Surface Solar Radiation in Xinjiang and Applicability of CERES/SSF Satellite Data: Postprint

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Abstract

Using 2017 radiation data, this study investigated the spatiotemporal distribution characteristics of total solar radiation at 11 ground observation stations in Xinjiang, revealing that the diurnal variation of total radiation irradiance exhibits a unimodal distribution; sunshine duration peaks in summer at approximately 17 h, followed by spring and autumn at 14 h and 15 h respectively, and reaches its minimum in winter at only 12 h; and the seasonal average maximum value occurs in spring in Hotan at 589.61 W · m-2, while the minimum is approximately 102.29 W · m-2, observed in winter in Urumqi. Satellite-retrieved radiation spatial distribution characteristics indicate that: in spring, irradiance in southern Xinjiang is significantly higher than that in northern Xinjiang; the summer average irradiance distribution most closely resembles the annual pattern, followed by winter; in autumn, the difference between southern and northern Xinjiang is minimal; and seasonal variation is smallest in Aksu. Based on fitting analysis of satellite and ground radiation data, the analysis of variance shows that F-values for southern Xinjiang are consistently high, reaching a maximum of 6,215.53, suggesting that under clear-sky conditions, the retrieval performance of CERES/SSF satellite data is superior in southern Xinjiang compared to northern Xinjiang and the Turpan-Hami Basin.

Full Text

Preamble

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Abstract

The spatiotemporal distribution of total solar radiation at 11 meteorological stations in Xinjiang was studied based on analyzing solar radiation data recorded at minute scale in 2017. The results showed that the curve of daily variation of total solar radiation was unimodal, and the daily sunshine duration was the highest (about 17 hours) in summer, followed by spring and autumn (about 14 and 15 hours respectively), and it was the lowest (about 12 hours only) in winter. Regionally and seasonally, the maximum value (589.61 W·m ^{2}) occurred in Hotan in spring, and the minimum one (102.29 W·m ^{2} only) in Urumqi in winter. The spatial distribution of satellite retrieval radiation showed that the radiation in south Xinjiang was obviously higher than that in north Xinjiang; the average radiation in summer was the most similar to the annual average irradiance, then in winter; the difference between north Xinjiang and south Xinjiang was not significant, and the seasonal difference was the lowest in Aksu. The fitting analysis of satellite and surface radiation data revealed that the F-value in south Xinjiang was as high as 6215.53, that is, under the condition of clear sky, the retrieval of CERES/SSF satellite data in south Xinjiang was better than that in north Xinjiang and the Turpan-Hami Basin.

Keywords: CERES/SSF; irradiance; downward shortwave radiation; error; Xinjiang

3. Results and Analysis

3.1 Temporal Variation Characteristics of Surface Solar Radiation

Based on minute-scale observational data from 11 meteorological stations in Xinjiang in 2017, the daily variation of irradiance values exhibits a unimodal distribution pattern [Figure 1: see original paper]. The daily sunshine duration reaches its maximum in summer at approximately 17 hours, followed by spring and autumn at about 14 and 15 hours respectively, and drops to its lowest in winter at only around 12 hours.

Seasonal average irradiance values at the 11 stations show significant regional differences [Figure 2: see original paper]. The annual average irradiance ranges between 403–1080 W·m ^{2} across stations. Specifically, spring values span 821–1080 W·m ^{2}, indicating relatively high and uniform distribution; summer values range from 272–780 W·m ^{2}, showing substantial spatial variation; autumn values fall between 216–690 W·m ^{2}, with notable decreases in certain regions; and winter values show the greatest disparity, from 164–402 W·m ^{2}.

The maximum seasonal average irradiance of 589.61 $\mathrm{W \cdot m}^{2}$ occurs in Hotan during spring, while the minimum of 102.29 $\mathrm{W \cdot m}^{2}$ occurs in Urumqi during winter. The spring average reaches 468.69 $\mathrm{W \cdot m}^{2}$, with Hotan recording the highest at 798.04 $\mathrm{W \cdot m}^{2}$. Summer observations show an average of 246.91 $\mathrm{W \cdot m}^{2}$, with the southern regions exhibiting higher values than the north. Autumn measurements average 202.42 $\mathrm{W \cdot m}^{2}$, though some stations show elevated values due to local terrain effects. Winter averages 181.67 $\mathrm{W \cdot m}^{2}$ in spring-like conditions, but drops to 164.07 $\mathrm{W \cdot m}^{2}$ in winter proper, representing only one-third to one-half of summer values.

3.2 Satellite Retrieval Validation and Error Analysis

Using CERES/SSF satellite data at 0.5°×0.5° resolution, we compared satellite-retrieved shortwave solar radiation flux with ground-based observations. The spatial distribution of satellite retrievals for 2017 [Figure 3: see original paper] demonstrates that radiation in southern Xinjiang significantly exceeds that in northern regions.

Validation results against 5 stations in southern Xinjiang [Figure 5: see original paper] reveal strong agreement under clear-sky conditions. The correlation coefficient (R) reaches 0.99, with 95% of data points falling within acceptable error bounds. Statistical analysis shows mean bias errors of -7.28 $\mathrm{W \cdot m}^{2}$ and root-mean-square errors of 156.33 $\mathrm{W \cdot m}^{2}$. The F-value of 6215.53 indicates excellent model performance, with over 40% of variance explained. For irradiance values between 900–1000 $\mathrm{W \cdot m}^{2}$, satellite observations closely match ground measurements ($R > 0.96$). At lower irradiance levels (~700 $\mathrm{W \cdot m}^{2}$), some discrepancies emerge due to cloud contamination and atmospheric conditions.

For northern Xinjiang and the Turpan-Hami Basin, validation against 6 stations [Figure 6: see original paper] shows comparatively larger errors. The mean bias error is -72.35 $\mathrm{W \cdot m}^{2}$, with root-mean-square error of 190.34 $\mathrm{W \cdot m}^{2}$. However, correlation coefficients remain high ($R = 0.91$–0.99), indicating systematic rather than random errors. The analysis of variance (ANOVA) confirms significant differences between regions ($F > 5000$, $p < 0.01$).

Table 2 presents detailed error statistics for clear-sky conditions across all stations. The results demonstrate that CERES/SSF satellite retrievals perform better in southern Xinjiang than in northern regions, particularly under clear-sky conditions. The high correlation coefficients ($R > 0.9$) and statistically significant F-values confirm the reliability of satellite data for solar resource assessment in Xinjiang.

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