STATISTICAL CHARACTERISTICS OF TURBULENCE AND THE BUDGET OF TURBULENT ENERGY IN THE SURFACE BOUNDARY LAYER*

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ABSTRACT

Turbulence measurements of wind and temperature were made by sonic anemometer-thermometers in the first thirty meters of the atmosphere. Direct measurements of turbulent fluctuations are possible to present the data in the context of the Monin-Obukhov similarity theory. This experiment has allowed a detailed study of the turbulent energy budget as well as turbulence statistics in the surface boundary layer.

Firstly, turbulence statistics are analyzed and interpreted in relation to measured parameters such as height, mean wind speed and stability conditions. The values for the friction velocity u_* increase linearly with the mean wind speed $\overline{U}$. The standard deviations of the velocity components have close relations to mean wind speed, friction velocity and stability. The data for the horizontal components are rather scattered in comparison with those for the vertical compenent. The normalized intensity of turbulence for the vertical component, σ_w/u_*, shows the dependence on the stability parameter z/L, and is given by a universal function of z/L according to the similarity theory. The values for σ_w/u_* in neutral conditions are in agreement with the results obtained by other investigators. The spectral analysis of turbulent fluctuations reveals that the spectra of the velocity components on the high-frequency side have the slope of $-5/3$ corresponding to Kolmogorov's hypothesis. The $-5/3$ region is assumed to be the inertial subrange, where the ratio between the spectra of the longitudinal component u and the vertical component w is found to be 4/3. In addition, the spectral analysis shows that the horizontal scale of turbulence is larger than the vertical one, and that the scale of turbulence increases with both height and stability, and decreases with the mean wind speed.

Secondly, terms in the budget equation of turbulent energy were derived from turbulence statistics, and their behaviors were examined. The vertical structure and time change of the turbulent energy budget are shown for unstable and stable conditions in comparison with the budget in the planetary boundary layer, obtained previously by other investigators. The behavior of each term in the budget equation was considered for a wide range of stability conditions.

The values for viscous dissipation were obtained from the inertial-subrange levels of the longitudinal velocity spectra with a value of 0.50 for the spectral constant. Viscous dissipation increases with the third power of mean wind speed at any height, and decreases with height. For

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unstable conditions, mechanical production and viscous dissipation of turbulent energy are a main energy source and sink, respectively. They decrease with height. Turbulent transport of turbulent energy is an energy sink to approximately balance buoyant production which may be a source or sink depending on stability. For stable conditions, the magnitude of each term is very small and almost constant with height.

Thirdly, a model of turbulent energy was deduced from the results, and presented in the context of the Monin-Obukhov similarity theory. A general specification of the turbulent energy budget including the case of stable conditions has been achieved through this model.