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Simulating the Climate of the Early Holocene

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A considerable effort has been put into reconstructing and modeling the climate of the mid Holocene (6000 years ago). Typically, this time slice has been modeled in climate or earth system models by changing earth orbital parameters and greenhouse gas concentrations only. With a few exceptions, other effects have not been taken into account. Whereas this approach might be justified for the mid Holocene, it is definitely not justified for the early Holocene. 9000 years ago the entire Hudson Bay was covered by a slowly decaying ice sheet of several hundred meters thickness.

In this paper the influence of factors like e.g. insolation, topography, ice sheet decay on early Holocene climate is investigated using a set of quasi-steady state experiments with a complex earth system model. The model applied in this study consists of the atmospheric general circulation model ECHAM5 (resolution T31, 19 levels), the ocean general circulation MPI-OM (with 40 levels and a dynamic-thermodynamic sea-ice component) and the dynamic vegetation model LPJ. No artificial flux correction is used in the earth system model. In order to be able to study the near equilibrium response, the model has been spun up for more than 1000 years for each of the experiments.

The insolation changes - similar to the mid Holocene climate changes - lead to an amplification of the North African and Indian monsoon, reduced Arctic sea ice thickness and a marked summer warming over Eurasia and North America. The North American ice sheet causes a large-scale cooling over the Arctic and North Atlantic with marked influence on European climate. A weakening of the Atlantic meridional overturning circulation contributes to the North Atlantic cooling. This effect is amplified by the meltwater input from the decaying Laurentide ice sheet. Vegetation changes amplify the simulated climate changes. The Sahara becomes greener in all simulations with early Holocene insolation, which further amplifies the North African monsoon. The shift of the taiga-tundra margin amplifies the temperature changes especially in spring and early summer. Whereas the insolation changes alone would cause a northward spread of boreal forest almost to the coast of the Arctic ocean both in North America and Eurasia, the effect of the North American ice sheets leads to a zonally less uniform response.