Geophysical Research Abstracts,
Vol. 11, EGU2009-12950, 2009
EGU General Assembly 2009

Examination of the local equilibrium assumption in LES of boundary layer turbulence using a nonlinear approach

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The assumption of local equilibrium between the rate of dissipation of kinetic energy and the subgrid scale (SGS) production was examined in large eddy simulation of boundary layer turbulence using a zero-equation nonlinear SGS approach. This approach is based on the dynamic structure model and satisfies the consistency of material frame indifference of the SGS stress tensor. Under the local equilibrium assumption, an overall kinetic energy transfer from unresolved scales to resolved scales (sometimes referred to as 'backscatter') is not allowed. The nonlinear approach is originally derived from the Taylor expansion of the SGS stress tensor, and does not employ a formulation of eddy viscosity. Thus, it does not purely dissipate kinetic energy at any resolved scale, and compared with most SGS models it is better able to deliver kinetic energy from small to large scales. The approach is computationally efficient; the cost is as low as the traditional Smagorinsky model. Tests of the new model were performed through a systematic comparison with well-established empirical formulations and theoretical predictions of a variety of characteristics such as mean shear, energy spectrum, and generalized log law. The statistics of the simulated velocity fields showed remarkable agreement with the theory and little dependence on resolution.