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A numerical investigation on the fluid flow at the interface of a porous and a free flow domain

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Approaches in sediment transport modeling can be roughly subdivided into two categories: 1) Models based on the theory of mixtures using a macroscopic, volumetrically-coupled two-phase (fluid and sediment) continuum approach and 2) interface-coupled, i.e. staggered approaches assuming a rigid boundary at the sediment bed, calculating the shear stresses at the bed surface, in combination with an algebraic relation to calculate the sediment transport and in the last step, the change in morphology.

Neither of these approaches takes into account the (Darcy / Brinkman) flow inside the sediment bed and how the different physics of the flow patterns influence each other. Hence we have developed a sediment transport model based on a three-phase mixture, which takes into account the notion that the porous sediment bed and the mobilized particles (commonly termed “bed load”) show distinctly different physical behaviours: The sediment bed can be described as a (more or less) rigid porous medium, while the mobilized particles exhibit a fluid-like behaviour.

Here, we concentrate on a numerical investigation of the fluid flow at the interface between a porous medium and a free flow domain using a range of different coupling mechanisms between the equations governing the free (Navier-Stokes) and the porous medium (Brinkman) flows in order to examine the interaction mechanisms between both domains. The goal of this study is to answer the following questions: 1) How is the fluid flow in the porous domain influenced by the flow in the free flow domain, and, conversely, what is the influence of the porous domain on the free flow, and 2) Do these effects have a stabilizing or a destabilizing effect, i.e. are there any forces induced by the interdependence of the flow patterns in the two different domains that would lead to enhanced sediment erosion or deposition at the interface?

The current implementation is based on the FE-Code Comsol Multiphysics. For the Navier-Stokes and Brinkman equations, common and widely-used stabilization schemes are applied for numerical stability. To work out the interfacial effects, we numerically analyse three different geometries each containing a free flow and a porous domain.