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The impact of iceberg calving on climate: a model study with a fully coupled ice-sheet – climate model

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In the current period of climate change the understanding of the interactions between different parts of the climate system gets more and more important. The ice–sheets and ice-shelves, an important part of this system, experienced strong changes in the geological past, ranging from fully ice free to ice covered – thereby altering the whole climate. In the present climate, thousands of icebergs are released every year from Greenland and Antarctica, acting as a moving source of freshwater and a sink of latent heat. As a consequence, these icebergs alter the oceans' stratification and facilitate the formation of sea ice, thus influencing the state of the ocean and of the atmosphere. Up to now, the impact of icebergs on climate has been addressed in different studies which utilize climate models using freshwater and latent heat fluxes to parameterize icebergs. Mostly these fluxes were equally distributed around the coast. However, more recently iceberg modules were integrated into climate models to take into account the temporal and spatial distribution of the iceberg melting.

In the presented study, an earth system model of intermediate complexity - iLOVECLIM - that includes a 3D dynamic – thermodynamic iceberg module (Jongma et al., 2008) is coupled to the Grenoble ice shelves and land ice model – GRISLI (Ritz et al., 1997, 2001). In GRISLI, ice sheets evolve according to the precipitation and temperature received from iLOVECLIM. In turn, GRISLI provides its topography and the ice mask to the atmospheric component of iLOVECLIM and all freshwater fluxes (ablation and calving) to its oceanic component. The ablation is directly put into the uppermost layer of the ocean, whereas the calving is used to generate icebergs at the calving sites following the size distribution of Bigg et al. (1997).

Using this model set-up we analyse the evolution and the equilibrium state of the Greenland ice-sheet under pre-industrial conditions within three different coupling methods. All methods share that GRISLI is coupled to iLOVECLIM on a yearly basis with exchange of accumulation/temperature and albedo /topography fields. They differ in the method used to provide the freshwater feedback to the ocean component. The first method assumes no water-feedback, this implies that there is no influence of calving and runoff from GRISLI on iLOVECLIM. In the second set-up, the freshwater-feedback (ablation and calving) is included but only in the form of liquid water: the thermal and distribution effect of icebergs is ignored and calving is given as a simple freshwater flux at the calving site to the oceanic component. In the third coupling procedure, calving is used to generate icebergs.

By comparing these three experiments we are able to identify the influence of the water feedback on the climate. Moreover, the impact of the icebergs compared to direct freshwater fluxes is displayed by the fact that the resulting ocean cooling in the first few hundred years is relatively weak and is located close to Greenland, while it becomes stronger and more wide-spread later on. These differences in response to the forcing (icebergs/liquid runoff at the calving site) seem to decrease with time. These findings reveal that parameterizing icebergs using freshwater fluxes is a useful approach under constant forcing, yet, when investigating extreme events it will lead to a different timing of the climatic response.

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