

Interactive comment on “Increasing persistent hazes in Beijing: potential impacts of weakening East Asian Winter Monsoons associated with northwestern Pacific SST trend since 1900” by Lin Pei et al.

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We thank the referee for the helpful comments. We give a point-by-point reply below. All the comments will have been taken into account in the revised version.

General comments

This paper studies in detail the statistics of persistent haze events in the Beijing region in China, i.e. of at least 4 consecutive days with haze at more than one station in the region. After discussing the statistics and trends in the duration of the haze events, the

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study links the occurrence of haze to changes in the meteorological situation, mainly the wind regime connected to the East Asian Winter Monsoon and correlated changes in the northwestern Pacific sea surface temperature (SST). They find that a shift from fresh northerly to more southerly winds in the Beijing region favors the trapping of pollution. The southerly winds also transport more moisture into the region further supporting the occurrence of haze. The study puts together different data sets in order to show correlations of haze occurrence and wind speed and direction, geopotential height and SST. The correlations give support to the explanations for the occurrence of haze days in the region without showing that they are the only reason (as mentioned by the authors in the title “potential impacts of...” and in the outlook in line 341-343). The caveats and open issues should receive some more space in the discussion section. The English language needs some improvements as already promised by the authors in the online discussion and as suggested in the “Technical corrections:” below.

Reply: We agree with the reviewer to further address the caveats and relevant issues in the discussion section. In general, haze refers to an atmospheric phenomenon caused by fine particulate pollutants from various sources under specific meteorological conditions (Wang et al., 2013). The increased emissions of pollutants into the atmosphere due to rapid development in China undoubtedly serve as the most important reason for increasing hazes in Beijing, as mentioned in many studies (e.g. Liu and Diamond, 2005; Wang et al., 2013; Wang et al., 2014). Nevertheless, hazes especially PHEs in Beijing happened under specific weather conditions. It remained interesting whether large-scale climate change would cause more frequent occurrences of such weather conditions. The results of the present observational analysis depicted a potential mechanism linking the increasing PHEs in Beijing and large-scale climatic warming, which could serve as a novel point of view deserving further studies.

We'd confirm here to find a native editor to improve English in the revised version.

Specific comments:

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1. Line 152-155: Please clarify what kind of wind values you are using. Are you calculating mean and standard deviation of the daily NCEP/NCAR winds and do you do this month by month or using one mean and standard deviation for the whole winter?

Reply: We'd modify the description as: "Thus, a practical index for measuring EAWM, I_w , is defined as the mean meridional wind anomaly at 850 hPa during the boreal winter (December, January and February, DJF) over the region (30-50N, 105-125E) as outlined in Figure 1. This seasonal anomaly (I_w) is calculated with respect to the climatological mean level (I_{wmean}) during 1981-2010 based on NCEP1 reanalysis (Kalnay et al., 1996). An extreme southerly day is defined if the daily meridional wind anomaly exceeds 2σ (the standard deviation of the I_w series) beyond the climatological mean level (I_{wmean}), representing an unusually weak winter monsoon weather condition."

2. Lines 199/200: "The duration of haze events have tended to be longer in the past decades." This sentence is difficult to understand. Probably you mean something like: "The duration of haze events tends to get longer over the last decades from 1980 to 2016."

Reply: We'd modify the sentence as you suggested.

3. From Fig. 2b it looks like if the largest shift in the maximum of the PDF occurred from the 1980s to the 1990s. From the 1990s to 2000s the maximum of the PDF does not shift to longer durations but rather there are more events with durations longer than 5 days than before and the maximum only gets lower. Interestingly, in Fig. 4c the largest shift in the PDF distribution of extreme southerly episodes seems to occur from the 1990s to the 2000s. Do you have an explanation for this somewhat different behavior?

Reply: You are right that, from Fig.2b, the largest shift in the maximum of the PDF occurred from the 1980s to the 1990s, with higher probability of events with durations longer than 3 days. Since then, the maximum of the PDF has been decreasing with increasing probability of the persistent pollution events longer than 5 days.

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For comparison, from Fig.4c, from the 1980s to the 1990s, the maximum of the wind PDF gets higher without much change towards the longer duration end, indicating mainly an increasing probability of extreme southerly events lasting for 2-4 days. Since then, the maximum of the PDF has been decreasing with increasing probability of the extreme southerly episodes with longer durations.

Therefore, the changes in the PDF of the anomalous southerly wind episodes could, by and large, explain those in PHEs in Beijing over the period from 1980 to 2016. However, the relationship between the two is not as simple as linear. The striking shift of the PDF of haze events from 1980s to the 1990s, indicating a rapid increasing probability of longer duration haze events, is notable. The rapid increase of pollution in the region during the 1990s might be responsible for this. As pointed out by Guo et al. (2011), there was a significant increase of aerosol optical depth (AOD) from 1980 to the 1990s in most of China, especially in North China, corresponding to rapid development of both urbanization and industrial activities in the region in the time.

Thanks for the helpful comments. We would add some discussion as supra in the revised version.

According to both reviewers' comments, we would modify the title as "Increasing persistent hazes in Beijing: potential impacts of weakening East Asian Winter Monsoons associated with northwestern Pacific SST trends".

Meanwhile, we would accept all the technical corrections. Thanks very much for all comments.

The references are listed as follow: Wang, S.Y., Yao, L., Liu, Z.R., Ji, D.S., Wang, L.467 L, and Zhang, J.K.: Formation of haze pollution in Beijing-Tianjin-Hebei region and their control strategies. Bull. Chinese Acad. Sci., 28(3)353-363. 2013. Liu, J. and Diamond, J.: China's environment in a globalizing world. Nature, 435, 1179-1186, 2005. Wang, L.T., Wei, Z., Yang, J., Zhang, Y., Zhang, F.F., Su, J., Meng, C.C. and Zhang, Q.: The 2013 severe haze over southern Hebei, China: model evaluation, source apportion-

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ment, and policy implications. *Atmos. Chem. Phys.* 14(6): 3151-3173. 2014. Kalnay, Bayabkina, Sizov A.A., Zhukov, A.N. and Pryakhina.: The NCEP/NCAR 40-year re-analysis project. *Bull. Amer. Meteor. Soc.*, 77, 437-470. 1996. Guo, J., Zhang, X., Wu, Y., Zhaxi, Y., Che, H., La, B., Wang, W. and Li, X.: Spatiotemporal variation trends of satellite-based aerosol optical depth in China during 1980-2008. *Atmos. Environ.* 45, 6802-6811. 2011.

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