AR41 Cruise Report

R/V *Neil Armstrong*
18-22 November 2019
Woods Hole, MA to Woods Hole, MA

Chief Scientist: Leah McRaven
Co-chief Scientists: Mathieu Dever and Laura Stolp

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A. Introduction and General Description

R/V *Neil Armstrong* cruise AR41 took place from 18-22 November, 2019, departing from and returning to Woods Hole, MA. The cruise was comprised of (1) projects funded by WHOI Institutional Ship Days and, (2) the Multibeam Echosounder Quality Assurance Testing project funded by the National Science Foundation. The following is a list of each project included in the cruise activities together with PIs.

AR41 projects funded by WHOI Institutional Ship Days:

1. WHOI Ship Time: Statistical Assessment of Salinity Sensors Experiment (SASSE)
    - Leah McRaven (lmcraven@whoi.edu), PO
    - Susan Wijffels (swijffels@whoi.edu), PO
    - Pelle Robbins (probbins@whoi.edu), PO
    - John Toole (jtoole@whoi.edu), PO
    - Heather Furey (hfurey@whoi.edu), PO
    - Joshua Eaton (jeaton@whoi.edu), UNOLS East Coast Winch Pool
    - Magdalena Andres (mandres@whoi.edu), PO
2. WHOI Ship Time: A deep-ocean test of X-Spar 2.0
    - Carol Anne Clayson (cclayson@whoi.edu), PO
    - James B. Edson (jedson@whoi.edu), AOP&E
    - John M. Toole (jtoole@whoi.edu), PO
3. WHOI Ship time request for field testing of a newly developed underway profiler: the EcoCTD
    - Mathieu Dever (mdever@whoi.edu), PO
    - Mara Freilich (mfreilich@whoi.edu), PO
    - Amala Mahadevan (amala@whoi.edu), PO
4. WHOI Ship Time: Active Heave Compensation Quantification
    - Joshua Eaton (jeaton@whoi.edu), UNOLS East Coast Winch Pool

AR41 projects funded by the National Science Foundation:

1. NSF Ship Time: Multibeam Echosounder Quality Assurance Testing
    - Laura Stolp (lstolp@whoi.edu), OSS
    - Kevin Jerram (kjerram@ccom.unh.edu), University of New Hampshire Center for Coastal and Ocean Mapping / Multibeam Advisory Committee

As expected for the time of year AR41 took place, poor weather conditions impacted ship scheduling and the cruise was shortened by one day. The shortened schedule resulted in the rescheduling of an EM122 Multibeam calibration exercise, which was part of the Multibeam Echosounder Quality Assurance Testing project. Once the modified cruise schedule was finalized, science objectives for AR41 were as follows:

AR41 science objectives:

1. Perform CTDs to assess salinity calibration methods and validate stand-alone salinity sensors
2. Deploy/recover an X-Spar buoy
3. Perform underway testing of the EcoCTD

4. Collect data from the Armstrong Active Heave compensation system
5. Perform a calibration ‘patch test’ of the shipboard EM710 Multibeam system

In addition to objectives 1-5, a number of ancillary science operations were carried out, which focused on calibration and maintenance of onboard science systems. This included underway testing of the OS38 Shipboard ADCP and shipboard Multibeam systems. The AR41 cruise also facilitated the recovery of a malfunctioning OOI glider, deployment of an MRV Argo float, and deployment of an MRV ALAMO float. A detailed AR41 map including the location of these events is shown below (Figure A1). Finally, Jayne Doucette, Director of Digital Assets, WHOI Communications, joined AR41 to photograph and record video of science operations while at sea. Content collected during the cruise will be used by WHOI for general science outreach efforts and to help PIs in developing outreach products. The following cruise log details all relevant science events for AR41.

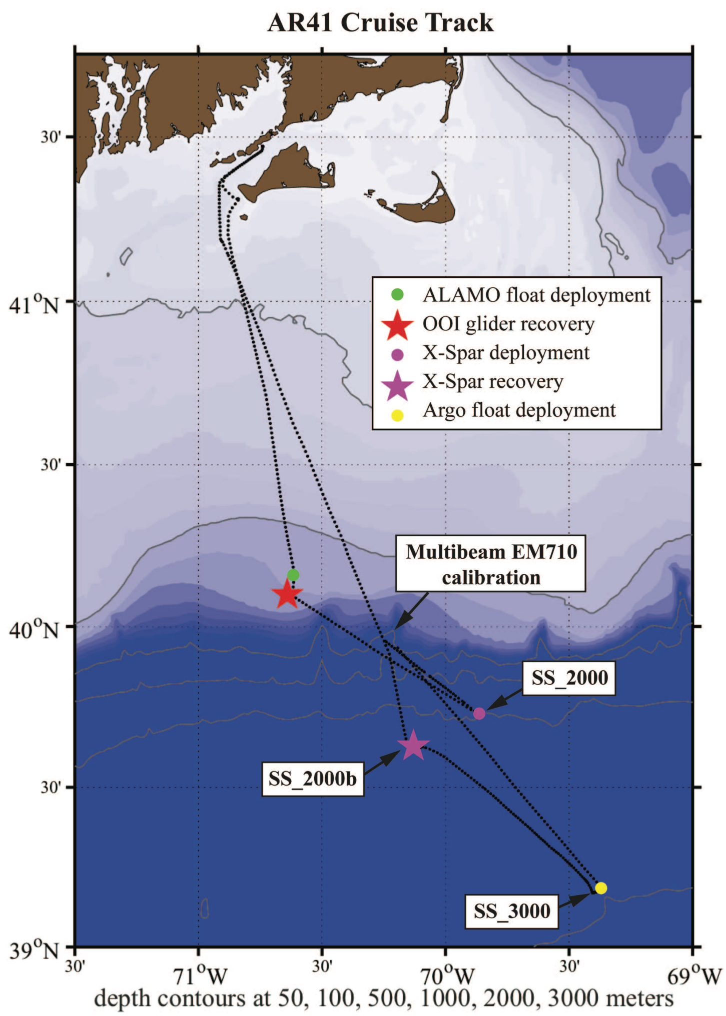

Figure A1: *AR41 cruise track together with instrument deployment and recovery locations. The three study locations used (SS_3000, SS_2000, and SS_2000b) are shown, as well at the Multibeam calibration site.*

AR41 Event Log 18-22 November 2019								
Event / station name	**CTD Station**	**Time (UTC)**	**Latitude (deg)**	**Latitude (min)**	**Longitude (deg)**	**Longitude (min)**	**Approx CTD Target Depth (m)**	**Ship Operations**
Departure		Nov 18 19:00						
CTD school	001	Nov 18 21:15	41	18.67	70	50.32	n/a	CTD test in Vineyard Sound, RBR CTDs and D2 CTD mounted on rosette
Transit to SS_2000								SADCP OS38 NB mode on
ALAMO float deployment		Nov 19 04:43	40	09.54	70	36.88		
OOI glider recovery		Nov 19 05:24	40	06.09	70	38.41		
SSS_2000	002	Nov 19 10:00	39	43.73	69	51.85	2000	RBR CTDs and D2 CTD on rosette
X-Spar Deployment		Nov 19 12:48	39	43.77	69	51.87		Observed to be drifting 2-3 kts due W
SSS_2000	003	Nov 19 13:05	39	43.58	69	52.07	2000	RBR CTDs and D2 CTD on rosette, D2 CTD removed after cast
Transit to EM710 site								with EcoCTD testing at 7 and 8 knots, Multibeam testing, and SADCP OS38 BB mode on
Multibeam SSV CTD	004	Nov 19 17:34	39	57.28	70	14.72	800	RBR CTDs on rosette, CTD for Multibeam Sound Speed Velocity
GPS calibration and EM710 patch test		Nov 19 18:48 - Nov 20 00:31						EcoCTD testing during Multibeam patch test
XBT deployment		Nov 19 18:21						Multibeam Sound Speed Velocity
Transit to SS_3000								SADCP OS38 BB mode on
SS_3000	005	Nov 20 06:39	39	11.00	69	21.61	3000	
SS_3000	006	Nov 20 10:13	39	10.99	69	21.60	3000	
SS_3000	007	Nov 20 13:22	39	10.94	69	21.73	3000	
SS_3000	008	Nov 20 16:32	39	11.04	69	21.75	3000	
Argo float deployment		Nov 20 19:13	39	11.07	69	22.19		
SS_3000	009	Nov 20 19:42	39	11.02	69	21.89	3000	
SS_3000	010	Nov 20 22:55	39	11.01	69	21.92	3000	
SS_3000	011	Nov 21 02:17	39	10.93	69	22.13	1600	RBR CTDs on rosette, Active Heave Compensation testing
SS_3000	012	Nov 21 04:20	39	10.80	69	22.50	2000	RBR CTDs on rosette

SS_3000	013	Nov 21 06:52	39	10.67	69	22.60	2000	RBR CTDs on rosette
SS_3000	014	Nov 21 09:27	39	10.49	69	23.10	2000	RBR CTDs on rosette
Transit to X-Spar location								SADCP OS38 NB mode on
X-Spar sighting								Ship positioned down-element of buoy during following CTD work
SSS_2000b	015	Nov 21 18:15	39	37.49	70	06.06	500	EcoCTD and RBR CTDs on rosette
SSS_2000b	016	Nov 21 19:51	39	37.42	70	07.20	500	EcoCTD and RBR CTDs on rosette
X-Spar recovery		Nov 21 21:30	39	37.73	70	07.88		
SSS_2000b	017	Nov 21 21:48	39	37.73	70	07.93	500	EcoCTD and RBR CTDs on rosette
SSS_2000b	018	Nov 21 23:13	39	37.71	70	08.66	500	RBR CTDs on rosette
Transit to Woods Hole								SADCP OS38 NB mode on

Special care was taken throughout cruise preparations and during at sea operations to ensure the AR41 science party fully benefitted from available ship time. As of the completion of the cruise, all PIs reported that sufficient shipboard opportunity was provided in order to satisfy the agreed upon scientific objectives planned for the cruise. Below are the individual reports for each component of the cruise. These include descriptions of the operations, locations of sampling, and, where possible, some brief highlights of initial results.

We acknowledge Captain Sheasley and the crew of the Armstrong, whose hard work and dedication enabled us to carry out our science operations in a safe and productive environment. Shipboard technicians Amy Simoneau and Cris Seaton, who monitored all shipboard science systems to ensure they ran smoothly throughout the cruise. David Fisichella and the WHOI Marine Facilities & Operations group, who advocated for all science operations for AR41. We also acknowledge Rose Dufour (NSF) and Jim Holik (NSF) for supporting the Multibeam Echosounder Quality Assurance Testing. Lastly, we would like to thank Timothy Twomey, Director of Ship Operations, and Robert Munier, Vice President for Marine Facilities & Operations, for supporting the fieldwork of all AR41 projects.

B: WHOI Ship Time: Statistical Assessment of Salinity Sensors Experiment

Contributing authors: Leah McRaven (lmcraven@whoi.edu), Pelle Robbins (probbins@whoi.edu), and John Toole (jtoole@whoi.edu)

Funding Source: WHOI Institutional Ship Time

Principal investigators: Leah McRaven[1], Susan Wijffels[1], Pelle Robbins[1], John Toole[1], Heather Furey[1], Joshua Eaton[2], and Magdalena Andres[1]
[1]Physical Oceanography, [2]UNOLS East Coast Winch Pool

Cruise Participants:

1. Leah McRaven, Chief Scientist
2. Astrid Pacini, CTD watch leader
3. Heather Furey, CTD watch leader
4. Leah Houghton, Hydrographer
5. Pelle Robbins, CTD watch stander
6. Bill Dullea, CTD watch stander
7. Joshua Eaton, CTD winch data expert

Project Summary: The SASSE portion of the AR41 cruise collected data in order to address the following scientific objectives:

1. To quantify the impact of systematic biases related to data collection methods, salinometer performance, and statistical methods used on shipboard salinity-calibrated CTD data.
2. To compare three models of stand-alone CTD sensors with shipboard CTD data: RBR CTDs that are used in the Argo Program, and the D-2 CTD sensor.
3. To assess the Armstrong's CTD Active Heave Compensation (AHC) performance in facilitating measurements of fine-scale temperature and salinity profiles.

During the AR41 cruise, 18 CTDs were performed and 303 salinity samples were drawn and analyzed on a Guildline Autosal. These data will be used to assess at-sea salinometer performance in the Armstrong lab space, and to quantify the repeatability of CTD salinity calibrations with in situ salinity bottle samples using a number of statistical methods. Three manufacturers of stand-alone CTD sensors were also attached to the CTD frame for various subsets of casts. Once final, salinity-calibrated CTD data are produced for AR41, comparisons will be made between the varying models and manufacturers of stand-alone CTD sensors deployed. CTD station locations, times, approximate CTD target depths, and notes on additional sensors mounted on the CTD frame, are summarized in the Cruise Event Log (Section A). Lastly, CTD station 11 was performed using the Armstrong's AHC system. Details covering winch performance are highlighted in Section E.

Brief Highlights:

Shipboard CTD and salinometer data: Overall, performance of the shipboard CTD system was excellent. Both primary and secondary CTD sensor suites indicated a history of good care for CTD sensors deployed. CTD cast 10 experienced a biofouling event in the primary sensor suite, however the secondary sensors were not impacted. The sensors were cleaned and no further biofouling impacted sensors for the remainder of the cruise. During casts deeper than 1000m, the CTD winch experienced wire wrap issues that caused delays during up-casts. The Guildline Autosal used at sea exhibited stable performance. Initial plots of shipboard CTD data and salinity bottle data are shown in Figure B1. Pre-conductivity calibration (before applying calibrations using salinity bottle data) CTD data demonstrate that while there were some “fly away” salinity bottle samples (CTD cast 8 had many), bottle data are appropriate for use in further calibrations of the CTD conductivity sensors and to address scientific objectives detailed in the SASSE proposal.

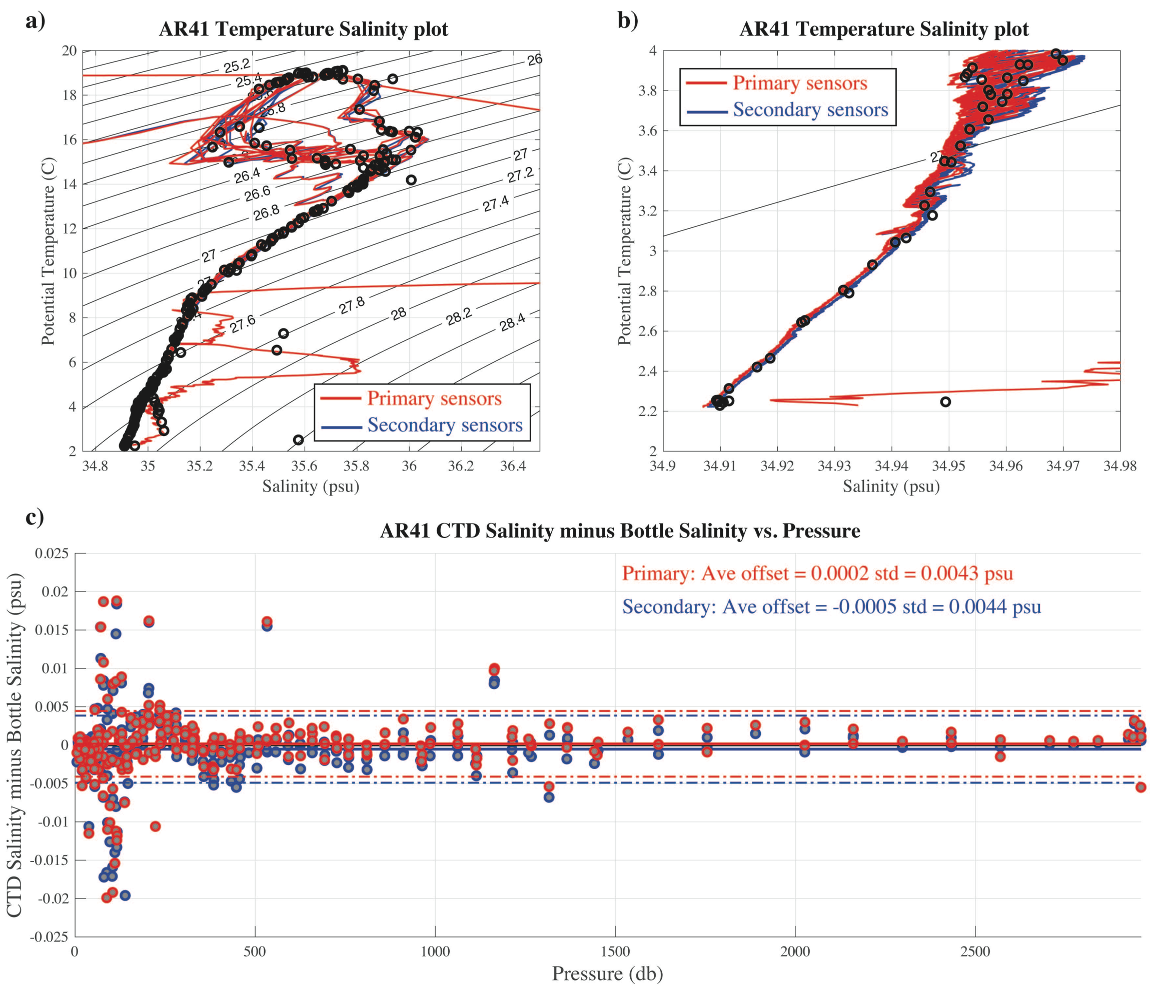

Figure B1: *a) Potential Temperature vs. Salinity for all CTD casts completed on AR41 (primary and secondary data shown). Salinity bottle values are shown in black. b) Potential Temperature vs. Salinity for all deep CTD casts (deeper than ~2500 m). c) CTD salinity minus bottle salinity as a function of pressure for all bottle data collected (primary and secondary differences shown). Before CTD conductivity calibration, bottle differences indicate that the CTD sensors used were in good health, but could be improved by salinity bottle calibration methods.*

During CTD stations 2 and 3, salinity bottle samples were collected from all available Niskins at one depth. These data were collected to estimate the effective CTD Niskin/salinometer accuracy for the AR41 hydrographic setup. Station 2 Niskins were closed at a pressure of 1975 dB. After controlling for two fly away samples, the standard deviation of sample values was 0.00069 psu, with an average salinity of 34.952 psu. Station 3 Niskins were closed at a pressure of 1011 dB. After controlling for two fly away samples, the standard deviation of sample values was 0.00125 psu, with an average salinity of 34.985 psu. After further examination, it became clear that two Niskins consistently produced troublesome samples throughout the cruise. While the two standard deviations differ by a factor of two, initial values show promising performance of the Guildline Autosal and Armstrong laboratory setup.

RBR CTD data: On stations shallower than 2000 dbar, three RBR Concerto CTDs (serial numbers 60667, 60668, and 60670) were attached to the rosette frame to collect data in parallel to the Armstrong’s shipboard CTD. Stand-alone CTD sensors are calibrated in static environments, thus there is limited information on sensor dynamic response in environments of changing pressure and temperature. The primary objective during AR41 was to gather temporal response data from the RBR CTD sensors in a situation with additional independent estimates of salinity (shipboard CTD and bottle samples). All three CTDs performed correctly and returned useful data. This data will be combined with results from other ship-based comparisons to yield improved accuracy for RBR CTDs on autonomous platforms.

Figure B2: *The AR41 shipboard rosette showing stand-alone CTD sensor attachment points*

D-2 CTD data: R/V *Armstrong* cruise AR41 afforded another opportunity to acquire data from a new Conductivity-Temperature-Depth (CTD) sensor being developed by D-2, Inc. Under NOPP funding, J. Toole is running a program to field trial D-2 CTDs in piggyback mode with research cruises of opportunity. The CTD and a self-contained data logging system are mounted on the research vessel's hydrographic sampling frame, and data from the D-2 sensor are acquired in parallel with the ship's system. Joint analysis of these data is being used to assess the performance of the new sensor.

After 2 casts of the Armstrong's CTD package with the D-2 system installed (lowerings that returned full round trip sensor data from the D-2 sensor), oil was observed to be leaking from the D-2 instrument (believed to be coming from the pressure compensating bladder fitted to the conductivity sensor). The D-2 CTD was removed from the hydrographic frame and on completion of the cruise, the sensor was returned to the manufacturer for diagnosis and repair. While disappointing, the AR41 cruise returned the first full-depth ocean data from a D-2 CTD sensor - observations that will guide the ongoing development of this instrument.

Active Heave Compensation Data: CTD station 11 was performed using the Armstrong's AHC system. Details on CTD cast 11 protocols are highlighted in Section E. As part of this cast, winch payout speed was set to different speeds during the downcast: 15 m/min, 30 m/min, 45 m/min, and 60 m/min, while the ACH system was engaged. Based on initial figures of AHC impact on temperature and salinity profile data, it is clear that the Armstrong's system negatively impacts data and does not facilitate measurements of fine-scale temperature and salinity profiles. This includes clear examples of CTD package reversals (velocity sign change) during all speeds used in the downcast. A follow-up report on the AHC system will be provided to WHOI Shipboard and Marine Operations departments once analysis is complete.

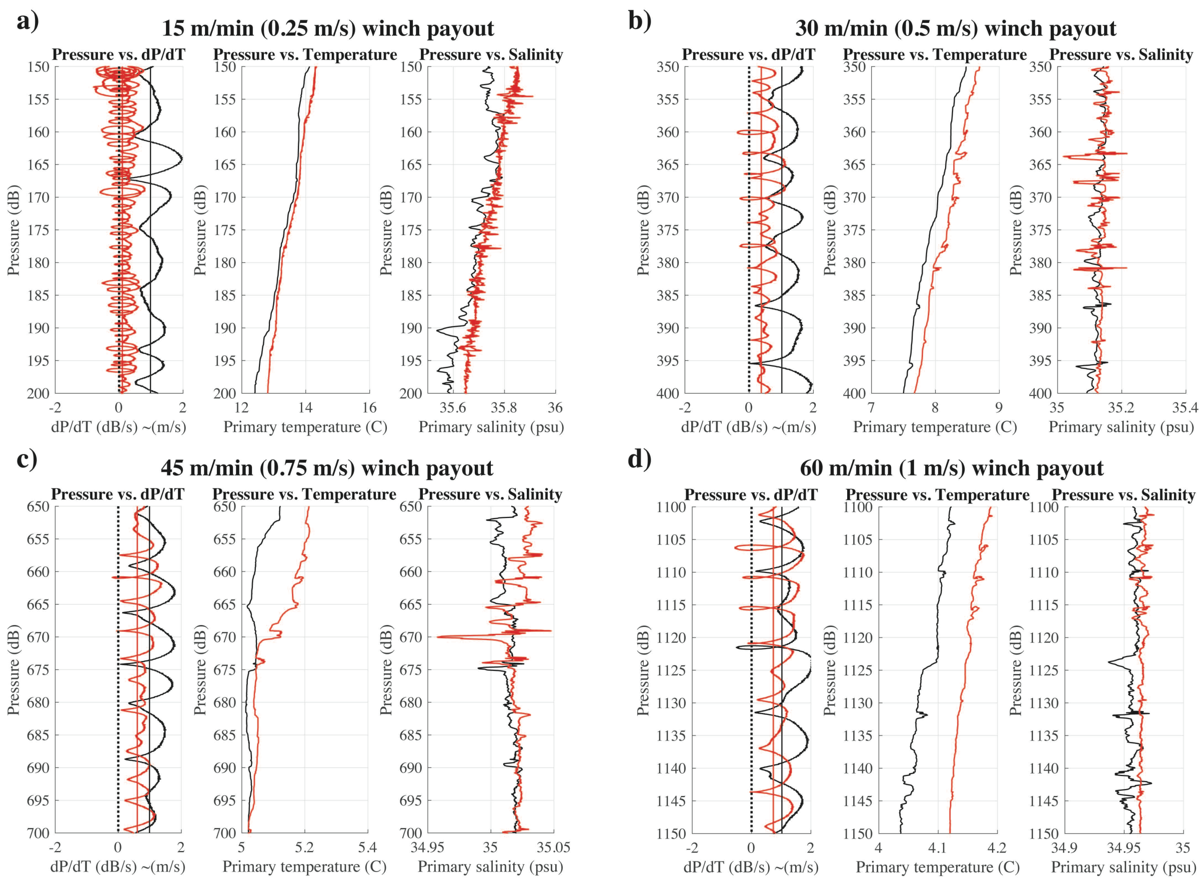

Figure B3: *Shipboard CTD data plots comparing cast 11 data (AHC ON) in red, to cast 12 data (AHC off) in black. Cast 11 downcast payout speeds were varied from a) 15 m/min, b) 30 m/min, c) 45 m/min, and d) 60 m/min. Cast 12 downcast payout was held constant at 60 m/min (representative of a standard CTD cast). The first panel of each subplot shows dP/dT (rate of change of pressure with respect to time) as an estimate for CTD velocity, with solid lines indicating the average CTD velocity over the pressure range shown. Positive dP/dt values indicate downward motion. The second and third panels show CTD temperature and salinity profile data.*

Synergistic activities with other funded projects:
There are two CTD products that will be made available to all AR41 cruise participants. The first is 24-Hz processed data to allow for dynamic comparisons between all stand-alone sensors mounted on the CTD frame during AR41. The second is salinity post-calibrated CTD data to allow for conductivity sensor accuracy/precision comparisons between all stand-alone sensors mounted on the CTD frame during AR41. During the cruise, CTD data provided sound speed velocity corrections for Multibeam operations and ocean profile measurements for the X-Spar project.

C: WHOI Ship Time: A deep-ocean test of X-Spar 2.0

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The Office of Naval Research has provided funding to develop and construct a second-generation eXpendable Spar buoy (X-Spar) for use in future air-sea interaction studies (Fig. C1). The X-Spar concept is a free-drifting spar buoy with the ability to support a variety of sensors above and below the ocean surface to observe processes contributing to air-sea interaction. A unique capability of the X-Spar is the ability to process the high frequency (20 Hz) data to compute turbulent fluxes in near real-time. The fluxes and associated mean variables are then telemetered to any desired location via Iridium messages. The ability to telemeter the data in near real-time means that researchers do not need to recover the X-Spar to collect the desired measurements. This unique attribute is what make the X-Spar expendable. The project is a joint effort between Carol Anne Clayson and John Toole in the PO Department and James Edson in AOP&E. The construction of the X-Spar was led by AOP&E engineers Tom Lanagan, Steve Faluotico, Jason Kapit and Jon Ware. Support to complete the final assembly of the X-Spar, purchase the rigging and other supplies required for the sea-trial, and provide time for the sea-going team was provided by the Center for Air-Sea Interaction and Marine Science (CASIMAS) through donations from Eastman Chemical.

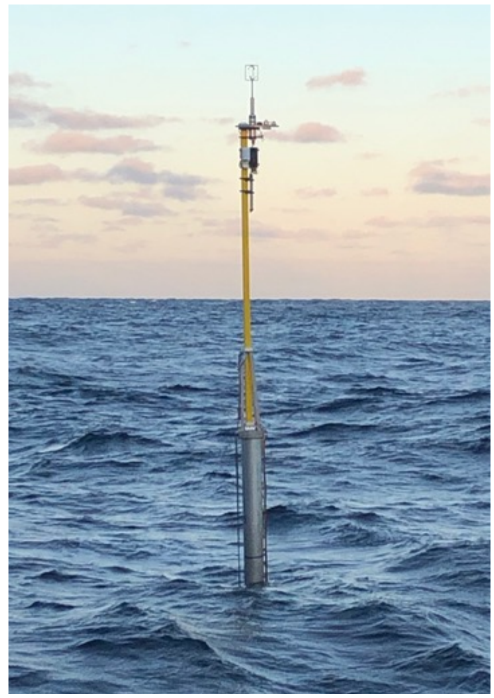

Figure C1. The second generation X-Spar as viewed shortly before recovery during the test-cruise.

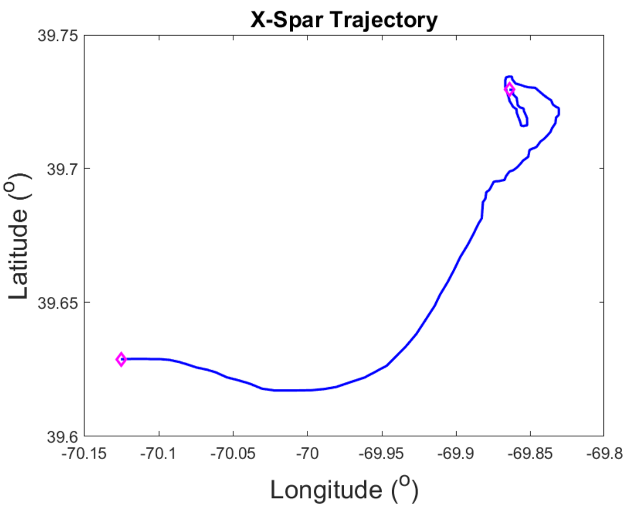

Figure C2. The position of the X-Spar during the two-day test deployment. The positions were provided by the GPS onboard the X-Spar.

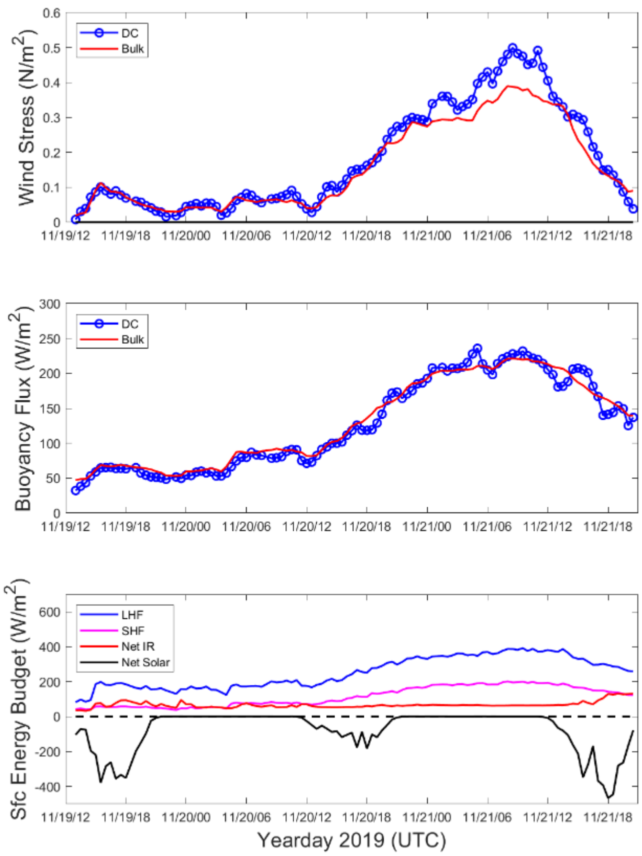

Figure C1. Time series of DC surface stress and buoyancy fluxes and all terms required to compute the net heat flux into the ocean. The data shown in blue and red in the upper most plots represent direct covariance and bulk estimates of the fluxes, respectively.

R/V Armstrong ship time was provided to the X-Spar team to conduct a deep-water test of X-Spar. The sea-going team of Clayson, Edson and Lanagan participated in the deployment, collection and analysis of data (via Iridium), and recovery of the X-Spar during the 5-day cruise. The X-Spar was deployed at approximately 39°44’ N, 69°52’ W and recovered two days later at 39°38’ N, 70°7.5’W as shown in Fig. C2. The distance between these points was approximately 25 km (as the crow flies). The deployment location was south of the shelf break front and Pioneer Array in 2000 m of water. Once deployed, the data acquisition and telemetry system worked flawlessly. Solar and IR radiation; air pressure, temperature and RH sensors; a GPS receiver; and subsurface pressure, sea temperature and salinity sensors, where all logged by a Campbell data logger (CdL). A Direct Covariance Flux System (DCFS) logged a sonic anemometer and motion sensors to directly compute the turbulent fluxes of momentum (surface stress) and buoyancy. The DCFS also ingested the data stream output from the CdL. Once every 30 minutes the fluxes and means were computed onboard the X-Spar and “emailed” back to the ship via Iridium. This allowed us to see the conditions encountered by the X-Spar during its entire transect while the R/V Armstrong was assisting with other experiments at the 4000 m site. This is included direct estimates of the fluxes as well as all the terms required to compute the surface heat budget as shown in Fig. C3. Importantly, the transmitted data also contained precise measurement of the buoy location from the onboard GPS receiver. This led us directly to the X-Spar for recovery on Day 3.

The R/V Armstrong cruise also provided a means to conduct several important engineering tests. For example, in addition to the scientific data, the test deployment allowed us to confirm that:

- The X-Spar floats!
- The X-Spar operates well in rough seas.
- Even is strong winds, the buoy follows the depth averaged current. This includes the sub-mesoscale eddy shown at the beginning of its transect in Fig. C3 This is a very advantageous characteristic of the X-Spar as it allows flux measurements in a frame of reference that follows the ocean current as required by theory.
- The fairing on the upper most (yellow) mast of the X-Spar effectively acted as a vane to keep the instruments pointed into the wind even as it was drifting with the currents. Again this is very advantageous for calculation of fluxes, and a welcome surprise as it was not completely expected.

Of course, there were also a number of additional lessons learned during the test-cruise. First and foremost were the difficulties encountered during deployment and recovery. During deployment, the X-Spar needs to be lowered into the water at a much steeper angle than during the test-cruise. The X-Spar was nearly horizontal as it entered the water during the test-cruising causing the meteorological sensors to be dunked before it righted itself. Fortunately, the sensors survived the dunking and provided the data shown in Figure C3. The recovery started well but some control over the bottom end of the X-Spar was lost when a tag-line was severed. After some on-the-fly rigging was added to the X-Spar, it was brought aboard with some damage to the instrumentation. Although rougher than desired, a great deal was learned about how best to recover the X-Spar after its next deployment. Of course, the recovery may no longer be necessary once sufficient refinements to the X-Spar has been finalized, which will allow us to deploy it in expendable mode.

The assistance of the R/V Armstrong crew during deployment and recovery of the X-Spar was greatly appreciated.

D: WHOI Ship time request for field testing of a newly developed underway profiler

Contributing author: Mat Dever (mdever@whoi.edu)

Cruise objectives

The EcoCTD is a bio-physical towed profiler designed to measure biogeochemical tracer distributions at high resolution from underway research vessels. Because the EcoCTD was only recently developed, the opportunity to conduct further field-testing to better characterize the EcoCTD's sampling characteristics was very valuable. The cruise aimed to address three main sampling characteristics of the EcoCTD:

1. Free-falling behavior
    a. Measure acceleration within the EcoCTD, as well as on deck, to ensure the EcoCTD is free-falling independently of the cruising speed
    b. Measure gyroscope data to estimate the rate of rotation of the EcoCTD while profiling
2. Determine winch characteristics
    a. Determine the pay-in and pay-out rate of the winch as a function of time
    b. Measure the amount of line required to profile
3. Cover the full parameter space in terms of ship speed and profile depths
4. Quantify line tension during a profile

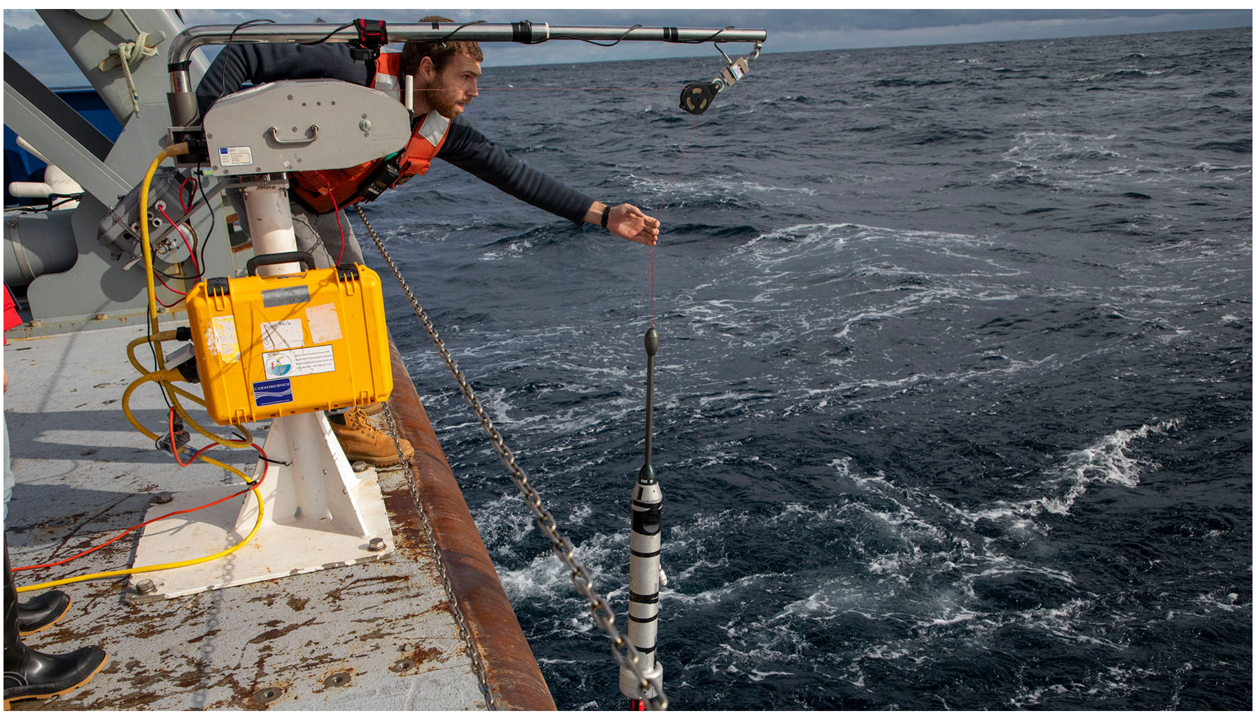

Figure D1: Deployment of the EcoCTD. The GoPro camera looking down at the drum, as well as the load cell installed on the pulley are visible in the picture. Picture by Jayne Doucette.

Data collected
A total of 28 profiles were collected during the cruise, at ship speeds varying from 4 to 8 knots and profile depth ranging between 193 and 410 m. For each profile, 3-axis acceleration, rotation rate and magnetometer data were collected inside the EcoCTD, and on the ship's deck. Additionally, the number of rotations of the winch's drum was recorded by a GoPro camera sampling at 720 frames per second. Finally, the amount of line spooled in/out was measured both optically using the same GoPro camera, and manually by marking the line every 20 m and counting line markings.

A load cell was installed at the tip of the davit, above the pulley, to measure the load on the pulley, and indirectly, the tension in the line. Additionally, a magnet and hall-effect sensor were installed on the winch as a redundant way of counting drum rotations. Unfortunately, the data logger for both of these sensors malfunctioned and no data were recorded. The load cell had to be removed anyway, due to line chafing in the way it was installed. Line tension will therefore not be estimated, but pay-in/out rates will still be able to be determined from the optical data.

Preliminary results
Preliminary results are encouraging and show:

- The EcoCTD rapidly reaches it terminal velocity, and profile at a very constant rate (see Figure D2).
- The EcoCTD does not seem to be excessively spinning with only a few rotations observed in a deeper, randomly selected, cast (see Figure D3).
- Temporal resolution between profiles depend on profile depth and ship speed, ranging from 5 to 12 minutes. Spatial resolution ranged between 600 and 2400 m (see Figure D4).
- The EcoCTD seems to be decoupled from the ship's motion. Further investigation is required on this, but at 6 knots, and in relatively rough seas (10 ft waves), no correlation could be found between vertical acceleration recorded on the deck of the ship, and in the EcoCTD (see Figure D5).
- The pay-in/pay-out rate of the winch is time-varying. Further image processing is required to established concrete results to date.

Synergistic activities with other funded projects
The sampling for the NSF-funded calibration of the echo sounder EM710 was very compatible with the EcoCTD testing. We were able to leverage the relatively slow-ship speed required by this group to complete of all EcoCTD profiles required for our proposed work. This collaboration also provided a great opportunity for the EM710 calibration group to use the observations of temperature and salinity collected along their calibration lines by the EcoCTD to determine a more precise sound speed profile and refine their calibration efforts.

Another collaboration with the CTD team allowed the EcoCTD team to complete two casts with two different EcoCTD probes mounted on the ship's rosette. The EcoCTD team will greatly benefit from these profiles, for which precise salinity measurements were made using a salinometer, to calibrate the EcoCTD.

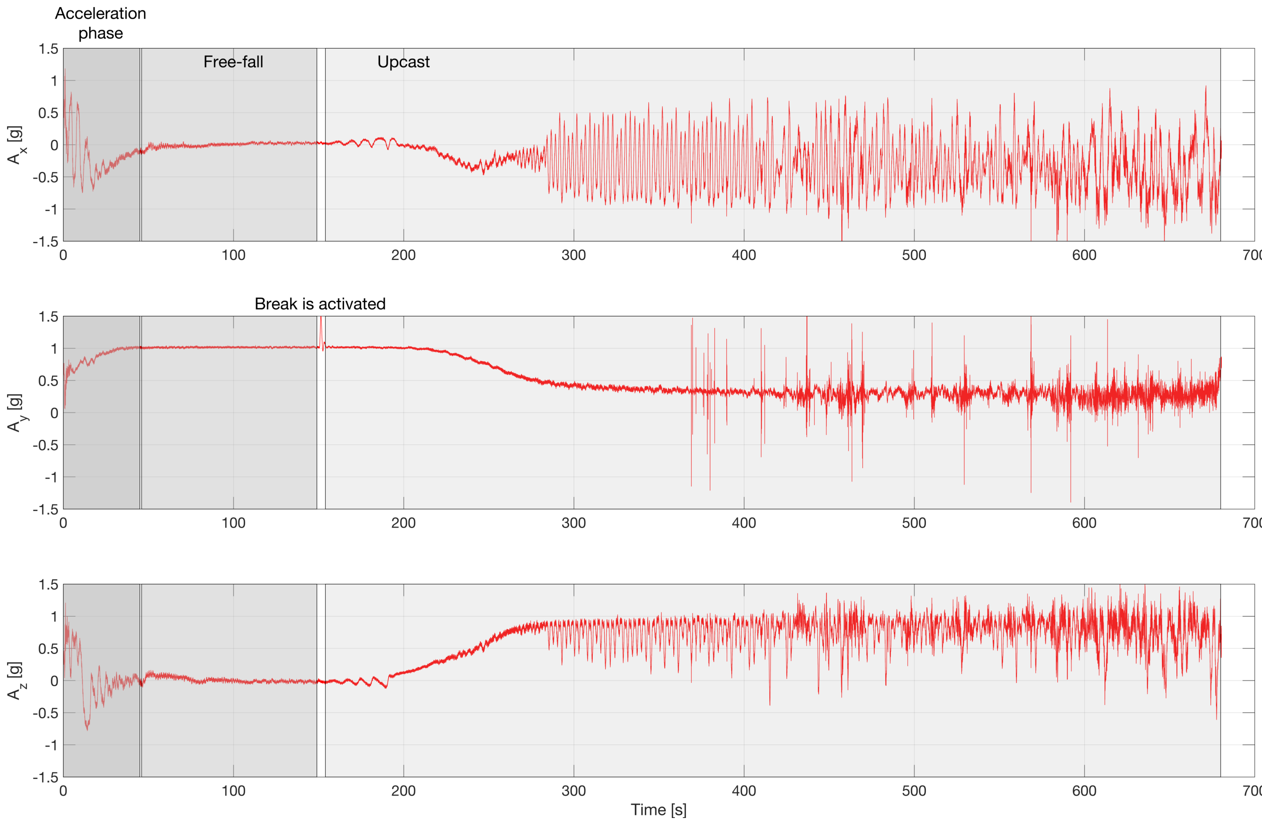

Figure D2: Time series of the acceleration of the EcoCTD along its three dimensions for an example profile to 400 m deep. The downcast acceleration phase (about 45 s), the downcast profiled at terminal velocity (45 to 150 s) and the upcast (> 150 s) are clearly visible. The 1 g acceleration recorded in the vertical (A_y) confirms that the probe indeed falls perfectly vertically, and at a very constant rate, throughout the profile

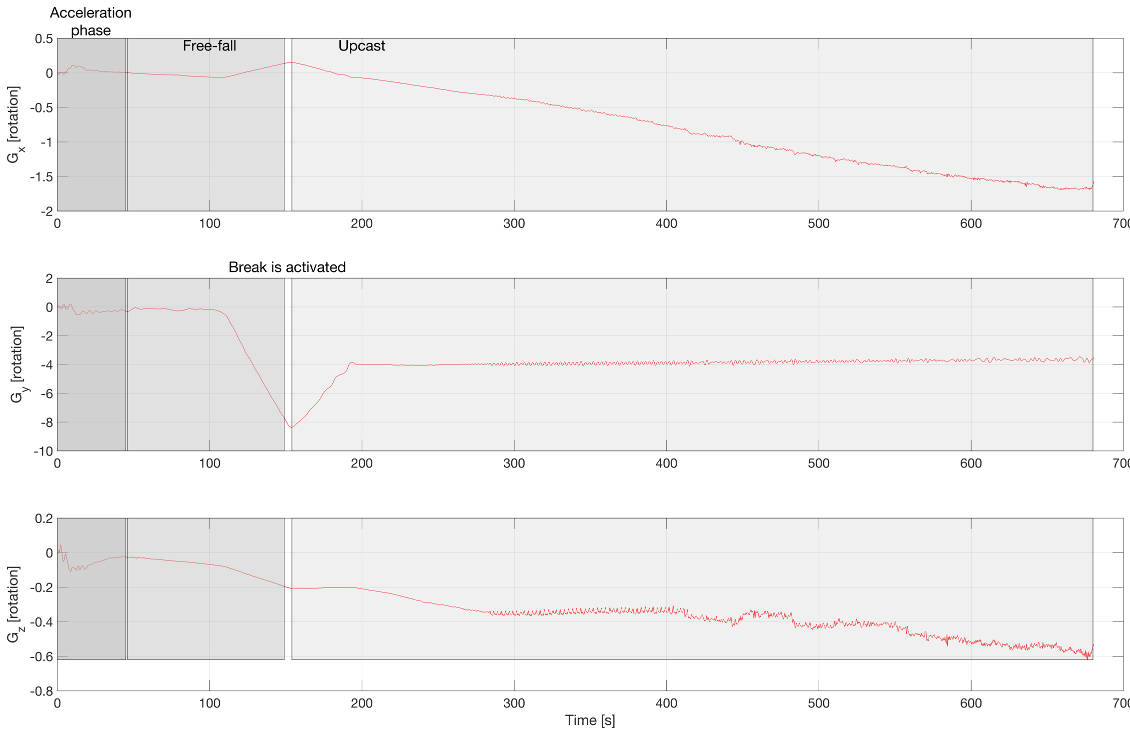

Figure D3: Time series of the integrated rotation rate of the EcoCTD along its three dimensions for the same profile as in Figure D2. Some rotation around the longitudinal axis of the EcoCTD (G_y) was observed, starting suddenly after 100 s of free-falling. 8 total rotations are observed on the downcast. 4 rotations are completed in the opposite direction in the beginning of the upcast, then the EcoCTD stops rotating.

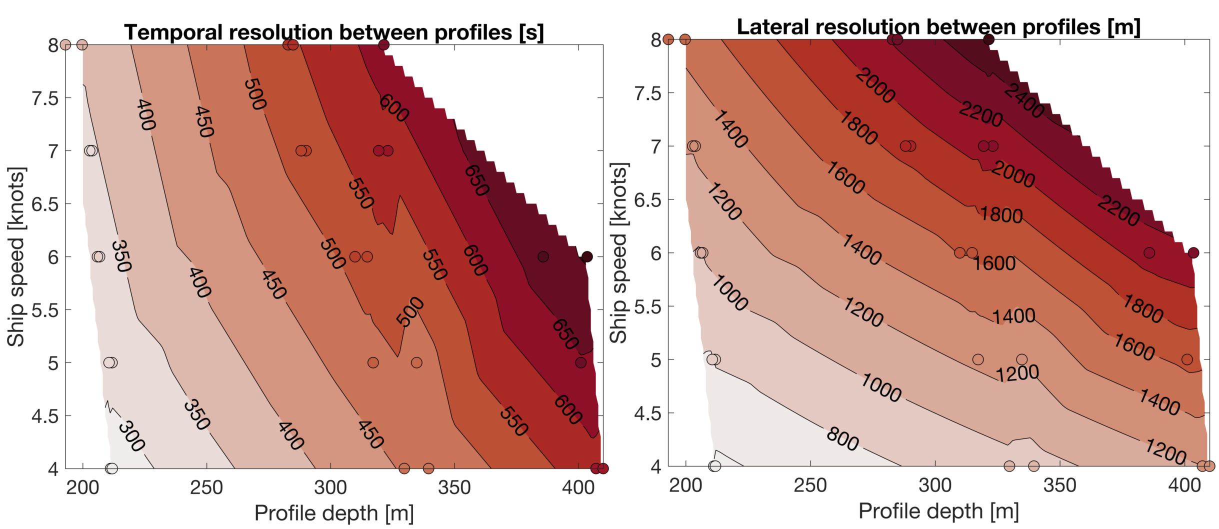

Figure D4: [left] Temporal resolution (in s) and [right] spatial resolution (in m) between profiles collected by the EcoCTD for varying ship speeds and profile depths. Data points used to create the contour plot are superimposed.

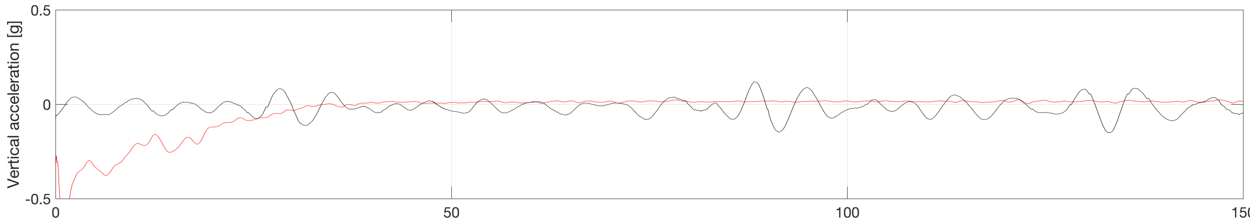

Figure D5: Time series of vertical acceleration (in g) on the downcast, for the same profile as shown in Figure D2 as recorded from IMUs placed on the ship's deck, and in the EcoCTD. No statistical correlation could be established between those two time series.

E: WHOI Ship Time: Active Heave Compensation Quantification

Contributing Author: Joshua Eaton (jeaton@whoi.edu)

Project Title: Active Heave Compensation Quantification
Funding Source: NSF
Principal Investigators: Joshua Eaton, Leah McRaven
Additional Cruise Participants: N/A

Project Summary:
The objective of the project is to quantify the Active Heave Compensation (AHC) system on board the R/V Neil Armstrong. This quantification will provide guidance for future users of the system, as well as foster discussions with Markey Machinery and the UNOLS East Coast Winch Pool for improvements to UNOLS fleet wide systems and future systems. Discussions with the WHOI port office are also open.

Methods:
Overboarding point Motion Parameterization:
A serial connection was established with the LARS Motion Reference Unit (MRU) to record the raw motion data. This data was to parameterize the motion of the overboarding point in a station keeping condition. This forms the basis of the requirements of effective AHC. AHC data was collected over several CTD casts. Preliminary analysis of the correlation between the MRU velocity data and CTD pressure data verify the validity of the MRU data.

AHC Cast Characterization:
Conducting a cast at various speeds and payouts provide data on effectiveness of the current implementation. The cast consisted of a deployment following the SOP to 150 meters. At 150 meters the AHC function was enabled and engaged. Following engagement of the function the package was lowered at a commanded velocitiesof 15, 30, 45, and 60 m/min using the Cast Hold function. Each velocity was maintained for a period of 10 minutes. Following the end of the Cast Hold function the system was operated in manual mode with a commanded velocity of 60 m/min for a period of 5 minutes. The five tests characterize the AHC function in "live joystick" operations. The cast was then stopped around 1500 meters. The AHC function was left on for a period of five minutes followed by a similar period with the function off. The package was then recovered to a depth of 160 meters using the Cast Hold function at a commanded velocity of 60 m/min with the AHC function off. At 160 meters a test corresponding to the 1500 meter test. These two tests examines the effect that the wire layer on the winch drum has of the AHC function.

Preliminary Results:
Overboarding point Motion: It was found the MRU data correlated with the motion of the CTD package when AHC was off. The motion sensor and the package motions were in phase. It was found that the amplitude of the MRU velocity data was smaller than that of the package. This posits the theory that actual overboarding point differs from the MRU overboarding point.

AHC Cast Charecterization: First order analysis of the AHC function as compared with the package motion found that the package began to move out of phase from the motion sensor. It was also found that the AHC function was not aggressive enough to remove all motion from the package. Further, as the package became out of phase with the motion sensor it is posited that the acceleration values for the winch are too conservative.

F: NSF Ship Time: Multibeam Echosounder Quality Assurance Testing

Contributing author: Kevin Jerram (kjerram@ccom.unh.edu)

Project Title
EM710 and EM122 Multibeam Echosounder Quality Assurance Testing

Funding
NSF (WHOI-coordinated ship time and UNH-coordinated for MAC time)

Principal Investigators
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UNH Center for Coastal and Ocean Mapping / Multibeam Advisory Committee

Cruise Participants
Amy Simoneau, Cris Seaton, Rebecca Hudak, Phil Forte

Project Summary
The Multibeam Advisory Committee works with the UNOLS fleet to coordinate performance testing on an opportunistic basis with the aim of improving multibeam data quality across the fleet. Sea acceptance testing (SAT) for the EM710 and EM122 multibeam echosounders on R/V *Neil Armstrong* were completed in early 2016 (see report on MAC website at http://mac.unols.org/category/ships/neil-armstrong). The MAC coordinated with Laura Stolp and Leah McRaven to plan calibrations ('patch tests') and other quality assurance testing (QAT) for the EM710 and EM122 among several other work packages during AR41. Due to elevated sea state, the cruise was shortened and the EM122 calibration (requiring a significant transit to Physalia Seamount and ~12 hours on site) was removed from the schedule. Thanks to careful at-sea coordination among the work packages, all other QAT activities were completed by taking advantage of a weather window for calibration and collecting data during transits.

Methods
The AR41 MAC QAT visit included several assessments for each multibeam echosounder:

1. a review of system geometry and software configuration;
2. position/motion system antenna calibration;
3. geometric calibration ('patch test', EM710);
4. swath coverage / extinction testing;
5. impedance proxy (BIST) testing for the TX array, RX array, and receiver; and
6. documentation of post-cruise configurations.

Figure F1 shows an overview of multibeam data collection during AR41, including the EM710 calibration site at Atlantis Canyon and swath coverage data collection during transits. The system geometry review revealed no changes from the SAT (AR01-03). The EM710 calibration (Fig. F2) was performed between approximately 2019-11-19 1830 UTC and 2019-11-20 0030 UTC, immediately following CTD and XBT profiles for comparison and application in SIS.

The system geometry review, POS MV antenna (GAMS) calibration, and EM710 calibration indicated no significant changes since AR01-03; very small changes were made to the EM710

Attitude 1 angular offsets in SIS (Fig. F3) and no changes were made to the EM122. Swath coverage and hardware impedance analysis is ongoing (preliminary results are shown in Figs. F4-F5).

NOTE: All QAT activities, results, and post-cruise configurations will be documented in a separate MAC cruise report; this report will be sent to the SSSG group for review and then made available on the MAC website (mac.unols.org).

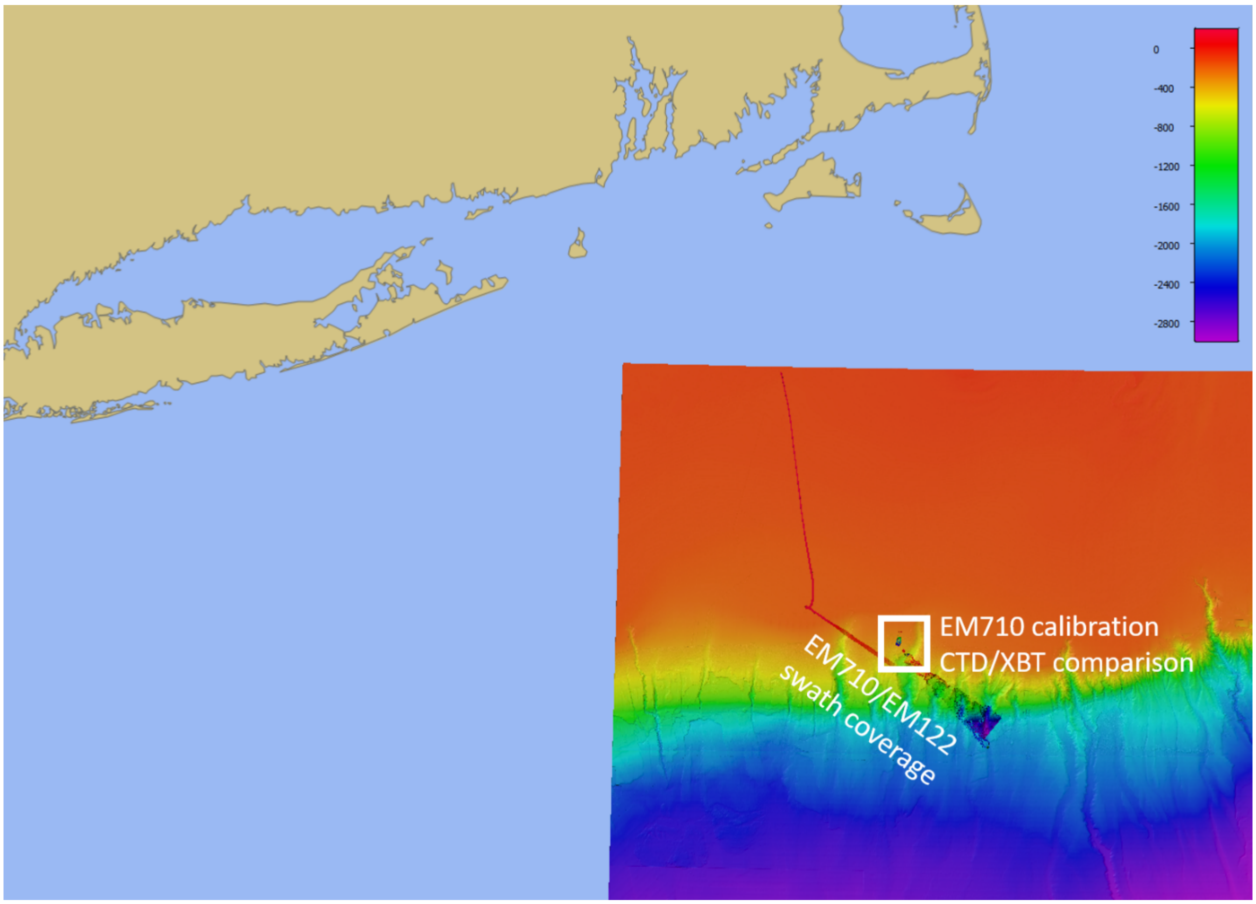

Figure F1. Multibeam data collection overview. Depth color scale is for background bathymetry (GMRT, marine-geo.org)

EM710 Calibration	Waypoint	Decimal Degrees		Degrees Decimal Minutes			
		Lat.	Lon.	Lat. Deg.	Lat. Min.	Lon. Deg.	Lon. Min.
Pitch	A / 0	39.977569	-70.257403	39	58.6542	-70	15.4442
	B / 1	39.939881	-70.207055	39	56.3928	-70	12.4233
Roll	C / 2	39.990971	-70.276066	39	59.4583	-70	16.5639
	D / 3	40.035436	-70.266718	40	2.1262	-70	16.0031
Heading 1	E / 4	39.974986	-70.260668	39	58.4991	-70	15.6401
	F / 5	39.937298	-70.210320	39	56.2379	-70	12.6192
Heading 2	G / 6	39.980153	-70.254138	39	58.8092	-70	15.2483
	H / 7	39.942463	-70.203790	39	56.5478	-70	12.2274

EM710 calibration waypoint order

1. Pitch cal line 1 (A→B) at **6 kts**
2. Pitch cal line 2 (B→A) at **6 kts**
3. Roll cal line 1 (C→D) at **5 kts**
4. Roll cal line 2 (D→C) at **5 kts**
5. Heading cal line 1 (E→F) at **4 kts**
6. Transit to Heading cal line 2 (F→G) at **5 kts** for EcoCTD
7. Heading cal line 2 (G→H) at **4 kts**

Other notes

1. All bridge echosounders secured if possible
2. Doppler speed log may be requested (test interference w/EM710)
3. EcoCTD casts will be ongoing throughout calibration lines
4. XBTs may be required before pitch and roll if no EcoCTD data available
5. Add'l processing time may be necessary between sets of lines
6. Bathymetry at right is in meters

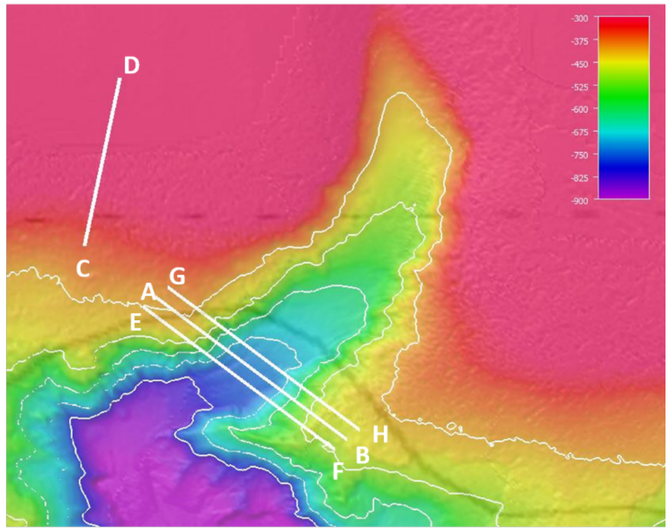

Figure F2. EM710 calibration plan with reduced speeds for simultaneous EcoCTD testing.

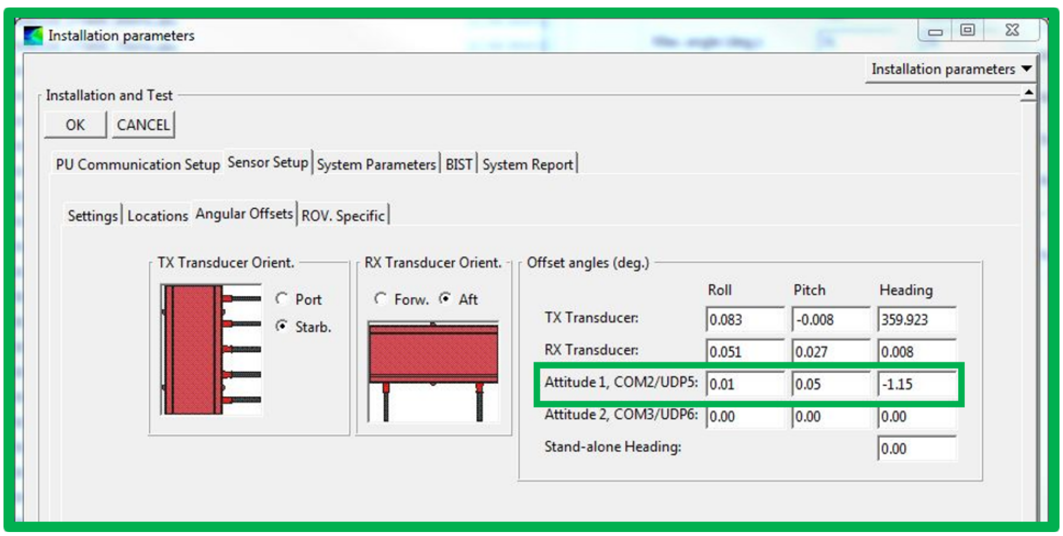

Figure F3. EM710 calibration results applied in SIS Installation Parameters for Attitude 1.

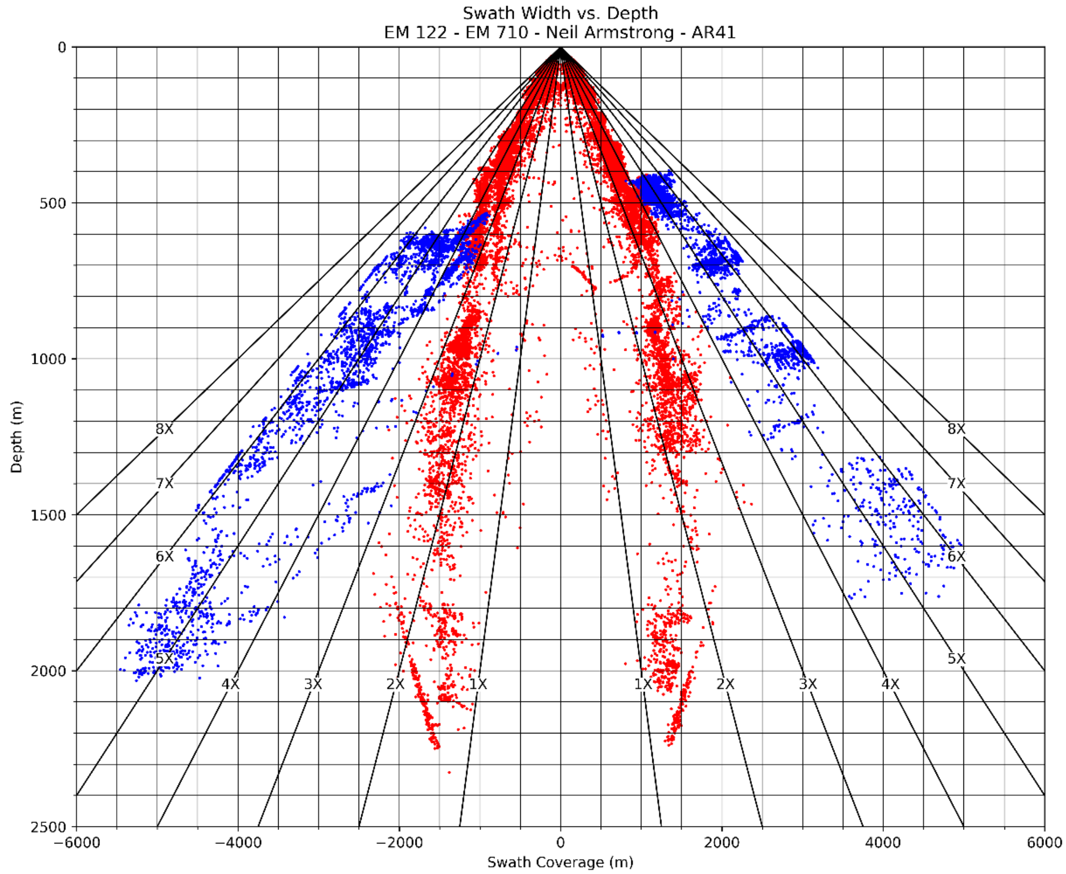

Figure F4. EM122 (blue) and EM710 (red) swath coverage achieved during AR41. Lines indicate multiples of water depth. Swath coverage observed during AR41 may not be representative of typical coverage due to elevated sea state.

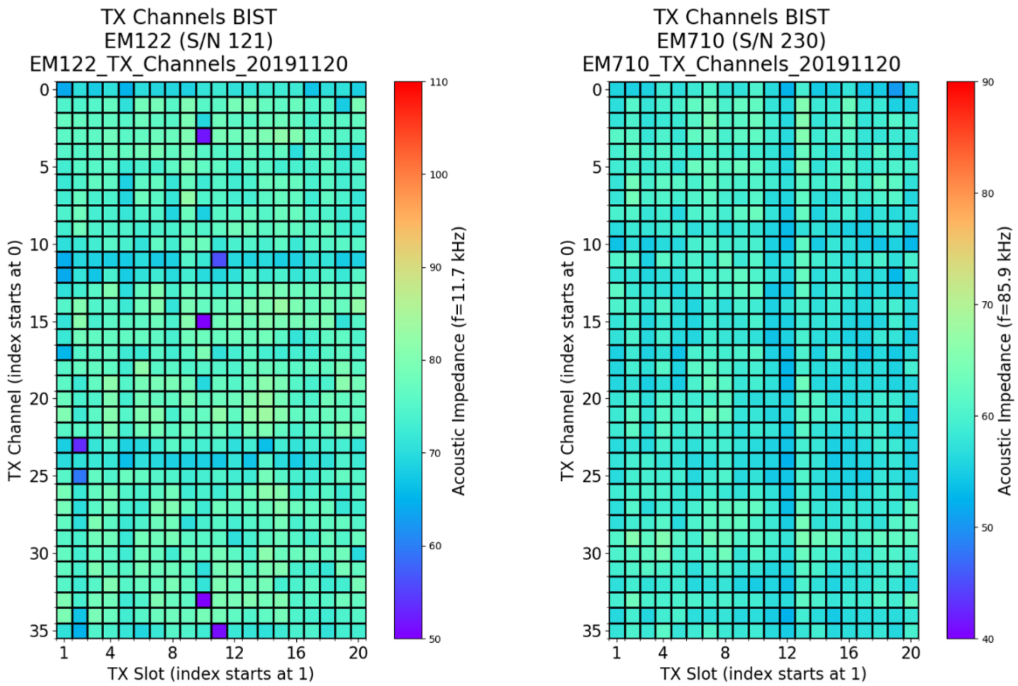

Figure F5. EM122 and EM710 transmitter array impedance as measured through TX Channels BISTs. Compared to the SAT impedance tests, no significant changes or channel failures are noted.