W
32	Nov 28	17:45	19:15	06°30’N	23°00’W
33	Nov 28	22:10	23:30	06°00’N	23°00’W
34	Nov 29	02:30	03:45	05°30’N	23°00’W
35	Nov 29	06:45	08:05	05°00’N	23°00’W
36	Nov 29	11:15	12:30	04°30’N	23°00’W
37	Nov 29	20:50	22:25	04°00’N	23°00’W
38	Nov 30	17:00	18:20	03°30’N	23°00’W
39	Nov 30	21:25	22:40	03°00’N	23°00’W
40	Dec 01	02:25	03:40	02°30’N	23°00’W
41	Dec 01	07:20	08:40	02°00’N	23°00’W
42	Dec 01	10:40	11:55	01°45’N	23°00’W
43	Dec 01	13:50	15:15	01°30’N	23°00’W
44	Dec 01	17:05	18:20	01°15’N	23°00’W
45	Dec 01	20:15	21:35	01°00’N	23°00’W

46	Dec 01	23:25	00:45	00°45’N	23°00’W
47	Dec 02	02:30	03:50	00°30’N	23°00’W
48	Dec 02	05:45	07:00	00°15’N	23°00’W
49	Dec 02	11:25	13:53	00°00’N	23°00’W
50	Dec 02	15:45	17:10	00°15’S	23°00’W
51	Dec 02	18:55	20:15	00°30’S	23°00’W
52	Dec 02	22:05	23:25	00°45’S	23°00’W
53	Dec 03	01:10	02:25	01°00’S	23°00’W
54	Dec 03	04:10	05:25	01°15’S	23°00’W
55	Dec 03	07:10	08:30	01°30’S	23°00’W
56	Dec 03	10:10	11:30	01°45’S	23°00’W
57	Dec 03	14:00	15:25	02°00’S	23°00’W
58	Dec 03	18:15	19:40	02°30’S	23°00’W
59	Dec 03	22:35	23:55	03°00’S	23°00’W
60	Dec 04	02:55	04:15	03°30’S	23°00’W
61	Dec 04	07:10	08:30	04°00’S	23°00’W
62	Dec 04	11:15	12:35	04°30’S	23°00’W
63	Dec 04	15:25	16:40	05°00’S	23°00’W
64	Dec 04	19:30	20:50	05°30’S	23°00’W
65	Dec 05	00:20	01:40	06°00’S	23°00’W
66	Dec 05	04:30	05:50	06°30’S	23°00’W
67	Dec 05	08:35	09:55	07°00’S	23°00’W
68	Dec 05	13:00	14:15	07°30’S	23°00’W
69	Dec 05	17:05	19:50	08°00’S	23°00’W

The latitude-depth section of temperature from the CTD casts shows the warmest sea surface temperatures (SSTs) concentrated in the 3°N-13°N latitude band of the intertropical convergence zone (ITCZ) (Figs. 4, 5). SSTs in the ITCZ region exceed 27°C and drop to 24°C-26°C to the north and south. A sharp seasonal thermocline is present at the base of the mixed layer at all locations, with the temperature decreasing approximately 10°C over a distance of 10-20 m. The meridional slopes of the isotherms are consistent with the dominant zonal currents in the eastern tropical Atlantic: the westward North Equatorial Current (NEC) between 10°N-20°N, the eastward North Equatorial Countercurrent (NECC) between 3°N-10°N, and the westward South Equatorial Current between 2°S-8°S. The thermocline is shallowest near 10°N-13°N, the region between the NEC and NECC known as the Guinea Dome. Here the depth of the 20°C isotherm has been used to approximate the depth of the thermocline.

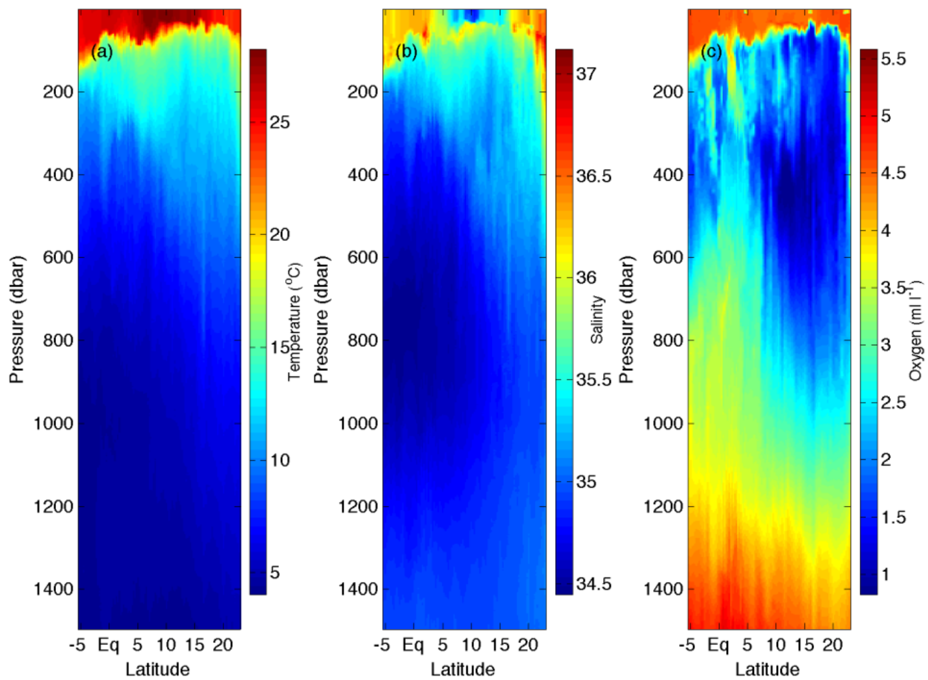

Figure 4 Latitude-depth sections of (a) temperature, (b) salinity, and (c) oxygen acquired along 23°W during the cruise.

The salinity section shows the low-salinity core of the Antarctic Intermediate Water between 400 and 1200 dbar, strongest at 8°S and diminishing in strength to the north (Figs. 4, 5). High-salinity subtropical water (>36.5 PSS) is apparent at depths of 50-100 m at 20°N and to a lesser extent between 40-70 m on the equator. These high-salinity water masses can be traced in part to the subtropical North Atlantic, where an excess of surface evaporation over precipitation leads to the highest surface salinity in the global ocean. The subtropical salinity maximum water subducts and travels poleward in the eastern tropical North Atlantic. In the subtropical South Atlantic, high-salinity water subducts and travels northward to the equator, where it is carried eastward in the Equatorial Undercurrent. The high-salinity features visible at 20°N and on the equator in the latitude-depth section are consequences of the subduction of subtropical salinity maximum water in the North and South Atlantic, respectively. The subsurface maximum in salinity between 5°N-10°N may be caused by the subduction and southward flow of subtropical salinity maximum water, followed by eastward transport in the NECC and North Equatorial Undercurrent. Much lower values of salinity (34.5-35.5) in the upper 40 m between 4°N-13°N result from an excess of precipitation over evaporation in the ITCZ.

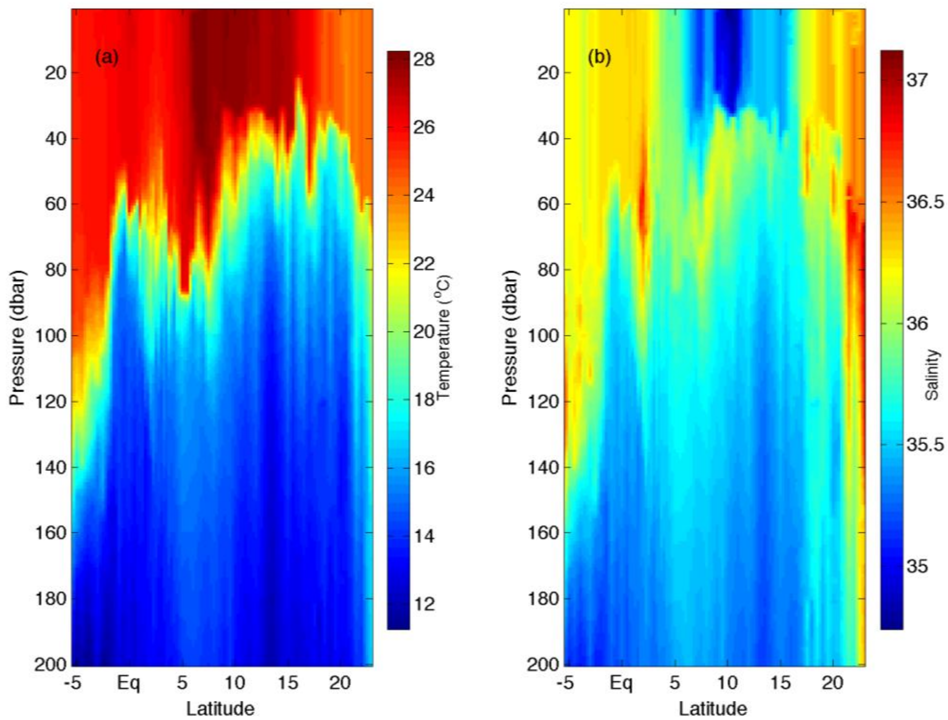

Figure 5 Same as Figure 4 (a) and (b) except showing only the upper 200 m.

The dissolved oxygen section along 23°W shows high concentrations (> 4 ml l^{-1}) in the surface mixed layer and below 1200 dbar (Fig. 4). There is a pronounced oxygen minimum zone centered at a depth of about 300-500 m between 5°N-20°N. This water is in the stagnant shadow zone of the North Atlantic, which is not part of the circulation associated with the ventilated thermocline of the subtropical gyre.

Salinity values from the first and second sensors agreed very well during most of the casts. The RMS difference was less than 0.01 for 46 out of 69 casts (67%) and less than 0.05 for 58 casts (84%). The mean offset between the sensors (sensor #1 minus sensor #2) ranged from -0.003 to 0.015 for each cast. For 63 of 69 casts (91%), the mean offset was between 0.001 and 0.007. There was a noticeable increasing linear trend in the difference between the salinity from the sensors. The difference, based on the linear trend, was 0.003 during cast #1 and 0.0065 during cast #69, resulting in a time-dependent offset of $S_{diff} = 0.00287 + 0.0000525c$, where S_{diff} is the value from sensor #1 minus sensor #2 and c is the cast number.

Salinity calibration values from the CTD bottle samples are available for each cast. The autosal worked well throughout the cruise without any obvious biases or drifts. The bottle values can therefore be used to assess the accuracy of the sensor values and the cause of the linear drift between the sensors. It was found that the difference between salinity sensor #1 and the bottle calibration values can be expressed as $S_{cal1} = -0.00702 - 0.0000181c$, where S_{cal1} is the value from sensor #1 minus the bottle calibration value and c is the cast number. The difference between salinity sensor #2 and the bottle calibration values can be expressed as $S_{cal2} = -0.0112 - 0.0000645c$, where S_{cal2} is the value from sensor #2 minus the bottle calibration value and c is the cast number. It therefore appears that the cause of the relative sensor drift is primarily a larger negative drift in sensor #2 compared to sensor #1. The mean offset for sensor #1 is -0.00765 (bottle values are higher) and for sensor #2 it is -0.0135. The RMS differences, averaged over all depths and all casts, are 0.00670 for sensor #1 and 0.00673 for sensor #2. These preliminary results suggest that both sensors should be corrected for linear drifts and mean biases, with sensor #2 needing the largest corrections.

The RMS difference between oxygen values from the sensors was less than 0.03 ml l^{-1} for 62 of 69 casts (90%) and less than 0.02 ml l^{-1} for 45 casts (65%). For five casts, the RMS difference exceeded 0.04 ml l^{-1}, with the largest value reaching 0.13 ml l^{-1} during cast #3. There was a noticeable decrease in the RMS difference between the oxygen sensors for cast #23 compared to cast #22 that most likely resulted from the sensor swap. The lower RMS differences were present for the remainder of the casts after the swap. The mean offset between the oxygen sensors (sensor #1 minus sensor #2) ranged from -0.03 to 0.007. There was a noticeable linear decrease in the magnitude of the offset between casts #23 and #69 that can be described by the equation $O_{diff} = 0.000280 - 0.0300c$. There is an opposite-signed trend between casts #1 and #22, though there is not enough data to conclude whether the trend is robust.

Oxygen calibration values from the CTD bottle samples are available for each cast. The oxygen titration for each sample was performed during the cruise by Grant Rawson. Larger than expected offsets between the calibration values and sensor values were noticed during the first 16 casts and were likely caused by suboptimal sampling procedures. Beginning on cast #17, adjustments were made to the sampling technique, including deeper injection of the chemicals into the bottles and more vigorous shaking of the bottles after injection. The adjustments seemed to improve the calibration values, decreasing the average RMS difference between the sensor values from 0.0406 ml l^{-1} for casts #1-16 to 0.0340 ml l^{-1} for casts #17-69. The bottle values after cast #16 are therefore more reliable for calibrating the sensors. The titration was re-standardized after cast #22, though this does not appear to have influenced the calibration values. Table 3 summarizes the procedures taken during the oxygen titration analysis.

It was found that the difference between oxygen sensor #1 and the bottle calibration values for casts #23-69 can be expressed as $O_{cal1} = -0.0466 + 0.000542c$, where O_{cal1} is the value from sensor #1 minus the bottle calibration value and c is the cast number. The difference between salinity sensor #2 and the bottle calibration values can be expressed as $O_{cal2} = -0.0133 + 0.000289c$, where O_{cal2} is the value from sensor #2 minus the bottle calibration value and c is the cast number. It is therefore unclear what caused the relative drift between sensor #2 compared to sensor #1, since the sensors' drifts compared to the calibration values are in the opposite sense compared to the sensors' drifts relative to each other. The mean offset for sensor #1 is -0.0305 ml l^{-1} (bottle values are higher) and for sensor #2 it is -0.0107 ml l^{-1}. The RMS differences, averaged over all depths and all casts, are 0.0356 ml l^{-1} for sensor #1 and 0.0459 ml l^{-1} for sensor #2.

Table 3 Noteworthy procedures during oxygen sampling and analysis.

Time	**Activity**
Before Cast 01	Set up equipment, made Thio Sulfate. Ran initial standards and blanks.
Before Cast 17	Improved sampling technique: More shaking and deeper injections.
Before running cast 18 samples	Changed Blank to 2.
Before Cast 23	Re-standardized chemicals.
Before Cast 33	Adjusted pipettes (they looked a little off from 1ml).
Before Cast 37	Adjusted Oxygen Chemical #2 to 1.25mL and re-standardized.
Cast 51	Started taking bottle draw temperatures.
Before Cast 61	Re-standardized final time.
Samples from casts 60, 61, 63	Ran cases in this order - 60, 63, 61 because cases were stacked in the wrong order.

2.2. ADCP casts

Several experimental ADCP casts were conducted during the cruise with the goals of assessing (1) the impact of a smaller upward-looking ADCP bin size on velocity measured in the deep ocean (500-1500 dbar) and (2) the impact of hanging the CTD package at various depths and for various durations during the cast (Table 4). The ultimate goals were to determine the optimal procedures for obtaining velocity in the upper 30 m of the ocean and to ensure that the procedures did not diminish the quality of deeper velocity measurements. For all experiments, the downward-looking ADCP bin size was set to 8 m.

The first set of experiments took place at 20°N, 38°W on November 16 and consisted of four casts. The first two casts had target pressures of 100 dbar and an uplooking ADCP bin size of 4 m. The first cast included a hang at 100 m for five minutes and the second did not. In the upper 100 m, the cast with no hang shows an eastward velocity that is about 5 cm s^{-1} larger compared to the cast with no hang (Fig. 6). Below 100 m, the differences are much smaller. The meridional velocities are in much better agreement in the upper 100 m. The errors are comparable between 20 m and 200 m, and in the upper 15 m, the cast with the hang has errors that are about 7 cm s^{-1} larger compared to the cast with no hang. It is surprising that the cast with the hang has larger errors, since more data are acquired during the hang. It is possible that the oceanic conditions differed significantly between the casts, leading to the differences in zonal velocity and differences in error. Another set of experiments (described later in this section) was designed to test the impact of different hang durations and depths.

Table 4 Location, target pressure, hang duration and depth, and upward-looking ADCP bin size for experimental lowered ADCP casts. During "hangs," the CTD package was stopped at the given depth for the given amount of time before continuing the upcast.

cast #	location	target pres.	hang	hang depth	bin size
444	20°N, 38°W	100 dbar	5 min	100 m	4 m
445	20°N, 38°W	100	none		4
446	20°N, 38°W	1500	none		4
001	20°N, 38°W	1500	none		8
101	20.5°N, 23°W	100	none		4
102	20.5°N, 23°W	100	1 min	100 m	4
103	20.5°N, 23°W	100	5 min	100 m	4
104	20.5°N, 23°W	100	10 min	100 m	4
201	20.5°N, 23°W	200	none		4
202	20.5°N, 23°W	200	5 min	200 m	4
203	20.5°N, 23°W	200	5 min	100 m	4

204	20.5°N, 23°W	200	5 min	50 m	4
205	20.5°N, 23°W	200	5 min	200, 100, 50 m	4
801	4°N, 23°W	100	5 min	100 m	8
802	4°N, 23°W	100	5 min	100 m	4

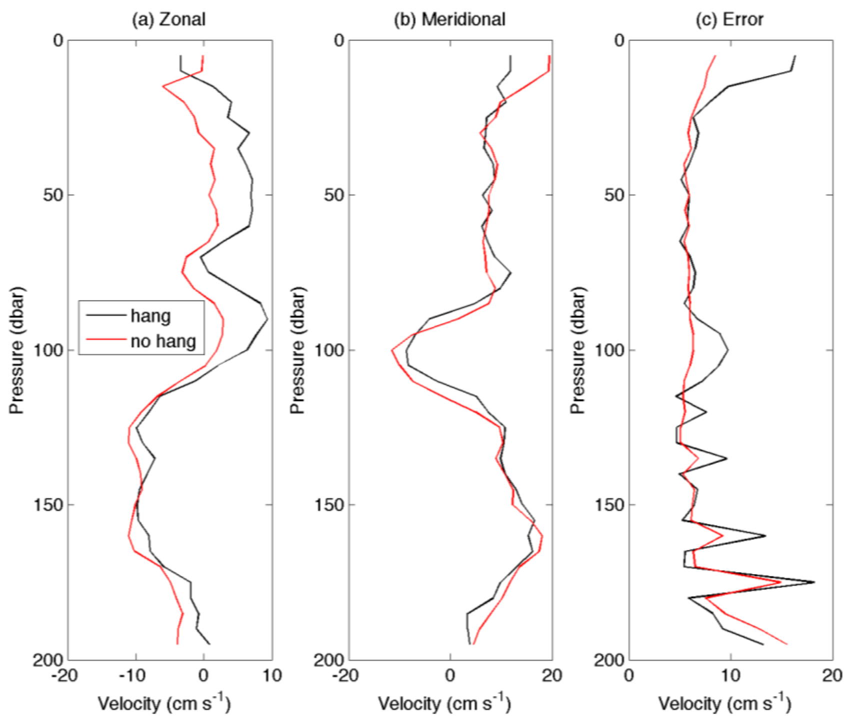

Figure 6 Results from ADCP test casts performed with (black) and without (red) hanging the CTD package at a depth of 100 m for 5 minutes during the upcast. Zonal (a) and (b) meridional velocity components are shown as a function of pressure. Error estimates in (c) were provided by the ADCP processing software. Each cast was taken to a target pressure of 100 dbar, with an upward-looking ADCP bin size of 4 m and downward-looking bin size of 8 m.

After the casts to test the impact of a hang on the upper-ocean velocity measurements, two casts to 1500 dbar were conducted, the first with a bin size of 4 m on the uplooking ADCP and the second with a bin size of 8 m. The goal was to test the impact of bin size on measurements of deep velocity (500-1500 dbar). Zonal velocity is very similar between the casts, while the meridional component shows larger differences that at some depths approach 10 cm s^{-1} (Fig. 7). As expected, the error is larger when the smaller bin size is used because there is less data going into each ensemble. However, the small degradation in data quality was deemed acceptable, and it was decided to proceed with an uplooking bin size of 4 m in order to gain more information on the vertical velocity structure near the surface.

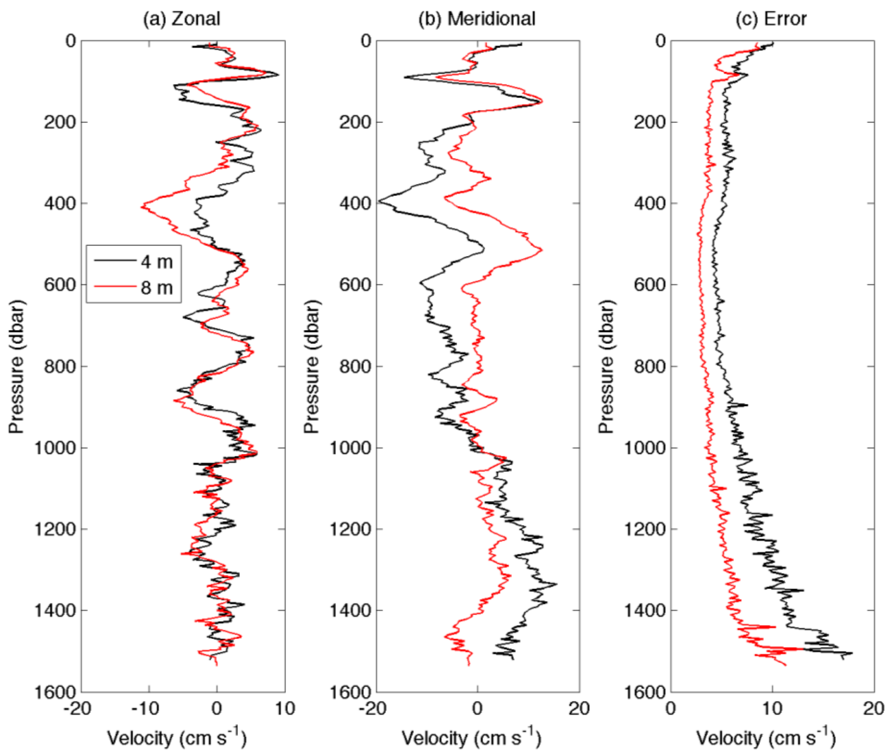

Figure 7 Same as Figure 6 except the upward-looking ADCP bin size was set at either 4 m (black) or 8 m (red). The CTD package was not hung on the upcast, and the target pressure of each cast was 1500 dbar.

In order to gain more insight into the impact of CTD hang duration and depth on the ADCP velocity profiles, a second set of experiments was conducted at 20.5°N, 23°W on November 22. First, four casts to 100 dbar were completed, each with a different hang duration at 100 dbar (no hang, 1-min. hang, 5-min. hang, 10-min. hang). The results show a high degree of inter-cast variability in the zonal and meridional velocity profiles, especially in the upper 100 dbar (Fig. 8). The variability between the casts was likely caused by changes in the ocean's circulation and measurement uncertainty from the ADCPs. The errors are largest in the upper 20 dbar, as expected. Consistent with the previous experiment that compared casts with a 5-min hang and no hang, the error is largest for the longest-duration hangs (5 min. and 10 min.) and lower for the 1-min hang and no hang. Given the large spread between velocity profiles from each cast, the larger errors for longer hang durations may be caused by larger natural velocity variability and hence mean velocity profiles with more uncertainty. Interestingly, the error is smallest for the 1-min hang and not for no hang. It is unclear why this was the case.

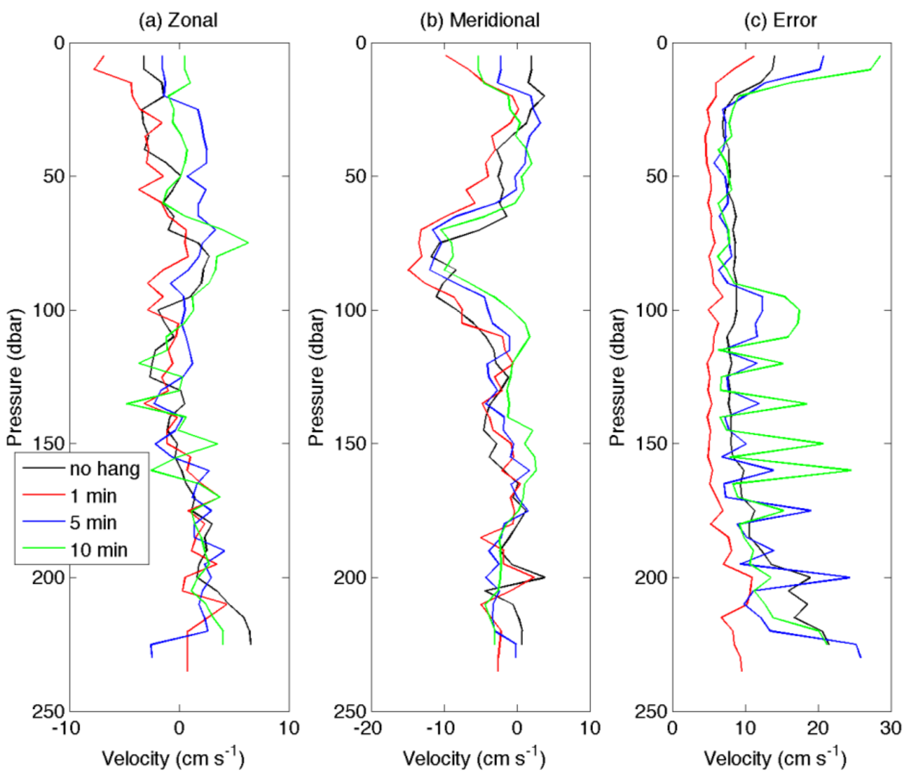

Figure 8 Same as Figure 6 except different hang durations were tested: no hang (black), one-minute hang (red), five-minute hang (blue), and ten-minute hang (green). The upward-looking ADCP bin size was 4 m for all casts, and the target depth of each cast was 100 m.

To test the impact of the hanging depth, five casts were performed (no hang, hang at 200 dbar, 100 dbar, 50 dbar, and at all three depths). All hang durations were five minutes. The results are difficult to interpret since it appears that the error profiles are incorrect for the casts with hangs (Fig. 9). The cause of the unrealistic error profiles will be investigated in the future.

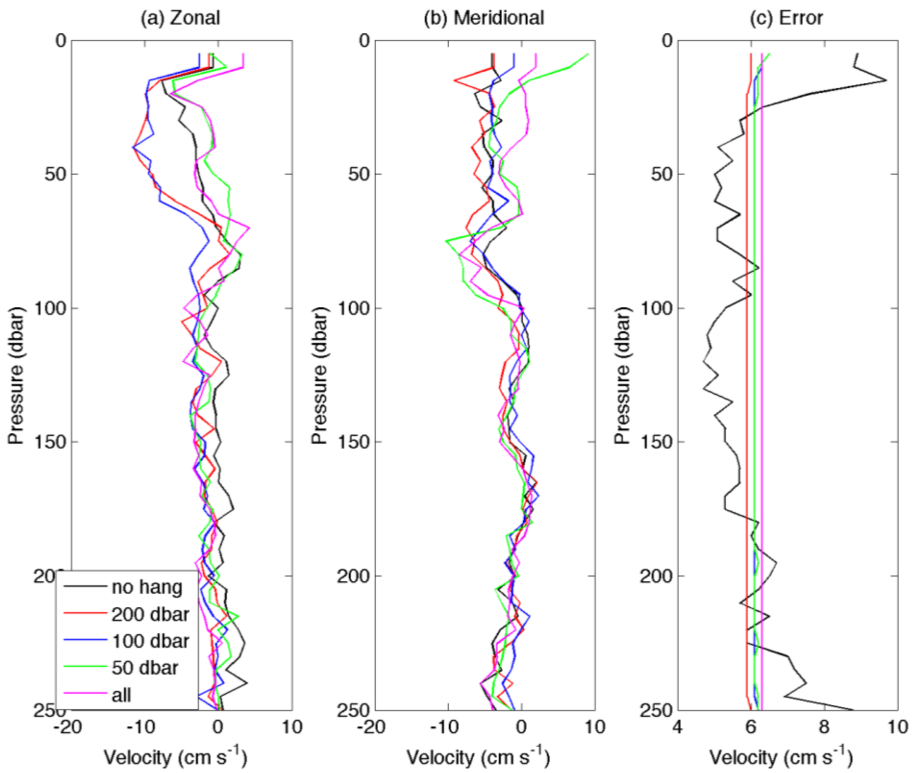

Figure 9 Same as Figure 6 except different pressure levels for the hang were tested: no hang (black), hang at 200 dbar (red), 100 dbar (blue), 50 dbar (green), and at all three depths (purple). All casts had a target pressure of 200 dbar.

A final set of test casts was performed at 4°N, 23°W on November 29 consisting of a cast to 100 dbar with 8-m bin size on the uplooker and a hang duration of 5 minutes at 100 dbar, and a cast that was the same except the upward bin size was changed to 4 m. The goal was to determine whether a larger bin size improved the velocity measurements in the upper 100 m. Results from the casts are similar except the profile with the 4 m bins appears to provide additional information on the vertical current shear in the upper 15 m (Fig. 10). However, it is unclear how useful this additional information is, based only on our preliminary analysis. In summary, the test casts are inconclusive regarding the benefits of hanging the CTD package in order to gain additional data from the upward-looking ADCP.

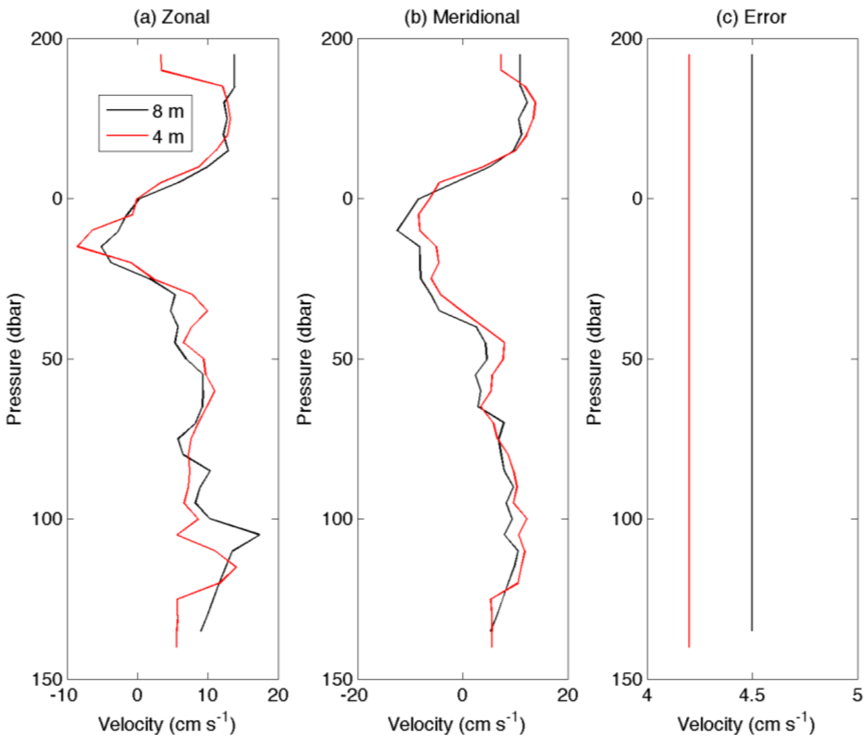

Figure 10 Same as Figure 7 except the CTD package was stopped at 100 dbar for five minutes during each cast. The black curve shows the results for the cast with the bin size on the upward-looking ADCP set to 8 m, and the red curve had a bin size of 4 m.

During the third test cast at 20°N, 38°W the ADCP processing software reported that the downward-looking ADCP (serial number 13279) had "beam 4 weak," with a strength of 76%. During the fourth test cast at 20.5°N, 23°W the software reported "beam 4 bad," with a strength of 61%. Prior to cast #5 (20°N, 23°W) on November 22, the ADCP startup computer could not communicate with the downward-looking ADCP, which was configured as the master. Cast #5 was therefore performed without any working ADCPs. On cast #6, the upward-looking slave ADCP (serial number 13493) was configured as the master down-looker, and the broken down-looker (serial number 13279) was removed from the CTD frame. For cast #7, it was decided to switch the ADCP (#13493) back to an up-looker and configure it as the master without a down-looker. During casts #7-16, this ADCP configuration was used successfully. However, no ADCP data was acquired during casts #8 and #16 due to glitches downloading the data after the casts. Prior to cast #17, it was discovered that the cause of the broken ADCP was a blown fuse inside the ADCP housing. The fuse was replaced and the ADCPs were mounted to the CTD frame in the original configuration (#13279 as master downlooker and #13493 as slave uplooker). The ADCPs worked for the remainder of the casts (#17-69), though the downlooker's beam 4 strength was consistently low (30-60%).

The presence of a weak beam 4 on the downward-looking ADCP during all casts, and our use of only one ADCP configured as an uplooker on casts #7-16, presented data-processing challenges. The version of the ADCP processing software that we used during the cruise could not ignore the weak beam 4 and produce a "three-beam solution." The downward-looking ADCP data were therefore compromised. In addition, the software could not be configured to process the casts in which the upward-looking ADCP was used as a master without a slave. We are hopeful that these issues will be resolved when we transition to a newer version of the software. Table 5 summarizes the main challenges encountered during ADCP deployments and data processing. We anticipate that the quality of the ADCP data will also improve when the ship's ADCP measurements are incorporated into the lowered ADCP processing routine. With the help of the RHB's CST, the ship's broadband ADCP settings were set to 128 bins with lengths of 4 m and a 4-m blanking distance. The goal was to capture more information on the upper-ocean vertical velocity shear.

The preliminary lowered ADCP data, processed without the three-beam solution on the downlooker and without the ship's ADCP, show the basic features of the circulation in the eastern tropical Atlantic (Fig. 11). In general, there is westward flow between 12°N-14°N associated with the North Equatorial Current, eastward flow of the North Equatorial Countercurrent between 4°N-12°N, and the westward South Equatorial Current between 5°S-3°N. The strongest signatures of these currents are in the upper 50 m. There is also pronounced eastward flow centered on the equator and at depths of 25-125 m that is associated with the Equatorial Undercurrent. There is pronounced northward flow in the upper ocean (0-50 m) between the equator and 4°N associated with the cusp of a tropical instability wave. Currents are generally southward between the equator and 2°S, consistent with the easterly surface winds and equatorial upwelling.

Table 5 Summary of problems with lowered ADCP data acquisition and processing.

cast #	location	ADCP config.	comments
1-4	20°N, 38°W	up, down	weak beam 4, no 3-beam solution
17-69	8°S - 14°N, 23°W	up, down	weak beam 4, no 3-beam solution
6	19.5°N, 23°W	down only	
7, 9-15	19°N, 15°N-18°N	up only	unable to process data
5,8,16	20°N, 18.5°N, 14.5°N	up, down	no data

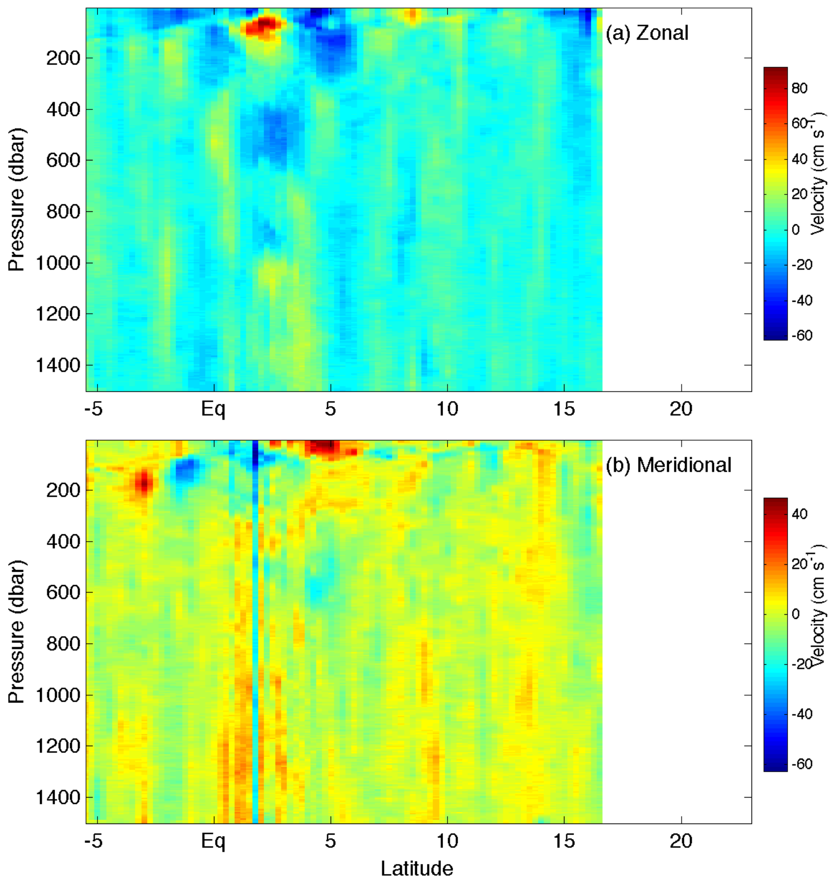

Figure 11 Zonal (a) and meridional (b) velocity sections along the 23°W cruise track from the lowered ADCP casts.

3. Satellite-tracked surface drifting buoys and Argo floats

Twenty surface drifting buoys were deployed along 23°W (Table 6, Fig. 12). Single drifters were deployed at 9°14'N and at 6°27'N. Pairs of drifters were deployed at 4°59'N, 4°02'N, 2°58'N, 2°27'N, 1°59'N, 1°27'N, 0°56'N, and 0°18'S to enable studies of ocean surface dispersion. The pairs of drifters were deployed into the leading edge of a tropical instability wave (TIW), characterized by northwestward surface flow of up to 1 m s^{-1}. The goal was to sample the TIW densely as a function of latitude as it passed in order to learn about its circulation and associated surface divergence/convergence. Preliminary data from the drifters reveals regions of surface convergence outside of the TIWs and eastward flow outside of the equatorial waveguide (Fig. 13). Two Argo floats were deployed, both on November 14: one at 17°04'N, 48°06'W (WHOI float #7170), one at 17°36'N, 46°17'W (WHOI float #7203).

Table 6 Serial number, location, date, and time of surface drifting buoys deployed during the cruise.

deployment #	serial #	location	date (UTC)	time (UTC)
1	116259	9°14'N	Nov 27	19:24
2	116106	6°27'N	Nov 28	19:38
3	116130	4°59'N	Nov 29	08:16
4	116140	4°59'N	Nov 29	08:16
5	116387	4°02'N	Nov 30	13:33
6	116388	4°02'N	Nov 30	13:33
7	116282	2°58'N	Nov 30	23:15
8	116108	2°58'N	Nov 30	23:15
9	116107	2°27'N	Dec 01	04:09
10	116141	2°27'N	Dec 01	04:09
11	116281	1°59'N	Dec 01	08:54
12	116381	1°59'N	Dec 01	08:54
13	116382	1°27'N	Dec 01	15:42
14	116254	1°27'N	Dec 01	15:42
15	116283	0°56'N	Dec 01	22:06
16	116383	0°56'N	Dec 01	22:06
17	116384	0°30'N	Dec 02	05:00
18	116385	0°30'N	Dec 02	05:00
19	116132	0°18'S	Dec 02	16:55
20	116139	0°18'S	Dec 02	16:55

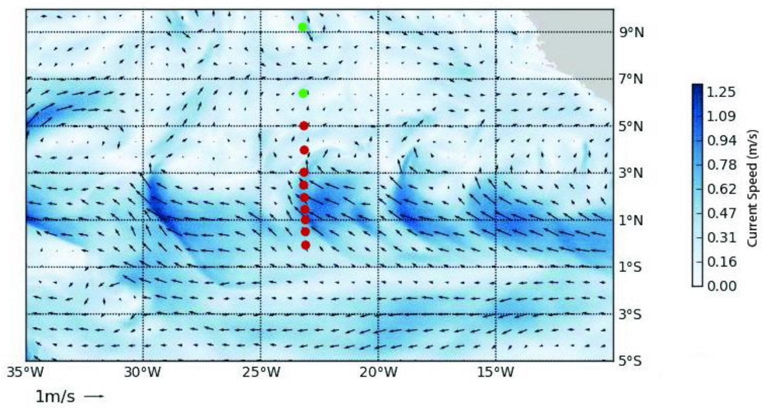

Figure 12 Locations of single surface drifter deployments (green circles) and pairs of drifter deployments (red circles) during the PNE2013b cruise. Blue shading indicates the strength of surface currents on 30 November 2013, when the drifters were deployed at 4°N. Black arrows show the strength and direction of the surface currents. Surface velocity map is from the Mercator Ocean operational analysis.

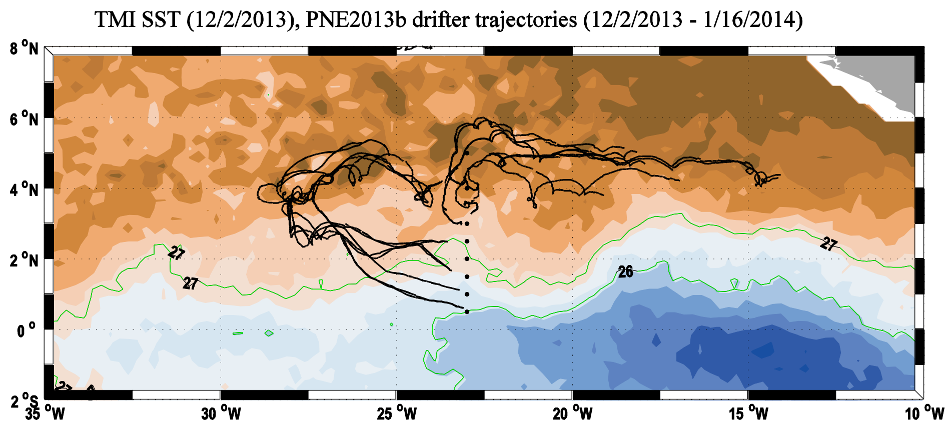

Figure 13 December 2 – January 16 trajectories of the surface drifters deployed during the PNE2013b cruise (black lines). Shading and contours show SST from the TRMM Microwave/Imager satellite at the beginning of the period.

4. Expendable Bathythermograph (XBT) casts

XBT comparison drops were performed in collaboration with Sippican, Inc (Table 7). The company provided selected XBTs with different characteristics to be dropped in pairs simultaneously and as close as possible in space and time to CTD casts. The goal of the project is to improve the estimation of depth from the XBT's fall rate. All XBTs were launched from the stern of the ship, using hand launchers and the WinMk21 software for data acquisition.

Table 7 Location, date, and time of XBT pairs deployed during the cruise. XBTs were dropped nearly simultaneously and in pairs.

Pair #	date (UTC)	time (UTC)	latitude	lon	CTD	Notes
1	Nov 22	02:34	20°26.85'N	23°09.52'W	4	
2	Nov 22	02:38	20°26.85'N	23°09.52'W	4	
3	Nov 22	02:42	20°26.84'N	23°09.52'W	4	
4	Nov 22	02:46	20°26.83'N	23°09.51'W	4	
5	Nov 22	02:50	20°26.83'N	23°09.52'W	4	
6	Nov 22	02:54	20°26.83'N	23°09.51'W	4	
7	Nov 22	02:58	20°26.83'N	23°09.52'W	4	Comp. froze (316 m)
8	Nov 22	03:03	20°26.83'N	23°09.51'W	4	Comp. froze (136 m)
9	Nov 26	02:44	11°27.85'N	23°00.23'W	22	
10	Nov 26	02:47	11°27.85'N	23°00.23'W	22	
11	Nov 26	02:51	11°27.85'N	23°00.24'W	22	
12	Nov 26	02:55	11°27.86'N	23°00.25'W	22	
13	Nov 26	02:58	11°27.86'N	23°00.26'W	22	
14	Nov 26	03:01	11°27.86'N	23°00.26'W	22	
15	Nov 26	03:04	11°27.87'N	23°00.26'W	22	
16	Nov 26	03:08	11°27.87'N	23°00.27'W	22	
17	Nov 26	03:11	11°27.85'N	23°00.23'W	22	
18	Nov 26	03:14	11°27.85'N	23°00.23'W	22	
19	Nov 26	03:17	11°27.85'N	23°00.23'W	22	
20	Nov 29	19:35	04°00.20'N	23°00.01'W	37	
21	Nov 29	19:38	04°00.24'N	23°00.03'W	37	
22	Nov 29	19:42	04°00.29'N	23°00.06'W	37	
23	Nov 29	19:46	04°00.33'N	23°00.11'W	37	
24	Nov 29	19:50	04°00.32'N	23°00.18'W	37	
25	Nov 29	19:54	04°00.30'N	23°00.32'W	37	
26	Nov 29	19:57	04°00.28'N	23°00.41'W	37	
27	Nov 29	20:01	04°00.26'N	23°00.50'W	37	
28	Nov 29	20:04	04°00.25'N	23°00.60'W	37	

29	Nov 29	20:07	04°00.25’N	23°00.68’W	37	
30	Nov 29	20:10	04°00.23’N	23°00.77’W	37	
31	Dec 02	07:08	00°15.19’N	22°59.78’W	48	
32	Dec 02	07:12	00°15.19’N	22°59.78’W	48	
33	Dec 02	07:16	00°15.20’N	22°59.76’W	48	
34	Dec 02	07:19	00°15.20’N	22°59.76’W	48	
35	Dec 02	07:23	00°15.20’N	22°59.75’W	48	
36	Dec 02	07:26	00°15.20’N	22°59.75’W	48	
37	Dec 02	07:29	00°15.21’N	22°59.75’W	48	
38	Dec 02	07:32	00°15.21’N	22°59.74’W	48	
39	Dec 02					No data (pre. launch)
40	Dec 02	07:39	00°15.22’N	22°59.73’W	48	
41	Dec 04	21:03	05°29.70’S	22°59.94’W	64	
42	Dec 04	21:07	05°29.68’S	22°59.93’W	64	
43	Dec 04	21:11	05°29.66’S	22°59.93’W	64	
44	Dec 04	21:16	05°29.66’S	22°59.93’W	64	
45	Dec 04	21:20	05°29.68’S	22°59.94’W	64	
46	Dec 04	21:24	05°29.70’S	22°59.96’W	64	
47	Dec 04	21:27	05°29.72’S	22°59.97’W	64	
48	Dec 04	21:31	05°29.73’S	22°59.98’W	64	

Atmospheric Data (AEROSE) (from Nick Nalli, NOAA/NESDIS/STAR)

1. Radiosonde Observations (RAOBs)

A total of 97 Vaisala RS92 rawinsondes, measuring pressure, temperature, humidity (PTU) and winds were launched (see Figs. 14, 15), with a single loss due to telemetry problems shortly after launch. Of these, 47 were launched for S-NPP (a new environmental satellite undergoing intensive cal/val), 24 for MetOp-A and 26 for MetOp-B satellite overpasses. The 2013b PNE/AEROSE launches put the cumulative AEROSE total soundings at 892 PTU RAOBs acquired over the tropical Atlantic.

Comment [NRN1]:

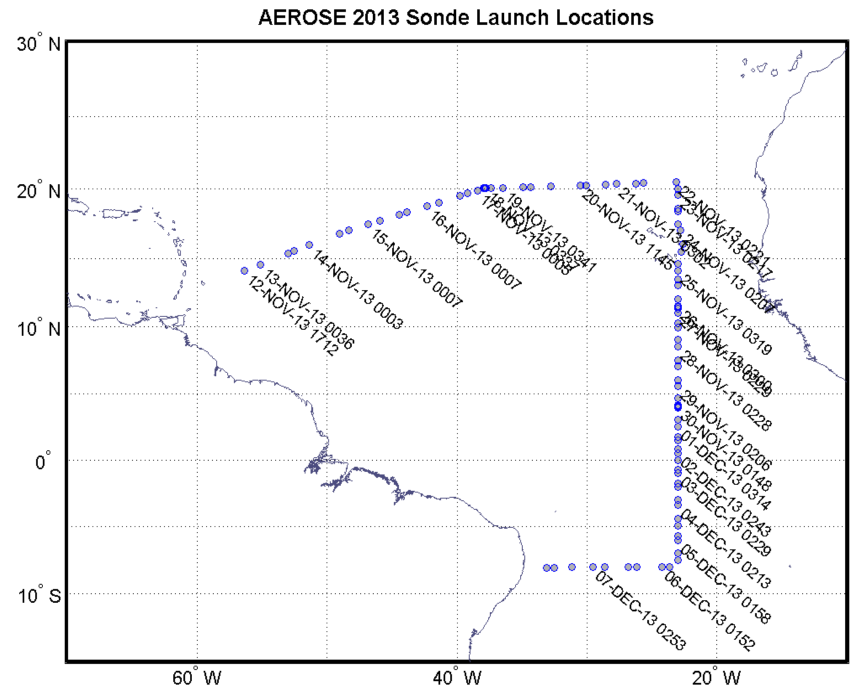

Figure 14 AEROSE 2013b Vaisala RS92 rawinsonde launch locations and times.

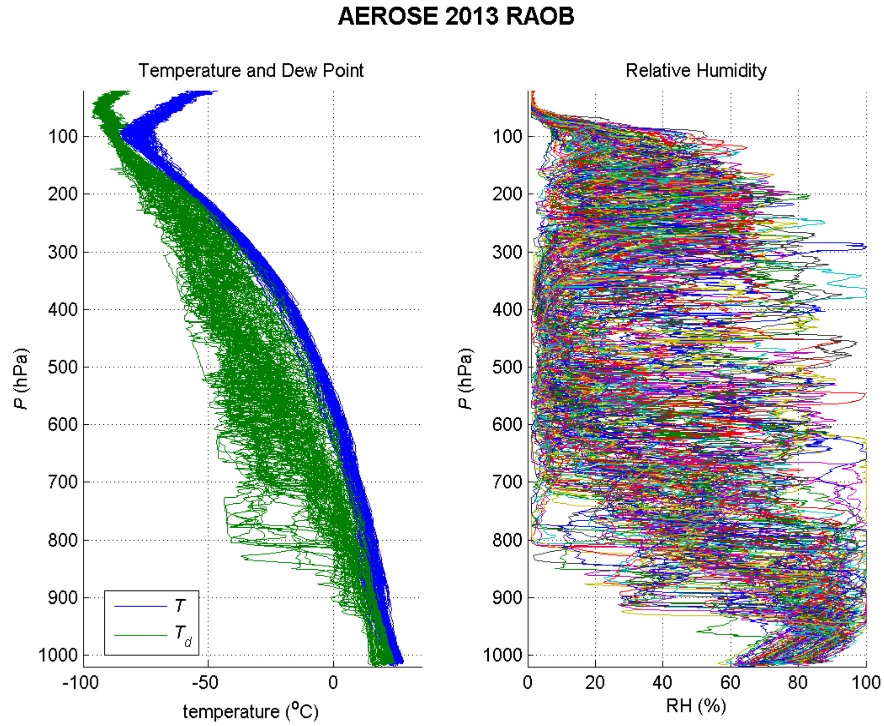

Figure 15 AEROSE 2013b Vaisala RS92 soundings, (left) atmospheric vertical temperature and dew point profiles, and (right) relative humidity (RH) profiles.

2. Ozonesonde (O_3) Observations

A total of 19 EN-SCI electrochemical concentration cell (ECC) ozonesonde packages were interfaced with the RS92 radiosondes, providing a sounding of the O_3 partial pressure in addition to the PTU measurements (see Figs. 16, 17). All ozonesondes were launched coordinated for either S-NPP, MetOp-A or MetOp-B overpasses for validation of satellite sounder ozone profile products. The 2013b PNE/AEROSE launches have also now put AEROSE at a total of 156 ozone soundings acquired over the tropical Atlantic. Initial and Day-of-Flight chemical preps for ozonesondes were carried out regularly with no major issues.

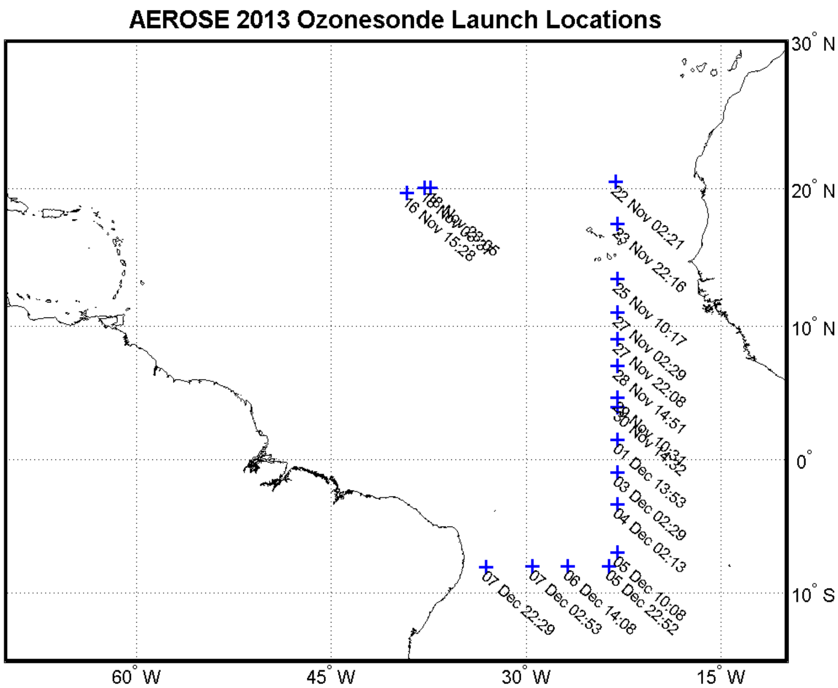

Figure 16 AEROSE 2013b ozonesonde launch locations and times.

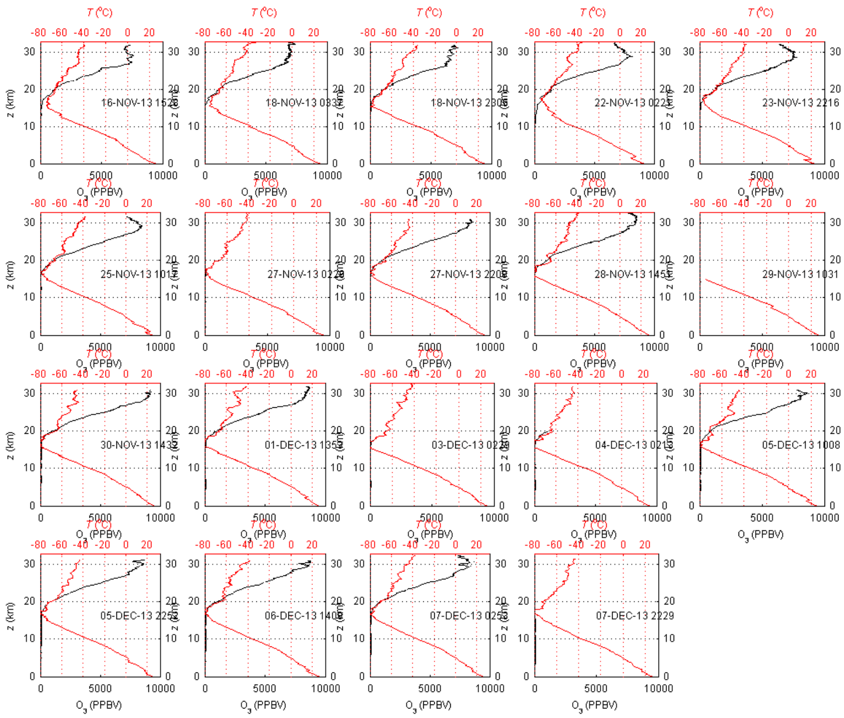

Figure 17 AEROSE 2013b ozonesonde atmospheric profiles (ozone partial pressure in black, ambient temperature in red).

3. Microtops Sunphotometer

Handheld Microtops sunphotometer measurements of multichannel aerosol optical depths (AOD) were performed on a daily basis (Fig. 18), except for periods where excessive cloud cover prevented taking measurements. The Microtops AOD measurements plotted in Fig. 18 reveal that the ship passed through a number of different aerosol outflow regimes, most notably background marine aerosols, Saharan dust, biomass burning smoke, and mixed dust-smoke.

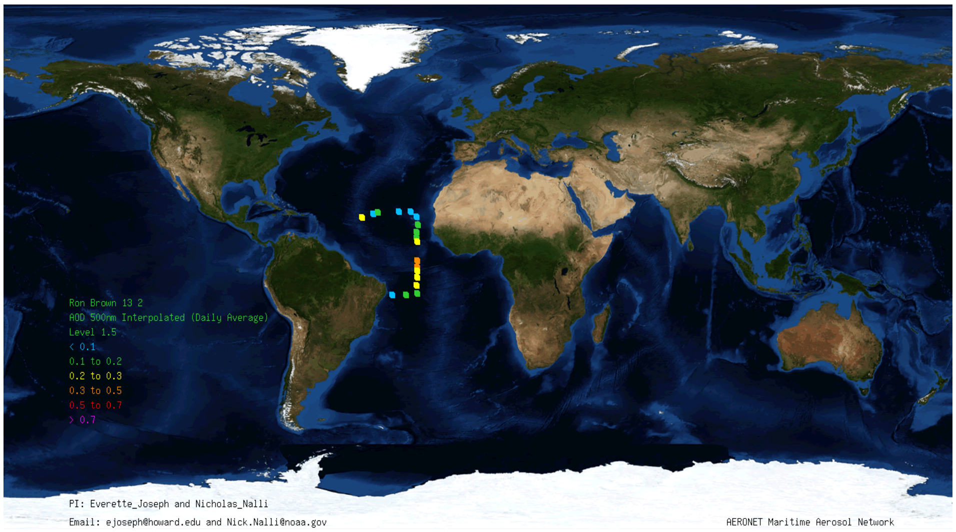

Figure 18 AEROSE 2013b Microtops sunphotometer solar-spectrum AOD measurements at 0.5 micrometers (GSFC Maritime Aerosol Network processing).

4. Downwelling Broadband Surface Fluxes

Pyranometers and pyrgeometers deployed by Howard University and University of Miami measured downwelling shortwave and longwave radiative fluxes, respectively throughout the duration of the cruise; Fig. 19 shows the measurements obtained from the Howard University intstruments.

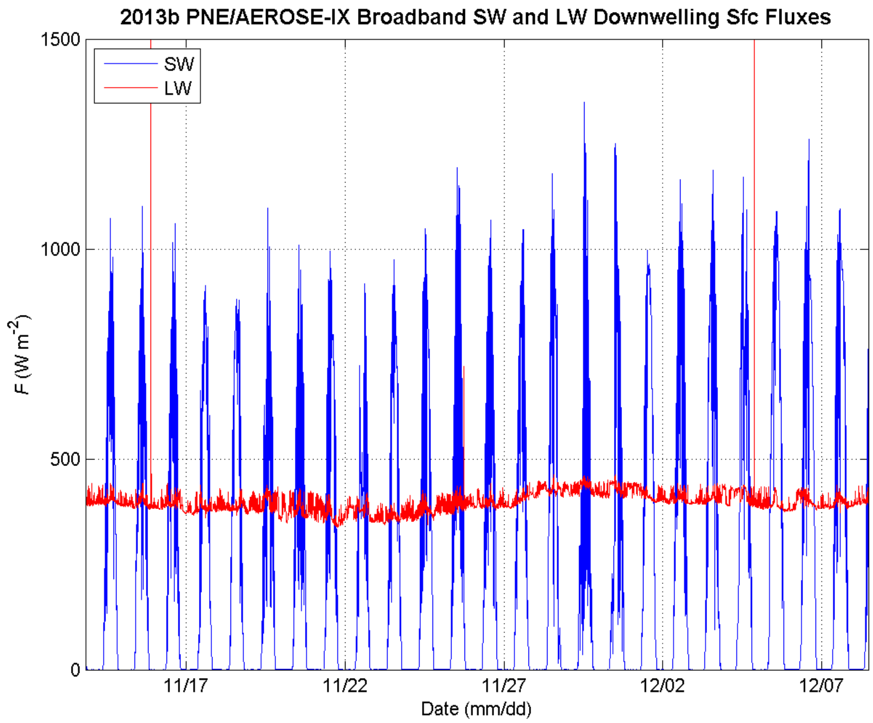

Figure 19 AEROSE 2013b broadband shortwave (blue) and longwave (red) downwelling fluxes at the surface.

5. Surface O_3 and NO-NO_X Measurements

Surface *in situ* trace gas measurements, including ozone and NOx, were taken throughout the cruise.

6. Biological and Chemical Sampling

Biological and laser particle counter (LPC) samples were collected throughout the cruise.