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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Regional differences in Chinese SO_2 emission control efficiency and policy implications" *by* Q. Q. Zhang et al.

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1. SO2 control will accompany with the change of NOX and hydrocarbons emissions which can induce the O3, OH and H2O2 variation. This would lead to gas phase and aqueous oxidation process of SO2. The uncertainty analysis should be done to consider these processes.

Response: We agree with the reviewer that SO2 emission control may accompany with changing emissions of NOX and VOCs, because these pollutants have common sources as SO2. However, while coal combustion is the dominant source of SO2, it is not the most important source for NOX or VOCs (transportation being another equally important source for those species). In addition, the technologies used to control SO2

emissions from coal power plants cannot remove NOX or VOCs to the same extent as SO2, and they may not affect NOX and VOCs equally. To address the impact of changing emissions of co-emitted species on SO2 chemistry, we conducted a new set of sensitivity tests considering the extreme circumstance in which NOX and VOCs emissions are also decreased by 8%, equal to the magnitude of SO2 emission change in the S1 scenario. The results from this sensitivity test are within $\pm$2% of those from S1 for all the metrics we considered. For example, the decrease of national mean SO2 and sulfate concentrations is 7.80% and 5.76%, respectively; the corresponding value is 7.90% and 5.70% from the S1 simulation. This indicates that the change in NOX and VOCs emissions as a result of SO2 emission control processes has a negligible impact on SO2 oxidation and as such it will not affect the conclusion of this study. Please refer to the revised manuscript in Section 4.3.

2. In Page 14, the authors analyzed SO2 conversion and emphasized that the aqueous oxidation is very important process. However in page 15, the results showed that all three regions, the relative decrease of gas phase oxidation is greater than that of aqueous oxidation, more explanations should be given to this point.

Response: Aqueous phase oxidation (mainly by H2O2) of SO2 contributes 45%, 64% and 73% to sulfate over NC, SC and SWC, respectively. The lower humidity over NC inhibits the aqueous phase oxidation, and the stronger NOX emissions from NC raise the OH concentration and then enhance the gas phase oxidation, so both of them are the reasons for the higher percentage of gas phase SO2 oxidation over North China. SO2 emission changes affect both gas- and aqueous-phase oxidation processes, but the magnitude of the influence depends on whether the process is SO2 limited or not. In most-polluted areas with high NOX emissions (like China), the aqueous oxidation tends to be oxidants limited rather than SO2-limited, because of the impact of high-NOX concentrations on OH, H2O2, and O3. Previous sensitivity studies (Berglen et al., 2004) have found that the gas-phase oxidation is more limited by SO2. Therefore, SO2 emission change will have a stronger impact on gas phase oxidation than aqueous phase oxidation and this explains why when SO2 emissions decrease, the relative decrease of gas phase oxidation is larger than that of aqueous phase oxidation. We have clarified this point in the text; please refer to the revised manuscript in section 4.1.

3. More detailed information should be added to describe how to calculate the sulfur outflow flux. Some references should be cited to show the Winter and Spring are the significant seasons for pollutants export.

Response: Previous studies have found that pollution outflow from East Asia to the Pacific peaks in spring (Chin et al., 2007; Clarisse et al., 2011), while winter is also a significant contributor (Feng et al., 2007), so we calculate the sulfur flux to Western Pacific in each scenario for the winter and spring seasons. We have added those references in the manuscript. The transport flux is evaluated at the boundary of 123°E and 22°N - 42°N within the troposphere, and the sulfur flux includes both SO2 and sulfate. We define eastward flux as positive, the sulfur fluxes for both seasons are positive, indicating the net export of sulfur compounds from China to the Western Pacific. Please refer to the revised section 3.4 in the manuscript.

4. Why SO2 concentration is not one of the impact metrics?

Response: The reviewer's point is well taken. We have added SO2 as one of the impact metrics. Comparing SO2 metrics from the four emission scenarios, the national mean SO2 concentration is also most sensitive to SO2 emission changes from NC (S2 scenario), resulting in the emission control efficiency factor of 1.0. SO2 emissions from NC are 36% and 129% higher than those from SC and SWC, respectively. Because of the short lifetime of SO2, reducing SO2 emissions from one region has a small effect on SO2 concentrations over the other regions, and thus the national-mean SO2 concentration is most sensitive to SO2 emissions from NC. This result is also robust without a strong dependence on meteorology or magnitude of SO2 emission reduction. Please refer to Section 3.2, 4.3 and the new Figure 6a in the revised manuscript.
