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Marine ice sheet stability and grounding line dynamics

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Rapid thinning of marine ice sheets, such as the West-Antarctic ice sheet, may have different origins. For instance, a gradual ocean warming may cause increased melting under ice shelves (Shepherd et al., 2004), which could lead to an acceleration of grounded ice flow (Payne et al., 2004). However, increased melting or lubrication under ice streams may also result in an acceleration of ice flow. In order to differentiate between the different mechanisms at the origin of ice sheet speedup and thinning, we analyze the response of a marine ice sheet to different perturbations near the grounding line using a numerical ice sheet model that takes into account longitudinal stress coupling and grounding line migration at sub-grid precision. Later drag is incorporated and its effect evaluated with respect to ice sheet stability for different bedrock sloping types. Results show that grounding line migration is a function of the length scale over which the basal conditions change from frozen to the bed to floating, the "transition zone". We demonstrate that thinning of the ice shelf due to bottom melting has a negligible effect on the grounded ice mass, irrespective of the amount of lateral drag near the grounding line. Only perturbations at the grounding line or reduction in buttressing of the ice shelf may substantially thin the grounded ice sheet. Inland response was investigated with a 3D numerical thermomechanical ice-sheet model including higher-order stress gradients. This model is extended with a steady-state model of subglacial water flow, based on the hydraulic potential gradient. Different basal sliding scenarios show that ice stream variability (both temporal and spatial) can be explained by changes in the size in the upstream catchment area due to ice piracy. The response of the grounding line to such changes is analysed as a function of transition zone type.