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Nonlinear waves in deforming porous media with the finite difference method

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The actual trend in computational geodynamics tends toward the development of coupled multi-physics models. The resulting models involve various types of nonlinear processes such as non-Newtonian rheologies and multi-physics coupling. One of the main challenge is to treat these nonlinearities in order to preserve the predictive power of these forward models.

In this framework, we designed two dimensional (2D) finite difference models using both implicit and explicit discretisations. We apply the models to study the initiation and the propagation of nonlinear waves in deforming porous media (porosity waves). A strong coupling of a Stokes solver to a nonlinear Darcy flow is required to describe the complex evolution of permeability and porosity in space and in time. In our models, we also take into account porosity-dependant permeability and rheologies that are representative of major reservoir rock type (i.e. tight shales).

We conduct numerical simulations and show that both implicit and explicit approaches capture the channeling instabilities and the development of focused flow. We perform quantitative comparison of the two methods and discuss the treatment of multi-physics coupling and rheological nonlinearities. We show that implicit and explicit discretisations converge to similar solutions only if the nonlinearities are accurately resolved. Explicit numerical algorithms can therefore be attractive because they are very comprehensible and well suited for HPC while implicit models are performing well on desktop computations.