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Woods Hole Oceanographic Institution

The Northwest Tropical Atlantic Station (NTAS):

NTAS-19 Mooring Turnaround Cruise Report
Cruise On Board RV Ronald H. Brown
October 14 – November 1, 2020

By

Albert J. Plueddemann, Ben Pietro, Emerson Hasbrouck

Woods Hole Oceanographic Institution
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Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration
under Grant No. NA19OAR4320074.

Upper Ocean Processes Group
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Approved for Distribution:

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Abstract

The Northwest Tropical Atlantic Station (NTAS) was established to address the need for accurate air-sea flux estimates and upper ocean measurements in a region with strong sea surface temperature anomalies and the likelihood of significant local air–sea interaction on interannual to decadal timescales. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near 15°N, 51°W by successive mooring turnarounds. These observations will be used to investigate air–sea interaction processes related to climate variability.

This report documents recovery of the NTAS-18 mooring and deployment of the NTAS-19 mooring at the same site. Both moorings used Surlyn foam buoys as the surface element. These buoys were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 160 m of the mooring line were outfitted with oceanographic sensors for the measurement of temperature, salinity and velocity. Deep ocean temperature and salinity are measured at approximately 38 m above the bottom.

The mooring turnaround was done on the National Oceanic and Atmospheric Administration (NOAA) Ship *Ronald H. Brown*, Cruise RB-20-06, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution. The cruise took place between 14 October and 1 November 2020. The NTAS-19 mooring was deployed on 22 October, with an anchor position of about 14° 49.48′ N, 51° 00.96′ W in 4985 m of water. A 31-hour intercomparison period followed, during which satellite telemetry data from the NTAS-19 buoy and the ship's meteorological sensors were monitored. The NTAS-18 buoy, which had gone adrift on 28 April 2020, was recovered on 20 October near 13° 41.96′ N, 58° 38.67′ W. This report describes these operations, as well as other work done on the cruise and some of the pre-cruise buoy preparations.

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1. Introduction

The Northwest Tropical Atlantic Station (NTAS) project for air–sea flux measurement was conceived in order to investigate surface forcing and oceanographic response in a region of the tropical Atlantic with strong sea surface temperature (SST) anomalies and the likelihood of significant local air–sea interaction on interannual to decadal timescales. Two intrinsic modes of variability have been identified in the ocean–atmosphere system of the tropical Atlantic, a dynamic mode similar to the Pacific El Niño–Southern Oscillation (ENSO) and a thermodynamic mode characterized by changes in the cross-equatorial SST gradient. Forcing is presumed to be due to at least three factors: synoptic atmospheric variability, remote forcing from Pacific ENSO, and extra-tropical forcing from the North Atlantic Oscillation (NAO). Links among tropical SST variability, the NAO, and the meridional overturning circulation, as well as links between the two tropical modes, have been proposed. At present neither the forcing mechanisms nor links between modes of variability are well understood.

The primary scientific objectives of the NTAS project are to determine the in-situ fluxes of heat, moisture and momentum, to use these fluxes to make a regional assessment of flux components from numerical weather prediction models and satellites, and to determine the degree to which the oceanic budgets of heat and momentum are locally balanced. To accomplish these objectives, a surface mooring with sensors suitable for the determination of air–sea fluxes and upper ocean properties is being maintained at a site near 15° N, 51° W (Fig. 1) by means of annual "turnarounds" (recovery of one mooring and deployment of a new mooring at the same site).

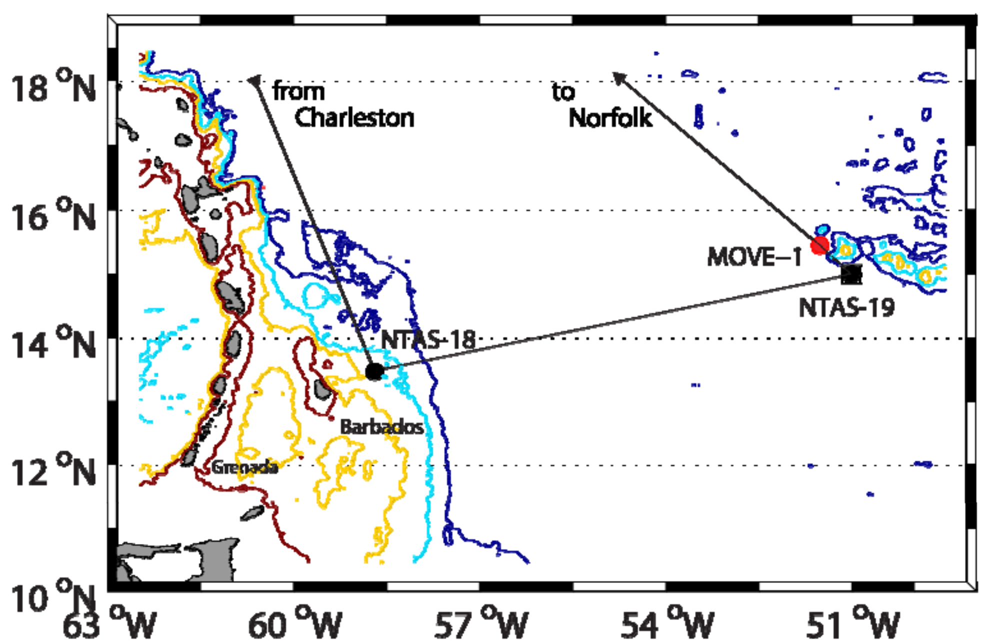

Figure 1. Location of the NTAS-19 deployment site (15 N, 51 W), the NTAS-18 recovery location, and the MOVE-1 site. A schematic cruise track is also shown.

The surface elements of the moorings are Surlyn foam discus buoys outfitted with two complete Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 160 m of the mooring line is outfitted with oceanographic sensors for the measurement of temperature, salinity and velocity. Starting in 2011, measurements of deep ocean temperature and salinity (38 m above the anchor) were added.

The NTAS-19 mooring turnaround was done on the National Oceanic and Atmospheric Administration (NOAA) Ship *Ronald H. Brown*, Cruise RB-20-06, by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI). The NTAS-18 mooring deployed in January 2020 (Bigorre et al., 2020) was recovered during the cruise and the NTAS-19 mooring was deployed.

There were 5 primary objectives for the NTAS project: 1) recover the NTAS-18 drifting buoy, 2) recover the NTAS-18 mooring riser, 3) deploy the NTAS-19 mooring, 4) conduct a full-depth CTD cast at the NTAS-19 site, and 5) perform field validation (ship-buoy comparison) at the NTAS-19 site. Three additional objectives were associated with the Meridional Overturning Variability Experiment (MOVE) of the Scripps Institution of Oceanography. These goals included 6) recovery of the MOVE-1 subsurface mooring (Fig. 1), 7) a full-depth CTD cast at the MOVE-1 mooring site, and 8) recovery of a Pressure and Inverted Echo Sounder (PIES) at the MOVE-1 site. Objectives 1-7 were completed; objective 8 was postponed due to concerns about success given the conditions at the time.

Brown departed for NTAS/MOVE from Norfolk, VA on 10 October 2020. The WHOI group joined the ship by small boat in Charleston Harbor on 14 October. The cruise was completed in 19 days, between 14 October and 1 November, 2020. A schematic cruise track is shown in Fig. 1.

This report consists of five main sections, describing pre-cruise operations (Sec. 2), the NTAS-19 mooring (Sec. 3), the NTAS-19 mooring deployment (Sec. 4), and the NTAS-18 mooring and buoy recovery (Sec. 5). Six appendices contain ancillary information.

2. Pre-Cruise Operations

a. Staging and Loading

Pre-cruise operations were conducted at the NOAA Marine Operations Center – Atlantic port facility in Norfolk, Virginia. A shipment consisting of a flat bed truck and a 53’ box truck left Woods Hole for Norfolk on 16 September 2020. Major items in the shipment were the buoy hull, tower top and base, glass balls, Tension Stringing Equipment (TSE) winch, air tugger, winding and tension carts, anchor, mooring instrumentation, miscellaneous deck and lab equipment, wire baskets with synthetic line, and dragging gear.

Ben Pietro, Emerson Hasbrouck and Al Plueddemann traveled to Norfolk on 16 November, met the trucks, and set up an operation area on the port grounds for work to be done prior to loading *Brown*. Pre-cruise operations took place from 17-19 September. *Brown* was loaded on the 19th. Pre-cruise operations included assembly of the buoy tower top and well, evaluation of ASIMET data, a buoy spin, and insertion of the tower top assembly into the hull. During the set up and evaluation, real-time data telemetered to WHOI via Iridium satellite were accessed via the web.

Due to the COVID-19 pandemic, pre-cruise procedures included Shelter-In-Place (SIP) periods and COVID testing for the WHOI team and the *Brown* crew. The WHOI and NOAA COVID protocols differed. Based on discussions between the WHOI Coronavirus Task Force and the NOAA Office of Marine and Aviation Operations, a compromise was reached where WHOI personnel would satisfy a 14-day WHOI SIP overlapped with a 12-day NOAA SIP. The ship's crew would complete a 7-day NOAA SIP followed by a 5-day shipboard "bubble" at sea. The WHOI team would join the ship 12 days after the start of NOAA SIP. The original timing had the WHOI personnel starting SIP on 9/20 and joining the ship on 10/4. However, sea trials conducted during 9/21-22 revealed problems with the ship's propulsion system (starboard Z-drive), requiring the manufacturer to send a representative to the ship to conduct repairs. This resulted in a delay of 10 days to the sailing date. The NOAA SIP period changed accordingly. In addition, the COVID testing location and embarkation port for the WHOI team changed from Norfolk VA to Charleston NC.

The revised plan required the WHOI team to conduct a 12-day NOAA SIP at a different location (Charleston) with the first full day being 10/2. Since SIP had already been established for the WHOI team on 9/20, with an initial (negative) COVID test on 9/21, the decision was made to continue SIP rather than break isolation and re-start. Thus, the WHOI SIP period was extended to 24 days, with the WHOI team joining the *Brown* on 10/14. A second COVID test for the WHOI team was conducted under NOAA protocol on 10/9 and results (negative) were received on 10/13. The team joined *Brown* by small boat from Charleston harbor on 10/14.

b. Sensor Evaluation

The UOP advance party started work in Norfolk on 17 September 2020. The buoy well and tower top were unpacked from the container and assembled. By the end of the day, the buoy was operating and transmitting meteorological data. Evaluation of telemetered data on 19 September indicated that all sensors were functioning as expected, with the exception of the wind modules, where a discrepancy of ~30° in wind direction was observed. It was difficult to find an independent reference for the winds in the Norfolk parking area, so evaluation was made based on the buoy spin conducted at WHOI on 9 September, where it was found that System 1 (L05, SN 221) had larger direction offsets. It was decided to replace wind SN 221 with the spare, SN 346.

A buoy spin was conducted in Norfolk on 18 September in Norfolk after the WND module change described above. The results are shown in Fig. 2. For this buoy spin, the reference direction was oriented towards 235°. A four-point spin was done rather than the usual eight-point spin as a time saving measure. The compasses (not shown) had an offset of about 4° from the sighting direction and variability of 3-4° from the mean. The wind direction results showed errors somewhat larger than desired for both systems, but appeared to be an improvement relatively to a ~30° discrepancy.

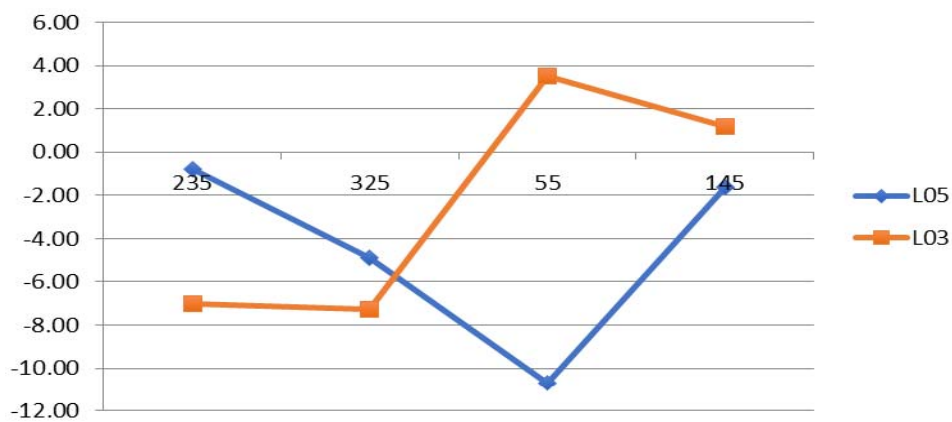

Figure 2. Buoy spin results from Norfolk on 19 September 2020. System 1 (L05) contains WND 346 and System 2 (L03) contains WND 210. Wind direction difference in degrees relative to the sighting direction is plotted vs buoy rotation angle.

Evaluation of 1 min logged ASIMET data on 19 September indicated that all sensors were functioning as expected; no changes were made to the ASIMET setup in Norfolk other than the wind module swap described above.

Unfortunately, problems with wind direction persisted after deployment. The two WND modules agreed on wind speed, but differed in direction by ~40°. An evaluation of buoy wind direction vs. ship's wind direction indicated that the module showing a northerly component was in error – this was System 1 (L05, SN 346), located on the port side of the buoy. It was speculated that the module had been damaged by the crane headache ball upon deployment (see Sec. 4). A small boat trip to the buoy was conducted on 24 October, two days after deployment. System 1 WND SN 346 was swapped for SN 221 (the same one that had been removed in Norfolk). There was no change in the wind direction discrepancy after the swap. Later feedback from NDBC indicated that the System 2 wind direction would be rejected based on a 40-45° difference from NDBC buoy 41040 and model data. Apparently both SN 221 and SN 346 on System 1 were correct, there was no damage from the crane during deployment, and the Chief Scientist's conclusion that System 1 did not match the ship was wrong. By then the *Brown* had left the NTAS site and it was too late to rectify the problem.

The subsurface Iridium telemetry system was started in Norfolk, but failed to complete the boot-up sequence. The interpretation was a problem with the Iridium modem. A request was made for a spare modem, as well as a complete spare subsurface Iridium unit, to be shipped to Norfolk to allow debugging and/or replacement. The Xeos Brizo-X surface wave unit was started, and the boot sequence indicated it was running. However, no telemetered data were received. Guidance was requested from the manufacturer.

After loading the ship on 19 September and securing the gear for sea, the WHOI team departed for SIP. Monitoring of telemetered data during the SIP period showed reasonable sensor performance, considering that the buoy was on deck with significant light and wind blockage. Monitoring of the Xeos Rover messages indicated that one of the two units was not transmitting. Knowing that start up can sometimes be problematic, it was decided to re-start the unit upon boarding the ship.

Upon boarding the ship on 14 October, a variety of assessment and debugging activities were undertaken. The Rover was restarted, but failed to send messages after repeated attempts. A firmware update was done according to manufacturer's guidance, but did not change the performance. It was decided that a functioning unit would be removed from the NTAS-18 buoy after recovery and mounted on the NTAS-19 buoy tower. The replacement modem was installed in the subsurface Iridium unit and tested. One message was sent upon boot-up, but the system then exhibited the same problem as before. Rather than install the full replacement subsurface Iridium unit that had been shipped from WHOI, it was decided that we would remove the functioning subsurface Iridium unit from the NTAS-18 buoy after recovery and install it in the NTAS-19 buoy well. This swap was eventually done, and receipt of Iridium messages by the WHOI server was confirmed. However, after deployment it was determined that the messages had no data content (all zeros). Thus, the NTAS-19 mooring will not have real time subsurface data available.

The Brizo-X was started again on 14 October and exhibited the same behavior as in Norfolk. A capture file was sent to the manufacturer, and it was determined that the parameters were not set correctly for telemetry. A revised startup command sequence was received from the manufacturer. The unit was re-started on 16 October with the modified commands and telemetry was received. The data records were variable, some with seemingly reasonable values and others with all zeros or unreasonable values. This was attributed to the buoy being on its side on the ship. After deployment, the unit continued to telemeter data, but the nature of the records (wild points and zeros) did not improve.

The 1 min logger data were offloaded on 14 October. Evaluation showed all sensors functioning as well as could be expected on the deck of the ship. Wind direction looked reasonable for some directions and problematic for others. This was attributed to blockage onboard the ship. The exception was the precipitation modules, which did not agree during a rain event on 29-30 September. It was speculated that the System-1 sensor (L05, SN 215) had a blockage and failed to drain (Fig. 3). It was replaced with the spare, SN 501.

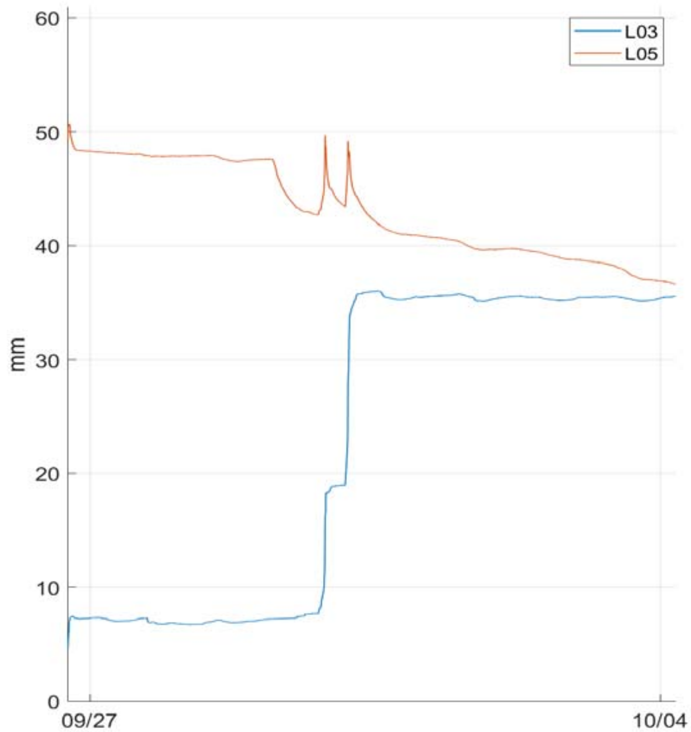

Figure 3. Precipitation from the NTAS-19 buoy before departure. A rain event on 9/29-9/30 was observed by the Logger 3 precipitation module, but Logger 5 showed behavior consistent with blockage of the drainage tube.

During instrument preparation while in transit to the NTAS-19 deployment site, it was found that the Nortek current meter inductive modem (IM) coil failed the self-test. Contact with the manufacturer provided a few suggestions for debugging, which were attempted with no improvement. It was decided that the instrument would be deployed without a functional IM. Given that the subsurface telemetry system in the buoy failed (see above), the lack of inductive communication from this instrument was irrelevant.

3. NTAS-19 Mooring, Systems, and Sensors

a. Mooring Design

The mooring is an inverse-catenary design of compound construction (Fig. 4), utilizing chain, wire rope, nylon and Colmega (buoyant synthetic line). The top section of the mooring, from the buoy to 85 meters depth, was designed to accommodate inductive telemetry from subsurface instruments. The mooring scope (ratio of total mooring length to water depth) is about 1.25. The watch circle has a radius of approximately 2.1 nm (3.8 km). A urethane-encapsulated termination for the wire to synthetic transition, introduced on NTAS-11, was used for NTAS-19.

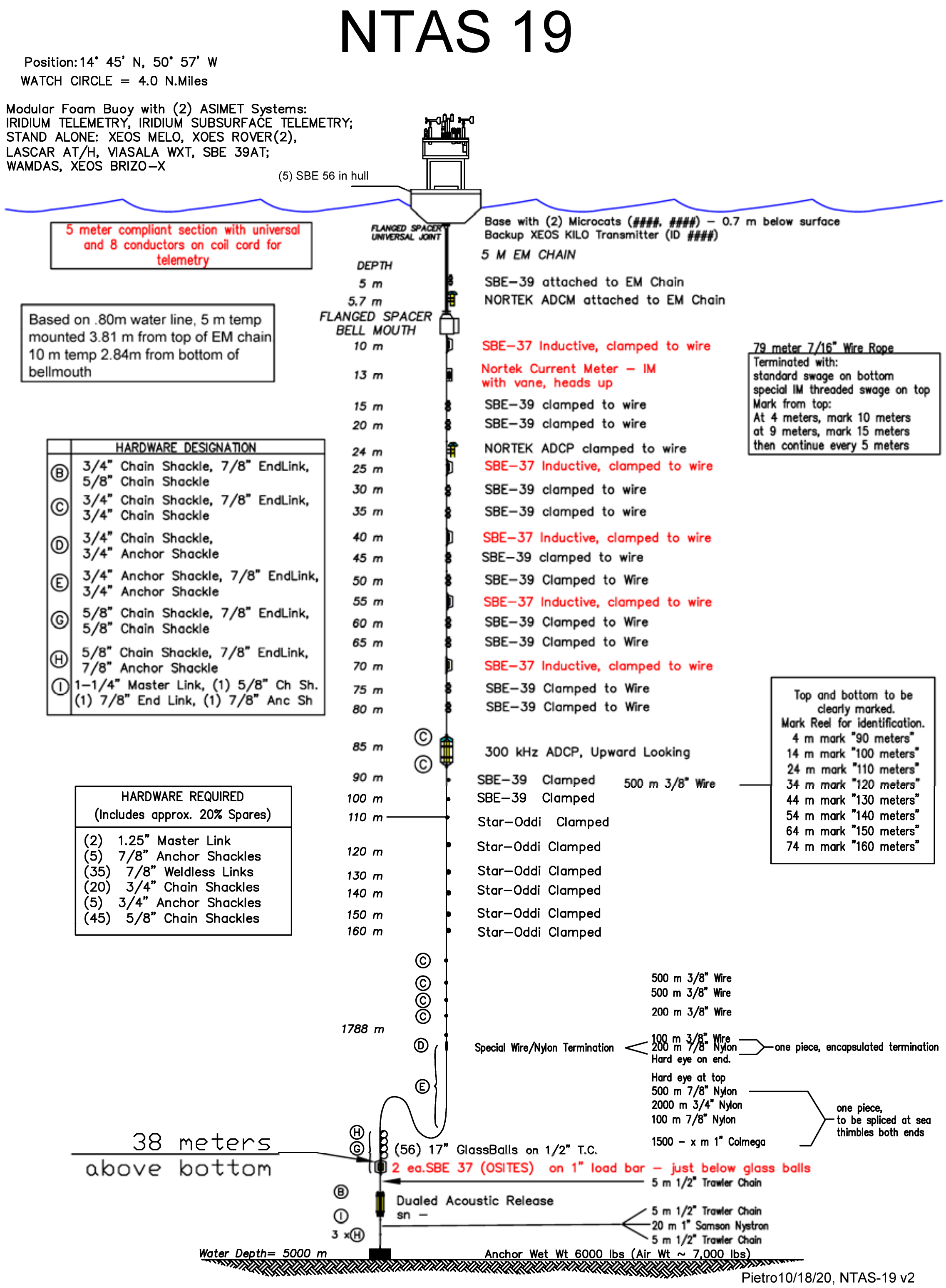

Figure 4. NTAS-19 mooring diagram.

The surface element is a 2.7-meter diameter Surlyn foam buoy with a watertight electronics well and aluminum instrument tower. The two-layer foam buoy is “sandwiched” between aluminum top and bottom plates, and held together with eight 3/4" tie rods. The total buoy displacement is 15,000 pounds, with reserve buoyancy of approximately 11,000 lb when deployed in a typical configuration. The modular buoy design can be disassembled into components that will fit into a standard ISO container for shipment. Data loggers, electronics for satellite telemetry, electronics for inductive telemetry, and batteries fit into the instrument well. Meteorological instrumentation, marine lanterns, antennas, and other equipment are attached to the upper section of the two-part aluminum tower at a height of about 3 m above the water line. The temperature and relative humidity sensors are mounted on arms extending outboard from the tower on either side. A Xeos Melo and two Xeos Rover GPS beacons are attached to the tower. All three beacons transmit buoy position via Iridium satellite; the Melo also records internally. The buoy vane houses a radar reflector. The vane is extended using a rectangular plastic sheet to reduce the angle of the buoy face relative to the wind. A Xeos Kilo GPS beacon was mounted within an access tube in the foam hull. This system is activated only if the buoy were to capsize.

Sea surface temperature and salinity are measured by instruments bolted to the underside of the buoy hull and cabled to the loggers via an access tube that runs vertically through the buoy foam. A universal joint couples the buoy base to a 5 m electro-mechanical (EM) chain section as part of the subsurface telemetry system (Sec. 3c). The EM chain terminates at a mooring-wire coupling assembly with a flanged spacer on top for electrical connections and a “bell-mouth” below for strain relief. The universal joint, EM chain and coupling assembly allow electrical cabling to run from the buoy well to the upper wire rope section. The EM chain was instrumented with a Seabird SBE-39 temperature sensor and a Nortek current meter (Fig. 5).

The majority of instrumentation is along the upper 160 m of the mooring line (Fig. 4). Internally-recording temperature sensors were clamped to wire rope below the EM chain at depths from 15 m to 160 m. Inductively coupled temperature/conductivity (T/C) sensors were clamped to the wire at 10, 25, 40, 55 and 70 m depth. A load cage (attached in-line between wire sections) was used to deploy an upward-looking ADCP at 85 m depth. Additional velocity sensors were a current meter at 13 m (inductively coupled) and a current profiler (uplooking) at 24 m. A pair of deep T/C sensors was placed just below the glass balls at approximately 38 m above the bottom.

Dual acoustic releases were placed approximately 30 m above the anchor. Above the releases are fifty-six 17” glass balls, which keep the release upright and ensure separation from the anchor after the release is fired. The number of glass balls was specified to ensure sufficient flotation to raise the lower end of the mooring to the surface if the buoy were to part from the mooring.

Figure 5. NTAS-19 buoy assembly on deck. (left) Wire termination, bell mouth, EM chain, universal joint and buoy base. (right) SBE-39 temperature sensor and Nortek current meter mounted on EM chain.

b. Buoy Instrumentation

The buoy was outfitted with two independent ASIMET systems (Hosom et al., 1995; Colbo and Weller 2009) to provide redundancy. Sensor modules are connected to a central data logger and addressed serially using the RS485 communication protocol. Modules also log internally using compact flash (CF) memory. As configured for NTAS-19, each system included six ASIMET modules mounted to the tower top (Fig. 6), one Sea-Bird SBE-37 "MicroCAT" mounted on the buoy base, a data logger mounted in the buoy well (Fig. 7), and an Iridium modem mounted inside the logger electronics housing. The seven-module set measures ten meteorological and oceanographic variables (Table 1). Variables measured by the tower-top ASIMET modules are wind speed and direction (WND), barometric pressure (BPR), relative humidity and air temperature (HRH), shortwave radiation (SWR), longwave radiation (LWR), and precipitation (PRC). The MicroCAT measures sea temperature and conductivity (STC). The MicroCATs were specified with an RS485 interface option, and thus could be addressed by the ASIMET logger in the same manner as the meteorological modules on the tower top.

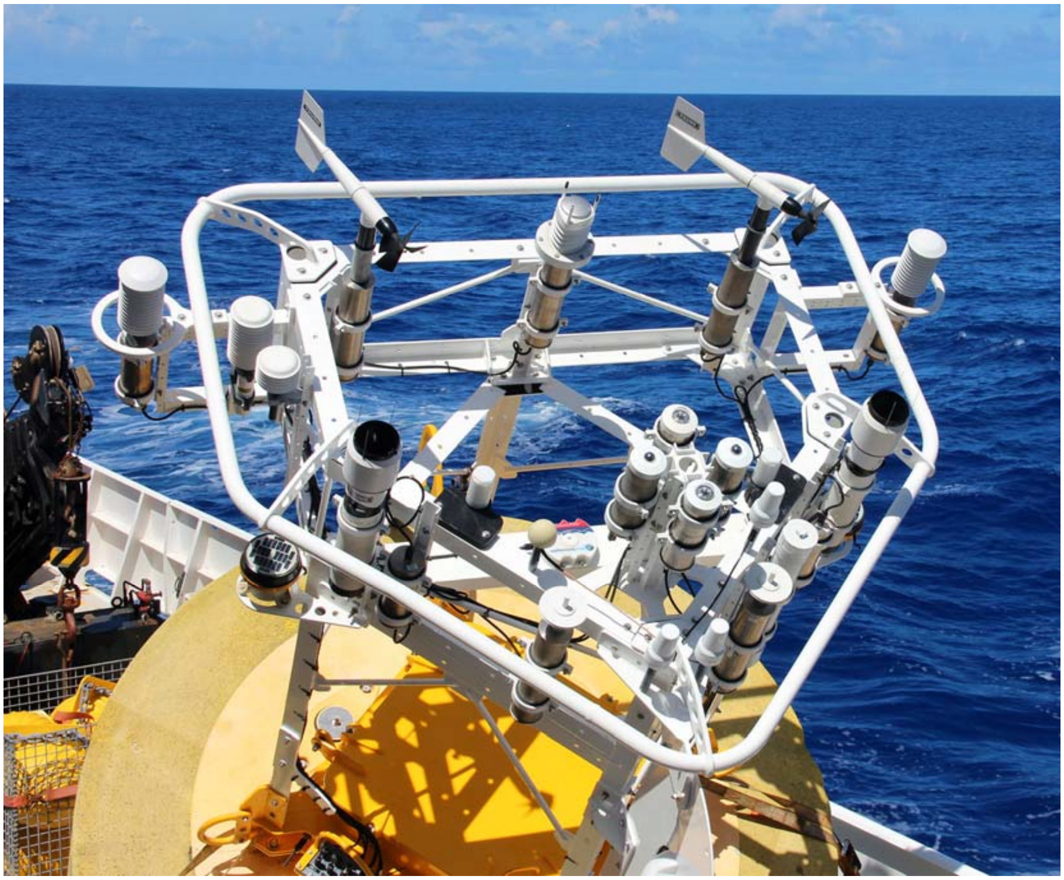

Figure 6. NTAS-19 tower top photo.

ASIMET sensor specifications are given in Table 1. Precision values are based on the manufacturer's specifications. Short-term accuracies, e.g. as expected for comparison of 1 min data in the field, are reported as well as long-term accuracies, e.g. as expected for daily mean values after post calibration and processing. Conservative accuracy values are reported based on prior publications (Hosom et al., 1995; Colbo and Serra et al., 2001; Weller, 2009; Bigorre et al., 2013).

Serial numbers of the sensors and loggers comprising the two ASIMET systems are given in Table 2, along with the various stand-alone sensors and telemetry system components. The sensor heights relative to the buoy deck, and relative to the water line, are given in Table 3. The water line was determined to be approximately 70 cm below the buoy deck by visual inspection after launch.

Each tower-top module records one-minute data internally at one-hour intervals. The STC module records internally at five-minute intervals. The logger polls each module during the first few seconds of each minute, and then goes into low-power mode for the rest of the minute. Further details of the sampling scheme are described in Plueddemann et al. (2001).

Table 1. ASIMET sensor specifications					
Module	Variable(s)	Sensor	Precision	Short-term Accuracy [1]	Long-term Accuracy [2]
BPR	barometric pressure	Heise Inc.	0.01 mb	0.3 mb	0.2 mb
HRH	relative humidity	Rotronic	0.01 %RH	3 %RH	1 %RH
	air temperature	Rotronic	0.02 °C	0.2 °C	0.1 °C
LWR	longwave radiation	Eppley PIR	0.1 W/m^2	8 W/m^2	4 W/m^2
PRC	precipitation	RM Young	0.1 mm	20%	10%
STC	sea temperature	SeaBird	0.1 m°C	0.2 °C	0.1 °C
	sea conductivity	SeaBird	0.01 mS/m	10 mS/m	5 mS/m
SWR	shortwave radiation	Eppley PSP	0.1 W/m^2	20 W/m^2	5 W/m^2
WND	wind speed	RM Young	0.002 m/s	8%	5%
	wind direction	RM Young	0.1 °	10 °	5 °

[1] Expected field accuracy for 1 min values.

[2] Expected accuracy for daily mean values after post calibration.

The logger writes one-minute data to the memory card once per hour, and also assembles hourly averaged data for transmission through the Iridium modem. Transmissions are Iridium Short Burst Data messages at 1 hr intervals, each containing a single hourly-averaged record.

A wind vane on the tower top keeps the “bow” of the buoy oriented towards the wind. A radar reflector is mounted in a cut-out in the upper vane. Wind modules are mounted in locations that minimize obstructions along the downwind path. Radiation sensors, mounted at the stern of the buoy, are at the highest elevation to eliminate shadowing. Two marine lanterns were mounted on either side of the tower, just outboard of the PRC modules. The two HRH modules were mounted on 18” extension arms off the port and starboard sides of the buoy to maximize aspiration and minimize self-heating.

Several additional sensors serve as back-ups to the ASIMET modules: a SBE-39 temperature sensor, a Lascar temperature/humidity sensor, and a Vaisala WXT 520 mult-parameter instrument. The SBE-39 was configured with a radiation shield to serve as a backup AT sensor and mounted on the port side HRH mounting arm (Fig. 6). The Lascar, which measures temperature and humidity, was outfitted with a radiation shield and mounted behind the SBE-39 on the port side.

The Vaisala WXT 520 was configured as a stand-alone ASIMET module and deployed on the forward rail of the NTAS-12 tower, between the two RM Young wind modules (Fig. 6). The WXT measures pressure, temperature, relative humidity using a set of capacitive sensors, wind speed and direction with a three-axis sonic anemometer, and precipitation with a horizontal piezoelectric plate. The WXT is powered by an independently wired set of batteries in the buoy well and serves as a backup for the ASIMET BPR, HRH, WND and PRC modules.

Table 2. NTAS-19 ASIMET system serial numbers and sampling

System	Module	Type	Serial No.	Firmware Version [1]	Sample Rate [2]
ASIMET-1	BPR	ASIMET-Heise	203	ASIBPR v5.44 ASPIC24 RevA	1 min
	HRH	ASIMET-Rotronic	505	ASIHRH v5.44 ASPIC24 RevA	1 min
	LWR	ASIMET-Eppley	253	VOSLWR53 4.02cf	1 min
	PRC	ASIMET-Young	215	VOSPRC53 4.03cf	1 min
	STC	Seabird SBE-37	1725	SBE 2.3b	5 min
	SWR	ASIMET-Eppley	216	VOSSWR53 4.01cf	1 min
	WND	ASIMET-Young	221	VOSWND53 4.02cf	1 min
	Logger	C530	L-05	LGR53 4.38-1spurs2	1 min
	Iridium	surface met		300234063854580	4 hr
ASIMET-2	BPR	ASIMET-Heise	502	VOSBPR53 4.03cf	1 min
	HRH	ASIMET-Rotronic	258	VOSHRH53 4.29cf	1 min
	LWR	ASIMET-Eppley	214	VOSLWR53 4.02cf	1 min
	PRC	ASIMET-Young	218	VOSPRC53 4.03cf	1 min
	STC	Seabird SBE-37	1305	SBE 2.3b	5 min
	SWR	ASIMET-Eppley	353	VOSSWR53 4.01cf	1 min
	WND	ASIMET-Young	210	VOSWND53 4.02cf	1 min
	Logger	C530	L-03	LGR53 4.38-1spurs2	1 min
	Iridium	surface met		300234063341510	4 hr
	Iridium	subsurface		300224010043720	4 hr
Stand-Alone	AT	SBE-39	5272	3.1b	5 min
Stand-Alone	HRH	Lascar	1111	0.9	1 hr
Stand-Alone	VWX	Vaisala WXT-530		VAISALA24 v5.65	1 min
NDBC	waves	WAMDAS		not transmitting	1 hr
Xeos	waves	Brizo-X	370	300125060155490	1 hr
Xeos	GPS	Melo		300034013709580	4 hr
Xeos	GPS	Rover (tower)		300434064537420	4 hr
Xeos	GPS	Rover (tower)		300434063297420	4 hr
Xeos	GPS	Kilo (buoy hull)		300234067205440	3 hr

[1] For Iridium and GPS, IMEI is given rather than firmware version

[2] All modules sample internally. The logger samples all modules.
For Iridium and GPS, "sample rate" is the transmission interval.

Table 3. NTAS-19 ASIMET module heights			
	Relative [1]	Absolute [2]	Measurement
Module	Height (cm)	Height (cm)	Location
SWR	282	352	base of dome
LWR	282	352	base of dome
WND	260	330	prop axis
HRH	230	300	top of case
BPR	240	310	center of port
PRC	260	330	top of cup
Vaisala	245	315	base of shield
Lascar	230	300	base of shield
SBE39	230	300	base of shield
STC	-150	-80	center of port

[1] Relative to buoy deck, positive upwards

[2] Relative to water line, positive up, NTAS-19 WL= -70 cm

Figure 7. NTAS-19 buoy well showing major electronic components.

Two surface wave measurement systems were deployed on the NTAS-19 buoy. The first was a National Data Buoy Center (NDBC) Wave and Marine Data Acquisition System (WAMDAS). The system includes a 3-axis motion package, a data logger, a GPS receiver and an Iridium transmitter. The GPS and Iridium functions were not enabled for

NTAS-19, so no real-time data were available. The data were stored in raw and processed format on a 1 GB compact flash card in the WAMDAS. The second system was a Xeos Brizo-X, which uses GPS and Global Navigation Satellite System (GLONASS) signals to measure buoy motion and determine wave height and direction. The self-contained unit was mounted externally on a cross bar added to the lower portion of the buoy tower top (Fig. 6).

c. Subsurface Instrumentation

The NTAS-19 deployment included six inductively coupled subsurface sensors, five SBE-37s and a Nortek Aquadopp current meter, clamped to the upper wire section. Each inductive sensor had a unique telemetry ID (Table 4) polled by the inductive modem at 10 min intervals. The SBE-37s were set to log internally at 10 min intervals and respond to inductive polling by sending the last sampled value. The Nortek sample rate was 20 min, and the instrument responded to polling by sending the last sampled record. The telemetry controller creates hourly average data for transmission to shore every 4 hours. The inductive message is a subset of the data returned from inductive polling: Only temperature and conductivity (later converted to salinity) are transmitted from the SBE-37s. The Aquadopp data record is reduced to just 8 variables, east, north and vertical velocities, heading, temperature, and echo amplitude from the three beams.

Table 4. NTAS-19 Subsurface Telemetry Configuration

Msg order	Modem ID	Instrument Make	Instrument Model	Serial Number	Depth (m)	Sample* Interval
1	03	Seabird	SBE-37	13409	10	10 min
2	04	Seabird	SBE-37	13410	25	10 min
3	05	Seabird	SBE-37	13411	40	10 min
4	07	Seabird	SBE-39	13412	55	10 min
5	08	Seabird	SBE-39	13413	70	10 min
6	41	Nortek	Aquadopp	23281	13	20 min

* Internal recording is at Sample Interval, inductive polling at 10 min intervals requests last internally recorded sample

Four SBE-56 temperature sensors were installed in the buoy hull to provide a SST measurement within about 15 cm of the mean water line. These instruments are relatively small and light, with a diameter of 25 mm. This allows them to be recessed directly into the buoy hull by drilling a hole in the foam and inserting the sensor. For NTAS-19, three sensors were inserted at the “bow” of the buoy (180^0 from the fin) at depths of 80, 95 and 110 cm below the buoy deck. Two more were inserted at approximately 90^0 and 270^0 at a depth of about 80 cm. The configuration is summarized in Table 5. Visual inspection of the buoy after deployment indicated that the 95 and 110 cm sensors were seldom exposed, i.e. they remained submerged below the ~70 cm water line.

Table 5. NTAS-19 Buoy Hull SST Configuration					
Rel depth (cm) [1]	Abs depth (cm)	Angle (deg) [2]	Instrument	SN	Sample rate
80	10	90	SBE-56	7206	1 min
80	10	180	SBE-56	7207	1 min
95	25	180	SBE-56	7208	1 min
110	40	180	SBE-56	7209	1 min
80	10	270	SBE-56	7210	1 min

[1] depth = below buoy deck, NTAS-19 WL = 70 cm

[2] angle = clockwise from buoy vane

A summary of locations, serial numbers, and sample rates for instruments mounted on the mooring line below the buoy hull is given in Table 6. A brief description of the individual sensors is provided below. NTAS-19 subsurface sensors were configured for 18 month (540 day) endurance.

Thirteen Seabird SBE-39 temperature sensors were deployed on the mooring. All were internally recording units. The shallowest SBE-39 was attached to the compliant section at 5 m depth and the remaining 12 were attached directly to the wire in the upper 100 m. The SBE-39s were power limited for an 18 month deployment, able to sample at 5 min intervals. Five SBE-37 temperature/conductivity sensors were attached to the wire at 10, 25, 40, 55, and 70 m. All included inductive modems. The SBE-37s were power limited for an 18 month deployment, able to sample at 10 min intervals. The vertical spacing for temperature (combined SBE-37/39) was 5 m in the upper 80 m, increasing to 10 m spacing below.

Two Aquadopp current meters, measuring three components of velocity along with temperature and pressure, and one 600 kHz Aquadopp profiler, were deployed on NAS-19. The Aquadopp configuration parameters are given in Table 7. The current meter at 5. 7 m depth was clamped to the EM chain. The current meter at 13 m was inductively coupled and included a vane to reduce vibration that could compromise performance The profiler was upward-looking from 24 m depth, configured with 15 bins of 2 m each. The current meters could sample at 20 min intervals for 18 months, while the profiler could only sample once per hour. A priority was placed on resolving surface wave motion within each averaging interval. Each 20 min sample consisted of an average over at least 180 samples at 1 Hz. The current meter configuration included the collection of diagnostic data (a short time series of 1-s samples) once per day. The predicted horizontal velocity precision was 0.8 cm/s for the current meters and 1.6 cm/s for the profiler.

All SBE-37 used “poison plugs” and copper sensor guards as antifouling measures. A plastic block was bolted to the wire beneath the protruding sensor guard to deter entanglement by fishing line. Desitin, typically applied to the exterior of the SBE-37 conductivity cells and Nortek transducer heads, was not available for NTAS-19.

Table 6. NTAS-19 Oceanographic sensor information				
Depth (m)	**Instrument** [1]	**SN**	**Variable(s) measured** [2]	**Sample rate**
5	SBE-39	7680	T	5 min
5.7	Aquadopp	12688	T, V, P	20 min
10	SBE-37 [IM]	13409	T, C	10 min
13	Aquadopp [IM]	16085	T, V	20 min
15	SBE-39	7681	T	5 min
20	SBE-39	7682	T	5 min
24	Aquapro	15795	T, V, P	1 min
25	SBE-37 [IM]	15795	T, C	10 min
30	SBE-39	7683	T	5 min
35	SBE-39	7684	T	5 min
40	SBE-37 [IM]	13411	T, C	10 min
45	SBE-39	7687	T	5 min
50	SBE-39	7688	T	5 min
55	SBE-37 [IM]	13412	T,C	10 min
60	SBE-39	7689	T	5 min
65	SBE-39	7690	T	5 min
70	SBE-39 [IM]	13413	T, C	10 min
75	SBE-39	7691	T	5 min
80	SBE-39	7693	T	5 min
85	RDI ADCP	2125	T, V	60 min
90	SBE-39	7694	T	5 min
100	SBE-39	7696	T	5 min
110	Starmon	5275	T	10 min
120	Starmon	5276	T	10 min
130	Starmon	5277	T	10 min
140	Starmon	5278	T	10 min
150	Starmon	5279	T	10 min
160	Starmon	5280	T	10 min
4947	SBE-37	33411	T,C	5 min
4947	SBE-37	48282	T,C	5 min
[1] [IM] = equipped with inductive modem				
[2] T = temperature, V = velocity, C = conductivity, P = pressure				

Six Star-Oddi Starmon Mini temperature loggers were attached to the mooring wire at 10 m intervals between 110 and 160 m depth. The Starmons were memory limited; the minimum sampling interval appropriate for an 18 month deployment was 10 min (605 days duration). No antifouling protection was used on the Starmons.

A 300 kHz RD Instruments Workhorse ADCP was deployed at 85 m depth with transducers facing upwards. The instrument was housed in a welded aluminum load cage and placed in-line between wire sections of the mooring. Details of the Workhorse configuration are given in Table 8. Conversion of the original plastic pressure housing to a longer aluminum housing allowed three alkaline battery packs to be used. The hourly sampling scheme with 180 pings per ensemble allowed 18 months endurance with an estimated power usage of 80%. The predicted velocity precision was 0.3 cm/s. No antifouling protection was used on the Workhorse.

Table 7. NTAS-19 Aquadopp configuration

Parameter	5.7 m depth SN 12688	13 m depth SN 16085	24 m depth SN 15795 [1]	Units
Transmission interval	1	1	1	sec
Averaging interval	180	180	240	sec
Sample interval	20	20	60	min
Blanking Distance	1.0	0.35	0.5	m
Diagnostics interval	1440	1440	n/a	min
Diagnostics samples	100	50	n/a	---
Measurement load	4	4	25	%
Power level	"HIGH-"	"HIGH-"	"HIGH"	---
Compass update rate	1	1	1	sec
Coordinate system	ENU	ENU	ENU	---

[1] Aquadopp profiler, 15 bins of 2 m each

Table 8. NTAS-19 Workhorse configuration

Parameter	Value	Units
Time between pings	1	sec
Pings per ensemble	180	---
Ensemble interval	60	min
Number of depth bins	25	---
Depth bin length	4	m
Blank after transmit	3	m
Transducer orientation	up	---
Coordinate system	earth	---

Two Seabird SBE-37 temperature/conductivity sensors were deployed as a back-to-back pair on a load bar just below the glass balls. Their height was estimated to be 38 m above the bottom. A sample rate of 5 min was specified for an 18 month deployment.

4. NTAS-19 Mooring Deployment

The nominal NTAS deployment site is 15° N, 51° W, near the southwestern flank of Researcher Ridge. A SeaBeam bathymetry survey during the NTAS-2 cruise (Plueddemann et al., 2002) showed that there were two relatively flat regions within an area of approximately 200 nm^2 (700 km^2) centered at 14° 46′ N, 50° 58′ W. The "northern" area, near 14° 50′ N, 51° 01′ W, showed depths of 4980 m ±60 m. This is the nominal anchor site for the “odd” NTAS deployments. The “southern” area, near 14° 45′ N, 50° 56′ W, showed depths of 5040 m ±50 m. This is the nominal anchor site for the “even” NTAS deployments. The northern site was to be occupied by NTAS-19. The NTAS-19 anchor target was chosen as 14° 49.50′ N, 51° 01.00′ W, about 6 nm (11 km) to the northwest of the NTAS-18 anchor.

Winds from the bridge anemometers and currents from the shipboard ADCP were noted while maneuvering to the deployment starting point. Winds were about 22 kt from the east (91^0), and currents were 0.5 kt to the NW. Wind waves were 3-5 ft and swell was 5-7 ft from the northeast. It appeared that the best approach would be from just north of due West. A set-and-drift test conducted by the bridge confirmed this assumption. It was decided to steam to a starting point approximately 6.0 nm from the drop point with an inbound course of 100^0 and hold position to set up for deployment operations. The waypoint for the bridge was an anchor drop point, 0.2 nm beyond the anchor target to allow for an expected fall-back of about 350 m.

Preparation for deployment included connecting the EM chain to the universal joint, connecting the bell mouth to the EM chain, and attaching the upper end of the 79 m wire section to the bell mouth. The 79-meter section of wire was partially offspooled from the TSE winch, laid out on deck and fed around the port quarter to the bell mouth. The SBE-39 and Nortek current meter were clamped to the compliant section. Additional instruments down to 50 m were clamped to the mooring wire.

Deployment operations began approximately 08:50 (local) on 22 October 2020 with *Brown* at a distance of 6.2 nm from the drop site (Fig. 8). The first step of the deployment procedure was the lowering the EM chain over the port side of the ship. The port-side crane was connected to the outer frame of the bell mouth and used to lift the EM chain with instruments attached over the rail (Fig. 9). A slip line was connected to the inner frame of the bell mouth. Ship’s deck crew handled a tag line to control the crane’s headache ball. The bell-mouth slip line was stopped off to the rail and the crane was disconnected. The EM chain was then slipped out and the mooring wire with instruments clamped to it was fed over the bulwark into the water by wire handlers stationed at the stern and along the port rail. Approximately 40 meters of the mooring wire with instruments attached was lowered in this manner. This formed a loop of wire and instruments hanging from the buoy, and leading back towards the port quarter.

The next phase of the operation was to launch the surface buoy. The port crane was positioned above the buoy lifting bale, and a quick release was installed. Slip lines were rigged on the base, deck, and tower mid-section D handle to maintain control during the lift. The straps lashing the buoy to the deck were removed. The buoy was then raised up and swung outboard as the slip lines kept the hull stable (Fig. 10). The bottom slip line was removed first, followed by the tower slip line. the slip line to the buoy deck bale was cleared immediately and an attempt was made to trip the Peck and Hale quick-release. Unfortunately, the quick release mechanism became fouled and the buoy was not immediately released.

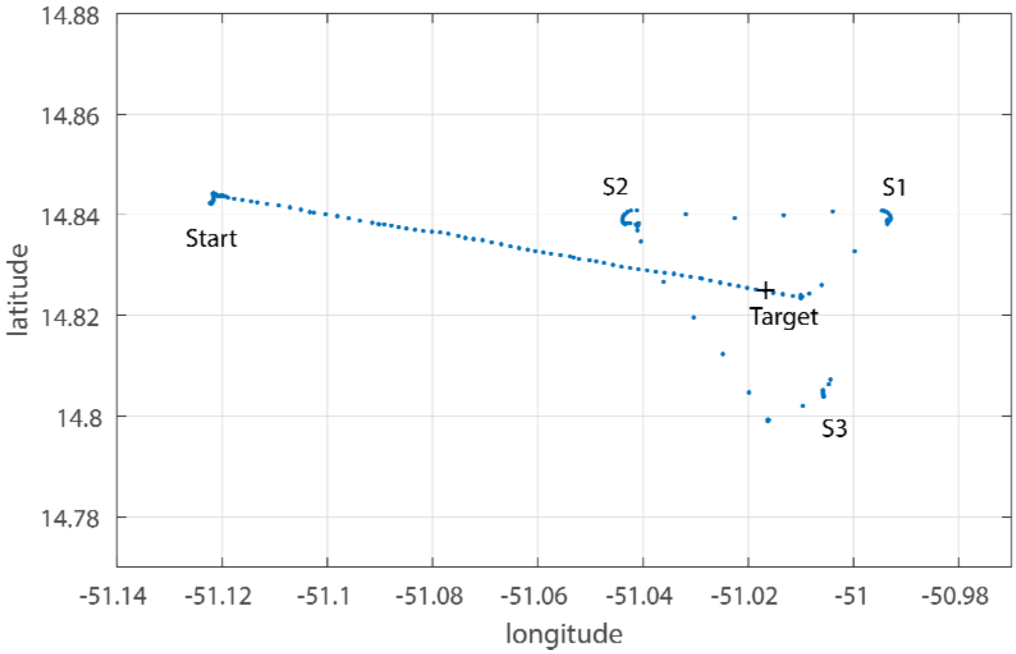

Figure 8. Ship track during NTAS-19 deployment. The start of the approach was from 6.2 nm away on a course of 100º. The ship continued past the anchor target before dropping the anchor to account for fall-back. After deployment, the ship occupied three anchor survey locations (S1, S2, S3).

The release was eventually tripped with the buoy in the water. However, the crane headache ball swung across the tower and damaged the PRC sensor on the port side (System 1). The PRC module was later replaced with a spare using the small boat to send personnel to the buoy. It was unclear whether other modules had also been impacted by the headache ball, but based on a large discrepancy (~40°) in wind direction after deployment, it was assumed that the port-side wind sensor was also damaged. The port WND module was replaced during the small boat trip, but this turned out to be the incorrect choice – the starboard wind direction was the one in error (see Sec. 2.b).

Once the buoy was released, the ship maneuvered slowly ahead, with the 50 m of payed out mooring wire and instrumentation provided scope for the buoy to clear the stern.

The remainder of the mooring was deployed over the stern. Once the buoy was behind the ship, speed was increased to about 0.5 knots and the remaining portion of the instrumented wire rope was slipped off the stern. The wire was slowly hauled back using the TSE winch and the 55 m instrument was attached. At that point, the TSE payed out wire and instruments were attached until the end of the 79 m wire section was reached.

Figure 9. NTAS-19 EM chain deployment. The crane lifts the EM chain over the port rail with the buoy still in place on the deck.

Figure 10. NTAS-19 buoy deployment. Tag lines for the crane headache ball, quick release, buoy base, buoy deck, and buoy tower can be seen.

The bottom of the 79-meter section of mooring wire was stopped off at the transom and disconnected from the mooring wire on the winch. A snatch block was suspended by the air tugger winch on the A-frame. The mooring wire from the TSE winch was passed through this block. The RDI ADCP cage was shackled into the mooring, and the mooring wire from the winch was connected to the bottom of the ADCP cage. The mooring tension was pulled up on the winch and the stopper lines were removed from the mooring.

The TSE winch was used to pay out the upper 500 m wire section as the ship moved ahead at ~0.5 kt. Instruments were clamped onto the wire at the transom after it passed through the block. Once all the instruments were attached the mooring, the ship speed increased to about 1 kt and payout continued until the 1700 meters of wire rope and 200 meters of nylon that had been spooled onto winch were payed out.

The final section of mooring line on the winch was the wire to nylon transition. This consisted of a 100-meter section of 3/8” wire and 200 meters of 7/8” nylon line. The termination is encapsulated in urethane providing a controlled transition from the stiff mooring wire to the flexible nylon line. As the end of the nylon came off the winch, it was payed out slowly until the thimble was about 10 ft from the transom, at which point stopper lines were attached to the termination, and the winch leader was removed from the end of the line.

The H-bit cleat was positioned approximately 20 feet from the transom, and secured to the deck. The 500 m nylon section, and the remaining 2000 m of nylon and 1500 m of Colmega, had been spliced together and were faked out in wood-lined wire baskets for deployment. The free end of the spliced nylon/Colmega line was wrapped onto the H-bit and passed to the stopped-off mooring line. The shackle connection between the two nylon sections was made. The line handler at the H-bit pulled in all the residual slack and held the line tight while the stopper lines were then eased off and removed. The H-Bit line handler kept the mooring line parallel to the H-bit with moderate back tension. The line handler and one assistant then eased the mooring line out of the wire basket and around the H-bit at an appropriate payout speed relative to the ship’s speed. Another person sprayed water on the H-bit to keep the line from overheating. The hanging block was lowered all the way to the deck to maintain a low departure angle from the H-b it. As the synthetic line was payed from the wire baskets through the H-bit, the 56 glass balls were staged on deck and pre-rigged with shackles and links.

With approximately 20 meters of Colmega line behind the H-bit, payout was stopped and a Yale grip was used to take tension off the line. The winch leader was shackled to the hard eye at the end of the Colmega line. The mooring was stopped off with stopper lines on the Yale Grip. The slack Colmega was removed from the H-bit and wound onto the winch. The winch was hauled in, up taking the mooring tension away from the stopper lines on the Yale grip. The stopper lines and Yale grip were removed.

The winch payed out the mooring line until all but one meter of the Colmega line was over the transom.

The first two sets of glass balls were dragged into position (aligned fore and aft) and shackled together. The aft end was attached to the mooring line at the transom. The forward end was shackled to the winch leader. The winch pulled the mooring line tight, stopper lines were removed, and the winch then payed out until only one ball remained on the deck. Stopper lines were attached, the winch leader was removed, and two more strings of glass balls were inserted into the mooring line. This process was repeated until all 56 balls were deployed.

When the final set of glass balls were over the transom, a check on ETA at the anchor drop site indicated about 1 hr 40 min to go. The deck was set up to tow for about an hour, with stopper lines attached to the link at the end of the glass balls. With 45 min to go to the drop site, deployment operations commenced.

Just below the glass balls on a 1” titanium load bar, two SBE 37’s were shackled into the mooring and lifted over the transom. The winch took tension on the mooring, stopper lines were removed, and a chain hook connected to the air tugger lifted the instruments off the deck. When the instruments were lifted, the A-frame was moved outboard and the TSE winch leader was payed out. Once the instruments cleared the transom, the winch was stopped and the tugger line removed. The same approach was used to deploy the acoustic releases.

The anchor, positioned on the starboard side inboard of the A-frame, was rigged with a 5-meter section of 1⁄2” chain. The 5-meter chain section was shackled to the 20 m Nystron line. An expendable backstay was rigged from the eye of the anchor to a deck eye to keep it from slipping off of the deck prematurely. With approximately 1/2 hour still to go until the anchor drop, a 3⁄4” bull rope was attached to the winch leader using a bowline knot and fed through the working end of the Nystrom and brought back to the winch leader and tied off with another bowline.

With about 10 minutes to the drop site, the chain binders holding the anchor in place were removed and the 3/4” bull rope slip-line that was tied with bowlines on the winch took the load from the stopper line. The crane was positioned over the forward end of the tip plate. The crane hook was secured to the chain bridle on the tip plate. The chain lashings were removed from the anchor. As the ship approached the launch site, the winch payed out slowly and put the load to the anchor and the backstay. Upon receiving a signal from the bridge that the drop point had been reached, the backstay was cut and the tension on the mooring was enough to pull the anchor off the tip plate and into the water. The anchor was dropped at 1903 UTC on 22 October 2020 at 14° 49.445′ N, 51° 00.781′ W in water of depth 4985 m.

An anchor survey was done to determine the exact anchor position and allow estimation of the anchor fall-back from the drop site. Three positions about 1.5 nm away from the drop site were occupied in a triangular pattern (Fig. 8). WHOI’s Edgetech

8011M deck gear and an over-the-side transducer were used to range on the release. The anchor survey began at about 1610 local on 22 October and took about 2 hours to complete. Triangulation using the horizontal range to the anchor from the three sites gave an anchor position of 14° 49.475′ N, 51° 00.963′ W (Fig. 11). The fallback from the drop site was about 329 m, or ~7 % of the water depth.

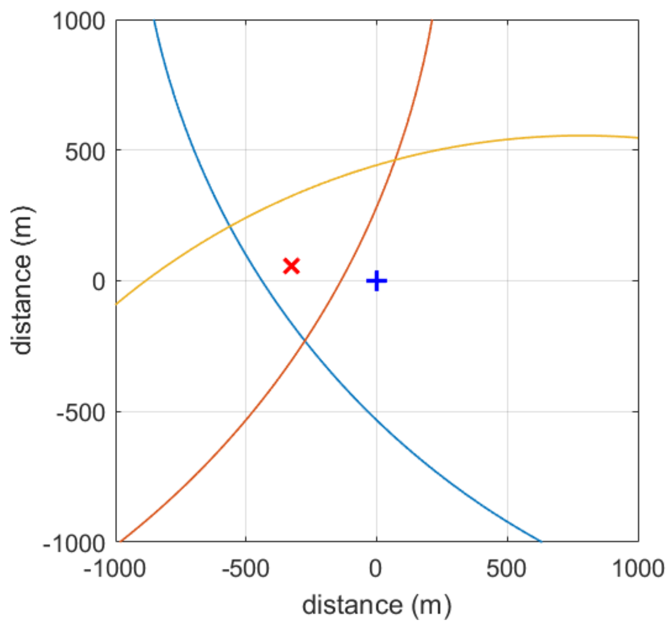

Figure 11. NTAS-19 post-deployment anchor survey. The anchor drop location (+), survey range arcs, and calculated anchor position (x) are shown.

A close pass by the buoy the next morning allowed observation from the bridge. Visual observations showed the tower top instrumentation intact except for the damaged PRC sensor, and the buoy riding smoothly with a nominal waterline about 70 cm below the buoy deck. Note that the expectation of a Campbell-based backup met system on the NTAS_19 buoy along with WAMDAS and Brizo wave sensors led to the decision to use a deep well to accommodate more batteries. This presumably accounts for the water line being 5-10 cm higher than prior NTAS deployments.

5. NTAS-18 Mooring Recovery

The NTAS-18 buoy was found clearly outside of its watch circle on 29 April 2020 and it was determined that the mooring parted at 0600 UTC 28 April based on assessment of buoy position relative to the watch circle. The buoy drifted slowly to the west over the next 5 months (Fig. 12), a net displacement was about 450 nm at an average speed of about 4 nm/day (0.18 kt or 0.9 cm/s). Meteorological data and subsurface data down to 80 m continued to be received during the drift, indicating that at least the upper 79 m wire section was attached to the buoy. The complete mooring recovery consisted of two operation: first. retrieval of the buoy and upper portion of the mooring, and second, retrieval of the lower portion of the mooring by firing the release at the anchor site.

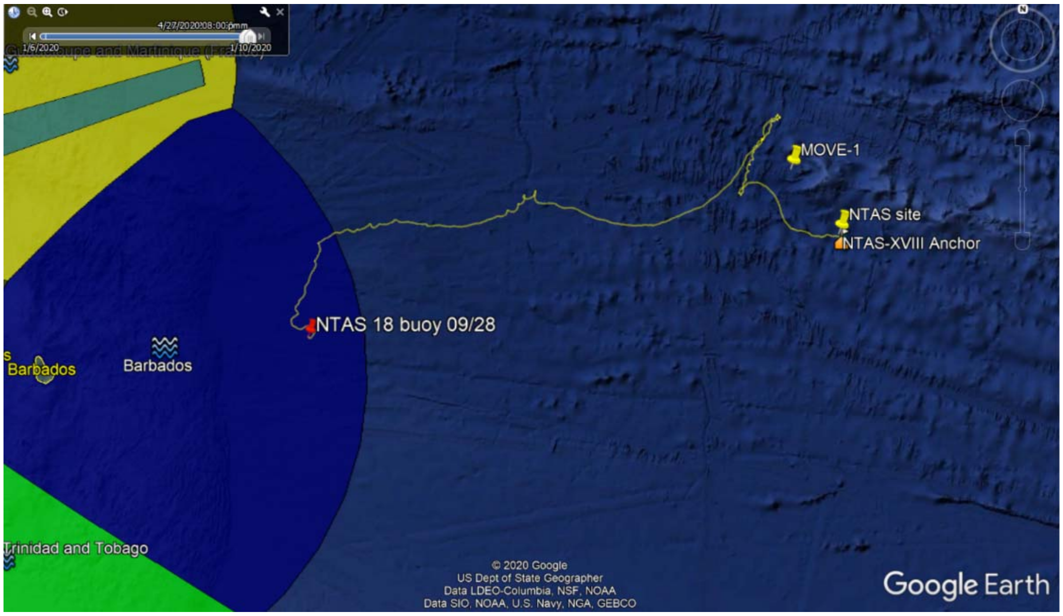

Figure 12. Google Earth map of the NTAS-18 buoy drift from 28 April to 28 September 2020. The buoy continued to drift westward before recovery on 20 October.

The *Brown* made its way to the vicinity of the drifting buoy using position updates from the Xeos Rover GPS beacon on the buoy tower. The Rover had been remotely configured to send positions every hour, which were available from the UOP server via the internet and were also forwarded to an Iridium phone onboard the ship. An updated position was sent to the bridge the evening before recovery. The buoy was approached before dawn on 20 October, initially identified by the marine lanterns, and later picked up on radar from a few nm away. The buoy was eventually hooked at 13° 41.96′ N, 58° 38.67′ W, about 452 nm from the anchor and only ~60 nm from Barbados.

Recognizing that there was at least 79 m of wire with instrumentation beneath the buoy, and considering that there could be a full mooring's worth of wire, it was determined that the *Brown's* traction winch was needed to lift the buoy safely out of the water through the A-frame. The traction winch has a safe working load of 23,000 lbs and the max amount of load that the winch would be picking up would be 7,800 lbs. In comparison, the TSE winch has a working load of 6700 lb. The day before the Ron Brown arrived at the drifting mooring the deck was set up. The traction winch was fed through the A-frame block and sent around the starboard quarter to the CTD station. Where it was shackled into the UOP titanium hook with a 12' pendent. Two air tuggers were placed on the port and starboard portion of the fan tall and the TSE had a winch leader wrapped around its drum. Three deck cleats were put down: port, starboard, and mid ship.

Recovery operations started at about 0845 h (local) on 20 October as the ship made an approach to the buoy for recovery, maneuvering so that the buoy was along the starboard rail amidships (at the location of the CTD sampling station). Conditions were very favorable for recovery. Winds were light, about 5 kt from 230°, with minimal wind sea and 1-2 ft swell.

A hauling line from the traction winch was fed through the A-frame and around the starboard quarter to the CTD station. During the approach, line handlers were stationed along the starboard rail and quarter to tend the traction winch wire. The starboard Z-drive was secured. The UOP titanium snap hook was inserted into a 17 ft pick-up pole to connect the hauling line to the buoy. At approximately 0920 local the buoy was in reaching distance from the CTD station. Using the pick-up pole and the pre-attached hook, the buoy was successfully hooked through the lifting bail. Ship speed was increased to .25 knots to maneuver the buoy aft. As the buoy shifted towards the transom line handlers dropped the wire one by one to ensure that the wire didn't dive under the ship. Wire was also being taking up on the traction winch to assist with the slack line.

With the buoy a comfortable distance behind the ship, the plan was to haul in on the traction winch to lift the buoy. However, it was found that the traction winch storage drum would only pay out, so that wire feeding off of the tension drums was going slack during haul-back. Line handlers had to be used in the winch room to control the slack wire during the low-tension part of the haul back. The ship speed was still .25 knots over ground. As the buoy approached the ship two air tuggers were rigged with snap hooks with square stocks to hook up to the D-Handles on the buoy. With the buoy staged for lifting at the transom, the line handlers departed the winch room leaving a short section of wire un-tended during the high-tension part of the recovery.

The next evolution was to pick the buoy up using the traction winch and the two pre-rigged air tuggers. The buoy was lifted and both air tugger snap hooks were clipped into the buoys D-handles (port and stb) to control rotation. After the buoy was in the air the A-frame was brought in while the buoy was kept level and the tuggers kept tight to ensure a safe and effective operation (Fig. 13). The A-frame was brought all the way in and the traction winch lowered the buoy to the deck. The compliant section trailed over the transom, with the bell mouth just below the water line.

Once the buoy was lowered to the deck it was stopped off using multiple ratchet straps and a chain grab. The next step was to remove the SBE 39 and Nortek instruments from the EM chain. The traction winch was removed from the pick-up bail and transferred to the bell mouth. Due to the unknown weight of the mooring below the EM chain, it was decided to evenly disperse the weight on two different lines. Each line was connected to opposite ends of the bell mouth ears using two snap hooks with a 12 ft pendent. The traction winch then lifted the bell mouth, creating a loop in the EM chain. An air tugger was used to pull the EM Chain inboard and both instruments were removed. After removing the instruments, the buoy could now be safely moved forward to bring the EM chain on deck.

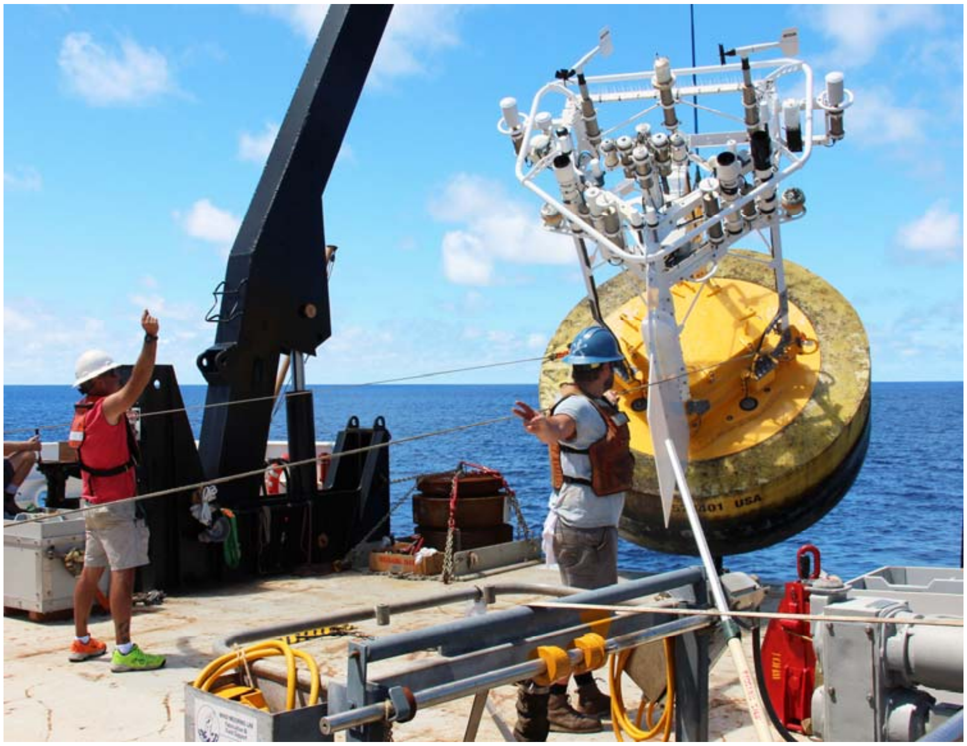

Figure 13. NTAS-19 buoy being recovered through the *Brown* A-frame.

The next stage of recovery involved a variety of mechanical pulling devices. The TSE winch leader was shackled into the cut-out below the buoy's wind vane. The ships starboard crane was attached to the buoy pick up bail. Air tuggers stabilized the buoy during the operation. Ratchet straps and the chain hook were released from the buoy and the tension was transferred to the crane and the TSE. The traction winch hauled in, lifting the EM chain and bell mouth about 4 ft above the transom. The A-frame was brought inboard and the curve in the EM chain allowed tension to be transferred to the EM chain off of the buoy. The buoy was then lifted in the air with the crane while the TSE pulled forward. Forward motion was stopped when the loop in the EM chain straightened out, with buoy approximately 10 ft forward of the transom. This allowed the bell mouth to be accessed at the transom. Stopper lines on the bell mouth were used to transfer the load from the EM chain to the bell mouth.

With the mooring under tow from the bell mouth, the EM chain was removed from the buoy base and the bell mouth. The buoy was then tipped upright and moved to starboard to clear deck space for line to run from the transom to the TSE winch. An air tugger was rigged through the A-frame block and used to raise the bell mouth. This allowed instrumentation on the upper 13 m of the wire to be removed. The TSE leader was then connected to the bell mouth and used to haul forward exposing approximately 12 ft of 7/16" jacketed wire rope below the bell mouth on deck.

With the jacketed wire rope exposed, two soft eye Yale grips and two Klien grips were attached to the wire (Fig. 14). Tension was transferred to the Yale and Klien grips, the bolts holding the 79 m wire termination to the bell mouth were unscrewed and the wire termination was exposed. The bell mouth was removed and a 20 ft section of of 5/8th spectra line was fed through the termination head and attached to the TSE winch leader. The winch leader was fed through the UOP Red German block, suspended from an air tugger line that was fed through the ships A-frame block. The tension was then transferred to the TSE. The Yale grips and Klien Grips were removed.

Figure 14. NTAS-18 drifting buoy recovery. The buoy has been recovered and the EM chain removed. Yale grips and Klein grips are used to take up tension on the wire below the bell mouth.

The TSE winch then began hauling the 79 m section of wire rope. Hauling on the TSE was periodically stopped and instruments were removed, inspected and photographed as they were encountered along the wire. The 85 m ADCP cage was stopped off using two stopper lines and the instrument was removed. Tensions were then transferred back to the TSE off of the stopper lines and the recovery of the mooring continued. Hauling on the TSE continued, and instruments were removed from the mooring line all the way down to the last Star Oddi at 160 m. Hauling continued until the mooring break was encountered approximately half way through the third 500 m 3/8 wire rope section.

Recovery operations for the lower portion of the NTAS-19 mooring began at 0806 (local) on 22 October 2020. The *Brown* was positioned at 1.0 nm from the anchor site with the anchor upwind and to starboard. Winds were about 18 kt from 52°, with 3-5 ft wind sea and 4-6 ft swell. The forecast was for conditions to improve during the day. An EdgeTech over-the-side transducer and deck box were used to communicate with the release. The release was fired at 0814 local (1214 UTC) on 22 October. The ship held position for another few minutes while repeated ranging was done on the release. The mooring was considered released from the anchor when ranging indicated that the release had traveled about 500 m. After about 60 minutes, the glass balls were spotted on the surface.

In preparation for recovery of the glass balls the TSE winch leader was fed through the A-frame block and run around the port quarter and up to the side of the ship. Once the glass balls were on the surface, the ship deployed their Fast Rescue Boat (FRB) to make the attachment to the glass balls. After the FRB made a secure connection to the ball cluster and reported the heading of the Colmega line on the surface, the ship maneuvered to meet the small boat at the stern. The hauling line was connected to the TSE winch. A heaving line connected to a hauling line was passed from the ship to the small boat. The small boat connected the line and backed away from the ball cluster. The ship continued ahead slowly (0.25 kt) to straighten out the line while the FRB was recovered.

Once the mooring was trailing behind the ship, the TSE winch hauled in to bring the cluster of glass balls up over the stern. The cluster was raised as high as possible towards the A-frame block. The A-frame was then moved inboard while tag lines and an air tugger were used to control the glass balls as they were pulled forward and lowered to the deck. Once all of the glass balls were on board, a stopper line was snapped into a sling link leading to the upper four glass balls which hung over the port side of the transom. The Colmega line trailed astern from that four-ball section, thus the mooring tension was transferred from the glass ball cluster to the stopper line. The TSE winch was disconnected from the ball cluster and used to haul the dual SBE-37s, trailing over the starboard side of the transom, on deck. The instrument load bar was disconnected and the same technique was used to haul the releases aboard.

The next step was the disassembly and removal of the glass balls from the working area. Once the glass balls were clear from the deck, a nylon line was tied around the thimble of the Colmega and wrapped around the ship's capstan. The capstan took the load of the mooring, and the stopper lines were removed. The capstan was used to haul in 1500 meters of Colmega and 2600 m of nylon line. The line was deposited directly into bags in the wood-lined wire baskets. When the hard-eye termination for the final 200 m of nylon (leading to the wire to nylon termination) came through the block, the load was transferred to the TSE winch. The winch was used to haul in the reaming portions of the mooring.

Recovery of the lower portion of the mooring ended part way through the lower 500 m wire section. A break was found in the wire, mirroring the break found during recovery of the buoy (Fig. 15). A kink in the wire about 6 ft from the break suggested that the wire had looped back on itself (Fig. 16). Wear on the plastic jacket suggested that the loop was in contact with a hard/sharp surface. The hypothesis is that tension on the wire was lost at some point during deployment or anchor drop resulting in the wire twisting and creating a loop. This loop then caught on a nearby termination (e.g. the 500 m to 200 m wire termination) and subsequent mooring motion resulted in the termination hardware fatiguing and eventually breaking the wire.

Figure 15. Upper (left) and lower (right) ends of the broken 500 m wire section recovered from the NTAS-18 mooring. Note the chafing of the plastic jacket on the lower end.

Figure 16. Lower end of the broken 500 m wire section from the NTAS-19 mooring. Permanent kinks indicated that the wire had looped back on itself.

Acknowledgments

The captain, officers and crew of the NOAA Ship *Ronald H. Brown* were flexible in accommodating the science mission, and exhibited a high degree of professionalism throughout the cruise. The capabilities of the ship and crew were critical to the success of the mooring operations. This project is funded by the Global Ocean Monitoring and Observing (GOMO) Program of the National Oceanic and Atmospheric Administration (NOAA; CPO FundRef number 100007298), through Cooperative Agreement NA14OAR4320158 with the Cooperative Institute for the North Atlantic Region (CINAR) at the Woods Hole Oceanographic Institution.

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Appendix 1: Cruise Participants

Captain: Keith Golden (Commanding Officer)

Officers

Stephen Barry (Executive Officer)
James McEntee (Medical Officer)
Aaron Maggied and Alex Creed (Operations Officers)
Tim Montero (ENS)
Jesse Pierce (ENS)

Deck Department

Mike Lastinger (CB)
MaryBeth Phillis
Ryan Walker
Tracy Davis
Ryan Walker
Mike Gornto
Nick Granozio

Survey Department: Bryce Dewees (ST)

Electronics Department: Mike Peperato (ET)

Science Party

Albert Plueddemann (Chief Scientist, WHOI)
Ben Pietro (WHOI)
Emerson Hasbrouck (WHOI)

Appendix 2: CTD Casts

Ten CTD casts were completed during the NTAS-19 cruise. Three were test casts; science casts 2-7 and 10 are reported here. Cast 2 (Fig. A2-1) was done at the NTAS-18 drifting buoy prior to recovery and included release tests. Casts 3-7 were done at the NTAS-19 site after deployment, during the meteorological intercomparison period. Cast 3 (Fig. A2-2) was to full ocean depth, the others were to 500 m (Fig. A2-3). Cast 10 (Fig. A2-4) was a full-depth cast done at the MOVE-1 mooring site after recovery. Cast 10 included Niskin bottles at 12 depths for salinity. The 500 m casts were done at a position about 0.5 nm from the mooring, while the deep cast were done 1.0 nm away. The Data were processed onboard using Seabird processing code and the figures were created during the cast by the *Brown* Survey Tech.

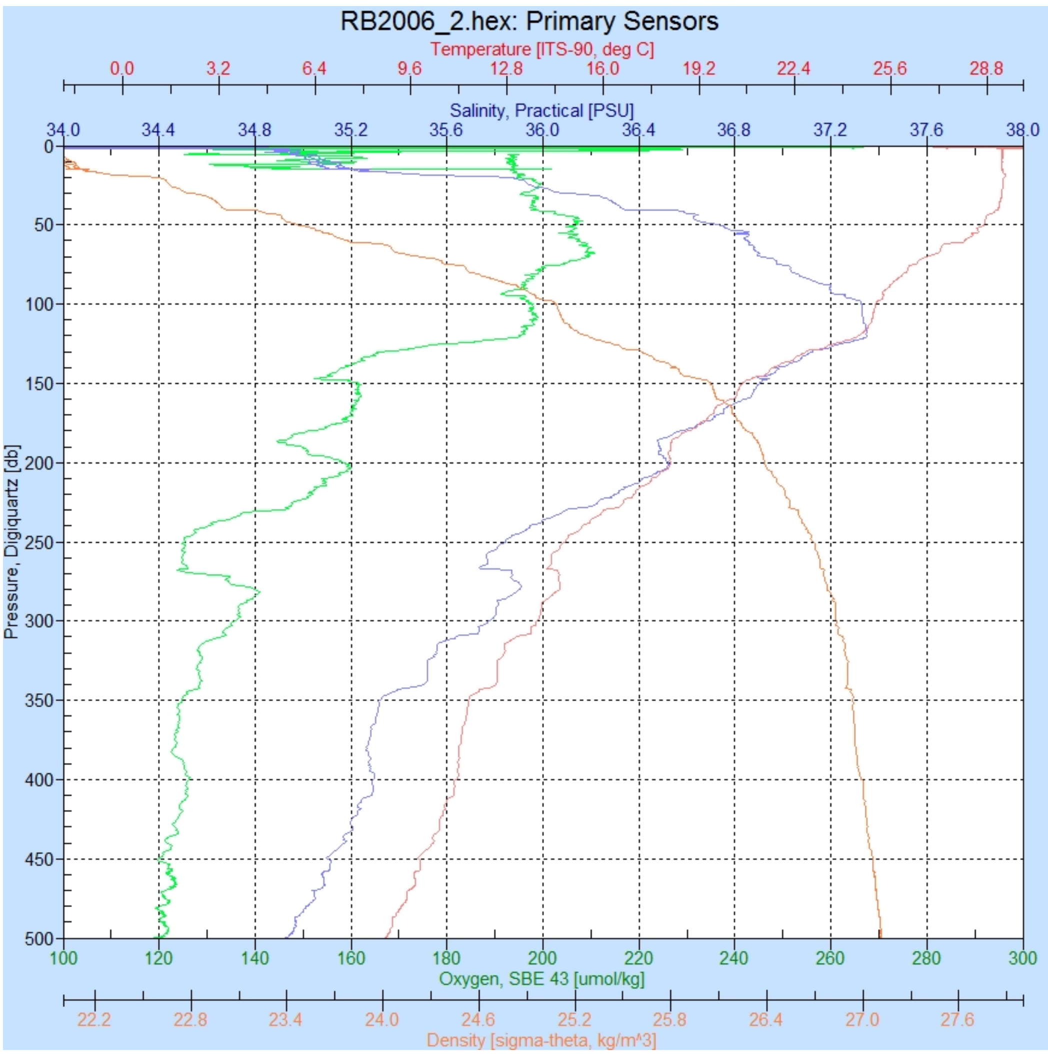

Figure A2-1. CTD cast at the NTAS-18 drifting buoy prior to recovery.

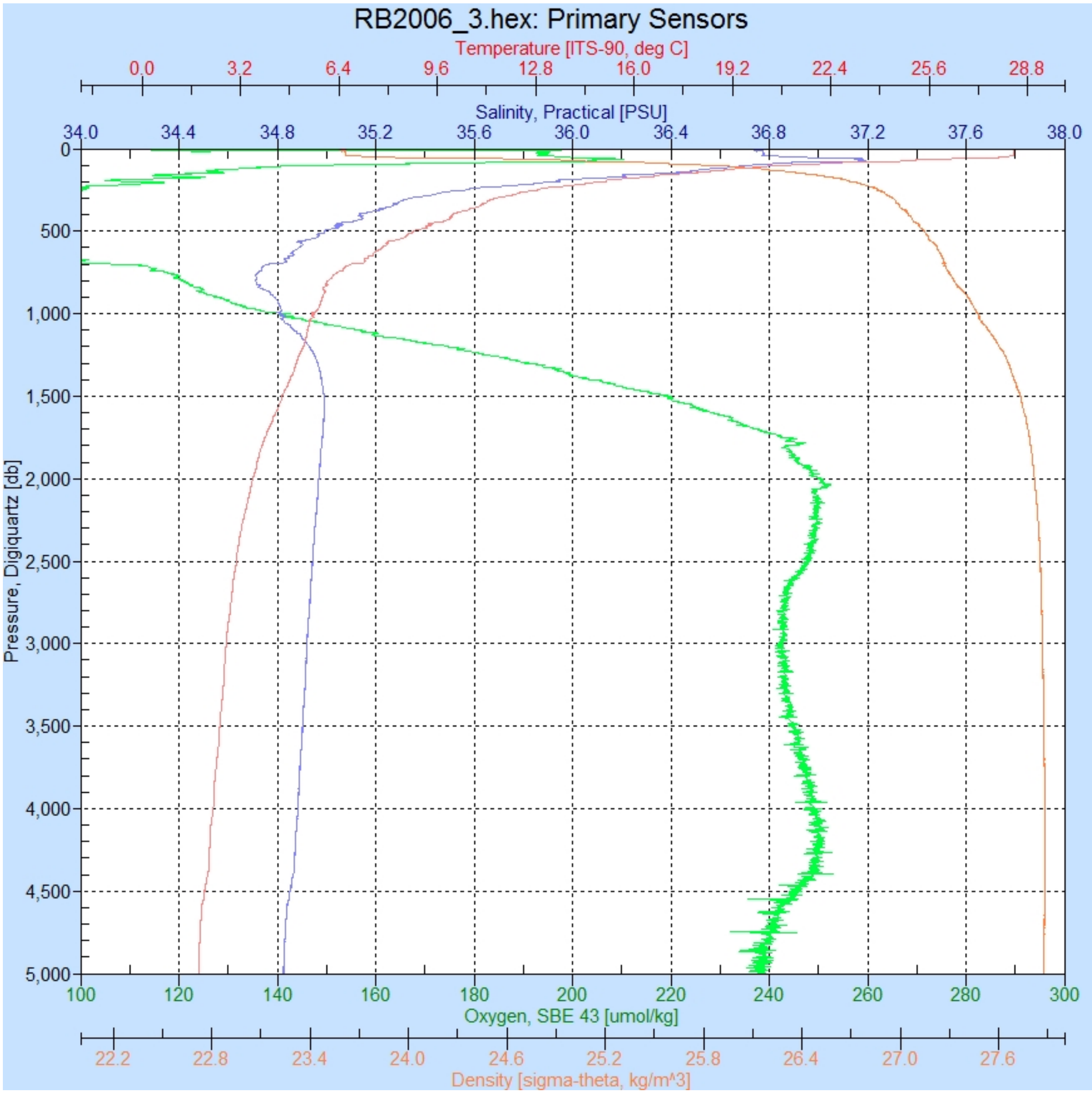

Figure A2-2. Full-depth CTD cast at the NTAS-19 site done a few hours after deployment.

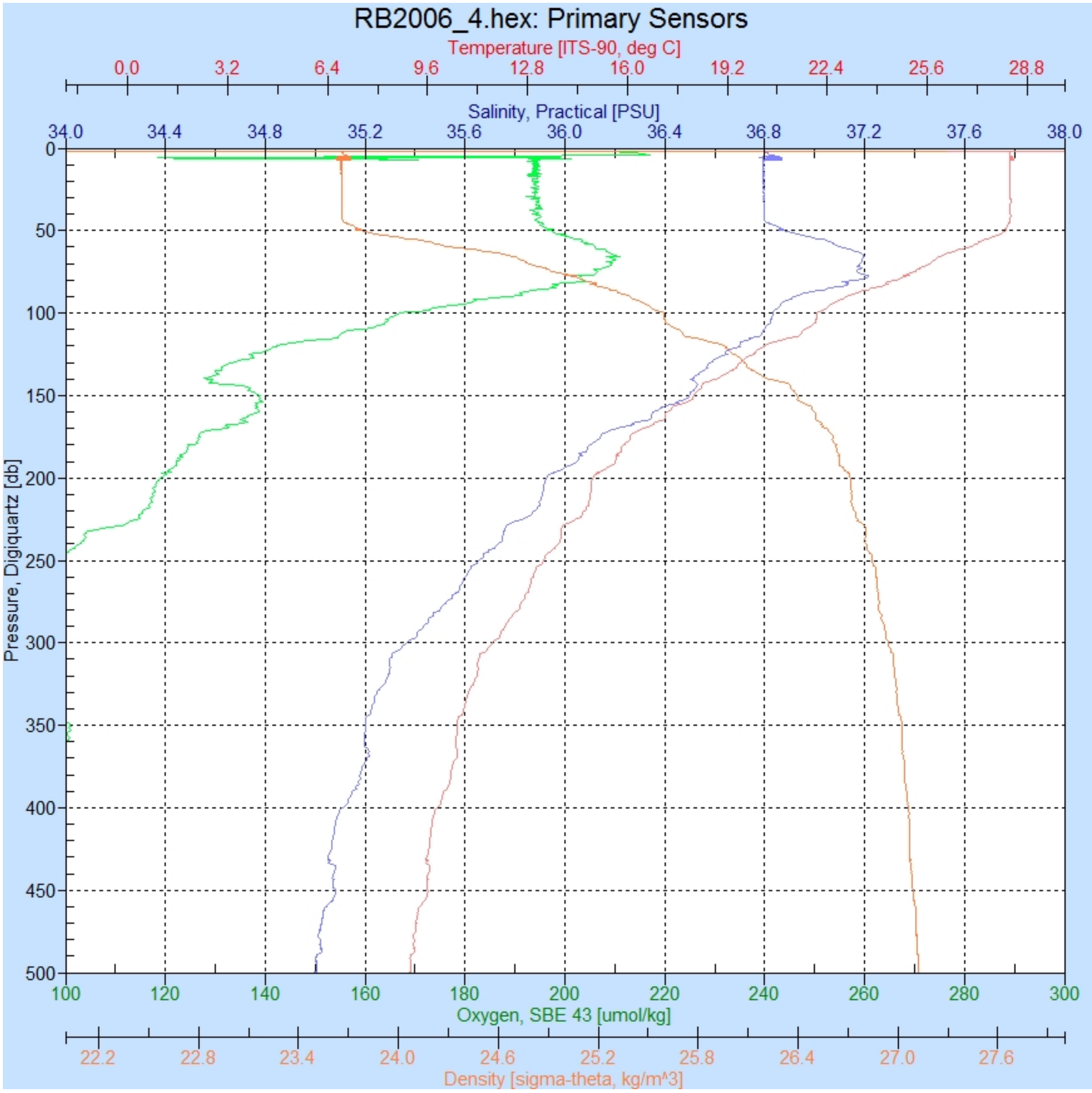

Figure A2-3. A 500 m CTD cast done at the NTAS-19 site during the intercomparison period. 3 additional casts were done at 4 hr intervals and showed similar features.

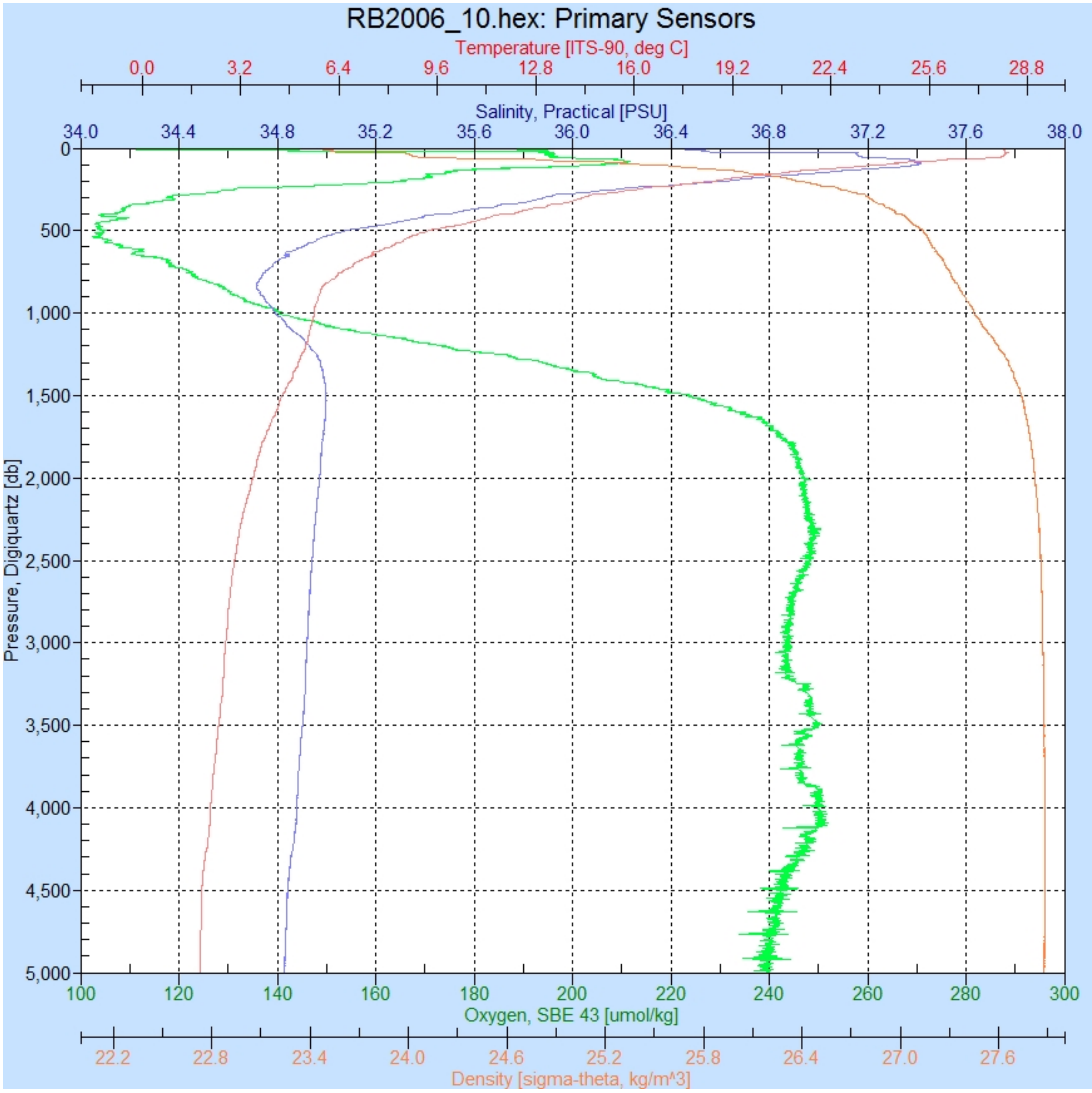

Figure A2-2. Full-depth CTD cast at the MOVE-1 site done a few hours after recovery.

Appendix 3: NTAS-18 Recovered Subsurface Instruments

Figure A3-1. NTAS-18 buoy hull.

Figure A3-2. NTAS-18 SBE-39 and Nortek current meter from EM chain.

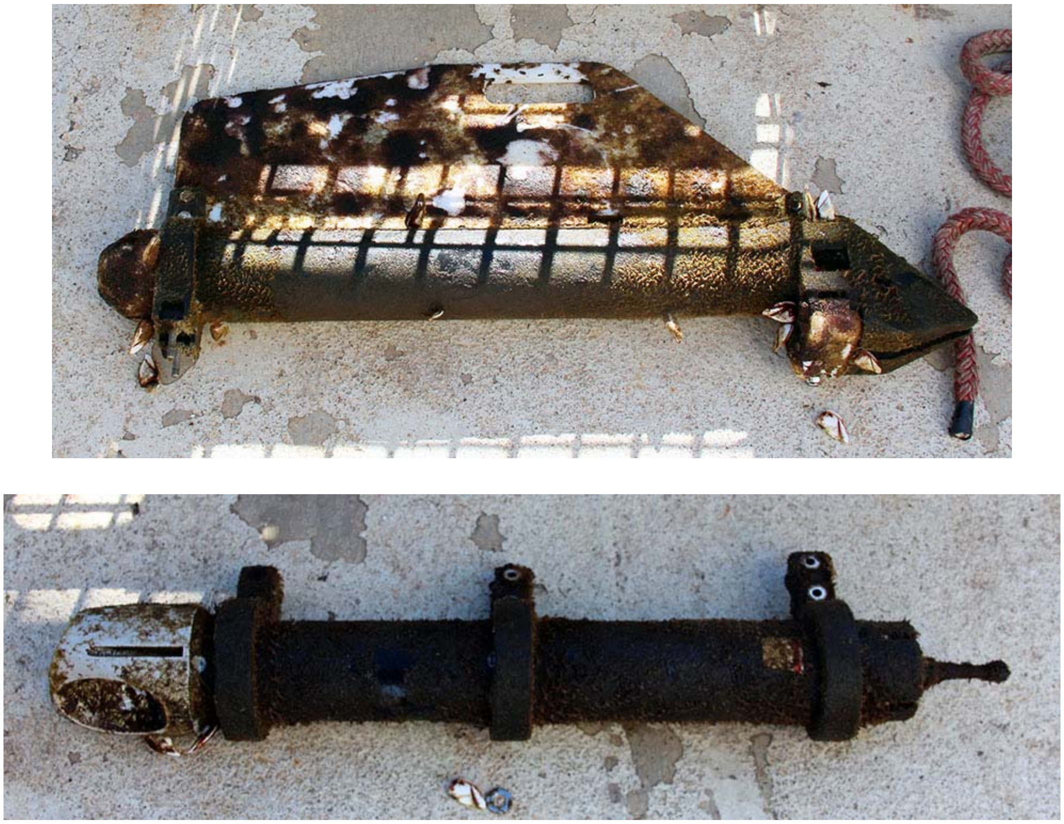

Figure A3-3. NTAS-18 Nortek current meter (13 m) and profiler (24 m).

Figure A3-4. NTAS-18 RBR Solo-D instruments from 6 and 83 m.

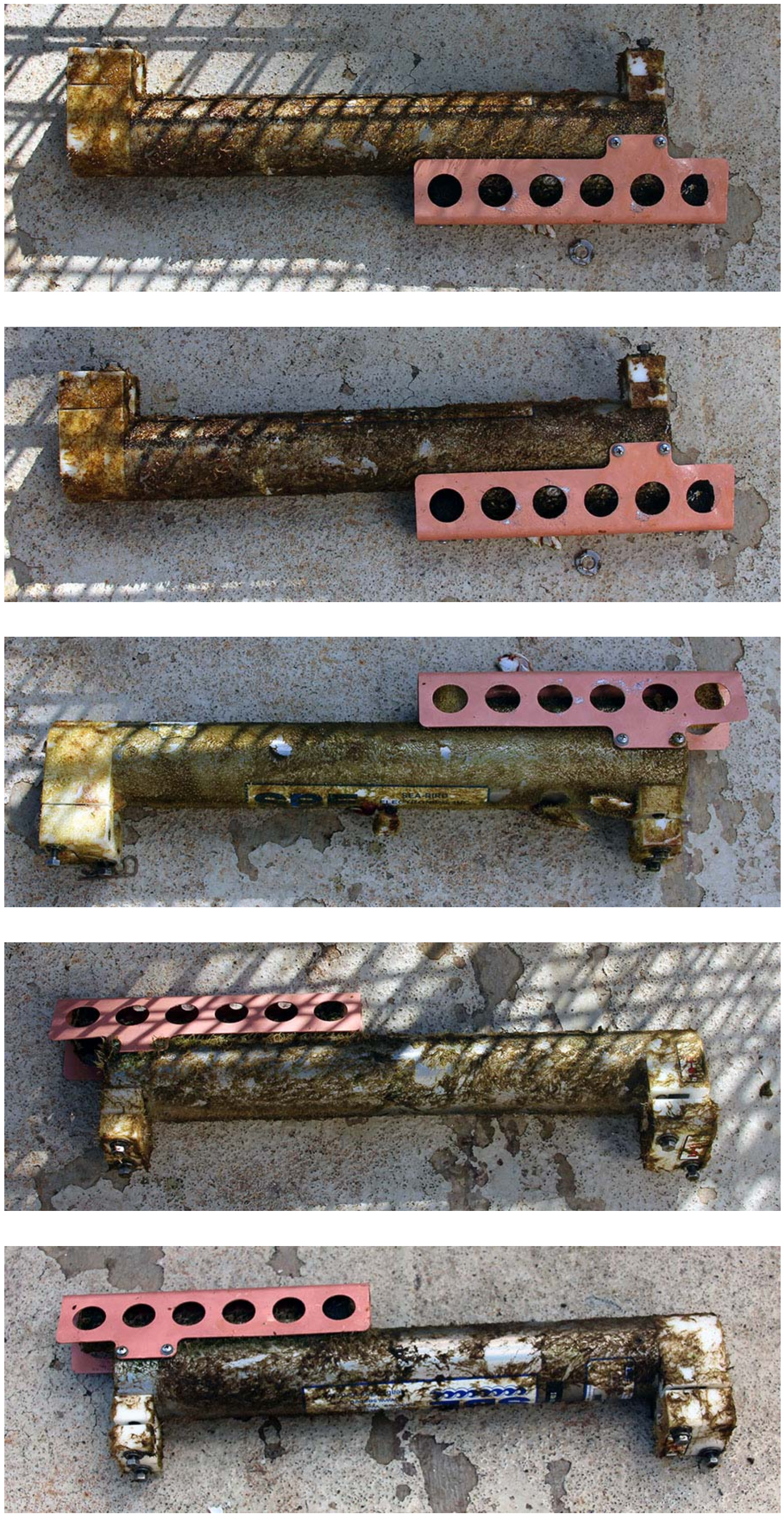

Figure A3-5. NTAS-18 SBE-37s from 10, 25, 40, 55 and 70 m (upper to lower).

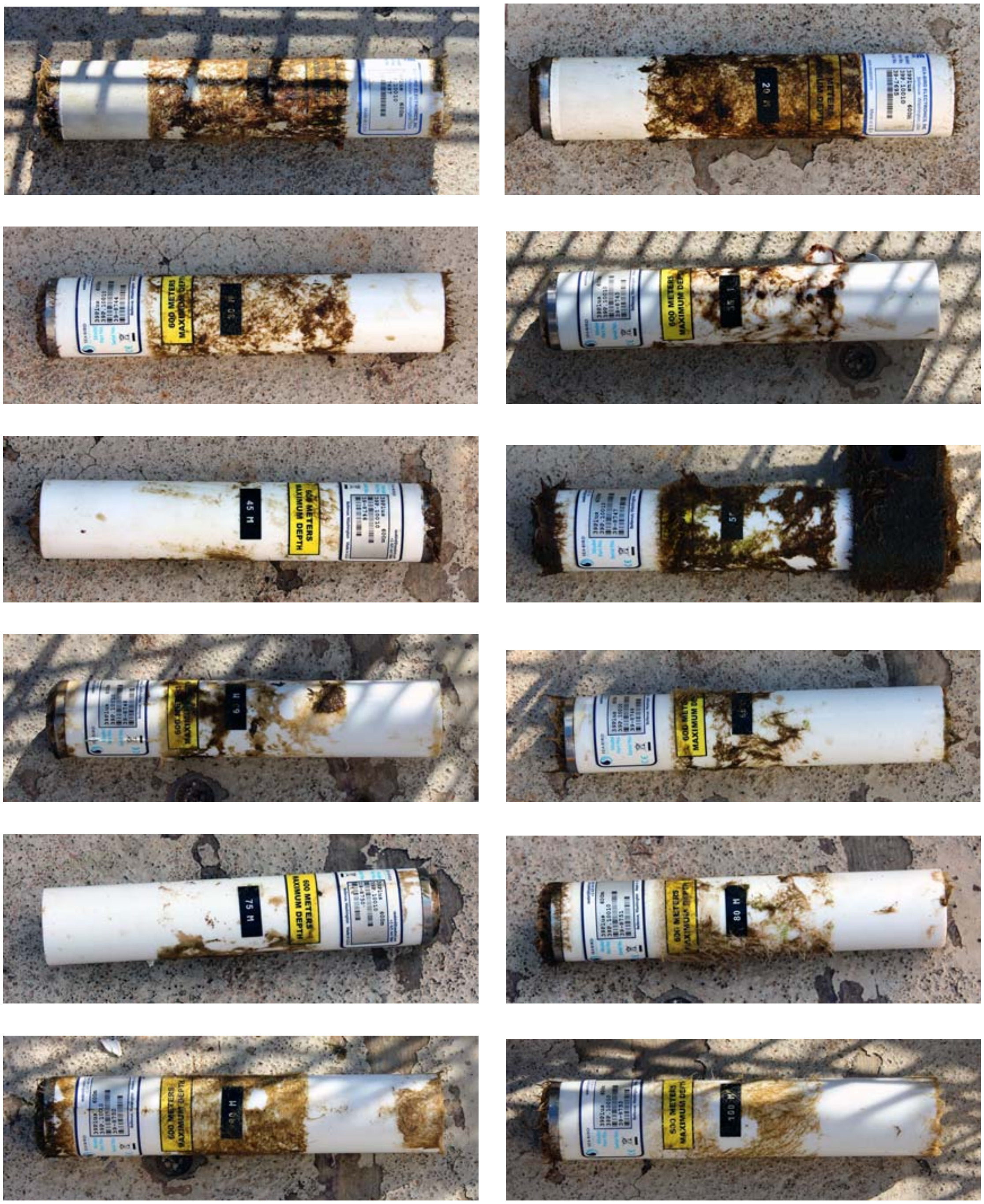

Figure A3-6. NTAS-18 SBE-39s from 15-100 m. Instruments below 100 m showed very little evidence of biofouling.

Figure A3-7. NTAS-18 RDI ADCP from 85 m.

Appendix 4. Operations at the MOVE-1 Site

Due to concerns that COVID restrictions and ship schedules would not allow the Scripps group to service equipment before batteries were exhausted, the WHOI group was requested to conduct three operations at the MOVE-1 site (Fig. A4-1): Recovery of the MOVE1-13 subsurface mooring, recovery of PIES SN 198 and a full-depth CTD nearby the mooring.

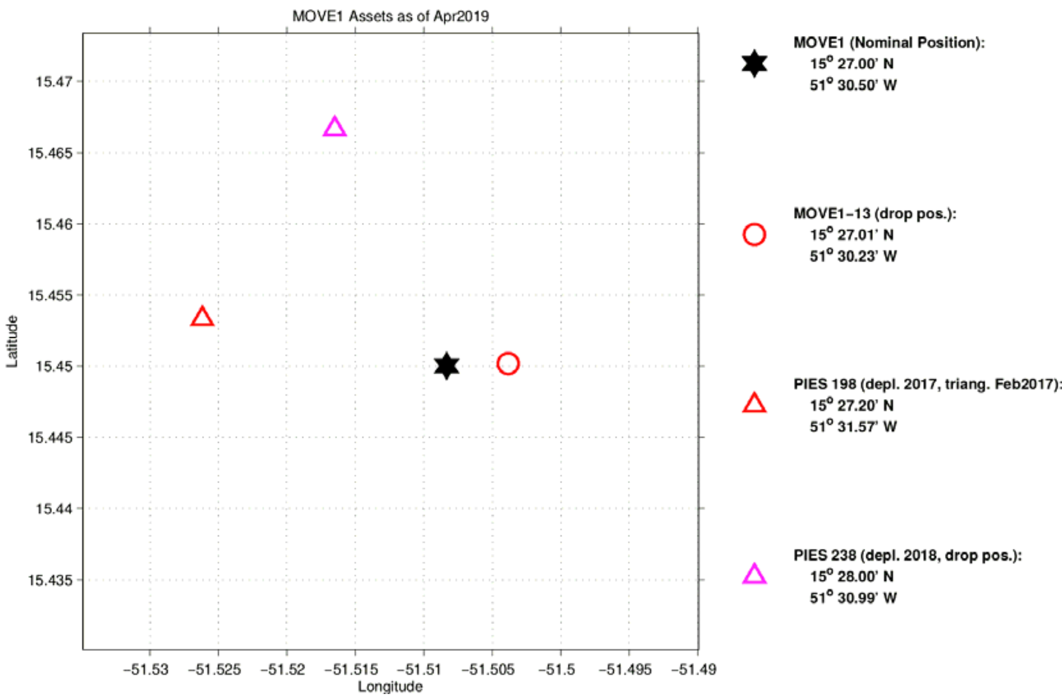

Figure A4-1. Map of assets at the MOVE1 site. The MOVE1-13 mooring (nominal position black star) and PIES 198 were to be recovered.

The Brown arrived at the MOVE-1 site the evening of 10/24. The plan was to conduct a full-depth CTD with water samples at the MOVE-1 mooring location, wait overnight, and start the mooring recovery in the morning. The CTD wire had been re-terminated the day before due to the presence of kinks in the wire just above the rosette. Unfortunately, the new termination was not sound, the deck box breaker tripped, and the cast had to be aborted. Given the time necessary to complete a new termination, and the desire to conduct acoustic communication tests, the decision was made to postpone the CTD until after the mooring recovery.

Acoustic communication tests were conducted at both the MOVE-1 mooring site and the PIES 198 site. The hand-held transducer and Teledyne Benthos deck box were used. At the mooring, the ship stood off 0.7 nm and held station in DP mode with the anchor location off the starboard bow. Each of the two releases were enabled, multiple range pings were sent, and the release was then disabled. It was our understanding from the

MOVE technicians that there would be no positive confirmation of enable (disable) other than the ability (inability) to get a good range. Knowing the water depth (4989 m) we expected ranges of about 5100 m. Although there were many spurious ranges, a series of four ranges of 5086 were received from the first release before disabling and four ranges near 5098 from the second release before disabling. However, even after sending multiple disable commands apparently spurious ranges continued to be received. At the PIES, the ship stood off 0.5 nm and held station. The release was enabled, two spurious ranges were received (apparently the two response pings), several reasonable ranges near 5115 m were received when enabled, and no good range pings were received after disabling.

The morning of 10/25 the Brown set up 0.75 nm from the MOVE-1 mooring for recovery. The release was enabled, a series of reasonable ranges were received, and the release command was sent. Subsequent ranging did not provide reasonable values, but within 10 min the bridge observed the upper glass ball pair and flag on the surface. The ship transited slowly "down" the mooring line (upwind) identifying a sequence of ball clusters as they rose to the surface. After four clusters were found, the bridge lost the ability to spot the top of the mooring. This led to concern about steaming further down the mooring, and the ship fell back to a position about 0.1 nm from the mooring top.

Approximately 1 hr after the release was fired, the ship began its approach to the mooring top. The bale of the two-ball float was hooked along the starboard rail and the line was brought around to the stern where it was run through a block to the TSE winch. Successive glass ball clusters were brought aboard and disconnected. Instrumentation found on the mooring wire between clusters was disconnected and stowed after serial numbers were checked against the mooring drawing. The 1069 m glass ball cluster came aboard with no tension on the winch, and it was found that there was a break in the wire below the cluster. It appeared to be a fresh break, associated with a series of kinks in the wire. A review of the opeation afterwards suggested that the ships track resulted in crossing the upper part of the mooring over the lower part, which perhaps had not completed its rise to the surface when recovery began.

After the bitter end of the broken line was aboard, the ship re-positioned for a second round of recovery operations. The lower set of glass balls (4917 m) was brought along the starboard rail and hooked. After the releases were recovered, hauling commenced to bring the remainder of the mooring aboard. All of the line and instrumentation was recovered, with a break in the wire found above the 1725 m SBE-37, as expected.

After the mooring recovery, the ship steamed back towards the PIES site (~6 nm away) but at only about half speed (6 kt) with one generator on line. Once the second generator was on line and time to the set up location could be estimated, it was determined that the earliest the PIES could be released would be 1530 local. Considering the burn wire delay and the rise time, the PIES would not be on the surface until 17:30 at the earliest. Local sunset was at 17:00. Discussions with the MOVE team were initiated by text. Consideration of the sea state (20 kt, 3-5' wind sea with whitecaps, 6-8' swell) and the possibility that the strobe on the PIES would not work resulted in a decision to stand down on the PIES recovery.

The ship re-positioned for a full-depth CTD at the MOVE mooring site. A successful cast was made to 4951 m depth in 4973 m of water. Twelve Niskin bottles were fired on the upcast at the 4951, 4500, 4000, 3500, 3000, 2500, 2000, 1500, 1000, 500, 10 and 5 m. Water samples for salinity were taken from 11 of the 12 Niskins; the 3500 m Niskin did not fire.

Appendix 5: Moored Station Logs

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. NTAS 18 MOORED STATION NO.

Launch (anchor over)

Date (day-mon-yr) 10-01-20 Time 17:45 UTC

Deployed by Pietro / Hasbrouck Recorder/Observer Bigorre

Ship and Cruise No. Ron Brow RB 20-01 Intended Duration 365 days

Depth Recorder Reading 5018 m Correction Source historical sound

Depth Correction +37 m speed 1511 m s⁻¹ (not 1500)

Corrected Water Depth 5055 m Magnetic Variation (E/W)

Anchor Drop Lat. (N/S) 14° 44.728' Lon. (E/W) 050° 56.488'

Surveyed Pos. Lat. (N/S) 14° 44.581' Lon. (E/W) 050° 56.706'

Argos Platform ID No. Additional Argos Info on pages 2 and 3

Acoustic Release Model Edgetech 8242XS Tested to 2,000 m

Release No. 1 (sn) 30844 Release No. 2 (sn) 33041

Interrogate Freq. 11 kHz Interrogate Freq. 11

Reply Freq. 12 kHz Reply Freq. 12

Enable 166475 Enable 314277

Disable 166504 Disable 314306

Release 151330 Release 332235

*Recovery (release fired) *buoy adrift, mooring riser recovered separately

Date (day-mon-yr) 24-OCT-2020 Time 1214 UTC

Latitude (N/S) 14° 45.300 N Longitude (E/W) 50° 57.427 W

Recovered by Hasbrouck/Pietro Recorder/Observer Plueddemann

Ship and Cruise No. RB-20-06 Actual duration days

Distance from waterline to buoy deck ~~76~~ 75 cm

1

ARRAY NAME AND NO. NTAS 18 MOORED STATION NO.________

Surface Components

Buoy Type MOB Color(s) Hull Tower Blue hull, Yellow deck, White tower

Buoy Markings If found adrift, contact Woods Hole Oceanographic Institution, Woods Hole MA 02543 USA, 508 457 1401

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET logger	L16		Port side
HRH	223	231	
BPR	216	240	
WND	225	266	
PRC	210	254	
LWR	206	283	
SWR	214	283	
SST	3602		SBE 37
Iridium	J10C7M		imei 3002 3406 3167 170
ASIMET logger	L12		Starboard side
HRH	246	231	
BPR	240	240	
WND	344	266	
PRC	702	254	
LWR	256	283	
SWR	215	283	
SST	1419		SBE 37
Iridium	J10D2M		imei 3002 3406 3164 170
Standalone WXT	209	248 (white ring)	
SA Lascar AT/HRH	32208	200	
SA SBE39 AT	1446	229	
CAMPBELL HRH		231	
CAMPBELL BPR		217	
CAMPBELL PRC		254	
CAMPBELL LWR		282.5	
CAMPBELL SWR		282.5	

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. NTAS-18 **MOORED STATION NO.**________

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SST SBE 56	6980	85	FWD (Bow)
SST SBE 56	6981	95	FWD (Bow)
SST SBE 56	6979	92	Port (315°)
SST SBE 56	6982	92	Starboard (045°)
WAMDAS	4003		
Brizzo	116		imei 3001 2506 0055 060
SIM	1		imei 3002 2401 0043 720
Xeos kilo			3002 3406 2644 350
Xeos Melo			3000 3401 3709 960
Xeos Rover			3004 3406 3297 420
Xeos Rover			3004 3406 3547 190

†Depth below buoy deck in centimeters

3

ARRAY NAME AND NO. NTAS 18 MOORED STATION NO.________

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
1		buoy			1240	10/20/2020 ~~1322~~	buoy adrift 4-28-2020 recovered 10-20-2020
2	5	EM chain				1558	
3		SBE39	5	8743	1239	1625	
4		Nortek ADCM	5.7	9407	1239	1625	
5		RBR Solo-D	6 m	78197	1239	1625	
6	79	7/16" wire					
7		SBE37 IM	10	669	1239	1650	inductive, clamped
8		Nortek ADCM	13	5973	1239	1818	inductive, clamped
9		SBE39	15	7697	1239	1825	clamped
10		SBE 39	20	7695	1239	1854	clamped
11		Nortek ADCP	24	12391	1239	1855	clamped
12		SBE37 IM	25	683	1239	1856	inductive, clamped, Poss. broken magnet coil on recovery
13		SBE39	30	8744	1239	1857	clamped
14		SBE 39	35	8745	1239	1858	clamped
15		SBE37 IM	40	684	1241	1859	inductive, clamped
16		SBE39	45	8746	1243	1900	clamped
17		SBE 39	50	8747	1248	1901	clamped
18		SBE37 IM	55	685	1249	1902	inductive, clamped
19		SBE 39	60	8748	1254	1903	clamped
20		SBE 39	65	8749	1256	1904	clamped
21		SBE37 IM	70	686	1258	1905	inductive, clamped
22		SBE39	75	8750	1300	1907	clamped
23		SBE39	80	8751	1306	1907	clamped
24		RBR Solo-D	83	78198	1308	1908	clamped
25		RDI ADCP	85	23281	1308	1908	upward looking

4

ARRAY NAME AND NO. NTAS 18 MOORED STATION NO.________

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
26	500	3/8" wire		17165-2		1908	time back is for upper termination
27		SBE39	90	8752	1308	1911	clamped
28		SBE 39	100	8753	13 13	1914	clamped
29		SBE 39	110	8754	1316	1916	clamped
30		Star-oddi	110	5282	1316	1916	clamped
31		Star-oddi	120	5283	1318	1916	clamped, recovered at 110m slid up the wire
32		Star-oddi	130	5284	1319	1918	clamped
33		Star-oddi	140	5285	1320	1919	clamped
34		Star-oddi	150	5286	1322	1920	clamped
35		Star-oddi	160	5287	1322	1921	clamped
36	500	3/8" wire		19027-4		1932	
37	500	3/8" wire		19027-3	1339	1946	$\boxed{\text{mooring break}}$ approx 1/2 way through this wire shot
38	200	3/8" wire			1407	1710	mooring riser recovery 24-OCT-2020
39	100	3/8" wire			1418	1705	encapsulated termination
40	200	7/8" nylon				1700	
41	500	7/8" nylon			1440	1641	spliced at sea
42	2000	3/4" nylon					
43	100	7/8" nylon				1603	
44	1500	1" Colmega			1510	1533	
45		glass balls (56)			1630 (end)	1410	~~IIII~~ ~~IIII~~ IIII 3 broken on recovery
46	5	SBE 37	5017	11392	1740	1424	Deep T/S for OSITES on load bar
47		SBE 37	5017	11393	1740	1424	
48	5	1/2" chain					
49		acoustic release		30844	1742	1429	dualed
50		acoustic release		33041	1742	1429	

5

ARRAY NAME AND NO. NTAS 18 MOORED STATION NO.________

5018

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
51	5	1/2" chain					
52	20	1" Nystron					
53	5	1/2" chain					
54		anchor			1745	~~174~~	air weight ~7,000 lbs
55							
56							
57							
58							
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							
70							
71							
72							
73							
74							
75							

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. NTAS-19 MOORED STATION NO.________

Launch (anchor over)

Date (day-mon-yr) 22-Oct-2020 Time 1903 UTC

Deployed by Pietro/Hasbrouck Recorder/Observer Plueddemann

Ship and Cruise No. R.Brown RB-20-06 Intended Duration 365 days

Depth Recorder Reading ________ m Correction Source XBT sound speed profile for multibeam

Depth Correction ________ m

Corrected Water Depth 4985 m Magnetic Variation (E/W)________

Anchor Drop Lat. (N/S) 14° 49.445 Lon. (E/W) 51° 00.781

Surveyed Pos. Lat. (N/S) 14° 49.475 Lon. (E/W) 51° 00.963

Argos Platform ID No. N/A (Iridium) Additional Argos Info on pages 2 and 3

Acoustic Release Model Edgetech 8242 BACS Tested to 500 m

Release No. 1 (sn) 33411	Release No. 2 (sn) 48282
Interrogate Freq. 11 kHz	Interrogate Freq. 11 kHz
Reply Freq. 12 kHz	Reply Freq. 12 kHz
Enable 361167	Enable 570013
Disable 361205	Disable 570030
Release 346426	Release 551262

Recovery (release fired)

Date (day-mon-yr) ________ Time ________ UTC

Latitude (N/S) ________ Longitude (E/W) ________

Recovered by ________ Recorder/Observer ________

Ship and Cruise No. ________ Actual duration ________ days

Distance from waterline to buoy deck 70cm

1

ARRAY NAME AND NO. NTAS-19 MOORED STATION NO.________

Surface Components

Buoy Type MDB **Color(s) Hull Tower** blue hull, yellow deck

Buoy Markings If found adrift... WHOI 508-457-1401

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET LGR	L05	—	port side
HRH	505	230	PIC-24, SD card
BPR	203	240	PIC-24, SD card
WND	~~346~~	260	replaced w/SN 221] damaged on deployment
PRC	~~501~~	260	replaced w/SN 215]
LWR	253	282	
SWR	216	282	
SST	1725	-150	
Iridium			IMEI 300234063854580
ASIMET LGR	L03	—	
HRH	258	230	
BPR	502	240	
WND	210	260	
PRC	218	260	
LWR	214	282	
SWR	253	282	
SST	1305	-150	
Iridium			IMEI 300234063341510
WXT	202	245	
SBE39-AT	5272	230	
Lascar	1111	230	

*Height above buoy deck in centimeters

2

ARRAY NAME AND NO. NTAS-19 MOORED STATION NO.________

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SBE-56	7206	80	90° CW from vane
SBE-56	7207	80	180°
SBE-56	7208	95	180°
SBE-56	7209	110	180°
SBE-56	7210	80	270°
WAMDAS			not transmitting
Brizo-X	0370		IMEI 300125060155490
Xeos Melo			IMEI 300034013709580
Rover			IMEI 300434064537420
Rover	*		IMEI 300434063297420
Kilo			IMEI 300234067205440
Subsurf. Iridium	*		IMEI 300224010043720
			*transferred from NTAS18 buoy after recovery

†Depth below buoy deck in centimeters

3

ARRAY NAME AND NO. NTAS-19 **MOORED STATION NO.**________

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
1		buoy			1311		PRC broken on deployment
2	5	EM Chain					
3		SBE-39	5	7680	1311		
4		Nortek CM	5.7	12688	1311		
5	79	7/16" wire					
6		SBE-37	10	13409	1312		IM
7		Nortek CM	13	16085	1312		IM (Sailed)
8		SBE 39	15	7681	1312		
9		SBE 39	20	7682	1312		
10		Nortek ADCP	24	15795	1312		uplooking
11		SBE-37	25	13410	1312		IM
12		SBE-39	30	7683	1313		
13		SBE-39	35	7684	1313		
14		SBE 37	40	13411	1315		IM
15		SBE 39	45	7687	1315		
16		SBE 39	50	7688	1315		
17		SBE 37	55	13412	1319		IM
18		SBE 39	60	7689	1323		
19		SBE 39	65	7690	1325		
20		SBE 37	70	13413	1329		IM
21		SBE 39	75	7691	1331		
22		SBE 39	80	7693	1333		
23		RDI ADCP	85	~~23281~~	1338		uplooking
24	500	3/8 wire		2125	1338		
25		SBE 39	90	7694	1340		

4

ARRAY NAME AND NO. NTAS-19 MOORED STATION NO.________

Item No.	Length (m)	Item	Depth	Inst No.	Time Over	Time Back	Notes
26		SBE 39	100	7696	1342		
27		star-oddi	110	5275	1343		
28		star-oddi	120	5276	1344		
29		star oddi	130	5277	1346		
30		star-oddi	140	5278	1347		
31		star oddi	150	5279	1348		
32		star-oddi	160	5280	1349		
33	500	3/8 wire		20090-2	1408		
34	500	3/8 wire		20090-1	1426		
35	200	3/8 wire		19027-5	1443		
36	100	3/8 wire		19027-6	1449		special termination encapsulated
37	200	7/8 nylon			1454		
38	500	7/8 nylon			1511		
39	2000	3/4 nylon					
40	100	7/8 nylon					
41	1500	1" colmega			1550		
42		glass balls			1634		44444 44444 4444 = 56
43		SBE 37			1821		38m above bottom
44		SBE 37			1821		
45	5	1/2 chain					
46		release		33411	1827		dual releases on load bracket
47		release		48282	1827		
48	5	1/2 chain					
49	20 ~~5~~	1" nystron ~~1/2 chain~~					
50		Anchor			1903		

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16. Abstract (Limit: 200 words)

The Northwest Tropical Atlantic Station (NTAS) was established to address the need for accurate air-sea flux estimates and upper ocean measurements in a region with strong sea surface temperature anomalies and the likelihood of significant local air–sea interaction on interannual to decadal timescales. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near 15°N, 51°W by successive mooring turnarounds. These observations will be used to investigate air–sea interaction processes related to climate variability.

This report documents recovery of the NTAS-18 mooring and deployment of the NTAS-19 mooring at the same site. Both moorings used Surlyn foam buoys as the surface element. These buoys were outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 160 m of the mooring line were outfitted with oceanographic sensors for the measurement of temperature, salinity and velocity. Deep ocean temperature and salinity are measured at approximately 38 m above the bottom.

17. Document Analysis a. Descriptors

Upper Ocean Processes Group
The Northwest Tropical Atlantic Station (NTAS)
NTAS-19 Mooring Turnaround Cruise, October 14 - November 1, 2020

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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