1. PUBLISHABLE SUMMARY

One of the major impacts of anthropogenic climate change is sea level rise. Reliable estimates of the contribution of ice sheets to future sea level rise are important to policy makers and the civil society. Remote sensing measurements from the recent decades indicate a positive increasing contribution to sea level rise from the ice sheets of Greenland and Antarctica. In the case of Greenland, the current contributions from enhanced ice discharge to the oceans and increased surface melt have been estimated to be of similar importance (van den Broeke et al., 2009). In addition to sea level rise, ice sheet change might produce an impact on the global climate through modified freshwater fluxes in the areas of deep-water convection. Also, ice sheets modify local and large-scale climate through changes in surface albedo and in their own topography.

Ice sheets, unlike ocean circulation, sea-ice, interactive vegetation, or the carbon cycle, are not yet standard components of climate models. First attempts have been done in this direction with several climate models, and it is foreseeable that in several years ice sheets will be included as interactive components of most models.

Within this project, the first successful attempt of simulating ice sheet surface mass balance with a global climate model has been performed. Up to date, global climate models have not been considered suitable to model ice sheet surface mass balance, due to model biases and insufficient resolution. Regional climates are the state-of-the-art in simulating ice sheet surface mass balance. The main outcome of this project is the first simulations with the global climate CESM (http://www.cesm.ucar.edu/) including a new land ice component. This project has also been key in the implementation of this new land ice component. The results on the mass balance of the Greenland ice sheet have been presented in international conferences and workshops, and in three manuscripts aimed at a Special Collection of the Journal of Climate on CESM. Owing to realistic modeling of present-day climate and snow processes including albedo evolution and meltwater refreezing, and to an adequate downscaling method, CESM has been shown to realistically simulate GIS surface climate and SMB. The CESM results for 1960-2005 have been shown to agree well with in-situ and remote sensing data, as well as state-of-the-art regional models.

The first projections with CESM of the future contribution of the Greenland ice sheet to 21[st] century sea level rise have been done. Under RCP8.5 forcing, the simulated GIS SMB decreases from 372±100 Gt yr^{-1} in 1980-99 to -78±143 Gt yr^{-1} in 2080-99. 2080-99 near-surface temperatures over the GIS increase by 4.7 K (annual mean) with respect to 1980-99, which is 1.3 times the simulated global increase (+3.7 K). Snowfall increases by 18%, and surface melt doubles. The ablation area, e.g. the area with net surface mass loss, increases from 9% of the GIS in 1980-99 to 28% in 2080-99 (Fig.1).

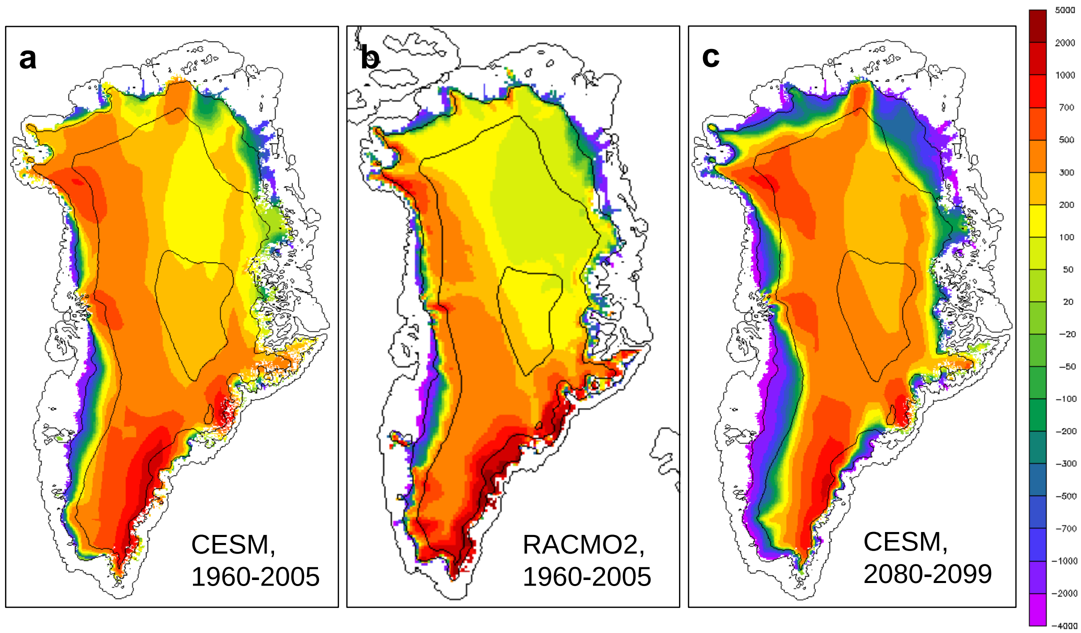

Figure 1. Simulated Greenland Ice Sheet Surface Mass Balance. a) 1960-2005, from CESM; b) same period, from RACMO2; c) projected by CESM for 2080-99 under anthropogenic greenhouse forcing following RCP8.5. Units are kg per m2 per year.

The work done within this project has brought together two communities: European regional climate modelers and the new Land Ice Working Group from CESM. The state-of-the-art climate regional model RACMO2/GR, developed at the Royal Netherlands Meteorological Institute (KNMI) in collaboration with the Institute of Marine and Atmospheric Research (IMAU) at Utrecht University, has been a key component of the work done within this project. The Land Ice Working has as task to develop and utilize the land ice component in CESM. The work done within this project is preparing ongoing and future development and scientific application of CESM for ice sheet studies.

A second line of research within this project has been the improvement an application of a formerly coupled ice sheet model to the climate model ECHAM5-MPIOM from the Max Planck Institute of Meteorology in Germany. Due to the much coarser resolution of the atmospheric component and a much simpler treatment of snow processes than in CESM, the simulation of ice sheet surface mass balance is not as accurate as in CESM. However, the model permits long simulations and therefore paleo- studies and the investigation of sensitivities to various forcing (e.g. to several anthropogenic greenhouse scenarios). The outcome of the collaboration between the fellow and MPI has been presented at several international conferences and workshops and it will be submitted to peer-review journals. In addition, it has contributed to the FP7 projects THOR and COMBINE through collaboration with participating scientists. Also, the collaboration with the MPI has contributed to the ongoing research and model development on the ice sheet-climate interactions at this major climate center.

The fellow Miren Vizcaino will continue working on the field of the modeling of ice sheet-climate interactions with global climate models from her new position as Assistant Professor at the Department of Geoscience and Remote Sensing of the Delft University of Technology.