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Variably-saturated flow in large weighing lysimeters under dry conditions: inverse and predictive modeling

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A reliable quantification of the soil water balance in semi-arid regions requires an accurate determination of bare soil evaporation. Modeling of soil water movement in relatively dry soils and the quantitative prediction of evaporation rates and groundwater recharge pose considerable challenges in these regions. Actual evaporation from dry soil cannot be predicted without detailed knowledge of the complex interplay between liquid, vapor and heat flow and soil hydraulic properties exert a strong influence on evaporation rates during stage-two evaporation. We have analyzed data from the SEPHAS lysimeter facility in Boulder City (NV) which was installed to investigate the near-surface processes of water and energy exchange in desert environments. The scientific instrumentation consists of 152 sensors per Lysimeter which measured soil temperature, soil water content, and soil water potential. Data from three weighing lysimeters (3 m long, surface area 4 m^2) were used to identifiy effective soil hydraulic properties of the disturbed soil monoliths by inverse modeling with the Richards equation assuming isothermal flow conditions. Results indicate that the observed soil water content in 8 different soil depths can be well matched for all three lysimeters and that the effective soil hydraulic properties of the three lysimeters agree well. These results could only be obtained with a flexible model of the soil hydraulic properties which guaranteed physical plausibility of water retention towards complete dryness and accounted for capillary, film and isothermal vapor flow. Conversely, flow models using traditional parameterizations of the soil hydraulic properties were not able to match the observed evaporation fluxes and water contents. After identifying the system properties by inverse modeling, we checked the possibility to forecast evaporation rates by running a fully coupled water, heat and vapor flow model which solved the energy balance of the soil surface. In these numerical simulations, atmospheric measurements of temperature, humidity, and wind speed were used as transient boundary conditions.