Geophysical Research Abstracts
Vol. 14, EGU2012-6800, 2012
EGU General Assembly 2012


# Evaporation from soils subjected to natural boundary conditions at the land-atmospheric interface

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Bare soil evaporation is a key process for water exchange between the land and the atmosphere and an important component of the water balance in semiarid and arid regions. However, there is no agreement on the best methodology to determine evaporation under different boundary conditions at the land surface. This becomes critical in developing models that couples land to the atmosphere. Because it is difficult to measure evaporation from soil, with the exception of using lysimeters, numerous formulations have been proposed to establish a relationship between the rate of evaporation and soil moisture and/or soil temperature and thermal properties. Different formulations vary in how they partition available energy. A need exists to systematically compare existing methods to experimental data under highly controlled conditions not achievable in the field. The goal of this work is to perform controlled experiments under transient conditions of soil moisture, temperature and wind at the land/atmospheric interface to test different conceptual and mathematical formulations for the soil surface boundary conditions to develop appropriate numerical models to be used in simulations. In this study, to better understand the coupled water-vapor-heat flow processes in the shallow subsurface near the land surface, we modified a previously developed theory by Smits et al. [2011] that allows non-equilibrium liquid/gas phase change with gas phase vapor diffusion to better account for dry soil conditions. The model did not implement fitting parameters such as a vapor enhancement factor that is commonly introduced into the vapor diffusion coefficient as an arbitrary multiplication factor. In order to experimentally test the numerical formulations/code, we performed a two-dimensional physical model experiment under varying boundary conditions using test sand for which the hydraulic and thermal properties were well characterized. Precision data under well-controlled transient heat and wind boundary conditions was generated and results from numerical simulations were compared with experimental data. Results demonstrate that the boundary condition approaches varied in their ability to capture stage 1- and stage 2- evaporation. Results also demonstrated the importance of properly characterizing soil thermal properties and accounting for dry soil conditions. The contribution of film flow to hydraulic conductivity for the layer above the drying front is dominant compared to that of capillary flow, demonstrating the importance of including film flow in modeling efforts for dry soils, especially for fine grained soils. Comparisons of different formulations of the surface boundary condition validate the need for joint evaluation of heat and mass transfer for better modeling accuracy. This knowledge is applicable to many current hydrologic and environmental problems to include climate modeling and the simulation of contaminant transport and volatilization in the shallow subsurface.

Smits, K. M., A. Cihan, T. Sakaki, and T. H. Illangasekare (2011). Evaporation from soils under thermal boundary conditions: Experimental and modeling investigation to compare equilibrium- and nonequilibrium-based approaches, Water Resour. Res., 47, W05540, doi:10.1029/2010WR009533.