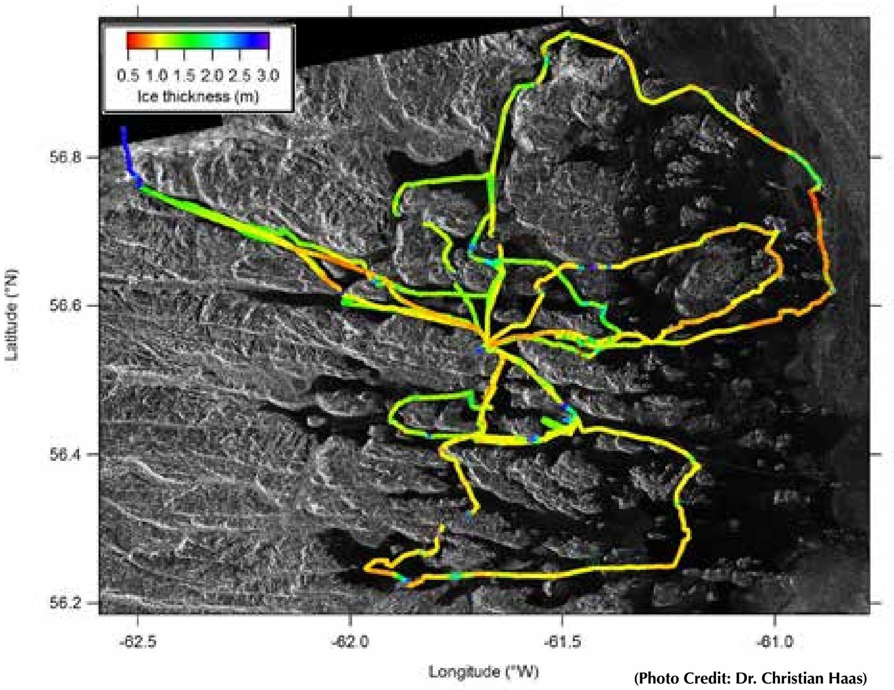
SmartICE for Arctic Mapping

Real-Time Sea Ice Data to Facilitate Travel in Northern Canada

By Andrew Safer

Disrupted patterns in the freezing and breakup of ice in Canada's North due to climate change have created unpredictable and potentially unsafe conditions for the Inuit, or "People of the Ice". Travel, which is necessary for hunting, firewood collection in the subarctic and cultural activities, has been impacted. In the unusually warm winter of 2009 to 2010, half of the surveyed residents of Nain were unable to use their common travel routes, and three-quarters could not predict the ice conditions. In this community of 1,200 on the Nunatsiavut coast, one out of 12 who were surveyed reported falling through the ice.

Sparked by that unseasonably warm winter, an effort is underway to marry a suite of technologies with traditional knowledge to provide Northern communities with current and accurate ice thickness and snow depth information for commonly used travel routes. Memorial University of Newfoundland's Sea-ice Monitoring And Real-Time Information for Coastal Environments (SmartICE) is initially a five-year project that began in Nain in 2013 and, in 2016, expanded to include the community of Pond Inlet on northern Baffin Island. SmartICE, supported by $2.5 million in project funding from the Research and Development Corp. of Newfoundland and Labrador, the Nunatsiavut government and Polar Knowledge Canada, incorporates the use of electromagnetic induction sounding, buoys featuring strings of thermistors that measure the temperature gradient between the atmosphere and the ocean and electrical conductivity, satellite imagery and a geospatial Web portal.



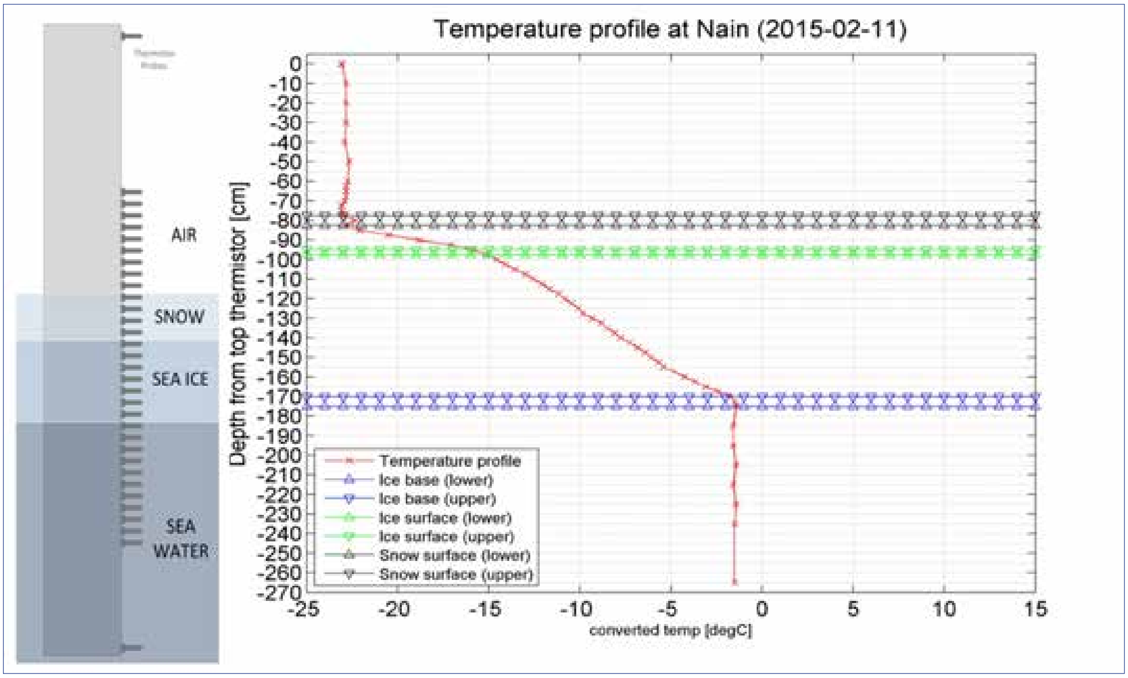
(Photo Credit: Dr. Christian Haas)

Ice thickness along snowmobile routes in the region of Nain, Labrador, gathered by the SmartICE project between March and May 2015. Background image shows satellite radar data from the European Space Agency's Sentinel-1 satellite. Repeat surveys have been carried out in some regions in March and April/May, showing the amount of ice thinning due to melt in the period between surveys.

The Way Forward

"We intend to provide a thematic map of ice types and hazards to support sea ice travel," said Dr. Trevor Bell, SmartICE principal investigator and professor of geography at Memorial University. This will be done more frequently during the dangerous shoulder seasons and less often during midwinter when the ice is stable and thick.

"These maps right now show a simple scheme of 'Go', 'No Go' and 'Slow Go' areas," he added, "but will become more sophisticated as we learn how to interpret the satellite images for this scale and format of ice classification. Our Inuit experts are crucial to this interpretation process."



(Photo Credit: SmartICE)

(Top) Plot (right) showing a typical temperature profile from the SmartSENSOR with the inferred snow/ice/ocean interfaces, and a diagram (left) of the SmartSENSOR concept showing the thermistors embedded into the different media. (Middle) SmartICE researcher next to the SmartSENSOR prior to deployment. (Bottom) SmartSENSOR deployed in front of Nain's community ice station with researchers in the background.

(Photo Credit: SmartICE)

Seeing the winter of 2009 to 2010 as a "window into the future", Bell assembled the team, including Inuit residents from Nain and more recently Pond Inlet, who are collaboratively working on SmartICE. Beyond the current project's focus, Bell pointed to applications for shipping, noting that the MV *Arctic* was recently stuck in the ice on the way to Voisey's Bay and that SmartICE was used to show where the ice was thinner and easier to navigate for the vessel.

Nain's community ice station is a low-tech source of ice thickness and snow depth information, first deployed on the sea ice in the winter of 2008/09. While the station has served the community well, since the information is site-specific, the data cannot be extrapolated over a broad area. Another limitation is that when the ice at the station is deemed to be unsafe for walking, the station must be dismantled and removed.

SmartQAMUTIK Ice Sled

To address the gaps in knowledge regarding ice thickness, in 2015, SmartICE introduced the SmartQAMUTIK in Nain—a conductivity meter mounted on an ice sled hauled behind a snowmobile that records ice thickness as it's being driven ("qamutik" is the local Inuktitut word for ice sled on Baffin Island).

Dr. Christian Haas, professor of Earth and space science and engineering and Tier 1 Canada Research Chair for Arctic Sea Ice Geophysics at York University in Toronto, developed the prototype for the SmartQAMUTIK more than six years ago for hunters. "We study changes of ice in response to changes in environmental boundary conditions between air temperatures, winds and currents," he explained.

(Photo Credit: Dr. Robert Briggs)

In determining sea ice thickness, there is a highly resistive layer on top (ice) and a highly conductive layer underneath (seawater). The instrument continuously transmits low-frequency electromagnetic fields. Due to the resistivity of ice, the fields penetrate with little effect, and when they reach the seawater, eddy currents are induced around the field lines and produce a secondary electromagnetic field, which passes back up through the ice to the instrument. The strength of the secondary field is measured. It decreases with the distance between the instrument and the surface of the seawater or bottom of the ice, respectively—and therefore with ice thickness.

On the dashboard of the SmartQAMUTIK are a data logger and computer LCD display showing the ice profile. Alarms signal to the driver when the ice is getting too thin.

Joey Angnatok, SmartICE's local sea ice specialist in Nain, surveying ice thickness with the SmartQAMUTIK to inform coastal ship navigation for the MV Arctic *through the ice.*

If the traveler sees a feature of interest, such as a transition from rough to smooth ice, he stops to capture it visually using a GPS-enabled camera. On his return, he downloads video and/or still images along with any notes he has taken and sends them to the SmartICE project manager to aid in the development of thematic sea ice maps. Ultimately, the SmartQAMUTIK operator will upload the information directly to the SmartICE Web portal so the community can access it.

"We would like to make the SmartQAMUTIK smarter by adding more sensors to map the surface conditions of sea ice, including snow and slush, ice thickness and surface roughness of the ice," noted Bell, who added this would be another three-year technology development and validation program.

Rodd Laing, research manager for the Nunatsiavut government, reports that ice thickness data are currently not available to the SmartQAMUTIK operator in real-time because the differential between the two lines representing the electromagnetic fields has to be calculated using an algorithm processed by Haas. However, Laing reports that he is able to gauge relative ice thickness on the fly. "You can see how far apart the two lines are on the data logger," he reported. "You can see the variation."

Regarding residents who won't be accessing the SmartICE Web-based maps because they don't have computers, he foresees posting a weekly ice bulletin at local grocery stores and government buildings and having it announced on the radio.

SmartSENSOR

Two in-situ buoys, or SmartSENSORs, were installed near Nain's community ice station in January 2016. Designed and built by C-CORE of St. John's, it incorporates a chain of 60 thermistors with probes every 2.5 cm that measure temperature. The bottom thermistors were placed in the water beneath the ice. The buoy is ballasted so that approximately one-third is above the water line and two-thirds is below. Unless there is exceptionally thick ice or heavy snowfall, there should always be thermistors exposed to the air and in the ocean water below the ice.

The seawater remains within a narrow temperature band through the winter, whereas the air temperature gets progressively colder. For example, in early January, the air temperature might be -10° C, dropping to -15° C in late January, and -20° C in February.

"The bottom of the ice is at the temperature of the ocean, about -1.5 Celsius or so," said Dr. Rob Briggs, SmartICE project manager and research engineer at C-CORE, "and the top of the ice is the temperature of the snow, which reflects the air temperature. Because of the gradient, you can identify the interfaces between air, snow, ice and ocean." The locations of the interfaces indicate the depth of the snow and thickness of the ice. The SmartSENSOR data are transmitted daily via satellite first to C-CORE and then to EMSAT in St. John's, the company that is storing and displaying the SmartICE data online. (Once the process is automated, the data will go directly to EMSAT.) The SmartSENSOR data help to validate the SmartQAMUTIK when it passes by one of the sensors. Based on data from the buoy, residents will be able to better understand the conditions of the sea ice surrounding their community.

Toward the end of the season, as the air temperature warms, the temperature of the atmosphere approaches that of the ocean and, due to the loss of a gradient, it becomes difficult to identify the interfaces using this method. This prompted Briggs' colleagues at C-CORE to develop an electrical conductivity sensing capability within the SmartSENSOR, which makes use of the metal casings of adjacent thermistors to measure the resistance. The ones in the salty ocean have low resistance; those in the atmosphere have very high resistance; and the ones in the ice fall in the middle. This provides another basis for identifying the interfaces between water, ice, snow and air. This new version was piloted in Moreton's Harbour, Newfoundland, where sea ice typically forms in the local bay. The sensor was deployed by boat into the water, moored in place and left for the ice to form around it, providing a field test of a new deployment technique to record the dangerous shoulder ice seasons. During the freeze-up period, it records the temperature every 6 hr., and for the majority of the season, when the ice growth is less dynamic, the buoy sends one daily reading via Iridium satellite to C-CORE. This frequency was chosen to conserve battery life. Two SmartSENSORs including both temperature and electrical conductivity sensors, with improved assembly and enhancements, were installed in Pond Inlet in April 2016.

Sea Ice Map, Geospatial Web Portal

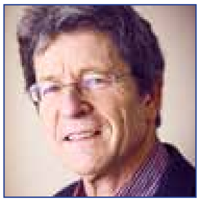
SmartICE, together with partners C-CORE and the Canadian Ice Service, has been working toward the development of a prototype sea ice map of common travel routes in the vicinity of Nain that is currently under review by community members. It involves the analysis of RADARSAT-2 and Sentinel-1 satellite images, ancillary data and ground-truth information collected by community partners. Analysts use observations submitted by the SmartQAMUTIK operators and SmartSENSOR data to help interpret the satellite imagery. "Rough ice can be inferred from the brighter pixels in the image, smooth ice is less bright and open water is dark," observed Briggs.

The project goes beyond land/ocean and land/ice classifications to include the ice conditions and naming conventions that the Inuit sea ice travelers use to describe the ice, which hasn't been done before on an operational level.

In order to make the ice thickness and snow depth information readily available to the community, EMSAT has developed a Web-based portal where SmartICE's geospatial information can be publicly displayed. Since the project is currently in the validation phase, the portal has not yet been made public. On the home page is the SmartQAMUTIK track around Nain and the most recent measurements from the ice stations. The photos and videos taken by the SmartQAMUTIK operators will be accessible by mouse clicking over the corresponding areas on the map. "The whole concept of this type of visualization for ice data," said EMSAT Corp. CEO Dan Brake, "as far as we are aware, doesn't exist anywhere else right now." EMSAT stores the data on its cloud-based platform.

Because Internet service in the North provides significantly less bandwidth than elsewhere, EMSAT has to massively reduce the number of data points that will be used to display information to users without compromising any detail. For example, 200,000 bits of data from the SmartQAMUTIK is reduced to 20,000 before being viewed by an end-user. Map information will be updated when new SmartSENSOR and SmartQAMUTIK data are connected to the system, and eventually all processes will be automated for instantaneous integration of new data sets.

Bell pointed out that the project builds training and capacity among Inuit in the communities while empowering them to design and manage their own community-based research. When he presented on SmartICE during the Arctic Science Summit Week in Fairbanks, Alaska, in March 2016, community members from around the Arctic were enthusiastic about the potential of this operational service for their own regions. "The vision is that SmartICE would be in every northern community where coastal ice information is needed for safe travel and shipping, from Chukotka to Canada and all points in between," said Bell. **ST**



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