Climatology Comparison Studies of Precipitations Between GPCP and Rain Gauges in China*

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(Received October 18, 2004; revised September 13, 2005)

ABSTRACT

The Global Precipitation Climatology Project (GPCP) monthly rainfall data and the rainfall records observed by 740 rain gauges in the mainland of China are used to analyze similarities and differences of the precipitation in China in the period from January 1980 to December 2000. Results expose significantly consistent rainfall distributions between the both data in multi-year mean, multi-year seasonal mean, and multi-year monthly mean. Departures of monthly rainfall for each dataset also show a high correlation with an over 0.8 correlation coefficient. Analysis indicates small differences of both datasets during autumn, winter, and spring, but relative large ones in summer. Generally, the GPCP has trend of overestimating the rainfall rate. Based on above good relationship of both datasets, the GPCP data are used to represent distributions and variations of precipitation in the Tibetan Plateau and Northwest China. Results indicate positive departures of precipitation in summer in the west part of Tibetan Plateau in the 1980s and negative departures after the 1980s. For the west part of Northwest China, analysis illustrates precipitation decreases a little, but no clear variation tendency.

Key words: China precipitation, Global Precipitation Climatology Project (GPCP), rain gauges

1. Introduction

Precipitation plays a dominant role in the global energy and water cycle. As precipitation distributions have drastic spatial and temporal variations, it is difficult to accurately estimate them within a given region among all meteorological elements. Rain gauge observation is one of the most direct measuring methods with better accuracy to a point located at the rain gauge, but the point records can not represent directly for a wide area. Radar measurements are proved to supply preferable spatial and temporal precipitation distributions within a region on basis of some preconditions, but its measuring range is limited, and affected by topographic condition. However, in the last two decades, the microwave instruments boarding on satellites and other measurements from infrared and precipitation observations, retrieval and data merging have made significant progresses in factors (Liu and Curry, 1992; Aonashi et al., 1996; Sheu et al., 1996; Fu and Liu, 2001, 2003; Liu and Fu, 2001; Fu et al., 2003; Wilheit et al., 2003; Kongoli et al., 2003), which result in the Global Precipitation Climatology Project (GPCP). The GPCP merges satellite observations together with about 6000 rain gauge measurements in the globe, and supplies monthly precipitation data in horizontal of $2.5° \times 2.5°$grid from 1979 to now. Based on the GPCP data, many studies open up features of precipitation distributions and their variations in the globe (Huffman et al., 1997, 2001; Adler et al., 2003).

In this paper, we try to expose similarities and differences of the precipitation between the GPCP data and the precipitation recorded by 740 rain gauges in the mainland of China, especially in East China, in the period from January 1980 to December 2000. Then, the GPCP data are used to characterize distributions and variations of precipitations in the Tibetan Plateau and Northwest China on the basis of better consistency between the two data.

2. Data

The GPCP Version 2 data combine precipitations retrieved from satellite observations and rain gauge records including 160 rain gauges in China. The

*Supported by Grants of NKBRDPC (No.2004CB418304), NSFC grant of the Joint Research Fund for Overseas Chinese Young Scholars (No.40428006), NSFC (Nos.40175015 and 40375018).

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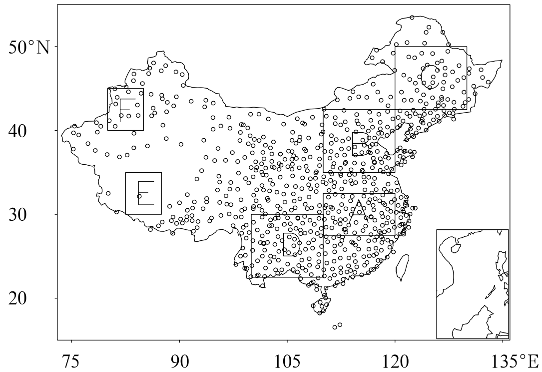

Fig.1. Locations of rain gauges in the mainland of China.

satellite precipitation estimations are based on retrievals from measurements of infrared and microwave instruments. The infrared signals are observed by GOES (Geostationary Operational Environmental Satellites), GMS (Geostationary Meteorological Satellite), Meteosat (Meteorological Satellite), and NOAA (National Oceanic and Atmospheric Administration) polar-orbiting satellites, and the microwave signals are detected by the Special Sensor Microwave/Imager (SSM/I) of the Defense Meteorological Satellite Program (DMSP) satellites that fly in sun-synchronous low-earth orbits. There are four algorithms used in precipitation retrievals (Adler et al., 2003): the SSM/I emission based technique, the SSM/I scattering based algorithm, the GPI (Global Precipitation Index), and the OPI (OLR based Precipitation Index) based techniques, the TOVS (Television Infrared Observational Satellite Operational Vertical Sounder) based approach.

The rain gauge records daily used in this study are observed by the 740 weather stations since their being established in the mainland of China. Locations of these rain gauges are shown in Fig. 1. To fit horizontal resolution of GPCP data, we interpolate 740 rain gauge records into daily $2.5° \times 2.5°$grid data, and then generate monthly mean grid data from January 1980 to December 2000.

3. Results

3.1 *Characteristics of mean rainfall distributions*

Firstly, the distributions of 21-yr averaged rain rate generated by GPCP and rain gauges are plotted in Fig. 2 that shows the both data significantly consistent in rain rate decreasing from Southeast China to Northwest China. It is clear that locations of contour over 4 mm d^{-1} cover regions from South Yangtze to South China contrary to less than 1mm d^{-1} rain rate in Northwest China. The both data also clearly show the biggest rain rate gradient located in Jiang-Huai Valley where is known as climatic transition zone.

The consistent precipitation distributions between the both data are also clearly displayed in multi-year seasonal mean and multi-year monthly mean field. Figure 3 presents multi-year monthly mean rain rate distributions in January, April, July, and October. The both data identically show seasonal variations of precipitation in spatial and temporal, step-up from Southeast China to Northwest China from January to July and step-down from Northwest China to Southeast China from October to January. Furthermore, the biggest rain rate ($\sim$7 mm d^{-1}) covering South China

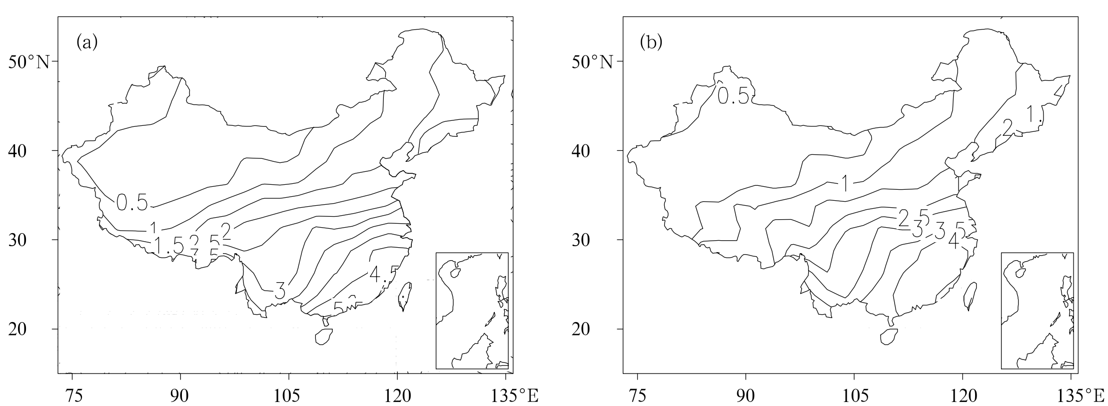

Fig.2. Distributions of 21-yr averaged rain rate (mm d^{-1}) issued by GPCP (a) and rain gauges (b).

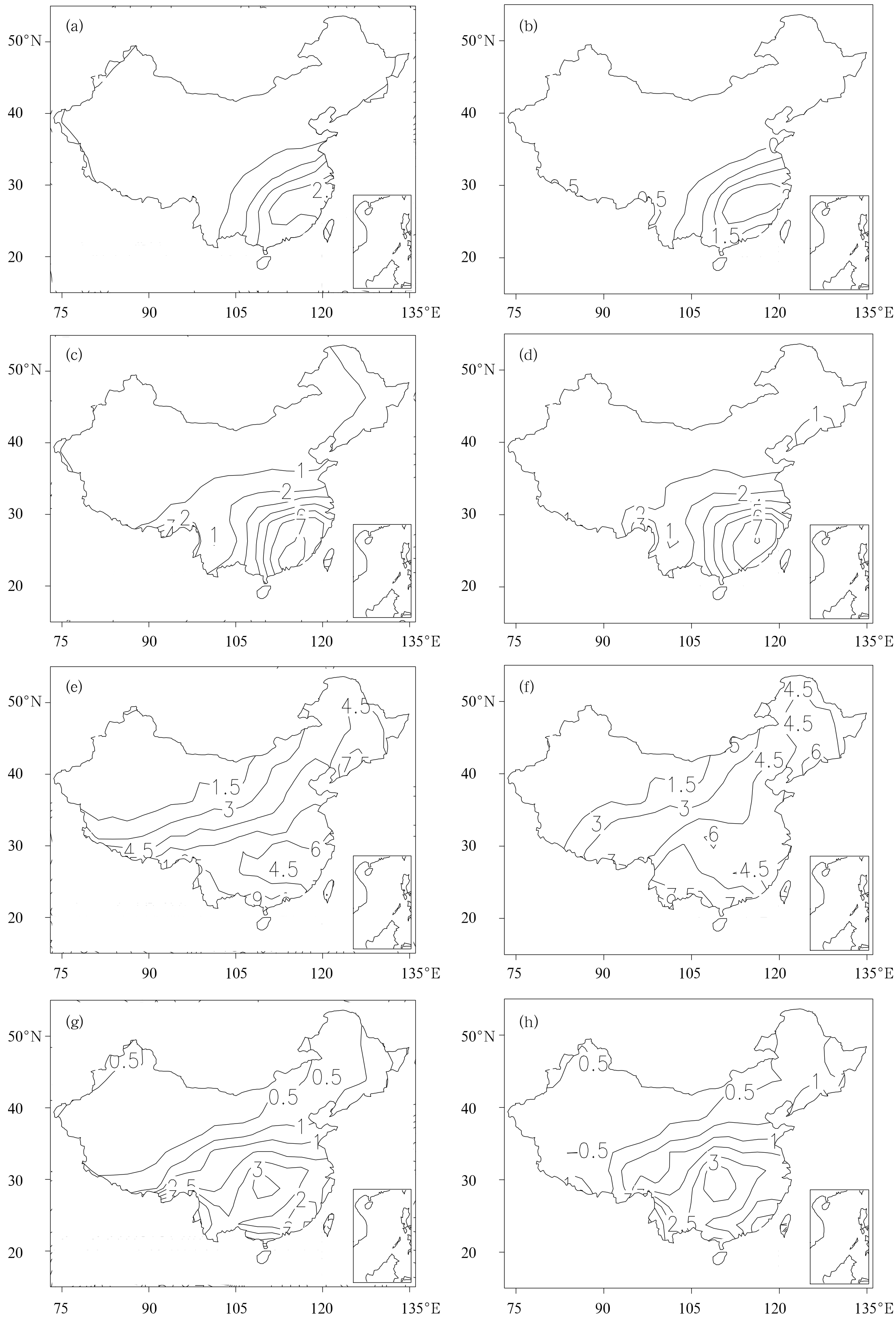

Fig.3. Mean rain rate distributions in January (a, b), April (c, d), July (e, f), and October averaged by 21-yr issued by GPCP (left panel) and rain gauges (right panel).

in spring is obviously represented by the both data, which is usually named as the prophase of flooding season in South China. However, a fewer differences between the both data can be found in summer. The GPCP data show the biggest rain rate location in the downriver of the Yangtze Valley and Southwest China, but rain gauge records indicate the location in the upriver of the Yangtze Valley and Southwest China. The difference maybe results from strong scattering precipitations in summer and limited rain gauge observations. The above explanation can be indirectly validated by significantly similar distribution of precipitation between the both data in autumn and winter due to activities of large-scale weather systems such as fronts and cyclones during the both seasons.

3.2 *Differences between GPCP and rain gauge records*

To indicate the differences of the both data, we plot the scattering diagram of rain rate (less than 0.1 mm d^{-1} not included) for 21-yr annual mean, 21-yr seasonal mean, and 21-yr monthly mean in January, April, July, and October , respectively, in Fig. 4. Basically, it is shown a good similarity between the

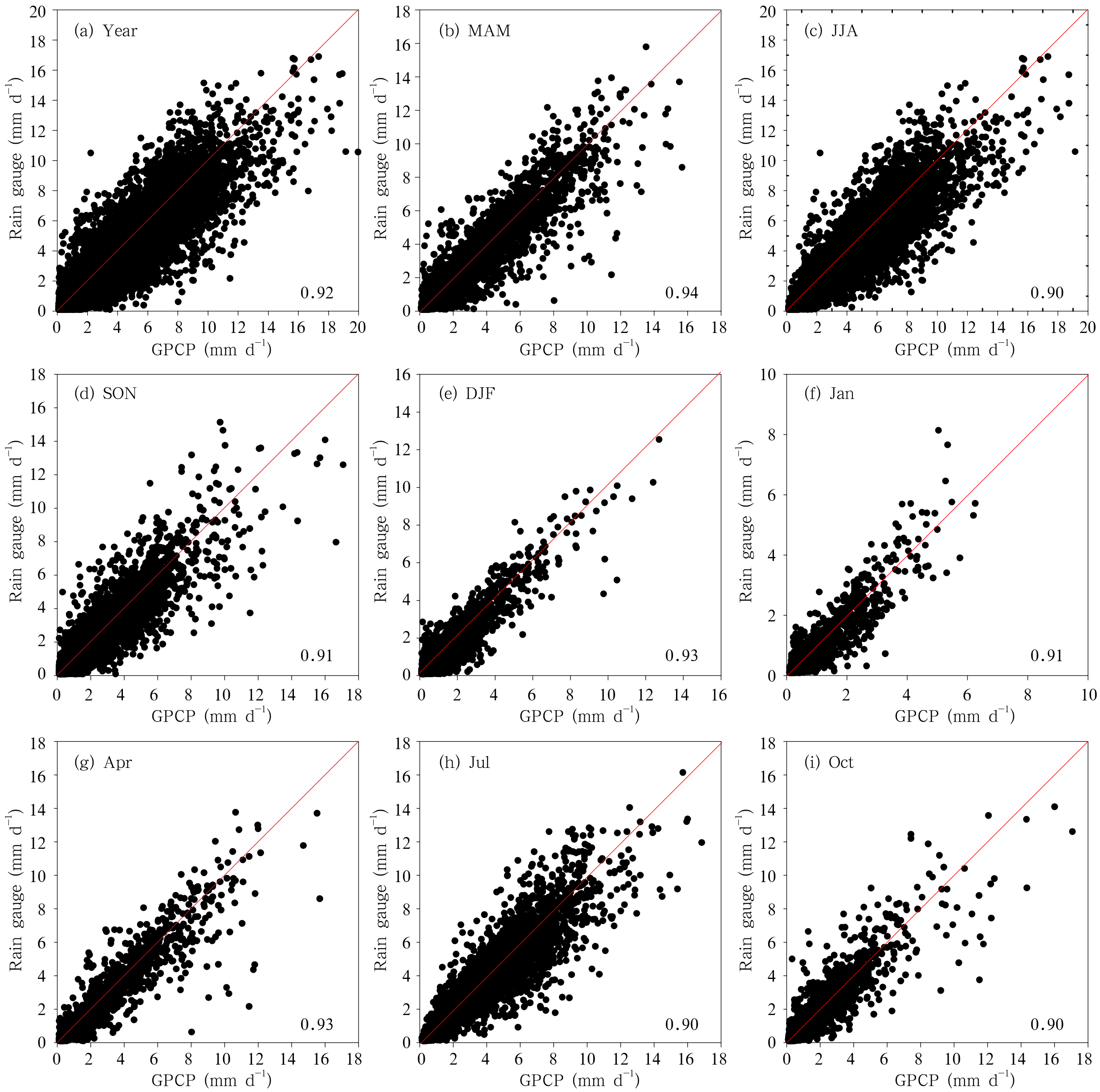

Fig.4. Scattering plot of rain rate in the mainland of China for 21-yr annual mean (a), at 21-yr seasonal mean (b, c, d, e), and 21-yr monthly mean in January, April, July, and October (f, g, h, i), respectively.

both data in mean fields. The correlation coefficient of the 21-yr mean rain rate distribution between the both data reaches 0.92, but a little over estimation of the GPCP data can be viewed from the scattering diagram (Fig. 4a), especially as rain rate increases. The correlation coefficients in of 21-yr seasonal mean are over 0.90 (Figs. 4b, c, and d), including the maximum 0.94 in spring and the minimum 0.90 in summer. Similar results are displayed for 21-yr monthly mean in Figs.4f, g, h, and i. This illustrates a good consistency between GPCP and rain gauge records in the mainland of China although there are differences between the both data, especially in summer.

There are two factors to cause the discrepancy between the two data. Firstly, seasonal discrepancy such as more differences in summer (e.g., dispersed scattering plot) indicates shortages of the GPCP retrieval algorithms (e.g., considered upper clouds as precipitation clouds), which leaves space for development of the algorithms. Secondly, the distribution density of rain gauges can induce the discrepancy between the both data. To explain the point, we select two GPCP grid points stochastically, grid point I (27.5°-30°N, 87.5°-90°E) and grid point II (40°-42.5°N, 122.5°-125°E). There are 4 and 9 rain gauges located in the grids I and II (see Tables 1a and 1b), respectively. In Table 1a, the 21-yr mean rain rate of GPCP at the grid I is 1.62 mm d^{-1}. While the maximum rain rate recoded by the 4 rain gauges within the grid I is 1.2 mm d^{-1}, the minimum is 0.77 mm d^{-1}, and the mean value is 1.01 mm d^{-1} that is 0.6 mm d^{-1} less than GPCP and equals 37% of the GPCP. However, in Table 1b, it shows 2.2 mm d^{-1} for 21-yr mean rain rate of GPCP at the grid II and 2.0 mm d^{-1} for 9-gauge mean within the grid although the maximum rain rate among the 9 rain gauges is 2.58 mm d^{-1}, the minimum value is 1.32 mm d^{-1}. Only 0.2 mm d^{-1} average difference (that occupies 9% of GPCP) occurs between the both data.

Time series of monthly mean rain rate for the both data from 1980 to 2000 at the grids I and II are shown in Fig. 5. At the grid I, it is obvious that the GPCP values are larger than the mean averaged by the 4-gauge records although the both data display clearly seasonal cycle, and both correlation coefficient

Table 1a. Locations of rain gauges and their mean rainfall rate within a GPCP grid I (28.75°N, 88.75°E) of 1.62 mm d^{-1} rainfall rate averaged in 21-yr period

Location	Longitude	Latitude	21-yr average (mm day^{-1})
Lazi	87.60°E	29.08°N	0.90
Rikaze	88.88°E	29.25°N	1.18
Jiangzi	89.60°E	28.91°N	0.77
Pali	89.08°E	27.73°N	1.20

Table 1b. Locations of rain gauges and their mean rainfall rate within a GPCP grid II (41.25°N, 123.75°E) of 2.20 mm d^{-1} rainfall rate averaged in 21-yr period

Location	Longitude	Latitude	21-yr average (mm day^{-1})
Zhangwu	122.53°E	42.42°N	1.32
Qingyuan	124.92°E	42.10°N	2.10
Anshan	123.67°E	41.08°N	1.87
Shenyang	123.45°E	41.73°N	1.78
Benxi	123.78°E	41.32°N	2.01
Fushun	124.08°E	41.92°N	2.06
Youyan	123.28°E	40.28°N	2.00
Kuandian	124.78°E	40.72°N	2.58
Dandong	124.33°E	40.05°N	2.28

is 0.85. On the other hand, better consistency of the both data present at the grid II. There is a 0.94 correlation coefficient at the grid because more rain gauges are located within it. To demonstrate the fact further more, we map the distributions of correlation coefficient between the both data in summer and winter in Fig. 6. Comparing to the location distribution of rain gauges shown in Fig.1, we can find that better consistency (coefficient greater than 0.7) in the region eastward from 100°E where has more rain gauges than that (coefficient less than 0.7) in the region westward from 100°E where has fewer rain gauges regardless in summer or winter. Thus, we conclude that the number density of rain gauges at a given regions affects directly the consistency of their mean rain rate to the GPCP rain rate in the region. The more rain gauges, the less differences between the both data. Moreover, Fig.6 also shows up that the both data have better consistency in winter than in summer in the region eastward from 100°E, which says complicated spatial and temporal distribution of precipitations in summer in East China because of strong localizations of precipitations in summer over there.

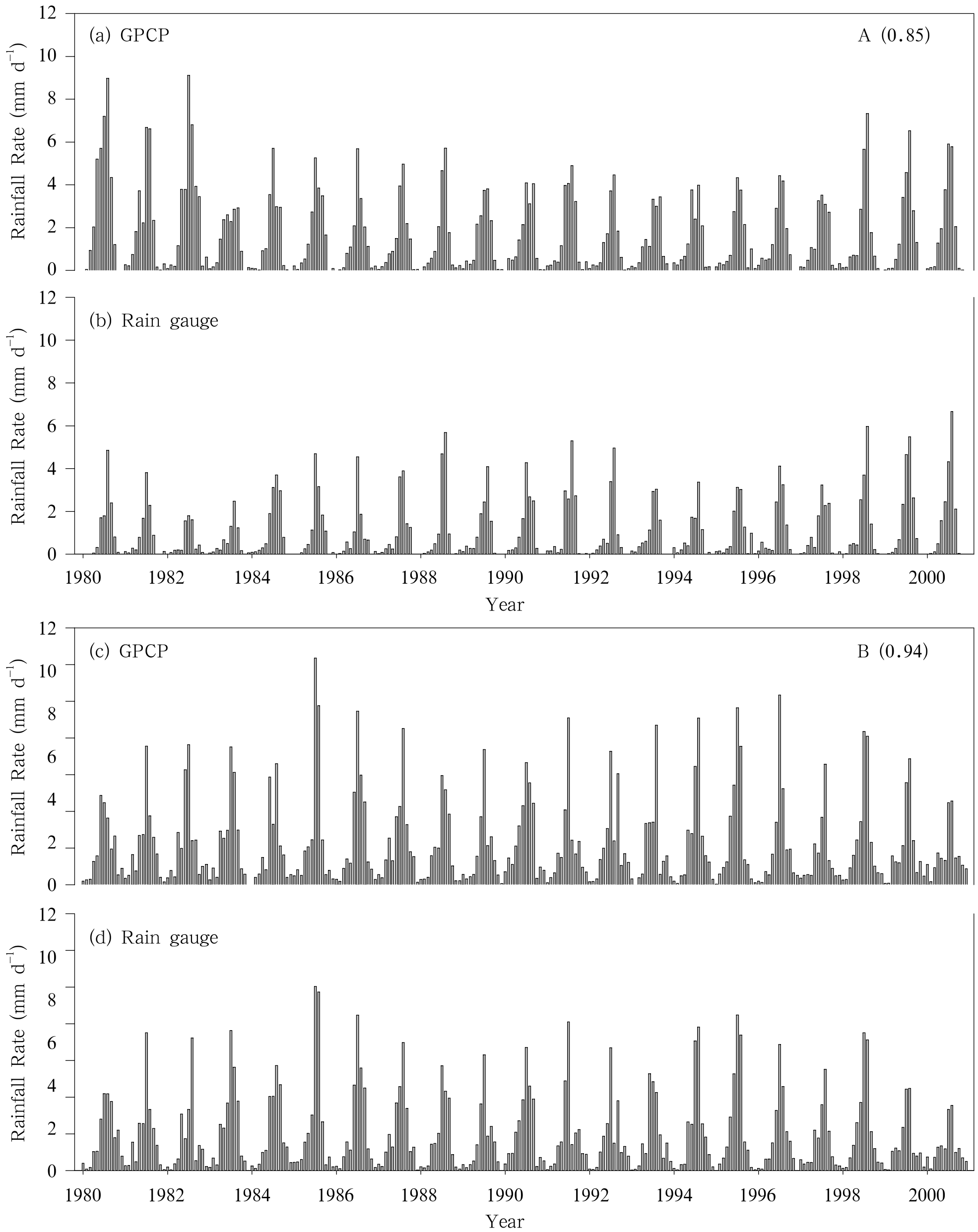

Fig.5. Time series of monthly rain rate for the both data from 1980 to 2000 at grids I (a, b) and II (c, d). The correlation coefficient is marked on the top right panel. (a), (c) GPCP; (b), (d) rain gauge.

3.3 *Departure differences between GPCP and rain gauge records*

The similarity or difference between the GPCP and rain gauge records in multi-year mean, multi-year seasonal mean, and multi-year monthly mean prescribes the consistency of the both data from a view of climatological mean. Besides, we need to know the departure difference between the both data. Based on the climatological characteristics of precipitation in the mainland of China shown in Figs.2 and 3, we focus on the regions of downriver Yangtze (27.5°-32.5°N,110°-120°E, named as region A), Northern China (35°-42.5°N, 110°-120°E, named as region B), Northeast China (42.5°-50°N, 120°-130°E, named as region C), and Southwest China (22.5°-30°N,100°-110°E, named as region D) to analyze the departure difference of precipitation between the both data in

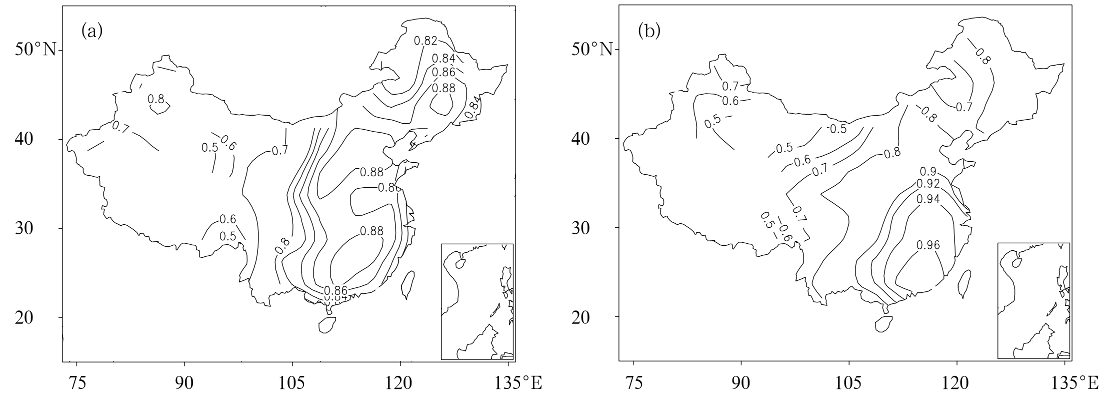

Fig.6. Distributions of correlation coefficient for rain rate between GPCP and rain gauge in each grid in summer (a) and winter (b).

each region. Figure 7 shows the time series of precipitation departure in each region. Basically, it indicates that the time series of precipitation departure of both data have receivable consistency. The departure correlation coefficients of the both data in four regions are 0.90, 0.83, 0.91, and 0.89, respectively. Now, we can summarize that the GPCP data represent nicely precipitations in China in not only in climatological mean but also in climatological departure.

3.4 *Precipitations in the Tibetan Plateau and Northwest China based on GPCP*

Many Chinese scholars have studied the precipitation characteristics in the Tibetan Plateau and Northwest China using limited rain gauges' records and cloud images from satellites (Liu et al., 1999; Wei et al., 2000, 2003; Yu et al., 2003; Huang et al., 2004), but because of complex topography and exiguous rain gauges over there, we still lack information about large-scale precipitations in the Tibetan Plateau and Northwest China. In this part, the GPCP data are used to represent distributions and variations of precipitations in the both regions based on good consistency between the GPCP and rain gauge records discussed in the above section.

Figure 8 shows the distributions of mean rain rate

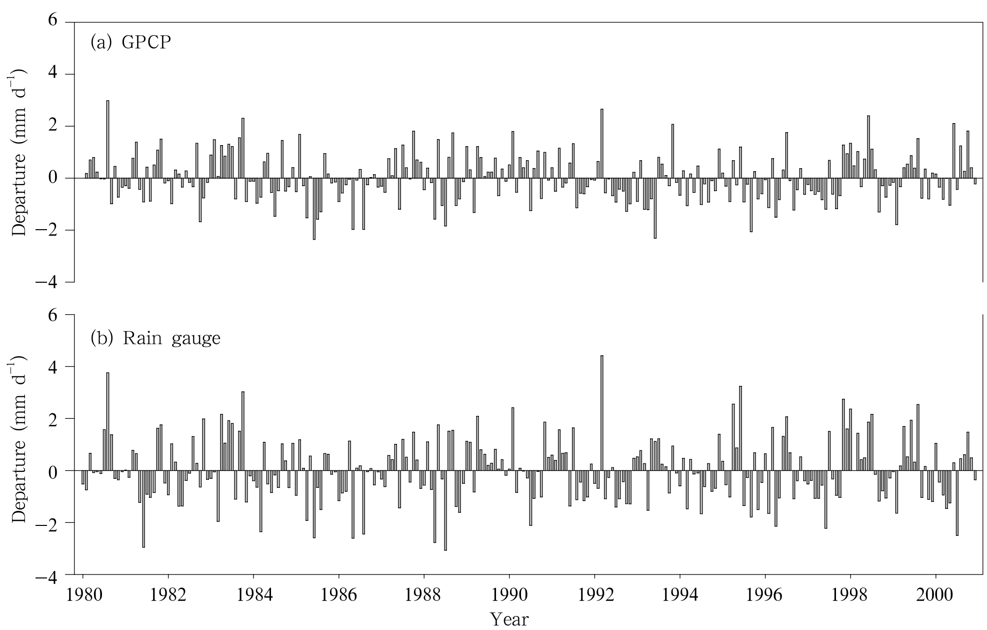

Fig.7. Time series of rain rate departure in downriver Yangtze (region A; a, b), Northern China (region B; c, d), Northeast China (region C; e, f), and Southwest China (region D; g, h), respectively.

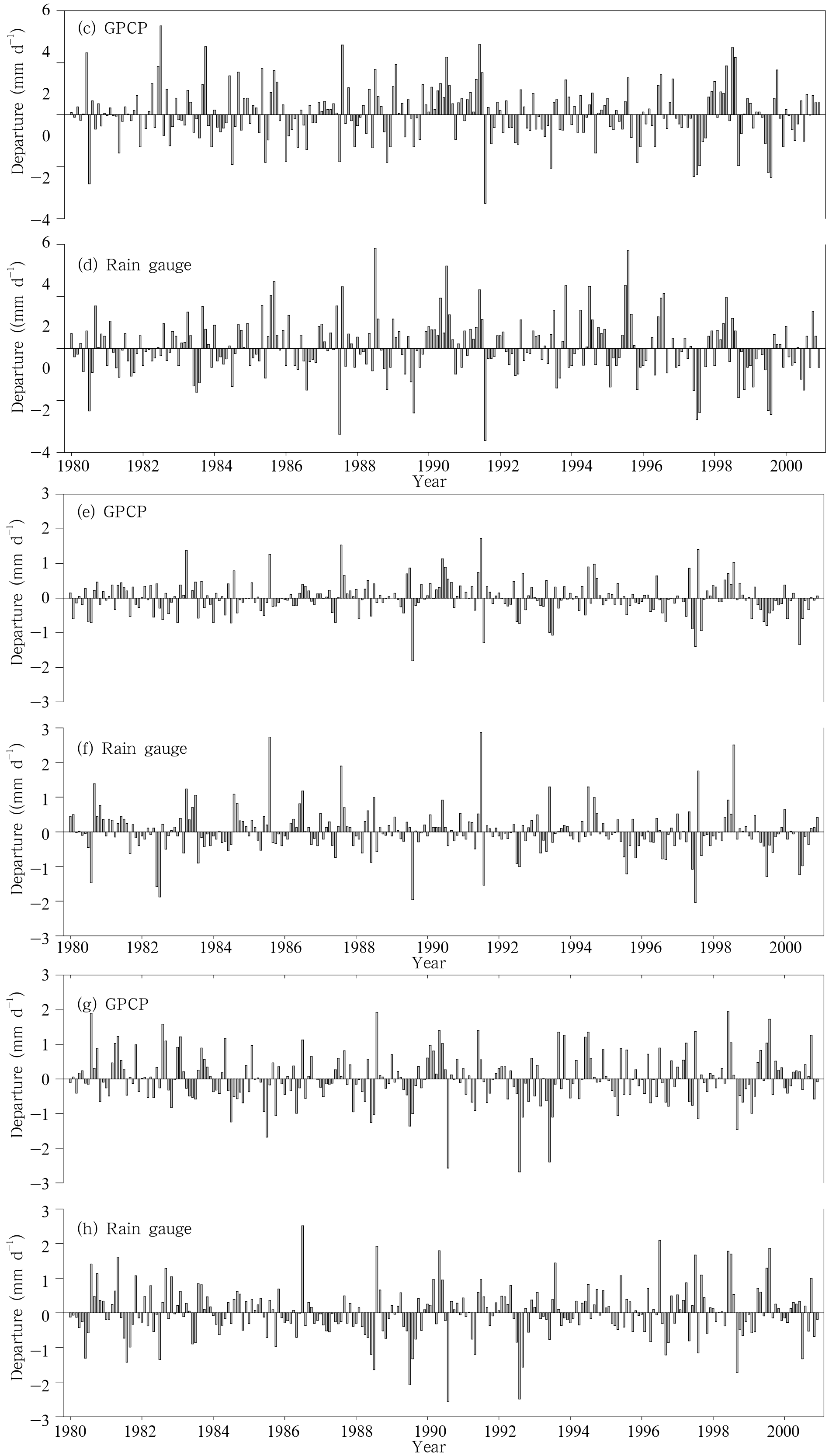

Fig.7. Continued

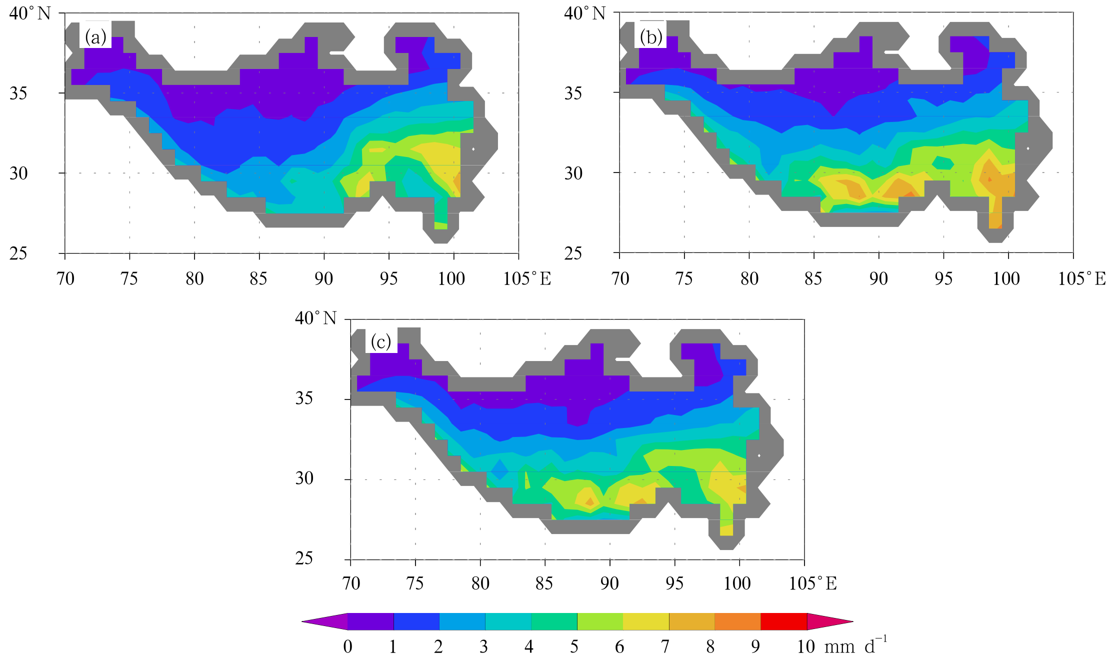

Fig.8. Distributions of mean rain rate in the Tibetan Plateau in June (a), July (b), and August (c) by GPCP from 1980 to 2000.

in the plateau in June, July, and August issued by GPCP from 1980 to 2000. It indicates that the precipitations move from the southeast plateau to northwest plateau from June to August. In June, the region covering rain rate over 5 mm d^{-1} is located in the southeast plateau including the three-river valleys and the west Sichuan Basin where rain rate is more than 6 mm d^{-1}. In July and August, over 2 mm d^{-1} rain rate covers the main part of plateau, and 7 mm d^{-1} rain rate is mainly located in the Brahmaputra Valley. Figure 8 also exposes rain rate distribution step-down from the south plateau to the north, and the maximum gradient of rain rate occurs near the north of the Brahmaputra Valley.

To exposure the seasonal variability of precipitations in the plateau and Northwest China, we select region E (30°- 35°N, 82.5°-87.5°E) and region F (40°-45°N, 80°-85°E) (see Fig. 1) to represent for the west part of the plateau and Northwest China, respectively. Figure 9 shows the time series of monthly rain rate and its departure in the region E from January 1980 to December 2000 issued by the GPCP. The time series of monthly rain rate clearly indicate the seasonal cycle of precipitations in the west plateau, more rainfall in summer and less in winter. However, the variation of precipitation departures shows more precipitation in the beginning of 1980s in the last century in the west plateau, especially in 1980, 1982, and 1985, which is the same as Wei's analysis (Wei et al., 2003), and months of less precipitation increase since the 1990s. If the variation tendency of precipitation in the west Plateau is related to the global warming, we need to carry out more detailed researches.

Studies basis on rain gauges indicate more precipitations in the 1960s, precipitation decrease in the beginning of 1970s, more again in the 1980s, and decrease again in the 1990s in Northwest China (Wei et al., 2000). Figure 10 shows the time series of rain rate in the west part of Northwest China (region F) represented by GPCP and rain gauge, respectively, from 1980 to 2000. Clearly seasonal precipitation varies displayed consistently by the both data in the figure although rain gauges distribute sparsely in Northwest China comparing to dense rain gauges in East China. The correlation coefficient between the both data is 0.73, and 0.72 for both data departures. The time series of rain rate departures in the west part of Northwest China (region F) issued by GPCP and rain gauge,

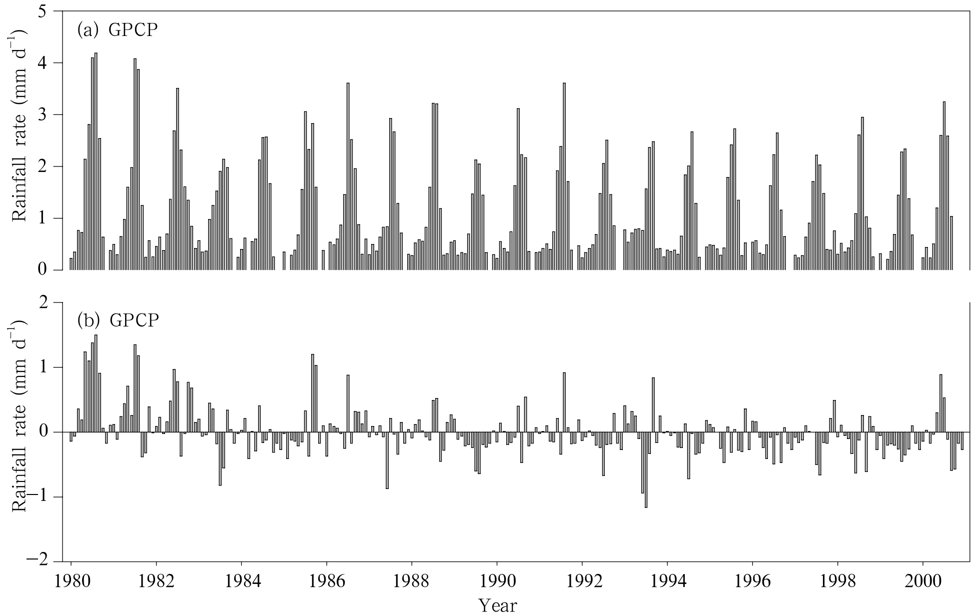

Fig.9. Time series of monthly rain rate (a) and its departure (b) in the west plateau from 1980 to 2000 by GPCP.

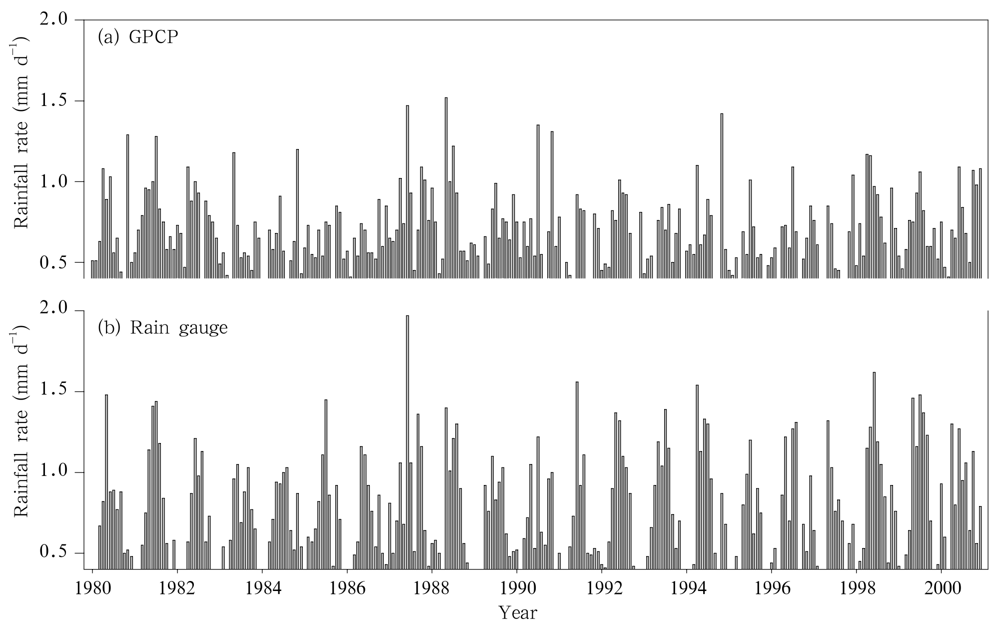

Fig.10. Time series of monthly rain rate in the west part of Northwest China (40°-45°N, 80°-85°E) issued by GPCP (a) and rain gauge (b), respectively, from 1980 to 2000.

respectively, from 1980 to 2000 shown in Fig.11 indicates that months with less precipitation are more than those with more precipitation. If a month with more or less than 0.2 mm d^{-1} is considered as abnormal month, GPCP data illustrates that there are 36 months of less precipitation and 34 months of more precipitation, while rain gauges show that there are 45 months of less precipitation and 40 months of more precipitation. Generally, less precipitation and drought feature in the west part of Northwest China are inarguable. But, we have not found a clear tendency of precipitation variation as the one occurs in the west part of Tibetan Plateau.

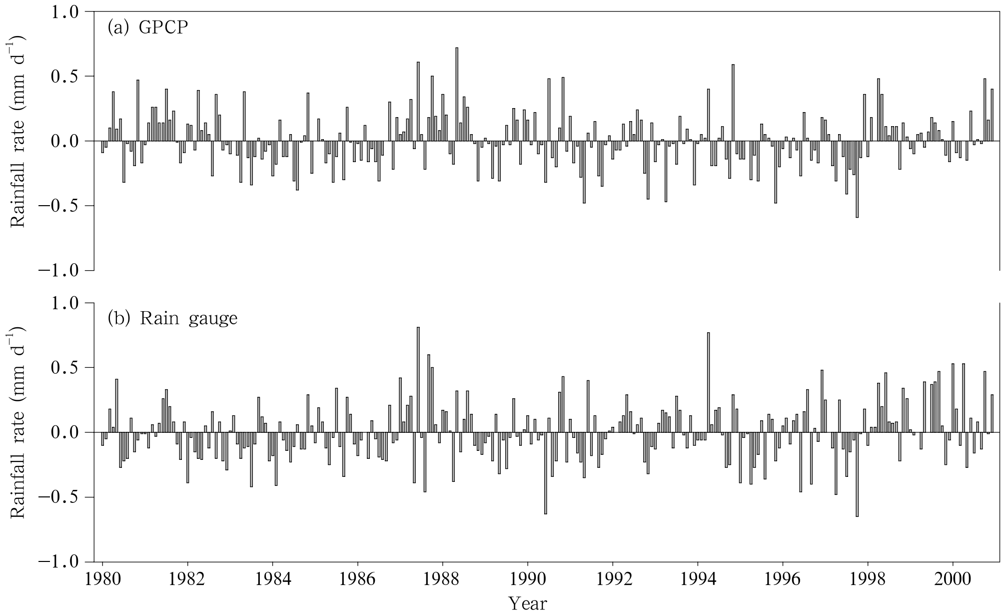

Fig.11. Time series of rain rate departure in the west part of Northwest China (40°-45°N, 80°-85°E) issued by GPCP (a) and rain gauge (b), respectively, from 1980 to 2000.

4. Conclusions

In this paper, the GPCP monthly rain rate data are analyzed and compared with records observed by 740 rain gauges in the mainland of China in the period from January 1980 to December 2000 in order to issue whether the GPCP data can be used to represent the distribution and variation of precipitation in the mainland of China. If a good relationship exists between the both data, we hope to use the GPCP data to represent precipitation characteristics in Northwest China and the Tibetan Plateau where there are fewer rain gauges.

The results expose that: (1) The GPCP monthly precipitation data and the rainfall records observed by 740 rain gauges in the mainland of China have significantly consistent on precipitation distributions in multi-year mean, multi-year seasonal mean, and multi-year monthly mean, and the correlation coefficients of the both data are at least over 0.8. The mean precipitation distributions shown by the GPCP data can display seasonal precipitation variations in China, step-up from Southeast China to Northwest China and step-down from Northwest China to Southeast China. (2) The time series of precipitation departure analysis indicates the both data also have considerable consistency, and the correlation coefficients are over 0.80. The discrepancy analysis shows that the both data have smaller differences in spring, autumn and winter, more differences in summer. Generally, the GPCP data overestimates precipitation than rain gauges observation. Moreover, the number density of rain gauges at a given regions affects directly the consistency of their mean rain rate to the GPCP rain rate in the region. The more rain gauges, the less differences between the both data. Thus, the GPCP data needs to revise further by more rain gauge observations for accurate describing precipitation in China. (3) GPCP data issue that there are more precipitation in the 1980s and less precipitation in the 1990s in the west part of Tibetan Plateau, while drought feature is inarguable in the west part of Northwest China, but there is not a clear variation tendency of precipitation over there.

Acknowledgments. Helpful comments from anonymous reviewers are greatly appreciated.

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