

A novel technique for automated mapping of Antarctic supraglacial lakes in Sentinel-1 SAR imagery using deep learning

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[Link to Sentinel-1 Publication](#)

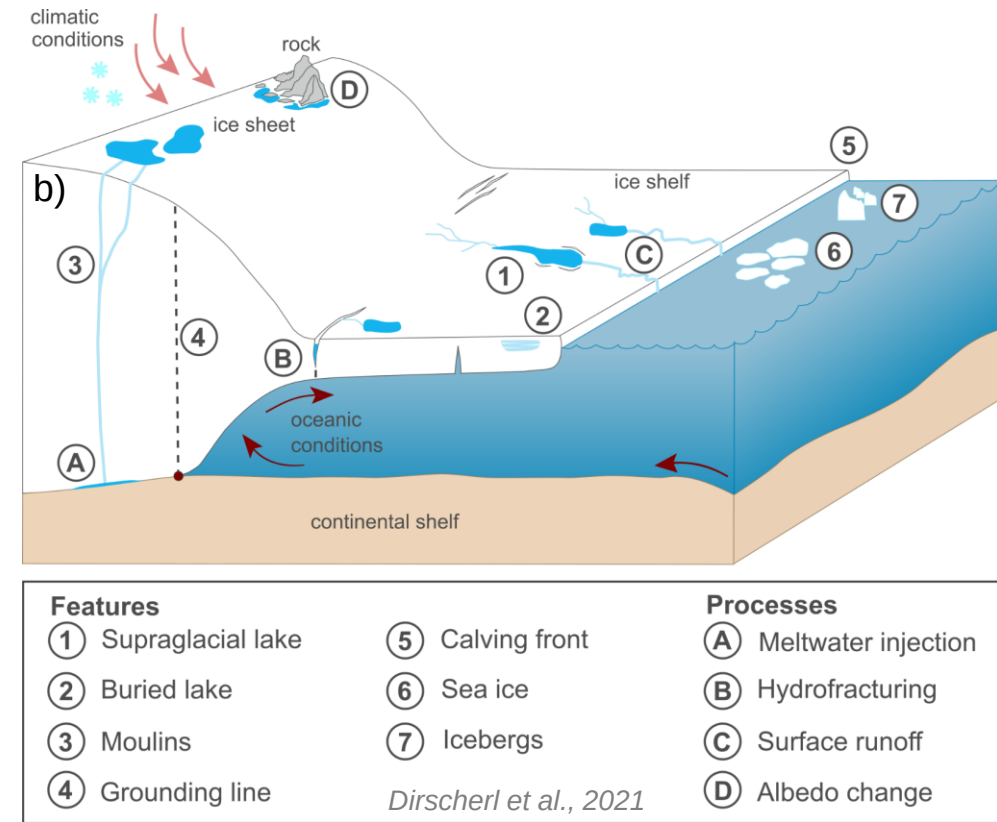
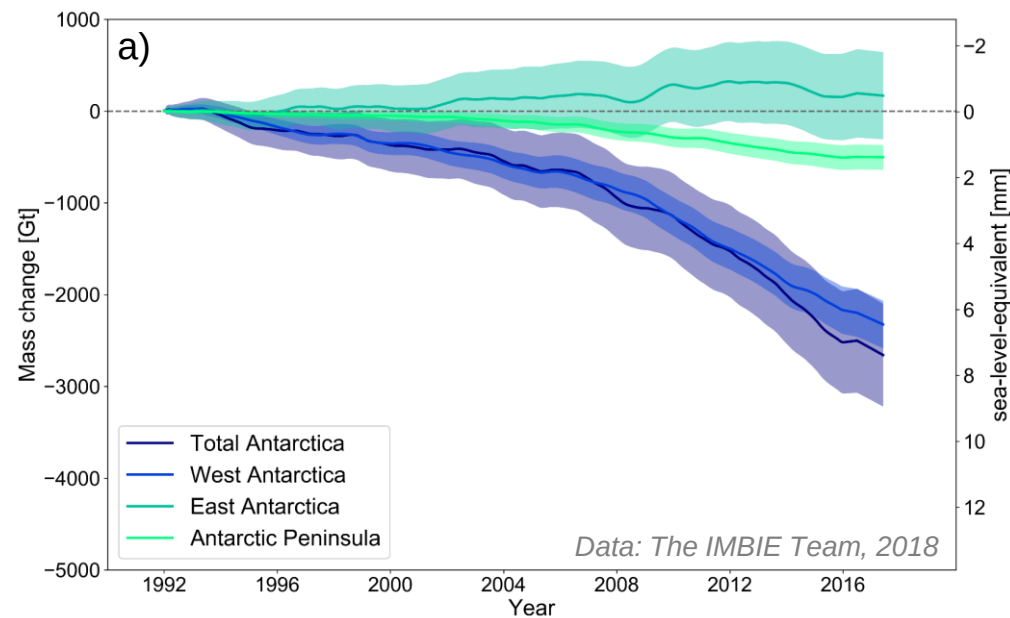


Knowledge for Tomorrow



Why is the mapping of Antarctic surface hydrology important?

Supraglacial meltwater accumulation and runoff may impact the Antarctic ice sheet through several processes (b, A-D) potentially causing ice flow acceleration, increased ice discharge, surface thinning or accelerated melting through albedo feedback mechanisms (e.g., Arthur et al., 2020; Bell et al., 2018). For example, Antarctic Peninsula ice mass loss and associated sea-level-rise in 1992-2017 (a) was largely influenced by meltwater-induced ice shelf collapse (The IMBIE Team, 2018).



10 km George VI Ice Shelf, Antarctic Peninsula, January 2020

Antarctica

Surface melting is already widespread around Antarctica!

Study aim & overall workflow

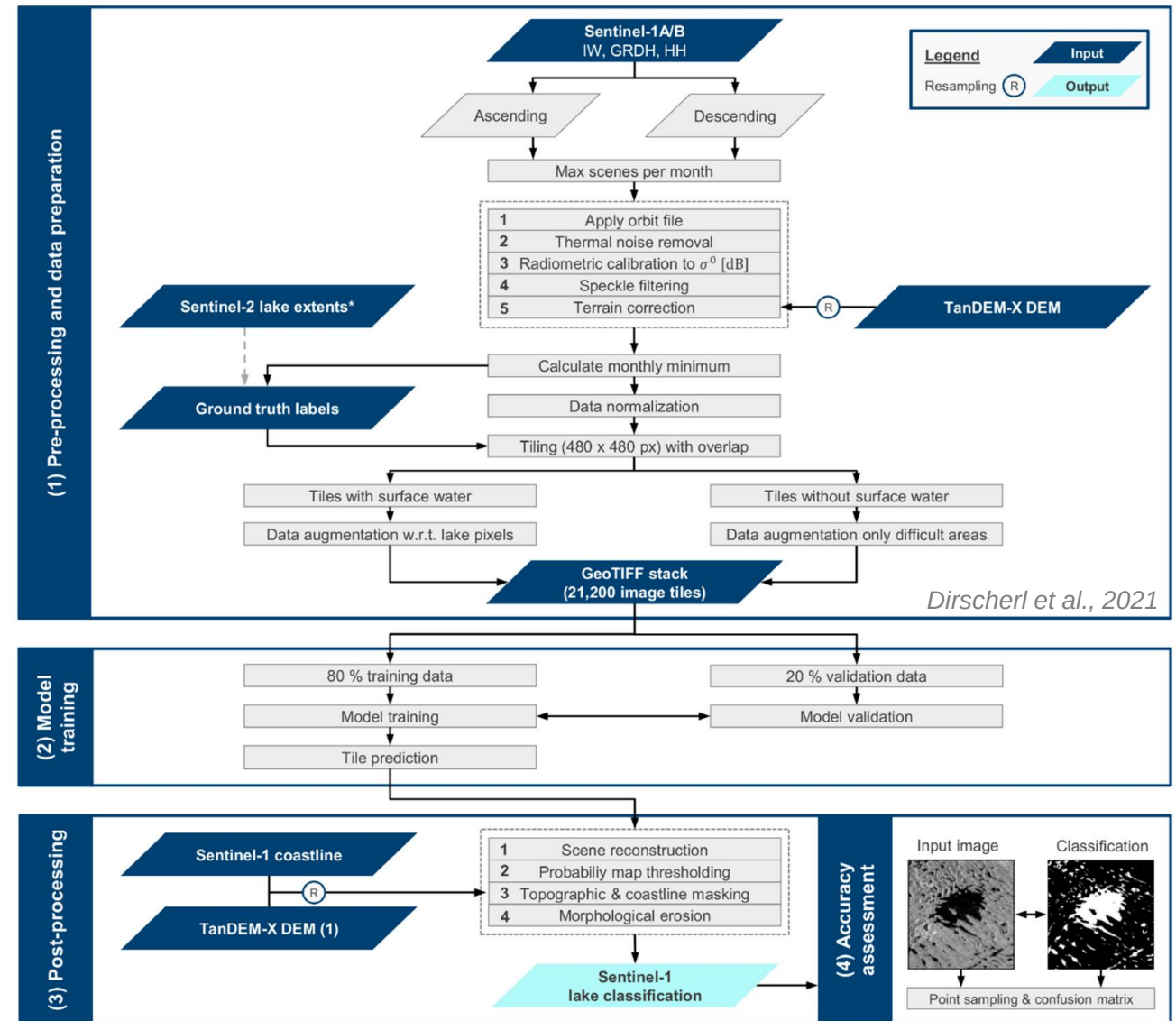
Study aim

Development of an automated supraglacial lake extent mapping method using single-polarized **Sentinel-1** SAR imagery and deep learning.

The development of a SAR-based mapping technique is particularly important in order to complement a previously developed optical **Sentinel-2** supraglacial lake detection algorithm based on Random Forest (Dirscherl et al., 2020) with an overall F-score of **95%** in algorithm V2.0 yet restricted when cloud cover or Antarctic polar night hinders data acquisition.

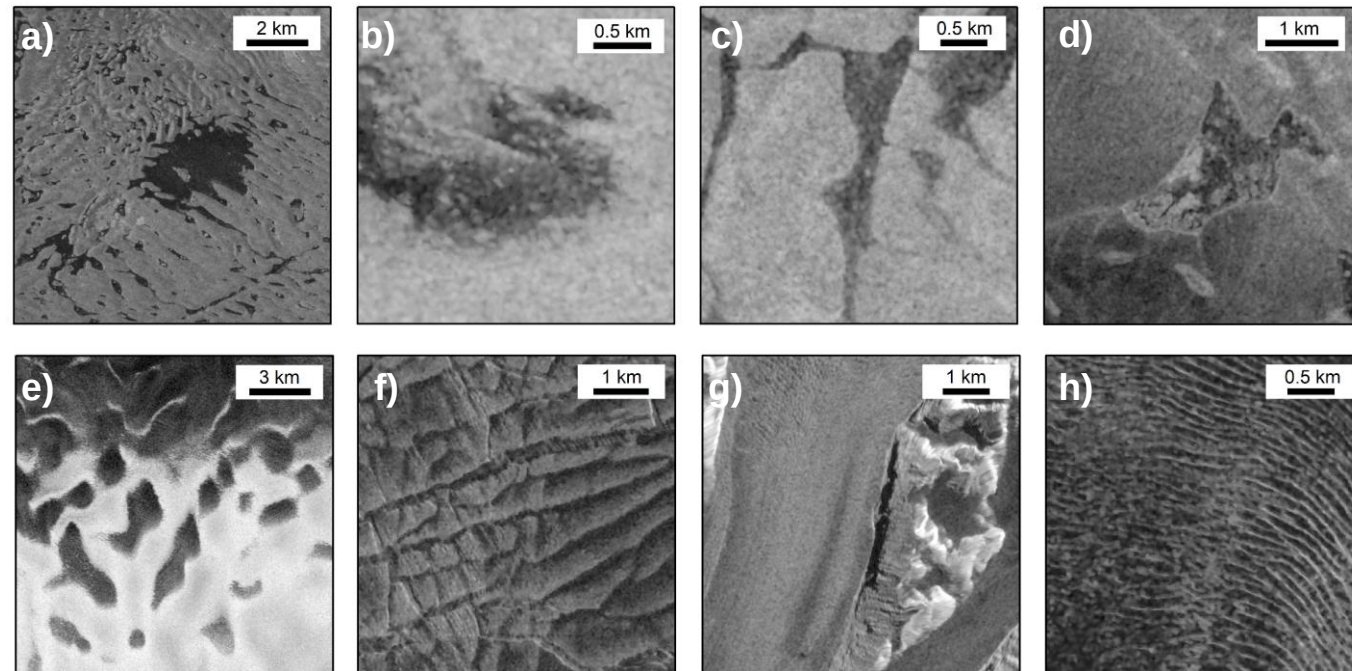
Workflow

- 1) Pre-processing and data preparation
- 2) Model training
- 3) Post-processing
- 4) Accuracy assessment



Background on the appearance of ice sheet features in SAR imagery

Appearance of supraglacial lakes (a-d) and “similar” features such as blue ice, wet snow or topographic shadow (e-h) in single-polarized Sentinel-1 imagery:



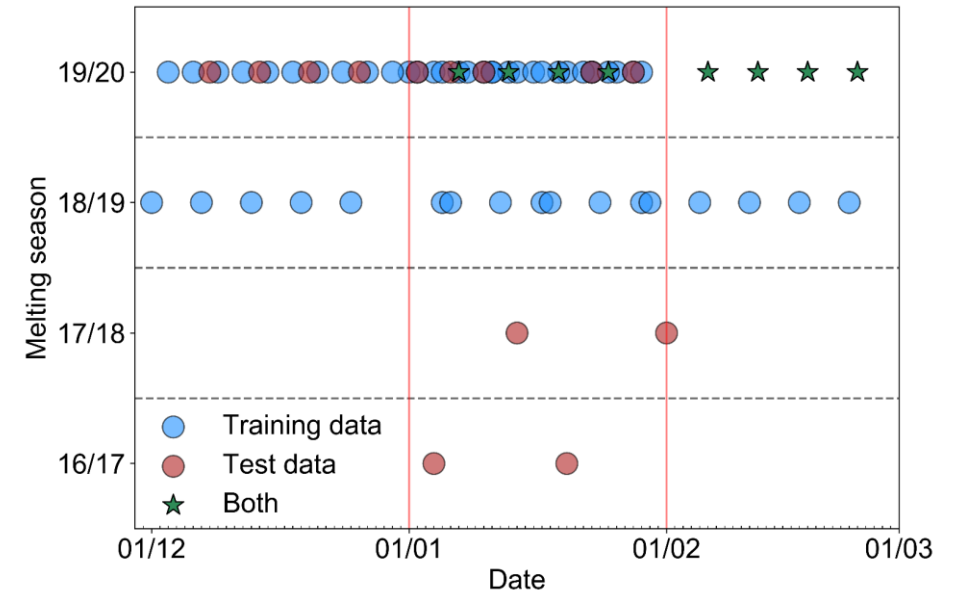
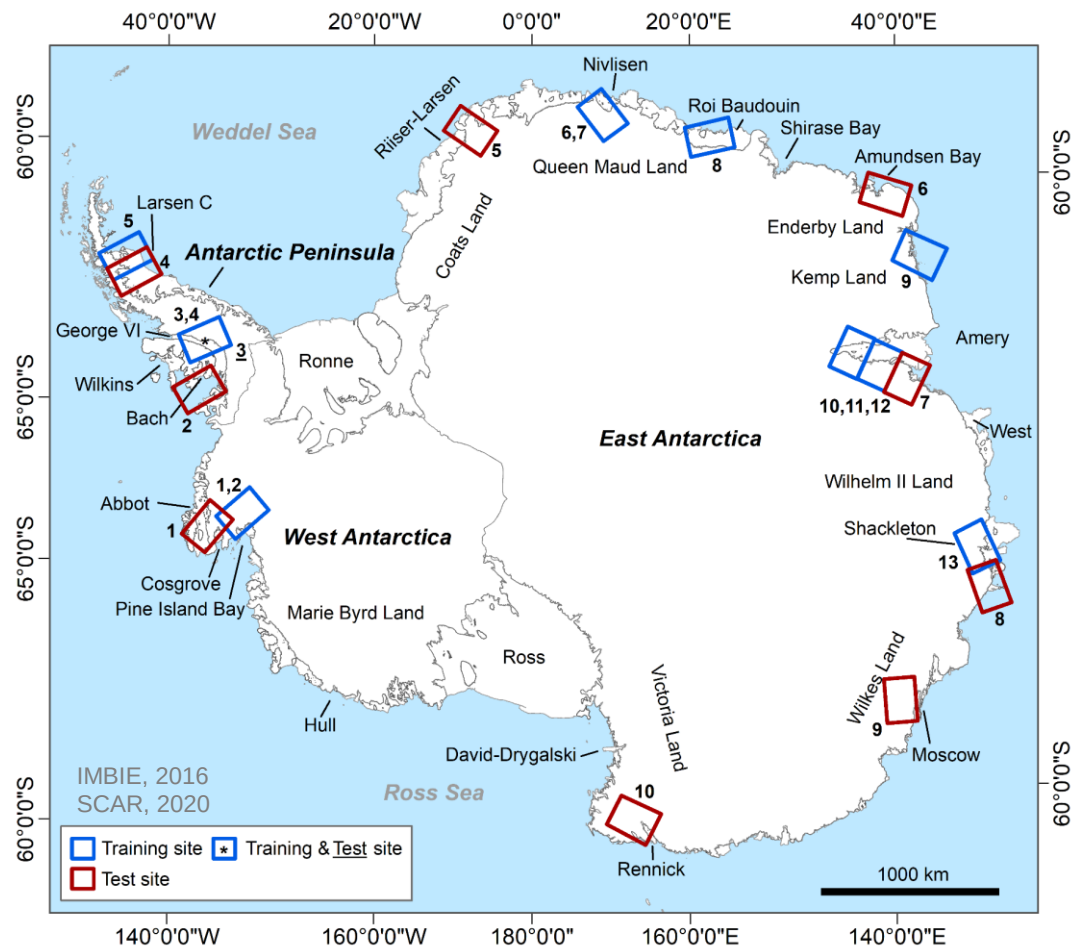
Copernicus Sentinel-1 data

Some features are difficult to differentiate from lakes if no additional image information is available (e.g., dual-polarized SAR data, temporal image information). **Deep learning** can overcome this through consideration of the spatial image context!



Data selection and spatio-temporal distribution

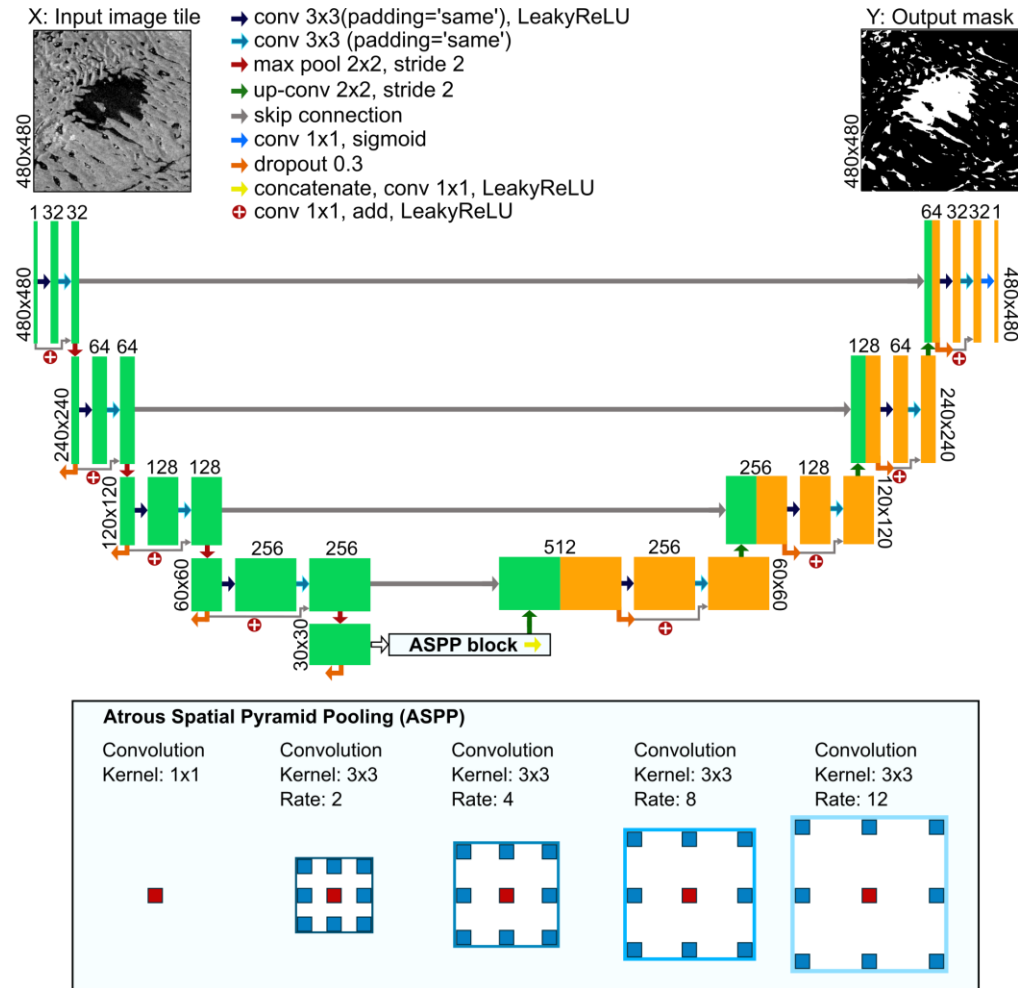
Sentinel-1 training (2018/2019, 2019/2020) and test data (2016/2017, 2017/2018, and 2019/2020):



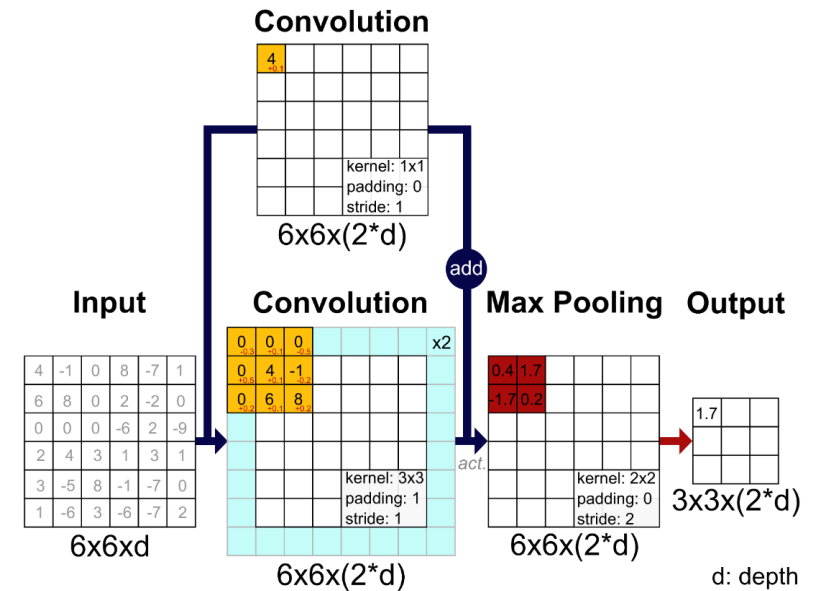
All training data were augmented through tiling with overlap as well as tile flipping, rotating and shifting in order to artificially increase the training dataset.

Model training

Deep learning architecture based on ResUNet (CNN)



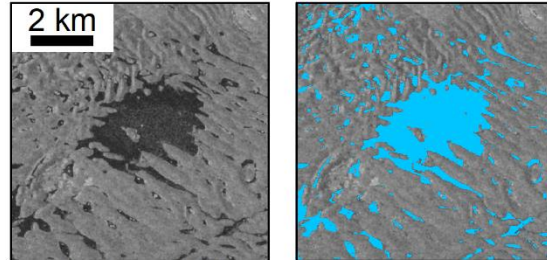
Sketch of a single downsampling block



→ Trained with 21,200 Sentinel-1 image tiles

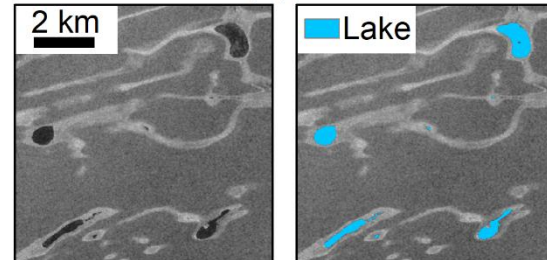
Exemplary mapping results

George VI Ice Shelf (B)



13 Jan 2020

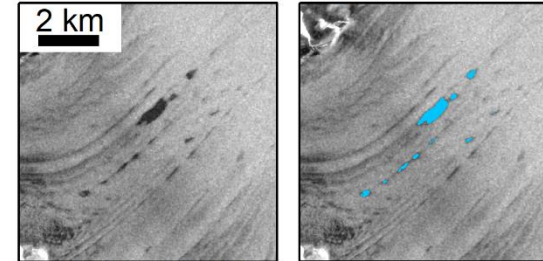
Bach Ice Shelf (A)



28 Jan 2020

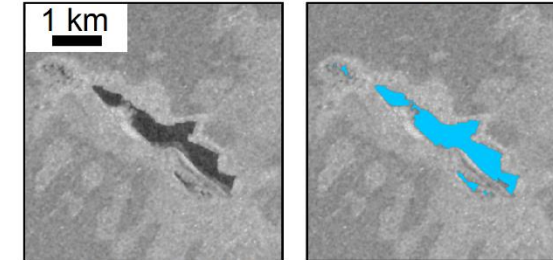
Copernicus Sentinel-1 data; SCAR 2020

Larsen C Ice Shelf (C)



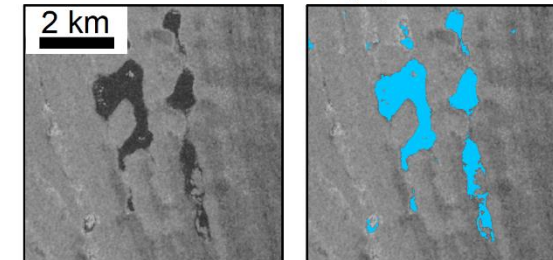
14 Jan 2018

Riiser-Larsen Ice Shelf (D)



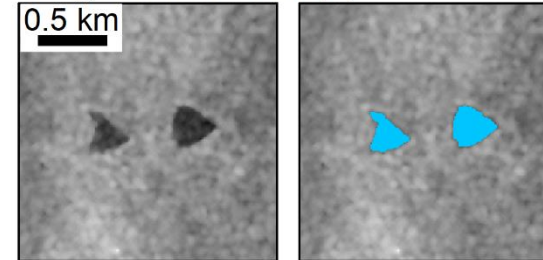
20 Jan 2017

Moscow U. Ice Shelf (E)

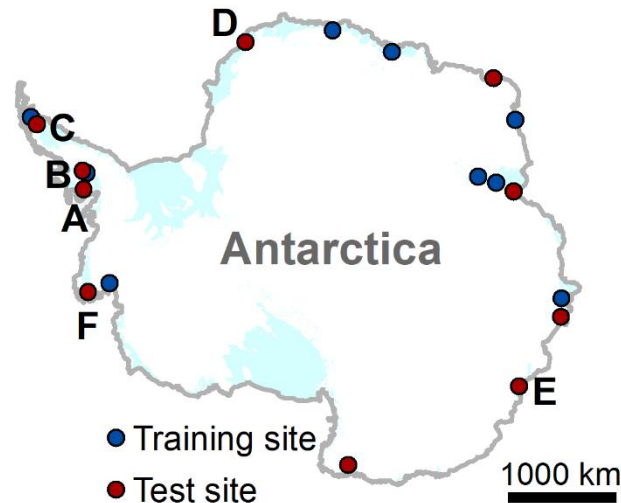


23 Jan 2020

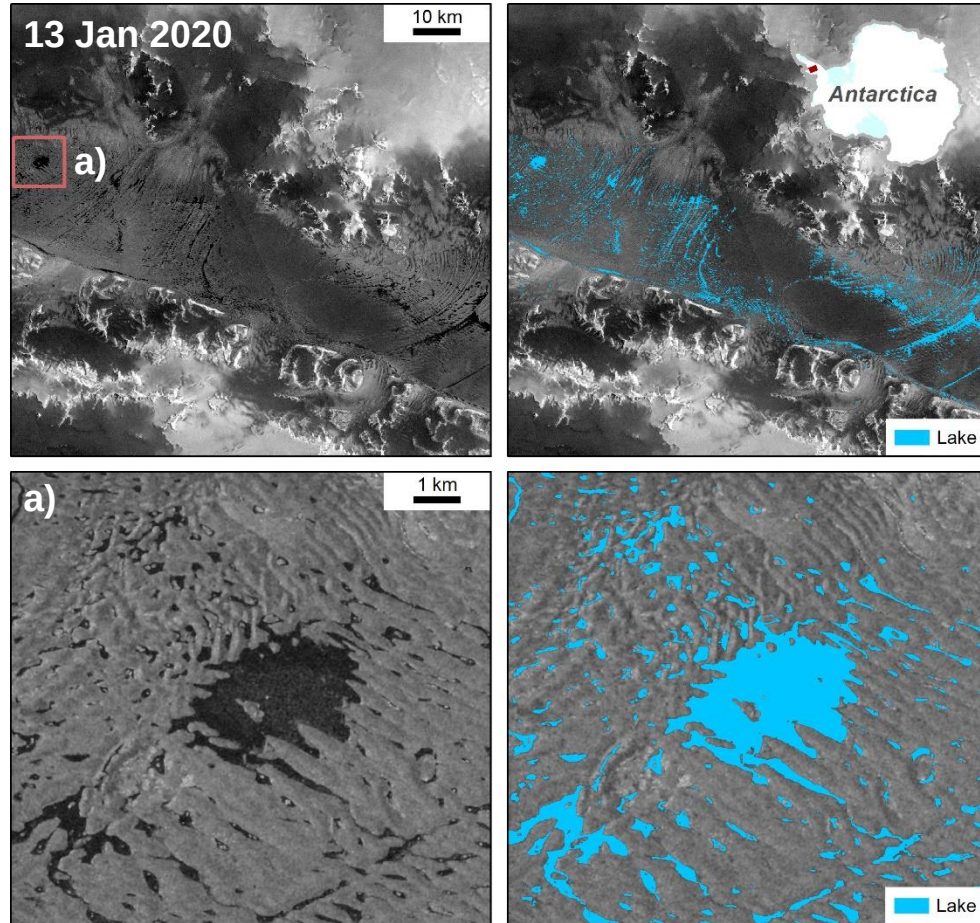
Cosgrove Ice Shelf (F)



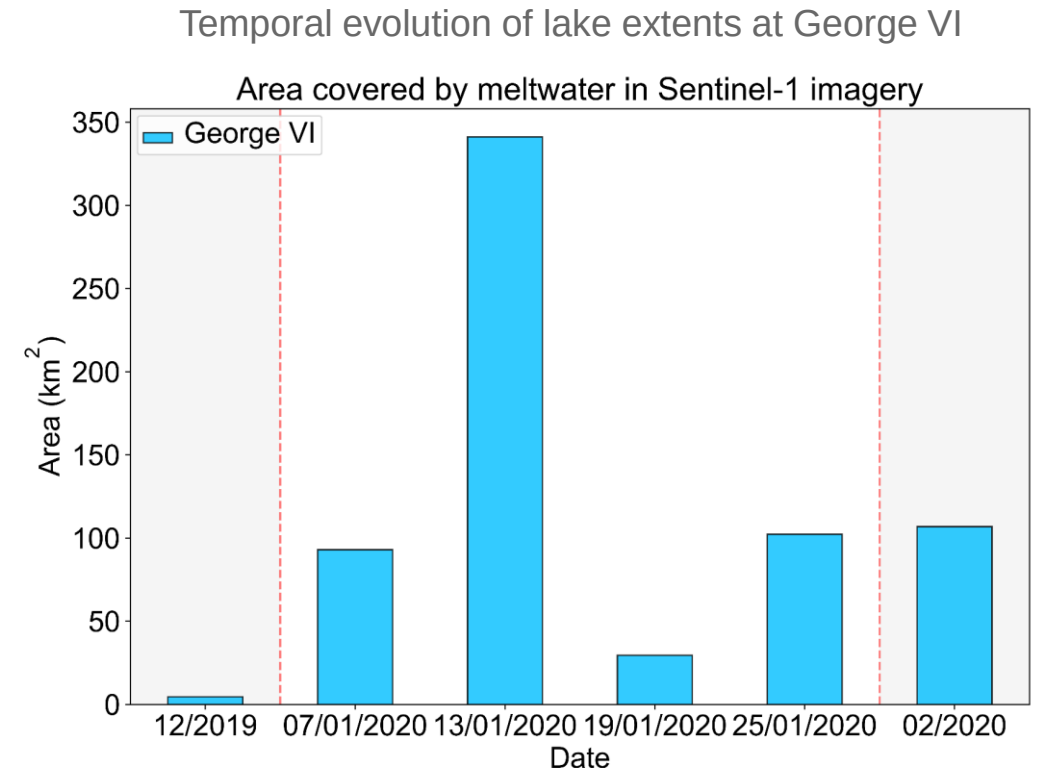
06 Jan 2020



Exemplary mapping results: George VI ice shelf



Copernicus Sentinel-1 data; SCAR, 2020

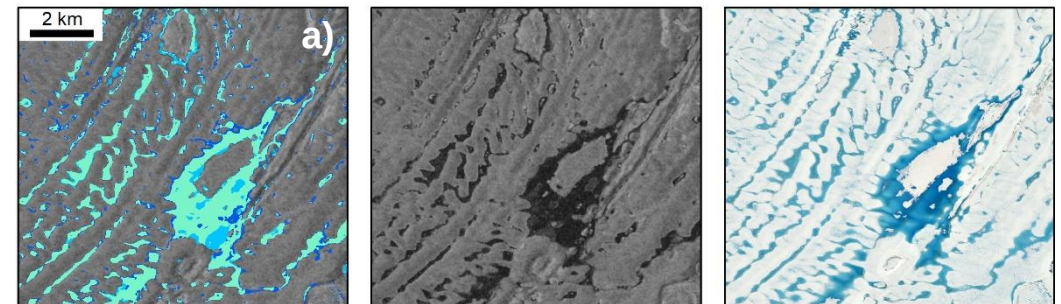
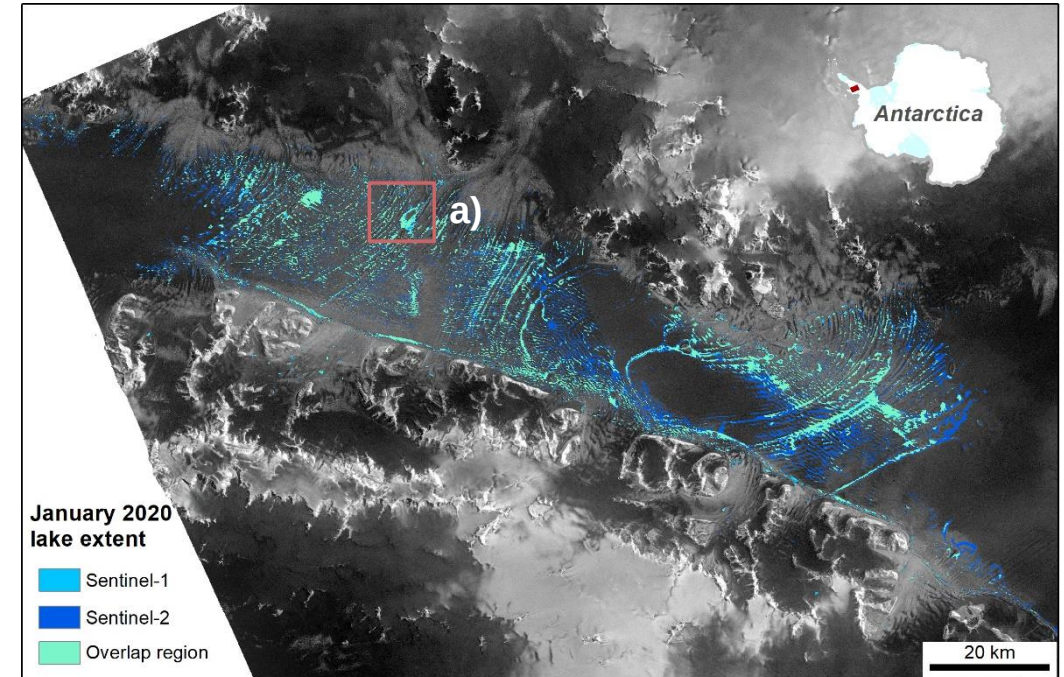


Exemplary mapping results: George VI ice shelf

The fusion of **Sentinel-1** and **Sentinel-2** (Dirscherl et al., 2020) classification products provides a more complete picture of supraglacial lake formation. The overall supraglacial lake extent in January 2020 was computed at **770 km²**.

- 5% detected in Sentinel-1 SAR imagery only
- 50% detected in optical Sentinel-2 imagery only
- 45% detected in Sentinel-1 and Sentinel-2

The Sentinel-1 and Sentinel-2 lake extent is slightly smaller than the estimate of 1200 km² for 19 January 2020 in Banwell et al. (2021) most likely due to different AOI sizes, sensors as well as mapping techniques.

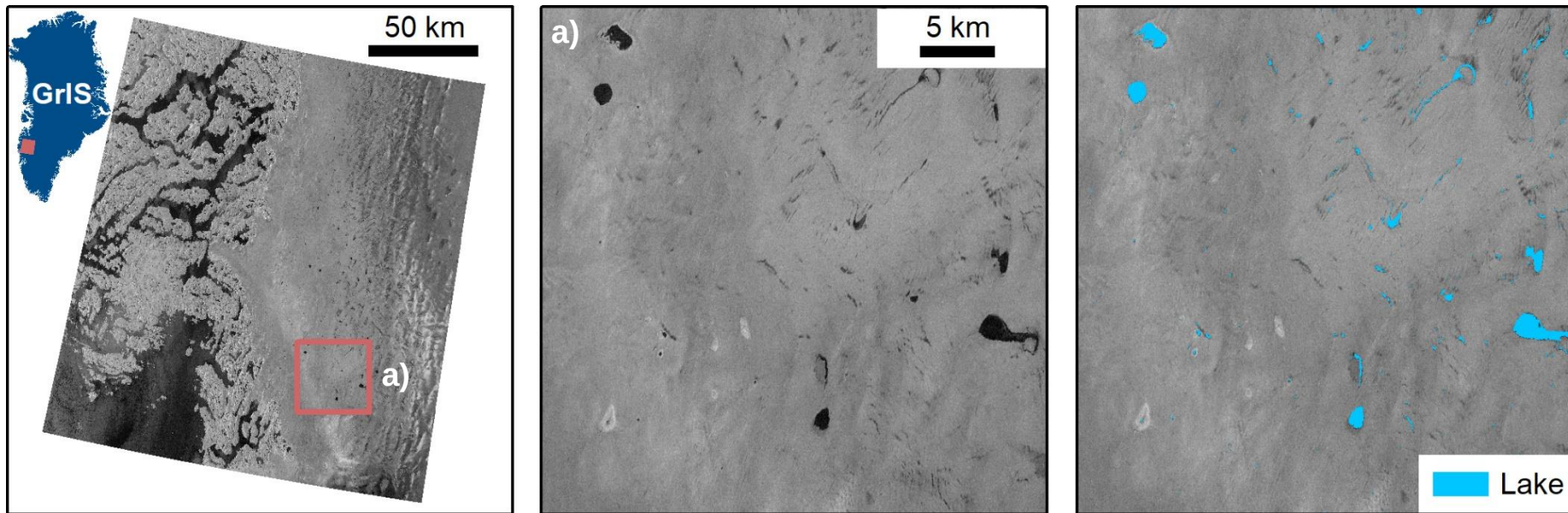


Copernicus Sentinel data; SCAR, 2020

Dirscherl et al., 2021

Exemplary mapping results: Greenland ice sheet

Additional test site covering supraglacial lakes on 28 July 2018 in southwest Greenland:



Copernicus Sentinel-1 data; GEUS, 2020

Potential for spatial transferability of algorithm also to Greenland but need to test over difficult lakes and integrate training data covering supraglacial lakes and other surface features in Greenland!

Accuracy assessment

The mapping results were evaluated by means of **23,000** point samples as well as a confusion matrix which allowed deriving common statistical accuracy metrics including Recall (R), Precision (P), F-score (F_1), Errors of Commission (EC) and Omission (EO) as well as Cohen's Kappa (K). The overall Kappa of both classes was calculated at 0.925 and the F-score of the water class was computed at 93%.

Remaining errors need to be addressed in future work and were mostly related to false positive lake pixels over wet snow, blue ice, shadow or ocean patches.

<i>Dirscherl et al., 2021</i>						
Metrics						
Class	EO [%]	EC [%]	R [%]	P [%]	F_1 [%]	K
Water	1.17	11.1	98.83	88.90	93.0	0.925
Non-water	0.83	0.14	99.17	99.86	99.51	0.925

Conclusion & outlook

- Sentinel-1 provides valuable data for mapping Antarctic supraglacial lake dynamics
- The **fusion** of Sentinel-1 and Sentinel-2 classification products provides a more complete picture of surface ponding over a given time period and allows to exploit and overcome sensor-specific advantages and disadvantages
- Future work involves geoscientific analyses on lake dynamics, drivers and impacts as well as the generation of circum-Antarctic supraglacial lake extent mapping products using both Sentinel-1 and Sentinel-2 to be provided as part of DLR's [EOC GeoService](#)
- Additional future work includes the advancement of the optical Sentinel-2 classification method in order to improve the discrimination between frozen lakes and open water lakes important for correct derivation of lake volumes



References

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