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Marine ice sheet profiles and stability under Coulomb basal conditions

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The behavior of marine-terminating ice sheets, like the West Antarctic Ice Sheet, is of interest due to the possibility of rapid grounding line retreat and consequent catastrophic loss of ice. Critical to modeling this behavior is a choice of basal rheology, where the most popular approach is to relate the ice sheet velocity to a power-law function of basal stress. Recent experiments, however, suggest that near-grounding line tills exhibit Coulomb friction behavior. Here we address how Coulomb conditions modify ice sheet profiles and stability criteria. The basal rheology necessarily transitions to Coulomb friction near the grounding line due to low effective stresses, leading to changes in ice sheet properties within a narrow boundary layer. Ice sheet profiles 'taper off' towards a flatter upper surface, compared to the power-law case, and basal stresses vanish at the grounding line, consistent with observations. In the Coulomb case, the grounding line ice flux also depends more strongly on flotation ice thickness, which implies that ice sheets are more sensitive to climate perturbations. Furthermore, with Coulomb friction, the ice sheet grounds stably in shallower water than with a power-law rheology. This implies that smaller perturbations are required to push the grounding line into regions of negative bed slope, where it would become unstable. These results have important implications for ice sheet stability in a warming climate.