Orbitally forced differences in the variability of the Northern Hemisphere atmospheric flow during two periods of the Holocene

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Motivation

The aim of this study is to investigate the variability in atmospheric circulation during the past two interglacials. Since the planet may move into a "super-interglacial", studying past interstadials is an urgent issue.

Approach

High resolution simulations with a comprehensive climate model allow the assessment of changes in atmospheric variability on a regional scale. As a prerequisite we evaluate the model testing two present-day runs (AMIP & CNTRL) against reanalysis data. In a next step we compare a pre-industrial simulation (PI) and a early Holocene (8000 BP) simulation as two Holocene snap-shots which just differ in the orbital forcing. Future experiments will include snapshots from the Eemian and sensitivity studies altering the ice sheet topography.

Model

The four 30-year time-slice simulations on a 1.25°×0.9° grid with fixed lower boundary conditions (sea-ice concentration (SIC) and sea-surface temperature (SST)) are performed with the earth system model CESM1 (active atmosphere and land component). The SIC and SST data are taken from the HadISST1 reanalysis (Rayner et. al., 2003) for the AMIP run and for the CNTRL, PI and 8000 BP runs from appropriate T31 CCSM3 output, respectively.

Simulation setup

The AMIP and CNTRL run have the same present-day setup and are just used for model evaluation.

The PI and 8000 BP runs differ in incoming solar radiation (Fig. 1). All other forcings are held on PI-level and ice sheets are modern.

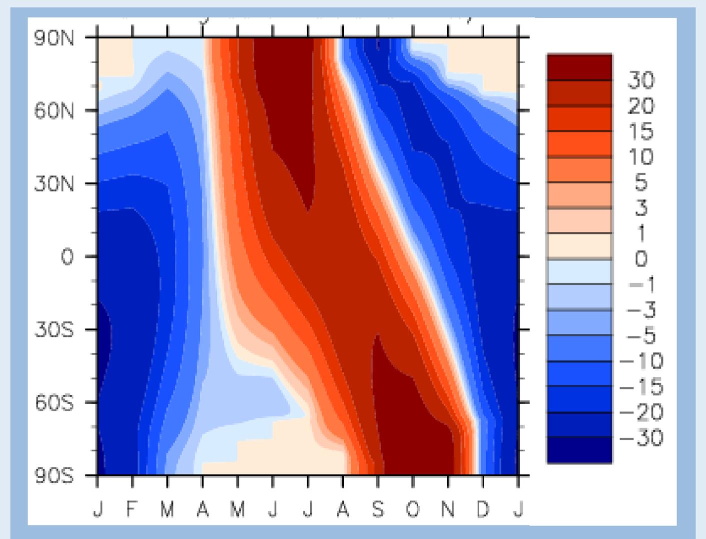

Figure 1: Seasonal cycle of difference (8000BP – PI) in solar radiation [W/m²]

References:

Rayner, N. A. et al. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. J. Geophys. Res. 108, 4407 (2003)

New, M. et. al. . Representing twentieth century space-time climate variability. Part 1: development of a 1961–90 mean monthly terrestrial climatology. J. Climate, 12, 829–856 (1999)

Kalnay, E. et al. The NCEP/NCAR 40-year reanalysis project. Bull. Am. Meteorol. Soc. 77, 437–471 (1996)

Acknowledgments:

Simulations were performed at the Swiss National Supercomputing Centre (CSCS)

The CCSM3 output used is provided by the Team of Michael Schulz (University of Bremen)

Model evaluation

Comparing state-of-art reanalysis products and the AMIP and CNTRL runs, we assess the pure **model bias** (AMIP-OBS), the **SST/SIC forced bias** (CNTRL-AMIP) due to the error of the low resolution CCSM3 output used as lower boundary conditions and the added up **total bias** (CNTRL-OBS) which emerges for this time-slice approach.

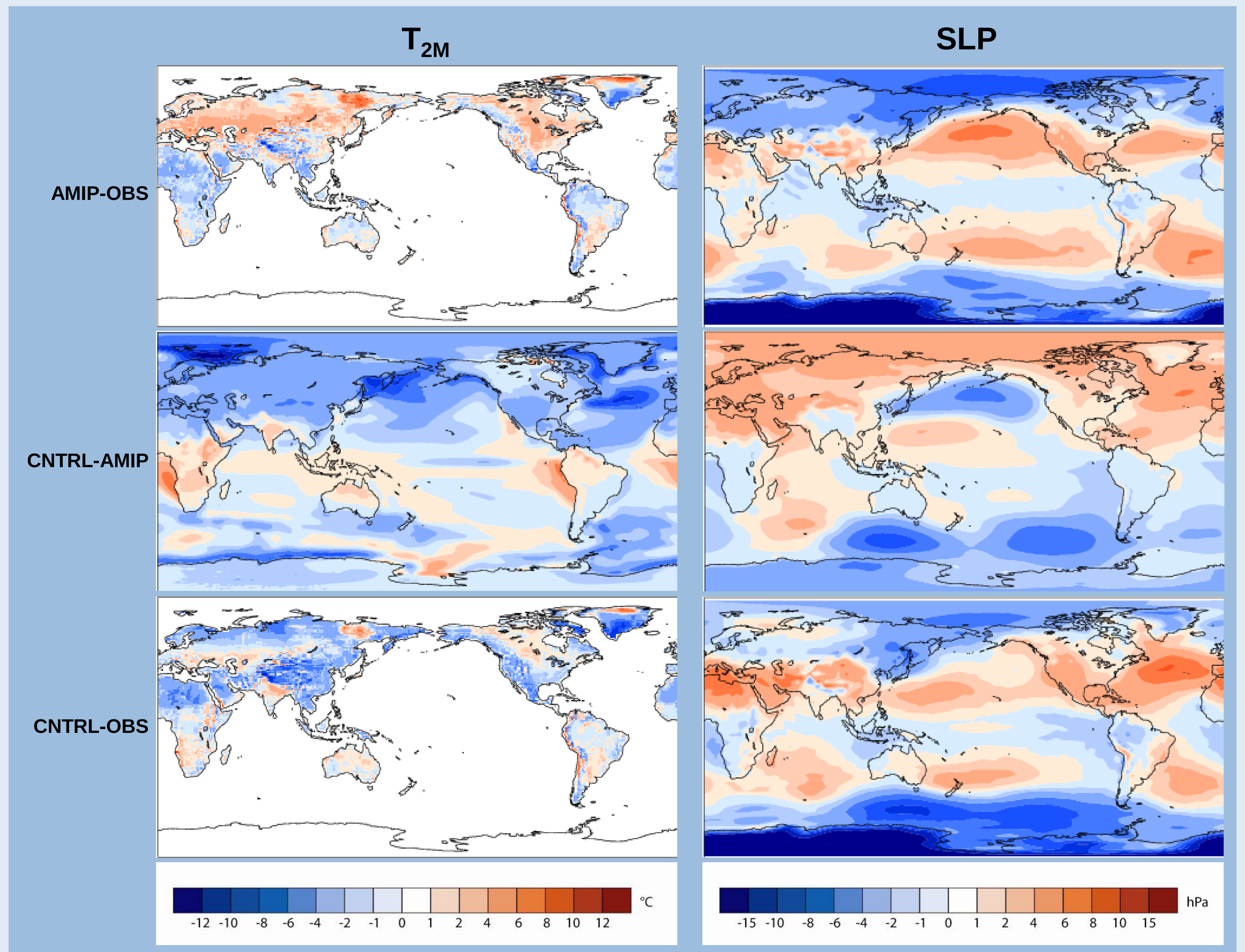

*Figure 2: Overview of the three types of annual mean model biases for 2-meter temperature (T_{2M}) (left panels) and sea-level pressure (SLP) (right panels): AMIP-OBS displays the **model bias**, CNTRL-AMIP exhibits the **SST/SIC induced bias** originating in the coarse resolution of the CCSM3 output used as the lower boundary conditions and CNTRL-OBS shows the combined **total bias.***

When comparing T_{2M} with the IPCC/CRU dataset (New et. al., 1999) (**Fig. 2, left panels**) the total bias appears to be dominated by the SST/SIC induced bias where too excessive sea-ice and too cold oceans (not shown) cause a general cold bias over the northern continents.

In contrast, the main features of the total bias in SLP (e.g., high pressure band over mid-latitudes) (**Fig. 2, right panels**) determined with NCEP reanalysis data (Kalnay et. al. 1996) mainly originate in the model bias.

Comparing biases of many atmospheric fields it can be stated that both present-day runs (AMIP & CNTRL) simulate well the present climate on a regional scale. Primarily, the biased SST and SIC fields lead to certain errors in different fields.

Atmospheric variability at 8000 BP vs. PI

Whereas the annual means of SLP for PI and 8000 BP do not show significant differences, the increased seasonality in the early Holocene exhibits interesting changes during the summer and winter months (**Fig. 3**)

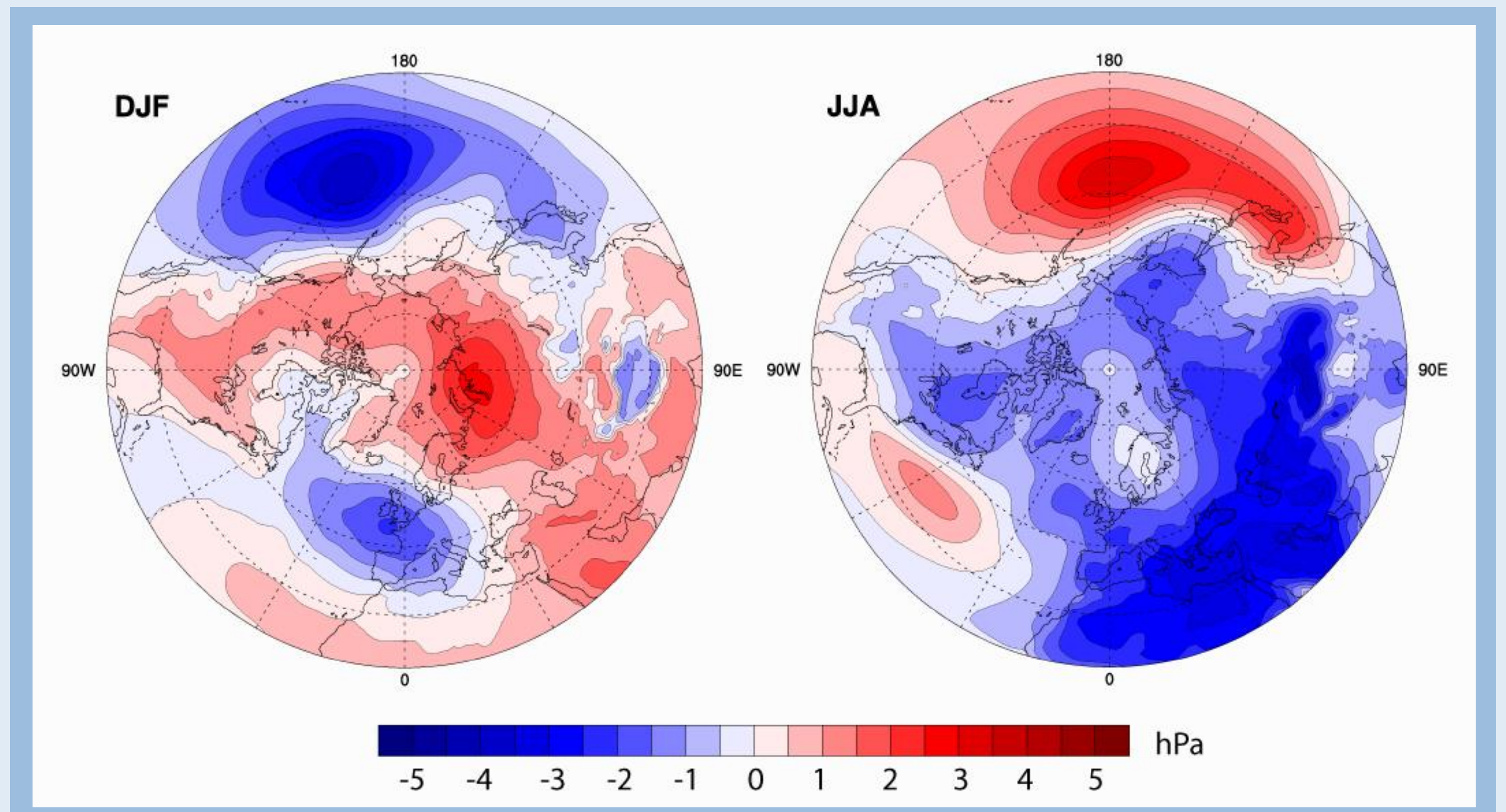

Figure 3: 8000 BP-PI mean difference of SLP in the Northern Hemisphere during winter months (left) and summer months (right) due to orbital forcing.

The DJF pattern indicates a decrease in blockings for Europe and an intensification of the Siberian High and the Aleutian Low. The JJA pattern is less clear and SLP decreases almost uniformly over Eurasia, only the Aleutian Low is damped.

Applying an EOF analysis (not shown), the leading modes of atmospheric variability over the North Atlantic show no change in location for any season. During the winter months the frequency of the 1st mode, i.e., the NAO-like pattern, is increased at 8000 BP compared with PI at the expense of the frequency of the 2nd mode. Together with the DJF SLP-pattern this denotes a more zonal circulation over Europe.

Conclusions

- Model evaluation shows that in addition to the CESM1 model bias the biased SST/SIC fields from coarse resolution CCSM3 output used in our time-slice approach cause some significant errors.
- Orbitally forced differences (8000 BP-PI) in the winter SLP field indicates a decrease in blockings over Europe during the early Holocene.

Outlook

- Applying blocking and cyclone detection schemes to assess two major phenomena of synoptic-scale variability.
- Use of a back-trajectory tool to investigate changes in the moisture transport to the ice sheets and compare these results with proxy data from ice cores.

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