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Three-dimensional full-Stokes modelling of the grounding line dynamics

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The West part of Antarctica is mostly constituted of floating marine ice shelves, connected to the continent through grounded ice streams. The dynamics of the grounding line, i.e. the line dividing the grounded ice stream from the downstream ice shelf, has a major influence on the whole ice sheet mass balance. Most of the ice-sheet models use simplifications of the flow equations (do not include all the stress gradients) and are known to incorrectly represent the dynamics of the grounding line dynamics. Recently, parametrization of the ice flux at the grounding line has been proposed in the idealistic case of a 2D flow line model (Schoof 2007 JGR), and is pragmatically exported to 3D ice sheet models (Pollard 2009 Nature). Here, we present prognostic simulations based on numerical solutions of the full-Stokes equations for the dynamics of marine ice sheets. A contact problem is solved to determine where ice is floating or in contact to the bedrock, in order to compute the grounding line position, around which a constant and refined grid is maintained by the use of moving mesh techniques. Such an approach, recently developed and validated for 2D flow line simulations, is here extended to more realistic 3D geometries. Simulations are performed using the open-source finite-element code Elmer/Ice deploying parallel computing techniques. The 3D version of the model is first evaluated using a simple geometry extruded from 2D results. Then, starting from an initial steady state, various perturbations in the mechanical properties, the bed topography and the basal friction, spatially uniform or not, are applied. Such an approach allows to evaluate the validity of a flux parametrization in 2D and investigate the validity of using such a parametrization in a 3D case.