International Max Planck Research School on
EARTH SYSTEM MODELLING

Long-term interactions between ice sheets and climate under anthropogenic greenhouse forcing

Simulations with two complex Earth System Models

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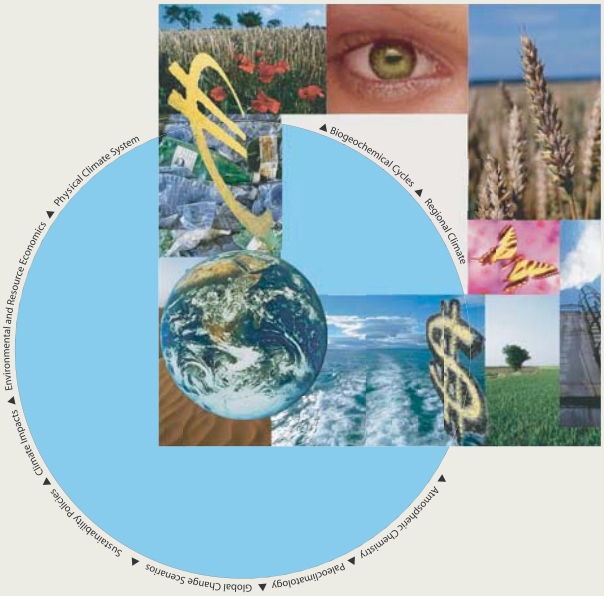

Abstract

The ice sheets of Greenland and Antarctica store the largest amount of continental water on Earth. Changes in their mass balance due to the climate change associated with the increasing atmospheric concentration of greenhouse gases could produce important changes in the sea level. Besides, changes in their mass balance could have an impact on ocean circulation via modified meltwater fluxes and on the atmosphere via changes in albedo and topography.

Most of the studies of the mass balance of the ice sheets focus on the evolution until the year 2100. Some of them do not include the effect of changes in the dynamics of the ice sheets on the total mass balance. In this study an ice sheet model is bi-directionally coupled to two different Earth System Models. It has been used to study the multi-century evolution of global ice sheets in scenarios of anthropogenic greenhouse forcing, the impact of their mass balance changes on the climate system, and how these changes can modify their own mass balance. The use of General Circulation Models for the ocean and atmosphere in both Earth System Models permits a proper identification of these potential ice sheet-climate feedbacks.

The Earth System Models used in this study are ECHAM3/LSG2/LPJ/-HAMOCC/SICOPOLIS (ESM1) and ECHAM5/MPI-OM/LPJ/SICOPOLIS (ESM2). Several stabilisation and IPCC SRES scenario simulations have been performed with ESM1. Changes in the North Atlantic Meridional Overturning Circulation (NAMOC) are mostly driven by increased atmospheric moisture fluxes, with a minor contribution from meltwater fluxes from the Greenland ice sheet (GrIS). The mass balance of the GrIS has been found to be very sensitive to changes in the northward heat transport due to the weakening/collapse of the NAMOC in the simulations. The mass balance of the Antarctic ice sheet is dominated by increased snowfall rates in all the simulations.

The ice sheet-atmosphere feedbacks related to albedo and atmospheric circulation were found not to be relevant for the mass balance of the Greenland ice sheet until the ice sheet decayed to 3/4 of its original area and volume. The sign

of these feedbacks was found to be positive, with a dominant role of the albedo changes.

First results of a model with bidirectional coupling of an ice sheet to an AOGCM (model ESM2) without flux corrections are presented. The results with ESM2 show stronger melting rates of the GrIS than with ESM1 and positive contribution of the Antarctic ice sheet to sea level rise in the high stabilisation scenario 4xCO_2.