The Antarctic ice sheet and environmental change: a three-dimensional modelling study

Der antarktische Eisschild und globale Umweltveränderungen: Eine dreidimensionale Modellstudie

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Philippe Huybrechts

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ABSTRACT

This thesis addresses the response of the Antarctic ice sheet to changes in environmental conditions, both on the longer palaeoclimatic time scale (10^4-10^5 y) as on the shorter time scale (10^2 y) associated with future greenhouse warming. The Antarctic ice sheet is of large interest because changes in its elevation and extent have an important role in modulating global atmospheric and oceanographic processes, and because these fluctuations contribute significantly to world-wide sea levels. The possibility of a surge of the marine-based West Antarctic ice sheet is often mentioned as an important aspect.

In a first part a qualitative description is given of the role of the ice sheet in the global environmental system and the possible modes of interaction are discussed. An overview is also presented of the ice sheet's glacial history and of available field evidence of ice sheet expansion during the last glacial cycle.

Subsequently, the Antarctic ice sheet is investigated using a high-resolution 3-D flow model covering the entire ice domain. This model incorporates a coupled ice shelf, grounding-line dynamics, basal sliding and isostatic bed adjustment. It has a full coupling between thermal field and ice flow and the ice sheet geometry is freely generated in response to specified environmental conditions. The model is driven by changes in sea level, surface temperature and mass balance.

A simulation of the present ice sheet reveals that the model is able to yield realistic results. A series of climatic experiments are then performed, in which the model is used to examine the ice sheet during the last glacial-interglacial cycle. This involves a sensitivity study with respect to changing environmental conditions and a time-dependent simulation of the last glacial cycle. In line with glacial-geological evidence, the most pronounced changes occur in the West Antarctic ice sheet configuration. These fluctuations are essentially controlled by variations in eustatic sea level, whereas typical glacial-interglacial changes in temperature and ice deposition rates tend to balance one another.

On the shorter greenhouse warming time scale, the model's response is determined by changes in the mass balance. It is found that as long as the temperature rise is below 5°C, the Antarctic ice sheet will probably grow, because melting at the ice sheet edge can still be offset by higher deposition rates on the plateau. The hypothesis of a catastrophic collapse of the West

Antarctic ice sheet is not supported by the model results presented in this thesis.