Reply to reviewers and editors:

We thank all of the reviewers for their careful reading of the manuscript, and for their many constructive feedbacks. The original comments by reviewers are in black font, our replies are in blue.

Reviewer #1

General comments:

The paper presented dynamic concentration downscaling and emission downscaling methods for air quality analysis and forecasts. Using the inverse modeling posterior results for October 2013 over China from a companion paper, they applied the downscaling methods to generate both analysis and forecast surface SO2 and NO2 concentrations for November 2013 over China. The results are quite impressive. The paper is well organized, and the overall presentation is very clear.

Thanks for the positive comments.

Specific comments:

Lines 19-20: It is an understatement or even a misleading statement to say that the joint assimilation of SO2 an NOx is to save computational time.

Thanks for the comment. We want to emphasize emission inventories are initially optimized at coarse resolution. To avoid misleading, we have changed it to "This work thus introduces several approaches to downscaling coarse-resolution (2°×2.5°) posterior SO_2 and NO_x emissions for improving air quality assessment and forecasts over China in October 2013. As the Part I of this study, these 2°×2.5° posterior SO_2 and NO_x emission inventories are obtained from GEOS-Chem adjoint modeling with the constraints of OMPS SO_2 and NO_2 products retrieved at 50 × 50 km^2 at nadir and ~190 × 50 km^2 at the edge of ground track."

Line 193: What is the height of the lowest layer?

The height of the lowest layer is in the range of 115 m to 135 m, as shown in the figure below. We have added information to the manuscript and this figure to supplement.

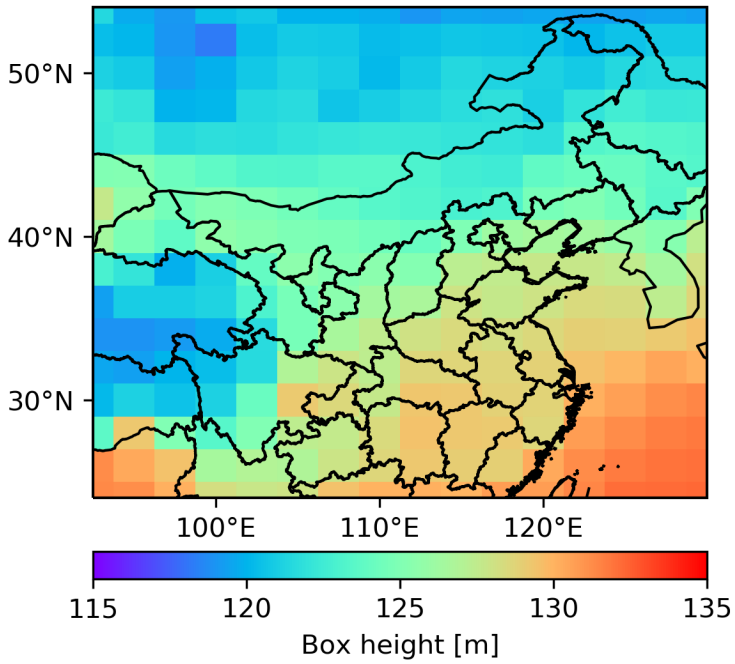


Figure S1. The box height of the lowest layer of GEOS-Chem in October 2013.

Lines 297-8: Does "monthly variation(s)" refer to the temporal variation within the month? Please clarify.

Thanks for pointing out this. Here "monthly variation(s)" refers to temporal variations among different months. Temporal variation within a month is not considered. We have added corresponding clarification in the manuscript.

Lines 341-2 : Do the authors believe that the negative NMB implies CGS effect? Would 43.4% NMB imply that MIX-DDC-PRI avoided the CGS effect?

These are good questions. We acknowledge that simulation bias is at least affected by emission bias and the CGS effect. Thus, negative NMB may be CGS effect as well as emission bias. Similarly, 43.4% NMB does not necessarily imply that MIX-DDC-PRI could completely avoid the CGS effect. Compared with 2°x2.5° simulations, 0.25°x0.3125° simulations help to decrease the CGS effect, but it is likely that 0.25°x0.3125° simulations or downscaling 2°x2.5°

simulations to the resolution of 0.25°x0.3125° (such as MIX-DDC-PRI) still cannot completely avoid the CGS effect. Zheng et al. (2017) showed that surface SO_2 (NO_2) concentration simulations from WRF-CMAQ, when evaluating with in situ observations, have a NMB of -23% (%0), 7% (32%), and 41% (45%) at the resolutions of 36 km (~0.36°), 12 km (~0.12°), and 4 km (~0.04°), respectively, which suggests that (1) the CGS effect and other non-linear resolution-dependent processes can affect the results and (2) these problems are alleviated at the resolution of 0.25°x0.3125°, but are not completely avoided. We have added that CGS effect is only reduced in part, and other factors needs to be investigated (section 4.1 and section 4.2).

Line 351: In what sense is the spatial distribution worse than the original coarse resolution simulations?

We have add "in terms of NCRSME" in the sentence. NCRSME is a good metric for spatial distribution.

Figure 6: How many ratios have been tested here? Showing the actual data points instead of smooth lines will be better.

Thanks for the suggestion. The ratios increase from 0.7 to 1.0 with a step of 0.01. We have replaced Fig. 6 by the figure below.

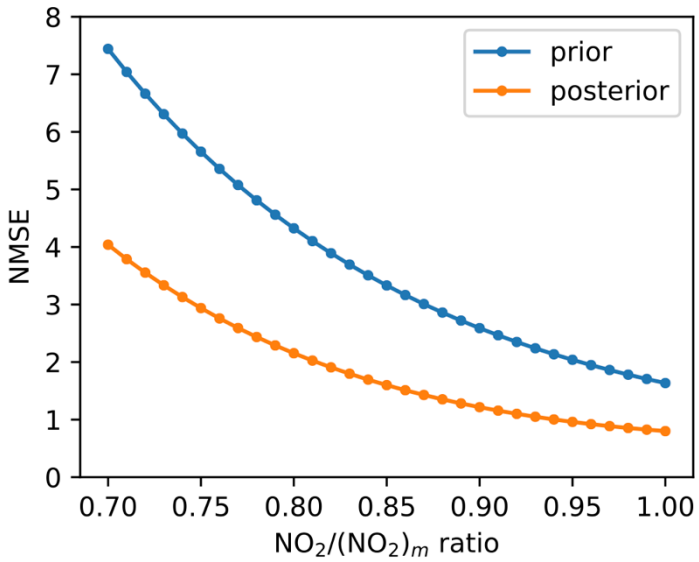


Figure 11: Can the separate NMSEs of SO2 and NO2 be shown as well? It would be helpful for the readers to understand the model behavior.

Yes. Figure of separate NMSEs of SO_2 and NO_2 are helpful for the readers to understand the model behavior. In revision, figures below are added the figures to the supplement (Figure S4), with a short description in the main text.

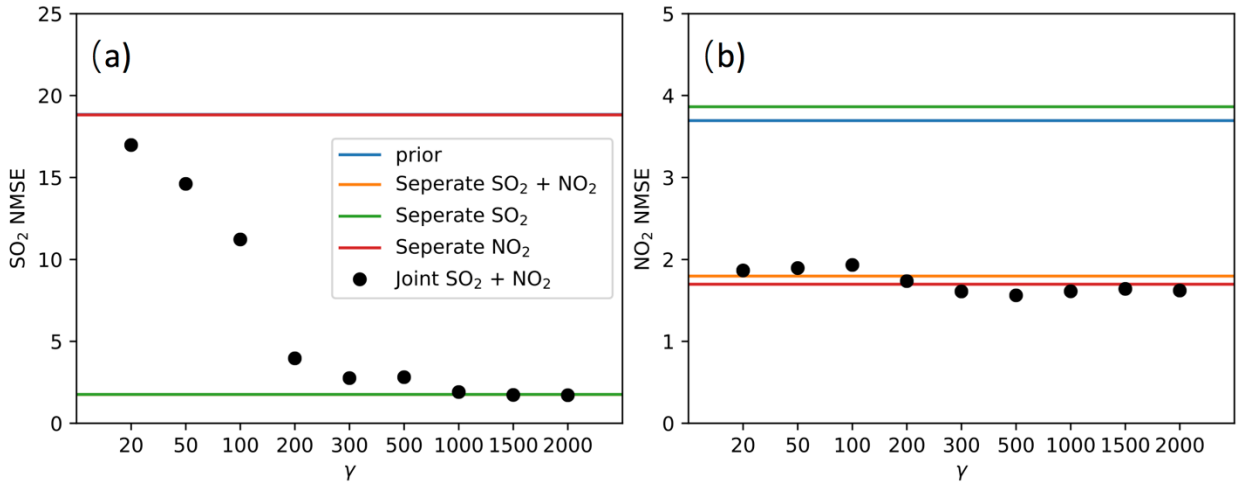
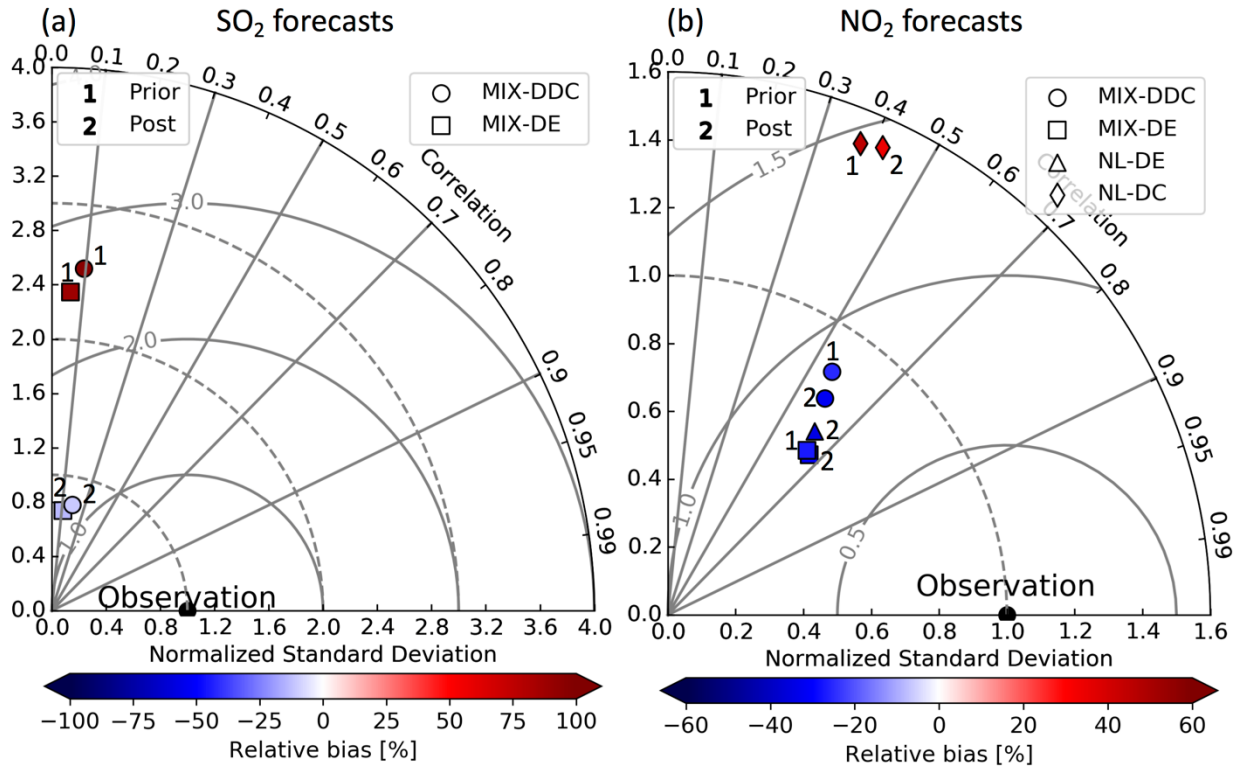


Figure S4. Normalized mean squared error (NMSE) of surface SO_2 (a) and NO_2 (b). All surface SO_2 and NO_2 simulations come from MIX-DDC and NL-DC, respectively. Black dots are posterior simulations from Joint-F-POS. The blue line is prior simulation results with SO_2 NMSE from MIX-DDC-PRI and NO_2 NMSE from NL-DC-PRI, respectively. The orange line is simulation results with SO_2 NMSE from MIX-DDC-POS and NO_2 NMSE from NL-DC-POS, respectively. The green line is similar to orange line, but posterior SO_2 emission from separate assimilation and prior NO_x emission are used. The red line is similar to orange line, but posterior NO_x emission from separate assimilation and prior SO_2 emission are used. In the figure (a), the blue line is covered by the red line, and the orange line is covered by the green line.

Figure 13. "Expected" is misleading as no one would expect the models can achieve such perfect results.

To avoid misunderstanding, we have replaced “Expected” by “Observation” in the manuscript, as shown below.



Technical correction:

Line 27: Add "(NL)" after Nighttime light. Line 286: "is use" -> is used. Line 327: "excepted" -> expected

Corrected.

Line 391: Duplicate "Northern China".

Corrected.

Line 397: MIX-DDC-POS should be MIX-DE-POS.

Corrected.