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MULTISTABILITY AND HYSTERESIS IN THE CLIMATE-CRYOSPHERE SYSTEM

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The stability of Quaternary climate is analysed with the Earth system model of intermediate complexity CLIMBER-2. The model includes low resolution modules, which describe the atmosphere, sea ice, ocean and biosphere, and the high resolution polythermal ice-sheet model SICOPOLIS. The latter simulates the thickness, velocity, temperature and water-content for grounded ice sheets and is coupled bi-directional with climate component of CLIMBER-2.

To study stability of the climate-cryosphere system, we performed a set of model experiments with varied orbital parameters, CO_2 concentrations and different initial conditions. It shows that orbital settings with low Northern Hemisphere summer solar insolation drives the model into glacial state, while orbital settings with high Northern Hemisphere summer solar insolation prevents glaciation and lead to an interglacial state. Experiments with orbital parameters owing intermediate summer insolation reveal two stable equilibria: the glacial and the interglacial state. For pre-industrial CO_2 concentration, the bistability of climate-cryosphere system appears within a broad range of orbital parameter values including those corresponding to present-day insolation. At the same time, in experiments with high summer solar insolation, representing the Eemian (125 kyr BP), there is only one equilibrium: the interglacial state. Similarly, experiments with low summer solar insolation, corresponding to the time of the last glacial inception (116 kyr BP), exhibit only one equilibrium as well: the glacial state. In this context, the glacial inception can be regarded as a bifurcation from the interglacial to the glacial state. Such transition is associated with a rapid increase in ice-sheet area, which explains the very fast sea-level drop during the glacial inception recorded in the palaeodata.

The multi-stability of the coupled system ice sheets and climate is manifested by the hysteresis behaviour of ice volume versus summer solar insolation, which we pinpoint through several model experiments. Such a hysteresis phenomenon is similar to that known from the theory of the thermohaline ocean circulation. The existence of hysteresis behaviour of the climate-cryosphere system has important implications for the understanding of the Earth's climate response to orbital forcing and the nature of the observed 100 kyr cyclicity.