Mapping macroalgae in fjords in SW Greenland using Sentinel 2 MSI

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Living Planet Symposium

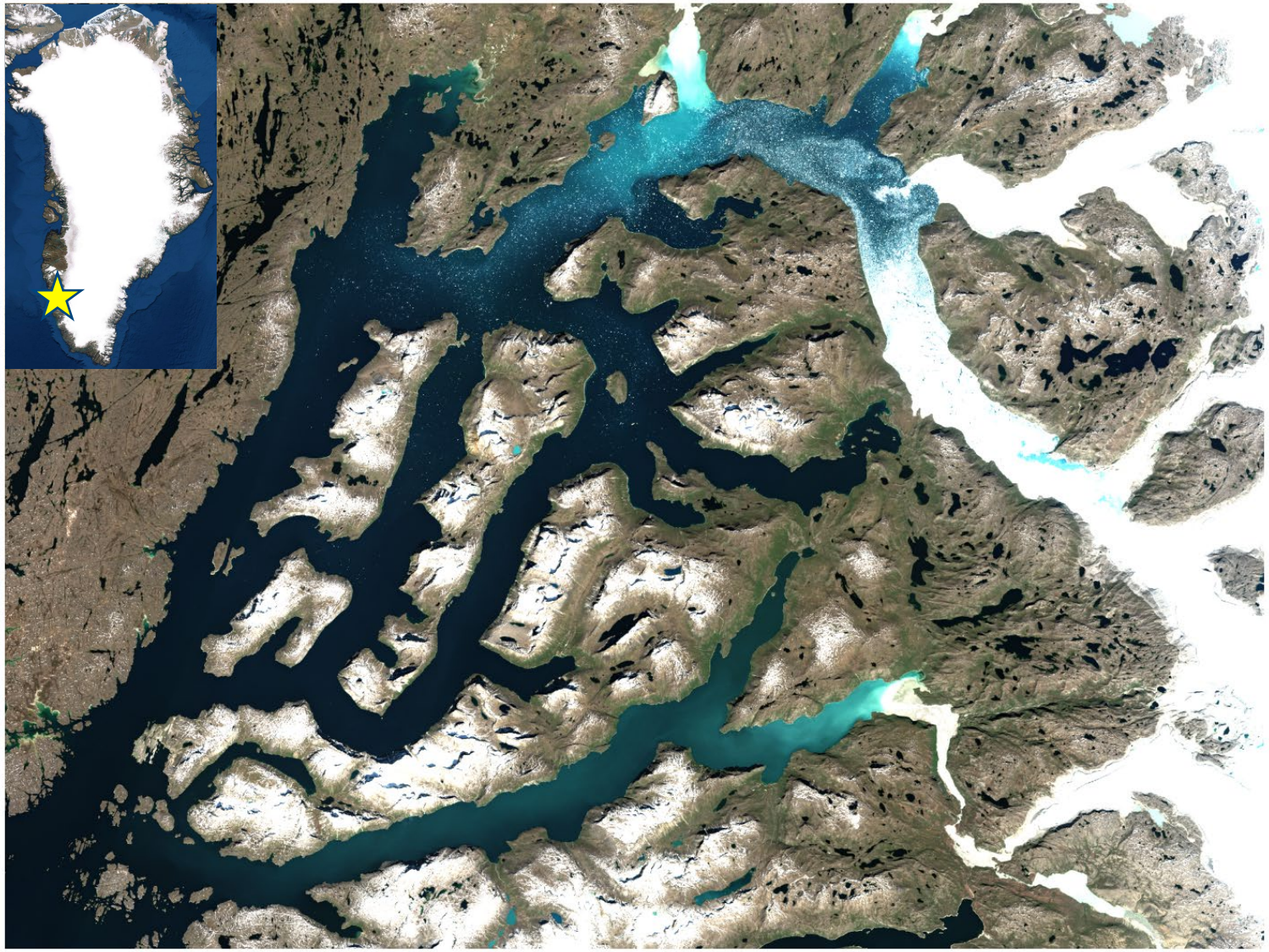
Helmholtz-Zentrum hereon

Motivation

- Greenland is the world's largest island with a rocky coastline that provides substrate for macroalgae
- Macroalgae in Greenland may be expanding and may contribute to carbon sequestration (Blue Carbon)
- Large area with harsh weather conditions makes in situ monitoring difficult
- Map the distribution of macroalgae using Sentinel-2 MSI

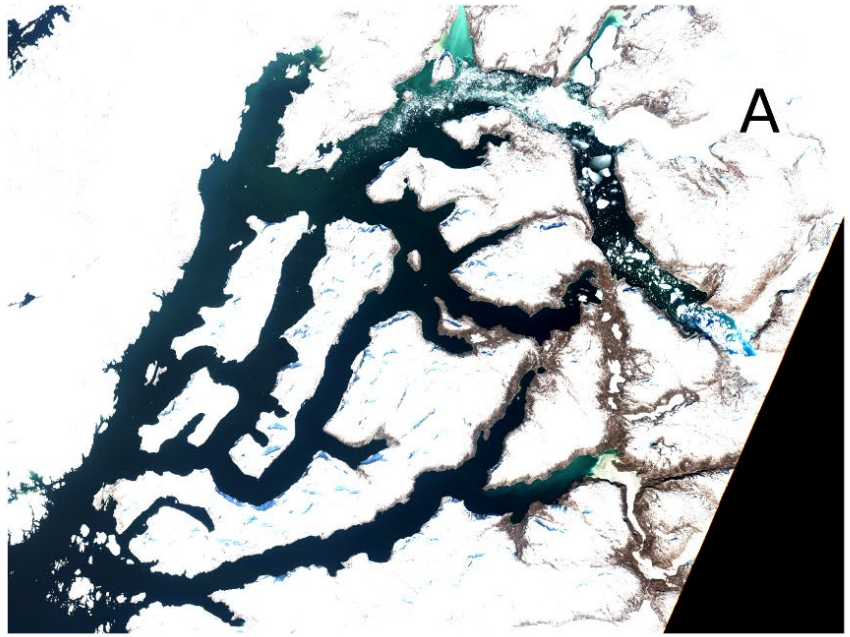
Study Area

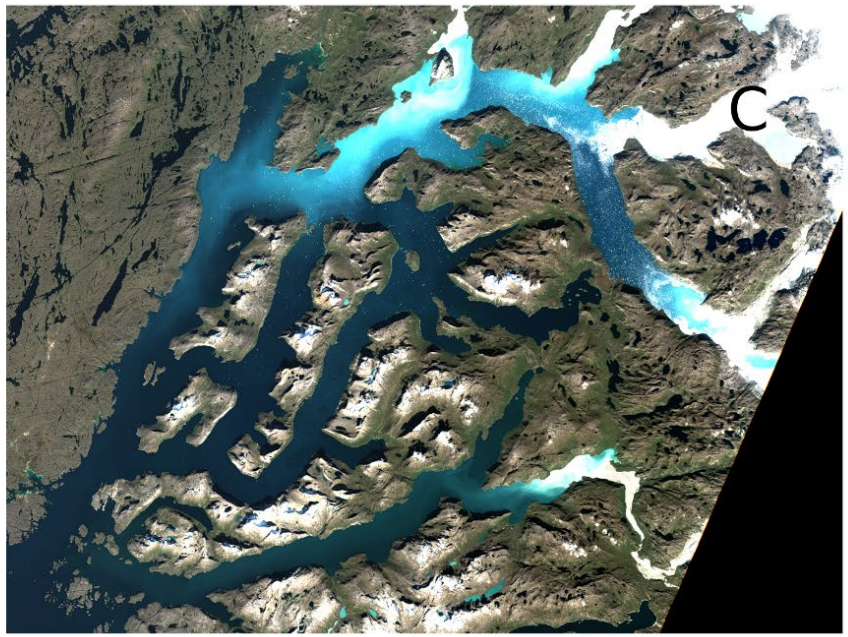
- Preliminary mapping in Nuup Kangerlua (Godthåbsfjord) and Ameralik Fjord
- Wealth of in situ data - GINR
- Marine area of 2372 sq km
- Three marine terminating glaciers
- Turbid surface runoff
- Tidal range ~4 m
- Mountainous topography
- Optically complex environment

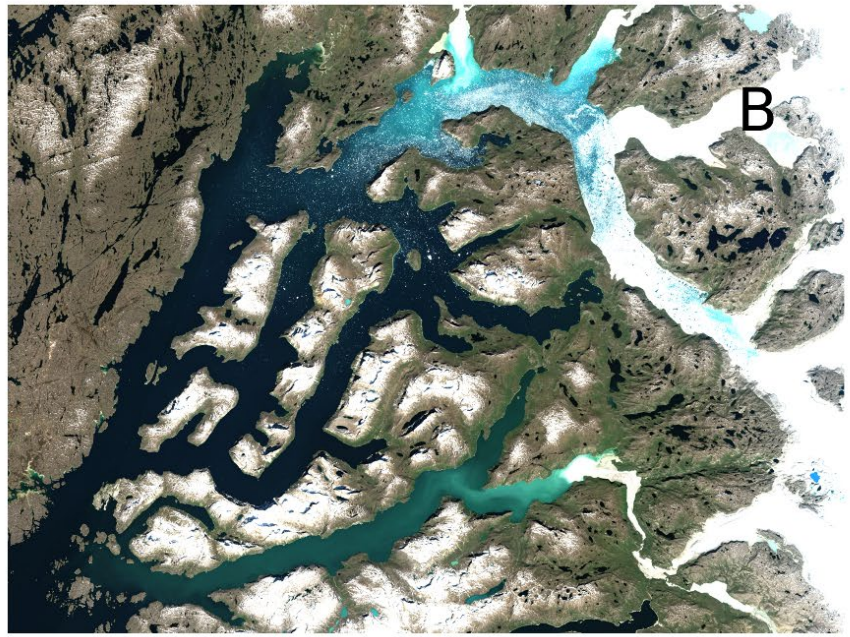


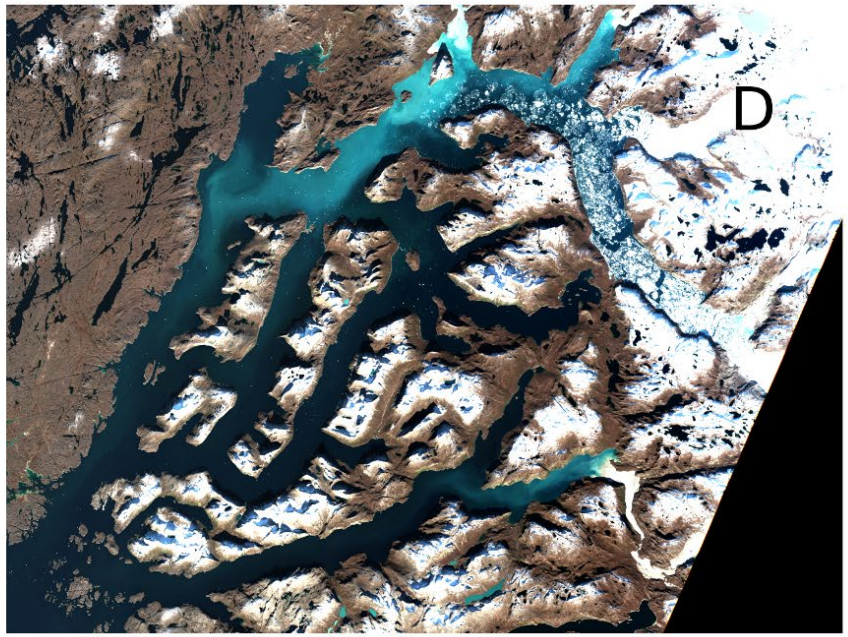
Study Area

- Sea ice breaks up in late May
- Icebergs in inner fjord June-August
- Turbid surface runoff increases and peaks in September
- Sea ice starts to form in late September



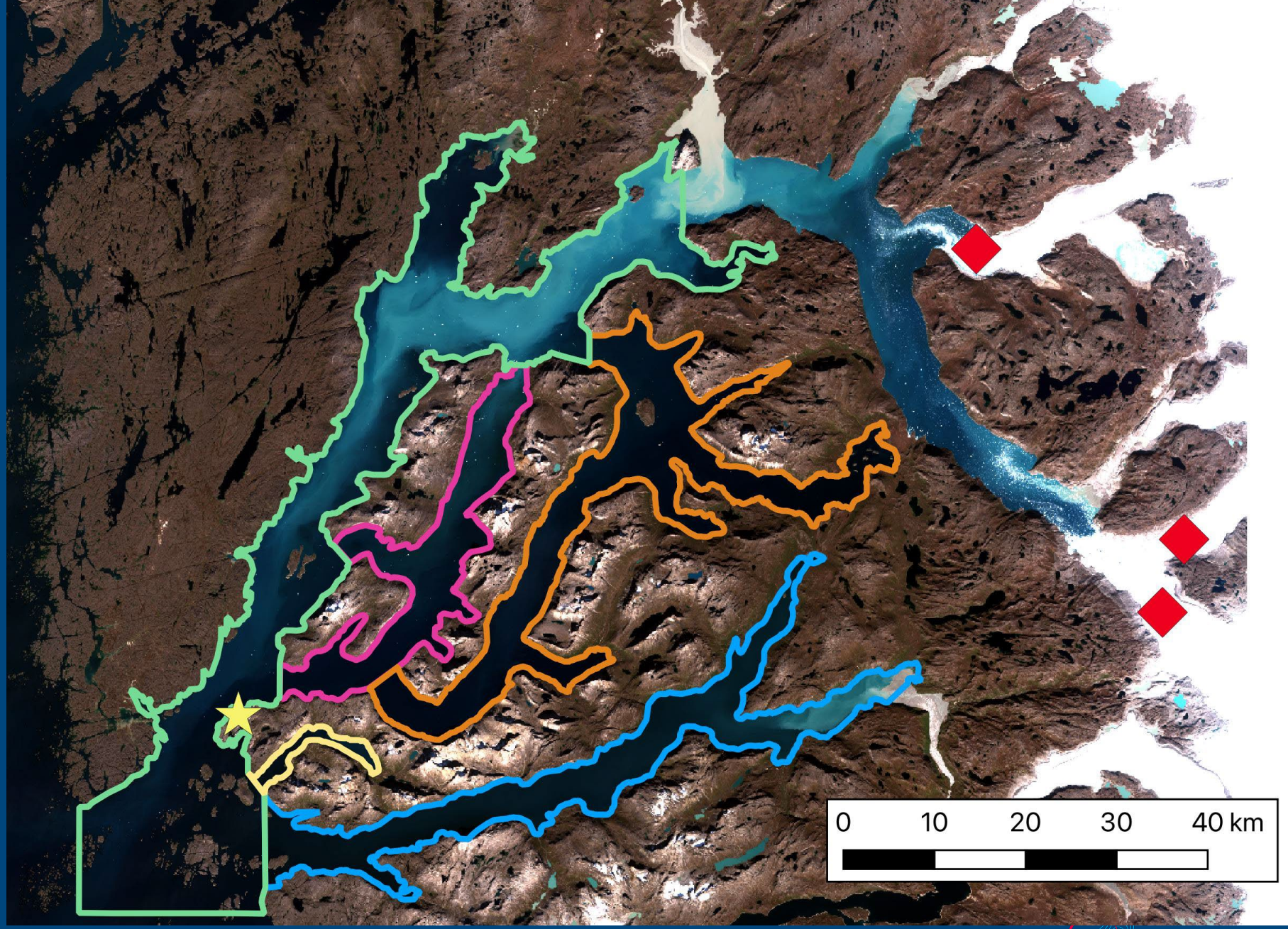






Study Area

- Icebergs, sea ice, and turbid surface waters in inner fjord make presence of macroalgae unlikely
- Expect to find macroalgae from mid to outer fjord



Macroalgae

- Tidal: *Ascophyllum nodosum* and *Fucus spp*.
- Subtidal: *Saccharina latissima* and *Agarum clathratum*
- Eelgrass beds
- Steep fjord boundaries limit macroalgae to narrow band of shallow water
- Macroalgal canopies do not reach the surface

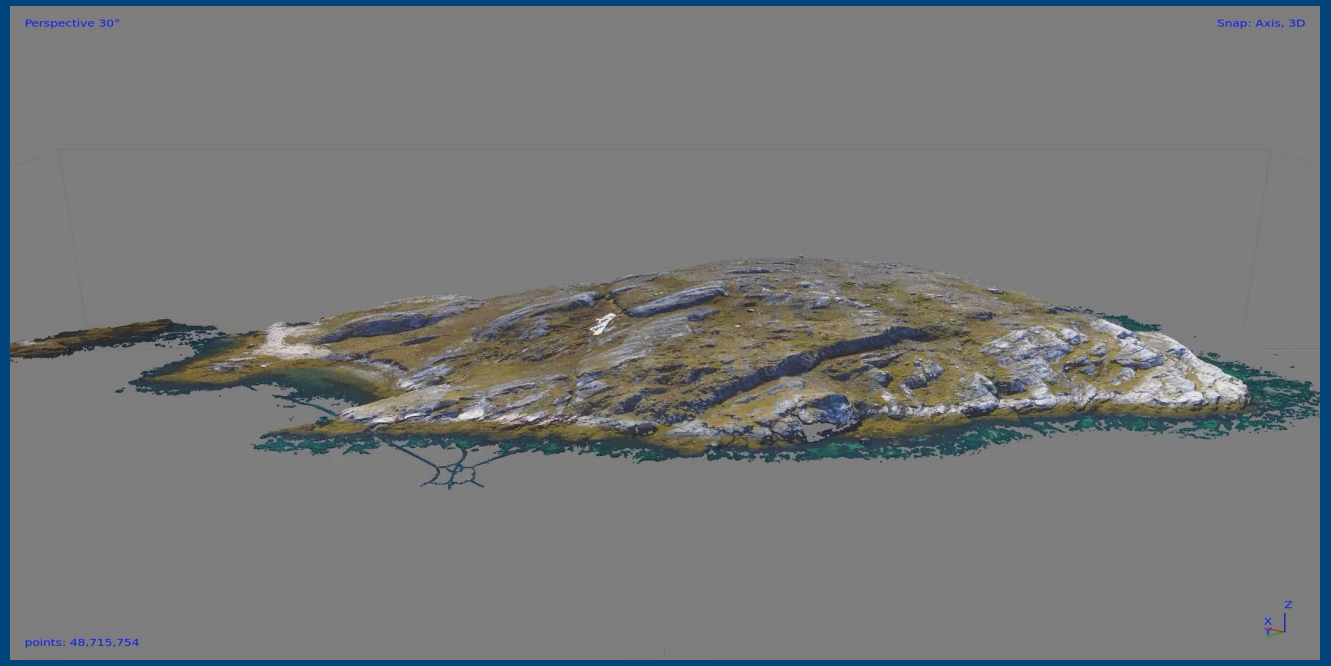
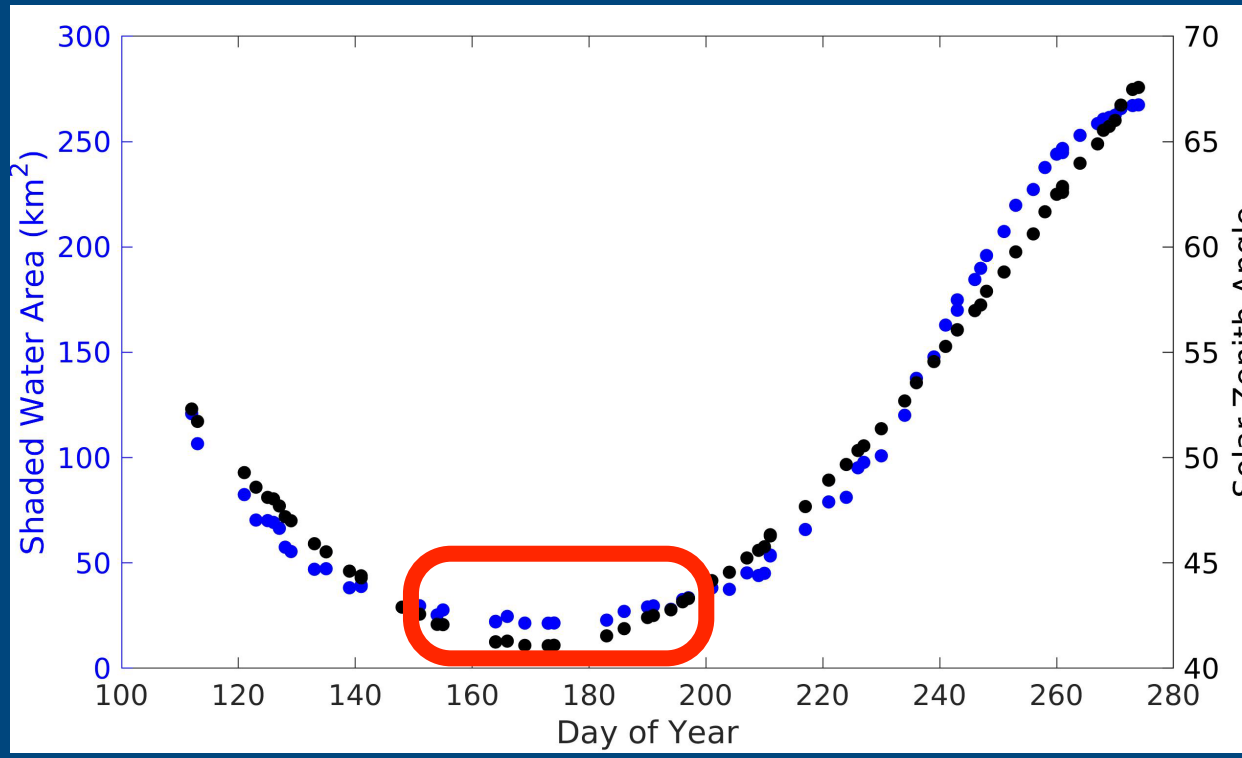


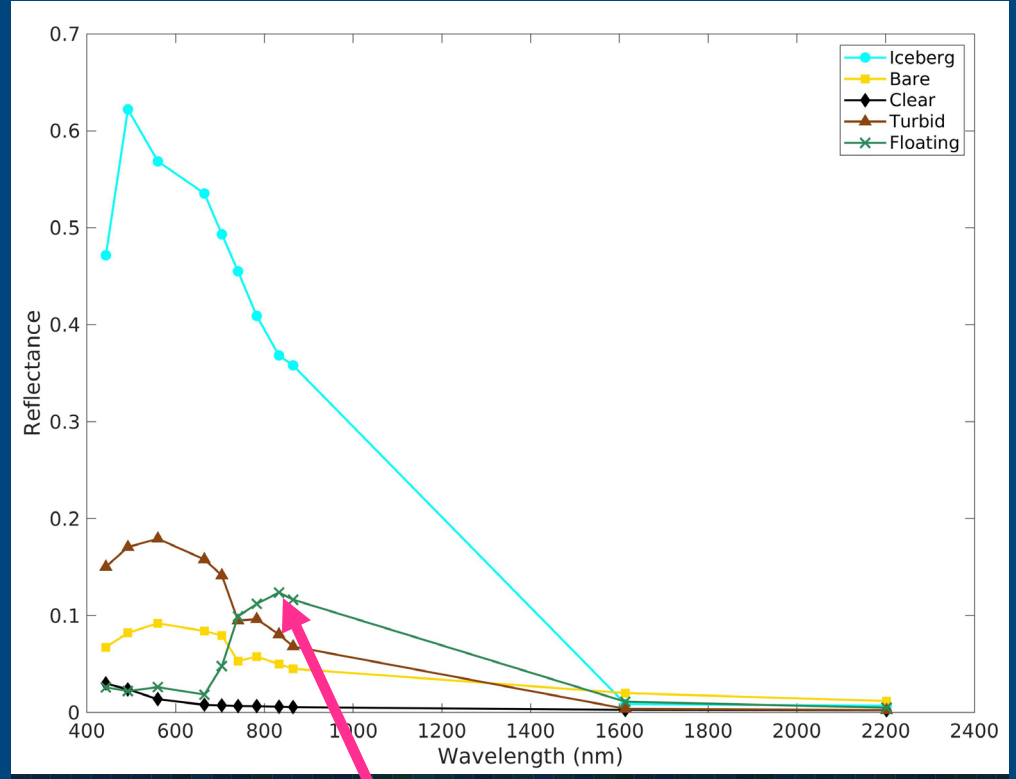
Image selection, atmospheric correction & masking

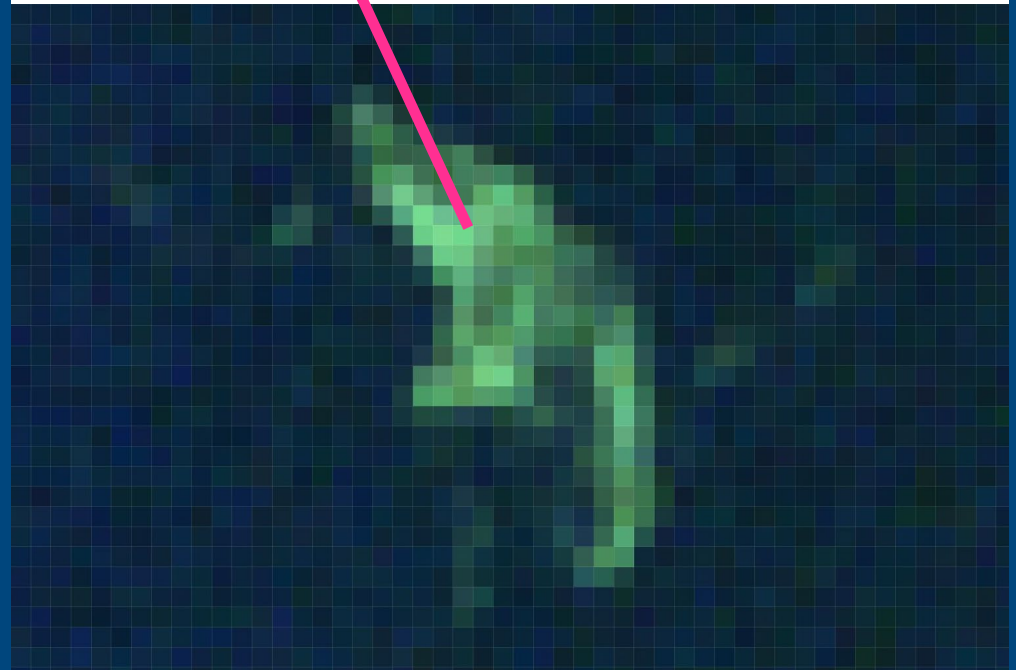
- Cloud-free S2 images in May-September
- Hillshade used to mask terrain shadows
- Images from June-July selected to minimize terrain shadows
- Low tide - high tide included to quantify impact of water level
- Six images total were analyzed
- 2017, 2018, and 2021
- ACOLITE atmospheric correction
- DEM and SWIR used to mask land



Classification

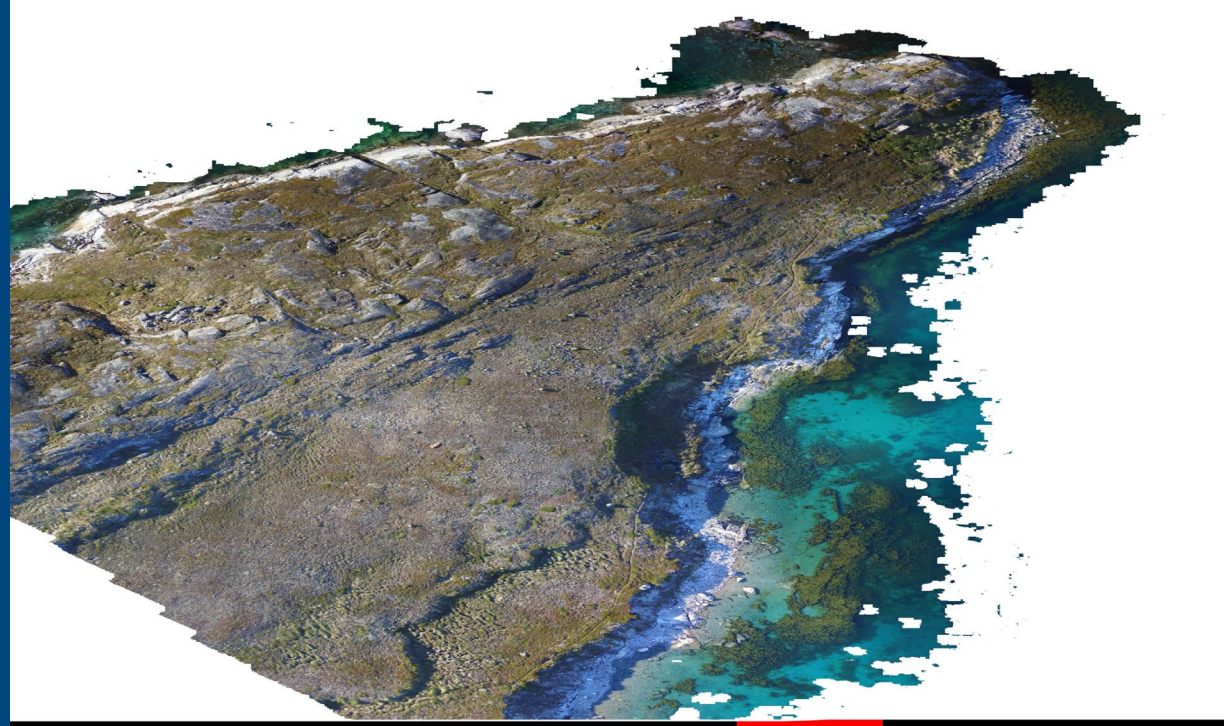
- Macroalgae identified using vegetation indices and spectral mixture analysis (SMA)
- Spectral unmixing in SNAP
- 5 spectral end members
- Floating macroalgae visually identified
- Spectral end member also used to identify macroalgae exposed at low tide
- Normalized Difference Vegetation Index
- Floating Algae Index (Hu, 2009)
- Enhanced Vegetation Index (Huete et al., 1999)





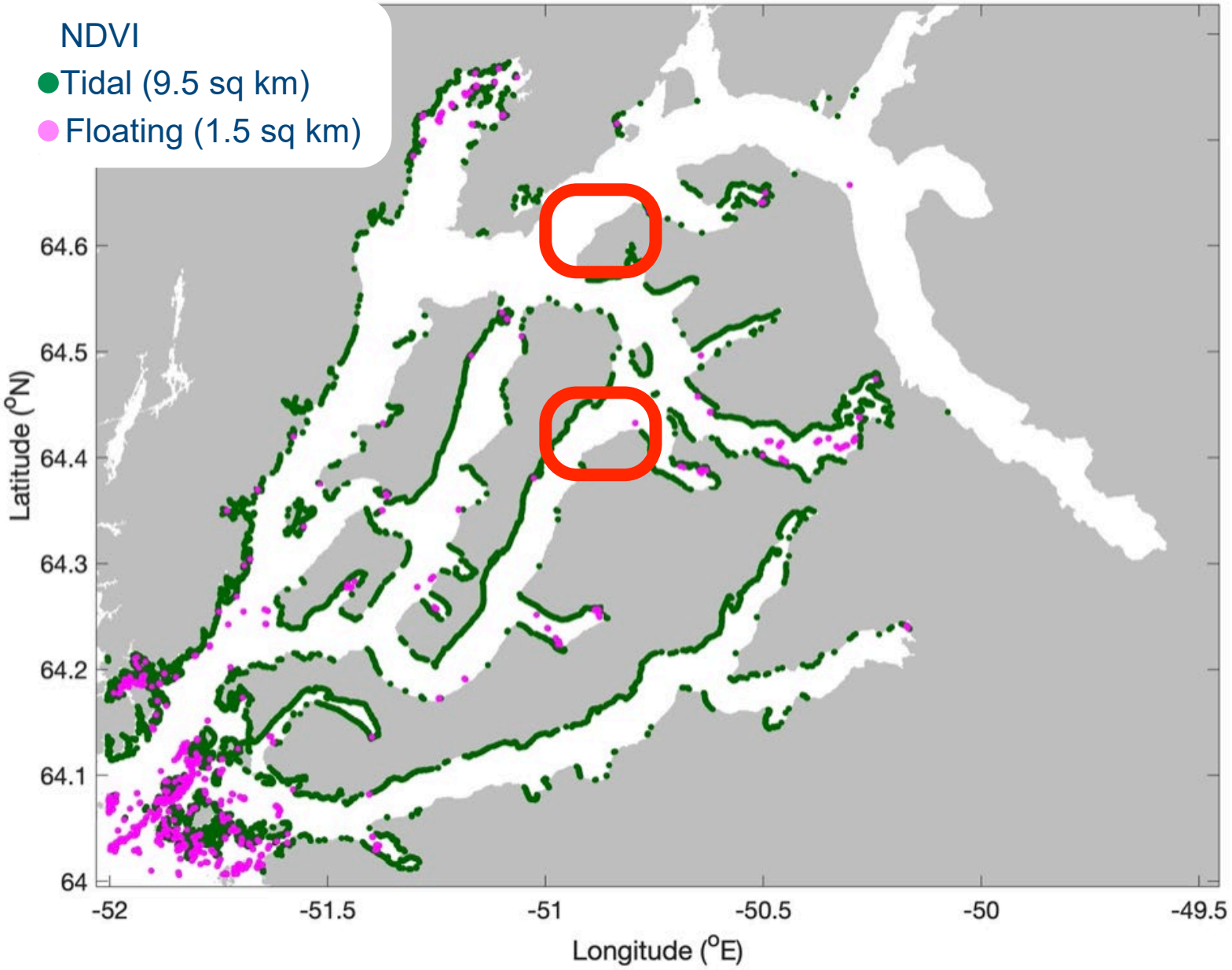
Validation

- High resolution (~cm) drone orthomosaics
- Imagery processed in Agisoft Metashape
- USGS workflow for coastal areas (Over et al., 2021)
- NDVI and FAI: 74% overall accuracy, 77% user accuracy, 76% producer accuracy
- EVI and SMA had higher errors of omission and commission
- Thresholds adjusted to maximize accuracies for all classifiers



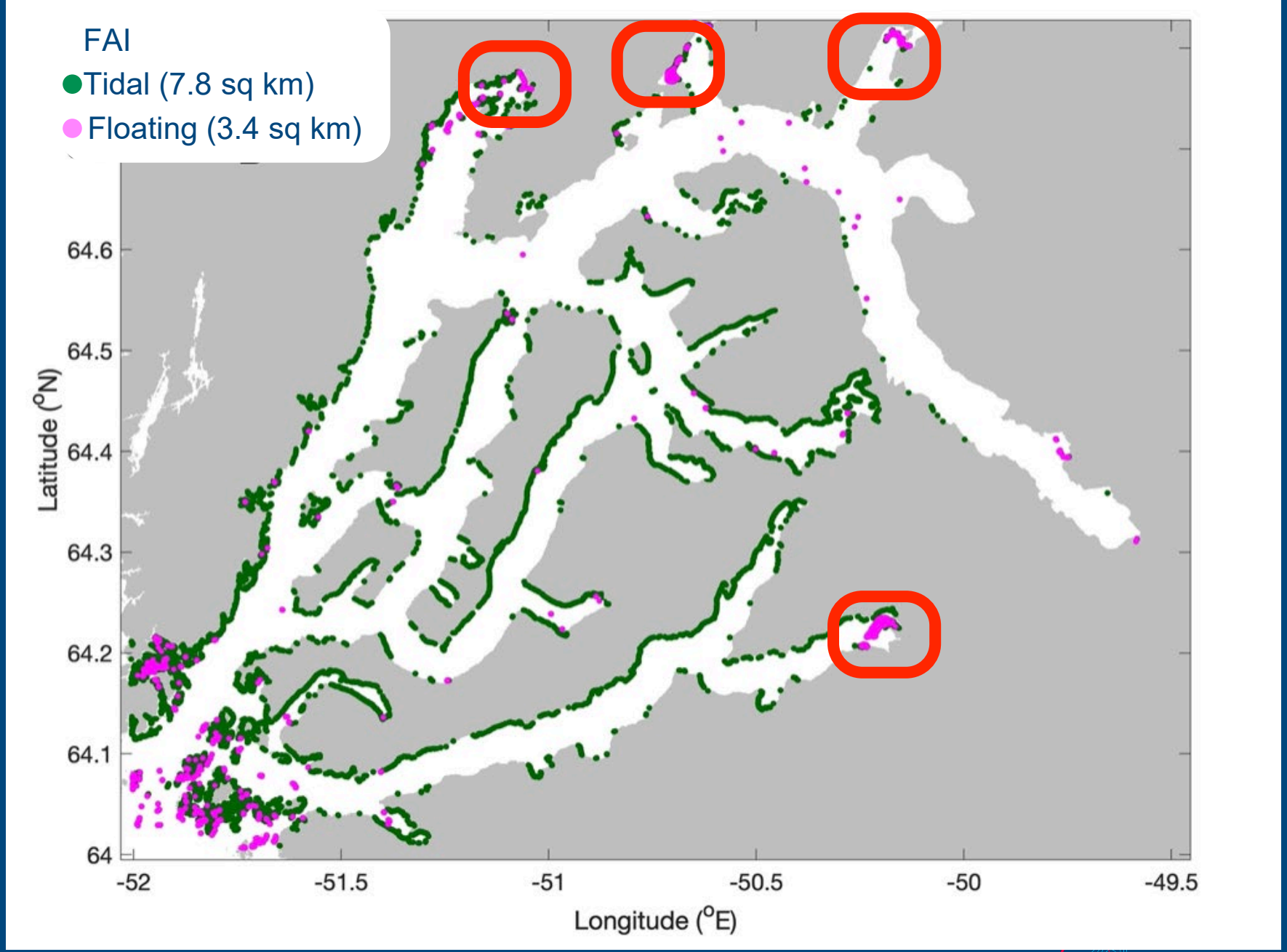
Results
NDVI

NDVI = (NIR-R)/(NIR+R)



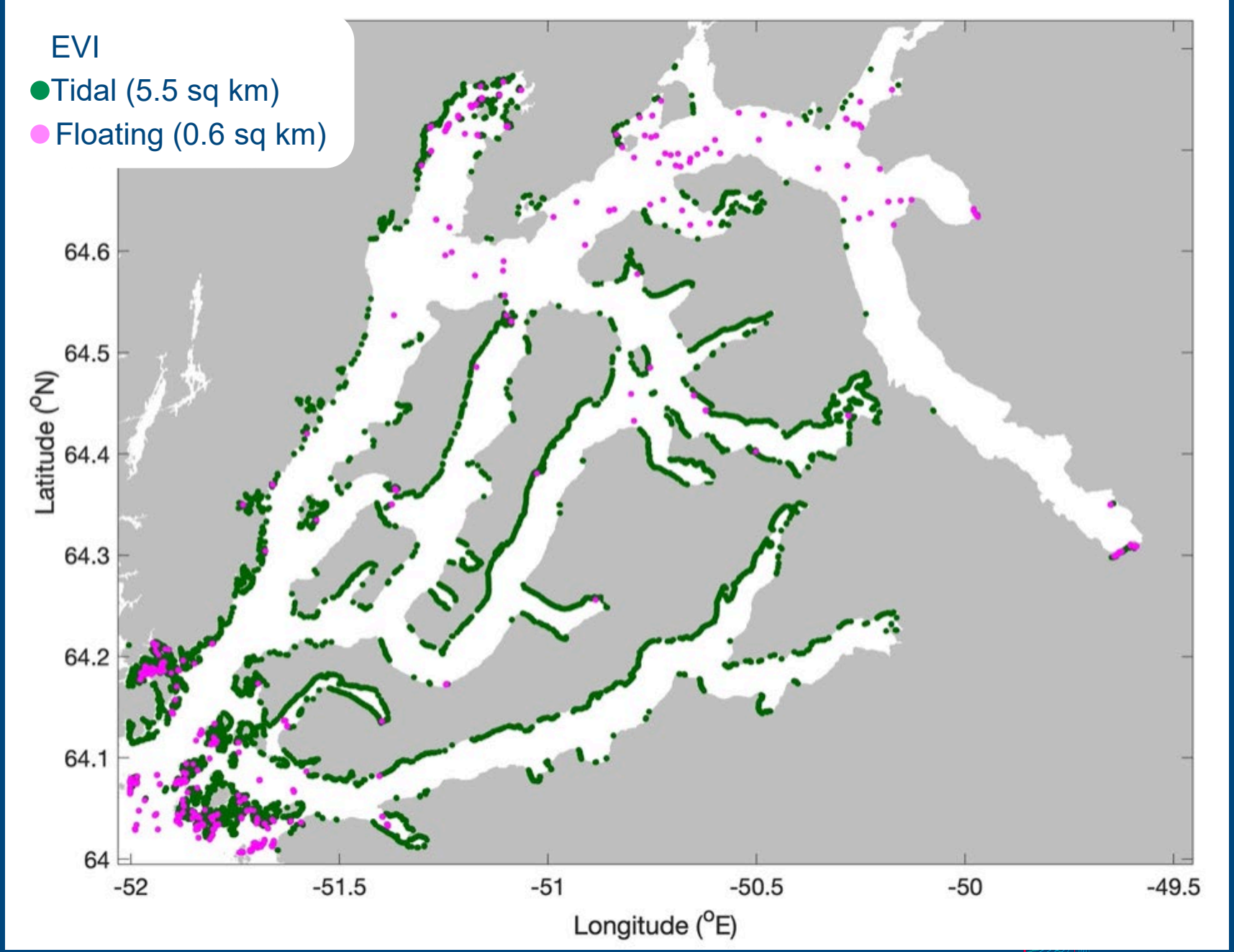
Results
FAI

FAI = NIR-(R+(SWIR-R)*(λNIR-λRed)/(λSWIR-λRed))



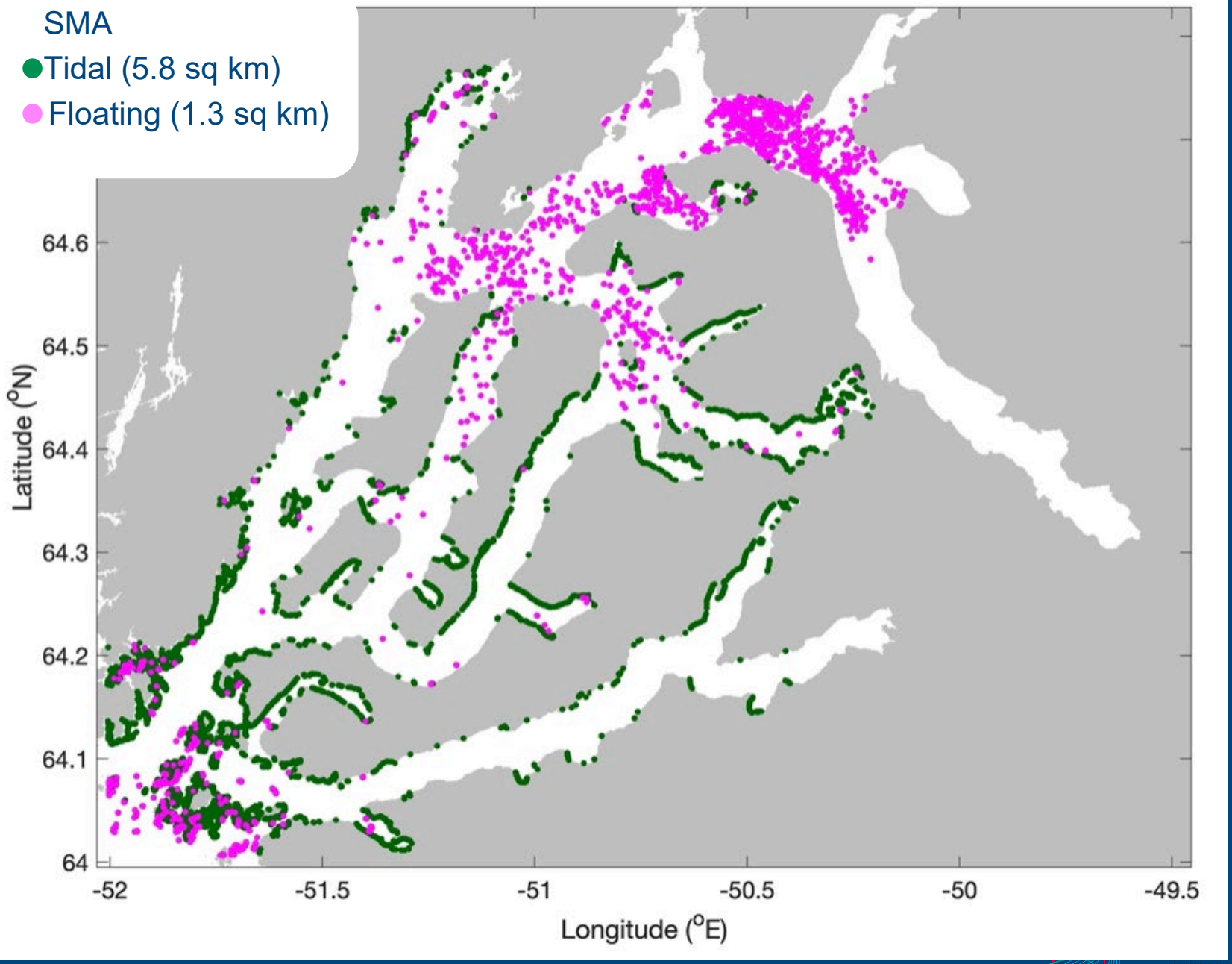
Results
EVI

EVI = 2.5*(NIR-R)/(NIR+6*R-7.5*B+1)



Results
SMA

Submerged iceberg keels classified as floating macroalgae



Summary

- Tidal macroalgal cover ~10 sq km
- Spatial extent corresponds to light availability in the fjord and substrate
- Limited to macroalgae exposed at low tide
- Drops to ~1 sq km at high tide
- Macroalgae growing deeper than 1-2 m not detected
- Bathymetry data required to map submerged macroalgae
- Macroalgae growing in terrain shadows not detected
- Validation imagery lacks turbid water and ice
- Validation data lacking in Ameralik Fjord

Outlook

- Sentinel-2 MSI imagery can be used to map the spatial extent of shallow macrophytes
- S2 methods could be applied to other areas of Greenland
- Shallow macroalgae cover estimates are sensitive to land mask and water level
- Nuup Kangerlua is one of the most studied fjords in Greenland, with a wealth of published literature and in situ data

Thanks!

This research was supported by the

Independent Research Fund Denmark (8021-

00222B) CARMA

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