

Further Comments on “Bias in CMIP6 models as compared to observed regional dimming and brightening” manuscript

The authors have thoroughly revised the manuscript and it now appears much improved than before, providing a more comprehensive assessment of observed SDSR trends and those simulated by CMIP6 models. I have provided a few detailed comments on the discussion of the new section 4.1 below and a few more minor comments further down on the revised manuscript.

I found the new section 4.1 very interesting, in that most (80%) of the observed positive trend in SDSR over China in the 1990s is down to instrument error. This “jump” in the 1990s also occurs in the Japan dataset (Fig. 2e) so I wonder is this could be due to the same issue here? The error in Chinese observations has been discussed in 4.1 but having read this and looking at Figure 10 in the Yang et al., (2018) paper I think more emphasis needs to be made in the text that the trend reversal is mostly an instrumental error. The trend reversal is consistently mentioned in other sections of the text and perhaps too much emphasis is still made that the models are not capturing this trend, even though we now know the observations presented over China in this period are mostly in error. There are also more similarities between the temporal trend in the SO₂ emissions and the new homogenised dataset e.g. increasing emissions up to ~2005, which coincides with the minimum SDSR in the Yang et al., (2018) homogenised data.

However, given the above I do not believe that this finding would change the main outcome of this paper much in that CMIP6 models underestimate the observed dimming signal over Asia and are unable to reproduce the recent brightening potentially due to uncertainties in the emission inventories. However, I think the direction of and timing of the temporal trends in observed and simulated SDSR over China (and Asia) would possibility match up better than with those observations currently presented in the manuscript i.e. the new observations show a dimming signal until ~2005 and then brightening. I was wondering if there is anyway to include the dataset from Yang et al., (2018) on any of the figures in the manuscript to provide a more direct comparison of the new and old observations with the model simulations? Also, I think some minor changes to text to include more reference to this observational change would be beneficial. This could go some way to addressing the current comparison for China (and also for Asia in Fig 2c), where the obvious discrepancy in the figures is the sharp change in observations in the 1990s, which we now know was not really observed.

As mentioned above the CMIP6 models would still underestimate the magnitude of the dimming signal across China and do not represent the observed brightening from ~2005, highlighting that there are uncertainties in the magnitude and timing of emissions over China. Therefore, potentially including some brief discussion on the recent literature of emission estimates of SO₂ over China, particular for recent years, would prove beneficial and aid the conclusions of the paper regarding SO₂, SO₄ and SDSR (e.g. Lu et al., 2010; Koukouli et al., 2018; Zheng et al., 2018).

Below are a few minor comments for the authors to consider.

A general comment (and mentioned specifically below) is to consider making more reference in the results to the fact that aerosols influence multi-decadal trends in SDSR and other variables (clouds) are more important for short term variability.

Within the revised manuscript there appear to be references to Figures, tables and Appendix items that need to be updated. For example, the results section refers to a Figure 5 but I have not seen a

Figure 5 in the revised manuscript. Also there does not appear to be a reference to Figure A1 in the text.

Page 2 line 31-33 – Not sure I understood this sentence properly, could do with clarifying a bit.

Page 2 lines 39-41 – Could link to the updated IPCC definitions, aerosol radiation interactions (Ari) and aerosol-cloud interactions (Aci).

Page 5 line 140 – I think hist-piNCTCF does not fix CH₄ at pre-industrial levels so this might need to be removed from the description.

Page 7, line 213 – remove ‘the’ before 1961

Page 8 line 229 – remove ‘between’

Page 9 line 258 – perhaps refer to multidecadal dimming signals

Page 9 line 261 – perhaps include ‘changes in’ before anthropogenic aerosol emissions’

Page 9, line 274-275 – perhaps again include reference to ‘multidecadal trends in’ all sky SDSR

Page 9, line 283-284 – but could this be due to the errors in the observations pointed out in Section 4.1?

Page 10 line 310-311 – Potentially remove/reword ‘not by changing cloud cover’ as could be misleading. Yes aerosols change the brightness of clouds but what about aerosol the effect on cloud lifetime?

Page 11 lines 229 – The calculation of the impact of changes in cloud cover on SDSR is presented but not really discussed. A simple sentence on the implications of this finding would improve its usefulness.

Page 11 line 236-237 – Based on the all-sky and clear-sky results can you say then that the dimming is primarily caused by direct aerosol radiation interacts, with a smaller impact from aerosol-cloud interactions?

Page 11 line 340 – should you not specifically mention sulphate aerosols here, as not all aerosol scatter shortwave radiation?

Page 12 line 358-359 – Based on section 4.1 can we say that GEBA, as it is presented in Figure 4b provides a reasonable representation of the historical development of SDSR over China?

Page 15 line 458 – should we expect a trend reversal in emissions given that this was mostly identified as an observation error in section 4.1?

Appendix A3 Line 518 – makes reference to rsds twice.

References

Koukouli, M. E., Theys, N., Ding, J., Zyrichidou, I., Mijling, B., Balis, D., and van der A, R. J.: Updated SO₂ emission estimates over China using OMI/Aura observations, *Atmos. Meas. Tech.*, 11, 1817–1832, <https://doi.org/10.5194/amt-11-1817-2018>, 2018

Lu, Z., Streets, D. G., Zhang, Q., Wang, S., Carmichael, G. R., Cheng, Y. F., Wei, C., Chin, M., Diehl, T., and Tan, Q.: Sulfur dioxide emissions in China and sulfur trends in East Asia since 2000, *Atmos. Chem. Phys.*, 10, 6311–6331, <https://doi.org/10.5194/acp-10-6311-2010>, 2010.

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