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Development of a nonlinear subgrid model for large-eddy simulation of the atmospheric boundary layer

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Subgrid-scale (SGS) modeling is a critical component in large-eddy simulation of the atmospheric boundary layer. A nonlinear SGS approach, as a simple alternative to the standard eddy-viscosity/diffusivity closure, has been introduced and implemented in simulations of a neutral atmospheric boundary layer and a stable atmospheric boundary layer. The new approach computes the structure of the SGS stress/flux (relative magnitude of components) based on the normalized gradient tensor/vector, which is derived from the Taylor expansion of the exact SGS stress/flux. The SGS magnitudes are estimated based on the local-equilibrium hypothesis. To resolve the instability issue of the original gradient model and ensure numerical stability, we adopt a clipping procedure to avoid local negative SGS dissipation rates. The approach using constant coefficients and coefficients determined using dynamic procedures is assessed through a systematic comparison with well-established theoretical predictions and reference results of various flow statistics. Simulation results show good agreement with the reference results and an evident improvement over results obtained using standard eddy-viscosity/diffusivity models.