# ICE MONITORING OF DECEPTION BAY

## *Contract #1459*

**Deliverables no.1 to no.4**

**Reports submitted to**

Kativik Regional Government

Renewable Resources, Environment,

Lands and Parks Department

**Attention: Michael Barrett, Associate Director**

Kuujjuaq (Quebec)


**Prepared by**

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# ICE MONITORING OF DECEPTION BAY

## *Reconnaissance visit to Deception Bay and to the Communities of Salluit and Kangiqsujuaq*

**Report submitted to**

Kativik Regional Government

Renewable Resources, Environment,

Lands and Parks Department

**Attention: Catherine Pinard, Assistant Director**

Kuujjuaq (Quebec)


**Prepared by**

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**Deliverable no.1**

July 15th, 2015

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The project "ice monitoring of Deception Bay" is conducted through a technical and administrative agreement between the Kativik Regional Government (KRG) and Raglan Mine, a Glencore Company. INRS acts as a consultant to KRG and is a partner to the project.

The global objective of the project is to better understand the interactions between the ice cover of Deception Bay, changing climate, winter navigation, safe access to the territory for Inuit communities and protection of the Bay's ecosystem. The specific objective of this agreement is to assess various monitoring techniques to document the characteristics, processes and variability of the ice cover during three winter seasons (2015-2018). Satellite images, on site cameras, ice profiling devices, ice thickness stations and ground penetrating radar will be jointly used. Control observations and measurements will be acquired in the neighbouring communities of Salluit and Kangiqsujuaq (Figure 1).

**Figure 1: Location of the study area.**

According to the services contract between KRG and INRS, the latter has the following responsibilities:

- To participate in a reconnaissance visit of the site at Deception Bay.
- To collect geographical information about the site and information about available technical facilities on site.
- To describe the proposed technology and provide the installation plan.
- To do an inventory of the available satellite imagery of the study area and to propose an acquisition plan.
- To participate in meetings with the Raglan Mine representatives and with the communities of Salluit et Kangiqsujuaq
- To proceed with the purchase and installation of the on-site cameras.
- To prepare the collected data for archival and distribution.
- To link the Deception Bay project and the Avativut project (Kativik School Board) through the participation of Nunavik students in ice observations and measurements at the witness sites of Salluit and Kangiqsujuaq.
- To participate in project management.

This work will lead to the following deliverables by INRS:

1. Visit report (Deception Bay, Salluit, Kangiqsujuaq)
2. Site characterization report (including the instruments installation plan and the satellite images acquisition plan
3. Installation report for the cameras and the data archival and dissemination plan.
4. Final report.

The present report is deliverable #1 and concerns the visit to Deception Bay in May 2015 and the visit to the communities of Salluit and Kangiqsujuaq in June 2015.

# 2 VISIT TO DECEPTION BAY

## 2.1 Objective of the visit

The objective of this trip (May 6-12, 2015) was to meet with the Raglan representatives at the Katinniq complex and to make an exploratory visit of Deception Bay. Specifically, we needed to answer the following two questions:

- What are the potential sites for instrumentation?
- What is the available technical and logistical support from Raglan Mine?

## 2.2 Day to day activities and discussions

**Wednesday May 6, 2015**

Jimmy Poulin (INRS) and Yves Gauthier (INRS) leaves by car from Quebec to Montreal.

**Thursday May 7th**

Departure from Dorval to Katinniq, with stop in Rouyn-Noranda. Flight postponed to the next day due to bad weather at destination. Staying in Rouyn-Noranda for the night. Met with Frédéric Lapointe (Raglan Mine), our assigned contact on site. Took the opportunity to complete Raglan Mine's on line mandatory training before arrival at Katinniq.

**Friday May 8th**

Arrival at Katinniq at 11:30. Brief visit of the building, health and safety training. Lunch with Véronique Gilbert (KRG).

In the afternoon, the three of us meet with:

*Frédéric Lapointe (Supervisor - Environment)*
*Jonathan Marceau (senior technicien – environment), Marc Gagné, Isabelle Deguise (Coordonnators - Environment),*
*Dave Laroche (in charge of telecom)*

Discussion:

We present the details of the project, the objectives, the partners, the potential benefits for Raglan Mine and for the communities.

We discuss the feasibility of installing a near-real time camera near the high antenna uphill from the central building at the Deception Bay site. Dave Laroche confirms that it would be possible within 100m or less of the small shed. There would be power supply and access to the internet. A PTZ model is proposed (pan, tilt, zoom) to scan the Bay from North to South. Defrost function necessary. Would it be a POE model (power over Ethernet)? They suggest the Panavisio model because they already manage 60 of them. We give the specs of the Campbell Scientific camera to Dave. Raglan Mine offers to build the posts to hold the cameras.

There may exist ice data from a few years ago. Alain Poirier or Clément Binette, at Deception Bay (DB) should know about it. Véronique will contact Frédéric to obtain the data. There should also be a bathymetry map at the DB building.

We discuss the SWIP and IPS instruments: deployment, potential sites, and installation requirements.

We discuss the ice stations (hot wire gauges): principle, deployment, and who will make the measurements. Raglan Mine agrees that one of their technicians could be mandated. However, due to safety considerations, he/she would start measurements when they are really sure of the safety and would stop when they start doubting the safety.

We discuss the visit at Deception Bay, scheduled for the next two days. Raglan Mine representatives highlight the fact that safety is a priority for the company, including at DB.

**Saturday May 9$^{th}$**

Departure for DB at 8:30, by road. Blowing snow. Jonathan Marceau (Senior Technician - Environment) is the driver. Arrival at 10:00.

10:30: Meeting with our Inuit guides from Salluit:

*Michael Cameron, his son and Chris Gosselin-Alaku.*

Planning of the afternoon outing. We explain where we would like to go and why. We study the bathymetry map found in the office of the site supervisor.

11:00: We climb on the hill with Jonathan to look at the antenna site (Figure 2). Limited visibility. Jimmy acquires GPS points. Yves takes pictures. Site is judged acceptable.

**Figure 2: Antenna site and northern view from the base of the tower.**

11:30: We climb down and continue to the Bay shore, between the port infrastructures of Raglan Mine and Canadian Royalties to look for a potential site for the ice monitoring station (Figure 3). Ice along the shore is rough and piled up. Access could be tricky. Jonathan says that it was ok a month ago. The ice station could be on the Bay, just past the rough area (at 200m from the shore).

Figure 3: Potential site for the ice station

12:45: We (Jimmy, Yves, Véronique) leave on snowmobiles with our Inuit guides. Jonathan stays on shore and asks that we call him every 30 minutes on a radio. Yves will ensure communication. Jimmy will take photos with the Reconyx camera. Temperature is about -5 degrees. It snows. Low visibility. But the guides know the area perfectly.

First stop: Black Point (7 km from Raglan Mine site) (Figure 4). We climb on the hill. Nice view point. But for now, visibility is minimal. Could be a good site for the camera. Chris mentions that there are a lot of burial sites in the area. But lower on the hill.

Figure 4: Stop at Black Point

Second stop: Moosehead Island. We climb on the higher point. Good view point. But again, visibility is minimal. We also look for a good site to install the SWIP.

Third stop: Sea markers on the west shore. Slope too abrupt.

Fourth stop just a few hundred meters south. The slope is less steep. Jimmy climbs the hill and identifies a potential site for the camera (Figure 5).

Figure 5: Climbing to sea marker

Back to port at 15:00. We discuss with Jonathan as to whether we stay at DB or go back to Katinniq. It is decided that we should stay in case there is a better visibility on the next day.

16:00 Debriefing (Jimmy Poulin, Yves Gauthier, Véronique Gilbert)

- We discuss the visited sites: Access, view, authorizations.
- We discuss the installation of the cameras, height of post needed. Max 6 or 7 feet so a ladder is not required to access the memory card. Jimmy will make a sketch of the required post for Raglan Mine. Véronique mentions that KRG does have a battery powered drill, similar to the one that INRS owns. This could be a good back up or provide spare batteries during installation.
- About the SWIP, Véronique will check the material they have at KRG. Yves will talk to Mélissa Gagnon (former KRG Environment specialist) to know more about the system that KRG has. Then we will contact Jan Buermans at ASL for the IPS. Véronique asks if the echosounders could disturb the marine fauna. Yves will check.
- About the ice station: Véronique will check the storage room at KRG Environment to inventory the ice station material. Yves will send the NSIDC guide to Véronique. We will check with Mélissa Gagnon what were the elements that KRG wanted to improve on the ice station.

**Sunday May 10th**

Windy and blowing snow. Road is closed. We stay at DB for another day. We climb on the hill several times. Visibility is slightly better than the day before. We can sometimes see Moosehead Island and Black point. We take pictures.

Yves and Véronique prepare the contract between KRG and INRS (responsibilities, deliverables, payment schedule, ownership of material and data, IP).

**Monday May 11th**

The sun is back. Good visibility. We go back on the hill to take pictures (Figure 6).

Figure 6: View of Moosehead Island from the Antenna site

The road reopens. We go back to Katinniq with an employee from DB. Arrival at 12:00.

Jimmy asks Raglan mine if we could reinstall one of their anemometers that are stored in the shed at DB. Raglan Mine accepts.

14:00 Departure for Quebec (Yves and Jimmy).

**Tuesday May 12th**

Véronique takes pictures of the metal post that will serve as a model for the one we will use for the camera. She sends the dimensions to Jimmy as well.

Véronique finds a map of the archeological sites located on and around the Raglan Mine property. She takes a picture and send it to Yves and Jimmy.

Departure for Kuujjuaq (Véronique Gilbert).

# 3 VISIT TO SALLUIT AND KANGIQSUJUAQ

## 3.1 Objective of the visit

The objective of this trip (June 14-19, 2015) was to meet with the representatives of the Salluit and Kangiqsujuaq communities, in order to present and discuss the ice monitoring project. Specifically, we needed to answer the following questions:

- Is the project acceptable for the communities?
- Would the communities like to add specific objectives to this study?
- Are the proposed sites for instrumentation of Deception Bay acceptable?
- Where would they like to locate the “witness” ice stations in their community?
- Would it be possible to involve local ice experts for the measurements at the ice stations?

We also wanted to meet with the science teachers at the schools to discuss the Avativut project and its link with the DB ice monitoring project.

## 3.2 Day to day activities and discussions

**Sunday June 14, 2015**

Yves Gauthier (INRS) leaves by car from Quebec to Montreal.

**Monday June 15, 2015**

Departure from Dorval to Kuujjuaq on First Air. Meet with Véronique Gilbert (KRG) in Kuujjuaq. Transfer to Air Inuit for Kuujjuaq-Salluit. Arrival at 17:30. Lodging at the CEN’s house (Figure 7).

**Figure 7: CEN’s house in Salluit**

**Tuesday June 16, 2015**

9:00 Yves and Véronique meet at the Ikusik highschool of Salluit with:

*Bernard Lefebvre, Principal*
*Dafe Atawo, professor of science (English)*
*Youcef Boualem, professor of science (French)*
*Hugo Jourdain, professor of science (French)*
*Tayeb Chalab professor of science (French)*

We present the Avativut program and discuss how it has been perceived by the teachers so far. The Ice Mission was implemented late this year. Not all teachers knew about it. Only one has tried to do it, partly.

We explain the link of the Ice Mission with the DB project and the ice measurements that will be made in their community. Strong interest from the teachers. They want to participate if they are better informed and trained before the activity.

13:30 Yves and Véronique meet at the conference room of the Nunavik Village of Salluit with:

*Paulusie Saviadjuk, Mayor*
*Peta Piguatuk, NV*
*Amana Saviadjuk, NV*
*Ialla Kaitak, NV*
*Annie Kenuayuk, NV*
*Ittualluk Saviadjuk, Assistant manager and Raglan employee (Human Ressources)*
*Johnny Alaku, President, QAQQALIK Land Holding*
*Jean-Jacques Morissette, QAQQALIK Land Holding*
*Michael Cameron, KRG Salluit*

We present the project's background, objectives, instrumentation plan, proposed sites and data dissemination. We discuss about the support we need from the communities. Here are some questions or comments received:

- Who will ensure maintenance of the cameras?
- What is the time frequency of the sonar beeps?
- How is the sonar powered?

- How long will the sonar stay underwater?
- Can the battery leak?
- Could mussels attach themselves to the sonar cable?
- Will the sonar disturb or scare the marine fauna?

We have to find clear answers to these concerns. (Enquiries were made following the meeting)

- An ice bridge was acquired by the Salluit NV (or LHC?) but was not used yet. The elder who was maintaining the natural ice bridge over the ship's track has died. Since that time, nothing is being done.
- There is a comment about the ship from Canadian Royalties, who seems to move around more than necessary. The ships do not always follow the same paths.
- Participants to the meeting express a concern about Raglan Mine using the results of this project against them.
- Where are the posts (camera) fabricated? Why not in Salluit?
- How many pictures acquired every day?
- How long will the camera stay there?
- All sites for cameras are acceptable. However, one is on Category 2 land, the other on category 3 and the other one on an island (Federal?).
- Eventually, the ice bridge should be installed near the Raglan Mine infrastructure.
- In Salluit, for the ice station, we should use metal posts. The youth will break wooden posts.
- Who will make the thickness measurements?
- When will the students start the Avativut Ice Mission?
- How long will they do it?
- Do not install the ice station of Salluit in front of the village. The area is used for a competition of Kite surfing. Should be installed north, near the snowmobile trail.
- Data/results dissemination should be done by a presentation in the village, a radio report by the mayor, and a paper copy distributed in the village.
- The mayor and LHC president would like to receive the documents used in this meeting (Done).
- Projects follow-up should be made to the mayor and LHC president.

**Wednesday June 17th**

Departure from Salluit. Arrival in Kangiqsujuaq at 10:00 (Figure 8).

Figure 8: Kangiqsujuaq

13:30 Yves and Véronique meet at the conference room of Nunavik Park in Kangiqsujuaq with:

*Markusi Qisiiq, Park director, Nunavik Park*
*Noah Annahatak, Park warden , Nunavik Park*
*Maali Tukirqi, Nunavik Park*
*Elaisa Alaku, Nunavik Park*
*Pierre Philie, Nunavik Park*
*Elijah Ningiurvik, Town Manager*
*Jaaji Pilurtuut, President Nunaturlik Land holding Corporation*
*Betsy Palisser, Scientific advisor for the communities, KRG*

We present the project's background, objectives, instrumentation plan, proposed sites and data dissemination. We discuss about the support we need from the community. Here are some questions or comments received:

- Where does funding for the project come from?
- What will happen in three years?
- Will the study include Lake Françoys-Malherbe? There is a problem of dust on snow and ice due to the road.
- Has the IPS technology been proven for use in the Arctic?
- Divers from Kangiqsujuaq are available to help in the installation.
- How often will ice thickness measurements have to be made at the ice station?
- Will there be a camera installed in Kangiqsujuaq?

- The local site for installation of the ice thickness station will probably be windy and without snow. It will be determined before winter.
- People from the community will be available to make the ice thickness measurements. M. Qisiiq already participated in such a study a few years ago. He regrets that it didn't go on.
- It would be interesting to measure ice thickness in Lake Françoys-Malherbe as well.
- Pierre Philie has old documents relating ice observations dating from the Hudson Bay Cie. He is preparing a summary that should be available later this fall.
- It is mentioned that Robert Fréchette, from Avataq, took daily pictures of the ice a few years ago during one season.
- For data and information dissemination in the community, an email to the leaders is better.

At the end of the meeting, the participants give an official go ahead to the project, based on the presentation and discussion, and on the fact that Salluit's representatives were positive also.

Additional notes:

- We should contact Avataq for any ice information in the two communities and to inquire about Robert Frechette's ice photos.
- When the Salluit and Kangiqsujuaq students go at the ice station with the community ice expert, they should also do the Avativut protocole (using an auger) nearby. This will enable comparison with other schools.
- Ask the CEN's webmaster (Luc Cournoyer) to add a page to the Avativut website for data entry of the three ice stations. As soon as the data are validated and approved by Raglan mine, send an email to the community leaders for display in the village.
- When new Landsat images are available, also send an email to the community leaders for display in the village.

# 4 FUTURE VISITS

The next visit to Deception Bay is scheduled for mid-September 2015, for installation of the cameras and echo sounders. Another visit is scheduled for December 2015, to install the ice station and start ice thickness measurements. A third visit should be done in March or April 2016, for more in situ ice measurements.

The next visit to Salluit and Kangiqsujuaq should be during fall 2015, as to provide training to the science teachers about the Avativut Ice Mission, and to confirm the sites and local experts for the ice station (ice thickness measurements). Another visit should be done during March or April to accompany the science classes during the Ice Mission, and the local expert at the ice station.

# ICE MONITORING OF DECEPTION BAY

## *Site Characterization Report*

**Report submitted to**

Kativik Regional Government

Renewable Resources, Environment,

Lands and Parks Department

**Attention: Michael Barrett, Assistant Director**

Kuujjuaq (Quebec)


**Prepared by**

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**Deliverable no.2**

August 31st, 2015

INRS UNIVERSITÉ DE RECHERCHE

MINE RAGLAN UNE COMPAGNIE GLENCORE

KATIVIK

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The project “ice monitoring of Deception Bay” is conducted through a technical and administrative agreement between the Kativik Regional Government (KRG) and Raglan Mine, a Glencore Company. INRS acts as a consultant to KRG and is a partner to the project.

The global objective of the project is to better understand the interactions between the ice cover of Deception Bay, changing climate, winter navigation, safe access to the territory for Inuit communities and protection of the Bay’s ecosystem. The specific objective of this agreement is to assess various monitoring techniques to document the characteristics, processes and variability of the ice cover during three winter seasons (2015-2018). Satellite images, on site cameras, ice profiling devices, ice thickness stations and ground penetrating radar will be jointly used. Control observations and measurements will be acquired in the neighbouring communities of Salluit and Kangiqsujuaq (Figure 1).


Figure 1: Location of the study area.

According to the services contract between KRG and INRS, the latter has the following responsibilities:

- To participate in a reconnaissance visit of the site at Deception Bay.
- To collect geographical information about the site and information about available technical facilities on site.
- To describe the proposed technology and provide the installation plan.
- To do an inventory of the available satellite imagery of the study area and to propose an acquisition plan.
- To participate in meetings with the Raglan Mine representatives and with the communities of Salluit et Kangiqsujuaq
- To proceed with the purchase and installation of the on-site cameras.
- To prepare the collected data for archival and distribution.
- To link the Deception Bay project and the Avativut project (Kativik School Board) through the participation of Nunavik students in ice observations and measurements at the witness sites of Salluit and Kangiqsujuaq.
- To participate in project management.

This work will lead to the following deliverables by INRS:

1. Visit report (Deception Bay, Salluit, Kangiqsujuaq);
2. Site characterization report (including the instruments installation plan and the satellite images acquisition plan);
3. Installation report for the cameras and the data archival and dissemination plan;
4. Final report.

The present report is deliverable #2 and concerns site characterization, instruments installation plan and satellite images acquisition plan.

# 2 SITE CHARACTERIZATION

## 2.1 Objective

This section is not an exhaustive description of the physical, biological and human environment of Deception Bay. It presents some general information that will help for selecting the location of monitoring instruments, as well as to support the description, analysis and understanding of ice processes.

## 2.2 Study area

The main study site of this project is Deception Bay (62º11'N, 79º45'W). The area being monitored is enclosed between Neptune and Arctic Islands (Hudson Strait) and the mouth of Deception River (South) (Figure 2). The valley has a length of 16 km and a width (at the center) of 2.5 km, for an area of 40 km². Two port infrastructures are present on the south-west shore: Raglan Mine (a Glencore Company) and Canadian Royalties.

For the purpose of this research project on ice monitoring, the control sites are located in the bays in front of Northern villages of Salluit and Kangiqsujuaq, respectively 40 km and 160 km from Deception Bay.

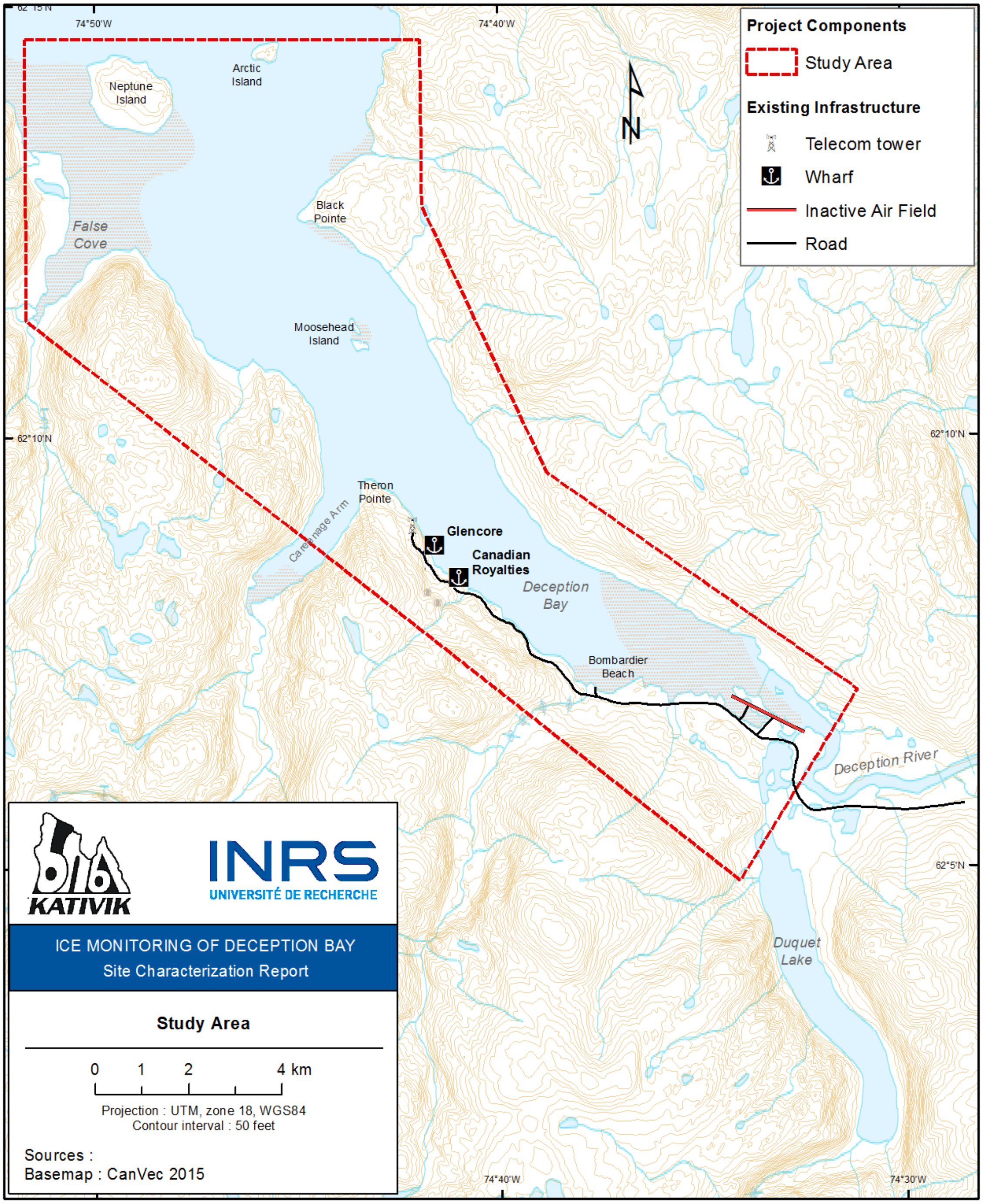


**Figure 2 : Ice monitoring area of Deception Bay.**

## 2.3 Relief and bathymetry

Deception Bay is a deep fjord valley. It is bounded by small rounded rocky hills peaking at 580 m of altitude. The slopes of these hills plunge almost directly into the bay. The shoreline generally is between 50 and 100 m wide. These relief features are typical of the overdeepening of the valley's bedrock by glacial flow (GENIVAR, 2012). The main channel of the bay is between 30m and 70m deep (Figure 3).

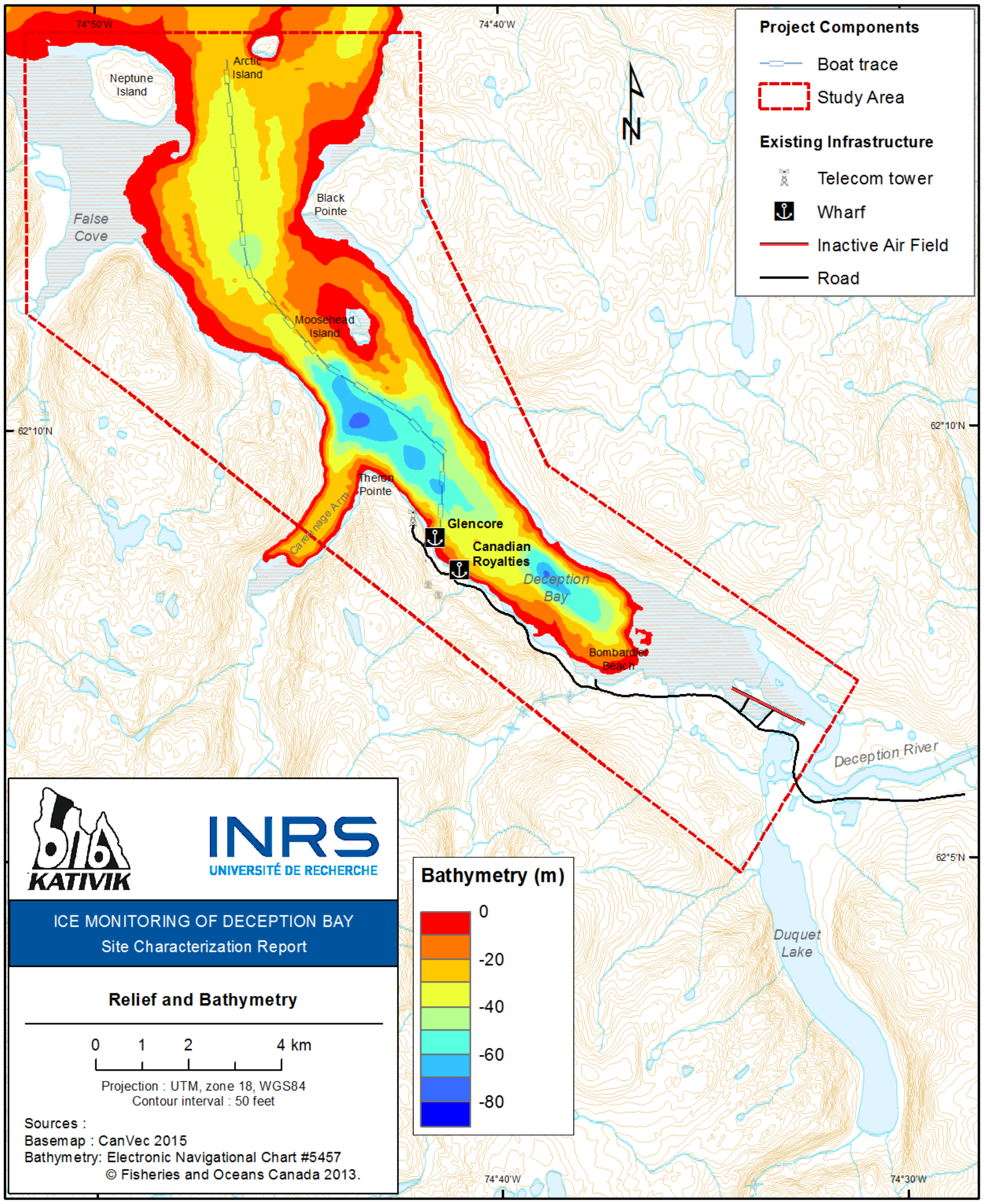


Figure 3 : Bathymetry of Deception Bay.

Salluit and Kangiqsujuaq are also located in fjord valleys, providing an excellent point of comparison for ice processes.

## 2.4 Tides and currents

The tidal characteristics were established by GENIVAR (2012), based on the water levels measured during their 2012 survey campaign. The tide that enters Deception Bay is semi-diurnal, meaning that it presents two complete oscillations per day, i.e. two high waters (high tide) and two low waters (low tide) (Table 1). The mean tidal range is estimated at 3.9m and the large tidal range goes up to 5.7m. Table 2 shows the hourly predicted water levels by Environment Canada in Deception Bay during our visit of May 2015.

**Table 1 : Tides in Deception Bay (from GENIVAR, 2012)**

| Characteristic | | (m, CD)[1] |
|---|---|---|
| Higher high water large tide | HHWLT | 5.8 |
| Higher high water mean tide | HHWMT | 4.9 |
| Mean water level | MWL | 2.9 |
| Lower low water mean tide | LLWMT | 0.9 |
| Lower low water large tide | LLWLT | 0.1 |
| Mean tidal range | | 3.9 |
| Large tidal range | | 5.7 |
| Extreme high water[2] | | 5.8 |
| Extreme low water[2] | | 0.0 |

[1] Values expressed relative to the Tide Gauge Bench Mark
[2] Predicted values

**Table 2 : Predicted water levels at each hour from May 8th to 14th 2015 (Environment Canada).**

| Date | Hour | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EDT | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 2015/05/08 | 4.9 | 4.6 | 3.8 | 2.8 | 1.8 | 1.0 | 0.7 | 0.8 | 1.4 | 2.4 | 3.4 | 4.3 | 4.7 | 4.7 | 4.1 | 3.2 | 2.2 | 1.4 | 1.0 | 1.0 | 1.4 | 2.2 | 3.2 | 4.1 |
| 2015/05/09 | 4.6 | 4.7 | 4.3 | 3.5 | 2.5 | 1.6 | 1.0 | 0.8 | 1.1 | 1.7 | 2.6 | 3.6 | 4.3 | 4.6 | 4.4 | 3.8 | 3.0 | 2.1 | 1.4 | 1.1 | 1.2 | 1.7 | 2.5 | 3.3 |
| 2015/05/10 | 4.1 | 4.5 | 4.5 | 4.0 | 3.3 | 2.4 | 1.6 | 1.2 | 1.0 | 1.3 | 1.9 | 2.8 | 3.6 | 4.2 | 4.4 | 4.2 | 3.7 | 2.9 | 2.1 | 1.6 | 1.3 | 1.4 | 1.9 | 2.6 |
| 2015/05/11 | 3.3 | 4.0 | 4.3 | 4.3 | 3.9 | 3.2 | 2.4 | 1.8 | 1.4 | 1.2 | 1.5 | 2.0 | 2.8 | 3.5 | 4.1 | 4.3 | 4.1 | 3.7 | 3.0 | 2.3 | 1.8 | 1.5 | 1.5 | 1.9 |
| 2015/05/12 | 2.5 | 3.2 | 3.8 | 4.2 | 4.2 | 3.9 | 3.3 | 2.6 | 2.0 | 1.6 | 1.4 | 1.5 | 2.0 | 2.7 | 3.4 | 3.9 | 4.2 | 4.2 | 3.8 | 3.2 | 2.5 | 2.0 | 1.6 | 1.5 |
| 2015/05/13 | 1.8 | 2.4 | 3.0 | 3.7 | 4.2 | 4.3 | 4.1 | 3.6 | 2.9 | 2.2 | 1.7 | 1.4 | 1.5 | 1.9 | 2.5 | 3.3 | 3.9 | 4.4 | 4.4 | 4.1 | 3.4 | 2.7 | 2.0 | 1.6 |
| 2015/05/14 | 1.4 | 1.6 | 2.2 | 2.9 | 3.7 | 4.2 | 4.5 | 4.3 | 3.8 | 3.1 | 2.3 | 1.6 | 1.3 | 1.3 | 1.7 | 2.4 | 3.3 | 4.1 | 4.6 | 4.7 | 4.3 | 3.6 | 2.8 | 2.0 |

According to GENIVAR, 2012, the flow variations of the water masses in Deception Bay are generally associated with the tidal effect, in addition to local effects near the shores, such as those associated with breaking waves. Finally, wind plays a significant role in the surface currents and in shallow zones. Dominant wind is southwesterly.

## 2.5 Climate and ice regime

According to GENIVAR, 2012, the climate of the Deception Bay study area is generally characterized as follows:

- *An average annual temperature on the order of -6.6°C, with the hottest and coldest months being July and January with monthly means of 8.7ºC and -25.1°C respectively;*
- *Freeze-free period of just 20 days on average;*
- *Precipitation on the order of 350 mm per year, 60% of which is snow;*
- *Primarily southwesterly winds at an average annual velocity of 18.7 km/h, with speeds greater than 20.5 km/h more than 40% of the time;*
- *Length of day reaching a maximum of 20 hours in summer and a minimum of 5 hours in winter;*
- *Mean annual relative humidity of 78.7% in the morning (6 a.m.) and 72.0% in the afternoon (3 p.m.), with a maximum in September (86.5% in the morning);*
- *Fog episodes are more frequent in March, May, August and September, peaking in September at about one-third of the hours of observation.*

Figure 4 shows the mean daily temperature for the 2014-2015 season at the Salluit airport.

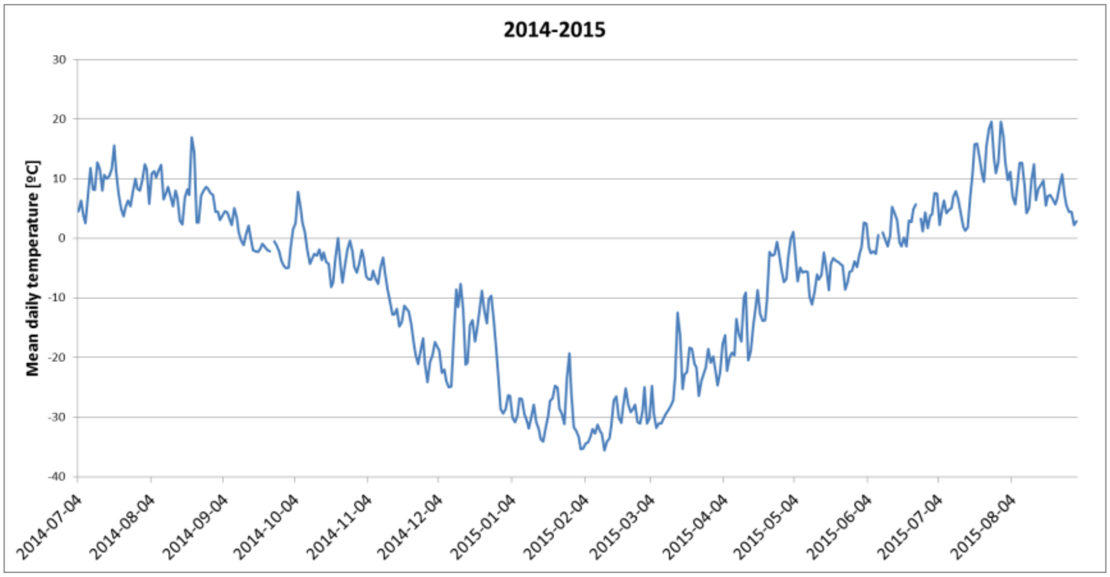


**Figure 4 : Mean daily temperature at the Salluit airport in 2014-2015 (from Environment Canada).**

According to GENIVAR, 2012:

*In Deception Bay, ice forms from late October to early December. Based on observations by hunters, however, it seems to be systematically forming in December in recent years and, above all, becoming thick more slowly (Don Cameron, Nuvumiut Developments Inc., pers. comm., 2007). Ice generally begins to form in the centre of Deception Bay, then progresses southeast toward the Deception River and later northwest toward Hudson Strait.*

*The ice reaches its maximum thickness of about 1.7 to 2 m around late May. In June, melting of the ice can first be seen by puddles forming over the ice cover, and then by open areas where the Deception River and other rivers discharge freshwater into the bay. Before June ends, the ice-free area extends from the head to the middle of Deception Bay around Pointe Théron. Where the pack ice remains, it is too thin to safely travel over it. In late June, or early July at the latest, southeasterly winds may completely free the bay of ice in a single day, while winds in the opposite direction can push floes into the bay. As with ice formation, global warming seems to be changing the break-up period, which recently tends to occur earlier (Don Cameron, Nuvumiut Developments Inc., pers. comm., 2007).*

The Sea Ice Climatic Atlas for the Northern Canadian Waters 1981-2010 (Environment Canada) describes the ice regime in Hudson Strait-Ungava Bay:

*Freeze-up usually begins near the shore in western Hudson strait in November, then ice formation progresses to cover the entire area by early December, and by mid December the first-year stage predominates. Except for quite extensive shore-fast ice among the islands from Big Island to Cape Dorset, the ice is in constant motion because of strong currents and frequent gale force winds. Ridging, rafting and hummocking are continually taking place, and ice congestion often affects Ungava Bay and the south side of Hudson Strait. Conversely, a shore or flaw lead is frequently present on the north side of the Strait. At times small concentrations of second year ice drift into the area from Foxe Basin. Multi Year ice also enters eastern portions from Davis Strait.*

*Open water leads develop in May, slowly expand in June. Clearing becomes extensive during July but Ungava Bay often remains encumbered with heavy deformed ice, with some embedded old ice in July. Complete clearing has taken place as early as mid-July and as late as the end of August. However it is worth noting that incursions of second year ice from Foxe Channel occur in some years.*

*In Hudson Strait, freeze-up has started as early as mid October and as late as the first week of December, while complete clearing has occurred as early as late July and as late as early September. Freeze-up in Ungava Bay has begun as early as late October and has been delayed until the second week of December.*

Figure 5 and Figure 6 show the mean freeze-up and breakup dates in Eastern Canadian Arctic waters. For the Hudson Strait near Deception Bay, freeze-up would be around December 4 while breakup would be around July $2^{nd}$.

The historical total accumulated ice coverage of the Fox Basin, Hudson Bay, Hudson Strait and Ungava Bay area (Figure 7) varies over the years but is has been consistently lower than normal since the late 1990s.

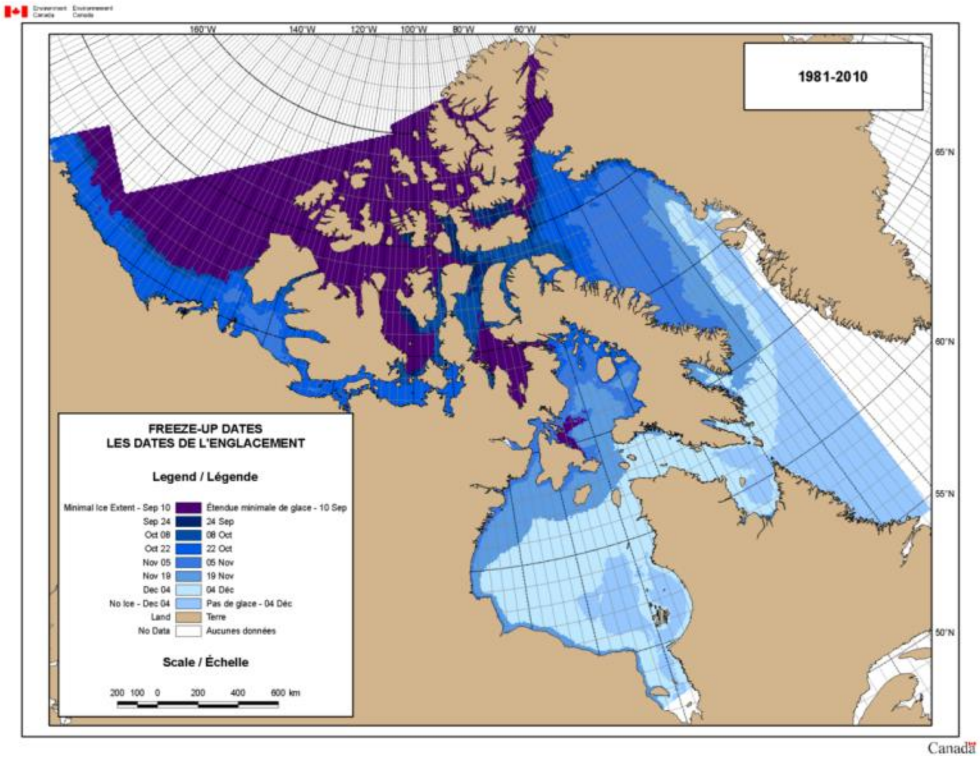


**Figure 5 : Climatic Ice Atlas 1981-2010 - Canadian Ice Service - Environment Canada - Region: Northern Canadian Waters – Freeze-up dates.**

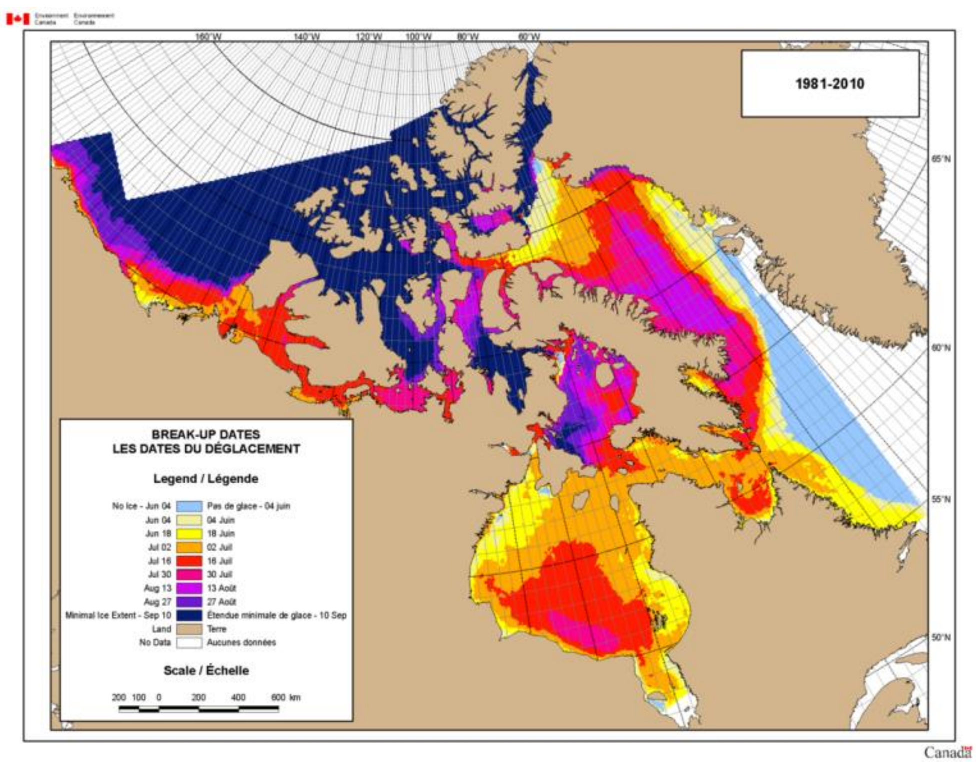


**Figure 6 : Climatic Ice Atlas 1981-2010 - Canadian Ice Service - Environment Canada - Region: Northern Canadian Waters – Breakup dates.**

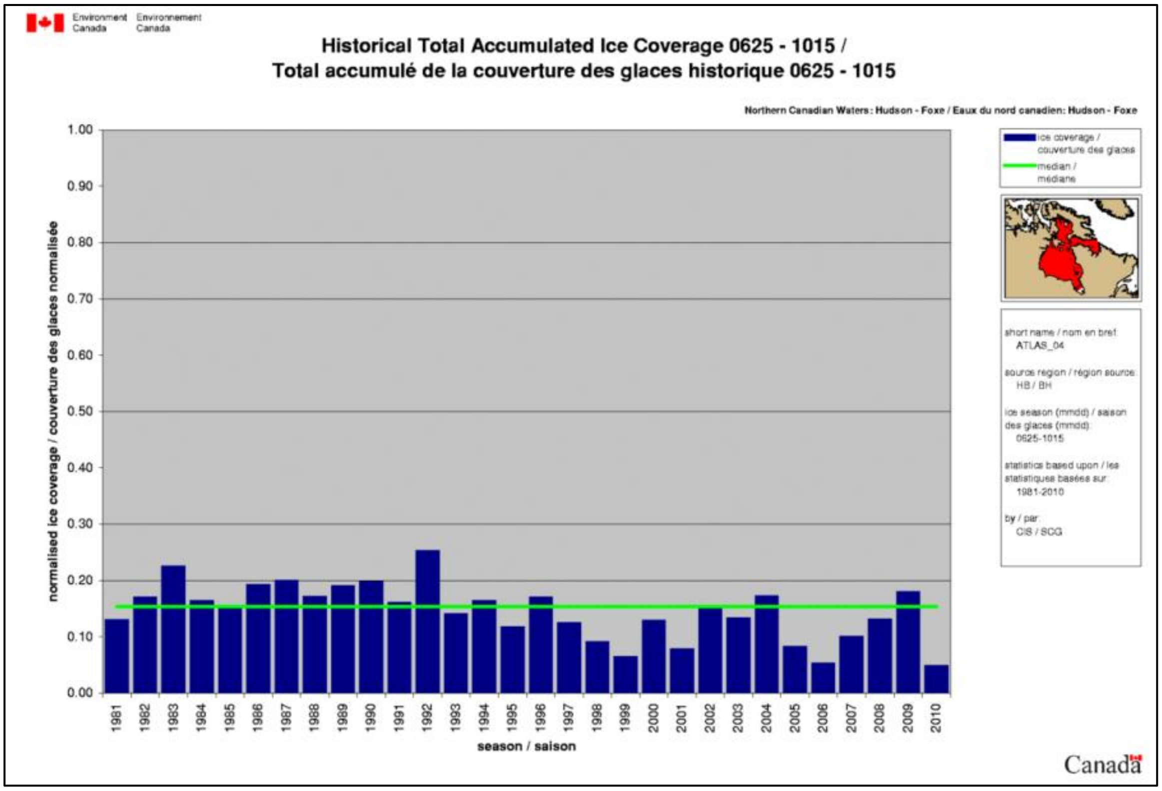


**Figure 7 : Historical total accumulated ice coverage for the Fox Basin-Hudson Strait area (Climatic Ice Atlas 1981-2010 - Canadian Ice Service - Environment Canada).**

During the course of a single winter in northern portions of the Canadian Arctic Archipelago, undisturbed bare ice can grow to a maximum of about 240 cm. In the central and western Arctic, maximum thickness is about 200 cm. Farther south, in James Bay and along the Labrador coast, the thickness of locally developed ice can reach about 120 cm.

Location of ice measurements taken by Raglan Mine from 2003 to 2007 along the ship's track are shown in Figure 8. Table 3 shows measurements from May 2003 and 2004, which should be close to those years' maximum ice thickness (1.2 to 1.4 m). These values are slightly lower than what was mentioned by GENIVAR, 2012 (1.7 to 2.0 m). From 2005 to 2007, measurements by Raglan mine were made earlier during the winter and are not shown here.

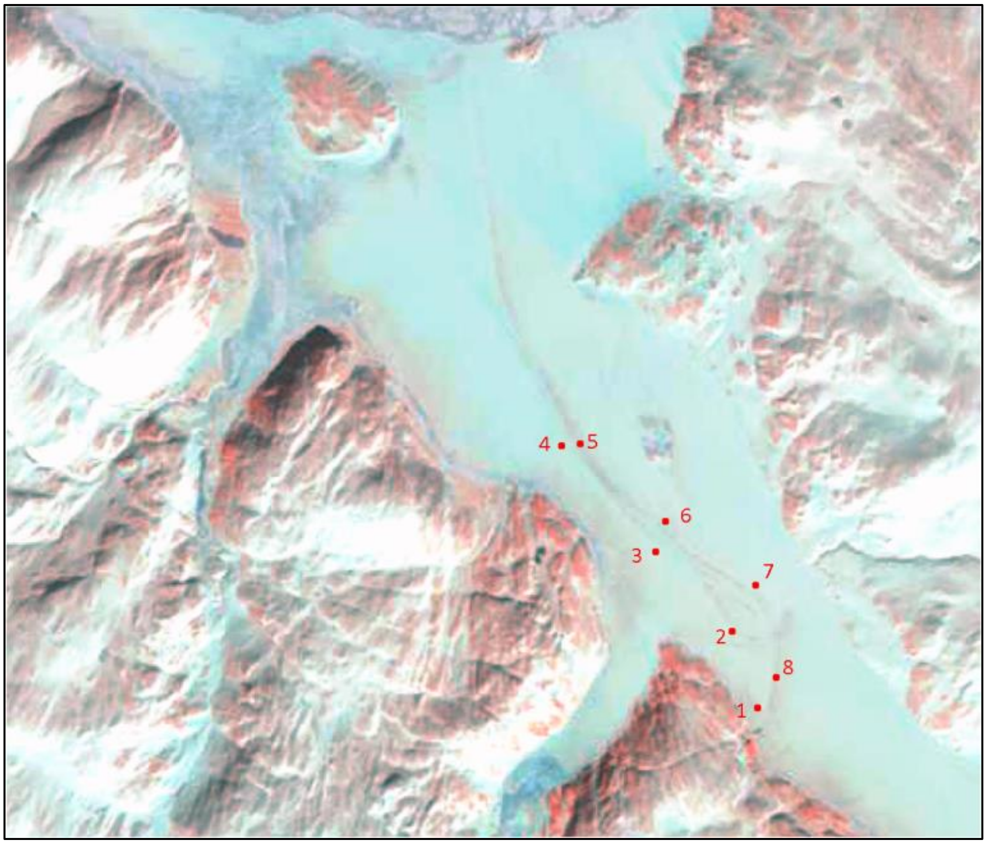


**Figure 8 : Location of ice thickness measurements made along the ships track from 2003 to 2007. The Landsat-7 background image (ice cover in light blue) is from March 2003.**

**Table 3 : Ice thickness measurements made along the ships track on May 10, 2003 and May 06, 2004 (from Raglan Mine data).**

| *Date* | *Pt* | *Ice thickness* |
|---|---|---|
| *10-05-03* | *1* | *1.575 m.* |
| *10-05-03* | *2* | *1.525 m.* |
| *10-05-03* | *3* | *1.498 m.* |
| *10-05-03* | *4* | *1.550 m.* |
| *10-05-03* | *5* | *1.321 m.* |
| *10-05-03* | *6* | *1.422 m.* |
| *10-05-03* | *7* | *1.448 m.* |
| *10-05-03* | *8* | *1.422 m.* |
| *06-05-04* | *1* | *1.372m* |
| *06-05-04* | *2* | *1.270m* |
| *06-05-04* | *3* | *1.270m* |
| *06-05-04* | *4* | *1.549m* |
| *06-05-04* | *5* | *1.270m* |
| *06-05-04* | *6* | *1.295m* |
| *06-05-04* | *7* | *1.168m* |
| *06-05-04* | *8* | *1.270m* |

## 2.6 Travel routes

According to GENIVAR 2012, Deception Bay is still an environment prized by the Inuit of the region, mostly those of Salluit. It is frequented mainly for fishing, seal and beluga hunting, and gathering blue mussels. Given its easy access by watercourses and its proximity, Deception Bay may also be frequented by people from Kangiqsujuaq, but it seems that this is more occasional. These observations were confirmed during our consultations in Salluit and Kangiqsujuaq in June 2015.

During the ice season, ships from both Raglan Mine and Canadian Royalties are coming into the Bay. However, there is a no-navigation agreement from mid-March to mid-June, covering the period during which seals congregate on pack ice for pupping and for nursing pups.

Figure 9 shows the main Inuit travel routes in Deception Bay and the main track from ship navigation (from GENIVAR 2012). From a Landsat-8 image of early April 2015 (Figure 10), we can also detect the ships track leading to both port infrastructures.

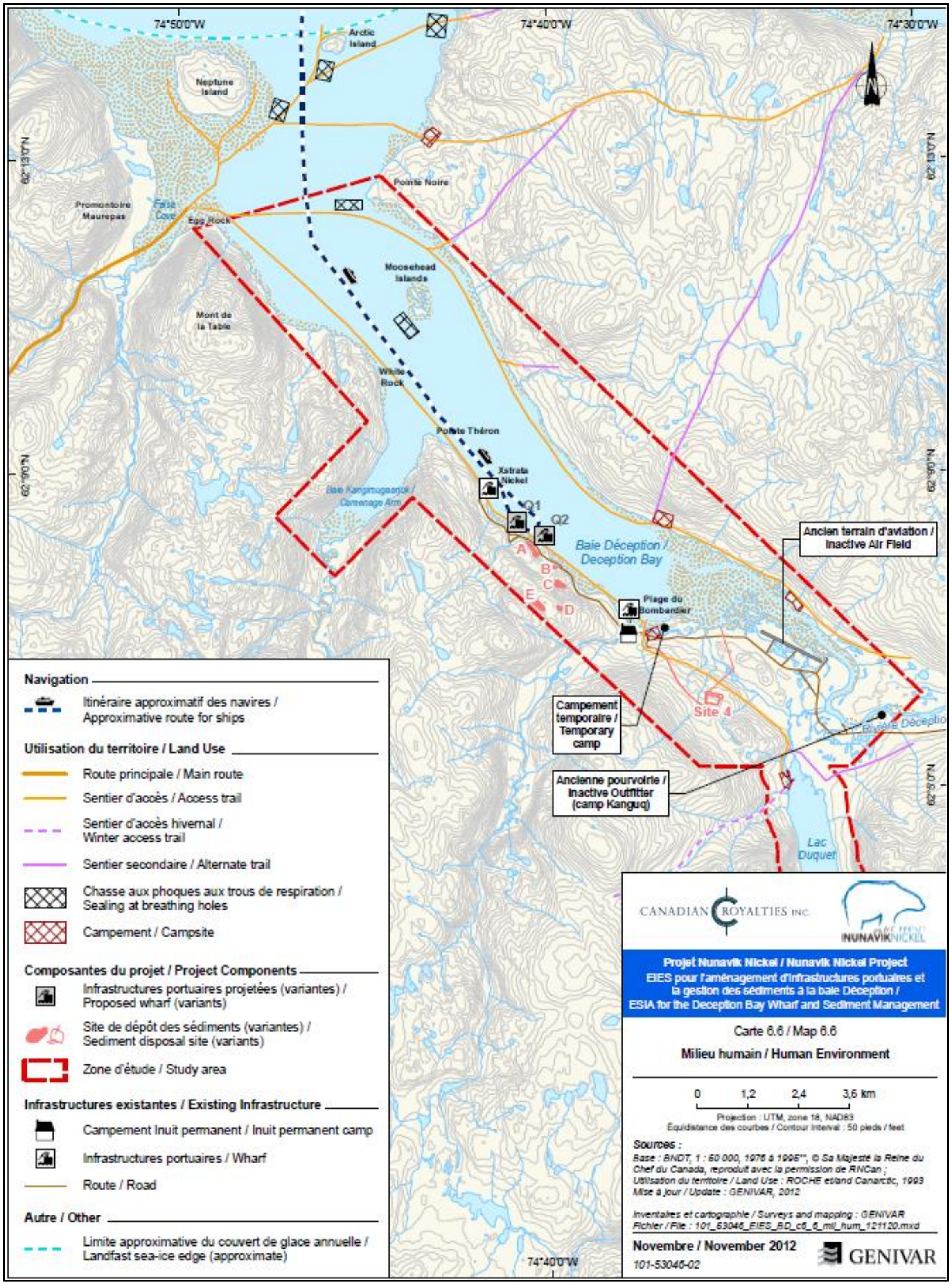


**Figure 9: Inuit Travel routes and ships route (from GENIVAR 2012).**

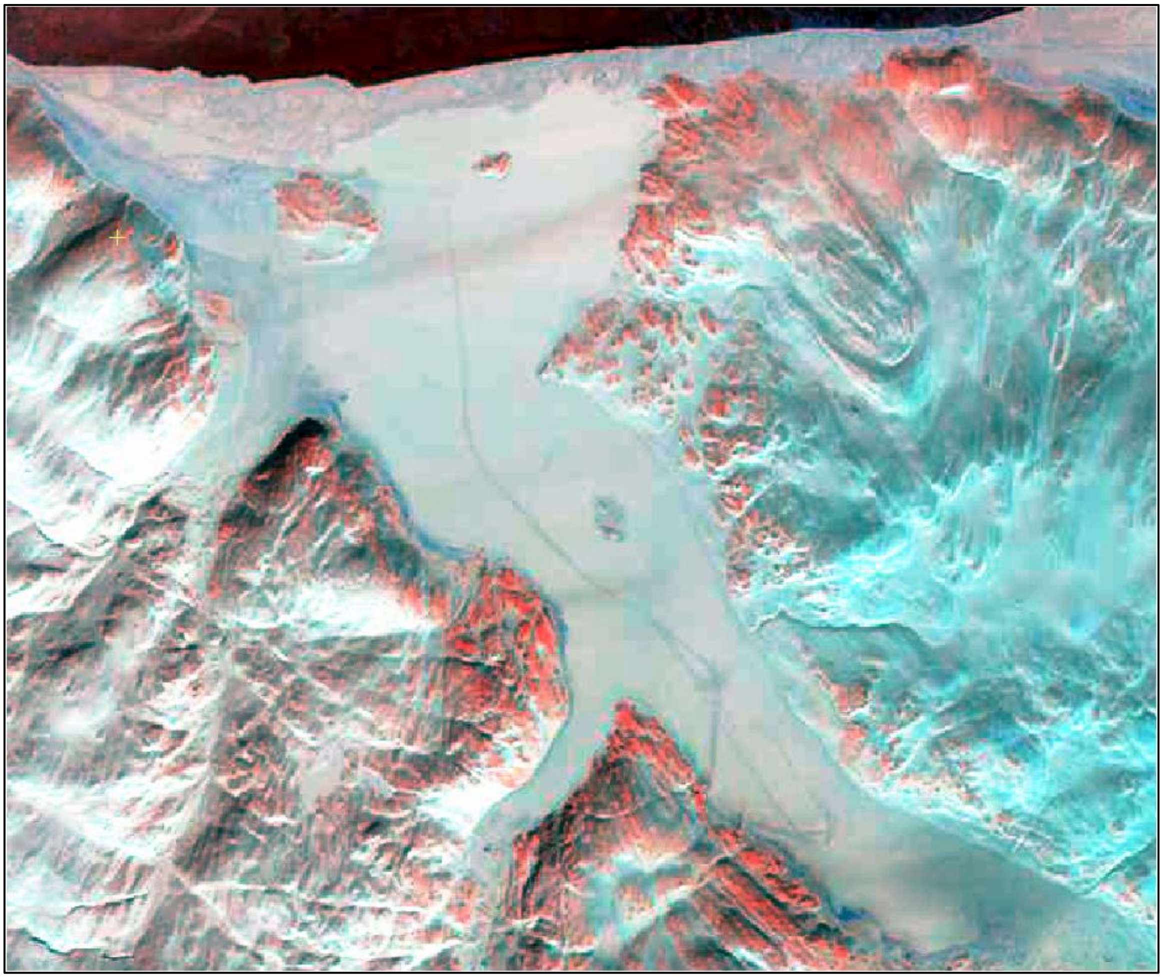

**Figure 10 : Ships track still visible in the ice cover (darker linear feature on the center of the Bay) on a Landsat-8 image of early April 2015.**

# 3 INSTRUMENTATION PLAN

## 3.1. On-site cameras

On-site cameras will enable the monitoring of ice conditions over the entire Bay and throughout the entire ice season. They will also permit observation of some meteorological phenomena such as snow, storms and waves. One camera gives just a local view of the Bay. We propose multiple cameras to cover the entire study area and to test different models. To select the type of camera suitable for Deception Bay, three elements have to be considered:

- Resistance to extreme conditions
- Power requirements
- Transmission function.

As for the sites, they should have the following characteristics:

- High location with a good down view on the Bay;
- Well distributed to maximise coverage of the entire Bay;
- Accessible by foot (from boat or snowmobile);
- Outside any known site of archeological interest;
- If possible, access to power and network.

Camera type selection was done accordingly with site selection. Where power and network are available, it is possible to use a camera requiring some heating. When no power or network is available, cameras should be autonomous for power and data storage. During the visit of May 2015, five potential sites were identified (Figure 11). Authorizations were requested and obtained for all (see section 3.6). The final choice of three sites was made in order to get the most coverage with the least instruments. Site #1 has access to power and network while the northern sites do not. Therefore, an IP (Internet Protocol) camera was selected for the southern site while hunting cameras were selected for the two northern sites.

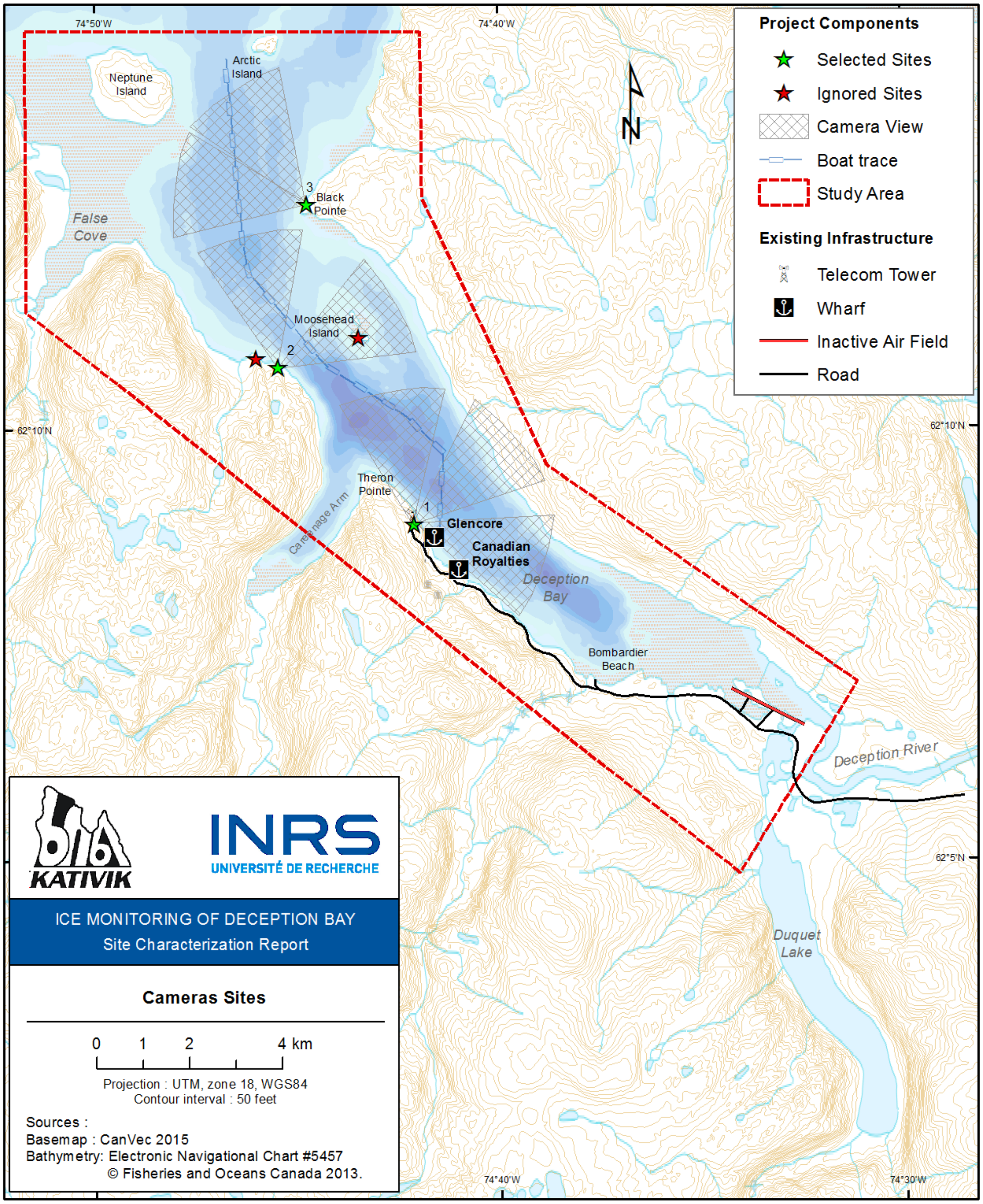


**Figure 11 : Potential and final sites for cameras. For the final selected sites, their expected field of view are shown in grey.**

The IP or network camera is a type of digital video camera commonly employed for surveillance, and which can send and receive data via a computer network and the Internet. Several models are commercially available. Some propose a fixed field of view while others (PTZ models) are capable of remote directional and zoom control.

Considering the available power and network and the configuration of the Bay at the southern site, a PTZ model allows for 180 º coverage. The selected model is the WV-SW598 from Panasonic (Table 4). This specific model is already used by Raglan, which will facilitate integration to their network. However, a supporting structure had to be built because Raglan Mine does not allow us to install an instrument directly on the telecom tower.

Raglan Mine built the structure, which design was based on the dust collector used by their Environment services and adapted according to the specifications provided by INRS. Raglan Mine is also providing human resources to achieve power and network connections between the camera and their system. It is suggested to use a 10ft high structure (Figure 12). A four feet transversal mount is planned in the eventually of adding an anemometer. The camera would be installed at a height of six feet.

Table 4 : Characteristics of the Panasonic WV-SW598

| | | |
|---|---|---|
| **Image Sensor** | Approx.1/3 type MOS Sensor |   |
| **Effective Pixels** | Approx. 2.4 megapixel | |
| **Zoom Ratio** | 30x / 90x with extra optical zoom (at 640x360) | |
| **Panning Range** | 360° endless | |
| **Number of Preset Positions** | 256 | |
| **Power Source and Power Consumption** | AC24 V : 3.5 A, 55 W | |
| **Ambient Operating Temperature** | AC24 V and Tested PoE Injector (60 W) : –50 °C ~ +55 °C (-58 °F ~ 131 °F) * with limitations | |

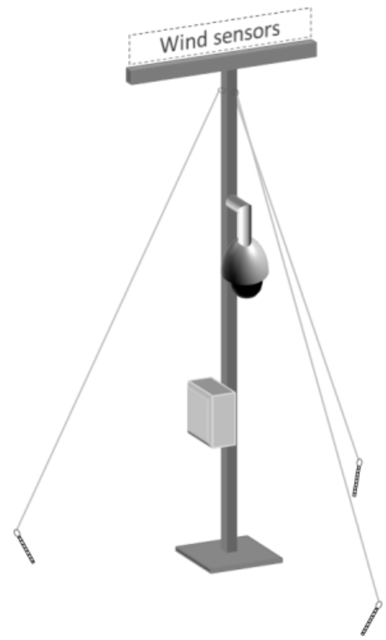


Figure 12 : Supporting structure for the network camera

For sites #2 and #3, hunting type cameras were selected. Less expensive than the network camera, they have a low power consumption and internal data storage capacity. To optimally cover the Bay while staying within budget, four cameras will be installed. First, a Reconyx PC800 model will be installed at each site. We have already used this model in other projects in Nunavik and it has performed very well in extreme conditions. Examples of these pictures can be viewed at: http://www.krg.ca/en/ice-movement. Then, since the objective of the project is to assess the complementarity of different monitoring techniques, we will test two other hunting type models: the Strike Force HD from Browning and the Tiny-Plus from SpyPoint (Table 5). They are also less expensive than the Reconyx while providing a much better resolution.

The proposed supporting structure for the two northern sites is identical (Figure 13). It is an eight feet high mast welded to a square metal base of 18 inches. The base is pre-pierced at the corners so it can be bolted in the rock. Again, the structure is being built by Raglan Mine. An aluminum box is holding the 12V battery and the power regulator. A solar panel is providing power to the battery. The cameras are placed on top of the mast, slightly inclined and aiming adjacent areas.

**Table 5 : Characteristics of the selected hunting type cameras**

| | **PC800**  | **Strike Force HD**  | **Tiny-Plus**  |
|---|---|---|---|
| **Image resolution (MP)** | 3.1 | 10 | 10 |
| **Video** | 3.1 Mpx (Near video) | HD (720p) with sound | HD (720p) with sound |
| **Memory Card Type:** | Secure Digital (SD® or SDHC®) | Secure Digital (SD® or SDHC®) | Secure Digital (SD® or SDHC®) |
| **Image Detail:** | Color by Day, Monochrome Infrared by Night | Color by Day, Monochrome Infrared by Night | Color by Day, Monochrome Infrared by Night |
| **Image Data:** | Camera ID, Time, Date, Temperature & Moon Phase | Camera ID, Time, Date, Temperature & Moon Phase | Camera ID, Time, Date, Temperature & Moon Phase |
| **Battery Quantity / Size:** | 12 AA | 6 AA | 6 AA |
| **Alternative Power** | 12V Power jack | 12V Power jack | 12V Power jack |
| Extreme Duty Conformal Coated Electronics: | Included | NA | NA |
| Time-Lapse Mode | Yes | Yes | Yes |
| Time-Lapse Scheduling: | Yes | Yes | Yes |

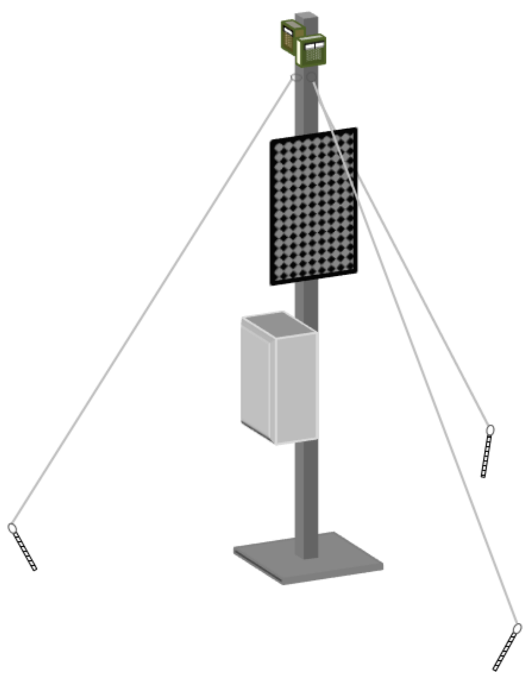

**Figure 13 : Supporting structure for the hunting type camera**

## 3.2. Shallow Water Ice Profiler

### 3.2.1. Description of the instrument and principles

This section is based on the work from Buermans et al (2011), Fissel et al (2008) and Marko et al (2006). The Shallow Water Ice Profiler (SWIP) is a real-time acoustic ice thickness measurement (ice draft) instrument for shallow water applications, manufactured by ASL Environment Sciences (http://www.aslenv.com/swip.html). The underwater components include a low-cost acoustic transducer, a tilt sensor, a high-precision pressure sensor and a temperature sensor, all providing suitably high resolution for shallow water measurements.

The SWIP has been designed as a self-contained or real-time instrument to observe stationary or moving ice through the sonar's field of view (Figure 1). Since SWIP shares its software, firmware, and main electronic components with the IPS (see section 3.3), its principles of operation are identical. The SWIP sensors and housing configuration have been optimized for deployment depths of between 2 and 20 m below the surface, looking upward. At intervals set by the deployment software, the acoustic transducer transmits a pulse of programmable duration. The sound travels in the form of a conical beam toward the surface. Some of the sound is absorbed as it travels through the water and some of the sound is reflected by frazil, slush, and thermal ice, the water-air interface or other targets it may encounter. The acoustic transducer listens for these reflections (echos) from the water column. The voltage signal generated by the transducer is amplified to account for spreading and absorption losses and it is then digitized by the analog-to-digital (A/D) converter. This digitized voltage output is referred to as the return strength. With the standard digitization rate of 64 kHz, the instrument has a time resolution of about 16 microseconds. The attainable resolution in space is of the order of 1 cm.

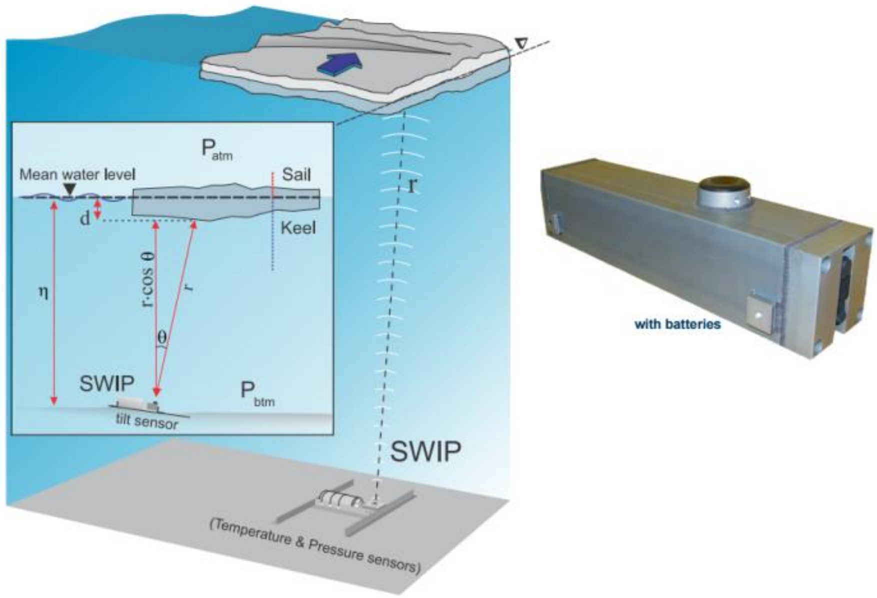


Figure 14 : The SWIP instrument (from ASL)

In target mode, which is designed specifically for ice draft measurements, the SWIP examines the return strength from echoes. Using a well-established algorithm, the instrument then decides which part of the signal is returned from the bottom of the ice or from the water-air interface in the absence of ice. The interval between transmission and receipt of the selected target is referred to as the Travel Time. This parameter is measured and recorded internally onto removable CompactFlash memory or transmitted in real-time over the serial interface. The SWIP can record the maximum Amplitude, the duration (Persistence) and Travel Time of up to a maximum of 5 detected targets. The Travel Time is then used to compute the range (r) to the detected target using a best estimate of the water speed of sound.

### 3.2.2. Ice draft and ice thickness computations from SWIP data-Target mode

Ice draft computation using data obtained from an upward looking sonar deployed in a saltwater environment, is well understood (Fissel et al. 2008). The SWIP parameters measured include Travel Time (from which range(r) to the underside of the ice is computed), tilt in two planes ($tilt_x$ and $tilt_y$), absolute water pressure at the instrument ($P_{btm}$), and near-bottom water temperature. Barometric pressure ($P_{atm}$) needs to be measured separately. It may also be useful to conduct water column measurements of the speed of sound while the body of water is ice covered. To compute ice draft, this information needs to be entered into Eq. 1 thru 4 below. For salt water applications (Marko, 2006), the critical, accuracy-limiting factor in ice profiling is knowledge of the mean sound speed. The actual speed of sound is only available with accuracy over the full water column at the start and end of a deployment through direct conductivity-temperature-density (CTD) profile measurements for temperature and salinity. For intermediate times, sound speed estimates are obtained as an integral part of the data processing/analysis program. This is done by establishing values of β (Eq.4) which correctly yield zero draft values from Eq. 3 using range, r, and water level, η, values at times when there is unambiguous presence of open water above the SWIP instrument.

$$\eta = (P_{btm} - P_{atm})/ \rho g - \Delta D \qquad [1]$$

Where:

$\eta$ is the water depth above the acoustic transducer
$P_{btm}$ is the hydrostatic (bottom) pressure as measured by the SWIP
$P_{atm}$ is the atmospheric pressure
$\rho$ is density of water
$g$ is acceleration of gravity
$\Delta D$ is the physical separation in the vertical direction between the deployed acoustic and hydrostatic pressure sensors

$$\theta = (tilt_x+tilt_y)^{1/2} \qquad [2]$$

where:

$\theta$ is the tilt magnitude with respect to the vertical
$tilt_x$ is the measured tilt angle in the x-plane
$tilt_y$ is the measured tilt angle in the y-plane

$$d = \eta - \beta \cdot r \cdot \cos \qquad [3]$$

where:

$d$ is the ice draft
$\beta$ is a “to be determined” factor which accounts for changes over time in the mean sound speed in the upper water column
$r$ is the range to the ice as measured by the acoustic transducer

$\beta = c_{act} / cIPSLink$ [4]

where:

$c_{act}$ is the actual mean speed of sound in the water column and cIPSLinkis the speed of sound entered in the IPSLink software for the instrument deployment.

Without a snow cover and with relatively flat ice, the ice thickness ($T_{ice}$) can be estimated if the densities of water ($\rho_{water}$) and ice ($\rho_{ice}$) are known:

$T_{ice} = d \cdot \rho_{water} / \rho_{ice}$ [5]

### 3.2.3. Proposed site for the installation of the SWIP in Deception Bay

In Deception Bay, the SWIP will be used to measure ice thickness growth near MooseHead Island (Figure 15). The bottom depth at this location is around 8m below the Datum Chart.

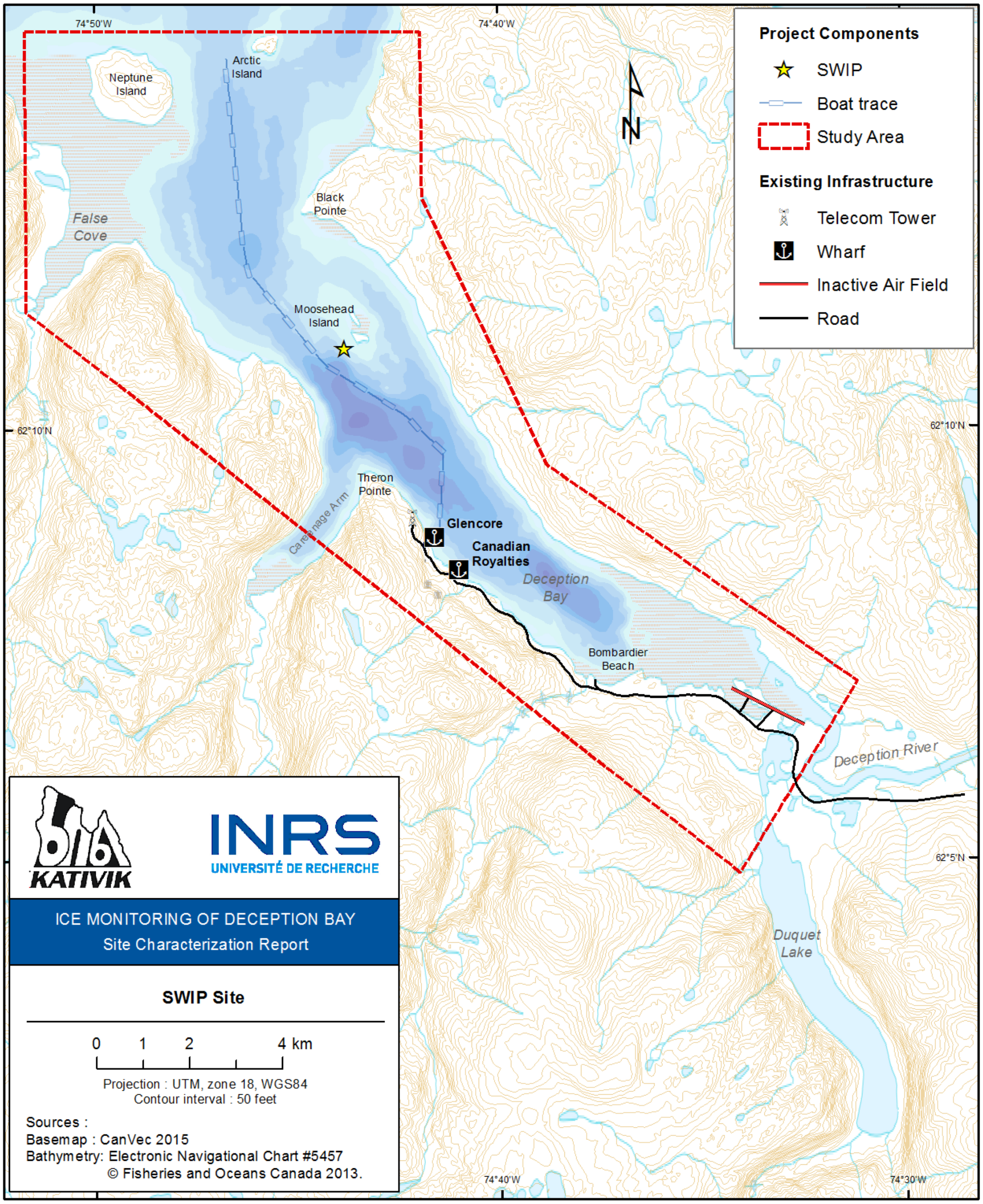


**Figure 15 : Proposed site for the installation of the SWIP.**

## 3.3. Ice Profiler Model IPS5

### 3.3.1. Description of the instrument and principles

This ice profiling sonar (Table 6) is also manufactured by ASL Environment Sciences (http://www.aslenv.com/ips.html) and has been designed for the express purpose of ice draft measurements in Polar Regions for prolonged periods at 100% duty cycle during the presence of ice (without gaps). Over 147 instruments have been built and deployed over more than 500 Arctic and Antarctic ice seasons. The typical deployment duration for the instrument is 12 months over the winter. Some instruments have been continuously deployed for 2 years before recovery and some for as much as 3 years before recovery. With the appropriate sensors and setup, the instrument is capable of measuring ice thickness profiles, wave height profiles, and vertical profiles acoustic backscatter returns within the water column.

**Table 6 : IPS-5 components**

| Item | Description |
|---|---|
| 1 | **Internally powered Ice Profiling Sonar (IPS-5)**<br>Standard Model with the following features:<br>➢ Transonics 420 Khz 1.8 degree transducer<br>➢ Paros 0-200 psia (0-300psia or 0-400 psia) Digiquartz Pressure Sensor<br>➢ 2-axis tilt sensor<br>➢ Thermistor temperature sensor (± 0.1 °C)<br>➢ Full aluminum pressure housing (600m) with battery<br>➢ ULS-5 Digital board (with Persistor CF-2) with 16-bit A/D converter, software reset capability, downloadable firmware<br>➢ 8 Gbyte Sandisk Extreme III Compact Flash Memory<br>➢ Ruggedized aluminum shipping box<br>➢ Manuals and IPSLink Software and One year warranty |
| 2 | **Dual cage taut-line mooring frame** (For use with item 1, see attached pamphlet)<br>*Features:*<br>➢ 316 Stainless steel<br>➢ Electrical isolation for the IPS instrument<br>➢ With set of eight (8) 12B3 Vinys (120 kg (264 lbs) of buoyancy)<br>➢ Zinc anodes |
| 3 | **Full replacement battery (200 A-hr)**<br>With maintenance replacement kit consisting of: Desiccant, oring, clock battery for microprocessor, necessary hardware and detailed instructions. |


The IPS instrument works very well at ranges to the ice of up to 100m with minimal missed (null) ice targets. As the IPS instrument is placed deeper, the percentage of null targets increases as instrument noise levels also rises at longer distances.

### 3.3.2. Proposed site for the installation of the IPS in Deception Bay

In Deception Bay, the IPS will be used to measure ice thickness variability and refreezing rate following the manoeuvers of the icebreaker leaving dock (Figure 16). The bottom depth at this location is around 50m below the Chart Datum.

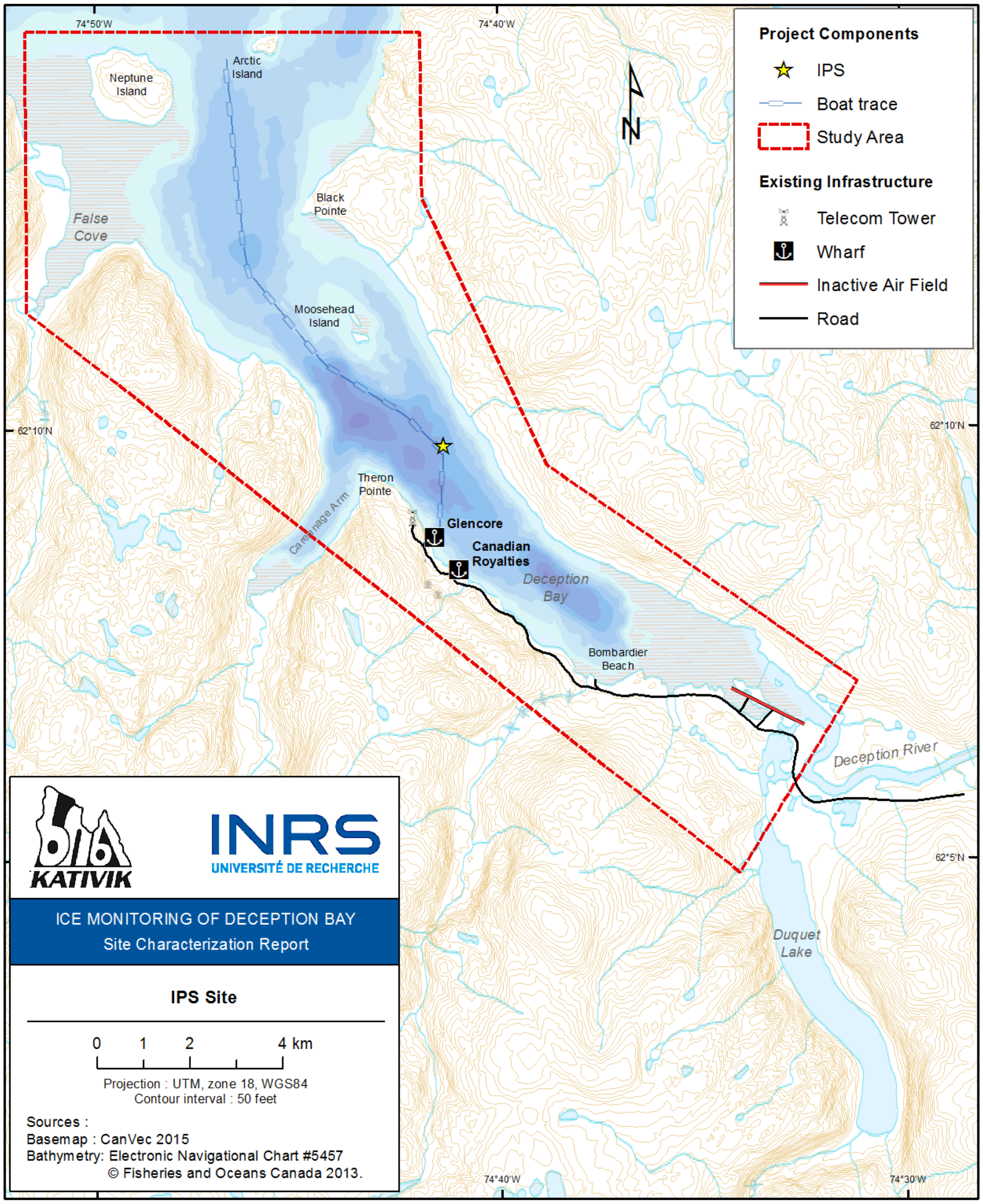


Figure 16 : Proposed site for the installation of the IPS.

### 3.3.3. Ice Profiling Sonar Taut-line Mooring Arrangement

The taut line mooring configuration for the IPS (Figure 17) may be used at various water depths from shallow (10m) to very deep (+2000m) with the IPS instrument positioned near the surface.

The instrument depth can be controlled with the length of line between the mooring frame and the anchor; the instrument depth should be set such that the ice cover (and icebergs) do not come in contact with the instrument and mooring frame. Positioning the instrument too deep will result in a higher power consumption and more null targets (especially at >150m). The pressure sensor range for the IPS instrument should be selected accordingly.

Careful design of the mooring components ensures minimal IPS instrument tilt (< 5 degrees), reliable mooring operation and high quality data. The depth rating of the flotation, the depth rating of the IPS, the slope of the bottom and the water current speed profile all need to be considered.

ASL Environmental Sciences offers several different proven “off-the-shelf” mooring solutions including bottom frames.

Acoustic releases, pingers, buoys, ADCP and other equipment are available from ASL Environmental Sciences on a lease basis.

To resolve quasi-spatial components of ice velocity and water velocity profiles, it is possible to mount the ADCP instrument below the IPS on the same taut-line mooring if the water depth allows this.

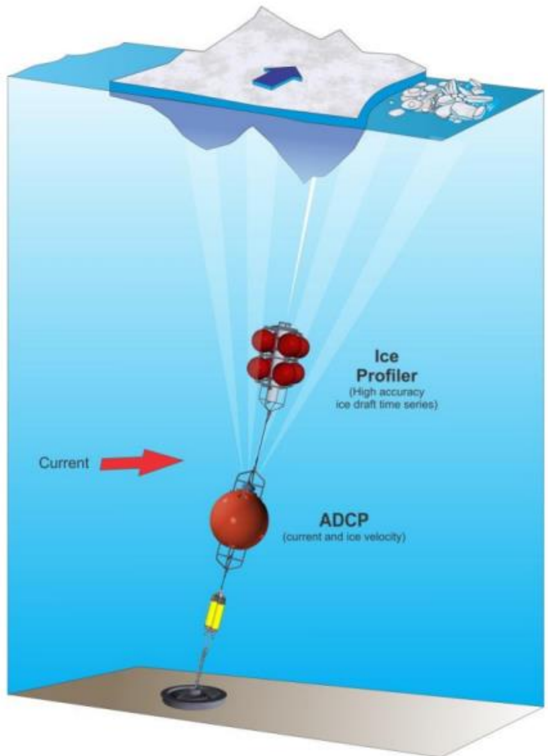


Figure 17 : Deployment of the IPS (from http://www.aslenv.com/ips.html)

### 3.3.4. Ice thickness calculations

The instrument operates by emitting and detecting surface returns from frequent short pulses (pings) of acoustic energy (420 kHz) concentrated in narrow beams (less than 2°). The narrow beam results in a “footprint” of less than 0.5 m, at typical operating depths of 30 m. Precise measurements of the delay times between ping emission and reception are converted into ranges separating the instrument’s transducer and the ice undersurface. Contemporary data from the instrument’s onboard pressure sensor are then combined with atmospheric surface pressure data and estimates of the mean sound speed in the upper water column (obtained from data collected during absences of ice above the instrument) to derive estimates of ice draft. The pressure sensor (Paroscientific Digiquartz), incorporated within each IPS, is used to measure water level changes caused by tidal and wind forcing, as well as apparent water level changes associated with depression of the mooring in response to current drag. Correction for these effects is necessary in the computation of ice keel depths. The IPS also contains tilt-x and -y sensors, to permit compensation for instrument tilt, and collects near-bottom ocean temperature data. Through this approach, the draft of the level ice can be measured to an estimated accuracy and precision of ±0.05 m.

The measurement of ice draft can be related to ice thickness by invoking Archimedes' principle, with the total weight of the ice and snow equal to the weight of the water displaced. If we assume that the ice at each measurement is in isostatic equilibrium, then this can be expressed as: $\rho_i Z_i + \rho_s Z_s = \rho_w D$ where $\rho_i$, $\rho_s$ and $\rho_w$ are the densities of ice, snow and water, respectively. $Z_i$ and $Z_s$ are the thicknesses of ice and snow, respectively, and D is the ice draft.

### 3.3.5. Questions and Answers concerning the installation of echo-sounders in Deception Bay

During community consultations held in Salluit and Kangiqsujuaq in June 2015, some questions arose pertaining to the installation of acoustic ice profilers in Deception Bay. These answers were provided to the communities.

**Question #1:**

Has the Ice Profiling Sonar (IPS) and Shallow Water Ice Profiler (SWIP) technology been proven for use in the Arctic?

**Answer:**

The IPS5 instrument has been designed for the express purpose of ice draft measurements in Polar Regions for prolonged periods at 100% duty cycle during the presence of ice (without gaps). Over 147 instruments have been built and deployed over more than 500 Arctic and Antarctic ice seasons. The typical deployment duration for the instrument is 12 months over the winter. Some instruments have been continuously deployed for 2 years before recovery and some for as much as 3 years before recovery.

The SWIP has been used in lakes and rivers, and in the Koksoak River estuary: http://www.aslenv.com/reports/ASL-CMOS-SWIP-IPY.pdf.

**Question #2:**

How are the acoustic profilers powered?

**Answer:**

The instrument is powered by a battery enclosed in a full aluminum pressure housing (600m). There may be a need to replace the battery during the summer depending on deployment parameters. The housing also protects from leakes.

**Question #3:**

How long will the sonar stay underwater?

**Answer:**

The ice profilers will operate during the three years of the project (2015-2018). The instruments have to be recovered each summer for maintenance. When recovering the instrument to extract the data, it is recommended to clean the transducer, replace the anodes and replace the battery.

**Question #4:**

Could mussels attach themselves to the instrument or cable?

**Answer:**

For some deployments of acoustic instrument in warmer waters it is possible to have build-ups of marine growth to stop the acoustic energy. It can be cleaned up when recovering the instrument for maintenance.

**Question #5:**

Will the instruments disturb or scare the marine fauna?

**Answer:**

The frequencies of the IPS (420 kHz) and SWIP (546 kHz) are generally considered to be well above the hearing range (less than 150 kHz based on Wikipedia) of marine mammals.

The acoustic frequencies, 420 and 546 kHz signals from the IPS and SWIP, have a limited horizontal range and narrow vertical beams. After about ~300 and ~200m respectively, the signals disappear in the background since the seawater absorbs these frequencies very quickly in comparison with much lower frequencies.

With a pulse duration of about 1/15,000 second, the average sound energy they put into the water is very low.

Furthermore, the instrument has an internal clock where it keeps track of the date. We will set a sleep phase during open water season.

**Question #6:**

How often will the instruments emit?

**Answer:**

The Ping Period is the number of seconds that the instrument will wait between successive acoustic transmissions or pings. The minimum is .5 seconds and the maximum is 255 seconds. It will be shorter during freeze-up and breakup and longer during total ice cover.

## 3.4. Snow and ice thickness measurement station

### 3.4.1. Description of the instrument

An ice and snow measurement site will be installed in Deception Bay, as well as in the witness sites of the neighbouring communities of Salluit (Salluit fjord) and Kangiqsujuaq (Wakeham Bay).

Such a site consists of four hotwire gauges and nine snow stakes (Figure 18).

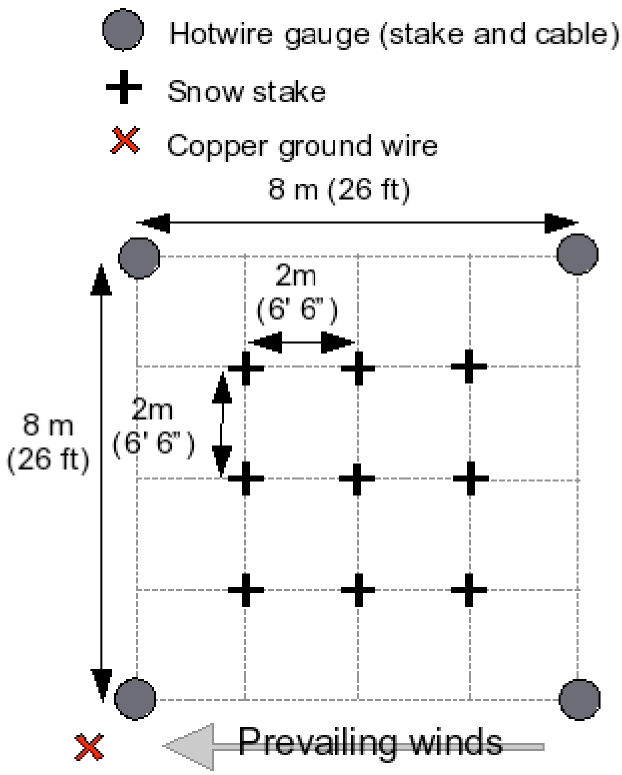


Figure 18 : Ice and snow measuring site (from Mahoney and Gearheard)

A Hotwire gauge consists of a thickness stake and a cable. The thickness stake has a metric measurement tape on it. The cable has a wooden handle at one end and a metal bar at the other. Installation of these requires drilling two holes through the ice with an ice auger, approximately 2.5 cm apart. The first hole is used to settle the stake. The second hole is where the cable is put through the ice. The Hotwire gauge is completed by a copper grounding wire installed on the site as well. The gauge cannot be installed before the ice is safe to travel on and often, it is lost at ice breakup.

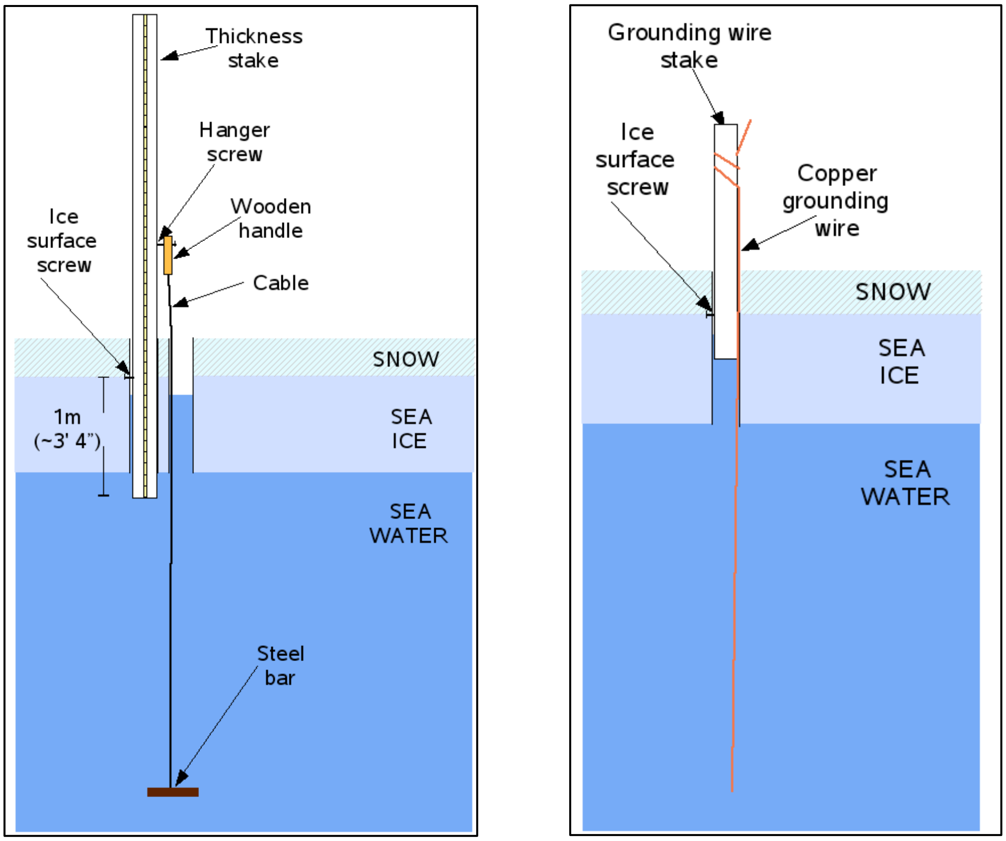


Figure 19 : Hot wire gauge (from Mahoney and Gearheard)

In order to measure sea ice thickness, the Hotwire cables need to be melted loose during each visit on site, by running electric current through them. This is done by connecting the Hotwire cable and the copper grounding wire to a generator (Figure 20). The seawater beneath the ice completes the circuit and the current heats the cable so that it melts free. Then you pull the wire until the steel bar stops beneath the ice cover. And you put the top of the handle against the measuring tape, giving you the ice thickness.

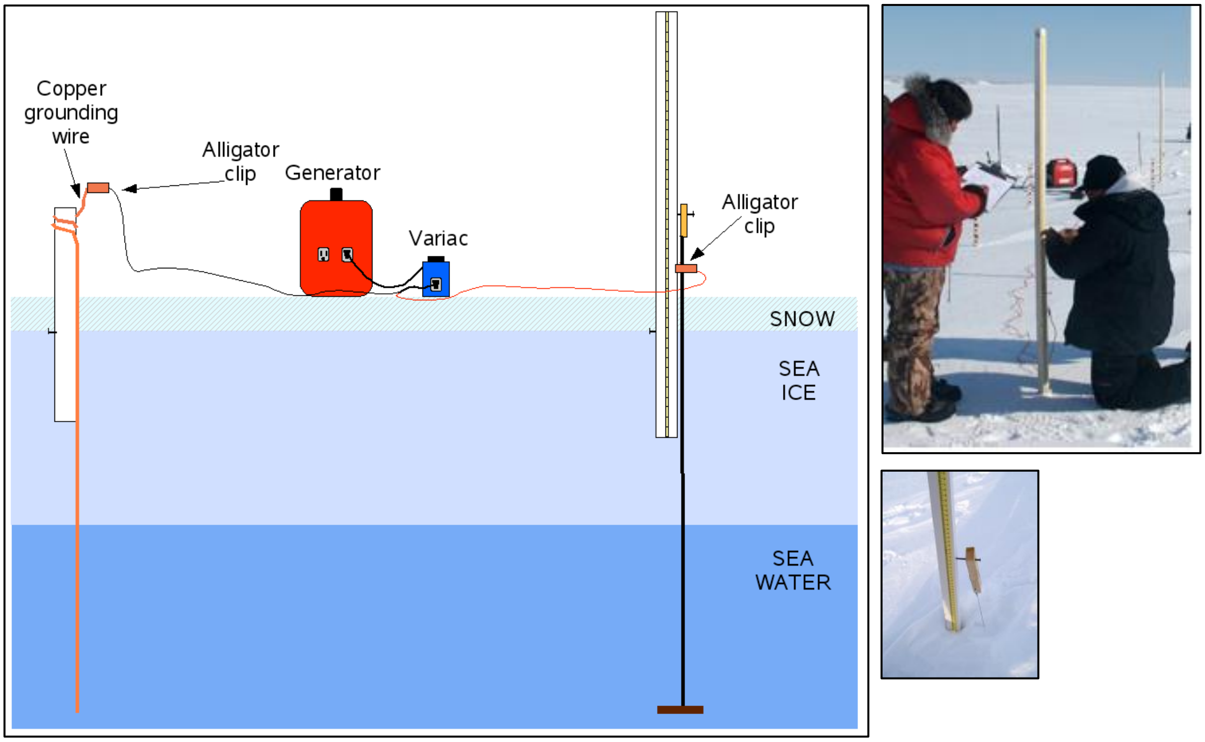


**Figure 20 : Heating the Hotwire (from Mahoney and Gearheard)**

The snow depth is averaged from the nine snow stakes, installed at the center of the site, as previously shown in Figure 18. A snow stake is a simple graduated stake.

### 3.4.2. Proposed sites for the ice and snow measurement stations

In Deception Bay, the proposed ice and snow measurement site is around 200m from the shore, just south of the marine infrastructures of Raglan Mine.

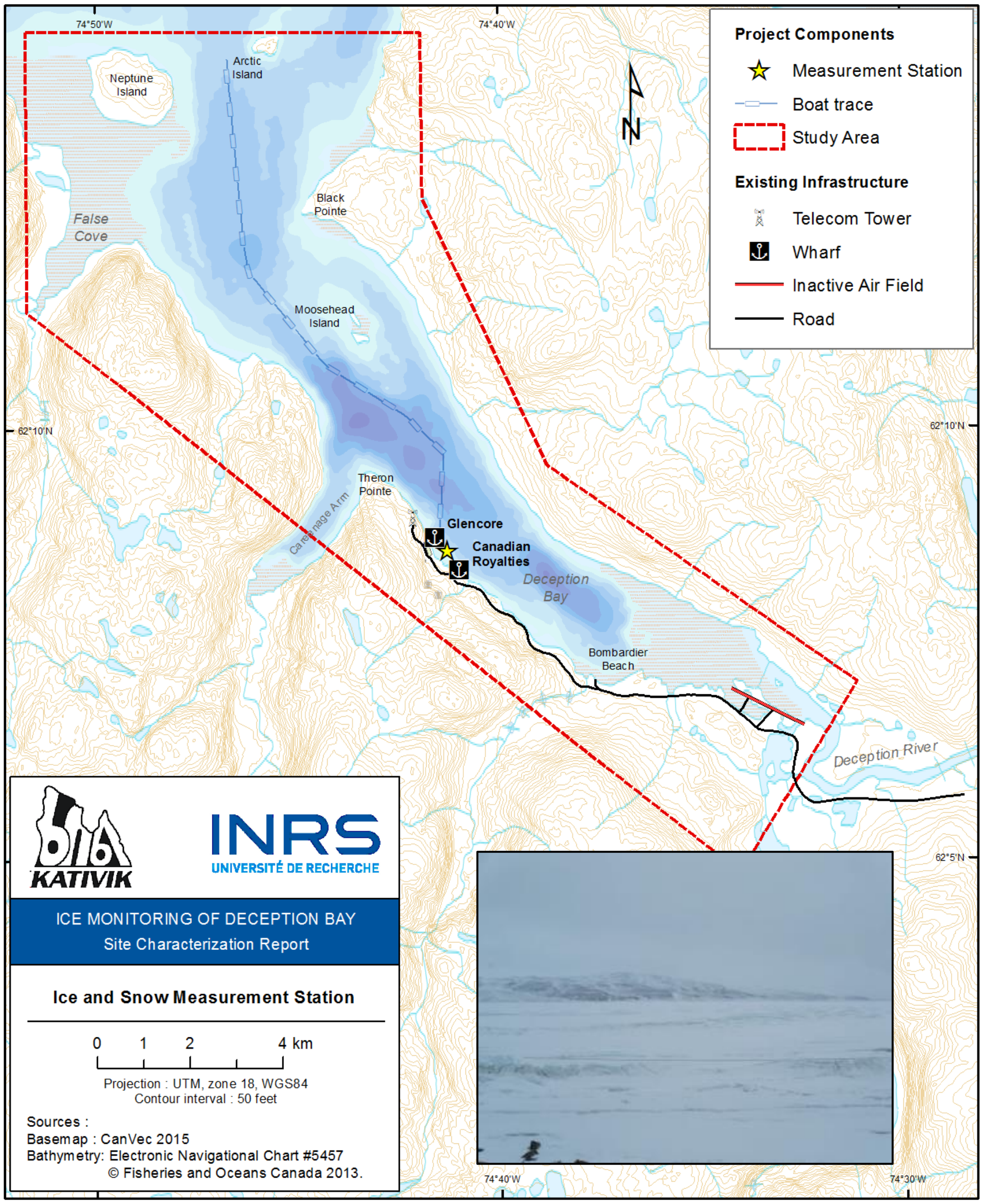


**Figure 21 : Proposed location for the ice and snow measurements station**

In Salluit and Kangiqsujuaq, the location of the ice and snow measurements station will be decided by the community, just prior to installation (Figure 22).

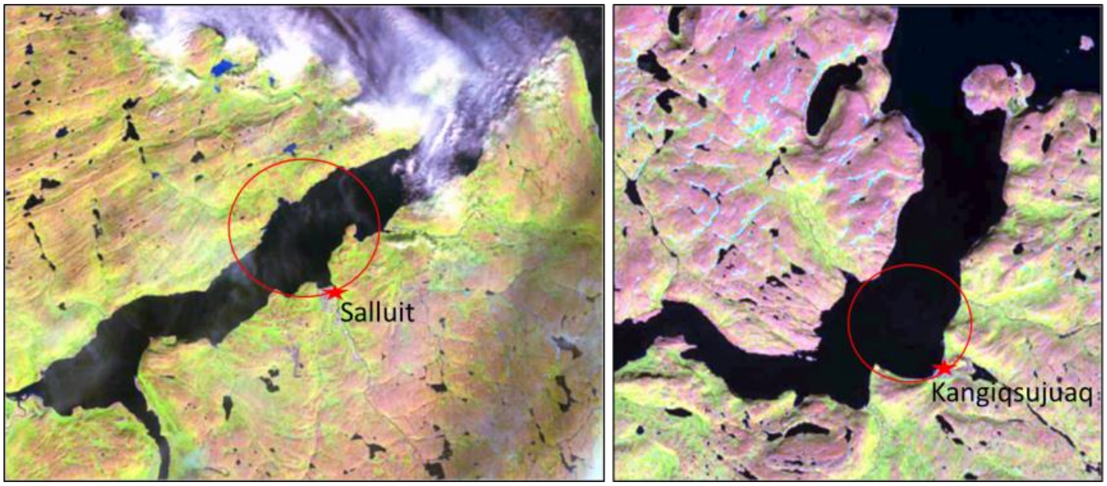


**Figure 22: The location of the ice and snow measurements station would ideally be within a radius of 4 km north of the community of Salluit and of the community of Kangiqsujuaq.**

## 3.5. Installation schedule and plan

Installation of the camera and echo sounders is planned for the second week of September 2015. Two research professionals from INRS (Yves Gauthier and Jimmy Poulin) and one environment specialist from KRG (Véronique Gilbert) are responsible for planning and execution. They should be aided for installation by an Inuit guide and two divers. Employees of Raglan Mine will also assist for the installation of the camera near the telecommucation tower. We estimate the work load to one day per camera installation (total 3 days) and one day for the installation of the SWIP and IPS (total 1 day). Transportation to sites will be by boat.

Installation of the ice and snow measurement station is planned for December 2015 or January 2016, depending on ice formation and availability of personnel. One PhD student from INRS (Sophie Dufour-Beauséjour), one intern from INRS (to be determined) and one environment specialist from KRG (Véronique Gilbert) will be responsible. They should be aided by an Inuit guide at each site. We estimate the work load to half a day per station. Transportation to sites will be by snowmobile. The entire trip over Salluit, Deception Bay and Kangiqsujuaq should take seven to nine days, including transport and potential weather delays.

Transportation in and out of Deception Bay and logistics on site are provided by Raglan Mine.

## 3.6. Authorisations

For the site of Deception Bay, the instrumentation plan was discussed with the proper authorities. Raglan Mine gave its approval for the installation of a camera next to their telecommunication tower.

For the other potential camera sites (West shore, Moosehead Island, Black Point), Avataq was informed and based on their database of the area, the cameras would not interfere with any known archaeological sites (see email below and Figure 23).

**From:** Elsa Cencig <elsacencig@avataq.qc.ca>
**Subject: deception**
**Date:** 14 mai 2015 15:06:45 HAE
**To:** Daniel Gendron <severian@avataq.qc.ca>

Bonjour Daniel,

J'ai vérifié avec notre base de données et le MCCQ, il n'y a pas de site archéologique au 4 emplacements ciblés par l'INRS. Par contre ce sont pour la plupart des secteurs qui n'ont pas encore été prospectés.

Il y a KaFi-1 pas bien loin de leur site ciblé le plus au sud (proche de Qinnuajuarsitik). Sinon le KbFi-3 près de la pointe Inirjuat (Pointe Noire) (au nord-est). Mais les deux sont relativement loin.

À propos d'Inirjuat, en effet c'est un secteur fréquenté durant la période historique, mais les sites sont plus dans le détroit et comme le mentionne Yves Gauthier, la falaise est probablement ok.

Toutefois le site ciblé à l'ouest, près de Turaagaq, va peut-être poser problème car c'est un secteur qui n'a jamais été prospecté et il offre un bon potentiel.

Je t'ai mis une image Google Earth avec Nunatop + ISAQ. Les infos nécessaires sont dessus.

Elsa

--
Elsa Cencig
Archéologue / Archaeologist
Institut culturel Avataq
4150, rue Ste-Catherine O., Suite 360
Westmount (Québec) H3Z 2Y5

**Figure 23 : Proposed camera sites (red) in the Deception Bay area and potential archeological sites (green) identified by Avataq Cultural Institute (personal communication, Elsa Censig, Avataq).**

For entry and access to islands, we had to fill an application to be reviewed by the land owner (Makivik Corporation). After this process, access was granted by Makivik (ref Adam Lewis).

In addition to entry and access from Makivik, we were required to have the project screened by the Nunavik Marine Region Impact Review Board (NMRIRB). This process was done with Ms. Mishal Naseer, Regional Planner at the NMRIRB. Here is the conclusion of the project screening report:

> *"The NMRIRB has carefully considered factors set out in sections 7.4.2 (a) and 7.4.2 (b) of the NILCA. The Board regards the project to have minimal impact on Deception Bay at this time. However, the Board would like to ensure that any and all permitting conditions placed on this project by the Nunavik Marine Region Wildlife Board must be adhered to.*
>
> *Additionally, any protective measures to be undertaken on the monitoring sites must include accessibility deterrents for any marine mammals in close proximity of the site. Any activities to be undertaken by the research team must be ensured are not in conflict with the hunting season and any related harvesting and shipping activities within the area. Any and all communication regarding the project between the local communities and the research team must be clear and transparent. It is preferable that the project utilize wherever appropriate local expertise and services.*

*The NMRIRB will also request that the research team provides a report of their activities after completion of the field-work and apprise the Board of the results of their analysis in a report format of the monitoring process at reasonable process intervals.*

*Therefore, pursuant to Section 7.4.4 (a) of the NILCA, the Board concludes that the Project may proceed without a review under Part 5 or 6 of the NILCA.*

*The NMRIRB looks forward to your communication on this matter with the Project Coordinator in question as well as any relevant parties to this decision.*

*Yours Truly,*
***Putulik Papigatuk***
*Chairperson*
***Nunavik Marine Region Impact Review Board***
*Email: info@nmrirb.ca*

*Dated: Friday August 7th 2015, at Kuujjuaq, QC"*

The project has also been presented to the authorities of Salluit and Kangiqsujuaq, as mentioned in delivery #1. We were given permission to go on with the project. Furthermore, the sites for installing the ice and snow measurement stations in these villages will be selected by the local authorities.

# 4. SATELLITE IMAGERY

## 4.1. LANDSAT imagery

For this three years project, we will use images from the Landsat-8 optical satellite. Landsat-8 is an American Earth Observation satellite launched on February 11, 2013. It is the eighth satellite in the Landsat program; the seventh to reach orbit successfully. Originally called the Landsat Data Continuity Mission (LDCM), it is a collaboration between NASA and the United States Geological Survey (USGS). Landsat-8 operates in the visible, near-infrared, short wave infrared and thermal infrared spectrums. Spatial resolution in the visible to shortwave infrared is 25m. Images are freely available through the USGS earth Explorer website (http://earthexplorer.usgs.gov/).

Landsat-8 images are acquired on the same orbit every 16 days around 10:00 am local time. Deception Bay is covered by two different overlapping orbits (Figure 24). Therefore, it may be covered every week or so. The same applies for Salluit and Kangiqsujuaq. All cloud-free images will be used to help to determine the ice-in and ice-out process in Salluit, Deception Bay and Kangiqsujuaq.  From Landsat-8 images and other previous Landsat satellites, we can retrieve a series of cloud free or partially cloudy archived images (173) from 1982 to today. This information will be used in combination with other satellite sources to document the historical and actual ice processes in the study area. Figure 25  and Figure 26 show examples of Landsat-8 image subsets.

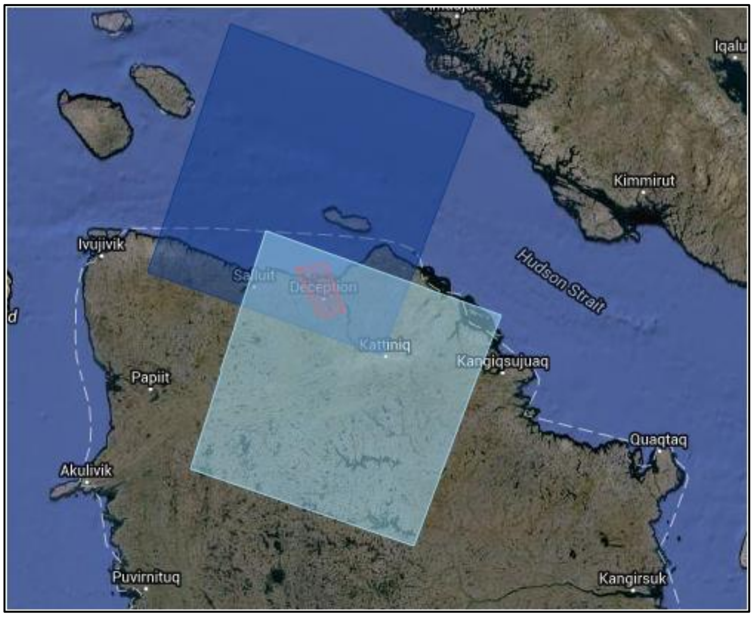


**Figure 24: Coverage of Landsat-8 images. From left to right, Paths #21 and #20.**

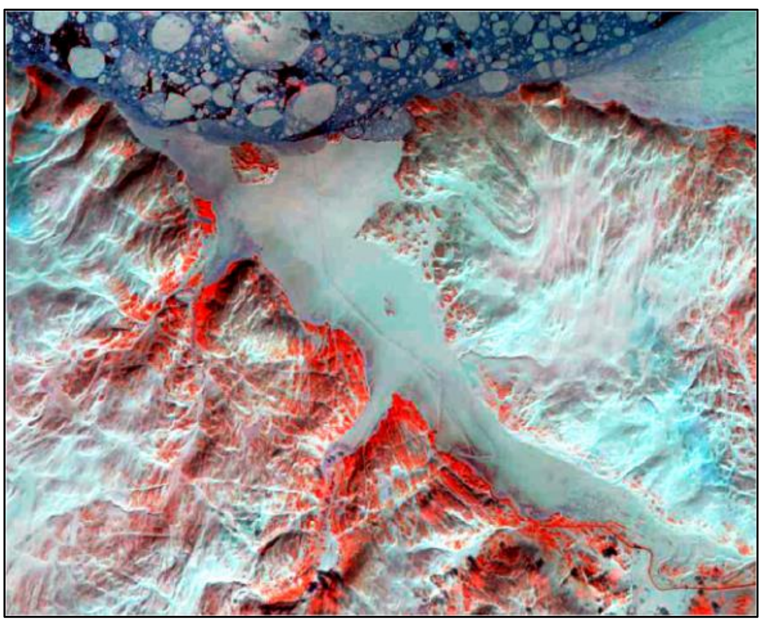

**Figure 25: Landsat-8 subset of Deception Bay showing a complete ice cover (light blue) on April 21, 2015.**

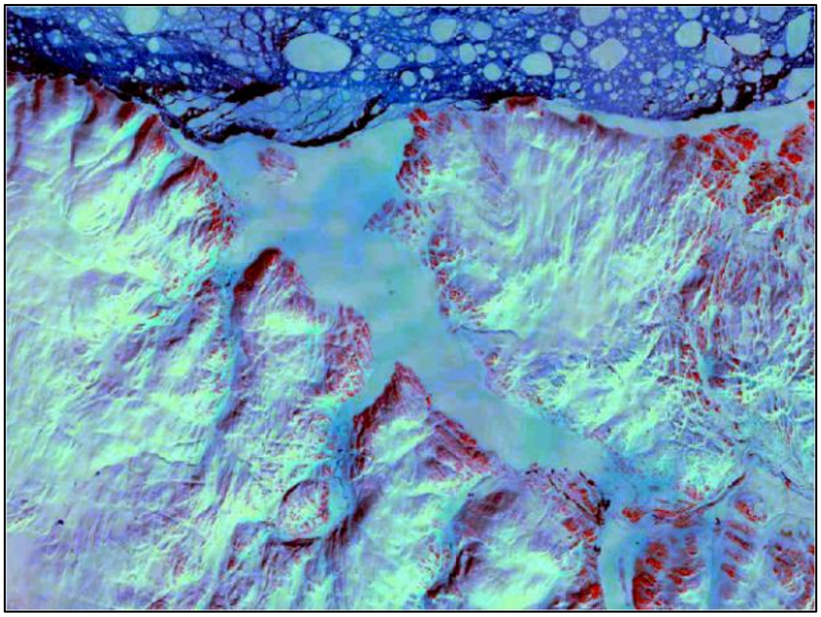

Figure 26: Landsat-8 subset of Deception Bay showing a complete but melting ice cover (light to dark blue) on May 30, 1991.

## 4.2. MODIS imagery

The three study areas are covered two times a day by a single MODIS image, at a spatial resolution of 250-500m. The Moderate-resolution Imaging Spectroradiometer (MODIS) is a payload scientific instrument that was launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. MODIS images are distributed by NASA on http://rapidfire.sci.gsfc.nasa.gov. A MODIS image subset over Deception Bay is shown in Figure 27.

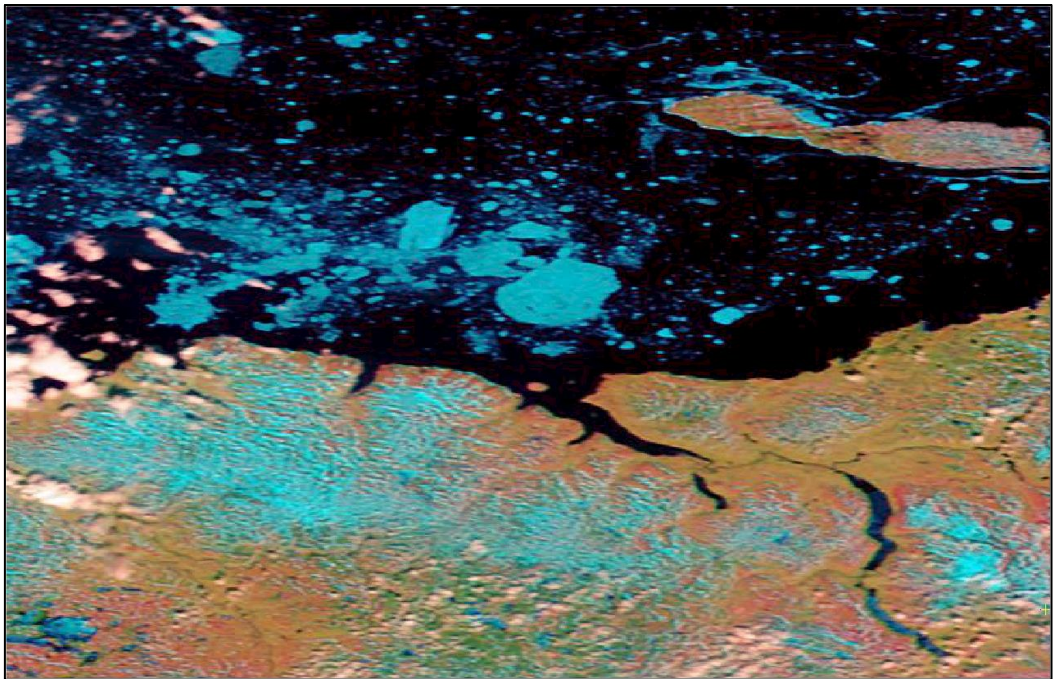

**Figure 27 : Subset of a low resolution MODIS image from July 2, 2015. Open water is in black, snow and ice is in light blue and bare ground is in orange.**

As with Landsat images, many days are cloudy, particularly during freeze-up. So it is the combination of all satellite sources that will give us a portrait of the freeze-up and breakup processes.

## 4.3. RADARSAT imagery

RADARSAT-1 is Canada's first commercial Earth observation satellite. It utilized synthetic aperture radar (SAR) to obtain images of the Earth's surface to manage natural resources and monitor global climate change. Launched in 1995, it was declared non-operational in March 2013 and is no longer collecting data. RADARSAT-2 is a follow-on to RADARSAT-1, offering new acquisition mode (such as polarimetric mode) and a finer spatial resolution.

The plan proposes the acquisitions of Radarsat-2 polarimetric images covering the sites of Salluit, Deception Bay and Kangiqsujuaq (Figure 28) every 24 days (Table 7) from December 2015 to April 2016 (and eventually until 2018). The three study sites are covered within seven days. The specific objective of these acquisitions is to document the ice cover changes at the local scale, exploring a link between variation in the ice thickness and changes in the polarimetric characteristics of the radar signal.

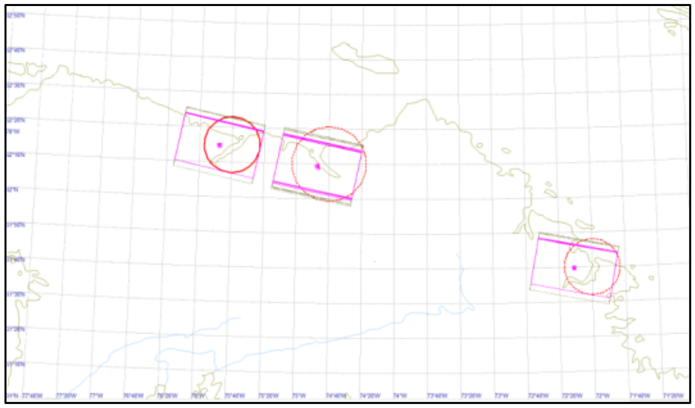

**Figure 28 : Coverage of the new RADARSAT-2 image acquisitions (rectangles) over the three study sites.**

The WideFine mode provides images at a spatial resolution of 10m. The selected orbit is “descending” (6:00am) to avoid melting snow conditions, which would mask the information on the underneath ice cover. For the same reason, we stop acquisitions in April (but could eventually extend it to May if weather permits). Images will be gratefully provided through an agreement (joint project) with the Canadian Ice Service. This specific aspect (ice thickness) of the ice monitoring project will be carried out by Sophie Dufour-Beauséjour, PhD student at INRS (Monique Bernier, director).

Table 7 : Calendar of RS-2 2015-2016 acquisitions for Salluit, Kangiqsujuaq and Deception Bay

| Site | Date of acquisition + GMT time | Orbit | Mode | Polarisations | |
|---|---|---|---|---|---|
| Sal | 2015-Dec-19 11:29:49.150 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2015-Dec-23 11:13:12.184 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2015-Dec-26 11:25:38.676 | DES | WideFQ (FQ16W) | H+V | H+V |
| Sal | 2016-Jan-12 11:29:49.139 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2016-Jan-16 11:13:12.133 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2016-Jan-19 11:25:38.709 | DES | WideFQ (FQ16W) | H+V | H+V |
| Sal | 2016-Feb-05 11:29:49.069 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2016-Feb-09 11:13:12.102 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2016-Feb-12 11:25:38.717 | DES | WideFQ (FQ16W) | H+V | H+V |
| Sal | 2016-Feb-29 11:29:49.118 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2016-Mar-04 11:13:12.202 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2016-Mar-07 11:25:38.767 | DES | WideFQ (FQ16W) | H+V | H+V |
| Sal | 2016-Mar-24 11:29:49.091 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2016-Mar-28 11:13:12.187 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2016-Mar-31 11:25:38.847 | DES | WideFQ (FQ16W) | H+V | H+V |
| Sal | 2016-Apr-17 11:29:49.122 | DES | WideFQ (FQ16W) | H+V | H+V |
| Kan | 2016-Apr-21 11:13:12.188 | DES | WideFQ (FQ17W) | H+V | H+V |
| DB | 2016-Apr-24 11:25:38.828 | DES | WideFQ (FQ16W) | H+V | H+V |

To get the historical context, we will use archived RADARSAT images. RADARSAT-1 images were acquired over the study area by the Canadian Ice Service since 1996, in ScanSAR mode, at a 100m spatial resolution. Images from 1996 to 2007 are freely available for downloading through the Polar Data Catalogue (https://www.polardata.ca/pdcsearch/), collection « RADARSAT Polar Science Dataset ». There are approximately 20 images per year (mid-October to mid-July period) covering Deception Bay (example in Figure 29), the Salluit Fjord and Wakeham Bay (Kangiqsujuaq).

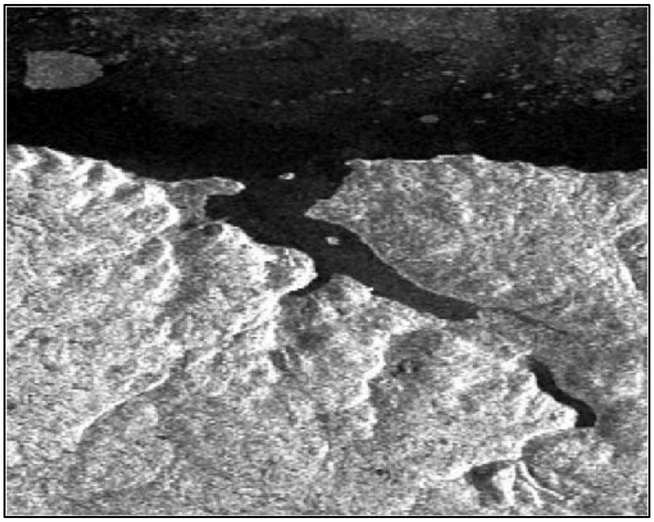

**Figure 29 : Deception Bay on a subset from a RS-1 ScanSAR image of June 28, 2006.**

Images from 2008-2013 were also acquired but were not made available through the Polar Data Catalogue. We are continuing our efforts to access these images.

Since its launch in 2007, RADARSAT-2 has also been acquiring ScanSAR images of the study area (Figure 30) every 1 to 3 days. There are a little more than 1000 available images covering the ice season (mid-October to mid-July) over the study area during this period. It has not yet been ascertained if these images will be available for the project.

We will process all available RADARSAT images in combination with Landsat and MODIS images in order to determine the ice-in and ice-out process in Salluit, Deception Bay and Kangiqsujuaq for each available year.

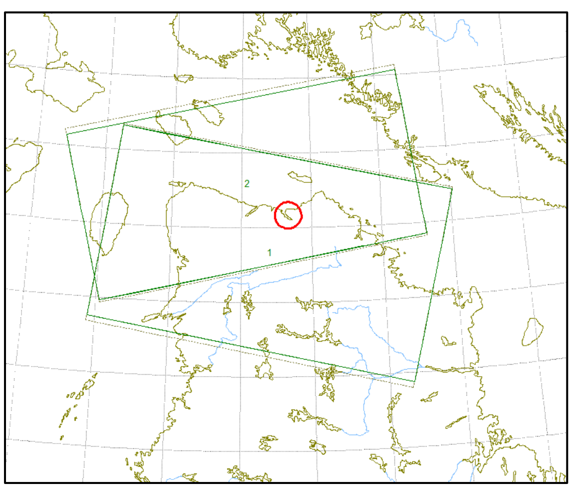

**Figure 30: ScanSAR coverage of the study area in Ascending or Descending mode.**

# 5. FIELD WORK

Apart from the regular ice and snow measurements conducted at the hotwire stations by a local collaborator, field work is also planned by INRS during at least two annual visits to the sites. In particular, ice thickness will be measured with a ground-penetrating radar and through ice core drilling.

## 5.1. Ground-Penetrating Radar (GPR)

The first activity will use a Ground Penetrating Radar (GPR) to obtain non-disruptive ice thickness measurement over various transects. This instrument, owned by INRS, is hauled with a snowmobile (Figure 31). It uses 250 MHz and 400 MHz antennas.

**Figure 31: Use of a GPR for ice thickness measurements by INRS team (Koksoak River, 2008).**

In profiling mode, the emitting antenna sends an electromagnetic pulse towards the ground, or in this case into the ice. This radar signal propagates downwards in the ice and is partially reflected when the propagation medium changes (for instance when ice becomes water). These reflections are measured by the receiving antenna. The time delay between the signal emission and the measured reflections depends on the depth of the feature responsible for reflecting the signal. When the speed of light in the propagation medium is known, time can be converted to depth. All vertical features that generate partial reflections can in theory be identified with this instrument. In the case of this field work, the frequencies used should enable detection of the ice/water interface and perhaps of the snow/ice interface. GPR measurements will therefore lead to ice thickness values across transects on the ice.

Use of GPR to measure ice thickness is widespread, particularly in freshwater ice (rivers, lakes, glaciers). Measurement of sea ice, which contains brine inclusions, is more challenging. The presence of brine in the ice changes the electromagnetic properties of the ice, specifically its permittivity, which in turn determine the speed of light. For this reason, scientific literature on measuring sea ice thickness with GPR recommends that the speed of light be measured on site. This will be done by taking ice cores at several points along the GPR transects. The direct measurement of the ice thickness will be combined with the GPR trace at that spot to determine the speed of light; this value will be used to convert the whole transect into an ice thickness measurement.

## 5.2. Ice core drilling

The second activity consists of extracting ice cores in order to describe the vertical ice profile. This will be done at some points along the GPR transects, using a Kovacs ice corer (Figure 32).

**Figure 32: Use of a Kovacs ice corer for vertical ice profiling by INRS team (Koksoak River, 2009).**

At the drilling site, snow height is measured with a ruler before the spot is cleared of snow prior to coring. The Kovacs ice corer can then be operated by field workers to quickly extract an ice core. This measure readily yields snow and ice thickness, as well as ice freeboard and draft (by measuring, in the hole through the ice, its thickness relative to the water level). At the control sites in Salluit and Kangiqsujuaq, in depth analysis of some ice cores will be possible in the community schools' science laboratory. The chosen relevant cores brought back to the lab will first be photographed against both a black and a white background; changes in ice type and structure can be observed on such photographs. The cores will then be cut in vertical sections to measure vertical profiles of certain parameters. Ice density is obtained through weight and volume measurements (the sample is weighted and its thickness and diameter is measured). Ice salinity is retrieved by measuring the conductivity of the melted ice core sample.

# 6. CONCLUSION

This report is deliverable #2 of the contract between INRS and the Kativik Government for setting up an ice monitoring system in Deception Bay. The first section, site characterization, gives a general description of Deception Bay in terms of physiography, bathymetry, water levels, climate, ice regime and travelling routes.

The second section details the instrument installation plan, describing what will be installed and where. Five cameras will document the ice regime of the entire Bay. Two echo sounders will document ice growth and ice thickness in shallow and deep waters. In situ measurements of snow thickness, ice thickness and ice vertical profile will be done in Deception Bay as well as on the control sites of Salluit and Kangiqsujuaq to complete the information. Installation of cameras and sonars are planned during the second week of September 2015. Installation of the snow and ice measurement stations is planned in January 2016.

The final section of the report lists the availability of satellite images (archived or new acquisitions) for documenting the ice regime of the three sites. A combination of optical and radar images are available at medium to low spatial resolution over the last decades. New Radarsat-2 acquisitions are planned for the 2015-2016 ice season.

The next deliverable (October 31, 2015) will be the instrumentation report. It will describe and document the activities conducted during the instrumentation of the Deception Bay site.

The last deliverable (March 31rst) will be the final report and will concern the activities conducted during the 2015-2016 ice season: installation of the snow and ice measurement stations, in situ measurements, activity with the science classes in Salluit and Kangiqsujuaq, and satellite image analysis. It will also include an executive summary.

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# ICE MONITORING OF DECEPTION BAY

## *Instrumentation of Deception Bay*

**Report submitted to**

Kativik Regional Government

Renewable Resources, Environment,

Lands and Parks Department

**Attention: Michael Barrett, Associate Director**

Kuujjuaq (Quebec)

**Prepared by**

**Yves Gauthier, Jimmy Poulin and Monique Bernier**

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**Deliverable no.3**

October 31rst, 2015

For more information, please contact:
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# 1 PROJECT BACKGROUND AND OBJECTIVES

The project “Ice monitoring of Deception Bay” is conducted through a technical and administrative agreement between the Kativik Regional Government (KRG) and Raglan Mine, a Glencore Company. INRS acts as a consultant to KRG and is a partner to the project.

The global objective of the project is to better understand the interactions between the ice cover of Deception Bay, changing climate, winter navigation, safe access to the territory for Inuit communities and protection of the Bay’s ecosystem. The specific objective of this agreement is to assess various monitoring techniques to document the characteristics, processes and variability of the ice cover during three winter seasons (2015-2018). Satellite images, on site cameras, ice profiling devices, ice thickness stations and ground penetrating radar will be jointly used. Control observations and measurements will be acquired in the neighbouring communities of Salluit and Kangiqsujuaq (Figure 1).


Figure 1: Location of the study area.

According to the services contract between KRG and INRS, the latter has the following responsibilities:

- To participate in a reconnaissance visit of the site at Deception Bay.
- To collect geographical information about the site and information about available technical facilities on site.
- To describe the proposed technology and provide the installation plan.
- To do an inventory of the available satellite imagery of the study area and to propose an acquisition plan.
- To participate in meetings with the Raglan Mine representatives and with the communities of Salluit et Kangiqsujuaq
- To proceed with the purchase and installation of the on-site cameras.
- To prepare the collected data for archival and distribution.
- To link the Deception Bay project and the Avativut project (Kativik School Board) through the participation of Nunavik students in ice observations and measurements at the witness sites of Salluit and Kangiqsujuaq.
- To participate in project management.

This work will lead to the following deliverables by INRS:

1. Visit report (Deception Bay, Salluit, Kangiqsujuaq)
2. Site characterization report (including the instruments installation plan and the satellite images acquisition plan
3. Installation report for the cameras and the echo-sounders, the data archival and dissemination plan.
4. Final report.

The present report is deliverable #3 and concerns the visit to Deception Bay in September 2015 for the instrumentation activities.

# 2 CHRONOLOGY OF ACTIVITIES

## 2.1 Objective of the visit

The objective of this trip (September 8-14, 2015) was to proceed with the instrumentation of Deception Bay for ice monitoring, in collaboration with the Raglan Mine representatives. Specifically, the instrumentation plan (Deliverable #2) concerned the installation of on-site cameras and echo-sounders at this time.

## 2.2 Day to day activities and discussions

**Monday September 7, 2015**

Yves Gauthier (INRS) leaves by car from Quebec to Montreal.

**Tuesday September 8, 2015**

Departure of Yves Gauthier from Dorval to Katinniq, with stop in Rouyn-Noranda. Arrival at 14:00.

Departure of Jimmy Poulin (INRS) and Véronique Gilbert (KRG) respectively from Quaqtaq and Kuujjuaq. The divers could not come the same day due to a mortality in their family. Arrival at 15:30.

We were welcomed by Monica Thibodeau (Coordinator Environment, Raglan Mine)

Distribution of IPE (boots, protection glasses, helmets and security vests).

At 17:00, coordination meeting. Were present:

Telecom Supervisor (François Baril), Telecom Analyst (Dave St-Martin), Construction supervisor (Sébastien Gauthier), Superintendant Environment (Mélanie Côté), Coordinator Environment (Monica Thibodeau), Environment specialist KRG (Véronique Gilbert), Research professional INRS (Jimmy Poulin), Research professional INRS (Yves Gauthier).

- Discussion about alternative scenarios concerning the divers and the installation of the SWIP.
- Examination of the Network camera and planning its installation.
- Planning the logistics of the next day at Deception Bay.

At 18:30, recovery of our material in the container and at the storage facility.

**Wednesday September 9, 2015**

At 7:00, preparation and loading of our material. Departure for Deception Bay at 8:30 with Monica Thibodeau. Arrival at 10:00.

Meeting with the Inuit guides from Salluit (Denis Napartuk et Jani Kenuajuak), and with the Construction and Telecom people (Rock… and Evin Blouin (Construction), Dave St-Martin (Telecom).

Selection of site #1. Starting the installation of tower #1 (Network Camera) (Figure 2). Raglan Mine is taking care of the power and network connexions. INRS and KRG, with the help of the Inuit guides, are taking care of the tower and camera. Late in the afternoon, the camera is connected and functional. However, we have to wait for the cement to dry before we can lift and bolt the tower.

In the evening, INRS, KRG and the Inuit guides start the preassembly of tower #3 in the workshop at Deception Bay (Figure 2).

**Figure 2: On site work (tower #1) and preassembly work (tower #3).**

**Thursday September 10, 2015**

In the morning, we complete the preassembly of tower #3. We start the preassembly of tower #2.

At 12:30, INRS, KRG and the Inuit guides depart by boat to Black Point. Sunny day. Selection of the site and installation of tower #3 at Black Point (Figure 3).

**Figure 3: Preparing transport and installation work at site #3.**

Tests of the cameras. Functioning. However, due to the sudden arrival of fog, we can't confirm the proper orientation and field of view of the cameras. We will need to come back.

Return to DB at 17:00. We continue preassembly of tower #2. We also add cement in some anchors of tower #1.

We get confirmation that the divers won't come this week. Potential availability on September 24-26.

**Friday September 11, 2015**

At 8:00, we complete preassembly of tower #2.

At 9:00, INRS, KRG and the Inuit guides depart by boat to site #2 (West shore, hill facing Moosehead Island). Selection of the site, installation of tower #3. Tests of the cameras (Figure 4).

**Figure 4: Installation work at site #2 and tests.**

We verify water depths near Moosehead Island for planning the installation of the SWIP.

At 13:30, we go back to Black Point. We restart the Reconyx camera, add dessicant and check the fields of view. We acquire GPS points.

**Figure 5: Acquiring GPS points at Black Point.**

At 14:30, we cross to Arctic Island. We acquire GPS points. We try to land on Neptune Island but waves and rocks make it too dangerous. We go to Moosehead Island. We acquire GPS points. We add some points on the east shore.

At 16.30, we go back to DB.

**Saturday September, 12, 2015**

At 8:00, INRS and KRG complete installation of tower #1. We will need to add 2 guy wires on the T bar to stabilize the post. It will be done during the next visit to the site.

At 10:00, inside, we test the network camera, transfer files and restart the SWIP.

At 13:00, we transport the SWIP and its anchor in the garage, with the help of Marc Gagné (Coordinator Environment, Raglan Mine).

At 13:30, we acquire GPS points at site #1.

At 14:30, we verify and adjust the anchor and the SWIP attachments. Met with Michel Bujold, employee of Raglan Mine and diver from Salluit.

At 16:30, discussion on the next steps of the project.

Discussion points:

The potential sites in DB, Salluit and Kangiqsujuaq for the installation of the ice stations will be identified from satellites images and bathymetry maps. Final choice in December, when going on site. Véronique will try to find and recover the material still existing in some of the villages. And order what is missing. Installation should be in December if ice is strong enough. Installation at all three sites should be made during the same trip. If not possible in December, it would be delayed to mid-January. Véronique should be accompanied by Monique Bernier (professor, INRS) and Sophie Dufour-Beauséjour (PhD candidate, INRS), and with the local Inuit resources who will be responsible for the measurements.

Concerning the Avativut component: In March, Yves will be in Salluit and Kangiqsujuaq to support students during the Ice Mission. The work on the ice will be coordinated with the measurements at the ice stations. And the students will be interviewing local ice experts (elders) about ice in DB and in the village.

It is budgeted in this project to buy an ice corer. It should be used for taking ice samples for the project. It will also be used by the students in Avativut. Yves will transfer the information to Veronique to plan this purchase.

At 17:30, Departure of Véronique for Katinniq with Marc Gagné.

**Sunday September 13, 2015**

During the morning, we work on the report and on programming the network cam.

At 12:00, Departure of Yves and Jimmy to Katinniq with Maxime Gauthier (Cima+). Arrival at 13:30.

At 17:00 Jimmy meets with Dave St-Martin for a discussion about the network cam.

At 18:00, Debriefing session with Mélanie Côté (Superintendant environment), Monica Thibodeau (Coordinator Environment), Véronique Gilbert (Environment specialist KRG), Jimmy Poulin (Research professional INRS), Yves Gauthier (Research professional INRS).

**Monday September 14, 2015**

At 8:00, departure of Véronique for Kuujjuaq

From 9:00 to 11:00, Jimmy works on programming the network cam with Dave St-Martin.

At 14:00, Departure of Yves and Jimmy for Montreal. Arrival at 18:30. Arrival in Quebec City at 22:00.

# 3 INSTRUMENTATION

## 3.1 Objective

The instrumentation plan for Deception Bay (Deliverable #2) planned for:

- A time-lapse camera system over three sites
- Two echo-sounders (one in shallow waters, one in deep waters)
- An ice thickness station

The September 2015 visit concerned the installation of the cameras and echo-sounders.

## 3.2 Ice monitoring cameras

Four potential sites have been proposed in the instrumentation plan for the installation of cameras at Deception Bay. As a function of facilities, accessibility and viewpoint, three sites have been instrumented (Figure 6).

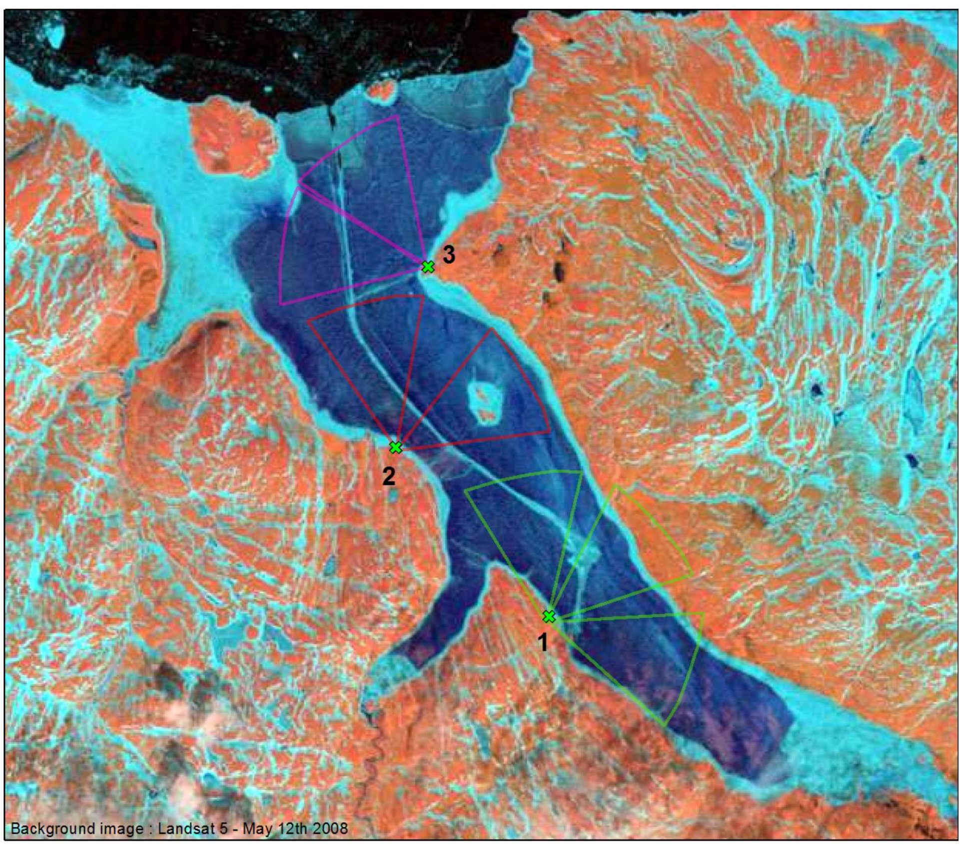


Figure 6 : Map of camera sites

The next section details the instruments characteristics at each site. Step by step assembly and setup of solar powered cameras system is presented in Annex 1.

**Site #1**

Site #1 is located on the hill behind the Deception Bay Raglan Mine complex (Figure 7), next to the telecommunication antenna. Electricity and access to the network are available. Hence, the motivation to install a network camera (Table 1). Connection (electricity and network) has been made by the Raglan construction department. Assembly and setup of the equipment have been made by INRS and KRG (Figure 8).

**Figure 7 : Telecom hill site.**

Table 1 : Description of instruments at site #1

| | | |
|---|---|---|
| **Location** | Telecom hill | |
| **Camera Model** | Panasonic SW598<br>360 degrees Pan tilt zoom<br>Resolution 2.4 Mp<br>Optical zoom 30x to 90x |  |
| **Power** | Electric, AC24 V | |
| **Network** | Ethernet | |
| **Tower** | 10 feet | |

**Figure 8 : Tower #1**

This camera will provide a panoramic view of the entire Bay (Figure 9). Live images are available for Raglan Mine on their restricted internal telecom network. An hourly low resolution panorama (4 photos) is automatically captured and transferred by FTP at INRS.


14/09/2015 16:02:38
BAIE DECEPTION
PANORAMA 4.16


14/09/2015 15:47:38
BAIE DECEPTION
PANORAMA 3.17


**Figure 9 : Panoramic view of the Bay (From North to South)**

## Site #2

Site #2 is located on a west shore hill, mid-way of the Bay, facing Moosehead Island (Figure 10). The system includes two types of hunting cameras (Table 2). They are powered by batteries and solar panel (Figure 11) and record photos on a SD card. This card will have to be retrieved periodically.

**Figure 10: Site #2 – West shore – facing Moosehead Island**

**Table 2 : Description of instruments at site #2**

| | | |
|---|---|---|
| **Location** | West shore – facing Moosehead Island | |
| **Camera Model #1** | RECONYX PC800 HYPERFIRE PROFESSIONAL SEMI-COVERT IR<br>Hunting Camera<br>Programmable<br>Resolution 3.1 megapixels<br>Field of view : V: 30° H: 40°<br>***Camera purchased by Transport Quebec*** |  |

| | | |
|---|---|---|
| **Camera model #2** | BROWNING STRIKE FORCE HD<br>Hunting Camera<br>Programmable<br>Resolution  10 megapixels |  |
| **Power** | Solar panel; 30W, 1.65A and battery 12V, 55 Ah | |
| **Recording** | SD card 16Gb Class 10 | |
| **Tower** | 8 feet | |

Figure 11 : Tour 2

The Reconyx camera (top of post) aims East, with Moosehead Island centered in the photo. The Browning camera (below the Reconyx) aims to the North-East, towards the mouth of the Bay (Figure 12). Photos are captured and stored each hour between 6:00 and 18:00.



**Figure 12 : View of the Reconyx (left) and Browning (right) cameras**

## Site #3

Site #3 is located on Black Point, on the East shore, at the mouth of the Bay (Figure 13). The system includes two types of hunting cameras (Table 3). They are powered by a battery and solar panel (Figure 14) and record photos on a SD card. This card will have to be retrieved periodically.

**Figure 13: Site #3 – Black Point**

**Table 3 : Description of instruments at site #3**

| | | |
|---|---|---|
| **Location** | East shore – Black Point | |
| **Camera Model #1** | RECONYX PC800 HYPERFIRE PROFESSIONAL SEMI-COVERT IR<br>Hunting Camera<br>Programmable<br>Resolution 3.1 megapixels<br>Field of view : V: 30° H: 40°<br>***Camera purchased by Transport Quebec*** |  |
| **Camera model #2** | SPYPOINT TINY PLUS<br>Hunting Camera<br>Programmable<br>Resolution 10 megapixels |  |
| **Power** | Solar panel; 30W, 1.65A and battery 12V, 55 Ah | |
| **Recording** | SD card 16Gb Class 10 | |
| **Tower** | 8 feet | |

**Figure 14: Tour 3**

The Reconyx camera (top) aims West, towards Neptune Island. The SpyPoint camera (bottom) aims North, towards Arctic Island (Figure 15). Photos are captured and stored each hour between 6:00 and 18:00.


Figure 15: View of the Reconyx (left) and SpyPoint (right) cameras

At each site, a notice is posted (Figure 16).


**Figure 16: Notice applied on each tower.**

All photos will be later processed by INRS. Analysed jointly with satellite images, they will give a spatial and temporal portrait of freeze-up and breakup processes in the Bay. They will also provide some information on the ice behavior during and after ships passage in the presence of ice.

In order to calculate ice surface concentration from the oblique photos, it is necessary to apply a vertical transformation. To do this, we need the geographic coordinates and altimetry information of features that are potentially visible on the photos, ideally at the ocean level. Therefore, we have acquired a series of GPS points on Black Point, Arctic Island and Moosehead Island. We haven't been able to access Neptune Island due to waves and rocks. We have also acquired a few points on the shores of the Bay.

All points are listed in Table 4 .

**Table 4 : Control points for vertical transformation**

| Site | Latitude | Longitude | Elevation (m) | Name | Description |
|---|---|---|---|---|---|
| Artic Island | 62,24070 | -74,76924 | 1 | PTE ILE | Island pointe |
| | 62,23983 | -74,76756 | 9 | FISSURE NOIRE | Black crack |
| | 62,23963 | -74,76472 | 9 | VEINE | Vein |
| | 62,23958 | -74,76571 | 11 | VEINE3 | Vein |
| | 62,23950 | -74,76383 | 7 | LIMITE BLANC | White border |
| Black Point | 62,21098 | -74,74593 | 8 | PT.60 | Rock |
| | 62,21096 | -74,74627 | 7 | PT.59 | Rock |
| | 62,21072 | -74,74663 | 7 | PT.58 | Rock |
| | 62,21058 | -74,74645 | 3 | PT.57 | Rock |
| | 62,21035 | -74,74684 | 7 | PT.56 | Rock |
| | 62,21030 | -74,74697 | 7 | PT.55 | Rock |
| | 62,20880 | -74,74809 | 15 | veine1 | Vein |
| | 62,20875 | -74,74764 | 21 | VEINE2 | Vein |
| Moosehead Island | 62,18905 | -74,72805 | 4 | PLANCHE | Plywood |
| | 62,18892 | -74,72774 | 5 | INUK | Inukshuk |
| | 62,18386 | -74,72309 | 9 | COIN PLAGE | Beach border |
| | 62,18380 | -74,72578 | 7 | INUK SUD | Inukshuk |
| East shore | 62,18245 | -74,69279 | 7 | ROCHE RIVE EST | Rock |
| Telecom | 62,14981 | -74,70278 | 63 | PT.61 | Inukshuk |
| | 62,14926 | -74,70118 | 59 | PT.62 | Inukshuk |
| | 62,14805 | -74,70182 | 75 | PT GEO | Geodetic point |

Figure 17, Figure 18, Figure 19 and Figure 20 are showing the ground features.


Pt.55 Pt.57



Pt.58 Pt.59 Pt.60

**Figure 17: GPS points on the beach at Black Point**



Pt. Limite blanc Pt. Veine3 Pt. Fissure noire

Pt. Pointe île

**Figure 18: GPS points on Arctic Island**

Pt. Inuk

Pt. Planche

Pt. Inuk sud

Pt. Coin plage

**Figure 19: GPS points on Moosehead Island**

Pt. Roche rive est

Pt.61 Pt62 Pt. Geo

**Figure 20: GPS points on the shores**

## 3.3 Echo-sounders

The instrumentation plan called for the installation of two echo-sounders. The first one is the Shallow Water Ice Profiler (SWIP), for measuring the ice thickness at depths of 7 to 20m; the second one, the Ice Profiling Sonar (IPS), for measuring ice thickness at depths up to 60m.

The SWIP and its anchor have to be installed on the ocean floor by divers. The IPS is deployed from a boat. The detailed information about these two instruments was provided in Deliverable #2.

The IPS has been acquired by KRG as planned. However, the supplier's quotation did not include an acoustic release device, essential for retrieving the instrument at the end of data collection. Because of additional costs and delays, it was impossible to install this instrument this fall. We have decided to postpone installation to summer 2016, in order to properly plan how the instrument will be installed and retrieved.

KRG is already the owner of a SWIP instrument, which had been used in the past on the Koksoak River. Several actions had to be pursued in preparation of its new deployment in Deception Bay: verification of all components, battery replacement, memory card replacement, system parametrization, and anchor fabrication. This has been done by KRG (Figure 21).

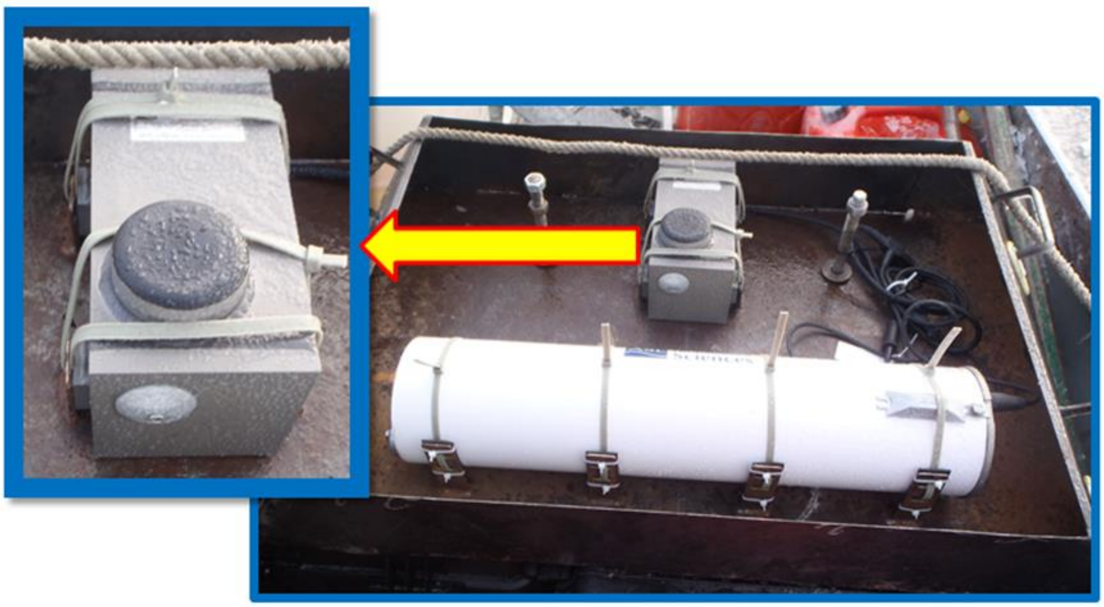

Figure 21 : The SWIP (grey box), the battery (white cylinder) and the anchor.

The installation of the SWIP was planned during the September 8-14 trip to Deception Bay. However, due to mortality in the family of the divers, it was postponed to October 28$^{th}$.

The selected site for the installation of the SWIP is just off Moosehead Island, in an area of adequate bathymetry (min of 7m at low tide and max of 20m at high tide) (Figure 22).

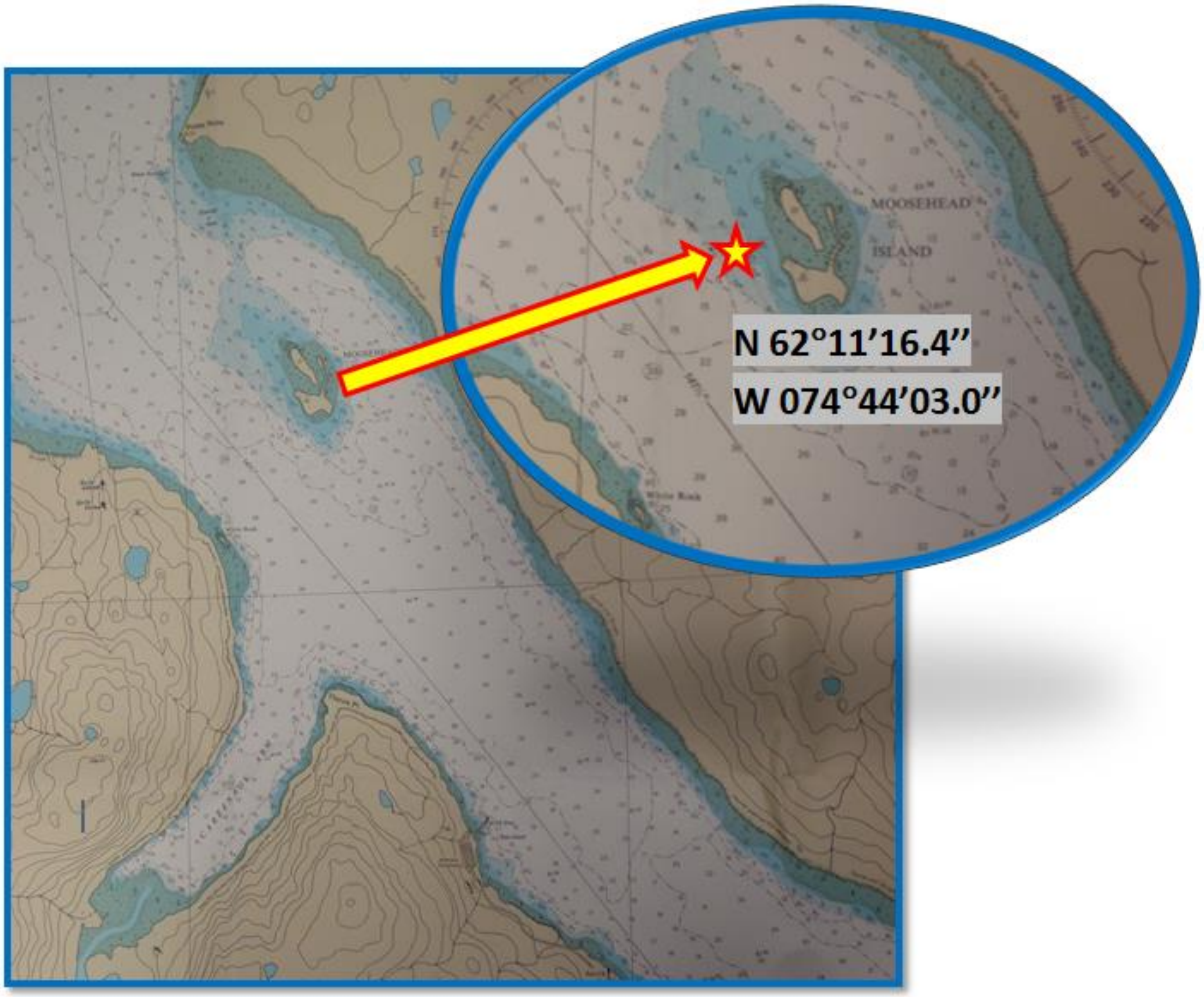


**Figure 22: Location of SWIP. Water depths are in Fathoms (1 Fathom = 1.8m) at low tide.**

The SWIP has finally been installed at a depth of 7.25m. At the time of installation (3h45 pm on October 29, 2015), it was low tide. Since the average tide in Deception Bay is about 5.5 m, the SWIP should be at a maximum depth of 13 m. In order to take valid data, the eco-sounder also has to be installed at a perpendicular angle with the water surface, or with an angle less than 20°. The instrument was placed on a flat surface.

For the instrument installation, the crew (KRG environment specialist, 2 divers, a guide and a helper) planned to go to Deception Bay from Salluit by boat (Figure 23). The travel took place on October 28th and the sea conditions were harsh (-15°C and 40 km/h wind), resulting in a longer travel time to reach Deception Bay (2h30). The crew went directly to the Raglan Mine facilities at their arrival to Deception Bay because the SWIP and his anchor have been stored at the Katinniq garage in September. The divers and KRG employee rehearsed the deployment in the garage and it was decided to fix the instrument on the anchor while still on the shore in order to facilitate the diver's work underwater. The whole equipment weighs 105 kg. They used extra tough tie-wraps to fix the instrument and battery on the anchor. The water conditions have got better during the afternoon but there were still 2 feet high waves which were limit for the diver's security (maximum 3 feet high for diving). The instrument was transported by boat nearby the selected site, when arrived on site, the boat has anchored. The guide slowly dropped the equipment under water using a rope that was tied around a cleat. At the same time, the two divers were following the equipment underwater in order to make sure it lands on the right location (Figure 24).

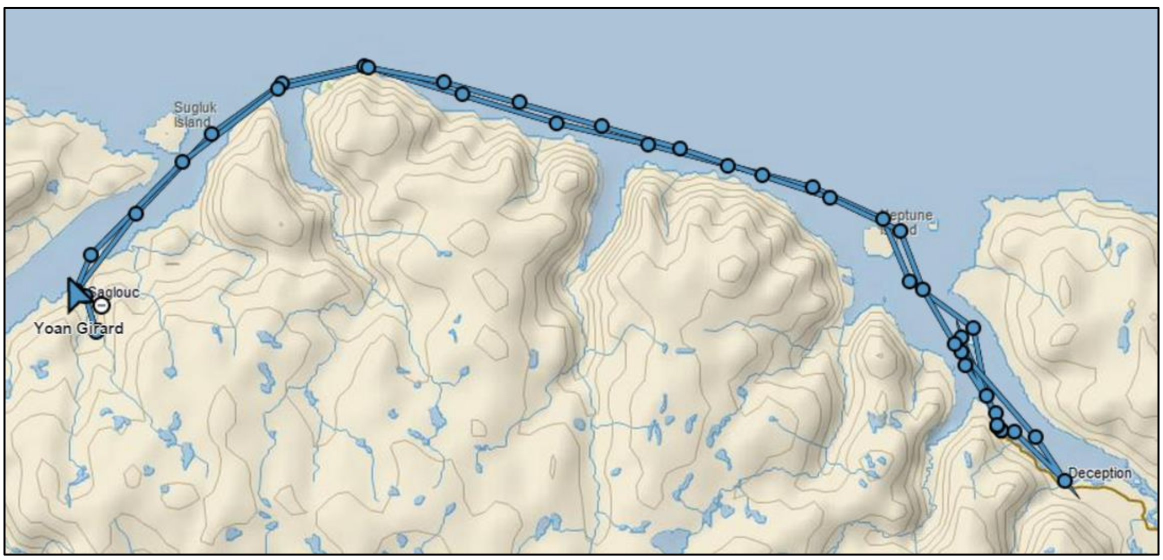


**Figure 23 : Route used from Salluit to Deception Bay by crew members**

**Figure 24: Loading off the SWIP from the boat and divers installing it on the bottom of the bay**

It took 11 minutes for the divers to fix the instrument on the right spot and to come back on the boat. The crew (Figure 25) overnight at the Raglan Mine facilities at Deception Bay and came back to Salluit the next day, October 29th. The sea conditions were nicer but there was an ice cover forming in Deception Bay.

Figure 25 : The crew from left to right Elijah Ningiuruvik (diver), Juupi Tuniq (guide and captain of the boat), Peter Arngak (diver) and Eyetsiaq Papigatuq (helper). Photograph: Véronique Gilbert, KRG.

The SWIP was emitting at the time of installation and will continue until July 2016. It will stop during ice free season to avoid any interference with marine fauna, although none is foreseen. The instrument will be retrieved by divers during summer 2016. Data will be downloaded, battery will be changed and a second season of data recording will be programmed in the system before it is put back in the water. The instrument will start to emit just before probable first ice appearance. Data will be processed by INRS.

# 4 DATA ARCHIVAL AND DISSEMINATION PLAN

All photos acquired by the network camera are automatically and daily uploaded on the FTP site at INRS: ftptele.ete.inrs.ca.

Photos acquired by the hunting camera are stored on local memory cards. They will be retrieved at the end of the ice season by an Inuit collaborator or by the team going on site to work on the SWIP. Memory cards will be sent by mail (pre-addressed envelopes) to INRS. All photos will be archived on a dedicated server at INRS.

One daily photo from each camera will be put online on a dedicated website, controlled by INRS. They will be accessible to public. The website will be created during fall 2015.

A link to this site is already planned on the KRG website, from the “Ice monitoring near marine infrastructures in Nunavik” page: http://www.krg.ca/en/ice-movement (Figure 26).

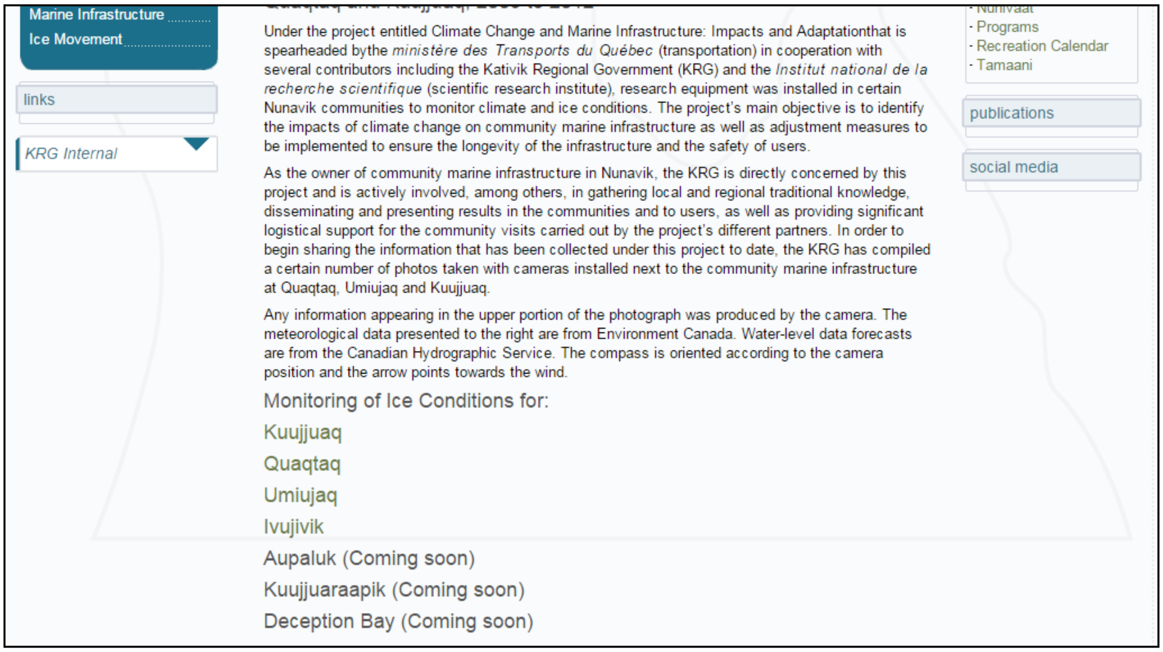


**Figure 26: KRG-Transport website**

Data from the echo-sounders will be retrieved on site by KRG and transferred to INRS for processing. Data will be archived on the dedicated server. When the raw data will have been processed and the ice thickness available, these will be put online on the project’s website, under graphic form.  Eventually, the data measured at the ice stations of Deception Bay, Salluit and Kangiqsujuaq and the other data collected by INRS during field work (eg. GPR), will be added under similar form. Measurements and observations from students participating in the Avativut program in Salluit and Kangiqsujuaq will also be available.

# 5 FUTURE VISITS

The next visit to Salluit and Kangiqsujuaq is scheduled for the first week of November 2015, to provide training to the high school science teachers about the Avativut Ice Mission. Then, in January 2016, the ice stations will be installed in Deception Bay, Salluit and Kangiqsujuaq by KRG and INRS, with the help of community members. Some preliminary ice measurements could be made with the GPR and the ice corer if under safe conditions. Another visit on each site is scheduled for March or April 2016 to proceed with more detailed ice measurements. At the same time, the team will accompany the science classes during the Ice Mission, and the local expert at the ice station.

# 6 REFERENCES

Deliverable No.1: ICE MONITORING OF DECEPTION BAY - Reconnaissance visit to Deception Bay and to the Communities of Salluit and Kangiqsujuaq. INRS, July 15th, 2015.

Deliverable No.2: ICE MONITORING OF DECEPTION BAY - Site Characterization and instrumentation plan. INRS, September 30th, 2015.

Deliverable No.3: ICE MONITORING OF DECEPTION BAY - Instrumentation of Deception Bay. INRS, October 31rst, 2015.

# ANNEX 1

## Installation of the solar powered camera systems

Two solar powered camera systems were installed in two different sites. Each system has the same structure and alimentation. The supporting structure consist of a 8’ post of type Superstrud® with a 18” square base drilled in the four corners The post is fixed to the ground with four threaded rods ½”-13 UNC of 8” length in stainless steel and leveled with nuts and washers (Figure 27).

**Figure 27 : The structure is fixed with threaded rod and leveled with nuts and washers**

An isolated aluminum enclosure is fixed to the post with two bolts 3/8”-16 UNC of 3” length. The solar panel is fixed to the post with four “L” shaped aluminum bar. The bars are symmetrically disposed on either side of the post and bolted with two bolts 3/8”-16 UNC of 3” length. The solar panel is fixed to the bars with bolts ¼”-20 UNC of a length of ¾”. The post is solidified with three guy-wires using cables of gauge 7*19 CAG 3/16” and jaw/eye turnbuckles with a threaded size of 3/8” (Figure 28). The cables are fixed with aluminum compressed oval sleeves. On the ground, the guy-wires are fixed with eyebolts ½" anchored in the rock and secured with cement. On the post, the guy-wires are fixed with eye nuts ½"-13 UNC (Figure 29).

**Figure 28 : Guy-wire with jaw/eye turnbuckles**

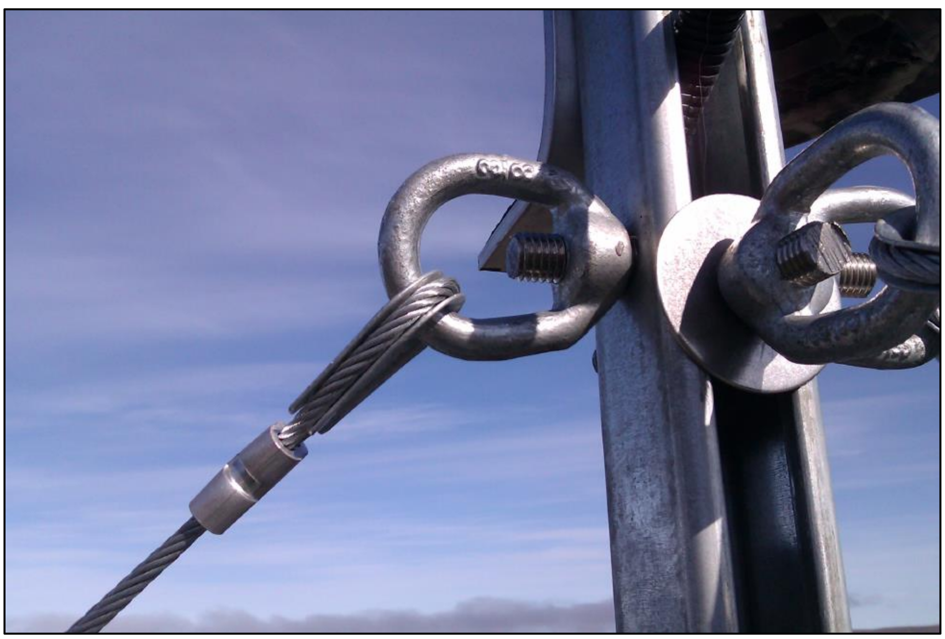

**Figure 29 : Guy-wires fixed with eye nuts and threaded rod**

The cameras are positioned at the top of the pole. The Reconyx cameras are fixed on supports using ¼”-20 UNC bolts. The supports are formed of two U-channel fitted one into the other and enable the adjustment of the vertical angle using as pivot bolt 3/8”-16 UNC (Figure 30). The supports are attached to the pole using two worm-drive clamps. The Spypoint and Browning cameras are fixed to a folded aluminum bar with ¼”-20 UNC bolt. The aluminum bar is bolted to the post.

**Figure 30 : Support for Reconyx cameras (Photo from Aupaluk)**

The solar panel is connected to a solar charge controller fixed to the back plate in the aluminum enclosure (Figure 31). The controller is then connected to a 12V battery, also placed in the enclosure. The Reconyx cameras are powered only by this battery. The SpyPoint and Browning cameras are also powered by AA batteries.

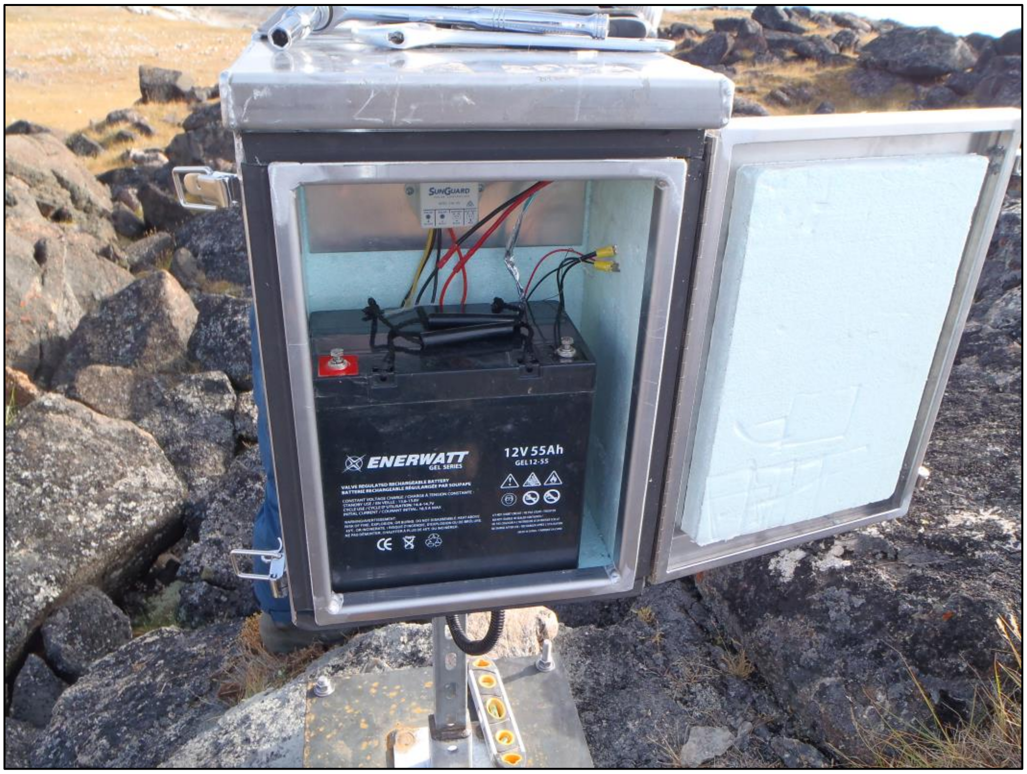


**Figure 31 : Solar charge controller and 12V battery**

# ICE MONITORING OF DECEPTION BAY

## ***<u>Field work - Winter 2016</u>***

## ***<u>(Final report)</u>***

**Report submitted to**

Kativik Regional Government

Renewable Resources, Environment,

Lands and Parks Department

**Attention: Michael Barrett, Associate Director**

Kuujjuaq (Quebec)

**Prepared by**

**Yves Gauthier, Jimmy Poulin and Monique Bernier**

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**Deliverable no.4**

April 30, 2016

INRS UNIVERSITÉ DE RECHERCHE

MINE RAGLAN UNE COMPAGNIE GLENCORE

KATIVIK

For more information, please contact:
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# 1 PROJECT BACKGROUND AND OBJECTIVES

The project "Ice monitoring of Deception Bay" is conducted through a technical and administrative agreement between the Kativik Regional Government (KRG) and Raglan Mine, a Glencore Company. INRS acts as a consultant to KRG and is a partner to the project.

The global objective of the project is to better understand the interactions between the ice cover of Deception Bay, changing climate, winter navigation, safe access to the territory for Inuit communities and protection of the Bay's ecosystem. The specific objective of this agreement is to assess various monitoring techniques to document the characteristics, processes and variability of the ice cover during three winter seasons (2015-2018). Satellite images, on site cameras, ice profiling devices, ice thickness stations and ground penetrating radar will be jointly used. Control observations and measurements will be acquired in the neighbouring communities of Salluit and Kangiqsujuaq (Figure 1).

Figure 1: Location of the study area.

According to the services contract between KRG and INRS, the latter has the following responsibilities:

- To participate in a reconnaissance visit of the site at Deception Bay.
- To collect geographical information about the site and information about available technical facilities on site.
- To describe the proposed technology and provide the installation plan.
- To do an inventory of the available satellite imagery of the study area and to propose an acquisition plan.
- To participate in meetings with the Raglan Mine representatives and with the communities of Salluit et Kangiqsujuaq
- To proceed with the purchase and installation of the on-site cameras.
- To prepare the collected data for archival and distribution.
- To link the Deception Bay project and the Avativut project (Kativik School Board) through the participation of Nunavik students in ice observations and measurements at the witness sites of Salluit and Kangiqsujuaq.
- To participate in project management.

This work will lead to the following deliverables by INRS:

1. Visit report (Deception Bay, Salluit, Kangiqsujuaq)
2. Site characterization report (including the instruments installation plan and the satellite images acquisition plan
3. Installation report for the cameras and the echo-sounders, the data archival and dissemination plan.
4. Final report.

The present report is deliverable #4 and concerns the field work conducted in Deception Bay, Salluit and Kangiqsujuaq during the winter of 2016.

# 2 CHRONOLOGY OF ACTIVITIES

## 2.1 Objective of the field campaigns

The objective of the field campaigns was to collect data on the ice characteristics over the sites of Deception Bay, Salluit and Kangiqsujuaq.

## 2.2 Day to day activities

**<u>First field campaign</u>**

**Monday January 18, 2016**

Pierre-Olivier Carreau (intern) and Sophie Dufour-Beauséjour (PhD student) leave from Quebec (INRS) to Montreal.

**Tuesday January 19, 2016**

Check-in completed at 8h. Flight postponed to the next day due to bad weather at destination (Katinniq). Stayed in Montreal for another night. Véronique Gilbert's flight from Kuujjuaq was also delayed.

**Wednesday January 20, 2016**

Arrived in Katinniq at noon. The road to Deception Bay is closed but opens up during the afternoon. Met Isabelle Deguise and Louis Marcoux (Coordonators – Environment). Véronique Gilbert arrived at 16h30. Left with Martin Charette at around 19h for BD. Arrived in BD in the evening. Prepared the wood stakes in the shop (added ruled tape, a stop-screw and a red flag) for the ice stations in BD and Kangiqsujuaq. The Canadian Royalties ship left its harbour that evening.

**Thursday January 21, 2016**

Met with our two guides, Juupi Tuniq and Jimmy Kakayuk, at 8h30. We determined the most convenient place for the ice station with them: close to plage Bombardier and their camp. We drove to plage Bombardier (east end of the bay) with their truck and were on the ice by 9h. From there, we used snowmobiles with sleds to install the ice station and conduct the measurements on the ice. At noon so we went back to BD camp for lunch. At 13h, the guides went to get one of the snowmobiles and sled from the beach which took two trips by truck. At 14h Sophie, Pierre-Olivier, Juupi and Jimmy set out on the ice from the Raglan Mine infrastructures while Véronique went uphill to the camera to check on the structure and instrument. The ice team was back by 16h. We left at 20h for Katinniq; Marc Gagné was the driver. Arrived at Katinniq around 21h30.

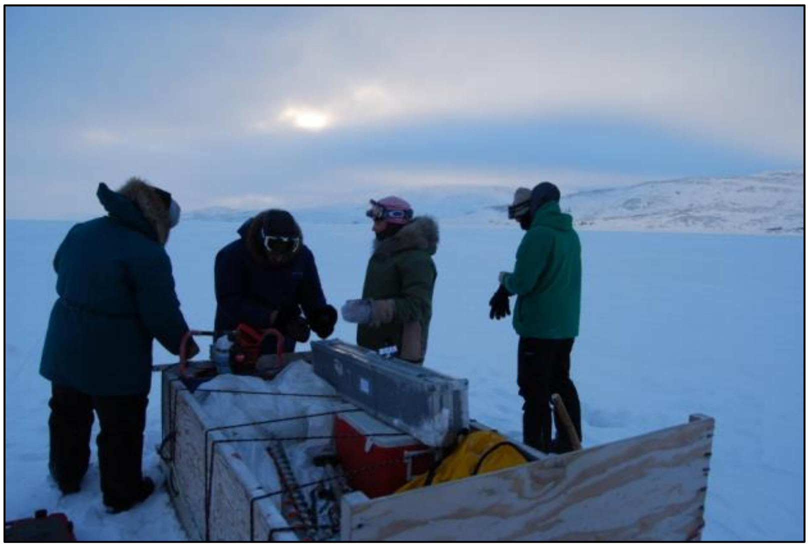


Figure 2 : Preparing for field work.

**Friday January 22, 2016**

Met with the Raglan Mine environment team at 7h30 to do a verbal report of our work at Raglan Mine (Louis Marcoux, Marc Gagné, Monica Thibodeau). Left for Kangiqsujuaq at around 8h30. By 9h00 we were ready to start the day and Elijah Ningiuruvik (park director) had arrived to pick us up. We finished preparing the wood stakes at the park's garage and then left for the bay with three park guides: Elijah Qisiiq (guide), Danny Alaku and Charlie Alaku. The guides chose the spot for the ice station, in the western end of the bay. We installed the ice station and collected some ice measurements before lunch at the hotel. Elijah came to pick us up at 13h. We did more ice measurements in the afternoon. We were back at the garage at 15h15 and Elijah drove us back to the inn.

**Saturday January 23, 2016**

Charlie came to pick us up at the inn at 9h15 and brought us to the garage. We left for the ice with two snowmobiles and two sleds, heading towards the west portion of the bay. We conducted more ice measurements and were back at the inn later for lunch. We melted the ice samples by putting the bags into a pan of hot water. After dinner we got started on the salinity measurements.

**Sunday January 24, 2016**

A day of rest. Left at 17h for Salluit. Juupi came by at 20h30 to drop off the wood stakes we had given him in BD. Together we went over the plan for the following day. He suggested a spot for the ice station east of the village. After he left we prepared the ruled stakes for the ice station and repaired our ruled stick used to measure the ice thickness.

**Monday January 25, 2016**

Juupi came to get us at the CEN's house around 9h30 and we went out on the bay to install the ice station and proceed with the ice measurements. We were back at the house around 13h. He came back to pick us up at 14h15 and do more measurements. We were back at the CEN house by 16h30.

**Tuesday January 26, 2016**

In the morning, Pierre-Olivier and Sophie conducted some analysis (polishing, photographing, slicing, and cataloging) on the ice core samples that were brought back. In the afternoon, samples were melted and the salinity was measured.

**Wednesday January 27, 2016**

Véronique's flight to Kuujjuaq was on time around 9h, but Pierre-Olivier and Sophie's flight to Donaldson had a two-hour-delay. We contacted Louis Marcoud at Raglan Mine to make arrangements for the likely event of us missing the flight back down south. We arrived in Donaldson at 3h20 PM and had indeed missed the flight. We left our cargo in the security office at Donaldson (and our ice cooler in their freezer) and took the bus to Katinniq. We were attributed rooms and spent the night at Katinniq.

**Thursday January 28, 2016**

The flight south was delayed by three hours but still managed to leave that day, so we got in Montreal at 9h30 PM.

## Second field campaign

**Monday April 18, 2016**

Yves Gauthier (Researcher), Pierre-Olivier Carreau (intern) and Sophie Dufour-Beauséjour (PhD student) left from Quebec (INRS) to Kangiqsujuaq. Véronique Gilbert (KRG) got on the plane in Kuujjuaq. Arrival in Kangiqsujuaq at around 16h15. We worked on creating the Facebook page for the project.

**Tuesday, April 19, 2016**

The weather is gorgeous. Maasiu Arngak is our guide for the day. He came with a Nunavik Park's snowmobile and also brought his own snowmobile. We therefore split the team in two. Véronique and Yves did the ice drilling/ice thickness measurements. Sophie, Pierre-Olivier and Massiu did the ice coring and GPR. During the morning, we were able to do about a third of the work.

At 13:30, Yves went to the school to join the science teachers and their students. The rest of the team went on the ice to continue the work. At 14:00, Yves, the 2 teachers and the 20 students walked from the school to the nearest sampling point (1 km), where the rest of the team met them. For one hour, we had the students participate in ice measurements. After they left, we resumed the work as in the morning. We came back at the hotel at 17:30. There are only a couple of sampling points that we didn't have time to visit. At the hotel, Sophie and Pierre-Olivier did the salinity analysis on the day's ice cores.

**Wednesday, April 20, 2016**

There was blowing snow in Kangiqsujuaq in the morning. Maasiu waited a bit to see how the weather evolved and decided we were good to go out. He left with Véronique, Pierre-Olivier and Sophie with one snowmobile at around 10h; Yves stayed at the Inn to work on the KRG/Raglan Mine final report. The team did took the ice cores/GPR measurements on two sampling points and did the ice drilling/thickness measurements on three other sites. Then they came back to the hotel around noon. After lunch, Sophie and Pierre-Olivier did the salinity analysis on the day's ice cores. One ice core was extracted for the science class. At 15:00, we went to the school to give it to Bentley Anderson, the science teacher.

The afternoon flight to Salluit was cancelled due to bad weather. We worked on the KRG/Raglan Mine report and on the Facebook page. Yves also discussed with one of the science teacher (Catherine Fouquet) in Salluit (where the school is closed) to manage this weather delay and try to reschedule the activity with the students on Friday morning. The school also has to deal with a delicate situation, which poses more challenges for the ice activity. In the end, the teachers decided that because of the situation, they could not participate to the ice activity. Therefore, Yves changed his plane tickets so that he wouldn't go to Salluit but rather take the flight back to Quebec City directly from Kangiqsujuaq on Friday morning. Then in the evening, the assistant director from the school in Salluit said that it could be a good thing to have the students go outside on Friday morning. We decided that if so, Véronique, Sophie and Pierre-Olivier would manage the activity without Yves.

**Thursday, April 21, 2016**

In the morning Véronique learned that Michael Cameron would be unavailable to help us in Salluit but that he would find us people to work with. Catherine Fouquet emailed Véronique and Sophie to tell them that the teachers were all eager and willing to go out on the ice with us on Friday if we had time and that there could be up to 60 students. In the afternoon the flight to Salluit was cancelled due to freezing rain on the landing strip. We definitely cancelled the activity with the students in Salluit. We decided it was best to focus on Deception Bay for the rest of the trip because it was now impossible to do the required work in both Salluit and Deception Bay. The plan became to leave for DB by snowmobile as soon as possible once we made it to Salluit. At 15:00, Yves, Sophie and Pierre-Olivier met Bentley, Jacob and their students in their classroom to work on the ice core. The students were interested and the teachers seemed to be happy with how things went. In the evening, we worked on the KRG/Raglan Mine report and on the Facebook page.

**Friday, April 22, 2016**

Yves left for the airport at 9h20 and the plane left around 11:00. The rest of the team prepared for the next leg of the trip. The plane for Salluit finally made it there at 18:30. The team prepared at the CEN's house and left by snowmobile with the Inuit guides (Johnny, Joanasie and Adamie) at 21:15. It took about 2 hours to reach Deception Bay. Everything went smoothly.

**Saturday, April 23, 2016**

No work was done in the morning because of a mechanical problem with a snowmobile. After dealing with this, the team left on the ice at 13h30. Again, the team was split in two. Johnny, Joanasie, Pierre-Olivier and Sophie took care of the ice coring/GPR measurements while Adamie and Véronique did the ice drilling/thickness measurements. Work was again delayed because the motor adapter of the ice corer was left in Kangiqsujuaq. After a solution was found, work resumed. All measurements were completed before the end of the day. Veronique also removed the sticks from the ice station so that there wouldn't be too much garbage when ice breaks up. One was kept so that Juupie can take measurements until breakup.

**Sunday, April 24 2016**

Everyone got up at around 8 AM. The ice core samples were photographed and melted in the morning. Their salinity was measured, but two samples were contaminated because the bags had teared a bit at the bottom. The guides came to eat lunch and take some gas for their snowmobiles. Veronique went up the hill to check if the camera is still in good shape, which was the case. Our ride (Myriam Ilgun from the mine security) arrived around 2h, we finish packing and left for Katinniq around 3h, arrived at 4h30.

Veronique met with Charles Levac, Martin Gagnon and Amélie Rouleau from the mine for another subject. Sophie and Pierre-Olivier brought back the EPI to the environment department and talk with Marc Gagné.

**Monday, April 25 2016**

Everyone was up at around 7h45 AM. Everyone worked in the public room until lunch. The flight south was officially canceled at 3h15 PM.

**Tuesday, April 26 2016**

Pierre-Olivier and Sophie left with the first flight at around 14:00. They were in Montreal at 17:00 and took the 18:00 PM bus to Québec. Veronique's flight has been canceled at 16h30.

**Wednesday, April 27 2016**

Veronique worked in Environment Department office until noon then left for Donaldson at 1h. The flight left around 14h30 and she arrived in Kuujjuaq around 18h30 (Figure 3).

**Figure 3 : Ice in Ungava Bay during return flight to Kuujjuaq.**

# 3 SNOW AND ICE THICKNESS STATIONS

## 3.1 Objective

Snow and ice thickness stations were described in the instrumentation plan for Deception Bay (Deliverable #2). The initial objective is to conduct non-intrusive snow and ice thickness measurements at the stations, on a regular basis.

## 3.2 Material

The material for the ice stations was prepared by KRG, based on the “Handbook for community-based sea ice monitoring” written by Andy Mahoney and Shari Gearheard from the National Snow and Ice Data Center of University of Colorado. A few modifications have been made to the original list of material proposed by the “Handbook”. This protocol is mainly based on the use of a “hot wire cable” to measure the ice thickness. After many trials to make it work, the “hot wire cable” has been modified and KRG decided to install only one experimental “hot wire” in Kangiqsujuaq. The main problem being that KRG didn’t have the ideal type of wire for the system to work properly. In addition, the use of the generator system connected to a current transformer has proved complex and expensive for the use in remote area. KRG decided to install the “hot wire” in Kangiqsujuaq because the ice station is not far from the village and because KRG employees will be in charge of the measurements. It was decided that the ice thickness measurements on each ice station will be taken with a regular ice fishing drill. This decision was made to facilitate the work done by the Inuit collaborators.

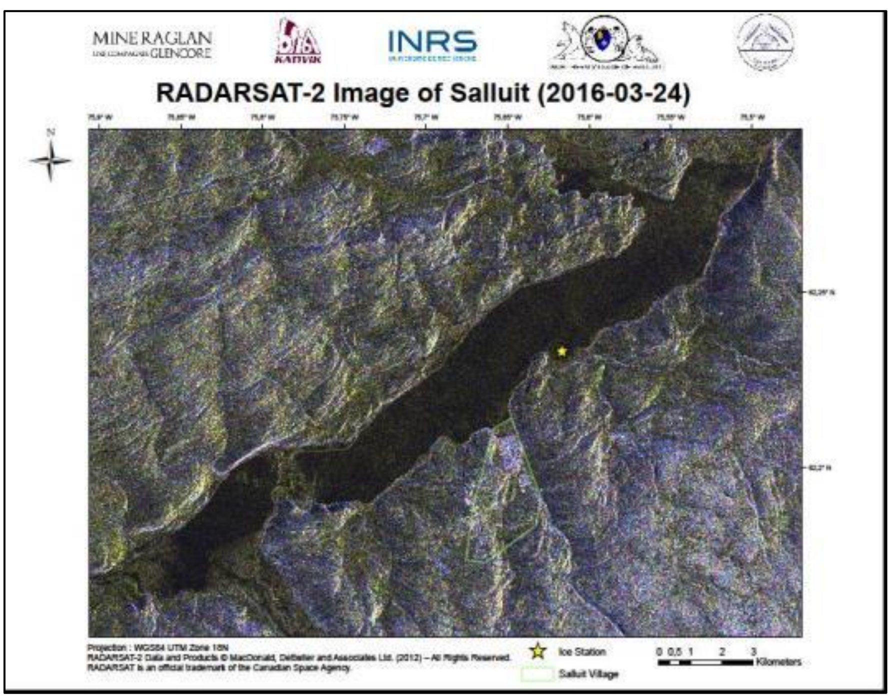
The list of material used for each ice station was:

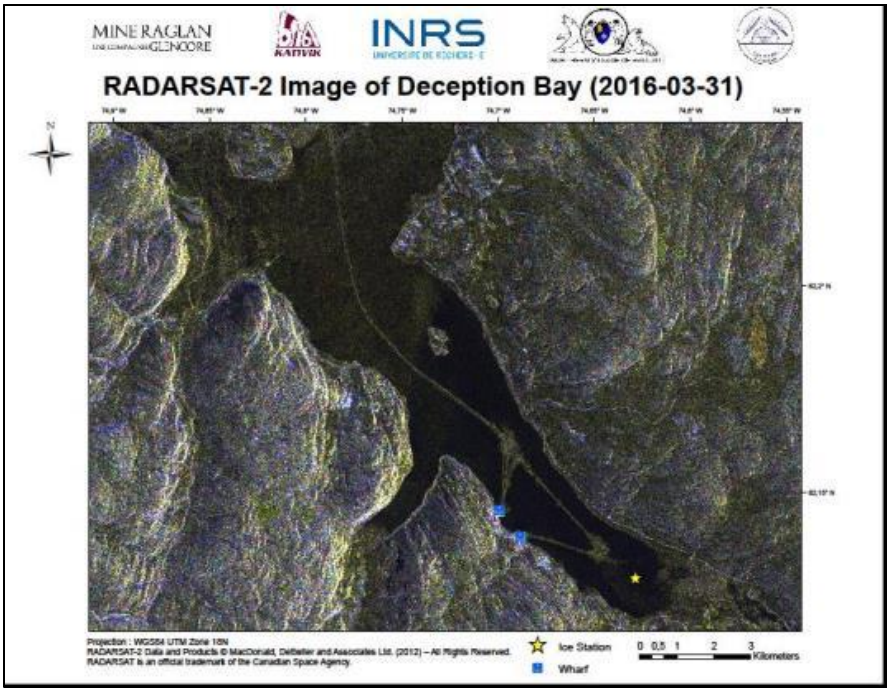
- 4 wooden posts, 2m long, painted in white and with an orange flag. To be installed in the 4 corners of the station to measure the ice thickness. In Kangiqsujuaq, 2 of these wooden posts have a “hotwire cable” on 2 opposite corners.
- 9 wooden posts (1,5 meter long), painted in white. To be installed in the center of the ice station to measure the snow accumulation (Figure 4).
- 1 wooden post painted in white, with a sign identifying the ice station.

The wooden posts were made by Raglan Mine carpenters and have been transported to Deception Bay by Raglan Mine employees.

Figure 4: Wooden posts for the ice station.

Then the wooden posts for Salluit and Kangiqsujuaq have been transported in Kangiqsujuaq by KRG and in Salluit by the Inuit guide. Final location for the installation of the ice stations was selected by the Inuit guides (Figure 5). The final installation in Kangiqsujuaq is shown in Figure 6.





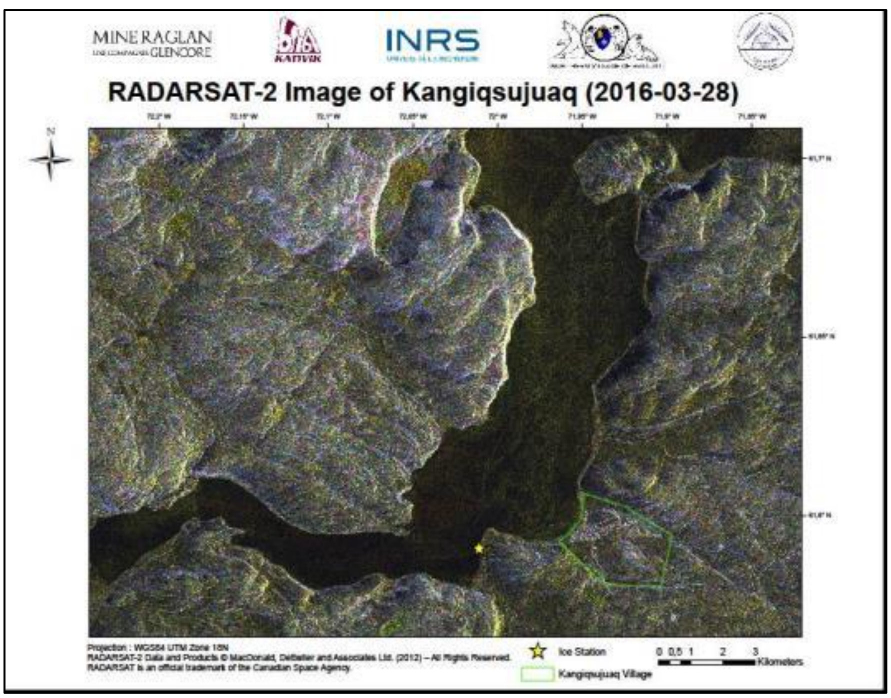




**Figure 5 : Location of the ice station at each site.**

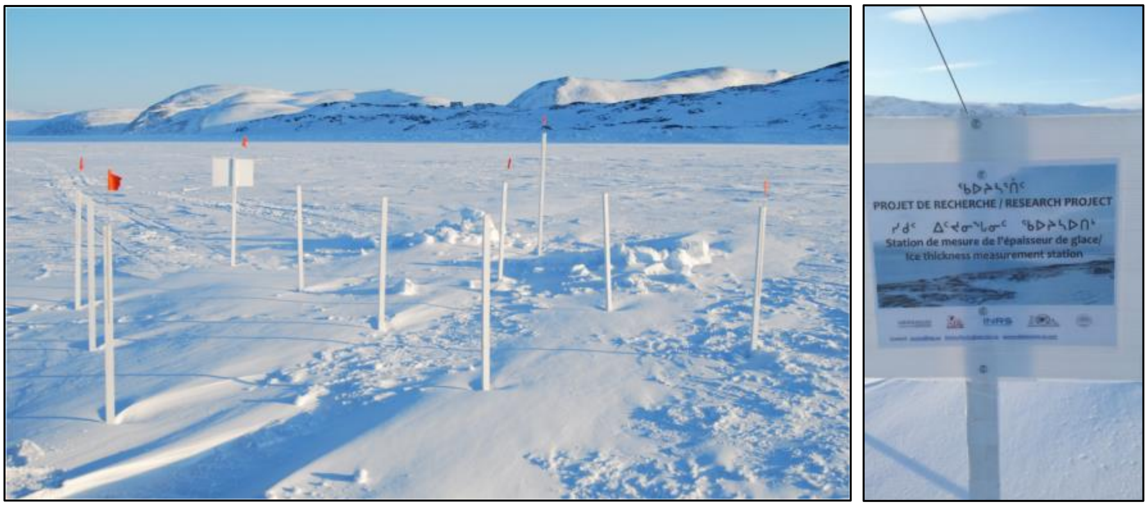
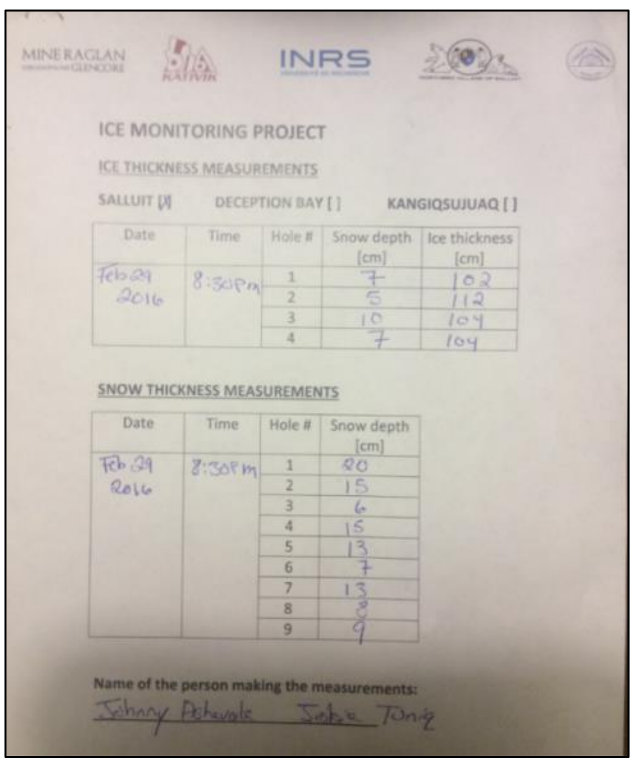



Figure 6 : Snow and ice thickness station on Wakeham Bay (Kangiqsujuaq).

## 3.3 Measurements

Inuit collaborators were mandated to conduct measurements at the snow and ice stations every two weeks or so. They would fill out, photograph and send the form shown in Figure 7.



MINE RAGLAN GLENCORE    INRS

ICE MONITORING PROJECT

ICE THICKNESS MEASUREMENTS

SALLUIT [X]    DECEPTION BAY [ ]    KANGIQSUJUAQ [ ]

| Date | Time | Hole # | Snow depth [cm] | Ice thickness [cm] |
|---|---|---|---|---|
| Feb 29 2016 | 8:30Pm | 1 | 7 | 102 |
| | | 2 | 5 | 112 |
| | | 3 | 10 | 104 |
| | | 4 | 7 | 104 |

SNOW THICKNESS MEASUREMENTS

| Date | Time | Hole # | Snow depth [cm] |
|---|---|---|---|
| Feb 29 2016 | 8:30Pm | 1 | 20 |
| | | 2 | 15 |
| | | 3 | 6 |
| | | 4 | 15 |
| | | 5 | 13 |
| | | 6 | 7 |
| | | 7 | 13 |
| | | 8 | 8 |
| | | 9 | 9 |

Name of the person making the measurements:
Johnny Pilurak    Sinbia Tuniq

Figure 7 : Form used to enter ice thickness measurements.

Because of some logistical and material problems, only a few measurements were made this year. But this would help to better plan for next year. Complete data are presented in Annex 1. Table 1 shows the range of snow and ice thicknesses as measured by the Inuit collaborators between the 2 field campaigns.

**Table 1 : Average values from the measurements taken by Inuit collaborators at ice stations between the 2 field campaigns**

| Site | Total range of snow depth | Total range of ice thickness |
|---|---|---|
| Kangiqsujuaq<br>March 14th, 2016 | 38-61 cm | 83-86 cm |
| Deception Bay<br>February 12th, 2016<br>February 26th, 2016<br>March 18th, 2016 | 3-17 cm | 118-142 cm |
| Salluit<br>February 5th, 2016 | 7-20 cm | 81-95 cm |

# 4 FIELD WORK

## 4.1 Objective

Field campaigns are conducted to collect data on the characteristics of the ice cover (ice vertical structure, ice thickness, ice salinity profile). Field campaigns were conducted from January 20th to 26th and from April 18th to 25th (Table 2).

**Table 2 : Field campaigns schedule**

| Field campaign #1 | Field campaign #2 | Site |
|---|---|---|
| Jan. 20-22, 2016 | April 23-25, 2016 | Deception Bay |
| Jan 23-24, 2016 | April 18-20, 2016 | Kangiqsujuaq |
| Jan 25-26, 2016 | April 21-22, 2016<br>(cancelled) | Salluit |

## 4.2 Protocols

The sampling patterns for the January field campaign was partially planned prior to the field work, based on RADARSAT-2 images of late December 2015. It was then adjusted with local conditions and recommendations from the local guide. Based on this experience, the sampling patterns for the April campaign were planned more extensively prior to the field work. All sampling points were located in the GPS in a grid pattern (Figure 8).

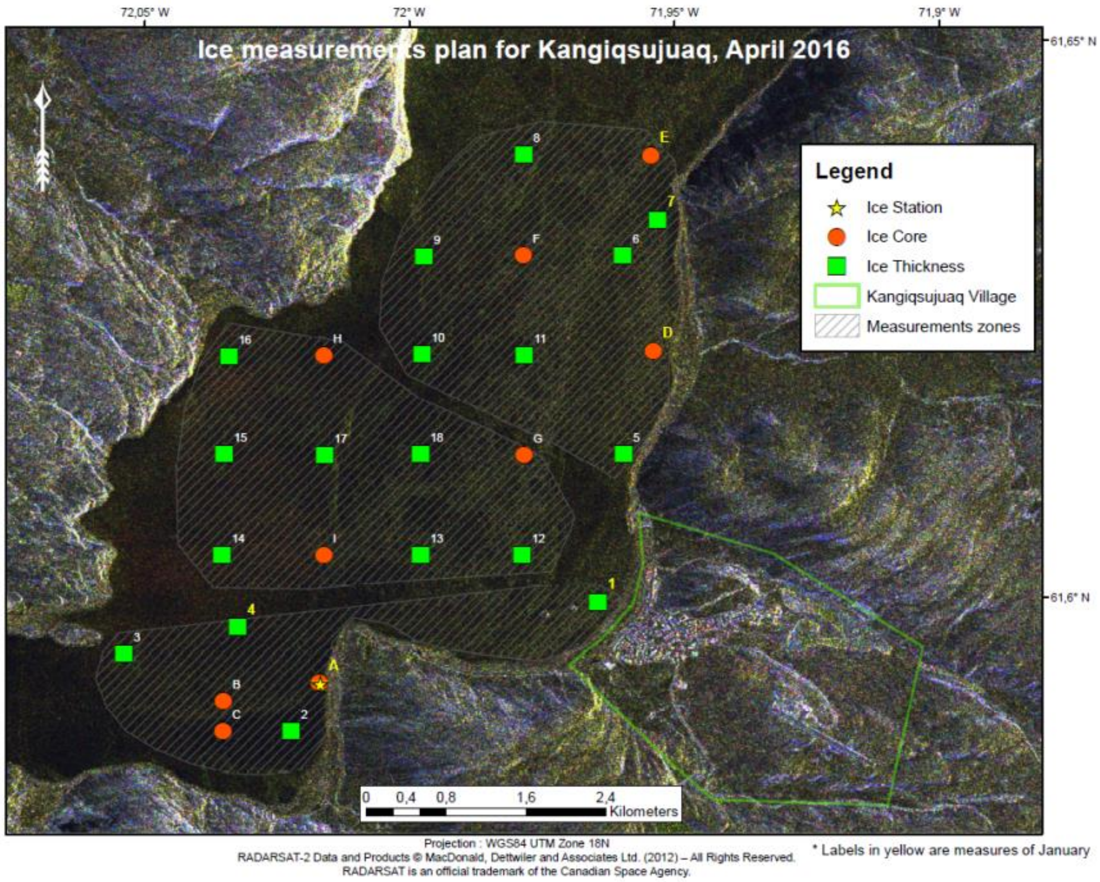



**Figure 8 : Sampling pattern for the Kangiqsujuaq measurements.**

<u>Drilling</u>

Ice thicknesses are measured using ice augers. Two types were used (Table 3; Figure 9).

**Table 3 : Equipment used for ice drilling**

| Model | Diameter | Power |
|---|---|---|
| Kovacs | 5 cm | Electric |
| Jiffy | 20 cm | Gas |

The Kovacs auger is easier to use and less disruptive of the ice cover. The larger auger makes larger holes which flood the ice surface.

Figure 9 : Drilling with the Kovacs auger (left) and Jiffy auger (right)

Ice coring

Ice vertical structure is identified from an ice core. A Kovacs Mark III ice corer was used. Note that with this instrument, some gas motors rotate in the wrong direction. You have to use a clockwise motor. Extracted ice cores were laid on a dark sheet to be examined and photographed. Samples (5 cm thick) were cut at different depth and bagged for further analysis (Figure 10).

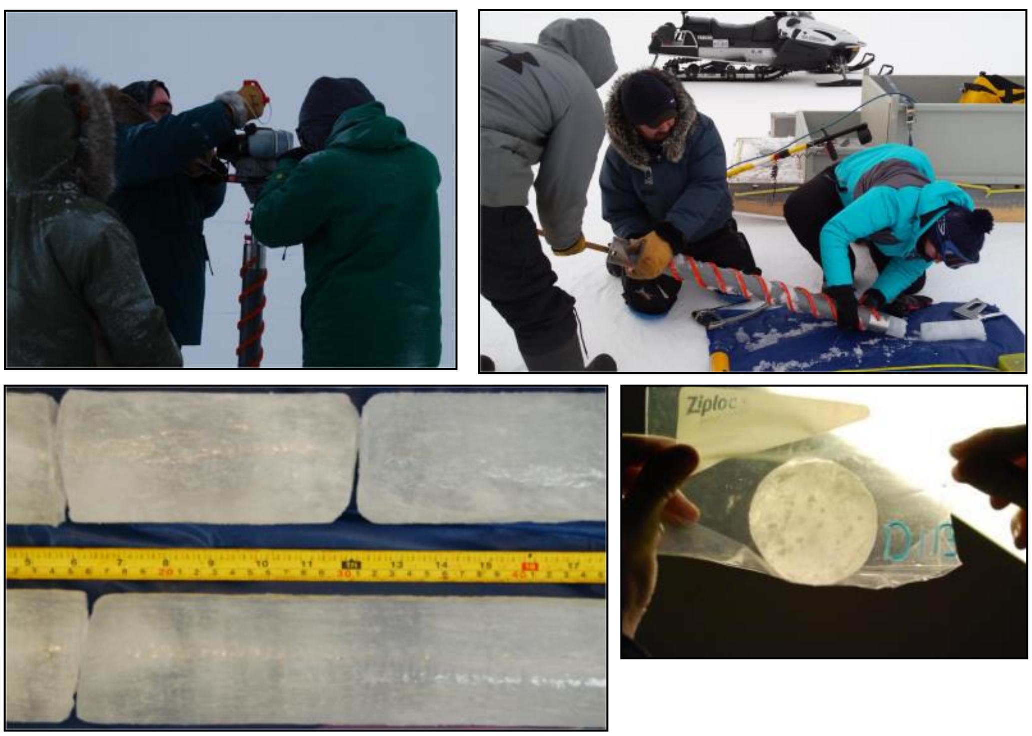


Figure 10 : Extracting ice cores

The samples were later melted and salinity was measured across the profile using a Hanna sea water refractometer. First, the lens of the sensor is cleaned and calibrated to zero. Then, drops of the melted ice sample are put on the sensor with a clean pipette. After measure of salinity is confirmed, pipette is cleaned and the lens is cleaned before the next measurement. For each ice sample, three measurements are conducted as described.

Figure 11 : Using the sea water refractometer to measure ice salinity.

Ground Penetrating Radar (GPR)

GPR measurements were conducted in order to measure ice thickness across longer sections of the ice cover. Antennas with 400 and 900 MHz frequencies were used. The instrument can be carried behind a snowmobile or by foot (Figure 12). This technology has proven useful for freshwater ice but is still uncertain for sea ice because of the salt content. Therefore, these measurements are exploratory. The parameters setting id presented in Table 4.

Table 4 : Parameters to be used with the GPR for ice thickness measurements

| |
|---|
| • Collect |
| ○ Radar |
| ▪ Antenna (select either 400 or 900 MHz) |
| ▪ T_rate (leave at 100 kHz) |
| ▪ Mode (select time) |
| ▪ GPS (toggle GPS on) |
| ○ Scan |
| ▪ Samples (select 1024 samples/scan) |
| ▪ Format (select 16 bits) |
| ▪ Range (25 ns = 2m, 50 ns = 4m, 100 ns = 8m adjust for optimal res) |

| |
|---|
| ▪ Diel (start with 3.5, changes with ground truth) |
| ▪ Rate (select 64 scans/sec, means separated by more than 0.01 s. Could be lowered to be able to do longer transects without stopping.) |
| ▪ Scn/ Unit (N/A, leave at 18) |
| o Gain |
| ▪ Auto (toggle auto over a representative area) |
| ▪ Points (N/A when auto) |
| ▪ GP1 (N/A when auto) |
| ▪ GP2 (N/A when auto) |
| ▪ … |
| o Position |
| ▪ Auto (toggle auto over a representative area) |
| ▪ Offset (leave at 25 ns unless direct coupling not displayed; in that case, reduce) |
| ▪ Surface (automatically set from other position parameters; cuts out the top) |
| o Filters |
| ▪ LP_IIR (leave at 800) (currently 1000) |
| ▪ HP_IIR (leave at 100) (currently 125) |
| ▪ LP_FIR (leave at 0) |
| ▪ HP_FIR (leave at 0) |
| ▪ Stacking (select 0) |
| ▪ BGR_RMVL (select 0) |
| • Playback |
| • Output |
| • System |
| o Units (select metric) |
| o Setup |
| o Path (change for every site) |
| o Backlight (make as low as possible to save battery) |
| o Date/time |
| o Battery |
| o Version |

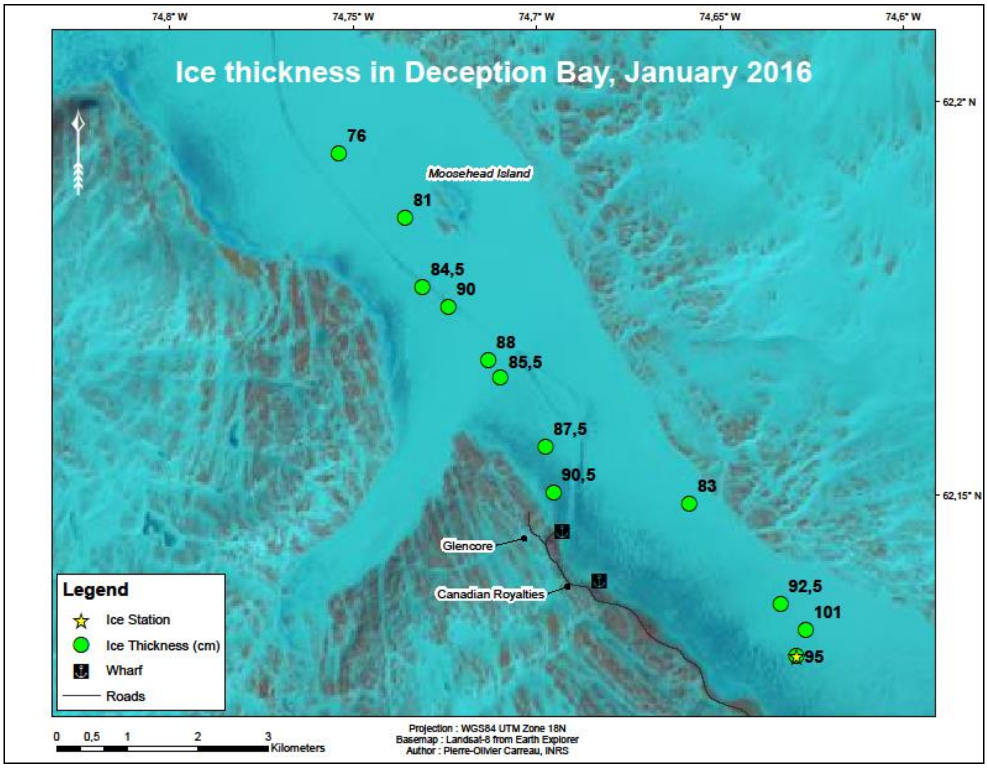
Figure 12 : During a GPR measurement.

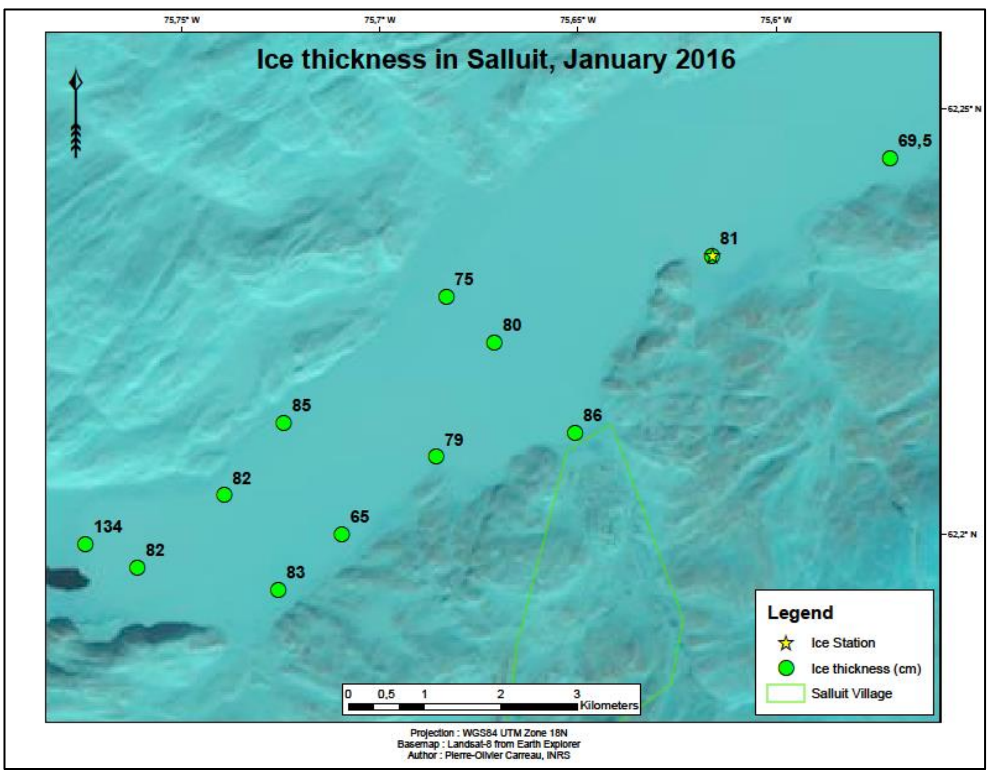
## 4.3 Measurements

Ice thickness

Figure 13 shows the ice thickness measurements for Kangiqsujuaq, Salluit and Deception Bay in January 2016, compiled from the ice drilling and ice cores. In Kangiqsujuaq, the average thickness was 70 cm. It was 82 cm in Salluit and 88 cm in Deception Bay. Figure 14 shows the ice thickness measurements for Kangiqsujuaq and Deception Bay in April, compiled from the ice drilling and ice cores. In Kangiqsujuaq, the average thickness was 118 cm and in Deception Bay, it was 138 cm. No measurements could be made in Salluit where the blizzard there stopped all flights from coming or going for two days.

Between the two field campaigns (86 days), the average ice thickness in Kangiqsujuaq increased from about 48 cm. This would correspond to a growth of 0.6 cm/day. In Deception Bay (91 days), it grew by 50 cm for a growth rate of also 0.6 cm/day. A complete summary of the measurements is presented in Annex 2. Figure 15 shows the evolution of the ice thickness at the Deception Bay ice station from measurements taken during the field campaigns and between.


74,8° W
74,75° W
74,7° W
74,65° W
74,6° W
62,2° N
62,15° N
Ice thickness in Deception Bay, January 2016
76
Moosehead Island
81
84,5
90
88
85,5
87,5
90,5
83
Glencore
Canadian Royalties
92,5
101
95
Legend
Ice Station
Ice Thickness (cm)
Wharf
Roads
0 0,5 1 2 3 Kilometers
Projection : WGS84 UTM Zone 18N
Basemap : Landsat-8 from Earth Explorer
Author : Pierre-Olivier Carreau, INRS


75,75° W
75,7° W
75,65° W
75,6° W
62,25° N
62,2° N
Ice thickness in Salluit, January 2016
69,5
81
75
80
85
86
79
82
134
82
65
83
Legend
Ice Station
Ice thickness (cm)
Salluit Village
0 0,5 1 2 3 Kilometers
Projection : WGS84 UTM Zone 18N
Basemap : Landsat-8 from Earth Explorer
Author : Pierre-Olivier Carreau, INRS

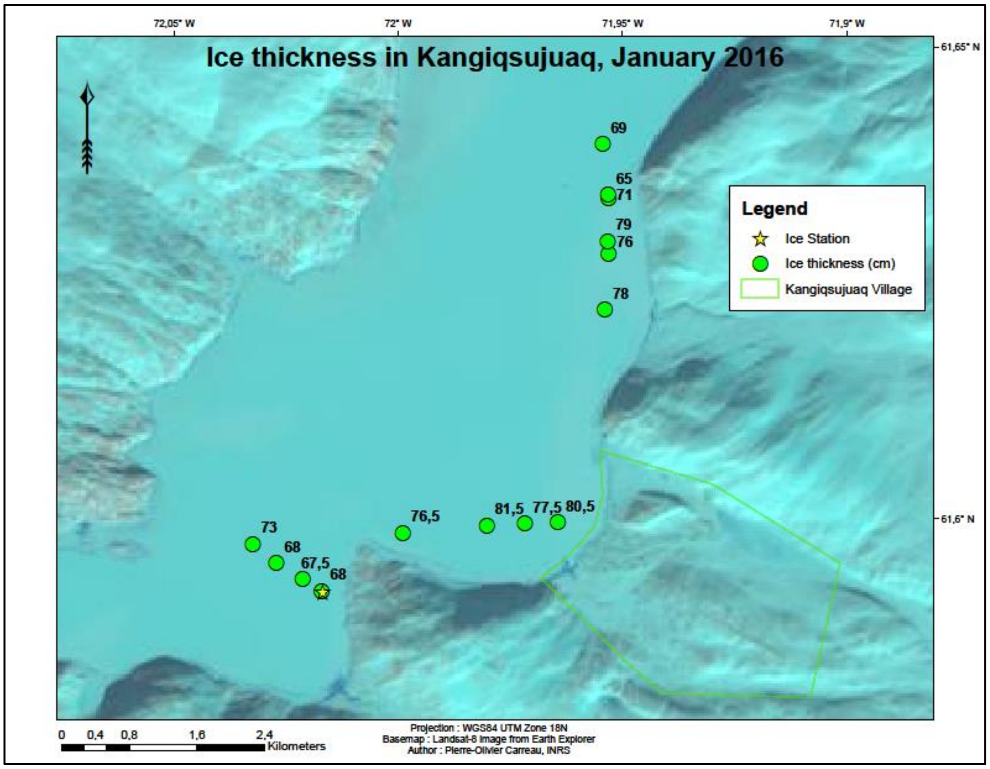
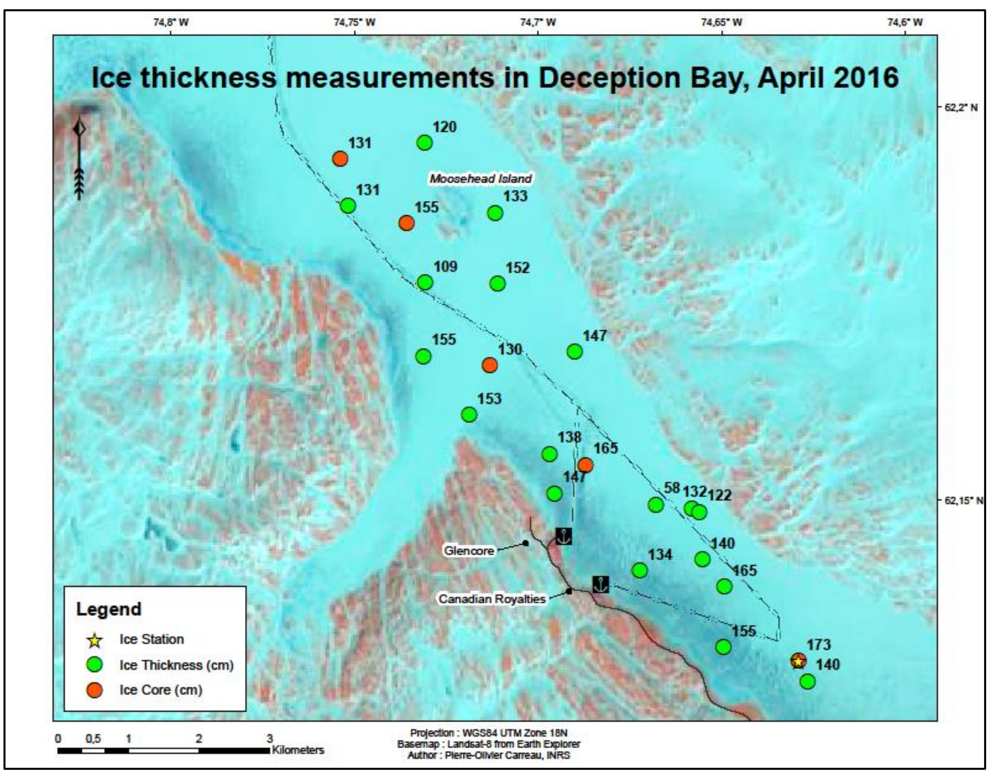



**Figure 13 : Ice thickness measurements over the three sites in January 2016.**



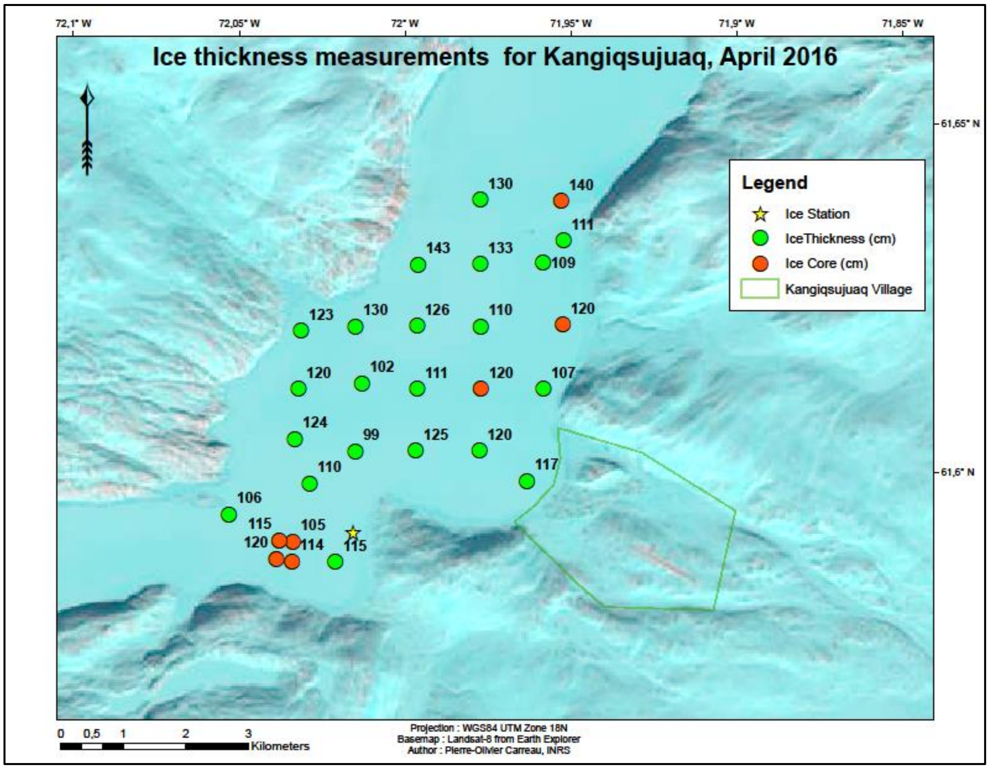



Figure 14 : Ice thickness measurements over the three sites in April 2016.

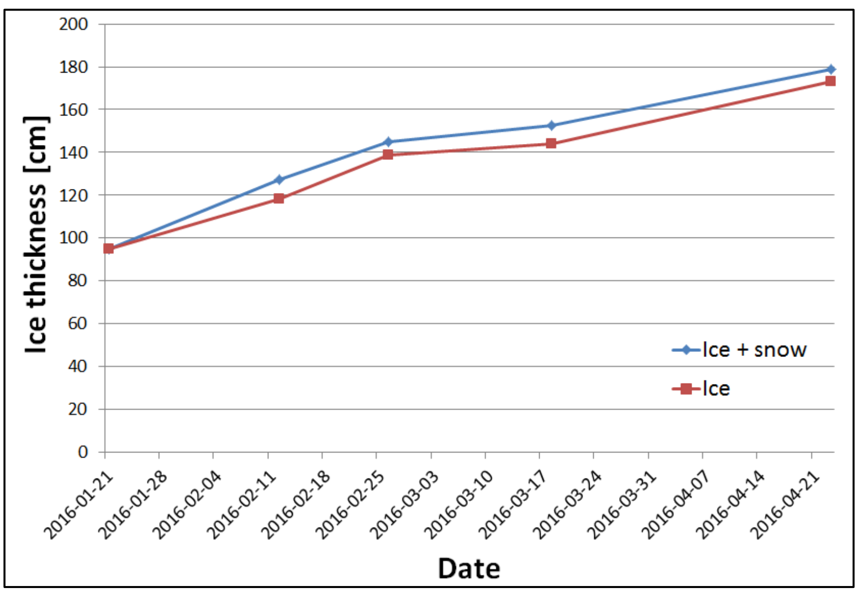



Figure 15 : Ice cover growth at the ice station in Deception Bay

Ice structure and salinity

The graphs in Figure 16 show the ice salinity as a function of ice depth at sampling site K2 in Kangiqsujuaq in January and April 2016. The salinity is measured in parts per thousand. The salinity of sea water is 35 ppt and first year sea ice typically has a salinity ranging from 3 to 12 ppt, with 6 ppt on average. Our measurements fall within this range, with values going from 4 to 8 ppt.

At site K2, the ice was 76 cm thick in January and 140 cm thick in April. The average salinity of the ice in January decreased vertically from approximately 7 to 4 ppt. The complete ice core is on the right of the salinity graph. We can see that the color and transparency of the ice changes with depth. In some places the ice is milky and whitish, and in other it is almost transparent. Also shown are pictures of the ice core sections before they were melted to measure their salinity. We can see many small air and salt water bubbles in the ice where it is milky. In the sections taken from the transparent parts of the ice core, we can sometimes see cross shapes that stand out from the transparent part of the section. These are drainage channels that run vertically in the ice. The salt water drains out of the ice through these channels and into the water underneath the ice.

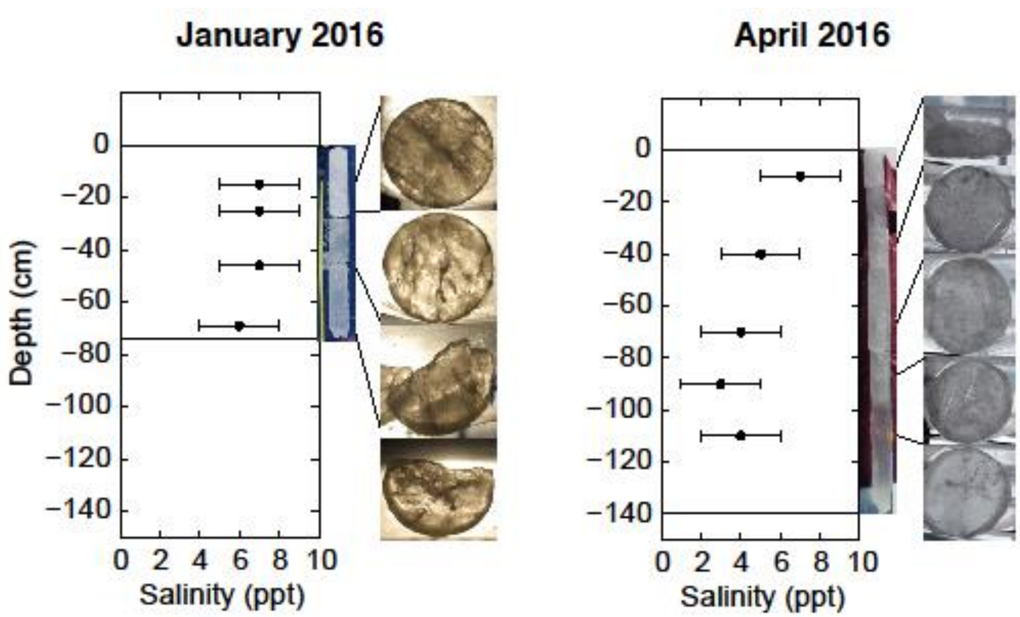



**Figure 16 : Salinity profile of an ice core from the K2 sampling site (Kangiqsujuaq) in January and April 2016. The pictures show the ice core and the samples from which the salinity was calculated.**

It's hard to identify clearcut transitions in ice type as a function of depth, even though we can see that the ice changes color. In lake or river ice cores, it is easier to identify frazil ice that has large air bubbles and thermal ice that is transparent. In sea ice however, the thermal ice is always a bit white because of the salt, which makes it harder to separate from episodes of frazil ice.

## 4.4 Youth involvement

Activity on the ice and in the classroom

An activity on the ice was planned with the science classes from the high schools of Kangiqsujuaq and Salluit in April 2016. This is in link with the AVATIVUT program (Ice Mission), which is implemented in the science and technology curriculum by the Kativik School Board (Figure 17).


**Figure 17 : Ice Mission student's booklet, prepared by INRS and KSB.**

Although the students do not have the Ice Mission on the program this school year, we took the opportunity to involve the students with the "Ice monitoring in Deception Bay" project. The short presentation produced for introducing the activity to the students is presented in Annex 3. The activity was held with the secondary level students of the Arsaniq School in Kangiqsujuaq on April 19th. 25 students and two teachers came on the ice for an hour and a half (two periods). Once there, the group was split in two. One group proceeded with drilling and ice thickness measurements while the other group extracted an ice core, measured it and bagged it. Then the groups were switched. Then on April 21st, we joined the students in their classroom where they examined the ice structure, cut samples of the ice core and measured their salinity (Figure 19;Figure 20).

**Figure 18 : Students from the Arsaniq School in Kangiqsujuaq participating in ice measurements.**

**Figure 19 : Cutting samples from an ice core and measuring ice salinity in the classroom.**

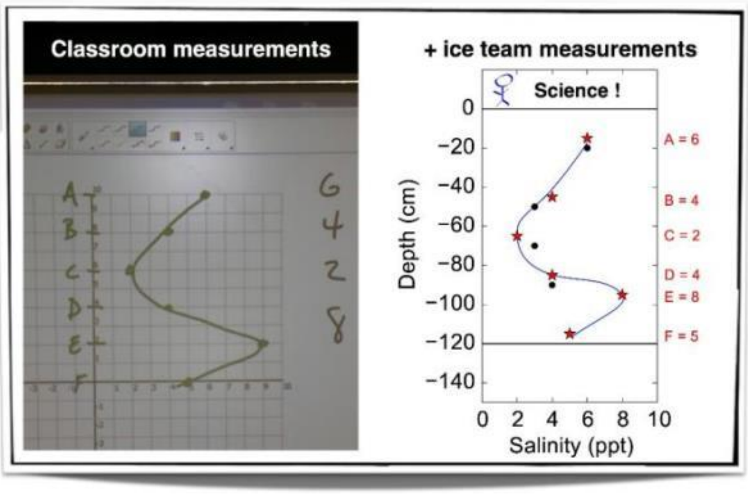



**Figure 20 : Salinity profile from the experiment with the students. A to F are samples from top to bottom of the ice core.**

The activity in Salluit was supposed to be held on April 21st. 50 students and 3 teachers were preparing for the activity. However, due to the prolonged blizzard, we could not leave for Salluit until late Friday the 22nd. The activity was cancelled.

## Facebook page

To transfer information about the research project to the communities and particularly to the students we set up a Facebook page. It is called «Ice Monitoring in Salluit Fjord, Deception Bay and Wakeham Bay» and the content is accessible whether you have a Facebook account or not: https://www.facebook.com/IceMonitoringNunavik/. The page was launched during the April 2016 field campaign. As of now there is a photo album of fieldwork pictures in Kangiqsujuaq with some explanations the techniques that are used, how the equipment works, what the results mean, etc. Figure 21 shows screenshots of the page and the Kangiqsujuaq - April 2016 album. People with questions or comments related to the project can communicate with us through this page either by commenting on the pictures, commenting on the page itself or writing to it privately. It is updated several times a week with new content; when we aren't in Nunavik doing fieldwork, we will still update it with satellite images, some data as it is analyzed, and other things linked to the project that might interest people in the communities.

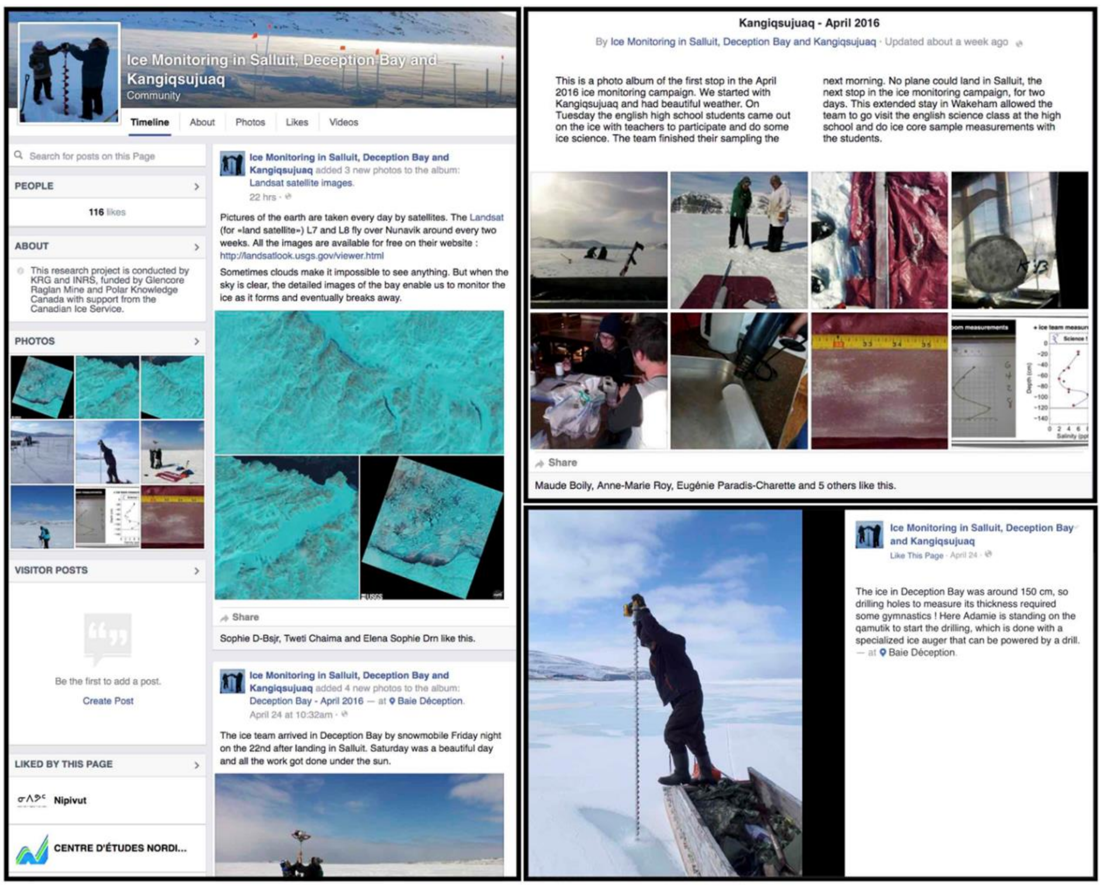



Figure 21: Facebook page for the ice monitoring project

# 5 SATELLITE IMAGERY

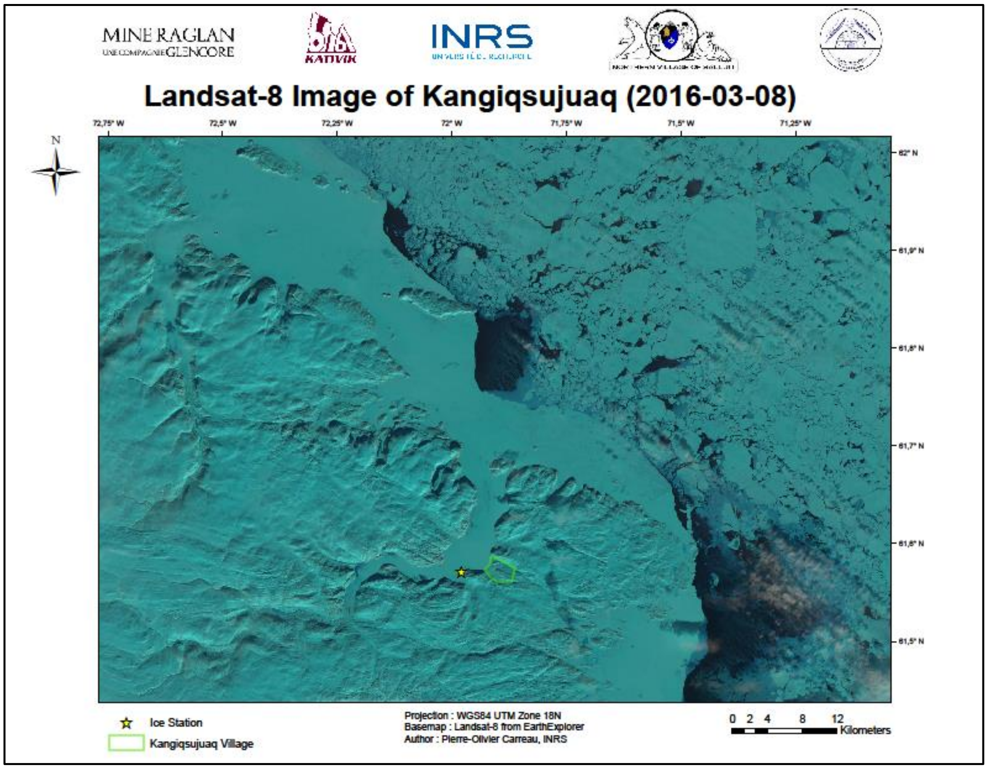
## 5.1 Optical images

The satellite image acquisition plan (deliverable #2) considered two sources for optical data. MODIS images (250m resolution, daily coverage) and Landsat-8 images (25m resolution, bimonthly coverage). Presently, only Landsat-8 images have been retrieved for this project (Table 5).

**Table 5 : List of cloud-free Landsat-8 images over the study sites for the October 2015-April 2016 period.**

| Deception Bay | | Kangiqsujuaq | | Salluit | |
|---|---|---|---|---|---|
| **Name** | **Date** | **Name** | **Date** | **Name** | **Date** |
| LC80210162016018LGN00 | 2016-01-18 | LC80180172015298LGN00 | 2015-10-25 | LC80220162015294LGN00 | 2015-10-21 |
| LC80200162016027LGN00 | 2016-01-27 | LC80180172015314LGN00 | 2015-11-10 | LC80220162015310LGN00 | 2015-11-06 |
| LC80210162016034LGN00 | 2016-02-03 | LC80190172015321LGN00 | 2015-11-17 | LC80220162015326LGN00 | 2015-11-22 |
| LC80200172016043LGN00 | 2016-02-12 | LC80190172015337LGN00 | 2015-12-03 | LC80210172015335LGN00 | 2015-12-01 |
| LC80210162016050LGN00 | 2016-02-19 | LC80190172016004LGN00 | 2016-01-04 | LC80210172016018LGN00 | 2016-01-18 |
| LC80210162016082LGN00 | 2016-03-22 | LC80190172016020LGN00 | 2016-01-20 | LC80210162016050LGN00 | 2016-02-19 |
| LC80200172016091LGN00 | 2016-03-31 | LC80180172016029LGN00 | 2016-01-29 | LC80220162016057LGN00 | 2016-02-26 |
| | | LC80190172016036LGN00 | 2016-02-05 | LC80220162016073LGN00 | 2016-03-13 |
| | | LC80190172016052LGN00 | 2016-02-21 | LC80220162016089LGN00 | 2016-03-29 |
| | | LC80180172016061LGN00 | 2016-03-01 | LC80210162016098LGN00 | 2016-04-07 |
| | | LC80190172016068LGN00 | 2016-03-08 | | |

These images, in combination with the other sources of satellite images, will help to establish freeze-up and breakup dates and to document general ice processes. Some examples of Landsat-8 images are presented in Figure 22, Figure 23, and Figure 24. Snow and ice are in light blue while open water appears in black.



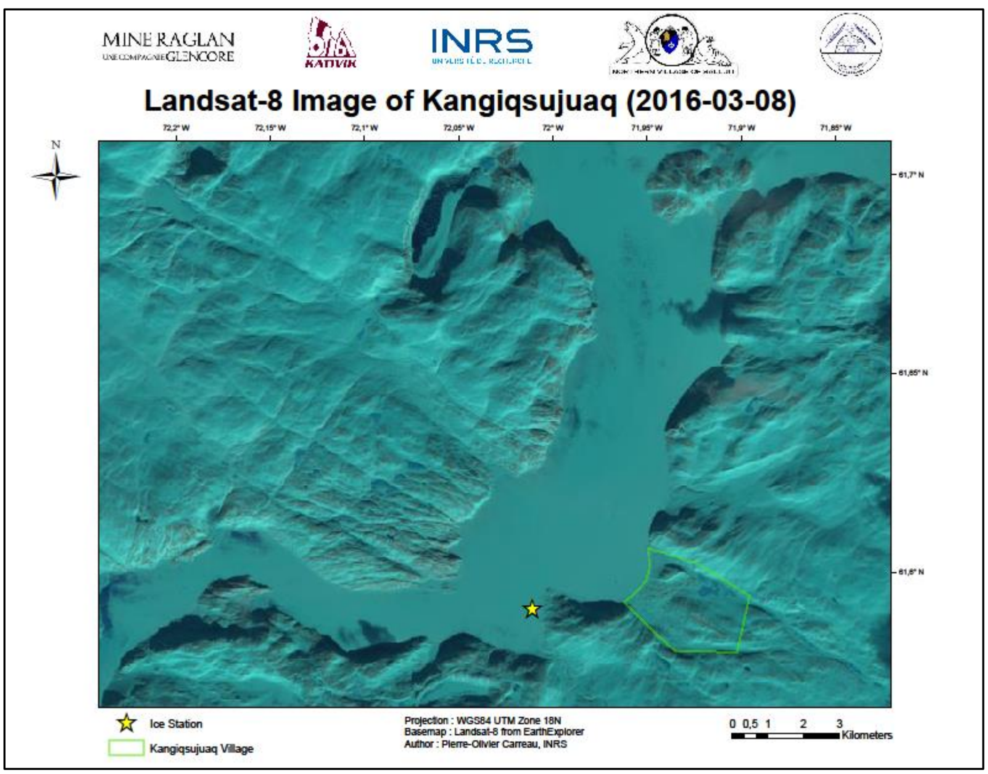
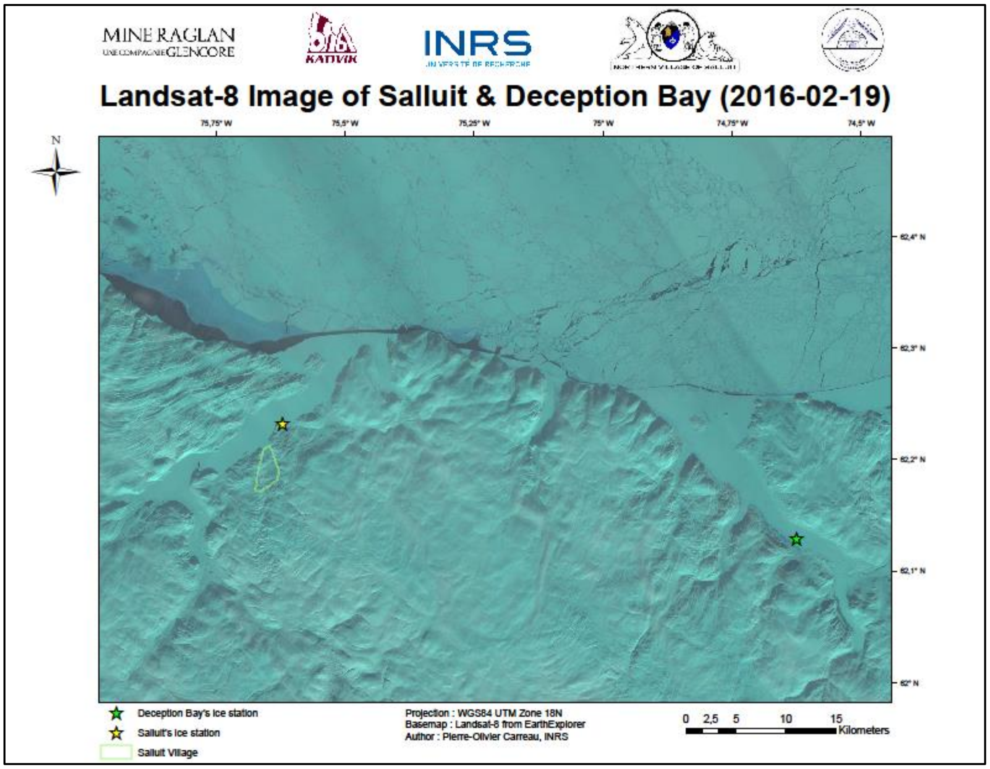




**Figure 22 : Example of a Landsat-8 image covering Wakeham Bay, with a zoom over Kangiqsujuaq.**



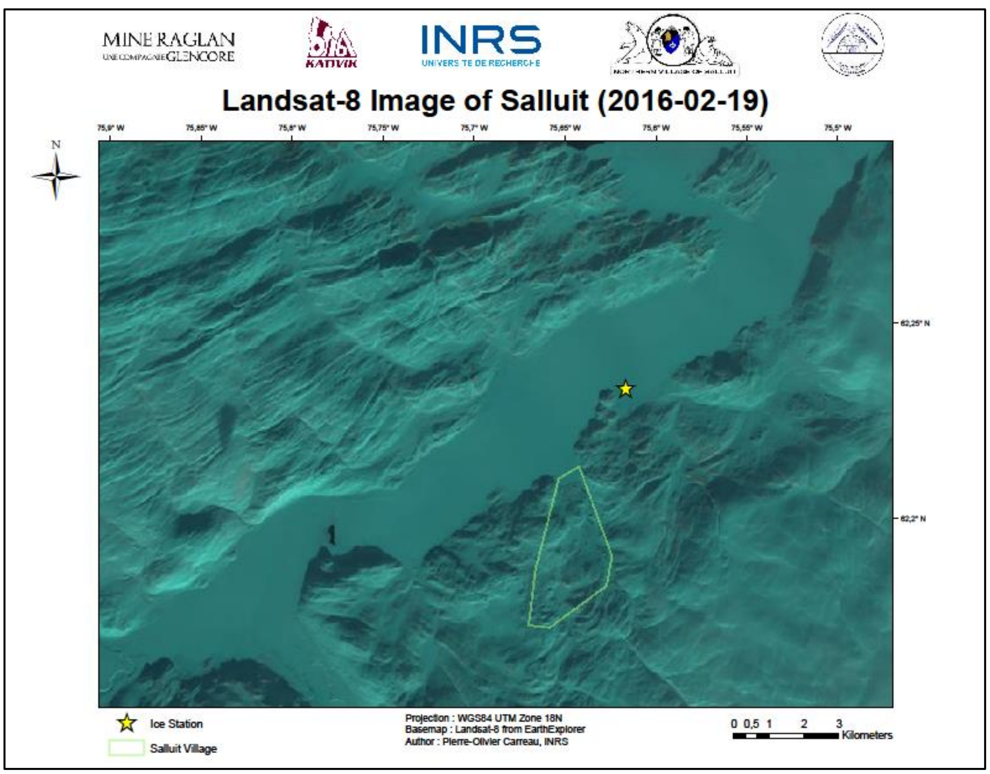




**Figure 23 : Example of a Landsat-8 image covering Salluit Fjord and Deception Bay, with a zoom over Salluit.**

## 5.2 Radar images

An agreement has been signed between INRS and the Canadian Ice Service (CIS) for the sharing of Radarsat images for this ice monitoring project. This agreement entitles INRS to use archived images of both Radarsat-1 and Radarsat-2 satellites to help document ice processes over Salluit, Deception Bay and Kangiqsujuaq. This part of the work hasn't started yet. Furthermore, the agreement also includes new acquisitions of Radarsat-2 images over the three study sites. In such cases, CIS agrees to work around potential acquisition conflicts. For the 2015-2016 winter, 17 images were acquired (Table 6). Only 1 couldn't be deconflicted (March 7$^{th}$).

**Table 6 : List of RADARSAT-2 images planned and acquired.**

| Site | Date of acquisition + GMT time | Orbit | Mode | Polarisations | | Status |
|---|---|---|---|---|---|---|
| Salluit | 2015-Dec-19 11:29:49.150 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2015-Dec-23 11:13:12.184 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2015-Dec-26 11:25:38.676 | DES | FQ16W | H+V | H+V | Received |
| Salluit | 2016-Jan-12 11:29:49.139 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2016-Jan-16 11:13:12.133 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2016-Jan-19 11:25:38.709 | DES | FQ16W | H+V | H+V | Received |
| Salluit | 2016-Feb-05 11:29:49.069 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2016-Feb-09 11:13:12.102 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2016-Feb-12 11:25:38.717 | DES | FQ16W | H+V | H+V | Received |
| Salluit | 2016-Feb-29 11:29:49.118 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2016-Mar-04 11:13:12.202 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2016-Mar-07 11:25:38.767 | DES | FQ16W | H+V | H+V | **Cancelled** |
| Salluit | 2016-Mar-24 11:29:49.091 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2016-Mar-28 11:13:12.187 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2016-Mar-31 11:25:38.847 | DES | FQ16W | H+V | H+V | Received |
| Salluit | 2016-Apr-17 11:29:49.122 | DES | FQ16W | H+V | H+V | Received |
| Kangiqsujuaq | 2016-Apr-21 11:13:12.188 | DES | FQ17W | H+V | H+V | Received |
| Deception Bay | 2016-Apr-24 11:25:38.828 | DES | FQ16W | H+V | H+V | Received |

An example of an enhanced Radarsat-2 image over Deception Bay is shown in Figure 24. The darker background is the smooth sea ice cover. The ships track (rough ice) can be seen as a bright linear feature across the Bay. The ice cover of the Bay presents a smooth dark green pattern in the southern part and a lighter pink pattern north of Moosehead Island. This will be investigated further and could be related to ice salinity.

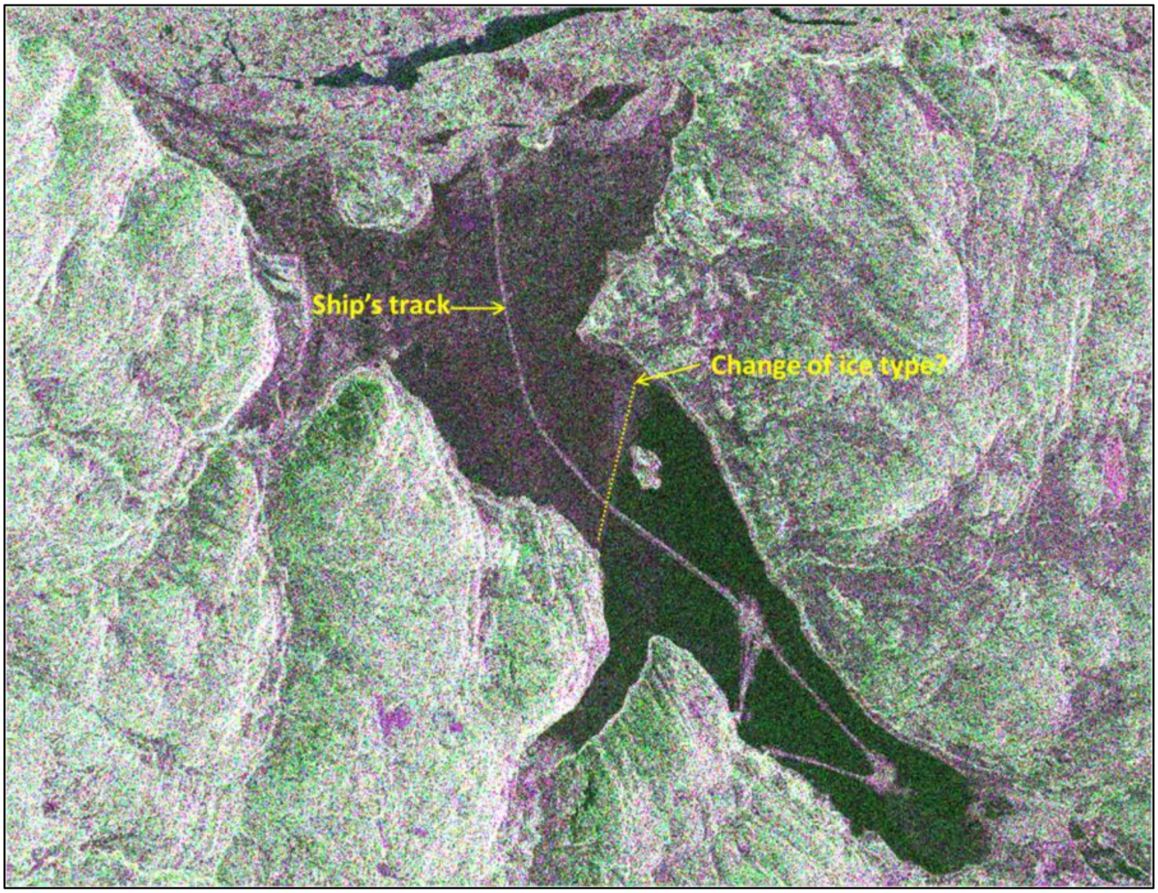



**Figure 24 : Extract of a Radarsat-2 image acquired over Deception Bay on March 31, 2016.**

*RADARSAT-2 Data and Products © MacDonald, Dettwiler and Associates Ltd. (2012) – All Rights Reserved. RADARSAT is an official trademark of the Canadian Space Agency.*

For now, the new images have only been used to help plan the field campaigns. For example, ice cores have been extracted from both the pink and the green areas in Deception Bay. Furthermore, the radar images will be at the core of a PhD study trying to link radar polarimetric data to sea ice thickness. This work will be pursued at INRS by Ms. Sophie Dufour-Beauséjour, under the supervision of Dr Monique Bernier (2015-2018).

# 6 TIME-LAPSE PHOTOS

The network camera installed near the telecom tower at the Deception Bay facilities (Deliverable No.3) has been taking photos of the bay every hour since September 14th 2015 (more than 10 000 photos). It pans the bay with four photos, 15 minutes apart, from south to north. The camera settings for photo capture and transfer have been changed during the season, explaining some differences in the field of view between certain dates. The wind can also affect the framing of the photo. From these photos, we could determine the freeze-up date to November 11, 2015 (Figure 25). On April 23rd, the team was on the ice to perform ice measurements. Their presence can be seen on Figure 26.

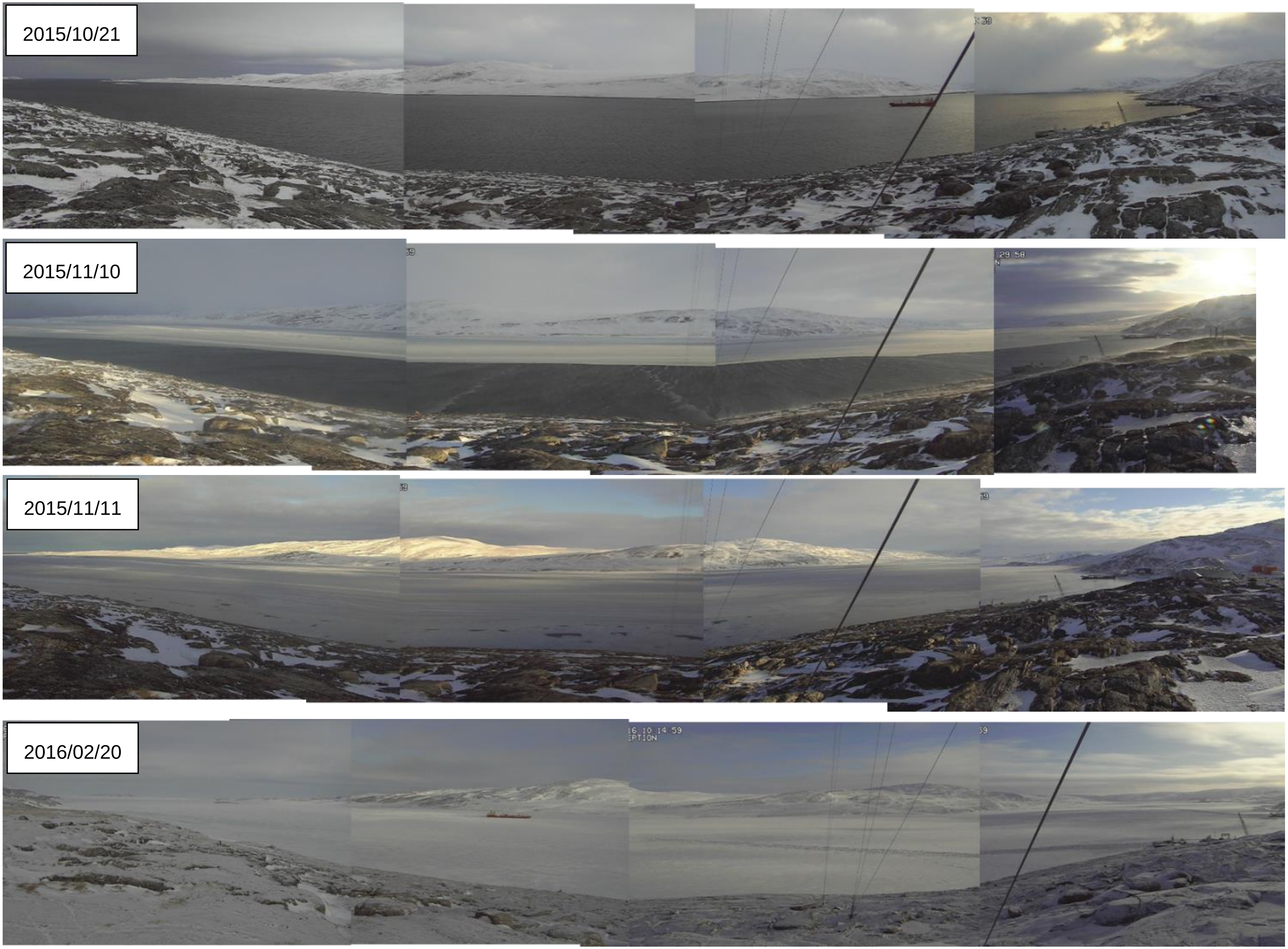



Figure 25 : Examples of the panoramic view of Deception Bay during freeze-up.

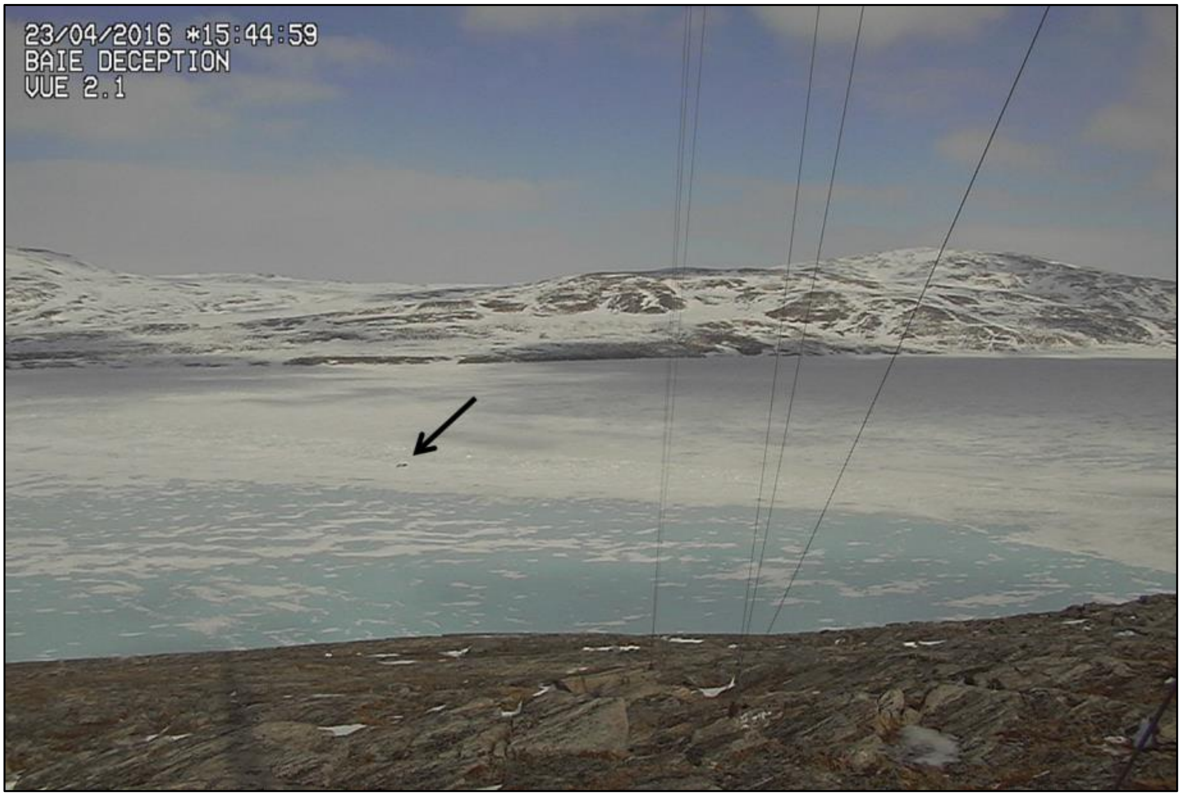




**Figure 26 : Presence of the field team detected by the real time camera (top) on April 23rd, 2016. The position is confirmed by the inReach tracking.**

# 7 REFERENCES

Deliverable No.1: ICE MONITORING OF DECEPTION BAY - Reconnaissance visit to Deception Bay and to the Communities of Salluit and Kangiqsujuaq. INRS, July 15th, 2015.

Deliverable No.2: ICE MONITORING OF DECEPTION BAY - Site Characterization and instrumentation plan. INRS, September 30th, 2015.

Deliverable No.3: ICE MONITORING OF DECEPTION BAY - Instrumentation of Deception Bay. INRS, October 31rst, 2015.

Mahoney, A. and S. Gearheard, 2008. Handbook for community-based sea ice monitoring. Special Report #14, National Snow and Ice Data Center, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA, 30 June, 2008.
https://nsidc.org/pubs/documents/special/nsidc_special_report_14.pdf

# ANNEX 1

Data recovered from the data sheets of Inuit collaborators at the ice stations.

## Deception Bay

| Ice thickness measurements | | Hole # 1 | | Hole #2 | | Hole #3 | | Hole #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness | |
| 2016-02-12 | 16:00 | 5 | 118 | 7 | 120 | 5 | 118 | 12 | 118 | |
| 2016-02-26 | 09:00 | 5 | 142 | 5 | 140 | 7 | 137 | 7 | 137 | |
| 2016-03-18 | 20:00 | 7 | - | 10 | - | 7 | - | 14 | - | * Problem with drill |

| Snow thickness measurements | | Snow depth (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Hole # 1 | Hole # 2 | Hole # 3 | Hole # 4 | Hole # 5 | Hole # 6 | Hole # 7 | Hole # 8 | Hole # 9 |
| 2016-02-12 | 16:00 | 7 | 8 | 10 | 7 | 8 | 10 | 8 | 12 | 17 |
| 2016-02-26 | 09:00 | 6 | 3 | 7 | 4 | 7 | 10 | 2 | 7 | 8 |
| 2016-03-18 | 20:00 | 7 | 5 | 10 | 5 | 6 | 10 | 7 | 10 | 14 |

## Salluit

| Ice thickness measureme | | Hole # 1 | | Hole #2 | | Hole #3 | | Hole #4 | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness |
| 2016-02-05 | 15:00 | 20 | 81 | 7 | 95 | 13 | 91 | 11 | 94 |

| Snow thickness measurer | | Snow depth (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Hole # 1 | Hole # 2 | Hole # 3 | Hole # 4 | Hole # 5 | Hole # 6 | Hole # 7 | Hole # 8 | Hole # 9 |
| 2016-02-05 | 15:00 | 20 | 16 | 7 | 16 | 14 | 8 | 13 | 9 | 11 |

## Kangiqsujuaq

| Ice thickness measureme | | Hole # 1 | | Hole #2 | | Hole #3 | | Hole #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness | Snow depth | Ice thickness | mean snow |
| 2016-03-14 | 02:30 | 62 | 84 | 59 | 85 | 56 | 83 | 38 | 86 | |

| Snow thickness measurer | | Snow depth (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Hole # 1 | Hole # 2 | Hole # 3 | Hole # 4 | Hole # 5 | Hole # 6 | Hole # 7 | Hole # 8 | Hole # 9 |
| 2016-03-14 | 02:30 | 60 | 61 | 60 | 50 | 54 | 58 | 48 | 47 | 54 |

## ANNEX 2

<u>Data from the January and April 2016 field campaigns.</u>

The locations of ice drilling are in green while the ice cores are in red. The same color code is repeated in the corresponding data sheet.

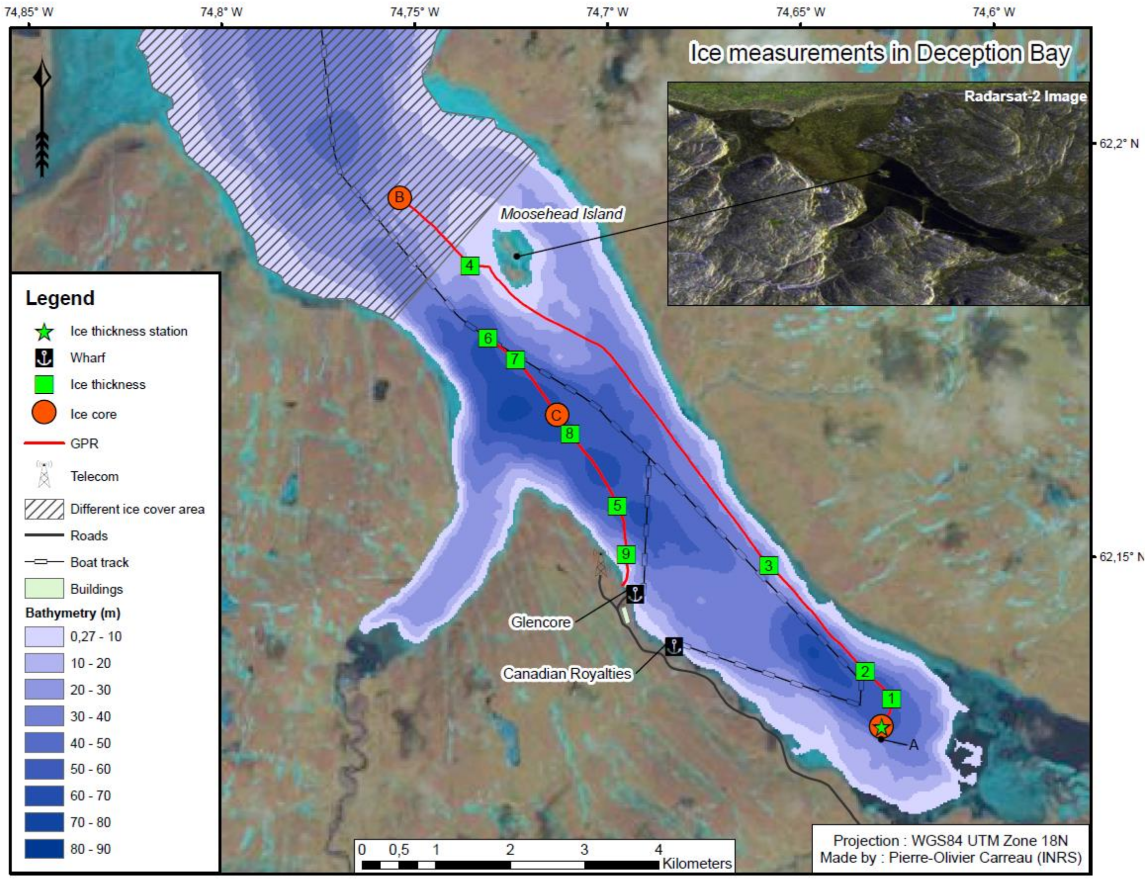



Figure 27 : Distribution of sample points for the January 20116 field measurements in Deception Bay

### Table 7 : Data from Deception Bay field measurements – January 2016.

| ID Map | Description | GPS ID start | GPS ID end | GPR ID | Sample # 1 | | Sample # 2 | | Ice core ID | Depth (cm) | Salinity (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ice (cm) | Snow (cm) | Ice (cm) | Snow (cm) | | | |
| | Starting point | BD1 | | | | | | | | | |
| A | Ice Station Ice core D1 | BD2 | | | 95 | - | | | 16-01-D1A | 13 | 3 |
| | | | | | | | | | 16-01-D1B | 27 | 4 |
| | | | | | | | | | 16-01-D1C | 57 | 4 |
| | | | | | | | | | 16-01-D1D | 88 | 5 |
| | 400 MHz | | | 3 | | | | | | | |
| | 900 MHz | | | 4 | | | | | | | |
| | 900 MHz | BD2 | BD3 | 5 | | | | | | | |
| 1 | Thickness | BD3 | | | 102 | 10 | 100 | 13 | | | |
| | 900 MHz | BD3 | BD4 | 6 | | | | | | | |
| 2 | Thickness off track | BD4 | | | 95 | 0 | 95 | 25 | | | |
| | 900 MHz | BD4 | BD5 | 7 | | | | | | | |
| 3 | Thickness | BD5 | | | 83 | 25 | | | | | |
| | 900 MHz | BD5 | - | 8 | | | | | | | |
| | 900 MHz | - | BD6 | 9 | | | | | | | |
| 4 | Thickness SWIP location | BD6 | | | 81 | 5 | | | | | |
| | 900 MHz | | | 10 | | | | | | | |
| | 900 MHz | BD6 | BD7 | 11 | | | | | | | |
| B | Ice core D2 | BD7 | | | 76 | - | | | 16-01-D2A | 9 | 5 |
| | | | | | | | | | 16-01-D2B | 26 | 5 |
| | | | | | | | | | 16-01-D2C | 48 | 5 |
| | | | | | | | | | 16-01-D2D | 66 | 6 |
| | 400 MHz | | | 12 | | | | | | | |
| | 400 MHz | BD7 | - | 13 | | | | | | | |
| | 400 MHz | - | - | 14 | | | | | | | |
| | 400 MHz | - | BD8 | 15 | | | | | | | |
| | 400 MHz | 53 | 54 | 16 | | | | | | | |
| 5 | Thickness | 54 | | | 84 | 6 | 91 | 8 | | | |
| | 400 MHz | 54 | 55 | 17 | | | | | | | |
| C | Ice core D3 | 55 | | | 88 | 10 | 89 | - | 16-01-D3A | 13 | 6 |
| | | | | | | | | | 16-01-D3B | 48 | 5 |
| | | | | | | | | | 16-01-D3C | 62 | 5 |
| | | | | | | | | | 16-01-D3D | 82 | 6 |
| | 400 MHz | 55 | 56 | 18 | | | | | | | |
| 6 | Thickness | 56 | | | 82 | 18 | 87 | 11 | | | |
| | 900 MHz | 56 | 57 | 19 | | | | | | | |
| 7 | Thickness | 57 | | | 91 | 14 | 89 | 14 | | | |
| | 900 MHz | 57 | 58 | 20 | | | | | | | |
| 8 | Thickness | 58 | | | 85 | 3 | 86 | 7 | | | |
| | 900 MHz | 58 | 59 | 21 | | | | | | | |
| 9 | Thickness | 59 | | | 92 | 2 | 89 | 2 | | | |

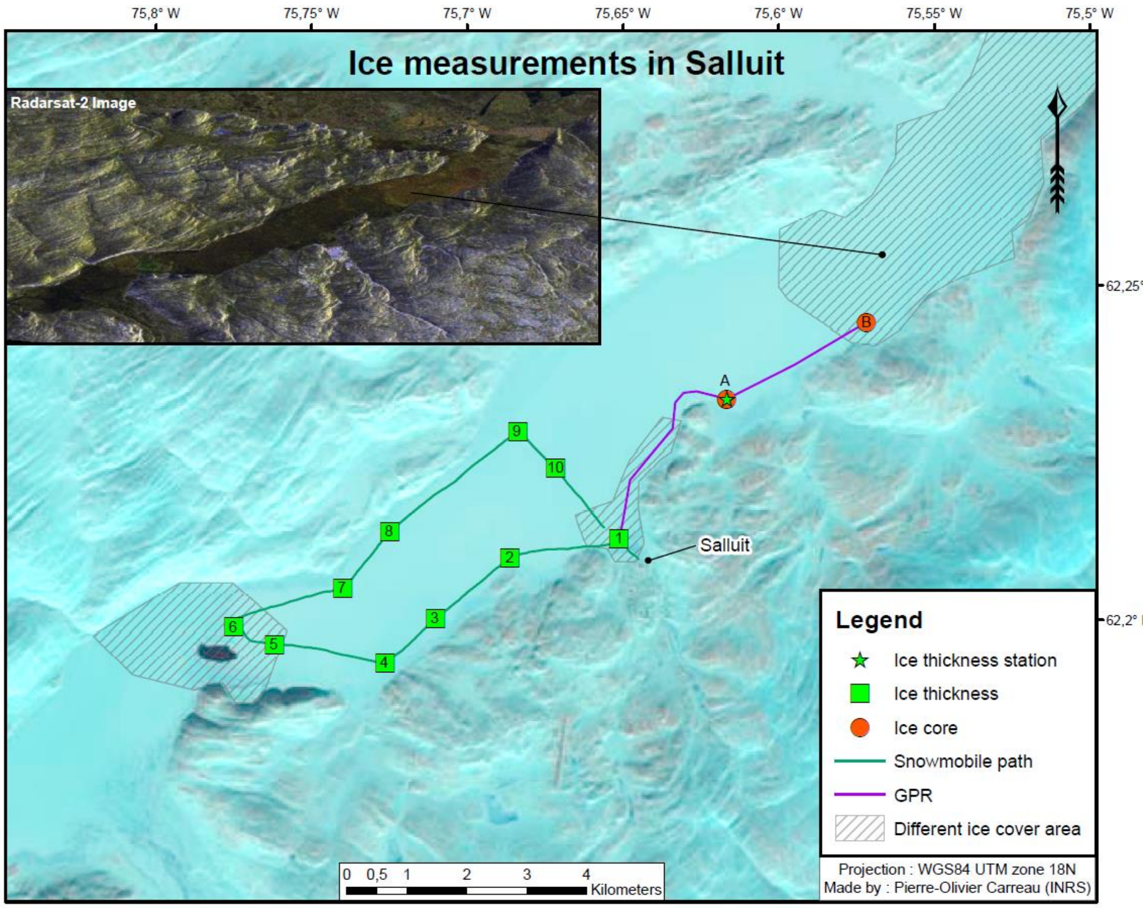



**Figure 28 : Distribution of sample points for the January 2016 field measurements in Salluit.**

### Table 8 : Data from Salluit field measurements – January 2016.

| ID Map | Description | GPS ID start | GPS ID end | GPR ID | Sample # 1 | | Sample # 2 | | Ice core ID | Depth (cm) | Salinity (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ice (cm) | Snow (cm) | Ice (cm) | Snow (cm) | | | |
| | Gas station | 84 | | | | | | | | | |
| 1 | Thickness | 85 | | 1 | 86 | | | | | | |
| | 400 MHz | 85 | - | 2 | | | | | | | |
| | 400 MHz | - | 86 | 3 | | | | | | | |
| * | Station corner thickness | | | | 93 | 2 | | | | | |
| | Station corner thickness | | | | 90 | 2 | | | | | |
| | Station corner thickness | | | | 88 | 5 | | | | | |
| | Station corner thickness | | | | 84 | 2 | | | | | |
| | First ice core S1 hole | | | | 80 | 10 | | | | | |
| A | Ice core S1 | 87 | | | 83 | - | 83 | 10 | 16-01-S1A | 18 | 6 |
| | | | | | | | | | 16-01-S1B | 35 | 4 |
| | | | | | | | | | 16-01-S1C | 50 | 5 |
| | | | | | | | | | 16-01-S1D | 65 | 4 |
| | 400 MHz | 87 | 88 | 4 | | | | | | | |
| | 400 MHz | 88 | 89 | 5 | | | | | | | |
| B | Ice core S2 | 89 | | | 69 | 15 | 68 | 15 | 16-01-S2A | 14 | 6 |
| | | | | | | | | | 16-01-S2B | 29 | 6 |
| | | | | | | | | | 16-01-S2C | 42 | 5 |
| | | | | | | | | | 16-01-S2D | 54 | 4 |
| | 900 MHz | 89 | 90 | 6 | | | | | | | |
| | 900 MHz | 90 | 91 | 7 | | | | | | | |
| | 900 MHz | 91 | 92 | 8 | | | | | | | |
| 2 | Thickness | 93 | | | 79 | 20 | | | | | |
| 3 | Thickness | 94 | | | 65 | 18 | | | | | |
| 4 | Thickness | 95 | | | 83 | 15 | | | | | |
| 5 | Thickness | 96 | | | 82 | 14 | | | | | |
| 6 | Thickness | 97 | | | 134 | 10 | | | | | |
| 7 | Thickness | 98 | | | 82 | 10 | | | | | |
| 8 | Thickness | 99 | | | 85 | 10 | | | | | |
| 9 | Thickness | 100 | | | 75 | 20 | | | | | |
| 10 | Thickness | 101 | | | 80 | 20 | | | | | |

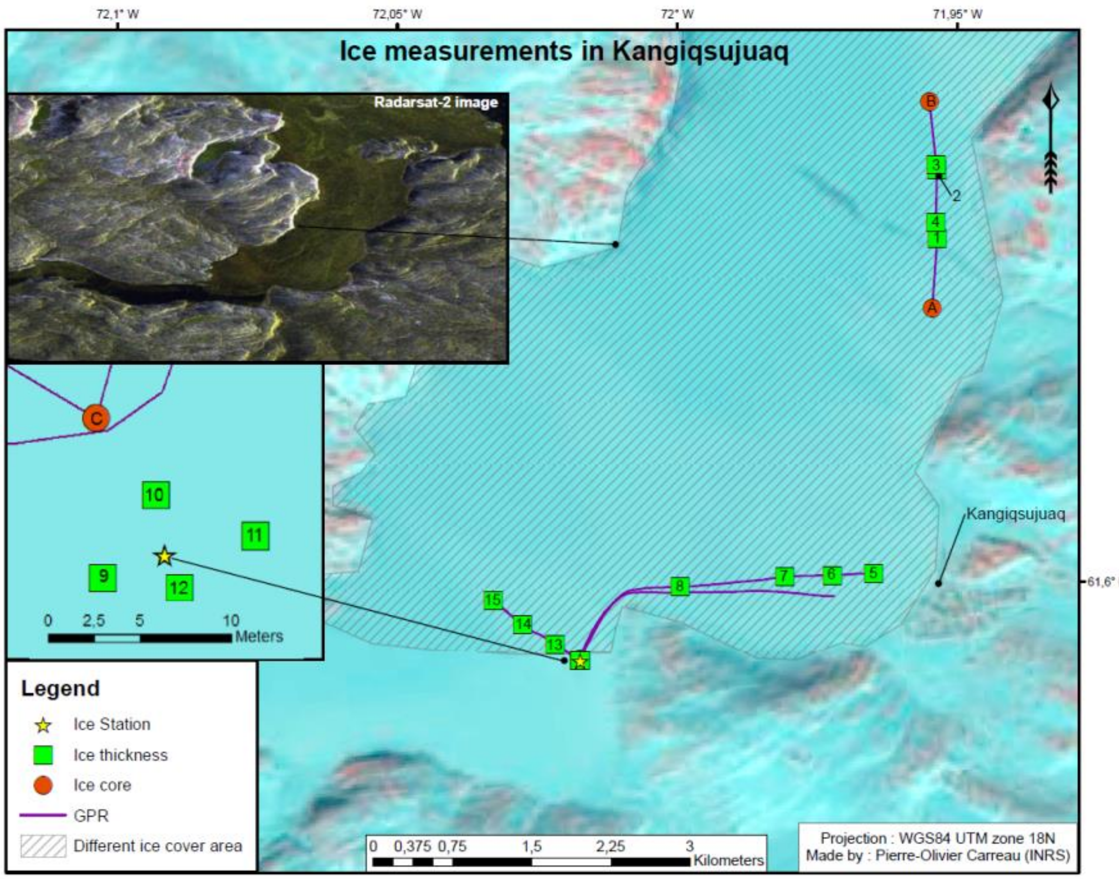



**Figure 29 : Distribution of sample points for the January 2016 field measurements in Kangiqsujuaq.**

## Table 9 : Data from Kangiqsujuaq field measurements – January 2016.

| ID Map | Description | GPS ID start | GPS ID end | GPR ID | Sample # 1 | | Sample # 2 | | Ice core ID | Depth (cm) | Salinity (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ice (cm) | Snow (cm) | Ice (cm) | Snow (cm) | | | |
| A | Ice core K1 | 60 | | 22 | 78 | 1 | 106 | 11 | 16-01-K1A | -16 | 5 |
| | | | | | | | | | 16-01-K1B | 20 | 9 |
| | | | | | | | | | 16-01-K1C | 49 | 5 |
| | | | | | | | | | 16-01-K1D | 76 | 6 |
| | 900 MHz | 60 | 64 | 23 | | | | | | | |
| 1 | Thickness | 64 | | | 75 | 20 | 77 | 24 | | | |
| | 900MHz | 64 | 65 | 24 | | | | | | | |
| 2 | Thickness | 65 | | | 70 | 13 | 71 | 15 | | | |
| | 900 MHz | 65 | 66 | 25 | | | | | | | |
| B | Ice core K2 | 66 | 69 | 24 | 74 | - | | | 16-01-K2A | 15 | 7 |
| | | | | | | | | | 16-01-K2D | 25 | 7 |
| | | | | | | | | | 16-01-K2B | 46 | 7 |
| | | | | | | | | | 16-01-K2C | 69 | 6 |
| | 400 MHz | 66 | 67 | 26 | | | | | | | |
| 3 | Thickness | 67 | | | 60 | 16 | 70 | 20 | | | |
| | 400 MHz | 67 | 68 | 28 | | | | | | | |
| 4 | 68 | | | | 82 | 14 | 76 | 14 | | | |
| | 400 MHz | 68 | - | 29 | | | | | | | |
| 5 | Thickness | 69 | | | 82 | 28 | 79 | 31 | | | |
| | 400 MHz | 69 | 70 | 30 | | | | | | | |
| 6 | Thickness | 70 | | | 77 | 26 | 78 | 25 | | | |
| | 400 MHz | 70 | 71 | 31 | | | | | | | |
| 7 | Thickness | 71 | | | 81 | 20 | 82 | 22 | | | |
| | 400 MHz | 71 | 72 | 32 | | | | | | | |
| 8 | Thickness | 72 | | | 78 | 18 | 75 | 20 | | | |
| | 400 MHz | 72 | 73 | 33 | | | | | | | |
| C | Ice core K3 | 73 | | 68 | 19 | 71 | - | | 16-01-K3A | 11 | 7 |
| | | | | | | | | | 16-01-K3B | 30 | 9 |
| | | | | | | | | | 16-01-K3C | 43 | 7 |
| | | | | | | | | | 16-01-K3D | 65 | 6 |
| Star * | Ice station | 74 | | | | | | | | | |
| 9 | Station corner thickness | 75 | | | 68 | 25 | | | | | |
| 10 | Station corner thickness | 76 | | | 62 | 32 | | | | | |
| 11 | Station corner thickness | 77 | | | 71 | 30 | | | | | |
| 12 | Station corner thickness | 78 | | | 70 | 30 | | | | | |
| | 900 MHz | 73 | 79 | 34 | | | | | | | |
| 13 | Thickness | 79 | | | 70 | 18 | 65 | 14 | | | |
| | 900 MHz | 79 | 80 | 35 | | | | | | | |
| 14 | Thickness | 80 | | | 68 | 16 | 68 | 16 | | | |
| | 900 MHz | 80 | 81 | 36 | | | | | | | |
| 15 | Thickness | 81 | | | 73 | 18 | 73 | 14 | | | |
| | 900 MHz | 81 | 82 | 1 | | | | | | | |
| | 900 MHz | 82 | 83 | 2 | | | | | | | |

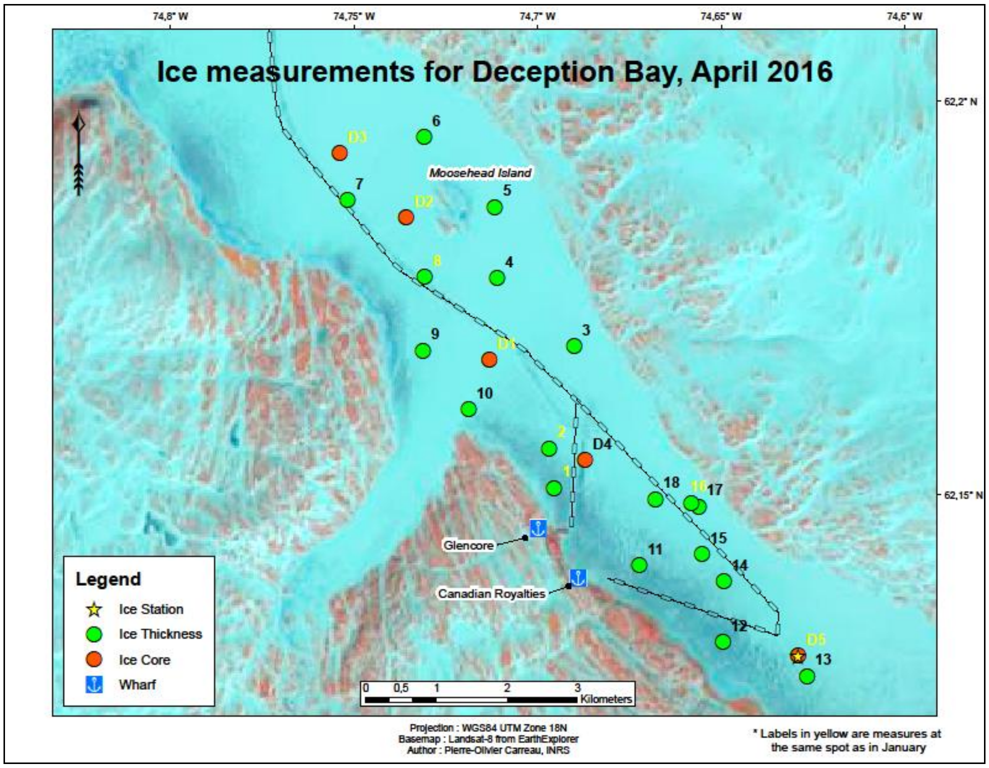



Figure 30 : Distribution of sample points for the April 2016 field measurements in Deception Bay.

**Table 10 : Data from Deception Bay field measurements – April 2016 (values in pink were contaminated).**

| ID Map | Description | GPS ID start | GPS ID end | GPR ID | Sample # 1 | | Ice core ID | Depth (cm) | Salinity (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ice (cm) | Snow (cm) | | | |
| 10 | Thickness | WP0130 | | | 153 | 0 | | | |
| 9 | Thickness | WP0131 | | | 155 | 2 | | | |
| D1 | Ice core D1 | 122 | | | 130 | 30 | 16-04-D1A | 15 | 5 |
| | | | | | | | 16-04-D1B | 30 | 5 |
| | | | | | | | 16-04-D1C | 60 | 5 |
| | | | | | | | 16-04-D1D | 80 | 2 |
| | | | | | | | 16-04-D1E | 100 | 4 |
| | 900 MHz point | 122 | | 16 | | | | | |
| | 400 MHz point | 122 | | 17 | | | | | |
| | 400 MHzv line | 122 | 122 | 18 | | | | | |
| 8 | Thickness | WP0132 | | | 109 | 25 | | | |
| D2 | Ice core D2 | 123 | | | 155 | 5 | 16-04-D2A | 20 | 3 |
| | | | | | | | 16-04-D2B | 50 | 2 |
| | | | | | | | 16-04-D2C | 80 | 3 |
| | | | | | | | 16-04-D2D | 100 | 5 |
| | | | | | | | 16-04-D2E | 120 | 2 |
| | 400 MHz point | 123 | | 19 | | | | | |
| | 400 MHz line | 123 | 123 | 20 | | | | | |
| 7 | Thickness | WP0133 | | | 131 | 18 | | | |
| D3 | Ice core D3 | 124 | | | 131 | 22 | 16-04-D3A | 25 | 4 |
| | | | | | | | 16-04-D3B | 50 | 4 |
| | | | | | | | 16-04-D3C | 80 | 5 |
| | | | | | | | 16-04-D3D | 100 | 5 |
| | | | | | | | 16-04-D3E | 120 | 6 |
| | 400 MHz point | 124 | | 21 | | | | | |
| | 400 MHz line | 124 | 124 | 22 | | | | | |
| 6 | Thickness | WP0134 | | | 120 | 25 | | | |
| 5 | Thickness | WP0135 | | | 133 | 33 | | | |
| 4 | Thickness | WP0136 | | | 152 | 14 | | | |
| D4 | Ice core D4 | 125 | | | 165 | 0 | 16-04-D4A | 20 | 3 |
| | | | | | | | 16-04-D4B | 50 | 4 |
| | | | | | | | 16-04-D4C | 90 | 3 |
| | | | | | | | 16-04-D4D | 140 | 4 |
| | | | | | | | 16-04-D4E | 160 | 6 |
| | 400 MHz point | 125 | | 23 | | | | | |
| 3 | Thickness | WP0137 | | | 147 | 8 | | | |
| 2 | Thickness | WP0139 | | | 138 | 20 | | | |
| 1 | Thickness | WP0140 | | | 147 | 5 | | | |
| 18 | Thickness | WP0141 | | | 58 | 30 | | | |
| 11 | Thickness | WP0142 | | | 134 | 23 | | | |
| 12 | Thickness | WP0143 | | | 155 | 0 | | | |
| 13 | Thickness | WP0144 | | | 140 | 10 | | | |
| 14 | Thickness | WP0145 | | | 165 | 13 | | | |
| 15 | Thickness | WP0146 | | | 140 | 29 | | | |
| 17 | Thickness | WP0147 | | | 122 | 40 | | | |
| 16 | Thickness | 126 | | | 132 | 36 | | | |
| D5 | Ice core D5 Ice station | 127 | | | 173 | 6 | 16-04-D5A | 30 | 4 |
| | | | | | | | 16-04-D5B | 45 | 4 |
| | | | | | | | 16-04-D5C | 60 | 4 |
| | | | | | | | 16-04-D5D | 90 | 4 |
| | | | | | | | 16-04-D5E | 125 | 3 |
| | | | | | | | 16-04-D5F | 140 | 4 |

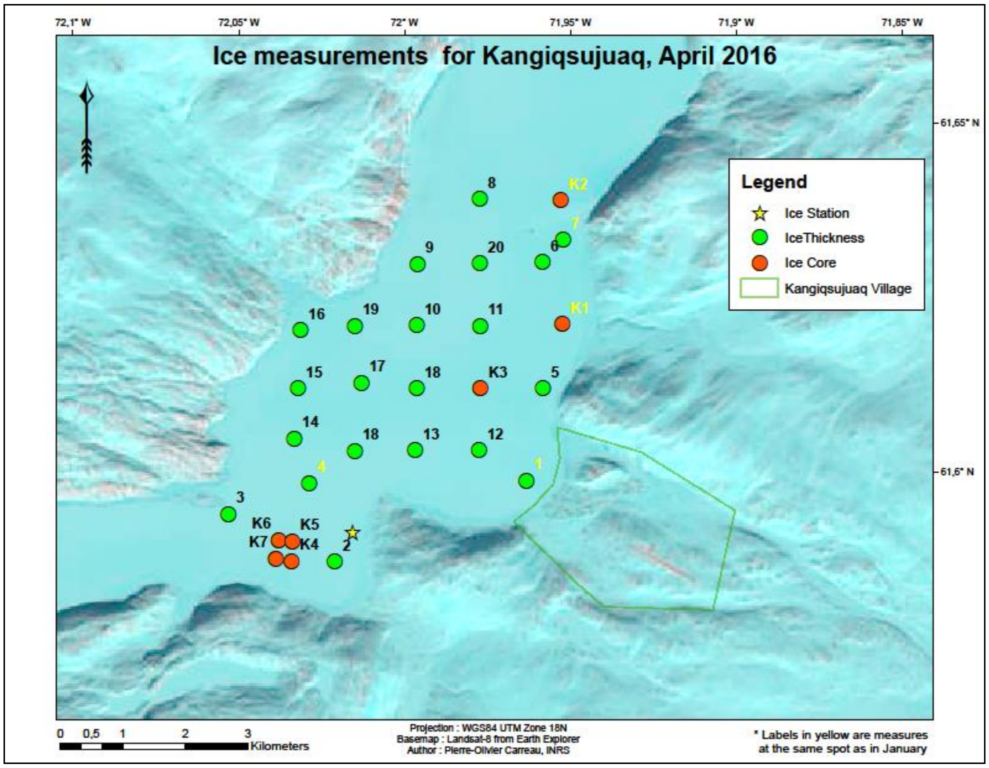


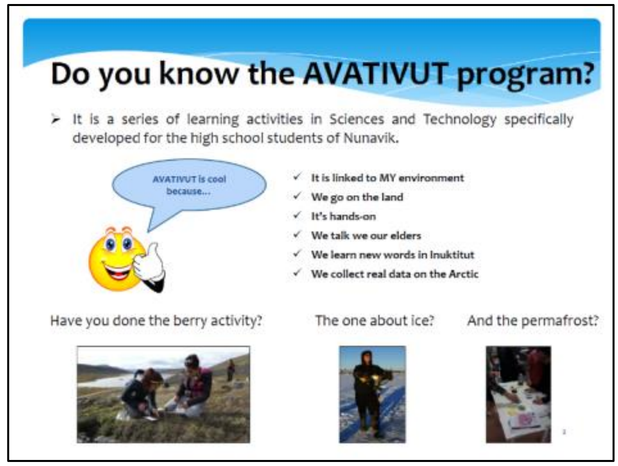

**Figure 31 : Distribution of sample points for the April 2016 field measurements in Kangiqsujuaq.**

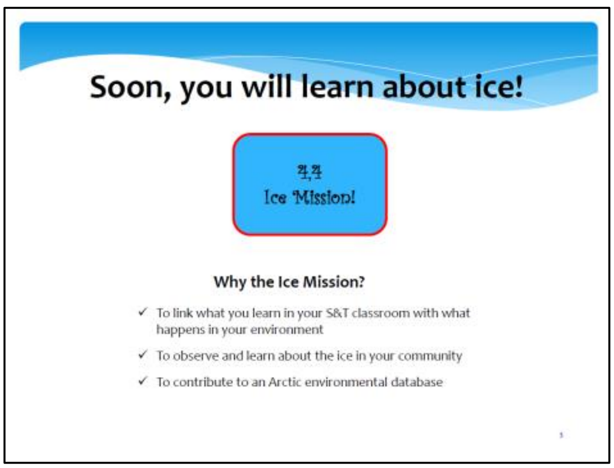
## Table 11 : Data from Kangiqsujuaq field measurements – April 2016.

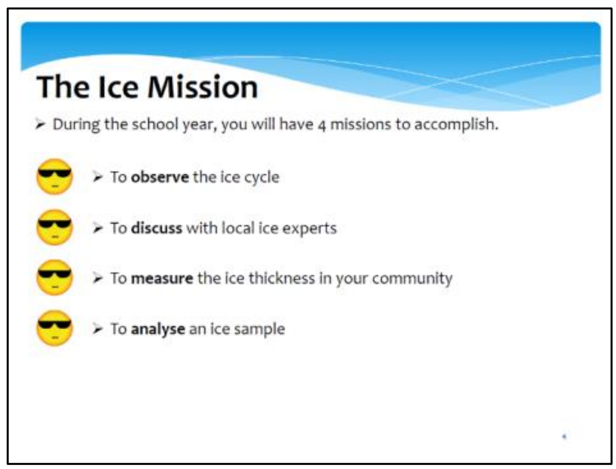
| ID Map | Description | GPS ID start | GPS ID end | GPR ID | Sample # 1 | | Ice core ID | Depth (cm) | Salinity (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ice (cm) | Snow (cm) | | | |
| 5 | Thickness | WP0113 | | | 107 | 47 | | | |
| K1 | Ice core K1 | 105 | | | 120 | 40 | 16-04-K1A | 20 | 4 |
| | | | | | | | 16-04-K1B | 40 | 3 |
| | | | | | | | 16-04-K1C | 60 | 4 |
| | | | | | | | 16-04-K1D | 80 | 4 |
| | | | | | | | 16-04-K1E | 100 | 3 |
| | 400 MHz line | 105 | 106 | 1 | | | | | |
| | 900 MHz line | 106 | 105 | 2 | | | | | |
| 6 | Thickness | WP0114 | | | 109 | 25 | | | |
| 7 | Thickness | WP0115 | | | 111 | 29 | | | |
| K2 | Ice core K2 | 107 | | | 140 | 18 | 16-04-K2A | 10 | 7 |
| | | | | | | | 16-04-K2B | 40 | 5 |
| | | | | | | | 16-04-K2C | 70 | 4 |
| | | | | | | | 16-04-K2D | 90 | 3 |
| | | | | | | | 16-04-K2E | 110 | 4 |
| | 900 MHz line | 107 | 108 | 3 | | | | | |
| | 400 MHz line | 108 | 107 | 4 | | | | | |
| 8 | Thickness | WP0116 | | | 130 | 19 | | | |
| 9 | Thickness | WP0117 | | | 143 | 6 | | | |
| 10 | Thickness | WP0118 | | | 126 | 10 | | | |
| 11 | Thickness | WP0119 | | | 110 | 28 | | | |
| K3 | Ice core K3 | 109 | | | 120 | 40 | 16-04-K3A | 20 | 6 |
| | | | | | | | 16-04-K3B | 50 | 3 |
| | | | | | | | 16-04-K3C | 70 | 3 |
| | | | | | | | 16-04-K3D | 90 | 4 |
| | 400 MHz point | 109 | | 5 | | | | | |
| | 900 MHz point | 109 | | 6 | | | | | |
| 12 | Thickness | WP0120 | | | 120 | 43 | | | |
| 13 | Thickness | WP0121 | | | 125 | 34 | | | |
| 18 | Thickness | WP0122 | | | 111 | 32 | | | |
| 1 | Thickness with students. Each thickness are separated by 20 foots | | | | 118 | 25 | | | |
| | | | | | 119 | 35 | | | |
| | | | | | 110 | 56 | | | |
| | | | | | 115 | 35 | | | |
| | | | | | 120 | 26 | | | |
| | | | | | 114 | 24 | | | |
| | | | | | 115 | 24 | | | |
| | | | | | 124 | 32 | | | |
| K4 | Ice core K4 | 110 | | | 114 | 20 | 16-04-K4A | 10 | 6 |
| | | | | | | | 16-04-K4B | 40 | 5 |
| | | | | | | | 16-04-K4C | 60 | 4 |
| | | | | | | | 16-04-K4D | 90 | 3 |
| | 400 MHz line | 110 | 111 | 7 | | | | | |
| | | 111 | 112 | 8 | | | | | |
| | | 112 | 113 | 9 | | | | | |
| | | 113 | 110 | 10 | | | | | |
| K5 | Ice core K5 | 114 | | | 105 | 42 | 16-04-K5A | 15 | 8 |
| | | | | | | | 16-04-K5B | 40 | 4 |
| | | | | | | | 16-04-K5C | 75 | 5 |
| | | | | | | | 16-04-K5D | 90 | 4 |
| 2 | Thickness | WP0123 | | | 115 | 18 | | | |
| 3 | Thickness | WP0124 | | | 106 | 4 | | | |
| 4 | Thickness | WP0125 | | | 110 | 18 | | | |
| 14 | Thickness | WP0126 | | | 124 | 14 | | | |
| 15 | Thickness | WP0127 | | | 120 | 25 | | | |
| 16 | Thickness | WP0128 | | | 123 | 0 | | | |
| 17 | Thickness | WP0129 | | | 102 | 30 | | | |
| K6 | Ice core K6 | 115 | | | 115 | 27 | 16-04-K6A | 30 | 4 |
| | | | | | | | 16-04-K6B | 45 | 4 |
| | | | | | | | 16-04-K6C | 60 | 4 |
| | | | | | | | 16-04-K6D | 90 | 6 |
| | 400 MHz point | 115 | | 14 | | | | | |
| K7 | Ice core K7 | 116 | | | 120 | 5 | 16-04-K7A | 20 | 4 |
| | | | | | | | 16-04-K7B | 45 | 3 |
| | | | | | | | 16-04-K7C | 70 | 3 |
| | | | | | | | 16-04-K7D | 100 | 4 |
| | 400 MHz point | 116 | | 15 | | | | | |
| 18 | Thickness | 117 | | | 99 | 30 | | | |
| 19 | Thickness | 118 | | | 130 | 1 | | | |
| 20 | Thickness | 119 | | | 133 | 25 | | | |

## ANNEX 3

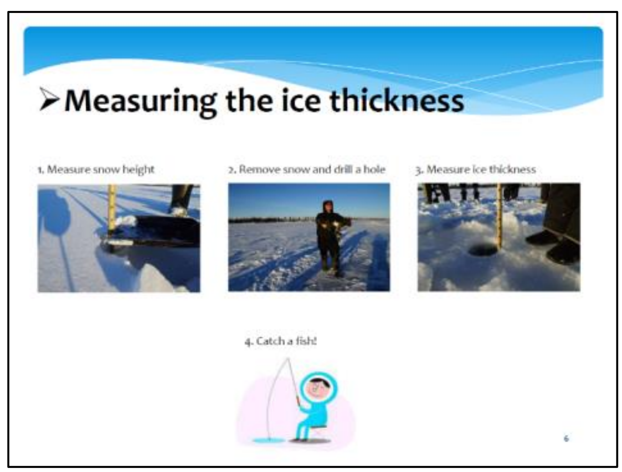
How the project was presented to the students.

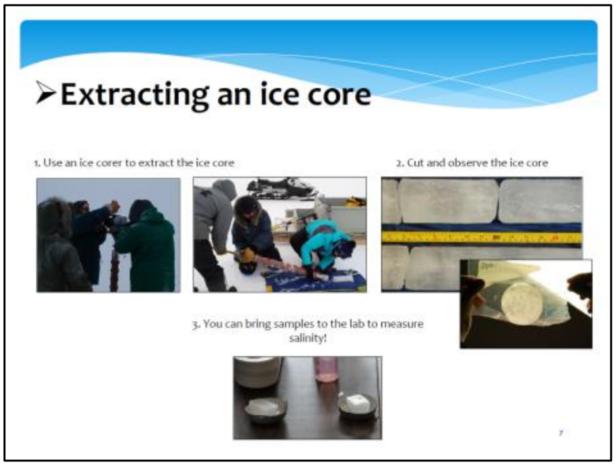



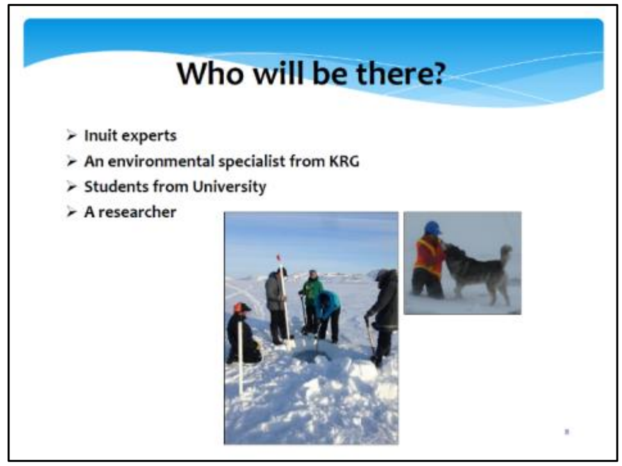








➢Extracting an ice core
1. Use an ice corer to extract the ice core
2. Cut and observe the ice core
3. You can bring samples to the lab to measure salinity!
7


Who will be there?
➢ Inuit experts
➢ An environmental specialist from KRG
➢ Students from University
➢ A researcher
8


Why are we doing it?
➢ To better understand the interactions between the ice cover, changing climate, winter navigation, safe access to the territory for Inuit communities and protection of the environment.
Ice monitoring in Deception Bay, Salluit Fjord and Wakeham Bay
MINE RAGLAN
GLENCORE
KATIVIK
INRS
9