Pakt for Research and Innovation: The Research Network Coupled Flow Processes in Energy and Environmental Research

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Coupled Flow Processes — an Interdisciplinary Problem

Appearance of coupled flow processes: energy research, geo sciences, environmental and climate research, civil engineering, materials science

Research topics of the network:

- reactive transport of dissolved species
- interaction between free flow and flow in porous media
- exchange processes in multi-phase flows

Mathematical models:

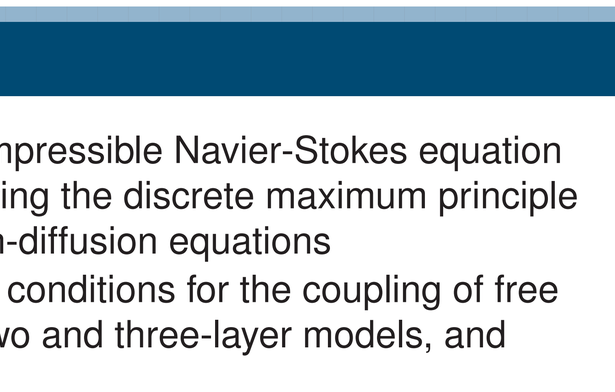
- free flow: (incompressible) Navier-Stokes equation
- porous media flow: Darcy and Brinkman model
- soil hydrology: (stochastic) Richards equation
- species transport: reaction-diffusion-convection equation
- interface conditions: boundary layer theory, Beavers-Joseph, ...

The Projects

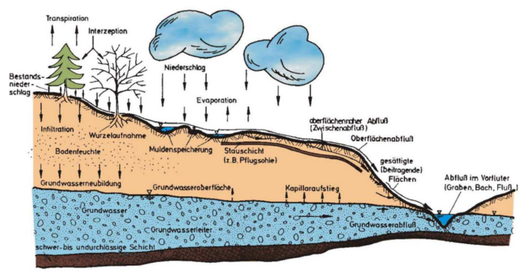
- **WIAS-I**: discretization of incompressible Navier-Stokes equation by covolume methods preserving the discrete maximum principle in coupled reaction-convection-diffusion equations
- **WIAS-II**: appropriate interface conditions for the coupling of free flow and porous media flow, two and three-layer models, and numerical implementation
- **PIK-I**: coupling of dynamic climate model CLM with the soil model TERRA-ML, horizontal water transport in soil and groundwater
- **FU-I**: simulation of the stochastic Richards equation for water flow in homogeneous soil and coupling with atmosphere processes, systematic uncertainty analysis using polynomial chaos expansion
- **FU-II**: Analysis of Ekman boundary layer for variations in the vegetation height and derivation of new boundary conditions for atmosphere-land-surface interaction, systematic uncertainty analysis using polynomial chaos expansion
- **FAU-I**: efficient simulation of multi-phase flow with Marangoni convection at the free surface between liquid and gas

Main Applications

- **fuel cells**:
  - electrochemistry in WIAS-I and WIAS-II
  - bubble transport in FAU-I



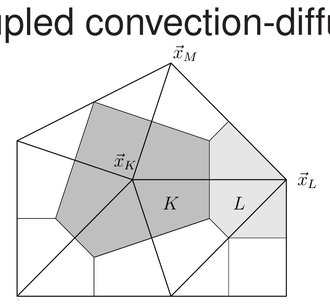
- **regional climate modelling**
  - flood protection in PIK-I and FU-I
  - flow simulation of the atmosphere in FU-II



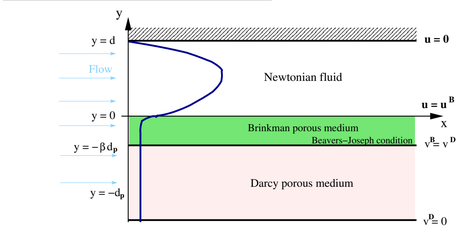
State of the Work

Project WIAS-I:

Taylor-Hood finite element discretization yields to a violation of the discrete maximum principle for a coupled convection-diffusion eq.



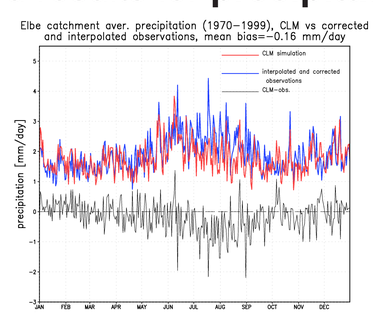
Project WIAS-II:

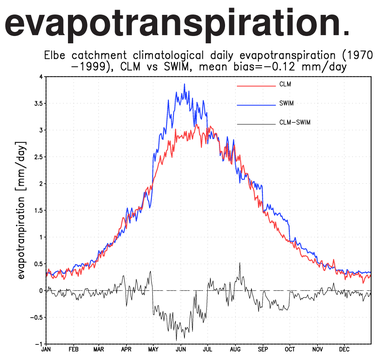


Three-layer model using a Brinkman model to resolve properly the boundary layer structure at the fluid-porous interface

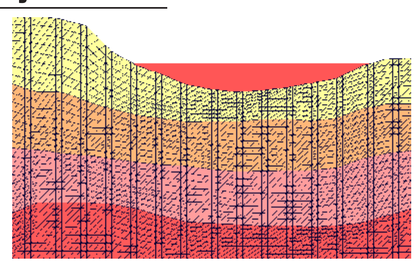
Project PIK-I:

Elbe catchment: CLM and measured data.
Good results for **precipitation** and **evapotranspiration**.





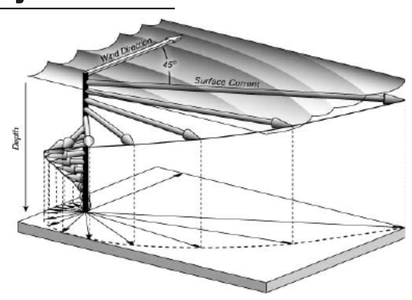
Project FU-I:



Numerical modelling for seepage of a lake:

Layers in the ground: sand, loamy sand, sandy loam, loam

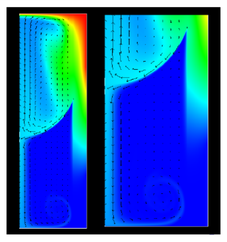
Project FU-II:



The Ekman Boundary Layer:

Wind directions close to earth surface

Project FAU-I:



Liquid propellant behavior under microgravity conditions

International Cooperations

The network cooperates with international outstanding scientists:

- Prof. R. Eymard, Université de Marne-la-Vallée
- Prof. O. Knio, Johns-Hopkins-University, Bessel prize winner
- Prof. Ch. Schär, ETH Zürich, Institut für Atmosphäre und Klima