Geophysical Research Abstracts
Vol. 15, EGU2013-11431, 2013
EGU General Assembly 2013

Study of the effect of wind speed on evaporation from soil through integrated modeling of atmospheric boundary layer and shallow subsurface

Hossein Davarzani (2), Kathleen Smits (1), Ryan Tolene (1), and Tissa Illangasekare (1)

(1) Colorado School of Mines, ksmits@mines.edu, tissa@mines.edu, Golden, CO, U.S.A., (2) Bureau de Recherches Géologiques et Minières (BRGM), Direction Eau, Environnement et Ecotechnologies (D3E), Orléans, France.

The study of the interaction between the land and atmosphere is paramount to our understanding of many emerging problems to include climate change, the movement of green house gases such as possible leaking of sequestered CO_2 and the accurate detection of buried objects such as landmines. Soil moisture distribution in the shallow subsurface becomes a critical factor in all these problems. The heat and mass flux in the form of soil evaporation across the land surface couples the atmospheric boundary layer to the shallow subsurface. The coupling between land and the atmosphere leads to highly dynamic interactions between the porous media properties, transport processes and boundary conditions, resulting in dynamic evaporative behavior. However, the coupling at the land-atmospheric interface is rarely considered in most current models and their validation for practical applications. This is due to the complexity of the problem in field scenarios and the scarcity of field or laboratory data capable of testing and refining coupled energy and mass transfer theories. In most efforts to compute evaporation from soil, only indirect coupling is provided to characterize the interaction between non-isothermal multiphase flows under realistic atmospheric conditions even though heat and mass flux are controlled by the coupled dynamics of the land and the atmospheric boundary layer. In earlier drying modeling concepts, imposing evaporation flux (kinetic of relative humidity) and temperature as surface boundary condition is often needed.

With the goal of improving our understanding of the land/atmospheric coupling, we developed a model based on the coupling of Navier-Stokes free flow and Darcy flow in porous medium. The model consists of the coupled equations of mass conservation for the liquid phase (water) and gas phase (water vapor and air) in porous medium with gas phase (water vapor and air) in free flow domain under non-isothermal, non-equilibrium conditions. The boundary conditions at the porous medium-free flow medium interface include dynamical, thermal and solutal equilibriums, and using the Beavers-Joseph slip boundary condition. What is unique about this model is that the evaporation rate and soil surface temperature conditions come directly from the model output. In order to experimentally validate the numerical results, we developed and used a unique two dimensional wind tunnel placed above a soil tank equipped with a network of different sensors. A series of experiments under varying boundary conditions, using a test sand for which the hydraulic and thermal properties were well characterized, were performed. Precision data for soil moisture, soil and air temperature and relative humidity, and also wind velocity under well-controlled transient heat and wind boundary conditions was generated.

Results from numerical simulations were compared with experimental data. Results demonstrate that the coupling concept can predict the different stages of the drying process in porous media with good accuracy. Increasing the wind speed increases the first stage evaporation rate and decreases the transition time at low velocity values; then, at high values of wind speed the evaporation rate becomes less dependent of flow in free fluid. In the opposite, the impact of the wind speed on the second stage evaporation (diffusion dominant stage) is not significant. The proposed theoretical model can be used to predict the evaporation process where a porous medium flow is coupled to a free flow for different practical applications.