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Adaptability Evaluation of TRMM Satellite Rainfall and Its Application in the Dongjiang River Basin

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Abstract

Global rainfall data is very important for climate change research, and the current rainfall data are mainly from the rain gauge on the ground, ground radar and spaceborne passive radiometer. Rain gauge rainfall represents the point rainfall distribution, which would cause inaccurate result when calculating average rainfall in a region with statistical methods (such as the use of intra-variance method). This study mainly focus on the applicability of TRMM satellite radar rainfall through the comparison between the observed precipitation and the near real-time monitoring TRMM 3B42RT rainfall data in the Dongjiang River Basin in south China, and its performance in hydrological modeling. Results showed that TRMM 3B42RT rainfall data has a high precision and a good correlation with the observed precipitation in the basin. But at point scale, precision of TRMM 3B42RT rainfall data is limited. Besides, streamflow simulated by the observed precipitation has a smaller bias and a higher coefficient of efficiency than that simulated by TRMM 3B42RT rainfall data.

Keywords: TRMM satellite; Dongjiang River; Hydrological modeling; streamflow

1. Introduction

TRMM (Tropical Rainfall Measuring Mission) satellite has achieved some research progress since its launch in 1997. Viltard et al (2000)[1] have combined the data materials of PR and TMI to estimate the influence of rain droplet size spectrum on precipitation inversion. Prabhakara et al (2002)[2] have used the observation results of PR and TMI to make example statistics and analysis of the land convective precipitation and stratus precipitation and explored the way of illustrating land precipitation through 4GHz and 37GHz vertical polarization difference of TMI. Tao et al (1993)[3] have proposed a vertical outline inversion algorithm to estimate latent heat release by TRMM data. Iguchi et al (2000)[4] have put forward a way to estimate precipitation outline by TRMM radar. Harris et al (2000)[5] have made a comparison and analyzed the brightness temperature of NCEP and TRMM/PR and explained the spatial-temporal variations of the height of melting layer. Domestically, Yao et al (2003)[6] have chosen the brightness temperature information of the 85.SGHz vertical polarization channel which is very sensitive to liquid water change in the clouds from TRMM/TMI data and determined the land surface microwave emissivity through discrete ordinate vector radiation transmission mode and the step-by-step approach and made an inversion of the amount and distribution of the liquid water in the clouds effectively with the iteration method. Fu et al (2003)[7] have used TRMM/PR and TMI to make

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some analysis and researches on the precipitation structure of two mesoscale excessively heavy rains, thus getting to know the vertically spatial distribution of showerclouds, which demonstrated the fine application prospect of PR data in research fields such as precipitation properties, the vertical and horizontal structure of rainfall, vertical distribution of microphysical rainfall process and so on. At the same time, he used TRMM/PR to make an inversion of vertical rainfall structure outline and conducted quantification and parameterization of it. Besides, he made full use of TMI brightness temperature data to separate various kinds of vertical rainfall outline from average ones.

TRMM is the first meteorological satellite specially used to gauge tropical and subtropical precipitation quantificationally. It runs in an orbit which is not synchronous to the Sun. As a result, it comes to the same point at different time and is proper to study the daily change of rainfalls. The main purpose is to know a further step about the global energetic and hydrologic cycle through research on precipitation and latent heat in tropical zone and the influence of tropical rainfall on global cycling mechanism, to improve various kinds of medium-term and short-term forecasting and diagnosis mode and to better understand, diagnose and forecast El'Nino, Southern oscillation and 30~60d agitation of tropical atmosphere.

The paper uses different rainfall accuracy estimation indexes to estimate the precision of real-time precipitation data gained from TRMM satellite in Dongjiang River Basin of south China according to the station gauging data. A hydrologic model is used to further analyze the influence of the TRMM rainfall on streamflow simulation so as to study its applicability in hydrologic simulation and flood forecasting in the basin.

2. Study basin

The Dongjiang River Basin (Fig.1) lies in 113°25' E ~ 115°49' E, 22°28' N ~ 25°14' N. It is located in the eastern part of Guangdong Province and southern part of Jiangxi Province and the basin takes on a fan-shaped look from the northeast to the southwest. The main part of Dongjiang water supply region is in Guangdong Province, covering an area of 21823 km2, while 3502 km2 in Jiangxi Province. The catchment area of Dongjiang (Boluo hydrologic station upwards) is 25325 km2. The topography of Dongjiang water supply region is high in northeast and low in southwest and the land feature is a series of valleys and peaks from the north to the east.

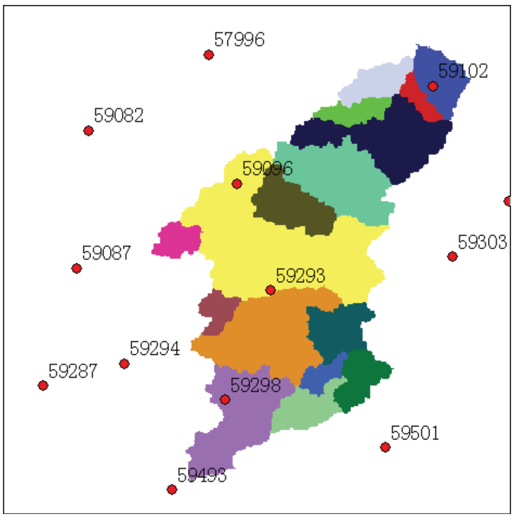

Figure 1. The Dongjiang River Basin and rainfall stations

3. Data

The observed precipitation in this study comes from 10 stations in Guangdong Province, that is Nanxiong (57996), Shaoguan (59082), Lianping (59096), Fogang (59087), Heyuan (59293), Zengcheng (59294), Huiyang (59298), Shenzhen (59493), Shanwei (59501), Wuhua (59303) and one in Jiangxi Province, Xunwu (59102), as shown in Fig.1. The rainfall data is recorded every day from 8 to 20 of Beijing time.The TRMM 3B42RT rainfall data, with a grid resolution of 0.25°, has a fixed form and every file records a 3-hour observing result. The period of 2002 to 2009 is chosen as a estimation period.

As the stations cover more than the Dongjiang River Basin, the Thiessen Polygon Method is used here to calculate the average value of observed daily precipitation as the daily precipitation of the basin. When calculating the average daily precipitation of the basin from TRMM data, superimpose the precipitation from 12 o'clock to 24 o'clock of the last day and intraday from 0 to 12 as the precipitation of that day, thus corresponding to 20 to 20 of Beijing time and preparing for afterwards work. TRMM data not only needs to be compared with the observed data in the basin, but also with the daily precipitation of every station so as to demonstrate the reliability of TRMM data from more aspects. According to the given station names and their longitude and latitude, it is necessary to find the adjacent grid from TRMM observation files and accumulate the grid data in accordance to the time in every file to calculate the daily precipitation of TRMM satellite. As there are few data in January, 2002, the comparing period comes from February, 2002 to December, 2009.

Bias, MAE (Mean Absolute Error), RMSE (Root Mean Square Error), CC (Correlation Coefficient), POD (Probability Of Detection), FAR (False Alarm Ratio), CSI (ETS, Equitable Treat Score) and NSCE (Nash-Sutcliffe Coefficient of Efficiency) are calculated as follows to evaluate the precision of the TRMM rainfall data.

$$Bias = \frac{Y_i - Q_{i,o}}{Q_{i,o}} \times 100\% \tag{1}$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N} | Y_i - Q_{i,o} | \tag{2}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_i - Q_{\mathrm{i,o}})^2} \tag{3}$$

$$CC = \frac{\sum_{i=1}^{N}(Y_i - \overline{Y})(Q_{i,o} - \overline{Q}_o)}{\sqrt{\sum_{i=1}^{N}(Y_i - \overline{Y})^2}\sqrt{\sum_{i=1}^{N}(Q_{i,o} - \overline{Q_o})^2}} \tag{4}$$

$$POD = \frac{H}{H+M} \tag{5}$$

$$FAR = \frac{F}{H+F} \tag{6}$$

$$CSI(ETS) = \frac{H - H_r}{H + M + F - H_r} \tag{7}$$

$$NSCE = \frac{\sum(Q_{i,o} - \overline{Q_o})^2 - \sum(Q_{i,o} - Q_{i,c})^2}{\sum(Q_{i,o} - \overline{Q_o})^2} \tag{8}$$

Where Y_i is simulated streamflow with TRMM data; N is number of samples; $\overline{Y}$ is average streamflow simulated with TRMM data; $Q_{i,o}$ is observed rainfall; $Q_{i,c}$ is TRMM rainfall; $\overline{Q_o}$ is average observed streamflow (Li et al., 2009)[8]; H is number of detected rainfall events; M is number of missed rainfall events; F is number of false-alarmed rainfall events; Hr is number of detected rainfall events randomly.

4. Results

Fig. 2 shows the relationship of daily average precipitation between the observed and TRMM data in the basin. From Fig. 2, it is evident that TRMM 3B42RT rainfall data is a bit smaller than the observed one. Besides, the observed maximum precipitations of 2002, 2003, 2005, 2006 and 2008 are all larger than TRMM data.

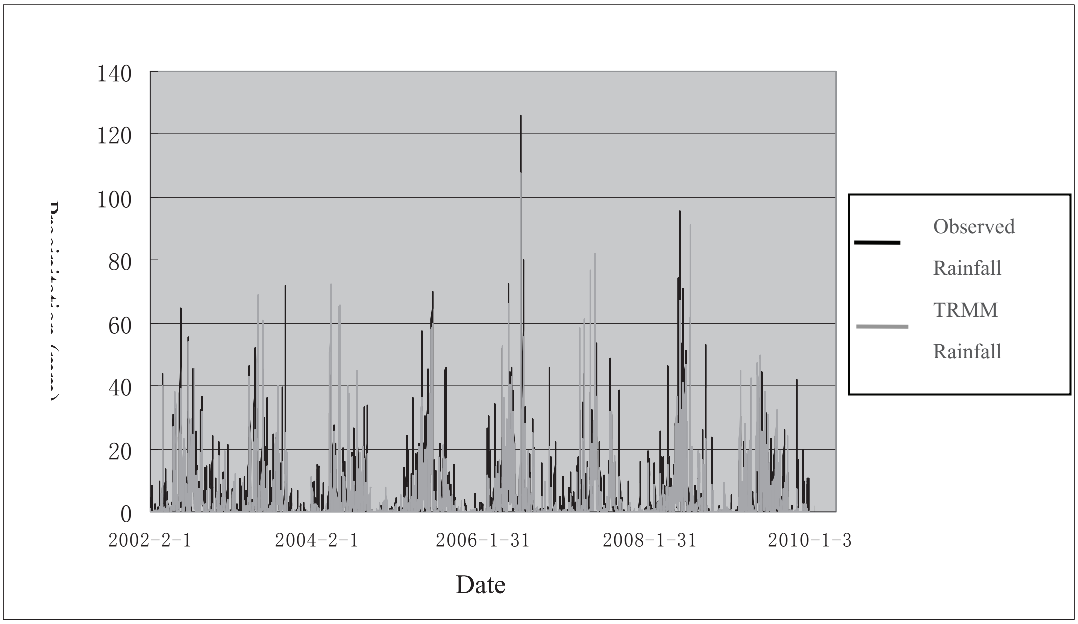

Figure 2. The comparison between the two precipitations

The correlationship between the observed precipitation and TRMM 3B42RT rainfall data is shown in Fig. 3. It can be concluded from Fig. 3 that the two time series have a linear relation generally and the correlation coefficient is 0.822.

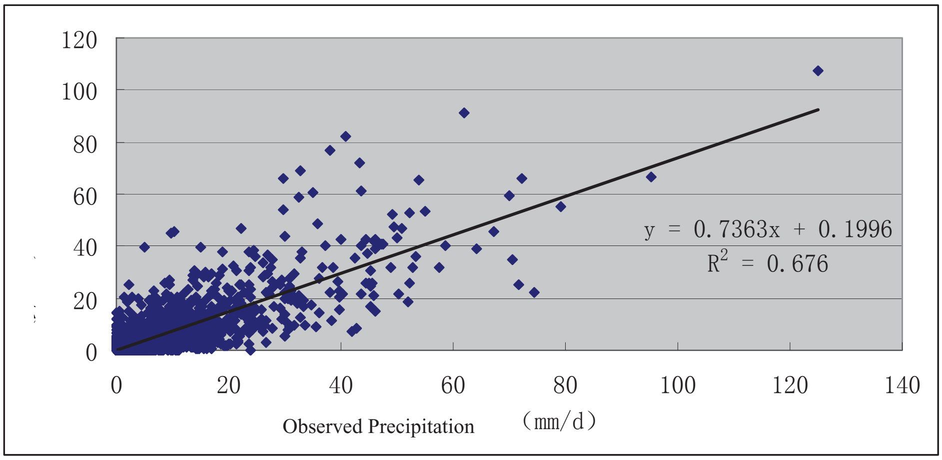

Figure 3. The correlativity between the two precipitation

As shown in Table 1 the statistical result indicates that Bias of the TRMM rainfall is -22.1%, probably because of the small area of the basin. However, the high correlation coefficent demonstrates the high correlativity of the observed and TRMM 3B42RT rainfall data at the basin scale.

Table1. Comparison of average precipitation in this basin

Bias(%)	MAE (mm/d)	RMSE (mm/d)	CC
-22.1	2.632	5.685	0.822

Table 2. The comparison of precipitation parameters between the observed data and TRMM data

Station name	Bias	MAE	RMSE	CC	POD	FAR	CSI
Nanxiong	-26.68%	3.277	8.693	0.613	0.659	0.209	0.561
Shaoguan	-34.15%	5.235	13.303	0.183	0.497	0.366	0.386
Lianping	-30.88%	5.579	13.966	0.184	0.531	0.321	0.425
Fogang	-31.09%	6.202	16.165	0.290	0.520	0.321	0.418
Heyuan	-25.23%	5.765	15.665	0.283	0.525	0.373	0.400
Zengcheng	-22.89%	6.982	19.655	0.239	0.489	0.335	0.392
Huiyang	-4.53%	6.721	19.727	0.235	0.494	0.418	0.365
Shenzhen	-11.80%	6.871	20.340	0.255	0.451	0.419	0.341
Shanwei	-23.69%	6.800	21.666	0.244	0.420	0.457	0.310
Wuhua	-17.53%	5.258	14.177	0.187	0.499	0.418	0.367
Xunwu	-29.87%	5.317	13.889	0.162	0.538	0.373	0.408
Station Average	-23.48%	5.819	16.113	0.261	0.511	0.365	0.397
Basin Average	-22.12%	2.635	5.590	0.820	——	——	——

From Table 2, the station Nanxiong (57996) has a relatively high precision. The station lies in the northern part of the region and low plain is the main topography in this area. However, as station Shanwei (59501) lies in the southern part of the region and valleys and peaks interlace, some blind zones probably exist in TRMM observation. So the estimating precision has dropped a lot and Bias and MAE are much larger. Correspondingly, it has a lower correlation coefficient with the observed data. At the same time, from the comparison between station average value and basin average value, it can be concluded that the average correlation coefficient of the basin, 0.820, is much higher than that of stations, 0.261, thus showing TRMM satellite has a much better observing capability of a basin than that of stations.

From the comparison above, TRMM 3B42RT rainfall data has a lower precision for single station than for the basin. Therefore, TRMM satellite is more suited for rainfall observation of basin scale.

5. Hydrological modeling

A conceptual hydrologic model, Xin'anjiang model proposed by Zhao Renjun is used in the study area. In this study, the model is applied to simulate the streamflow of the Dongjiang River Basin. The model is calibrated from 1990 to 2001 and then is used to simulate the streamflow of the basin from 2002 to 2005. The Bias and NSCE of the calibration period are separately -11.78% and 0.706. Xin'anjiang model is suitable for this basin.The relationship among observed streamflow, streamflow simulated with TRMM 3B42RT rainfall data and streamflow simulated with observed precipitation and the relationship between the observed rainfall and TRMM 3B42RT rainfall data are shown as follows:

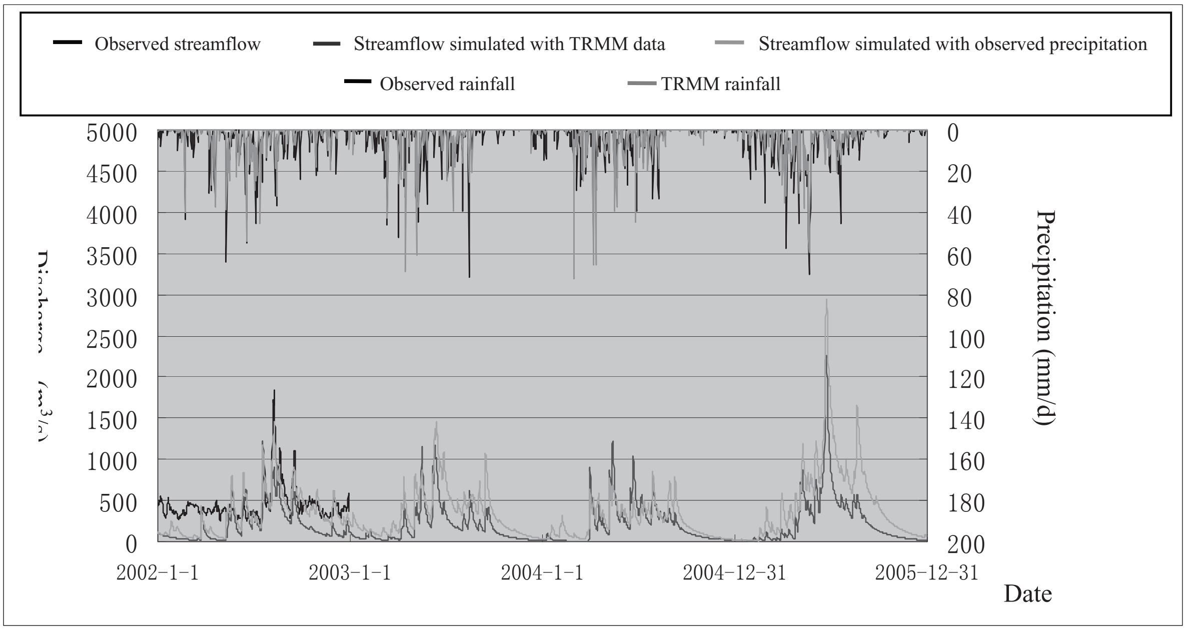

Figure 4. The relationship of precipitation and streamflow between observed and TRMM data

Streamflow simulated with TRMM data is smaller than the observed streamflow and much smaller than the streamflow simulated with the observed precipitation, as shown in the Fig.4. That may be due to the fact that TRMM 3B42RT rainfall data is smaller than the observed one.

Table 3. Parameters of the relationship among the observed streamflow, streamflow simulated with TRMM data and streamflow simulated with the observed precipitation of 2002

	Observed average (m^3/s)	Calculated average (m^3/s)	Absolute error (m^3/s)	Bias (%)	NSCE
TRMM simulated	448.411	207.516	-240.895	-0.537	0.615
Observed simulated	448.411	350.762	-97.649	-0.218	0.710

Table 3 shows that the absolute error and the Bias of the streamflow simulated with the observed precipitation are both smaller than that simulated with TRMM data while the NSCE is higher. According to the principle of the Xin'anjiang model, streamflow has a close relationship with precipitation. As there are some differences between TRMM data and the observed one, the error of streamflow simulated with TRMM data is inevitably larger and the NSCE is much lower than that of the streamflow simulated with the observed precipitation.

There are only the streamflow simulated with TRMM data and the one simulated with the observed precipitation after 2003, which are 207.034 m3/s and 356.211 m3/s in average respectively. So, a conclusion can be drawn that the average streamflow simulated with TRMM data is smaller than the one simulated with the observed precipitation.

6. Conclusion

From the comparisons between gauged precipitation and TRMM 3B42RT rainfall for both the basin and every station, results indicate that TRMM data has a fine correlation with station observed data in the Dongjiang River Basin of southern China, and the TRMM rainfall data can be used to study hydrologic simulation and water resources after systemic calibration. Generally, the TRMM rainfall data is reliable and it has a higher precision in the basin than single points with a correlation coefficient of 0.820. At the same time, the average value of streamflow simulated with TRMM data is smaller than that simulated by the observed precipitation by 149.177m3/s, which accounts for about two fifths of the latter. The streamflow simulated with the observed precipitation is closer to the observed streamflow.

Acknowledgments

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