

NSF-INSPIRE: Acoustic Sensor Networks for Ice-Covered Seas

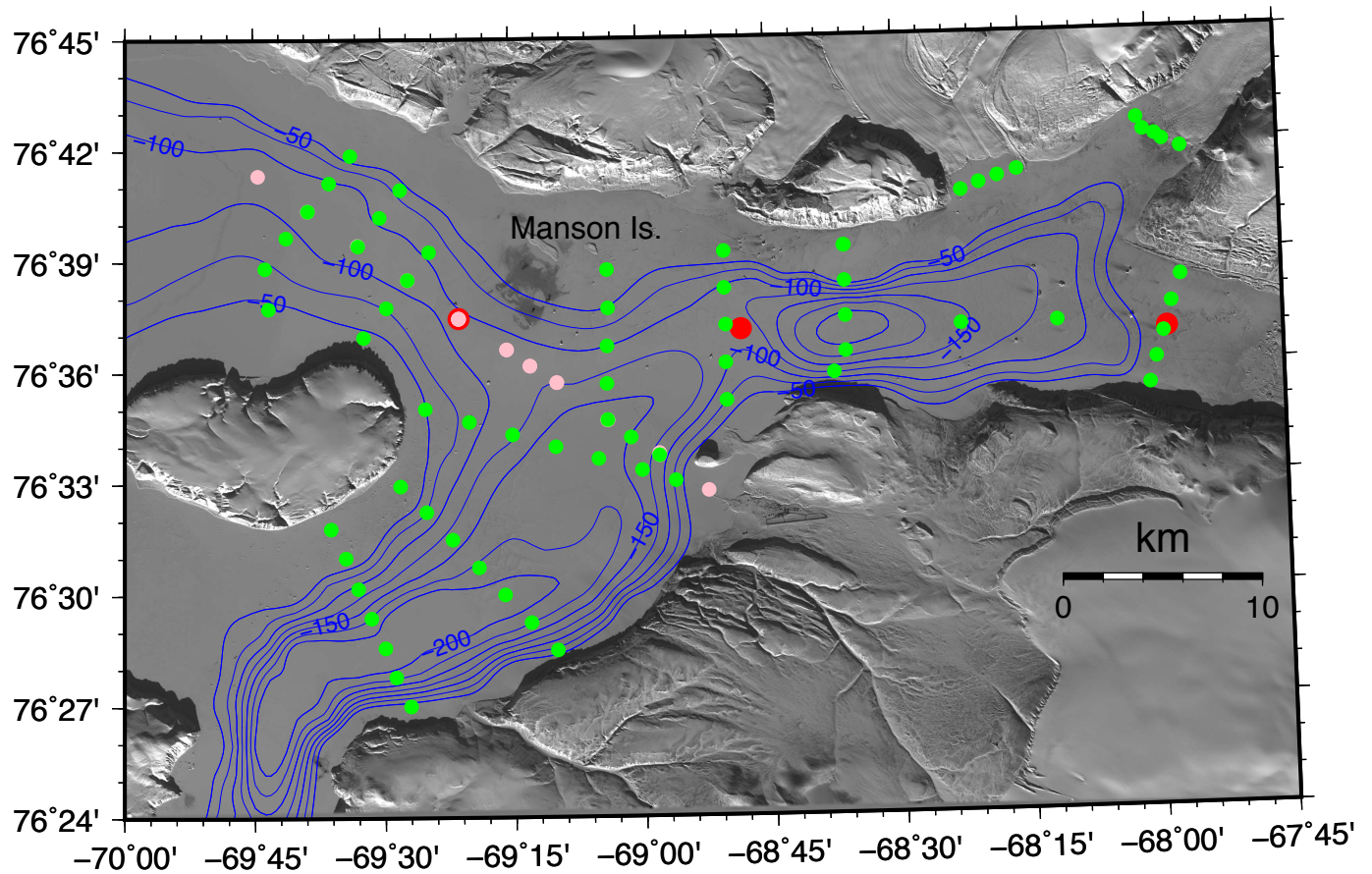
Preliminary Expedition Report

March 11 to April 21, 2017

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University of Delaware

April 29, 2017



Wolstenholme Fjord, Greenland with Spring 2017 science stations. Red dots are acoustic mooring locations.

1. Introduction

The US National Science Foundation (NSF) funded a project to “design and develop an integrated underwater acoustic sensor network for ice-covered seas.” Wolstenholme Fjord adjacent to Thule Air Base (TAB) in Greenland was identified to test and deploy this communication network to provide a real-time data connection between a remote transmit and a coastal receive unit via several data hops from modem to modem. The envisioned system shares features of a cell phone network where data passes from caller to receiver via cell phone towers.

The fjord is covered by land-fast sea ice during spring and thus provides a stable platform from which to test, deploy, and recover a range of oceanographic and acoustic sensor systems via snowmobiles during day-light hours when air temperatures are generally above -25°C .

During the first phase from Mar.-11 through Mar.-25 we conducted ice thickness surveys, placed an automated weather station (AWS) on the sea ice along with a provisional shelter and deployed an oceanographic thermistor mooring in water 110 m deep at the center of the study area.

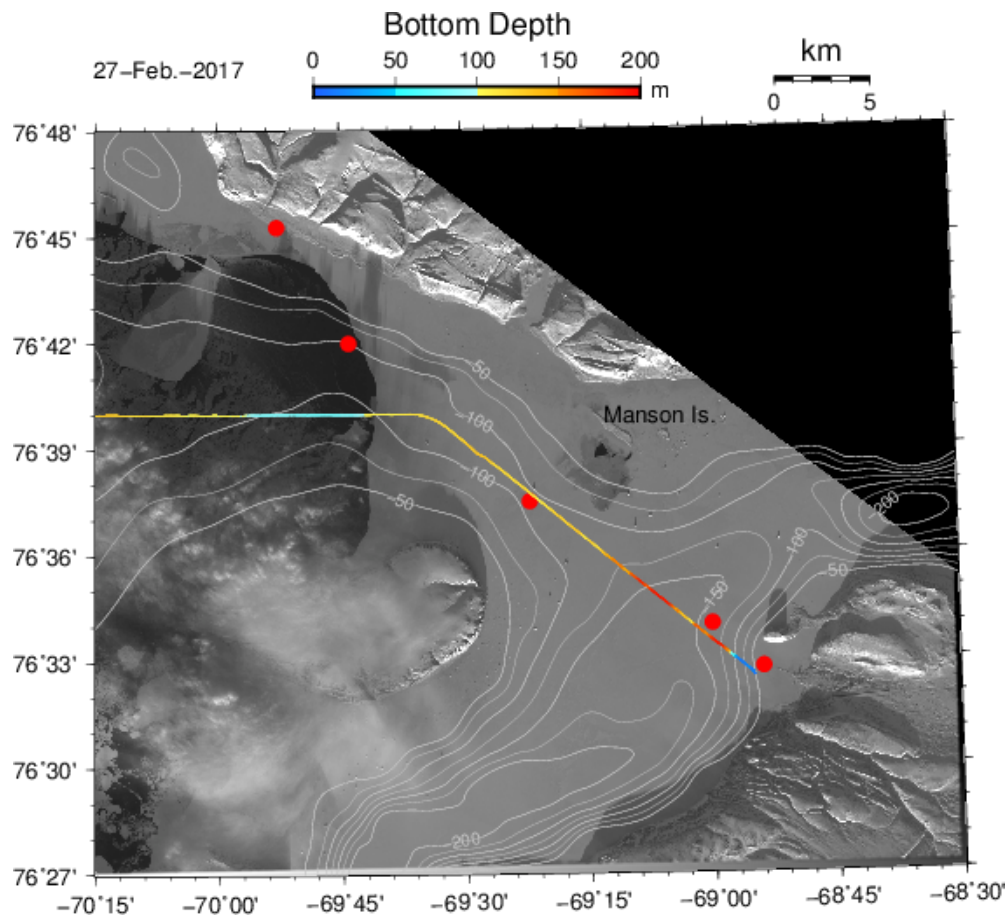


Figure-1: LandSat image of Wolstenholme Fjord on Feb.-27, 2017 with bottom contours. Thule Air Base is at bottom right. Dark areas are thin ice or open water such as the recurrent polynya to the south of Manson Islands. Red dots are station locations between Thule Pier (bottom right) and the abandoned town of Moriuaq (top left). Colored lines indicate depths measured by USCGC Healy in 2003.

A second phase (Mar.-26 to Apr.-6) included the design, construction, and deployment of research sled *R/S Peter Freuchen*. The sled was towed by a snow machine and carried electrical winch, 2kW generator, tripod, self-contained CTD sensors, battery-powered echo-sounders and GPS. It enabled efficient measurement of vertical profiles of sea water properties such as temperature and conductivity at 84 locations throughout the fjord from which to estimate salinity, density, and speed of sound.

A final third phase (April-7 to April-19) included testing and deployment of the acoustic array and its integration with the automated weather station. The project succeeded in the demonstration that ocean data can be moved acoustically from a source via a node and forwarded by the node to a base station connected by cable to the weather station transmitting data via Iridium phone to any receiving location. Our accomplished range of ~ 40 km was limited only by the extend of land-fast sea ice not acoustic capabilities. We thus feel comfortable to deploy the entire array in August 2017 for a 6-9-month operational deployment in Wolstenholme Fjord.

	Phase	Tasks	Personnel
1.	Mar.-11 to Mar.-25	Ice Thickness Surveys, AWS and Ocean Mooring	Muenchow ¹ , Jacobsen ²
2.	Mar.-26 to Apr.-6	Ocean Property Surveys, Ocean Moorings	Muenchow, Huntley ¹ , Jacobsen
3.	Apr.-7 to Apr.-19	Acoustics Ocean Property Surveys Mooring recoveries	Freitag ³ , Johnson ³ , Washam ¹ , Muenchow, Huntley, Jacobsen

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2. Remote Sensing

Safe navigation by snowmobile on sea ice requires up-to-date knowledge of landmarks such as icebergs, sea ice, open water, and features on land. LandSat provides 15-m resolution optical imagery that we used extensively. Geo-referenced .tif files were acquired and processed at the University of Delaware to aid navigation on the sea ice. Figure-1 shows the first such image for 2017 that shows a large area of open water in the north-west of our study area. Subsequent LandSat imagery shows this area to be covered by land-fast ice during our ice and ocean surveys. Cloud-free LandSat images for our study area are available at about weekly intervals.

Date	LandSat-Path-Row-Time
Feb.-27	LC8-031-006-2017060-LGN00
Mar.-13	LC8-033-005-2017072-LGN00
Mar.-22	LC8-032-005-2017083-LGN00
Mar.-24	LC8-030-006-2017083-LGN00
Mar.-31	LC8-031-006-2017090-LGN00
Apr.-2	LC8-029-006-2017092-LGN00
Apr.-5	LC8-034-005-2017095-LGN00
Apr.-7	LC8-032-005-2017097-LGN00
Apr.-14	LC8-033-005-2017104-LGN00
Apr.-16	LC8-031-005-2017106-LGN00
Apr.-21	LC8-034-005-2017111-LGN00

Augmenting optical imagery, we also acquired and processed complementary synthetic aperture radar (SAR) data provided by the European Space Agency (ESA) via the public data archive at

<https://scihub.copernicus.eu/dhus/>

We use Sentinel-1 GRD files in HH polarization and IW mode which gives spatial resolutions of better than 15-m. These are ~800 MB geo-referenced .tif files processed with the SNAP software provided by ESA that include calibration, geometric corrections, conversion to engineering units, and sub-setting to our study area. Unlike LandSat the SAR imagery is little impacted by either cloud-cover or the polar night. Sentinel-1 has a 6-day repeat orbit which for the Thule study region occurs March-7 (Sentinel-1B), March-13 (Sentinel-1A), etc., to April-18 (Sentinel-1A). Interpretation of the SAR (and LandSat) imagery requires verification in terms of ice thickness and snow cover.

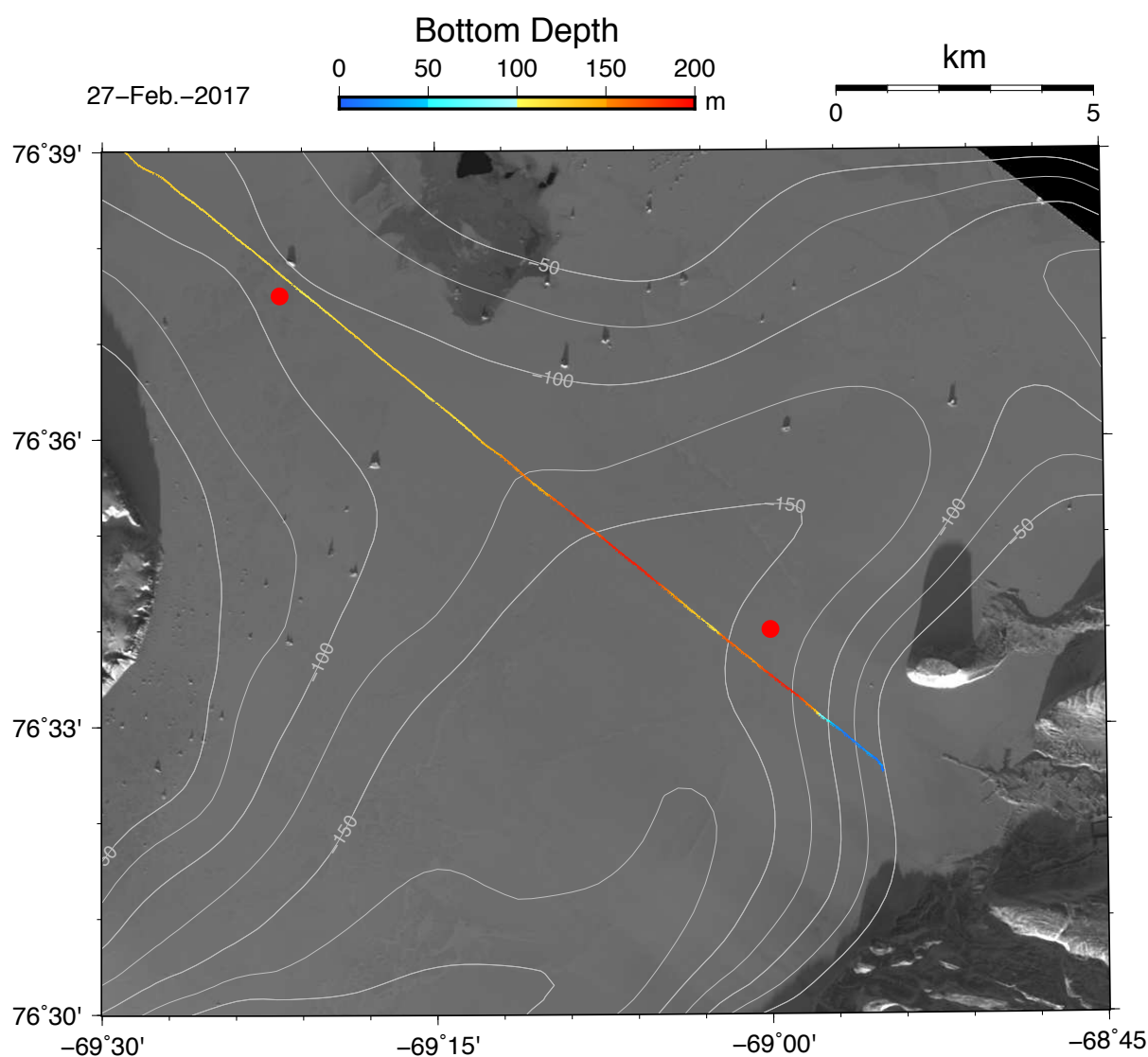


Figure-2: Navigational detail on 15-m resolution LandSat imagery such as large icebergs that were used to avoid thin sea ice of the Manson Island polynya (76:38 N 69:15 W). Red dot 2 km to the east is our AWS. Mount Dundas and Thule Pier are in the bottom right corner.

3. Ice Reconnaissance

A first sea ice thickness and snow depth survey was conducted close to shore and TAB collaboratively with a group from the US Naval Academy on Mar.-10/11 when air temperatures dropped to -33 °C. The surveys utilized a Kovacs 2'' drill with expendable blades that were powered by an 18 V DeWalt hand drill. Batteries and drill bit were attached and removed immediately before and after a hole was drilled and stored close to the body in order to save battery power in the cold and prevent accidental damage to the sharp edges of the drill. We averaged about 10 holes per 18 V battery pack in first-year sea ice about 0.9 to 1.3 m thick.

More extensive surveys were conducted Mar.-18 to Mar.-23 with an emphasis on the area to the east and west of the Manson Island Polynya where we measured sea ice as thin as 0.12 m. The thickest ice we found near Thule Pier at 1.28 m in April. The surveys aided interpretation of remotely sensed sea ice features captured by 15-m resolution LandSat and Sentinel data. Ice thickness measurements were shared with the National Ice Center who also provided us with daily assessment of ice cover in our study area.

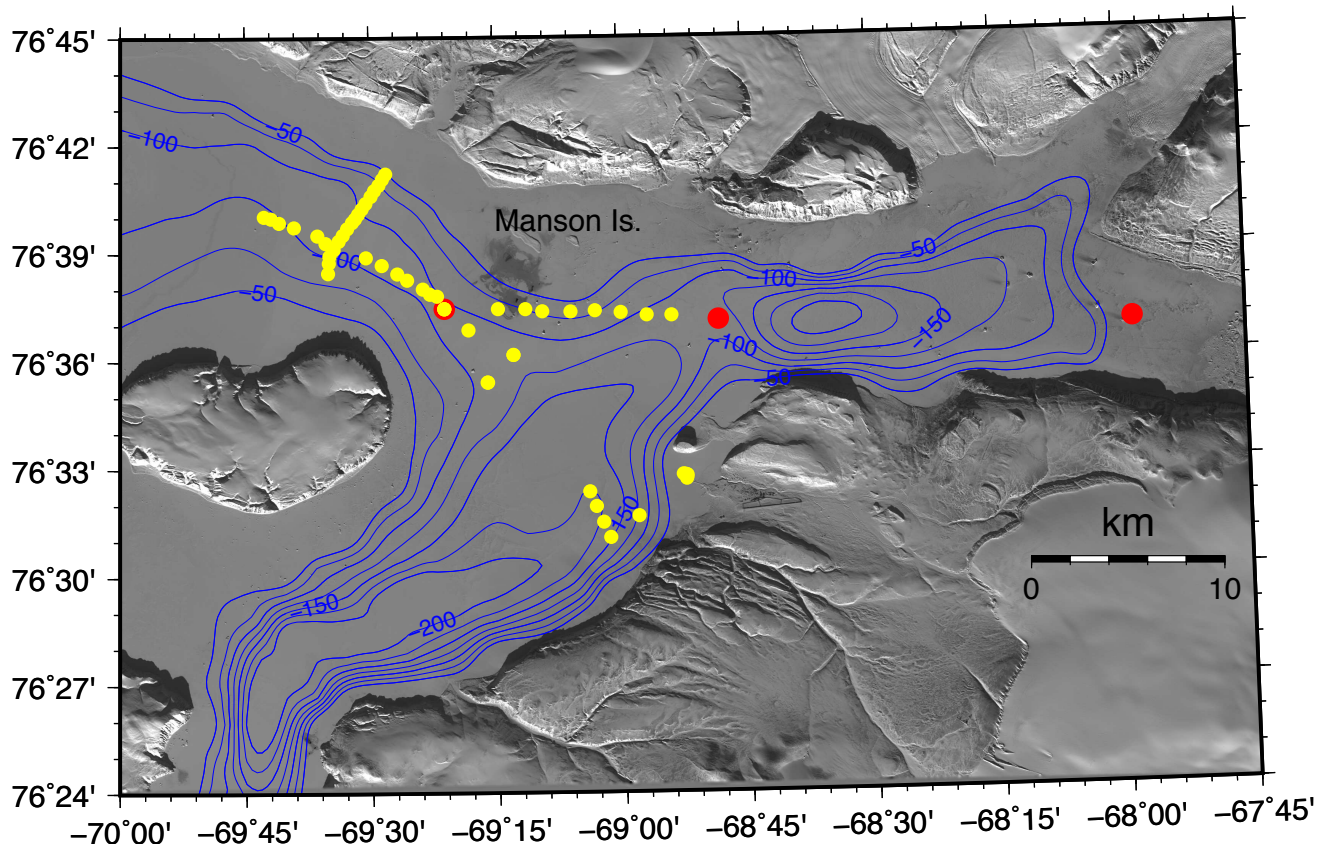


Figure-3: Sea ice thickness surveys Mar.-11 to Mar.-23 2017 (yellow) over IBCAO bottom topography (blue contours) and LandSat image from Mar.-22, 2017. Red dots are final acoustic modem location with the receive modem connected to the AWS near 69° 21' W. Minimal ice thickness of 0.12 m was measured 2 km to east of the AWS near the polynya to the south of Mason Island.

4. Weather Station

An automated weather station (AWS) was placed Mar.-23, 2017 on the sea ice at

76° 37.463' N and 69° 21.077' W

after a successful test deployment outside Bldg.-353 at TAB. It was designed to report wind, air, and surface ocean temperature at the center of the sea ice study area via an Iridium satellite link to Bldg-353 every 30 minutes. This operational capability mitigates the risks of working away from the Air Base where local topography other than sea ice dominates atmospheric flows. Nevertheless, scientific goals were met such as acquisition of a time series of atmospheric and ocean conditions (via a cabled sensor). The AWS also served as the terminus for the acoustic receive modem whose data cable connects to the AWS.

Mechanical set-up took about 2.5 hours with 2 people. The wind sensor attachment caused some trouble, as it was unclear which piece connected to the central mast. We jury-rigged an acceptable solution from available pieces. Electrical connections took another 2 hours, because some wires attached to data logger and battery had come loose during travel over the ice by snowmobile. First data were uploaded via Iridium at 17:35 UTC as indicated by the modem turning on as scheduled in software.

The AWS is controlled by a Campbell Scientific CR1000 data logger and powered by a 55 Ah battery at 12 V that is recharged by a 20 W solar panel via a GenaSun regulator. Sensors include

3.2 m	R.M. Young Wind Monitor	Model 05103-5
2.6 m	Vaisala Humidity and Temperature Probe	Model HMP155
1.8 m	Vaisala Humidity and Temperature Probe	Model HMP155
2.5 m	Sonic Snow Depth Sensor	Model SR50
2.5 m	Iridium antenna	
1.0 m	Pressure sensor	

The wind sensor was oriented to true North at 18:34 UTC on Mar.-24, 2017 with the “nudge” on the south-side pointing towards me when I face North. Winds at the time were from the south-east to the north-west with the propeller facing towards TAB. Data were shared with the military weather forecasters daily at 05:30 am (local) via updated files posted at

<http://ows.udel.edu/ice>

The initial code is listed in the Appendix as it was running the station until April-15, 2017 when the acoustic communication network was connected to the serial port previously claimed by the snow depth sensor. About 12 software versions were uploaded to the AWS via Iridium to implement codes that captured the stream of acoustic data. Each of these frequent software updates requires a reboot of the CR1000 data logger with attendant intermittent data drops and sensor adjustments on April 15/16.

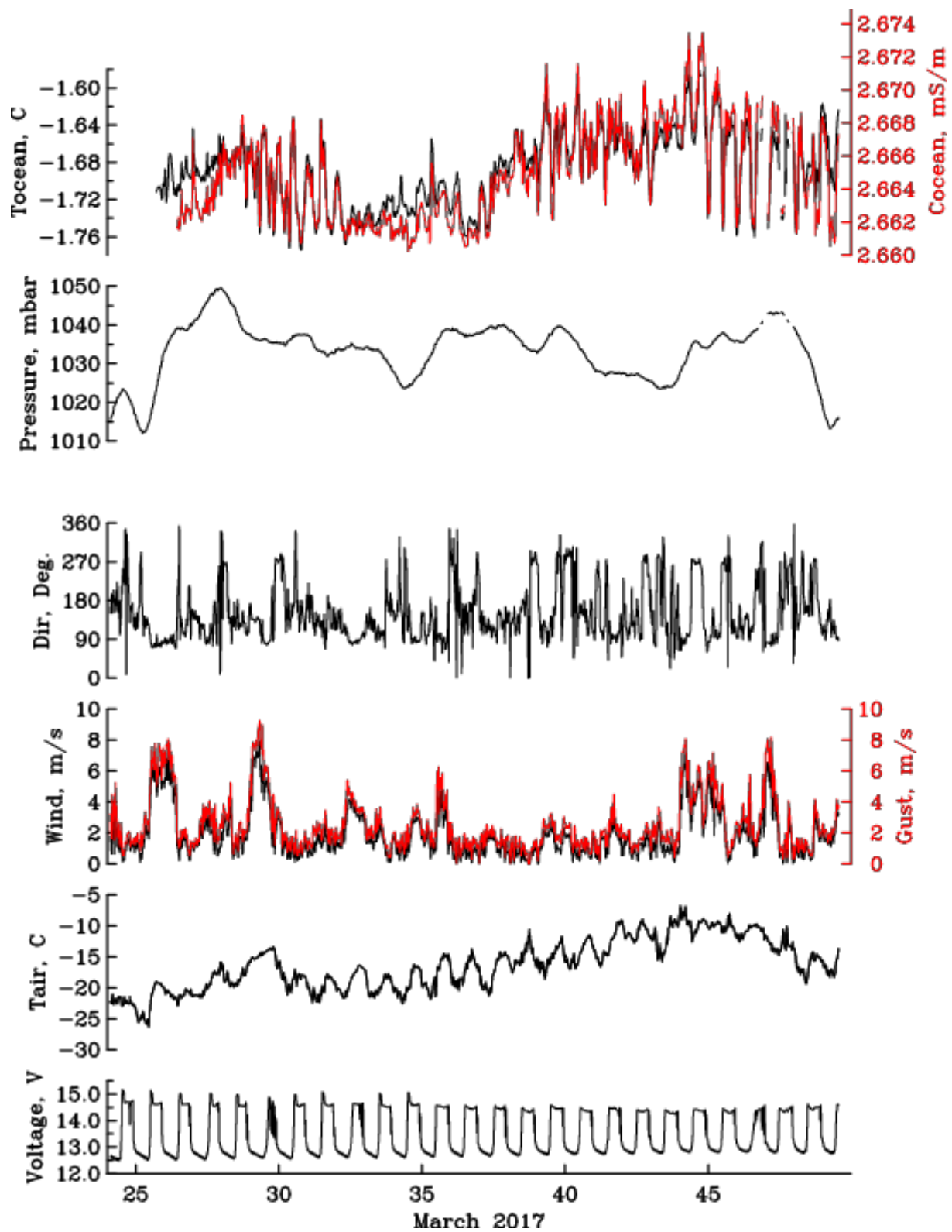


Figure-4: Time series of data received at Thule from the sea ice AWS via Iridium "Circuit Switched Data" from Mar.-25 through Apr.-18, 2017.

5. Ocean Moorings

A first ocean mooring was deployed at the AWS on Mar.-25, 2017 from the surface of the ice. It was successfully recovered on April-18 via a number of 2'' drill holes without loss or damage to sensors or attached cables and rope. A load-bearing 3/8'' Kevlar line was paired with two 3-conductor cables. The surface element of the mooring was 5-m below the top of the sea ice (0.63 m thick) and consisted of an SBE37sm (S/N 2910) that measured ocean temperature and conductivity and transmitted data via the 3-conductor cable to the AWS that distributed its data via Iridium along with the atmospheric data. We placed 20 self-contained Vemco Minilog II-T thermistors at 5-m intervals, that is, Vemco S/N 357-802 was placed at 10-m, S/N 357-801 at 15-m, etc., until S/N 357-783 at 105 m below the top of the sea. Vemco states temperature accuracy of 0.1 °C and clock stability of about 1 minute per month. A second cabled SBE37sm at 110-m (S/N 2920) failed, probably because of a faulty termination conducted on the sea ice to shorten the cable before connecting it to the AWS data logger.

Figure-5 shows a photo of the mooring after deployment through a 10'' hole and a rope tie-off to a piece of wood. All thermistors sampled temperature once every minute.

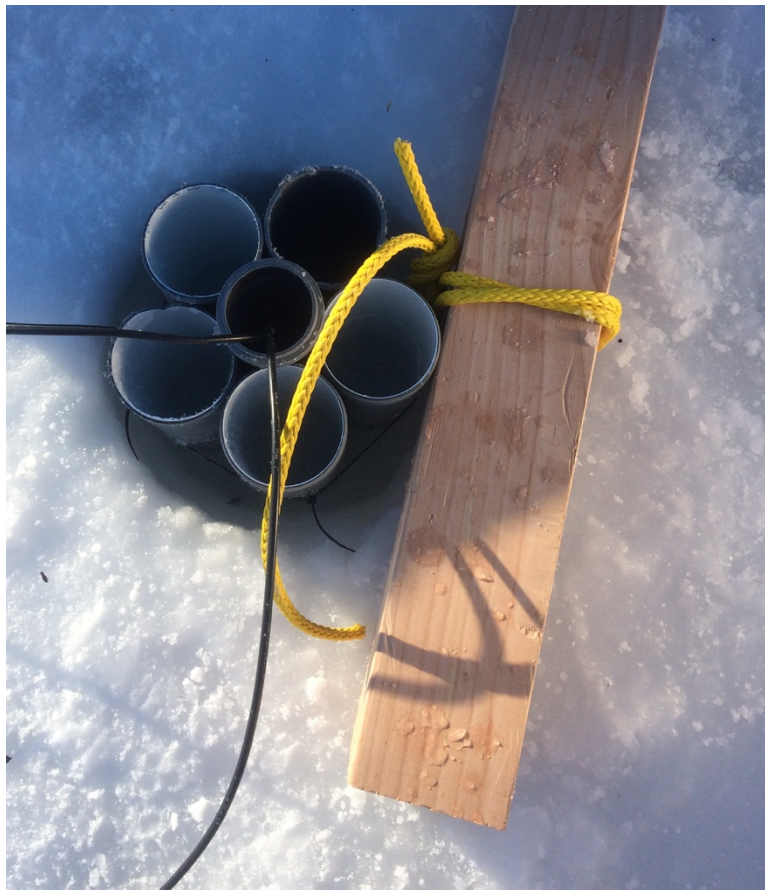


Figure-5: Surface termination of a through-ice ocean mooring. Yellow Kevlar rope and black conducting cables exit the ice via a 1 m PVC plumbing pipe surrounded by 0.5 m PVC pipe to guide 2'' drill holes to free the center pipe. The 2'' drilling worked fine during rapid recovery 3 weeks later.

A second type of ocean mooring was deployed via a single 2'' hole on Mar.-31 that fitted a round 1.9'' wooden stick with a pendulum attached to its bottom end deployed just below the underside of the sea

ice. These TCM-1 Current Meters made by Lowell Instruments, LLC in Woods Hole, MA measure accelerations along three orthogonal spatial axes as well as all three rotations around these axes. We deployed three such units at

68.96487 W	76.56305 N	S/N 125
69.16215 W	76.59527 N	S/N 124
69.35175 W	76.62428 N	S/N 126

The drag due to ocean currents causes deviations of the pendulum of its vertical position at rest, however, from careful laboratory calibrations of tilt angles and rotations these measured properties can be inverted to estimate ocean currents that caused the drag on the pendulum. It is a promising new and simple technology that we put to the test.



Figure-6: Deployment of a Lowell tilt sensors through 2'' drill hole on Mar.-31, 2017.



Figure-7: CTD storage box on sled. Notice the hair dryer inside the box (top right) that connects to a 2-kW generator in the adjacent aluminum box. The frame holds both SeaBird19plusV2 as well as RBRconcerto CTDs. The center part of the box is also covered by a loose piece of Styrofoam cover (not shown) that channels the warm air towards the sensors at the bottom of the box.

6. CTD Profiling

Vertical profiles of ocean properties were collected with two separate and independent sensor systems that both measured pressure, temperature, and conductivity. A main problem in Arctic applications of these sensors is to prevent freezing of the conductivity cell when wet, because freezing salt water inside the cell (a) can temporarily modify cell characteristics, (b) permanently damage cell components, or (c) cause blocked orifices by salt crystals or frazil ice. Keeping sensors warm before they enter and after they exit the sea water thus becomes a prime concern.

Our first system is a small and robust sensor package, the RBRconcerto (S/N 60522) that fits into the inside of a warm parka pocket. The RBR system was calibrated at the factory Mar. 6-8, 2017. It was used exclusively until April-2 attached by hose clamps to a Kevlar rope that was hauled mostly by hand even when connected to an electrical winch, because the light weight of the sensor package did not provide enough tension on the winch and caused wire angles as large as 20 degrees. Starting April-2, 2017, we deployed a larger, heavier, and more accurate SBE19plusV2 system (S/N 19-7774) that was mounted inside a stainless-steel frame designed to fit through a 10'' ice hole. The sensors were calibrated at the factory in January 2017.

A friend and colleague, Dr. Humfrey Melling of the Canadian Institute of Oceans Sciences prepared us with these words of practical wisdom regarding SeaBird CTD profiling in Arctic winter conditions:

"... CTDs are particularly sensitive to the challenge of cold, principally because a useful measurement of seawater conductivity needs to be very accurate. Accretion of even minute amounts of ice on the conductivity cell has unacceptable impact on accuracy and can be very difficult to detect both visually at the time and subsequently when processing data. Ice accretion occurs when the CTD enters the water with a temperature close to or below freezing temperature. In addition, there is a continuous formation of crystals of frazil ice within the augured hole through which the CTD must pass - there is no way to eliminate their presence. Such crystals will be ingested by the conductivity cell, particularly if it is pumped, where they can obstruct or block the flow of water through the cell and at times jam the pump. The consequent lengthening of cell response time and shift in calibration are very difficult to detect even if the data can be viewed carefully in real time.

Freezing problems make the Seabird CTDs very difficult to use in cold environments. They are bulky and difficult to maintain at a temperature (perhaps 5C) suitable for an expeditious launch from the carrying box to the sea. The small diameter of the conductivity cell makes it very prone to blockage; its small heat capacity (a desirable feature in a profiling instrument) means that it cools below freezing very rapidly (a second or two) after it is removed from its box and almost inevitably accretes ice unless you work in a shelter; the pumping system, while great for profiling, jams easily either via ice ingestion or by freezing. The SBE19 has two additional disadvantages: 1) it is an internally recording CTD, so that the user lacks information to the data stream wherein some of these problems might be detected and mitigated; 2) the pressure sensor links to the environment via a capillary tube, which is oil-filled but not completely; it is very common for a tiny drop of seawater to freeze against the meniscus in the top of the tube and isolate the pressure sensor from the environment (i.e. no depth data during the cast); you don't know this unless you can see the data ..."

In response to these concerns we fitted the wooden carrying box with a 1 kW hair dryer that raised the temperature both prior and after deployment well above the freezing point (Figure-7). Figure-8 shows the trace of measured temperature as the CTD package is moved from the carrying box into the water within about 5 seconds and lowered by winch to 9-m depth within 30 seconds. The sensor package was generally “soaked” in sea water for 5 to 20 minutes when it was also flushed several times moving it from the surface to 5 or 10 m depth and back up. Only after this soaking and flushing did we commence to collect profile data at speeds of 0.5 to 0.8 m/s.

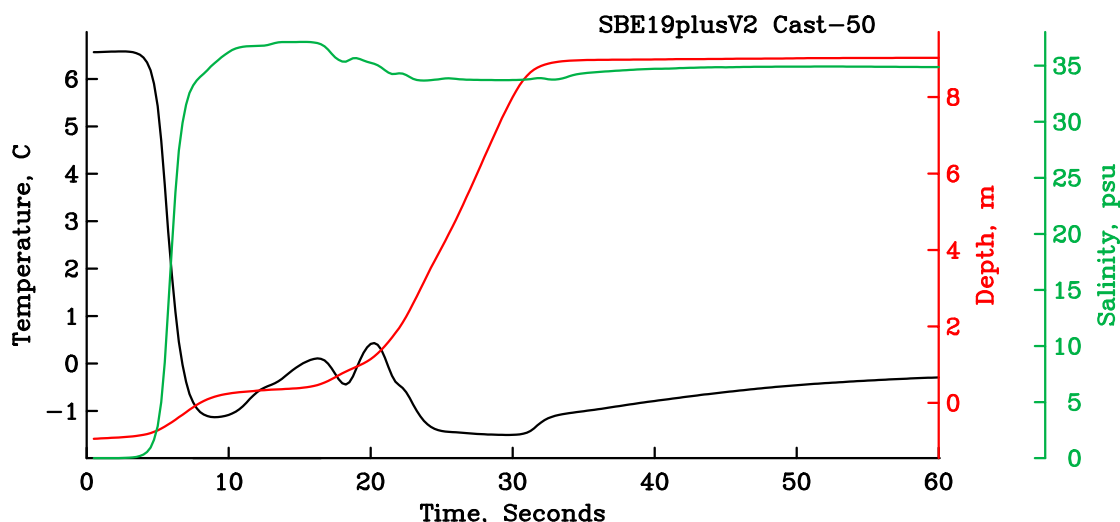


Figure-8: Sensor temperature, salinity, and depth during the first 60 seconds of deployment at station H3 (Cast-50) on April 16, 2017. It took 5 seconds to move the instrument from its heated wooden box into the sea water at air temperatures well below -10°C .

Initial data processing and inspection reveals no apparent aliasing in the pressure measurements, however, conductivity measurements and salinity estimation will require some careful scrutiny, because we removed the pump from the system that traditionally moves water at a fixed rate through the conductivity cell. This will change the time constant of the (slow) conductivity relative to the (fast) temperature measurement. Temperature and conductivity thus will have to be aligned carefully in post-processing to reliably estimate salinity for the same parcel of water that is profiled at different times for temperature and conductivity. Initial experimentation reveals that the recommended advance of the conductivity measurement by $+0.1$ seconds relative to temperature measurement for the pumped system may need to be changed to -0.48 seconds for the un-pumped system. Future work of CTD processing will need to verify and confirm this.

The CTD instruments were deployed via 10'' holes drilled by a propane powered ice auger. The auger could be operated by a single person who completed a hole through 1-m thick ice within about 30 seconds. A tripod was then placed over the hole at the back of the sled that guided a 3/8'' sheathed Kevlar line from a drum vertically into the water (Figure-8). The drum was driven by an electrical motor powered by the same 2 kW generator that also powered the hair dryer to keep sensor packages warm in transit as well as prior and after deployment. A line-counter attached to a shift did not work, as it froze up within a few turns at low temperatures, and thus was removed from our system.

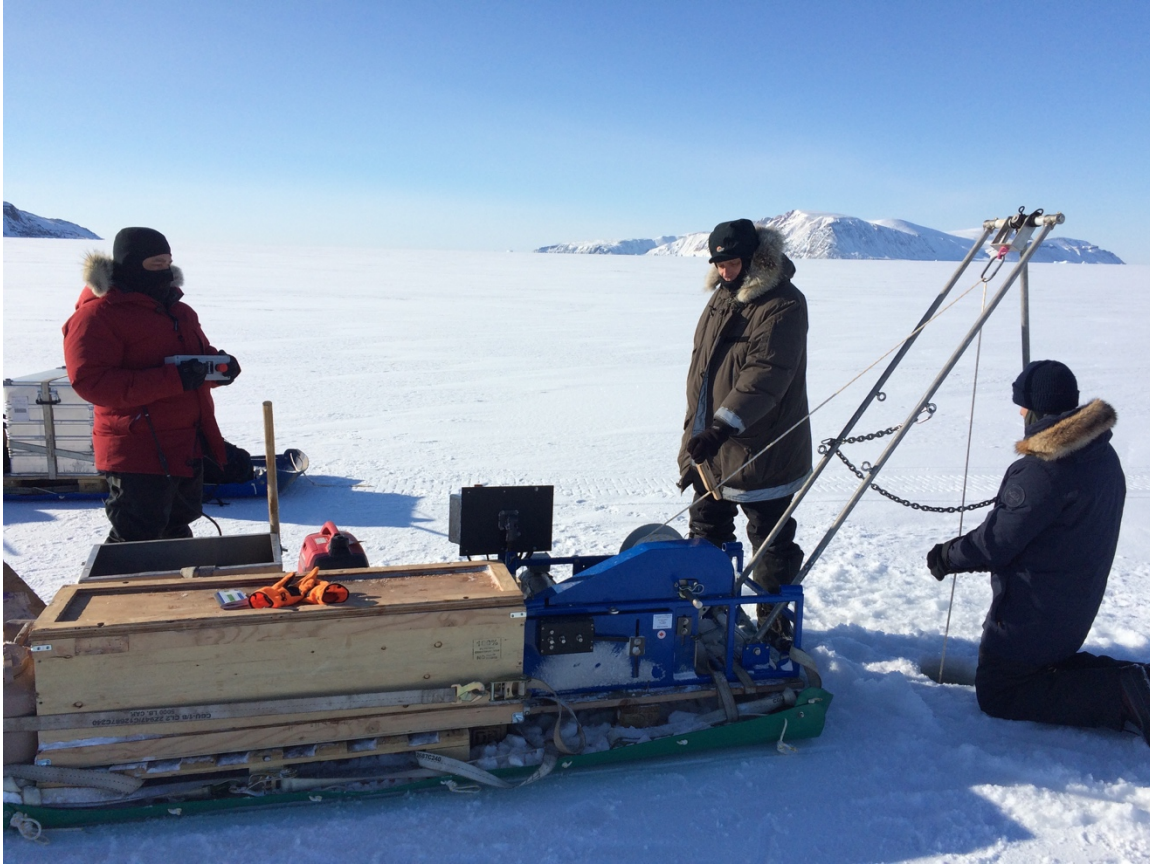


Figure-9: R/S Peter Freuchen with wooden CTD storage box, electrical winch, tripod, and electrical motor during deployment on Apr.-7, 2017. View is to the west with Cape Atholl on the left and Wolstenholme Island on the right background. David Huntley operates the winch via joy stick while monitoring the instrument's descent through water column via a "FishFinding" sonar (Figure-10).

Descent of the instrument package through the water was tracked in real time with a "fish-finding" commercial sonar that also tracked the bottom. The Garmin "Striker" was ruggedized for this application by soldering connection cables for power directly to the motherboard and using a 55 Ah 12V gel cell battery for power. We even monitored, I speculate, seals diving away from our instrument package as it is lowered towards the bottom

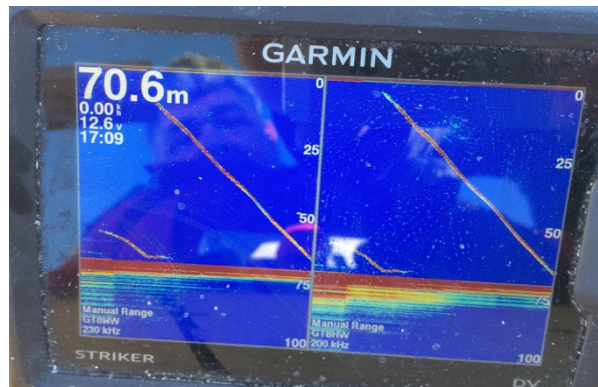


Figure-10: "FishFinding" sonar tracking the CTD sensor package as it descends through the water with an unrelated secondary target diving towards the bottom in a more curved path before disappearing from view.

The efficient design of the CTD-profiling sled christened “R/S Peter Freuchen” enabled us to profile wide areas quickly, because each profiling station was generally completed within 30 minutes. The work requires two people who can accomplish all tasks comfortably. Figure-11 shows the locations of our 84 CTD casts that are also listed in the Appendix.

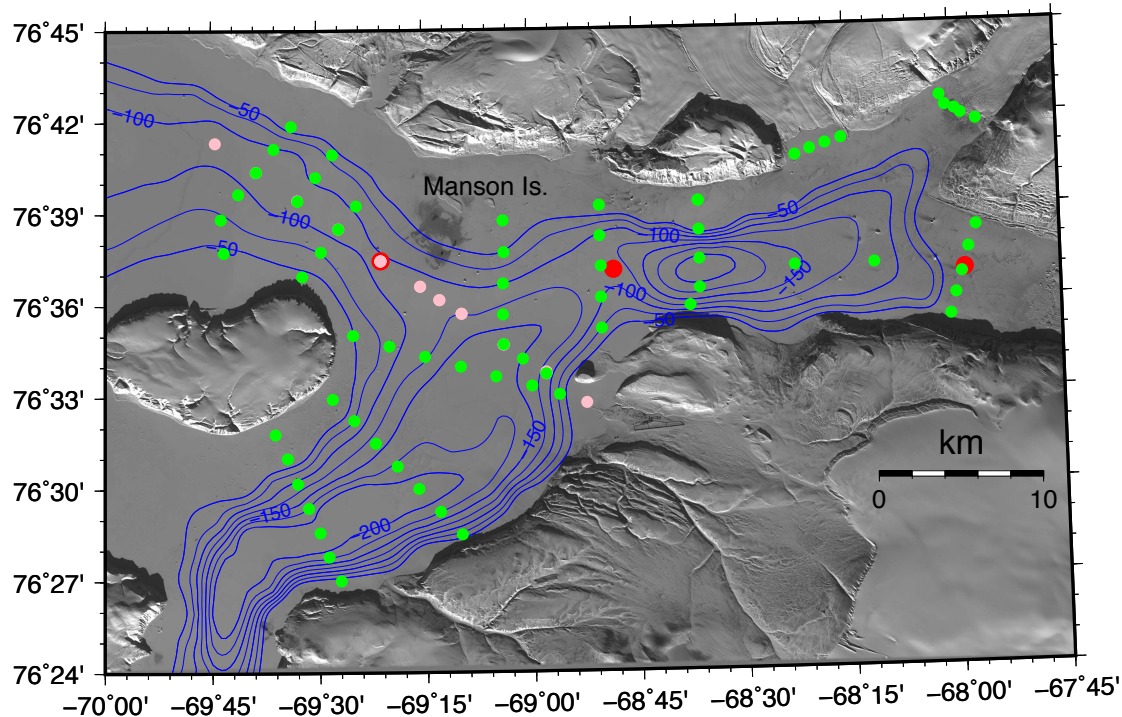


Figure-11: CTD station locations covered from Mar.-25 through Apr.-19, 2017 in Wolstenholme Fjord. Green dots indicate stations occupied by SBE19plusV2 and RBRconcerto while pink dots indicate RBRconcerto stations only. Larger red dots are acoustic mooring locations.

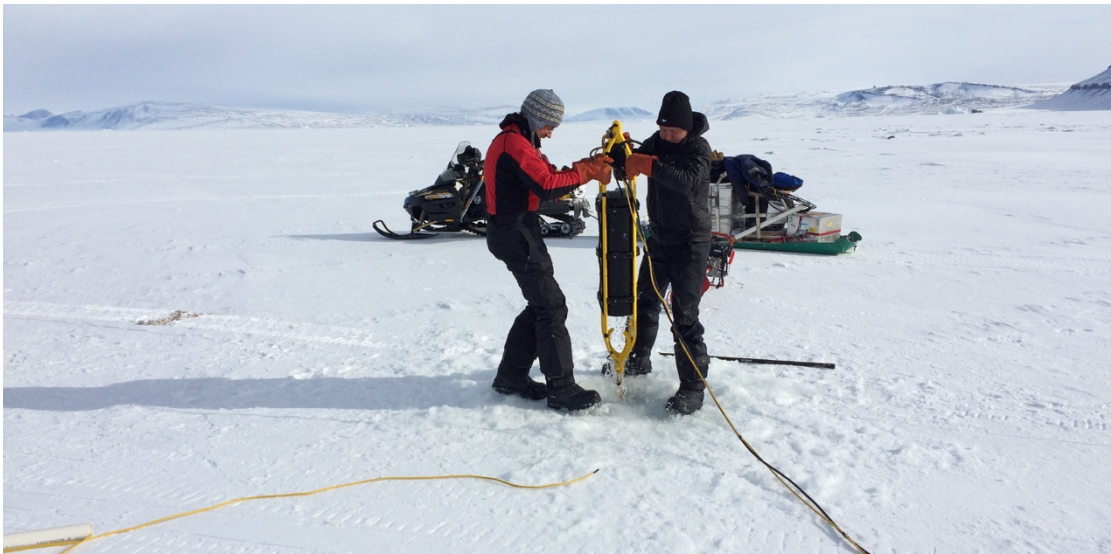


Figure-12: Recovery of acoustic mooring on Apr.-18, 2017 by Lee Freitag and Tyler Johnson of Woods Hole Oceanographic Institution.

7. Acoustic Moorings

The acoustic system consisted of three modems operating at frequencies of about 5-10 kHz. Two of these modems (A and B) are self-contained and connect to ocean sensors (SBE37sm) while the third so-called “base modem” is powered from the surface via at 24 V via a custom-made 7-conductor cable. This 1000’ long RS-485 cable connects the subsurface receive modem via a converter board to an RS-232 serial port of the AWS data logger and thus to the Iridium phone at the surface on the sea ice. It received data from the two far-field modems A and B either directly from both modems or from modem B that receives data from modem A to process and forward it to the acoustic base station and Iridium surface unit. After 10 days of testing (a) individual system components, (b) acoustic propagation paths, and (c) mooring deployment and recovery methods via 10’’ holes, we successfully deployed and operated the entire system for 2.5 days between April-15 and April-18, 2017.

All acoustic work was led by Lee Freitag of Woods Hole Oceanographic Institution whose group designed and manufactured the acoustic system that was purchased by the University of Delaware with support from the NSF-INSPIRE grant. The acoustic work interfaced smoothly and collaboratively with the oceanographic work and much synergies developed via shared mooring, drilling, logistics, and ocean profiling operations. Sharing work and living spaces at the NSF dorm Bldg-353 on Thule Air Base facilitated seamless and efficient interactions with minimal organizational overhead. I here merely summarize activities of the acoustics group as a time table:

Apr.-6	Arrival of acoustics team; Orientation and briefing with sea ice excursion
Apr.-7	Unpacking and lab testing of acoustic components
Apr.-8	Initial test of cable and power to base station at Thule Pier
Apr.-9	Range testing and sound recording at 3, 6, 12, and 15 km from Thule Pier
Apr.-10	Data analyses of sound recordings and tuning of acoustic modems
Apr.-11	Range testing and sound recordings at 15 to 30 km ranges
Apr.-12	Preparing mooring hardware and rope for deployment
Apr.-13	Final acoustic communication tests at Thule Pier
Apr.-14	Deployment of far-field modem A in Moltke Fjord; Deployment of mid-field modem B near CTD station F3 fails as B does not hear A
Apr.-15	Deployment of mid-field modem B near CTD station G3 where it hears A at 80-m; Deployment of base modem and connection to AWS via 1000’ cable
Apr.-16	Writing software to receive and decode acoustic data from AWS Iridium at Thule Iridium
Apr.-17	Acoustic system runs unattended
Apr.-18	Mooring recoveries of modem base, AWS, and mid-field modem B
Apr.-19	Mooring recovery of far field modem A and sound recordings near CTD station G3
Apr.-20	Cleaning, packing, storing gear
Apr.-21	Acoustic and oceanography teams leave Thule at 0800 local

The initial plan called for a deployment along a line extending from the Pier at Thule Air Base towards the abandoned town of Moriusaq to the north-west with the location of the AWS as a mid-point; see Figure-1 for locations. The range testing that we conducted on Apr.-9 and Apr.-11 indicated that the entire 30 km from Thule Pier to the edge of the land-fast sea ice can be covered acoustically by a single direct transmission without the need for any additional modems that receive and forward transmission. This lack of signal attenuation came as a surprise given both complex topography that varied from 27-

m to 180-m and back up to 110-m depth and the absence of a direct sound channel in water properties. It does demonstrate, however, excellent performance of both source and receivers along the chosen transmission path that perhaps was helped by generally smooth, un-ridged, and first-year ice generally less than 0.8 m thick.

In response to this performance we changed our initial design to increase range by deploying the remote modem in the fjord carved out by Moltke Glacier about 40 km from our AWS (Figure-10). Bottom bathymetry along this path is less well mapped and numerous icebergs along the line of sight potentially complicate the transmission path further. The initial placement of the forwarding modem near station F3 failed to hear the source (Moltke Glacier). We thus moved the forwarding modem 5 km closer to the remote Moltke Glacier modem to CTD station G3 (Figure-10), but successful signal receptions occurred only as we moved the modem vertically from its initial 50-m to 80-m depth. Inspection of water properties at G3 indicate the presence of a weak local speed of sound minimum at 60-m depth:

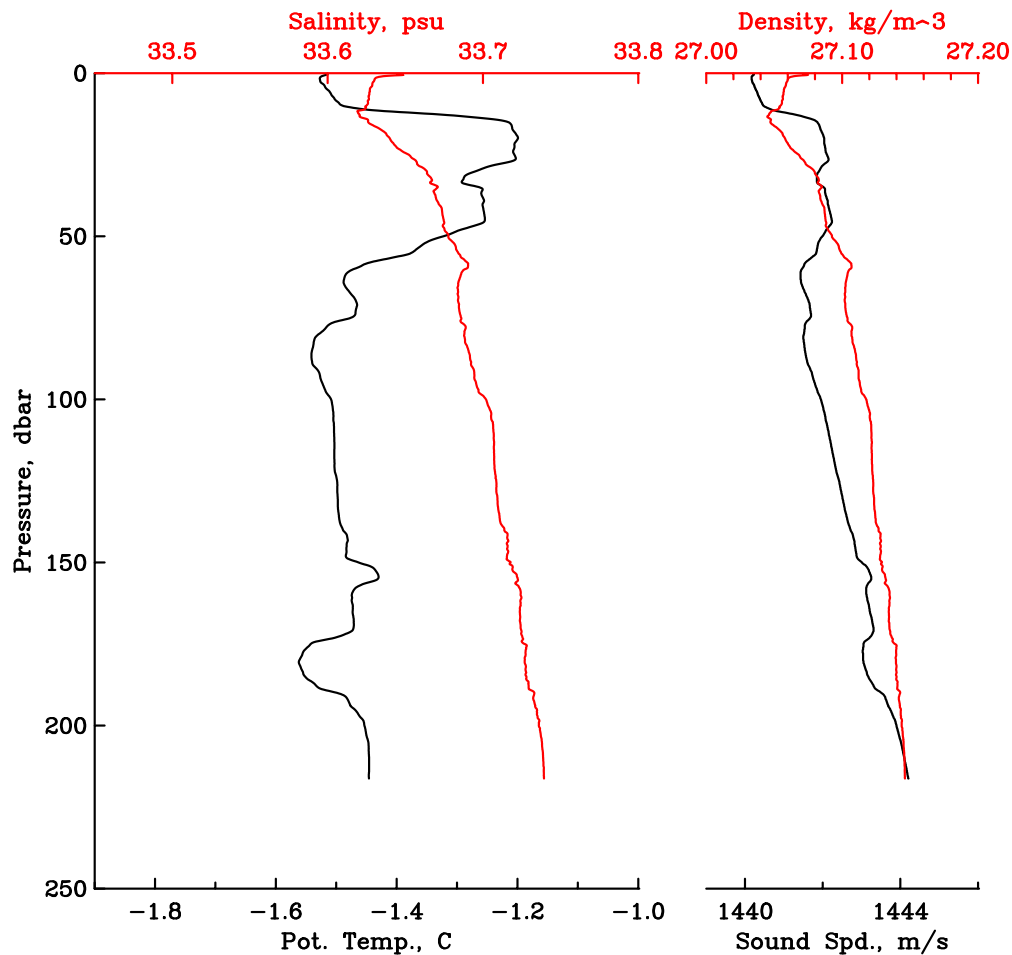


Figure-13: Water properties estimated from SBE19plusV2 CTD system at G3 showing a weak sound channel as a sound speed minimum near 60-m depth. It is caused by a subsurface temperature maximum which, I speculate, also relates to the presence of generally thin ice along the northern shores of Wolstenholme Fjord.

With this east to west transmission set-up we cover 40 km range that along a path that requires the forwarding motion. We thus expanded our initial design to one more challenging that bears hope to

accomplish larger ranges along the transmission path from Thule Pier with the cabled base modem far beyond the land-fast edge of the sea ice near Moriusaq towards the deeper waters of Baffin Bay to the north-west. We are hopeful to deploy this expanded array in the summer of 2017 by to place the cabled base modem on the sea floor to run up to Thule Pier to receive data for 6 to 9 months from a far-field location to the west of 70° W longitude.

8. Outreach

Outreach activities in the spring of 2017 were limited to interactions and public presentations with US military, Danish civilian, and Greenlanders at the Knud Rasmussen Community Center on Thule Air Base. While valuable to connect to US and Danish personal working at Thule Air Base, it did not connect well with Greenlanders whom we met both during and after a brief visit on Apr.-7 of a seasonal hunting camp at Narssarssuk about 15 km to the west of Thule. The hunters from Savissivik both at the camp and a different group we met later on Thule Air Base were particular interested in what we were doing on the sea ice where they saw our tracks and we saw theirs. The two hunters at the camp spoke neither Danish nor English, but we communicated our activities via photos on smart phones after prompted by the hunters who showed us videos of their narwhale, seal, and polar bear hunts on their smart phones. They invited us for tea and biscuits in their kerosene-heated hut. They also inspected our guns and sleds with much interest as I opened boxes with scientific instrumentation for them to see. It also percolated that they had visited our AWS and shelter during their hunting trips in Wolstenholme Fjord.

On Apr.-14 we were visited by a group of 3 Greenlanders at Bldg.-353 as they were looking to barter muskox meat for alcohol or cash. While we politely declined, we invited them in to socialize. The hunter in this group spoke English and indicated that they had come by dog sled from Savissivik via a 3-day journey to Thule to participate in the dog sled races organized by the Air Force during Armed Services Day the weekend. Again, the hunter wanted to know what we were doing on the sea ice which I explained by giving him a tour of Bldg.-353 and in particular our laboratory and workshop spaces.

I also queried him about visits of Qaanaaq and Savissivik that I tried to arrange via Danish contacts, but that had all failed to materialized for sluggish or absent responses to e-mails I sent. He responded by saying that “You do not understand Greenland until you live here,” which I took as a fatalistic statement, that I am wasting both his and my time with such short visits. Challenging his statement, I asked how long I would have to live in Greenland to understand.” The answer was “You have to come live with us for 10 years,” which prompted me to ask “How would I eat and support myself for such a long time in a small community of 70 people without becoming a burden,” to which he responded, after a long minute of thought, “I teach you.” We exchanged e-mails and discussed sea ice physics, oceanography, global politics, and different perspectives on both climate and political change for well over an hour. The name of the hunter is Vittus Q. Petersen and I am tempted by his offer to teach me to understand Greenland.

9. Risk Assessment and Mitigation

This Thule project started in August of 2015 during a forced 2-day stay at Thule Air Base on an unrelated NSF project when I made informal contact with long-term local resident Thorbjorn Jorgensen. He provided unique introductions to the potentials, risks, and their mitigation of working out of Thule. Initial plans were finalized during a week-long stay at Thule in August of 2016 that included informal interactions with military engineering and security staff who again shared experiences generously.

These visits served as a first step in risk assessment and mitigation as it fostered situational awareness and preparation via informal social contacts and interactions with people who have lived and worked in the area. Following these early scouting excursion, we went through several layers of safety briefings with project personnel and staff of CH2MHILL that culminated into the 2017 Season Plan that is attached. The plan includes details on identified risks, responsibilities, and elements of mitigation as discussed during a Jan.-27, 2017 conference call with all members of the field party and Polar Service staff.

The major risks identified fell into three categories:

Risk-1: Stability of sea ice for travel by loaded snowmobiles;

Risk-2: Protection from cold and potentially rapidly changing weather;

Risk-3: Protection from Polar Bears.

Two of three UDel personnel had attended an NSF-sponsored 4-day Wilderness First Aid and Survival course “Learn-to-Return” in 2004. The same two people also worked at Paramedics during prior lives in Germany and New Jersey.

Mitigation-1: All remote sensing work outlined in Section-2 relates to an operational preparation for safe travel on sea ice. Available operational sea ice products such as provided by the National Ice Center and Danish Meteorological Institute are NOT sufficient for travel on sea ice by snowmobile, because these products have poor resolutions. Instead we opted to process 15-m native resolution data that also documents the entire ice season starting in Nov.-2016. Three blog posts by this author document this process

<https://icyseas.org/2017/02/07/sea-ice-from-satellite-at-20-m-resolution/>

<https://icyseas.org/2017/01/30/north-greenland-sea-ice-wolstenholme-fjord-and-thule-air-base/>

<https://icyseas.org/2016/10/02/sea-ice-oceanography-and-natures-way-to-paint/>

Armed with 15-m resolution geo-referenced remote sensing products at weekly intervals that I fine-tuned to this specific study area, a first initial sea ice survey was conducted in a region of particular thin and potentially unstable ice. This survey was conducted with an experienced local guide (Sonny Jacobsen) after talking to several (Danish) people on TAB who recreationally travel on the sea ice with snowmachines. Details of these surveys are listed in Appendix-A and Figure-3 on p.-4

Mitigation-2: Thule Air Base sits on land nestled in a valley with North and South Mountains providing a channel from the Greenland ice sheet in the east to the ocean in the west. Atmospheric conditions such as air temperature, winds, and inversions are locally tied to topography and may differ substantially from conditions on the sea ice 10 or 20 km away from Thule. In order to aid better prediction of sea ice weather conditions we established both an automated weather station reporting every hour via Iridium as well as a shelter at this site 15 km from Thule. The shelter was meant to allow retreat during inclement weather with low visibility near the center of our operations. It also served as a comfort zone during lengthy ocean mooring work nearby (Figure-16 on p.22). The shelter included wooden pallets as well as propane and propane heaters inside. Emergency supplies of food, sleeping bags, tents, etc. were always carried on all snowmobile excursions.

Mitigation-3: I struggled with the acceptance of guns for polar bear protection that I considered unnecessary as a very low risk, e.g.

<https://icyseas.org/2016/12/20/polar-bears-and-guns-and-politics/>

however, overwhelming response to the above blog post by a diverse set of people working and traveling around Greenland led to all field parties to always carrying a loaded 12-gauge shotgun and/or 0.338 rifle. Following military regulations, I checked out guns and ammunition every morning from the USAF Armory across Bldg.-353 and returned them every evening.

In preparation I took a 2-day State-sponsored hunter safety course on Feb.-18/19, 2017, bought a 12-gauge shotgun, and conducted safety briefings and live firing exercises for all UDel project personnel at a State-owned shooting range. At Thule we I fired 4 rounds for practice on the sea ice.

10. Storage

All University of Delaware instrumentation, sensors, cables, tools, and gear was cleaned and placed in cold storage in an interior room in Bldg. 2403 atop pallets. Total weight is about 2,200 lbs.



Figure-14: Cold storage as left Apr.-21, 2017

Acknowledgements

Many people and institutions came together to support Arctic field work at the scale and scope discussed here. This includes logistical and management support by Polar Service (Jessy Jenkins and Kyli Coper), shipping support by U.S. Air Force at McGuire AFB (Suzy West) and ATPAC (Julianna Pagliei), and the infamous Thule-Can-Do attitude of USAF officers and crew. I am grateful to Prof. Ron Sletten of the University of Washington for the loan of his gun and rifle, to Pat Smith of Polar Services for superb preparation and maintenance of snowmobiles and trucks, and to Pat Ryan of the University of Delaware for tirelessly shipping spare parts, gear, and satellite remote sensing products up North. John Woods of NASA's Operation IceBridge is thanked for his whirlwind efforts to get the best possible connectivity across diverse federal agencies including the Department of Defense while several group and agencies worked side by side in Thule.

Most of all, however, I am indebted to Sonny Jacobsen who spent most of his free time from Greenland Contractors with us in the field building, designing, rigging, and executing a complex and diverse science program. He guided us through beautiful landscapes with a relaxed sense of humor and urgency to get the best science done safely without losing a sense of wonder and adventure. He taught us how to drive snow machines, how to read tracks on the ice for wild and other life, and how to prepare for working efficiently in the cold. He got me on and off very thin ice both literally and figuratively.

The work was funded by U.S. taxpayers via the National Science Foundation grant OPP-1344264.



Figure-15: Sonny Jacobsen building and rigging Research Sled R/S Peter Freuchen for ocean profiling.

Appendix-A: Ice Thickness Surveys

Year	Month	Day	Latitude	Longitude	Ice, m	Bottom, m	Comment
2017	03	10	76 31.660	68 58.070	0.98		
2017	03	11	76 31.073	69 01.483	0.98		
2017	03	11	76 31.498	69 02.295	0.90		
2017	03	11	76 31.940	69 03.127	0.97		
2017	03	11	76 32.349	69 03.899	0.95		
2017	03	12	76 32.679	68 52.296	1.08		
2017	03	12	76 32.726	68 52.256	1.15		
2017	03	12	76 32.774	68 52.231	1.19		
2017	03	12	76 32.788	68 52.430	1.16		
2017	03	12	76 32.804	68 52.688	1.12		
2017	03	18	76 35.412	69 15.967	0.74	96	
2017	03	18	76 35.411	69 15.919	0.41	120	
2017	03	18	76 37.814	69 21.919	0.51	125	
2017	03	18	76 37.870	69 22.772	0.51	122	
2017	03	18	76 38.017	69 23.627	0.51	122	
2017	03	18	76 38.270	69 25.509	0.62	121	
2017	03	18	76 38.443	69 26.685	0.69	126	
2017	03	18	76 38.681	69 28.535	0.73	115	
2017	03	18	76 38.901	69 30.442	0.76	119	
2017	03	18	76 39.132	69 34.302	0.78	113	
2017	03	18	76 39.305	69 35.284	0.78	112	
2017	03	18	76 39.517	69 36.266	0.84	106	
2017	03	18	76 39.747	69 39.085	0.49	103	
2017	03	18	76 39.875	69 40.873	0.39	106	
2017	03	18	76 39.996	69 41.833	0.40	102	
2017	03	18	76 40.047	69 42.697	0.76	106	
2017	03	18	76 39.364	69 33.697	0.73	115	
2017	03	18	76 39.530	69 33.210	0.65	119	
2017	03	18	76 39.714	69 32.665	0.60	126	
2017	03	18	76 39.883	69 32.078	0.43	123	
2017	03	19	76 36.866	69 18.192	0.30	132	Seal-Hole
2017	03	19	76 37.463	69 21.077	0.60	110	AWS-Shelter
2017	03	19	76 39.984	69 31.712	0.44	121	
2017	03	19	76 40.109	69 31.339	0.41	118	
2017	03	19	76 40.258	69 30.906	0.33	120	
2017	03	19	76 40.409	69 30.444	0.26	112	
2017	03	19	76 40.606	69 29.821	0.26	106	
2017	03	19	76 40.763	69 29.379	0.20	103	

2017 03 19	76 40.917	69 28.852	0.37	95
2017 03 19	76 41.077	69 28.423	0.32	82
2017 03 19	76 41.224	69 28.022	0.42	76
2017 03 19	76 38.945	69 34.828	0.81	89
2017 03 19	76 38.752	69 34.899	0.84	80
2017 03 19	76 38.467	69 34.998	0.90	75
2017 03 23	76 37.451	69 14.624	0.12	Thin Ice
2017 03 23	76 37.439	69 11.331	0.28	
2017 03 23	76 37.373	69 09.306	0.49	
2017 03 23	76 37.359	69 05.907	0.60	
2017 03 23	76 37.381	69 02.992	0.65	
2017 03 23	76 37.321	68 59.892	0.71	
2017 03 23	76 37.242	68 56.776	0.66	
2017 03 23	76 37.227	68 53.804	0.75	

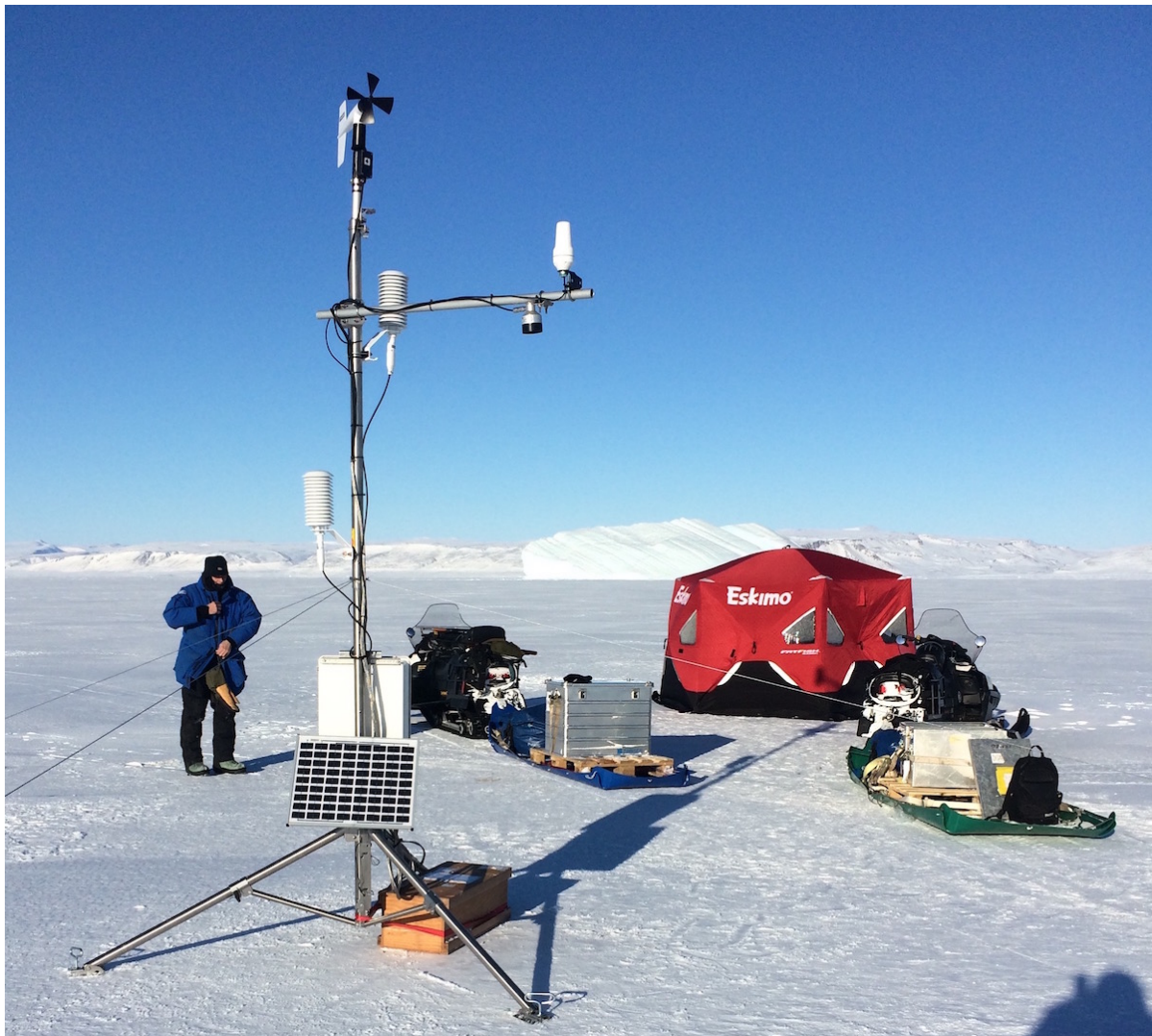


Figure-16: Weather station and shelter on sea ice in Wolstenholme Fjord, Greenland in March 2017.

Appendix-B: Ocean Profile Station Locations

The RBRconcerto instrument were used on the first 16 casts. Starting Apr.-2, we generally used both SBE19plusV2 and RBRconcerto CTD systems mounted in the same stainless steel frame.

Date	Long. W	Lat. N	Cast	Station	H,m	Ice, m	Comment
Mar.-25	69.35128	76.62438	RBR-01	AWS	113	0.63	Failed cast, then T-string mooring depl.
Mar.-26	69.35128	76.62438	RBR-02	AWS	113	0.63	hauled by hand, then glacier survey
Mar.-28	69.35128	76.62438	RBR-03	AWS	113	0.63	1 kW generator fails to drive winch (need 2 kW)
	69.21375	76.60282	RBR-04	A04.5	136	0.72	loose socket pin on winch fails electric motor
	69.21375	76.60282	RBR-05	A04.5	136	0.72	hauled with 18V hand-drill, sonar cable frozen in
Apr.-1	68.87063	76.54602	RBR-06	A01	27	1.25	
	68.96487	76.56305	RBR-07	A02	142	0.85	
	69.06423	76.57815	RBR-08	A03	130	0.85	
	69.16215	76.59527	RBR-09	A04	153	0.93	
	69.25870	76.61028	RBR-10	A05		0.65	
	69.35175	76.62428	RBR-11	A06	110	0.62	
Apr.-02	69.35175	76.62428	RBR-12	A06	110	0.62	
	69.45030	76.64193	RBR-13	A07	123	0.66	
	69.54668	76.65743	RBR-14	A08	121	0.67	
	69.64402	76.67310	RBR-15	A09	121	0.55	
	69.74058	76.68890	RBR-16	A10	118	0.28	
Apr.-04	69.53630	76.61607	SBE-02	B1	37	0.93	10'' drill power head piston fails (out of specs?)
	69.49167	76.62933	SBE-03	B2	72	0.99	
	69.45030	76.64193	SBE-04	B3	123	0.70	
	69.40810	76.65435	SBE-05	B4	124	0.24	
Apr.-05	69.54627	76.65727	SBE-06	D0	45	0.57	
	69.50372	76.67007	SBE-07	D1	66	0.57	
	69.46363	76.68242	SBE-08	D2	96	0.49	
	69.72088	76.62907	SBE-09	D3	120	0.59	
	69.72742	76.64732	SBE-10	D4	117	0.18	
	69.68615	76.66103	SBE-11	D5	71	0.22	
	69.64387	76.67312	SBE-12	C3	120	0.71	
	69.60217	76.68535	SBE-13	C4	120	0.34	

	69.56028	76.69798	SBE-14	C5	96	0.41	
Apr.-7	69.60153	76.52993	SBE-15	E7	24	0.73	
	69.57315	76.51688	SBE-16	E6	111	0.77	
	69.54970	76.50305	SBE-17	E5	152	0.77	
	69.52460	76.48980	SBE-18	E4	186	0.86	Bottom Contact
	69.49797	76.47632	SBE-19	E3	228	0.58	
	69.47762	76.46325	SBE-20	E2	211		
	69.44970	76.45010	SBE-21	E1	34	0.76	
Apr.-10	68.96513	76.56208	SBE-22	A02	141		
	69.01942	76.57027	SBE-23	A25	144	0.89	
	69.06407	76.57828	SBE-24	F1	129	0.93	
	69.06475	76.59455	SBE-25	F2	178	0.85	
	69.06368	76.61142	SBE-26	F3	174	0.75	
	69.06122	76.62850	SBE-27	F4	107	0.64	
	69.06200	76.64580	SBE-28	F5	35	0.65	
	68.83423	76.65337	SBE-29	G5	98	0.85	
	68.83425	76.63680	SBE-30	G4	123	0.80	
	68.83260	76.62027	SBE-31	G3	224	0.78	
	68.83330	76.60332	SBE-32	G2	83	0.77	
	68.83285	76.58643	SBE-33	G1	69	0.81	
Apr.-12	68.02307	76.70902	SBE-34	R7	160	1.20	Salinity Spiking at Tgrad
	68.01098	76.70357	SBE-35	R6	160	1.11	
	67.98818	76.70152	SBE-36	R5	95	0.96	
	67.97432	76.69900	SBE-37	R4	40	0.96	
	67.93877	76.69557	SBE-38	R2	91	0.60	
Apr.-14	68.01062	76.58978	SBE-39	M1	197	0.88	electric winch fails
	67.99715	76.60130	SBE-40	M2	208		Smin at 20-m ?
Apr.-16	69.46673	76.54912	SBE-41	I7	35	0.82	
	69.41663	76.53742	SBE-42	I6	113		
	69.36670	76.52497	SBE-43	I5	194	0.81	
	69.31650	76.51242	SBE-44	I4	234	0.88	
	69.26670	76.50005	SBE-45	I3	208	0.84	
	69.21638	76.48742	SBE-46	I2	35	0.75	
	69.16672	76.47500	SBE-47	I1	16	1.20	
	68.62320	76.59812	SBE-48	H1	73		tape measure broke
	68.60017	76.60760	SBE-49	H2	218		
	68.59975	76.62333	SBE-50	H3	255		
	68.60007	76.63917	SBE-51	H4	184		
	68.59977	76.65500	SBE-52	H5	164		
	68.60100	76.65500	SBE-53	H6	132		
Apr.-17	69.41775	76.58378	SBE-54	J7	23	0.93	
	69.33278	76.57782	SBE-55	J6	44	0.50	
	69.24927	76.57197	SBE-56	J5	156	0.74	

	69.16540	76.56640	SBE-57	J4	188	0.90	
	69.08277	76.56083	SBE-58	J3	177	0.96	
	68.99863	76.55555	SBE-59	J2	201	0.95	
	68.93410	76.55077	SBE-60	J1	27	0.96	
Apr.-19	68.37500	76.61878	SBE-61	T1	246	0.70	
	68.18768	76.61920	SBE-62	T2	170	0.73	
	67.98187	76.61277	SBE-63	M3	213	0.85	
	67.96512	76.62608	SBE-64	M4	211	0.85	
	67.94598	76.63803	SBE-65	M5	91	0.88	
	68.25921	76.68738	SBE-66	L1	17	0.70	
	68.28717	76.68477	SBE-67	L2	28	0.75	
	68.33360	76.68190	SBE-68	L3	75	0.73	
	68.36907	76.67863	SBE-69	L4	52	0.87	

Appendix-C: Code to run AWS

The code below controlled all components of the automated weather station including its ocean sensors connected to RS-232 serial ports until Apr.-15, 2017 when the acoustic communication system was added.

```
' muenchow@udel.edu Mar.-21, 2017
' Declare Constants
'Declare Variables and Units
StationName Thule_Sealce
Public Checkup As Boolean
Public Batt_Volt, IntBatt, version
Public NBytesReturned
Public WindSpd, WindDir, WindGood As Boolean
Public AirTC_3M, AirTC_1M
Public RH_3M, RH_1M
Public BP_mbar, Press_mb
Public SR50(2),DistCor
Public SensorIn(2) As String *50
Public TOcean(2),SOcean(2),POcean(2)
Public SplitStrings(4) As String *20
Public Baud,Port As String *4
'Variables for Iridium Configuration
Public SetupStr As String * 51
Public Register_Modem As String *50
Public configure_modem As Boolean
Alias SR50(1) = RawDist
Alias SR50(2) = SignalQuality
'Define Data Tables
DataTable(T1AWS_Hourly,true,-1)
  OpenInterval
  DataInterval(0,60,Min,10)
  Average(1,Batt_Volt,IEEE4,0)
  Average(1,AirTC_3M,IEEE4,0)
  Average(1,AirTC_1M,IEEE4,0)
  Average(1,RH_3M,IEEE4,0)
  Average(1,RH_1M,IEEE4,0)
  WindVector(1,WindSpd,WindDir,IEEE4,WindGood,0,0,1)
  Maximum(1,WindSpd,IEEE4,0,1)
  Average(1, Press_mb, IEEE4, 0)
  Average (1,TOcean(1),IEEE4,0)
  Average (1,SOcean(1),IEEE4,0)
  Average (1,POcean(1),IEEE4,0)
  Average (1,TOcean(2),IEEE4,0)
  Average (1,SOcean(2),IEEE4,0)
  Average (1,POcean(2),IEEE4,0)
  Average(1,RawDist,IEEE4,0)
  Minimum(1,IntBatt,FP2,0,False)
  Sample(1,version,fp2)
' CardOut (0 ,-1)
EndTable
'
BeginProg
  Scan(1,Min,3,0)
```

```

        Battery(Batt_Volt)
        IntBatt = Status.LithiumBattery
        Delay(0,2,Sec)
        VoltSe(AirTC_3M,1,mV2500,1,0,0,_60Hz,0.14,-80)
        VoltSe(RH_3M,1,mV2500,2,0,0,_60Hz,0.1,0)
        If (RH_3M > 100.0) Then
            If (RH_3M < 108) Then
                RH_3M = 100
            EndIf
        EndIf
    EndIf
    Delay(0,2,Sec)
    VoltSe(AirTC_1M,1,mV2500,3,0,0,_60Hz,0.14,-80.0)
    VoltSe(RH_1M,1,mV2500,4,0,0,_60Hz,0.1,0)
    If (RH_1M > 100.0) Then
        If (RH_1M < 108) Then
            RH_1M = 100
        EndIf
    EndIf
    PulseCount(WindSpd,1,1,1,1,0.098,0)
    If WindSpd = NAN Then
        WindGood = true
    Else
        WindGood = false
    EndIf
    BrHalf(WindDir,1,mV2500,8,1,1,2500,True,0,_60Hz,355.0,0)
    If WindDir>=360 Then WindDir=0
    ,
    If TimeIntoInterval(12,15,Min) Then PortSet(1, 1)
    If TimeIntoInterval(0,60,Min) Then
        VoltSe(BP_mbar, 1, mV2500, 12, False, 0, _60Hz, 0.240, 515.8)
        SDI12Recorder (SR50(),7,0,"M!",1.0,0)
    Press_mb = BP_mbar
        BP_mbar = BP_mbar * 10 ' Convert to get all the way down to tenths place when
converted
    ,
        DistCor = RawDist*(SQR(1+(AirTC_1M/273.15)))
        PortSet(1, 0)
    EndIf
    CallTable(T1AWS_Hourly)
    ,
    If TimeIntoInterval (12,15,Min) Then
        SerialOpen (Com2,4800,0,0,50)
        SerialOpen (Com3,4800,0,0,50)
    ,
        SerialOutBlock (Com2,CHR(13),1)
        SerialOutBlock (Com3,CHR(13),1)
    ,
        Delay (0,2000,mSec)
    ,
        SerialOutBlock (Com2,"ts"+CHR(13),3)
        SerialOutBlock (Com3,"ts"+CHR(13),3)
    ,
        SerialFlush(Com2)
        SerialFlush(Com3)
    ,
    SerialIn(SensorIn(1),Com2,100,"S>",50)
    SerialIn(SensorIn(2),Com3,100,"S>",50)

```



```

    Delay (0,1500,mSec)
,
    SerialOutBlock (Com2,"qs"+CHR(13),3)
    SerialOutBlock (Com3,"qs"+CHR(13),3)
,
    SerialClose (Com2)
    SerialClose (Com3)
,
    SplitStr (SplitStrings(),SensorIn(1),"",4,0)
    TOcean(1) = SplitStrings(1)
    SOcean(1) = SplitStrings(2)
    POcean(1) = SplitStrings(3)
,
    SplitStr (SplitStrings(),SensorIn(2),"",4,0)
    TOcean(2) = SplitStrings(1)
    SOcean(2) = SplitStrings(2)
    POcean(2) = SplitStrings(3)
EndIf

' Power On to Iridium 12 minutes into 1440 minute interval
'   If TimeIntoInterval (492,1440,Min) Then PortSet (9,1)
'   If TimeIntoInterval (32,60,Min) Then PortSet(9,1)
' Power off Iridium 30 minutes into the 1440 minute interval
'   If TimeIntoInterval (510,1440,Min) Then PortSet (9,0)
'   If TimeIntoInterval (0,60,Min) Then PortSet(9,0)
'   If IfTime (495,1440,Min) Then configure_modem = true
'   If IfTime (35,60,Min) Then configure_modem = true
'   If configure_modem = true Then
'       SerialOpen (ComRS232,19200,0,0,2000)
'       Delay (0,1,Sec)
'Send the Iridium configuration to Iridium ISU
'       SetupStr = "AT&F0 S0=1 &D0 +IPR=6,0 V0 &K0 &W0 &Y0" & CHR(13) & CHR(10)
'       SerialOut (ComRS232,SetupStr,"",0,0)
'       configure_modem = false
'       SerialClose (ComRS232)
'   EndIf
'Fake call
'   Register_Modem = "ATDT 1234" & CHR(13) & CHR(10)
'   SerialOpen (ComRS232,19200,0,0,2000)
'   Delay (0,1,Sec)
'   SerialOut (ComRS232,Register_Modem,"",0,0)
'   SerialClose (ComRS232)
NextScan
EndProg

```

PROJECT INFORMATION

Lead Principal Investigator	Andreas Muenchow
Institute	University of Delaware, College of Marine and Earth Studies
Project Title (Grant #)	INSPIRE Track 1: Acoustic Sensor Networks for Ice-Covered Seas (1344264)
NSF Program and Manager	NSF\GEO\OPP\ARC\ANS; Dr. William Wiseman
Polar Field Project Manager	Kyli Cospers

Note: This season plan covers CPS support for the March/April field work. We will update and redistribute this plan as details for the PI's summer visit come in to more focus.

LOGISTICS SUMMARY

This INSPIRE award is partially funded by the Arctic Natural Sciences Program. The PIs will design and develop an integrated underwater acoustic sensor network for ice-covered seas.

During the one year of field work in 2017, researchers will deploy and monitor their underwater communications network system in Thule, Greenland. Starting in March, the PI will travel to Thule and spend about a week traveling on the sea ice via snow machine conducting ice/ocean profiling and the Differential Global Positioning System (DGPS) placement. He will then travel on to Qaanaaq for another week for outreach and data analyses. During the next month, until approximately the third week in April 1-5 team members will travel to Thule and then on to the sea ice via snow machine for ocean profiling, modem siting and modem testing. All travel to Thule will be via the Air Mobility Command (AMC). The DGPS will then be recovered ending this part of the campaign.

Pending success of early season work, researchers will return for a summer deployment in July/Aug for a mooring deployment of a fully deployed acoustic underwater system to include attachment of a cable from the water to the pier.

CPS will provide Thule clearances, lodging at Bldg 353, generator, truck and snow machine use, miscellaneous camping gear, communications gear, and daily check-in support while in the field. The investigators will arrange and pay for all other logistics, including a bear guard and cargo coordination, from the grant.

For the complete CPS online project record for this grant, including science objectives, go to:
http://www.polar.ch2m.com/arlss_reports/arlss_projectsdetail.asp?cbPropNum=1344264

PLANNING MILESTONES AND NOTES

Issue	Responsibility	Comment
Review support plan for accuracy and distribute to all field team members.	PI	
Obtain all necessary permits for fieldwork.	PI	
Visit all hyperlinks and review all documents referred to in the season plan.	Entire Field Team	
Identify a person to review your Risk Assessment with the entire field team.	PI	
Know the terms of your grant, and discuss with your institution's risk management experts their policies on medical evacuation, liability, workers' comp insurance, etc.	PI	
Provide Institution emergency contacts information.	PI	See Table Below
Complete Critical Success Factors	PI	See Table Below.
Bear Guard Services/Firearm Plan	PI	Pending – Research team coordinating
Communications Plan	PI/CPS	Pending
Safety/ Travel Plan	PI	Pending

FIELD ITINERARY

Name	Institute	Email	Arrive GRL	Depart GRL
Andreas Muenchow	Univ of Delaware	muenchow@udel.edu	09 March	21 April
David Huntley	Univ of Delaware	dhuntley@udel.edu	30 March	14 April
Lee Freitag	Woods Hole Oceanographic Inst.	lfreitag@whoi.edu	06 April	21 April
Tyler Johnson	Woods Hole Oceanographic Inst.	tjohnson@whoi.edu	06 April	21 April
Peter Washam	Univ of Delaware	pwasham@udel.edu	06 April	21 April
Justin Eickmeier	Univ of Delaware	jeickmei@udel.edu	06 April	21 April
TBD – University funded bear guard			~30 March	~21 April

* Field team POC (Point of Contact)

Date In	Date Out	Location	Activity
~10 Mar	~16 Mar	Thule AB	DGPS placement & ice/ocean profiling. Sea ice daytrips via snow machine. (Muenchow w/ US Naval Academy personnel.) See <i>Smith/FieldschoolUSNA</i> Season Plan for USNA details.
~15 Mar	~23 Mar	Thule AB/ Qaanaaq	Outreach & data analyses (Muenchow). No sea ice travel. ~2 days for Qaanaaq outreach, PI arranged and grant funded travel.
~22 Mar	~30 Mar	Thule AB	Sensor preparations & data analyses (Muenchow). No sea ice travel.
~30 Mar	~06 Apr	Thule AB	Ocean profiling & modem testing (Muenchow & Huntley). Sea ice daytrips via snowmobile.
~06 Apr	~13 Apr	Thule AB	Modem testing & modem siting (Muenchow, Freitag, Johnson, Washman, and Eickmeier). Sea ice daytrips via snowmobile.
~12 Apr	~20 Apr	Thule AB	Modem siting & modem recovery (Muenchow, Freitag, Johnson, Washman, and Eickmeier). Sea ice daytrips via snowmobile.

ALLOCATIONS AND SERVICES

Communications Equipment Allocations from CPS Inventory

Quant/Unit	Item
3ea	Iridium 9505A Satellite Phone
4ea	Artex PLB
3ea	Radio, VHF handheld
For additional comms within Defense Area, tetra radios are available on-site at Bldg 353. (See Greenland Contractors training manuals located in the literature area in Bldg 353 under the communications white board.)	

Equipment Allocations from CPS Inventory

Quant/Unit	Item
2ea	Snowmachine, Skandic SUV 550 WT
6ea	Snowmachine helmets (various sizes available on-site)
TBD	Mogas, generator and vehicle use
1ea	2kW generator, EU2000i
2ea	Siglin sled
3ea	Survival bags (each bag made for 2 people)
1ea	Arctic Oven, 10 x 10 (Research team will provide ice screws/anchors appropriate for sea ice use)

Other Services coordinated by CPS

Service	Comments
Thule AB Clearances, USAF & Danish Ministry permissions	1 month lead time required.
Travel, Air Mobility Command (AMC) travel reservations	<p>Travel of military personnel via AMC takes precedence over that of civilians. CPS will work with PI to rearrange AMC travel if needed.</p> <p>Baggage/carryon restrictions provided to all travelers with clearance paperwork.</p> <p>Research teams will be invoiced directly for AMC travel.</p>
C17 Freight	CPS will coordinate cargo if research team needs to utilize April 6 C17 flight to/from Thule
AMC Freight	CPS will provide AMC point of contact for AMC freight.
Lodging, Bldg 353	<p>Beds are two to a room; during high traffic timeframes, double occupancy is likely. Sheets, pillow, duvet, and duvet cover provided.</p> <p>Bldg. 353 does not receive janitorial services. Researchers are responsible for the upkeep of the offices, the kitchen and bathroom facilities.</p> <p>See Thule Guide for more details.</p>
Internet Access at Bldg. 353	<p>Limited bandwidth. Limit large data transfers. Disable auto updates/Apple users disable iCloud.</p> <p>The use of chat applications that run video feed is not allowed i.e. – no video Skype or video g-chatting without pre-approval/notice.</p>
Communications equipment training	CPS will provide communications equipment training on-site week of 09 March.
Snowmachine training	<p>CPS mechanic will provide snow machine training to PI Muenchow week of 09 March.</p> <p>CPS mechanic will arrive in advance of project team arrival to service and ready snow machines for use. Mechanic will be in Thule during the following timeframes: 09 March – 16 March and 30 March – 06 April</p>
Vehicle	<p>NSF owned vehicle provided for movement of cargo/science gear on base.</p> <p>NSF vehicles are not to be used for recreational travel.</p> <p>Vehicle check-out and fuel log sheets needs to be completed once per week.</p> <p>Taxis are available on base for general passenger shuttling, meals, etc.</p>
Mogas	Mogas for generator and vehicle use provided from NSF mogas tank. PI Muenchow will work with CPS to coordinate and pay for resupply of mogas to Thule later in the season.
Daily Check-In Support	<p>09 Mar – 16 Mar - Daily check-in support with CPS personnel on-site at Thule AB.</p> <p>30 Mar – 21 Apr – Daily check-in support with CPS Kangerlussuaq office.</p> <p>If unplanned travel off-base needs to occur between 16 Mar – 29 Mar, PI to contact PM to make check-in arrangements.</p>
Off-season storage	Potential winter 2017 storage for 2 kW Honda generator and 2 x 10" ice augers. PI will arrange for other retro of equipment in 2018 via vessel as needed.

Other Services coordinated by Research Group

Service	Comments
Hazmat request form	Required by Thule AB Installation HAZMAT Management Plan (IHMP). Science team to complete in advance of cargo arriving at Thule AB.
Adherence to field safety protocols	Travel off base requires vigilant attention to weather, wildlife, and Thule AB HILLTOP protocols.
Cold weather clothing	Research team will provide all cold weather clothing needed for operating at Thule AB and on sea ice.
Misc. allocations	Research team will provide any gear and science equipment required that is not captured in above communications and equipment allocation tables. Research team will provide ice auger and heater needed for sea ice operations. Research team will provide Arctic Oven ice screws/anchors appropriate for sea ice use
Propane accessories	Research team will provide refillable propane cylinders for use with ice auger operations. Research team is responsible for providing needed adapters/fittings to connect 20lb propane tank to refillable cylinders as well as PPE necessary to perform transfer of propane.
AMC freight	Research team applied for TAC # for all AMC freight charges. Research team will coordinate delivery of cargo to/from McGuire AFB.
Travel, CONUS & Qaanaaq outreach	CPS will reserve AMC passenger travel. Research team will be invoiced directly. All other non-AMC related travel to be coordinated by research team including Qaanaaq outreach visits.
Bear Guard & firearms	Research team will coordinate bear guard services directly. CPS will process Thule AB clearances for bear guard if identified. Research team is responsible for providing firearms and obtaining training required for use of firearms in the field. Government of Greenland permitting requirements are the responsibility of the research team.

LOCATION INFORMATION

Researchers should set their phones to work in Greenland mode to avoid incurring huge expenses.

Thule AB - <http://www.peterson.af.mil/units/821stairbase/index.asp>

Thule Guide

Thule Guide provides en route and location-specific Thule, Greenland information. Prior to deployment, your entire field team should be familiar with the content of the Thule Guide available via our website's Greenland menu.

CARGO AND CUSTOMS

All cargo required for your project should arrive in Scotia, NY **no later than 2 weeks prior** to the desired northbound Air National Guard (ANG) flight, must be entered into our online Cargo Tracking System (<https://cpsportal.ch2m.com>) and must be properly registered with Customs. Current ANG flight schedules are available in the Cargo Tracking System.

Customs instructions are available in the *Greenland Guide* on our website: <http://cpspolar.com/>

Note: All staff and researchers are required to abide by Greenland import and customs laws. Review rules regarding importation of alcohol prior to travel. Rules are subject to change.

<http://www.greenland.com/en/plan-your-trip/practical-travel-info/ofte-stillede-spoergsmaal.aspx>

AMC & ANG Northbound Cargo Requirements:

Items	Weight/Cube
AMC shipment 1	~1,000 lbs./ 90 cu ft.
AMC shipment 2	~500 lbs./ 60 cu ft.
ANG shipment via Apr 06 C17, as needed	TBD

AMC Southbound Cargo Requirements:

Items	Weight/Cube
None identified at this time	

Reminder: Researchers are responsible for coordination and payment of cargo shipments from their home institutions to/from McGuire AFB (AMC) or Stratton AFB (ANG) unless special arrangements with CPS have been made. If you are leaving cargo in Greenland, please contact your project manager.

PROJECT CONTACT INFORMATION

Research Team

Role	Name	Email	Phone
Principal Investigator	Andreas Muenchow	muenchow@udel.edu	302.831.0742
Co-PI	Mohsen Badiey	badiey@udel.edu	302.831.3687

Health and Safety Emergency Contact

Role	Name	Email	Phone
Emergency Contact	Sharmayne Burns	sburns@udel.edu	302.831.8255

CPS Team Members

Contact for	Name and Email	Primary Phone
Thule science planning & support	Kyli Cospers kyli@polarfield.com	Cell: 303.489.2151
Thule science planning & support	Jessy Jenkins jessy@polarfield.com	Cell: 303.325.1745
Kangerlussuaq, field operations (Opens for season on 27 March 2017)	Tracy Sheeley cpskangerops@polarfield.com	Office: 011.299.841598 Cell: 011.299.524218

CPS Offices

Thule AB	Scotia
CH2M HILL Polar Services PSC 1501 Unit 82501, APO AE 09704 Tel: 719.474.3840 x7353	Earl Vaughn C/O 109 th Aerial Port, Bldg. 20 Stratton Air Base Scotia, NY 12302-9752 Cell: 518.605.0979

CRITICAL SUCCESS FACTORS

Factors
Snow machines in good working conditions

GOVERNMENT AND PERFORMANCE REPORTING ACT OF 1993 (GPRA)

NSF/OPP requires your help in complying with the Government Performance and Reporting Act of 1993 (GPRA). One measure of CPS' performance is a "facility-performance metric" which counts the number of productive days your project has in the field while relying on CPS facilities or support. Please keep track of any "lost days" and report these to us at the end of the season.

PERMITS, ENVIRONMENT, HEALTH, and RISK

Permits: Any science team planning to work in Greenland must comply with all permitting requirements of the Government of Greenland. An overview of these requirements can be found on the Ministry of Domestic Affairs, Nature and Environment website: <http://naalakkersuisut.gl/en/About-government-of-greenland/Travel-activities-in-remote-parts-of-Greenland>. Please alert your Greenland project manager to all permit requirements that you have identified.

Endangered Species: Researchers working in locations where polar bears are present should follow the interaction guidelines developed by CPS and NSF. The interaction plan can be found at <http://cpspolar.com/for-researchers/environmental-compliance-support/>.

University of Colorado-Denver (UCD)/Wilderness Medicine: If you need medical advice/assistance while in the field, do not hesitate to contact UCD using the information below. For further information on UCD, please visit: www.coloradoWM.org

UCD 24/7 Telemed service contact information:

Phone #: 844.285.4555 or 720.848.2828 (both numbers go to the same line)

Member ID: ARCTIC FIELD SUPPORT

Website: www.coloradoWM.org

Medical Kits: Standard kits with first aid and over-the-counter drugs are available upon request. Note that prescription drugs are not included. Researchers who wish to include prescription drugs should contact their personal physicians. Kits will be issued to the PI or lead field team member and will become their responsibility for use in the field. The kit must be returned to CPS at the end of each field season so we can maintain and replenish them prior to reissue.

Risk Assessment: This Risk Assessment is intended to help you plan for your project. It lists some potential hazards and gives suggestions for how to minimize or manage them. It is not a complete list of the hazards researchers may be exposed to but is intended to help get you started on hazard analysis. You should review it with your team, brainstorm other potential hazards, and take action as needed. Ultimately you should consult with your institutional risk management/HSE department. It is important that the institutions involved in the grant understand the risks of the project and contribute to the process.

A Risk Assessment call, inclusive of both risks and suggested mitigations, was provided on 27 January 2017. Attendees included Kyli Cosper, Jessy Jenkins, and Matt Irinaga of Polar Field Services; Joseph Smith of US Naval Academy; Andreas Muenchow, Patricia Ryan, Peter Washman, David Huntley, and Justin Eickmeier of University of Delaware; Lee Freitag of WHOI.

Additionally, via email on 02 Feb 2017, PFS' Matt Irinaga provided additional information regarding the potential dangers of handling propane and results of propane leaks and requirements to perform propane transfers from 20lb tanks to 16oz cylinders.

An onsite risk assessment refresher will be held in Thule prior to commencement of field work with PI Muenchow, US Naval Academy team, and on-site CPS personnel.

Note: The PI and his/her university/institution are responsible for the safety of team members conducting field work on the grant. Read [NSF Grant General Conditions 1a. and 48](#) for specific language regarding responsibility and liability. Please visit our website for additional information on Field Risk Management, including information on workers' comp, insurance and emergency contacts that you may choose to use before you go into the field: <http://cpspolar.com/for-researchers/know-before-you-go/>

If your project involves an activity with an AHA (Activity Hazard Analysis), a copy of the AHA can be obtained from your project manager. This is a written document outlining the hazard and risk reduction in detail.

Hazard type	Potential Mitigations
Personal Responsibility	<p>CPS is available to assist, but field teams are responsible for their own safety</p> <ul style="list-style-type: none"> Review Know Before You Go Know the terms and conditions of your grant, and your institution's policies on medical evacuation, liability, workman's comp insurance, etc. Med Evac insurance is recommended for many locations. Ensure your field location is covered by the specific insurance. Assess your field team's level of experience and provide training as appropriate

Personal Responsibility (cont.)	<ul style="list-style-type: none"> Be aware that weather and other factors may delay even an emergency departure from the field Practice "What If" thinking and develop good habits Use good judgment and consider decisions and their ramifications carefully ** Remember that though CPS and others assist, you are responsible for your own safety.
Alcohol & drugs	Follow all federal and local rules regarding possession and use, including not driving under the influence.
Communications	<ul style="list-style-type: none"> Carry the appropriate communications system (satellite phone, VHF radio, maritime radio, ground to air, tetra, etc.) <ul style="list-style-type: none"> Verify your phone and/or radio works and is fully charged before going out Carry a spare battery Keep radios/batteries inside coats to keep batteries warm, dry, and operating efficiently Work with your project manager or local camp management to establish a check-in which should include a regular check in and an overdue time that will result in a Search and Rescue (SAR) being launched. <ul style="list-style-type: none"> Be aware of the chain of events when a SAR is initiated. Make sure the person who you are checking-in with is known to CPS so that person can be contacted if someone needs to get in touch with you. Provide your project manager with a non-deploying field team point of contact who has your team's travel plan and emergency contact information.
Communications - Near Miss/Incident Reporting	<ul style="list-style-type: none"> Report any near misses or incidents to your PM as soon as possible. An incident is an event that results in injury, illness to people or damage to field equipment. A near miss is an event that did not result in injury, illness or damage, but had the potential to do so. Reporting is not punitive, rather used for analysis and preventing accidents.
Emergencies	<ul style="list-style-type: none"> See Field Emergency Action Procedures (EAP) for Researchers as a helpful resource to prepare for an incident before leaving for the field Compile a list of emergency contacts for your field team and share it with critical participants including your home institution and CPS. Know your local Emergency Contact numbers <ul style="list-style-type: none"> See Thule, On-Site Emergency Contacts Keep relevant phone numbers with you at all times <p>Institute Resources:</p> <ul style="list-style-type: none"> Discuss your project with your institute's Director of Administrative Services or equivalent, reviewing insurance coverage before deployment Discuss your project with your institute's Risk Management Office, reviewing your institution's emergency response procedures before deployment Provide your PM with contact information for the Risk Management POC for your project at your institution before deployment Understand how a Search and Rescue would occur in the area you are working
Medical or fitness concerns for remote work	<ul style="list-style-type: none"> Serious medical emergencies may require evacuation by air. Weather, flight schedules, or local conditions may delay even an emergency departure from the field. Discuss your physical condition with physician and concerns they may have for your location. Inform others in team of concerns, medications, allergies, relevant medical history etc. Even if medical pre-qualification is not required, consider a doctor's checkup prior to deployments. It is recommended to bring at least 7 extra days of medication to a remote field site. Be aware of necessary vaccinations. Be realistic about the physical and emotional fitness of team members deploying for fieldwork. Lead by example and modify field work to the lowest common denominator. <p>Medical Kit:</p> <ul style="list-style-type: none"> If receiving CPS Medical Kit, review contents prior to field deployment.

Medical or fitness concerns for remote work (cont.)	<ul style="list-style-type: none"> ▪ CPS provides a 24/7 medical call in service for all NSF projects. If you have a medical emergency or question call 844-285-4555 or 720-848-2828. A physician trained in wilderness medicine is available. ▪ Review emergency call-in instructions (included in Season Plan and attached to kit)
Anaphylaxis/Severe Allergic Reaction	<ul style="list-style-type: none"> ▪ Ask about food, insect or other allergies among your group. It is possible that some young adults may not be aware of a serious allergy. ▪ Consult with your Institution's Risk Management, HSE or medical advisor about possession and use of an Epi Kit for anaphylaxis. ▪ The Red Cross and other organizations offer classes in-person and online on epinephrine injection.
Level of field team experience & responsibilities unknown	<ul style="list-style-type: none"> ▪ Assess your field team's level of experience and provide training as appropriate. ▪ Identify key positions and skill sets for field team such as first aid, leader, and mechanic. ▪ Don't underestimate the importance of defining who takes the leadership position in an emergency. Competent leadership will make all the difference.
Cold weather	<ul style="list-style-type: none"> ▪ Participate in a cold weather injury training which is part of the Wilderness First Aid or Wilderness First Responder curriculum. ▪ Wear proper clothing and/or extreme cold weather gear and bring extra items (socks, gloves, etc.). ▪ Travel with a partner. Watch other team members for signs of cold weather injury - they may not be aware of it themselves. ▪ Choose appropriate camping gear and adequately rated sleeping bags and/or emergency gear. ▪ Check the forecast and watch for changing weather conditions. ▪ Stay hydrated - carry sufficient food. ▪ Share your travel plans with your team. ▪ Develop an emergency plan for bad weather. ▪ Batteries for electronic devices should be kept warm and insulated to ensure they will work. Lithium batteries perform better in cold temperatures than regular batteries and are available in typical sizes (such as AA and AAA). ▪ Know if there are any cold-weather limitations or cut-off temperatures for the equipment being used.
Poor weather conditions	<ul style="list-style-type: none"> ▪ As with any High Arctic location, weather at Thule can be unpredictable, including high winds and fog ▪ Thule's temps can range from up to 70F in the summer to -50F in the winter ▪ Monitor Thule's weather activity daily on local TAB weather channels ▪ Be flexible with travel plans ▪ Discuss possible scenarios and how to respond prior to arrival. Determine safe operating parameters ahead of time and shut down operations if conditions exceed the limits. <p>Note Storm Season Travel Requirements apply Sept 15 – May 15</p>
Communal Living/ Personal Health	<p>Structure Fire</p> <ul style="list-style-type: none"> ▪ Ensure fire, smoke and CO detectors are functional. GC performs checks of Bldg 353. Do not disarm detectors. Alert GC if any issues. ▪ Have an emergency plan in place <p>Personal Health</p> <ul style="list-style-type: none"> ▪ Wash your hands frequently ▪ Avoid contact with others if you are sick. ▪ Use your own washcloth, towels, not communal towels. ▪ Clean living and work spaces regularly
Truck travel	<ul style="list-style-type: none"> ▪ Adhere to all local laws ▪ Check for travel, road, and wildlife advisories ▪ Do a pre-use check for damage, fluids and tires. Let CPS know if any warning lights come on. ▪ Ensure the truck has spare tire and jack for extended trips ▪ Do not ride in the bed of the truck. ▪ Adjust driving to accommodate for local conditions (visibility, road surface, residential areas etc...). ▪ Carry basic survival gear with truck. ▪ Plug in and warm up vehicles during winter months or below +20F. ▪ Some trucks have hubs that can be locked to provide additional 4WD traction - review the issued truck during orientation.

All Remote Travel (boat, foot, ski, snowmobile, vehicle, aircraft, glacier, ice, etc.)	<ul style="list-style-type: none"> Carry maps of the area you plan to travel in. USGS topo maps or other detailed maps are preferred. (http://store.usgs.gov) Identify potential problems/hazards along your route and have contingency plan to deal with them. Develop a plan for dealing with emergencies and understand how a rescue would happen. Emergency Action Plan template is available Carry communications device, GPS unit and/or PLB. Carry spare batteries. Create a travel plan (field itinerary) and adhere to your camp check-in/check-out procedures. Field itinerary template is available from CPS website. Carry appropriate first aid, survival and repair equipment for your mode of travel. Avoid traveling alone. Use a guide as necessary. Take PFS-provided snowmobile training in Thule regarding safe operation, building of sled loads, etc.
Off base travel	<ul style="list-style-type: none"> Follow required Thule check-in/out procedures established by HILLTOP <ul style="list-style-type: none"> Have a communication plan in place Carry appropriate communications device tetra and/or PLB and GPS unit. Carry maps of the area you plan to travel in Be aware of your environment including weather and wildlife (See “Bears” factor below) Identify potential problems/hazards along your route and have contingency plan to deal with them Develop a plan for dealing with emergencies and understand how a rescue would happen Carry appropriate first aid, survival and repair equipment for your mode of travel Carry maps of the area you plan to travel in. USGS topo maps or other detailed maps are preferred. (http://store.usgs.gov). Create a travel plan and adhere to your check-in/check-out procedures.
Darkness/limited visibility	<ul style="list-style-type: none"> Each team member should have a personal headlamp with spare batteries. Be aware of obstructed views working in pressure ridges on sea ice, snow drifts and the ice shelf and in mountainous terrain. Be organized and prepared to leave on schedule in order to maximize short daylight hours.
Sea/lake/river ice travel	<ul style="list-style-type: none"> Participate in sea/lake/river ice training. Maintain proper rescue equipment and know how to use it. Hire an ice-safety expert. Recent satellite imagery can help understand the ice conditions.
Sea Ice	<ul style="list-style-type: none"> Monitor sea ice conditions prior to deployment http://pafc.arh.noaa.gov/ice.php?img=ice. Be flexible as sea ice dynamics will ultimately determine where you can work. Be aware of tidal cracks near land forms like headlands, islands etc. Watch for open water or thin ice. Verify ice thickness with measurements if unsure. Be aware that thin, early season ice may be covered with snow and appear thicker than it really is. Monitor tides and offshore wind. Look for signs of instability/movement while traveling and working on the sea ice. Be aware if working on ungrounded sea ice, scan the surroundings to maintain situational awareness. Always be prepared to leave the site at a moment's notice. Report any polar bear or walrus sightings.

Snow machine travel, including sleds/loads:	<ul style="list-style-type: none"> Participate in snow machine training. Work with CPS to familiarize yourself with the machine, its operation, tools and spare parts. Use appropriate protective equipment such as helmets. Check fuel, oil, drive belt, undercarriage and suspension before use. Warm up the machine, break track and suspension loose. Carry survival gear on all trips. Secure sled loads adequately. Check hitch connections on sleds with every use. Establish a system/schedule of communication between machines and sleds. Refer to separate Activity Hazard Analysis (AHA) on snow machine use available from your CPS project manager. Drive responsibly and do not carry more passengers than the snow machine is rated for.
Bears	<ul style="list-style-type: none"> Review Polar Bear Interaction Plan. See CPS website for additional bear safety resources. Review Greenland Bear and Firearm Safety. Discuss firearm guidelines for TAB with project manager. Participate in bear safety training Carry radios to alert others to bear in area Travel in groups Adhere to local TAB rules. Hire knowledgeable local guides. When hiring a guard, provide clear expectations/procedures. Do not expect them to be a team member as their job is to be a lookout. <p>***Note: If traveling more than 500m from vehicle, travel in pairs is required by TAB/GC***</p>
Firearms	<ul style="list-style-type: none"> The NSF has recommended that all ARSLS participants, including direct bill and interagency project personnel, who take firearms into the field as part of the Arctic Program must complete a firearms safety training class provided by a recognized organization such as the National Rifle Association or affiliated organization, or through a local law enforcement agency such as police or sheriff's department. It is the PI's responsibility to ensure his/her team has the appropriate training. Researchers should consult their institution's risk management group to confirm that it allows employees and/or volunteers to carry firearms in the field. Develop a written firearms policy for your project and discuss it with your group. Include firearm protocol in transit, storage, loading and maintain a roster of who has received training. Ask for input on appropriate types of firearms and ammunition. Review Greenland Bear and Firearm Safety
Wildlife	<p>All members of team must be diligent in watching for wildlife.</p> <ul style="list-style-type: none"> Muskoxen <ul style="list-style-type: none"> As with any other wild animal, do not agitate or approach Musk oxen may charge without warning, give muskox plenty of space. <ul style="list-style-type: none"> A stressed muskox group may form a defensive line and face you. Stressed and agitated animals may begin to sway their head from side to side. Avoid unnecessary disturbances. Exit the area as calmly and quickly as possible. Arctic fox, sometimes rabid. <ul style="list-style-type: none"> Don't excite the animal, back away cautiously. If approaching fast, get away as fast as you can. Sled dogs <ul style="list-style-type: none"> Remember that sled dogs in Greenland are working dogs and not like pets. Treat sled dogs as you would other wildlife. Bears <ul style="list-style-type: none"> See separate risk factor specific to this species. Birds <ul style="list-style-type: none"> Be aware that several bird species will become aggressive when threatened, including Arctic terns, gulls, etc.

Dangerous goods and equipment	<ul style="list-style-type: none"> Identify any potentially hazardous piece of equipment or materials to your project manager. Examples may include vacuum instruments, ovens, pressure tanks, steam drills, explosive devices, lithium batteries or energy storing equipment capable of accidental discharge or release. Obtain all manuals for equipment. Ensure all users are properly trained. Wear personal protective equipment.
Hazardous materials, cylinder and fuel handling	<ul style="list-style-type: none"> Identify hazardous materials to field team members and CPS. Review MSDS/SDS (Material Safety Data Sheet/Safety Data Sheets). Work with your home institution to assure materials are properly packaged and documented for safe transport. Work with your home institution to review safe handling procedures for cylinders and hazardous materials. Develop a plan for fuel spills/first aid and request a current Activity Hazard Analysis explaining safe fuel handling procedures. Properly store and segregate hazardous materials including labelling. Collect and dispose of hazardous waste in compliance with local and federal regulations.
Heavy lifting/body strains & sprains	<ul style="list-style-type: none"> Use proper lifting techniques. Ask for help if needed.
Multiple fuels	<ul style="list-style-type: none"> Label all fuel types clearly. Label fuel tanks on motors/heaters with type of fuel to be used. Make sure all members of the team understand there are different fuels and which motors/heaters use which type of fuel. If the wrong fuel is used, empty the tank and start over to avoid damage to the engine or possible fire.