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20.3 EVALUATION OF A COUPLED LAND-SURFACE AND DRY DEPOSITION MODEL THROUGH COMPARISON TO FIELD MEASUREMENTS OF SURFACE HEAT, MOISTURE, AND OZONE FLUXES

Jonathan E. Pleim[1], Aijun Xiu[2], Peter L. Finkelstein[1], and John F. Clarke[1]
[1]Atmospheric Sciences Modeling Division, NOAA, Research Triangle Park, NC 27711
(on assignment to the National Exposure Research Laboratory, US Environmental Protection Agency)
[2]Environmental Programs, MCNC, Information Technologies Division, Research Triangle Park, NC

1. INTRODUCTION

The Fifth Generation Mesoscale Model (MM5,Grell et al. 1993) has been modified to include an improved land-surface scheme with explicit treatment of soil moisture and evapotranspiration. A key aspect of this work is an indirect soil moisture nudging scheme which adjusts soil moisture according to model errors in surface level temperature and humidity. Since stomatal resistance is an important component of both evapotranspiration and dry deposition, a chemical dry deposition model is coupled to the land surface scheme through the use of several common elements. Both aerodynamic and bulk stomatal resistance computed in the evapotranspiration model are used to compute dry deposition of gaseous species. This technique has the advantage over many other dry deposition models of being able to respond to changing soil moisture conditions. Also, the soil moisture adjustment scheme should result in more realistic stomatal conductances and dry deposition velocities.

In a previous evaluation study (Pleim et al., 1996), model simulations of surface energy fluxes, dry deposition velocities, and planetary boundary layer (PBL) evolution, were compared to field measurements made near Bondville, IL during the summer of 1994. The model predictions compared quite well to observations for all parameters, including dry deposition velocity, over a corn field during moderately moist conditions. The current study focuses on comparison of model simulations to field measurements made in a soybean field in southern Kentucky during the summer of 1995.

2. SURFACE/PBL MODEL

Pleim and Xiu (1995) describe the development and initial testing of a land surface and PBL model for use in mesoscale models. Since that paper we have continued development of this model and applied it in full 3-dimensional form in a modified version of MM5. The key elements of our modifications are a surface model including soil moisture and evapotranspiration based on the work of Noilhan and Planton (1989), and a non-local closure PBL model developed by Pleim and Chang (1992). The surface model includes a two layer soil scheme with a 1 cm surface layer and a 1 m root zone layer. Evaporation has three pathways: direct soil surface evaporation, vegetative transpiration, and evaporation from wet canopies. Ground surface (1 cm) temperature is computed from the surface energy balance using a force-restore algorithm for heat exchange within the soil. Stomatal conductance is parameterized according to root zone soil moisture, air temperature and vapor pressure deficit, leaf area index (LAI), and photosynthetically active radiation (PAR). Our modifications to the original Noilhan and Planton (1989) model include the addition of a canopy shelter factor to account for shading within denser canopies and modification of some of the stomatal functions with respect to environmental parameters.

We have included a soil moisture adjustment scheme which uses the errors in the predicted values of temperature and relative humidity for the lowest model layer as compared with gridded analyses of surface observations to nudge (correct) root zone and upper layer soil moisture. The concept is that errors in low level temperature and humidity may be due to erroneous partitioning of latent and sensible surface heat fluxes which in turn may be caused by unrealistic soil moisture conditions. Nudging coefficients must be carefully prescribed to act only when and where coupling is strong between soil moisture and surface heat and moisture fluxes so that soil moisture nudging is not employed when model errors have other causes. Therefore, we prescribe nudging coefficients as functions of model parameters such as solar insolation, air temperature, leaf area, soil texture, vegetation coverage, and aerodynamic resistance.

3. DRY DEPOSITION MODEL

A new dry deposition model has been developed for use in 3-dimensional chemistry transport models. The aerodynamic resistance, which is a measure of turbulent transport within the atmospheric surface layer, and the stomatal resistance, which is a measure of resistance to uptake or emission through stomatal pores, produced by the surface model in MM5 are also used in the dry deposition model. Since both of these variables depend only on physical characteristics of the atmosphere and vegetation, they can be applied to any quantity for which these processes are important. The only adjustment needed for gaseous dry deposition is to weight the stomatal resistance by the ratio of molecular diffusivities of the chemical species and water vapor. Other dry deposition resistances, including cuticle resistance, ground resistance, water resistance, and a pathway through the vegetative canopy to the ground, are parameterized according to relative reactivity and solubility.

4. RESULTS

The modified version of MM5, including the land surface and dry deposition model (MM5-DD), was run for a continuous period of August 1 - September 16, 1995 with 54x54 km grid cells and 30 vertical layers. In addition to the soil moisture assimilation scheme described above, direct data assimilation was used for winds at all levels, and temperature and humidity above the PBL. Grid cell values of land use related parameters (LAI, vegetation coverage, surface roughness length and minimum

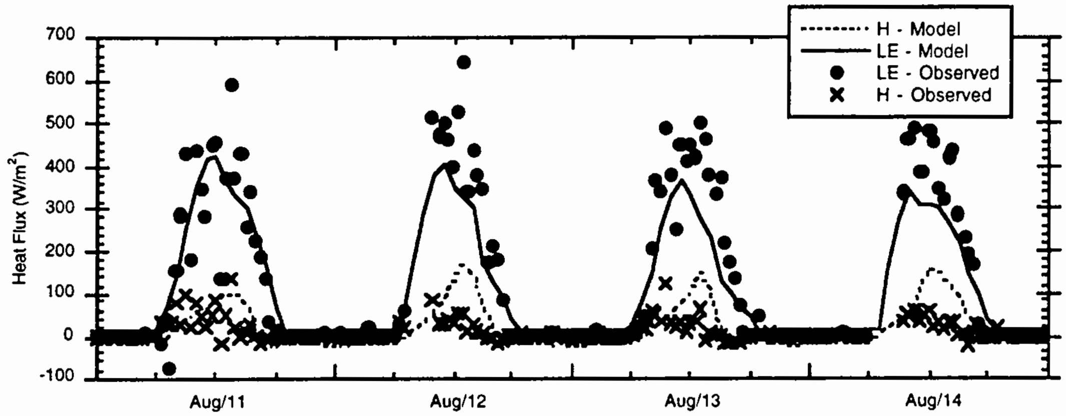

Figure 1. Modeled and measured sensible and latent heat flux at the Keysburg, KY site in 1995.

stomatal resistance) were derived from a detailed vegetation/land use.

Comparison of modeled and measured sensible and latent heat fluxes for 4 days in Keysburg, KY are shown in Figure 1. See Finkelstein et al. (1997) in this volume for a description of the field experiment. In this early part of the modeling period the partitioning of available energy is mostly into latent heat flux due to the relatively moist conditions. The model clearly did an excellent job of simulating both latent and sensible heat fluxes. Towards the end of the period, when the soil was much dryer, the energy partitioning was reversed with the sensible heat flux greater than the latent heat flux. The model was also able to simulate these dry conditions well (not shown) reflecting the models ability to respond to different moisture and vegetation regimes.

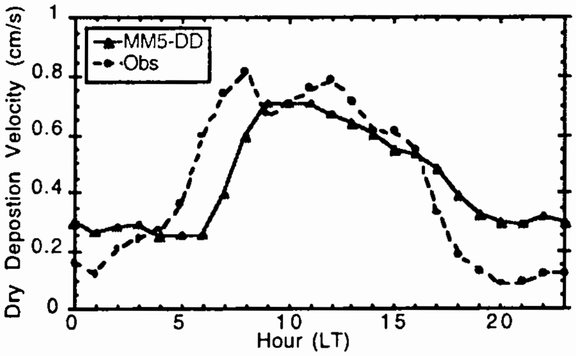

Figure 2. Modeled and measured O_3 dry deposition.

Figure 2 shows the average diurnal pattern of modeled and measured ozone dry deposition velocity at Keysburg. For each hour of the day the modeled and measured values are averaged over all days. While the modeling period covered 46 days, the number of days for which data was available for each hour ranged from 10-26. Figure 2 shows that during daylight hours the MM5-DD, on the average, compares very well to the observations but often overpredicts at night. The relatively accurate predictions during daylight hours, when the plants are transpiring, demonstrates the advantage of using stomatal conductance from the new surface model in the MM5-DD.

These results show that a 3-dimensional model with soil moisture and vegetation simulation can compare well with field measurements for both moisture and chemical fluxes.

DISCLAIMER

5. REFERENCES

Finkelstein, P. F., J. F. Clarke, T. G. Ellestad, and J. E Pleim, 1997, Diagnostic evaluation of the multi-layer deposition velocity model. In this volume, P20.1.

Grell, G.A., Dudhia, J., and Stauffer, D.R., 1993, A Description of the Fifth-Generation PENN STATE/NCAR Mesoscale Model (MM5), NCAR Technical Note, NCAR/TN-398+IA.

Noilhan, J. and Planton, S., 1989, A simple parameterization of land surface processes for meteorological models. *Mon. Wea. Rev.*, 117:536-549.

Pleim, J. E., J. F. Clarke, P. L. Finkelstein, E. J. Cooter, T. G. Ellestad, A. Xiu, and W. M. Angevine, 1996. Comparison of measured and modeled surface fluxes of heat, moisture and chemical dry deposition. In: Air Pollution Modeling and its Application XI, Ed: Gryning and Schiermeier, Plenum Press, New York.

Pleim, J. E. and Chang, J. S., 1992, A non-local closure model for vertical mixing in the convective boundary layer, *Atmos. Environ.*, 26A:965-981.

Pleim, J. E. and Xiu, A., 1995, Development and testing of a surface flux and planetary boundary layer model for application in mesoscale models, *J. Appl. Meteor.*, 34:16-32.

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16. ABSTRACT

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