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Experimental Study of the Atmospheric Surface Layer Turbulent Structure above Inhomogeneous Surface

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Parameterization of air-sea/land fluxes is of obvious relevance for the modelling of coupled atmosphere-ocean/land system, including climate modelling, weather forecasting, environmental impact studies, and many other applications. Traditionally, the flux-gradient relationships in the surface layer are described by Monin-Obukhov similarity theory (MOST), which assumes horizontal homogeneity of the underlying surface, including surface fluxes, aerodynamic and thermal roughness. Statistical properties of turbulence in the atmospheric surface layer have been extensively studied over homogeneous surfaces. However, detailed description of disturbances in the flow, generated over transition zones between surfaces with different roughness remains an important subject of theoretical and experimental studies.

We present the results of experimental studies of the turbulent structure of the surface layer above inhomogeneous surface. Experiments were conducted over a small lake surrounded by forest. The purpose of this study is evaluation of turbulent transport in the system "lake– surface air layer – forest". In order to distinguish the influence of the inhomogeneous landscape on the turbulent exchange in the atmosphere-surface system, excluding the effects of the thermal regime of the lake, the experiment was carried out in winter time over an ice-covered lake surface. In the first case we used an array of acoustic anemometers mounted on lake ice at different distances from the lake margin. In the second case 6-meter mast with three levels of measurements was installed in the center of the lake. Turbulent fluxes were calculated with Eddy Covariance and gradient methods.

The results showed that calculation of the energy exchange characteristics over an inhomogeneous surface, using traditional methods, including the conclusions of similarity theory, are unsuitable in some cases. When the turbulence of the atmosphere is significant, strong vertical mixing leads to a significant heat flux directed from the atmosphere to the surface (negative flux). And there isn't layer of constant fluxes in this case.

Inhomogeneity also generates meso-scale eddies and waves. These meso-scale motions may significantly contribute to the vertical structure of the boundary layer and hence, to the vertical exchange of heat and mass between the surface and the atmosphere.

The data of experiments in the Black sea coastal zone also were used. The data allow comparison of turbulent fluxes and other statistics as well as investigations of surface-layer scaling for different surfaces, including relatively smooth sea surface conditions and aerodynamically rough inland areas. Both stable and unstable stratifications were observed. The drag coefficient and diurnal variation of sensible heat flux were found to be indicators for different surface footprints. With onshore flow, the internal boundary layer in the coastal zone varied dramatically at the land-surface discontinuity. The offshore flow of generally warm air over cooler sea surface produced a stable internal boundary layer over the ocean surface downstream from the coast. The coastal inhomogeneities violate assumptions underlying the MOST, but the deviations of data from MOST were less profound for the scaled standard deviations and the dissipation rate under stable conditions. This work was supported by a grant from the RSF 17-17-01210.