

Interactive comment on “Dust deposition and ambient PM₁₀ concentration in central Asia: Spatial and temporal variability” by Xiao-Xiao Zhang et al.

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We thank anonymous referee #2 for his/her supportive and thoughtful remarks.

Anonymous Referee #2

Comments

Question 1: P. 2, l. 10-11: The authors motivate their study by stating that Pye (1987) suggested a lack in reliable dust deposition data. This reference is almost 30 years old. I would suspect that more data has been collected since. In fact, the authors list several newer references for data on dust deposition in their Table 1. In my opinion a more comprehensive overview and discussion on currently available dust deposition

C1

data is needed.

Reply: We have revised the paper with a more comprehensive overview and discussion on currently available dust deposition data in the Introduction (Page 2, Line 11-25). New citations have been added to the Introduction to support the above discussion. Citations added to the Introduction include:

Duce, R.A., Liss, P.S., Merrill, J.T., Atlas, E.L., Buat-Menard, P., Hicks, B.B., Miller, J.M., Prospero, J.M., Arimoto, R., Church, T.M., Ellis, W., Galloway, J.N., and Hansen, L.: The atmospheric input of trace species to the world ocean, *Global Biogeochem. Cycles*, 5, 193-259, doi: 10.1029/91GB01778, 1991.

Ginoux, P., Chin, M., Tegen, I., Prospero, J.M., Holben, B., Dubovik, O., and Lin, S.: Sources and distributions of dust aerosols simulated with the GOCART model, *Journal of Geophysical Research*, 106(17), 20255-20273, doi: 10.1029/2000JD000053, 2001. Ginoux, P., Prospero, J.M., Gill, T.E., Hsu, N.C., and Zhao, M.: Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products, *Reviews of Geophysics*, doi: 10.1029/2012RG000388, 2012.

Huneeus, N., Schulz, M., Balkanski, Y., Griesfeller, J., Prospero, J., Kinne, S., Bauer, S., Boucher, O., Chin, M., Dentener, F., Diehl, T., Easter, R., Fillmore, D., Ghan, S., Ginoux, P., Grini, A., Horowitz, L., Koch, D., Krol, M. C., Landing, W., Liu, X., Mahowald, N., Miller, R., Morcrette, J.J., Myhre, G., Penner, J., Perlwitz, J., Stier, P., Takemura, T., and Zender, C. S.: Global dust model intercomparison in AeroCom phase I, *Atmos. Chem. Phys.*, 11, 7781-7816, doi:10.5194/acp-11-7781-2011, 2011.

Mahowald, N.M., Kohfeld, K.E., Hansson, M., Balkanski, Y., Harrison, S.P., Prentice, I.C., Michael, S., and Rodhe, H.: Dust sources and deposition during the last glacial maximum and current climate: a comparison of model results with paleodata from ice cores and marine sediments, *J. Geophys. Res.* 104, 15895-916, 1999.

C2

Mahowald, N.M., Engelstaedter, S., Luo, C., Sealy, A., Artaxo, P., Benitez-Nelson, C., Bonnet, S., Chen, Y., Chuang, P.Y., Cohen, D.D., Dulac, F., Herut, B., Johansen, A.M., Kubilay, N., Losno, R., Maenhaut, W., Paytan, A., Prospero, J.M., Shank, L.M., and Siefert, R.L.: Atmospheric iron deposition: global distribution, variability, and human perturbations, *Annu. Rev. Marine. Sci.*, 1, 245-278, doi: 10.1146/annurev.marine.010908.163727, 2009.

Prospero J.M.: Long-range transport of mineral dust in the global atmosphere: impact of African dust on the environment of the southeastern United States, *Proc. Natl. Acad. Sci.* 96, 3396-3403, doi: 10.1073/pnas.96.7.3396, 1999.

Zhang, X.Y., Arimoto, R., and An, Z.S.: Dust emission from Chinese desert sources linked to variations in atmospheric circulation, 102(D23), 28041-28047, doi:10.1029/97JD02300, 1997.

Question 2: P. 2, l. 25-26: What are the processes governing dust emissions, transport, and deposition in Asia? And what data was used by Shao et al. (2011) and Groll et al. (2013) as the basis of their findings (note that the reference should be Shao et al. (2011) rather than Shao (2011))? I think these questions need more attention in the paper, especially to support interpretation of the spatial and temporal variability observed in Xinjiang Province. How is the data presented in the manuscript on hand different/better than the data used in earlier studies? What drives the trends and spatial variability? These questions appear mostly unanswered in the present paper.

Reply: The Eurasian atmospheric circulation is governing dust emissions, transport, and deposition in central Asia. Compared with earlier studies, the data presented in this manuscript were observed at 14 environmental stations in Xinjiang, northwest China during 2000-2013 with a monthly temporal resolution, which would be helpful to improve our knowledge of dust impact on regional air quality. The 14-year continuous deposition data was collected according to Chinese national standards, which fills the gap in the central Asian arid region where observations are scarce. The atmospheric

C3

circulation such as cyclones (Shao et al., 2013) primarily drives and influences the trends and spatial variability of dust deposition and ambient PM10 concentration. We added this discussion in Section 3.4.

Question 3: Are the 14 environmental monitoring stations the same as the air-quality monitoring stations where the API is obtained from?

Reply: Yes, the 14 environmental monitoring stations are the same as the air-quality monitoring stations where the API is obtained from.

Question 4: P. 4, l. 3: "Dust-in-suspension constitutes days: :". Present weather reports refer to the time of observation, not to the whole day. What category is used for a day in p. 7, l.4 if the 3-hourly data shows two different reports on the same day, e.g. blowing dust and dust in suspension? The authors have chosen to not show the results of their present weather report analysis (p. 7, l. 6). However, it would be interesting to see the outcome and compare to earlier studies using a similar method (see first reference in my comment 8).

Reply: We used the most severe dust category if two or more observations were made on a single day. For example, if both blowing dust and dust in suspension were observed at one meteorological station during a single day, we categorized this event as a blowing dust day. A comparison of our method to methods used in earlier studies is provided in Fig. S1 (in the Supplement).

Question 5: P. 5, l. 2: It is stated that high dust depositions in the industrial belt were caused by "industry, coal burning and vehicle exhaust". What are the underlying references or data used to support this statement? Or is this a hypothesis? Does the API data used later in the paper provide any evidence in that regard?

Reply: We revised the text 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

C4

of the anthropogenic aerosol with transported desert dust contributed to deposition in Changji and Urumqi (Li, et al., 2008).” Both Fig. 2 and 8 (API data used later in the paper) provide evidence that dust deposition in Changji and Urumqi is due to industry or vehicles. New references have been added to 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.

Question 6: P. 5, l. 31: Based on their data, the authors “suggest a positive relationship between dust deposition and PM10 concentration”. This is to be expected as - apart from wet scavenging through precipitation – dust deposition is caused by gravitational settling and turbulent diffusion. Both processes are dependent on dust concentration, i.e. the higher the dust concentration, the higher the dust deposition. I think a more detailed discussion of the observation results on the basis of the physics underlying dust deposition would be needed here. Correspondingly, I would suggest to present dust deposition as a function of PM10 concentration in Fig.7 (and discuss results accordingly) rather than vice versa.

Reply: We have briefly discussed the physics of dust deposition in Section 3.2 in the revised manuscript (Page 6, Line 9-16). Moreover, we changed the x-axis and y-axis of Fig. 7 to present dust deposition as a function of PM10 concentration, and added discussion in this section.

C5

Question 7: P. 6, l. 20-21: The authors state that “weather appears to be a dominant factor” driving dust concentration and deposition in arid regions. This is very vague and only very few details are discussed in the following. It seems clear that atmospheric and land-surface conditions are decisive for local dust entrainment and that atmospheric flow determines dust transport. A more detailed discussion of the predominant regional circulations in Xinjiang province would also help interpretation of the spatio-temporal variability of dust deposition in the area.

Reply: A more detailed discussion of the predominant regional circulation in Xinjiang province has been added in Section 3.4 (Page 7, Line 5-9) to interpret the spatio-temporal variability of dust deposition in the study area.

Question 8: Section 3.4: How do the results obtained in this paper (e.g. trends) compare to earlier studies on dust variability in central Asia (see for example Shao et al. (2013, doi:10.1002/jgrd.50836) and Xi and Sokolik (2015, doi:10.1002/2015JD024092)). I think more consideration need to be given to previous works, even though they might not deal with the exact same area.

Reply: The results obtained in this paper are based on the measurement from observation, which reflect the regional dust characteristics. The high PM10 concentration in 2001 and 2002 over study region (Fig. 6) is in accordance with Shao et al. (2013) as described “years of high dust activities in east Asia”. Moreover, the decreasing trend of PM10 concentration and dust deposition in the study is consistent with Shao et al. (2013) as described “declining dust activities in east Asia since the late 1970s”. Further consideration of earlier studies has been given, and we added the following citations to the discussion section:

Shao, Y., Kolse, M., and Wyrwoll, K.: Recent global dust trend and connections to climate forcing, *Journal of Geophysical Research*, doi: 10.1002/jgrd.50836, 2013.

Xi, X., and Sokolik, I.N.: Dust interannual variability and trend in Central Asia from 2000 to 2014 and their climatic linkages, *Journal of Geophysical Research*, doi:

C6

10.1002/2015JD024092, 2015.

Question 9: P. 7, l. 19-20: “These results suggest that dust source[s] in central Asia affect regional air quality and [are] a potential contributor of global dust.” Other studies (e.g. Shao et al., 2011, doi: 10.1016/j.aeolia.2011.02.001, and references therein; Huneus et al., 2011, doi: 10.5194/acp-11-7781-2011; Ginoux et al., 2012, doi: 10.1029/2012RG000388) have shown that some of the world’s major dust sources are located in central Asia. Please rephrase the statement so that it becomes clear in what way the present results support earlier findings, and in what way they may differ.

Reply: In above papers by Shao et al., 2011; Huneus et al., 2011; and Ginoux et al., 2012; they suggested that uncertainty in dust deposition is an important problem in current research because of a limited number of observations. This uncertainty severely influences the accurate estimation from models. Our observation confirmed that the study area is a potential dust source region as described by Shao, et al. (2011) and Ginoux et al. (2012). We rephrase the statement in the Conclusion (Page 8, Line 19-21).

Question 10: P. 7, l. 31: “: :this work can aid in adjusting model parameters: : :”. While measured dust depositions can certainly be used to evaluate dust model outputs, it does not seem that this is a direct follow-up on the present manuscript or an objective of this study. In my opinion, this work can rather – if further detailed discussions are added – support understanding of dust deposition along with its spatio-temporal variability in the study area (of course this could then also support model development and evaluation in the future) and I would suggest to motivate the paper as such.

Reply: We’re now preparing the next manuscript of modeling on dust deposition in the study area.

Please also note the supplement to this comment:

C7

<http://www.atmos-chem-phys-discuss.net/acp-2016-512/acp-2016-512-AC2-supplement.pdf>

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-512, 2016.

C8

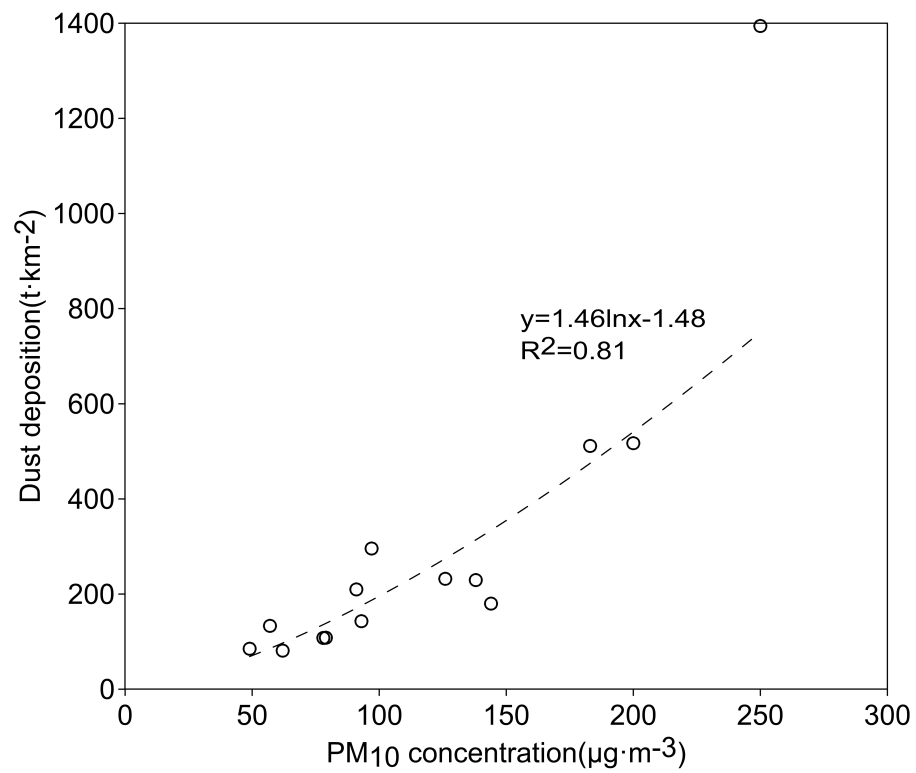


Fig. 1. Figure 7. Relationship between annual dust deposition and PM10 concentration in Xinjiang Province. Each point represents data averaged across 2000 to 2013 at one station.