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Transient climate rainfall downscaling using a combined dynamic-stochastic methodology

Aidan Burton, Stephen Blenkinsop, Hayley J. Fowler, and Chris G. Kilsby
Civil Engineering and Geosciences, Newcastle University, UK. (Contact aidan.burton@ncl.ac.uk)

Managers of water resource systems need downscaled climate change projections that are relevant at the catchment scale and at a range of future time horizons. However, the uncertainty in future climate projections and the natural variability of the climate system affect the robustness of their decisions. Dynamic downscaling of discrete future time-slices also limits the analysis of the temporal development of climate change impacts, as only steady state scenarios are widely available. Addressing these issues a new transient (i.e. temporally non-stationary) rainfall simulation methodology has been developed which combines dynamical and statistical downscaling to generate a multi-model ensemble of transient daily point-scale rainfall timeseries. Each timeseries is sampled from a continuous stochastic simulation of the control-future time period and exhibits climatic non-stationarity in accordance with GCM/RCM projections. The ensemble as a whole represents aspects of both climate model uncertainty and natural variability and provides a basis for probabilistic time-horizon analyses such as when a particular impact will occur or when a particular threshold will be reached.

The methodology is demonstrated for a case study raingauge located near the Brévilles spring in Northern France. Thirteen RCM projections from the PRUDENCE project for both control (1961-1990) and future (2071-2100) time-slices were obtained to form the basis of a multi-model representation of climate change. Each dynamically downscales the climate from either the ECHAM4/OPYC or the HadCM3 GCM. Multiplicative ‘change factors’ were evaluated for a set of statistics of daily rainfall for each RCM. These quantify the future value of each statistic as a multiple of the control value for each calendar month in turn. Multiplying the case study raingauge statistics by the change factors provides future projections with an implicit correction for biases in the RCM control runs and a representation of the variability exhibited between the RCMs.

In the absence of transient RCM projections a ‘scale factor’ approach was adopted to estimate climate change throughout the transient period. Future changes were assumed to occur in proportion to global annual average temperature change. Scale factors were evaluated for four 30-year time-slice integrations of the GCMs, for which global average temperatures were available. These were linearly interpolated for the intervening years. Transient change factors were then estimated in proportion to the scale factors. Applying these to the observed rainfall statistics gave a transient projection of the daily rainfall statistics for the case study location, for each RCM for a continuous period from 1997 to 2085.

A new transient formulation of the Neyman-Scott Rectangular Pulses (NSRP) stochastic rainfall model has been developed. This model was used for stochastic downscaling to the point scale and to model natural rainfall variability at the daily scale. A piecewise smoothly varying transient NSRP parameterization was obtained by fitting to the transient projected rainfall statistics. Transient NSRP simulations then produced continuous daily rainfall time series which exhibit climatic non-stationarity. The simulation was realized 100 times to generate an ensemble, which models natural climate variability. Repeating for each RCM in turn generates a multi-model ensemble of 1300 transient downscaled daily rainfall timeseries. The ensemble improves on RCM simulations of the present-day climate and exhibits a time varying decrease in annual and summer rainfall and a time varying increase in winter rainfall amounts. The 10-year return period daily extreme rainfall is also likely to increase over the simulated period.