Anonymous Referee #1

I suggest minor revisions before publication.

We thank the reviewer for their positive comments and suggestions. Please find below our replies and the related modifications to the manuscript. The page and line numbers refer to the version of the manuscript with the accepted changes.

Line 33: GEOS-Chem is a global transport model with relatively coarse resolution (~ 0.5 degree). Comparing the modelled concentrations between NAME-AtChem2 which focus in Beijing and GEOS-Chem is not needed in the main text. You have enough interesting results to show and including such comparison doesn't give more information. I suggest move it to SI or delete it from the manuscript.

We respectfully disagree with the reviewer and we think that the GEOS-Chem section is important to the overall message of the paper. GEOS-Chem is a state-of-the-art 3D chemical transport model. It is extensively used for simulations of atmospheric composition and compared against measurements worldwide. Geos-Chem is a full Eularian Chemical transport model compared to NAME that is a Lagrangian model and therefore, running GEOS-Chem is not the same as running NAME and NAME-Atchem2.

GEOS-Chem runs take into account the emissions and chemistry for other pollutants such as NO2, CO for every grid cell, whereas with NAME we don't use any chemistry and with NAME-Atchem2 we add chemistry but assume this chemistry is homogeneous throughout the footprint.

To inform our conclusions we think it is important to be able to compare the five scenarios of NAME-Atchem2 against the GEOS-Chem results. This allows us to understand how the assumptions made in each scenario impact the results in comparison to a complete chemical transport model.

Line 125 – 130: It's weird that you don't use consistent emission inventories for all species. You mentioned that "ethylene, acetylene and ethanol emission inventories are not part of MEIC", is it true?

Ethylene, acetylene and ethanol are indeed not included/ or available as speciated products in the MEIC emission inventories received for this study. See Li et al., (2014) for more information. The method using NAME-AtChem2 needs speciated emissions for best results, and therefore we used another emission inventory (CEDS) which includes those three species.

In GEOS-Chem and many other chemical transport models (CTMs), many individual NMVOC species are lumped together according to similarities in chemical structure or reactivity. The most commonly used chemical mechanisms in CTMs include the State Air Pollution Research Center 1999 version (SAPRC-99, Carter, 2000). The NMVOC species in MEIC are mapped from SAPRC-99 species (Li et al.,(2014)) and therefore ethylene, acetylene and ethanol were not included in GEOS-Chem in this study.

Line 141: "ethene" or "ethylene" (as shown in Line 128)? Please keep it consistent throughout the paper.

Everything is corrected to ethene

Figure 2: How about the chemistry during transport before arriving at Beijing? The lifetime of most VOC species is less than 24 hours.

Due to the lack of measurements outside of Beijing, we assumed that the concentrations measured inside Beijing were the same for the whole footprint, as explained in lines 247 – 250. We used the five scenarios described in section 3.3 to evaluate how sensitive our results are to this assumption and to see how different conditions affect the VOC concentrations.

Line 153 – 165: suggest moving this part to SI or delete it.

As mentioned in the above comment, we feel that is important to keep the GEOS-Chem results in the main manuscript.

Line 249 – 259: this are very interesting and valuable sensitivity test.

Thank you very much.

Figure 6: How about formaldehyde? It's more sensitive to chemistry. Please add similar plots for formaldehyde.

Formaldehyde and Acetone plots added in Figure 6 and 7.

Figure 8: Poor correlations between OVOCs and NOx in the model. Any reasons for this bias?

We think that the poor correlation between OVOCs and NOx in the model is likely due to uncertainties and missing sources in the emission inventory and possible underestimation of oVOC concentrations in the AtChem2 box model. This certainly warrants further investigation, but we feel that with the limited information on this category of species in Beijing (only three were measured) we cannot elaborate further. Please see also the reply to a similar comment by Referee 2.

Line 463 – 465: Worst performance for S5 by constraining OH is found compared to other cases. Can I interpret it in this way, constraining OH is NOT a good option for further box modeling?

The model makes assumptions about the concentration of OH along the air mass footprint (see lines 247 – 250 ) due to the fact that we only have OH measurements at a single location. OH levels are possibly different along the air mass pathway and outside of Beijing. We do not know what the OH levels are along the trajectory and for this reason we test the different scenarios. For short timescales, OH can be considered a reasonably good option for box modelling; however, for longer transport times the uncertainty in this assumption becomes larger which explains why the performance of the model becomes worse.

Line 476 – 478: I don't quite understand this statement. Reducing VOC will decrease formaldehyde, and then further decrease ozone formation, right?

That is right.

The text was revised to say: "Reducing the concentrations of the VOCs investigated in this study will lead to a decrease in formaldehyde concentrations which will further decrease $O_3$ formation."

Line 481 – 484: You mean in winter, it's in transition regime, and in summer, it's VOC limited? Can you explain more on this? Also, in summer, the biogenic VOC emissions can play a key role. How will isoprene emissions in summer affect your conclusion?

Yes that is what we mean. It is important to understand the NOx/VOC relationship in order to accurately implement controls to reduce ozone formation.

During the summer, emissions of biogenic VOCs are higher. Isoprene is very reactive with OH, which could lead to ozone formation and also affect VOC concentrations but isoprene was not included in the emission inventories (MEIC and CEDS) and therefore in this study we are only focusing on VOCs emitted from anthropogenic sources which are included in the emission inventories.

Line 479 – 484: To clarify this point, this section was changed to the following:

"Moreover, the relationship between NOx and VOCs reveals the possibility that different control measures need to be implemented during winter and summer to control the ozone formation in Beijing, specifically focusing on decreasing both NOx and VOC emissions during the winter, and more on the VOC emissions during the summer. Furthermore, during the summer there are higher emission of biogenic VOCs, which could also lead to ozone formation. Future work is needed that includes biogenic VOCs along with the anthropogenic VOCs to get a better understanding of the effect of biogenic VOCs on the VOC levels and atmospheric chemistry in Beijing."

References:

Carter, W. P.: Documentation of the SAPRC-99 chemical mechanism for VOC reactivity assessment, Contract, 92, 95–308, https://intra.engr.ucr.edu/~carter/pubs/s99doc.pdf (last access: 31 Jan 2023), 2000.

Li, M., Zhang, Q., Streets, D. G., He, K. B., Cheng, Y. F., Emmons, L. K., Huo, H., Kang, S. C., Lu, Z., Shao, M., Su, H., Yu, X., and Zhang, Y.: Mapping Asian anthropogenic emissions of non-methane volatile organic compounds to multiple chemical mechanisms, Atmos. Chem. Phys., 14, 5617–5638, https://doi.org/10.5194/acp-14-5617-2014, 2014.