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Modelling transition zones with a higher-order thermomechanical ice-sheet model

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Key areas in ice sheets are transition zones between ice frozen and ice not frozen at the bed. Such a transition zone is in a sense comparable to a grounding line between an ice sheet (high basal stress) and an ice shelf (stress-free base). Although ice flow over a lubricated area, such as a subglacial lake or an ice stream, is characterized by low driving stresses and hence governed by normal stretching and horizontal shearing, the transition zone (onset area in case of an ice stream) involves vertical shearing as well. Modeling such a system demands a higher-order model that incorporates all relevant stresses and (partly) solves the full Stokes system of equations.

Recently, both a two and three-dimensional thermomechanical higher-order model are developed and employed to study complex ice flow. The model solves the force-balance and flow-law equations in the form of a set of highly non-linear elliptic equations using the numerical method presented by Pattyn (2002). Model simulations that are presented here demonstrate the effect of higher-order stress gradients due to bedrock perturbations and slippery spots. Special attention is paid to ice flow over subglacial lakes and Lake Vostok in particular, where it is shown that the lack of basal stress leads to turning of ice flow, flattening of the ice surface and onset of enhanced ice flow. Finally, flowline experiments with the 2D model focus on the grounding line and the importance of longitudinal stress coupling in the dynamical response of grounding zones to environmental changes.