# Supplementary Figures

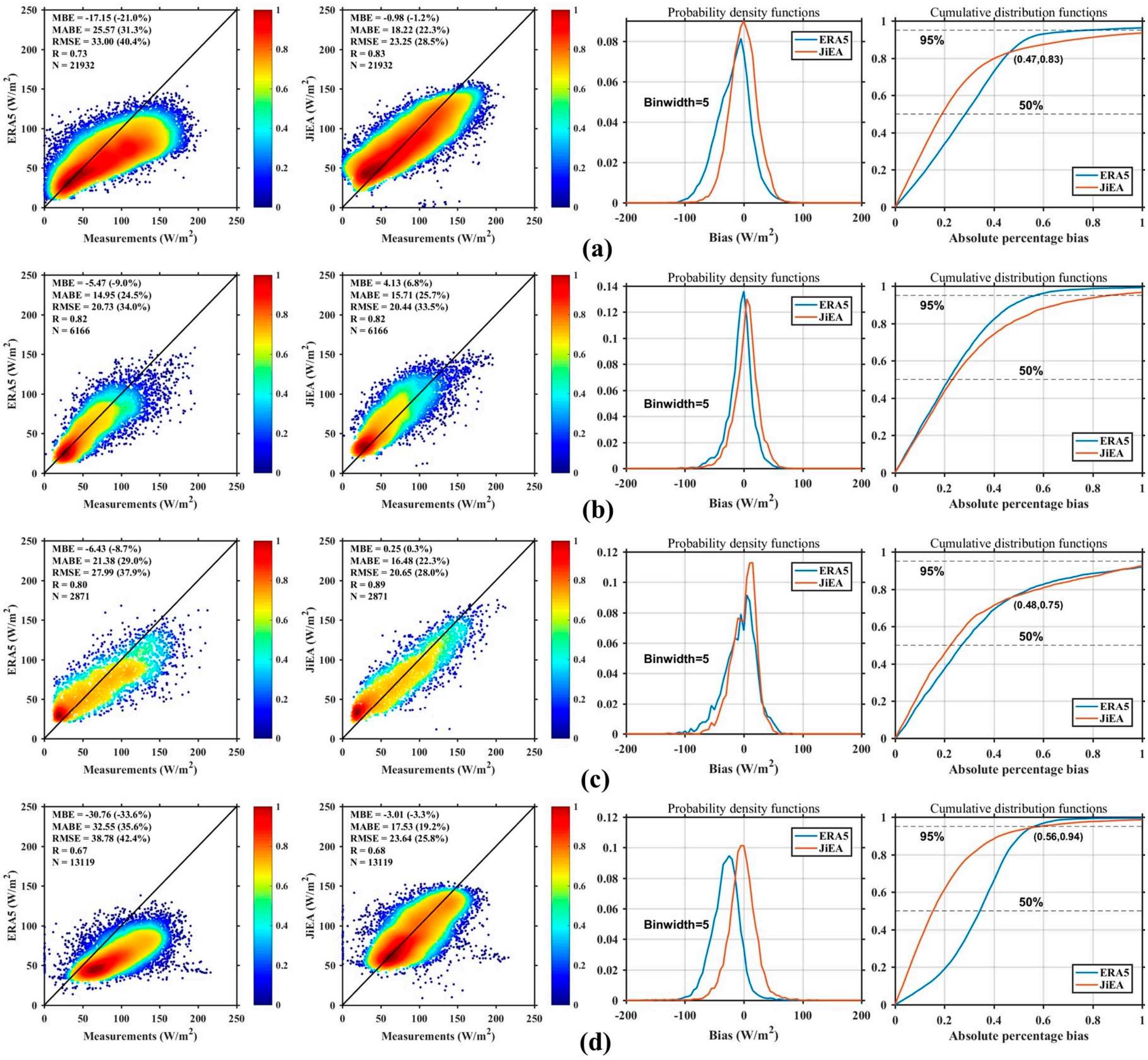


**Figure S1.** Evaluation results of $R_{dif}$ in different regions at daily mean scale. (**a-d**) Scatterplots for ERA5 (first column) and JiEA (second column) estimates versus ground measurements; PDFs (third column) and CDFs (fourth column) for Eastern China (**a**), Mongolian Plateau (**b**), Tibetan Plateau (c) and Deccan Plateau (**d**), respectively.

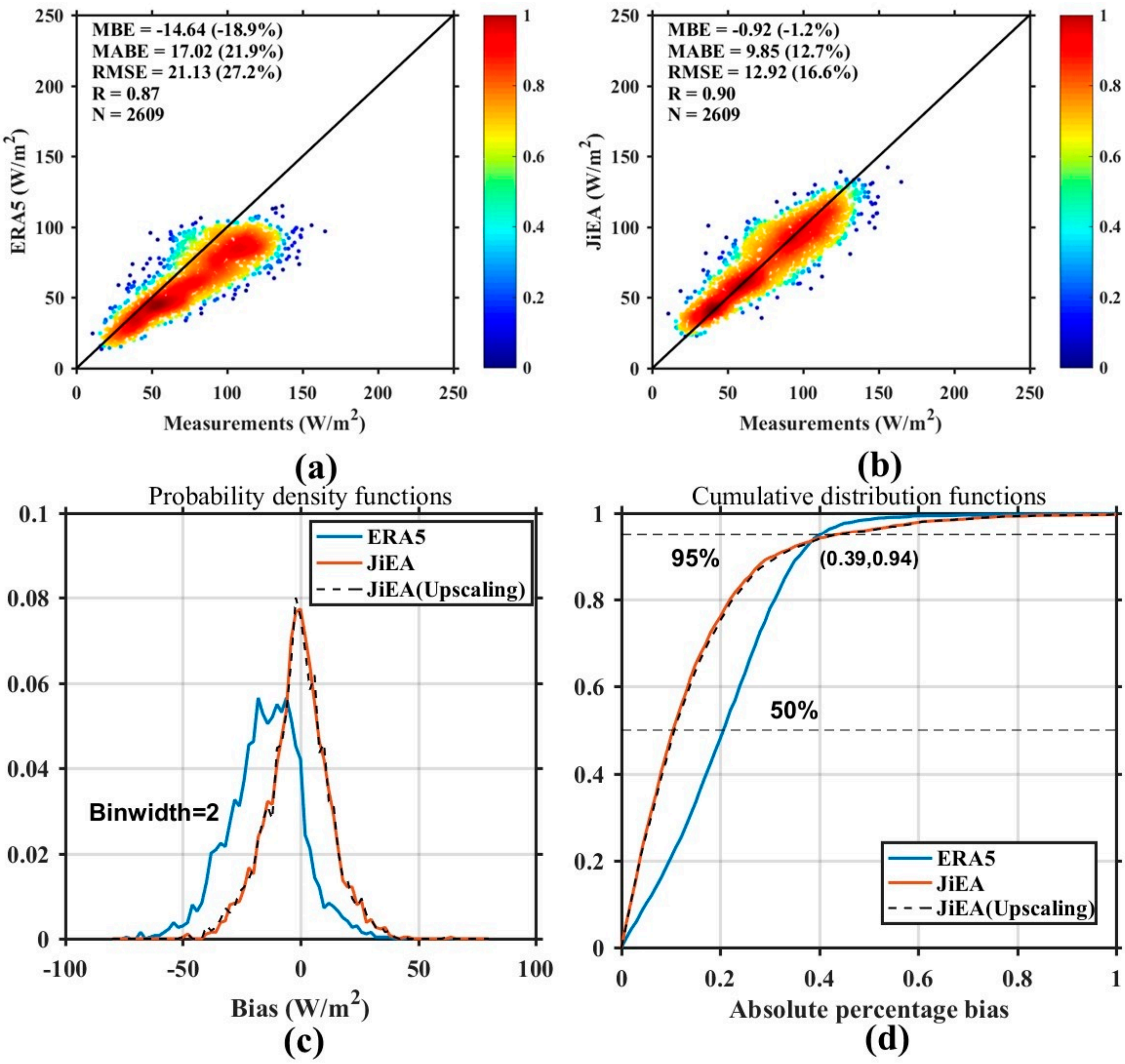


**Figure S2.** Evaluation results of monthly mean $R_{dif}$ estimates. (**a**) Density scatterplots between ERA5 estimates and CMA measurements. (**b**) Scatterplots for estimates of JiEA. At the upper left corner shows the values of validation metrics with their relative values in the brackets. Black lines represent the 1:1 lines. (**c**) PDF of bias for EAR5 (blue line) and JiEA (orange line). (**d**) The related CDF of absolute percentage bias. The dotted black lines represent the results for estimates of JiEA after upscaling the original monthly data to 0.25-degree grids (same to ERA5).

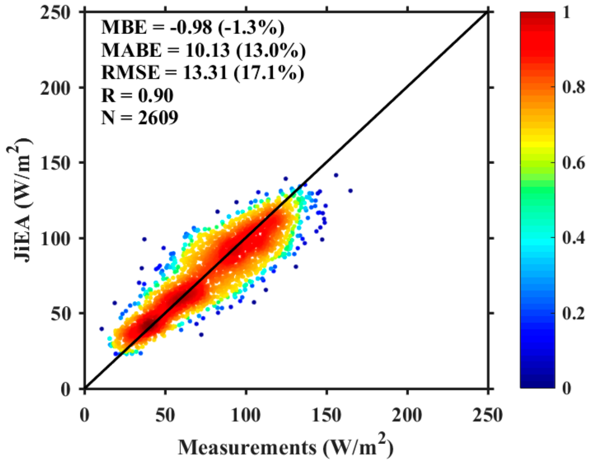


**Figure S3.** The effects of spatial resolution on evaluation results. Scatterplots of estimates of JiEA after upscaling to 0.25-degree grids versus monthly mean measurements.

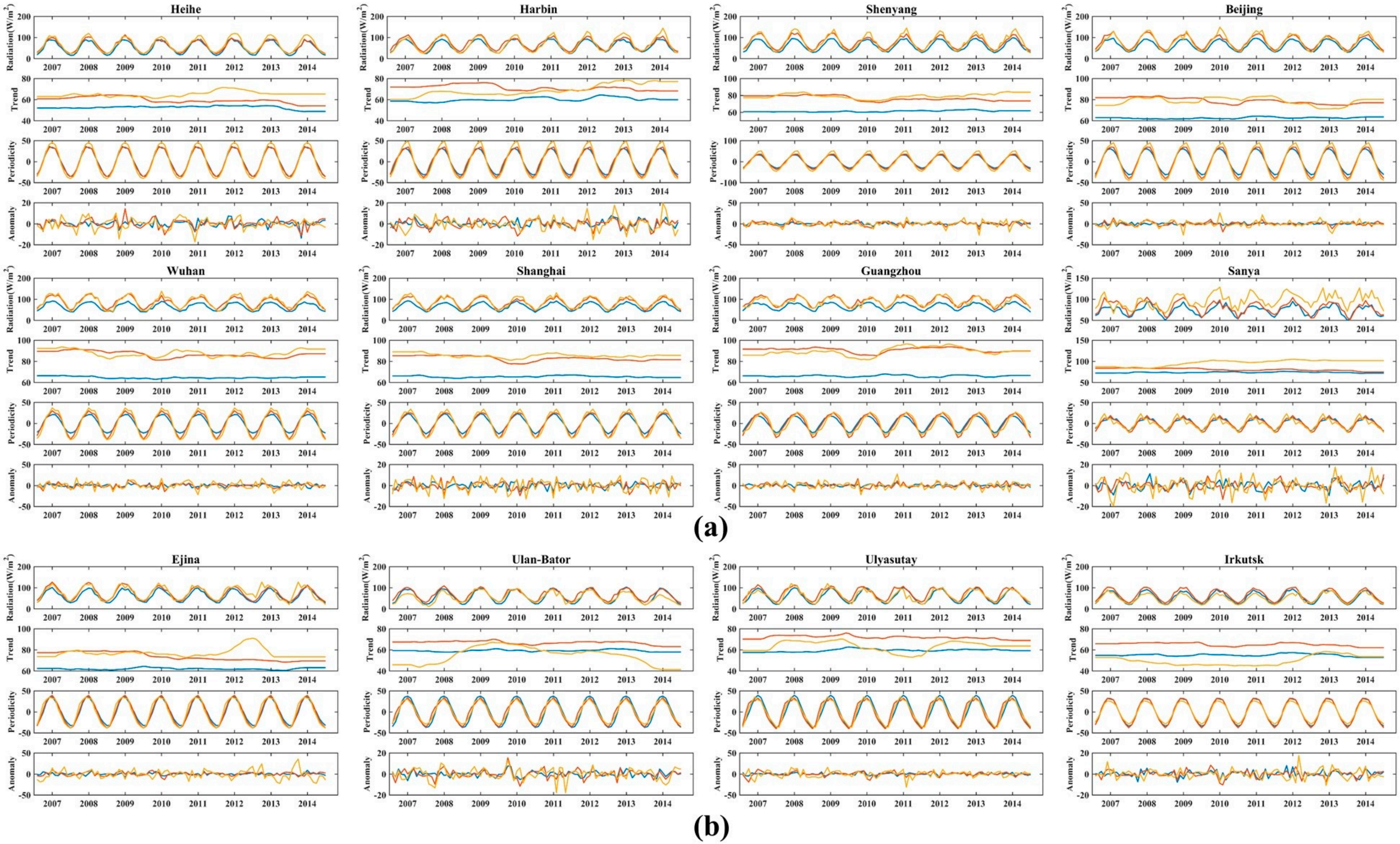


**Figure S4.** Results of time series decomposition. The blue, brown and yellow lines represent results of EAR5, JiEA and ground measurements, respectively. For each panel, sub-figures from top to bottom represent original monthly time series, temporal trends, seasonal periodicity and irregular anomaly in order. Estimates of JiEA are from upscaling 0.25-degree grids. We only show stations with relatively complete time series. Groups (**a-f**) are for Eastern China (**a**), Mongolian Plateau (**b**), Tibetan Plateau (**c**), Deccan Plateau (**d**), and other stations within China (**e**) or outside China (**f**), respectively.

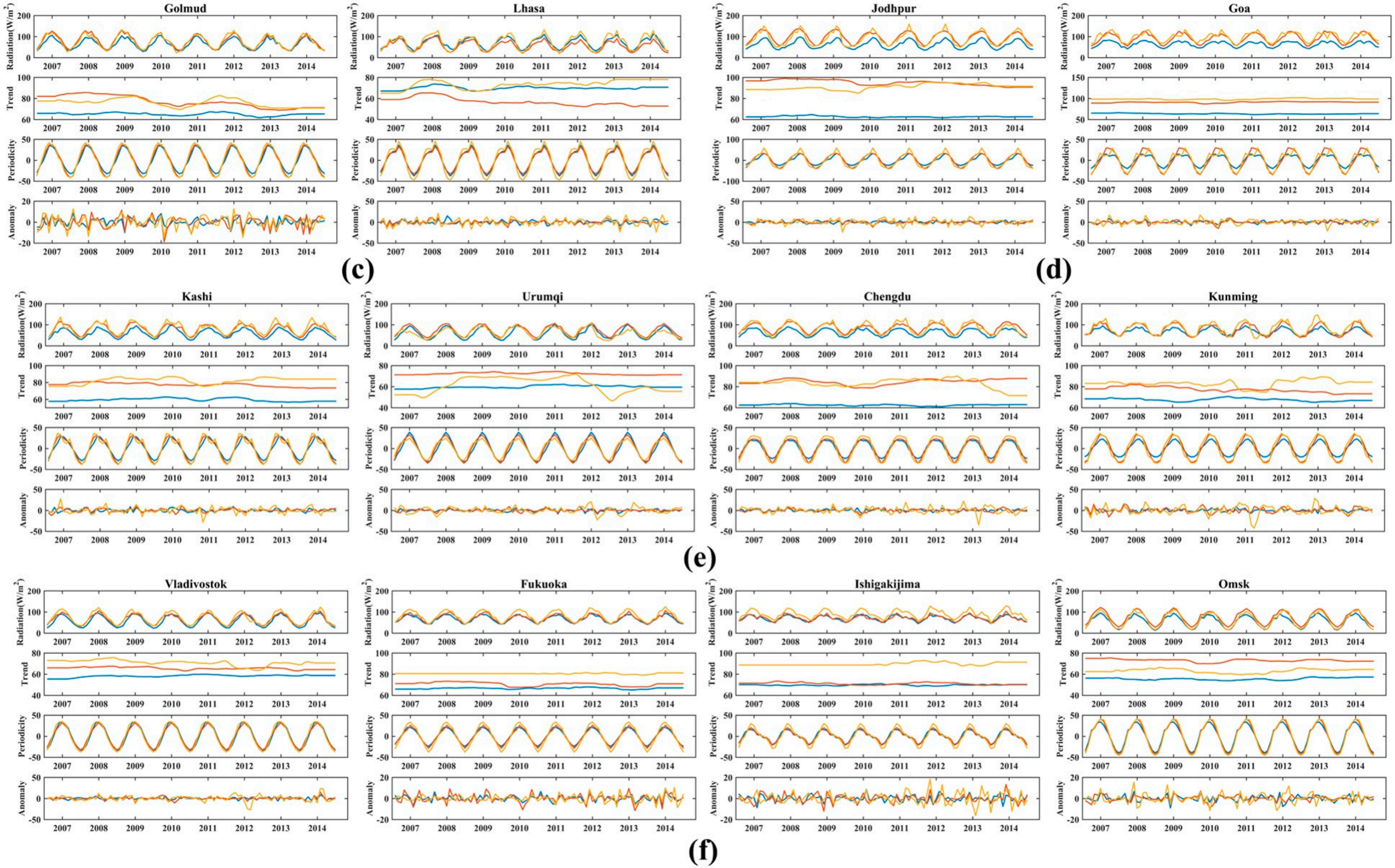


**Figure S4.** (*Continued*).

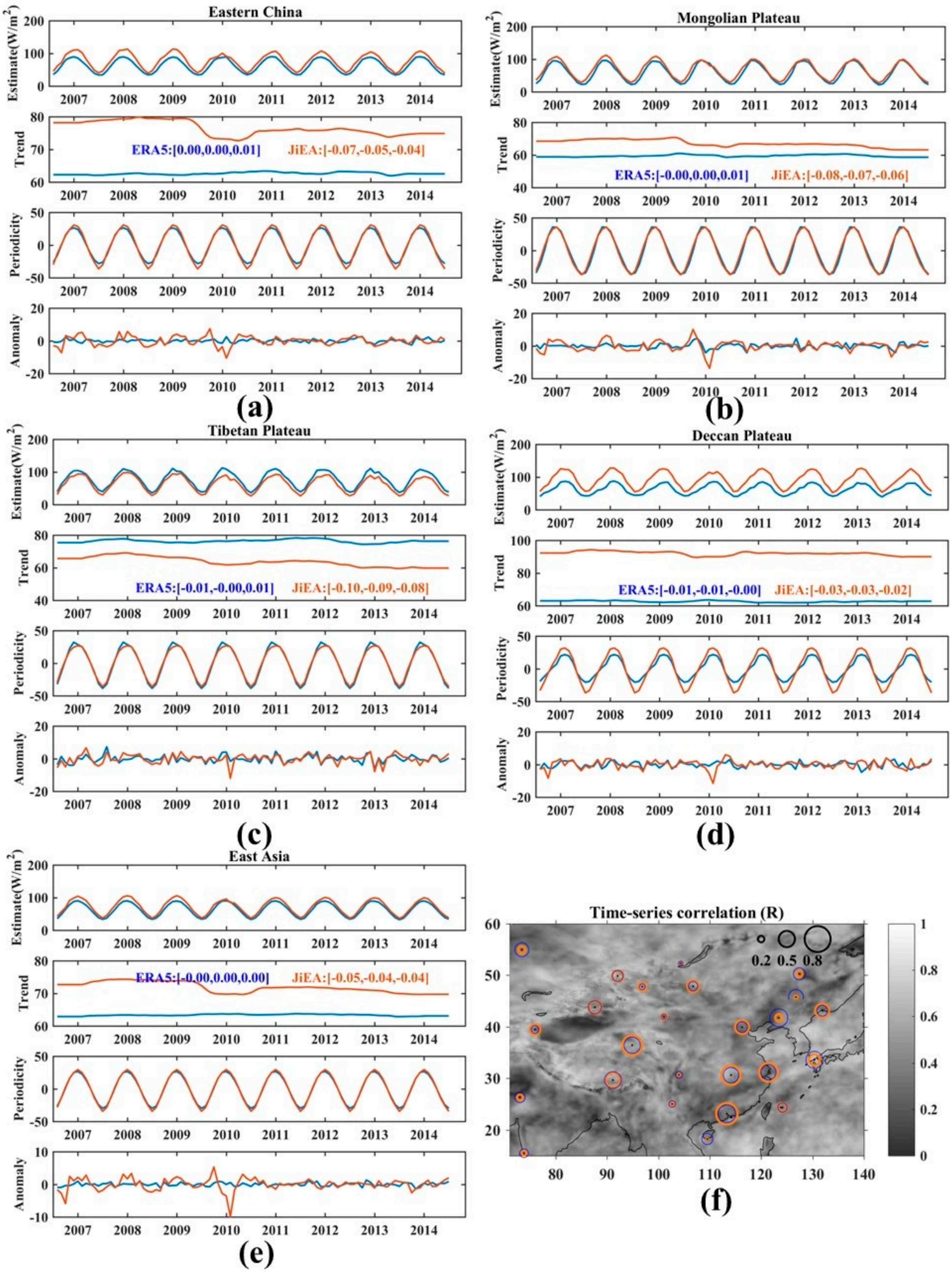

**Figure S5.** Results of time series decomposition in different regions. (**a**) Eastern China; (**b**) Mongolian Plateau; (**c**) Tibetan Plateau; (**d**) Deccan Plateau; (**e**) East Asia (the maximum overlapped coverage of two datasets) The blue and brown lines represent results of EAR5 and JiEA, respectively. Sub-figures from top to bottom represent original regional averaged monthly estimates, temporal trends, seasonal periodicity and irregular residuals, respectively. Values are the linear slopes versus times and the 95% confidence intervals. f, Correlation map of deseasonalized time series of ERA5 and JiEA. In addition, we display their correlations to ground measurements at stations involved in Figure S4 by variously sized circles.

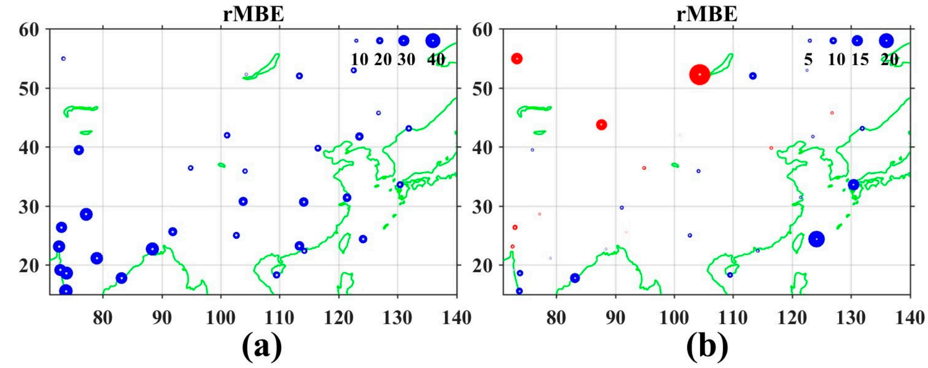


**Figure S6.** Spatial distribution of rMBE. (**a**) Results for ERA5; (**b**) Results for estimates of JiEA. Red symbols indicate an overestimation while others represent underestimation.

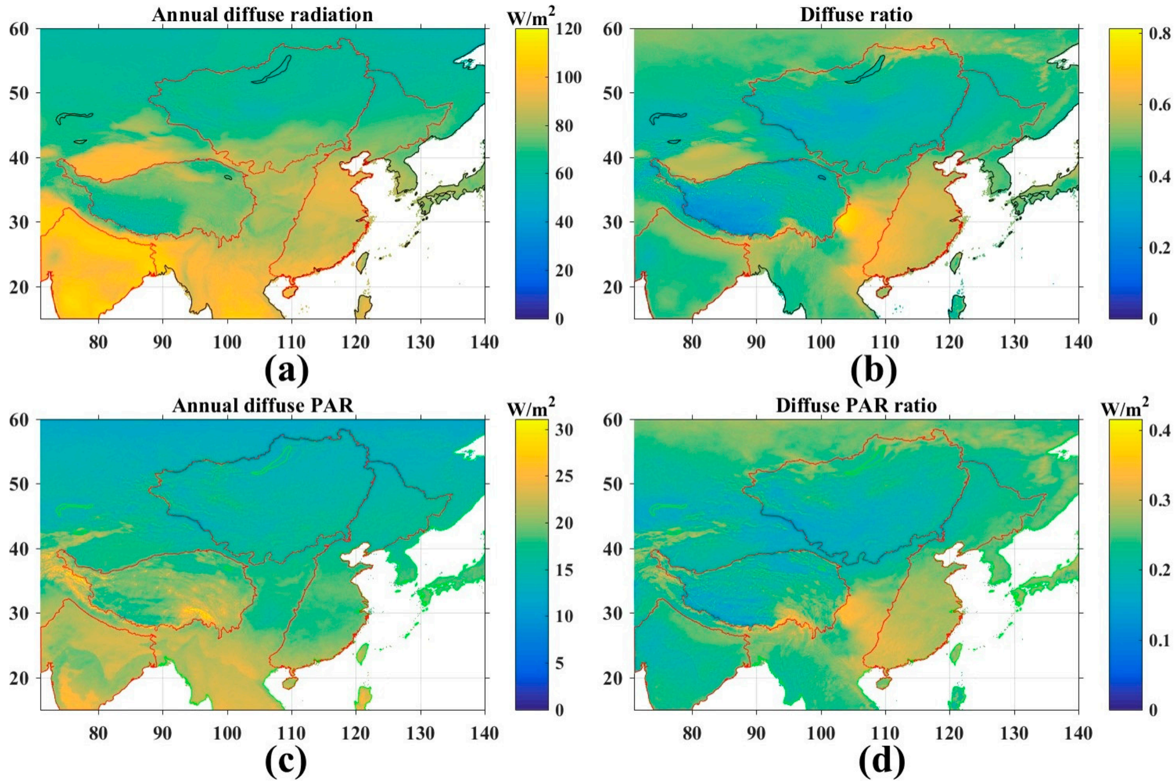


**Figure S7.** Spatial distribution of reference data. (**a-b**) Estimates of $R_{dif}$ (**a**) and its fraction (**b**) to $R_s$ from the SOLARGIS database (https://solargis.com/). (**c-d**) Estimates of diffuse PAR (**c**) and its fraction (**d**) to PAR in 2010 from the BESS database (http://environment.snu.ac.kr/).

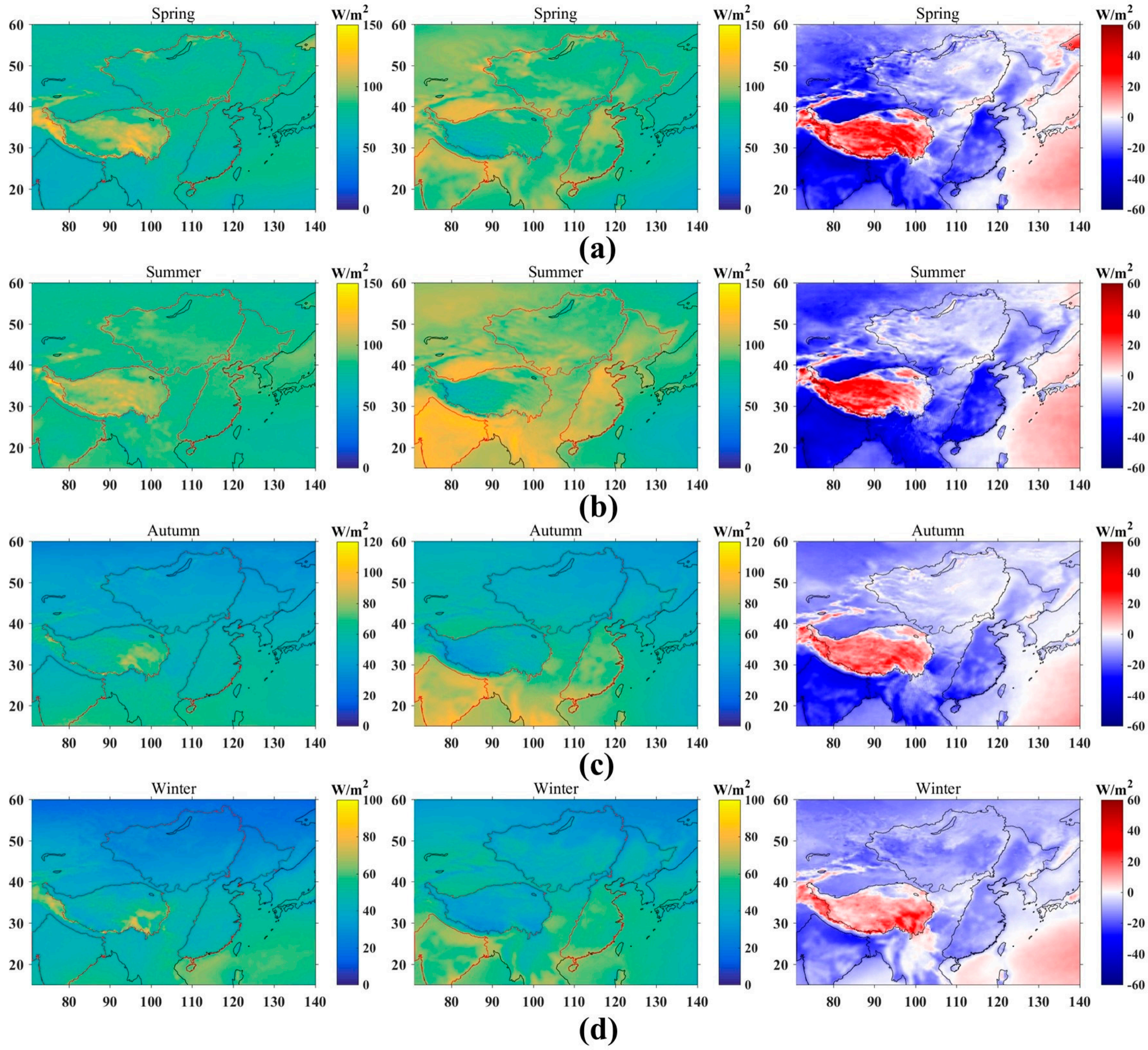


**Figure S8.** Seasonal spatial distribution of two datasets. (**a**) Spring; (**b**) Summer; (**c**) Autumn; (**d**) Winter. Left column: the results of ERA5. Middle column: the results of JiEA. Right: their differences in space (ERA5 minus JiEA).

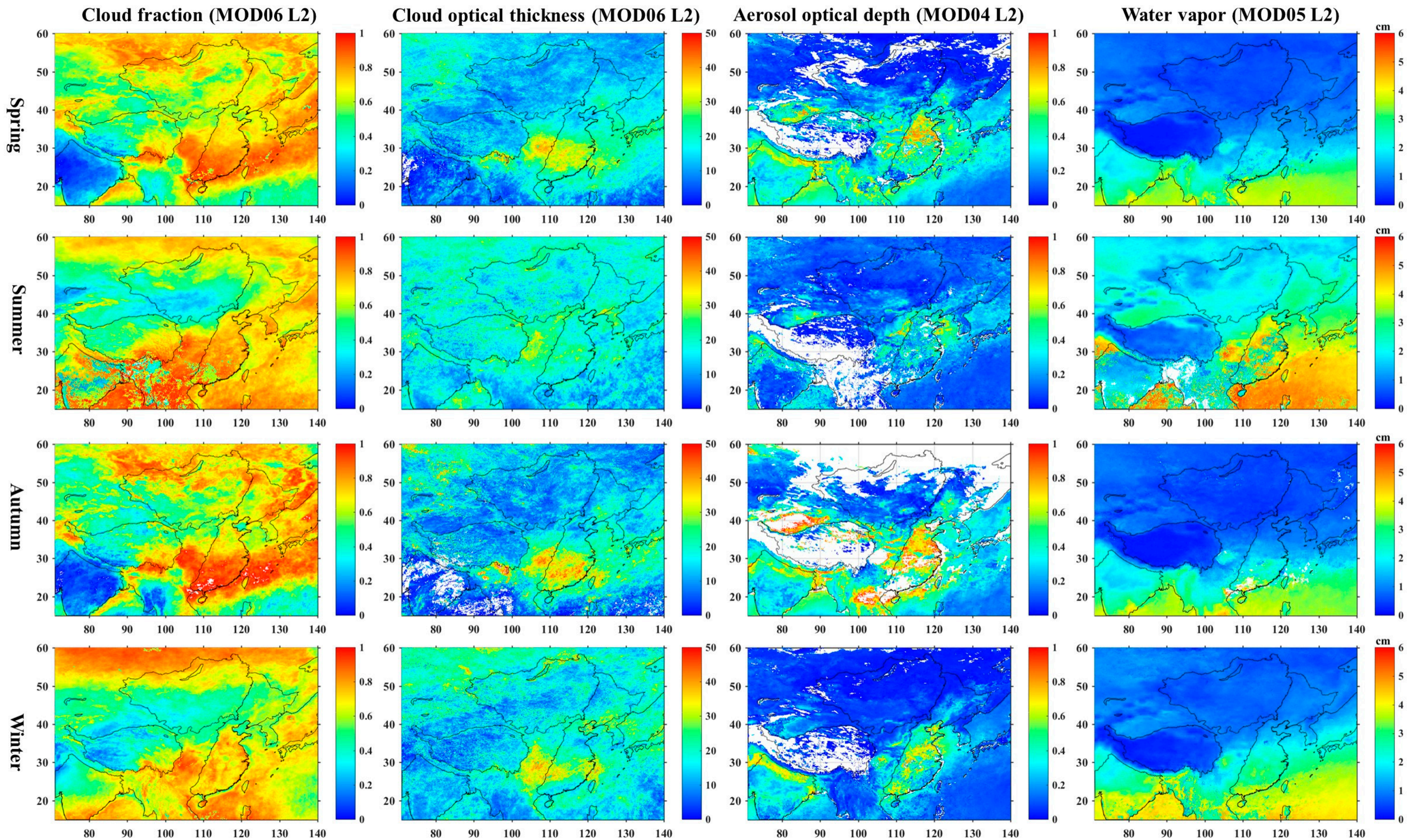


**Figure S9.** Seasonal spatial distribution of atmospheric parameters most relating to $R_{dif}$ estimation. We show the seasonal variations of MODIS derived parameters in 2010 at 0.1-degree-pixel resolution (https://neo.sci.gsfc.nasa.gov/).

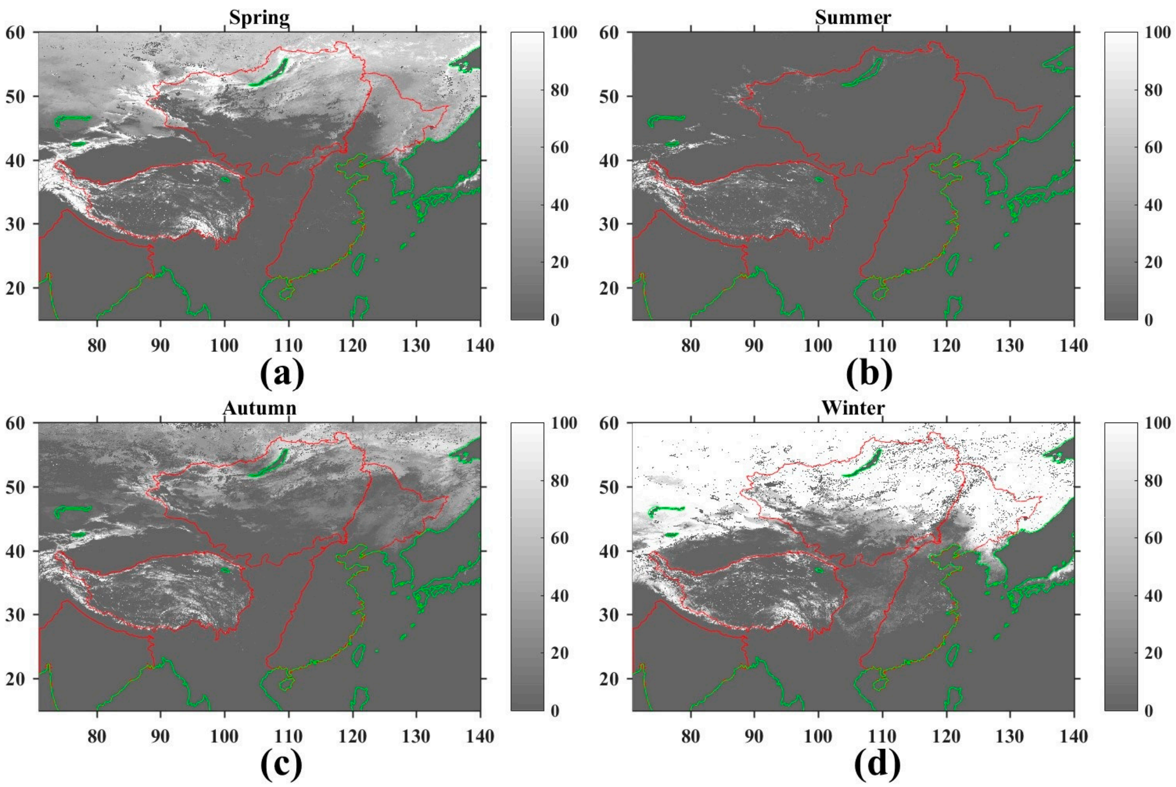


**Figure S10.** Seasonal snow/ice cover. (**a**) Spring; (**b**) Summer; (**c**) Autumn; (**d**) Winter. Data are from monthly products of MOD10.

## Supplementary Tables

**Table S1.** Basic information of surface radiation stations involved in this study.

| Name | Latitude | Longitude | Altitude | Valid Numbers[1] | Resources | Country |
|---|---|---|---|---|---|---|
| Beijing | 39.93 | 116.28 | 55 | (3691,-,-) | CMA | China |
| Chengdu | 30.67 | 104.02 | 506 | (3866,2862,95) | CMA | China |
| Ejina | 41.95 | 101.07 | 941 | (4042,-,-) | CMA | China |
| Golmud | 36.42 | 94.90 | 2808 | (4135,-,-) | CMA | China |
| Guangzhou | 23.13 | 113.32 | 7 | (3677,2860,96) | CMA | China |
| Harbin | 45.75 | 126.77 | 142 | (3571,2871,96) | CMA | China |
| Heihe | 50.25 | 127.45 | 166 | (3543,1433,84) | CMA | China |
| Hong Kong | 22.32 | 114.17 | 66 | (-,2156,72) | WRDC | China |
| Kashi | 39.47 | 75.98 | 1289 | (4122,-,-) | CMA | China |
| Kunming | 25.02 | 102.68 | 1891 | (3939,2763,93) | CMA | China |
| Lanzhou | 36.05 | 103.88 | 1517 | (4008,2772,93) | CMA | China |
| Lhasa | 29.67 | 91.13 | 3649 | (4068,-,-) | CMA | China |
| Sanya | 18.23 | 109.52 | 6 | (3932,1432,84) | CMA | China |
| Shanghai | 31.17 | 121.43 | 4 | (3685,-,-) | CMA | China |
| Shenyang | 41.73 | 123.45 | 43 | (3666,2840,95) | CMA | China |
| Urumqi | 43.78 | 87.62 | 918 | (4000,2843,96) | CMA | China |
| Wuhan | 30.62 | 114.13 | 23 | (3465,2798,85) | CMA | China |
| Zhengzhou | 34.72 | 113.65 | 110 | (3679,-,-) | CMA | China |
| Ahmadabad | 23.07 | 72.63 | 55 | (-,1464,41) | WRDC | India |
| Dum-Dum | 22.65 | 88.45 | 4 | (-,1291,-) | WRDC | India |
| Goa | 15.48 | 73.82 | 55 | (-,1933,59) | WRDC | India |
| Jodhpur | 26.30 | 73.02 | 217 | (-,2120,68) | WRDC | India |
| Nagpur | 21.10 | 79.05 | 308 | (-,687,17) | WRDC | India |
| New Delhi | 28.58 | 77.20 | 212 | (-,1213,35) | WRDC | India |
| Poona | 18.53 | 73.85 | 555 | (-,2281,35) | WRDC | India |
| Santacruz | 19.12 | 72.85 | 15 | (-,623,-) | WRDC | India |
| Shillong | 25.57 | 91.88 | 1600 | (-,452,12) | WRDC | India |
| Vishakhapatnam | 17.72 | 83.23 | 41 | (-,1507,44) | WRDC | India |
| Fukuoka | 33.58 | 130.38 | 3 | (-,1789,57) | WRDC | Japan |
| Ishigakijima | 24.33 | 124.17 | 6 | (-,1684,57) | WRDC | Japan |
| Dalanzadgad | 43.58 | 104.42 | 1469 | (-,-,36) | WRDC | Mongolia |
| Muren | 49.63 | 100.17 | 1288 | (-,-,23) | WRDC | Mongolia |
| Ulaangom | 49.85 | 92.07 | 934 | (-,-,94) | WRDC | Mongolia |
| Ulan-Bator | 47.85 | 106.75 | 1264 | (-,-,93) | WRDC | Mongolia |
| Ulyasutay | 47.75 | 96.85 | 1751 | (-,-,81) | WRDC | Mongolia |
| Chita | 52.02 | 113.33 | 671 | (-,2070,66) | WRDC | Russia |
| Irkutsk | 52.27 | 104.35 | 467 | (-,2659,90) | WRDC | Russia |
| Omsk | 54.93 | 73.40 | 119 | (-,2822,96) | WRDC | Russia |
| Vladivostok | 43.12 | 131.90 | 138 | (-,2840,94) | WRDC | Russia |

[1] The fifth column represents the numbers of valid records used for data evaluation at hourly, daily and monthly scales, respectively, after data quality check of measured values from 2007 to 2014.

**Table S2.** Requirements defined for downward short-wave irradiance at Earth surface.

| Application areas | Spatial resolution | | | Temporal scale | | | Uncertainty (W/m$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Goal* | *Break* | *Thres.* | *Goal* | *Break* | *Thres.* | *Goal* | *Break* | *Thres.* |
| **Global NWP**[1] | 10km | 30km | 100km | 1h | 3h | 12h | 1 | 10 | 20 |
| **Agricultural meteorology** | 1km | 5km | 20km | 24h | 2d | 7d | - | - | - |
| **Nowcasting and VSRF**[2] | 5km | 15km | 50km | 60s | 10m | 60m | 1 | 10 | 20 |
| **Climate monitoring** | 25km | 50km | 100km | 24h | 2d | 5d | 5 | 6.5 | 10 |

[1] NWP: Numerical Weather Prediction. [2] VSRF: Very Short Range Forecasting. These user-defined requirements are collected by the Observing System Capability Analysis and Review Tool (OSCAR, https://www.wmo-sat.info/oscar/variables/view/50) developed by World Meteorological Organization (WMO). *Goal*: an ideal requirement above which further improvements are not necessary; *Break*: an intermediate level which, if achieved, would result in a significant improvement for the targeted application; *Thres.*: the minimum requirement to be met to ensure that data are useful. The uncertainty characterizes the estimated range of observation errors with a 68% confidence interval.