Monitoring the Dynamics of Shallow Arctic Water Bodies from Space

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Mapping Water Bodies from Space Conference
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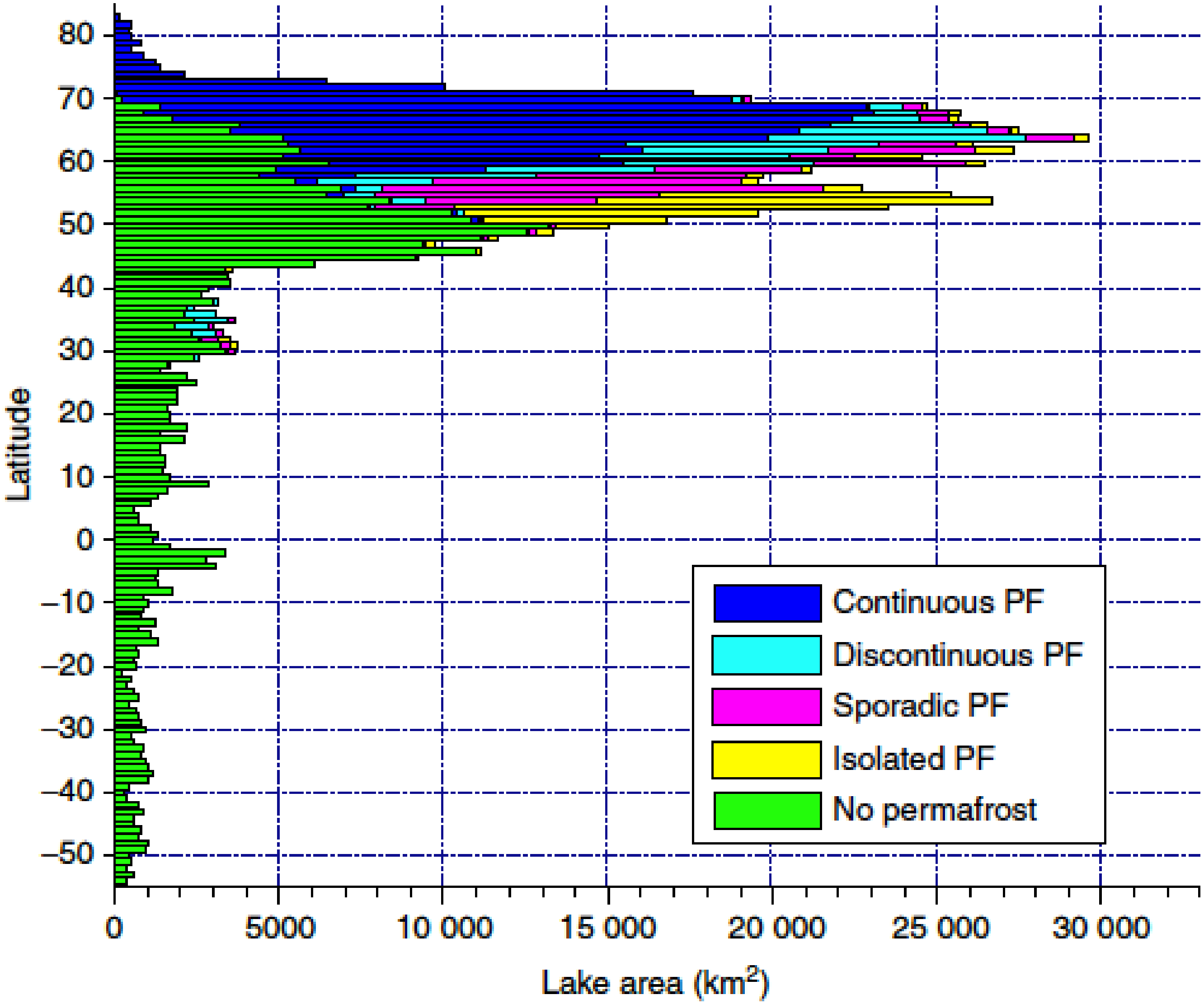
Background

Distribution of Water Bodies

Background



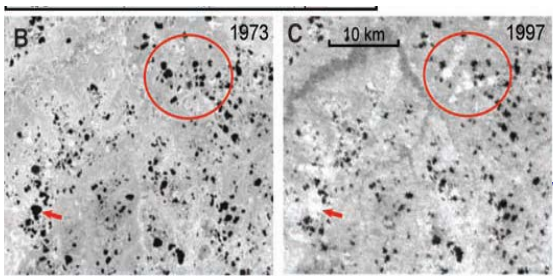
Plot of global lake area distribution as a function of latitude. *The majority of the Earth's lake area occurs in high northern latitudes (permafrost regions).*

Grosse *et al.*, 2013

Dynamics of Shallow Arctic Water Bodies

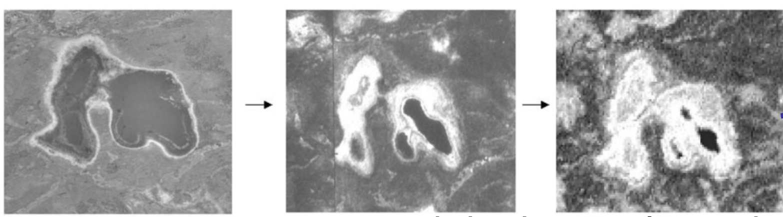
Shallow water bodies (i.e. lakes and ponds ca. less than 4 m deep)

Siberia



(Smith *et al*, 2005)

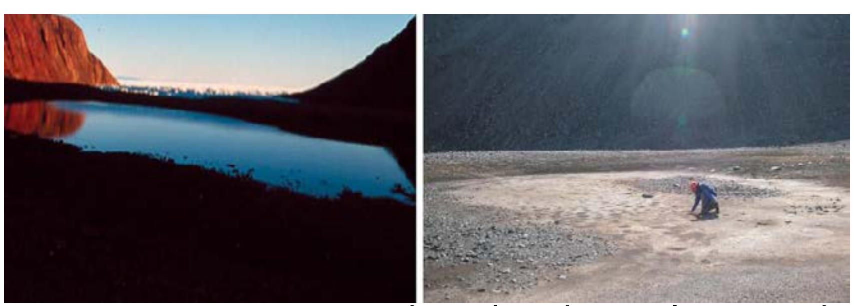
Alaska



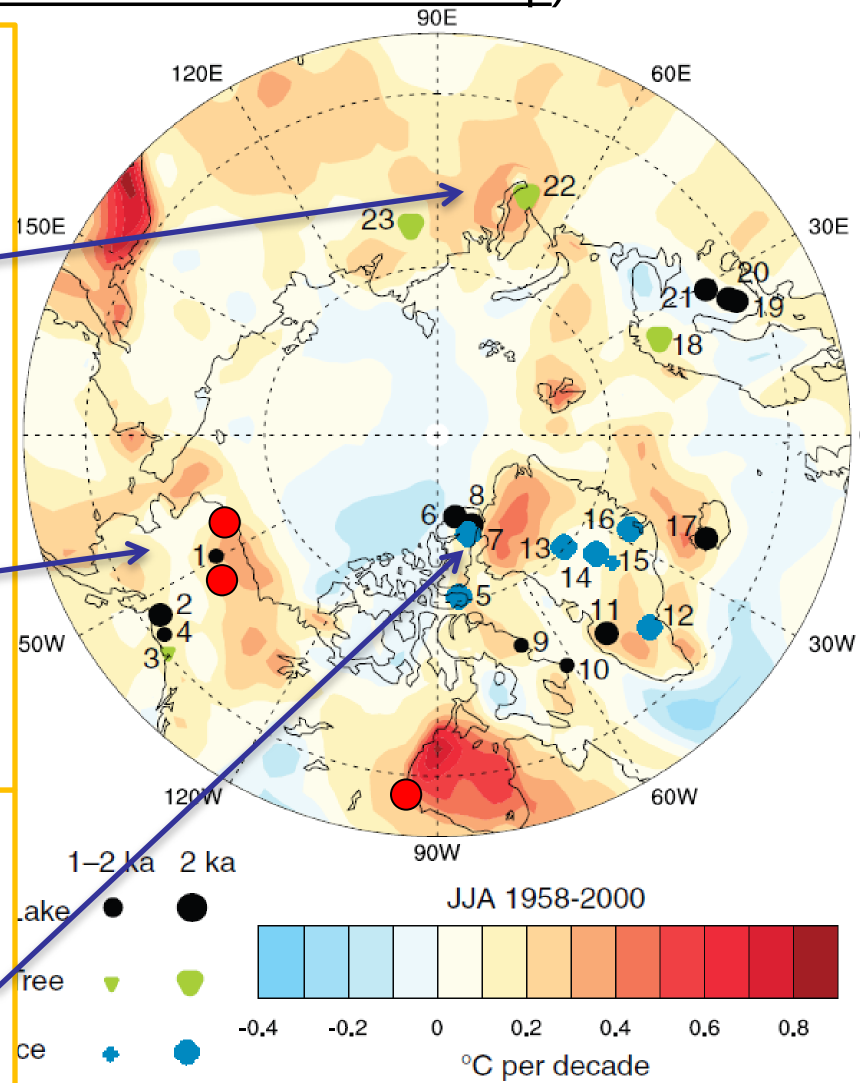
(Riordan *et al*, 2006)

1950s 1970s 2000

Nunavut



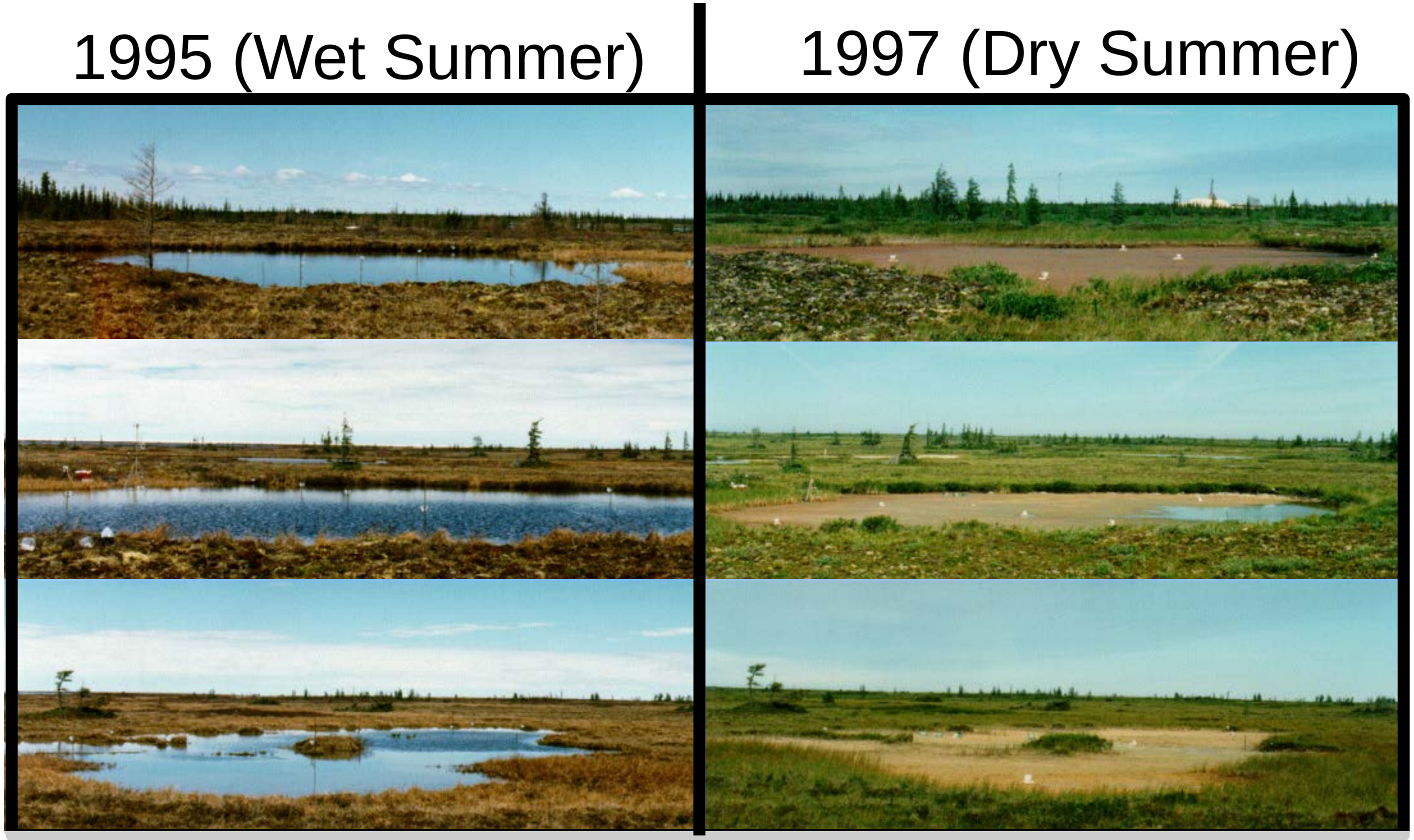
(Smol and Douglas, 2007)



Study areas in this presentation

(Modified from Kaufman *et al*, 2009)

Dynamics of Shallow Arctic Water Bodies



- ***Are shallow water bodies drying or expanding with Arctic climate change?***
- ***What factors are driving trends and variability?***
- ***What parameters should be monitored from space for furthering our understanding of the response of these water bodies to a changing Arctic climate?***

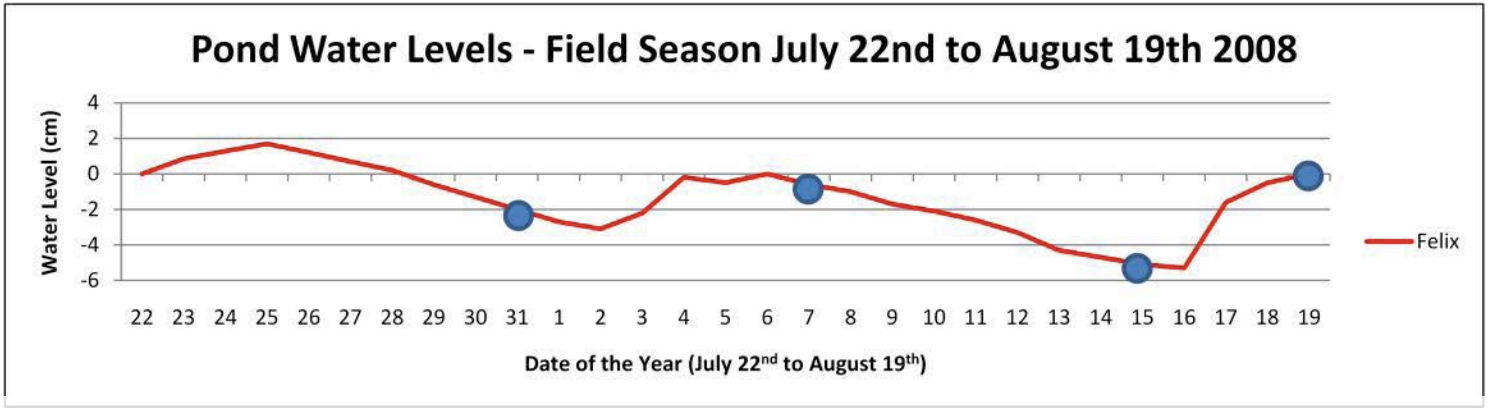
Dynamics of Shallow Arctic Water Bodies

July 31st 2008

August 7th 2008

August 15th 2008

August 19th 2008



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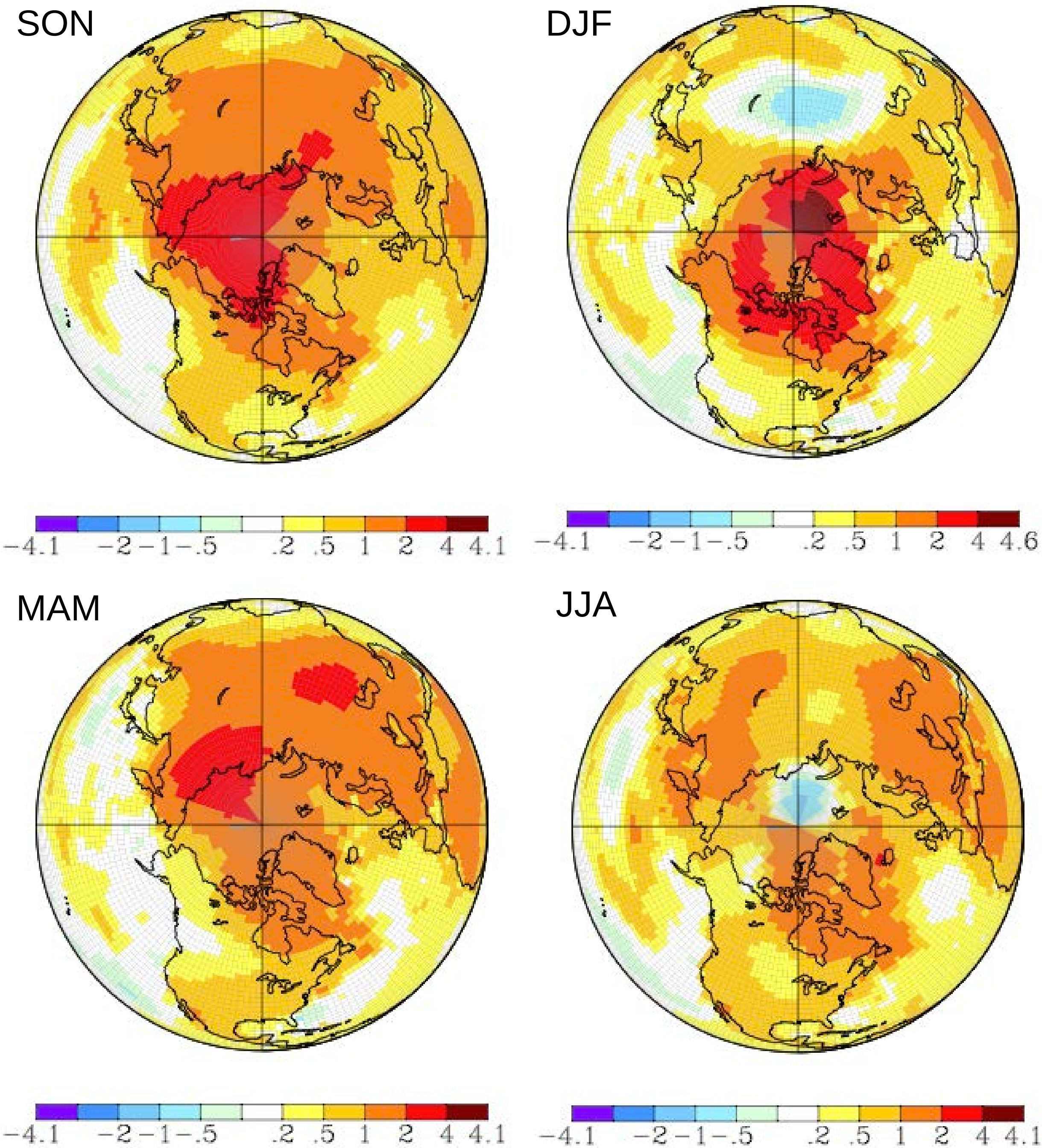


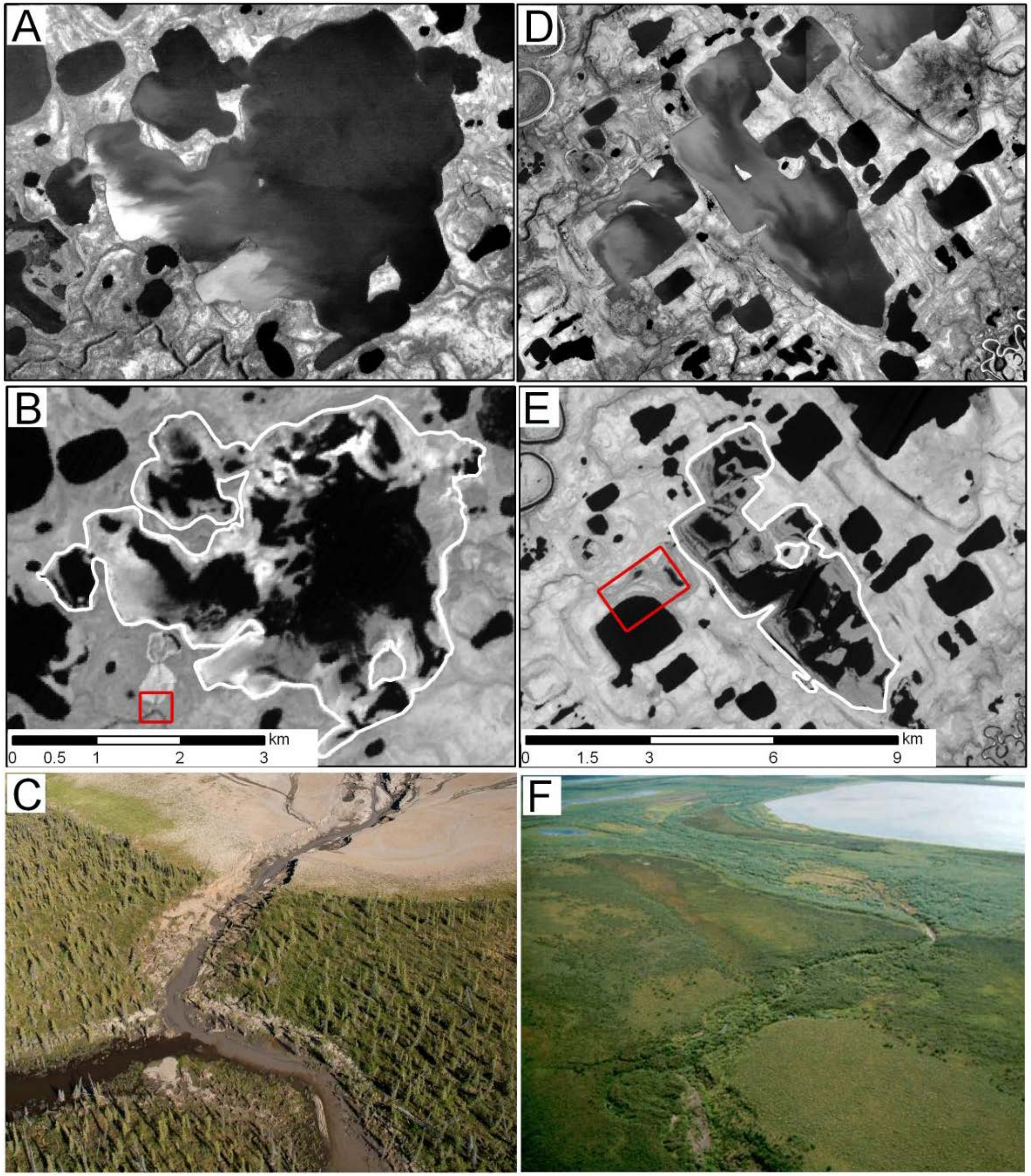
Data source: http://data.giss.nasa.gov/gistemp/

<u>Seasonal surface air temperature anomalies</u>
2005-2014 relative to 1951-2000)

Shallow Arctic Water Bodies from Space: Recent

Monitoring of shallow Arctic water bodies from space

- Work to date has largely focused on mapping changes (trends) in the areal extent of shallow lakes and ponds.
  - Aerial photographs (ca. last 60 years) and very high (< 2 m), high (~2-30 m), and moderate (~100-250 m) spatial resolution satellite imagery have been used with focus on optical (largely manual digitizing).
  - Occasionally supported by estimates of water balance (Precipitation minus Evaporation; P-E) to relate change to a regional climate signal. Also, lakes that have sharp banks/flat bottoms may experience a change in water level which is not expressed by a change in areal extent.
  - Monitoring changes in **areal extent** is useful but it provides only one of several parameters needed to document and understand the dynamics of shallow Arctic lakes. ***We need to take a more holistic approach***.
  - Other parameters of interest obtainable from satellite remote sensing include: **water level, fraction of bedfast ice, ice freeze-up/break-up dates** and duration, surface water temperature, and water turbidity (and gyres).



Aerial extent

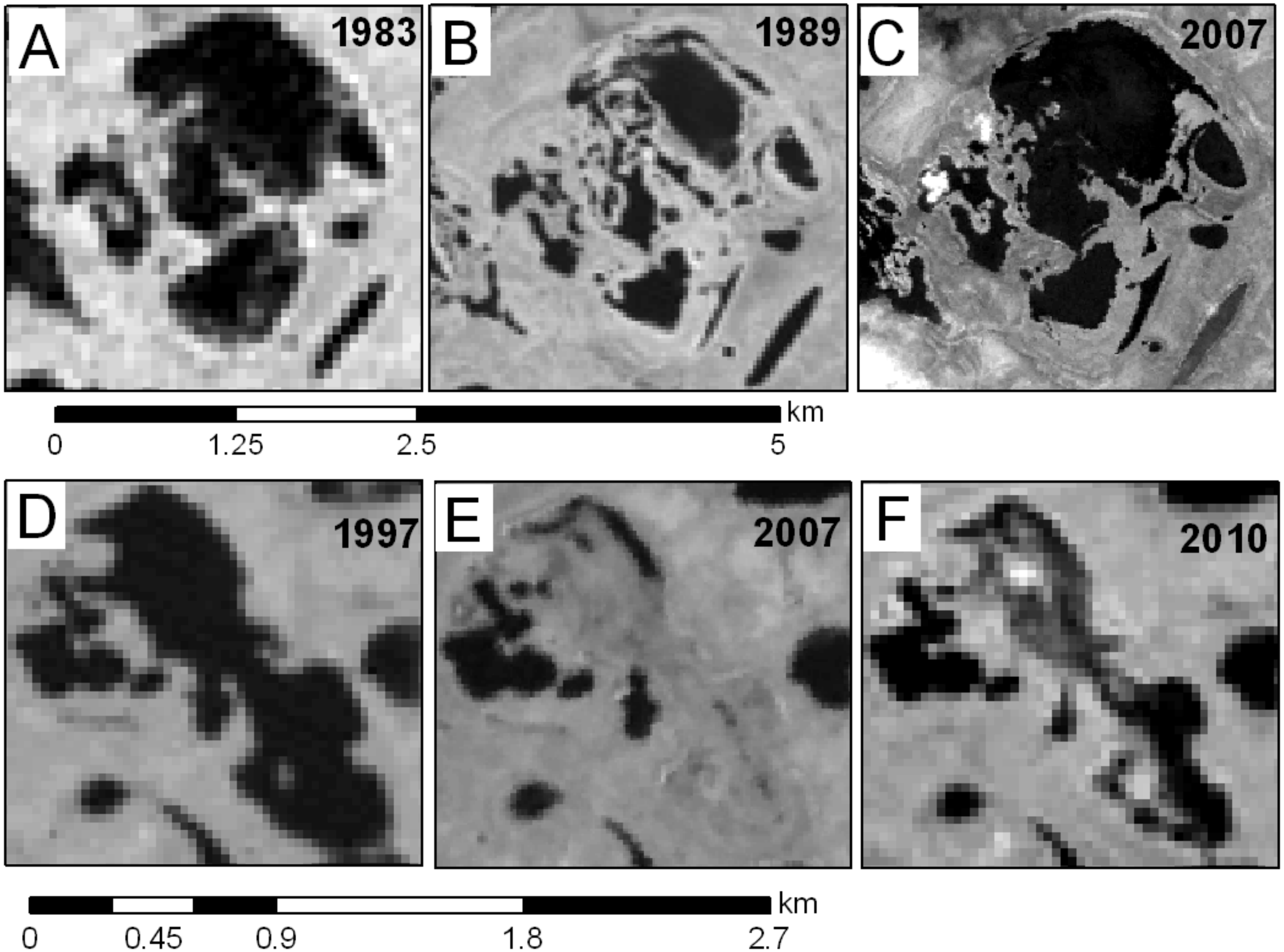
Examples of two large catastrophic drainages in Old Crow Flats, YT, Canada:

A) ***<u>Zelma Lake</u>*** prior to drainage in 1972, **B)** Zelma lake following catastrophic drainage in 2007, **C)** oblique photo showing the new outlet where Zelma lake drained into the Crow River,

D) ***<u>Netro Lake</u>*** in 1972 prior to Drainage, **E)** Netro lake in 2007, 24 years following catastrophic drainage, **F)** oblique photo showing the outlet where Netro lake drained into the Crow River in 1983.

Labrecque *et al.*, 2009
Lantz and Turner, in press

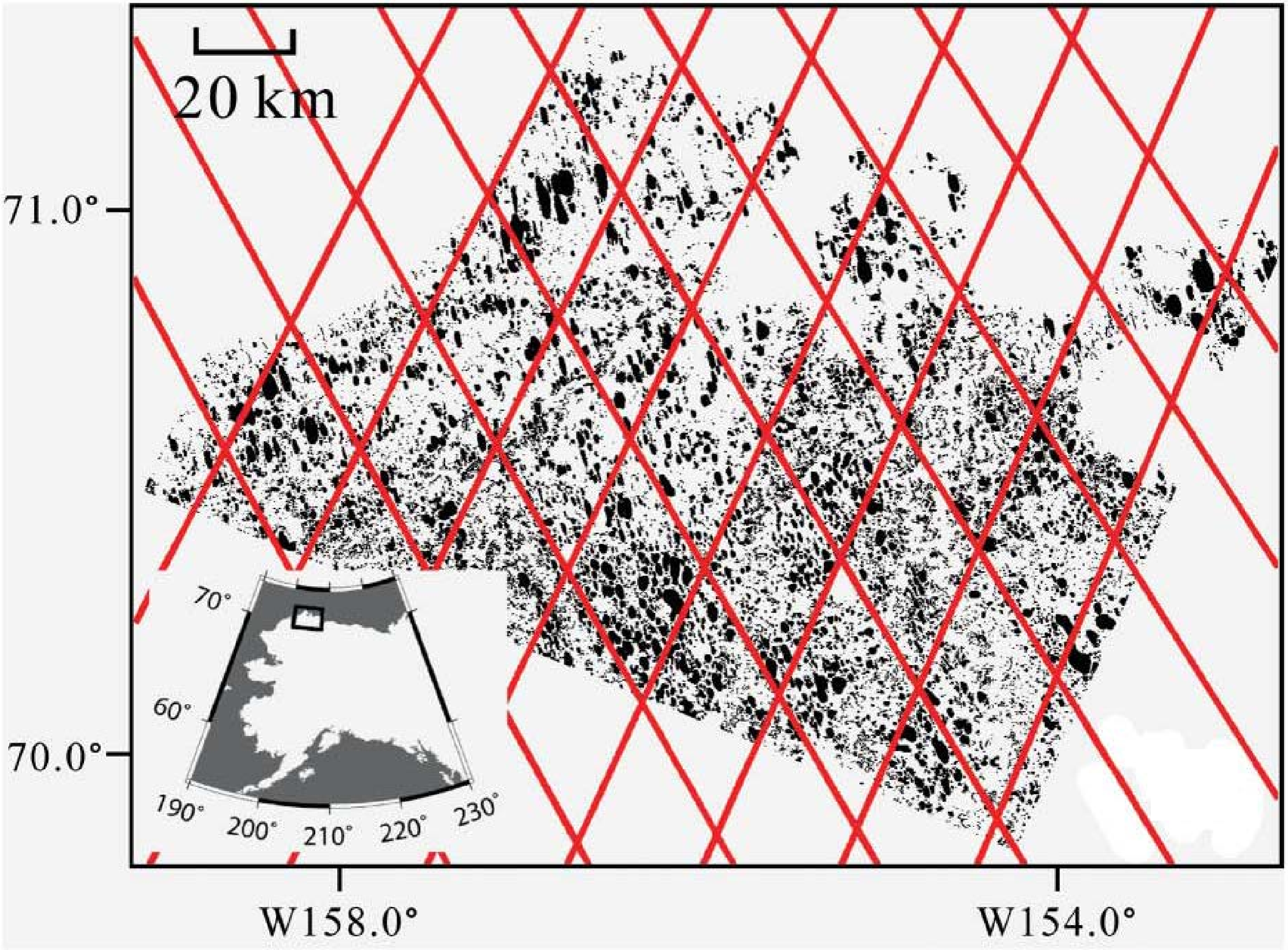
Aerial extent



Examples of bi-directional fluctuations in lake area in the Old Crow Flats. Images A-F show lakes that exhibit decreases followed by increases in areal extent.

Lantz and Turner, in press

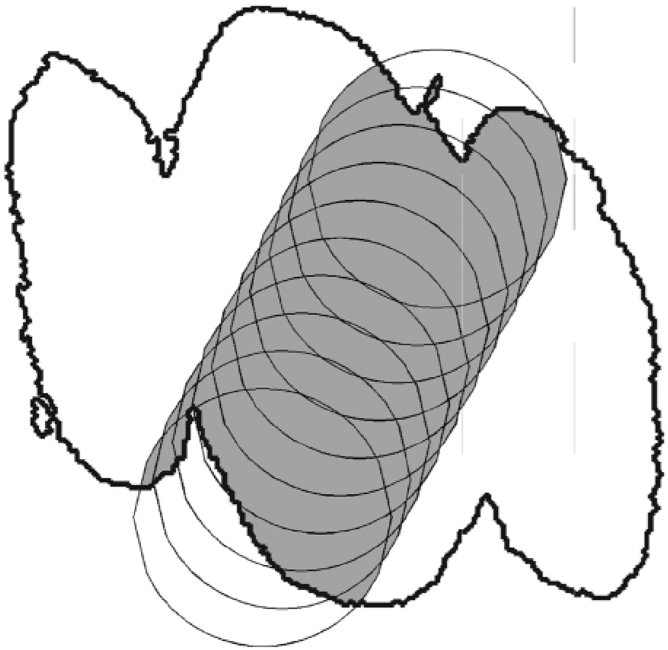
Water level

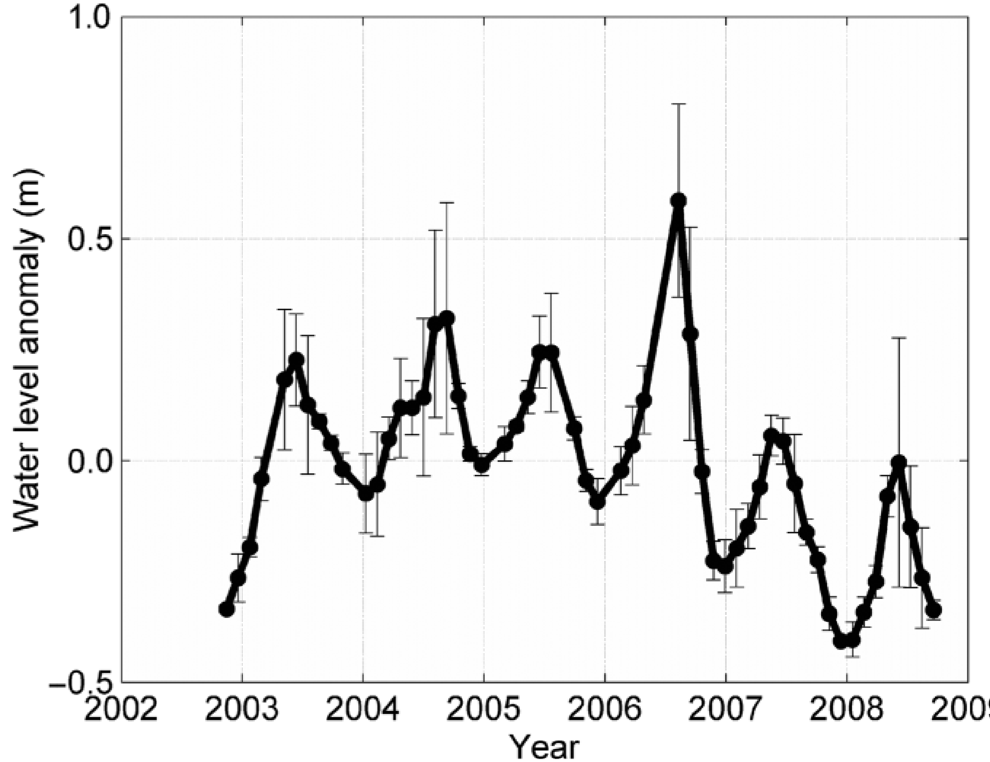


Water mask with Envisat tracks over North Slope of Alaska

Lee *et al.*, 2010

Water level

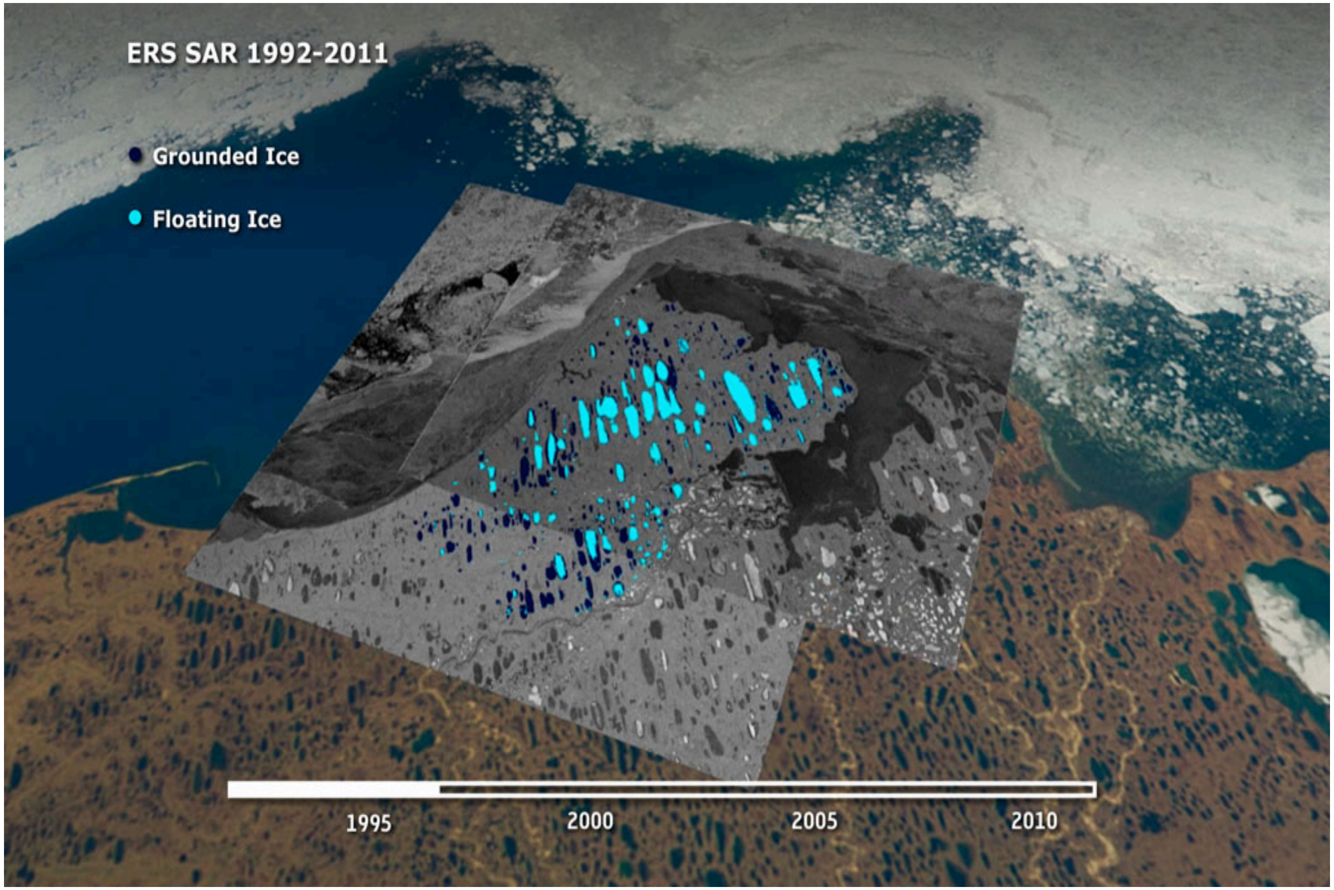




Examples of Envisat-observed water elevation anomaly over lake on North Slope of Alaska.

Lee *et al.*, 2010

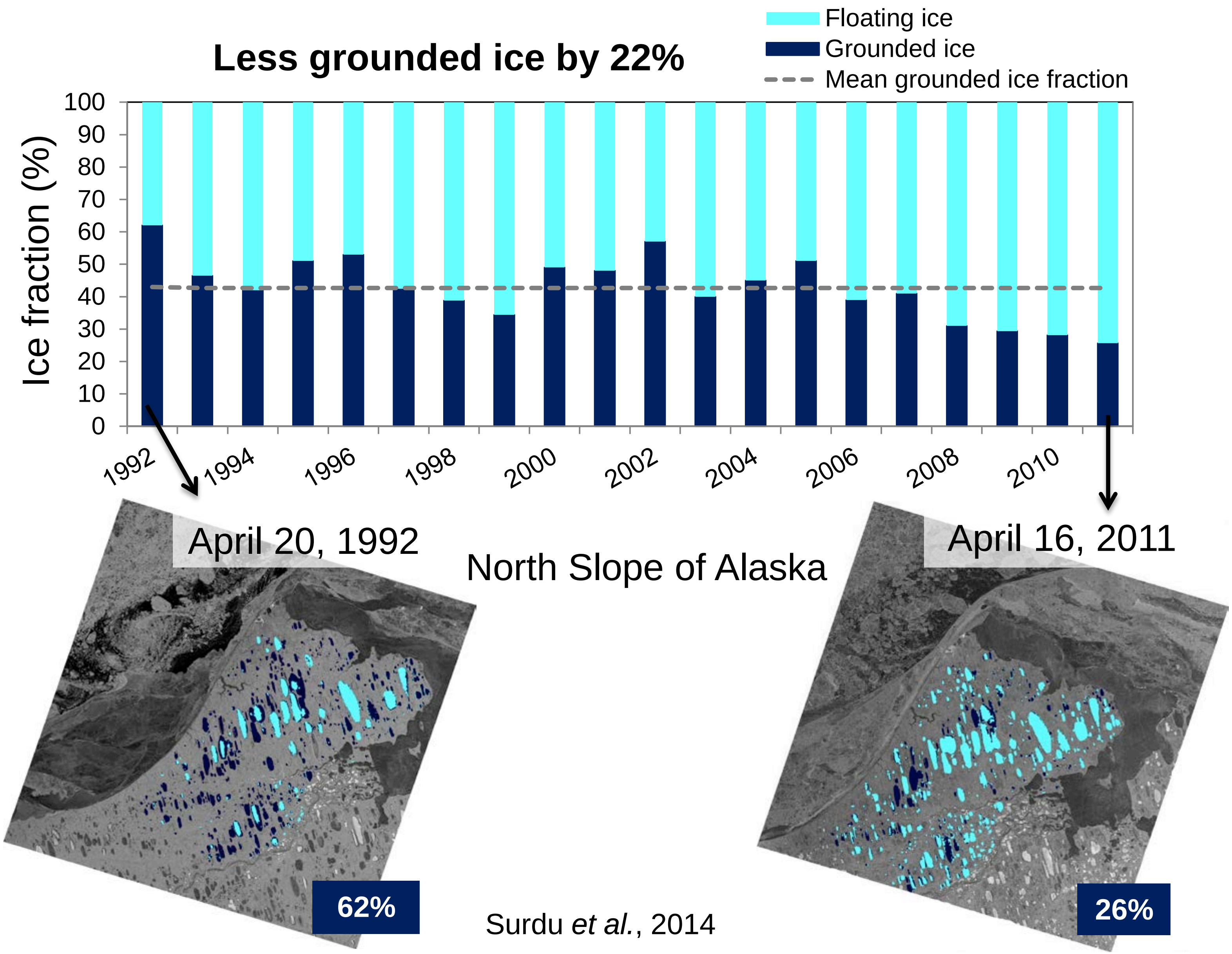
Fraction of bedfast ice



- ERS-1/2 SAR imagery (C-band, VV-pol 100-m pixels; 35-day repeat pass), North Slope of Alaska
- Image segmentation with Iterative Region Growing with Semantics (IRGS)
- Percentages (%) of grounded (bedfast) and floating ice

Surdu *et al.*, 2014

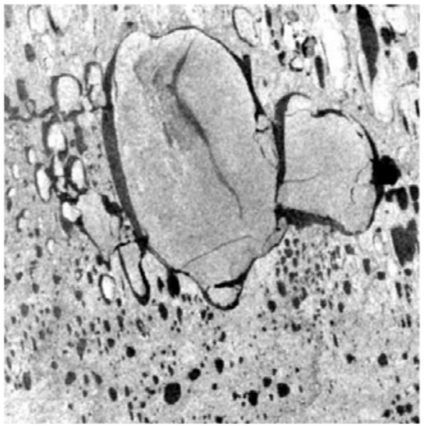
Fraction of bedfast ice



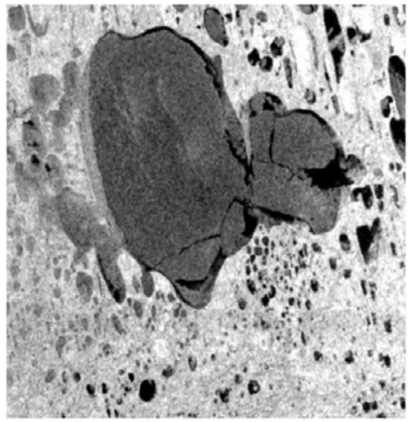
Surdu *et al.*, 2014

Break-up/freeze-up dates

ASAR WS (2008)

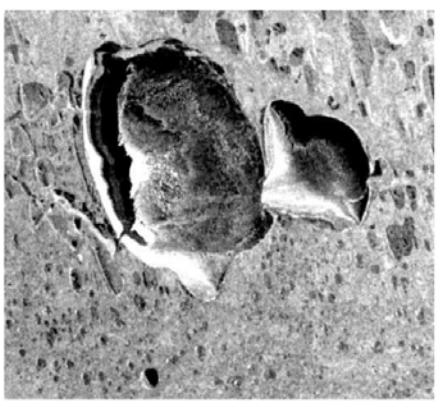


June 26, 2008 (HH)

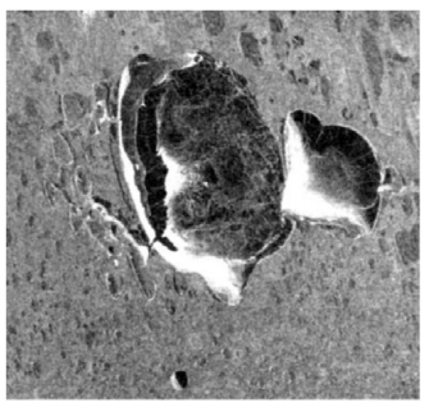


June 29, 2008 (VV)

June 30, 2008 (HH)



October 6, 2008 (HH)



October 12, 2008 (HH)

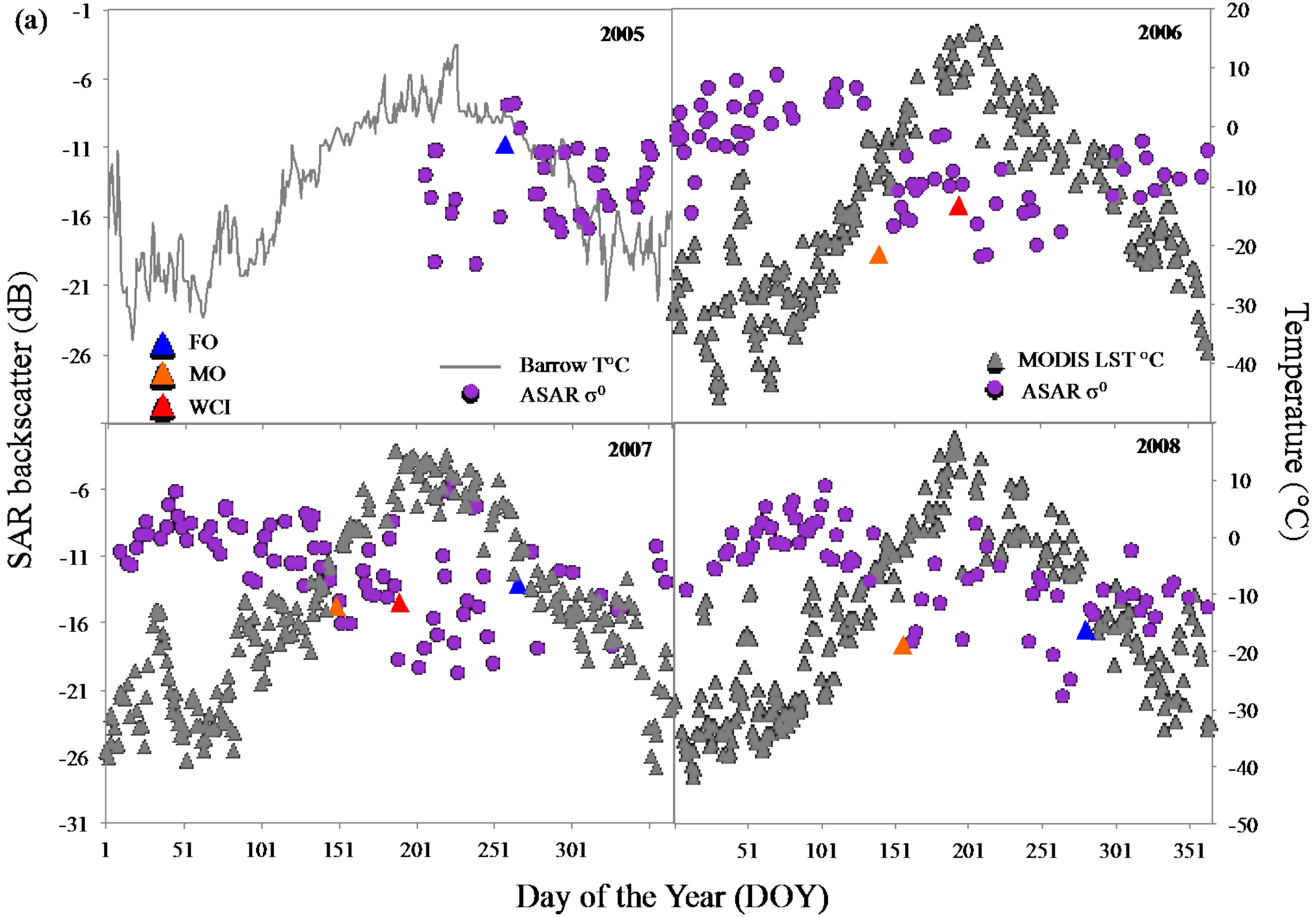
October 29, 2008 (HH)

Teshekpuk Lake, North Slope of Alaska

Pan *et al.*, in prep.

Break-up/freeze-up dates

FO: Freeze onset
MO: Melt onset
WCI: Water clear of ice



Temporal evolution of ASAR-WS backscatter over a shallow lake near Barrow, Alaska (2005-2008)

Surdu *et al.*, accepted

Some issues/challenges in monitoring shallow Arctic water bodies with recent EO missions

- **Temporal resolution:** Optical imagery (e.g. once weekly with Landsat) is not sufficient in most cases (given cloud cover issue)

- **Polar darkness and cloud cover:** Limits the usefulness of optical imagery during the freeze-up period

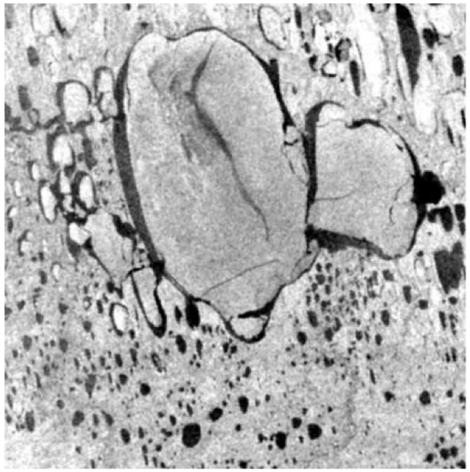
- **Spatial sampling:** Limits estimation of water levels to very few water bodies

- **Incidence angle/polarization:** Variations in these makes mapping of ice cover and open water areas difficult in many situations (e.g. wind effects)

Monitoring Shallow Arctic Water Bodies from Space: In the Era of the Sentinels

Break-up/freeze-up example (Alaska)

ASAR WS and Landsat-5/7 (2008)



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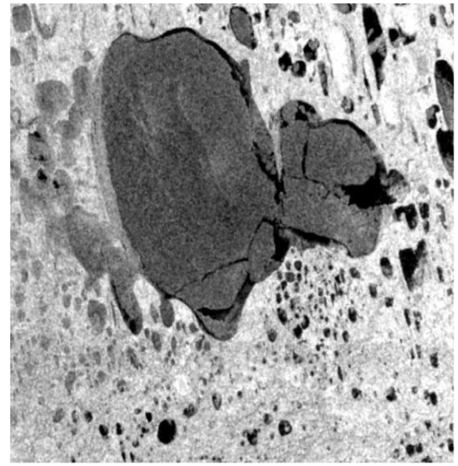

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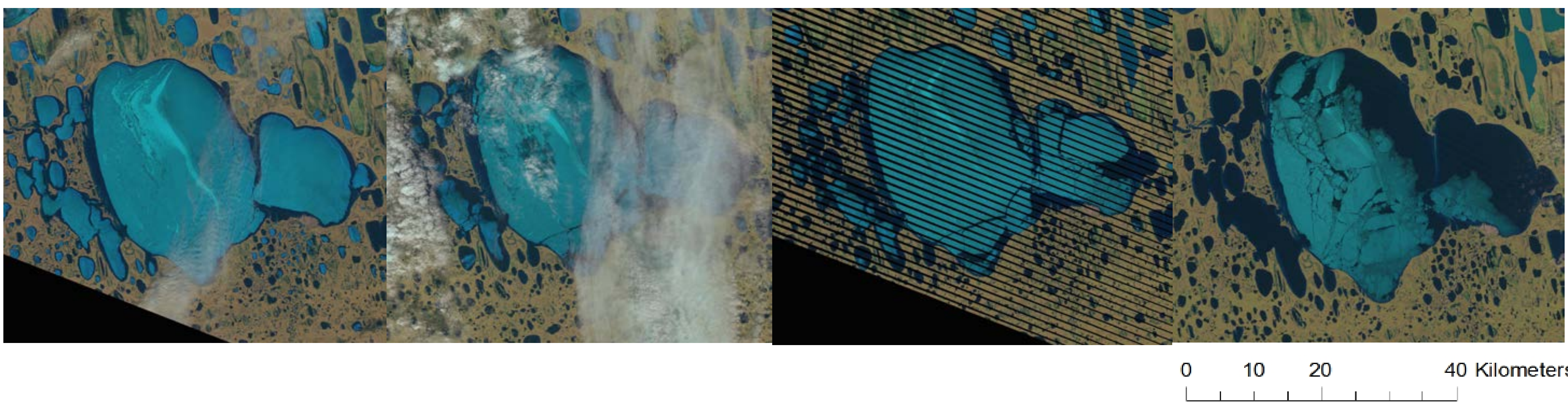


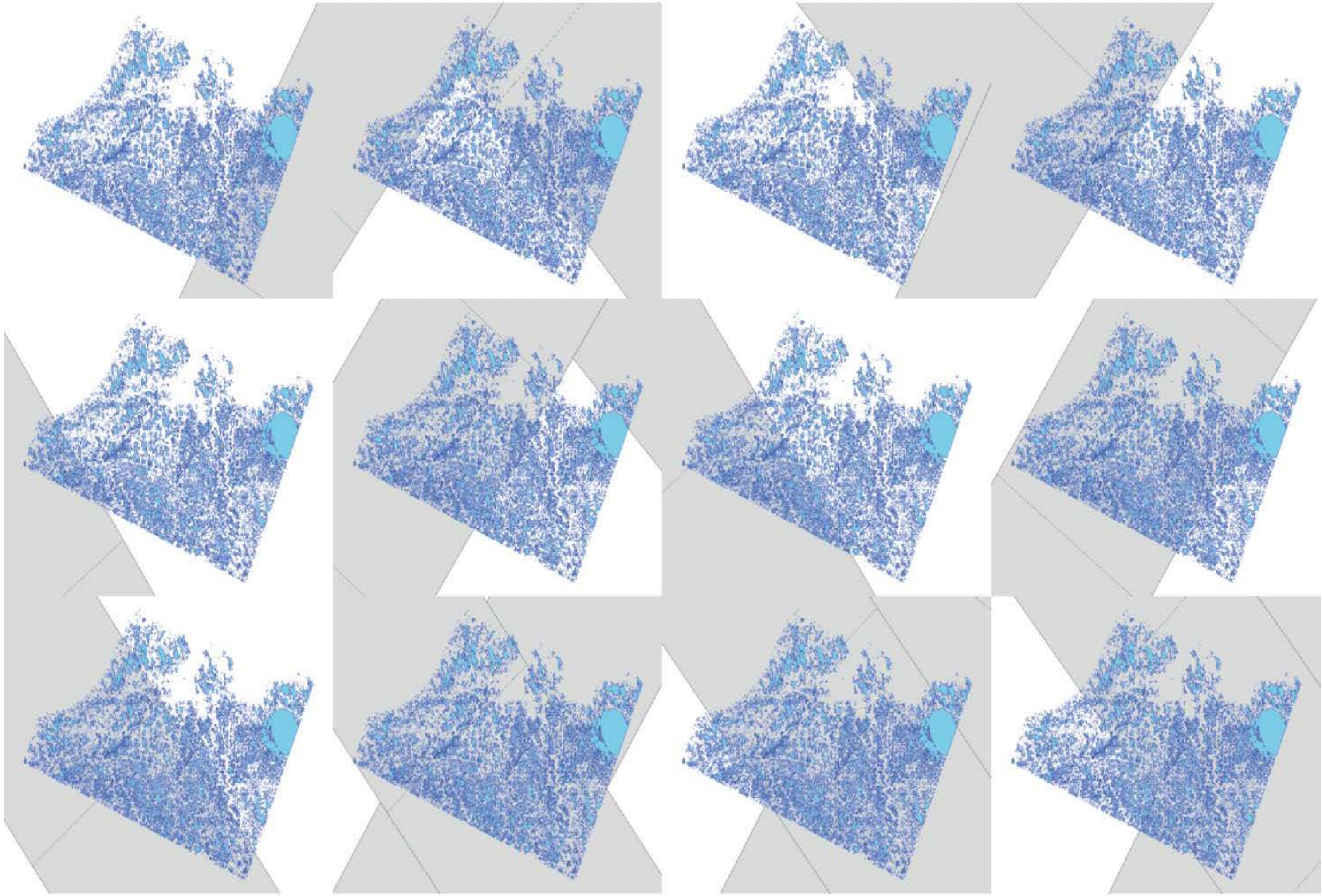
Landsat 5, June 21

Landsat 5, June 28

Landsat 7, June 29

Landsat 5, July 5

Water level coverage example (Alaska)



SWOT measurement swaths from the 22-day repeat period and 78 deg. inclination orbit (days 2, 3, 5, 6, 7, 9, 10, 12, 13, 15, 18, and 21 (from left to right and top to bottom)

Lee *et al.*, 2010

Strategy moving forward

- **Sentinels 1A/B (**20 x 40 m in extra-wide swath mode)**:** Fraction of bedfast ice, freeze-up/break-up dates, and surface water extent
- **Sentinel 2A/B** (10-20 m visible to SWIR bands)**:** Turbidity of water bodies (water colour)
- **Sentinels 1A/B and 2A/B:** Explore synergies for break-up dates and surface water extent
- **Sentinel 3A/B** (300-1000 m)**:** Surface water temperature, water colour, and water level for the largest lakes (e.g. Teshekpuk in Alaska)
- **RADARSAT-2 and RCM:** Fraction of bedfast ice, freeze-up/break-up dates, and surface water extent
- **SWOT:** Water level of lakes of ~1 ha and larger

Need to identify “target” lake regions for long-term monitoring across the circumpolar Arctic to assess the trajectory and magnitude of changes in the parameters of interest.

Questions?