Overall comments

Ma et al. proposed a RHtest-quantile approach to harmonize the observed and SunDu-derived incident solar radiation. This topic is important, and the Harmonized multi-source solar radiation data is valuable for the study of local dimming and brightening and multiple ecology processes. However, there are many major issues should be addressed. I have some comments that I hope can help improve manuscript quality.

Major comment

1. Quantitative accuracy and uncertainty of the harmonized dataset are missing. Please show more metrics or evidence to present the accuracy and uncertainty of the proposed dataset. This is very important for users. Because the author harmonized the observed and SunDu-derived solar radiation simultaneously, so it's less convincing to use the comparison results of these two datasets before and after homogenization showing the feasibility and validity of the proposed approach. In addition, the figure showing comparison results (Figure. 4) needs to be improved because it's not easy to see the improvement of the close relationship between observed and SunDu-derived solar radiation after the homogenization.

   Response: Thanks for the reviewer's comments and we highly appreciate these constructive comments. In the revised paper, we rewrote the Introduction part and reviewed more on the homogenization methods. In Section 2.2, more

details in how to use the RHtest method to homogenize the raw R_s observations were added. Compared to the simple method proposed by Katsuyama (1987), RHtest method provides more options for us to check the changepoints in the raw data series. We added three new figures (Figs. 4-6) to demonstrate the differences between observed R_s and SunDu-derived R_s after homogenization generally become smaller than those before homogenization. Furthermore, exploring the relationship between R_s and other independent variables such as clouds and aerosols provides an alternative way to determine whether the variation in R_s is reasonable. Based on this independent validation, uncertainties in homogenized series are explored and homogenized SunDu-derived R_s are proved to be more reliable in depicting the evolution of R_s. Finally, we highlight the differences of trends of R_s over Japan before and after homogenization.

2. The methodology should be clarified clearer with more details. It's very difficult to follow the methodology part, especially how to find the inhomogeneity between the observed and SunDu-derived solar radiation and use the approach to adjust the dataset. It seems that the abstract section shows much more details on this harmonization than the methodology section. Please give more details in the methodology section.

   Response: According to the reviewer's comment, we added more information in the Method Section 2.2 in Lines 174-206 for better understanding RHtest.

3. The independent homogenization method proposed by Katsuyama was used to harmonize the SunDu-derived solar radiation to valid the accuracy of the proposed approach. I think Katsuyama's approach (Eqs. 2-3 is very simple and efficient), why not directly use this approach to harmonize this solar radiation? Please clarify it.

   Response: We agree with the reviewer's comment that the homogenization method proposed by Katsuyama is very simple and efficient. However, the RHtest method provides more options for us to check the changepoints in the raw data series. We add Lines 216-223 to address this issue.

4. For the data implications, it's better to give some examples to show the necessity of data harmonization for soar radiation for practical applications. For example, you can compare the trends of solar radiation before and after harmonization to show whether there are any significant improvements in the trend analysis.

   Response: Thanks for the reviewer's constructive comment. Follow this suggestion, we emphasized this issue in Introduction Section in Lines 142-145, Results in Section 3 in Lines 274-276 and Lines 359-372, Conclusions in Section 5 in Lines 421-423 and Lines 434-442.

Specific comment

(1) L66-70, it's strange to shift the replacement of thermopile pyranometers in Japan to the instrument replacements-induced inhomogeneity in China.

Response: We rewrote the Introduction Section, and these sentences are reorganized. We first review the replacements issue in China, Italy, United States and central Europe, and then introduce the replacement of instruments in surface incident solar radiation observations happened in Japan. Details are in Lines 54-70 and Lines 106-118.

(2) L171, what's the meaning of grid?

Response: We rewrote the Equation (4):

$$CCRE'(lat, lon, y, m) = CC'(lat, lon, y, m) \times CRE(g, m)/\overline{CC}(g, m) \quad (4)$$

Where (lat, lon) instead of grid are used to demonstrate the geographical information.

(3) L172, what's the meaning of long-term mean cloud cover?

Response: We rewrote this sentence in Lines 239-240: $\overline{CC}$ is the climatology of cloud cover in 12 months.

(4) L187-189, why not directly use the monthly data for comparison?

Response: We added an explanation in Data Processing Section in Lines 262-264:

As the brightening and dimming over Japan were the main concern in this study, monthly values were converted into annual values for calculation.

(5) L190, it's quite difficult to find the following results from Figure 4. Please refine this figure to show the key message clearer.

Response: We added Figures 4-6 in the revised paper for better understanding the major improvements after homogenization in Lines 278-289. Details can be see the response to the first major comment in this document.

(6) L198-200, rewrite this sentence, please present the key message clearer. For example, the improved patterns of time series of surface incident solar radiation after homogenization highlight the necessity and feasibility…

Response: We corrected this sentence according to reviewer's comment in Lines 293-295.

(7) L204-208, remove this paragraph, it's not consistent with the sub-title

Response: We moved this paragraph to the Section 2.3, which is closely related with clouds.

(8) L207, with the previous results (i.e. Figure 4 in Tsutsumi and Murakami, 2012)

Response: We corrected it in Lines 254-256: The regional average cloud amount over Japan in Figure 10 (blue line) increases at a rate of 0.7% per decade from 1960 to 2015,

which is consistent with the previous results (Figure 4 in Tsutsumi and Murakami (2012)).

General comments

This study presents first homogenized century long datasets of observed surface incident solar radiation and sunshine duration derived solar radiation over Japan. After homogenization, the two independent estimates of surface solar radiation are more consistent in trends, which is also consistent with our expectation from clouds and dust storm. The reviewer recommends this great effort, which provides key datasets to understand regional climate change. It is also useful for studies for energy and water cycle, and ecological process.

Major comment

1. I have some major comments to help the authors to improve their presentation. A more comprehensive literature review is needed. Most cited articles are several years ago. This field is fast developed, the authors should add more recent publications and provide more critical literature review.

   Response: Thanks for the reviewer's encouragement. This study was revised fully considering these comments. We rewrote the Introduction Part and added more recent publications. We also provided more critical literature review on the global dimming and brightening studies and homogenization procedures in Lines 47-151.

2. The homogenization process should be more clearly presented, which is essential for authors to understand the derived dataset.

   Response: According to the reviewer's comment, we rewrote RHtest homogenization method part in Section 2.1 in Lines 174-206 for better understanding.

Specific comment

(1) Line 34-35: the specific definition of a sharp decrease and a gradual decline.

Response: We rewrote this sentence in Lines 34-37 in the revised paper.

(2) Line 99: suggest to review all the relative homogenization methods and point out the reason to use RH method.

Response: According to this comment, we added a literature review on homogenization methods and pointed out the reason to use RHtest method in Lines 125-141 in the revised paper.

(3) Line 121-122: misleading sentence—"before 1990" may be replaced by "until 1990" or "since 1990"?

Response: Corrected it as suggested.

(4) Line 129-130: the variables should be italic.

Response: Corrected it as suggested.

(5) Line 145: confirm the reference format. Generally, it should be author (date) format.

Response: Corrected it as suggested.

(6) Line 150: the variables should be italic.

Response: Corrected it as suggested.

(7) Line 187-189: suggest to move this part to method section.

Response: To address this comment, we added a data processing section in 2.4 and we moved this part to this new section.

(8) Line 198-199: why figure 5 only show the time series of HAMADA site, how about the performance of other stations. Please provide more related information.

Response: Details in the improvements after homogenization at most stations can be traced back to Figures 4, 5 and 6.

(9) Line 202-203: Please provide some information on how you calculate the average time series in figure 6-7 at 41 sites or 156 sites.

Response: We added a data processing section in 2.4 in Lines 261-266.

(10) Line 262: add the method for trend calculation.

Response: We added a data processing section in 2.4 in Lines 262-263.

Lines 262-263: The linear regression was used for trend calculation.

(11) Line 327-336: rewrite this part to highlight what you do and the value of this work.

Response: Thanks for the constructive comments. We rewrote this part in Lines 421-425.