7.9 EFFECT OF TWO MM5 LAND SURFACE PARAMETERIZATIONS ON AN INLAND TROPICAL STORM SIMULATION

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1. Introduction

Do land surface processes (LSPs) and land atmosphere interaction processes (LAIPs) matter even for synoptic weather events such as the tropical storms? This is the focus of our ongoing investigation. Traditionally LAIPs have been considered important under weak synoptic conditions. However, there is growing evidence that with high grid spacing in numerical models, the ability to simulate fine scale features and hence the structure and intensity of land – atmosphere feedback will be better. To that end, we review the performance of two land – atmosphere interaction schemes within MM5 modeling system to simulate an inland tropical storm evolution. We hypothesize that, if the two land – atmosphere interactions representations do significantly differ, then the results are indeed dependent on the correct representation for land – atmosphere processes in weather models, for land falling hurricane and other tropical / synoptic events.

In this study, a triple-nested version of the fifth generation PSU-NCAR Mesoscale Model (MM5) is employed to study the surface radiation budget and precipitation patterns of Tropical Storm Allison as she passed through eastern North Carolina in the middle of June 2001. Use of a nested model provides better lateral boundary conditions for regions of interest. Two simulations of the MM5 were completed. The first simulation employed the Oregon State University (OSU) land surface model (LSM) with the MRF PBL scheme, while the second simulation was completed using the Pleim Xiu (PX) land surface model with the asymmetric convective model (ACM). A comparison of the two LSM's will be explored to understand the importance of land surface processes in mesoscale and synoptic scale weather phenomena.

2. Review of The Synoptic Setting

TS Allison traveled up the Atlantic seaboard 14 June through 18 June 2001. On 15 June 2001 at 00 UTC a strong ridge of high pressure was centered 200 km off the Florida coast and extended northward to off the New Jersey coast. Strong ridging at the surface and aloft forced Allison to move in a northward direction paralleling the coastline. By 15 UTC 16 June 2001, Allison was centered over northern Virginia. During the next 6 hours a prefrontal trough was analyzed moving through western and central North Carolina. A sea breeze front was also observed moving westward through eastern North Carolina. The outer circulation signature of Allison extended southward into central North Carolina. Locally heavy rain over central North Carolina is believed to be the result of the convergence of the prefrontal trough, sea breeze front and outer rain bands from Allison.

Due to the distinct nature of the boundaries over central North Carolina, the surface flow pattern was very complex.

Over the next 24 hours, a surface cold front moved off the eastern coastline, and Allison accelerated out into the Atlantic east of New Jersey. As Allison pulled away, she intensified under more favorable surface and upper-level atmospheric conditions. High pressure ridged over the Carolina's following the departure of the surface cold front.

3. Model and Data

The MM5 uses surface layer similarity for the constant flux layer and MRF/ACM planetary boundary layer (PBL) parameterization schemes for the mixed layer. The model also uses explicit equations for cloud water, rainwater, ice and water vapor. The Kain-Fritsch cumulus parameterization scheme is used for sub-grid scale convection in both model simulations. Lower boundary conditions are maintained using the Cloud-radiation scheme. In this study, we use three nests with one-way interaction between the respective domains.

Operational analysis from NMC, produced by the National Center for Environmental Prediction (NCEP), and archived by the National Center for Atmospheric Research (NCAR) are used in this study. The resolution of the archived data is 2.5 ° x 2.5 ° latitude-longitude with 15 standard pressure layers. The MM5 default surface variables such as land use, vegetation type, roughness and topography are found within the MM5 data library and are all considered for the lateral boundary conditions and kept constant during the integration of the model. The above data are interpolated onto the model grid to serve as initial values and boundary conditions for the integration of the model. The above data

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corresponding to 00 UTC 15 June 2001 was utilized for both model simulations. Both model simulations were integrated up to a period of 72h until 00 UTC 18 June 2001.

For this study, a triple nested version of the MM5 is utilized: The Course Grid Mesh (CGM), and Medium Grid Mesh (MGM) and Fine Grid Mesh (FGM) covered an area of (25.01°N-43.10°N; -102.1°W- -67.20°W), (28.20°N-38.15°N; -88.20°W- -71.50°W), (31.10°N-36.50°N; -85.25°W- -75.20°W) respectively, as shown in Figure 5. The horizontal resolutions for the CGM and MGM and FGM were 45, 15 and 5 km, respectively. Further, the CGM, MGM and FGM domains comprised of (54 x 82), (76 x 112) and (112 x 193) grid points, respectively. All three domains had 36 vertical σ levels (between 1000hPa and 100hPa). Both simulations of the model were integrated for 72-h and generated six-hourly output solutions.

Simulation 1 was run using the OSU MRF coupling. The OSU LSM model is coupled with the MRF PBL scheme. The OSU model uses four soil layers, and the thickness of each layer from the ground surface to the bottom are 0.1, 0.3, 0.6, and 1.0 m, respectively. The total soil depth is 2 m, with the root zone located in the upper 1 m of soil. The lower 1 m of soil acts like a reservoir with gravity drainage at the bottom. The depths of the different vegetation roots can be specified as a function of vegetation type. Maximum soil moisture and soil temperature both depend heavily on soil texture. The OSU LSM is relatively more complex than the PX LSM. Simulation 2 was run using the PX LSM. The PX LSM is coupled with the ACM PBL. The PX LSM includes a two-layer soil model with a 1-cm surface layer and 1-m root zone layer. Soil moisture and temperature are based on the Interaction Soil Biosphere Atmosphere (ISBA) model. Surface fluxes are parameterized using local vegetation data.

4. Results and Conclusions

These numerical studies were done to understand the impact, if any, land surface processes and land atmosphere interactions have on the surface radiation budget and mesoscale and synoptic scale weather phenomena.

However, the results from this study suggest that the MM5 coupled with the OSU-MRF scheme and the PX-ACM scheme both resulted in significantly different model results. For this particular case, the results from the OSU-MRF are in better agreement with the observations (particularly the precipitation amounts and the overall spatial distribution of the surface fluxes) over North Carolina than the MM5 coupled with the PX LSM.

The results thus indicate that representation of the land – atmosphere interactions is important even for simulating synoptically driven events. This because, land surface processes will modulate the evolution of surface fluxes, which in turn drive both the structure and dynamics of mesoscale and synoptic scale weather phenomena. Indeed if these modulations were important only for synoptically weak weather events, the two simulations developed under this study, would yield the same results for boundary layer height, surface sensible heat flux, surface latent heat flux, precipitation patterns, and surface temperature anomalies. This study shows that the model simulation of the inland TS structure and intensity differ significantly based on the land – atmosphere interaction represented in the model.

In conclusion, land surface processes do affect the surface energy budget and in turn the dynamical processes in both mesoscale and synoptic scale weather phenomena. Indeed efforts should be directed to detect this land – atmosphere feedback and the effect of land surface heterogeneity on mesoscale circulations even under synoptically dominant (as against weak) events. Future efforts are needed to review the role of different land surface process models coupled to same boundary layer scheme and their ability to simulate the structure and intensity of tropical systems particularly as they approach landfall or are already traveling inland.

5. References:

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