Beyond multi-fractals: surrogate time series and fields

Victor Venema and Clemens Simmer
Meteorologisches Institut, Universität Bonn, Germany, Victor.Venema@uni-bonn.de

Most natural complex are characterised by variability on a large range of temporal and spatial scales. The two main methodologies to generate such structures are Fourier/FARIMA based algorithms and multifractal methods. The former is restricted to Gaussian data, whereas the latter requires the structure to be self-similar. This work will present so-called surrogate data as an alternative that works with any (empirical) distribution and power spectrum. The best-known surrogate algorithm is the iterative amplitude adjusted Fourier transform (IAAFT) algorithm.

We have studied six different geophysical time series (two clouds, runoff of a small and a large river, temperature and rain) and their surrogates. The power spectra and consequently the 2nd order structure functions were replicated accurately. Even the fourth order structure function was more accurately reproduced by the surrogates as would be possible by a fractal method, because the measured structure deviated too strong from fractal scaling. Only in case of the daily rain sums a fractal method could have been more accurate. Just as Fourier and multifractal methods, the current surrogates are not able to model the asymmetric increment distributions observed for runoff, i.e., they cannot reproduce nonlinear dynamical processes that are asymmetric in time. Furthermore, we have found differences for the structure functions on small scales.

Surrogate methods are especially valuable for empirical studies, because the time series and fields that are generated are able to mimic measured variables accurately. Our main application is radiative transfer through structured clouds. Like many geophysical fields, clouds can only be sampled sparsely, e.g. with in-situ airborne instruments. However, for radiative transfer calculations we need full 3-dimensional cloud fields. A first study relating the measured properties of the cloud droplets and the radiative properties of the cloud field by generating surrogate cloud fields yielded good results within the measurement error.

A further test of the suitability of the surrogate clouds for radiative transfer is evaluated by comparing the radiative properties of model cloud fields of sparse cumulus and stratocumulus with their surrogate fields. The bias and root mean square error in various radiative properties is small and the deviations in the radiances and irradiances are not statistically significant, i.e. these deviations can be attributed to the Monte Carlo noise of the radiative transfer calculations. We compared these results with optical properties of synthetic clouds that have either the correct distribution (but no spatial correlations) or the correct power spectrum (but a Gaussian distribution). These clouds did show statistical significant deviations.

For more information see: http://www.meteo.uni-bonn.de/venema/themes/surrogates/