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Antarctic ice sheet response to combined surface and oceanic sub-ice shelf melt during past interglacials and in the future

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New sediment core records from the Ross Embayment (ANDRILL; Naish et al., Nature, 2009) and time-continuous modeling of the Antarctic ice sheet-shelf system (Pollard and DeConto, Nature, 2009) imply dramatic, orbitally paced variability of the West Antarctic Ice Sheet (WAIS) through the Plio-Pleistocene. Model-simulated episodes of WAIS retreat are common during the warm Pliocene, but they also occur during some interglacials in the colder Pleistocene. The relatively modest forcing of these simulated past retreats hints at the future vulnerability of the ice sheet. In our previous long-term simulations, the ice-sheet model was driven by parameterized climatologies (surface temperature, precipitation, sea level, and oceanic sub-ice shelf melt) scaled mainly to deep-sea benthic oxygen isotope records. In the model, WAIS was found to be highly sensitive to sub-ice-shelf melt rates, with modest increases ($\sim$2 m/yr) capable of triggering sudden grounding-line retreat and dynamic thinning in the Ross, Weddell and Amundsen Sea sectors- largely in response to reduced ice-shelf buttressing.

Here we present new ice sheet-shelf simulations of specific past interglacials and future scenarios with elevated greenhouse gasses. The model is driven by atmospheric climatologies from a new high-resolution Regional Climate Model adapted to the South Polar region and modest increases in circum-Antarctic ocean temperatures. The model (accounting for past greenhouse gas and orbital forcing) shows that melt on ice-shelf surfaces played a contributing role in prior Pleistocene WAIS retreats, but increased oceanic sub ice-shelf melt was likely the dominant mechanism driving those past retreats. At levels of atmospheric CO_2 exceeding 2x preindustrial levels (560 ppmv), surface melt on ice-shelf surfaces becomes increasingly important. As CO_2 levels approach 4x preindustrial levels, surface melt on ice shelves and the low-elevation flanks of WAIS is sufficient to cause near complete WAIS collapse within several thousand years, without any increase in ocean temperature and oceanic sub-ice melt. On millennial timescales, the loss of WAIS ice is partially compensated by increased accumulation on East Antarctica, but the transfer of mass from West to East Antarctica has significant implications for local relative sea level adjustment. These results suggest oceanic sub-ice melt likely played the dominant role in previous Pleistocene WAIS retreats, but surface melt will begin to play an increasingly important role in the long-term future dynamic response of WAIS in response to elevated greenhouse gas concentrations.