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Fully-coupled 3D modelling of Halvfarryggen Ice Rise, Dronning Maud Land, East Antarctica

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Antarctica is fringed by floating ice shelves through which more than 80% of the overall ice is discharged. These ice shelves provide the main interface between the Antarctic Ice Sheet and the surrounding ocean. Virtually all ice shelves are either laterally constrained by embayments or locally reground on topographic highs causing the formation of ice rises. In both cases the locally enhanced friction is transmitted upstream, resulting in a restraining force that decelerates ice discharge and controls rates of sea-level rise. As ice rises are typically on the order of tens of kilometers in diameter, they are usually not resolved, both in the observations and the physical approximations, in large-scale ice-sheet models. In addition to their stabilising influence, ice rises also provide a proxy for stable ice-sheet condition in the past as they archive their own evolution in their stratigraphy, providing the opportunity to derive a Pan-Antarctic archive for the deglaciation history.
To adequately simulate ice rise evolution, the full stress balance needs to be considered including the full coupling of ice sheet, ice shelf, and ice rise. Here, we use the Full-Stokes ice-sheet model Elmer/Ice for the Ekström Ice Shelf embayment in Dronning Maud Land, East Antarctica, to study the effect of ice rises on the overall stability of the ice sheet. We initialise the model for prognostic simulations using today's surface velocity to invert for basal drag and ice-shelf rigidity in full Stokes. To account for inconsistencies in the input data we relax the initial geometry over 10 years resulting in a quasi-steady state which stays close to today's observations. As a first application of this 3D model including the fully coupled system with a dynamic grounding line, we derive erosion rates for the outlet glaciers of the Ekström Ice Shelf embayment, revealing moderate rates of up to $\sim$0.75 mm/yr, using published sliding-erosion ratios from others areas. This will be compared to sedimentary structures derived from seismic measurements.
Our perturbation experiments of the Ekström Ice Shelf embayment will investigate the effect of changing atmospheric/oceanic conditions on ice-rise evolution and divide migration using for the first time a fully coupled 3D ice-sheet model. This approach will permit to unambiguously show if and how much changes in external forcing influence divide position and internal stratigraphy, a proxy that has been widely used to deduce stable ice-flow and grounding-line conditions, but from studies that either use simplified model physics or omit the coupling between ice rise and ice shelf. Our novel modelling set-up will help to unravel the importance of ice rises for the past and future timing of sea-level rise, and represents a first step towards using ice rises as a Pan-Antarctic archive to constrain paleo ice-sheet simulations.