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Statistical downscaling of GCM-simulated precipitation using Model Output Statistics

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Increased concentrations of greenhouse gases are associated not only with rising global temperatures, but are also expected to lead to considerable changes in global precipitation patterns. Estimates for precipitation changes on a local scale are difficult to obtain because General Circulation Models (GCMs) are unable to resolve the small-scale processes that are important to precipitation formation and distribution. Consequently, statistical downscaling is often used to establish relationships between atmospheric processes occurring at different spatial scales. Such statistical links are typically derived from real-world observations and then applied to the output of future GCM simulations to estimate local precipitation changes. This so-called 'perfect-prog' method requires GCM-simulated predictors to be fed directly into the statistical model, therefore assuming the GCM to be a 'perfect' representation of large-scale reality.

An alternative approach is to derive statistical models that correct the simulated precipitation. It is known as 'Model Output Statistics' (MOS) and is used routinely in numerical weather prediction. In applying MOS to GCMs, the fundamental requirement is a simulation of some historical period in which the large-scale circulation captures observed temporal variability. As GCM simulations do not typically assimilate observations, the MOS approach has not yet been used for estimating long-term precipitation changes directly from GCM simulations.

We have conducted a simulation for the period 1958-2001 using the ECHAM5 GCM in which key circulation and temperature variables are nudged towards equivalent fields from the ECMWF Reanalysis (ERA-40). Such a forcing allows for simulated precipitation, which crucially is not nudged and is calculated independently from prognostic fields, to represent the day-to-day variability in observations. Correlation maps showing the relationship between simulated and observed (GPCC gridded dataset) monthly precipitation reveal an estimate for the spatial skill of ECHAM5 precipitation given a realistic circulation.

Here we use a number of MOS downscaling methods to reconstruct regional monthly precipitation (1958-2001) directly using the precipitation field from the nudged ECHAM5 simulation as a predictor. The first MOS method, a simple local scaling of simulated precipitation, shows ECHAM5 precipitation to have excellent potential as a downscaling predictor variable. Correlations with GPCC observations are as high as 0.9 in parts of the Northern Hemisphere and Australasia. A second, non-local, downscaling approach uses Maximum Covariance Analysis (MCA) to estimate point-scale precipitation from simulated precipitation within a surrounding spatial grid. Reconstruction of European winter (summer) precipitation shows a mean correlation with observations of 0.72 (0.51).

All methods using ECHAM5 precipitation as a predictor variable show greater performance than conventional perfect-prog approaches. Reconstruction of European winter precipitation using MCA downscaling models with geopotential height and specific humidity at 1000hPa as predictors show a mean correlation with observations of 0.54 and 0.44 respectively. Summer precipitation is generally more difficult to reconstruct with the strongest predictors being geopotential height at 850hPa and relative humidity at 1000hPa (mean correlations of 0.34 and 0.32 respectively).

It is anticipated that further downscaling methods, including Canonical Correlation Analysis (CCA), using ECHAM5 precipitation as a predictor will be implemented and compared with perfect-prog methods. There

is also scope for downscaling precipitation on a daily time scale with particular focus on extreme values. The most successful methods will then be applied to a future ECHAM5 simulation used in the IPCC Fourth Assessment Report (AR4) with the overall goal of identifying key areas where estimates of precipitation changes are considered most reliable.