National Oceanography Centre
Cruise Report No. 65
TERIFIC project

26 November – 10 December 2019

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ABSTRACT

The purpose of the fieldwork activities detailed in this report was to deploy a range of autonomous platforms to measure physical oceanographic properties at the west Greenland margin and Labrador Sea. The land-based fieldwork spanned the dates in this report, while the seagoing activities were accomplished with 1 day of work onboard the *Adolf Jensen*, a 30m Greenlandic vessel.

The autonomous platforms used included: two Seagliders (sg602 and sg638) equipped with CTDs, oxygen and biooptics (WETlabs triple puck); an autonomous surface vehicle (Sailbuoy Artemis) measuring surface temperature and salinity, surface wind speed and direction and air temperature, and a wave sensor; 50 standard Global Drifter Program drifters measuring temperature and their position; and 3 drifters measuring surface temperature and salinity sensors and barometric pressure. The drifters were deployed at the continental shelf edge offshore of Qaqortoq, Greenland on December 4. The gliders and autonomous surface vehicle were deployed on the shelf and transited offshore to the central Labrador Sea.

ISSUING ORGANISATION

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Name	*Position*
Eleanor Frajka-Williams	National Oceanography Centre (NOC)
Ilona Goszczko	NOC
Jared Mazlan	National Marine Facilities (NMF)

Table 1.1: Details of science personnel.

Name	*Position*
Louis	Captain, 60north.gl
Karl Kristian Dorph	60north.gl
Mickey	60north.gl
Pauline	60north.gl

Table 1.2: Details of ship's crew.

2 *M/V Adolf Jensen*

The *M/V Adolf Jensen* is a privately owned vessel managed by `60north.gl` (Director: Rasmus Rasmussen, Vice president: Jimmy Hansen). It is a single-hulled vessel with 3 main levels (lower level with science cabins, engines and hold), main level with galley and mess, crew cabins, toilet, shower and corridors for storage as well as a forward section with seating area and additional science cabins and lockers, and 01 deck with the bridge, navigation and captain's quarters and wc. The main working deck was mid-ship: forward of the accommodation block and aft of the forward accommodation. Some deck space was taken up by a hatch to the hold below, and by a winch (we did not use). A crane is available on the bow, over the forward accommodation with some access to the port side, but better access to starboard. Power on the vessel was via 2-pronged European plugs.

Ship info	
Length	30.35 m
Beam	7.01 m
Cruising speed	8.5 kts
Gross tonnage	167
Year built	1967
Complement	3–4 crew and ~9 scientists

Table 2.1: Operating characteristics of the *M/V* Adolf Jensen.

Computing. Eleanor and Ilona brought Macbook pros; Eleanor brought a Galaxy book (table PC) running Windows, and Jared had a windows computer. While on the vessel, we did not use the computers, but in general, the windows machines were needed to communicate with the gliders via Tera Term, and the RBR CTD using provided Windows-only software.

Most connections required a serial connection, which was achieved through serial-to-usb adapters, and further through a USB-to-USB-C adaptor for the Galaxy book.

Positioning. For our ship track and positioning, we used a Garmin etrex 30x with additional sim card. The batteries (2 AA) lasted about 24 hours, though it could've been powered via a mini-USB connection to an external powerbank.

Communications. While on land, we used mobile phones for communication and had wifi internet in the apartments. Jared had roaming on his O2 plan which included Greenland. Eleanor had purchased a Greenland sim card (TUSASS `tusass.gl`, +299 29 52 55). The sim card was locked (pin 2707) but retrieved by calling the TUSASS help number. The call rate was 1.77 dkk per minute and 200 dkk for 250 mb of data.

At sea we had two satellite devices, an Iridium GO modem and an Iridium phone from the MARS group. Iridium GO is a two-way communication device that allows telephone calls and short messages to be sent via an app on a Smartphone. Service was provided by MetOcean, and purchased from RS Aqua. Balance can be checked by calling 2888 from the iridium phone.

- **Iridium GO phone number is 8816XXXXXXXX.**

Free text messages could be sent to the Iridium GO, use `http://messaging.iridium.com` with the address to `8816XXXXXXXX@msg.iridium.com`, to a maximum of 160 characters (body only, no subject). A maximum of 5 messages can be sent in a ten minute period. Any more than 5 are deleted.

Two smartphone apps were required to get full functionality from the Iridium GO: Iridium Go and Iridium mail. Iridium mail requires the creation of an Iridium e-mail account which can be done online prior to the trip: `https://www.iridium.com/mailandweb/`.

3 Itinerary

Depart the main public dock in Qaqortoq at noon on 4 December 2019, and return at 14:00 on 5 December 2019 alongside another vessel in the harbour.

4 Introduction

The TERIFIC (Targeted Experiment to Reconcile Increased Freshwater with Increased Convection) project is an ERC (European Research Council) Starting Grant Fellowship funded through the Horizon 2020 programme by the EU (803140, 2018–2023). It aims to use large numbers of drifters on the shelves of Greenland, and surface and subsurface autonomous vehicles, to characterise the balance of processes controlling convection and restratification. The purpose of this cruise was to deploy the drifters at the southwest Greenland shelf break and the autonomous vehicles to transit from Greenland to the Labrador Sea where they will overwinter.

This cruise is the first of several planned drifter deployments for the TERIFIC project. The project website is `http://terific.org`.

4.1 Scientific background

The ocean Meridional Overturning Circulation (MOC) is responsible for poleward heat transport, and deep storage of heat and carbon. Climate models generally predict that a slowdown of the MOC will occur this century, with dramatic regional and global climate changes, but how the slowdown will occur is subject to debate. It is widely recognised that convection – the downward limb of the MOC – is sensitive to freshwater fluxes, and recent investigations have suggested that the increased melt from the Greenland Ice Sheet has already reduced convection. Yet in 2015, convection returned, and was anomalously strong. Despite the expectation that the MOC is sensitive to freshwater forcing, we do not understand the processes by which freshwater inputs influence the MOC.

The two key gaps in our understanding are: how freshwater reaches the regions of deep convection, and the relative importance of freshwater to convection and restratification. Numerical simulations give conflicting results on freshwater pathways, and convective parameterisations neglect small-scale restratifying processes. Traditional observational approaches cannot capture the spatial and temporal variability of these processes without inordinate cost.

TERIFIC addresses these gaps in understanding through new observations, to characterise how freshwater reaches and affects the regions of deep convection, and enable a critical ground truth of numerical simulations of these processes for climate models.

4.2 Objectives

The first cruise of the TERIFIC project will deploy 2 Seagliders, 1 Sailbuoy, 50 SVP drifters and 3 salinity drifters on the shelf offshore of Qaqortoq, Greenland. This first cruise wlil begin the fieldwork for two work packages of the TERIFIC project, including WP1 on the exchange of freshwater from the Greenland shelf to the open Labrador Sea, and WP2 on the convection and restratification in the Labrador Sea. The cruise track is shown in Fig. 5.1.

4.3 Logistics & Travel

A container was shipped in advance, arriving November 18 to Qaqortoq. Due to some confusion with the shipping company, it was shipped collect, and so Jimmy Hansen (60north) paid the shipping fee upon our arrival (Nov 26), which was repaid by Peters and May. The container contents included:

- 50 drifters, shipped 8 to a cardboard carton (6 cartons) with 2 additional in a smaller carton, each on a pallet.
- 3 NKE drifters, packaged in individual cardboard boxes.
- The Sailbuoy crate
- Two Seaglider boxes
- A large Zarges with Seaglider spares PPE
- A recovery hook and u-shaped stabiliser for the Seaglider
- Three smaller Zarges boxes with PPE and stationery
- Two pallets and a wedge between the Sailbuoy crate and Seaglider boxes

Travel itinerary. During the winter, there was no direct flight to Narsarsuaq from Copenhagen, so we flew via Kangerlussuaq, then took the helicopter from Narsarsuaq to Qaqortoq. The travel itinerary is summarised in Table 4.1.

Date	Time	Date	Time	Transport/Lodging	Carrier	Notes
25 Nov	14:00			Taxi to LHR T2	English Rose	Pick up
25 Nov	18:40		21:25	Flight LHR–CPH	SAS1516	Airbus A320neo
25 Nov	22:00	26 Nov	9:00	Hotel @CPH	Best Western CPH	
26 Nov	10:45		11:30	Flight CPH–SFJ	Air Greenland	Airbus A330-200
26 Nov	12:45		14:30	Flight SFJ–UAK	Air Greenland	Dash 8
26 Nov	15:30		15:55	Helicopter UAK–JJU	Diskoline	Bell212
26 Nov	16:30	10 Dec	07:00	Qaqortoq	60north.gl	Apartment B642
10 Dec	07:20		09:15	Ferry to UAK	Diskoline	
10 Dec	10:30		12:15	Flight UAK–SFJ	Air Greenland 426	Dash 8
10 Dec	13:10		21:30	Flight SFJ–CPH	Air Greenland 782	Airbus A330-200
10 Dec	22:00	11 Dec	11:00	Hotel @CPH	Best Western CPH	
11 Dec	14:50		16:00	Flight CPH–LHR	SAS 505	Airbus A320neo
11 Dec	16:00		19:00	Taxi home	English Rose	T2 @Information Desk

Table 4.1: Travel itinerary to-and-from Qaqortoq, Greenland.

5 Diary of Events

All times are local time unless specified.

Monday, 25 November 2019

We arrived at LHR Terminal 2 in good time, and the flight departed on time at 18:40 and landed at 21:30. Luggage was retrieved at CPH and we took a taxi to the hotel (Best Western Copenhagen Airport) which took about 5 minutes.

Tuesday, 26 November 2019

We took the airport shuttle at 09:00 to the airport, arriving in good time for our 10:45 flight, and were onboard at 10:20. Upon arriving in Kangerlussuaq, we went for a short walk out from the airport finding the weather brisk (-13°C, with a 'feels like' of -22°C). We returned to the airport for hot drinks, then boarded our 'free seating' flight to Narsarsuaq.

Upon arrival in Narsarsuaq, we retrieved our luggage then checked it in for the helicopter flight leaving less than an hour later. They were more strict about only one piece of hand luggage than last time. We boarded with 9 passengers, 5 facing forward on a bench seat behind the luggage in a cargo net and the single pilot in front, and 4 passengers in the rear (two on each side). Ear protection was provided and all hand luggage was stored in the tail. The flight was smooth and the view incredible (the snowy fjords and sunset).

Eleanor texted Jimmy Hansen (60north.gl) our flight details, and we were met by someone from 60north upon arrival who gave us a ride to the apartments and the keys. We dropped our luggage, then went to the hotel for dinner and the grocery store for the next day's breakfast items.

Wednesday, 27 November 2019

We headed to *60North* for 9am but took a short detour to look at the Adolf Jensen alongside the Royal Arctic Line yard. At 60North, we found Jimmy Hansen having breakfast, where he told us the container was still in the yard as there were fees to be paid (on the order of 36,000 dkk). He agreed to pay them, and then collect the container that day. On our way out, we took a tour of the Adolf Jensen with Karl Kristian and Mickey, including the spacious mid-ship deck, the bridge and galley, and a forward meeting room.

We arranged to meet again at 11:30, and Jimmy texted that the container was picked up by 11:15. We headed back to 60North, and managed to open the container with the help of an angle grinder from 60North, then unloaded what we could (Zarges boxes and glider boxes), and arranged for a forklift the next morning around 8am. The glider boxes were opened up, and carried outside to do their self-tests.

Thursday, 28 November 2019

We met for breakfast at 07:15, then headed to 60North for 08:00, where the forklift driver unloaded the rest of the container (Sailbuoy and cartons of drifters). We tested 2 cartons of drifters, one before lunch and one after. The gliders were also set outside to do sim dives, managed by the MARS group in Southampton. Jared's computer shut down either due to the cold or the battery. The Sailbuoy was also unpacked and assembled, then set outside to check communications. Eleanor's computer also shut down in the cold, but since the Sailbuoy could be communicated with via the web, so it was not necessary to stay outside.

Friday, 29 November 2019

We met again for breakfast at 07:15 to head to 60North after. Today, 3 cartons of drifters were tested, as well as the 3 NKE drifters and the 2 extra standard drifters.

The gliders went out for a second run of the sim dives as on the first run each glider had failures.

We discovered that the Sailbuoy and RBR CTD were missing comms cables. The Sailbuoy was proprietary, so we could not replace this cable. From the RBR manual, we determined that we needed an RJ11 connector on the RBR side and a serial connector on the computer site. We e-mailed support@rbr-global.com and they sent the pin diagram for the cable.

The NKE drifters weren't showing up on the Seechart service, but Solene Routaboul asked us to leave them on longer since the messages sent were test messages only. Since they only call in once every three hours, this meant we would need to repeat the NKE drifters on Saturday.

Saturday, 30 November 2019

We checked the Stark hardware store in search of an RJ11 connector, but did not find any. The proprietor told us we should check the Tele-Post store, which would be open on Monday. Two guys from 60north workshop were also there, and they said they had the right connector. The first cable they had was only 2 pins, but the second had four. Unfortunately, it was too wide to fit in the RBR. Melik from 60north was able to file down the end of the connector to a size that would fit (loosely).

We finished the final carton of drifters and set the NKE drifters out again for 2 call-ins. Before leaving for the day at noon, we tidied up the area with the sealed drifter boxes and gliders in crates.

In the afternoon, we visited the Christmas market at the high school.

Sunday, 1 December 2019

The 60north workshop is closed on Sundays, and it was a big celebration day in Qaqortoq (1st Sunday of Advent). We were invited to attend church at 10am, the tree lighting ceremony at 16:00, and dinner at Rasmus Rasmussen's.

Jared also finished the RBR cable and we tested it, and discovered the XR420 firmware was too old (4.2) for the Ruskin software and required the earlier software (RBR connect). This was downloaded and installed. We set the RBR to log continuously at the shortest interval available (10 seconds), in case the cable stopped working.

The Adolf Jensen left shortly after 17:00 to rescue a fishing boat, the Nanoq, that was without power 40nm offshore and with 17 fishermen on board.

Monday, 2 December 2019

The weather was not suitable for fieldwork today, so we set about working on sg602 which had a faulty pressure sensor (reading constant zeros). We tested pulling a vacuum on the glider using the shop vacuum cleaner and some duct tape around the hose end. We managed to get it down to just under 11 psi, but it lost about 0.7 psi while trying to close the valve. So we pulled the vacuum, fully closed the valve, then slightly opened it, and pulled the vacuum again. It held at 11 psi.

The next step was to open the glider pressure case over the electronics. We put the glider in its cradle on a stack of plywood, tied back hair and used headlamps (as they were working on the power in the workshop, and it would occasionally turn off). We pulled off the fairing, then Jared opened the pressure case and it was held to the side while he inspected the electronics. It turned out the pressure cable was offset by one pin, and so was not talking. This was fixed, then the o-ring checked for dust, and the glider sealed and vacuum applied.

Eleanor agreed with Jimmy a plan to sail on Tuesday at midnight, completing the work on Wednesday and returning after. The Adolf Jensen was not in the harbour, but was behind the town where it had pulled in.

Tuesday, 3 December 2019

We arrived at 8am to 60north anticipating loading, but the Adolf Jensen was still not back. We were advised it would be back by 9:30 or 10:30am. We were then told that we could not sail that evening, but perhaps on Wednesday. With the extra time, Jared performed additional tests on the O2 sensor on sg602, but to no avail.

After a quick lunch, we loaded the vessel, starting at 13:15 with a forklift at 60north to load equipment on a flatbed truck, then used the ship's crane to unload the truck directly onto the ship. It took two loads as 6 pallets only would fit on the flatbed and we had 7 cartons of drifters, 1 pallet of Zarges boxes plus the two gliders. Sailbuoy was walked to the harbour. Once loading was completed, we did a buoyancy check on sg602 off the port side of the vessel. It floated well, so the gliders were set in recovery mode, upright in cradles on the port side. We were then advised that the Adolf Jensen would need to reposition the Nanoq (fishing vessel) in the morning because another ship was coming in to the main dock, and we would need to move the gliders off the port railing.

Wednesday, 4 December 2019

We met for breakfast at 7:15, and headed down to boat by 8am to put the gliders flat. The boat rotation (one boat off of one dock, to make space for the Nanoq, then the Nanoq repositioning) wrapped up around 10am. Eleanor and Ilona had gone to 60north to discuss when we could sail as there was some ongoing uncertainty with the weather. Jared remained onboard. When the repositioning finished, the Adolf Jensen did not return to the dock, but instead headed out into the fjord to test the autopilot. The vessel returned to the dock shortly after 11 where the autopilot was further inspected, and two of the crew members went for groceries.

We set sail at 11:55am, making 8–9 kts towards WP5 where we would start with the inshore-most drifter deployments. We arrived at WP5 around 17:20. The conditions were a bit rolly, with significant wave height forecasts of 1–2m, and the deck icey. Deck lights were turned on as sunset was around 15:00, and some salt added to the ice, but it was still slippery. We wore safety boots with ice grips, X4 suits and red inflatable work vests. We planned to start with an NKE drifter, but after removing the magnet to turn it on, and the initial quick beeps, the status tone two minutes later was a constant tone rather than the 10 short beeps indicating ready to deploy. A second NKE drifter was turned on with the same result. We switched to standard drifter deployments. Ilona's work vest inflated on the first deployment, so Eleanor swapped in for deployments and Ilona for logging and getting a second work vest.

After deploying the 10 standard drifters at WP5, we carried on to WP4 (about 20 min between stations) and deployed 10 drifters there. Between WP4 and WP3, Ilona tried putting an NKE drifter inside to warm up before removing the magnet to turn it on. When we tested it after the 10 standard drifters were deployed at WP3, it emitted the 10 short tones, indicating that it was ready for deployment. Thereafter, we warmed up each NKE drifter before turning it on, and salinity drifters were deployed at WP3, WP4 and WP5 (instead of WP1, WP3 and WP5). All drifters were deployed by about 19:45.

Given the timing and conditions, we decided to use the 'plan B' glider deployment site at WP7 and go at first light. Like WP6 (plan A), it was in 300 m of water, but about 15 nm further inshore. Jared tried to contact the MARS team in Southampton to tell them we were aiming for an 8am start, but his Iridium phone wasn't working. We sent a message using the Iridium GO instead. We arrived at WP7 around midnight, where the sea state was much calmer.

Thursday, 5 December 2019

We remained at WP7 until daylight, having a cooked breakfast at 07:00 and then heading out to the deck to get ready for the vehicle deployments. Sunrise was around 09:00, but it started getting light

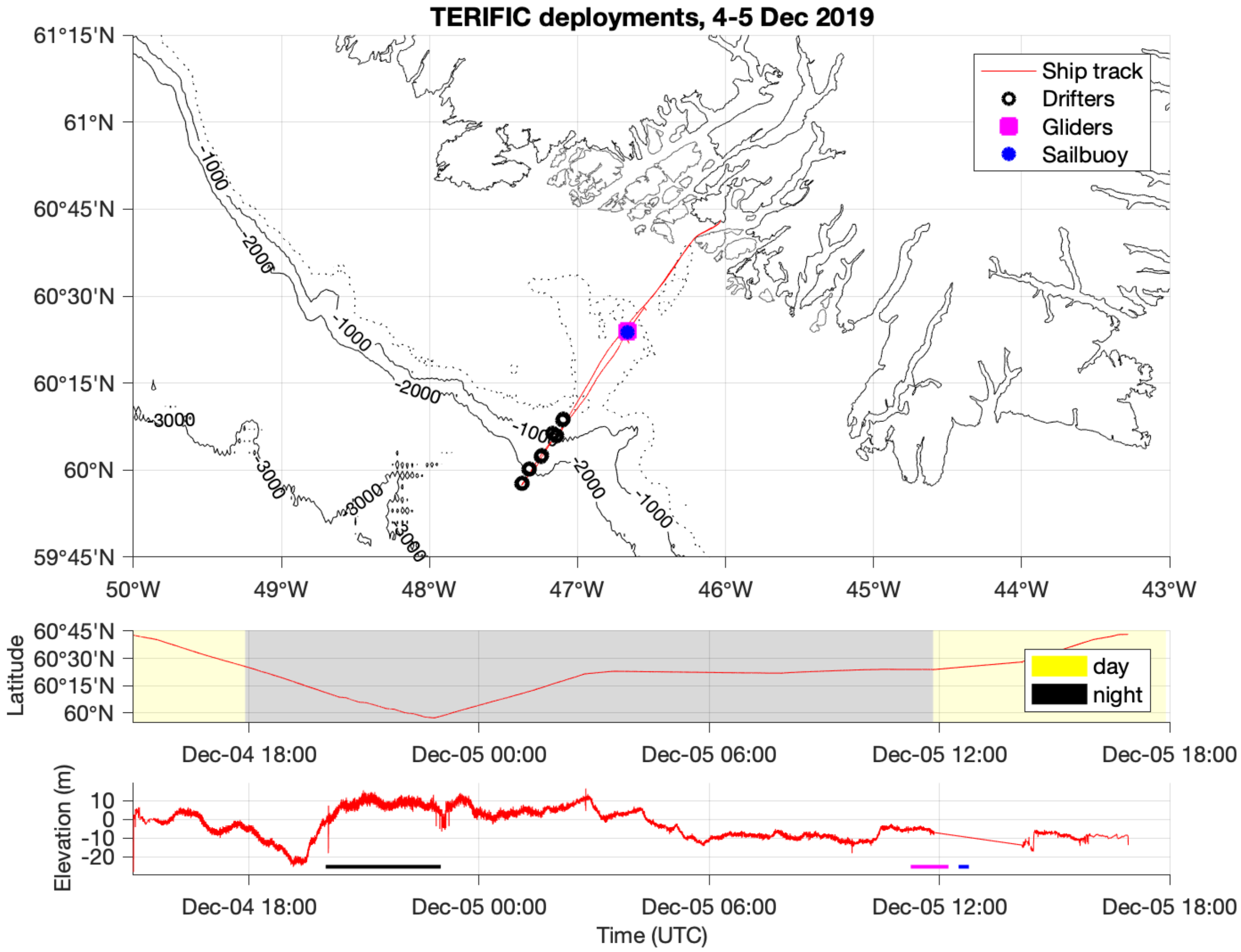

Figure 5.1: Cruise track and deployment timing. Black circles are actual drifter call-ins, from WP5 (right) to WP1 (left). WP7 is at the glider/sailbuoy deployment locations. Day and night indicators are based on sunrise and sunset, but it was light a little before sunrise and after sunset.

around 08:00. Both gliders had become encrusted with ice overnight, including on the wings, fairing, outside of sensors and straps. Ice was removed by hand and with a couple buckets of warm water (being used to de-ice the deck).

The first glider to be deployed was sg602, which we moved to the starboard side. It was deployed smoothly, but initially lying too flat in the water, possibly due to ice. After a few minutes, it tilted nose down and then was sent down for a dive. The deployment of sg638 was a little quick on the crane, but also went in the water without any issues. It was lying nose down from the outset. Once it was sent down for initial dives by the Southampton-based pilots, and both gliders appeared in good shape, the Sailbuoy was deployed. This was a very quick process, after which David Peddie (Offshore Sensing, AS) did some initial checks and then set it out to sea. We then carried out a single CTD cast to the full length of the rope (150m) using a hand-reel.

Once the CTD cast was completed, and the Southampton glider pilots verified the status of the gliders, we headed to port. We arrived in Qaqortoq around 14:00. As the public dock was not available, we pulled up alongside another vessel and so could not immediately unload our gear. We dispursed to the apartments for a leisurely afternoon.

Eleanor rebooked return travel from Thursday to Tuesday (flights, hotel, ferry, taxi). Eleanor also contacted Peters & May for the return shipment of the container of empties to Southampton.

Friday, 6 December 2019

We checked whether we could unload the Adolf Jensen, but it was still double parked. Peters & May booked the return voyage on a vessel (Malik Artica) leaving on Monday the 9th (next sailing not till the 20th), so Eleanor contacted Jimmy. He agreed it would be possible to move the container there in time, and we got a call at 3pm that the crew of the Adolf Jensen were bringing it alongside the main dock for unloading. We unloaded the Zarges boxes, cradles, empty cardboard and pallets by hand (the crew using wood saws to cut down the cardboard boxes). The 60north truck to move the container from the workshop to the dockside could not lift the container, however, and the larger truck was undergoing repairs. We then booked a taxi (small pickup truck) to get the gear to the workshop and into the container, but did not tie things down.

We went to Cafe Heidi for a Christmas dinner around 6pm, at which time Jimmy called to ask if we had a lock to secure the container. I told him I did not, and also that we had not tied everything down yet. We arranged to meet at the dockside at 8am.

Saturday, 7 December 2019

We went to the harbour at 08:00 to tie things down in the container, but the container didn't arrive till 09:00. We used the pallets to wedge gear in, and blue rope to secure. Jimmy brought a lock which we used to lock the container.

The rest of the day was mostly relaxing, and then we were invited to Rasmus' for dinner again.

Sunday, 8 December 2019

Sunday was a free day. The container was loaded onto the Malik Artica container ship, and departed before sunrise on the 9th.

Monday, 9 December 2019

Eleanor and Ilona met with Jimmy around 10:00 to get the invoice for this trip, and discuss the next activities.

Tuesday, 10 December 2019

The Diskoline ferry from Qaqortoq to Narsarsuaq via Narsaq was scheduled for 07:20 departure, the the tickets specifying that we should be there 30 minutes in advance. We arrived at the dock at 06:50 and were the first ones there. However, by 06:56 there were 8 other passengers waiting. Two boats were scheduled for 07:20, the other being direct and it loaded first. The ride started out very bumpy, with sea spray coming up over all windows, but eased up slightly in the fjord. The ferry was still making good speed, and we arrived just 5 minutes late at Narsarsuaq (09:20) with the bus getting us to the terminal at 09:30.

Our flight from Narsarsuaq to Kangerlussuaq was delayed from 10:30 to 11:00, then 11:15 departure. As our scheduled layover in Kangerlussuaq was only 55 minutes, this did not bode well for catching the transatlantic flight. However, when we boarded the plane the flight attendant said that the next flight would wait for us. We arrived, went through the terminal and security, and then boarded our flight at 13:25, 15 minutes after the scheduled departure time. The flight time was only 4:10 min, so our scheduled arrival into Copenhagen was only 10 minutes late.

Wednesday, 11 December 2019

We had a long morning in Copenhagen, then took the 14:50 flight to London Heathrow.

6 Drifters

Ilona Goszczko

The Global Drifter Program (GDP) is long-term program and a principal component of the Global Surface Drifting Buoy Array. The Lagrangian Drifter Laboratory at the Scripps Institution of Oceanography (SIO) leads the engineering aspects of the Lagrangian drifter technology.

The 50 GDP drifters equipped with temperature sensors and GPS positioning system were shipped from California, US to Southampton, UK in October 2019 and departed 22 October in the container with all the other equipment to Qaqortoq, Greenland. The GDP drifters travelled in cardboard boxes on pallets: 8 drifters in 6 big cartons, and 2 drifters in one smaller box. All of the drifters had the serial numbers written/painted on them and magnets installed inside sponges and taped with paper tape. They were all (except of single item unpacked for internal check in Southampton on a day of container packing) wrapped/laminated in plastic (with deployment instruction attached) during the entire travel time.

Three NKE (SC40 SVP-BSC) drifters equipped with temperature, conductivity and barometric pressure sensors were shipped together with all the other drifters, they were also wrapped/laminated in the plastic (buoy + drogue) and needed to be unwrapped before testing. They also were marked with the serial numbers written on the buoys.

6.1 Setup and selftests

In Qaqortoq, the drifters were moved from the container with a forklift by a person from 60North and stored in the workshop. They were further unpacked manually. We eventually settled on removing the top layer (4 drifters), then tipping the cardboard box on its side to gain easier access to the bottom layer. All of the boxes had the list of the included devices attached in a laminated pocket on the outside of the box. The list on the small box was incorrect: one drifter was missing (300234066416890) while another was found inside (300234066416930) that was not present on the list provided by manufacturer. After communication with Scripps on 29th Nov the new drifter was activated and a WMO number assigned to it (the missing drifter got a WMO # 0 in the system). In several stages (on 28–30th Nov) the drifters were unpacked and moved outside the workshop. To reduce manual handling, the drifters were removed from their plastic covering then placed three to a pallet to be wheeled outside for communication tests using a pallet jack. The paper tape and magnets were removed (sponges were left as they were; *attention – magnets are strong and can hurt bare hand skin, gloves need to be used!*). After successful transmission (which usually occurred after a few minutes, though one drifter was unsuccessful and had to be tested the next day), the magnets were returned to their original position and taped with either electrical tape, duct tape or masking tape. We determined that masking tape was the best solution as it was sticky in cold weather, and easiest to remove with gloved hands during deployment (simply by ripping the magnet out by its string). Later, the drifters were returned to a carton, starting by putting three in while it was lying on its side, then tipping the box to vertical and packing the remaining drifters manually from above.

Similarly, 3 NKE drifters were unpacked, moved outside on a single pallet with the palletjack. The magnets were removed (different shape and not as strong as the GDP ones) at 08:52 UTC on 30 Nov and the transmission started immediately (5 initial beeps followed by 10 beeps meant successful communication and readiness for deployment). As the data were being displayed by Seechart, which was not previously set up, we needed to set them out a second day for 2 transmissions (separated by 3 hours), in order for the decoders to be setup properly.

All cardboard boxes were sealed with duct tape across the top, and still attached to their pallets. They were moved to the Adolf Jensen on Tuesday, 3 December and loaded (together with the pallets) by the ship's crane. All were stored on the starboard side, secured with a single rachet strap, ready to be open during deployment.

6.2 Deployment

The deployment was scheduled after the initial several hours of steaming to the most inshore position (WP5) on the shelf break. Just before arriving to the position the first cardboard box (containing 8 GDP drifters, 10 needed to be deployed at one location) was open and on one side, the cardboard was cut down halfway to provide access to the devices without unnecessary climbing. The aft part of the deck was slippery and required full attention during the deployment. The magnets were removed again and the numbers were noted in the log sheets together with the UTC time.

At the first station (WP5), when the NKE magnet was removed, rather than sounding the 10 beeps indicating it was ready for deployment, it gave a long continuous beep indicating there was a problem. A second NKE drifter was turned on with the same result. No NKE drifters were deployed at the either of the first two stations (WP5 or WP4). Between WP4 and WP3, one NKE drifter was moved inside the hallway of the Adolf Jensen, in case the error was due to temperatures out-of-bound (too cold for ocean temperatures). When it was turned on at WP3, it sounded the 'ready' beeps, and was deployed. The process of warming up each NKE drifter before deployment was repeated at WP2 and WP1.

The whole operation (53 drifters at 5 waypoints) took three hours. A table of deployment locations (determined from the GPS track) and times is shown in Tables 6.1–6.3.

WP	No.	WMO	Lat (°N)	Lon (°W)	Date	Time (local)
5	1	513050	60°28.77'	46°32.1'	04/12/2019	17:21:00
5	2	515010	60°28.57'	46°32.5'	04/12/2019	17:23:00
5	3	514030	60°28.48'	46°32.68'	04/12/2019	17:24:00
5	4	513060	60°28.38'	46°32.9'	04/12/2019	17:25:00
5	5	514020	60°28.27'	46°33.14'	04/12/2019	17:26:00
5	6	646930	60°28.19'	46°33.33'	04/12/2019	17:27:00
5	7	513300	60°28.09'	46°33.54'	04/12/2019	17:28:00
5	8	514050	60°28.09'	46°33.54'	04/12/2019	17:28:00
5	9	416830	60°27.91'	46°33.98'	04/12/2019	17:30:00
5	10	416410	60°27.82'	46°34.21'	04/12/2019	17:31:00

Table 6.1: Table of drifter deployment locations

WP	No.	WMO	Lat (°N)	Lon (°W)	Date	Time (local)
4	1	416810	60°25.53’	46°38.84’	04/12/2019	17:54:00
4	2	416770	60°25.42’	46°39.06’	04/12/2019	17:55:00
4	3	416860	60°25.42’	46°39.06’	04/12/2019	17:55:00
4	4	416780	60°25.32’	46°39.25’	04/12/2019	17:56:00
4	5	416840	60°25.22’	46°39.46’	04/12/2019	17:57:00
4	6	416690	60°25.12’	46°39.64’	04/12/2019	17:58:00
4	7	515030	60°25.02’	46°39.85’	04/12/2019	17:59:00
4	8	416870	60°24.91’	46°40.05’	04/12/2019	18:00:00
4	9	516050	60°24.81’	46°40.25’	04/12/2019	18:01:00
4	10	515050	60°24.71’	46°40.45’	04/12/2019	18:02:00
3	1	516000	60°21.1’	46°46.86’	04/12/2019	18:35:32
3	2	516010	60°21.04’	46°46.97’	04/12/2019	18:36:07
3	3	516020	60°20.96’	46°47.12’	04/12/2019	18:36:53
3	4	516030	60°20.85’	46°47.31’	04/12/2019	18:37:47
3	5	513040	60°20.67’	46°47.65’	04/12/2019	18:39:34
3	6	511050	60°20.6’	46°47.76’	04/12/2019	18:40:12
3	7	512040	60°20.51’	46°47.92’	04/12/2019	18:41:03
3	8	511060	60°20.43’	46°48.04’	04/12/2019	18:41:45
3	9	513030	60°20.35’	46°48.16’	04/12/2019	18:42:30
3	10	512030	60°20.25’	46°48.29’	04/12/2019	18:43:15
3	11	8706100	60°20.13’	46°48.48’	04/12/2019	18:44:26

Table 6.2: Table of drifter deployment locations. Add three hours for the time in UTC. (cont.)

WP	No.	WMO	Lat (°N)	Lon (°W)	Date	Time (local)
2	1	512050	60°17.63’	46°52.03’	04/12/2019	19:06:00
2	2	512010	60°17.53’	46°52.19’	04/12/2019	19:07:00
2	3	510050	60°16.97’	46°52.92’	04/12/2019	19:11:30
2	4	511010	60°16.89’	46°53.02’	04/12/2019	19:12:15
2	5	511020	60°16.83’	46°53.1’	04/12/2019	19:12:45
2	6	510030	60°16.76’	46°53.18’	04/12/2019	19:13:15
2	7	510000	60°16.7’	46°53.25’	04/12/2019	19:13:45
2	8	511040	60°16.64’	46°53.34’	04/12/2019	19:14:15
2	9	510040	60°16.59’	46°53.41’	04/12/2019	19:14:45
2	10	510060	60°16.53’	46°53.49’	04/12/2019	19:15:15
2	11	7905840	60°16.46’	46°53.57’	04/12/2019	19:15:45
1	1	517050	60°13.88’	46°57.09’	04/12/2019	19:37:39
1	2	519000	60°13.8’	46°57.18’	04/12/2019	19:38:16
1	3	519020	60°13.71’	46°57.31’	04/12/2019	19:38:58
1	4	517030	60°13.66’	46°57.37’	04/12/2019	19:39:30
1	5	519040	60°13.59’	46°57.47’	04/12/2019	19:40:05
1	6	518050	60°13.54’	46°57.54’	04/12/2019	19:40:30
1	7	519010	60°13.49’	46°57.61’	04/12/2019	19:40:59
1	8	519050	60°13.4’	46°57.73’	04/12/2019	19:41:39
1	9	514040	60°13.3’	46°57.87’	04/12/2019	19:42:28
1	10	516040	60°13.21’	46°58.02’	04/12/2019	19:43:20
1	11	7909790	60°12.95’	46°58.38’	04/12/2019	19:45:35

Table 6.3: Table of drifter deployment locations. Add three hours for the time in UTC. (cont.)

Platform-ID	WMO-ID	Platform-ID	WMO-ID
300234066416410	6401809	300234066513040	6402514
300234066416690	6401810	300234066513050	6402515
300234066416770	6401811	300234066513060	6402516
300234066416780	6401812	300234066513300	6402517
300234066416810	6401813	300234066514020	6402518
300234066416830	6401814	300234066514030	6402519
300234066416840	6401815	300234066514040	6402520
300234066416860	6401816	300234066514050	6402521
300234066416870	6401817	300234066515010	6402522
300234066416930	6401818	300234066515030	6402523
300234066510000	6401819	300234066515050	6402524
300234066510030	6401820	300234066516000	6402525
300234066510040	6401821	300234066516010	6402526
300234066510050	6401822	300234066516020	6402527
300234066510060	6401823	300234066516030	6402528
300234066511010	6401824	300234066516040	6402529
300234066511020	6402505	300234066516050	6402530
300234066511040	6402506	300234066517030	6402531
300234066511050	6402507	300234066517050	6402532
300234066511060	6402508	300234066518050	6402534
300234066512010	6402509	300234066519000	6402535
300234066512030	6402510	300234066519010	6402536
300234066512040	6402511	300234066519020	6402537
300234066512050	6402512	300234066519040	6402538
300234066513030	6402513	300234066519050	6402533

Table 6.4: List of Platform IDs and WMO number pairings.

7 Gliders

Jared Mazlan

Two Kongsberg Seagliders were deployed during the field work. Both were equipped with the same standard sensor suite: Optode, CTD and WETLabs. Glider SG 602 was deployed with a standard fairing and standard hardware. Glider SG 638 was deployed with an Ogive fairing and contained a SciCon controller board. Full configuration details and serial numbers are listed in Table 7.1. Calibration sheets for sensors can be found in Appendix C.

Unit Number [Name]	SG 602 [Scapa]	SG 638 [Ziggy]
Manfacturer	Kongsberg	Kongsberg
Owner	NOC-MARS	NOC-MARS
Physical	Standard fairing	Ogive fairing
	Long antenna	Short Antenna
Hardware	Standard 15V system	SciCon 15V system
Sensor configuration	Sea-Bird Unpumped Glider CT Sail [s/n 0272] Aanderaa Oxygen Optode 4831 [s/n 243] WETLabs BBFL2 ECO Puck [s/n 1171] ARGOS tag [s/n 18U0199]	Sea-Bird Unpumped Glider CT Sail [s/n 0303] Aanderaa Oxygen Optode 4831 [s/n 103] WETLabs BBFL2 ECO Puck [s/n 5496] ARGOS tag [s/n 12S0016]

Table 7.1: Seaglider hardware configuration: Sensors

7.1 Setup and selftests

The gliders were set-up in Qaqortoq harbour for self-tests post shipping. These self-tests are to confirm the glider is functioning as both were post-refurbishment. The tests can be used to diagnose any possible faults that may have come about due to transport conditions, and to double check the work done in the workshop. Simulation dives are then run on the gliders to test the hardware and data generation to confirm the glider is fully operational. The gliders were set up outside of the 60North workshop in the adjacent dockyard, propped up at 60 degrees with antennae installed. These were initially run on glider internal battery, but for the extended testing of sg602 (from the third set of sim dives), mains power was provided to the Seaglider.

The ARGOS tags are attached to the antennae but run as a separate system from the gliders. These were checked to be set to communicate during daylight hours when deployed and with appropriate wet/dry sensor settings. The Iridium satellite phone was checked for sufficient credit balance and communication with the glider piloting team phone back in the UK.

Selftests and sim dives on sg602: Two oddities were recorded during the field testing of sg602. The pressure sensor on sg602 gave readings of constant zeros which, while appropriate for sea-level tests, was far too uniform a reading to be correct. Additionally, when running sim dives on the glider, the pressure sensor gave errors regarding the zero readings. After numerous tests of software-based fixes, it was decided that the highest probability was a loose/cut cable internally, or a broken pressure sensor. The conclusion was that the glider was non-deployable in this state. Given

Figure 7.1: Seagliders undergoing sim dives.

Figure 7.2: Vacuum hose used to pull a vacuum on sg602.

the reasonable state of the workshop environment in Qaqortoq, and that the glider was already in a non-deployable state, field surgery was deemed viable.

The vacuum on the internal pressure casing of sg602 was released, and a make-shift vacuum pump was used to draw down the internal glider pressure (Fig. 7.2). The valve was sealed and it was proved that the vacuum pump could draw the glider down to approximately 11 psia. Typical Seaglider internal pressures are around 9 psia. However, after testing the pump and bleed cycles at 11 psia, the glider proved to still be able to operate the full range of its buoyancy drive, taking only about a minute longer to bleed down from a surface state.

Once confirmed that the vacuum solution was adequate, the glider was then opened in the workshop away from the elements, whilst minimal other work was occurring in the space. Hairnets were improvised from scarves. The forward fairing was removed and the glider was propped up with the main hull on the edge of the cradle and the aft end-cap in the middle of the netting. Only the electronics hull was opened (but not disconnected). The pressure sensor cable needed to be re-seated as it was misaligned. The O-rings were checked for debris with a flashlight before the hull was sealed together again. Testing then confirmed the pressure sensor was reading correctly. Vacuum was pulled to 11.06 psia and then fairings replaced. SG602 was then taken outside and self-tests and sim dives were run into the evening.

The second problem became evident after these dives in that the optode was not producing data during the sim dives. No values would be present in the optode fields of the report. Testing of the optode configuration through direct comms revealed the unit could interface with the sensor normally. Testing of several variations of configuration file for the sensor did not produce any different results. Checking the sensors own internal configuration and changing parameters did not produce any progress. Swapping the known working optode from sg638 to sg602, the fields still did not produce data. Due to the non-critical nature of the sensor, it was decided that after half a day of working on it, it would be left defunct. The sensor stayed on the glider however as the vehicle required it for the ballasting solution it was shipped with.

Other than this, the glider passed the functional checkout standards of the NOC-MARS glider group with no other oddities or failures.

Selfests and simdives on SG 638 The glider passed the functional checkout standards of the NOC-MARS glider group with no oddities or failures.

Figure 7.3: Buoyancy check of sg602.

Buoyancy check: A buoyancy check on sg602 was done from the Adolf Jensen whilst alongside in port (Fig. 7.3). This gave practice for the crew on deployment/handling of the equipment and confirmed that the gliders would float at maximum buoyancy in the fresher dock waters (density of 1025, according to the RBR CTD), hence were safe to deploy offshore. They sat in the ideal position at the surface. There was no time to bleed the glider down to find the neutral buoyancy drive value but this would have been a valuable test to determine whether the gliders would be able to sink in the denser offshore water. As both gliders were ballasted to the same weight in water, the buoyancy check was only carried out on one glider.

7.2 Deployment

Both gliders were put into “sea-launch” mode and on 1.5-hour call-backs and then loaded onto the Adolf Jensen. They were strapped to the side rail, pitched at about 60 degrees with wings, rudder and antennas installed. This was to allow the gliders to continually call in until deployment and, by being put in sea-launch mode, removed the need to do this procedure on deck. This reduced hazards to the field team and reduced overall deployment time from the vessel. However, this does use slightly more battery than activating once on location.

Confirmation was given to the UK pilot team that launch would be at 08:00 (local) 05/12/2019. This confirmation was given at least 3 hours in advance to allow the call-back duration to be reduced to 3 minutes. Waiting for sunrise, it was found that the gliders had been heavily iced over during passage in the night (Fig. 7.4). Warm water was used to remove as much as possible and CT sail glass tubes were checked for cracking. Caps were left on the sensors overnight which sheltered them from heavy icing.

Figure 7.4: Ice formed overnight on Seagliders.

Gliders were deployed using a slip-pin release and the forward finger-crane on the Adolf Jensen. SG602 was launched first at 08:43 in location 60°23.91’N, 46°39.96’W. Heavy icing on the antenna caused the glider to initially lay very flat in the water after release. As the air was displaced in the fairing and the ice melted in the water, the position of the glider became ideal at the surface. The glider then successfully dove to 30m and on progressively deeper dives. SG638 was deployed next at 09:10 in location 60°28.01’N, 46°32.95’. Similar problems were seen, but as the antenna was shorter, less of a moment was caused. SG638 also successfully dived to 30 m and then onto progressively deeper dives.

The ship stayed at position until confirmation from pilot team that they were satisfied with glider operation at 10:28 (13:28 UTC) on 05/12/2019.

8 Sailbuoy

Eleanor Frajka-Williams

One autonomous surface vehicle, a Sailbuoy from Offshore Sensing, AS was deployed during the cruise. The Sailbuoy is instrumented with a meteorological sensor, a wave sensor and surface temperature/salinity. Details of the sensor suite and variables measured by each are shown in Table 8.1.

Vehicle	Sailbuoy
Name	SB Artemis
Manufacturer Owner	Offshore Sensing AS NOC-MPOC
Sensors	Aanderaa conductivity/temperature Airmar weatherstation 200WX Datawell MOSE-G1000
Directly measured variables	Relative wind speed and direction Heading, pitch, roll, and rates Air temperature 1 m subsurface temperature & conductivity Position
Inferred variables	True wind speed and direction Salinity Significant wave height Wave period

Table 8.1: Sailbuoy hardware configuration: Sensors and measurements.

8.1 Setup and selftests

The setup of the Sailbuoy involved installing the sail and attaching the sheets. Following the deployment checklist provided by the manufacturer, the mast was lubricated then fixed in place over the wear disk, and sail lock fastened. The sheet quick link was fastened to the sail, movement checked to be very near to ± 45 port/starboard. The sheet quick link was hand tightened with a spanner. The seacock was secure and tight, and the vehicle was turned on outside. The rudder movement was verified.

The settings for the Airmar weather station were configured in Bergen prior to delivery since they required firmware updates to include more NMEA strings. The configuration used is shown in Fig. 8.1.

No data cable was included in the box for the Sailbuoy, so it was not possible to connect to the data logger and verify settings. David Peddie (Offshore Sensing) assured us that all settings could be controlled via the Iridium connection, so we left it.

The Sailbuoy was secured to the trolley using two rachet straps snuggly fit (but not heavily racheted down) over the protective cover on the solar panels. We planned to deploy in autopilot mode, which requires the autopilot to be restarted (magnet put on and left for 1 minute) about 5 minutes prior to deployment.

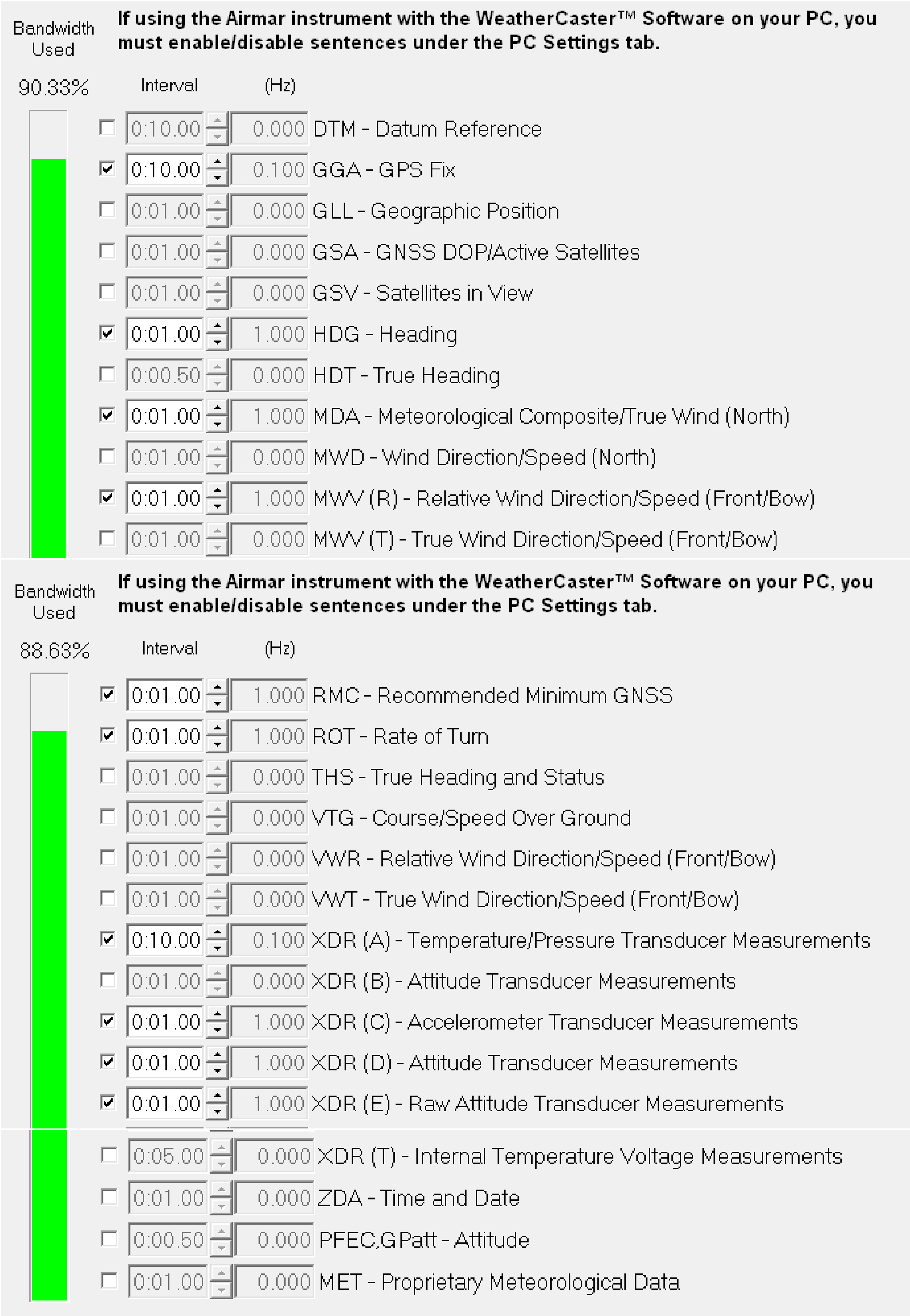

Figure 8.1: Logging rate for the Airmar WeatherStation, where ROT – Rate of turn from the rate gyro, XDR (D) – Attitude transducer (pitch, roll and yaw, compensated) from the magnetoinductive XYZ sensors, XDR (C) – Accelerometer transducer measurements from the MEMS accelerometer for pitch, roll and yaw rates, and XDR (E) – Attitude transducer (pitch, roll and yaw), raw.

8.2 Deployment

The Sailbuoy was deployed at 09:47 05/12/2019 at position 60°28.01’N, 46°32.95’W, while the gliders were still performing initial dives. The Adolf Jensen was positioned so that the wind was over the port side so that the Sailbuoy would move away from the vessel once deployed. The Sailbuoy was deployed over the starboard side using the crane to lift it via two lightweight racket straps (hook ends) with the hooks through the forward and aft strongpoints on the Sailbuoy.

Once the vehicle was in the water, the straps were lifted clear. In spite of the intended positioning relative to the wind, the vehicle still drifted towards the bow of the ship. The sea state was very calm, and so the vehicle only grazed lightly against the side. It was soon clear of the vessel, and David Peddie (Offshore Sensing, AS) took over piloting and initial tests of the Sailbuoy in the water.

9 CTD

Due to conditions, only one CTD cast was attempted. This was following the deployment of the gliders and Sailbuoy.

We used a 740 m rated RBR XR420 with a 10 second sampling interval from the NOC Sensors and Moorings group. It was previously calibrated in 2010 (according to onboard calibration information, see §D. Note that the XR420 is powered by CR23 batteries which were not readily available in Greenland. We had two spare sets.

9.1 Instrument setup and testing

The instrument was set up using UTC time with a start time of 'now' and immediate logging. We left it logging for several days before the cruise as the cable we had for it was a patch job. The CTD was tested the morning of the deployment and still working, so we went for a 150 m cast (full length of the rope). Communications were done via an older version of RBR connect on a Samsung Galaxy book.

We tested the RBR in the harbour off the dock (about 4 m of water) and verified that it was logging as anticipated. Data were downloaded and then logging resumed for the fieldwork.

9.2 Deployment

We had a hand reel with 100 m of line, to which an additional 50 m were added before attaching the RBR CTD. No additional weight was used. Eleanor and Ilona lowered the CTD, then the three of us wound the rope back on the reel under tension.

9.3 CTD processing

The RBR data were downloaded 5 December 2019 following the profile on the cruise. The file contained several days of logging, including the dockside test cast and the profile at sea in a single file, `010822_20191205_1437utc_profile_by_glider.dat`. No additional processing was applied. The sea cast is displayed in Fig. 9.1.

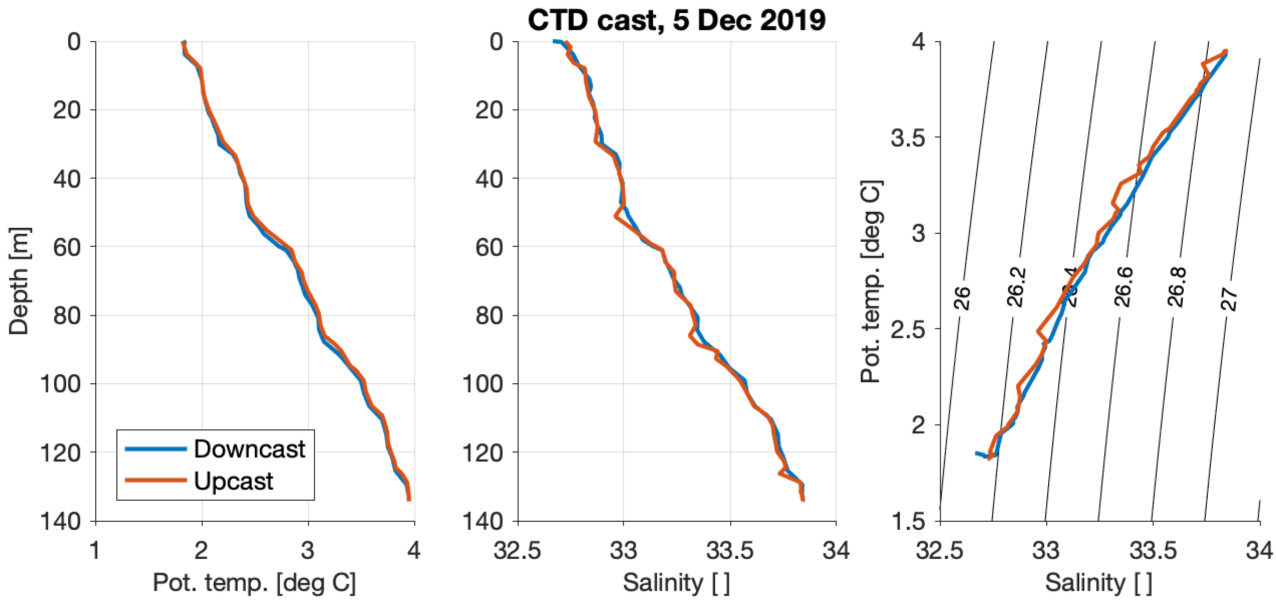

Figure 9.1: CTD profile at the glider deployment location.

10 Data intercomparison (preliminary)

The initial tracks of the autonomous platforms are shown in Fig. 10.1. The drifters headed with the boundary current to the northwest, with drifters deployed at WP3–5, over the 1500, 1000 and 500 m isobaths going faster than those from WP1 and 2 (2500 and 2000 m respectively). The gliders were set on constant heading as the compasses were about 30 degrees off from true. The Sailbuoy was made good progress towards the drifter deployment locations and across the line (WP5 to WP1), then was steered strongly to the north in the boundary current and later by the winds. Continued piloting attempts were made to bring it back south. By 09:30 UTC, 9 December 2019, the datalogger battery had been depleted and the logger shut down. It did not resume until 14 December 2019, and was restarted with all sensors off (saved configuration using `$SAVE`), logging every 30 minutes and calling in every 6 log intervals (every 3 hours).

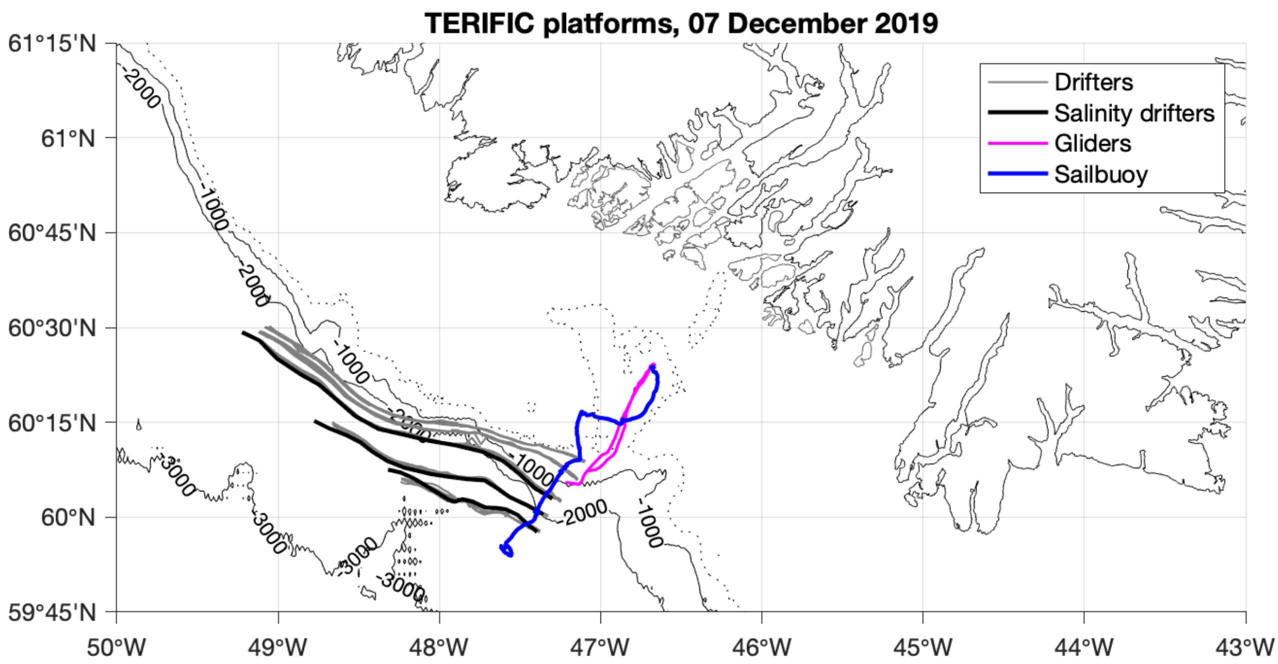

Figure 10.1: Initial tracks of autonomous platforms.

The Sailbuoy, standard drifters and salinity drifters all measure SST, albeit with the Sailbuoy sensor located in the keel about 1 m below the surface. The range of values after the first 2 days are plotted in Fig. 10.2. All drifters are reading comparable temperature values, with the standard (SIO) drifters having more cold values than the salinity (NKE) drifters, as the SIO drifters were deployed at the two inshore positions (WP4 and WP5) while NKE drifters were only deployed at the three outermost positions (WP1–3). Sailbuoy recorded temperatures are colder than the drifters, which may be accounted for by the time spent further inshore on the shelf. A more detailed intercomparison will be required. Sailbuoy salinities are generally between 32 and 34 psu, which is consistent with the CTD cast (salinities ranging from 32.5–34 in the top 140 m). However the NKE drifters appear to be recording much higher salinities at and above 36 which are unlikely for the region. This is an issue that will be addressed with the manufacturer.

The temperature gradients across the boundary current are visible in the mapped plot of the SSTs (Fig. 10.3, top), showing the transition from temperatures near 1.5°C to 6°C across a distance of about 45 nm. The issue with the NKE salinity sensors is visible in Fig. 10.3 (bottom).

Seaglider sections (plotted against dive number) are shown in Fig. 10.4 and 10.5. The presence of cold fresh water near surface, and warm salty water below is clear.

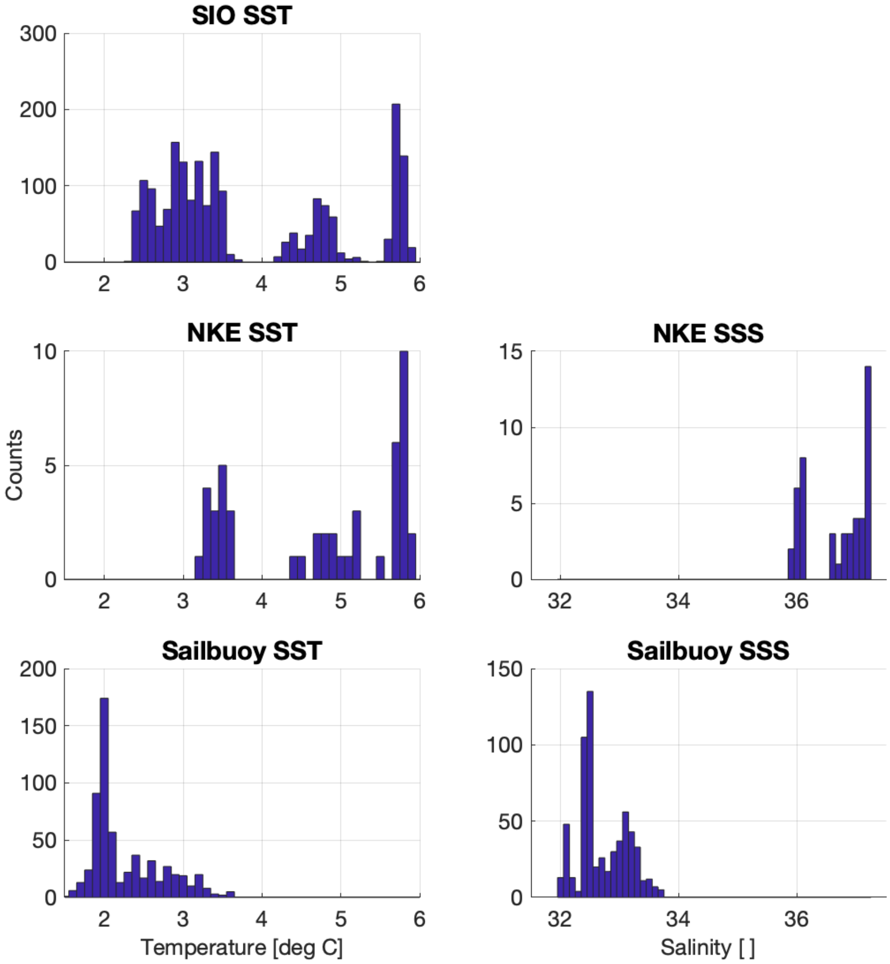

Figure 10.2: Histograms of temperatures (left) and salinities (right) recorded by the standard drifters (top row, SST only), NKE salinity drifters (middle row) and Sailbuoy (bottom row). Note that the Sailbuoy sensor is in the keel, approximately 1 m below the surface.

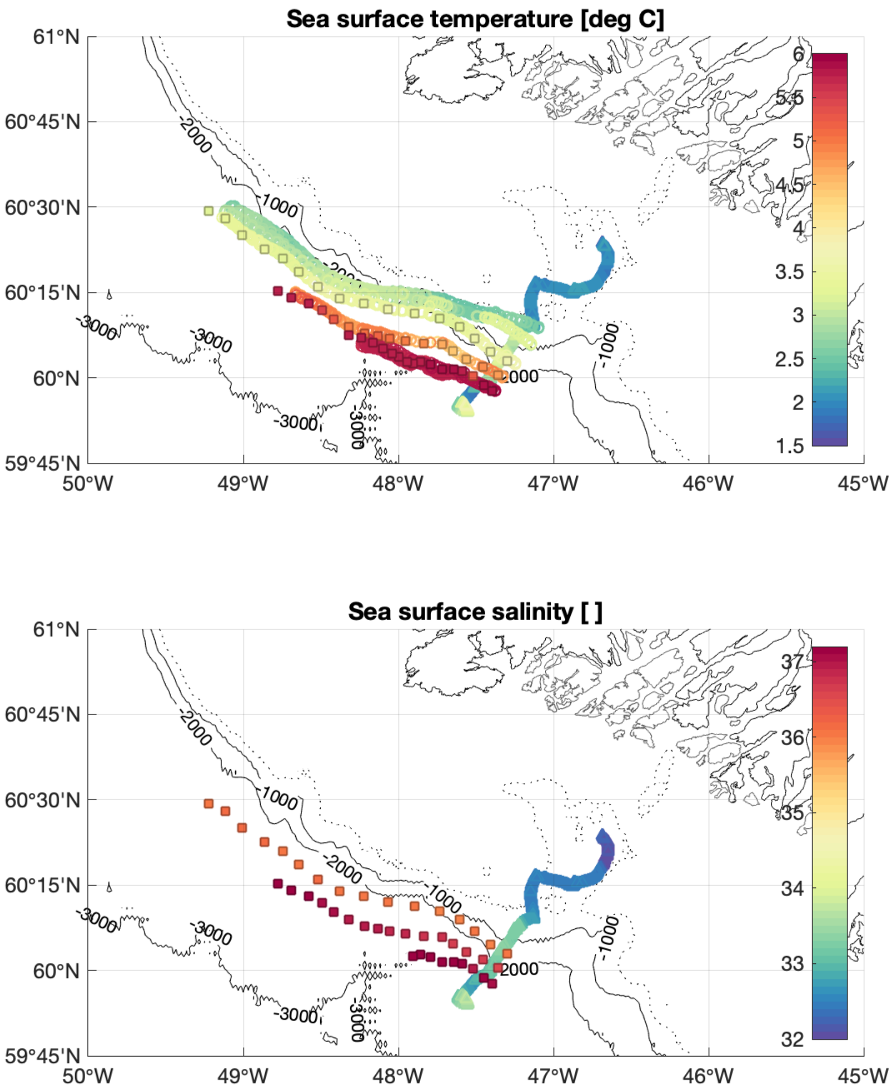

Figure 10.3: Maps of SST (left) and SSS (right) values from the surface drifters and Sailbuoy (near surface values), recorded in the first two days.

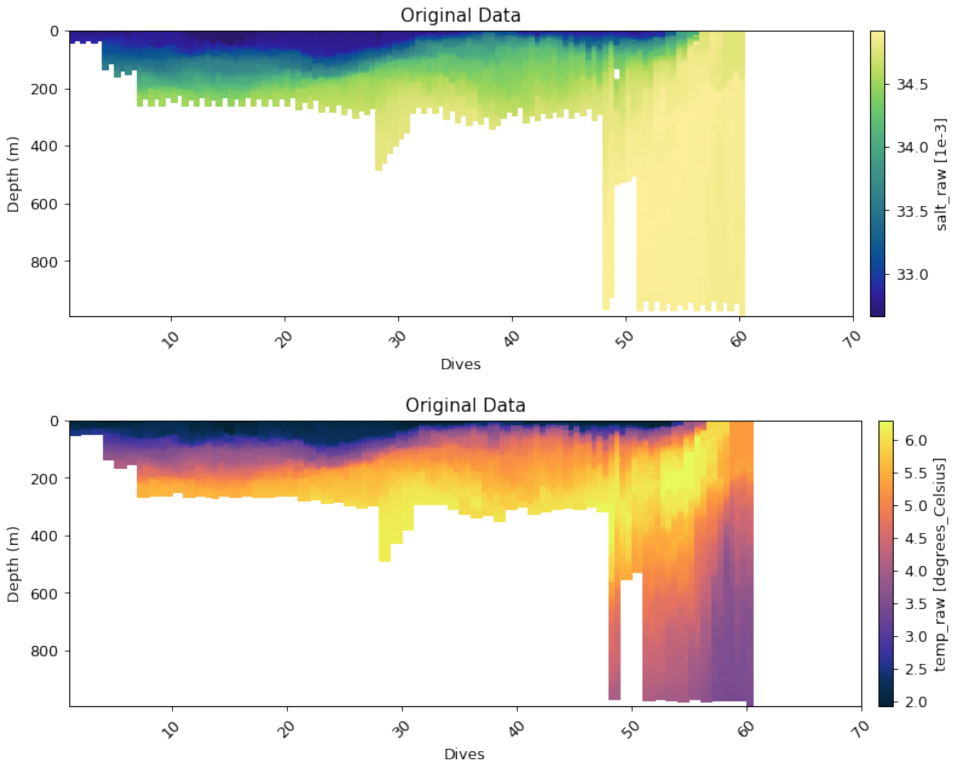

Figure 10.4: Sections of salinity (top) and temperature (bottom) from sg638.

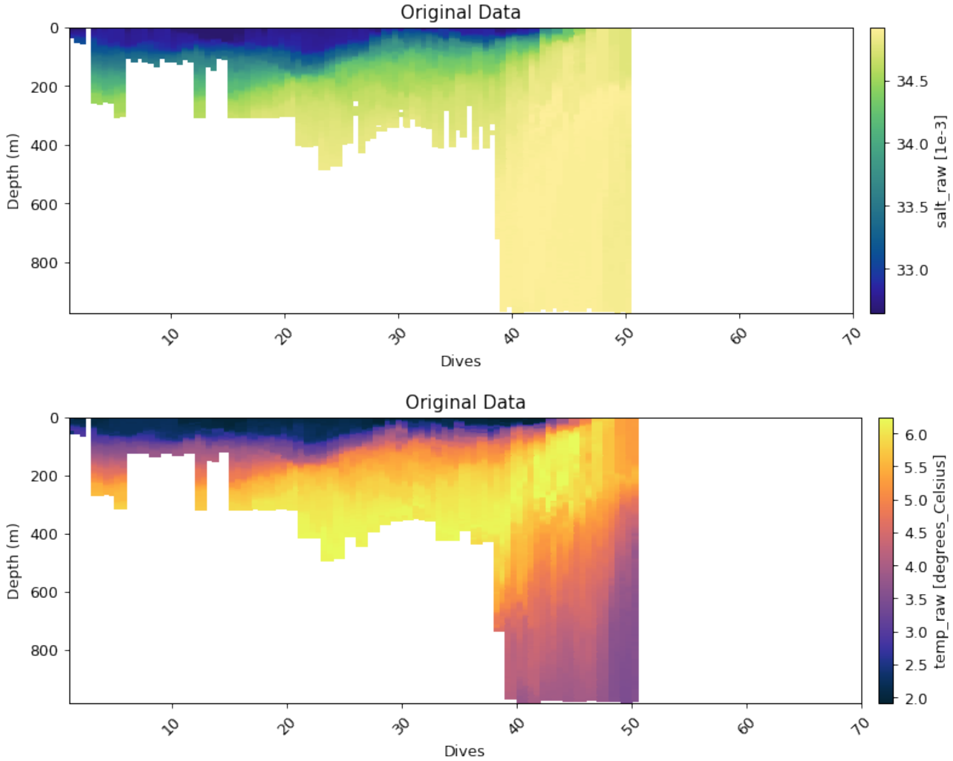

Figure 10.5: Sections of salinity (top) and temperature (bottom) from sg602.

11 Acknowledgments

Many thanks to 60North for their exceptional help and friendliness. Fiamma Straneo for advice and recommendations for working in south Greenland. Eric Siegel and Annie Fergusson from RBR for wiring diagrams for the RBR cable. David Peddie for piloting the Sailbuoy while we were at sea. The NOC MARS group for glider preparations and especially Steve Woodward and Adeniyi Adenaya for mid-fieldwork assistance and piloting. NKE for advice on testing the drifters; CLS for updates of Seechart so we could see the drifters and data.

A Planning

A.1 Field site

We were based in Qaqortoq, Greenland. The tourist map is in Fig. A.1, as posted in the Heliport waiting room.

Figure A.1: Photograph of the map on the wall in the Qaqortoq heliport.

- Population: 3000
- Nearest airport: Narsarsuaq (UAK, 60km away, accessible by helicopter or ferry)
- Amenities: Port (receives containers), 1 hotel, 1 hostel, grocery store, cafe with wifi
- Currency: Danish krone (100 dkk = £12)
- Language: Greenlandic, Danish

- Phone numbers for taxi: +299 64 11 11 and +299 64 44 44.

Accommodation was secured through `60north.gl`, their Apartment B642 units 1, 2 and 3. The B642 apartment is in the city centre, across the street from a small grocery store (Pissifik Elia). Each apartment has one bedroom, a small kitchen, a bathroom and living area. Laundry is situated behind the building.

- Contact: Rasmus Chr. Rasmussen (Director), Jimmy Hansen (Vice President)
- Address: 60 North Greenland Aps, Torvevej 163, Postboks 199, 3920 Qaqortoq
- Telephone: +299 64 31 87
- Email: booking@60north.gl
- Email: rasmus@60north.gl (Rasmus), jimmy@60north.gl (Jimmy)

A.2 Stores and services

The city is well-developed with multiple supermarkets, a couple of restaurants, a post office, electronics store, home store and schools. We visited most of the stores in Qaqortoq. We visited most of the stores in Qaqortoq. Location numbers for the town map in Fig. A.1 are given after the store name.

Stores:

Pissifik Elia, 30 A smaller grocery store, with some fresh fruit and vegetables, frozen meats, dairy (milk, butter, eggs), canned and jarred goods, and a small selection of batteries and other household essentials.

Brusen supermarket, 18 A large grocery store with a good selection of fresh fruit and vegetables, household essentials (batteries, fishing and camping gear), and also beer and wine.

Pissifik Pilivik, 14 A large grocery store with perhaps the largest selection of fresh foods, and an upstairs section with clothing, electronics, kitchen appliances and makeup.

Spar supermarket, 19 A much smaller grocery store with limited selection of snack-type foods and wide selection of somewhat random stuff (pantyhose, stationery).

Other shops and services:

Tele-Post, 27 A post office with a selection of mobile devices and services (including Iridium and Garmen satellite phones). Monthly plans including data start from 299 dkk/mo (£36.50/mo), or pre-paid plans from Tusass (`tusass.gl`). Pre-paid plans cost 100 dkk/250 mb of data (about 20p/mb) and 1.75 dkk/minute for local calls.

Stark hardware, 11 A smaller hardware store with tools, small toolboxes, some line (available in complete spools), foul weather gear, red work vests with compressed gas (~700 dkk), and electronic supplies. A taxi ride from the city centre to here cost 60 dkk.

Olie Kompagniet, near 6 A gas station with small selection of marine supplies including line by the metre, small hardware for splicing eyes into line and various chemicals including some loctite.

Greenland Sagalands, 1 A tourist information shop with some terrain maps, souvenirs (t-shirts, postcards and stamps, local crafts, and some local guided excursions.

Arctic Import, on the road between 18 and 15 Apparently an electronics repair shop (from Google search) but we found a good selection of basic stationery supplies (pens, markers, clipboards, report folders, notebooks). Near here were also two hair salons.

Royal Arctic line depot, near 34 This is the loading and container storage area for the Royal Arctic line. It appears that ships use the cranes on the vessel for loading/unloading. Smaller cruise ships also docked alongside (Fig. A.2).

Figure A.2: (Left) Waterside. 60North is in the 2-story pale green building. (Right) Royal Arctic Line depot.

Restaurants:

Hotel Qaqortoq - restaurant, 2 A hotel overlooking the water at Qaqortoq with a cafe and restaurant. The cafe has reasonably priced food (hamburger for 99 dkk, veggie burger, pasta dishes with chicken or salmon, grilled meats, salads, open-faced sandwiches), a couple beers on tap and some wine. The cafe is open from noon. It is pub-style (order and pay at the bar, food brought to table). The second, fancier restaurant is not open in the winter.

Cafe Heidi, 16 A cafe at Sinniffik Inn with cappucinos, a few pasta dishes, burgers and nachos. One pasta dish was vegetarian.

Rockhouse bar, 28 This is a local bar open from 3pm.

Inbox Thai Cafe, 34 In the back of the Royal Arctic Line warehouse. Closed from 30 November - 30 January for holiday.

A.3 Mobile and communication

Based on our visit to Greenland in August, we determined that we would need mobile internet access. Mobile data prices for UK plans were mostly exorbitant (Table A.1). We had Virgin Mobile (Eleanor, Ilona) and O2 (Jared), as well as a Tusass prepaid card. Internet was available (wifi) in the B642 apartments, though it was not very fast (3 MBps download, 3.3 Mbps upload, SSID: `60North_1`, password: B642Greenland, and `60North2`, password: SNTB642Greenland).

Carrier	plan	Make calls (per min)	Receive call (per min)	Send text	Data (per MB)
Virgin Mobile	pay monthly	£4.80	£1.50	£1.20	£12.50
Three	prepaid	£2.00	£1.25	35p	£6.00
1pmobile	prepaid	£1.75	£1.75	25p	50p
O2	pay monthly (>20gb)	120 min		120 txt	included
Tusass (GL)	prepaid	21–37p		2p	10p

Table A.1: Mobile costs in Greenland.

A.4 Emergency services in Greenland

Useful contacts in Greenland (from `https://bit.ly/2GKXWrZ`).

- Marine Rescue Coordination Centre (MRCC) and Island Commander Greenland
  Arktisk Kommando
  TEL: +299 69 19 11 FAX: +299 69 19 49
  AFS: BGGDYXYX
  Email: ako@mil.dk
- Rescue Coordination Centre (RCC) Sondrestrom, Kangerlussuaq
  NAVIAIR
  P.O. Box 1005
  DK-3910 Kangerlussuaq
  TEL: +299 84 12 01, or 84 11 35 and 84 10 34
  FAX: +299 84 10 20
  AFS: BGSFYCYX
  E-mail: rcc@naviair.dk
- The Secretariat, Operational Section, at The Chief Constable Office, Nuuk
  P.H. Lundsteensvej 1
  P.O. Box 1006
  DK-3900 Nuuk
  TEL: +299 32 14 48 local 258/259 FAX: +299 32 41 94
  AFS: BGGHYCYX
  E-mail: politi@politi.gl
- Selected local police stations
  Qaqortoq: TEL: +299 64 22 22
  Narsarsuaq: TEL: +299 665 222, Mobile: +299 497 414, FAX: +299 665 450
- Hospital in Qaqortoq
  TEL:+299 64 22 11
- Radio Administration
  P.O. Box 399
  DK-3920 Qaqortoq
  Tel: +299 64 31 22 FAX: +299 64 31 23
  E-mail: Radioforvaltningen@nanoq.gl

- In case of emergency, dial 112
- In case of fire, dial 113

B NKE drifter calibration sheets

Calibration Report

nke INSTRUMENTATION

Date : 01/10/2019
Product : Mosens CT
Serial number : 4A5C

Temperature (T90) Date : 01/10/2019 4A5C

Accuracy: 5 m°C
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

7 calibration points - Bennett equation

Reference temperature (°C)	Temperature (°K)	Raw data	Calculated temperature (°C)	Deviation (°C)
34,7758	307,9258	24179,00	34,7758	0,0000
29,808	302,958	29687,00	29,8076	0,0004
24,8943	298,0443	36575,00	24,8944	-0,0001
20,0168	293,1668	45256,00	20,0167	0,0001
15,1434	288,2934	56324,00	15,1436	-0,0002
10,2072	283,3572	70748,00	10,2068	0,0004
5,1229	278,2729	90096,00	5,1230	-0,0001

Bennett Coefficients t(°C) = 1 / (A+B*LN(x)+C*LN(x)^2+D*LN(x)^3) - 273,15

Coefficient A **7,6823076233E-04**
Coefficient B **2,4915678659E-04**
Coefficient C **-2,0094012143E-06**
Coefficient D **1,6456374397E-07**

Conductivity Date : 03/10/2019 4A5C

Accuracy : 0,04 mS/cm
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

Raw data	Reference Conductivity (ms/cm)	Calculated conductivity (ms/cm)	Deviation (ms/cm)
114 138,00	33,9239	33,9172	0,0067
130 115,00	38,6895	38,6965	-0,0071
146 192,00	43,5105	43,5193	-0,0088
162 548,00	48,4449	48,4396	0,0053
179 397,00	53,5317	53,5229	0,0088
196 802,00	58,7864	58,7895	-0,0031
214 702,00	64,2208	64,2225	-0,0017

polynomial approximation

Coefficients p(dbar) = A*x^2+B*x+C

Coefficient A **2,61897E-11**
Coefficient B **0,000292742**
Coefficient C **0,163065476**

Page 1 de 1

Calibration Report

Date : 01/10/2019
Product : Mosens CT
Serial number : 4A5C

Temperature (T90) Date : 01/10/2019 4A5C

Accuracy: 5 m°C
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

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34,7758	307,9258	24179,00	34,7758	0,0000
29,808	302,958	29687,00	29,8076	0,0004
24,8943	298,0443	36575,00	24,8944	-0,0001
20,0168	293,1668	45256,00	20,0167	0,0001
15,1434	288,2934	56324,00	15,1436	-0,0002
10,2072	283,3572	70748,00	10,2068	0,0004
5,1229	278,2729	90096,00	5,1230	-0,0001

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Coefficient C **-2,0094012143E-06**
Coefficient D **1,6456374397E-07**

Conductivity Date : 03/10/2019 4A5C

Accuracy : 0,04 mS/cm
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

Raw data	Reference Conductivity (ms/cm)	Calculated conductivity (ms/cm)	Deviation (ms/cm)
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162 548,00	48,4449	48,4396	0,0053
179 397,00	53,5317	53,5229	0,0088
196 802,00	58,7864	58,7895	-0,0031
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Page 1 de 1

Calibration Report

Date : 01/10/2019
Product : Mosens CT
Serial number : 4A5C

Temperature (T90) Date : 01/10/2019 4A5C

Accuracy: 5 m°C
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

7 calibration points - Bennett equation

Reference temperature (°C)	Temperature (°K)	Raw data	Calculated temperature (°C)	Deviation (°C)
34,7758	307,9258	24179,00	34,7758	0,0000
29,808	302,958	29687,00	29,8076	0,0004
24,8943	298,0443	36575,00	24,8944	-0,0001
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Coefficient D **1,6456374397E-07**

Conductivity Date : 03/10/2019 4A5C

Accuracy : 0,04 mS/cm
Bain Fluke 7051A
Seabird SBE37SMP : 15/002

Raw data	Reference Conductivity (ms/cm)	Calculated conductivity (ms/cm)	Deviation (ms/cm)
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polynomial approximation

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Coefficient B **0,000292742**
Coefficient C **0,163065476**

Page 1 de 1

C Seaglider calibration sheets

C.1 SG602 CT calibration

SEA·BIRD SCIENTIFIC

Sea-Bird Electronics, Inc.
13431 NE 20th Street
Bellevue, WA 98005 United States

Phone +1-425-643-9866
Fax +1-425-643-9954
www.seabird.com

SERVICE REPORT

Service Request 1005506777
Date 23-APR-2019
Sales Order 315400617

CUSTOMER INFORMATION

Name: KONGSBERG UNDERWATER TECHNOLOGY INC
Account : 40280537
ROSS HEALY
ross.healy@km.kongsberg-us.com
2069538309

PO Number:

Bill To Address
19210 33RD AVE W;SUITE A;
LYNNWOOD,WA,98036,US

Ship To Address
19210 33RD AVE W;SUITE A;
LYNNWOOD,WA,98036,US

PRODUCT INFORMATION

Item: APL-GLIDER.LEGACY
Item Description: (LEGACY) APL Glider
Serial: CT-0272

Special Notes
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.

Problems Found:
Instrument's frequency "zero" was compared to Calibration sheet at checkin and it was within .5 Hz, our spec is within 1 hz. After calibration and frequencies were within .2Hz.

Services Performed:
Perform initial diagnostic evaluation.
Performed "POST" cruise calibration.

Item	Item Description	Qty

Unbilled Items

Item	Item Description	Qty
CAL_SEAGLIDER	Calibrate Seaglider conductivity and temperature sensors	1
CNCRTSEAGLDR	CONFIRM & RE-CERTIFY SEAGLIDER CTD	1

Page **1** of **1**

SEA·BIRD SCIENTIFIC

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0272
CALIBRATION DATE: 18-Jan-19

Glider APL TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

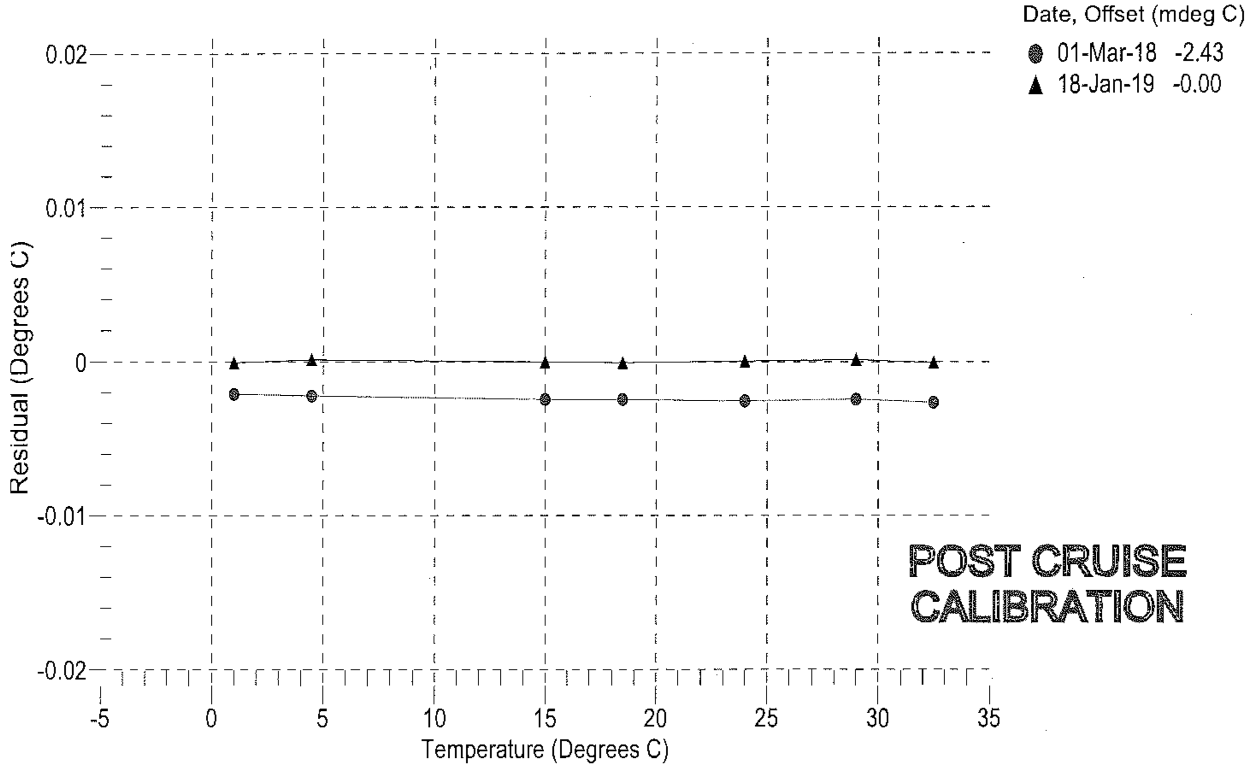
g = 4.41006584e-003
h = 6.46413445e-004
i = 2.59728773e-005
j = 3.14499373e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	3425.706	0.9999	-0.00006
4.5000	3700.634	4.5001	0.00010
15.0000	4619.542	15.0000	-0.00003
18.5000	4958.470	18.4999	-0.00009
24.0000	5525.346	24.0000	0.00004
29.0000	6077.908	29.0001	0.00013
32.5000	6486.230	32.4999	-0.00009

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0272
CALIBRATION DATE: 18-Jan-19

Glider APL CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.82776500e+000
h =   1.15834699e+000
i =  -2.98347742e-003
j =   3.07174351e-004

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

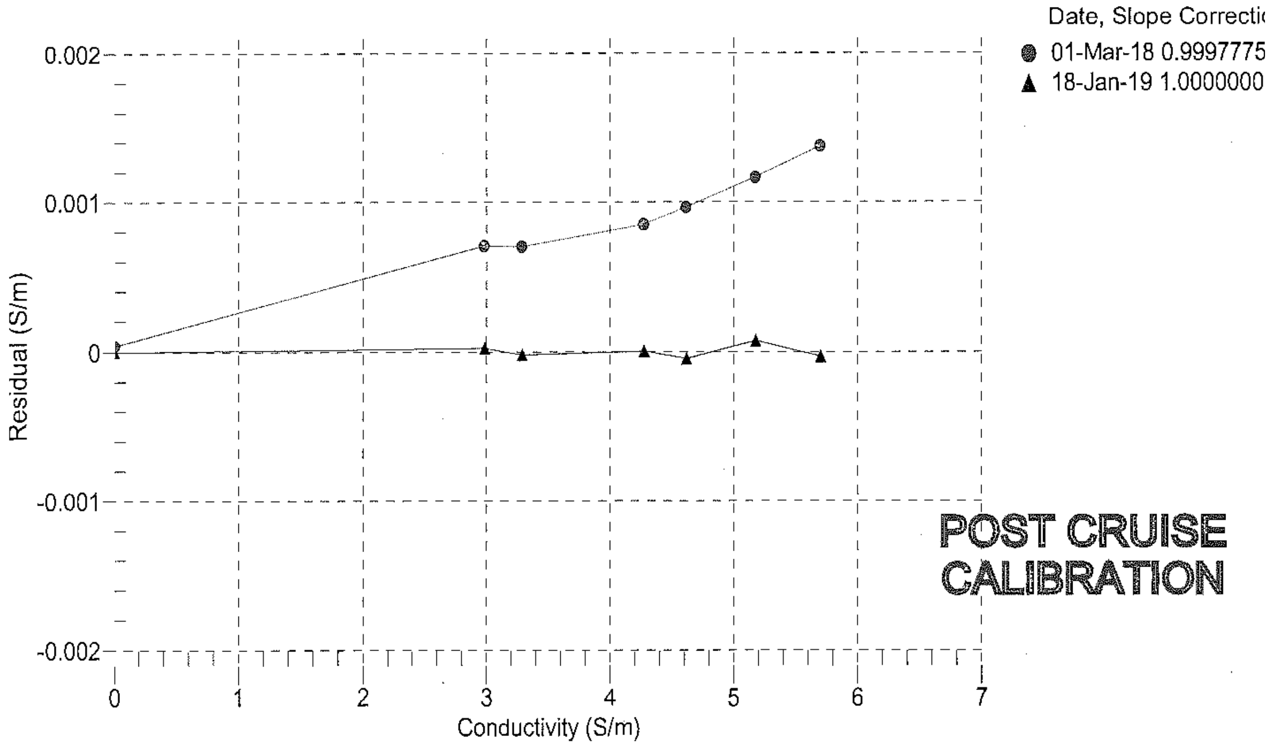
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2.92047	0.00000	0.00000
1.0000	34.8936	2.98194	5.86802	2.98197	0.00002
4.5000	34.8735	3.28959	6.09102	3.28957	-0.00002
15.0000	34.8305	4.27317	6.75412	4.27317	0.00000
18.5000	34.8218	4.61902	6.97198	4.61897	-0.00005
24.0000	34.8113	5.17796	7.31017	5.17804	0.00007
29.0000	34.8048	5.70065	7.61236	5.70062	-0.00003
32.5000	34.7993	6.07336	7.82076	6.07372	0.00036

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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C.2 SG602 WETLabs calibration

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 5/16/2018 S/N: BBFL2IRB-1171

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark counts)

	Digital
Dark counts	47 counts
Scale Factor (SF)	0.0129 µg/l/count
Maximum Output	4130 counts
Resolution	1.0 counts
Ambient temperature during characterization	22.3 °C

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations in-situ is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (Thalassiosira weissflogii). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO CDOM Fluorometer Characterization Sheet

Date: 5/16/2018 S/N: BBFL2IRB-1171

CDOM concentration expressed in ppb can be derived using the equation:

CDOM (ppb) = Scale Factor * (Output - Dark Counts)

	Digital
Dark Counts	42 counts
Scale Factor (SF)	0.0770 ppb/count
Maximum Output	4150 counts
Resolution	1.5 counts
Ambient temperature during characterization	22.3 °C

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

C.3 SG638 CT calibration

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0303
CALIBRATION DATE: 13-Mar-19

Glider APL TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

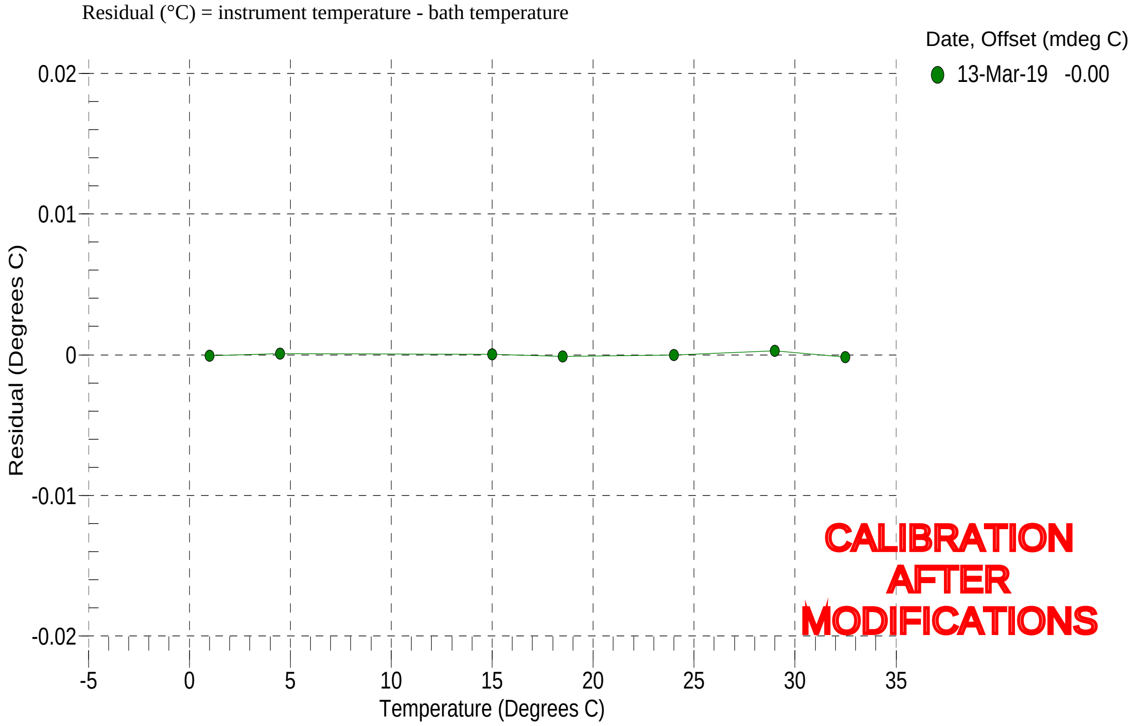
COEFFICIENTS:
g = 4.39715594e-003
h = 6.34557301e-004
i = 2.52009509e-005
j = 3.05416827e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	3429.727	0.9999	-0.00006
4.5000	3710.056	4.5001	0.00010
15.0000	4649.583	15.0000	0.00002
18.5000	4996.984	18.4999	-0.00013
23.9999	5578.952	23.9999	-0.00004
28.9999	6147.276	29.0002	0.00026
32.5000	6567.802	32.4998	-0.00015

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[\ln(f0 / f)] + i[\ln^2(f0 / f)] + j[\ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0303
CALIBRATION DATE: 13-Mar-19

Glider APL CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.93176708e+000
h =   1.16065782e+000
i =  -1.15047952e-003
j =   1.64438482e-004

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

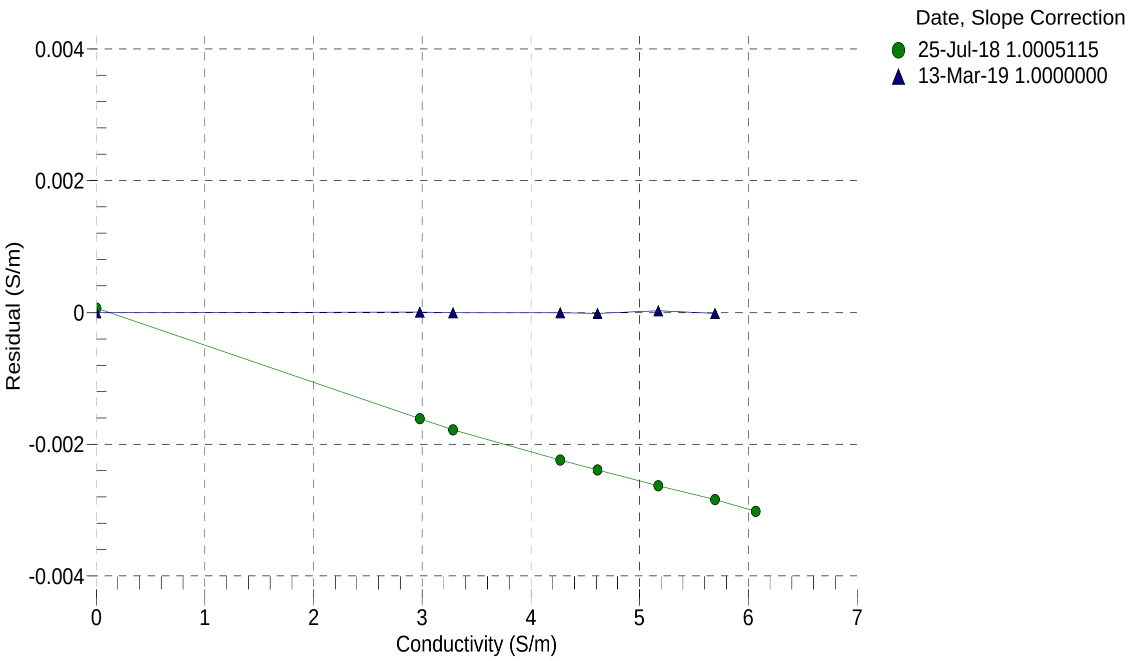
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2.92771	0.00000	0.00000
1.0000	34.8442	2.97812	5.85223	2.97813	0.00001
4.5000	34.8248	3.28545	6.07400	3.28544	-0.00000
15.0000	34.7830	4.26796	6.73365	4.26796	-0.00000
18.5000	34.7739	4.61335	6.95048	4.61333	-0.00002
23.9999	34.7627	5.17152	7.28709	5.17155	0.00003
28.9999	34.7552	5.69343	7.58804	5.69342	-0.00001
32.5000	34.7477	6.06538	7.79530	6.06534	-0.00004

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) /10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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C.4 SG638 Optode calibration

AANDERAA a xylem brand **CALIBRATION CERTIFICATE**

Form No. 710, Nov 2013

Sensing Foil Batch No: 1206
Certificate No:

Product: Oxygen Optode 4831
Serial No: 103
Calibration Date: 07 Jun 2018

This is to certify that this product has been calibrated using the following instruments:

Parameter: Internal Temperature*:*

Calibration points and readings:

Temperature (°C)	0.96	11.97	24.02	36.01
Reading (mV)	775.08	436.71	44.09	-325.62

Giving these coefficients

Index	0	1	2	3	4	5
TempCoef	2.53888E01	-3.12001E-02	2.95491E-06	-4.33330E-09	0.00000E00	0.00000E00

Parameter: Oxygen:

	O2 Concentration	Air Saturation
Range:	0-500 µM [1]	0 - 120%
Accuracy[1]:	< ±8µM or ±5% (whichever is greater)	±5%
Resolution:	< 1 µM	< 0.4%
Settling Time (63%):	< 25 seconds	

Calibration points and readings[2]:

	Air Saturated Water	Zero Solution (Na_2SO_3)
Phase reading (°)	3.22363E+01	6.09086E+01
Temperature reading (°C)	9.90761E+00	2.41800E+01
Air Pressure (hPa)	9.86176E+02	

Giving these coefficients

Index	0	1	2	3
PhaseCoef	0.00000E00	1.00000E00	0.00000E00	0.00000E00
ConcCoef	-2.45992E00	1.10723E00		

[1] *Valid for 0 to 2000m (6562ft) depth, salinity 33 - 37ppt*

[2] *The calibration is performed in fresh water and the salinity setting is set to:* 0

Date: 08 Jun 2018

Sign:

Tor-Ove Kvalvaag

Tor-Ove Kvalvaag, Calibration Engineer

CALIBRATION CERTIFICATE

Form No 770. , Jun 2008

Certificate No: 3853_1206E_41134
Batch No: 1206E
Product: O2 Sensing Foil PSt3
Calibration Date: 13 Aug 2012
Serial No: 1206

Calibration points and phase readings

Index	Temperature (°C)	Phase Reading (°)	Oxygen reference (µM)	Index	Temperature (°C)	Phase Reading (°)	Oxygen reference (µM)
0	3.088	63.586	0.00	32	39.178	34.676	86.08
1	3.087	59.547	19.04	33	39.178	26.472	179.90
2	3.091	56.583	38.07	34	39.173	22.918	258.25
3	3.091	50.047	95.17	35	6.512	63.396	0.00
4	3.088	42.297	190.35	36	6.512	59.118	17.49
5	3.088	33.166	397.83	37	6.514	56.071	34.98
6	3.087	28.868	571.06	38	6.513	49.146	87.46
7	9.936	63.206	0.00	39	6.513	41.334	174.92
8	9.937	58.688	15.95	40	6.515	32.286	365.56
9	9.937	55.558	31.90	41	6.514	28.070	524.73
10	9.936	48.245	79.75	42	14.845	62.851	0.00
11	9.937	40.371	159.49	43	14.846	58.053	14.34
12	9.941	31.406	333.29	44	14.847	54.780	28.69
13	9.941	27.271	478.41	45	14.846	47.231	71.72
14	19.753	62.495	0.00	46	14.845	39.292	143.45
15	19.756	57.418	12.74	47	14.849	30.439	299.78
16	19.757	54.002	25.48	48	14.851	26.415	430.28
17	19.755	46.217	63.70	49	24.657	62.056	0.00
18	19.753	38.213	127.40	50	24.641	56.776	11.58
19	19.756	29.471	266.26	51	24.639	53.228	23.16
20	19.761	25.559	382.15	52	24.642	45.285	57.89
21	29.560	61.617	0.00	53	24.640	37.283	115.79
22	29.526	56.133	10.42	54	24.641	28.666	241.99
23	29.521	52.454	20.84	55	24.643	24.833	347.33
24	29.528	44.354	52.08	56	34.379	61.214	0.00
25	29.527	36.353	104.17	57	34.356	55.482	9.51
26	29.526	27.861	217.71	58	34.354	51.696	19.02
27	29.525	24.107	312.51	59	34.355	43.480	47.56
28	39.198	60.811	0.00	60	34.353	35.515	95.12
29	39.186	54.832	8.61	61	34.352	27.167	198.81
30	39.186	50.938	17.21	62	34.349	23.513	285.38
31	39.182	42.606	43.03	63			

AANDERAA a xylem brand CALIBRATION CERTIFICATE

Giving these coefficients

Index	FoilCoefA	FoilCoefB
0	-2.988314E-06	-3.560390E-07
1	-6.137785E-06	3.816713E+03
2	1.684659E-03	-4.475507E+01
3	-1.857173E-01	4.386164E-01
4	6.784399E-04	-7.146342E-03
5	-5.597908E-07	8.906236E-05
6	1.040158E+01	-6.343012E-07
7	-5.986907E-02	0.000000E+00
8	1.360425E-04	0.000000E+00
9	-4.776977E-07	0.000000E+00
10	-3.032937E+02	0.000000E+00
11	2.530496E+00	0.000000E+00
12	-1.267045E-02	0.000000E+00
13	1.040454E-04	0.000000E+00

Using the following monomial degrees

Index	FoilPolyDegT	FoilPolyDegO
0	1	4
1	0	5
2	0	4
3	0	3
4	1	3
5	2	3
6	0	2
7	1	2
8	2	2
9	3	2
10	0	1
11	1	1
12	2	1
13	3	1
14	4	1
15	0	0
16	1	0
17	2	0
18	3	0
19	4	0
20	5	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0

Date: 13 Aug 2012

Sign: Tor-Ove Kvalvaag

Tor-Ove Kvalvaag, Calibration Engineer

C.5 SG6388 WETLabs calibration

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Scattering Meter Calibration Sheet

2/19/2019
Wavelength: 700 S/N BBFL2IRB-5496

Use the following equation to obtain "scaled" output values:

$$\beta(\theta_c)\ m^{-1}\ sr^{-1} = \text{Scale Factor} \times (\text{Output} - \text{Dark Counts})$$

• **Scale Factor for 700 nm**	=	3.595E-06	$(m^{-1}sr^{-1})$/counts	
• **Output**	=	meter reading	counts	
• **Dark Counts**	=	46	counts	
Instrument Resolution	=	1.1	counts	3.82E-06 $(m^{-1}sr^{-1})$

Definitions:

- **Scale Factor**: Calibration scale factor, $\beta(\theta_c)$/counts. Refer to User's Guide for derivation.
- **Output**: Measured signal output of the scattering meter.
- **Dark Counts**: Signal obtained by covering detector with black tape and submersing sensor in water.

Instrument Resolution: Standard deviation of 1 minute of collected data.

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ECO Chlorophyll Fluorometer Characterization Sheet

Date: 2/19/2019 S/N: BBFL2IRB-5496

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark counts)

	Digital
Dark counts	46 counts
Scale Factor (SF)	0.0120 µg/l/count
Maximum Output	4130 counts
Resolution	1.0 counts
Ambient temperature during characterization	23.3 °C

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations in-situ is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (Thalassiosira weissflogii). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

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ECO CDOM Fluorometer Characterization Sheet

Date: 2/19/2019 S/N: BBFL2IRB-5496

CDOM concentration expressed in ppb can be derived using the equation:

CDOM (ppb) = Scale Factor * (Output - Dark Counts)

	Digital
Dark Counts	50 counts
Scale Factor (SF)	0.0913 ppb/count
Maximum Output	4130 counts
Resolution	1.0 counts
Ambient temperature during characterization	23.3 °C

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

BBFL2IRB-5496.xls Revision S 10/4/07

D RBR XR420 calibration coefficients

The latest calibration coefficients from the RBR were:

```
Calibration  1: -0.182001938000000
                120.689619900000000
                0.004007656000000
                -0.014377576000000 mS/cm
Calibration  2: 0.003509024000000
                -0.000256746200000
                0.000002257374000
                -0.000000137101500 Degrees_C
Calibration  3: 0.436861261849000
                1620.004437743449900
                116.061641931533000
                73.533119827975000 deciBars
```