7.3 Performance of High-Resolution Satellite Precipitation Products over China

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1. INTRODUCTION

In recent years, the satellite-based precipitation estimates have been developed on sub-daily time resolution over the globe by combining information from microwave (MW) and infrared (IR) observations (Hsu et al. 1997, Turk et al. 2004, Huffman et al. 2004, Huffman et al. 2007 and Joyce et al. 2004). While these estimates have been utilized widely in climate diagnostics, numerical models verifications and forcing hydrological models, quantitative examinations are needed to provide critical information on their performance upon which further improvements may be made and strategy to combine them with other observations (such as gauge-based analyses) may be designed. Several research has been available to examine the regional performance of the satellite precipitation products in reproducing spatial and temporal variation patterns on time scale of daily or longer (e.g. Ebert et al. 2006, Xie et al. 2007). Due to the lack of a gauge-based analysis of sub-daily resolution, it is not an easy task to assess the performance of high-resolution satellite precipitation products on a time scale of 3-hourly or better.

Recently, using gauge reports from about 2400 stations over China collected by the China Meteorological Administration (CMA), we have created an analysis of hourly precipitation on a spatial resolution of 0.25^{o}lat/lon grid over mainland China and applied it to verify the performance of six high-resolution products of satellite precipitation estimates. This paper provides a general description of the gauge-based hourly precipitation analysis and the verification results from January to August, 2007.

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2. THE GAUGE-BASED HOURLY PRECIPITATION ANALYSIS

An analysis of hourly precipitation is constructed on a 0.5^{o}lat/lon grid over mainland China for a period from January to August, 2007 by interpolating gauge observations at about 2400 gauge stations (fig.1). The overall interpolation strategy is a modification of Xie et al. (2007) who developed a three-step algorithm to produce precipitation analyses over East Asia. The interpolation also includes the GTS station data outside China dissegregated by the fine-resolution satellite estimates to reduce the boundary effects.

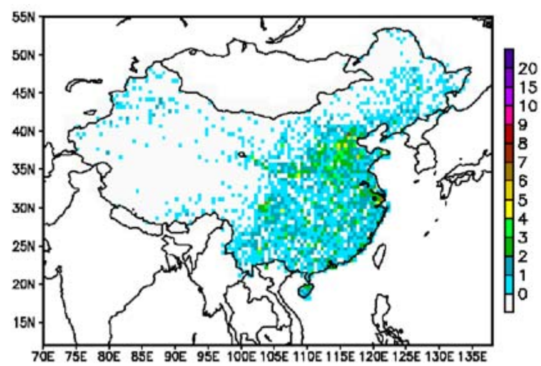

Fig. 1: Number of gauges in a 0.5^{o}lat/lon grid box used in the interpolations.

First, a gridded analysis of daily precipitation climatology is created for each of the 365 calendar days using about 700 daily precipitation reports for a 20-year period from 1978 to 1997. For this purpose, daily precipitation climatology is defined for stations within the domain with 90% or higher reporting rates by accumulating the first 6 harmonic components of the 365-day time series of the 20-year mean values. Analyzed fields of daily precipitation climatology are then defined by interpolating the station climatology through Shepard (1968) and by adjusting it against the PRISM (Daily et al. 1994) monthly climatology over the region. The purpose of this adjustment is to better represent the orographic effects in precipitation that are not accounted for in the interpolation of the daily station climatology through Shepard (1968) which is primarily an inverse-distance technique.

The second step of the algorithm involves the definition of an analyzed field of ratio of hourly precipitation to daily climatology. This is done by interpolating the corresponding station values, defined as the ratio of hourly observation at a station to the daily climatology at the grid box at the gauge location, using the Optimal Interpolation (OI) algorithm of Gandin (1965).

In the final step, the analysis of total hourly precipitation is calculated by multiplying the analyzed daily climatology with the ratio.

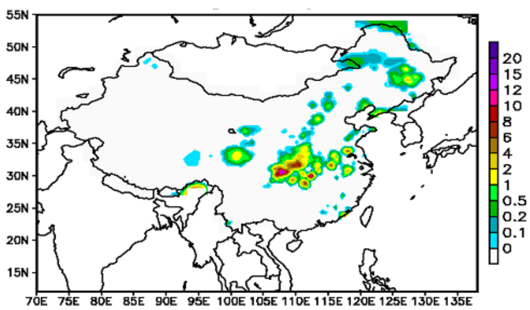

Fig.2 Distribution of gauge-based hourly precipitation (0.1mm/hr) for 09Z, May 23, 2007.

Fig.2 shows an example of the gauge-based analysis of hourly precipitation for 09Z, May 23 of 2007. A band of heavy rainfall, passing over the target area with a maximum of more than 20 mm/day, is well depicted by our gauge-based analysis. In this study, we have created the gauge-based hourly precipitation for an 8-month period from January to August of 2007.

3. EXAMINATIONS OF THE SATELLITE PRECIPITATION PRODUCTS

The gauge-based analysis of hourly precipitation is integrated into 3-hourly accumulation and applied to assess the performance of several satellite-based high-resolution precipitation estimates for an 8-month period from January 1 to August 31, 2007. The satellite products examined here include 1) the CPC MORPHing products (CMORPH) of Joyce et al. (2004); 2) simple average of the microwave-based estimates used in creating the CMORPH (COMB); 3) MW-adjusted IR products using Artificial Neural Network (PERSIANN, Hsu et al. 1997); 4) PDF matching MW-IR products NRL (Turk et al. 2004); 5) the gauge-adjusted MW-IR merged analysis of TRMM 3B42 (Huffman et al. 2007); and 6) its real-time version TRMM 3B42RT which is a MW-IR merged product without gauge adjustments (Huffman, et al. 2004). Details of the satellite products may be found from their respective references. Comparison of CMORPH and COMB provides us with an estimation of how much the precipitation products are improved by including information from the IR observations.

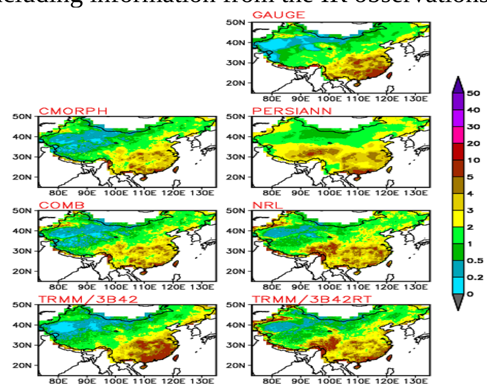

Fig.3 Distribution of precipitation for January –August, 2007, from a) our gauge-based analysis (Gauge), b) CMORPH, c) PERSIANN, d) COMB, e) NRL, f) the GPCC gauge-based analysis of monthly precipitation TRMM 3B42, and g) TRMM 3B42RT.

Distribution of precipitation over the target domain is well depicted by all of the satellite products examined here (fig.3). Satellite-based products, however, tend to miss small-scale features and contain bias compared to our gauge-based analysis. PERSIANN exhibits substantial over-estimation of precipitation over the Tibetan Plateau accumulated mostly during winter and early spring when surface is cold (not shown). The NRL and 3B42RT, meanwhile, present positive bias over the eastern slope of the Tibetan Plateau. The gauge-adjusted TRMM/3B42 shows some improvements upon the unadjusted 3B42RT in representing overall magnitude of precipitation. The bias, however, still exist, partially due to the fact that the GPCC gauge-based analysis they used in the adjustment is derived by interpolating gauge reports from only 200 stations without orographic corrections.

Figure 4 presents the spatial distribution of serial correlation between our gauge-based analysis and the selected satellite products on 0.25^{o}lat/lon and 3-hourly resolution. Reasonable correlation is observed over most of the region and for all of the satellite products examined here. Overall, satellite estimates perform better over wet regions than over dry areas. Among the six satellite products, CMORPH shows the best correlation over most of the regions.

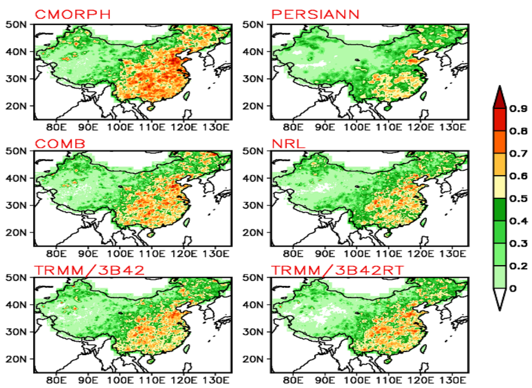

Fig. 4 Serial correlation between the gauge analysis and satellite estimates of 3-hourly precipitation on a 0.25°lat/lon grid.

Figure 5 shows bias of the selected satellite products relative bias to our gauge-based analysis. Relatively small bias is observed over most of the region and for all of the satellite products examined here. Overall, satellite estimates exhibit smaller bias over wet regions than over semi-arid and arid areas over the west. PERSIANN has the largest relative bias in Tibetan plateau.

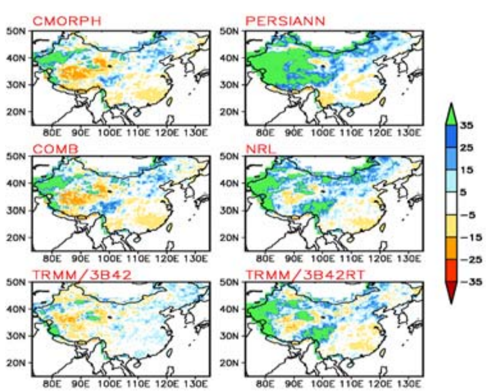

Fig. 5 Relative bias between the gauge analysis and satellite estimates of 3-hourly precipitation on a 0.25° lat/lon grid.

Pattern correlation for 3-hourly precipitation (fig.6) is relatively low during cold season when mean precipitation is small and reaches a stable level during mild and warm seasons starting from the mid of May. The CMORPH exhibits the best correlation with gauge-based analysis throughout the comparison period. Bias is

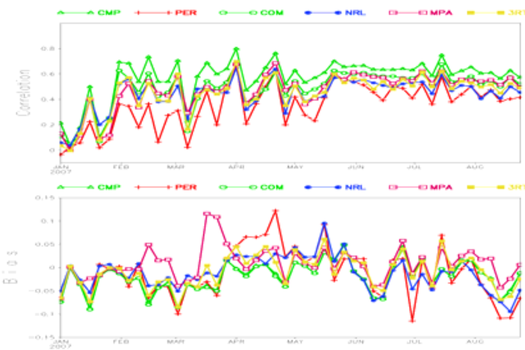

Fig.6 Time series of pattern correlation and bias between our gauge-based analysis and the selected satellite precipitation products on 0.25°lat/lon grid boxes and in 3-hourly time-resolution. Only data over grid boxes with al least one gauge are included in calculating the statistics.

Table 1 summarizes the comparison statistics for the satellite precipitation products for different seasons. For all satellite products, the best performance is achieved during the mild season (Apr.-Jun.) when precipitation is generated mostly by weather systems of larger scales. For all seasons, CMORPH exhibits the highest correlations for all of the three seasons examined. All satellite products present negative bias compared to the gauge analysis, except the gauge-adjusted TRMM/3B42 over-estimated precipitation over our examination period.

Table 1: Results of Comparison between the Gauge-Based Analysis and the Selected Satellite Products on a 0.25°lat/lon Grid over China, for January – August, 2007. Cold season for January and February; Mild season from March to May; Warm season from June to August.

Satellite Products	All months		Cold	Mild	Warm
	Bias(%)	Corr	Corr	Corr	Corr
CMORPH	-10.57	0.637	0.599	0.658	0.630
PERSIANN	-7.67	0.465	0.230	0.500	0.455
COMB	-10.81	0.565	0.494	0.563	0.564
NRL	-8.13	0.505	0.424	0.535	0.497
3B42	5.65	0.553	0.453	0.554	0.558
3B42RT	-3.66	0.531	0.427	0.537	0.529

Differences in correlation between CMORPH and COMB, reduces from 0.105 in cold season to 0.066 in warm season, implying that including IR information contributes more in cold season than in warm season.

Our gauge-based analysis detected a bi-mode diurnal cycle in the precipitation over China (fig.7). Two peaks are observed during local morning and late afternoon, respectively. The satellite products reproduced the diurnal cycle reasonably well. The afternoon peak is captured with an excessive amount of rainfall and a delay of ~3 hours, while the morning peak is under-estimated slightly.

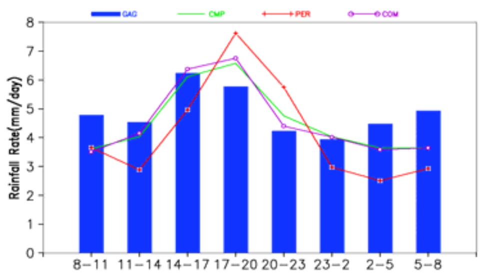

Fig.7 Diurnal cycle of precipitation derived from our gauge analysis (bar), the combined microwave (COMB, purple), CMORPH (green), and PERSIANN (red) satellite estimates over eastern China during warm season (June – August) of 2007.

4. SUMMARY

An analysis of hourly precipitation is constructed on a 0.25°lat/lon grid over mainland China and applied to examine the performance of six high-resolution satellite precipitation products, including CMORPH, PERSIANN, COMB, NRL, TRMM 3B42 and TRMM 3B42RT from January to August, 2007. Our preliminary results showed:

1) All of the six satellite products are capable of capturing the overall spatial distribution and temporal variations of precipitation reasonably well;
2) Performance of the satellite products varies for different regions and different precipitation regimes with better performance in warm season and wet regions;
3) Diurnal cycle of precipitation is estimated relatively well but the early morning peak is under-estimated;

Further work is underway to perform seasonal and regional case studies and to combine the gauge analysis with the satellite products. Detailed results will be reported at the workshop.

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