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A Probabilistic Model for Sediment Entrainment: the Role of Bed Irregularity

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A generalized probabilistic model is developed in this study to predict sediment entrainment under the incipient motion, rolling, and pickup modes. A novelty of the proposed model is that it incorporates in its formulation the probability density function of the bed shear stress, instead of the near-bed velocity fluctuations, to account for the effects of both flow turbulence and bed surface irregularity on sediment entrainment. The proposed model incorporates in its formulation the collective effects of three parameters describing bed surface irregularity, namely the relative roughness, the volumetric fraction and relative position of sediment particles within the active layer. Another key feature of the model is that it provides a criterion for estimating the lift and drag coefficients jointly based on the recognition that lift and drag forces acting on sediment particles are interdependent and vary with particle protrusion and packing density. The model was validated using laboratory data of both fine and coarse sediment and was compared with previously published models. The study results show that for the fine sediment data, where the sediment particles have more uniform gradation and relative roughness is not a factor, all the examined models perform adequately. The proposed model was particularly suited for the coarse sediment data, where the increased bed irregularity was captured by the new parameters introduced in the model formulations. As a result, the proposed model yielded smaller prediction errors and physically acceptable values for the lift coefficient compared to the other models in case of the coarse sediment data.