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Evaporation rate from square capillaries limited by corner flow viscous losses

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High evaporation rates from soil surfaces are sustained by capillary flows drawing water from the receding drying front along liquid pathways in crevices of the pore space. With increasing depth of the drying front viscous losses add to growing gravitational head and at a certain depth overcome capillary drive and disrupt liquid pathways. Viscous losses are significant in fine textured media resulting in earlier capillary failure than predicted by gravity-capillary force balance. To reproduce limitations of viscous corner flow on evaporation rates from angular pores (capillaries) we imaged drying dynamics from a square shaped glass capillary using a high speed camera, to provide for detailed record on receding menisci and thickness of liquid corner films including detachment dynamics at the top of the capillary. Additionally, deposition patterns of dye delineated regions of high rates of phase change (evaporation) showing a decrease in drying rate with recession of menisci and films into the capillary due to increasing diffusive path and reduced gradients. Effects of viscous losses on evaporation dynamics were systematically evaluated by varying ratio of viscous, gravity and capillary forces using different liquids (water, ethanol and octane), capillary geometry (0.5 and 1.0 mm width), and flow rate and direction with respect to gravity (horizontal and vertical arrangement). Experimental results were compared with analytical solutions for corner flow considering viscous losses. Preliminary results indicate that the maximum (main) meniscus depth supporting corner flow is not only dependent on the effective conductivity behind the interfaces, but also on interfacial processes taking place at the very top of the capillary. The pore scale findings will be incorporated into macroscopic models for determining viscous losses from soils and for estimating elapsed times for transition from high capillary-sustained evaporation rates to diffusion limited rates.