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On the numerical simulation of random fields with a truncated power-law correlation function.

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Flow and solute transport in fractured media have become a viable research topic since several countries have decided on or pondering the use of fractured rock as host medium for the deposition of nuclear waste. Due to the highly hazardous potential of nuclear material for the biosphere precise as well as effective computational tools must be provided in order to facilitate risk analysis for decision makers. One of the challenges for the accurate description of fractured media is the fractal nature of the permeability. This means that heterogeneities appear continuous over a wide range of spatial scales, without any preference as well as separation amongst them. Di Federico and Neuman (WRR 1997) showed how such permeability fields can be represented by stochastic fields with a truncated power-law correlation function. The power law accounts for the fractal nature of the heterogeneities, whereas the truncation represents the finite size of any real medium confining the fractal behavior within certain bounds. Common methods for the generation of random fields, like the Fourier method, are not able to adequately generate random fields with such features.

In our study we investigate and compare two newer methods; the Randomization method as well as the Fourier-Wavelet method. We evaluate these methods with respect to their ability to represent the correlation function over a number of spatial scales as well as the Gaussianity of the generated fields. We furthermore compare these two methods with respect to computational costs. Results show that the Randomization method performs well if only a few number of spatial scales (4-6 orders of magnitude) need to be represented. Due to its simpler implementation it can be preferred over the Fourier-Wavelet method. For a larger interval of spatial scales (9-12 orders of magnitude) however, the Randomization method fails to represent the correlation function. Under such circumstances the Fourier-Wavelet method should be used. In addition to this comparison we also investigate structural features of the generated permeability fields by means of the Euler number and the chord distribution. Results show the transition from a fractal regime for small length scales to a classic (Gaussian or exponential) regime for larger length scales. We interpret these findings with respect to flow and transport properties.