Proceedings of ICEGEE 2026 Symposium: Sustainable Environment and Ecology
DOI: 10.54254/2753-8818/2026.34459

Impacts of Aerosol and Cloud Radiative Interactions on Surface Shortwave Radiation Changes over China from 2001 to 2025

Xinran Liu

College of Environmental Science and Engineering, Beijing University of Technology, Beijing, China
1343919711@qq.com

Abstract. Surface shortwave radiation (SSR) is an important part of the surface energy budget. It is closely linked to climate change, ecosystem change, and the use of solar energy resources. In China, SSR changes in a complex way. Its temporal changes and spatial distribution are quite different across regions. Previous studies have shown that clouds and aerosols are key factors that affect SSR in China. But their relative roles in different regions and periods are still not fully clear. Using CERES-SYN satellite observation data, this study examined the spatiotemporal changes in SSR over China from 2001 to 2025. It also assessed the relative effects of clouds and aerosols on SSR changes. The results show that high SSR values mainly occur in northwestern China and on the Qinghai–Tibet Plateau. By contrast, SSR values are generally lower in the southeastern coastal regions. In terms of temporal change, SSR showed clear period-based features during the study period. A marked shift occurred around 2013. From 2001 to 2013, SSR generally increased in most parts of China. In the northwestern plateau region and the Qinghai–Tibet Plateau, changes in SSR were highly consistent with cloud changes. From 2014 to 2025, SSR changes in the northwestern and southwestern plateau regions remained closely related to cloud changes. In the eastern and southern coastal regions, SSR changes were more closely linked to aerosol changes. In general, clouds and aerosols affect SSR changes in different ways across regions and periods. Their combined effects have shaped the regional features of SSR change in China. These findings may also offer a useful basis for later studies on regional climate and solar energy resource assessment.

Keywords: surface shortwave radiation, aerosol radiative effects, cloud radiative effects

1.Introduction

Surface solar radiation (SSR) is an important component of the Earth's climate system and is also one of the primary sources of the surface energy budget. Variations in surface solar radiation not only affect changes in surface temperature and atmospheric circulation [1, 2], but are also closely associated with many ecological processes such as the hydrological cycle, evaporation processes, vegetation photosynthesis, and the carbon cycle [3, 4]. In addition, surface solar radiation is an

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

important basis for the formation of solar energy resources. Its distribution characteristics and variation conditions directly affect the efficiency of photovoltaic power generation and are also related to the overall development potential of renewable energy. In recent years, with the continuous development of the photovoltaic industry and the increasing global demand for computing power, the role of surface solar radiation variation in solar energy resource assessment and energy utilization has gradually attracted more attention [4, 5]. Therefore, research on the long-term variation characteristics and driving factors of surface solar radiation is helpful, on the one hand, for gaining a deeper understanding of the evolution processes of regional climate and ecosystems, and on the other hand, for providing reliable references for solar energy resource development and energy management.

From an astronomical-scale perspective, solar radiation is relatively stable overall. However, during the process in which solar radiation passes through the atmosphere and reaches the Earth's surface, it is jointly affected by various natural and anthropogenic factors. Therefore, SSR often exhibits relatively obvious differences across different regions and time periods [6]. Existing studies have shown that such variations are closely related to atmospheric composition, among which clouds and aerosols are considered important factors affecting SSR variation [7]. Aerosols can weaken the solar shortwave radiation reaching the surface through scattering and absorption effects [8-10], while also influencing cloud formation processes and cloud microphysical properties, thereby indirectly altering the surface radiation budget [11, 12]. Clouds mainly regulate the surface radiation budget through reflection and absorption processes [13, 14]. Due to differences in atmospheric environments and climatic backgrounds among regions, the relative roles of clouds and aerosols in SSR variation are not entirely consistent, which also causes SSR to exhibit relatively complex characteristics in both temporal variation and spatial distribution.

China is a region with relatively high aerosol emissions globally and is also significantly influenced by the East Asian monsoon. The distributions of clouds and aerosols exhibit obvious regional differences; therefore, the variation characteristics of SSR in China are relatively complex [15]. Existing studies have pointed out that surface radiation in China experienced continuous "dimming" from the 1950s to the 1980s [16-18], the decreasing trend slowed after the 1990s [19, 20], and then shifted to "brightening" after the 2000s [21, 22]. The earlier "dimming" was mainly associated with the rapid increase in aerosol concentrations caused by large-scale fossil fuel combustion and transportation emissions during the process of industrialization [16, 23, 24].

Since the start of the 21st century, China has kept improving its air pollution control measures. Aerosol levels have dropped clearly, and SSR in some Chinese areas has started to rise again [25]. Li et al. [26] studied SSR changes in eastern China between 2005 and 2015. They found that higher SSR links closely to lower aerosol optical depth (AOD) and higher single scattering albedo (SSA). Schwarz et al. [27] noted that China's surface "brightening" ties to weaker atmospheric absorption. This means less aerosols can let more solar radiation reach the ground. Besides, some works stress the key part clouds play in SSR recovery. Norris and Wild [28] said about half of China's SSR rise from 1990 to 2002 came from less cloud cover. Yang et al. [21] added that clouds might affect SSR more than aerosols during China's SSR "brightening" period.

Many studies have looked at SSR changes and their driving factors in China, but some unclear points still exist. More exactly, how aerosols and clouds each affect SSR changes is not fully understood yet. Early research mostly relied on data from ground observation stations. They judged aerosol or cloud impacts via trend and correlation analysis. These methods work well, but they lack wide spatial coverage and steady time records [15]. As satellite observation data grew, researchers began to use satellite products to study SSR changes. This provides a new method to explore SSR shifts in large areas and different time frames [27]. For this reason, this work uses the CERES-SYN satellite product. It analyzes surface shortwave radiation's spatial and temporal changes in China from 2001 to 2025. It also measures how much aerosols and clouds each contribute to SSR changes. In short, this study further shows the recent changing features of SSR in China.

2.Methods

2.1 Research area

The study area is mainland China (73°–135° E, 18°–54° N). This region has complex topography, large differences in population distribution and industrialization level, and strong effects from the East Asian monsoon. These factors cause clear spatial differences in aerosols and clouds. They also directly affect the spatiotemporal distribution and long-term change of SSR.

2.2 Data sources

This study uses monthly mean SSR data from the CERES-SYN satellite product. The study period is from January 2001 to December 2025. The spatial resolution is 1° × 1°. The CERES-SYN dataset provides longwave and shortwave radiation data at both the surface and the top of the atmosphere. It includes radiation data under all-sky, clear-sky, all-sky-no-aerosol, and pristine clear-sky-no-aerosol conditions [29]. These surface radiation data are calculated with the NASA Langley Fu-Liou radiative transfer model. The input parameters of the model include cloud property data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Goddard Earth Observing System (GEOS). They also include GEOS atmospheric and surface temperature data, aerosol compositions from the Model of Atmospheric Transport and Chemistry (MATCH), and MODIS spectral aerosol optical depth [30]. Related studies have shown that this dataset has relatively high accuracy for SSR observation over China. Therefore, it can be used to analyze the spatiotemporal variation of SSR in China [15].

2.3 Calculation methods

This study first carried out strict quality control on the CERES-SYN SSR data. All missing values (NaN) and abnormal values were removed to ensure the reliability and validity of the data used in the analysis. Area-weighted methods were used to calculate regional mean SSR and its radiative effects. This was done to reduce the influence of differences in grid area on the averaged results.

To quantify the effects of clouds and aerosols on SSR, this study calculated the cloud radiative effect (CRE) and aerosol radiative effect (ARE) based on SSR data. CRE was obtained from the difference between all-sky SSR and clear-sky SSR. It was used to show the modulation effect of clouds on surface shortwave radiation. Negative CRE values indicate a cooling effect. A larger absolute value of negative CRE means a stronger scattering effect of clouds on SSR. ARE was calculated from the difference between clear-sky SSR and clear-sky-no-aerosol SSR. It was used to show the contribution of aerosols to SSR. Negative ARE values indicate a cooling effect. A larger absolute value means a stronger scattering effect of aerosols on SSR.

In addition, this study used the least squares method to analyze the temporal trends of SSR and other variables. T-tests were then conducted on the regression coefficients. The statistical significance of the trends was evaluated at the 10% significance level. To quantitatively assess the contributions of clouds and aerosols to SSR variation, relative trend percentages were also calculated. This indicator was based on the absolute values of SSR trends under all-sky-no-aerosol, clear-sky, and clear-sky-no-aerosol conditions. It was used to further clarify the relative roles of clouds and aerosols in SSR variation.

3.Results and discussion

This study first analyzed SSRALL_SKY, CRE, and ARE in China during 2001–2025. The results are shown in Figure 1. SSRALL_SKY showed a clear spatial distribution pattern of "higher in the west and lower in the east." The northwestern region had the highest SSRALL_SKY values. The mean SSRALL_SKY was higher than 260 W m^{-2}. In contrast, the southeastern coastal regions had relatively lower values, at only about 100 W m^{-2}. This pattern reflects the dry and clear climate in western China and the higher cloud cover in eastern China. Further analysis of the effects of aerosols and clouds on SSR showed that CRE was negative as a whole. This was especially clear in South China and the middle and lower reaches of the Yangtze River, where values reached as low as −120 W m^{-2}. This indicates abundant cloud cover and a strong shielding effect on surface SSR in these regions. The overall negative ARE values were within −50 W m^{-2}. They were mainly found in North China and East China, showing that aerosols had a certain weakening effect on surface SSR. As shown in the figure, all-sky SSR gradually decreased from west to east across China. The spatial distributions of CRE and ARE also showed clear regional features. Together, they formed a pattern of clear skies and high radiation in northwestern China, and higher cloud cover with clear aerosol effects in eastern China.

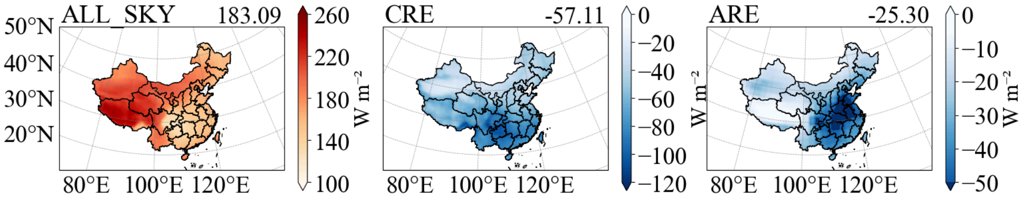

Figure 1. Annual mean SSR under all-sky conditions, cloud radiative effect (CRE), and aerosol radiative effect (ARE) from January 2001 to December 2025. The values in the upper-right corners represent area-weighted averages across China (W·m−2)

To better understand the changing features of SSR across mainland China, this work calculated the yearly trends of SSRALL_SKY. The results are presented in Figure 2. SSR showed obvious stage differences around 2013. It went up from 2003 to 2013, but turned to a downward trend from 2013 to 2022. Between 2001 and 2013, SSRALL_SKY had an upward trend with a yearly change rate of 0.221 W m^{-2} yr^{-1}. This means the surface received more solar radiation each year. In the same period, the yearly change rate of CRE was 0.382 W m^{-2} yr^{-1}. It shows that clouds blocked less surface radiation, so the ground got more solar energy. The yearly change rate of ARE was −0.163 W m^{-2} yr^{-1}. This tells us aerosols had a stronger blocking effect on surface radiation. In this stage, the rise of SSR mainly linked to changes in cloud radiative effects. From 2014 to 2025, SSRALL_SKY had a downward trend with a rate of −0.087 W m^{-2} yr^{-1}. This means the solar radiation reaching the surface slowly became weaker. In the same period, the yearly change rate of CRE was −0.160 W m^{-2} yr^{-1}. It shows clouds blocked more surface radiation. The yearly change rate of ARE was 0.106 W m^{-2} yr^{-1}. This means aerosols had a weaker blocking effect on surface radiation. In this stage, the drop of SSR was mainly affected by joint changes in clouds and aerosols. In general, SSR in China followed a "rise first, then fall" pattern from 2001 to 2025. The year around 2013 was a clear turning point. Clouds mainly influenced the early stage, and both aerosols and clouds affected the later stage.

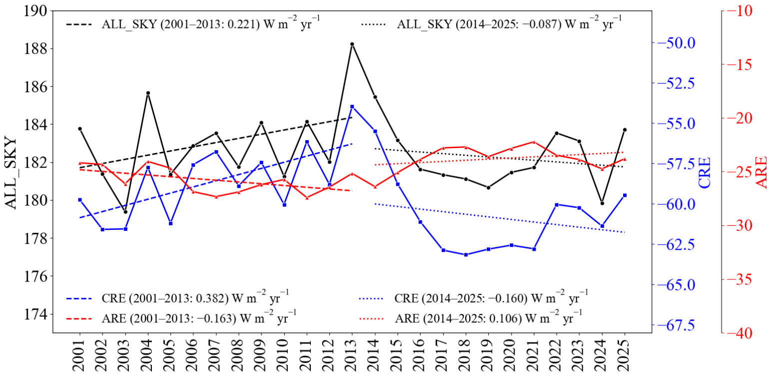

Figure 2. Interannual trends of SSR under all-sky conditions, CRE, and ARE from January 2001 to December 2025 in China

This work further looked at the spatial changing features and change rates of SSR in China across different periods. The results are shown in Figure 3. From 2001 to 2013, SSRALL_SKY generally had an upward trend in most parts of China, with an average change rate of about 0.10 W m^{-2} yr^{-1}. Meanwhile, CRE also rose in this period, at a rate of 0.52 W m^{-2} yr^{-1}. Its spatial pattern was mostly the same as the changes of SSRALL_SKY. The change range of ARE was small, at −0.13 W m^{-2} yr^{-1}, and it had little effect on SSRALL_SKY changes. The three factors had clear regional differences. The southeastern Qinghai–Tibet Plateau and southwestern China saw relatively large rises, with local values over 2 W m^{-2} yr^{-1}. These rises came from weaker cloud cooling effects on radiation, so more shortwave radiation reached the ground. But SSR changes in southern coastal areas and Taiwan were small, even with slight drops. This mainly happened because the cloud cooling effect became stronger. From 2014 to 2025, SSRALL_SKY generally showed a downward trend, with an average change rate of about −0.26 W m^{-2} yr^{-1}. The drop of CRE slowed down, at a rate of −0.08 W m^{-2} yr^{-1}, while ARE rose clearly at 0.20 W m^{-2} yr^{-1}. This means aerosols had a stronger effect on SSR in some areas. For spatial distribution, western Sichuan, southern Qinghai and southern Xinjiang had the most obvious drops in SSRALL_SKY. Local drops here were over −3 W m^{-2} yr^{-1}. These changes mainly resulted from a stronger cloud cooling effect, which weakened or reflected some shortwave radiation before it reached the surface. On the other hand, southern coastal areas and Taiwan had upward SSR trends, with local rises of about 0.2 W m^{-2} yr^{-1}. These changes linked mainly to weaker cooling effects of aerosols and clouds on radiation. In general, SSRALL_SKY changes in China had clear regional differences. Cloud and aerosol change rates varied by area, and their combined effects shaped the spatial changing features of SSRALL_SKY.

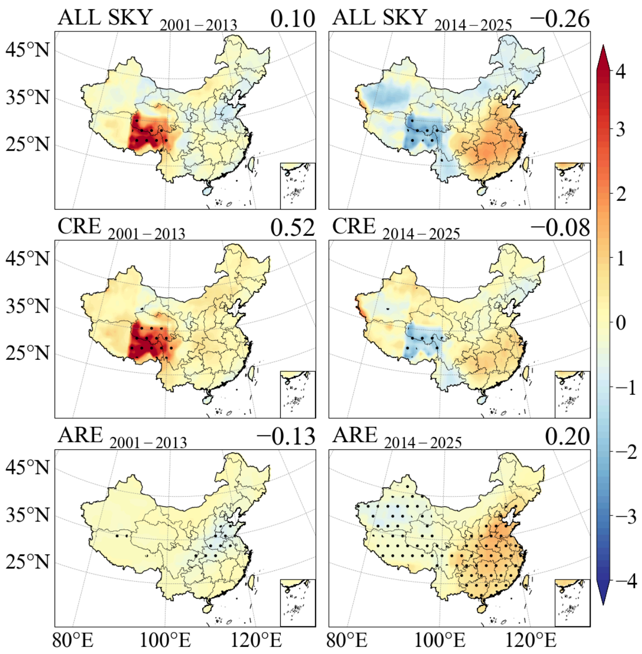

Figure 3. Spatial distribution of the temporal trends of SSR under all-sky conditions, CRE, and ARE during 2001–2013 and 2014–2025 across China

To examine the effects of clouds and aerosols on SSR variation, this study further calculated their relative contributions to SSR changes. The results are shown in Figure 4. The results show that the regional contributions of the two factors differed greatly during different periods. During 2001–2013, SSR in most regions of China was mainly influenced by clouds. The contribution rates exceeded 60%, making clouds the main factor affecting surface radiation changes. Clouds made large contributions in the Qinghai–Tibet Plateau, western Sichuan, Yunnan, and other southwestern regions, leading to significant increases in SSR. In the southern coastal regions, such as Guangdong and Guangxi, stronger cloud effects also caused decreases in SSR. During the same period, the contribution of aerosols to SSR variation was relatively small. It was lower than 30% in most regions, and only had slight suppressing or compensating effects on SSR variation in some local areas. During 2014–2025, the contribution of aerosols to SSR variation increased clearly. In East China, Central China, and the southern coastal regions, weaker aerosol effects led to increased SSR. The contribution rates in some regions reached 50% or even exceeded the influence of clouds. At the same time, stronger cloud effects in northwestern China, Qinghai, and western Sichuan further reduced SSR. Overall, with changes in aerosol emissions, the main factors controlling the spatial variation of SSR showed clear regional differences. After 2014, changes in surface shortwave radiation gradually became jointly regulated by both clouds and aerosols.

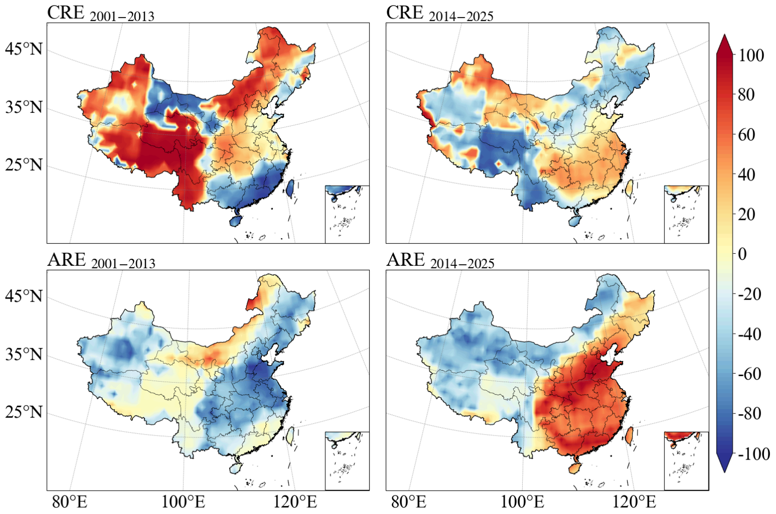

Figure 4. Relative contributions of clouds and aerosols to changes in SSR across China during 2001–2013 and 2014–2025

4.Conclusion

Using CERES-SYN satellite data, this work carried out a systematic analysis of the spatial and temporal changing features of surface shortwave radiation across China from 2001 to 2025. It also measured how much clouds and aerosols affect changes in this radiation. The findings indicate that surface shortwave radiation in China has obvious spatial and temporal differences, as well as changes in different stages. The highest levels of surface shortwave radiation appeared in the northwestern plateau areas and the Qinghai–Tibet Plateau, with average values over 260 W m^{-2}. But the southeastern coastal regions had the lowest levels, at only about 100 W m^{-2}. By looking at time series and spatial changing features, a clear turning point emerged around 2013. From 2001 to 2013, surface shortwave radiation mostly went up, with an average yearly rise rate of about 0.10 W m^{-2} yr^{-1}. In this stage, changes in surface shortwave radiation mainly linked to shifts in clouds. Clouds contributed over 70% in the northwestern plateau areas and the Qinghai–Tibet Plateau. Aerosols had a relatively weak influence, with values below 30% in most regions. From 2014 to 2025, surface shortwave radiation turned to a general downward trend, with an average yearly change rate of about −0.26 W m^{-2} yr^{-1}. Among these areas, surface shortwave radiation dropped more clearly in northwestern China, Qinghai and western Sichuan. These drops directly came from stronger cloud effects. On the other hand, surface shortwave radiation rose in eastern and southern coastal areas. At the same time, aerosols played a much bigger role, with local contribution levels reaching about 50%. In general, surface shortwave radiation in China shows obvious differences in different periods and areas. How clouds and aerosols control this radiation also varies a lot from area to area. These results offer clear data support for studying regional climate shifts and surface energy balance in China. They also have great practical value for evaluating and using solar energy resources.

References

[1] Stephens, G.L.; Li, J.; Wild, M.; Clayson, C.A.; Loeb, N.; Kato, S.; L'Ecuyer, T.; Stackhouse, P.W.; Lebsock, M.; Andrews, T. An Update on Earth's Energy Balance in Light of the Latest Global Observations. Nature Geosci 2012, 5, 691–696, doi: 10.1038/ngeo1580.

[2] Wild, M. The Global Energy Balance as Represented in CMIP6 Climate Models. Clim Dyn 2020, 55, 553–577, doi: 10.1007/s00382-020-05282-7.

[3] Wild, M.; Gilgen, H.; Roesch, A.; Ohmura, A.; Long, C.N.; Dutton, E.G.; Forgan, B.; Kallis, A.; Russak, V.; Tsvetkov, A. From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface. Science 2005, 308, 847–850, doi: 10.1126/science.1103215.

[4] Shi, H.; Zhang, J.; Zhao, B.; Xia, X.; Hu, B.; Chen, H.; Wei, J.; Liu, M.; Bian, Y.; Fu, D.; et al. Surface Brightening in Eastern and Central China Since the Implementation of the Clean Air Action in 2013: Causes and Implications. Geophys. Res. Lett. 2021, 48, e2020GL091105, doi: 10.1029/2020GL091105.

[5] Sun, H.; Zhi, Q.; Wang, Y.; Yao, Q.; Su, J. China's Solar Photovoltaic Industry Development: The Status Quo, Problems and Approaches. Applied Energy 2014, 118, 221–230, doi: 10.1016/j.apenergy.2013.12.032.

[6] Wang, Q. Y. (2023). Assessment of land surface radiation budget over East Asia and its influencing factors (Doctoral dissertation, Nanjing University of Information Science and Technology).

[7] Wild, M.; Folini, D.; Schär, C.; Loeb, N.; Dutton, E.G.; König-Langlo, G. The Global Energy Balance from a Surface Perspective. Clim Dyn 2013, 40, 3107–3134, doi: 10.1007/s00382-012-1569-8.

[8] Charlson, R.J.; Schwartz, S.E.; Hales, J.M.; Cess, R.D.; Coakley, J.A.; Hansen, J.E.; Hofmann, D.J. Climate Forcing by Anthropogenic Aerosols. Science 1992, 255, 423–430, doi: 10.1126/science.255.5043.423.

[9] Charlson, R.J.; Langner, J.; Rodhe, H.; Leovy, C.B.; Warren, S.G. Perturbation of the Northern Hemisphere Radiative Balance by Backscattering from Anthropogenic Sulfate Aerosols. Tellus A 1991, 43, 152–163, doi: 10.1034/j.1600-0870.1991.00013.x.

[10] Satheesh, S.K.; Ramanathan, V. Large Differences in Tropical Aerosol Forcing at the Top of the Atmosphere and Earth's Surface. Nature 2000, 405, 60–63, doi: 10.1038/35011039.

[11] Hansen, J.; Sato, M.; Ruedy, R. Radiative Forcing and Climate Response. J. Geophys. Res. 1997, 102, 6831–6864, doi: 10.1029/96JD03436.

[12] Twomey, S. The Influence of Pollution on the Shortwave Albedo of Clouds. J. Atmos. Sci. 1977, 34, 1149–1152, doi: 10.1175/1520-0469(1977)034%3C1149: TIOPOT%3E2.0.CO; 2.

[13] Ramanathan, V.; Cess, R.D.; Harrison, E.F.; Minnis, P.; Barkstrom, B.R. Cloud-Radiative Forcing and Climate: Results from the Earth Radiation Budget Experiment. Science 1989, 243, 57–63.

[14] Wang, W.-C.; Rossow, W.B.; Yao, M.-S.; Wolfson, M. Climate Sensitivity of a One-Dimensional Radiative-Convective Model with Cloud Feedback. J. Atmos. Sci. 1981, 38, 1167–1178, doi: 10.1175/1520-0469(1981)038%3C1167: CSOAOD%3E2.0.CO; 2.

[15] Wang, Q.; Zhang, H.; Yang, S.; Chen, Q.; Zhou, X.; Shi, G.; Cheng, Y.; Wild, M. Potential Driving Factors on Surface Solar Radiation Trends over China in Recent Years. Remote Sensing 2021, 13, 704, doi: 10.3390/rs13040704.

[16] Che, H.Z.; Shi, G.Y.; Zhang, X.Y.; Arimoto, R.; Zhao, J.Q.; Xu, L.; Wang, B.; Chen, Z.H. Analysis of 40 Years of Solar Radiation Data from China, 1961–2000. Geophysical Research Letters 2005, 32, 2004GL022322, doi: 10.1029/2004GL022322.

[17] Shi, G.-Y.; Hayasaka, T.; Ohmura, A.; Chen, Z.-H.; Wang, B.; Zhao, J.-Q.; Che, H.-Z.; Xu, L. Data Quality Assessment and the Long-Term Trend of Ground Solar Radiation in China. Journal of Applied Meteorology and Climatology 2008, 47, 1006–1016, doi: 10.1175/2007JAMC1493.1.

[18] Wang, Y.; Wild, M. A New Look at Solar Dimming and Brightening in China. Geophysical Research Letters 2016, 43, 11, 777-11, 785, doi: 10.1002/2016GL071009.

[19] He, Y.; Wang, K.; Zhou, C.; Wild, M. A Revisit of Global Dimming and Brightening Based on the Sunshine Duration. Geophysical Research Letters 2018, 45, 4281–4289, doi: 10.1029/2018GL077424.

[20] Tang, W.-J.; Yang, K.; Qin, J.; Cheng, C.C.K.; He, J. Solar Radiation Trend across China in Recent Decades: A Revisit with Quality-Controlled Data. Atmos. Chem. Phys. 2011, 11, 393–406, doi: 10.5194/acp-11-393-2011.

[21] Yang, S.; Wang, X.L.; Wild, M. Causes of Dimming and Brightening in China Inferred from Homogenized Daily Clear-Sky and All-Sky in Situ Surface Solar Radiation Records (1958–2016). Journal of Climate 2019, 32, 5901–5913, doi: 10.1175/JCLI-D-18-0666.1.

[22] Yang, S.; Wang, X.L. Homogenization and Trend Analysis of the 1958–2016 In Situ Surface Solar Radiation Records in China. Journal of Climate 2018, 31, 4529–4541, doi: 10.1175/JCLI-D-17-0891.1.

[23] Liang, F.; Xia, X.A. Long-Term Trends in Solar Radiation and the Associated Climatic Factors over China for 1961-2000. Ann. Geophys. 2005, 23, 2425–2432, doi: 10.5194/angeo-23-2425-2005.

[24] You, Q.; Sanchez-Lorenzo, A.; Wild, M.; Folini, D.; Fraedrich, K.; Ren, G.; Kang, S. Decadal Variation of Surface Solar Radiation in the Tibetan Plateau from Observations, Reanalysis and Model Simulations. Clim Dyn 2013, 40, 2073–2086, doi: 10.1007/s00382-012-1383-3.

[25] Wang, Y.; Yang, Y.; Han, S.; Wang, Q.; Zhang, J. Sunshine Dimming and Brightening in Chinese Cities (1955-2011) Was Driven by Air Pollution Rather than Clouds. Clim. Res. 2013, 56, 11–20, doi: 10.3354/cr01139.

[26] Li, J.; Jiang, Y.; Xia, X.; Hu, Y. Increase of Surface Solar Irradiance across East China Related to Changes in Aerosol Properties during the Past Decade. Environ. Res. Lett. 2018, 13, 034006, doi: 10.1088/1748-9326/aaa35a.
[27] Schwarz, M.; Folini, D.; Yang, S.; Allan, R.P.; Wild, M. Changes in Atmospheric Shortwave Absorption as Important Driver of Dimming and Brightening. Nat. Geosci. 2020, 13, 110–115, doi: 10.1038/s41561-019-0528-y.
[28] Norris, J.R.; Wild, M. Trends in Aerosol Radiative Effects over China and Japan Inferred from Observed Cloud Cover, Solar "Dimming, " and Solar "Brightening." J. Geophys. Res. 2009, 114, 2008JD011378, doi: 10.1029/2008JD011378.
[29] Wang, G.; Wang, T.; Xue, H. Validation and Comparison of Surface Shortwave and Longwave Radiation Products over the Three Poles. International Journal of Applied Earth Observation and Geoinformation 2021, 104, 102538, doi: 10.1016/j.jag.2021.102538.
[30] Rutan, D.A.; Kato, S.; Doelling, D.R.; Rose, F.G.; Nguyen, L.T.; Caldwell, T.E.; Loeb, N.G. CERES Synoptic Product: Methodology and Validation of Surface Radiant Flux. Journal of Atmospheric and Oceanic Technology 2015, 32, 1121–1143, doi: 10.1175/JTECH-D-14-00165.1.