University of Stuttgart
Cluster of Excellence EXC 2075 „Data-Integrated Simulation Science“
Faculty 2: Civil and Environmental Engineering

Scientific Colloquium

Hydromechanics

Place:
Pfaffenwaldring 7, Room 2.157

Friday, 20 September 2024
09:00 – 09:45 am
Dr. Timo Koch

11:15 – 12:00 pm
Dr. Kata Kurgyis

02:00 – 02:45 pm
Dr. Huhao Gao

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Reduced-dimensional modeling and simulation of hydromechanical systems

Dr. Timo Koch
University of Oslo, Norway

I present my research, which focuses on modeling and simulation and the design of targeted numerical schemes for hydrosystems and flow and transport in porous media. To this end, I build mechanistic models (and digital twins by integrating subject-specific data) to advance the understanding of such systems. Complex hydrosystems feature coupled physical processes and structures at various spatial and temporal scales with direct implications on the system behavior. Pipe, channel, or fracture-like features are common to hydrosystems across science and engineering but challenge or preclude the efficiency, robustness, or accuracy of standard numerical and simulation approaches and increase model complexity with additional interfaces and structural heterogeneity. In this talk, at the example of specific environmental, technical, and biological applications, I demonstrate that using reduced-dimensional and mixed-dimensional models based on coupled systems of PDEs can be an effective strategy allowing the simulation of real systems that would otherwise be infeasible. My results show that the "thinness" has important implications across the simulation pipeline: in the mathematical and numerical modeling, the accuracy of numerical approximations, and the design of robust discretizations, fast solvers, and efficient software. I conclude with several open questions regarding method development and applications that may be addressed with the developed techniques.

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Innovations in Carbon Capture and Nuclear Waste Disposal: A Research Journey Towards Climate Neutrality

Dr. Kata Kurgyis
Technische Universität Bergakademie Freiberg, Germany

My research journey is driven by a commitment to addressing climate change and enhancing sustainable energy solutions. Initially, I focused on CO2 sequestration (CCS) during my BSc and MSc theses, where I explored hydromechanical simulation software tools. My PhD work expanded this interest in developing a new module for the DuMuX simulation tool, addressing retention effects during chemically tuned smart water injection.

Currently, I coordinate the URS-cluster, a national collaboration involving 18 German institutes. This project is pivotal to Germany's site selection process for nuclear waste repositories aiming to improve safety by addressing uncertainties in geological and geophysical data through a multidisciplinary approach.

Looking ahead, my primary research objective is to revitalize CCS research to support Germany's goal of climate neutrality by 2045. My future research will focus on the following areas:

1. Exploring depleted gas reservoirs and aquifers for **CO2 sequestration using optimized experimental designs** inspired by nuclear waste disposal research.
2. Investigating **THMC1 process models during CO2 injection and migration**, with a focus on developing robust process models and a THMC gallery for model validation.
3. Conducting **comprehensive long-term safety analyses** using numerical and surrogate models (e.g. PINN2) to ensure the secure underground sequestration of CO2.

Through these efforts, I aim to significantly contribute to the field of CO2 storage and sequestration, ultimately forming a global research consortium to support Germany’s ambitious energy policy objectives.

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Pore-scale simulation of interfacial reaction and interphase mass transfer in dynamic two-phase flow in porous media

Dr. Huhao Gao
University of Goettingen, Germany

Fluid-Fluid Interfacial Area (FIFA) is an important parameter relevant in numerous hydrogeological applications where two phases of fluids exist and interphase reactive mass transfer can happen. Pore-scale modeling plays an important role in understanding the interface dynamics and interphase reactive mass transfer processes. We developed a new Phase-Field-Method based Continuous-Species-Transfer (PFM-CST) model, which can deal with processes such as interfacial reaction, partitioning between the two fluids, and advective-diffusive transport of species in dynamic two-phase flow at the pore scale. Through the numerical simulation, we studied the FIFA and transport of interfacially reactive tracers in porous media with various grain sizes and extents of surface roughness for various two-phase displacement regimes, including stable and fingering displacement. We investigated the effects of the pore space stagnant zones induced by the capillary trapped fluids on the interphase mass transfer coefficients. With this knowledge and column experiments, we proved the concept of a new kinetic interface sensitive (KIS) tracer to measure FIFA in primary drainage or push-pull processes for porous media two-phase flow systems. Future research includes micro-model experiments to visualize the interfacial reaction and interphase mass transfer directly and to pinpoint the strong and weak points of the models developed.

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