Levante Report 2023

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Project: 1164
Project title: Quantifying millennial timescale grounding-line retreat in East Antarctica
Principle investigator: Clemens Schannwell
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Scientific project description

As a joint project between the MPI-Met and the University of Tübingen, we have performed a range of simulations to investigate ice rises and ice rumples, features found in ice shelves in coastal Antarctica. An understanding of ice rises and ice rumples is important because these features act to regulate the flow of ice and play a role in large-scale grounding line migration patterns. In a paper (Henry et al., 2022), we showed that ice rises and ice rumples, and the surrounding ice shelf respond with hysteresis to sea level variation.

In the most recent part of the project, we have run simulations of Derwael Ice Rise, an ice rise located in the Roi Baudouin Ice Shelf in East Antarctica. These simulations are a blueprint for the simulation of ice rises around Antarctica and are important in the use of ice rises as a climate archive, for example in planning ice coring projects. The simulations of Derwael Ice Rise allow the comparison of modelled and observed isochrones (Fig. 2), which serve to validate the model. Simulations with Glen's flow law exponents of $n = 3$ and $n = 4$ allow for investigation of the differences in ice flow dynamics. We find that at a depth of 95 %, simulations with a Glen's flow law exponent of $n = 3$ produce ice which is, on average, 335 years older than in the $n = 4$ simulations, which has implications for the use of models to predict the age-depth field of an ice rise. We see significant differences in the shear strain rates in the shear zones around the ice rise, which has consequences for fracture mechanics simulations. Furthermore, our simulations show that the oldest ice is found at the ridge divide and the stoss side of the ice rise.

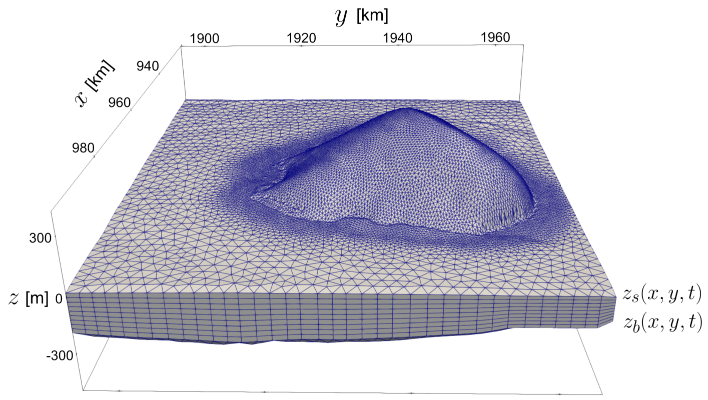

Figure 1: The model set up with horizontal distances in Antarctic polar stereographic projection. The area encompassing the ice rise has a characteristic resolution of 500 m and the surrounding area has a resolution of 2000 m. The upper ice surface is denoted by $z_s = z_s(x, y, t)$ and the lower ice surface by $z_b = z_b(x, y, t)$.

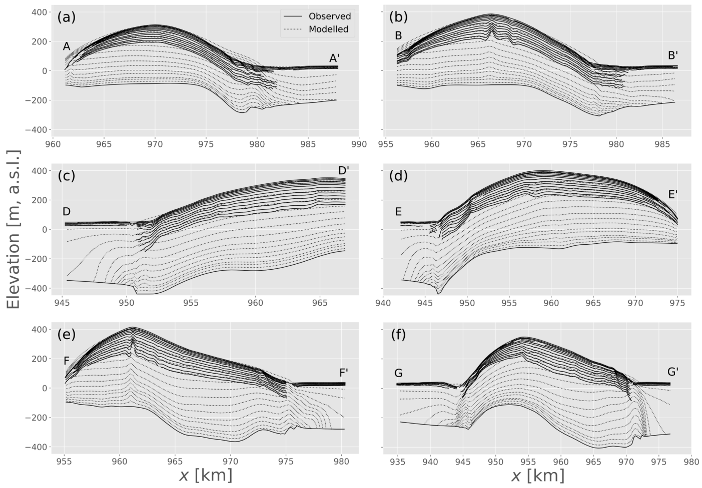

Figure 2: Comparisons between modelled and observed stratigraphy along radar profiles. The figures (a), (c), and (e) show comparisons for a Glen's flow law exponent of $n = 3$, and the figure (b), (d), and (f) show comparisons for a Glen's flow law exponent of $n = 4$.

Simulation details

Using the finite element model Elmer/Ice, we used a domain size of roughly 60×80 km and 10 vertical layers (Fig. 1). The set up of the model and the test simulations run involved the following steps:

- Reading in geometry using BedMachine data.
- Simulations varying the basal mass balance.
- Surface mass balance simulations with RACMO data (smoothed and unsmoothed) and stratigraphy-derived data.
- Simulations varying the Glen's flow law exponents ($n = 3$ and $n = 4$).
- Simulations varying the enhancement factor for each Glen's flow law exponent.
- Various basal friction coefficients
- Simulations with various resolutions (for testing and final results).
- Simulations to set up the domain flux conditions correctly.
- Simulations of the age field of the ice rise for comparison with observed isochrones.
- Simulations during the process of smoothing data (e.g. bed elevation anomalies caused divergence of the model solvers in some cases)

1 Reference

[1] Henry, A. C. J., Drews, R., Schannwell, C., and Višnjević, V.: Hysteretic evolution of ice rises and ice rumples in response to variations in sea level, The Cryosphere, 16, 3889–3905, https://doi.org/10.5194/tc-16-3889-2022, 2022.