CRUISE REPORT

***R/V Neil Armstrong* Cruise AR69-02**

OSNAP Program
July 22 - Aug. 12, 2022
Reykjavik, Iceland to Reykjavik, Iceland

1. Introduction and Objectives

The Overturning in the Subpolar North Atlantic Program (OSNAP) is an international program designed to provide a continuous record of the full-water column, trans-basin fluxes of heat, mass and freshwater in the subpolar North Atlantic. It is a collaborative program among science teams from several nations, including the U.S., U.K., the Netherlands, Germany, Canada, and France. The OSNAP observing system consists of two legs: one extending from southern Labrador to the southwestern tip of Greenland across the entrance of the Labrador Sea (OSNAP West), and the second from the southeastern tip of Greenland to Scotland (OSNAP East). The observing system also includes subsurface floats in order to trace the pathways of overflow waters in the basin and to assess the connectivity of currents crossing the OSNAP line.

Cruise AR69-02 was the fourth U.S.-sponsored cruise working along the OSNAP East line, following earlier cruises in 2014 (R/V Knorr), 2018 (R/V Armstrong), and 2020 (R/V Armstrong). In 2015 and 2016, U.S. scientists joined cruises sponsored by other nations (The Netherlands in 2015, on R/V Pelagia; and the U.K. in 2016, on RRS Discovery) to conduct science operations along the OSNAP East line. Scientists from the U.S. (University of Miami) and the Netherlands (NIOZ and Utrecht University) participated in this cruise.

The specific objectives of cruise AR69-02 were to:

1. To perform mooring operations along the OSNAP East line between the Iceland and Irminger basins, including servicing (recovery and redeployment) of 12 current meter moorings.
2. To conduct standard CTD (Conductivity-Temperature-Depth) and Lowered ADCP (Acoustic Doppler Current Profiler) stations at approximately 44 sites along the same mooring line.
3. To acquire continuous underway data (vessel-mounted ADCP data, meteorological data, and surface temperature and salinity data) along the cruise track, and to perform selected additional CTD stations along the cruise track for instrument testing and calibration.

2. Cruise Synopsis

The cruise departed from Reykjavik harbor at 1000 UTC on July 22nd and the ship got underway toward the first planned CTD station along the OSNAP line. (All times listed in the remainder of this report are in UTC, which was also the time zone used for local time onboard the ship for the duration of the cruise.) At 1958 on July 22 the ship stopped in the northern Iceland Basin once we crossed the 1000 m isobath to perform a test cast for the CTD/LADCP profiling system (CTD001). The CTD was lowered to 1000 m and the Niskin bottles were all fired at 1000 m. Once retrieved, the Niskin bottles were inspected for leaks, and bottle samples for salinity were drawn by all the CTD watch standers that would be drawing seawater samples on the cruise, and the CTD sensors and LADCP were checked for functionality. The next CTD station (CTD002) was done at 1804 on July 23rd in the central Iceland Basin, which was one of several calibration-dip casts (hereafter "caldip" casts) done on the cruise for the numerous SeaBird microcat (SBE37) instruments that were to be deployed on the moorings. On these casts, microcats were mounted on small airplane straps attached to the CTD frame, and the CTD cast was performed in normal fashion except that the bottle stops on the upcast were 5 minutes (or in some cases 10 minutes) long. The temperature, conductivity and pressure measurements from the microcats and the SBE911+ CTD were then compared during the bottle stops to check the calibration of the microcats. As many as 22 microcats were mounted on the CTD for these casts.

The strategy for the mooring operations was to start in the central Iceland Basin with the most eastward of the University of Miami moorings and work westward across the Reykjanes Ridge to the NIOZ Irminger Sea moorings. In between the mooring operations, which were conducted in daylight hours, CTD/LADCP stations would be acquired along the OSNAP mooring line, mainly during the evening and early morning hours.

The work along the OSNAP line started at 0025 on July 7th with CTD003, which marked the eastern end of the CTD/LDCP section that was to be occupied during the cruise, extending from the central Iceland Basin across the Reykjanes Ridge into the central Irminger Basin. By incredible coincidence, we arrived at CTD003 at the same time the RRS James Cook - with our U.K. OSNAP colleagues aboard - were finishing up the deployment of their last OSNAP mooring in the Iceland Basin, and greetings were exchanged as the ships sailed past each other. The timing was also auspicious, as the U.K. team had just completed their CTD section across the eastern Iceland Basin, and so there would be almost no lag between the end of their section and the beginning of ours, as part of the overall plan to combine the OSNAP CTD sections occupied by the different research cruises this summer into a full section across the entire subpolar basin.

U. Miami mooring D5 was recovered on the morning of July 25th followed by redeployment of the new D5 mooring that afternoon. Acoustic communications with the mooring releases were somewhat difficult during the mooring release as well as during the post-deployment mooring survey, even though the sea conditions were relatively quiet. We found that the acoustic communications were better when the ship was slowly moving, rather than when stopped and using the bow thrusters, suggesting that bubbles under the hull might be creating extra noise. Swapping deck boxes (both Benthos UDB-9000 series units) did not show any improvement, nor did switching the acoustic communications from the auxiliary 12 kHz transducer to the ship's echo-sounding (Knudsen) transducer. CTDs were continued through the night and on the morning of July 26th, mooring D4 was successfully recovered and redeployed that afternoon. Once again the acoustic communications with the releases were subpar, even though ocean conditions were still quiet, with many commands either not being answered or we could not hear the replies clearly. Using the ship's Knudsen echo-sounder in "pinger mode" to help listen to the acoustic comms also showed no clear response to many commands, and also showed an unusual amount of noise for the conditions.

After continuing CTDs through the night, tall mooring M2 was successfully recovered and redeployed on July 27th. The acoustic communications were initially challenging with this mooring as well, but - based on an observation from ship's SSSG Croy Carlin that he could not hear the outgoing commands through the hull as well as he normally does - we began using higher power for the outgoing commands, which greatly improved the reliability of the responses from the releases. For the rest of the cruise, output power levels of at least -9 dB, and up to 0 dB, were used to communicate with the releases, which is a much higher power level than we normally use with the Benthos UDB9400 deck units (more typically we use power levels of -15 dB in quiet conditions and -12 dB in moderately noisy conditions). We did not ever come to a complete understanding of the problem, but suspect that the power output from the Benthos deck units through the junction box to the ship's transducers was less than normal, for unknown reasons. Using higher power levels for the rest of the cruise led to more reliable communication with the U. Miami mooring releases, even under noisier ambient conditions.

The same pattern of operations, a mooring turnaround during the day and CTD stations at night, was continued for the next two days, with the successful turnaround of mooring D3 on July 28th and mooring D2 on July 29th. The general strategy for the nighttime CTD work during the cruise was to try to work ahead of the mooring operations to the extent possible, so that comparison CTD and LADCP profiles could be acquired at the stations nearest the moorings before the mooring recoveries were accomplished.

Mooring D1 was successfully recovered on the morning of July 30th, however after its redeployment in the afternoon, it released from the bottom just after its triangulation survey was completed. The reasons for this unexpected release are unclear, but it appears that one of the acoustic releases mis-interpreted a "disable" command - sent to it to put it into sleep mode - as a release command. The mooring was immediately recovered in late afternoon of July 30th, using the backup TSE winch, since we were unable to hook into the bottom of the mooring to recover it in reverse order, which would have otherwise allowed it to be spooled directly onto the Lebus winch for redeployment. Since the recovered mooring wire would have to be respooled in reverse order prior to redeployment, and the wire also needed to be inspected for any damage that occurred during the recovery (due to various tangles), it was decided to proceed with the mooring turnaround operations at U. Miami mooring M1 the next day and return to redeploy D1 at a later time.

Mooring M1 was successfully recovered on the morning of July 31st and redeployed the same afternoon. After completing several more CTD stations westward along the CTD line that night, it was decided to proceed with the recovery of NIOZ moorings IC4 and IC3 on the following day, so that instruments on those moorings that needed to be turned around for their redeployment could be brought on board for data download, post-recovery caldip, and servicing. The NIOZ team tested their IXSEA release deck unit with the ship’s transducer after the D1 recovery. The first deck unit did not generate a signal, neither on the ship's transducer or on its own hand-held transducer. The second deck unit worked with the hand-held transducer, but failed to work with the ship's transducer. Therefore it was decided to use the hand-held transducer, deployed over the side at the CTD deck. This worked well throughout the cruise, with all releases replying quickly and clearly. Mooring IC4 was successfully recovered on the morning of Aug. 1st, followed by the recovery of mooring IC3 that afternoon. A post-recovery caldip CTD with the microcats from both IC4 and IC3 was done at CTD032 at the location of IC3. Once those moorings were onboard, the U. Miami mooring team began respooling the recovered wire from mooring D1 back onto the Lebus winch so that D1 could be redeployed the following day. Apart from a few small nicks on the recovered D1 wire, which were repaired with sealant and self-vulcanizing tape, the recovered wire looked to be in sufficiently good shape for re-use.

Mooring D1 was finally redeployed on the morning of Aug. 2nd, using a spare anchor and spare set of acoustic releases, and this time stayed down after the mooring survey and the final release communications were completed. This concluded the mooring operations for the U. Miami team on the cruise.

NIOZ moorings IC4 and IC3 were successfully deployed on the morning and afternoon of Aug. 3, respectively. The NIOZ moorings used dyneema line instead of plastic coated steel cable for the first time. The shackles used to connect line pieces are quite large and some care must be taken that the paid out line does not get caught behind them as it comes off the spool. This had to be watched closely during the deployment of all moorings and will be taken up with the supplier. CTD's were continued during the night, and on the morning of Aug. 4th, NIOZ mooring IC2 was recovered, followed by recovery of mooring IC1 that afternoon. In order to provide time to download and prepare some of the recovered instruments on these mooring prior to their redeployment, additional CTDs were done during the night (including a caldip CTD for the recovered microcats at CTD039 at the location of IC1), and the redeployment of IC2 took place on the afternoon of Aug. 5th. Plans for CTD work during the night of Aug. 5th were interrupted by a failed CTD cast at station 042, which required two test casts (and re-termination of the CTD as well as replacement of a pigtail connector on the CTD) to fix, so that no CTD stations were completed during that night.

Mooring IC1 was successfully deployed on the morning of Aug. 6th. The design of the deployed IC1 was changed; additional current meters were added as backup above the ADCP because the ADCP had failed for unexplained reasons after one year. An Aquadopp on loan from U. Miami replaced a flooded NIOZ Aquadopp. The last NIOZ mooring, IC0, was recovered on the afternoon of Aug. 6th, and, due to a forecast for worsening conditions the following day, was redeployed during the evening of Aug. 6th after a remarkably fast turnaround of instruments by the NIOZ team. This concluded the mooring operations for the entire cruise. Following the deployment of IC0, the remaining 5 CTD stations along the line were completed (CTD's 042-046), two of which were performed as caldip CTD casts for post-calibration of all of the recovered SBE microcats from the U. Miami moorings and the two last microcats recovered from the IC0 mooring.

Due to the acceleration of the mooring work over the last part of the cruise and overall favorable weather conditions during the cruise, there was extra time to conduct science operations before transiting back to Reykjavik. Nearly a day of planned ship time was also saved by fewer CTD stations being occupied westward into the central Irminger Basin than initially planned, after it was learned that the following WHOI (Straneo/Pickart) cruise would perform CTD's all the way across the Irminger Basin from the crest of the Reykjanes Ridge, obviating the need to extend our section to "join up" with their CTD line in the western Irminger Basin. This extra time was used to perform an additional 21-station section farther north in the Iceland Basin across the Reykjanes Ridge near 60°N. The purpose of this section was to: (1) observe the Irminger Current farther downstream (northward) along the western flank of the Reykjanes Ridge where one of its cores is believed to branch offshore into the Irminger Basin, and (2) along the eastern side of the Ridge, to observe the deep flow and property structure of the Iceland-Scotland Overflow plume farther upstream in the Iceland Basin, prior to the point where models and our OSNAP observations suggest that it bifurcates into two branches as it crosses the OSNAP line. This section, dubbed the "RR North" section - consisting of CTD's 47-67 - was commenced at 1200 on Aug. 8th and completed at on 2110 on Aug. 10th.

This concluded the science operations for cruise AR69-02. The ship then steamed toward Rejkjavik, arriving off Rekjavik harbor at 0400 on Aug. 12, and completed docking by 1030. The cruise was 100% successful, and additional objectives were accomplished due to time saved in operations and generally favorable weather. The full ship track for the cruise is shown in Figure 1.

3. Scientific Personnel

Name	Position	Organization
Bill Johns	Ch. Sci.	RSMAS/ U. Miami
Eduardo Jardim	Technician	RSMAS/ U. Miami
Joseph Bretl	Technician	RSMAS/ U. Miami
Cedric Guigand	Technician	RSMAS/ U. Miami
Emma Worthington	Scientist	RSMAS/ U. Miami
Manish Devana	Student	RSMAS/ U. Miami
Leah Chomiak	Student	RSMAS/ U. Miami
Houraa Daher	Scientist	RSMAS/ U. Miami
Femke de Jong	Scientist	NIOZ
Leon Wuis	Technician	NIOZ
Toon Koopman	Technician	NIOZ
Nora Fried	Student	NIOZ
Elodie Duyck	Student	NIOZ
Aleksandr Fedorov	Student	NIOZ
Daan Reijnders	Student	Utrecht University

4. Cruise Operations

4.1 Mooring Operations

The moorings were mostly deployed and recovered using a Lebus double-capstan winch system that was provided by the UNOLS West Coast winch pool. This system allows separate wire reels to be loaded on an auxiliary spooler and fed into the main double capstan winch without having to pre-spool all the wire reels onto a traction winch before deployment, such as is required with commonly-used mooring winches such as the TSE winch. This saves considerable time in on-deck preparation for new mooring deployments and was an extremely valuable asset on the cruise.

All of the taut-wire moorings were deployed in traditional fashion by laying out the mooring components from top to bottom while steaming into the wind at approximately 1.0 - 1.5 kts and dropping the anchors at selected "fallback" distances from the target site depending on the length of the moorings and observed ocean currents at the deployment sites. Moorings were recovered by grapneling onto pickup lines at the tops of the moorings, usually from the starboard side of the vessel, and hauling in and sequentially removing mooring components from the top to the bottom of the moorings.

Most of the U. Miami moorings came with tangles, some of which were severe and required extra time to stop off extra multiple wire segments streaming aft and safely bring them aboard. This has been common in the mooring recoveries during OSNAP, where the moorings often come up in a tight cluster due to relatively weak currents, and the mooring elements begin to tangle with each other before we can get hooked onto the mooring and straighten it out. Swivels are not routinely used on the U. Miami moorings and their addition to the moorings could help to reduce this problem. The NIOZ moorings, owing to their design - which relies mainly one large float for buoyancy rather than the distributed flotation used on the U. Miami moorings, and also includes swivels on the moorings - came up with no tangles.

Mooring Recoveries

A total of 12 moorings were recovered on the cruise, at the locations listed in Tables 1 and 2 and shown in Figure 2.

Table 1. U.S. Mooring Recoveries (U. Miami)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
M1	M490	58° 52.31'	30° 31.85'	1710	31/07/2022
M2	M491	58° 02.21'	28° 01.19'	2370	27/07/2022
D1	M485	58° 44.83'	30° 07.01'	1740	30/07/2022
D2	M486	58° 32.00'	29° 27.63'	2513	29/07/2022
D3	M487	58° 18.37'	28° 49.10'	2180	28/07/2022
D4	M488	58° 00.57'	26° 58.12'	2680	26/07/2022
D5	M489	58° 00.24'	25° 40.49'	2705	25/07/2022

Table 2. Dutch Mooring Recoveries (NIOZ)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
IC0	IC0-5	59° 13.11'	35° 07.53'	2951	06/08/2022
IC1	IC1-5	59° 06.24'	33° 41.54'	2472	04/08/2022
IC2	IC2-5	59° 01.29'	32° 44.01'	1904	04/08/2022
IC3	IC3-5	58° 57.51'	31° 57.02'	1630	01/08/2022
IC4	IC4-5	58° 53.41'	31° 17.80’	1483	01/08/2022

Mooring Deployments

A total of 12 moorings were deployed at the locations listed in Tables 3 and 4 and shown in Figure 3. Acoustic surveying of the on-bottom position of the moorings was successfully completed after each mooring deployment.

Table 3. U.S. Mooring Deployments (U. Miami)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
M1	M497	58° 52.30'	30° 31.77'	1710	31/07/2022
M2	M498	58° 02.20'	28° 01.14'	2370	27/07/2022
D1	M492	58° 44.81'	30° 07.06'	1740	02/08/2022
D2	M493	58° 32.00'	29° 27.59'	2513	29/07/2022
D3	M494	58° 18.37'	28° 49.08'	2180	28/07/2022
D4	M495	58° 00.56'	26° 58.25'	2680	26/07/2022
D5	M496	58° 00.36'	25° 40.78'	2705	25/07/2022

Table 4. Dutch Mooring Deployments (NIOZ)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
IC0	IC0-6	59° 13.19'	35° 07.32'	2948	06/08/2022
IC1	IC1-6	59° 06.20'	33° 41.09'	2505	06/08/2022
IC2	IC2-6	59° 01.30'	32° 43.61'	1879	05/08/2022
IC3	IC3-6	58° 57.44'	31° 57.08'	1637	03/08/2022
IC4	IC4-6	58° 53.47'	31° 17.86’	1470	03/08/2022

4.2 CTD/LADCP Stations and Water Sampling

A total of 67 CTD/LADCP stations were conducted during the cruise (Table 5, Figure 4). At each station, profiles of temperature, salinity (conductivity), dissolved oxygen concentration, fluorescence, turbidity, and light transmission/attenuation were collected from the surface to within approximately 20 m of the bottom, using a Sea-Bird SBE-911plus CTD system. A Sonardyne altimeter was used to detect the bottom and worked very reliably throughout the cruise with a typical range of acquisition of the bottom of 90-100 m. Ten of the CTD stations were "caldip" casts to provide calibration data for SBE micro-cat instruments to be deployed on, and recovered from, the moorings. During these casts, microcats were securely attached to straps on the CTD frame and the CTD package was lowered to its target depth, with 5-10 minute bottle stops during the package retrieval. These casts are indicated by an asterisk (*) in Table 5.

Water samples for calibration of the salinity were collected using a 24-bottle Rosette system containing 10 liter Niskin bottles. Only 12 bottles were used and so bottles 13-24 were removed from the package. For most of the deep stations (>2500 m) where samples were drawn, 12 bottle samples were collected, whereas on shallower casts the number of bottles was reduced to 8. As the cruise progressed, and a base calibration for the CTD salinity sensors was established using the already measured bottle samples, bottles were fired only on every other cast to save time and lessen the load of running the salinity samples on the ship's Autosal.

The salinity samples drawn from each of the fired bottles were analyzed on a Guildline Autosal salinometer, standardized with IAPSO standard seawater (Batch P165, 35.994 psu, K_{15}= 0.99986). Calibration checks with the same batch of standard seawater were done prior to and after each Autosal run, which typically consisted of 1-2 cases of salinity bottles (24-48 samples). The Autosal remained in perfect calibration (within 0.001 psu based on the calibration checks) for the entire cruise. A problem occurred with the sampled salinities early in the cruise where it was found that a number of samples were reading high compared to the corresponding CTD salinities. After discounting other possibilities, it was concluded that salt crystals from the threads of the bottle cap were being introduced into the bottles as the caps were unscrewed, just before inserting the bottles into the Autosal. The problem appeared to be more severe for salt cases that were left sitting for several days before being run, the theory being that this allowed more time for the seawater trapped in the threads to evaporate and form crystals. From that point onward, rubber seals (the cut-off fingers of vinyl gloves) were used to seal each bottle before screwing on the caps, which solved the problem and resulted in consistent bottle-CTD comparisons for the remainder of the cruise.

The CTD package included dual temperature and conductivity sensors, and single sensors for the rest of the variables. All of the sensors performed consistently throughout the cruise and none were swapped out. However, fouling of the primary temperature and conductivity channel occurred on CTD 040, probably by biological material that plugged up the pumping/venting system, and resulted in bad data for the primary T and C data over approximately the top 70 m. This persisted through CTD 049, after which the problem was finally cleared, and CTDs 050 and onward showed good data for the primary T and C channel. The secondary T and C sensors were unaffected by this fouling. Preliminary calibrations of the both the primary and secondary conductivity sensors showed that they had stable behavior and consistent offsets of 0.002-0.003 psu with respect to bottle salinity samples, which should result in a relatively straightforward final CTD salinity calibration after the cruise.

Current profiles were measured at the stations using a dual (paired upward and downward-looking) 300 kHz Workhorse Acoustic Doppler Current Profiling system (LADCP). The LADCP system was provided by Woods Hole (configured and installed by D. Torres); both 300 kHz ADCPs worked very reliably throughout the cruise. The LADCP data was processed using version IX_13 of the LDEO LADCP MATLAB processing toolbox maintained by M. Visbeck & A. Thurnherr. Details of the LADCP operations can be found in Appendix 1.

The CTD and LADCP operations went very smoothly throughout the cruise, and the Markey Launch and Recovery System ("LARS") used handle the CTD package made the overboarding process very simple and safe for the deck personnel, in addition allowing CTD casts to be safely performed in rougher sea conditions when manual handling would have been tenuous.

Table 5. CTD/LADCP Station Information

CTD Number	Date time	Latitude N		Longitude W		Max Press.	Depth
	UTC	deg	min	deg	min	dbar	m
001⁺	Jul 22 2022 20:26:55	62	55.96	22	57.64	1013	1018
002*	Jul 23 2022 18:14:36	59	14.73	24	08.63	2686	2667
003*	Jul 24 2022 08:25:21	57	57.60	24	29.42	2849	2827
004*	Jul 24 2022 14:06:51	57	57.50	25	07.24	2776	2750
005*	Jul 24 2022 19:47:43	57	57.57	25	44.95	2760	2740
006	Jul 24 2022 23:57:34	57	57.53	26	04.42	2819	2793
007	Jul 25 2022 19:38:10	57	57.58	26	22.73	2849	2826
008	Jul 25 2022 23:05:13	57	57.60	26	42.22	2761	2745
009	Jul 26 2022 02:27:14	57	57.60	27	00.47	2689	2674
010	Jul 26 2022 05:34:30	57	58.04	27	17.81	2420	2406
011	Jul 26 2022 18:27:32	57	58.65	27	33.87	2274	2257
012	Jul 26 2022 21:14:50	57	59.30	27	50.42	2397	2390
013	Jul 27 2022 00:14:11	57	59.70	28	04.38	2424	2410
014	Jul 27 2022 03:04:52	58	05.03	28	20.39	2315	2303
015	Jul 27 2022 20:39:07	58	10.44	28	37.17	2321	2306
016	Jul 27 2022 23:15:49	58	15.74	28	53.21	2193	2178
017	Jul 28 2022 02:06:10	58	20.10	29	05.48	2182	2169
018	Jul 28 2022 18:38:09	58	24.75	29	19.06	1837	1946
019*	Jul 28 2022 20:34:00	58	27.60	29	27.72	2375	2353
020	Jul 28 2022 23:39:55	58	29.39	29	32.21	2528	2520

021	Jul 29 2022 01:52:49	58	30.04	29	34.90	2439	2510
022	Jul 29 2022 18:35:15	58	33.39	29	44.11	2021	2012
023	Jul 29 2022 21:14:25	58	37.64	29	56.88	1999	1985
024	Jul 29 2022 23:34:40	58	42.02	30	10.34	1715	1726
025	Jul 30 2022 19:59:29	58	45.77	30	21.96	1622	1622
026	Jul 30 2022 22:04:13	58	49.84	30	34.68	1653	1654
027	Jul 31 2022 00:25:52	58	50.21	30	48.26	1470	1470
028	Jul 31 2022 18:34:21	58	50.54	31	02.20	1525	1538
029	Jul 31 2022 20:46:50	58	50.94	31	15.97	1459	1455
030	Jul 31 2022 22:41:15	58	52.31	31	29.64	1518	1514
031	Aug 01 2022 00:54:18	58	53.74	31	43.34	1634	1630
032*	Aug 01 2022 15:48:11	58	55.13	31	57.14	1775	1768
033	Aug 02 2022 19:24:54	58	56.68	32	12.67	1493	1494
034	Aug 02 2022 21:30:10	58	58.20	32	27.90	1868	1864
035	Aug 02 2022 23:57:13	58	59.70	32	42.11	1858	1861
036	Aug 04 2022 00:50:33	59	01.40	32	58.44	2175	2171
037	Aug 04 2022 03:58:46	59	02.91	33	14.04	2162	2151
038	Aug 04 2022 16:42:27	59	04.47	33	29.60	2252	2242
039*	Aug 04 2022 19:46:50	59	06.09	33	45.10	2158	2168
040	Aug 05 2022 00:12:57	59	07.71	34	00.96	2815	2780
041	Aug 05 2022 03:28:47	59	09.37	34	17.55	2612	2588
042*	Aug 07 2022 00:47:53	59	11.01	34	33.73	2859	2829
043	Aug 07 2022 05:14:09	59	12.71	34	49.85	2503	2502
044*	Aug 07 2022 08:54:06	59	14.61	35	06.81	3052	3029
045	Aug 07 2022 13:33:15	59	15.97	35	22.34	2995	2985
046	Aug 07 2022 18:20:10	59	16.85	35	40.58	3115	3087
047	Aug 08 2022 12:07:44	61	08.24	32	20.88	2573	2549
048	Aug 08 2022 15:23:40	61	05.03	31	56.96	2428	2411
049*	Aug 08 2022 18:22:16	61	01.60	31	33.31	2449	2444
050	Aug 08 2022 21:48:59	60	58.45	31	09.81	2211	2196
051	Aug 09 2022 00:51:14	60	55.37	30	45.95	2049	2038
052	Aug 09 2022 03:57:54	60	52.11	30	22.24	1705	1702
053	Aug 09 2022 06:32:04	60	48.89	29	58.63	1705	1700
054	Aug 09 2022 09:20:20	60	45.69	29	34.98	1545	1539
055	Aug 09 2022 11:56:52	60	42.40	29	11.39	1448	1438
056	Aug 09 2022 15:00:24	60	39.21	28	47.61	1017	1020
057	Aug 09 2022 17:15:59	60	35.88	28	23.96	1006	1018
058	Aug 09 2022 19:26:29	60	29.50	28	06.57	1517	1520
059	Aug 09 2022 21:43:44	60	23.21	27	48.93	1374	1373
060	Aug 10 2022 00:03:52	60	17.24	27	31.57	1649	1644
061	Aug 10 2022 02:35:58	60	10.96	27	14.51	1731	1736
062	Aug 10 2022 05:13:37	60	04.96	26	58.00	2039	2041

063	Aug 10 2022 07:44:33	59	59.15	26	41.94	2006	2007
064	Aug 10 2022 10:22:10	59	53.66	26	27.06	2315	2300
065	Aug 10 2022 13:15:04	59	46.30	26	08.25	2118	2107
066	Aug 10 2022 16:15:34	59	39.71	25	49.79	2428	2408
067	Aug 10 2022 19:28:27	59	32.43	25	30.25	2487	2464

+ Test cast
* Instrument calibration casts

4.3 Underway Measurements

Thermosalinograph

Values of surface temperature and salinity were continuously monitored using a Sea-Bird TSG system (including SBE45 and SBE48 temperature sensors and SBE45 salinity sensor) installed in the ship's seawater intake line, and logged by the vessel's underway recording system.

Shipboard Acoustic Doppler Current Profiler

Upper ocean currents were continuously measured with the triple vessel-mounted Acoustic Doppler Current Profiler (ADCP) system installed on the R/V Armstrong, consisting of a 300 kHz Workhorse VM ADCP and 150kHz and 38 kHz Ocean Surveyor systems. All systems provided good data to their nominal working depths with the OS38 system preforming particularly well and often providing good data to 1200 m. However, in heavier sea state conditions the range and quality of the OS38 system in particular was significantly reduced. Data were first-pass processed onboard in real time using the UHDAS acquisition system. Gyrocompass data were continuously corrected by a POS-MV inertial navigation system.

5. Preliminary Results

The CTD/LADCP section across the OSNAP line displays deep reaching banded circulation patterns from the eastern end of the section in the Iceland Basin to the eastern flank of the Reykjanes Ridge (Figs. 4 and 5). Upper ocean temperature and salinity observations show a relatively cold, fresh core of flow at ~26° W dominated by south-westward flow that is likely recirculating Subpolar Mode Water. At mid-depths (1000-1600 m) in the Iceland Basin we observe cold, fresh Labrador Sea Water that diminishes along the western ridge flank. To the west, upper ocean salinity and temperature increased in the upper 500 meters over the ridge flank where the East Reykjanes Ridge Current is typically located (31-29 °W). The banded velocity observations in this region suggest anti-cyclonic eddy activity or meandering flow may be dominating during the observation period. Sea surface height across this portion of the section (Fig.7) shows evidence for both a local anticyclone and south-westward flow turning northeast to cross the ridge axis and join the Irminger Current. Both features could be responsible for the banded velocity structure seen in the upper ocean from the LADCP.

On the western side of the ridge the upper ocean is notably colder and fresher than the eastern side. The interior here also shows a thick layer of cold, fresh mid-depth waters, similar to the Iceland Basin. Immediately west of the ridge axis we observe strong northward flow from the Irminger current between 32-31°W. Further to the west, the upper ocean flow is dominated by a large core of eastward flow between 34-32°W. The elevated easterly flow is associated with elevated sea surface height, indicating either an anticyclone or significant meandering of the flow. Temperature and salinity are both notably elevated through the upper 500 meters in the same region.

In the deep layers on the eastern flank of the ridge, the Iceland Scotland Overflow Water (ISOW) layer is clearly shown with its characteristic bottom intensified salinity signal. The ISOW salinities are highest along the ridge flank and weaken slightly towards the interior of the basin. Bottom enhanced south-westward flow in the ISOW layer is observed primarily in 3 cores: one at the base of the ridge flank near 26°W, one within the rift valley where the D2 mooring is located (29.5°W), and one higher up along the flank near 30°W. The flow at the base of the ridge is the strongest ISOW flow observed in this section. This flow appears linked to the locally strong southward upper ocean flow. Between the cores along the ridge flank (29-28°W) the bottom flow is weakly northward with localized stronger flow near larger topographic features.

On the western side of the ridge, bottom salinity in the ISOW layer is also elevated but to a lesser degree than on the eastern flank. This indicates that ISOW has likely become more diluted and as it crossed through gaps in the ridge. Bottom velocities here do not show a strong ISOW flow. Instead, we observe upper ocean velocities diminishing with depth and no clear bottom enhanced branches of ISOW.

The northern section completed across the Reykjanes Ridge shows similar hydrographic structure to the main OSNAP section. Warmer, saltier upper ocean waters are found on the eastern flank and colder, fresher waters along the western flank. The ISOW salinity signal is also stronger on the eastern flank than the western flank. The velocity observations show a strong barotropic Irminger Current flow on the western flank of the ridge. On the eastern flank the upper ocean velocities show banded structure similar to the OSNAP line but weaker in magnitude. Bottom velocities on the eastern flank show three bottom enhanced branches of ISOW flow with the strongest velocities found farthest to the east near 25.6°W.

6. Compliance with consent to perform research in foreign waters

In accordance with the provisions specified in the cruise prospectus and application for Icelandic research clearance, a report summarizing the results of the research conducted on cruise AR69-02 will be provided to the Icelandic Ministry of Foreign Affairs within 6 months of the termination of the cruise.

7. Acknowledgements

The support and able assistance provided by the Captain and crew of the R/V Neil Armstrong is gratefully acknowledged. Support for the scientific research was provided by the U.S. National Science Foundation under grants OCE1756231 and OCE1948198. The NIOZ contribution to OSNAP is financially supported by the Innovational Research Incentives Scheme of the Netherlands Organisation for Scientific Research (NWO) under grant agreement nos. 016.Vidi.189.130 “From ice to ocean; where does the freshwater go” and by UU-NIOZ grant “The Impact of atmospheric noise on the Atlantic Meridional Overturning Circulation”.

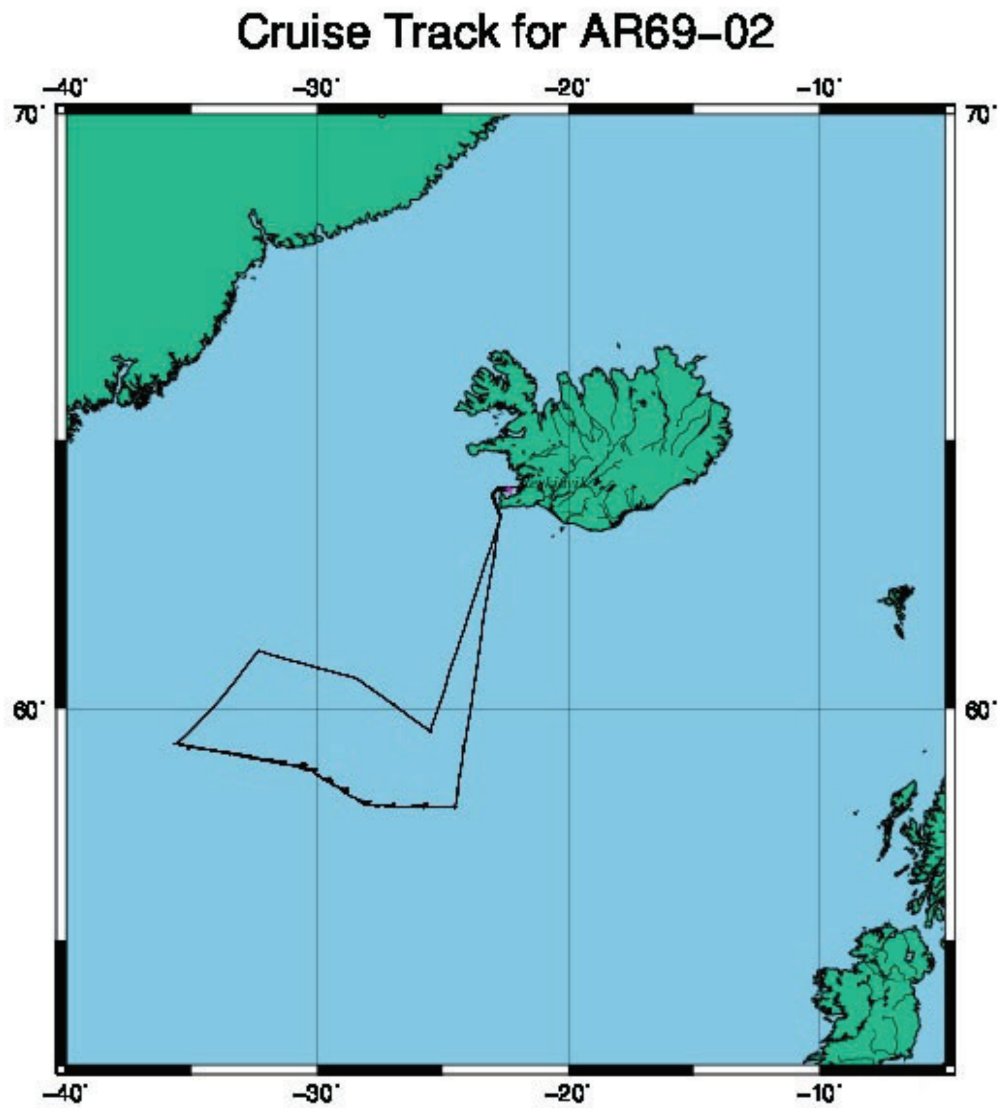

Figure 1. Cruise track for AR69-02.

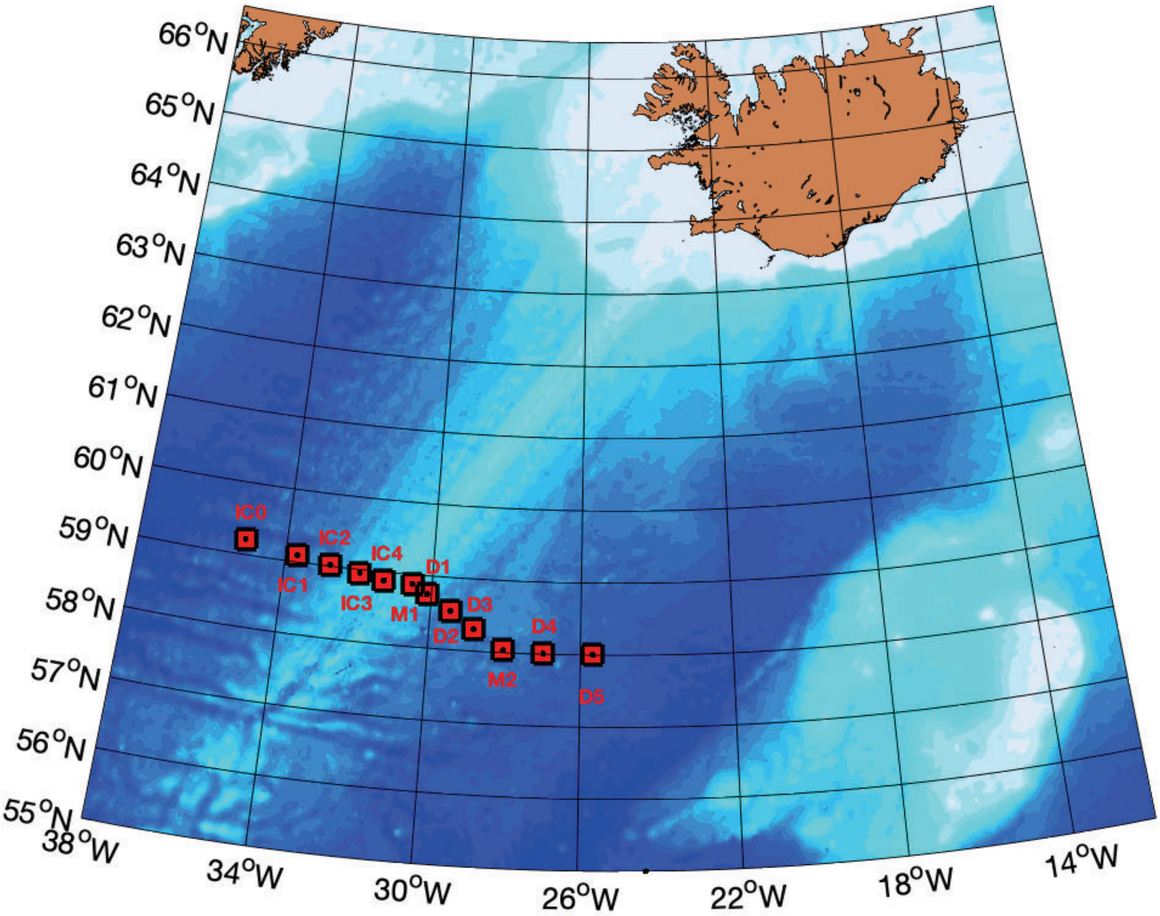

Figure 2. Current meter moorings serviced (recovered and redeployed) on AR69-02.

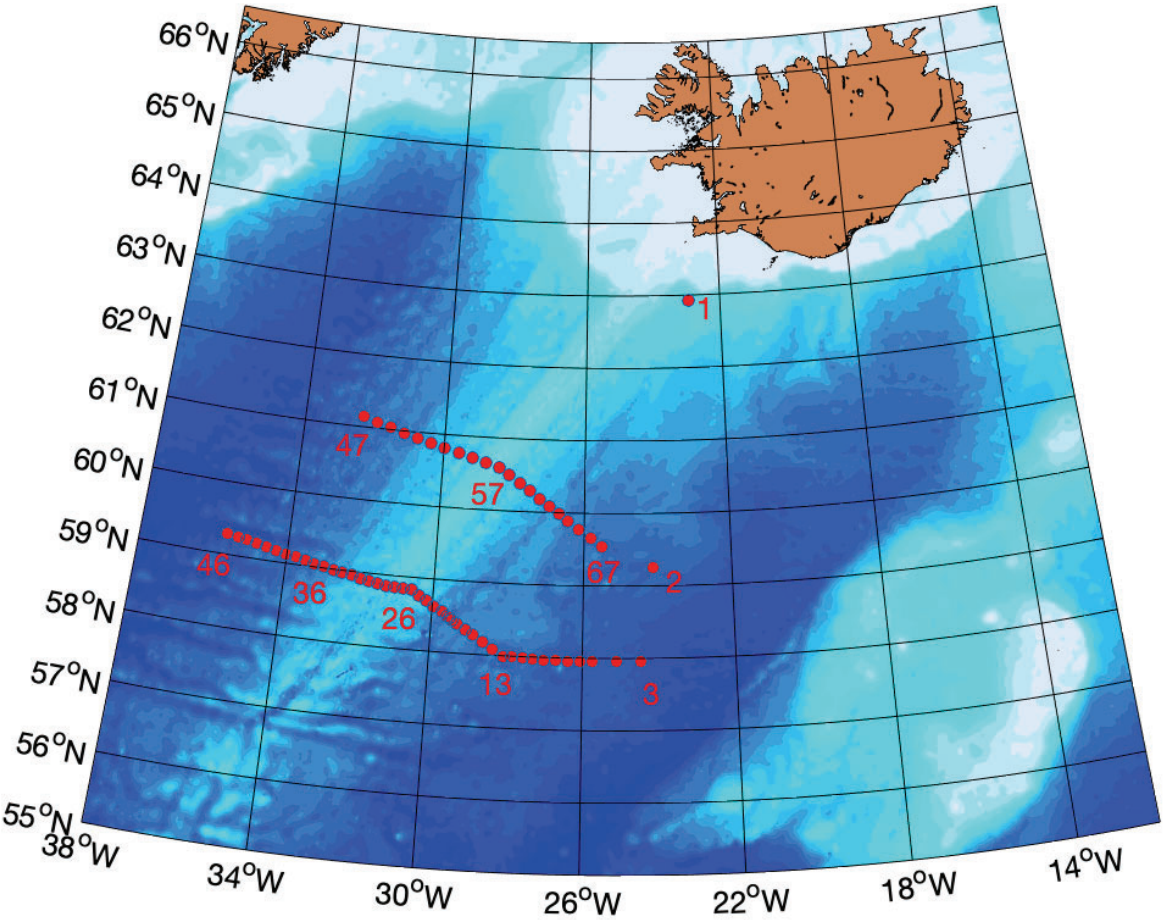

Figure 3. CTD/LADCP station occupied during AR69-02. Station numbers are indicated for selected stations along the track.

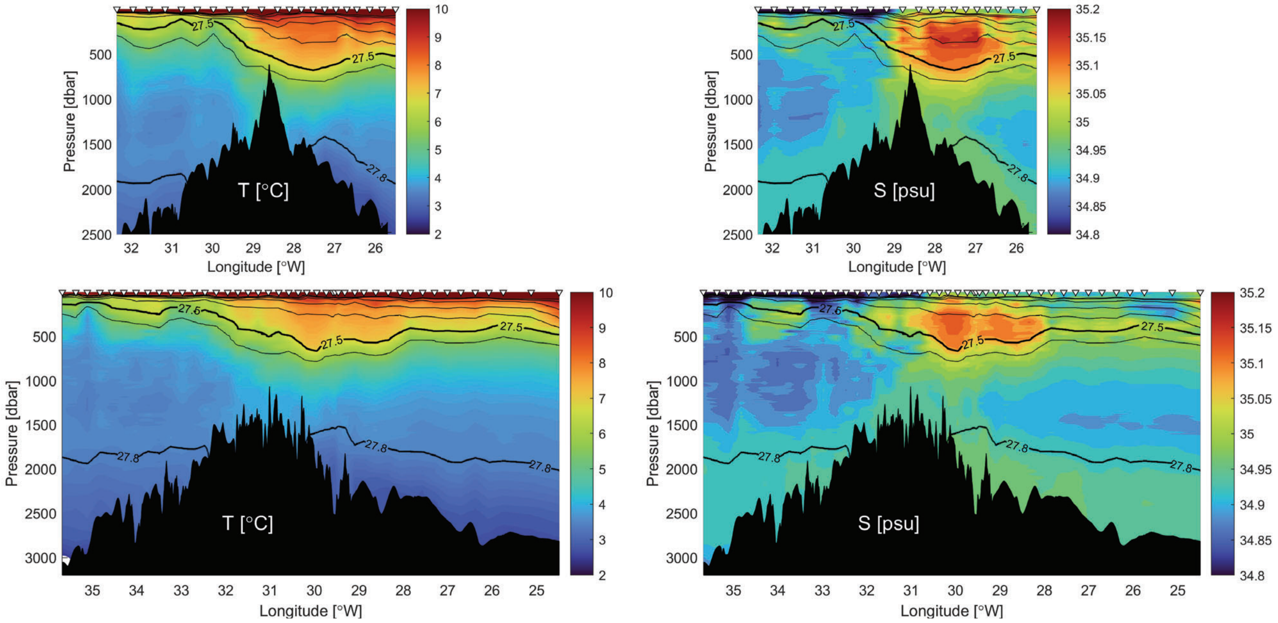

Figure 4. Sections of temperature and salinity (with sigma-theta in black contours) for the main CTD line (lower panels), and for the northern section across the Reykjanes Ridge (upper panels).

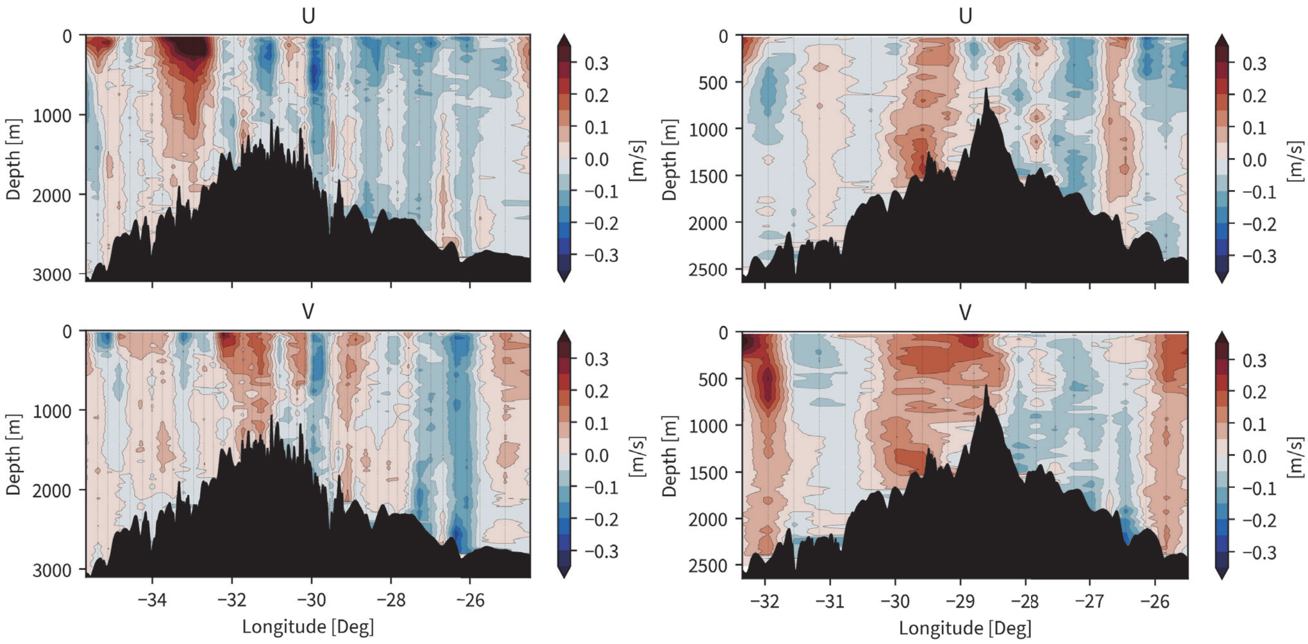

Figure 5. Absolute velocity section from LADCP data along the main CTD section (left), and along the northern line (right), with density (sigma-theta) surfaces from the preliminary CTD data overlain: zonal velocity (top) and meridional velocity (bottom).

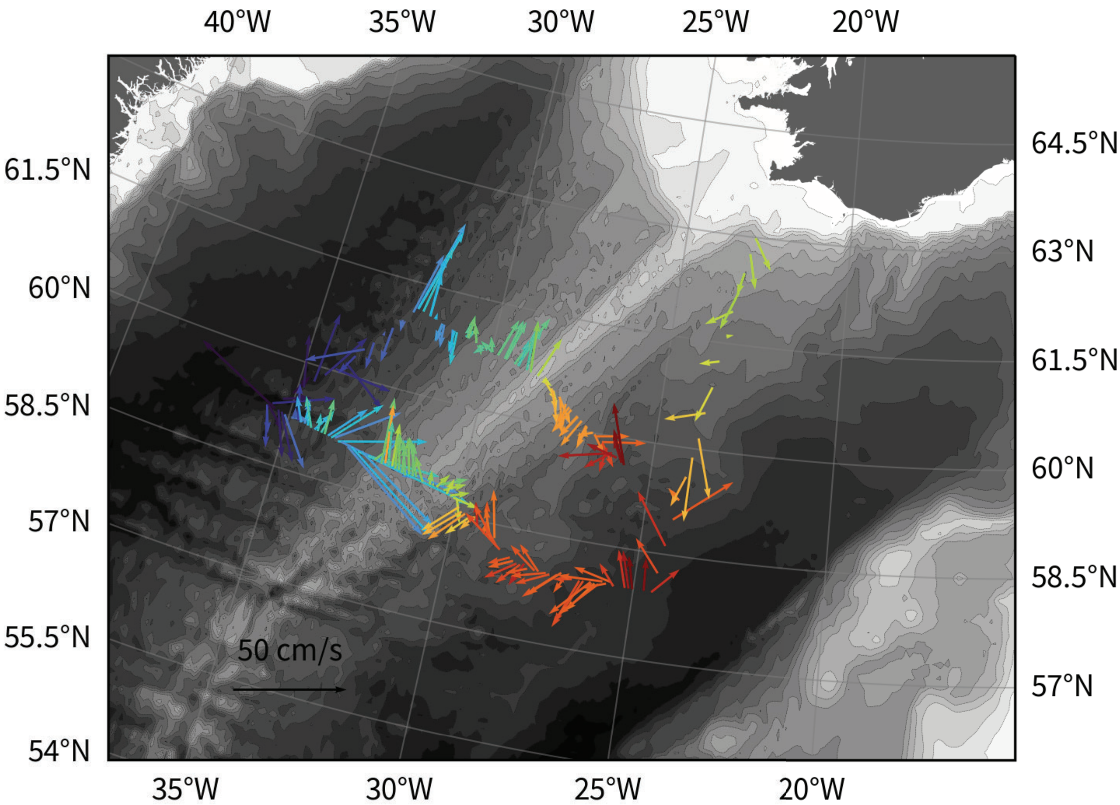

Figure 6. Near-surface velocity vectors derived from OS38 shipboard ADCP data along the cruise track. Surface temperatures are indicated by the color of the current vectors.

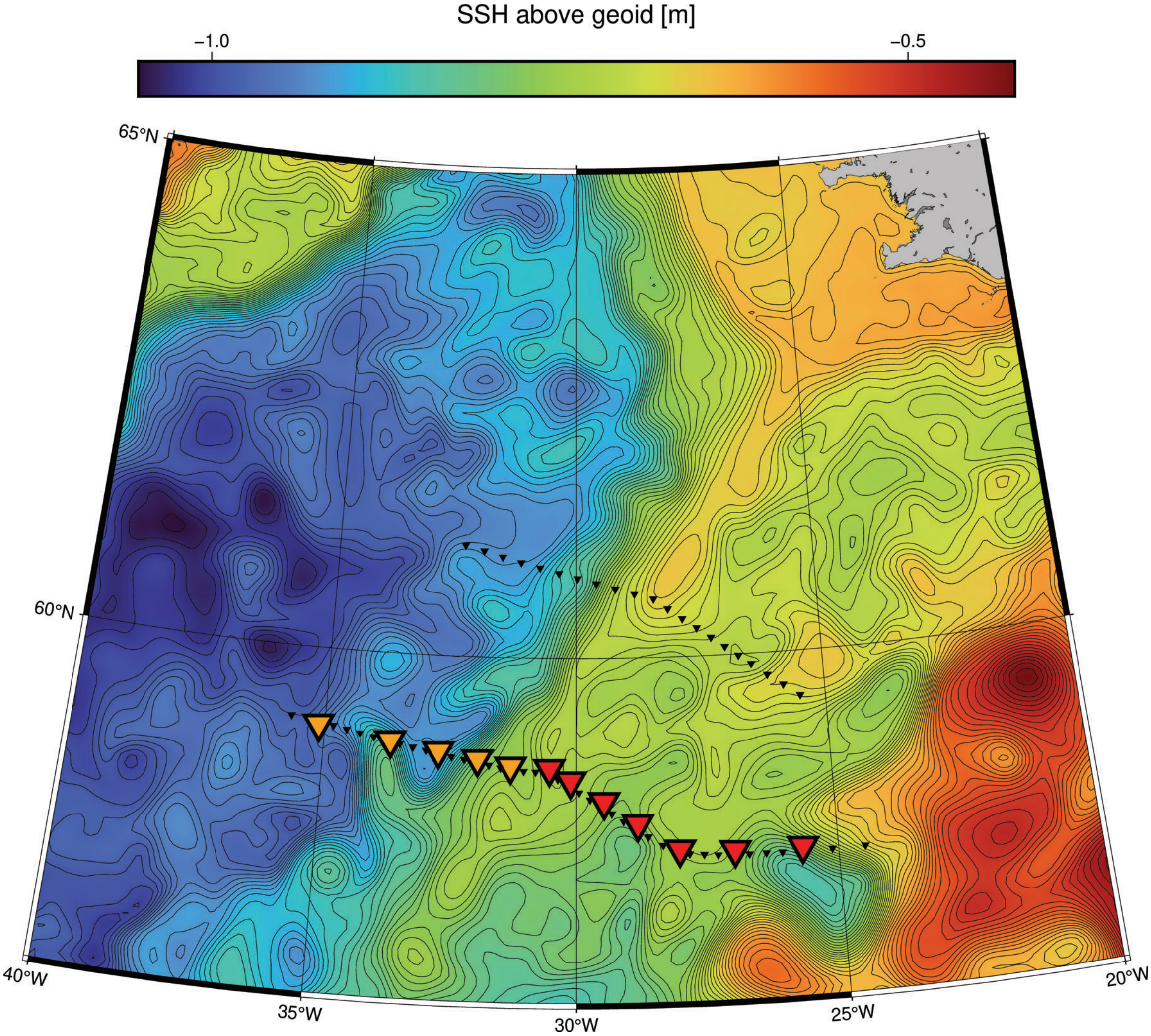

Figure 7. Map of sea surface height above the geoid from the Mercator 1/12° analysis and forecast model for Aug. 1st, 2022, about midway through the cruise (obtained from the Copernicus Marine Environment Monitoring Service, http://marine.copernicus.eu). The locations of CTD stations along the cruise track are shown by small symbols; large symbols show the mooring locations (red: U. Miami; orange: NIOZ).

Appendix 1. Lowered ADCP Operations, AR69-02

LADCP Setup:
Full water column velocity profiles were collected using a dual 300kHz Workhorse master/slave configuration. Most of the instruments, cables, and related equipment were supplied by Dan Torres of Woods Hole Oceanographic Institution, with spare star-cables supplied by U. Miami. The primary downward-looking 300 kHz ADCP was S/N 10417 and the primary upward-looking 300 kHz ADCP was S/N 4896. Three custom-made 48-volt deep-sea batteries were supplied by WHOI as well. The two Workhorse ADCPs were mounted on a 24-bottle CTD rosette, with mounting brackets for the ADCPs and battery provided by WHOI (see Fig. A1). The upward-looking ADCP was mounted on the outer edge of the rosette, situated above the upper rim of the frame. The downward-looking ADCP was mounted offset from the center of the frame adjacent to the SBE9 CTD. The sea-battery was secured to the side opposite the downward-looking ADCP using brackets bolted to the bottom of the rosette frame. Both ADCP's were wired to run off a single battery pack using the supplied star-cable.

Data Acquisition Setup:
The ADCPs were configured for narrowband mode, with 25 10-meter bins, 1.5 second, staggered single-ping ensembles, and an ambiguity velocity of 300 cm s^{-1}. Measurements were saved in beam coordinates, with 3-beam solutions and bin-mapping disabled. The upward looking ADCP blanking distance was set to 8 meters, and the lower set to 4 meters. Inside the wet lab of the Armstrong, a dedicated PC running Ubuntu Linux with dual serial ports was set up as the primary data acquisition platform. A dual-terminal program written in Python, part of the UH-DAS ADCP software was used to communicate with the instruments. Data files downloaded to the acquisition PC were transferred to another laptop via shared network drive for processing and archiving. An Amrel LPS-305 power supply was used as the primary battery charger. The supply was programmed to output a constant 56 Volts (+/- 28V) with a variable current limited to 1.6 Amperes. Two long ADCP power/communication cables were set up to program the instruments and download data. The charger was connected to one of these cables.

Deployment and Recovery:
The LADCP deployment procedure was as follows:

- About 10 minutes prior to arrival on station, the LADCP operator wakes up the two ADCPs using the UHDAS terminal program and shut off the battery charger.
- Internal clock, memory and instrument voltage check are made. Clocks are synchronized to the ship's GPS.
- The appropriate command file is then sent to the instrument to initiate sampling. The output from this operation is captured to a log-file.
- Once the 'cs' command was sent, the operator would listen for audible 'pings' from both ADCPs to verify operation.
- The operator would then disconnect the two serial cables, and insert the dummy plugs.

Upon the safe recovery of the rosette the operator would begin the recovery procedure:

- Once the rosette is secured on deck, the operator connects the two serial cables to the instruments. The 'break' command is sent to halt pinging and close out the data files.
- The battery charger is powered on as soon as possible to maximize the time available for charging.
- The recovery initialization process is run on both ADCPs, The most recent good data file is transferred to a temporary cruise directory on the acquisition computer.
- The operator copies the downloaded data files to a separate folder, labeled by station number. The files are renamed here using the cruise convention: 'ar692_dn_nnn.dat' or 'ar692_up_nnn.dat' where 'nnn' is the station number.
- The baud rates are changed back to 9600 and the ADCPs are powered down.

Data Processing:
The two raw ADCP data files were first copied form the LADCP acquistion computer to a "ladcp" subdirectory in the "science share" folder on the ship's server, which was set up to be done automatically by the ship's server by having it sync (every 10 minutes) to the LADCP acquisition computer. These files were then copied from the ship's server down to a dedicated laptop for processing the LADCP casts, and manually renamed to add the cruise ID (os2207) to the filenames and strip off the file suffix (.e.g., the file "dn003_01.dat" copied from the server would be renamed to "os2207dn_003.dat", and the same for the "up" file from that cast).

The raw CTD data files for the cast were also manually copied down from ship's server (from "data_on_memory/ctd") and a script was run on the LADCP processing computer (called "osnap_batch_proc") that generates 1 dbar and 1 Hz versions of the CTD files that would be used in the LADCP cast processing. After completing these steps, each LADCP cast was processed in Matlab using the script "process_cast.m" (which has its data paths and other parameters set by the script "set_cast_params.m"), and by default is also configured to pull in the shipboard 38 kHz ADCP velocity profiles collected by the ship's UHDAS system to use in the "2nd pass" processing of the LADCP casts. (An option to process the casts without using the ships ADCP data, referred to as "1st pass" processing, can also be implemented by using the script "process_cast_no_SADCP".)

The processing of the LADCP casts was done using version IX_13 of the LDEO LADCP MATLAB processing toolbox maintained by M. Visbeck & A. Thurnherr. The 'process_cast(nnn)' script was run, with 'nnn' representing the station number, which calls subroutines to copy, load, scan in, and run the shear and least-squares inverse methods. About a dozen graphics are generated with useful diagnostic information and the final water column profile. The main processing script used the scripts loadnav_aeh.m and loadctd_aeh.m scripts, which call the load_sbe9_aeh.m function, to read in the 1-Hz bin-averaged CTD timeseries which includes latitude and longitude information. The file 'set_cast_params.m' was modified to specify the correct file naming convention and locations of the raw data. Additionally, in order to apply the proper magnetic declination, the processing code had to be altered to use the "older" magdev routine, rather than the newer function, referred to as 'magdec'. The reason for this change was that the magdec function is provided in the LDEO package as un-compiled code, and not an executable function. While it would have been a simple matter to compile the code on a Linux-based system, the processing computer was Windows-based, and therefore without the means to compile code. The processing code was set to generate final profiles with 20-meter bins.

The dual 300 kHz ADCPs performed very well during the cruise, with no serious communication or power issues. In total, 100 full-depth profiles were collected. The total combined profile range regularly exceeded 300m on any given cast, and the final error velocities were typically <5 cm/s.

The command files used for the upward and downward looking 300 kHz ADCPs on the CTD package were as follows:

wh300_dn_cmd	**wh300_up_cmd**
CR1	CR1
WM15	WM15
TC2	TC2
TB 00:00:01.30	TB 00:00:01.30
TE 00:00:00.80	TE 00:00:00.80
TP 00:00.00	TP 00:00.00
WP1	WP1
WN22	WN22
WS800	WS0800
WF0000	WF0000
WV300	WV300
EZ0011101	EZ0011101
EX00100	EX00100
CF11101	CF11101
RN _RDI_	RN _RDI_
LZ30,230	SM2
SM1	SA011
SA011	SS0
SW05000	ST0
CL0	CL0
CS	CS

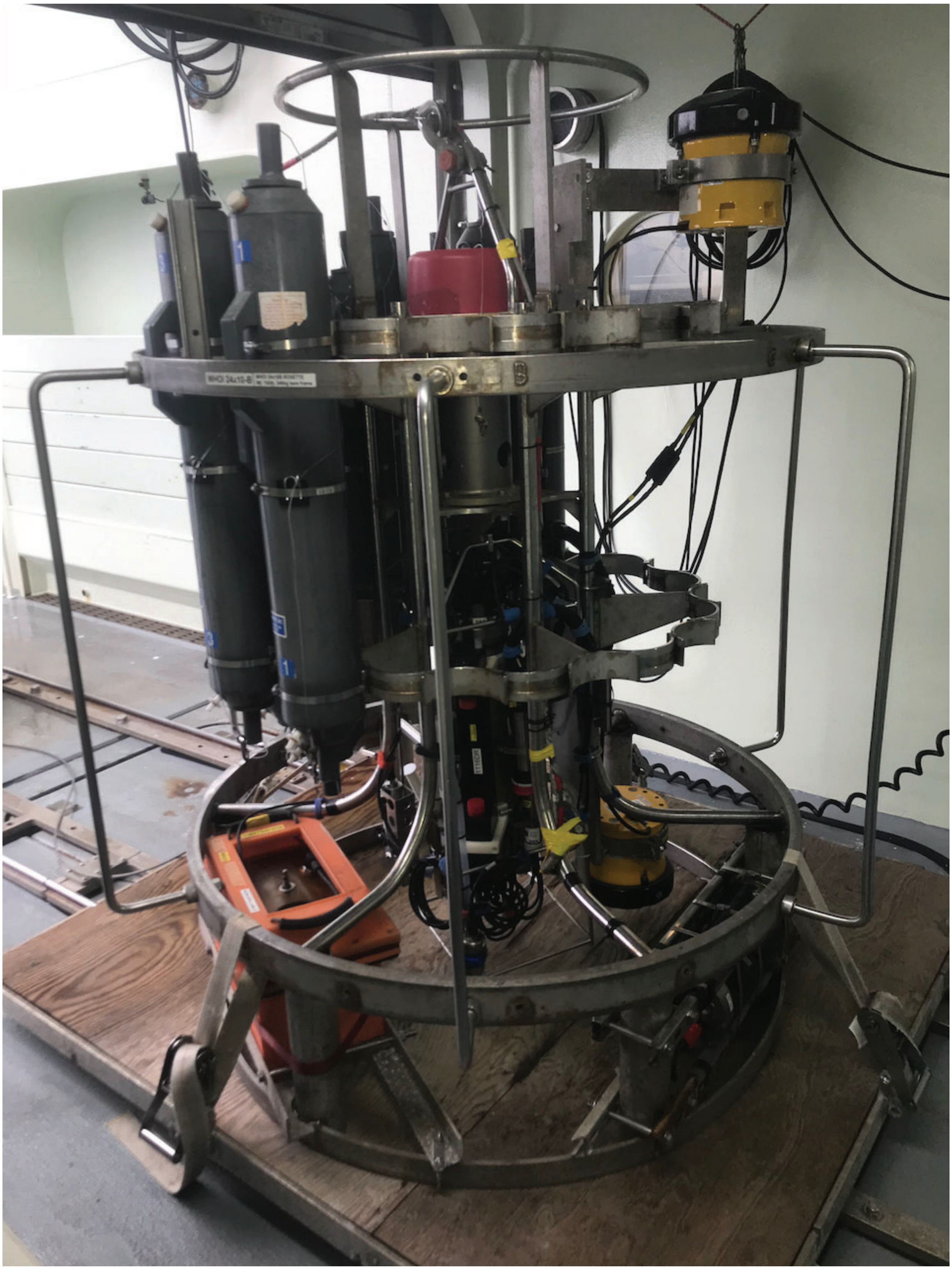

Figure A1. The CTD rosette aboard the R/V Neil Armstrong, showing the configuration of the dual 300 kHz lowered ADCPs.