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Statistical description of the temperature field near the surface – multipoint measurements

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A.M. Obukhov and A.S. Monin described the hydromechanics of the surface layer by the method of statistical moments and created a semi-empirical theory of a stationary and horizontally uniform surface layer. Later, A.M. Obukhov predicted a power law for a one-dimensional spectrum of a locally isotropic field of a passive admixture. The predicted regularity was observed later in the temperature spectra not only in the interval where it is possible to assume local isotropy, but also far beyond its limits, including also the interval that makes the main contribution to the vertical turbulent heat flux. It became obvious that the heat is transferred by the inhomogeneities of the velocity and temperature fields, which have vertical dimensions that cover the entire surface layer.

In order to investigate such inhomogeneities, regular multi-point measurements of vertical temperature profiles were initiated. To analyze the information received, we used several approaches.

1) Investigation of probability distributions. Temperature distributions turned out to be asymmetric, and, with nonequilibrium stratification, the absolute value of asymmetry is minimal near the underlying surface, and with increasing height it grows. The asymmetry of the probability distributions for spatial temperature differences can be explained by the asymmetry of the shape of the observed large-scale emissions, known as the ramp structures. The coefficient of excess of these distributions was close to 5.

2). Investigation of coherent structures. We define coherent structures in unstable conditions as positive large-amplitude outliers that occur synchronously on the interval of heights between 0.1 and 1 in units of Obukhov scale. At each altitude, the observed sequence of such emissions of random duration with a random distance between them was represented as an alternation of 1 and 0, i.e., a telegraph signal. It was found that the correlation functions and the spectra of the telegraph and initial implementation are strikingly similar, and the spectrum is close to a power-law spectrum with an exponent of about $-5/3$.

3). Study of the statistical characteristics of profiles. Considering the sequence of instantaneous profiles, it is possible to calculate the average profile, the deviation from it, the covariance matrix and the natural orthogonal basis . The first eigenfunction does not change sign and its eigenvalue is about 60% of the total variance. It describes the synchronous deviation of a large amplitude from the mean value at all altitudes, i.e., the passage of a coherent structure.

4). Temperature maps. Multipoint measurements made it possible to get the maps of isothermal surfaces. It turned out that stratification is observed not only with a 20-minute averaging but also with a one-second averaging. In the Boussinesq approximation, surfaces of equal density practically coincide with isotherms. So, in the incompressibility approximation, the motion of the air, by virtue of the Lagrangian invariance of the density, goes along tangents to surfaces of equal density, that is, under given conditions on isothermal surfaces.