High-Temporal Antarctic Glacier Terminus and Ice Shelf Front Mapping from Sentinel-1 – A Deep Learning Approach

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Introduction

- Antarctica's glacier termini and ice shelf fronts can be sensitive indicators of glaciological and environmental change
- High-temporal mapping of Antarctic calving front fluctuations has been challenging due to a lack of data and time-consuming manual delineation
- An abundance of satellite imagery exists since the launch of Sentinel-1 in 2014
- We developed a method for automatic calving front delineation from Sentinel-1 imagery
- This allows high-temporal tracking of glacier and ice shelf front fluctuations

Workflow

- The core of our approach is the segmentation of each Sentinel-1 scene into land ice and ocean with the deep learning architecture U-Net
- We trained our weights with 21 data stacks combining pre-processed dual-pol Sentinel-1 scenes and a TanDEM-X digital elevation model covering the training area (see map)
- Post-processing ensures hole filling and generates georeferenced vector files from the segmentation results
- With the trained weights we extracted calving front positions for several dates along entire Marie Byrd Land (see Fig. 3)

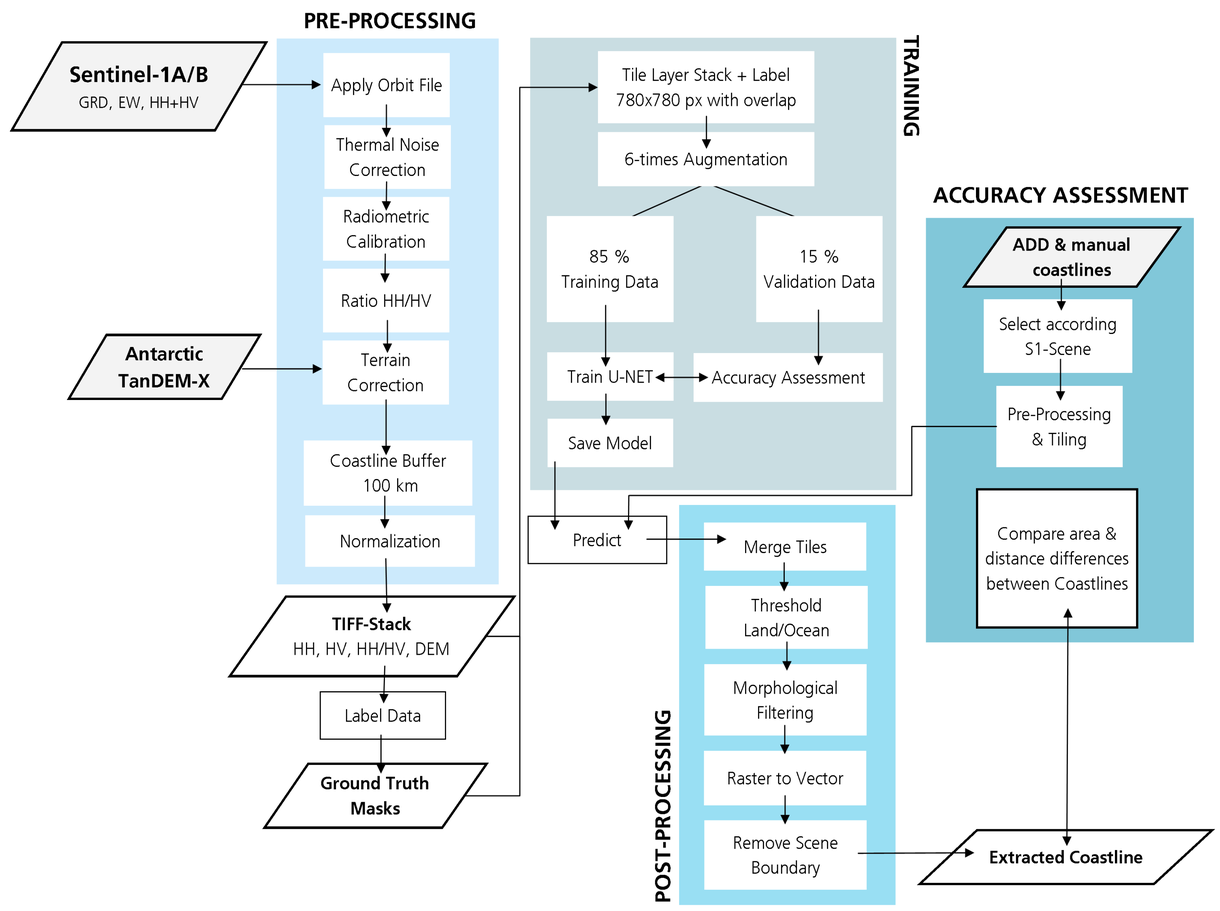


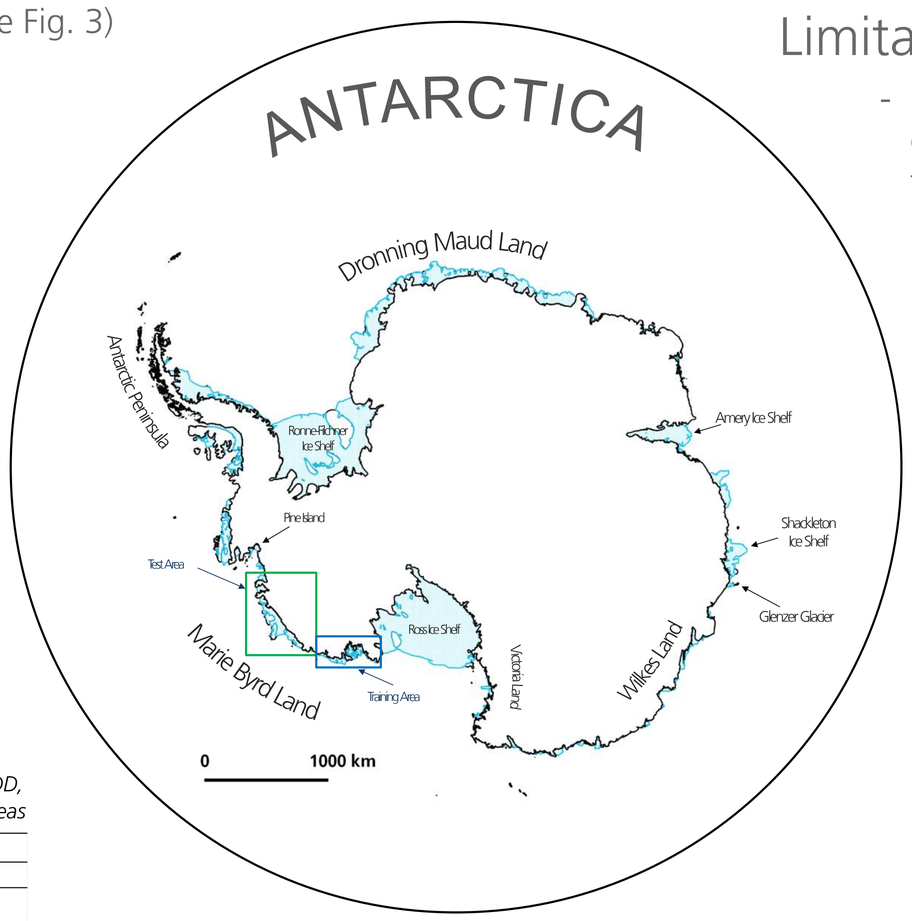
Fig. 1: *Workflow to extract calving fronts from Sentinel-1 imagery (Baumhoer et al. (in prep)).*

Accuracy Assessment

- Accuracies are calculated between the predicted coastline and a manually delineated one as well as an external coastline from the Antarctic Digital Database in June 2018
- The U-net classification performs well compared to our manual labels with an f1-score of 94 % for the classes land ice and ocean within a 2 km buffer along the coastline
- To estimate the accuracy between the manual, automated and ADD coastline we calculated distance differences along transects (see Tab. 1)

Tab. 1: *Calculated median and absolute mean differences between ADD, manual and predicted coastline for June 2018 along training and test areas*

	train-area		test-area	
	mean	**median**	**mean**	**median**
ADD-manual	1654.76 m	76.19 m	466.49 m	61.51 m
manual-predicted	290.32 m	-24. 89 m	255.13 m	-70.19 m
predicted-ADD	1620.30 m	60.21 m	517.19 m	-0.21 m



Limitations & Challenges

- Huge differences between manually delineated coastlines demonstrate the subjectivity of calving front extraction from satellite imagery (Fig. 2/Tab. 1).
- Melt during summer and wind-roughened sea make front delineation in SAR imagery very difficult (see Fig 2 A/B). Those scenes have to be excluded.

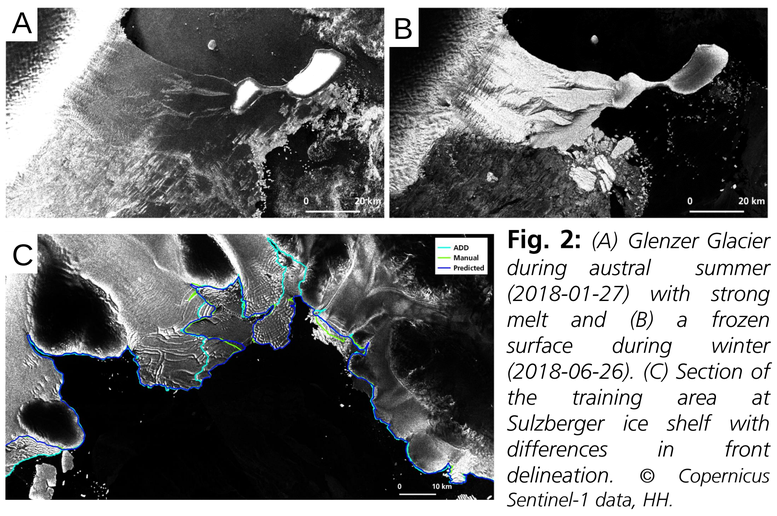
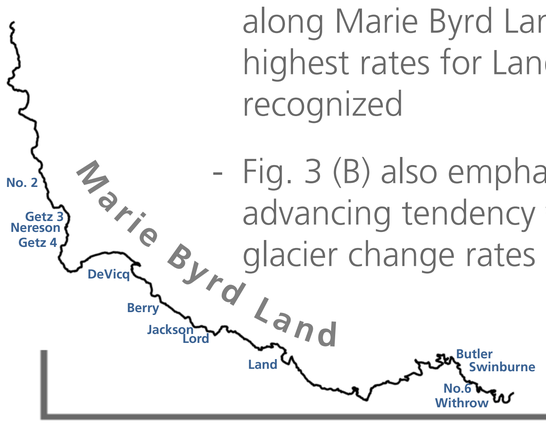


Fig. 2: *(A) Glenzer Glacier during austral summer (2018-01-27) with strong melt and (B) a frozen surface during winter (2018-06-26). (C) Section of the training area at Sulzberger ice shelf with differences in front delineation. © Copernicus Sentinel-1 data, HH.*

Results

- Fig. 3 (A) displays glacier and ice shelf front position changes for Marie Byrd Land since July 2017
- A tendency for advancing fronts along Marie Byrd Land with the highest rates for Land glacier can be recognized
- Fig. 3 (B) also emphasizes the advancing tendency with positive glacier change rates



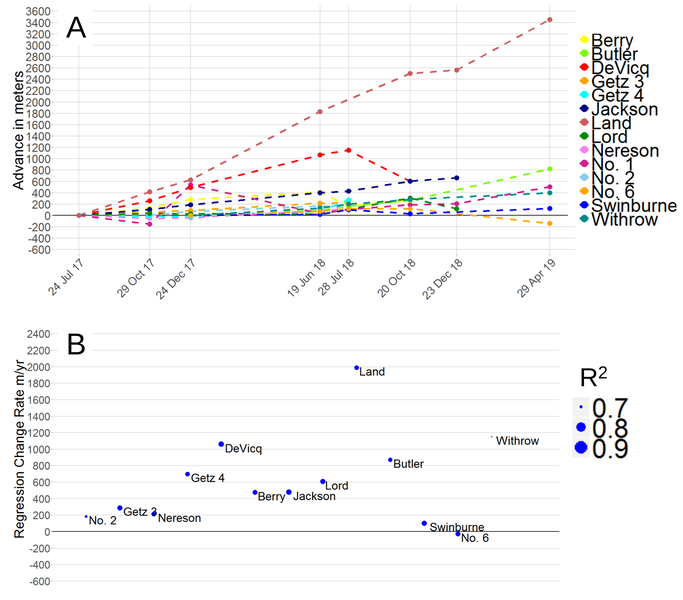


Fig. 3: *(A) Calving front fluctuations for representative glaciers in Marie Byrd Land and (B) the mean regression change rate for each glacier between July 2017 and April 2019. The point size indicates the R^2 value for the regression calculation.*

Conclusion

- Extraction of Antarctic glacier fronts is challenging and even manual delineations can vary significantly
- Challenges exist for summer months and difficult ice conditions
- Our method offers an objective and transferable approach for calving front delineation and allows to create consistent time-series
- The presented time-series reveals an advancing tendency for calving fronts along Marie Byrd Land for the last two years

References

- *Baumhoer, Celia, Andreas Dietz, Stefan Dech, Claudia Kuenzer, 2018. „Remote Sensing of Antarctic Glacier and Ice Shelf Front Dynamics—A Review". Remote Sensing 10 (9): 1445. https://doi.org/10.3390/rs10091445.*
- *Baumhoer, Celia, Andreas Dietz, Stefan Dech, Claudia Kuenzer, (in prep.): Automated extraction of Antarctic ice fronts from Sentinel-1 imagery using deep learning.*

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