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Synchrotron based X-ray imaging of thick liquid films controlling evaporation from porous media

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The evaporation rate during initial stages of a drying process is typically not limited by the hydraulic conductivity of a porous medium. As air invades emptying pores near the surface, water remains in crevices and grain contacts forming a network of thick films. These hydraulic connections between the evaporation surface and the receding drying front sustain sufficient water supply to maintain a constant evaporation rate. We hypothesize that when these film-based hydraulic connections are disrupted water transport to the surface becomes limited to rates supported by vapor diffusion. We thus made concurrent observations of evaporation rates and liquid phase configuration above the drying front to relate the end of the constant (first stage) drying with liquid film connectivity. We used a 5 mm diameter column filled with sand and glass beads and imaged it at a resolution of 7 microns using X-rays from synchrotron. We first delineated solid phase and pores in a completely saturated column, then imaged the evaporation process. To enhance the contrast between liquid and air phases a Calcium Iodide solution was used. As lower boundary condition we fixed the position of the drying front at a prescribed level using a water reservoir connected to the column. The failure of liquid connections between the front and the surface was marked by increase in salt concentration in isolated water elements. Improved understanding of relationships between pore scale effects, liquid configuration and evaporation processes enhances predictability of drying rates. The relatively short scanning time due to the high photon flux density at the synchrotron facility provides opportunities to observe such highly dynamic displacement processes.