Modelling time dependent flow fields over three dimensional dunes

Hardy, R.J., Marjoribanks, T.I., Parsons, D.R., Reesink, A.J., Murphy, B., Ashworth, P.J. and Best, J.L.

The flow field over dunes has been extensively measured in laboratory conditions and there is now a general understanding of the nature of the flow over dunes formed under equilibrium flow conditions. However, fluvial systems typically experience unsteady flow and therefore the sediment-water interface is constantly responding and reorganizing to this unsteadiness, over a range of both spatial and temporal scales. This is primarily through adjustment of bed forms (including ripples, dunes and bar-forms) which then subsequently alter the flow field. This paper investigates, through the application of a Large Eddy Simulation (LES) model, the influence of these roughness elements on the overall flow and the variation in flow resistance during a change in flow conditions.

To provide boundary conditions and a validation dataset for the LES model, a series of physical experiments were undertaken in a flume, 16m long and 2m wide, where fine sand (D_{50} of 239µm) was water worked under a range of unsteady hydraulic conditions that generated a series of quasi-equilibrium three-dimensional bed forms. During the experiments flow was measured with a series of acoustic Doppler velocimeters. On four occasions, the flume was drained and the bed topography measured with terrestrial LiDAR to create digital elevation models. LES was used to simulate the three-dimensional time-dependent flow fields over the four static bed topographies from the experiments. The numerically predicted flows were analyzed by standard Reynolds decomposition approaches and a Lagrangian coherent flow structure identification method. The results show that superimposed bed forms, that are common to bed form fields adjusting to changes in flow conditions, can cause changes in the nature of the classical separated flow regions in the lee side of dunes. In particular, the number of locations where vortices are shed and the points of flow reattachment, which effect the time dependent prediction of shear stress, were found to alter substantially. This has significant implications for both the flow dynamics over dunes and of the increased resistance caused by the superimposed bed forms generated by unsteady flow as well as the sediment entrainment and sediment transport dynamics as the results enable improved process understanding of three dimensional nature of bed form adjustment to changes in flow conditions.

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bedforms in unsteady flows