

## **Response to Reviewer #1's Comments:**

Ruixue Li et al. (Author)

**We are very grateful for the Reviewer #1' detailed comments and suggestions, which help us improve this paper significantly. Based on the comments and suggestions from reviewer, we reorganize the abstract, introduction, datasets and methods, results and conclusion sections to highlight the innovations, key points of this study and improve coherence between sections. In addition, we add some interpretations and delete some superfluous information in each section in order to make the manuscript clearer.**

### **Important revision includes:**

- (1) Section 1, Introduction, is rewritten to enhance clarity regarding the significance and innovations of the manuscript. Superfluous information is removed, and specifically, we highlight the reasons for studying the changes in reflected solar radiation (RSR) at finer spatiotemporal scales and the importance of assessing the applicability of different radiation datasets with longer record in hemispheric symmetry studies. More details are described in Line 65-138. The abstract is also further reorganized to summarize the main findings of this paper.
- (2) In Section 2, Datasets and Methodology, we update the CERES data to the latest version (CERES-EBAF 4.2) and correct some bugs in the data processing, and revise the corresponding descriptions.
- (3) We agree the reviewer's comments. In Section 3.1, we acknowledge that there is a little bit overlap between Fig. 1 and previous studies. However, the focus of this section is on analyzing changes in RSR and its components at the latitude and monthly scales. We have reorganized Section 3.1 and added an expanded discussion on hemispheric RSR trends, highlighting the contributions of finer spatiotemporal scales to these trends. Additionally, we have analyzed the changes in the contribution rates of different components to the RSR.
- (4) The content discussing the contribution of different factors to latitudinal zones in extreme years (Section 3.2) is removed. The adjustment allows us to maintain a more focused and streamlined discussion, centering on the primary objectives and findings of the study.
- (5) We substantially expand the original Section 3.3 (now revised as Section 3.2) to systematically quantify the performance of four radiation datasets in reproducing hemispheric differences and symmetry

of RSR observed by CERES at hemispheric and finer temporal-spatial scales. This expansion ensures a smoother and tighter connection with Section 3.1.

(6) In the Section 4, Discussion and Summary, we revise the main conclusions of this study and delete some superfluous information.

(7) In each section, we also add some interpretations about the comments from reviewers.

**Please see our point-by-point reply to comments. All revisions are shown in revised manuscript by using track changes.**

**General responses:**

1. The authors cite large amounts of published studies on hemispherical albedo symmetry. The authors analyze southern and northern hemispheres' surface and atmosphere contributions. However, the result of the zonal analysis is mainly that higher land albedo in the northern hemisphere present in the mid-latitude is compensated by clouds over southern ocean, which was pointed out in earlier studies (e.g. Stephens et al. 2015). Hemispherical albedo trends were analyzed by Datseries and Stevens (2021). Therefore, most of their results are reproduction of the results of earlier studies. Among three main results discussed in the discussion and summary session, only 3), which is the result of the comparison of different products, might be new. But the result is not essential in understanding the hemispherical albedo symmetry. In addition, as far as I know, AVHRR and ISCCP data products were not used in analyzing hemispherical albedo symmetry in earlier studies. Therefore, the motivation of the comparison is not clear. New knowledge added by this study is not significant enough to worth publication. However, because the extensive coverage of earlier studies, there might be a path forward. Because of the good coverage of earlier studies on this subject, I suggest converting this manuscript to a review paper.

**Response:** We agree with the reviewer and are very appreciated for reviewer providing such helpful comments and suggestions. Indeed, our research results exhibit consistency and similarity with previous studies. In fact, the aim of this study is to interpret the characteristics of variations in hemispheric planetary albedo at finer temporal and spatial scales, thereby providing support for the investigation of hemispheric symmetry mechanisms. Additionally, we aim to systematically evaluate the applicability of existing long-term radiation data in hemispheric symmetry studies. We

acknowledge the reviewers' concern regarding the lack of emphasis on the manuscript's highlights, potentially causing confusion about its novelty. Following the suggestion from reviewer, therefore, we reorganize the manuscript, remove redundant content, and focus on addressing two key issues: (1) the characteristics of hemispheric reflected solar radiation variations at different latitudes and months, and (2) the ability of four datasets to accurately reproduce hemispheric differences and symmetry of reflected solar radiation observed by CERES.

### **Specific Responses:**

1. Line 69-70 The location of ITCZ shifting with season is known before 2007.

**Response:** Thanks for your comment! Indeed, as early as 1993, Waliser and Gautier (1993) systematically investigated seasonal variations in the intensity and location of the ITCZ. Hu et al. (2007) further noted that the seasonal shift in the global average ITCZ is not smooth, but jumps from the winter hemisphere to the summer hemisphere. The relevant reference is added in the revised manuscript: “For example, the Intertropical Convergence Zone (ITCZ) plays an important role in regulating cloudiness in the 10°S-10°N region, with its location and intensity varying seasonally (Waliser and Gautier, 1993; Hu et al., 2007).”

Please see the Line: 69-71.

2. Line 70-71 There are many places that sentences are either awkward or do not make sense. In addition to this sentence, the sentence on line 84-85, line 290 “contribution rate”, line 294 “molecular part of Eq. (14), line 360 (10a)-1 awkward units, for example.

**Response:** We very thank reviewer for providing detailed comments and suggestions. We have carefully reviewed the manuscript and made the necessary revisions to address the issues you raised. Specifically, we have rephrased these sentences in the revised manuscript.

Please see the Line: 73-76, 96-98, 296, 299-301, 357.

3. Line 80 the authors used “oblique pressure activity” several places in the manuscript. I think what they mean is mid-latitude baroclinic low pressure systems or synoptic systems, but I am not sure.

**Response:** We are sorry to confuse the reviewer by the term “oblique pressure activity”. It includes the mid-latitude baroclinic synoptic systems. For clarity, we correct the term and statement in the

revised manuscript: “In addition, recent studies have emphasized the impact of the distinct land-sea distribution between hemispheres, which leads to enhanced baroclinic activities at mid-latitudes in the SH, resulting in an increase in baroclinic synoptic systems (Hadas et al., 2023).”

Please see the Line: 82-85.

4. Line 88-90. If the authors are telling that aerosols increase deep convective clouds, could you cite papers?

**Response:** Thanks for your comments. Both model simulations (Wang et al., 2014) and satellite observations (Zhang et al., 2007) have pointed out that aerosols, as cloud condensation nuclei, act on the microphysics and dynamics of deep convective clouds, altering the cloud structure, elevating the cloud top heights, and inducing the development of deep convective clouds. The relevant references are added in the revised manuscript: “This, in turn, increases the amount of deep convective clouds due to the indirect effects of aerosols (Zhang et al., 2007; Wang et al., 2014). The increased deep convective clouds can strengthen the storm track in the Pacific Ocean and increase the contribution of the cloud component (Wang et al., 2014).”

Please see the Line: 101-103.

5. Line 97-98. I do not think that available data limit studying hemispherical albedo symmetry. The authors might mean studying how the symmetry changes with time?

**Response:** We are sorry that our expression has caused confusion to the reviewer. Yes, it means the available data limit the study of hemispherical albedo symmetry changes with time. In the revised manuscript, we correct the inappropriate statements: “However, the CERES observational record is relatively limited (2000-present), we cannot determine how hemispheric symmetry changes over time.” (See the Line: 117-118).

6. Line 139 Why do the authors mention filtered radiance here?

**Response:** We are sorry to mislead the reviewer. Filtered radiation is mentioned here to explain the process of generating monthly regional TOA radiative fluxes from the original CERES measurements. We correct the inappropriate statements in the revised manuscript: “The radiance received by the CERES instrument is first converted from digital counts to calibrated "filtered"

radiances. This is then converted to unfiltered radiances to correct for imperfections in the spectral response of the instrument (Loeb et al., 2001), and then transformed into TOA instantaneous radiative fluxes using an empirical angular distribution model (Su et al., 2015). Instantaneous fluxes are converted to daily-averaged fluxes using sun-angle dependent diurnal albedo models (Loeb et al., 2018).”

Please see the Line: 160-165.

7. Section 2.2.1 is largely the reproduction of earlier study.

**Response:** Thanks for your comments. In section 2.2.1, we have adopted the planetary albedo decomposition method proposed by Stephens et al. (2015) and therefore most of the formulas are derived from previous research. We retained this section for the purpose of enhancing clarity and providing a comprehensive understanding for the readers. This decision allows readers to understand the method more effectively within the context of our study.

8. Equation (12) Weighting by clear and cloud fraction is missing in the equation.

**Response:** Thanks for your comments. The cloud contribution  $F_{\text{cloud}}^{\uparrow}$  in Equation (12) is the difference between the all-sky atmospheric contribution  $F_{\text{atm}}^{\uparrow}$  and the clear-sky atmospheric contribution  $F_{\text{atm,clear}}^{\uparrow}$  (see equation (13)). Its definition is similar to the shortwave radiative effect of clouds, and thus not need to be weighted by clear and cloud fractions.

9. Equation (14) area weighted mean is probably sufficient instead of introducing the equation.

**Response:** Thanks for your suggestion. In the revised manuscript, we replaced the regional weighted average method with the geodetic weighting method as recommended by the CERES website. This updated approach takes the Earth's oblate spheroid shape into account. Consequently, we have maintained these formulas and adjusted their introduction accordingly. The following is the revised text:

“In calculating regional averages radiative flux, the study employs a geodesic weighting method consistent with the official CERES product. This method assumes Earth’s oblate spheroid shape and takes into account the annual cycle of the Earth's declination angle and the sun-Earth distance (details about the method can be found in the website:

“[https://ceres.larc.nasa.gov/documents/GZWdata/zone\\_weights.f](https://ceres.larc.nasa.gov/documents/GZWdata/zone_weights.f)”). The regional averaged TOA RSR  $F_k$  is spatially aggregated using the following calculation formula:

$$F_k = \frac{\sum_{i=1}^{N_k} W_{ki} \cdot F_{ki}}{\sum_{i=1}^{N_k} W_{ki}} \quad (14)$$

Here,  $N_k$  is the number of grid samples in region k, and  $F_{ki}$  is the RSR flux corresponding to grid i in the region k. Moreover,  $W_{ki}$  is the geodetic zonal weight for the grid i, which can be obtained from “[https://ceres.larc.nasa.gov/documents/GZWdata/zone\\_weights\\_lou.txt](https://ceres.larc.nasa.gov/documents/GZWdata/zone_weights_lou.txt)”. Regional averages for other variables are calculated according to the similar weighting equation.”

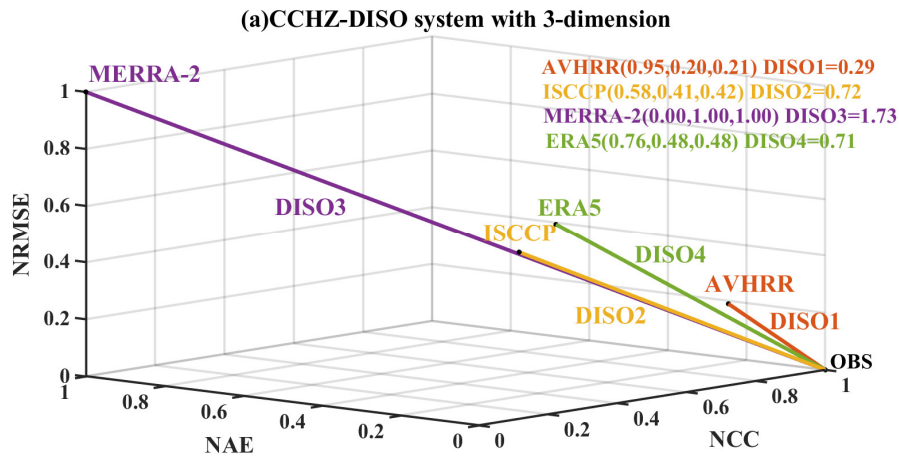
Please see Line 283-293 for more details.

10. Equation (20). Generally, we do not put variables with different units in an equation. Correlation coefficient is a non-dimensional number while mean and RMS have units.

**Response:** We very thank reviewer for providing detailed comments and suggestions. in the revised manuscript, the metrics (CC, AE, RMSE) are normalized to non-dimensional metrics (NCC, NAE, NRMSE), which are between 0 and 1, using the normalization formula following Chen et al. (2024) as:

$$NS_a = \frac{S_a - \min(S)}{\max(S) - \min(S)} \quad (20)$$

Where S indicates the metric (CC, AE, and RMSE). Here, a=0, 1, ..., m, “0” indicates the observed data, and m is the total number of model data used for comparison. Please note that Eq. (20) is a newly added equation in revised manuscript, and the Eq. (20) in the original manuscript is now renumbered as Eq. (21). After correcting this statistical error, we redraw the Fig. 5 in Section 3.2 in the revised manuscript (see the Fig. R1). The Fig. R1 (same as the Fig. 5a in the revised manuscript) indicates that the performance of ERA5 is better than the ISCCP in reproducing CERES observed hemispheric difference (NH-SH) of total RSR compared with our previous results. Please see Line 333-338 and 616-636 for more details.



**Figure R1 (same as the Fig. 5a in the revised manuscript):** CCHZ-DISO system with 3-dimension for hemispheric difference of annual-average total RSR between NH and SH. The coordinate axis consists of three statistical indicators, normalized correlation coefficient (NCC) for x-axis, normalized absolute error (NAE) for y-axis, and normalized root mean square error (NRMSE) for z-axis. OBS indicates observations, here referred to as CERES EBAF.

11. Figures are generally too small to see the details.

**Response:** Thanks for your comments. We have enlarged the text in all figures in the revised manuscript.

**Reference:**

Chen, F., Wang, D., Zhang, Y., Zhou, Y., and Chen, C.: Intercomparisons and Evaluations of Satellite-Derived Arctic Sea Ice Thickness Products, *Remote Sensing*, 16, 508, <https://doi.org/10.3390/rs16030508>, 2024.

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