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Barometric pumping of a fractured porous medium

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Fluctuations in the ambient atmospheric pressure result in motion of air in porous and fractured media. This mechanism, known as barometric (or atmospheric) pumping, efficiently transports gaseous species through the vadose zone to the atmosphere. This is of interest in many environmental and engineering fields, such as transport of trace gases from soil to atmosphere, environmental remediation of contaminated sites, radon in buildings and last but not least detection of nuclear explosions or leakage from carbon sequestration sites.
The physical situation has been addressed in the following way. The fractures are modeled as polygonal plane surfaces with a given transmissivity embedded in a porous medium with a given permeability. The fluid is slightly compressible and is assumed to obey Darcy's law in the fractures and the porous medium with exchanges between them. The solute obeys convection-diffusion equations in both media again with exchanges between them.
The fractures and the porous medium located in between them are meshed by triangles and tetrahedra. The equations are discretized by the finite volume method. In order to improve numerical precision, a Flux Limiting Scheme is applied to the transport equations ; moreover, special care is devoted to the description of the solute transfer between the fractures and the porous medium. The resulting equations are solved by conjugate gradient algorithms.
This model is applied to the Roselend Natural Laboratory. At a 55 m depth, a sealed cavity allows for gas release experiments across fractured porous rocks in the unsaturated zone. The fractures are hexagons with a radius of 5m; their density is larger than 2.4 10-3 m-3; the aperture is of the order of 0.5 mm. The pressure fluctuations are sinusoidal, of amplitude 0.01 bar and period 1 week. The solute concentration is supposed to be equal to 1 at the bottom of the site.
Systematic results will be presented. First, the precision of the calculations is assessed. Second, the pressure fluctuations and the solute concentration in the fractured porous medium is displayed and discussed. Third, the influence of the major parameters (fracture density and aperture, porosity, diffusion coefficient,. . .) is illustrated and discussed.
These results are discussed in terms of the amplification of solute transfer to the ground surface by the pressure fluctuations.
Finally, it should be emphasized that the codes can be easily modified to address time dependent thermal transfers in fractured porous media.