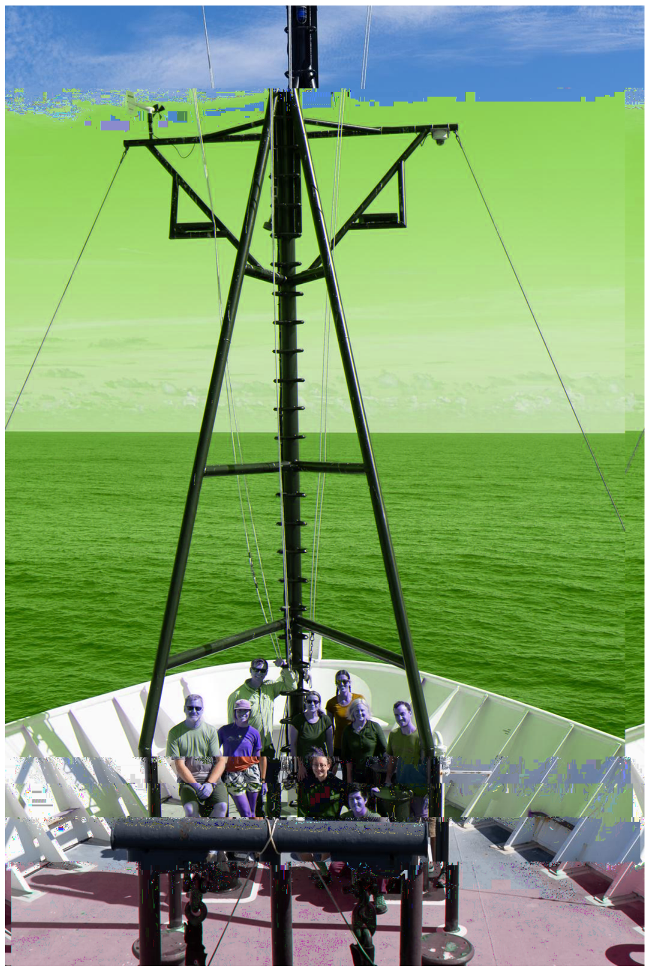
Cruise Report
PIRATA Northeast Extension 2021b
NOAA Ship *Ronald H. Brown*
RB-21-05

November 12 – December 19, 2021
St. Petersburg, FL – Praia, Cape Verde



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PIRATA Northeast Extension 2021b Scientific Party

Hydrography: Renellys Perez (NOAA/AOML), Diego Ugaz (CIMAS/AOML), Christian Saiz (CIMAS/AOML), Grace Owen (Volunteer, UM/RSMAS), Clara Gramazio (Volunteer, UM/RSMAS)

Moorings: Kenneth Connell (*NOAA/PMEL*), Steve Kunze (*NOAA/PMEL*)

Sargassum: Alyson Myers, Tiffany Anderson (*Fearless Fund*)

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

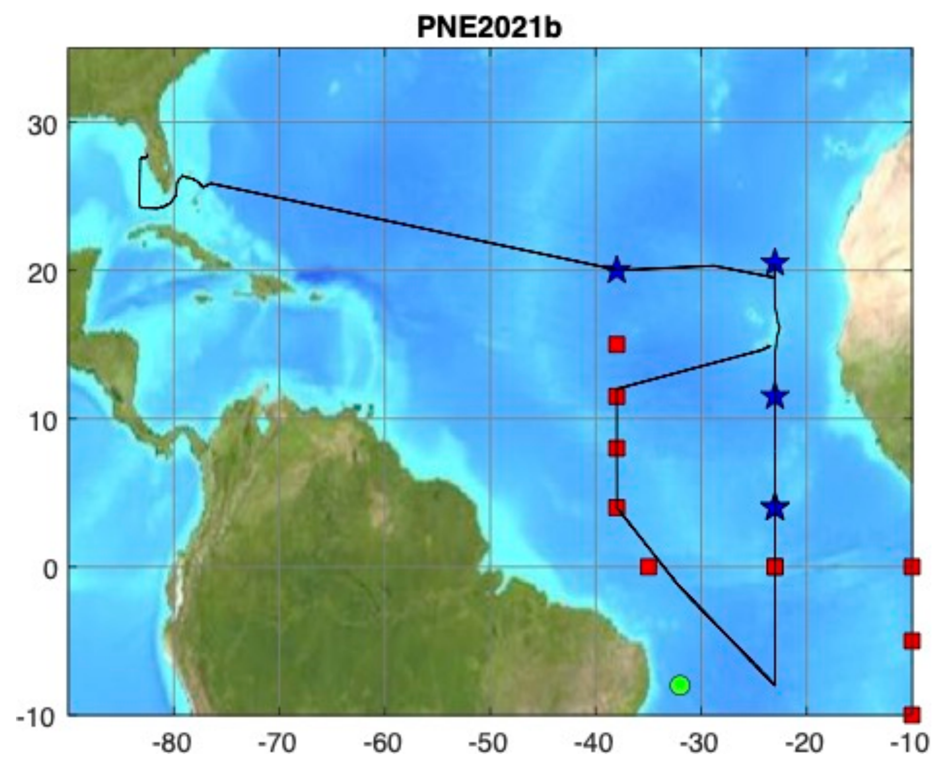

Figure 1. Actual cruise track (black line) for the PNE2021b cruise. Blue stars indicate the PNE moorings that were recovered and redeployed. Red squares indicate PIRATA backbone moorings, including the 0°N, 23°W mooring that was serviced and the 12°N, 38°W mooring that was recovered.

OVERVIEW

Planned science: The FY2022 Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) Northeast Extension (PNE) cruise began on November 12, 2021 in St. Petersburg, FL and ended on December 19, 2021 in Praia, Cape Verde (a total of 38 days at sea). The PNE2021b (also referred to as RB-21-05) cruise was designed to (1) Recover and redeploy the PIRATA Northeast Extensions' four TFlex moorings and service one French PIRATA backbone mooring, (2) Collect oceanographic and meteorological observations in the northeastern tropical Atlantic, (3) Collect upper-ocean water samples and Sargassum tissue in support of a DOE (Department of Energy) funded project, and (4) deploy 15 surface drifting buoys and 7 Argo profiling floats. The oceanographic component of (2) includes measurements of conductivity, temperature, pressure, oxygen concentration, and horizontal velocity from casts, and horizontal velocity measurements from the hull-mounted ADCP. Most of the measurements were acquired along the 23°W meridian, which samples the southeastern corner of the subtropical North Atlantic, a region of subduction that is important for the subtropical cell circulation; the Guinea Dome and oxygen minimum zone, where the subtropical and tropical gyres meet; and the tropical current system and equatorial waveguide. One additional CTD was obtained at the 20°N, 38°W PIRATA mooring and three test CTD casts were performed at the beginning of the cruise. The meteorological component of (2) focused on measurements of air temperature, relative humidity, wind velocity, shortwave radiation, longwave radiation, and rainfall from the ship's meteorological sensors. All of the scientific goals of RB-21-05 (PNE2021b) were achieved.

Additional science: After the port was changed from Cape Town, South Africa to Praia, Cape Verde, we deployed an additional 4 Argo profiling floats (total 11 Argo floats), and tried to recover three Brazilian PIRATA backbone moorings (4°N, 8°N, and 12°N along 38°W). The first two Brazilian moorings were missing, but we were able to recover the Brazilian PIRATA mooring at 12°N, 38°W. We also did a regular CTD cast using the aft winch and a deep 3000 m CTD cast using the forward winch at the 12°N, 38°W mooring.

We thank the crew and officers of the *Ronald H. Brown* for their work during the cruise and their help with mobilization of equipment before and demobilization after the cruise. Five surface moorings were successfully recovered and four moorings were redeployed, by Chief Bosun Michael Lastinger and the deck crew using an efficient method that eliminated the need for small boat operations. Thanks to the survey technicians, Shane Mallory and Joan Bonilla-Pagan, and the Electronic Technician, Dave Moore, for their assistance during CTD casts. Thanks also to the rest of the crew, including the winch operators, engineers, and galley crew, who kept operations running smoothly and morale high. Finally, we appreciate the Chief Operations Officer, LT Caroline Wilkinson, and Commanding Officer, CAPT Keith Golden, and the NOAA Corps officers for their efforts to ensure efficient operations. We note that there were less frequent direct communications between the science party and the Commanding Officer which was a departure from previous cruises.

Introduction

1. PIRATA Northeast Extension

The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) is a three-party project involving Brazil, France, and the United States that seeks to monitor the upper ocean and near-surface atmosphere of the tropical Atlantic via the deployment and maintenance of an array of moored buoys with subsurface sensors and automatic meteorological stations. The array consists of up to 18 moorings, 10 of which were deployed in 1997-1998, running along the equator and extending southward along 10ºW to 10ºS and northward along 38ºW to 15ºN. Following the success of this initial array, additional moorings were deployed in the southwestern tropical Atlantic in 2005 and in the northeastern tropical Atlantic in 2006-2007 (the PIRATA Northeast Extension; Fig. 1). All of these moorings continue to be maintained as part of the sustained ocean observing system.

The PIRATA Northeast Extension (PNE) samples a region of strong climate variations on intraseasonal to decadal scales, with impacts on rainfall rates and storm strikes for the surrounding regions of Africa and the Americas. The northeastern tropical Atlantic includes the southern edge of the North Atlantic subtropical gyre, defined by the westward North Equatorial Current (NEC), and the northern edge of the clockwise tropical/equatorial gyre defined by the North Equatorial Countercurrent (NECC). This area is the location of the North Atlantic's oxygen minimum zone, found between depths of 400 m and 600 m. The size and intensity of this zone is a potential integrator of long-term North Atlantic circulation changes, and the extremely low oxygen values have significant impacts on the biota of the region. The cyclonic Guinea Dome is centered near 10ºN, 24ºW, between the NECC and NEC in the eastern tropical Atlantic. It is driven by trade wind-induced upwelling and may play an active role in modulating air-sea fluxes in this region.

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

2. Sargassum Science

Fearless Fund (fearlessfund.org), a 501(c)3, leads a DOE ARPA-E (Advanced Research Projects Agency - Energy) MARINER (Macroalgae Research Inspiring Novel Energy Resources) research effort in conjunction with NOAA to produce macroalgae at energy (or carbon dioxide removal) scale. The Fearless team's focus is to design an environmentally beneficial, coastal management regime to sustainably harvest *Sargassum natans* and *fluitans* before it arrives on beaches with negative impact to marine environments, including corals, sea grasses, and dissolved oxygen. The team joined the PNE cruise for the first time in January-February 2021 to better understand the production system of the Great Atlantic Sargassum Belt (GASB) in the tropical Atlantic, which has been established since 2011. The GASB is typically found between 3ºN and 10ºN along 23ºW, and PNE offers an opportunity to study distribution of Sargassum in the GASB and provides an opportunity to advance the research agenda toward the Administration's goals of reducing emissions by 50% by 2030.

Order of Operations

All personnel were required to be vaccinated for COVID-19 and shelter in place for one week either in their residences in the Miami area or in hotels in Miami or St. Petersburg. This included the R/V *Ronald H. Brown* (RHB) crew as well. On the fourth day of the one-week period, everyone was given two COVID-19 tests (simultaneously for improved accuracy) and one test prior to boarding the ship. Once underway, all mask and social distancing restrictions were lifted because everyone on board tested negative for COVID-19. No one became ill during the entire cruise.

The RHB departed St. Petersburg, Florida on November 12th at 14:30 UTC and transited around the southern coast Florida, through the Bahamas, and to the first PIRATA mooring. We did not record underway data during the transit through the Bahamas' EEZ. We conducted three fully instrumented test CTDs on November 16th and 17th on the way to the first mooring (#000, #997, #996). The first test cast (#000) was done on the forward winch. We experienced modulo errors at the commencement of the downcast, and many more modulo errors occurred during the upcast. At 1200 m depth, all the sensor readings flatlined and the deck unit made a persistent noise. We turned off the deck unit, stopped data collection, and brought the package to the surface. We also noted large fluctuations on the current readout on the deck box during the whole cast, and a big drift between the primary and secondary sensors. We switched to the aft winch after it was re-terminated. During that time, the E/T found a severed ground cable on the forward winch drum which was the source of the error on the forward winch. We decided to stay on the aft winch, if possible, for the remainder of the PNE cruise.

During the second cast (#997), we had major conductivity sensor issues with unrealistic salinity values on the second test cast that were so high they shut off the pumps. After a few deck tests of the sensors and pumps, we decided to swap out both conductivity sensors on the 3rd test cast. The 3rd test cast (#996) at 23° 54.99'N, 63° 31.31'W happened on November 17th at 14:12 GMT and was considered to be our first successful test cast. Instruments included in the test cast and all subsequent casts include dual temperature, conductivity, and oxygen, as well as upward- and downward-looking 300 kHz ADCPs. A summary of all CTD casts performed during the cruise is available in Table 1 in Section 2.1 in "Oceanic data". CTD logfiles and notes written during the cruise keep track of sensor swaps made throughout the cruise. Table 2 in Section 2.1 in “Oceanic data” also keeps track of the CTD configuration changes throughout the cruise.

The RHB arrived near the first mooring site (20°00.86’N, 37°51.04’W) around 21:06 UTC on November 22nd. Because we needed to wait for daylight to start mooring operations, we first conducted a CTD/ADCP cast down to 1500 m a few nm from the buoy. The buoy recovery started at about 10:00 UTC on November 23rd and a new mooring was deployed. All mooring operations ended by 20:00 UTC. The buoy that was deployed included 15 AOML/PhOD Nortek current meters, as part of the Tropical Atlantic Current Observations Study (TACOS) to measure the upper-ocean horizontal velocity and its vertical shear. Previously, TACOS sampled at 4°N, 23°W. This was the first TACOS deployment at the 20°N, 38°W mooring. The PMEL team (Ken and Steve) confirmed that all surface and subsurface sensors on the new buoy were transmitting, except two of the TACOS current meters.

We were scheduled to arrive at the next mooring (20°26.96'N, 23°08.54'W) at night (approximately 21:00 local time). Instead of waiting at the mooring until sunrise the following day, we proceeded to two CTD stations directly south of the mooring site (19°29.99’N, 23°00.06’W) for cast #004, then traveled north and conducted cast #003 at 20°00.04’N, 23°00.10’W, and lastly performed CTD cast #002 near the mooring site at 20°27.87’N, 23°05.61’W just before the mooring recovery. The buoy recovery and redeployment went very smoothly, with 100% data transmission from the new buoy. At the start of cast #003, the oxygen sensor and conductivity sensors were drifting at the very beginning of the cast due to ingesting some marine organisms (possibly squid or jellyfish). We brought the instrumentation back on deck and flushed the sensors and plumbing, and repeated the cast. During the second attempt at CTD cast #003, we noticed that the primary oxygen sensor consistently read about 20% higher than the secondary sensor, and the bias continued to increase during the upcast. As best as we could tell there was still residual biological fouling of the secondary oxygen sensor. Note, during the #003 upcast at around 350 m, we also had an unexpected full reboot of all of the ship’s computers that we couldn’t override. As a result, the data from #003 is broken up into two files that were later merged together. The secondary oxygen sensor was still low relative to the primary oxygen sensor during cast #002 at the mooring, so we replaced the secondary oxygen sensor with a new one just before cast #005 (Table 2).

CTD/ADCP casts were performed every 0.5° of latitude between 19°N (#005) and the third PNE buoy near 11.5°N. Once again to maximize daytime mooring operations, we travelled south of the buoy to do cast #021 at 11°00.06’N, 23°00.04’W prior to the CTD cast #020 at the mooring (Table 1). Along 23°W, when requested by Fearless Fund, we closed an extra bottle near the surface (usually between 3 and 5m) during daylight hour CTD casts for subsequent nutrient analysis. We did not collect/process salinity or oxygen from these near-surface water samples. Note: we had some comms/data issues with the #006 and #007 casts upward looking ADCP. After some testing, we changed the comms ports and we switched from using ship’s power to using port power to charge the LADCP battery and that seems to have solved the problem. The third PNE mooring recovery and redeployment started around 09:00 GMT on December 1st at 11°28.58'N, 22°59.45'W. The Fearless Fund successfully collected Sargassum that was deployed at the base of the mooring in a PVC container near the auto-release. They froze these samples for analysis after the cruise. A new PVC container was deployed near the auto-release with a fresh Sargassum sample.

After mooring operations were completed, we resumed the hydrographic line between 10.5°N (#022) and the fourth PNE mooring near 4°N. We noted a persistent bias between primary and secondary temperature and conductivity sensors and we swapped the secondary temperature and conductivity sensors prior to cast #022 (Table 2). There was still a disagreement between the primary and secondary conductivity sensor so we tried one last sensor replacement for cast #025, only to decide that we were better off returning to the previous sensor. No further sensor swaps were performed, although we kept trying to trouble shoot some spikes that we occasionally observed in secondary conductivity and oxygen sensors between 0 and 100 m throughout the rest of the cruise (Table 2). We thought it was pump/plumbing/cable related, but we never found the source of the error. We tried using all six conductivity sensors on the ship and had issues with almost all of them. Perhaps they were not properly cleaned during calibration by Seabird – this is something to follow up on with the instrumentation group. Between 12°N and 4°N along 23°W, we traveled through some areas with strands and mats of Sargassum. When detected, Sargassum sampling typically occurred after a CTD cast and before the ship resumed underway operations. The Sargassum team, with the help of the bosun and deck crew, collected Sargassum samples using nets affixed to long poles. A handheld instrument was also used at many of the CTD cast sites to measure near-surface ocean temperature, salinity, oxygen, and pH during the daytime. These measurements were collected both when Sargassum was absent and when Sargassum was present.

We arrived at the last PNE mooring in time to do a CTD (#035) at 05:58 GMT on December 4th, and then start mooring operations at 4°04.04'N, 22°59.66'W at approximately 09:00 GMT. The mooring operations went smoothly, and completed at around 17:00 GMT that day. A PVC container was deployed near the auto-release with a fresh Sargassum sample by the Fearless Fund, which is the first time it was deployed at this site. We often used seawater collected from 1500 m to keep the Sargassum sample fresh until we could get to the mooring site. We then continued doing CTDs between 3.5°N (#036) and the French 0°N, 23°W PIRATA mooring, increasing to high density (0.25° latitude spacing between CTD stations) as we sailed from 2°N southwards (#039).

We arrived at the 0°N, 23°W PIRATA mooring at around 08:00 GMT on December 6th, and decided to do the deep 3500 m CTD cast (#047, 0°00.19'N 22°59.94'W) after mooring operations were completed. Steve and Ken were able to bring the mooring back online, using two small boat trips, so we did not have to do a mooring recovery and redeployment. They replaced the data logger and met sensors. Most of the subsurface sensors were responding. Mooring operations finished around 12:00 GMT on December 6th. For the deep CTD cast, and one shallower (1500 m) cast prior to this one, we affixed a mesh bag with a live Sargassum sample to see the effects of a short immersion at depth on Sargassum. The experiment was only done in an exploratory fashion, and further analysis/experimentation if conclusive results are desired. We continued with high density sampling until 2°S (cast #055) on December 7th at 14:21 GMT. After that we continued with 0.5° latitude spacing until cast #067 on December 9th at 17:22, completing the 23°W CTD line.

We then began heading northwest to the Brazilian 4°N, 8°N, and 12°N, 38°W PIRATA moorings to try to recover those moorings. They had all been in the water for over three years, and two of the three were no longer reporting position data (4°N and 8°N). Along the way, we deployed Argo floats and drifters (see Tables 8 and 9, respectively). We also monitored for Sargassum, although less was found in the vicinity of the Brazilian moorings than along 23°W. Neither the 4°N or 8°N moorings were visibly detected or showing up on ship's radar. Ken and Steve communicating with the acoustic release and determined it was horizontal (i.e., laying on the seafloor rather) which means that the mooring line was broken. We decided to not collect CTD data at those locations, to save time. On December 15th, we were able to find the 12°N, 38°W mooring at 11°59.64'N, 37°59.94'W. Mooring recovery operations started at approximately 14:00 GMT. We then did a normal 1500 m CTD cast (#068) at the mooring site. We then switched to the forward winch to do a 3000 m deep CTD cast (#069, our 70th station setting a new record for PNE) at 12°00.16'N 37°59.71'W on December 15th at 18:32 GMT. This last CTD was done on behalf of the scheduled A13.5 cruise subsequent to our cruise to ascertain that both winches were functional. We then steamed towards Praia, Cape Verde for an early morning arrival on December 19th.

The 12-hour CTD watches consisted of Renellys Perez and Christian Saiz (12 pm – 12 am), Diego Ugaz and Grace Owen (12 am – 12 pm), and Clara Gramazio (6 am – 6 pm). Ugaz and Saiz conducted all oxygen titration of CTD water samples (with some help from Owen and Gramazio). Perez, Owen, and Gramazio performed all salinity calibration readings in the temperature-controlled autosal room. LADCP data was downloaded by Perez, Ugaz, and Saiz. Roughly once a day, Perez sent CTD data to Francis Bringas at AOML to upload onto the WMO global telecommunications system (GTS). During the cruise, calibration data was compared against the bottle data files by Perez to make sure that the calibrations were going well. Throughout the cruise, Clara Gramazio produced a daily report noting the presence or absence of Sargassum, with observations recorded approximately every two hours during daylight. Sargassum sightings were also recorded using the ship's event logging system, and this information was provided to the Fearless Fund to help inform Sargassum sample collection. This was particularly important because we weren't sailing during the season where high quantities of Sargassum are typically found in the GASB (i.e., in November there isn't as much Sargassum compared to March), and we didn't want to miss viable sampling opportunities. There is a value to continuing this routine Sargassum sampling, independent of what ancillary Sargassum teams join for the PNE cruise. The Sargassum information compiled by Clara Gramazio was emailed on a daily basis to scientists (Chuanmin Hu and Shuai Zhang) at the University of South Florida, and they used this information to compare with satellite detection of Sargassum.

Renellys collected dust samples from two of the PNE buoys' meteorological sensors (the 20°N, 23°W and 11.5°N, 23°W moorings) for Vernon Morris at Arizona State University, only traces of dust were observed at the other moorings. The Marine-Atmospheric Emitted Radiance Interferometer (M-AERI), an instrument maintained by Peter Minnett and Miguel Izaguirre at RSMAS, operated during the cruise. It measured spectra of infrared radiation emitted by the ocean surface and atmosphere and took all-sky camera images of clouds. Standard meteorological variables and incident short-wave and long-wave radiation were also measured as part of the M-AERI project.

Underway systems: One of the survey techs, Joan Bonilla-Pagan, noted that there may be an issue with the shipboard ADCP (i.e., some diagnostics were failed and there may be distortion of the flow below 700 m), so we will need to compare the SADCP data against the LADCP data once the cruise is completed. Joan noted a shell was clogging the TSG system flow which may have affected the flow through data on or about November 25th. On this day, Joan also mentioned issues with the forward windbird sensor, and how it converts from relative wind speed to “true” wind speed (i.e., previous survey techs on the ship had set up the conversion to use data from the ship’s other windbird sensors). If anyone uses the forward windbird “true” wind data, they need to be aware of this issue. The other two windbird "true wind" readings are fine. The relative wind speed data from all three sensors are also fine. Joan did a calibration of the total alkalinity system on November 19th at the request of Chris Hunt and Denis Pierrot. Note: there was a power outage for 30 minutes on December 14th at 2am ship time which caused issues with some of the underway systems and cause one of the -80°C freezer to malfunction. Around that time, Joan switching to a different pump for the flow-through system that hadn’t been properly flushed which led to a clogged filter. Joan could not find a replacement filter in the forward science stores.

Table 1. CTD number and station number, latitude and longitude, start date and time of downcast, depth and bottom depth of CTD casts. Casts done out of sequence for mooring operation efficiency are shaded in yellow. Casts done in shallow topography are shadowed orange. Deeper casts are in gray.

CTD # (Station #)	Latitude (Deg., Min., N/S)			Longitude (Deg., Min., E/W)			Date, Time GMT	Cast Depth	Bottom Depth
1 (000)	24	36.79	N	68	08.62	W	16-Nov 13:30	1500	5695
1 (997)	24	27.70	N	67	08.68	W	16-Nov 20:17	560	5689
1 (996)	23	54.99	N	63	31.31	W	17-Nov 14:12	1500	5858
2 (001)	20	01.70	N	37	49.90	W	22-Nov 21:06	1500	5525
3 (004)	19	29.99	N	23	00.06	W	26-Nov 18:08	1500	3392
4 (003)	20	00.04	N	23	00.10	W	26-Nov 23:37	1500	4229
5 (002)	20	27.87	N	23	05.61	W	27-Nov 04:47	1500	4410
6 (005)	19	00.16	N	22	59.99	W	28-Nov 01:49	1500	3801
7 (006)	18	29.99	N	22	59.97	W	28-Nov 06:00	1500	3613
8 (007)	17	59.96	N	22	59.92	W	28-Nov 10:10	1500	3997
9 (008)	17	30.00	N	23	00.01	W	28-Nov 14:17	1500	3413
10 (009)	16	59.98	N	22	48.97	W	28-Nov 18:57	1225	1225 to 1250
11 (010)	16	29.92	N	22	44.10	W	28-Nov 23:28	1499	2129
12 (011)	15	59.97	N	22	35.97	W	29-Nov 04:02	570	582
13 (012)	15	29.81	N	22	49.08	W	29-Nov 07:50	1500	2673
14 (013)	14	59.86	N	22	51.91	W	29-Nov 11:58	1500	3148
15 (014)	14	29.87	N	22	59.92	W	29-Nov 17:14	1500	4091
16 (015)	14	00.03	N	23	00.04	W	29-Nov 21:20	1500	4323

17 (016)	13	29.86	N	23	00.02	W	30-Nov 01:35	1500	4547
18 (017)	12	59.96	N	23	00.00	W	30-Nov 05:47	1500	4742
19 (018)	12	30.03	N	22	59.97	W	30-Nov 09:37	1500	4921
20 (019)	12	00.11	N	22	59.89	W	30-Nov 14:37	1500	5050
21 (021)	11	00.06	N	23	00.04	W	30-Nov 21:26	1500	5155
22 (020)	11	27.87	N	23	00.02	W	01-Dec 01:46	1500	5121
23 (022)	10	30.00	N	23	59.59	W	01-Dec 23:07	1500	5190
24 (023)	9	59.99	N	22	59.99	W	02-Dec 03:15	1500	5049
25(024)	9	29.96	N	22	60.00	W	02-Dec 07:18	1500	4640
26 (025)	8	59.83	N	22	59.94	W	02-Dec 11:28	1500	4891
27 (026)	8	30.06	N	22	59.98	W	02-Dec 15:27	1530	4782
28 (027)	8	00.14	N	22	59.93	W	02-Dec 19:42	1500	4418
29 (028)	7	29.97	N	23	00.02	W	03-Dec 00:08	1500	4386
30 (029)	7	00.09	N	23	00.01	W	03-Dec 04:10	1465	1466
31 (030)	6	30.08	N	23	00.05	W	03-Dec 08:17	1490	3138
32 (031)	6	00.07	N	22	59.91	W	03-Dec 12:47	1500	4100
33 (032)	5	30.04	N	23	00.00	W	08-Feb 00:00	1500	4233
34 (033)	5	00.03	N	22	59.92	W	03-Dec 22:04	1500	4209
35 (034)	4	30.00	N	22	59.98	W	04-Dec 05:58	1500	4120
36 (035)	4	04.04	N	22	59.66	W	04-Dec 09:00	1500	4198
37 (036)	3	30.01	N	22	59.97	W	04-Dec 20:07	1500	4396
38 (037)	3	00.05	N	23	00.04	W	05-Dec 00:18	1500	4646
39 (038)	2	30.03	N	23	00.03	W	05-Dec 04:33	1500	4768
40 (039)	2	00.02	N	22	59.99	W	05-Dec 08:48	1500	4335
41 (040)	1	45.06	N	23	00.03	W	05-Dec 11:42	1500	3957
42 (041)	1	30.04	N	23	00.02	W	05-Dec 14:37	1500	4344
43 (042)	1	14.99	N	23	00.08	W	05-Dec 17:31	1500	3301
44 (043)	1	00.19	N	22	59.94	W	05-Dec 20:25	1500	3222
45 (044)	0	45.04	N	22	59.99	W	05-Dec 23:18	1500	4298
46 (045)	0	29.96	N	22	59.98	W	06-Dec 02:10	1500	3744
47 (046)	0	15.02	N	23	00.04	W	06-Dec 05:00	1500	3873
48 (047)	0	00.01	N	22	60.00	W	06-Dec 12:45	3500	3959
49 (048)	0	14.92	S	22	59.99	W	06-Dec 16:58	1500	4544
50 (049)	0	29.91	S	23	00.03	W	06-Dec 19:50	1500	4634
51 (050)	0	45.01	S	23	00.00	W	06-Dec 22:47	1500	3672
52 (051)	1	00.05	S	23	00.04	W	07-Dec 01:38	1500	4119
53 (052)	1	14.98	S	23	00.03	W	07-Dec 04:35	1500	4266
54 (053)	1	30.02	S	23	00.04	W	07-Dec 07:18	1500	4922
55 (054)	1	45.07	S	22	59.98	W	07-Dec 10:09	1500	4864

56 (055)	2	00.05	S	23	00.09	W	07-Dec 14:21	1500	5237
57 (056)	2	30.00	S	23	00.06	W	07-Dec 18:32	1500	5773
58 (057)	3	00.04	S	23	00.05	W	07-Dec 22:43	1500	5476
59 (058)	3	30.02	S	23	00.04	W	08-Dec 02:49	1500	5483
60 (059)	4	00.02	S	23	00.04	W	08-Dec 06:50	1500	5865
61 (060)	4	29.96	S	22	59.97	W	08-Dec 11:04	1500	5168
62 (061)	4	59.93	S	23	00.07	W	08-Dec 15:18	1500	5199
63 (062)	5	29.93	S	23	00.09	W	08-Dec 19:27	1500	5077
64 (063)	6	00.01	S	22	59.98	W	08-Dec 23:33	1500	5237
65 (064)	6	30.03	S	22	60.00	W	09-Dec 03:45	1500	5457
66 (065)	7	00.01	S	23	00.02	W	08-Dec 09:13	1500	5254
67 (066)	7	30.13	S	22	59.96	W	09-Dec 13:22	1500	5453
68 (067)	8	00.02	S	23	00.01	W	09-Dec 17:22	1500	5606
69 (068)	11	59.78	N	37	59.60	W	15-Dec 14:45	1500	4615
70 (069)	12	00.16	S	37	59.71	W	15-Dec 18:32	3000	4625

Table 2. CTD sensor history. First date (stations number) when CTD sensors were added/changed on the frame. For the entire cruise, the upward looking ADCP was S/N #2-4616, and downward looking ADCP was S/N #1856. The altimeter used throughout the cruise was S/N #48952. The CTD fish serial number was #1335, and the carousel number was #1087. All of the successful casts used the aft winch, except for the last cast.

Date (Station number)	**Temp1**	**Temp2**	**Cond1**	**Cond2**	**Oxy1**	**Oxy2**	**Pump1**	**Pump2**	**Other Notable Changes**
11/12/2021 (000)	2946	5233	3854	1347	2940	2949	7889	51072	
11/17/2021 (996)			4204	1346					Also swapped out T-duct, O-ring connections checked
11/26/2021 (005)						0703			
12/1/2021 (022)		2958		43861					Swapped Temp2 and Cond2 to try fix anomalies, also swapped secondary temperature cable
12/2/2021 (025)			41335						Still had offsets, tried swapped Cond1 sensor
12/2/2021 (026)			4204						That made it worse, switched back to previous Cond1
12/3/2021 (028)									Replaced O-Ring on Cond-2, flushed conductivity sensors with bleach
12/5/2021 (041)								7739	Trying to figure out spikiness happening

									sometimes between 50-100m on secondary sensors
12/5/2021 (043)									New Y connector on secondary
12/8/2021 (063)									Changed bubbler and tubing on secondary sensor side, reseated connectors
12/9/2021 (066)									Changed pump cable
12/15/2021(069)									Test of forward winch

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

1. Recovery and redeployment of TFlex moorings at 20°N, 38°W; 20.5°N, 23°W; 11.5°N, 23°W; and 4°N, 23°W.
2. Replacement of surface wind sensor and central processing unit on the French 0°, 23°W mooring and bringing that mooring back online.
3. Visited the sites of the Brazilian moorings at 4°N, 38°W and 8°N, 38°W to attempt to recover them. We confirmed that they were lost/went adrift.
4. Recovered the 12°N, 38°W Brazilian Atlas mooring.
5. CTD/O_2/ADCP profiles to 1500 m at 70 locations, including each mooring site.
6. Deep CTD/O_2/ADCP profile to 3500 m near 0°, 23°W and to 3000 m near 12°N, 38°W.
7. Salinity of the CTD bottle samples collected with Niskin bottles.
8. Dissolved oxygen concentration of the CTD bottle samples collected with Niskin bottles.
9. Collection of 175 water samples in the upper 10 m from CTD bottles, to be analyzed by AOML/OCED for phosphate and nitrate concentrations (Sargassum Group).
10. Near-surface ocean temperature, salinity, oxygen, and pH of CTD water samples from a Hanna handheld instrument (Sargassum group).
11. Sargassum tissue collected; underwater pictures and videos of upper ocean near Sargassum mats (Sargassum group).
12. Deployment of Sargassum tissue, housed in a container, to the bottom of the ocean on the 4°N and 11.5°N, 23°W mooring's acoustic release, recovery of Sargassum tissue deployed previously at 11.5°N, 23°W mooring (Sargassum and mooring groups).
13. Visual Sargassum surveys conducted several times during daylight hours when Sargassum was present.
14. Deployment of 11 Argo floats and 15 surface drifting buoys.
15. Continuous recording of shipboard ADCP data.
16. Continuous recording of Thermosalinograph (TSG) data.
17. Heading data from the Meridian Attitude and Heading Reference System (MAHRS) and the Position and Orientation Systems for Marine Vessels (POS MV).
18. Weatherpak meteorological sensors (Univ. Miami).
19. Microwave radiometer (Univ. Miami).
20. Marine Atmospheric Emitted Radiance Interferometer (M-AERI) (an infrared Fourier transform spectrometer (FTS)) to measure uplooking and downlooking spectral

radiances, marine boundary layer profiles of temperature and water vapor, and skin SST (Univ. Miami).
21. Dust samples collected from two of the PNE buoys' meteorological sensors (PNE on behalf of AEROSE).
22. Mole fraction of carbon dioxide in air (NOAA/AOML).
23. Automated surface pCO_2 and total alkalinity (NOAA/PMEL).

Oceanic Data

1. Moorings (excerpt from Kenneth Connell's NOAA/PMEL report)

Summaries of the mooring operations (Table 3), lost or damaged instruments (Table 4), pre-deployment hardware failures (Table 5), acoustic releases employed (Table 6), and evidence of vandalism (Table 7) are presented in the tables below.

Table 3: Summary of Mooring Operations

Site	Mooring ID #	Operation
20°N, 38°W	PT038 / PT046	Recover / Deploy
20.5°N, 23°W	PT039 / PT047	Recover / Deploy
11.5°N, 23°W	PT040 / PT048	Recover / Deploy
4°N, 23°W	PT041 / PT049	Recover / Deploy
0°-, 23°W	PT045(b)	Repair (tube & wind swap)
4°N, 38°W	PT024	Recovery: Lost at Sea
8°N, 38°W	PI253	Recovery: Lost at Sea
12°N, 38°W	PI254	Recovery

Table 4: Lost or Damaged Instruments and Equipment *(from rec moorings)*

Site	Mooring ID	Sensor type	Serial No	Comments
20°N, 38°W	PT038	SBE37-IMP	9211	Missing shield.
20.5°N, 23°W	PT039	Rain	1554	Lost and cable cut
20.5°N, 23°W	PT039	SBE37-IMP	15379	Cracked case near case screw. Flooded?
20.5°N, 23°W	PT039	O2	2239	IMM slipped off sensor
11.5°N, 23°W	PT040	SBE37-IMP	7806	Shield & top tube missing
4°N, 23°W	PT041	O2	2533	Scratch on Optode Lens (light shines thru)
0°-, 23°W	PT045	Tube	0003	Failed. No vis damage.
0°-, 23°W	PT045	Wind	16340034	Failed. No vis damage.
4°N, 38°W	PT024	**ALL**	**ALL**	**Lost at Sea**
8°N, 38°W	PI253	**ALL**	**ALL**	**Lost at Sea**
12°N, 38°W	PI254	Wind	80485	Propeller missing. Vane body broken.

12°N, 38°W	PI254	SWR	38710	Lost and cable cut
12°N, 38°W	PI254	SSTC	15342	Lost and cable cut
12°N, 38°W	PI254	TP	15386	Lost (except net-shed)

Table 5: On-deck instrument or hardware failure *(pre-deployment)*		
Sensor type	**Serial No**	**Comments**
LWR	36386	Failed on deck testing. Swapped with spare S/N: 35960.
SBE39 (T140)	6194	Failed on deck testing. Swapped with spare S/N: 5681.

Table 6: Acoustic Releases
All acoustic releases performed well. But, deck set S/N 50238 was faulty: Keypad '1' button failed; difficulty communicating. Deck set S/N 51177 performed well.

Table 7: Fishing and Vandalism		
Site	**Mooring ID**	**Comments**
20°N, 38°W	PT038	One small rope on bridle, but not clear if from fishing or simply flotsam debris that entangled with the buoy bridle. No monofilament encountered on mooring. Buoy in good condition.
20.5°N, 23°W	PT039	Some monofilament on the bridle. A couple of small pieces of rope (lines). Rain gauge lost & cable cut.
4°N, 23°W	PT041	One small rope on bridle. Some monofilament fishing line on several sensors.
0°-, 23°W	PT045	One line (rope and chain) attached to tower leg. Approximately, 15m (50-ft) of floating line floating behind buoy. Attached to buoy by a short 1-2m (3-6 ft) length of chain shackled to the pad-eye at the base of the tower. Otherwise buoy, cables, and all sensors appeared to be untouched and in good condition.
12°N, 38°W	PI254	A lot of hawser lines (mostly blue polypropylene rope) entangled in the bridle and top 40 m of NILSPIN™. Traces of netting surrounding the buoy (covered in barnacles). Top section cable was severed. SSTC missing from bridle. No monofilament line or longline tackle at all.

Shipping Notes

Two step-bed trucks were loaded at PMEL on 25 Oct 2021 for transport to St. Petersburg, FL. The equipment was loaded onto the *Ronald H. Brown* in St. Petersburg, FL on 1 Nov 2021, supervised by Denise Kester.

We are scheduled to air-ship all Sea-Bird sensors back from Cabo Verde. All remaining equipment remained on board the Ronald H. Brown during its transit to Miami, FL after the cancelled A13.5 cruise. The offload occurred in Miami in January 2022.

Noteworthy Operational Details

20°N, 38°W

PT038 Recovery: The 20°N, 38°W mooring was recovered on 23 Nov 2021. Upon arrival on site the buoy was quickly located. A few minor issues were encountered while communicating with release: deck set S/N 50238 appeared to be faulty: The '1' button on the deck unit stopped working and we had difficulty getting response from release. We switched deck unit to S/N 51177 and the number pad worked well, but we still encountered some difficulty getting release response with the same transducer (from 50238). We switched transducer and transducer cable and the transmit sounds were louder and we were able to ping on the release with immediate response. The recovered buoy was in reasonably good shape, despite one SBE37-IMP missing a shield (refer to Table 4). No monofilament fishing line was observed on the mooring. Many in the Deck crew were new to this ship, but the Chief Bosun implemented well planned training and operations and everyone worked together safely and efficiently under his deck leadership.

PT046 Deployment: The 20°N, 38°W mooring was deployed on 23 Nov 2021. The deployment operations were also well executed. This mooring had 18 instruments on deck for the top 83m of wire faked out on deck. This was the first deployment with 16 Nortek Aquadopps (15 are AOML TACOS project sensors; 1 is PMEL standard Aquadopp sensor). Unfortunately, Aquadopps at 48.6m (12058) and 89.6m (9843) were not communicating over Iridium following the deployment. All initial values are 1E+35 for those two sensors. There was no indication of why they failed after successful testing on deck for over 1 week. All other sensors were operating as expected following deployment.

20.5°N, 23°W

PT039 Recovery: The 20.5°N, 23°W mooring was recovered on 27 Nov 2021. Prior to arrival on site we noted that Rain sensor had failed on 10 Jun 2021 and the 10m TC sensor failed on 24 Jun 2021. This buoy had some minor evidence of fishing vandalism, including monofilament on the bridle, a couple of small pieces of rope (lines), and the Rain gauge was missing (Table 4). Table 4 also lists subsurface sensors with damage including an SBE37-IMP with a cracked case and evidence of flooding in the endcap as well as a dissolved oxygen (DO) sensor with the Inductive Modem Module (IMM) clamp separated from the sensor. A significant knot (wuzzle) was observed in the NILSPIN™ just below the 500 m SBE39-TP (Figure 2). We cut the knot out and continued recovery using the YaleGrip™ on the NILSPIN™. It was noted that the 300m NILSPIN™ was the yellow-jacketed NILSPIN™, which is different from the orange-jacketed

NILSPIN™. The yellow NILSPIN™ has a softer more pliable jacketing. During the deployment that followed this recovery, it was noted that the yellow-jacketed 300m NILSPIN™ is especially prone to twisting and when the swivel came through the block the swivel spun a lot more than is typical. We are not sure if this may have contributed to forming the knot, but it is something to consider. We saved the knot for inspection after return to the lab. A Saharan dust sample was taken from AT/RH shields to send to AEROSE project for processing after the cruise.

PT047 Deployment: The 20.5°N, 23°W mooring was deployed on 27 Nov 2021. The deployment operations were very well executed with a focused, but relaxed deck crew. There were fewer people assisting on deck today than during the previous deployment due to night shift commencing for CTDs at regular intervals. But there was still plenty of deck support to distribute the workload, and operations were efficient. It was noted that the 300m NILSPIN™ was the yellow-jacketed NILSPIN™, which is a bit more soft/pliable plastic and grippier on the capstan. Unfortunately, this yellow-jacketed NILSPIN™ seemed to hold more of a twist memory as it gripped onto the capstan and once the swivel passed through the block it spun a lot more than what is typically observed using the orange-jacketed NILSPIN™. This mooring had dissolved oxygen (DO) sensors (provided by GEOMAR) planned for 79.5m and 299.5m. These were shifted to the even mark (i.e., 79.0 and 299.0, respectively) because the instrument would not fit at the half-meter mark without touching the instrument below it. We recommend future DO sensor deployments be moved to the even meter mark. The 150m DO sensor is at 150.0m because there is no sensor in the immediate vicinity. All DO sensors were deployed in stand-alone on-board data mode (i.e., no real-time data).

Figure 2. Knot observed on the NILSPIN™ wire immediately below the 500m mark during the 20.5°N, 23°W mooring (PT039) recovery. *(Photo: Renellys Perez)*

<u>11.5°N, 23°W</u>

PT040 Recovery: The 11.5°N, 23°W mooring was recovered on 1 Dec 2021. The recovered buoy was in reasonably good shape, despite damage to the 40m TC sensor (Table 4). A PVC Sargassum vessel (provided by Fearless Fund) was mounted to release. After recovery this vessel was cut open using a power grinder. The contents were still in the mesh bag, but appeared to be the consistency of a muddy mush. Recovery operations were efficient and well executed.

PT048 Deployment: The 11.5°N, 23°W mooring was deployed on 1 Dec 2021. The planned 140m SBE39-T sensor (S/N: 6194) was swapped out with spare sensor S/N: 5681 after S/N: 6194 failed on deck after a reset & testing period on deck. The deployment operations were smooth and efficient. Dissolved Oxygen sensors are provided by GEOMAR and set to onboard logging only (no real-time data). This deployment also included a new Sargassum vessel from Fearless Fund. The same design was used as the previous deployment, with the exception of adding a screw-cap to facilitate access to the Sargassum inside the vessel.

4°N, 23°W

PT041 Recovery: The 4°N, 23°W mooring was recovered on 4 Dec 2021. The recovered buoy was in reasonably good shape, despite some minor fishing line evidence and a scratch on the 499 m DO sensor optode (Table 4). The SSTC sensor had failed with intermittent data since March 2021 and no data (1E+35) since 20 May 2021. There was biofouling, but no damage to SSTC pigtail nor the top section cable. No visual indicators that would have contributed to the SSTC failure. The downloaded SSTC data file from instrument appears to be complete and similar size as other TC data records.

PT049 Deployment: The 4°N, 23°W mooring was deployed on 4 Dec 2021. This deployment also included a new Sargassum vessel from Fearless Fund deployed on the acoustic release. Dissolved Oxygen sensors are provided by GEOMAR and set to onboard logging only (no real-time data). Operations were efficient.

0°-, 23°W

PT045 Repair: The 0°-, 23°W mooring was repaired on 6 Dec 2021. Prior to the cruise, the 0°-, 23°W mooring had shut down entirely and stopped transmitting all data (including GPS positions) since 13 Oct 2021. Despite this, the surface buoy appeared to be in reasonably good shape. An approximately 15m line was floating behind buoy. This was attached to the buoy by a short 1-2m length of chain shackled to the pad-eye at the base of the tower. Otherwise, the buoy, cables, and all sensors appeared to be intact and in good condition. Two buoy rides were completed to repair this mooring: 1) a tube swap was completed during the first buoy ride and most of the mooring came back online, but the wind, SSTC, and 60m TC sensors failed. The SSTC and 60m TC sensors failed much earlier in the deployment (SSTC failed on 21 July 2021 and 60m TC failed on 1 Apr 2021). We could not replace those subsurface sensors. However, we were able to replace the wind sensor during the second buoy ride (Figure 3). At the completion of the repair, all sensors were transmitting except for the SSTC and 60m TC.

Figure 3. Replacing the wind sensor on 0°-, 23°W mooring (PT045b). (Photo: Mark Watson)

<u>4°N, 38°W</u>

PT024 Recovery: The 4°N, 38°W mooring was confirmed lost at sea on 13 Dec 2021. When we arrived on site, there was no evidence of any mooring on RADAR and no visual sighting of the mooring. We sent down the acoustic transducer from the deck unit to communicate with release at 13:45 UTC. We enabled the release then sent the code, but received a response of "Tilted and not released" (7 pings @ 2s interval). This indicated that the buoy had broken free of its mooring and was adrift and lost at sea. The last transmitted position from this mooring was Sep 2019.

<u>8°N, 38°W</u>

PI253 Recovery: The 8°N, 38°W mooring was confirmed lost at sea on 14 Dec 2021. When we arrived on site, there was no evidence of the mooring on RADAR and no visual sighting of the mooring. We sent down the acoustic transducer from the deck unit to communicate with release at 12:02 UTC. We enabled the release then sent the code, but received a response of "Tilted and not released" (7 pings @ 2s interval). This indicated that the buoy had broken free of its mooring and was adrift and lost at sea. The last transmitted position from this mooring was Jan 2019.

<u>12°N, 38°W</u>

PI254 Recovery: The 8°N, 38°W mooring was recovered on 15 Dec 2021. There was quite a bit of rain during the recovery. As expected following a >3-year deployment, there were a lot of hawser lines (mostly blue polypropylene rope) entangled in the bridle and the top 40 m of NILSPIN™ (Figure 4). This took a lot of time to cut through. Other than a small amount of netting around the buoy (and encrusted with thick cover of barnacles), we found no other fishing gear (no monofilament or long-line fishing tackle). Shackles & clevis beneath the bridle were heavily worn and we have saved them for EDD. 2 shackles beneath the bridle were missing nuts and only held in place by tension, cotter pins, and a lot of poly rope. Bird cage was also missing nuts. The wind sensor was broken and the nose cone propeller was missing. The SWR sensor was lost and the cable was severed. The SSTC sensor was lost and Top Section cable was severed. The 500m TP sensor was also missing. Only the net-shedder cone at the 500m mark was left on the wire. Aside from the extensive rope cutting, the rest of the recovery was well executed and uneventful.

Figure 4. 12°N, 38°W mooring (PI254) recovery. Note rope in bridle *(Photo: Grace Owen)*

Instrument and Hardware Notes
Lost or damaged instruments are summarized in Table 4 above.

NILSPIN™
A significant knot (wuzzle) was observed in the recovered 20.5°N, 23°W (PT039) NILSPIN™ just below the 500 m SBE39-TP (Figure 2). We do not know what caused the wuzzle. However, it is notable that the 300m NILSPIN™ section of the mooring used a yellow-jacketed NILSPIN™ (Figure 5), which is different from the orange-jacketed NILSPIN™ that we typically use on moorings. The yellow-jacketed NILSPIN™ has a softer, more pliable jacketing with ridges (presumably the ridges are designed to reduce drag). During the PT047 deployment that followed this recovery, the yellow-jacketed 300m NILSPIN™ section was very prone to twisting and when the 5-ton swivel came through the block and was loaded with tension, the swivel spun a lot more

than is typical to release the twisting. This amount of twisting had not been observed in the past using the orange-jacketed wire. We do not know if this may have contributed to forming the knot, but it is something to consider. We have saved the knot for engineering review.

Figure 5. Yellow-jacketed NILSPIN™ wire with soft, pliable jacketing with ridges.

Clevis, Shackle, Chain Hardware Following Extended Deployments

The mooring recovered at 12°N, 38°W (PI254) had been deployed over 3 years (1,143 days). This provided an interesting opportunity to evaluate the condition of mooring hardware after an extended deployment period. The hardware that appeared to suffer the greatest damage from wear and tear were the clevis, shackles, and chain directly below the bridle (Figure 6). We have saved this hardware for engineering review.

Figure 6. Worn clevis from 12°N, 38°W (PI254) recovery.

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

2.1 CTD casts

AOML's CTD package was configured with 24 Niskin bottles: 12-13 bottles to be fired at various depths during the casts (to collect water samples for salinity and dissolved oxygen calibration) and the remainder were spare bottles. The sensors on the CTD frame consisted of primary and secondary temperature, conductivity, and oxygen (six total) and upward- and downward-looking 300 kHz ADCPs. We had to swap out multiple sensors throughout the cruise (see Table 2). In particular, we needed to go through a surprising number of conductivity and oxygen sensors to find a good pair. As mentioned earlier the secondary salinity and conductivity sensors exhibited some unusual spikes in the upper 100 m of the water column that we were unable to resolve despite some sensor and plumbing swaps. This affected the last third of the CTD casts.

A total of 70 CTD/ADCP casts, including two deep casts, were conducted by Renellys Perez, Diego Ugaz, Christian Saiz, Grace Owen, and Clara Gramazio, with assistance from the Survey Technicians (Table 1). CTD processing was performed using Seabird software. After acclimating in the autosal room for at least twelve hours, salinity samples were calibrated using an autosal provided by AOML by Renellys Perez, Grace Owen, and Clara Gramazio. Oxygen titration was performed by Diego Ugaz and Christian Saiz in order to calibrate dissolved oxygen concentration obtained from the CTD sensors.

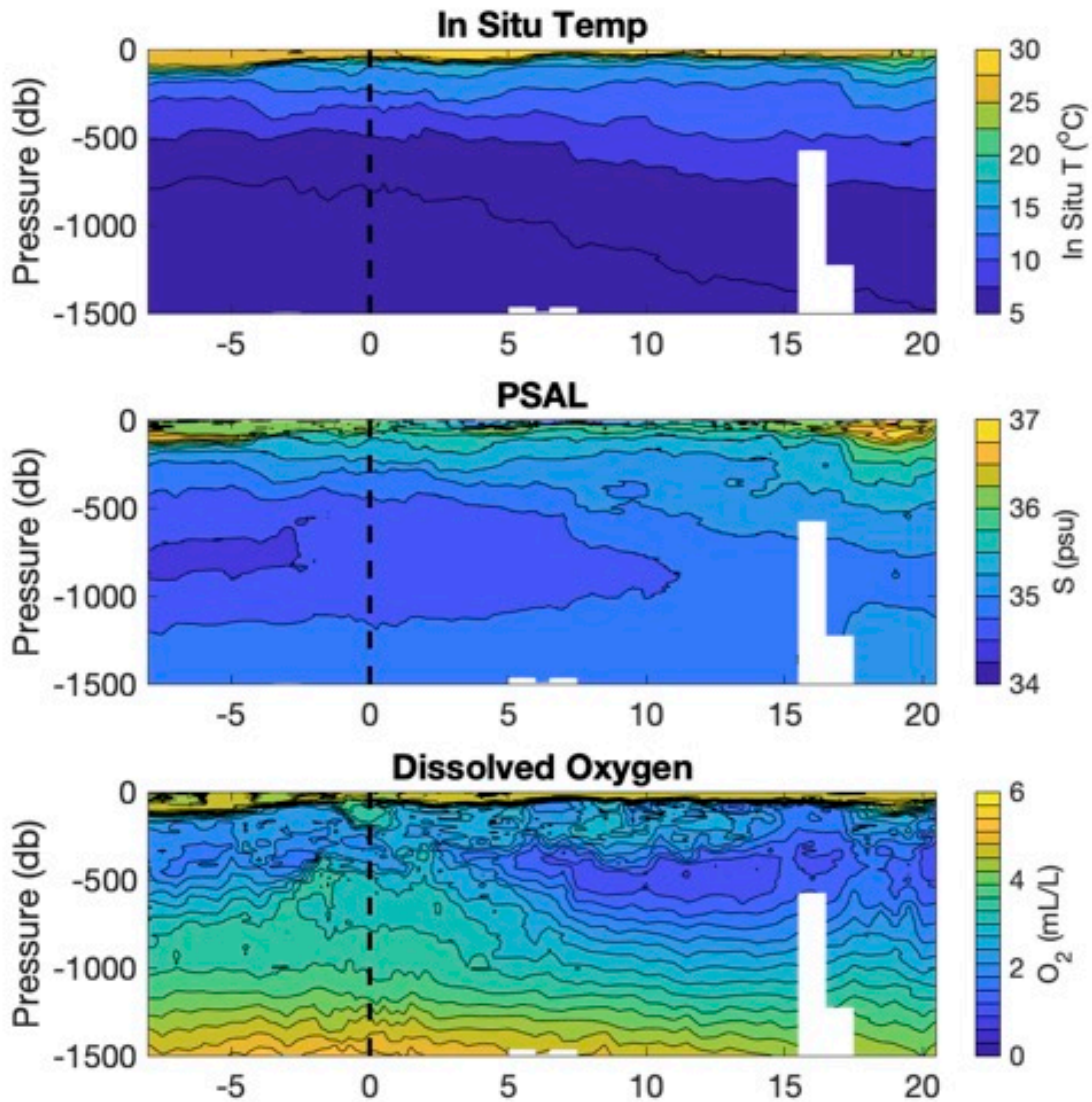

Figure 7. Latitude-depth sections of (upper panel) in situ temperature, (middle panel) salinity, and (lower panel) dissolved oxygen acquired along 23°W during the cruise from the primary sensors.

The latitude-depth section of *in situ* temperature from the casts shows the warmest sea surface temperatures (SSTs) were concentrated in the 3°N-7°N latitude band (Figure 7a). SSTs in the intertropical convergence zone (ITCZ) region exceed 28.5°C and drop to 27°C between 8°S-0° and below 27°C north of 12°N. The thermocline, marked by the 20°C isotherm, was approximately 50 m deep between 3°S and 15°N and deepened to 100 m poleward of this region.

The salinity section shows the low-salinity core of the Antarctic Intermediate Water (AAIW) between 400 and 1200 dbar. The freshest waters are at 8°S and centered around 800 dbar and becoming saltier to the north (Figure 7b). High-salinity waters (>36.4 psu) are apparent at in the upper 200 dbar between 16°N and 20.5°N and to a lesser extent between 8°S-4°S centered at 100 dbar. The high-salinity water mass north of 16°N can be traced in part to the subtropical North Atlantic, where an excess of surface evaporation over precipitation leads to the highest surface salinity in the global ocean. The high-salinity features visible at 20°N and south of the equator in the latitude-depth section are consequences of the subduction of subtropical salinity maximum water in the North and South Atlantic, respectively. Between the equator and 12°N much lower salinity values (< 35.5 psu) are observed between the surface and 50 dbar, consistent with excess precipitation over evaporation in the ITCZ region.

The dissolved oxygen section along 23°W shows high concentrations greater than 4 ml l^{-1} in the surface mixed layer between 0 and 100 dbar and between 1200 and 1500 dbar (Figure 7c). The oxygen minimum zone (oxygen concentrations less than 2 ml l^{-1}) is centered at a depth of about 300-600 m between 5°N-20°N.

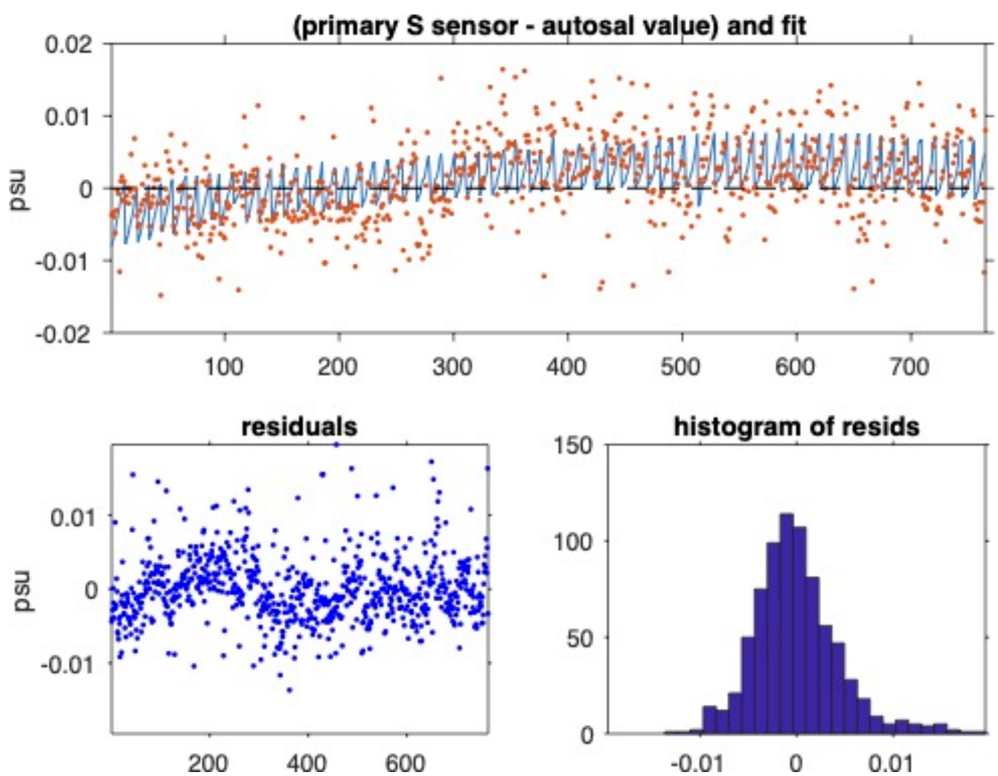

Figure 8. Top panel: Salinity residuals (sensor minus autosal values, red dots) and model fit (blue line) for the primary sensor. The bottom left figure shows the residuals from the model fit, and the bottom right figure shows the histogram of the residuals.

Salinity calibration values from the bottle samples are available for each cast. The autosal performed well and the room temperature remained fairly stable, within about one degree of 24°C. Autosal work was primarily done by Grace Owen, Clara Gramazio, and Renellys Perez. The error for the calibrated primary salinity sensor is 0.00444 psu, which is higher than the WOCE standard of 0.002 psu (Figure 8, upper panel). Although the values were slightly larger than the secondary salinity sensors (0.00427 psu), we used the primary salinity sensor because of spikiness detected in the secondary salinity and oxygen sensors (mentioned earlier). Before correcting the sensor values based on the calibration readings, the calibration readings were corrected for any spurious trends identified during each autosal run, using the Matlab code provided by Jay Hooper. Upon comparing the salinity sensor and autosal data, we noted a temporal drift in both the primary (Figure 8) and secondary (not shown) salinity sensors relative to the autosal that leveled out after the first 25 casts or so. This may be attributed to autosal drift, or an improvement in the way salinity samples were processed as the cruise progressed. Our processing sessions became more efficient (shorter times) as the cruise progressed. We were able to correct for this drift in our post cruise processing.

Oxygen calibration values from the bottle samples are available for each cast. The oxygen titration for the samples was performed during the cruise by Diego Ugaz and Christian Saiz. As noted previously in the report, we changed dissolved oxygen sensors multiple times (Table 2). Figure 9 (upper panel) shows the drift in the primary oxygen sensor values vs. the calibrated values over time that started around station #045, which shows up as an shift in the residuals over time (Figure 9, bottom left panel). This drift was also present for the secondary oxygen sensor (not shown). The beginning of the drift doesn't align to time periods for which we changed the oxygen titration chemicals – although the probe for the titration system was later changed during the processing of cast #051. The error for the calibrated oxygen for the primary sensor is 0.0382 ml/l, which is roughly 1% of the measured oxygen concentrations and within the range recommended by WOCE. The errors were substantially larger for the secondary oxygen sensor (0.0427 ml/l) which is why we opted to use the primary oxygen sensor data.

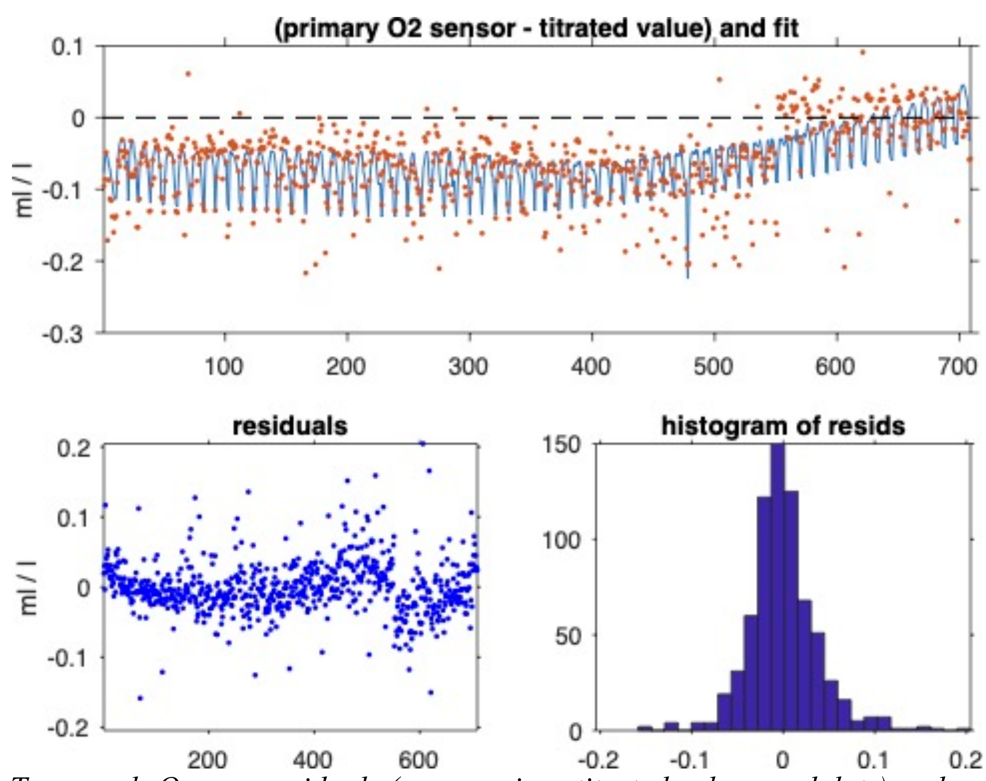

Figure 9. Top panel: Oxygen residuals (sensor minus titrated values, red dots) and model fit (blue line) for the primary sensor. The bottom left figure shows the residuals from the model fit, and the bottom right figure shows the histogram of the residuals.

2.2. ADCP casts

A total of 70 lowered ADCP casts was obtained using upward- and downward-looking 300 kHz ADCPs. The resultant meridional sections along 23°W of zonal and meridional velocity are shown in Figure 10. The eastward equatorial undercurrent is clearly visible within about 2° of latitude from the equator, with strong eastward velocities from the surface down to 150-200m. Strong westward flow of the South Equatorial Current (SEC) is noticeable north and south of the undercurrent core. We also resolve a fairly strong eastward North Equatorial Countercurrent (NECC) between 4°N-6°N. Strong off-equatorial eastward undercurrents are observed, as well as a relatively strong westward flow near 800 m below the equatorial undercurrent.

In terms of the meridional currents, strong northward flows were detected from the surface down to 1000 m north of 16°N (Figure 10). We also observed strong near-surface poleward flows associated with the tropical/subtropical cells. During the cruise, we crossed through a late fall tropical instability wave (TIW), unexpected but not unheard of during this time of year (Figure 11). This TIW was responsible for the strong northward flow between 2°N and 4°N from the surface down to 250 m. Daily maps obtained from Mercator of surface velocity, salinity, temperature and sea surface height enabled us to identify these features and deploy drifters accordingly.

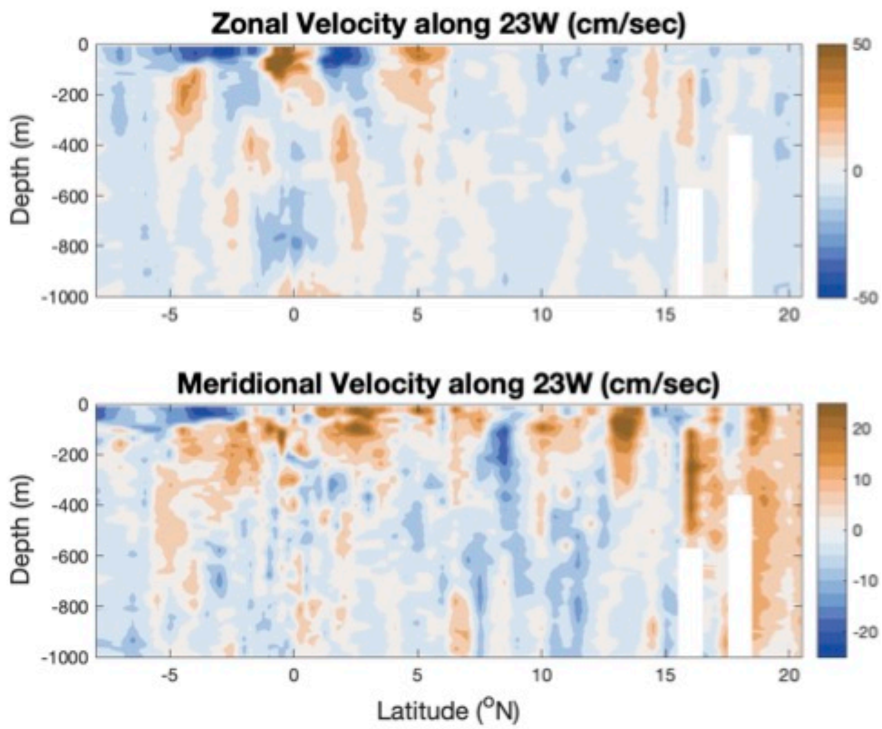

Figure 10. Zonal (upper) and meridional (lower) velocity sections along the 23°W cruise track from the lowered ADCP casts.

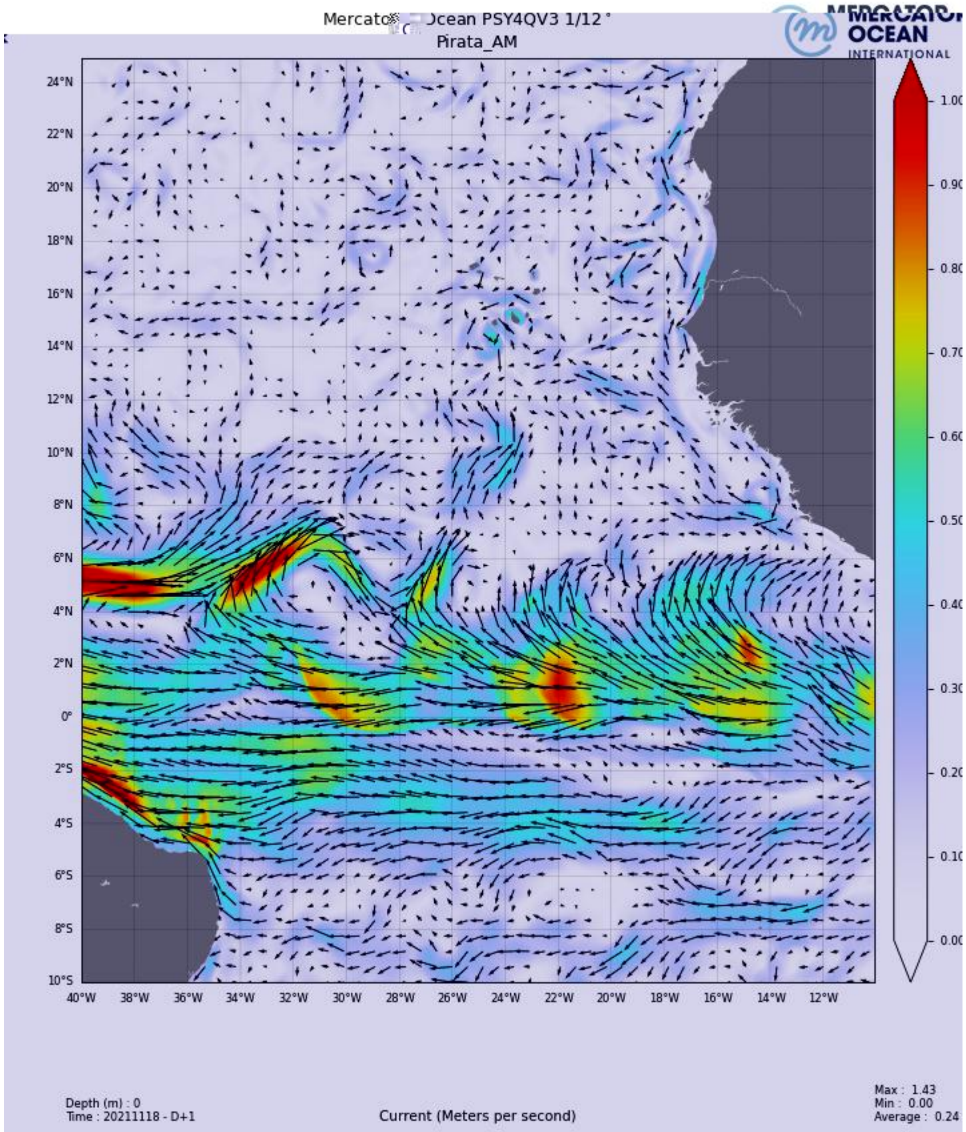

Figure 11. Sample daily map of surface currents from Mercator used to detect the presence or absence of tropical instability waves.

3. Ancillary measurements and data collection

3.1. Argo deployments

A total of 11 Argo floats were deployed in locations specified by Pelle Robins at WHOI to fill in gaps in the spatial coverage of the Argo array (Figure 12 and Table 8 for details). The locations were modified as the cruise track changed, and we deployed four more Argo floats than the original seven floats that were planned. They were housed in individual cardboard boxes with straps around them that were held together by a water-activated release. A long rope was provided for lowering the box over the railing off the back of the ship. Within a few seconds of hitting the water, the release activated, setting free the float in the box and allowing us to pull up the straps and release. The straps and releases were saved for later shipment to WHOI.

Additional data from the Argo floats deployed during this cruise can be obtained here: http://argo.whoi.edu/solo2/maps/2021cruises.html.

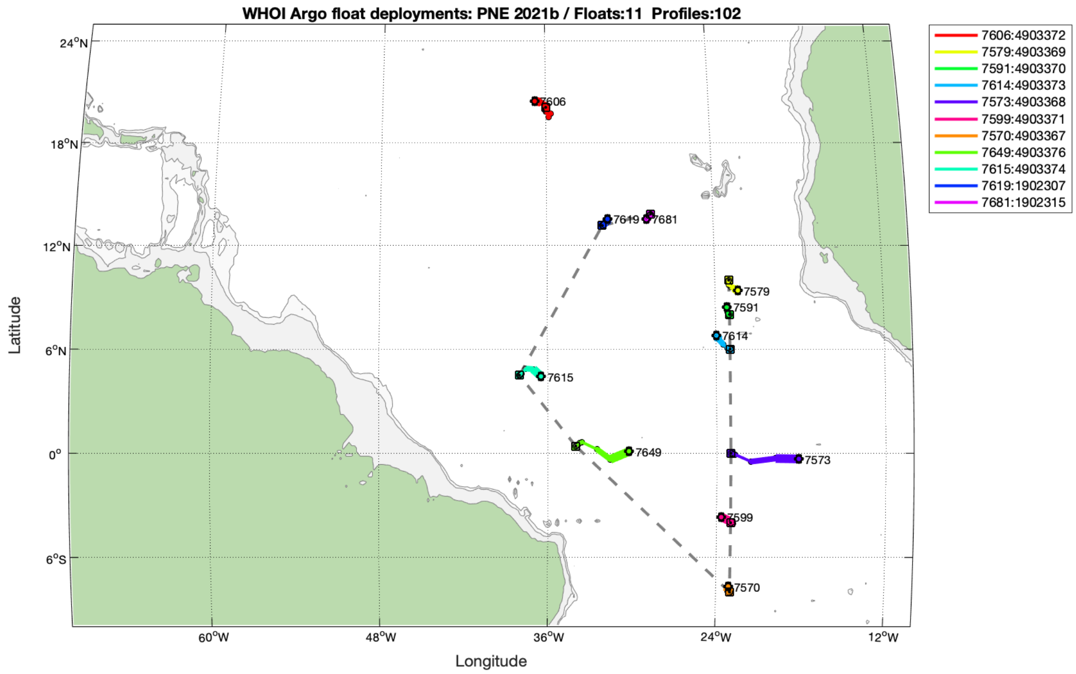

Figure 12. Location of the 11 Argo float deployments with initial locations subsequent to deployment as of 19 January 2022 (courtesy of Pelle Robbins).

Table 8. Latitude and longitude of Argo deployments, including float ID numbers.

	Latitude		Longitude			Argo
Deg.	Min	N/S	Deg.	Min.	E/W	ID Number
20	03.96	N	35	59.41	W	7606
9	59.17	N	23	00.06	W	7579
7	59.61	N	23	00.21	W	7591
6	00.04	N	22	59.88	W	7614
0	00.09	N	22	59.89	W	7573
4	00.03	S	22	59.94	W	7599
7	59.62	S	23	00.15	W	7570
0	24.24	N	34	00.62	W	7649
4	30.32	N	37	59.99	W	7615
13	08.92	N	31	59.90	W	7619
13	48.91	N	28	29.86	W	7681

3.2. Drifter deployments

Fifteen satellite-tracked drifters were deployed during the cruise. The drifters are mini-Surface Velocity Program types, drogued at 15m to follow mixed layer currents; all included a thermistor on the surface buoy for SST. Their data are transmitted in real time via the Iridium system. All of the drifters were launched from either side of the A-frame on the fantail. Five of the drifters were special drifters for Meteo-France. These five Meteo-France drifters were supposed to be deployed between the equator and 4°S, however one was deployed early at 2°N. Because of the presence of a strong TIW (Figure 11), we added deployments north of the equator between 0° and 5°N. The other locations were specified by Shaun Dolk as regions where drifters were needed to fill in gaps in the global spatial coverage of the drifter array (Figure 12).

Table 9. Latitude and longitude of drifter deployments, including drifter ID numbers. Asterisk indicates the Meteo-France drifters.

Latitude			Longitude			ID numbers
Deg.	Min	N/S	Deg.	Min.	E/W	
9	59.43	N	23	00.06	W	61282050
5	00.31	N	22	59.65	W	61282060
4	02.24	N	22	58.96	W	61281340
2	59.99	N	23	00.01	W	61281320
2	00.06	N	23	00.05	W	*66437960
1	01.05	N	22	59.91	W	61281370
0	00.04	N	22	59.90	W	*66437890
1	00.02	S	22	59.99	W	*66438000
1	59.97	S	23	00.11	W	*66437880
3	00.28	S	23	00.09	W	*66437900
4	00.01	S	23	00.00	W	61281290
0	00.02	N	33	33.11	W	61281240
1	00.15	N	34	39.87	W	61280360
2	0.00	N	35	46.51	W	61280370
3	0.03	N	36	53.22	W	61280390

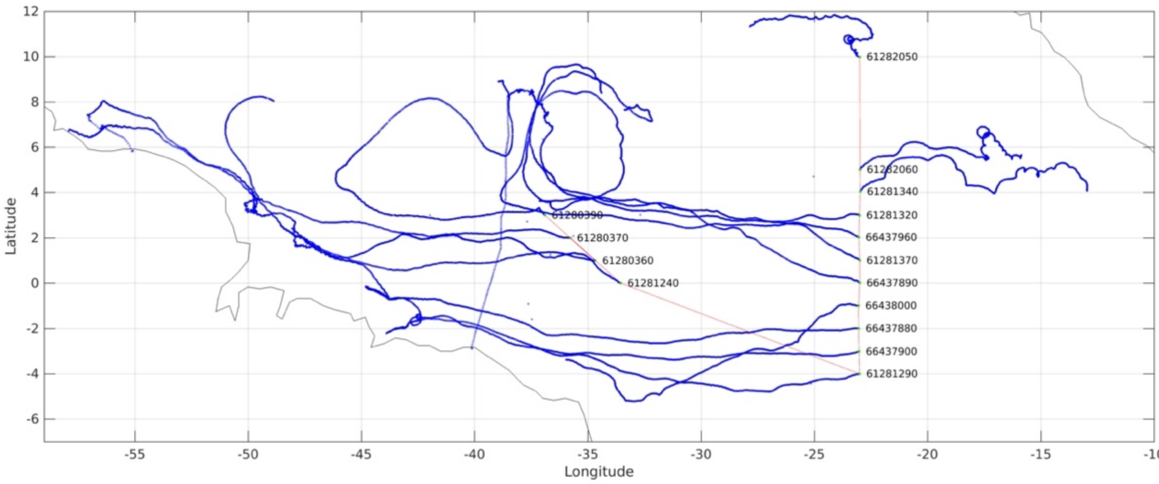

Figure 12. Locations of the drifters deployed during the PNE2021b cruise as of February 2022. One drifter appears to have been recovered by a vessel and taken to land.

3.3 Sargassum Science

The team conducted the following tasks to support the DOE, NOAA MARINER program:

1. Examined satellite imagery to ground truth Sargassum occurrence,
2. Collected sea water samples (175 total, 3 per depth) at CTD sites (surface and 10 m) for nutrient analysis,
3. Harvested macroalgae opportunistically at CTD stations and buoy deployment sites,
4. Collected visual records at the site of large Sargassum mats,
5. Deployed hand-held instruments in surface waters of mats to measure multiple parameters (pH, DO, temp), and
6. Deployed (at 4°N and 11.5°N, 23°W moorings) and retrieved (at 11.5°N, 23°W mooring) PVC canisters of macroalgae to the deep sea to gather data on the potential for carbon sequestration.

As part of the AOML team, Clara Gramazio produced a daily report noting the presence or absence of Sargassum, with observations recorded approximately every two hours during daylight. This Sargassum information was later compared with satellite detection of Sargassum by USF researchers (Figure 13).

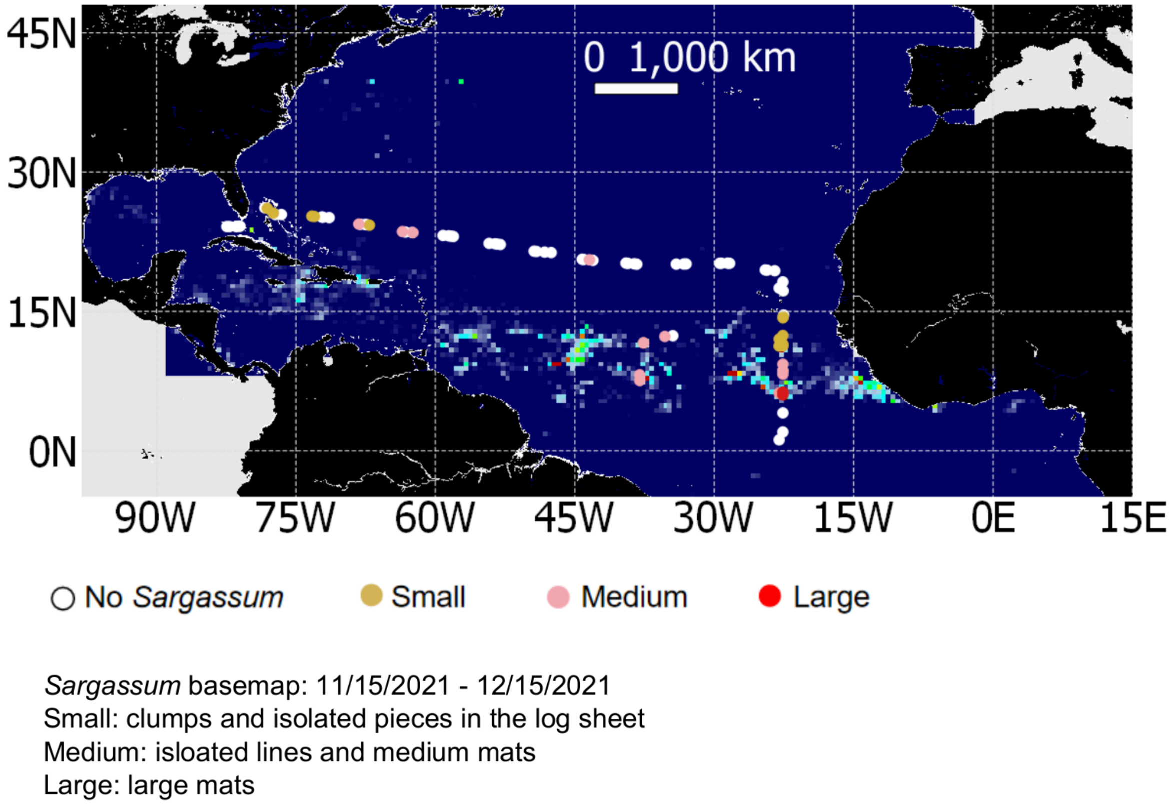

Figure 13. Locations of visual Sargassum surveys overlaid on satellite map of Sargassum (courtesy of Chuanmin Hu).

3.4 Dust Samples

Dust samples were collected at from the buoys at 20°N, 38°W and 20°N, 23°W. Surprisingly, very little dust was observed at other mooring sites. Dust samples will be analyzed by Vernon Morris at Arizona State University in order to determine the different particles in the dust and their temporal and spatial distribution over the Atlantic Ocean.