On the influence of the thickness of the sediment moving layer in the definition of the bedload transport in Exner system

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We are interested in the study of sediment transport in shallow water regimes. In particular we study bedload transport which is the part of the total load that is travelling immediately above the bed. In this context, a mass conservation law also called Exner equation is used to update the bed elevation. This equation is often coupled with the shallow water equations describing the overland flows. The complete system of PDE may be written in the form

$$\begin{cases} \partial_t h + \partial_x(hu) = 0 \\ \partial_t(hu) + \partial_x(hu^2 + gh^2/2) = -gh\partial_x(z_b + z_r) \\ \partial_t z_b + \partial_x q_b = 0 \end{cases}$$

where h is the water depth, u is the flow velocity, and z_b is the sediment layer that moves with the fluid. This sediment layer is supposed to stay on a non-erodible fixed layer of thickness z_r which is usually called the bedrock layer (see Figure 1).
One could assume that the sediment layer can be decomposed in two layers: a layer that moves due to the action of the river, whose thickness is denoted by z_m, and a layer composed by sediments that are not moving but are susceptible to move and denoted by z_f. We have the relation $z_b = z_m + z_f$.

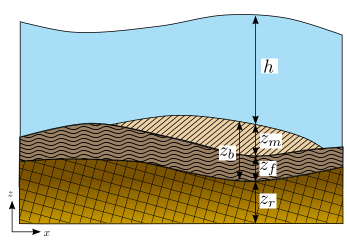

Figure 1: Sketch of shallow water over an erodible bed.

In general, the solid transport discharge may depend on all the unknowns $q_b = q_b(h, hu, z_b, z_f)$ but classical formulae for this bedload transport only depend on the hydrodynamical variables h and u and they do not take into account the thickness of the sediment layer. As a consequence the mass conservation law for the sediment layer may fail.
We propose a modified general definition for bedload transport flux that takes into account the thickness of the sediment layer. Compared to classical formulae this one has the advantage of preserving sediment mass in situations where sediment is isolated inside the considered domain. This new formulation reduces to the classical one when we consider quasi-uniform regimes. Moreover, it considers two layers of sediment: one that is actually moving due to the fluid and one that is not moving but could be entrained into the moving layer. As a consequence, the ideas taken into account are closer to the physics of the problem. Numerical simulations show that this generalization of solid transport flux is very promising. In particular, we remark that the vertical profiles on the front of an advancing dune (characteristic when using a classical formulation) are avoided and smoothed in a more realistic way.

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