PIRATA Northeast Extension/AEROSE
2019 Cruise Report
NOAA R/V *Ronald H. Brown*
RB-19-02

1 March - 29 March 2019
Charleston, South Carolina to Charleston, South Carolina

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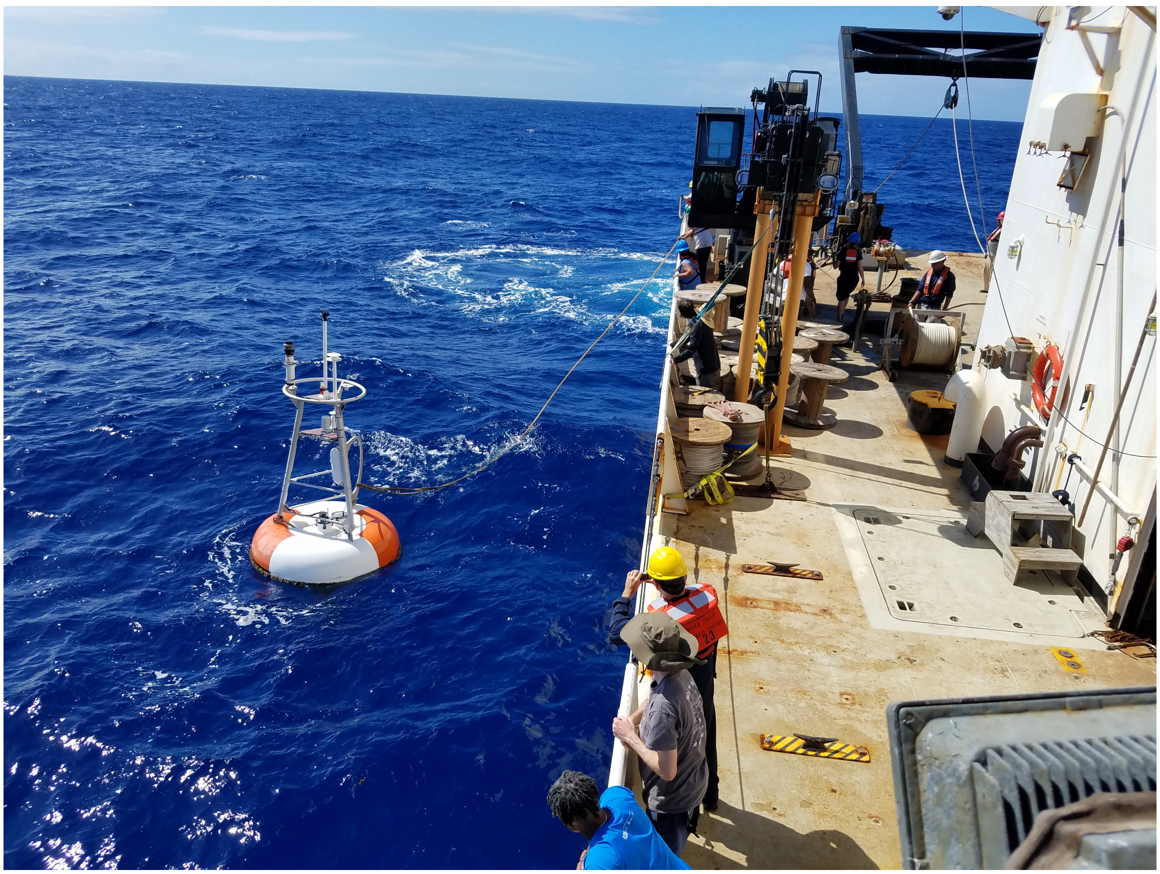


PIRATA Northeast Extension 2019 Scientific Party:

Figure 1: Scientific party just offshore of Praia, Cabo Verde (front left to right): LT Eduardo Dubeux, Diego Ugaz, Steve Kunze, Jessica Capista; (back left to right): 2o Sargento Eric Silva, Chief Scientist Renellys Perez, Kafayat Olayinka, Daniel Yeager, Nick Nalli, Aqua Sanders, Christopher Thomas, Vernon Morris, Francis Mensah, Brian Carroll, Erik Valdes, Jonathan Christophersen, Felix Lopez, Denise Kester (not in picture).

Oceanographic Observations:

Renellys Perez (NOAA/AOML), Erik Valdes, Diego Ugaz, Jonathan Christophersen (UM/CIMAS, NOAA/AOML), Jessica Capista, Felix Lopez (volunteers)

ATLAS, T-FLEX Moorings:

Steven Kunze (NOAA/PMEL), Denise Kester (UW/JISAO, NOAA/PMEL), LT Eduardo Dubeux, 2º Sargento Eric Silva (Brazilian Navy)

Atmospheric and Meteorological Observations:

Vernon Morris (Howard University), Nick Nalli (NOAA/NESDIS), Kafayat Olayinka, Daniel Yeager, (Howard University), Francis Mensah, Christopher Thompson (Virginia Union University), Aquanette Sanders (UNC), Brian Carroll (UMBC)

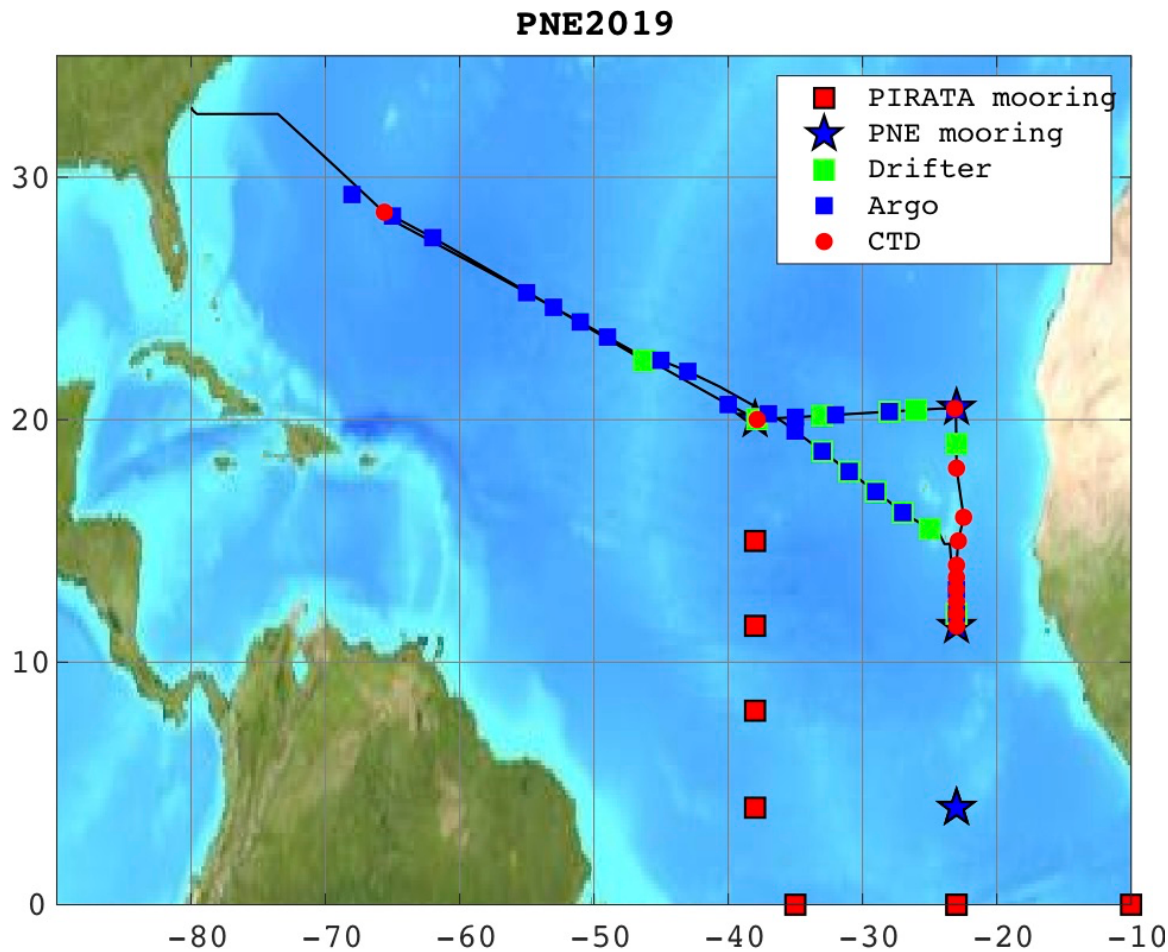


Figure 1: Cruise track of PNE2019 (black), Charleston, South Carolina to Charleston, South Carolina. Blue stars indicate the locations of PIRATA Northeast Extension moorings; red squares indicate some of the PIRATA backbone moorings; red dots are the locations of CTD casts conducted during the cruise. Blue and green squares indicate the locations of Argo profiling float and drifter deployments, respectively.

OVERVIEW: The primary goals of the 2019 PIRATA Northeast Extension (PNE2019) and the Saharan Dust AERosols and Ocean Science Expeditions (AEROSE) Cruise (RB-19-02) was 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 along a cross-equatorial transect along 23°W, and to collect atmospheric observations in support of the AEROSE project, as well auxiliary measurements for the Marine Atmospheric Emitted Radiance Interferometer (M-AERI) project. The cruise track passed through subtropical North Atlantic and tropical regions in both hemispheres of the Atlantic Ocean. Key oceanographic regions sampled include the southeast corner of the subtropical North Atlantic (a region of subduction for the subtropical cell circulation); the western boundary of the subtropical North Atlantic (a region with surface and subsurface western boundary currents that transport key water masses); the Guinea Dome and oxygen minimum shadow zone where the subtropical and tropical gyres meet. These regions are climatologically significant, and the data collected will provide an improved picture of seasonal-to-interannual oceanic and atmospheric variability in the tropical Atlantic.

Not all of the major scientific goals of RB-19-02 were achieved. Due to delays related to the government shutdown and mechanical issues stemming from work done during shipyard repairs by Caterpillar, the days at sea (DAS) for the RB-19-02 cruise were whittled down from 41 to 29 DAS. This reduction in days at sea, combined with long steams to/from Charleston, South Carolina meant that both PNE and AEROSE could not meet all of their science objectives before the Ronald H. Brown even sailed (most of the hydrographic stations were cut). In addition, a crew member became ill midway through the cruise. After servicing the 11.5°N, 23°W mooring, the ship returned to Praia to evacuate the crew member via small boat. After the crew member was safely ashore, the decision was made by leadership to cut the cruise short. This decision meant that the 4°N, 23°W mooring was not recovered and redeployed, despite only being 2 days away from reaching that mooring. We abruptly ended AEROSE operations along 23°W and missed the opportunity to fully sample a big Saharan air layer event that was occurring.

We thank the crew of the *Ronald H. Brown* for their work and input before and during the cruise during a challenging mission and following the government shutdown. The Field Operations Officer LT Rachel Pryor, the scientific and engineering teams on the lab and on the ship, and the deck crew did an exemplary job of developing and executing a plan to rapidly and efficiently make cruise preparations rapidly after the government shutdown. Mooring operations were very efficient thanks to the efforts of Chief Bosun Mike Lastinger and his crew, as well as experienced maneuvering lead by CAPT Dan Simon and NOAA Corps Officers. Diligent work by the E.T. and survey techs allowed us to quickly troubleshoot CTD technical problems and to conduct as many CTDs as possible given the constraints, as well as seamlessly collect shipboard and atmospheric observations throughout the cruise.

Introduction

1. PIRATA Northeast Extension (PNE)

PIRATA stands for "Prediction Research Moored Array in the Tropical Atlantic" and is a three-party project between 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. This array is the Atlantic's analogue of the Pacific Ocean's Tropical Atmosphere Ocean (TAO) array. The PIRATA array consists of a backbone of ten moorings that runs along the equator and extends 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 on rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. The northeastern Tropical Atlantic includes the southern edge of the North Atlantic subtropical gyre, defined by the westward North Equatorial Current (NEC), and the northern edge of the clockwise tropical/equatorial gyre defined by the North Equatorial Countercurrent (NECC). The mean meridional currents in the northeastern Tropical Atlantic are typically weak (on the order of 5 to 10 cm/sec) compared with the robust mean zonal velocities of the South Equatorial Current (SEC), Equatorial Undercurrent (EUC), NEC, and NECC. However, both zonal and meridional velocity can exhibit large fluctuations between 5ºS and 5ºN along 23ºW associated with the passage of tropical instability waves. This area is home to the North Atlantic's oxygen minimum zone (OMZ) 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 TA. 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 latitude band of 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 and the Caribbean islands. Prominent examples include Andrew (1992), Floyd (1999), Ivan (2004), Irma (2017), and Florence (2018). An average season has two Cape Verde hurricanes, but some years have up to five while others have none. There is uncertainty regarding the specific atmospheric/oceanic conditions that determine which atmospheric waves will develop into tropical cyclones and then hurricanes. Specifically, the quantitative effects of the Saharan Air 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., El Niño South Oscillation 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 except for the 38ºW line of moorings extending north to 15ºN. In 2005, a formal Northeast Extension of PIRATA was proposed as a joint project between NOAA/AOML and NOAA/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 on the equatorial backbone mooring there), and a fourth extending the 38°W arm up to 20°N.

In June 2006, the first two moorings of this extension were deployed on *Ronald H. Brown* during RB-06-05a. 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 moorings were added at 20.5°N, 23°W and 20°N, 38°W. The four moorings were planned for servicing during the April 2008 cruise RB-08-03. Due to the cancellation of this cruise, the buoys failed and a data gap was introduced in mid to late 2008. All four sites were subsequently serviced in November 2008 by NOAA charter of the French R/V *Antea*. In 2009-2011, the four moorings were serviced by *Ronald H. Brown* cruise during RB-09-04, RB-10-03, and RB-11-01. Cancellation of the cruise RB-12-05 led to another gap in the record. After the make-up cruise in January-February 2013, all four buoys, which need to be serviced annually, were once again reporting meteorological and oceanographic data onto the Global Telecommunications System for weather and climate forecasting. The optimal configuration to conduct a PNE cruise and service the moorings is once every 12 months. The five most recent cruises have occurred within 9-15 months of one another, and have on average met that mark: November-December 2013 on *Ronald H. Brown* during RB-13-06, January-February 2015 on the UNOLS R/V Endeavor, and November-December 2015 on the NATO R/V Alliance, February-March 2017 on *Ronald H. Brown* during RB-17-01, and March-April 2018 on *Ronald H. Brown* during RB-18-02.

Three of the four PNE moorings were serviced during the PNE2018 cruise and are currently successfully reporting meteorological and oceanographic data onto the Global Telecommunications System for weather and climate forecasting. The mooring at 20.5°N, 23°W was not serviced, due to rough seas and strong winds. However, the French were able to replace the surface sensors in April 2018, minimizing any data gaps. 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 cannot 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.*

Ronald H. Brown's cruise RB-19-02 served to honor this commitment for the fiscal year 2019.

2. Aerosols and Ocean Science Expeditions (AEROSE)

Uncertainties remain in our understanding of the impact of mineral dust and biomass burning aerosols on the weather, climate, and atmospheric chemistry of the tropical Atlantic. The African continent is one of the world's major source regions of mineral dust and biomass burning aerosols. Saharan dust storms are estimated to inject over 3×10^{12} kg of mineral aerosols into the troposphere annually, with large quantities advecting westward over the tropical North Atlantic within tropical easterly winds and waves. These aerosols influence phenomena ranging from convection, cloud seeding and precipitation, ocean fertilization, and downstream air quality and ecosystem impacts in the Caribbean and U.S. eastern seaboard. Red tides, increasing rates of asthma, and precipitation variability in the eastern Atlantic and Caribbean have also 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 remain important topics of ongoing research.

The detailed interplay between thermodynamics, microphysics, and aerosol chemistry are currently unknown and limited by the shortage of field measurements in remote but critical regions like the tropical Atlantic. In order to advance our understanding of these complex interactions during the atmospheric lifecycle of atmospheric particulate originating from Africa and to improve predictive models, it is important that we address gaps in our understanding of regional and trans-boundary aerosol issues. This makes the need for understanding the transport and evolution of aerosols originating from natural and anthropogenic processes in Africa a high priority. Mineral dust aerosols are predominantly solid particulate so the chemical processing is largely restricted to the surface of the particulate. In situ observation of the SAL conducted aboard a research vessel transecting the tropical Atlantic enables both Eulerian and semi-Lagrangian measurements of dust-laden air masses with little influence from surface emissions for days to weeks at a time. Additionally, a significant challenge in chemistry and transport models is capturing the interaction of different aerosol types within the same air mass (e.g. mineral dust aerosols and biomass burning aerosols). The physical and chemical coupling of these unique particulate in a single aerosol column likely have non-additive affects on radiative balance, chemistry, and cloud microphysics. At the same time that they are interacting with each other, they also evolve compositionally based on the atmospheric conditions in the marine troposphere. AEROSE seeks to collect measurements that will enable answers to fundamental questions regarding the chemical evolution of the surface of the mineral dust particulate, how mineral dust and biomass burning aerosol interact in the atmospheric column, the nature of dynamics of the microbial populations during transport - especially the viable fraction, and the feedbacks between aerosol properties and gas phase chemistry.

The NOAA Aerosols and Ocean Science Expeditions (AEROSE) constitute 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. The project, involving international coordination of monitoring in Puerto Rico, Mali, the Canary Islands, and Senegal, 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 campaigns (to date, comprised of thirteen separate trans-Atlantic Project legs) have provided 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. AEROSE has sought to address three central scientific questions:

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

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

Order of operations:

Loading for the PNE2019 was conducted at Pier Papa in Charleston, South Carolina on February 19-20, 2019. Because we were onboarding a heavy 20-foot container on the forward 02 deck for the AEROSE group, a shoreside crane was rented for loading. The shoreside crane was also used to load the PhOD 20-foot container on the main aft deck on the port side inboard spot. The Field Operations Officer LT Rachel Pryor and the deck crew led by Chief Bosun Mike Lastinger did an exemplary job of developing and executing a plan to move equipment around and keep the deck space as clear as possible.

After a few unsuccessful sea trials and a 11-day delay of the cruise start date due to several mechanical issues (generator #2 full overhaul and replacement of a broken dishwater motor), the *Ronald H. Brown* left Charleston, South Carolina and commenced PNE2019 on March 1st at 12h00 EST. During the delay, the scientific party set up the conductivity temperature depth (CTD) frame with temperature, conductivity, and oxygen sensors and the LADCPs (see Table 1 for the list of sensors), arranged equipment in the laboratory spaces, and connected the field laptops to the computer network. We spoke with the survey techs, hydrography team, and Chief Ops Officer about the first test CTD cast, and the status of the forward and aft winches. We decided to try to use the aft winch first because it had the newer cable. We decided to do a first test cast with the railroad wheel (load test), followed by a second test cast with our instrument package (electrical test). The aft winch was used throughout the entire cruise.

Table 1. CTD sensor history. Date when CTD sensors were added/changed on the frame. For the entire cruise, the upward looking ADCP was S/N #15329, and downward looking ADCP was S/N #24472. The CTD fish serial number was #1165.

Date	Temp1	Temp2	Cond1	Cond2	Oxy1	Oxy2	Pump1	Pump2
2/21/2019	4799	2958	1346	3858	2934	2948	7742	7705

The *Ronald H. Brown* had a long steam to the first PNE mooring at 20°N, 38°W. After the first day of the steaming, on March 2, it was noted by the AOML ocean chemistry team in Miami, Florida that there were issues with the thermosalinograph (TSG) data, specifically an offset the temperature values recorded in two different portions of the throughflow. It was determined that the location of the SBE38 sensor in the flow-through system was not good. A temporary fix of the SBE38 positioning was performed on March 9th, which helped for the time being. A more permanent solution is needed when the *Ronald H. Brown* is in drydock. Note: It was determined that the pCO2 data was fine as it uses a different SST estimate (TSG45).

The hydrography team consisted of Renellys Perez (Chief Scientist), Diego Ugaz, and Felix Lopez on the day shift (5:30am – 5:30pm), with Erik Valdes (Night Watch Leader), Jonathan Christophersen, and Jessica Capista on the night shift (5:30pm – 5:30am). Each shift was responsible for any CTD operations, drifter and Argo float deployments that happened during those hours. Renellys and Jonathan were responsible for running the Autosal on alternating shifts, and Diego and Erik for oxygen titrations on alternating shifts. The volunteers ran the console, and everyone participated with sampling. We also trained the volunteers on Autosal and oxygen titrations during the cruise. Because of the limited number of CTDs, when appropriate, the hydrography team also aided with radiosonde and ozonesonde launches, microtops data collection (which measure solar irradiance from which we can infer optical depth), and mooring deployments and recoveries.

On March 2, Renellys Perez developed a strategy with one of the volunteers, Felix Lopez, on the best way to conduct Sargassum surveys throughout the cruise. Additional input on survey data collection was received from our PIRATA colleague in France, Bernard Bourles. We decided to track the date, time, latitude and longitude coordinates, the type/shape of Sargassum observed (absence, trace, filaments, mats), and the sea surface temperature (SST) and sea surface salinity (SSS) readout from the ship's TSG system. This information was tabulated by Felix and Renellys (see later section on Sargassum surveys and Figure 7).

The load test down to 1500 m was done on March 4th at 28°33.47'N, 65°36.15'W and was successful. There was adequate tension on the winch cable during the downcast and upcast. The second test cast with our CTD package was done after the load test at 16:32 GMT down to ~1500 m, and all went well. After these two tests, we continued steaming to the first mooring. During the transit, we deployed five Argo profiling floats. We arrived at the 20°N, 38°W mooring on March 10th and conducted mooring recovery and deployment operations from around 1pm to midnight local ship time. Upon deployment, the anchor traveled further than intended and landed in a region slightly shallower than planned. The TC sensor at 20m depth wasn't communicating. Despite, these two issues, the deployment was considered to be a success. After the mooring operations were completed, a CTD (station #002) was performed at 20°0.38'N, 37°50.50'W on March 11th. at 02:09 GMT.

We then started transiting toward the 20°N, 23°W mooring. During this transit we deployed five drifters and three Argo profiling floats. We arrived at the mooring site on March 14th at 08:00 local time. The recovered mooring was extremely barnacle encrusted and there was excessive damage to sensors from fishing lines and/or biofouling due to the mooring being in the water for an extra year. The ship's crew had some difficulties hooking the mooring during the recovery and the ship had to maneuver to catch the buoy. As a result, the meteorological instruments and the tower got damaged during the recovery (i.e., damage occurred when the buoy hit the side of the ship). Otherwise, the recovery and redeployment went well. The anchor landed in the right location and there was a hundred percent data return from all of the sensors. The CTD (station #003) at 20°27.46'N 23°7.51'W was done after mooring operations were completed at 19:01 on March 14th and was successful.

Because of the time of our arrival at the next mooring we were able to squeeze in eight CTD casts during the transit between 20°N and 12°N (see Table 2). We tried to focus these stations closer to 12°N (mostly south of 16°N) to at least collect some hydrographic data in the oxygen minimum zone. We hoped to be able to do additional CTDs between the 12°N and 4°N mooring, if the mooring operations continued to be efficient and there were some time savings. Note, because of so many CTD stations being cancelled we collected duplicate samples for additional sensitivity testing of the Autosal analysis and Winkler titration process at most of the stations. During the transit to the next mooring, we deployed three Argo floats and two drifters.

On March 17th, we arrived at the 11.5°N, 23°W mooring and conducted a successful recovery and deployment starting at approximately 08:00 local ship time. After the mooring operations, we conducted another CTD (station #012) at 18:24 GMT. After deployment, there were some communication issues between the mooring, but we decided to continue southward to wait for the next communications with Iridium before deciding what to do next. While awaiting successful communications with the mooring, the ship's officers informed us that a crew member had a medical issue and that he needed to head to Praia, Cape Verde for immediate treatment. The crew evacuated the crew member off the ship using the small boat. At that point, NOAA made the decision to end the cruise and we started steaming back to Charleston on March 18th.

Cancelling the cruise early meant that we were unable to recover and redeploy the 4°N, 23°W mooring and that no hydrographic casts or underway shipboard measurements occurred south of 11.5°N, 23°W. We were also in the middle of a very strong Saharan dust event, and we were unable to finish sampling through that. At 4°N, 23°W, we had planned to redeploy eleven Aquadopps as part of the Tropical Atlantic Current Observations Study (TACOS).

While steaming back to Charleston, we continued to launch sondes (Figures 8-10), deploy drifters and Argo profiling floats, and collect ocean and atmospheric underway measurements. AEROSE needed to remap all of their satellite overpasses and trajectories, and the hydrography team needed to change the plan for our drifter and Argo deployments (six drifters and nine Argo floats were deployed during the return home). On March 23rd, we intercepted a French adventurer, Jean-Jacques Savin, who was travelling in a barrel (Figure 11). We provided him with water, food, and some supplies before he continued on his journey. We arrived in Charleston on March 29th at 12:16 local time, and scientists remained for 2-3 days for the offload. A shoreside crane was rented for the offload of the AEROSE and PhOD 20-foot vans.

Problems/Issues

Mechanical delays and government shutdown. Because of mechanical delays and the government shutdown, the PNE2019 cruise could not slide to the right in the Ronald H. Brown's schedule. For this reason, we lost 11 days at sea which was incredibly detrimental to the hydrography component of the cruise, only allowed us to do mooring operations at 3 of the PNE moorings, and prevented us from collecting underway ocean and atmospheric measurements south of 11°N. Because we could not visit the 4°N, 23°W mooring, we were unable to refresh TACOS array during this cruise. Luckily, a subsequent cruise aboard the UNOLS R/V Thomas Thompson was able to conduct the recovery and redeployment of the 4°N, 23°W. We were also unable to do a flyby at the French PIRATA mooring at 0°, 23°W and the Brazilian PIRATA mooring at 8°N, 38°W, as planned. This was particularly unfortunate for the Brazilian mooring as that mooring stopped reporting in January 2019. If time had permitted, we would have searched for and possibly recovered the mooring.

Summary of PNE2019 data collected and operations conducted on this cruise:

1. Successful recovery of PNE T-Flex moorings at 20°N, 38ºW and along 23°W at 20.5°N and 11.5°N and redeployment of T-Flex moorings at these three locations. We did not do mooring operations at 4°N, 23°W.
2. The moorings at 20.5°N and 11.5°N were deployed with total dissolved oxygen loggers.
3. 12 CTD/LADCP profiles out of the planned 61 profiles were collected. These hydrographic casts were collected at a test cast location, at the 20°N, 38ºW, 20.5°N, 23°W, and 11.5°N, 23°W moorings, and at eight stations along 23°W between the second and third mooring. All of the casts extended down to 1500 m (or just above the seafloor for one cast where the topography was shallower than 1500m).
4. Salinity of the water samples collected from 12 Niskin bottles on the CTD rosette.
5. Dissolved oxygen concentration in the water samples collected with the bottles.
6. We collected duplicate samples for additional sensitivity testing of the autosal analysis and Winkler titration process.
7. Successful autosal analysis and Winkler titrations to calibrate the CTD cast data.
8. Successful deployment of 22 Argo profiling floats.
9. Successful deployment of 14 surface drifters.
10. Continuous recording of shipboard ADCP data.
11. Shipboard heading data for ADCP processing
12. Continuous recording of Thermosalinograph (TSG) data and pCO_2 data, albeit with some issues in the SBE38 data (as noted above).

13. AEROSE successfully conducted 101 radiosonde and 8 ozonesonde launches.

Mooring Operations

Summaries of the mooring operations, lost or damaged instruments, pre-deployment hardware failures, acoustic releases employed, and evidence of vandalism are presented in the tables and text below.

Summary of Mooring Operations		
Site	Mooring ID #	Operation
20N38W	PT021 / PT027	Rec / Depl
20.5N23W	PT012 / PT028	Rec / Depl
11.5N23W	PT022/ PT030	Rec / Depl
4N23W	PT009 / PT023	Scheduled Rec / Depl Cancelled

Lost or Damaged Instruments and Equipment *(from rec moorings)*				
Site	Mooring ID	Sensor type	Serial No	Comments
20N38W	PT021	SBE37-IMP	15419	½ of cable clamp missing
20N38W	PT021	SBE39-TP-IMP	4875	Thermistor guard cage missing
20.5N23W	PT012	Gill Wind	16020032	Top sheared off on recovery
20.5N23W	PT012	Rain	1048	Broken on recovery
20.5N23W	PT012	SBE37-IMP	12669	Broken in half
20.5N23W	PT012	SBE37-IMP	12680	Both parts of clamp missing
20.5N23W	PT012	Tower	7-12	Ring bent, rain mount damaged
11.5N23W	PT022	Top section	43	SST/C cable severed
11.5N23W	PT022	SBE37-IMP	13821	½ of cable clamp missing
11.5N23W	PT022	SBE37-IMP	12678	Both parts of clamp missing

On-deck instrument or hardware failure *(pre-deployment)*		
Sensor type	Serial No	Comments
Nortek Aquadopp	13656	No inductive comms
Rain Gauge	1674	No data ~50% of the time

Acoustic Releases
All Acoustic Releases Performed Well

Fishing and Vandalism		
Site	Mooring ID	Comments
20N38W	PT021	Clump of longline fouling on top of sensor. 20m sensor missing half of clamp
20.5N23W	PT012	Encased in longline. Sensor broken in two below head
20.5N23W	PT012	Both parts of clamp missing. Sensor was resting on the 60m sensor.
11.5N23W	PT022	Cable chafing caused by hawser looped around base of tower cable leg
11.5N23W	PT022	40m and 60m sensors longline fouled, clamps parted, and resting on 79.5m O2 sensor

Shipping notes:

Two step bed trucks were loaded for transport to Charleston. Both arrived on time and were offloaded easily from the pier using a ship crane and forklift.

Due to our inability to turn around the 4N23W mooring and subsequent acquisition of ship time onboard the R/V Thomas G. Thompson to complete that work, the offload at the end of the cruise was separated into two individual shipments with one bound for Seattle on a 48' step bed truck and the other into a 40' container bound for Cape Town, South Africa. Denise Kester remained in Charleston to oversee this offload. In regards to this, the deck department is routinely fully engaged in these evolutions and are very capable at it. With that considered, it is not always necessary to have more than one PMEL participant involved during Charleston loading and offloading operations. However, it is prudent to check with the Chief Bosun on the matter as it should be considered to be a favor to PMEL on their part.

To augment the shipment to Cape Town, three separate shipments were Fed-Ex'd to Charleston containing the following: Reel stand+axles (2), 1ea Nortek Aquadopp, and an Action Packer box containing ratchet straps and reel bushings.

Noteworthy Operational Details:

20N38W-

PT021 Recovery: The site had been flagged for erratic TC120. C10 and C60 were noted as high. The 10m sensor was fouled with longline and the 20m sensor was missing ½ of the cable clamp and found resting atop the 40m sensor. The thermistor guard cage on the 500m sensor was missing. Data from all sensors appears to be complete.

PT027 Deployment: The 20m sensor had failed at some point between the time we lost RF reception during deployment and the flyby. One of the SBE-39IM sensors (it mistakenly wasn't recorded) is being held on to the wire with a single screw in the clamp but felt secure. It was reinforced with zip ties. Anchor fallback was much greater than anticipated and the depth recorded at flyby was shallow which gave us a .995 scope. It was discovered late in the operation that the multi-beam depth sounder was giving false readings. The ET was woken up to turn on the single beam for the reading and it took about an additional hour to finally acquire a believable depth. Some intermittent data were observed on the rest of the inductive loop. Observations of the iridium dial-ins indicated this as well yet most hourly data were fine for temperatures. As of this writing (3/28) the inductive temperature data return looks to have stabilized over the past week.

20.5N23W-

PT012 Recovery: This mooring was unable to be recovered during the previous PNE cruise due to heavy seas and high winds. Dave Zimmerman and Denise Kester were subsequently sent to Cape Verde to meet with the French R/V Thalassa for an emergency servicing in which all of the meteorological sensors and the SST/C sensor were replaced. The 1m, 11.6m, 20m, 300m, and 500m sensors had failed prior to our arrival. The happy hooker malfunctioned (came apart) twice on attempts to grab the teacup handle under a rough sea state and 20kt winds. The ship re-positioned but then hit the tower ring and broke the wind and rain gauges. The tower was not re-usable. There was moderately heavy dust on the surface and heavy biofouling on the shallow underwater sensors. The 20m sensor was found broken in half between the head and the case and was wadded up in a lot of longline. Both halves of the clamp on the 40m sensor were missing and the sensor had come to rest on top of the 60m unit. The 11.6m Aquadopp was recovered with dead batteries and ~6.7mb of data were acquired through external power. The 120m sensor failed during data recovery indicating "Upload failed. Too many retries. Block size < than minimum of 32." The 300m and 500m sensors had failed early in the deployment and were recovered with dead batteries. A new single battery cell was swapped in to acquire the data from each of them and the files recovered were quite small indicating that the battery drain was the probable cause of failure.

11.5N23W-

PT022 Recovery: There was 1 system reset documented while deployed. On recovery the SST/C pigtail was found severed and had been so for quite some time. There were scant remnants of hawser evident at the base of the cable leg and chaffing to the multi-rad cable had worn through the jacketing exposing the shielding. The entire surface package was heavily covered in dust. The Aquadopp dummy plug was gone. Also missing were half of the 40m sensor cable clamp and the whole clamp on the 60m sensor. Both sensors were resting on top of the 79.5m O2 GEOMAR sensor and heavily entwined in longline. Despite the absence of the Aquadopp plug >6mb of data were recovered and the date/time were fine. All other sensors were downloaded without issues.

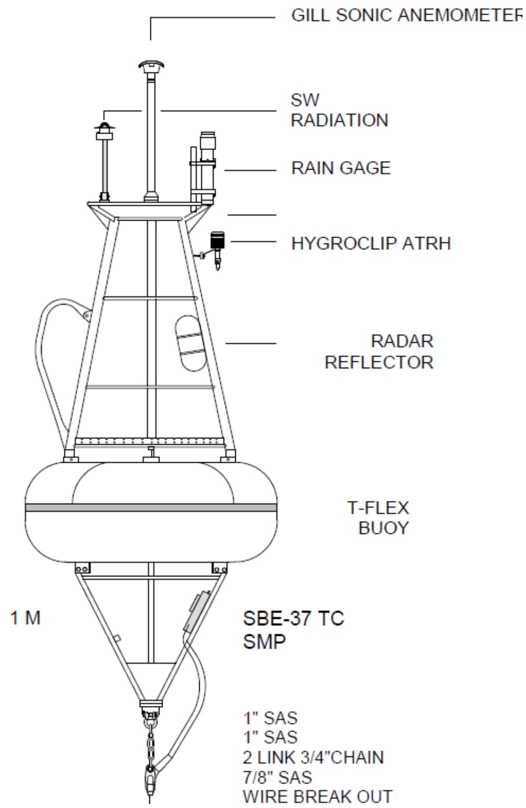
PT030 Deployment: RF communications with the mooring on flyby were unsuccessful despite outstanding reception during deployment and even so after re-sending the calibration file with the Aquadopp included (v1.16, RT O2, w/Nortek) after 700 meters of wire were in the water. Well over an hour was spent at the buoy which was located only a short distance away and in direct line of sight of the antenna. The initial iridium dial-in took place at about an hour after anchor drop and all looked good except for some added blank lines in the O2 data. Due to time constraints the ship headed south with a contingency to return if needed. A check of the next 6 hour dial-in continued to show good indications for all of the sensors but for the curious format of the O2 sensors. The ship meteorological sensor observations were recorded for the operations report. In an email from atlasrt it was stated that the irregularities in the O2 data were not unexpected.

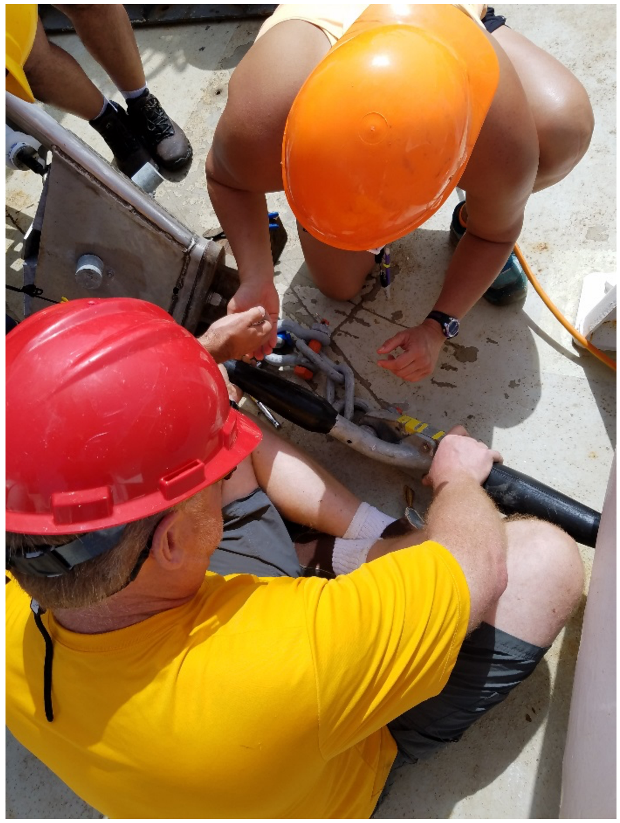
Instrumentation and Hardware Notes:

Nilspin: RAMA marked wire was sent for this cruise versus properly labeled PIRATA wire. This caused a few delays as we needed to measure for the 200 meter OTN sensor placement for all deployments as well as the 150 meter O2 sensor at 20.5N23W.

TFLEX Top Sections: After the issues of inconsistent top section fit were looked at post PI4-17-RB it appears that the inconsistency has been resolved. However, each top section would only mount easily if it was routed in the less desired path around the lead weight pocket. This routing makes the top section much more susceptible to chaffing on the bridle and we did observe this chaffing on one of the recoveries in which it was mounted this way.

A properly fitted top section should follow the most direct path and bend away from the lead pocket when exiting the cable clamp in one continuous catenary going straight to the nilspin socket. All of our mooring diagrams illustrate how this fit should be. If they were to be drawn the way that the top sections currently fit then the cable would bend around the back of the lead pocket and come into the nilspin socket from the left side. It should be pointed out that the mooring diagrams incorrectly illustrate the nilspin socket orientation by 90 degrees.





When we looked at this as a group over at building 8 it was immediately pointed out that the pre-rigged demo had the cable routed in this less desired fashion. I lack the in-depth knowledge to say how this may have come about but one change that has happened over time is that the moorings used to use 3 links of chain versus the 2 links in the current design. This of course offsets the connection by 90 degrees hence, if the cable design strictly in regard to this connection did not alter as the mooring design did, then you would have a much less than optimal fit. Perhaps the fix is as simple as adding one more link back into the chain.

Software Notes:

Filemaker: The new way of reporting operations via Filemaker was a success. One of the more recent changes to the logs involved enlarging the details and comments fields so as to enter longer descriptions and comments without the need for scrolling. This ensured that others that utilize the logs at PMEL would not accidentally miss important information that would formerly be hidden from view. Unfortunately, the text size also increased proportionally and text can still be hidden from view and is not scrollable. To make matters worse, the user is much more limited in the amount of text that can be entered into the field before Filemaker prompts you to continue in the general comments section. This is a big step in the wrong direction and needs a remedy. The changes resulted in greatly increasing the size of the recovery log in particular to 10 pages without any tangible benefits.

XCTU: The newer version of local modem software still cannot find the device on the first try in most instances when initializing the program. In many cases it takes more than a couple of tries to accomplish this. It is frustrating when one is trying to perform daily checks on multiple systems so we reverted, again, back to using the older version which does not have this problem. If we need to be enlightened on something unbeknownst to us with the new version then please communicate this.

CTD Notes:

The CTD system as a whole worked very well. A new spool of CTD cable had been installed onto the ship sometime prior to this cruise. See next section for additional details.

Ship Notes or issues:

Prior to this cruise the ship's ET, Jeff Hill, installed an additional cable so as to make the ORE 8011M deck units that we are now using compatible with the RHB hull mounted transducer. The existing cable for the older 8011/8011A deck units is still ready and available as well. A small table extension was constructed during the cruise to accommodate the deck unit and the user has a choice of either cable type readily available to plug in depending on the version of deck unit in use. This greatly streamlines the release interrogation process.

The multi-beam depth sounder was missing critical files needed to display accurate depths prior to the cruise. This was remedied after the first mooring deployment.

Ancillary Projects:

German GEOMAR oxygen loggers augmented the TFLEX deployments at 20.5N and 11.5N-23W and were configured for real-time oxygen data. All of the oxygen sensors were prepared and logging prior to receipt at PMEL for shipping. They required no interfacing prior to deployment and tested well without incident. OTN sensors were also provided and installed at 200m on each deployment and have been a regular addition to the moorings for several years now.

Miscellaneous:

Brazilian Navy Participation: Two representatives from the Brazilian Navy, Lt. Eduardo Dubeux and Sgt. Eric Silva, were our guests for this cruise as observers. They are regular participants on the Brazilian PIRATA cruises where Eduardo works on the bridge and Eric is involved in deck operations. They were very courteous and helpful throughout the cruise and we enjoyed their company. We interchanged ideas and techniques with them and it was a beneficial endeavor to have them along for the cruise. They were very impressed with the hanging block technique and plan to incorporate it into their operations. Due to present IT regulations they were only allowed to use NOAA computers configured specifically for their internet use. Plans were arranged and the computers were provided by the port captain office as loaners during the cruise planning process. They were placed in the main lab and set up by ET Jeff Hill. The command expressed an interest in making this a permanent feature for future foreign national guests.

Recommendations:

Initiate a checklist for the preparation of subsurface sensors for shipment and also provide spare hardware and clamps for them. Insufficient preparation has been somewhat of an issue for the last two PNE cruises, more specifically for the Nortek current meters.

The two halves of the inductive modem core on the seabird sensors continue to have issues with remaining in place for mounting and dismounting during operations. It is more of an issue on recoveries as they can easily fall out and be lost to the sea when the units are removed from the nilspin cable. This is also sometimes the case with the Nortek current meters but they incorporate o-rings to aid keeping the core intact. A solution to help better keep these parts in place would be welcome. The clamps for the SBE-39IM sensors continue to occasionally disrupt deployments as it is still not all that uncommon to strip the threads in the clamp from the tension applied to them during installation despite the use of hand tools versus power tools and a careful mindset. Calls for a more robust solution to this have been problematic for our group.

Mock up a mooring at PMEL utilizing a 3-link chain below the bridle to get a better assessment of TFLEX top section fit.

Conductivity-Temperature-Depth (CTD) casts

During the course of the cruise, only twelve CTD/LADCP casts were conducted (Table 2). We did not need to swap any of the CTD and LADCP sensors throughout the cruise, which makes it easier to examine the performance of the sensors. We were able to perform calibrations of all of the CTD data. However, there weren't enough stations to do as rigorous and robust a calibration as we are normally able to achieve with more CTD stations (i.e., getting through more than a handful of Autosal sessions and Winkler titrations to make sure all of the systems are working properly). Once we were certain that the Autosal and Winkler titrations were working well, we were already done collected CTDs.

Table 2. CTD station number (and number used for file naming convention), latitude and longitude, start date and time of downcast, depth and bottom depth of CTD casts. CTD casts done at mooring locations are shaded in yellow.

Activity	Latitude			Longitude			Start Downcast	Cast	Total
	Deg.	Min		Deg.	Min.		Date / Time UTC	Depth	Depth
CTD1 (001)	28	33.47	N	65	36.15	W	04-Mar 16:32	1499	5385
CTD2 (002)	20	0.38	N	37	50.50	W	11-Mar 02:09	1499	5312
CTD3 (003)	20	27.46	N	23	7.51	W	14-Mar 19:01	1501	4435
CTD7 (004)	18	0.22	N	22	59.91	W	15-Mar 09:45	1501	3495
CTD11 (005)	15	58.52	N	22	28.21	W	15-Mar 22:46	1100	1125
CTD13 (006)	15	0.15	N	22	51.87	W	16-Mar 06:09	1501	3166
CTD15 (007)	14	0.14	N	23	0.04	W	16-Mar 13:29	1500	4319
CTD16 (008)	13	30.04	N	23	0.02	W	16-Mar 17:39	1500	4536
CTD17 (009)	13	0.05	N	23	0.01	W	16-Mar 21:42	1500	4739
CTD18 (010)	12	30.06	N	22	59.98	W	17-Mar 01:46	1500	4925
CTD19 (011)	11	59.94	N	22	59.93	W	17-Mar 05:56	1500	5046
CTD20 (012)	11	29.23	N	22	59.17	W	17-Mar 18:24	1500	5118

However, this is what a preliminary view of the CTD data along looks like (Figures 2-4). The standard deviation of the primary salinity values after the model fit (to correct for sensor drifts) was 5.53×10^{-3} psu (which is much larger than the 2×10^{-3} psu WOCE standards, again we note that this may be because we only had 12 stations), whereas the standard deviation of the secondary salinity values after the model fit was almost the same value, 5.52×10^{-3} psu. Both primary and secondary conductivity sensors performed about the same. We noted a small drift over the twelve stations in the differences between the primary and salinity sensors and the Autosal values over time. The drifts were very similar for both sensors (see drifts for primary sensors below in Figure 2). We will use the primary calibrated salinity sensors as our published values for the cruise.

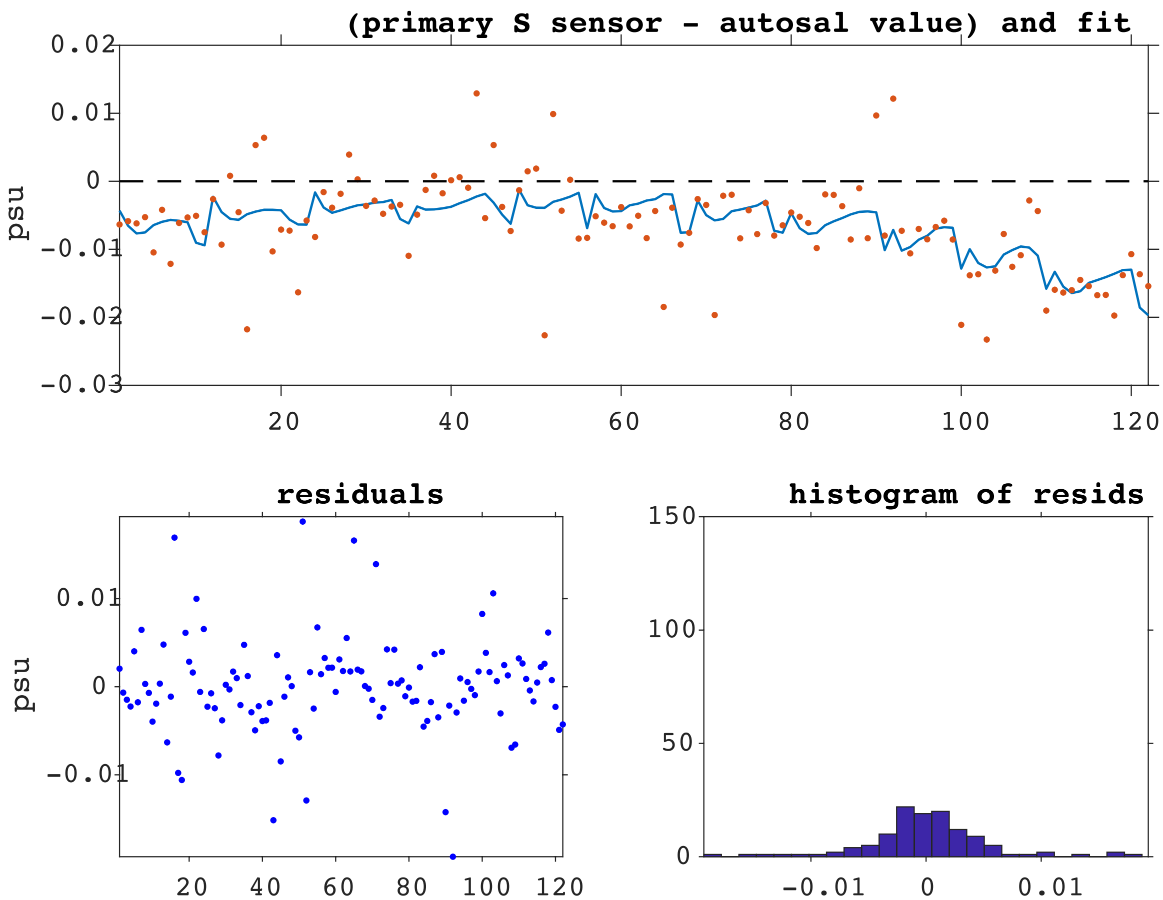


Figure 2. Analysis of the primary salinity sensor data relative to the Autosal estimates. Blue line is the model fit to the primary sensor – Autosal value residuals.

The primary and secondary O2 sensors, however, had very different standard deviations of the O2 sensor values after the model fit, 4.22×10^{-2} mL/L and 3.32×10^{-2} mL/L, respectively. Because the errors are smaller between the secondary O2 sensors and the titration, we will use the secondary calibrated oxygen sensors (Figure 3).

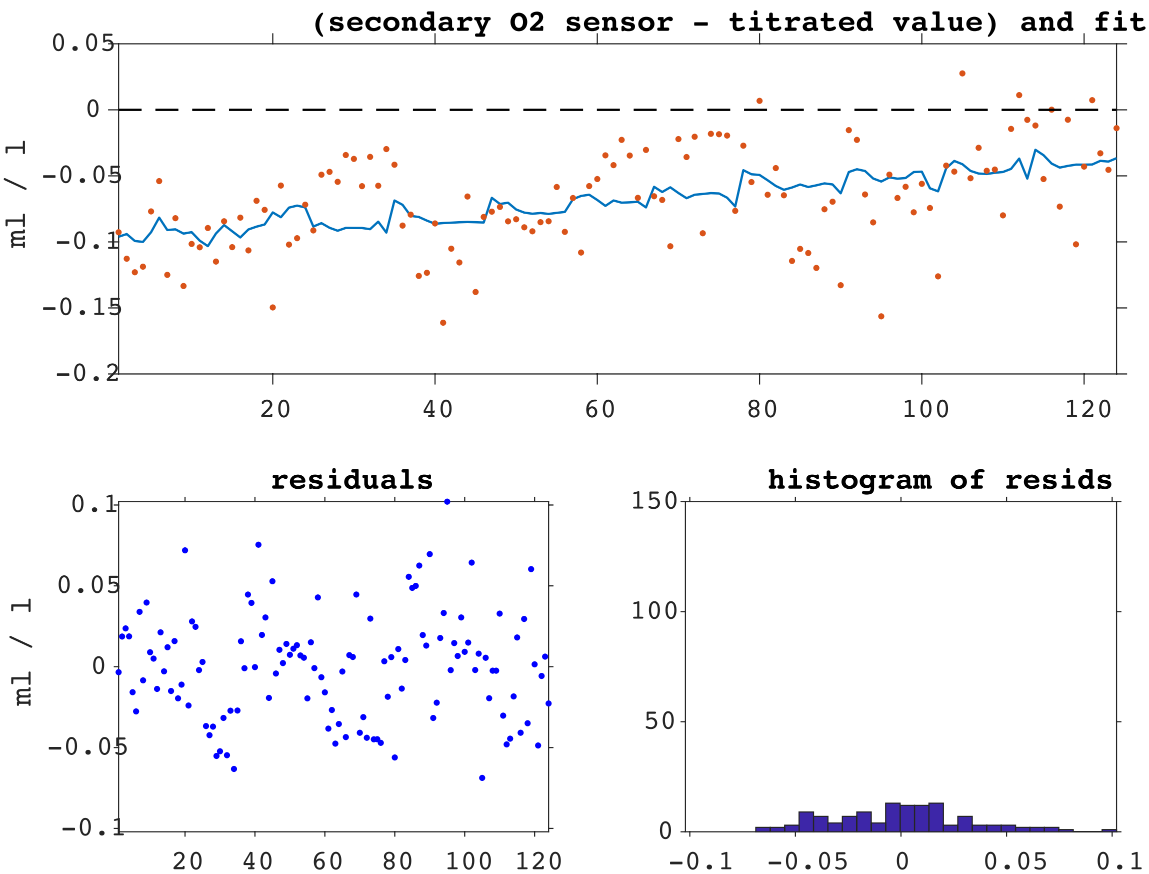


Figure 3. Analysis of the secondary oxygen sensor data relative to the Winkler titration estimates. Blue line is the model fit to the secondary sensor – titration value residuals.

We did not sample through the entire 23°W line, but we were able to collect some samples through part of the oxygen minimum zone between 11.5°N and 20.5°N (Figure 4). The lowest dissolved oxygen values were centered near 400 m depth south of 16°N. The largest surface salinity values were observed near the 20.5°N, 23°W mooring. Below 600m depth, we sampled through a region of minimum salinity, that had the largest vertical extent near the 11.5°N, 23°W mooring.

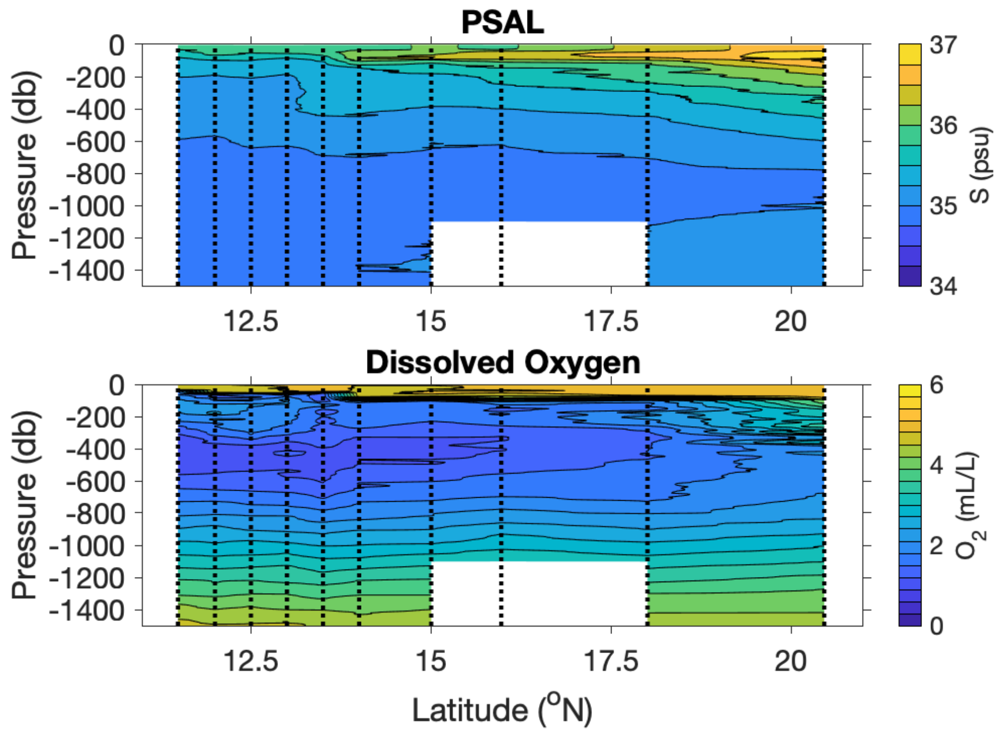


Figure 4. Calibrated salinity and dissolved oxygen along 23°W for the primary conductivity and secondary oxygen sensors (post-cruise calibration performed by Renellys Perez)

Lowered ADCP (LADCP) data

LADCP processing was performed by Renellys Perez (day shift) and Jonathan Christophersen (night shift). Both the upward and downward looking LADCPs worked well throughout the entire cruise. To process the data during the cruise, we used a mixture of the old way of processing the LADCP data (i.e., Renellys used scripts developed by Ryan Smith) and the new way using scripts developed by Pedro Peña (tested by Jonathan). In subsequent cruises, we will fully migrate to the new LADCP processing scripts developed by Pedro Peña. Processed LADCP and shipboard ADCP (SADCP) section data for PNE2019 will be made available after the cruise.

The LADCP sections are shown below between 11.5°N and 20.5°N along 23°W (Figure 5). During the PNE2019 cruise, there was a strong subsurface eastward flow (positive zonal velocity) extending from 50 m which reached down to 1500 m (only velocity down to 1000 m depth is shown in the figure below). Between 11°N and 18°N, primarily westward flow was observed in the upper 100 m to 200 m of the water column. The meridional velocity in the upper 200 m was mostly northward, with the strongest flow (greater than 20 cm/sec) observed between 14.5°N and 16°N, along 23°W. A fairly strong northward current from the surface down to 1000m was also detected near 12°N, 23°W.

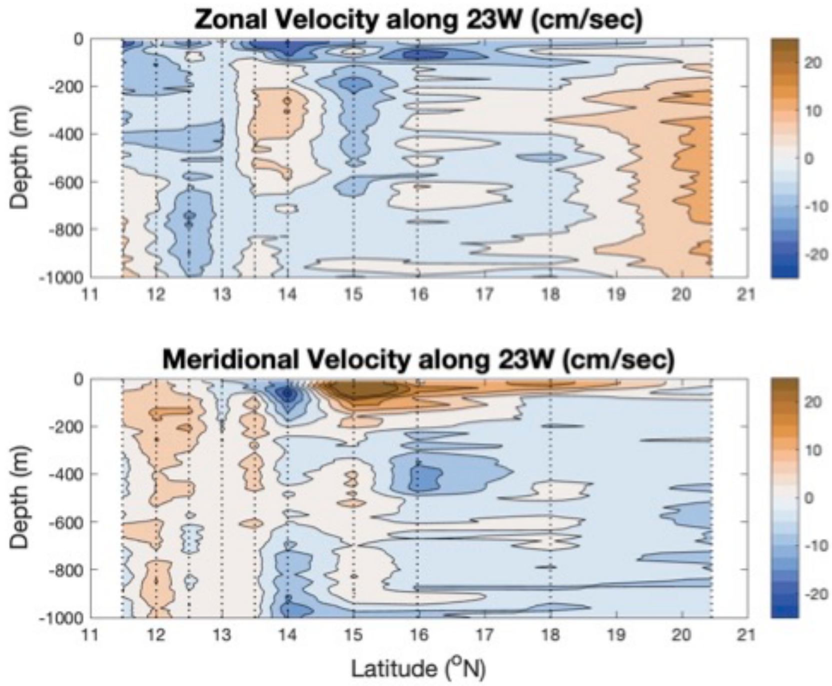


Figure 5. Map of zonal (upper panel) and meridional (lower panel) velocity data from the lowered ADCP as a function of latitude along 23°W (i.e., excluding the LADCP data collected at the test CTD and 20°N, 38°W CTD stations).

Satellite-tracked Surface Drifters

A total of 14 satellite-tracked drifters were deployed during the cruise (Figure 1 and Table 3). The drifters are mini-Surface Velocity Program (SVP) types, drogued at 15 m to follow mixed layer currents; all included a thermistor on the surface buoy for SST. Their data are transmitted in real time via the Iridium system. All of the drifters were launched from either side of the A-frame on the fantail. Due to the early termination of the PNE2019 cruise, we adapted float deployment locations in coordination with Shaun Dolk from the Global Drifter Program at UM/CIMAS. Some of the drifters were deployed in pairs (i.e., near 20.33°N, 28°W; and where we encountered Jean-Jacques Savin).

Table 3. Latitude and longitude of drifter deployments, including float ID numbers.

	Latitude		Longitude			ID number
Deg.	Min		Deg.	Min.		
20	1.54	N	37	50.85	W	66619950
20	10.02	N	32	59.98	W	66435900
20	20.01	N	27	59.56	W	66619960
20	20.01	N	27	59.56	W	65386680
20	24.01	N	26	0.13	W	67112360
18	59.96	N	23	0.01	W	67112300
11	59.76	N	22	59.78	W	67113250
15	30.01	N	24	59.95	W	67113280

16	10.06	N	27	0.13	W	67115250
17	2.01	N	29	0.53	W	67114340
17	51.68	N	30	59.53	W	67117300
18	41.76	N	32	59.85	W	67118280
22	26.52	N	46	15.30	W	67118270
22	26.52	N	46	15.30	W	67119270

Satellite-tracked Argo profiling floats

A total of 22 Argo profiling floats were deployed from the sides of the A-Frame on the fantail. The floats were programmed to perform the standard Argo mission - measuring a 2000 dbar profile every 10 days with drift at 1000 dbar in between. Data will be reported to the Argo GDAC (Global Data Assemble Center) and the GTS (Global Telecommunications System) via the US Argo DAC at AOML. Figure 6 and Table 4 indicate the locations where Argo floats were deployed. Due to the early termination of the PNE2019 cruise, we adapted float deployment locations in coordination with Pelle Robbins at WHOI.

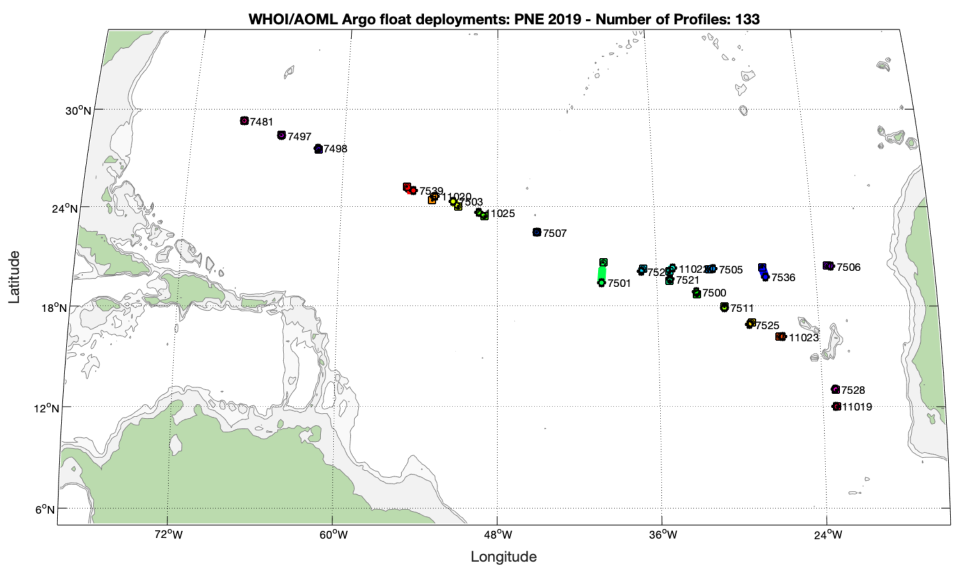


Figure 6. Map of locations that Argo profiling floats were deployed during PNE 2019.

Table 4. Latitude and longitude of Argo deployments, including float ID and WMO numbers.

Latitude			Longitude			ID number	WMO number
Deg.	Min	N/S	Deg.	Min.	E/W		
25	14.35	N	55	0.74	W	7539	4903056
24	38.11	N	53	0.84	W	11020	4903219
24	1.69	N	51	1.08	W	7503	4903320
23	24.52	N	48	59.40	W	11025	4903214
20	37.58	N	39	59.91	W	7501	4903218
20	5.97	N	34	59.93	W	11022	4903213

20	12.01	N	31	59.91	W	7505	4903052
20	19.99	N	28	0.25	W	7536	4903221
20	25.00	N	23	7.54	W	7506	4903057
12	59.69	N	23	0.03	W	7528	4903058
11	59.99	N	22	59.84	W	11019	4903211
16	10.05	N	27	0.10	W	11023	4903212
17	2.01	N	29	0.53	W	7525	4903215
17	51.75	N	30	59.69	W	7511	4903059
18	41.76	N	32	59.85	W	7500	4903052
19	31.97	N	35	1.15	W	7521	4903217
20	14.66	N	37	0.49	W	7527	4903055
21	59.48	N	43	0.55	W	7504	FAILED
22	27.01	N	45	0.65	W	7507	4903054
27	30.43	N	62	0.12	W	7498	4903051
28	23.91	N	65	0.05	W	7497	4903050
29	17.25	N	68	0.99	W	7481	4903044

Sargassum Surveys

A pilot Sargassum survey was conducted during the PNE2019 cruise with daytime surveys of Sargassum on approximately hourly intervals (Figure 7). The following information was recorded: date, time, latitude, longitude, presence or absence of Sargassum (if Sargassum was present was it found in trace amounts, in isolated clumps, filaments, rafts, or mats), and the SST and SSS readout from the TSG. We recorded data along the entire cruise track which crossed through Sargassum between 20°N and 32°N, both at the beginning and end of the cruise. Because the cruise ended before we could pass through the Great Atlantic Sargassum Belt between 6°N and 10°N, we did not get a chance to observe Sargassum near the tropics.

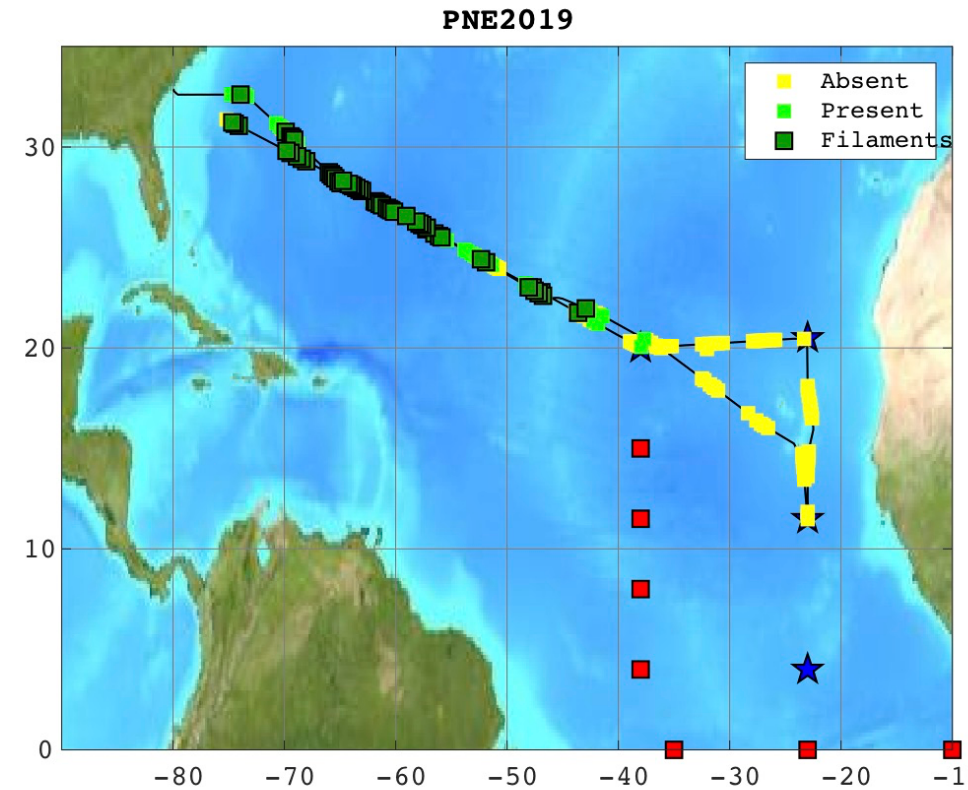


Figure 7: Map of Sargassum sightings during the PNE2019 cruise. Open light green (yellow) squares indicate where Sargassum was present (absent). Closed dark green squares indicate where filaments and/or larger collections of Sargassum (i.e., rafts and mats) were observed.

AEROSE

The AEROSE team were responsible for the atmospheric sciences mission, which included continuous observations of the atmospheric chemistry and physics, launches of balloon-borne instrumentation, sampling of the air and airborne particulate originating from the Saharan Desert, filter sampling and measurement of trace gaseous pollutants.

Operations during the eastern portion of the cruise included launching satellite-dedicated radiosondes and ozonesondes on a generally higher frequency (up to four per day during NOAA and EUMETSAT satellite overpasses) and intensifying sample collections. The ship encountered several interesting atmospheric conditions including a minor stratospheric injection event and two distinct Saharan Air Layer (SAL) events. The SAL, in particular, was expected to be rich in Saharan dust and particulate from biomass fires, which can strongly influence the chemistry of the atmosphere. The team successfully collected data during the SAL dust events, biomass outflows, and "mixed" air masses that contained both dust and smoke particulate. These are very rare and unique observations that contribute to the rich data set that AEROSE has generated over the past decade and a half. The locations and the dates of the radiosonde and ozonesonde launches are shown in Figures 8 and 9, and the ozonesonde profiles in Figure 10 below.

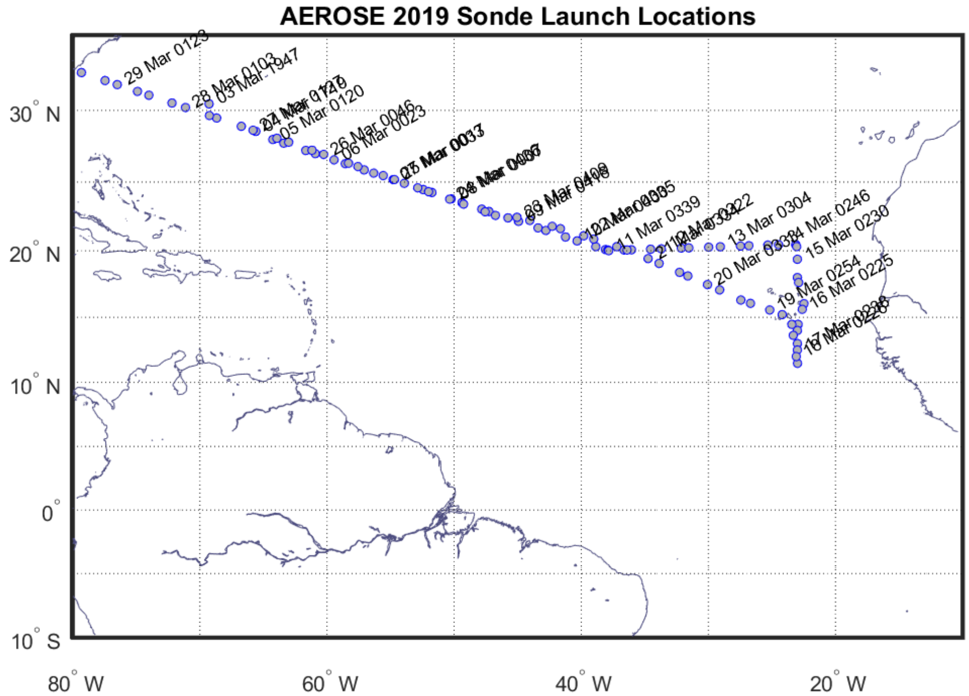


Figure 8: Locations and times of the AEROSE satellite-dedicated radiosonde launches.

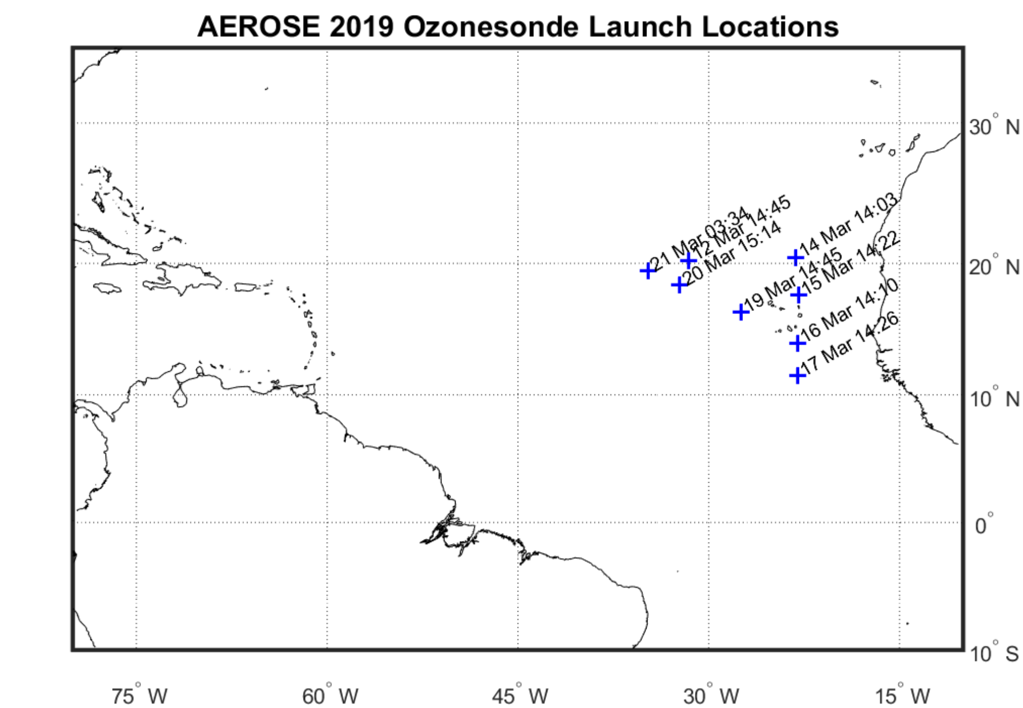


Figure 9: Locations and times of the AEROSE satellite-dedicated ozonesonde launches.

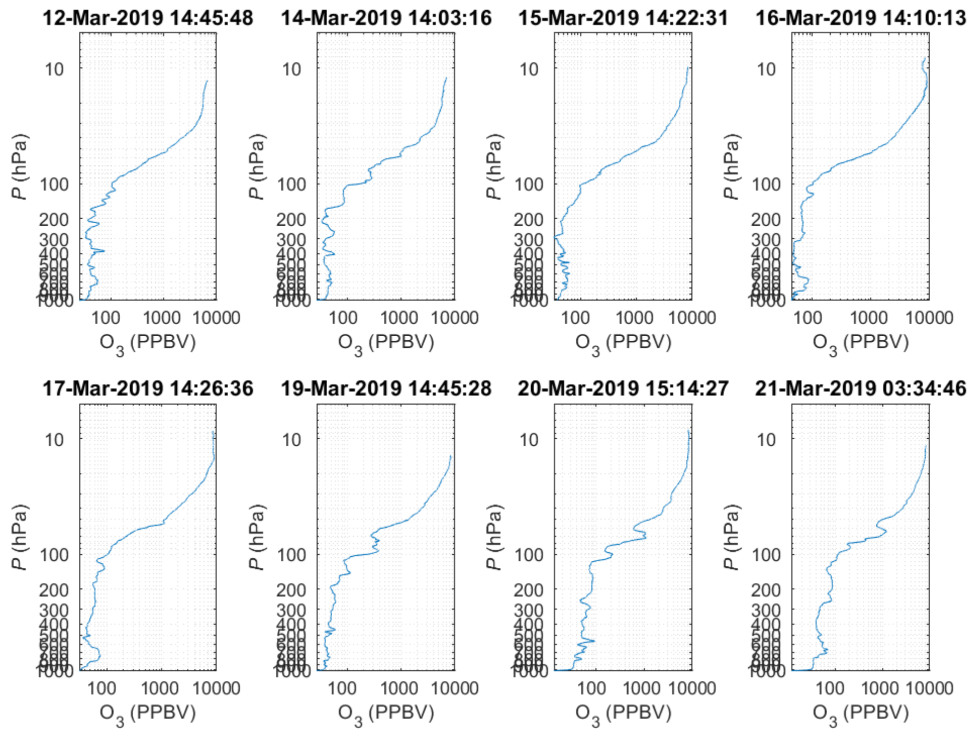


Figure 10: AEROSE satellite-dedicated ozonesonde profiles (converted to volume mixing ratios, ppbv).

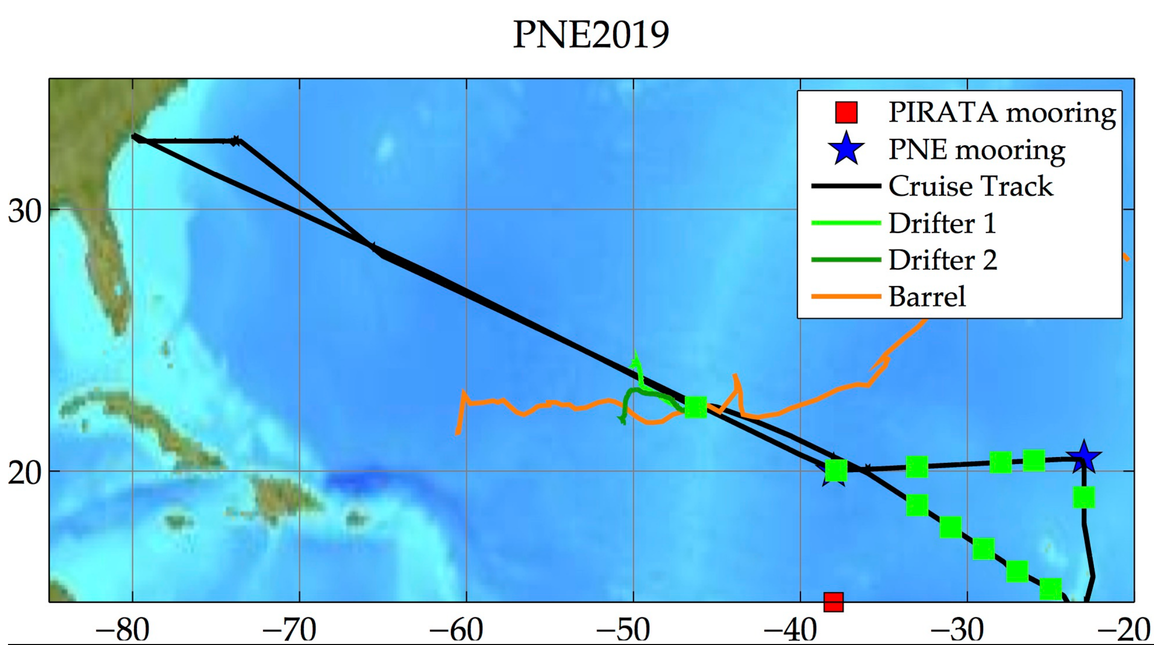
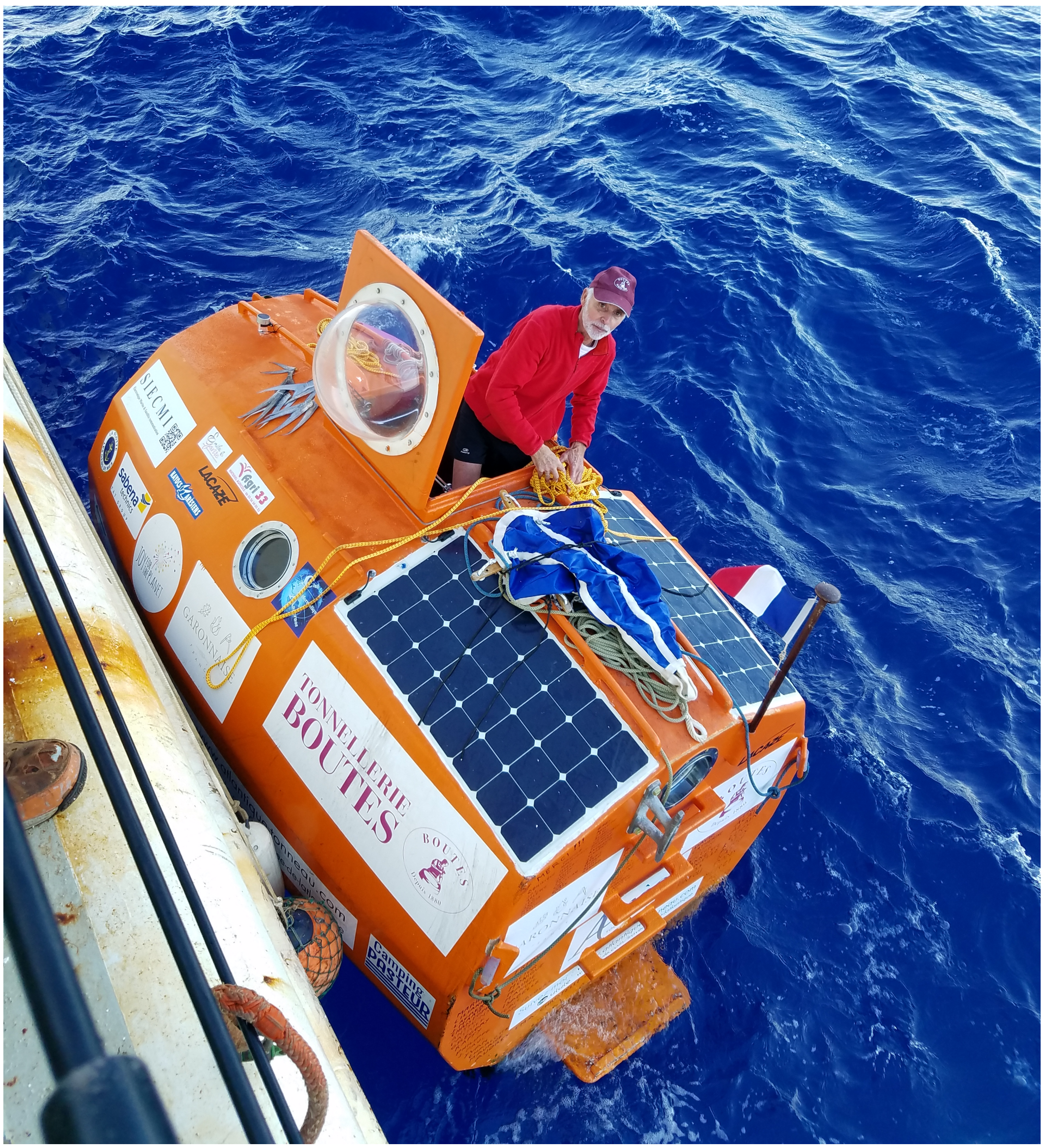


Figure 11: Map of showing the PNE2019 cruise trajectory (black lines) and the trajectory of Jean-Jacques Savin's barrel (orange lines). The location of the drifter deployments are also shown as green squares, and the trajectory of the two drifters deployed in the vicinity the barrel are shown as green lines.

French Adventure: Jean-Jacques Savin

During the cruise, the Ronald H. Brown crossed paths with and provided aid to French adventurer Jean-Jacques Savin. Jean-Jacques is transiting across the Atlantic from Spain in an orange wooden barrel propelled only by the currents and wind with the hope of reaching the Caribbean. Although he departed Spain in December 2018, he was still nearly 1,000 nautical miles from his destination when he encountered the Brown. The ship's crew supplied Jean-Jacques with food and water and wished him well on his journey. The AOML team deployed two GPS-tracked surface drifters in his wake to test whether they could assist in tracking his barrel's movements (Figure 11). After we parted, Jean-Jacques Savin was able to successfully complete his journey.



Picture of Jean-Jacques Savin, French Adventurer.