Classification of Arctic Sea Ice Surface Types During the Melt Season in High-Resolution IceBridge Imagery

Ellen Buckley[1,1], Sinéad Farrell[2], Kyle Duncan[3,3], Laurence Connor[4,4], John Kuhn[4,4], RoseAnne Dominguez[5,5], and Sinéad Farrell[2]

[1]University of Maryland College Park
[2]NOAA Laboratory for Satellite Altimetry, NCWCP
[3]University of Maryland
[4]NOAA Laboratory for Satellite Altimetry
[5]Universities Space Research Association Moffett Field

November 30, 2022

Abstract

Melt ponds play an important role in the seasonal evolution of Arctic sea ice. During the melt season, snow atop the sea ice begins to metamorphose and melt, forming ponds on the ice. These ponds reduce the albedo of the surface, allowing for increased solar energy absorption and thus further melting of snow and ice. Analyzing the spatial distribution and temporal evolution of melt ponds helps us understand the sea ice processes that occur during the summer melt season. It has been shown that the inclusion of melt pond parameters in sea ice models increases the skill of predicting the summer sea ice minimum extent. Previous studies have used remote sensing imagery to characterize surface features and calculate melt pond statistics. Here we use new observations of melt ponds obtained by the Digital Mapping System (DMS) flown onboard NASA Operation IceBridge (OIB) during two Arctic summer melt campaigns which surveyed thousands of kilometers of sea ice and resulted in more than 45,000 images. One campaign was conducted in the Beaufort Sea (July 2016), and one in the Lincoln Sea and the Arctic Ocean north of Greenland (July 2017). Using these data we expect to advance our understanding of the differences and similarities between melt pond features on young, thin sea ice seen in the Beaufort Sea versus those on multi-year ice. We have developed a pixel-based classification scheme by considering the different RGB spectral values associated with each surface type. We identify four sea ice surface types (level ice, rubbled ice, open water, and melt ponds). The classification scheme enables the calculation of parameters including melt pond fraction, ice concentration, melt pond area, and melt pond dimensions. We compare results with data from the Airborne Topographic Mapper (ATM), a laser altimeter also operated during these OIB missions. Given the extent over which the OIB data are available, regional information may be derived. Leveraging existing satellite data products, we examine whether the high-resolution airborne statistics are representative of the region and can be scaled up for comparison against satellite-derived parameters such as ice concentration and extent.

C31D-1563

Classification of Arctic Sea Ice Surface Types During the Melt Season in High-Resolution IceBridge Imagery

Ellen M. Buckley[1], Sinead Louise Farrell[2,3], Kyle Duncan[2,3], Laurence N. Connor[3], John M. Kuhn[3], Roseanne Dominguez[4]

[1]Dept. of AOSC, University of Maryland, College Park, MD. [2]Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD. [3]NOAA Laboratory for Satellite Altimetry, College Park, MD. [4]Universities Space Research Association; NASA Ames Research Center

Importance of Melt Ponds on Summer Sea Ice

- Melt ponds have a critical role in sea ice evolution. Pond formation on sea ice at melt onset reduces albedo of the surface contributing to the positive ice-albedo feedback mechanism.
- Melt pond detection from satellites is limited because the small scale of the ponds is difficult to detect on medium and low resolution imagery. Additionally, the presence of clouds over the Arctic in the summer reduces the ability to measure the surface from remote sensing platforms.
- Melt ponds manifest differently depending on the ice type on which they form. On the thick multi-year ice, meltwater ponds in low lying topographical features and can partially drain through pores that develop in the ice. On the flat topography of un-deformed first year ice, the meltwater spreads laterally.
- Here, we classify melt ponds in airborne imagery to understand different melt pond types

Observation of Summer Sea Ice

- The **Digital Mapping System (DMS)** used on **Operation IceBridge (OIB)** flights, produces high resolution digital imagery providing surface details over thousands of kilometers of rapidly changing sensitive and critical areas of the Arctic
- The DMS data have 10cm resolution and each image covers approximately 400m x 600m.
- Here we use data from two Operation IceBridge Arctic summer campaigns (**2016** in the **Beaufort Sea**, and in **2017 north of Ellesmere Island and Greenland**) (**Figure 1**)
- The total flight line length for these two campaigns is approximately 20,000 km allowing for over 2,000 square kilometers of cloud-free sea ice imagery data collection.
- A total of over 45,000 images were collected, of which 18,500 are used in analysis.
- **GOAL:** classify sea ice surface features: level ice, rubbled ice, open water and melt ponds.

Date	Flight Name	Total Images Collected
July 13, 2016	SIZRS1 (20160713)	6106
July 14, 2016	Buoy Farm1 (20160714)	7625
July 15, 2016	WildWest1 (20160715)	3396
July 19, 2016	Clean Up1 (20160719)	3596
July 20, 2016	Linkswiler Line 1 (20160720)	1587
July 21, 2016	Southeast Beaufort (20160721)	3300

Date	Flight Name	Total Images Collected
July 17, 2017	Convergence West (20170717)	3195
July 18, 2017	West Central (20170718)	4535
July 24, 2017	Russell 40 (20170724)	5374
July 25, 2017	Greely North ((20170725a)	3874
July 25, 2017	Convergence West 2 (20170725b)	3581

IceBridge Summer Arctic Flights

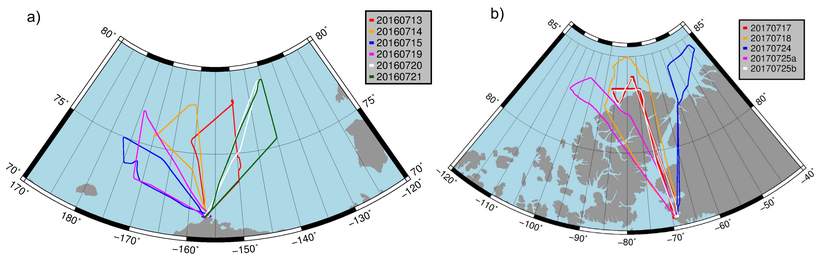


Figure 1: Flight lines for IceBridge Arctic summer campaigns in 2016 in the Beaufort and Chukchi (a) and in 2017 north of Greenland and Ellesmere Island (b).

Project Status

- Algorithm development is in the final steps. Testing on subset of images (see **E** right)
- Next steps: Implement and apply algorithm to complete dataset to extract parameters including ice concentration and melt pond fraction, area, dimensions, and type.

Acknowledgements: This study is supported under the NASA Cryosphere Program Grant 80NSSC17K0006. This study utilizes the IceBridge DMS L1B Geolocated and Orthorectified Images, Version 1 data set [Dominguez, R. 2010, updated 2016, IceBridge DMS L1B Geolocated and Orthorectified Images, Version 1, [2010-2016], Boulder, Colorado USA, NASA National Snow and Ice Data Center Distributed Active Archive Center, doi: http://dx.doi.org/10.5067/OZ6VNOPMPRJ0]. We also acknowledge the support of the NASA IceBridge teams for their diligence in collecting these data.

Melt Pond Algorithm Classification Steps

Preprocessing of DMS Image Dataset

Acquire DMS data from NSIDC https://nsidc.org/data/iodms1b → Filter data based on aircraft pitch, roll, and altitude. → Discard images with land, clouds, or if they are entirely open water **(A)**

Masking Border Pixels

Find the corner points in the image. → Connect the corner points, every pixel outside of the corner point lines is identified as border → Use the blue channel pixel values to determine which remaining pixels are part of the border **(B)**

Classifying Ice Pixels

Analyze the histogram of the red channel of the remaining pixels **(C)** → Determine if there is rubbled ice in the image → Identify the rubbled ice and level ice based on red channel pixel values

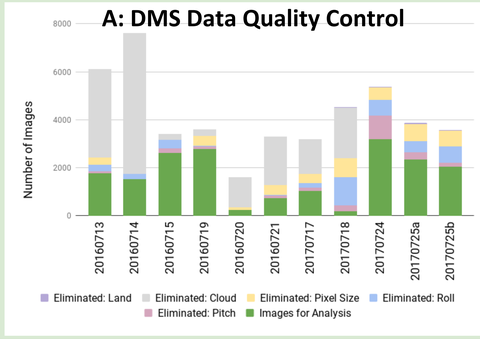
Classifying Open Water Pixels

Segment the image into 16 elements → Examine the blue and green channels of the remaining pixels in each element → Determine the pixels associated with open water in the image. **(D)**

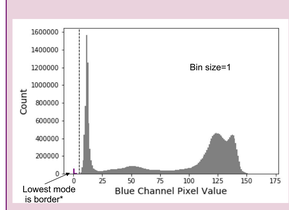
Classifying Melt Pond Pixels

Created masked array showing surface features. **(E)** ← Categorize light melt ponds and dark melt ponds. ← Remaining pixels are identified as melt ponds.

A: DMS Data Quality Control

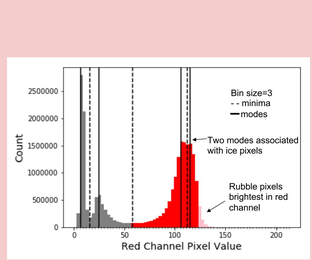


B: Masking DMS Border Pixels

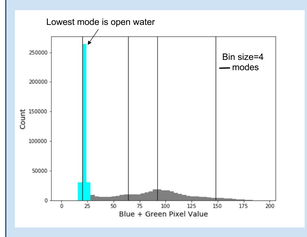


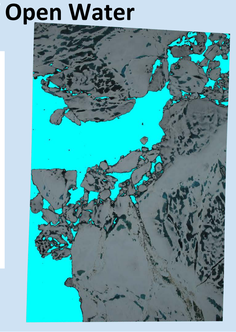
*Majority of border pixels masked in first step.

C: Classification of Ice Pixels



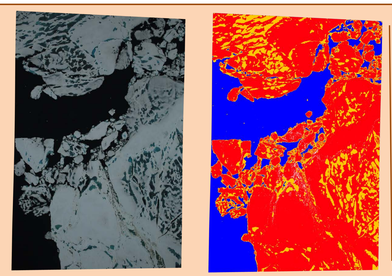
D: Classification of Open Water



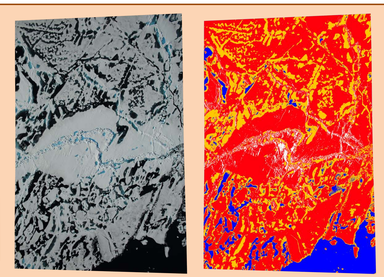


E: Results

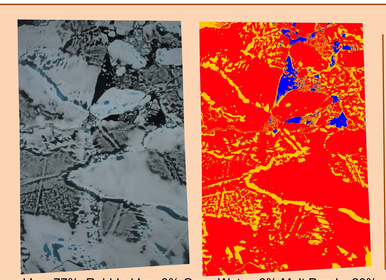
Level Ice
Rubble Ice
Melt Pond
Open Water



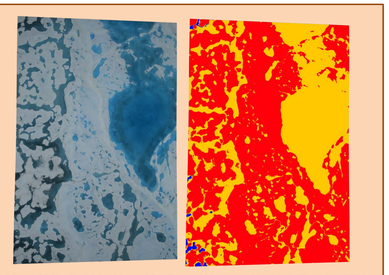
Level Ice: 61%, Rubbled Ice: <1% Open Water: 23% Melt Ponds: 16%
Melt Pond Fraction: 26% Ice Concentration: 77%



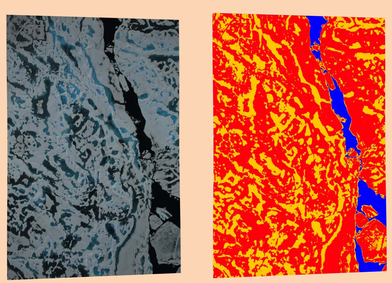
Level Ice: 64%, Rubbled Ice: 4% Open Water: 10% Melt Ponds: 22%
Melt Pond Fraction: 32% Ice Concentration: 90%



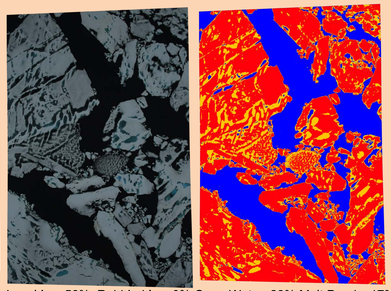
Level Ice: 77%, Rubbled Ice: 0% Open Water: 3% Melt Ponds: 20%
Melt Pond Fraction: 26% Ice Concentration: 97%



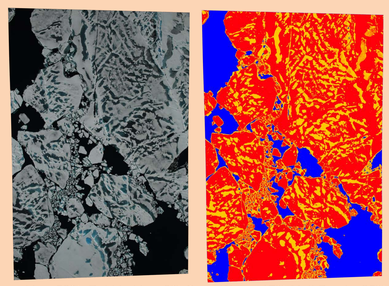
Level Ice: 62%, Rubbled Ice: 0% Open Water: <1% Melt Ponds: 37%
Melt Pond Fraction: 60% Ice Concentration: >99%



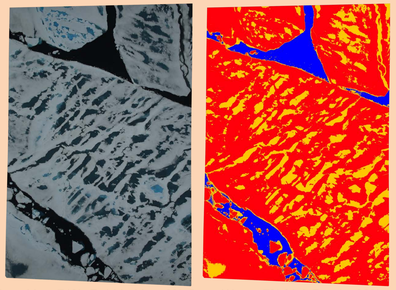
Level Ice: 64%, Rubbled Ice: 0% Open Water: 5% Melt Ponds: 31%
Melt Pond Fraction: 48% Ice Concentration: 95%



Level Ice: 56%, Rubbled Ice: 0% Open Water: 28% Melt Ponds: 17%
Melt Pond Fraction: 30% Ice Concentration: 72%



Level Ice: 58%, Rubbled Ice: 0% Open Water: 17% Melt Ponds: 25%
Melt Pond Fraction: 43% Ice Concentration: 83%



Level Ice: 71%, Rubbled Ice: 0% Open Water: 7% Melt Ponds: 22%
Melt Pond Fraction: 31% Ice Concentration: 93%