Simulation of Atmospheric Boundary Layer Processes Using Local- and Nonlocal-Closure Schemes

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ABSTRACT

A soil–vegetation–atmospheric boundary layer model was developed to study the performance of two local-closure and two nonlocal-closure boundary layer mixing schemes for use in meteorological and air quality simulation models. Full interaction between the surface and atmosphere is achieved by representing surface characteristics and associated processes using a prognostic soil–vegetation scheme and atmospheric boundary layer schemes. There are 30 layers in the lowest 3 km of the model with a high resolution near the surface. The four boundary layer schemes are tested by simulating atmospheric boundary layer structures over densely and sparsely vegetated regions using the observational data from the First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment (FIFE) and from Wangara.

Simulation results indicate that the near-surface turbulent fluxes predicted by the four boundary layer schemes differ from each other, even though the formulation used to represent the surface-layer processes is the same. These differences arise from the differing ways of representing subgrid-scale vertical mixing processes. Results also indicate that the vertical profiles of predicted parameters (i.e., temperature, mixing ratio, and horizontal winds) from the four mixed-layer schemes differ from each other, particularly during the daytime growth of the mixed layer. During the evening hours, after the mixed layer has reached its maximum depth, the differences among these respective predicted variables are found to be insignificant.

There were some general features that were associated with each of the schemes in all of the simulations. Compared with observations, in all of the cases the simulated maximum depths of the boundary layer for each scheme were consistently either lower or higher, superadiabatic lapse rates were consistently either stronger or weaker, and the intensity of the vertical mixing was either stronger or weaker. Also, throughout the simulation period in all case studies, most of the differences in the predicted parameters are present in the surface layer and near the top of the mixed layer.

1. Introduction

In regional meteorological modeling, the performances of physical parameterization schemes of varying complexity are usually intercompared by simulating a weather system driven by a strong mesoscale or synoptic-scale forcing. For example, Mahfouf et al. (1987) tested different atmospheric boundary layer (ABL) schemes in simulating mesoscale circulations initiated by surface contrasts. Stull and Driedonks (1987) showed that modeled mesoscale circulations and rainfall are sensitive to the representation of subgrid-scale vertical mixing processes. However, simulation of weakly forced synoptic circulations such as those that typically exist during the summer months over the United States is of lesser interest to meteorological modelers, because of the limited weather activity during these periods.

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