Geophysical Research Abstracts,
Vol. 11, EGU2009-1501, 2009
EGU General Assembly 2009

Large-eddy simulation experiments with nudging to observed mean meteorological profiles

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Large-eddy simulations (LES) are now recognized as useful numerical method to study turbulent flows in details. However, it is difficult to get experimental conditions of the LES runs in reasonable correspondence with realistic conditions resulting in the observed mean profiles of meteorological quantities. Inability to investigate the turbulent flow properties consistent with the observed mean or instant profiles reduces utility of the LES in practical applications, e.g. in air quality monitoring and short-term prediction. The problem addressed in this work may be formulated as follows: given the observed mean profiles of wind, temperature and scalar concentration, find a 3D fluctuations of those quantities which statistics are consistent (in some mathematical sense) with the given mean profiles. Generally, the problem may not have or may have non-unique solution. Nevertheless, a part of the problem, namely, reconstruction of the turbulent statistics, typically in vertical direction, consistent with the given mean profiles is nothing else but the widely employed turbulence closure approach. This work makes one step beyond that traditional approach. Using LES and additional relaxation terms in its equations, the algorithm iterates LES to reconstruct a 3D fluctuation field with restriction on the fluctuation energy imposed by consistency with the given profiles. At this stage only the simplest nudging has been used in the experiments. It is demonstrated that the technique can reconstruct the consistent statistics in a shear-driven flow. This reconstruction requires considerably less iterations than unrestricted simulation from suitable initial conditions. The reconstruction produces reasonable spectrum of fluctuations. Under proper choice of the computational domain, the large-scale part of the spectrum in unaffected by the relaxation procedure. The large-scale self-organization of turbulence, the major dynamical process affecting the turbulent transport, can be reproduced through nudging of the LES.