

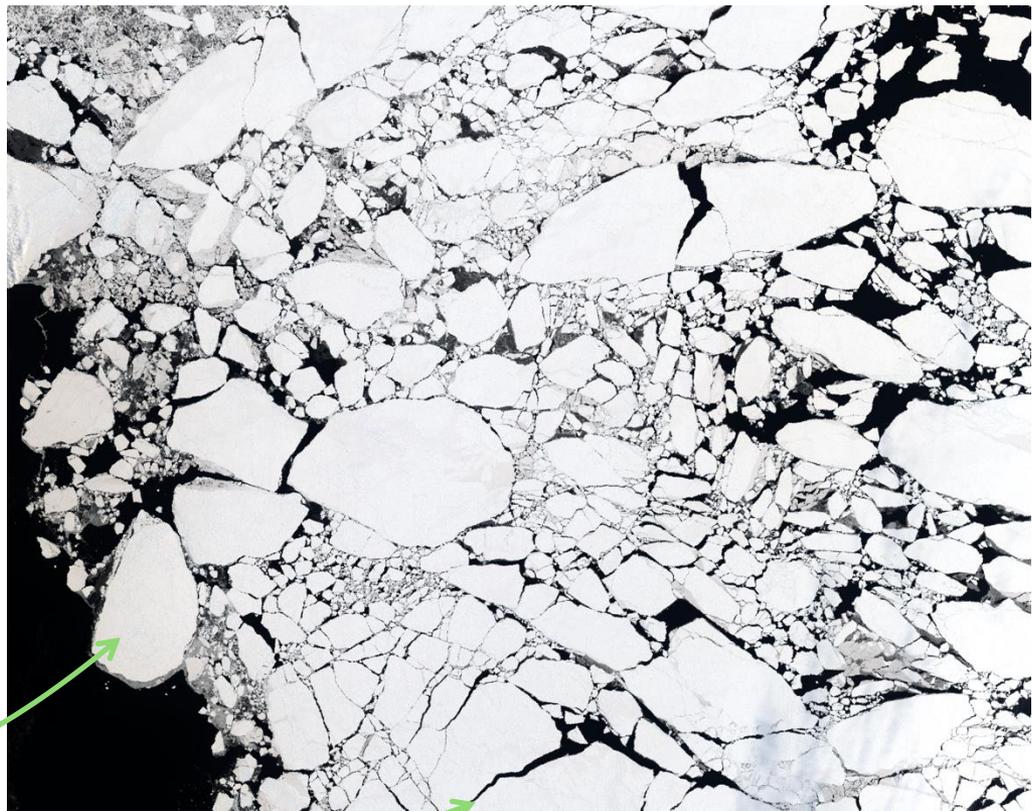


Detecting Sea Ice Leads and Floes in the Northwest Passage using CryoSat-2

Amy Swiggs, Isobel Lawrence, Andy Ridout, Andy Shepherd



Sea ice complexities
can be hard to resolve
at the satellite scale

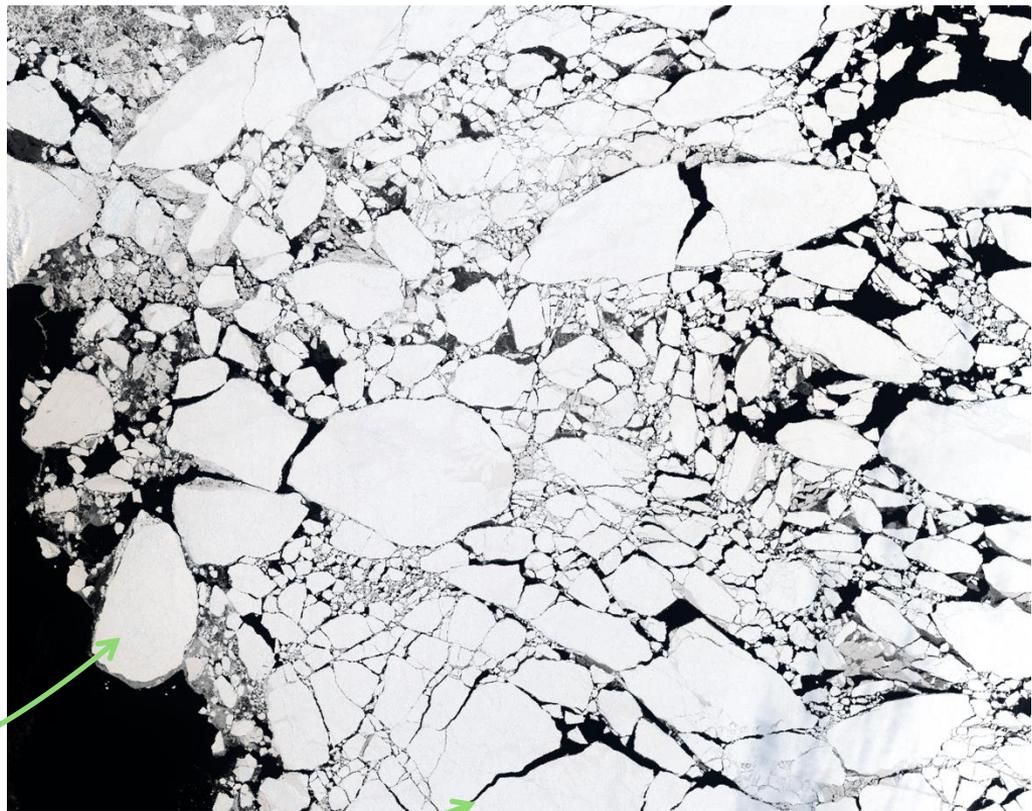


Floe

Lead

Importance of leads

- Heat & moisture exchange
- Shipping
- Marine productivity

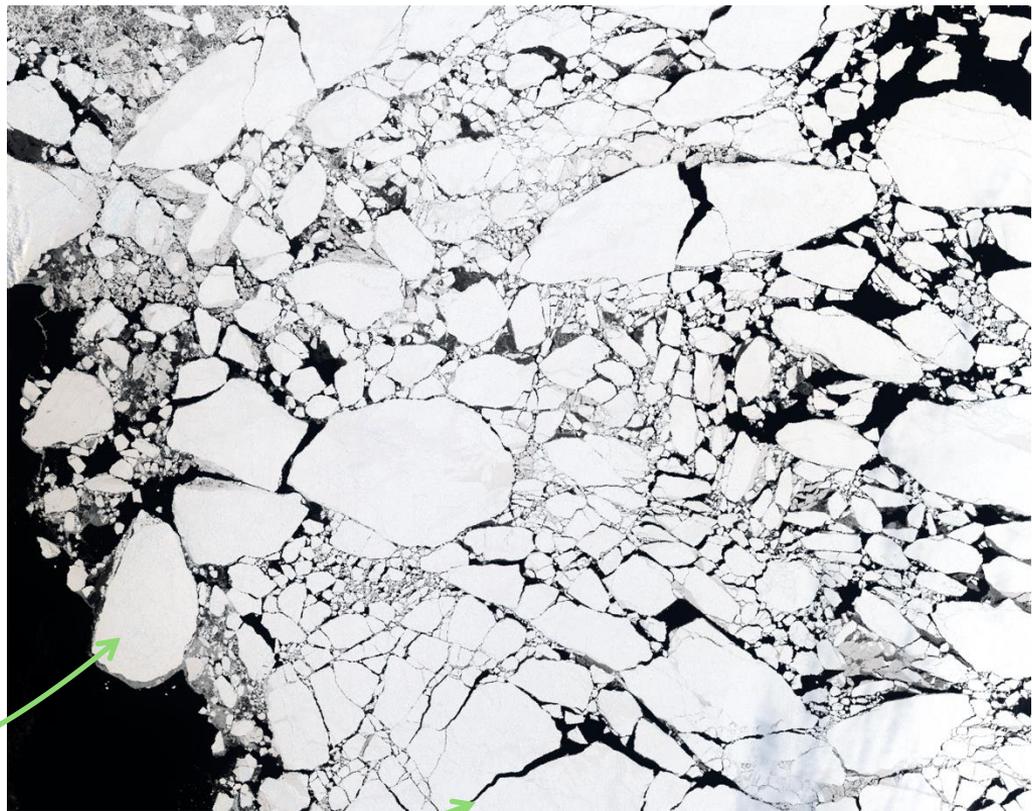


Floe

Lead

Importance of floes

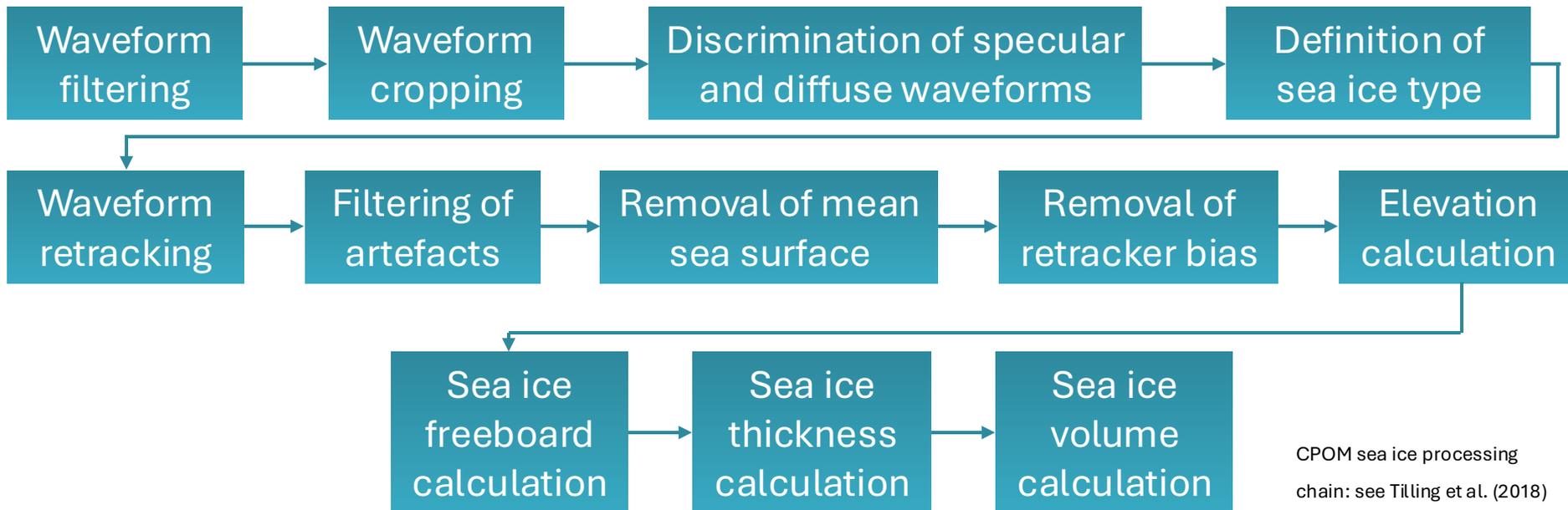
- Icepack stability
- Habitats 
- Radiation reflectance 



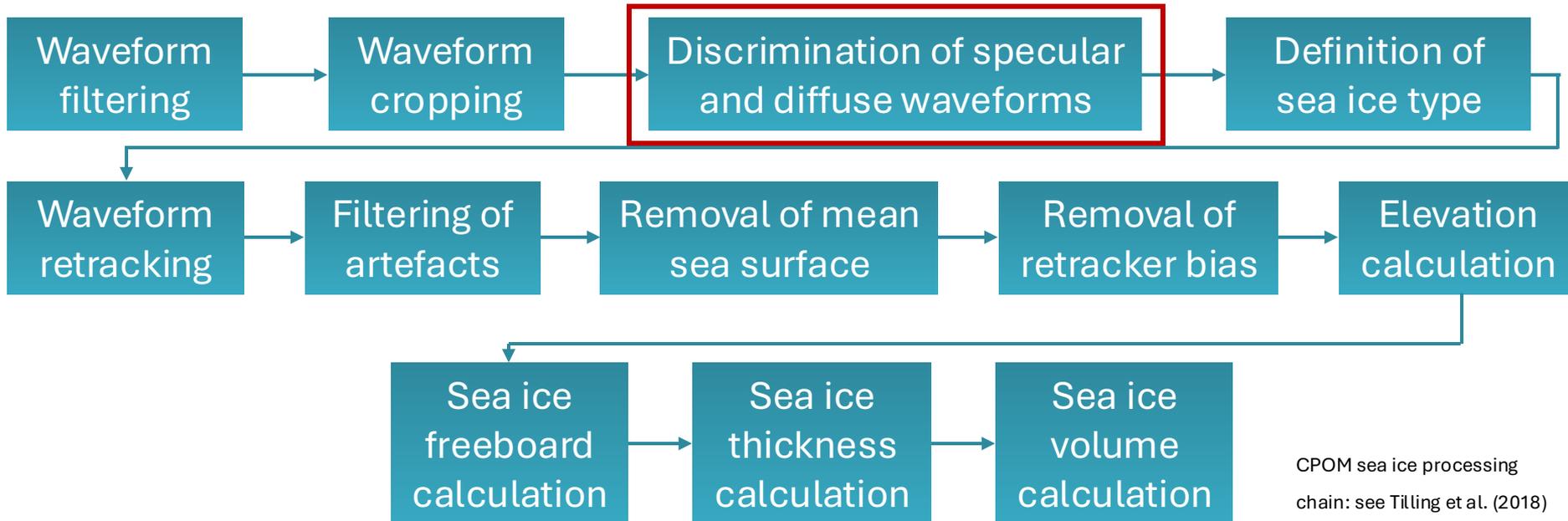
Floe

Lead

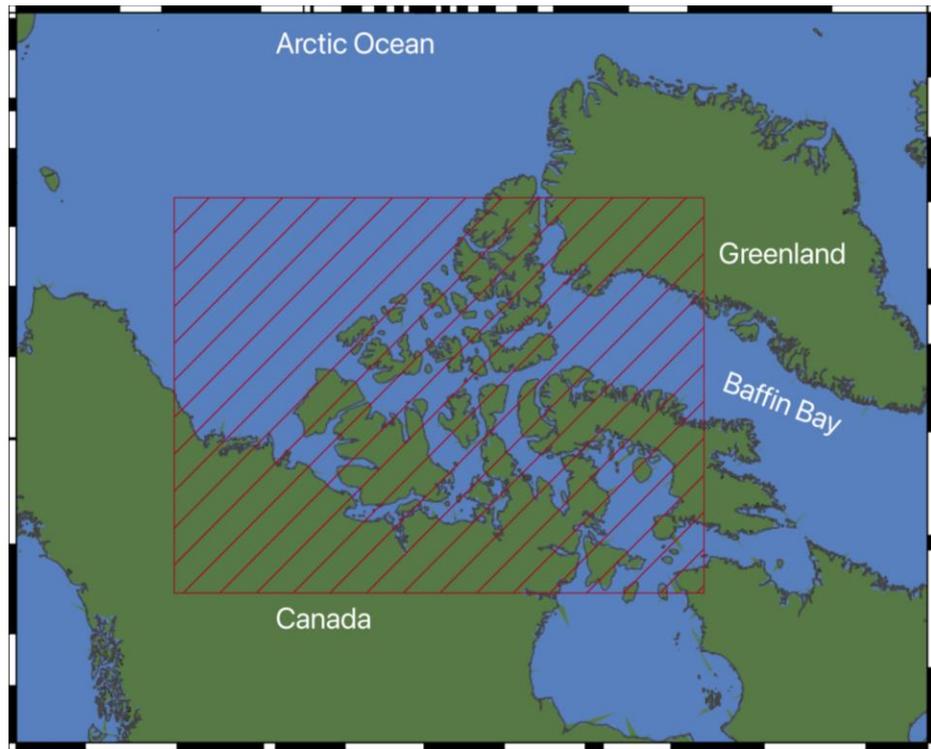
Lead & floe discrimination essential for CryoSat-2 sea ice processing



Lead & floe discrimination essential for CryoSat-2 sea ice processing

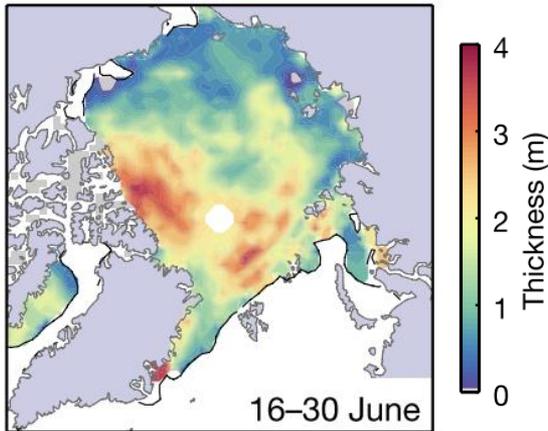


The Canadian Arctic Archipelago & Northwest Passage are challenging but important regions for satellite observations



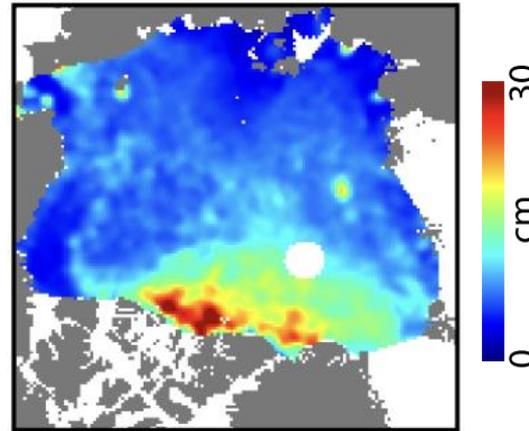
Canadian Arctic Archipelago frequently excluded from satellite observations

Sea ice thickness



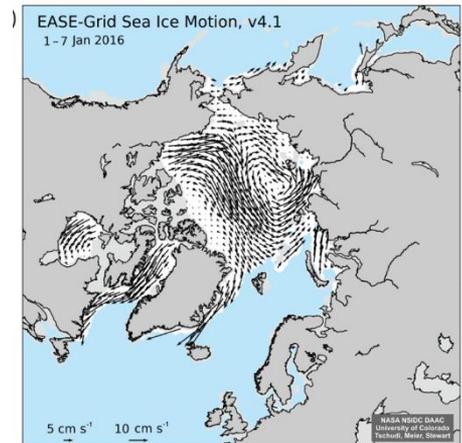
Landy et al. (2022) *Nature*

Sea ice freeboard



Kwok et al. (2020) *JGR: Oceans*

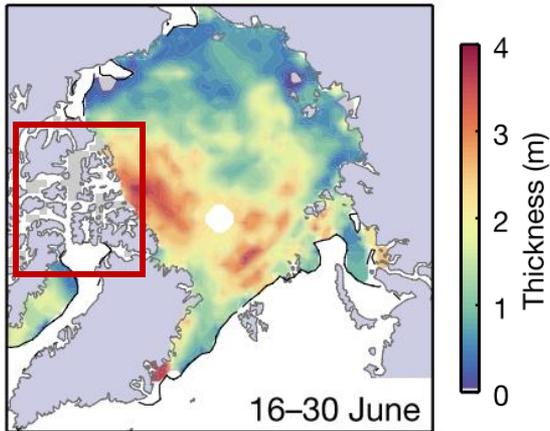
Sea ice motion



Tschudi et al. (2020) *The Cryosphere*

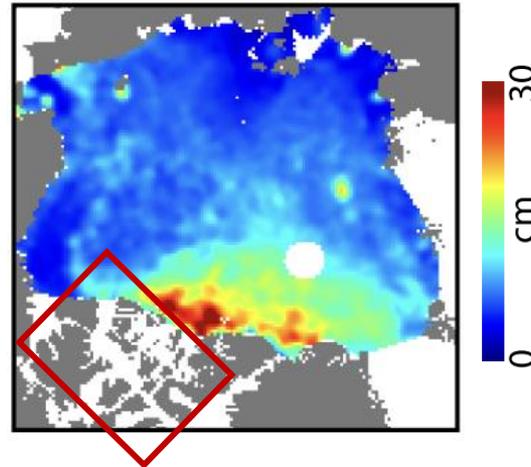
Canadian Arctic Archipelago frequently excluded from satellite observations

Sea ice thickness



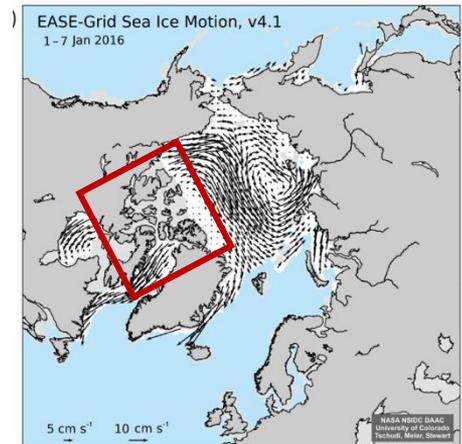
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Sea ice freeboard

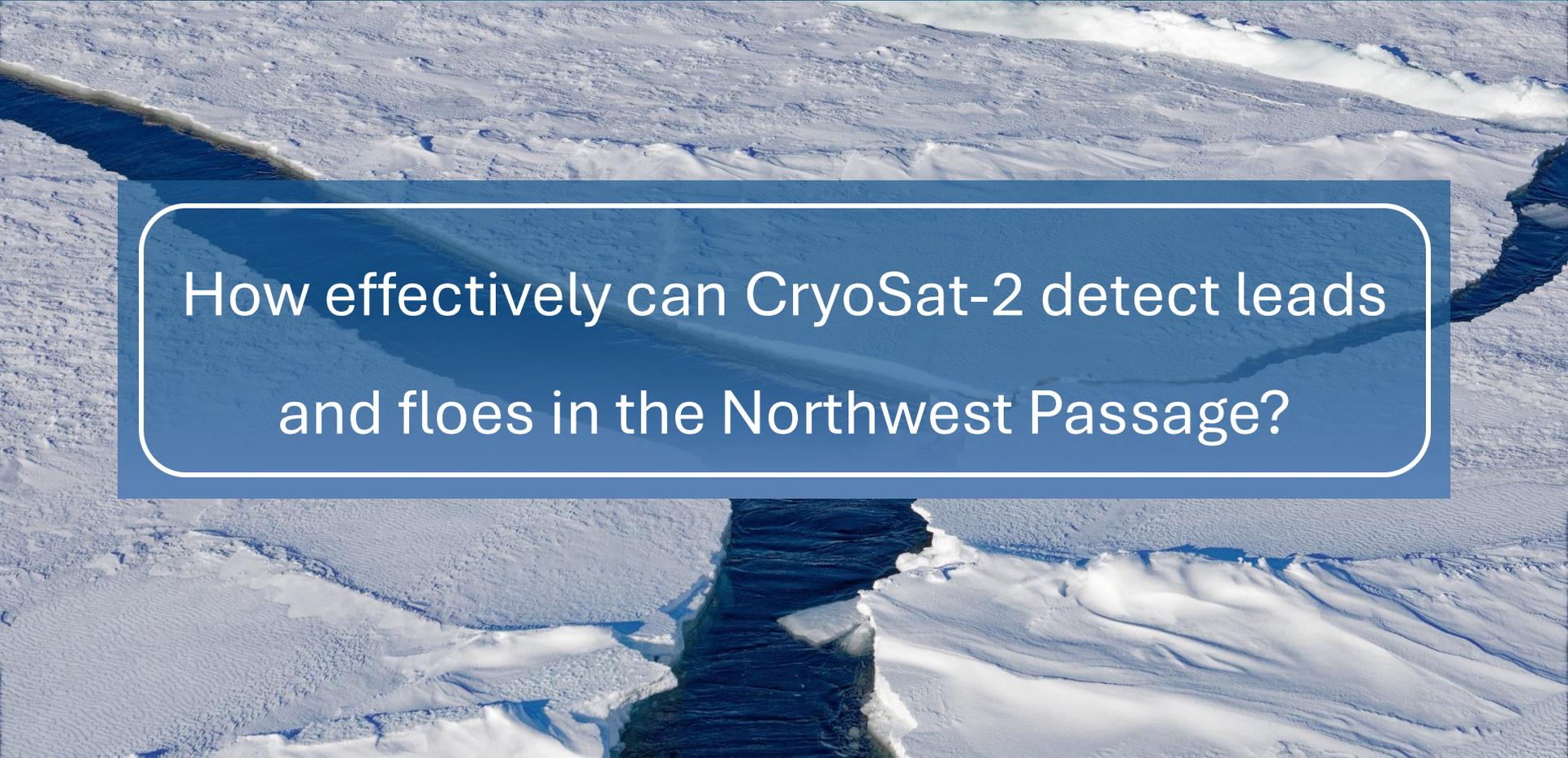


Kwok et al. (2020) *JGR: Oceans*

Sea ice motion



Tschudi et al. (2020) *The Cryosphere*



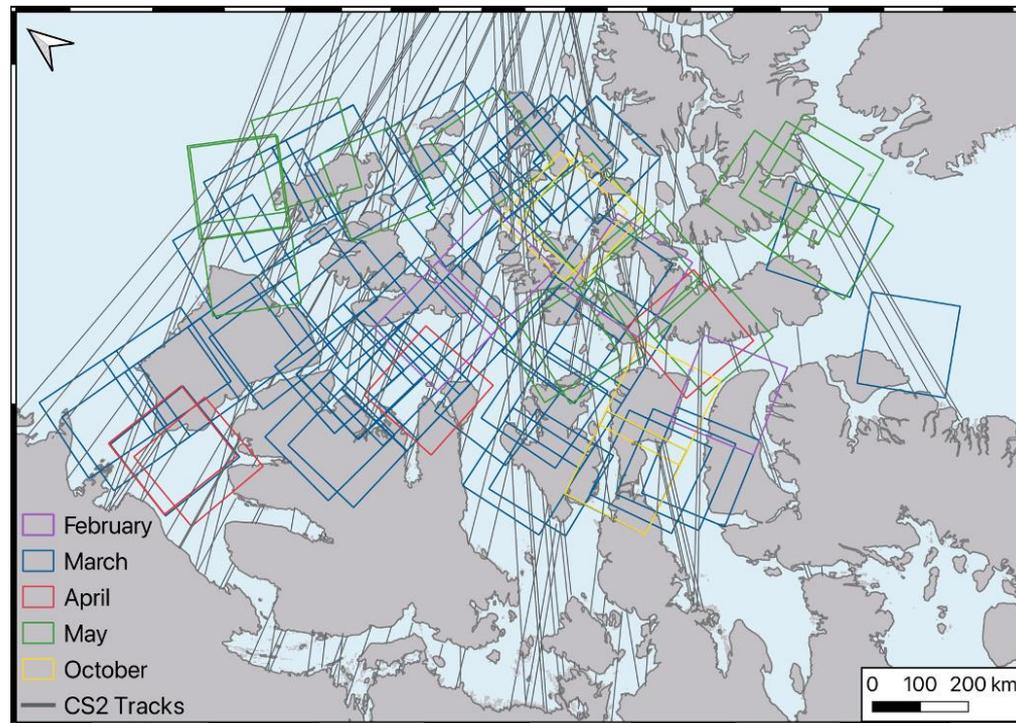
How effectively can CryoSat-2 detect leads and floes in the Northwest Passage?

82 near-coincident Landsat 8 images used to validate CryoSat-2

returns

- Within 2-hour timeframe
- From 2010 to 2023
- > 25 km in overlap

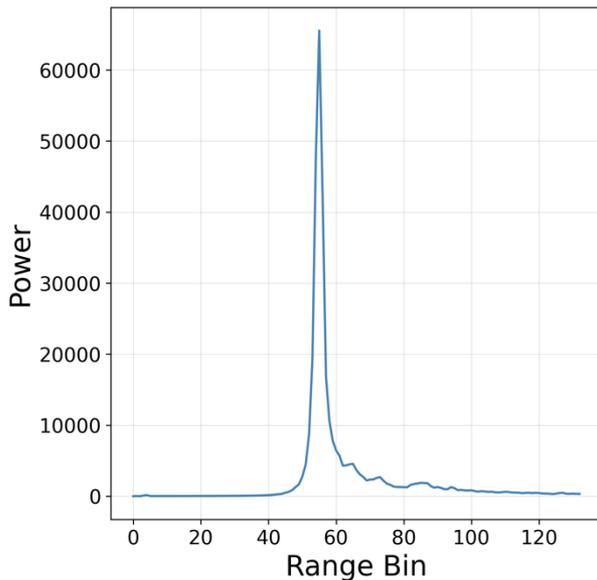
length



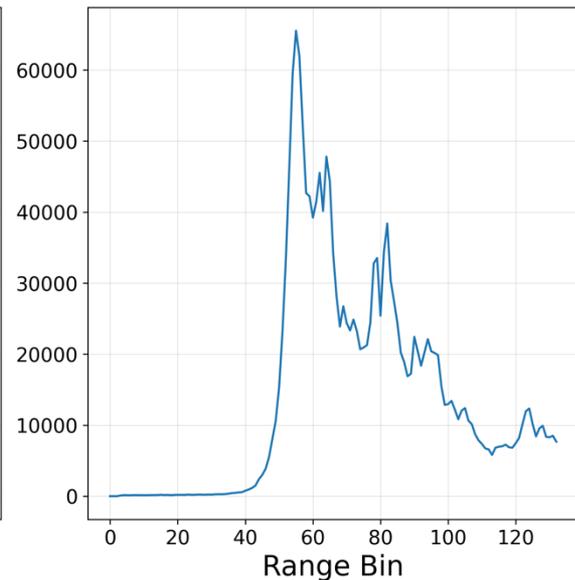
CryoSat-2 waveforms discriminated into leads & floes based on return power

- Pulse Peakiness
- Stack Standard Deviation
- Sea Ice Concentration

Specular waveform (Lead)

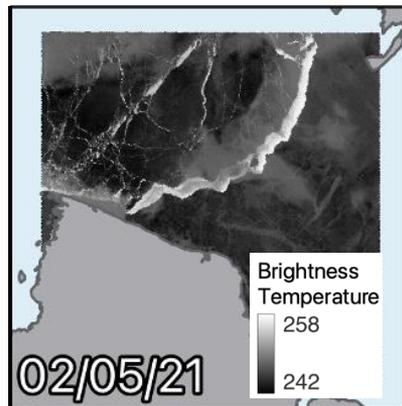
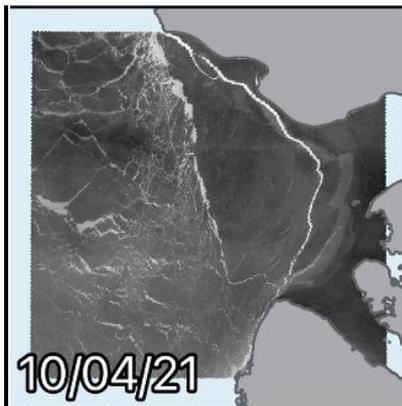


Diffuse waveform (Floe/Ocean)



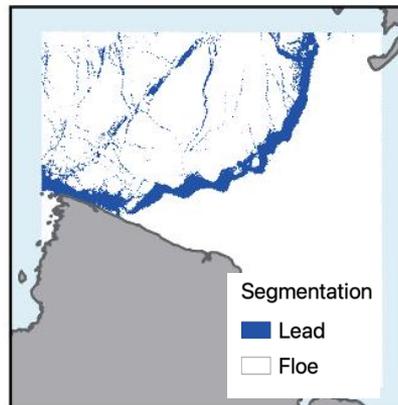
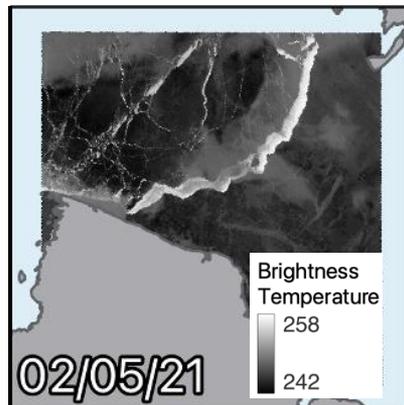
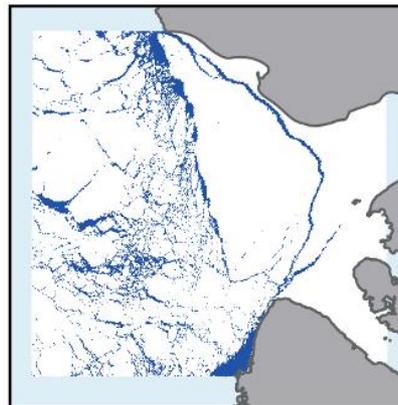
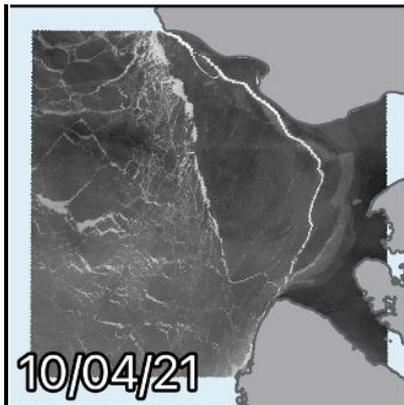
1

Landsat 8 imagery
segmented using
brightness
temperatures



1

2

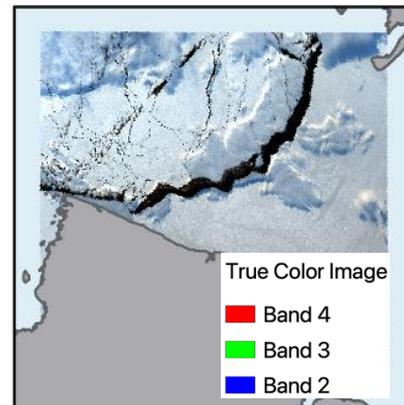
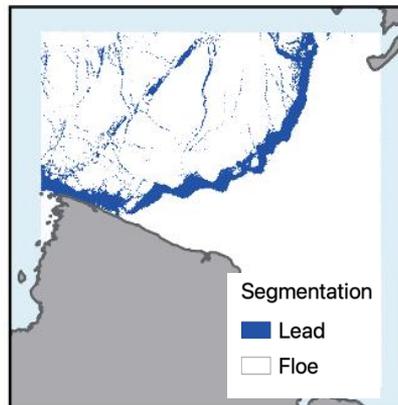
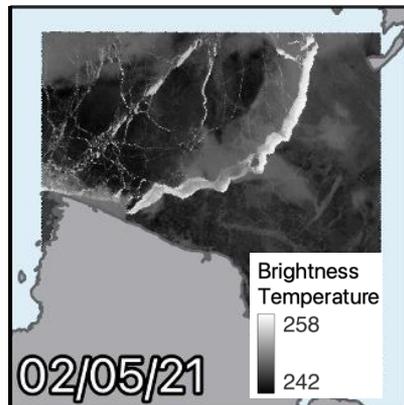
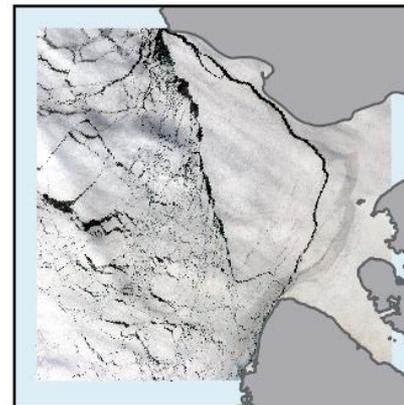
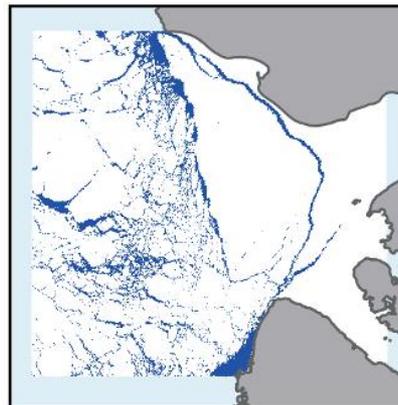
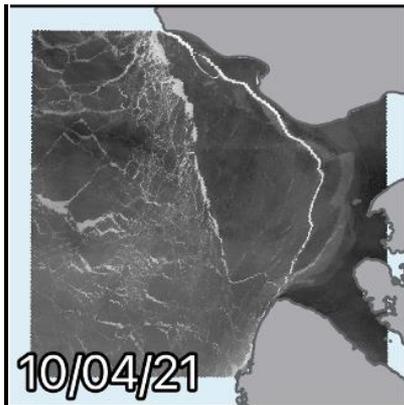


Landsat 8 imagery
segmented using
brightness
temperatures

1

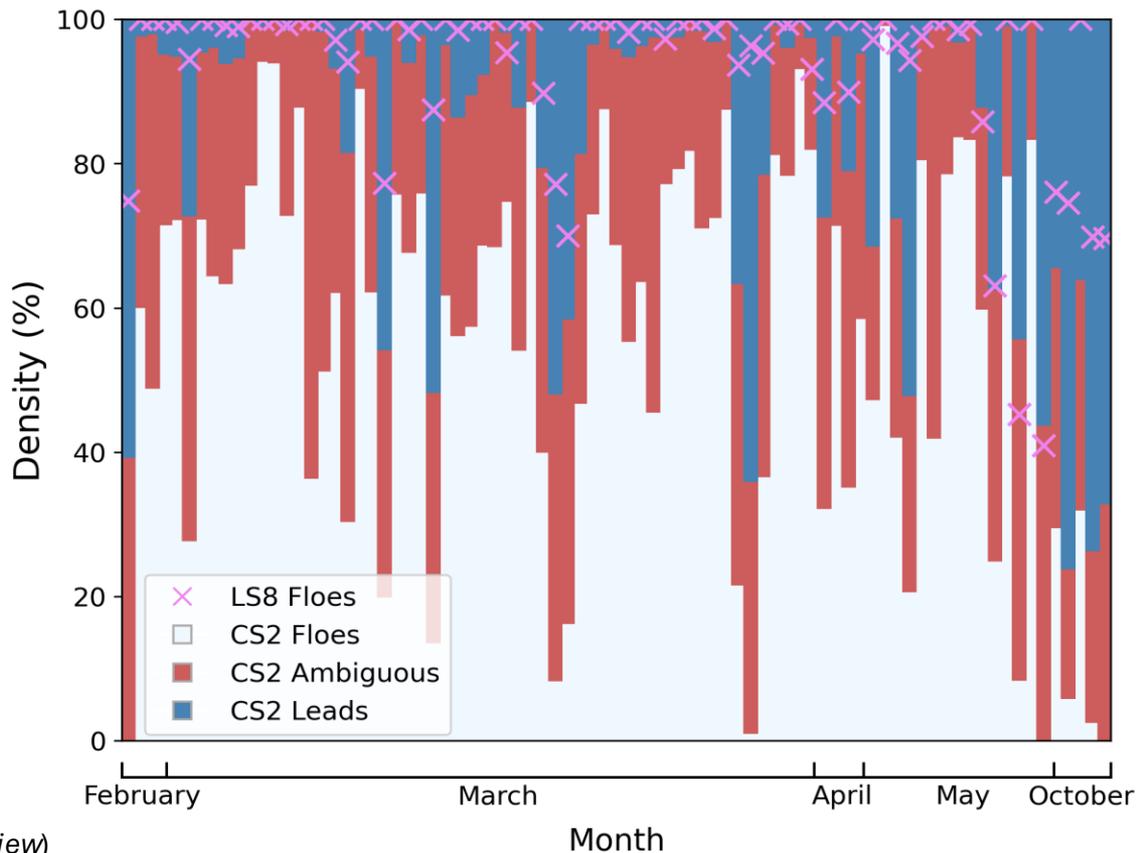
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3

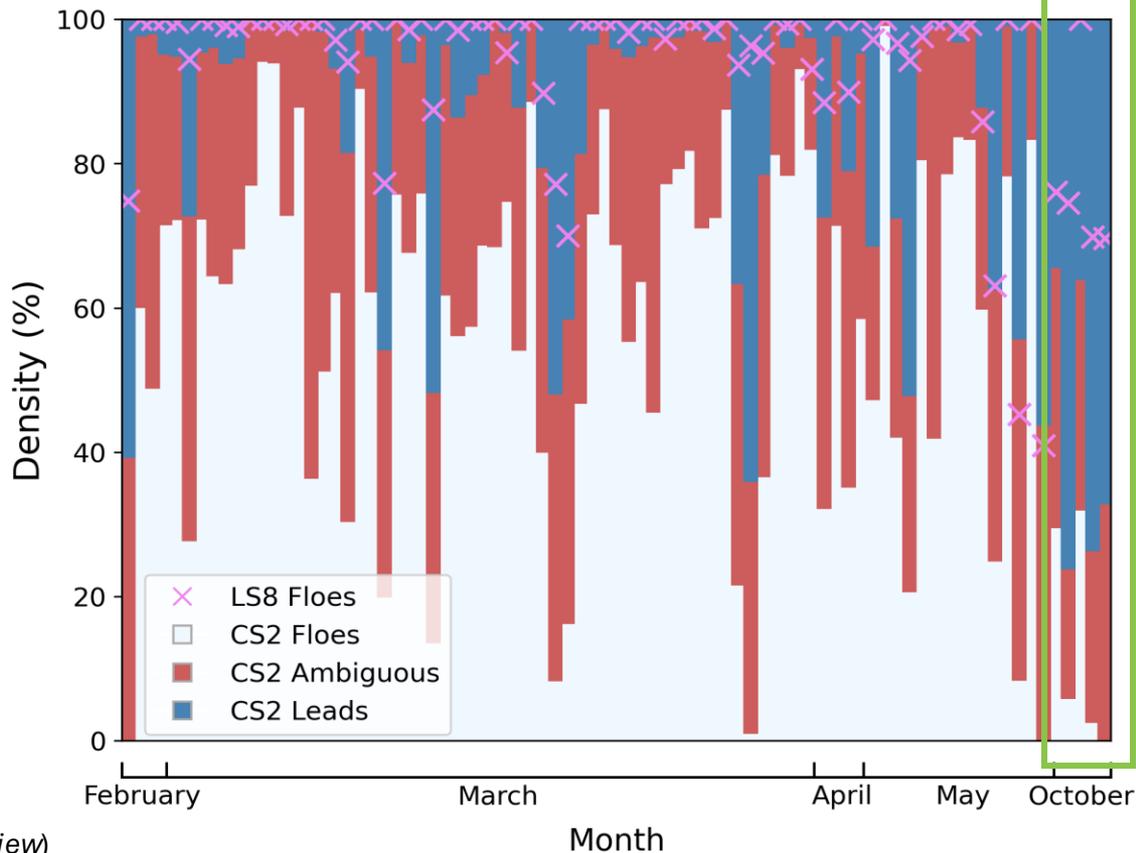


Landsat 8 imagery
segmented using
brightness
temperatures

CryoSat-2 floe density
45% lower & lead density
14% higher than Landsat 8

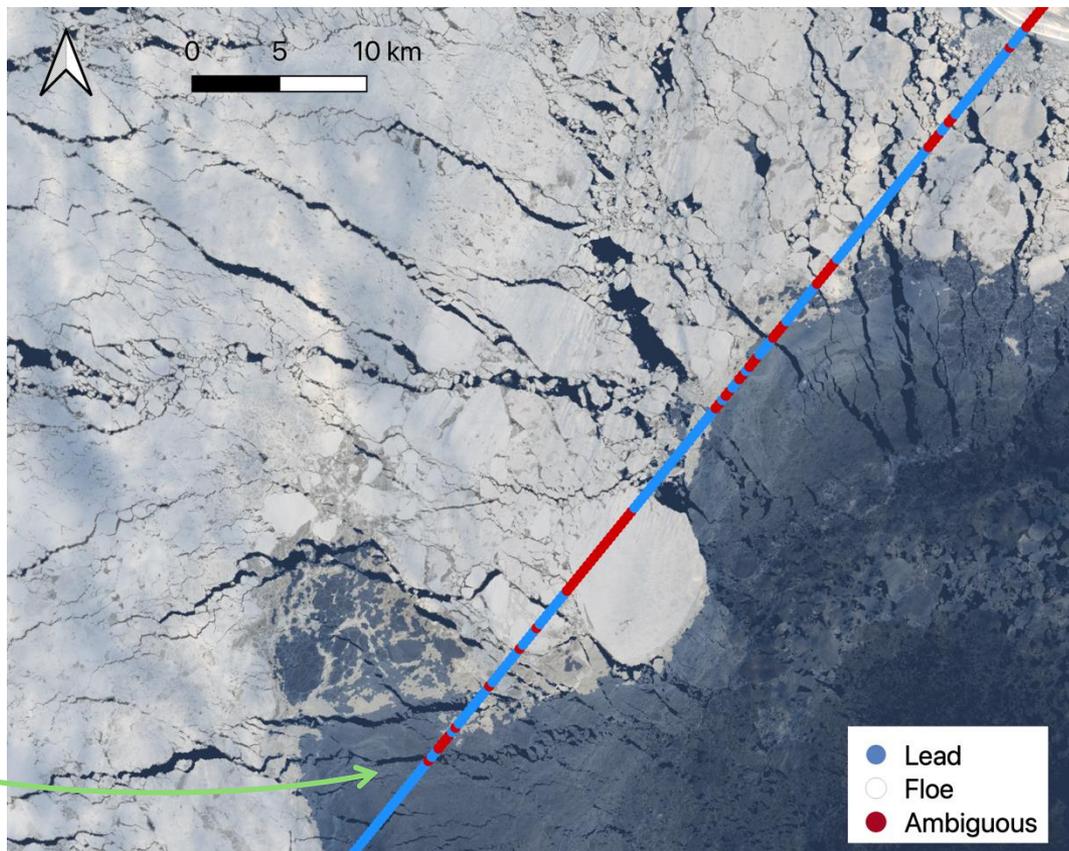


Agreement is poorest
in October



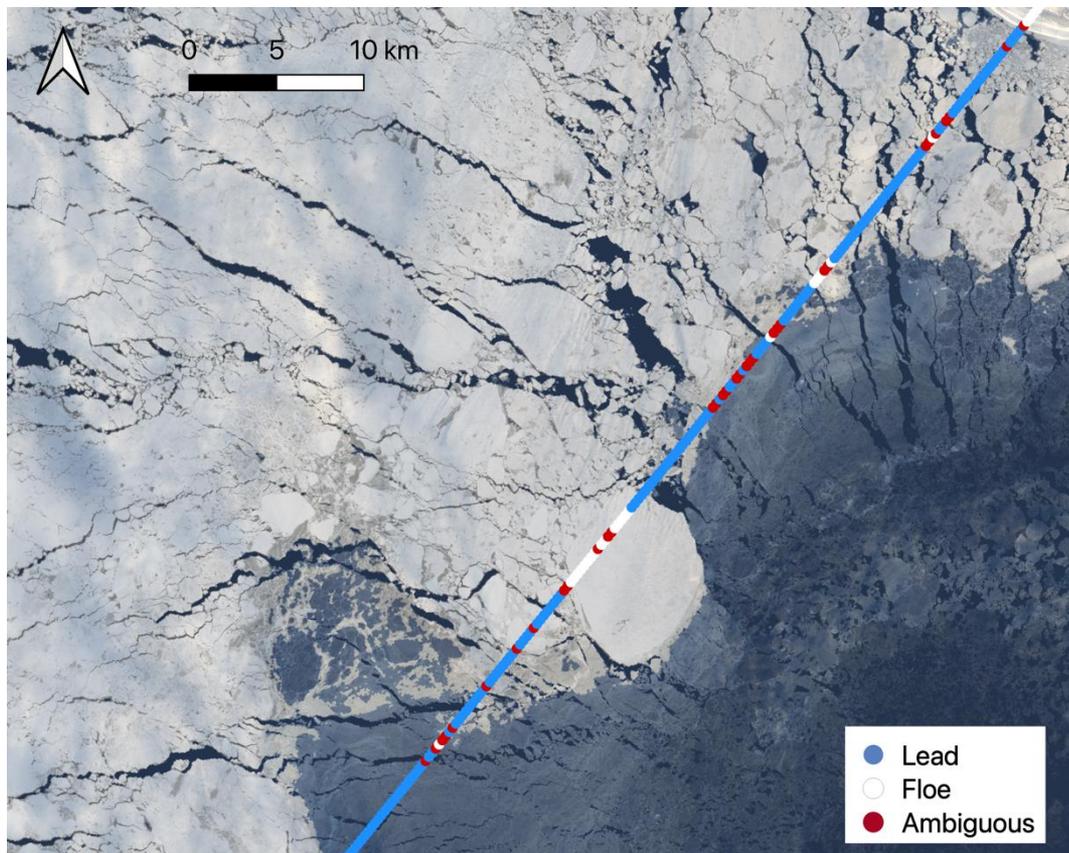
Along-track classification

Zero floes identified
in this track segment



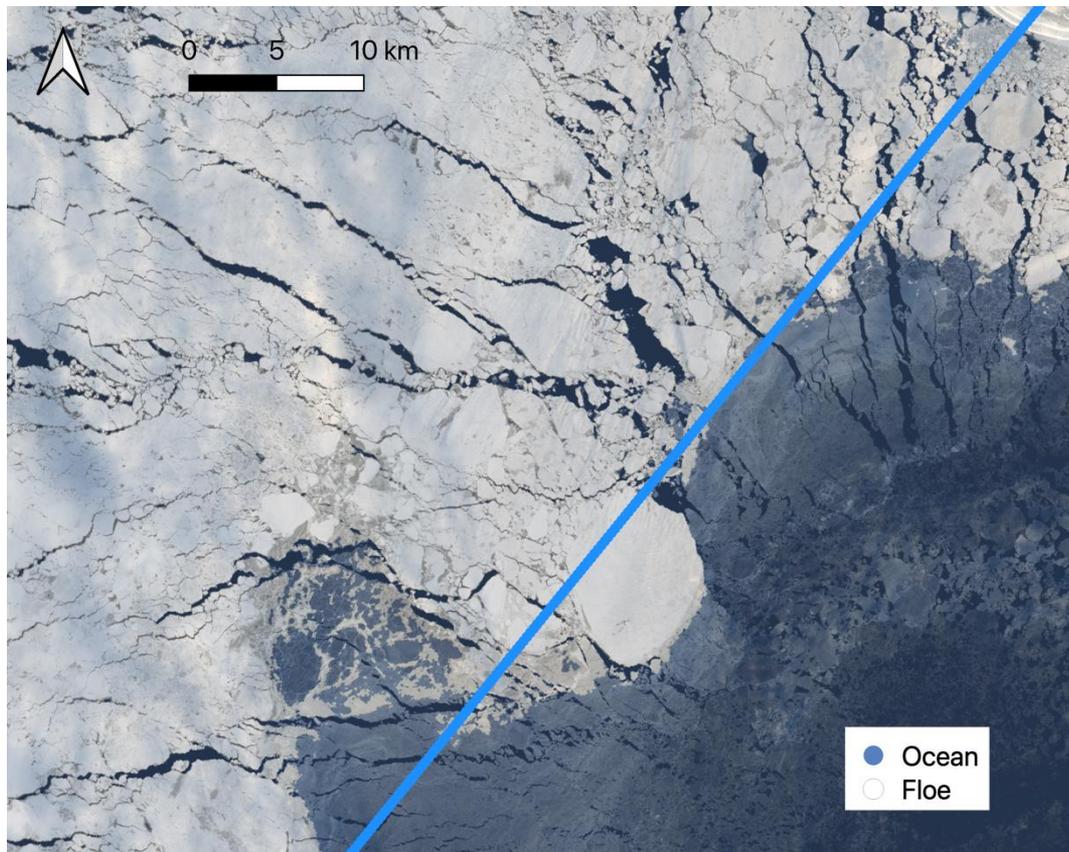
Along-track pulse peakiness

- Identification of large floes
- Poor identification where there are mixed surface types within the footprint



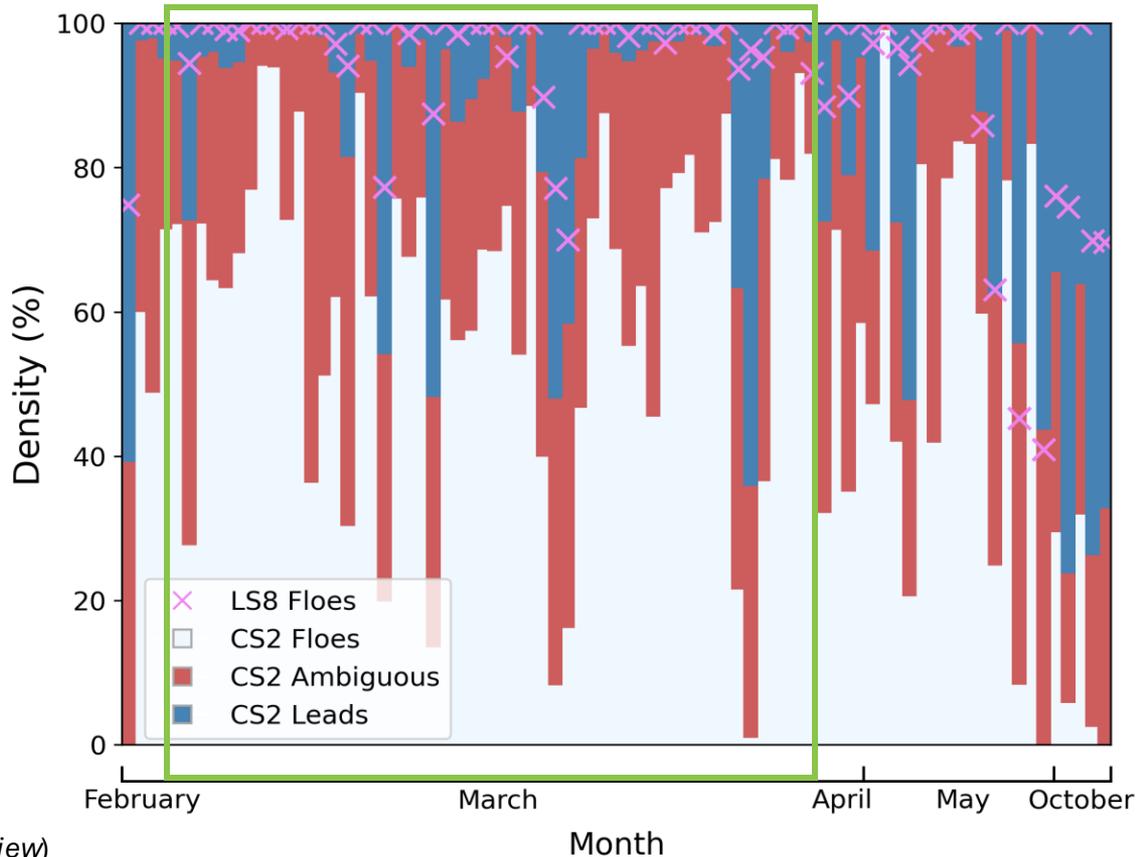
Sea Ice Concentration Threshold

- Can inhibit correct identification of floes

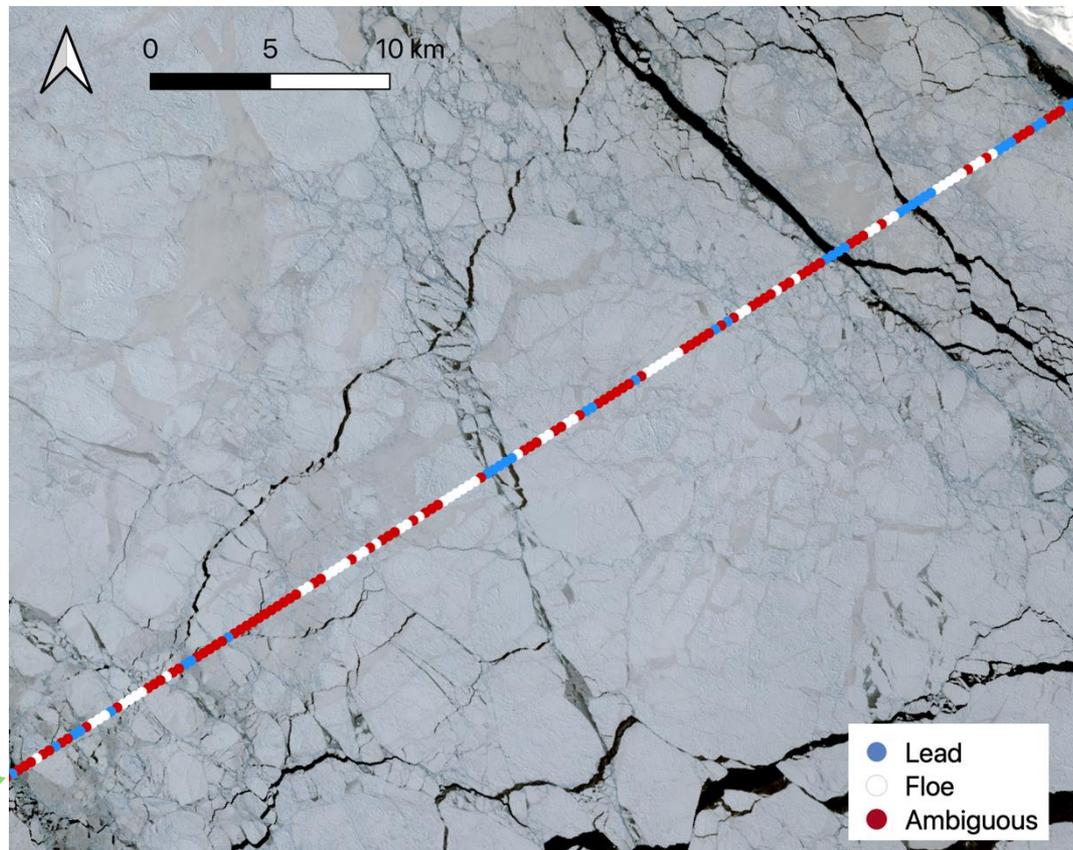


Agreement highest in
March, when there are
the most data pairs

But, misclassifications
occur in all months

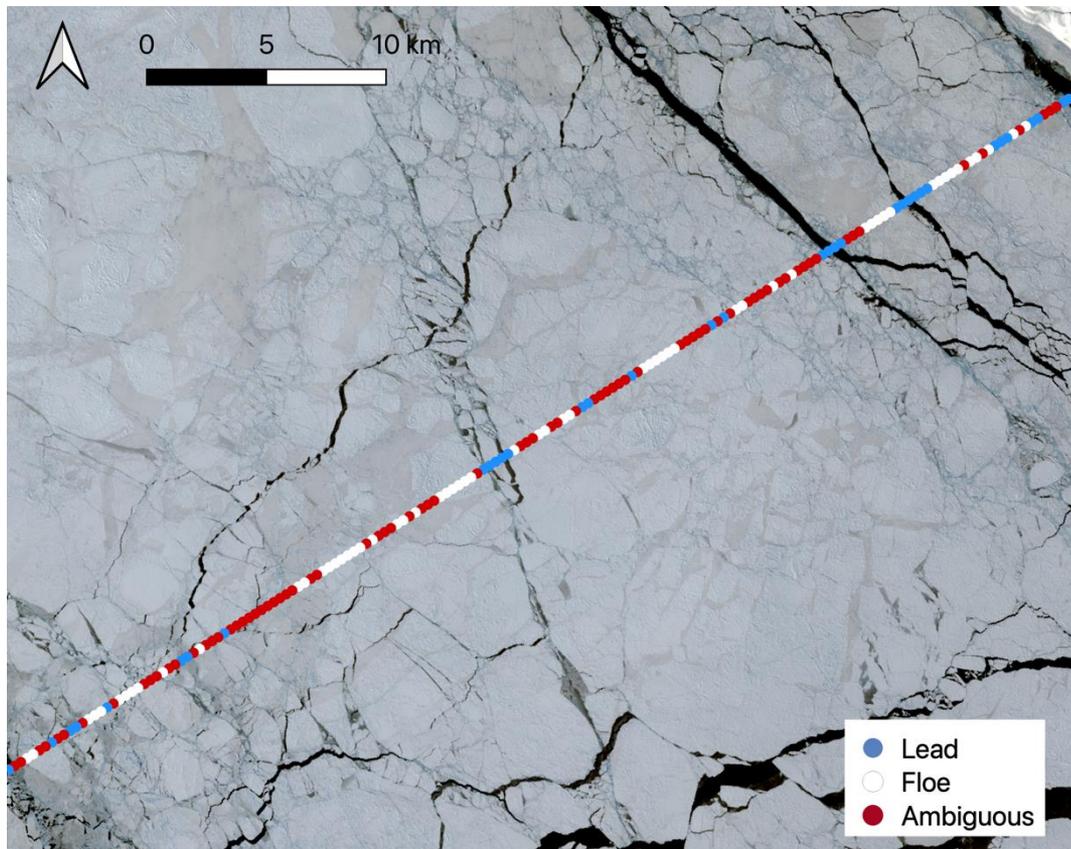


Along-track classification



Along-track pulse peakiness

- Ambiguity of large sections of floes



Possible causes of low agreement

CryoSat-2 off-nadir ranging

Mixed surface types within
radar footprint

Sea ice drift

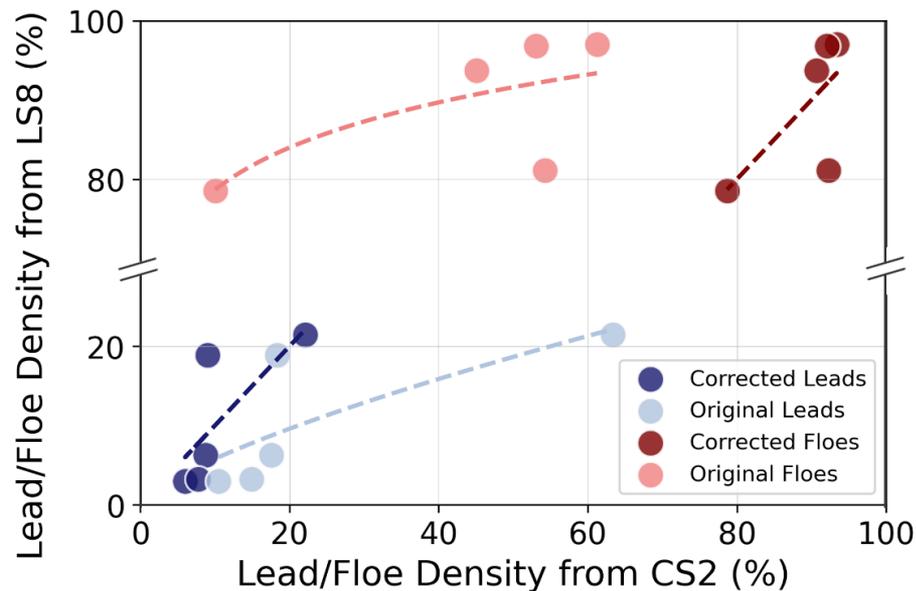
Sea ice and snow surface
characteristics

Incorrect Landsat 8
masking

Coarser spatial resolution of
CryoSat-2

Improvement not found when using different CryoSat-2 waveform classification parameters

- Bias adjustment therefore generated
- RMSD reduced to $<5.5\%$



- 82 Landsat 8 images used to validate CryoSat-2 returns in the Northwest Passage
- CryoSat-2 found to underestimate floe density and overestimate lead density
- Correction generated to improve classification of lead and floe density in Northwest Passage
- Further validations should be conducted in other basins