Accuracy of bed-load transport models in eddy-resolving simulations

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This work investigates the accuracy of commonly used bed-load transport models when applied in combination with high-resolution Navier-Stokes solvers. Empirical bed-load models predict the transport rate of sediments based on the average bottom shear-stress, while eddy-resolving approaches allow for a space- and time-dependent description of the bottom shear-stress distribution D'Alessandro et al. (2021). We discuss the effect that a fine-graining of the stress distribution provided by the flow solver has on the transport model predictions, as shown for instance in Figure 1. To this aim, we performed Direct Numerical Simulation of a channel flow and used the resulting database to mimic Wall-Resolved and Wall-Modelled Large-Eddy Simulations.

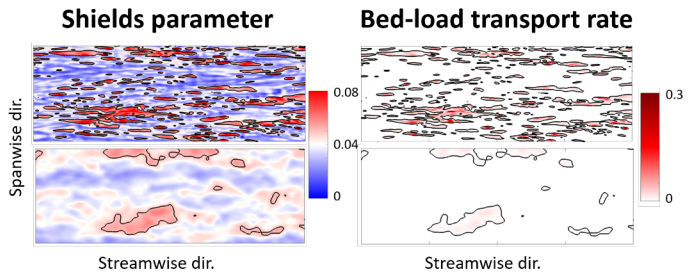

Figure 1: [Left] Contours of the instantaneous Shields parameter $\theta(x,z)$, for a case with average $\langle\theta\rangle = 0.04$; (top) DNS; (bottom) Wall-Modeled LES. [Right] Contours of the bed-load transport rate, $\Phi[\theta(x,z)]$, predicted with DNS (top), and Wall-Modeled LES (bottom). The value $\theta_{cr} = 0.05$ used in the model by Engelund and Fredsoe (1976) is shown as a solid contour.

We compared several bed-load transport models to experimental measurements to identify and highlight their limitations. We find that for small values of the Shields parameter (ratio of viscous and gravitational forces) the fine spatial and temporal resolution of wall-resolved simulations can yield overestimation of the bed-load transport rate; whereas more coarse-grained methods, such as wall-modelled Large Eddy Simulations, result in improved predictions. We also show that a short-time averaging of the force exerted by the fluid on the sediments, which we tested in three different configurations (channel flow with smooth and rough walls and flow over an idealized two-dimensional river dune), improves the accuracy of the bed-load transport predictions.

References

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