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Two and three-dimensional quantitative neutron imaging of the water distribution during ponded infiltration

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Information on spatial and temporal water and air distribution in a soil sample during hydrological processes is important for evaluating current and developing new water transport models. Modern imaging techniques such as neutron imaging (NI) allow relatively short acquisition times and high resolution of images. At the same time, the appropriate data processing has to be applied to obtain results free of bias and artifacts. In this study a ponded infiltration experiments were conducted on two soil samples packed into the quartz glass columns of inner diameter of 29 and 34 mm, respectively. First sample was prepared by packing of fine and coarse fractions of sand and the second sample was packed using coarse sand and disks of fine porous ceramic. Ponded infiltration experiments conducted on both samples were monitored by neutron radiography to produce two dimensional (2D) projection images during the transient phase of infiltration. During the steady state flow stage of experiments neutron tomography was utilized to obtain three-dimensional (3D) information on gradual water redistribution. The acquired radiographic images were normalized for background noise and spatial inhomogeneity of the detector, fluctuations of the neutron flux in time and for spatial inhomogeneity of the neutron beam. The radiograms of dry sample were subtracted from all subsequent radiograms to determine water thickness in the 2D projection images.

All projections were corrected for beam hardening and neutron scattering by empirical method of Kang et al. (2013). Parameters of the correction method uses were identified by two different approaches. The first approach was based on fitting the NI derived water thickness representing the water filled region in the layer of water above the sample surface to actual water thickness. In the second approach the NI derived volume of water in the entire sample in given time was fitted to corresponding gravimetrically determined amount of water in the sample.

Tomography images were reconstructed from the both corrected and uncorrected water thickness maps to obtain the 3D spatial distribution of water content within the sample. Without the correction the beam hardening and scattering effects overestimated the water content values close to the sample perimeter and underestimated the values close to the center of the sample, however the total water content of whole sample was the same in both cases.