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Unsteady resurgence flows in karstic media

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Geological porous media are heterogeneous materials which in addition contain discontinuities such as fractures and conduits which facilitate fluid transport.

Fractures are relatively plane objects which strongly interact with the surrounding porous medium because of their large contact surface. A different situation occurs in karsts where distant regions of the medium can be connected by relatively thin conduits which have little if any hydrodynamic interaction with the porous medium that they cross, except at their ends.

This phenomenon is called resurgence because of the obvious analogy with rivers which suddenly disappear underground and go out at the ground surface again. Similar ideas have already been developed in other fields, such as Physics with random networks and Geophysics with electrical tomography.

Media with resurgences are addressed in the following way. They consist of a double structure. The first one is the continuous porous medium described by the classical Darcy law. The second one is composed by the resurgences modeled by conduits with impermeable walls which relate distant points of the continuous medium. When non steady regimes are considered, it appears necessary to confer a capacity to these conduits in addition to their hydrodynamic resistance. Therefore, the conduits are able to store some quantity of fluid. In addition, two kinds of resurgence are addressed, namely punctual and extended; in the second case, the dimensions of the ends of the conduit are not negligible compared to the characteristic length scales of the embedding porous medium. Capacities and extended resurgences are new features which were not taken into account in our previous studies.

The punctual resurgence is described by a spatial network with a finite number of conduits embedded in a continuous porous medium. The flow in the network is described by the classical Kirchhoff law (including capacities). The equations for flow in the network and in the continuous medium are related by the unknown flow rates jn(t) (n = 1,2, . . . , N) depending on time at the nth vertices of the network. Application of the conservation law at the vertices yields a system of integral equations for jn(t). The structure of this system depends on the structure of the network. The Laplace transformation yields a linear algebraic system. When this system is solved, the flow rates jn(t) can be constructed by the inverse Laplace transform. Extended resurgences are modeled as extensions of punctual resurgences when instead of two vertices at each edge two domains are connected point by point by an uncountable number of edges. Another type of extended resurgence is described by a non local integral operator.

A numerical finite difference method is also applied to solve the equations. Examples of network with two and more vertices are detailed.

The mathematical aspects will be kept to a minimum during the presentation and emphasis will be put on the physics and on several illustrative examples.