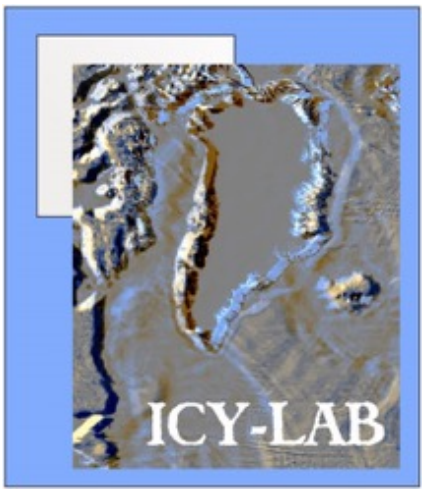
RRS Discovery Cruise DY081, July 6th – August 8th 2017

St John's, Canada – Southampton, UK

ICY-LAB

Isotope CYcling in the LABrador Sea



Cruise Report

Katharine R. Hendry, University of Bristol

CONTENTS

Table of Contents

Many thanks to the Master and crew of the RRS Discovery for all their assistance during this mission.

ICY-LAB is funded by the European Research Council.

Chapter 1: Personnel on board

All crew

1	COX	JOANNA LOUISE	Master
2	MAHON	ANDREW	C/O
3	LEGGETT	COLIN JAMES	2/O
4	WILLIAMS	THOMAS JAY	3/O
5	WOODLAND	HAZEL ELIZABETH	Doctor
6	BILLS	JAMES	C/E
7	KEMP	CHRISTOPHER MARTIN	2/E
8	EVANS	DANIEL CHRISTOPHER	3/E
9	QUITHER	MARTIN	3/E
10	BRAZIER	THOMAS PHILIP	ETO
11	BULLIMORE	GRAHAM	PCO
12	MACDONALD	JOHN	CPOS
13	COOK	STUART CLIVE	CPOD
14	GREGORY	NATHANIEL JAMES	POD
15	CRABB	GARY	SG1A
16	WILLCOX	SIMON PAUL	SG1A
17	PEPPIN	CHRISTOPHER	SG1A
18	DWYER	ANDREW	SG1A
19	BROOMHALL	NATHAN	ERPO
20	LYNCH	PETER ANTHONY	H/Chef
21	LINK	WALTER JOHN THOMAS	Chef
22	CARAHILLO	CLEMENTINA MARIA	Stwd
23	WILLIAMS	DENZIL	A/Stwd
24	ANNETT	AMBER LUELLA	Scientist
25	BADGER	MARCUS	Scientist
26	BATES	STEPHANIE LAUREN	Scientist
27	COOPER	ADAM JOHN	Scientist
28	CUSHMAN	GRACE GARCIA	Scientist
29	GOODWIN	CLAIRE ELOISE	Scientist
30	HENDRY	KATHARINE	PI
31	HOY	SHANNON KELSEY	Scientist
32	HUVENNE	VEERLE ANN IDA	Scientist
33	JACOBEL	ALLISON WOOD	Scientist
34	NG	HONG CHIN	Scientist
35	OPHER	JACOB GEORGE	Scientist
36	PICKERING	REBECCA ANN	Scientist
37	ROBINSON	LAURA FRANCES	Scientist
38	ROWLAND	GEORGE HENRY	Scientist
39	SAMPERIZ VIZCANINO	ANA	Scientist
40	TAYLOR	MICHELLE LISA	Scientist
41	WILLIAMS	JAMES	Scientist
42	TURNER	DAVID RUSSELL	Tech
43	MOUNTIFIELD	DOUGAL	Tech
44	CAMERON	CANDICE ANNE	Tech
45	EDGE	DAVID	Tech
46	DAVIES	ALLAN	Tech
47	LOCKE	RUSSELL ANDREW	Tech
48	WEBB	ANDREW THOMAS	Tech
49	RICHARDS	ELLA LOUISE	Tech
50	LEADBEATER	ANDREW JOHN	Tech
51	VIERA RIVERO	JOSUE DANIEL	Tech
52	BRIDGER	MARTIN JOHN	SST

Science party watch list

8am – 8pm

Dr Katharine Hendry (University of Bristol)

4am – 4pm

Watch Leader: Dr Veerle Huvenne (National Oceanography Centre, Southampton)
Dr Amber Annett (University of Southampton)
Dr Marcus Badger (The Open University)
Grace Cushman (Columbia University, US)
Dr Claire Goodwin (Huntsman Marine Science Centre)
Dr Allison Jacobel (Columbia University, US)
Jacob Opher (British Antarctic Survey)
Rebecca Pickering (Dauphin Laboratory, University of Alabama, US)*
Ana Samperiz (University of Bristol)

* watch rescheduled on some days for incubation experiments

4pm-4am

Watch Leader: Prof Laura Robinson (University of Bristol)
Shannon Hoy (University of New Hampshire, US)
Dr Hong Chin Ng (University of Bristol)
Dr Michelle Taylor (Oxford University)
George Rowland (University of Bristol)
Adam Cooper (University of Southampton)
James Williams (Cardiff University)
Dr Stephanie Bates (University of Bristol)

Chapter 2: Rationale, aims and objectives

The high-latitude regions are experiencing some of the most rapid changes observed in recent decades. Arctic temperatures are rising twice as fast as the global mean, Greenland's glaciers are experiencing significant mass loss, multi-year Arctic sea-ice is declining, and the Nordic Seas are warming at an accelerated rate. These processes are important locally, but their effects are likely to have a global impact: for example, the North Atlantic receives freshwater from the Arctic, Greenland and Canada and is a formation locus of the deep-water masses, which represent a major component of ocean circulation that drives global heat and nutrient fluxes.

Concurrently to the recently observed changes in ice dynamics and accessibility, there has been a significant increase in commercial interest of the natural resources in the ecosystems of the Arctic, surrounding seas and high-latitude North Atlantic. An understanding how natural resources - including fisheries, bird and mammal stocks that are essential for food and tourism – will respond in the future to increasing anthropogenic stress on a regional and global scale relies on an understanding of marine biogeochemistry and the sources and sinks of essential nutrients.

The overall aim of ICY-LAB is to understand nutrient and isotope cycling in the climatically critical but understudied regions of the Labrador Sea and Greenland fjords, and the impact of cryosphere, biosphere and hydrosphere on the biogeochemistry of the region and the global oceans. The approach of ICY-LAB will be to capture the whole biogeochemical system in areas of marked environmental change using careful field sampling strategies, with research expeditions to coastal Greenland and the open ocean Labrador Sea. DY081 represents the key oceanic component of this sampling campaign, focusing on the influence of meltwater on nutrient cycling in the Labrador Sea, using the silicon cycle as a model system. Silicon is a key nutrient for diatoms, algae that are responsible for a large proportion of carbon uptake in marine systems.

The sampling objectives of the cruise

Objectives to be carried out by Dr Kate Hendry and Dr Hong-Chin Ng, with project partners named in parentheses.

1) Mapping of sampling areas (Dr Veerle Huvenne)

2) Detection and sampling of freshwater input from glaciated environments
    a. Physical oceanography (Jacob Opher; Dr Kate Hendry and research group)
    b. Water column acoustics (Shannon Hoy)
    c. Geochemical tracers of freshwater (Dr Kate Hendry and research group)
    d. Nutrient and nutrient isotope sampling (Kate Hendry and research group; also sampling for Dr Sian Henley (University of Edinburgh))

3) Investigation of interactions at the sediment-water interface (Dr Kate Hendry and research group)
    a. Megacore and push core sampling
    b. Porefluid sampling
    c. Core incubation experiments

4) Investigation of biogeography of siliceous organisms
    a. Chlorophyll sampling (Kate Hendry and research group)
    b. Silicon-32 uptake experiments (Rebecca Pickering, Prof Jeffrey Krause (Dauphin Lab))

c. Sponge sampling for taxonomy and biogeography (Claire Goodwin)

5) Complementary studies and projects
   a. Trace metals and trace metal isotopes (Dr Amber Annett, and sampling for Dr Susan Little, Prof Tina Van der Flierdt (Imperial College, London), and Dr Kevin Burton (Durham University))
   b. Benthic biology and genetics (Dr Michelle Taylor, and sampling for Dr Joana Xavier)
   c. Phytophysiology (sampling for Dr Rupert Perkins (Cardiff University))
   d. Organic geochemistry (Dr Marcus Badger)
   e. Habitat mapping (Dr Veerle Huvenne)
   f. Palaeoclimate (Prof Laura Robinson and George Rowland; Dr Allison Jacobel and sampling for Prof Jerry McManus (Columbia University); James Williams)
   g. Microplastics research (Prof Laura Robinson, with Dr Lucy Woodall)

Chapter 3: Cruise overview

Timeline

TABLE 1: TIMELINE OF CRUISE EVENTS AND LOCATIONS.

Date		Location	Activity
July 6th	Transit		
July 7th	Transit	Orphan Knoll	CTD operations CTD01, SAP01; Multibeam survey
July 8th		Orphan Knoll	Multibeam survey; Coring MGA01 + GVY01; ROV dive 327 (start)
July 9th		Orphan Knoll	ROV dive 327 (end); Deploy Towfish FSH01; Survey
July 10th		Orphan Knoll	Retrieve Towfish; ROV dive 328 (aborted); ROV dive 329 (start)
July 11th		Orphan Knoll	ROV dive 329 (end); Coring MGA02 + GVY02; ROV dive 330 (start)
July 12th		Orphan Knoll	ROV dive 330; CTD02; ROV dive 331 (start)
July 13th	Transit	Orphan Knoll	ROV dive 331 (end); Deploy Towfish; Multibeam survey; Start transit to Greenland; SADCP turned on.
July 14th	Transit		
July 15th	Transit		
July 16th	Transit		
July 17th	Transit	Nuuk	GLD01; GLD02; SAPS test; MGA03; Start of CTD grid
July 18th		Nuuk	CTD grid continues. Bad weather halts over the side science.
July 19th		Nuuk	Science continues as weather improves. CTD grid continues.
July 20th		Nuuk	ROV dive 332 (aborted) followed by ROV dive 333.
July 21st		Nuuk	ROV dive 334; transit to southern line; SAPS.
July 22nd		Nuuk	ROV dive 335.
July 23rd		Nuuk	Multibeam survey; ROV dive 336. CTD15.
July 24th	Transit	Nuuk	CTD16, and SAPS at same location. Recovered gliders successfully; MGA04.
July 25th	Transit		
July 26th	Transit	SW Greenland	CTD17. Towfish recovered. ROV337 (aborted), towfish deployed, CTD18.
July 27th		SW Greenland	CTD19, SAP05, MGA05, ROV338 (start).
July 28th		SW Greenland	ROV338, MGA06.
July 29th		SW Greenland	ROV339, Towfish in, CTD20.
July 30th		SW Greenland	CTD21, CTD22.
July 31st	Transit	SW Greenland	CTD23, CTD24, SAP06, MGA07, GVY03, GVY04, GVY05.
August 1st – 8th	Transit		

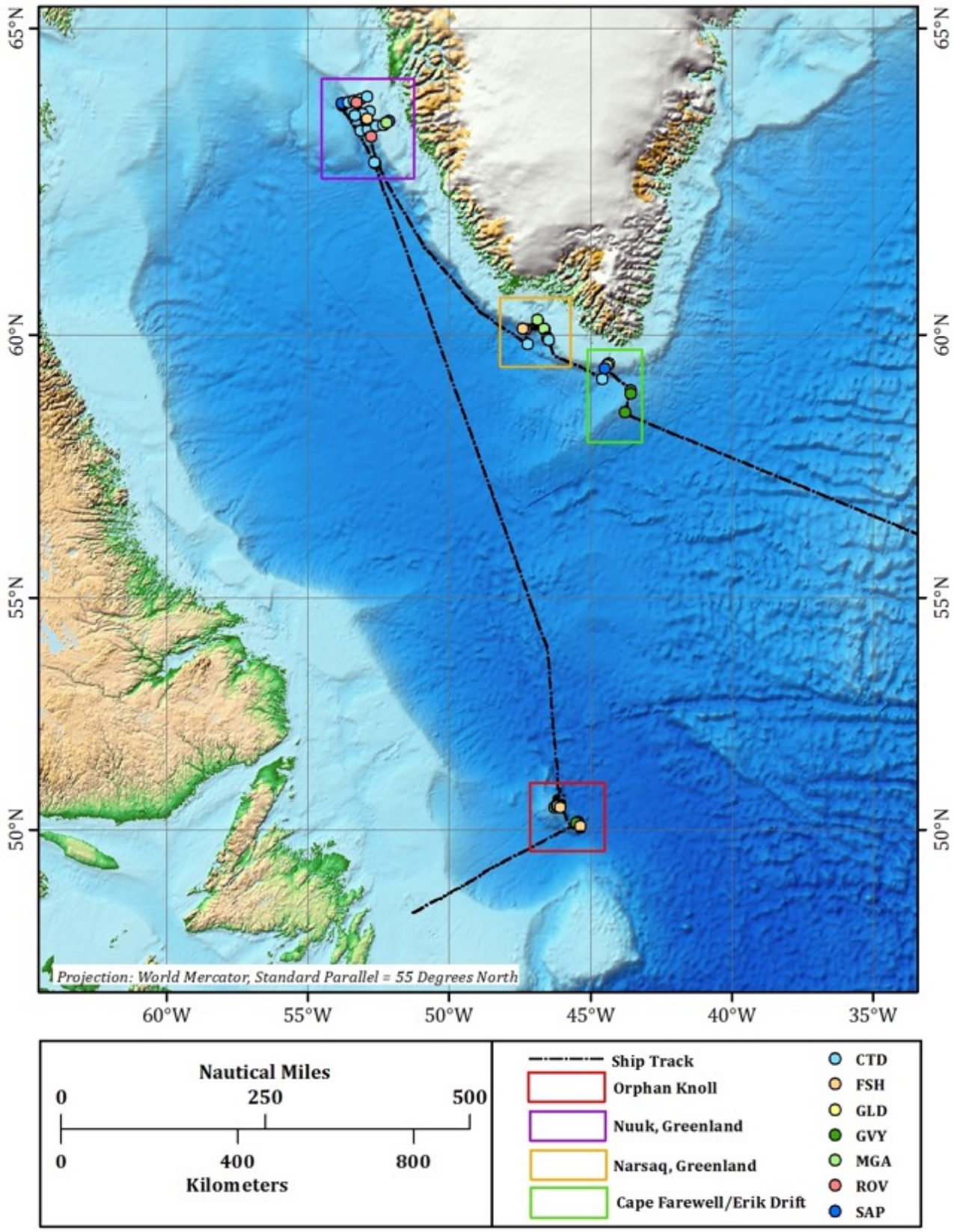


FIGURE 1: OVERVIEW MAP OF DY081 SHIP ROUTE. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 55˚N.

Cruise narrative

Times are ship time, unless stated.

Sunday 2nd July 2017: Most of the science party arrive in St John's, Canada.

Monday 3rd July 2017: Remainder of science party arrive in St John's, Canada.

Tuesday 4th July 2017: Safety briefing for science party 1100. Briefing with captain 1300; informed by captain that sailing due to be delayed approx. 24 hours due to crew change.

Wednesday 5th July 2017: Radionuclide safety briefing 1030. ROV walk through 1300. Database planning meeting 1600.

Thursday 6th July 2017: Ship sails 0800 (ship time changed to GMT-2). CTD walkthrough 1400. Muster and lifeboat drill 1600. Introductory science talk 1700.

Friday 7th July 2017: Ship arrives at Orphan Knoll. **STN001** CTD down to 3800m at 1600 with bottles fired at 12 depths (time on deck 2036 GMT). **STN002** SAPS at 2400 and 200 metres water depth (two SAPS at each depth, with GFF and Supor filters) (time on deck 0212 GMT). One SAPS flooded, and two battery failures part way through pumping but material collected on all filters. CTD cable apparently damaged post-SAPS, but successfully fixed. Multibeam survey of Orphan Seamount.

Saturday 8th July 2017: Survey complete and core site located to northwest of Orphan Seamount. **STN003** Megacore at 3700m metres depth, with 8 successful cores (time on deck 1024 GMT). **STN004** gravity core in same location, successful, with 5m 15cm collected from 3700m (time on deck 1346 GMT). Core catcher collected, and core sectioned in to 1.5 metre lengths.

Sunday 9th July 2017: Recovery of **STN 005** ROV327 in 3600m water depth on Orphan Seamount, southern side; successful collection of sponges and corals; 12 x sediment cores; 6 x Niskin (1 failure). **STN 006** towfish deployed overnight, with three sampling events (deployed 1815 GMT; recovered 0720 GMT). It was noted that the Towfish needed to be pulled in before finalising the ROV position for a dive.

Monday 10th July 2017: Deployment of **STN 007** ROV 328 in 1700m water depth. Collection of cup corals, black coral, sponges, and ophioroids for genetics; push cores and Niskins. Horizontal thruster ground fault led to aborted dive (time on deck 1632 GMT). Also some problems with the suction device. Ground fault problems not diagnosed at surface, but all systems appeared to be operating fully. Redeployed **STN 008** ROV239. Collection of live and fossil solitary corals, and armoured holothurians; push cores and Niskins.

Tuesday 11th July 2017: ROV 239 on deck 1737 GMT. **STN 009** Megacore MGA02 deployed 1900 GMT in water depth of 1770m; four tubes successful sampled for porefluids, core incubation experiment and sections. **STN 010** gravity core GVY02 deployed 2035 GMT, with 4.5m sediments recovered. Deployment of **STN 011** ROV330 at 2315 GMT, collection of fossil and live corals, sponges with crinoids, and collection of images for photogrammetry.

Wednesday 12th July 2017: ROV 330 continued, recovered at 1214 GMT. **STN 012** CTD02 deployed in 1800m water depth, with 24 bottles fired at 8 depths (recovered 1453 GMT). Deployment of **STN 013** ROV 331 at 1609 GMT, collection of fossil corals, living corals, sponges and other biology, push cores. The Kraft arm leaked oil, so there was a slightly early recovery.

Thursday 13th July 2017: ROV 331 continued, but an oil problem relating to an arm meant that the crew retrieved the ROV approximately an hour early at 0630 GMT. Towfish in water for **STN 014**. Multibeam survey to north of ROV 328-331, before commencing transit to Greenland. Shipboard ADCP turned on, and Multibeam survey carried out on transit. Towfish samples collected at intervals. Due to weather, decision was taken to visit SW Greenland site first.

Friday 14th July 2017: Transit continued.

Saturday 15th July 2017: Transit continued. Weather forecast improved, so decision made to go to Nuuk site first as originally planned.

Sunday 16th July 2017: Transit continued.

Monday 17th July 2017: Transit to Nuuk site. Arrive to south of Nuuk site, deployed **STN 015** GLD01 (Coprolite) off starboard side in water at 0611 GMT and diving by 0650; **STN 016** GLD02 (HSB) in water at 0755 GMT. Connectivity issues resulted in minor file corruption, which was resolved before the glider dived at 0910 GMT. **STN 017** CTD03 was deployed at 0949 GMT nearby to calibrate the gliders (approx. 2000m water depth), and to provide a SVP for the Multibeam acoustics. Water samples were only taken for silicon 32 experiments and radium measurements. Transit and Multibeam survey to Nuuk site, stopping before CTD grid for SAPs test (in water 1810 GMT and back on deck 2040); previously flooded casing was shown to be watertight at 1000m for 1 hour. **STN 018** MGA03 deployed and recovered at 2212 GMT, with 8 full tubes. After a short transit, the "Glorious Grid" started with **STN 019** CTD04 deployed. High fluorescence layer was shallower in the water column on the way up, with other evidence for dynamic surface layers.

Tuesday 18th July 2017: **STN 020** SAP02; one SAP only pumped 8L, the others worked well. Didn't manage to get the bottom SAPs down fully to depth due to slow deployment of wire, so sampled at approximately 650 rather than 900m. CTD grid continued with **STN 21** CTD05 (Niskin 7 leaked), **STN 22** CTD06 (Niskins 9 and 18 didn't fire), and **STN 23** CTD07 (7 leaked and 18 didn't fire) on the first line. Weather prevented continuing work on the shelf; transit and Multibeam bathymetry survey during bad weather.

Wednesday 19th July 2017: Over-the-side science continues after weather improved. **STN 24** CTD08 (potentially moved due to current) and **STN 25** CTD09 on third line (note that there was a cautious approach to the bottom due to steep topography). Pause for wind to die down before moving on to **STN 26** CTD10 (Niskins 5 and 7 didn't fire or leaked) and **STN 27** CTD11 (with new Niskin 7) on the shelf, followed by **STN 28** CTD12 (no LADCP) and **STN 29** CTD13 off the shelf. Towfish recovered at end of last CTD.

Thursday 20th July 2017: **STN 030** ROV dive 332 was deployed but recovered due to a ground fault on deployment. Problem rectified and **STN 031** ROV dive 333 was deployed with same aims and objectives as 332. Collection of sponges, corals, bivalves, fossil corals and sediment cores with Niskins fired. ROV dive recovered at 2305 GMT. **STN 32** Towfish in water at 2323 GMT.

Friday 21st July 2017: Final CTD of the "Glorious Grid" **STN 33** CTD 14; further CTDs shorewards were not considered due to time and water depth constraints, and consideration of water profile. **STN 34** ROV dive 334 reson and photogrammetry dive back on wall found during ROV 333, recovered 1605 GMT; also collected push cores (one broken) for porefluids and another net of fossil corals. **STN 35** SAP03 recovered 2340 GMT; Minnie failed (only pumped 14L) but other SAPS successful with approximately 600L pumped through both Supors.

Saturday 22nd July 2017: Transit further south for **STN 36** ROV dive 335; collection of live and fossil corals, sponges, sediments (with porefluid sampling). At the end of the dive, the currents were very strong and there were no good sediments to sample.

Sunday 23rd July 2017: Recover ROV 335 at 0337 GMT. Transit and Multibeam survey to prepare for **STN 37** ROV 336; collection of sponges, corals, photo transit (interrupted by octopus), sediments (with porefluid sampling). Towfish **STN 38** FSH04 at 2105 GMT. Continue third grid line further into glacial trough with **STN 39** CTD15, attempting to sample lower salinity layers (Niskin 9 leaked).

Monday 24th July 2017: Continued third grid line into trough with **STN 40** CTD16; **STN 41** SAPS at same location with last unit on deck at 0714 GMT, with three successful filters. Transit and Multibeam to site of glider recovery. Successful recovery of Coprolite at 1313 GMT (end of STN 15); successful recovery of HSB at 1425 GMT despite the fog rolling in (end of STN 16). Transit south, via man-over-board drill and Megacore at **STN 42** MGA04 with eight successful cores. Begin transit to SW Greenland site. Multibeam survey on route.

Tuesday 25th July 2017: Transit to SW Greenland site. Multibeam continues.

Wednesday 26th July 2017: Arrival at SW Greenland site. **STN 43** CTD17 in strong currents; bottle 9 leaked again. Otherwise, a successful cast. Multibeam survey for ROV site. Towfish recovered. **STN 44** ROV 337 was deployed, but was aborted due to strong currents. Towfish redeployed at **STN 45**. Transit to **STN 46** CTD 18 in trough. Noted surface salinity dropped considerably.

Thursday 27th July 2017: Continue to work at same location with **STN 47** CTD 19, sampled for Dr Amber Annett only (note possible jellyfish fouling could have impacted backscatter), and **STN 48** SAP05, with four successful pumps. Look for sediment coring site on the trough site, resulting in **STN 49** MGA05 with 8 successful cores, and one Niskin (filtered). Further Multibeam to locate possible new ROV site; also keeping an eye on the ADCP for current strength. Site located, with surface currents less than previously, dropping at depth. **STN 50** ROV 338 deployed; initially dived to seafloor to check landing in the currents (all was fine with deployment and diving) and to take push cores, before heading to planned dive start.

Friday 28th July 2017: Continued ROV 338, managing to make a course despite challenging conditions of strong surface currents and icebergs. Collected sponges, fossil coral framework, and Desmophyllum solitary coral. Had difficulty finding further good sediment push cores at depth; on deck 1814 GMT. **STN 51** MGA06, with 8 successful cores, and one Niskin (filtered); recovered 2217 GMT. Multibeam survey for new dive site.

Saturday 29th July 2017: Continue Multibeam survey, finding new site for **STN 52** ROV 339. Start of dive at deepest point, with sandy bottom, rocks, sponges, solitary corals, holothurians and a ray. Dive had to 'bluewater' to avoid iceberg activity; restarted again to complete dive, recovered at 2151 GMT. Towfish in for **STN 53** FSH 06. Short steam to nearby open water for **STN 54** CTD20, 1200m. All Niskins now working after previous bottle change and maintenance.

Sunday 30th July 2017: CTD20 recovered at 0018 GMT. Transit and Multibeam to Cape Farewell. Arrival at station, with slight delay to allow the ROV to be winched to mid-aft deck for demob. Followed promptly by **STN 55** CTD21. All Niskins worked. Transited further into land to attempt a CTD, but was repositioned due to sea-ice conditions. **STN 56** CTD 22 as close as possible to sea-ice edge (all Niskins worked), then retreat further for additional potential CTD site. Decided to search for coring site, and carried out **STN 57** MGA07; all eight cores, but short lengths.

Monday 31st July 2017: Further retreat from sea-ice for **STN 58** CTD 23 (for Dr Annett only) and **STN 59** CTD 24. Followed at the same locations by **STN 60** SAP06; all worked except deeper GFF filter, Chloe. Short transit to Erik Drift. **STN 61** GVY03 at 1660m, 4.8m, but with void so decided to try again. **STN 62** GVY04 came back with only 82cm, but decided to carry on to deeper waters. **STN 63** GVY05. Increasing winds brought forward the end of over-the-side science. Multibeam and shipboard ADCP continued during transit back to UK.

Saturday 5th August 2017: Multibeam and shipboard ADCP turned off on entry into Irish EEZ at 1202 GMT.

Tuesday 8th August 2017: Docking at National Oceanography Centre, Empress Dock, Southampton.

Station list

TABLE 2: STATION LIST FOR CRUISE DY081. CTD = CONDUCTIVITY TEMPERATURE DEPTH AND 24-NISKIN ROSETTE; SAP = STAND ALONE PUMPS; MGA = MEGACORE; GVY = GRAVITY CORE; ROV = REMOTELY OPERATED VEHICLE; FSH = TOWFISH; GLD = GLIDER.

Site	Station	Gear	Jday Start	Start Time (GMT)	Start Lat (DD)	Start Lon (DD)	Start Depth (m)	Jday End	End Lat (DD)	End Lon (DD)	End Depth (m)
Orphan Knoll	1	CTD001	188	17:25:00	50.17428	-45.43948	3813.0	188	50.1743	-45.4395	3814.0
Orphan Knoll	2	SAP001	188	22:03:00	50.17430	-45.43948	3815.0	189	50.1743	-45.4395	3814.0
Orphan Knoll	3	MGA001	189	07:57:00	50.15915	-45.50830	3721.0	189	50.1592	-45.5083	3721.0
Orphan Knoll	4	GVY001	189	11:24:00	50.15919	-45.50835	3721.0	189	50.1592	-45.5083	3721.0
Orphan Knoll	5	ROV327	189	16:19:00	50.04158	-45.37940	3550.8	190	50.0832	-45.3594	1941.0
Orphan Knoll	6	FSH001	190	18:10:00	50.08318	-45.35940	1932.0	191	50.5528	-46.1944	1677.0
Orphan Knoll	7	ROV328	191	07:50:00	50.55481	-46.19323	1669.2	191	50.5564	-46.1956	1576.7
Orphan Knoll	8	ROV329	191	20:48:00	50.55182	-46.19227	1792.0	192	50.5698	-46.1836	1527.0
Orphan Knoll	9	MGA002	192	19:02:00	50.51547	-46.27902	1769.8	192	50.5155	-46.2790	1770.0
Orphan Knoll	10	GVY002	192	20:35:00	50.51546	-46.27900	1770.0	192	50.5155	-46.2790	1770.0
Orphan Knoll	11	ROV330	192	23:23:00	50.55118	-46.19071	1825.5	193	50.5512	-46.1934	1717.0
Orphan Knoll	12	CTD002	193	13:11:00	50.54236	-46.17057	1850.0	193			1846.0
Orphan Knoll	13	ROV331	193	16:15:00	50.50629	-46.08250	1848.0	194			1586.0
Orphan Knoll	14	FSH002	194	07:11:40	50.50770	-46.08840	1837.1	200	50.5755	-45.9865	1594.0
Nuuk	15	GLD001	198	06:11:00	62.90416	-52.62882	2357.0	205	63.7147	-53.0865	1313.0
Nuuk	16	GLD002	198	07:55:00	62.92231	-52.65246	2333.0	205	62.9269	-52.6561	620.0
Nuuk	17	CTD003	198	09:49:00	62.92231	-52.65246	2123.0	198			2064.0
Nuuk	18	MGA003	198	21:14:00	63.81541	-53.77431	1301.0	198	63.8154	-53.7743	1301.0
Nuuk	19	CTD004	198	23:22:00	63.85162	-53.79918	1084.0	199	63.8516	-53.7992	1084.0
Nuuk	20	SAP002	199	02:42:00	63.85227	-53.79763	1080.0	199	63.8530	-53.7981	1080.0
Nuuk	21	CTD005	199	07:14:00	63.87635	-53.56517	966.0	199	63.8822	-53.5674	972.0
Nuuk	22	CTD006	199	10:17:00	63.90095	-53.36405	659.0	199	63.9010	-53.3641	657.0
Nuuk	23	CTD007	199	12:56:00	63.91773	-53.13293	103.0	199	63.9177	-53.1329	103

Nuuk	24	CTD008	200	01:11:00	63.41803	-53.14670	1681.0	200	63.4286	-53.1528	1711
Nuuk	25	CTD009	200	05:22:00	63.45380	-52.87985	915.0	200	63.4538	-52.8799	922
Nuuk	26	CTD010	200	09:43:00	63.49629	-52.61218	339.0	200	63.4963	-52.6122	338
Nuuk	27	CTD011	200	14:55:00	63.72713	-52.83125	69.6	200	63.7271	-52.8313	70.2
Nuuk	28	CTD012	200	17:44:00	63.69635	-53.08266	653.3	200	63.6963	-53.0827	653
Nuuk	29	CTD013	200	20:28:00	63.66162	-53.33311	1550.0	200	63.6616	-53.3331	1549
Nuuk	30	ROV332	201	02:45:00	63.86858	-53.28953	964.0	201	63.8704	-53.2901	950
Nuuk	31	ROV333	201	03:49:00	63.86612	-53.28869	970.0	201	63.8657	-53.2834	805
Nuuk	32	FSH003	201	23:23:00	63.86599	-53.28424	822.8	202	63.9535	-52.9167	67
Nuuk	33	CTD014	202	02:24:00	63.95358	-52.91682	66.5	202	63.9536	-52.9168	66.7
Nuuk	34	ROV334	202	07:00:00	63.86511	-53.28258	807.0	202	63.8651	-53.2784	683
Nuuk	35	SAP003	202	20:36:00	63.59505	-52.95646	786.0	202	63.5950	-52.9565	784.8
Nuuk	36	ROV335	203	03:38:00	63.33217	-52.77710	1281.00	204	63.3317	-52.7550	898
Nuuk	37	ROV336	204	10:51:00	63.60375	-52.91897	515.0	204	63.6112	-52.9032	345.9
Nuuk	38	FSH004	204	21:05:00	63.61123	-52.90324	351.2	207	60.0941	-47.3158	1056
Nuuk	39	CTD015	204	23:54:00	63.51954	-52.35627	446.4	205	63.5195	-52.3563	445.6
Nuuk	40	CTD016	205	02:29:00	63.57532	-52.14668	487.3	205	63.5753	-52.1467	486.6
Nuuk	41	SAP004	205	04:41:00	63.57537	-52.14660	486.0	205	63.5754	-52.1463	488
Nuuk	42	MGA004	205	20:23:00	63.55297	-52.22512	518.8	205	63.5530	-52.2291	519
S. Greenland	43	CTD017	207	05:10:00	59.84621	-47.24472	2780.0	207	59.8517	-47.2485	2782
S. Greenland	44	ROV337	207	17:33:00	60.09451	-47.31853	1037.2	207	60.1063	-47.4009	1048
S. Greenland	45	FSH005	207	20:30:00	60.11090	-47.41771	1050.00	208	60.0898	-46.6496	1111.4
S. Greenland	46	CTD018	207	23:37:00	60.24523	-46.88678	536.0	208	60.2452	-46.8868	536
S. Greenland	47	CTD019	208	02:46:00	60.23971	-46.85244	501.0	208	60.2391	-46.8544	503
S. Greenland	48	SAP005	208	05:30:00	60.24474	-46.88747	534.0	208	60.2447	-46.8875	534
S. Greenland	49	MGA005	208	10:53:00	60.26180	-46.89084	522.3	208	60.2618	-46.8908	572
S. Greenland	50	ROV338	208	18:46:00	60.09000	-46.62533	603.50	209	60.0862	-46.6497	1064
S. Greenland	51	MGA006	209	21:20:00	60.11595	-46.66351	1326.0	209	60.1160	-46.6635	1327

S. Greenland	52	ROV339	210	07:04:00	59.94672	-46.54810	1148.0	210	59.9423	-46.5069	589
S. Greenland	53	FSH006	210	22:07:00	59.94239	-46.50713	596.0	212	59.9395	-43.7783	1907
S. Greenland	54	CTD020	210	23:00:00	59.90837	-46.49170	1270.6	211	59.9084	-46.4917	1270
S. Greenland	55	CTD021	211	12:56:00	59.21163	-44.58042	2030.4	211	59.2162	-44.6061	2036
S. Greenland	56	CTD022	211	18:16:00	59.48646	-44.36462	884.7	211	59.4865	-44.3646	884
S. Greenland	57	MGA007	211	21:21:00	59.45644	-44.41508	1291.0	211	59.4565	28.1216	1292
S. Greenland	58	CTD023	211	23:37:00	59.39499	-44.49790	1521.0	212	59.3950	24.4314	1522
S. Greenland	59	CTD024	212	01:33:00	59.39502	-44.49837	1522.0	212	59.3951	24.4419	1522
S. Greenland	60	SAP006	212	03:44:00	59.39518	-44.49851	1522.0	212	59.3953	24.4501	1521
S. Greenland	61	GVY003	212	11:14:00	58.99701	-43.58429	1670.0	212	58.9967	60.5188	1669
S. Greenland	62	GVY004	212	13:11:00	58.94073	-43.59906	1608.0	212	58.9397	57.0991	1608
S. Greenland	63	GVY005	212	17:49:00	58.60611	-43.77831	1907.0	212	58.6061	37.0833	1907

Chapter 4: Site summaries and maps

Orphan Knoll

Orphan Knoll site was selected as a distal comparison site for the ICY-LAB project, and for complementary palaeoclimate, biological and habitat mapping studies. The site was divided into southern and northern regions.

FIGURE 2: MAP OF ORPHAN KNOLL WITH SHIP TRACK. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

FIGURE 3: MAP OF SOUTHERN ORPHAN KNOLL WITH STATION LOCATIONS. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

FIGURE 4: MAP OF NORTHERN ORPHAN KNOLL WITH STATION LOCATIONS. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

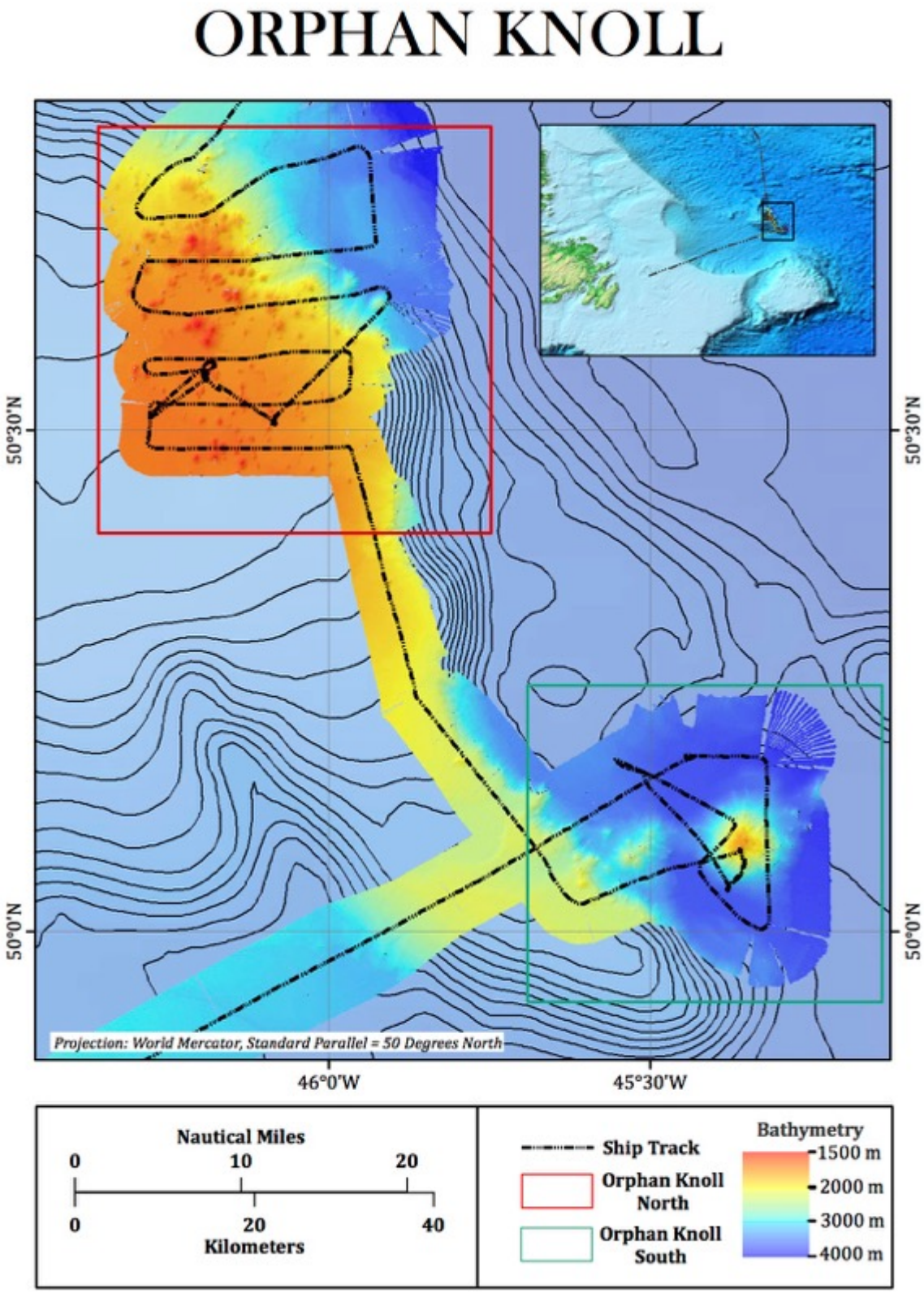

ORPHAN KNOLL
50°30'N
50°0'N
46°0'W
45°30'W
Projection: World Mercator, Standard Parallel = 50 Degrees North
Nautical Miles
0
10
20
0
20
40
Kilometers
Ship Track
Orphan Knoll North
Orphan Knoll South
Bathymetry
1500 m
2000 m
3000 m
4000 m

Figure 2

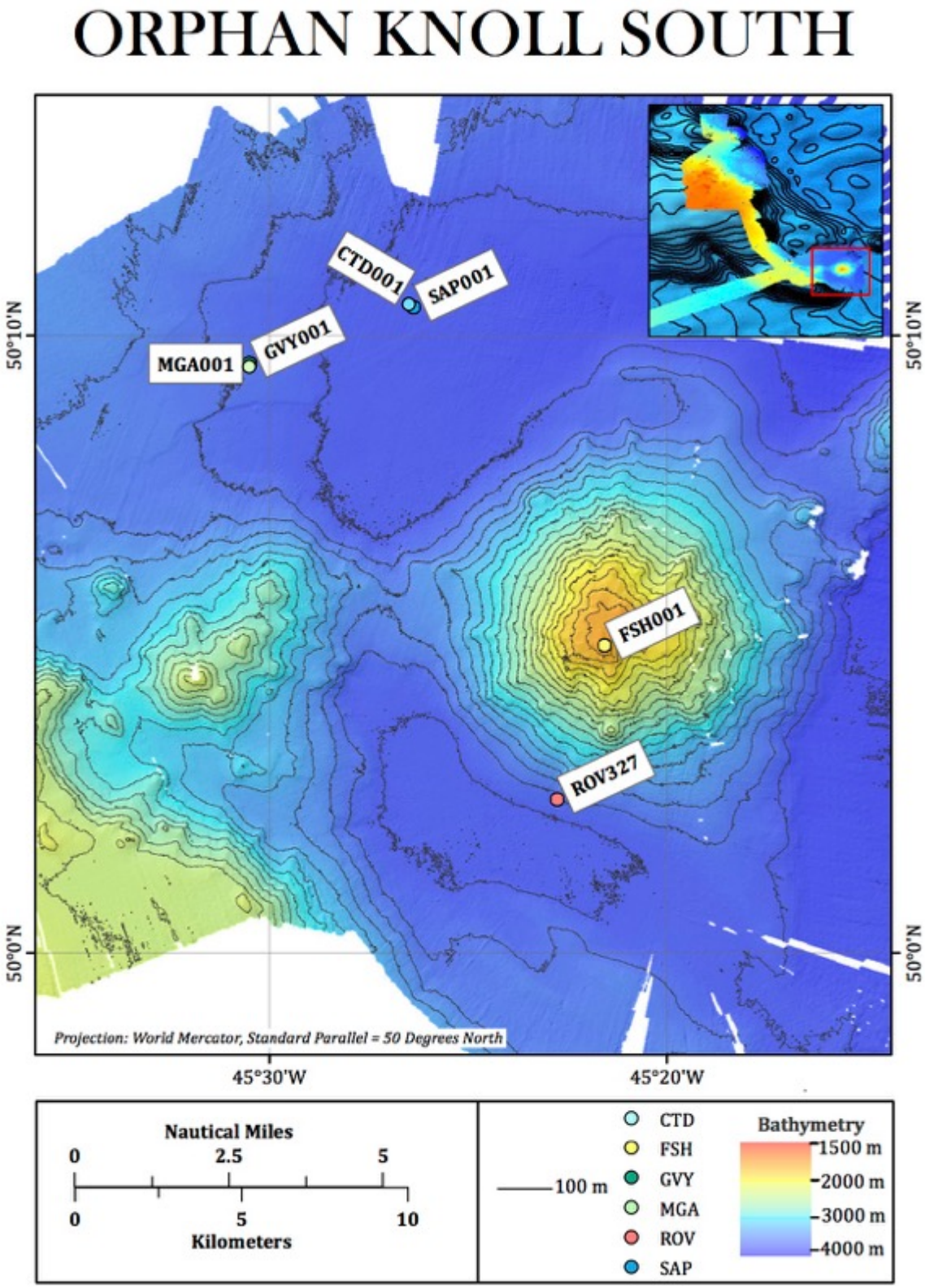

ORPHAN KNOLL SOUTH
CTD001
SAP001
GVY001
MGA001
FSH001
ROV327
50°10'N
50°0'N
45°30'W
45°20'W
Projection: World Mercator, Standard Parallel = 50 Degrees North
Nautical Miles
0
2.5
5
0
5
10
Kilometers
100 m
CTD
FSH
GVY
MGA
ROV
SAP
Bathymetry
1500 m
2000 m
3000 m
4000 m

Figure 3

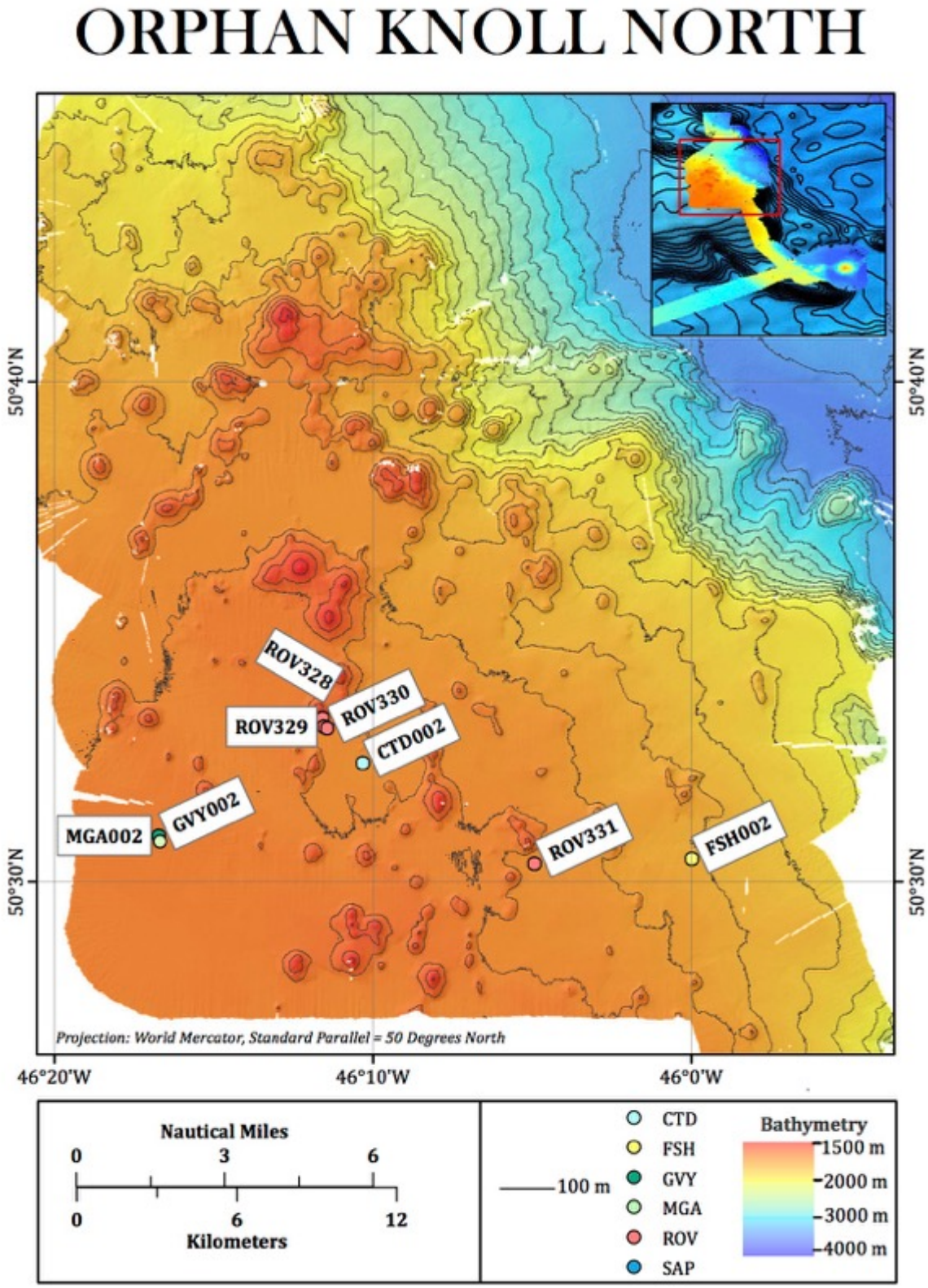

ORPHAN KNOLL NORTH
50°40'N
50°30'N
46°20'W
46°10'W
46°0'W
ROV328
ROV330
ROV329
CTD002
GVY002
MGA002
ROV331
FSH002
Projection: World Mercator, Standard Parallel = 50 Degrees North
Nautical Miles
0
3
6
0
6
12
Kilometers
100 m
CTD
FSH
GVY
MGA
ROV
SAP
Bathymetry
1500 m
2000 m
3000 m
4000 m

Figure 4

Nuuk

The Nuuk site was selected the main study location for the ICY-LAB project, and included a CTD grid and glider deployment for high-resolution water column studies surrounding glacial troughs, in addition to the other methodologies employed throughout the cruise.

FIGURE 5: MAP OF NUUK SITE WITH CRUISE TRACK AND STATIONS (OVER THE PAGE). PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

Southern Greenland

The Southern Greenland site was selected for providing glacial troughs that could act as direct comparisons to the Nuuk site for the ICY-LAB project. The site is strongly influenced by both icebergs and sea-ice. The site is divided into two regions termed Narsaq and Cape Farewell.

FIGURE 6: MAP OF SOUTHERN GREENLAND SITE WITH CRUISE TRACK (OVER THE PAGE). PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

FIGURE 7: MAP OF SOUTHERN GREENLAND SITE (NARSAQ) WITH STATIONS. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

FIGURE 8: MAP OF SOUTHERN GREENLAND SITE (CAPE FAREWELL AND ERIK DRIFT) WITH STATIONS. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

NUUK, GREENLAND

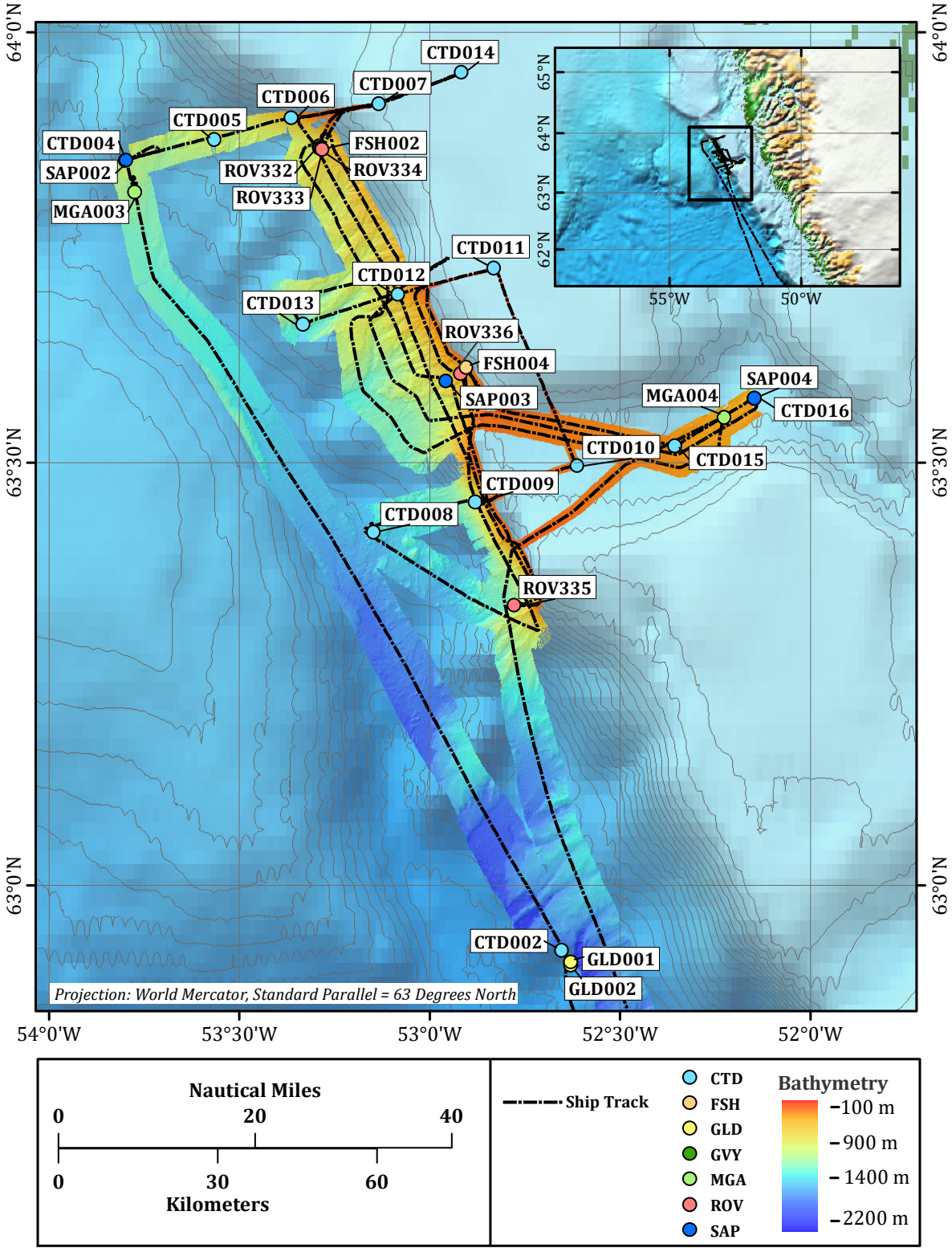


Figure 5

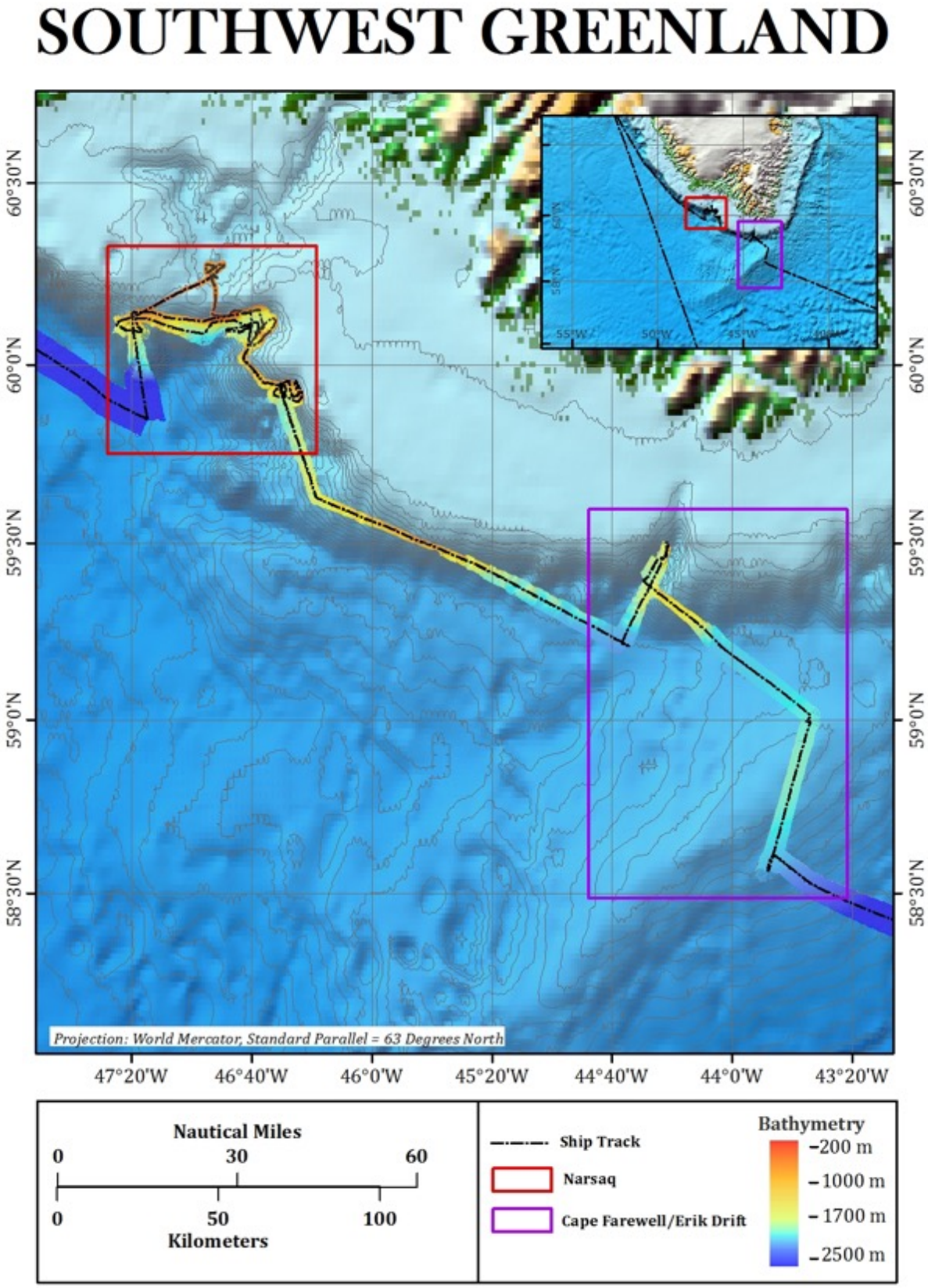

SOUTHWEST GREENLAND
60°30'N
60°0'N
59°30'N
59°0'N
58°30'N
55°W
50°W
45°W
40°W
Projection: World Mercator, Standard Parallel = 63 Degrees North
47°20'W
46°40'W
46°0'W
45°20'W
44°40'W
44°0'W
43°20'W
Nautical Miles
0
30
60
0
50
100
Kilometers
Ship Track
Narsaq
Cape Farewell/Erik Drift
Bathymetry
-200 m
-1000 m
-1700 m
-2500 m

Figure 6

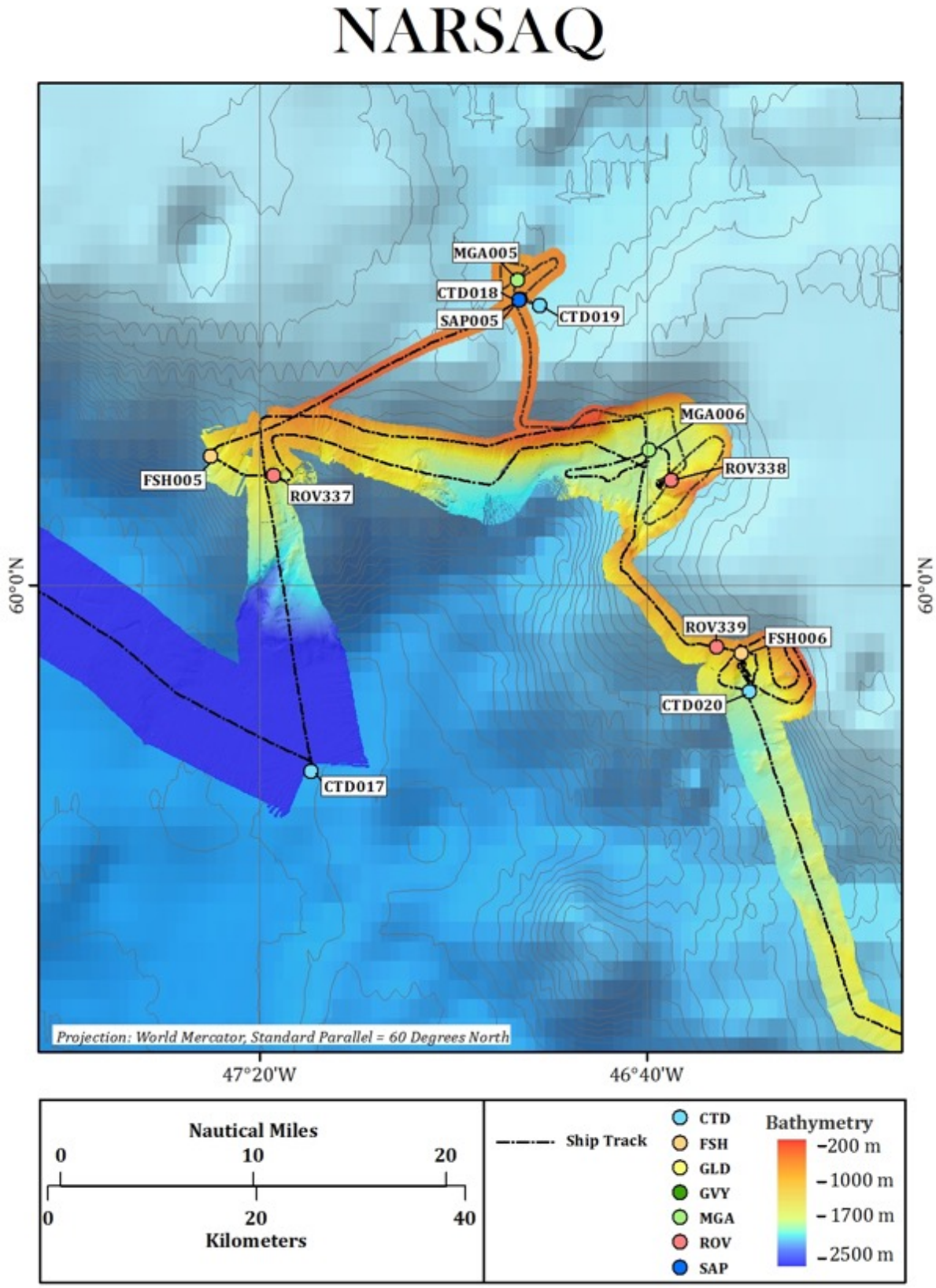

NARSAQ
MGA005
CTD018
SAP005
CTD019
MGA006
ROV338
FSH005
ROV337
ROV339
FSH006
CTD020
CTD017
60°09'N
60°09'N
Projection: World Mercator, Standard Parallel = 60 Degrees North
47°20'W
46°40'W
Nautical Miles
0
10
20
0
20
40
Kilometers
Ship Track
CTD
FSH
GLD
GVY
MGA
ROV
SAP
Bathymetry
-200 m
-1000 m
-1700 m
-2500 m

Figure 7

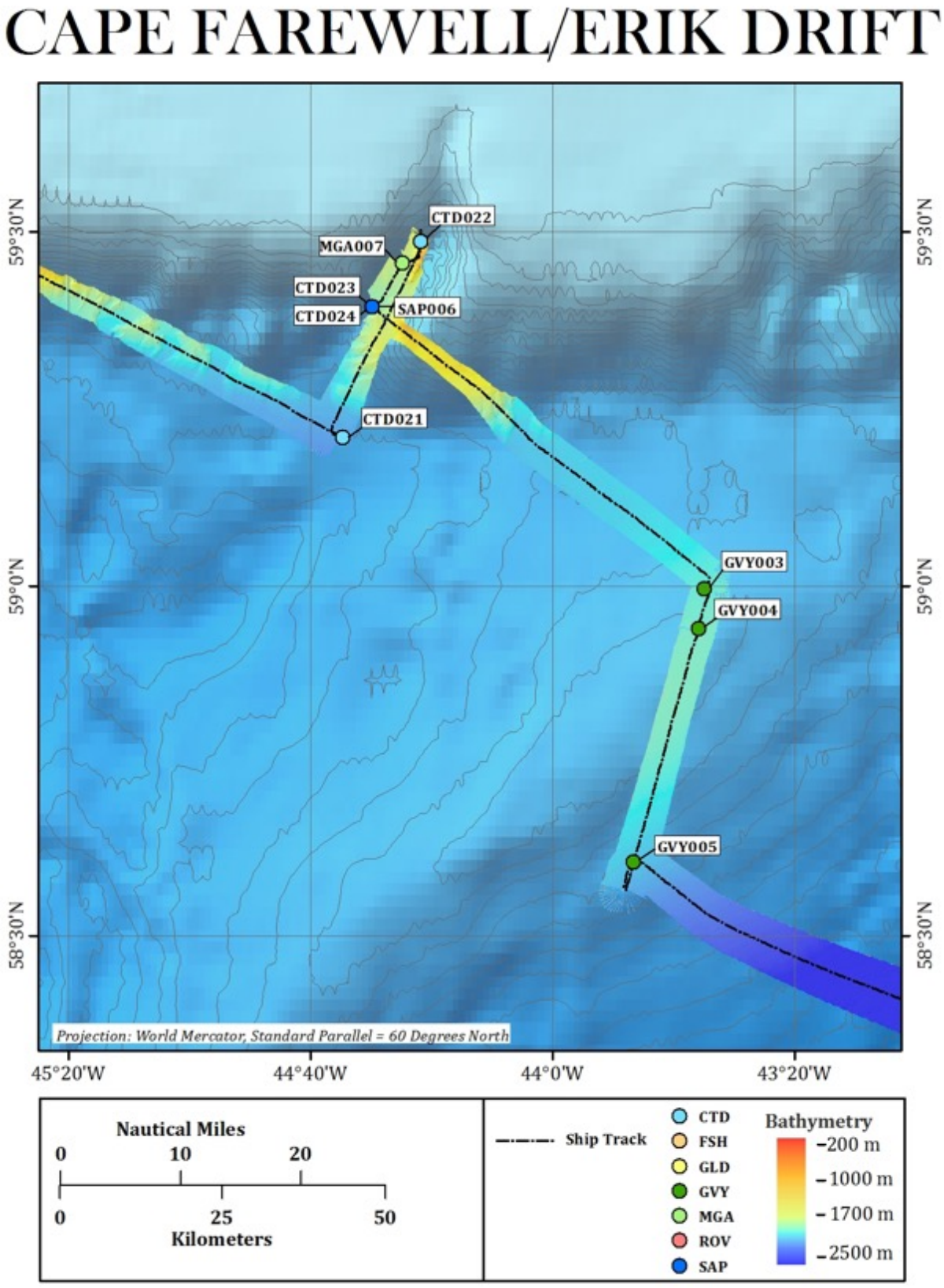

CAPE FAREWELL/ERIK DRIFT
CTD022
MGA007
CTD023
CTD024
SAP006
CTD021
GVY003
GVY004
GVY005
59°30'N
59°0'N
58°30'N
45°20'W
44°40'W
44°0'W
43°20'W
Projection: World Mercator, Standard Parallel = 60 Degrees North
Nautical Miles
0
10
20
0
25
50
Kilometers
Ship Track
CTD
FSH
GLD
GVY
MGA
ROV
SAP
Bathymetry
-200 m
-1000 m
-1700 m
-2500 m

Figure 8

Chapter 5: Technical report

Acoustics operations

During DY081, six acoustic systems were run from the ship, and one from the ROV:

- EM122 multibeam echosounder (12 kHz)
- EM710 multibeam echosounder
- SBP120 sub-bottom echosounder (2.5 – 6.5 kHz)
- EK60 fish finding echosounder (18, 38, 70, 120, 200, 333 kHz)
- Teledyne OS075 ADCP (75 kHz)
- Teledyne OS150 ADCP (150 kHz)
- Reson 7125 multibeam echosounder (400 kHz)

The ship acoustic systems were coordinated via the K-Sync system (Figure 9), to avoid interference and crosstalk. For the majority of operations, the EM122, SBP120, EK60, and the OS150 were synced to ping concurrently, with the EM122 set as the master external trigger. The OS75 was offset from the main trigger group and the EM710 was set to free ping.

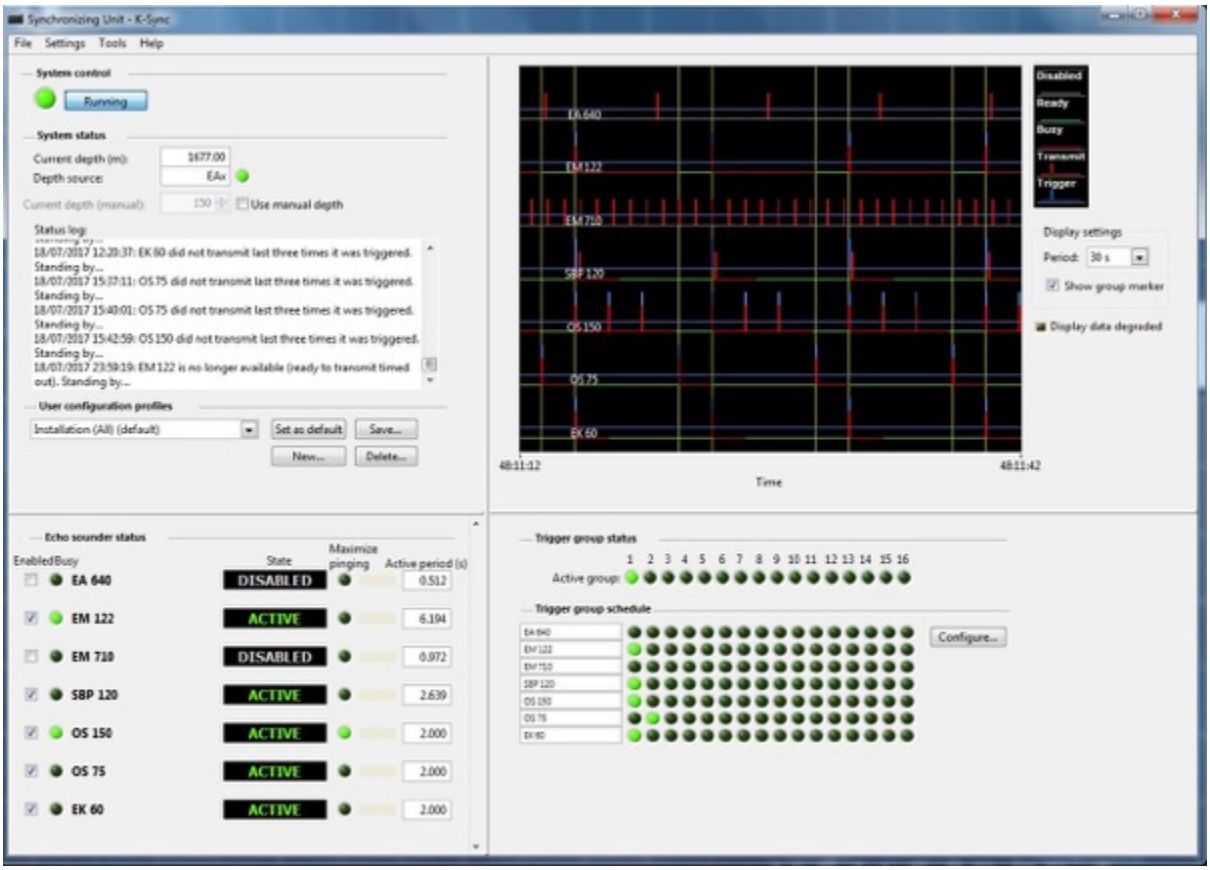


FIGURE 9: K-SYNC SET-UP FOR OPERATIONS WITH ALL SYSTEMS RUNNING.

Basic manual logs were kept during the operations, and have been scanned as pdf documents. Summaries of these are provided in the tables below.

EM122 Multibeam Echosounder

The EM122 multibeam echosounder was the main mapping system used throughout the cruise. The maps were used to inform further sampling, and specifically to design the ROV dives. EM122 data were collected continuously during transits, in addition to the specific surveys that were carried out at each of the study areas. Table 4 summarises the basic parameters for each of the sections of data. In total, 55,868 square kilometres were mapped with the EM122. The table below summarises the basic parameters for each of the sections of data.

TABLE 3: RECORDING TIMES, SVP AND LINE NUMBERS FOR EM122 DATA FOR EACH OF THE STUDY AREAS.

EM122 log																		
From								To								Data type		SVP	Comments
JD	Time	Lat d	Lat min	Lon	Long min	Depth	Line	JD	Time	Lat d	Lat min	Lon	Long min	Depth	Line	Bathy	WC		
187	13:29	47	43.484	52	11.5	189	0	188	16:43	50	10.561	45	25.929	3814	59	x		DY080_CTD003	Transit 1: St John's - Orphan Knoll
189	02:37	50	10.614	45	24.383	3801	60	189	07:08	50	10.908	45	33.069	3613	74	x		DY081_CTD001	Orphan Seamount initial survey - SVP from CTD001
189	14:22	50	8.96	45	30.375	3708	75	190	15:38	50	4.8	45	21.6	2056	77	x		DY081_CTD001	EM122 data around Orphan Seamount
190	18:49	50	4.972	45	21.55	1963	78	191	07:30	50	33.28	46	11.59	1689	112	x		DY081_CTD001	Transit from Orphan Seamount and survey on Orphan Knoll N
194	07:50	50	33.832	46	0.246	2084	113	194	18:05	50	55.834	46	9.428	2702	145	x		DY081_CTD001	Final part of survey on Orphan Knoll N
194	18:12	50	56.647	46	9.758	2789	146	198	05:46	62	54.218	52	37.826	2359	318	x	x	DY081_CTD002	Transit 2: Orphan Knoll to Greenland
198	11:32	62	55.652	52	39.394	2036	319	198	17:32	63	49.709	53	46.83	1242	331	x	x	DY081_CTD002	EM122 data around Nuuk
198	22:20	63	48.959	53	46.504	1273	332	199	17:41	63	41.781	53	4.881	701	348	x	x	DY081_CTD003	EM122 data around Nuuk
199	18:16	63	40.15	53	3.4641	760	349	205	20:20	63	33.178	52	13.507	518	467	x	x	DY081_CTD006	EM122 data around Nuuk. Piece-wise, several software restarts
205	21:37	63	33.063	52	14.366	520	468	207	05:45	59	50.773	47	14.682	2751	536	x	x	DY081_CTD006	Transit 3: Nuuk to SW Greenland (Narsaq)
207	08:15	59	50.743	47	14.666	2755	537	207	16:30	60	5.627	47	18.649	1145	562	x	x	DY081_CTD017	EM122 survey around SW Greenland (Narsaq)
207	18:21	60	5.669	47	21.158	985	563	207	23:32	60	14.706	46	53.246	527	577	x	x	DY081_CTD017	EM122 data around Narsaq -piece-wise
208	02:12	60	14.706	46	51.147		578	210	22:55	59	54.505	46	29.502	1254	627	x	x	DY081_CTD018	further EM122 data around Narsaq, using SVP from CTD18
211	00:33	59	54.399	46	29.497	1283	628	211	12:16	59	12.713	44	34.85	2006	654	x	x	DY081_CTD020	Transit 4: Narsaq to Cape Farewell. Switched to next SVP at 01:03
211	14:47	59	12.974	44	36.381	2012	655	211	23:35	59	23.699	44	29.874	1521	665	x	x	DY081_CTD020	EM122 data around Cape Farewell. Stop-start, no info on end
212	06:34	59	23.545	44	29.41	1486	666	212	17:38	58	36.346	43	46.757	1883	684	x	x	DY081_CTD020	Survey for Eirik drift & coring work
212	20:33	58	36.547	43	46.327	1881	686	217	12:02	52	2.937	15	54.423	3297	904	x	x	DY081_CTD020	Transit 5: Eirik drift - Irish EEZ

Acquisition settings:

Vessel speed: specific surveys were carried out at 8kn, otherwise data were collected at the speed that was most appropriate for the vessel (e.g. 10-11 kn during transit);

Swath angle: 60deg, except in cases when overlap was not sufficient, e.g. when the course had to be altered because of ice;

Data format: data were stored as Kongsberg .all files, with .wcd files for the water column information;

Navigation: GPS data from the POS-MV system (the usual SeaPath GPS had problems at the start of the cruise, hence the POS-MV was used for the duration of the expedition);

Further settings information is provided in the Figure 10.

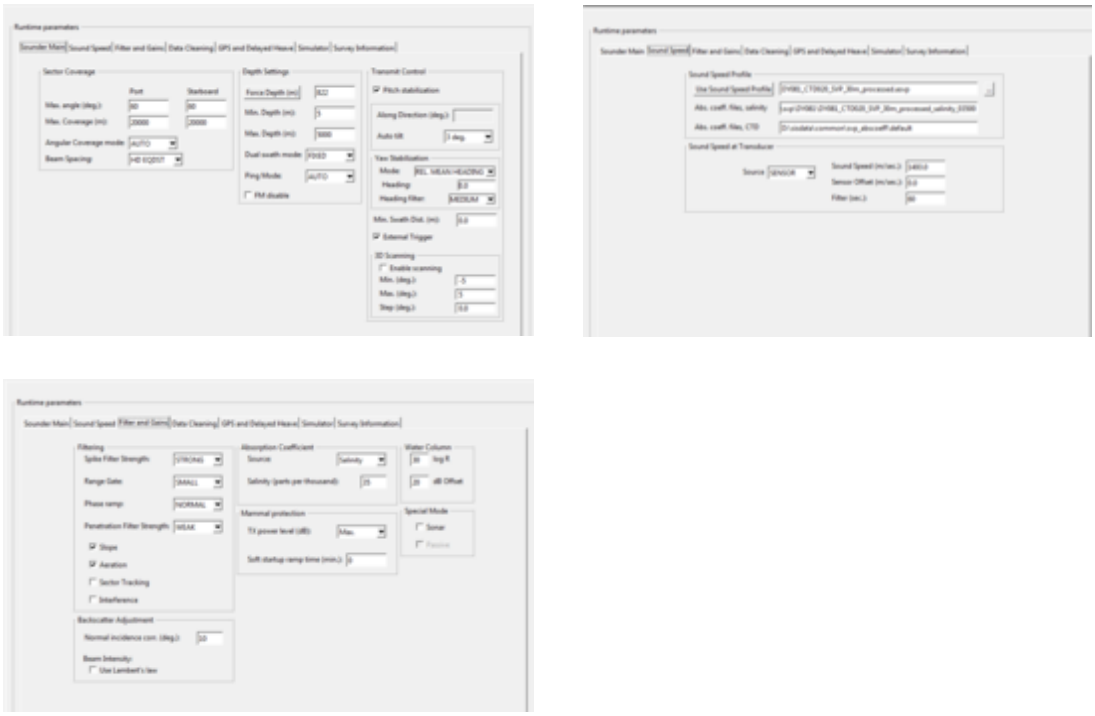


FIGURE 10: SETTINGS FOR EM122 ECHOSOUNDER.

Sound velocity information was taken from the various CTD casts carried out throughout the cruise, which were applied to the data as soon as they were available (see Table 3 for information on which SVP was used in which area). In addition, the sound velocity at the transducer was also used. It was noted that, due to working in shallow conditions close to river and meltwater inputs, the sound velocity at the transducer was often significantly different from the surface water sound velocity in the SVP profiles (red alarm on SIS).

Data Processing:
The data types recorded from the EM122 system include bathymetry, backscatter and water column data. Bathymetry data were processed on-board with the Caris HIPS & SIPS software v.8, using standard settings and procedures (data import, navigation and attitude check, application of a “zero tide”, gridding into a 25mx25m pixel BASE surface). Each bathymetry grid, as well as an interpolated surface, was exported to an ASCII grid, a GeoTiff, as well as a Fledermaus SD object. The vessel file Disco_EM122_POS_MV.hvf was used for processing, with the following offsets:

Time Corr: 0.00
X (m): -0.005
Y (m): 35.219
Z (m): 7.438
Pitch (deg): 0.00
Roll (deg): 0.00
Yaw (deg): 0.00

While post processing on-board, some errors were apparent in the bathymetric grids. These could be either due to the rapidly changing water masses, or to some systematic offset. Further processing is required to determine and fix these errors.

The final bathymetry grids are listed in Table 4 and presented in Figure 11. Backscatter data were processed using the default settings in Fledermaus FMGT and exported as GeoTiff. Water column data were collected, but except for occasional quality control, were not processed further on-board.

TABLE 4: FINAL EM122 GRIDS.

Location	File Name	Lines Contained	Projection	Resolution (m)	Area (km^2)
TRS 1	DY081_EM122_TRS_1a_25m	0000 - 0015	WGS84 UTM 22 N	25	108
TRS 1	DY081_EM122_TRS_1b_25m	0016 - 0038	WGS84 UTM 22 N	25	1083
TRS 1	DY081_EM122_TRS_1c_25m	0039 - 0055	WGS84 UTM 23 N	25	1962
Orphan Knoll	**DY081_EM122_OK_25m**	**0056 - 0147**	**WGS84 UTM 23 N**	**25**	**3414**
TRS 2	DY081_EM122_TRS_2a_25m	0147 - 0170	WGS84 UTM 23 N	25	2558
TRS 2	DY081_EM122_TRS_2b_25m	0168 - 0195	WGS84 UTM 23 N	25	2716
TRS 2	DY081_EM122_TRS_2c_25m	0194 - 0221	WGS84 UTM 23 N	25	2816
TRS 2	DY081_EM122_TRS_2d_25m	0220 - 0244	WGS84 UTM 22 N	25	3183
TRS 2	DY081_EM122_TRS_2e_25m	0242 - 0285	WGS84 UTM 22 N	25	4354
TRS 2	DY081_EM122_TRS_2f_25m	0284 - 0317	WGS84 UTM 22 N	25	3230
Nuuk	**DY081_EM122_Nuuk_25m**	**0318 - 0479**	**WGS84 UTM 22 N**	**25**	**2538**
TRS 3	DY081_EM122_TRS_3a_25m	0478 - 0509	WGS84 UTM 22 N	25	2406
TRS 3	DY081_EM122_TRS_3b_25m	0508 - 0531	WGS84 UTM 22 N	25	1981
Narsaq	**DY081_EM122_Narsaq_25m**	**0530 - 0637**	**WGS84 UTM 23 N**	**25**	**1295**
TRS 4	DY081_EM122_TRS_4_25m	0636 - 0653	WGS84 UTM 23 N	25	429
Cape Farewell	**DY081_EM122_CapeFarewell_25m**	**0653 - 0688**	**WGS84 UTM 23 N**	**25**	**1088**
TRS 5	DY081_EM122_TRS_5d_25m	0829 - 0874	WGS84 UTM 27 N	**25**	4711
TRS 5	DY081_EM122_TRS_5e_25m	0871 -0904	WGS84 UTM 28 N	**25**	3780
				TOTAL AREA =	**55868**

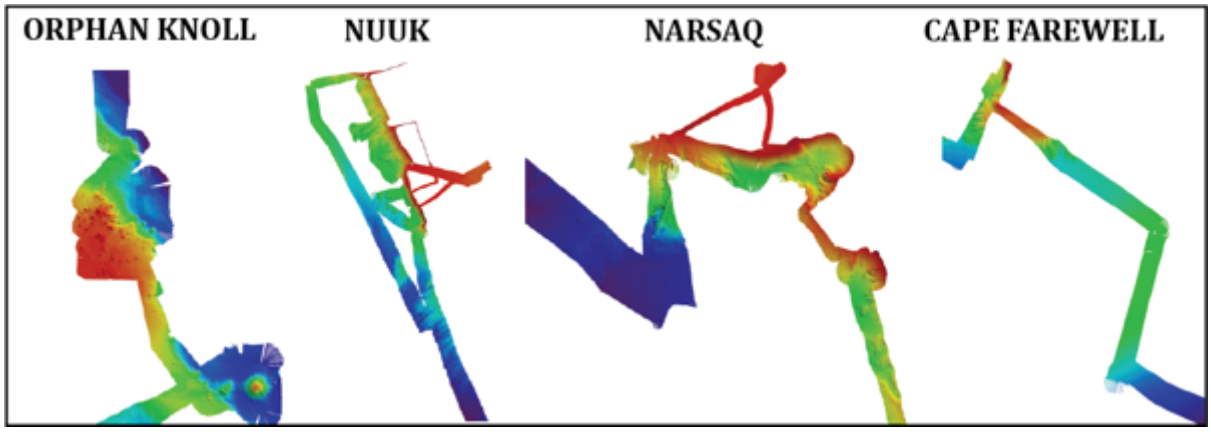


FIGURE 11: OVERVIEW OF THE BATHYMETRIC GRIDS OBTAINED IN THE MAIN STUDY AREAS.

EM710 Multibeam Echosounder

The EM710 system was used initially for seabed mapping on the first transit in the shallow waters offshore St John's. However, later on in the cruise this system was set up specifically for water column surveying down to 250mwd, which meant that no further seafloor maps were created with this system. An overview of the basic parameters and line numbers for each of the cruise sections is provided in Table 5.

TABLE 5: RECORDING TIMES, SVP AND LINE NUMBERS FOR EM710 DATA FOR EACH OF THE STUDY AREAS.

EM710 log																		
From								To								Data type		SVP	Comments
JD	Time	Lat d	Lat min	Lon	Long min	Depth	Line	JD	Time	Lat d	Lat min	Lon	Long min	Depth	Line	Bathy	WC		
187	13:19	47	42.367	52	13.939	186	0	188	00:23	48	43.48	49	27.7067	1238	22	x		DY080_CTD003	Transit 1: St John's to deep water
194	19:19	51	6.977	46	9.775	3926	30	197	23:07						169		x	DY081_CTD002	first acquisition of water column data . Computer froze @23:07
198	11:33	62	55.689	52	39.386	2028	170	198	17:35	63	49.861	53	46.883	1189	180		x	DY081_CTD002	EM710 WC data around Nuuk
198	22:24	63	49.526	53	46.914	1289	181	199	17:41	63	41.783	53	4.881	641	194		x	DY081_CTD002	EM710 WC data around Nuuk
199	17:55	63	41.7439	53	4.8032	642	195	205	20:10	63	33.178	52	13.507	518	301		x	DY081_CTD006	EM710 WC data around Nuuk. Piece-wise datasets
205	21:37	63	33.063	52	14.366	521	302	207	05:46	59	50.773	47	14.691	2751	362		x	DY081_CTD006	Transit 3: Nuuk - SW Greenland (Narsaq)
207	08:16	59	50.747	47	14.661	2754	363	207	16:30	60	5.627	47	18.649	1145	379		x	DY081_CTD017	survey around Narsaq site. New SVP at 10:36
207	20:56	60	6.71	47	25.09	1032	380	210	05:53	59	55.644	46	29.898	1080	419		x	DY081_CTD018	EM710 data around Narsaq site. New SVP at 02:221 on JD208
211	00:35	59	54.33	46	29.521	1307	420	211	12:16	59	12.713	44	34.85	2006	443		x	DY081_CTD020	Transit 4: Narsaq - Cape Farewell. New SVP at 01:05
211	14:47	59	12.974	44	36.381	2012	444	211							448		x	DY081_CTD020	EM710 data around Cape Farewell. No info about end time
212	06:36	59	23.422	44	29.137	1408	449	212	17:37	58	36.346	43	46.757	1883	465		x	DY081_CTD020	survey for Eirik drift and coring work
212	20:33	58	36.547	43	46.327	1881	466	217	12:02	52	2.937	15	54.423	3297	675		x	DY081_CTD020	Transit 5: Eirik drift - Irish EEZ

Settings:

Vessel speed: specific surveys were carried out at 8kn, otherwise data were collected at the speed that was most appropriate for the vessel (e.g. 10-11 kn during transit);

Swath angle: 60deg, except in cases when overlap was not sufficient, e.g. when the course had to be altered because of ice;

Data format: data were stored as Kongsberg .all files, with .wcd files for the water column information.

To collect high resolution data of the upper 250 meters of the water column, the following methods (as suggested by John Hughes Clarke) were followed:

- Sonar Mode (Runtime Parameters > Filter and Gains > Sonar Mode)
- Ping Mode set to Shallow
- Depth Settings (min = 0 meters, max = 250 m)
- EM710 free pinging (unsynced from the EM122)

Further settings information is provided in the figure below.

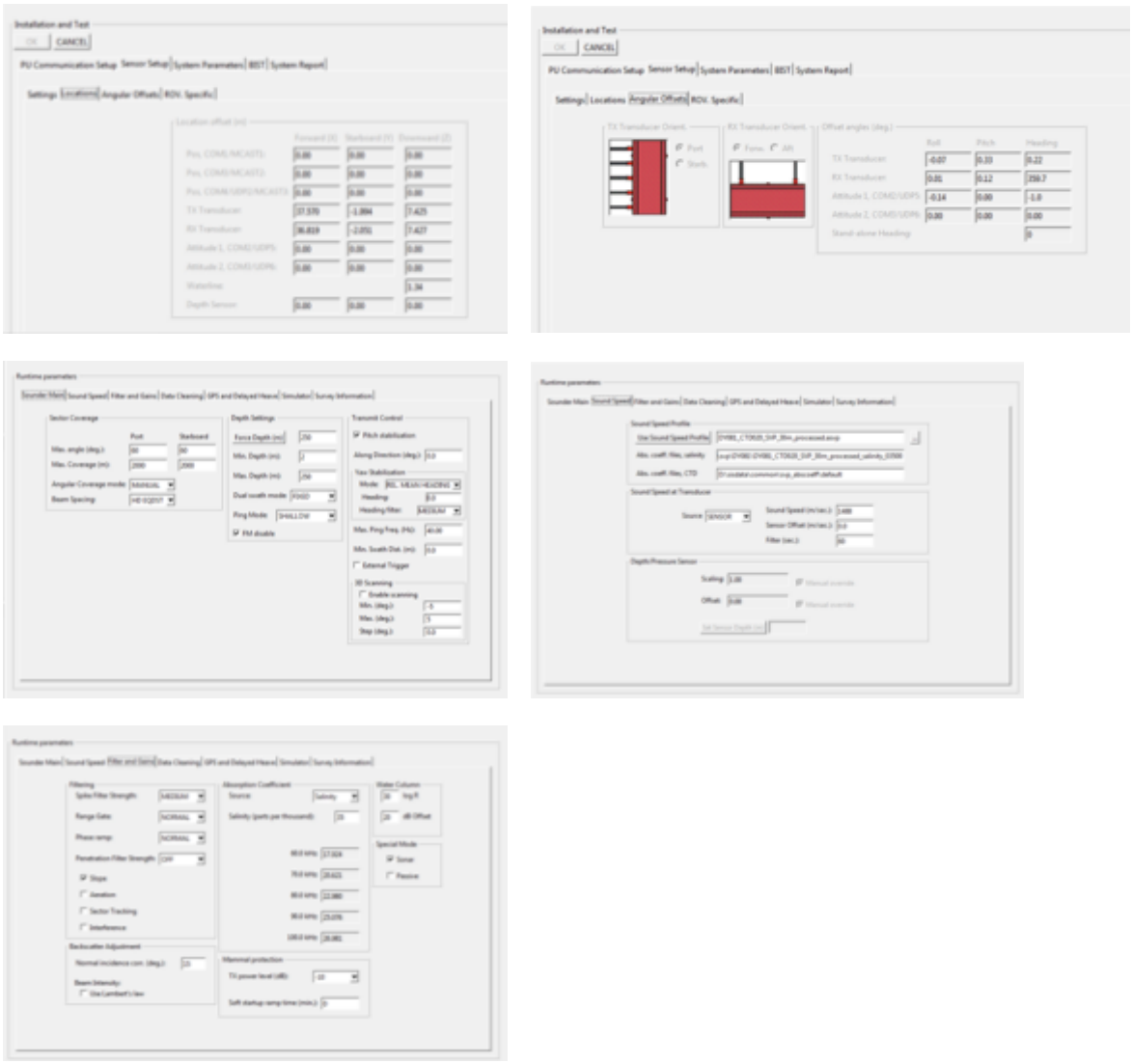


FIGURE 12: SETTINGS FOR EM710 ECHOSOUNDER.

Data processing:
Data processing for the EM710 was similar to the EM122: using Caris Hips & Sips v.8 for bathymetry (Table 5), Fledermaus FMGT for backscatter, and no further systematic on-board processing for the watercolumn data. Equally to the EM122, the POS-MV based Discovery EM710 vessel file was used for the bathymetry processing (Disco_EM710_POS_MV.hvf).

Offsets were:

Time Corr: 0.00
X (m): -2.051
Y (m): 36.819
Z (m): 7.427
Pitch (deg): 0.00
Roll (deg): 0.00
Yaw (deg): 0.00

An example of the water column data is provided in Figure 13.

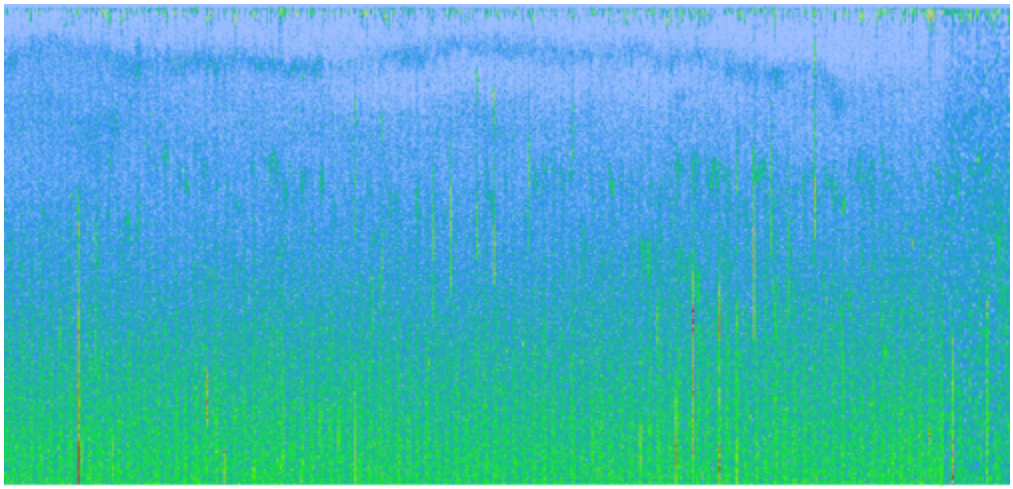


FIGURE 13: EXAMPLE IMAGE OF THE EM710 WATERCOLUMN SIGNAL, PLOTTING PING NUMBER (HORIZONTAL AXIS) AGAINST DEPTH (VERTICAL AXIS, 0-250M). COLOUR INTENSITY INDICATES BACKSCATTER STRENGTH. THE DEEP SCATTERING LAYER CAN BE IDENTIFIED IN THE UPPER WATER COLUMN.

SBP120 Sub-Bottom Profiler

Profiles of the seabed and sub-seabed were obtained with the Kongsberg SBP120 sub-bottom profiler. This is a chirp system with varying frequency, which shares the receiver transducers with the EM122 multibeam echosounder. The system was switched on for every transit, during multibeam surveys and when the ship moved between stations. It was used specifically help determine suitable coring sites. An overview of the basic parameters and recording times for the SBP120 is provided in Table 6.

TABLE 6: RECORDING TIMES, SVP AND LINE NUMBERS FOR SBP120 DATA FOR EACH OF THE STUDY AREAS.

SBP120													
From							To						
JD	Time	Lat de	Lat min	Long (	Long mi	Depth	JD	Time	Lat de	Lat min	Long (	Long mi	Depth	Comments
187	13:39	47	44.8169	52	9.074	191	188	17:34	50	10.457	45	26.369	3814	Transit 1: St John's to Orphan Knoll
189	02:28	50	10.465	45	26.363	3800	189	07:08	50	10.317	45	33.131	3612	survey of Orphan Seamount - to find core site
189	14:25	50	8.741	45	30.136	3747	189	15:25						SBP120 data around Orphan Seamount
190	18:54	50	4.889	45	2.165	2041								transit from Orphan Seamount to Orphan Knoll N
194	06:13	50	30.762	46	5.184	1594								looking for coring site on Orphan Knoll N
194	07:53	50	34.099	45	59.83	2118	194	18:05	50	55.834	46	9.428	2702	final survey of Orphan Knoll N
194	18:12	50	56.647	46	9.758	2789	198	05:46	42	54.218	52	37.82	2335	Transit 2: Orphan Knoll to Greenland
198	11:35	62	55.762	52	39.401	2014	205	20:20						SBP120 data around Nuuk. Piece-wise data
205	21:38	63	33.059	52	14.404	509	207	05:47	59	40.77	47	14.681	2778	Transit 3: Nuuk - SW Greenland (Narsaq)
207	08:19	59	50.813	47	14.677	2755	210	05:53	59	56.644	44	29.898	1047	SBP120 data around Narsaq. Piece-wise
211	00:36	59	54.218	46	29.503	1312	211	12:16	59	12.713	44	34.85	2006	Transit 4: Narsaq - Cape Farewell. Note: no 'raw' data logged
211	14:47	59	12.974	44	36.381	2012	211	21:05	59	27.385	44	24.904	1291	SBP120 data around Cape Farwell. Piece-wise
212	06:37	59	23.321	44	28.933	1363	212	17:38	58	36.346	43	46.757	1883	Survey for Eirik drift and coring work
212	20:34	58	36.3	43	46.169	1883								Transit 5: Eirik drift - Southampton

Acquisition settings:

Data format: SBP120 data were saved both as raw segy files (.raw) and as 'processed' data (.seg), i.e. convoluted with the source sweep, using a date and time-stamp as file name. During operations, screenshots were also saved as identification of suitable coring sites etc.

Further settings were mainly based on the default configuration available on the RRS Discovery, and are presented in Figure 14.

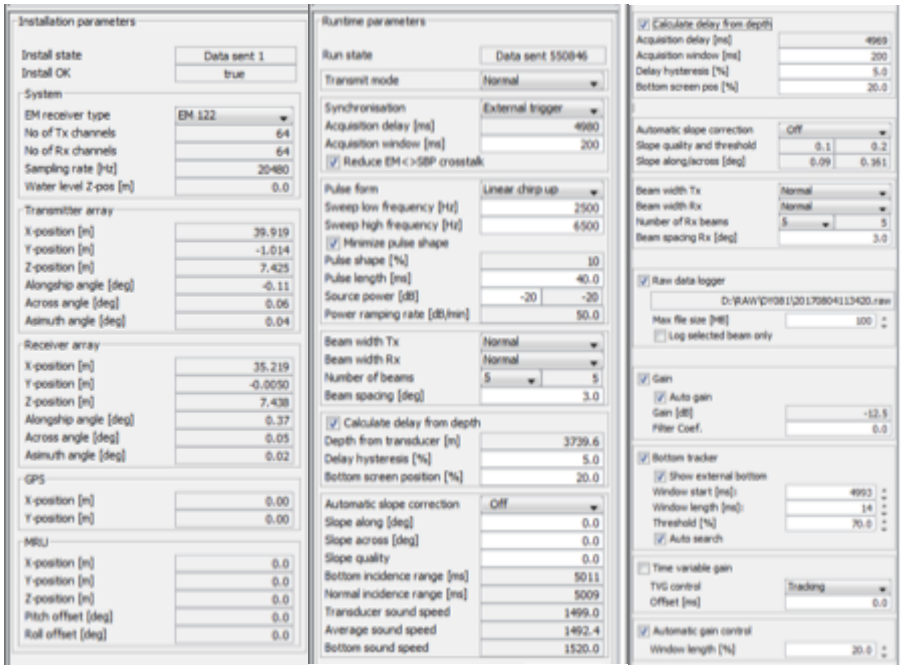


FIGURE 14: SETTINGS FOR SUB-BOTTOM PROFILER.

Data processing:

Basic data processing and visualisation for the SBP120 profiles was carried out using the Linux freeware 'Seismic Unix' software. A simple command line was used to read in the .seg files, add in the time delays and plot the profiles in post-script format. An example of the result is shown in Figure 15.

Segyread tape= /cdrive/Data/SBP120/seg/20170718221312.seg endian=0 |segyclean | sushift tmin=1.2 tmax=2.2 | supsimage perc=98 > /cdrive/Data/SBP120/ps/20170718221312.ps

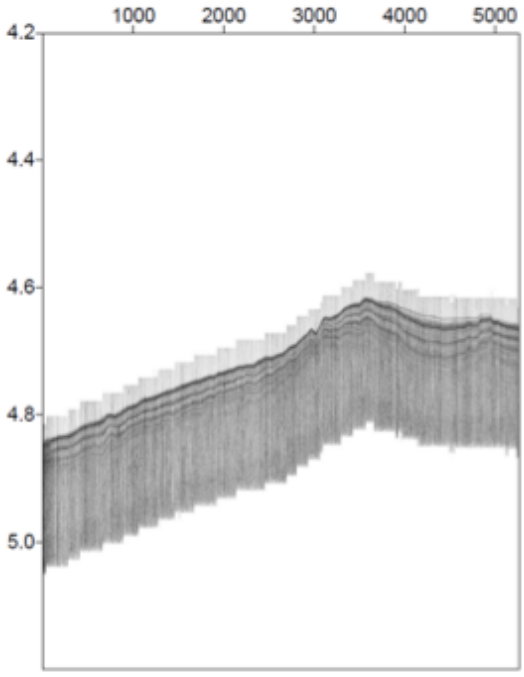


FIGURE 15: EXAMPLE SBP120 PROFILE FROM TRANSIT 2, DISPLAYING TWO-WAY TRAVEL TIME AGAINST SHOTPOINT NUMBER.

EK60 fish-finding echosounder

The Kongsberg EK60 system was used to image the watercolumn, more specifically to image the deep scattering layer and the potential contacts between water masses (shown in Figure 16). It was only switched on at the start of the work around Nuuk. Data were recorded both during transits and while stationary at e.g. CTD stations. An overview of the recording times for each of the research areas during the cruise is given in Table 7.

TABLE 7: RECORDING TIMES FOR EK60 DATA FOR EACH OF THE STUDY AREAS.

EK60													
From							To						Comments
JD	Time	Lat de	Lat min	Long	Long min	Depth	JD	Time	Lat de	Lat min	Long	Long min	Depth	
198	11:36	62	55.84	52	39.447	2009	205	20:20						EK60 surveys around Nuuk - various sections, splitting lines between 'moving' and 'stationary'
205	20:20						207	08:20	59	50.862	47	14.696	2756	Transit 3
207	08:20	59	50.862	47	14.696	2756	207	16:32	60	5.64	47	18.795	1108	survey around SW Greenland (Narsaq) - EK60 crashed at 10:12, restarted 10:30
207	21:10	60	7.709	47	21.47	712	210	02:30						further work around Narsaq - EK60 crased at 02:30 on JD210
210	11:47	59	55.696	46	30.024	1062	210							further work around Narsaq - EK60 logging was off at 211 00:39, not sure since when
211	00:39	59	54.002	46	29.99	1364	211	12:16	59	12.713	44	34.859	2006	Transit 4: Narsaq - Cape Farwell. EK60 stopped pinging at 05:25 and 06:54
211	12:16	59	12.713	44	34.859	2006	212							further work around Cape Farewell - EK60 fell over at 01:08
212	07:03	59	21.127	44	23.435	843	212	20:33	58	36.547	43	46.327	1881	Survey for Erik drift & coring work
212	20:33	58	36.547	43	46.327	1881	213	19:24	57	15				Transit 5: Erik drift - Southampton. Stopped logging because of bad data.

FIGURE 16: EK60 DISPLAY SHOWING DIURNAL MIGRATION AT THE NUUK SITE.

Acquisition settings:

The EK60 was setup as per instructions by Kevin Jerram, Center for Coastal and Ocean Mapping, as shown in Figure 17.

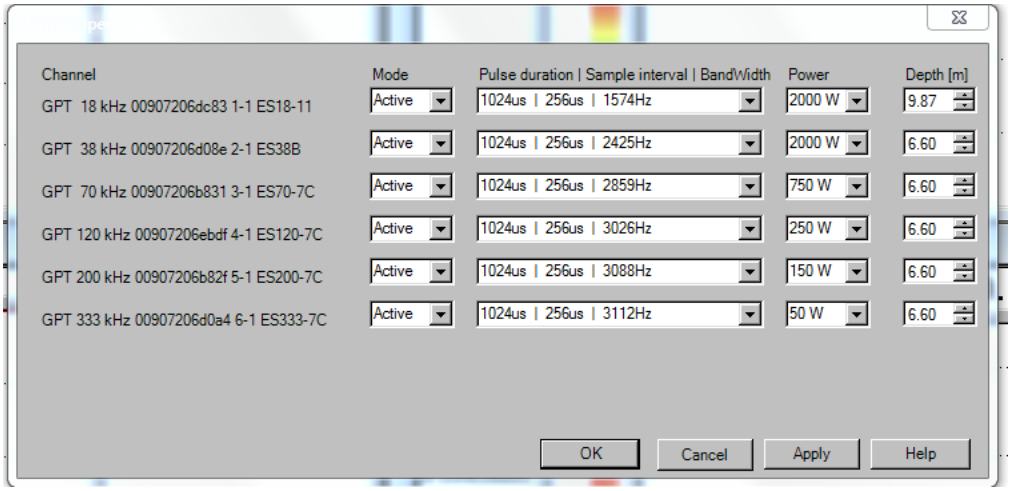


FIGURE 17: ACQUISITION SETTINGS USED FOR THE DIFFERENT FREQUENCIES OF THE EK60 SYSTEM.

Three days after switching on the EK60, it was discovered that the EK60 had previously not been receiving navigation information. This was caused by an incorrect position talker id used during setup (IN vs GP). To correct this, the following method was employed:

INSTALL > NAVIGATION

POSITION TALKER ID = GP

No data processing was performed on-board for the EK60.

Teledyne Acoustic Doppler Current Profilers

The Ocean Surveyor (OS) instruments are Vessel Mounted Acoustic Doppler Current Profilers (VMADP) manufactured by Teledyne RD instruments. They are secured on a drop keel in surface waters near the centre and beneath the RRS Discovery. The VMADPs measure the horizontal current velocity profile. The parameters were held constant for the duration of OS measurements (13th July – 5th August), and the tracking mode was alternated. Bottom tracking mode was suitable for periods spent on the shelf when the water was sufficiently shallow and water tracking mode was selected in deeper waters and on the continental slope. The collection of bottom tracking data is necessary for the instrument calibrations, not carried out on board this cruise. In reality success for the bottom tracking mode was only achieved in regions where the bottom depth was no more than 200m for the 150 kHz device. Bottom tracking data were only collected for the 150 kHz instrument close to Nuuk intermittently between 18th July – 24th July.

Real-time data was periodically acquired from the VMADCPs. As it came in, these data were displayed through the VmDas software (version 1.48) on a monitor for each ADCP. Standard logging checks were established to ensure that the current profilers were continuing to collect data. Log sheets were filled out to confirm that the ensemble number was incrementing and that the data files in the output directory were increasing in size. Another important thing to monitor was the drift of the internal clock of the computer running the VmDas software from the ships GPS clock. There were no problems with the data acquisition to report. To limit the size of the output data files and assist future processing, the VMADCPs were reset and thus new files initiated. Files were reset usually daily but occasionally ran without resetting for as long as 3 days. Raw data files were automatically stored in the Acoustics folder of the cruise network drive.

TABLE 8: CONFIGURATIONS FOR SHIP-MOUNTED ADCPS.

Teledyne OS075 ADCP	***Teledyne OS150 ADCP***
Configurations:	***Configurations:***
Narrowband, single ping profile mode	Narrowband, single ping profile mode
16m depth bins	8m depth bins
8m blanking distance	4m blanking distance
3 seconds between ensembles	2 seconds between ensembles
1200m maximum searching depth	800m maximum searching depth

Reson 7125 multibeam echosounder

One ROV swath dive was completed during the cruise (Dive334), and the set-up chosen was for forward mapping as developed under the CODEMAP programme (Huvenne et al., 2011; Robert et al., 2017). This meant that the SCORPIO camera was taken off the vehicle to make space for the Reson7125 to be mounted on the front. The port biobox and Niskin bottles (see technical report for the ROV operations) were taken off, in order to accommodate the electronics bottle of the Reson system. The setup is illustrated in Figure 18.

FIGURE 18: RESON 7125 TRANSDUCER SETUP ON ROV ISIS.

The system settings for this survey are listed in Table 9, and the offsets of the various sensors versus the common reference point on ISIS are listed in the table below. In addition, inside the 7Sk acquisition software, the hardware configuration offsets between Rx and Tx were set as follow X= -0.125m, Y= -0.125m and Z= 0.031m with head tilt= 0°. Roll stabilisation was switched off, as it has been noted before that this gives errors during the survey.

The vehicle was flown in a set of parallel passes, each pass being carried out at a constant depth and with an approximately constant distance from the cliff face (see tables below). Surveys were carried out with a nominal heading of 135° for the first section of the cliff, and 214° for the second section. Data were recorded at 40-50m (depths of 755m and 775m) and 20-25m (depths of 740m, 765m and 790m) distance from the wall.

TABLE 9: RESON SURVEY SETTINGS FOR DIVE334

MBES Frequency	**400 kHz**							
Distance wall	40 m				20 m			
Depth	755 m	775 m			740	765	790	
Beam angle	120 - 140°							
Power	203 - 207 dB							
Gain	40 dB							
Absorption	90 dB/km							
Spreading	30 dB/km							
Duration (at seabed)	4h 40 min							
Survey speed	0.2 - 0.3 kn							
Max pulse rate	10 p/s							
Pulse length	40 µs							

TABLE 10: OFFSETS FOR THE VARIOUS SENSORS VERSUS A COMMON REFERENCE POINT ON ISIS (FRONT OF VEHICLE) AS USED FOR THE FORWARD MAPPING APPROACH, WITHIN THE CONVENTIONAL VEHICLE REFERENCE FRAME (X: POSITIVE STARBOARD, Y: POSITIVE FORWARD, Z: POSITIVE UP, ALL IN METRES).

	X	**Y**	**Z**
Compatt (USBL)	1.46	-1.01	0.36
Doppler	-0.17	-0.58	2.19
MBES	0.34	-0.22	-0.12
Octans (attitude)	-0.49	0.00	0.86
Parascientific (depth)	0.00	-0.55	1.48

Coring operations

Identification of coring sites

Seabed surveying was performed prior to coring operations at each location using a Kongsberg Sub-Bottom Profiler (SBP-120) and a Kongsberg Multibeam Echosounder (EM-122). Sampling sites were selected in areas of flat bathymetry, characterized by thick layers of sediment displaying features consistent with quasi-linear sedimentation (e.g. identifiable stratigraphic layers). An example of a sub-bottom profile acquired from Nuuk for megacore MGA04 can be seen in the figure below.

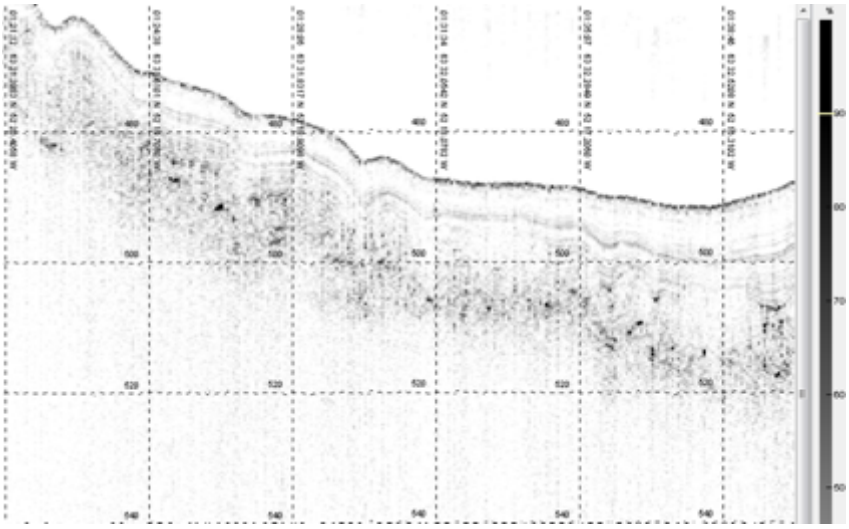


FIGURE 19: EXAMPLE OF SBP PROFILE FROM NUUK.

Megacore

Sediments were collected using the NMF megacorer (Figure 20), to obtain short cores and undisturbed sediment-water interface material for biogeochemical research. The megacorer was deployed and recovered off the starboard side on the trawl winch. Eight tubes were used for each deployment: four without holes and four with holes drilled for porefluid sampling (taped up with duct tape for deployment). Once on deck all core barrels were removed from the rig and plugged with rubber bungs. Cores were secured in a refrigerated room using a wooden rack and remained in this location until sub sampling commenced. Sediment sub-samples were stored in either the refrigerated room or in a -20°C freezer depending on the analyses planned.

In addition to sediments, the megacorer was equipped with a 10 L Niskin bottle to collect bottom-water samples. The Niskin bottled was rigged to fire on impact with the sea floor.

FIGURE 20: RECOVERY OF MEGACORE MGA04 ON JULY 24TH. ALL EIGHT CORES CONTAINED SEDIMENT AND THE SEDIMENT-WATER INTERFACE: HALF OF THE TUBES WERE DRILLED FOR POREFLUID SAMPLING, AND TAPED UP FOR DEPLOYMENT. PHOTO BY M. BADGER.

Gravity core

Sediments were collected using a 6m long barrel gravity core (Figure 21) lowered to the seafloor, deployed from the starboard side on the trawl winch, lowered initially at 40m/min before slowing to 10-15m/min at 100m above the seafloor. The corer was sunk into sediments with the aid of a 1-ton (approximate) weight on top of the barrel. Due to the limitations of the trawl winch, the barrel length was limited to 6m and deployment to 4000m.

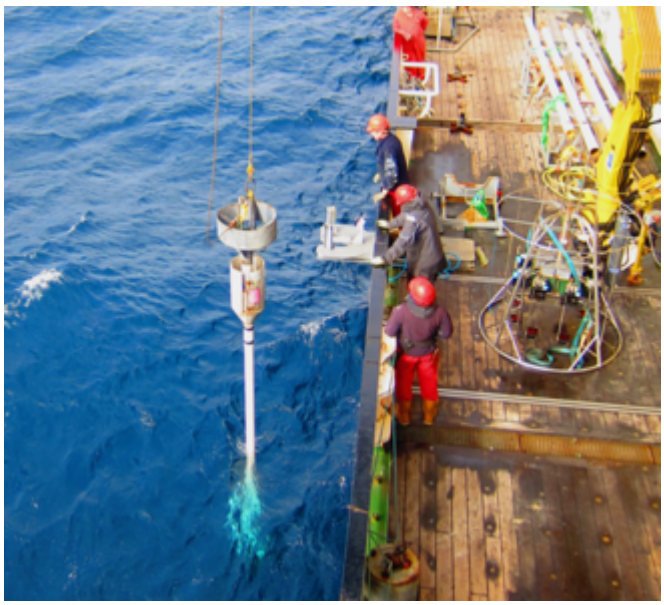


FIGURE 21: GRAVITY CORE RECOVERY. PHOTO BY A. JACOBEL.

Push cores

The ROV was equipped with 6-12 tubes for the collection of small cores. The Kraft arm was used to pick up each core using a T-handle inserted at the top of each cylinder, and push it into the sediment. Three or four replicate cores were collected at each sampling site. Some tubes were drilled with holes for the collection of porefluids (taped up during deployment). See ROV technical details for further information.

CTD operations

All CTD casts were undertaken with the stainless steel CTD frame and used 10L Niskin water samplers (Figure 22). Sea-Bird 35 Temperature and Sea-Bird 3P temperature sensors were installed on the 9Plus underwater unit. A cable connected the Sea-Bird 35 to both the 9Plus and the Sea-Bird 32 carousel. Housed on the vane were the Sea-Bird 43 Oxygen and the secondary Sea-Bird 3P temperature and 4C conductivity sensors.

For each deployment the crew directed all deck operations and drove the winch, lines were attached to the frame to steady the package whilst it was either lifted off the deck overboard, or lifted on deck inboard. The technician assisted in this process. Once in the water, the crew lowered the package to an initial depth of 10m, allowing the Sea-Bird 5T pumps to prime and start operating. Once this had occurred for most casts, and where weather allowed, the package was raised to near the surface then lowered to a near bottom. Input from the scientific party dictated the required bottle stops, and the number of bottles to fire at each depth. Bottle leakages occurred on several casts (see cruise narrative for details), but these issues were solved by replacing bottles and spare parts. Otherwise, there were no further issues with hardware. Refer to NMF technical report for further details.

Upon completion of the cast the package was either landed on deck, moved into the hanger and stowed in the CTD deck plate for the scientists to commence sampling. Due to the configuration of the lifting hoist and slow operating speed, this typically added a five-minute delay to the scientists before they were able to start their sampling.

Between stations sensors were flushed with Milli-Q and the whole CTD rinsed with fresh water to prevent salt crystals forming in the sensors, associated tubing and carousal.

Immediately after each cast the raw data was backed up to the network drive, to reduce the risk of data loss and to make the data available to the scientific party.

Basic Sea-Bird processing of the raw data then took place by NMF technicians using Sea-Bird Data Processing software. The full BODC “Recommended steps for basic processing of SBE-911 CTD data.” Version 1.0 October 2010 was followed for all casts. Bottle data were processed producing average, standard deviation, minimum and maximum of data from 2.5 seconds before and after bottle firing (5 second total). The CTD data was additionally used to produce a SBE Data Processed Sound Velocity Profile (SVP) in each main site.

FIGURE 22: CTD DEPLOYMENT, SHOWING LADPCS AND OTHER SENSORS. PHOTO K.HENDRY.

LADCP

Two LADCPs were mounted on the CTD rosette (Figure 22): Master (downward looking, attached to base of frame) and Slave (upward looking attached to outside of frame). Each cast the fitted LADCP's were set up to log data via the PC using a pre-configured script file. The LADCPs were set up before each cast with the following commands:

TABLE 11: COMMAND FILES FOR MASTER AND SLAVE LADCPS.

; DY081 Hendry, Bristol. LADCP Master	; DY081 Hendry, Bristol. LADCP Slave
; Dougal Mountifield	; Dougal Mountifield
PS0 ; Display System Confuration	PS0 ; Display System Confuration
CR1 ; Restore Factory Defaults	CR1 ; Restore Factory Defaults
WM15 ; LADCP Water Mode 15	WM15 ; LADCP Water Mode 15
CF11101 ; Disable Serial Output	CF11101 ; Disable Serial Output
EA00000 ; Zero Beam 3 Misalignment	EA00000 ; Zero Beam 3 Misalignment
EB00000 ; Zero Heading Bias	EB00000 ; Zero Heading Bias
ED00000 ; Zero Transducer Depth	ED00000 ; Zero Transducer Depth
ES35 ; Salinty 35PSU	ES35 ; Salinty 35PSU
EX11111 ; Earth Coordinates use defaults	EX11111 ; Earth Coordinates use defaults
EZ0011101 ; Use Heading pitch and roll sensors	EZ0011101 ; Use Heading pitch and roll sensors
TE00:00:01.00 ; 1 Second Minimum Time Per Ensemble	TE00:00:01.00 ; 1 Second Minimum Time Per Ensemble
TP00:01.00 ; 1 Second Minimum Time Between Pings	TP00:01.00 ; 1 Second Minimum Time Between Pings
LP00001 ; 1 Ping Per Ensemble	LP00001 ; 1 Ping Per Ensemble
LD111100000 ; Collect and Process all data	LD111100000 ; Collect and Process all data
LF0500 ; LADCP 5m Blank	LF0500 ; LADCP 5m Blank
LN016 ; LADCP 16 Bins	LN016 ; LADCP 16 Bins
LS1000 ; LADCP 10m Bins	LS1000 ; LADCP 10m Bins
LV250 ; LADCP 250cm/s Ambiguity Velocity	LV250 ; LADCP 250cm/s Ambiguity Velocity
LJ1 ; LADCP High Receiver Gain	LJ1 ; LADCP High Receiver Gain
LW1 ; LADCP Narrow Bandwidth	LW1 ; LADCP Narrow Bandwidth
LZ30,220 ; LADCP Default Bottom Detect and Correlation Thresholds	LZ30,220 ; LADCP Default Bottom Detect and Correlation Thresholds
SM1 ; RDS3 Master	SM2 ; RDS3 Slave
SA001 ; Send Sync Pulse Before Water Ping	SA001 ; Send Sync Pulse Before Water Ping
SW05000 ; Ping 500ms after Sending Sync Pulse	ST0 ; Wait Indefinitely FOr Sync Pulse From Master
CK ; Save As User Defaults	CK ; Save As User Defaults
CS ; Start Pinging	CS ; Start Pinging

Before one cast (CTD12), there was no communication between the LADCP and the datalogging computer, so no current data were recorded. This was part of the CTD grid at Nuuk, so the cast continued as it was considered that current data density was already sufficient. For CTD21, the Master and Slave LADCPs were switched, and this was recorded in the logging sheets. Refer to NMF technical report for further details.

Sensors

The full list of mounted sensors is as follows:

TABLE 12: LIST OF SENSORS MOUNTED ON 24-WAY STEEL CTD ROSETTE.

Instrument / Sensor:	Model:	Serial No:	Channel:	Casts Used:
Stainless steel 24-way frame	NOCS	SBE CTD1	N/A	**All casts**
24-way Carousel	SBE 32	32-0423	N/A	**All casts**
Primary CTD deck unit	SBE 11plus	11p-0589	N/A	**All casts**
CTD Underwater Unit	SBE 9plus	09p-0943	N/A	**All casts**
Primary Temperature Sensor	SBE 3P	3p-2729	F0	**All casts**
Primary Conductivity Sensor	SBE 4C	4c-3258	F1	**All casts**
Digiquartz Pressure sensor	Paroscientific	110557	F2	**All casts**
Secondary Temperature Sensor	SBE 3P	3p-4816	F3	**All casts**
Secondary Conductivity Sensor	SBE 4C	4c-2165	F4	**All casts**
Primary Pump	SBE 5T	05-3085	N/A	**All casts**
Secondary Pump	SBE 5T	05-7371	N/A	**All casts**
Dissolved Oxygen Sensor	SBE 43	43-2818	V0	**All casts**
Dissolved Oxygen Sensor	SBE 43	43-2575	V1	**All casts**
Altimeter	Benthos 916T	59494	V2	**All casts**
Light Scattering Sensor	WETLabs BBRTD	BBRTD-169	V3	**All casts**
PAR Down-looking UWIRR	Biospherical QCP Cosine PAR	70520	V4	**All casts**
PAR Up-looking DWIRR	Biospherical QCP Cosine PAR	70510	V5	**All casts**
Transmissometer	WET Labs C-Star	1602DR	V6	**All casts**
Fluorometer	CTG Aquatracka MKIII	88-2615-126	V7	**All casts**
10L Water Samplers	OTE	1A-24A	N/A	**All casts**
Down-looking Master LADCP (Aluminium)	TRDI/WHM300kHz	1855	n/a	**n/a**
Up-looking Slave LADCP (Aluminium)	TRDI/WHM300kHz	23444	n/a	**n/a**
LADCP battery pack pressure case	**NOCS**	**WH007**	**n/a**	**n/a**

Glider operations

Configuration

Prior to loading on RRS Discovery in Southampton, UK Slocum Units 331 and 439 underwent in-house refurbishment and were ballasted for 1027.0 at 3 ˚C in preparation for deployment. The gliders were configured as in the table below.

TABLE 13: CONFIGURATION OF SLOCUM GLIDERS.

Unit 331	Unit 439
Slocum TWR FWD: SN: 1400153 (INV.260002528) **Slocum TWR AFT:** SN: 1400115 (INV.260002513) **Slocum deep pump:** SN: 120 (INV.260001982) **G2 DigiFin:** SN: 1467 (INV. 260000277) **Slocum science bay (pumped CT):** SN: 1115 (INV.250008907) **Aanderaa Optode:** SN: 143 (INV.250008327) **Firmware:** GliderDos: 7.18 / SciDos: 3.21 **WETLabs puck:** SN: 3354 (INV.260002075)	**Slocum TWR FWD:** SN: 1300108 (INV.260002521) **Slocum TWR AFT:** SN: 1300100 (INV.260002505) **Slocum deep pump:** SN: 210 (INV.260000276) **G2 DigiFin:** SN: ____ (INV. 26000____) **Slocum science bay (pumped CT):** SN: 1103 (INV.260001980) **Aanderaa Optode:** SN: 243 (INV.250002409) **Firmware:** GliderDos: 7.18 / SciDos: 3.21 **WETLabs puck:** SN: 3347 (INV.260002070)

Deployment plan

Due to the strength and direction of prevailing currents, a deployment plan was finalised such that the gliders would travel in a northerly direction, following the current whilst transecting the shelf in repeated 'zig-zags'. Recovery position was anticipated to be in approximately the middle of the Nuuk survey site. Deployment was carried out in accordance with NMF procedural operations, without any issues.

The units were piloted by Steve Woodward (NOC, Southampton), with Candice Cameron as the onboard technician. The units were deployed from 62° 54.198'N, 52° 37.816'W on 17th July 2017. Unit 331 – "Coprolite" – was deployed first, followed by Unit 439 – "HSB". The anticipated recovery position was 63° 35.096'N, 53° 16.663'W.

Mission

The path of the gliders differed from planned due to strong currents (Figure 23). However, both gliders recorded data on three crossings of the shelf break each. See technical report for details on the mission and pilot logs[1].

Recovery

Recovery was carried out on 24th July 2017 at 1320 (Unit 331) and 1430 (Unit 439) GMT in accordance with NMF guidelines and, despite poor glider visibility during the search, the gliders were eventually located and recovered safely on deck without further issue. See Figure 24.

[1] MARS – Gliders Expedition Report for DY081: ICY-LAB, C. Cameron. 2017.

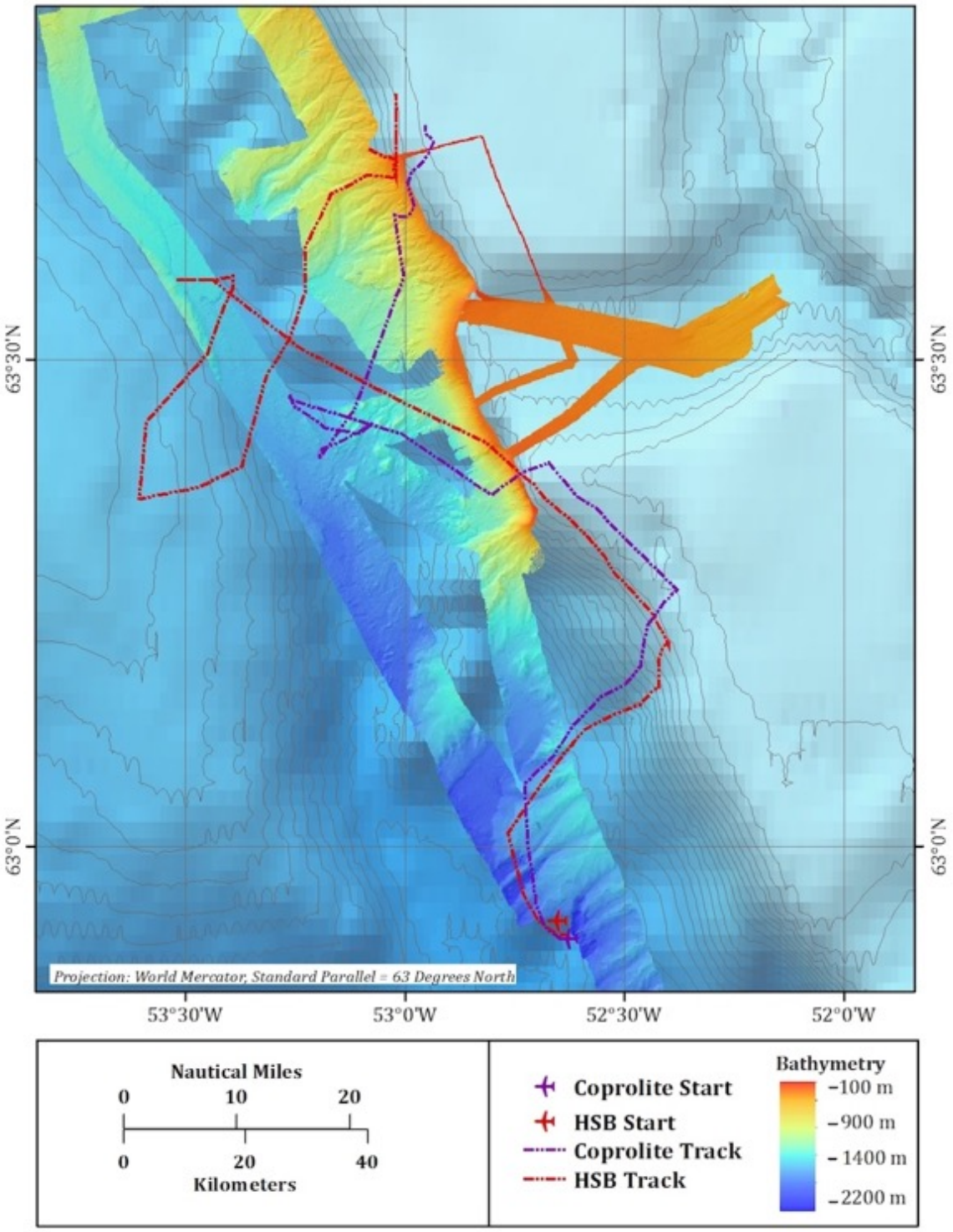


FIGURE 23: MAP OF GLIDER ROUTES ON DY081.

FIGURE 24: RECOVERY OF GLIDER UNIT 331 'COPROLITE'. THE TOWLINE IN THE NOSE CONE IS USED TO WINCH THE GLIDER VERTICALLY, BEFORE BEING LOWERED ON TO DECK AND SECURED. PHOTOS BY K. HENDRY.

Remotely Operated Vehicle operations

The Remotely Operated Vehicle (ROV) – *Isis* – was deployed to collect sediment samples from glaciated regions, where conventional coring may be inappropriate, and to collect samples for complementary projects. Dive plans and maps were generated prior to each launch, to suit the objectives of the specific dive.

General description

- Depth rated 6500m
- ROV is tethered to ship with high voltage, optic fibre cable for real time video feeds
- Two manipulator arms (Kraft (port) and Schilling (starboard))
- "Slurp" suction system and nets for sample collection
- Main biobox, biotubes, push cores, nets on the front tray, with port and starboard bioboxes, and six 1.7L Niskins bottes, five "slurp" chambers at the rear (see Figure 25)
- A Seabird 49 CTD is attached to the ROV frame and data are recorded throughout the dive; processing of the raw CTD data then took place by PSO using Sea-Bird Data Processing software
- Three high definition video cameras are attached: HDSci (on pan-tilt module, controlled by lead scientist), HDPilot (on pan-tilt module, controlled by pilot) and Scorpio (fixed view, with 4672 x 2628 (16:9 Format) stills taken typically every 30 seconds); lower definition mini-cams (uplook, drawer, sampler/gauges) and low-definition Mercury monochrome aft camera are also attached; aft camera also recorded on PAL on occasion
- All videos are recorded onto KiPro tapes, with 2 hour intervals then saved onto Master and Backup Lacie drives
- Lasers were attached to Scorpio and HCSci at 10cm spacing
- ROV is controlled from van with two pilots and lead scientist at front console, and 2-3 other observers at the rear console
- Logging is carried out on hard copy and using OFOP logging software
- Navigation, Sensor, and stills are also copied onto a Master and Backup Lacie drives, and Navigation, Sensor, Scorpio images and video were additionally backed up as a working copy on a further Lacie drive for the University of Bristol

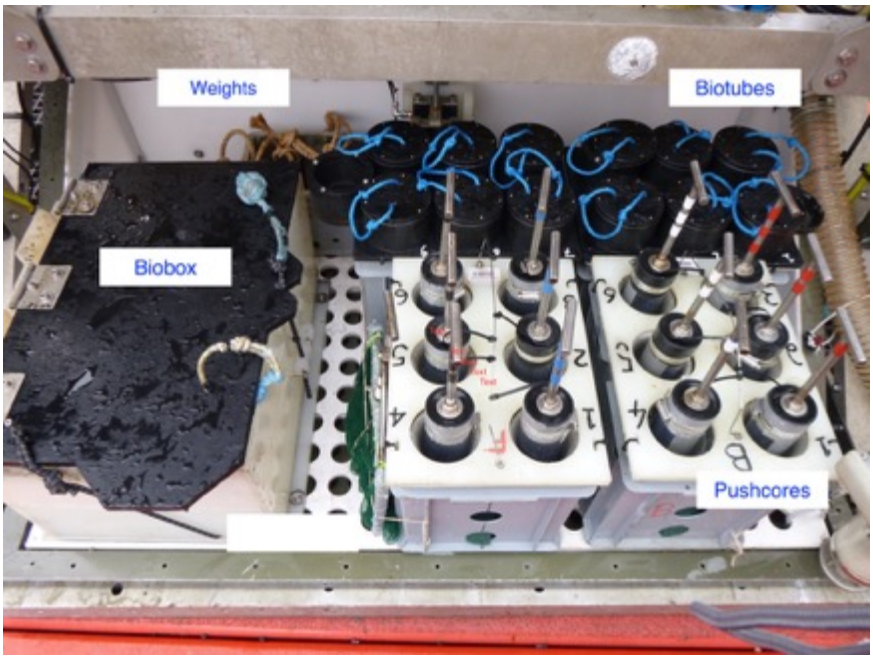


FIGURE 25: EXAMPLE OF ROV TRAY CONFIGURATION FROM ROV DIVE 337.

TABLE 14: TABLE OF LOCATIONS OF ROV DEPLOYMENTS; OK = ORPHAN KNOLL; SG = SOUTHERN GREENLAND.

Note: a = ROV331 and ROV337 were aborted; ROV334 was a Multibeam reson dive and no Scorpio images are available

Site	Station	Gear	Jday Start	Start Time (GMT)	Start Lat (DD)	Start Lon (DD)	Start water depth (m)	JDay End	End Time (GMT)	End Lat (DD)	End Lon (DD)	End water depth (m)
OK	5	ROV327	189	16:19:00	50.04158	-45.37940	3550.8	190	18:01:00	50.0832	-45.3594	1941.0
OK	7	ROV328	191	07:50:00	50.55481	-46.19323	1669.2	191	16:21:00	50.5564	-46.1956	1576.7
OK	8	ROV329	191	20:48:00	50.55182	-46.19227	1792.0	192	17:28:00	50.5698	-46.1836	1527.0
OK	11	ROV330	192	23:23:00	50.55118	-46.19071	1825.5	193	12:00:00	50.5512	-46.1934	1717.0
OK	13	ROV331[a]	193	16:15:00	50.50629	-46.08250	1848.0	194	06:24:00			1586.0
Nuuk	30	ROV332	201	02:45:00	63.86858	-53.28953	964.0	201	03:06:00	63.8704	-53.2901	950.0
Nuuk	31	ROV333	201	03:49:00	63.86612	-53.28869	970.0	201	23:11:00	63.8657	-53.2834	805.0
Nuuk	34	ROV334[b]	202	07:00:00	63.86511	-53.28258	807.0	202	16:05:00	63.8651	-53.2784	683.0
Nuuk	36	ROV335	203	03:38:00	63.33217	-52.77710	1281.0	204	03:32:00	63.3317	-52.7550	898.0
Nuuk	37	ROV336	204	10:51:00	63.60375	-52.91897	515.0	204	20:53:00	63.6112	-52.9032	345.9
SG	44	ROV337[a]	207	17:33:00	60.09451	-47.31853	1037.2	207	20:19:00	60.1063	-47.4009	1048.0
SG	50	ROV338	208	18:46:00	60.09000	-46.62533	603.50	209	18:12:00	60.0862	-46.6497	1064.0
SG	52	ROV339	210	07:04:00	59.94672	-46.54810	1148.0	210	21:46:00	59.9423	-46.5069	589.0

See Acoustics Operations section for details on reson settings for dive ROV334.

See ROV technical report for further information on the vehicle's technical performance[2].

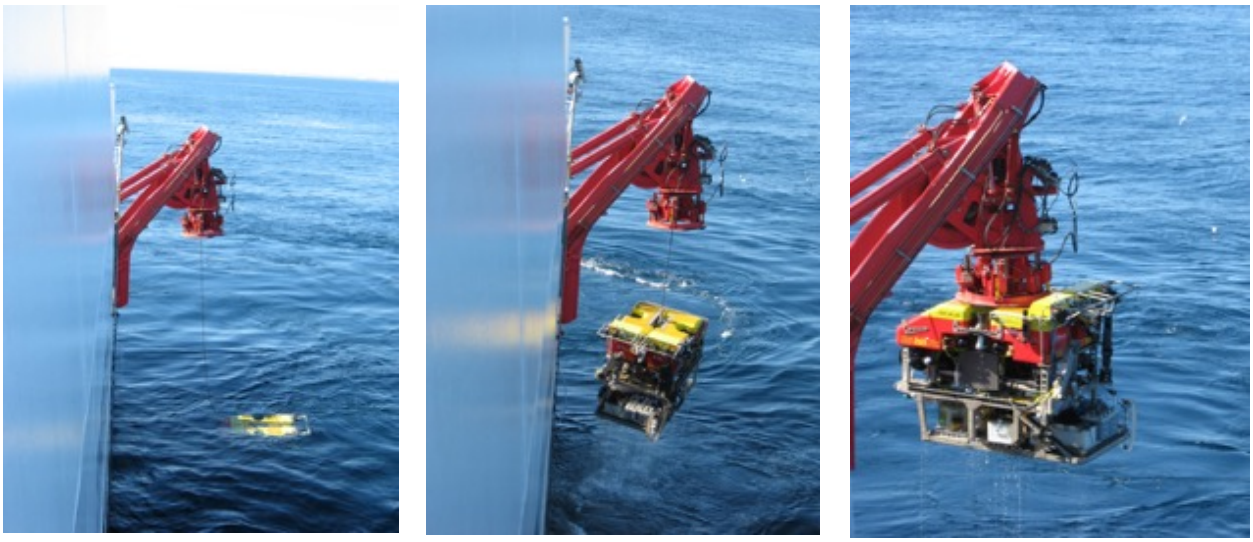


FIGURE 26: RECOVERY OF ROV DIVE 338. PHOTOS BY VEERLE HUVENNE.

FIGURE 27: ROV DIVE SITE 327 (OVER THE PAGE). PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

FIGURE 28: ROV DIVE SITE 328-330. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

FIGURE 29: ROV DIVE SITE 331. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 50˚N.

FIGURE 30: ROV DIVES 333 AND 334. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

FIGURE 31: ROV DIVE 335. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

FIGURE 32: ROV DIVE 336. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

FIGURE 33: ROV DIVE 338. PRODUCED IN MERCATOR PROJECTION WITH A STANDARD PARALLEL OF 63˚N.

[2] Isis ROV System: Expedition Report. RRS Discovery (DY 081). D. Turner. 2017.

DIVE 327

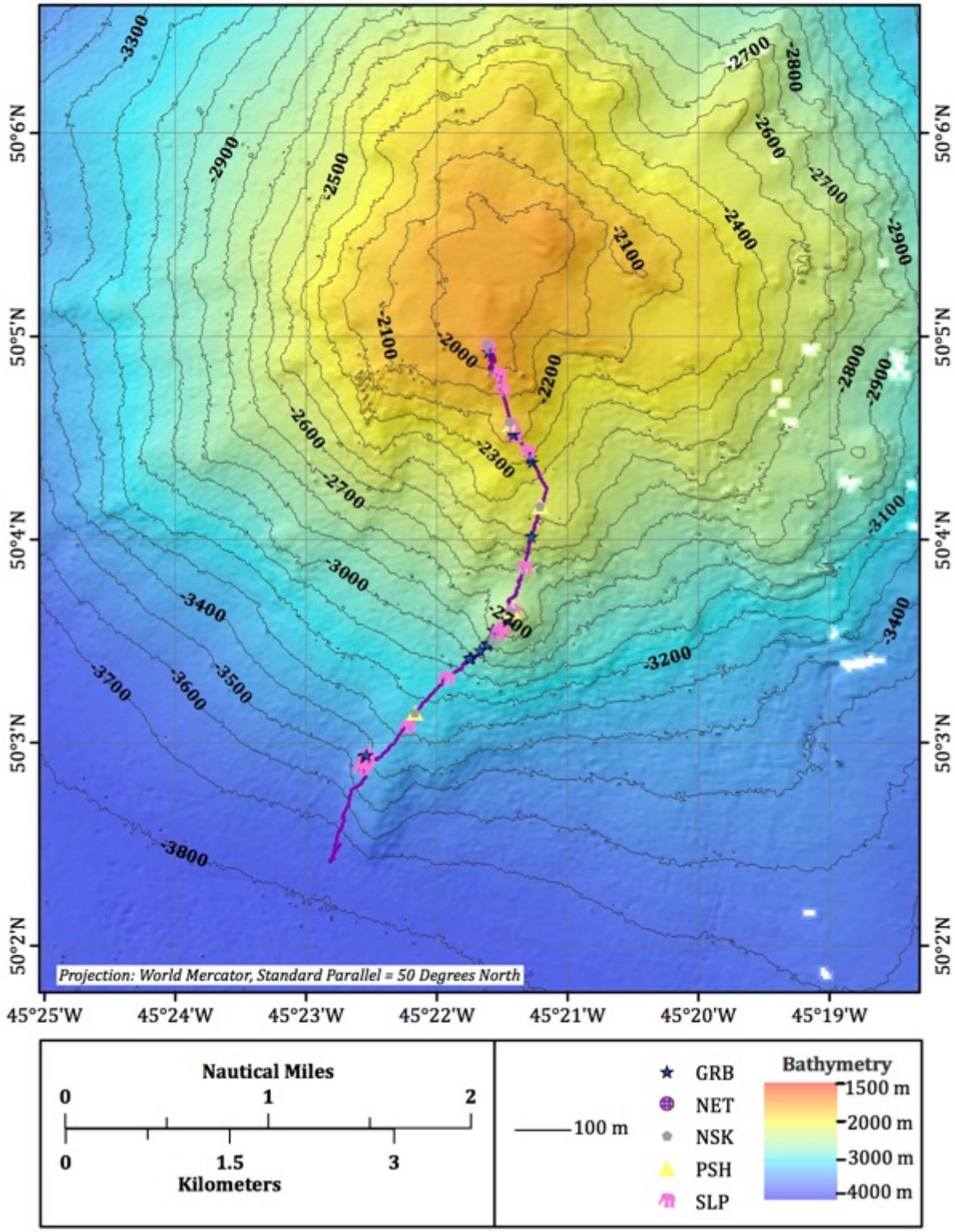


Figure 27

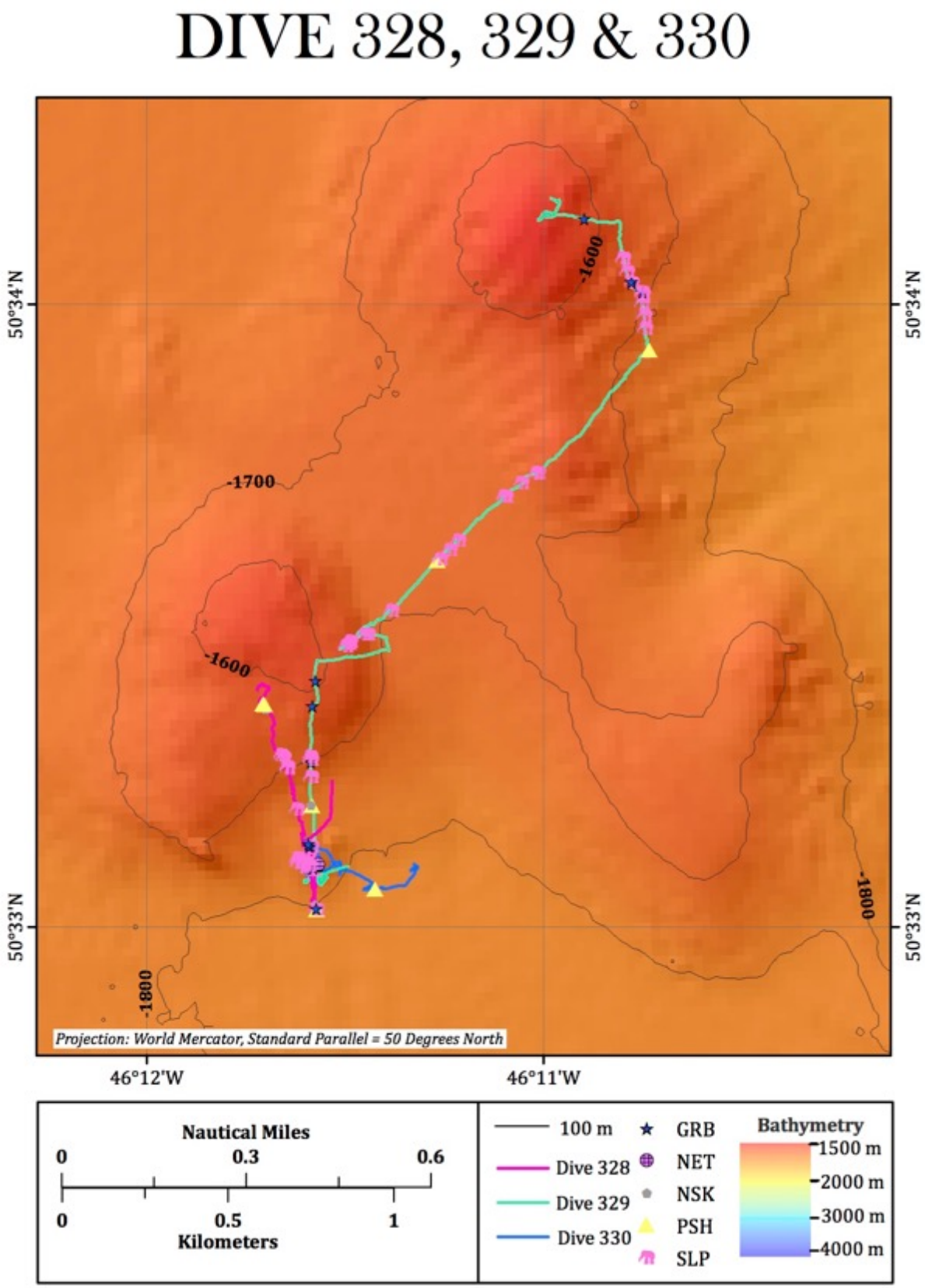

DIVE 328, 329 & 330
50°34'N
50°33'N
46°12'W
46°11'W
-1600
-1700
-1600
-1800
-1800
Projection: World Mercator, Standard Parallel = 50 Degrees North
Nautical Miles
0
0.3
0.6
0
0.5
1
Kilometers
100 m
Dive 328
Dive 329
Dive 330
GRB
NET
NSK
PSH
SLP
Bathymetry
1500 m
2000 m
3000 m
4000 m

Figure 28

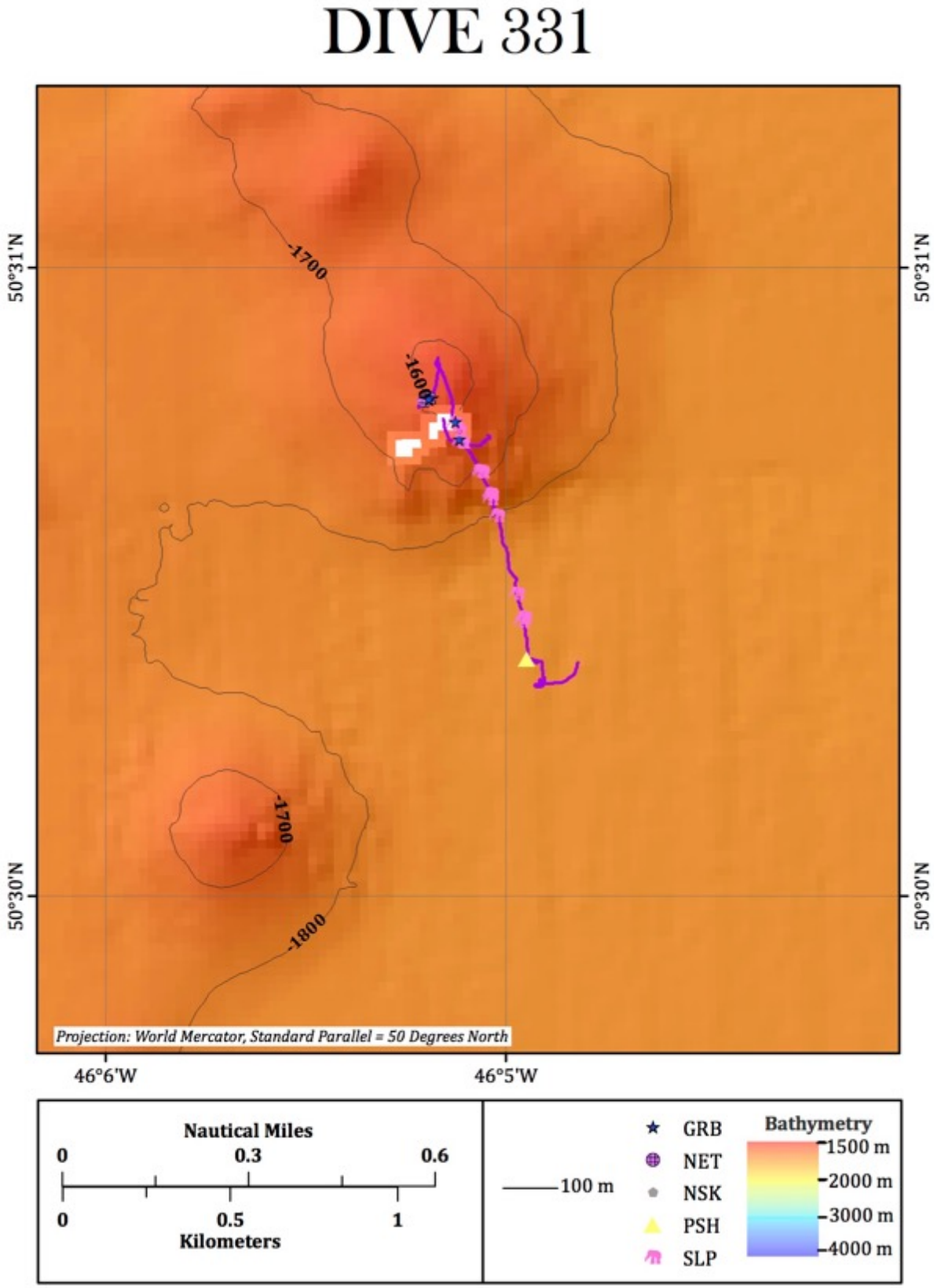

DIVE 331
50°31'N
50°30'N
46°6'W
46°5'W
-1700
-1600
-1700
-1800
Projection: World Mercator, Standard Parallel = 50 Degrees North
Nautical Miles
0
0.3
0.6
0
0.5
1
Kilometers
100 m
GRB
NET
NSK
PSH
SLP
Bathymetry
1500 m
2000 m
3000 m
4000 m

Figure 29

DIVE 333 and 334

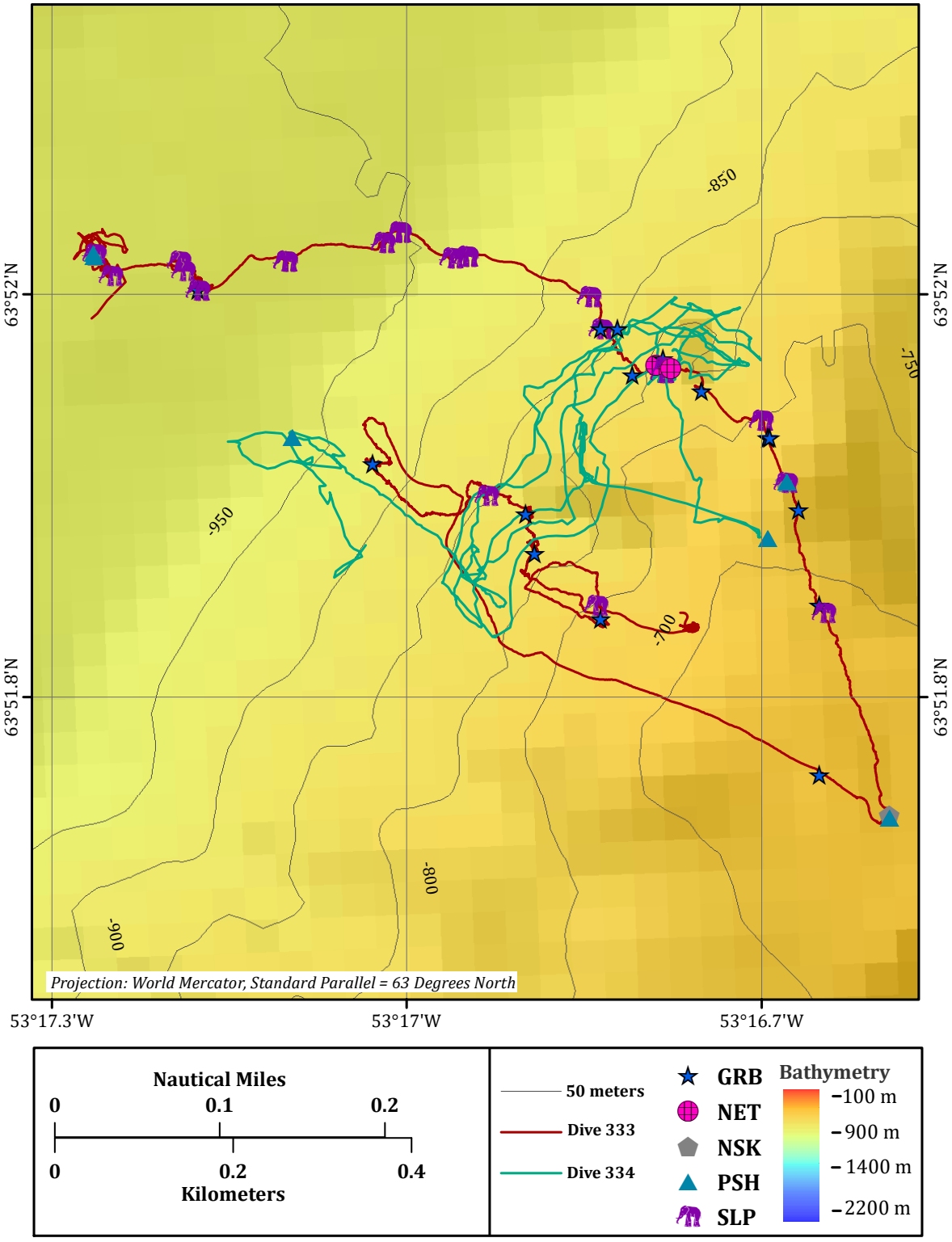


Figure 30

Dive 335

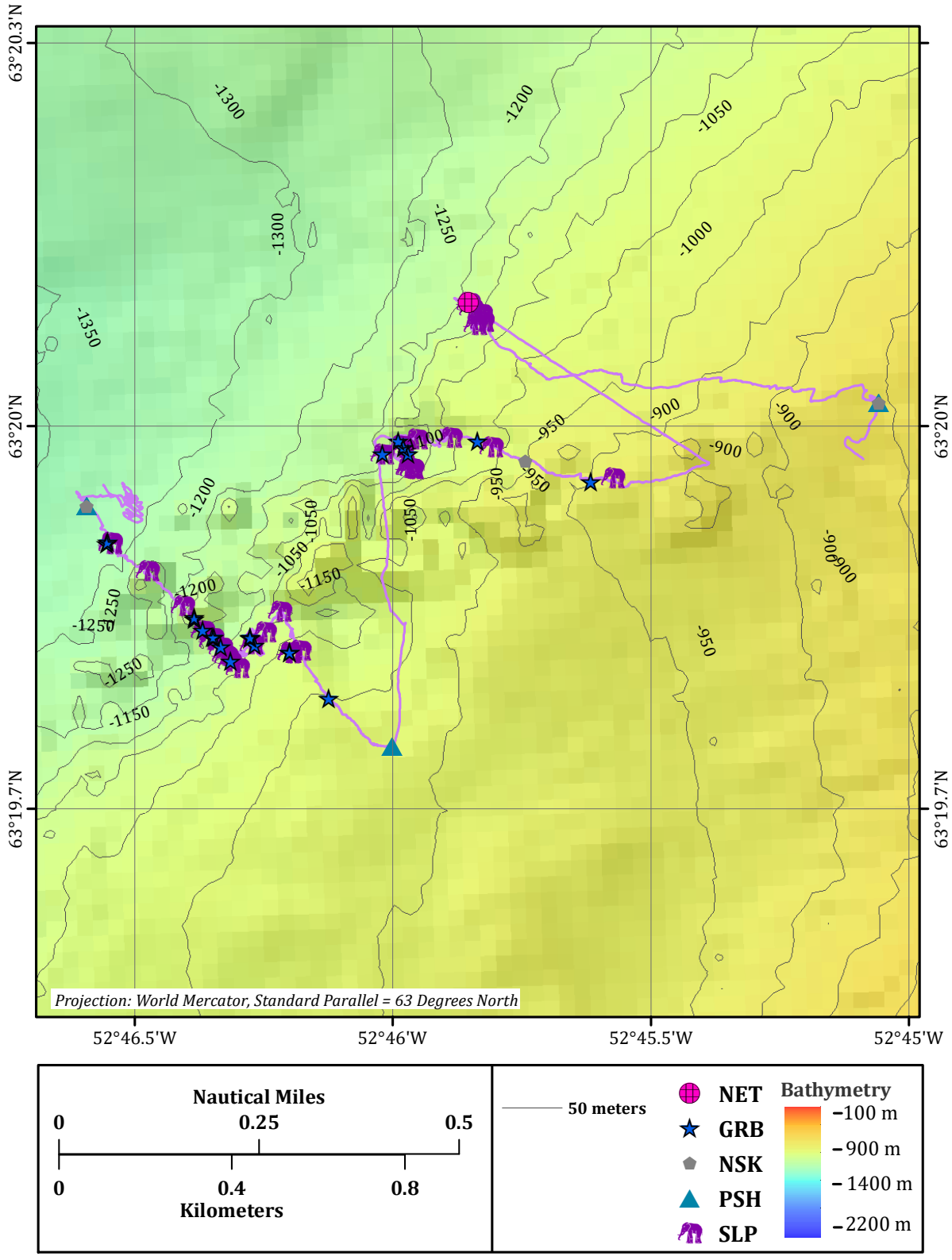


Figure 31

Dive 336

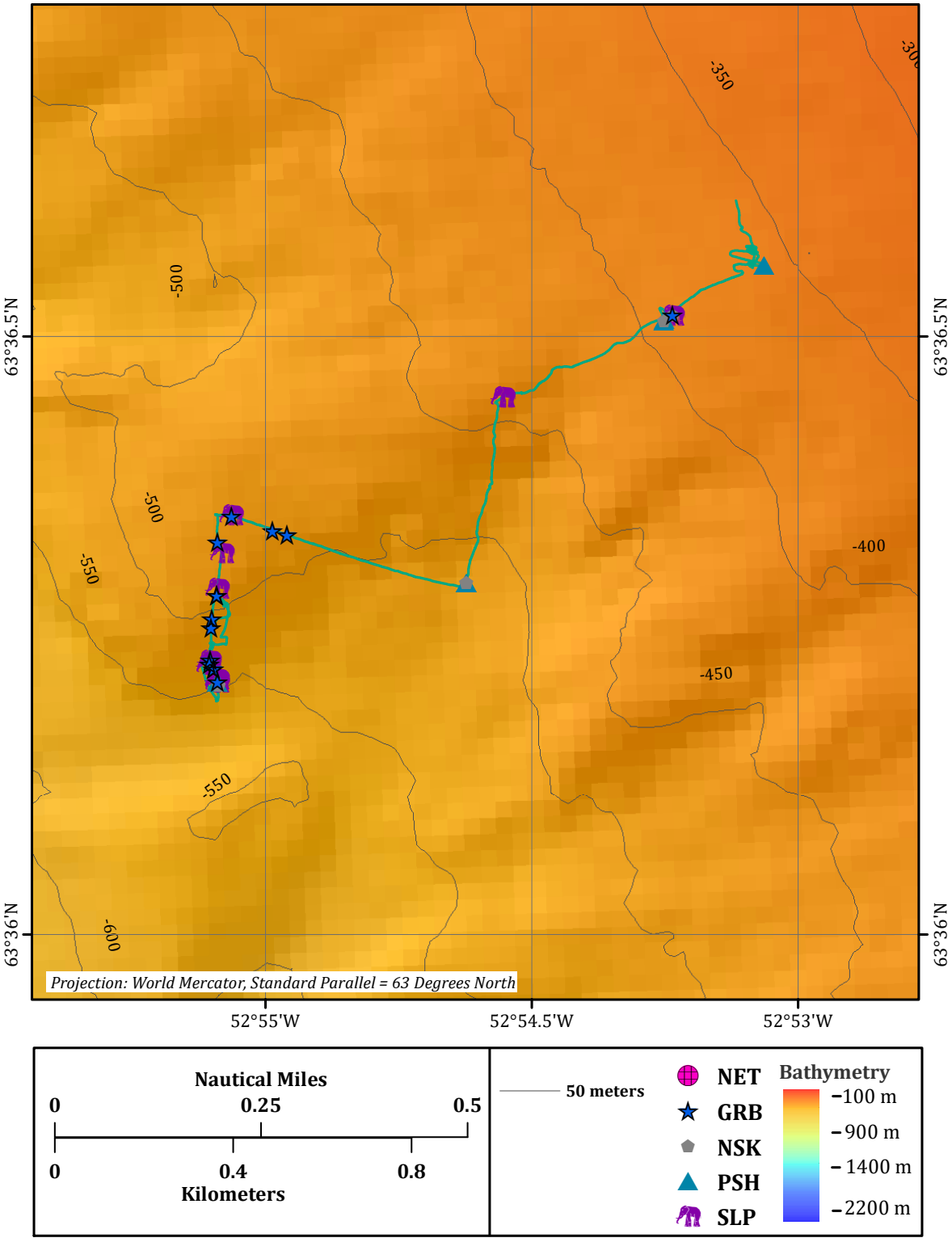


Figure 32

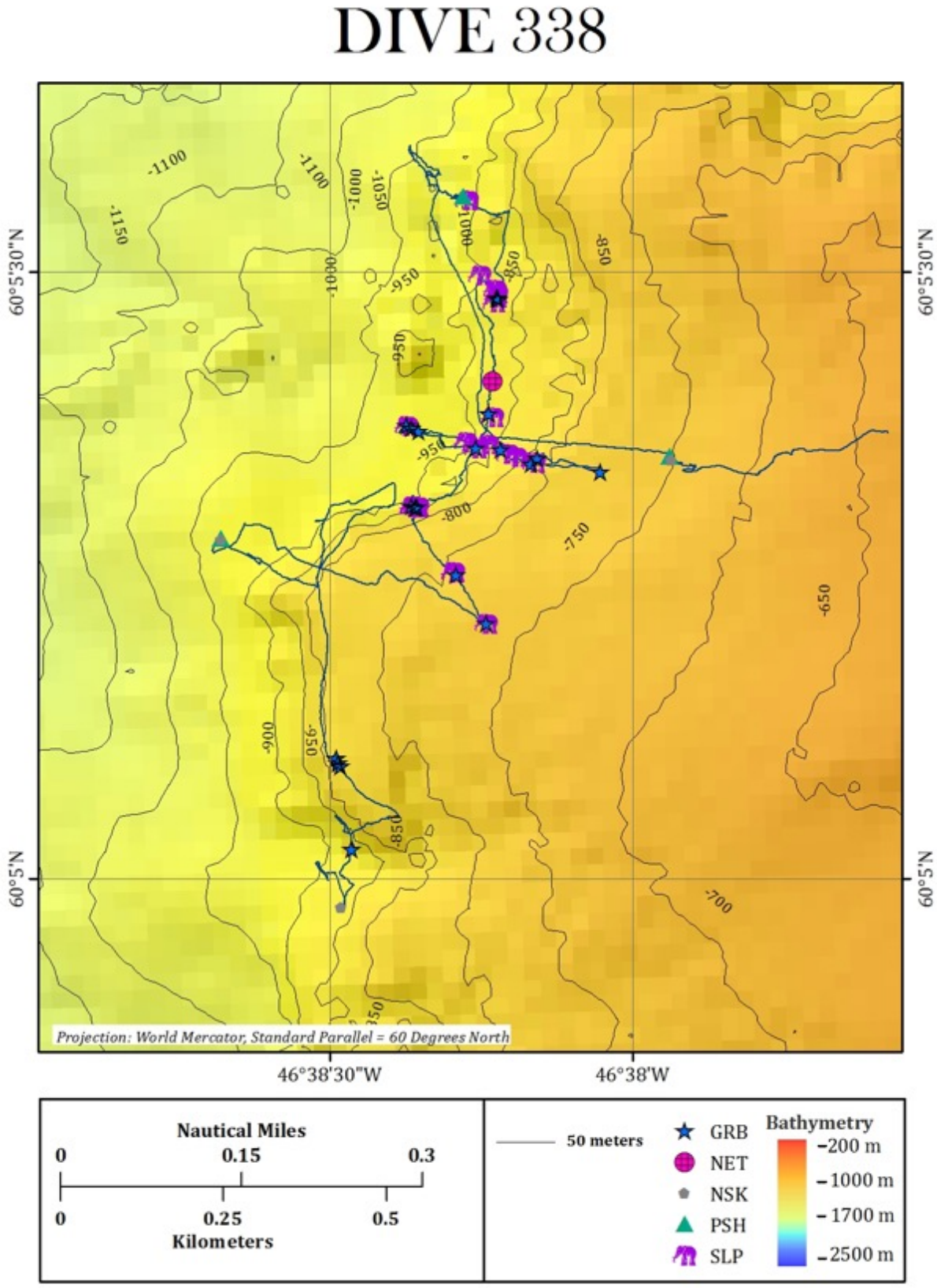

DIVE 338
60°5'30"N
60°5'N
46°38'30"W
46°38'W
-1100
-1150
-1050
-1000
-950
-900
-850
-800
-750
-700
-650
Projection: World Mercator, Standard Parallel = 60 Degrees North
Nautical Miles
0
0.15
0.3
0
0.25
0.5
Kilometers
50 meters
GRB
NET
NSK
PSH
SLP
Bathymetry
-200 m
-1000 m
-1700 m
-2500 m

Figure 33

SAPs operations

Stand alone pumps (SAPs) were deployed to collect particles from the water column to address the key questions of the research project and for other biogeochemical research. Four SAPs were available for the expedition: “Minnie” (S/N 88395331), “Chloe” (S/N 94K004003), “Sandie” (S/N 01K000394) and “Polly” (S/N 94K004001). At each station, one or two pumps were deployed at two different depths, with either a Glass Fibre Filter (GFF) or Supor 0.45 μm filter fitted into pancake filter housings. The SAPs were clamped to CTD wire (Figure 34) and weighed down, initially with 100kg for the first deployments, then with the 500kg weight to help with deployment speed. The pumps were programmed to pump for 1.5 hours at depth, then recovered.

The SAPs were each fitted with a Seabird 39 (SBE39-6756) and a strain-gauge pressure sensor. Basic Sea-Bird processing of the raw data then took place by NMF technicians using Sea-Bird Data Processing software.

There were some minor issues that arose with the SAPs, mainly surrounding housing “Minnie” (see cruise narrative for details). Despite these problems, only one filter was significantly compromised (SAP05 “Chloe”). Refer to NMF technical report for further information.

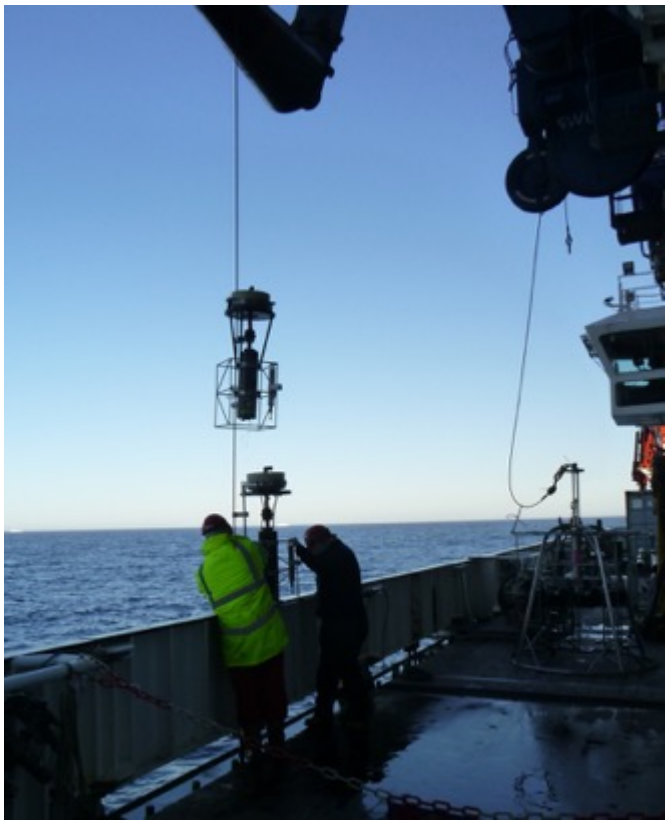


FIGURE 34: RECOVERY OF SAPS. PHOTO BY K. HENDRY.

Towfish operations

The Towfish was used to collect uncontaminated water for trace metal sampling, and was kindly loaned to us by Prof Eric Achterberg of Uni. Southampton and GEOMAR in Kiel following DY080. The system consists of a weighted fish lowered into the water as far from the ship as possible ~5m below the surface. The fish holds a length of acid-cleaned tubing connected to an air-powered pump on deck. The glider-shaped fish keeps the tubing pointed into clean water and away from the ship, and flow is directed into the clean chemistry lab for sampling.

Deployments were done with the help of the crew and NMF technicians, keeping the open end of the fish tubing covered as much as possible to prevent contamination. The Towfish was deployed 6 times on DY081 (Table 15) from the crane on the port side of the aft deck.

TABLE 15: DEPLOYMENT OF THE TOWFISH DURING DY081.

Gear number	Time in	Lat/Long		Time out	Lat/Long	
FSH01	9/7/17 18:10	50.08318	-45.35940	10/7/17 07:20	50.5528	-46.1944
FSH02	13/7/17 07:11	50.50770	-46.08840	19/7/17 22:19	50.5755	-45.9865
FSH03	20/7/17 23:23	63.86599	-53.28424	21/7/17 04:51	63.9535	-52.9167
FSH04	23/7/17 21:05	63.61123	-52.90324	26/7/17 16:34	60.0941	-47.3158
FSH05	26/7/17 20:30	60.11090	-47.41771	27/7/17 17:14	60.0898	-46.6496
FSH06	29/7/17 22:07	59.94239	-46.50713	31/7/17 19:18	59.9395	-43.7783

Whilst the fish was in the water, the pump was left on continuously. Sampling for trace metals was performed only when the ship was moving at >0.5 kts. When stationary and whenever the uncontaminated water supply was not being sampled for trace metals, the water was directed out of the clean lab and into the hangar, where it could be sampled for radium isotopes or was drained via the deck drains.

Chapter 6: Physical oceanography

Introduction

Physical oceanographic studies were carried out on DY081, to characterise the water column structure in each location, specifically to locate and quantify the freshwater inputs in the Greenland sites. These data will help us understand the oceanographic pathways of water masses in the Labrador Sea, and assess the impact of freshwater inputs on the biogeochemistry of West Greenland.

Physical data were obtained using rosette and ROV mounted sensors, glider mounted sensors, and water column acoustics (to be processed on shore).

Geochemical data will be used to support the physical sensor data (See Chapter 7).

Summary of sensor deployments and preliminary results

Sensor data from CTD rosettes

Preliminary results from Orphan Knoll

CTD profiles showed sub-thermocline warm, saline waters were underlain by Labrador Sea Water and likely overflow waters. The water column structure was more complex over Orphan Knoll itself, likely illustrative of mesoscale processes (Figures 35, 36).

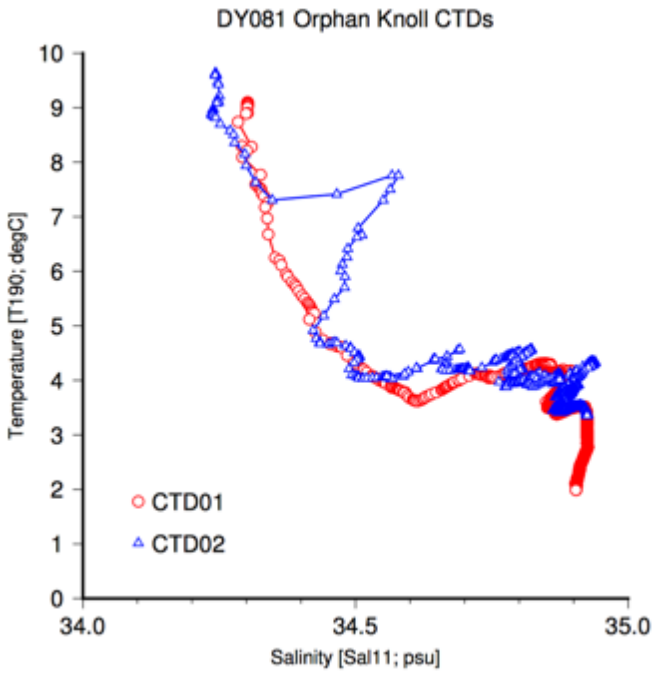


FIGURE 35: T-S PLOT FROM ORPHAN KNOLL.

FIGURE 36: CTD DEPTH PROFILES FROM CTD01 ORPHAN KNOLL (OVER THE PAGE).

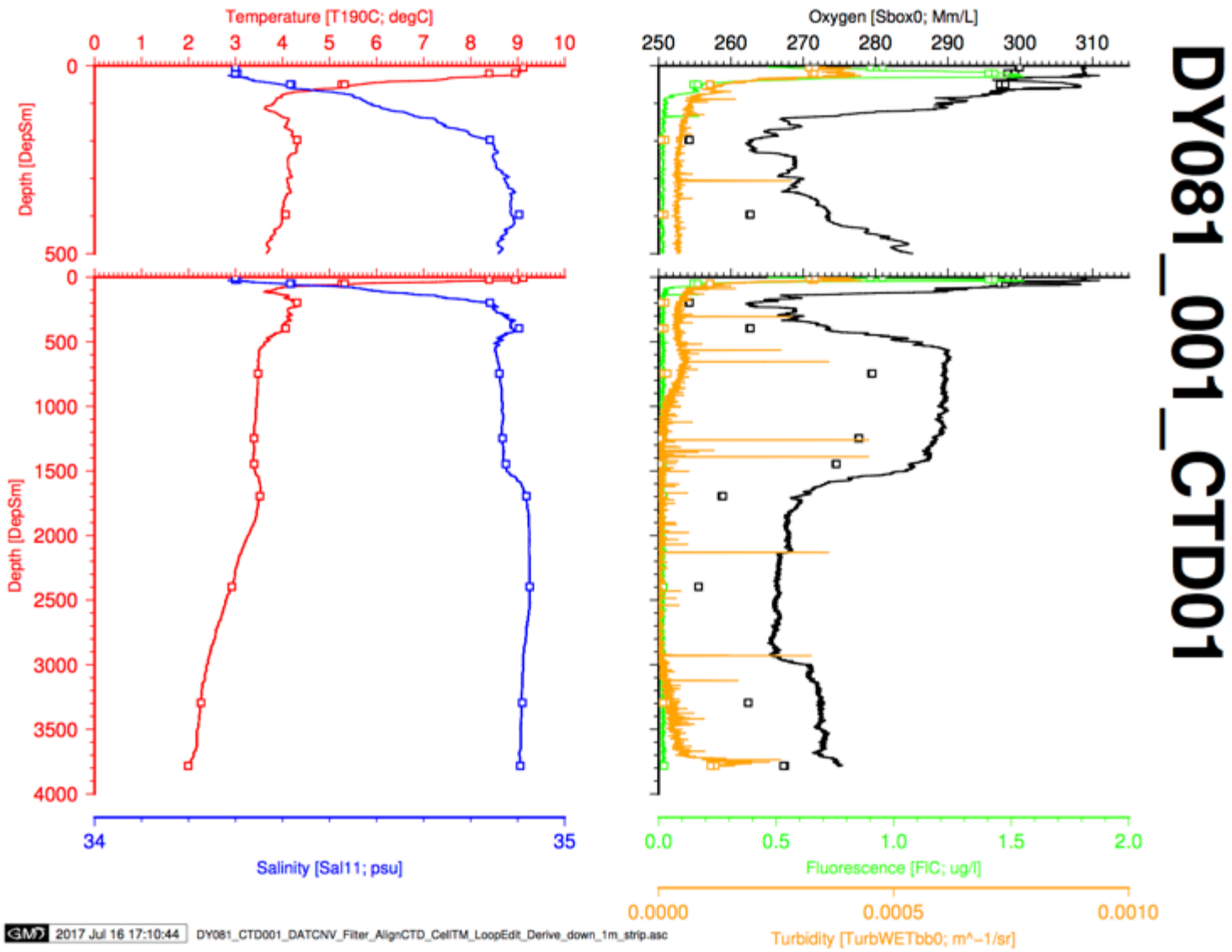

Temperature [T190C; degC]
Oxygen [Sbox0; Mm/L]
Depth [DepSm]
Salinity [Sal11; psu]
Fluorescence [FlC; ug/l]
Turbidity [TurbWETbb0; m^-1/sr]
DY081_001_CTD01
2017 Jul 16 17:10:44
DY081_CTD001_DATCNV_Filter_AlignCTD_CellTM_LoopEdit_Derive_down_1m_strip.asc

Figure 36

Preliminary results from Nuuk

Following a relatively open ocean CTD cast (CTD03) to the south of the study area, further CTD casts in the study area formed a grid to cover the off-slope, slope, and shelf regions of the area, to investigate freshwater supply and transport from Greenland. The first line of the grid was designed to overlap with the Fylla Bank line (e.g. Stein & Buch, 1991), with the southern-most line covering a glacial trough area.

1) General structure illustrated by CTD03 to the south of this study area and CTD004 (Figure 37): Cold, subsurface water is found at <100m, overlying a strong thermocline; Atlantic Water (T>3˚C, salinity<34.5) is found below the thermocline; temperature peaking at approximately 400m, most likely the core of Irminger Water inflow from East Greenland.
2) Shelf area to north (Fylla Bank) generally well mixed: a thermocline is present at approximately 40m at point 2.3 (CTD11), but absent in point 1.5, CTD14 (Figures 38, 39).
3) Analysis of the southern portion of the grid indicates mid-water polar water inputs, which were then targeted for SAPS deployment. Layers of cold, marginally fresher waters (also associated with higher turbidity peaks) are observed at approximately 220 and 420m at point 3.3 (CTD10). These layers are also observed at similar depths (slightly deeper) at point 2.2 (CTD12), suggesting the input from the trough flows westward into the boundary current and is carried north (Figure 38; supported by LADCP data, see below).
4) High productivity at all sites resulted in high turbidity in surface waters. PAR declined rapidly, generally at 0% by 15-40m. Subsurface peaks in turbidity were observed e.g. at approximately 160-170m depth in CTD16, which were also targeted for SAPS deployment.

FIGURE 37: DEPTH PROFILE (OFF SLOPE) FOR CTD04 (OVER THE PAGE).

FIGURE 38: TEMPERATURE AND SALINITY PLOTS FOR CTD GRID, PLOTTED WITH BATHYMETRY DATA.

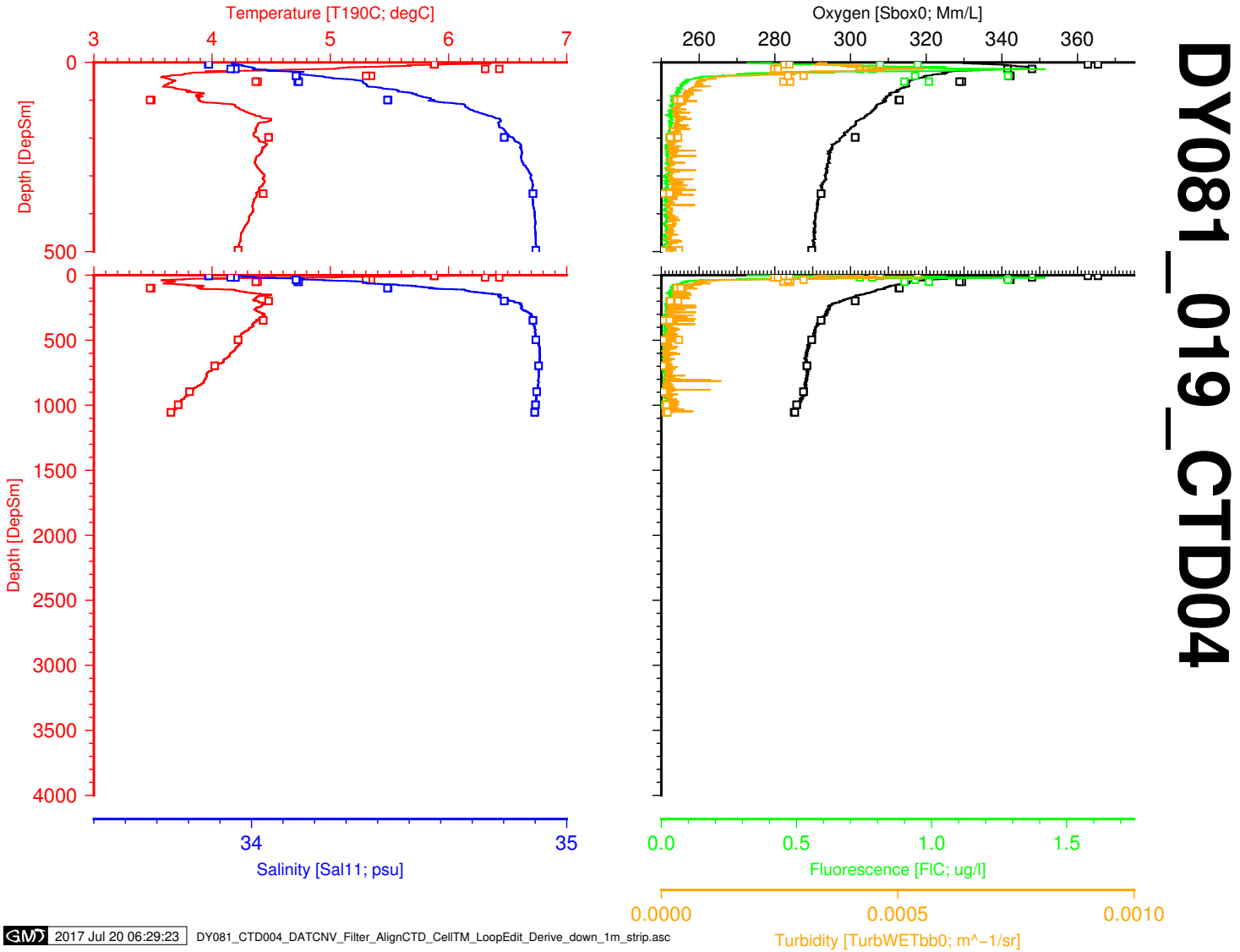

Temperature [T190C; degC]
3
4
5
6
7
Oxygen [Sbox0; Mm/L]
260
280
300
320
340
360
Depth [DepSm]
0
500
0
500
1000
1500
2000
2500
3000
3500
4000
34
35
Salinity [Sal11; psu]
0.0
0.5
1.0
1.5
Fluorescence [FlC; ug/l]
0.0000
0.0005
0.0010
Turbidity [TurbWETbb0; m^-1/sr]
2017 Jul 20 06:29:23
DY081_CTD004_DATCNV_Filter_AlignCTD_CellTM_LoopEdit_Derive_down_1m_strip.asc
DY081_019_CTD04

Figure 37

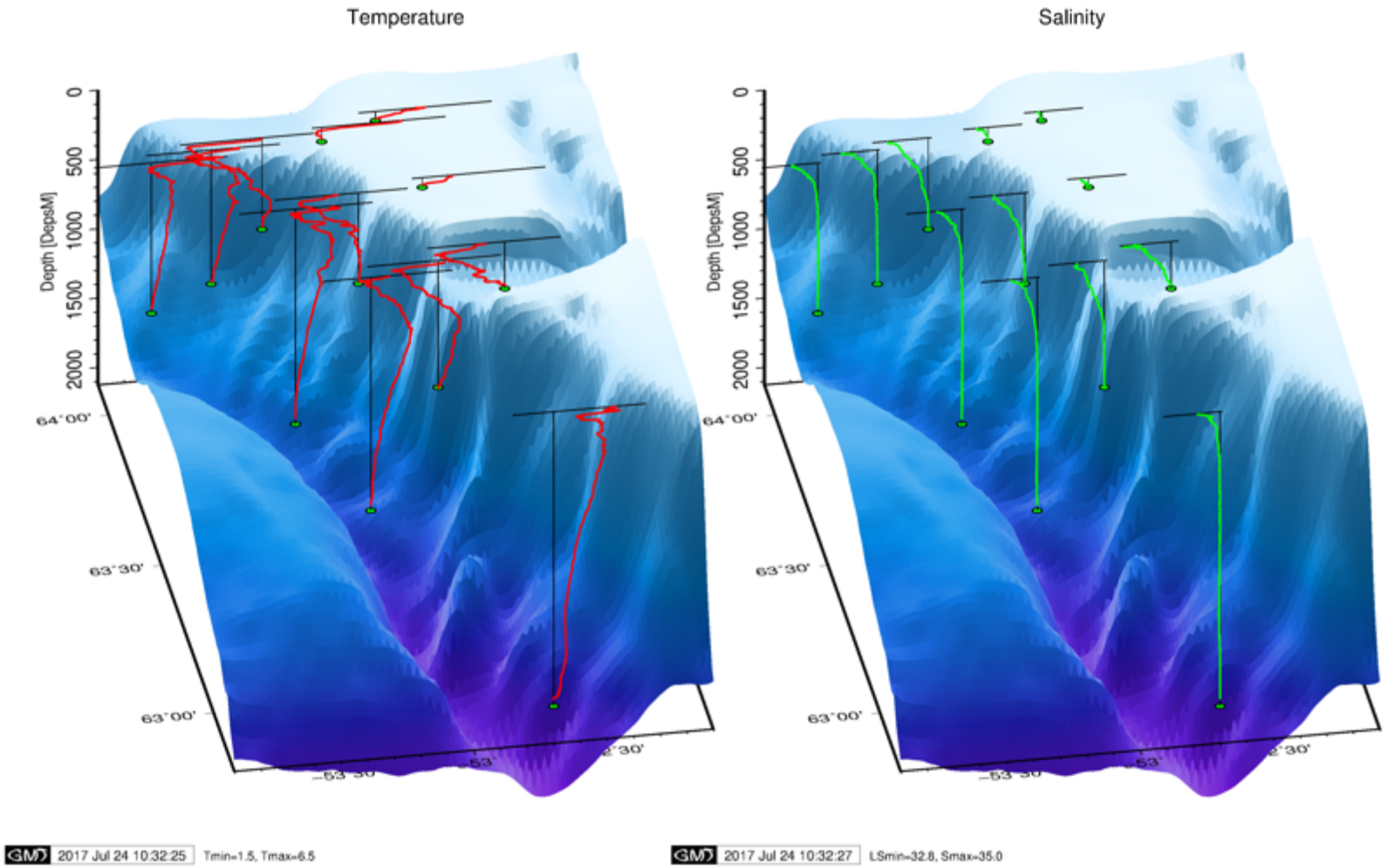

Temperature
Salinity
Depth [DepsM]
0
500
1000
1500
2000
64°00'
63°30'
63°00'
GMT 2017 Jul 24 10:32:25 Tmin=1.5, Tmax=6.5
GMT 2017 Jul 24 10:32:27 LSmin=32.8, Smax=35.0

Figure 38

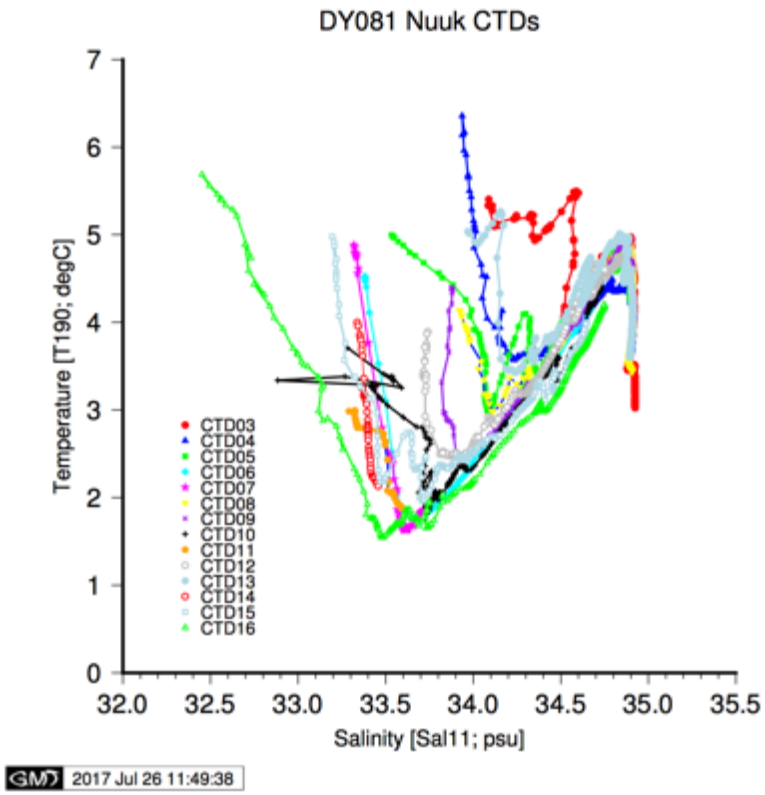


FIGURE 39: T-S PLOTS FOR NUUK CTDS.

Preliminary results from SW Greenland

Two additional glacial troughs were identified at the southern tip of Greenland, and were studied as additional case studies for freshwater supply and routing from the shelf off the slope. Shorter transects of three CTDs (off slope, on slope and shelf) were planned in each of these locations, near Narsaq and Cape Farewell respectively.

A generally typical open ocean profile gave way to profiles characterised by very low salinity subsurface polar waters overlying warmer, Atlantic waters in regions towards shore near Narsaq; low salinity surface waters were also encountered near a likely sea-ice edge on Cape Farewell (Figures 40-42).

FIGURE 40: DEPTH PROFILE FOR CTD17 (OFF SLOPE, NEAR NARSAQ).

FIGURE 41: DEPTH PROFILE FOR CTD19 (ON SHELF, NEAR NARSAQ; NOTE THE LOW SALINITY SURFACE WATERS).

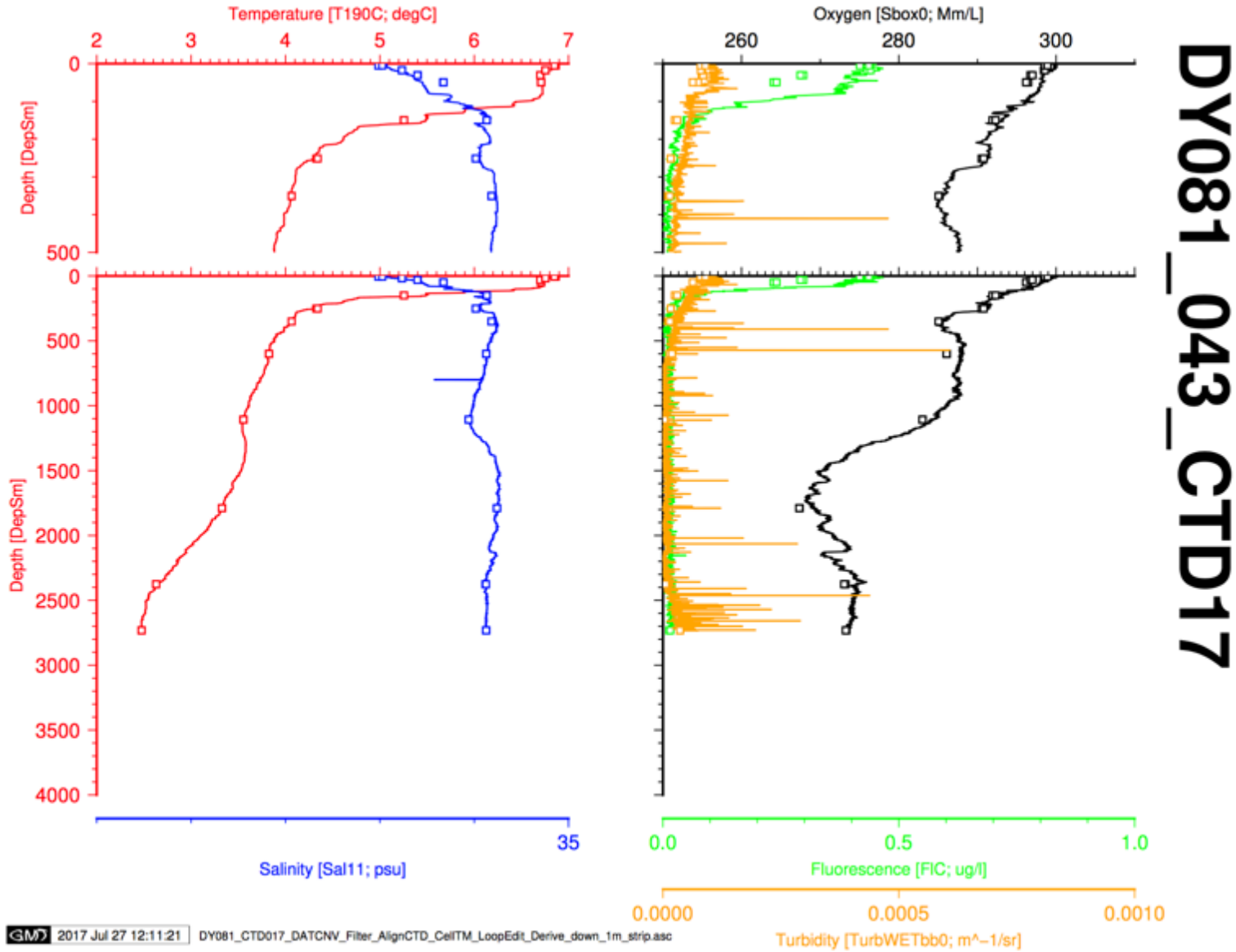

Temperature [T190C; degC]
2
3
4
5
6
7
Depth [DepSm]
0
500
0
500
1000
1500
2000
2500
3000
3500
4000
Salinity [Sal11; psu]
35
Oxygen [Sbox0; Mm/L]
260
280
300
0.0
0.5
1.0
Fluorescence [FlC; ug/l]
0.0000
0.0005
0.0010
Turbidity [TurbWETbb0; m^-1/sr]
2017 Jul 27 12:11:21
DY081_CTD017_DATCNV_Filter_AlignCTD_CellTM_LoopEdit_Derive_down_1m_strip.asc
DY081_043_CTD17

Figure 40

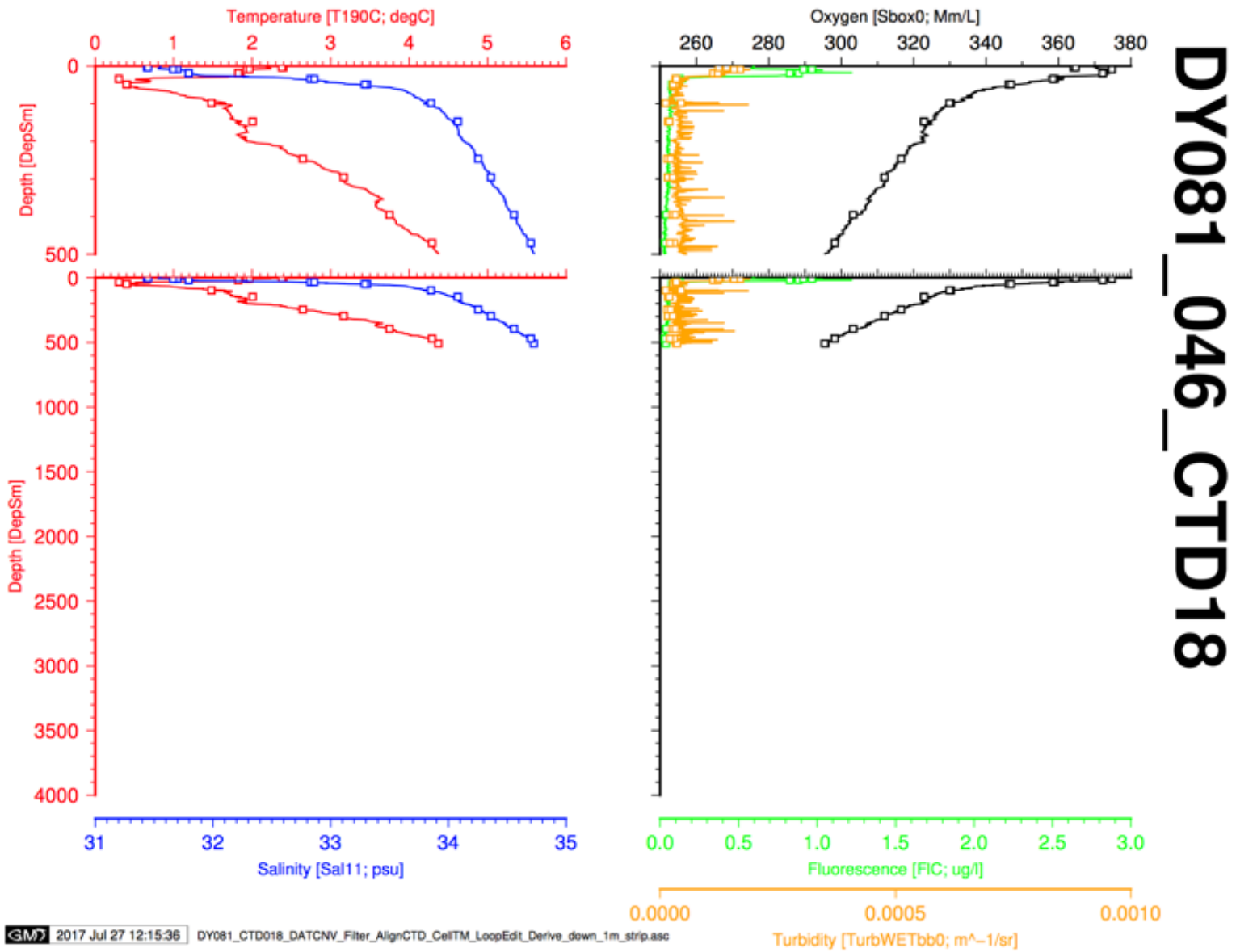

Temperature [T190C; degC]
Oxygen [Sbox0; Mm/L]
Depth [DepSm]
Salinity [Sal11; psu]
Fluorescence [FIC; ug/l]
Turbidity [TurbWETbb0; m^-1/sr]
GMT 2017 Jul 27 12:15:36
DY081_CTD018_DATCNV_Filter_AlignCTD_CellTM_LoopEdit_Derive_down_1m_strip.asc
DY081_046_CTD18

Figure 41

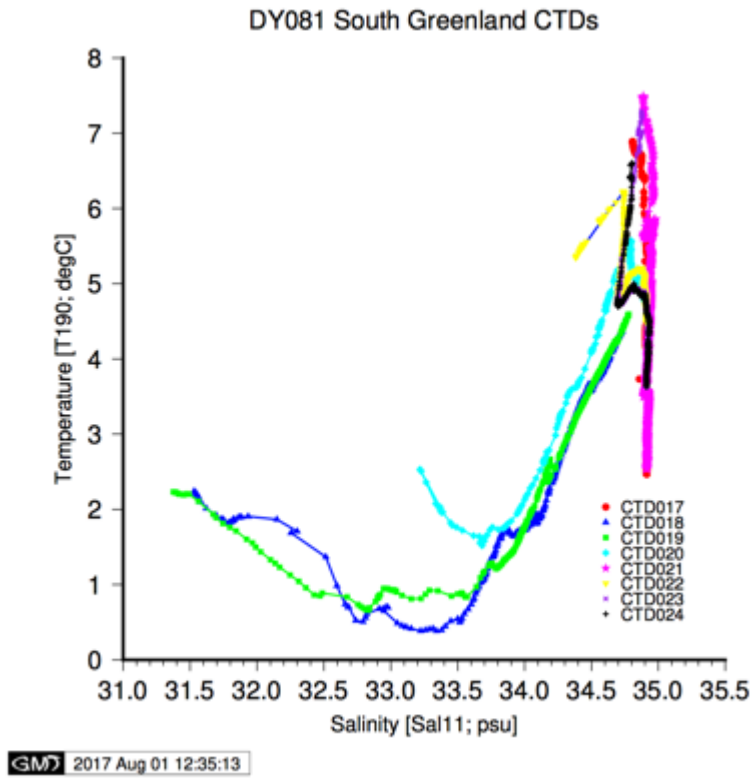


FIGURE 42: T-S PLOT FOR ALL CTD DATA FROM NARSAQ AND CAPE FAREWELL.

LADCP data from CTD rosette

Raw LADCP data files were processed with the LDEO LADCP processing software version IX_8, which was run on Matlab. The processing version was set to bottom tracking mode and employed auxiliary CTD time series data. Processed CTD profile files also incorporated GPS data stored parallel in time, arriving from the ship's 1 Hz feed. Pairing the CTD profile data with the LADCP casts in time is executed by correlating the pressure time series of the CTD file with the depth of the LADCP cast, itself calculated through integration of the vertical velocity. Shipboard ADCP data were not included in the processing procedure. Throughout the processing task, there were only intermittent and minor issues with the casts flagged up by the software. One warning consistently generated after cast 14 was = 'no fixed pinging rate'. This warning was deemed noteworthy but insignificant.

To customise the input, the script 'set_cast_params_v4.m' was used as a template that was modified accordingly. Here, the down-looking and up-looking LADCP files were selected and the output file paths set. The CTD input data were the 2 Hz .cnv files with header intact. Once all the necessary modifications were made, 'process_cast_v4.m' was ran with the station number as the only argument. Running this code automatically saved 14 figures in .ps format as well other output logging files and the vertical profiles saved in a .lad file. All processed files for each cast were stored in the cruise drive in the directory: '/Volumes/public/DY081/LADCP_processing'.

Difficulties were encountered for the CTD stations near Nuuk in waters with a bottom depth shallower than 100m (station 11 and station 14). Here the surface and bottom echo interference resulted in a broken code and no inverse solution. There were also issues with the cast from CTD station 22. Here, the velocity magnitudes were impossibly high. Upon inspection, the error seems to originate from the lack of correlation found between the CTD and LADCP profile data, so the CTD profile is discarded resulting in an end coordinate of 0°N 0°W. Scrutinising the CTD input file yields no obvious reason for these correlation issues. It may be related to discontinuities in the

CTD time series on the cast ascent – with sampling gaps longer than 2 minutes. For the time being, this LADCP cast was ran through the processing software without auxiliary data.

Preliminary LADCP results are shown in Figures 43 and 44. Figure 43 shows LADCP velocity in a CTD line between station 8 (63.418°N' -53.15°W) and station 16 (63.58°N' -52.15°W), with stations 9,10 and 15 in the interior, collected over a 5-day period. Figure 44 shows the LADCP velocity profile at station 16 produced by the LDEO software carried out following the steps outlined above.

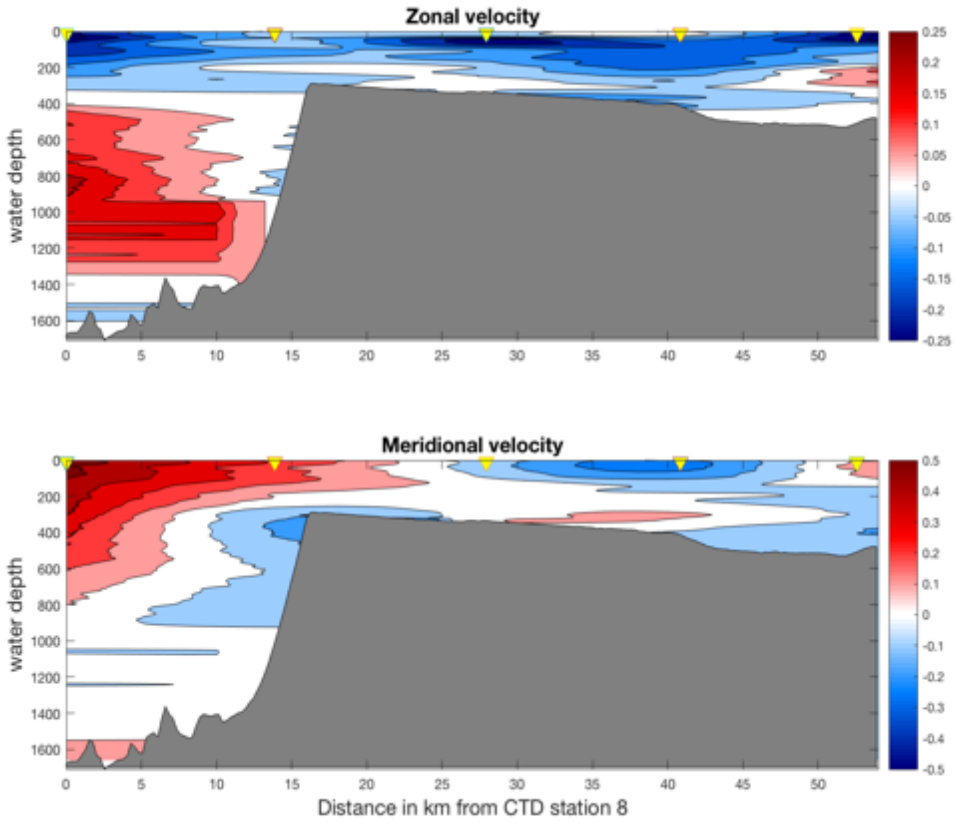


FIGURE 43: ZONAL (TOP) AND MERIDIONAL (BOTTOM) VELOCITY AT THE CTD SECTION NEAR NUUK. YELLOW INVERTED TRIANGLES ARE, FROM LEFT TO RIGHT, THE CTD STATIONS 8-10 AND 15-16. THE BATHYMETRY WAS OBTAINED FROM THE MULTIBEAM DATA GATHERED DY081.

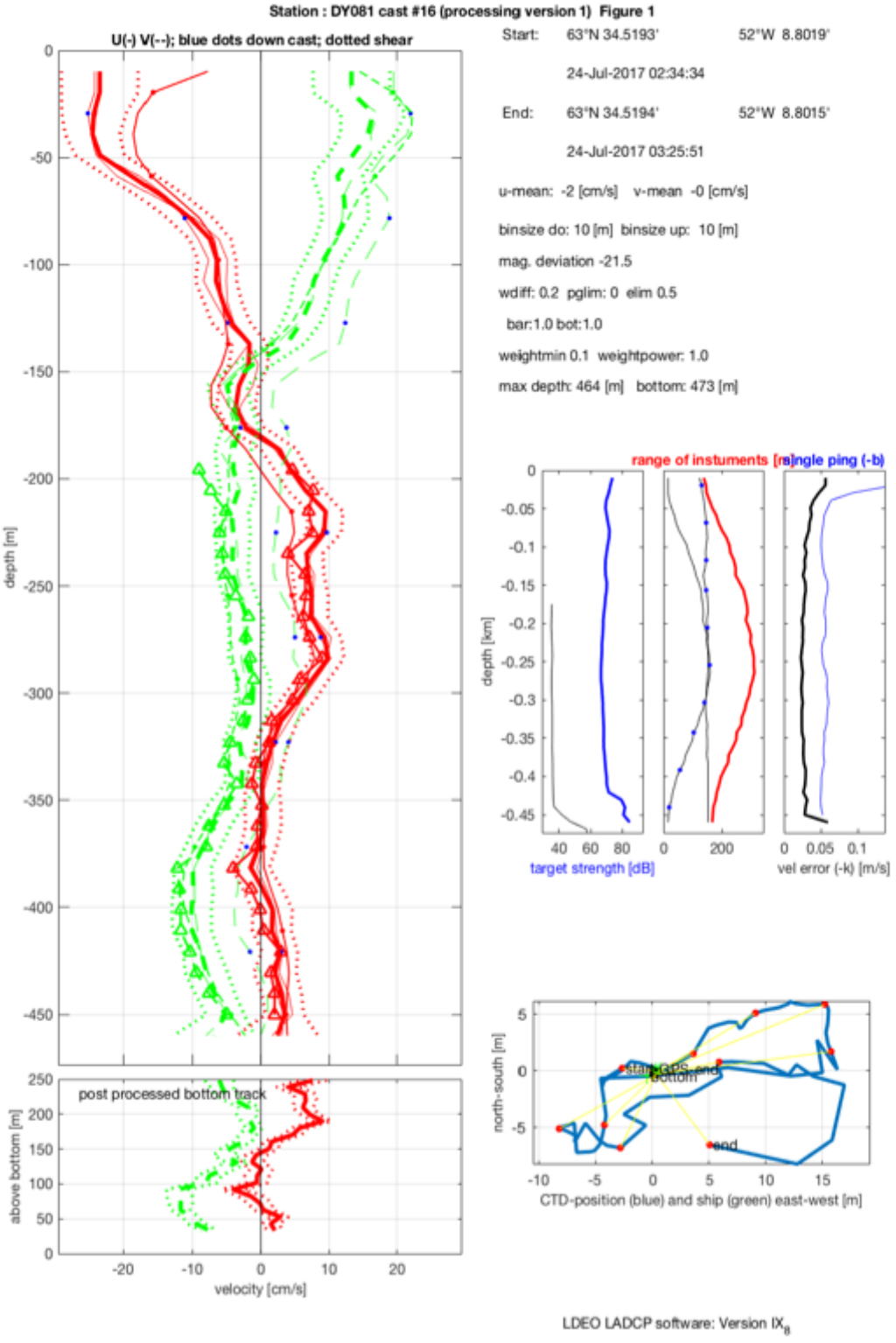


FIGURE 44: THE PROCFIG1 OUT FROM LDEO PROCESSING SOFTWARE SOLUTION FROM CAST #16 WITH VERTICAL VELOCITY IN THE LEFT PANEL. VELOCITY COMPONENTS ARE MERIDIONAL (GREEN) AND ZONAL (RED) AND VELOCITY FROM BOTTOM TRACKING IS BELOW IN THE BOTTOM LEFT PANEL. TOP RIGHT PANEL CONTAINS META DATA AND KEY PARAMETERS USED. CENTRE RIGHT PANEL GIVES THE TARGET STRENGTH AND RANGE OF INSTRUMENTS AND BOTTOM RIGHT IS THE POSITION OF THE SHIP AND INSTRUMENT DURING THE CAST

Instrumentation and sensors on other tethered equipment

Additional temperature, salinity and depth data were processed from both the SAPs (temperature only) and ROV CTD. The data will be used for the main project as additional constraints on water column structure, and by complementary projects. The results highlight the dynamic nature of the study areas (e.g. Figure 45).

Shipboard ADCP data will be calibrated and worked up on shore.

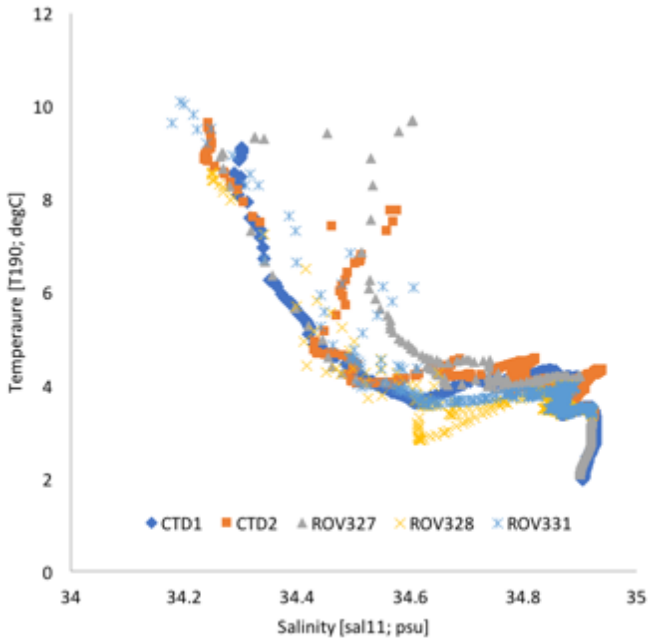


FIGURE 45: EXAMPLE T-S PLOT FOR ROV CTD DATA, COMPARED TO NEARBY CTD ROSETTE DATA, FROM ORPHAN KNOLL.

Summary of glider deployments

Gliders (NMF Slocum gliders, units 331 and 439) were deployed in the Nuuk region to obtain high spatial and temporal information about the water column structure, specifically the transport of fresher water out of the shelf region and across the slope. The planned glider paths covered the shelf break, several times, and the mouth of the main glacial trough.

As per NMF protocol, the gliders were not opened at sea, and data will be downloaded once returned to the workshop in Southampton. Preliminary data transmitted by the gliders show that colder, fresher waters, were captured, in addition to variability in chlorophyll content and turbidity.

Chapter 7: Water sampling

Introduction

Water samples are being collected as part of DY081, to quantify: 1) freshwater inputs (see Chapter 6); 2) nutrient concentrations and fluxes; 3) nutrient isotope ratios; and to carry out other complementary projects. Particulates were collected for biogenic silica, chlorophyll *a*, and other pigments in surface waters, to help quantify the production of siliceous organisms.

Summary of water sampling events

Site	Gear no.	Events (Niskins)	CO3	DI14C	Nuts	d30Si	d14N	U-ser	d18O	Stable Nd	Rad Nd	Sal	BSi	Chla	POC/PON
Orphan Knoll	CTD01	24	12	12	12x2	12	12x2		12x2		12	6	5	4	1
Orphan Knoll	CTD02	24			8	8	8x2		8x2			3	8	4	8
Nuuk	CTD04	24	12	12	12x2	12	12x2		12x2		12	12	7	4	7
Nuuk	CTD05	24			12x2	12	12x2		12x2			12	4	4	4
Nuuk	CTD06	24			11x2	11	11x2		11x2		4*	11	4	4	4
Nuuk	CTD07	24			8x2	8	8x2		8x2			8	4	4	4
Nuuk	CTD08	24			12x2	12	12x2		12x2		3*	12	4	4	4
Nuuk	CTD09	24			12x2	12	12x2		12x2			12	4	4	4
Nuuk	CTD10	24	8	8	8x2	8	8x2		8x2		8*	8	4	4	4
Nuuk	CTD11	24			8x2	8			8x2			8	4	4	4
Nuuk	CTD12	24			12x2	12			12x2			12	4	4	4
Nuuk	CTD13	24			12x2	12			12x2			12	4	4	4
Nuuk	CTD14	24			12x2	6	12x2		12x2		1	12	12	12	12
Nuuk	CTD15	24			12x2				12x2			12	4		
Nuuk	CTD16	24			12x2	8			12x2			12	5		
SGreen	CTD17	24	12	12	12x2	12	12x2		12x2	2	10	12	7		
SGreen	CTD18	24			12x2	12	12x2		12x2	3	4	12	4	4	4
SGreen	CTD20	24	12		12x2				12x2			3	4	4	
SGreen	CTD21	24			12x2	12			12x2			3	4	4	4
SGreen	CTD22	24			12x2	12	12x2		12x2	12		12	4	4	4
SGreen	CTD24	24			12x2	12		3	12x2			12	5	5	5

* Radiogenic Nd sample splits for U-series work

CO3 = carbonate chemistry; DI14C = dissolved inorganic radiocarbon; Nuts = nutrients; d30Si = dissolved silicon isotopes; d15N = nitrogen isotopes; U-ser = uranium series isotopes; Stable Nd = stable neodymium isotopes; Rad Nd = radiogenic neodymium isotopes; Sal = salinity; BSi = biogenic silica; Chla = chlorophyll a,b,c; POC/PON = particulate organic carbon and nitrogen

Table 16

Site	Gear no.	Events (Niskins)	Nuts	d30Si	d14N	Rad Nd
Orphan Knoll	MGA01†	1	1x2	1	1x2	
Orphan Knoll	MGA02†	1	1x2	1	1x2	
Nuuk	MGA03†	0				
Nuuk	MGA04†	1				1
SGreen	MGA05	1				1
SGreen	MGA06†	1				1
SGreen	MGA07†	0				

† Core top water also sampled for nutrients and silicon/nitrogen isotopes

Table 17

Site	Gear no.	Events (Niskins)	CO3	Nuts	d30Si	d18O
Orphan Knoll	ROV327	6		2x2 3	4	2
Orphan Knoll	ROV328	6		2x2	2	1x2
Orphan Knoll	ROV329	6		3x2	3	3x2
Nuuk	ROV333	3		3x2		3x2
Nuuk	ROV335	6		3x2	3x2	3x2
Nuuk	ROV336	6		3x2	3x2	3x2
SGreen	ROV338	6	2		2	2x2
SGreen	ROV339	3		2		2

Table 18

Summary of ICY-LAB project seawater parameters

Parameters, listed in the order of collection from the Niksin rosette

1. Dissolved oxygen

Note that calibration of bottle data with CTD oxygen sensors was bad due to titrator failure, and no further bottle oxygen analysis was carried out by titration after Orphan Knoll. Protocol followed is given below for reference.

Prior to first use, the PVC tube should be soaked in clean sea water for at least one day to prevent bubble formation. The PVC tubing is placed over the Nisin outlet valve. A small volume of seawater is run through to remove air. A 250 mL glass bottle is rinsed 3 times with seawater from the Niskin bottle before being filled and allowed to overflow for about twice the volume of the bottle. Care was taken to avoid bubbles inside the sampling tube and bottle. The temperature of the water was immediately recorded to 0.1 ˚C using a handheld thermometer. MnCl2 and NaOH/NaI (1 mL each) is added immediately to seawater using bottle-top dispensing pipettes, before stoppering the bottle. In the laboratory, the bottle is swirled to mix the precipitates, and the gap around the stopper is filled with unfiltered surface seawater to create a water seal to prevent evaporation and bubble formation. The samples are stored at room temperature in the dark, and analysed within 12 hours of collection.

2. Carbonate chemistry

Carbonate chemistry parameters (pH, alkalinity) can be useful parameters in investigating freshwater input, and are useful for a number of complementary studies (e.g. growth of scleractinian corals).

A 250 mL borosilicate glass bottle is rinsed twice with seawater from the Niskin before being filled using a PVC tube and allowed to overflow one volume. The glass stopped is placed in, to displace excess seawater; another 2.5 mL of seawater is pipetted off to allow a 1% headspace. The sample is poisoned with 50 μL saturated mercuric chloride solution. The bottle stopper is sealed using Apiezon L grease, and taped with electrical tape. The sample is homogenised and stored in a cool, dark place.

Carbonate analysis will be carried out in GEOMAR, Germany. For TDIC carbonate species are converted to CO_2 by addition of phosphoric acid (10% in 0.7 M NaCl), this generated CO_2 is then carried into the measurement cell using N_2 and analysed by coulometric titration using a VINDTA 3C (Marianda, Germany) connected to a 5011 coulometer (UIC, USA). For TA samples are titrated with 0.1 M HCl (prepared in 0.7 M NaCl) in 150 μL increments until the carbonic acid equivalence point is reached. The titration is monitored with the VINDTA 3C in a closed cell titration (Dickson, Sabine and Christian, 2007)

The temperature, salinity and nutrient concentrations of the samples at time of sampling are then combined with the TDIC and TA measurements to calculate CO_2 system parameters.

3. Radiocarbon

The radiocarbon content will be used to determine the age of the waters.

Rinse a 250 mL glass bottle and cap three times, with seawater from the Niskin via a dedicated silicone tube. The bottle is filled and allowed to overflow one volume. The sample is poisoned with 25 μL saturated mercuric chloride solution, sealed and homogenised. The glass bottle is handled with care, and only placed on clean, new plastic. The bottle is stored in a plastic bag, in a cool, dark place.

The radiocarbon content of dissolved inorganic carbon will be analysed at a later stage.

4. Nutrients

Nutrient measurements are a key component of the ICY-LAB project. The samples were taken whilst wearing vinyl gloves only, and taken in duplicate. The bottles were rinsed three times with seawater from the Niksin, filtered using either an Acropak or in line filter (0.2 μm)[3]. Headspace is left, and the sample is frozen at -20 ˚C.

The nutrients will be analysed back ashore by using a 5-channel segmented flow autoanalyser made by Bran and Luebbe, and with high resolution colorimeters, the nutrients analysed will be Nitrate+Nitrite, Nitrite, Silicate, Phosphate and Ammonium (Brewer & Riley,1965; Grasshoff, 1976; Mantoura & Woodward, 1983; Kirkwood, 1989; Zhang & Chi, 2002). Samples will be defrosted from frozen and the bottles washed and dried to ensure no contamination on opening the bottles from outside influences. Samples will be analysed along with a nutrient reference material (KANSO Technos, Japan) that will be sampled to ensure correct calibrations are made and to act as a cross reference.

5. Silicon isotopes

Silicon isotopes (denoted by δ^{30}Si) provide information about the processes involved in the silicon cycle, and so are a key component of the ICY-LAB project. The bottles were rinsed twice with seawater from the Niksin, filtered using either an Acropak or in line filter (0.2 μm). The bottles are stored in the cool and dark.

Silicon isotopes will be analysed on shore using a method adapted from de Souza et al., 2012, in the Bristol Isotope Group, University of Bristol. Briefly, seawater will be precipitated using sodium hydroxide, before being redissolved and chemically purified using cation exchange resin, and analysed using a Multi-Collector Inductively Coupled Plasma Mass Spectrometer (Thermo Neptune MC-ICP-MS).

6. Oxygen isotopes

Water oxygen isotopes (denoted by δ^{18}O) are used in freshwater budget calculations, and so are a key component of the ICY-LAB project. 60 mL of unfiltered seawater are sampled cleanly in duplicate, sealed and stored in cool stow.

The samples will be measured at the NERC Isotope Geosciences Laboratory, NIGL, using the VG SIRA (with isoprep 18) mass spectrometer system.

7. Salinity (bottle)

Bottle salinities were measured for freshwater budget calculations, by NMF technicians (see below and technical report for further information). Unfiltered water samples are collected in glass bottles and sealed with a plastic stopper and metal cap for measurement on board (see below).

8. Uranium series

Uranium series isotopes can be used to investigate weathering processes, and so are an important part of the ICY-LAB project. 5 litres of water were filtered leanly through 0.2 μm Acropak or polycarbonate inline filter and acidified to 0.1% v/v hydrochloric acid (Romil UpA). The samples were stored in cool stow for analysis in the UK.

Uranium series isotopes will be analysed at the University of Bristol following Auro et al., 2012.

[3] Given they have the same poresize, these two filter types were used interchangeably in all cases of filtering with the exception of POC/PON and chlorophyll.

9. Particulates

Remaining water was filtered for biogenic silica (polycarbonate filters dried and sealed), chlorophyll *a, b,* and *c* analysis (GFF filters, see shipboard analyses), POC/PON (GFF filters, flash frozen at -80 ˚C and stored at -20 ˚C) and phytophysiology experiments (see shipboard analyses). Volumes passing through each filer type were logged.

Particulate biogenic silica will be analysed after alkaline extraction using a photospectrometric method, following Demaster et al., 1981. POC/PON will be analysed by Dr Sian Henley, University of Edinburgh.

Samples were initially collected for phytophysiological research, but the Pulse Amplitude Modulation (PAM) device did not function during the cruise and no data were collected. On the first run the PAM was exhibiting problems with the saturating pulse. After trouble shooting, it was determined that the battery was fried and was not charging to the proper voltage. After replacement, the gain was still too high and there was no rise in yield from fluorescence before the saturation pulse to the yield reached during the last saturation pulse. After numerous tries to get the detector working and troubleshooting other problems, it was believed that the detector was fried and the saturating pulse was not working correctly. Samples were no longer collected for PAM analysis.

Some additional surface samples were filtered for SEM imaging of diatom assemblages at Cardiff University, and stored under cool, dark conditions (Williams, Cardiff).

TABLE 19: TABLE OF SAMPLES TAKEN FOR DIATOM IMAGING.

Site	Station No	Gear No	Niskin bottles filtered
Nuuk	19	CTD004	20
Nuuk	19	CTD004	12
Nuuk	19	CTD004	9
Nuuk	19	CTD004	24
Nuuk	24	CTD008	24 - 1
Nuuk	24	CTD008	24
Nuuk	26	CTD010	18
Nuuk	26	CTD010	20
Nuuk	27	CTD011	18, 16, 2
Nuuk	28	CTD012	24, 20
Nuuk	28	CTD012	22, 18
Nuuk	29	CTD013	22, 18
Nuuk	29	CTD013	24, 20
Nuuk	33	CTD014	12, 18, 4
Nuuk	33	CTD014	24, 20, 18, 12
Nuuk	33	CTD014	22, 20
Nuuk	33	CTD014	20, 14, 8, 6
Nuuk	33	CTD014	4
Nuuk	39	CTD015	24, 22, 20, 19, 18
Nuuk	40	CTD016	24, 20
S. Greenland	46	CTD018	22, 17
S. Greenland	46	CTD018	24, 20
S. Greenland	54	CTD020	24, 23, 22, 21
S. Greenland	56	CTD022	24, 22, 20, 18
S. Greenland	59	CTD024	24, 22 , 20, 18

Sampling protocols for complementary studies

Nitrogen isotopes

Nitrogen isotopes (denoted by $\delta^{15}N$) provide information about nitrogen cycling in seawater, a complementary system to the silicon cycle. The samples were taken whilst wearing vinyl gloves only, and taken in duplicate. The bottles were rinsed three times with seawater from the Niksin, filtered using either an Acropak or in line filter (0.2 µm). Headspace is left, and the sample is flash frozen at -80 ˚C, then frozen at -20 ˚C. The samples will be will be analysed by Dr Sian Henley at the University of Edinburgh.

Silicon-32 incubation experiments

Incubations with radioactive silicon-32 were carried out (Table 20) to quantify the degree of kinetic limitation of Si uptake by ambient silicic acid to determine whether silicic acid limitation limits the production of diatom silica, and potentially, diatom growth. The results from DY081 will be complied and compared to results from similar experiments from the Krause Laboratory in the Bering Sea (June 2017) and coastal Greenland (April – June 2017).

TABLE 20: SILICON-32 SAMPLING EVENTS DURING CRUISE DY081.

ICY-LAB Station	Samples Collected	32 Si Depths Sampled	A,E, or K	Incubation Time
DY081_001_CTD001	Full 12 Depth Profile	5 Surface Depths	Ambient & Enhanced	24 hours
DY081_012_CTD002	Full 12 Depth Profile + Kinetic	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_012_CTD002	Full 12 Depth Profile + Kinetic	20.9	Kinetic	12 hours
DY081_017_CTD03	Kinetic from AUV Calibration	7.7	Kinetic	12 hours
DY081_019_CTD04	Full 12 Depth Profile + Kinetic	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_019_CTD04	Full 12 Depth Profile + Kinetic	17.2	Kinetic	12 hours
DY081_022_CTD06	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_023_CTD07	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_024_CTD08	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_025_CTD09	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_026_CTD10	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_027_CTD11	Full 8 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_029_CTD13	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_033_CTD14	Full 12 Depth Profile + Kinetic	14.9	Kinetic	12 hours
DY081_033_CTD14	Full 12 Depth Profile + Kinetic	10 Top Depths	Ambient & Enhanced	24 hours
DY081_039_CTD15	Full 13 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours

DY081_040_CTD16	Full 13 Depth Profile	5 Surface Depths	Ambient & Enhanced	24 hours
DY081_043_CTD17	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 hours
DY081_046_CTD18	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 Hours
DY081_054_CTD20	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 Hours
DY081_055_CTD21	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 Hours
DY081_056_CTD22	Full 12 Depth Profile	4 Surface Depths	Ambient & Enhanced	24 Hours
DY081_059_CTD24	Full 12 Depth Profile	5 Surface Depths	Ambient & Enhanced	24 Hours

At each CTD location, surface waters in or just below the photic zone were collected for ^{32}Si incubations. The samples were spiked with the radionuclide and allowed to incubate in ambient water conditions (temperature, light saturation) for a 24-hour light cycle. Replicates at each depth were given 20 μM silicate enhancements for comparison against ambient water samples. Following incubations, the samples were filtered through a 1.2 μm 25mm polycarbonate filter and dried for further analysis following the cruise. During the cruise, we completed twenty 24-hour incubations and five 12-hour kinetic incubations, finishing the cruise with a total of 202 samples. Upon returning to the Dauphin Island Sea Lab, samples will be allowed to sit for 5-months to establish secular equilibrium with ^{32}P and analyzed on a Beta counter to determine Si uptake.

Radium isotopes

Radium (Ra) is produced continuously from lithogenic material by the decay of thorium (Th) and thus displays elevated concentrations near any sediment-water interface. Thus, Ra can be used to investigate the fate of solutes sourced from benthic sediments or glacial meltwater. Radium is present in the ocean as four naturally-occurring radioactive isotopes: ^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra, with half-lives (11.4 d, 3.66 d, 1600 y and 5.75 y, respectively) spanning a range of time scales relevant to both vertical fluxes of (micro)nutrients out of sediments into the overlying water column, as well as horizontal advection. As Ra is not particle reactive, the decrease in concentration of each short-lived isotope away from the source (sediments) can be used to trace pathways of advection as well as constrain time scales of transport. The primary objective of the radium (Ra) work done with ICY-LAB is to investigate the fate of trace metals from Greenland glacial meltwater when this water enters the Labrador Sea. Ra measurements, trace metals and oxygen isotopes will be combined to investigate the magnitude of any Fe supply in the Nuuk region and along the coast of southwest Greenland (Annett NERC Fellowship).

Ra sampling requires very large volumes of water, as Ra activities are typically very low away from sediment sources. Samples of ~200 L were collected from the trace metal clean Towfish. The Towfish was deployed from the aft port crane, to a depth of ~5m (depth when stationary). The pump was run continuously while the fish was underwater, towing at speed up to 10 knots. When necessary, the fish was brought up to 1m for CTD ops, or recovered onto deck for ROV work.

Samples were collected while underway or stationary (Table 21), and stored in 20 L collapsible plastic containers. Each 20 L water sample was weighed using a beam scale, and stored on shelves in the hangar space. Additional samples were also collected from the stainless-steel Sea-Bird CTD system, Niskin bottle on the megacore frame, and core-top water from megacores. These samples were collected into 20 L bottles as for Towfish water.

The samples were then passed through a column holding 20 g of MnO_2-coated acrylic fiber, which strongly binds Ra. The fibers were then rinsed with Milli-Q and loaded into a Ra Delayed Coincidence Counter (RaDeCC; Scientific Computer Instruments, USA) system purged with He gas, and decay of Ra was counted for 6-10 h to quantify ^{223}Ra and ^{224}Ra content. Following decay of these short-lived isotopes, the fibers will be re-analysed using the RaDeCC to determine the activity of the parent isotopes (^{227}Ac and ^{228}Th).

For towfish samples, a subsample was collected into acid-clean 250 mL LDPE bottles for analysis of the long-lived ^{226}Ra isotopes by mass spectrometry for calibration.

A total of 43 samples were collected for Ra isotopes, from all three main sites as well as the Nuuk to southwest Greenland transit. Of these, 25 were surface samples collected from the towfish providing a good spatial coverage to investigate meltwater derived Ra distribution. Eleven samples were large volumes pooled from Niskin bottles on the CTD rosette, 2 were near-bottom samples collected from the Niskin bottle on the megacore frame, and 4 coretop water samples were collected from the megacores, giving additional information on benthic fluxes at each of the three sites.

TABLE 21: RADIUM SAMPLING EVENTS DURING CRUISE DY081.

	DY081		**Radium sample list**			
	Location	Date	Station	Gear	Event	Vol (L)
1	OK	07/08/17	3	MGA01	1	2.5
2	OK	07/08/17	3	MGA01	9	0.98
3	OK	07/10/17	6	FSH01	2	199.34
4	OK	07/12/17	12	CTD02	1-9	90.22
5	Nuuk	17/7/17	17	CTD03	1-10	103.27
6	Nuuk	17/7/17	17	CTD03	11-22	125
7	Nuuk 1.1	17/7/17	14	FSH02	14	230.25
8	Nuuk 1.2	18/7/17	14	FSH02	17	211.18
9	Nuuk 1.3	18/7/17	14	FSH02	19	209.34
10	Nuuk 1.4	18/7/17	14	FSH02	21	200.38
11	Nuuk 1.4	18/7/17	23	CTD07	11-20	72.75
12	Nuuk 3.1	19/7/17	14	FSH02	22	205.94
13	Nuuk 3.2	19/7/17	14	FSH02	25	209.54
14	Nuuk 3.3	19/7/17	14	FSH02	27	199.33
15	Nuuk 2.3	19/7/17	14	FSH02	29	215.5
16	Nuuk 2.3	19/7/17	27	CTD11	7-14	82.97
17	Nuuk 2.2	19/7/17	14	FSH02	31	203.98
18	Nuuk 2.1	19/7/17	14	FSH02	33	211.75
19	Nuuk 1.5	21/7/17	32	FSH03	2	144.28
20	Nuuk 1.5	21/7/17	32	FSH03	2	116.5
21	Nuuk CTD15	23/7/17	38	FSH04	3	184.92
22	Nuuk CTD16	24/7/17	38	FSH04	5	164.88
23	Nuuk CTD16(2)	24/7/17	38	FSH04	9.5	183.98
24	Nuuk Core	24/07/17	42	MGA04	6	0.96
25	SWG-400	25/07/17	38	FSH04	11	215.92

26	SWG-300	25/07/17	38	FSH04	14	211.9
27	SWG-200	25/07/17	38	FSH04	17	206.56
28	SWG-100	25/07/17	38	FSH04	20.5	214.9
29	SWG1	25/07/17	38	FSH04	25	206.69
30	SWG2	26/07/17	45	FSH05	2	206.72
31	SWG2	27/07/17	47	CTD19	1-8	81.93
32	SWG2	27/07/17	47	CTD19	9-16	83.35
33	SWG2	27/07/17	47	CTD19	17-24	82.41
34	SWG2	27/07/17	49	MGA05	xx	1.63
35	SWG3	29/07/17	53	FSH06	2	208.175
36	SWG3	30/07/17	53	FSH06	11	213.58
37	SWG3	30/07/17	53	FSH06	16	212.63
38	SWG3	31/07/17	58	CTD23	1	82.15
39	SWG3	31/07/17	58	CTD23	9	81.745
40	SWG3	31/07/17	58	CTD23	17	82.655
41	SWG3	30/07/17	57	MGA07	1	9.46
42	SWG3	30/07/17	57	MGA07	1	10.05
43	SWG3	30/07/17	57	MG07	9	9.12
					Total:	5991.315

Trace metals and trace metal isotopes

Trace metal samples were collected from the trace-metal clean towfish system when the ship was moving at >0.5 kts. The water flow was directed into the clean lab, and left running for ~1 minute to flush the tubing. A 0.2μm acropak cartridge filter was attached and flushed with at least 0.5L of seawater. Dissolved trace metal (dTM) samples were then collected into acid-washed 250 mL HDPE bottles, and acid-washed 4L bottles for trace metal isotope analysis. Filtered water was also collected for nutrient analysis. Unfiltered water was collected into 125mL acid-washed 125 mL HDPE bottles for total dissolvable trace metal (TdTM) analysis, and a 4L sample was collected for particulate trace metals (pTM). Samples for oxygen isotopes ($\delta^{18}O$) were also collected from the unfiltered towfish water. All sampling and handling was performed following clean lab protocols, wearing tyvek lab coats, hair nets, and class-100 particle-free gloves. Nutrient samples were frozen at -20 ˚C, and will be analysed at the Plymouth Marine Laboratory, UK. Samples for dTM and TdTM were acidified with 1 mL L^{-1} ultrapure hydrochloric acid and stored at room temperature in the dark.

Samples for pTMs were immediately filtered onto 25mm Supor filters, 0.45μm pore size. Filters were attached to adaptors on the 4L bottles, and pressure filtered at <5 PSI for 2-3 hours or until the bottle was empty. Filters were gently dried using a clean syringe for suction, and by dabbing the filter on an acid-clean blotter filter. pTM samples were stored frozen at -20 ˚C. All filter manipulations were performed in a laminar flow hood with acid washed equipment. dTM, TdTM and pTM samples will be analysed at the Sherrell Lab at Rutgers University in New Jersey, USA.

A total of 83 sampling events were undertaken for trace metals (Table 22). All three main sampling locations were covered, including the full CTD grid at Nuuk. Samples were also collected during the transits from Orphan Knoll to Nuuk, Nuuk to southwest Greenland, and southwest Greenland to Erik Drift. Additional large-volume samples were also collected from the filtered, clean seawater supply for project partners from selected sites, e.g. for trace metal isotope analysis (Dr Susan Little at Imperial College London), and neodymium isotope analysis (for Prof Kevin Burton, University of Durham).

TABLE 22: TRACE METAL SAMPLING EVENTS DURING CRUISE DY081.

	Stn	Gear	Evnt	Date	dTm	TdTM	pTM	TM-isos	Nd isos	$\delta^{18}O$	$\delta^{30}Si$	Nuts
1	3	FSH01	1	07/09/17	✔	✔	✔					
2	3	FSH01	3	07/10/17	✔							
3	14	FSH02	2	13/07/17	✔							
4	14	FSH02	3	14/07/17	✔							
5	14	FSH02	4	14/07/17	✔							✔
6	14	FSH02	5	14/07/17	✔							✔
7	14	FSH02	6	15/07/17	✔							
8	14	FSH02	7	15/07/17	✔	✔	✔					✔
9	14	FSH02	8	16/7/17	✔							✔
10	14	FSH02	9	16/7/17	✔							✔
11	14	FSH02	10	16/7/17	✔							✔
12	14	FSH02	11	17/7/17	✔	✔	✔					✔
13	14	FSH02	12	17/7/17	✔							✔
14	14	FSH02	13	17/7/17	✔	✔	✔	✔				
15	14	FSH02	15	18/7/17	✔	✔						
16	14	FSH02	16	18/7/17	✔	✔	✔	✔				
17	14	FSH02	18	18/7/17	✔	✔	✔					
18	14	FSH02	20	18/7/17	✔	✔	✔	✔				
19	14	FSH02	21.5	18/7/17	✔			✔				
20	14	FSH02	23	19/7/17	✔	✔	✔					
21	14	FSH02	24	19/07/17	✔	✔	✔	✔				
22	14	FSH02	26	19/7/17	✔	✔	✔	✔				
23	14	FSH02	28	19/7/17	✔	✔	✔	✔				
24	14	FSH02	30	19/7/17	✔	✔	✔	✔				
25	14	FSH02	32	19/7/17	✔	✔	✔	✔				
26	32	FSH03	1	21/07/17	✔	✔	✔	✔				
27	38	FSH04	1	23/07/17	✔							✔
28	38	FSH04	2	23/07/17	✔	✔	✔					
29	38	FSH04	4	24/07/17	✔	✔	✔	✔				
30	38	FSH04	6	24/07/17	✔							
31	38	FSH04	7	24/07/17	✔							✔
32	38	FSH04	8	24/07/17	✔							✔
33	38	FSH04	9	24/07/17	✔		✔					✔
34	38	FSH04	10	25/07/17	✔	✔				✔		✔
35	38	FSH04	12	25/07/17	✔	✔	✔			✔		✔
36	38	FSH04	13	25/07/17	✔	✔	✔			✔		✔
37	38	FSH04	15	25/07/17	✔	✔	✔	✔		✔		✔
38	38	FSH04	16	25/07/17	✔	✔	✔			✔		✔
39	38	FSH04	18	25/07/17	✔	✔	✔			✔		✔
40	38	FSH04	19	25/07/17	✔	✔				✔		

41	38	FSH04	20	25/07/17	✔	✔	✔		✔	✔		✔
42	38	FSH04	21	25/07/17	✔	✔	✔	✔		✔		✔
43	38	FSH04	22	26/07/17	✔	✔	✔		✔	✔		✔
44	38	FSH04	23	26/07/17	✔	✔	✔	✔				
45	38	FSH04	24	26/07/17					✔			
46	38	FSH04	26	26/07/17	✔	✔						✔
47	38	FSH04	27	26/07/17	✔							✔
48	45	FSH05	1	26/07/17	✔	✔	✔					✔
49	45	FSH05	3	27/07/17	✔	✔	✔		✔			✔
50	45	FSH05	4	27/07/17	✔							
51	45	FSH05	5	27/07/17	✔	✔						
52	45	FSH05	6	27/07/17	✔							✔
53	45	FSH05	7	27/07/17	✔	✔	✔					✔
54	45	FSH05	8	27/07/17	✔							✔
55	45	FSH05	9	27/07/17	✔							✔
56	45	FSH05	10	27/07/17	✔							✔
57	45	FSH05	11	27/07/17	✔	✔						✔
58	45	FSH05	12	27/07/17	✔							✔
59	45	FSH05	13	27/07/17	✔							✔
60	45	FSH05	14	27/07/17	✔	✔	✔					✔
61	45	FSH05	15	27/07/17	✔	✔						✔
62	45	FSH05	16	27/07/17	✔	✔	✔					✔
63	45	FSH05	17	27/07/17	✔	✔	✔					✔
64	53	FSH06	1	29/07/17	✔	✔	✔					
65	53	FSH06	3	30/07/17	✔	✔						
66	53	FSH06	4	30/07/17	✔	✔	✔					✔
67	53	FSH06	5	30/07/17	✔	✔	✔					✔
68	53	FSH06	6	30/07/17	✔	✔	✔					✔
69	53	FSH06	7	30/07/17	✔	✔	✔					✔
70	53	FSH06	8	30/07/17	✔	✔	✔					✔
71	53	FSH06	9	30/07/17	✔	✔	✔					✔
72	53	FSH06	10	30/07/17	✔	✔	✔					
73	53	FSH06	12	30/07/17	✔	✔	✔					
74	53	FSH06	13	30/07/17	✔	✔				✔	✔	✔
75	53	FSH06	14	30/07/17	✔	✔	✔			✔	✔	✔
76	53	FSH06	15	30/07/17	✔	✔						
77	53	FSH06	17	31/07/17	✔	✔						
78	53	FSH06	18	31/07/17	✔		✔					✔
79	53	FSH06	19	31/07/17	✔	✔	✔					✔
80	53	FSH06	20	31/07/17	✔	✔	✔					✔
81	53	FSH06	21	31/07/17	✔	✔	✔					✔
82	53	FSH06	22	31/07/17	✔	✔	✔					✔
83	53	FSH06	23	31/07/17	✔	✔	✔					✔

Neodymium isotopes (radiogenic)

Neodymium isotopes (radiogenic and stable) in seawater reflect weathering and seafloor exchange processes, and have been sampled for, to help constrain inputs of material from terrestrial and marine weathering. Samples for radiogenic Nd isotopes were collected for Prof Tina van der Flierdt (Imperial College); samples for stable Nd isotopes were collected for Prof Kevin Burton (University of Durham).

Filter 10 litres of water through 0.2 μm Acropak filter or inline filter and acidified to 0.1% v/v hydrochloric acid (Romil UpA). Stored in cool stow for analysis in the UK.

Neodymium isotopes (stable)

Filter 10 litres of water through 0.45 μm Acropak filter or inline filter. Stored in cool stow for analysis in the UK. Some samples also taken by Towfish (see above).

Porefluid sampling and core incubations

One of the key aims of ICY-LAB is to investigate the interaction between seawater and sediments in glacial regions. To this end, we collected porefluid samples to be paired with sediment and overlying seawater samples, and we carried out core incubation experiments.

Porefluids

Rhizon filters (Rhizosphere®) were used to filter porefluids from both megacore and push core tubes (Figure 46). Approximately half of the solutions were stored under cool conditions, and the remainder was frozen at -20 ˚C. Some of the porefluids were measured for dissolved silicon on the ship (the remainder will be carried out on shore). Porefluid silicon isotope analysis will be carried out at the University of Bristol (following unpublished methods from Lucie Cassarino and Dr Katharine Hendry). The frozen samples will be analysed for remaining nutrients, and for nitrogen isotopes by Dr Sian Henley.

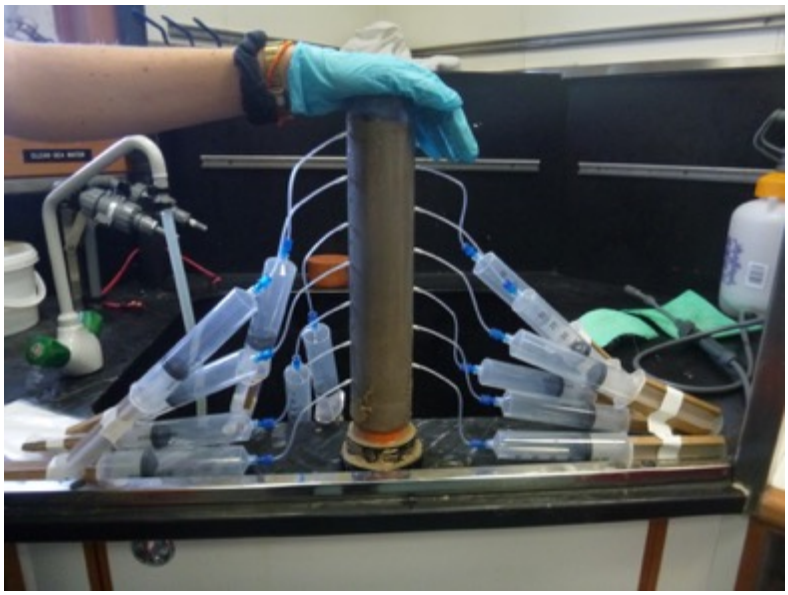


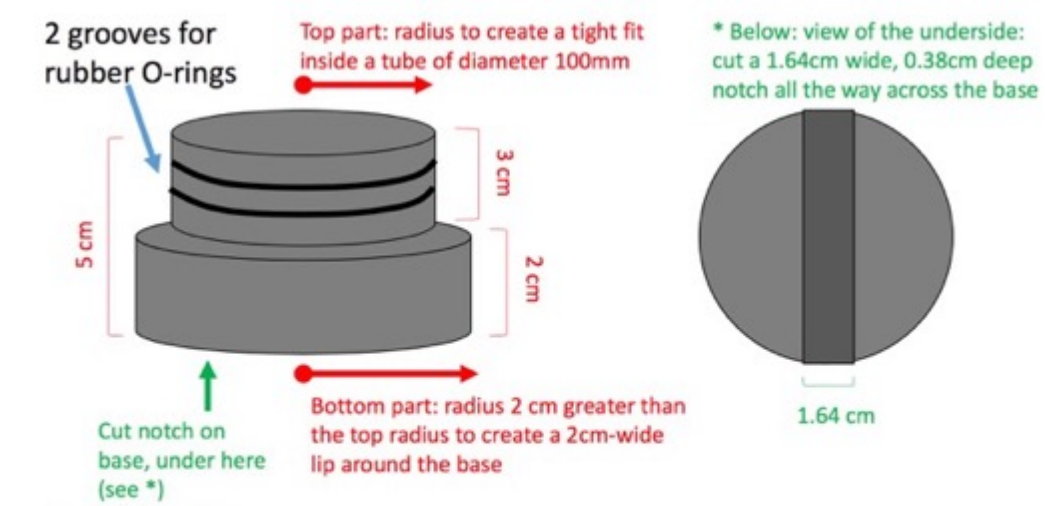
FIGURE 46: POREFLUID SAMPLING OF A PUSH CORE. PHOTO BY A. JACOBEL.

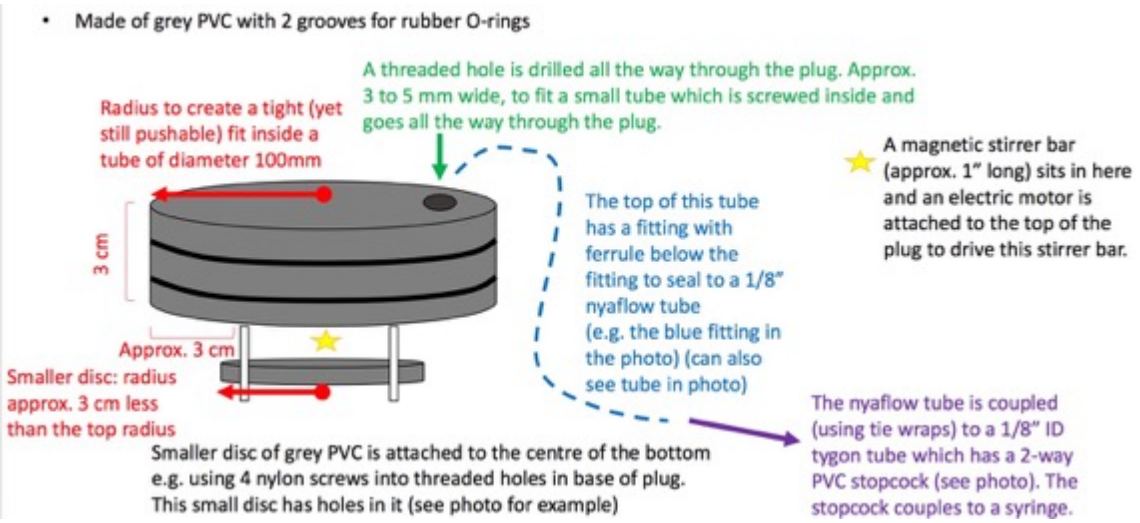
In addition, when material was available, two megacores were sectioned at 2-5cm intervals and frozen for Prof Tina van der Flierdt, Imperial College.

Core incubations

Core incubations were used to assess the supply of dissolved nutrients from sediments and porefluids into overlying seawater via diffusion over time.

One megacore tube per recovery was fitted with a tight lower seal, and an upper seal with a sampling device and magnetic stirrer attached whilst on deck (Figure 47). Initially, small amounts of air were removed from the overlying space (so that only overlying seawater remained) and a sample was taken. The core was left under controlled temperature and light conditions and sampled ever two hours for at least 24 hours. The samples were filtered; 84pprox.. 25-30 mL was stored under cool conditions, and 25-30 mL was frozen at -20 ˚C.





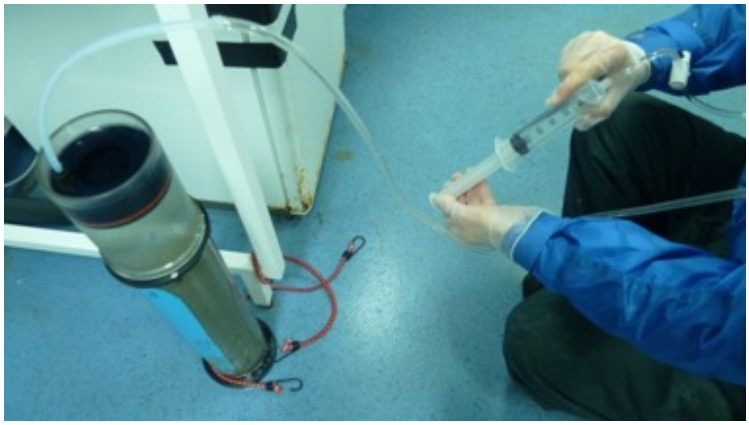


FIGURE 47: CORE INCUBATION DESIGN (BASE AND TOP PLUGS, OVER THE PAGE) AND IMPLEMENTATION (ABOVE) DURING DY081.

TABLE 23: POREFLUID AND CORE INCUBATION SAMPLES FROM DY081. OK = ORPHAN KNOLL; SG = SOUTHERN GREENLAND.

Station	Gear	Event	Site	Depth (m)	Lat	Long	Purpose	#Samples
003	MGA001	002	OK	3721	50.16	-45.51	Incubation	26
003	MGA001	004	OK	3721	50.16	-45.51	Pore Fluids	1
003	MGA001	007	OK	3721	50.16	-45.51	Pore Fluids	1
003	MGA001	009	OK	3721	50.16	-45.51	Pore Fluids	34
008	ROV329	020	OK	1745	50.55	-46.19	Pore Fluids	9
008	ROV329	040	OK	1682	50.56	-46.19	Pore Fluids	9
008	ROV329	053	OK	1711	50.57	-46.18	Pore Fluids	3
009	MGA002	002	OK	1770	50.52	-46.28	Incubation	245
009	MGA002	003	OK	1770	50.52	-46.28	Pore Fluids	13
018	MGA003	001	Nuuk	1301	63.82	-53.77	Pore Fluids	32
018	MGA003	002	Nuuk	1301	63.82	-53.77	Incubation	20
034	ROV334	001	Nuuk	940	63.87	-53.29	Pore Fluids	12
034	ROV334	007	Nuuk	683	63.86	-53.28	Pore Fluids	12
035	ROV335	074	Nuuk	845	63.33	-52.75	Pore Fluids	10
035	ROV335	003	Nuuk	1326	63.33	-52.78	Pore Fluids	8
035	ROV335	042	Nuuk	1002	63.32	-52.77	Pore Fluids	0
035	ROV335	002	Nuuk	1326	63.33	-52.78	Pore Fluids	4
035	ROV335	041	Nuuk	1002	63.33	-52.77	Pore Fluids	11
035	ROV335	073	Nuuk	845	63.33	-52.75	Pore Fluids	2
037	ROV336	043	Nuuk	381	63.61	-52.90	Pore Fluids	15
037	ROV336	034	Nuuk	499	63.60	-52.91	Pore Fluids	16
037	ROV336	005	Nuuk	549	63.60	-52.92	Pore Fluids	19
037	ROV336	035	Nuuk	497	63.60	-52.91	Pore Fluids	16
037	ROV336	006	Nuuk	569	63.60	-52.92	Pore Fluids	16

037	ROV336	045	Nuuk	349	63.61	-52.90	Pore Fluids	7
42	MGA004	002	Nuuk	519	63.55	-52.23	Pore Fluids	18
42	MGA004	003	Nuuk	519	63.55	-52.23	Incubation	24
049	MGA005	002	SG	573	60.26	-46.89	Incubation	24
059	MGA005	003	SG	573	60.26	-46.89	Pore Fluids	29
050	ROV338	004	SG	742	60.09	-46.63	Pore Fluids	16
050	ROV338	005	SG	742	60.09	-46.63	Pore Fluids	12
050	ROV338	023	SG	957	60.09	-46.64	Pore Fluids	8
050	ROV338	058	SG	983	60.08	-46.64	Pore Fluids	12
050	ROV338	059	SG	983	60.08	-46.64	Pore Fluids	24
051	MGA006	002	SG	1326	60.12	-46.66	Pore Fluids	30
051	MGA006	003	SG	1326	60.12	-46.66	Incubation	24
052	ROV339	003	SG	1085	59.93	-46.50	Pore Fluids	19
052	ROV339	038	SG	807	59.93	-46.50	Pore Fluids	17
052	ROV339	040	SG	532	59.94	-46.51	Pore Fluids	18
052	ROV339	004	SG	1085	59.93	-46.50	Pore Fluids	21
052	ROV339	037	SG	807	59.93	-46.50	Pore Fluids	21
052	ROV339	041	SG	532	59.94	-46.51	Pore Fluids	8
052	MGA007	002	SG	2149	59.46	-44.42	Incubation	24
052	MGA007	003	SG	2149	59.46	-44.42	Pore Fluids	12

Shipboard water analyses

Salinity

Salinity was measured on board by NMF technicians according to standard protocol using an Guildline Autosal salinometer and software, cross-checked with IAPSO standards (see NMF technical report for more details). At the west Greenland sites, all Niskins that were sampled for oxygen isotopes were also sampled for salinity, to carry out freshwater budget calculations (e.g. Hendry et al., 2011). At other sites, only 3-4 Niskins were sampled for salinity, to carry out a sensor calibration.

Dissolved silicon

Dissolved silicon was measured in some porefluid profiles using Hach Ltd reagents for ultra-low range SiO_2 detection. Measurements were carried out on a V-1200 Vis spectrophotometer, and samples were calibrated against a ten-point standard curve.

The measurement protocol is as follows:

- Fourteen drops of molybdate solution are added to blank, standards and samples and left for four minutes.
- Citric acid powder (1 sachet) is added to each blank, standard and sample and left for one minute.
- Amino acid catalyst (1 sachet) is added to each standard and sample (not blank) and left for two minutes.
- The solutions are measured at 810 nm, blank-corrected and standardised.

Dissolved oxygen

Dissolved oxygen measurements were attempted, to calibrate the oxygen sensor on the CTD. However, due to titrator failure, the measurements were abandoned. Instead, the oxygen sensors will be calibrated post-cruise.

For reference, the measurement protocol is as follows:

Start up

- Move burette tip to the electrode holder.
- Flush the burette tip with fresh thiosulphate.
  - Menu>OK>Manual control>OK>PREP>OK.
  - This flushes 10 mL through the burette, 2 cycles by the piston, good if not used recently.
  - DOS>OK>Start (hold down) to manually dispense desired amount.
  - Press Back to return to main menu.
  - Rinse excess thiosulphate from the burette tip with MQ.
- Select Dissolved O2 method.
  - Method>OK>Dissolved O2>OK.
- Move electrode to electrode holder.
- Rinse the electrode with MQ, if a big drop of MQ is hanging off the electrode bulb remove it gently with a kim wipe.
- Dispense 1-2 mL of H_2SO_4 to get fresh acid in the pipette tip.

Running samples

- Select next sample.
- Remove water seal with pipette and completely dry around the stopper with a kim wipe.
- Remove stopper by twisting and gently pulling. Avoid “chinking” the stopper as this can chip the stopper and render the bottle calibration incorrect. If you cannot remove the stopper do not force it.
- Add 1 mL of H_2SO_4 to the sample with the pipette tip just below the sample surface. Gently tip the bottle and run the acid down the side of the bottle. This is to prevent the introduction of bubbles and to avoid disturbing the precipitate.
- Using the stirrer bar retriever, trace a small stirrer bar down the neck of the bottle and to the bottom of the bottle. This also is to prevent the introduction of bubbles and to avoid disturbing the precipitate.
- Place sample on stirrer plate.
- Lower the electrode and burette tip into the sample.
- On the Titrino.
  - Ensure the “Dissolved O2” method is selected. If not refer to the start up section.
  - Press “Start”
  - Enter the short ID in ID1. ID1>OK>WXXXX>Accept>OK. The key pad can be used to enter numbers (Num Lock must be on) but not letters, and BS=backspace.
  - Enter the bottle number in ID2. ID2>OK>XX>Accept>OK.
  - Ignore the unit line.
  - Press “Start” to begin the titration.
- The titration will take about 60 sec.
- Write down the titer volume on the Dissolved O_2 log sheet.
- Raise the electrode and burette tip high enough so as not to catch the bottle on the electrode bulb.
- Remove the sample.
- Rinse the electrode and burette tip with MQ, if a big drop of MQ is hanging off the electrode bulb remove it gently with a kim wipe

- Retrieve the stirrer bar from the sample, dry the stirrer bar, cap the bottle, return to the box and select the next sample.

Chlorophyll pigments

A trichromatic method (Mackereth et al., 1978) was used to determine chlorophyll-a, b and c spectrophotometrically in the near surface seawater samples (except CTD01). The samples were passed through a 25mm GFF filters and frozen until extraction. Extraction was carried out using aqueous acetone and magnesium carbonate, in order to prevent acidity that could damage the pigments. Once left to steep for 24 hours in the dark at 4˚C, the samples were centrifuged and analysed at 750 nm (to correct for turbidity), 664, 647 and 630 nm on a V-1200 Vis spectrophotometer. Absorbance values were then used in equations 1 to 3 to calculate the concentration of chlorophyll-a, b and c per volume of filtered sample (Eq. 4).

Chlorophyll *a* (mg/L) = 11.85*(OD664) – 1.54*(OD647) – 0.08*(OD630) (1)

Chlorophyll *b* (mg/L) = 21.03*(OD647) – 5.43*(OD664) – 2.66*(OD630) (2)

Chlorophyll *c* (mg/L) = 24.52*(OD630) – 7.60*(OD647) – 1.67*(OD664) (3)

Chlorophyll *x*, mg/m^3 = (Chl *x*) * extract volume, L/ Volume of sample, m^3 (4)

Chapter 8: Stand Alone Pumps

Introduction

We collected water column material using Stand Alone Pumps (SAPs) for biogenic silica, major/minor elements, and organic matter, to quantify the particulates released in freshwaters from West Greenland and to compare them to particulates from an open ocean comparison site (Orphan Knoll).

Summary of SAPS events

TABLE 24: TABLE OF SAPS SAMPLING EVENTS DURING CRUISE DY081 (OVER THE PAGE).

Sampling protocol

Nylon pre-filter meshes were acid cleaned and GFF filters were ashed prior to the cruise, and wrapped in ashed foil. GFF and Supor filters were cleanly fitted into the cleaned pancake filters (one per filter) and attached to the SAPS.

The SAPS were deployed (see Chapter 5) and pumped for 1.5 hours. When retrieved, total volume pumped is recorded and the pancake filters removed and allowed to drain under cool conditions. GFF filters were removed cleanly in a fume hood and split in two, labelled and photographed, folded in two and wrapped in pre-ashed, clean foil, and flash frozen directly at -80 ˚C and then stored at -20 ˚C. The Supor filters were removed cleanly in a laminar flow hood, divided into three pieces, which are photographed and labelled, folded in half and placed in a clean bag, and flash frozen at -80 and moved to -20 for storage. Nylon mesh filters were frozen for storage, or acid washed and reused. Blanks were taken by installing and removing both types of filters into the pancake housings under the conditions in the laboratory.

Site	Station No	Gear No	JDay (Start)	Depth (m)	Filter type	Pump time (mins)	Pumping vol (L)	ID	Comments
Orphan Knoll	2	SAP001	188	2400	GFF	90	1212	CHLOE	
Orphan Knoll	2	SAP001	188	2400	Supor	47?	338	SANDIE	
Orphan Knoll	2	SAP001	188	200	GFF	90	1170	POLLY	
Orphan Knoll	2	SAP001	188	200	Supor	90?	604	MINNIE	Smaller pumping volume may be partly due to shorter battery life
Nuuk	20	SAP002	199	630	GFF	90	1074	CHLOE	
Nuuk	20	SAP002	199	630	Supor	90	679	SANDIE	
Nuuk	20	SAP002	199	100	GFF	90	1015	POLLY	
Nuuk	20	SAP002	199	100	Supor	90	8	MINNIE	Filter housing was full of water that was reluctant to drain when opened
Nuuk	35	SAP003	202	450	GFF	90	1228	CHLOE	
Nuuk	35	SAP003	202	450	Supor	90	723	SANDIE	
Nuuk	35	SAP003	202	250	GFF	90	14	MINNIE	MINNIE still pumping small volume, later to find faulty pump parts
Nuuk	35	SAP003	202	250	Supor	90	593	POLLY	
Nuuk	41	SAP004	205	400	GFF	90	1139	CHLOE	
Nuuk	41	SAP004	205	165	Supor	90	557	SANDIE	Supor filter not cut during sampling
Nuuk	41	SAP004	205	100	GFF	90	238	MINNIE	Spiral plate installed upside down
SGreen	48	SAP005	208	350	GFF	90	990	CHLOE	
SGreen	48	SAP005	208	350	Supor	90	636	SANDIE	
SGreen	48	SAP005	208	100	GFF	90	513	POLLY	
SGreen	48	SAP005	208	100	Supor	90	816	MINNIE	
SGreen	60	SAP006	212	500	GFF	90	13	CHLOE	Filter torn
SGreen	60	SAP006	212	500	Supor	90	723	SANDIE	
SGreen	60	SAP006	212	150	Supor	90	673	POLLY	
SGreen	60	SAP006	212	150	GFF	90	1110	MINNIE	Small tear in filter

Table 24

Chapter 9: Sediment sampling

Introduction

Sediment sampling was carried out on DY081, to assess the role of sediment-water interactions in biogeochemical cycling in the Labrador Sea, and for complementary palaeoceanographic and proxy calibration projects. Sediment-water interactions were characterised using porefluid profiling and core incubations.

Coring strategy and sample collection

The DY081 sediment coring strategy was designed to obtain core top sediments and long sediment cores from multiple locations at each of the three main stations: Orphan Knoll, Nuuk and Southwest Greenland. Specifically, at Orphan Knoll we selected core sites likely to be influenced by Proto-North Atlantic Deep Water and outflow from the Hudson Strait as a component of Labrador Sea Waters (LSW). At Nuuk, we targeted sediments locally influenced by the outflow of shallow subglacial meltwater and particulates, in addition to sediments located at the bottom of the continental shelf and influenced by the ambient water masses. Finally, at Southwest Greenland our sampling strategy was targeted at obtaining sediments influenced by the surficial flow of the East Greenland Current (bringing cold and freshwater from the Arctic Ocean), Iceland-Scotland Overflow Water (ISOW) and recirculated LSW.

Sample Collection

Sediment samples to fulfill DY081 objectives were collected using three different techniques which were applied at each of the study sites according to the specific site objectives. Where possible sediments were sampled such that undisturbed coretop samples can be matched with Niskin, CTD, and SAPS data and water samples. Ideally, sediment and porewater data can be paired with data from the overlying water column to provide insights into processes occurring at the sediment-water interface. Undisturbed coretop samples were captured using both an 8 round megacore rig and push cores taken using the ROV Isis's arms.

At Orphan Knoll and Southwest Greenland an additional objective was to obtain long, continuous sediment cores that will be useful for paleoceanographic reconstructions. Long-core sampling was performed using a gravity core rig. After recovery, sediment captured by the gravity core barrel were extruded and cut into 1.5m sections following standard protocol.

Sediment samples and subsamples were named following the conventions outlined elsewhere in this report. Gear identifiers are MGA, PSH and GVY for megacores, push cores and gravity cores respectively. Sub-samples are labeled with the cruise name, station number, gear name and number, event number and sediment interval. An example of a complete identifier for the first gravity core of the cruise would be as follows: DY081_004_GVY001_EV01_0-1cm.

Megacoring

Sediments successfully retrieved using the megacore were sliced and preserved in plastic bags for future sampling and study. The sampling resolution was determined on the basis of the designated recipient and planned use of the sediment. Successful MCH tubes designated for porefluid sampling were first relieved of coretop water and then subsequently Rhizons were inserted every 2cm down core to extract the porefluids. To increase the efficacy

of porefluid removal, 50 mL syringes were attached to the Rhizons and a vacuum was created inside the syringes by locking them 'open' using wooden blocks[4].

Each of the megacores deployed on DY081 had one tube of mud selected for core incubation. Additional information about core incubations can be found in the water sampling chapter of this report.

In addition to capturing sediment, the megacore rig also deployed a 10-L Niskin bottle to capture water samples from just above the sea floor. Details on the sub-sampling and analysis of this water can be found in the water sampling chapter of this report.

Push Coring

To obtain a larger number of coretop samples, the ROV Isis was outfitted with up to 12 cylinders to retrieve small sediment cores (see Chapter 5; Figure 48). To obtain the maximum amount of coretop material at a given location, these push cores were often taken in triplicate. Replicates were also commonly taken in locations where push cores with porefluid holes were deployed, retrieve both sediments for porefluid extraction and traditional analyses. Depending on the success of retrieval - and whether or not porefluids were obtained from the cores - push cores were sub sampled at up to 1 cm resolution. All samples were subsequently stored under refrigerated conditions.

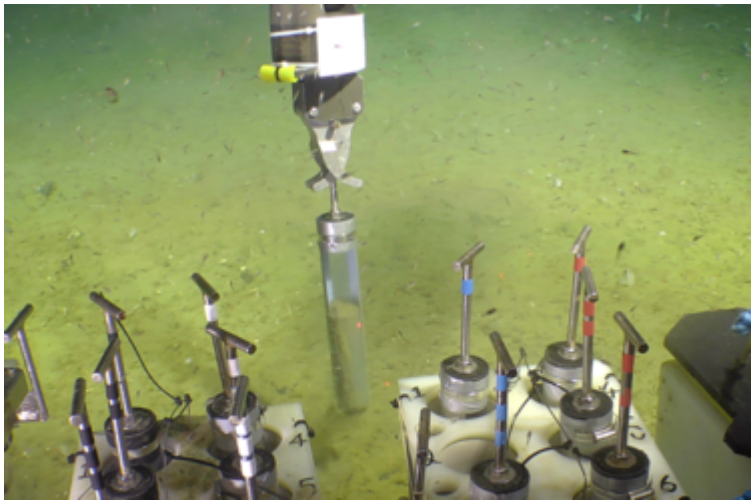


FIGURE 48: PUSH CORING FROM THE ROV.

Gravity Coring

Gravity cores were deployed at Orphan Knoll and SW Greenland to obtain long sediment sequences for paleoceanographic analysis. Successful cores were cut into 1.5 m sections and labeled alphabetically in order of extrusion from the core barrel. Subsequently core sections were re-labeled such that older sediments are in successively higher numbered tubes. Core sections were split onboard using a specially designed router and cradle provided by Veit Huhnebach of NOC. The core liner was first routed on one side and then rotated 180 degrees and routed a second time. The core was then lifted from the cradle and a monofilament line was passed lengthwise between the two cuts to separate the core into two halves. One of the halves was designated to be the archive half of the core and the other the working half. Both sides of the core were then cleaned/leveled using glass slides, photographed, and the archive half described. Sub sampling was then carried out on the working half.

[4] Information on megacore and push core porefluid sampling, storage and analyses can be found in the water sampling sections.

Sediment Recovery

Site Summaries

Coring operations on DY081 recovered 5 gravity cores, 52 megacore barrels and 89 push core samples for a total of more than 52 m of sediment. The breakdown of sediment retrieval by site and coring technique is presented in Table 25 and Figure 49. ROV push cores are not depicted in map view because of the high density of cores taken at each of the three locations. Further details about the distribution of cores within water masses can be found below in the sections on core recovery at each site.

TABLE 25: SUMMARY OF CORING SITES AT EACH LOCATION.

Site Name	Lat. Range (DDS)	Long. Range (DDS)	# Gravity Cores	Gravity Core Sediment (m)	# Mega cores	Megacore Sediment (m)	# Push cores	Push core Sediment (m)
Orphan Knoll	(50.05)-(50.57)	(-46.28)-(-45.10)	2	9.64	12	4.26	33	6.14
Nuuk	(63.33)-(63.87)	(-53.77)-(-52.23)	0	0	16	6.05	34	5.46
SW Greenland	(58.61)-(60.26)	(-46.89)-(-43.58)	3	9.23	24	7.06	22	4.41
Totals			5	18.87	52	17.37	89	16.01

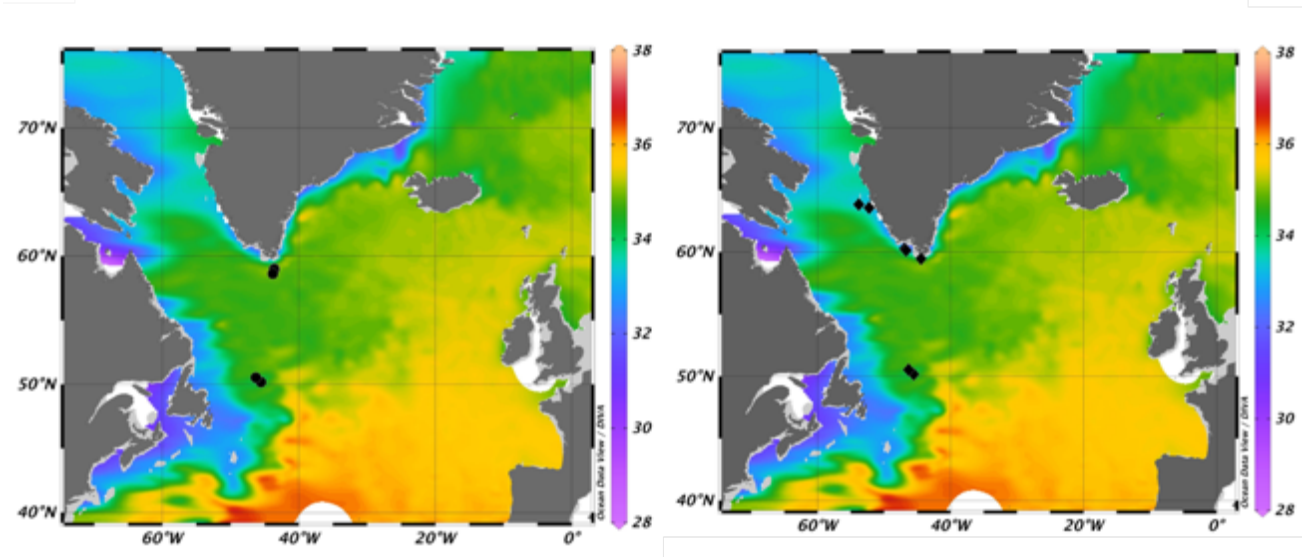


FIGURE 49: MAPS OF GRAVITY CORE (DOTS) AND MEGACORE (DIAMONDS) LOCATIONS ON A BASEMAP OF PSS-78 SALINITY AT 50 M WATER DEPTH FROM THE GLODAP V2 DATABASE. MAPS GENERATED USING OCEAN DATA VIEW.

Orphan Knoll

Coring operations at Orphan Knoll targeted sediment between 3,721 and 1,628 m water depth (Figure 50). MGA 002 and GVY002 at 1,770 m may have sampled sediments bathed by the upper limb of the deep Labrador Current as indicated by the oxygen minima in the figure below. The bathyal distribution of all sediment cores from Orphan Knoll are also depicted in the figure below, illustrating the good coretop coverage provided by push core samples between depths of 1,682 and 2656 m.

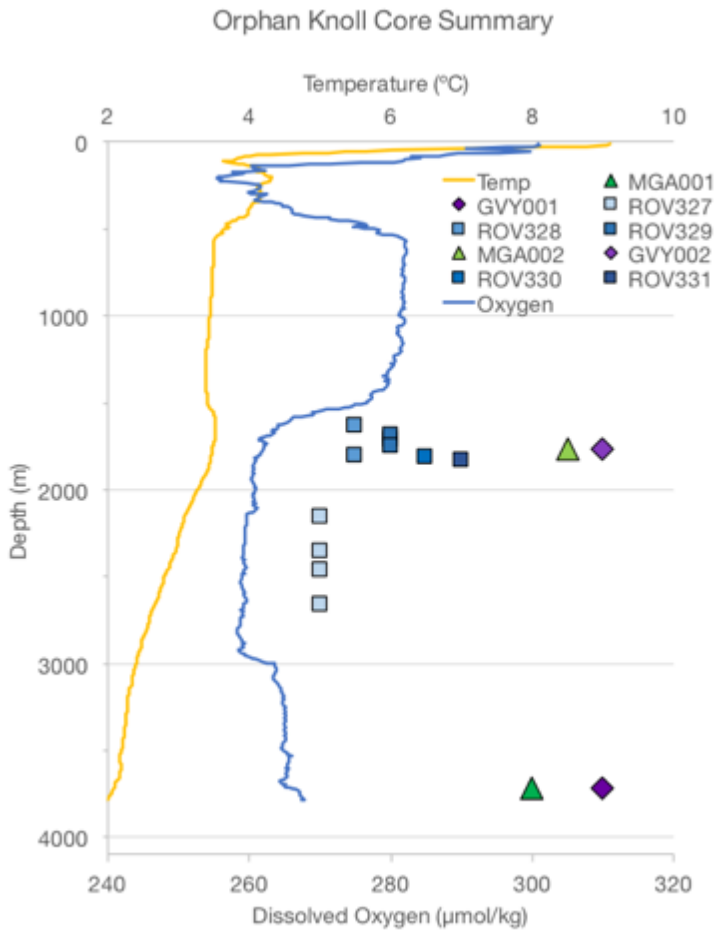


FIGURE 50: DEPTH DISTRIBUTION OF SEDIMENT CORES FROM ORPHAN KNOLL. OVERLAY IS LOCAL CTD DATA REFLECTING WATER TEMPERATURES AND DISSOLVED OXYGEN CONCENTRATIONS.

Nuuk

Coring operations at Nuuk targeted the sediments that layer the continental shelf and slope between 1,326 and 349 m water depth. Because of the strong gradients in temperature and salinity that result from the site's proximity to conduits for glacial meltwater, sampling at Nuuk sites was more spatially distributed than at other DY081 sites where watermasses were targeted by varying the depth of coring efforts. The spatial heterogeneity of watermasses at Nuuk is well illustrated in Figure 51, which depicts coring locations in relation to CTD profiles of water temperature. Cores at Nuuk include sediments bathed by both the flow of ambient waters in the trough surrounding Greenland as well as those influenced by fresh, cold water sourced from glacial melt.

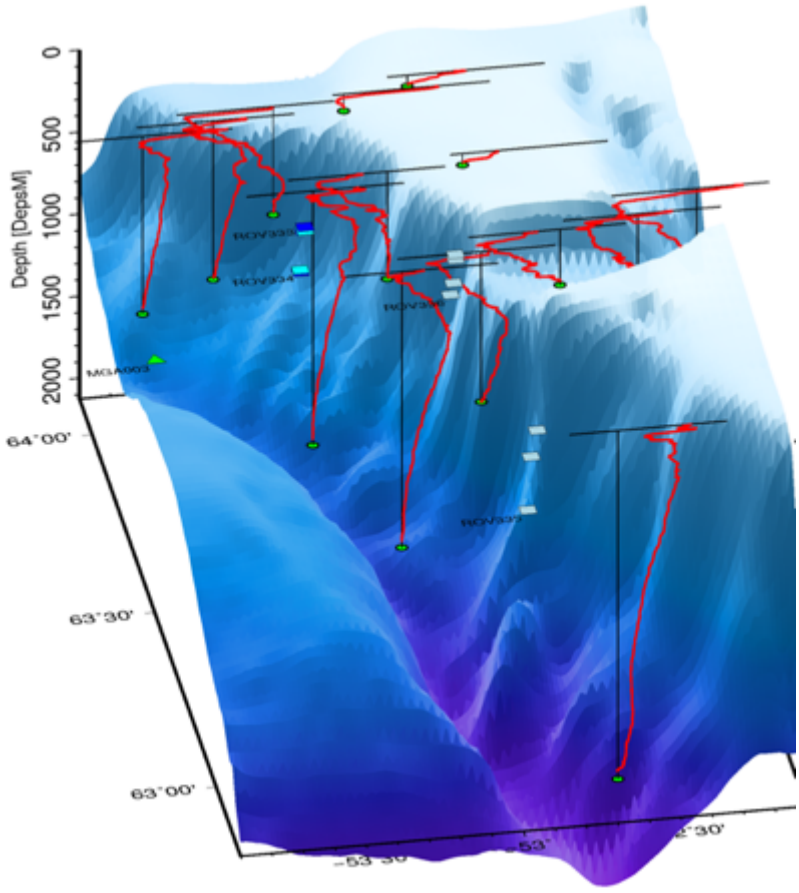


FIGURE 51: BOTTOM BATHYMETRY OF NUUK SAMPLING SITES WITH CTD TEMPERATURE PROFILES IN RED, GREEN TRIANGLES = MGA (EXCEPT 04), BLUE SQUARES = ROV PUSH CORE SITES (SAME COLOUR = SAME DIVE).

SW Greenland

Coring operations at SW Greenland sites (Cape Farewell and Erik Drift) targeted sediment between 1,907 and 532 m water depth. Although the deep CTD profile taken at 59.21˚N, -44.58˚W does not show easily identifiable water mass structure in temperature space (Figure 52), the dissolved oxygen measurement does suggest that at least two different water masses may bathe the core depths sampled. We hypothesize that between 500 and 1,000 m waters are representative of recirculated Labrador Sea water as it flows southwards along the eastern coast of Greenland. Below ~1,500m waters may be representative of a greater proportion of Iceland Scotland Overflow Water (ISOW) and it is possible that the deepest core at 1,907m may be influenced by a mixture of water masses that include Denmark Strait Overflow Water and ISOW. Further analysis of DY081 CTD data and Niskin samples will be necessary to confirm these tentative water mass designations. If our hypothesis proves correct, sediment cores from SW Greenland beautifully capture the deep-water masses present at the southern tip of Greenland.

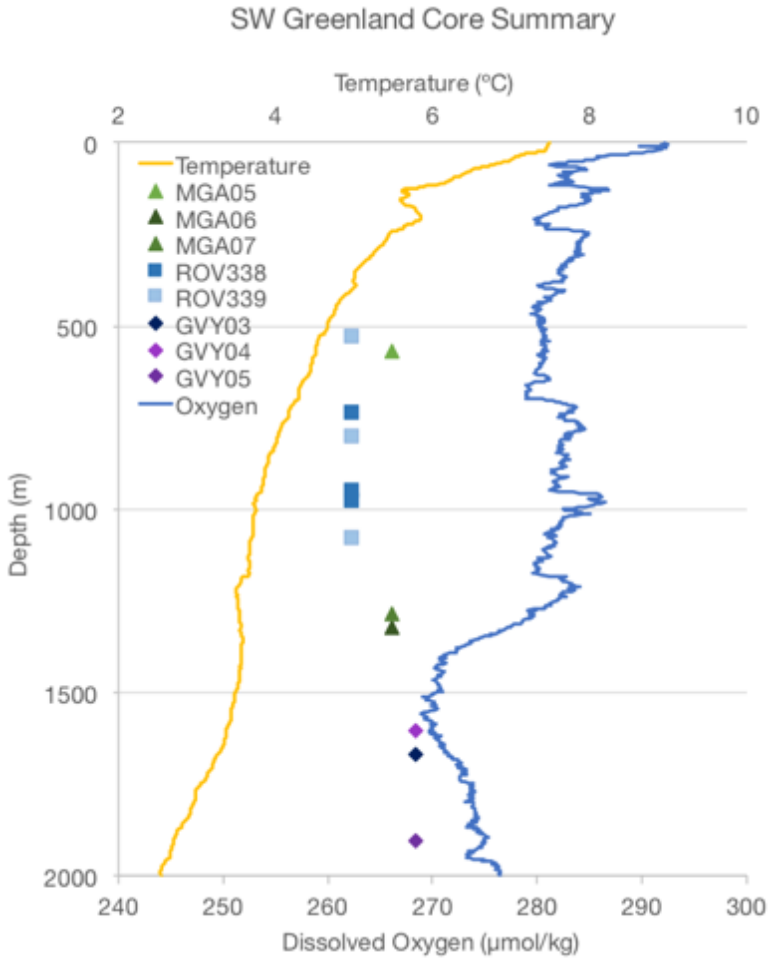


FIGURE 52: DEPTH DISTRIBUTION OF SEDIMENT CORES FROM SOUTHWEST GREENLAND. OVERLAY IS LOCAL CTD DATA REFLECTING WATER TEMPERATURES AND DISSOLVED OXYGEN CONCENTRATIONS.

Shipboard Analyses

Upon retrieval each sediment core was entered into the sediment database and its length recorded. Cores were photographed with their cruise identifier and a ruler for scale. Subsequently a description was made of the core to denote its major characteristics. Features noted included color, grain size, mineralogy, foraminifera abundance, sedimentary matrix, cohesiveness, water content/porosity, smell, and the presence, abundance and size of anomalous clasts (often ice rafted debris). Core descriptions were done by hand, scanned and grouped by event number for ease of access.

Sediment Sub-sampling

Significant effort was made on board to sub-sample sediment cores so that they could easily be distributed to labs for analysis. A complete accounting of the nature of each of these sub samples is beyond the scope of this report but is readily available online. A summary of subsamples taken can be found in the tables below where they are grouped by gear type in chronological order.

TABLE 26: SUMMARY OF SUBSAMPLES FROM ORPHAN KNOLL.

Station	Gear	Event	Water Depth (m)	Lat (DDS)	Long (DDS)	Date	Max length (cm)	# Sub samples
003	MGA001	002	3721	50.16	-45.51	8/7/17	23.5	0
003	MGA001	003	3721	50.16	-45.51	8/7/17	39.5	37
003	MGA001	004	3721	50.16	-45.51	8/7/17	37.3	14
003	MGA001	005	3721	50.16	-45.51	8/7/17	40.5	46
003	MGA001	006	3721	50.16	-45.51	8/7/17	36.5	10
003	MGA001	007	3721	50.16	-45.51	8/7/17	31.5	14
003	MGA001	008	3721	50.16	-45.51	8/7/17	38.5	34
003	MGA001	009	3721	50.16	-45.51	8/7/17	40	0
004	GVY001	001	3721	50.16	-45.51	8/7/17	514	620
005	ROV327	021	2344	50.05	-45.37	8/7/17	17	13
005	ROV327	022	2348	50.05	-45.37	8/7/17	?	1
005	ROV327	023	2349	50.05	-45.37	8/7/17	19	19
005	ROV327	047	2656	50.06	-45.36	9/7/17	13.5	7
005	ROV327	048	2656	50.06	-45.36	9/7/17	17	13
005	ROV327	049	2656	50.06	-45.36	9/7/17	25	20
005	ROV327	054	2458	50.07	-45.35	9/7/17	27	26
005	ROV327	055	2457	50.07	-45.35	9/7/17	21	21
005	ROV327	056	2447	50.07	-45.35	9/7/17	22	22
005	ROV327	067	2152	50.08	-45.36	9/7/17	18	13
005	ROV327	068	2152	50.08	-45.36	9/7/17	18	9
005	ROV327	069	2152	50.08	-45.36	9/7/17	20.5	22
007	ROV328	004	1800	50.55	-46.19	10/7/17	18.5	15
007	ROV328	005	1800	50.55	-46.19	10/7/17	29.5	24
007	ROV328	021	1628	50.55	-46.20	10/7/17	19	14
007	ROV328	022	1628	50.55	-46.20	10/7/17	13	1
007	ROV328	023	1628	50.56	-46.20	10/7/17	24	1
007	ROV328	024	1628	50.56	-46.20	10/7/17	17	1
008	ROV329	020	1745	50.55	-46.19	11/7/17	24	1
008	ROV329	021	1745	50.55	-46.19	11/7/17	11	11
008	ROV329	040	1682	50.56	-46.19	11/7/17	24.5	1
008	ROV329	041	1682	50.56	-46.19	11/7/17	27.5	27
008	ROV329	052	1711	50.57	-46.18	11/7/17	19	19
008	ROV329	053	1711	50.57	-46.18	11/7/17	26.5	1
009	MGA002	002	1770	50.52	-46.28	11/7/17	38	0
009	MGA002	003	1770	50.52	-46.28	11/7/17	28	1
009	MGA002	004	1770	50.52	-46.28	11/7/17	35.5	40
009	MGA002	005	1770	50.52	-46.28	11/7/17	37.5	40
010	GVY002	001	1770	50.52	-46.28	11/7/17	450	535
011	ROV330	001	1808	50.55	-46.19	12/7/17	17	17
011	ROV330	002	1808	50.55	-46.19	12/7/17	10	2

011	ROV330	003	1808	50.55	-46.19	12/7/17	15	4
011	ROV330	004	1808	50.55	-46.19	12/7/17	16	16
011	ROV330	005	1808	50.55	-46.19	12/7/17	8	2
011	ROV330	006	1808	50.55	-46.19	12/7/17	5	1
013	ROV331	001	1827	50.52	-45.10	12/7/17	27	24
013	ROV331	002	1827	50.52	-45.10	12/7/17	27	23
013	ROV331	003	1827	50.52	-45.10	12/7/17	18	4

TABLE 27: SUMMARY OF SUBSAMPLES FROM NUUK.

Station	Gear	Event	Water Depth (m)	Lat (DDS)	Long (DDS)	Date	Max length (cm)	# Sub samples
018	MGA003	001	1301	63.82	-53.77	17/7/17	37	1
018	MGA003	002	1301	63.82	-53.77	17/7/17	36.5	14
018	MGA003	003	1301	63.82	-53.77	17/7/17	36	10
018	MGA003	004	1301	63.82	-53.77	17/7/17	36	10
018	MGA003	005	1301	63.82	-53.77	17/7/17	38	15
018	MGA003	006	1301	63.82	-53.77	17/7/17	37	64
018	MGA003	007	1301	63.82	-53.77	17/7/17	37	34
018	MGA003	008	1301	63.82	-53.77	17/7/17	38.5	28
031	ROV333	003	953	63.87	-53.29	20/7/17	19.5	16
031	ROV333	004	953	63.87	-53.29	20/7/17	19	16
031	ROV333	005	953	63.87	-53.29	20/7/17	18	16
031	ROV333	046	704	63.87	-53.28	20/7/17	12	10
031	ROV333	047	704	63.87	-53.28	20/7/17	10	9
031	ROV333	048	704	63.87	-53.28	20/7/17	16	14
031	ROV333	053	658	63.86	-53.28	20/7/17	19.5	16
031	ROV333	054	658	63.86	-53.28	20/7/17	14.5	11
031	ROV333	055	658	63.86	-53.28	20/7/17	6	6
034	ROV334	001	940	63.87	-53.29	21/7/17	25	1
034	ROV334	002	940	63.87	-53.29	21/7/17	10	2
034	ROV334	003	940	63.87	-53.29	21/7/17	26	24
034	ROV334	005	683	63.86	-53.28	21/7/17	18	11
034	ROV334	006	683	63.86	-53.28	21/7/17	--	--
034	ROV334	007	683	63.86	-53.28	21/7/17	20	1
036	ROV335	001	1326	63.33	-52.78	22/7/17	11	10
036	ROV335	002	1326	63.33	-52.78	22/7/17	11	1
036	ROV335	003	1326	63.33	-52.78	22/7/17	10	1
036	ROV335	004	1326	63.33	-52.78	22/7/17	12	12
036	ROV335	041	1002	63.33	-52.77	22/7/17	17.5	1
036	ROV335	043	1002	63.33	-52.77	22/7/17	14.5	11
036	ROV335	073	845	63.33	-52.75	23/7/17	8	1
036	ROV335	074	845	63.33	-52.75	23/7/17	13	1
036	ROV335	075	845	63.33	-52.75	23/7/17	8	3
037	ROV336	003	569	63.60	-52.92	23/7/17	21	19

037	ROV336	005	549	63.60	-52.92	23/7/17	21.5	1
037	ROV336	006	569	63.60	-52.92	23/7/17	23	1
037	ROV336	032	497	63.60	-52.91	23/7/17	22.5	19
037	ROV336	033	499	63.60	-52.91	23/7/17	20	17
037	ROV336	034	499	63.60	-52.91	23/7/17	18	1
037	ROV336	035	497	63.60	-52.91	23/7/17	19	1
037	ROV336	042	381	63.61	-52.90	23/7/17	25.5	22
037	ROV336	043	381	63.61	-52.90	23/7/17	20.3	1
037	ROV336	044	349	63.61	-52.90	23/7/17	6	5
037	ROV336	045	349	63.61	-52.90	23/7/17	11	1
042	MGA004	002	519	63.55	-52.23	24/7/17	41	1
042	MGA004	003	519	63.55	-52.23	24/7/17	41	1
042	MGA004	004	519	63.55	-52.23	24/7/17	38	10
042	MGA004	005	519	63.55	-52.23	24/7/17	35	10
042	MGA004	006	519	63.55	-52.23	24/7/17	40	39
042	MGA004	007	519	63.55	-52.23	24/7/17	41	80
042	MGA004	008	519	63.55	-52.23	24/7/17	38	34
042	MGA004	009	519	63.55	-52.23	24/7/17	35	15

TABLE 28: SUMMARY OF SUBSAMPLES FROM SW GREENLAND.

Station	Gear	Event	Water Depth (m)	Lat (DDS)	Long (DDS)	Date	Max length (cm)	# Sub samples
049	MGA005	002	573	60.26	-46.89	27/7/17	38	1
049	MGA005	003	573	60.26	-46.89	27/7/17	37	1
049	MGA005	004	573	60.26	-46.89	27/7/17	36	16
049	MGA005	005	573	60.26	-46.89	27/7/17	39	33
049	MGA005	006	573	60.26	-46.89	27/7/17	37	64
049	MGA005	007	573	60.26	-46.89	27/7/17	34	25
049	MGA005	008	573	60.26	-46.89	27/7/17	36	11
049	MGA005	009	573	60.26	-46.89	27/7/17	32	9
050	ROV338	002	741	60.09	-46.63	28/7/17	20	16
050	ROV338	003	742	60.09	-46.63	28/7/17	23.5	20
050	ROV338	004	742	60.09	-46.63	28/7/17	20	1
050	ROV338	005	742	60.09	-46.63	28/7/17	18	1
050	ROV338	022	957	60.09	-46.64	28/7/17	12	9
050	ROV338	023	957	60.09	-46.64	28/7/17	10	1
050	ROV338	056	983	60.08	-46.64	28/7/17	24	20
050	ROV338	057	983	60.08	-46.64	28/7/17	24	20
050	ROV338	058	983	60.08	-46.64	28/7/17	22	1
050	ROV338	059	983	60.08	-46.64	28/7/17	26	1
051	MGA006	002	1326	60.12	-46.66	28/7/17	38	1
051	ROV339	002	1085	59.93	-46.50	28/7/17	26	19
051	MGA006	003	1326	60.12	-46.66	28/7/17	41	1
051	MGA006	004	1326	60.12	-46.66	28/7/17	37	10

051	MGA006	005	1326	60.12	-46.66	28/7/17	39	11
051	MGA006	006	1326	60.12	-46.66	28/7/17	42	70
051	MGA006	007	1326	60.12	-46.66	28/7/17	35	25
051	MGA006	008	1326	60.12	-46.66	28/7/17	38	17
051	MGA006	009	1326	60.12	-46.66	28/7/17	37	32
052	ROV339	003	1085	59.93	-46.50	29/7/17	24	1
052	ROV339	004	1085	59.93	-46.50	29/7/17	22.5	1
052	ROV339	005	1085	59.93	-46.50	29/7/17	25	21
052	ROV339	035	807	59.93	-46.50	29/7/17	17	15
052	ROV339	036	807	59.93	-46.50	29/7/17	18.5	15
052	ROV339	037	807	59.93	-46.50	29/7/17	23	1
052	ROV339	038	807	59.93	-46.50	29/7/17	20	1
052	ROV339	039	532	59.94	-46.51	29/7/17	14	12
052	ROV339	040	532	59.94	-46.51	29/7/17	21.5	1
052	ROV339	041	532	59.94	-46.51	29/7/17	12	1
052	ROV339	042	532	59.94	-46.51	29/7/17	18.5	16
057	MGA007	002	1286	59.46	-44.42	30/7/17	15	1
057	MGA007	003	1286	59.46	-44.42	30/7/17	16	1
057	MGA007	004	1286	59.46	-44.42	30/7/17	15	14
057	MGA007	005	1286	59.46	-44.42	30/7/17	13	13
057	MGA007	006	1286	59.46	-44.42	30/7/17	14	13
057	MGA007	007	1286	59.46	-44.42	30/7/17	14.5	12
057	MGA007	008	1286	59.46	-44.42	30/7/17	10	10
057	MGA007	009	1286	59.46	-44.42	30/7/17	13	10
061	GVY003	001	1669	59.00	-43.58	31/7/17	480	570
062	GVY004	001	1608	58.94	-43.60	31/7/17	81.5	100
063	GVY005	001	1907	58.61	-43.78	31/7/17	362	437

Coretop samples from megacores and push cores will be stored at The University of Bristol and gravity core samples will be stored at the British Ocean Sediment COre Research Facility (BOSCORF).

Chapter 10: Biological sampling

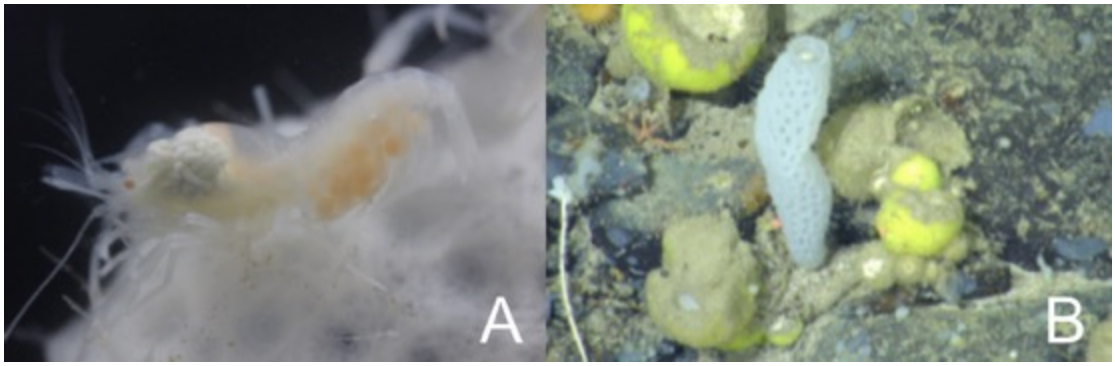


FIGURE 53: GHOST SHRIMP FOUND LIVING INSIDE EUPLECTELLA SPONGE.

Introduction

Remotely Operated Vehicle operations were the primary tool for biological collections on DY081. Every time a sample was collected it was recorded as an event in the sample event log and notes were taken about the time, depth, latitude, longitude, physical description (colour, size etc.), and any *in situ* photos taken of the specimen. Once on deck samples were carried in pre-chilled seawater into the cold room (4 °C) to commence sampling triage. Each container on the ROV (tray area, net, biotubes, and bioboxes) that contained specimens was given a unique number – this was the parent number to every specimen within the container. Each specimen itself was then given a unique number, its "parent number" noted alongside its event number, a general taxonomic description, any further comments and details of any subsample taken e.g. for genetics work, drying for isotopic research, etc. Most specimens were sub-sampled for genetic analysis (preserved in 95% ethanol), the remainder of the specimen was preserved in either 100% ethanol or in a -20°C freezer (with some special considerations for sponge collections, explained below). Before sub-sampling each specimen had a scaled picture taken.

There were 1117 lots of specimens collected totalling 1551 specimens across 10 Phyla (Figure 55).

FIGURE 54: ACESTA SP. CLAMS BEING COLLECTED.

Of these collections, several will form key parts of future population genomic analyses. This includes members of the Ophiuroidea, *Psolus* sp., *Acesta* sp. (Figure 54), *Lophelia pertusa*, *Solenosmilia* sp., and *Anthomastus*.

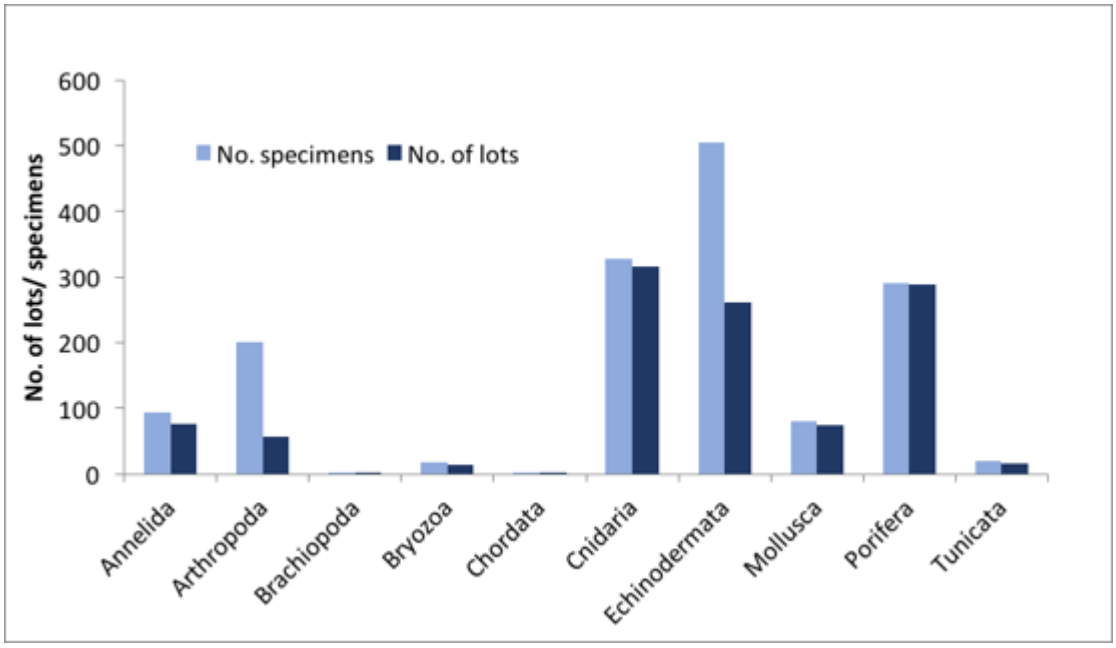


FIGURE 55: BREAKDOWN OF PHYLA FROM DY081. NOTE 'CHORDATA' WERE EMPTY SHARK EGG CASES AND ONE UNFORTUNATE HAGFISH SAMPLES IN A MEGACORE.

Corals

After the discovery of *Lophelia* off Greenland in 2011 (Tendal et al., 2013; Kenchington et al, 2017) it is unsurprising that assessment of these reefs was one of the biological aims of DY081. In total there were 315 Cnidaria collected. Scleractinia were targeted for undergoing population genomic, phylogenomic and geochemical research (see Chapter 11).

Although only 104 were collected there were a wider variety of Octocorallia, as seen in Figure 56. These specimens will form part of phylogenomic research that is currently underway.

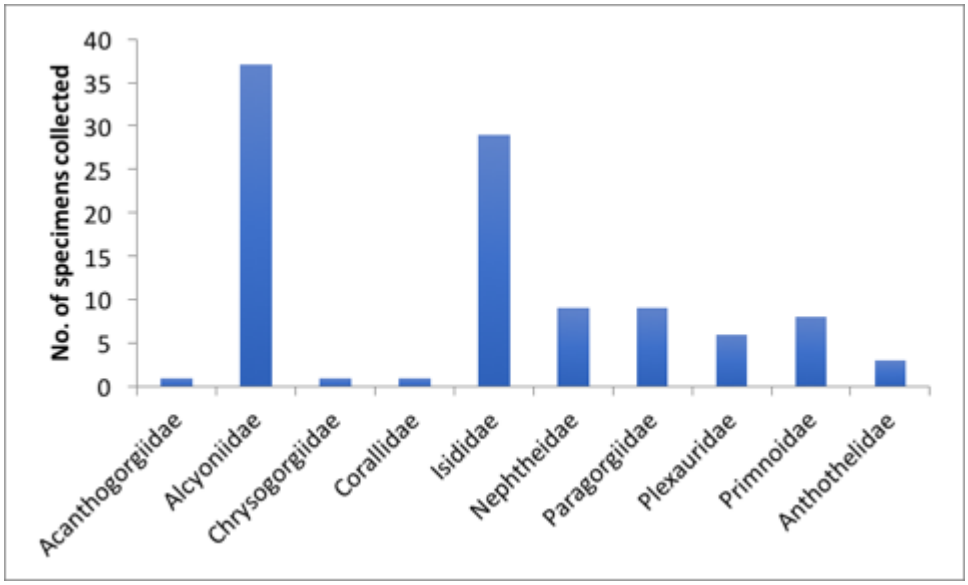


FIGURE 56: BREAKDOWN OF MAJOR OCTOCORALLIA GROUPS COLLECTED ON DY081.

For further details about biological collections please contact Dr Michelle Taylor: michelle.taylor@zoo.ox.ac.uk.

FIGURE 57: ISIDIDAE CORAL FOUND ON ORPHAN KNOLL.

Sponges

Sponge communities at Orphan knoll were characterised by *Geodia* sponge grounds (Figure 58) with hexactinellid-dominated communities in the deeper areas (Figure 59). At the Greenland sites communities seemed to have more diverse demosponge communities and large numbers of encrusting species (Figure 60).

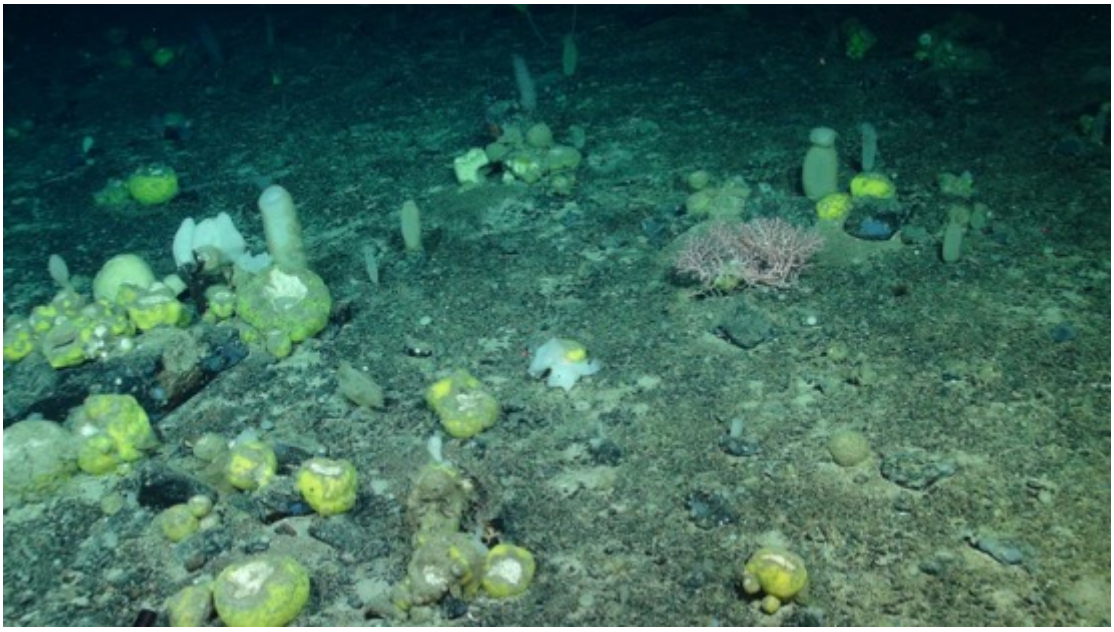


FIGURE 58: GEODIA DOMINATED SPONGE COMMUNITIES AT ORPHAN KNOLL, ROV327, DEPTH 2666M.

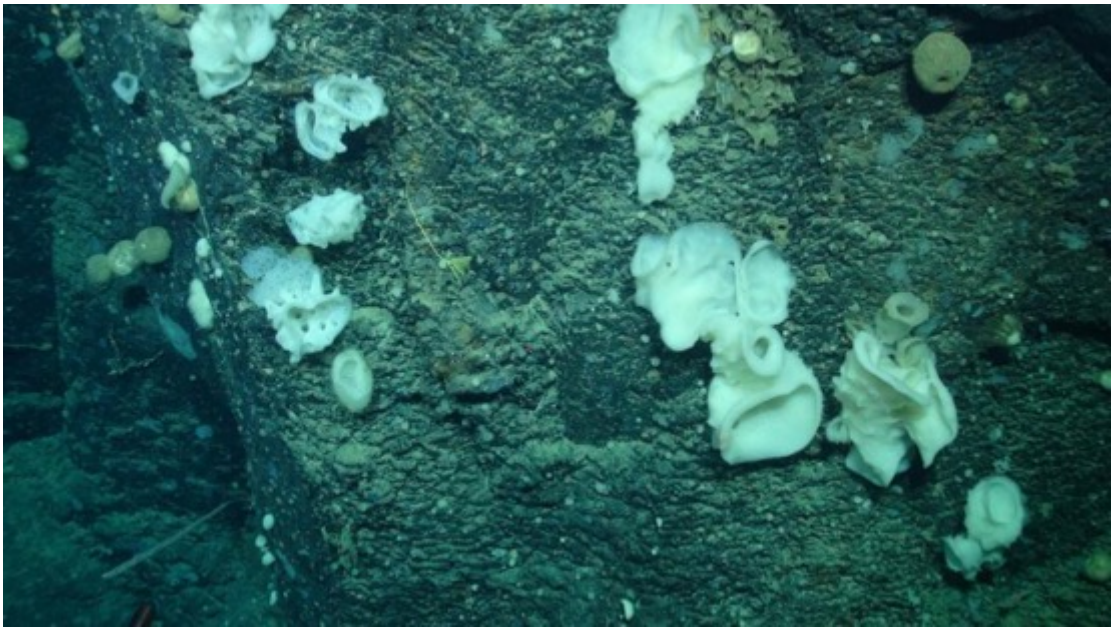


FIGURE 59: HEXACTINELLID DOMINATED COMMUNITY AT 3440M, (ROV 327).

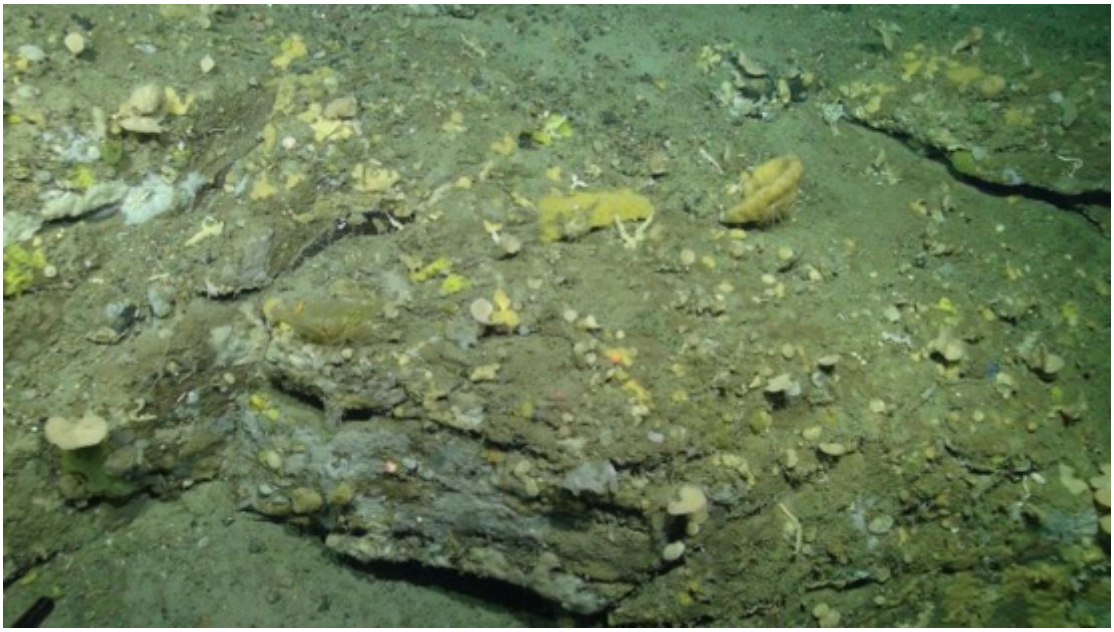


FIGURE 60: SPONGE COMMUNITIES ON BEDROCK, GREENLAND, (ROV 339).

In total 291 specimens of sponges were collected. Specimens that were large enough were subsampled as following:

1) Genetic sample for taxonomy (95% ethanol)
2) Genetic sample for population genomics (95% ethanol)
3) Dry sample for silicon isotope work
4) -80 frozen sample for study of bacterial communities
5) Remainder preserved in 95% ethanol or frozen for taxonomic work.

A few specimens were frozen intact for study of their structure and samples of specimens from *Geodia* populations from Orphan Knoll were frozen for metabolomic work (to be carried out by Dr Paco Cardenas, Uppsala University, as part of the separate SponGES project. Taxonomic work on the communities and study of sponge structure will be undertaken as part of a PhD studentship at the University of Bristol (commencing autumn 2017). Information collected on ROV dives on sponge communities will be used by Department of Fisheries and Oceans Canada to ground-truth species distribution prediction models.

Further information on sponges collected can be obtained from Dr Claire Goodwin claire.goodwin@huntsmanmarine.ca.

Chapter 11: Scleractinian corals

Live and fossil scleractinian corals were collected from Orphan Knoll, Nuuk and South Greenland. Corals will be analysed as a collaborative project to examine (paleo)biogeography, controls of deep-sea coral populations. Samples of suitable ages will be used for paleoclimate studies of the past history of the oceans.

Sampling Protocol

Samples were collected using the ROV using the manipulator arms, the slurp gun or through using a net. The samples were brought on deck and into the cold room where they were categorised using Biology Specimen numbers (see Chapter 10). After sampling for genetic materials samples were cleaned and dried. Live specimens were bleached, rinsed and dried to remove tissue. Dead specimens were rinsed in seawater then freshwater then air dried. Samples were then catalogued and packed using biology specimen numbers and sub-divisions (a, b etc.) where multiple samples were recovered under one ID (e.g. from nets).

Sampling Locations

Orphan Knoll

Samples were recovered on dives 327, 328, 329, 330 and 331. Live solitary corals ranged in depth from 2638m to 1573m. Dead solitary corals were recovered from 1826m to 1581m. Dead corals were typically coated in thick black ferromangnese crusts, unless they were recovered from under the sediment. Many specimens were bored by endolithic organisms. Collections using nets proved particularly effective at collecting fossil coral debris found at the base of vertical features (Figure 61).

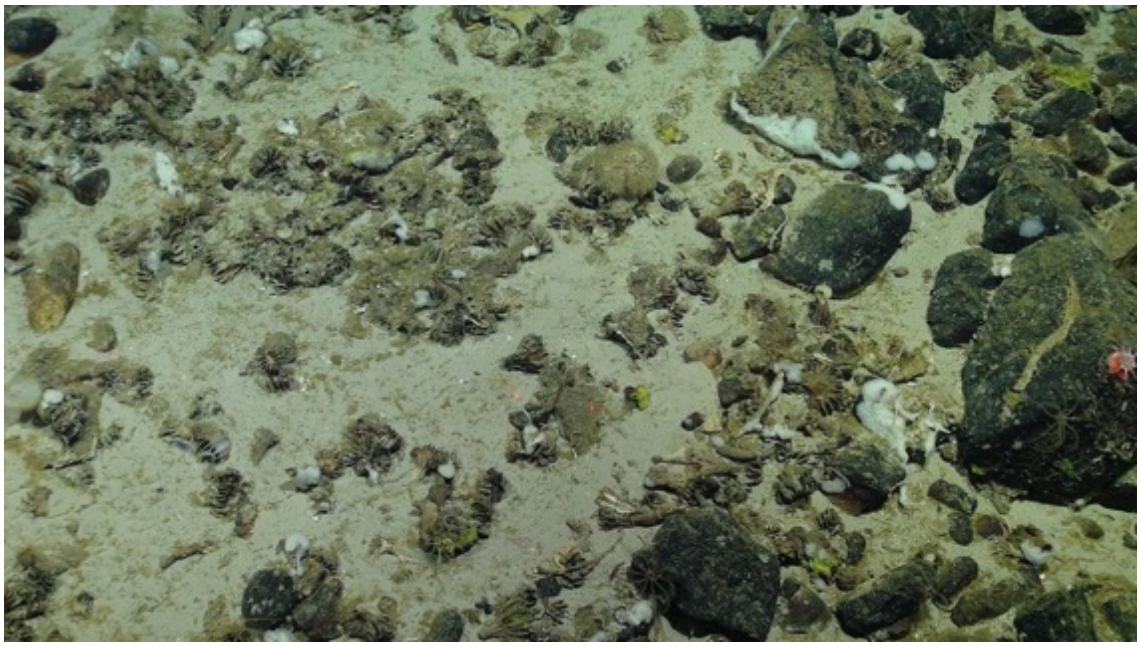


FIGURE 61: FOSSIL D. DIANTHUS IN THE SEDIMENT AT THE BASE OF SMALL VERTICAL WALL ON ORPHAN KNOLL. LASERS SEPARATED BY 10CM.

Nuuk

Samples were recovered on dives 333 and 334. Live solitary corals ranged in depth from 1216m-943m. Dead solitary corals were recovered from 1171m-1107m. Live colonial corals ranged in depth from 1144-752m. Dead colonial corals were recovered from 1231-761m. Dead corals ranged from a dark brownish colour to very pale with little evidence of boring or heavy ferromanganese encrustation (Figure 62)

FIGURE 62: DARK BROWN COLONIAL DEAD CORALS FROM OFF SHORE NUUK. SCALE BAR IN CM DIVISIONS.

South Greenland

Samples were recovered on dives 338 and 339. Live solitary corals ranged in depth from 1084-794m. Dead colonial corals were recovered from 934m. Dead corals were brownish, with little evidence of boring or heavy ferromanganese encrustation.

Chapter 13: Microplastics sampling

Introduction

Microplastics (fibres) have been observed in open ocean deep sea sediments. However, the distribution and fluxes in different parts of the ocean are not well known. We collected sediments from DY081 to test whether microplastics are also accumulating in the Labrador Sea. The cruise locations allowed for sampling sediments from Orphan Knoll, and from Greenland close to Nuuk and further south. Marine litter would have been collected by the ROV if possible, but such litter was rare and could not be collected, e.g. large fishing net, an object that appeared to be a tyre completely colonised by sponges.

Summary of samples

Nine cores were dedicated to microplastics work, including 6 megacores and 3 push cores (Table 30, over the page). The samples were distributed across the three main working sites with three each from Orphan Knoll (3721-2152m), Nuuk (1301-519m) and southwest Greenland (1326-573m).

Sample acquisition

Sediments for microplastics were either collected by megacore or by push core. Drilled cores were not selected for microplastic work. For megacores a piece of cotton was placed over the cores before the rubber bung was plaved on the core tube. Samples were stored and covered under cold conditions, until they could be subsampled.

Sample Processing

Whole sediment cores were taken to be processed in the ‘sealed lab’. The sealed lab is a small lab which was closed to other purposes and only entered by trained personnel. It was cleaned thoroughly using filtered water at the beginning of the expedition, and before every sampling activity. The air inlet was covered with cotton to filter out plastic fibres. Where possible plastics were removed from the laboratory, and any plastics in the room were thoroughly washed before entry. Samplers donned protective gear (cotton boiler suit) and then standard core slicing procedures were followed using an all metal device for slicing the core. No gloves were worn to minimise the possibility of contamination. Damp filter papers were exposed to the laboratory environment during the core slicing process to provide background samples of ambient contamination. All sediment slices were wrapped in aluminium foil, then placed into a cardboard box and removed to a freezer (or fridge for the last samples where freezer space was no longer available). Subsamples and filter controls are summarised in Table 30.

The core will be worked by in collaboration with Dr Lucy Woodall following established procedures for deep sea sediments.

Notes for contamination

Gravity cores were taken using yellow plastic core liners. Opening these cores produced large amounts of yellow plastic shavings. This work was performed on deck and in the main hanger. Cross contamination should be minimised by performing the sampling in the sealed lab. However, fragments of this distinct yellow plastic should be excluded from any future microplastic counts.

TABLE 29: SUMMARY OF SAMPLES AND SUBSAMPLES TAKEN FOR MICROPLASTICS STUDY.

Gear	Event	Water Depth	Lat (Deg)	Long (Deg)	Total Length (cm)	Number of samples	Length of sample (cm)
MGA001	006	3721	50.16	-45.51	36.5	10	2
MGA001	006	na	na	na	na	4 blanks	na
ROV327	47	2656	50.06	-45.36	13.5	7	2
ROV327	47	na	na	na	na	4 blanks	na
ROV327	68	2152	50.08	-45.36	18.5	9	2
ROV327	68	na	na	na	na	4 blanks	na
MGA003	005	1301	63.82	-53.77	38	7	1
MGA003	005	1301	63.82	-53.77	38	8	2
MGA003	005	1301	63.82	-53.77	38	2	5
MGA003	005	na	na	na	na	3 blanks	na
ROV334	005	683	63.86	-53.28	18	8	1
ROV334	005	683	63.86	-53.28	18	3	2
ROV334	005	na	na	na	na	3 blanks	na
MGA004	009	519	63.55	-52.23	35	10	1
MGA004	009	519	63.55	-52.23	35	5	2
MGA004	009	na	na	na	na	3 blanks	na
MGA005	004	573	60.26	-46.89	36	11	1
MGA005	004	573	60.26	-46.89	36	5	2
MGA005	004	na	na	na	na	3 blanks	na
MGA006	008	1326	60.12	-46.66	38	9	1
MGA006	008	1326	60.12	-46.66	38	5	2
MGA006	008	1326	60.12	-46.66	38	2	5
MGA006	008	na	na	na	na	3 blanks	na
MGA007	009	1286	59.46	44.42	13	10	1
MGA007	009	na	na	na	na	3 blanks	na

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