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Influence of atmospheric stability and local turbulence structure upon model coefficients for large eddy simulation of the atmospheric boundary layer

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Parameterization of subgrid-scale (SGS) phenomena in large eddy simulation of turbulent flows is still a major challenge for scientists and engineers. The complexity of the problem is greatly enhanced when the subject is simulation of the atmospheric boundary layer. Effects due to mean shear, buoyancy, heterogeneity and non stationarity of boundary conditions compromise the performance of the SGS parameterizations currently available. The objective of this study is to use data obtained from field experiments to study the performance of the simplest model available (Smagorinsky model) under different flow conditions. The main goal is to uncover systematic dependencies of the Smagorinsky coefficient upon dimensionless parameters that characterize the local flow conditions. The local flow can be characterized using a local definition of the gradient Richardson number, the distance from the surface, the filter width and the invariants of the velocity gradient tensor. These invariants are related to some fundamental dynamic/kinematic characteristics of turbulent flows, such as enstrophy, vortex stretching, self-amplification of strain rate, and are expected to play an important role in scale-interactions of relevance to SGS modeling. In this a-priori study we use the HATS field data obtained from 14 3D-sonic anemometers arranged in two horizontal arrays in the atmospheric surface layer (DNS data is used for comparison). We make use of conditional averages to investigate how the SGS dissipation and the Smagorinsky coefficient depend on local properties of the resolved field. Results show that the local Richardson number is capable of capturing important effects of atmospheric stability on the values to be assigned to the coefficient. The local structure of the turbulent flow field also has a strong effect on the behavior of the Smagorinsky coefficient. We briefly discuss how this information can be used to improve dynamic SGS models.