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Analysis of the Impact of Soil Heterogeneity on the Spatial Variation of Unsaturated Flow

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Modelling infiltration into soils with deterministic models requires knowledge of the hydraulic properties of that soil. Informing a model with these properties is complex because of the spatial heterogeneity of hydraulic properties that naturally occurs in all soils . The objective of this work was to analyze the effects that contrasting synthetic heterogeneities have on spatial outflows using a three-dimensional numerical model. An undisturbed soil column of 32 cm diameter and 50 cm height was used in an outflow experiment in the laboratory, where outflow was collected from the bottom of the column in 145 spatially-varied outflow cells and the column was subjected to multiple inflow rates. After the completion of the experiment, 30 sub-cores of 8 cm diameter and 5 cm height were extracted from the column and used to measure hydraulic properties and texture through a combination of pressure plate extractor, automated evaporation method, and a dewpoint potentiometer. The spatial heterogeneity of the soil in the column was represented by a Local Indicator of Spatial Autocorrelation (LISA – Local Moran's I) clustering algorithm, which used both texture and Electrical Resistivity Tomography data to identify significant clusters of points with high (HH) and low (LL) values and values that were not part of a significant cluster (NS). Each cluster was also assigned a numerical index based on LISA. Effective hydraulic properties were assigned to the HH and LL clusters and NS points based on the location of the 30 sub-cores and their average hydraulic properties. Resistivity data were used with omni-directional variograms with ranges of 5 and 15 cm and a nugget of 0.25 to conditionally simulate 50 realizations of 3-D data based on each variogram. The LISA algorithm was then used to detect significant clusters in these data and classify them as HH, LL or NS. Importing the resulting 100 sets of synthetic clusters and their corresponding effective hydraulic properties into the numerical model HYDRUS 3D (PC-Progress, Prague, Czech Republic) based on the numerical indices assigned by LISA, was automated. Each of the 100 realizations were run at 10 different inflow rates ranging from 1.44 cm/d to 74.4 cm/d. Each of the 1000 simulations produced resulted in an output of 487 spatially-varied outflows, allowing spatial analysis of the model outputs and comparison to the spatial outputs from the column experiment. Analysis of the effects of the size and spatial location of the synthetic hydraulic property clusters at different flow rates on the spatial distribution of outflow will be presented and discussed.