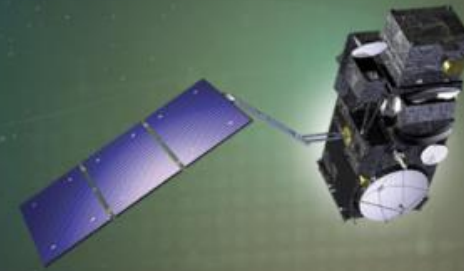




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# 7<sup>th</sup> Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

**Comparison of Sentinel-3, Jason-3, and Sentinel-6 altimetric and radiometric measurements over freshwater ice: Case study of Great Slave Lake (Canada) and Lake Oulujärvi (Finland)**

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## RATIONALE: Lake-atmosphere interactions at northern latitudes

- The presence (or absence) of ice cover and its extent affect climate and weather events (e.g., lake-effect snowfall, thermal moderation)
- EO observations of lake surface state (e.g., ice cover/open water and surface temperature) from multiple satellite missions can help improve the prediction of weather events from NWP models



Data Source: NASA Terra/MODIS image (11 February 2016) showing snow bands over the Great Lakes of North America.

## RATIONALE: Lake-atmosphere interactions at northern latitudes

### Lake-effect snowfall\* (case study)

- 17-19 Nov. 2014: ~150 cm of snow fell over areas just east of Buffalo
- A second lake-effect event on 19-20 Nov. dropped another ~30-120 cm

Result: 13 fatalities, hundreds of major roof collapses and structural failures, thousands of stranded motorists, power outages

### Other notable impacts of lakes on weather

- Thermal moderation (warmer near-surface air temperatures) due to the formation of cloud cover from ice-free or partly ice-free lake(s)
- Conductive heat flow from the warmer lake water through the lake ice and overlying snow cover to the atmosphere with ice growth



\* Bajinath-Rodino, J.A., C.R. Duguay, and E.F. LeDrew, 2018. Climatological trends of snowfall over the Laurentian Great Lakes Basin. *International Journal of Climatology*, 38: 3942–3962, <https://doi.org/10.1002/joc.5546>.



## OBJECTIVES

- To examine the sensitivity of brightness temperature ( $T_b$ ) and backscatter ( $\sigma^0$ ) data collected from satellite microwave radiometry and altimetry to ice and on-ice snow properties.
  - To characterize how the evolving nature of these properties impacts  $T_b$  and  $\sigma^0$  at frequencies available aboard the Sentinel-3, Jason-3 and Sentinel-6 altimetry missions.
- The overarching goal is to use EO-derived products of lake surface state during the ice growth and transitioning open water/ice cover periods from multiple satellite missions to improve: 1) the prediction of weather events from NWP models and 2) estimates of parameters in atmospheric reanalysis products such as ERA5.

## DATA AND METHODS

**This presentation**

T<sub>b</sub>, σ<sup>0</sup>, waveform satellite observations



### Missions used

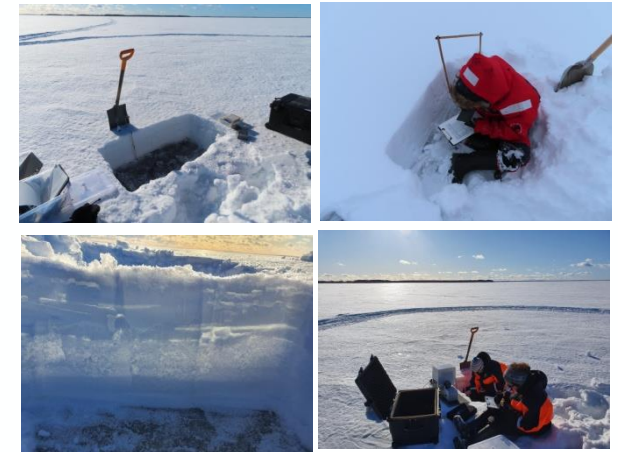
Satellite	Period	Altimeter (Radiometer)	Band/Frequency	Revisit (day)
Jason-3	Jan 2016 Jun 2021	Poseidon-3B LR (AMR)	Ku/13.6 and C/5.3 GHz (18.7, 23.8, 34.0 GHz)	10
Sentinel-3A	Feb 2016 – pres.	SRAL PLRM (MWR)	Ku/13.6 and C/5.4 GHz (23.8 and 36.5 GHz)	27
Sentinel-6	Dec 2020 – pres.	Simultaneous LR and HR (AMR-C)	Ku/13.575 and C/5.41 GHz (18.7, 23.8, 34.0 GHz)	10

T<sub>b</sub>, σ<sup>0</sup>, WF simulated vs observed

calibration  
T<sub>b</sub>, σ<sup>0</sup>, waveform simulations

Microwave radiative transfer models

Field observations of ice properties or ice thickness simulations by thermodynamic model



**3 campaigns in winter 2021 on Lake Oulujärvi (Finland)**

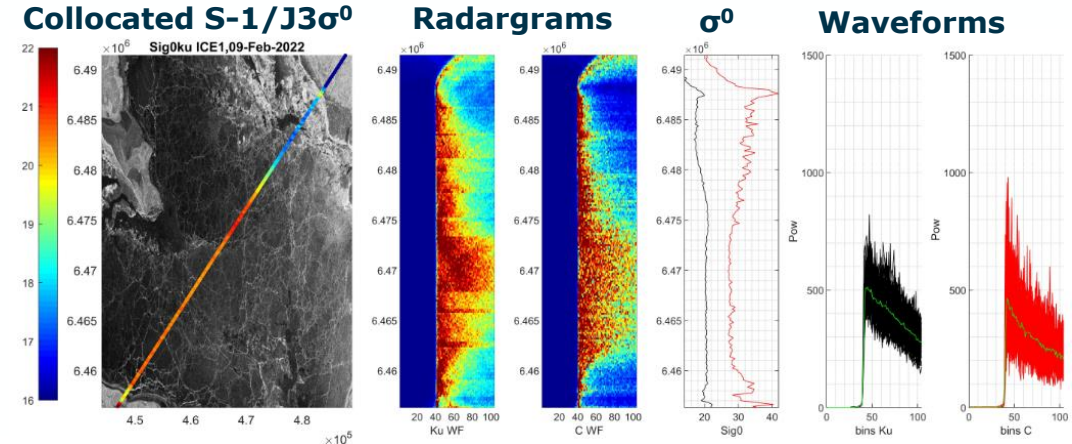
## DATA AND METHODS

Tb,  $\sigma^0$  and waveforms  
(satellite observations)

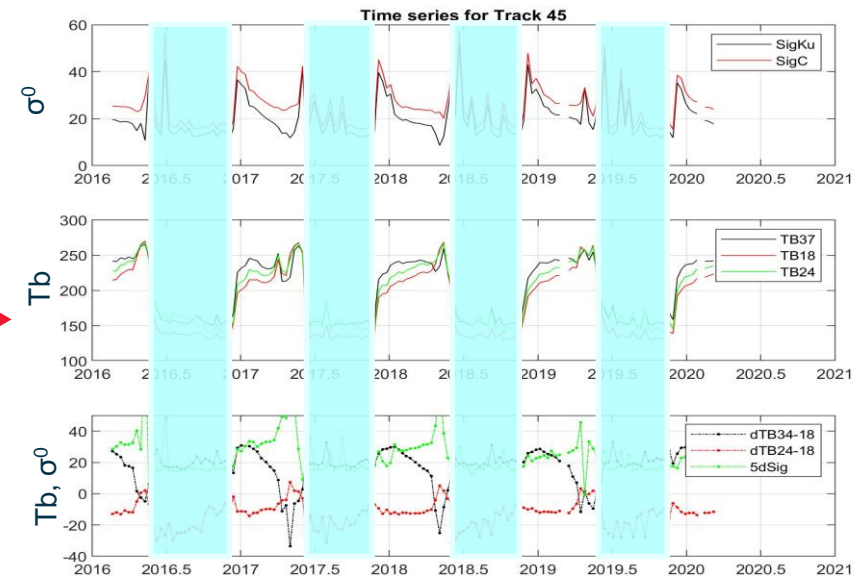
### Two approaches:

#### 1. Along-track analysis

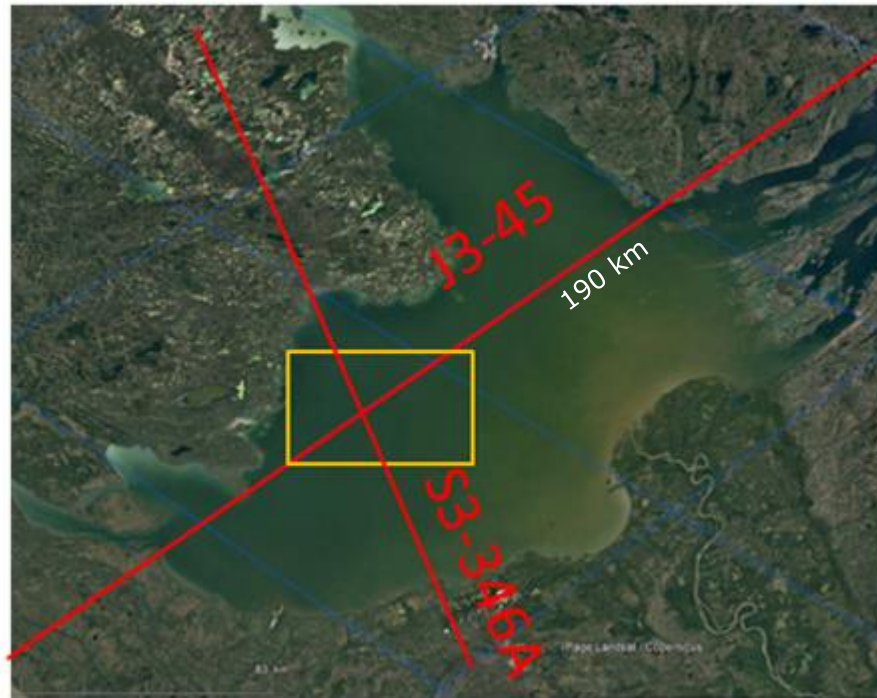
See poster of Mugunthan et al. on machine learning



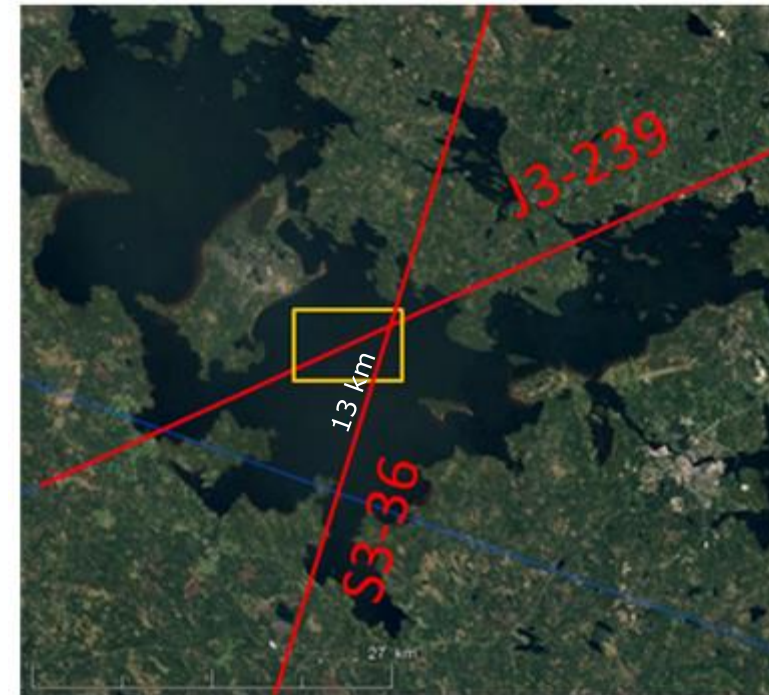
#### 2. Temporal variability of parameters with ice growth



## STUDIED LAKES



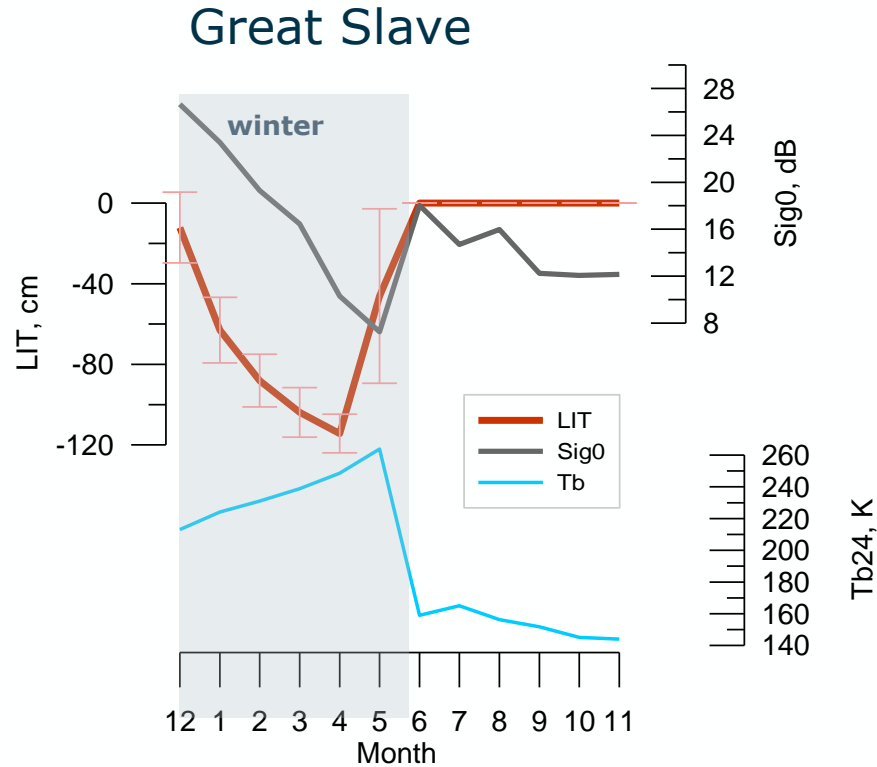
**Great Slave:** ~100x200 km, LIT up to 150 cm, shallower and denser snow, cold winters



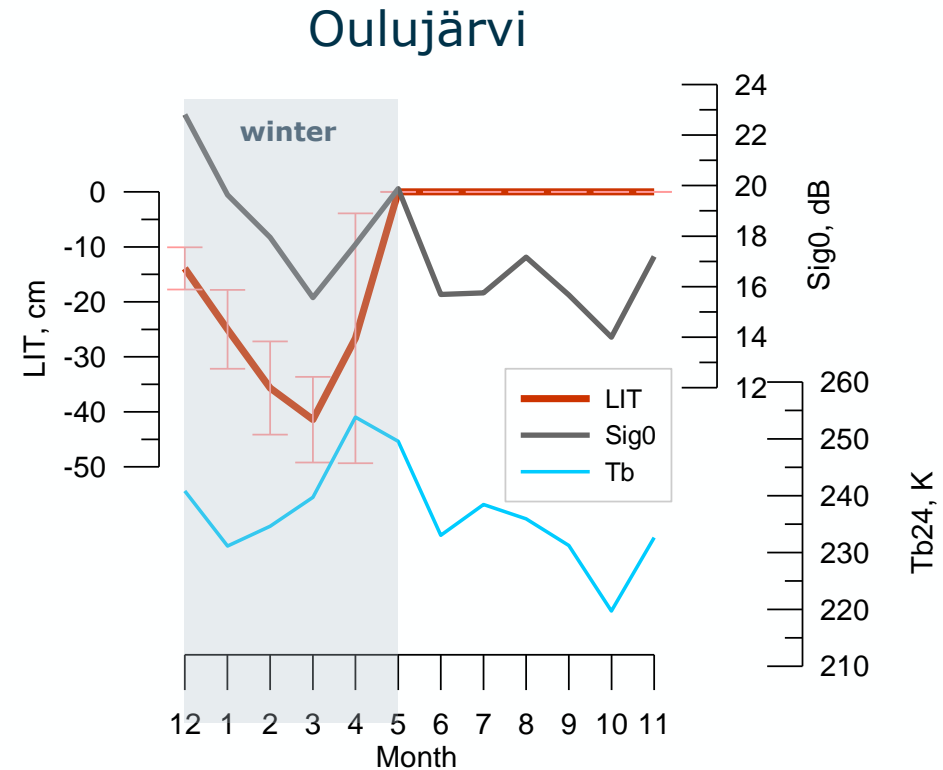
**Oulujärvi:** ~16x18 km, LIT up to 80 cm, deeper snow and of lesser density, warm winter episodes

## RESULTS

### Mean monthly variability of Sentinel-3 observations and observed/simulated LIT



LIT from CLIMo for 50%40m configuration

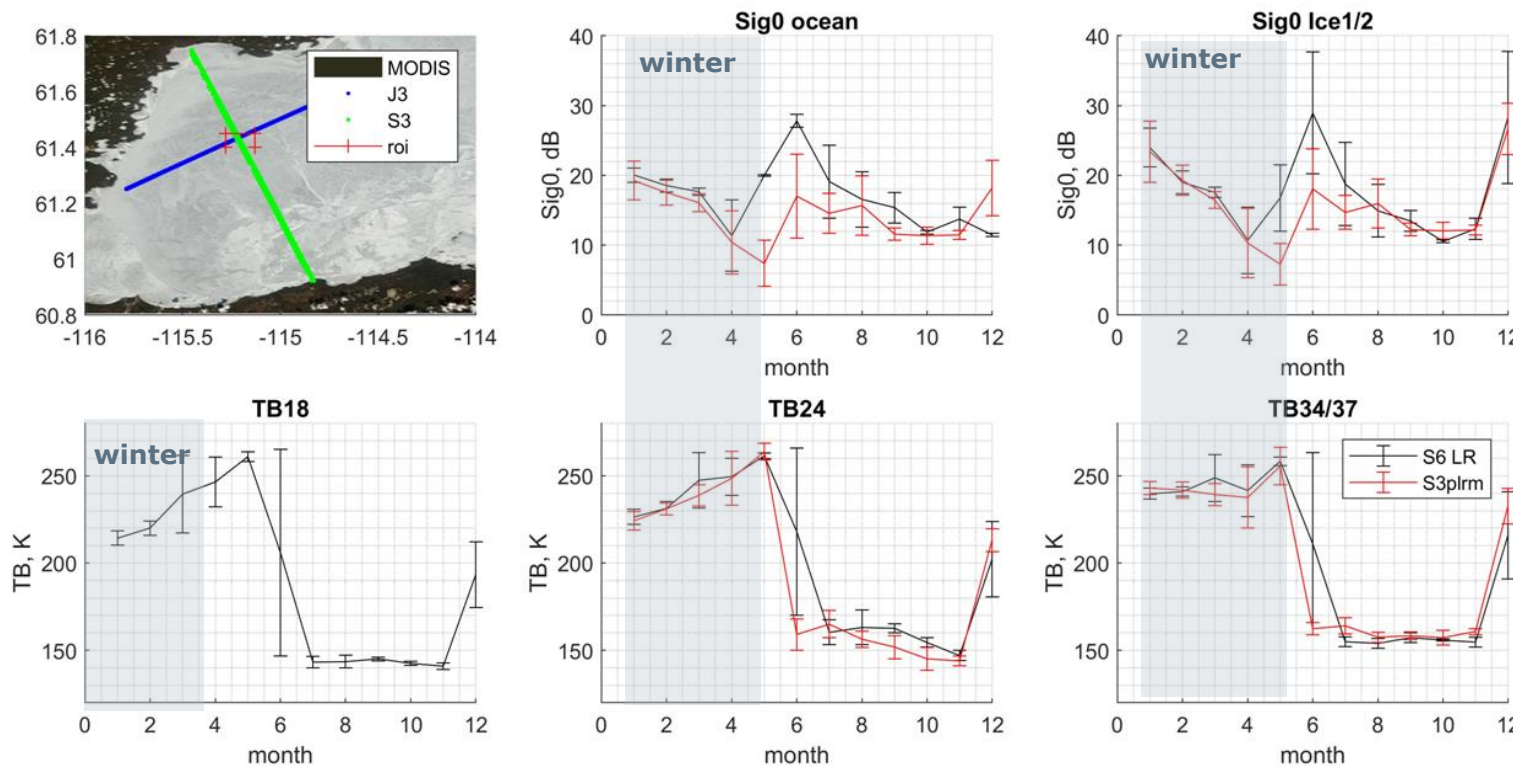


LIT from in situ observations

## RESULTS

### S6 LR – S3 PLRM comparison over Great Slave at S6-S3 crossover

#### Seasonal variability of mean monthly values



For large lake and similar ice conditions at crossover:

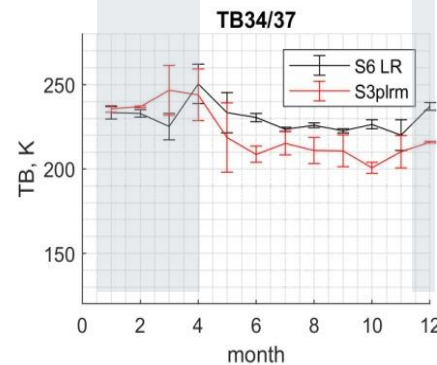
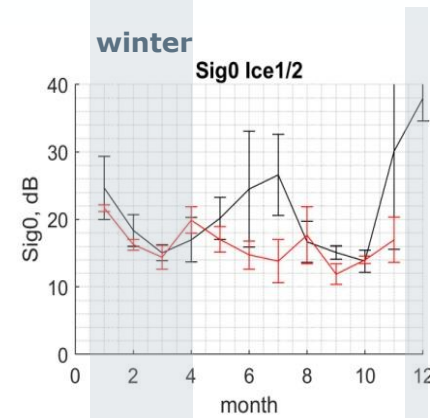
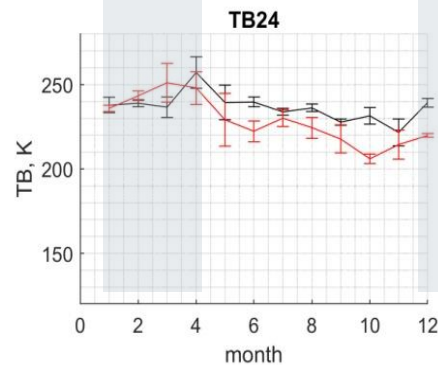
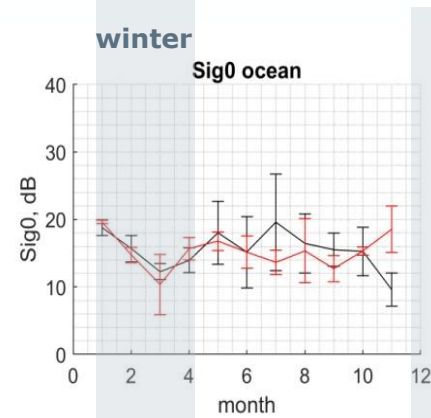
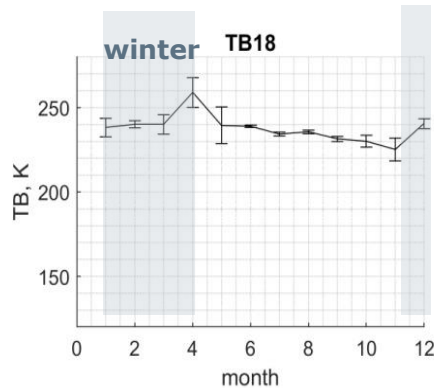
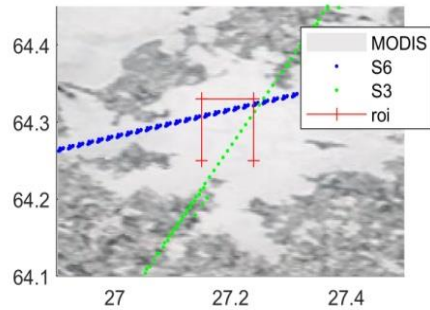
- Good consistency in  $\sigma^0$  ICE1/ICE2 during winter: **Intersatellite bias is <2dB for  $\sigma^0$  ICE in winter**
- Good consistency in Tb 24 GHz during the winter : **Intersatellite TB bias is low (<3°K) in winter; higher in summer (<9°K) and very high during transitional months** (due to spatio-temporal ice variability)

## RESULTS

### S6 LR – S3 PLRM comparison over Oulujarvi

#### Seasonal variability of mean monthly values

~2-4 km distance between missions



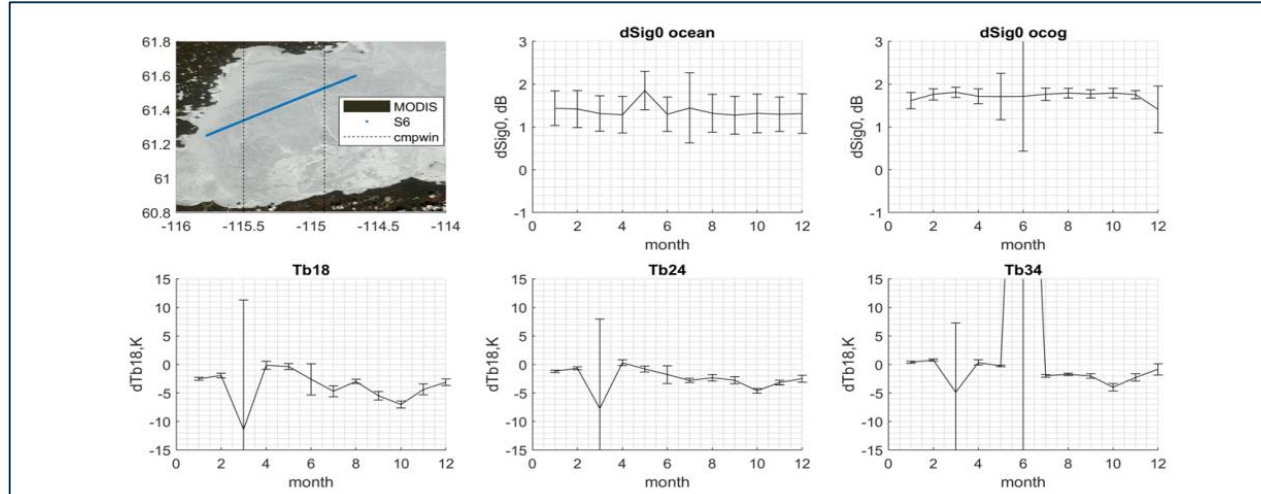
For smaller lake and close tracks' location, but different %land in footprint:

- Good  $\sigma^0$  ICE1/ICE2 consistency during winter: **Intersatellite bias is <3dB (low land effect)**
- Good Tb 24 GHz consistency during the winter: **Intersatellite Tb24 bias <2-8°K in winter**

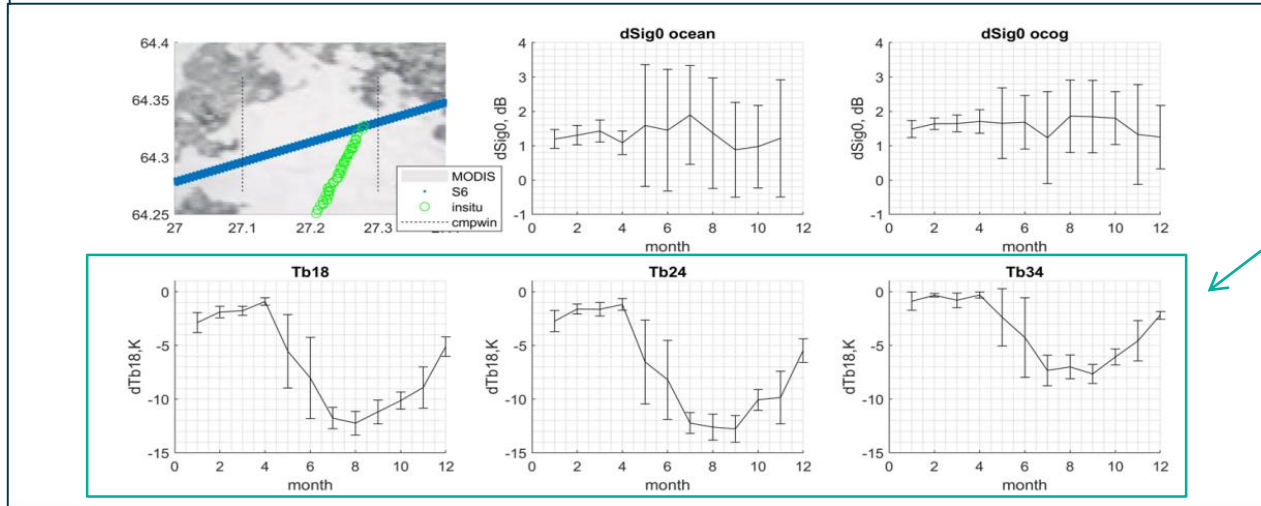
## RESULTS

### S6 LR – J3 intersatellite bias for different months

GSL



Oulujärvi



Intersatellite  $\sigma^0$  bias :

**<2dB for ICE retracker**

Intersatellite Tb bias:

- low (<3°K) in winter;
- significantly varies seasonally for Oulujärvi

## CONCLUSIONS AND OUTLOOK

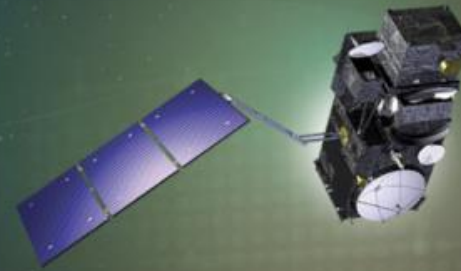
- Both  $\sigma^0$  and **Tb18/24** GHz are sensitive to LIT variations over large lakes (Great Slave)
- Over smaller lakes (Oulujärvi) the  $\sigma^0$  signal is more consistent than Tb signal with LIT winter increase
- Small  $\sigma^0$  intersatellite biases found between Jason-3, Sentinel-3 and Sentinel-6 LR modes during the ice season
- Intersatellite **Tb** bias is low in winter and increases in summer, especially over smaller lake (Oulujärvi)
- The next step will consist of forward modelling of **Tb**,  $\sigma^0$  and waveforms using radiative transfer models:
  - HUT snow emission model: the model allows the simulation of emission from a vertically stacked structure of multiple snow and ice layers, making possible the simulation of microwave emission over snow covered lake ice and examination of land contamination
  - Radar altimeter waveforms and  $\sigma^0$  : First-order radiative transfer waveform model (Tonboe et al., 2006, 2010) to simulate the effective scattering horizon observed by radar altimeters when measuring snow-covered sea ice (here for lake ice)



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## Thank you for your attention!

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