How do porous terrestrial surfaces control evaporation into the atmosphere?

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Globally, evaporation consumes about 25% of solar energy input and is a key hydrologic driver with approximately 60% of terrestrial precipitation returning to the atmosphere via evapotranspiration. Quantifying evaporation is important for assessing changes in hydrologic reservoirs and surface energy balance, and for many industrial and engineering applications. Keey (1972) commented that “evaporation is a commonly practiced art, but a neglected science”. In general, dynamic interactions of evaporating surfaces with internal transport mechanisms and with environmental conditions remain largely empirical. Evaporation dynamics from porous media is significantly different than from free water surfaces due to withdrawal of liquid from internal pore spaces, and nonlinear interactions between drying surfaces across the air boundary layer. Porous media properties determine abrupt transition from initially high (and relatively constant) evaporation rate (stage 1) to a slower diffusion-controlled stage 2. This well-documented behavior is attributed to disruption of capillary liquid continuity essential for supplying surface evaporation. Evaporation rate is a highly nonlinear function of surface porous medium water content. This nonlinear behavior is attributed to enhanced vapor fluxes from active pores as a surface dries and remaining pores become increasingly isolated. Increased spacing between evaporating pores under low atmospheric demand (thick boundary layer) significantly increases evaporative flux per pore that, in turn, may fully compensate for reduced evaporative surface area and thus sustain a constant evaporation rate. Implications of the findings for estimates of evaporative losses used in hydrological and climate models will be discussed.