Reduction of single phase flow models in porous media using a quantity of interest

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In hydrogeology, the calibration of the inputs of flow models is based on in-situ measurements such as well or seismic data. However, these calibration workflows usually require several runs of a flow simulator leading to a large computational effort. In this context, the reduced basis (RB) technique may be a solution to lower the overall simulation cost. In this work, we consider a porous rock saturated with a slightly compressible fluid. Writing the mass balance equation along with Darcy's law gives:

$$\Phi \rho c_t \frac{\partial p}{\partial t} - \nabla.(\frac{\rho \mathbf{k}}{\mu}(\nabla p + \rho g \nabla z)) = q \text{ in } \Omega \times (0,T) \tag{1}$$

where ϕ is the rock porosity, p the pressure, c_t the total compressibility, $\mathbf{k}$ the rock permeability, ρ the density, μ the viscosity, g the gravity constant and q the well source term. Equation (1) is closed by imposing the following boundary and initial conditions over $\partial\Omega = \Gamma_{\mathrm{D}} \cup \Gamma_{\mathrm{N}}$:

$$p = p_{\mathrm{D}} \text{ on } \Gamma_{\mathrm{D}} \times (0,T), \tag{2}$$

$$\frac{\rho \mathbf{k}}{\mu}(\nabla p + \rho g \nabla z) \cdot \mathbf{n} = h_{\mathrm{N}} \text{ on } \Gamma_{\mathrm{N}} \times (0,T), \tag{3}$$

$$p(x, t=0) = p^0(x) \text{ in } \Omega. \tag{4}$$

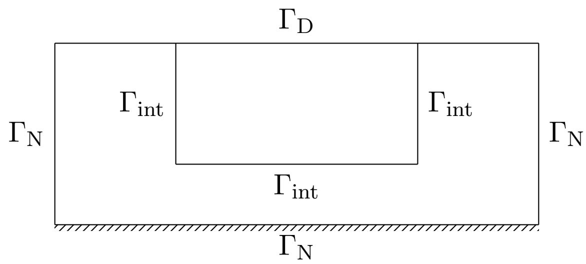

Figure 1: Boundaries of the domain

In practice, we have to solve (1)–(4) at all time steps for many values of $\mathbf{k}$ and several depths of the geological horizons. This work aims at being predictive on the time evolution of the flux $\mathbf{s}$ defined by

$$\mathbf{s} = \int_{\Gamma_{\mathrm{int}}} \frac{\rho \mathbf{k}}{\mu}(\nabla p + \rho g \nabla z).\mathbf{n} \, \mathrm{ds}$$

over the interior boundary Γ_{int} represented on figure 1. To avoid the induced computational cost, we construct a reduced model by using a Greedy-POD algorithm. The greedy basis generation process relies on a posteriori error estimate of the output of interest $\mathbf{s}$, which requires a construction of reduced bases for both the primal and dual problems. Numerical results are presented to illustrate the methodology for the aforementioned parameters, the convergence of the greedy algorithm and the efficiency of the a posteriori error estimate.