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Grounding-line migration in plan-view marine ice-sheet models: results of the ice2sea MISMIP3d intercomparison

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Predictions of marine ice-sheet behaviour require models able to simulate grounding line migration. We present results of an intercomparison experiment for plan-view marine ice-sheet models. Verification is effected by comparison with approximate analytical solutions for flux across the grounding line using simplified geometrical configurations (no lateral variations, no buttressing effects from lateral drag). A unique steady state grounding line position exists for ice sheets on a downward sloping bed under those simplified conditions. Perturbation experiments specifying spatial (lateral) variation in basal sliding parameters permitted the evolution of curved grounding lines, generating buttressing effects. The experiments showed regions of compression and extensional flow across the grounding line, thereby invalidating the boundary layer theory. Models based on the shallow ice approximation, which neither resolve membrane stresses, nor reproduce the approximate analytical results unless appropriate parameterizations for ice flux are imposed at the grounding line, are invalid. Steady-state grounding line positions were found to be dependent on the level of physical model approximation. Models that only include membrane stresses result in ice sheets with a larger span than those that also incorporate vertical shearing at the grounding line, such as higher-order and full-Stokes models. From a numerical perspective, resolving grounding lines requires a sufficiently small grid size (<500 m), or sub-grid interpolation of the grounding line. The latter still requires nominal grid sizes of <5 km. For larger grid spacings, appropriate parameterizations for ice flux may be imposed at the grounding line, but the short-time transient behaviour is then incorrect and different from models that do not incorporate grounding line parameterizations. The numerical error associated with predicting grounding line motion can be reduced significantly below the errors associated with parameter ignorance and uncertainties in future scenarios.