Flow fields over unsteady three dimensional dunes

Hardy, R.J., Ressink, A., Parsons, D.R., Ashworth, P.J. and Best, J.L.

The flow field over dunes has been extensively measured in laboratory conditions and there is general understanding on 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 these unsteady flows, 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 numerical model, the influence of these roughness elements on the overall flow and the increase in flow resistance. A series of experiments were undertaken in a flume, 16m long and 2m wide, where a fine sand (D50 of 239μm) mobile bed was water worked under a range of unsteady hydraulic conditions to generate a series of quasi-equilibrium three dimensional bed forms. During the experiments flow was measured with acoustic Doppler velocimeters, (aDv's). On four occasions the flume was drained and the bed topography measured with terrestrial LiDAR to create digital elevation models. This data provide the necessary boundary conditions and validation data for a Large Eddy Simulation (LES) model, which provided a three dimensional time dependent prediction of flow over the four static beds. The numerical predicted flow is analyzed through a series of approaches, and included: i) standard Reynolds decomposition to the flow fields; ii) Eulerian coherent structure detection methods based on the invariants of the velocity gradient tensor; iii) Lagrangian coherent structure identification methods based upon direct Lyapunov exponents (DLE). The results show that superimposed bed forms can cause changes in the nature of the classical separated flow region in particularly the number of locations where vortices are shed and the point of flow reattachment, which may be important for sediment entrainment and sediment transport dynamics during bed form adjustment. Finally, the flow predictions enable a reassessment of the drag caused by the superimposed bed forms generated by unsteady flow.

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