LARGE EDDY SIMULATIONS OF FLOW OVER TWO DIMENSIONAL DUNES

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This paper presents Large Eddy Simulation (LES) of turbulent open channel flow over a two-dimensional dune. The results of the computations are compared with recently reported Laser Doppler Velocimetry (LDV) measurements. The experimental data validate the simulations, which in turn provide an ideal complement to the experiments in order to investigate the mean and instantaneous flow properties with a high spatial resolution. The Reynolds number Re_τ, based on the average friction velocity u_τ and the average flow depth *h*, is approximately 3000. Figure 1 shows time and width averaged streamlines of the flow over one wavelength of the dune. The flow separates at the dune crest, and reattaches just before the bed elevation increases towards the next crest. The flow recovers after a large recirculation zone, and develops a new boundary layer over the stoss-side of the next dune. As can be seen in Figure 2 below, the time-averaged velocities calculated by the LES are in very good agreement with the observed data predicting all the features of the turbulent flow over dunes. In addition, the second order statistics, namely the Reynolds stresses show a good match to the LDV measurements. Furthermore, the instantaneous flow field is investigated with special emphasis on the occurrence of coherent structures. Figures 3 and 4 visualize the occurrence of coherent large-scale turbulent structures on the dune leeside. Depending on the water-depth-to-dune-height-ratio, these structures may convect up to the free surface where they result in the so-called boils (Bennett and Best, 1996). For the case of $h/k=4$ investigated here these structures do not reach the free surface but dissipate at a height of approximately $3k$. The two figures clearly show the mechanism of large-scale turbulence structure. The flow separates at the dune crest and forms vortices which travel downstream and at the same time move upwards. The upper part of the structure reaches faster flowing fluid (indicated by the red color) that stretches the vortices and breaks them up into smaller parts until they finally dissipate.

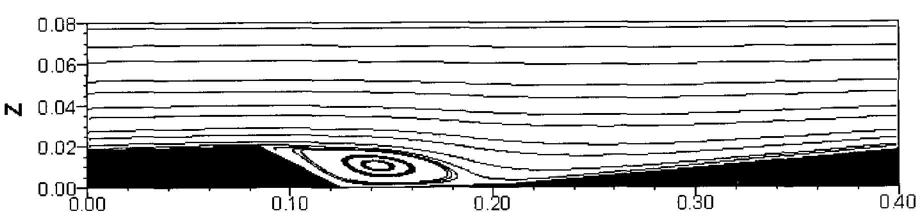

Fig. 1 Time and width averaged streamlines for the flow over a dune

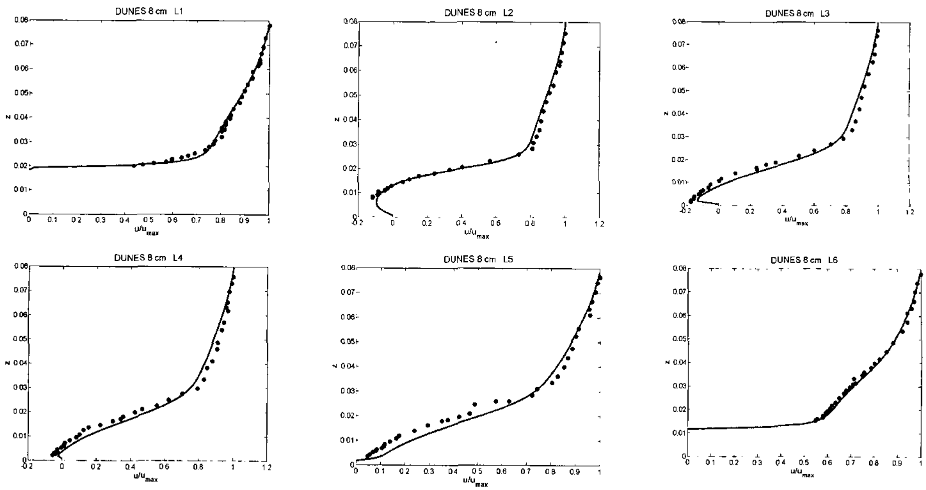

Fig. 2 Comparison of time-averaged streamwise velocities along the measurement verticals L1-L6

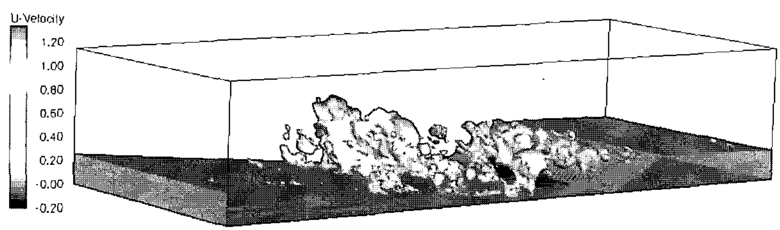

Fig. 3 Isosurfaces of turbulent pressure fluctuations p' colored with the instantaneous streamwise velocity at an instant t=0

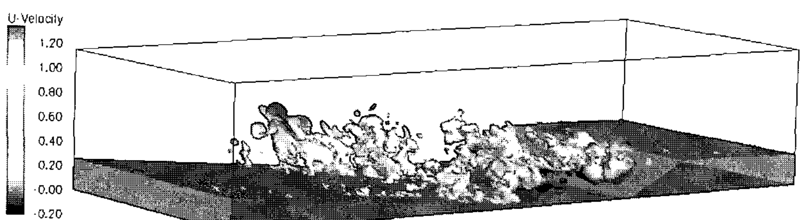

Fig. 4 Isosurfaces of turbulent pressure fluctuations p' colored with the instantaneous streamwise velocity at an instant t=0+Δ t