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Ice sheet (de)stabilization via grounding zone processes

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Much of the threshold behavior of marine ice sheets is thought to result from processes occurring at the grounding zone, where the ice sheet transitions into the ice shelf. At short time-scales (decades to centuries), grounding zone behavior is likely to be influenced by ongoing sediment deposition, which can stabilize the grounding zone position. Tidally driven flexure just inland of an ice shelf can further enhance stabilization by compacting subglacial till and thereby locally increasing basal shear stress. However, these stabilization effects compete with ocean-driven melt across a several-kilometers-wide grounding zone, where warm ocean water infiltration around bedrock obstacles can result in rapid grounding line retreat. Here we present a suite of geophysical observations (ice-penetrating radar, active-source seismic, GPS, and laser altimetry data) for one relatively stable (Whillans Ice Stream) and one potentially unstable (Thwaites Glacier) grounding zone in West Antarctica. The geophysical data show that estuaries occur beneath ice sheet grounding zones, where interactions between ocean water, subglacial hydrology, sediment, and tidal processes are complex and occur across a several-kilometers-wide grounding zone. We adapted an ice sheet flowband model and a hybrid three-dimensional shallow-ice/shallow-shelf approximation ice sheet model to include these effects. Our results indicate that ice stream stabilization on bedrock highs narrower than the length of the tidally-influenced grounding zone may be ephemeral if circulating warm ocean waters reduce basal resistance and enhance melt across the grounding zone. Stabilization is, however, significantly enhanced by effectively plastic beds and zones of high basal shear stress, which can be created via till compaction from tidal flexure. Thus accurate future projections of sea level require correct understanding of till rheology, subglacial hydrology, and local grounding zone processes (interaction of sediment, ocean water, subglacial water, and tidal processes), which are not presently included in modern whole-ice-sheet models.