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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Mitigation of $PM_{2.5}$ and Ozone Pollution in Delhi: A Sensitivity Study during the Pre-monsoon period" *by* Ying Chen et al.

Anonymous Referee #1

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General Comments

Chen et al. describe the use of a numerical framework for emulation and sensitivity analysis of a regional air quality model in the development of air quality mitigation strategies for the megacity Delhi. They find that a combination of reduction in traffic emissions within the city, combined with simultaneous reductions in all emission sources in the surrounding region would lead to a reduction of PM2.5, while avoiding an increase in ozone. The reduction of traffic emissions from Delhi alone would increase peak ozone in Delhi due to the high emissions of NOx from traffic, with the resultant reduction in ozone due to changes in the O3-NOx titration effect.

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Discussion paper

These results are certainly plausible, and consistent with previous work. The potential for ozone to increase when high local NOx emissions are decreased has been well understood for decades, as has the transboundary nature of ozone and the corresponding need to control precursor emissions over large spatial scales in order to achieve reductions in ozone. The authors themselves also cite previous work showing that a large fraction of the PM2.5 in Delhi originates outside of the city. I would generally regard the results presented by Chen et al. as unremarkable, and not of sufficient scientific novelty to warrant publication in Atmospheric Chemistry and Physics.

The most novel aspect of the study as I see it is the use of a statistical model emulator, combined with a technique called "global sensitivity analysis" to rapidly discover and evaluate effective emission mitigation options with a minimal amount of computational expense. The paper would potentially have merit if it had more of a technical focus on the methodology. Unfortunately, the methods are not described or evaluated well enough in the present version of the manuscript for me to be able to recommend publication. In order to be recommendable for publication, the manuscript needs major revisions focusing on better description and evaluation of the methods for model emulation and sensitivity analysis. I give suggestions for improving the manuscript in my specific comments, below.

Specific Comments

The introduction is concise and well written, but since the novelty of the paper is in its methodological advances, it needs an expanded discussion of model emulation and global sensitivity analysis.

Line 134: WRF-Chem is an online model, which is capable of calculating its own meteorology. Please describe how the model is "driven" by the ECMWF meteorological data. Are they used as boundary conditions? Is some kind of nudging or data assimilation used?

Line 181: The reference given here (Iooss and Lemaitre, 2015) appears to use "global

sensitivity analysis" as an umbrella term to describe a range of techniques. The authors should be more specific about what kind of global sensitivity analysis they describe in this manuscript.

Line 185: The paper by Saltelli et al. (1999) is behind a paywall. Simply giving a reference to this study is not enough to describe the method they employ. The authors must also give a summary of how this works and how it is specifically employed in their study.

Line 188: Similarly, "Gaussian process emulation" is not sufficiently well described in the manuscript. A summary of how this technique works and how it is applied must be included.

Lines 209-210: "10,000 random samples" are performed to check that the emulator "can fully represent the results of WRF-Chem". Does this mean that the authors performed 10,000 runs of WRF-Chem, and compared them with 10,000 runs of the emulator? Or did they do something else? What do each of the points in Fig. 3 actually represent? This is not clear at all. The authors seem to be relying on this analysis to show that the emulation "provides a good representation of the model", but in my opinion this has not been shown at all. Much more detail is needed here.

Line 256: NOx appears to be significantly underestimated by WRF-Chem during the middle of the day, when peak ozone concentrations are also modelled. Given the central role of NOx as an ozone precursor, it appears that the modelled peak ozone is being well simulated for the wrong reasons. There is likely a compensating error in some other aspect of the model. The authors should provide some discussion about how these errors in WRF-Chem would propagate into their emulator and affect the global sensitivity analysis.

Line 267: "We remove these sources". From what? WRF-Chem itself, or the emulator?

Lines 311-312 and Fig. 5b: It should be pointed out somewhere in the discussion that

the overwhelming dominance of traffic NOx emissions on ozone in Delhi is actually through anti-correlation. Presenting the sensitivity indices of "TRA" and "NCR" together on the same plot is potentially quite misleading unless the authors make it clear that their respective influences have opposite sign.

Section 3.5: This is a nice example of the potential power and utility of the methodology. Figure 7d is an especially clear illustration of the emissions control trajectory which is required to prevent an increase in ozone in Delhi despite reducing local NOx emissions. As mentioned in my general comments, this general approach to emission control (reducing ozone by focusing on regional-scale emissions) is consistent with current understanding of ozone chemistry, so this result by itself is rather unremarkable. What is really interesting here is the ability to rapidly discover an optimal emission mitigation pathway, and quantify its effects. What is missing here though, is a verification that the same combined emission controls for TRA and NCR would result in the same reductions in PM and ozone when employed in the full WRF-Chem model. It would only take one WRF-Chem run to verify this result. In my opinion this extra run is necessary for the authors to be able to show that their approach really is capable of what they claim.

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