Review comments to manuscript acp-2022-752

Impact of aerosol optics on vertical distribution of ozone

by Yan S. et al.

Review Comments

The paper seeks to quantify the impact of aerosols on ozone formation processes and vertical profiles in the boundary layer (BL) by combining direct observations from a ground-based site in Nanjing,China with a suite of WRF-Chem simulations. Specifically, three model runs are designed and performed to represent different aerosol mixing states (internal, core-shell and external mixing) and to quantify how ozone vertical profiles and photolysis rates are impacted with respect to a control run where no aerosol-radiation feedbacks are enabled. The key finding is that on the analyzed days, aerosols decrease ozone concentrations within the whole BL (although the signal is more pronounced at lower altitudes) during daytime with some sensitivity shown as a function of the mixing state.

Although the topic is of interest for Atmospheric Chemistry and Physics, the study is limited in the generalizability and robustness of its results, as well as in the model setup. Major concerns are listed in the general comments below.

General comments:

- A wider literature review needs to be incorporated to better provide background information on modeling features of aerosol mixing states and on prior studies on the topic, particularly in different parts of the world. This will provide a more complete statement of the problem, current uncertainties and gaps and further contextualize the presented results.

- A clear definition of the mixing states is missing and particularly how WRF-Chem treats them and what existing modeling limitations are. A discussion on the role of aerosol composition vs physical properties should be included. Please refer to the relevant literature including but not limited to the following:

  Riemer, N., Ault, A. P., West, M., Craig, R. L., & Curtis, J. H. (2019). Aerosol mixing state: Measurements, modeling, and impacts. Reviews of Geophysics, 57, 187– 249. https://doi.org/10.1029/2018RG000615

- Generalizability of the results. The WRF-Chem simulations are performed over a period of 4 days, while most of the presented analyses focus on a single day. Given the authors apply WRF-Chem in a configuration with a very small one-nested domain, the computational cost is very limited, so a justification on why the analysis is limited to such a few days should be provided, particularly in the context of the generalizability of the results. Robust statistics should be presented to make claims on physical and chemical mechanisms occurring in the atmosphere. Further, the authors should consider how different emission and meteorological conditions may play a role in impacting ozone processes. For example, it would be relevant to analyze different ozone regimes by looking at a full year of simulations. At the least, simulations of a representative month for each season (or the season with most ozone formation) should be included.

Specific Comments:

- Line 51: as mentioned in the general comments, the three mixing states need to be defined and explained also in the context of the modeling tool adopted. Also, an explicit discussion on the role of aerosol composition should be included. Are measurements of aerosol composition available at that or nearby sites?
- Line 72: how much representative of the overall physics and chemistry of the atmosphere are the chosen days of November 2020 whose anthropogenic emissions may be still strongly impacted by COVID lockdowns?
- Line 73: How were the vertical profiles of meteorological and chemical species measured? At which heights?
- Line 82: a reference for WRF-Chem should be included
- Section 2.2 (Model configuration): More details and clarifications are needed. For example, the defined domains are unusually small (less than 100 x 100 grid cells) which raise concerns about the model's ability to develop proper meteorology and also chemical processes. Also, is 9 km resolution small enough to capture the spatial variability in ozone? Are there other ground-based sites in the region that would enable a more complete model evaluation (so at more than one point)? The authors mention the MEIC emissions are used. What is their temporal and spatial resolution? From the listed website it appears that the latest emission inventory available is for the year 2017. However, WRF-Chem was run over November 2020, a year that experienced significant changes in most anthropogenic emissions due to COVID lockdowns. How was this mismatch in emissions accounted for? Also, how often were the boundary conditions from ERA-5 and chemical species updated?
- Line 114: the quantified WRF-Chem skills should be put into the context of other literature studies (not necessarily in the same region) to verify if the model performance with the proposed setup is aligned with prior published work. Adding more sites to the evaluation and extending the simulation to more days/months will make the assessment of WRF-Chem performance more robust.
- Line 200: how is ADVC defined and computed?