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Online generation of temporal and spatial fractal red noise

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In this paper a noise generator will be presented, that can be used in a stochastic parameterisation scheme for e.g. atmospheric models. The generator only needs to store two different noise fields and this only for the current time step. The noise is fractal and correlated in time; in space more complicated correlation functions are possible, as well.

A relatively new method to estimate the uncertainties of weather predictions is the use of ensembles. An elegant way to introduce noise in such complex systems in order to generate adequate spread between the ensemble members is by varying the parameterisations of the model (stochastic parameterisations). The right type of noise is an important part of a stochastic parameterisation scheme. It is known that white noise has only little influence on the ensemble spread. The reason for this is still unclear. One reason might be that the model needs stochastic dynamic equations that explicitly take subscale variability into account. Another direction meteorologists are looking at is the use of spatially and temporally correlated noise. Some schemes create correlated noise by fixing the noise in hypervolumes in space and time, e.g. keeping the disturbance constant for a certain period. Also cellular automatons are used to generate correlated noise. Assuming that the variability of many atmospheric constituents is well approximated by a fractal, self-similar structure, the most elegant correlated noise would be fractal red noise. Especially for moist processes like clouds and rain, which are of special interest here, many studies suggest a near fractal structure. Thus, such a structure seems a good first guess as long as we do not have better estimates of the properties of the disturbances the parameterisations need.

Up to now, our considerations were mainly statistical. The choice of the noise generator should, however, also be driven by the physical mechanisms one suspects behind the stochastic nature of a parameterisation. In case of the stratiform rain parameterisation, the assumption could be that the disturbances are due to deviations from climatological values of rain conversion factors (related to number and composition of aerosols) or sub-scale variances. An important consequence of this physical picture is that you would expect the disturbance to be advected like a passive scalar in the model. Also this could be simulated with our noise generator.

The algorithm involves two steps: First, the spatially correlated red noise is calculated from a white noise field using Fourier filtering. Here one can also use non-fractal filters. Then we allow the white noise field to evolve temporally correlated by the addition of small amounts of Gaussian noise. In other words, every pixel of the white noise field represents an independent fractal Brownian noise time series. We introduced a small bias towards zero to make sure that the Brownian noise time series does not diverge. Fortunately, the spatially correlated noise field retains the fractal nature of the temporal structure of the white noise field.

We hope to find someone at EGU who is interested in investigating the properties of this preliminary scheme and in implementing it into a stochastic parameterisation scheme. More information on (and the code of) this algorithm can be found on:

http://www.meteo.uni-bonn.de/venema/essays/2005/online_generation_of_spatial_temporal_noise/