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Flow Patterns at the Interface Between Free Flow and Sediment Bed

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Bedload transport phenomena in rivers and reservoirs are driven by the flow pattern that develops at the interface between free flow and sediment bed. This is a very difficult area to investigate, due to heterogeneous flow which is often restricted to small length scales and hard to resolve with measuring instruments. Yet its interpretation is of prime interest for the understanding of the mass and momentum exchange between the free flow and the sediment. When dealing with the sediment transport triggering mechanism, most studies focus on the flow that develops above the bed, while the characteristics of the flow inside the bed are usually extrapolated from above or simply neglected. This approach yields an incomplete picture of what happens at the interface. Motivated by this, we propose a study where a free-surface flow tops a permeable bed composed of layers of equally-sized spherical beads. The physics of this configuration, originally analyzed with an experimental setup at the University of Aberdeen, was only partially understood, due to the difficulties in measuring velocity and pressure inside the pores. With a Large-Eddy Simulation (LES) we resolve the velocity and pressure fields in both the free flow and inside the porous bed. The no-slip boundary along the beads' surface is imposed using immersed boundaries, which also allows to compute the force exerted by the flow. We observe the development of momentum exchange between free flow and the porous bed, which activates turbulence penetrations that affect the pores closer to the surface of the permeable bed, and has two important consequences. First, the streamwise velocity in these pores is lower than that in the lower layers, a fact that challenges the usual assumption of a monotonically decreasing velocity profile within the bed. Secondly, the turbulence penetration generates an extra fluctuating component in the sphere lift forces whose role for the initiation of their movement is still not clear.