Response to Referee #2

First High-Resolution Surface Spectral Clear-Sky Ultraviolet Radiation Dataset across China (1981–2023): Development, Validation, and Variability

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Dear editor and reviewers,

We would like to thank the editor for handling our manuscript and the reviewers for their careful evaluation of our work and the valuable comments, suggestions, and questions. Our point by point response to the comments made by Reviewers are given below, we have also marked changes in the manuscript. Please find a detailed point-by-point response to each comment.

Yours sincerely,
Wenmin Qin, Qinghai Qi and co-authors

General Comment:

This study presents a 10 km high-resolution hourly surface solar ultraviolet (UV) radiation dataset under clear-sky conditions across mainland China from 1981 to 2023. The dataset is reconstructed using the SMARTS spectral model based on ERA5 and MERRA2 reanalysis data. To validate its performance, the authors conduct comprehensive statistical comparisons with the CERES UV product, demonstrating clear advantages in terms of spatial-temporal resolution and data quality. Using this dataset, the study further analyzes the spatial distribution characteristics of clear-sky UV radiation intensity over China at multiple temporal scales, including hourly, daily, and annual means. It also discusses possible reasons for poor fitting at specific stations, as well as the seasonal and interdecadal variations in UV radiation. The results fill a data gap by providing a high-resolution, long-term, and hourly UV radiation dataset for China, which holds value for future studies on the effects of UV radiation on human health and the natural environment. The manuscript is generally well-organized, and the methods are rigorous and sound. My comments are as follows:

Response:

We sincerely thank the reviewer for raising this critical point regarding the representation of aerosols, which has significantly helped us improve the manuscript. We have fully addressed the comment through clarifications in the methodology, an expanded discussion, and the inclusion of relevant literature.

Major Comments:

(1) *The validation of this dataset relies on 37 stations, which are unevenly distributed*

and heavily biased toward inland areas. In contrast, coastal regions—where ultraviolet (UV) radiation interacts with ocean-atmosphere processes (e.g., sea salt aerosols, high humidity, and differences in surface albedo between land and ocean)—are severely underrepresented in the validation network. This introduces uncertainties regarding the dataset's accuracy in coastal regions, which are crucial for both terrestrial and marine-related applications. If available, the validation dataset should be expanded to incorporate UV observation data from coastal meteorological stations or marine research platforms. Additionally, a sensitivity analysis should be conducted targeting coastal-specific parameters.

Response:

We are grateful to the reviewer for this insightful comment regarding the importance of coastal regions.

Regarding the limitation to inland areas, we would like to provide the following clarification for the reviewer's consideration. Our dataset is derived from the ERA5 reanalysis product (at 0.25°×0.25° and 0.1°×0.1° resolution). A specific technical challenge we encountered was that, at these resolutions, the ERA5-Land product resulted in data gaps precisely at the locations of the three critical coastal CERN sites we had initially intended to include. This precluded their use in our current validation and analysis.

We fully agree with the reviewer that the absence of these coastal sites is a significant limitation, as it omits a key region for studying aerosol-cloud-radiation interactions. Specifically, section 3.1 now explicitly states: "*The spatial coverage of this product is constrained by the continuous availability of ERA5 reanalysis data, resulting in the exclusion of certain coastal observation stations at CERN.*" Consequently, the Discussion section acknowledges that while the findings are reliable for inland regions, the model's performance in coastal environments remains an important topic for future research.

(2) *The manuscript identifies aerosol optical depth (AOD), total column ozone (TCO3), and forecast albedo (FAL) as key drivers of UV radiation (Section 4.3), but not account for the modulation of these drivers by ocean-atmosphere feedback processes in coastal regions. In Sections 2.2 and 3.2, it is necessary to clarify whether the MERRA-2 AOD data include sea salt aerosol components, or if terrestrial AOD data are used for coastal grids. If sea salt aerosols are not explicitly modeled, the limitation should be discussed, and adjustments for future research should be proposed. Finally, it is recommended to cite relevant literature on ocean-atmosphere interactions and UV radiation to strengthen the scientific basis.*

Response:

We thank the reviewer for raising this critical point regarding aerosol speciation in MERRA2 and its implications for coastal regions. The AOD from MERRA-2 used in our study is indeed a sum of contributions from multiple aerosol species, including sulfate, organic carbon, black carbon, dust, and sea salt. For the radiative transfer modeling with SMARTS, and considering our primary focus on continental regions, we explicitly selected the built-in "Continental" aerosol model as the input. This model is

representative of typical inland atmospheric conditions but does not explicitly separate sea salt aerosols.

We fully acknowledge that this approach is a limitation when our analysis indirectly involves coastal grids or marine air masses advecting inland. In the revised manuscript, we have added a paragraph in the section 4.3 to explicitly state this limitation. "*A key limitation in this study arises from the selection of the aerosol model in the SMARTS radiative transfer simulations. To maintain consistency with the continental focus of our work, the built-in "Continental" aerosol model was employed. While this model is representative of typical inland aerosol species such as sulfates, nitrates, black carbon, and dust, it does not include an explicit parameterization for sea salt aerosols. This discrepancy could introduce systematic biases in simulated UV radiation in coastal regions and inland areas subject to marine air mass advection, as sea salt aerosols differ significantly from continental types in their size distribution, and scattering efficiency (Zhu et al., 2022; Kouvarakis et al., 2002; Chatzopoulou et al., 2025). Future research should aim to integrate a more sophisticated hybrid or maritime aerosol model and couple it with higher-resolution aerosol reanalysis or observational data to better constrain the aerosol-type dependence and improve the accuracy of UV estimates in complex coastal-continental transition zones.*"

Zhu, L., Shu, S., Wang, Z., and Bi, L.: More or less: How do inhomogeneous sea-salt aerosols affect the precipitation of landfalling tropical cyclones? Geophysical Research Letters, 49, e2021GL097023. https://doi.org/10.1029/2021GL097023, 2022.

Kouvarakis, G., Y. Doukelis, N. Mihalopoulos, S. Rapsomanikis, J. Sciare, and M. Blumthaler: Chemical, physical, and optical characterization of aerosols during PAUR II experiment, J. Geophys. Res., 107(D18), 8141, doi:10.1029/2000JD000291, 2002.

Chatzopoulou, K., Tourpali K., Bais A. F., and Braesicke, P.: Effects of different aerosol types on surface UV radiation in the 21st century. Atmos. Environ. 362, 121595,https://doi.org/10.1029/2000JD000291, 2002.

Minor comments:

(1) *The term "Methodologys" should be corrected to "Methodology"?*

Response:

Thank you for pointing out the issue. We have made the suggested changes.

(2) *Line 209: The phrase "compared with 196,170 observed data points from 37 CERN…" is unclear. A clearer expression could be: "Out of the 196 original observed data points from 37 CERN during 2005–2013, 170 were selected after applying …"*

Response:

Thank you for your suggestions for improvement. Modifications have been made as suggested.

(3) *Line 245 and elsewhere: Ensure that all subplot borders are clearly visible and consistent in line width throughout the figures.*

Response:

We would like to express our gratitude for highlighting the deficiencies in the manuscript's figure. The aforementioned documents have undergone a thorough revision process in accordance with the specified request.

(4) *Line 325: The color differences among the lines in Figure 8 are not sufficiently distinguishable; please enhance the contrast or adjust the color scheme for clarity.*

Response:

Thank you for pointing out the shortcomings in the diagrams. In Figure 8, we have adopted a completely new color scheme to convey the information more clearly.

(5) *Line 362: In Figure 10(a), only the top layer is clearly visible, while the lower layers are largely obscured. As a result, this subplot may not be very informative. The similar Figure A1 in the appendix presents the information more effectively.*

Response:

Thank you for your valuable queries. Figure 10(a) primarily displays the SMARTS model`s band-by-band results at 0.5 nm resolution across the 280-400nm wavelength range. Figure A1 presents results for specific bands, serving a different purpose. Given the 241 bands, displaying each individually would be impractical.

(6) *Ensure that all energy flux units are uniformly expressed as "W m⁻²".*

Response:

As suggested, the unit of solar radiation is unified as "$W\ m^{-2}$". We have reviewed the entire manuscript and standardized the units.

(7) *Add the definition of FAL (Forecast Albedo) and explicitly state whether it is land-focused.*

Response:

As indicated in the ERA5 product description: Forecast albedo is measure of the reflectivity of the Earth`s surface. It is the fraction of solar (shortwave) radiation reflected by Earth`s surface, across the solar spectrum, for both direct and diffuse radiation. Meanwhile, based on the actual implementation of the "**ERA5-Land hourly data from 1950 to present"** product, values over ocean and lake surfaces are uniformly replaced with NAN values. In summary, we consider this product is land-focused.

The following content has now been added to Section 3.2: "*The forecast albedo (FAL) from the ERA5-Land product is a land-specific parameter, as its values over ocean and lake surfaces are systematically set to NAN, making it suitable for continental-scale analysis.*"

(8) *Provide a table to summarize the characteristics of the validation stations, including latitude, longitude, elevation, and climatic conditions.*

Response:

Thank you for your suggestion. We have provided all the CERN site information tables used in Section 3.1.