# PIRATA Northeast Extension 2014 Cruise Report
# R/V *Endeavor*
# EN-550

28 December 2014 – 12 February 2015
Bridgetown, Barbados to San Juan, Puerto Rico



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## PIRATA Northeast Extension 2014 Scientific Party:

### Oceanographic Observations:

Rick Lumpkin, Zach Barton, Shaun Dolk, Kyle Seaton, Erik Valdes (NOAA/AOML); Chunlin Ning (China's First Institute, Qingdao)

### ATLAS, T-FLEX and Hydrophone Moorings:

J. Michael Strick, Korey Martin (NOAA/PMEL)

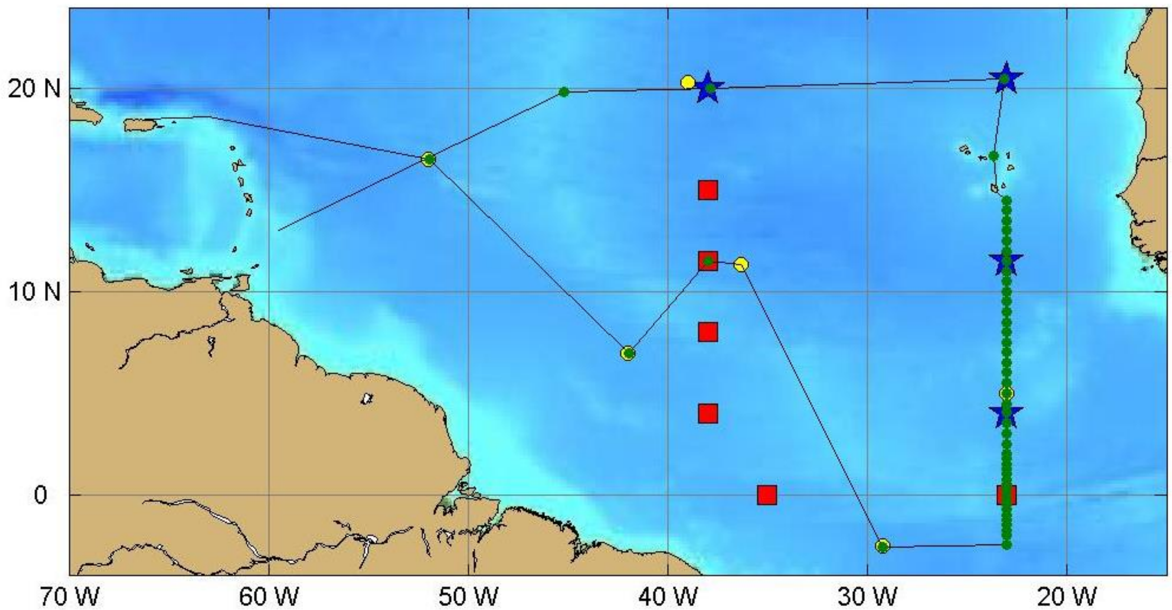



Fig. 1: Cruise track of PNE2014 (black), Barbados to San Juan. Blue stars indicate the locations of PIRATA Northeast Extension ATLAS moorings; red squares are PIRATA backbone moorings. Yellow circles indicate the locations of subsurface hydrophone moorings. Greet dots are the locations of CTD casts conducted during the cruise. During the cruise, a next-generation T-FLEX mooring was recovered at 20°N 38°W and redeployed at 4°N 23°W.

OVERVIEW: The 2014 PIRATA Northeast Extension Cruise EN-550 was designed to collect observations in the northeast Tropical Atlantic, to service the northeast extension of the PIRATA array, to collect CTD casts at each of the mooring sites, and to recover six subsurface hydrophone moorings in an NSF-funded study (the cruise was co-chartered by NSF). The cruise track passes through the climatologically significant Tropical North Atlantic region, including the southeast corner of the subtropical North Atlantic (a region of subduction for the subtropical cell circulation); the Guinea Dome and oxygen minimum shadow zone where the subtropical and tropical gyres meet, and the Tropical Atlantic current system and equatorial waveguide. All major scientific goals of EN-550 were achieved.

Due to size and endurance constraints and the cruise length of 45 days, this cruise was not able to accommodate the Aerosols and Ocean Science Expeditions (AEROSE) component of PNE. This atmospheric sampling component of the project adds significant value at little extra cost, but adds an additional ~10 members to the science party and requires a 20' van forward on a vessel. It is hoped that AEROSE will return for the 2015 PNE cruise.

We thank the crew of the *Endeavor* for their work and input before and during the cruise. Endurance and deck space were significantly challenged, and the efforts of Chief Bosun Chris Wroblewski and his crew were exemplary. Highly experienced maneuvering lead by Captain McMunn allowed mooring deployments and recoveries without launching the small boat, which was often precluded by high wind and wave states. Tireless work by Ship Technician Erich Gruebel allowed us to conduct around-the-clock CTD work and collect shipboard observations without any significant interruptions due to technical problems. The food was excellent – certainly the best enjoyed by many of us on a research vessel.

## **Introduction**

*1. PIRATA Northeast Extension (PNE)*

The Pilot 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 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.

The northeastern and north central Tropical Atlantic is a region of strong climate variations from intraseasonal to decadal scales, with impacts upon 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 at a depth 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-driven upwelling, and may play an active role in modulating air-sea fluxes in this region.

The Tropical North Atlantic is the Main Development Region (MDR) of tropical cyclones. Many major hurricanes that ultimately threaten the eastern United States begin as atmospheric easterly waves that propagate off the African continent. Once over the MDR in the band 10-20ºN, these waves are exposed to convective instability driven by the upper ocean's 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. Prominent examples include Andrew (1992), Floyd (1999) and Ivan (2004). An average season has two Cape Verde hurricanes, but some years have up to five while others have none. 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 (on average, one of ten). 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 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. The SST signal in the MDR has been correlated with the North Atlantic Oscillation (NAO) on decadal time scales. The multi-decadal signal indicates that an extended period of increased hurricane activity is to be expected. Other historical studies have also demonstrated spatial variability in storm formation areas and landfall locations on longer timescales.

Despite the climate and weather significance of the Tropical North Atlantic region, it was not sampled by the PIRATA backbone array apart from the 38°W-line of moorings extending north to 15°N (Fig. 1). In 2005, a formal Northeast Extension of PIRATA was proposed as a joint project between NOAA/AOML and PMEL (Rick Lumpkin, Mike McPhaden and Bob Molinari, co-principal investigators). This PIRATA Northeast Extension (PNE) was proposed to consist of four moorings, three creating a northward arm up 23°W (building upon the equatorial backbone mooring there), and a fourth extending the 38°W arm to 20°N.

In June 2006, the first two moorings of this extension were deployed during RB-06-05a (NOAA ship *Ronald H. Brown)*. The mooring at 11.5°N, 23°W was deployed on June 7, and the mooring at 4°N, 23°W was deployed on June 11. Both moorings were replaced in May 2007, during RB-07-03, and two more moorings were added at 20.5°N, 23°W and 20°N, 38°W. The four buoys were planned for servicing in the April 2008 cruise RB-08-03. Due to the cancellation of this cruise (mechanical problems with the *Ronald H. Brown*), the buoys failed and a data gap was created in mid to late 2008. All four sites were subsequently serviced in November 2008 by NOAA charter of the French R/V *Antea*. In 2009, the moorings were serviced during RB-09-04, 11 July—11 August. In 2010, the moorings were serviced during RB-10-03, 26 April—22 May. The 2011 PNE cruise was a "PNE-lite" cruise with CTD casts only at the mooring sites due to limited ship time, conducted aboard the R/V Ronald H. Brown on July 21 to August 21, from Charleston, SC, USA to Cape Town, South Africa. The 2012 PNE cruise was delayed until early 2013 due to mechanical problems with the *Ronald H. Brown*, and was conducted (as PNE2013a) January 8 to February 13, from Charleston, SC to San Juan, Puerto Rico. PNE2013b was conducted on the *Ronald H. Brown* on November 11 to December 8, from Bridgetown, Barbados to Recife, Brazil.

All four PNE moorings were serviced during the PNE2014 cruise and are currently successfully reporting meteorological and oceanographic data onto the Global Telecommunications System for weather and climate forecasting. In the Memorandum of Understanding from the PIRATA-12 meeting (November 2006), the United States agreed that

> [I]t is recognized that the Parties are dependent upon year-to-year funding allocations from their governments, and thus commitments for future funding and logistical support can not be guaranteed. Given this proviso, the Parties affirm that PIRATA is a high priority for Brazil, France, and the United States, and that

> the institutions are making plans for continued support … NOAA will provide ship time for maintenance of four moorings in the North East Extension.

The *Endeavor* cruise EN-550 served to honor this commitment for 2015.

## Order of operations:

Prior to cruise commencement, on 3 December, the PNE ATLAS buoy at 20°N, 38°W broke loose from its mooring and began drifting westward. The original cruise plan called for deployment of the replacement mooring at this location first, then recovery of this mooring; due to its displaced westward location, rescue of this mooring required its recovery as the first operation.

Loading for EN-550 was conducted in Bridgetown, Barbados on Dec. 28. Deck space was extremely tight, requiring items such as empty D-containers to be stored in the wet lab and main lab.

The *Endeavor* left Bridgetown, Barbados and commenced EN-550 on the afternoon of 29 December, and transited to the drifting ATLAS buoy. Due to strong winds (often exceeding 20 knots) and significant waves, the ship was unable to transit at the planned 10 knots. The location of the buoy was inferred from dead reckoning of Argos positions, and was intercepted at ~0500 UTC on January 3. The buoy was located on radar within a mile of its anticipated position and successfully recovered by maneuvering the ship alongside, as small boat operations were precluded by weather conditions. The buoy had broken lose immediately beneath the base of the buoy; all subsurface sensors had been lost. Although no dust was visible on the buoy, a dust sample was collected for analysis. At this location, a test CTD was conducted to 200m. All sensors on the CTD package performed well on the test cast. The *Endeavor* then transited to the 20°N 38°W site to redeploy the ATLAS mooring and recover the T-FLEX mooring there.

The *Endeavor* arrived at the 38°W (more precisely, 37°51'W) at ~1400 UTC on 5 January. A quick bathymetric survey was verified with the bottom sounder at the planned deployment site, and then – after a drift test – the ship set up for deployment ~3 ½ miles updrift. Depths were consistent with earlier bathymetric surveys. The ATLAS buoy and mooring were successfully deployed, and a CTD cast conducted to 1500m. Recover of the T-FLEX mooring was planned for the morning of 6 January. This was immediately challenged by the inability to find the buoy on the radar; after approximately a half-hour of searching the known deployment location, the buoy was seen visually … missing the tower with its radar reflector, antenna, and all meteorological sensors. The T-FLEX buoy and mooring were then successfully recovered.

The *Endeavor* then transited westward to the first hydrophone mooring site at 20°20'N 38°58'W, arriving on the evening of 6 January. After release, the uppermost float was spotted via flasher approximately ½ mile from its anticipated location. The mooring was recovered without incident.

The *Endeavor* then transited to the PNE mooring site at 20.5°N 23°W. As with the earlier transit, speed was reduced (~ 9 knots average) due to high wind and wave conditions, and the need to slow in order to spool line and assemble the mooring for the 20.5°N 23°W deployment. During this transit, the downward-looking 300kHz ADCP was replaced on the CTD package as processing of the data revealed significant problems with the original ADCP. The original cruise plan called for the *Endeavor* to conduct ½ degree CTD casts from 20.5°N to Cape Verde, arrive in Cape Verde on 12 January, and depart 15 January; those CTD casts were dropped from the plan, and Cape Verde in-port time was shifted to 14-16 January to reflect the additional transit time needed.

The *Endeavor* reached 20.5°N 23°W on 11 January and deployed the replacement ATLAS mooring that evening, after which a CTD cast was conducted to 1500m. On the morning of the $12^{th}$, the older ATLAS mooring at this site was recovered. Some dust was present on the buoy, which was sampled for analysis.

Once at 23°W, the sea state was sufficiently calmer that the ship was able to make up some time. An additional CTD cast was conducted at 16°42’N 23°20’W to 1500m en-route to Praia, Cape Verde. The *Endeavor* docked in Praia on the morning of 14 January.

While in Praia (14-16 January), Kyle Seaton left the scientific party and Shaun Dolk and Erik Valdes joined. Chief scientist Rick Lumpkin met with Ian Sage of the R/V *Alliance* to discuss operations and logistics for the 2015 cruise aboard that vessel.

After departing Praia on 16 January, the *Endeavor* transited to 14.5°N 23°W to commence the ½ degree CTD line down 23°W. CTD operations were conducted around-the-clock starting at this cast, and casts were conducted every ½ degree latitude (every ¼ degree latitude between 2°N and 2°S) to 1500m depth to 2.5°S. The CTD shifts consisted of Zach Barton, Erich Gruebel and Chunlin Ning (5:30am to 5:30pm local) and Rick Lumpkin, Shaun Dolk and Erik Valdes (5:30pm to 5:30am local).

The *Endeavor* reached the PNE site at 11.5°N 23°W on 17 January and deployed the replacement ATLAS buoy at this location. This buoy included an experimental spray system designed at AOML (lead PI Greg Foltz) and built around a secondary shortwave radiometer. A CTD cast was conducted during the evening. In the morning of 18 January, the original mooring was recovered. This buoy was heavily dust covered, and samples were collected for analysis.

An attempt to recover the hydrophone mooring at 5°N 23°W was conducted on the evening of 20 January. The acoustic release replied with a solid range indicating that the mooring was upright and within 50m of the ship laterally, but repeated attempts to “release” were greeted with a “vertical, not released” message. Five attempts were made over an hour, with unchanging range (apart from changes induced by ship drift), before recovery was abandoned as the *Endeavor* is not equipped for mid-depth dragging (the uppermost part of the hydrophone mooring is at several hundred meters depth).

The *Endeavor* reached 4°N 23°W on 21 January, and in an intensely productive day, a CTD cast was conducted, the replacement ATLAS mooring was deployed, and the older ATLAS mooring recovered. The recovered ATLAS mooring was broken down on the morning of the 22nd, and deployment of the T-FLEX mooring was planned for that afternoon. Unfortunately, major problems spooling wire rope onto the TSE winch delayed morning preparations, and - although the PMEL technicians were able to communicate with all T-FLEX sensors (including a large number of additional current meters sponsored by AOML, lead PI Renellys Perez) on the O-1 deck - communications were not able to be established once the mooring was staged on the fantail. After trying numerous possibilities, a tube swap was attempted and proved successful; deployment was postponed until the morning of the 23rd to allow the crew and especially the PMEL technicians to rest. This deployment was subsequently conducted without incident, completed by the early afternoon, and the CTD line was continued southward.

2°N was reached at ~0730UTC on 24 January (CTD cast #30), and CTD cast spacing was reduced to ¼ degree from here to 2°S (26 January, CTD cast #46).

Eq-23°W was reached at ~4:45 local time on January 25 and a flyby of the French backbone mooring was conducted. A small surface float, possibly including an Argos transmitter, was observed tied to the buoy. Small boat operations were required to repair the mooring, which was scheduled to be visited by the French in one month. Launching and recovering the boat was estimated as a total of 5 hours – this, plus approximately two hours on site and a 1.5 hour wait until after breakfast when the operation could commence, meant that a total of at least 8 hours would have been consumed. Given that the cruise was still slightly behind the originally planned schedule, chief scientist Lumpkin decided to cancel the repair operations of this mooring.

While en-route to CTD cast 46 at 2°S, it was apparent that there was not sufficient time to complete the originally planned ½ degree CTD line to 5°S. Casts south of 2.5°S were abandoned in order to guarantee sufficient time to recover all the remaining hydrophone moorings (two of which did not have flashers or were "flasher status uncertain) and return to Puerto Rico by 11 February. The final 23°W cast, cast #47, was completed at 2.5°S at ~1230UTC on 26 January.

The *Endeavor* then transited westward to the hydrophone mooring at 2.5°S 29°W, arriving early in the morning on 28 January. Release and recovery were conducted successfully and followed by a CTD cast. While en-route back northwestward, "pollywog" to "shellback" conversion operations were conducted for several of the science party and crew. Due to extremely favorable wind and wave states, the vessel was able to make excellent time, often exceeding 11 knots, and quickly caught up with the originally-planned schedule.

The *Endeavor* reached the hydrophone mooring at 11.3°N 36.3°W late in the evening of 31 January and successfully recovered it without incident. It then (on the afternoon of 1 February) conducted a flyby of the Brazilian PIRATA backbone mooring at 11.5°N 38°W and conducted a CTD cast there.

Transit to the next hydrophone mooring, 7°N 42°W, was conducted at maximum speed to allow arrival before sunset on 2 February as this mooring was deployed without a flasher. The mooring was successfully released half an hour before sunset and the mooring was recovered by early evening. This put the ship well ahead of the original schedule, allowing daylight arrival at the final hydrophone mooring (16.5°N 52°W), a mooring with "flasher status uncertain". CTD casts were conducted at both these mooring sites. The combined time savings won by not lingering until morning at the two sites allowed the *Endeavor* to reach San Juan, Puerto Rico on the morning of 10 January, a day ahead of schedule.

Offloading and packing of a 20' container (for hydrophone equipment) and a 40' container (mooring equipment) was conducted on 11 February. All members of the science party departed on 13 February.

## ***<u>Problems/Issures</u>***

### ***Temperature control of the special purpose lab (autosal room)***

The temperature of the autosal room was not easy to maintain at the desired 24°C to optimize autosal results. Temperatures fluctuated from ~22—26°C when the thermostat was solely relied upon. After trial and error, it was determined that the temperature could be held relatively steady by blocking air conditioning vents in the evening and removing some of this blocking in the morning. Autosal results after casts 14-26 were more stable as a consequence, and were used for subsequent sensor calibration. Autosal #71464 was used for PNE. As an experiment, autosal #71502 was set up and used to re-run one batch of samples. However, numerous bubbles were observed in the autosal chamber and results vs. sensor values were extremely noisy; this autosal was not reused.

### ***Problems with oxygen sampling setup***

Large variance was found in early oxygen titration results (i.e., titrated oxygen minus sensor value). On 23 January, during discussions between the night and day shift on this issue, Erich Gruebel noted that he had occasionally observed bubbles in the pump for reagent #2 (sodium iodide). After cast 27, this pump was replaced and results were generally much less noisy.

## Oceanographic and atmospheric data collected on this cruise:

1. Recovery and redeployment of standard ATLAS moorings at 20°N, 38°W; 20.5°N, 23°W; 11.5°N, 23°W; and 4°N, 23°W
2. Recovery of T-FLEX mooring at 20°N, 38°W and redeployment at 4°N, 23°W
3. Recovery of five hydrophone moorings
4. CTD profiles to 1500m depth at all four PNE sites and five additional sites (see Fig.1)
5. Dual 300 kHz lowered acoustic Doppler current profiler observations for all CTD casts
6. Salinity of the water samples collected with Niskin bottles
7. Dissolved oxygen concentration of the water samples collected with Niskin bottles
8. Deployment of 12 surface drifting buoys of the Global Drifter Program
9. Continuous recording of shipboard ADCP data.
10. Shippboard heading data for ADCP processing
11. Continuous recording of Thermosalinograph (TSG) data

**ATLAS moorings and T-FLEX mooring** (text inputs from J. Michael Strick)

| **Summary of Mooring Operations** | | |
|---|---|---|
| **Site** | **Mooring ID #** | **Operation** |
| 20°N 38°W | PI199 | Rec_drifting ATLAS |
| 20°N 38°W | PI217 | Dep |
| 20°N 38°W | PT003 | Rec_TFLEX |
| 20° 20.17'N 38° 58.02'W | Hydrophone_EA-1 | Rec |
| 20.5°N 23°W | PI200/PI218 | Rec/Dep |
| 11.5°N 23°W | PI201/PI219 | Rec/Dep |
| 4° 59.28'N 22° 59.47'W | Hydrophone_EA-2 | Not Rec |
| 4°N 23°W | PI202/PI220 | Rec/Dep |
| 4°N 23°W | PT004 | Dep_TFLEX |
| 0° 23°W | PI203 | Flyby |
| 2° 30.96'N 29° 13.09'W | Hydrophone_EA-8 | Rec |
| 11° 30.1'N 37° 58.2'W | PI210 | Flyby |
| 11° 19.09'N 36° 20.53'W | Hydrophone_EA-7 | Rec |
| 6° 58.05'N 41° 59.99'W | Hydrophone_EA-6 | Rec |
| 16° 30.51'N 51° 58.91'W | Hydrophone_EA-5 | Rec |

| Lost or Damaged Instruments and Equipment *(from recovered moorings)* | | | | |
|---|---|---|---|---|
| **Site** | **Mooring ID** | **Sensor type** | Serial No | **Comments** |
| 20°N 38°W | PI199 | Sontek | D369 | Lost |
| 20°N 38°W | PI199 | TV | 15681 | Lost |
| 20°N 38°W | PI199 | TC | 14669,14723,15265,14751 | Lost |
| 20°N 38°W | PI199 | T | 12883,15520,14707,15521 | Lost |
| 20°N 38°W | PI199 | TP | 15798,15799 | Lost |

| | | | | |
|---|---|---|---|---|
| 20°N 38°W | PT003 | AT/RH | 60780273 | Lost |
| 20°N 38°W | PT003 | WIND | 12110044 | Lost |
| 20°N 38°W | PT003 | RAIN | 1676 | Lost |
| 20°N 38°W | PT003 | SWR | 34935 | Lost |
| 20°N 38°W | PT003 | LWR | 35561 | Lost |
| 20°N 38°W | PT003 | BARO | 127688 | Lost |
| 20°N 38°W | PT003 | TC | 7800 | Cond. shield missing |
| 20°N 38°W | PT003 | TC | 7803 | Cond. shield missing |
| 20°N 38°W | PT003 | TP | 3838 | Bent T probe |
| 20.5°N 23°W | PI200 | SWR | 37700 | Bent shield |
| 20.5°N 23°W | PI200 | TC | 15429,14054 | Lost |
| 20.5°N 23°W | PI200 | Sontek | D770 | Lost |
| 20.5°N 23°W | PI200 | TV | 15596 | Lost |
| 20.5°N 23°W | PI200 | T | 15516 | Lost |
| 20.5°N 23°W | PI200 | OTN | 11475 | Lost |
| 11.5°N 23°W | PI201 | SWR | 35978 | Bent shield |
| 11.5°N 23°W | PI201 | TC | 15717 | Lost |
| 4° 59.28'N 22° 59.47'W | EA-2 | Hydrophone | H-?? | Lost |
| 4°N 23°W | PI202 | T | 15153 | Lost |

| **On-deck instrument or hardware failure** ***(pre-deployment)*** | | |
|---|---|---|
| **Sensor type** | **Serial No** | **Comments** |
| | | |

| **Acoustic Releases** | | |
|---|---|---|
| **Model** | **Serial no** | **Comments** |
| 8242AA | 16565 | Hydrophone EA-2. Upright but not released-Disabled before departing site. |

| **Fishing and Vandalism** | | |
|---|---|---|
| **Site** | **Mooring ID** | **Comments** |
| 20.5°N 23°W | PI200 | Longline gear 10-20 m |
| 4°N 23°W | PI202 | Longline gear 20-500 m |

**Shipping notes:**
The R/V *Endeavor* was tied up at the cruise ship terminal in Bridgetown, Barbados. Loading was scheduled for December 29th at 08:00. Containers (1-40'+1-20') arrived dockside at 09:00 local, the lateness due to a high volume of cruise ship traffic at the port. Mr. Neil Crichton was on scene representing the expeditor. He was most communicative and efficient. He kept the ship and J. M. Strick (PMEL) informed as to the status when operations would start and had constant updates about what would happen next. An attentive and competent crew of Bajan dockworkers

professionally offloaded the containers.  The *Endeavor* used their starboard side knuckle boom and main crane to convey the PMEL mooring gear to the work deck.  The deck crew, Korey and Strick made quick work of stowing the gear and the whole operation of offloading the containers was completed by16:00 (local). The German O2 sensors and Dalhousie University Ocean Tracking Network sensors were already on board and quickly located.

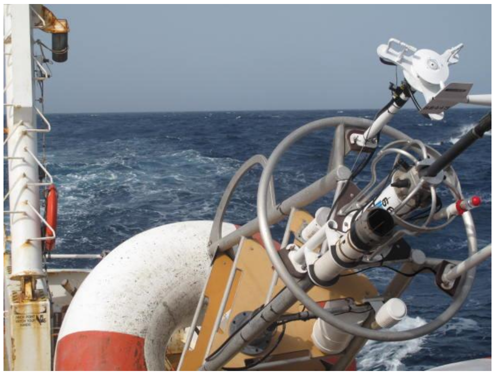
**Instrumentation and Hardware Notes:**
T-FLEX tower at 20°N 38°W (PI003) missing. At 4°N 23°W (PI202) there was a nut missing from the bottom of the McCartney rain mount causing the rain gauge to be leaning over (not vertical).

**Software Notes:**
No operational  problems with software.

**Ship Notes or issues:**
None.  This crew was absolutely fantastic, and were excellent communicators.  M. Strick was always informed of schedule changes or problems with potential to impact mooring.  Technically, the crew were fantastic and handled the recovery and deployment operations flawlessly. The Bosun ship handling was par excellence, the best Strick has ever encountered.

**AOML SWR SPRITZING UNIT:**

11.5°N 23°W was the first deployment of the Foltz Spritzer (AOML-designed cleaning system, lead PI Greg Foltz).  This consisted of a water reservoir, pump, tubing and control unit that would spray the dome of a SWR sensor by means of two small spritzing units located on either side of the dome. The purpose is to keep, as clean as possible, the sensing dome of the SWR sensor from dust accumulation.



**German Oxygen Sensors**

German O2 sensors were deployed at 11.5°N 23°W and 4°N 23°W, at 300m and 500m.

**DALHOUSIE UNIVERSITY-OCEAN TRACKING NETWORK (OTN)**

Dalhousie University instruments incorporating acoustic tracking technology were again deployed on PNE surface moorings. 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.

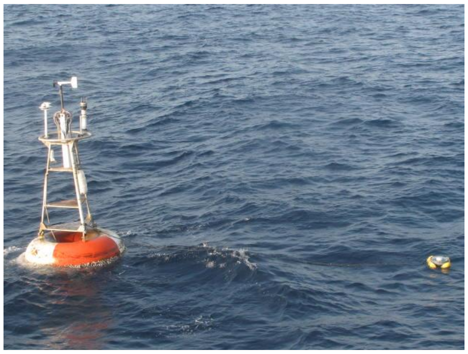
OTN sensors were deployed at the following sites:

20°N 38°W: Not deployed / 20.5°N 23°W (200m) / 11.5°N 23°W (200m) / 4°N 23°W (200m)

**Miscellaneous:** The workload on PI3-14-EN was quite atypical. The ship's capstan that normally would have been used for deployments and recoveries of mooring line was not rated for continuous use. Typically in such a situation PMEL would send a portable capstan, however, due to mechanical and logistic issues one was not available for PI3-14-EN. As a substitute the *Endeavor* mounted a TSE winch. This was used to deploy the nilspin component of moorings and to completely recovery moorings (nilspin + nylon) onto the TSE reel. This resulted in having to 'off-spool' the mooring line back onto PMEL standard wooden spools. Hydrophone moorings, likewise, had to be recovered in the same fashion. This took a exceeding long time and huge amount of effort. Essentially each mooring was recovered twice. This was not ideal, but workable.

**0° 23°W VISIT/FLYBY**

The buoy and all met sensors appeared to be in good shape. The buoy was riding well. There was some sort of contraption trailing off the buoy that we thought initially was put there by the French when they deployed the buoy. TAO_OPS contacted our French partners and they indicated that no "accessories" were added to the mooring. They suggested it could be an ARGO transmitting platform left by fisherman. Note the missing SWR shield.



**<u>Hydrophone moorings</u>** (text by Bob Dziak and Russell Pate)

An autonomous hydrophone array along the East Pacific Rise (EPR) was first deployed in May 1996 through a cooperative effort by NOAA/PMEL Tropical Atmosphere and Ocean project (TAO) and Vents Program personnel. The EPR earthquake dataset derived from the hydrophones represents a unique time series of acoustic data from a fast-spreading ridge, providing a view of the seismicity over a wide range of magnitudes and reducing the earthquake magnitude of completeness to 2.5-3.0 mb from 4.5 mb of the land seismic networks. This hydrophone earthquake dataset was used to predict (retrospectively) earthquakes of magnitude 5.4 or greater seafloor transform faults on the EPR. In March 2001, an intense swarm of small earthquakes detected by the hydrophones was used to direct a research vessel to the location of a previously unknown hydrothermal vent site along the EPR ridge crest. These discoveries would not have been made if not for the TAO-Vents collaboration that lead to the EPR hydrophone experiment.

A similar experiment was also undertaken in the Atlantic Ocean with deployment of autonomous hydrophones moored on the flanks of the Mid-Atlantic Ridge (MAR). In February 1999, a consortium of U.S. investigators (NSF and NOAA) deployed a 6-element hydrophone array for long-term monitoring of (MAR) seismicity south of the Azores between 15—35°N. The array was recovered in 2005. In May 2002, an international collaboration of French, Portuguese, and U.S. researchers deployed a 6-element hydrophone array north of the Azores Plateau from 40—50°N, led by Dr. Jean Goslin in IUEM at the University of Brest, France. The North Azores array was recovered in September 2003. The improved detection capability of the hydrophones allowed for a better view of the overall spatio-temporal patterns in MAR earthquakes. From February 1999 to July 2002, a total of 9,376 earthquakes were located along the MAR using hydrophone data; by comparison only 626 earthquakes were located along the MAR during this time by land-based seismic networks. We recorded in near real-time, and for the first time, a volcanic eruption at the axis of the MAR just south of the Azores. In many ways the patterns in seismicity we recorded along the ridge axis changed the way people think about how slow-spreading ridges works and the different contributions between magmatic diking and faulting in seafloor spreading. Based on these successes, there is an expressed interest by both NOAA/PMEL and French-IUEM hydroacoustic researchers in expanding the MAR hydrophone array south toward the equatorial Atlantic.

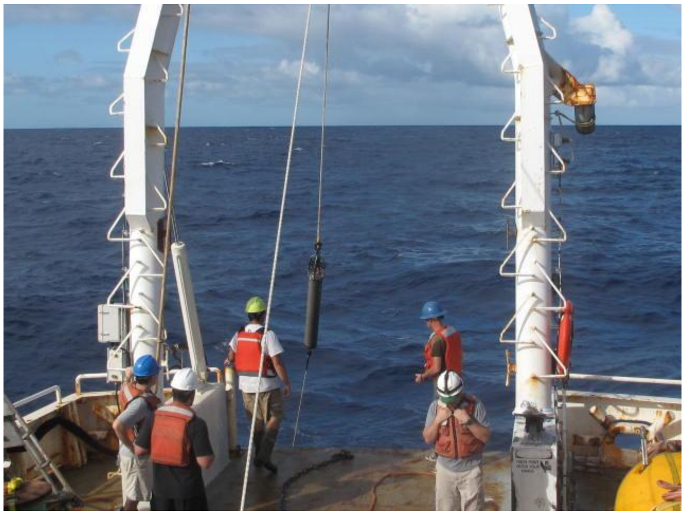
The main goal of the Atlantic hydrophone moorings is to collect seafloor earthquake information to test earthquake prediction hypotheses previously posed for fault activity observed in the Pacific. The PIRATA array locations are optimally situated to observe seismic activity from a noted seafloor fault, referred to as the Romanche Fracture Zone (RFZ). The RFZ is one of the largest transform faults on Earth and routinely generates large magnitude (M>4) earthquakes. The RFZ trends roughly west-east between 0°-25°W and 0°-15°W, and therefore, hydrophone moorings deployed near the PIRATA sites will allow near perfect coverage of earthquake acoustic waves emanating from the fault. The juxtaposition of the PIRATA array and RFZ will allow investigation of earthquake prediction models at a slow-spreading ridge and thus, under very different ocean crust and plate motion conditions than have previously been studied in the fast-spread Pacific Ocean crust.

Deploying hydrophones at the PIRATA mooring locations also allows monitoring the entire South Atlantic which has never before been achieved with a long-term hydrophone array. As an example, during 2002-2003 our hydrophone array in the North Atlantic detected a massive seafloor volcanic eruption from along the Walvis Ridge, a large seafloor edifice that extends from the Island of Tristan da Cunha to beneath continental Africa. The source of the volcanic signals could not be precisely located using the past configuration of hydrophones in the North Atlantic.

Adding these equatorial hydrophones should make it possible to localize the source of this volcanic activity, and to understand better the eruption's environmental impacts.

All hydrophone data will be made available online (both the digital data as well as processed earthquake locations) once the data are recovered and transferred to PMEL (http://www.pmel.noaa.gov/Vents/acoustics/seismicity/seismicity.html). Vents PIs have been studying how to apply the hydrophone data for various climate research topics (estimates of wind speed, wave heights, etc.) so in the future the PIRATA community might have a significant interest in the hydrophone data.

| | | |
|---|---|---|
| **EA-1** | 20 20.172N_38 58.020W | RECOVERED |
| **EA-2** | 4 59.279N_22 59.468W | NOT RECOVERED |
| **EA-8** | 2 30.9567N_29 13.0907W | RECOVERED |
| **EA-7** | 11 19.093N_36 20.537W | RECOVERED |
| **EA-6** | 6 58.056N_41 59.999W | RECOVERED |
| **EA-5** | 16 30.513N_51 58.918W | RECOVERED |



## Conductivity-Temperature-Depth (CTD) casts

AOML's yellow-frame CTD package was set up with 19 Niskin bottles in rosette positions 2-11 and 14-22, 12 to be fired at various depths to collect water samples for sensor calibration, and six as spares. Dual upward- and downward-looking 300kHz ADCPs were included on the package.

The following sensors were used on all casts (numbers indicate serial numbers):

| | |
|---|---|
| Temperature: | 5855 (primary), 5237 (secondary) |
| Conductivity: | 4204 (primary), 3854 (secondary) |
| Oxygen: | 2944 (primary), 2940 (secondary) |
| Pumps: | 7268 (primary), 7739 (secondary) |

The CTD casts were conducted by Rick Lumpkin, Kyle Seaton and Zach Barton during leg one (Barbados to Cape Verde). During leg 2 (Cape Verde to San Juan PR), CTD operations were conducted by Zach Barton, Erich Gruebel and Chunlin Ning (5:30am to 5:30pm local) and by Rick Lumpkin, Shaun Dolk and Erik Valdes (5:30pm to 5:30am). Oxygen was sampled by Gruebel and Dolk, while salinity was sampled by Ning, Lumpkin and Valdes.

CTD processing was performed using Seabird software, with calibration done by Matlab routines developed at AOML. Salinity samples were calibrated by Erik Valdes using Autosal 71464. Oxygen samples were titrated by Shaun Dolk.

During the course of the cruise, 51 CTD casts were conducted (see table below), including 45 along 23°W.

| Cast # | Lat | | | Lon | | | Month | Day | Hour (UTC) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 19° | 49.7' | N | 45° | 11.8' | W | 1 | 3 | 08 |
| 2 | 20° | 1.4' | N | 37° | 50.2' | W | 1 | 5 | 22 |
| 3 | 20° | 28.1' | N | 23° | 7.0' | W | 1 | 12 | 04 |
| 4 | 16° | 41.9' | N | 23° | 40.1' | W | 1 | 13 | 13 |
| 5 | 14° | 30.1' | N | 22° | 60.0' | W | 1 | 16 | 14 |
| 6 | 14° | 0.4' | N | 23° | 0.1' | W | 1 | 16 | 19 |
| 7 | 13° | 30.6' | N | 23° | 0.1' | W | 1 | 16 | 23 |
| 8 | 13° | 0.4' | N | 23° | 0.1' | W | 1 | 17 | 03 |
| 9 | 12° | 30.5' | N | 23° | 0.1' | W | 1 | 17 | 08 |
| 10 | 12° | 0.0' | N | 22° | 60.0' | W | 1 | 17 | 12 |
| 11 | 11° | 30.2' | N | 23° | 1.9' | W | 1 | 18 | 01 |
| 12 | 10° | 60.0' | N | 22° | 59.9' | W | 1 | 18 | 16 |
| 13 | 10° | 30.6' | N | 23° | 0.3' | W | 1 | 18 | 20 |
| 14 | 10° | 1.1' | N | 22° | 59.9' | W | 1 | 19 | 00 |
| 15 | 9° | 31.0' | N | 23° | 0.2' | W | 1 | 19 | 05 |
| 16 | 8° | 59.9' | N | 23° | 0.3' | W | 1 | 19 | 09 |
| 17 | 8° | 30.1' | N | 22° | 59.9' | W | 1 | 19 | 14 |
| 18 | 8° | 0.0' | N | 23° | 0.1' | W | 1 | 19 | 18 |
| 19 | 7° | 30.6' | N | 22° | 59.8' | W | 1 | 19 | 22 |

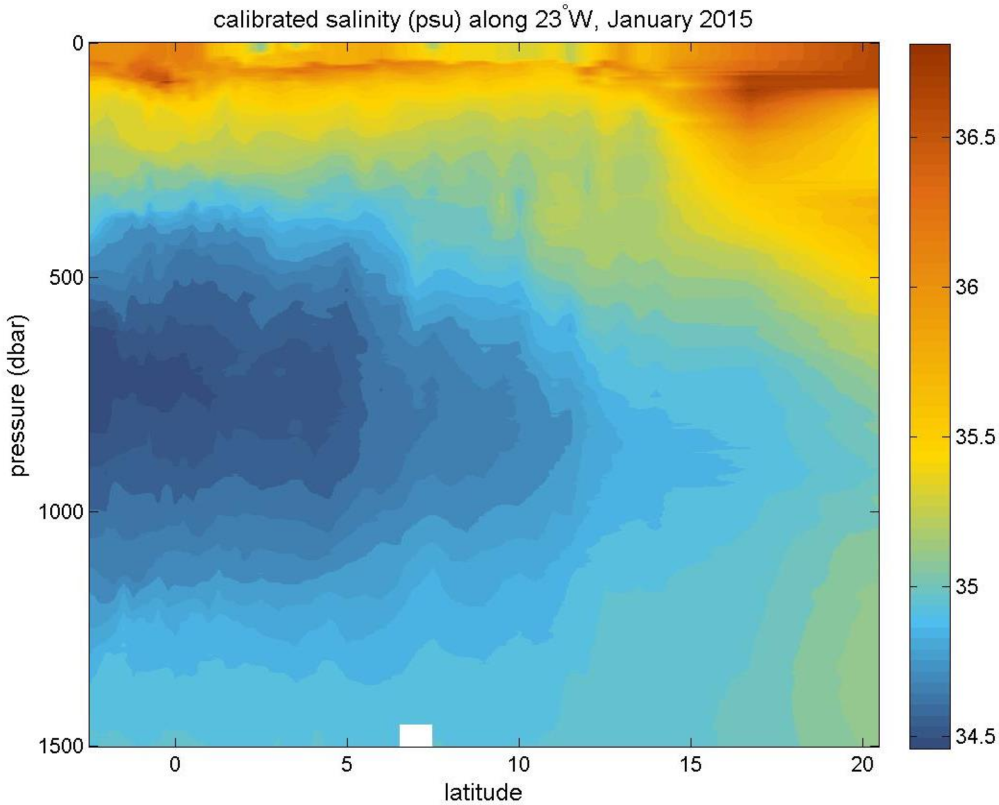
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 7° | 0.8' | N | 22° | 59.9' | W | 1 | 20 | 03 |
| 21 | 6° | 30.9' | N | 23° | 0.0' | W | 1 | 20 | 07 |
| 22 | 6° | 0.7' | N | 22° | 59.8' | W | 1 | 20 | 12 |
| 23 | 5° | 31.7' | N | 22° | 59.7' | W | 1 | 20 | 16 |
| 24 | 4° | 59.3' | N | 22° | 59.9' | W | 1 | 20 | 21 |
| 25 | 4° | 29.6' | N | 23° | 0.2' | W | 1 | 21 | 02 |
| 26 | 4° | 3.6' | N | 23° | 1.4' | W | 1 | 21 | 05 |
| 27 | 3° | 31.5' | N | 23° | 0.1' | W | 1 | 23 | 18 |
| 28 | 3° | 0.7' | N | 23° | 0.2' | W | 1 | 23 | 22 |
| 29 | 2° | 30.4' | N | 22° | 60.0' | W | 1 | 24 | 03 |
| 30 | 2° | 0.8' | N | 22° | 60.0' | W | 1 | 24 | 07 |
| 31 | 1° | 45.7' | N | 23° | 0.0' | W | 1 | 24 | 10 |
| 32 | 1° | 30.9' | N | 22° | 60.0' | W | 1 | 24 | 13 |
| 33 | 1° | 15.8' | N | 23° | 0.0' | W | 1 | 24 | 16 |
| 34 | 1° | 0.6' | N | 23° | 0.1' | W | 1 | 24 | 19 |
| 35 | 0° | 45.2' | N | 23° | 0.1' | W | 1 | 24 | 22 |
| 36 | 0° | 30.4' | N | 22° | 59.9' | W | 1 | 25 | 00 |
| 37 | 0° | 15.5' | N | 23° | 0.0' | W | 1 | 25 | 03 |
| 38 | 0° | 0.1' | N | 23° | 0.0' | W | 1 | 25 | 06 |
| 39 | 0° | 14.5' | S | 23° | 0.3' | W | 1 | 25 | 10 |
| 40 | 0° | 29.2' | S | 22° | 60.0' | W | 1 | 25 | 13 |
| 41 | 0° | 44.6' | S | 23° | 0.0' | W | 1 | 25 | 16 |
| 42 | 0° | 59.4' | S | 23° | 0.1' | W | 1 | 25 | 19 |
| 43 | 1° | 13.9' | S | 23° | 0.0' | W | 1 | 25 | 22 |
| 44 | 1° | 29.9' | S | 23° | 0.2' | W | 1 | 26 | 01 |
| 45 | 1° | 44.8' | S | 23° | 0.0' | W | 1 | 26 | 03 |
| 46 | 1° | 59.8' | S | 23° | 0.0' | W | 1 | 26 | 06 |
| 47 | 2° | 29.3' | S | 23° | 0.2' | W | 1 | 26 | 11 |
| 48 | 2° | 34.4' | S | 29° | 13.6' | W | 1 | 28 | 00 |
| 49 | 11° | 30.1' | N | 37° | 59.0' | W | 2 | 1 | 10 |
| 50 | 6° | 58.4' | N | 41° | 55.2' | W | 2 | 2 | 23 |
| 51 | 16° | 31.7' | N | 51° | 57.3' | W | 2 | 6 | 14 |

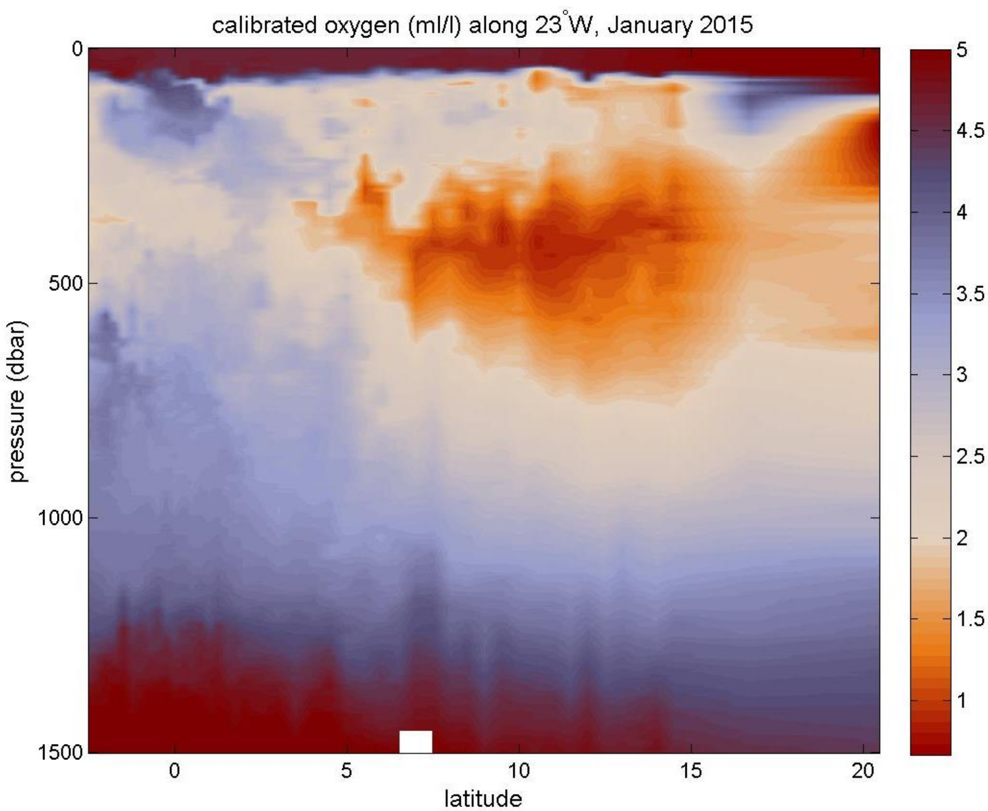
Salinity and oxygen values from the primary and secondary sensors agreed very closely in all casts except cast 24, when an organic object ~4cm in length was ingested into the primary sensors at ~600m on the downcast. For this cast alone, the secondary sensor values were used for the calibrated values. The object was removed from the primaries after cast 24 and subsequent casts were unaffected.

Autosal values minus raw salinity sensor values appeared to be very clean for the first few batches (casts 1-20) processed by Erik Valdes, but displayed an abrupt and significant shift to a fresher mean offset for casts 21-26 and a lesser, but still significant fresher shift, for casts 27-30. These offsets may have been related to temperature swings in the Special Purposes lab in which the autosal and oxygen titration setup were installed. Shaun Dolk and Erik Valdes were subsequently extremely diligent to moderate the temperature of the room in order to maintain a nearly constant 24°C, and results were much more consistent thereafter. Only results from casts after 30 were used for calibrating all sensor values. Residuals indicated little dependence on pressure or salinity, with some minor fluctuation in time (modeled as cast number), with a standard deviation indicating errors of $2.19\times10^{-3}$ psu.

The initial oxygen titration setup included erroneous coefficients which resulted in a loss of usable titration values for casts 1-4. This was noticed and fixed by Shaun Dolk, who conducted subsequent titrations. Large variance was found in oxygen titration results (i.e., titrated oxygen minus sensor value) for a number of subsequent casts. On 23 January, during discussions between the night and day shift on this issue, Erich Gruebel noted that he had occasionally observed bubbles in the pump for reagent #2 (sodium iodide). After cast 27, this pump was replaced and results were generally much less noisy. Some casts before 27 also produced clean and consistent results. The difference between a "good" and "bad" cast were very clear in residuals – evidently the failure in the reagent pump was effectively binary – allowing straightforward determination of the good casts throughout the cruise to use for calibration. The following casts were used: 4, 6—8, 10, 11, 15, 18—23, 25—51. Differences were a clear function of pressure and oxygen, with remaining residuals indicating errors of $3.31\times10^{-2}$ ml/l.

The following figures show the distribution of salinity and oxygen along 23°W from 20.5°N to 2.5°S. The salinity section reveals Central Water at intermediate densities, with northern hemisphere Central Water saltier than the southern hemisphere water. The lowest salinity measurements indicate the presence of Antarctic Intermediate Water. Local minima in surface salinity are associated with the Intertropical Convergence Zone (ITCZ), which was near 4°N during this cruise. Maximum salinity measurements were seen in the near-surface, associated with salinity maximum water created in the subduction region of the subtropical North Atlantic. The oxygen section reveals the oxygen minimum of the North Atlantic, with minimum calibrated values of 0.66—0.86 ml/l.


calibrated salinity (psu) along 23°W, January 2015
pressure (dbar)
latitude
0
500
1000
1500
0
5
10
15
20
36.5
36
35.5
35
34.5


calibrated oxygen (ml/l) along 23°W, January 2015
pressure (dbar)
latitude
0
500
1000
1500
0
5
10
15
20
5
4.5
4
3.5
3
2.5
2
1.5
1

**Satellite-tracked Surface Drifters**

Twelve satellite-tracked drifters were deployed during the cruise. The drifters are mini-Surface Velocity Program types, drogued at 15m to follow mixed layer currents; all included a thermistor on the surface buoy for SST. Their data are transmitted in real time via the Argos system. All of the drifters were launched in pairs from either side of the A-frame on the fantail (initial separation distance 3-4m), to permit studies of ocean dispersion. For more information on these instruments, see http://www.aoml.noaa.gov/phod/dac.
Drifter deployments conducted during the cruise were:

| IDs | Lat | Lon | Date | Time (UTC) |
|---|---|---|---|---|
| 127029, 114951 | 20°27.4'N | 33°41.5'W | 8 Jan | 1530 |
| 127005, 114916 | 17°20.53'N | 23°35.37'W | 13 Jan | 0950 |
| 114943, 127004 | 12°55.24'N | 22°59.76'W | 17 Jan | 0545 |
| 127003, 114877 | 03°05.27'N | 32°09.07'W | 29 Jan | 1414 |
| 114921,109069 | 10°14.04'N | 35°49.27'W | 31 Jan | 1430 |
| 109068, 11446 | 9°15.42'N | 44°20.45'W | 3 Feb | 2050 |

**Dust sampling**:

Dust from the SWR of the following sites was collected for analysis:

20°N 38°W (adrift) / 20.5°N 23°W / 11.5°N 23°W / 4°N 23°W

This was done as part of the "Source regions of African dust over the tropical Atlantic Ocean" project. The goal of this project is to determine the source regions of African dust that is transported across the tropical Atlantic Ocean. Improving our knowledge of the continental origins of dust aerosols will enhance our understanding of role of dust in ocean biogeochemistry and sea surface temperature variability. This project is in collaboration with Andi Andreae at the Max Planck Institute for Chemistry, Amato Evan at Scripps Institution of Oceanography, Moacyr Araujo at Federal University of Pernambuco in Brazil, and Paulo Nobre at National Institute for Space Research in Brazil. Our Brazilian partners will sample dust during their 38°W PIRATA cruises, while the PNE group (Rick Lumpkin, Greg Foltz, Claudia Schmid, and Renellys Perez) will sample at 20°N 38°W and along 23°W. All samples will be sent to the Max Planck Institute for analysis.

Previous work identified six moorings of the PIRATA array that are subject to significant dust buildup during their yearlong deployments in the tropical North Atlantic (8°N, 12°N, 15°N, and 20°N along 38°W; 20.5°N and 11.5°N along 23°W). During the

PIRATA Northeast Extension cruise in early 2013, dust samples were collected from the radiometers on three buoys and sent to the Max Planck Institute for isotope analysis. By comparing the ratios of different elemental isotopes present in the dust, the regions in Africa from which the dust originated were determined. For example, some of the dust collected during the 2013 cruise likely came from the Bodélé depression in Chad. Dust samples will continue to be obtained from PIRATA moorings during each PNE cruise (run by NOAA) and 38°W cruise (run by Brazil) with the goal of building up a robust database of isotope ratios that can be used to trace African dust aerosols to their geographic origins.

The ability to obtain samples depends on the time of year in which the PIRATA cruise took place because there is strong seasonality in dust buildup on the sensors. During some years there is no dust buildup on a particular buoy because recent rainfall has washed it away. Future plans include building simple aerosol collectors that can be mounted to the PIRATA moorings to ensure consistent sampling throughout the year.