X-ray Tomographic Imaging and Hydraulic Modeling of Plant Roots

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This presentation will describe a study of imaging a plant root system, simulating three dimensional water flow inside roots in interactions with surrounding soils, and assessing how root hydraulic process affects soil hydrological properties under unsaturated conditions. A 3-D structure of a plant root was imaged using an X-ray tomography facility (X-Tek/Metris XTH 320/225 kV system) at Environmental Molecular Science Laboratory (EMSL), a BER facility located at PNNL. The data were collected at 85 kV and 190 A x-ray power for optimum image quality and contrast. The sample was rotated continuously during the scan with momentary stops to collect each projection (shuttling mode) to minimize ring artifacts. 3142 projections were collected over 360 degrees with 1 second exposure time and 4 frames per projection. Image voxel size was 31x31x31 microns. The raw images were reconstructed to get a three-dimensional dataset to produce a volume file of approximately 1500x1500x1000 voxels in dimension. The reconstructed volume file was used to create a stack of images, which were further processed to segregate the root from the surrounding soil. The 3-D images of the root system were then digitized to form 3-D numerical domains of the root and surrounding soils at the voxel resolution. A unified multi-scale model, which merges Navier Stokes equation with Darcy law to form a single set of equations under both saturated and unsaturated conditions, was used to simulate coupled flow inside the roots driven by water demand from the plant canopy. Day and night change of water demand from the canopy was used as external force in the simulation for water flow inside and outside of the plant roots. The high density simulation results were then used to evaluate the effective parameterization of unsaturated flow, and to assess the importance of root hydraulic flow in simulating water migration in soils.