Anonymous Referee #2

A revised edition is encouraged for resubmission. Some detailed comments are provided for the authors as follows

We thank the reviewer for their 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.

How many VOC species were detected by GC-FID? Could you present detailed observation data? In the manuscript, only limited species were listed and used for comparison with modelling results. Better to use more species if there were.

Thirty species were measured using the DC-GC-FID in total. For more information, please see Shi et al., (2019) and Whalley et al., (2021). In this study we only focus on the anthropogenic VOCs that had speciated emission inventories to use with our modelling, and that is why we are only showing a selection of the measured VOCs.

The method used to estimate OFP is irrational. The VOCs measured in the ambient are already reacted. Since the OH concentration in summer is usually higher than that in winter, the photooxidation is more reactive in summer and thus in general higher O3 production. One should use corrected VOC concentrations to calculate OFP, otherwise will lead to wrong conclusion.

The reviewer rightly points out that the ambient VOCs we measure at the surface are likely to have already undergone reactions. In this study, we aim to compare the different scenarios from our model, and therefore must use the measured VOC concentrations as they are, since our AtChem2 modelling is intended to account for the reactivity.

We calculated the ozone formation potential of a specific species by multiplying the maximum incremental reactivity of the species with the measured ambient concentration of the species.

The method is widely used in many publications using measured concentrations. Please see a few of the examples here: Wang et al., (2008); Li et al., (2020); Cordell et al., (2021); Wang et al., (2021).

What's the uncertainty of modelling results in this study? In Table 1, the variations in modelled VOC concentrations are small among different scenarios. It's difficult to tell they are real changes due to different settings.

The modelling results are affected by several different uncertainties. There are uncertainties in the meteorological data, the models themselves, the chemical mechanisms and the emission inventories. Most of these uncertainties are difficult to quantify. We briefly discuss in section 3.3 the underestimations and overestimations in the emission inventories and provided a relevant reference (Acton et al., 2020).

The purpose of running the different scenarios is to allow us to evaluate the sensitivity of the VOC concentrations to the different chemistry conditions. Since the NOx and O3 data are available only at a single location and we assume their concentrations are homogeneous throughout the footprint, we use the five different scenarios to evaluate the sensitivity of our modelling to the assumptions we make in order to understand how robust our methodology is.

L64-67. I do not clearly understand this sentence. But according to Gu et al. (2019), the concentrations of NMVOCs in winter polluted days were highest, followed by summer polluted days, summer normal days, and winter normal days.

We understand that the sentence was not clearly written and it was revised to: “For example, Gu et al. (2019) studied the presence of 99 non-methane VOCs (NMVOCs) in Beijing during winter and summer. They found that the concentrations of total NMVOCs were the highest in the winter polluted days, followed by the summer polluted days, then the summer normal (i.e. less polluted) days, and the least polluted in the winter normal days. On the other hand the oxygenated volatile organic compounds (OVOC) were the highest in the summer polluted days, followed by the summer normal days, then the winter polluted days and least polluted in the winter normal days.”

From my side, It seems better to put the description of VOC/CO ratio (Sect. 3.1), the region division for NAME (in Sect. 3.2), and the scenarios description (in Sect. 3.3) to Sect. 2.

We respectfully disagree with the comment. We think that the discussion in those sections are part of our results and not part of the methodology and therefore it would not be appropriate to have them in Section 2.

What does APHH VOC/CO * CO APHH mean in Fig.3? In my understanding, APHH VOC/CO * CO APHH = VOC APHH.

An average ratio of VOC/CO was calculated from the measurements and then multiplied by the CO concentration measured during the campaign to determine whether you can predict the VOC concentrations by using a VOC/CO ratio in the absence of VOC measurements.

The legend of Figure 3 was changed to be more clear and more information was added in the caption.

L223-225: “During the summer campaign, … to the 20% that was observed in the winter.” It’s difficult to understand this statement.

The sentence was revised to: “During the summer campaign, an increase in the VOCs affecting Beijing that originates from outside of Beijing was observed within one day of travel. During the summer approximately 35% of the VOC concentrations were transported to Beijing from regions outside of the city compared to the 20% that was observed in the winter.”

Fig.9: Poor correlation between NOx and VOCs for both measured and modelled data. What’s the reason? Do you have any explanations?

Please see our explanation below:

In Figure 4 in the manuscript, we show the percentage of time the air masses spent over each region before arriving at the measurement station and in Figure 5 we show the percentage contribution from each sector during the winter campaign and the summer campaign.

As observed during the summer campaign there are differences in the air mass pathways compared to the winter. There are also differences in the contribution by each emission sector. Moreover, in Fig. 5 we observe higher local contributions of VOCs during the winter compared to the summer. This is explained in section 3.2. There is also possibly a higher contribution of biogenic sources during the summer and higher photochemistry in the summer, which leads to higher OH, but in this study the focus is on anthropogenic VOCs.

As stated in Lines 325 – 327, the above observations lead us to believe that the poor correlation of NOx and VOC during the summer indicates that VOCs and NOx are possibly emitted from different sources compared to the winter. See also the response to a similar comment by Referee 1.

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