P1.3 STUDY OF MODIS RETRIEVED DATA AND THEIR IMPACT ON WEATHER SIMULATIONS

Shu-Hua Chen[1*], Aidong Chen[1], Jennifer Haase[2], Zhan Zhao[1], and Francois Vandenberghe[3]

[1]Department of Land, Air, and Water Resources, University of California, Davis, CA
[2]Department of Earth and Atmospheric Sciences, Purdue University, W. Lafayette, IN
[3]National Center for Atmospheric Research, Boulder, CO

1. INTRODUCTION

Terra, the spacecraft of the first NASA Earth Observing System mission, was launched in February 2000, and a companion satellite Aqua joined it in May 2002. Both satellites are equipped with Moderate Resolution Imaging Spectrometer (MODIS) instruments. Some satellite observations, in particular from microwave channels, are available only over ocean, while the MODIS data are available over land and ocean and their spatial resolution is considerably high (5 km for this study). However, the MODIS data are limited to cloud free regions or the areas above cloud tops. Here, to better understand the characteristics and quality of the MODIS retrieved total precipitable water (TPW), the data are compared with radiosondes and ground-based Global Positioning System (GPS) TPW.

A code has been developed to assimilate MODIS TPW into the Weather Research and Forecast (WRF) model three-dimensional variational data assimilation (3DVAR) system. Because of its high resolution over both land and ocean, MODIS data appears to have a potential to make some impact on severe weather simulations and forecasts. This new capability is demonstrated on Hurricane Isidore (2002) study.

2. COMPARISON with OBSERVATIONS

The radiosonde data (about 500 points) from Australia at 0000 UTC January and July, 2003 are used for data comparison. The reason of choosing Australia is because MODIS data are available over the area around 0000 UTC (near Infra-Red (nIR) data available only at day time) when radiosondes are launched worldwide. There is one cloud flag that comes along with the MODIS nIR data (MOD05), and in this study only cloud free MODIS nIR pixels are compared with radiosonde data.

Corresponding author address: Shu-Hua Chen, Land, Air, and Water Resource, Davis, CA 95616.

Figure 1a shows the difference (or error) of retrieved MODIS nIR TPW from that of radiosonde (mm) with respect to MODIS TPW (mm). The error becomes larger as the water vapor content increases. The overall root mean square error is about 4 mm. It is noticed that there exists positive biases for most MODIS TPW data, and the values increase with the increase of water vapor content as well. However, some large negative biases are also found in Fig. 1a. Since the retrieved MODIS nIR TPW is the integral of water vapour above the cloud top, we suspect that those underestimation points could be due to the existence of clouds which are not detected by the retrieval algorithm (i.e., treated as cloud free by the algorithm).

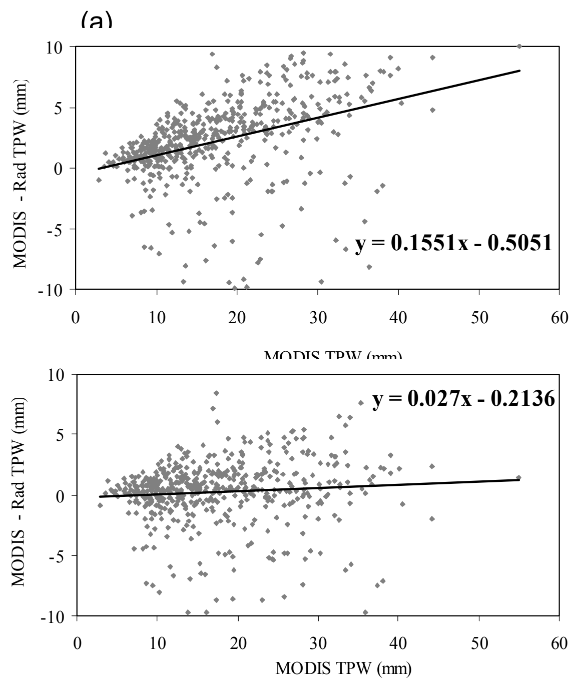

Fig. 1: (a) Difference of retrieved MODIS near Infra-Red (nIR) TPW from radiosonde TPW (mm) versus MODIS nIR TPW (mm). (b) Same as (a) except after correction of MODIS nIR TPW data. The regression equations before and after bias correction are also shown.

Figure 1b shows the same information as Fig. 1a, except after the bias correction. According to the regression equation in Fig. 1a, the bias correction is calculated as follows:

$$NEW = OLD * (1 - 0.1551) + 0.5051 \quad (1)$$

where NEW and OLD are MODIS TPW before and after bias correction, respectively. The room mean square error is then reduced to 2.61 mm after data correction.

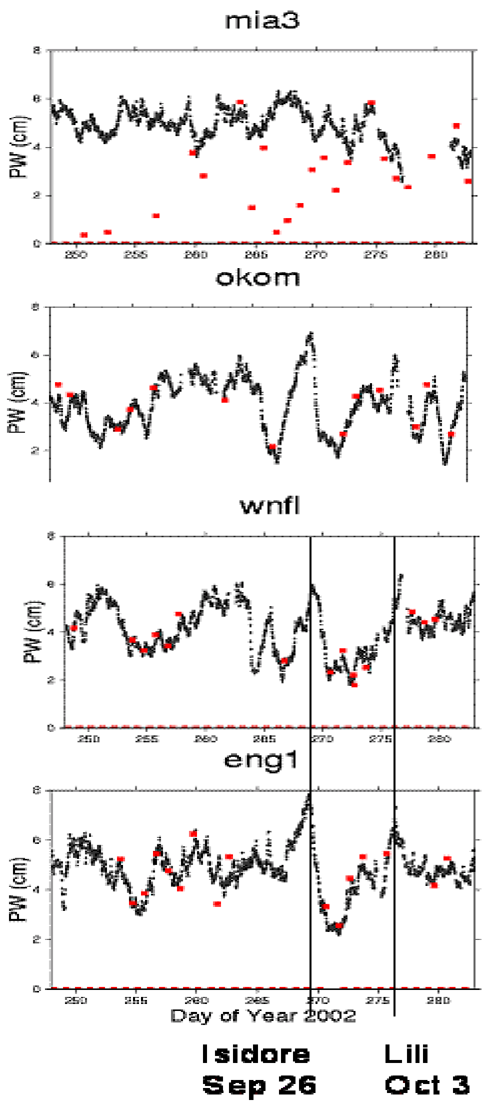

Fig. 2: MODIS nIR TPW comparison with GPS TPW (cm) for four sites of the GPS network over the southeast US.

Figure 2 shows the comparison of TPW between MODIS and ground-based GPS at sites over the southeast US. The results are of comparable high quality, with the exception of the site near Miami, MIA3.

3. NUMERICAL EXPERIMENT DESIGN

The WRF model (Michalakes *et al*. 2001; Skamarock *et al*. 2001) V2.0 with a two-domain (30 km and 10 km), two-way nested interaction is used for Hurricane Isidore (ISID; 2002) simulation. The grid's dimensions are 144 x 132 x 31 and 226 x 187 x 31 in x, y, and z directions in domains 1 and 2, respectively. Three experiments (CNTL, MOD, and MODC) are conducted (Table 1). MOD assimilates original retrieved MODIS nIR TPW with a standard deviation of 4 mm, while MODC assimilates MODIS data after bias correction using Eq. (1) with a standard deviation of 2.5 mm. Both domains 1 and 2 are initialized with WRF 3DVAR analysis for MOD and MODC. In each simulation, the Purdue-Lin microphysics scheme (Chen and Sun 2002), new Kain-Fritch cumulus parameterization (Kain 2004) which includes deep and shallow convection, YSU boundary layer parameterization, and Dudhia shortwave (Dudhia 1989) and RRTM longwave radiation parameterization (Mlawer et al. 1997) are activated. Model integrates 54 hours, starting from 1800 UTC 17 September, 2002.

Run	*Assimilated data*	*Error*
CNTL	None	
MOD	MODIS TPW	4 mm
MODC	Bias corrected MODIS TPW	2.5 mm

Table 1: Numerical experiments design.

4. RESULTS

Figures 3 shows time evolutions for the observed and simulated minimum sea level pressure (SLP) at the Isidore's center and the maximum 10-m wind speed. The simulated minimum SLPs from all numerical experiments are deeper than observed before 24-h simulation and become weaker afterwards. It is interesting to mention that results from all experiments are very similar during the first 24-h simulation. At the end of the integration, the simulated minimum SLPs are about 22 hPa and 14 hPa weaker than the observation from CNTL and MOD experiments, respectively.

Simulated maximum 10-m winds are weaker than observation during the entire simulation period. Although the improvement of hurricane intensity after the assimilation of MODIS TPW is not dramatic, the improvement is clearly shown.

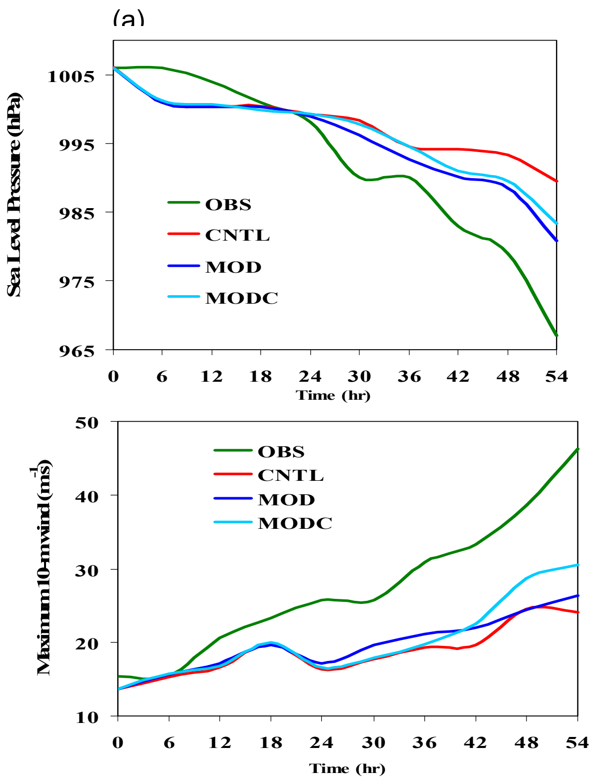

Fig. 3: Time evolution of (a) the minimum sea level pressures (hPa) at the Isidore hurricane center and (b) the maximum 10-m winds from best track observation (OBS) and model simulations.

The difference of assimilating MODIS TPW with (i.e., MODC) and without (i.e., MOD) bias correction is marginal. The simulated minimum SLP from MODC is slightly weaker than that from MOD. The simulated maximum 10-m wind from MODC is weaker and than becomes stronger than that from MOD. Although there are biases shown in the comparison between MODIS and Radiosonde TPW, it does not guarantee that the biases are from MODIS data. In addition, the data that used for comparison are most available over the land, while the study case occurred over the ocean. Therefore, the bias over land might not be representative the bias over ocean. Figure 4 shows the difference (or error) of TPW between MODIS nIR TPW vs. the latitude. It is interesting to note that most MODIS TPW data over radiosonde sites have positive biases, except one close to 16.3 ^{o}S, Willisid, which is located at a small island. This might imply that the MODIS niR TPW retrieved algorithm may introduce different biases over land and ocean.

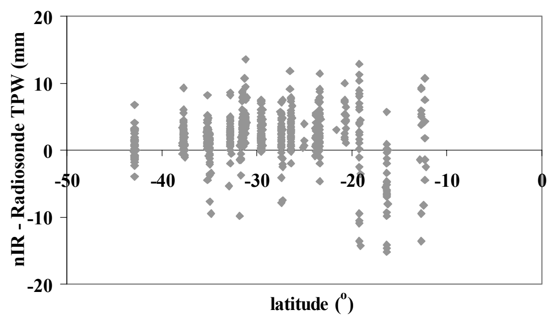

Fig. 4: Difference of retrieved MODIS nIP TPW from radiosonde TPW (mm) versus latitude (^{o}). Negative indicates stations in the southern hemisphere.

5. SUMMARY

The error estimation and quality control of observations are important to data assimilation. Comparisons between MODIS TPW with radiosondes and ground-based GPS TPW show that the quality of MODIS nIR TPW is reasonable; the error is about 4 mm and increases with the water vapor content. It is suspected that there exists bias for retrieved TPW data, in particular over land and the value also increases with the water vapor content. To better understand and use MODIS TPW, more studies on MODIS data characteristics are required.

The assimilation of MODIS TPW data into the WRF model simulations has been demonstrated for the case of Hurricane Isidore (2002). While this work is still preliminary to draw concrete conclusions on the impact on forecast, the improvement of Isidore intensity prediction is clearly shown. This improvement is expected because the accuracy of the global reanalysis data is relatively poor over ocean due to data sparseness. These preliminary results will be refined following further study of the MODIS data quality. It will also be interesting to access the impact of MODIS data on severe weather simulations and forecasts over land, and this will be conducted in the near future.

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REFERENCE:

Chen, S.-H., and W.-Y. Sun, 2002: A one-dimensional time-dependent cloud model, J. Meteor. Soc. Japan, 80, 99-118.

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

Kain, J. S., 2004: The Kain-Fritsch Convective Parameterization: An Update. J. Appl. Meteor., 43, 170-181.

Michalakes, J., S.-H. Chen, J. Dudhia, L. Hart, J. Klemp, J. Middlecoff, W. Skamarock 2001: “Development of a next generation regional weather research and forecast model” in developments in teracomputing. Proc. 9th ECMWF Workshop on the Use of High Performance Computing in Meteor. Eds. W. Zwieflhofer and N. Kreitz. World Scientific, Singapore. 269-276.

Mlawer, E. J., S. J. Taubman, P. D. Brown, M. J. Iacono, and S. A. Clough, 1997: Radiative transfer for inhomogeneous atmosphere: RRTM, a validated correlated-k model for the long-wave. J. Geophys. Res., 102(D14), 16663-16682.

Skamarock, W. C., J. B. Klemp, and J. Dudhia, 2001: Prototypes for the WRF (Weather Research and Forecast) model. Ninth Conf. Meso. Processes, AMS, J11-J15 (also see http://www.wrf-model.org).