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Temperature Dynamics during Drying of Porous Surfaces – Non-Isothermal Evaporation

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The gradual drying of porous surfaces during evaporation results in changes in energy partitioning leading a gradual increase in mean surface temperature even when the evaporative flux from the surface remains constant. The constancy of evaporative flux as the surface dries (stage-1 evaporation) is attributed nonlinear enhancement of vapor diffusion flux from remaining pores as pore spacing increases with larger pores being gradually invaded as the surface dries. This flux compensation mechanism was recently quantified by Shahraeeni et al. (2012) for isothermal conditions. Evidence suggests that, under a wide range of conditions the process is not isothermal and increased surface temperature may affect vapor pressure gradient between evaporating water menisci and air mass. We quantified the evolution of surface temperature during drying (for stage-1 evaporation with main vaporization plane at the surface) by considering details of temperature fields forming around individual evaporating pores. The analytical solution to the thermal-evaporative process considers the interplay between increased energy input and enhanced diffusion per pore with surface drying (and increased pore spacing). Mean surface thermal and evaporative response is deduced from spatial (and temporal) superposition of pore-wise diffusive and thermal interactions considering feedbacks affecting local vapor gradient (non-isothermal conditions). Model predictions are compared with measurements using infrared thermography. Links between pore size distributions, evaporative demand and surface temperature dynamics are discussed.