Impacts of aerosol-photolysis interaction and aerosol-radiation feedback on surface-layer ozone in North China during a multi-pollutant air pollution episode

In this study, Yang et al. investigate the impact of aerosol-radiation interactions on O_3 formation during a multi-pollutant air pollution episode in Northern China. Additionally, the study uses process analysis to analyze how the aerosol-radiation interactions affect O_3 through various physical and chemical mechanisms. This is an interesting research topic with valid research methods and an overall well written and well-structured manuscript. However, the period of analysis is far too short (i.e., 7 days) to robustly quantify the impact of aerosol-radiation impacts in this region or to describe any variability. Additionally, the time period analyzed appears somewhat arbitrary and is nearly a decade removed from current conditions. For these reasons, the manuscript is not currently at the scientific level of the Atmospheric Chemistry and Physics Journal. However, this manuscript would be suitable for publication in ACP if either it is restructured to focus on how the methods used are unique and different from past work or if the authors investigate longer periods to generate more robust analysis and conclusions. Please find my major and minor comments below.

Major Comments:

1) The novelty of this study is that it is the first time that API and ARF are investigated for synchronous occurrences of high $PM_{2.5}$ and O_3 concentrations. This is a rather broad research question to be focused on only one region and one very minor time period. Why do the authors not conduct simulations for either several of these small pollution episodes in this region or for similar episodes in other locations in China?

2) Given that government controls have substantially changed emissions in the last decade and will continue into future, how will this research remain relevant in the future or how relevant is it to today's air pollution in China, since the period examined is 7 years ago?

3) Is the focus of this research the method in which API and ARF are investigated or the impact of API and ARF in North China? If it is the former than the authors need to reword the abstract, conclusions, and objectives to make it clear that this study is a "proof-of-concept" study on how to best investigate API and ARF in high O_3 and $PM_{2.5}$ episodes. If the focus is the latter, the authors need to do additional simulations of other high multi-pollutant episodes, perhaps some closer to current conditions and others in the mid 2000s to see if there is change over time or to make the analysis and conclusions more robust.

4) Does this version of WRF-Chem's CBM-Z and MOSAIC modules have a volatility basis set (VBS) option to simulate secondary organic aerosols and if so is it used? Given that, this is a high O_3 and $PM_{2.5}$ episode there should be a substantial amount of secondary organic aerosol from abundant oxidants and precursors that may be missed in the model

without an advanced SOA scheme. How do the author's address the impact of SOA on their conclusions?

5) The authors are investigating aerosol radiation interactions, but the authors do not evaluate the model's performance against either radiation balance datasets or aerosol optical depth. Since these parameters are more important than surface evaluations of air pollutants to understanding API and ARF, the authors should evaluate their model configuration against satellite AOD and radiation variables such as MODIS or CERES-EBAF.

6) Are there only three meteorological observation stations in the domain against? If so, why do the authors not also validate their meteorological performance against gridded products like the Climate Research Unit (CRU) datasets to ensure their performance statistics are robust?

7) Given that interactions between O_3 and $PM_{2.5}$ are non-linear, how do the authors justify using a simple ratio value (i.e., ROP) to relate these interactions? If this ratio does not account for non-linearity, how useful is this value?

8) The axis labels and legends of Figure 7 are difficult to read. Either each panel should be larger overall or the font sizes of the axes and legends need increased.

Minor Comments:

1) In the abstract, there is no context for the values listed. Further reading into the manuscript reveals that these values are the averages in the areas of the complex air pollution areas. The authors should briefly state that these values are for daytime average changes in complex air pollution areas in the abstract.

   I would also suggest adding a more processed based explanation of the changes in atmospheric state rather than simply listing a long series of values. For example, the authors could state something similar to the following:

   "Aerosol radiation interactions lead to shortwave dimming at the earth's surface of X, which reduce photolysis rates by X. The dimming stabilizes the atmosphere via surface cooling of X, which reduces PBL height by X. The stabilized atmosphere increases saturation in the lower atmosphere by X. etc…."

2) Make it clear throughout the manuscript when you are referring to surface level O_3 and $PM_{2.5}$.

3) Lines 179-181: The missing $PM_{2.5}$ could also be from missing SOA formation pathways, as mentioned above, if no advanced SOA formulations are used.

4) Is "downward shortwave radiation in the atmosphere" the SWDNT variable from WRF-Chem? If so, the name of this variable is "downward shortwave radiation at the top of the atmosphere".

5) Lines 217-218: If ATM_SW is the SWDNT variable, what is causing it to increase? SWDNT is usually controlled by the solar constant. Is it possible this is reflected upward shortwave (SWUPT)?

6) Lines 248-249: This should be revised to make it clearer that ARF primarily impacts O_3 through changing the NOx distribution.

7) Lines 270-281: Is VMIX increasing surface O_3 because it is mixing down higher O_3 concentrations from aloft or because vertical mixing is suppressed due to a stable atmosphere?

8) Lines 282-294: Why does the VMIX contribution increase because of API?

9) Lines 295-301: Explain why VMIX_DIF and CHEM_DIF are positive during the day due to ARF.

10) Lines 315-316: Explain how different vertical O_3 gradients can cause this change.

Line Comments:

1) Line 49: This should be "Earth's radiative balance" or "Earth's energy balance"

2) Lines 54-56: Are these studies all focused on China? If so, state that in the sentence. Change "were" to "are".

3) Lines 56-63: State the domain and time period of Gao et al., (2015) at the beginning of this statement rather than the end

4) Line 66: Add "the" before North China Plain

5) Lines 66-67: If this is referring to surface $PM_{2.5}$ concentrations, add "surface" before $PM_{2.5}$ concentrations.

6) Line 204: should be "attention"

7) Line 256: Center align the equation.

8) Line: 259: Why are there parentheses in the units?

9) Lines 288-289: This sentence is a little confusing. Is Net_DIF the sum of CHEM_DIF, VMIX_DIF, and ADV_DIF? If so, state that explicitly and then indicate what Net_DIF describes.

10) Line 321: Remove "in the"

11) Line 361: Remove "the contribution from VMIX and"

12) Line 373: Either "A recent study" or "Recent studies have"