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Adaptive Mesh Refinement Applied to Grounding Line and Ice Front Dynamics

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Grounding line (GL) evolution plays a major role in marine ice sheet dynamics, as they are a fundamental control of marine ice sheet stability. Calving is a natural process of ice discharge and impacts the ice front (IF) position, which in turn affects the stress state of marine ice sheets. Numerical modeling of grounding line and ice front dynamics requires significant computational resources and the accuracy of their positions depends on grid or mesh resolutions. A technique that can improve accuracy with reduced computational cost is the adaptive mesh refinement (AMR) approach. We implement AMR in the Ice Sheet System Model (ISSM) for both GL and IF dynamics and test different refinement criteria to minimize the computation time while preserving model accuracy.

The AMR capability in ISSM relies on two different and independent meshers: Bamg and NeoPZ. Bamg is a bidimensional anisotropic mesh generator developed by Hecht (2006) and embedded in ISSM. NeoPZ is a finite element library developed by Devloo (1997) dedicated to high adaptive techniques. We test different refinement criteria based on: a) the distance to the GL and/or the IF, b) the ZZ error estimator developed by Zienkiewicz and Zhu (1987), and c) different combinations of criteria a) and b). We run the MISMIP3d (Pattyn et al., 2013) and MISMIP+ (Asay-Davis et al., 2016) experiments using the Shelfy-Stream Approximation to compare the results obtained with both approaches as well as the performance of each criterion in terms of computational time and GL/IF position accuracy.

We find that for the MISMIP+ setup, there is a minimum distance of 30 km of high resolution required around the GL to produce similar GL positions with the AMR and uniformly refined meshes. This sensibility is not noticed for MISMIP3d setup, for which a distance equal to 5 km is sufficient to produce accurate results. In both setups, the ZZ error estimator presents high values around GL and IF and proves to be a good indicator of the minimum distance that should be used, mainly for MISMIP+ setups. We also notice that IF position accuracy depends on the refinement around both IF and GL. Our comparison results show that computational time with AMR depends on the required accuracy, but for all cases, it is significantly smaller than the uniformly refined meshes cost.