

We would like to thank the anonymous reviewer for the comments that significantly improved the clarity and readability of the manuscript. Our point-by-point responses are found below in blue ink. The revised content is highlighted in yellow.

This study assessed the effectiveness of reducing NH<sub>3</sub>, NO<sub>x</sub>, and SO<sub>2</sub> emissions on PM<sub>2.5</sub> in December 2018 by using the CMAQ model. In general, the method is well recognized, and the study is logically designed. A few modifications and clarifications are needed.

1. The title can be modified as ‘mitigating winter PM<sub>2.5</sub> in Taiwan’ to be more accurate.

A: Thanks for the reviewer’s comment. The title was revised to “Assessing the Effectiveness of SO<sub>2</sub>, NO<sub>x</sub>, and NH<sub>3</sub> Emission Reductions in Mitigating Winter PM<sub>2.5</sub> in Taiwan Using CMAQ Model”.

2. Equation 3: I don’t understand how the log calculation appeared here.

A: Based on the chain rule of logarithmic differentiation,  $\frac{d(\log y)}{dx} = \frac{1}{y} \cdot \frac{dy}{dx}$ . In equation 3, the calculation processes was simplified as  $\frac{E_X}{Y} \frac{\Delta Y}{\Delta E_X} = \frac{\Delta \log(Y)}{\Delta \log(E_X)}$  (In our study, we use  $\Delta$  instead of  $d$  because our current data are discrete rather than continuous.) To reduce the confusion, the equation in the content was revised as

$$S_{X,Y} = \frac{E_X}{Y} \frac{dY}{dE_X} = \frac{d\log(Y)}{d\log(E_X)} \approx \frac{\Delta \log(Y)}{\Delta \log(E_X)}$$

3. Model performance: For evaluation model performance on meteorology and air quality, there are certain criteria and statistical matrix to evaluate. The model performance can be accepted when compared to these criteria. A reference can be: Atmos. Chem. Phys., 16, 10333–10350, 2016.

A: We appreciate the reviewer’s suggestion. The mean fractional bias and mean fractional errors were provided for further criteria comparison. The information is incorporated in Table 3, while the first paragraph in section 3.1.1 was revised to address this analysis as follows: “The comparison between WRF model results and TW-MOENV observations ..., mean bias errors, mean absolute error, mean fractional bias, and mean fractional errors. .... The mean bias error at Shalu and Qianzhen meets the criteria suggested by Hu et al. (2016), while the mean absolute error at Tamsui, Shalu, and Qianzhen meets the criteria. At Taixi, the model tends to be underestimated, resulting in a higher mean absolute error. Overall, these findings demonstrate satisfactory model performance.” In addition, the following sentence is added to section 3.1.2. (Lines 204-205) “The correlation coefficients for PM<sub>2.5</sub> concentration range from 0.42 to 0.71, and the mean fractional bias and mean fractional error for PM<sub>2.5</sub> are within the acceptable criteria (Table 3), affirming the model’s reliability (Fig. S2).”

4. Some more detailed discussion on performance on the components should be provided, such as time series plots of obs vs. pre sulfate, nitrate and ammonium, as these are the core of the study.

A: We appreciate the reviewer's suggestion. Figure S6 is added to show time series plots of sulfate, nitrate, and ammonium with the following content added to section 3.1.2 (Lines 221-227). "The correlation coefficients of PM<sub>2.5</sub> between observation and model at Shalu and CSMU are 0.76 and 0.65, respectively, demonstrating consistency of model results for concentration and change trend at these two stations (Fig. S5). However, the correlation between observation and model at Zhushan and Xitou is poor, likely due to the influence of the complex topography at these two places. Further analysis in Fig. S6 presents the trends and correlation coefficients for PM-sulfate, PM-nitrate, and PM-ammonium across the four stations. The data reveal a slight underestimation trend for PM-sulfate, particularly at Shalu and Zhushan. The simulation for PM-ammonium appears reasonably accurate, whereas PM-nitrate shows a tendency for overestimation. ..."

5. The results in Fig. S7 and S9 are averages from 1-14 December. Why?

A: In Fig. 2, the PM<sub>2.5</sub> concentration trend throughout December exhibits two cycles of a high pollution period followed by a clean period. The results using the first cycle are consistent with the changing trend of the monthly data for reducing single-component emissions, as shown in Fig. R1. Therefore, to conserve computational resources, the "ER2 runs" experiments are only performed for the first half of the month.

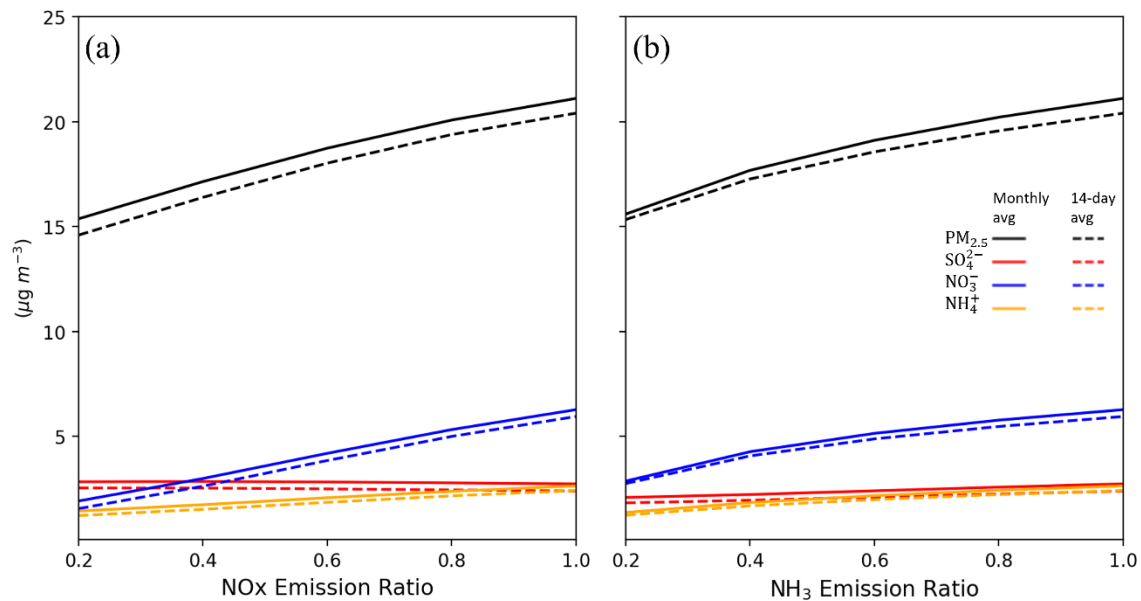


Figure R1: The response of PM<sub>2.5</sub> and major secondary inorganic components (sulfate, nitrate, and ammonium) to the emission ratio of (a) NO<sub>x</sub> and (b) NH<sub>3</sub>. Solid lines are the average data of December 2018 for the surface layer of central Taiwan, and the dashed

lines are the average data from 1<sup>st</sup> to 14<sup>th</sup> December 2018 for the surface layer of central Taiwan.

6. It will be more interesting to see whether the ‘effectiveness’ differs during the ‘high pollution’ period (such as beginning of December and middle December) and during relatively clean period.

A: We appreciate the reviewer’s suggestion. Figures S12 and S13 were added to show the effectiveness of emission reduction during the high pollution period and relatively clean period. The following sentences were added to section 3.5 (Lines 373-379). “... Additionally, the PM<sub>2.5</sub> reduction efficiency during relatively clean period and high pollution period is presented in Figs. S12a and S13a, respectively. During the clean period (6<sup>th</sup> to 12<sup>th</sup> December), NH<sub>3</sub> reduction maintains the highest efficiency, followed by SO<sub>2</sub> and NO<sub>x</sub>. However, during the high pollution period (16<sup>th</sup> to 22<sup>nd</sup> December), NH<sub>3</sub> reduction still has the highest efficiency, but NO<sub>x</sub> is higher than SO<sub>2</sub>. This indicates that during high pollution periods, reducing SO<sub>2</sub> emission has a limited effect on the total amount of PM<sub>2.5</sub> concentration, and continued reducing SO<sub>2</sub> emission does not improve efficiency. The average results of these two different conditions explain the crossover pattern observed for SO<sub>2</sub> and NO<sub>x</sub> emission reduction in Fig. 7a.”

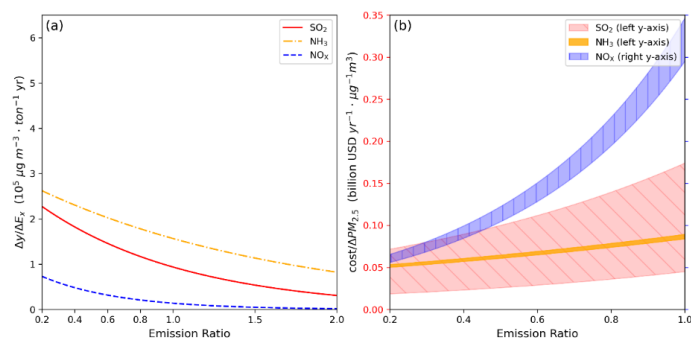


Figure S12: (a) PM<sub>2.5</sub> reduction efficiency and (b) reduction cost as a function of emission ratio for SO<sub>2</sub>, NH<sub>3</sub>, and NO<sub>x</sub> during the clean period of 6<sup>th</sup>-12<sup>th</sup> December 2018.

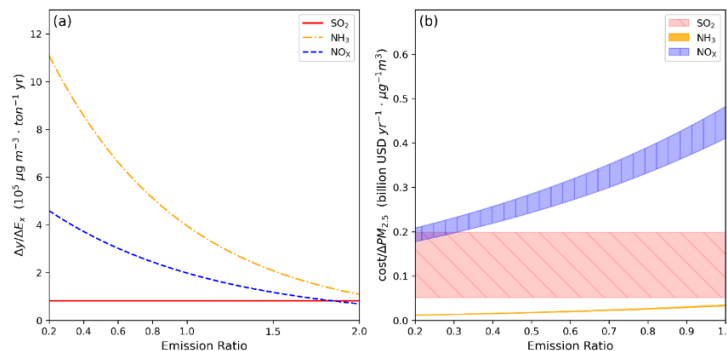


Figure S13: (a) PM<sub>2.5</sub> reduction efficiency and (b) reduction cost as a function of emission ratio for SO<sub>2</sub>, NH<sub>3</sub>, and NO<sub>x</sub> during the high pollution period of 16<sup>th</sup>-22<sup>th</sup> December 2018.