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Percolation theory and connectivity of multiscale porous media

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It is well known that flow and transport properties in porous media vary as non-linear functions of the porosity and that the macroscopic conductivity of a soil sample is stronly dependent on the connectivity of the pore network observed at a microscopic scale. Connectivity is a key parameter which is still difficult to quantify. We present first a review on the basic concepts of percolation theory and on their application to the standard modelling of critical transitions in the connectivity of pore or fracture subnetworks. Then we show how these concepts have to be revisited when the pore network is non longer randomly distributed, and namely when the medium is structured on multiple embedded organisation scales. We finally present some novel research results obtained on multiscale fractal soil models as regards the probability for pore or solid networks to percolate as a function of the type of geometrical organization : in particular we highligt the possibility of high porosity structures supporting impaired flow and transport. The presentation of several computer simulations illustrates the theoretical concepts. In turn, the theoretical formalism will serve as a guide for assessing the asymptotic behavior of multiscale simulated networks, in the growing research field of network modelling applied to complex natural systems.