Project: **1164**

Project title: **Quantifying millennial timescale grounding-line retreat in East Antarctica**

Principal investigator: **Clemens Schannwell**

Report period: **2021-05-01 to 2022-04-30**

As a joint project between the MPI-Met and the University of Tübingen, we have performed an ensemble of ice-sheet 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. Ice rises and ice rumples differ in their flow regimes and their buttressing effect on the upstream ice shelf, with ice rises having a local, radial flow regime, emulating small ice sheets, whereas ice rumples have a flow regime aligned with that of the surrounding ice shelf.

The simulations of idealised ice rises and ice rumples were performed using the Elmer/Ice finite element model, solving the full Stokes equations for a domain size of 60x60km, with an unstructured grid in the horizontal and a 10-layer extrusion in the vertical (Fig. 1). A high resolution of 350m was used in the area surrounding the feature to allow sufficient dynamic grounding line migration. A constant influx is prescribed on one side of the domain causing a flow of ice, emulating an ice shelf. Various bed geometries, bed elevations and basal friction coefficients were tested, and the response of the ice rises and ice rumples to sea level perturbations was analysed. Furthermore, the simulated results allowed us to make comparisons with analytical ice flow solutions (shallow ice approximation and Vialov profile).

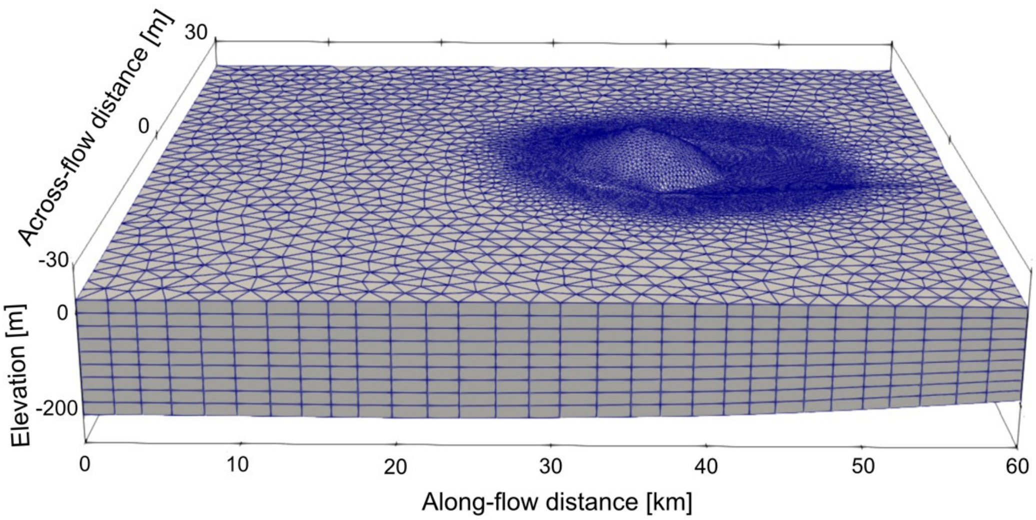

Figure 1: The domain size of the simulations is 60x60km. The horizontal resolution is 350m in the area surrounding the ice rise and 2000m elsewhere. The mesh is extruded in the vertical by 10 layers. Figure from Henry et al., 2022.

Our model simulations show that ice rises and ice rumples exhibit hysteric behaviour in response to sea level perturbation (Fig. 2). This is seen not only in the grounded area of the ice rise or ice rumple, but also in the upstream ice shelf velocity field. An increase in sea level causes a transition from ice rise to ice rumple, with the existence of a steady state ice rumple occurring in lower friction cases. In a high friction case, however, a transition from ice rise to ice rumple was immediately followed by complete ungrounding of the feature. This indicates that ice rumples with a high friction bed found in Antarctica are likely to have formed by means other than a transition from an ice rise. A comparison between the simulated results and the shallow ice approximation shows the locality of the flow field in an ice rise. In the case of a high basal friction coefficient, the ice rise is barely influenced by the stresses of the surrounding ice shelf, whereas in the lower basal friction scenarios, the ice rise is seen to be influenced by the stresses of the surrounding ice shelf, particularly on the stoss (landward) side of the ice rise. Furthermore, we show that a comparison with the Vialov profile can be used to diagnose whether basal sliding is an active process beneath ice rises.

We have also performed initial simulations for the next stage of the project, where we investigate a specific ice rise in the Roi Baudouin Ice Shelf in eastern Antarctica called Derwael Ice Rise (DIR).

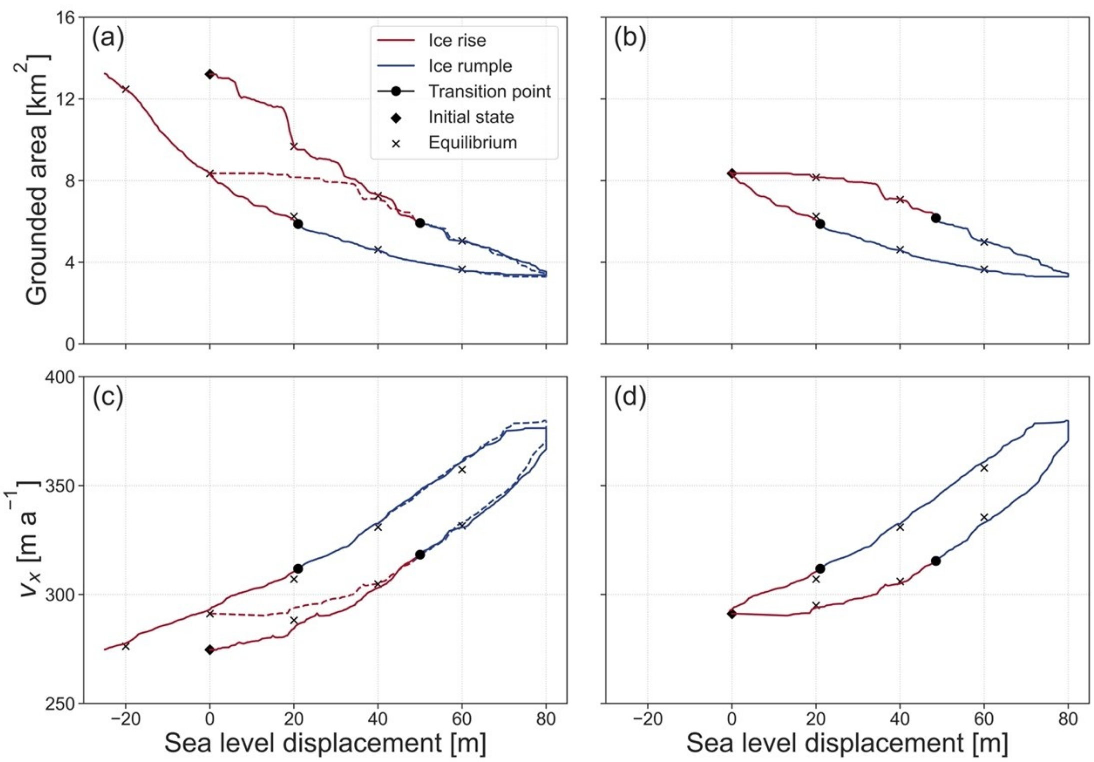

Figure 2: The response of grounded area and upstream ice shelf velocity to sea level perturbation. Panels (a) and (c) show the evolution for the first sea level increase and decrease cycle in blue and red. Panels (b) and (d) show the evolution for the second increase and decrease cycle. These curves are also plotted in panels (a) and (c) in with dashed red and blue lines for comparison. The crosses represent the results of steady state branches of the transient simulations at corresponding sea levels. The transition from ice rise to rumple and vice versa is represented by the black dots and a change in colour of the curve. Figure from Henry et al., 2022.

References

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, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-128, 2022.