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Double-averaged turbulent structure of gravel-bed river flows

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River modelers need input on the flow turbulence structure from actual field measurements in order to resolve turbulence equation closures. The present work presents and discusses instantaneous velocity measurements made in the Swiss river Venoge using a 3D Acoustic Doppler Velocity Profiler. The measurements were made on a 3x5 rectangular horizontal grid (x-y). Fifteen velocity profiles were equally spaced in the spanwise direction with a distance of 10 cm, and in the streamwise direction with a distance of 15 cm. The vertical resolution of the measurements is roughly 0.5 cm. A measuring grid covering a 3D control volume was defined. The local topography of the riverbed was determined by the sonar-backscattered response. The instantaneous velocity profiles were measured for 3.5 min with a sampling frequency of 26 Hz. The riverbed is hydraulically rough, composed of coarse round gravel, with relative submergence of 2.94. The presence of large roughness in river flows induces major changes in the turbulence structure, especially within the inner layer. Turbulent intensities and turbulent kinetic energy values grow roughly according with the expected for smooth flows from the surface until roughly $z/h \approx 0.40$; maximum turbulent kinetic energy values are typically observed at the upper limit of the roughness layer. Below this level their distribution is determined by local effects of the randomly distributed bed-forms where large spatial variations are observed. The large spatial deviations in the turbulence structure of the flow may only be adequately account for by applying double-averaging (both in space and time) methods – DAM. This methodology constitutes an adequate theoretical supported framework to account for the spatial and time variability of low submergence flows. From the application of a spatial averaging operator to the Reynolds Averaged Navier-Stokes equations, the terms related the influence of the bed form become evident: changes in the velocity profiles, and form-induced vs. Reynolds stresses. The application of the double-averaged methodology allows for the distinction of layers where flow similarities are observed.

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