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Modeling the drainage of two- and three-dimensional heterogeneous media: influence of water mobility and air availability

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While a number of three-dimensional multiphase flow models have been developed over the last two decades, very few of them are being applied to problems involving water flow in the vadose zone of soils. Typically, simplified modeling approaches (two-dimensional models and/or single phase flow models) are used instead. Such simplified approaches may not provide a thorough understanding of the controlling processes for flow in unsaturated porous media. In particular, reduced dimensionality might limit the ability for water to drain quickly (defined here as water mobility) and a single phase flow model ignores the issue of the availability of air to replace water during drainage. In this study, single phase and multiphase numerical flow simulations are used to investigate the relevance of water mobility and air availability as processes controlling the drainage of heterogeneous soils. Two- and three-dimensional simulations are conducted using the code FEHM (Finite Element Heat and Mass transport code), developed by Los Alamos National Laboratory. Four situations are investigated: (i) a homogeneous porous medium; (ii) a two-material heterogeneous porous medium consisting of a background material in which a layer of fine sand is embedded; (iii) a five-material randomly heterogeneous medium; and (iv) a five-material randomly heterogeneous medium in which a layer of fine sand is embedded. It is found that (i) large-scale geologic features play an important role, while random fluctuations of soil properties do not significantly influence water mobility and air availability; (ii) there are only slight difference between three-dimensional single phase and multiphase flow models; (iii) there are only slight differences between two- and three-dimensional single phase flow approaches; and (iv) a two-dimensional multiphase flow model yields significantly different results, due to a reduced air availability. In light of these results, increased attention should be paid when applying to field situations considerations obtained from numerical or laboratory studies involving multiphase flow in two-dimensional heterogeneous media.