Modeling bare soil evaporation with a turbulent free flow/ Darcy flow coupled model

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.

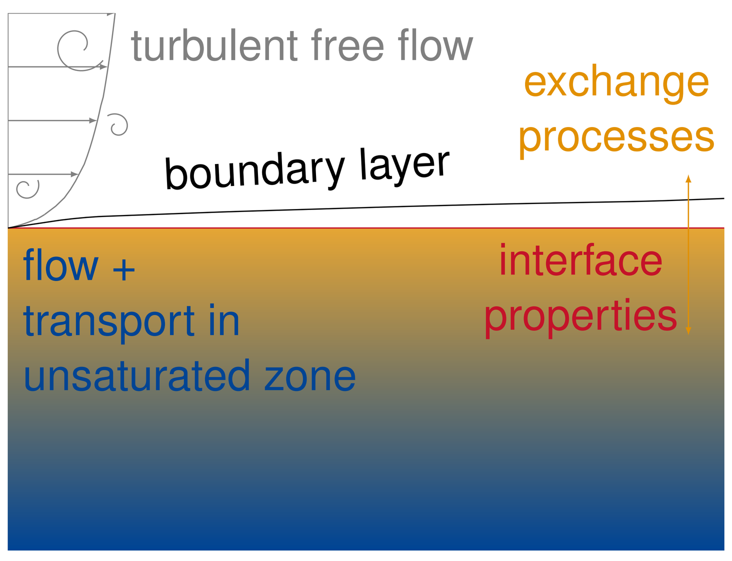


Figure 1: *Relevant processes for modeling evaporation from bare soil.*

Preliminary Concept

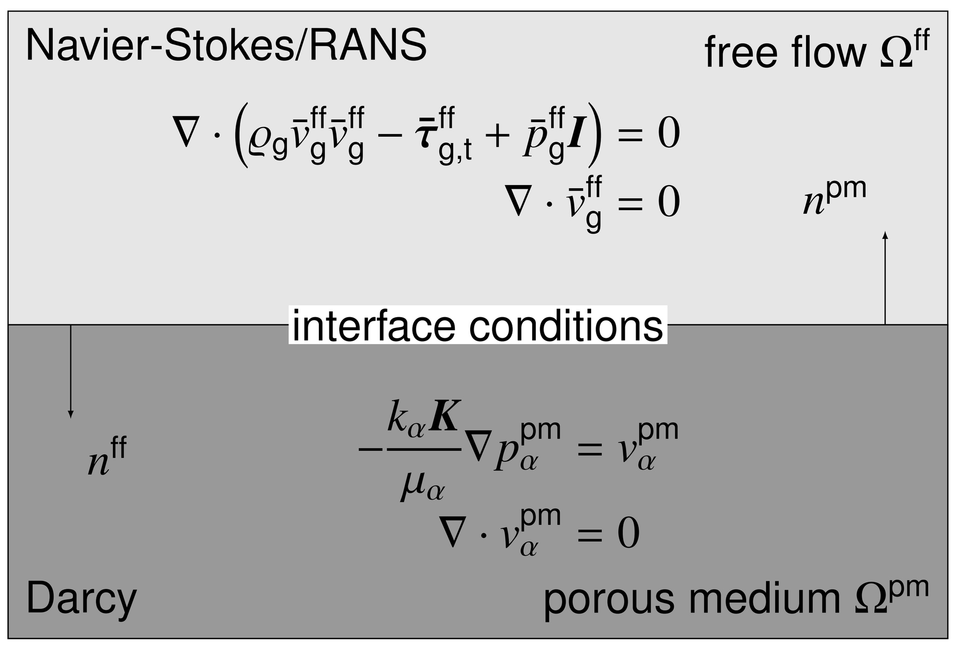
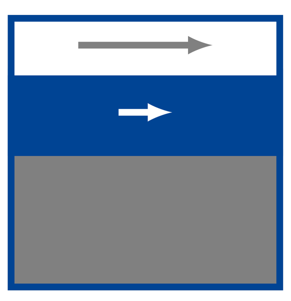


Figure 2: *Sketch of the two-domain concept, after [4].*

- box-method
- monolithic, fully implicit
- local thermal equilibrium
- flux continuity
- roughness concept [1, 3]

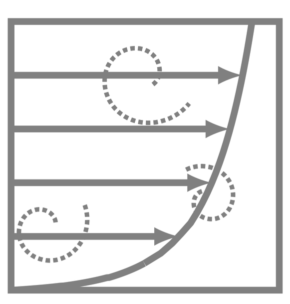
Future Coupling Concept

Porous-Medium Model



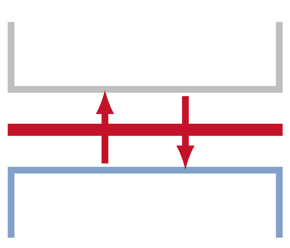
- REV concept
- Darcy's law
- two fluid phases (gas, liquid)
- two components (air, water)
- non-isothermal

Free Flow Model



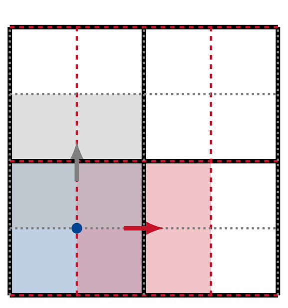
- laminar/ turbulent (k-ε, k-ω)
- Reynolds-averaged Navier-Stokes
- single fluid phase (gas)
- two component (air, water)
- non-isothermal

Coupling Concept



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

Discretizations



- free flow: staggered grid, FV
- porous medium: cell centered, FV
- time: implicit Euler
- sequential or fully implicit

Preliminary Results

Wind Tunnel Evaporation Experiments [2]

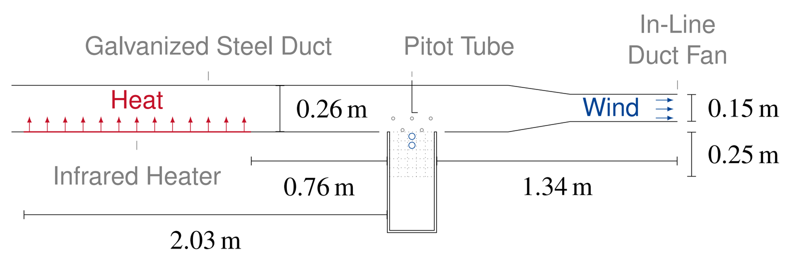
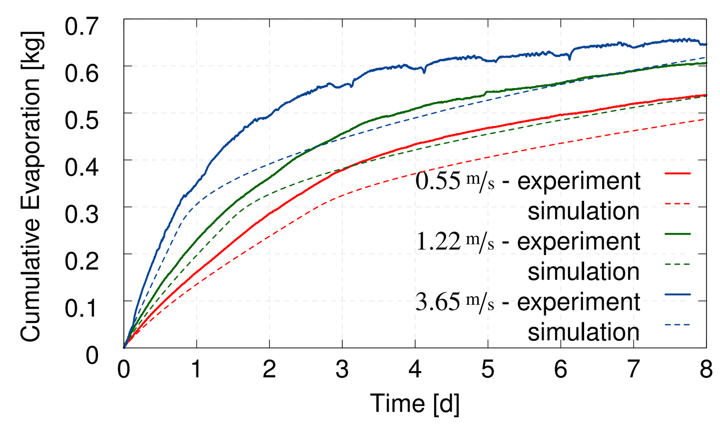


Figure 3: *Setup for evaporation experiments performed by [2].*



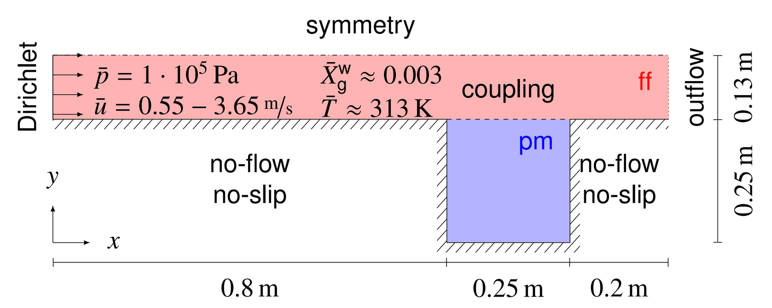
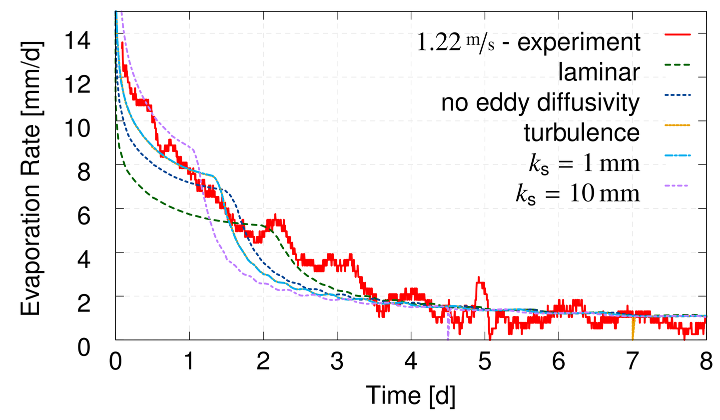


Figure 4: *Simulation setup.*



Heterogeneity

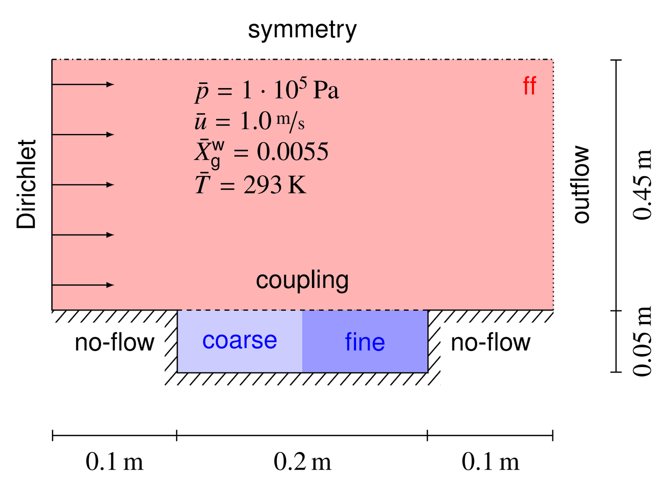
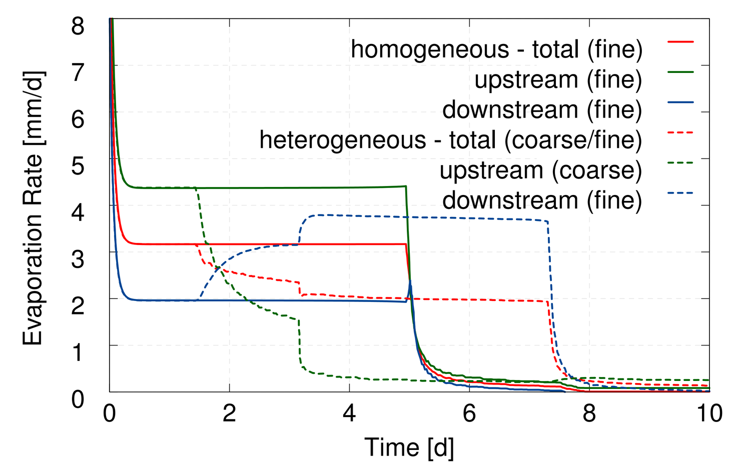


Figure 5: *Simulation setup for evaporation from soil with a heterogeneity.*



Outlook

Short-Term

- further evaluation of results
- implementation of new coupling concept
- including gravitational forces

Long-Term

- analysis of pore scale effects
- design of new experiments for comparison of numerical results
- 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] 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.

[4] 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.

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

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