Assimilating Surface Data to Improve the Accuracy of Atmospheric Boundary Layer Simulations

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ABSTRACT

Large errors in atmospheric boundary layer (ABL) simulations can be caused by inaccuracies in the specification of surface characteristics in addition to assumptions and simplifications made in boundary layer formulations or other model deficiencies. For certain applications, such as air quality studies, these errors can have significant effects. To reduce such errors, a continuous surface data assimilation technique is developed. In this technique, surface-layer temperature and water vapor mixing ratio are directly assimilated by using the analyzed surface data. Then, the difference between the observations and model results is used to calculate adjustments to the surface fluxes of sensible and latent heat. These adjustments are then used to calculate a new estimate of the ground temperature, thereby affecting the simulated surface fluxes on the subsequent time step. This indirect data assimilation is applied simultaneously with the direct assimilation of surface data in the model's lowest layer, thereby maintaining greater consistency between the ground temperature and the surface-layer mass-field variables. A one-dimensional model was used to study the improvements that result from applying this technique for ABL simulations in two cases. It was found that application of the new technique led to significant reductions in ABL modeling errors.

1. Introduction

The accuracy of modeled atmospheric boundary layer (ABL) structure critically depends on 1) the accuracy of initial conditions and specified surface parameters, 2) the kind of formulation used to represent surface and turbulent processes, 3) the spatial resolution of the model, and 4) the effective simulation of mesoscale and large-scale dynamics. A large number of studies (e.g., Pleim and Xiu 1995; Sistla et al. 1996; Alapaty et al. 1997b; Alapaty and Mathur 1998; Niyogi et al. 1999; Russell and Dennis 2000) have confirmed that ABL modeling errors can arise from one or more of these factors. Also, several of these studies found that such errors can have damaging effects in subsequent air pollution modeling (Sistla et al. 1996; Alapaty and Mathur 1998; Russell and Dennis 2000).

To alleviate such simulation errors, Ruggiero et al. (1996) have studied the effects of frequent assimilation of surface observations using an objective analysis in an intermittent technique. They found that their simple intermittent data assimilation improved mesoscale analyses and forecasts. However, intermittent assimilation can lead to dynamic imbalances and mass inconsistencies each time the model is restarted, which is undesirable for certain applications such as air quality studies (Seaman 2000). Stauffer et al. (1991) studied the impacts of direct assimilation of surface temperature observations in a continuous four-dimensional data assimilation (FDDA). They found that this approach reduces surface temperature errors but can lead to serious errors

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