Modeling and analysis of the movement of fluid-fluid interfaces in porous media coupled with free flow

K. Mosthaf, R. Helmig

Department of Hydromechanics and Modeling of Hydrosystems, University of Stuttgart, Germany

MUSIS

P7

Multi-Scale Interfaces in Unsaturated Soil

Motivation

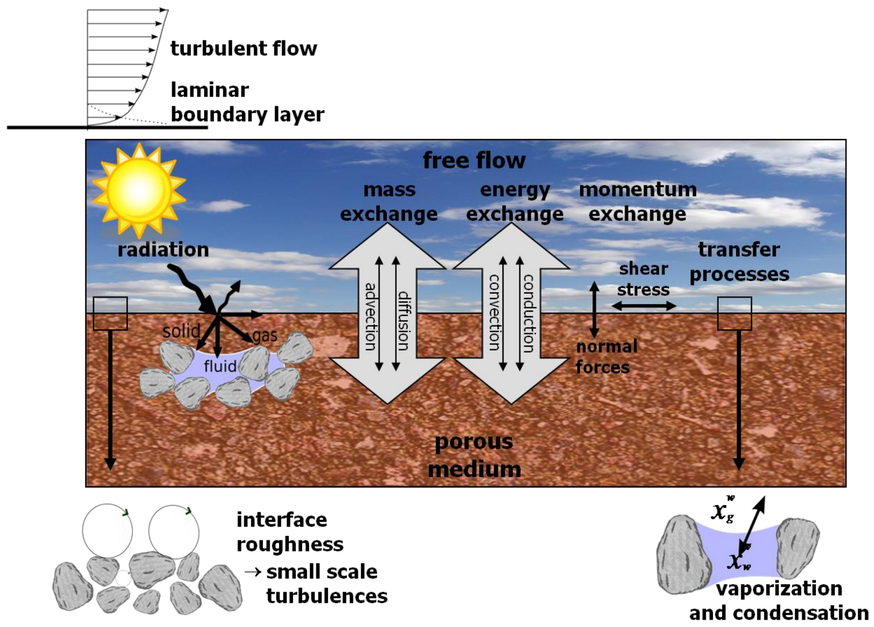


Fig.1: Relevant interface processes for evaporation

In this project, we focus on the modeling and analysis of infiltration and evaporation fronts in unsaturated porous media and on the movement and stability properties of liquid-gas interfaces. We analyze the fluid behavior at interfaces of different porous materials and at the interface between porous media and atmosphere (free flow). A special focus is on the development of a sophisticated numerical model that is able to correctly capture and reproduce the complex processes on the REV scale.

Coupling Soil and Atmosphere

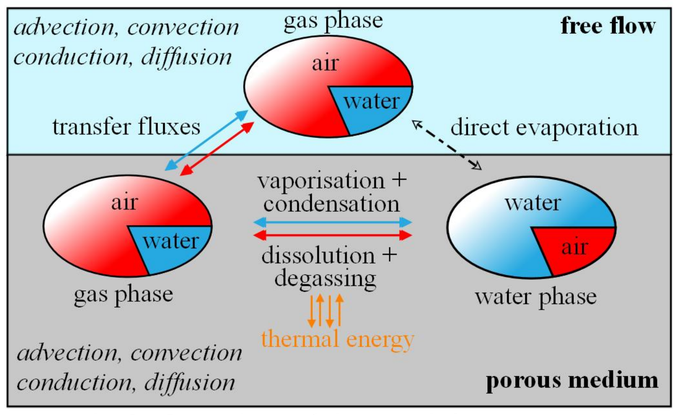


Fig.2: Overview of the model concept

Development of a coupled model composed of:

- a **porous medium** (non-isothermal compositional two-phase porous-medium flow using Darcy's law)
- a **free flow** (non-isothermal compositional single-phase Navier-Stokes)
- based on the continuity of fluxes and local thermo-dynamic equilibrium [*Mosthaf et al., 2011*]
- implementation within the modeling framework of DuMu^x / DUNE (dune-multidomain, S. Müthing)

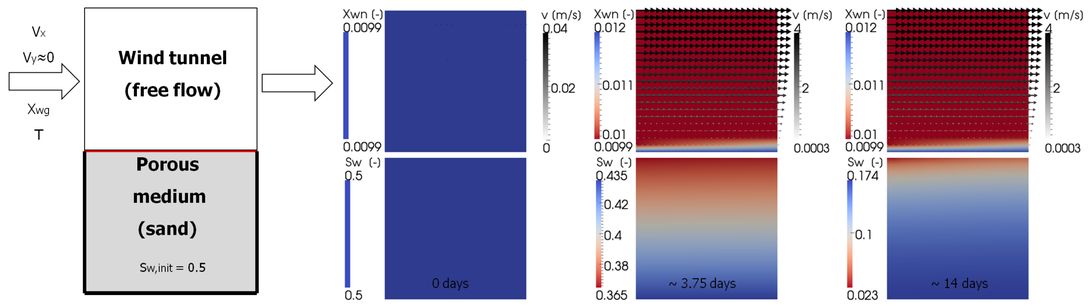


Fig.3: Numerical example of evaporation influenced by wind

Evaporation experiments with an unsaturated porous medium in contact with a wind tunnel for the validation of the numerical model, measurement of:

- evaporation rate, air velocity and humidity
- temperature, evolution at the surface

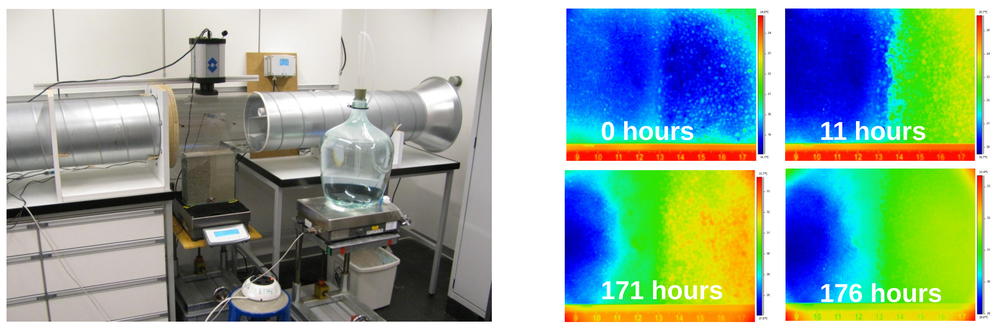


Fig.4: Experimental setup at the ETH Zürich (P3) and temperature evolution at the soil surface (top view) of a heterogeneous evaporation experiment

Infiltration / Front Stability

Capture saturation overshoots and fingering and examination of the stability of infiltration fronts in homogeneous and heterogeneous porous media

- analysis of different concepts to capture dynamic capillary pressure (Hassanizadeh and Gray, Barenblatt, Juanes) and comparison with experimental data (P6)
- scale dependent instability analysis (in cooperation with F. Kissling and C. Rohde)

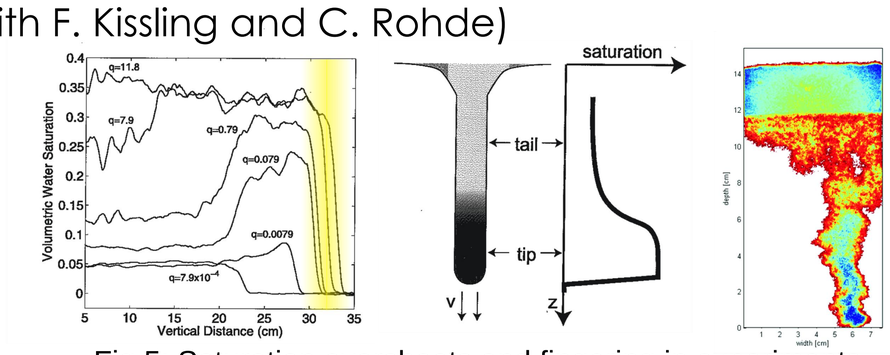


Fig.5: Saturation overshoots and fingering in experiments ([*DiCarlo, 2004*] and P6)

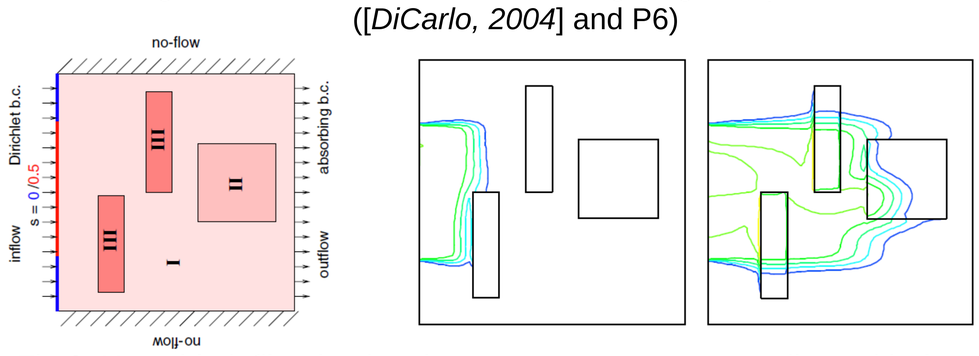


Fig.6: Unstable infiltration in a heterogeneous porous medium with dynamic capillary pressure [*Hassanizadeh and Gray, 1990; Helmig et al., 2008*]

Future Work

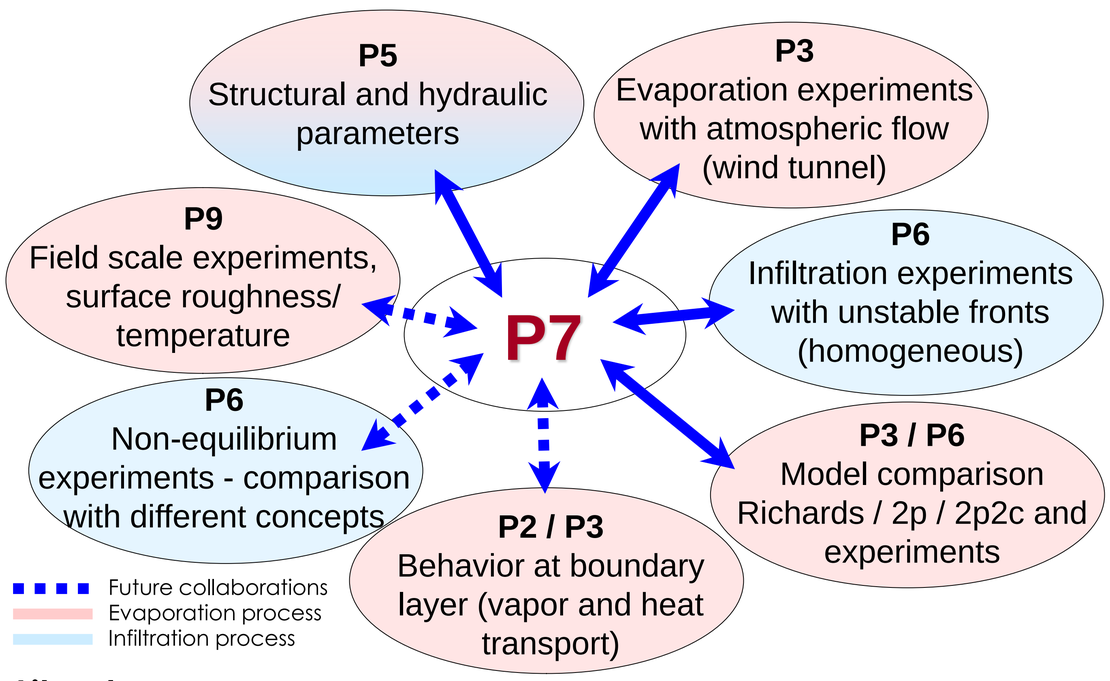
Coupling soil and atmosphere

- comparison of experimental data (P3) and numerical results (homogeneous, simple heterogeneous structures)
- sensitivity study (soil parameters, BJ coefficient, flow velocity in the free flow, …)
- check of assumptions and conditions
- simulation of sequences of infiltration and evaporation under the influence of radiation
- account for turbulent behavior in free flow as averaged quantity at the interface (surface roughness)
- examination of the processes in the boundary layer (vapor and heat transport)
- comparison of field scale measurements (P9) with the numerical model output

Infiltration / front stability

- variation of viscosity ratio → fingering
- comparison with homogeneous and heterogeneous infiltration experiments (P6)

Cooperation



Literature

- Hassanizadeh, S.M. and Gray, W.G., AWR, 13(4), 169-186, 1990.
- Helmig et al., *Computational Geosciences*, 13, 373-390, 2008.
- Kissling F., Rohde C., submitted to *Hyperbolic Problems: Theory, Numerics and Applications*, Beijing, 2010.
- Mosthaf et al., in preparation for WRR 2011.
- Shavit, U., *Transport in Porous Media*, 78, 327-540, 2009.

Works and results on this poster are in collaboration with F. Kissling, D. Or, E. Shaaraeeni, A. Weiss and B. Wohlmuth

LH²

Universität Stuttgart

Deutsche Forschungsgemeinschaft DFG