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

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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	Date	Flight Name	Total Images Collected
July 13, 2016	SIZRS1 (20160713)	6106	July 17, 2017	Convergence West (20170717)	3195
July 14, 2016	Buoy Farm1 (20160714)	7625	July 18, 2017	West Central (20170718)	4535
July 15, 2016	WildWest1 (20160715)	3396	July 24, 2017	Russell 40 (20170724)	5374
July 19, 2016	Clean Up1 (20160719)	3596	July 25, 2017	Greely North ((20170725a)	3874
July 20, 2016	Linkswiler Line 1 (20160720)	1587	July 25, 2017	Convergence West 2 (20170725b)	3581
July 21, 2016	Southeast Beaufort (20160721)	3300			

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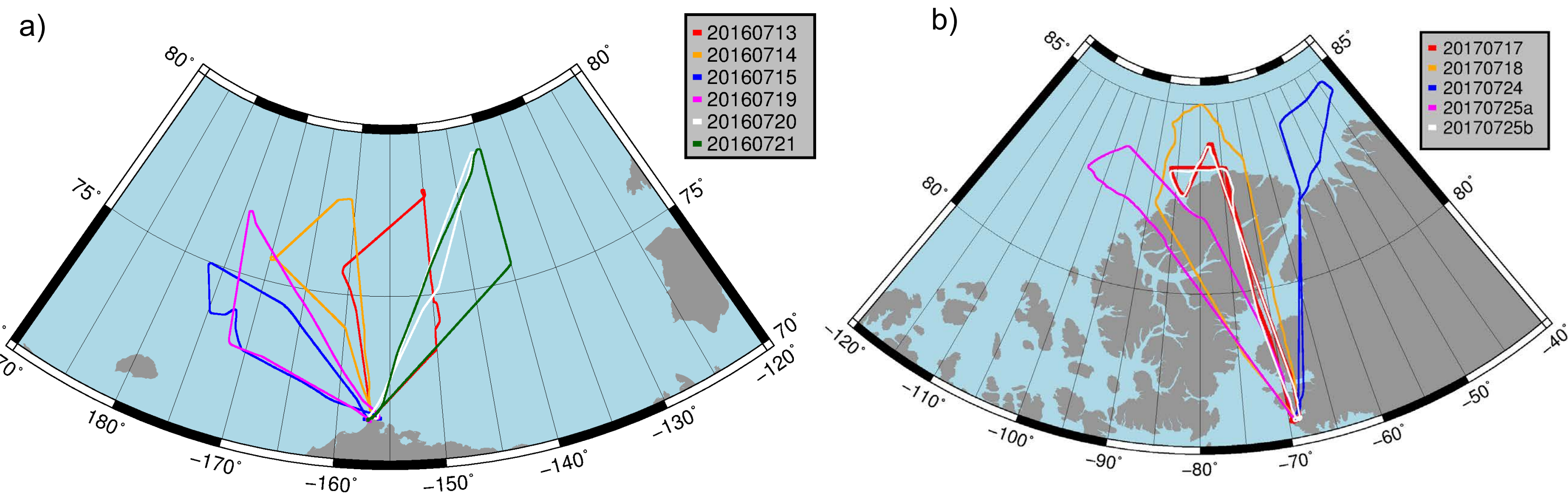
Figure 1: Flight lines for IceBridge Arctic summer campaigns in 2016 in the Beaufort and Chukchi (a) and in 2017 north of Greenland and Ellesmere Island (b).

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.

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

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

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

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

Classifying Melt Pond Pixels

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

A: DMS Data Quality Control

Legend: Eliminated: Land, Eliminated: Cloud, Eliminated: Pixel Size, Eliminated: Roll, Eliminated: Pitch, Images for Analysis

B: Masking DMS Border Pixels

Bin size=1

Lowest mode is border*

*Majority of border pixels masked in first step.

C: Classification of Ice Pixels

Bin size=3, minima, modes

Two modes associated with ice pixels

Rubble pixels brightest in red channel

D: Classification of Open Water

Lowest mode is open water

Bin size=4, modes

E: Results

Legend:
- Level Ice (red)
- Rubble Ice (white)
- Melt Pond (yellow/orange)
- Open Water (blue)

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%