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The role of surface warming on accelerating the Greenland ice sheet mass loss

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Recent observations show that the Greenland ice sheet (GrIS) has been losing mass with an increasing speed during the last decades. It is observed that the ice dynamics contributes to two-third of the total GrIS mass loss (Rignot and Kanagaratnam, 2006). Several recent studies suggested that the dynamic mass loss was triggered by increased submarine melting at the ice-ocean interface. Yet surface warming and melt of ice might also lead to mechanical and rheological weakening of ice, which in turn, can enhance ice flow, resulting in greater calving rates (Straneo et al, 2013). However the role of surface warming in speeding up the ice flow and retreat is not clear.

In this work the GrIS response to a warming climate is studied using a fully coupled global climate model with a dynamical ice sheet model for the GrIS. The coupled model system, EC-EARTH – PISM, consisting of the EC-EARTH, an atmosphere, ocean and sea ice model system, and the Parallel Ice Sheet Model (PISM), has been employed for a 1400-year simulation forced by CMIP5 historical forcing from 1850 to 2005 and continued along an extended RCP8.5 scenario with the forcing peaking at 2200 and stabilized hereafter. The simulation reveals that, while the GrIS starts losing mass slowly in the 21st century, the rate of mass loss from the GrIS increases substantially after 2100 and continues hereafter at a constant rate of approximately 0.5 m sea level level rise equivalence per 100 years, even as the warming rate gradually levels off. As the coupled setup does not include the direct impact of oceanic forcing, the mass loss is due to the combination of a negative surface mass balance and a dynamic response to the surface warming. Increased melt exceeds regional precipitation increases in the surface mass balance, while the surface warming increases the enthalpy (per unit volume) of the ice sheet potentially impacting the rheology and thereby the ice flow.

The relative roles of the surface mass balance changes and the dynamic response of the ice flow are further investigated using additional ice sheet model sensitivity experiments, where the ice sheet is forced by the time-varying surface mass balance from the coupled model. We aim to quantify the impact of the simulated surface warming on the ice flow by means of a hybrid simulation where the ice sheet is forced by the surface mass balance from the coupled setup while keeping the ice surface temperature constant. This allows for assessment of the impact of the surface mass balance change, isolated from the dynamical response to the warming surface. The sensitivity of the dynamic response to ice sheet model resolution will also be assessed.

References

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