Numerical Experiments with MM5 and WRF using the Upgraded Unified Noah Land Surface Model

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1. INTRODUCTION

Since its implementation in the WRF and MM5 models, the Unified Noah land surface model (LSM) have been verified under different scenarios (Chen and Dudhia 2001; Ek et al 2003, Tewari et al 2004). In the Noah LSM, we have recently made some improvements that include (a) introduction of surface emissivity as function of landuse types in the Noah LSM surface energy balance calculation, (b) enhancing Noah LSM with a simple treatment of urban landuse and c) incorporating a simple treatment of urban landuse. We have introduced the emissivity in the surface energy balance equation for both snow and non-snow surface and revised the energy balance. For the present study, we have used the seasonal values of surface emissivity derived from Wilber et al. (1999).

In this study, we would present some results of the coupled WRF-Noah and MM5-Noah modeling systems with recent Noah LSM modifications for selected summer and winter cases and their comparison with surface and aircraft data sets. The purpose of the study is to evaluate the performance of the upgraded Noah LSM coupled with WRF and MM5 models as compared with standard Noah for different seasons.

2. NUMERICAL EXPERIMENTS

Various numerical experiments were conducted to test the performance of the coupled WRF-Noah and MM5-Noah systems. For the MM5 tests, we have used a single domain run at a horizontal resolution of 45 km. The model is initialized with 1° NCEP GFS datasets. For the initialization of soil conditions, AGRMET (Agricultural Meteorology modeling system) data which is available at 47 km resolution is used. We selected one winter and one summer case starting at Feb 1, 2003 and June 15, 2003 respectively. For each of these cases the model is integrated for 24 hrs starting at 18Z, which is 9pm local time, and three numerical experiments were performed

(i) Using simple slab model referred to as "SLAB"
(ii) Using Noah LSM referred to as "Noah" and
(iii) Using upgraded Noah LSM referred to as "Noah total".

Three test cases are presented here: 1) a wintertime simulation (1 February 2003) using MM5/Noah for the Southwest Asia region; 2) the case study for May 29 2002 during IHOP field experiment using WRF/Noah coupled model (with 10 km grid spacing), which was initialized with Edas (Eta land data assimilation systems) data at 12Z and was integrated for 24 hours; 3) a wintertime WRF/Noah was conducted at in order to see the impact over the snow areas due to the modification of emissivity in Noah LSM. We selected a winter storm case of March18 2003 and integrated the model at 22 km resolution for 36 hrs starting at March18 2003, 00Z. For these cases, we have compared the modified Noah (referred to as Noah_total) with Noah LSM in WRF1.3.4). In order to see the impact of urban zone modifications, we selected a domain over the Houston area for the WRF-Noah run with 4km grid spacing. The model was integrated for 24 hours starting at 12z of Aug 25, 2000. The results of "Noah_total" are compared with Noah model.

In the following section, we would show some of the results of the above experiments.

3. RESULTS AND CONCLUSIONS

Fig 1 shows the 45 km domain which we have selected over the South West Asia for coupled MM5-Noah tests.

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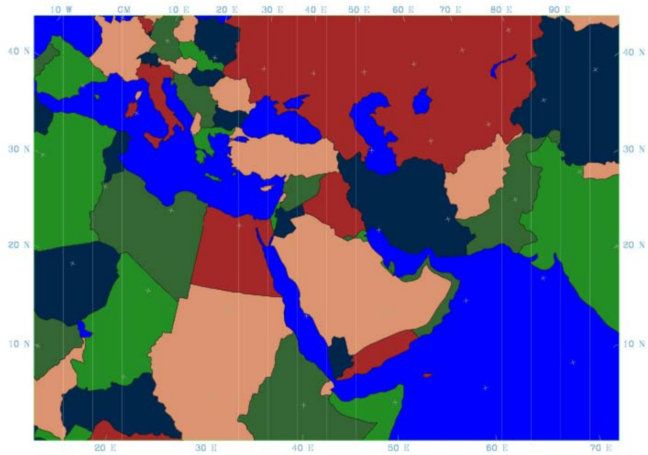

Fig:1 South West Asia domain for MM5-Noah (at 45 km resolution) simulation

The domain has 180 points in east-west and 130 points north-south. For verification, we have used a number of surface observations which were available over the domain. Figure 2 show typical observations sites which was available for temperature verification at 21Z.

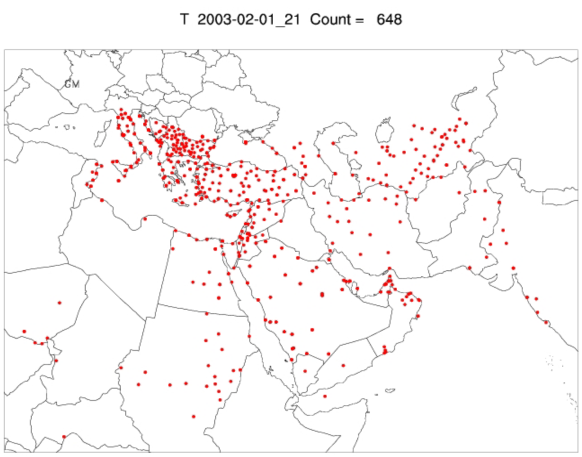

Fig 2: Observation sites used for MM5-Noah verification

Figures 3 and 4 show the 2-meter temperature comparison for the 3 cases (SLAB, Noah and Noah_total) valid at 21Z of Feb 1 2003 (local time 12'O clock night) and 09Z Feb 2 2003 (local noon) respectively. In each of these figures, Noah_total is compared against Noah in the last figure of the panel.

We notice that the introduction of surface emissivity increased the 2-meter temperature over the whole domain in the range of 0.5–2.5 °C in nighttime and

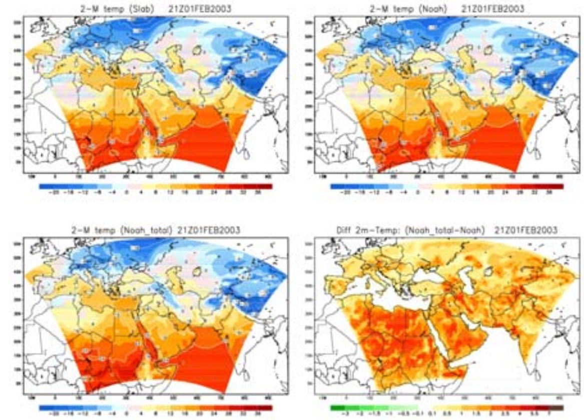

Fig 3: 2-meter temperature valid at 21Z, Feb 1 2003 for Slab, Noah and Noah_total

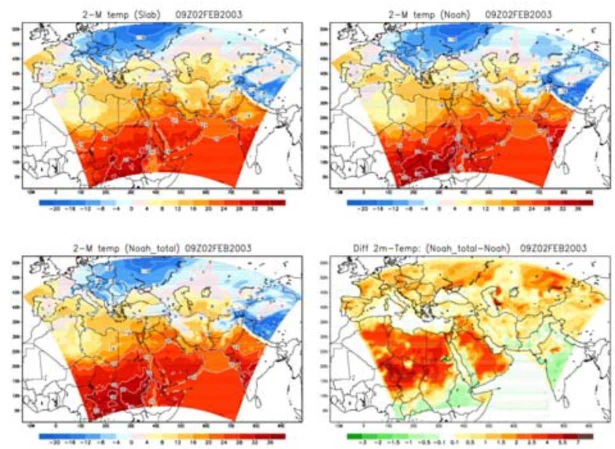

Fig 4: 2-meter temperature valid at 09Z, Feb 2, 2003 for Slab, Noah, Noah_total

0.5-4° C in daytime. Since the MM5/Noah showed cold bias initially, this increase in temperature is expected to reduce the cold bias over the whole domain in general. A comparison of the 2-meter mixing ratio (MR) for the 3 cases show that the MR is high in the range of about 0.5 to 1 g/kg in day and night time when we compare Noah_total vs Noah. Similar results were found for June 15 case which is not shown here for brevity. Figure 5 and 6 shows the 2-meter temperature and mixing ratio verification over the domain. It is found that Noah_total reduces the cold bias and performs better than Noah and Slab model. Also, it reduces the RMSE as compared to Noah model although the slab model has slightly lower RMSE as compared to Noah_total.

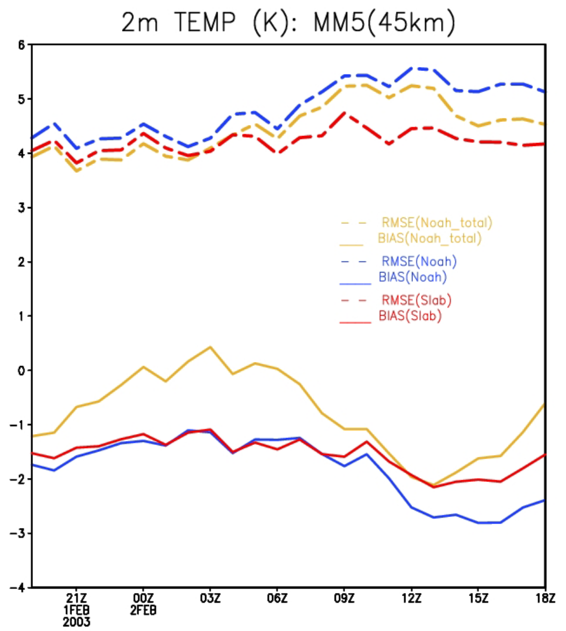

Fig 5: 2-meter temperature verification (Red: Slab, Blue: Noah, Yellow: Noah_total)

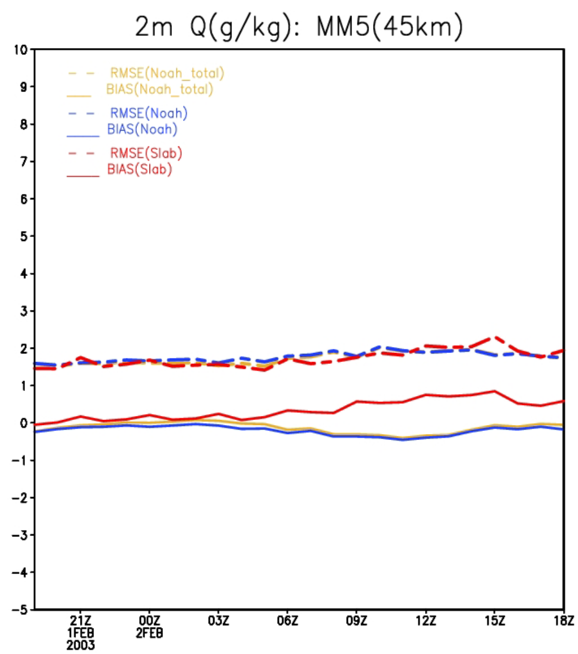

Fig 6: 2-meter mixing ratio verification (Red: Slab, Blue: Noah, Yellow: Noah_total)

The 2-meter mixing ratio verification shows that Noah_total is slightly better than Noah model. The 2-meter relative humidity verification (not shown here) shows reduction in bias for Noah_total as compared to Noah and Slab. Also the RMSE is lower in the Noah_total case as compared to Noah for most of the period during the diurnal cycle.

For the coupled WRF-Noah tests, we performed numerical experiments with Noah and Noah_total. For the May 29, 2002 case, we found that the temperatures are generally higher in nighttime (about 0.5-2°C) and slightly lower in daytime (about 0.5°C) over the whole domain when we compared Noah_total with Noah (not shown here).

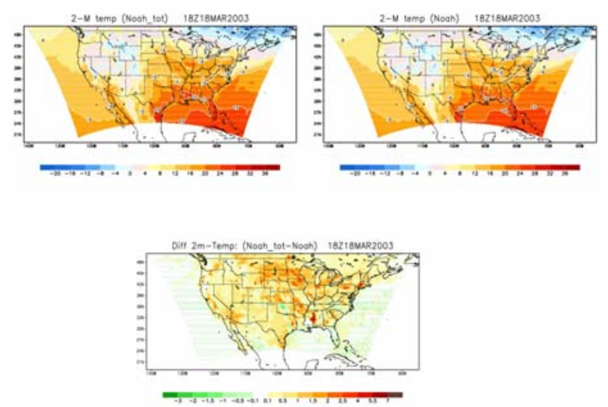

Fig 7: 2-meter temperature valid at 18Z, March 18, 2003 (Coupled WRF-Noah_total Vs WRF-Noah)

For the winter case (Mar 18, 2003, 18Z), we found that with Noah_total, there is, in general, an increase of temperature (~0.5- 2.5° C) over the whole domain when we compare Noah_total with Noah (Fig 7). Similar results were found for coupled MM5-Noah model for the winter case.

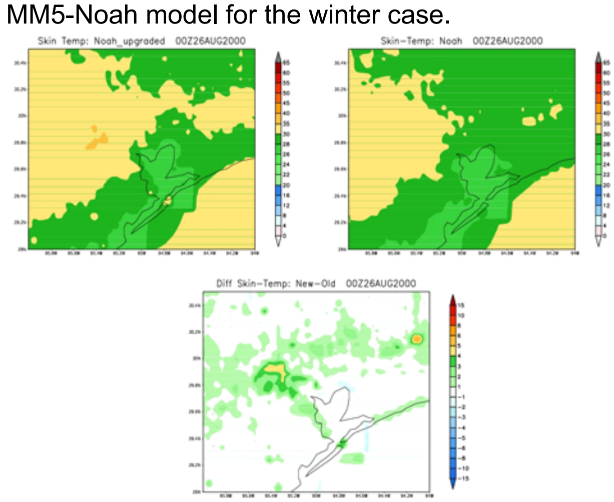

Fig 8(a): Skin Temperature comparison for Noah_total and Noah at 00Z of Aug 25, 2000. Bottom panel is the difference of Noah_total and Noah.

The third set of experiment was conducted in order to see the impact of combined emissivity and urban zone treatment in the coupled WRF-Noah model. Here also, we compare the performance of

Noah_total against Noah. Fig 8 (a) and (b) shows Skin Temperature as simulated by Noah_toal and Noah model coupled with WRF model at 00Z (about 6pm) and 06Z (about midnight). It is found that skin temperature over the urban areas are higher as predicted by Noah_total as compared with Noah by about 3-4° C at these hours. Since the urban zone starts radiating heat during evening and nighttime which results in higher temperature over these regions, these results with Noah_total is quite encouraging.

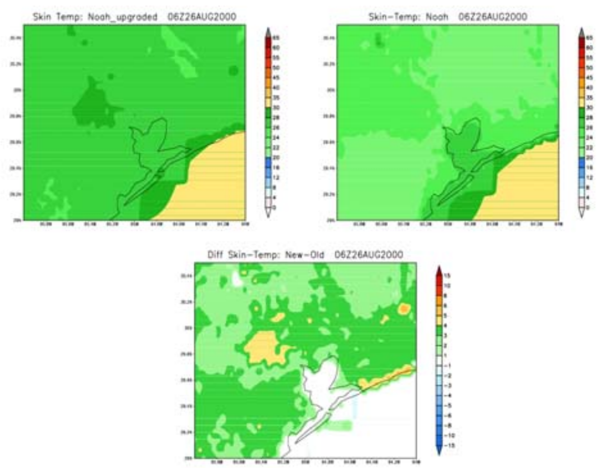

Fig 8(b): Same as fig 8(a) except for 06Z 26 August 2000

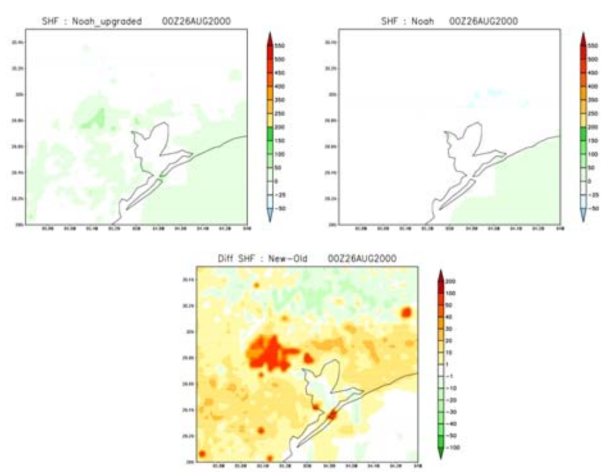

Fig 9 (a) : Sensible heat flux at 00Z of 25 August 2000 for Noah_total and Noah. Bottom panel is the difference of Noah_total and Noah.

A similar comparison for Noah_total and Noah for SHF is shown in Figures 9(a) and (b). It is found that Noah_total predicts fluxes over the Houston area which is higher by about 40 W/m^2 at 00Z and 10 W/m^2 at 06Z.

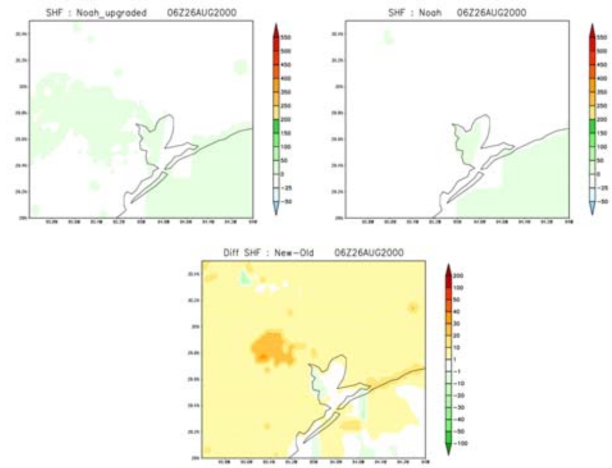

Fig 9 (b): Same as 9(a) except for 06Z of 26 August 2000.

In general, the upgraded Noah LSM improves the simulations of 2-meter temperature and mixing ratio for both MM5 and WRF models and for both summer and winter cases. The urban modifications increased the surface temperature and sensible heat flux over the urban areas, and seemed to capture a few important features related to urban heat island. Further experiments with the coupled models are underway and would be presented at the conference

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