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# NUMERICAL EXPERIMENTS WITH UPGRADED WRF/NOAHLSM MODEL

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## 1. INTRODUCTION

During the past decade, the land surface processes and their parameterization have become increasingly importance due to the availability of more computer resources (in order to execute higher resolution integration for better land surface parameter simulations) and also due to increased cooperation and sharing of multidisciplinary knowledge. An evolution of the unified Noah land surface model (LSM) which is the result of a major collaboration among NCEP, NCAR, AFWA and OSU is one such effort. Its chronology is well documented in Ek et al. (2003). Chen et al (2003) studied the land surface heterogeneity over an area of lower Walnut river watershed using models and measurements from CASES-97. One of the major results from their study is that modeled heat fluxes are better compared with aircraft heat fluxes along the flight tracks when the surface heterogeneity is pronounced. Tewari et al (2004) has shown in their study some of the implementation/verification results of coupled WRF/Noah model over for summer and winter cases.

In the WRFV2 release, we have made few upgrades in the Noah LSM with reference to the introduction of surface emissivity as a function of landuse type and simple treatment of urban landuse. The surface emissivity values used here are taken from Wilber et al (1999). In the present work we would show some results of the coupled upgraded Noah LSM and Weather Research and Forecast (WRF) modeling system for selected cases. The results are compared for the nested high resolution runs at a horizontal resolution of 1.3 km with aircraft and surface observations from the International H2O Project 2002 (IHOP) field experiment. The purpose of the present work is to 1) evaluate the impact of introduction of surface emissivity on performance of the coupled WRF/Noah LSM model, and 2) study the impact of land surface heterogeneity (by using higher horizontal resolution) on coupled WRF model simulations by comparing the results with aircraft and surface observations.

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## 2. NUMERICAL EXPERIMENTS

Numerical experiments were performed with a view to test the enhancements of Noah LSM and also to compare the performance of the model between a coarse and high resolution run.
(a) In order to see the impact of enhancement of Noah LSM with respect to urban landuse type, we have selected a domain over the Houston area. For this set of experiments a horizontal resolution of 4 km is selected for a case study of August 25, 2000.
(b) For this set of experiment, we have compared the model performance for May 29, 2002. The purposes of these experiments is: to see if the model could capture the surface heterogeneity over the IHOP stations better than the coarse resolution and to evaluate if there is an improvement in the model results by comparing the fluxes and boundary layer depth with the aircraft and surface datasets available during this time. For this purpose, the fluxes and boundary layer depths would be compared for a resolution of 1.3 km from a 3 domain run of 12, 4, and 1.3 km nested grid) with a single domain 10km run. The finest resolution in the nested run has 154X90 in the east-west, north-south direction respectively. We have used EDAS soil data source for initialization. The model was integrated for 24 hours in each case starting from 12Z. In the following section, we would show some of the results of the above experiments.

## 3. RESULTS AND CONCLUSIONS

Here we would show the results from the first set of experiments which shows the impact of modest

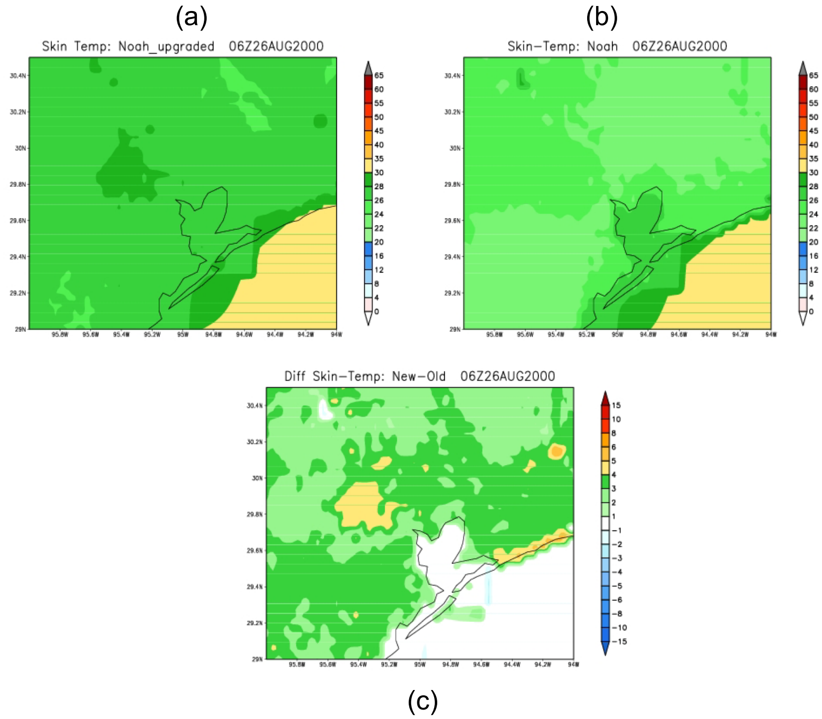


**Figure 1: Skin temperature (in °C) for (a) Noah_total (b) Noah and (c) difference of Noah_total and Noah**

treatment of urban areas in the Noah LSM. Since the urban areas can greatly affect the wind, temperature and humidity in the boundary layer, so for an improved mesoscale NWP, it is essential to have a better representation of urban areas. The Noah LSM is upgraded by modifying the albedo, roughness length, soil thermal properties. For the domain over the Houston area, a preliminary investigation of the coupled model result is shown in fig 1. This is a 3-panel chart for skin temperature showing Noah_total (upgraded Noah), Noah and their difference for 06Z of Aug 26 2000 respectively. Similar results were found for 00Z of 26 Aug 2000 which are not shown here. As expected, the urban affects are more realistically simulated with upgraded Noah where the skin temperature over these areas are higher by about 4-5° C at 00z and 06z since the urban areas store the incoming radiation more than the surroundings leading them to be at higher temperatures even after sunset. The resulting higher sensible heat flux with Noah_total is also observed at 00Z and 06Z of 26 Aug, 2000 (not shown here).

With the introduction of surface emissivity as a function of landuse type, we modified the surface energy balance equation. Surface emissivity is important for correctly determining the longwave radiation leaving the surface and also the surface temperatures.

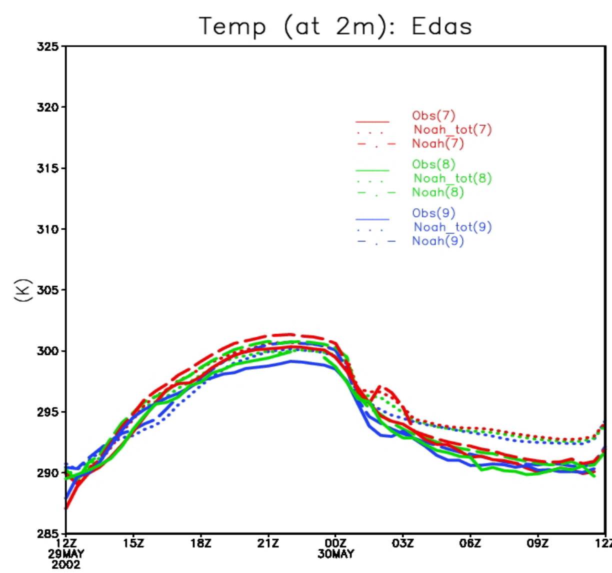


**Figure 2: Diurnal variation of air temperature (K) at 2-m for Noah_total, Noah and observation for 29 May 2002 for the sites 7 (red), site 8 (green) and site 9 (blue).**

A comparison of 2-m air temperature for Noah_total and Noah with IHOP surface observations (site 7, 8 and 9) is shown in fig 2. It is found that Noah_total produces warmer (about 0.5°C) afternoon temperatures.

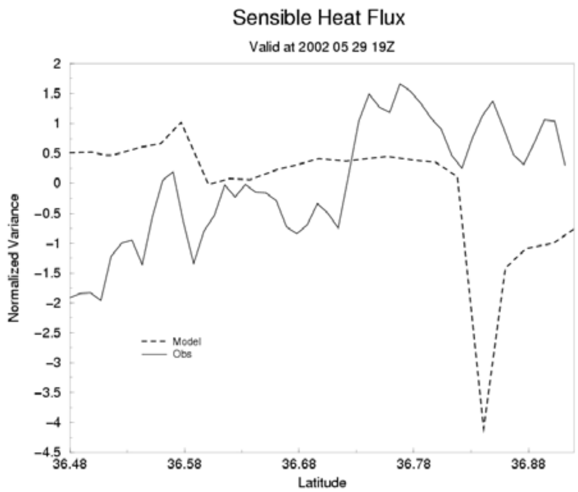


**Figure 3: Normalized variance of sensible heat flux as compared to aircraft observation. Solid lines is observation and dashed lines are the model results.**

In order to better capture the spatial variability along the latitudes when compared with aircraft datasets, we used a horizontal resolution of 1.3 km for the following validation. A comparison of the normalized variance of latent (not shown here) and sensible heat flux (fig 3) along the latitude western track of the aircraft showed that there is not an exact match of pattern along the track but the model does capture some of the maxima and minima for latent and sensible heat fluxes south of 36.8°N. An area of disagreement with observation is north of 36.8°N. The latitude versus PBL height plot over the western track is shown in fig 4. It is noticed that the that the model results are off by a few degrees of latitude as far as maxima and minima are concerned. Here again the pbl height shows a completely opposite trend around 36.8° N. This shift may by attributed to the reasons that the model soil moisture at this place may be quite low as compared to the observations where due to some high precipitation (which occurred on May 27, 2002), we found lower pbl depths for regions south of 36.8° N. In general, an increasing trend of PBL height from south to north is well captured by the model (from 36° to 37.4° N).

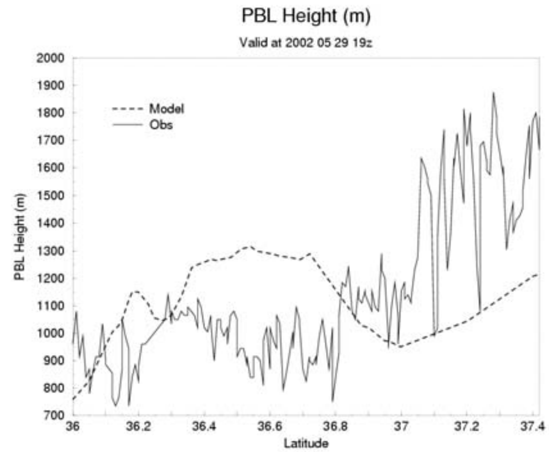


**Figure 4: PBL height (in m) for the model (dashed lines) and observations (solid lines).**

In this study, we found that with the enhancement of Noah LSM with respect to urban treatment, we were able to simulate more realistic simulations such as urban heat island which was missing with the original Noah LSM. In general, the model performs reasonable well in capturing the surface heterogeneity. Surface emissivity is important for determining surface temperatures. In the earlier version of unified Noah LSM, surface emissivity was taken as unity but in the upgraded version (Noah_total), we have introduced surface emissivity as a function of landuse type and used seasonal values from Wilbur et al (1999). Introduction of surface emissivity produced warm bias in the afternoon/ evening hours as compared to the earlier version. This could be due to specification of the emissivity values for some of regions under consideration. The results from the high resolution run (1.3 km) with the model are better compared with aircraft measured fluxes and boundary layer depths. The range of the boundary layer depths are quite well simulated by the model which is quite encouraging.

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