

Interactive comment on “Mixing layer transport flux of particulate matter in Beijing, China” by Yusi Liu et al.

Yusi Liu et al.

tgq@dq.cern.ac.cn

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We would like to thank you for your comments and helpful suggestions. We have revised the manuscript accordingly. General Comments: To quantifying the transport flux of atmospheric pollutants for understanding the causes of atmospheric pollution levels and development of decisions regarding the prevention and control of atmospheric pollution, the mixing layer height and wind profile inside the mixing layer were measured by ceilometer and doppler wind radar, respectively. The variation characteristics of atmospheric transport capacity (TC) were analyzed on this data base: TC is strongest in spring and weakest in autumn. The TC influence on the PM_{2.5} concentration was determined and there shows a strong inverse correlation between the PM_{2.5} and TC in spring, autumn and winter and a weak positive correlation in summer. The transport

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flux (TF) of fine particles in Beijing is highest in spring and lower in the other three seasons. The transport occurs mainly between 14:00 and 18:00 LT. The TF was large in the pollution transition period and decreased during heavy pollution periods. Comment 1: The application of TC, TF and VC should be explained in more detail: why these parameters are used and which advantages it provides in comparison to alternative parameters. Response 1: Thank you for your helpful suggestion. After careful consideration, we think that “atmospheric transport capacity” is prone to ambiguity, so we changed this term to “atmospheric dilution capability”. Atmospheric dilution is composed of vertical and horizontal dilutions, which can be characterized by the mixing layer height (MLH) and wind speed in the mixing layer (WSML), respectively. The ventilation coefficient (VC) is obtained by combining MLH and WSML and can be used for a comprehensive evaluation of the vertical and horizontal dilutions, where a higher VC indicates a stronger dilution capability. The TF represents the transport flux of PM_{2.5}, which can quantify the amount of pollutants passing through the area to assess the impact of regional transport. To avoid confusion, changes were made in the paper. Comment 2: It is concluded that the transportation influence in southern regions is of higher influence in the transition period of pollution, while local emissions are more important in the heavy pollution period. My main concern is why the whole discussion with TC, TF and VC up to section 3.2 is without wind direction. In section 3.3 it would be helpful to discuss MLH also. Response 2: Thank you for your helpful suggestion. After careful consideration, we have revised the structure of the paper according to your suggestion. Section 3.1 mainly discusses the seasonal and diurnal variations of the atmospheric dilution capability and PM_{2.5} concentration; section 3.2 mainly discusses the evolution of the TF, both temporally and spatially; and section 3.3 analyzes the evolution of the TF under different pollution degrees in detail. The revised structure will make it easier for readers to understand. Thank you very much for your suggestions. In addition, we have added the evolution of the MLH under different pollution degrees in section 3.3 as suggested. We found that the MLH decreases gradually with the worsening of the pollution (Fig. 1). This result also supports the conclusion

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that the transport is weak during heavy pollution. Comment 3: The conclusions are a summary and in this summary no relation to the existing knowledge / papers are given. What is new and what is supported by this study? The paper addresses relevant scientific tasks. The paper presents novel concepts, ideas and tools. The scientific methods and assumptions are valid and clearly outlined so that substantial conclusions are reached. The description of experiments and calculations allow their reproduction by fellow scientists. Response 3: Thank you for your helpful suggestion. Joint prevention and control have been recommended for a long time to solve the problem of heavy pollution in northern China. Even so, no concrete implementation plan has been established. To break through this embarrassing situation, this study quantifies the transport flux to explain the time period when the transport occurs, the main areas affected in Beijing and the height of transport. The important role of transport in the initial period of pollution is emphasized. The innovation of this study has been added to the conclusion. Comment 4: The quality of the figures is good. The figure captions should be improved so that these are understandable without the overall manuscript: terms must be explained, description of parameters. Response 4: Thank you for your helpful suggestion. According your suggestion, we added more detail to make the figures more readable, such as descriptions of the parameters and explanations of the abbreviations. Specific Comments: Comment 1: Line 46: The values are valid for which time period? Response 1: Thank you for your helpful suggestion. The phrase has been revised to “the annual average fine particulate matter concentration”. Comment 2: Line 57: How TC is defined? Reference? Line 59: What about wind direction? Line 64: How VC is defined? Reference? Response 2: Thank you for your helpful suggestion. As mentioned in the response to comment 1 in the “General Comments”, we changed “TC” to “atmospheric dilution capability”. Definitions of the atmospheric dilution capability and VC have also been described in the beginning of section 2.4. The wind direction in this study refers to the average wind direction in the mixing layer. For ease of understanding, we modified the expression to “average wind direction in the mixing layer”. Comment 3: Line 81: When this happened? Response 3: Thank

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you for your helpful suggestion. This event happened in 2016, and this information has been added to the paper. Comment 4: Lines 110 – 113: This explanation is not correct. Explain clearly what do you mean. Response 4: Thank you for your helpful suggestion. This section was removed during the revision process. Comment 5: Line 116: What is $-(d\beta/dx)$? Response 5: Thank you for your helpful suggestion. β is the backscatter coefficient, and x is the distance between the lidar and scattering volume (Münkel et al. 2007). $-(d\beta/dx)$ represents the maximum negative gradient value in this paper. Considering that $-(d\beta/dx)$ has no practical meaning in the paper, it has been deleted. Comment 6: Line 128: time resolution not time accuracy Response 6: Thank you for your helpful suggestion. This section was corrected the revision process. The phrase “A time accuracy of 1 h” has been revised to “hourly”. Comment 7: Lines 142 – 144: Why this is an explanation? Height profile instead of “by height” Response 7: Thank you for your helpful suggestion. Although previous studies have shown that the concentration of particulate matter in the mixing layer is basically uniform, there are still large differences in some time periods, especially in time periods with transport effects. Based on your suggestion and that of Reviewer 2, we find it inappropriate to so rashly use the near-surface PM_{2.5} concentration as the concentration in the mixing layer. Because the ceilometer can measure the atmospheric backscattering coefficient, it is possible to obtain the vertical profile of the particles. Therefore, in the revised draft, we analyzed the relationship between the backscattering coefficient at 100 m measured by the ceilometer and the near-surface PM_{2.5} concentration, discussed their correlations in different seasons, and obtained the fitting curves of different seasons. Using these four equations, we obtained the PM_{2.5} concentration at different heights in different seasons. According to this result, we have recalculated the TF in the revised draft. Comment 8: Line 353: How PM_{2.5} concentration is related to photochemical reactions? Response 8: Thank you for your helpful suggestion. Through subsequent analysis, we found that our previous inference was wrong. Considering that this part is not closely related to the topic, it has been deleted from the manuscript. Comment 9: Line 366: concentration column? What do you mean? Technical corrections Indicate

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if there are papers in Chinese. Response 9: Thank you for your helpful suggestion. We apologize for this mistake. We have revised “concentration column” to “column concentration”. References: Münkel, C., N. Eresmaa, J. Räsänen, and A. Karppinen: Retrieval of mixing height and dust concentration with lidar ceilometer, Bound-Lay. Meteorol, 124, 117-128, <https://doi.org/10.1007/s10546-006-9103-3>, 2007.

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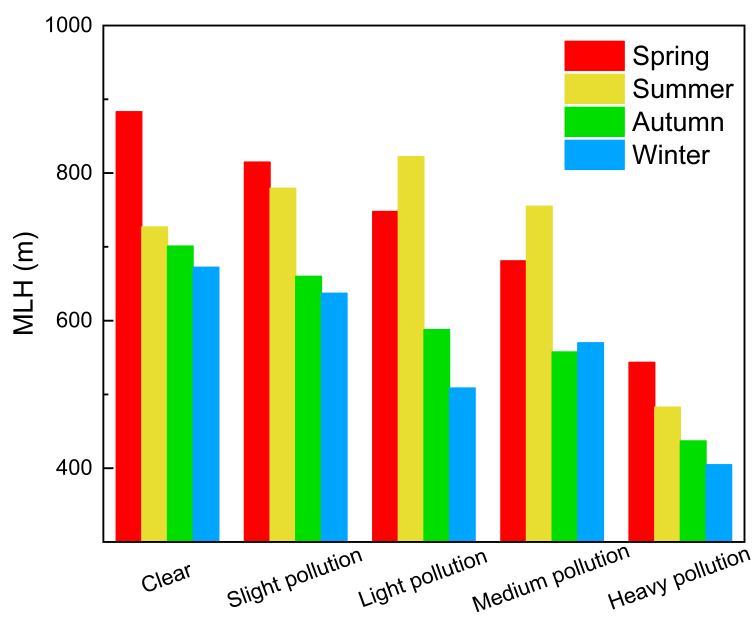


Fig. 1. Mixing layer height under different degrees of pollution in different seasons in Beijing.

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