Monitoring supraglacial lake dynamics in Antarctica with machine learning

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Motivation

Monitoring supraglacial lake dynamics is important for understanding their impact on ice shelf stability and possible changes in the context of climate change. Supraglacial meltwater accumulation can drive accelerated ice discharge through various processes: surface runoff leading to ice thinning, basal meltwater injection causing basal sliding, and hydrofracture triggering ice shelf collapse and subsequent glacier acceleration. Furthermore, the increased presence of supraglacial lakes around the Antarctic margin can enhance melting due to the low albedo of lakes, which increases solar radiation absorption. Continuous monitoring is therefore essential for improving our understanding of the seasonal variations in the extent of supraglacial lakes, their effects on ice shelf stability, and the surface mass balance of ice sheets.

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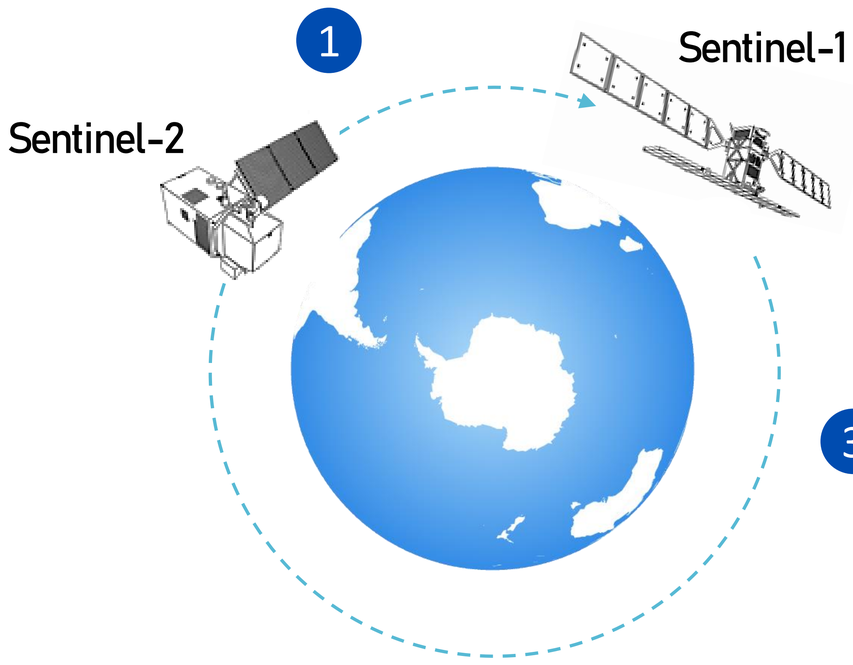
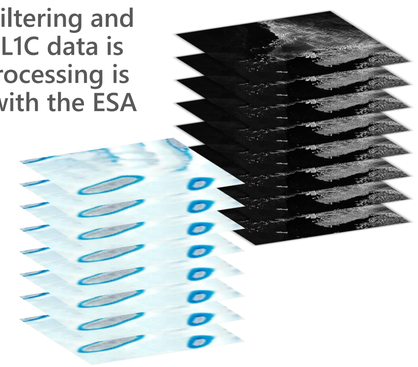


2 Internal Data Access

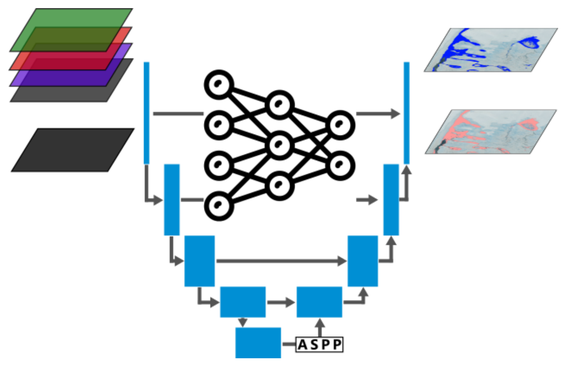
Continous search for new files over Antarctic supraglacial lakes during austral summer months (Nov-Mar)

3 Pre-Processing

Pre-processing for Sentinel-1 IW data includes calibration, speckle filtering and orthorectification. Sentinel-2 L1C data is processed to L2A data. Pre-processing is performed on a HPC cluster with the ESA SNAP Toolbox.



4 Lake Detection with DL

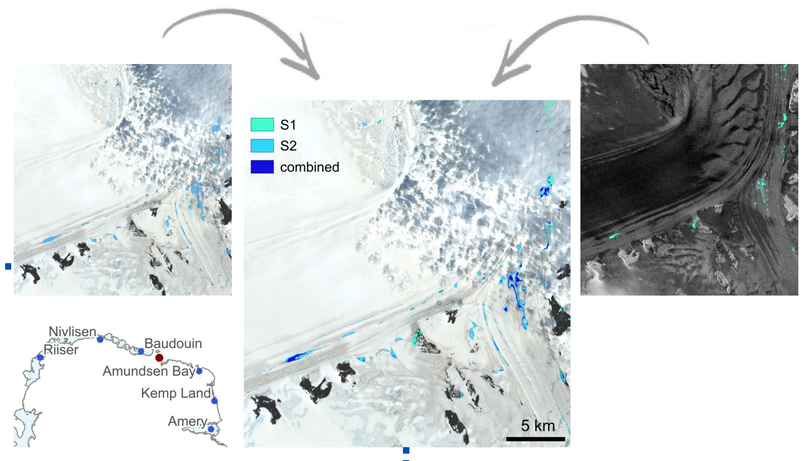


Neural Network Training

The neural network architecture is based on a U-Net with an additional ASPP (Atrous Spatial Pyramid Pooling) module for multiscale feature extraction. The architecture was trained separately for Sentinel-1 (S1) and Sentinel-2 (S2) data. Training with S2 was performed on 33 scene subsets from 15 different S2 scenes distributed along the Antarctic coastline based on four layers (green, red, SWI, AWEInsh). Training for S1 is only based on the channel with HH polarization over nine coastal regions. Accuracies based on random validation points have a Kappa coefficient of 0.925 (0.87) and a F1-score of 0.93 (0.87) for S1 and S2, respectively.

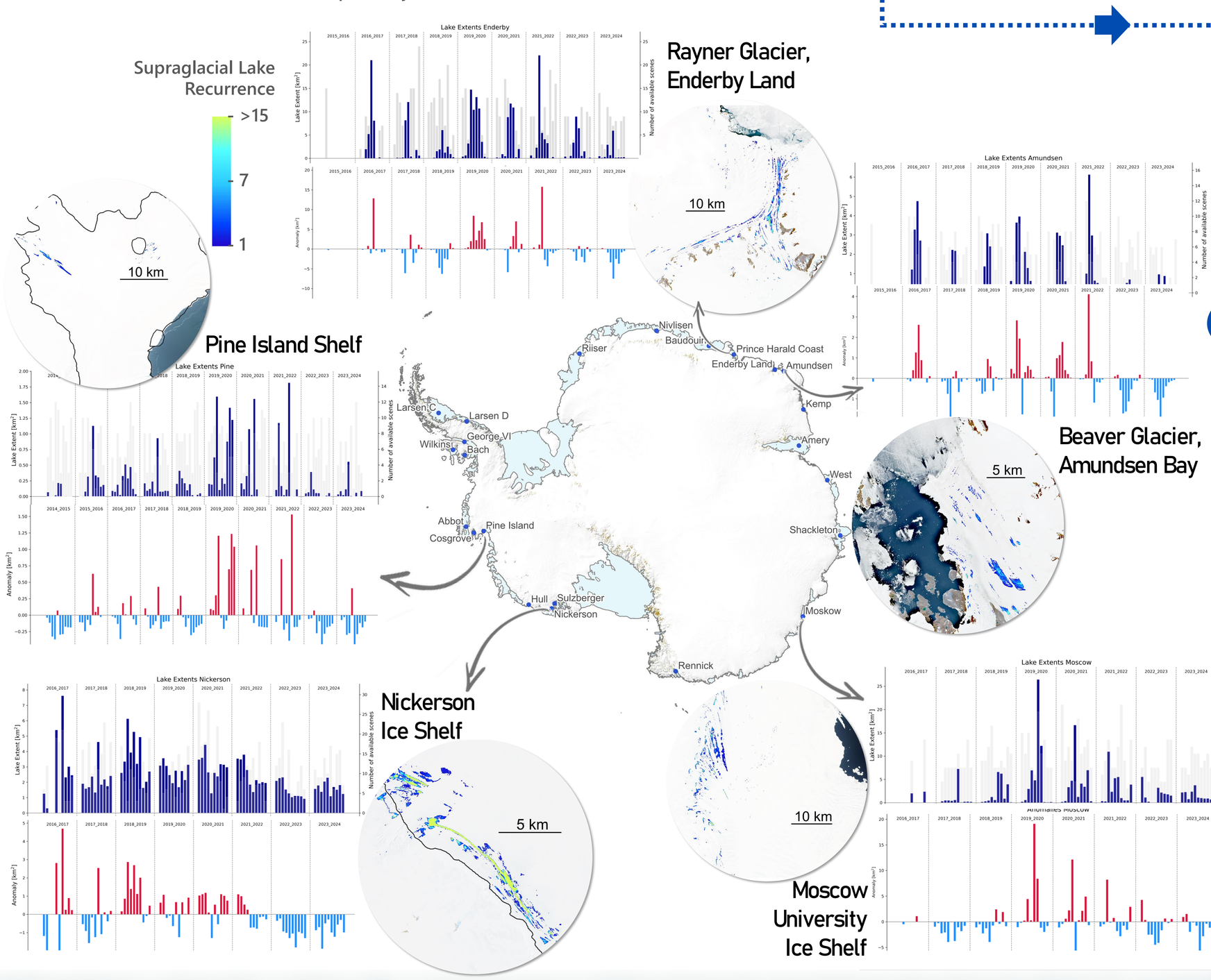
5 Merging Lake Predictions

All available supraglacial lake predictions for the first and second half of the month are merged to a bi-weekly maximum lake extent layer. Especially in cloudy conditions, Sentinel-1 SAR data provide important additional information.



6 Analysing Lake Dynamics

Based on the time series since summer 2014/15 bi-weekly statistics on maximum lake extents, anomalies based on the long-term mean (2014-2024), and recurrence maps are automatically generated.



Outlook

The combination of Sentinel-1 and Sentinel-2 data enables the generation of bi-weekly supraglacial lake extents since 2014/15. The presented processing workflow will be included in the automated processing pipeline to provide a seasonally updated dataset on supraglacial lake dynamics. Moreover, the derived and evaluated mapping products of the Lakes4Antarctica project will be used for modelling (e.g. hydrological routing).

Lakes4Antarctica.
eoc.dlr.de

References

[1] M. Dirscherl, A. J. Dietz, and C. Kuenzer,. Seasonal evolution of Antarctic supraglacial lakes in 2015-2021 and links to environmental controls. The Cryosphere, 15, 5205-5226, https://doi.org/10.5194/tc-15-5205-2021.

[2] M. Dirscherl, A. J. Dietz, C. Kneisel, and C. Kuenzer, 2021. „A Novel Method for Automated Supraglacial Lake Mapping in Antarctica Using Sentinel-1 SAR Imagery and Deep Learning“, *Remote Sensing*, Bd. 13, Nr. 2, Art. Nr. 2, doi: 10.3390/rs13020197.

[3] C. A. Baumhoer, A. J. Dietz, K. Heidler, and C. Kuenzer, 2023. „IceLines – A new data set of Antarctic ice shelf front positions“, *Sci Data*, Bd. 10, Nr. 1, Art. Nr. 1, doi: 10.1038/s41597-023-02045-x.