Sea Ice Thickness Retrieval based on Predictive Regression Neural Networks using L-band Microwave Radiometry Data from the FSSCat mission

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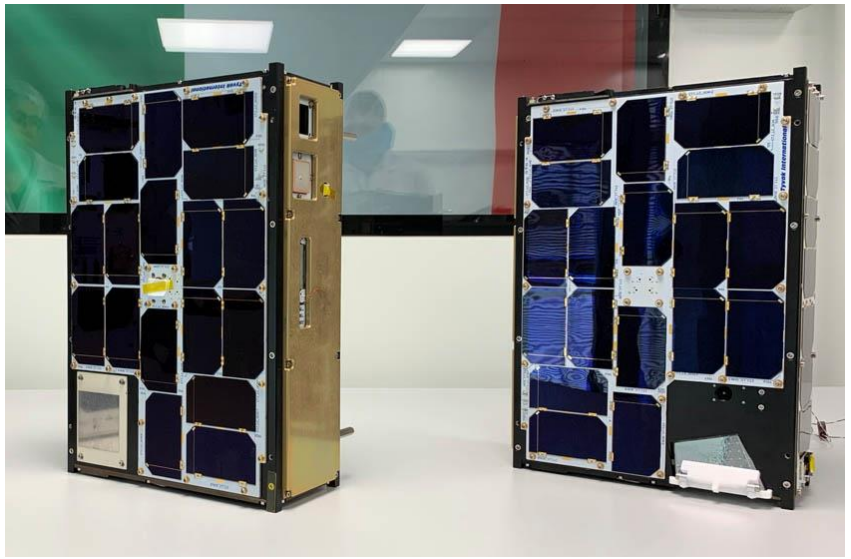
FSSCat CubeSat mission

- Tandem mission of two 6U CubeSats (launch date: **3 September 2020**)
- Winner of the 2017 ESA Small Sentinel Satellite Challenge and the overall Copernicus Masters Competition
- Carrying the Flexible Microwave Payload-2 (FMPL-2) consisting of a **GNSS-Reflectometer** and an **L-band radiometer**
- Providing global coverage T_B data to retrieve **sea ice thickness** (**SIT)** and **extent** over polar areas, and low-resolution **soil moisture** over land
- Footprint: approx. 350 x 500 km²



Introduction

- **Brightness temperature (T_B)** at L-band (1.4 GHz) sensitive to **sea ice thickness (SIT) up to 0.6 m**
- **Altimetry observations** sensitive to **SIT > 1 m**
- **CubeSats** may be a moderate-cost alternative to complement large satellite missions (SMOS, SMAP)
- **Neural networks (NN)** finds hidden links between non-linearly related sea ice parameters
  - NNs often perform better on complex problems then process-based models (snow cover, ice types)
  - NNs adaptive to new data (changing sea ice conditions and intermittent periods of freeze up and melting)

Objectives

- **Infering sea ice thickness** from T_B observations of the FSSCat mission and auxiliary data
- Training **two** individual regression networks: **(i) thin SIT model (< 0.6 m)** and **(ii) full-range model**
- **Providing SIT maps** over polar areas (Arctic and Antarctic region)

Regression Neural Network

- Training of **two** individual SIT models with Arctic datasets
  - **(i) thin SIT model (< 0.6 m):** T_B
  - **(ii) full-range SIT model:** T_B + altimetry data

Regression neural network

FSSCat FMPL-2 data:

Brightness temperature

Ancillary data:

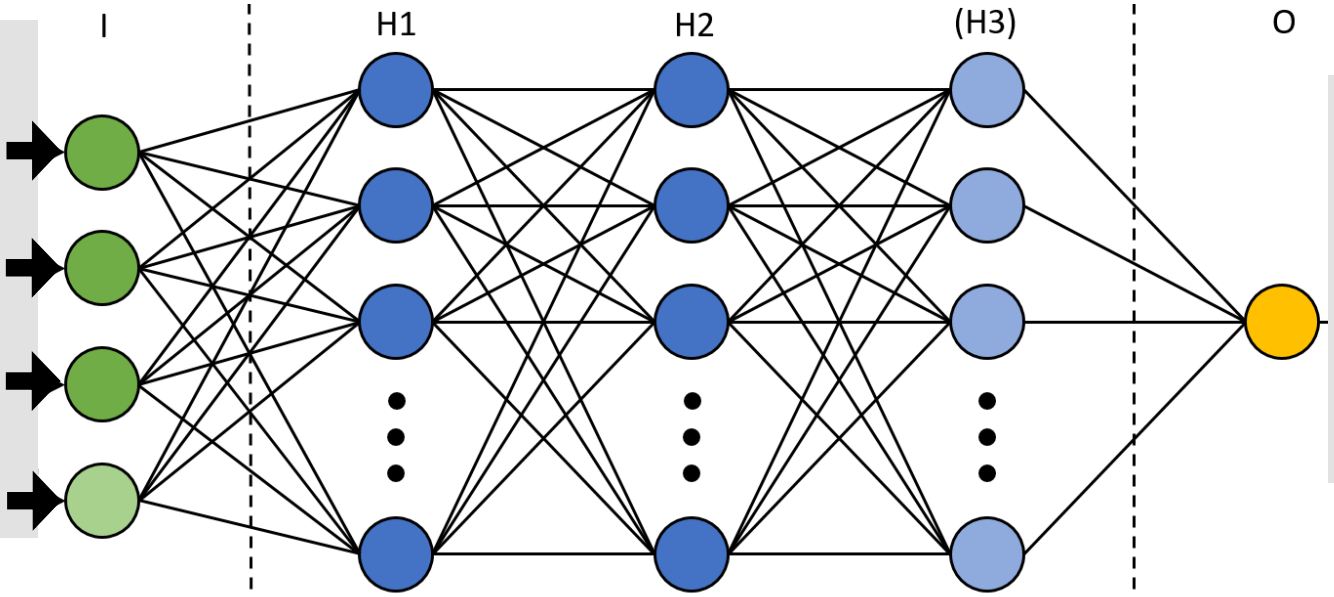
Sea ice concentration

+

Skin temperature

+ (ii)

Sea ice freeboard (CryoSat-2)



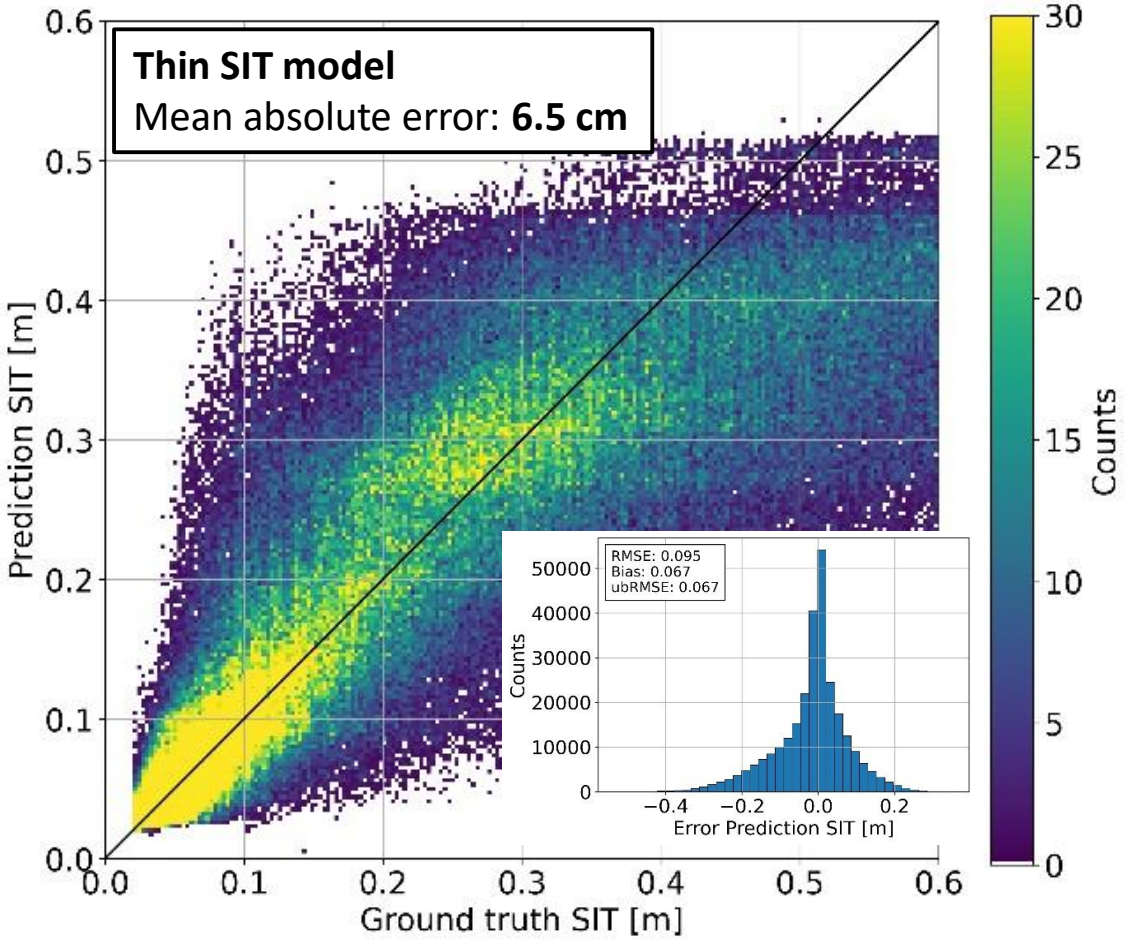
Ground truth (Arctic):

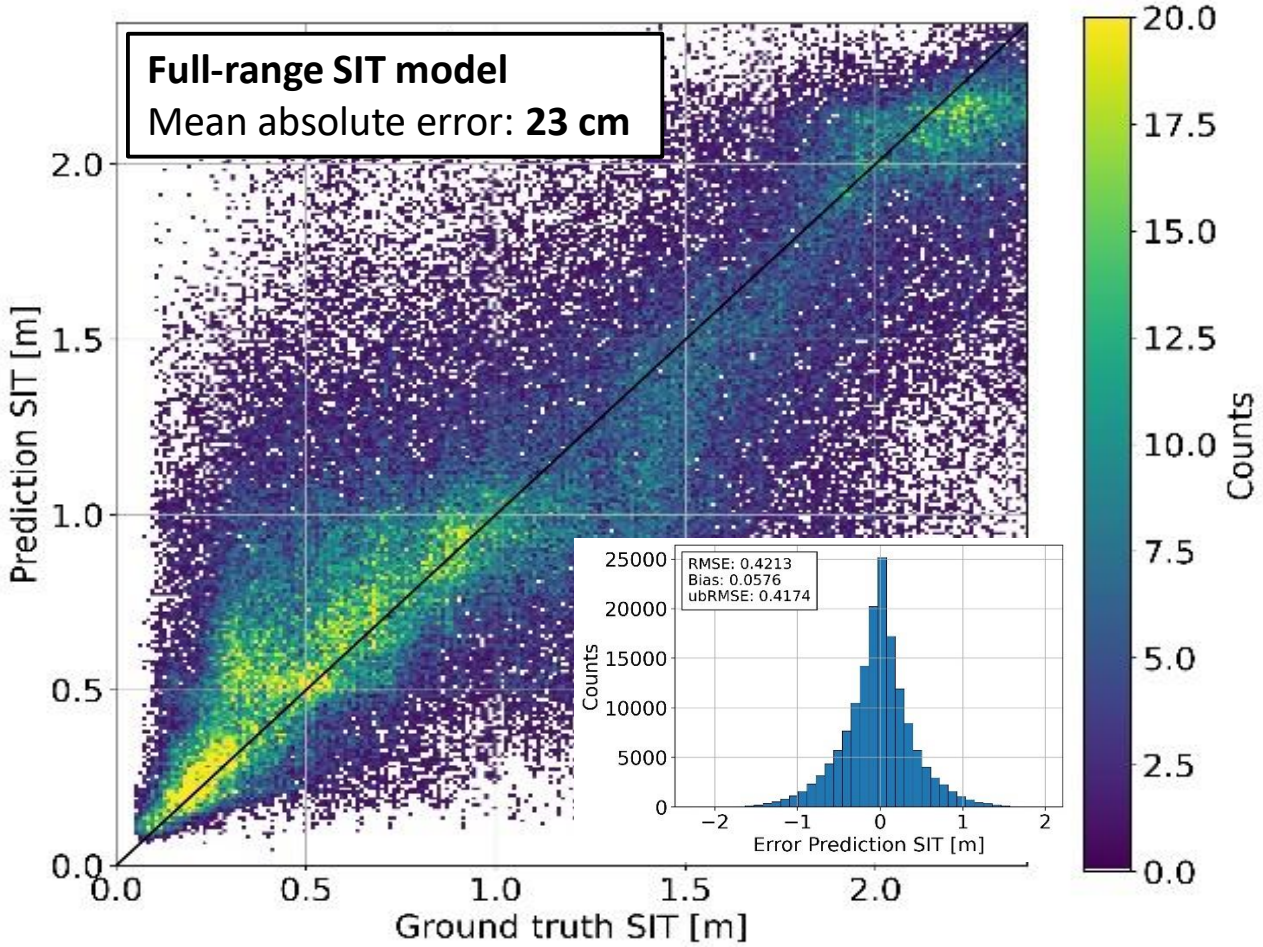
(i) SMOS-derived thin SIT product

(ii) SIT merged product (CryoSat-2 + SMOS)

(provided by Alfred Wegener Institute for Polar and Marine Research)

Model training and prediction

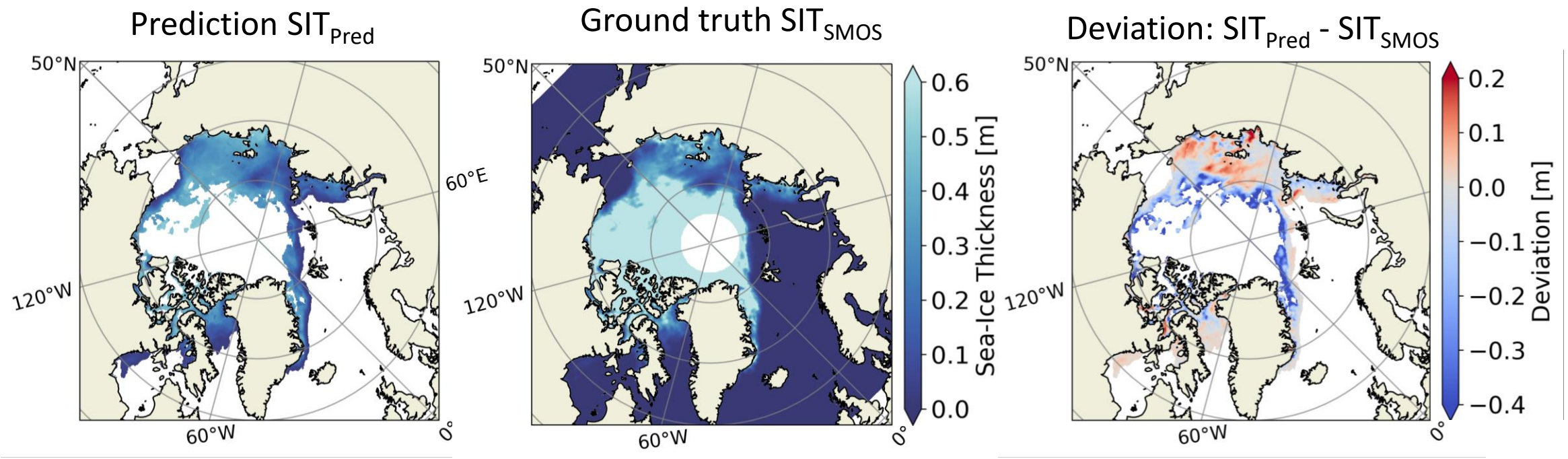




Trained period: **1 October – 4 December 2020**

Thin model – Arctic SIT < 0.6 m

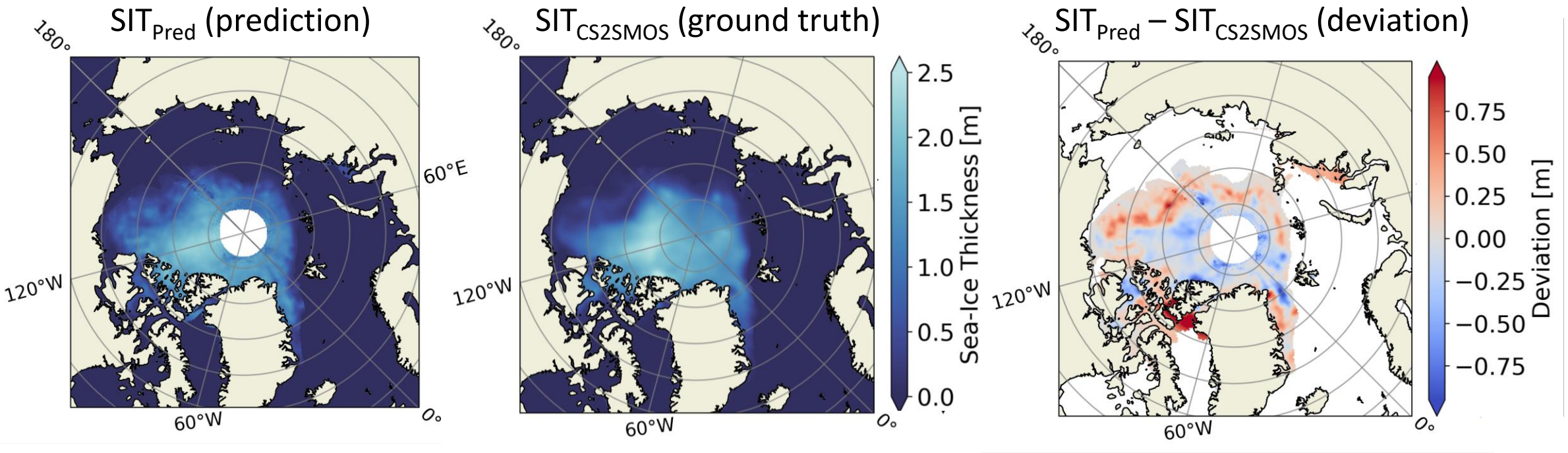
Estimated Arctic thin SIT (< 0.6 m) – weekly composite (12–18 November 2020)



- Model generalizes well up to a SIT of 0.5 m
- Underestimation for higher SIT values

Full-range model – Arctic SIT

Estimated Arctic full-range SIT – weekly composite (22–28 October 2020)

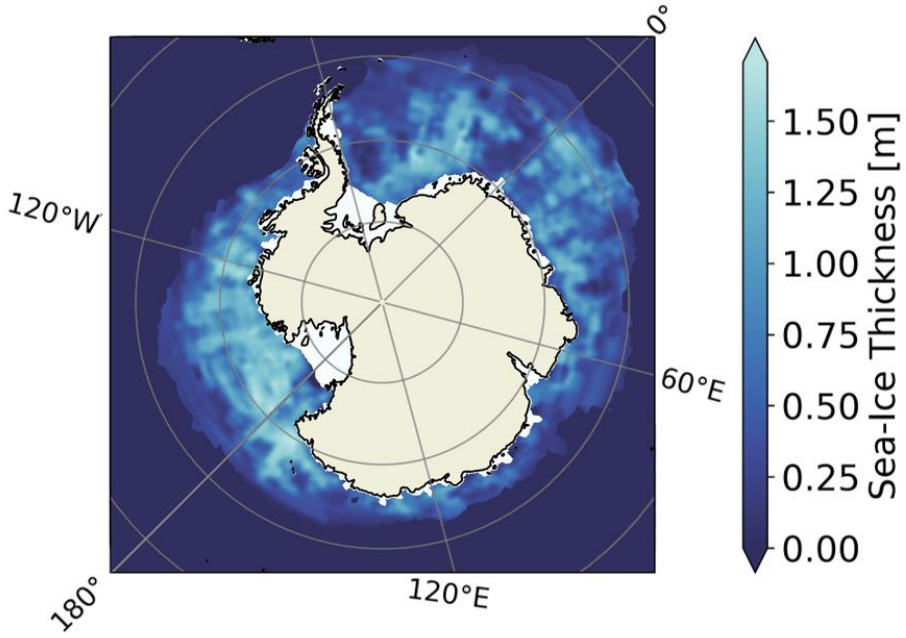


- Model performs well for thin ice and SIT above 1.5 m
- Main deviation originates from predicted values in the intermediate SIT range between 0.5 – 1.5 m

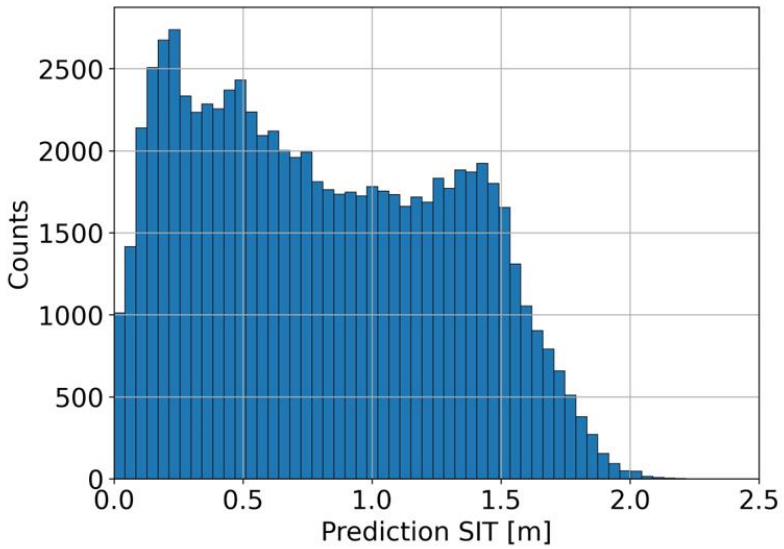
Full-range model – Antarctic SIT

- Application of Arctic model to Antarctic data
- Antarctic full-range SIT – monthly composite (15 October – 14 November 2020)

SIT_{Pred} (prediction)

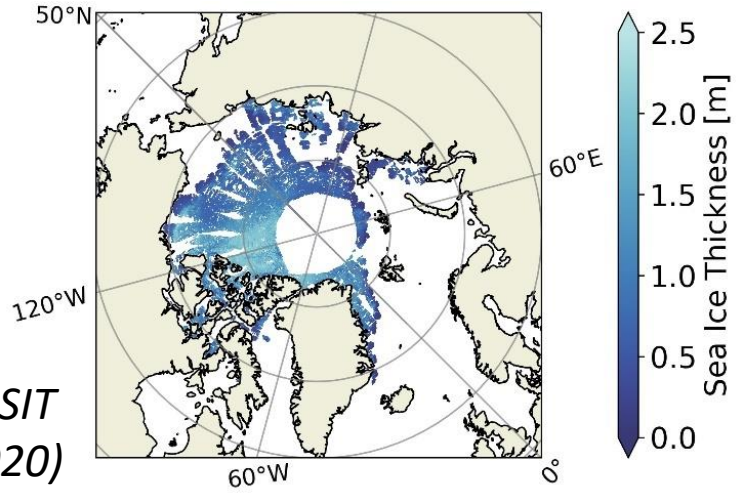


SIT distribution



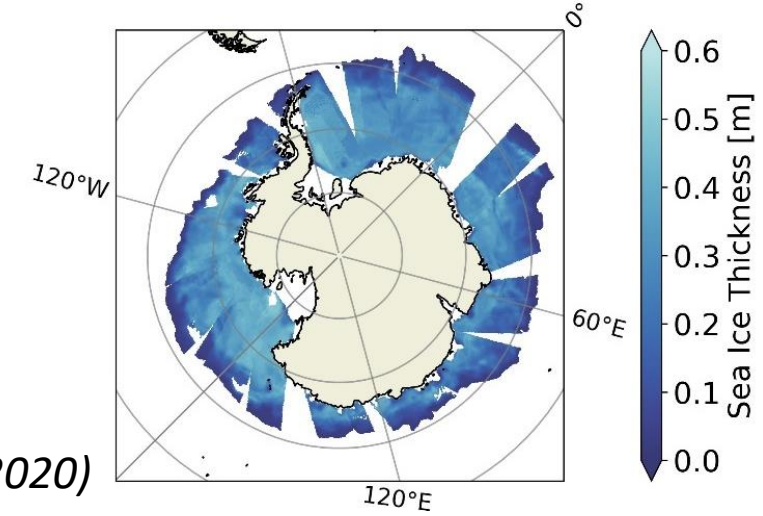
SIT product overview

- Arctic products
  - Level-2 Daily Arctic thin SIT
  - Level-3 Weekly composite thin SIT (running mean)
  - Level-4 Weekly composite full-range SIT (running mean)



Ex. Level-4 full-range SIT (November 9 – 15, 2020)

- Antarctic products
  - Level-2 Daily thin SIT
  - Level-3 Weekly composite thin SIT (running mean)
  - Level-4 Weekly composite full-range SIT (running mean)



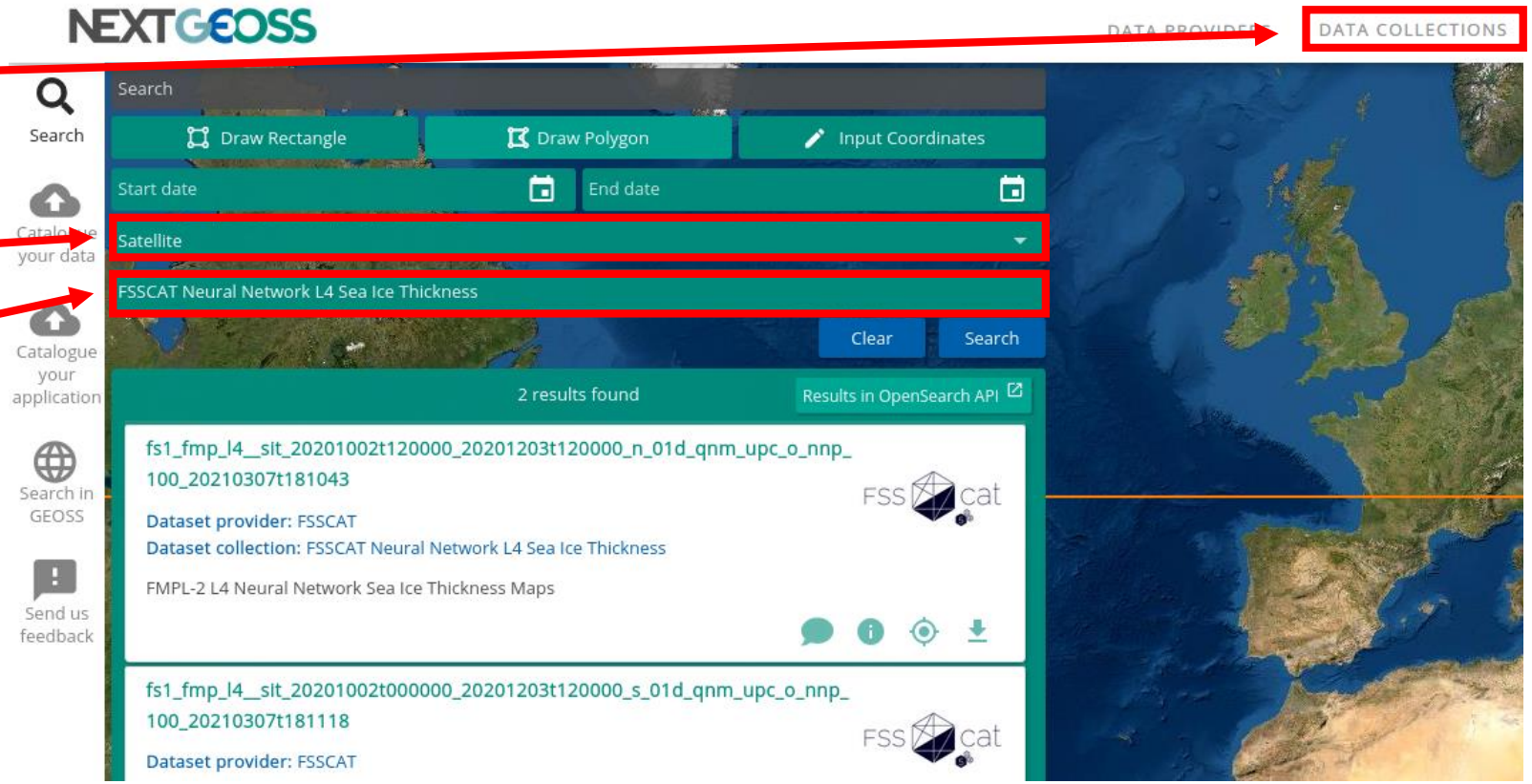
12.5 km Equal-Area Scalable Earth Grid (EASE-Grid 2.0)

Ex. Level-3 thin SIT (October 10 – 17, 2020)

FSSCat dataset availability

- All Products available at ... (including FMPL-2 T_B, GNSS-R, sea ice extent, soil moisture) https://catalogue.nextgeoss.eu/
- Search for datasets:
  - Data Collections: **FSSCAT**

  OR
  - Acquisition type: **Satellite**
  - Collection: **FSSCAT 'product_name'**
- NetCDF format
- Product User Guide ... http://deimos.pt/FSSCAT ProductsUsersGuide.pdf



Conclusion

- Retrieval of SIT maps based on predictive regression neural networks
- Two individual models implemented and trained with Arctic data to yield maps of thin and full-range SIT
  - Mean absolute error of 6.5 cm of SIT predictions w.r.t. the SMOS-derived product
  - Mean absolute error of 23 cm of SIT predictions w.r.t. the merged CS2SMOS product
- Using a **constellation of similar CubeSats** may help **bridging possible gaps** of non-existent data to guarantee the **continuous monitoring** of polar regions

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