Modeling atmospheric boundary layer flow over heterogeneous terrain

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Abstract

Predicting the spatial distribution of surface fluxes of momentum, sensible heat and water vapor over heterogeneous surfaces is of great importance for wind energy and environmental applications. Understanding land-air exchange requires detailed knowledge of turbulence over a wide range of spatial and temporal scales, and the complexity of such flows makes it difficult to obtain all the needed information through field experiments alone, and often necessitates high resolution eddy resolving numerical studies.

One of the outstanding issues that affect LES performance is treatment of the surface boundary conditions. Monin-Obukhov similarity theory (MOS) [Monin and Obokhov, 1954] has provided the most common boundary condition formulations for LES of ABL flows which compute the surface fluxes using the information in the surface layer. It has been shown that the direct application of the log-law for prediction of surface shear stress downwind of transitions can lead to large errors because the similarity theory is strictly valid only when applied over homogeneous surfaces and considering averages quantities.

In this study, large-eddy simulation (LES) with a scale dependent dynamic SGS model is used to simulate turbulent flows over heterogeneous terrain. Surface heterogeneity is added to the simulation in the form of streamwise transitions in surface temperature and aerodynamic roughness. The effect of surface heterogeneity on the average surface heat flux and stress is assessed. The growth of thermal internal boundary layer (IBL) after transitions is analyzed and compared with the available analytical formulations. In addition, the validity of the similarity theory for estimating of surface fluxes in heterogeneous terrain will be discussed in detail.

Keywords: Atmospheric boundary layer; Large-eddy simulation; Surface heterogeneity; Surface flux