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Capturing 3D Water Flow in Rooted Soil by Ultra-fast Neutron Tomography

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Non-invasive imaging techniques are the key for better understanding the root-soil interaction which is of great relevance for both plant and soil scientists. Neutron imaging has proven a powerful non-destructive technique to study the architecture of root systems and the water distribution in the surrounding soil in situ. Due to its high temporal resolution (few seconds) 2D neutron radiography is capable to capture dynamic changes in the local water distribution of the sample. Using D2O as tracer substance NR has been successfully applied to visualize water transport phenomena in plants, e.g. root uptake, axial transport in the xylem and the formation of embolisms. These studies provided valuable insights into the root uptake and axial water transport in plants. The analysis of water flows were, however, intrinsically restricted by the two-dimensional imaging approach. Extending the observation to three dimensions promises a great leap forward in understanding the water flow into the roots. Insufficient time resolution has certainly been the greatest obstacle for visualizing three-dimensional flows by means of neutron tomography. The acquisition of a tomogram usually takes more than an hour. Drastic acceleration of the acquisition process is, therefore, necessary to resolve the water dynamics of the rhizosphere in three dimensions. Employing a new exposure mode we boosted the acquisition speed achieving time resolutions of 10 s per tomogram. This technical breakthrough paves the way for dynamic studies of three flow processes in porous media. Performing a series of tracer experiments we succeeded to visualize an ascending water front in the soil column including the subsequent root water uptake time-resolved in three dimensions.