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.

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).

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.

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).

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.

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 Zech, Claudia Kuenzer. (in prep.). Automated detection of Antarctic ice fronts from Sentinel-1 imagery using deep learning.

Celia Baumhoer
German Aerospace Center (DLR)
Earth Observation Center (EOC)
German Remote Sensing Data Center (DFD)
Oberpfaffenhofen
82234 Wessling
Tel.: +49 8153 28-3697
E-Mail: celia.baumhoer@dlr.de

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

<table>
<thead>
<tr>
<th>Area</th>
<th>Median</th>
<th>Mean</th>
<th>Absolute Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADD manual</td>
<td>100.9</td>
<td>101</td>
<td>75.03</td>
</tr>
<tr>
<td>manual predicted</td>
<td>289.5</td>
<td>281</td>
<td>253.53</td>
</tr>
<tr>
<td>predicted ADD</td>
<td>164.5</td>
<td>162</td>
<td>137.79</td>
</tr>
<tr>
<td>predicted</td>
<td>124.5</td>
<td>124</td>
<td>108.79</td>
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</tbody>
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