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Downscaling GCM-simulated precipitation for the last millennium

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Climate variability in the pre-instrumental period can be estimated either from climate proxy data or from numerical simulations. Both approaches still have considerable uncertainties and consistency tests are crucial for identifying robust features. One of the problems when comparing simulations with proxy-based reconstructions are potential scale mismatches. If the proxy-based reconstructions represent regional climate a direct comparison with simulated variables from global climate models, which in palaeoclimate applications are run with coarse resolutions, can lead to misleading results for two reasons: (i) the climate model might be biased even on large spatial scales, and (ii) small-scale spatial variability cannot be represented by the climate model. This problem can be expected to be particularly relevant for precipitation because of its high spatial variability. One way of addressing this problem is by applying downscaling techniques to the simulations.

We have applied a statistical downscaling and correction method to precipitation from a simulation for the last millennium with the MPI for Meteorology Earth System Model, which uses ECHAM5-T31 as the atmosphere component. Our downscaling method, which is based on model output statistics (MOS), has been shown to outperform more standard (so-called perfect-prog) statistical downscaling methods when applied to simulated precipitation from the second half of the twentieth century, but it has not yet been applied to palaeoclimate simulations. Our aim is two-fold: to assess (a) whether downscaling using MOS yields additional information about long-term changes in regional climate and (b) to what extent the downscaled simulations may be in greater agreement with proxy-based reconstructions than raw model output. Two MOS downscaling methods, based on local scaling and principal component regression, are calibrated 'event-wise' (i.e. between contemporaneous sequences of simulated and observed events) using precipitation from a simulation of ECHAM5 (nudged to ERA-40) and gridded observations. Both methods are then applied to simulated precipitation for the last millennium.

Our findings show that, under cross-validation for the period 1958-2001, downscaling with MOS from the T31 resolution to a 0.5° x 0.5° target grid produces precipitation estimates that generally match the temporal variability of the observed record in large parts of Europe. MOS also shows good skill in estimating monthly precipitation amounts at small scales that are more realistic than raw model output. In comparison with a multi-proxy gridded reconstruction (Pauling et al., 2006) it is shown that reconstructed precipitation falls within the range of the downscaled ensemble spread in some parts of Europe. However, in many areas MOS fails to produce downscaled estimates that are in agreement with either the temporal evolution or magnitude indicated by the proxy record. Ultimately, this inconsistency limits the potential for such a comparison to be used as a validation tool except in individual cases.