Geophysical Research Abstracts, Vol. 7, 09680, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09680

Large-eddy simulation of stably stratified atmospheric boundary layer turbulence: a locally-averaged scale-dependent dynamic modeling approach

S. Basu, F. Porté-Agel and E. Foufoula-Georgiou
St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN 55414, USA. (basus@msi.umn.edu)

Following the pioneering works of Deardorff LES has become over the years an indispensable tool for the study of atmospheric boundary layer turbulence. However, until now LES models have not been sufficiently faithful in reproducing the characteristics of moderately and strongly stable boundary layers. The main weakness of LES is associated with our limited ability to accurately account for the dynamics that are not explicitly resolved in the simulations. Under stable conditions - due to flow stratification - the characteristic size of the eddies becomes increasingly smaller with increase in atmospheric stability, which eventually imposes an additional burden on the LES subgrid-scale (SGS) models. The recent GABLS (Global Energy and Water Cycle Experiment Atmospheric Boundary Layer Study) LES intercomparison study highlights that LESs of moderately stable BLs are quite sensitive to SGS models at a relatively fine resolution of 6.25 m. At a coarser resolution (12.5 m), a couple of commonly used SGS models even laminarised spuriously. This breakdown of traditional SGS models undoubtedly calls for improved SGS parameterizations in order to make LES a more reliable tool to study stable boundary layers.

In this work, a new-generation tuning-free subgrid-scale modeling approach, termed “locally-averaged scale-dependent dynamic” (LASDD) model, is developed and implemented to perform reliable large-eddy simulation of stable boundary layers. Overall, the agreement between the statistics of our LES-generated turbulence and those of the observations, as well as the reproduction of some well-established empirical formulations and theoretical predictions (e.g., Nieuwstadt’s Local Scaling hypothesis) are remarkable. The results show clear improvements over most of the traditional

SGS models in the surface layer. Also, in contrast to previous LESs of stable boundary layers that show strong dependence on grid resolution, the simulated statistics obtained with the LASDD model show relatively little resolution dependence for the range of grid sizes considered here. In essence, we show that tuning-free simulations of stable boundary layers are feasible even with relatively coarse resolutions if one uses a robust and reliable SGS scheme.