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Combining intermediate complexity models and seasonal palaeo records: how to deal with model and climate variability?

H.J. de Boer, S.C. Dekker, and M.J. Wassen

Utrecht University, Faculty of Geosciences, Environmental Sciences, Utrecht, Netherlands (h.deboer@geo.uu.nl)

Earth System Models of Intermediate Complexity (EMICs) are popular tools for palaeo climate simulations. Recent studies applied these models in comparison to terrestrial proxy records and aimed to reconstruct changes in seasonal climate forced by altered ocean circulation patterns. To strengthen this powerful methodology, we argue that the magnitude of the simulated atmospheric changes should be considered in relation to the internal variability of both the climate system and the intermediate complexity model.

To attribute a shift in modelled climate to reality, this ‘signal’ should be detectable above the ‘noise’ related to the internal variability of the climate system and the internal variability of the model. Both noise and climate signals vary over the globe and change with the seasons. We therefore argue that spatial explicit fields of noise should be considered in relation to the strengths of the simulated signals at a seasonal timescale. We approximated total noise on terrestrial temperature and precipitation from a 29 member simulation with the EMIC PUMA-2 and global temperature and precipitation datasets. To illustrate this approach, we calculate Signal-to-Noise-Ratios (SNRs) in terrestrial temperature and precipitation on simulations of an El Niño warm event, a phase change in Atlantic Meridional Oscillation (AMO) and a Heinrich cooling event.

The results of the El Niño and AMO simulations indicate that the chance to accurately detect a climate signal increases with increasing SNRs. Considering the regions and seasons with highest SNRs, the simulated El Niño anomalies show good agreement with observations (r^2 = 0.8 and 0.6 for temperature and precipitation at SNRs > 4). The AMO signals rarely surpass the noise levels and remain mostly undetected. The simulation of a Heinrich event predicts highest SNRs for temperature (up to 10) over Arabia and Russia during Boreal winter and spring. Highest SNRs for precipitation (up to 12) are predicted over equatorial South America and the monsoon regions during Boreal summer.

Our results indicate that the chance to accurately model a climate signal, increases with increasing signal-to-noise ratios. This approach can be used to focus the intercomparison between intermediate complexity models and proxy records on those regions and seasons where signal-to-noise ratios are highest.