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A method for 3D mapping of sub-resolution porosity from X-ray tomography images

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Sub-resolution pore space is increasingly being accounted for in Lattice-Boltzmann models of water flow and solute transport. However, robust methods to estimate the permeability and porosity of sub-resolution voxels in 3D X-ray images, which are needed for model parameterization are lacking. The grey-value of a voxel in a 3D X-ray tomography image is approximately proportional to the density. Since the density in a voxel depends on the volume fractions of solids, air and water, and the densities of these phases, a grey-value cannot be directly translated to a porosity value. The objective of this study was to develop a reliable method for 3D estimation of sub-resolution porosity in undisturbed soil samples using data obtained from standard industrial X-ray tomography images. To achieve this we used the differences in X-ray attenuation between samples saturated with water and saturated with a potassium iodide (KI) solution.

We collected ten intact soil cores (5.5 cm high, 6.5 cm diameter) in aluminium cylinders from the topsoil of an arable field in south-west Sweden. The samples had a large variations both in soil texture and organic carbon content. The samples were scanned using X-ray tomography after being slowly saturated with water from the bottom. The water was then replaced by a KI solution (30 g I L^{-1}) with a larger X-ray attenuation than water, and the samples were scanned a second time. The grey-values of the resulting 3D images were scaled by the known densities of air, water and aluminium and the images were registered (i.e. spatially aligned). Macropores, sand grains and gravel were then removed from the images. The difference in attenuation between the two final images was then used to calculate the sub-resolution porosity (i.e. the degree of saturation) in all voxels in the remaining image of the soil matrix. Average porosities for individual samples, which were in the range 0,34–0.45, were significantly correlated to matrix porosities estimated from soil water retention measurements.