EGU24-11984, updated on 17 Jan 2025
https://doi.org/10.5194/egusphere-egu24-11984
EGU General Assembly 2024

Dependence of simulated variability of surface climate on model complexity – insights from an ensemble of transient simulations of the Last Deglaciation

Elisa Ziegler[1], Nils Weitzel[1], Jean-Philippe Baudouin[1], Marie-Luise Kapsch[2], Uwe Mikolajewicz[2], Lauren Gregoire[3], Ruza Ivanovic[3], Paul Valdes[4], Christian Wirths[5,6], and Kira Rehfeld[1]
[1]Department of Geosciences, University of Tübingen, Tübingen, Germany
[2]Max Planck Institute for Meteorology, Hamburg, Germany
[3]Institute of Climate and Atmospheric Science, School of Earth and Environment, University of Leeds, Leeds, United Kingdom
[4]School of Geographical Sciences, University of Bristol, Bristol, United Kingdom
[5]Climate and Environmental Physics (CEP), University of Bern, Bern, Switzerland
[6]Oeschger Center for Climate Change Research, University of Bern, Switzerland

Climate variability is crucial to our understanding of future climate change and its impacts on societies and the natural world. However, the climate records of the observational era are too short to explore long-term variability. Conversely, an exploration of long transient simulations from state-of-the-art Earth System Models (ESMs) poses high computational demands. It is therefore pertinent to identify the level of complexity sufficient to simulate the variability of surface climate from annual to centennial and longer timescales.

To this end, we use an ensemble of transient simulations of the Last Deglaciation, the last period of significant global warming. The ensemble covers an energy balance model (EBM), models of intermediate complexity (EMICs), general circulation models (GCMs) and ESMs. This constitutes a hierarchy that we categorize based on employed atmosphere and ocean components and their resolution, as well as implemented radiation, land hydrology, vegetation and aerosol schemes.

To investigate the simulated variability of surface temperature and precipitation, we analyze changes in the shapes of their distributions as characterized by their higher order moments – variance, skewness, kurtosis – with warming. These higher order moments relate the tails to the extremes of the distributions. We identify spatial and temporal patterns and how they depend on model complexity. The EMICs can generally match the global and latitudinal changes in temperature variability found in more complex models. However, they lack in precipitation variability. We further find that the EMICs fail to simulate the tails of the precipitation distributions. We observe dependency of variability on the background state, generally increasing with model complexity. However, there is still a large spread between models of similar complexity, some of which can be related to differences in forcings. Furthermore, questions remain on the abilities of models of any complexity to simulate a magnitude of long-term variability similar to that found

regionally in proxy reconstructions. Our analysis offers implications as to the complexity needed and sufficient for capturing the full picture of climate change and we offer some first insights into how the findings translate to future projections of climate change.