Modeling Evaporation Using Coupled RANS/Darcy Models

International Research Training Group nupus

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Motivation

This project focuses on understanding and modeling the relevant processes of evaporation. Evaporation is strongly influenced by the interaction of different physical processes:

- in the free flow
- at the interface
- inside the porous medium

The main goal is to describe these processes and to simulate porous-medium flow with an adjacent free flow. The developed concept can be used for improving soil salinization simulations, analyzing water balance relations or technical applications, like fuel cells or drying and cooling processes.

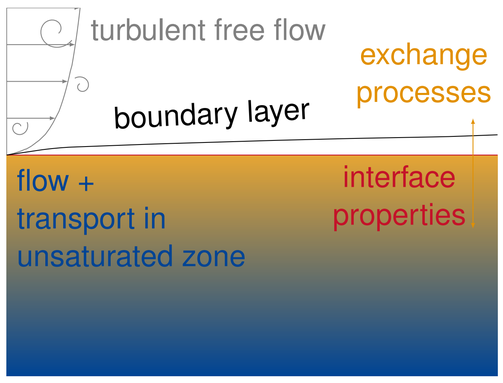


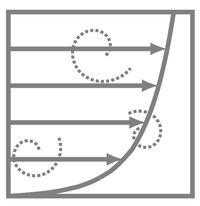
Figure 1 : *Relevant processes for modeling evaporation from bare soil.*

Concept

Porous Medium

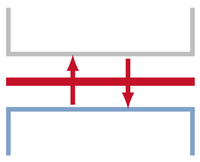
- REV concept
- Darcy's law
- two fluid phases (gas, liquid)
- two components (air, water)
- non-isothermal

Free Flow



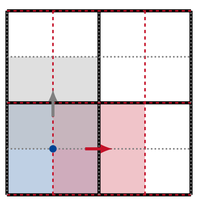
- laminar/ turbulent (ν_t)
- Reynolds-averaged Navier-Stokes
- single fluid phase (gas)
- two component (air, water)
- non-isothermal

Coupling



- local thermodynamic equilibrium
- continuity of fluxes
- extension of [5] to turbulent conditions
- wall functions for rough interfaces [1, 4]

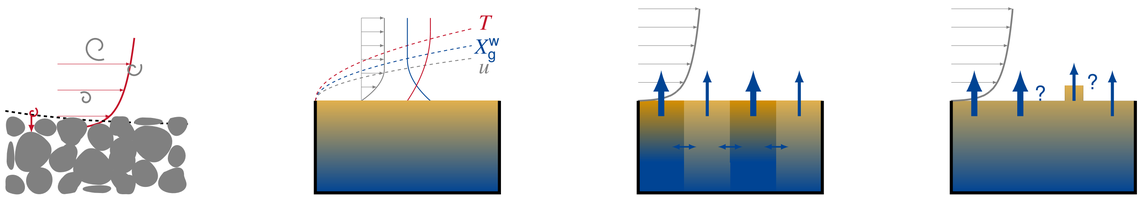
implementation



- monolithic, fully implicit
- time: implicit Euler
- free flow: box, (future: staggered grid)
- porous medium: box, (future: cc)

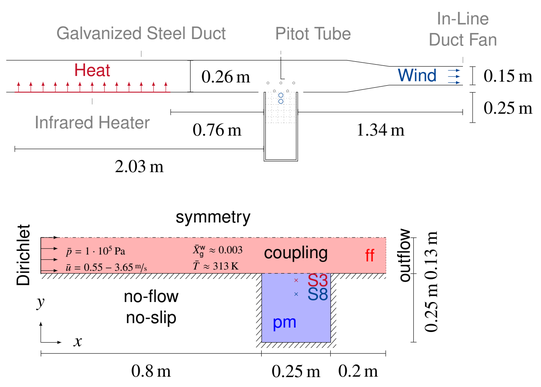
Analysis

The analysis focuses on the influence of properties and processes like roughness, boundary layers, heterogeneities, and obstacles on the coupled free-flow porous-medium interactions.



Preliminary Results

Evaporation Rates



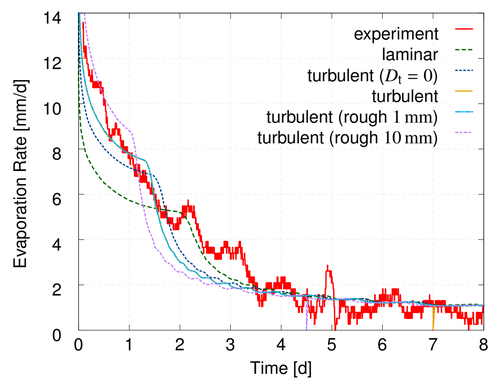


Figure 2 : *Setup for laboratory evaporation experiments [2], setup of the corresponding numerical simulation and their results [3].*

Porous Medium

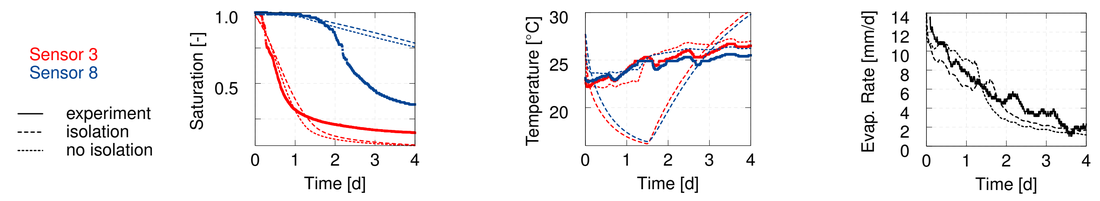


Figure 3 : *Influence on the porous-medium quantities [3].*

Heterogeneity

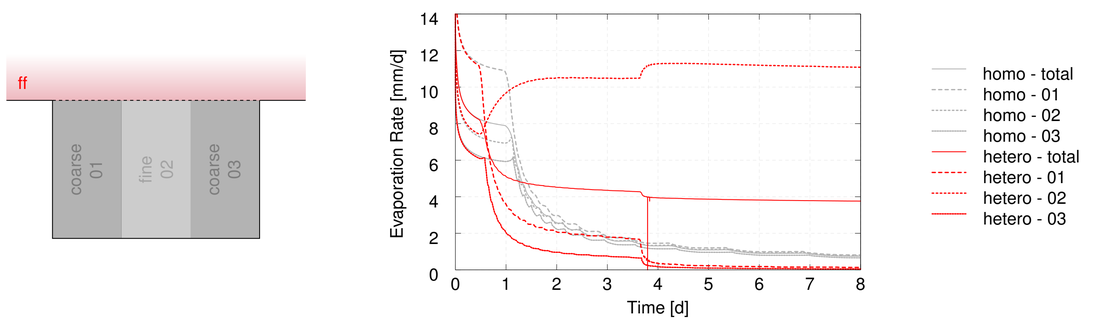


Figure 4 : *Evaporation rates from heterogeneous soils.*

Outlook

Short-Term

- further evaluation of heterogeneity results
- implementation of new coupling concept (staggered grid-cc)
- coupling a simple transport model for the free flow to porous medium (cc-cc)
- including gravitational forces

Long-Term

- analysis of pore scale effects
- reduction of model complexity

Literature

[1] Cebeci, T. (1978). Calculation of Incompressible Rough-Wall Boundary Layer Flows. *AIAA Journal*, 16(7):730–735.

[2] Davarzani, H., Smits, K., Tolene, R. M., and Illangasekare, T. (2014). Study of the effect of wind speed on evaporation from soil through integrated modeling of the atmospheric boundary layer and shallow subsurface. *Water Resources Research*, 50:1–20.

[3] Fetzer, T., Smits, K., M., and Helmig, R. (2015). Effect of Turbulence and Roughness on Coupled Porous-Medium/Free Flow Exchange Processes. *Transport in Porous Media*, submitted.

[4] Kuznetsov, A. and Becker, S. (2004). Effect of the interface roughness on turbulent convective heat transfer in a composite porous/fluid duct. *International Communications in Heat and Mass Transfer*, 31(1):11–20.

[5] Mosthaf, K., Baber, K., Flemisch, B., Helmig, R., Leijnse, A., Rybak, I., and Wohlmuth, B. (2011). A coupling concept for two-phase compositional porous-medium and single-phase compositional free flow. *Water Resources Research*, 47(10):W10522.

DuMu^x

Simulations are performed using the open-source simulator DuMu^x.

DFG

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Link to the poster