Project: **1021**

Project title: **Paleo-Constraints on Monsoon Evolution and Dynamics (PACMEDY)**

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Report period: **2017-01-01 to 2017-12-31**

Project overview

Monsoon systems influence the water supply and livelihoods of over half of the world. Past climates provide an opportunity to link recent and future changes and to improve understanding of mechanisms and predictability of monsoon variability. This project uses palaeoenvironmental records of climate variability and simulations with Earth System Models over the past 6000 years and investigate the Indian, Africa and South American monsoon systems, to provide a better understanding of their dynamics and interannual to multidecadal variability (IM). The simulations contribute to the Paleo Model Intercomparison Project (Kageyama et al., 2016) as part of the 6th phase of the WCRP Coupled Model Intercomparison Project (CMIP6, Eyring et al., 2016).

Work accomplished by MPI/HZG

We contributed to the Integrated Hamburg Holocene Project with partners from Hamburg University, HZG, and MPI-M). Transient simulations with MPI-ESM-LR (a pre-CMIP6 version) have been carried out covering the time period 8 kyr BP to 1850 CE. These simulations feature unprecedented model resolution for such long transient experiments. Moreover, some of these simulations were run with interactive carbon cycle and others included novel reconstructions of volcanic and solar forcing. Owing to the availability of MHG and HZG resources, no PACMEDY resources had to be used. For the PACMEDY project, we are presently contributing to analyses of monsoon-related aspects in these simulations and in CMIP5 experiments for the Holocene and other background climates (D'Agostino et al., 2017).

We had planned to use the transient simulations as starting points for mid-Holocene (6 kyr BP) time slice simulations as part of CMIP6/PMIP4. Unfortunately, the CMIP6 compatible model version of MPI-ESM-LR was not available until late 2017. Nevertheless, the base-line CMIP6/PMIP4 mid-Holocene experiments shall be carried out in 2017. We have started to prepare the sensitivity experiments on the effect of dust reduction during the Mid Holocene (Pausata et al., 2017, Egerer et al., 2016). Following Pausata et al. (2017), the default aerosol optical depth (AOD) climatology used in the transient Holocene and standard Mid-Holocene simulations has been modified by reducing 80% the value of the coarse mode AOD over the Sahara for both long and short-wavelengths (Fig. 1a). Preliminary results indicate a large impact of the Saharan dust worldwide. RDUST exhibits a reduction in precipitation in the Sahel and Maritime Continent with respect to the CNTRL (not shown). The dust reduction leads a contraction toward the equator of the Hadley Cell and its strengthening, resembling an El-Niño like pattern (Fig. 1b).

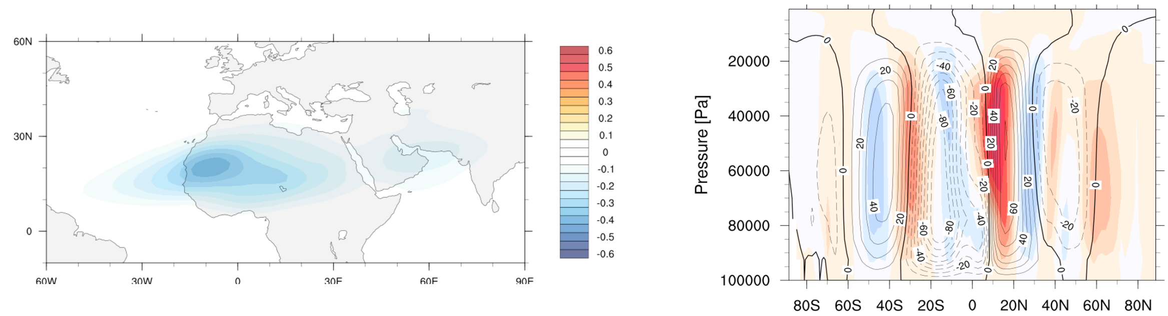

Figure 1: *Preliminary results from sensitivity experiments exploring the effect of reduced dust load from the Sahara in the mid Holocene. A) total AOD difference between the RDUST experiment and the control run. B) meridional mass stream function difference (shaded colors). Black contours represents the stream function for the control run.*

References

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Egerer, S., et al.: The link between marine sediment records and changes in Holocene Saharan landscape: simulating the dust cycle. ***Clim. Past,*** 12, 1009-1027, 2016.

Pausata, F.S.R. et al.: Greening of the Sahara suppressed ENSO activity during the mid-Holocene. ***Nature Comm***., 8, 16020, doi:10.1038/ncomms16020, 2017.

Work accomplished by AWI

High-resolution climate modeling offers a number of opportunities for improved understanding of past climates, including climate processes that can dictate regional climate changes (e.g. equatorial waves, coasts, hi latitudes), and comparison of climate model experiments with observations at spatial scales that are similar to those incorporated by data archives. One study has pointed out that within a few decades, the ocean circulation can have significant changes not only in their magnitude, but also for their positions (Yang et al. 2016). With the help of our climate model, the detailed structure of climate change can be evaluated.

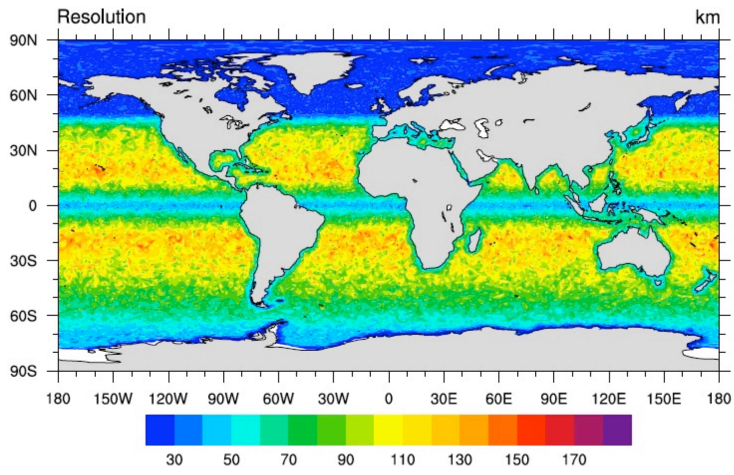

Figure 1.: *AWI-CM ocean component (i.e., FESOM) resolutions.*

The AWI Climate Model (AWI-CM), a coupled configuration of the Finite Element Sea Ice-Ocean Model (FESOM) with the atmospheric model ECHAM6, uses a novel multi-resolution approach: Its ocean component builds on a finite element dynamical core supporting unstructured triangular surface grids, allowing to distributing the grid points in a flexible manner. This allows to concentrating resolution in dynamically important regions, with a continuous transition zone to the coarser resolution in other areas (Wang et al. 2014). The model is an ideal tool to study the influence of explicit resolution of smaller scales in dedicated experiments. Figure 1 shows the FESOM resolution in our simulations.

Since the model version has been changed several times due to changes in parameterization scheme and technical issues. Our final simulations have only started in September 2017 when the version was frozen. Following the experimental set-up for the PMIP4/CMIP6 protocol (Otto-Bliesner et al., 2016), the middle Holocene (6k) and pre-industrial spin-up simulation have partly been completed. We started furthermore an early Holocene (9k) set-up by applying a corresponding orbital forcing and boundary condition of ice sheet and land-sea mask. We propose that our spin-up simulations are done by the end of Nov 2017. The first analysis of the model results are shown below. Furthermore, we are close to finish the preparation of the fully interactive water isotope model in the system. The production run can be started in 2018.

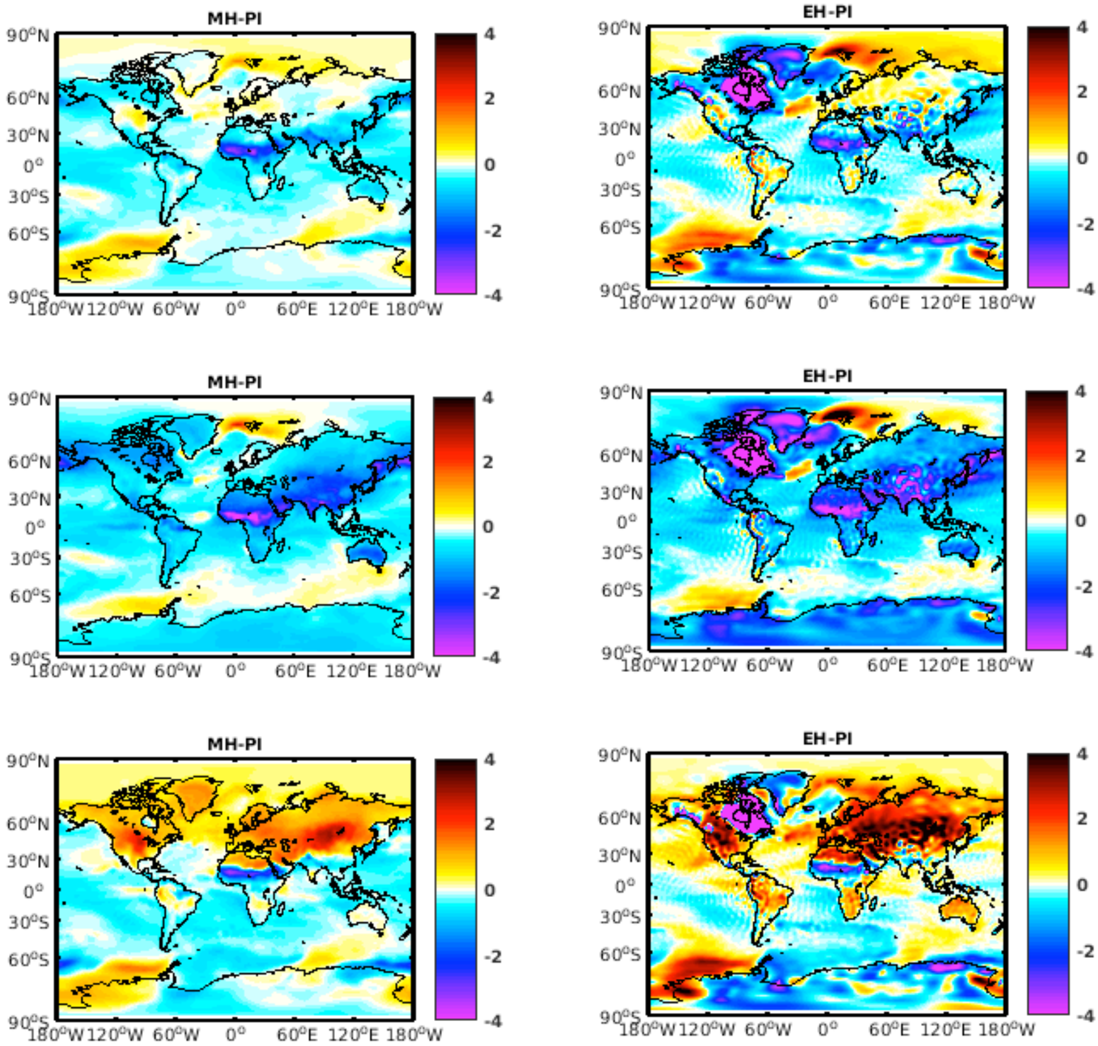

Figure 2.: *Simulated surface air temperature differences for the Mid-Holocene (left) and Early Holocene (right). Displayed are annual mean (top), DJF (middle), JJA (bottom).*

References

Yang, H., G. Lohmann, W. Wei, M. Dima, M. Ionita, and J. Liu (2016), Intensification and poleward shift of subtropical western boundary currents in a warming climate, J. Geophys. Res. Oceans, 121, 4928–4945, doi:10.1002/2015JC011513.

Wang, Q. , Danilov, S. , Sidorenko, D. , Timmermann, R. , Wekerle, C. , Wang, X. , Jung, T. and Schröter, J. (2014): The Finite Element Sea Ice-Ocean Model (FESOM) v.1.4: formulation of an ocean general circulation model , Geoscientific Model Development, 7 (2), 663-693 . doi: 10.5194/gmd-7-663-2014

Otto-Bliesner, B., et al.: Two Interglacials: Scientific objectives and experimental design for CMIP6 and PMIP4 Holocene and Last Interglacial simulations. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2016-279, 2016 (in press for GMD, 2017)

Lohmann, G. et al.: A model-data comparison of the Holocene global sea surface temperature evolution. Clim. Past, 9, 1807-1839, doi:10.5194/cp-9-1807-2013, 2013.