Sea ice surface property detection during the summer melt period: Using ship-based passive microwave and UAVs in Canada's northern waters

Maddie Harasyn[1](harasynm@myumanitoba.ca), Dustin Isleifson[1,2], Nariman Firoozy[1,2], David Babb[1] and David Barber[1]

[1]Centre for Earth Observation Science, University of Manitoba, Winnipeg, MB

[2]Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB

Background

Passive microwave (PMW) remote sensing is highly useful for detecting sea ice due to the contrast in the dielectric properties of uniform sea ice and open ocean. During the summer melt period, Arctic sea ice experiences a highly dynamic change in extent and appearance, transitioning from a uniform layer to thermodynamically complex floes. Changes in surface properties alter the dielectric properties of the ice body making ice detection more complicated (Onstott et al. 1987). *In situ* PMW and unmanned aerial vehicle (UAV) data were collected during summer melt within the Labrador Sea (Figure 1) to study how these changing properties affect radiometric readings of sea ice.

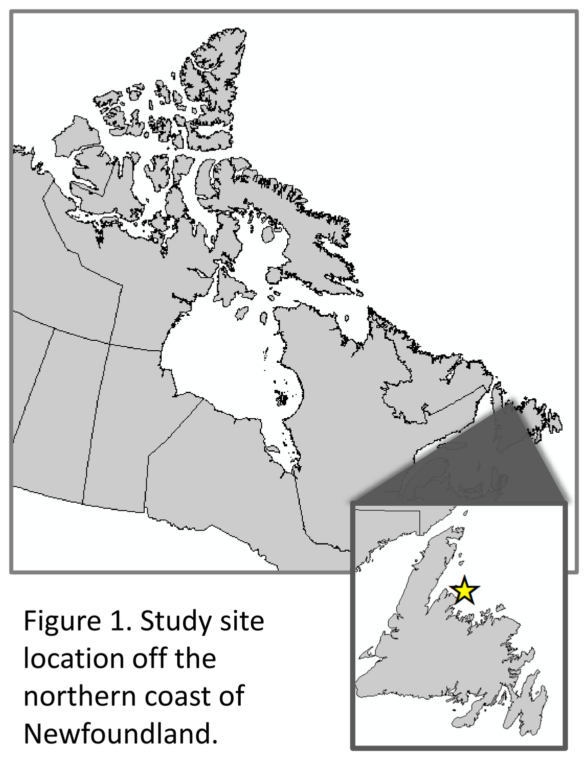

Figure 1. Study site location off the northern coast of Newfoundland.

Objective: relate the thermodynamic floe surface properties to the change in measured brightness temperatures through the combination of *in situ* PMW and UAV data collection

Data Collection

In situ data collection was conducted aboard the CCGS *Amundsen* during June 2017 (Figure 2). The following parameters were collected for 3 representative floes within the region:

- *In situ* PMW brightness temperatures for a floe of interest for 19, 37 and 89 GHz for a range of incidence angles, at both vertical and horizontal polarizations
- Camera images coincident to each radiometric reading for each given incident angle
- Floe physical characteristics including snow depth and temperature for snow pits and ice cores
- High-resolution photogrammetric UAV imagery of a 600 by 650m area surrounding the ship

Figure 2. Images of: 1) floe surface sampling, 2) drone image capture and 3) *in situ* data collection using the PMW radiometer.

Sea Ice Physical Sampling

- Ice floes were sampled through drilling ice cores and digging snow pits (Figure 4)
- Temperature and salinity measurements were taken at intervals across the pit and core, along with a measurement of snow depth and snow wetness

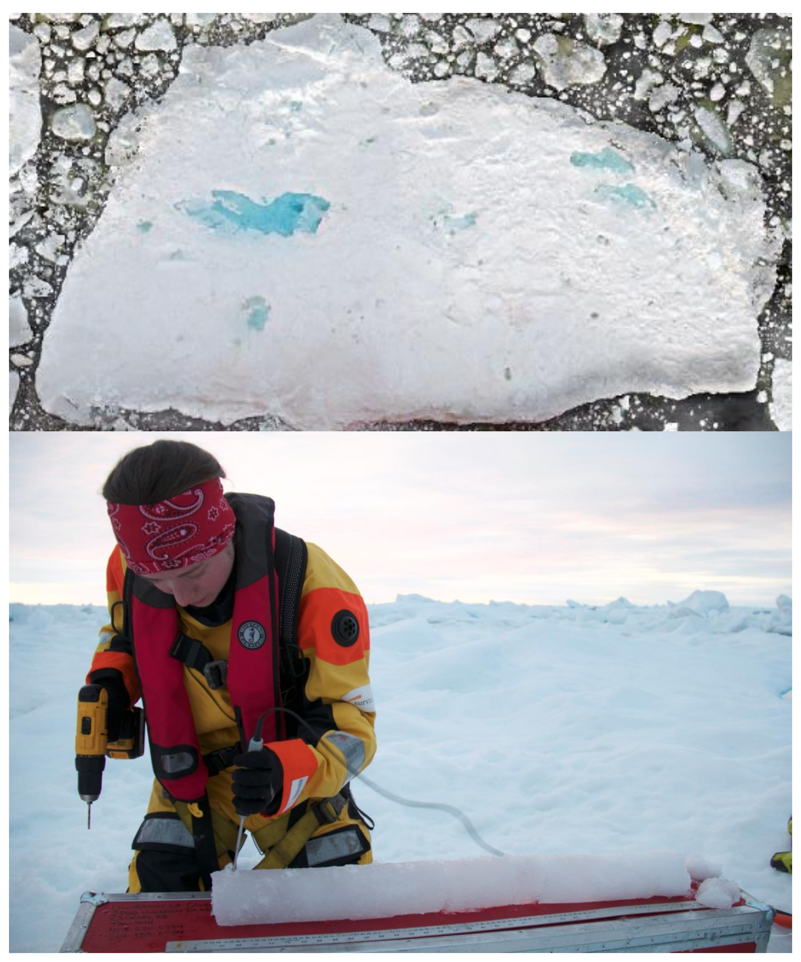

Figure 4. Aerial image of the sampled floe, and an image of temperature measurement along an ice core sample.

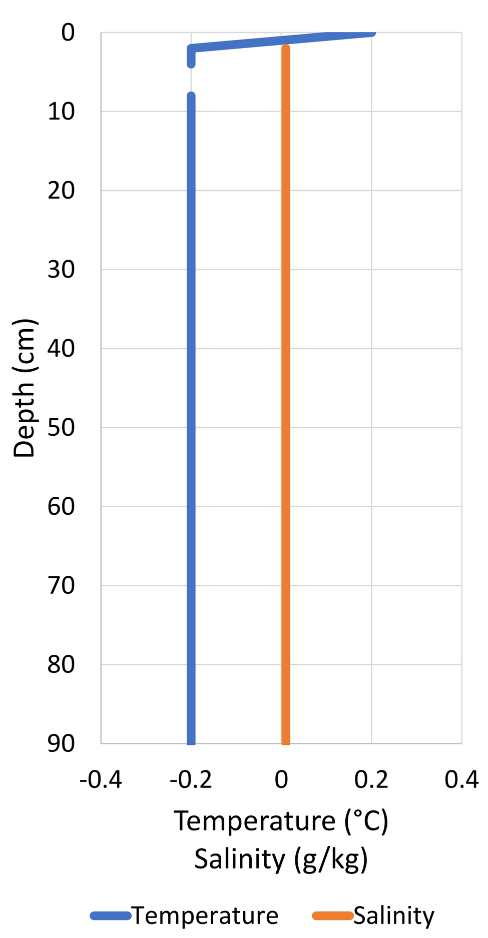

Figure 5. Temperature and salinity profile for the full thickness of the sampled floe.

Results

- The floe was isothermal and had uniform salinity with depth, with temperature readings of -0.2°C and salinity readings of 0.01 g/kg
  - Air temperature was recorded to be 0.02°C
- Snow depth was 6.5 cm, with a large grain size and presence of liquid water
- Melt ponds ranged from 57 m^2 to 0.39 m^2 and covered 36% of the floe
  - Total floe area was 2687 m^2 with a maximum length of 83 m and a depth of 4.39 m

In Situ Brightness Temperatures

- Brightness temperatures (T_B) for all frequency/ polarization combinations compared across transect (Figure 3)
- Polarization ratios (PR) were calculated for each frequency to allow for a more in-depth analysis (Markus and Dokken, 2002)

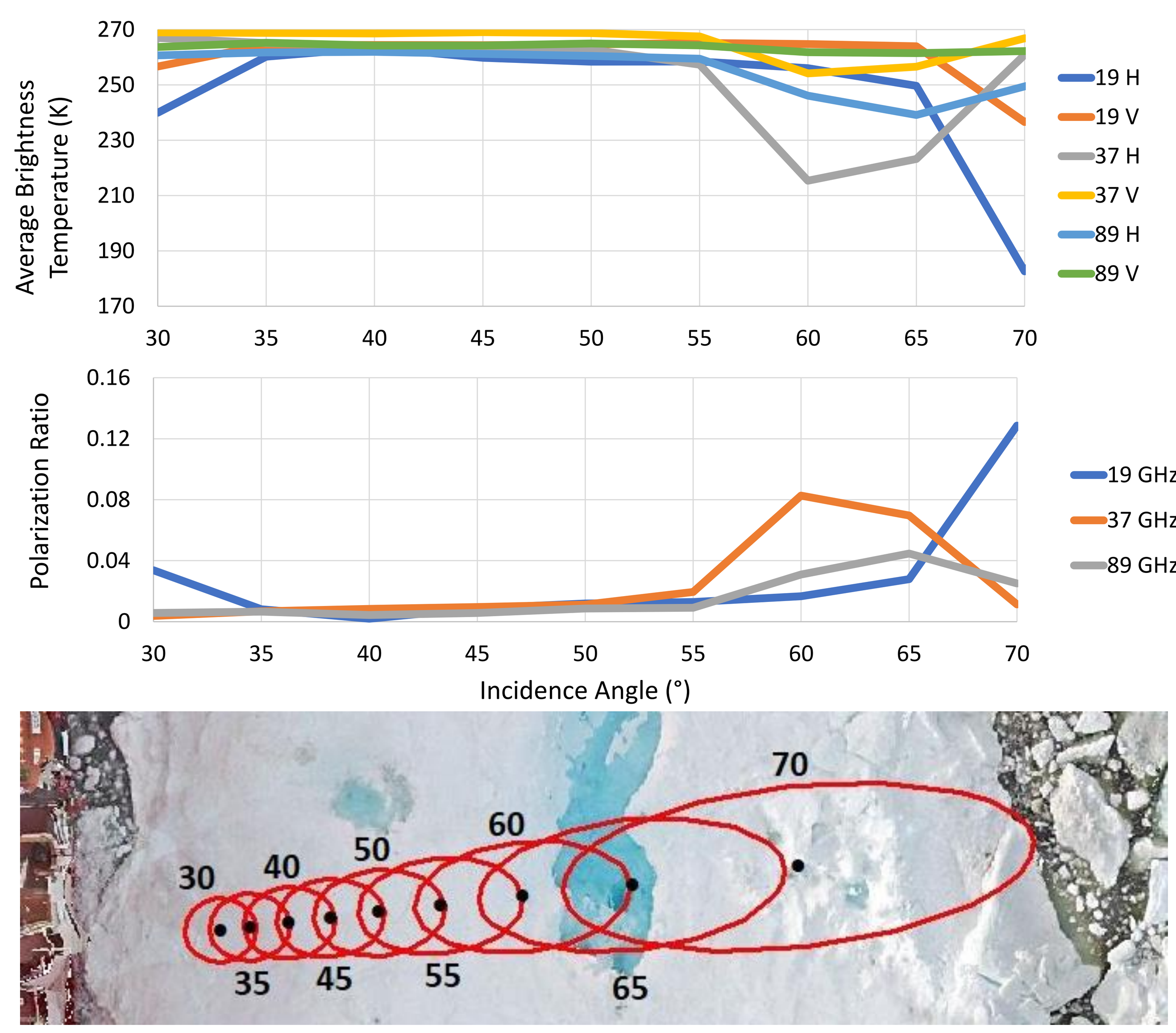

Figure 3. Brightness temperatures (top) and polarization ratios (middle) plotted for each incidence angle, along with the FOV footprint for each angle shown across the scanned floe.

Results

- Brightness temperatures remain uniform between 35-55°, where FOV's contain 100% smooth ice
- From 60-70°, T_B fluctuates as varying surface properties are included in the FOV
  - Features include large liquid melt pond and ice ridges
- Suggest that melt ponds and open ocean may influence multifrequency emissions independently

UAV Ice Survey

- UAV surveys were analyzed using ENVI to generate maps for total ice and melt pond cover
  - A decision tree classification with specified thresholds for ice and pond pixel RBG values, based on values from Rösel 2013
- Sea ice and melt pond concentration estimates were generated using a raster-to-polygon analysis in ArcMap 10.5 (Figure 5)
- Digital Elevation Models (DEM) were generated through photogrammetric techniques using image overlap

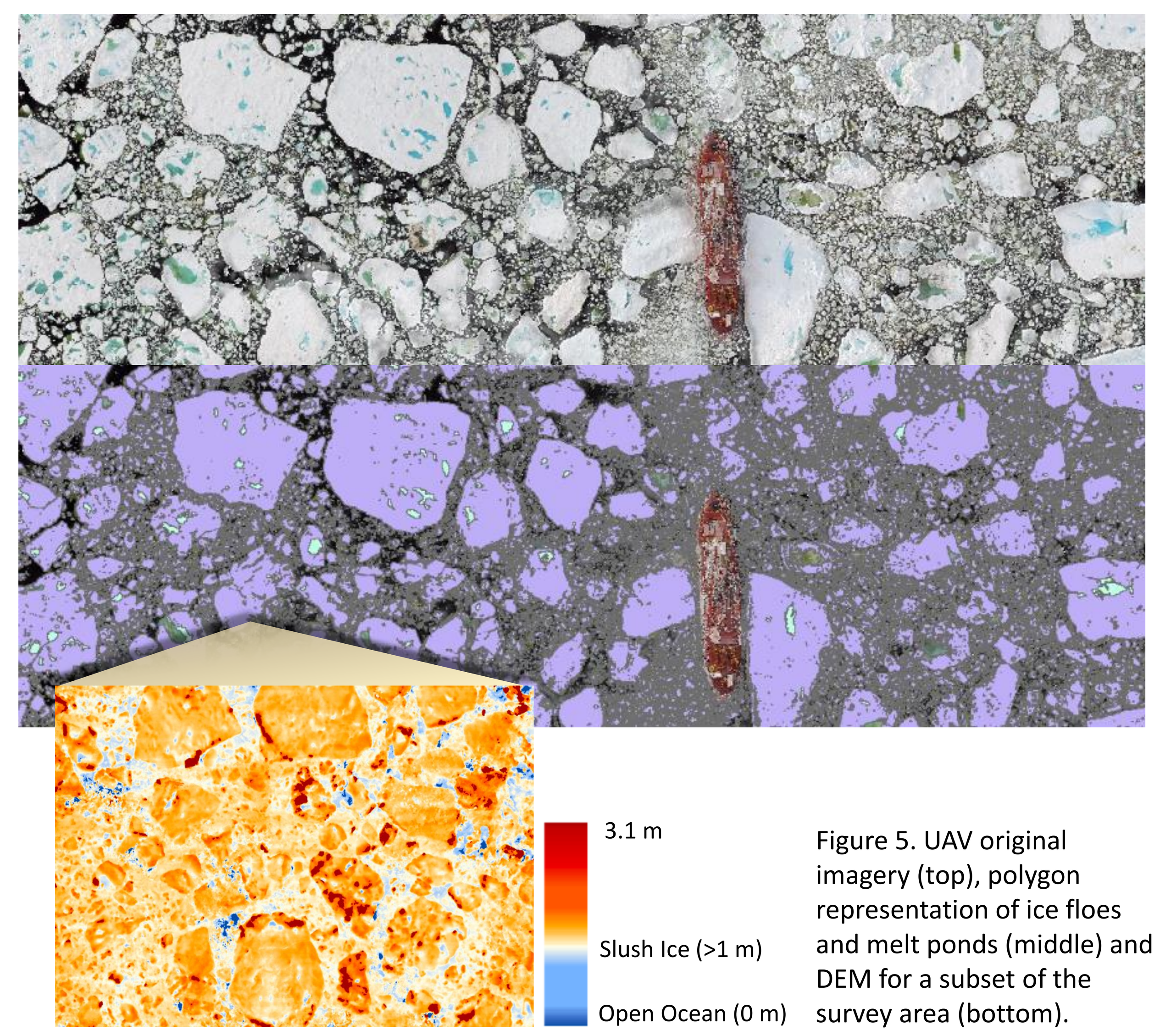

Figure 5. UAV original imagery (top), polygon representation of ice floes and melt ponds (middle) and DEM for a subset of the survey area (bottom).

Results

- Floe concentration in the survey area was 61%, with melt ponds overlapping 2% of the floe area
- DEM analysis showed variable surface roughness across floes, with ice ridges reaching up to 10.3 ft.

Future Work

Temporally coincident brightness temperature values retrieved by AMSR-2 will be compared to *in situ* surface measurements. Through this comparison, a relationship allowing for sub-pixel analysis of satellite data will be generated. A second dataset to support this project will be collected during the 2018 BAYSYS campaign aboard the CCGS *Amundsen*, for which sampling techniques will be refined based on current data analyses.

Acknowledgements

This research would not be possible without the excellent support from the CCGS *Amundsen* crew. As well, funding support from the NSERC Discovery Grant program and BAYSYS (Hudson Bay System Study) made field data collection and analysis possible, along with contributions for the Canada Excellence Research Chair (CERC) and Canada Research Chair (CRC) programs. This work is a contribution to the ArcticNet Networks of Centres of Excellence and the Arctic Science Partnership (ASP) asp-net.org.

Onstott R. G., Grenfell T. C., Matzler C., Luther C. A. and Svendsen E. A. (1987), "Evolution of microwave sea ice signatures during early summer and midsummer in the marginal ice zone". Journal of Geophysical Research, 92(C7): 6825-6835.

Rösel, A. (2013). Detection of Melt Ponds on Arctic Sea Ice with Optical Satellite Data. Hamburg Studies on Maratime Affairs, 25. doi: 10.1007/978-3-642-37033-5