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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Solar radiation trend across China in recent decades: a revisit with quality-controlled data" *by* W.-J. Tang et al.

W.-J. Tang et al.

yangk@itpcas.ac.cn

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We would like to thank the reviewer for the comments and suggestions, which contribute to improve the quality of our paper. We have made revisions and have replied to all comments and suggestions. Please, find a detailed point-by-point response to each comment.

1. The authors find that only six stations in China have solar measurements meeting their standards of quality (this may be true). Six stations, as the authors recognize, are not sufficiently geographically representative of the entire nation of China. They therefore use data from these six stations to construct two empirical models for solar radiation based on various meteorological inputs, and then apply these models to the much larger network of meteorological stations to construct solar radiation time series

covering all of China. The fatal weakness of this approach, however, is that the input parameters are very likely insufficient to capture the actual physical changes producing long-term trends in surface solar radiation. In this case, the fact that they find smaller trends than previous studies is not due to lack of a real trend but rather their model cannot sufficiently reproduce nature.

Response: The reviewer might have misunderstood the process of our work. As the reviewer mentioned, it is critical to get adequate input data to reflect the producing long-term trends. We adopted two models. The first is a physical model; it is NOT calibrated with any radiation data presented in this work. Instead, it is just used to simulate solar radiation from observations at all 716 meteorological stations. The other model is the ANN-based (Artificial Neutral Network) model, which was trained with observed solar radiation data between 1994 and 2006 at each station and then the trained model is applied to simulate the solar radiation at this station for the period between 1979 and 2006. This procedure for the six stations is exactly the same for all 96 radiation stations. In a word, the two models are independent from specific station information. No calibration has been done to get the trends at the six stations; the procedure to get the trends at the six stations is identical to that at all other stations.

2. More specifically, two factors are the principal cause of inter-annual and decadal variability in surface solar radiation: clouds and aerosol. The input parameters to the neural network model are daily temperature range, daily mean temperature, relative humidity, sunshine duration, precipitation, and air pressure. Several of these are related to clouds, but it is known that clouds are not the cause of multi-decadal solar radiation trends over China. There is no parameter that is clearly related to aerosol, which has likely experienced a large trend during this time period. Sunshine duration has partial correspondence, but it will not distinctly show how aerosol partially reduces radiation so long as it is still strong enough to affect the sunshine recorder. Temperature range is also related, but many factors beside aerosol can change temperature range. The hybrid model uses information from Global Aerosol Data Set, but so far as I can tell, this

dataset is purely climatological and does not include how aerosol changes from year to year and decade to decade. If none of the input parameters properly represent how aerosol changes affected surface solar radiation, then there is no reason to expect that the constructed time series will show the full magnitude of the solar radiation trends that may have occurred.

Response: It is well known that cloud and aerosol are the two major factors influencing inter-annual and decadal variability in surface solar radiation. It is critical to find adequate input data to show cloud and aerosol's effects on the solar radiation change, as mentioned by the Reviewer. One method is to directly introduce cloud and aerosol information into a radiative transfer model. The major trouble of this method is that we do not have reliable long-term data for cloud and aerosol. The other method is to introduce a parameter that can show their impacts on the solar radiation change. In this work, the latter one is adopted and the sunshine data is used as such a parameter. According to the definition by The World Meteorological Organization (WMO) in 1981, the sunshine duration is the length of time for which solar direct normal irradiance exceeds a threshold value of 120 W mˆ-2. Therefore, the sunshine duration is an index of irradiance and its change includes the information of both cloud and aerosol. In the hybrid model, the Global Aerosol Data Set is used to reflect the aerosol's effect on the climatology of solar radiation, while the sunshine duration is introduced to reflect the aerosol and cloud's effects on radiation change. The consistency between the observed trends and the estimated trends (in Figure 3) may suggest that this strategy does work. Regarding the point that clouds are not the cause of multi-decadal solar radiation trends over China, we believe it is worthy of a discussion. Actually, this issue has been discussed in the manuscript. We presented the results over the Tibetan Plateau, where the decrease of solar radiation was found similar or even stronger than other regions of China. As human activities in the Tibet are still limited as far as the aerosol loads are concerned, the result suggests that the cloud change (or climate change) is the main cause for this decrease.

3. The authors compare their constructed time series with observed series in Fig. 2, and I see substantial discrepancies. This leads me to believe that while the authors' empirical models can produce some resemblance to the actual solar radiation time series, I have some doubt about the ability of the models to reproduce long-term trends. The most convincing plot is Fig. 3, which compares modeled and observed trends. I would prefer that this plot show trends for the pre-1990 and post-1990 period separately. What is most important is a demonstration of the models' ability to accurately reproduce trends during the "dimming" period.

Response: Thank you for this comment. It is worth separating the period for the trend analysis, but another problem arises. If we separate the period into the pre-1990 and post-1990, the sample size of each period will become too small, which will lead to the trends with big uncertainties. Nevertheless, we will try to show the trends for the pre-1990 and post-1990 period separately.

4. Why start at 1979? Most of the reported dimming happened prior to that. In generally, I think it is bad practice to show trends for the entire 1979-2006 time period since that encompasses both the dimming and post-dimming periods. Since this study is revisiting trends, why not focus on the separate periods when the long-term trends are downward and flat/upward?

Response: Good comment. We selected 1979 as a starting point, simply because the continuity of the meteorological data is poor before 1979 and we would have a smaller number of validation stations meeting the standards of radiation quality. This will weaken the representation of the validation dataset for model validation. Nevertheless, it is a good idea to show trends for the dimming and post-dimming periods. We will try to extend the starting year 1979 to earlier year.

5. The term "weakening trend" is ambiguous. Does it mean that the trend magnitude is becoming weaker or that solar radiation is becoming weaker (i.e., a decreasing trend)?

Response: We appreciated reviewer's suggestion and will change "weakening trend"

to “decreasing trend” in the revised manuscript.

6. Page 18399 lines 12-14: Wouldn’t the recovery from the Pinatubo eruption have possibly produced and increase in solar radiation around 1993-1994?

Response: This effect seems possible to a global averaged or local radiation, but it looks not so significant for China. The Tibetan radiation stations (Lhasa, Naqu, and Shiquanhe) provide the opportunity to detect this effect. If the volcano ash from Pinatubo eruption was transported to China, the aerosol effect on solar radiation at the Plateau stations would be significant, because the Tibetan Plateau has an average elevation of 4000 m above sea level and the aerosol concentration is the lowest one in the world. However, the annual mean sunshine duration at these three stations around 1993-1994 is still at a low level (see Figure 7 in the manuscript). This suggests little effect of the Pinatubo eruption on the radiation in this region; at least, it is difficult to identify the volcano effect from the complex climate changes.

7. Section 5.2: Norris and Wild (2007) show that satellite-based surface radiation records are not reliable for trends, both due to lack of time-varying aerosol and due to artifacts in the satellite cloud record.

Response: Thank you for your good suggestion! We will add this information in the revised manuscript.

8. It is extremely difficult to distinguish filled stars from filled circles in Fig. 1.

Response: We will change Fig. 1 in the revised manuscript and hope they can be distinguished easily.

9. Fig. 2 is too small. I had to zoom in on the computer to examine it.

Response: We will enlarge Fig. 2 in the revised manuscript. The small figure is also due to the typesetting at the webpage.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 18389, 2010.