MUSIS

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

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SP2

Multi-Scale Interfaces in Unsaturated Soil

Results from the first project period

Coupling concept and numerical model (REV-scale)

→ couples a non-isothermal compositional two-phase **porous-medium (Darcy) model** and a respective laminar single-phase **free-flow (Stokes) model** based on the continuity of fluxes and local thermodynamic equilibrium [*Mosthaf et al., 2011, Baber et al., 2011*]

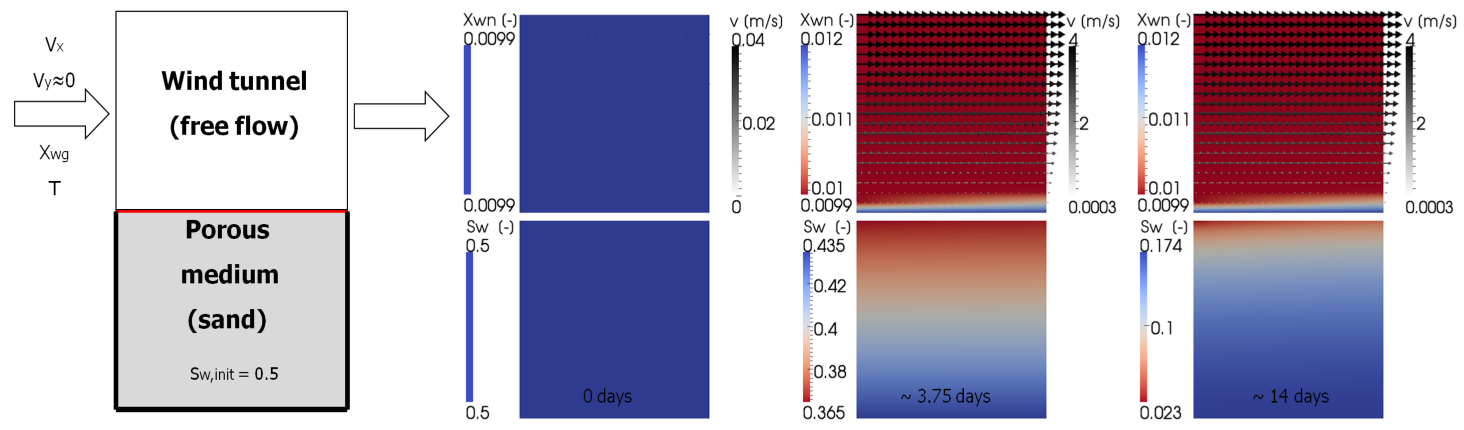


Figure 1: Numerical example of evaporation influenced by wind

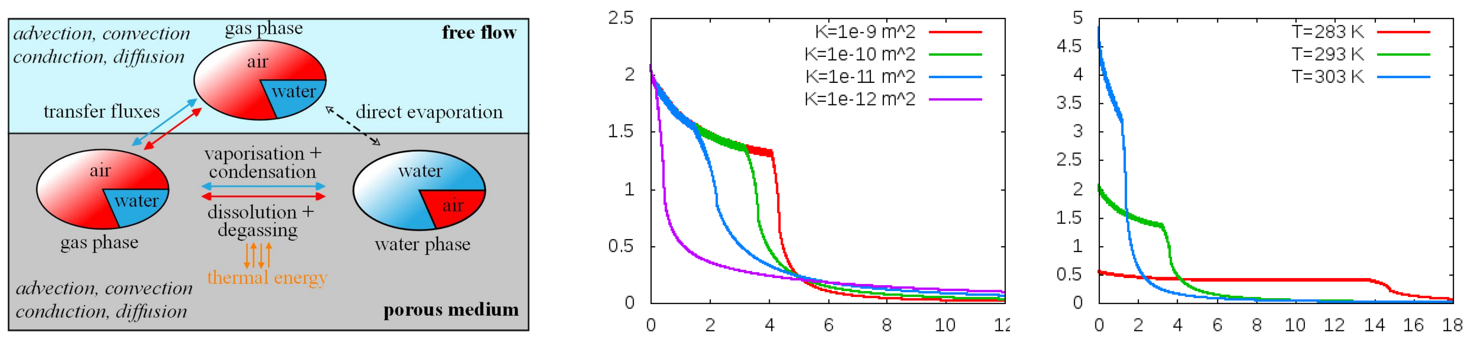
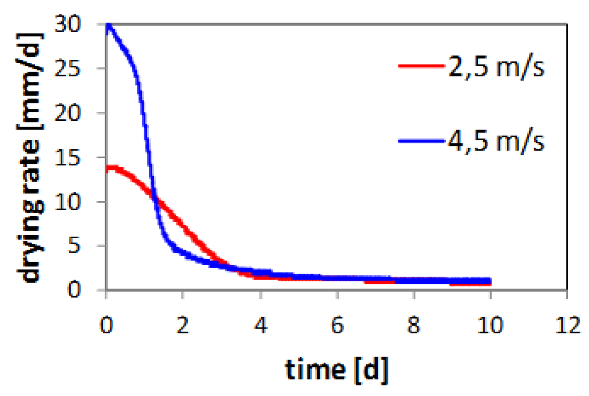


Figure 2: Model concept (left) and comparison of simulated evaporation rates [mm/d] over time [d] for different permeabilities and temperatures

Evaporation experiments in a wind tunnel (P3, Zürich)



Model development and comparison study: Front stability and saturation overshoots

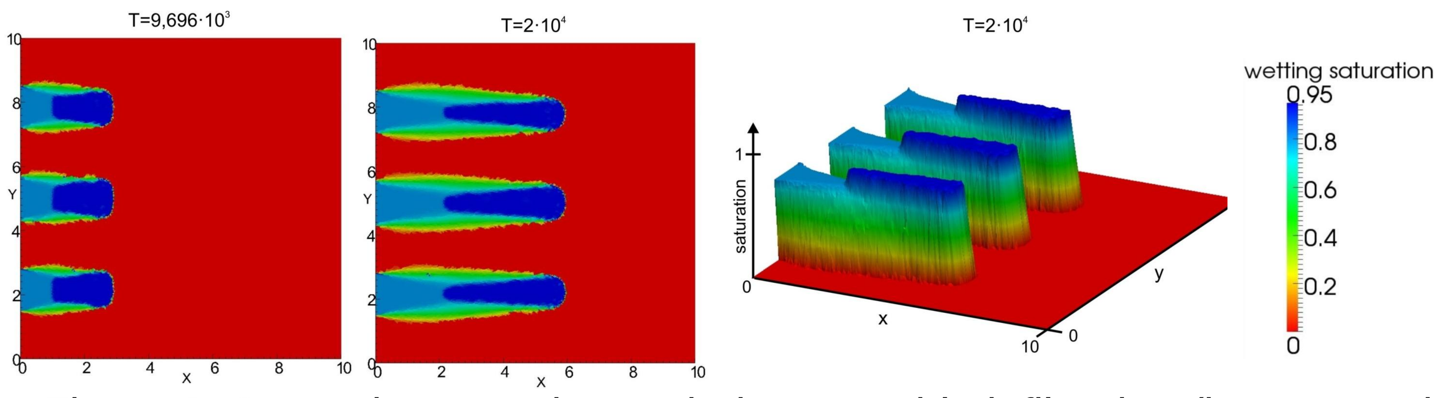


Figure 3: Saturation overshoots during unstable infiltration (in cooperation with F. Kissling and C. Rohde)

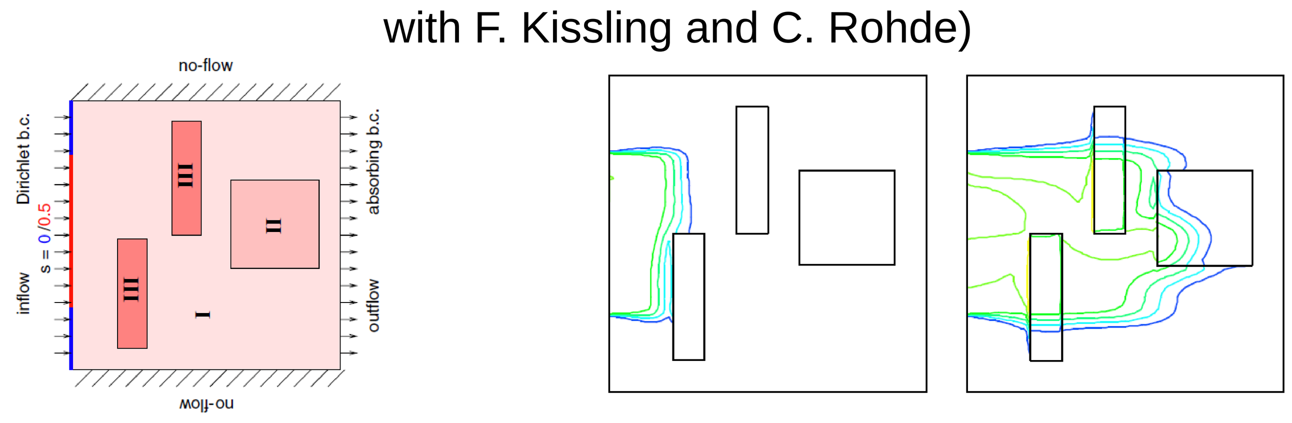


Figure 4: Stability of fluid fronts [Weiss et al., 2009]

Open questions and challenges

- Influence of turbulent flow, surface roughness and boundary layers on evaporation
- Radiative energy input and heat transfer at the soil-atmosphere interface
- Applicability limits of classical concepts for evaporation

Objectives

Influence of turbulent flow on mass, momentum and energy exchange

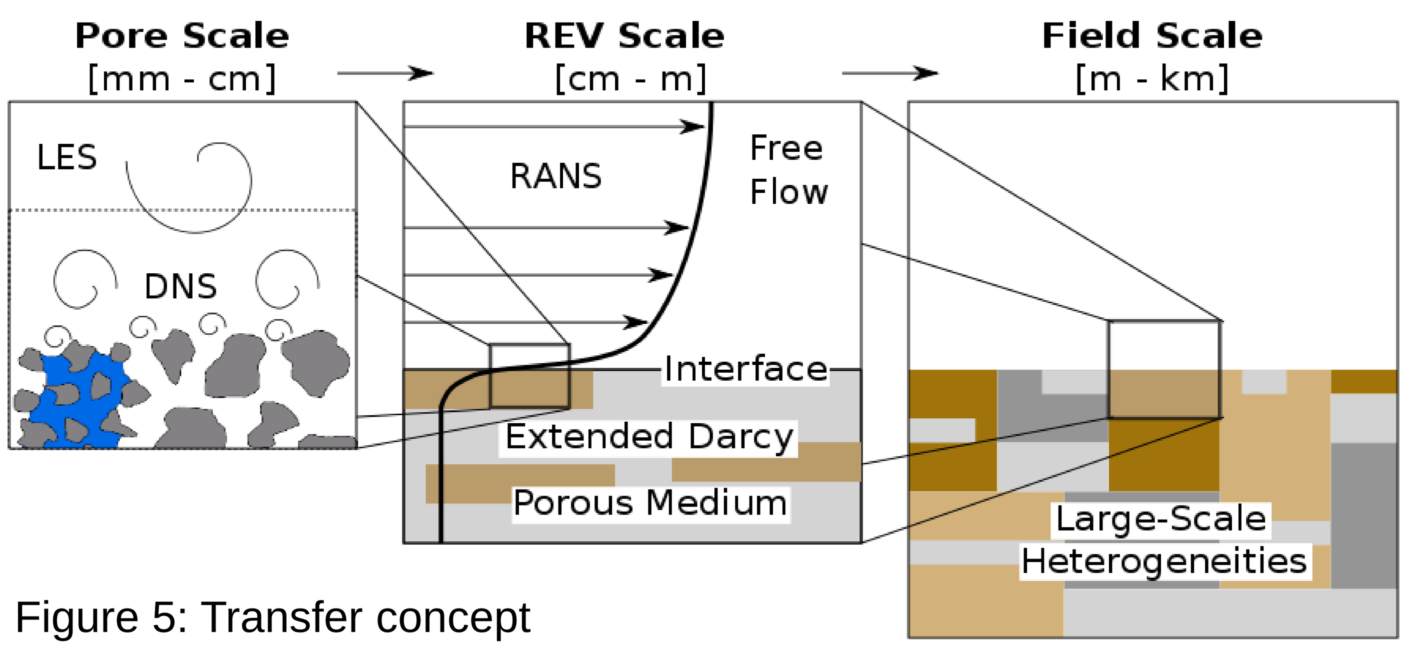


Figure 5: Transfer concept

- extension of the coupled model from the first project phase in order to correctly capture and reproduce the exchange of mass, momentum and energy on the REV scale under turbulent conditions in the free flow, accounting for the influence of boundary layers
- modeling and interpretation of evaporation from porous media influenced by atmospheric processes

→ coupling of porous-medium model to a Reynolds-averaged Navier-Stokes (RANS) model
→ effective parameters from pore-scale (DNS/LES) simulations (SP1) and measured data (SP6)
→ validation with experiments (SP3-SP5)

Radiation and heat exchange at the pm-ff interface

- inclusion of the surface energy balance in the numerical model employing realistic data
- examination of the thermal-equilibrium assumption at the ff-pm interface

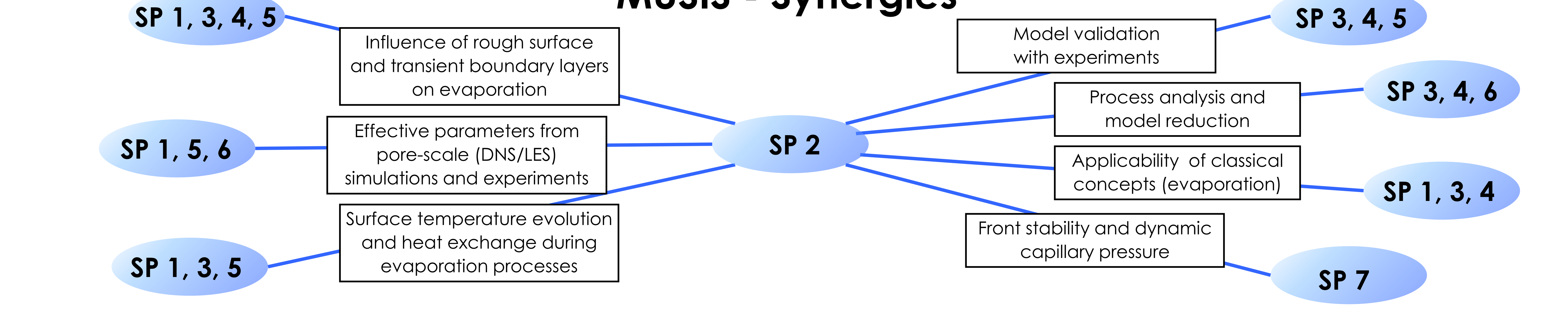
Stability of infiltration fronts and fluid-fluid interactions at the interface of different soil materials

- analysis of the flow processes at heterogeneous soil structures
- simulation of realistic scenarios with sequences of evaporation and infiltration, modeled as variable source term at the interface
- comparison study of different concepts for dynamic capillary pressure and experimental data (SP7)

Expected results

- Coupling concept and simulation tool for the modeling of evaporation processes from bare soils at the interface to the atmosphere with turbulent conditions
- Analysis of the relevant processes on different scales
- Criteria for the required model complexity for evaporation processes (→ model reduction)

MUSIS - Synergies



Literature

Mosthaf, K., Baber, K., Flemisch, B., Helmig, R. Leijnse, A., Rybak, I. and B. Wohlmuth (2011): A coupling concept for two-phase compositional porous-medium and single-phase compositional free flow. WRR, 47, W10522

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Baber, K., Mosthaf, K., Flemisch, B. Helmig and B. Wohlmuth (2011): Numerical scheme for coupling tow-phase compositional porous-media flow and one-phase compositional free flow. Submitted to IMA J Math.

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