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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Assessment of the effect of air pollution controls on trends in shortwave radiation over the United States from 1995 through 2010 from multiple observation networks" *by* C.-M. Gan et al.

C.-M. Gan et al.

chuenmeei@gmail.com

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I had great pleasure in reviewing this manuscript. The assessment of the effect of air pollution controls in the US is based on an extensive set of SW irradiance measurement data. The separation of clear-sky data from the all-sky data is in particularly interesting.

We thank the reviewer for the overall positive assessment of the manuscript.

The interpretation of the data, however, needs some more work. The paper can be

accepted if the following revisions are made:

1) In section 2.5: The abbreviations BON, GWN, PSU, SGP, TBL, FPK and DRA are given without explanations. Such are given in Table 1, but they should also be given in the main text when introduced.

Following the reviewer's suggestion, in the revised manuscript we have added the following:

These sites Bondville (BON), Table Mountain (TBL), Goodwin Creek (GWN), Desert Rock (DRA), Fort Peck (FPK), and Penn State (PSU) have been operated for more than a decade.

2) Page 23731 lines 27-29: "In theory, the direct SW radiation is affected by clouds, absorptive aerosols and certain radiatively active gases (e.g. water vapour and ozone) while the diffuse SW radiation is influenced by the clouds, scattering aerosols and atmospheric molecules." This is not correct. Additionally, Rayleigh scattering of atmospheric molecules affects both direct and diffuse SW irradiance. Water vapour and ozone also affect the diffuse SW irradiance. Regarding the aerosols it is essential in the context of the paper that both absorbing and scattering aerosols affect the direct irradiance through extinction. The diffuse SW irradiance is also affected by both absorbing and scattering aerosols. The scattering aerosols at low AODs will increase the diffuse SW irradiance, while absorbing aerosols will decrease the diffuse SW irradiance. The lines in the text should be changed accordingly.

Agreed. Sentence is reworded as below:

In general, the SW radiation (i.e. both direct and diffuse) is affected by clouds, aerosol (e.g. scattering and absorptive), atmospheric molecules and certain radiatively active gases (e.g. water vapour and ozone).

3) Page 23732 lines 1-2. It is not correct to neglect Rayleigh scattering due to the amplitude of this, however, the argument can be made that Rayleigh scattering can

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well be assumed constant over time and therefore does not affect a trend study such as this. Please correct the lines accordingly.

We agree with the reviewer's assessment and have modified the discussion to reflect this point:

The contribution of Rayleigh scattering of molecules is neglected in this study. This is because Rayleigh scattering of molecules is assumed constant over time and therefore is assumed to not affect the SW radiation trends analyzed in the study.

4) Page 23732, lines 15-19. In these lines, the aerosol indirect effect is suggested as a reason for the SW trends. Other possible reasons should also be listed, such as overall changes in the atmospheric circulation over the US in the period investigated. Whether the atmospheric circulation is affected by ENSO and global warming in the analysed period is also important to discuss here.

More discussion is added page 23732 line 15:-

Moreover, the study of SW and LW radiation by Augustine and Dutton (2013), and SW by Long et al. (2009), suggests that the SW brightening in the US is related to a decrease in cloud coverage and aerosol direct effects may only play a smaller role in this phenomenon. However, aerosols may be contributing to the decrease in cloud cover through indirect effects whereby reduced concentrations of cloud condensation nuclei (CCN) can cause reductions in cloud albedo and lifetime (Lohmann and Feichter, 2005). On the other hand, changes in atmospheric circulation patterns that may have occurred over this time period may also have contributed to the observed changes in cloud cover. For example, Augustine and Dutton (2013) mentioned that during this study period not only the greenhouse gases were affecting the surface radiation budget but the atmospheric circulation associated with ENSO (El Niño/Southern Oscillation) can also potentially dissipate the excess sensible heat from the major increase in the surface radiation. Overall, while the all-sky downwelling SW radiation is . . .

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5) Page 23736, lines 17-19: "For all-sky, the "brightening" occurs at the same time that cloudiness exhibits a decreasing trend suggesting indirect effects of the decreasing aerosols." Such a conclusion cannot be drawn. As stated in comment 4, the trends in clouds can have multiple reasons. Indirect aerosol effects are still poorly understood and need further investigation as the authors correctly state earlier in this section. The lines should be changed to reflect this uncertainly or the mentioning of aerosols in this lines should be removed.

Sentence is restructured as below: For all-sky SW radiation, the "brightening" occurs at the same time that cloudiness exhibits a decreasing trend suggesting the possibility that indirect effects of decreasing aerosols may be a contributing factor. However, association does not prove causation, especially considering that trends in cloud cover can have many other reasons.

6) Abstract, page 23720, line 28: "... diffuse SW..." It should be specified whether it is diffuse all-sky SW or diffuse clear-sky SW that is referred to here.

Fixed. It refers to clear-sky diffuse SW.

7) Abstract, page 23721, lines 1-4: "In contrast to the eastern US, radiation observations in the western US do not show any indication of "brightening" which is consistent with the observations (...) that show the aerosol loading increasing slightly." This conclusion is not in agreement with the results. In both Figs. 7 and 8 (all-sky and clear-sky) significant brightening is seen for both the eastern and western US. The brightening is slightly weaker in the west than in the east, i.e. trends of 0.5131 vs 0.6296 are given in Table 2, which partly could be due to AOD, however, stating that there is no indication of brightening is wrong. The sentence should be changed to be in accordance with the results.

Table 2 shows brightening in both regions (east and west) in all-sky and clear-sky total and diffuse downwelling SW, all with greater than 95% confidence level. For the east and west the all-sky direct SW is also increasing, correlated with decreasing cloudi-

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ness, but the clear-sky direct SW shows no significant trend. The all-sky total SW trends align those of Augustine and Dutton (2013), and all the all-sky and clear-sky total, diffuse, and direct SW results align with those of Long et al 2009 (i.e. brightening trend for total and diffuse SW in US). However due to the limited available measurements, it is difficult to conclude what is causing the significant brightening especially in the western US.

Following this reviewer's suggestion, we have modified the discussion on p23721, line 1-6 as below: "The clear-sky radiation observation in the western US also show indication of "brightening" even though the AOD, PM2.5 and surface concentration do not vary drastically. This aerosol outcome is not unexpected because the CAA controls were mainly aimed at reducing air pollutants emission in the eastern US and air pollutant level in the western US are much lower since the beginning. This suggests other factors affect the "brightening" especially in the western US."

8) References: In the first reference the letters: "<2341:SANSRB>" can be seen. This looks like an error.

Thank you for noticing this. It was checked and seems like it is correct. Augustine, John A., John J. DeLuisi, Charles N. Long, 2000: SurfradâĂŤa national surface radiation budget network for atmospheric research. Bull. Amer. Meteor. Soc., 81, 2341–2357. doi: http://dx.doi.org/10.1175/1520-0477(2000)081<2341:SANSRB>2.3.CO;2

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 23719, 2013.