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Water flow in soil and plants: the importance of good contacts

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Water flow in unsaturated porous media is controlled by the continuity of the liquid phase through the pore system. In many cases, the pore system is composed of regions with different material properties separated by interfaces containing macro-pores or gaps that are easily drained. When these gaps are drained the continuity of the liquid flow path may break, with a consequent decrease in the conductivity of the medium.

We present two examples demonstrating the controlling role of interfaces on water flow. The first example describes an aggregated soil. Due to the aggregate roughness, the inter-aggregate contacts contain macro-pores which are rapidly drained. The hydraulic behavior of contacts varies from highly conductive when water fills the contact to a bottle-neck to flow as water pressure drops and contact asperities rapidly drained. The conductivity of the system is determined by the water-filled contact area between aggregates, rather then by the average volumetric water content.

The second example refers to the contacts between soil and roots. By means of X-ray tomography we showed that during periods of drought, roots shrink and may lose contact with the soil, with a consequent reduction in water uptake. When the soil is irrigated again, roots swell partially refilling the gaps. Opening and closing of gaps may help plant to optimize water use, to prevent water loss when soil dries, and to restore the soil-root continuity after irrigation. Additionally, soil-root continuity is improved by root exudates and root hairs, which make the soil-root interface a complex and dynamic biomaterial with specific and unique properties.

These two examples show that interfaces between heterogeneous media can have a big impact on water flow in porous media and demonstrate that volumetric averaging for predicting transport properties can lead to wrong results. An approach based on flow cross sections and interfacial properties may be the way to a deeper understanding and modeling of flow in porous media.