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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Characteristics and formation mechanism of continuous extreme hazes in China: a case study in autumn of 2014 in the North China Plain" *by* Y. Yang et al.

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Authors' Response to Anonymous Referee #1

This manuscript provides case study on the characteristics and formation mechanism of the extreme haze evens in the North China Plain. The recent heavy haze pollution in China has drawn much attention, and the authors of this paper analyzed formation process of four haze events based on chemical measurements in one site of Beijing in October of 2014. Considering there have been many similar studies, it is necessary for the authors to clarify their novelty. Also, parts of the conclusions seem lack cor-

responding support. At least a major revision is needed before the consideration of publication. Some specific comments are as follows:

Overall Response: We thank the reviewer for the careful reading and the valuable comments that helped improving our paper. The novelty in this research is clarified in specific in the third Response. According to the reviewer's suggestions, we made revisions in our manuscript. In revised article, we made further analysis between PM2.5 and SOR, NOR, try our best to explain the relationships between them in section 3.2.1. Nevertheless, we recognized that even the biomass burning accelerate the haze formation, its influence was at the beginning of the haze. Once the haze is formed, deterioration of haze will be dominated by the formation of new SO42-, NO3- and NH4+. We clarify this points in section 3.2.2. More innovations was added in conclusion part In order to make it clear for reading, we attached a copy of the manuscript with all changes to this "Authors' Response to Comments". In the revised manuscript, words with purple (red) font are the deleted or added parts. At last, we would like to answer the comments and suggestions one by one as following.

1.The title: how did the author define "extreme haze"? Compared with haze events in other seasons or the same periods in other years? Previous studies show that heavy pollution is common in October in northern China.

Response: We accept the suggestion. We recognize that the word "extreme" may not be the most appropriate, we delete it in the revised manuscript. Meanwhile, we would like to explain that the haze we concerned about was heavier than that happened in previous autumn. Firstly, higher concentration of PM2.5 in autumn. The concentration of PM2.5 in this study is much higher than those happened in other autumns. Concentrations of PM2.5 didn't exceeded 250 μgâĂćm-3 in October 2009 (Ji et al., 2012), 300 μgâĂćm-3 in September, 2011 (Liu et al. 2014) and 380 μgâĂćm-3 in October, 2013 (Feng et al. 2014). In this study, the peak value of PM2.5 was 469 μgâĂćm-3, which was higher than before. Secondly, in this study, the higher RH promotes the hygroscopic growth of aerosols, which will leads to lower visibility. We reanalyze the RH

in October 2014 (calculate the daily average value) to compare it with RH in October 2013 (Feng et al. 2014). It is clearly found that RH increased much during the haze episodes in October 2014 and RH in 2014 is obvious higher than that in October 2013. Even with same level of PM2.5 concentration, higher RH can leads to quite different level of haze episode, let alone the PM2.5 concentration in 2014 is higher.

Fig.1 Comparisons of RH in a) October, 2013 (Feng et al. 2014) and b) October, 2014

Reference: Feng, X., Li, Q., Zhu, Y.J., Wang, J.J., Liang, H.M., Xu, R.F., 2014.Formation and dominant factors of haze pollution over Beijing and its peripheral areas in winter. Atmos. Pollut. Res., 5, 528-538. Ji, D.S., Wang, Y.S., Wang, L.L., Chen, L.F., Hu, B., Tang, G.Q., Xin, J.Y., Song, T., Wen, T.X., Sun, Y., Pan, Y.P., Liu, Z.R., 2012. Analysis of heavy pollution episodes in selected cities of northern China. Atmos. Environ., 50, 338-348. Liu, X.G., Li, J., Qu. Y., Han, T.T., Hou, L., Gu, J., Chen, C., Yang, Y.R., Liu, X., Yang, T., Zhang, Y.H., Tian, H.Z., Hu, M., 2013. Formation and evolution mechanism of regional haze: a case study in the megacity Beijing, China. Atmos. Chem. Phys., 13, 4501-4514.

2.The content: the authors tried to explain the haze events with several key factors such as low PBL and high RH, which are common in previous studies such as Liu et al., 2013. What's new in this study? What's the predominant factor, and how about their respective quantitative contributions? It can be confusing if the authors listed various factors without their clear contributions, especially in the section 4.

Response: It is true that Liu et al. (2013) inspired us a lot, but we still try our best to be innovative. Firstly, we raised up the concept of increase rate of PM2.5, SOR and NOR. This change in analysis was little, but people seldom do this and it was more suitable to explain the formation process of hazes, since it make the deterioration of hazes more straightforward. We can easily find how fast a haze is formed and compared it with each other. Secondly, different from Liu et al. (2013), we introduced the biomass burning into the analysis. It induce haze event, aggravate the stable synop-

tic environment and at last accelerate the haze formation. Thirdly, we explained how large scale topography influence the movement of wind. At last, the research on RH is much more complete since we conclude how RH influence the haze formation in three major ways: accelerating the chemical transformation of secondary pollutants, hygroscopic growth of aerosols, altering the thermal balance of the atmosphere. But Liu et al., 2013 only focus on hygroscopic growth for aerosols scattering ability. Formation mechanism of haze is very complex. We clarify with might and main how important factors as topography, meteorology, pollutants emission, regional transport and chemical transformation results in sever hazes. These factors interactively influence haze formation. For example, the decline of the height of PBL may contribute in stationary synoptic condition while unstable synoptic condition will leads to lift the PBL. The interactive influence makes respective quantitative contributions of each factor difficult to decide.

3.Conclusions in several parts lack sufficient data support: 1) The authors said that biomass burning played an important contribution, but there was a decrease in the fraction of BC in haze events; and the biomass burning was usually concentrated in the first half of October

Response: As we showed in Fig 6, the BC fraction of BC in haze events is lower than that in non-haze period as a whole. It was caused by the times of increase of SO42-, NO3- and NH4+ in the later periods of haze event. However, a sudden increase in the concentration before each haze period was found for the organic matter, Cl- and BC. This indicated spatial transport of pollutants from straw burning. Once the haze event formed, the deterioration of haze will be dominated by the formation of new SO42-, NO3- and NH4+. However, in the beginning of haze event, unusual increase of BC, Cl- and organic matter can be found. We will add more explanation of difference of beginning part and later part of haze in section 3.2.2 in the revised manuscript. It will make the research more complete. There are 659 fire points found between 17 to 20 October and 106 fire points found in 23 October. Shanxi, Henan and Hebei province

was concerned and influenced the Beijing city. In conclusionïijŇwe still hold the view that influence of BC is important during formation of hazes in October 2014.

4. If secondary transformation was considered important, the authors should put Figure 7 and Figure 2 together, and present their correlation;

Response: We found the suggestion inspiring. Even though we chose not put Figure 7 and Figure 2 together, since they are in different parts, we did draw another picture to show the correlation between PM2.5 and SOR, NOR. As we found in the figure, PM2.5 is well fitted with SOR and NOR. The correlation coefficient was 0.62 between PM2.5 and SOR and 0.79 between PM2.5 and NOR which means with SOR and NOR can be higher with higher concentration of PM2.5.

Fig.2 Relationship between PM2.5 and SOR, NOR

5. In Figure 16, if radiation absorption was considered the direct reason of higher temperature, please give the data support. I think higher temperature was more relevant with the regional circulation.

Response: Water vapor is well known as greenhouse gas. It is indicated that for the cloudy sky case the contribution due to water vapor to the total longwave and shortwave radiative forcing were 75 WâĂćm−2 and 38 WâĂćm−2, respectively (Kiehl and Trenberth, 1997). In Dai et al. (1999)'s study, it is pointed out that atmospheric water vapor can increases both max and minimum temperature in a day. We believe that regional circulation has direct influence in instantaneous temperature variation, but the influence of high humidity can't be neglected. Reference: Kiehl, J.T., Trenberth, K.E., 1997. Earth's annual global mean energy budget. B Am. Meteorol. Soc., 78(2), 197-208. Dai, A., Trenberth, K.E., Karl, T.R., 1999. Effects of clouds, soil moisture, precipitation, and water vapor on diurnal temperature range. J. Climate, 12(8), 2451-2473.

6. This study was mainly based on ground measurements in one site of Beijing, can it

explain the widespread haze pollution in northern China, where emission sources and chemical characteristics can be very different.

Response: We believed that Beijing was a good representative of North China Plain (NCP). Cities in NCP were under frequent pollutants transfer where even emission sources can be different in each city, the chemical component of atmosphere will become similar after the regional transfer. In previous studies, Beijing is always influenced by surrounded cities. Thus, the chemical characteristics can reflect what happened in NCP. Furthermore, when the haze attacked NCP, the whole region was normally under the same synoptic system and influenced by the same atmospheric circulation. The analysis in Beijing can highly represented the meteorological conditions in NCP. Of course, we recognized that analysis of Beijing won't cover total formation mechanism in NCP, but the hazes happened in October 2014 are regional and Beijing is good research location with the completed database.

The whole response and the reivsed manuscript is at the Supplement.

Lastly, we would express our appreciation to three anonymous reviewer and editor for their warm-hearted help and useful suggestions. Thank you very much!!!!

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/15/C2775/2015/acpd-15-C2775-2015-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 10987, 2015.

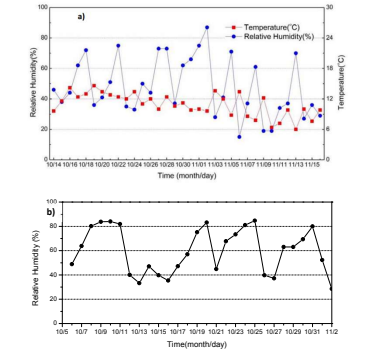

Fig.1 Comparisons of RH in a) October, 2013 (Feng et al. 2014) and b) October, 2014

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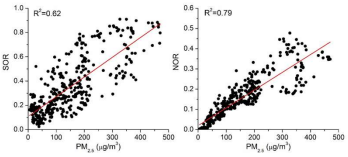

Fig.2 Relationship between $PM_{2.5}$ and SOR, NOR

Fig. 2. Relationship between PM2.5 and SOR, NOR