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The climate - Greenland ice sheet Feedback as simulated by the coupled ice sheet/climate model EC-EARTH – PISM

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Recent observations show that mass loss from the Greenland ice sheet has increased during the past decades, in line with the warming trend in the Arctic. Studies have suggested that the ice sheet mass discharge through fast moving outlet glaciers and ice streams may be triggered by intrusions of warm seawater into fjords, implying the possibility for fjord-terminating glaciers to respond to ocean and atmospheric changes on annual to decadal time scales. Meanwhile, the rapid changes in ice sheet topography and surface runoff could alter the atmospheric and ocean circulation. To understand the interactions of ice sheet and atmosphere and ocean, process based, climate – ice sheet coupled models are needed.

Recently a fully coupled global climate model with a dynamical ice sheet model for the Greenland ice sheet, EC-EARTH – PISM, has been developed. The model system consists of the atmosphere, ocean and sea ice model system, EC-EARTH, and the Parallel Ice Sheet Model, PISM. The coupling of the PISM includes a modified surface physical parameterization in EC-EARTH adapted to the land ice surface over glaciated regions in Greenland. The PISM ice sheet model is forced with the surface mass balance (SMB) directly computed inside the EC-EARTH atmospheric module and accounting for the precipitation, the surface evaporation, and the melting of snow and ice over land ice. PISM returns the simulated basal melt, ice discharge and ice cover (extent and thickness) as boundary conditions to EC-EARTH. This coupled system is mass and energy conserving without being constrained by any anomaly correction or flux adjustment, and hence is suitable for investigation of ice sheet – climate feedbacks. PISM is initialized with the standard paleo-climatological spin-up followed by forcing with the EC-EARTH preindustrial climate to reach an equilibrium state with the model preindustrial climate. The EC-EARTH – PISM system is then integrated under preindustrial conditions until it has reached a quasi-stationary state for a considerably long period (control experiment).

Two 350-year climate change experiments using the coupled system are performed and compared with the control as well as their counterpart of the uncoupled standard CMIP5 simulations: one being abruptly quadrupling the CO_2 concentration, and another one an idealized 1% per year CO_2 increase from the preindustrial level until it reaches four-times CO_2 (i.e. stabilized at $4xCO_2$ for 210 years). The evolution of the Greenland ice sheet under the warm climate and its impacts on the climate system are investigated. Freshwater fluxes from the Greenland ice sheet melt and discharge to the Arctic and North Atlantic basin and their influence on the strength of the North Atlantic Meridional Overturning Circulation are analysed. The regional climate changes associated with the dynamic and thermodynamic impact of the Greenland ice sheet changes are quantified. The interaction between the Greenland ice sheet and Arctic sea ice is also examined.