Upscaling hydraulic parameters of Green-Ampt model for heterogeneous layered soils

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While Green-Ampt model has been widely used in infiltration calculations through unsaturated soils, upscaling this model for applications in heterogeneous formations remains difficult. In this study, how to upscale soil parameters in the Green-Ampt model for vertically layered soils is examined. The main idea of upscaled effective parameters is to capture infiltration behavior in layered soil formations using only one set of parameters derived from the parameters of individual layers, such that the layered system can be replaced by an equivalent homogeneous medium. The general p-order power mean was proposed to represent the upscaling schemes of the Green-Ampt model. The optimal p value was determined by a general requirement of same total infiltration time for the layered formation and the equivalent homogeneous medium. The p-order power mean for the Green-Ampt parameters can capture the infiltration rates in the layered formations well, illustrating that the proposed upscaling schemes are reasonable to represent the overall behaviors of the heterogeneous layered formations. The structure of layered formations can significantly influence the upscaling results. However, when the number of layers becomes large, the layered formations tend to show homogeneity and the layer structure becomes less important. The results demonstrated that the scheme based on the harmonic mean for the saturated hydraulic conductivity and the general p-order power mean for the wetting front suction head can well capture the overall infiltration behaviors in both the coarse-layer-on-top and fine-layer-on-top formations, and thus is recommended as a general upscaling scheme when using the upscaled Green-Ampt model in layered formations.