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Cyclic behaviour on millennial time scale due to creep instabilities in western Dronning Maud Land, Antarctica

Thomas Kleiner and Angelika Humbert

Alfred Wegener Institute for Polar and Marine Research, Section Glaciology, Bremerhaven, Germany
(thomas.kleiner@awi.de)

At the base of a thick ice sheet the temperature locally reaches the pressure melting point and melting generates a thin subglacial water layer. The basal water lubricates the base and thus enhances the sliding of the ice sheet. As a consequence of sliding, the heat source of internal strain heating decreases and the basal ice cools down over time. When frictional heat and heat advection do not counterbalance this, the ice will become frozen to the bedrock again. In addition, strain heating within a temperate ice layer generates a liquid water fraction in the ice, leading to a softer material and enhanced deformation. If the horizontal or vertical advection of cold ice to the base is weak, this positive feedback will lead to a local creep instability. The effect of basal water is thus twofold: it affects the sliding, as well as the rheology and via both ways the ice dynamics. Subglacial water is therefore a crucial component in the dynamic evolution of ice sheets.

We present numerical simulations of the present day ice flow using the three-dimensional thermo-coupled full-Stokes model $\mathrm{TIM-FD^3}$ on a 2.5 km horizontal grid in the area of the western Dronning Maud Land, Antarctica, including the three ice streams Stancomb-Wills, Veststraumen and Plogbreen and the adjacent Brunt and Riiser- Larsen ice shelves. Three different flux routing algorithms for the subglacial meltwater and a modified Weertman-type sliding relation were implemented in the model to account for higher sliding velocities under wet basal conditions.

Subsequent to spin-up simulations different sliding simulations considering wet and dry basal conditions were performed. The simulations show a cyclic behaviour on millennial time scale at distinct locations in the model domain. We estimate the distribution of subglacial water based on different flux routing methods and the effect on the ice flow and the basal thermal regime. We further present our analysis of the involved feedback mechanism between ice flow, temperature and rheology, that are related to the simulated cyclic behaviour.