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Interactive Comment

Interactive comment on "Possible influence of atmospheric circulations on winter hazy pollution in Beijing-Tianjin-Hebei region, northern China" *by* Z. Zhang et al.

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Dear Reviewer, We sincerely thank you for your positive and constructive comments and suggestions on our work; your comments substantially improved this paper. Our responses follow the "»" signs in the response file and are marked in the revised manuscript with the "track changes" mode in word.

1. In the abstract, the authors just simply claim that "all of the six indices have significant and stable correlations with the winter visibility…"; it's better to provide more detailed and conclusive descriptions of these relations in the abstract so that read-

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ers can find what you found quickly. Besides, it's better to include a summary of the possible mechanism (sect. 3.4) in the abstract.

»Answer: Well, We added some important conclusions in the revised abstract, such as "In the raw (unfiltered) correlations, the correlation coefficients between the six indices and the winter visibility (number of hazy days) varied from 0.57 (0.47) to 0.76 (0.6) with an average of 0.65 (0.54); in the high-frequency (<10 yr) correlations, the coefficients varied from 0.62 (0.58) to 0.8 (0.69) with an average of 0.69 (0.64). The six circulation indices together can explain 77.7% (78.7%) and 61.7% (69.1%) variances of the winter visibility and number of hazy days in the year-to-year (inter-annual) variability, respectively". Moreover, the possible linkage mechanism between the winter hazy pollutions and the circulations were also summarized in the revised abstract, such as "The increase of Ic (a comprehensive index derived from the six individual circulation indices) can cause a shallowing of the East Asian trough at the middle troposphere and a weakening of the Siberian high pressure field at sea level, and then accompanied by a reduction (increase) of horizontal advection and vertical convection (relative humidity) in the lowest troposphere and a reduced boundary layer height in BTH and its neighboring areas, which are favorable for the formation of hazy pollutions in BTH winter, and vice versa".

2. In sect. 2.1, the authors defined hazy days as "visibility $\leq$ 5km and RH < 90%", which is different from CMA's definition (visibility < 10km, [1]). Why do the authors use a different definition in this study?

»Answer: Yes, the definition of hazy days in this paper is different from CMA's definition published in 2010. This is because that a new definition for hazy days (visibility $\leq$ 5km and RH < 90%) will be released by CMA in the near future and executed in the national meteorological operation departments and the relevant research institutes. During the past one year, many scientists, forecasters and the front-line observers have been called together to discuss the new criterion for hazy days in CMA. The new criterion have took into consideration many factors related to hazy pollutions, such as

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the operability in forecast and monitor, the accuracy of instrument, the hazy days re-calculation in the history, and so on. So far, the draft has passed the first reviewed in CMA. The authors' group was one of the drafters for the new standard. Thus we try to use the new definition in this study.

3. In Table 1 and Sect. 3.2, the authors show that visibility and EU, WP, and SBH are highly correlated, but the reasons were not given and this information is not used in the later built model. How to link the correlations between visibility and EU, WP, and SBH to the statistical model?

»Answer: In this research, we first want to know what the relationships between the hazy pollutions in BTH and the most common atmospheric teleconnection or oscillation indices over the northern mid-high latitude are, such as AO, NAO, PNA, EU, WP and SBH. Since most of them have significant influence on the winter climate in most of China, especially in north China. However, the results are not as expected. The correlations between the hazy pollution and the AO, NAO and PNA are very weak. Only EU, WP and SBH correlated closely with the visibility and hazy days. Thus we further examined the spatial distribution of the correlation coefficients between the hazy pollutions and the most common meteorological fields, so as to explore the key areas and factors which may exert more important influence on the winter hazy pollutions in BTH. So the possible links between the winter EU, WP and SBH are not discussed immediately in this paragraph.

In fact, the index I4 is very similar to the EU pattern (introduced in the second paragraph of Sect. 3.2). According to Wallace and Gutzler (1981), the EU index was defined as -H500 (55N, 20E)/4 + H500 (55N, 75E)/2 - H500 (40N, 145E)/4. In this study, the I4 is defined as H500 (46∼64N, 50∼92E) - H500 (28∼44N, 16∼28E; 28∼42N, 120∼156E). The minor difference is that we use the average values derived from the center area, not a point. Both of them reflect a "–+–" wave train pattern along the Eurasia-west Pacific in the mid-high latitude. This pattern suggests that a deepening of East Asian trough and a weakening of blocking will favor the winter visibility increase in the BTH

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region.

As for WP pattern, the expression is [H500 (60N, 155E) - H500 (30N, 155E)]/2. It can be seen that this pattern is also reflected in Fig. 3c, a negative and a positive center dominated along the northwest Pacific. However, the positive correlation center are not significant in our concern. Compared with the I4 or EU, this pattern is secondary. As for SBH, the Fig. 3a show that it was not the most important pattern or factor in the sea leave pressure correlated with the winter visibility (hazy days) in BTH. As mentioned in the second paragraph of Sect. 3.2, a positive correlation center dominated most of East Asian continent and a negative correlation center dominated the area from northeast Asia to northwest Pacific, which reflect the effects of land-sea thermal contrast on the lower troposphere condition over BTH region. Generally, we think the information or component of the EU, WP and SBH patterns were included partly in the new six indices, although they were not used directly in the statistical model.

4. The numbers in Fig. 3, 4 and 6 are hard to read. In addition, Fig. 3(e) was plotted, but there is no explanation in the figure title and this plot is not explained in the paper.

»Answer: We re-plotted the Fig.3, 4, and 6, increased the font size and the intervals. The Fig.3 (e) in the raw Fig.3 should be removed. It was a mistake when I uploaded the figure files. Now it has been corrected in the revised manuscripts. In fact, the Fig.3 (e) is totally same as Fig. 4 (a).

Figure 3. Spatial distribution of correlation coefficients between visibility and SLP (a), UV850 (b), H500 (c) and U200 (d) (Area significant at the 0.05 level are shaded; either U850 or V850 significant at the 0.05 level are shaded in b)

Figure 4. Spatial distribution of correlation coefficients between visibility and T200 (a), T150 (b), T100 (c) and T70 (d) (Area significant at the 0.05 level are shaded)

Figure 6. The climatological mean fields of SLP (a) and H500 (b) averaged in winter 1981 to 2010, and the spatial distribution of the regression coefficients of SLP (c) and

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H500 (d) upon the Ic over the period 1981 to 2015 (Area significant at the 0.05 level are shaded)

5. Fig. 3 show the correlation between SLP, UV850, etc and visibility over most areas of the world. Where do these visibility data come from? Not sure if reanalysis data provide visibility information. In 3b, how is the correlation coefficient represented? What means positively correlated and what means negatively?

»Answer: Well, Fig. 3 presented the spatial distribution of correlation coefficients between visibility and the most common meteorological fields. Here, the visibility data were the winter mean visibility which derived from the 19 synoptic meteorological stations located in the BTH region. That is to say, the meteorological fields (SLP, UV850, etc) are the grid data derived from the reanalysis datasets, the mean visibility is a time series. The visibility data are the same time series in Fig. 3 (a), (b), (c) and (d).

In Fig. 3 (b), the vectors are the resultant values of r1 (the correlation coefficients between U850 and visibility) and r2 (the correlation coefficients between V850 and visibility). Concretely, we first calculated the r1 value for each grid, then calculated the r2 for each grid, and then both of the r1 and r2 were plotted in one figure by using the vectors. The advantage is that, not only the value but also the directionality (meridional wind and zonal wind) can be showed simultaneously in one figure. For example, the northerly pattern dominated eastern China, especially in the BTH region, which suggested the winter mean visibility in BTH were highly positive correlated with the meridional wind. The strong northerly wind can increase the visibility in BTH. (In meteorology, the positive (negative) values of meridional wind denote the southerly (northerly) wind, the positive (negative) values of zonal wind denote the westerly (easterly) wind.)

6. Page 22501, line 20, the authors claim that “the significantly negative correlation Suggest. . . ”. However, the latitudes of BTH region range from 36N to 42N (Fig. 7), which lie in the positive correlation region, not the negative correlation, so the conclu-

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sion based on these is problematic.

»Answer: It seems to be a little misunderstood about this point. In Fig. 4, it can be seen that the negative correlation centers dominated the areas from eastern Siberia to the northern North Pacific in both levels, and the highest and significant correlation center occurred in T200. This phenomena suggest the links between the winter visibility in BTH and the warming at the tropopause to lower stratosphere over eastern Siberia to the northern North Pacific are stable. Thus we will take the temperature at 200 hPa over eastern Siberia to the northern North Pacific as a potential predictor for hazy pollutions in BTH. For more clear, we added some words in the sentence in the revised manuscript, such as "The significantly negative correlation suggest that the warming at 200 hPa over eastern Siberia to the northern North Pacific would indicate a decreasing of winter visibility, namely a worsening of hazy pollutions in the BTH region".

7. Table 2 gives the expressions for the six indices, but the authors didn't provide any basis for the expression. For example, U850 is defined as the difference between U850 within region A (55ï¡đ75N, 40ï¡đ110E) and region B (40ï¡đ50N, 45ï¡đ75E). These regions are not the BTH region, why are these selected to express the indexes? Other indexes have the same problem.

»Answer: Well, the basis for the expressions listed in Table 2 is mainly based on the key regions shown in the correlation coefficients maps in Fig. 3 and 4 (mentioned in the fourth paragraph of Sect. 3.2). It's not random. That is to say, we choose the most important (highly and significantly correlated) areas as the key areas, not confined to the areas of BTH. Take the index of I4 (similar to EU) for example, it covers the most of Eurasia, extending from the central-eastern Europe through Siberia to north China-Korean peninsula-Japan-northwest Pacific Ocean, looks like a "–+–" wave train pattern along the Eurasia-west Pacific in the mid-high latitude. Although there patterns were not confined in BTH, the high and stable correlation coefficients suggested that they may exert important influence on the winter visibility and hazy days in BTH.

8. The authors attributed the bad performance of the statistic estimation model after 2008 to air pollution control. However, there is no evidence showing that the emission changes after 2008 are much higher than before 2008. The substantial emission increases after 2000 might be higher than the air pollution control changes that happened after 2008, but it seems that the model is not affected around 2000 in Fig. 5.

»Answer: According the records in statistical yearbooks of China and Beijing, the annual total energy consumption (million tons of standard coal) of Beijing, Tianjin and Hebei were shown in Figure S1, respectively. It can be seen that the total energy consumption in BTH regions increased distinctly during the last three decades. In view of the improvement of energy utilization technology, the increase of the total energy consumption does not mean an increase of pollutant emission. As shown in Figure S2, the total SO2 emissions in Beijing increased gradually in the 1980s and 1990s, but it decreased significantly during the last decades. The total soot emissions are similar to variations of SO2 emissions. The total industrial dust emissions decreased generally except an abrupt increase around 1998. Moreover, the total industrial dust emissions (Figure S2.b) and the total soot emissions (Figure S2.c) rebounded slightly since 2009 and 2010, but the SO2 emissions did not change like this. Although there is no the accurate emission data in winter in the BTH region, we guess the emissions in winter are similar to the annual changes. However, the mean winter visibility (number of hazy days) did not decreased (increased) obviously or decreased (increased) first and then increased (decreased). Thus we speculate the inter-annual variability of the hazy pollutions (visibility and hazy days) may be more dependent on the meteorological conditions. On the other hand, due to the lack of enough awareness about environmental issues during the rapid economic growth and urbanization, the regional or even national emissions control was very rare during the past time, especially before the 2008 Olympic Games in Beijing. According the government's announcements and the related literatures (An et al., 2007; Zhang et al., 2010; Gao et al., 2011), we know the pollutant emissions over northern China around 2008 were controlled widely and strictly by the Chinese government in order to host the 2008 Olympic Games in Bei-

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jing, and then a similar control was carried out for hosting APEC 2014 in Beijing. During these periods, except the strict controls in Beijing, a lot of factories, constructions and traffics around the BTH region or even the whole northern China were temporary closed or limited. In view of this point, the winter pollutant emissions in BTH or even norther China over the last three decades may be roughly stable during the last three decades.

From the perspective of the long-term statistic models, the influences of the possible changes or long-term trends of pollutant emissions may be secondary. In operations, if there are dramatic changes in emissions caused by policy or other important events, we should split the entire periods into different stages and then build the different statistical models to avoid the possibly systematic deviations. Assuming the pollutant emissions are same as usual in the future winter, an anomalous high Ic may warn that a severe hazy pollution is likely to happen. However, the coming hazy pollution will be alleviated partly if the government to take actions in controlling pollutants discharge. In this sense, the circulation indices are more indicating the winter meteorological conditions over the BTH region, which are conducive to the accumulation of pollutants and the formation of hazy pollutions or not.

Figure S1. Curves of the annual total energy consumption (million tons of standard coal) in Beijing (a), Tianjin (b) and Hebei province (c)

Figure S2. Curves of the annual total SO2 (a), industrial dust (b) and soot emissions (c) in Beijing

9. Page 22506, line 9: it's better to provide some explanation of how relative humidity degrades visibility.

»Answer: Well, we added a simple explanation in the revised manuscript, such as "This is because that the high relative humidity is favorable for the accumulation and hygroscopic growth of pollutants, which can strengthen the light scattering and absorption by atmospheric particles and gases and then cause the visibility degradation directly (Baumer et al., 2008; Zhang et al., 2015)".

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/15/C7096/2015/acpd-15-C7096-2015-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 22493, 2015.

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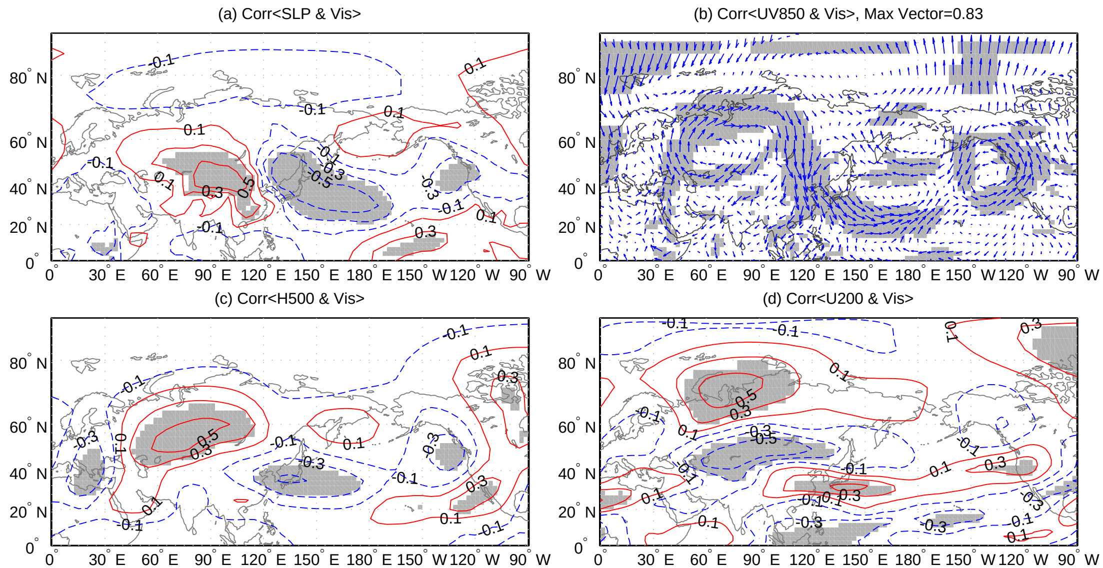

Fig. 1. Figure 3. Spatial distribution of correlation coefficients between visibility and SLP (a), UV850 (b), H500 (c) and U200 (d) (Area significant at the 0.05 level are shaded; either U850 or V850 signific

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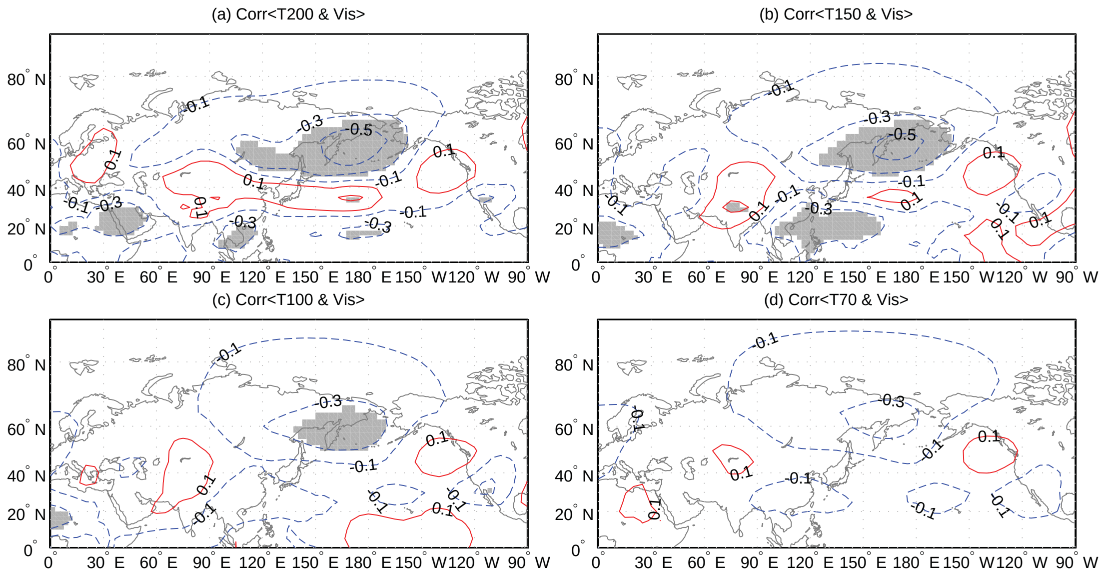

Fig. 2. Figure 4. Spatial distribution of correlation coefficients between visibility and T200 (a), T150 (b), T100 (c) and T70 (d) (Area significant at the 0.05 level are shaded)

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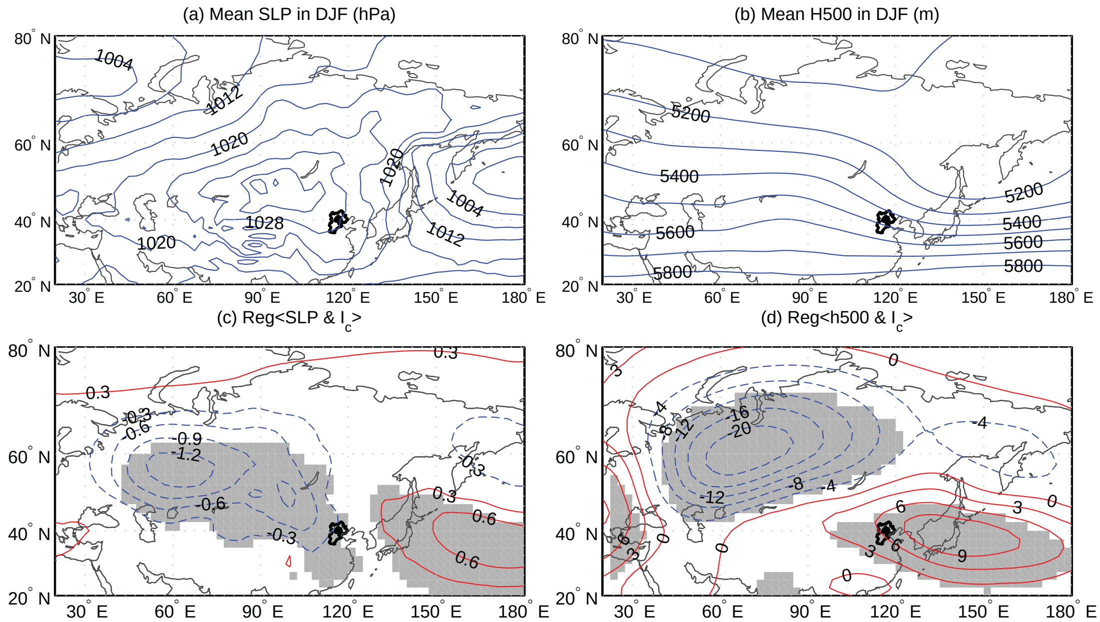

Fig. 3. Figure 6. The climatological mean fields of SLP (a) and H500 (b) averaged in winter 1981 to 2010, and the spatial distribution of the regression coefficients of SLP (c) and H500 (d) upon the Ic over t

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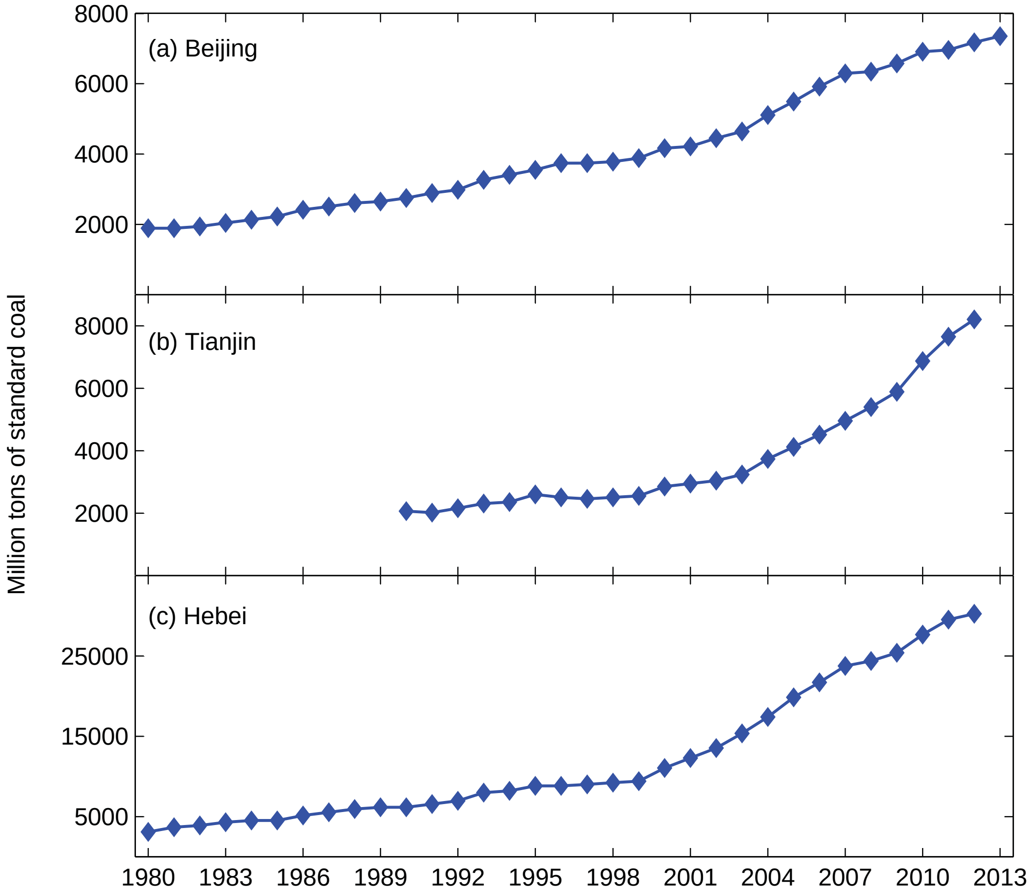

Fig. 4. Figure S1. Curves of the annual total energy consumption (million tons of standard coal) in Beijing (a), Tianjin (b) and Hebei province (c)

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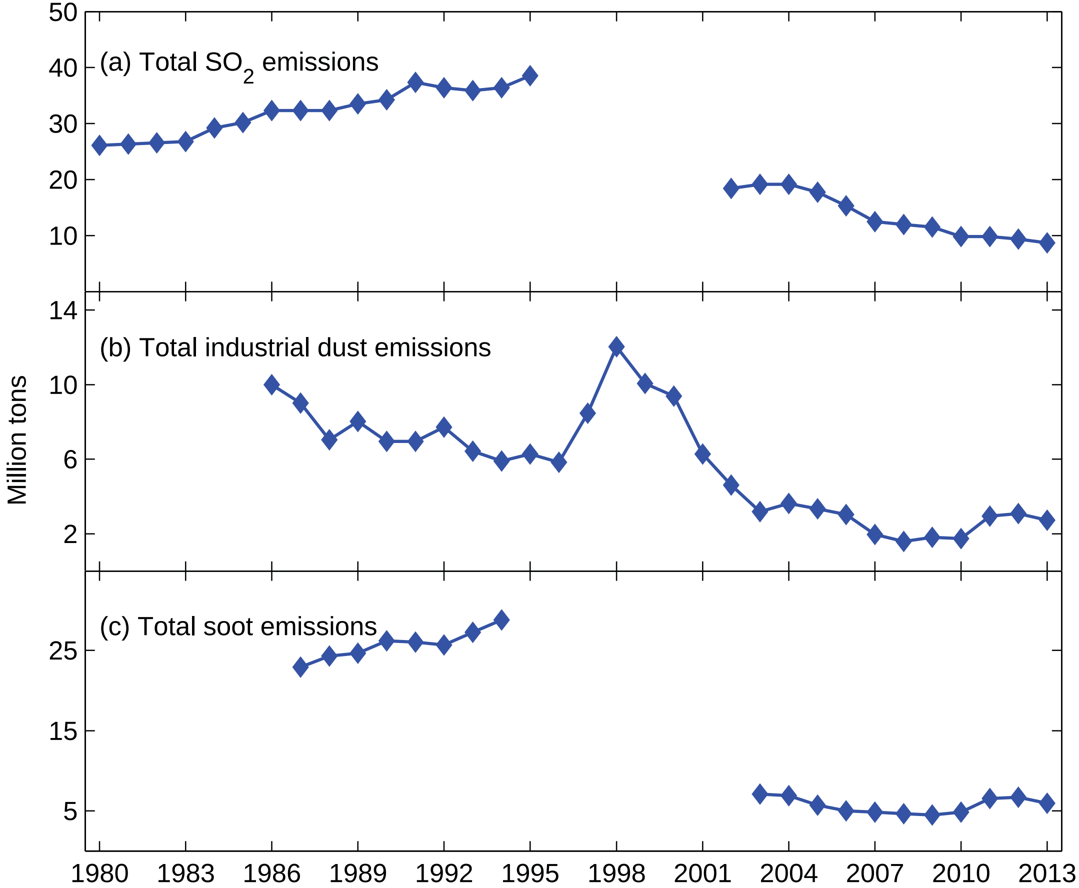

Fig. 5. Figure S2. Curves of the annual total SO2 (a), industrial dust (b) and soot emissions (c) in Beijing

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