Modeling of underground flows. Application to reactive transport

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In this talk, we present models that are alternatives to the 3D-Richards equation for describing water flow in shallow aquifers. They exploit the low thickness of the aquifer and consist in capturing very different physical phenomena: the fast and essentially vertical leakage coming from the surface through an unsaturated soil and the slow and essentially horizontal displacement in the saturated part of the aquifer. These models are easier to manipulate numerically since the original 3D problem is replaced by the coupling of a 2D problem with several independent 1D-problems (which can be solved in parallel). This implies significant time savings in the numerical processing. An asymptotic analysis is used to prove that each model of the new class and the 3D-Richards equation are associated with the same effective problem for any time scale [C. Bourel, C. Choquet, C. Rosier and M. Tsegmid (2020)].

The mathematical study of this class of models is particularly delicate because of the nonlinearities, the free boundary between each area and the difficulty resulting from the coupling between the two zones which is expressed in terms of flux at the interface. We show how taking into account the low compressibility of the fluid eliminates the nonlinearity in the time derivative of the Richards equation. Then, we use the general framework of parabolic equations in non-cylindrical domains introduced by Lions in [J. L. Lions (1957)] to give a global in time existence result for this problem [S. Al Nazer, C. Rosier, M. Tsegmid (2022)].

This model is then coupled to the transport equations describing kinetic chemistry as well as to the algebraic system describing equilibrium chemistry [R. Awada, J. Carrayrou, C. Rosier (to appear)].