Coupled porous-medium and free flow under turbulent and rough conditions

International Research Training Group nupus

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Gordon Research Conference, 6th - 11th July 2014

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.

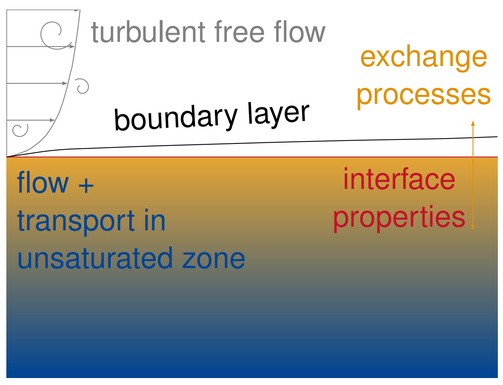


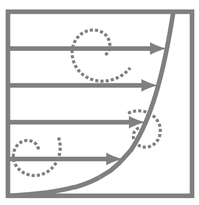
Figure 1: *Relevant processes for modeling evaporation from bare soil.*

Model Concept

Porous Medium Model

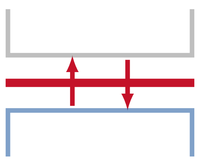
- REV concept
- Darcy's law
- two fluid phases (gas, liquid)
- two components (air, water)
- non-isothermal

Free Flow Model



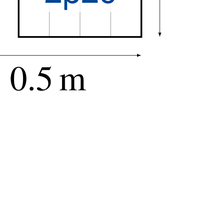
- laminar/ turbulent [4]
- Reynolds-Averaged-Navier-Stokes
- single fluid phase (gas)
- two component (air, water)
- non-isothermal

Coupling Concept



- local thermodynamic equilibrium
- continuity of fluxes
- extension of [1] to turbulent conditions

Discretizations

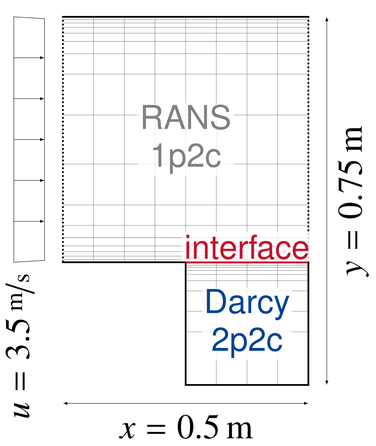


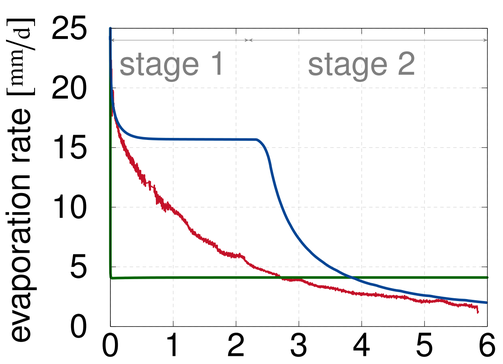
- free flow: staggered grid
- porous medium: cell centered
- time: implicit Euler
- one matrix

Preliminary Results

Wind Tunnel Evaporation Experiments

– experiment – laminar – turbulent (algebraic)





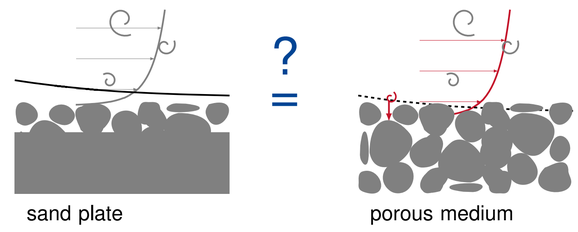
Analysis

Cooperations

- wind tunnel experiments: CESEP, Colorado School of Mines
- DNS: IRMB, TU Braunschweig

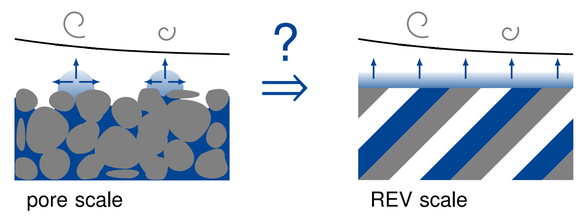
Roughness

- velocity boundary layer [2]
- flow/ turbulence in porous medium



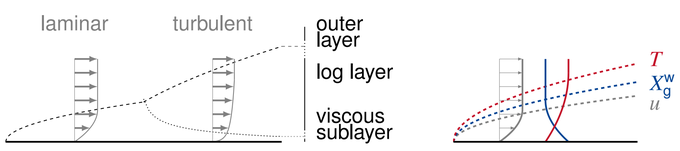
Surface Water Content

- roughness as $f(S_w)$
- effect on mass/ heat transfer [3]
- integration in REV scale models



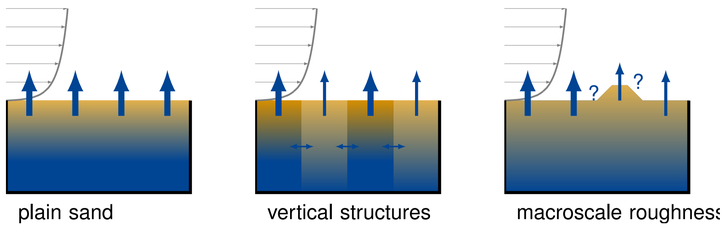
Boundary Layers

- effects of evaporation on velocity boundary layer
- interactions between different boundary layers



Soil Structures

- evaporation
- upscaling
- atmospheric influences



Outlook

Short-Term

- evaluation of experimental results
- DNS experiments
- implementation of low-Re models
- implementation of new coupling concept

Long-Term

- compositional/ non-isothermal flow
- gravitation
- analysis of pore scale effects
- reduction of model complexity

Literature

[1] 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.

[2] Schlichting, H. and Gersten, K. (1997). *Grenzschicht-Theorie*. Springer, Berlin, 9. edition.

[3] Suzuki, S. and Maeda, S. (1968). On the mechanism of drying of granular bed. *Journal of Chemical Engineering of Japan*, 1:26–31.

[4] Wilcox, D. C. (1998). *Turbulence Modeling for CFD*. DCW Industries, La Cañada, California, 2. edition.

DuMu^x

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

DFG

Support of the German Research Foundation is gratefully acknowledged.

MUSIS

This study is done in cooperation with the research unit MUSIS.

Link to this poster.