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Interactive comment on "Merging ground-based sunshine duration with satellite cloud and aerosol data to produce high resolution long-term surface solar radiation over China" *by* Fei Feng and Kaicun Wang

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Reviewer #1 OVERALL 1) Comment: This is a nice work, in which SunDu-derived surface solar radiation (Rs) data are merged with satellite-derived cloud fraction and AOD data to generate high spatial resolution (0.1âŮę) Rs over China. Both direct Rs observations (pyranometer data) at âĹij100 stations and sun duration records at 2400 stations are used in this study to demonstrate the reliable performances of the merging results. A striking result is that AOD plays a negligible role in the merging results, which indicates that the estimation method of Rs from sunshine measurements is robust and

reliable. The result is valuable because long-term AOD retrievals are not accessible when building long-term Rs data. The paper is well organized. I suggest to accept this submission after following issues are addressed. Reply: The authors would like to thank anonymous referee #1 for his detailed and helpful comments. Below are our point by point responses to his comments.

GENERAL COMMENTS 2) Comment: It is not clear how to calculate clear sky Rs although a simple equation is given. A detailed introduction to the method is required since the conclusion mainly relies on the method. I wonder whether aerosol effect on Rs is accounted for by Sunshine duration measurement or by the equation used for the calculation of clear sky Rs. Addition, pls introduce more clearly which data are used in the calculation of clear sky Rs. Reply: For the clear sky Rs, τc_dir and τc_dif are calculated using a modified a broadband radiative transfer model by simplifying Leckner's spectral model (Leckner, 1978), which the effect of transmittance functions of permanent gas absorption, Rayleigh scattering, water vapour absorption, ozone absorption, and aerosol extinction are parameterized using the surface air temperature, surface pressure, precipitable water, the thickness of the ozone layer, turbidity as inputs (Yang et al., 2006). Calculation of Rs also includes impacts of aerosols because SunDu is impacted by changes in both clouds and aerosols (Wang, 2014).

3) Comment: It was said that site dependent parameters were used in the equation 1 (e.q., a0-a2). I'm not sure how to derive these parameters at each station. Reply: a0, a1, and a2 are the station-dependent parameters by tuning this equation with measurements of Rs and SunDu and then the method is applied regionally (Wang, 2014). Instead using observations from weather stations in Japan (Yang 2006), observations in CMA are used (Wang, 2014).

4) Comment: Frankly speaking, I'm not comfortable with the statement that the CERES EBAF can be taken as the reference. This seems based on the result that the agreement between SunDu-derived Rs and EBAR is much better than that between SunDu-derived Rs and pyranometer measurements. My opinion is that there seems possibility

that aerosol effects were not properly accounted for by both SunDu-derived and satellite Rs algorithm. I mean this possibility cannot be fully eliminated, so it is suggestive to discuss this issue in somewhere. Reply: Thanks for your suggestion, we agree with anonymous referee #1 that the data uncertainties cannot be fully eliminated for both ground observations and satellite retrievals. We will also discuss data uncertainties in the revised manuscript. The satellite Rs retrievals and SunDu derived Rs are generated by completely two different ways of measurements. Their correlation should be wake, but the high agreements of these two datasets from results indicate that CERES and SunDu-derived Rs can reflect the truth distribution of Rs in China to some extent. Similar results are also reported by (Wang et al., 2015) that SunDu-derived Rs have the best agreement with model-based Rs estimates, whereas satellite Rs retrievals, such as CERES, show best agreement with SunDu derived Rs and poor agreement with direct Rs observation due to the impact of thermal offset and directional response errors in direct observed Rs data. We notice that the biases of CERES EBAF are small. As mentioned in data section, the uncertainties of CERES EBAF data, reported by (Kato et al., 2018), in all sky global annual mean Rs is 4 W/m2. The SunDu data is a useful proxy of Rs, as mentioned in the data section. SunDu is almost free from influences of instrument replacement (Stanhill and Cohen, 2005). Even though, SunDu data do not provide a direct estimate of Rs and have the different sensitivity of atmospheric turbidity changes, compared with Rs observations, they are still a good proxy for variations of Rs (Manara et al., 2017). Moreover, existing studies have shown that SunDu-derived Rs estimates roughly depict long-term variability in Rs almost without the problems associated with early radiometry mentioned above (Wang, 2014; Wang et al., 2015).

MINOR ISSUES 5) Comment: Lines 31, 'Based on the SunDu-derived Rs from 97 meteorological observation stations: : :', the authors should mention that these 97 stations are co-located with those that direct Rs measurements sites. Reply: Thanks for your suggestion, we will add this information into the revised paper.

6) Comment: Lines 130-133, what about the quality of the datasets from (Tang et al. 2019) and (Stengel et al. 2020)? I suggest the authors add detailed descriptions of these datasets. Reply: Validation against the BSRN data indicated that SSR-tang have the mean bias error (MBE) of -11.5 W/m2 and root mean square error (RMSE) of 113.5 W/m2 for the instantaneous Rs estimates at 10 km scale, but (Tang et al., 2019) point out that care should be taken when using this dataset for trend analysis due to the absent of realistic aerosols input data. Stengel et al. (2020) also show that Rs derived from Cloud_cci AVHRR-PMv3 reveals a very good agreement against BSRN stations, with low standard deviations of 13.8 W/m2 and correlation coefficients above 0.98. While the bias for shortwave fluxes is small (1.9 W/m2). However, default an aerosol optical depth of 0.05 or data from Aerosol cci Level-2 or NASA MODIS Level-2 aerosol data are used in BUGSrad model to calculate clear sky Rs, indicating that impact of aerosols is not perfect parameterized in Cloud_cci AVHRR-PMv3. We will add this information into the revised paper.

7) Comment: Lines 164 to 165, the authors show that interpolation results have uncertainties due to the lack of detailed high spatial resolution information. What about the performances of machine learning methods in simulation of Rs. I suggest add more references here. Reply: The performances of different machine learning methods have been evaluated in many previous studies, including simulation Rs at regional scale with support of satellite retrievals (Wei et al., 2019; Yeom et al., 2019) and site scale by using routine meteorological observations (Cornejo-Bueno et al., 2019; Hou et al., 2020). Whatever models or training data are selected, the impacts of spatial relationship are not taken into account in these machine learning methods and therefore large number of input data are required to ensure accuracy. We will add this information into the revised paper.

8) Comment: Line 178, "0.1" changes to "0.1âŮę". Reply: We will correct it in the revised paper.

9) Comment: Lines 177 to 179, the authors merge the SunDu-derived Rs data with

satellite-derived cloud fraction (CF) and AOD data. Why not directly merging the SunDu-derived Rs data with current Rs products? Reply: We realize that we have not clearly explained this issue. Merging current Rs products with SunDu-derived Rs can also be applicable. Since many long-term Rs satellite products use climatology aerosols data as input, in this study, we want to know whether the merged product can achieve reliable Rs data without support of satellite derived aerosols input data.

10) Comment: Line 183,"sunDu" changes to "SunDu". Reply: We will correct it in the revised paper.

11) Comment: Add spatial resolution of each dataset and the references of each dataset in table 2. Reply: We will correct it in the revised paper.

12) Comment: Line 291, why not use MODIS AOD as input data in this study. Reply: We did not use MODIS AOD due to the impact of missing data. MODIS AOD conation missing values and can't meet the requirements of spatiotemporal continuity of AOD input in this study.

13) Comment: Lines316 to 317, SunDu derived Rs also contain the information of clouds, what about merging SunDu-derived Rs data only with AOD data? Reply: We agree with reviewers that SunDu derived Rs also contain the information of clouds. As cloud data can provide high resolution input data, we use cloud data to improve the spatial resolution of our merged data. We believe that with the support high resolution of AOD data, the merged data can produce more accurate results. However, the spatial resolution of current available AOD are 1 degree.

14) Comment: Lines 390 to 392, two validation sites are randomly selected to evaluate the seasonal and annual variations in Rs. I suggest two sites with high AOD values and low AOD values. Reply: We have checked the selected validation sites. The multiyear mean of AOD from Changchun and BeiHai are 0.49 and 0.70, respectively.

15) Comment: Line 474, "0.1" changes to "0.1âŮę". Reply: We will correct it in the

revised paper.

16) Comment: Line 518, "0.1" changes to "0.1âŮę". Reply: We will correct it in the revised paper.

17) Comment: Lines 535 to 536, deleted "We also plan to expand our Rs dataset from 1983 to 2017 by using AVHRR based cloud retrievals." Since this study focus the period from 2000 to 2016. Reply: We will correct it in the revised paper.

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