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Ice-shelf Basal Melt Rates in the Energy Exascale Earth System Model (E3SM)

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The processes responsible for freshwater flux from the Antarctic Ice Sheet (AIS) -- ice-shelf basal melting and iceberg calving -- are generally poorly represented in current Earth System Models (ESMs). Here, we document the first effort to date at simulating the ocean circulation and exchanges of heat and freshwater within ice-shelf cavities in a coupled ESM, the Department of Energy's Energy Exascale Earth System Model (E3SM). As a step towards full ice-sheet coupling, we implemented static Antarctic ice-shelf cavities and the ability to calculate ice-shelf basal melt rates from the heat and freshwater fluxes computed by the ocean model. In addition, we added the capability to prescribe forcing from iceberg melt, allowing us to realistically represent the other dominant mass loss process from the AIS. In global, low resolution (i.e., non-eddying ocean) simulations, we find high sensitivity of modeled ocean/ice shelf interactions to the ocean state, which can result in a tipping point to high melt regimes under certain ice shelves, presenting a significant challenge to representing the ocean/ice shelf system in a coupled ESM. We show that inclusion of a spatially dependent parameterization of eddy-induced transport reduces biases in water mass properties on the Antarctic continental shelf. With these improvements, E3SM produces realistic and stable ice-shelf basal melt rates across the continent under pre-industrial climate forcing. We also show preliminary results using an ocean/sea-ice grid that makes use of E3SM’s regional-refinement capability, where increased resolution (down to 12km) is placed in the Southern Ocean around Antarctica, bypassing the need for parameterization of eddy-induced transport in this region. The accurate representation of these processes within a coupled ESM is an important step towards reducing uncertainties in projections of the Antarctic response to climate change and Antarctica's contribution to global sea-level rise.