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Comparison of an integral solver to coupled modelling approach for hydraulic exchange at surface water-groundwater interface along rippled streambed

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The hyporheic zone is the transitional zone between aquifer (groundwater) and river (surface water). It is a band of permeable sediments surrounding a river, where surface water and groundwater mix including river beds, river banks, sediments under dry bars, riparian and floodplain areas. Due to interaction of groundwater and surface water, steep physical and biogeochemical gradients occur in this zone. Many modelling efforts are conducted to address such interactions and quantify fluxes, conservative and reactive transport, residence times of substances and purification effects. In most cases, these are based on using coupling schemes of groundwater flow (using Darcy or Forchheimer law, etc) and surface water flow (shallow water or Navier-Stokes equations). More recently integral approaches have been developed which apply the same model concept (Navier-Stokes equations with turbulence models) for surface water and groundwater flow, however different porosities and resistance terms.

This contribution compares an integral solver to a coupled modelling approach focusing on small-scale high resolution hydraulic exchange processes along a rippled streambed. Surface water is first modelled with a Navier-Stokes model (InterFoam solver of OpenFOAM) and the computed pressure head distributions along the rippled streambed serve as boundary conditions for a groundwater flow model (PCSiWaPro using Darcy law). This coupled approach is then compared with an integral approach implemented as porousInter solver in OpenFOAM using the same mesh.

We compare velocities, pressure distributions and their hotspots in different vertical sections and along the streambeds. We also check how well the integral solver can resolve small scale recirculation zones in between ripples. Moreover, we discuss computational performance for both approaches. We expect an agreement of both approaches for a certain range of porosities and grain-size diameters, deviations far away from the interface. Further we expect to compute more realistic results with the integral approach in the domain close to the interface, especially where the groundwater flow is out of the range of the Darcy law.