Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2017-757-AC2, 2017

Atmospheric Chemistry and Physics Discussions

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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Received and published: 18 December 2017

We found the above response had not uploaded successfully. So we upload this response again. Sorry for the inconvenience. We thank the referee for the review and comments. We give a point-by-point reply below. In the revised version all comments have been taken into account.

1. This manuscript seemed like to summarize the previous studies and applied them in Beijing. The tiny difference was the "persistent hazes". For example: The relationship

between haze and east Asia winter monsoon was revealed by Li Q et al (2015, DOI: 10.1002/joc.4350). The atmospheric circulations related to severe haze was described by Chen and Wang (2015, doi:10.1002/2015JD023225). Particularly and should be considered, the figure 3 was quite similar with Figure 7 in Chen and Wang (2015).

Reply: As you have noted, this study is to draw attention to the persistent haze events (PHEs). We consider that PHEs should be related to some persistent-type weather phenomena. Based on this consideration, our analysis is designed to look at possible changes in any persistent-type weather conditions such as the frequency of persistent anomalous southerlies during the winter monsoon season in the region. We believe that this is a novel point of view in studying how local pollution events in Beijing could be associated with large-scale climate change via changes in typical regional atmospheric circulation such as the East Asian winter monsoon (EAWM). In fact, we demonstrated a significant relationship during the last few decades between PHEs and frequency of extremely anomalous southerlies at 850hPa over North China, which also can serve as a practical index of EAWM, and then explored the relationship between EAWM and SSTA over the northwestern Pacific for the centennial period 1900-2012. These allow us to further depict an observation-based mechanism explaining a possible link between long-term change of local PHEs in Beijing and large-scale climate warming. We believe that these results bring new insights into the field of pollution-climate change studies.

Specifically, previous papers were mainly focused on the role of meteorological conditions in forming haze weather. Some studies explored the ambient conditions in severe haze case studies (e.g. Zhang et al., 2014; Liao et al., 2014; Zhu et al., 2016; Wu et al., 2017). Some studies pointed out the role of underlying climatic factors in modulating regional weather conditions associated with severe haze events (e.g. Niu et al., 2010; Wang et al., 2015; Chen and Wang 2015; Li et al., 2016; Cai et al., 2017; Zou et al., 2017). We cited the relevant studies, of which each partly supports the present findings.

Li et al., (2016) analyzed the interannual variability of fog-haze days over eastern China and investigated its relationship with East Asian winter monsoon. They deal with haze and fog as a whole and count a fog-haze day if one of them exists in that day's weather phenomena observation records. In fact, the characteristics of haze and fog are different, including meteorological parameters, the size distributions and number concentrations of aerosol particles and fog droplets (Quan et al., 2011). Figure 7 in Chen and Wang (2015) described the composite anomalous distributions of atmospheric backgrounds for severe haze cases in the region. While, Figure 3 in our paper depicts the correlation patterns between the number of PHEs in Beijing and the anomalous atmospheric indices from near-surface to upper troposphere. As mentioned above, the present study is aimed at PHEs, which were not well noticed in previous papers at all.

2. The mechanisms about the impacts of SSTA on haze pollutions were not explained sufficiently. The only discussion was "As discussed above, this notable warming phase in the subtropical Pacific could lead to a weakened EAWM, with increasing number of extreme southerly episodes, and hence increasing PHEs in Beijing." The authors need to show some evidences and argue. In a reference you cited, Yin et al. pointed out the negative SSTA in the subtropical western Pacific SSTA intensified the haze basing on observational and model analysis. It seemed like there was some contradictions. This enhanced the necessity to argue about the physical mechanisms.

Reply: We would add some discussion in the final version about the linkage between SSTA in the northwestern Pacific and EAWM with consideration of PHEs in Beijing. First of all, let's make clear the present findings. The present paper draws attention to an increasing trend of PHEs in Beijing during the past few decades (Figure 2) and a direct climate background of increasing frequency of persistent anomalous southerlies in the region due to weakening EAWM. Our analysis suggested that an anomalous warm high-pressure system in the mid-lower troposphere over the northwestern Pacific could result in anomalous southerlies over North China, underlying a shallow East Asian Trough and northward East Asian jet stream in the troposphere (Figure 3). The

change in the extremely anomalous southerlies corresponded well to that of the PHEs in Beijing (Figure 4); and that of SSTA over the NW Pacific was closely related to meridional wind anomalies even in the centennial period 1900-2012, when the SSTA showed a wavy warming trend. The combination of MDV and secular trend of SSTA exhibited a notable warming phase since the mid-1980s. This notable warming phase in the NW Pacific should correspond to an anomalous warm high-pressure system in the mid-lower troposphere, giving rise to weakening EAWM and increasing anomalous southerly episodes in North China, hence increasing PHEs in Beijing.

Yin and Wang (2015) suggested that the negative SSTA in the subtropical western Pacific SSTA intensified the winter haze days over North China. This seemingly contradictory result might be partly due to the different SSTA locations of focus between the different studies, and partly due to the different definitions of a haze day. In Yin and Wang (2015), a haze day was defined when visibility was less than 10 km and relative humidity lower than 90% at 14:00 local time. In the present study, a haze day is defined if a haze weather phenomenon is recorded with a daily mean visibility below 10 km and a daily mean relative humidity below 90%. Zhao et al., (2010) demonstrated that these two definitions could lead to different even opposite seasonal trends. Wu et al., (2014) pointed out that the result based on the 14:00PM conditions could neglect the haze caused by humidity rising in the morning and night. According to Figure 2 in Yin and Wang (2015), the first EOF mode of winter haze day in North China showed a decreasing trend from 1979 to 2012, contradictory to other studies (e.g. Niu et al., 2010; Ding and Liu, 2014; Chen and Wang, 2015; Wang et al., 2015).

Sun et al., (2016) proposed a possible mechanism for the modulation of North Pacific SST on the variations of EAWM based on observation and simulation. They pointed out that a positive SSTA zone over the North Pacific could weaken the EAWM by weakening the East Asian Trough and enhancing the North Pacific Oscillation through changing air-sea interaction over the North Pacific. This is in general consistent with the physical mechanism depicted in the present paper.

3. “Increasing persistent hazes in Beijing: potential impacts of weakening East Asian Winter Monsoons associated with northwestern Pacific SST trend since 1900” Since 1900?

Reply: To avoid possible misunderstanding, we would delete ‘since 1900’ and revise the title as “Increasing persistent hazes in Beijing: impacts of weakening East Asian Winter Monsoons associated with northwestern Pacific warming” in the final version.

4. The language was needed to be improved.

Reply: We will find a native editor to improve English in the final version.

Specific Comments: 1. The calculation of haze data was possibly not preciseness and should be illustrated more detailed.

Reply: We would add some details and discussions about the haze data processing. “In China, the standard observation procedures and criteria for identifying haze using visibility were not unified until around 2000, and thus the weather phenomenon observation code cannot be directly used in climate research (Wu et al., 2009). However, the observations of visibility and humidity were quite evenly distributed with longer temporal range, by which long-term series of haze could be established. There were mainly three methods for defining a haze day. A haze day should be of a weather phenomenon record of ‘haze’ with visibility<10km and relative humidity<90%. These three methods are based on these criteria with any single observation beyond the criteria in the day, the daily mean and the observation at 14:00PM, respectively. Via a comparative analysis, Wu et al. (2014) suggested that the calculation based on the daily mean criteria would involve more widespread and lasting haze processes, while that based on records at 14:00PM would neglect the haze with poor visibility caused by humidity rising in the morning and night. In the present study, a haze day is defined if a haze weather phenomenon is recorded with a daily mean visibility below 10 km and a daily mean relative humidity below 90%.”

2. In Figure 3b, the shading was red over North China, indicating larger wind speed. Different from the discussion of the authors.“Consequently, North China is covered by the anomalous southerlies, resulting in a significant decrease in wind speed (Fig. 3b).”

Reply: The dominant feature of the winter monsoon over East Asian is the northwesterly winds. In Figure 3b, the shading indicates significant positive wind speed anomalies (anomalous southerlies) over eastern China, implying weakened northerly winds during PHEs. We will modify in the final version:“Consequently, North China is covered by widespread anomalous southerlies, implying significant weakening of the northerly winds or even reverse of wind direction in the region (Fig. 3b).”

3. In Figure 7, the vertical profile was not located in the right location, which was easy to be confused.

Reply: We will modify Figure 7.

The references are listed as follow: Quan, J., Zhang, Q., He, H., Liu, J., Huang, M., and Jin, H.: Analysis of the formation of fog and haze in North China Plain (NCP), Atmos. Chem. Phys., 11, 8205-8214, https://doi.org/10.5194/acp-11-8205-2011, 2011. Wu D, Wu X, Zhu X. 2009. Fog and Haze in China. China Meteorological Press: Beijing, 37–59 (in Chinese). Zhao P SïijŇZhang X LïijŇXu X F. 2011. Comparison between two methods of distinguishing haze days with daily mean and 14 o’clock meteorological data. Acta Scientiae CircumstantiaeïijŇ31(4) : 704-708 (in Chinese). Wu D, Chen HZ, Wu M, Liao BT, Wang YC, Liao XN, Zhang XL, Quan JN, Liu WD, Gu Y, Zhao XJ, Meng JP, Sun D. 2014. Comparison of three statistical methods on calculating haze days-taking areas around the capital for example. China Environmental Science, 34(3), 545-554. (in Chinese) Sun, J.Q., Wu. S. and Ao. J.: Role of the North Pacific sea surface temperature in the East Asian winter monsoon decadal variability. Clim.Dyn. 46(11-12):3793-3805. 2016

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