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Pore network 3D image analysis for improving soil hydrological characterization near saturation

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The heterogeneities of the inter-aggregate pore-network create local-scale non-equilibrium conditions between faster and slower flow pore regions. Very often the discrepancy between observed and predicted processes may results from the limitation of accurately characterizing and incorporating in models such pore-scale heterogeneities.

Capillary bundle models for unsaturated hydraulic conductivity lie on the knowledge of the pore-size distribution (PSD). They require accurate experimental descriptions of different domains eventually existing in the porous system and are especially sensitive to the PSD shape near saturation. A further critical point of these models is the estimation of the tortuosity and connectivity factor, which is only empirically fixed to either a literature or a fitted value.

In this study the effects of the near saturation pore-size geometry of porous media were estimated for different soils by comparing the pore system micromorphology and the equivalent pore-size distribution deduced from hydraulic measurements. Pore geometry measurements were performed by coupling high resolution X ray microtomography (SKYSCAN 1172) and 3D image analysis procedures. The “successive opening” algorithm and the pore-throat analysis based on the medial axis transform were applied leading to the estimation of PSD, tortuosity and connectivity factors (especially in the range of the inter-aggregate pore-network).

Tension tables, Wind’s and tension infiltrometer apparatus were used in the same soils for deducing water retention and hydraulic conductivity from which an equivalent PSD was deduced.

The comparison of the two pore measurement/estimation procedures provided interesting results. The successive opening algorithm allowed good interpretation of water retention properties while the pore-throat analysis results showed strong linkage with hydraulic conductivity.