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Mathematical modelling of the air movement and passive tracers transport over a non-uniform surface with complex topography

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In numerous experimental studies focused on description of the turbulent exchange processes over uniform vegetation canopy the possible influence of spatial heterogeneity of surface topography is usually ignored that can obviously result in some uncertainties of local flux estimations. Within the framework of the study an improved 2D model allowing for effects of surface topography was developed and a stable finite-difference scheme for a numerical solution of the corresponding initial-boundary value problem was suggested.

The initial-boundary value problem includes the system of averaged Navier-Stokes equation, continuity equation and two equations for turbulent kinetic energy end the rate of its dissipation. The problem is solved in the domain with a curvilinear lower boundary that simulates the surface topography. In the first step we make conversion of the variables x, z and t into new variables x^*, z^* and t^* as follows: $x = L \cdot x^*$, $z = h(x) + (H - h(x)) \cdot z^*$, $t = L^2 \cdot t^*$ (where L is the length of the computational domain, H is its height, and the function $z = h(x)$ describes the topography) that allows to transform the computational domain to some rectangle. As the result of this variable conversion the additional terms, containing mixed derivatives, were appeared in the equations that make their numerical solution using finite-difference method more complicated.

The proposed finite-difference scheme is based on the method of splitting by processes that leads to two auxiliary problems: the Poisson equation for excess pressure and diffusion-advection type equations for all other functions. For their numerical solution the stable algorithms, based on matrix sweep method and implicit schemes, were developed. The results on numerical experiments with developed model showed that the influence of non-uniform surface topography on atmospheric fluxes within the atmospheric surface layer is relatively large. It is depended on surface slope and elevation range and can exceed observed effects of spatial vegetation heterogeneity.

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