Geophysical Research Abstracts
Vol. 13, EGU2011-12059, 2011
EGU General Assembly 2011

Modeling evaporation influenced by ambient air flow

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Evaporation from partially saturated soils into the ambient air is usually influenced by a variety of complex interacting processes. It depends on the fluid and soil properties and on external factors such as the ambient air temperature, air humidity and wind velocity. In a natural system, solar radiation may deliver energy into the soil, which enhances the evaporation rate. Turbulent behavior in the ambient air flow may create a boundary layer and influence the mixing of air and subsequently the evaporation rate.

Usually, the free-flow and the porous-medium compartments are modeled separately using boundary conditions and several empirical parameters. However, the complex interactions in an evaporation process are often not accurately captured. In order to determine and extend the limits of conventional models, we have developed a concept on the continuum scale which consists of a non-isothermal compositional single-phase Stokes submodel in the free flow compartment and a non-isothermal two-phase compositional Darcy submodel in the porous medium. Those two domains are coupled by suitable interface conditions without need for specifying boundary conditions at the interface between soil and atmosphere.

The coupling conditions are based on flux continuity and local thermodynamic equilibrium at the interface. The evaporation rate is an output of the model. The coupling concept with the relevant interface conditions will be briefly introduced and the ideas, how to capture the relevant processes will be elaborated. The concept was implemented in our modeling environment Dumux. Simple numerical examples will be shown. Furthermore, in cooperation with E. Shahraeeni and D. Or (ETH Zurich), evaporation experiments with soil samples in a wind tunnel using different air velocities and soil types were performed. In the course of the experiments, the evaporation rate and the temperature evolution at the interface (among other parameters) were determined. Measurements will be shown and compared to the numerical model output.