Arctic-Wide Bedfast Lake Ice Mapping With Sentinel-1

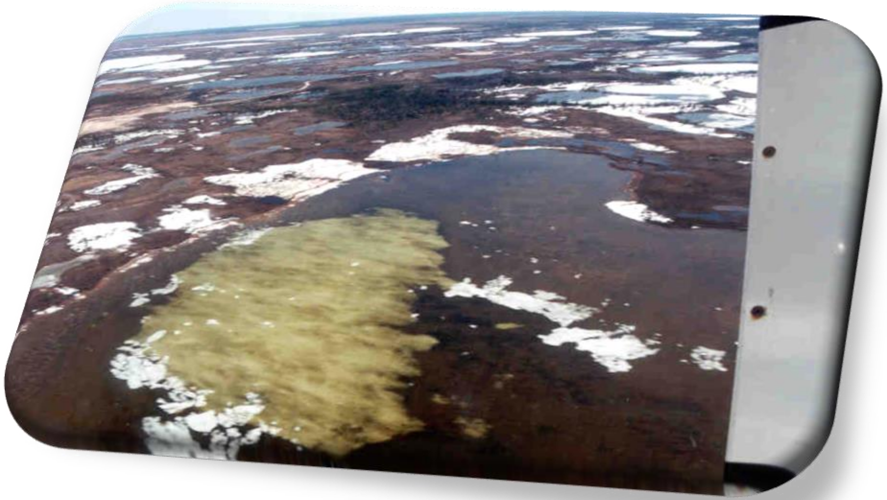
living planet symposium | MILAN 13–17 May 2019

Claude Duguay[1,2] and Junqian Wang[2]

[1] University of Waterloo, Canada
[2] H2O Geomatics, Waterloo, Canada

Background

- Shallow lakes (less than 3-4 m deep) are a widespread feature in many regions underlain by permafrost.
- Knowing when (timing) and where the ice becomes grounded (bedfast) or remains afloat is relevant for climate monitoring and for improving the representation of thermokarst in land surface models.

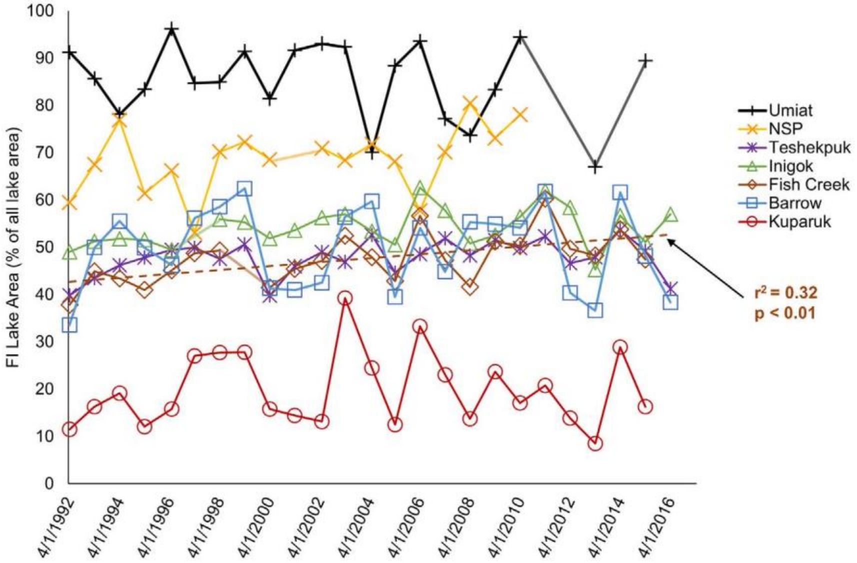


Aerial view – Bedfast and floating ice during spring break-up

Background

- Shallow lakes are showing signs of thinner late-winter (April-May) ice covers in some regions, resulting in a larger fraction of lakes with floating ice.
- A shift from a bedfast ice to a floating ice regime can initiate talik development underneath lakes that could potentially release large stocks of carbon previously frozen in permafrost in the form of methane.

SAR-based floating ice regime (April) for 7 regions of Alaska, USA



Engram et al., 2018

Background

- There has been a longstanding interest in mapping/monitoring the floating ice (FI) and bedfast ice (BI) regime of shallow Arctic/sub-Artic lakes from SAR remote sensing.
- With the exception of Antonova et al. (2016), focus has been on SAR analysis at time of maximum ice thickness (April-May).

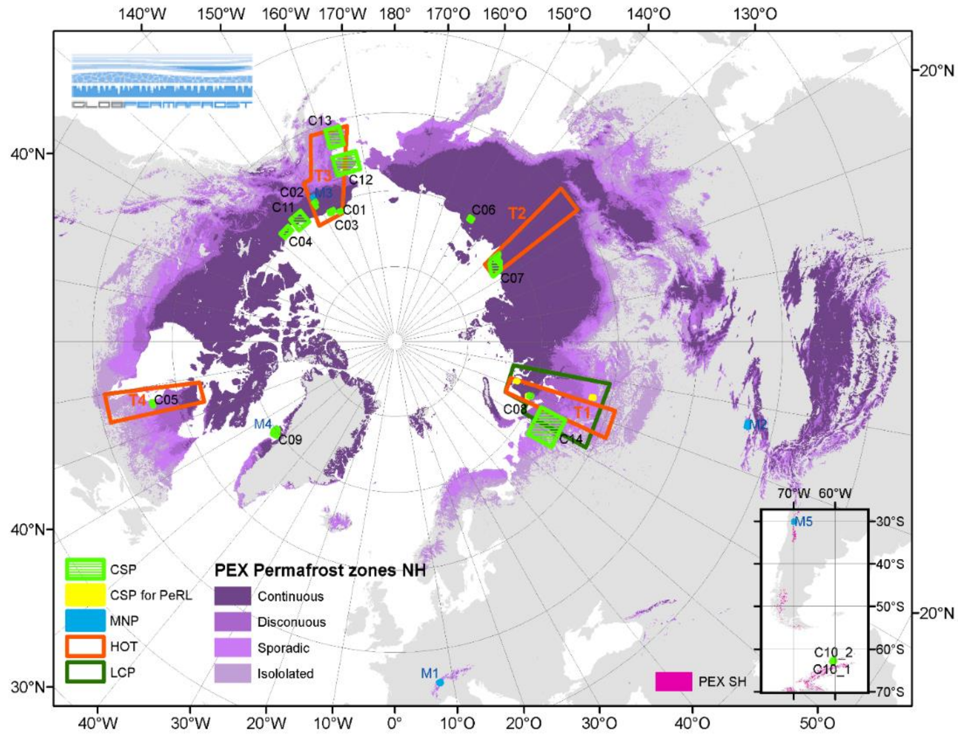
Approach to FI and BI Mapping	Reference
Thresholding	Kozlenko and Jeffries (2000) Duguay and Lafleur (2003) Brown et al. (2010) Arp et al. (2012) Grunblatt and Atwood (2014) Bartsch et al. (2017) Engram et al. (2018) Pointner et al. (2018)
Region-based	Surdu et al. (2014) Pointner et al. (2018)

Objectives

As the primary contribution to ESA's DUE GlobPermafrost project (2016-2019): to evaluate various algorithms for the generation of a lake ice product (bedfast and floating ice) from Sentinel-1A/B Extra Wide Swath (EW) imagery (**April**, 2015-2018) for service case regions.

- To generate novel products (40-m grid) from EW and Interferometric Wide Swath (IW) imagery for **full ice seasons** consisting of:
  1. Day of year (DOY) when the ice becomes bedfast
  2. Lake bathymetry *(up to the maximum ice thickness reached by the end of winter)*

Service Case Regions



ID	Region name
C01	Barrow (Alaska, USA)
C03	Teshekpuk (Alaska, USA)
C04	Mackenzie Delta (Canada)
C06	Kytalyk (Russia)
C07	Lena Delta (Russia)
C08	Yamal (Russia)
C12	Seward Peninsula (Alaska, USA) C12_1 Cape Espenberg Lowland C12_2 Central Seward Peninsula

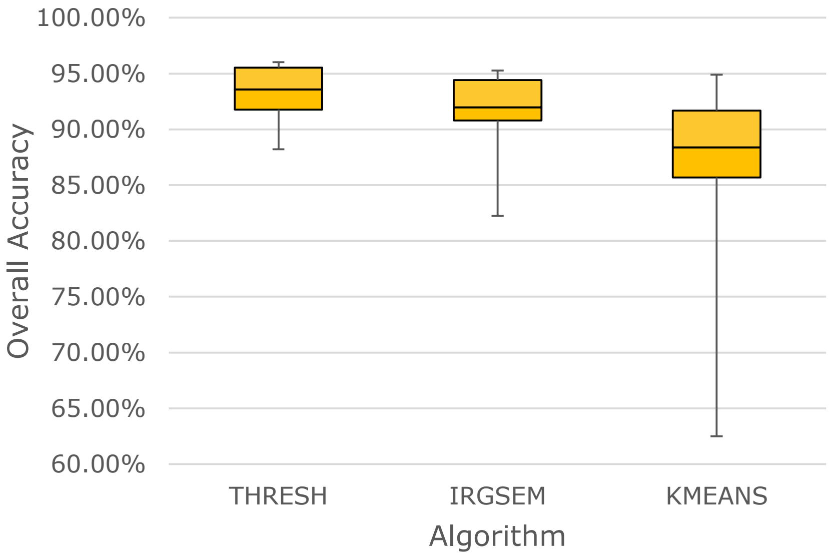
Evaluation of Algorithms

1. Image thresholding

- The magnitude of drop in backscatter intensity from floating to bedfast ice is used with incidence angle normalization

2. Unsupervised image segmentation approaches

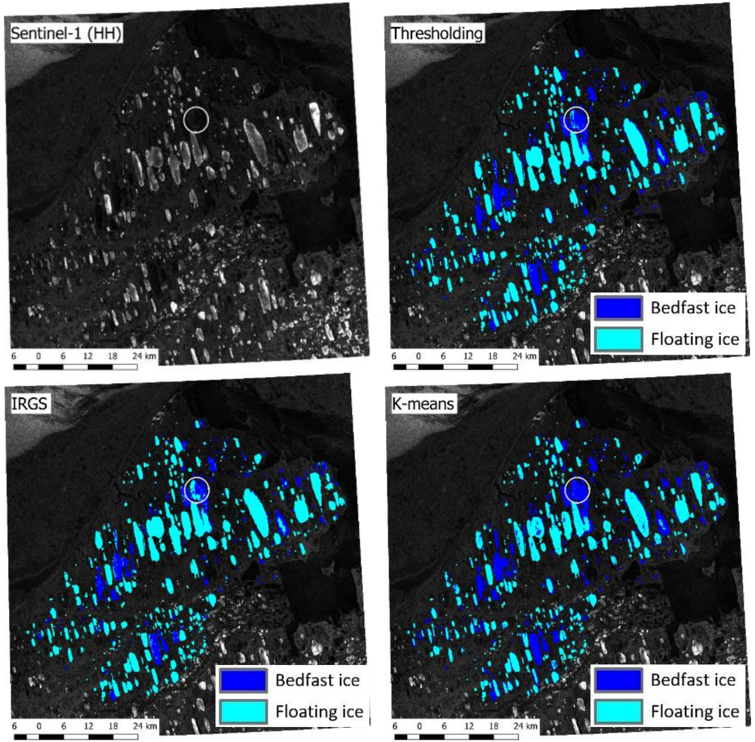
- K-means
- Iterative Region Growing using Semantics (IRGS) algorithm (Clausi et al., 2010; Surdu et al., 2014)



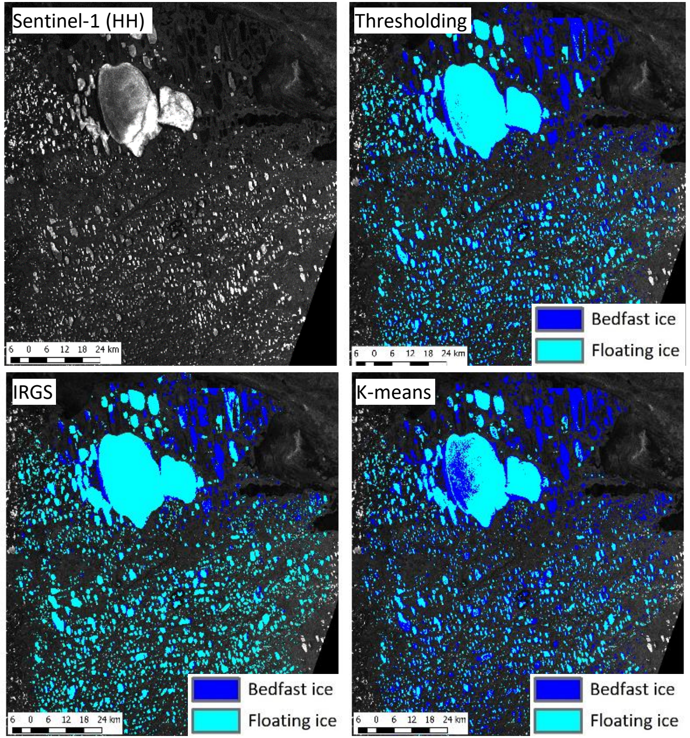
n = 6000
(6 lake regions - Alaska, Canada and Russia)

Evaluation of Algorithms

Barrow, Alaska (17 April 2017)

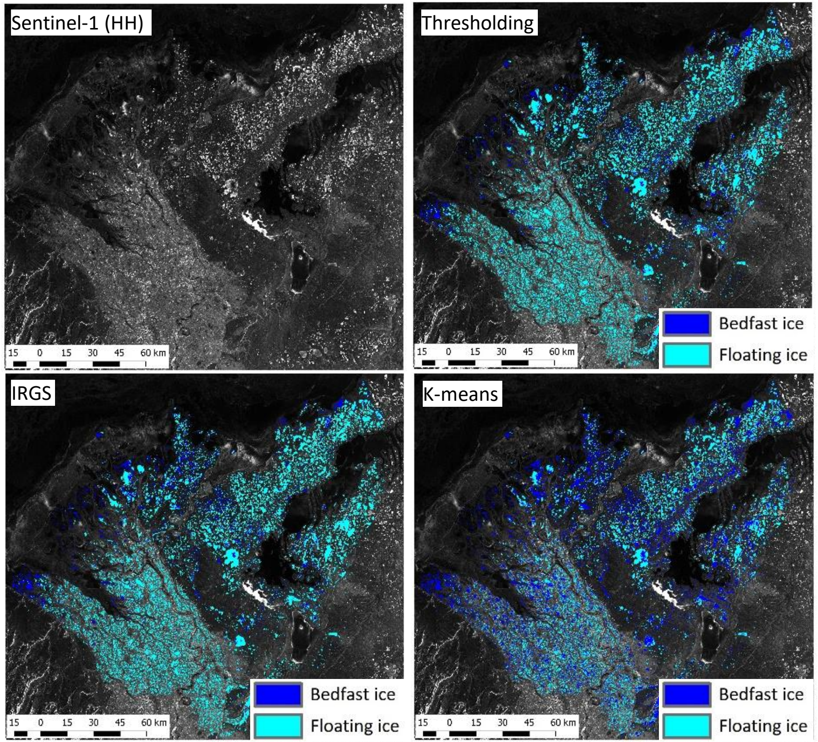


Teshekpuk, Alaska (12 April 2016)

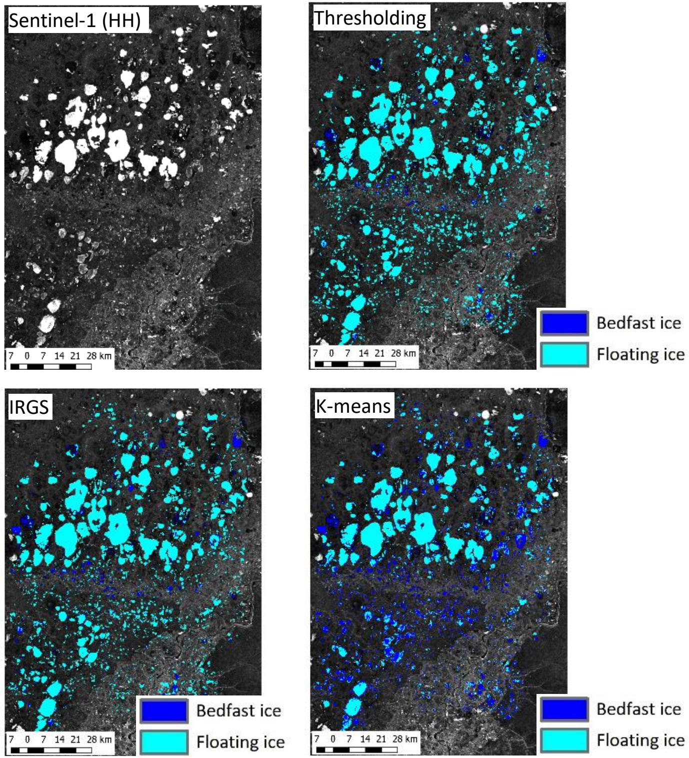


Evaluation of Algorithms

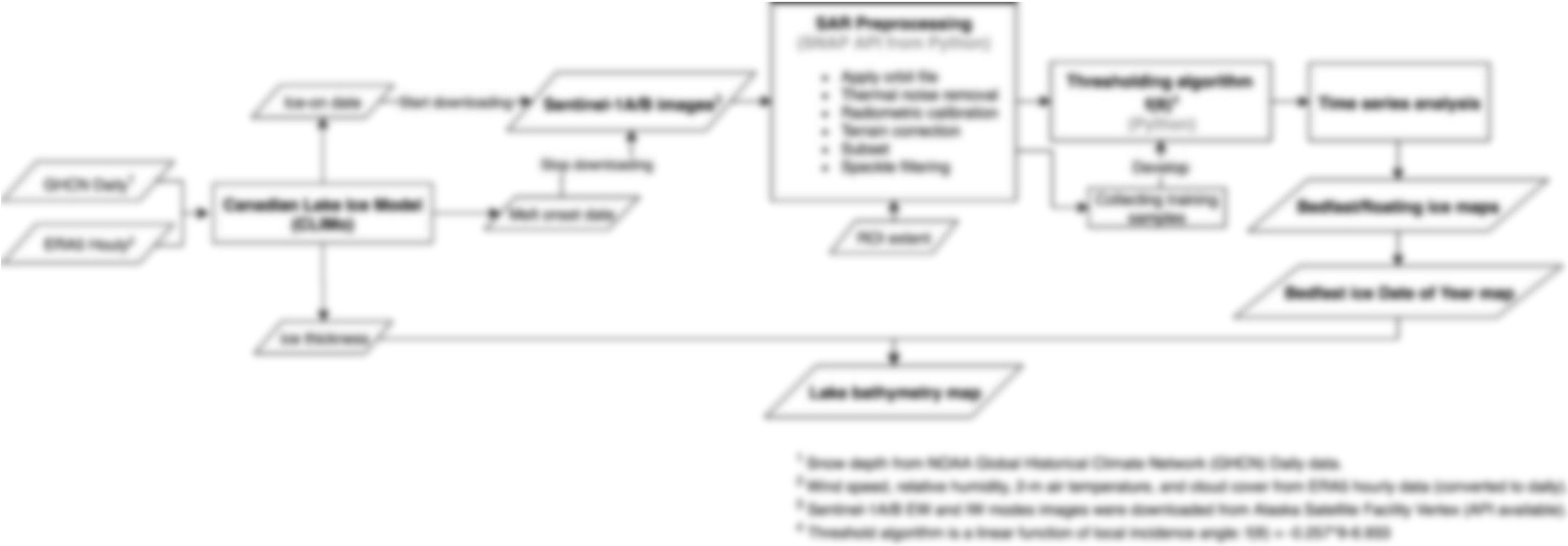
Mackenzie Delta, Canada (24 April 2017)



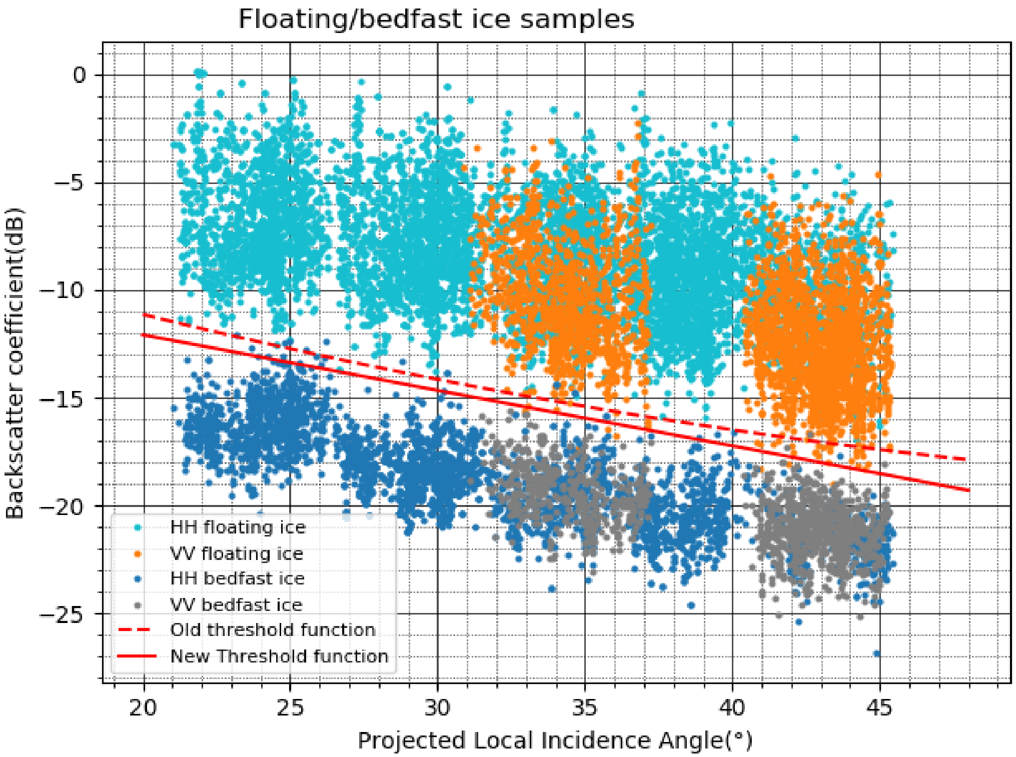
Kytalyk, Russia (22 April 2016)



Bedfast/Floating Ice Processing Chain

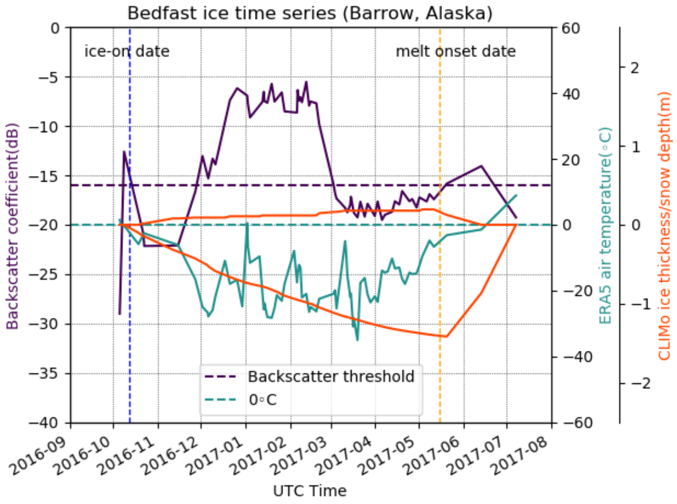


Thresholding Algorithm

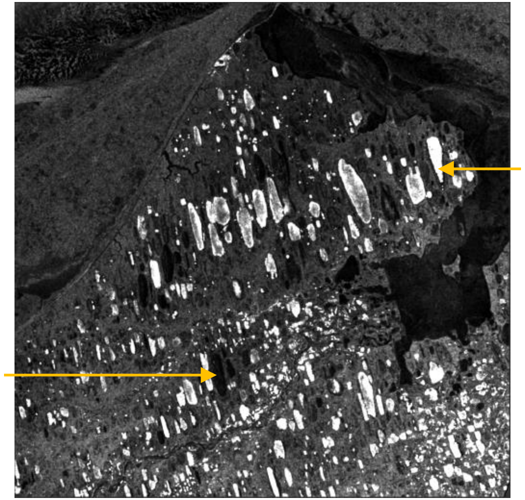


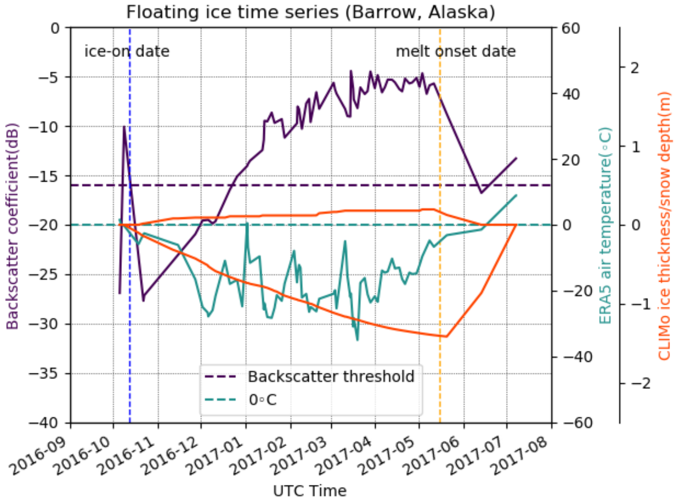
Backscatter, air temperature, ice thickness

EW only: Oct 2016 – Jul 2017 (87 images)



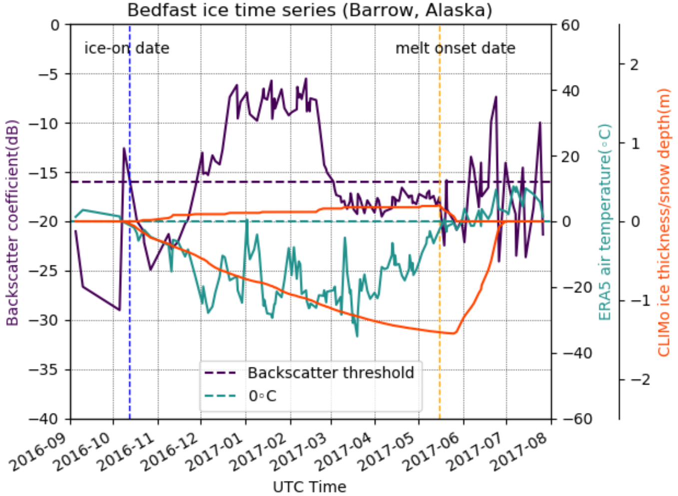
Sentinel-1 (Barrow, Alaska)



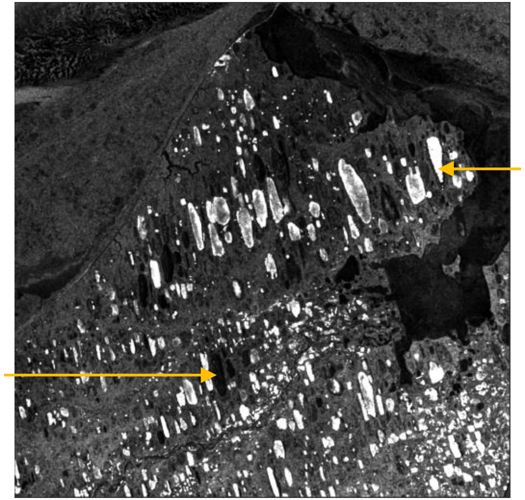


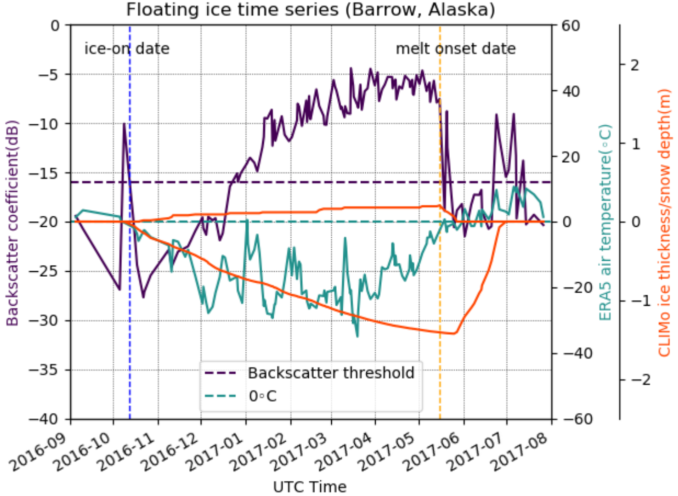
Backscatter, air temperature, ice thickness

EW + IW: Sep 2016 – Jul 2017 (153 images; 89 images from ice-on to melt onset)



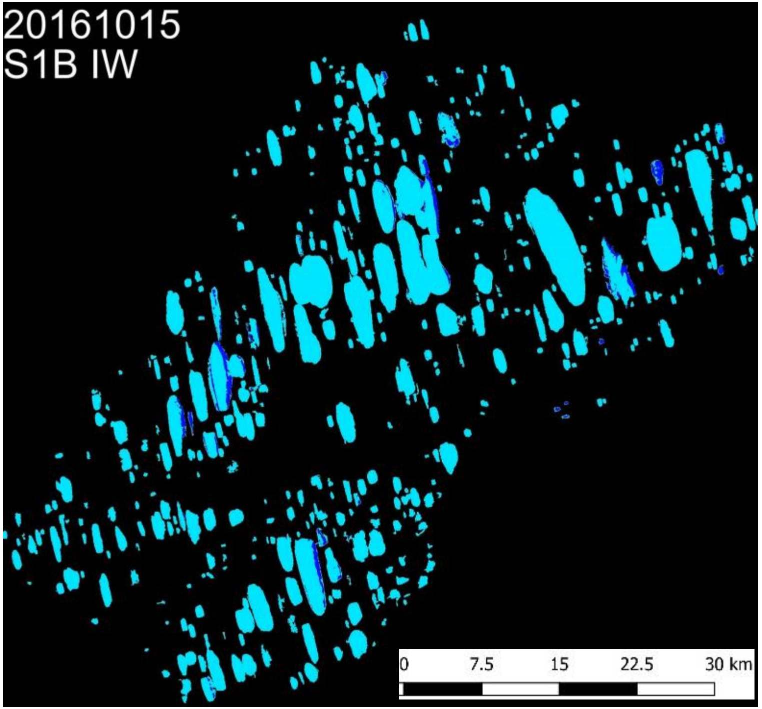
Sentinel-1 (Barrow, Alaska)



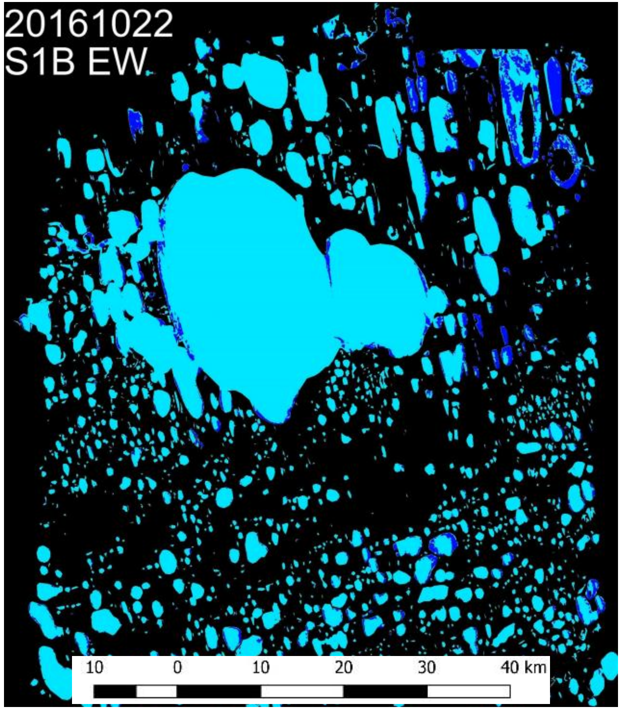


Bedfast/Floating Ice Maps From Time Series

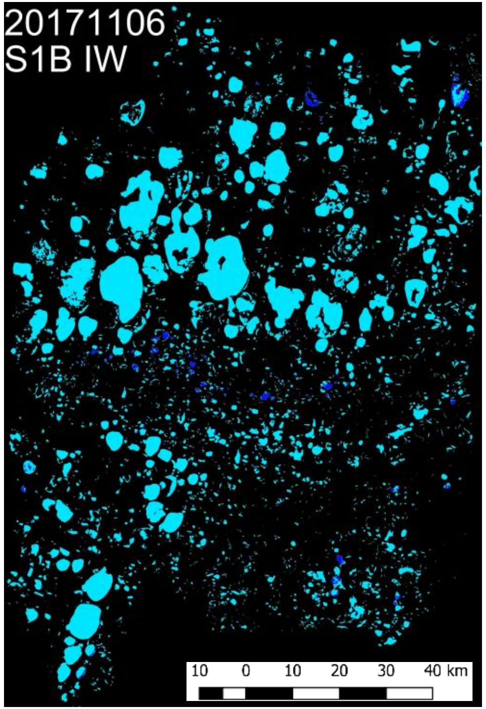
Barrow, Alaska
(89 images, 2016-2017)



Teshekpuk, Alaska
(28 images, 2016-2017)

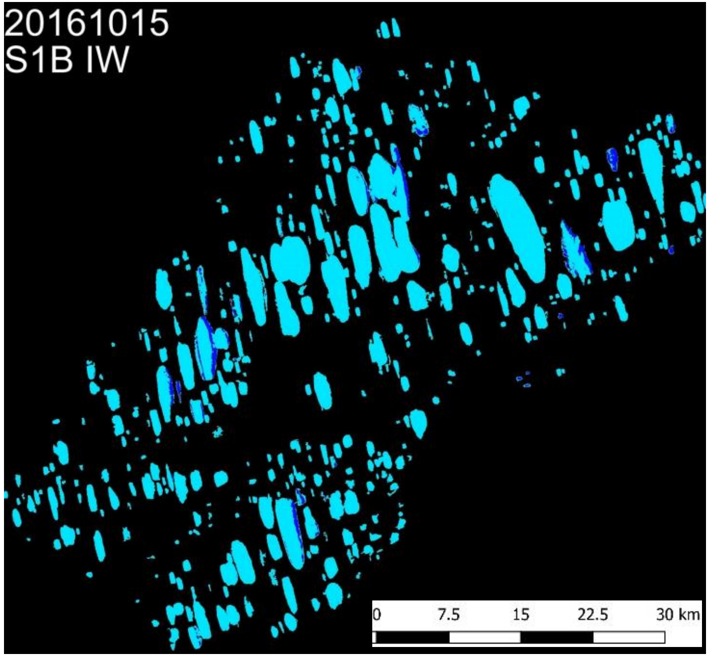


Kytalyk, Russia
(16 images, 2017-2018)

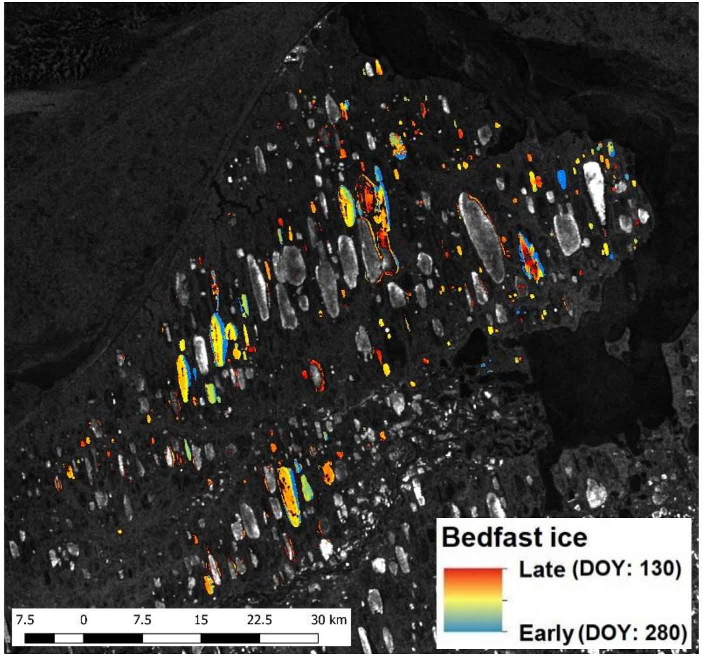


From BI/FI Maps to DOY Bedfast Ice Map

Barrow, Alaska
(89 images, 15 Oct 2016- 15 May 2017)

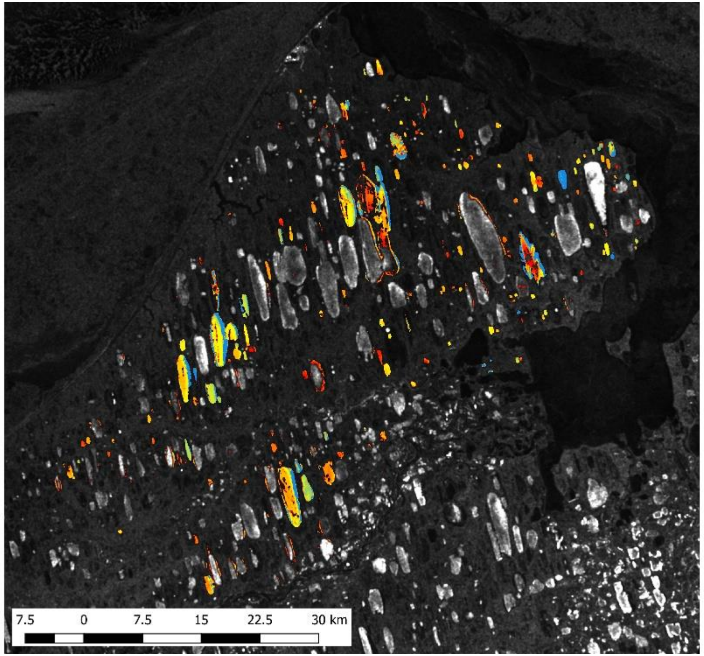


Barrow, Alaska
(DOY bedfast ice, 2016-2017)

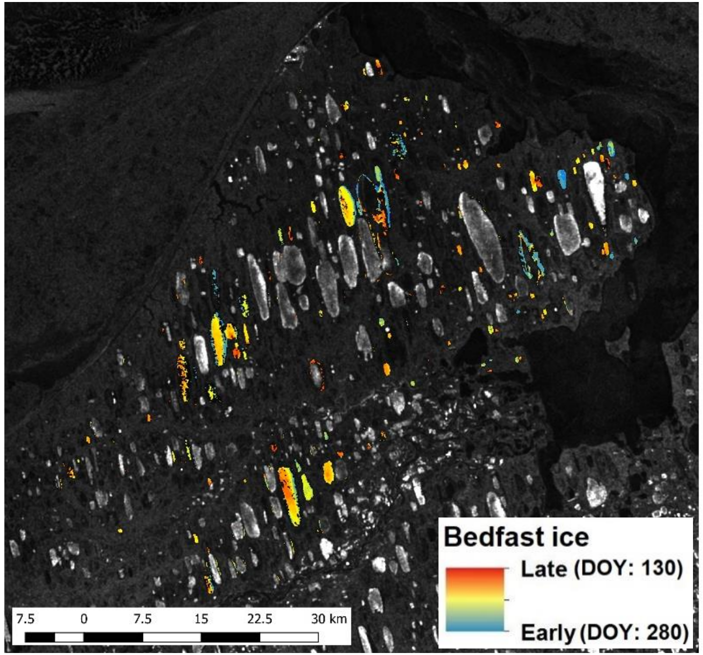


DOY Bedfast Ice Maps

Barrow, Alaska (C01)
(winter 2016-2017)

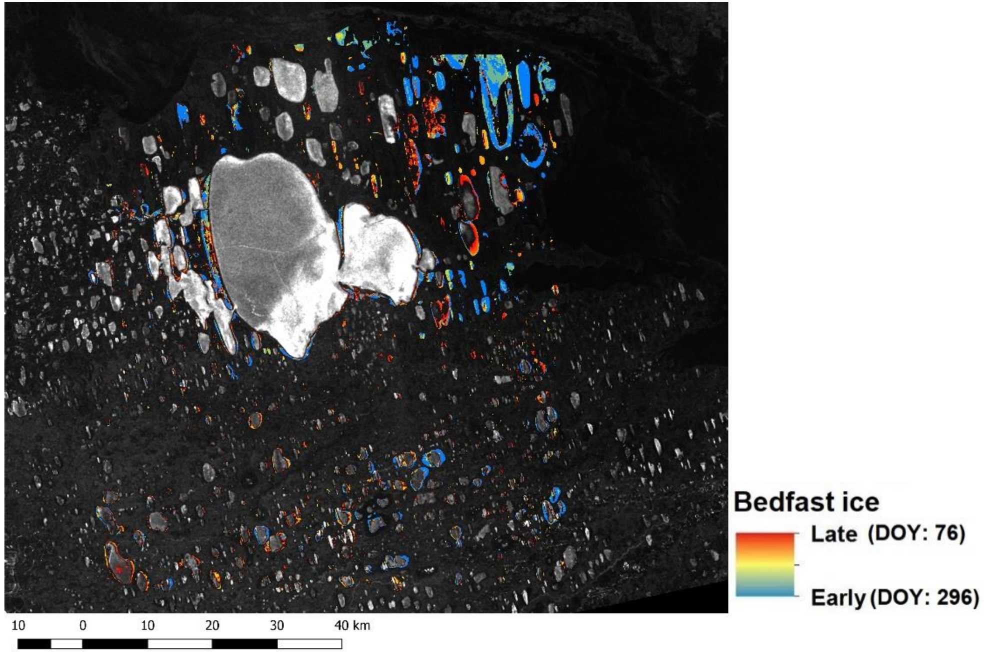


Barrow, Alaska (C01)
(winter 2017-2018)

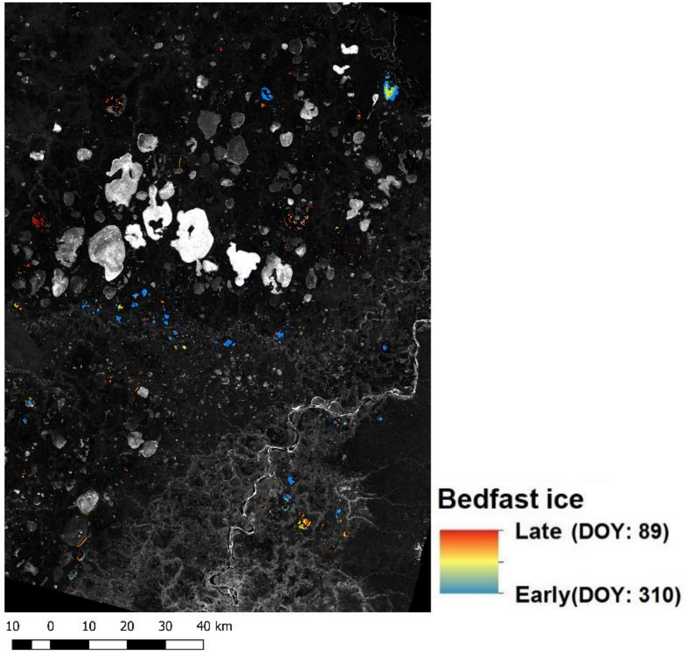


DOY Bedfast Ice Maps

Teshekpuk, Alaska (C03)
(28 images, 2016-2017)

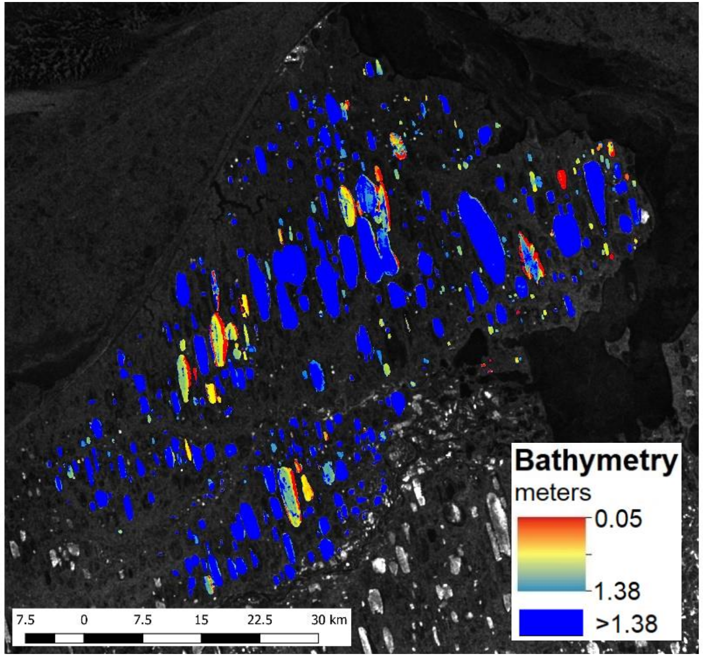


Kytalyk, Russia (C06)
(16 images, 2017-2018)

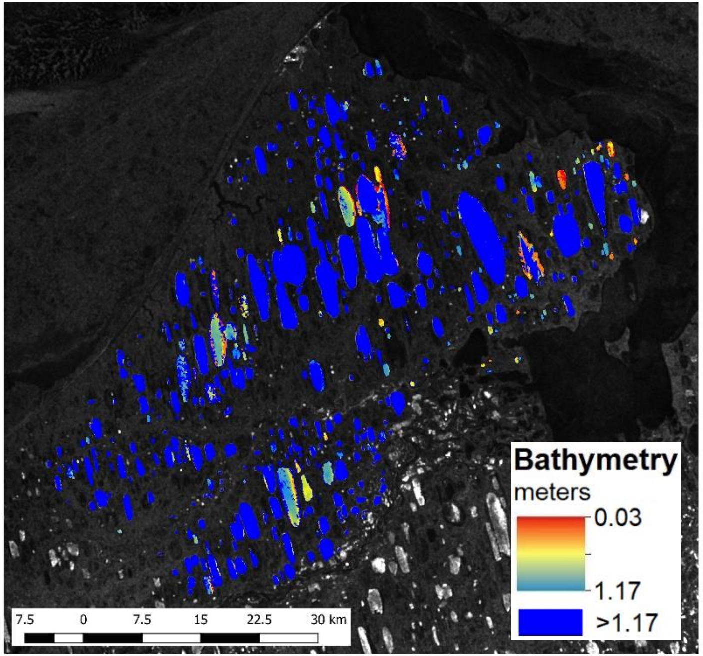


Lake Bathymetry Maps

Barrow, Alaska
(winter 2016-2017)

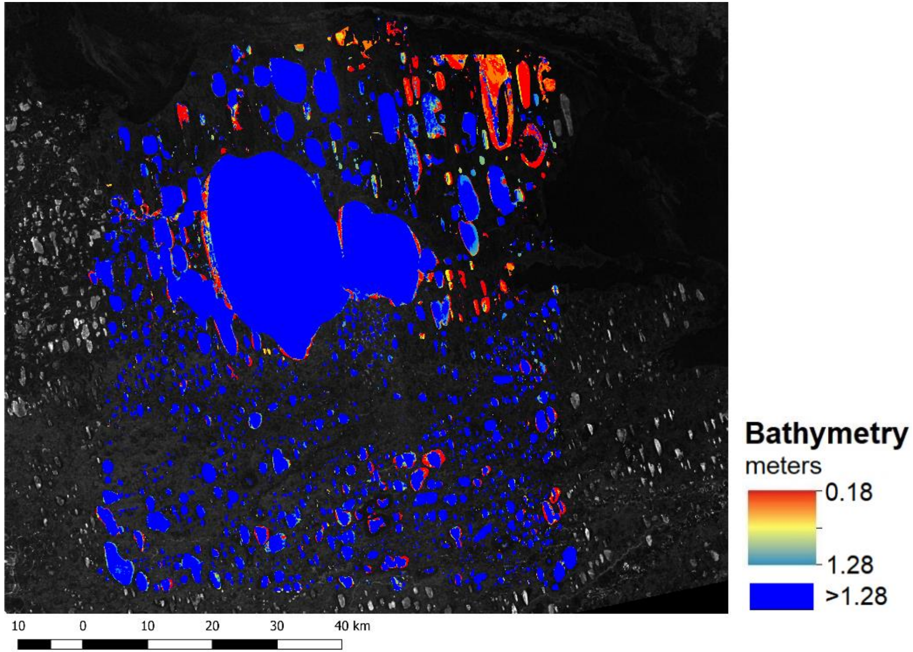


Barrow, Alaska
(winter 2017-2018)

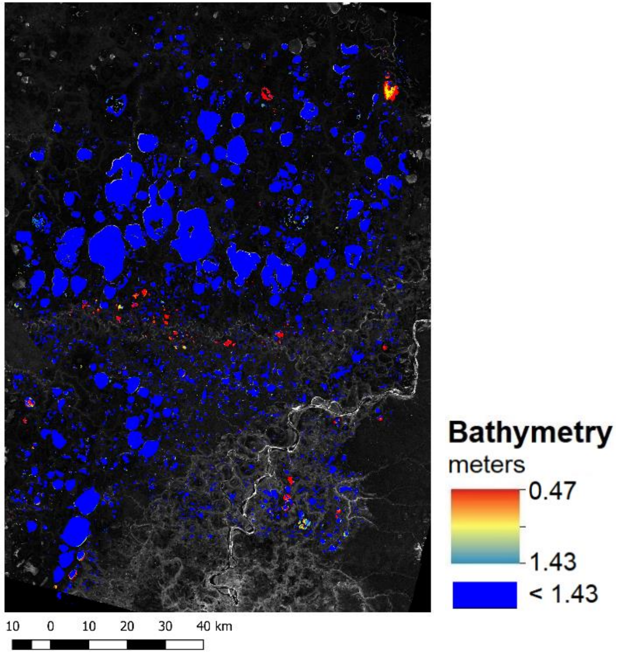


Lake Bathymetry Maps

Teshekpuk, Alaska (C03)
(winter 2016-2017)



Kytalyk, Russia (C06)
(winter 2017-2018)



Moving Forward

- Create a Climate Data Record (CDR) from archived (late winter) ERS-1/2, RADARSAT-2, Envisat and Sentinel-1 SAR data for multiple shallow-lake regions (e.g. Surdu et al., 2014; Engram et al., 2018 for Alaska; 20 -25 years)
- Further develop and evaluate DOY and bathymetry products from high-density time series (Sentinel-1 EW/IW modes)
- Integrate data from the Canadian RADARSAT Constellation Mission (RCM – scheduled for launch 11 June 2019) in the processing chain as soon as they become available

Thank you for your attention!

@crduguay