Project: 1164
Project title: Quantifying millennial timescale grounding-line retreat in East Antarctica
Principle investigators: Clemens Schannwell and Clara Henry
Report period: 2023-05-01 to 2024-04-30

1 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 (pinning points), 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 continental grounding line migration (Favier and Pattyn, 2015). In earlier phases of the project, a number of results were attained using Mistral and then Levante resources. This included a publication showing that ice rises and ice rumples, and the surrounding ice shelf respond with hysteresis to sea level variation (Henry et al., 2022). Owing to the writing up of Clara Henry's PhD thesis during the latter parts of 2023 and early months of 2024, the number of simulations performed on Levante was lower than anticipated and explains in large part the expired resources.

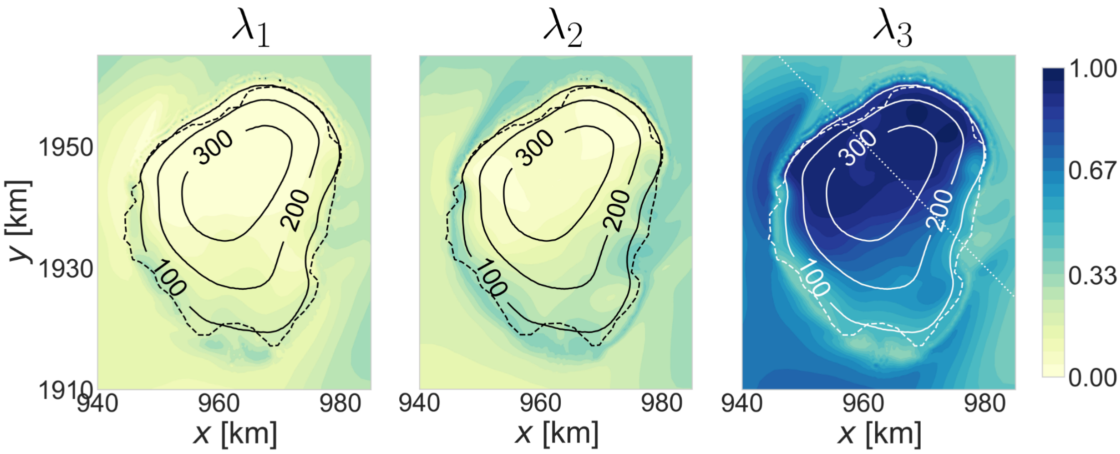

Figure 1: The eigenvalues, λ_1, λ_2 and λ_3, of the crystal orientation tensor in the $\alpha = 0$, $\iota = 1$ simulation at an elevation of $z = 0$, corresponding to sea level. The solid lines, black in the plots showing λ_1 and λ_2, and white in the plot showing λ_3, are contours of depth below the upper ice surface and the dashed lines show the grounding line.

2 Simulation details

In all of the simulations in this project, the finite element model, Elmer/Ice (Gagliardini et al., 2013) is used with a Stokes solver. The ice-flow dynamics in coastal Antarctica are complicated given the contact problem which needs to be solved where the ice starts to float. For this reason, simulations need to be performed with a computationally-expensive, full Stokes solver rather than with ice-flow approximations which are often used in coarser, larger scale simulations. The set up of the model and the simulations performed involved the following steps and are outlined on a study-by-study basis.

2.1 Study 1: Derwael Ice Rise stratigraphy simulations

We performed simulations calculating the age of ice in a real-world ice rise, which has significantly advanced this area of research through the three-dimensional simulation of ice stratigraphy (layers) which had previously only been performed in two dimension. These simulations have allowed us to compare the modelled and observed stratigraphy of a real-world ice rise (Derwael Ice Rise) and has resulted in a manuscript, which is in the revision process (Henry et al., 2023). The simulations in the latest compute project phase were performed in order to address reviewer comments.

2.2 Study 2: Derwael Ice Rise anisotropy simulations

The simulations presented here were performed entirely within the latest compute project phase and have resulted in a manuscript with an external collaborator at the British Antarctic Survey (BAS), Cambridge, UK. In this work, we simulated Derwael Ice Rise using a crystal orientation tensor evolution equation with parameter choices found in previous literature (Fig. 1). This work is important for an understanding of the influence of parameters on the resulting anisotropy field and for aiding future comparisons with radar observations of crystal anisotropy.

2.3 Study 3: Idealised pinning point simulations

The simulations performed for this study are preliminary and have been included in the PhD thesis of Clara Henry. The goal of these simulations is to investigate the dominant factors influencing pinning point buttressing (upstream force) and is important for our understanding of the varying buttressing force of pinning points, whose loss is likely to result in an acceleration of mass loss into the ocean. This work is in collaboration with a researcher at Oxford University, UK.

2.4 Study 4: Ekström Ice Shelf simulations

The simulations performed here are thus far exploratory and will form a collaboration with the above-mentioned researcher in BAS and researchers in Copenhagen, Denmark. Extending on the study of the anisotropy field of Derwael Ice Rise, we have begun modelling the anisotropy field of Ekström Ice Shelf, where the German polar research station, *Neumayer*, is located. This work will allow the comparison between the modelled anisotropy field and the observed anisotropy field, obtained using quad-polarimetric radar.

References

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