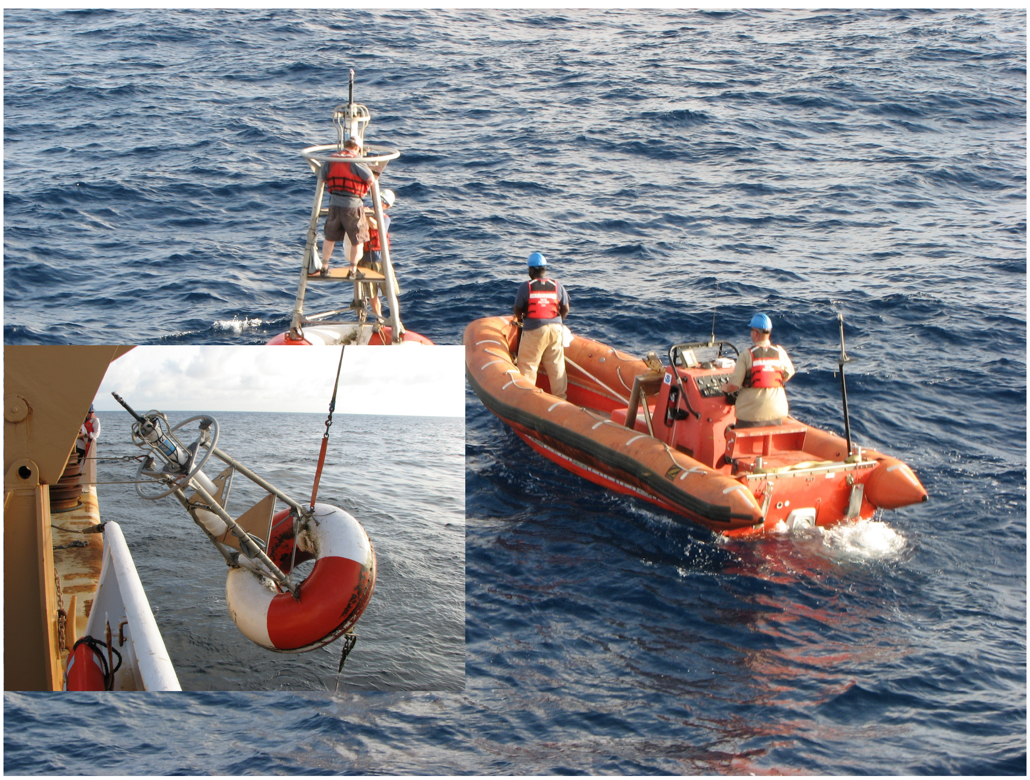
Cruise Report
PIRATA Northeast Extension 2013 & AEROSE VIII

NOAA Ship *Ronald H. Brown*
RB-13-01

January 8 — February 13, 2013

Charleston, SC, USA – San Juan, PR, USA



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Note: this cruise report addresses only the hydrographic and mooring work associated with the PIRATA Northeast Extension collaboration between AOML and PMEL in detail. Work performed by the AEROSE team is in a separate document. All figures and results reported here are subject to revision after quality control and final calibration.

OVERVIEW: the 2013 PIRATA Northeast Extension (PNE) and Aerosols and Ocean Science Expedition (AEROSE) Cruise RB-13-01 was designed to: (1) collect a suite of oceanographic and meteorological observations in the northeast Tropical Atlantic; (2) recover and redeploy the four moorings that belong to the Northeast Extension of the PIRATA array; (3) recover and redeploy the TFlex mooring near 20N, 38W; (4) to perform a sensor swap for the PIRATA mooring at 0ºN, 23ºW; and (5) to recover and redeploy two hydrophone moorings as well as deploy an additional hydrophone mooring. The oceanographic component of (1) includes the collection of data along 23ºW using CTD-O2/rosette/LADCP, XBTs and an underway CTD and the collection of XBT and underway CTD profiles on the return transit to Puerto Rico. The 23W section cuts through the climatologically significant Tropical North Atlantic (TNA) 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. The meteorological component of (1) focused on the measurement of aerosols, ozone and atmospheric conditions. All scientific goals of RB-13-01 were achieved.

We thank the crew and officers of the Ronald H. Brown for their tireless work and input before and during the cruise. The bosun Bruce Cowden and the deck crew recovered seven moorings, deployed eight, and conducted several small boat operations. Their efficiency and familiarity with mooring deployment operations was evident. We thank the survey technicians, Jonathan Shannahof and Laurie Roy, for their continuous assistance. We also thank all the crew who kept ship operations running smoothly, including the winch operators, electronic technician, engineers (who had to tackle difficult repairs during the cruise), galley crew, and all the other crew members of the Brown.

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. Given the widely varying dynamics of various sub-regions of the Tropical Atlantic the PIRATA array was extended into the Northwest, Southeast and Southwest.

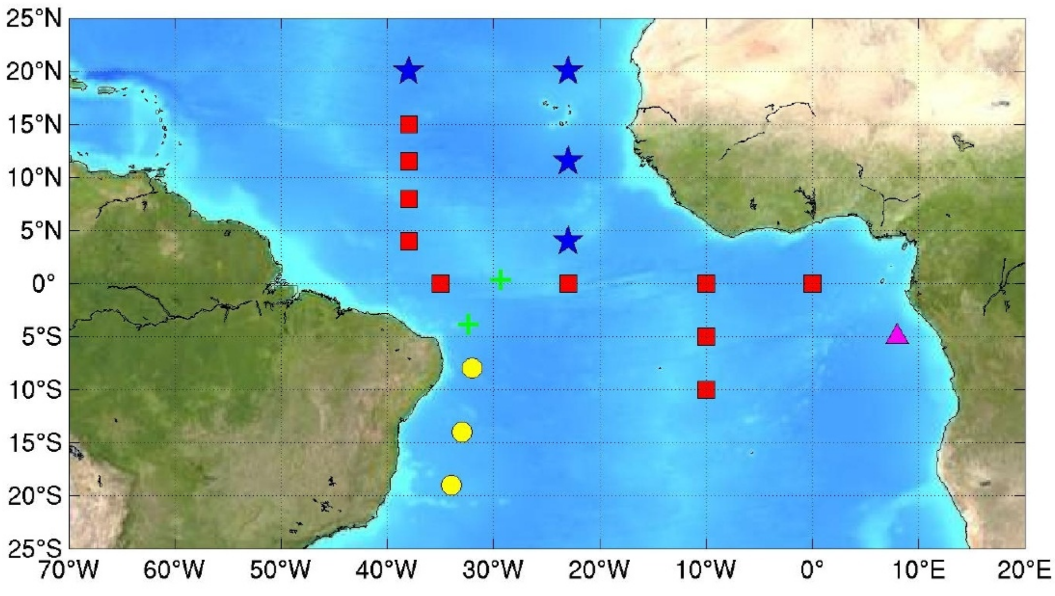

Fig. 1: The Tropical Atlantic, showing the PIRATA backbone (red squares), automatic meteorological stations (green +), southwest extension

(yellow circles), southeast extension pilot site (magenta triangle), and the Northeast Extension (blue stars).

The Northeast Extension is important for the collection of data in a region of strong climate variations from intraseasonal to decadal scales, with impacts upon rainfall rates and storms for the surrounding regions of Africa and the Americas. Moored observations in these regions will improve our knowledge of atmosphere-ocean heat exchanges and dynamics impacting the West African Monsoon, marine Intertropical Convergence Zone, upper ocean dynamics affecting heat content and SST variability in the TNA, possible connections between SST patterns and North Atlantic climate regimes of variability, and the development of atmospheric easterly waves into tropical cyclones. A better understanding of the processes driving SST anomalies in the TNA region will lead to better predictions of rainfall and other climate signals across a broad geographical domain at timescales from seasonal to decadal.

2. Aerosols and Ocean Science Expedition (AEROSE)

Large uncertainties remain in our understanding of the impact of mineral dust and biomass burning aerosols on weather and climate. The African continent is one of the world's major source regions of mineral dust and biomass burning smoke aerosols. These aerosols are transported within prevailing easterly winds as large-scale outflow plumes over the tropical Atlantic, impacting phenomena ranging from cloud-seeding and precipitation, ocean fertilization, downstream air quality and ecosystem impacts in the Caribbean and U.S. eastern seaboard, tropical cyclone development, net surface heat flux, tropospheric ozone and other trace gases, 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 quantities 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 just 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.

With these considerations in mind, the NOAA Aerosols and Ocean Science Expeditions (AEROSE) attempt to achieve a comprehensive measurement-based approach for gaining understanding of the impacts of long-range transport of mineral dust and smoke aerosols over the tropical Atlantic (Morris et al., 2006; Nalli et al., 2011). The project hinges on multi-year, trans-Atlantic field campaigns conducted in collaboration with PNE project over the tropical Atlantic. AEROSE is supported through collaborative efforts with 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 at Howard University.

The AEROSE trans-Atlantic campaigns (to date, comprised of nine, 4-week Project legs) 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). Beginning with the first campaign in 2004, AEROSE has sought to address three central scientific questions (Morris et al., 2006):

1. How does 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 is the capability of satellite remote sensing and numerical models for resolving and studying the above processes?

Order of operations:

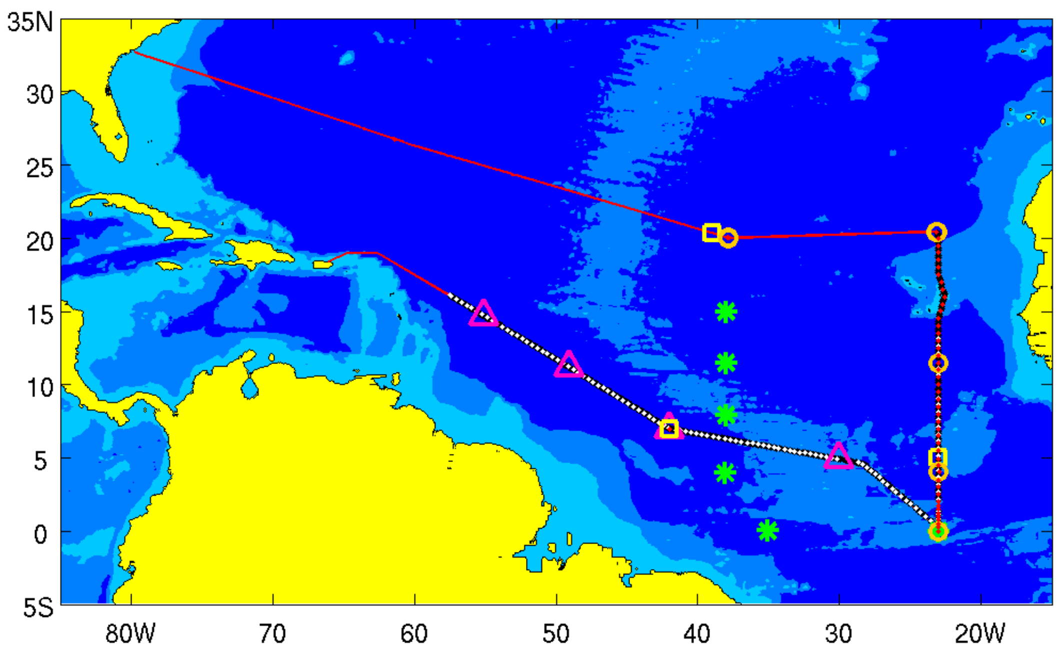

Fig. 2: cruise track of the R/V *Ronald H. Brown* during RB-13-01. Track (red line) with PNE recovery and deployment sites (circles), CTD stations (red dots), XBT profiles (black dots), UCTD profiles (white dots), hydrophone mooring sites (squares) and Argo deployment locations (triangles).

The R/V *Ronald H. Brown* (RHB) departed from Charleston, SC on January 8 at 12:00 UTC, and proceeded to steam east-southeastward towards the first mooring site. On January 8 at about 4:20pm, after the emergency drills were done, an electrical fire broke out at the jacket water heater in the engine room, near generator 1. Thanks to the actions of the crew the fire was quickly extinguished and we were underway again at about 6pm.

The damage done by the fire could be repaired with the equipment available on board. On the same day emails were received that we have clearance for all the EEZ we requested in preparation for the PNE cruise in the summer of 2012 that had to be canceled.

On the transit to the first mooring site, the hydrophone mooring EA-1 at about 20.3ºN, 39ºW, the AEROSE team kept busy by collecting atmospheric data and launching rawinsondes and ozonesondes (four sonde launches per day during S-NPP and MetOp satellite overpasses), while the hydrographic team set up the the XBT and Underway CTD (UCTD) systems and prepared the CTD/LADCP/rosette system. On January 10 the RHB stopped the transit for half an hour to test the work boat after it had been checked out the day before to ensure it will work well during the mooring operations. A CTD/LADCP test cast was then performed on January 12 at 17:00 UTC. The work of the AEROSE time was done throughout the whole cruise.

Fig. 3: group photo showing the hydrographic team, the mooring team and the AEROSE team (left to right: Steve, Zach, Dillon, Grant, Claudia, Mayra, Greg, Chris, Elsa, Bill, Ebony, Everette, Nick, Vernon).

On January 17 at about 10:00 UTC the release of the hydrophone mooring EA-1 at 20.3ºN, 39ºW was triggered. The recovery went smoothly and was completed at about 13:00 UTC. A seabeam survey was done before starting the deployment of a new mooring at the same location. The deployment itself was started at 1600 UTC and completed at 1930 UTC. After a triangulation of the position of the release and confirming it with a drive-over, the ship continued eastward towards the Atlas and TFlex moorings at 20ºN, 38ºW. The site of the Atlas mooring recovery at 20N, 38W at about 1:45 UTC on January 18, where CTD/LADCP cast was done. In the morning the recovery of the Atlas mooring was started at 9:30 UTC with the triggering of the release. The redeployment at a nearby location was started after a seabeam survey at 14:30 UTC and completed with a fly-by at 20:45 UTC, about 45 minutes after the anchor was dropped. The night was used for another CTD cast followed by an XBT comparison drop of 10 pairs of XBTs increasing speeds (about 2 through 8 knots). The next morning the TFlex mooring recovery was started at 9:30 UTC and finished within about 6 hours. After a seabeam survey a new TFlex mooring was deployed at the same location and the RHB continued on its way around 21:00 UTC. Less than 2 hours later a blackout occurred that also caused a loss of propulsion, but the situation was quickly resolved by the engineers and the RHB was underway again within 15 minutes. On January 20, the UCTD system was tested.

In the early morning on January 23, the RHB reached the northern end of the 23ºW section, where the first CTD/LADCP cast of the hydrographic section was taken. This work was followed by XBT comparison drops and a seabeam survey of the Atlas mooring site. The 20.5ºN, 23ºW Atlas mooring recovery was started at 9:30 UTC and completed in about 4 hours. A seabeam survey was done before the deployment of the new mooring was started at 15:00 UTC and completed about 3.5 hours later.

On the way to the next mooring site at 11.5ºN CTD/LADCP casts, XBT drops and UCTD casts were taken along 23ºW. The UCTD casts were discontinued for a while due to a loss of the probe. On January 25 in the afternoon the starboard steering motor failed. The RHB was partly driving with only one propulsion engine, but also was stationary for about 4 hours, to make it possible for the engineers to replace the steering motor. The work on the steering system had to be continued on and off for a few days to fully resolve the problem (1.5 hours of stopping on January 26, 1 hour on January 27, and a shorter period of time followed by half-speed for about 1 hour on January 28). Thanks to the skills of the engineers the repair was successful. On January 27 a set of XBT comparison drops and a CTD/LADCP cast were taken prior to the arrival at the 11.5ºN, 23ºW Atlas mooring site. The mooring recovery and redeployment was started at 10:00 UTC and completed at 20:00 UTC

On January 30 the RHB reached the hydrophone mooring EA-2 at 5ºN, 23ºW on the approach to the mooring a set of XBT comparison drops was done, which was followed by a CTD/LADCP cast. The mooring recovery started at 9:45 UTC. The redeployment was completed about 7 hours later and the hydrographic section was continued on the way towards the 4ºN, 23ºW Atlas mooring. At the mooring site a CTD cast and a set of XBT comparison drops was done. The mooring was recovered and redeployed on January 31 between 8:30 to 17:30 UTC. Departing from the mooring site the collection of hydrographic observations on the way south to the equatorial Atlas mooring at 23ºW. A sensor replacement and tube reprogramming was performed on this mooring during small boat operations between 16:00 and 19:00 UTC. This was followed by the last CTD cast along the 23W line and the last set of XBT comparison drops.

Once the work along 23W was done the RHB started to steam towards the last hydrophone mooring site (EA-6) at 7N, 42W. Along the way hydrographic observations were continued with hourly XBT casts and UCTD casts every other hour. The hydrophone mooring was deployed on February 7 and a short CTD cast was done for the purpose of monitoring the performance of the sensors of the UCTD.

Oceanographic and atmospheric work performed and data collected on this cruise:

1. Atlas moorings of the Pilot Array in the Tropical Atlantic (PIRATA) were recovered and redeployed at four existing sites. These moorings compose the PIRATA Northeast Extension (PNE), a US contribution to PIRATA. A TFlex mooring (the next generation Atlas mooring) was replaced near an Atlas mooring site. A sensor swap and tube reprogramming was performed on the French PIRATA backbone mooring at 0°, 23°W. The moorings are relaying real-time data including air temperature, relative humidity, wind speed and direction, rain rate, incoming shortwave and longwave radiation, barometric pressure, sea surface temperature, subsurface currents at ~10m depth, and subsurface temperature, salinity and currents at multiple points through the upper 500m of the water column.
2. CTD data were collected at 50 stations, including 48 stations on a meridional section from 0ºN to 20.5°N along 23ºW. Most stations have an LADCP profile as well. Whenever possible, stations were conducted to a pressure of 1500 dbar, or the bottom (if shallower). The only exceptions of this are selected stations that were done to the deep ocean bottom (between 3000 and 4500 dbar), most of these were within 1 degree of the equator. Another exception is the single CTD station done during the transit to Puerto Rico for the purpose of calibration of the UCTD. On all except for the last station water samples were taken at various depths to calibrate salinity and oxygen sensors.
3. expendable bathythermographs (XBTs) were launched along the 23°W section and during the transit to Puerto Rico to measure temperature profiles of the upper ocean.
4. UCTD profiles were taken along the 23°W section and during the transit to Puerto Rico to measure temperature and salinity profiles of the upper ocean, and to test the UCTD system.
5. 5 ARGO floats were deployed to measure temperature and salinity profiles in the upper 2000 dbar and currents at 1000 dbar as part of the 3000 float global array.

6. Shipboard current measurements were collected using a narrow band and a broadband hull-mounted Acoustic Doppler Current Profiler (SADCP). Heading data for the SADCP was provided by the MAHRS system, with data from the ship's gyro for comparison.
7. Two hydrophone moorings were replaced and one hydrophone mooring was deployed at a new mooring site.
8. Microtops handheld sun photometers measured total column multichannel aerosol optical depths (AOD)
9. A total of 111 Vaisala RS92 radiosondes measuring tropospheric profiles of pressure, temperature, humidity and wind were launched during S-NPP and MetOp overpasses for studies of the Saharan air layer and the validation of the S-NPP Cross-track Infrared Microwave Sounder Suite (CrIMSS) and Infrared Atmospheric Sounder Interferometer (IASI) temperature and moisture environmental data records (EDRs)
10. A total of 24 ozonesondes measuring ozone profiles were launched during S-NPP and MetOp overpasses for studies of ozone dynamics and validation of CrIMSS and IASI trace gas products
11. Laser particle counters
12. Broadband pyranometer to measure solar radiation flux
13. Broadband pyrgeometers to measure downwelling infrared radiation flux
14. In situ trace gas monitors (Ozone, NO_x, CO, VOC, and SO_2)
15. Sequential aerosol sampler
16. Multi-stage aerosol impactors
17. CrIMSS and NOAA-unique IASI granules (sensor data records and EDRs) matched to the radiosonde launch locations/times
18. Hourly SEVIRI multichannel imager data for the entire AEROSE domain

OCEANIC DATA (PNE)

On this cruise, XBT temperature profiles, UCTD temperature/salinity profiles and CTD temperature/salinity profiles were transmitted in near-real time via the Global Telecommunication System (GTS) for model calibration and validation. The RHB is the first ship to have CTD data transmitted in near-real time for weather and climate prediction. This was first done during the 2006 PNE/AMMA cruise.

ATLAS, TFlex and hydrophone moorings

Nine mooring sites were visited during this cruise (as listed in Table 1).

20.3N, 39.0W (Hydrophone mooring EA-1)

Mooring stations are listed in the appendix in Table 1.

Fig. 4: talking to the release of hydrophone mooring EA1.

<u>20N-38W</u>
PI164 Recovery:
TC2 and TC4 had failed on deployment. The SSC later went low, SWR and LWR failed simultaneously, V10 intermittent, TC1 intermittent, and rain failed for zero accumulation. It appeared that a fishing boat had tied up to the buoy. The tower ring was bent, an upper middle shelf frame cross member was broken, and the toroid was badly cracked on top. Longline was found on the bridle and at 300m. The SWR and LWR sensors had been unbolted at the mast base and one cable had been cut while the other was disconnected. The rain funnel was gone. All subsurface sensors were recovered. TC2 and TC4 had dead batteries, The SSC looked OK. The Sontek vane was broken off but otherwise was fine. TC1 had dead batteries.
PI181 Deployment:
Routine deployment. SSC was flagged as high from the start. The correct serial number was confirmed with the lab.
PT001 TFLEX Recovery:
The SST/C had failed during deployment. Other than some long line found on the 4^{th}spool of nylon the mooring was in good shape however the bulkhead connector on the

SBE37SMP (SST/C) had been severed off flush and the pigtail connector was severed as well. It was packed pending data retrieval at PMEL.

PT002 TFLEX Deployment:

Routine. All sensors reporting. Deployed closer to the ATLAS location.

21N-23W

PI165 Recovery:

Failures during deployment included the SSC intermittent and low, TC2 bad, V10 insufficient samples, rain has zero accumulation with high percent time raining, TP10 intermittent and the transmit battery was low. Transmissions on arrival indicated hourly SST was zero while the 24hr average was okay. The SSC was reading low and TC2, TP9, and TP10 were zero as well. There was long line fouling from 10m to 13.3m and the Sontek vane was broken off. TC2 was missing with only the mounts remaining. TP9 andTP10 had dead batteries and TP9 is pending data retrieval at PMEL. Communications with it couldn't be established with a good battery. It only displayed some unreadable font. The rain gauge was physically okay.

PI182 Deployment:

Routine. C3 failed on flyby yet T3 okay. Rain sensor was flagged afterwards as failing on deployment for unreasonable accumulation.

12N-23W

PI166 Recovery:

Sensors flagged included a failed wind, V10 intermittent, TP9 intermittent, SSC high, rain failed for zero accumulation and high percent time raining. Satellite transmission reception ceased 4 days before recovery. The wind propeller assembly was missing upon arrival. The vane body fell out of the tail piece when the sensor was removed and sank. The Sontek was recovered in good condition and data was recovered however a badly pinched red wire was found in the TV module. TP9 had dead batteries and the SSC module was in good shape. The rain gauge was physically okay.

PI183 Deployment:

Routine. Scheduled rain gauge 1046 wouldn't siphon before deployment so it was changed out. Reverse flushing fixed the blockage but the sensor should be opened up and inspected for foreign matter inside the tube.

4N-23W

PI167 Recovery:

TP10 had failed on deployment. Later C7 went low then was OK, the SSC went low, and SST became intermittent. The transmit battery went low, the reception was intermittent, and buoy was noted as moving, then it quit transmitting after 255 days of deployment. The last satellite position indicated that it was 18nm from the deployment location. A German vessel relayed that the buoy was spotted at the original deployment site on 11/1/12. The buoy was found at the deployment location in good condition without any evidence of fishing or vandalism. The logic battery was still good and 542 days of data were recovered. The transmit battery was low at 5 volts. The SSC end cap was broken at the mount. TC11 had dead batteries yet the date and time were okay. TC2 was missing and TP10 had severe battery leak damage inside.

PI184 Deployment:
Routine. There was an error in reporting the serial number of TC6. It was reported as 14620 but that sensor was deployed, as scheduled, as TC3 at PI182. Were unable to confirm the serial number one way or the other but it is very likely that the scheduled module 14612 was used here.

0-23W

PI176 Repair:
The module configuration was remapped mistakenly by the French before they had deployed this buoy. No more than 7 ‘C’s can be configured in the tube software and the French saw this as an error when they had 8 ‘C’s to deploy on the mooring. This caused C7 to fail on deployment. TC6, V10, and T5 had been flagged as intermittent and AT/RH failed. On arrival transmissions indicated TC6, T12, C7 and AT/RH were bad. The AT/RH was swapped out on the buoy ride and an attempt was made to download the tube data but the data transfer was too sluggish so that was aborted. The module configuration was corrected and C7 came back in realtime. After the ship moved on the lab reported that the AT values had been steadily increasing and the replacement sensor was flagged.

Hydrophone Mooring Deployments:
Two hydrophone mooring recovery/deployments and one deployment at a new site were undertaken by the Seattle PMEL contingent. PMEL Newport provided no personnel for the work on this cruise as they had in years past but the work involved was within the capabilities of the party. No interfacing with the hydrophones was involved. The turnarounds were performed at the nominal locations of 20.5N-39W and 5N-23W and the new deployment took place at 7N-42W. Mooring lights and batteries were not sent thus the two recovered flashers were re-deployed as was and the new site does not have one. A clamp for the installation of a light at 7N-42W will need to be provided for the next turnaround. All three locations were surveyed as per Newport’s request and each mooring was also triangulated on.

German Oxygen Data Loggers:
Oxygen Sensors were recovered and deployed at 300m and 500m on the 4N & 11.5N, 23W moorings. The recovered sensors were air freighted to Kiel Germany via DHL from San Juan.

Instrumentation and Hardware Notes:
The spare 4480# and 5980# anchors are planned to be stored in Charleston. This will add to the existing 5980# already there.

Software Notes:
Nylon histories didn’t work properly in Filemaker for serial numbers that didn’t begin with the letter ’Y’.

CTD Notes:
Casts to 1500 dbar were performed at all surface mooring locations.

Ship Notes or issues:
The EM 122 multi-beam system operated flawlessly for the entire cruise. 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. The survey department also recorded the EM 122 data at our mooring locations to augment our existing mapping.

A hull mounted 12khz transducer was interfaced with the 8011A deck unit. Interrogation of the acoustic releases can be done without mechanically lowering a transducer anymore.

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 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.

Recommendations:
The Ron Brown method of attaching tag lines during buoy recoveries would serve our group well on the foreign cruises. The pole mounted hooks are a quick and safe way to secure a buoy as it is picked out of the water. A similarly designed heavy duty hook could probably be used for teacup handle grabs during rough conditions when small boat operations are not advisable.

CTD/LADCP stations

We conducted 50 CTD/LADCP stations, including a test station at 26.8ºN, 61.4ºW (Fig. 2 and Table 3 in the appendix). For all deep stations 12 Niskin bottles were used to collect water samples. Oxygen and salinity were sampled from 12 of these bottles for sensor calibration.

Due to the update of the seasave software it became necessary to also update the processing software provided by SBE, and to change existing programs that read the output of the SBE software. Programs for the LADCP processing had to be adapted as well, mainly the part that reads the navigation data from the ship and the part that reads the CTD and SADCP data. The changed programs use the GPS data from the science-grade GPS Trimble 1. Titration of oxygen samples from the test cast was done on January 15. After adapting the programs to read the oxygen files, a comparison with the measurements from CTD showed the expected results (actual oxygen is on the order of 10% larger than the values recorded by both oxygen sensors).

During testing of the CTD/ Rosette/LADCP system the downloading of the LADCP data did not work with the LADCP computer, due to do a problem with the serial port. This could be fixed. A problem encountered with the CTD was an unreliability of the firing of the bottles. This improved significantly after replacing cables between the computer and the CTD and updating the seasave software. A CTD/LADCP test cast was then performed on January 12 at 17:00 UTC. All bottles were fired successfully, but the report of the firing was not always received (this required getting some of the data needed in the btl file from the up-profile in the file with the extension asc; the fixed btl file has the file extension btl.fixed). It was found out later, that an extra cable was attached to the “fish” that is not needed and caused interference with the signal transmission related to firing the bottles. After this cable was removed the sampling worked perfectly.

After reaching the site of the Atlas mooring recovery at 20N, 38W at about 1:45 UTC on January 18, a CTD/LADCP cast was done. The bottle firing including the reporting back to the seasave software worked perfectly.

To summarize the casts with problems:

- LADCP data for station 42 require work. They are only in the log file. The downloaded data files were overwritten during cast 43.
- on station 48 the secondary conductivity sensor started returning bad data during the down cast. There was no problem with that sensor during the shallow cast at station 49.

LADCP processing was performed with the routines developed by Visbeck, with modifications by Claudia Schmid during the cruise.

Recommendation for the future:

- Find out if there is a way to change the settings of bbtalk to get a warning if a data file is overwritten.
- Improve the documentation of the advanced data processing software

CTD/LADCP stations are listed in Table 3, and preliminary sections are shown at the end of this preliminary cruise report.

Underway CTD (UCTD) casts

On January 20 the UCTD system was tested with a cloth tied to the line which worked fine. All members of the hydrographic team operated the system without problems. The test with the dummy probe was not as successful. When the motor was engaged to start the recovery, there was no response and after repeated attempts to cycle the equipment and get the motor working, recovery was done by hand with periodic attempts at trying the motor again. At first it was believed this was the same issue encountered in 2012 and the controller board/motor was to blame. After repeated attempts at starting it though it was noticed that the level winder did move when the motor was switched on, as it should. It was quickly deduced that it must be a power issue and it might be a blown fuse as turned out to be the case. There was a 3-amp fuse installed in a 30 Amp socket. Once the correct fuse (spares provided by Oceanscience were the correct amperage) was installed there were no further issues with the motor.

Measuring UCTD profiles was started along the 23ºW section, with planned locations between CTD stations (for station spacing of 30 nm, XBT' was dropped after 10nm and after 20nm, the UCTD was used after the second XBT; for 15nm stations spacing an XBT and UCTD profile was measured at the halfway point). One CTD casts with the UCTD probe 1 and two CTD casts with the UCTD probe 2 strapped to the frame were done for calibration purposes. During the recovery of the UCTD at about 19.2ºN, 23ºW probe 1 was lost because the line snapped. During the initial phase of the recovery the brake was applied, perhaps too abruptly, and the line wrapped around the top of the pulley. When the clutch and motor were engaged the line tightened around the pulley and cut the line. Contributing factors were the rough seas, limited visibility at night, and a new user who had been trained how to run the equipment once in the early days of the cruise. UCTD casts were resumed with probe 2 at 13.1ºN, 23ºW and continued to the end of the 23ºW section. On the transit towards Puerto Rico UCTD profiles were measured every 2 hours until the ship reached the EEZ of the Caribbean. A list of UCTD casts can be found in Table 5 in the appendix.

Occasionally after a cast there were issues downloading the data from the probe to the computer through the Bluetooth serial port. It appeared that every so often there was a bad scan of data in the file and that would cause the program to abort the upload. If it did not complete the download after repeated tries the only way to get the data was to stream the cast from the instrument and do a capture screen, which was real time, so for a CTD comparison cast it would take 1.5 – 2 hours. If there was a hardwired serial connection instead of a Bluetooth connection we could download data faster in the case of a hiccup in the Bluetooth and if the Bluetooth fails we can still get the data. The connection could be on the outside or inside of the probe tail end cap.

At the end of one cast a loose screw was noticed in the brass head of the probe that holds the conductivity cell in place. This could have led to a cracked cell or lose of part of the probe. After tightening that screw, no further issues were encountered.

Some recommendations for equipment are: (1) Hand held GPS for marking drop positions and time of probe deployments. (2) Stopwatch for timing the fall of the probe and knowing when to start recovery. (3) Headlamps for doing night deployments and recoveries. (4) Cover for winch housing. (5) Spare rewinder control board. (6) Loctite for ensuring no loose screw damage the probes.

expendable bathythermograph (XBT) and CTD (XCTD) casts

A total of 373 XBTs were dropped during the cruise (Tables 5 and 6) along 23ºW and on the transit from the equator at 23ºW to Puerto Rico.

Aside from the regular XBT profiles (Table 6 in the appendix; 265 XBTs) six sets of XBT/XCTD comparison drops were performed near selected CTD stations (Table 7 in the appendix; 108 XBTs and XCTDs). The first set with 10 pairs of XBT drops was done in the night of January 18 to 19 in the vicinity of CTD station 2. Because the computer clocks had not been synchronized before the drops started the times in the data files for the XBTs dropped with launcher 1 are about 13 seconds earlier than the times in the data files for the XBTs dropped with launcher 2 (the computers record the GPS150 positions at the start of the profile but not the times from the GPS). Similar correctable time differences exist for some of the other comparison sets. Set 2 was done near CTD station 3, set 3 near CTD station 21, set 4 near CTD station 34, set 5 near CTD station 36, and set 6 near CTD station 47.

Argo Floats

Five Argo floats were deployed during the cruise, as shown in Table 4 in the appendix.

Preliminary figures of the data

Surface features in the temperature sections include the warm, thick subtropical gyre and warmer, shallow tropical surface water layer (Fig. 6). Below the mixed layer the temperature drops rapidly within the thermocline to less than 10ºC. The horizontal slopes of the isotherms can be associated with specific currents. E.g.: the rapidly shoaling isotherms from 13ºN to 11ºN around the depth of about 400 dbar may be associated with the westward flow on the northern side of the cyclonic Guinea Dome (Siedler *et al.*, 1992). This flow can also be seen in Figure 7.

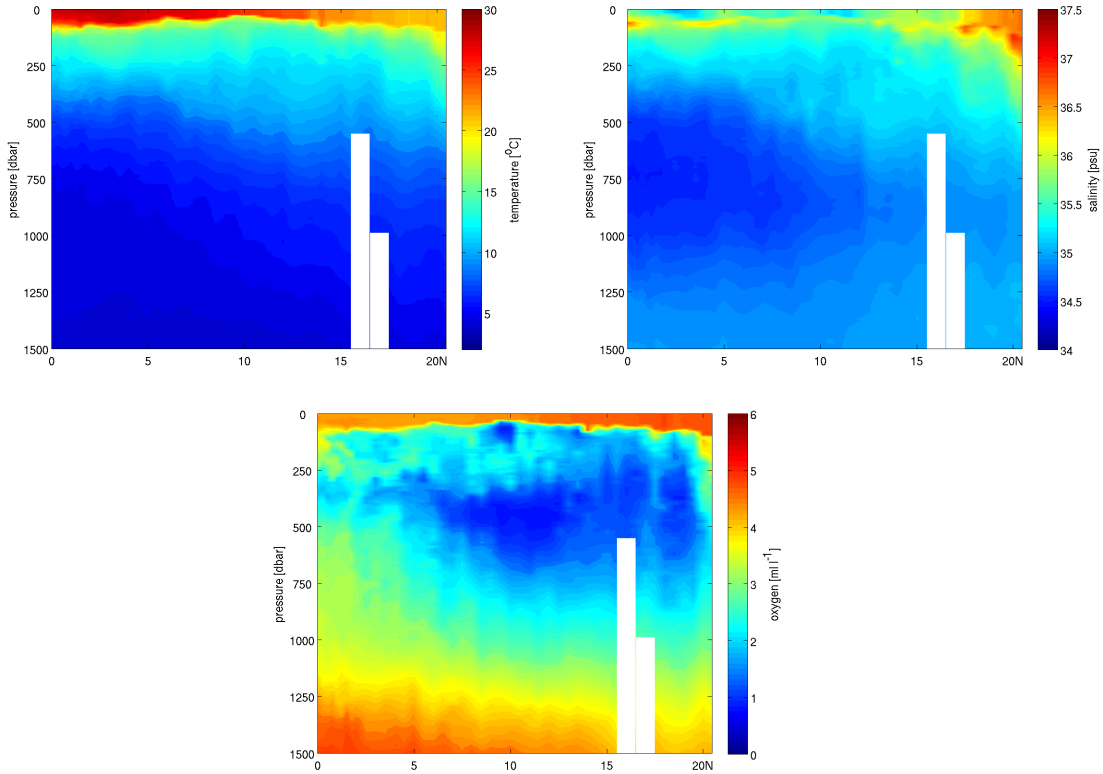

Fig. 6: CTD section along 23ºW.

The salinity section reveals the low-salinity core of the Antarctic Intermediate Water coming in from the south between 500 and 1000 dbar, the high-salinity subtropical water in the north and the fresh near-surface water in the latitude range that is under influence of the seasonally migrating Intertropical Convergence Zone.

The oxygen section shows the subsurface oxygen minimum zone, that is of interest due to the impact of the low oxygen of the ecosystem, very clearly. This water is in the stagnant shadow zone of the North Atlantic, that is not participating in the circulation associated with the ventilated thermocline of the subtropicall gyre (e.g., Luyten and Stommel, 1986). The abrupt increase in oxygen values north of 14ºN marks the Cape Verde Frontal Zone, which also marks the boundary between North and South Atlantic Central Water (Stramma *et al*., 2005).

The LADCP sections in Figure 7 also show the eastward Equatorial Undercurrent and the alternating westward and eastward equatorial deep jets below it (within 1 degree of the equator, the profiles go to the ocean bottom, which is not shown in this figure). Just north of the Equatorial Undercurrent two eastward currents, the Northern Equatorial Countercurrent at the surface and the Northern Intermediate Countercurrent can be seen.

The meridional velocity is predominantly southward near the surface and alternating between northward and southward at depth in relatively narrow bands.

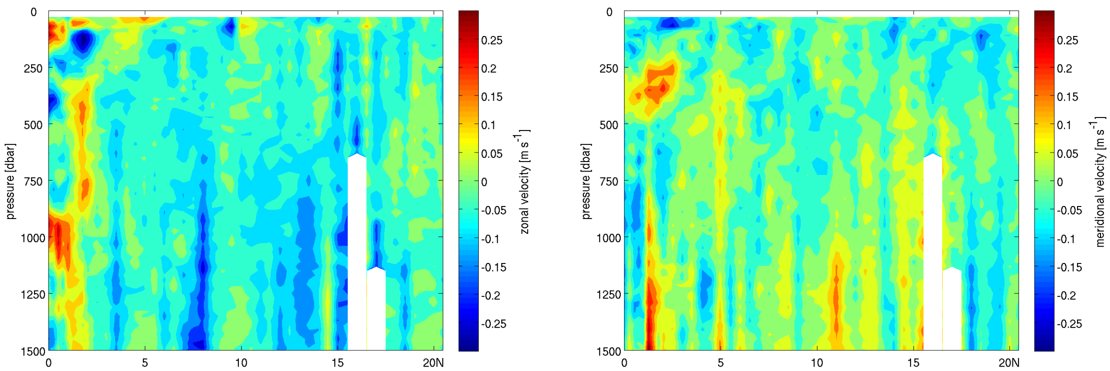

Fig. 7: LADCP section along 23ºW

The UCTD and XBT sections along 23ºW (Fig. 8, left and Fig. 9) show the temperature and salinity of the transect at a higher horizontal resolution. These observations will be useful for analyzing changes of the mixed layer heat balance and the dynamics of the shallow tropical cells.

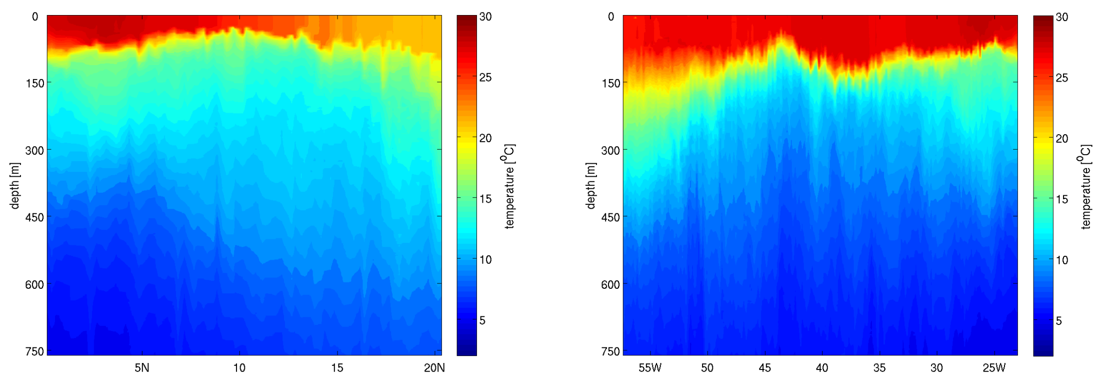

Fig. 8: XBT sections along 23ºW and from 23W, equator towards Puerto Rico.

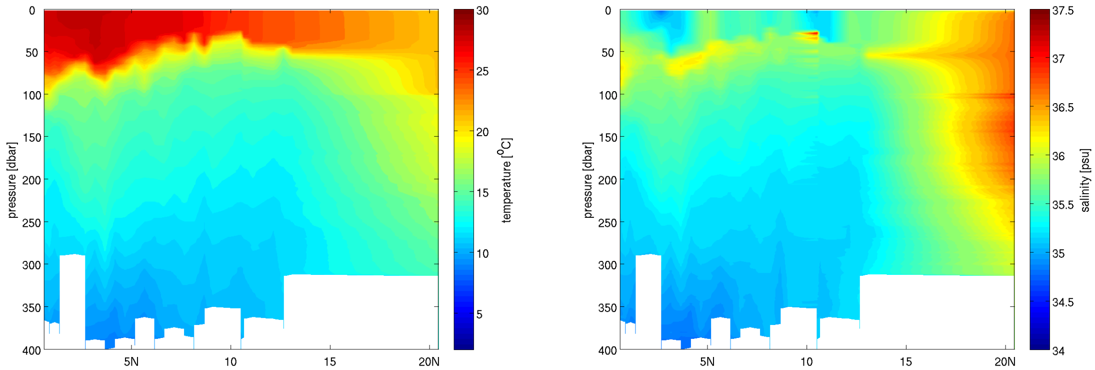

Fig. 9: UCTD section along 23ºW

The west-northwestward transect towards Puerto Rico shows the changes of the temperature and salinity in the transition from the tropics to the subtropical gyre and also shows signs of the impact of the Amazon outflow as low mixed layer salinity near 50ºW.

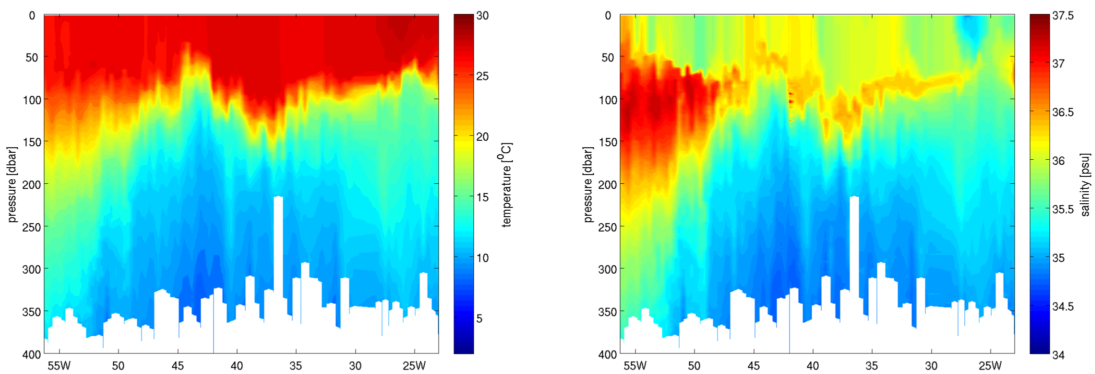

Fig. 10: UCTD section from 23W, equator towards Puerto Rico.

The salinity and oxygen fields shown above have undergone preliminary comparisons with estimates from the water samples. Differences between estimates of salinity and oxygen concentration from the water samples versus the corresponding measurements of all individual CTD profiles are mostly less than 0.01 psu and 0.3 ml/l, respectively.

Comparison casts with the UCTD probe attached to the CTD showed quite good agreement of temperature and salinity. The exception is in the halocline, where the UCTD produces noisy salinity data and overestimates the salinity by about 0.1 psu or more. Because the sensor on the UCTD does not have a pump it relies on the throughflow generated by its motion through the water. When attached to the CTD the motion through the water column is slow and more irregular, when compared with the quite rapid fall rate of the UCTD during regular UCTD casts.

XBT comparison drops were done in collaboration with Sippican. The company provided selected XBTs and XCTDs of different characteristics to improve the accuracy of the estimation of the depth from the fall rate (Fig. 11). Multiple pairs of XBTs were deployed in the vicinity of CTD profiles.

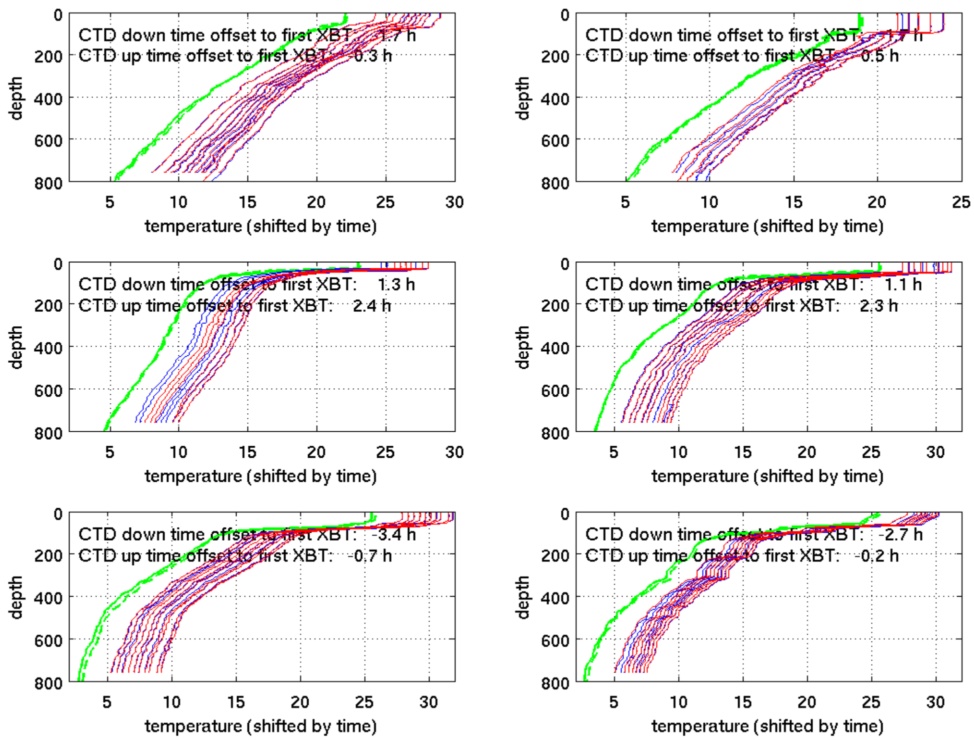

Fig. 11: XBT comparison experiment. XBT profiles (blue for launcher 1 and red for launcher 2) have been shifted by time. CTD profiles (green, solid for down profile and dashed for up profile) have been shifted to the left of all other profiles.

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Appendix

Table 1: list of mooring stations.

mooring	date	hour	latitude	longitude	duration	task
EA-1	2013-1-17	9	20.32719	-38.97348	5	Hydrophone rec.
EA-1	2013-1-17	14	20.34405	-38.97384	5	Hydrophone depl.
20n38w, PI164A	2013-1-18	9	20.01910	-37.85940	5	Atlas recovery
20n38w, PI181A	2013-1-18	14	20.00350	-37.84310	6	Atlas deployment
20n38w, PT001A	2013-1-19	9	20.03187	37.79873	6	TFlex recovery
20n38w, PT002A	2013-1-19	15	20.03187	37.79873	6	TFlex deployment
21n23w, PI165A	2013-1-23	9	20.45120	-23.12070	5	Atlas recovery
21n23w, PI182A	2013-1-23	14	20.44360	-23.14140	5	Atlas deployment
12n23w, PI166A	2013-1-27	9	11.47990	-22.99580	5	Atlas recovery
12n23w, PI183A	2013-1-27	14	11.47570	-22.99100	5	Atlas deployment
EA-2	2013-1-30	9	4.99100	-22.99300	4	Hydrophone rec.
EA-2	2013-1-30	13	4.99100	-22.99300	4	Hydrophone depl.
4n23w, PI167A	2013-1-31	4	4.04370	-22.99100	6	Atlas recovery
4n23w, PI184A	2013-1-31	10	4.04560	-22.98460	7	Atlas deployment
0n23w, PI176A,B	2013-2-2	14	0.00490	-22.99360	3	Atlas repair
EA-6	2013-2-7	13	6.96760	-41.99998	5	Hydrophone depl.

Tables 2: list of lost sensors on moorings and lists of other equipment issues related to mooring work.

Lost or Damaged Instruments and Equipment *(from rec moorings)*			
Mooring	**Sensor type**	Serial No	**Comments**
20n38w, PI164A	Rain	745	Funnel missing
	SWR	33362	Missing
	LWR	35236	Missing
	Sontek	D717	Fin broken off
	Rad post		Missing
	Toroid	F-9-10	Crushed on top
	Tower		Broken
	Nylon	Y822	Broken strand
20n38w, PT001A	SBE37SMP	7772	Bulkhead connector broken, exposed
	Top section	TFLEX03	SSC pigtail connector severed off
21n23w, PI165A	Sontek	D721	Fin broken off
	TC module	14949	Missing
	Nylon	Y533	Broken strand
	Nylon	Y567	Broken strand
12n23w, PI166A	Wind	101152	Prop assy gone. Vane body fell out on
	Nylon	Y566	recovery

			Broken strand
4N23W, PI167A	SSC module TC module	12979 15428	End cap broken at mount Missing

On-deck instrument or hardware failure ***(pre-deployment)***		
Sensor type	**Serial No**	**Comments**
8011A deck unit	30646	Bad out of the box
rain gauge	1046	Wouldn't siphon. Reverse flushing fixed that but not used. Needs to be inspected for foreign matter inside

Fishing and Vandalism	
Mooring	**Comments**
20N38W, PI164A	The mast for the LWR and SWR had been unbolted and removed. One cable was disconnected while the other had been cut. The rain gauge funnel was gone and there was long-line fouling on the bridle and at 300m. The tower was broken at a cross member and the ring was bent. The toroid was crushed on top enough not to be considered for turnaround.
20N38W, PT001A	SSC bulkhead connector was severed flush. Long-line fouling on 4^{th} spool of nylon.
21N23W, PI165A	Long-line fouling 10m-13.3m

Table 3: list of CTD/LADCP stations.

station	**day**	**month**	**year**	**hour**	**minute**	**latitude**	**longitude**
0	12	1	2013	17	4	26.78033	-61.42617
1	18	1	2013	1	58	20.02450	-37.89750
2	18	1	2013	22	10	20.04967	-37.81500
3	23	1	2013	6	3	20.44150	-23.16283
4	23	1	2013	22	26	19.99717	-23.00033
5	24	1	2013	2	38	19.49967	-22.99967
6	24	1	2013	6	57	19.00017	-23.00200
7	24	1	2013	11	2	18.49950	-23.00117
8	24	1	2013	16	22	18.00017	-23.00133
9	24	1	2013	21	12	17.49883	-22.99933
10	25	1	2013	2	28	16.99967	-22.81767
11	25	1	2013	7	16	16.49733	-22.73317
12	25	1	2013	12	44	15.99983	-22.59883
13	25	1	2013	18	36	15.49750	-22.73467
14	26	1	2013	2	3	15.01467	-22.86283
15	26	1	2013	7	18	14.49683	-23.00100

16	26	1	2013	11	12	13.99900	-22.99933
17	26	1	2013	15	7	13.50067	-22.99750
18	26	1	2013	19	55	13.01417	-22.99983
19	26	1	2013	23	56	12.50183	-23.00050
20	27	1	2013	3	55	12.01017	-22.99783
21	27	1	2013	8	21	11.44950	-23.01867
22	27	1	2013	21	58	11.00283	-23.00050
23	28	1	2013	1	58	10.50050	-22.99683
24	28	1	2013	6	9	10.00183	-22.99800
25	28	1	2013	10	58	9.49900	-22.99900
26	28	1	2013	15	49	8.99783	-22.99617
27	28	1	2013	20	30	8.50133	-22.99833
28	29	1	2013	1	17	7.99983	-22.99667
29	29	1	2013	6	5	7.49967	-22.99883
30	29	1	2013	12	5	6.98183	-23.01050
31	29	1	2013	17	11	6.49867	-22.99883
32	29	1	2013	21	52	5.99983	-22.99900
33	30	1	2013	2	34	5.49783	-22.99567
34	30	1	2013	7	40	4.95867	-23.00250
35	30	1	2013	20	31	4.49983	-22.99883
36	31	1	2013	2	31	4.04733	-22.95067
37	31	1	2013	21	28	3.50033	-23.00083
38	1	2	2013	2	47	3.00133	-23.00100
39	1	2	2013	8	11	2.50017	-23.00067
40	1	2	2013	13	11	2.00000	-22.99983
41	1	2	2013	16	26	1.74983	-22.99967
42	1	2	2013	19	31	1.49933	-23.00183
43	1	2	2013	22	46	1.24967	-22.99967
44	2	2	2013	1	53	1.00167	-23.00033
45	2	2	2013	6	1	0.75017	-22.99983
46	2	2	2013	10	38	0.50000	-23.00000
47	2	2	2013	19	29	-0.02700	-22.99283
48	3	2	2013	0	58	0.25067	-22.99967
49	7	2	2013	17	2	6.96583	-41.97717

Table 4: list of deployed floats identified by WHOI float Serial number & WMO ID

Argo float	**Date UTC**	**Time UTC**	**latitude**	**longitude**
7102/1901671	2013-02-04	22:20	4.91000	-29.98833
7119/1901674	2013-02-07	18:50	6.99348	-42.00358
7116/1901672	2013-02-09	10:25	11.16798	-49.03588
7110/1901670	2013-02-10	20:11	14.68917	-55.05567

Table 5: list of UCTD casts.

UCTD	day	month	year	hour	min	sec	latitude	longitude
on CTD 3	23	1	2013	6	3	6	20.44150	-23.16283
1	26	1	2013	19	24	0	13.11167	-22.99992
2	26	1	2013	23	15	0	12.64350	-22.99973
3	27	1	2013	3	15	0	12.15017	-22.99997
4	27	1	2013	21	29	0	11.10133	-23.00048
5	28	1	2013	1	9	0	10.65800	-22.99983
on CTD 23	28	1	2013	9	59	0	10.50050	-22.99683
6	28	1	2013	15	11	0	9.07853	-22.99977
7	28	1	2013	19	22	0	8.66333	-23.00083
8	29	1	2013	0	19	0	8.14667	-23.00117
9	29	1	2013	5	6	0	7.64933	-23.00033
10	29	1	2013	9	59	0	7.14183	-22.99967
11	29	1	2013	16	21	0	6.62633	-22.99988
12	29	1	2013	20	50	0	6.15283	-23.00017
13	30	1	2013	1	35	0	5.64683	-22.99950
14	30	1	2013	6	18	0	5.15900	-22.99545
15	30	1	2013	19	28	0	4.65650	-22.99767
16	31	1	2013	1	40	0	4.15467	-22.99335
17	31	1	2013	20	15	0	3.66000	-22.99750
18	1	2	2013	1	25	0	3.15645	-23.00066
19	1	2	2013	6	44	29	2.66708	-23.00010
20	1	2	2013	12	16	0	2.13467	-23.00011
21	1	2	2013	22	1	0	1.36250	-23.00012
22	2	2	2013	0	1	0	1.12087	-23.00010
23	2	2	2013	5	15	0	0.85750	-23.00017
24	2	2	2013	10	1	0	0.58660	-23.00017
25	2	2	2013	14	24	0	0.34283	-23.00017
26	3	2	2013	0	12	0	0.13038	-23.00005
27	3	2	2013	5	6	0	0.41904	-23.20750
28	3	2	2013	7	7	0	0.70833	-23.56267
29	3	2	2013	9	5	0	0.99225	-23.91088
30	3	2	2013	11	5	0	1.28867	-24.27483
31	3	2	2013	13	3	0	1.55992	-24.61350
32	3	2	2013	15	10	0	1.85833	-24.97583
33	3	2	2013	17	7	0	2.12500	-25.29667
34	3	2	2013	19	4	0	2.38188	-25.61692
35	3	2	2013	22	25	26	2.69257	-25.99863
36	3	2	2013	23	0	53	2.90175	-26.25552
37	4	2	2013	1	10	38	3.18028	-26.59925
38	4	2	2013	3	5	58	3.42557	-26.89932
39	4	2	2013	5	4	48	3.66242	-27.19048

40	4	2	2013	6	59	59	3.89518	-27.47677
41	4	2	2013	9	3	15	4.12902	-27.76450
42	4	2	2013	11	7	43	4.36187	-28.05105
43	4	2	2013	13	8	34	4.58560	-28.32668
44	4	2	2013	15	12	34	4.67367	-28.66842
45	4	2	2013	23	3	5	4.93073	-30.12922
46	5	2	2013	1	6	35	4.99963	-30.52390
47	5	2	2013	3	1	30	5.06475	-30.89207
48	5	2	2013	5	3	26	5.13243	-31.28288
49	5	2	2013	7	3	31	5.19985	-31.66682
50	5	2	2013	9	5	9	5.26700	-32.05195
51	5	2	2013	11	16	3	5.33685	-32.45252
52	5	2	2013	13	10	0	5.39800	-32.81357
53	5	2	2013	15	11	42	5.46125	-33.16563
54	5	2	2013	16	53	0	5.51668	-33.48188
55	5	2	2013	19	8	0	5.58617	-33.88833
56	5	2	2013	21	12	0	5.65400	-34.27117
57	5	2	2013	23	4	13	5.71437	-34.61806
58	6	2	2013	1	10	49	5.78233	-35.00702
59	6	2	2013	3	4	53	5.84375	-35.35948
60	6	2	2013	5	4	56	5.90940	-35.73648
61	6	2	2013	7	2	28	5.98288	-36.10970
62	6	2	2013	9	1	19	6.04207	-36.49708
63	6	2	2013	11	8	0	6.11502	-36.91517
64	6	2	2013	13	8	0	6.18417	-37.31417
65	6	2	2013	15	13	0	6.25633	-37.72700
66	6	2	2013	17	6	0	6.32267	-38.10667
67	6	2	2013	19	5	0	6.39283	-38.51092
68	6	2	2013	21	5	2	6.46465	-38.92263
69	6	2	2013	23	3	10	6.53505	-39.32695
70	7	2	2013	1	7	21	6.60922	-39.75287
71	7	2	2013	3	4	50	6.67532	-40.13327
72	7	2	2013	5	1	56	6.73815	-40.49477
73	7	2	2013	7	4	26	6.80333	-40.86897
74	7	2	2013	8	59	54	6.86227	-41.20747
75	7	2	2013	11	3	0	6.92217	-41.55233
on CTD #49	7	2	2013	17	2	56	6.96583	-41.97717
76	7	2	2013	19	5	0	7.02400	-42.03867
77	7	2	2013	21	7	0	7.22167	-42.37275
78	7	2	2013	23	7	37	7.42999	-42.72136
79	8	2	2013	1	13	17	7.65041	-43.09266
80	8	2	2013	5	5	55	7.84912	-43.42664
81	8	2	2013	5	5	55	8.07061	-43.79930
82	8	2	2013	7	2	7	8.28196	-44.15513

83	8	2	2013	9	0	27	8.49976	-44.52191
84	8	2	2013	11	6	24	8.72683	-44.90500
85	8	2	2013	13	9	0	8.94700	-45.27583
86	8	2	2013	15	12	0	9.16317	-45.64350
87	8	2	2013	17	5	42	9.36017	-45.97332
88	8	2	2013	19	6	11	9.56772	-46.32468
89	8	2	2013	21	5	42	9.76900	-46.66362
90	8	2	2013	23	5	17	9.98068	-47.02245
91	9	2	2013	1	10	0	10.19787	-47.38887
92	9	2	2013	3	6	46	10.40378	-47.73878
93	9	2	2013	5	4	16	10.60952	-48.08648
94	9	2	2013	7	2	39	10.81437	-48.43542
95	9	2	2013	9	2	12	11.02130	-48.78305
96	9	2	2013	11	6	0	11.24268	-49.16152
97	9	2	2013	13	5	33	11.45200	-49.51817
98	9	2	2013	15	11	37	11.67300	-49.89317
99	9	2	2013	17	7	43	11.87652	-50.23967
100	9	2	2013	19	8	10	12.09353	-50.60317
101	9	2	2013	21	5	55	12.30150	-50.96350
102	9	2	2013	23	7	47	12.51531	-51.32837
103	10	2	2013	1	5	3	12.72143	-51.68002
104	10	2	2013	3	7	19	12.93318	-52.04187
105	10	2	2013	5	3	24	13.13280	-52.38347
106	10	2	2013	7	3	8	13.33785	-52.73460
107	10	2	2013	9	2	33	13.54418	-53.08782
108	10	2	2013	11	3	12	13.74932	-53.43948
109	10	2	2013	13	8	43	13.96437	-53.80882
110	10	2	2013	15	11	5	14.17017	-54.16250
111	10	2	2013	18	40	39	14.36800	-54.50233
112	10	2	2013	19	6	17	14.57317	-54.85600
113	10	2	2013	21	4	49	14.78450	-55.21983
114	10	2	2013	23	4	50	15.00277	-55.59663
115	11	2	2013	1	8	23	15.22087	-55.97285
116	11	2	2013	3	2	57	15.41977	-56.31637
117	11	2	2013	5	6	18	15.63295	-56.68525
118	11	2	2013	7	1	40	15.83452	-57.03423
119	11	2	2013	9	3	23	16.04772	-57.40373
120 tow-yo	11	2	2013	9	43	39	16.11823	-57.52628

Table 6: list of regular XBT casts.

XBT	day	month	year	hour	minute	second	latitude	longitude
169	23	1	2013	19	41	40	20.32783	-23.09058
170	23	1	2013	21	4	8	20.15945	-23.04394

171	23	1	2013	21	5	22	20.15689	-23.04314
172	24	1	2013	0	56	43	19.82707	-22.99991
173	24	1	2013	1	47	15	19.66364	-22.99999
174	24	1	2013	5	13	52	19.33351	-23.00003
175	24	1	2013	6	6	57	19.15658	-22.99992
176	24	1	2013	9	22	8	18.81255	-23.00031
177	24	1	2013	10	7	2	18.66369	-22.99999
178	24	1	2013	13	54	18	18.34061	-23.00015
179	24	1	2013	15	6	30	18.17082	-23.00008
180	24	1	2013	18	49	32	17.83527	-22.99989
181	24	1	2013	19	59	9	17.66638	-22.99991
182	25	1	2013	0	0	33	17.32357	-22.93526
183	25	1	2013	1	9	45	17.16878	-22.87868
184	25	1	2013	4	59	30	16.82642	-22.78767
185	25	1	2013	6	6	51	16.66284	-22.76049
186	25	1	2013	9	43	31	16.38062	-22.66295
187	25	1	2013	11	29	20	16.16901	-22.53809
188	25	1	2013	14	44	41	15.84049	-22.64279
189	25	1	2013	16	52	42	15.67053	-22.68928
190	25	1	2013	23	46	48	15.33919	-22.77661
191	26	1	2013	0	57	57	15.17231	-22.82070
192	26	1	2013	4	55	53	14.83627	-22.91019
193	26	1	2013	6	8	50	14.65759	-22.95842
194	26	1	2013	9	37	30	14.32619	-23.00006
195	26	1	2013	10	21	56	14.16740	-22.99977
196	26	1	2013	13	29	56	13.82864	-22.99998
197	26	1	2013	14	18	59	13.65682	-23.00055
198	26	1	2013	18	19	24	13.33276	-23.00007
199	26	1	2013	19	13	8	13.15259	-23.00004
200	26	1	2013	22	21	35	12.82584	-23.00012
201	26	1	2013	23	8	43	12.66569	-22.99996
202	27	1	2013	2	23	49	12.32482	-23.00010
203	27	1	2013	3	7	55	12.17247	-22.99996
204	27	1	2013	6	21	1	11.84017	-23.00144
212	27	1	2013	20	17	47	11.33060	-23.00217
213	27	1	2013	21	9	32	11.16590	-23.00178
214	28	1	2013	0	16	6	10.83400	-23.00025
215	28	1	2013	1	4	1	10.67276	-23.00009
216	28	1	2013	4	32	50	10.32832	-23.00008
217	28	1	2013	5	24	8	10.15557	-23.00061
218	28	1	2013	8	50	35	9.76122	-22.99993
219	28	1	2013	9	19	18	9.66320	-22.99987
220	28	1	2013	13	28	26	9.33632	-22.99998
222	28	1	2013	14	50	19	9.13482	-22.99991

223	28	1	2013	18	15	50	8.83298	-22.99967
224	28	1	2013	19	22	21	8.66364	-23.00078
225	28	1	2013	23	9	57	8.32814	-23.00041
226	29	1	2013	0	13	37	8.16014	-23.00032
227	29	1	2013	3	52	47	7.83819	-22.99966
228	29	1	2013	5	2	9	7.65958	-23.00048
229	29	1	2013	8	44	45	7.32776	-23.00031
230	29	1	2013	9	48	59	7.16721	-22.99993
231	29	1	2013	15	5	41	6.83417	-23.00004
232	29	1	2013	16	9	33	6.65994	-22.99999
233	29	1	2013	19	45	2	6.32028	-22.99991
234	29	1	2013	20	48	14	6.15976	-23.00002
235	30	1	2013	0	24	2	5.83078	-22.99973
236	30	1	2013	1	26	54	5.66929	-22.99991
237	30	1	2013	5	9	58	5.33403	-22.99781
250	30	1	2013	18	20	41	4.83729	-22.99529
251	30	1	2013	19	25	12	4.66396	-22.99762
252	31	1	2013	0	32	51	4.32902	-22.99676
253	31	1	2013	1	35	9	4.16600	-22.99362
264	31	1	2013	18	56	35	3.83726	-22.99522
265	31	1	2013	20	10	34	3.67260	-22.99721
266	1	2	2013	0	6	23	3.33566	-23.00006
267	1	2	2013	1	23	23	3.16246	-23.00038
268	1	2	2013	5	33	18	2.83594	-23.00012
269	1	2	2013	6	46	14	2.67436	-23.00012
270	1	2	2013	10	55	21	2.33293	-23.00010
271	1	2	2013	12	6	12	2.16065	-23.00009
272	1	2	2013	21	55	11	1.37601	-23.00010
273	2	2	2013	0	58	13	1.12822	-23.00014
275	2	2	2013	5	14	2	0.86351	-23.00011
276	2	2	2013	9	49	22	0.61955	-23.00013
277	2	2	2013	14	14	52	0.36831	-23.00052
287	3	2	2013	0	9	3	0.12488	-22.99994
288	3	2	2013	5	0	24	0.40783	-23.19374
289	3	2	2013	7	5	9	0.70342	-23.55638
290	3	2	2013	8	59	37	0.98120	-23.89738
292	3	2	2013	10	6	24	1.14612	-24.09967
293	3	2	2013	10	59	8	1.27601	-24.25907
294	3	2	2013	12	5	40	1.43288	-24.45157
295	3	2	2013	12	56	49	1.55345	-24.59971
296	3	2	2013	15	3	12	1.84212	-24.95409
297	3	2	2013	16	8	42	1.98946	-25.13494
298	3	2	2013	16	59	42	2.10439	-25.27602
299	3	2	2013	18	6	5	2.25289	-25.45849

300	3	2	2013	18	55	29	2.36251	-25.59310
301	3	2	2013	21	0	51	2.63869	-25.93241
302	3	2	2013	22	2	28	2.77473	-26.09952
303	3	2	2013	22	55	22	2.89025	-26.24146
304	4	2	2013	0	7	52	3.04619	-26.43313
305	4	2	2013	1	1	21	3.16157	-26.57472
306	4	2	2013	1	6	52	3.17300	-26.58959
307	4	2	2013	1	52	49	3.27114	-26.70948
308	4	2	2013	3	0	32	3.41660	-26.88833
309	4	2	2013	3	58	49	3.52565	-27.02235
310	4	2	2013	4	59	20	3.65133	-27.17684
311	4	2	2013	5	57	57	3.77118	-27.32426
312	4	2	2013	6	55	35	3.88688	-27.46657
313	4	2	2013	7	56	44	4.00446	-27.61124
314	4	2	2013	8	58	1	4.11959	-27.75293
315	4	2	2013	9	57	36	4.23156	-27.89070
316	4	2	2013	11	0	17	4.34844	-28.03459
317	4	2	2013	12	0	19	4.45986	-28.17170
318	4	2	2013	13	1	3	4.57218	-28.30996
319	4	2	2013	14	3	48	4.64264	-28.47581
320	4	2	2013	14	6	57	4.64419	-28.48427
321	4	2	2013	15	3	2	4.67127	-28.63925
322	4	2	2013	16	3	35	4.70336	-28.82401
323	4	2	2013	17	5	12	4.73641	-29.01243
324	4	2	2013	18	8	36	4.77074	-29.20933
325	4	2	2013	19	0	25	4.79897	-29.37150
326	4	2	2013	20	2	14	4.83294	-29.56544
327	4	2	2013	22	8	44	4.90274	-29.96513
328	4	2	2013	22	58	17	4.92855	-30.11425
330	5	2	2013	0	21	29	4.97531	-30.38083
331	5	2	2013	1	2	7	4.99761	-30.51000
332	5	2	2013	1	56	16	5.02827	-30.68394
333	5	2	2013	2	57	40	5.06254	-30.88029
334	5	2	2013	3	58	7	5.09686	-31.07329
335	5	2	2013	4	58	57	5.13006	-31.26885
336	5	2	2013	5	57	39	5.16377	-31.45802
337	5	2	2013	6	56	26	5.19609	-31.64590
338	5	2	2013	8	3	19	5.23293	-31.85659
339	5	2	2013	9	1	34	5.26509	-32.04101
340	5	2	2013	9	55	52	5.29531	-32.21431
341	5	2	2013	11	8	1	5.33272	-32.42889
342	5	2	2013	12	6	6	5.36367	-32.60594
343	5	2	2013	13	2	21	5.39376	-32.77851
344	5	2	2013	14	5	44	5.42738	-32.97132

345	5	2	2013	15	4	22	5.45751	-33.14407
346	5	2	2013	16	45	4	5.51076	-33.44944
347	5	2	2013	18	58	54	5.58180	-33.85688
348	5	2	2013	21	2	54	5.64896	-34.24204
349	5	2	2013	22	6	21	5.68315	-34.43824
350	5	2	2013	22	59	53	5.71203	-34.60475
351	6	2	2013	0	3	31	5.74662	-34.79991
352	6	2	2013	1	5	55	5.77976	-34.99227
353	6	2	2013	2	2	26	5.81018	-35.16694
354	6	2	2013	3	1	1	5.84170	-35.34754
355	6	2	2013	3	58	20	5.87309	-35.52748
356	6	2	2013	4	58	19	5.90585	-35.71572
357	6	2	2013	6	4	19	5.94197	-35.92292
358	6	2	2013	6	59	2	5.97274	-36.09927
359	6	2	2013	8	1	47	6.00813	-36.30265
360	6	2	2013	8	58	48	6.04075	-36.48929
361	6	2	2013	9	58	2	6.06927	-36.68588
362	6	2	2013	10	59	11	6.11008	-36.88753
363	6	2	2013	12	26	50	6.16058	-37.17698
364	6	2	2013	13	0	23	6.17972	-37.28712
365	6	2	2013	14	7	16	6.21841	-37.50885
366	6	2	2013	15	3	46	6.25129	-37.69808
367	6	2	2013	16	9	58	6.28968	-37.91882
368	6	2	2013	16	13	41	6.29188	-37.93113
369	6	2	2013	16	58	30	6.31796	-38.08070
370	6	2	2013	18	0	43	6.35470	-38.29205
371	6	2	2013	18	57	37	6.38849	-38.48587
372	6	2	2013	20	12	42	6.43364	-38.74486
373	6	2	2013	20	57	20	6.46022	-38.89696
374	6	2	2013	22	4	30	6.50025	-39.12748
375	6	2	2013	22	58	40	6.53242	-39.31207
376	7	2	2013	0	8	15	6.57368	-39.55017
377	7	2	2013	1	2	57	6.60665	-39.73805
378	7	2	2013	2	4	30	6.64173	-39.94011
379	7	2	2013	2	59	19	6.67223	-40.11612
380	7	2	2013	3	59	49	6.70493	-40.30346
381	7	2	2013	4	59	7	6.73659	-40.48630
382	7	2	2013	6	2	17	6.77066	-40.68161
384	7	2	2013	7	0	51	6.80162	-40.85890
385	7	2	2013	7	59	18	6.83156	-41.03104
386	7	2	2013	8	56	18	6.86050	-41.19740
387	7	2	2013	10	0	1	6.89226	-41.38001
388	7	2	2013	10	55	20	6.91873	-41.53148
389	7	2	2013	12	14	51	6.95638	-41.74963

390	7	2	2013	13	1	27	6.97918	-41.87970
391	7	2	2013	18	54	20	7.00456	-42.01270
392	7	2	2013	20	8	1	7.12467	-42.20907
393	7	2	2013	20	59	46	7.21025	-42.35285
394	7	2	2013	22	12	49	7.33510	-42.56261
395	7	2	2013	23	2	52	7.42179	-42.70812
396	8	2	2013	0	0	48	7.52416	-42.88038
397	8	2	2013	1	8	40	7.64272	-43.07959
398	8	2	2013	2	25	54	7.77806	-43.30721
399	8	2	2013	3	1	54	7.84228	-43.41510
400	8	2	2013	4	0	42	7.94866	-43.59456
401	8	2	2013	5	2	9	8.06391	-43.78814
402	8	2	2013	5	58	8	8.16587	-43.95939
403	8	2	2013	6	58	36	8.27593	-44.14474
404	8	2	2013	7	58	41	8.38611	-44.33032
405	8	2	2013	8	57	7	8.49411	-44.51221
406	8	2	2013	9	56	9	8.59986	-44.69082
407	8	2	2013	10	57	55	8.71322	-44.88133
408	8	2	2013	12	4	41	8.83315	-45.08372
410	8	2	2013	13	1	4	8.93333	-45.25251
411	8	2	2013	14	7	31	9.05009	-45.44954
412	8	2	2013	15	2	57	9.14864	-45.61579
413	8	2	2013	16	6	31	9.25947	-45.80295
414	8	2	2013	16	57	29	9.34628	-45.95055
415	8	2	2013	18	4	44	9.46369	-46.14779
416	8	2	2013	18	58	16	9.55607	-46.30371
417	8	2	2013	20	6	5	9.67133	-46.49786
418	8	2	2013	20	57	13	9.75605	-46.64242
419	8	2	2013	22	6	52	9.87561	-46.84315
420	8	2	2013	23	0	10	9.97198	-47.00781
421	8	2	2013	23	58	19	10.07286	-47.17801
422	9	2	2013	1	4	55	10.18960	-47.37478
424	9	2	2013	2	4	28	10.29418	-47.55156
425	9	2	2013	3	2	39	10.39738	-47.72696
426	9	2	2013	3	58	55	10.49721	-47.89572
427	9	2	2013	4	59	24	10.60126	-48.07319
428	9	2	2013	5	59	24	10.70638	-48.25046
429	9	2	2013	6	58	21	10.80748	-48.42341
430	9	2	2013	8	7	38	10.92814	-48.62654
431	9	2	2013	8	58	39	11.01579	-48.77337
432	9	2	2013	9	59	13	11.12168	-48.95662
433	9	2	2013	10	58	43	11.22904	-49.13761
434	9	2	2013	12	4	16	11.34476	-49.33474
435	9	2	2013	12	55	59	11.43667	-49.48990

436	9	2	2013	14	6	5	11.55978	-49.70065
437	9	2	2013	15	2	48	11.65890	-49.86889
438	9	2	2013	16	11	58	11.78042	-50.07515
439	9	2	2013	16	58	55	11.86241	-50.21528
440	9	2	2013	18	8	23	11.98477	-50.42347
441	9	2	2013	18	59	23	12.07506	-50.57847
442	9	2	2013	20	0	17	12.18476	-50.76404
443	9	2	2013	20	57	36	12.28776	-50.93985
444	9	2	2013	21	57	36	12.39304	-51.11943
445	9	2	2013	23	2	57	12.50732	-51.31433
446	9	2	2013	23	59	31	12.60670	-51.48407
447	10	2	2013	1	0	23	12.71371	-51.66680
448	10	2	2013	2	12	33	12.83928	-51.88143
449	10	2	2013	3	3	26	12.92695	-52.03117
450	10	2	2013	4	1	10	13.02610	-52.20068
451	10	2	2013	4	59	40	13.12683	-52.37315
452	10	2	2013	5	57	40	13.22567	-52.54233
453	10	2	2013	6	59	11	13.33150	-52.72350
454	10	2	2013	7	56	26	13.43054	-52.89324
455	10	2	2013	8	59	11	13.53881	-53.07866
456	10	2	2013	9	58	41	13.63966	-53.25158
457	10	2	2013	10	55	34	13.73670	-53.41794
458	10	2	2013	13	0	25	13.95083	-53.78558
459	10	2	2013	14	3	3	14.05703	-53.96793
460	10	2	2013	15	2	58	14.15775	-54.14097
461	10	2	2013	16	10	5	14.26990	-54.33394
463	10	2	2013	16	59	59	14.35408	-54.47872
464	10	2	2013	18	6	39	14.47047	-54.67878
465	10	2	2013	18	57	52	14.56020	-54.83343
466	10	2	2013	19	59	38	14.66935	-55.02150
467	10	2	2013	20	56	31	14.77112	-55.19671
468	10	2	2013	22	13	33	14.90993	-55.43601
469	10	2	2013	22	59	47	14.99395	-55.58083
470	11	2	2013	0	3	60	15.10830	-55.77826
471	11	2	2013	1	4	32	15.21473	-55.96209
472	11	2	2013	2	2	35	15.31479	-56.13492
473	11	2	2013	2	58	26	15.41227	-56.30343
475	11	2	2013	4	3	13	15.52522	-56.49871
476	11	2	2013	5	1	28	15.62501	-56.67141
477	11	2	2013	6	0	13	15.72691	-56.84789
478	11	2	2013	6	57	43	15.82796	-57.02278
480	11	2	2013	7	59	12	15.93542	-57.20905
481	11	2	2013	8	59	13	16.04068	-57.39154

Table 7: list of XBT and XCTD comparison experiment casts. Dashes in file number and time columns indicate that no profile could be recorded for those casts. Set number-CTD cast number pairs are:1-2; 2-3; 3-21; 4-34; 5-36; 6-47;

set	file #	day	mon	year	h	min	sec	latitude	longitude	file #	hour	min	sec
	Launcher 1									**Launcher 2**			
1	238	18	1	2013	23	55	59	20.06563	-37.81506	153	23	56	15
1	239	19	1	2013	0	7	8	20.07010	-37.80326	154	0	7	22
1	240	19	1	2013	0	11	53	20.07272	-37.79399	155	0	12	6
1	241	19	1	2013	0	18	57	20.07673	-37.77919	156	0	19	13
1	242	19	1	2013	0	23	1	20.07904	-37.77078	157	0	23	18
1	243	19	1	2013	0	27	43	20.08175	-37.76108	158	0	27	60
1	244	19	1	2013	0	31	42	20.08405	-37.75264	159	0	31	59
1	245	19	1	2013	0	35	37	20.08626	-37.74446	160	0	35	53
1	246	19	1	2013	0	39	32	20.08838	-37.73623	161	0	39	48
1	247	19	1	2013	0	48	16	20.09312	-37.71806	162	0	48	33
2	248	23	1	2013	7	57	33	20.42823	-23.16412	163	7	57	31
2	249	23	1	2013	8	1	7	20.42888	-23.15912	164	8	1	7
2	250	23	1	2013	8	5	41	20.43000	-23.15214	165	8	5	42
2	251	23	1	2013	8	12	51	20.43187	-23.13958	166	8	12	51
2	252	23	1	2013	8	20	16	20.43463	-23.12421	167	8	20	17
2	253	23	1	2013	8	27	43	20.43716	-23.10835	168	8	27	44
3	254	27	1	2013	7	11	58	11.66876	-23.01109	-	-	-	-
3	255	27	1	2013	7	16	59	11.65199	-23.01045	205	7	17	4
3	256	27	1	2013	7	22	33	11.63338	-23.00937	206	7	22	38
3	257	27	1	2013	7	27	27	11.61676	-23.00848	207	7	27	33
3	258	27	1	2013	7	32	2	11.60134	-23.00744	208	7	32	8
3	259	27	1	2013	7	36	36	11.58610	-23.00677	209	7	36	41
3	260	27	1	2013	7	41	22	11.56993	-23.00607	-	-	-	-
3	261	27	1	2013	7	46	34	11.55214	-23.00502	210	7	46	37
3	262	27	1	2013	7	51	19	11.53591	-23.00368	211	7	51	24
4	263	30	1	2013	6	44	50	5.09185	-22.99730	239	6	44	50
4	264	30	1	2013	6	51	8	5.07573	-22.99790	240	6	51	8
4	265	30	1	2013	6	55	52	5.06370	-22.99829	241	6	55	52
4	266	30	1	2013	7	3	15	5.04490	-22.99906	243	7	3	15
4	267	30	1	2013	7	7	40	5.03373	-22.99948	244	7	7	40
4	268	30	1	2013	7	13	56	5.01761	-23.00024	-	-	-	-
4	269	30	1	2013	7	18	14	5.00656	-23.00077	246	7	18	13
4	270	30	1	2013	7	22	11	4.99641	-23.00127	247	7	22	12
4	271	30	1	2013	7	26	50	4.98449	-23.00179	248	7	26	50
4	272	30	1	2013	7	30	27	4.97510	-23.00219	249	7	30	27
5	273	31	1	2013	5	58	30	4.04739	-22.95078	254	5	58	17
5	274	31	1	2013	6	4	21	4.04743	-22.95079	255	6	4	7
5	275	31	1	2013	6	9	38	4.04740	-22.95076	256	6	9	25

5	276	31	1	2013	6	15	12	4.04741	-22.95077	257	6	14	58
5	277	31	1	2013	6	20	26	4.04742	-22.95077	258	6	20	12
5	278	31	1	2013	6	25	4	4.04742	-22.95076	259	6	24	50
5	279	31	1	2013	6	30	22	4.04741	-22.95078	260	6	30	9
5	280	31	1	2013	6	34	28	4.04743	-22.95078	261	6	34	13
5	281	31	1	2013	6	41	42	4.04743	-22.95077	262	6	41	28
5	282	31	1	2013	6	45	55	4.04741	-22.95077	263	6	45	41
6	283	2	2	2013	22	23	18	-0.02501	-22.99047	278	22	23	8
6	284	2	2	2013	22	28	28	-0.02448	-22.98891	-	-	-	-
6	285	2	2	2013	22	31	56	-0.02509	-22.98748	280	22	31	46
6	286	2	2	2013	22	35	44	-0.02629	-22.98632	281	22	35	34
6	287	2	2	2013	22	39	37	-0.02797	-22.98586	282	22	39	27
6	288	2	2	2013	22	42	50	-0.02953	-22.98631	283	22	42	40
6	289	2	2	2013	22	46	31	-0.03120	-22.98751	284	22	46	21
6	290	2	2	2013	22	49	49	-0.03254	-22.98918	285	22	49	39
6	291	2	2	2013	22	53	5	-0.03356	-22.99122	286	22	52	55

ATMOSPHERIC DATA (AEROSE)

Radiosonde Observations (RAOBs)

- A total of 111 Vaisala RS92 rawinsondes, measuring pressure, temperature, humidity (PTU) and winds, were successfully launched (see Figures 12-13); a couple were lost due to various factors, including inclement weather (cross winds without sufficient ship slow-down or heading change) and telemetry problems. 67 radiosondes were launched timed with S-NPP (a new environmental satellite undergoing intensive cal/val) and 43 for MetOp satellite overpasses.
- The 2013 PNE/AEROSE launches have also now put AEROSE at a total of 791 PTU RAOBs acquired over the tropical Atlantic.

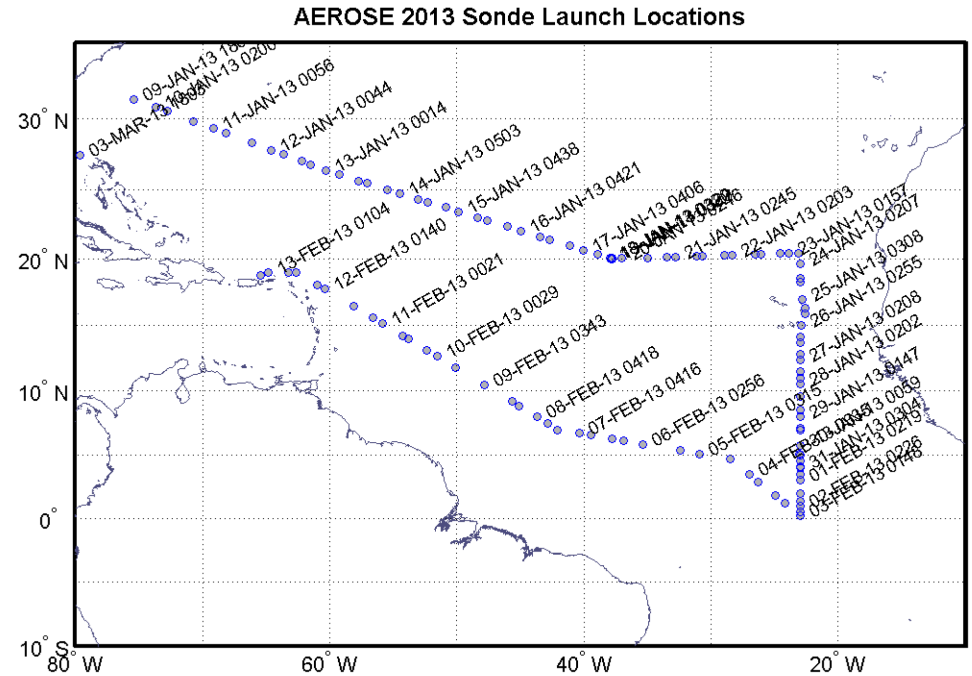

Fig. 12: AEROSE Vaisala RS92 rawinsonde launch locations and times

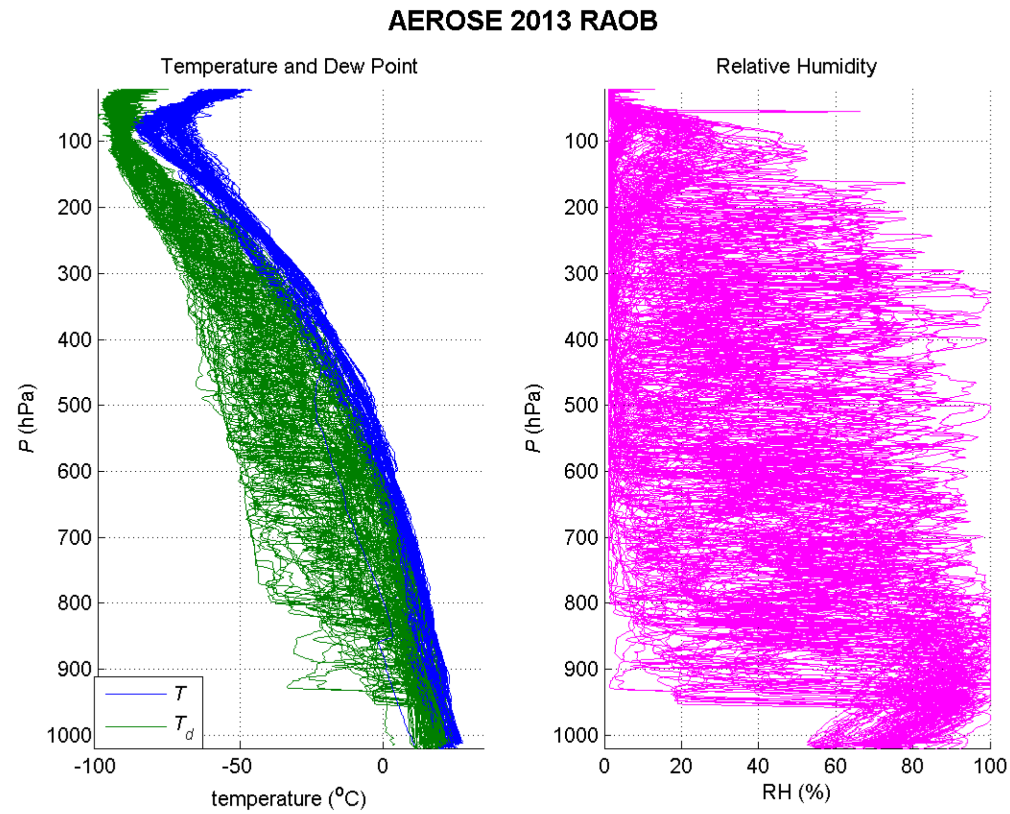

Fig. 13: AEROSE Vaisala RS92 soundings, (left) temperature and dew point, and (right) relative humidity (RH).

<u>Ozonesondes</u>

- A total of 24 EN-SCI ECC ozonesonde packages were interfaced with the RS92 sondes, this providing a sounding of the ozone partial pressure in addition to the PTU measurements (see Figures 14 and 15).
- The 2013 PNE/AEROSE launches have also now put AEROSE at a total of 137 ozone soundings acquired over the tropical Atlantic.
- Initial Preps (IPs) and Day of Flights (DOFs) for ozonesondes were carried out on a daily basis with no major issues.

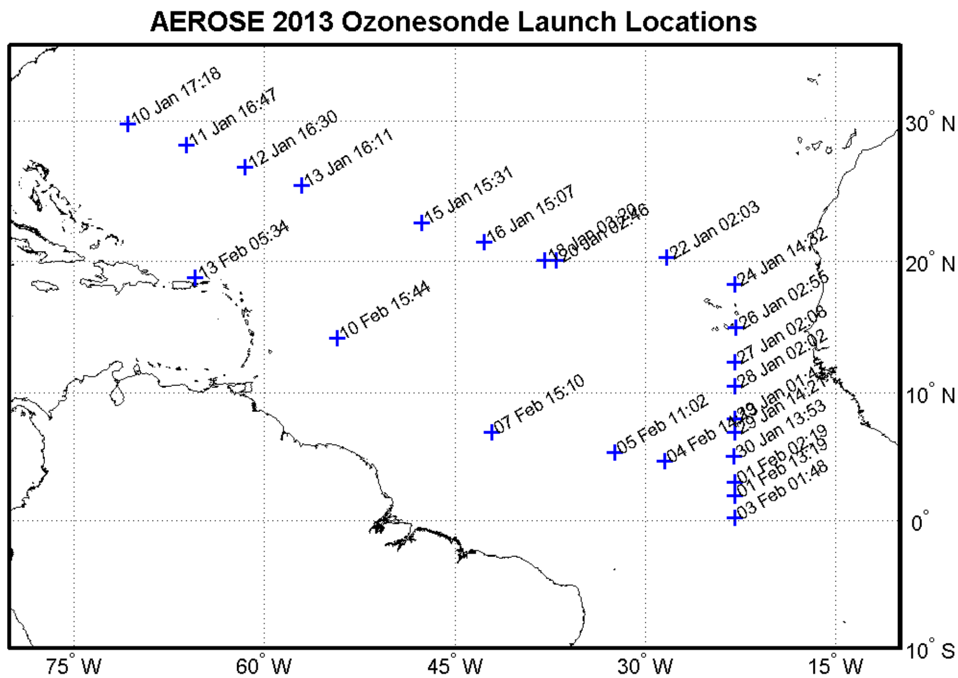

Fig. 14: AEROSE ozonesonde launch locations and times.

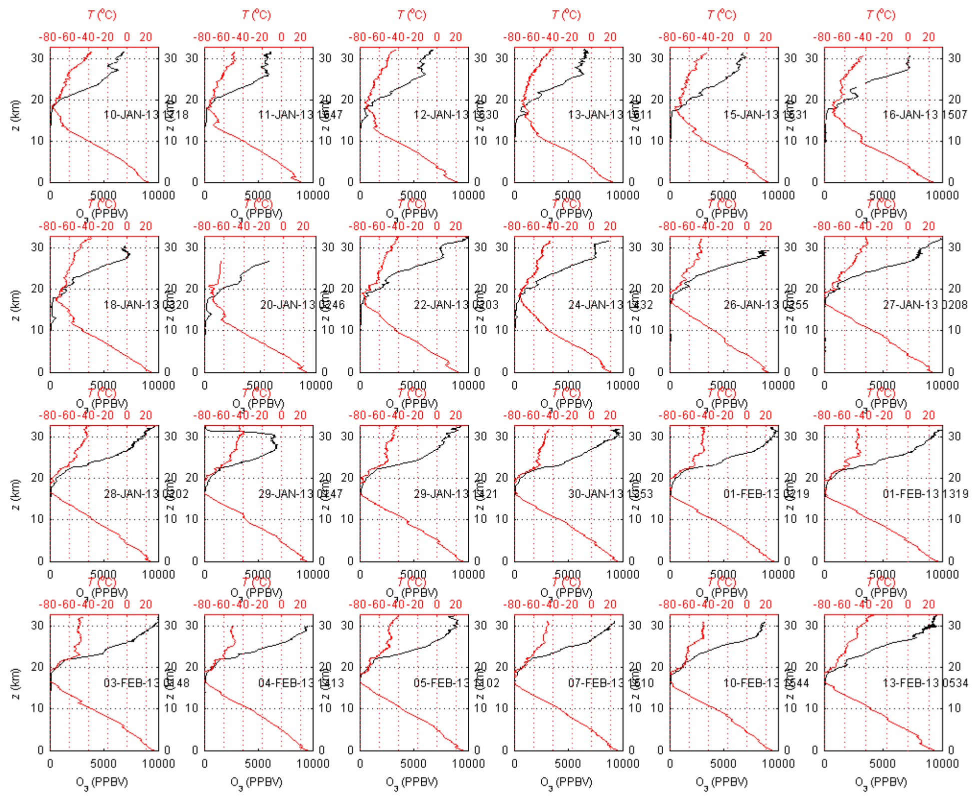

Fig. 15: AEROSE ozonesonde profiles (ozone partial pressure in black, ambient temperature in red).

Microtops Sunphotometer

- Handheld Microtops sunphotometer measurements of multichannel aerosol optical depths (AOD) were performed on a daily basis (Figure 16), except for periods where excessive cloud cover have prevented taking measurements.
- The raw Microtops measurements plotted in Figure 16 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.

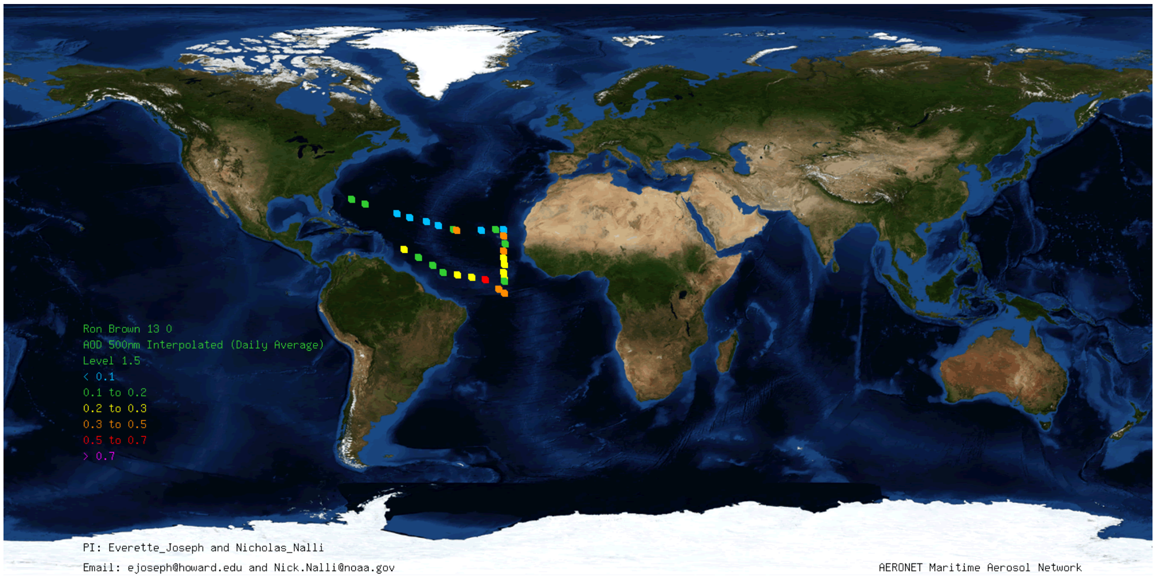

Fig. 16: AEROSE Microtops sunphotometer AOD measurements (GSFC Maritime Aerosol Network processing).

Downwelling Broadband Surface Fluxes

- Pyranometers and pyrgeometers measured downwelling shortwave and longwave radiative fluxes, respectively.

Surface O_3 and NO-NO_X Measurements

- Surface *in situ* ozone and NO_x measurements were taken throughout the cruise.
- Higher concentrations of ozone were noted during the smoke outflow regime.
- A strong anti-correlation was noted between O_3 and NO_x during the smoke regime.

Biological and Chemical Sampling

- Biological samples were collected during AEROSE.
- Laser particle counters (LPCs) ran nearly continuously during the cruise. Data collected from the LPCs appeared to be largely consistent with the aerosol regimes and other datasets described elsewhere.