Applicability Assessment of RFE2.0 Remote Sensing Precipitation Data in Xinjiang (Post-print)

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Abstract

This study combines daily precipitation data from 65 meteorological observation stations in Xinjiang and employs continuous verification statistical methods and categorical verification statistical methods to evaluate the applicability of RFE2.0 remote sensing precipitation data in Xinjiang. The results indicate that: (1) Through continuous verification statistical analysis, the mean bias error MBE (mean bias error) in the Xinjiang region generally overestimates daily precipitation, with a mean value of 0.4 mm, and over 70% of stations have values within 0.5 mm. The average correlation coefficient R between RFE2.0 remote sensing precipitation data and daily precipitation from ground observation stations is 0.4, exhibiting a relatively low correlation. In terms of deviation from true values, the simulated values in Eastern Xinjiang are closest to the observed values. (2) The categorical verification statistical method overestimates the frequency bias index FBI(frequency bias index) for precipitation events. Regionally speaking, areas with small overestimation values for precipitation events are mainly located in Northern Xinjiang, where the degree of overestimation is lower than the average level for the entire Xinjiang region. The correct rate POD (probability of detection) in Northern Xinjiang is greater than that in Southern and Eastern Xinjiang, while the false alarm rate FAR(False Alarm Rate) in Northern Xinjiang is also lower than that in Southern and Eastern Xinjiang. (3) The reliability of RFE2.0 in Northern Xinjiang, Southern Xinjiang, and Eastern Xinjiang was verified through case studies. These findings can provide a scientific basis for the application of RFE2.0 in Xinjiang.

Full Text

Evaluation of Applicability of Satellite-Based RFE2.0 Rainfall Data in Xinjiang

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Abstract

Using daily precipitation data from 65 meteorological stations across Xinjiang, China, this study employed verification methods including continuous statistics and classification statistics to evaluate the applicability of satellite-based RFE2.0 (Rainfall Estimation 2.0) data. The results demonstrate that RFE2.0 systematically overestimated daily precipitation in Xinjiang, with a mean bias error (MBE) of 0.4 mm. Over 70% of meteorological stations exhibited MBE values below 0.5 mm. The average correlation coefficient (R) between RFE2.0 and observed data was 0.4, indicating a relatively low correlation that decreased progressively from northern Xinjiang to eastern Xinjiang and then to southern Xinjiang. The mean absolute error (MAE) ranged from 0.23 to 4.7 mm, with an average of 1.16 mm, and more than 50% of stations showed MAE values smaller than 1 mm. The root mean square error (RMSE) varied between 1.03 and 9.7 mm, averaging 3.32 mm. The regional ranking based on MAE values, from highest to lowest relevance, was northern Xinjiang, southern Xinjiang, and eastern Xinjiang. In terms of deviation from observed values, simulated values in eastern Xinjiang were closest to ground observations.

From the perspective of classification statistics, 45 non-GTS stations were selected to verify precipitation event detection capability. The frequency bias index (FBI) in Xinjiang ranged from 0.82 to 3.71, with regional averages of 1.42, 2.1, and 2.53 for northern, southern, and eastern Xinjiang, respectively. The regional ranking by FBI magnitude was eastern Xinjiang, southern Xinjiang, and northern Xinjiang. Overall, RFE2.0 overestimated the probability of rainfall events across Xinjiang, though this overestimation was less pronounced in northern Xinjiang compared to the regional average. The probability of detection (POD) ranged from 0.12 to 0.95, with an average of 0.67. Regional POD averages were 0.74, 0.61, and 0.61 for northern, eastern, and southern Xinjiang, respectively, indicating higher detection capability in northern Xinjiang. The false alarm rate (FAR) ranged from 0.18 to 0.92, with an average of 0.58; 33% of

stations had FAR values below 0.5. Regional FAR averages were 0.43, 0.74, and 0.69 for northern, eastern, and southern Xinjiang, respectively, showing lower false alarm rates in northern Xinjiang. These findings provide a scientific basis for the appropriate application of RFE2.0 data in Xinjiang.

Keywords: rainfall; RFE2.0; validation; Xinjiang

1. Introduction

Accurate precipitation estimation is critical for hydrological modeling, drought monitoring, and water resource management in arid regions. Satellite-based precipitation products offer spatially continuous data that complement ground-based observations, particularly in areas with sparse station networks. The NOAA RFE2.0 (Rainfall Estimation 2.0) product integrates multiple satellite sources to provide quantitative precipitation estimates, but its performance varies regionally and requires thorough validation before operational use. Previous studies have evaluated satellite precipitation products in different contexts [16, 17], yet systematic assessment of RFE2.0 across Xinjiang' s diverse climatic zones remains limited. This study addresses this gap by comprehensively evaluating RFE2.0 accuracy using dense ground observations from 65 meteorological stations distributed across northern, southern, and eastern Xinjiang.

1.1 Study Area

Xinjiang Uygur Autonomous Region, located in northwestern China, covers an area of approximately 1.66×10 km². The region comprises three distinct climatic subregions: northern Xinjiang (including the Junggar Basin and Tianshan Mountains), southern Xinjiang (encompassing the Tarim Basin), and eastern Xinjiang. The terrain varies from high mountain ranges to vast desert basins, creating complex precipitation patterns. The average annual precipitation across the region is 157.4 mm [23], with significant spatial heterogeneity. The geographical locations of the 65 meteorological stations used in this study are shown in [Figure 1: see original paper].

1.2 Data

Daily precipitation data from 65 meteorological stations in Xinjiang were obtained from the China Meteorological Administration (http://data.cma.cn/) for the period March to October 2016. The data represent 12-hour accumulated precipitation measured from 20:00 to 08:00 and from 08:00 to 20:00 Beijing Time, with a data integrity rate of 100%. The RFE2.0 satellite precipitation product was acquired from NOAA' s Climate Prediction Center (ftp://ftp.cpc.ncep.noaa.gov/GIS/RFE/). RFE2.0 combines three satellite data sources: (1) DMSP SSM/I (Defense Meteorological Satellite Program Special Sensor Microwave/Imager), (2) NOAA AMSU-B (Advanced Microwave Sounding Unit-B), and (3) Meteosat GPI (GOES Precipitation Index) [27]. The product provides daily precipitation estimates at $0.1°\times0.1°$ spatial resolution

for the domain covering 10°–60°N, 20°–95°E. All RFE2.0 data for Xinjiang were extracted and reprojected using ArcGIS 10.2 to match the study period (March 1 to October 31, 2016), yielding 241 daily precipitation maps for analysis.

1.3 Methods

1.3.1 RFE2.0 Data Processing RFE2.0 data were processed to generate daily precipitation estimates corresponding to the 12-hour observation intervals. The satellite estimates were spatially interpolated to each meteorological station location for direct comparison with gauge observations. The verification analysis employed two categories of statistical methods: continuous statistics for quantitative accuracy assessment and classification statistics for event detection evaluation.

1.3.2 Verification Metrics Continuous verification metrics included the mean bias error (MBE), mean absolute error (MAE), root mean square error (RMSE), and correlation coefficient (R). Classification statistics comprised the frequency bias index (FBI), probability of detection (POD), and false alarm rate (FAR). These metrics were calculated at each station and regionally aggregated to assess spatial performance patterns. Threshold-based analyses were conducted at 0.4 mm and 0.6 mm precipitation levels to evaluate detection capability for light rainfall events.

2. Results

2.1 Continuous Statistics

The comparison between RFE2.0 and gauge observations revealed systematic overestimation across Xinjiang. At the 0.4 mm threshold, RFE2.0 exhibited a mean bias error (MBE) of -0.32 mm, indicating consistent positive bias. The correlation coefficient R averaged 0.4, with more than 90% of stations showing R values below 0.6. The mean absolute error (MAE) averaged 1.16 mm, with over 50% of stations having MAE less than 1 mm. The root mean square error (RMSE) averaged 3.32 mm, ranging from 1.03 to 9.7 mm across stations.

Spatial analysis revealed distinct regional patterns. The correlation between RFE2.0 and observations decreased from northern Xinjiang (highest) to eastern Xinjiang and then to southern Xinjiang (lowest). In terms of deviation from observed values, RFE2.0 performed best in eastern Xinjiang, where simulated values were closest to ground measurements. The MAE and RMSE showed similar spatial gradients, with northern Xinjiang exhibiting the largest errors and eastern Xinjiang the smallest.

[Figure 4: see original paper] and [Figure 5: see original paper] illustrate the daily precipitation comparisons between RFE2.0 and gauge data at representative stations, demonstrating the product's overestimation tendency and variable correlation strength across regions.

2.2 Classification Statistics

Classification statistics evaluated RFE2.0' s ability to correctly identify precipitation events. The frequency bias index (FBI) ranged from 0.82 to 3.71 across Xinjiang, with regional averages of 1.42, 2.1, and 2.53 for northern, southern, and eastern Xinjiang, respectively. Values greater than 1.0 indicate overestimation of event frequency, which was most pronounced in eastern Xinjiang and least in northern Xinjiang.

The probability of detection (POD) varied from 0.12 to 0.95, averaging 0.67 regionally. Northern Xinjiang achieved the highest POD (0.74 average), while eastern and southern Xinjiang both averaged 0.61. The false alarm rate (FAR) ranged from 0.18 to 0.92, with a regional average of 0.58. Approximately 33% of stations had FAR values below 0.5. Northern Xinjiang showed the lowest false alarm rate (0.43 average), compared to 0.74 in eastern Xinjiang and 0.69 in southern Xinjiang.

At the 0.6 mm threshold, RFE2.0 maintained similar performance characteristics, though detection capability decreased slightly for higher precipitation intensities. [Figure 6: see original paper] shows the spatial distribution of these classification metrics, revealing clear performance gradients across the region.

4. Discussion and Conclusion

This comprehensive validation of NOAA's RFE2.0 satellite precipitation product across Xinjiang demonstrates that while the dataset provides useful precipitation estimates, significant regional biases exist. The systematic overestimation (MBE = 0.4 mm) and moderate correlation (R = 0.4) indicate that RFE2.0 should be used with caution for quantitative applications requiring high precision. The product performs best in eastern Xinjiang for magnitude estimation and in northern Xinjiang for event detection, as evidenced by lower FAR and higher POD values.

The observed spatial performance patterns likely reflect the complex topography and varying precipitation regimes across Xinjiang. Northern Xinjiang' s relatively better detection statistics may be attributed to more frequent precipitation events and better satellite retrieval performance in that climate zone. Conversely, the extreme aridity and sporadic precipitation in southern Xinjiang challenge satellite algorithms, resulting in lower correlation and higher false alarm rates.

These findings provide critical guidance for hydrological and meteorological applications in Xinjiang. Users should consider regional performance differences and apply appropriate bias correction when using RFE2.0 for water resource management, drought monitoring, or flood forecasting. Future work should focus on developing region-specific calibration algorithms to improve RFE2.0 accuracy, particularly for southern and eastern Xinjiang where performance is suboptimal.

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Note: Figure translations are in progress. See original paper for figures.