DeepBedMap: Resolving the bed topography of Antarctica with a deep neural network

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November 22, 2022

Abstract

To better resolve the bed elevation of Antarctica, we present DeepBedMap - a deep learning method that produces realistic Antarctic bed topography from multiple remote sensing data inputs. Our super-resolution deep convolutional neural network model is trained on scattered regions in Antarctica where high resolution (250 m) groundtruth bed elevation grids are available, and then used to generate high resolution bed topography in less well surveyed areas. DeepBedMap takes in a low resolution (1000 m) BEDMAP2 dataset alongside other high spatial resolution inputs such as ice surface elevation, velocity and snow accumulation to generate a four times upsampled (250 m) bed topography map even in the absence of ice-thickness data from direct seismic or ice-penetrating radar surveys. Our DeepBedMap model is based on an Enhanced Super Resolution Generative Adversarial Network architecture that is adapted to minimize per-pixel elevation errors while producing realistic topography. We show that DeepBedMap offers a more realistic topographic roughness profile compared to a standard bicubic interpolated BEDMAP2, and also run model inversions to compare the basal traction of our DeepBedMap_DEM with other bed elevation models.

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DeepBedMap

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bed topography *of* ***Antarctica*** *with a* ***deep neural network***

1) Super-Resolution Model

Not just a fancy BEDMAP2[1] interpolator. The neural network is conditioned with high resolution ice surface datasets!

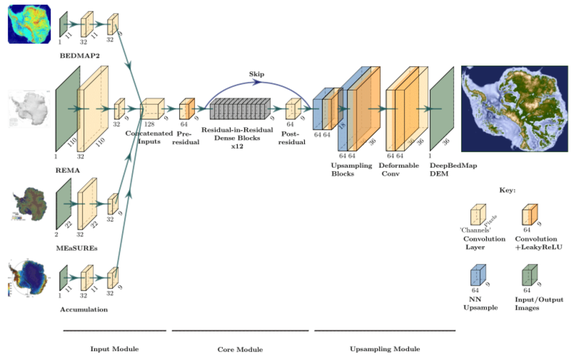

Fig 1: DeepBedMap **model architecture** adapted from the **Enhanced Super Resolution Generative Adversarial Network**[2] . The four inputs are: 1) **BEDMAP2**[1] (1km); 2) **Reference Elevation Model of Antarctica**[3] (100m); 3) **MEaSUREs Phase-based Ice Velocity**[4] (500m resampled); 4) **Snow Accumulation**[5] (1km).

2) Results

Our model can produce a **rougher** bed topography that **matches** groundtruth observations better.

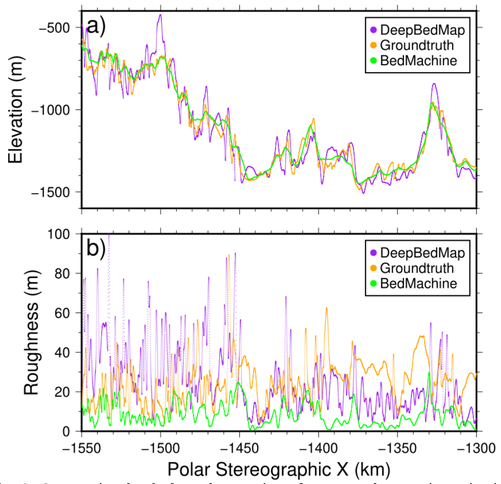

Fig. 2: Comparing **bed elevation** and **surface roughness** (standard deviation of elevation values) of each interpolated grid product (250 m resolution) over a transect. Purple values are from the super resolution **DeepBedMap** DEM; Orange values are from tension spline interpolated Operation IceBridge **groundtruth** points; Green values are from bicubic interpolated **BedMachine** Antarctica[6].

References
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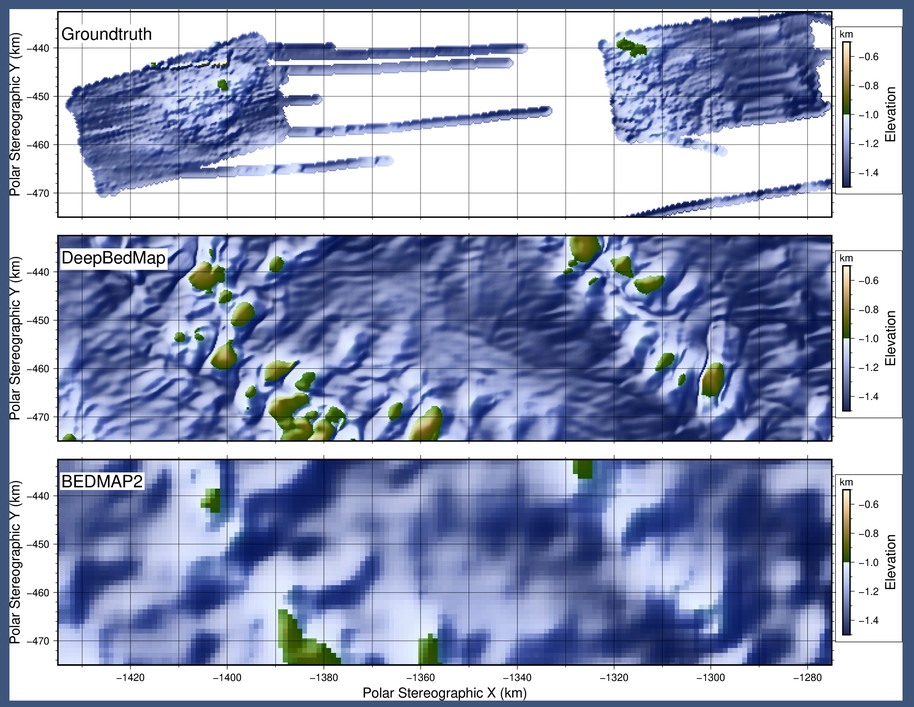
2. Wang et al., 2018. arXiv:1809.00219
3. Howat et al., 2019. doi:10.5194/tc-13-665-2019
4. Mouginot et al., 2019. doi:10.1029/2019GL083826
5. Arthern et al., 2006. doi:10.1029/2004JD005667
6. Morlighem et al., 2019 doi:10.1038/s41561-019-0510-8
7. Graham et al., 2017. doi:10.5194/essd-9-267-2017



4x higher resoluton (250m) DEM *than BEDMAP2 using a* ***Convolution Neural Network*** *trained on* ***remote sensing*** *data*

Dataset (beta)
https://osf.io/96apw

Code (Open Source)
https://github.com/weiji14/deepbedmap

Preprint (in review)
https://doi.org/10.5194/tc-2020-74

3) Applications

- For **ice sheet modellers** running **catchment-scale** simulations
- For **glaciologists** working on Antarctica's **subglacial hydrology** and **ice flow dynamics**

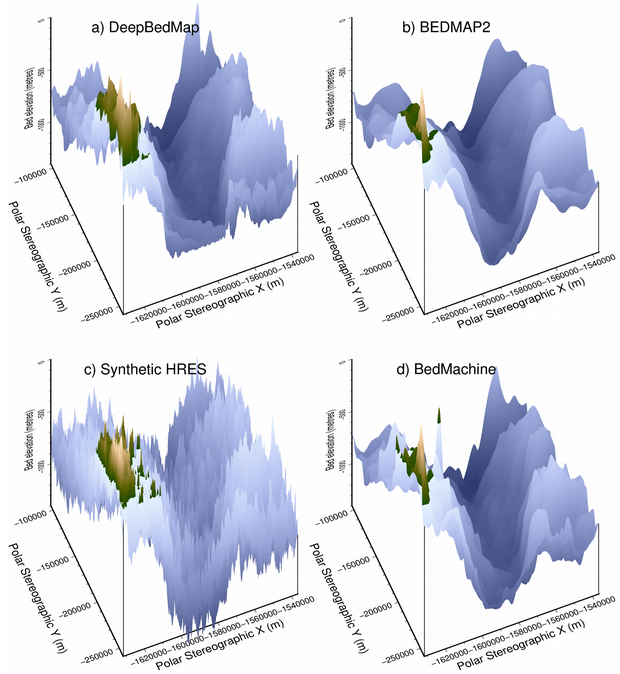


Fig 3: Closeup 3D perspective view of **bed topography** over **Pine Island Glacier**, West Antarctica. We compare the **DeepBedMap** DEM with **BEDMAP2**[1], a **Synthetic high resolution** grid[7] and **BedMachine** Antarctica[6].

4) Next steps

Better data => Better model
- Model performance will improve when trained with more **high-resolution grids** (e.g. from swath radar data)
- Combine **super-resolution** with **mass conservation** techniques.

DeepBedMap+BedMachine=>BEDMAP3?

Acknowledgements
This research was funded by the Royal Society of New Zealand's Rutherford Discovery Fellowship (Contract: RDF-VUW1602), with additional support from the Erasmus+ programme and International Glaciological Society early career travel award for presenting earlier versions of this work at other conferences. The friendly folks at the Antarctic Research Centre are awesome, and so are the Tesla P100 and V100 GPUs used for training this DeepBedMap model. We are grateful to Robert Bingham and Edward King for the Pine Island Glacier and Carlson Inlet datasets. Special mention to DongDong Tian and Leonardo Uieda for their work on the amazing PyGMT package used to produce the high quality figures in this poster. Also a big thank you to all the other scientists out there for freely and openly sharing their datasets and code online!