Geophysical Research Abstracts
Vol. 12, EGU2010-8123-1, 2010
EGU General Assembly 2010

Comparison of unstable water infiltration in porous media in 2D and 3D experiments

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Water infiltration into unsaturated soil is an important process for groundwater recharge and thus for water balance of natural hydrosystems. The characteristics of infiltration patterns depend on porous media properties and initial moisture content. Infiltration fronts into soil can be unstable in layered media with fine over dry coarse material. To predict arrival times of infiltration fronts and average water content in upscaled models, it is necessary to understand occurrence of instabilities. The unstable flow behavior is not captured by standard models and finger characteristics have mostly been investigated experimentally. Most experiments in the past were carried out in 2D setups and it is not clear how the results of such studies relate to real 3D systems. The aim of this study is to compare development and finger characteristics of unstable infiltration in 2D and 3D setups.

We carried out laboratory experiments on fast infiltration in 2D and 3D setups and measured water content in porous media with neutron transmission technology at the NEUTRA beam line at the Paul Scherrer Institute, Switzerland. The 2D experiments were carried out in a glass sandbox (260 mm high, 75 mm wide and 11 mm deep). For the 3D experiments aluminum cylindrical column (150 mm in height and 100 mm in diameter) were used. Both columns were filled homogeneously with coarse quartz sand (grain size 0.7 - 1.2 mm) below fine sand layer (0.1 - 0.3 mm) of 20 - 30 mm thickness. Two dimensional projection images of water content with spatial resolution of 125 microns were deduced from neutron images every 2 second. For the 3D setup water content distribution was reconstructed in 3D to monitor water content inside the fingers over time.

Water content and finger-width (15 - 23 mm) were similar for 2D and 3D setups. In both cases water content was maximum when the front passes and was decreasing afterwards (indicating “overshoot” behavior). Also the water content difference between values after passing the front and its maximum was comparable for 2D and 3D settings.

We also compared 2D and 3D unstable infiltration in heterogeneous structures consisting of fine textured sand (0.1 - 0.3 mm) in coarse background material (0.7 - 1.2 mm). Independent of the sizes and shapes the inclusions became wet without stabilizing the front or changing flow patterns.