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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impact of low-pressure systems on winter heavy air pollution in the northwest Sichuan Basin, China" *by* Guicai Ning et al.

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Thank you very much for your constructive comments which help us improve the quality of the manuscript. We have carefully modified the manuscript according to your comments. We hope you will be satisfied with our revisions.

The original comments are copied here in black color.

Author's responses are in blue color.

All changes to the manuscript have been highlighted with red color in the submitted revised manuscript.

General comments

Recently, air pollution issues loom large in most parts of China with the development of the economy. Sichuan Basin is one of the seriously polluted areas. This manuscript analyze the relationships between low-pressure systems and heavy air pollution events, and discuss the physical mechanisms of the heavy air pollution in winter in Sichuan basic. The ten heavy air pollution cases were used to analyse over urban agglomeration during 2006-2012 and 2014-2017 in winter, and the eight of those heavy air pollution cases were affected by a dry low-pressure system at 700hPa. When the urban agglomeration is located in front of the low-pressure system, the weather system is controlled by the warm south wind current, and the unstable condition appears at the top of the boundary layer at the same time. The results will be helpful to improve our understanding on environment studies and fall well within the scope of ACP. The minor revisions on the present manuscript are needed before it can be published as followings.

Response: Thank you very much for your positive comments and nice summary.

Minor comments

1. (P.4) Line 120-122: Why the daily average of PM10 is from the last noon to this noon during 2006-2012, but from the last midnight to this midnight during 2014-2017? Please try to describe the purpose.

Response: Thank you very much for your valuable comments.

The third revision of the “Ambient Air Quality Standard” (AAQS) (GB3095-2012) in China was released on February 29th, 2012, replacing the old “Ambient Air Quality Standard” (AAQS) (GB3095-1996). This new standard (GB3095-2012) began to be carried out gradually since 2013. Thus, the daily average of PM10 was from the last noon to this noon during 2006-2012 based on the new “Ambient Air Quality Standard” (AAQS) (GB3095-2012). However, based on the old “Ambient Air Quality Standard”

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(AAQS) (GB3095-1996), the daily average of PM10 was from the last midnight to this midnight during 2014-2017. These detailed descriptions have been added in the revised manuscript.

The third revision of the “Ambient Air Quality Standard” (AAQS) (GB3095-2012) was released on February 29th, 2012, replacing the old “Ambient Air Quality Standard” (AAQS) (GB3095-1996) and PM2.5 was adopted into the AAQS in China since 2013. The air quality monitoring stations needed to be updated and the data of air pollutants monitored in the three cities existed missing measurement during 2013. Thus, the winter heavy pollution events during 2013 had not been analyzed in this paper. Moreover, the PM10 daily mean concentration from 1 January 2014 to 28 February 2017 refers to the 24-hour average concentration of PM10 from 00:00 BST (Beijing Standard Time, i.e., Coordinate Universal Time (UTC) +8 h) to 24:00 BST on the current day based on the new “Ambient Air Quality Standard” (AAQS) (GB3095-2012). However, based on the old “Ambient Air Quality Standard” (AAQS) (GB3095-1996), the PM10 daily mean concentration from 1 January 2006 to 31 December 2012 refers to the 24-hour average concentration of PM10 from 12:00 BST on the previous day to 12:00 BST on the current day.

2. Fig.2: What time is the result in Fig.2?

Response: Thank you very much for this question. The weather maps at 700 hPa based on ERA-Interim daily data show Fig. 2(a) a trough from event 2 at 20:00 BST on 28 January, 2006 and Fig. 2(b) a low vortex from event 4 at 14:00 BST on 22 December, 2007. The information is added in the figure caption.

Fig. 2 Weather maps at 700 hPa based on ERA-Interim daily data showing (a) a trough from event 2 at 20:00 BST on 28 January, 2006 and (b) a low vortex from event 4 at 14:00 BST on 22 December, 2007. The blue lines are isopleths of geopotential height, the red lines are isotherms and the black arrows are wind vectors. The green dots show the location of the urban agglomeration.

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3. (P8) Line 218: from CASE 3, CASE 4, and CASE 5, the results that is the effect of the low pressure system at 700 hpa causing the value of Boundary Layer height fall. Please describe the reasonableness. We know, the inversion disappears at the higher level, the wind speed increases in the lower layer, the turbulent motion enhancement, and the boundary layer height increases in the boundary layer when the low-pressure system at 700 hPa passed.

Response: Thank you very much for your valuable comments.

First, Sichuan Basin belongs to a low wind speed zone in China due to its deep mountain-basin topography (Fig. 1). The wind speed in the boundary layer is often low and with small change magnitudes (Chen and Xie, 2012; Huang et al., 2017; Wang et al., 2018), and the cold air induced by the transit of low-pressure systems usually can't reach in the ground layer (Fig. 5). As a result, the increased magnitudes of wind speed (Fig. 6b, Fig. 7 c and 7d) and the change magnitudes of temperature (Fig. 6a, Fig. 7a and 7b) were very small in the boundary layer after the low-pressure system at 700 hPa passed. Especially for events 3 and 4, the wind speed decreased and a temperature inversion formed in the boundary layer. Thus, the boundary layer heights in air pollution events 3 and 4 decreased after transit of the low-pressure system.

Second, there was a typo in the sentence of "the boundary layer heights in air pollution events 2, 4, and 6 decreased after transit of the low-pressure system". For event 6 which occurred during the Spring Festival of China, the improvement of its air quality was mainly attributable to the stop of the letting-off of fireworks. As shown in Table 2 and Table 3, the study areas were still located in the front of the low-pressure system and the capacity for dispersion had not yet improved (including the boundary layer height decreased) when the air quality started to improve. Event 6 should be therefore removed in this sentence.

Third, the detailed descriptions about the reasonableness have been added in the revised manuscript according to your comments.

From Fig.6 and Fig.7, we also found some interesting features that the effects of the transit of low-pressure systems at 700 hPa on the meteorological factors within the boundary layer were weak. These features may be related to its deep mountain-basin topography (Fig. 1). Under the effects of the deep mountain-basin topography, wind speed in the boundary layer is often low and with small change magnitudes (Chen and Xie, 2012; Huang et al., 2017; Wang et al., 2018), and cold air induced by the transit of low-pressure systems usually can't reach to the ground layer (Fig. 5). As a result, the increased magnitudes of wind speed (Fig. 6b, Fig. 7 c and 7d) and the change magnitudes of temperature (Fig. 6a, Fig. 7a and 7b) were very small in the boundary layer after the low-pressure system at 700 hPa passed. Especially for events 3 and 4, the wind speed decreased and a temperature inversion formed in the boundary layer. These characteristics of the wind and temperature profiles in the boundary layer were the key factors leading to the evolution of boundary layer height as shown in Table 3.

4. Table 3, Please add instructions on how to calculate the boundary layer height. The values in the table 3 are average results, right?

Response: Yes, the values in the Table 3 are average results. The height of atmospheric boundary layer was obtained from the ERA-Interim daily dataset at the surface with 3 h temporal resolution (00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00, and 21:00 UTC)(http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/). This boundary layer height was defined as the level where the bulk Richardson number, based on the difference between quantities at that level and the lowest model level, reaches the critical value Ricr = 0.25 (Beljaars, 2006). The instructions on how to calculate the boundary layer height have been added in the revised manuscript.

5. CASE 6, the whole pollution process lasts a day, but the relative vorticity of air quality is 02:00 on February 3, but the air quality improvement is 14: 00 on February 3 in Table 2. Please confirm the reasonableness of the boundary layer height.

Response: Thank you very much for your valuable comments. The boundary layer height in event 6 has been confirmed to be correct according to your comments. As shown in the response to the third minor comment, in event 6, which occurred during the Spring Festival of China, the improvement of its air quality was mainly attributable to the stop of the letting-off of fireworks. As shown in Table 2 and Table 3, the study areas were still located in the front of the low-pressure system, and the capacity for dispersion has not yet improved (including the decrease in boundary layer height) when the air quality started to improve. The boundary layer height has not increased during the periods of improving air quality in event 6 because the low-pressure system has not yet passed.

6. CASE 6 and 7, the low-pressure system at 700 hPa throughout all the pollution process, the value of pollutant concentration was decreased quickly, why? due to fireworks only? are other processes affecting pollution ?

Response: Thank you very much for this constructive comment.

First, the effects of fireworks on air quality in Chengdu during Chinese New Year (CNY) from 2013 to 2017 have been investigated. The results showed that time-variations in PM10 concentration during CNY were similar in these five years, even though their meteorological conditions were different. As illustrated in Fig. S4, PM10 concentration increased sharply during the periods of the letting-off of fireworks in CNY, and began to decrease significantly after the letting-off of fireworks stopped. These results were consistent with the changes in particulate pollutant concentrations during CNY in other cities of China (http://www.zhb.gov.cn/gkml/hbb/qt/201702/t20170201_395336.htm). It is a common phenomenon that PM10 concentrations decreased sharply after the letting-off of fireworks stopped during CNY. Additionally, to evaluate the effects of excessive emission about fireworks on air quality in a better way, we analyzed the diurnal variations of the differences of averaged PM10 concentration in Chengdu between during in the periods of the letting-off of fireworks in CNY (defined as the period from 12:00 BST on the Eve of CNY to 12:00 BST on 1 Lunar January) and 5 days before the letting-off fireworks, and between during 5 days after the letting-off of fireworks in CNY and in the periods of the letting-off of fireworks from 2013 to 2017, see Fig. S5. The letting-off of fireworks during CNY was observed to have a significant effect on the air quality in Chengdu. Especially during 5 days after the letting-off of fireworks stopped, production was reduced, factories were shut-down and the numbers of vehicles were lower due to the week-long holiday of CNY (Liao et al., 2017). As a result, the maximum decrease in the magnitude of PM10 concentration was more than 220 μg m-3 and occurred at night from 00:00 BST to 06:00 BST (Fig. S5) which corresponded to the period of the centralized letting-off of fireworks.

Second, unlike in the normal heavy air pollution events, the concentrations of particulate matter began to decrease sharply in event 6 and 7 before the low-pressure system transited over the urban agglomeration (Fig. 8), when the strong temperature inversion still existed above the boundary layer (Fig. 10), the local secondary circulation was still confined in the boundary layer (Fig.9) and the capacity for dispersion has not yet improved significantly (Table 3).

Based on the above analysis results, we conclude that the sharp decreases in PM10 concentration for event 6 and 7 were mainly attributable to the significant reduction in emissions induced by the letting-off of fireworks stopped and the week-long holiday of CNY. The detailed discussions had been added in the revised manuscript.

7. Fig.6, some discussions about the evolution of the PBL height may be also good for a more complete picture.

Response: Thank you very much for this valuable comment. According to your comments, in-depth discussions of Fig. 6 and Fig. 7 were added to explain the evolution of PBL height. The detailed discussions had been made in the response to the third minor comment.

8. CASE 6 and CASE 7, the stronger wind shear at 850 hPa means the stronger dynamic turbulence (Fig. 9). How about the characteristics of the wind profile in the boundary layer (refer to Table 3) ?

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Response: As shown in the response to the third minor comment, wind speeds in the boundary layer is often low and with small change magnitudes (Fig. 6b, Fig. 7 c and 7d). In order to explain the evolution of PBL height in Table 3, the characteristics of the wind profile in the boundary layer have been analyzed and added in the revised manuscript.

9. Please unify the format of the references, such as uppercase and lowercase.

Response: the format of the references have been unified according to your comments.

References

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Please also note the supplement to this comment:

https://www.atmos-chem-phys-discuss.net/acp-2018-61/acp-2018-61-AC2-supplement.pdf

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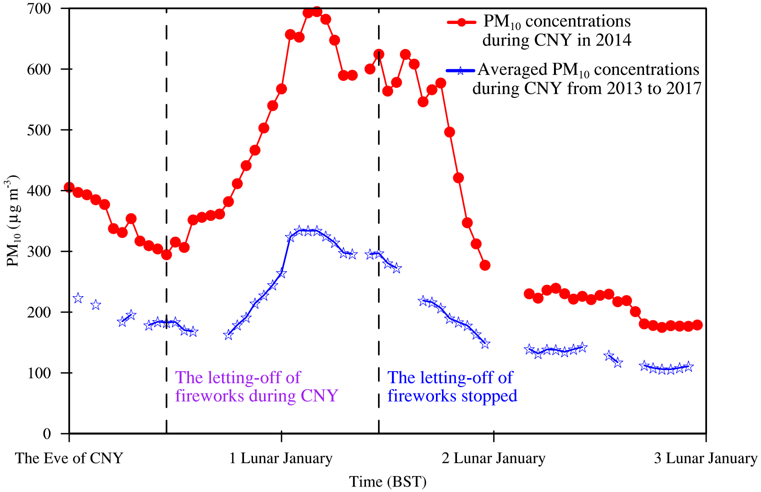

Fig. 1. Fig. S4 The hourly concentrations of PM10 during Chinese New Year (CNY) in 2014 for event 7 (red solid line) and the averaged PM10 concentrations during CNY in five years from 2013 to 2017 (blue solid

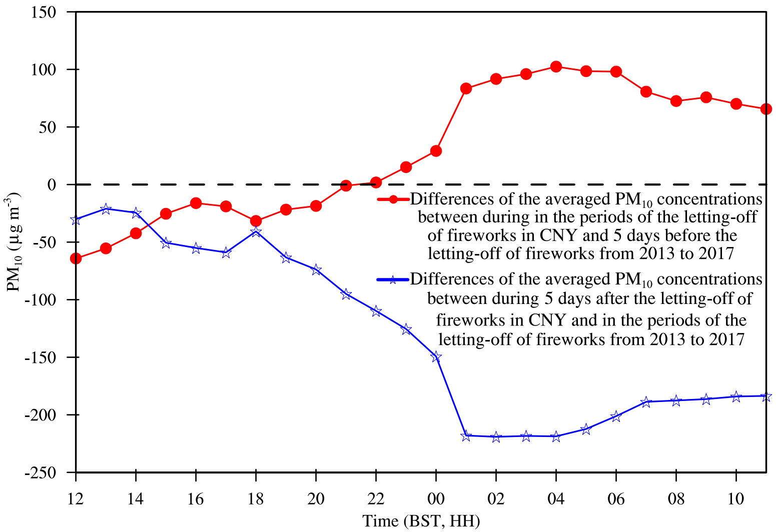

Fig. 2. Fig. S5 The diurnal variations of the differences of averaged PM10 concentration in Chengdu between during in the periods of the letting-off of fireworks in CNY and 5 days before the letting-off firew

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