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Reconstruction of the Eemian climate using a fully coupled Earth system model

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Climate of the Last Interglacial (LIG) between ca. 130 and 115 kyr BP is thought to be a good analogue for future climate warming. Though the driving mechanisms of the past and current climate evolution differ, analysis of the LIG climate may provide important insights for projections of future environmental changes. We do not know properly what was spatial distribution and magnitude of surface air temperature and precipitation anomalies with respect to present. Sparse proxy data are attributed mostly to the continental margins, internal areas of ice sheets and particular regions of the World Ocean. Combining mathematical modeling and indirect evidence can help to identify driving mechanisms and feed-backs which formed climatic conditions of the LIG.

In order to reproduce the LIG climate, we carried out transient numerical experiments using a fully coupled Earth System Model (ESM) consisting of an AO GCM, which includes decription of the biosphere, atmospheric and oceanic chemistry ets. (INMCM), developed in the Institute of Numerical Mathematics (Moscow, Russia) and the models of Greenland and Antarctic ice sheets (GrISM and AISM, Vrije Uninersiteit Brussel, Belgium). Though the newest version of the INMCM has rather high spatial resolution, it canot be used in long transient numerical experimemts because of high computational demand. Coupling of the GrISM and AISM to the low resolution version of the INMCM is complicated by essential differences in spatial and temporal scales of cryospheric, atmosphere and the ocean components of the ESM (spatial resolution $5^{\circ}\times4^{\circ}$, 21 vertical layers in the atmospheric block, $2.5^{\circ}\times2^{\circ}$, 6 min. temporal resolution; 33 vertical layers in the oceanic block; 20×20 km, 51 vertical layers and 1 yr temporal resolution in the GrISM and AISM). We apply two different coupling strategies. AISM is incorporated into the ESM via using procedures of resampling and interpolation of the input fields of annually averaged air surface temperatures and precipitation fields generated by the INMCM. To provide interactive coupling of the INMCM and the GrISM, we employ a special energy- and water balance model (EWBM-G), which serves as a buffer providing effective data exchange between sub-models. EWBM-G operates in a rectangle domain including Greenland and calculates annual surface mass balance (further transferred as an external forcing to the GrISM) and fresh water flux (transferred to the oceanic block of the INMCM).

Orbital parameters of the LIG were set with 1 kyr step with further interpolation to 100 years. Assuming concentrations of greenhouse gases during the LIG were not very much different from the preindustrial values, this potential forcing was neglected. Climatic block of the ESM was called every 100 model years to follow changes in orbital forcing. AISM and GrISM were asynchronously coupled to sub-models of the atmosphere and the ocean with the ratio of model years as 100 to 1. Obtained fields of deviations of air surface temperature from preindustrial values correspond in general to the estimates made in earlier studies. Evaluated contribution of the Greenland ice sheet to the global sea level rise (approximately 2 m) supports the newest estimates based on model results and proxy data analysis.