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Turbulence Generation in the Atmospheric Boundary Layer and Limitations of the Monin-Obukhov Similarity Theory

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Turbulent fluxes from the Cooperative Atmosphere-Surface Exchange Study in 1999 (CASES-99) field experiment are further analyzed for both day- and nighttime as a follow-on to the investigation of the nighttime turbulence in Sun et al. (2012). The behavior of momentum and heat fluxes is investigated as functions of wind speed and the bulk temperature difference between observation heights and the surface. Vertical variations of momentum and heat flux at a given height z are correlated and are explained in terms of the energy and heat balance in a layer above the ground surface in which the surface heating/cooling and momentum sink need to be included. In addition, the surface also plays an important role in constraining the size of the dominant turbulent eddies, which is directly related to turbulence strength and the length scale of turbulence generation. The turbulence generation is not related to local vertical gradients especially under neutral condition as assumed in Monin-Obukhov similarity theory. Based on the observed relationships between momentum and heat fluxes, a new bulk formula for turbulence parameterization is developed to mainly examine the above-mentioned surface effects on vertical variation of turbulent momentum and heat fluxes. The new understanding of the observed relationships between these turbulent variables and mean variables explains the observed nighttime turbulence regime change observed in Sun et al. (2012) as well as the daytime momentum and heat flux variations with height up to the maximum observation height of 55 m.