Geophysical Research Abstracts
Vol. 17, EGU2015-3246, 2015
EGU General Assembly 2015

Highly-resolved numerical simulations of bed-load transport in a turbulent open-channel flow

Bernhard Vowinckel (1), Tobias Kempe (1), Vladimir Nikora (2), and Jochen Fröhlich (1)

(1) Institute of Fluid Mechanics, Technische Universität Dresden, Dresden, Germany (bernhard.vowinckel@tu-dresden.de),
(2) School of Engineering, The University of Aberdeen, Aberdeen, Schotland

The study presents the analysis of phase-resolving Direct Numerical Simulations of a horizontal turbulent open-channel flow at small relative submergence, which is laden with a very large number of spherical particles. These particles have a mobility close to their threshold of incipient motion such that they are transported in bed-load mode constantly colliding with the sediment bed. The coupling of the fluid phase with the disperse phase is realized by an Immersed Boundary Method. The paper provides a detailed study addressing the impact of the collision model on the scenario of bed-load transport illustrating the necessity of a sophisticated representation of particle contact to reproduce patterns known from experimental evidence. Statistical tools are presented to identify and describe the key mechanisms governing the fluid-particle interaction. The Double-Averaging Methodology is applied for the first time to the situation of mobile rough beds. Taking advantage of the highly-resolved datasets produced, this methodology provides a framework to convolute the data in such a way that the most prominent flow features are well described by a handy set of double-averaged (in time and space) quantities. In addition, a systematic study elucidating in detail the impact of the key parameters mobility and sediment supply on the pattern formation of large-scale particle clusters will be presented. This is done using a very large computational domain to allow bed-forms to evolve with minimal spatial constraints. Similar to experimental observations, it is found that a low transport rate is linked to streamwise oriented ridges, while a large sediment supply results in large-scale clusters that propagate in streamwise direction. A detailed description of fluid quantities links the developed particle patterns to the enhancement of turbulence and ultimately to a modified hydraulic resistance. The large domain allows for a large number of independent erosion events, such that conditional averaging provides a very clear description of the processes involved for incipient particle motion. Furthermore, the detection of moving particle clusters as well as the investigation of their surrounding flow field is performed by an analysis using a moving frame coordinate system. The presented numerical method as well as the statistical tools are shown to be very suitable tools to study the complex situation of bed-load transport in open-channel flow and to give detailed insight into the key mechanisms of particle-laden flows.