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A THC Simulator for Modeling Fluid-Rock Interactions

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Fluid-rock interactions play an essential role in many earth processes, from a likely influence on earthquake nucleation and aftershocks, to enhanced geothermal system, carbon capture and storage (CCS), and underground nuclear waste repositories. In THC models, two-way interactions between different processes (thermal, hydraulic and chemical) are present. Fluid flow influences the permeability of the rock especially if chemical reactions are taken into account. On one hand solute concentration influences fluid properties while, on the other hand, heat can affect further chemical reactions. Estimating heat production from a naturally fractured geothermal systems remains a complex problem. Previous works are typically based on a local thermal equilibrium assumption and rarely consider the salinity. The dissolved salt in fluid affects the hydro- and thermodynamical behavior of the system by changing the hydraulic properties of the circulating fluid.

Coupled thermal-hydraulic-chemical models (THC) are important for investigating these processes, but what is needed is a coupling to mechanics to result in THMC models. Although similar models currently exist (e.g. PFLOTRAN), our objective here is to develop algorithms for implementation using the Graphics Processing Unit (GPU) computer architecture to be run on GPU clusters. To that aim, we present a two-dimensional numerical simulation of a fully coupled non-isothermal non-reactive solute flow. The thermal part of the simulation models heat transfer processes for either local thermal equilibrium or nonequilibrium cases, and coupled to a non-reactive mass transfer described by a non-linear diffusion/dispersion model. The flow process of the model includes a non-linear Darcian flow for either saturated or unsaturated scenarios. For the unsaturated case, we use the Richards' approximation for a mixture of liquid and gas phases. Relative permeability and capillary pressure are determined by the van Genuchten relations. Permeability of rock is controlled by porosity, which is itself related to effective stress. The theoretical model is solved using explicit finite differences, and runs in parallel mode with OpenMP. The code is fully modular so that any combination of current THC processes, one- and two-phase, can be chosen. Future developments will include dissolution and precipitation of chemical components in addition to chemical erosion.