Geophysical Research Abstracts
Vol. 16, EGU2014-6235, 2014
EGU General Assembly 2014

Simulation of rainfall times series with zero values and realistic statistical distribution in a Universal Multifractal framwork

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Rainfall is the result of many complex physical processes that induce particular features and make its observation complex. Simulation tools can be very helpful to generate synthetic rain fields able to represent “true” rain features at small spatial or temporal scales. These rain fields can be the starting point of many studies among which the test of the performances of a particular embedded observation device, beam filling effects, design of new systems, rain retrieval intercomparaison methods . . .
Due to its strong links with turbulence, precipitations have scale invariance properties leading to a power law energy spectrum. The Universal Multifractal Model (UMM) Schertzer and Lovejoy [1987] can be used to simulate geophysical fields with scaling properties. It is particularly well suited for various geophysical fields where turbulence is involved. In the case of rain, the problem is more complicated since the rain spectrum display several scaling regimes mainly due to the alternation of dry and wet/rainy periods (rain support) and high variability of rain. Indeed the UMM does not allow generate zero values and thus to represent dry periods. It follows that the use of the standalone UMM generates synthetic data that do not exhibit all the statistical properties of actual rainfall time series.
In this study, we propose a model based on UMM and allows generating synthetic rainfall time series at a fine resolution (15 seconds). In addition to zero values it displays the same statistical properties (multifractal properties, statistical distribution of rain intensity, events duration and volume, fractal co-dimension, multiple scaling regimes, autocorrelation) as actual measurements. The data used to develop the simulator were collected during 2 years in Palaiseau (France) at a resolution of 15 s.
Initially, we analyze the observed data in term of rain support. We find independence between the durations of rainy and dry periods. We are thus able to characterize rain time series as successive “rain events” spaced out by dry periods. It consequently leads to our simulation process of rainfall time series. The analysis of the observed rainy and dry periods’ probability distribution functions (pdf) shows a break at 5 minutes. To model dry and rainy periods, we have taken into account the presence of two behaviors. A mixed zipf and pareto distribution was used to model the short (<5 minutes) and long (>5minutes) durations. The simulated support showing the same fractal properties as the real one.
Then, UMM parameters are estimated on actual rain events. Events are simulated using UMM taking into account the average relation observed between intensities and durations of all events.
The resulting generator can simulate synthetic series of more than 2 years at a 15 seconds resolution that exhibit statistics properties at all scales that are identical to those observed. The necessary modifications to simulate synthetic rainfall series corresponding to other locations and other durations will be discussed.
Finally, in the last part the extension to the simulation of 2D rain maps is also discussed and some examples of synthetic maps are presented.