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Interactive comment on "Ozone formation under low solar radiation in eastern China" *by* Xuexi Tie et al.

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Responses to Reviewers:

Reviewer 1:

We thank the reviewer for the careful reading of the manuscript and helpful comments. We have revised the manuscript following their suggestions as is described below.

This study could be a very meaningful work. The paper addressed the relevant scientific questions within the scope of ACP. This manuscript studied the possible reasons enhancing the ozone formation under high PM2.5 concentrations. It is not a very novel concept since some previous studies already reported the positive correlation between PM2.5 and ozone, and analyzed the underestimated HONO sources in China and

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other areas in the world. However, better understanding the mechanisms in different locations is scientifically significant in modeling studies. In addition, as the authors mentioned, the results bring important insights for control strategy of air pollution, because both PM2.5 and ozone are significant air pollutants in China.

There sever major concerns as follows:

(1) Both cloud and aerosol can affect the solar radiation. In order to separate these two factors, especially for case studies, people usually will analyze the meteorological conditions during the measurement period, or only analyze the data under the cloud-free conditions. However, the authors of this manuscript never mentioned the cloud factor.

Thanks for the valuable comments of the reviewer. We have checked the meteorological condition (especially cloud condition) during the period of the case study (between Oct 5 and 6, 2015) in the Beijing region. It shows that there was close to the cloud free condition (see attached Fig-A1. Now it is Fig. 5 in the revised paper). In order to evaluate the effect of cloud, we made additional model runs (with thing and thick cloud conditions). The results show that clouds have important impact on the result of this study, and this study is more suitable for the cloud free conditions (see attached Fig-A2. Now it is Fig. 12 in the revised paper). The results show that the thin cloud (cloud cover in 2 km, with cloud water of 10 g/m3), could reduce the photolysis rate of HONO by about 40%, but the HONO could still remain important effects. However, with dense cloud condition (cloud covers at 2 and 3 km, with cloud water of 50 10 g/m3), the photolysis rate of HONO could reduce by 9-10 times by the cloud. In this case, adding photolysis rate of HONO cannot produce important effect on OH radicals and the production of O3. The above statements have been added in the revised manuscript.

(2) Several important previous studies should be mentioned so that some conclusions from this manuscript can be more solid. For example (but not limited to), Zhang et

al. (2016) already parameterized up-to-date HONO sources into WRF-Chem model such as the heterogeneous reactions on ground and aerosol surfaces, direct vehicle and vessel emissions, conversion of NO2 at the ocean surface, and emissions from soil bacteria. The modified WRF-Chem substantially reproduced the observed HONO levels, and greatly improved the ozone simulations. However, in this manuscript, the calculated HONO level was still very low in Fig. 6. More information about the WRF-Chem setup is needed. In addition, some other studies (e.g., Shi et al., 2015) already reported the positive correlation between aerosol and ozone. The ozone formation is also strongly dependent on the aerosol size and composition. The process might be a complex interaction between aerosols and photochemical reactions. For example, the scattering aerosol could considerably diffuse the solar radiation and enhance the flux density inside the boundary layer (He and Carmichael, 1999). Thus, the scattering aerosols may favor the ozone formation through increasing solar flux in the boundary layer (Shi et al., 2015). More discussions are needed in the manuscript.

Thanks for the valuable comments of the reviewer. We think that adding these previous studies will enhance the understanding of the highlights of our paper. The reviewer points that some recent versions of the WRF-Chem model add some missing HONO sources (surface emissions, conversion of NO2 at the ocean surface, etc.) can improve the HONO calculations (Shi et al., 2015). In our calculation, we only use the classical gas-phase chemistry to illustrate that the importance of these missing sources for the production of OH radicals. Adding these missing sources (there are not fully understand and remain a large uncertainty) could be a future work. In the revised paper, we add the above clarifications. We also add the reference of He and Carmichael (1999) to add their point that there maybe another factor that the ratio of the scattering and absorbing aerosols could be another factor to affect the relationship between aerosols and ozone. All the valuable references are included in the revised paper.

Zhang, L., Wang, T., Zhang, Q., Zheng, J., Xu, Z., & Lv, M. (2016). Potential sources of nitrous acid (HONO) and their impacts on ozone: A WRF/Chem study in a polluted

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subtropical region. Journal of Geophysical Research: Atmospheres, 121(7), 3645-3662.

Shi, C., Wang, S., Liu, R., Zhou, R., Li, D., Wang, W., ... & Zhou, B. (2015). A study of aerosol optical properties during ozone pollution episodes in 2013 over Shanghai, China. Atmospheric Research, 153, 235-249. He, S., & Carmichael, G. R. (1999). Sensitivity of photolysis rates and ozone pro- duction in the troposphere to aerosol properties. Journal of Geophysical Research: Atmospheres, 104(D21), 26307-26324.

Generally, this manuscript presents a significant study; however, the analysis should be in more depth. The authors should give proper credit to related work, and clearly indicate this manuscript's original contribution. I would not recommend using a vague word (such as "low solar radiation") in the title.

Thanks. We change title from "Ozone formation under low solar radiation in eastern China" to "Ozone enhancement due to photo-disassociation of nitrous acid in eastern China"

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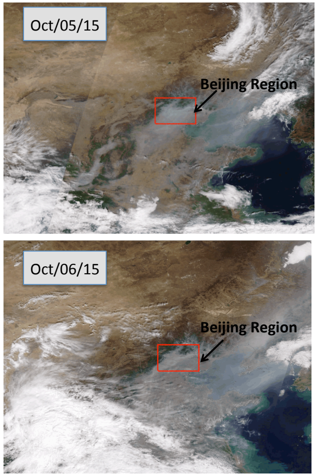

Fig-A1. The cloud condition during the period of the case study (between Oct 5 and 6, 2015 in the Beijing region. The bright white color shows the cloud covers, and the grey white shows the haze covers. The Beijing region is under the heavy haze conditions during the period.

Fig. 1.

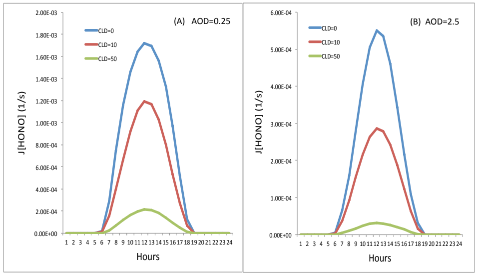

Fig-A2. The effect of cloud cover on the photolysis rate of HONO (J[HONO]). The blue, red, and green lines represent the cloud water vapor of 0 (cloud-free), 10 (g/m^3 – thin cloud), and 50 (g/m^3 – thick cloud), respectively. The left panel (A) represents the light aerosol condition, with AOD of 0.25, and the right panel (B) represents the heavy aerosol condition, with AOD of 2.5.

Fig. 2.

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