P2.10 IMPACT OF THE QUIKSCAT SURFACE WINDS ON THE SUMMER PRECIPITATION SIMULATION OVER THE US GRAT PLAINS

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I. Introduction

The NASA Quick Scatterometer (QuikSCAT) was launched in June 1999. It circles Earth at an altitude of 800 kilometers once every 101 minutes. The SeaWinds microwave radar sensor on board QuikSCAT measures the ocean surface winds using the relationship between the backscattered radar signal and the roughness of the ocean surface. The accuracy of the measured ocean surface wind reaches 2 m sec^{-1} in speed and 20^0 in direction, where help from independent information (e.g., numerical models) is needed to remove the ambiguity in the direction determination. These winds have been shown to have positive impact on the numerical weather forecast (Atlas et al., 2001). Currently, the QuikSCAT wind data have been routinely assimilated to the NCEP GDAS to help improving the weather prediction (Yu, 2003).

The aforementioned QuikSCAT impact studies mainly focus on improving the model initial fields, where the wind data are used during a pre-forecast period to generate better initial conditions to improve the subsequent numerical prediction. In this study, however, another kind of QuikSCAT impact experiment is conducted on the regional climate simulations, where the wind data are assimilated to the model *during* the simulation period (Stauffer and Seaman 1990). This kind of assimilation can provide information on the model responses to surface conditions and related physical processes, and thus provide guidance on improving model parameterizations and climate simulation, and potentially the future climate prediction. This is especially true when regional climate models have difficulties capturing climatological characteristics in the monthly to seasonal time scale.

We use a coupled Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (i.e. MM5, Grell et al. 1994; Chen, F., and J. Dudhia 2001)-Simplified Simple Biosphere (SSiB) scheme (Xue et al. 1991; Zhang et al. 2003) to perform such QuikSCAT impact experiments. Our interested area is the US Great Plains Region. We are particularly interested in to what extent the model could resolve the diurnal cycle of the low-level circulation and precipitation patterns, and how the assimilation of the QuikSCAT surface wind impacts them in the monthly scale integration. In the following, a review on the precipitation studies over the US Great Plains is first presented; the configuration of the coupled MM5-SSiB model is then described. Simulation results with and without the assimilation of the QuikSCAT wind are presented in section IV. Section V contains a brief summary.

II. Studies on US Great Plains Precipitation

The large spatial and temporal variability in the precipitation fields over the US Great Plains during summer months has been extensively investigated from observation studies (e.g., Wallace 1975; Higgins et al. 1996, 1997a-b, 1999; Dai et al 1999, 2001; Berbery and Fox-Rabinovitz 2003) and model simulations (e.g. Girogi 1990, 1991, 1994; Helfand and Schubert 1995; Schubert et al. 1998). A special precipitation feature in this region is that

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summer precipitation occurs most frequently from middle night to early morning, and the nocturnal precipitation contributes significantly to the total precipitation amount. This is quite different from other inland regions such as the Large-Scale Area-East (LSA-E) and the southwestern US, where the summer precipitation and thunderstorms tend to be more frequent during the afternoon.

Despite the large amount of studies on the Great Plains, quantitative precipitation forecasts (QPFs) of the fine scale precipitation events over this region at the timescales of a few days to weeks during the warm season still remain a great challenge. Many studies use general circulation models (GCMs) and regional climate models at a grid resolution of over 50 km to simulate the US Great Plains precipitation. However, those models at such resolutions could only treat clouds and precipitation in terms of the relative humidity and some convective systems at the sub-grid scale, and thus would likely fail to predict rain bands, line convection, topographically driven precipitation, as well as their related meso-β-scale circulations (Zhang et al. 2003). Moreover, the diurnal cycle and related processes and feedbacks, one of the crucial aspects related to the warm season precipitation predictability, are poorly represented in both Regional Mesoscale Models (RMMs) and GCMs (NAME 2003). The warm season QPFs are also limited due to the dominant weak dynamical forcing in the synoptic-scale environments and sub-grid-scale meteorological forcing and surface conditions (Zhang et al. 2003). Many studies indicated that the warm season precipitation at a few days to weeks and beyond was extremely sensitive to the surface conditions (e.g. Giorgi 1991, Xue et al. 1996, 2001; Paegle et al. 1996; Wen et al. 2000).

Recently, some efforts are devoted to improve the warm season QPFs by simply incorporating high grid-resolution, realistic model physics and land-surface parameterizations (Paegle et al. 1996; Xue et al. 2001; Chen and Dudhia 2001; Anderson and Roads 2002; Zhang et al. 2003). Zhang et al. (2003) modified MM5 and SSiB and then coupled them together. They have demonstrated that the coupled MM5/SSiB has the capability in reproducing well the regional climate features at the weekly to monthly time scales. More interestingly, many daily weather events are well reproduced even up to a month over LSA-E. With these capabilities, this model appears to be suitable for our purposes of simulating the Great Plains rainfall and performing QuikSCAT impact studies.

III. Model and Experimental Configurations

The coupled MM5/SSiB (Zhang et al. 2003) is used in this study. The planetary boundary layer (PBL) parameterization uses the Blackadar PBL scheme (Zhang and Anthes 1982), which performs better in realistically producing diurnal cycles of the surface temperatures and surface winds (Zhang and Zheng 2003), as well as the PBL in terms of temperature, mixing ratio, and depth (Bright and Mullen 2002). The new version of the Kain-Fritsch (1993) convective parameterization including the parameterized shallow convective effects (Deng et al. 2003) and a simple explicit treatment of cloud microphysics based on Dudhia (1989) is employed. The CCM2 radiation package is used for the terrestrial and solar radiative heating.

A two-way, nested-grid (45/15 km) technique is employed to achieve multi-scale simulations. The coarse domain, centered at 33.0ºN and 94.0ºW, covers the region approximately 19º-45ºN and 110º-77.5ºW and the fine domain covers region approximately 30.5º-41ºN and 101.5º-87.5ºW (see Fig. 1). The model has 30 vertical levels with the top of the atmosphere located at 50 hPa. The model is initiated at 0000 UTC 1 June 2000 and then integrated continuously for 30 days. Its initial conditions are obtained by an objective analysis where the radiosonde and surface data are combined with a first-guess field, which is taken from the NCEP 6-hourly Eta-model analyses at the resolution of 40 km on the Advanced Weather Interactive Processing System (QWIPS) 212 grid. The initial deep soil temperatures and moistures from the NCEP ETA analyses are both interpolated to the SSiB soil layers. The outermost coarse-mesh lateral boundary conditions are obtained by linearly interpolating NCEP Eta-model analyses using Perkey and Kreitzberg (1976) method and they are updated every 6 hours.

The simulation using the above described model configuration is referred as the 'standard' or 'control' run in the following. The sensitivity run is performed with assimilation of the QuikSCAT surface wind. The QuikSCAT Level 2B grid swath data taken from Jet Propulsion Laboratory (JPL) (http://podaac.jpl.nasa.gov/order/order_qscat.html) is used in this study. This dataset has a horizontal resolution of 25 km and is available twice a day over Gulf of Mexico (around 0000 and 1200 UTC), owing to the different ascending and descending orbital modes. Before the assimilation, the ascending and descending orbital data are first optimally interpolated to the nearest (within ±3 hours) standard output time 0, 6, 12, or 18, of the 6-hourly NCEP ETA analysis surface wind field to generate an 'enhanced' QuikSCAT+ETA surface wind analysis. The modeling system then assimilates the enhanced surface wind to the model surface wind using Four-Dimensional Data Assimilation (FDDA) scheme (Stauffer and Seaman 1990), in which the model surface wind is continuously nudged toward the QuikSCAT+ETA wind during the integration. The nudging coefficient is set to be 5×10^{-1} s^{-1} and no other variable nudging is done in this study.

IV. Results

Figure 2 shows comparisons of the monthly mean surface wind between the QuikSCAT, QuikSCAT+ETA, MM5-SSiB control run and MM5-SSiB simulation with the QuikSCAT assimilation. Fig. 2a and b suggest that the enhanced QuikSCAT+ETA is similar to the original QuikSCAT winds in direction over the Gulf of Mexico, though the magnitude of the enhanced wind is larger over the central Gulf of Mexico. Fig. 2d suggests that the control run have difficulties in reproducing the QuikSCAT+ETA surface winds over Gulf of Mexico with systematic errors exceeding 3 m sec^{-1} over most of this region. The FDDA procedure basically corrects these errors and the final modeled wind is very close to the QuikSCAT+ETA winds over Gulf of Mexico (Fig. 2f). These corrections have a large impact on the simulated US Great Plains precipitation patterns. Figure 3 shows a comparison of the June 2000 monthly mean precipitation (mm day^{-1}) over the fine domain between the observation, the model control run, and the simulation with the QuikSCAT assimilation. The observation is taken from the NCEP Climate Prediction Center (CPC) daily precipitation analysis at a 0.25° × 0.25° resolution (http://www.cpc.ncep.noaa.gov/products/precip/realtime). This dataset is obtained based on over 5000 rain-gauge stations in the U.S. The observation shows that a heavy rainbelt with a southwest-northeast orientation occurs in this month. In the control run, however, the orientation of the simulated rainbelt is tilted too east compared to the observation. With the QuikSCAT assimilation, the rainbelt orientation is basically the same as the observation. Detailed time series analyses in Fig. 4 and Fig. 5 suggest that this QuikSCAT improvement mainly occurs for the weather events during June10-12, where Fig. 4 is the time series of the area-averaged, daily accumulated precipitation over the fine domain and Fig. 5 shows the Homvöller diagram of the time-zonal cross section of the precipitation averaged over the latitudinal belt from 31^0N to 40^0N. Here the observation is taken from the hourly gauge-only National Precipitation Analysis (NPA) at a 4-km resolution **(http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/).** This dataset provide more detailed information on diurnal cycle of the precipitation evolution. As shown in Fig. 4, the precipitation magnitude of June 10-12 has been greatly improved with the QuikSCAT assimilation. In addition, Fig. 5 shows that the simulated rainbelt position of June 10-12 with the QuikSCAT assimilation has also been largely improved from the control run. Both of these magnitude and position improvements by the QuikSCAt assimilation lead to a better monthly mean precipitation as shown in Fig. 3.

V. Conclusion

Through an improvement of the surface wind field over Gulf of Mexico, the QuikSCAT data yield a positive impact on the summer precipitation pattern and its evolution over the US Great Plains as simulated by the coupled MM5-SSiB model. This impact likely occurs through a change of the PBL moisture flux and convergence fields associated with Gulf of Mexico. Detailed analyses of the precipitation diurnal cycle and moisture convergence fields in the control and QuikSCAT runs will be presented elsewhere.

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References

Ahijevych, D. A., R. E. Carbone, and J. D. Tuttle, 2001: Radar data and climatological statistics associated with warm season precipitation episodes over the continental United States. NCAR/Tech. Note-448+STR.

Anderson, B. T., and J. O. Roads, 2002: Regional simulation of summertime precipitation over the Southwestern United States. *J. Climate,* **15,** 3321-3342.

Atlas, R., R. N. Hoffman, S. M. Leidner, J. Sienkiewicz, T.-W. Yu, S. C. Bloom, E. Brin, J. Ardizzone, J. Terry, D. Bungato, and J. C. Jusem, 2001: The effects of marine winds from scatterometer data on weather analysis and forecasting. *Bull. Amer. Meteor. Soc.,* **82,** 1965-1990.

Berbery, E. H., and M. S. Fox-Rabinovitz, 2003: Multiscale diagnosis of the North American monsoon system using a variable resolution GCM. *J. Climate*, **16,** 1929-1947.

Bright, D. R., and S. L. Mullen, 2002: The sensitivity of the Numerical simulation of the southwest monsoon boundary layer to the choise of PBL turbulence parameterization in MM5. *Weather and Forecasting,* **17,** 99-114.

Carbone, R. E., J. D. Tuttle, D. A. Ahijevych, and S. B. Trier, 2002: Inferences of predictability associated with warm season precipitation episodes. *J. Atmos. Sci.,* **59,** 2033-2056.

Chen, F., and J. Dudhia, 2001: Coupling an advanced land surface-hydrology model with the Penn Stae-NCAR MM5 modeling system. Part I: Model implementation and sensitivity. *Mon. Wea. Rew.,* **129,** 569-585.

Dai, A., F. Fiorgi, and K. E. Trenberth, 1999: Observed and model simulated precipitation diurnal cycle over the contiguous United States. *J. Geophys. Res.,* **104,** 6377-6402.

Dai, A., 2001: Global precipitation and thunderstorm frequencies. Part II: Diurnal variations. *J. Climate,* **14,** 1112-1128.

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.

NAME, 2003: North American Monsoon Experiment (NAME): Science and implementation plan. Prepared by the NAME Project Science Team.

GCIP, 1996: Major activities plan for 1997, 1998 and outlook for 1999 for the GEWEX Continental-scale International Project (GCIP): Part I, IGPO pub. Series 25.

Giorgi, F., 1990: Simulation of regional climate using a limited-area model nested in a general circulation model. *J. Climate,* **3**, 941-963.

Giorgi, F., 1991: Sensitivity of simulated summertime precipitation over the United States to different physics parameterizations. *Mon. Wea. Rew.,* **119,** 2870-2888.

Giorgi, F., S. W. Hosteler, and C. Shields Brodeur, 1994a: Analysis of the surface hydrology in a regional climate model. *Quart. J. Roy. Meteor. Soc.,* **120,** 161-183.

Giorgi, F, C. Shields Brodeur, and G. T. Bates, 1994b: Regional climate change scenarios over the United States produced with a nested regional climate model. *J. Climate,* **7,** 375-399.

Grell, G. A., J. Dudhia, and D. R. Stauffer, 1994: A description of the fifth generation Penn State/NCAR Mesoscale Model (MM5). NCAR Tech. Note NCAR/TN 398_STR, 138 pp.

Helfand, H. M., and S. D. Schubert, 1995: Climatology of the Great Plains low-level jet and its contribution to the continental moisture budget of the United States. *J. Climate*, **8**, 784-806.

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. [Available from NCEP/Climate Prediction Center, W/NP52, Washinton, DC 20233.]

Higgins, 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.

Higgins, R.W., Y. Yao, and X. Wang, 1997b: Influence of the North American monsoon system on the United States summer precipitation regime. *J. Climate*, **10,** 2600-2622.

Higgins, R. W., Y. Chen, and A. V. Douglas, 1999: Interannual variability of the North American warm season precipitation regime. *J. Climate*, **12,** 653-680

Paegle, J., K. C. Mo, and J. Nogues-Paegle, 1996: Dependence of simulated precipitation on surface evaporation during the 1993 United States summer floods. *Mon. Wea. Rew.,* **124,** 345-361.

Perkey, D. J., and W. Kreitzberg, 1976: A time-dependent lateral boundary scheme for limited area primitive equation models. *Mon. Wea. Rev.,* **104,** 744-755.

Schubert, S. D., H. M. Helfand, C. Y. Wu, and W. Min, 1998: Subseasonal variations in warm-season moisture transport and precipitation over the central and eastern United States. *J. Climate,* **11,** 2530-2555.

Stauffer, D. R., and N. L. Seaman, 1990: Use of four-dimensional data assimilation in a limited-area mesoscale model. Part I: Experiments with synoptic-scale data. *Mon. Wea. Rew.,* **118,** 1250-1277.

Stensrud, D. J., and J. M. Fritsch, 1994: Mesoscale convective systems in weakly forced large-scale environments. Part III: Numerical simulations and implications for operational forecasting. *Mon. Wea. Rew.,* **122,** 2084-2104.

Wallace, J.M., 1975: Diurnal variations in precipitation and thunderstorm frequency over the conterminous United States. *Mon. Wea. Rev.,* **103,** 406-419.

Wen, L., W. Yu., C. A. Lin, M. Beland, R. Benoit, and Y. Delage, 2000: The role of land surface schemes in short-range, high spatial resolution forecasts. *Mon. Wea. Rev.,* **128,** 3605-3617.

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

Xue, Y. M. J. Fennessy, and P. J. Sellers, 1996: Impact of vegetation properties on U.S. Weather prediction. *J. Geophys. Res.,* **101,** 7419-7430.

Xue, Y., F. J. Zeng, K. E. Mitchell, Z Janjic, and E. Rogers, 2001: The impact of land surface processes on simulations of the U.S. hydrological cycle: A case study of the 1993 flood using the SSiB land surface model in the NCEP Eta regional model. *Mon. Wea. Rev.,* **129,** 2833-2860.

Yu, T.-W., 2003: Operational use of QuikSCAT winds in NCEP GDAS, 12th Conference on Satellite Meteorology and Oceanography, 9—13 February 2003, Long Beach, CA.

Zhang, D.-L., and J. M. Fritsch, 1988: Numerical sensitivity experiments of varying physics on the structure, evolution, and dynamics of two mesoscale convective systems. *J. Atmos. Sci.,* **45,** 261-293.

Zhang, D.-L., 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,* in press.

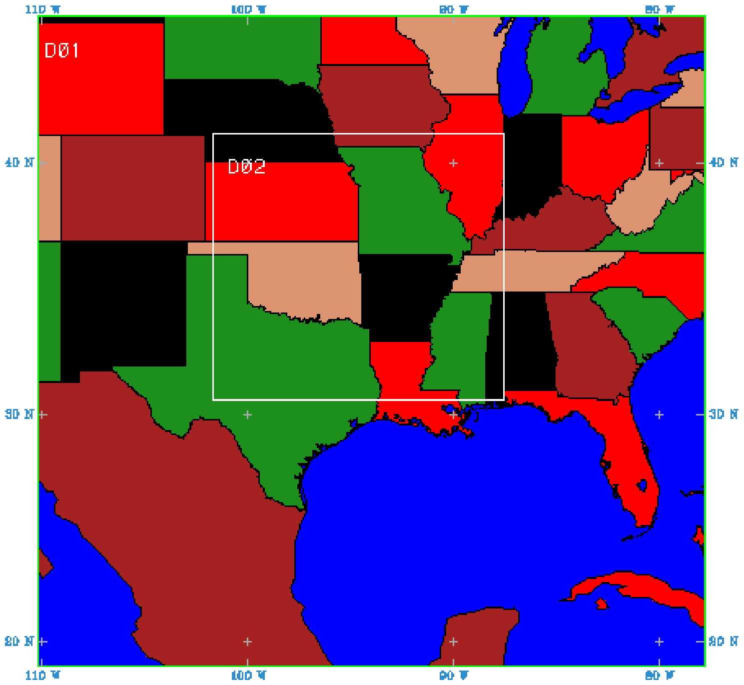


Fig.1 Domain of the nested simulation.

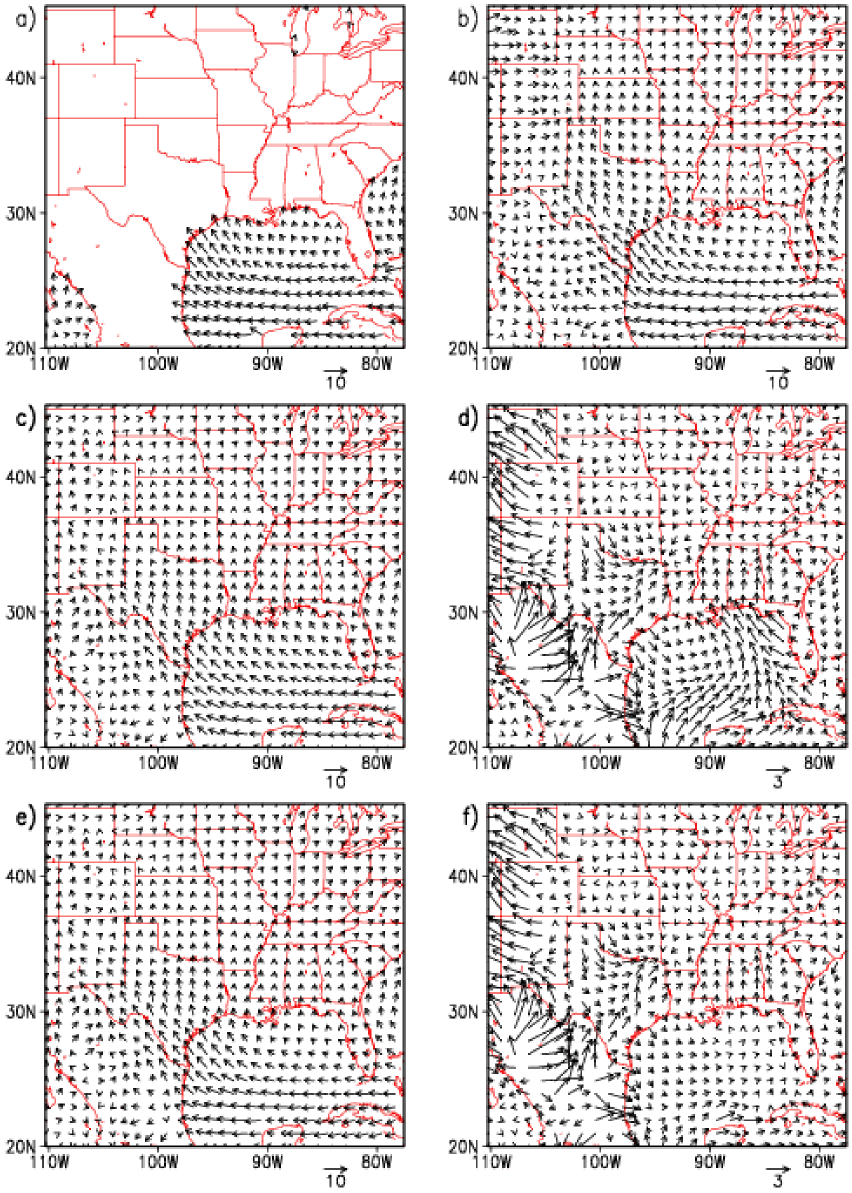
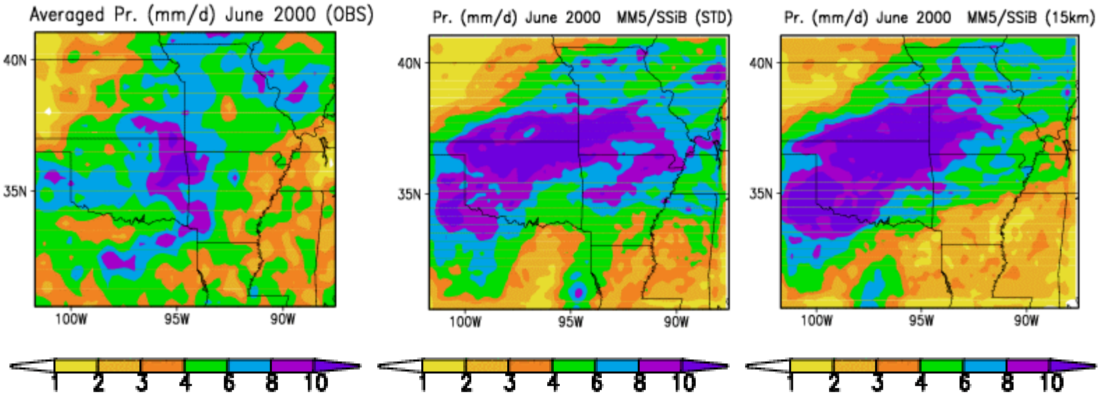
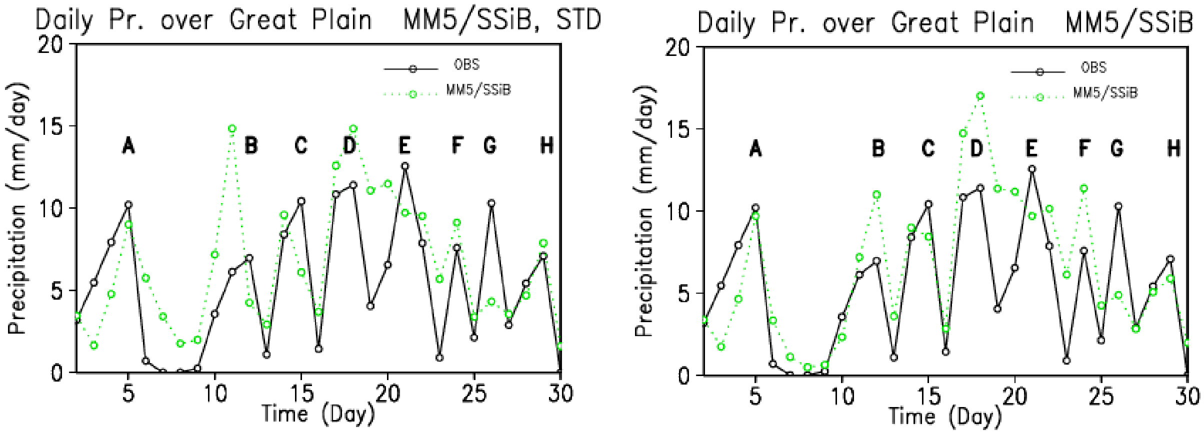


Fig. 2 Comparisons of the June 2000 monthly mean surface wind. (a) QuikSCAT; (b) ETA+QuikSCAT; (c) MM5/SSiB without the QuikSCAT assimilation (control run); (d) [(c)-(b)]; (e) MM5-SSiB with QuikSCAT assimilation; (f) [(e)-(b)].



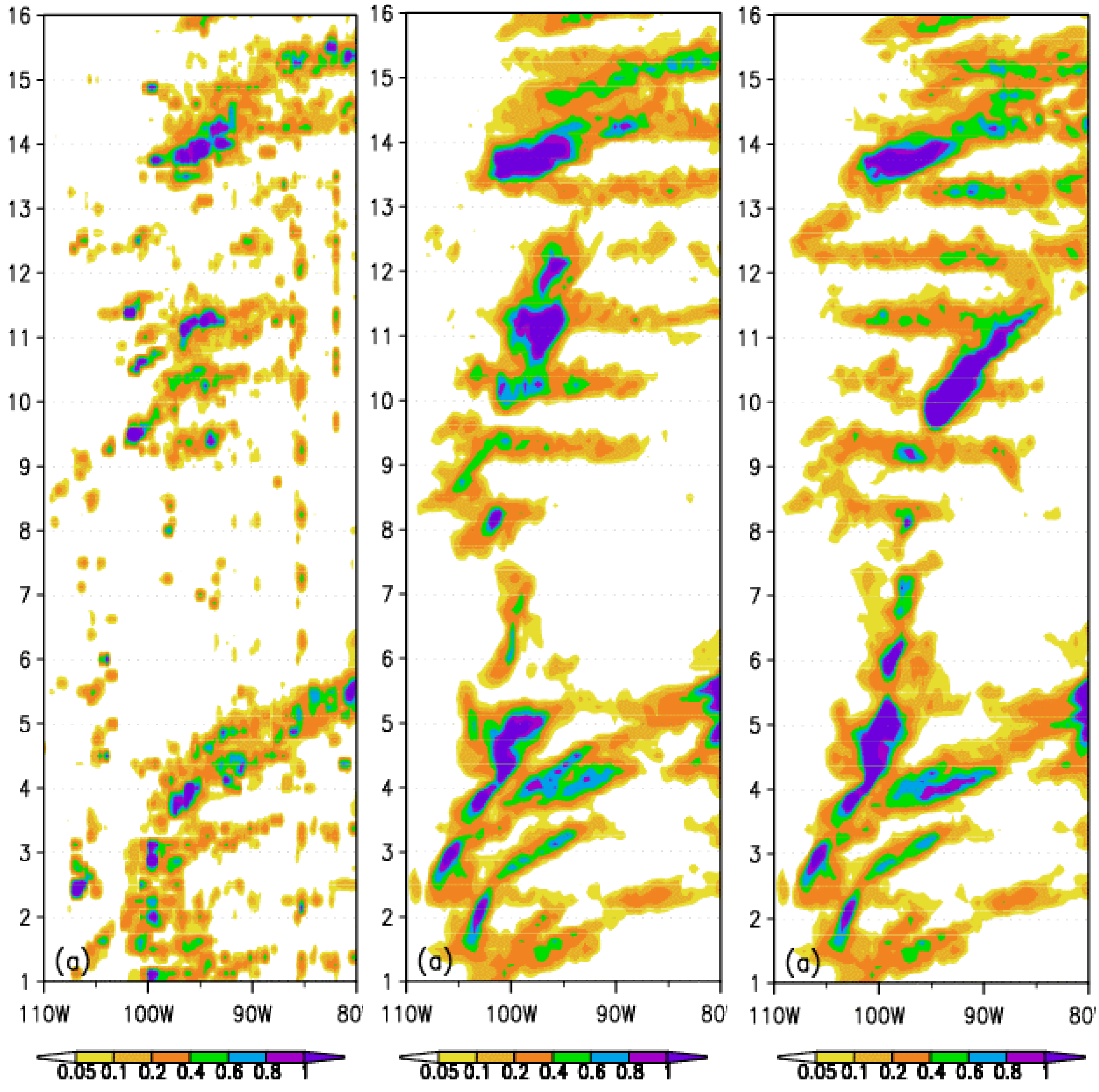
(a) (b) (c)

Fig.3 Comparison of the June 2000 mean precipitation between (a) observation, (b) simulation by MM5/SSiB control run, and (c) simulation by MM5-SSiB with the QuikSCAT wind assimilation. Observation is from NCEP/CPC daily precipitation analysis at a 0.25° × 0.25° resolution (http://www.cpc.ncep.noaa.gov/products/precip/realtime).



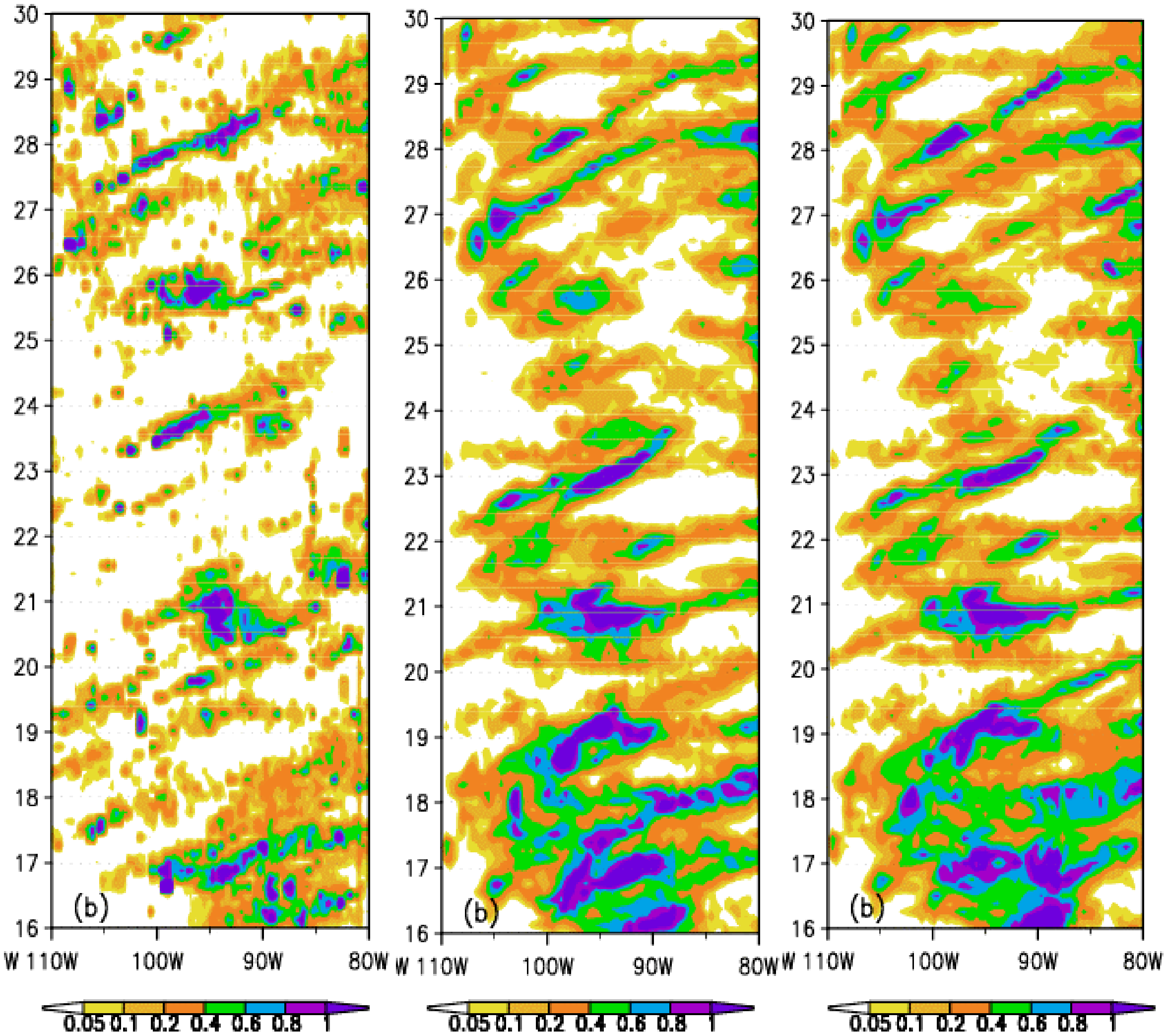
(a) (b)

Fig.4 Time series of the area-averaged, daily-accumulated precipitation (mm) over the fine domain. (a) Comparison between the observed (solid line) and simulated by MM5-SSiB (dashed line) without the QuikSCAT assimilation; (b) comparison between the observed (solid line) and simulated (dashed line) with the QuikSCAT assimilation. Observation is from hourly gauge-only National Precipitation Analysis (NPA) at a 4-km resolution **(http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/) .**



(a) (b) (c)

Fig.5 Homvöller diagram of the time-zonal cross section of the precipitation (mm hour^{-1}) averaged over the latitudinal belt from 31^{0}N to 40^{0}N. Longitude range is 80^0-110^{0}W and time rage is the first half of June 2000. (a) Observation, (b) MM5-SSiB simulation with the QuikSCAT surface wind assimilated; (c) MM5-SSiB standard simulation without the QuikSCAT assimilation. Note the differences in position and tilting angle of the rainfall during the June 10-12 events between the simulations with and without the QuikSCAT assimilation. Observation is from hourly gauge-only National Precipitation Analysis (NPA) at a 4-km resolution **(http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/).**



(a) (b) (c)

Fig. 5 (continued) Second half of June 2000. (a) Observation, (b) MM5-SSiB simulation with the QuikSCAT assimilation; (c) MM5-SSiB standard simulation without the QuikSCAT assimilation.