The study of the variation law of TRMM rainfall measurement precision on time scale

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Abstract. Hydrological scale is the leading issue in hydrology research. Precipitation is one of the biggest uncertain factors in runoff simulation and the most important information in flood forecasting. It is necessary to study the influence of time scale on the precision of satellite rain measurement. On the basis of the study of the daily scale accuracy test of the meteorological satellite rain measurement, the precision of the annual and monthly scale was checked, and the variation law of the rainfall precision of the TRMM rainfall measurement data on the time scale was finally obtained.

1. Preface

Meteorological satellite rain products are mainly used in meteorology. It has been widely applied in many fields such as precipitation measurement, precipitation forecast, rainstorm research, data assimilation and so on. In 2006, Md. Nazrul Islam validated the accuracy of TRMM Rainfall Product 3B42 in Bangladesh by using observed rainfall data. The results show that the measured values of TRMM rainfall data are small before the monsoon period, large after the monsoon period and small for the heavy rain [1]. The author has studied the daily average data of 25 stations in Heihe River and found that the correlation between the daily precipitation data of satellite rain-measuring products and the corresponding measured precipitation of the stations is poor. The grading and scoring method of satellite rain-measuring products is put forward, which provides a new way for the precision inspection and evaluation of satellite rain-measuring products [2]. Hydrological scale is one of the frontiers of hydrology research [3]. Since the early 1990s, the hydrological scale problem has been formally put forward, and has been widely concerned by scholars at home and abroad in the field of hydrology. Precipitation is one of the greatest uncertainties in runoff simulation and the most important information in flood forecasting [4]. Therefore, it is necessary to study the influence of time scale on the accuracy of satellite rainfall measuring products. On the basis of the previous research on the daily scale precision test of meteorological satellite rainfall measurement products, the accuracy of annual and monthly scale is further examined, and the variation law of the meteorological satellite precipitation data on time scale is analyzed.

2. Study of the variation law of TRMM rainfall measurement precision on time scale

2.1. Survey of research area

In this paper, the Heihe river basin is chosen as the study area, and the basin water system is shown in figure 1. Heihe basin is the second largest inland river basin in Northwest China, is located in the middle
of Hexi Corridor, generally between 98° to 101°30′E, 38° to 42°N. It is the largest inland river basin in Western Gansu and Mongolia. The Heihe basin is located in the middle of Eurasia, far away from the sea, surrounded by high mountains, the climate is mainly affected by the westerly belt in high latitude and polar cold air mass flow control effect, dry climate, scarce precipitation and concentrated, windy, sunny, strong solar radiation, the temperature difference between day and night.

Figure 1. Hydrologic station distribution map.

2.2. Research data
The study collected 1980-2003 day precipitation data from 25 hydrological stations in the basin (station distribution as shown in Figure 1). Monthly precipitation and annual precipitation required for accuracy assessment are accumulated by daily precipitation. The satellite precipitation data are the data sets of China's regional surface meteorological elements corresponding to hydrological stations. The data include near-surface temperature, near-surface pressure, near-surface air humidity, near-surface wind speed, ground-to-ground short-wave radiation, ground-to-ground long-wave radiation, ground precipitation rate, a total of seven elements (variables).

2.3. Accuracy inspection and evaluation method

2.3.1. Contingency Table Approach. Contingency Table Approach (CTA) is a scoring method for evaluating the predicted value of hydrologic station as a true value [5]. CTA as shown in table 2-3, represents a 2 * 2 matrix. Here, each element of the matrix represents whether the observations and satellite data values within a certain period of time reach or exceed a certain threshold. For example, if the observed value of a hydrological station at a certain point reaches or exceeds a certain threshold, but the satellite data does not reach that threshold, the number of "Ne" increases by 1.

Table 1. Contingency table layout.

| Hydrological station:Yes Satellite:Yes | NA   | Hydrological station:No Satellite:Yes |
|----------------------------------------|------|--------------------------------------|
| Hydrological station:Yes Satellite:No | NC   | Hydrological station:No Satellite:No |
|                                        | ND   |                                      |
According to the above Contingency Table Approach, FBI score (Frequency Bias Index), Probability of Detection (PDD), and False Alarm Rate (FAR) can be calculated. The deviation FBI score is defined as:

\[
FBI = \frac{F}{O} = \frac{N_A + N_B}{N_A + N_C}
\]  

Formula: \( F \) is the estimated value of satellite is equal to or exceeds the number of given thresholds. \( O \) is the number of measured stations equal to or above a given threshold. The deviation score reflects that the system of satellite estimates is higher (\( FBI > 1 \)) or lower (\( FBI < 1 \)) than that of rainfall stations. The range of deviation is from 0 to infinity, and the optimal value is 1.

The accuracy rate POD indicates the correct probability of precipitation estimation, the range of variation is 0 to 1, and the optimal value is 1. The false alarm rate FAR indicates the probability of error in precipitation estimation, and the range of variation is 0~1, and the optimal value is 0. The definitions of FAR and POD are as follows:

\[
FAR = \frac{N_B}{N_A + N_B}
\]

\[
POD = \frac{N_A}{N_A + N_C}
\]

Because the above score based on contingency table can only reflect the deviation degree of meteorological satellite values above a certain threshold, it can not determine the error of meteorological satellite precipitation measurement. Therefore, the mean MRE (Mean Relative Error) of absolute relative error must also be calculated to evaluate the error of meteorological satellites in estimating precipitation. For a given threshold, MRE is defined as:

\[
MRE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{T_i - S_i}{S_i} \right|
\]

Formula: \( T_i \) is the meteorological satellite rainfall measuring value. \( S_i \) is used for rainfall measurement at hydrological stations. \( n \) is the number of rainfall. The CTA method is the most commonly used method of precipitation accuracy evaluation at home and abroad[6].

2.3.2. Correlation coefficient method. Contingency. The correlation coefficient represents the statistical index of the correlation between the two factors. For two elements \( x \) and \( y \), if their sample values are \( x_i \) and \( y_i \) (\( i = 1, 2, ..., n \)), the correlation coefficients between them are:

\[
R = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}}
\]

\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i, \quad \bar{y} = \frac{1}{n} \sum_{i=1}^{n} y_i
\]
Formula: \( n \) is the total number of data records, \( x_i \) is the precipitation for meteorological satellite precipitation data. \( y_i \) is the observed precipitation for the corresponding hydrological stations in the corresponding time. BIAS is relative error. In practical operation, the coordinates of the grid elements at the site are calculated first by longitude and latitude of hydrological stations, and then the precipitation in the grid cell is taken as the value through MATLAB programming language. R reflects the consistency between the meteorological satellite precipitation data and the observed precipitation data. The value range is \([0, 1]\). The closer to 1, the better the data consistency. BIAS reflects the deviation between the meteorological satellite precipitation data and the observed precipitation data. The closer to 0, the more accurate the data will be [7].

2.4. Accuracy test results and error analysis

2.4.1. Annual scale accuracy test. The annual precipitation of 25 hydrological stations in the study area from 1980 to 2003 was taken as an independent variable, and the annual precipitation data of meteorological satellites in the grid of each hydrological station in the corresponding year were taken as a dependent variable for linear regression analysis, as shown in figure 2. The results show that the average correlation coefficient \( R = 0.938 \) and the slope \( K = 0.2788 \) between the meteorological satellite annual precipitation data and the observed precipitation show a good consistency between them. On the whole, the precipitation of meteorological satellite annual precipitation data is slightly lower than the measured precipitation. This may be due to the characteristics of the remote sensing method itself. This may be due to the characteristics of the remote sensing method itself.

![Figure 2. Annual rainfall correlation diagram.](image)

\[ y = 0.2788x + 3.4119 \]
\[ R^2 = 0.8803 \]

2.4.2. Monthly scale accuracy test. Eleven hydrological stations with complete data were selected from 25 hydrological stations. The measured values of the 11 hydrological stations in 1980 were taken as independent variables and the corresponding precipitation values of meteorological satellites were taken as dependent variables for correlation analysis, as shown in figure 3. Statistical calculation shows that the correlation of \( R=0.962 \) is better than that of annual precipitation, and the correlation is good;
k=0.285 shows that the monthly precipitation data of satellites are still less than those of hydrological stations, and the deviation is large.

![Figure 3. Monthly precipitation correlation diagram.](image)

2.4.3. **Accuracy test of daily scale.** Taking the measured data of all the precipitation at the Ebo Station in 1980 -1982 as the abscissa coordinates, and corresponding meteorological satellite data are used to make correlation diagrams for ordinates, as show in figure 4. It is found that the correlation coefficient R is only 0.447, and the correlation between measured precipitation and daily precipitation data of meteorological satellite rainfall products is poor.

![Figure 4. Daily precipitation correlation diagram.](image)

2.5. **Comprehensive influence analysis of time scale on rainfall accuracy**

In this paper, the effects of daily, monthly and annual scales on the precision of satellite rainfall measurement products are studied, the results are shown in table 2. It can be seen from the table that the average daily, monthly and annual correlation coefficients of satellite rainfall products and hydrological stations are R = 0.462, R = 0.864 and R = 0.768 respectively. The average MRE of daily rainfall is 0.872, that of monthly rainfall is 0.786, and that of annual rainfall is 0.688. Therefore, for the average of correlation coefficient, the daily scale < the annual scale < the monthly scale, indicating that the correlation between the annual scale and the monthly scale is much better than the daily scale. For MRE, the daily scale > the monthly scale > the annual scale, indicating that the accuracy of satellite rainfall products, annual scale is slightly better than the monthly scale, and the monthly scale is slightly better than the daily scale.
Table 2. Timescales affect the calculation table.

| Station name                    | Daily rainfall | Monthly rainfall | Annual rainfall |
|--------------------------------|---------------|-----------------|----------------|
|                                | Correlation   | MRE             | Correlation    | MRE             | Correlation    | MRE             |
| Babao River Qilian Station     | 0.447         | 0.976           | 0.991          | 0.698           | 0.970          | 0.671           |
| Changma River, Changma Fort    | 0.329         | 0.932           | 0.877          | 0.834           | 0.630          | 0.765           |
| Heihe high Cliff               | 0.568         | 0.744           | 0.869          | 0.784           | 0.816          | 0.696           |
| Heihe Yingluo Gorge            | 0.391         | 0.881           | 0.903          | 0.835           | 0.851          | 0.697           |
| Heihe Zhамashike               | 0.521         | 0.769           | 0.974          | 0.689           | 0.837          | 0.706           |
| Heihe Zhengyi Gorge            | 0.492         | 0.861           | 0.885          | 0.726           | 0.835          | 0.425           |
| New Station of flood river     | 0.419         | 1.023           | 0.835          | 0.793           | 0.775          | 0.735           |
| Shule River Panjiazhuang Station| 0.472         | 0.891           | 0.572          | 0.816           | 0.572          | 0.568           |
| Dam on Li Qiao reservoir       | 0.512         | 0.786           | 0.991          | 0.783           | 0.798          | 0.731           |
| Dalai River Ice trench         | 0.508         | 0.791           | 0.667          | 0.867           | 0.522          | 0.815           |
| Nine hills in Xiying           | 0.425         | 0.935           | 0.940          | 0.822           | 0.847          | 0.763           |
| Average value                  | 0.462         | 0.872           | 0.864          | 0.786           | 0.768          | 0.688           |

3. Conclusion

In this paper, the precipitation measured by hydrological stations in Heihe basin is used, and using contingency table approach, correlation coefficient method, the accuracy of meteorological satellite precipitation data on daily, monthly and annual scales was tested and evaluated. It is found that the correlation between annual scale and monthly scale is much better than that of daily scale.

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