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Coupled ice-climate simulation of future Greenland ice sheet evolution: mechanisms, thresholds and feedbacks for accelerated mass loss

Miren Vizcaino[1], Laura Muntjewerf[1], Raymond Sellevold[1], Carolina Ernani da Silva[1], Michele Petrini[1], Katherine Thayer-Calder[2], Meike Scherrenberg[1], Sarah Bradley[3], Jeremy Fyke[4], William Lipscomb[2], Marcus Lofverstrom[5], and William Sacks[2]
[1]Delft University of Technology, Geoscience and Remote Sensing, Delft, Netherlands (m.vizcaino@tudelft.nl)
[2]Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, USA
[3]Department of Geography, The University of Sheffield, Sheffield, UK
[4]Associated Engineering Group Ltd., Calgary, Alberta, Canada
[5]Department of Geosciences, University of Arizona, Tucson, Arizona, USA

The Greenland ice sheet (GrIS) has been losing mass in the last several decades, with a current contributing of around 0.7 mm per year to global mean sea level rise (SLR). Projections of future melt rates are often derived from standalone ice sheet models, forced by data from global or regional climate models. In many cases, the surface mass balance parameterization relies on simplified schemes that relate melt with surface temperature.

In this study, we present a mass and energy conserving, 350-year simulation with the Community Earth System Model version 2.1 (CESM2.1) bidirectionally coupled to the Community Ice Sheet Model version 2.1 (CISM2.1). In this simulation, the carbon dioxide concentration is initially increasing by 1% per year from pre-industrial levels (287 ppmv), to a quadrupling (1140 ppmv) and stabilization after year 140. The model simulates a global warming of 5.3 K and 8.5 K with respect to preindustrial by years 131-150 and 331-150, respectively, and a strong decline in the North Atlantic Meridional Overturning Circulation that is initiated before GrIS runoff substantially increases. 91% of the total GrIS contribution to global mean sea level rise (SLR, 1140 mm) is simulated in the two centuries following CO2 stabilization, as the mass loss increases from 2.2 mm SLR per year in 131-150 to 6.6 mm SLR per year in 331-351. This increase is caused by melt acceleration as the ablation areas expand, and Greenland summer surface temperatures predominantly approach melt conditions when the global warming exceeds a certain threshold (around 4.2 K). This enhances the albedo and turbulent heat fluxes contribution to total melt energy.