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Variably-saturated flow in large weighing lysimeters under dry conditions: parameter identification and predictive modelling using coupled water, vapor and heat flow theory

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The prediction of groundwater recharge in arid and semi-arid regions with simulation models requires an accurate simulation of actual evaporation. Actual evaporation from dry soil cannot be predicted without the consideration of the interplay between liquid, vapor and heat flow. Under dry conditions, soil water content and latent heat fluxes are generally low and temperature gradients close to the surface can become extremely high in bare-soil leading to temperature-induced vapor fluxes. Due to this and because of the temperature-dependence of saturation vapor pressure, the near-surface temperature fluctuations must be correctly modeled to predict actual evaporation. We have analyzed water, vapor and heat fluxes in a large weighing Lysimeter (length 3 m, area 4 m^2) in the Mohave desert, Nevada. The Lysimeter contains homogenized and packed desert soil and is instrumented with a total of 152 sensors for the measurement of local water content (TDR), matric potential (HDU) and soil temperature. The time series of the lysimeter mass was first corrected manually and semi-automatically to determine hourly fluxes across the upper boundary. Effective soil hydraulic properties were identified by inverse modeling of the lysimeter data. The soil hydraulic functions had to be parameterized with a flexible model accounting for water flow in completely and incompletely-filled capillaries to match the time series of water potential and local water content. The hydraulic properties were then used in a coupled model of water, vapor and heat flow which was driven by meteorological data and the energy balance of the ground surface. The coupled model provided an excellent prediction of local water contents, soil temperatures at different depths and actual evaporation from the lysimeter in a validation period. The difference between the actual evaporation measured with the lysimeter and the evaporation predicted by the process model was only 5 %.