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A smaller Antarctic Ice Sheet in the Pliocene and in the Future

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The middle Pliocene epoch (around 3.3 to 3) million years ago is often considered an analogue for future global climatic conditions, because mixing ratios of atmospheric CO_2 were similar to today and global mean temperature was about 3ºC warmer, comparable to projections of future climate at the end of this century (IPCC 2007). Importantly, some estimates of mid-Pliocene sea level are >20 m higher than today, implying the potential for significant retreat of the East Antarctic Ice Sheet (EAIS), in addition to complete loss of the Greenland and West Antarctic Ice Sheets (WAIS). Until now, most climate-ice sheet modeling studies have failed to simulate substantial Pliocene retreat of the East Antarctic ice margin, because at 400 ppmv CO_2, atmospheric conditions on the steep flanks of the ice sheet remain relatively cold, even during the warmest austral summer orbits.

Here, we use a hybrid ice sheet-shelf model coupled to a high-resolution regional climate model, to test the potential for both West and East Antarctic Ice Sheet retreat during the warm Pliocene and in the long-term future. In these simulations we apply new treatments of ice shelf calving and basal sliding (assuming a relationship between basal sliding coefficients and the rate of liquid water supply at the bed), and improved sub-glacial bathymetry using BEDMAP2. A range of plausible ocean warming scenarios (based on offline ocean modeling) are combined with the high-resolution regional climate model simulations to simulate the ice sheet's response to both Pliocene and long term future scenarios with elevated CO_2. Unlike our previous studies, the combination of improved bathymetric detail and more physically based model treatments of calving and basal sliding result in substantial grounding line retreat into the Wilkes sub-glacial basin of East Antarctica during the Pliocene, adding several meters of equivalent sea level in addition to the contribution from a retreated WAIS. In long-term (10^3-yr) future simulations with the same model improvements, we find the combination of modest ocean warming and $2xCO_2$ is sufficient to drive substantial WAIS retreat and some grounding line retreat in the Wilkes basin. At $4xCO_2$, we find substantial retreat into the Wilkes basin and around much of the Wilkes Land margin. While enhanced precipitation in the EAIS interior partially compensates for the marginal ice sheet retreat, the net sea level contributions are positive in all long term future scenarios, with the redistribution of ice mass from West to East Antarctica having an important effect on regional, glacio-isotatic adjusted sea level.