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Anisotropic mesh adaptation for marine ice-sheet modelling

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Improving forecasts of ice-sheets contribution to sea-level rise requires, amongst others, to correctly model the dynamics of the grounding line (GL), i.e. the line where the ice detaches from its underlying bed and goes afloat on the ocean. Many numerical studies, including the intercomparison exercises MISMIP and MISMIP3D, have shown that grid refinement in the GL vicinity is a key component to obtain reliable results. Improving model accuracy while maintaining the computational cost affordable has then been an important target for the development of marine icesheet models.
Adaptive mesh refinement (AMR) is a method where the accuracy of the solution is controlled by spatially adapting the mesh size. It has become popular in models using the finite element method as they naturally deal with unstructured meshes, but block-structured AMR has also been successfully applied to model GL dynamics. The main difficulty with AMR is to find efficient and reliable estimators of the numerical error to control the mesh size.
Here, we use the estimator proposed by Frey and Alauzet (2015). Based on the interpolation error, it has been found effective in practice to control the numerical error, and has some flexibility, such as its ability to combine metrics for different variables, that makes it attractive. Routines to compute the anisotropic metric defining the mesh size have been implemented in the finite element ice flow model Elmer/Ice (Gagliardini et al., 2013). The mesh adaptation is performed using the freely available library MMG (Dapogny et al., 2014) called from Elmer/Ice.

Using a setup based on the inter-comparison exercise MISMIP+ (Asay-Davis et al., 2016), we study the accuracy of the solution when the mesh is adapted using various variables (ice thickness, velocity, basal drag, . . .). We show that combining these variables allows to reduce the number of mesh nodes by more than one order of magnitude, for the same numerical accuracy, when compared to uniform mesh refinement. For transient solutions where the GL is moving, we have implemented an algorithm where the computation is reiterated allowing to anticipate the GL displacement and to adapt the mesh to the transient solution. We discuss the performance and robustness of this algorithm.