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Ensemble ice and sea-level change projections with the Earth system model of intermediate complexity LOVECLIM

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We present results from future ice-sheet evolution and sea-level change experiments with the Earth system model of intermediate complexity LOVECLIM. The model includes fully coupled three-dimensional thermomechanical models of the Greenland and Antarctic ice sheets (GIS, AIS), a global glacier melt algorithm to account for the response of mountain glaciers and small ice caps, and a diagnostic for oceanic thermal expansion. In the present study a large range of the model's sensitivity to greenhouse warming was sampled by systematic parameter variations. This led to an ensemble of model versions that simulate the present-day climate consistent with observations, while producing contrasted results for the future period. We first discuss results for the best validated model version under three different SRES forcing scenarios (B1, A1B and A2) extended over the third millennium. The relatively low climate sensitivity in this best model version combines with the relatively high polar amplification in LOVECLIM to yield a polar temperature response that is in line with more comprehensive models. Mountain glaciers are the fastest to disappear in all scenarios, followed by small ice caps, both representing minor contributions to sea level changes on longer time scales. Initially the strongest contribution, thermal expansion of the world oceans decelerates on multi-centennial time scales and is outpaced by GIS melting, the largest contribution to sea level rise at the end of the third millennium in all scenarios. The AIS contribution remains negative for scenario B1, due to increasing accumulation but is positive for the two other scenarios. Contributions from both the GIS and AIS are still accelerating at the end of the third millennium, demonstrating that they are far from equilibrium with the imposed warming and thus may contribute to sea level rise for many more centuries thereafter. Finally, we analyze sea-level contributions at the end of the third millennium of both ice sheets as a function of local average warming for the entire ensemble of model versions and for all three forcing scenarios. We find overlapping ranges of ice sheet response for changing the forcing scenario and for changing the climate sensitivity of the model. By 3000 AD, the GIS contribution to sea-level rise is more than one meter for a local average warming of less than 2 ˚C and increases by more than one meter per degree of additional warming limited by the total amount of Greenland ice. The sea-level contribution of the AIS is negligible or negative for less than 5 ˚C local warming and increases rapidly for an average warming above 8 ˚C. The volume response follows from a balance between changes in surface accumulation, marginal runoff, and dynamic changes of the grounding line driven by ice-shelf melting.