P2.3 A NUMERICAL STUDY OF THE DIURNAL PATTERNS OF SUMMER PRECIPITATION IN THE NORTH AMERICAN MONSOON

Cheng-Zhi Zou[1,2] and Weizhong Zheng[2,3]

[1]*NOAA/NESDIS, Office of Research and Applications, Camp Springs, Maryland*

[2]*Joint Center for Satellite Data Assimilation, Camp Springs, Maryland*

[3]*QSS Group, Inc., Lanham, Maryland*

I. Introduction

The North American monsoon is an important climate feature of the southwestern US and northwestern Mexico regions. Its peculiar precipitation characteristics have received great attention from both meteorologists and climatologists. The North American monsoon typically begins in early July and persists through the end of September, during which a belt of heavy rainfall occurs along the western slopes of the Sierra Madre Occidental with an averaged rain rate exceeding 200 mm per month (e.g., Douglas et al. 1993). The rainfall of this three-month period accounts nearly 60% to 80% of the annual total in the northwestern Mexico. The precipitation pattern over a large portion of the southwestern US continent, spanning through Arizona, New Mexico, Nevada, and Texas, is affected by the North American monsoon. The development and variation of the atmospheric circulation and its associated precipitation characteristics over a large area surrounding the monsoon core region in the northwestern Mexico is now referred by some meteorologists as the North American Monsoon System (NAMS). A historical review of the observed features, life cycle, dynamic mechanisms, as well as the ongoing research on NAMS have been well documented by Adams and Comrie (1997) and the North American Monsoon Experiment (NAME) Science and Implementation Plan (2003).

One of the important issues related to the NAMS dynamic mechanisms and life cycle is to understand the moisture source that feed the summer rainfall and the role of the diurnal cycle as well as the low level jet in the precipitation variations. Knowledge on these issues has recently been greatly enhanced owing to the availability of various analysis and reanalysis data products. Of particular note, Schmitz and Mullen (1996) investigated the structural characteristics of the moisture transport responsible for the NAMS summer precipitation patterns using the ECMWF analysis, where the moisture transport across the Gulf of Mexico has been addressed. Berbery (2001) performed moisture transport analysis using the NCEP-ETA regional forecast model analysis, where the role of the Gulf of California is particularly addressed since the ETA model has a higher resolution to resolve some fine features over this region.

Though rain gauge and analysis/reanalysis-based studies have provided many fundamental understandings on the NAMS precipitation processes, the successful simulation and prediction of its precipitation characteristics on the monthly to seasonal time scale still remain a great challenge. Unlike weather prediction where model initialization plays a critical role, simulation on the monthly scales does not rely too much on the initial conditions. Memory of the initial conditions is lost typically after a few days of integration. In contrast, the model physical parameterizations are required to reasonably represent both the external forcing such as the land surface moisture and vegetation and soil type's distribution, and the internal dynamics such as the diurnal cycle of the low level jet, heating field, and moisture transport, etc., in a much longer time scale than the weather prediction. In this regard, the requirement for the model parameterizations for seasonal simulation appears to be more crucial than for the weather prediction.

Through a two-month continuous integration over the NAMS region, this study attempts to evaluate the capability of the coupled MM5 and a land surface model known as the Simplified Simple Biosphere (SSiB, Xue et al. 1991) scheme in simulating the NAMS summer precipitation and its associated surface wind fields. Zhang et al. (2003) recently conducted this kind of monthly-scale continuous integration using MM5-SSiB over the Large-Scale-Area-East (LSA-E) region, during which many daily characteristics of the weather evolution can be reasonably reproduced. Their simulation greatly enhanced our

---

Corresponding author address: Dr. Cheng-Zhi Zou, Office of Research and Applications, NOAA/NESDIS, NOAA Science Center, Room 712, 5200 Auth Road, Camp Springs, MD 20746
E-mail: Cheng-Zhi.Zou@noaa.gov

understanding on the possibilities of extending the current weather prediction capabilities from a few days to weekly scale. This study will examine such possibilities over the NAMS core region where the dynamic and synoptic characteristics are different from the LSAE region. The assessment of the simulation will provide guidance for future development of the satellite data assimilation schemes and better parameterization schemes. The second goal of this study is to assimilate the QuikSCAT surface winds to the coupled MM5-SSiB model to examine its impact on the precipitation simulation. Here only some preliminary simulation results are presented.

The next section provides a description of the models. Section III describes the simulated precipitation and its comparison with observations. Section IV provides a brief summary.

II. Model Description

The coupled MM5-SSiB (Zhang et al. 2003) is employed in this study. It consists of a non-hydrostatic dynamic core and a suite of optional physical parameterizations integrated on a terrain-following vertical coordinate (sigma coordinate) system (Grell et al. 1995). A two-way interactive nesting configuration with a horizontal resolution of 45 km for the coarse domain and 15 km for the fine domain is used in this study. The coarse domain covers the region approximately 20^0-40^0N and 125^0-95^0W and the fine domain covers the Baja California, Gulf of California, and Sierra Madre Occidental regions (23^0-33^0N and 101^0-116^0W, see Fig. 1). The model has 30 vertical levels with the top of the atmosphere located at 50 hPa. The model integrated continuously from 0000 UTC 1 July through 0000 UTC 1 September 2002. The NCEP ETA model analyses with an update every 6 hours are used for the lateral boundary conditions of the coarse domain. The modified SSiB land surface model (Xue et al. 1991; Zhang et al. 2003) is coupled into the MM5 to represent the land surface processes. Other physical parameterizations used in this study are the newest version of the Kain-Fritsch (Kain and Fritsch 1993) convective parameterization including the parameterized shallow convective effects (Deng et al. 2003), the Blackadar high-resolution scheme (Zhang and Anthes 1982; Zhang and Zheng 2003) for the PBL parameterization, the simple ice scheme of Dudhia (1989) for the explicit moisture processes (without the mixed phase), and the CCM2 radiation package for the terrestrial and solar radiative heating.

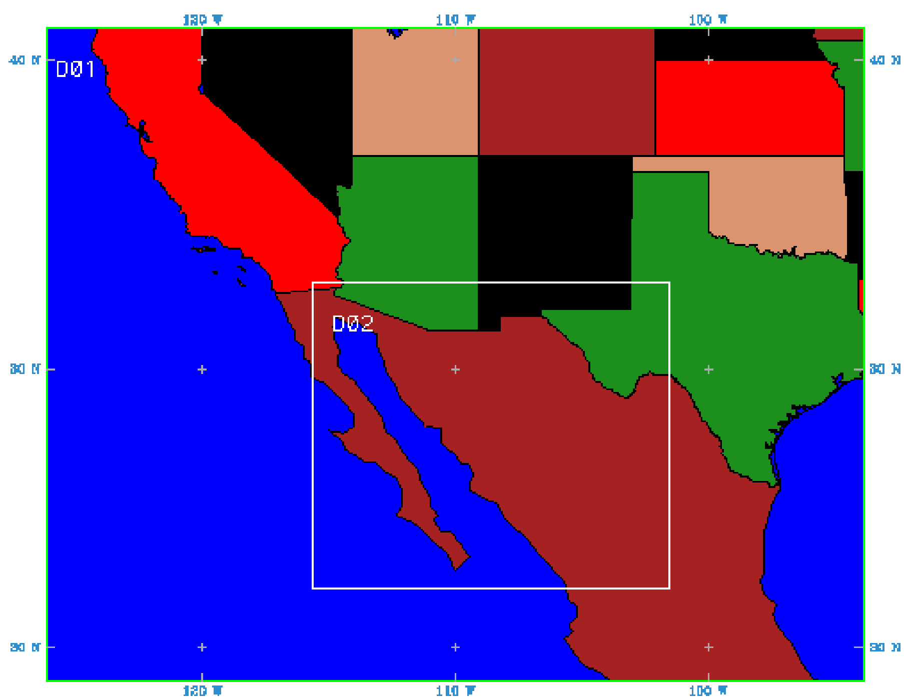
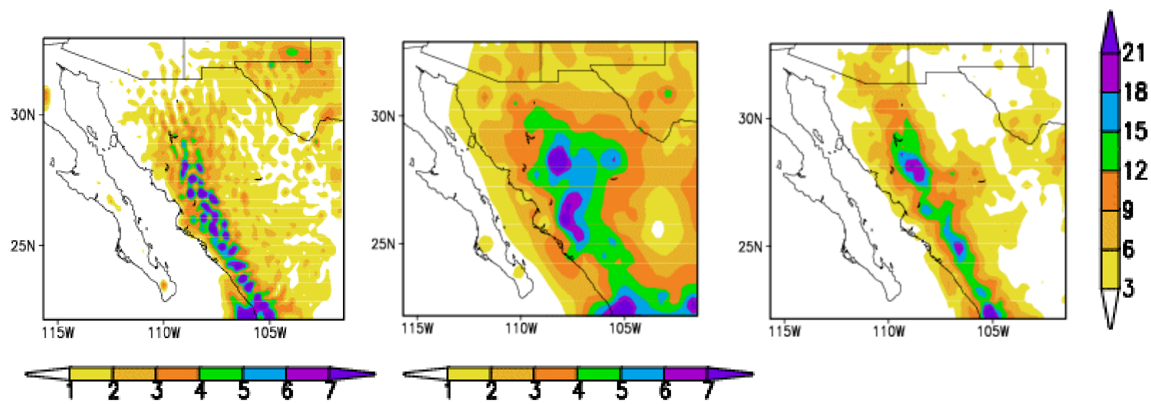


Fig.1 Domain of the nested simulation.

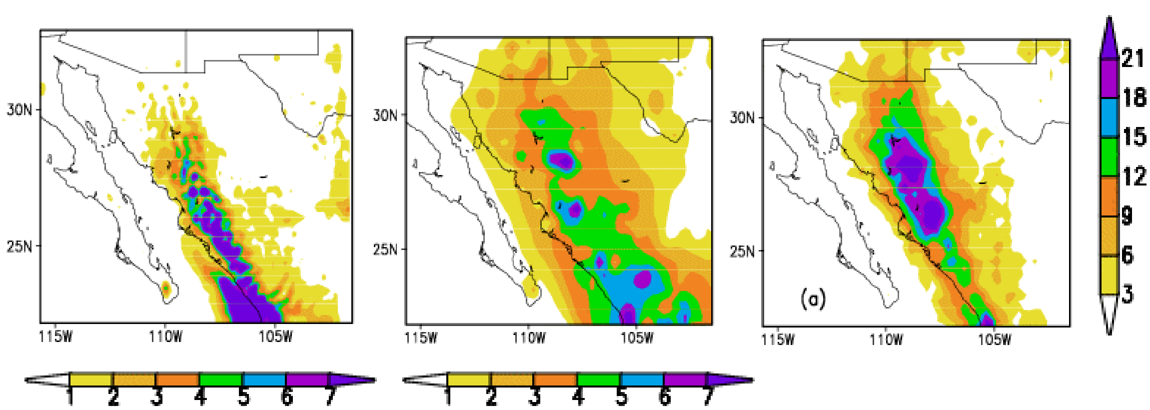
III. Model Simulated Precipitation and Its Comparison with Observations

Fig. 2 shows a comparison of the monthly mean precipitation for July 2002 between the MM5-SSiB simulation, NCEP/Climate Prediction Center (CPC) rain gauge-based daily analyses, (http://www.cpc.ncep.noaa.gov/products/precip/realtime) and the TRMM 3-hourly merged IR and microwave analyses (3B42RT product, Huffman and Bolvin 2003) over the NAMS core region (fine domain of Fig.1). Fig. 3 shows the same comparison for August 2003. These figures show that the heavy precipitation belt observed by the rain gauge data along the western slopes of Sierra Madre Occidental has been very well simulated by the coupled MM5-SSiB in all strength, position, and orientation. Typically, both the simulation and gauge-based data show a rainfall maximum about 7 mm day^{-1} along the western slopes of Sierra Madre Occidental. In addition, the position and orientation of the TRMM's heavy rainbelt is in excellent agreement with the MM5-SSiB simulation, especially during July 2003. However, the rainfall



(a) (b) (c)

Fig.2 Comparison of the July 2002 mean precipitation between the (a) MM5 simulated, (b) NCEP/CPC 0.25x0.25 daily analysis based on gauge observations (http://www.cpc.ncep.noaa.gov/products/precip/realtime/), and (c) TRMM 0.25x0.25 3-hourly merged microwave and IR precipitation (Huffman and Bolvin 2003).



(a) (b) (c)

Fig.3 Same as Fig. 1 except for August 2002. (a) MM5 simulated, (b) NCEP/CPC 0.25x0.25 daily analysis based on gauge observations (http://www.cpc.ncep.noaa.gov/products/precip/realtime/), and (c) TRMM 0.25x0.25 3-hourly merged microwave and IR precipitation (Huffman and Bolvin 2003).

amount of the TRMM estimates is about 2 times larger than both the gauge-based analyses and MM5-SSiB simulation. The larger rainfall estimates of the TRMM retrievals over the land areas have been noticed by the other researchers (Liu, personal communications). This large satellite estimate over the NAMS core region appears to be similar to that noticed by Berbery (2001) when he compares the precipitation from the Global Historical Climatology Network with the NASA GPROF 4.0 satellite microwave retrievals, where the GPROF 4.0 precipitation also reaches 20 mm day^{-1} along the heavy rainbelt as shown in Fig. 2 and 3. Realizing the magnitude differences between the TRMM and gauge-based precipitation, a caution is needed in the future model validation using TRMM. However, since the 3-hourly satellite data provide greater detailed information on the diurnal cycle, we will mainly use the satellite retrievals to compare with the MM5-SSiB simulation in the following.

Fig. 4 compares the diurnal cycle of the precipitation between the TRMM estimates and MM5-SSiB simulation. Both TRMM and MM5-SSiB show very well defined contrast between the afternoon (1400-2300 LST) precipitation and morning (0200-1100 LST) precipitation over the NAMS core region. The morning precipitation is confined to a small ocean area off the western coast of Mexico connected to the ITCZ. In contrast, large amount of afternoon precipitation develops over the western slopes of Sierra Madre Occidental. This diurnal cycle characteristics is consistent with Berbery's (2001) studies based ETA model analyses. This comparison suggests that the MM5-SSiB successfully simulate the diurnal cycle of the precipitation over the NASM core region.

IV. Conclusion

This study suggests that the current configuration of the MM5-SSiB can successfully simulate the monthly mean precipitation patterns and its diurnal patterns in the monthly scale integration.

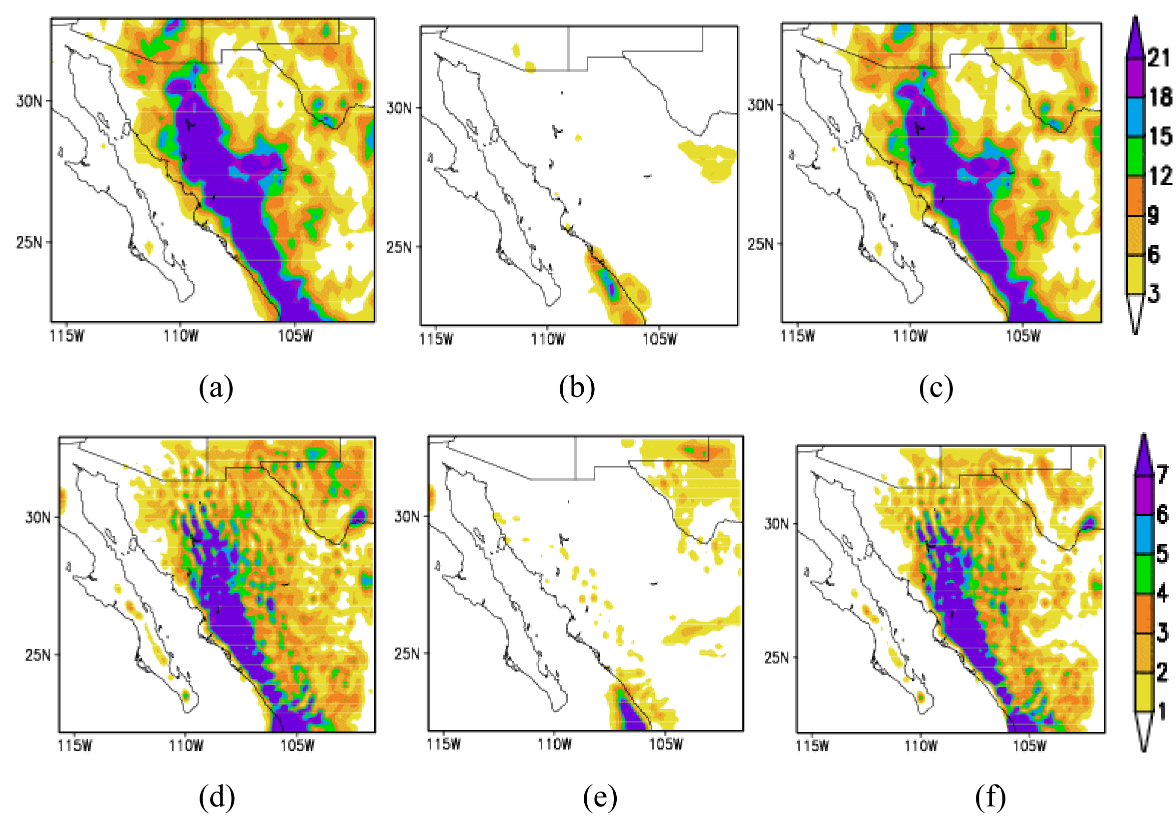


Fig.4 Diurnal cycle comparisons of precipitation between the MM5-SSiB simulation and TRMM estimates for July 2002. (a) TRMM afternoon; (b) TRMM morning; (c) TRIMM afternoon-morning; (d) MM5-SSiB afternoon; (e) MM5-SSiB morning; (f) MM5-SSiB afternoon-morning, where afternoon is defined as the period 1400-2300 LST and morning as 0200-1100 LST.

Acknowledgement The authors thank Dr. Xiaofan Li for providing some computing resources.

References

Adams, D. K., and A. C. Comrie, 1997: The North American Monsoon, *Bull. Amer. Meteorol. Soc.,* **78**, 2197-2213.

Berbery, E. H., 2001: Mesoscale moisture analysis of the North American Monsson, *J. Climate,***14***,* 121-137.

Deng, A., N. L. Seaman, and J. S. Kain, 2003: A shallow-convective parameterization for mesoscale models. Part I: Submodel description and preliminary application. *J. Atmos. Sci.,* **60,** 34-56.

Douglas, M. W., R. A. Maddox, K. Howard, and S. Reyes, 1993: The Mexicon Monsoon, *J. Climate*, **6**, 1665-1677.

Dudhia, J., 1989: Numerical study of convection observed during the winter monsoon experiment using a mesoscale two-dimensuional model, *J. Atmos. Sci*, **46**, 3077-3107.

Grell, G. A., J. Dudhia, and D. R. Stauffer, 1995: A description of the fifth-generation Penn State/NCAR Mesoscale Model (MM5), NCAR Tech. Note, NCAR/TN-398+STR, 122pp

Higgins, R. W., J.E. Janowiak, and Y. Yao,1996: A gridded hourly precipitation data base for the United States (1963-1993), NCEP/Climate prediction Center ATLAS No. 1, 47pp.

______, R.W., Y. Yao, E. S, Yarosh, J. E. Janowiak, and K. C. Mo, 1997a: Influence of the Great Plains low-level jet on summertime precipitation and moisture transport over the central United States, *J. Climate,***10***,* 481-507.

Huffman, G. J., and D. T. Bolvin, 2003: TRMM real-time multi-satellite precipitation analysis data set documentation, Laboratory for Atmosphere, NASA Goddard Space Flight Center, ftp://aeolus.nascom.nasa.fov/pub/merged/3B4XRT_doc.

Kain, J. S., and J. M. Fritsch, 1993: Convective parameterizations for mesoscale models: the Kain-Fritsch scheme. The representation of cumulus convection in numerical models, Meteor. Monogr., No 24, Amer. Meteor. Soc., 165-170.

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project, *Bull. Amer. Meteorol. Soc.*, **77**, 437-471.

North American Monsoon Experiment (NAME) Science and Implementation Plan, 2003, http://www.cpc.ncep.noaa.gov/products/precip/monsoon/

Schmitz, J.T., and S. L. Mullen, 1996: Water vapor transport associated with the summertime North American Monsoon as depicted by ECMWF analyses, *J. Climate,***9***,* 1621-1634.

Schubert, S.D., R. B. Rood, and J. Pfaendtner, 1993: An Assimilated dataset for earth science applications, *Bull. Amer. Meteorol. Soc.,* **74**, 2331-2342.

Xue, Y., P. J. Sellers, J.L. Kinter III, and J. Shukla, 1991: A simplified biosphere model for global climate studies, *J. Climate*, **4**, 345-364.

Zhang, D-L., and R.A. Anthes, 1982: A high-resolution model of the planetary boundary layer-sensitivity tests and comparisons with SESAME-79 data, *J. Appl. Meteor*, 21, 1594-1609.

______, W.-Z. Zheng, and Y.-K. Xue, 2003: A numerical study of early summer regional climate and weather over LSA-East. Part I: Model implementation and verification, *Mon. Wea. Rev.*, **131**, 1895-1909.

______, W.-Z. Zheng, 2003: Diurnal cycles of surface winds and temperatures as simulated by five boundary layer parameterizations. *J. Appl. Meteor*, 21, in press.