OSNAP GDWBC Cruise Report

R/V Neil Armstrong, AR46
08 August – 05 September 2020
Woods Hole to Woods Hole

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Abstract

This cruise report documents the fourth recovery and fifth deployment of the Deep Western Boundary Current array off the east coast of Greenland as part of the Overturning in the Subpolar North Atlantic Program (OSNAP). This marks the first time this array has been both recovered and deployed by the BowerLab at the Woods Hole Oceanographic Institution. In earlier years (2014, 2015, 2016), the array has been deployed by P. Holliday at the National Oceanography Center in Southampton, UK. The initial deployment by WHOI took place in 2018 on the R/V Armstrong cruise AR30.

In addition to the four 'GDWBC' mooring recoveries deployments, we completed a set of CTD casts both to test acoustic releases, calibrate the mooring instruments, and to measure water properties at the mooring sites for calibration purposes. This was the first time that this array included optodes, which were calibrated and deployed for Isabela Le Bras, WHOI. We also deployed a single Argo float for the WHOI Argo Program.

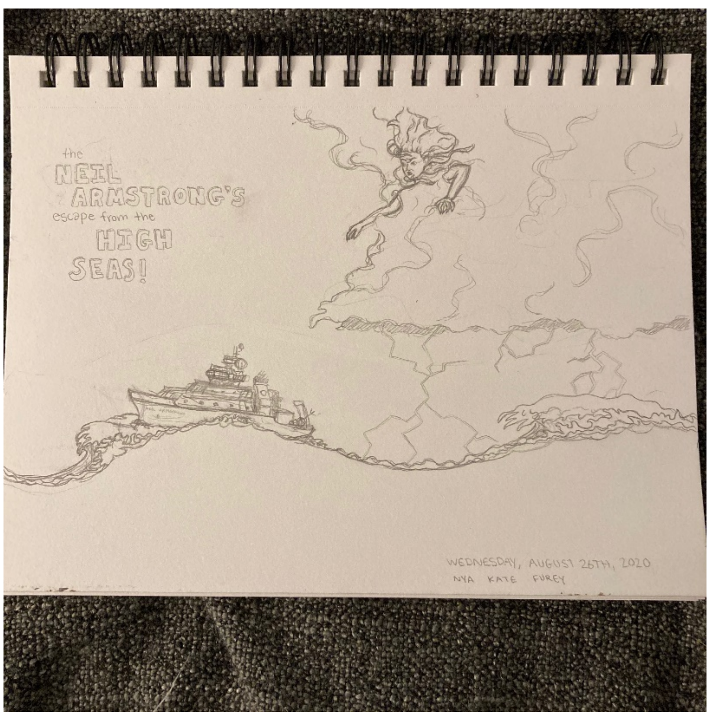


Table of Contents

1. Science Personnel

Sebastien Bigorre, WHOI, Chief Scientist, Lead OOI Scientist
John Kemp, WHOI, Lead mooring technician
Nico Llanos, WHOI, Mooring technician
Daniel Bogorff, WHOI, OOI technician
James Kuo, WHOI, OOI technician
Collin Dobson, WHOI, OOI technician
Jennifer Batryn, WHOI, OOI technician
Heather Furey, WHOI, co-Chief Scientist, Lead OSNAP Scientist
Ray Graham, WHOI, OSNAP technician
Sarah Nickford, URI, Water sampling and CTD
Robbie Laird, WHOI, SSSG
Austin McHugh, UNOLS Tech Pool, SSSG

Science party on back deck just after last mooring operation, the recovery of FLMB-6. John Kemp and James Kuo hold up a '5' and a '1' to indicate that they had done 51 different mooring operations over the course of two back-to-back cruises, in which they had not left the ship due to COVID-19 and self-quarantine requirements. (They should have swapped places to get the number correct, perhaps.) Weather turned foul just after this and we high-tailed it home.

2. Overview of OOI and OSNAP work

The R/V Armstrong left Woods Hole, Massachusetts on 08 July 2020 and steamed to the OOI Irminger Sea array area. OSNAP personnel, H. Furey and R. Graham, worked on OSNAP instrument preparation, including optode and microcat calibration dips and acoustic release tests while the OOI Irminger 7 deployment mooring work was being done. We then proceeded to do a pre-recovery CTD cast, recover and deploy four OSNAP moorings in the east Greenland Deep Western Boundary Current region. After the OSNAP recoveries, we did a post-calibration cast for all recovered microcats while the recovery phase of the OOI work (Irminger 6) continued. Due to the reduced science party size (due to the novel coronavirus – see below), we were unable to do a post-deployment CTD cast. During OSNAP-GDWBC2018, we had been forced to move M4 site 2 nm to the north, as M42016-2018 had not yet been recovered. During AR46, we moved the new M4 back to its original 2014-2018 site location. New to this years' field program were (1) adding optodes to the OSNAP moorings M1, M2, and M3, (2) doing a full turn-around of the OSNAP moorings, and (3) doing post-recovery calibrations of some of the OOI Irminger 6 microcats that are utilized as part of the OSNAP array. One Argo float was deployed. Figure 1 shows the overall station locations and cruise track.

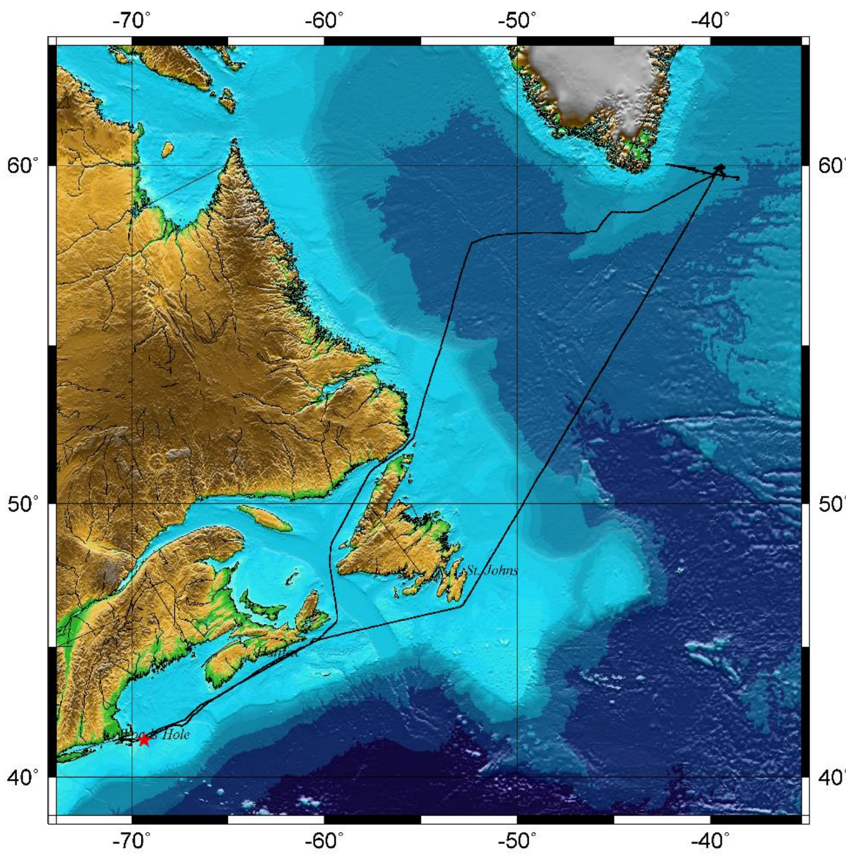
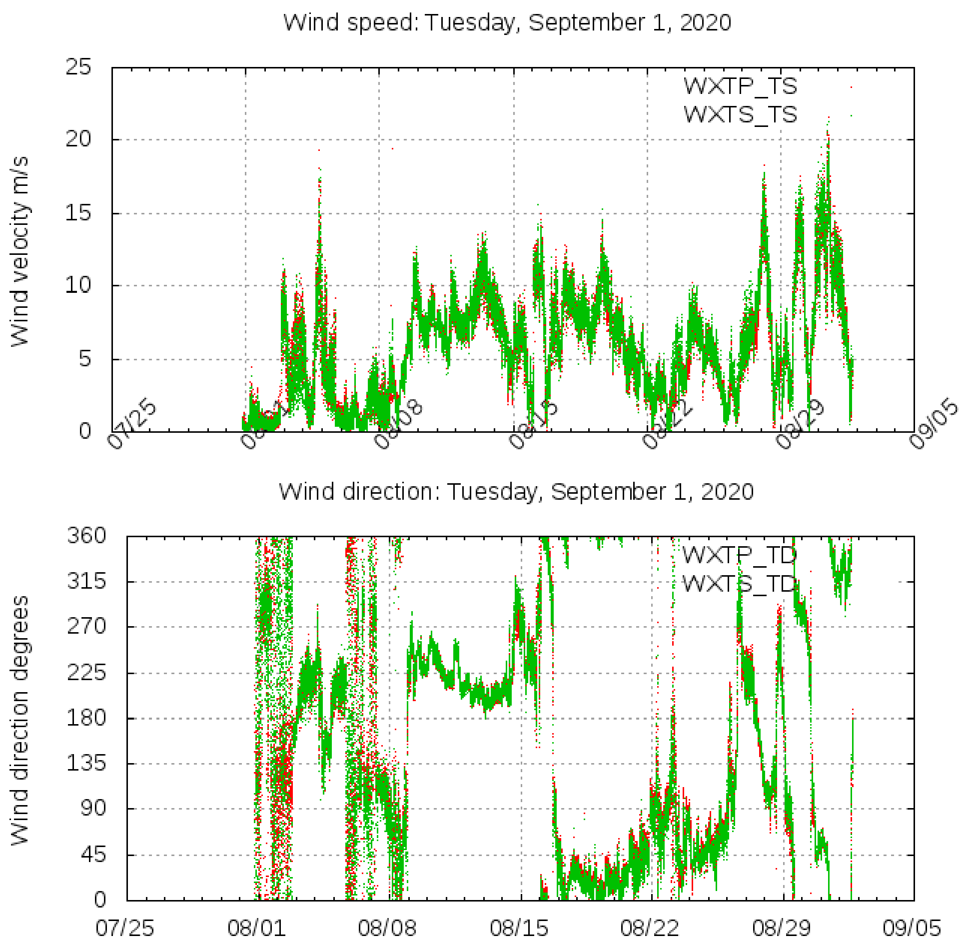


Figure 1. Overall cruise track for AR46, Woods Hole to Woods Hole, 08 August- 05 September 2020. Early departure from study site and deviation of return trip into Labrador Sea were in response to, and to successfully avoid, Hurricane Laura. Hurricane Laura was a Category 4 hurricane that came across the Gulf of Mexico, made a sharp right hand turn over the southeastern United States, and bounded up the

Gulf Stream once the storm made the leap from over land to over water at Cape Hatteras, and continued on into the Labrador Sea.

Once arriving at the work site, the weather was at first not favorable to mooring deployments, and we often had daily, or sometimes hourly changes in work plans. During rough weather periods we relied on getting releases tested and instruments calibrated during CTD casts. After the first few days on site, we settled into an extended calm period where winds were about 10 knots and joint OOI and OSNAP mooring ops were performed for eleven days continuously. Figure 2 shows wind speed, wind direction, air temperature, barometric pressure, and rain intensity during the cruise time period. Air temperatures during mooring deployments were generally 8-10°C except when transiting to and from Wood Hole, where air temperatures were up to 30°C.



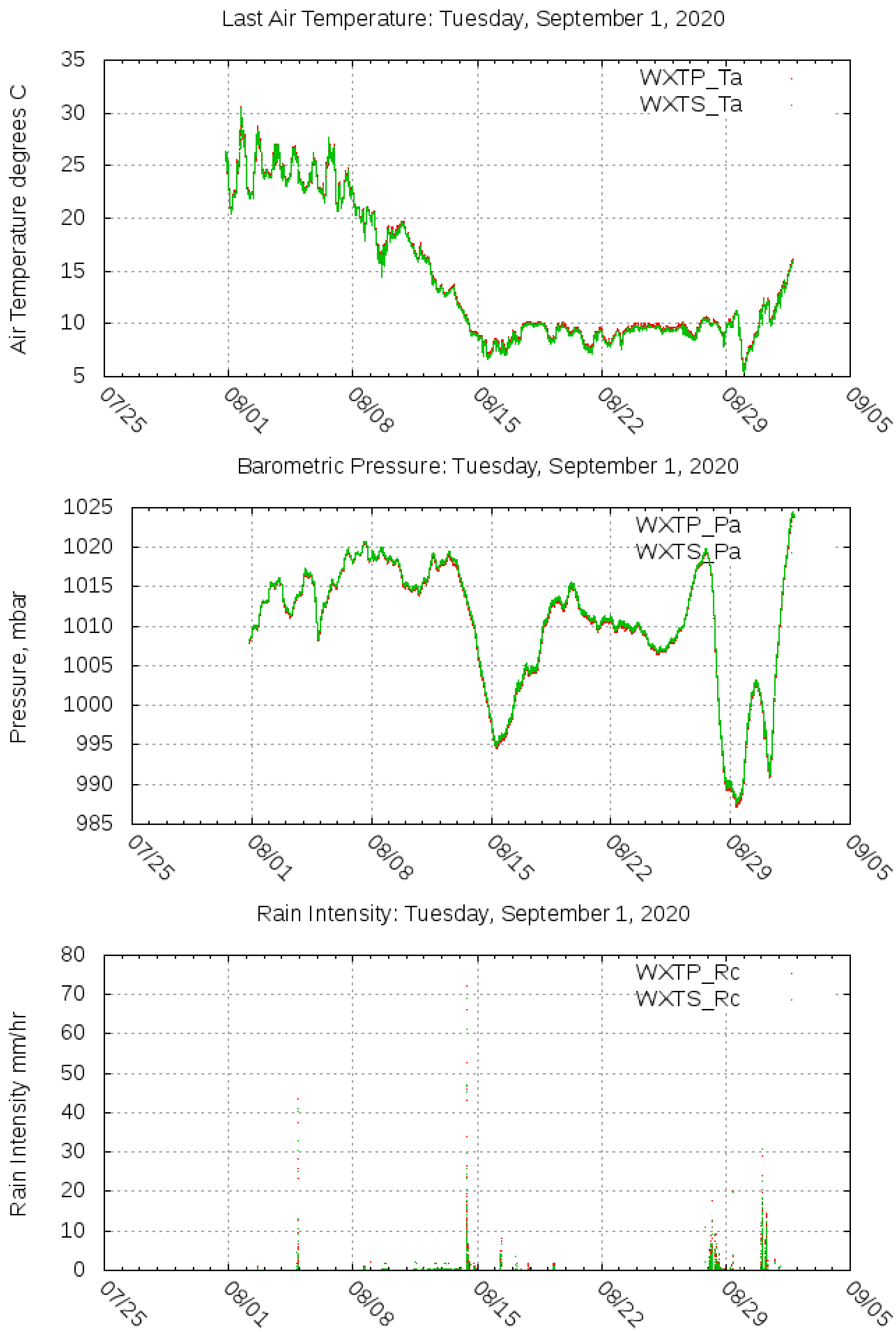


Figure 2. Weather conditions measured on the bow mast of the R/V *Armstrong* during AR46. Shown are wind speed, wind direction, air temperature, barometric pressure, and rain intensity for the in-port period prior to departure (data up to 08 August 8th), and for the cruise period.

3. Cruise Narrative relevant to OSNAP Operations

Below is a summary of CTD and mooring operations performed that were directly relevant to the OSNAP objectives. Work flow for OOI and for OSNAP were different due to mooring placement. For OOI, with two sites to toggle between, we were able to deploy before recovering. For OSNAP, due to co-location of deploy and recover sites (exception being M4), we were required to recover before deploying the new mooring. An additional consideration was that the OSNAP calibration casts had to be performed before recovery. Generally, we deployed all OOI moorings, turned around all OSNAP moorings, and then recovered all OOI moorings. In this way, we cleared the deck of all new mooring components before pulling onboard the old mooring components. This was critical for OOI work, because moorings contain large flotation spheres and a surface buoy, which completely filled the deck. Appendix A show cruise plan for all operations performed on AR46 (OOI and OSNAP).

Table 1. CTD and mooring operation relevant to OSNAP GDWBC.

Date	Day	Summary of OSNAP activities	Details
06 Aug 2020	THU	Wetlab setup.	Move on board R/V Armstrong. Zoom with D. Wellwood to setup wetlab, and go over sampling.
07 Aug 2020	FRI	Sampling review; sampling plan.	Refuel.
08 Aug 2020	SAT	CTD#001: test cast	Departed Woods Hole, ~0815. First CTD taken at 1400, cast to 100m depth,
09 Aug 2020	SUN	transit	Transit to OOI work site.
10 Aug 2020	MON	transit	Transit to OOI work site.
11 Aug 2020	TUES	transit	Transit to OOI work site.
12 Aug 2020	WED	transit	Transit to OOI work site.
13 Aug 2020	THU	Argo deployment	Transit to OOI work site. Deploy single Argo float for WHOI Argo in central Labrador Sea.
14 Aug 2020	FRI	transit	Transit to OOI work site. Arrive ~2000.
15 Aug 2020	SAT	CTD#004: calibration cast near SUMO site with all eleven RBR concerto optodes attached.	Transit to OOI work site. Spent time in morning deliberating SUMO-7 deployment, rough seas and wind, aborted deployment. Two quick 1000-m CTD casts (CTD#002, CTD#0003) to test OOI releases, 3 per cast. In middle of casts, deployed 3 OOI gliders. PAR was added to CTD#003 for glider calibration. CTD#004 performed at glider site with 11 OSNAP optodes. Two of three gliders needed to be recovered: one leaking, one with fixed position in North Falmouth.
16 Aug 2020	SUN	CTD#007: 19 OSNAP microcats attached for pre-deployment calibration cast.	Rough seas and wind meant no deployments. Three OOI release tested on CTD#005, with PAR sensor, at SUMO. Transit to glider site, did CTD#006 w/ PAR on frame to 200m with sampling for shallow sampling glider; transit to HYPM-6; CTD#007 at HYPM-6 with heavy oxygen sampling, OSNAP microcats attached.
17 Aug 2020	MON	CTD#008: 12 OSNAP microcats attached for pre-deployment calibration cast, one microcat put on a second time.	Deploy SUMO-7, early start, long transit to anchor site; tried to go to M#3 to get a pre-recovery CTD completed, but captain called it off due to rough seas and wrong direction of travel. Turned around and

			came back to SUMO7 area. Completed final pre-deploy microcat caldips for OSNAP moorings. Late night for OSNAP-affiliated, exhaustion for entire science party.
18 Aug 2020	TUES	CTD#009@SUMO with two OSNAP acoustic releases	Deploy HYPM-7, anchor survey HYPM-7, anchor survey SUMO-7, CTD#009 between SUMO-6 and -7. Lots of sampling. [31268 35321]
19 Aug 2020	WED	CTD#010@M3 including three OSNAP acoustic releases	Deploy FLMA-7, CTD#010 at M3, acoustic releases tested at 1000m. [31336 48276 35316]
20 Aug 2020	THU	Recover M3; CTD#011@M2	Deploy FLMB-7; Recover M3; CTD#011 at M2.
21 Aug 2020	FRI	Deploy M3; Recover M2; CTD#012@M1 including 3 OSNAP acoustic releases;	three OSNAP acoustic releases tested at 2800m [54690 28037 27687]
22 Aug 2020	SAT	Deploy M2; Recover M1; CTD#013 with post-recovery calibrations of M2 and M3 microcats, 14 total.	Long ADCP survey towards Greenland coast – lovely to see mountains and watch moon set. Northern lights.
23 Aug 2020	SUN	Deploy M1; anchor survey M1, M2, M3	Long hopscotch back to M4 site, with all delayed anchor surveys performed along the way. Kemp dictated getting all NAP work completed before returning to OOI recovery work. He wanted clear decks. This worked in OSNAP's favor.
24 Aug 2020	MON	CTD#015@M4; Deploy M4 at 2020 site, recover M4 from 2018 site	
25 Aug 2020	TUES	CTD#017 near HYPM sites with M1 and M4 (16) microcats for post-recovery calibration	Deploy repaired glider, recover FLMB-6 and HYPM-6.
26 Aug 2020	WED	CTD#019@HYPM-7 postrecovery calibration of FLMB-6 deep microcats	Recover SUMO-6
27 Aug 2020	THU	no OSNAP activities	Recover FLMA-6, secure deck, hightail-it away from storm path. Had to leave work area by early afternoon to outrun local storm, and then Hurricane Laura – operations ended before we could get post-recovery calibration of FLMA deep microcats.
28 Aug 2020	FRI	transit	Northern lights.
29 Aug2020	SAT	transit	
30 Aug 2020	SUN	transit	
31 Aug 2020	MON	transit	
01 Sep 2020	TUES	transit	
02 Sep 2020	WED	transit	
03 Sep 2020	THU	transit	Fishing.
04 Sep 2020	FRI	transit	

4. GDWBC Mooring Operations

Four OSNAP GDWBC moorings were recovered and deployed. The mooring team was led by John Kemp of CRL, with Nico Llanos as second deck lead working with Ray Graham. OOI team members James Kuo, Dan Bogorff, and Collin Dobson all assisted. The remaining science party, Jennifer Batryn, Sarah Nickford, Sebastien Bogorre and H. Furey worked on instrument serial number and position verification, photographing operations, working the clipboard, as well as other deployment tasks. A similar configuration of people was used during the OOI mooring operations. Figure 3 shows the locations of the newly deployed (2020) as well as previous GDWBC (2018) moorings, with the OOI mooring sites, CTD locations and the (OOI) glider deployment box. The OSNAP GDWBC moorings M1-M4 were deployed on the same line as two of the OOI moorings, FLMA and FLMB. OSNAP target positions are those provided in P. Holliday 2016 cruise report. In 2018, mooring M4 was deployed at a position 2 nm north of the target location because the 2016-2018 M4 had not yet been recovered. This year, we moved M4 back to its original target position. Details of mooring deployments and recoveries may be found in Tables 2, 3, and 4.

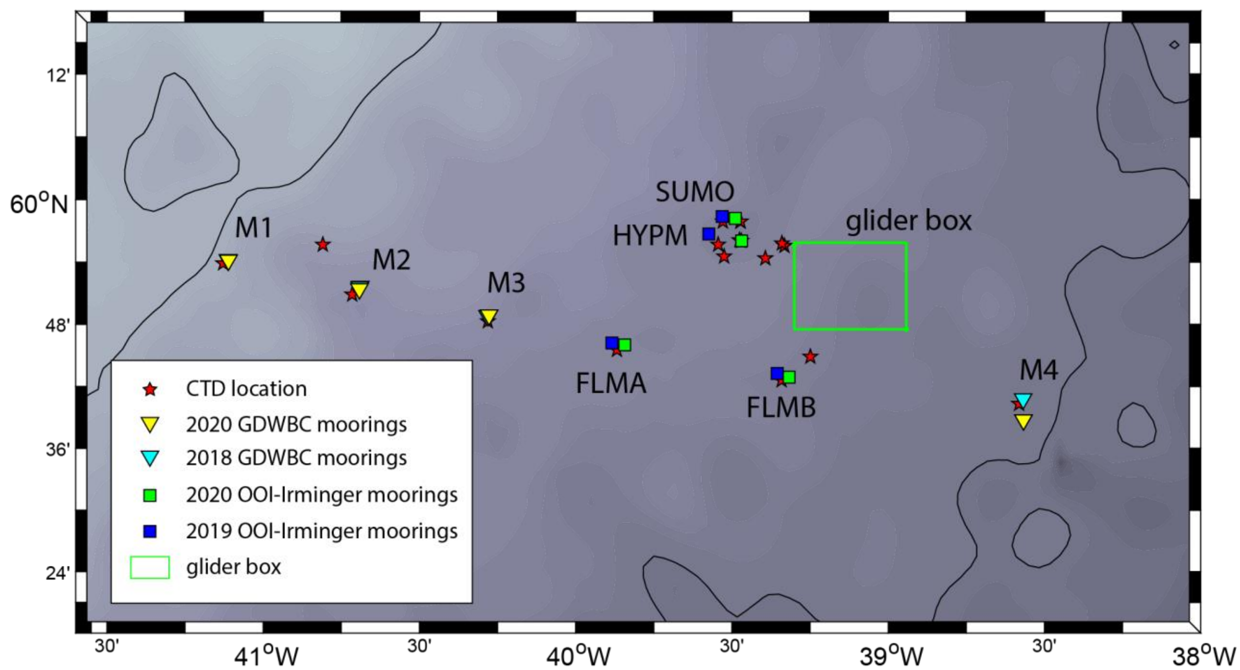


Figure 3. Cruise track with station locations coded by activity. The 2000-m and 3000-m isobaths are drawn as black lines, and bathymetry shaded every 100-m.

4.a. Mooring Recoveries

Moorings were all recovered in the afternoons, as the recovery operations were considered lower risk and simpler when compared to OSNAP deployments or the more complicated OOI-Irminger mooring operations in general. Table 2 contains information on the mooring recovery operations. Mooring recoveries went smoothly. There were wuzzles on moorings M2, at bottom flotation, and M4, at middepth, but everything was recovered safely. Recovery diagrams are included in Appendix B. The total instrument recovery counts were: 8 Edgetech acoustic releases, 19 Aanderaa Aquadopp current meters, and 30 Seabird microcats, all successfully recovered. Description of recovered instruments and data return are in 'Section 5: Mooring Instrumentation'.

Table 2. Mooring recovery table.

Mooring	Recovery Date	2018 Surveyed location	Time Release Fired	Release #	Length of time to recover
M1	22 August 2020	59° 54.154'N 41° 06.762'W	15:48UTC	51917	2hr 18min
M2	21 August 2020	59° 51.417'N 40° 41.741'W	15:22UTC	54685	1hr 49min
M3	20 August 2020	59° 49.021'N 40° 16.710'W	18:38UTC	30848	2hr 04min
M4	24 August 2020	59° 40.637'N 38° 34.121'W	15:49UTC	54683	1hr 49min

4.b. Mooring Deployments

Moorings were all deployed in the mornings. Tables 3 and 4 contain information on the mooring deployment operations. Mooring deployments went smoothly, with a few small events of note. One hold-up was that microcats sent for deployment were sent with the incorrect bracket bore. New holes had to be drilled in spare brackets prior to deployment, or swapped with recovered microcats once some were onboard. We decided to tape single microcats (those not in cages paired with current meters) to cover screws around the conductivity cell guards as a couple loose guard were recovered both on the OOI and OSNAP moorings. John Kemp and Nico Llanos performed all anchor surveys. H. Furey re-did all surveys with R. Weller m-files to double check. Anchor positons matched. Fallback numbers and distance between anchor and target locations are from R. Weller m-file 'anchpos2c.m'. Deployment diagrams are included in Appendix C. Anchor survey images and data are located in Appendix D. Description of deployed instrument setup are in 'Section 5: Mooring Instrumentation'.

In chronological order…

Mooring M3 deployment narrative: Kemp asked for 3.5-mile distance (or "3.5 hours down elements") from anchor drop and a 280 meter fall back estimate based on previous deployment. Bridge modified this to 2.5 miles' distance and course 050 for start of mooring operation. One knot "current wall" was 3 miles to the southwest, which affected bridge's decision. Kemp called bridge at 6:00 a.m. local time to give estimate, I called bridge at 7:30 a.m. local for adjusted course and distance. Deck setup occurred between 0600 and 0800 local time. I learned I needed to relay distance adjustment by bridge to Kemp. First flotation was put over side at 08:04 local time, and anchor was dropped 11:00 local time. I learned from Bigorre that I should note water depth at time ship passes over target positon to get good depth estimate for anchor survey. Sebastien recorded this for me at each deployment from multibeam data, which is corrected depth. Time between releases over and anchor drop, or time to finish steaming to anchor drop site, was 34 minutes. Total time of deployment, 2hrs 56 minutes.

Mooring M2 deployment narrative: Kemp again asked for 3.5-mile distance from anchor drop and a 280 meter fall back estimate based on previous deployment. I remarked about the P. Holliday 2016 fallback and distance down-element, to which Kemp replied "that was yesterday", and then, "different mooring design". Ah! Learned something there. I had not paid attention in 2018 to these details, so Kemp looked them up in his notes. Kemp called bridge at 6:30 a.m. local time to give estimate, I called bridge at 7:30 a.m. local for adjusted course (050) and distance (3.0nm). Deck setup occurred between 0600 and 0800 local time. First flotation was put over side at 08:00 local time, and anchor was dropped 11:26 local time. Some time was spent trying to communicate with I. Le Bras on shore about moving bottom optode higher up on wire to protect it during recovery. Calculated fallback greater than anticipated, and J. Kemp stated that the mooring is 'too light' for local conditions, and could be re-designed with heavier anchor (and therefore stronger wirerope). Time between releases over and anchor drop, or time to finish steaming to anchor drop site, was 38 minutes. Total time of deployment, 3hrs 26 minutes.
Mooring M1 deployment narrative: Kemp again asked for 3.5-mile distance from anchor drop and a 110 meter fall back estimate based on previous deployment. This is a taller mooring, so less fallback. Kemp called bridge at 6:00 a.m. local time to give estimate, I called bridge at 7:30 a.m. local for course (090) and adjusted distance (3.0 miles). Deck setup occurred between 0600 and 0800 local time. First flotation was put over side at 08:05 local time, and anchor was dropped 11:00 local time. Time between releases over and anchor drop, or time to finish steaming to anchor drop site, was 5 minutes. No XEOS beacon on sphere, none budgeted, none purchased, none planned.
Mooring M4 deployment narrative: Kemp asked for 3.5-mile distance from anchor drop and a 230 meter fall back estimate based on previous deployment. Kemp called bridge at 6:50 a.m. local time to give estimate, I called bridge at 7:30 a.m. local for course (055) and adjusted distance (3.0 miles). Deck setup occurred between 0600 and 0800 local time. First flotation was put over side at 08:11 local time, and anchor was dropped 11:01 local time. First long spool was incorrect on winch – had to pull back about 250 meters wire and reload winch with correct spool. Did not catch this until the mark for 2000m showed up and we were expecting 1750 m mark. This should have been caught as first termination of wire (marked with length) went over side. Time between releases over and anchor drop, or time to finish steaming to anchor drop site, was 40 minutes.

Table 3. Mooring deployment information.

Mooring	Distance from target at first buoy over	Fallback estimate used	Fallback actual	Mooring deploy duration	Conditions
M1	3.5 nm (adjustment by bridge to 3.0 nm)	110m	143m	2hr 55min	Calm
M2	3.5 nm (adjusted by bridge to 3.0 nm)	280m	654m	3hr 26 min	Calm
M3	3.5 nm (adjusted by bridge to 2.5 nm)	280m	343m	2hr 56min	Calm; 1 knot "current wall" 3.0 nm to southeast
M4	3.5 mn (adjusted by bridge to 3.0 mn)	240m	442m	2hr 50min	Calm

Table 4. Mooring anchor survey information.

Mooring	Anchor Drop		Surveyed Anchor Position		
	Date	**Position**	**Corrected Depth (m)**	**Trilaterated position**	**Distance between anchor and target position (m)**
M1	23 August 2020	59° 54.183'N 41° 06.575'W	2081m	59° 54.178'N 41° 06.652'W	107m
M2	22 August 2020	59° 51.680'N 40° 41.191'W	2433m	59° 51.436'N 40° 41.522'W	217m
M3	21 August 2020	59° 49.120'N 40° 16.477'W	2555m	59° 48.911'N 40° 16.628'W	37m
M4	24 August 2020	59° 38.834'N 38° 33.784'W	2984m	59° 38.737'N 38° 34.017'W	55m

All moorings were instrumented with Aquadopp current meters, Seabird SBE37 microcats and Edgetech acoustic releases. In addition, moorings M1-M3 were instrumented with RBR Concerto optodes, for PI Isabela Le Bras. The schematic in Figure 4 shows the general configuration of the mooring array. The total instrument deployment count was: 8 releases, 19 aquadopp current meters, 30 microcats, and 11 optodes. Current meter and CTD instruments were placed at nominal depths of [50 300 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000], except near the bottom, where instruments were located 40 meters above bottom depth, and at M2, where the second instrument from bottom was located mid-way between the bottom instrument pair and the one at 2000 m. Optodes were placed to target specific oxygen features throughout the water column. Details on all instrumentation may be found in Appendix C.

(left) Ray, Dan, and James replace microcat brackets on the fly. (right) Ray and Nico putting instruments inline on mooring deployment.

Moorings as deployed June 2020 AR46.

Mooring Name	M1	M2	M3	OOI FLM_A	OOI FLM_B	M4
Target Location	59 54.18'N 41 06.48'W	59 51.58'N 40 41.43'W	59 48.87'N 40 16.63'W			59 38.76'N 38 33.99'W
Bottom Depth (m)	2086	2423	2557			2984
Instrument Depths (m)						
50	aquadopp/ microcat/ox					
300	microcat					
500	aquadopp/ microcat /ox					
750	microcat					
1000	aquadopp/ microcat/ox	aquadopp/ microcat	aquadopp/ microcat/ox			
1250	microcat	microcat	microcat			
1500	aquadopp/ microcat	aquadopp/ microcat/ox	aquadopp/ microcat			aquadopp/ microcat
1750	aquadopp/ microcat/ox	microcat	microcat			microcat
2000		aquadopp/ microcat	aquadopp/ microcat/ox			microcat
2046	aquadopp / microcat / ox / two release					
2191		aquadopp / microcat/ox				
2250			aquadopp/ microcat			aquadopp/ microcat
2383		aquadopp / microcat / ox / two release				
2500						microcat
2517			aquadopp / microcat / ox / two release			
2750						microcat
2945						aquadopp / microcat / two release

Figure 4. Schematic of the 2020 GDWBC array. Mooring locations and corrected depths on the schematic are from P Holliday 2016 cruise report 'OSNAPY3L2report_NOC_CR_40.pdf', Table 6.4.

5. Mooring Instrumentation

Instrumentation setup for calibration casts, and for the mooring missions, calibration data download, mission data download, shut down and storage were performed by R. Graham. H. Furey double-checked all configuration files before mooring deployments for mission length, rep rate, battery, etc. All microcats and optodes were calibrated prior to deployment. All acoustic releases were tested to at least 1000m, and given at least 20 minute to chill to deep water temperatures before testing. All pre-deployment initialization files, pre- and post-calibration data, and mission data may be found in the AR46 data directory. Overview matrix of instrument calibration and mission configurations, and CTD protocol may be found in Table 5. Instrument serial number assignments for each mooring may be found in Table 6.

Table 5. Instrument protocol matrix.

OSNAP-GDWBC: AR46 08 August – 05 September 2020		
Event	Protocol	Comments
CTD cast salinity bottle stops	[50 300 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000] m salt water sampling, single samples. Wait at depth **1** minute before bottle fire.	The OSNAP 'standard depths'. (Leah does 30-second sit time.) Johns does 60-second sit time. Femke does 60-second soaks, fired bottle, then 60-second soaks.
CTD cast oxygen bottle stops	5 feature depths, 2 samples per depth. See 'O2-DWBC_OOI-AR46-2020_AugustUpdate.docx'.	2 samples per depth is pandemic protocol due to fact cannot do titrations at sea (limited personnel).
Microcat caldips	10-second rep rate; 10 minute soaks; 5 depths deeper than 1000m. Freshwater rinse when recovered. 10-sec rep-rate, 10-minute soaks, 5 depths in deep stable water. [1000 1500 2000 2500]m.	OSNAP-GDWBC/OOI 2018: A 2500-m cast with 15 microcats and 5 min bottle stops at the OSNAP stnd depths took 3 hours. 15 on frame max per dip. OSNAP protocol capdips before / after 2-year deployment.
Microcat Caldip Notes	F.Straneo: 15 minute soaks, 10-sec rep rate, @ 3 depths. J.Karstensen: 5 minute soaks, 6-10 depths, 10-sec rep-rate. B.Johns: 5 minute soaks, 12 bottle stops, 10-second rep rate. F.deJong: 5- or 10-sec rep rate, 10-min bottle stops, depths at inst depths (skip uppers) This cruise: 10-sec rep-rate, 10-minute soaks, 5 depths below 1000m.	
Microcat mooring deployment	**15-minute sample-rate**, start at whole hour, UTC! Midnight even better.	OOI mcats are 7.5 minute sample rate
Current meter mooring deployment	**30-minute sample-rate**, start at whole hour, UTC! Midnight even better.	OOI AQDs are 1-hour sample rate
Release testing	1000m min for cast depth; 3 per frame max; 20 minute soaks at depth before test.	3 on frame max per dip. Kemp soaks releases for 20 minutes each to get them to temp before testing. Shallowest 2018 ooi-osnap cast was to 1000m.

Oxygen sensor testing	Freshwater soak before dip; 10 minute soaks, 10-second rep-rate. 4 feature depths, with oxygen water sampling; OFF PRIOR TO DEPLOYMENT. Rinse w/ freshwater. NO SUNLIGHT. KEEP DAMP.	2 water samples taking per depth, pandemic protocol - 3 per depth on AR45, sampling data was good so reduced to 2/depth.
Optode deployment	15-minute sample-rate; start at whole hour interval; UTC; CAP OFF PRIOR TO DEPLOYMENT.	
Mooring site CTDs	0.5 nm	How close to site? Depends on watch circle. 1.0 nmiles is totally safe, 0.5 nmiles is good.

Table 6. Instrument assignments by mooring, in order of deployment (M3, M2, M1, M4).

Caged Pairs AQD	MC	mooring	depth
4700	3587	M3	1000
4023	3590		1500
7329	3589		2000
9313	5290		2250
7298	5915		2517
7299	5909	M2	1000
7328	5929		1500
7307	5933		2000
7327	5931		2191
9312	5932		2383
7306	5914	M1	50
4698	5930		500
7308	5913		1000
7301	5912		1500
4699	5911		1750
7309	5907		2046
7310	5908	M4	1500
7300	5904		2250
4702	5910		2945

Loose MC	mooring	depth
5916	M3	1250
5922		1750
5927	M2	1250
5926		1750
5925	M1	300
5924		750
3588		1250
5920	M4	1750
5921		2000
5918		2500
5917		2750

Loose Virtuoso	mooring	depth
204381	M3	1000
204382		2000
204380		2557
204373	M2	1500
204379		2200
204377		2423
204368	M1	50
204369		500
204362		1000
204378		1750
204371		2025
none	M4	none

Loose Release	mooring
31268	M3
35321	
35616	M2
31336	
48276	M1
28037	
27687	M4
54690	

5. a. Optodes

Pre-caldip

Eleven RBR Concertos with integrated with Aanderaa optodes were soaked in freshwater >24 hrs before caldip in a covered bucket, preventing sunlight from reaching the foil. The optodes were programmed to sample constantly at a frequency of one measurement every 10 seconds with their internal clocks synchronized to UTC time. These program files were saved with additional screen captures of the Ruskin interface.

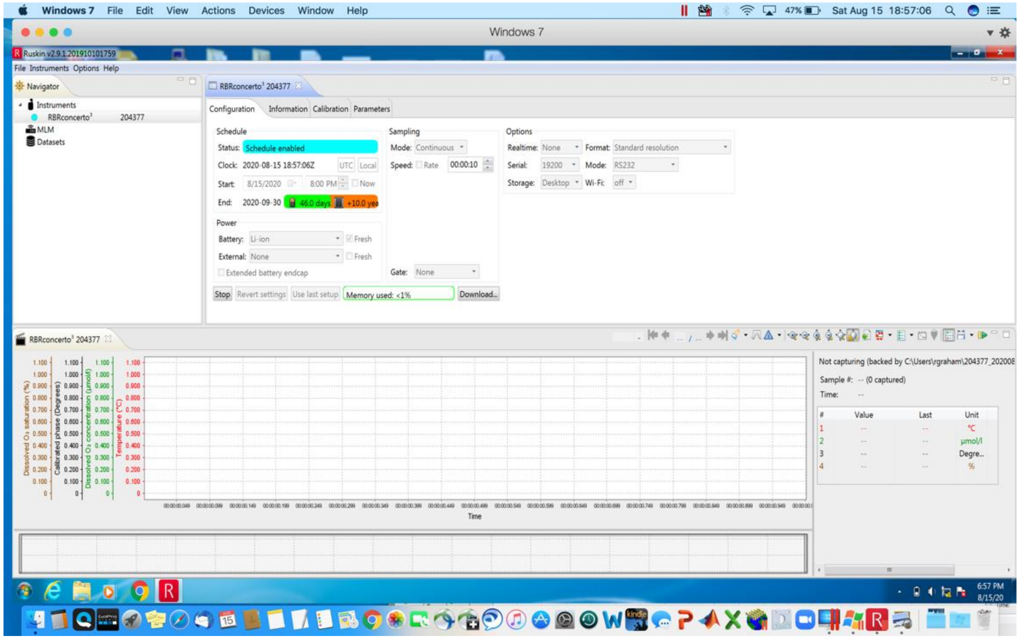


Figure 5. Screen capture of RBR Ruskin interface showing programmed settings for optode caldip.

Air-calibration and caldip

Eleven optodes were strapped to a CTD (cast # 004) for the calidip and remained on deck for 15 minutes for an air calibration prior to CTD cast. The CTD rosette was equipped with an Aanderaa 4831 sensor (provided by D. Nicholson and cable by M. Swartz). During the air calibration, there were minimal personnel in the area and no smoking was allowed on deck. After the air calibration, the CTD went to 2600 m and parked for 10 minutes at five depths (2597 m, 1801 m, 1303 m, 480 m, and 84 m) to give the sensors time to equilibrate. At each of these depths two Niskin bottles (one primary and a backup) were closed for water sampling upon arrival back on deck. After the CTD, instruments were stopped, and calibration data was downloaded.

Figure 6. RBR Concertos attached to CTD rosette using ratchet straps and hose clamps. Additional steps were using 3M Super 88 electrical tape around all hose clamps to ensure screws on hose clamps stayed in place.

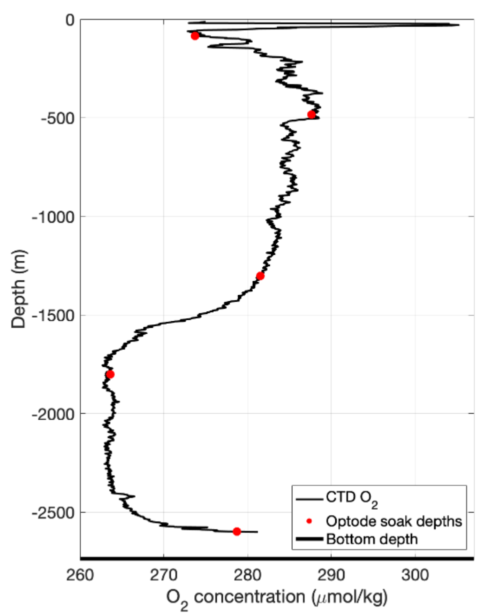


Figure 7. CTD 004 SBE O_2 profile with optode soak depths.

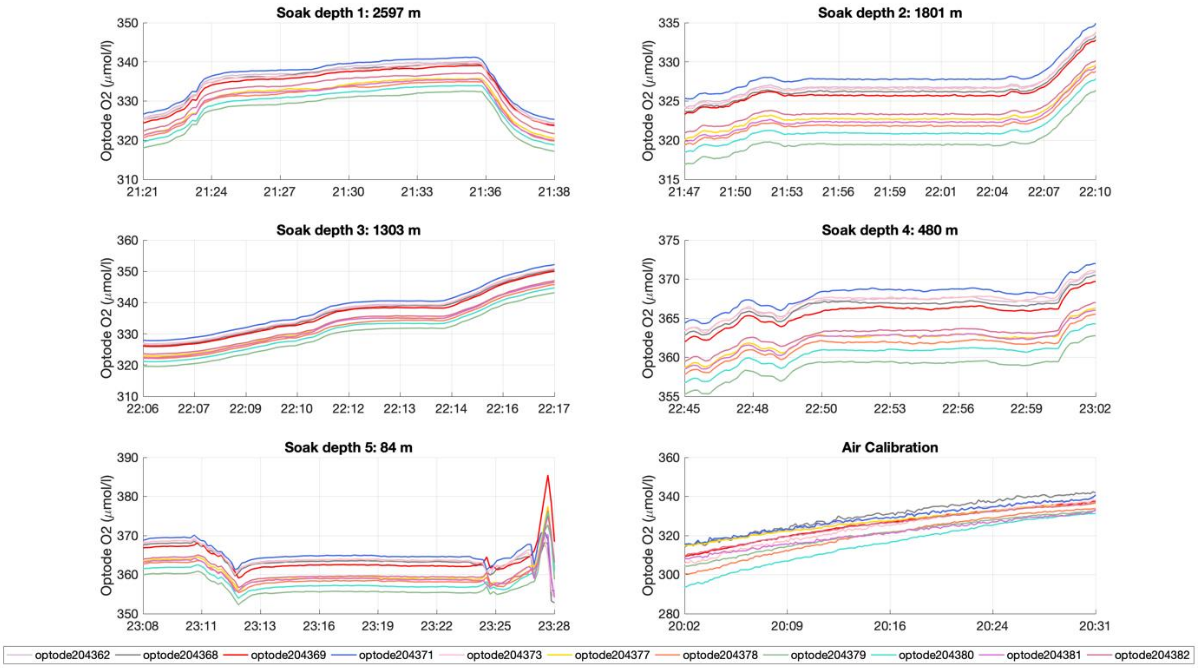


Figure 8. Soak depths and air calibration period for all eleven optodes.

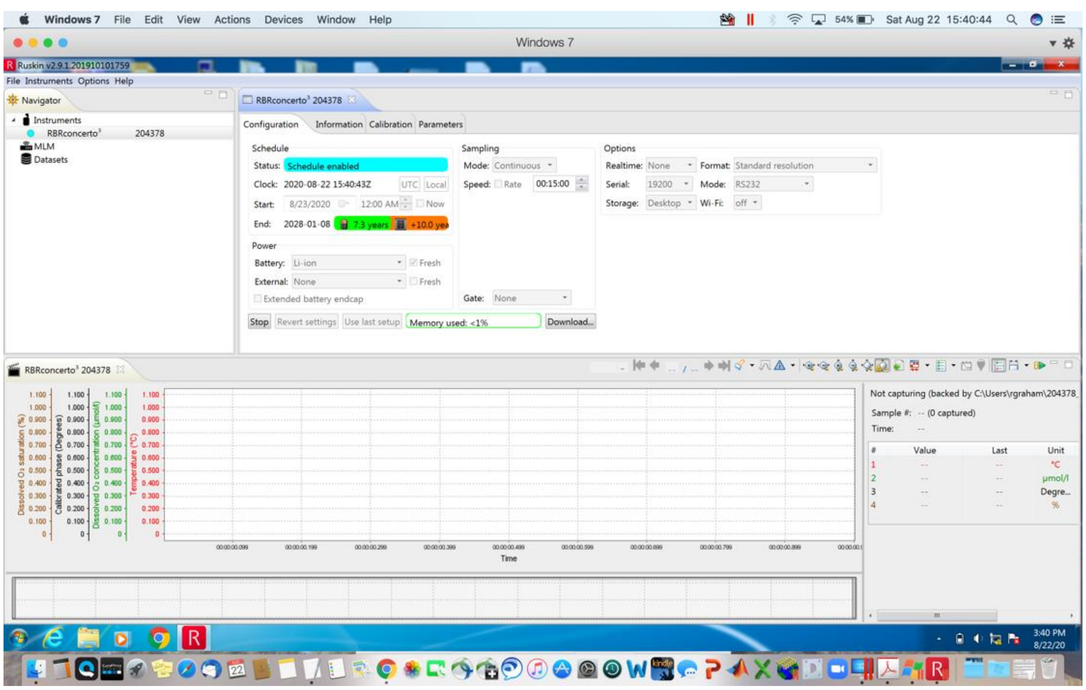


Figure 9. Screen capture of RBR Ruskin interface to show programmed settings for optode deployment.

Pre-deployment
The day prior to optode deployment for each mooring, the batteries were replaced (this step is also indicated in RBR software to insure correct battery life estimate), clocks were reset, the sampling frequency was set to 15 minutes to begin at midnight the night before deployment, and the the desiccant was replaced. A screen capture of the RBR interface was taken after the reprogramming of each optode prior to deployment (Figure 4). A visual inspection of the o-rings was done prior to closing instrument.

Deployment
The morning of deployment, the optodes were placed in clamps. The depths of instruments on the mooring were confirmed. Photos were taken of instrument serial numbers and as they were attached to mooring line. This process was repeated for moorings M1-M3. Optodes closest to the anchor on M2 and M3 were repositioned during deployment from just above flotation to 11 meters higher up the wirerope. This move was done to prevent instrument damage on recovery, as surely, if the optodes had been just above the flotation, they would have been entangled in the flotation. Initially, they were supposed to be positioned 5 meters above the flotation, but due to mismeasurement of the 16-m length cable from the top end rather than the bottom end, the optodes were placed 11 meters above the bottom flotation. Figure 11 shows where these instruments fall in terms of the on-site bottom oxygen maxima. Fortunately, the two bottom instruments on M2 and M3 are well within the bottom oxygen layer, despite being positioned 6 meters above depth agreed to by I. le Bras. Recommendation for next cruise: have the cables marked for the optodes by The Rigging Shop.

Figure 10. Example of documentation photos taken for each optode during deployment.

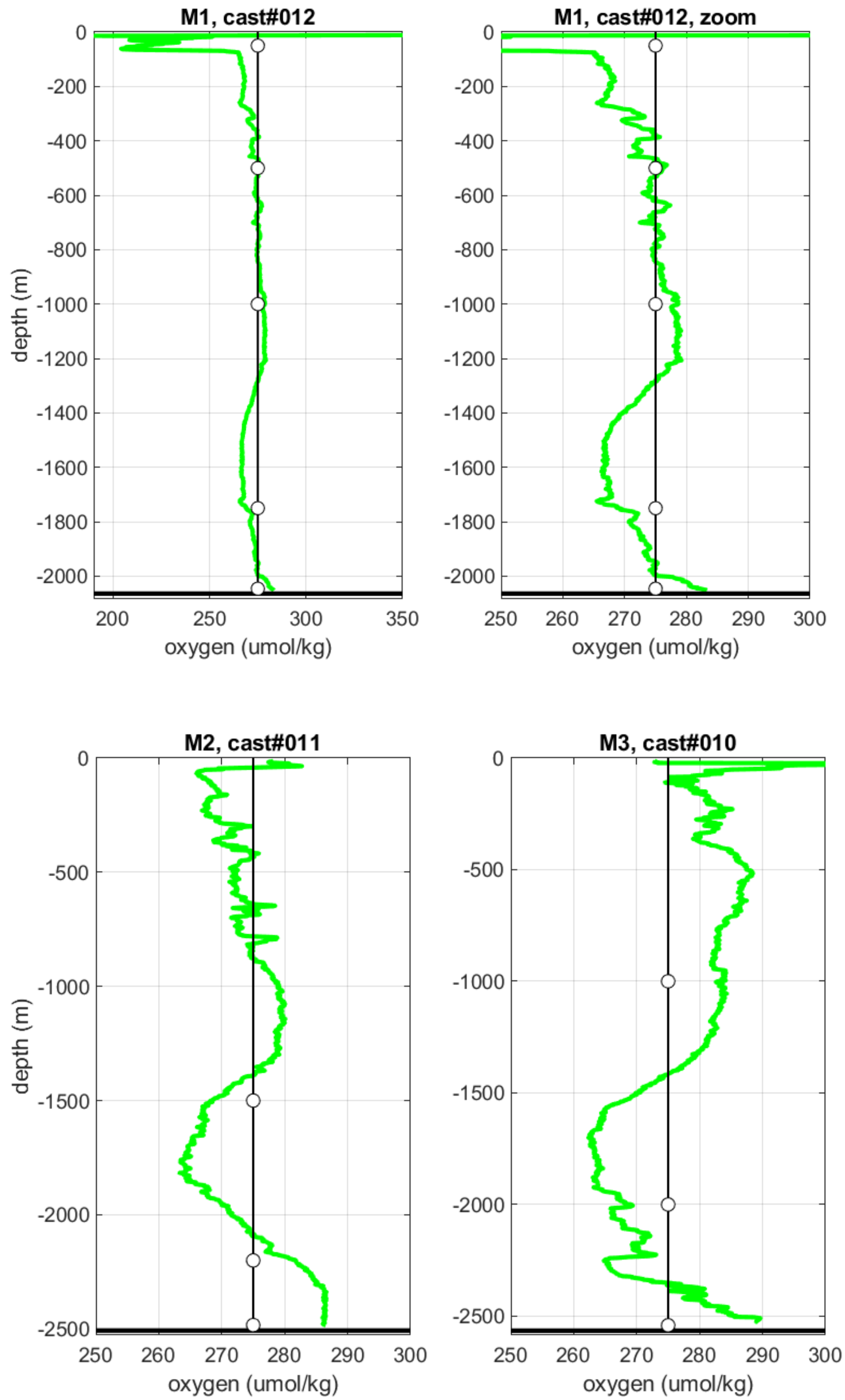


Figure 11. Resultant optode placement in relation to uncalibrated oxygen profile collected at the nearby CTD cast.

5b. Microcats and current meters

Pre-deployment calibration was performed by attaching the microcats to the rosette using ratchet straps, zip-ties and hoseclamps when microcats were bracket-less (when they had been removed from a cage where paired with a current meter), see Figure 12. Nineteen microcats were attached to CTD#007, and soaked for 10 minutes at depths of [1500 1800 2100 2500 2600] meters. Twelve microcats were attached to CTD#008, and soaked for 10 minutes at depths of [1500 1750 2000 2250 2500] meters.

Figure 12. Microcats strapped to the rosette frame, zipties were important at top of instrument to keep tight to the frame and limit strumming.

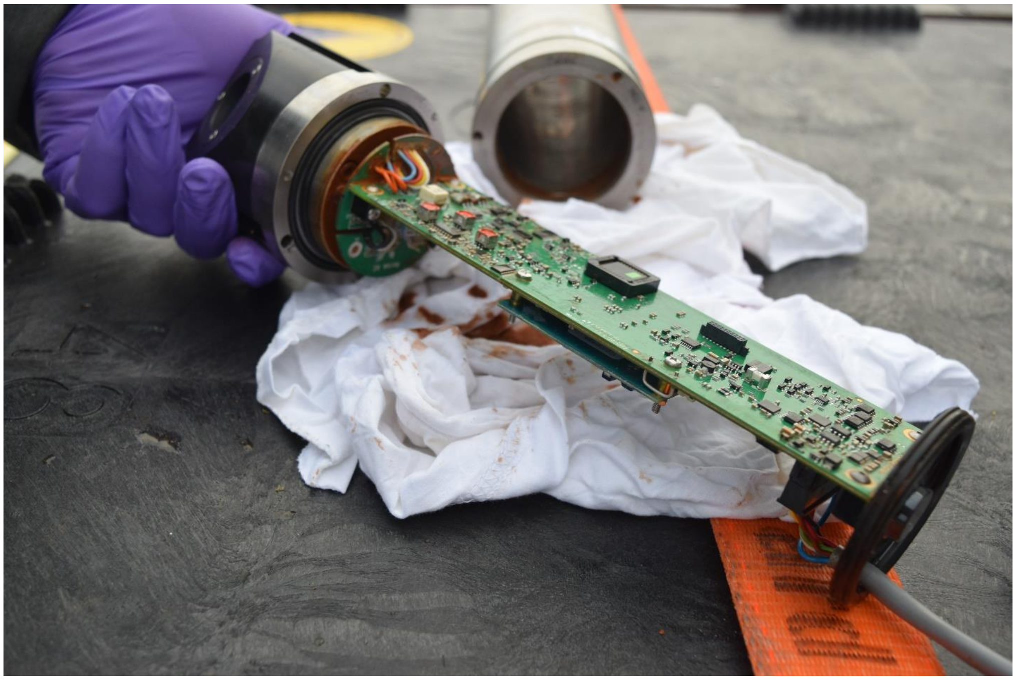
5.c. Post-recovery calibration of microcats

All microcats recovered from OSNAP moorings, and recovered from FLMB were strapped to the CTD rosette frame and calibrated by setting to run at at 10-second repetition rate for 10-minutes at 5 depths. Prior to calibrating, the 2-year mission data were downloaded from each instrument and inspected for "reasonable-ness". Microcats from M2 and M3 were calibrated on cast #013, with 10-minute soaks at depths of [1250 1500 2000 1750 2000 2250] meters. Microcats from M1 and M4 were calibrated on cast #017, with 10-minute soaks at depths of [1500 2000 2250 2500 2750] meters.

5.d. 2018-2020 instrument data return

Overall, we had 95% data return for all four moorings combined.

M1: 90% data return overall. One aquadopp (at 50m depth) failed after 3 weeks into a 26-month mission, and one microcat (at bottom) failed after 10 months.
M2: 100% data return.
M3: 99.9% data return, minus about 3 weeks on aquadopp at 1000m depth.
M4: ~90% data return. We had one aquadopp flood. The remaining 9 instruments (aquadopps and microcats) had 100% data return. Ray Graham and Jennifer Batryn pulled the current meter apart, and we will get it to Brian Hogue. We may be able to pull data off the memory The internal board looked in good condition, but instrument is non-responsive to attempts to 'talk to it'.



Picture of Aanderaa current meter s/n 6493 recovered from M4. Data may be retrievable once sent to factory.

Microcat and current meter data were plotted to assess data quality, and of the data we have in hand, most look useable. Some microcats have fouling of conductivity sensors, but this will not affect a large percentage of the data. Data plots are not included in this report, but may be found in the AR46 data drive. Summary files of recovered instrument data created by R. Graham may be found in Appendix E.

6. CTD Casts

CTDs were not completed sequentially along the OSNAP line due to OOI operations interleaved with OSNAP operations. CTD locations are presented in Figure 13. Table 7 lists all CTDs, sampling strategies, and instrumentation on rosette for calibration/testing. Each cast at an OSNAP mooring site sampled water at depths in a manner designated by past OSNAP cruises: at nominal [surface 100 200 300 400 600 800 1000 1300 1600 2000 2250 2500 2750 3000] meters depth. Winch problems plagued this cruise, and most casts were only to allowed depth of 2600 meters. This means that deepest OSNAP mooring instruments (and OOI FLMA/FLMB deep microcats) have no CTD calibration point prior to recovery. However, all recovered OSNAP microcats, and FLMA microcats, were calibrated on a CTD cast. Detailed report on CTD and seawater sampling may be found in report by S. Nickford, and included in Appendix F.

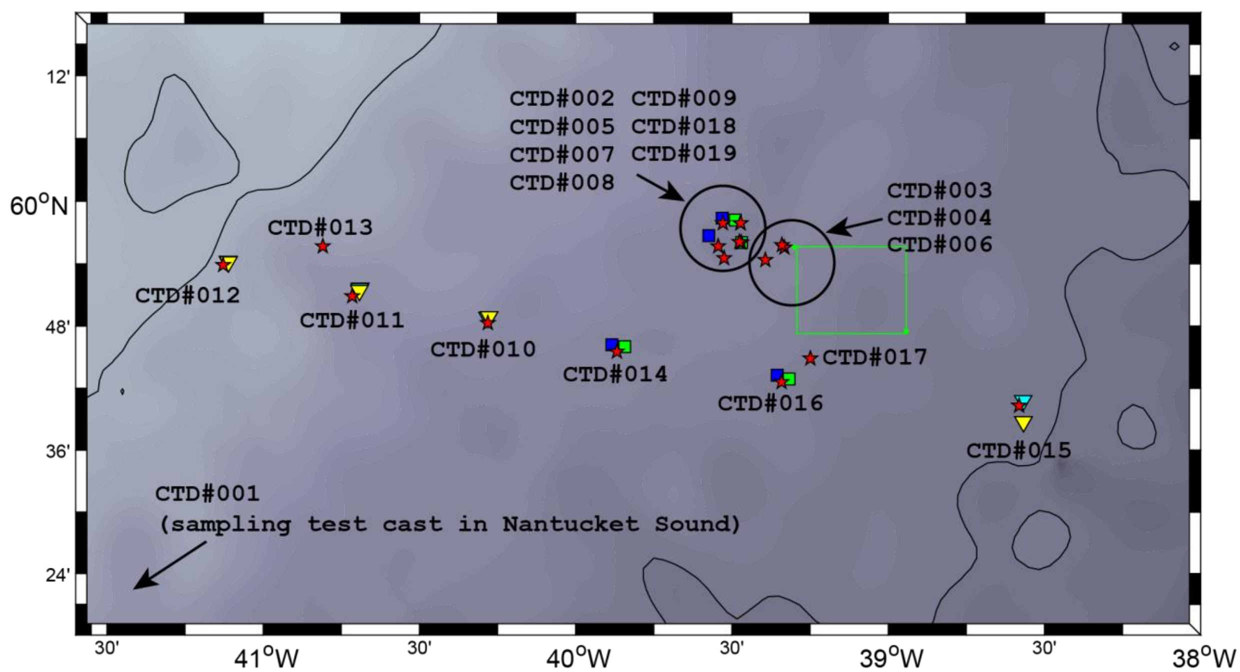


Figure 13. Map showing CTD station numbers relevant to OSNAP line and GDWBC moorings. CTD locations are marked as red stars, all other annotations as in Figure 3. Bathymetry as in Figure 3.

Table 7. Table of CTDs taken during AR46.

Cast #	Date	Time (UTC)	Site (at max depth)	Water Depth	Cast Depth	Water Samples
001	2020-08-08	18:16-18:58	41° 35.702' N 69° 21.746' W	140 m	100 m	Nantucket Sound; Test sampling procedures.
002	2020-08-15	09:08-10:28	59° 56.012' N 39° 28.212' W	2689 m	1000 m	Test 3 OOI acoustic releases. No samples taken.
003	2020-08-15	17:50-19:46	55° 55.75' N 39° 19.94' W	2736 m	1000 m	Test 3 OOI acoustic releases. No samples taken.
004	2020-08-15	20:36-23:31	59° 55.82' N 39° 20.44' W	2731 m	2600 m	OSNAP cal-dip with 11 optodes. Winch depth limited. OSNAP water samples: Salt, O_2
005	2020-08-16	09:44-10:57	59° 56.115'N 39° 28.593'W	2685 m	1000 m	Test 3 OOI acoustic releases. No samples taken.
006	2020-08-16	14:08-14:31	59° 54.42'N 39° 23.57'W	2730 m	200 m	OOI water samples: Salt, nitrate, Chl – glider sampling
007	2020-08-16	17:05-20:03	59° 57.87'N 39° 31.71'W	2661 m	2600 m	19 OSNAP mcats. HYPM-6 site; OOI water samples: Salt, O_2
008	2020-08-17	21:43-00:01	59° 54.51'N 39° 31.51'W	2691 m	2501 m	12 OSNAP microcats, SUMO-7 site, salt sampling only.
009	2020-08-18	17:54-20:32	59° 55.71'N 39° 32.62'W	2673 m	2500 m	1 OOI release, 2 OSNAP releases, SUMO-6&7 site, salt, O_2, DIC/Ta/pH, nitrate, Chl
010	2020-08-19	17:57-20:33	59° 48.339'N 40° 17.197'W	2564 m	2527 m	3 OSNAP releases, M3 site; salt, O_2
011	2020-08-20	22:33-00:39	59° 50.899'N 40° 42.907'W	2507 m	2483 m	M2 site; salt, O_2
012	2020-08-21	19:03-21:11	59° 53.902'N 41° 07.708'W	2064 m	2051 m	M1 site; salt, O_2
013	2020-08-22	19:29-21:50	59° 55.668'N 40° 48.551'W	2308 m	2248 m	Between M1&M2; microcats from M2 & M3 post-recovery calibration. Salt only.

Cast #	Date	Time (UTC)	Site (at max depth)	Water Depth	Cast Depth	Water Samples
014	2020-08-23	21:21-00:38	59° 45.561'N 39° 52.069'W	2699 m	2650 m	FLMA site; OOI water samples: Salt, O_2, pH, DIC/TA, Chl
015	2020-08-24	07:53-10:02	59° 40.306'N 38° 34.835'W	2980 m	2648 m	M4-2018 site; Salt only. (Winch problem meant CTD could only payout to 2650.)
016	2020-08-24	22:32-00:47	59° 42.623'N 39° 20.461'W	2822 m	2650 m	FLMB6&7 site; Salt, O_2, pH, DIC/TA, Chl. (Winch problem meant CTD could only payout to 2650.)
017	2020-08-25	21:04-23:33	59° 44.866'N 39° 14.935'W	2837 m	2742 m	Near FLMB6 site; M1 and M4 post-recovery microcat calibrations. Salt only. (Winch problem resolved and CTD allowed to payout to 2750.)
018	2020-08-26	21:30-22:14	59° 57.928'N 39° 28.350'W	2677 m	502 m	HYPM7 site; FLMB6 shallow-rated post-recovery microcat calibrations. Salt only.
019	2020-08-26	22:45-01:50	59° 57.928'N 39° 28.350'W	2675 m	2637 m	HYPM7 site; FLMB6 deep-rated post-recovery microcat calibrations. Salt, O_2, nitrate. Niskin bottles failed to fire on upper water column samples, so sampling only deep to ~300m.

7. Notes for next cruise, lessons learned, and supply list for 2022.

This cruise was performed under unusual circumstances, see 'An aside', below. It was very clear that on some days, a few more personnel on board would have been very helpful. Specifically, it was difficult for me to act as both lead OSNAP scientist, and also have to pay significant attention and time to water sampling strategy, hydrographic analysis, and running the CTD console and sampling. At least one more person (in addition to the job S. Nickford performed) is needed for that job. When OOI and OSNAP are back in 2022, either I will need to have the OOI folks help with documentation as was done on this cruise, or we need more OSNAP personnel. There was something very useful in having all of us onboard treat operations as joint operations, rather than separate programs. The flow of work was good with this system.

Specific items to bring on next cruise:

R. Graham states that we should have had a complete set of tools for OSNAP instrument operations. This was something lost in the pandemic shuffle. Although the FIXIT Lab (A. Davies) left all of their gear onboard, there were a few items which were lacking:

- Fish totes (2-4) in which to put instruments coming off of or going onto mooring lines.
- Scrubbing squares for cleaning instruments and Simple Green.
- All tools and hardware needed to access instruments and put on/remove from moorings.
- Spare un-drilled microcat clamps.
- A couple of 'candlesticks' with MOLEX connectors (battery packs and simple connectors that can be used for talking to dead instruments).

Items that would have been useful for H. Furey:

- A watch.
- Rite-in-Rain paper and pen.
- GPS handheld device.
- Camera from Graphics for documentation.
- More clipboards.
- Charting software and knowledge of how to use it.

Lessons learned:

1. Never stop on a downcast, it's bad form.
2. Always try to get to the bottom on a cast.
3. Quadruple check the waypoints going to the bridge. I had some sloppy numbers in there for a while, also bad form.

4. Hold the Line. Turn-around moorings should always have the same target positions year after year. These positons will be different than the location the mooring landed on the previous deployment.
5. Communicate bridge changes to deck lead. Even though, 99% of the time, the deck lead already has been in communication with the bridge.
6. Fallback is different from distance between anchor position and target location. (This confusion originally stemmed from fixed labeling on Art Newhall software, and inexperience.)
7. Note depth when boat passes over target to ensure good numbers in anchor survey software.
8. Talk directly to the bosun if winch depth affects winch operator or bosun.
9. Serial numbers/lengths of wirerope are important to note.
10. Pay attention to reels being loaded – there can be mistakes.
11. It's OK to ask for the mooring to be reeled back in to make a change.
12. Recording all variables in deployment and recovery (course, distance, estimate fallback, when release fired and which release, etc.) is important.
13. Calibrating CTD data with salts is a complex non-trivial task. Sampling and storage of anything other than salt is non-trivial.

An aside: *This cruise was completed under the pandemic conditions of the novel coronavirus. All crew and science had to self-isolate for 7 days, then self-quarantine for 8 days prior to boarding. Two covid-19 tests were completed: one before self-isolation, and one before self-quarantine. Self-isolation required participants to eliminate going to any stores or places where people gathered. They were still allowed to live at home if their family members worked outside of the house. Self-quarantine was stricter, and required participants to live in isolation if they had household members who worked outside the home. The science party was reduced to 10 participants (20 science party members were onboard during the AR30 2018 cruise), and OSNAP and OOI participants were integrated rather than working separate 'gigs'. It was an 'all hands on deck, all the time' type of cruise, and the long transits to and from Woods Hole, also dictated by the novel coronavirus, were welcome respites. Many crew and two science party members had been on the previous cruise, and had not left the ship in 60, and (for crew members) up to 100 days. One particular hurdle for this cruise was that no experienced hydrographer was available to participate. Therefore, URI student S. Nickford, with H. Furey assisting, were in charge of sampling, developing sample plan, and analyzing samples. Land setup of the wetlab were done using zoom with Dave Wellwood while still at dock. James Kuo had been trained by Leah McRaven on the salinometer on the previous cruise, and was able to transfer this knowledge to S. Nickford early in the cruise. Another hurdle was that oxygen samples were not able to be analyzed onboard, and were stored for immediate analysis on our return. This meant developing a new storage technique for the OOI oxygen bottles, and very careful work with sampling. Sampling was learned through a series of video snippets created by Isabela Le Bras – we had no in-person training.*

Appendix A: Work performed for both OOI and OSNAP.

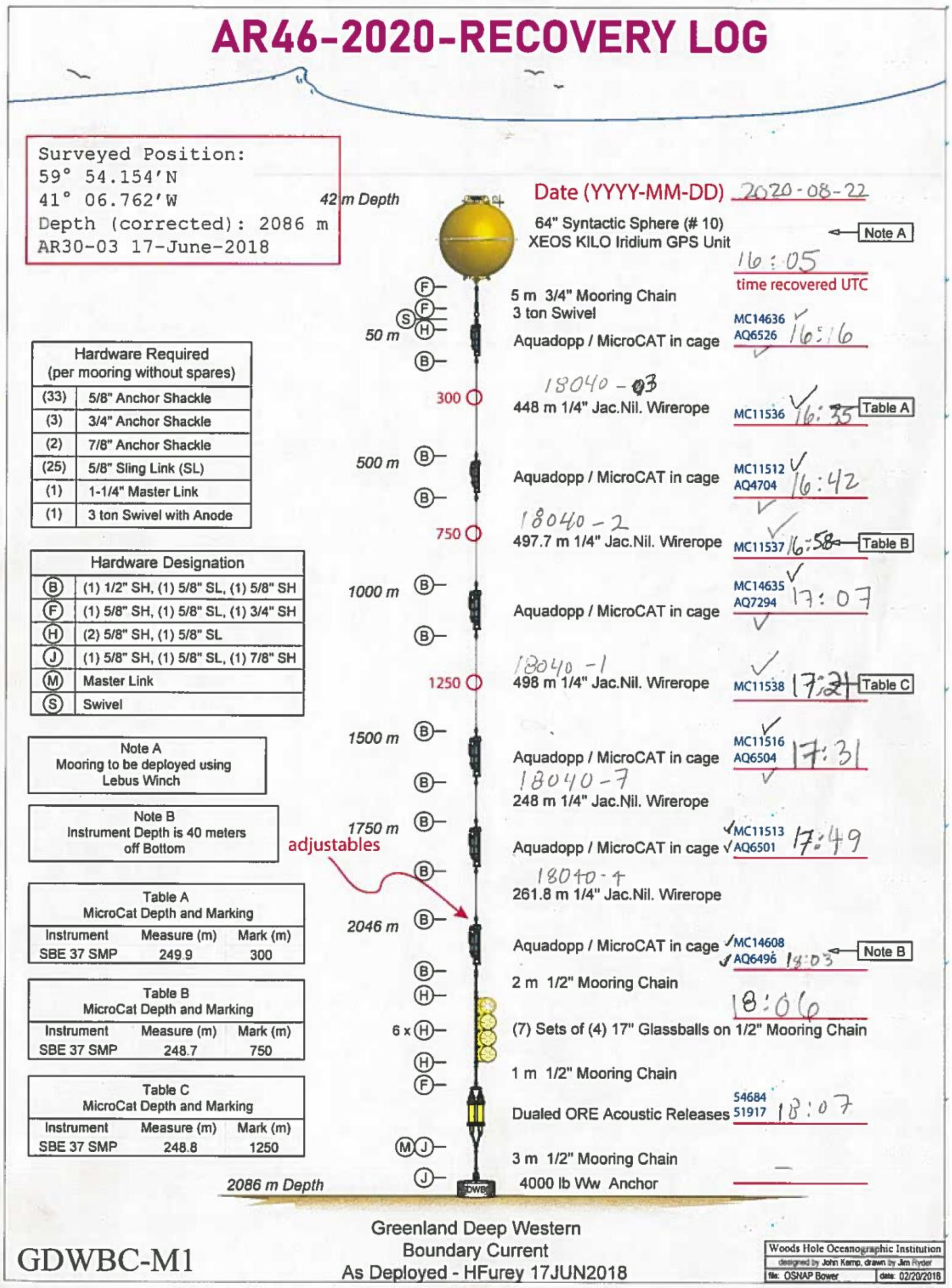
Days-at-Sea at start of operation	Hour of day at start of operation LOCAL TIME	Operation	Date
1	0000	Ship docked at WHOI	08 AUG, Saturday
1	0800	Transit WHOI to test cast site	
1	1400	**CTD#1:** on shelf in US waters CTD test and sampling practice (shallow depth); No sample data saved; slow practice of sampling and salinometer	
2		transit test cast site to Argo site	09 AUG, Sunday
3		transit test cast site to Argo site	10 AUG, Monday
4		transit test cast site to Argo site	11 AUG, Tuesday
5		transit test cast site to Argo site enter international waters ~20:00	12 AUG, Wednesday
6	1030	**Deploy Argo float** (>=2500m water requirement, somewhere during daylight hours in central Lab Sea)	13 AUG, Thursday
6		Transit Argo site to OOI site	
6		TIME CHANGE ONE HOUR FORWARD	
7		transit LabSea to OOI-OSNAP site	14 AUG, Friday
7	1900	Arrive on site	
7	1900	Check status of HYPM-6 (A-coms)	
7	1900	Prepare CTD w 3 releases to be ready for next morning test.	
7	2100	Overnight, ADCP reciprocal tracks near SUMO-6 (ship transits east-west at 5kts. Ship starts 5 nm west of buoy, goes 5 nm east of it, then returns at same speed in opposite direction. Then same thing north-south). Ship ADCP turned on.	
8	0630	**CTD #2:** @ SUMO7 site three OOI acoustic releases to 1000m (3 of 12) No sampling	15 AUG, Saturday
8	1000	Abort SUMO: late start, uncertain seas in afternoon, heave. Tough call, on the edge. Consensus was "let's not mess up the very first thing".	
8	1030	Transit to glider site	
8	1100	Deploy gliders Gl515 and Gl365 and Gl469	
8	1600	**CTD #3:** @ glider site three OOI acoustic releases to 1000m (6 of 12)	

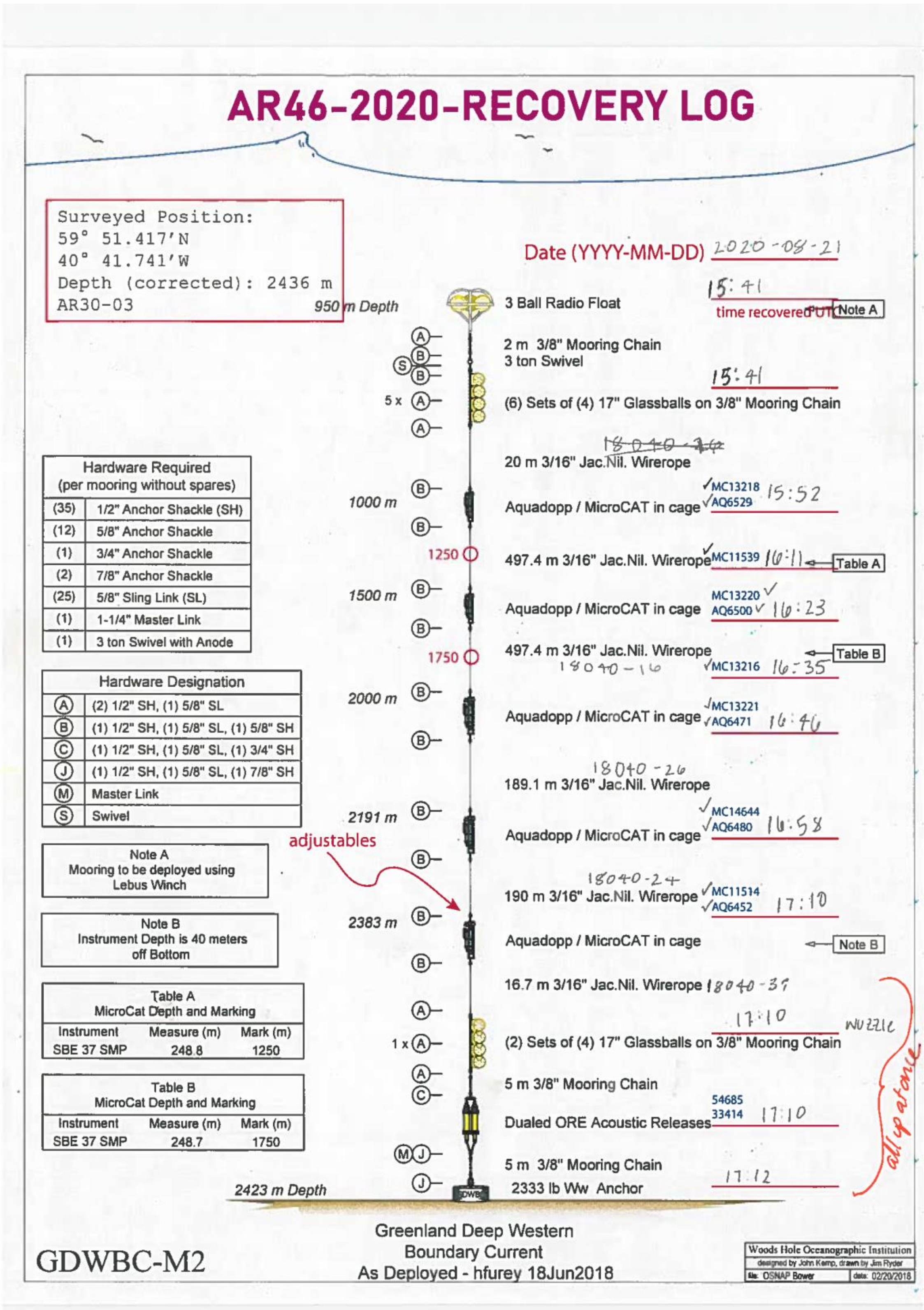
		PAR on CTD cast; No sampling	
8	1800	**CTD #4:** @ glider site Eleven OSNAP optode calibration to ~2600m (11 of 11) Sample salt and oxygen, OSNAP-style	
8	2100	**Recover Glider Gl469 - leaking**	
8	2200	**Recover Glider Gl365 – thinks it's in north falmouth**	
9	0630	**CTD #5:** @ SUMO site three OOI acoustic releases to 1000m (9 of 12) PAR sensor on; No sampling	16 AUG, Sunday
9	1030	Transit SUMO7 to glider site	
9	1100	**CTD #6:** @ glider site To 200m only, with PAR, just sample for glider in the water.	
9	1230	Transit glider site to HYPM6	
9		**CTD#7:** @HYPM6 predeploy caldip OSNAP 19 microcats (19 of 30) sample salts, **oxygen sampling**, OOI-style **Big O2 Sample Cast @START**	
9		Transit from HYPM6 back to SUMO7 for night	
10	0430	**Set up deck for SUMO7**	17 AUG, Monday
10	0630	**Deploy SUMO-7** (~10 hrs. incl set & drift; 6.5 hrs from first wire out)	
10	1430	Check Anchor status, report, shut down xeos msgs.	
10	1700	**CTD#8:** @ near SUMO7, could be anywhere predeploy caldip OSNAP 12 microcats, do one a second time (30 of 30) sample salts only at microcat soak depths - OSNAP-style	
11	0600	Deck setup HYPM-7	18 AUG, Tuesday
	0800	**Deploy HYPM-7** (~7 hrs, incl set & drift)	
11		HYPM7 anchor survey	
11		SUMO7 anchor survey	
11		Test optodes on rosette frame and wires on CTD to find source of bad optode values – now associated with OOI optode	
11		**CTD#9:** between SUMO 6 & 7, to 2600 m Sample salts, o2, nitrate, DIC, pH, Chl - OOI-style three OSNAP acoustic releases to 2600m (3 of 9)	
11	2100	Steam from glider launch site to FLMB6	
11	2200	check status of FLMB-6 (A-coms)	
11	2300	ADCP reciprocal tracks at FLMB-6	
12	0600	**Deploy FLMA-7** (~ 8 hrs, incl set & drift)	19 AUG, Wednesday

12	1400	Anchor survey FLMA-7	
12	1600	**CTD#10:** @ M3 three OSNAP acoustic releases to 2600m (6 of 9) Sample salts, o2 OSNAP-style	
12	2000	Transit to FLMA-6, for status check with A-coms ADCP reciprocal tracks at FLMA-6 overnight	
13	0600	**Deploy FLMB-7** (~ 8 hrs, incl set & drift)	20 AUG, Thursday
13	1300	Transit from FMLA to M3 (14nm)	
13	1600	**Recover M3**	
13	1900	Transit M3 to M2.	
13	1700	**CTD#11:** @M2 sample salts, oxygen - OSNAP-style	
14	0800	**Deploy M3** (~3 hours)	21 AUG, Friday
14	1130	transit to M2 (distance M3-M2=13nm)	
14	1330	**Recover M2**	
14	1430	Transit M2 to M1	
14	1600	**CTD#12:** @M1 sample salts, oxygen – OSNAP-style three OSNAP acoustic releases to 2800m (9 of 9) [28037 27687 54690]	
15	0800	**Deploy M2** (~3 hours)	22 AUG, Saturday
15	1130	transit to M1 (distance M2-M1=13nm)	
15	0100	**Recover M1**	
15	1400	**CTD#13:** between M1 and M2 in ~2400m water – just for postrecovery caldip seven M3 plus seven M2 microcats (14 of 30)	
16	0800	**Deploy M1** (~3 hours)	23 AUG, Sunday
16	1600	Anchor survey M1, M2, M3, (FLMB-7? If time).	
16	2100	**CTD #14 @ FLMA**	
16	2000	transit overnight to M4 (distance M1-M4=80nm)	
17	0500	**CTD#015@M4** old *(has cups attached)*	24 AUG, Monday
		Deploy M4new	
17	1100	Anchor survey M4	
17		**Recover M4old**	
17	1500	transit to FLMB (distance M4-FLMA=24nm)	
17	1700	Anchor survey FLMB	
17	1800	**CTD#016@FLMB**	

18	0500	Deploy Glider 365	25 AUG, Tuesday
18	0900	**Recovery FLMB-6** (5 hours)	
18		Steam FLMB to HYPM	
18	1500	**Recover HYPM-6**	
18	2000	**CTD#017:** @HYPM-ish postrecovery caldip OSNAP 9 M1 and 7 M4 microcats (30 of 30) sample salts	
19	0800	**Recover SUMO-6**	26 AUG, Wednesday
19	1500	Measure waterline of SUMO-7	
19	1600	transit to HYPM-7	
19	1700	**CTD#018:** @HYPM-7 (*rendezvous w/ gliders?*) postrecovery caldip OOI FLMB OSNAP microcats (4 of 8 OSNAP-OOI, plus addition OOI of their choice) double dip cast, short for shallow-rated microcats **Big O2 Sample Cast @END** sample salts, oxygen, nitrate, Chl - OOI-style 1000-m cast due to PAR sensor *(don't need if night)* **PAR sensor!**	
20	0600	**Recover FLMA-6** (5 hours)	27 AUG, Thursday
		Last checks with surrounding assets (wifi, A-coms)	
		Depart OOI/OSNAP study region	
21		transit OOI-OSNAP site to Woods Hole	28 AUG, Friday
22		transit OOI-OSNAP site to Woods Hole	29 AUG, Saturday
23		transit OOI-OSNAP site to Woods Hole	30 AUG, Sunday
24		transit OOI-OSNAP site to Woods Hole	31 AUG, Monday
25		transit OOI-OSNAP site to Woods Hole	01 SEP, Tuesday
26		transit OOI-OSNAP site to Woods Hole	02 SEP, Wednesday
27		transit OOI-OSNAP site to Woods Hole	03 SEP, Thursday
28		Arrive in Woods Hole 13:00 local time	04 SEP, Friday

Appendix B: Mooring recovery diagrams for moorings M1-M4.


AR46-2020-RECOVERY LOG
Surveyed Position:
59° 54.154'N
41° 06.762'W
Depth (corrected): 2086 m
AR30-03 17-June-2018
42 m Depth
Date (YYYY-MM-DD) 2020-08-22
64" Syntactic Sphere (# 10)
XEOS KILO Iridium GPS Unit
Note A
16:05
time recovered UTC
5 m 3/4" Mooring Chain
3 ton Swivel
50 m
Aquadopp / MicroCAT in cage
MC14636
AQ6526
16:16
Hardware Required
(per mooring without spares)
(33) 5/8" Anchor Shackle
(3) 3/4" Anchor Shackle
(2) 7/8" Anchor Shackle
(25) 5/8" Sling Link (SL)
(1) 1-1/4" Master Link
(1) 3 ton Swivel with Anode
18040-03
300
448 m 1/4" Jac.Nil. Wirerope
MC11536
16:35
Table A
500 m
Aquadopp / MicroCAT in cage
MC11512
AQ4704
16:42
18040-2
750
497.7 m 1/4" Jac.Nil. Wirerope
MC11537
16:58
Table B
Hardware Designation
(B) (1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
(F) (1) 5/8" SH, (1) 5/8" SL, (1) 3/4" SH
(H) (2) 5/8" SH, (1) 5/8" SL
(J) (1) 5/8" SH, (1) 5/8" SL, (1) 7/8" SH
(M) Master Link
(S) Swivel
1000 m
Aquadopp / MicroCAT in cage
MC14635
AQ7294
17:07
18040-1
1250
498 m 1/4" Jac.Nil. Wirerope
MC11538
17:21
Table C
Note A
Mooring to be deployed using
Lebus Winch
1500 m
Aquadopp / MicroCAT in cage
MC11516
AQ6504
17:31
18040-7
248 m 1/4" Jac.Nil. Wirerope
Note B
Instrument Depth is 40 meters
off Bottom
1750 m
adjustables
Aquadopp / MicroCAT in cage
MC11513
AQ6501
17:49
18040-4
261.8 m 1/4" Jac.Nil. Wirerope
Table A
MicroCat Depth and Marking
Instrument | Measure (m) | Mark (m)
SBE 37 SMP | 249.9 | 300
2046 m
Aquadopp / MicroCAT in cage
MC14608
AQ6496
18:03
Note B
2 m 1/2" Mooring Chain
Table B
MicroCat Depth and Marking
Instrument | Measure (m) | Mark (m)
SBE 37 SMP | 248.7 | 750
18:06
6 x
(7) Sets of (4) 17" Glassballs on 1/2" Mooring Chain
1 m 1/2" Mooring Chain
Table C
MicroCat Depth and Marking
Instrument | Measure (m) | Mark (m)
SBE 37 SMP | 248.8 | 1250
Dualed ORE Acoustic Releases
54684
51917
18:07
3 m 1/2" Mooring Chain
2086 m Depth
4000 lb Ww Anchor
Greenland Deep Western
Boundary Current
As Deployed - HFurey 17JUN2018
GDWBC-M1
Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower
date: 02/20/2018

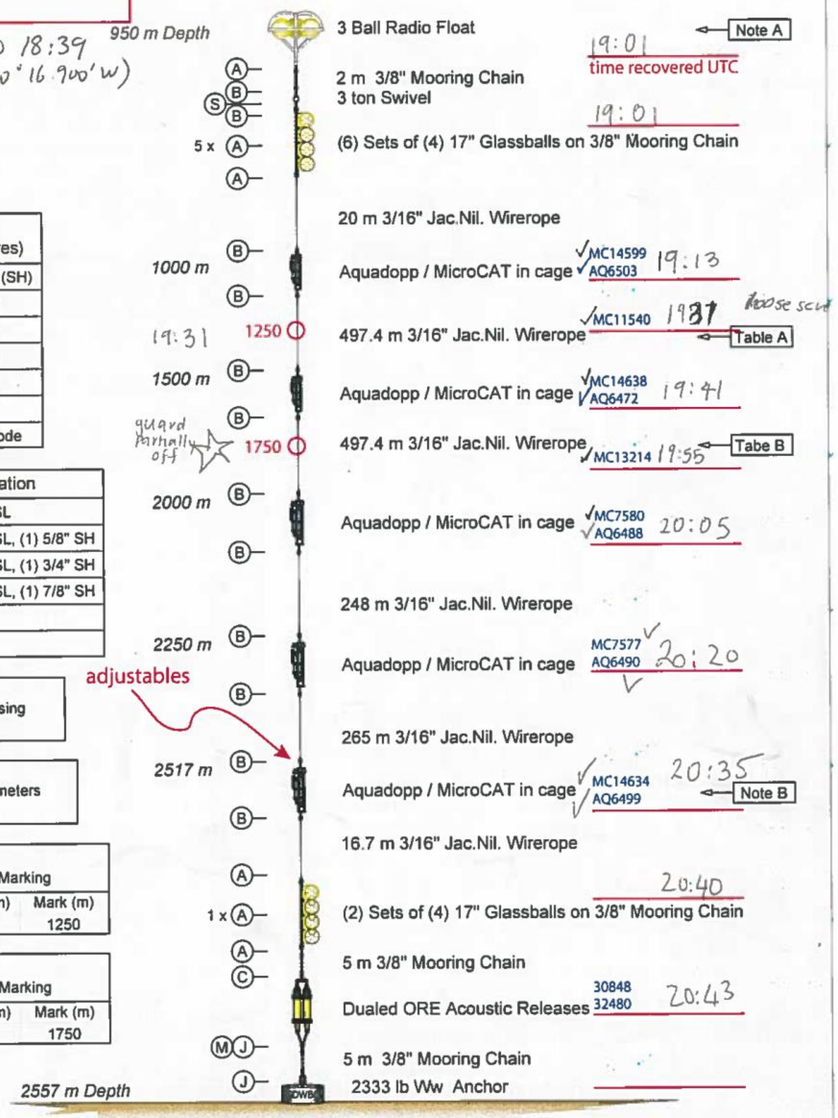

AR46-2020-RECOVERY LOG
Surveyed Position:
59° 51.417'N
40° 41.741'W
Depth (corrected): 2436 m
AR30-03
950 m Depth
Date (YYYY-MM-DD) 2020-08-21
3 Ball Radio Float
15:41
time recovered UTC
Note A
2 m 3/8" Mooring Chain
3 ton Swivel
15:41
5 x
(6) Sets of (4) 17" Glassballs on 3/8" Mooring Chain
20 m 3/16" Jac.Nil. Wirerope
Hardware Required
(per mooring without spares)
(35) 1/2" Anchor Shackle (SH)
(12) 5/8" Anchor Shackle
(1) 3/4" Anchor Shackle
(2) 7/8" Anchor Shackle
(25) 5/8" Sling Link (SL)
(1) 1-1/4" Master Link
(1) 3 ton Swivel with Anode
1000 m
Aquadopp / MicroCAT in cage
MC13218
AQ6529
15:52
1250
497.4 m 3/16" Jac.Nil. Wirerope
MC11539
16:11
Table A
1500 m
Aquadopp / MicroCAT in cage
MC13220
AQ6500
16:23
1750
497.4 m 3/16" Jac.Nil. Wirerope
18040-16
MC13216
16:35
Table B
Hardware Designation
(A) (2) 1/2" SH, (1) 5/8" SL
(B) (1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
(C) (1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
(J) (1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
(M) Master Link
(S) Swivel
2000 m
Aquadopp / MicroCAT in cage
MC13221
AQ6471
16:46
18040-26
189.1 m 3/16" Jac.Nil. Wirerope
2191 m
Aquadopp / MicroCAT in cage
MC14644
AQ6480
16:58
adjustables
Note A
Mooring to be deployed using Lebus Winch
18040-24
190 m 3/16" Jac.Nil. Wirerope
MC11514
AQ6452
17:10
Note B
Instrument Depth is 40 meters off Bottom
2383 m
Aquadopp / MicroCAT in cage
Note B
16.7 m 3/16" Jac.Nil. Wirerope 18040-37
Table A
MicroCat Depth and Marking
Instrument | Measure (m) | Mark (m)
SBE 37 SMP | 248.8 | 1250
17:10
1 x
(2) Sets of (4) 17" Glassballs on 3/8" Mooring Chain
Table B
MicroCat Depth and Marking
Instrument | Measure (m) | Mark (m)
SBE 37 SMP | 248.7 | 1750
5 m 3/8" Mooring Chain
Dualed ORE Acoustic Releases
54685
33414
17:10
all up at once
5 m 3/8" Mooring Chain
2333 lb Ww Anchor
17:12
2423 m Depth
GDWBC-M2
Greenland Deep Western
Boundary Current
As Deployed - hfurey 18Jun2018
Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower
date: 02/20/2018

AR46-2020-RECOVERY LOG

Surveyed Position:
59° 49.021'N
40° 16.710'W
Depth (corrected): 2557 m
AR30-03

Date (YYYY-MM-DD) 2020-08-20

Mooring released @ 18:39
[59° 48.829'N, 040° 16.900'W)
AR 46



Hardware Required (per mooring without spares)	
(35)	1/2" Anchor Shackle (SH)
(12)	5/8" Anchor Shackle
(1)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(25)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
J	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
M	Master Link
S	Swivel

Note A
Mooring to be deployed using Lebus Winch

Note B
Instrument Depth is 40 meters off Bottom

Table A MicroCat Depth and Marking		
Instrument	Measure (m)	Mark (m)
SBE 37 SMP	248.8	1250

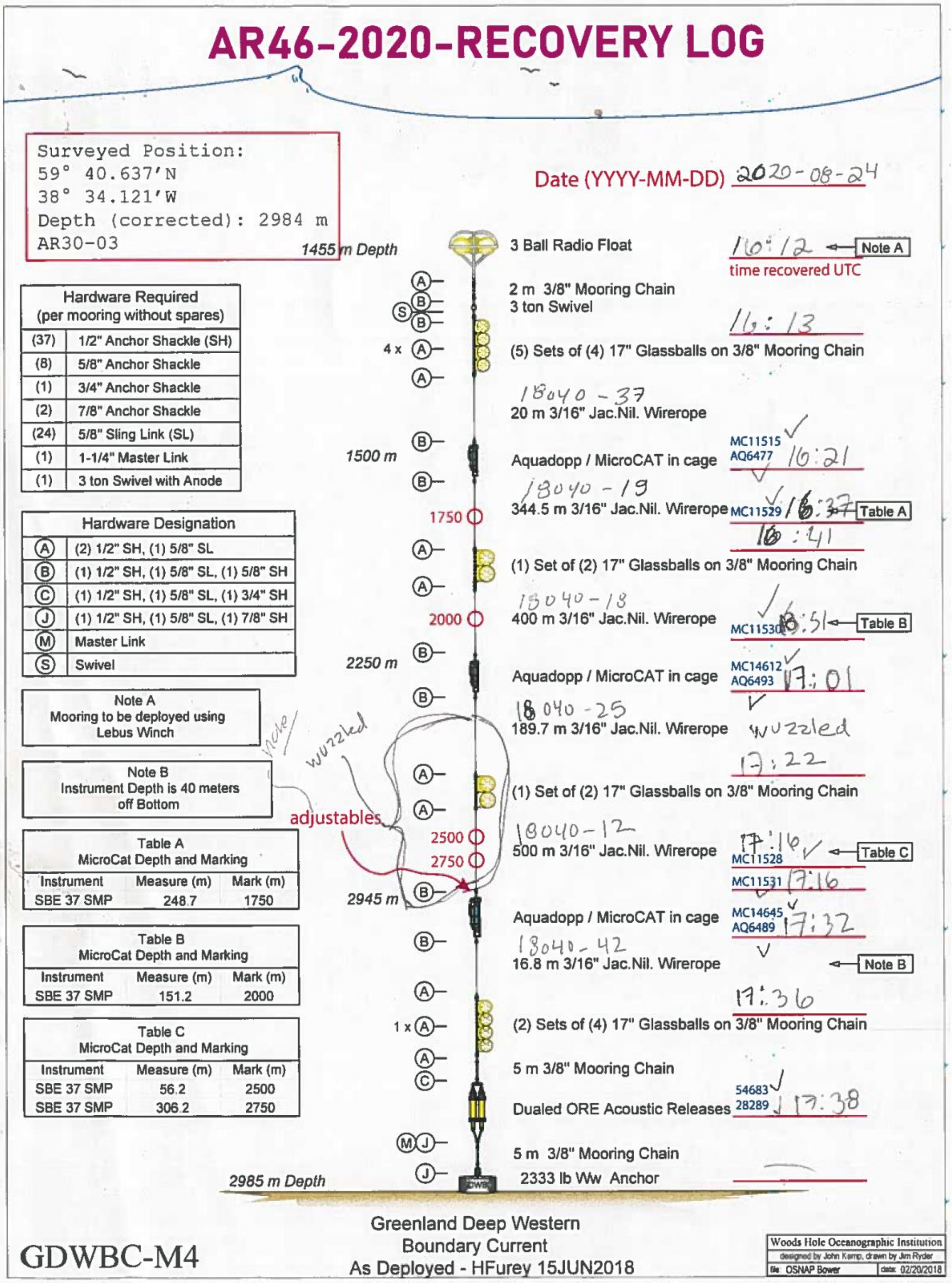
Table B MicroCat Depth and Marking		
Instrument	Measure (m)	Mark (m)
SBE 37 SMP	248.7	1750

GDWBC-M3

Greenland Deep Western
Boundary Current
As Deployed - hfurey 19 June 2018

Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower | date: 02/20/2018

AR46-2020-RECOVERY LOG



Hardware Required (per mooring without spares)	
(37)	1/2" Anchor Shackle (SH)
(8)	5/8" Anchor Shackle
(1)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(24)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation	
A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
J	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
M	Master Link
S	Swivel

Table A
MicroCat Depth and Marking

Instrument	Measure (m)	Mark (m)
SBE 37 SMP	248.7	1750

Table B
MicroCat Depth and Marking

Instrument	Measure (m)	Mark (m)
SBE 37 SMP	151.2	2000

Table C
MicroCat Depth and Marking

Instrument	Measure (m)	Mark (m)
SBE 37 SMP	56.2	2500
SBE 37 SMP	306.2	2750

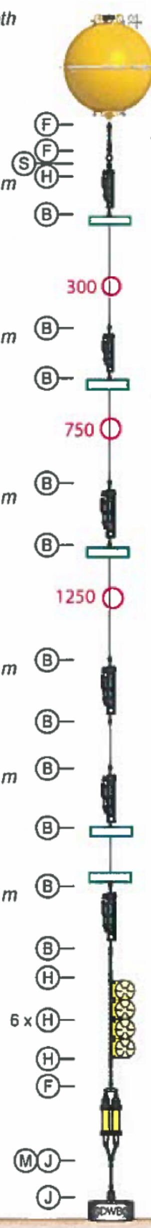
Appendix C: Mooring deployment diagrams for moorings M1-M4.

AR46-2020-DEPLOY LOG

Date (YYYY-MM-DD) 2020-08-23

13:58 past target

*** Please record serial number of wirerope segments.**



no XEOS sunsphere 64" Syntactic Sphere (# 10) ~~XEOS KILO Iridium GPS Unit~~	11:05 time deployed UTC
5 m 3/4" Mooring Chain 3 ton Swivel	
Aquadopp / MicroCAT in cage	MC5914 ✓ AQ7306 ✓ 11:05 ← Note A
20004-3 448 m 1/4" Jac.Nil. Wirerope *	204368 ✓ 11:05 MC5925 ✓ 11:20 ← Table A
Aquadopp / MicroCAT in cage	11:38 MC5930 ✓ AQ4698 ✓ ← Note A
20004-2 497.7 m 1/4" Jac.Nil. Wirerope	204369 ✓ 11:38 MC5924 ✓ ← Table B 11:4
Aquadopp / MicroCAT in cage	MC5913 ✓ AQ7308 ✓ 12:07 ← Note A
20004-1 498 m 1/4" Jac.Nil. Wirerope	204362 ✓ 12:07 MC3588 ✓ 12:16 ← Table C
Aquadopp / MicroCAT in cage	MC5912 ✓ AQ7301 ✓ 12:36 ← Note A
20004-5 248 m 1/4" Jac.Nil. Wirerope	
Aquadopp / MicroCAT in cage	MC5911 ✓ AQ4699 ✓ 12:57 ← Note A
20004-4 261.8 m 1/4" Jac.Nil. Wirerope	204378 ✓ 12:57 204371 ✓ 13:15
Aquadopp / MicroCAT in cage	MC5907 ✓ AQ7309 ✓ 13:15 ← Note A
2 m 1/2" Mooring Chain	
(7) ✓ Sets of (4) 17" Glassballs on 1/2" Mooring Chain	13:31 13:32
1 m 1/2" Mooring Chain	
Dualed ORE Acoustic Releases	48276 ✓ 28037 ✓ 13:55
3 m 1/2" Mooring Chain	
4000 lb Ww Anchor	14:00 anchor over UTC

Note A
Clamp RBR Virtuoso Below
50 meter Aquadopp
500 meter Aquadopp
1000 meter Aquadopp
1750 meter Aquadopp
2025 meter Aquadopp

Table A Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		300 m

Table B Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		750 m

Table C Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		1250 m

Hardware Required (per mooring without spares)	
(33)	5/8" Anchor Shackle
(3)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(25)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation	
(B)	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
(F)	(1) 5/8" SH, (1) 5/8" SL, (1) 3/4" SH
(H)	(2) 5/8" SH, (1) 5/8" SL
(J)	(1) 5/8" SH, (1) 5/8" SL, (1) 7/8" SH
(M)	Master Link
(S)	Swivel

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Greenland Deep Western Boundary Current M1
To Be Deployed 2020

Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower | date: 03/19/2020

AR46-2020-DEPLOY LOG

Target is 59° 51.580' N
040° 41.430' W

Date (YYYY-MM-DD) 2020-08-22

*** Please record serial number of wirerope segments.**

? Cage the bottom optodes in 2022

950 m Depth		3 Ball Radio Float		11:00 time deployed UTC
	A, B, S, B	2 m 3/8" Mooring Chain 3 ton Swivel		
	5 x A, A	✓ (6) Sets of (4) 17" Glassballs on 3/8" Mooring Chain		11:07
		20 m 3/16" Jac.Nil. Wirerope*	18040-35	
1000 m	B, B	Aquadopp / MicroCAT in cage	MC5909 ✓ AQ7299 ✓	11:13
1250		497.4 m 3/16" Jac.Nil. Wirerope	20004-8; MC5927 ✓ ← Table A	11:26
1500 m	B, B	Aquadopp / MicroCAT in cage	MC5929 ✓ AQ7328 ✓ ← Note A; 204373 ✓	11:49
1750		497.4 m 3/16" Jac.Nil. Wirerope	20004-10; MC5926 ✓ ← Table B	12:01
2000 m	B, B	Aquadopp / MicroCAT in cage	MC5933 ✓ AQ7307 ✓	12:15
		189.1 m 3/16" Jac.Nil. Wirerope	20004-17	
2191 m	B, B	Aquadopp / MicroCAT in cage	MC5931 ✓ AQ7327 ✓ ← Note A; 204379 ✓	12:36
		190 m 3/16" Jac.Nil. Wirerope	20004-15	
2383 m	B, B	Aquadopp / MicroCAT in cage	MC5932 ✓ AQ9312 ✓ ← Note A	12:51
		16.7 m 3/16" Jac.Nil. Wirerope	20004-24	
	A	← 5m space ☆ (from cage end)	204377 ✓	12:52
	1 x A, A	✓ (2) Sets of (4) 17" Glassballs on 3/8" Mooring Chain		
	C	5 m 3/8" Mooring Chain		13:48
		Dualed ORE Acoustic Releases	35316 ✓ ~~35610~~; 31336 ✓	13:48
	M J	5 m 3/8" Mooring Chain		
2436 m Depth	J	2333 lb Ww Anchor		14:26 anchor over UTC

Note A
Clamp RBR Virtuoso Below
1500 meter Aquadopp
2200 meter Aquadopp
2423 meter Aquadopp

Table A
Instrument Depth and Marking

Instrument	Serial No.	Mount at
SBE 37 SMP		1250 m

Table B
Instrument Depth and Marking

Instrument	Serial No.	Mount at
SBE 37 SMP		1750 m

Hardware Required
(per mooring without spares)

(35)	1/2" Anchor Shackle (SH)
(12)	5/8" Anchor Shackle
(1)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(25)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation

A	(2) 1/2" SH, (1) 5/8" SL
B	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
C	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
J	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
M	Master Link
S	Swivel

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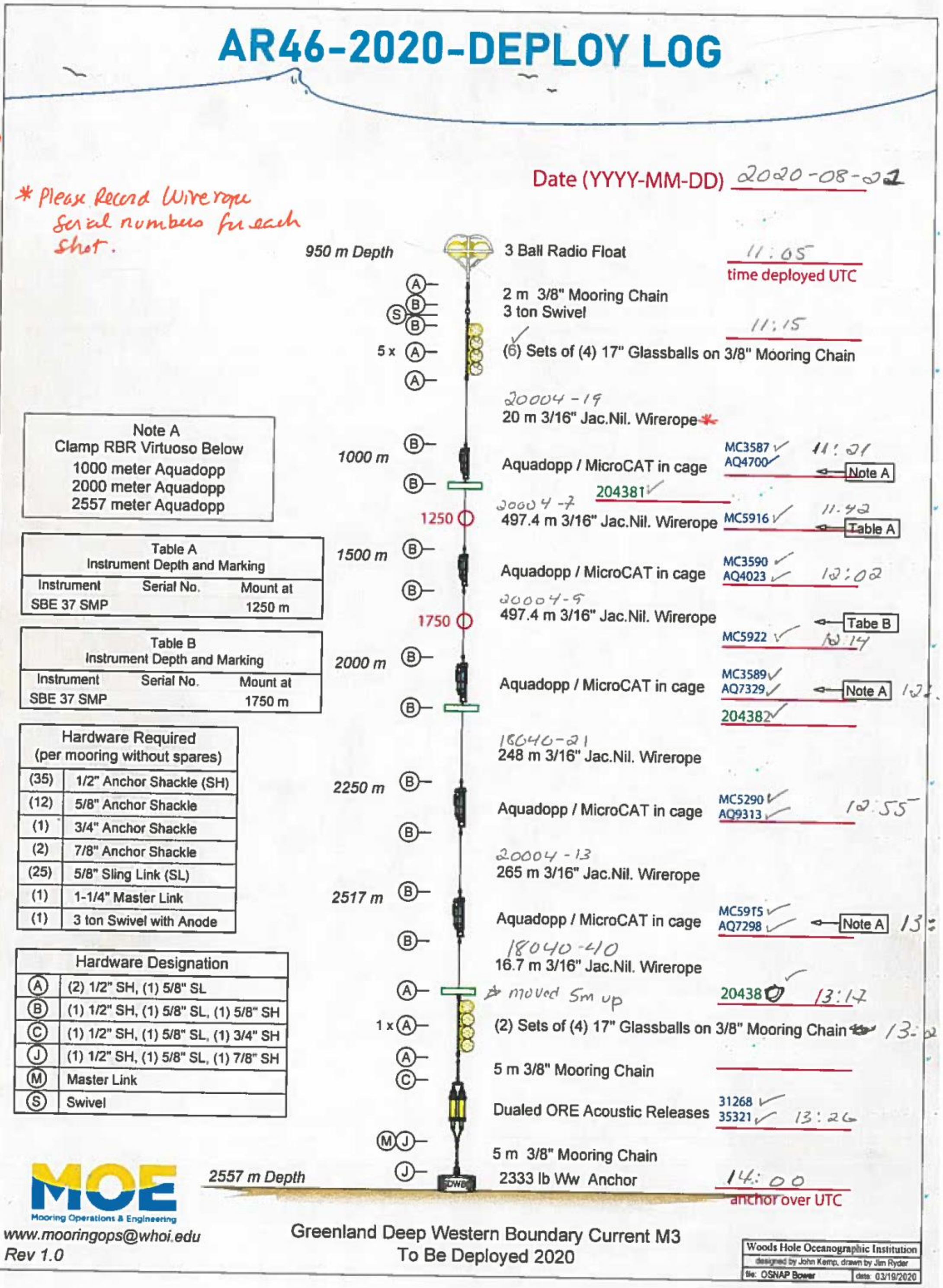
Greenland Deep Western Boundary Current M2
To Be Deployed 2020

Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower | date: 03/19/2020



AR46-2020-DEPLOY LOG

Anchor Over 55°49.120'N 040°16.477'W @14:00UTC M3 deploy

Date (YYYY-MM-DD) 2020-08-22

* Please Record Wire rope Serial numbers for each shot.

950 m Depth		3 Ball Radio Float		11:05 time deployed UTC
	(A), (B), (S), (B)	2 m 3/8" Mooring Chain; 3 ton Swivel		
	5 x (A), (A)	(6) Sets of (4) 17" Glassballs on 3/8" Mooring Chain		11:15
		20 m 3/16" Jac.Nil. Wirerope *	20004-19	
1000 m	(B), (B)	Aquadopp / MicroCAT in cage (Note A)	MC3587, AQ4700, 204381	11:21
1250		497.4 m 3/16" Jac.Nil. Wirerope (Table A)	20004-7; MC5916	11:42
1500 m	(B), (B)	Aquadopp / MicroCAT in cage	MC3590, AQ4023	12:02
1750		497.4 m 3/16" Jac.Nil. Wirerope (Tabe B)	20004-5; MC5922	12:14
2000 m	(B), (B)	Aquadopp / MicroCAT in cage (Note A)	MC3589, AQ7329, 204382	12:
		248 m 3/16" Jac.Nil. Wirerope	18040-21	
2250 m	(B), (B)	Aquadopp / MicroCAT in cage	MC5290, AQ9313	12:55
		265 m 3/16" Jac.Nil. Wirerope	20004-13	
2517 m	(B), (B)	Aquadopp / MicroCAT in cage (Note A)	MC5915, AQ7298	13:
		16.7 m 3/16" Jac.Nil. Wirerope	18040-40	
	(A)	moved 5m up	204380	13:17
	1 x (A)	(2) Sets of (4) 17" Glassballs on 3/8" Mooring Chain		13:22
	(A), (C)	5 m 3/8" Mooring Chain		
		Dualed ORE Acoustic Releases	31268, 35321	13:26
	(M)(J)	5 m 3/8" Mooring Chain		
2557 m Depth	(J)	2333 lb Ww Anchor		14:00 anchor over UTC

Note A
Clamp RBR Virtuoso Below
1000 meter Aquadopp
2000 meter Aquadopp
2557 meter Aquadopp

Table A Instrument Depth and Marking

Instrument	Serial No.	Mount at
SBE 37 SMP		1250 m

Table B Instrument Depth and Marking

Instrument	Serial No.	Mount at
SBE 37 SMP		1750 m

Hardware Required (per mooring without spares)

(35)	1/2" Anchor Shackle (SH)
(12)	5/8" Anchor Shackle
(1)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(25)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation

(A)	(2) 1/2" SH, (1) 5/8" SL
(B)	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
(C)	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
(J)	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
(M)	Master Link
(S)	Swivel

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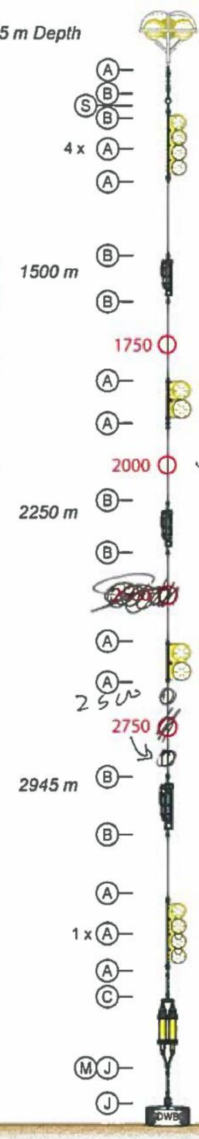
Greenland Deep Western Boundary Current M3
To Be Deployed 2020

Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower date: 03/19/2020

AR46-2020-DEPLOY LOG

Date (YYYY-MM-DD) 2020-08-24

* Please record serial number of wirerope segments.



3 Ball Radio Float		11:11 (time deployed UTC)
2 m 3/8" Mooring Chain		
3 ton Swivel		11:18
(5) Sets of (4) 17" Glassballs on 3/8" Mooring Chain	✓	
20 m 3/16" Jac.Nil. Wirerope*	20004-21	
Aquadopp / MicroCAT in cage	MC5908 ✓ AQ7310 ✓	~~11:01~~ 11:41
344.5 m 3/16" Jac.Nil. Wirerope	20004-12 (~~20004~~ -1 wrong shot, initially. Fixed); MC5920 ✓ → Table A	11:53
(1) Set of (2) 17" Glassballs on 3/8" Mooring Chain	✓	12:05
✓400 m 3/16" Jac.Nil. Wirerope	20004-11 ✓; MC5921 ✓ → Table B	12:10
Aquadopp / MicroCAT in cage	MC5904 ✓ AQ7300 ✓	12:28
189.7 m 3/16" Jac.Nil. Wirerope	✓ 20004-16 ✓; ~~MC5918~~ ✓	
(1) Set of (2) 17" Glassballs on 3/8" Mooring Chain	MC5918 ✓ 12:47	12:45
500 m 3/16" Jac.Nil. Wirerope	✓ 20004-6; MC5917 ✓ → Table C	12:59
Aquadopp / MicroCAT in cage	MC5910 ✓ AQ4702 ✓	13:13
16.8 m 3/16" Jac.Nil. Wirerope	20004-25 ✓	
(2) Sets of (4) 17" Glassballs on 3/8" Mooring Chain	✓	13:19
5 m 3/8" Mooring Chain		
Dualed ORE Acoustic Releases	27687 ✓ 54690 ✓	13:21
5 m 3/8" Mooring Chain		
2333 lb Ww Anchor		anchor over UTC

Table A Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		1750 m

Table B Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		2000 m

Table C Instrument Depth and Marking		
Instrument	Serial No.	Mount at
SBE 37 SMP		2500 m
SBE 37 SMP		~~2500~~ m 2750 m

Hardware Required (per mooring without spares)	
(37)	1/2" Anchor Shackle (SH)
(8)	5/8" Anchor Shackle
(1)	3/4" Anchor Shackle
(2)	7/8" Anchor Shackle
(24)	5/8" Sling Link (SL)
(1)	1-1/4" Master Link
(1)	3 ton Swivel with Anode

Hardware Designation	
(A)	(2) 1/2" SH, (1) 5/8" SL
(B)	(1) 1/2" SH, (1) 5/8" SL, (1) 5/8" SH
(C)	(1) 1/2" SH, (1) 5/8" SL, (1) 3/4" SH
(J)	(1) 1/2" SH, (1) 5/8" SL, (1) 7/8" SH
(M)	Master Link
(S)	Swivel

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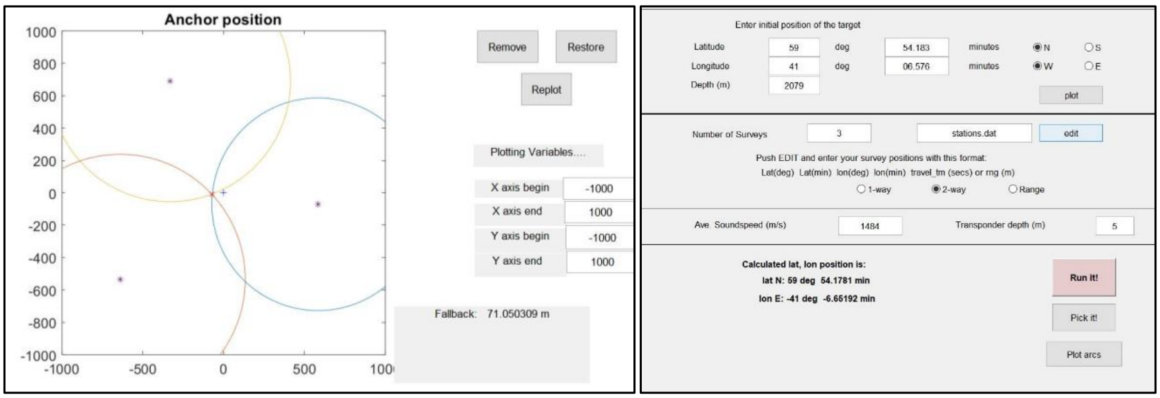
Greenland Deep Western Boundary Current M4
To Be Deployed 2020

Woods Hole Oceanographic Institution
designed by John Kemp, drawn by Jim Ryder
file: OSNAP Bower | date: 03/20/2020

Appendix D. Mooring Anchor Survey Information. Output is from John Kemp. Some anchor over positions are incorrect on Kemp documents, and therefore fallback. Table data is corrrect and reworked with Weller code, and Weller graphical output included here.

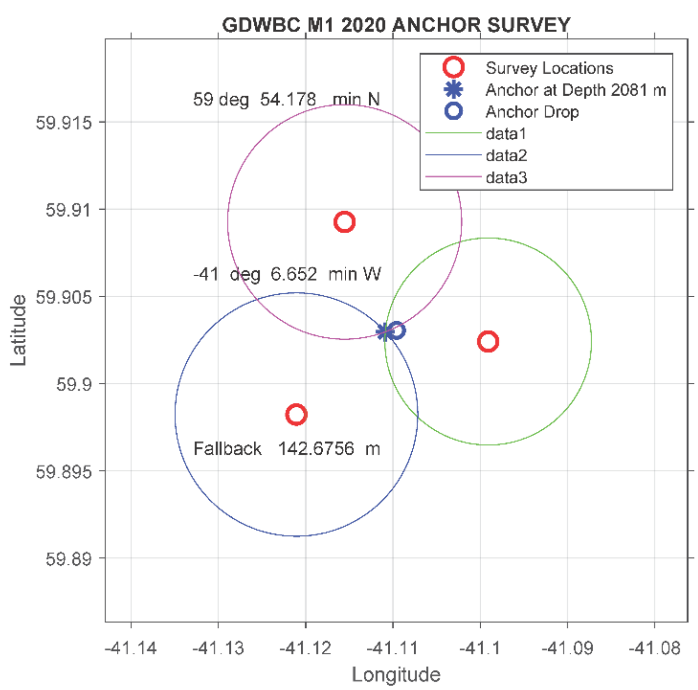
M1:

Newhall code output:



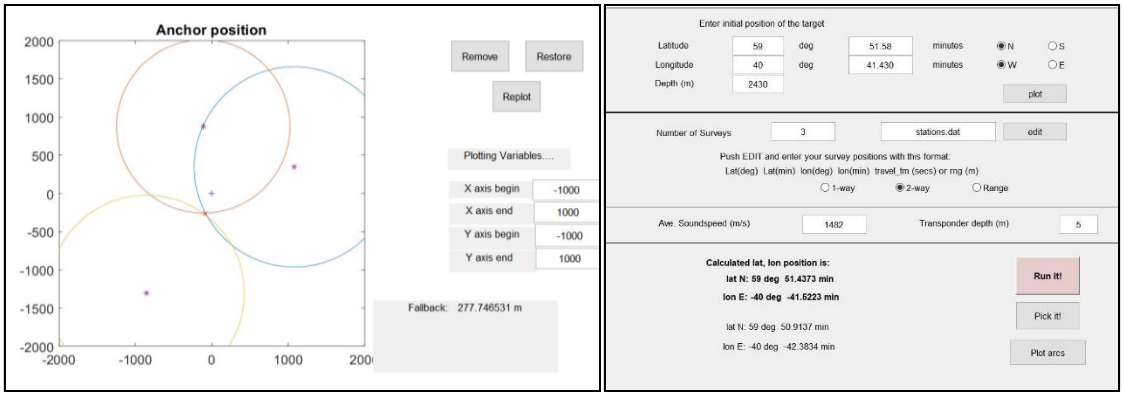
<u>M1 input data: Latitude (°N), longitude (°W), and 2-way travel time (seconds).</u>
59 54.1447 41 05.9455 2.932
59 53.8937 41 07.2637 2.983
59 54.5559 41 06.9320 2.970

Weller code output:



M2:

Newhall code output:



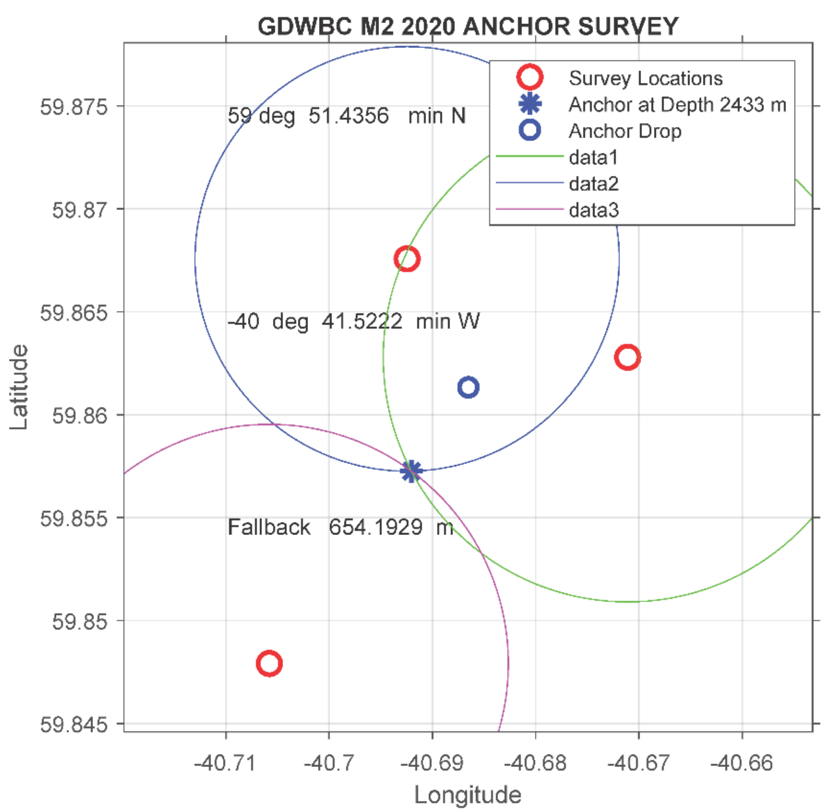
<u>M2 input data: Latitude (°N), longitude (°W), and 2-way travel time (seconds).</u>

59 51.7676 40 40.2654 3.720

59 52.0541 40 41.5469 3.613

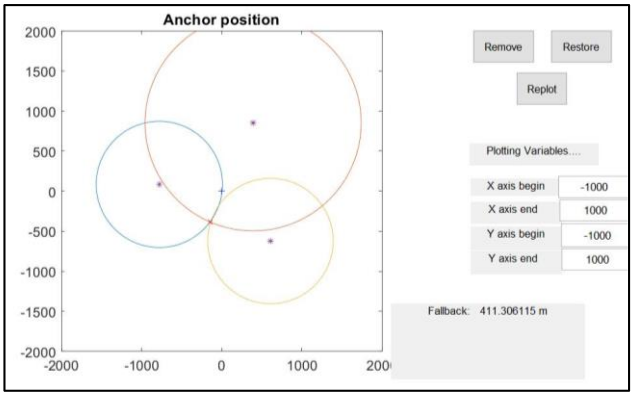
59 50.8749 40 42.3471 3.701

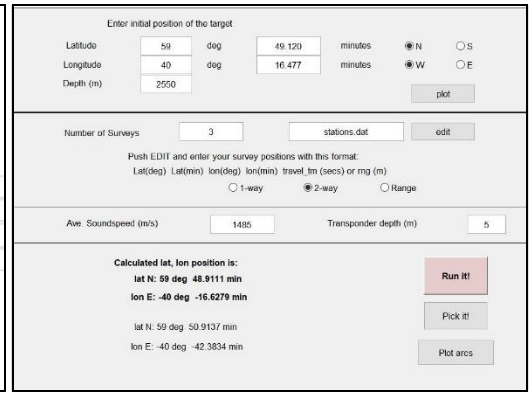
Weller code output:



M3:

Newhall code output:

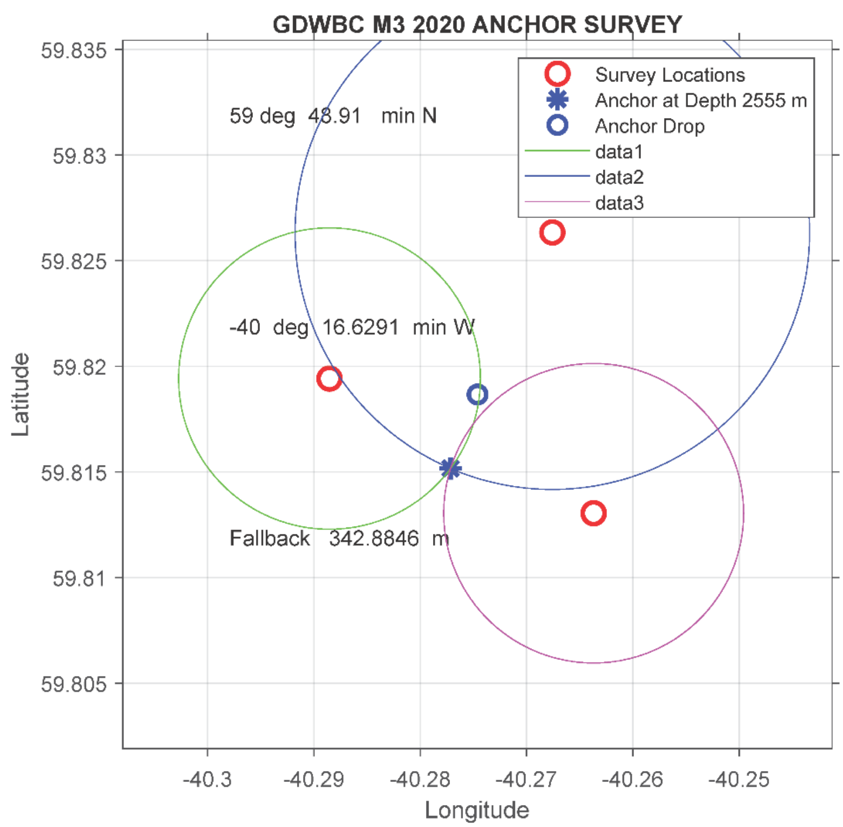




<u>M3 input data: Latitude (°N), longitude (°W), and 2-way travel time (seconds).</u>

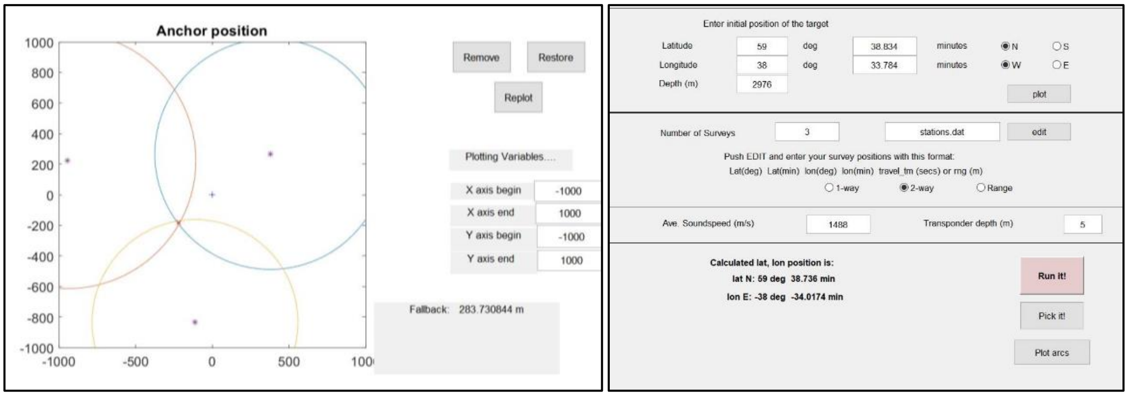
59 49.1653 40 17.3121 3.588
59 49.5801 40 16.0550 3.879
59 48.7829 40 15.8220 3.586

Weller code output:



M4:

Newhall code output:



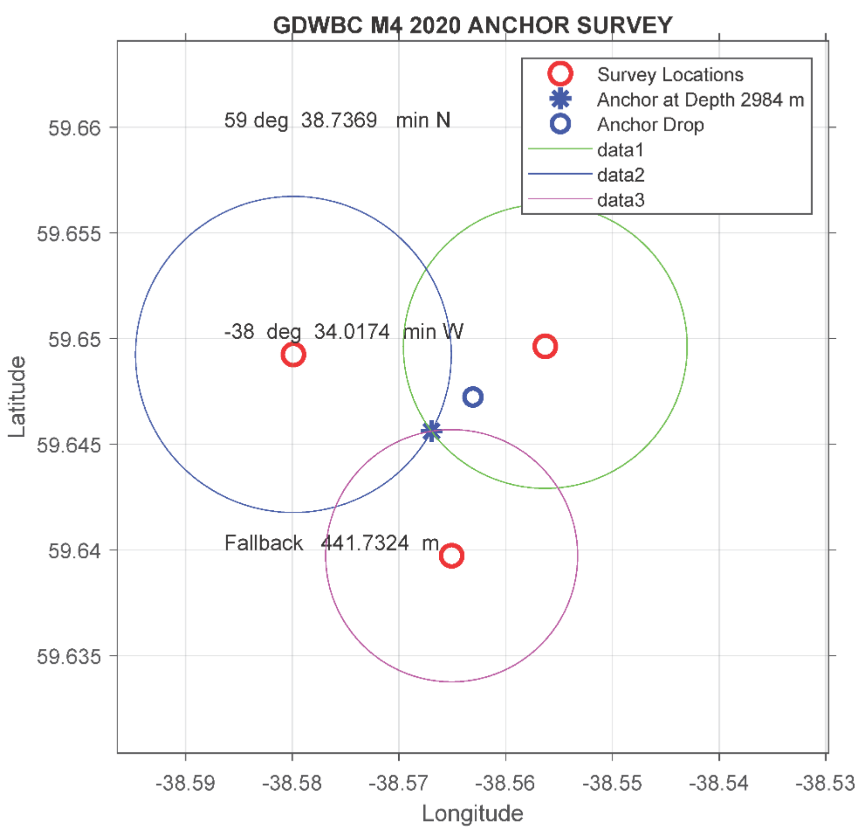
<u>M4 input data: Latitude (°N), longitude (°W), and 2-way travel time (seconds).</u>

59 38.9778 38 33.3773 4.120

59 38.9548 38 34.7937 4.149

59 38.3835 38 33.9038 4.094

Weller code output:



Appendix E: Recovered instrument summary.

The OSNAP GDWBC moorings utilize 3/16" (M2-M4) and 1/4" (M1) 3 x 19 plastic-jacketed galvanized wire rope with swaged sockets to fit 1/2" shackles. These mooring supplies were provided by the WHOI Mooring Lab. The moorings use a combination of instrumentation that are installed on the wire using both in-line rigid aluminum frames and Delrin wire clamps. Prior to deployment all instruments clocks were set to the correct UTC time using an internet synced computer clock. Following this, all of the SBE 37s were calibrated prior to deployment by mounting them onto the CTD rosette and running an in-situ calibration at prescribed depths. They were set to a sample rate of ten seconds and mounted on the rosette 19 and 12 at a time for a total of two casts. Once back onboard, they were set to stop sampling and the data was downloaded but left saved on the instruments as well. They were then reset to their deployment rate of 900 seconds and programmed to start at 00:00 UTC the day of each deployment. Upon recovery, a status message was queried from each instrument and the UTC time and internal instrument time were recorded in order to note the clock drift. The instruments were then set to stop; the time at which the stop command was sent was also noted. Instruments that did not respond were supplied with external power in order to note the clock drift and recover data. The table below gives an overview of the recovered instrumentation.

AR46 OSNAP-M1 2020 Recovery

DEPTH (M)	INSTRUMENT	SN	SAMPLE RATE (s)	UTC DATE	Time check UTC TIME	INST DATE	INST TIME	SAMPLE #	STOP
750	SBE 37	11537	900	8/22/2020	18:13:45	8/22/2020	18:13:11	77709	18:14:00
500	SBE 37	11512	900	8/22/2020	18:15:25	8/22/2020	18:15:22	77856	18:15:40
300	SBE 37	11536	900	8/22/2020	18:17:40	8/22/2020	18:17:44	77716	18:18:00
50	SBE 37	14636	900	8/22/2020	18:19:20	8/22/2020	18:19:29	77802	18:19:40
1250	SBE 37	11538	900	8/22/2020	19:18:05	8/22/2020	19:18:11	77731	19:18:20
2046	SBE 37	14608	900	8/22/2020	21:07:25	8/22/2020	21:07:08	30057	N/A *(see note A)
1500	SBE 37	11516	900	8/22/2020	19:21:50	8/22/2020	19:21:44	77867	19:22:05
1000	SBE 37	14635	900	8/22/2020	19:22:50	8/22/2020	19:22:57	77801	19:23:15
1750	SBE 37	11513	900	8/22/2020	21:31:50	8/22/2020	21:31:53	77803	21:32:10 *(see note B)
50	AQD	6526	1800	8/22/2020	21:40:37	8/29/2019	12:09:01	54048	21:40:37 *(see note C)
1500	AQD	6504	1800	8/22/2020	20:28:57	8/22/2020	20:31:21	3002844	20:28:57
1000	AQD	7294	1800	8/22/2020	21:22:07	8/22/2020	21:22:07	2946014	21:22:07* (see note D)
500	AQD	4704	1800	8/22/2020	20:36:29	8/22/2020	20:39:08	3002844	20:36:29
2046	AQD	6496	1800	8/22/2020	20:58:38	8/22/2020	21:01:15	3002844	20:58:38
1750	AQD	6501	1800	8/22/2020	20:57:04	8/22/2020	20:58:43	3002844	20:57:04

*Note A, SBE37_14608: No comms initially, supplied external power to establish comms and download data. Appears to have lasted ~1 year.

*Note B, SBE37_11513: No comms initially, supplied external power to establish comms and download data, appears to have logged for the full deployment.

*Note C, AQD_6526: no comms initially, supplied external power to establish comms and download data.

*Note D, AQD_7494: no comms initially, supplied external power to establish comms and download data.

AR46 OSNAP-M2 2020 Recovery

DEPTH (M)	INSTRUMENT	SN	SAMPLE RATE (s)	UTC DATE	UTC TIME (Time check)	INST DATE	INST TIME	SAMPLE #	STOP
2250	SBE 37	11514	900	8/21/2020	18:56:15	8/21/2020	18:56:11	77688	18:57
2517	SBE 37	11539	900	8/21/2020	18:58:05	8/21/2020	18:58:39	77684	18:58:25
2000	SBE 37	13220	900	8/21/2020	18:59:55	8/21/2020	18:59:44	77590	19:00:20
1500	SBE 37	13216	900	8/21/2020	19:01:30	8/21/2020	19:01:18	77733	19:01:50
1000	SBE 37	14644	900	8/21/2020	20:11:05	8/21/2020	20:11:41	77773	20:11:30
1250	SBE 37	13218	900	8/21/2020	20:12:30	8/21/2020	20:12:08	77549	20:12:50
1750	SBE 37	13221	900	8/21/2020	20:13:55	8/21/2020	20:13:52	77698	20:14:10
1500	AQD	6500	1800	8/21/2020	4:38:34	8/21/2020	4:39:56	2994972	04:38:34
1000	AQD	6529	1800	8/21/2020	4:54:58	8/21/2020	4:56:59	2994972	4:54:58
2000	AQD	6471	1800	8/21/2020	5:12:50	8/21/2020	5:14:12	2995014	5:12:50
2191	AQD	6480	1800	8/21/2020	5:39:34	8/21/2020	5:40:51	2995056	5:39:34
2383	AQD	6452	1800	8/21/2020	5:54:58	8/21/2020	5:57:07	2995056	5:54:58

AR46 OSNAP-M3 2020 Recovery

DEPTH (M)	INSTRUMENT	SN	SAMPLE RATE (s)	UTC DATE	UTC TIME (Time check)	INST DATE	INST TIME	SAMPLE #	STOP
2250	SBE 37	7577	900	8/20/2020	21:49:45	8/20/2020	21:51:04	77674	21:50:10
2517	SBE 37	7580	900	8/20/2020	21:51:05	8/20/2020	21:52:18	77604	21:51:30
2000	SBE 37	13214	900	8/20/2020	21:53:20	8/20/2020	21:52:49	77634	21:54:00
1500	SBE 37	14634	900	8/20/2020	21:56:00	8/20/2020	21:56:34	77519	21:56:15
1000	SBE 37	14638	900	8/20/2020	21:56:55	8/20/2020	21:56:47	77498	21:57:10
1250	SBE 37	14599	900	8/20/2020	21:58:15	8/20/2020	21:58:05	77416	21:58:35
1750	SBE 37	11540	900	8/20/2020	21:59:10	8/20/2020	22:00:06	77352	21:59:30
	AQD	6503	1800					2816356	22:03:55
	AQD	6490	1800	8/20/2020	22:26:32	8/20/2020	22:27:35	2987898	22:26:32
	AQD	6488	1800	8/20/2020	22:30:02	8/20/2020	22:31:07	2987898	22:30:02
	AQD	6499	1800	8/20/2020	22:31:38	8/20/2020	22:33:37	2987940	22:31:38
	AQD	6472	1800	8/20/2020	22:33:15	8/20/2020	22:35:36	2987940	22:33:15

AR46 OSNAP-M4 2020 Recovery

DEPTH (M)	INSTRUMENT	SN	SAMPLE RATE (s)	UTC DATE	UTC TIME (Time check)	INST DATE	INST TIME	SAMPLE #	STOP
1500	SBE 37	11515	900	8/24/2020	17:09:00	8/24/2020	17:08:57	78514	17:09:20
2000	SBE 37	11530	900	8/24/2020	17:11:40	8/24/2020	17:11:42	78479	17:11:55
1750	SBE 37	11529	900	8/24/2020	17:14:05	8/24/2020	17:14:26	78602	17:14:25
2250	SBE 37	14612	900	8/24/2020	17:25:05	8/24/2020	17:25:19	78521	17:25:20
2500	SBE 37	11528	900	8/24/2020	18:10:45	8/24/2020	18:10:30	78591	18:11:00
2750	SBE 37	11531	900	8/24/2020	18:12:25`	8/24/2020	18:12:38	78599	18:12:40
2945	SBE 37	14645	900	8/24/2020	18:14:30	8/24/2020	18:14:37	78473	18:14:45
2945	AQD	6489	1800	8/24/2020	18:31:30	8/24/2020	18:33:55	3025284	18:31:30
1500	AQD	6477	1800	8/24/2020	19:28:27	8/24/2020	19:31:03	3025326	19:28:27
2250	AQD	6493*							

*AQD6493: NO COMMUNICATION WITH/WITHOUT EXTERNAL POWER. REMOVED BATTERY ENDCAP, NO SIGN OF WATER INTRUSION.
ELECTRONICS FLOODED. NO SD CARD BOARD INSTALLED.

Appendix F: CTD and Sampling report.

AR46 CTD & Sea Water Sampling Report
R/V *Neil Armstrong*
OOI Irminger-7 / OSNAP Greenland Deep Western Boundary Current
August 8th – September 4th, 2020
Woods Hole, MA – Woods Hole, MA

Acknowledgements
Much of the preliminary processing and figure creation scripts were kindly provided by Leah Trafford McRaven.

CTD Summary

CTD package

24 Hz data was collected from a SeaBird 911plus CTD and deck unit. The CTD was equipped to measure conductivity, temperature, pressure, and oxygen voltage. In addition to the SBE43 Oxygen sensor, two additional oxygen optodes were supplied and integrated into the package: Aanderaa 4831 sensor provided by D. Nicholson (cable by M. Swartz), and Aanderaa 4831 sensor provided by OOI. Instrumentation on the CTD package is detailed in the table below.

Table 1. Sensor type, number, manufacturer, calibration data and stations each were used for during CTD casts on AR46.

Sensor	Number	Manufacturer	Calibration date	Stations used
Temperature 1	4252	SeaBird	15-May-2019	1-19
Temperature 2	4406	SeaBird	14-May-2019	1-19
Conductivity 1	1860	SeaBird	05-Sep-2019	1-19
Conductivity 2	3089	SeaBird	05-Sep-2019	1-19
Pressure	0383	SeaBird	15-May-2019	1-19
Oxygen (SBE43)	0794	SeaBird	09-Jul-2020	1-19
Fluorometer	FLNTURTD-FL-1013	WET Labs	Feb-2019	1-19
Turbidity Meter	FLNTURTD-TU-1013	WET Labs	Feb-2019	1-19
Transmissometer	CST-1191	WET Labs	06-Mar-2019	1-19
Aanderaa Oxygen 1 (OSNAP)	4831 (s/n 277)	Aanderaa	31-Oct-2013	1-19
Aanderaa Oxygen 2 (OOI)	4831 (s/n 503)	Aanderaa	22-Jan-2020	1-9
Aanderaa Oxygen 3 (OOI)	4831 (s/n 377)	Aanderaa	22-Jan-2020	10-19
PAR/Irradiance	QSP200L4S	Biospherical/Licor	11/21/16	1-3, 6
Altimeter	VA500-46507		2018	1-19

Stations

19 CTD stations were occupied, with one in Nantucket Sound, to test CTD function and practice water sampling, and 18 in the Irminger Sea (Figure 1). The CTD sampling plan was created to fit the needs of both OOI and OSNAP mooring and science goals. A CTD cast was done at each OSNAP mooring site (M1-M4) with salt sampling and oxygen sampling (M1-M3 only). Additionally, a CTD was done at the OOI 2019 and 2020 moorings or at a time when both were in the water. The water sampling plan was based on instrument depths for each mooring and other targeted water masses (such as O_2 minimum and maximum). Additionally, CTDs were done for pre- and post-deployment calibration dips, acoustic release tests, and glider sensor calibrations.

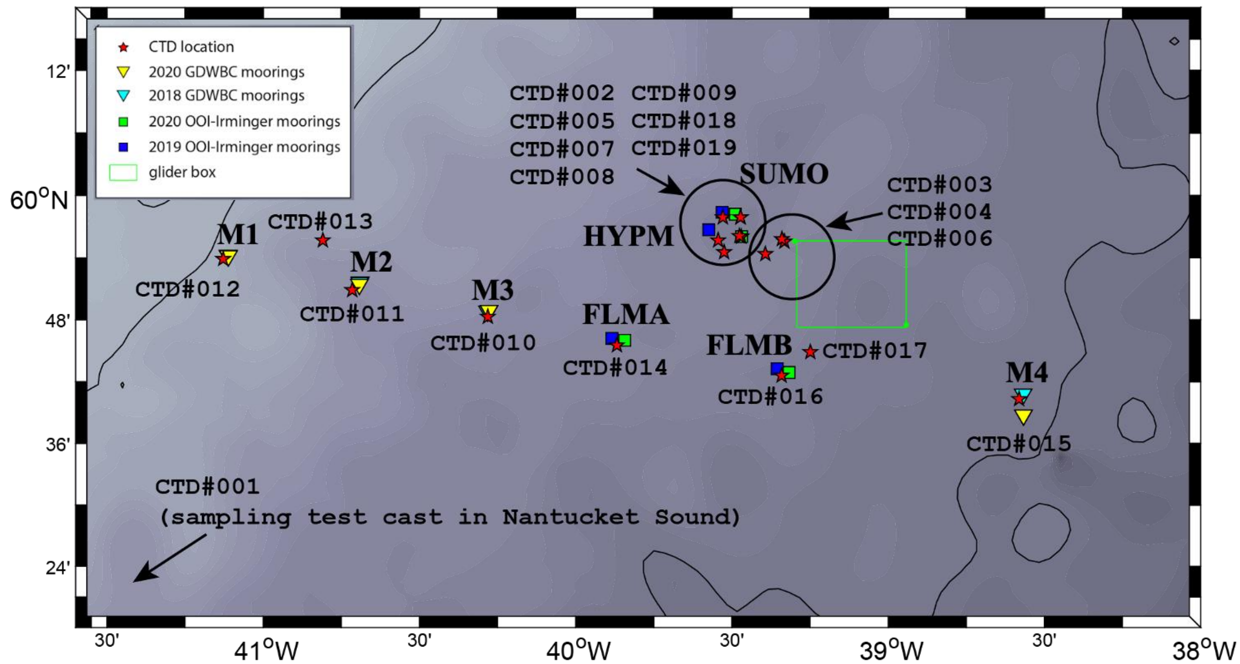


Figure 1. Map of OOI Irminger 7 and OSNAP GDWBC mooring sites and CTD locations.

Notable events

CTD 001: bottle #19 mechanically fired but did not successfully close.

CTD 002: bottle #2 mechanically fired but did not successfully close.

CTD 004: bottle #20 did not fire. All stop at 404 m due to wire wrap issue and was resolved.

CTD 007: bottle #19 did not close. Voltage on OOI Aanderaa sensor suspicious. Notified shore team.

CTD 010: swapped OOI Aanderaa optode with a different one of the same model, fixed previous issue. Unclear if it was a sensor or cable issue.

CTD 015: maximum depth 2650 m on most of the remaining casts due to level wind/wire wrap issue.

CTD 019: firing mechanism/software failure after Niskin #17. All samples collected from Niskin #1-16, as Niskin #17 was suspect. Unclear the cause of the issue. Not able to repeat cast due to time constraints and incoming storms.

Processing

Preliminary processing procedures included default processing by SEASAVE (SeaBird software, version 7.22.0). This software creates pressure, temperature, conductivity, and dissolved oxygen fields from the raw data, summarizes Niskin bottle data, aligns the oxygen sensor with pressure sensor by a time offset, removes unrealistic outliers, creates 2 db bins, applies a thermal mass correction to the conductivity cell, computes oxygen and salinity, and creates separate upcast and downcast files.

Preliminary figures with uncorrected conductivity/salinity

From a first look, no significant or prolonged biofouling events occurred. At the surface of most CTD casts, there was a large difference between the primary and secondary conductivity and temperature sensors which could be attributed to a foreign item in the intake pump however, these differences did not persist for the entire CTD cast.

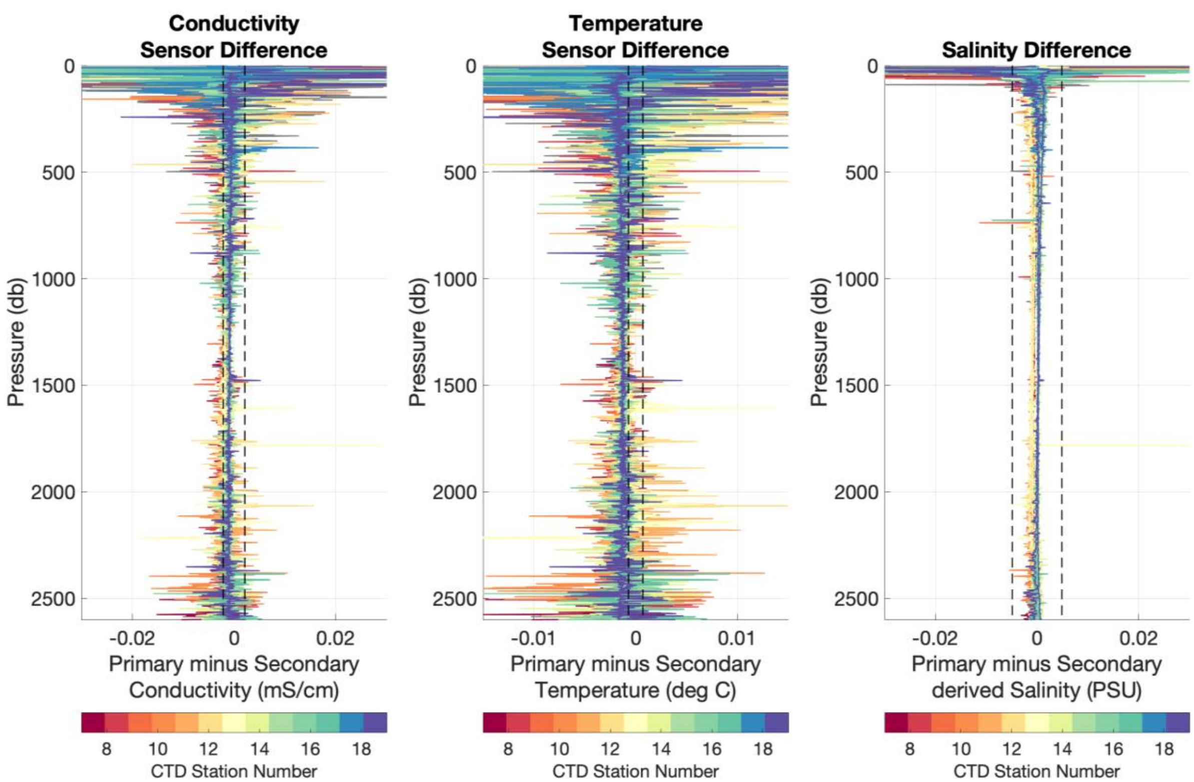


Figure 2. Differences between primary and secondary conductivity (uncorrected) and temperature sensors and the resulting salinity for CTD casts 001-019.

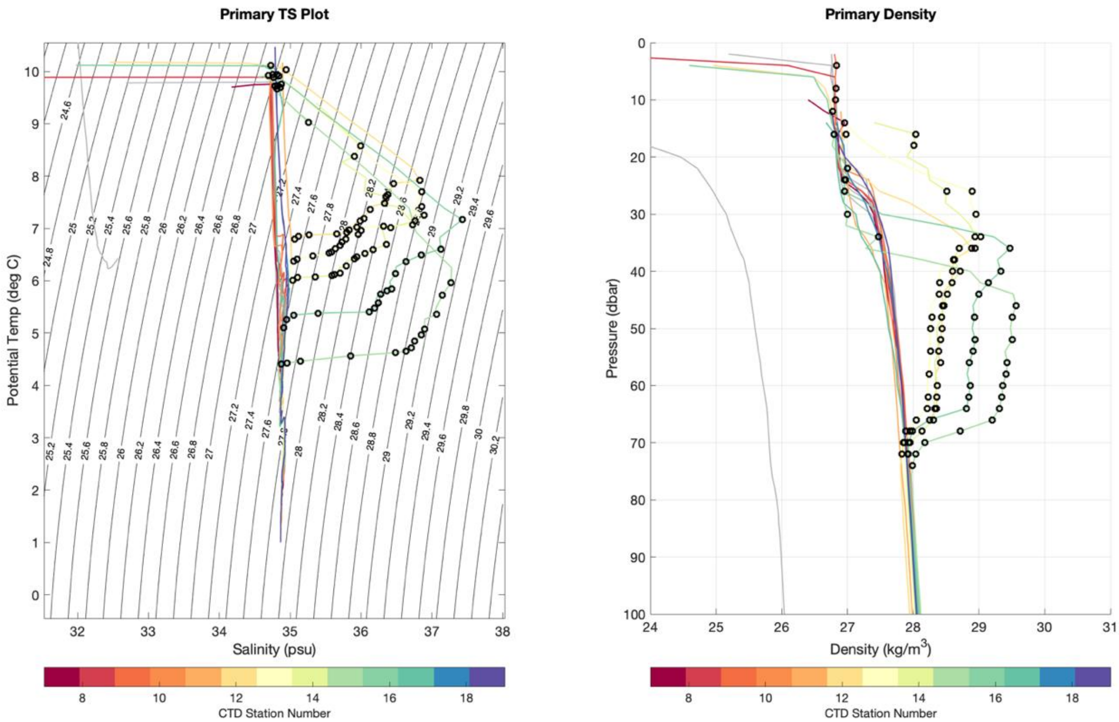


Figure 3. Primary Temperature-Salinity (uncorrected) plot and density anomaly profile. CTDs 7-19 are plotted in different colors. Black circles indicate density inversions of -0.002 kg m^{-3} or greater.

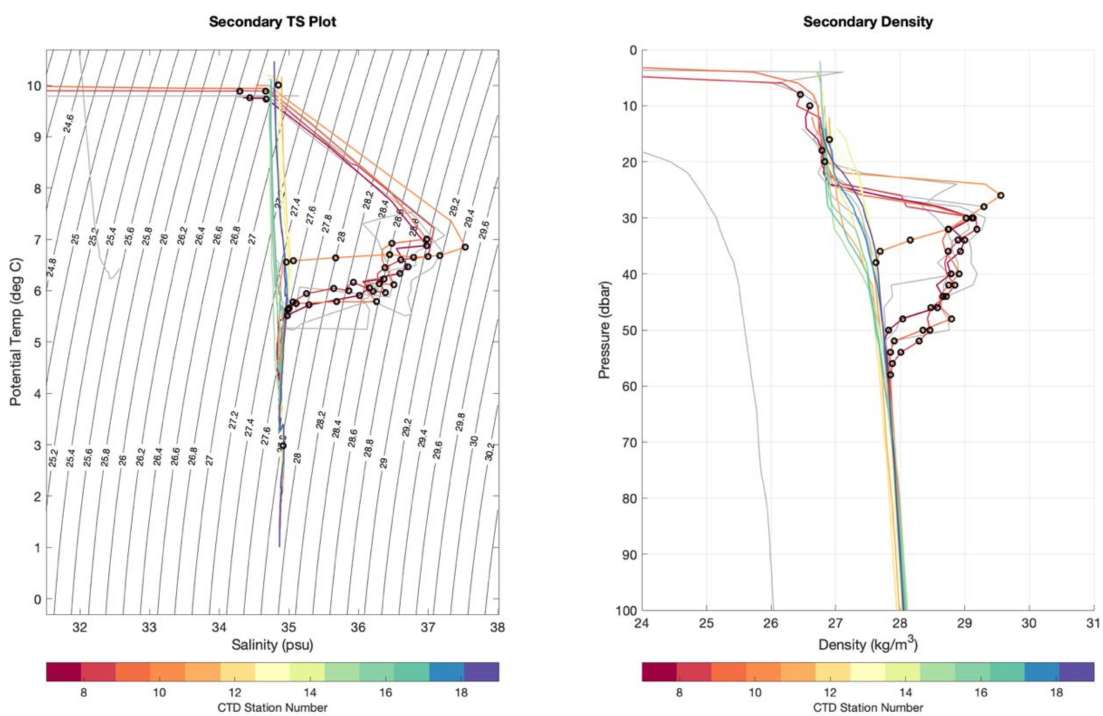


Figure 4. Secondary Temperature-Salinity plot (uncorrected) and density anomaly profile. CTDs 7-19 are plotted in different colors. Black circles indicate density inversions of -0.002 kg m^{-3} or greater.

Post-processing CTD conductivity calibration

The post-processing calibration procedures follow those described in Millard and Yang (1993). To correct CTD salinity only deeper salinity bottle samples (> 350 m) were used, as recommended by CalCOFI protocol. The conductivity can be calibrated using the following equation:

$$FC = m \cdot CC + b + \beta \cdot CP$$

where *FC* is the final conductivity, *m* is the conductivity slope, *CC* is the pre-cruise calibrated CTD conductivity, *b* is the conductivity bias, β is the linear pressure term, and *CP* is the CTD pressure. An attempt was made to perform this correction and each term is presented in Table 2 however, no final calibration was done. This step was left for a trained hydrographer to complete on shore.

Table 2. Conductivity correction terms for primary and secondary conductivity sensor.

Sensor	Stations	Conductivity bias	Conductivity slope	β
Primary				
1860	4, 6-19	-0.029349	0.0011402	8.2285 e -07
Secondary				
3089	4, 6-19	-0.030992	0.0011788	4.9028 e -07

CTD Water Sampling

Oxygen

A total of 126 oxygen samples were collected and prepared for long term storage according to the guidelines provided by the GOHSNAP team and Zhang et al. (2002). Due to a limited science party, onboard titrations were not possible on AR 46. Two types of sample bottles were available to use: 125 ml clear glass flare bottle (provided by D. Nicholson) and 150 ml brown glass tincture bottle (provided by D. Wellwood) (Figure 5). There are two CTD casts (007 and 019) in which two depths had four oxygen samples (duplicates of each type of bottle) for intercomparison. The deepest Niskin bottles were sampled first and every sample was collected in duplicates.

Tygon tubing was attached to the spigot of the Niskin bottle and opened to check for leaks. Then, the valve was opened allowing water to flow through the tubing. Once bubbles were cleared from the tubing, the sample bottle was rinsed three times before filling and overflowing 3x the volume of the bottle. Sample bottle was checked for bubbles after removing the tubing and $MnCl_2$ reagent was added, followed by NaOH/NaI reagent. After the cap of the bottle was inserted, the sample was shaken 15 times with a downward snapping motion to ensure the reagents thoroughly reacted with the oxygen in the sample. After all water samples were taken, the oxygen samples were taken back into the Wetlab, shaken again 20 times, and preserved for long-term storage.

Because there were two different bottle types used, there were two different long-term storage procedures. For the 125 ml clear glass flare bottles, the rim was filled with freshwater and stored by stretching an unlubricated condom over the top. The 150 ml brown glass tincture bottles were prepared by stretching an elastic band over the top and bottle and then submerged in a plastic jar was filled ¾ of the way with seawater from the underway system. All oxygen samples were stored in the walk-in refrigerator kept at 10°C.

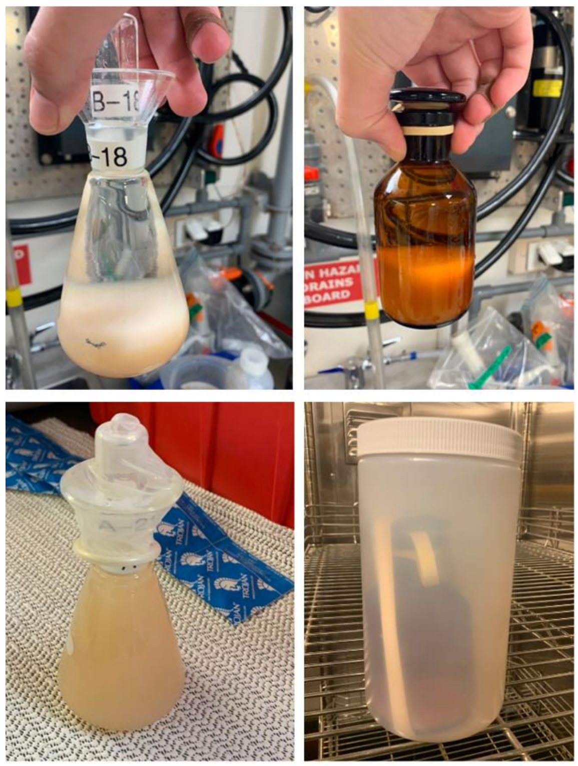


Figure 5. Oxygen sample bottle types and storage methods. (left) provided by D. Nicholson, (right) provided by D. Wellwood.

DIC/TA & pH

Samples were collected in 250 ml glass bottles with stopper and poisoned with 100 μl of Mercuric chloride. Sample tubing with filter was attached to the spigot and the glass bottles were rinsed three times with the water from the Niskin bottle being sampled. The bottles were filled to the necks, poisoned, and the stoppers were greased with Apiezon M grease before capping. Throughout the cruise, 6 DIC/TA samples and 9 pH samples were collected and stored at room temperature. Supplies were provided by Dave Wellwood and ____ is responsible for analyzing these samples on shore.

Salinity

Seawater samples were collected in 200 ml glass bottles from the Niskins on the CTD rosette, closed at predetermined depths. At the time of collection, each bottle is rinsed three times with the water from the Niskin that is to be sampled, then filled to the neck. Sample bottle numbers were recorded on the OOI Sea Water Sampling sheets for each CTD cast.

156 salinity water samples were collected from the CTD and analyzed at sea. Samples were analyzed using a Guideline Salinometer model 8400 B. Before each batch of samples, the salinometer was standardized using IAPSO Standard Seawater (batch P163). The bath temperature of the Salinometer was set to 24°C. Samples were brought to room temperature (21-22°C) before being analyzed. No samples were analyzed in room temperatures greater than 23°C. These samples are used for post-processing calibration of the CTD, as described above.

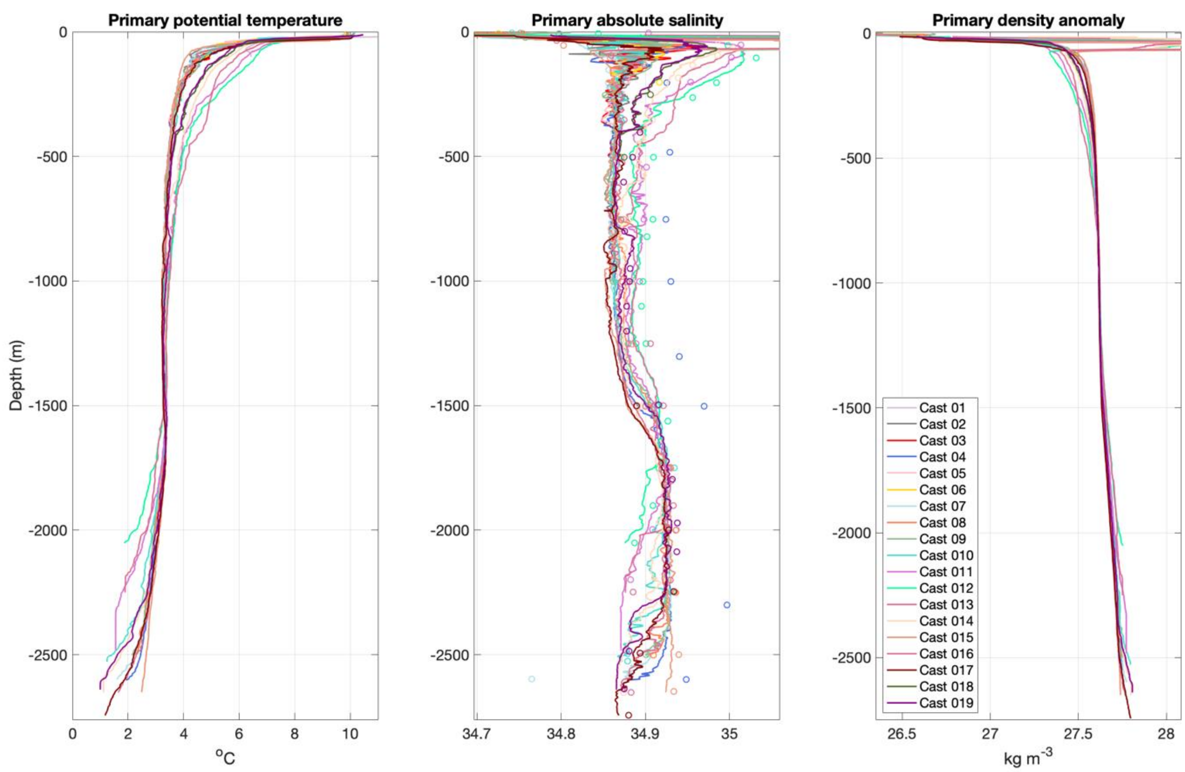


Figure 6. Potential temperature, absolute salinity, and calculated density anomaly using the uncalibrated primary sensors. Bottle salinity values are plotted for each cast that had samples.

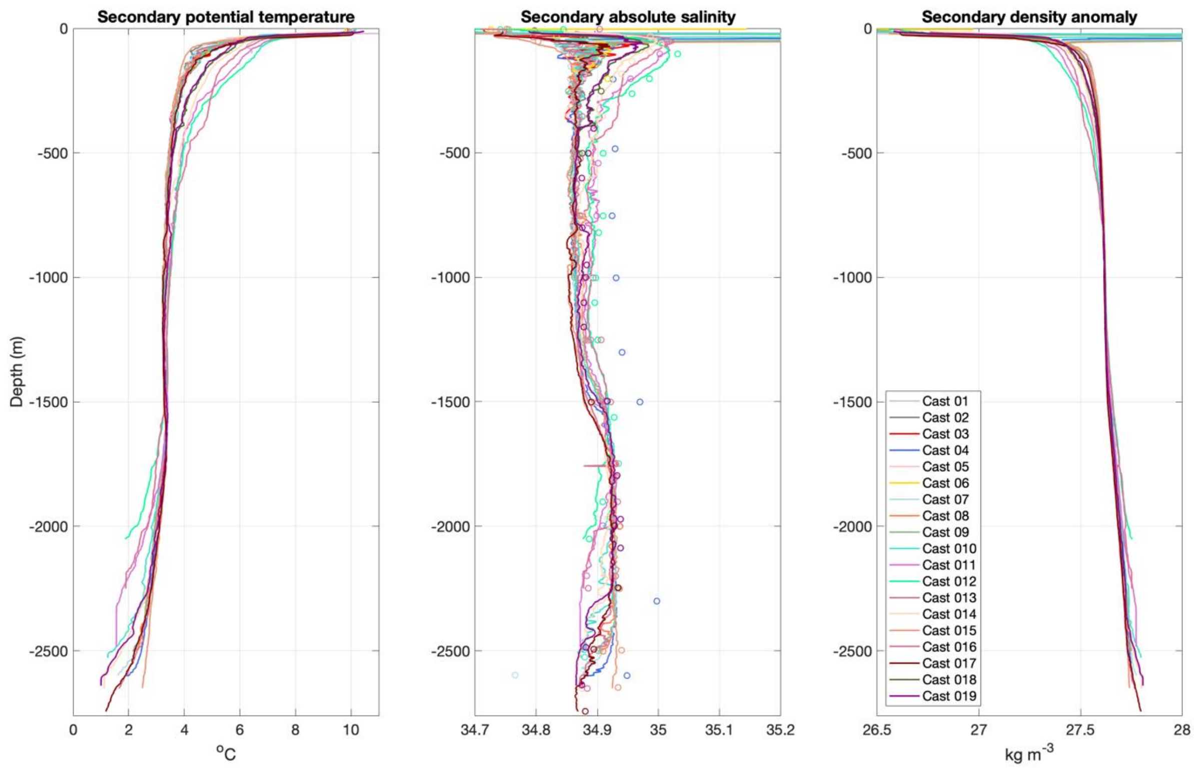


Figure 7. Potential temperature, absolute salinity, and calculated density anomaly using the uncalibrated primary sensors. Bottle salinity values are plotted for each cast that had samples.

Nitrate/Nitrite

Nutrient samples were collected using specified tubing and filter from the Niskin bottle. Each sample bottle and cap was triple rinsed before filling to the bottle neck and stored in the freezer at -80 °C. Supplies were provided by Dave Wellwood and ___ is responsible for analyzing these samples on shore.

Chlorophyll

Brown 1L plastic bottles were used to collect chlorophyll samples from the Niskin bottles. Samples were filtered on board through a 25 mm diameter glass microfiber filter. Filters were placed in a labeled case and stored in a -80 °C freezer. Supplies were provided by Dave Wellwood and ___ is responsible for analyzing these samples on shore.

Additional figures

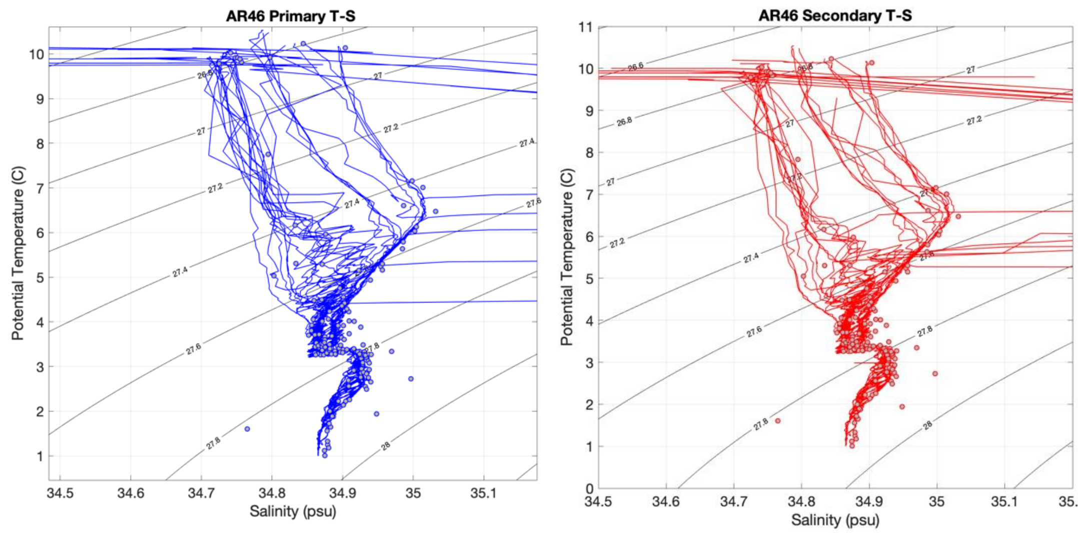


Figure 8. Uncorrected primary and secondary T-S plots with analyzed salt samples as points.