**Title**

Impact of Ice Sheet-Climate Interactions on Greenland Ice Sheet Mass Balance: Insights from Coupled CESM2-CISM2 Simulations

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**Abstract**

The Greenland Ice Sheet (GrIS), which stores freshwater equal to more than seven meters of potential sea level rise, strongly interacts with the global, Arctic and North Atlantic climate. In a warming climate, the GrIS has been losing mass and is projected to lose mass at an increasing rate. The interactions between the GrIS and the climate have the potential to amplify or dampen GrIS mass balance responses to a CO2 forcing. We investigate the impact of ice sheet-climate interactions on the mass balance and climate of the GrIS using the Community Ice Sheet Model version 2 (CISM2) coupled to the Community Earth System Model version 2 (CESM2). We compare idealized simulations with a non-evolving and evolving ice sheet topography in which we apply an annual 1 % increase until we reach four times pre-industrial (PI) CO2 concentrations. Furthermore, we analyze an idealized simulation in which we first apply a 4x PI CO2 forcing and thereafter annually reduce atmospheric CO2 by 5 % until PI concentrations are reached. By comparison of a 1- and 2-way coupled simulation, we find significant changes in atmospheric blocking, precipitation and cloud formation over Greenland as the GrIS topography evolves, acting as negative feedback mechanisms on mass loss. Besides, we find that a uniform temperature lapse rate misrepresents temperature changes in the ablation area, leading to an overestimation of the positive melt-elevation and melt-albedo feedback in 1-way coupled simulations, resulting in an overestimation of mass loss. During a 350 year 4xPI CO2 forcing period, the ice sheet loses a total mass of 1.1 m sea level equivalent, and part of its margins retreat land inward. When applying an annual 5 % decrease in CO2 to 1xPI CO2 concentrations, melt reduces rapidly. The small discharge concerned with the retreated state of the ice sheet allows for halting the GrIS mass loss, despite a surface mass balance that is only slightly positive under a remaining global warming of 2 K. During a complex transitional phase towards a colder climate, the GrIS, Arctic and North Atlantic ocean strongly interact, causing the area south of the GrIS to transition from a ’warming hole’ towards a ’cooling hole’. Elevated atmospheric temperatures, larger ocean heat transport and a poorer state of the snowpack, compared to the initial pre-industrial state, result in limited regrowth of the ice sheet under reintroduced PI CO2 conditions.