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Conceptual issues in upscaling of permeability of heterogeneous porous formations

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We consider heterogeneous aquifers whose hydraulic conductivity K may change by orders of magnitude in the same formation. The random variation is characterized by the logpermeability variance and the correlation length scale I. Upscaling of conductivity over blocks of size larger than I in models of aquifer flow is needed in order to reduce the numerical burden, especially when modeling flow in heterogeneous aquifers of 3D random structure. Also, in many applications the interest is in average values of the dependent variables over scales larger or comparable to the conductivity length scales I. Assigning values of the conductivity K_b to averaging domains, or computational blocks, is the topic of a large body of literature, the problem being of wide interest in various branches of geophysics and engineering. It is clear that upscaling causes loss of information and at best it can render a good approximation of the fine scale solution after averaging it over the blocks.The presentation focuses on upscaling approaches for random media. We show that upscaling can be usually achieved only approximately, and the result may depend on the particular upscaling scheme adopted. The typically scarce information on the statistical structure of the fine-scale conductivity imposes a strong limitation to the upscaling problem. The conceptual issues encountered in upscaling are illustrated for the case of flow under a slopping soil surface for a layered medium.