QikIce 2023– Towards an understanding of the light and ice interaction

April 19th to May 3rd, 2023, in Qikiqtarjuaq, Nunavut

Participants:

- PI leader: Marcel Babin (MB)
- Chief scientist: Marie-Hélène Forget (MHF)
- Research assistant: Joannie Ferland (JF), Guislain Becu (GB), Raphaël Larouche (RL)
- Invited researchers: Silvia G. Acinas (SGA) and Pablo Sánchez (PS)
- Students: Bastian Raulier (BR), Béatrice Lessard-Hamel (BLH), Christophe Perron (CP), Manon Gibaud (MG), Gabriel Lapointe (GL)

Objective: During the Arctic spring, the availability of light is the main limiting factor for the growth of in-ice, under-ice, and open water algae blooms. In winter, most of the sunlight gets backscattered by the snow to the atmosphere, giving the sparkling white color to the region. As spring approaches, the snow becomes thinner and moister, allowing more light to reach the underlying ice. While measuring the amount of light is relatively easy, understanding the radiative transfer process that occurs inside the ice is challenging.

To address this challenge, the QikIce 2023 mission, led by Marcel Babin, employed a combination of established and cutting-edge techniques. The Takuvik International Research Laboratory

developed new endoscopic techniques that are less disruptive and allow in-situ measurements directly on the icepack. The mission has two focus.

The first focus of the mission was on the optical properties of the ice-snow pack. Classical radiometers were used to measure the reflectance and transmittance of the sea-ice pack (CP, BR, RL, GB). In addition, in-ice tridimensional photon fluxes were measured using a calibrated 360 camera (RL, BR), and the scattering properties of the ice were measured using a diffuse reflectance probe (CP). Absorption coefficients were measured by filtering the contents of ice cores to observe their particulate and dissolved colored matter content (BR, MHF, JF, GB, BLH). The microstructure of the ice pack was also examined. Several snowpits were made to study the different layers of snow and the crystals composing them (BR). The crystallography of the ice was also studied by taking advantage of the natural birefringence of the sea ice (RL).

The second focus of the mission was on the life that can thrive in the brine channels. For the first time, a microscope specially designed for use directly in the ice captured images of microscopic algae without removing them from their habitat (BLH, GB). Ice samples will undergo taxonomic studies to confirm the in-situ measurements (BLH). A special probe was designed to measure the nutrients in the brine channels, which is critical for the growth of algae. For the first time, the brine channel liquid could be directly extracted and analyzed without taking the ice core out (GL). Collaborators from the Institute of Marine Sciences (ICM-CSIC, Barcelona) also collected brine samples and sea-ice core samples to proceed with genetic analyses of the microorganisms (SGA, PS).

All those measurements will fuel large scale numerical simulations and enable a better understanding of the Arctic and how it will evolve in the future.

Accommodation: Siku hotel and Geela's B&B

Local support:

- Johnny Kooneellosie (Siku hotel owner, storage of cargo prior arrival, storage or dryshipper in freezer)
- Geela Kooneellosie (B&B owner)
- Inuit guides: Lizzie Natsiapik, Goatamie Audlakiak, Jaypootie Moesesie
- Yves Christen (firearm and 2 Qamutiks)
- Billy and Daisy Arnaquq (3 skidoos rental and 1 Qamutik)
- Kitty Natsiapik (dessert/snack cooking)
- Dan MacDonald (School principal)
- Gideon Thwaites (Science teacher, laboratory access)

Operation sequence: 2 consecutive days on the field followed by one day in the lab/community

Field day trip schedule (9h-17h):

- 8h00 packing at the lab-15h
- 9h00 departure from community – 15h30 packing at station (6-7 hours on station)
- 40-60 min drive both ways
- Safety: helmet, firearm (1 banger, 2 rubbers, 2 slugs), Satphone, InReach, 3 VHF (channel 14 for communication, channel 26 for safety), offline maps of the area on 4 personal cell phones used as GPS
- Always guided by an Inuit on his own skidoo with his own firearm

Figure 1 Stations visited around Qikiqtarjuaq island, Baffin Bay, Nunavut

Table 1. Participants of the field per day. Black cells mean participants left Qikiqtarjuaq. Grey cells mean a day in the community/lab.

Commented [1]: Silvia and I left on Sunday 30, so we did not go to the field that day (Table below)

		Station	Marie-Hélène Forget	Marcel Babin	Joannie Ferland	Guislain Becu	Raphaël Lavoie	Chistophe Perron	Bastian Raulier	Béatrice Lessard Hamel	Gabriel Lapointe	Manon Gibaud	Sylvia G Acinas	Pablo Sanchez	Lizzie Natsiapik	Goatamie Audliakiak	Jaypootie Moesesie
Wednesday	2023-04-19	Arrival and mobilisation															
Thursday	2023-04-20	Mobilisation															
Friday	2023-04-21	QI01		x	x	x	x	x	x	x	x	x	x	x	x		
Saturday	2023-04-22	QI02		x	x	x	x	x	x	x		x	x	x		x	
Sunday	2023-04-23																
Monday	2023-04-24	QI03		x	x	x	x	x	x	x	x	x				x	
Tuesday	2023-04-25	QI04			x	x	x	x	x	x	x	x	x	x		x	
Wednesday	2023-04-26																
Thursday	2023-04-27	QI05			x	x	x	x	x	x	x					x	
Friday	2023-04-28	QI06			x	x	x	x	x	x	x	x	x	x		x	
Saturday	2023-04-29																
Sunday	2023-04-30	QI07			x	x	x	x	x	x	x	x	x	x		x	
Monday	2023-05-01	QI08			x	x	x	x	x	x	x						x
Tuesday	2023-05-02				School activity/Demobilisation												
Wednesday	2023-05-03				Cleanup and departure												

Thursday April 20th

Science meeting at 9h15

Security points :

- We are here under a licence and we are under Marcel's responsibility
- Always ask and inform the person in charge of any activity to be happening, any initiative should be discussed with Marcel and/or Marie-Hélène.
- Issues:
    - Ice: thickness, except the bay in from of the community inside the land limit, anywhere else is to be guided with an Inuit
    - Bear: Always be conscious that we are in their habitat
    - Cold: frostbit, hypothermia
- Sampling only in area listed in the licence, not at the dumb for example
- Skidoo driver needs to have been through Laval's training
- Solar noon is at 12:15 / Solar midnight 00:15
- Sunset 20:30 / Sunrise 4:07

Tour de table

Mobilisation

- Lab installation
- Siku battery and drylab installation
- Communication devices programed and charge
- Safety gear check
- Hire a guide for Friday

Ice core trial in the bay in front and lab mobilisation final

MilliQ installation took a long time as there were leakages at a lot of places in the plumbing prefiltering the system.

Friday April 21th

Station QI01 on the northern side of the island. First field day, beautiful sun

Inuit Guide: Lizzie Natsiapik, skidoo, firearm and Qamutik

Departure time: 11h00 Arrival time: 16h45

Objectives: Try all the instruments in the snow and in the ice, synchronize the choreography of the different teams as they need to share a few tools.

Bumpy ride in skidoo.

Operations were not fluid but it was normal as a first station.

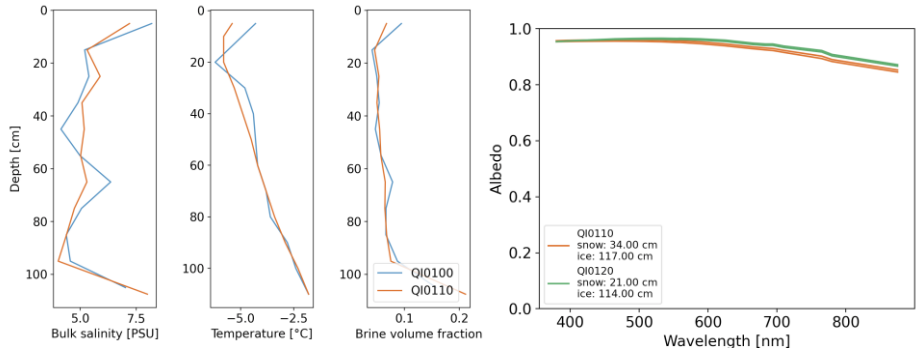
Missing some accessories for specific equipment to be fully efficient on the next station.

A snow station was achieved on the return on the landfast ice in front of the dump by the community for Manon's objective.

Total sites on station: 3 - 2 Bio sites /2 optics sites

Issue with the camera and the nutrient probe.

- Camera 2BW7X7 with covers, self-shading.
- The nutrient probe does not pump brine nor measure anything. The UV lamp is not working and the pumping system needs to be simplified and fixed with Guislain's support before going back on the field.



Saturday April 22th

Station QI02 on the southern side of the island. Beautiful sun again.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

Departure time: 9h00 Arrival time: 16h00

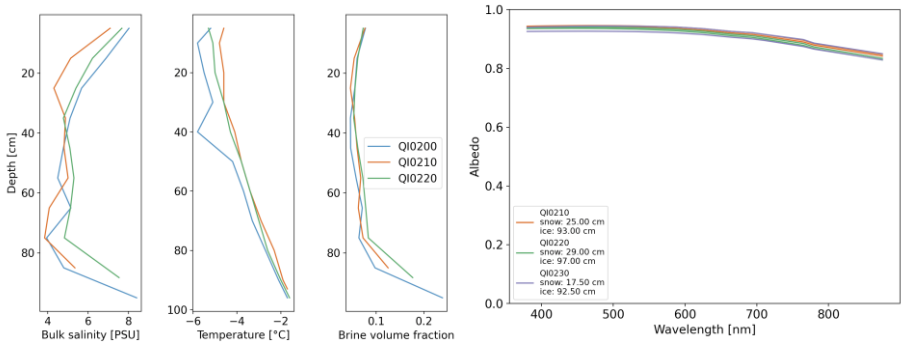
Soft skidoo ride and thick snow area.

Objectives: To set up a station with average snow cover (17.5 to 25 cm) in order to measure transmittance and reflectance in these conditions, which are often found around the island.

Total sites on station: 4 - 3 Bio sites /3 optics sites

Issue with the camera probe.

- Camera 2C9JCA no covers, self-shading



Monday April 24th

Station QI03 on the southern side of the island. Beautiful sun again.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

Departure time: 9h00 Arrival time: 16h00

Soft skidoo ride and blue ice station, by the coast.

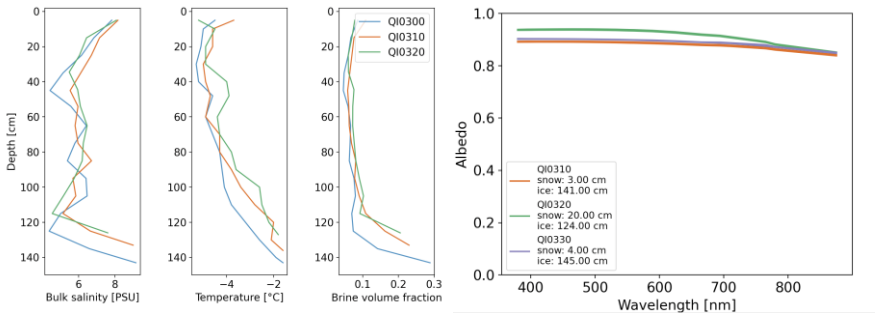
Objectives: Take measurements under conditions of minimum snow depth (2 cm). Measure the effect of local variability in snow depth (3 to 20 cm). This station was achieve very close to the

coast, so it is expected to have an effect on the presence of terrestrial contaminants in snow and ice.

Total sites on station: 4 - 3 Bio sites /3 optics sites

All instrument worked simultaneously for the first time

- Camera 2C9JCA, no cover with white tape to remove self-shading
- The microscope worked without a filter and ice algae could be seen for the first time in the brine.
- Pump for the nutrient probe was fixed and brine profile could be sampled for the first time.



Tuesday April 25th

Station QI04 on the southern side of the island. Thick fog, no visibility in the morning. Fog lifted by lunch time then wonderful day under blue sky.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

Departure time: 9h00 Arrival time: 16h00

Soft skidoo ride by the coast then slightly bumpy as we drive toward the middle of the channel. Green Edge station area is the target.

Objectives: Return to the GreenEdge site to make comparable measurements and attempt an analysis of the annual variability encountered at this exact location.

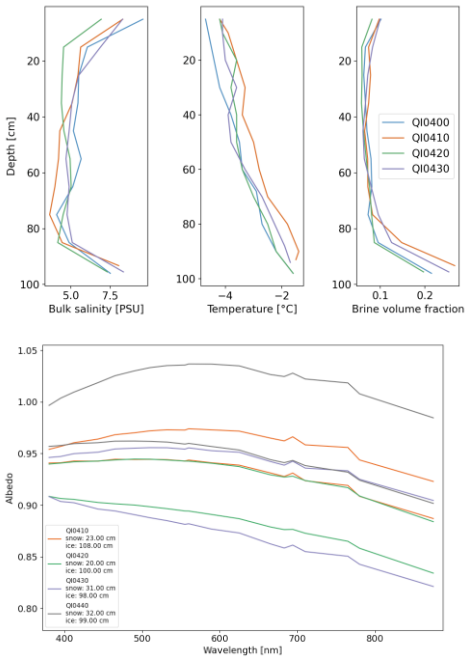
ICE and snow conditions

Total sites on station: 5 - 4 Bio sites /4 optics sites

The microscope worked without a filter and Béatrice could see for the first time a lot of live ice algae through her microscope.

Issue with the camera and or the IOP probe.

- IOPs probe fuse burned before 1rst measurement



Thursday April 27th

Station QI05 on the southern side of the island. Thick fog, no visibility in the morning. Fog lifted by lunch time then wonderful day under blue sky.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

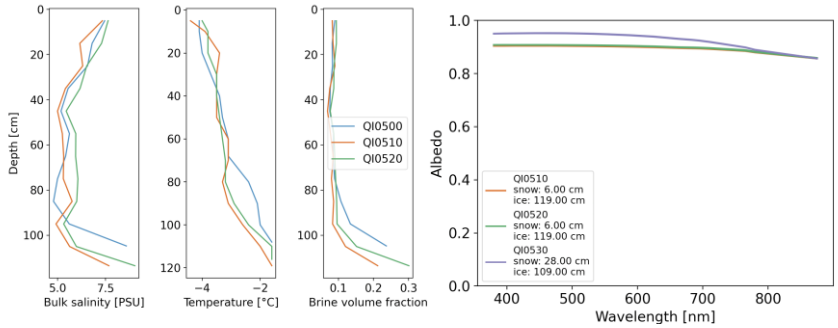
Departure time: 9h00 Arrival time: 16h00

Soft skidoo ride by the coast then slightly bumpy as we drive toward the middle of the channel. Target is to go further out from the GE station but due to thick fog condition, the station was based at the furthest out where we still saw the coast so not to far from " the cave"

Objectives: To make a station with an ocean signal away from the island, the coast and the fjords. Unfortunately, conditions of very low visibility made it impossible to move away from the coast. Nevertheless, it was possible to measure the effect of local variability in snow conditions (6 to 28 cm). This station also enabled us to make a "super-core", i.e. a complete profile of chlorophyll, dissolved colored organic matter (CDOM) and particulate absorption measurements, at a site with a snow depth of 6 cm.

Total sites on station: 4 - 3 Bio sites /3 optics sites

All instruments worked simultaneously.



Friday April 28th

Station QI06 on the northern side of the island. Thick fog, no visibility on the morning. Fog lifted by lunch time then wonderful day under blue sky.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

Departure time: 9h00 Arrival time: 16h00

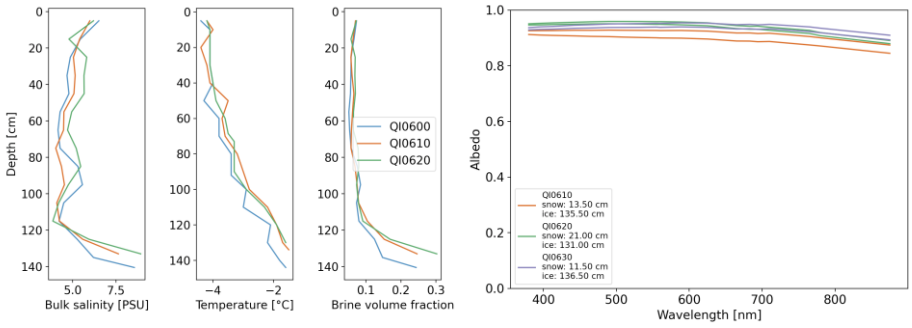
Target is to get to bumpier area with visible snow variability but not on the ridge area.

Objectives: This station in the north of the island was designed to move away from the coast and uniform ice once again, and into a more complex environment. The move to the north of the island was chosen to significantly reduce the effect of terrestrial contaminants, as the prevailing winds blow from north to south, reducing the likelihood of terrestrial contaminants. This station was also the subject of another complete ice core profile, this one at a location where the snow was 21 cm deep. The two complete profiles made at stations 5 and 6, being taken under two very different snow depths, will be able to inform optical modelling on the effect of absorption in the upper layers of the ice.

Total sites on station: 4 - 3 Bio sites /3 optics sites

Drone view for communication taken.

All instrument worked simultaneously



Sunday April 30th

Station QI07 on the southern side of the island. Nice sunny day.

Inuit Guide: Goatamie Audlkiak, skidoo, firearm and Qamutik

Departure time: 9h00 Arrival time: 16h00

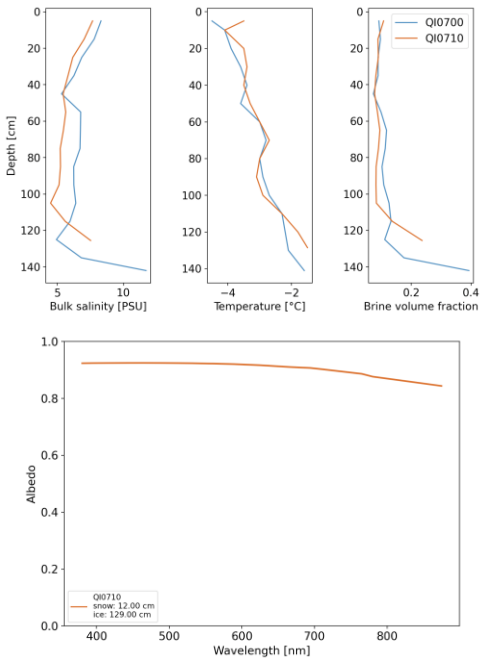
Special operation and revisit of station QI03 after a week, blue ice station by the coast.

A lot of photo were taken with the Takuvik Camera for all instruments and operations. Pictures were stored on the external disk. Great visual support for report/proposal/presentation.

Objectives: This station was one of special operations. In addition to the usual site, three experiments were carried out. The first experiment was designed to measure the effect of prolonged solar radiation on the reflectivity of the top layer of sea ice. The second was to measure the effect of immersion in water on the camera's field of view. Finally, the third experiment measured the light field in the ice, while the snow above was covered by a large black blob. The aim was to measure the horizontal travel of photons in the ice, in order to better understand the local effect of spatial variability in snow cover on available light.

Total sites on station: 4 - 2 Bio sites /1 optics site / 1 scrammssl site / 1 black tarp camera site

All instrument worked simultaneously



Monday May 1st

Station QI08 on the southern side of the island. Nice sunny day.

Inuit Guide: Jaypootie Moesesie, skidoo and firearm

Departure time: 9h00 Arrival time: 17h00

Target to the ridge area further out then the Green Edge station. The site “scramssl” from station QI07 was revisited at the end of the day to measure the changes on the ice surface after more than 24 hours.

Objectives: The main aim of the day was to measure the optical properties of compression peaks and compare them with those measured at previous stations.

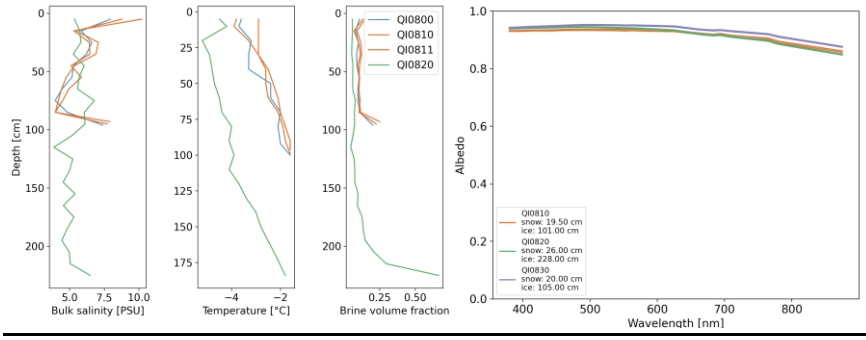
Average snow thickness and ice thickness variability and longest icecore (2.3m).

Total sites on station: 4 - 3 Bio sites /3 optics sites / QI07 scrammssl site

Drone view for communication taken.

All instrument worked simultaneously

School telescope was repaired by the engineers (BLH, RL, BR).



Tuesday May 2nd

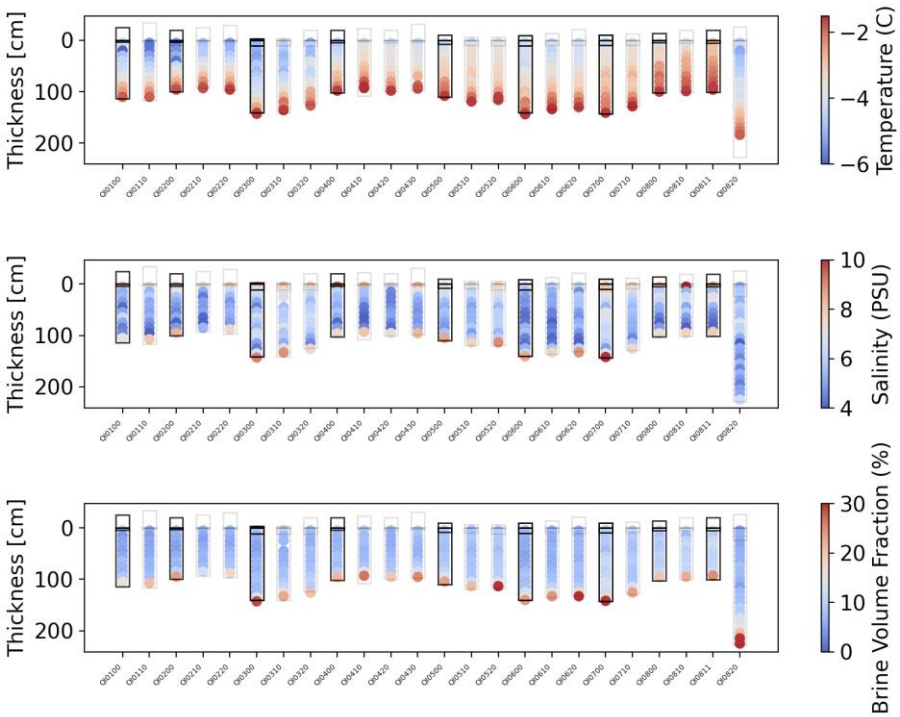
Inuksuit school activity with high school students.

4 stations in the labs and 2 on the ice in front of the school, plus snacks for the debriefing. (ADD PICTURES)

- Microscopy and ice algae observation (Béatrice) - LAB
- Filtration under green light (Manon) - LAB
- Ice crystal (polarisation) (Raphaël/Christophe) - LAB
- Salinity profile (Gabriel/Joannie) - LAB
- Ice coring and comparison experiment of dying freshwater versus saltwater icecore (Guislain/Marie-Hélène) - ICE
- Snowpit (Bastian) - ICE

Attendance was high, more than 20 students participated and were very interested and curious about the different topics presented. Photos/Video available.

Inuksuit newsletter to be written by the scientists and by the student on the appreciation of the activities presented.


Thickness [cm]
0
100
200
−2
−4
−6
Temperature (C)
Thickness [cm]
0
100
200
10
8
6
4
Salinity (PSU)
Thickness [cm]
0
100
200
30
20
10
0
Brine Volume Fraction (%)

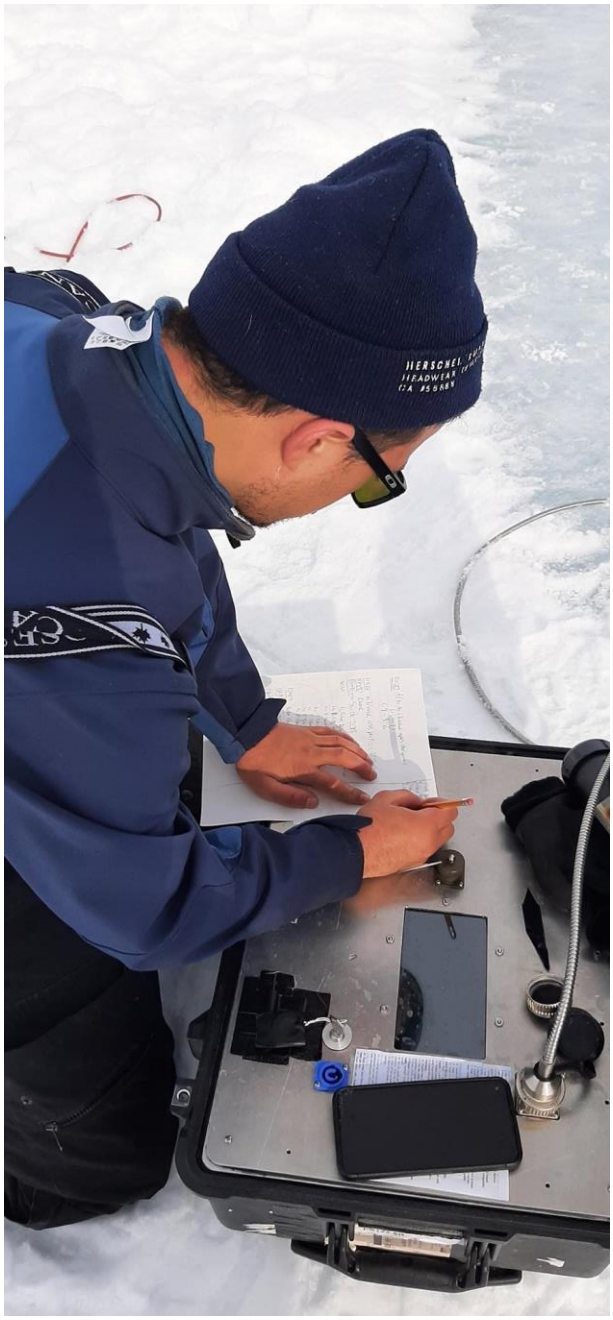
ANNEX 1- Instruments and their deployment (pictures)

NUTRIENT probe

MICROSCOPE probe

SNOWPIT

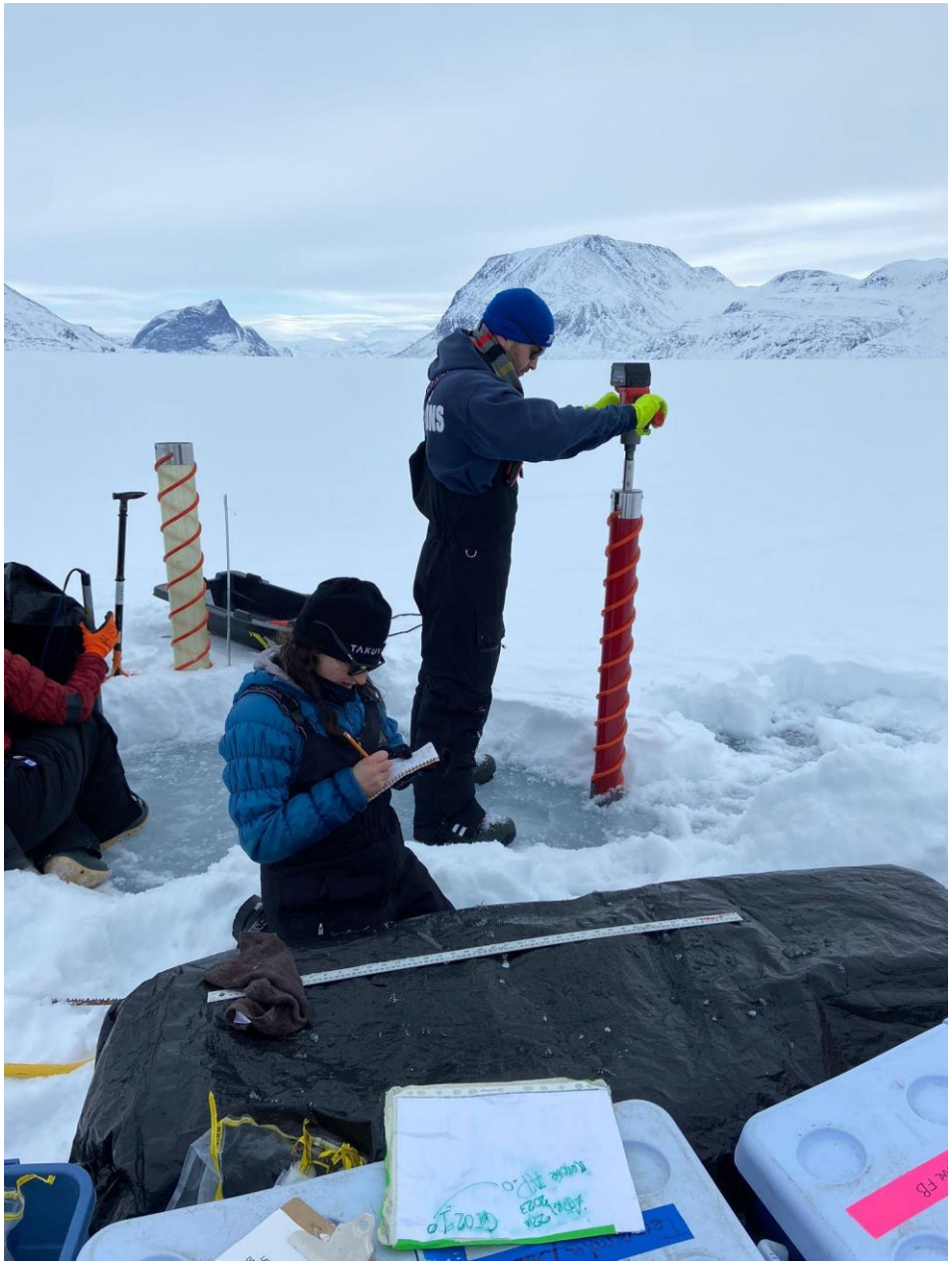
IOP probe


HERSCHEL


TAKUVIK
GOOSE

CAMERA 360

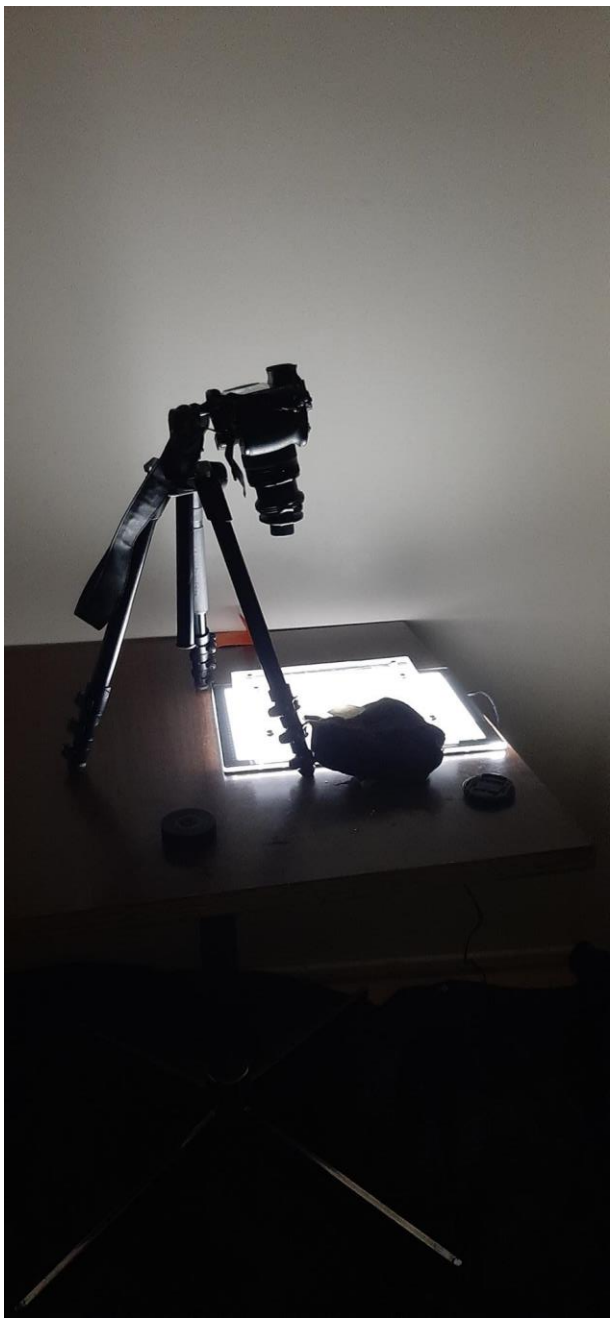
ICECORING



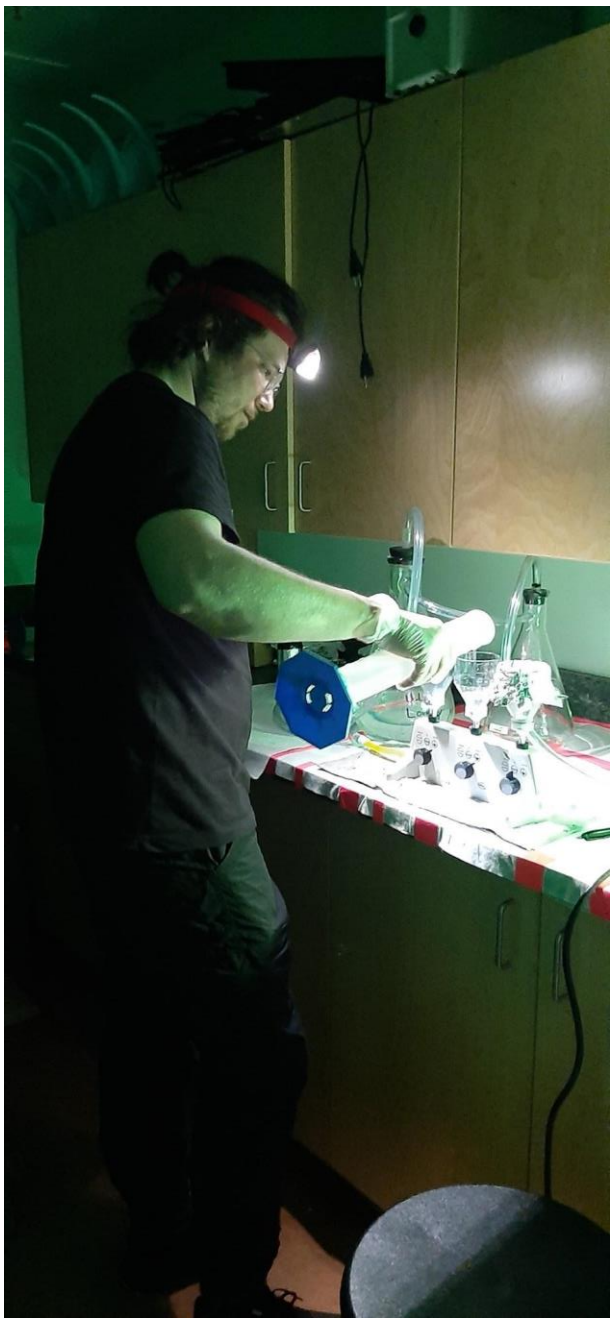

TAKUVIK

SACKHOLE

POLARISATION



LAB



Annex 2- Operations (excel sheet)

Annex 3 - Budget

Annex 4

Gabriel Lapointe:
My master's thesis is about the design of a probe that can measure the concentration of nitrate and nutrients in the brine pockets of sea ice. The QikIce mission was a great opportunity for me to test the concept of my instrument and the first design of its prototype. First, a really important part of the probe to test was the heating probe part, which was challenging to design because we had a limited power supply in the field and we were concerned that the heat wouldn't be enough to get deep enough and keep the water liquid through the pumping system. This part was tested by simply placing the endoscope section in the ice and waiting for the ice to melt as the water was pumped up. After a few problems with the control of the probing system, caused by an overload in the microcontroller, the system was able to get through most of the sea ice in a few hours, pumping brine water for each depth. Even though it took a considerable amount of time to penetrate the ice and only a small number of sites were explored, I would consider this part a success and only a few modifications would have to be made to upgrade the next prototype, such as better control of the heating and pumping system. Second, the part of the in-situ analysis didn't work as intended. The system was

supposed to pump the brine water into a liquid optical guide through which a UV light source would pass and come out again to analyze the absorption spectrum and measure the concentration of nutrients. Unfortunately, the UV light source we brought malfunctioned and wasn't usable for the entire mission. So instead, we collected many more samples to bring back to Quebec for analysis; when the problem is fixed with the UV lamp, we will compare the samples we collected with two analyses approach, the traditional method with the autoanalyzer and with this newly approach for field measurements. Finally, the collection of brine samples was measured by measuring the salinity of each sample. This part is the most exciting right now because it showed better results than expected. Not only was the instrument able to sample a salinity profile through the ice, but it was able to collect a non-negligible amount of water at a salinity point of over 90 ppt (the sea is at 35 ppt), and was much more concentrated in brine than the samples in sackholes or by coring. The sackhole technique, which involves drilling a hole in the sea ice without reaching the bottom of the ice and waiting for the brine to flow in and fill the hole, was also explored a bit for collecting brine. Since this is not the most popular protocol for brine sampling, it was really useful to test the limits of this protocol. For example, by drilling holes of different sizes, we found that the smaller the diameter, the saltier the collected brines are and the faster the hole fills. In conclusion, the mission was for the most part successful for my master and for the advancement of my project.

Béatrice Lessard-Hamel

Gaining microscopic insight into sea-ice's internal structure and biology has traditionally been limited to destructive and extrusive ice-core sampling methods. To make progress in the exploration of sea-ice micro-habitats, and in the study of sea-ice microorganisms with minimal disturbance, we are developing an innovative in-situ microscopic imaging system to observe the living microorganisms directly within sea-ice. I developed a prototype and tested it in the lab and my participation in the Qikice mission gave me the chance to test it on the field. The first tests were a success, and I achieved my goal of validating my prototype. With these results, we can demonstrate the potential for this new in-situ microscopic imaging system to revolutionize the way we study sea-ice and provide a deeper understanding of its complex microstructures and living microorganisms

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Christophe Perron

The inherent optical properties (IOPs) of Arctic sea ice play a fundamental role in our understanding of Arctic marine climate and ecosystems. Firstly, these IOPs are used to calculate the transformation of solar radiation into heat that melts sea ice. Secondly, they are used to calculate the quantity of light available for photosynthetic organisms in and under the sea ice.

However, it is very difficult to measure these IOPs without destroying the ice that we are trying to look at, which is why these properties have been studied very little. Simply taking a sample fractures the ice matrix, drains its liquid content and exposes the sample to melting caused by the sun. After which, all optical measurements on the sample are no longer accurate.

To solve this sample destructiveness issue, we have developed and tested three techniques for measuring the IOPs of sea ice directly in the medium. A spectral reflectance probe makes it possible to find the IOPs of the surface of the ice without even drilling a hole in it. Then, by drilling a small hole, 2 other endoscopic instruments called a radiance camera and a diffuse reflectance probe allow us to measure deeper inside the ice column while keeping a small footprint. These 3 techniques developed in our laboratory are unique in their kind and promise to improve our understanding of Arctic sea ice.

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light measurement inside sea ice (Raphaël Larouche)

Light availability for micro-algae at the bottommost part of the ice pack is controlled by ice's microstructure and optical properties. This spring mission to Qikiqtarjuaq was an opportunity to assess the spatial variability of sea ice optical properties around the island. In that regard, we deployed a new kind of optical sensor that measures light coming from all the directions. This gives the tri-dimensional structure of the light that gets transmitted at a certain point in sea ice. It was possible by transforming a commercial 360-degrees camera with a small form factor into a scientific radiometer. During the mission, we successfully acquired the angular distribution of the light in absolute units at different depths inside the top layer of snow, the ice and few centimeters in the ocean below, giving an unprecedent amount of information for all the scientific community.