Geophysical Research Abstracts
Vol. 20, EGU2018-1079, 2018
EGU General Assembly 2018

How wrong are climate field reconstruction techniques in reconstructing a climate with long-range memory?

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Modern approaches to validate paleoclimate reconstruction techniques often rely on general circulation model (GCM) data as the basis for pseudoproxy experiments. In contrast, the pseudoproxy experiments in this study are performed using idealized input data, where ensembles of target fields are drawn from a field of stochastic processes with prescribed dependencies in space and time. A novel approach was used to generate the data, providing the opportunity to vary the strength of persistence in the target data, while retaining a simplistic and temporally persistent model for the signal covariance structure.

The range of experiment setups include input data with different levels of persistence and levels of proxy noise, but without any form of external forcing. The input data are thereby extremely simplistic compared with data extracted from GCM simulations, yet the essential component in focus is the prescribed spatiotemporal structure. Using the Bayesian BARCAST climate field reconstruction (CFR) technique, ensemble-based temperature reconstructions are generated representing the European landmass for a millennial time period. Hypothesis testing in the spectral domain is used to investigate if the field and spatial mean reconstructions are consistent with either the fractional Gaussian noise (fGn) null hypothesis used to generate the target data, or the autoregressive model of order one (AR(1)) null hypothesis which is the assumed temperature model for the BARCAST reconstruction technique. The study reveals that the resulting field and spatial mean reconstructions are consistent with the fGn hypothesis only for noise-free or weak noise scenarios. The discrepancy from an fGn is most evident for the high-frequency part of the reconstructed signal, while the long-range memory is better preserved at frequencies corresponding to decadal time scales and longer. One single experiment setup was found to give reconstructions consistent with the AR(1) model. The remaining reconstructions are not consistent with either models.

Our results show that the use of target data with a different spatiotemporal covariance structure than the BARCAST model assumption can lead to a potentially biased CFR reconstruction and the associated confidence intervals, because of incorrect estimates of the reconstructed parameters.
The resulting CFR reconstruction, therefore, does not only reflect the variability in the target data and the associated noise, but is also subject to artifacts that are unrelated to the true climate process.