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Statistical properties of rain and river flow and their surrogates

Victor Venema (1), Susanne Bachner (1), Henning Rust (2), and Clemens Simmer (1)

(1) Meteorologisches Institut, Universitaet Bonn, Germany, (2) Potsdam Institut fuer Klimafolgenforschung, Germany (Victor.Venema@uni-bonn.de / fax: +49 (0)228 735188)

We are interested in the statistical properties of surrogate time series based on measurements of rain and river flow. Especially, we would like to know which statistical properties are maintained by our surrogates and, thus, for which questions the surrogate time series can be used as substitutes for real data. In future, we want to use surrogate data for filling gaps in and extending historical datasets and to improve on error estimates for extreme value statistics. Our study is based on about 100 years of daily rain sums from five German stations and river flow data from the Rhine.

The surrogate time series are generated with the Iterative Amplitude Adapted Fourier Transform (IAAFT) algorithm. The IAAFT generates time series with exactly the same distribution and almost the same Fourier spectrum as the measurements. For comparisons we also make Fourier surrogates, which only have the spectrum in common with the measurements and normally distributed values, and PDF surrogates, which have the same distribution, but no correlations.

First we need to know how the minimum length of the time series. By calculating the first four moments for intervals of increasing length we observe a considerable underestimation of the variance, skewness and kurtosis for rain measurements shorter than 3 to 10 years. For the river flow biases remain for up to 30 years. By repeating this calculation for Fourier and PDF surrogates, we found that in case of rain the causes of the slow convergence of the moments with the IAAFT are both the distribution and the correlation. In case of river flow the main cause is the correlation.

A general method to analyse the structure of time series is by structure functions (which are much used in multi-fractal analysis), which are the various moments of the

distributions of the increments. As expected from the methodology the second moment structure function of measurement and its surrogate is almost the same. Surprisingly, also the other moments are very well matched for scales larger than about 10 days for both rain and river flow. The Fourier surrogates do deviate strongly for moments other than the second. Thus, the distribution is very important for the structure of these measurements, emphasising the advantage of IAAFT surrogates.

The rain time series and their surrogates are also compared regarding their annual statistical properties, such as the number of rain days, rainfall intensity, high quantiles, and maxima. The differences were small and not statistically significant. Also special indices describing extreme conditions are investigated and similar studies are applied to the runoff series. The agreement between the river flow statistics and their surrogates is somewhat lower, but still acceptable. Furthermore, return values are calculated by fitting a Gumbel distribution. Here also, the surrogates give good results.