

Statistical analysis of atmospheric turbulence in urban canopy

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The main exchange of energy and mass between the atmosphere and the surface occurs through the means of turbulent processes in the boundary layer of the atmosphere. A modern atmospheric dynamics models use simplified schemes for calculating energy exchange with the surface, based on the Monin-Obukhov similarity theory (MOST). The main requirement of MOST is the uniformity of the underlying surface. This simplification reduces the accuracy of the forecast, especially in regions with heterogeneous orography, such as in urban surface. The obtained regularities in the future may allow us to choose the most accurate parameterisation for better use of MOST in urban conditions.

This paper presents the result of the analysis of the data obtained from the eddy covariance tower installed in the Meteorological observatory of Moscow State University. Acoustic anemometers with a frequency of 20 Hz record three components of wind speed and acoustic temperature at altitudes of 2.2 m, 11.1 m and 18.8 m. For processing high-frequency data and calculating the statistical characteristics of turbulence, a set of programs created by the authors was used.

The seasonal and daily variability of heat and momentum fluxes over an urban surface was analyzed based on data series for period from 2020 to 2022. The detailed statistical analysis of the influence of eddy structures was carried out on the formation of turbulent fluxes in the city. The method proposed in (Barskov et al., 2019) was used to identify coherent vortices. The method is based on the hypothesis of the relationship of third and second moments, described by the ratio:

$$\overline{w'w'c'} = C S_w (\overline{w'w'})^{1/2} \overline{w'c'},$$

where $C \sim 1$ is non-dimensional constant, S_w is skewness of vertical velocity, w is vertical velocity and c is value carried by the flux (Abdella, McFarlane, 1997; Zilitinkevich, 1999). The results obtained from the measurement data were compared with the results of direct numerical simulation. The results indicates a significant contribution of coherent structures to the formation of vertical fluxes over a geometrically complex surface, which is consistent with the estimates received earlier for natural and city landscapes (Barskov et al, 2022). A footprint was analyzed for various directions of wind and stratification conditions to assess the influence of an urbanized surface on the formation of heat and momentum fluxes. The calculation of footprints was carried out based on two-dimensional parameterisation (Kljun et al, 2015).

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