International Max Planck Research School on Earth System Modelling

Holocene and Eemian Climate Variability

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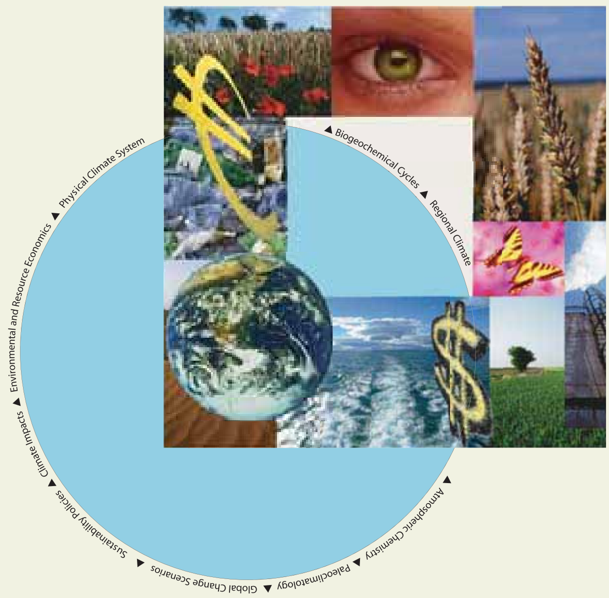

Abstract

Using a coupled atmosphere-ocean general circulation model (AOGCM) with applied orbital forcing, we investigate the climate evolution and variability of the last two interglacial periods, the mid-Holocene (6,000 years before present) and the Eemian (125,000 years before present). Earth's orbital parameters in these two periods lead to an increase in the Northern Hemisphere's seasonal insolation cycle which is stronger in the Eemian than in the Holocene. We focus on ocean circulation changes, its evolution and variability, and the seasonal temperature cycle.

Time-slice simulations of the two paleo periods reveal that the induced changes in annual mean temperature are regionally enhanced through atmosphere-ocean feedbacks. In high northern latitudes, an insolation induced temperature increase is enhanced by increased ocean heat transport and reduced sea-ice cover, resulting in an intensified ocean heat release. Orbital forcing has similar effects proportional to the forcing strength on climate and climate variability in the Holocene and the Eemian simulation. In a transient simulation from the mid-Holocene to today, we find that the orbital forcing strengthens the Atlantic meridional overturning circulation (AMOC) due to a density increase of the North Atlantic deep water produced in the northern ocean's convection regions. In the Labrador Sea, this results from the advection of more saline water from the eastern North Atlantic. In the Nordic Seas, decreasing temperatures cause a substantial increase in water mass density and result in enhanced overflows.

The AMOC exhibits variability on interannual and multi-centennial time-scales. The interannual variability is connected to atmospheric forcing, dominated by the North Atlantic Oscillation. The multi-centennial AMOC variability results from accumulating salinity anomalies in the sub-tropical gyre which, at some threshold, spread to the sub-polar gyre and trigger a change in AMOC strength. The irregular period and amplitude of the low-frequency variability indicates that it is an accumulated response of the coupled system to small scale perturbations.

Investigating the evolution of the seasonal temperature cycle, we find that its amplitude is determined by seasonal insolation changes in the low- and mid latitudes, and by sea-ice cover in the high latitudes. The sea-ice effect impacts the temperature response over the continents adjacent to the Arctic as is also visible in paleo temperature reconstructions.

In a first unaccelerated transient simulation of the mid- to late Holocene with a comprehensive AOGCM, we were able to investigate changes in the ocean state due to slowly varying forcing. We identified and attributed an AMOC increase and AMOC variability on time-scales from interannual to multi-centennial and found that the strength of the seasonal cycle is not only insolation dependent.