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Effect of changes in insolation in a complex climate model

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Modelling and predicting anthropogenic climate changes is one of key tasks for the climate modelling, as well as the validation of the models. As the instrumental records are too short, the combination of the paleoclimate reconstructions from proxy data in combination with paleoclimate modelling offer a possibility to validate the model response to known changes in forcing.

One of the often used time slices is the mid Holocene (6000 years before present). For this time slice good reconstructions of the various parameters (e.g. vegetation changes, lake levels) exist. This time period has also been used as one of the standard time slices in the Paleo Model Intercomparison Project (PMIP) and it has been studied by many different models.

The main differences in climate forcing are the changes in the earth's orbit (resulting in a stronger summer insolation in the northern hemisphere) and slight changes in the atmospheric composition.

The AOGCM model applied here is a coarse resolution version of the Max-Planck-Institute's IPCC model. The atmospheric part is ECHAM5 with a T31 horizontal resolution and 19 vertical levels, the ocean part is MPIOM with 40 vertical levels and a dynamic-thermodynamic sea ice component. The dynamic vegetation model LPJ treats vegetation prognostically.

In our study we investigate the effect of changes in insolation on the climate system. The changes in the other parameters are consistent with the setup suggested in the PMIP2 project. In order to test for potential nonlinearities in insolation response additionally two time slices of the previous Interglacials (Eemian, 126ky BP) and glacial inception (115ky BP) have been simulated. In each case the model has been integrated to quasi-steady state (with spinup time larger than 1000 years).

Model results show a strengthening of the African and South Asian monsoon in response to stronger summer insolation. Additional sensitivity experiments with prescribed vegetation indicate a strong positive feedback of vegetation. In boreal summer stronger insolation leads to a strong warming of North America and Eurasia. In boreal winter the weaker insolation leads to stronger winter cooling. In the vicinity of the Arctic ocean the reduction (and thinning) of Arctic sea ice leads to warmer surface air temperatures over the ocean and in adjacent land areas. The warmer summer temperatures lead to northward shift of the tundra/taiga boundary. The albedo effect further amplifies Arctic summer warming. Simulated temperature changes are very strong in the Barents Sea region, where enhanced advection of warm, saline Atlantic water further reduces sea ice and warms the overlying atmosphere.

The climate response to insolation changes of the last Interglacial is consistent with the mid Holocene changes. A similar, but stronger response in the Eemian and an opposite response in the Glacial Inception.

In general, the model results agree reasonable well with the proxy reconstructions for the mid Holocene, especially the wetter Sahara and the northward expansion of boreal forest over Eurasia.