Geophysical Research Abstracts
Vol. 13, EGU2011-6871, 2011
EGU General Assembly 2011

Effects of bed form structure on particle-turbulence interaction in unsteady suspended sediment-laden laboratory open-channel flows

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The mechanism of sediment transport in rivers and open channels is governed by complicated interactions between unsteady (accelerating and decelerating) turbulent flow, particle motion and bed configuration. Turbulence plays an essential role in suspended sediment transport, and in turn particle motion influences velocity profiles. Furthermore, understanding the dynamics of unsteady sediment-laden water flows and characterizing the velocity of suspended particles is essential for enhancing the predictive accuracy of sediment transport and its impact on environmental processes in the water column.
In order to simulate fine sediment dynamics over an armored bed in a river during the passage of a flood wave, unsteady (first accelerating, then decelerating) open-channel flow over a movable (but not moving) coarse gravel bed (D50 = 5.5 mm) was studied. A layer of fine sediment of mean particle size about 120 [U+F06D]m was placed on the coarse gravel bed. The thickness of the fine sediment layer on the gravel bed was varied between 2 mm and 6 mm. Quasi-instantaneous profiles of velocity and sediment concentration were taken simultaneously and co-located by combining an acoustic Doppler and imaging method (ADVP) with an optical method (PTV) for suspended sediment particle tracking. Measurements resolved turbulence scales.
Systematically higher friction velocities were observed in accelerating flow than in decelerating flow for comparable mean flow velocities. This indicates that for the same change of relative submergence, different flow dynamics are generated during accelerating and decelerating flows. During the final phase of the accelerating flow range, fine sediment suspension from the bed started in bursts and rapidly created a ripple pattern that remained nearly stationary. Thereafter, vortices, shedding from the ripple crests, produced most of the sediment suspension into the water column in the form of events, making suspension intermittent. Simultaneously, sediment particles rolled along the bed following the ripple structure, thus slowly advancing the ripple pattern in the direction of the flow. However, ripple geometry and ripple shape were not altered by this process. With the ripple bed established, flow deceleration had less obvious effects on particle motion. Due to the ripple structure, high sediment resuspension events continued to occur in bursts during the decelerating flow even though mean flow velocity and friction velocity decreased. This event structure in fine sediment suspension is seen by the ADVP and the PTV methods. PTV velocity vectors varied in speed and orientation, but were organized in large coherent packets, mainly in the near bed layers, but also extending well above the bed, supporting the concept that coherent structure events contribute to sediment suspension in unsteady flow.