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A multilayer Saint-Venant model with density variation effects applied to 2D submarine gravity flows

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A submarine gravity flow, more precisely a hyperpycnal current, is a flow of a dense sediment-water mixture along a submarine floor. This is a fast phenomenon induced by a major river flood or submarine slope instability.
Our major interest is to predict the evolution of the sedimentary filling due to the stacking of such flows over millions years. To understand the physical processes that induce these hyperpycnal flows, many researchers focused on an accurate description of the phenomenon, for example by solving the 3D Navier-Stokes equations coupled with a mass transport equation. Unluckily, if such approaches are well-suited for the description of a single event, they are too computationally expensive to predict the sedimentary deposit over millions of years, *i.e.* over millions of events.
In a first step, we propose here a simplified model of a single hyperpycnal event based on the Saint-Venant model. This approach, which derives from an asymptotic approximation of the Navier-Stokes equations, allows to obtain results with a low computational time (*i.e.* well-suited for millions of flows). Classically, in shallow water equations, a constant density assumption is considered. However, in our case, given the highly concentrated flows involved, this assumption is not valid anymore and hence, the temporal and spatial variation of fluid density cannot be neglected.
First, the extension of the classical derivation of the Saint-Venant equations to the case of variable density is presented. The resulting system, which takes into account the variation of density along the flow direction, is thus coupled to a density transport equation.
Then, due to the high density stratification in the fluid flow along the vertical direction, a multilayer approach is adopted. In essence, it consists in discretizing the flow thickness into different layers and hence, considering a Saint-Venant formulation associated to each vertical layer.
Numerical implementation of the model is discussed and the above-mentionned theoretical extension of the classical Saint-Venant model is validated through a comparison with classical benchmarks. The impact of the variable density assumption is analysed.