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A Hybrid-Dimensional Stokes–Brinkman–Darcy Model: Derivation, Analysis and Validation

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Coupled free-flow and porous-medium systems have received rising attention in recent years due to their broad applications in the environment, biology, and industry. A suitable coupling concept should be applied to characterize fluid behavior between the free flow and porous medium. However, the majority of coupling conditions are restricted to flows parallel to the fluid-porous interface.

In this talk, we present a hybrid-dimensional model for coupled free-flow and porous-medium systems which is suitable for arbitrary flow directions. We consider a narrow transition region between these two flow systems that stores and transports mass, momentum, and energy. The proposed hybrid-dimensional model incorporates the Stokes equations in the free flow, the averaged Brinkman equations along the transition region, and Darcy's law in the porous medium. Appropriate transmission conditions are considered between the three regions. The well-posedness of the developed hybrid-dimensional model is proven. The model is validated against the pore-scale resolved simulations and compared with other coupling concepts. Numerical simulation results demonstrate the advantages of the proposed model in comparison to the coupling concepts available in the literature.

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