Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2018-61-AC1, 2018

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.

Guicai Ning et al.

wangsg@cuit.edu.cn

Received and published: 5 July 2018

We would like to thank the referee for his/her valuable comments and suggestions which help us improve the quality of the manuscript. All the comments and concerns raised by the referee have been answered carefully point-by point as below and the corresponding parts in the manuscript have been improved.

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.

This paper conducted the weather analysis of heavy PM10 pollution events in Chengdu, Deyang, and Mianyang in the northwest Sichuan Basin. Authors extracted major weather patterns, including winds, air temperature, BLH, and pressure system during the occurrence of heavy pollution in this region. The Sichuan Basin is one of several heavily contaminated regions across China and has a typical geographic terrain and persistent weather system. It is necessary to summarize the influences of such the typical terrain and weather system on air pollution prediction in the Basin. To be published in ACP, the paper needs to be improved by addressing following points.

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

General comments

1. From my understanding, authors used measured met data in their weather analysis. They highlighted a dry low-pressure system at 700 mb, a warm southerly wind flow, and temperature inversion above the ABL as favorable weather pattern contributing to heavy pollution in their study area. A question might be rasied: what is the background weather pattern in Sichuan Basin? Perhaps a better way to present their analysis is to show anomalies of these met variables from their respective long-term means during the deteriorating and improving air quality, instead of real-time measurements, such as figures 2, 4, 5, 8, 9, etc. For example, many readers might not understand what fig.2 is all about because we cannot figure out that wind vectors in this figure are not prevailing winds vectors and if geopotential heights represent the background GH.

Response: Thank you very much for your constructive comments. In order to present our analysis in a better way, the anomalies of geopotential heights and wind vectors at 700 hPa, the anomalies of west-to-east vertical cross-section of 24-hour temperature change and wind vectors (synthesized by u and w), and the anomalies of temperature vertical profiles were analyzed in the revised manuscript.

To explore the differences between these low-pressure systems and the background of winter atmospheric circulation over there, the anomalies of wind vectors and geopotential heights at 700 hPa were calculated (Fig. S1). The calculation method is as follows: the averaged wind vectors and geopotential heights at 700 hPa during periods of deteriorating air quality in the above eight events subtracted from their winter mean values from 1 January 2006 to 31 December 2012 and from 1 January 2014 to 28 February 2017. As illustrated in Fig. S1, the anomalies of geopotential heights were negative in the northwest of the urban agglomeration during periods of deteriorating air quality in these heavy air pollution events. As a result, this urban agglomeration was located in front of an anomalous cyclone and was controlled by a strong southerly anomaly wind (Fig. S1).

Additionally, the anomalies of west-to-east vertical cross-section of 24-hour temperature change and wind vectors (synthesized by u and w) (Fig. S2), and the anomalies of temperature vertical profiles (Fig. S3) were also analyzed to further investigate the influencing mechanism of low-pressure system on heavy air pollution events. Fig. S2 shows that anomalous warming appeared above the atmospheric boundary layer, while anomalous cooling was observed within the boundary layer when the urban agglomeration was located in front of low-pressure system and was controlled by a southerly warm air flow at 700 hPa. This vertical structure of the anomalies of 24-hour temperature change led to an increase in the stability of the lower troposphere. As illustrated in Fig. S3, the positive anomalies of temperature between 1500 m and 3000 m above the ground level increased significantly with height. The maximum value of positive anomalies appeared at about 3000 m and was up to 9 °C. These features revealed that a strong temperature inversion existed above the boundary layer and suppressed the vertical exchange of atmosphere. As a result, the anomalous secondary circulation was also confined in the boundary layer, with its center located at about 925 hPa (Fig. S2). These results of anomalies analysis were consistent with the above analysis for real-time data, and further proved that the influencing mechanism of low-pressure system on heavy air pollution events is credible.

2. Likewise, Table 2 presents relative vorticity at 700 hPa showing positive in deteriorating air quality but seems not telling readers how these relative vorticities were calculated. Are these departure from the mean averaged over all deteriorating and improving air quality events? Similarly, how were positive and negative BLH, LTS, and MWS in Table 3 estimated?

Response: Thank you very much for your valuable comments. The values of relative vorticity at 700 hPa in Table 2 and the values of BLH, LTS, and MWS in Table 3 were not departure from the mean averaged over all deteriorating and improving air quality events. They all were estimated in each of the eight heavy air pollution events. It is considered as a better way to characterize the transits of low-pressure systems for each heavy air pollution event and to estimate the impacts of low-pressure systems on the dispersion capacity of air pollutants in the lower troposphere.

According to your comments, the detailed descriptions of the captions for these met variables in Table 2 and Table 3 have been revised as follows:

Table 2. Relative vorticity at 700 hPa during the periods of deteriorating and improving air quality in each of the eight heavy air pollution events.

Table 3. Height of the atmospheric boundary layer (BLH), lower tropospheric stability (LTS), and mean wind speed (MWS) in the lower troposphere during periods of deteriorating air quality in each of the eight heavy air pollution events, and the differences of them between periods of improving and deteriorating air quality in each event.

3. Authors constructed an index based on the results presented in Table 3 to predict the occurrence of heavy air pollution. To demonstrate the usefulness of this index, authors need to apply this index to several independent pollution events and see if the index could successfully forecast heavy pollution in the study area.

Response: Thank you very much for your valuable comments.

First, the index of mean wind speed (MWS) in the lower troposphere was constructed based on the concept of ventilation coefficient, which has been widely used to measure the capability of air pollutants' dispersion in the eastern plains of China (Deng et al., 2014; Lu et al., 2012; Tang et al., 2015). Thus, the MWS has a certain physical meaning and rationality. The construction basis and specific method of MWS have been added in the revised manuscript.

Sichuan Basin belongs to a low wind speed zone in China due to its deep mountain-basin topography, and the wind speed in the mixing layer is often low and with small change magnitudes (Chen and Xie, 2012; Huang et al., 2017; Wang et al., 2018). For analyzing air quality in Sichuan Basin, the meteorological conditions in the lower troposphere that can reflect ventilation should be considered. To quantitatively evaluate the horizontal dispersion of air pollutants in Sichuan Basin, the mean wind speed (MWS) in the lower troposphere was constructed based on the concept of ventilation coefficient (VC is a product of mixing layer height multiplied by average wind speed through the mixing height). In the eastern plains of China, the ventilation coefficient has been widely used to measure the capability of air pollutants' dispersion (Deng et al., 2014; Lu et al., 2012; Tang et al., 2015).

Second, the usefulness of this new index (WMS) have been demonstrated to be good by several independent pollution events. As shown in Table 3, the values of this new index (MWS) of these six events (1–5 and 8) increased significantly after the low-pressure systems had transited the urban agglomeration, and the air quality of these six events improved significantly. For the events 6 and 7 which occurred during the Spring Festival, the improvement of their air quality was mainly attributable to the stop of the letting-off of fireworks. These results revealed that the new index could successfully forecast heavy pollution in the study area.

4. Discussions on Figs. 4 and 8. Discussions and interpretations of these two figures could be improved by clearly describing the lifespan of the low-pressure system and other met conditions during the pollution event. For instance, Fig. 4a shows the beginning of weather pattern causing air pollution and Fig. 4d illustrates the met conditions

in the end of pollution event.

Response: Thank you very much for your valuable comments. This manuscript have been revised according your comments.

Other comments

1. Line 123, visibility, how is visibility measured? I don't think visibility helps discussions.

Response: We agree with your comments, and the visibility has been removed in our revised manuscript.

2. Line 143, not clear wind speed on the ground. In terms of no-slip condition, wind speed at the ground surface is zero. Or the wind speed at 10 m height? How many levels from the ground surface to 700 mb? V with an upper arrow is wind vector. If Eq 3 denotes wind speed, this upper arrow should be removed.

Response: Thank you very much for your valuable comments. In line 143, the new index (MWS) was calculated based on sounding data which were measured at Wenjiang station (see Fig. 1) in Chengdu. Thus, "Wind speed on the ground" has been revised to "Wind speed at the ground surface". The vertical levels from the ground surface to 700 mb were not fixed. In general, the number of vertical levels was more than six. The V in Eq 3 denotes wind speed, and thus the upper arrow of V has been removed in the revised manuscript.

3. Line 154, any criteria being used to define a "persistent" pollution event?

Response: A "persistent" pollution event was defined by two or more consecutive days with daily PM10 mean concentration $\geq 250\ \mu$g m-3. Moreover, this criteria being used to define a "persistent" pollution event has been added in the revised manuscript.

A "persistent" pollution event was defined by two or more consecutive days with daily PM10 mean concentration $\geq 250\ \mu$g m-3, which is reported to be harmful to the health of local residents (Chow et al., 2006; Guo et al., 2016c; Langrish et al., 2012; Lim et al., 2012).

4. Line 172, in front of low-pressure, better say east or west of the low-pressure system.

Response: Agreed and corrected in the revised manuscript.

5. Line 214, “being” should be “were”

Response: Agreed and corrected in the revised manuscript.

References

Chen, Y., and Xie, S.: Temporal and spatial visibility trends in the Sichuan Basin, China, 1973 to 2010[J], Atmos. Res., 112, 25-34, https://doi.org/10.1016/j.atmosres.2012.04.009, 2012.

Chow, J. C., Watson, J. G., Mauderly, J. L., Costa, D. L., Wyzga, R. E., Vedal, S., Hidy, G. M., Altshuler, S. L., Marrack, D., Heuss, J. M., Wolff, G. T., Arden Pope Iii, C., and Dockery, D. W.: Health effects of fine particulate air pollution: Lines that connect[J], J. Air Waste Manage. Assoc., 56, 1368-1380, https://doi.org/10.1080/10473289.2006.10464545, 2006.

Deng, T., Wu, D., Deng, X., Tan, H., Li, F., and Liao, B.: A vertical sounding of severe haze process in Guangzhou area[J], Sci. China Earth Sci., 57, 2650-2656, 10.1007/s11430-014-4928-y, 2014.

Guo, Y., Zeng, H., Zheng, R., Li, S., Barnett, A. G., Zhang, S., Zou, X., Huxley, R., Chen, W., and Williams, G.: The association between lung cancer incidence and ambient air pollution in China: A spatiotemporal analysis[J], Environ. Res., 144, 60-65, https://doi.org/10.1016/j.envres.2015.11.004, 2016.

Huang, Q., Cai, X., Song, Y., and Zhu, T.: Air stagnation in China (1985–2014): climatological mean features and trends[J], Atmos. Chem. Phys., 17, 7793-7805, https://doi.org/10.5194/acp-17-7793-2017, 2017.

Langrish, J. P., Li, X., Wang, S., Lee, M. M. Y., Barnes, G. D., Miller, M. R., Cassee, F. R., Boon, N. A., Donaldson, K., Li, J., Li, L., Mills, N. L., Newby, D. E., and Jiang, L.: Reducing personal exposure to particulate air pollution improves cardiovascular health in patients with coronary heart disease[J], Environ Health Perspect., 120, 367-372, https://doi.org/10.1289/ehp.1103898, 2012.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., Al-Mazroa, M. A., Amann, M., Anderson, H. R., Andrews, K. G., Aryee, M., Atkinson, C., Bacchus, L. J., Bahalim, A. N., Balakrishnan, K., Balmes, J., Barker-Collo, S., Baxter, A., Bell, M. L., Blore, J. D., Blyth, F., Bonner, C., Borges, G., Bourne, R., Boussinesq, M., Brauer, M., Brooks, P., Bruce, N. G., Brunekreef, B., Bryan-Hancock, C., Bucello, C., Buchbinder, R., Bull, F., Burnett, R. T., Byers, T. E., Calabria, B., Carapetis, J., Carnahan, E., Chafe, Z., Charlson, F., Chen, H., Chen, J. S., Cheng, A. T.-A., Child, J. C., Cohen, A., Colson, K. E., Cowie, B. C., Darby, S., Darling, S., Davis, A., Degenhardt, L., Dentener, F., Des Jarlais, D. C., Devries, K., Dherani, M., Ding, E. L., Dorsey, E. R., Driscoll, T., Edmond, K., Ali, S. E., Engell, R. E., Erwin, P. J., Fahimi, S., Falder, G., Farzadfar, F., Ferrari, A., Finucane, M. M., Flaxman, S., Fowkes, F. G. R., Freedman, G., Freeman, M. K., Gakidou, E., Ghosh, S., Giovannucci, E., Gmel, G., Graham, K., Grainger, R., Grant, B., Gunnell, D., Gutierrez, H. R., Hall, W., Hoek, H. W., Hogan, A., Hosgood, H. D., Hoy, D., Hu, H., Hubbell, B. J., Hutchings, S. J., Ibeanusi, S. E., Jacklyn, G. L., Jasrasaria, R., Jonas, J. B., Kan, H., Kanis, J. A., Kassebaum, N., Kawakami, N., Khang, Y.-H., Khatibzadeh, S., Khoo, J.-P., Kok, C., Laden, F., Lalloo, R., Lan, Q., Lathlean, T., Leasher, J. L., Leigh, J., Li, Y., Lin, J. K., Lipshultz, S. E., London, S., Lozano, R., Lu, Y., Mak, J., Malekzadeh, R., Mallinger, L., Marcenes, W., March, L., Marks, R., Martin, R., McGale, P., McGrath, J., Mehta, S., Memish, Z. A., Mensah, G. A., Merriman, T. R., Micha, R., Michaud, C., Mishra, V., Hanafiah, K. M., Mokdad, A. A., Morawska, L., Mozaffarian, D., Murphy, T., Naghavi, M., Neal, B., Nelson, P. K., Nolla, J. M., Norman, R., Olives, C., Omer, S. B., Orchard, J., Osborne, R., Ostro, B., Page, A., Pandey, K. D., Parry, C. D. H., Passmore, E., Patra, J., Pearce, N., Pelizzari, P. M., Petzold, M., Phillips, M. R., Pope, D., Pope, C. A., Powles, J., Rao, M., Razavi, H., Rehfuess, E. A., Rehm, J. T., Ritz, B., Rivara, F. P., Roberts, T., Robinson, C., Rodriguez-Portales, J. A., Romieu, I., Room, R., Rosenfeld, L. C., Roy, A., Rushton, L., Salomon, J. A., Sampson, U., Sanchez-Riera, L., Sanman, E., Sapkota, A., Seedat, S., Shi, P., Shield, K., Shivakoti, R., Singh, G. M., Sleet, D. A., Smith, E., Smith, K. R., Stapelberg, N. J. C., Steenland, K., Stöckl, H., Stovner, L. J., Straif, K., Straney, L., Thurston, G. D., Tran, J. H., Van Dingenen, R., van Donkelaar, A., Veerman, J. L., Vijayakumar, L., Weintraub, R., Weissman, M. M., White, R. A., Whiteford, H., Wiersma, S. T., Wilkinson, J. D., Williams, H. C., Williams, W., Wilson, N., Woolf, A. D., Yip, P., Zielinski, J. M., Lopez, A. D., Murray, C. J. L., and Ezzati, M.: A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010[J], Lancet., 380, 2224-2260, https://doi.org/10.1016/S0140-6736(12)61766-8, 2012.

Lu, C., Deng, Q.-h., Liu, W.-w., Huang, B.-l., and Shi, L.-z.: Characteristics of ventilation coefficient and its impact on urban air pollution[J], J. Cent. South Univ., 19, 615-622, 10.1007/s11771-012-1047-9, 2012.

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[J], Atmos. Chem. Phys., 15, 743-750, https://doi.org/10.5194/acp-15-12667-2015, 2015. Wang, X., Dickinson, R. E., Su, L., Zhou, C., and Wang, K.: PM2.5 pollution in China and how it has been exacerbated by terrain and meteorological conditions[J], Bull. Am. Meteorol. Soc., 99, 105-119, http://dx.doi.org/10.1175/BAMS-D-16-0301.1, 2018.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2018-61/acp-2018-61-AC1-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-61, 2018.

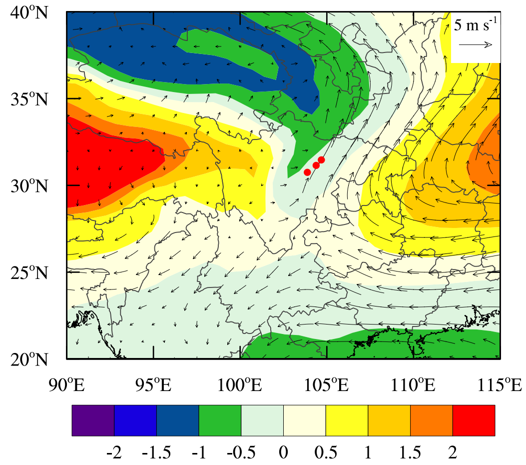

Fig. 1. Fig. S1 The anomalies of geopotential heights (shading, units: dagpm) and wind vectors (black arrows) at 700 hPa (the averaged wind vectors and geopotential heights at 700 hPa during periods of deteri

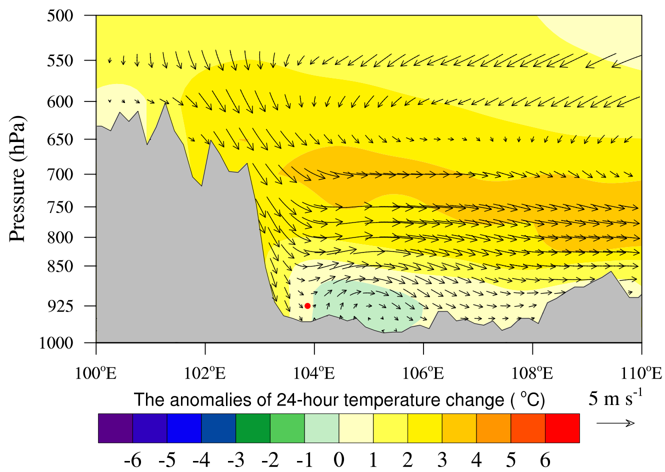

Fig. 2. Fig. S2 West-to-east vertical cross-section of the anomalies of 24-hour temperature change and wind vectors (synthesized by u and w) through the most polluted area (30.75° N) (the averaged 24-hour tem

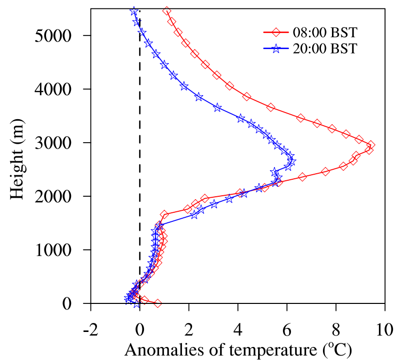

Fig. 3. Fig. S3 Vertical profiles of temperature anomalies at Wenjiang station (30.75° N, 103.875° E) measured by radiosonde (the averaged temperature during periods of deteriorating air quality in the eight