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Working towards a numerical solver for seismic wave propagation in unsaturated porous media

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Modeling the propagation of seismic waves in porous media gets more and more popular in the seismological community. However, it is still a challenging task in the field of computational seismology. Nevertheless, it is important to account for the fluid content of, e.g., reservoir rocks or soils, and the interaction between the fluid and the rock or between different immiscible fluids to accurately describe seismic wave propagation through such porous media. Often, numerical models are based on the elastic wave equation and some might include artificially introduced attenuation. This simplifies the computation, because it only approximates the physics behind that problem. However, the results are also simplified and could miss phenomena and lack accuracy in some applications.

We present a numerical solver for wave propagation in porous media saturated by two immiscible fluids. It is based on Biot's theory of poroelasticity and accounts for macroscopic flow that occurs on the same scale as the wavelength of the seismic waves. Fluid flow is described by a Darcy type flow law and interactions between the fluids by means of capillary pressure curve models. In addition, consistent boundary conditions on interfaces between poroelastic media and elastic or acoustic media are derived from this poroelastic theory itself.

The poroelastic solver is integrated into the larger software package NEXD that uses the nodal discontinuous Galerkin method to solve wave equations in 1D, 2D, and 3D on a mesh of linear (1D), triangular (2D), or tetrahedral (3D) elements. Triangular and tetrahedral elements have great advantages as soon as the model has a complex structure, like it is often the case for geologic models. We illustrate the capabilities of the codes by numerical examples.

This work can be applied to various scientific questions in, e.g., exploration and monitoring of hydrocarbon or geothermal reservoirs as well as CO_2 storage sites.