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Large eddy simulation of very-large-scale motions in the neutrally stratified atmospheric boundary layer

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Large eddy simulation was used to investigate the very-large-scale motions (VLSM) in the neutrally stratified atmospheric boundary layer at a very high friction Reynolds number. The vertical height of the computational domain is Lz = 1000 m, which corresponds to the thickness of the boundary layer. The horizontal dimensions of the simulation domain are chosen to be Lx = 32Lz and Ly = 4Lz respectively, in order to contain a sufficient number of large-scale structures. The spatially coherent structures associated with VLSM are characterized through flow visualization and statistical analysis. The instantaneous velocity fields in streamwise/spanwise planes give evidence of streamwise-elongated zones of low speed fluid with negative streamwise velocity fluctuation, which is flanked on either side by similarly elongated high speed ones. The pre-multiplied power spectra and two-point correlations indicate that the scales of these streak-like structures are very large, up to 20Lz in the streamwise direction and Lz in the spanwise direction. These features are similar to what have been found in the logarithmic region of laboratory-scale boundary layers by direct numerical simulations and experiments conducted at low to moderate Reynolds numbers. The three dimensional correlation map and conditional average of the three components of velocity further indicate that the low-speed and high-speed regions possess the same elongated ellipsoid-like structure, which is inclined upward along the streamwise direction, and they are accompanied by counter-rotating roll modes in the cross section perpendicular to the streamwise direction. These findings are in agreement with recent observations made from field campaigns in the atmospheric boundary layer.