Egusphere-2023-1150: Evaluation of WRF-Chem simulated meteorology and aerosols over northern India during the severe pollution episode of 2016

Agarwal et al.

Responses to Anonymous Reviewer 1

We thank anonymous reviewer 1 for the time they spent reviewing our manuscript. Our point-by-point responses to the comments are given below in blue.

In this manuscript, Agarwal et al. performed a diagnostic evaluation of the state-of-the-art meteorology chemistry models in their ability to simulate meteorology and air quality over the populous, polluted Indo-Gangetic plain. The simulation is compared to ground and satellite observations as well as reanalysis products. Such an evaluation is useful in that it provides a benchmark for future studies; additionally, the study also shows that more accurate emission inventory and better characterization of boundary layer processes are key for further improvements. The manuscript is overall well-written, and I recommend the publication of the manuscript after minor revisions.

Response: We thank the reviewer for their recommendation to publish, following attention to minor revisions.

Comments:

1. Line 32: The word 'This' refers to insufficient aspects of the modelling, but the previous sentence is stating the model is reasonably good.

Response: We have rephrased the sentence as follows:

"WRF-Chem performs better at simulating the monthly average daytime meteorology. The systematically overpredicted wind velocities (more prominent during the night) lead to enhanced dilution and mixing, which, combined with underestimated input emissions, are responsible for pollutant underestimations in the post-monsoon season."

2. Line 35: The author should simply point out that better diurnal characterization of the boundary layer processes and emission estimates are necessary. Whether or not such improvement makes the model suitable to understand aerosol feedbacks on meteorology remains to be demonstrated, considering that 'feedbacks' is not really discussed in the current study.

Response: We acknowledge this point and have rephrased the sentence to read:

"Overall, the model realistically captures the seasonal and spatial gradient of meteorology and ambient pollutants over northern India and highlights the need for improved emissions estimates for a better representation of complex aerosol chemistry during extreme episodic pollution."

3. Line 164: Can the author say a bit more than 'satisfactorily' so that the reader better understands the bias from the inventory?

Response: We have revised our text to point out biases reported for the EDGAR inventory:

“Moreover, compared with other global inventories of coarser resolution (e.g., ECLIPSE), the use of EDGAR-HTAPv2.2 has been found to simulate air quality over India with a greater local heterogeneity and to show slightly smaller overall biases when compared to reanalysis and satellite products (Upadhyay et al., 2020).”

4. Line 295: What is the reason for the better correlation in September? Is it due to the monsoon season?

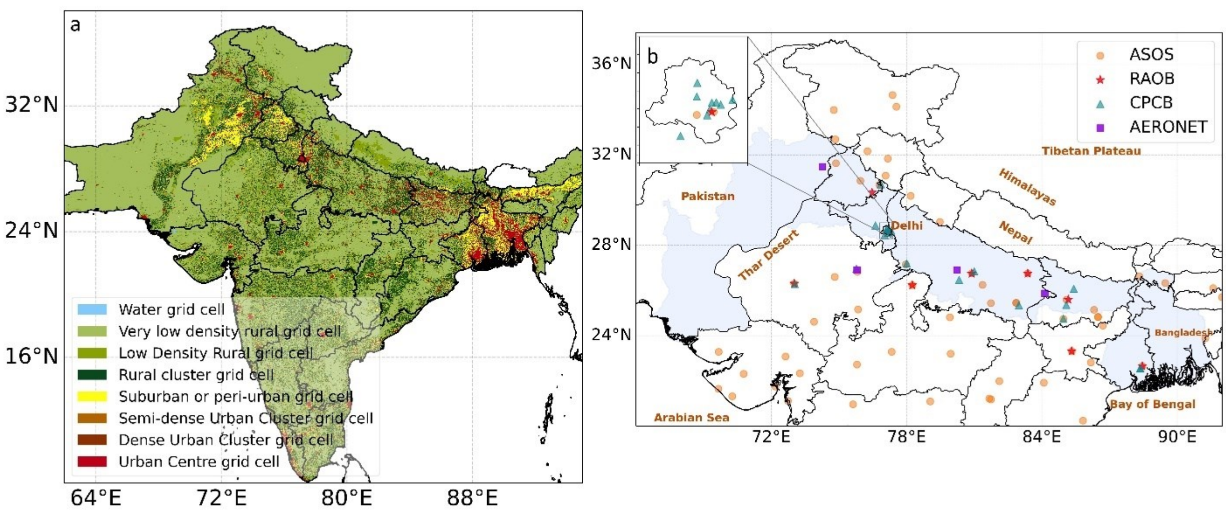
Response: A better correlation for September is likely due to seasonal differences in that a generally higher WS in this month is also associated with dominant westerly and southerly wind flow compared to October and November. The model can better predict the higher wind speeds prevalent during September compared with the low wind speeds during October and November.

5. Line 317: ERA-5 has positive bias in RH and is used to drive WRF-CHEM, how does it propagate to the negative bias in the simulations?

Response: We note from previous studies that systematic underestimations in simulating RH by WRF-Chem are reported when using other global datasets to drive the meteorological initial and boundary conditions (Ansari et al., 2019; Gunwani et al., 2023). So, the underestimation of RH in WRF-Chem likely stems from, first, the warm bias in the model and, second, the tendency to drift away from the large-scale driving prescribed meteorology towards drier conditions (Jain and Kar, 2017) because of uncertainties in closure assumptions in the convective parameterisation for numerical weather prediction (Grell and Dévényi, 2002). Additionally, the fact that the nudging coefficient is small, which allows for the model to simulate its own dynamic meteorology, and that no nudging is applied to meteorological variables in the planetary boundary layer may also explain why the model is still overall negatively biased for RH compared to ERA5.

6. Figure 1: The font size of the ticklabels should be increased. Fig 1a. Are there any water grid cells?

Response: We have increased the tick labels as shown in the revised Figure 1 below. There are very few water grid cells in the domain.



7. Figure 4 is wrongly placed before Figure 3. Also, the caption of Figure 3 is incomplete.

Response: We apologise for these two formatting errors in our Discussion paper which are now rectified in the revised MS.

8. Figures 6&7: The size of panels with similar contents should be adjusted to have the same size.

Response: We have made the panel size adjustments in the revised MS. Please find the revised figures below:

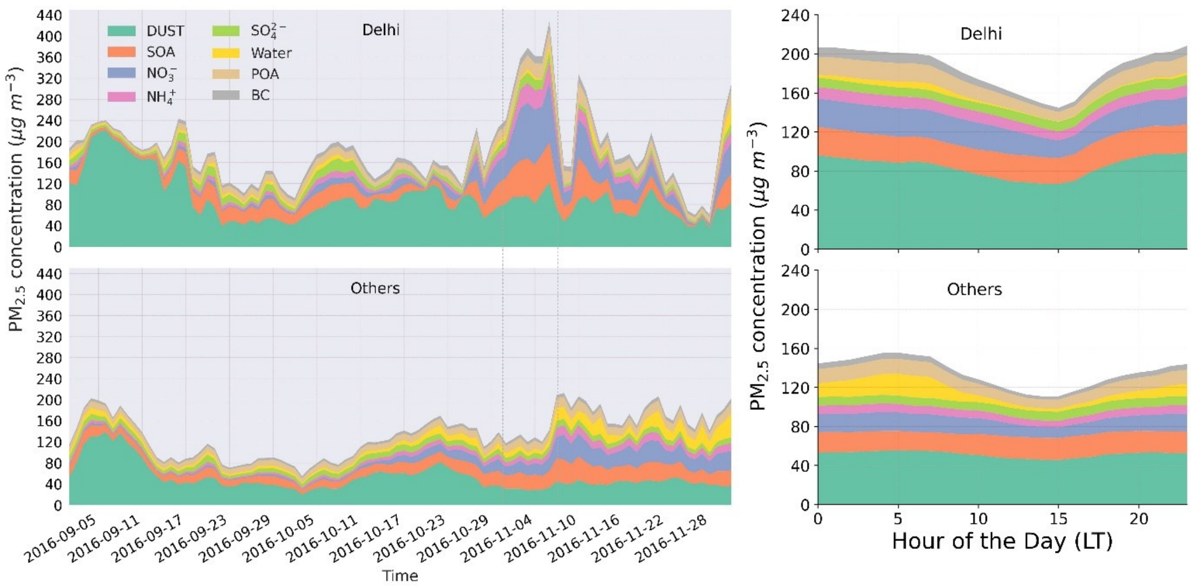


Figure 6. Time series of daily means (left) and mean diurnal cycles (right) of modelled individual $PM_{2.5}$ components averaged across 8 stations in Delhi and 12 stations over the rest of the domain (labelled 'Others') from September – November 2016. The individual species contribution abbreviations are: SOA (secondary organic aerosol), POA (primary organic aerosol), SO_4^{2-} (sulfate), NH_4^+ (ammonium), NO_3^- (nitrate), BC (black carbon). The vertical dashed lines delineate the period of severe high pollution between 30 October and 7 November. Note the different x-axis scales on each side.

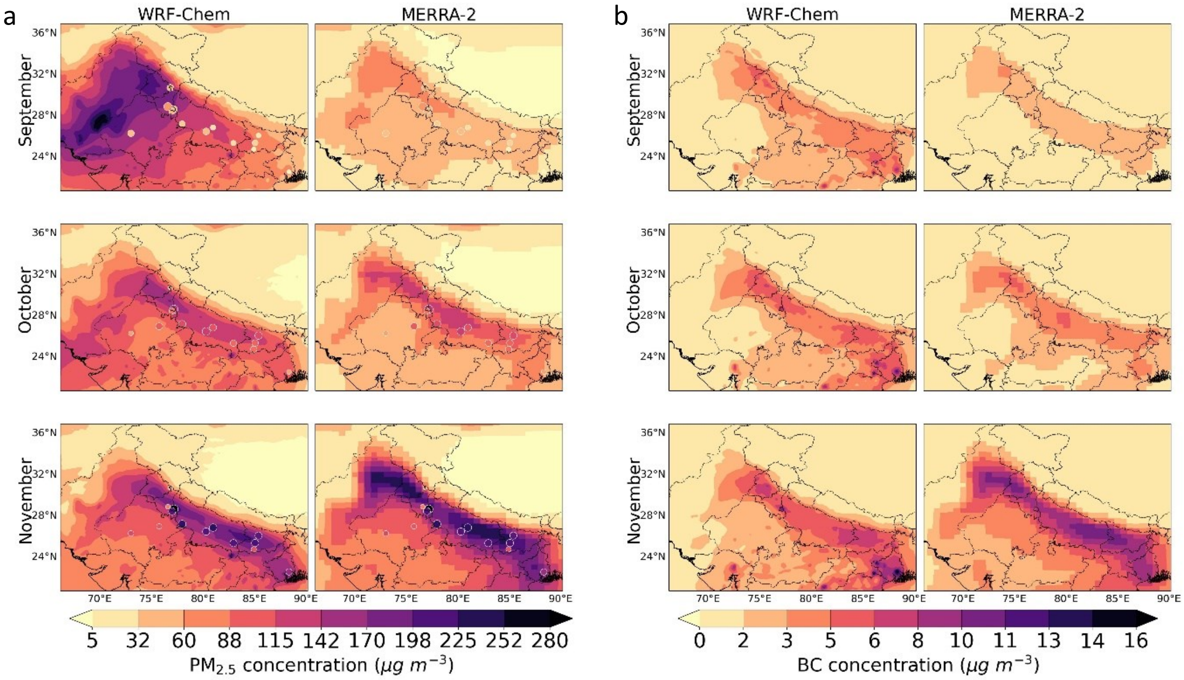


Figure 7. Spatial distributions of monthly mean concentrations (μg m^{-3}) of a) $PM_{2.5}$ and b) black carbon from the WRF-Chem model and MERRA-2 for September to November 2016. The monthly mean $PM_{2.5}$ at the measurement sites are shown in circles in a).

9. Fig S2: I find the colors for ERA and MERRA very difficult to distinguish.

Response: We believe the reviewer is referring to Fig. S3 and have adjusted the colour scheme.

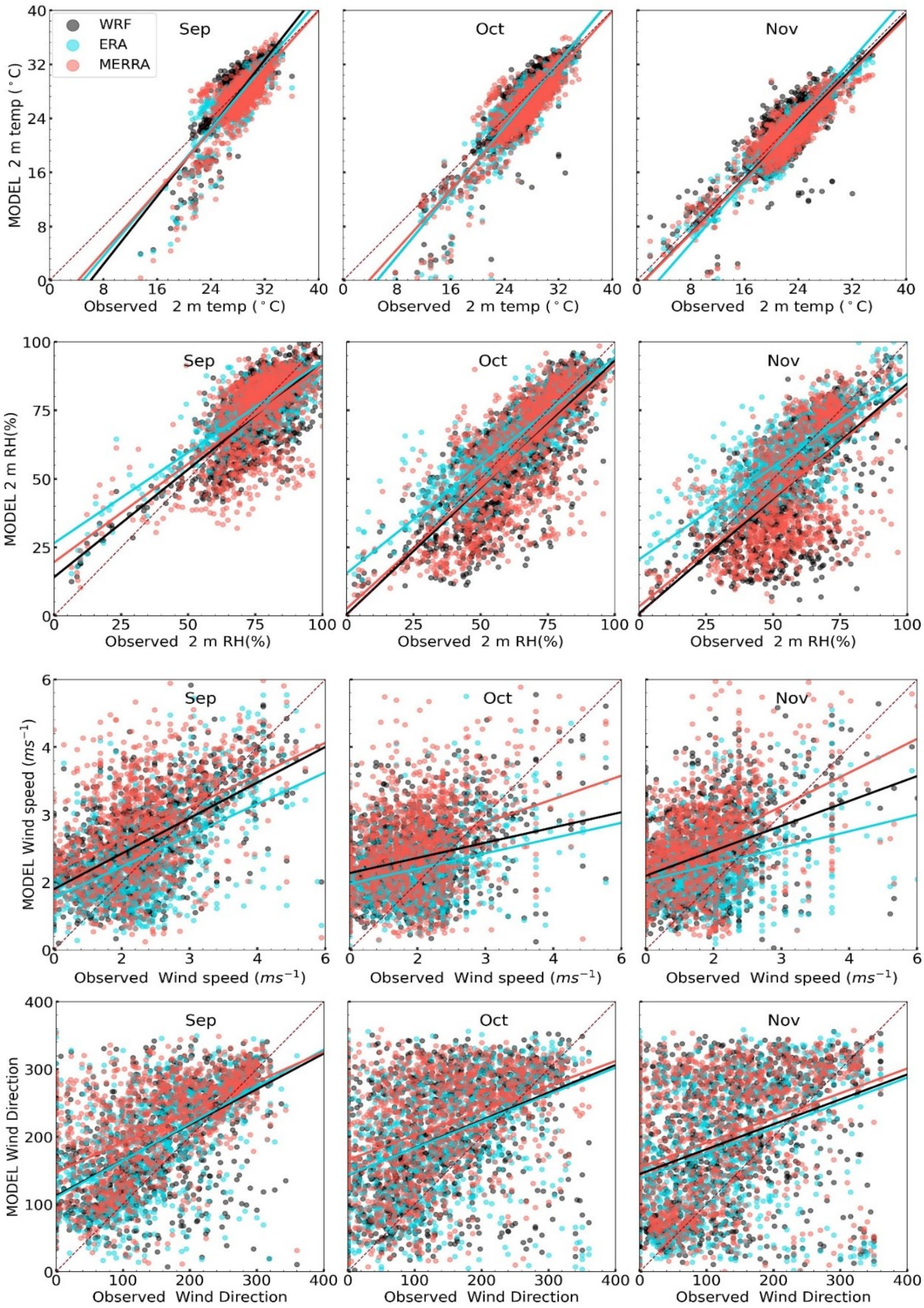


Figure S3. Scatter plots of daily mean measured and modelled surface meteorology variables derived from ERA-5, MERRA-2 and WRF-Chem across the 49 ASOS measurement sites for each of the 3 months of the study period: 2 m temperature, relative humidity (%), and wind speed (m s^{-1}). The 1:1 line is shown as red dashed.

Technical:

10. Line: 285: ‘very slightly low’ -> slightly lower

Response: The sentence has been amended as suggested

11. Line 572: revise the sentence ‘including because…’

The sentence has been amended as below:

“In addition, nearly all the measurement sites are in or near dense urban areas with heavy influences from traffic and local anthropogenic activities (for example, trash burning and residential cooking), which are not reflected in the monthly anthropogenic emission inputs.”

References cited in responses to Reviewer 1

Ansari, T. U., Wild, O., Li, J., Yang, T., Xu, W., Sun, Y., and Wang, Z.: Effectiveness of short-term air quality emission controls: a high-resolution model study of Beijing during the Asia-Pacific Economic Cooperation (APEC) summit period, Atmos. Chem. Phys., 19, 8651–8668, https://doi.org/10.5194/acp-19-8651-2019, 2019.

Grell, G. A. and Dévényi, D.: A generalized approach to parameterizing convection combining ensemble and data assimilation techniques, Geophysical Research Letters, 29, 38-1-38–4, https://doi.org/10.1029/2002GL015311, 2002.

Gunwani, P., Govardhan, G., Jena, C., Yadav, P., Kulkarni, S., Debnath, S., Pawar, P. V., Khare, M., Kaginalkar, A., Kumar, R., Wagh, S., Chate, D., and Ghude, S. D.: Sensitivity of WRF/Chem simulated PM2.5 to initial/boundary conditions and planetary boundary layer parameterization schemes over the Indo-Gangetic Plain, Environ Monit Assess, 195, 560, https://doi.org/10.1007/s10661-023-10987-3, 2023.

Jain, S. and Kar, S. C.: Transport of water vapour over the Tibetan Plateau as inferred from the model simulations, Journal of Atmospheric and Solar-Terrestrial Physics, 161, 64–75, https://doi.org/10.1016/j.jastp.2017.06.016, 2017.