Analysis of ice shelf front dynamics in Pine Island Bay (Antarctica) based on long-term SAR time series and deep learning

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Background

Ice shelves buttress the outflow of glaciers along the coastline of Antarctica. Loss of their stability leads to increased discharge contributing to global sea level rise. Thus, it is important to monitor ice shelf dynamics. The position of the calving front is a key parameter that has to be derived on long temporal scales in order to understand ongoing processes. The potential of SAR data has not yet been fully exhausted as data of early SAR satellites has only been used to a limited extent. Therefore, this study applies a deep learning framework to take advantage of the entire ERS AMI (VV polarisation) and Envisat ASAR (VV and HH polarisation) archive from 1992 to 2011 in West Antarctic Pine Island Bay, a region with drastic ongoing changes that requires detailed observation.

Method

- Calving fronts were automatically derived using the HED-Unet, a deep learning framework that combines segmentation and edge detection (Heidler et al., 2021)
- Incorporation of multi-resolution information is strengthened by a hierarchical attention mechanism and deep supervision

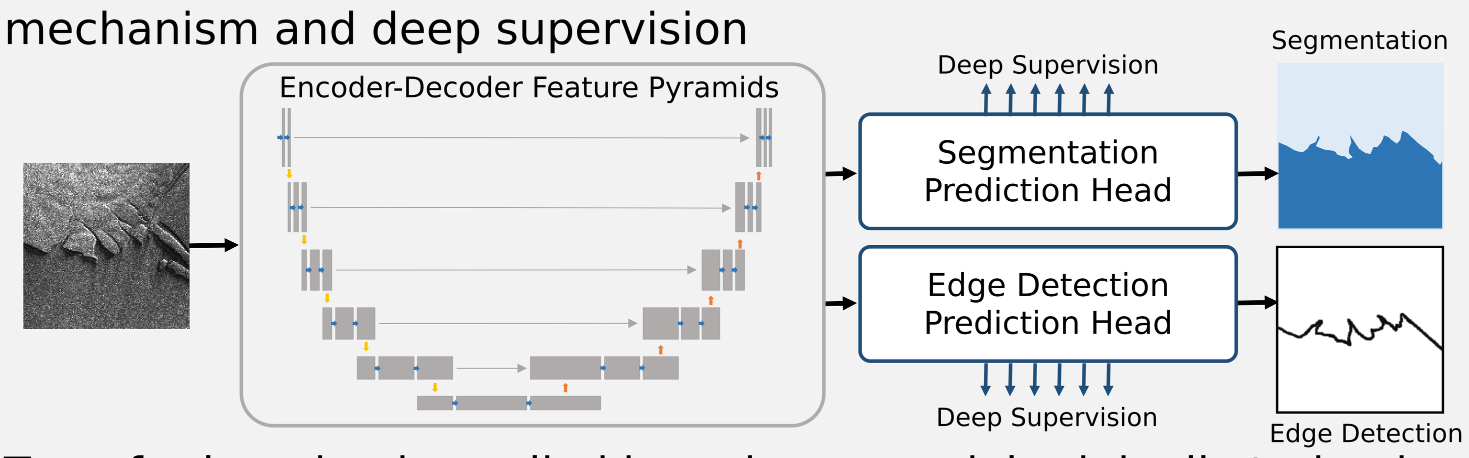


Fig.1: HED-Unet architecture (modified after Heidler et al., 2021)

- Transfer learning is applied based on a model originally trained on Sentinel-1 data for entire Antarctica (Baumhoer et al., 2023)
- Post-processing includes filtering and temporal compositing to remove artefacts from geolocation errors and limited data availability

Results

- The transfer of the deep learning framework proves suitable for the used data
- Mosaicking is effective to cope with uneven scene availability focusing on summer months
- The resulting product comprises yearly, seasonal and monthly calving fronts (if data is available)
- Segmentation accuracy of 96%
- Mean distance measured accuracy of 355m

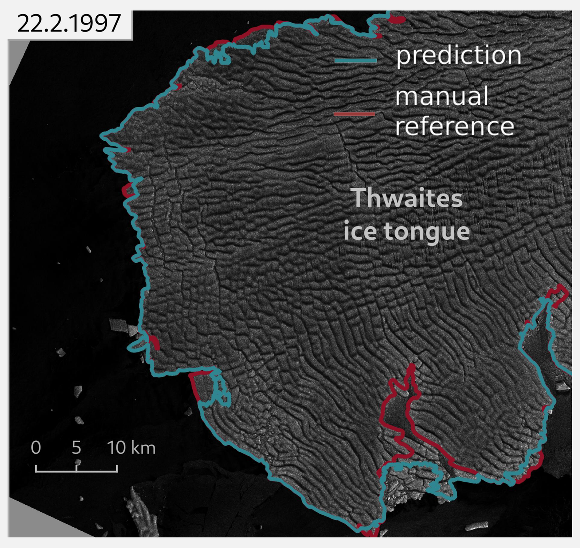


Fig.2: Comparison of predicted and manually drawn calving front of a selected ERS testing scene.

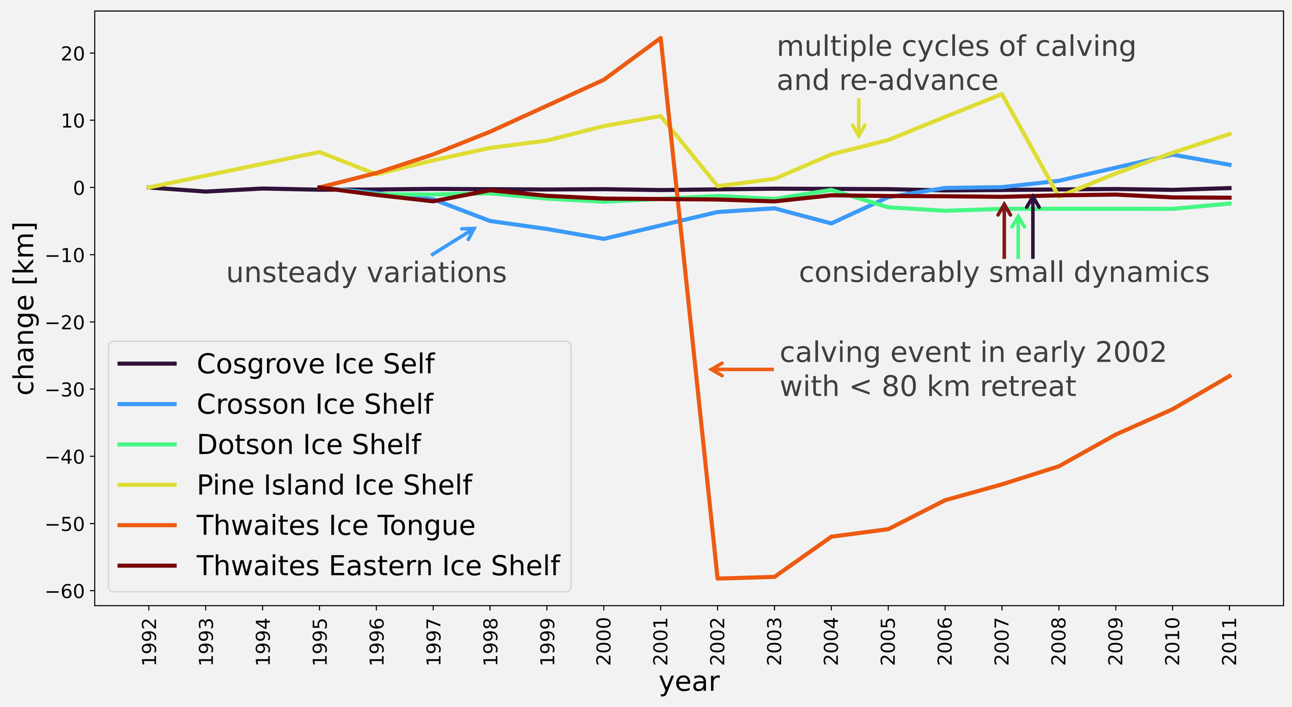


Fig.3: Time series of calving front position change along the centrelines for all investigated ice shelves.

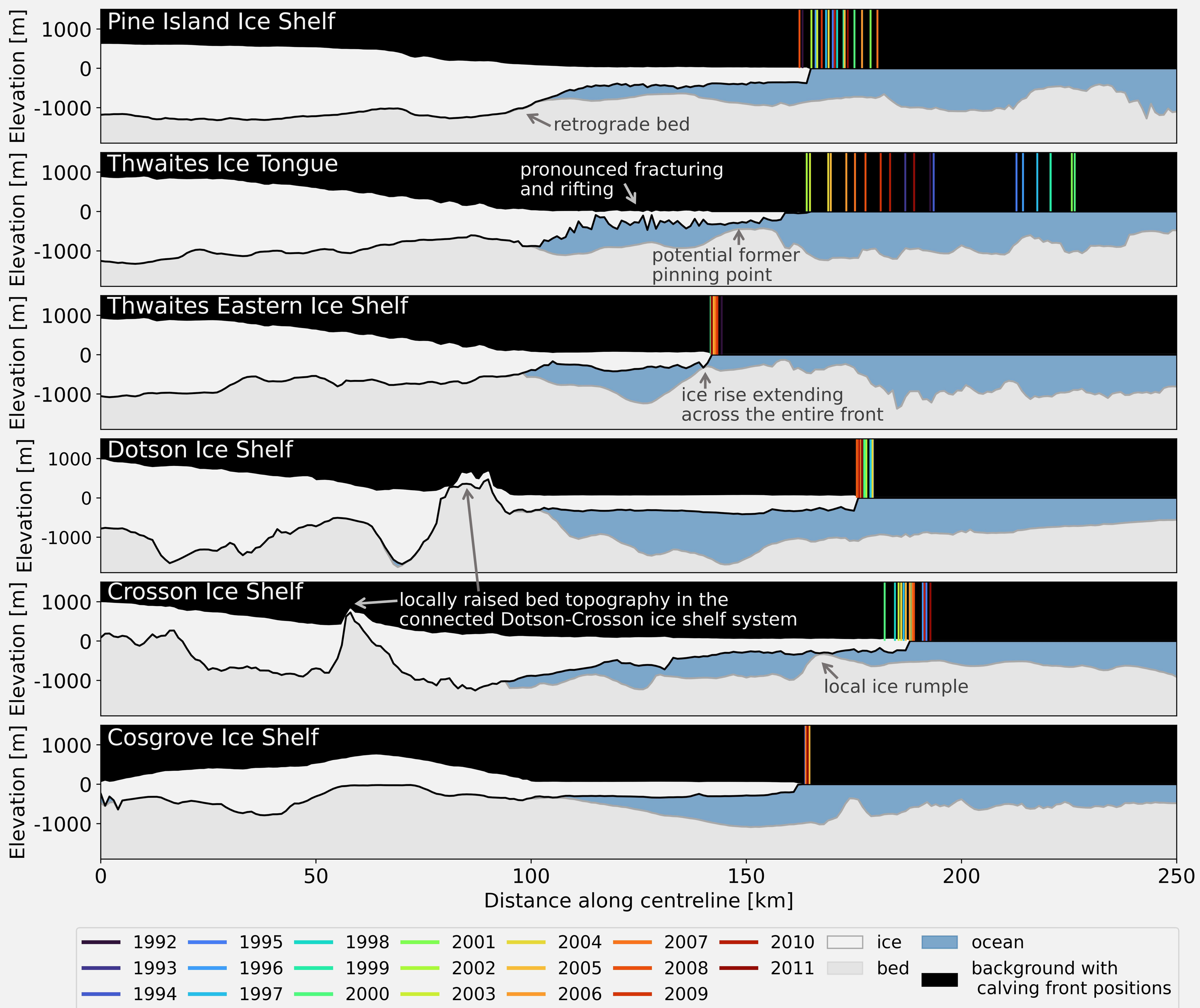
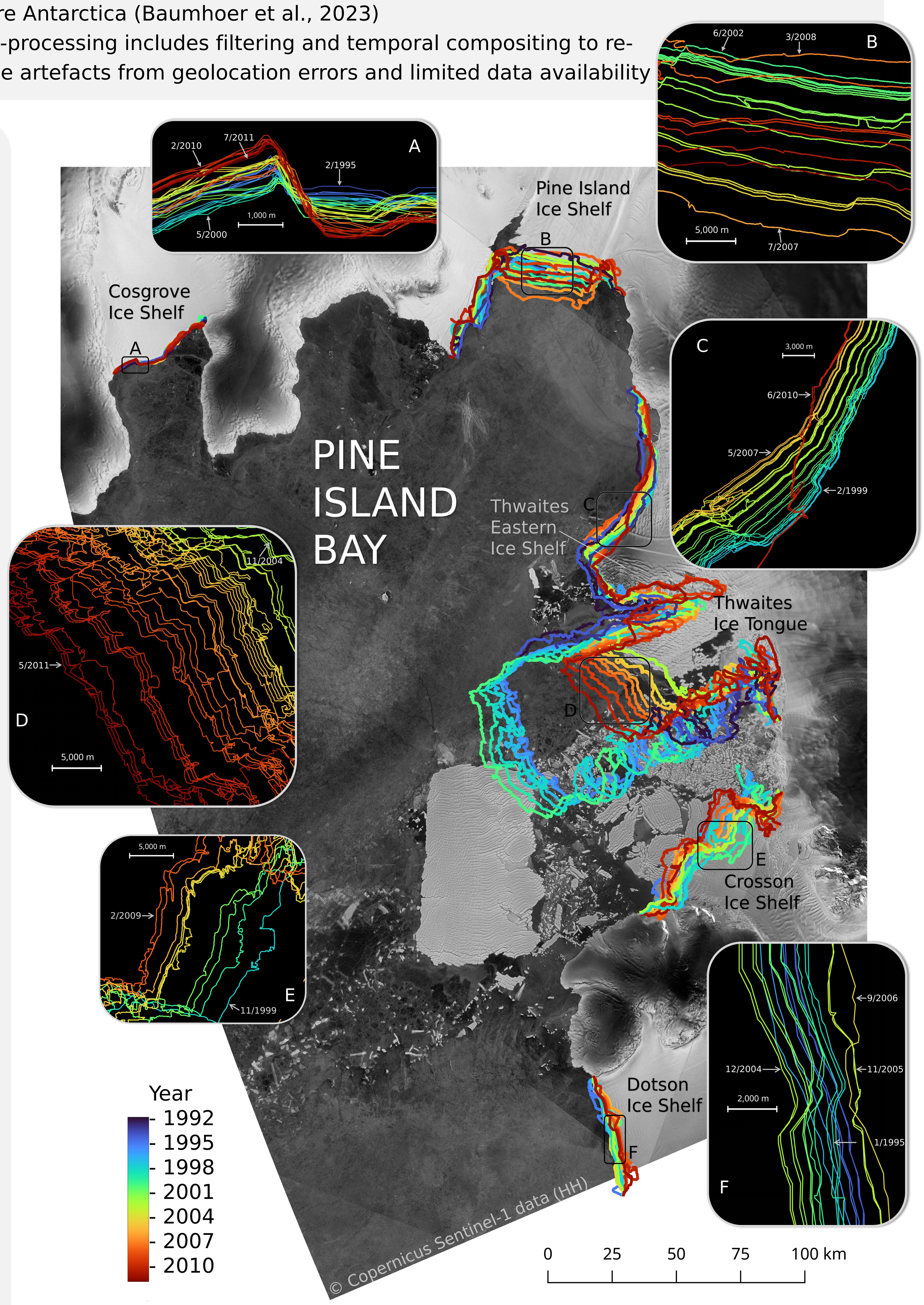


Fig.4: Profile plots along centrelines of all ice shelves demonstrate differences in ice shelf geometry and basal topography. The vertical lines show changes in calving front position throughout the study period (topography data source: BedMachine Antarctica v2).



Conclusion and Outlook

- The deep learning framework proves to be an effective tool to deliniate ice shelf fronts based on ERS and Envisat data
- The time series reveal individual patterns for all ice shelves
- Overall, a picture of destabalisation becomes apparent, not only through retreat, but also through fracturing, disintegration events and loss of connectivity to lateral confinements
- Expansion of the approach to broader regions and longer time scales, and analysis of the resulting time series in synergy with other parameters should be pursued further

References:
Baumhoer, C.A., Dietz, A.J., Heidler, K., Kuenzer, C. (2023), 'IceLines – A new data set of Antarctic ice shelf front positions', Sci Data 10, 138.
Heidler, K., Mou, L., Baumhoer, C. A., Dietz, A. and Zhu, X. X. (2021b), 'HED-UNet: Combined Segmentation and Edge Detection for Monitoring the Antarctic Coastline', IEEE Transactions on Geoscience and Remote Sensing 60, 1–14.
Wagner, L. (2023), 'Analysis of ice shelf front dynamics in Pine Island Bay (Antarctica) based on long-term SAR time series and deep learning', Master Thesis, University of Wuerzburg.