

COUPLED HYDRO-MECHANICAL-CHEMICAL PROCESSES IN SUBSURFACE SYSTEMS: FROM THEORY TO APPLICATIONS ACROSS SCALES

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ABSTRACT

Coupled hydro-mechanical-chemical (HMC) processes govern the behavior of natural and engineered subsurface systems across a wide range of spatial and temporal scales. These interactions are central to understanding and forecasting the evolution of porous and fractured media, particularly in the context of emerging geoenery and environmental applications. This session aims to bring together contributions that advance the fundamental understanding, modeling, characterization, monitoring, and practical implementation of coupled processes in both deep and shallow subsurface environments. The session will emphasize the interplay between fluid flow, mechanical deformation, and chemical reactions, including fully coupled HMC processes as well as partially coupled interactions, e.g., HC or MC effects. Contributions addressing processes from pore-scale to field-scale, and spanning analytical, numerical, experimental, data-driven approaches, and case studies are welcome. Applications of interest span several domains. These include geoenery systems in the deep subsurface, such as carbon capture and storage (CCS), geothermal energy production, and underground hydrogen or natural gas storage, which play a critical role in climate change mitigation and the energy transition. Environmental and waste management applications are also of interest, including nuclear waste disposal and groundwater contamination and remediation. In addition, the session addresses the so-called unconventional carbon management approaches, such as carbon mineralization, and soil-based carbon removal and enhanced weathering. Further relevant topics include the understanding of fundamental (hydro)geological processes, such as sediment compaction, channeling and wormhole formation, and karstification. By fostering dialogue across disciplines, this session will contribute to bridging fundamental research and practical applications, thereby advancing the understanding of coupled subsurface processes and addressing key challenges in energy and environmental systems.