Colloquium

From theory to applications: key questions and solution strategies for bridging the gap in porous-media research

organised by the Department of Hydromechanics and Modelling of Hydrosystems and SFB 1313 Interface-Driven Multi-Field Processes in Porous Media University of Stuttgart

16th November 2018
9:30 am – 1:00 pm

Pfaffenwaldring 61
70569 Stuttgart
MultiMedia Lab
Room U1.003

9:30 – 10:00 am
Jan Nordbotten: Vertical integration and CO2 storage: From a simple idea to practical simulation tools and new mathematics

Authors: M.A. Celia and J.M. Nordbotten

The concept of vertical integration for CO2 storage in the subsurface has had a great impact on how we think about modeling and simulation for these systems. In this talk, we show how these ideas have both given rise to complex yet efficient simulaton tools, but also how they have somehow been influential in a new family of mathematical models: Mixed-dimensional partial differential equations.

10:00 – 10:30 am
Holger Class: (M/E/T) Induced Calcite Precipitation and engineered biofilms in porous media

Authors: Holger Class, Johannes Hommel, Felix Weinhardt

We present a review of our activities in the field of induced calcite precipitation (ICP). ICP is considered an effective engineering measure to seal flow paths in the subsurface. The precipitation of calcite is based on an enzymatically (expressed by microbes or from jack bean extracts) catalyzed or temperature-induced hydrolysis of urea resulting in an increased pH-value which is favorable for precipitation of calcite.
A particular focus of the work we present is on the effects of ICP on the hydraulic properties, mainly porosity and permeability. Since our aim is modeling field-scale applications, we prefer the use of averaged, REV-scale models. We are fully aware that the pore-scale processes need to be well understood in order to have a proper description of the porosity-permeability relationship. Therefore, we have recently set up a work program to study ICP in microfluidic models.

10:30 – 11:00 am

Nima Shokri: Water table depth and soil salinity: A multi-scale analysis

Author: Nima Shokri

The excess accumulation of salt in soil is a global problem and is one of the most widespread soil degradation processes in the world. This process is of major concern in soil salinity, terrestrial ecosystem functioning, and water management. Furthermore, accumulation of salt in soil adversely influences the plant growth, vegetation and crop production. As water evaporates, salt concentration in the pore space increases continually until it precipitates. Recent studies confirmed experimentally the porous nature of the precipitated salt and the complex dynamics of its evolution during evaporation (Shokri-Kuehni et al., 2017a,b, 2018). The presence of porous salt at the surface causes top-supplied creeping of the solution feeding the growth of subsequent precipitation. This causes appearance and disappearance of cold-spots at the surface of porous media brought about by crust formation and preferential water evaporation through the precipitated salt. Such a phenomenon leads to additional water evaporation from soil far beyond the expected values when precipitated salt at the surface is treated as a non-porous dry layer.

In this study, we have conducted a series of laboratory-scale evaporation experiments to evaluate effects of salt on water evaporation from porous media in the presence of water tables fixed at various depths below the surface. Our results illustrate the significant impact of the presence of hydraulically connected precipitated salt at the surface with the water table on the total cumulative water losses. High-resolution thermal imaging enabled us to investigate the complex temperature dynamics at the surface of precipitated salt in the presence of a water table, providing further confirmation of salt crust contribution to the evaporation. Our results showed that as long as the water table was hydraulically connected to the surface, more salt precipitation occurred at the surface for the case of deeper water tables. In addition to the laboratory-scale experiments, we made use of two global-scale databases (Harmonized World Soil Database and Global Water Table Depth) containing topsoil salinity, soil texture and water table depth data to reveal the relevance of our laboratory-scale findings to the large-scale responses and the relationships between the water table depth and soil salinity at the global-scale. Our multi-scale analysis extends the physical understanding of the mechanisms controlling saline water evaporation from porous media in the presence of a water table.

11:00 – 11:30 am

Coffee break

11:30 – 12:00 am

Holger Steeb: Some comments on static and dynamic permeability

Author: Holger Steeb

Transient permeability tests, i.e. pressure diffusion and/or pore pressure oscillation methods, allow to measure the intrinsic permeability and the storage capacity of tight rocks in reasonable time with good signal-to-noise ratio (Song & Renner, 2007). In contrast to "classical" static permeability tests, where fluxes and pressure gradients have to measured (and/or controlled), only pressure transients have to be detected experimentally in the upstream and the downstream reservoir. Subsequently, pressure amplitude differences and phase shifts can be determined. Finally, in a post-processing step, storage capacity and effective intrinsic permeability can be determined from the analytical or numerical solution of a pressure-diffusion equation (Kranz, Saltzman, & Blacic, 1990). Further, inertia effects can be taken into account allowing to introduce a "dynamic" permeability coefficient (Johnson, Koplik, & Dashen, 1987) accounting for non-parabolic velocity profiles on the pore-scale at high Womersley numbers.

Here, we critically discuss some basic concepts of dynamic/harmonic permeability tests from a theoretical and an experimental perspective. It will be further discussed how the data analysis in the post-processing step could be improved by reformulating the pressure-diffusion equations in form of (complex) Helmholtz equations.

12:00 – 12:30 pm

Sorin Pop: Iterative methods for the numerical simulation of porous media flows

Author: Sorin Pop (joint work with K. Mitra, F.A. Radu, K. Kumar, S. Karpinski, J.M. Nordbotten)

The mathematical models for unsaturated or multi-phase flow in porous media are nonlinear, time dependent partial differential equations. For stability reasons, the time discretisation is based on implicit or semi-implicit methods, and therefore the resulting time-discrete or fully discrete problems are nonlinear as well. Moreover, the model may become degenerated in regions where one of the flowing phase is completely absent, or where one phase is occupying the entire pore space. In this case, Newton-based iterative approaches converge only if the time step is chosen very small, or even fail to converge, as the Jacobian matrices may become singular. In this presentation, we discuss alternative approaches, where the convergence is achieved under mild or even without constraints on the time step, and uniformly with respect to the spatial discretisation.

12:30 – 1:00 pm

Majid Hassanizadeh: Non-equilibrium capillarity effect at different scales

Author: S. Majid Hassanizadeh

Commonly, capillary pressure is presumed to be equal to and/or synonymous with the difference in the pressures of the two fluid phases. However, many theoretical and experimental studies have shown that this is the case but only under equilibrium conditions. Under dynamic conditions, the fluids pressure difference also depends on the time rate of change of saturation. This is known as the dynamic or non-equilibrium capillarity effect. Computational and experimental studies have been carried out to estimate the dynamic coefficient that arises in the theory. It is found that the range of values of the dynamic coefficient spans more than four orders of magnitude. We present an overview of these studies and the values of the dynamic coefficient and discuss their correlation with the length scale of the study. We find that its value increases with the size of the domain of interest. We provide an explanation for this correlation. In the light of these findings, we discuss the consequences of scale-dependence of dynamic capillarity coefficient for large-scale field situations.

from 1:00 pm

Lunch