Updates and Evaluation of the PX-LSM in MM5

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1. INTRODUCTION

Starting with Version 3.4 there is a new land surface model known as the Pleim-Xiu LSM available in the MM5 system. Pleim and Xiu (1995) described the initial development and testing of this land surface and PBL model for use in mesoscale models. Last year's workshop proceedings provided a basic description of the model and some evaluation (Pleim and Xiu, 2000). A recent journal article (Xiu and Pleim 2001) presents a more detailed description of the LSM and its implementation in MM5 and further evaluation. This paper outlines some bug fixes, updates, guidance for use, and more evaluation.

2. MODEL DESCRIPTION

The PX land surface model's key elements include soil moisture based on the Interactions between Soil, Biosphere, and Atmosphere (ISBA) model (Noilhan and Planton 1989), surface fluxes including parameterization of vegetation, and a non-local closure PBL model developed by Pleim and Chang (1992). The surface model includes a two-layer soil model with a 1-cm surface layer and a 1-m root zone layer. Evaporation has three pathways: direct soil surface evaporation, vegetative evapotranspiration, 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 air humidity, photosynthetically active radiation (PAR), and several vegetation parameters such as leaf area index (LAI) and minimum stomatal resistance. Although originally based on the ISBA model, the stomatal and canopy parameterizations are almost entirely new. New features include updated stomatal functions with respect to environmental parameters, and inclusion of a data assimilation scheme similar to the technique described by Bouttier et al. (1993). A simple parameterization for describing seasonal growth of vegetation, including leaf-out of deciduous trees, has also been developed and tested. Refer to Xiu and Pleim (2001) for the details of the model.

3. BUG FIXES

In the initial release of MM5v3.4 there was a bug in the PX LSM such that any radiation scheme other than the surface-only option would not work correctly. This bug was fixed and the current code available from the NCAR ftp site (mesouser) is correct.

A naming conflict between the PX LSM and the RRTM radiation scheme caused another problem. There was a subroutine named *surface.F* in */physics/pbl_sfc/pxpbl* and also a common block named *surface* in */physics/radiation/rrtm/rrtm.F*. The result was that the model would crash whenever both PX and RRTM were selected. We fixed this by renaming *surface.F* to *surfpx.F*. This fix is not yet in the mesouser code but will be for the next release. In the mean time, to run PX and RRTM together this change must be made.

4. UPDATES

In addition to these bug fixes several updates have been made to the PX code which will be available in future releases. None of these modifications are necessary for use of the PX option. All of these updates are related to surface layer and PBL parameterizations and should be considered incremental R&D improvements.

PBL Height

The method for determination of the PBL height has been updated from the method described by

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Holtslag et al. (1990) to the slightly different method suggested by Holtslag et al. (1995).

U_* Estimation

We have done two things to the U_* calculation. We removed the minimum of 0.1 m/s and we removed the convective velocity from the wind speed used in the calculation of U_* (see the MM5 model description: Grell et al. 1994). Figure 1 shows the effects of these changes. The curve labeled MM5 is the original version of MM5v3.4 run at 2 km grid resolution over central Tennessee and southern Kentucky. The curve labeled modified is a similar model run with the U_* modifications. Note that the most pronounced effect of the convective velocity is the much higher U_* values in during the daytime. These U_* values are quite unrealistic for these low wind speed conditions (see fig.2).

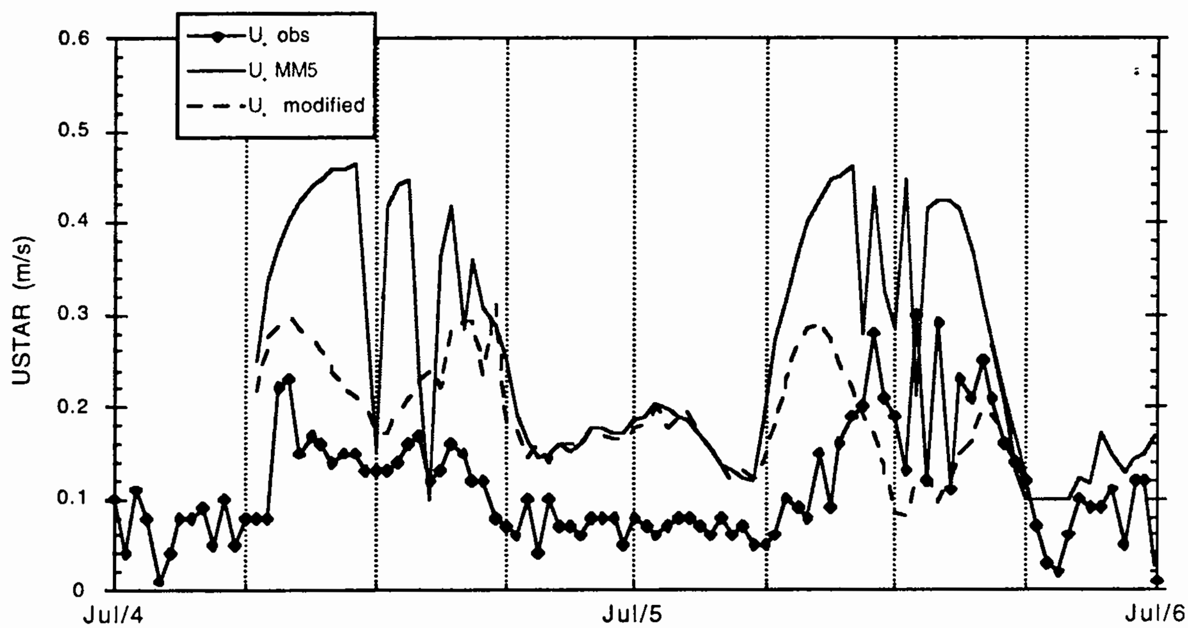

Figure 1. Observed and modeled U_* at Keysburg, KY

Flux-profile relationships

The technique for estimating the _ functions from bulk Richardson number has been updated to conform more closely to the Högström (1988) functions. The method in the current v3.4 release is essentially the same as in *hirpbl* (Blackadar 1979) using the 4 stability regimes. We have eliminated regime 3, which simply set the _ functions to zero, and have changed regimes 1 and 2 to reflect the stable and very stable regimes defined by Högström as z/L greater than and less than 1, respectively. The details of these updates will be published in a technical note. An important effect of these changes is to greatly increase nocturnal heat flux compared to the original Blackadar formulations.

Eddy diffusivity

The current release of pxpbl includes the asymmetric convective model (ACM) which is a modification of the Blackadar (1978) non-local scheme for convective conditions. For non-convective conditions the eddy diffusivity is estimated according to Blackadar (1979) as in *hirpbl*. Since v3.4 we have updated the length scale such that it increases with heigth above ground with an asymptotic limit of 80 m. We also changed the Richardson number function to be similar to the form suggested by Liu and Carroll (1996). The net effect of these changes is to greatly decrease eddy diffusivity under stable conditions.

Figure 2 shows the aggregate effect of these changes on wind speed at a site in southern Kentucky as simulated by MM5 at 2 km grid resolution. After all these updates the layer 1 wind speed (~19 m AGL) generally increases, especially at night. However, when adjusted to 2.5 m height using surface layer similarity theory, the model results compare very favorably with the 2.5 m observations.

moisture initialization is less important than for other LSMs. We have shown that when using the soil

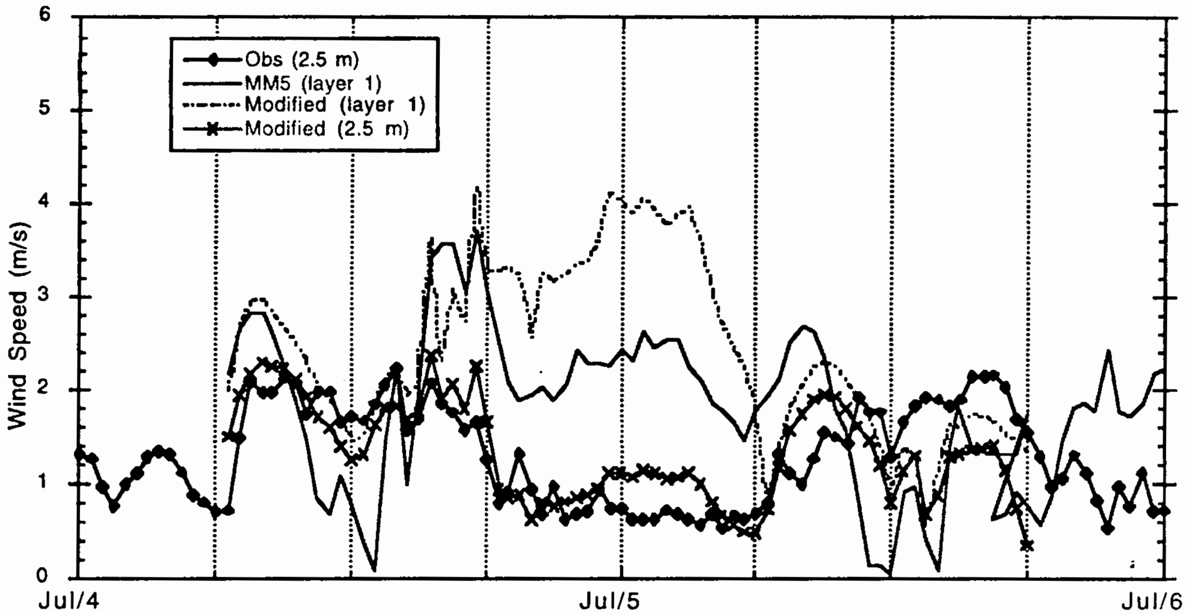

Figure2. Observed and modeled windspeed at Keysburg, KY.

5. USER GUIDANCE

For detailed instructions on how to run the PX LSM the reader is referred to the NCAR MM5 website under the heading *"What's New in Version 3 since its Release"*. In this paper we offer additional guidance on soil moisture initialization, chaining together long series of runs, soil moisture data assimilation, and vegetation growth options.

The two LSM options now available in the MM5 system as well as future additional LSMs have many similarities but also many important differences. The choice of model depends on the application since each model was developed for different purposes. The PX LSM was developed for mesoscale meteorology modeling used to drive atmospheric chemistry models for air quality research and policy. Therefore, the PX LSM was designed to be run primarily in retrospective mode for extended periods (weeks to months). Key parameters for air quality applications include PBL height, air temperature, boundary layer winds, and surface fluxes.

Given our emphasis on long-term retrospective modeling, the indirect soil moisture data assimilation scheme and the vegetation growth algorithms are important features of the PX LSM. Consequently, soil moisture nudging scheme with very different soil moisture initializations the simulations converge in about 3-6 days (see Figure 3). Because the soil moisture assimilation scheme uses the surface analyses of temperature and humidity, the analysis FDDA options must be activated.

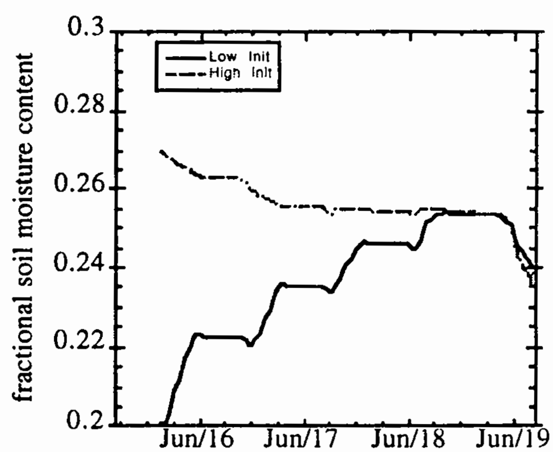

Figure 3. Deep (1m) soil moisture modeled at Dickson, TN with 2 different initializations

Typically we run 4-5 days then start the next run with a 2-12 hour overlap for spin-up. Soil moisture can be initialized in three different ways: 1. a generic initialization based on the moisture availability factor by land use, 2. interpolation from the Eta analyses of soil moisture, and 3. directly from MMINPUT. The first two options are used for the first of a series of runs. The third option is used to chain together runs into a continuous simulation. A utility program call *Interppx* is used to extract soil moisture and temperature for the initial time from a previous MMOUT file which are then added to MMINPUT.

There are three vegetation growth options that can be important for extended runs to account for seasonal changes in vegetation parameters. The first option uses the monthly VEGFRAC fields provided by *Terrain* to scale LAI and vegetation fractions for each grid cell. The second option estimates LAI of natural vegetation according to the model's deep soil temperature and estimates LAI, roughness length, and vegetation fraction of agricultural vegetation using simple growth algorithms starting from crop emergence, which is estimated from gridded planting data information read in from an additional ASCII file. Note that this option was created for a specific project studying pesticides where the focus was on agricultural areas. The third option is similar to the second except that the planting dates are estimated from the VEGFRAC fields thus obviating the need for the additional planting date input file. The second and third options were specifically designed for the winter-spring-summer transition. These schemes are particularly well suited for simulating year-specific leaf-out and early season crop growth, but they are not recommended for the autumn season. Note that the PX LSM aggregates vegetation parameters by grid cell from fractional land use and soil data rather then using the dominant land use category.

6. FUTURE WORK

Evaluation and development efforts are continuing. Our current focus is the simulation of the SOS Nashville 1999 field experiment.
Ideas for future development include comparison of the current Jarvis-type stomatal conductance model with a photosynthesis based stomatal model. If the photosynthesis model proves superior, the current scheme will be replaced. Another goal is to decouple the LSM from the PBL model so that other PBL models could be used with the LSM.

7. ACKNOWLEDGMENT

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

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