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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Dust deposition and ambient PM_{10} concentration in central Asia: Spatial and temporal variability" *by* Xiao-Xiao Zhang et al.

Xiao-Xiao Zhang et al.

zhangxx@ms.xjb.ac.cn

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We thank anonymous referee #1 for his/her supportive and thoughtful remarks.

Major comments

Question 1: The title of the paper is "Dust deposition and ambient PM10 concentration in central Asia: Spatial and temporal variability", while the paper only focus on Xinjiang province, China. However, the Central Asia is generally referred to the core region of the Asian continent which usually including Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan in the modern context. The title of the paper, therefore, should be reconsidered regarding study region and avoid possible confusion.

Reply: We have revised the paper to indicate that Xinjiang Province is located in east Asia. While Xinjiang Province is technically located at the western fringe of east Asia, the geography of the Province is very similar to central Asia. The title has been changed to "Dust deposition and ambient PM10 concentration in northwest China: Spatial and temporal variability".

Question 2: In the Introduction, the author cites Simonson (1995) and Pye (1987) to show that dust plays an important role in climate change and environmental quality. The paper cited here, which is published in 1990s and relatively outdated. Since then, the dust deposition data have been enriched, as listed in the Table.1. What is the current circumstance of dust deposition research? What is still unknown? I would suggest author include more recent paper in this field to strengthen the introduction section.

Reply: New citations have been added to the Introduction to support the discussion of the importance of dust in climate change and environmental quality. Citations added to the Introduction include:

Chen, S., Huang, J., Zhao, C., Qian, Y., Leung, L. R., and Yang, B.: Modeling the transport and radiative forcing of Taklimakan dust over the Tibetan Plateau: A case study in the summer of 2006, J. Geophys. Res. Atmos., 118, 797–812.

Chen, S., Zhao, C., Qian, Y., Leung, L. R., Huang, J., Huang, Z., Bi, J., Zhang, W., Shi, J., Yang, L., Li, D., and Li, J.: Regional modeling of dust mass balance and radiative forcing over East Asia using WRF-Chem, Aeolian Res., 15, 15–30.

Huang, J., T. Wang, W. Wang, Z. Li, and H. Yan, 2014: Climate effects of dust aerosols over East Asian arid and semiarid regions, Journal of Geophysical Research: Atmospheres, 119, 11398–11416, doi:10.1002/2014JD021796.

Huang, J., Fu, Q., Su, J., Tang, Q., Minnis, P., Hu, Y., Yi, Y., and Zhao, Q.: Taklimakan dust aerosol radiative heating derived from CALIPSO observations using the

Fu-Liou radiation model with CERES constraints, Atmos. Chem. Phys., 9, 4011–4021, doi:10.5194/acp-9-4011-2009, 2009.

Lin, Y., and Feng, J.: Aeolian dust contribution to the formation of alpine soils at Amdo (Northern Tibetan Plateau), Geoderma, 259-260, 104-115, doi:10.1016/j.geoderma.2015.05.012, 2015.

Shao Y P.: Physics and modeling of wind erosion, Dordrecht, Kluwer Academic Publishers, 225-278, 2000.

Varga, G., Cserháti, C., Kovács, J., and Szaliai, Z.: Saharan dust deposition in the Carpathian Basin and its possible effects on interglacial soil formation, Aeolian Research, 22, 1-12, doi:10.1016/j.aeolia.2016.05.004, 2016.

Zheng, Y., Zhao, T., Che, H., Liu, Y., Han, Y., Liu, C., Xiong, J., Liu, J., and Zhou, Y.: A 20-year simulated climatology of global dust aerosol deposition, Science of The Total Environment, 557-558, 861-868, doi:10.1016/j.scitotenv.2016.03.086 , 2016.

Question 3: The paper did not provide any discussion regarding dust source for deposition and PM10 in this region and thus the analysis was based on the unstated assumption that the only two dust sources are Taklimakan desert and Gurbantunggut desert. However, this might not be the case all the time, since long-range transport of dust from central Asia could also contribute to the dust deposition in Xinjiang province, despite the two large local dust sources. Without the analysis of dust source in the first place, the attempt to explain the spatial and temporal characteristic of dust deposition and ambient PM10 seems unwarranted. I would recommend the authors give a brief discussion of dust sources in the revised manuscript.

Reply: A brief discussion on dust sources in central and east Asia has been added to Section 3.4 to include the following: Deserts in central Asia are a source of atmospheric mineral dust (Miller-Schulze et al., 2015). Under the strong westerly circulation, atmospheric dust can be transported a few hundred kilometers to the east and

be deposited through wet scavenging and dry settling (Shao, 2000; Chen et al., 2014). Despite the Taklimakan and Gurbantunggut Deserts being local sources of dust in Xinjiang Province, long-range transport of dust from the central Asian Aralkum, Karakum, Caspian and Kyzylkum Deserts (Indoitu, et al., 2012) could also contribute to the dust deposition and ambient PM10 concentration in neighboring Xinjiang Province. Since the 1980s, the Aralkum Desert in Uzbekistan and Kazakhstan has become one of world's youngest deserts and a potential source of salt dust in east Asia (Indoitu, et al., 2012; Groll, et al., 2013; Opp, et al., 2016).

Question 4: In this study only one factor are considered and examined in Section 3.4, which is dust days, while the subtitle of the section mentioned "factors." Although dust event might be of the dominant factor, other factors should also be taken in account or at least be mentioned in the analysis. For instance, it is widely recognized that the wind speed and direction could be very influential to dust transport. In the manuscript, although data of wind speed and direction is mentioned in the section 2.2(Line 31), the analysis regarding this data was not provided in the manuscript. In addition to the wind, precipitation could also be a controlling factor. Further analysis of the other factors should also be provided in the manuscript.

Reply: We have considered precipitation and wind speed as climatic factors affecting PM10 concentration and dust deposition. The linkage between precipitation and wind speed and PM10 concentration and dust deposition are discussed in first and second paragraph of Section 3.4 in revised manuscript.

Minor comments

Question 1: Page 1, Line 17 : : :(particulate matter 10 m in aerodynamic diameter): : : Please rephrase the sentence in the parentheses.

Reply: Revised as "particulate matter in aerodynamic diameter $\leq$10 μm".

Question 2: Page 1, Line 26-27 : : :The arid climate likely influenced the high dust

deposition and PM10 concentration in the region: : : This sentence is uncorroborated by the manuscript.

Reply: This sentence was deleted.

Question 3: Page 1, Line 29 This study suggests that sand storms are a major factor affecting: : : Please change “are” to “is”.

Reply: This sentence was revised as “This study suggests that sand storm is a major factor affecting the temporal variability and spatial distribution of dust deposition in northwest China.”

Question 4: Page 2, Line 7-8: An understanding of atmospheric dust sources, emissions, and deposition is therefore essential to improve regional air quality. This sentence is not logically related to the information given before it. The discussion prior to it can’t lead to the conclusion that this kind understanding can be helpful to improve regional air quality.

Reply: This sentence was revised as “An understanding of atmospheric dust sources, emissions, and deposition is therefore essential to improve our knowledge of dust impact on regional air quality”.

Question 5: Page 2, Line 30 : : : that spans the 21st century. The sentence is overstated, since only 2000-2013 was analyzed in the study, which certainly did not span 21st century.

Reply: The description of “that spans the 21st century” has been deleted.

Question 6: Page 3, Line 31 Daily meteorological data, including surface wind speed and direction : : : Even though the surface wind speed and direction are mentioned in the data description, the analyses relating to them are not given in the manuscript.

Reply: This sentence was revised as “Daily meteorological data including dust days, surface wind speed and precipitation, were collected from the China Meteorological

Administration”. We do include information regarding wind speeds in Section 3.4 in revised manuscript.

Question 7: Page 5, Line 2 This industrial belt includes Changji and Urumqi. High dust deposition in the industrial belt was due to industry, coal burning and vehicle exhaust. This explanation is possible, with the anthropogenic source of dust is considered. Please further strengthen this conjecture with relevant papers. In addition to the Changji and Urumqi, Hami, which is also a city located in northern Xinjiang, also had a high dust deposition value as depicted in Figure.2. Why?

Reply: We revised it as “This industrial belt includes Changji and Urumqi. High dust deposition in the industrial belt was due to local industry, coal burning and vehicle exhaust (Matinmin and Meixner, 2011; Zhang et al., 2014b). Therefore, the mixing of the anthropogenic aerosol with transported desert dust contributed to deposition in Changji and Urumqi (Li, et al., 2008).” New references have been included in this section as:

Li, J., Zhuang, G., Huang, K., Lin, Y., Xu, C., and Yu, S.: Characteristics and sources of air-borne particulate in Urumqi, China, the upstream area of Asia dust, Atmospheric Environment, 42(4), 776-787, doi:10.1016/j.atmosenv.2007.09.062, 2008.

Mamtimin, B., and Meixner, F.: Air pollution and meteorological processes in the growing dryland city of Urumqi (Xinjiang, China), Science of the Total Environment, 409, 1277-1290, doi:10.1016/j.scitotenv.2010.12.010, 2011.

Zhang, X.X., Chen, X., Guo, Y.H., Wang, Z.F., Liu, L.Y., Paul, C., Li, S.Y., and Pi, H.W.: Ambient TSP concentration and dustfall variation in Urumqi, China, Journal of Arid Land, 6(6), 668-677, doi:10.1007/s40333-014-0069-6, 2014b.

Hami is located in eastern Xinjiang Province. The city has a population of over 0.5 million and lacks industry characteristic of Changji and Urumqi. The high dust deposition at Hami is due to dust storms originating in the Turpan Depression, not industry.

Question 8: Page 6, Line 17 .. data suggest that particulate matter is the main air pollutant in Xinjiang. The PM10 constituent accounted for 48.7% and 48.2% of the API in the Kuytun and Urumqi. It is necessarily suggest the particulate matter is the main air pollutant?

Reply: Yes! We re-checked the API daily data of the six selected stations (see section 3.3). “The PM10 constituent accounted for 48.7%, 78.4%, 96.2%, 91.5%, 99.5%, and 99.6% of the API in the respective above cities.” As for Kuytun, excellent air quality (API<50) accounted 51.3% (Fig.8), therefore, particulate matter is the main air pollutant.

Question 9: Page 6, Line 31-Page 7, Line 1-11 This decline in dust deposition or PM10 concentration could be due to a decrease in frequency of severe dust days versus frequency of dust days from 2000 to 2013 in the region: : :. Nevertheless, in examining the relationship between average annual dust days and dust deposition or PM10 concentration across stations, the frequency of dust days was closely related to dust deposition (R2=0.93) (Fig.10) and ambient PM10 concentration (R2=0.89) (Fig.11). There was a significant 10 increase in dust deposition (7.91 t km-2 day-1) and PM10 concentration (2.06 g m-3 day-1) associated with an increase in dust days. In this paragraph, the relationship between dust deposition/PM10 concentration and dust day frequency at each station is investigated. The result, admittedly, is evident show there is a connection. According to the definition of different dust days, which can be found in section 2.2(page4, line1-5), blowing dust and dust storm constitutes days in which dust is emitted at the station, while dust-in-suspension constitutes days in which dust is not emitted at the station. However, the scatter plot fails to distinguish the inherent difference between these three dust events. Moreover, since the dust is not emitted at this station during dust-in-suspension days, the conclusion given by author, that there appeared to be a close association between frequency of dust-in-suspension events and dust deposition, become unconvincing.

Reply: We examined trends in dust-in-suspension, blowing dust, and dust storms from

2000-2013. Note that there was no trend in blowing dust or dust storms from 2000 to 2013. Over this same time period, there was a significant decrease in frequency of dust-in-suspension. Although we did not show these trends in the paper, the trend for fewer dust-in-suspension coincides with the decline in dust deposition and PM10 concentration from 2000 to 2013. Based upon similarity in trends, there appeared to be some connection between dust-in-suspension and dust deposition.

Question 10: In page 10, Figure 2, please add units for dust deposition in the legend within the figure. In page 17, Figure 5, please add units for PM10 concentration in the legend within the figure.

Reply: We added units for dust deposition and PM10 concentration in Figure 2 and Figure 5 in revised manuscript.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2016-512/acp-2016-512-AC1-supplement.pdf

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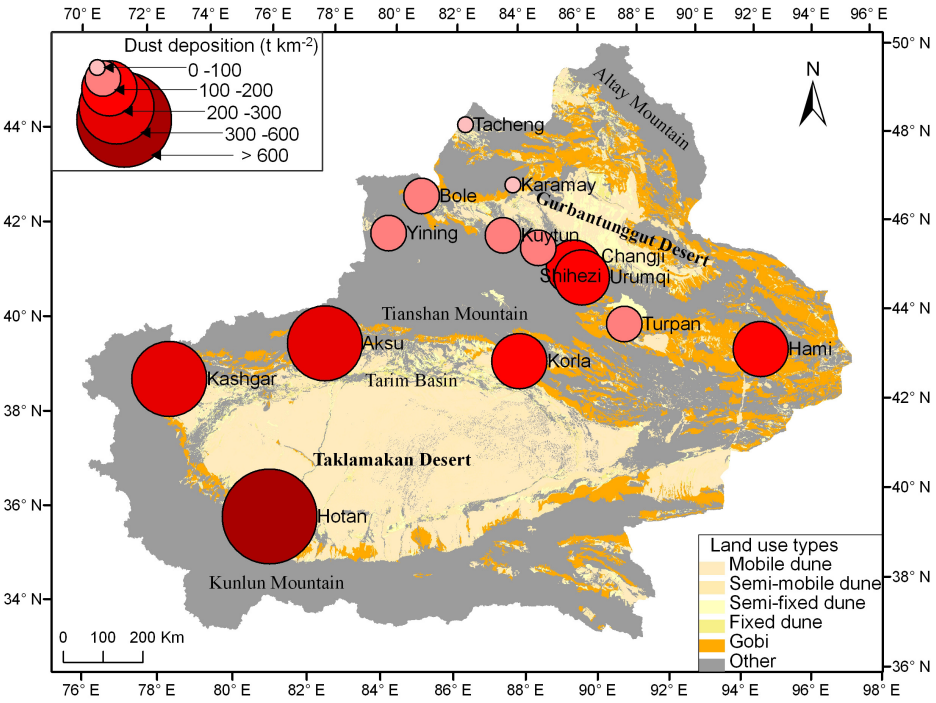

Fig. 1. Figure 2. Annual average dust deposition reported at 14 stations in Xinjiang Province from 2000-2013. Land use types across the province are identified according to Wang et al. (2005).

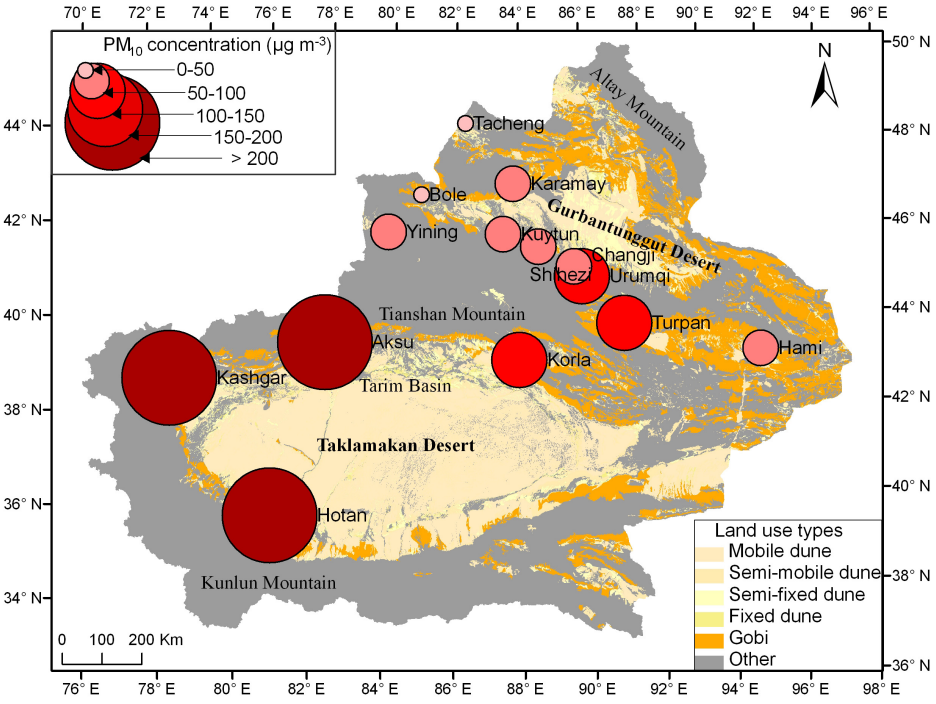

Fig. 2. Figure 5. Annual average PM10 concentration reported for 14 stations in Xinjiang Province from 2000-2013. Land use types are identified across the province according to Wang et al., 2005.