ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Section Paleoclimate Dynamics **Proposed Masterthesis-project**

Comparison of statistical characteristics of heat and rain extremes for different climate states, covering the Pliocene, the Pre-Industrial, as well as modern and potential future climate

Abstract

In the recent past various regions of the world have experienced weather extremes that appear to be unprecedented over the instrumental period. This observation has led to the suggestion that the effect of climate change may already have a negative impact on societies around the world. From the viewpoint of Europe, the extreme summer heat waves of the years 2003, 2006, 2015, and 2016 come to mind. A more recent example of extreme weather occurred in 2018, when large parts of middle and northern Europe were exposed to extreme heat and drought over a time period from weeks to months. In Germany alone, 2018's heat and drought caused damages in the range of billions of Euros, mostly due to crop failures and wildfires. These recent meteorological patterns felt extreme to many. Furthermore, the impression of an ever increasing frequency of extreme weather conditions, in contrast to weather that has been considered as 'normal' so far, have caused fear in the public that the most extreme events may not yet have arrived, and that rather intensity and duration of future heat and drought may increase (Frey, 2018).

From a scientific point of view these concerns, based on both human experience and observational data, raise questions about the changes in statistical characteristics of heat, drought, and rain one may have to expect in the future. Obvious topics of interest in this respect are the frequency, duration, and amplitude of extreme heat and rain events with respect to a sensibly defined baseline. In the proposed project this question shall be answered based on spatially and temporally resolved output from a coupled atmosphere-ocean climate model. The research will be conducted based on an ensemble of simulations of the climate of the Mid-Piacenzian Warm Period (MPWP, about 3.3 to 3.0 Million years ago), of the Pre-Industrial (that will serve as the baseline experiment), and of simulations with increased carbon dioxide concentrations in the atmosphere that potentially represent future conditions. All simulations were created in the framework of the Pliocene Model Intercomparison Project (e.g. Haywood et al., 2016) and are already available.

The MPWP is a relatively recent pre-Quaternary time-slice, located within the Piacenzian Stage of the Pliocene Epoch. For this project the MPWP is chosen as a time slice of interest based on the assumption that it could represent a potential past analogue for future climate. This idea is inspired by the inference that the MPWP land surface shows strong similarities to modern geography; furthermore, reconstructions

of MPWP atmospheric carbon dioxide reveal similarity to recent or modern conditions (Jansen et al., 2007, and references therein). Data sets available in the simulation ensemble provide monthly-resolved model output for a large variety of physical climate characteristics. Since monthly mean is a time-resolution too coarse for the proposed statistical analyses, the daily model output of relevant climate variables necessary for this study will be computed by rerunning the simulations for a short period ((100) model years) based on the spun-up climate states. The resulting data sets of daily resolution will then be analyzed with a focus on identifying differences in the statistical properties of heat waves as well as drought periods and rain events in the various climate simulations.

The employed Community Earth System Models (COSMOS), based on the atmosphere model ECHAM5 and the ocean model MPIOM, are not state-of-the-art any more. This is made up for by a fast execution speed and modesty with respect to computational resources. Both of these model characteristics are necessary in this project for practical reasons, in particular to allow for a large number of climate simulations to be created in a relatively short time. Yet, the most recent developments in climate modelling, that define most state-of-the-art climate models (i.e. dynamic land- and vegetation-processes), are included in COSMOS as well. Hence, COSMOS provides – with the exception of dynamic ice sheets – a rather realistic representation of the Earth System. Consequently, the results to be derived in this project will have relevance for the scientific community and stakeholders.

Among the expected outcomes of the proposed project is quantitative information on average and standard deviation of duration and intensity of extreme heat and rain events in various modelled climate states. Potentially, probability-density-functions may be created and compared. Inference on the simulated statistical characteristics of Pre-Industrial extreme heat and rain events shall illustrate whether the climate model in its current configuration is suitable for the simulation of such events. While middle and northern Europe are obviously interesting analysis regions, personal interest of the master student may be taken into account, and additional analysis regions may be considered as well. The project shall conclude with a discussion of correlations between simulated changes in spatial and temporal statistical characteristics of heat and rain events on one side, and employed forcings and boundary conditions on the other side.

References

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formal details

proposed project duration:	ca. 6 months
proposed supervisors:	- Dr. Monica Ionita (direct supervisor) - Dr. Christian Stepanek (direct supervisor) - Prof. Dr. Gerrit Lohmann (formal supervisor)
requirements:	- background in climate dynamics - solid basic knowledge on statistics and statistical analysis and the willingness to deepen the knowledge wherever necessary - basic knowledge/experience on employing common data-analysis software (e.g. python, R, octave, Matlab, CDO) or the motivation and ability to gain this 'on the fly' - experience with UNIX/SHELL is an advantage
skills to be gained in this project:	- writing scripts for data analysis in your preferred language - (more) experience with UNIX/SHELL and processing NetCDF - running climate models - analyzing climate model output - employing high-performance computers
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