We thank the reviewers for their time and insightful comments, which have substantially improved the manuscript. We have revised the manuscript and addressed the comments raised by the reviewers. The reviewers raised important comments on the rationales for our hypothesis, and the effects of our findings on future simulations. The main purpose of the study is to investigate the sensitivity of model predictions to the main inputs into the model. We apply different scenarios to evaluate the importance of major sources during the November 2017 extreme pollution episode over northern India. We feel this evaluation of inputs is needed to understand the extent that the forward model can be configured to capture the events. A contemporary way to try to capture such events in prediction mode is to employ data assimilation. The data assimilation results compensate for deficiencies in the inputs as well as structural problems within the models. But the effectiveness of data assimilation improves as the capabilities of the forward model improves. Therefore, our results are also important for those using data assimilation to improve predictability. Below, please find our responses to the reviewer's comments. The reviewer's comments are shown in black, our responses are shown in red, and the modified section of the manuscript is shown in blue.

We appreciate your time and comments and look forward to your decision.

Best Regards,

Behrooz Roozitalab, on behalf of all co-authors

RC3:

In this study, the authors used the WRF-Chem to simulate the pollution episode during Nov 2017 over New Delhi and evaluated the impacts of biomass burning emissions, long-range transport of dust, and dust emissions on simulated $PM_{2.5}$. The model was evaluated by comparing simulated meteorological parameters and simulated AOD and $PM_{2.5}$ with MERRA2 data and observational data. This study provides information on the sources that contribute to the severe PM pollution during Nov 2017. The paper is well organized but improvements in presentation are needed.

Authors Response:

We appreciate the reviewer for pointing to important issues. We try to address the comments and concerns here and below:

My comments are as follows.

RC3-1: In the design of the simulations, why increasing the emissions by 5, 7 or 10 times? Are these numbers chosen only to get a better simulation of PM in Delhi?

Authors Response:

We thank the reviewer for the point. Yes, we used simulation results in Delhi as the criteria for choosing the proper scaling factor. Moreover, the increasing factors were chosen arbitrarily and we have mentioned this as the limitation of our study in the revised version. In this study, we intended primarily to show the bias in biomass burning emission inventory is not systematic and clarify high uncertainty for extremely polluted days. Another bias correction study is required to find the relation between highly polluted days and optimized increasing factor to modify biomass burning emission inventories.

Text:

On the other hand, choosing the multiplication factor for increasing fire emissions was arbitrary in this study. Due to scarcity of observation data, we were not able to apply complicated mathematical scaling techniques based on data assimilation to scale the fire emissions (Saide et al., 2015).

RC3-2: Why this study chose to evaluate the impacts from only biomass burning and dust? How about other anthropogenic emissions which is also important source to severe $PM_{2.5}$ events.

Authors Response:

We focused on biomass burning and dust emissions in this study based on previous studies during this period (e.g. Beig et al. (2019)). However, we acknowledge the importance of anthropogenic emissions since emissions due to heating also increase as the weather gets cold during Oct. and Nov. We conducted another scenario, in which we increased the particles anthropogenic emissions by a factor of 2 (ID: BASE_ANTHRO2X). This modification increased $PM_{2.5}$ concentrations in Delhi up to ~150 μgm^{-3}, which led to overestimation (in contrast to underestimation in base scenario) at most of non-episode days (time-series shown below). Although this scenario did not help capturing concentrations

during the episode, it confirms the need for better anthropogenic emissions. On the other hand, it increased the AOD bias over southern IGP while reduced the bias over IGP (bias map shown below). These results suggest anthropogenic emission inventories have higher bias over IGP compared with non-IGP regions. However, we acknowledge the importance of having dynamic (daily) anthropogenic emission inventory.

Text:

Although different meteorological parameters can be responsible for the biases, accuracy of anthropogenic emissions is important. For example, recent local anthropogenic emission inventories developed for Delhi have higher particle emissions than in the regional inventory used in this study, which impacts modeled $PM_{2.5}$ concentrations for typical days (Kulkarni et al., 2020). We conducted BASE_ANTHRO2X scenario to investigate the effect of uncertainties in the anthropogenic emissions. This scenario increased $PM_{2.5}$ concentrations in Delhi up to ~150 μgm^{-3}, which led to overestimation (in contrast to underestimation in base scenario) at many of non-episode days (Fig. in the supplementary document). Although this scenario did not help in capturing the high concentrations during the episode, it confirms the need for better anthropogenic emissions. On the other hand, it reduced the bias over IGP (Fig. in the supplementary document). These results point out the need for best estimates of emissions of both anthropogenic and biomass.

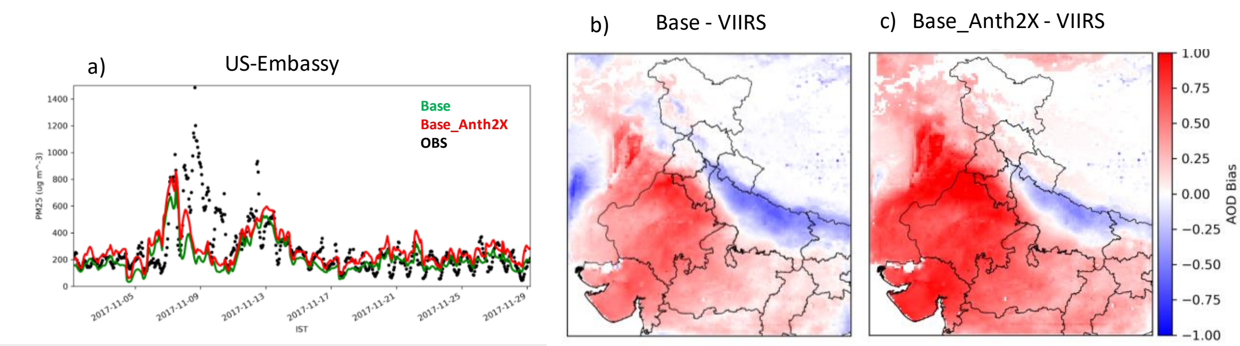

Figure 1 a) Timeseries for $PM_{2.5}$ concentration at the location of US embassy using Base scenario and Base_Anth2X scenario B) Bias of AOD at 550nm averaged over November 2017 base on b) base scenario c) base scenario with 2 times more anthropogenic particle emissions (ID: Base_Anth2X)

RC3-3: This study simulates the haze event during Nov 2017 by adjusting boundary conditions and emissions, how about other haze events in India? How to apply the findings of this study in the simulation of other haze events in India?

Authors Response:

We appreciate the reviewer for this important point. The main purpose of the study is to investigate the sensitivity of model predictions to the main inputs into the model. Prediction of extreme pollution events is important as they have major impacts on people and also make a strong impression regarding the capabilities of models. However, extreme events are hard to predict because they are often heavily impacted by episodic emission sources. Here we take the approach of systematically exploring the impacts of different boundary conditions, dust, fire and anthropogenic emissions on the predictions of the pollution episode in November 2017. We feel this evaluation of inputs is needed to understand the extent that which the forward model can be configured to capture the events. A contemporary way to try to capture such events in prediction mode is to employ data assimilation. The data assimilation results compensate for deficiencies in the inputs as well as structural problems

within the models. But the effectiveness of data assimilation improves as the capabilities of the forward model improves. Therefore, our results are also important for those using data assimilation to improve predictability.

Below, please also find other findings:

- **We showed that biomass burning emission inventories miss some small fire emission and introduced a new technique to use satellite data to fill these missing sources.**
- **We showed that biomass burning emission inventories occasionally underestimate emissions in hazy events up to 7 times lower, where bias correction techniques need to be applied.**
- **We showed either the plume rise in the model release the agricultural fire emissions too high or the model does not mix the smoke down fast enough. These should be considered in future hazy event simulations.**
- **We found Secondary aerosols comprise more than half of the particles in Delhi. It suggests simple aerosol modules like GOCART cannot simulate the actual speciation of particles in Delhi.**

Text:

The main purpose of this study is to investigate the sensitivity of model predictions to the main inputs into the model. Prediction of extreme pollution events is important as they have major impacts on people and also make a strong impression regarding the capabilities of models. However, extreme events are hard to predict because they are often heavily impacted by episodic emission sources. Here we take the approach of systematically exploring the impacts of different boundary conditions, dust, fire and anthropogenic emissions on the predictions of the pollution episode in November 2017. A contemporary way to try to capture such events in prediction models is to employ data assimilation (Kumar et al., 2020). The data assimilation results compensate for deficiencies in the inputs as well as structural problems within the models. But the effectiveness of data assimilation improves as the capabilities of the forward model improves. Therefore, our results are also important for those using data assimilation to improve predictability.

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