IMPACT OF LAND SURFACE DATA ON SIMULATED MONSOONREGIONAL CLIMATE DURING CONTRASTING EPISODES OF THE INDIAN SUMMER MONSOON

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ABSTRACT:

The Fifth-Generation National Center for Atmospheric Research / Penn State Mesoscale Model (MM5) is deployed to investigate the importance of realistic representation of land surface in a regional model for simulating the meteorological features associated with the southwest monsoon. Experiments are conducted to study the impact of satellite derived land surface data such as vegetation fraction, vegetation type (both derived from SPOT VEGETATION) and surface soil moisture (derived from SSM/I) on MM5 simulated meteorological fields for the contrasting Indian summer monsoon years 1998 & 2002. The incorporation of satellite derived land surface data in the MM5 initial condition improved the simulations both in 1998 and 2002 monsoon season, but improvement is not significant when the satellite derived land surface parameters individually incorporated in the model initial condition.

1. INTRODUCTION

The study by Zhao and Pitman showed that India is one of the regions in globe where land cover changes are predominant during last decades (Zhao and Pitman 2002). Experiments using global climate model by Chase et al. 1996 and Zhao et al. 2004 also showed the impact of land use changes on dynamical features, precipitation and temperature patterns of Indian summer monsoon (ISM). Chang and Wetzel (1991) pointed out that spatial variations of vegetation and soil moisture affect the evolution of surface baroclinic structures through differential heating. Furthermore, soil moisture and vegetation cover variability affect the development of deep convection over land (Pielke 2003). Satellite remote sensing provides a wealth of data describing the land surface and is becoming more accurate in calculating surface energy budgets. In view of this, an attempt is made to study the possible effect of land surface parameters on the ISM using a regional climate model. It should be mentioned here that vegetation/soil moisture over the Indian region changes rapidly and significantly during the monsoon period. The land surface parameterization scheme of the model specifies surface characteristics according to land use category. The accuracy of land-use information is important to obtain accurate simulations. The Fifth-Generation National Center for Atmospheric Research / Penn State Mesoscale Model (MM5), implemented/customized as regional climate model over the ISM domain through extensive sensitivity experiments using various land surface and cumulus convection schemes, is used in the present study.

2. BRIEF DESCRIPTION OF MODEL AND SIMULATION DESIGN

2.1 Model Description

The MM5 coupled with Noah Land surface model (Chen and Dudhia 2001) is used in this study. The model was run with two nested domains. 28 vertical levels are set with the top of the atmosphere fixed at 50 hPa. The major physics options in the experiments include the Grell cumulus parameterization (Grell et al., 1994), simple explicit treatment of cloud micro physics based on Dudhia (1989), MRF (Hong and Pan, 1996) scheme for PBL parameterization, and Coupled community climate model (CCM2) radiation package (Hack et al., 1993) for longwave and shortwave atmospheric radiative heating.

2.2 Simulation Design

The MM5 simulations are made to study the impact of satellite derived land surface parameters such as Vegetation type (VT), Vegetation fraction (VF) and Soil moisture (SM) in simulating monsoon regional climate over India for the years 1998 and 2002. The MM5 was run with different initial conditions for a period from 0000 UTC 20 June to 0000 UTC 31 August for the years 1998 and 2002. We have performed five sets of experiments namely EXP1, EXP2, EXP3, EXP4 and EXP5. In EXP1, we used the VT and VF of United States Geological Survey (USGS) and SM from NCEP to initialize MM5 model. The EXP2 is with VT derived from SPOT satellite and other land surface parameters same as EXP1. In EXP3 we used VF derived from SPOT and VT and SM same as EXP1. EXP4 uses SM derived from SSMI and other surface parameters same as EXP1. EXP5 is with VT and VF from SPOT and SM from SSMI. The initial and lateral boundary forcing for the domain were updated every 6 hourly by NCEP-NCAR (*http//: nomad3.ncep.noaa.gov/Pub*) reanalysis dataset having spatial resolution 2.5° in latitude and longitude.

3. SATELLITE DATA USED

3.1 Vegetation type/fraction and soil moisture

The vegetation type/fraction data is generated under Regional Climate Modeling (RCM) project of Indian Space Research Organization – Geosphere Biosphere Program (ISRO-GBP). More details about the generation of vegetation cover/fraction from

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SPOT vegetation data is available in Agrawal et al. (2003). The surface soil moisture data is derived from Spectral Sensor Microwave Imager (SSM/I) satellite. This data is also generated as part of RCM project of ISRO-GBP. A more detail on the estimation of volumetric soil moisture estimation from SSM/I data is available in Singh et al. (2004).

4. RESULTS AND DISCUSSION

4.1 ISM 1998

The model predicted fields from different experiments averaged for the months of June, July and August (JJA) are compared with mean fields from NCEP reanalysis. All the experiments overpredicted the 2meter air temperature (T2m) over the Indian land mass and among the experiments over prediction is comparatively less in EXP2 (not shown). All the experiments simulated more humid atmosphere as compared to the observation and the overprdiction of himidity over the Indian land mass is significantly reduced in EXP5 (also not shown). The predicted Sensible heat flux (SHF) by different experiments did not show significant differences among themselves (not shown). All the experiments overpredicted Latent heat flux (LHF) over the Arabian sea and Bay of Bengal and underpredicted LHF over the Indian land mass (Figure 1). The overprediction of LHF over Arabian sea and Bay of Bengal is significantly reduced in EXP5 (Fig. 1). The TRMM observed and predicted rainfall distributions from different experiments showed that the higher rainfall seen over the Arabian sea and southern part of India in experiments as compared to observation is significantly reduced in EXP5 (Figure 2). The rainfall distribution over north east part of India is better simulated by EXP3 and EXP4 (Fig. 2).

Figure 1. Average Latent Heat Flux (w/m^2) for JJA 1998 (a) from NCEP/NCAR Reanalysis and its Difference from Model Predicted Fields for Domain2 (b) (a) minus EXP1, (c) (a) Minus EXP2, (d) (a) minus EXP3, (e) (a) minus EXP4, (f) (a) Minus EXP5. 4
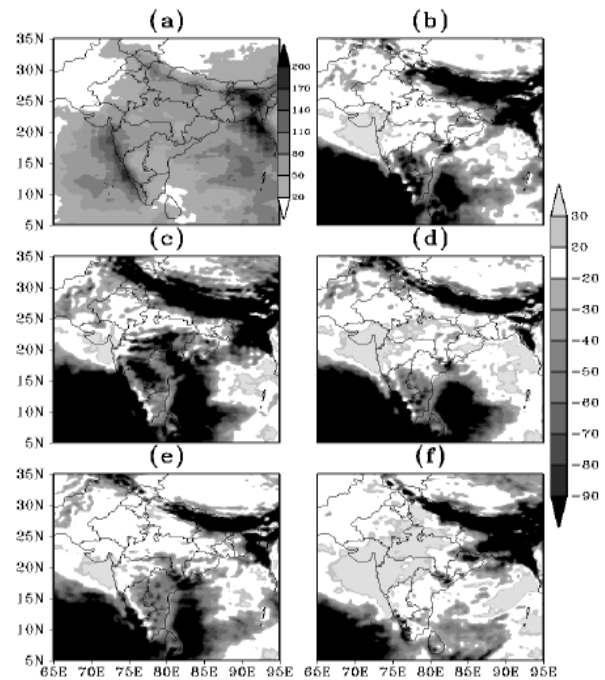

Figure 2. Accumulated Rainfall in cm for JJA 1998 (a) from TRMM and its Differences from the Model Simulated Rainfall for Domain2 (b) (a) minus EXP1, (c) (a) minus EXP2 (d) (a) minus EXP3, (e) (a) minus EXP4 (f) (a) minus EXP5

4.2 ISM 2002

Among the experiments the spatial distribution of predicted T2m by EXP5 is closer to the observation (not shown). All the experiments overpredicted humidity over the oceanic region and among the experiments overprediction is slightly less in EXP4 and EXP5 (also not shown). The predicted SHF by different experiments did not show significant differences among themselves (not shown). All the experiments overpredicted LHF over the Arabian sea and Bay of Bengal whereas over the Indian land mass LHF is underpredicted (Figure 3). The overprediction of LHF over the Arabian sea and Bay of Bengal is slightly less in EXP5 as compared to other experiments (Fig. 3). The comparison of model predicted rainfall distribution with observed rainfall showed that all the experiments overpredicted rainfall over the Arabian sea, Bay of Bengal and north east part of India and among the experiments overprediction is slightly less in EXP5 (Figure 4).

CONCLUSION

Results show that that all the experiments simulated a warm atmosphere over the Indian land mass particularly over western side of India and Himalayan regions. All the experiments simulated more humid atmosphere as compared to the observation. The error in predicted temperature and humidity is comparatively less in the experiment in which all the three type of land surface data are incorporated. The MM5 overpredicted rainfall over the Arabian sea, Bay of Bengal and north east part of India and among the experiments overprediction is slightly less in EXP5. The results demonstrate that MM5 qualitatively reproduces the spatial pattern and temporal variation in surface meteorological parameters during
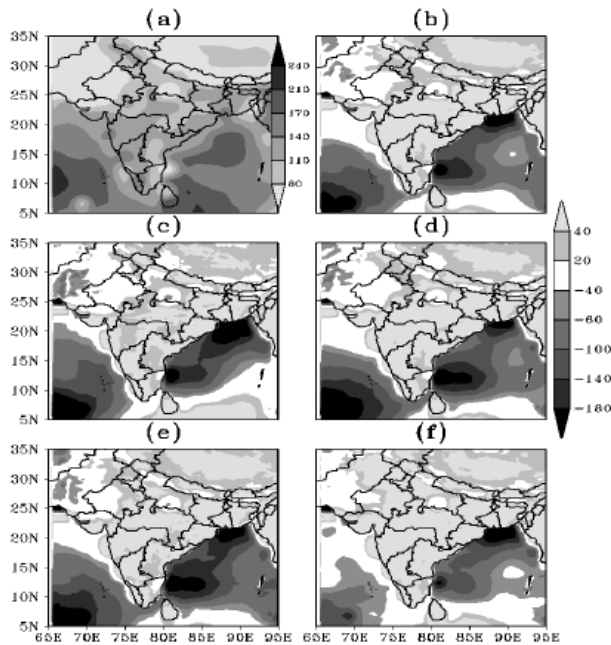
Indian summer monsoon 1998 and 2002. The results obtained for different experiments indicate that incorporation of satellite derived land surface data in model initial condition improved model simulation of surface parameters and rainfall over the Indian region. Significant improvement is not observed when satellite data are incorporated one at a time in the model initial fields.
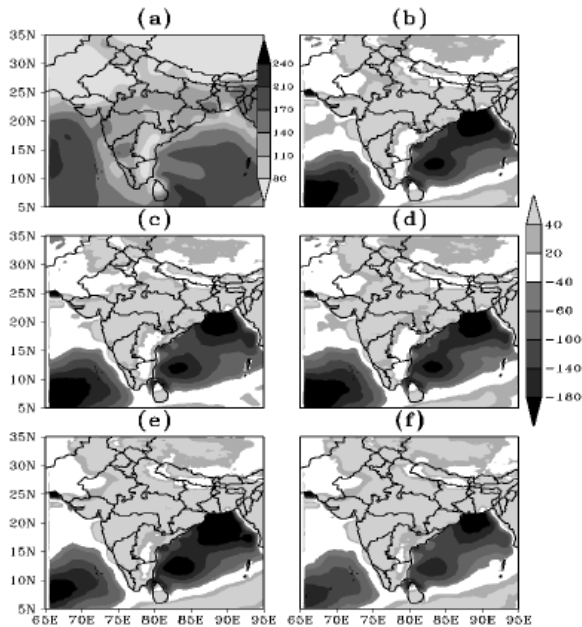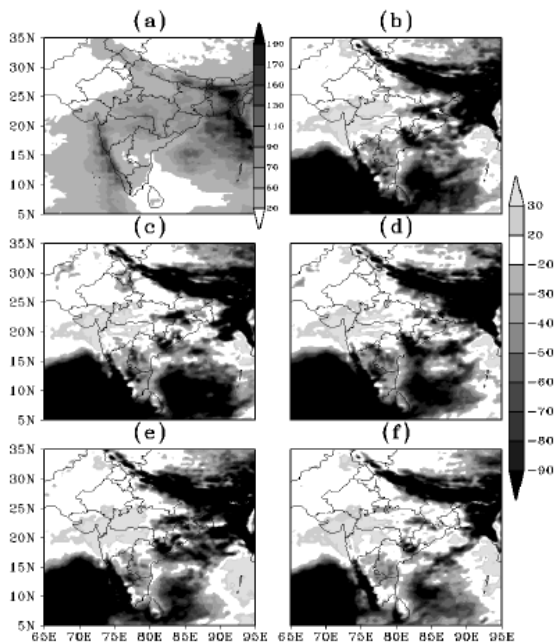

Figure 3. As in Fig. 1, but for JJA 2002

Figure 4. As in Fig. 2, but for JJA 2002

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