PRELIMINARY CRUISE REPORT

***R/V Knorr* Cruise KN-221-2**

OSNAP Program
July 6 – July 30, 2014
Reykjavik, Iceland to Reykjavik, Iceland

1. Introduction and Objectives

The Overturning in the Subpolar North Atlantic Program (OSNAP) program 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 with scientists from several nations, including the U.S., U.K., the Netherlands, Germany, France, and Canada. The OSNAP observing system consists of two legs: one extending from southern Labrador to the southwestern tip of Greenland across the mouth 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 KN221-2 was the first cruise to set out the observing system along OSNAP-East. Scientists from the U.S., the U.K., and the Netherlands participated in the cruise. The moorings that were deployed on this cruise will be serviced at 1-2 year intervals through 2018.

The specific objectives of cruise KN-221-2 were to:

1. Deploy 20 current meter and sound source moorings along the OSNAP East line, from west of the Reykjanes Ridge to the coast of Scotland.
2. Conduct standard CTD (Conductivity-Temperature-Depth) and Lowered ADCP (Acoustic Doppler Current Profiler) stations at selected sites along the same mooring line.
3. Launch an array of acoustically tracked RAFOS floats at selected sites near the mooring line, and
4. Deploy an autonomous glider off Hatton Bank at the eastern end of the Iceland basin.

2. Cruise Synopsis

The cruise departed from Reykjavik, Iceland at 0900 UTC on July 6. (All times listed in the remainder of this report are in UTC, which is also the time zone used for local time onboard the ship for the duration of the cruise.) The ship arrived at the first station, a test cast for the CTD/LADCP profiling system (CTD000), at 1241 on July 7. The CTD was lowered to 1000 m and all the Niskin bottles on the rosette sampler were fired at that depth. Once retrieved, the bottled were inspected for leaks, duplicate salinity samples were drawn by all the watch standers that would be drawing salt samples on the cruise, and the CTD sensors and LADCP were checked for functionality. The next CTD station (CTD001) was done on July 7 near 61°N, 35.5°W, which was one of five calibration casts done on the cruise (called "cal-dip" casts) for the many SeaBird Micro-cat instruments that were to be deployed on the moorings. On these casts, straps are added to the CTD frame that the Micro-cats can be mounted on, and the CTD cast is performed in normal fashion except that the bottle stops on the upcast are 5 minutes long. The temperature, conductivity and pressure measurements from the micro-cat and the SBE911 CTD are then compared during the bottle stops to check the calibration of the Micro-cats. Up to 18 Micro-cats were mounted on the CTD for each of these casts, and on some of the cal-dip casts acoustic releases were also sent down to be tested at depth.

The first mooring to be deployed was site IC0 (Table 1) at the western end of the Dutch Irminger Current array, on July 8. This was followed by three more cal-dip casts (CTD's 002-004) near the site of IC0, where depths >3000 m allowed for a full range of depths for testing the Micro-cats. At mooing IC0, and subsequent moorings, the Seabeam system on the R/V Knorr was used to help pick the best bottom locations for the moorings, which was extremely useful in the very rough topography around the Reykjanes Ridge. The expected depths at the mooring locations had been determined prior to the cruise from bathymetric databases such as ETOPO2 and Smith & Sandwell, but there were often smaller scale features not resolved in these databases that made finding appropriate spots for the moorings at depths close to their design depths challenging in some cases. Typically a 2-4 hour Seabeam survey was done in the vicinity of each mooring location, to pick a flat area for the mooring location and to adjust the mooring designs as necessary by adding or removing wire segments near the bottom of the moorings.

Mooring deployment operations continued on July 9 with the deployment of WHOI sound source mooring SS-5 and NIOZ mooring IC1. The Seabeam survey for mooring IC2 was completed at night on July 9 and mooring IC2 was deployed on the morning of July 10. The bottom survey and deployment of mooring IC3 followed on the afternoon of July 10. Seabeam surveys were completed for moorings IC4 and U. Miami mooring M1 on the night of July10, and both moorings were deployed on July 11. The same pattern of running ahead to the next two mooring sites and performing Seabeam surveys at night, then doubling back to deploy the two moorings in sequence the next day, was continued fort the next four days, with deployments of moorings D1 and D2 on July 12, moorings D3 and M2 on July 13, moorings SS-6 and D4 on July 14, and moorings M3 and SS-7 on July 15. Additionally, the final cal-dip CTD cast (CTD005) was performed on the evening of July 13 near mooring site M2, after mooring operations for the day were completed.

The last mooring in the Iceland Basin (M4) was deployed early on July 16th, starting at 0500, and was followed by deployment of a Seaglider a few miles east of the mooring site by SAMS personnel at 1030. The Seaglider will patrol the region east of M4 and across the Hatton and Rockall plateaus, and will be followed by other gliders on a rotating basis during OSNAP that will perform the same mission. Following the glider deployment the ship began the long (~21 hour) steam across Hatton and Rockall plateaus to get to the next mooring operation area in Rockall Trough at a reasonable hour on the next day. Enroute to Rockall Trough the ship stopped briefly at Rockall, the lone rock that juts out of the middle of Rockall plateau, at about 0500 on July 17 to visit and congratulate the adventurer Nick Hancock, who had just broken the record for an endurance stay on the "Rock", of 42 days.

Mooring operations resumed in Rockall Trough on July 17, which saw the successful deployment of both SAMS moorings that were planned for the western side of the Trough, RTWB1 and RTWB2. On July 18 the final two moorings of the cruise, RTEB1, and RTADCP2, were deployed on the eastern side of Rockall Trough. The deployment of RTADCP2 was particularly exciting, as this was a different type of mooring than all the others: a compact, trawl-resistant bottom lander that was lowered to just a few meters above the bottom with the trawl winch and then let go to settle to the bottom.

As mooring operations were coming to completion, attention turned to the hyrdographic work that would occupy the remainder of the cruise. Evaluation of the sensors on the CTD package showed that the dual temperature sensors were in good agreement (to within 0.001°C, but the two conductivity sensors were reading different values (by up to .01 mS/cm, or about a 0.008 psu difference in salinity), and furthermore their difference showed a distinct depth (pressure) dependence and a weak temporal trend. Comparisons with the bottle salinity samples run on the Autosal also indicated that both conductivity sensors were reading low, with the primary sensor being the farthest off and the secondary sensor having only a minor offset (~.002 psu). Once enough bottle samples were obtained, it became clear that the primary conductivity sensor was not only the farthest off in absolute terms but it also was the one with the pressure dependence and the temporal drift, and so it was replaced (starting at CTD017) with a backup conductivity sensor for the remainder of the cruise.

During the early part of the cruise there were also some problems with the Guildline Autosal salinometer used for measuring the bottle salinities, which complicated the assessment of the CTD conductivity sensors. After just a few measurement sessions, the Autosal began to develop bubble problems in one of its measurement cells, causing inaccurate readings. Ultimately the Autosal had to be opened and the cell cleaned out and air vents cleared in order to get it back to normal operation. These problems were fixed by station 17 (CTD017), and stable operation of the Autosal and both of the CTD conductivity sensors was achieved for the rest of the cruise.

CTD stations were performed on both sides of the Rockall Trough, stations 6-10 (east side) and 11-16 (west side), at a selected subset of the stations normally occupied during annual Ellett line cruises by SAMS. After steaming westward across Hatton plateau, the main CTD/LADCP line across the Iceland Basin and eastern Irminger Basin was begun. This section was intended to provide a snapshot comparison with the transport estimates to be derived later from the mooring arrays across the whole of the Iceland Basin, as well as for the sub-arrays across the Iceland-Scotland overflow DWBC and Irminger Current on each side of the Reykjanes Ridge. The line consisted of stations 17 to 65 and was completed on July 20-26. The stations resolution was nominally 20 nmi (37 km) across the central part of the Iceland Basin and narrowed to approximately 8 nmi (15 km) on both flanks of the Reykyanes Ridge. The CTD and LADCP operations went very smoothly throughout the whole section, with only minor interruptions due to a winch level-wind adjustment on one cast, and one cast that had to be aborted and restarted due to a software crash on the CTD acquisition computer.

During the CTD section, along the eastern flank of the Reykjanes Ridge, 10 RAFOS floats were launched that were ballasted for three different depths of 1800, 2000 and 2200 m to target the Iceland-Scotland Overflow Water (ISOW) layer flowing southwestward along the ridge. Two additional "monitoring" floats were also launched in the Iceland Basin to keep track of the performance of the sound sources.

All of the mooring, CTD, and RAFOS work was completed ahead of schedule, due to excellent working weather experienced on the cruise, and owing to the fact that less time had to be spent with Seabeam surveys for the mooring sites than anticipated.

With the main objectives of the cruise having been completed, the extra time remaining on the schedule was used to accomplish two further objectives. First, a mooring recovery was done of the "LOCO-2" mooring in the central Irminger Sea, which had been deployed by the Dutch in 2012 and was in urgent need of recovery. This mooring had been planned for recovery by a simultaneous German cruise in the region, but that cruise had to be postponed due to engine problems. LOCO-2 was recovered fully intact in a light fog on the afternoon of July 26. Near the site of LOCO-2, a third RAFOS "monitoring" float was launched, as well as a SOLO float with an acoustic receiver. Next, the ship transited back to the Reykjanes Ridge to do a short CTD section across the Bight Fracture Zone near 57°N, 34°W, which forms a deep gap through the Ridge that may be an important pathway for both deep and shallow flow through the Ridge. Prior to this cruise there were no documented measurements of the flow or hydrographic properties in Bight Fracture Zone, and obtaining such measurements will provide new insight into the circulation in the subpolar gyre and contribute directly to OSNAP goals. Nine CTD/LADCP stations (stations 66 to 74) were conducted across the two main deep channels through Bight Fracture Zone (BFZ) on July 27-28. The Seabeam system had unfortunately stopped functioning by this time, and stations were therefore picked from a high-resolution image of an earlier multibeam survey of the BFZ that was kindly sent to us by Dr. Richard Hey of the University of Hawaii.

Upon completion of the BFZ section at 1620 on July 28, the ship began its transit back to port in Reykjavik, performing a shipboard ADCP transect along the axis of the Reykjanes Ridge to complete the scientific data acquisition. The ship arrived off Reykjavik at approximately 1230 on July 30, in time to take on fuel before going to their assigned berth in the city center harbor. Berthed at 1830. The cruise was 100% successful, and additional objectives were accomplished due to time saved in operations and good weather.

3. Scientific Personnel

Name	Position	Organization
Bill Johns	Ch. Sci.	RSMAS/ U. Miami
Adam Houk	Scientist	RSMAS/ U. Miami
Mark Graham	Technician	RSMAS/ U. Miami
Robert Salom	Technician	RSMAS/ U. Miami
Yang Liu	Student	RSMAS/ U. Miami
Athanasia Papapostolou	Student	RSMAS/ U. Miami
Laura de Steur	Scientist	NIOZ
Leon Wuis	Technician	NIOZ
Marco Stoffelen	Student	NIOZ
Maurits Kooreman	Student	NIOZ
Amy Bower	Scientist	WHOI
Heather Furey	Scientist	WHOI
Stuart Cunningham	Scientist	SAMS
Clare Johnson	Scientist	SAMS
John Beaton	Technician	SAMS
Karen Wilson	Technician	SAMS
Rachel Vezza	Student	SAMS
Sijia Zou	Student	Duke Univ.

3. Cruise Operations

3.1 Mooring Operations

The moorings were deployed using a Lebus double-capstan winch system (aka "double-barrel" winch) that was brought by the Dutch group from NIOZ. This system allows separate wire reels to be loaded on an auxiliary spooler and fed into the main double-barrel 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 complement to the cruise. The winch performed very well for the duration of the cruise, except at the very end of the cruise, when the LOCO-2 mooring was being recovered, it began to have temporary failures in its ability to wind on (take up) wire, which were suspected to be a control box issue of some kind. A contemplated deployment of an additional sound source mooring in the Irminger Basin, near the site of LOCO-2, was therefore abandoned, and left to the next leg of KN221 as originally planned.

The auxiliary spooler brought by NIOZ that normally accompanies their double-barrel winch system could not be used on this cruise because the Knorr did not have an available transformer that could meet the power requirements of the auxiliary spooler. (The Knorr had been informed in advance about the power requirements of the main winch, but unfortunately not of the auxiliary spooler). Therefore the auxiliary spooler was left in Reykjavik and spoolers belonging to WHOI were used in its place. The best arrangement during the mooring deployments turned out to be to use a simple wire spool stand in free-spool mode, with adjustable tension, to feed the wire into the double barrel winch, and backspool it by hand as needed during brief take-ins. This worked just fine for the mooring deployments. For the LOCO-2 mooring recovery, it was challenging to match the uptake speeds of the two winches, and this required a lot of wire tending that would not be desirable for a large number of recoveries.

Mooring Deployments

A total of 20 moorings were deployed at the locations listed in Tables 1, 2 and 3 and shown in Figure 1. Acoustic surveying of the on-bottom position of most of the moorings was successfully completed after each mooring deployment.

Table 1. U.S. Mooring Deployments (U. Miami & WHOI)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
M1	M423	58° 52.33'	30° 31.95'	1712	11/07/2014
M2	M424	58° 02.26'	28° 01.29'	2370	13/07/2014
M3	M425	58° 00.77'	24° 25.72'	2850	15/07/2014
M4	M426	57° 59.56'	21° 08.61'	2923	16/07/2014
D1	M427	58° 44.77'	30° 07.01'	1740	12/07/2014
D2	M428	58° 32.11'	29° 27.82'	2517	12/07/2014
D3	M429	58° 18.42'	28° 49.12'	2174	13/07/2014
D4	M430	58° 00.58'	26° 58.07'	2670	14/07/2014
SS-5	n/a	59° 02.33'	34° 14.17'	2565	09/07/2014
SS-6	n/a	58° 01.26'	27° 49.01'	2344	14/07/2014
SS-7	n/a	58° 00.50'	22° 59.41'	2991	15/07/2014

Table 2. Dutch Mooring Deployments (NIOZ)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
IC0	n/a	59° 12.88'	35° 07.55'	2938	08/07/2014
IC1*	n/a	59° 05.93'	33° 40.93'	2500	09/07/2014
IC2*	n/a	59° 01.23'	32° 46.05'	1978	10/07/2014
IC3*	n/a	58° 57.33'	31° 57.54'	1635	10/07/2014
IC4*	n/a	58° 53.12'	31° 18.18’	1477	11/07/2014

* mooring location on bottom not surveyed after deployment.

Table 3. U.K. Mooring Deployments (SAMS)

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Deployment
RTWB1	n/a	57° 28.24'	12° 42.30'	1600	17/07/2014
RTWB2	n/a	57° 28.22'	12° 19.87'	1800	17/07/2014
RTEB1	n/a	57° 05.96'	9° 32.88'	1975	18/07/2014
RTADCP2*	n/a	57° 05.98'	9° 16.52'	396	18/07/2014

Mooring Recoveries

A single mooring, "LOCO-2" was recovered on the cruise (Table 4). This recovery was not originally planned as part of this cruise, but was done in spare time at the end of the cruise owing to the postponement of a separate German cruise that had been scheduled to recover and deploy it. The mooring was successfully recovered with all components intact.

Table 4. Mooring Recoveries

Mooring Site	Mooring Number	Latitude (ºN)	Longitude (ºW)	Depth (m)	Date of Recovery
LOCO-2	n/a	59° 12.21'	39° 30.32'	2985	26/07/2014

3.2 CTD/LADCP Stations

A total of 74 CTD stations were conducted during the cruise (Table 5, Figure 2). At each station, profiles of temperature, salinity (conductivity), dissolved oxygen concentration turbidity, and fluorescence were collected from the surface to within approximately 20 m of the bottom, using a Sea-Bird SBE-911plus CTD system. Five of these stations were performed to provide calibration data for SBE micro-cat instruments to be deployed on the moorings, which were lowered to specific depths not necessarily near to the bottom. During these casts, straps were added to the CTD frame to secure the moored instruments and the CTD package was lowered to its target depth, with 5 minute bottle stops during the package retrieval. These casts are indicated by an asterisk (*) in Table 5.

Water samples for calibration of the salinity and dissolved oxygen profiles were collected using a 24-bottle Rosette system containing 10 liter Niskin bottles. Only 12 bottles were used and so the outer rack of bottles was removed from the package. A bottle firing program was set up in the Seasave data acquisition software to fire these 12 bottles in sequence. Salinity samples were drawn from each of the fired bottles and subsequently analyzed on a Guildline Autosal salinometer. For most of the stations, 12 bottle samples were collected; however on very shallow stations as few as three bottles were fired, and during periods of the cruise that had a very close station spacing (e.g., over the top of the Reykjanes Ridge and in Bight Fracture zone), only 8 bottles were fired.

The CTD package included dual temperature and conductivity sensors, and single sensors for the rest of the variables. The only sensor change during the cruise was the primary conductivity sensor, which was swapped from S/N 2670 to S/N 2147 after stations 16, after it was determined to be inaccurate and drifting with time. Preliminary calibrations of the secondary conductivity sensor, and primary conductivity sensor after station 17, showed that they had stable behavior and only minor offsets with respect to bottle salinity samples, which should result in a relatively straightforward final CTD calibration after the cruise. No calibration samples were collected for dissolved oxygen or the other computed CTD parameters.

Current profiles were measured at the stations using a paired downward-looking 150 kHz Broadband and upward-looking 300 kHz Workhorse Acoustic Doppler Current Profiling 'hybrid" system (LADCP). The LADCP system was provided by Woods Hole (configured and installed by D. Torres); both units worked very reliably throughout the cruise. The LADCP data was processed using version 10.16 of the M. Visbeck & A. Thurnherr MATLAB toolbox, modified by G. Krahmann. Details of the LADCP operations can be found in Appendix 1.

Table 5. CTD/LADCP Station Information

Station Number	Date and Time	Lat DEG	Lat MIN	Lon DEG	Lon MIN	Depth m
0+	Jul 07 2014 13:41:20	61	31.80	32	36.66	2329
1*	Jul 07 2014 20:48:20	60	58.36	34	25.50	3014
2*	Jul 08 2014 15:59:13	59	15.20	35	7.11	3092
3*	Jul 08 2014 20:44:01	59	20.36	34	39.90	3116
4*	Jul 09 2014 01:15:10	59	20.10	34	39.54	3105
5*	Jul 13 2014 18:05:15	58	2.08	27	48.11	2373
6	Jul 18 2014 17:39:54	57	0.09	85	99.70	134
7	Jul 18 2014 18:53:32	57	3.02	91	29.80	313
8	Jul 18 2014 20:08:59	57	5.93	92	50.10	1416
9	Jul 18 2014 22:16:50	57	8.87	94	21.00	1943
10	Jul 19 2014 01:07:46	57	14.13	10	2.96	2111
11	Jul 19 2014 10:15:37	57	30.26	12	15.02	1812
12	Jul 19 2014 13:09:46	57	32.12	12	38.12	1645
13	Jul 19 2014 15:30:07	57	32.58	12	51.93	1079
14	Jul 19 2014 17:13:15	57	33.04	12	59.98	298
15	Jul 19 2014 18:45:16	57	33.96	13	19.73	178
16	Jul 19 2014 20:03:40	57	34.99	13	37.84	114
17	Jul 20 2014 10:36:59	57	39.94	18	41.86	716
18	Jul 20 2014 13:03:29	57	43.72	19	13.72	917
19	Jul 20 2014 15:33:47	57	47.50	19	44.82	1316

20	Jul 20 2014 18:07:48	57	50.12	20	8.37	1573
21	Jul 20 2014 20:35:05	57	52.68	20	29.85	2257
22	Jul 20 2014 23:25:52	57	54.91	20	51.31	2015
23	Jul 21 2014 02:19:06	57	57.30	21	11.97	3001
24	Jul 21 2014 06:45:17	57	57.58	21	51.40	3029
25	Jul 21 2014 11:04:29	57	57.47	22	30.72	2994
26	Jul 21 2014 15:17:44	57	57.62	23	10.37	3002
27	Jul 21 2014 19:24:10	57	57.67	23	49.82	2949
28	Jul 21 2014 23:28:16	57	57.66	24	29.41	2840
29	Jul 22 2014 03:44:18	57	57.56	25	6.95	2758
30	Jul 22 2014 07:55:32	57	57.66	25	44.73	2749
31	Jul 22 2014 11:41:40	57	57.68	26	22.72	2844
32	Jul 22 2014 15:44:04	57	57.67	27	0.69	2697
33	Jul 22 2014 19:23:09	57	58.63	27	34.11	2274
34	Jul 22 2014 23:10:40	57	59.70	28	4.25	2426
35	Jul 23 2014 02:12:52	58	4.97	28	20.44	2316
36	Jul 23 2014 05:26:15	58	10.34	28	36.77	2325
37	Jul 23 2014 08:11:30	58	15.64	28	52.85	2229
38	Jul 23 2014 10:42:09	58	20.07	29	5.44	2184
39	Jul 23 2014 13:22:43	58	24.74	29	18.81	1870
40	Jul 23 2014 15:51:19	58	29.38	29	32.35	2540
41	Jul 23 2014 18:48:42	58	33.30	29	44.02	2005
42	Jul 23 2014 21:38:06	58	37.49	29	56.77	2010
43	Jul 24 2014 00:02:40	58	41.92	30	10.05	1728
44	Jul 24 2014 02:13:29	58	45.70	30	21.90	1648
45	Jul 24 2014 04:22:43	58	49.81	30	34.65	1620
46	Jul 24 2014 06:21:42	58	50.18	30	48.32	1481
47	Jul 24 2014 08:12:48	58	50.49	31	2.07	1380
48	Jul 24 2014 10:09:02	58	50.94	31	16.01	1454
49	Jul 24 2014 12:04:30	58	52.32	31	29.66	1529
50	Jul 24 2014 14:02:41	58	53.66	31	43.30	1645
51	Jul 24 2014 16:06:04	58	55.01	31	57.02	1788
52	Jul 24 2014 18:13:49	58	56.69	32	12.54	1501
53	Jul 24 2014 20:06:33	58	58.22	32	27.93	1869
54	Jul 24 2014 22:10:43	58	59.68	32	42.11	1874
55	Jul 25 2014 00:27:34	59	1.38	32	58.64	2252
56	Jul 25 2014 03:03:03	59	2.85	33	14.03	2200
57	Jul 25 2014 05:25:54	59	4.46	33	29.53	2313
58	Jul 25 2014 07:51:15	59	6.03	33	45.33	2164
59	Jul 25 2014 10:17:13	59	7.64	34	1.15	2855
60	Jul 25 2014 13:05:38	59	9.32	34	17.71	2607
61	Jul 25 2014 15:48:20	59	10.98	34	33.85	2854
62	Jul 25 2014 18:43:14	59	12.62	34	49.94	2508
63	Jul 25 2014 21:24:39	59	14.59	35	6.77	3016
64	Jul 26 2014 01:05:18	59	16.09	35	21.91	3026
65	Jul 26 2014 04:33:57	59	17.64	35	38.55	3124

66	Jul 27 2014 21:58:13	56	40.40	33	40.61	1070
67	Jul 27 2014 23:22:57	56	42.48	33	41.96	1828
68	Jul 28 2014 01:21:08	56	43.96	33	43.02	2191
69	Jul 28 2014 05:02:15	56	46.01	33	43.98	1843
70	Jul 28 2014 07:08:25	56	48.09	33	44.94	1120
71	Jul 28 2014 08:41:33	56	51.18	33	47.18	1524
72	Jul 28 2014 10:30:16	56	53.75	33	49.12	2335
73	Jul 28 2014 12:45:51	56	56.41	33	51.18	2474
74	Jul 28 2014 15:02:45	56	58.48	33	52.95	1988

+ Test cast
* Instrument calibration casts

3.3 RAFOS Floats

Along the eastern flank of the Reykjanes Ridge, 10 RAFOS floats were released that were ballasted for three different depths of 1800, 2000 and 2200 m (Table 6). The general deployment strategy for the RAFOS floats was to release them where they would settle 100-200 m above the sea floor, to target the thin Iceland-Scotland Overflow Water (ISOW) layer flowing southwestward along the ridge. During float launches the ship would steam slowly forward at 1.0 to 1.5 kts, and floats were lowered over the stern in a launch tube that released them shortly after they entered the water. These launches were done either at CTD stations after completion of the CTD, or at chosen locations between stations. In addition to the 10 floats launched along the eastern flank if the Reykjanes Ridge, three sound source "monitoring" floats were launched (two in the Iceland Basin and one in the Irminger Basin), and a SOLO float with an acoustic receiver was launched in the Irminger Basin (Table 7). Details of the RAFOS float launches and procedures are given in Appendix 2.

Table 6. RAFOS and SOLO float deployments

Station	Instrument S/N	Deployment Date	Deployment Time GMT	Latitude (N)	Longitude (W)	Water Depth Meters	Ballast/Target Depth Meters	Iridium ID
26	1046	21-Jul-2014	17:18	57 58.13	23 9.23	3001	1000	300034010115350
32	1222	22-Jul-2014	17:37	57 57.71	27 0.56	2674	1000	300234060400580
n/a	1310	23-Jul-2014	23:09	58 37.21	29 58.96	1950	1800	300234061826920
41	1311	23-Jul-2014	20:42	58 37.5	29 56.02	2023	1800	300234061822910
n/a	1312	23-Jul-2014	21:24	58 34.26	29 48.04	2015	1800	300234061820930
40	1313	23-Jul-2014	15:39	58 29.41	29 32.07	2520	2000	300234061820920
n/a	1314	23-Jul-2014	12:30	58 20.65	29 7.05	2280	2000	300234061820910
n/a	1316	23-Jul-2014	18:00	58 31.75	29 35.25	2150	2000	300234061820890

n/a	1325	22-Jul-2014	22:54	57 59.56	28 2.39	2396	2200	300234061823900
33	1326	22-Jul-2014	22:27	57 58.86	27 55.57	2400	2200	300234061828890
n/a	1329	23-Jul-2014	04:20	58 4.92	28 24.21	2350	2200	300234061825830
36	1330	23-Jul-2014	05:00	58 8.52	28 32.5	2300	2200	300234061823850
n/a	1177	26-Jul-2014	19:30	59 12.78	37 28.66	3018	1000	300234010350940
n/a	SOLO958	26-Jul-2014	19:21	59 12.64	39 28.61	3018	1000	300034012176600

3.4 Seaglider operations

One Seaglider was deployed at the eastern end of the Iceland Basin a few miles east of the site of mooring M4, on July 16. A pre-deployment self test was carried out the evening prior to launch. Encompassing the sea-level test, autonomous self test and the internal pressure test, all sections of the self test were completed satisfactorily. Confirmation of glider to base communications was received from the pilot via email.

On the morning of launch weather conditions were clear and calm with no wind, offering ideal conditions. Pre launch set-up was carried out and once confirmed complete clearance to launch was received via satellite phone from the pilot. On reaching the launch site the ship came to a complete stop for the duration of the launch. The glider was lowered off the aft deck by the A-frame. It was secured by a soft rope around the rudder lifting point. On reaching the water the rope was slipped free and the glider maintained its position unaided. No buoyancy check was required before release as the glider had been tested in waters significantly fresher than the deployment location. The glider's orientation in the water was as expected, with the waterline at rudder-level and angle slightly off vertical. The ship moved away cautiously while the glider was observed until it began its first dive.

Launch team: John Beaton, Karen Wilson
Pilot: Estelle Dumont, Marie Porter
Serial number: SG604 Jura
Release position – 57° 59.0329' N, 21° 01.5287' W
Release time and date – 0941 16/07/2014 UTC

Progress of SAMS operated gliders and preliminary data can be viewed at: http://velocity.sams.ac.uk/gliders/. The full glider mission report will also be finalized within 6 months of the end of the mission and will be available at: http://velocity.sams.ac.uk/gliders/mission_list.php

3.5 Underway Measurements

Thermosalinograph

Values of surface temperature and salinity were continuously monitored using a Sea-Bird temperature-conductivity recorder 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 a dual vessel-mounted Acoustic Doppler Current Profiler (ADCP) system consisting of a 300 kHz and 75 kHz Ocean Surveyor system. The depth range of good velocity data from the 300 kHz system typically extended to 80 m below the vessel, and to approximately 600-800 m for the 75 kHz system, depending on sea state conditions. Data were processed onboard in real time using the UHDAS acquisition system. Gyrocompass data were continuously corrected by a POS-MV inertial navigation system.

4. Preliminary Results

The results from the CTD section (Fig. 3), and from both the LADCP and shipboard ADCP data (Figs. 4 and 5), revealed the main branch of the North Atlantic Current (NAC) flowing northward and slightly westward at about 24°W in the central Iceland Basin. Another branch of the NAC appeared to flow northward along the seaward slope of the Hatton Plateau at about 19-20°W. These branches are identified by their relatively warm and salty waters and downward sloping isopycnals to the east. In between these branches there was a region of southward flow, suggesting an imbedded eddy feature, which was also seen in near-real time altimetry data accessed during the cruise. In Rockall Trough, another band of high-salinity and temperature water is seen in the thermocline right along the Scottish slope, consistent with the expected location of the northward Scottish Slope Current, although the velocity profile data showed relatively weak or even southward currents on the Scottish slope during the time of the cruise.

Over the Reykjanes Ridge, another band of relatively warm and salty water was observed in the upper 1000 m, which is commonly found in previous hyrdrographic surveys across this region. This feature appears to be linked with a southwestward recirculation of NAC waters along the eastern flank of the ridge, after these waters have transited cyclonically around part of the Iceland Basin. The LADCP section also shows this southwestward flow over the eastern ridge flank, and just westward of it, over the western flank of the ridge, is a northward flow that appears to be a branch of the Irminger Current.

The deep flow across the section is characterized by an intense banded circulation in the Maury Channel (the deepest part of the Iceland Basin between about 20-26°W), which could be indicative a deep recirculation there or perhaps a transient deep eddy feature. Farther westward in the Iceland Basin the deep flow is generally southwestward with an uplift of the 27.8 isopycnal, and saltier deep waters, indicating the expected presence of Iceland-Scotland Overflow Waters (ISOW) moving southward along the eastern flank of the Reykjanes Ridge. The flow here also shows the characteristic vertically-coherent, banded structure associated with quasi-barotropic eddy features, with zonal scales of O(50 km), that are typically seen in previous absolute velocity sections in this region.

The above description is based on the data collected during the main CTD section as the ship moved westward across the array, during the latter half of the cruise, and it is noteworthy that some substantial differences are apparent in the shipboard ADCP data between this transect and the eastbound transect that took place earlier during the mooring operations (Fig. 5). In particular, the main branch of the NAC identified in the CTD section near 24°W is no longer so clearly apparent and may have been weaker and displaced westward during the first transect.

5. Release of Project Data

In accordance with the provisions specified in the cruise prospectus and application for U.K. research clearance, the full data results from this experiment will be provided to the U.K. Foreign and Commonwealth Office according to the following schedule:

Shipboard Measurements

All shipboard measurements, including underway data records and CTD/LADCP station data in U.K. territorial waters, will be provided within 6 months of the termination of the cruise (January, 2015).

Moored Instrumentation

Time series data records from the moored instruments deployed in U.K. territorial waters will be provided within 2 years of recovery of the instruments (nominally May, 2013).

6. Acknowledgements

The support and able assistance provided by the Captain and crew of the *R/V Knorr* is gratefully acknowledged. Support for the scientific research was provided by the U.S. National Science Foundation, the European Union 7th Framework Programme, and the U.K. National Environmental Research Council. The United Kingdom graciously granted privileges to conduct scientific research in their territorial waters.

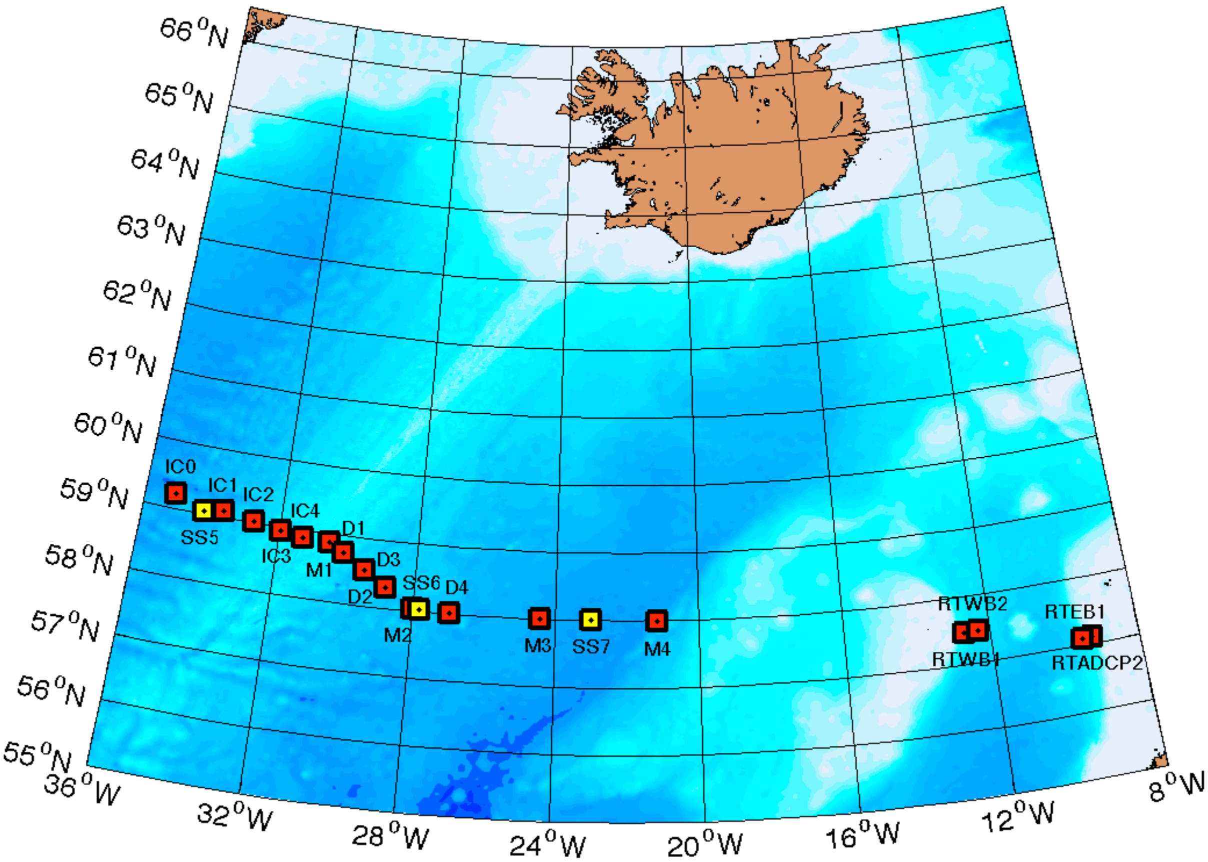


Figure 1. Current meter moorings deployed on KN221-2. Sound source moorings are shown in yellow symbols.

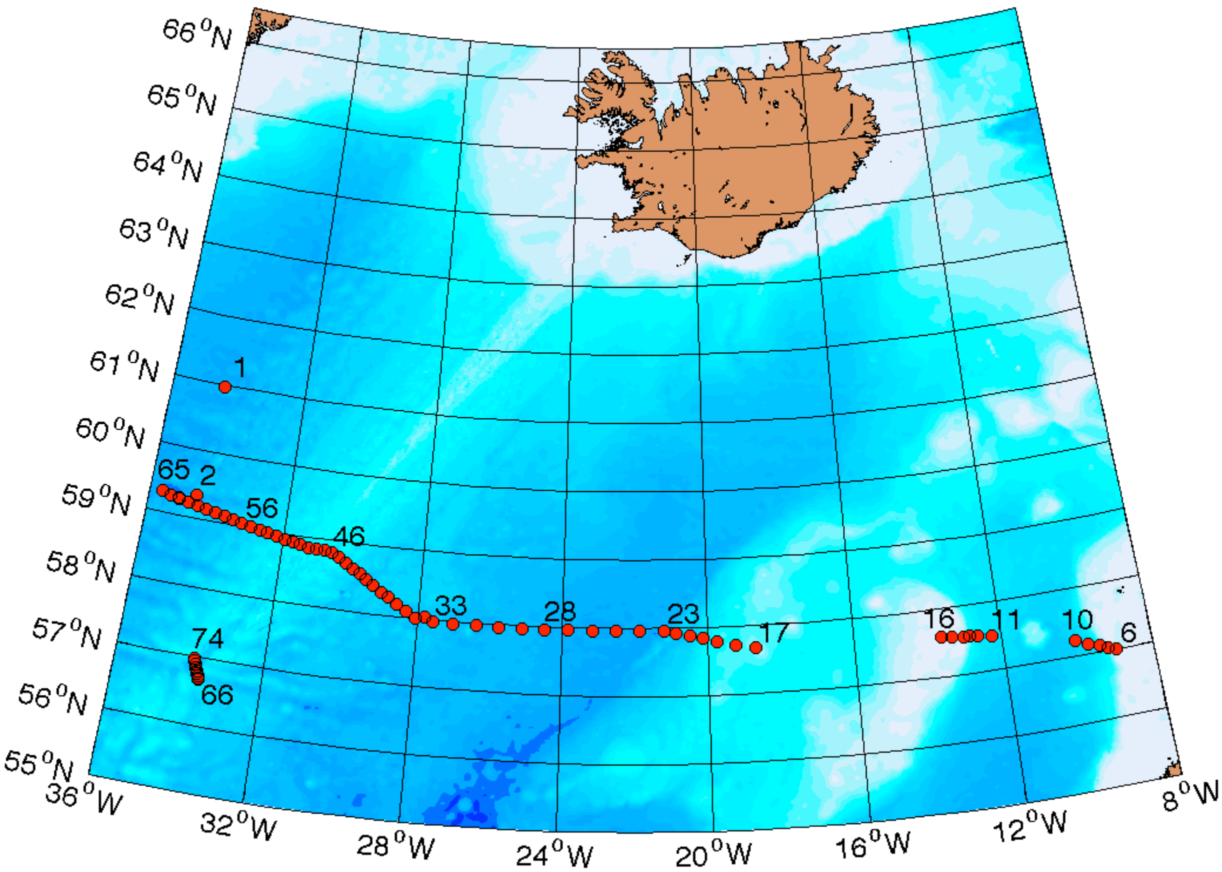


Figure 2. CTD/LADCP station occupied during KN221-2. Station numbers are indicated for selected stations along the track.

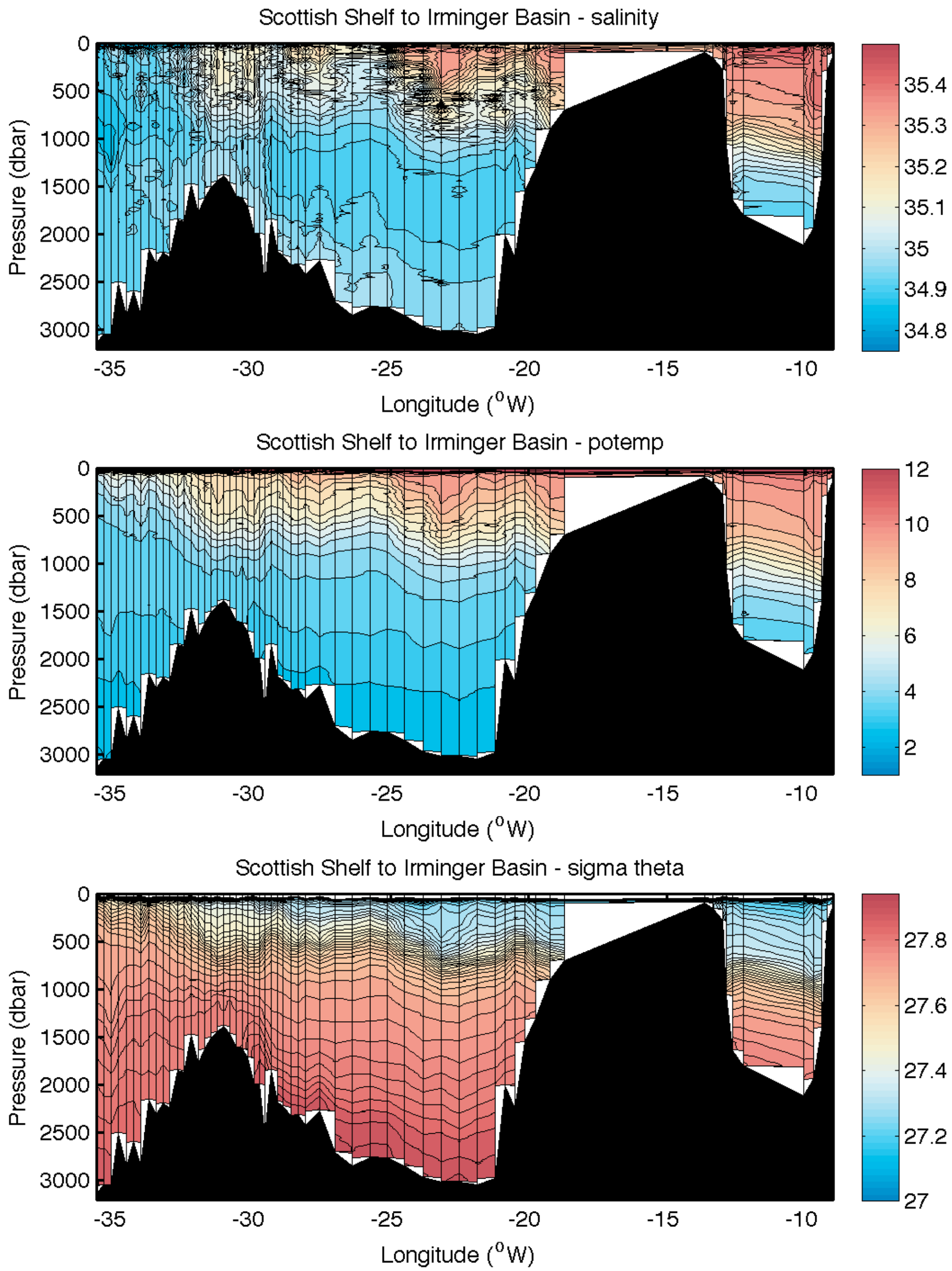


Figure 3. Sections of salinity, potential temperature, and density (sigma-theta) for the main CTD line across the eastern Irminger and Iceland basins, and in Rockall Trough (on the right side).

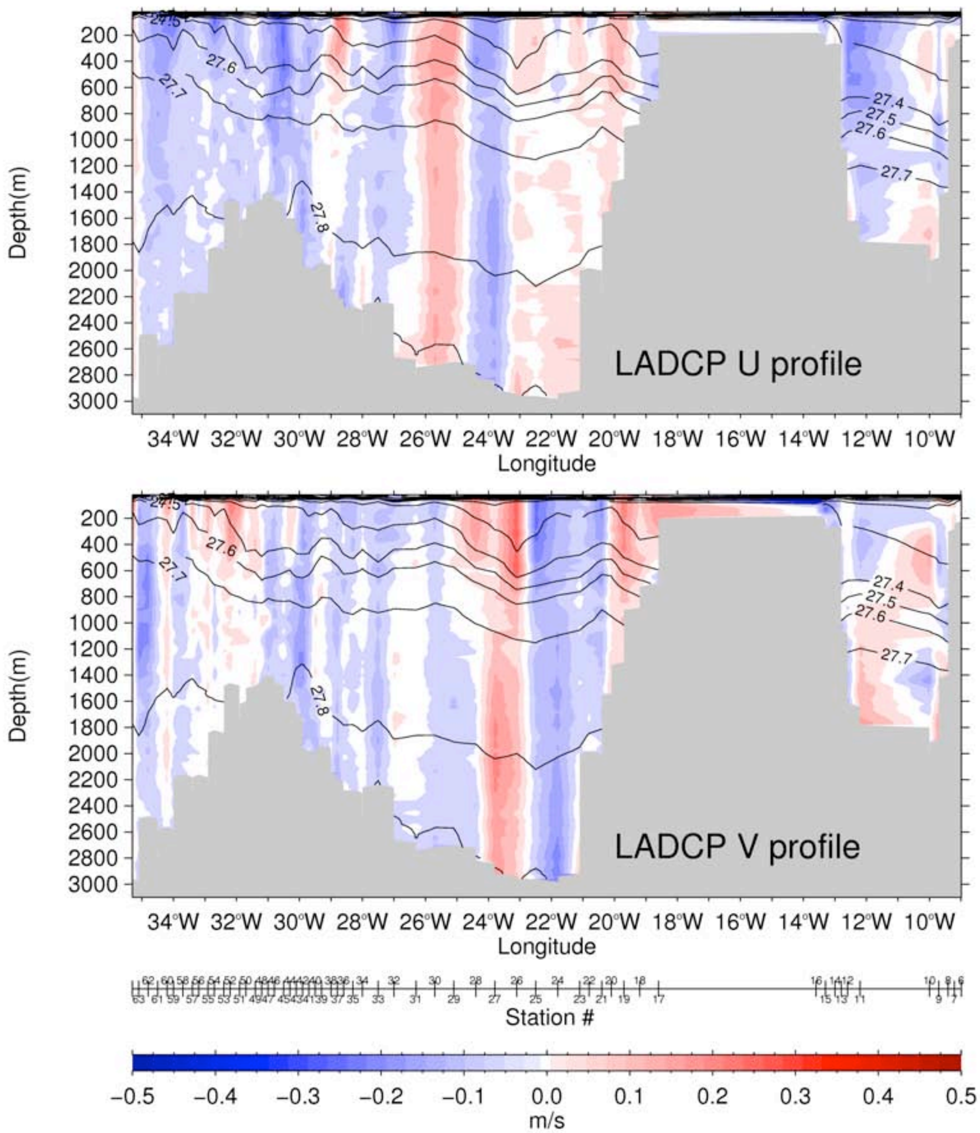


Figure 4. Absolute velocity section from LADCP data along the main CTD section: zonal velocity (top) and meridional velocity (bottom). Station locations are shown along the bottom of the plot.

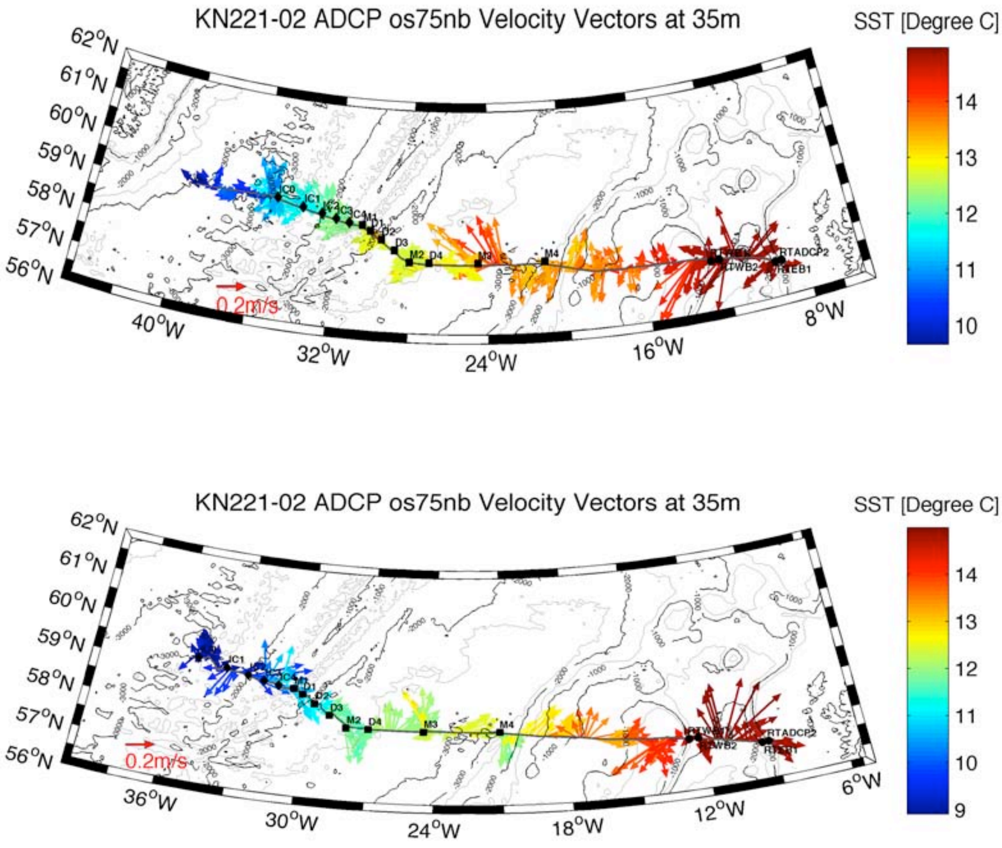


Figure 5. Near-surface (35 m) velocity vectors derived from shipboard ADCP data for the westbound crossing of the array during the main CTD section (bottom, July 18-26) and for the earlier eastbound crossing during mooring deployment operations (top, July 8-18). Surface temperature is indicated by the color of the current vectors.

Appendix 1. Lowered ADCP Operations, KN221-02

Adam Houk
28 July 2014

LADCP Setup:
Full water column velocity profiles for the OSNAP East July 2014 cruise were collected using a hybrid 150/300kHz Workhorse configuration. Most of the instruments, cables, and related equipment were supplied by Dan Torres of Woods Hole Oceanographic Institution, with two spare star-cables and chargers supplied by UM. The primary downward-looking 150 kHz ADCP was S/N 13656 and the primary upward-looking 300 kHz ADCP was S/N 10417. There was one spare 150 kHz and two spare 300 kHz profiles on board. One 300 kHz workhorse monitor (s/n 6820) belonged to the University of Miami. Two custom-made 48-volt deep-sea batteries were supplied by WHOI as well. The two Workhorse ADCPs were mounted on a 12-bottle CTD rosette, with mounting brackets for the ADCPs and battery provided by WHOI. The upward-looking ADCP was mounted near the outer edge of the rosette, situated above the upper rim of the frame. The downward-looking 150 kHz ADCP was mounted offset from the center of the frame adjacent to the SBE9 CTD; with the transducer face about 10cm off the bottom. 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.
The 150 kHz ADCP was configured for 16 16-meter bins, 10 meter blanking distance, and an ambiguity velocity of 350 cm s^{-1}. The 300 kHz ADCP was configured for 20 8-meter bins, zero blanking distance, and an ambiguity velocity of 330 cm s^{-1}. The units were configured for staggered single-ping ensembles; the upward-looking ADCP was set to 1 sec ensembles, and the downward-looking ADCP was set to burst-sample every 2 seconds with 0.8 seconds between pings. Measurements were saved in beam coordinates, with 3-beam solutions and bin-mapping disabled. Both ADCPs were running firmware version 51.40.

Data Acquisition Setup:
Inside the main lab of the Knorr, a dedicated PC running Ubuntu Linux with two native 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 my 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 58 Volts (+/- 29V) 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:
Lowered ADCP operations began on July 7th, 2014 with a "test" cast to 1000 meters near the beginning of the main transect line in 2300 meters of water. No operational problems were found with the hybrid setup. The first five stations were microcat "cal-dip" casts that took place soon after. Initial operations proceeded slowly at first as the two LADCP

shift operators needed to familiarize themselves with the equipment and procedures. As they became more comfortable with the equipment, the typical deployment procedure was as follows:

- About 10-15 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 would then be 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.

The operator then notes the time and position for the beginning of the cast, the maximum CTD depth, and the end of the cast on the log sheet. 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.
- There 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: 'os1407_nnn_dn.dat' or 'os1407_nnn_up.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 to a dedicated laptop for processing. Navigation data were extracted from the uncorrected one-second time-series CTD data provided by the CTD operator, downloaded over the ship's network. Once the files were in the proper directories, the "first-pass" processing could be executed.

The initial processing of the raw ADCP data was done using version 10.16 of the M. Visbeck & A. Thurnherr MATLAB toolbox, modified by G. Krahmann. The 'process_cast(nnn)' script was run, with 'nnn' representing the station number, which called 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 processing scripts required some code modifications, primarily to ensure the ADCP and GPS data were properly loaded. The prepnav.m script was modified to call the load_sbe9.m function, which reads in a 1-Hz bin-averaged CTD timeseries which includes latitude and longitude information. Manual changes to the 'prepare_cast.m' code were also necessary to ensure that only the navigation data would be used in the first-pass processing. Bottom-track processing was left enabled. A small section of code in 'misc_composefilenames.m' was commented out to better handle the raw LADCP filename convention. When the first-pass was finished, the operator would note in the log sheet the calculated depth based on the integrated vertical velocity and compare it to the maximum depth reported by the CTD.

Analysis:
The main transect line contained 60 CTD stations, (cast numbers: 6 through 65) starting on the eastern side of Rockall Basin and ending near mooring IC0 on the western slope of the Reykjanes ridge. An additional 9 casts were done across a trench cutting through the plate fracture zone south of the main transect line. Operationally there were few major problems during the first 64 stations. On station 65, however, the battery pack did not retain enough of a charge to run both instruments, and as a result there was no data collected for that cast. This failure was attributed to the frequency and duration of casts during the latter half of the transect line; stations were spaced about 30 minutes apart, and the battery did not have sufficient time to fully recharge after each cast. There was a minor issue with file transfers from the upward-looking ADCP on a few occasions, where if the downward-looking ADCP were to finish its file transfer before the upward ADCP and power down, the upward ADCP would experience timeouts in the y-modem transfer, and after a few attempts to recover, the transfer would fail before finishing. It would seem that by powering down, one ADCP was disrupting communications with the other. The solution was to prevent the downward ADCP from powering down at all during the upward ADCP transfer. It was not enough to simply restart the upward transfer while the lower was powered down; the file transfer would start, but fail after a few seconds. I have no explanation for this behavior at this time.
After examining the first 3 or 4 casts, we found that the effective range of the 150 kHz ADCP was exceptionally good. We decided to increase the number of bins recorded from 16 to 20 in an attempt to improve the profile coverage. While this was successful, and the profile error remained low, we noticed a distinctive striped noise pattern in the correlation and echo intensity plots had manifested throughout the entire cast (Fig. A1). It was initially theorized that the interference was caused by the proximity of the altimeter on the SBE9 package, however this was not found to be the cause. We found that for some as-yet unknown reason, changing the number of bins to 20 lead to this pattern developing. Setting the ADCP back to 16 bins appeared to eliminate the problem.
Another persistent problem with the data quality of the downward ADCP was a section of unusually high error velocity in the first 2-3 bins that occurred at almost the same depth in every cast and persisted for about 6-8 minutes before returning to normal levels (Fig. A2). This essentially produced a “hole” in the super-ensemble profile time-series where the data were rejected due to the high error (Fig. A3). While this appeared to have no noticeable effect on the final data quality, we were unable to find an explanation for why it was occurring so regularly. There was no appreciable change in echo intensity or correlation during this period.
A handful of casts near the end of the survey, at stations along the ridge cut, had problems related to bottom detection / bottom tracking. Return echo intensity near the sea floor did not appear to be strong enough to give the processing software clear bottom track pings that would accurately denote the bottom cutoff point. This resulted in certain profiles extending beyond the true bottom depth. A temporary solution to this problem was to adjust the processing parameter p.bottomdist from 0 (the default) to 1 in the

'cast_params.m' file. Changing this parameter forces the software to re-calculate the location of the sea floor based purely on echo intensity. This change resulted in better bottom detection, but higher final error velocities.

Summary:
Overall, the 150 & 300 kHz ADCPs performed quite well, with no serious communication or power issues. In total, 75 LADCP profiles were collected. The total combined profile range regularly approached 500m on any given cast, and the final error velocities were on the order of 5 cm/s. The depleted battery on cast 65 was the only real disruption in data collection, one that could perhaps be avoided in the future by having a second battery on standby, with a planned swap-out at some point during the survey to allow adequate recharge time for the first one. At this time we have no clear explanation for the striped interference pattern seen in the downward ADCP data when the number of bins sampled was set to 20. There is also no immediate explanation of the high error velocities in the first few bins of the 150 kHz ADCP. The increased error seemed to occur consistently at the same depth in the profile, around 1000 meters, but there is no corresponding drop in signal or correlation. Hopefully an explanation will be found in due course. In the end, however, these problems did not appear to have a significant impact on the quality of the final profile.

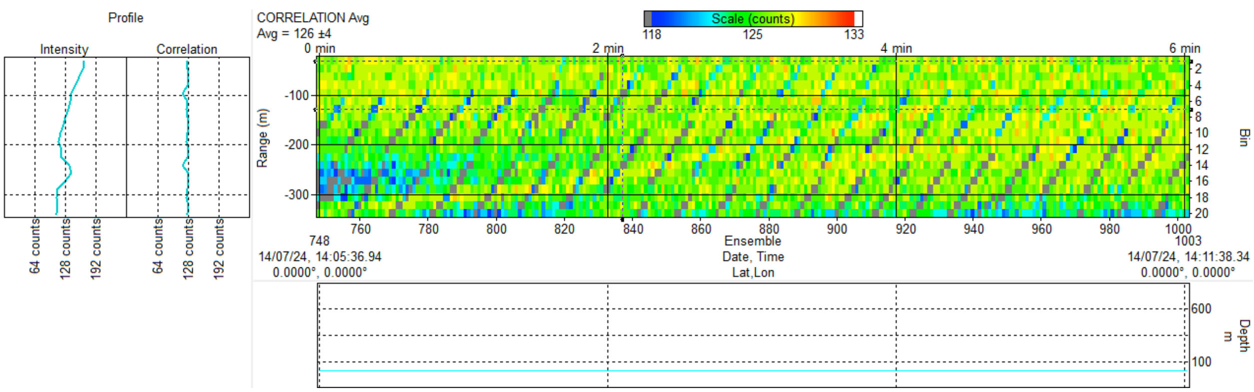


Figure A1. Downward ADCP contour plot of correlation showing interference pattern when the number of bins was set to 20.

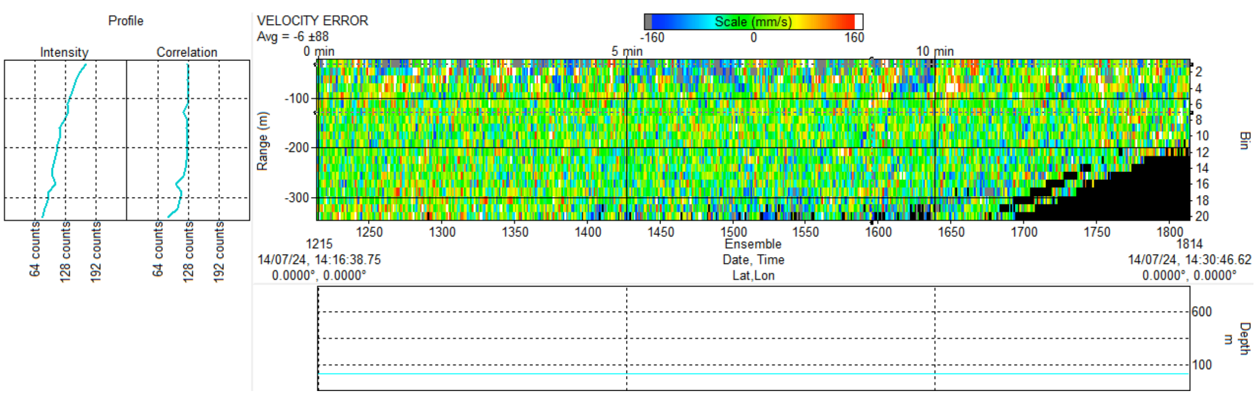


Figure A2. Section of downward ADCP time-series showing high error velocities in the first 3-4 bins closest to the transducer head.

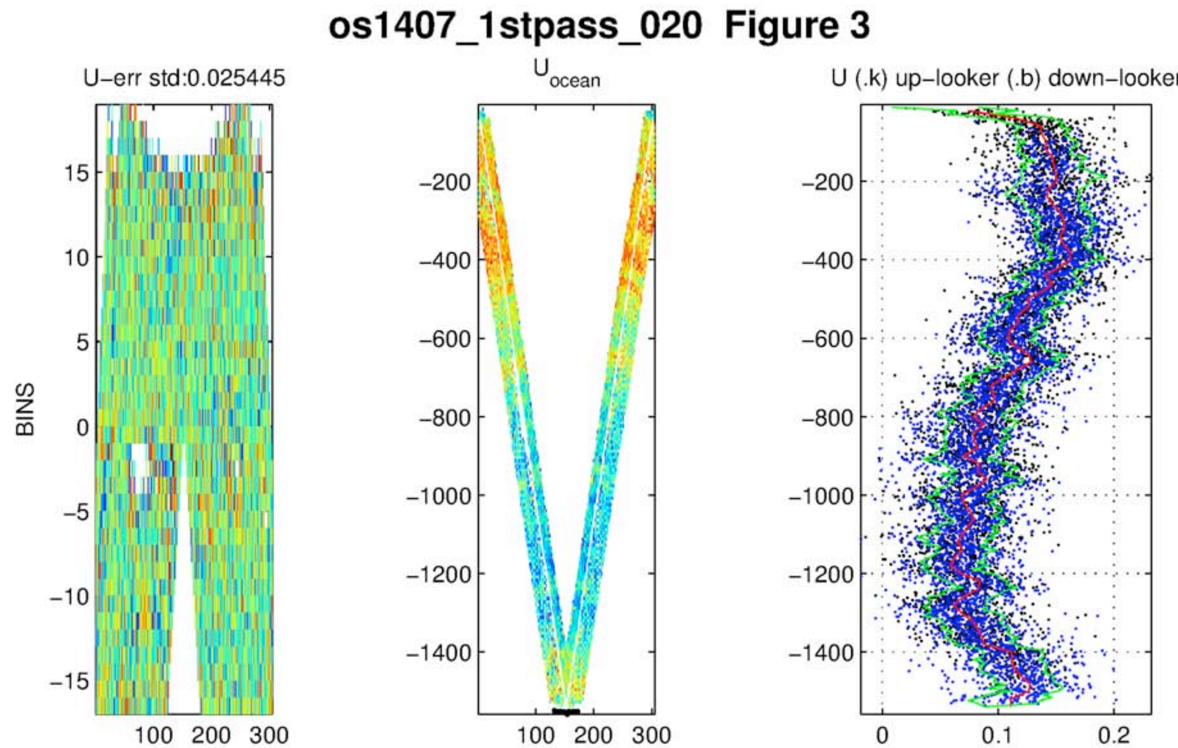


Figure A3. Example of the effect of high error velocity on a profile. A small "hole" in the super-ensemble error can be seen on the left-hand figure.

Appendix 2. OSNAP 2014 R/V Knorr Leg 2: RAFOS Float Program

A total of 120 subsurface acoustically tracked RAFOS floats are being released during 2014, 2015 and 2016 OSNAP cruises to directly observe the pathways of Overflow Waters (OW) throughout the subpolar North Atlantic. An array of 10 260-Hz sound sources will be used to track the floats until all the moored arrays are recovered in 2018. Figure 1 shows the approximate positions and pong times for all 10 sound sources. In addition, six short-mission RAFOS floats and one profiling SOLO float with acoustic receiver are being released in 2014 to confirm and monitor sound source performance.

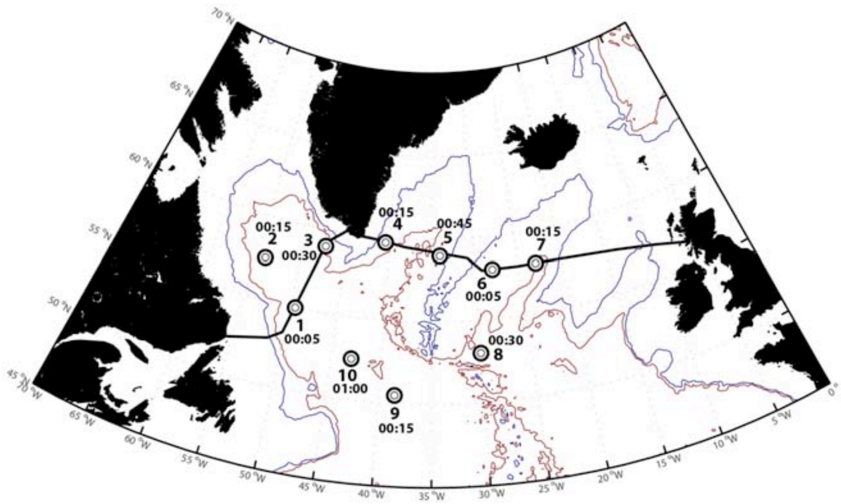


Figure 1. Sound source mooring positions and pong times (once daily) for ten sound sources deployed as part of the OSNAP program.

Deployments for 2014 are as follows:

- KN221-01: 10 RAFOS floats in the Charlie-Gibbs Fracture Zone (CGFZ); sound sources #8, 9 and 10; 2 monitoring RAFOS floats.
- KN221-02: 10 RAFOS floats on the eastern flank of the Reykjanes Ridge; sound sources #5, 6 and 7; 2 monitoring RAFOS floats in the Iceland Basin and 1 monitoring float in the Irminger Basin; 1 profiling SOLO float with acoustic receiver in the Irminger Basin.
- KN221-03: 19 RAFOS floats in the Overflow Water over the east Greenland slope; sound sources #1, 3 and 4; 1 monitoring RAFOS float in the Labrador Sea.
- R/V Thalassa: sound source #2 (Johannes Karstenson, chief scientist; replacement cruise for R/V Merien).

Tables 1 and 2 below give the deployment information for float and sound source deployments on KN221-02. RAFOS floats released on the eastern flank of the Reykjanes Ridge were ballasted for 1800, 2000 and 2200 m. The general deployment strategy was to release them 100-200 m above the sea floor of the ridge flank to target the thin Iceland-Scotland Overflow Water (ISOW) layer flowing southwestward there. Figure 2 shows the CTD temperature, salinity, and density sections with the float deployment sites superimposed.

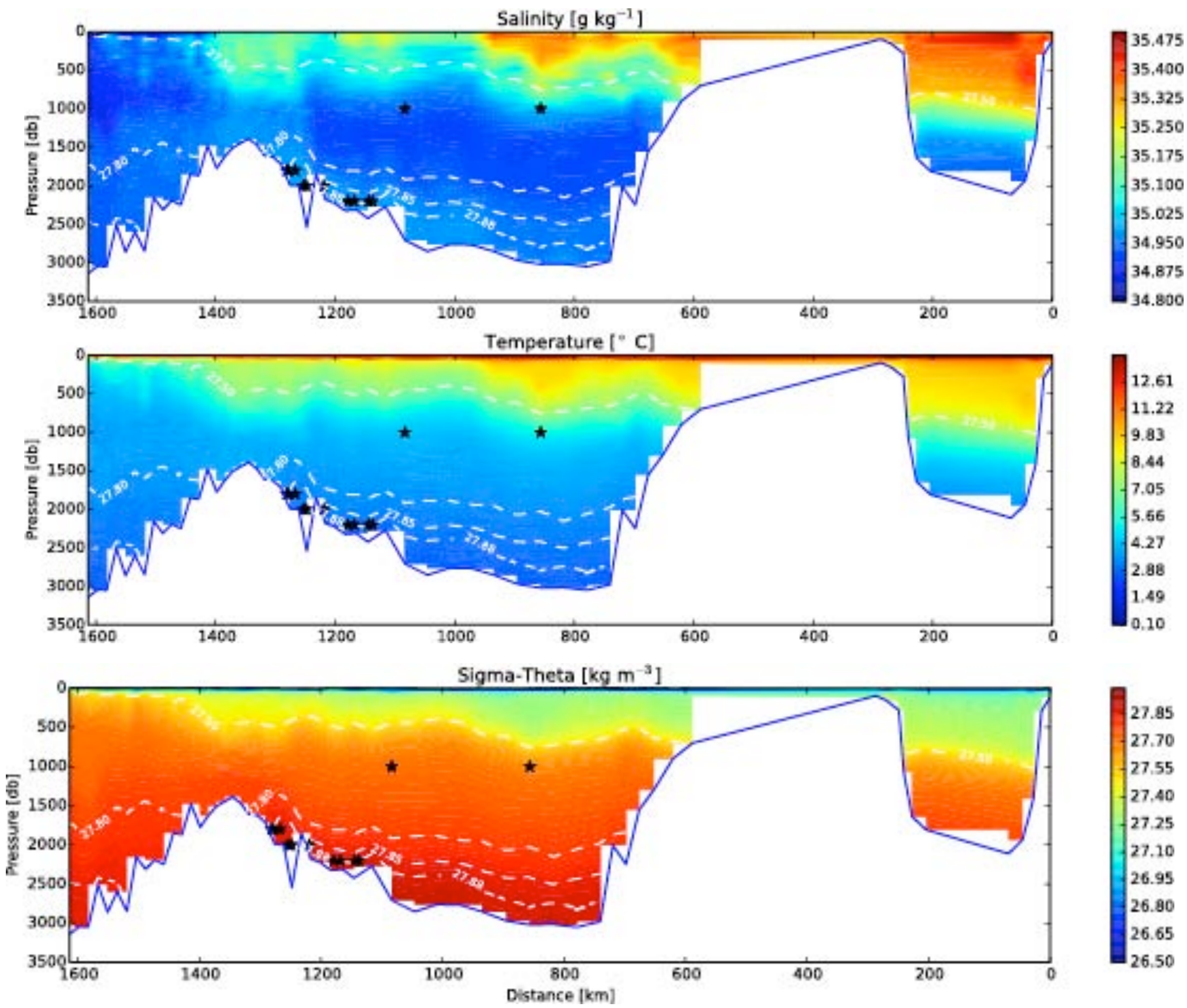


Figure 2. RAFOS float deployment locations and depths plotted on CTD salinity, temperature, and density. The two floats at ~1000 m were the monitoring floats deployed in the Iceland Basin. Not shown are the monitoring RAFOS and SOLO deployed in the Irminger Basin.

Most of the RAFOS floats were released using the "holey tube" made out of PVC with a piston and starch ring that would dissolve and release the float when submerged off the fantail. On one occasion (3rd monitoring RAFOS float s/n 1177), it was raining and the starch ring dissolved prematurely, and the float slipped into the water from above before the tube was submerged. On another occasion, the starch ring would not release and the float was removed from the tube and launched by hand.

Table 1. RAFOS and SOLO float deployment information.

Station	Instrument S/N	Deployment Date	Deployment Time GMT	Latitude (N)	Longitude (W)	RAFOS Windows	Water Depth Meters	Ballast/Target Depth Meters	Iridium ID
26	1046	21-Jul-2014	17:18	57 58.13	23 9.23	14	3001	1000	300034010115350
32	1222	22-Jul-2014	17:37	57 57.71	27 0.56	12	2674	1000	300234060400580
n/a	1310	23-Jul-2014	23:09	58 37.21	29 58.96	730	1950	1800	300234061826920
41	1311	23-Jul-2014	20:42	58 37.5	29 56.02	730	2023	1800	300234061822910
n/a	1312	23-Jul-2014	21:24	58 34.26	29 48.04	730	2015	1800	300234061820930
40	1313	23-Jul-2014	15:39	58 29.41	29 32.07	730	2520	2000	300234061820920
n/a	1314	23-Jul-2014	12:30	58 20.65	29 7.05	730	2280	2000	300234061820910
n/a	1316	23-Jul-2014	18:00	58 31.75	29 35.25	730	2150	2000	300234061820890
n/a	1325	22-Jul-2014	22:54	57 59.56	28 2.39	730	2396	2200	300234061823900
33	1326	22-Jul-2014	22:27	57 58.86	27 55.57	730	2400	2200	300234061828890
n/a	1329	23-Jul-2014	04:20	58 4.92	28 24.21	730	2350	2200	300234061825830
36	1330	23-Jul-2014	05:00	58 8.52	28 32.5	180	2300	2200	300234061823850
n/a	1177	26-Jul-2014	19:30	59 12.78	37 28.66	290	3018	1000	300234010350940
n/a	SOLO958	26-Jul-2014	19:21	59 12.64	39 28.61	n/a	3018	1000	300034012176600

Sound source moorings were deployed under the direction of Mark Graham of the RSMAS/U. of Miami, using NIOZ's double barreled capstan winch. Moorings were adjusted at each site to fit the mooring to the bathymetry, and maintain the sound source height between 1150 and 1200 meters. At Site #5 (sound source s/n 85), one 50-m shot of 3/16th wirerope was removed. At Site #6 (sound source s/n 86) a 10 m ¼ wirerope was replaced with a 50-m shot of identical diameter wire. At Site # 7 (sound source s/n 87) the 50-m and 41-m 3/16th wirerope were removed. A last minute change in cruise plans brought the Knorr quite close to the site for sound source #4, which was to be deployed on Leg 3. This gave us the opportunity to deploy this sound source off the OSNAP line, which would provide better tracking of floats when initially deployed on the line. This plan was scrapped however when the NIOZ winch suffered mechanical problems that would only allow for take-up and not pay-out.

Table 2. Sound source deployment information.

CTD Station	Instrument S/N	Pong Time	Deployment Date	Deployment Time GMT	Latitude (N)	Longitude (W)	Site Number	Water Depth Meters	Ballast/Target Depth Meters
n/a	SS85	00:45	9-Jul-2014	10:24	59 2.328	34 14.172	5	2565	1200
n/a	SS86	00:05	14-Jul-2014	18:18	58 1.260	27 49.014	6	2344	1200
n/a	SS87	00:15	15-Jul-2014	10:24	58 0.502	22 59.411	7	2991	1200

Sound source moorings were tri-laterated by Adam Houk RSMAS/U. of Miami to give exact position of acoustic release, and therefore anchor. Resultant plots of tri-laterated positions are shown in Figures 3 through 5.

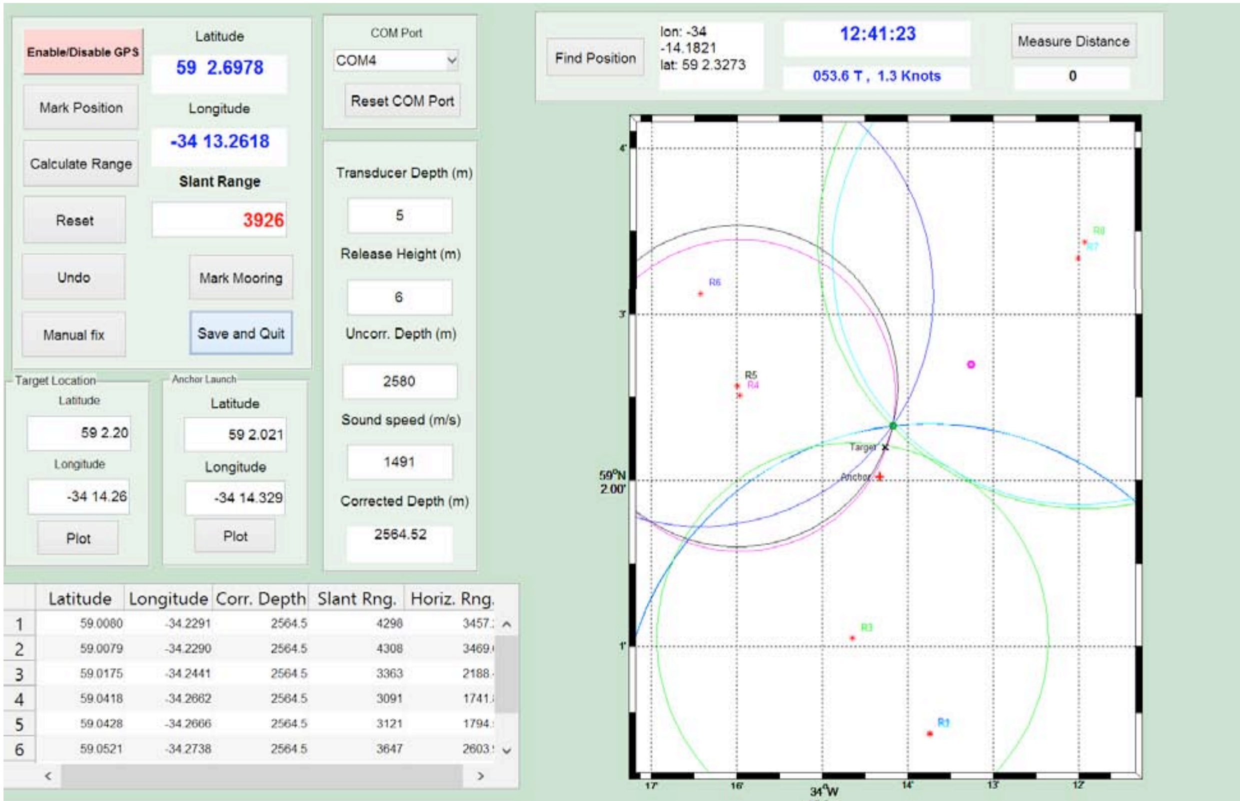
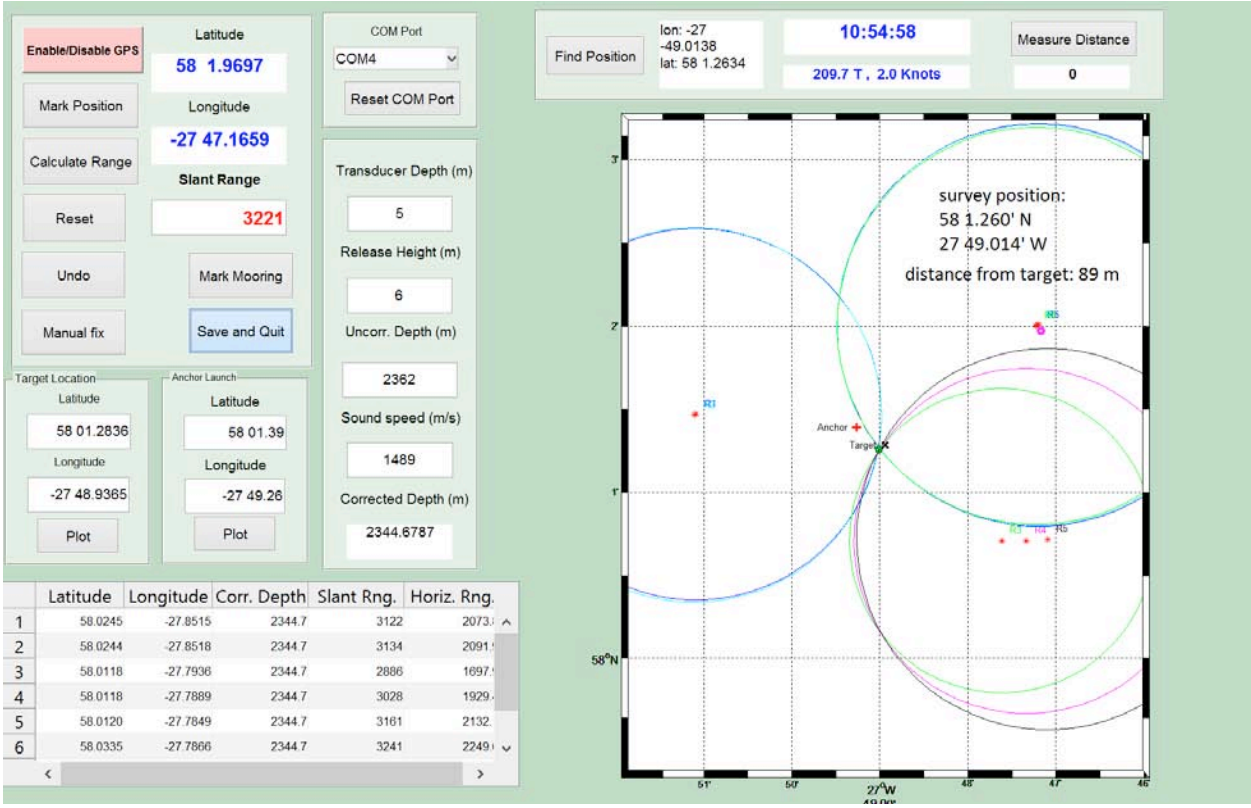
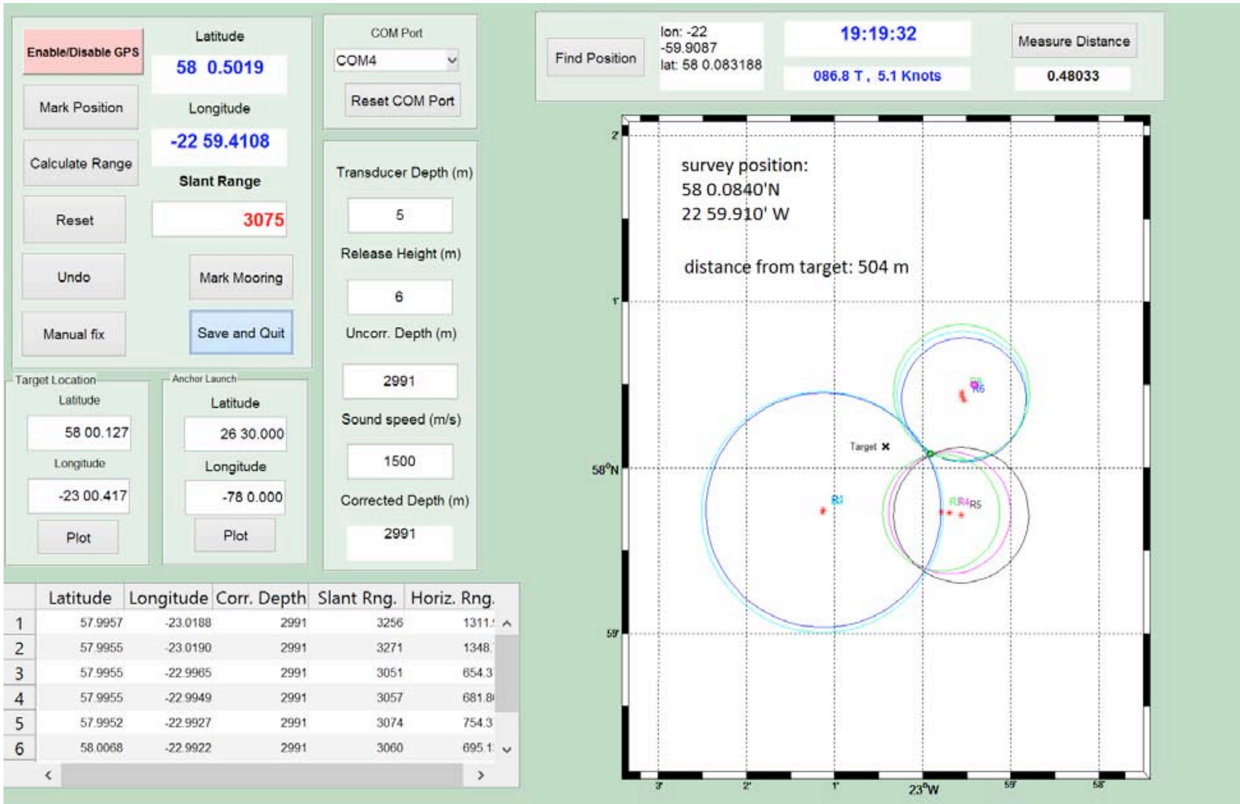


Figure 3. Trilateration of sound source #85 at site #5. We released this mooring asking the bridge for a 0.15 mile fallback.



	Latitude	Longitude	Corr. Depth	Slant Rng.	Horiz. Rng.
1	58.0245	-27.8515	2344.7	3122	2073.
2	58.0244	-27.8518	2344.7	3134	2091.
3	58.0118	-27.7936	2344.7	2886	1697.
4	58.0118	-27.7889	2344.7	3028	1929.
5	58.0120	-27.7849	2344.7	3161	2132.
6	58.0335	-27.7866	2344.7	3241	2249.

Figure 4. Trilateration of sound source #86 at site #6. We released this mooring asking the bridge for a 0.20 mile fallback.



	Latitude	Longitude	Corr. Depth	Slant Rng.	Horiz. Rng.
1	57.9957	-23.0188	2991	3256	1311.!
2	57.9955	-23.0190	2991	3271	1348.
3	57.9955	-22.9965	2991	3051	654.3
4	57.9955	-22.9949	2991	3057	681.8
5	57.9952	-22.9927	2991	3074	754.3
6	58.0068	-22.9922	2991	3060	695.1

Figure 5. Trilateration of sound source #87 at site #7. We released this mooring asking the bridge for a 0.20 mile fallback. In this case, target was input into the program as ‘anchor over’; actual target was 59.00N and 23.00W, closer to actual position than 504 meters shown in plot.