RESPONSE LETTER

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Multiplatform analysis of upper air haze visibility in downtown Beijing

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We deeply appreciate the reviewer for his/her careful reviews of this paper.

1. *I can't find the scientific significance and academic value of this article. Why study Up-Vis ïij´L0.1,0.3,0.5kmïijL'ïij§The authors have not pointed out the differences of Up-Vis at the three altitudes, nor have they studied the differences between them and the horizontal visibility on the ground. What is the purpose of using Up-Vis at three high altitudes? There are many detailed studies focusing on the relationship between visibility, relative humidity and other meteorological elements and PM2.5. The study method and conclusions of this article are too simple and general comparing with the related works.*

Response:

As we've known, the haze thickness (HT) is defined as the altitude where the upper air visibility (Up-Vis) is about 5 km (Han et al., 2016). This demonstrates the parameter of Up-Vis is key for obtaining the variation of HT. It is shown in Fig. 6 that the HT changes from 0.3 km to 0.6 km on haze days. So the Up-Vis at the altitudes of 0.1 km, 0.3 km, and 0.5 km are studied to characterize the HT. In addition, the Up-Vis at other altitudes can also be selected to study the characteristics of HT, as shown in Fig. R1. In Fig. R1, the similar phenomenon can be found compared with the results of Fig. 6. But considering the standard appearance of graphics, only three typical altitudes are shown in the paper.

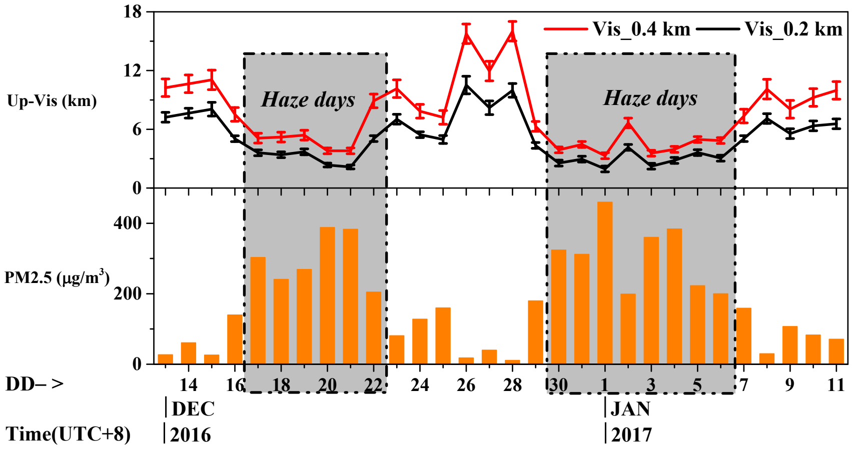

Figure R1: Daily variation of upper air visibility during successive haze episodes in the northwest of downtown Beijing.

According to the research of Tang et al. (2015), the atmospheric boundary layer (ABL) represents the atmospheric diffusion capacity in vertical direction, the aerosol optical thickness (AOT) directly reflects the particle concentration at a certain vertical distance, and the HT represents the main region of high concentration particles. The Up-Vis, the horizontal visibility at different altitudes, represents the horizontal particle concentration at a certain altitude. Therefore, the Up-Vis characterizes the horizontal haze situations at different altitudes; the ABL, AOT and HT characterize the vertical haze situation from different perspectives. And the correlation between vertical haze parameter (ABL, AOT and HT) and horizontal haze parameter (Up-Vis) characterizes the two-dimensional haze situations. Through comparing hourly variations of PM2.5 mass concentration and Up-Vis at different altitudes in certain period, the influence of vertical transport of pollutants on variation of haze parameters could be revealed indirectly. And according to the variation characteristics of Up-Vis and its correlation with vertical haze parameters (ABL, AOT and HT), the haze phenomenon in two dimensions can be analyzed, which provides more insights into haze phenomenon.

From Figs. 4-6, it is shown that the Up-Vis at the three altitudes have different variation ranges. The Figs. 7a shows the different correlation between the Up-Vis at the three altitudes and PM2.5 mass concentration. Figure 8 indicates the impact of vertical transport of pollutants on variation of haze parameters by analyzing the delayed variations of Up-Vis between high altitude and low altitude. Figure 9 reveals the correlation between horizontal haze parameter (Up-Vis at the three altitudes) and vertical haze parameters (ABL, AOT and HT). And Table 1 shows the statistical gradient of Up-Vis at different altitudes changing with the vertical haze parameters. Moreover, Table 2 displays the variation of Up-Vis at the three altitudes under different haze levels. Besides, the paper also indicates the minimum values of Up-Vis at the three altitudes are about 1.5 km, 2.5 km, and 4.2 km respectively on haze days, as shown in Lines 7-8 on Page 7. Therefore, the paper not only shows the numerical differences in Up-Vis at the three altitudes qualitatively and quantitatively, but also shows the different correlation between Up-Vis and vertical haze parameters (ABL, AOT and HT).

Atmospheric visibility basically includes horizontal visibility, slant range visibility and vertical visibility (Hey, 2015). The upper air visibility (Up-Vis) is defined as the horizontal visibility at different altitudes which is detailed in Page 4. The Up-Vis at different altitudes is regarded as the horizontal visibility above the ground, and the horizontal visibility usually indicates the horizontal visibility near the ground.

Until now, many studies on the visibility and its correlation with meteorological elements have been carried out to indicate the importance of visibility to air pollution studies (Yang et al., 2013; Sun et al., 2016; Wu et al., 2012; Bäumer et al., 2008; Pantazis et al., 2017). But these researches focus on the horizontal visibility and the slant range visibility rather than the upper air visibility. According to the obtained variation characteristics of Up-Vis, the influence mechanism of meteorological parameters to Up-Vis, and its correlation with vertical haze parameters (ABL, AOT and HT), the variation of Up-Vis would be significant to obtain the variation of haze thickness, and the haze phenomenon in two dimensions could be recognized, which provides more insights into haze phenomenon.

To be more scientific, we have changed the sentence “However, less focus was attached to the characteristics of upper air visibility (Up-Vis).” into “However, the above research mainly focused on the horizontal visibility near the ground, and less focus was attached to the characteristics of upper-air visibility (Up-Vis). Moreover, the research has been hardly found to report the two-dimensional haze characteristics.” (see Lines 14-16 on **Page 2**).

To well demonstrate the two-dimensional haze characteristics, the sentence "In addition, a higher atmospheric boundary layer improves upper air visibility." has been changed into "In addition, the two-dimensional haze characteristics could be studied by analyzing the correlation between vertical haze parameters (atmospheric boundary layer, haze thickness and aerosol optical thickness) and horizontal haze parameter (upper-air visibility)." (see Lines 12-14 on **Page 1**). The sentence "(2) reveal the impact of PM2.5 (particulate matter with a diameter less than 2.5 μm) mass concentration and haze parameters on upper air visibility;" has been changed into "(2) reveal the impact of the vertical transport of PM2.5 (particulate matter with a diameter less than 2.5 μm) mass concentration on Up-Vis and investigate the two-dimensional haze phenomenon based on the correlation between vertical haze parameter (ABL, AOT and haze thickness) and horizontal haze parameter (Up-Vis);" (see Lines 23-25 on **Page 2**). We have added the sentence "Besides, AOT is classified as vertical haze parameter because of its representative significance to pollutant concentration at a certain vertical distance." to classify the parameter of AOT (see Lines 19-20 on **Page 3**). The sentence "The Up-Vis is defined as the horizontal visibility at different altitudes." has been changed into "The Up-Vis is defined as the horizontal visibility at different altitudes, which is classified as horizontal haze parameter." (see Line 4 on **Page 4**). We have added the sentence "Therefore, HT reflects the main region of high concentration pollutions and can be classified as vertical haze parameter." to classify the parameter of HT (see Lines 13-14 on **Page 4**). The sentence "Tang et al. (2015) indicated the ABL represents the atmospheric diffusion capacity in vertical direction, so it can be classified as the vertical haze parameter." has been added to classify the parameter of ABL (see Lines 20-21 on **Page 4**). And the sentence "Therefore, a higher ABL has a positive influence on atmospheric visibility; and a lower HT or smaller AOT would enhance atmospheric visibility." has been changed into "The table 1 shows the statistical gradient of Up-Vis at different altitudes changing with the vertical haze parameters. It is obvious that the Up-Vis at altitude of 0.3 km changed faster than that at altitudes of 0.1 km and 0.5 km. Therefore, through the analysis of the correlation between vertical haze parameters (ABL, HT and AOT) and horizontal haze parameter (Up-Vis), the haze characteristics could be well investigated in two dimensions." (see Lines 11-14 on **Page 10**). The added table was shown in table R1 (see Table 1 on **Page 11**). We have changed the sentence "A higher ABL or lower HT as well as smaller AOT have a positive influence on the atmospheric visibility." into

"The correlation between vertical haze parameters (ABL, AOT and HT) and horizontal haze parameter (Up-Vis) can help investigate the two-dimensional characteristics of haze phenomenon." (see Lines 17-19 on **Page 12**).

Table R1: Statistical gradient of Up-Vis with different vertical haze parameters at different altitudes.

Vertical haze parameters	Vis_0.1 km	Vis_0.3 km	Vis_0.5 km
ABL	4.801	6.246	6.101
HT	2.275	3.674	2.787
AOT	1.108	1.365	1.111

References:

Bäumer, D., Vogel, B., Versick, S., Rinke, R., Möhler, O., and Schnaiter, M.: Relationship of visibility, aerosol optical thickness and aerosol size distribution in an ageing air mass over South-West Germany, Atmospheric Environment, 42, 989-998, 2008.

Han, R., Wang, S., Shen, W., Wang, J., Wu, K., Ren, Z., and Feng, M.: Spatial and temporal variation of haze in China from 1961 to 2012, Journal of Environmental Sciences, 46, 134-146, 2016.

Hey, J. D. V.: Determination of Cloud Base Height and Vertical Visibility from a Lidar Signal, Springer International Publishing, 2015.

Pantazis, A., Papayannis, A., and Georgousis, G.: Lidar algorithms for atmospheric slant range visibility, meteorological conditions detection, and atmospheric layering measurements, Applied Optics, 56, 6440, 2017.

Sun, T., Che, H., Wu, J., Wang, H., Wang, Y., and Zhang, X.: The variation in visibility and its relationship with surface wind speed in China from 1960 to 2009, Theoretical and Applied Climatology, 10.1007/s00704-016-1972-x, 2016.

Tang, G., Zhu, X., Hu, B., Xin, J., Wang, L., Münkel, C., Mao, G., and Wang, Y.: Impact of emission controls on air quality in Beijing during APEC 2014: lidar ceilometer observations, Atmospheric Chemistry and Physics, 15, 12667-12680, 2015.

Wu, J., Fu, C., Zhang, L., and Tang, J.: Trends of visibility on sunny days in China in the recent 50 years, Atmospheric Environment, 55, 339-346, 2012.

Yang, X., Ferrat, M., and Li, Z.: New evidence of orographic precipitation suppression by aerosols in central China, Meteorology and Atmospheric Physics, 119, 17-29, 2013.