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Accounting for dune sorting in modeling river morphodynamics and the river long profile

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River dunes, which occur in low-slope sand-gravel bed and sand bed river reaches, are generally characterized by an upward fining pattern, which results from sorting due to grain flows down their avalanche lee faces. Such grain flows make coarse particles preferentially deposit at lower elevations of the lee face, while finer ones show a preference for its upper elevations. In case of selective transport conditions (or even partial transport conditions), a less mobile (or immobile) coarse layer forms underneath the migrating bedforms. Before considering the effects of dune sorting on the river long profile, let us first have a look at some general trends along the river profile. Tributaries increasing the river's water discharge in streamwise direction induce a streamwise increase in flow depth. As under subcritical conditions mean dune height generally increases with increasing flow depth, dune height shows a streamwise increase, as well. As the standard deviation of bedform height linearly increases with its mean value, also the standard deviation of bedform height increases in streamwise direction. As a result, dune sorting results in a loss of coarse particles to the lower elevations of the bed that are less or even rarely exposed to the flow. This loss of coarse particles to lower elevations thus increases the rate of fining in streamwise direction. As finer material is more easily transported downstream than coarser material, a smaller bed slope is required to transport the sediment downstream. In other words, it is hypothesized that dune sorting adds to river profile concavity, compared to the combined effect of abrasion, selective transport, and tributaries alone. The authors have developed a bed layer-type mass conservation model that is inspired by the ones of Hirano (1971) and Ribberink (1987). The model consists of two active layers: a bedform layer representing the sediment in migrating bedforms of varying geometry and a coarse layer representing the less mobile coarse sediment underneath the bedforms. By definition, the sum of the exposure of both active layers equals unity. Although the bedform layer is homogeneous, its upward fining is accounted for in the submodels for the sediment fluxes within the bed. The exposure of the coarse layer is governed by the rate of sediment supply from upstream. If the sediment supply rate is smaller than the sediment transport capacity, the coarse layer becomes exposed. This approach is based on earlier work on exposure of river bedrock (e.g. Sklar & Dietrich, 2004, 2008). We have set up a numerical model that combines the above mass conservation model for mixed sediment with the shallow water equations and empirical relations for mixed sediment transport and friction. The resulting numerical model is validated against data from earlier flume experiments. The model results agree well with the experimental data and confirm how dune sorting adds to river profile concavity.