# Reply to the Comments of the Referee #1

**General Comments:**

**1. The tile was "Projected Changes in Haze Pollution Potential in China", but what were analyzed were the AEC and WVD. Thus, the quantized relationships between haze pollution (days) and AEC, WVD should be proved and illustrated. That is, why the AEC and WVD could be used to represent the haze?**

*Reply*: As mentioned in the manuscript, the AEC, which is associated with the wet deposition and the ventilation, provides a direct way to investigate the change of the haze pollution potential, and has been applied in the operational work for the forecasting of pollution potential in China Meteorological Administration (CMA). According to previous studies, high (low) AEC is disadvantageous (advantageous) for the occurrence of haze pollution; longer (shorter) WVD corresponds to more (less) haze pollution incidents. This is the theory foundation for the relationships between haze days and AEC, WVD.

In respond to the comment, we carried out further analysis to verify the relationships of the haze days with the AEC and the WVD. The observed data of haze days, which are based on daily visibility and relative humidity records from ~2400 observation stations in China, are provided by the CMA. The occurrence of a haze day is defined with the criteria: 1) daily mean visibility below 10 km; 2) daily mean relative humidity less than 90%. Because the visibility data were collected in different forms before and after 1980 caused by different observational rules, the period 1980-2016 is used for analysis. As shown in Fig. S1, the haze mainly occurs in eastern China, particularly in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, the Pearl River Delta, and Northeast China.

Correlations between annual haze days and AEC, WVD are calculated over each station. It shows that there are negative correlations between the haze days and the AEC, and positive correlations between the haze days and the WVD over most of stations, especially in eastern China where the haze mainly occurs (Figs. S2, S3).

Considering large uncertainties from emission sources and complex chemical process for the haze genesis, the relationships between haze days and AEC, WVD are quite robust and strong. The related analysis have been added in section 2.2.

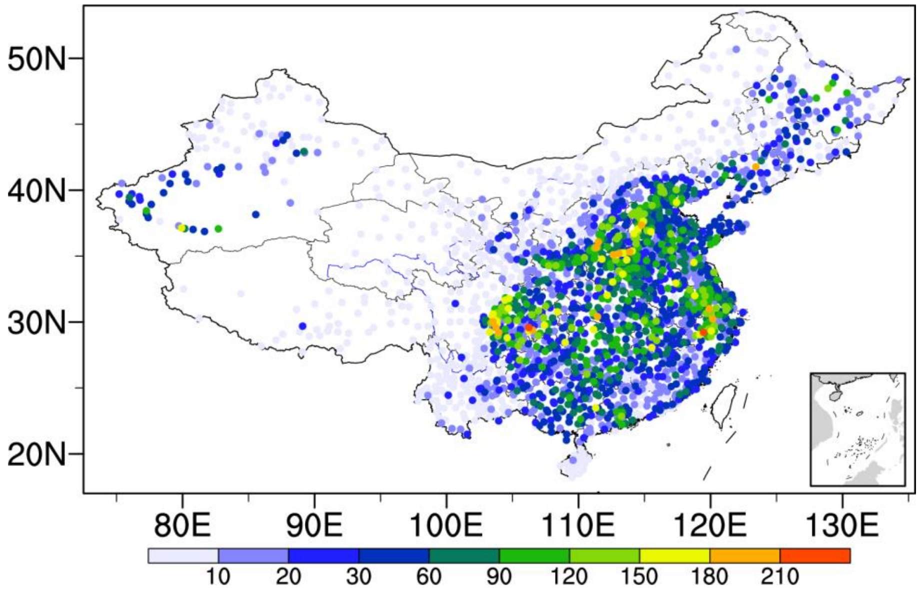


Fig. S1. Distribution of the averaged annual haze days over China during 1980-2016

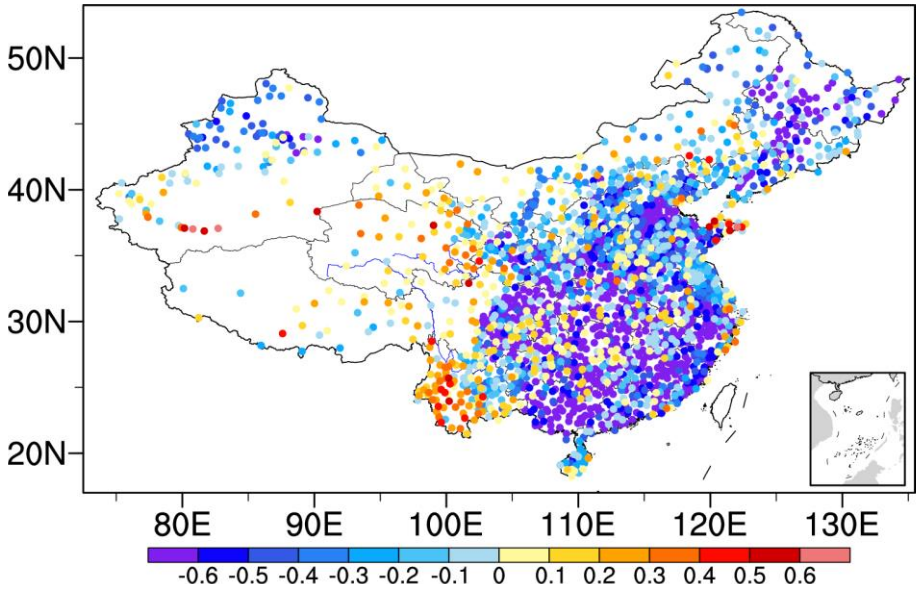


Fig. S2. Distribution of correlation coefficient between annual haze days and AEC

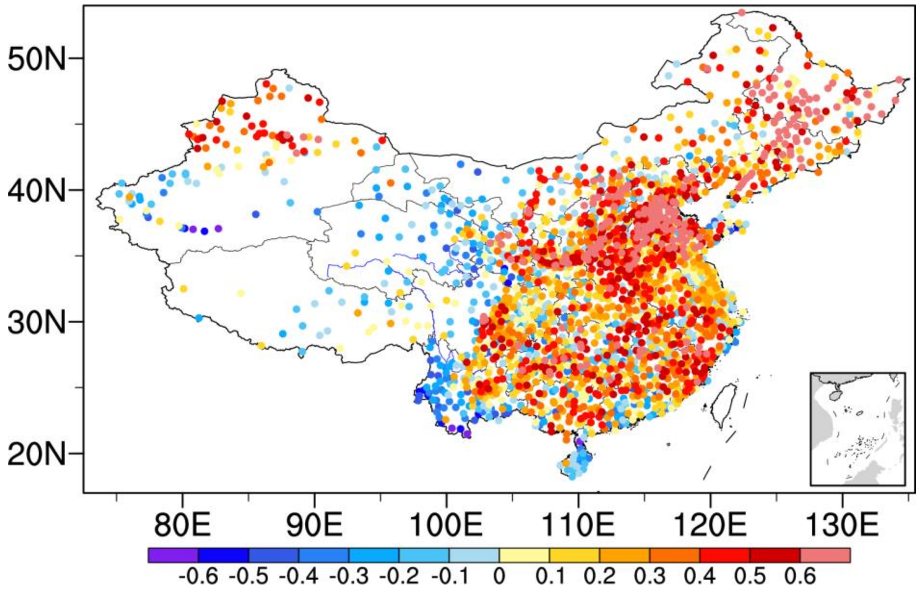


Fig. S3. Distribution of correlation coefficient between annual haze days and WVD

**2. According to prior studies, the relative humidity was vital for the incident of haze. If you want to evaluate the haze pollution potential, the moisture conditions must be considered.**

*Reply*: What we focus on in this study is the atmospheric carrying capacity, which is only related to the wet deposition and the ventilation. The relative humidity does be an important factor affecting the incident of haze. However, it is beyond the scope of this study. In the manuscript, we added a short discussion to clarify this issue in the last paragraph.

**3. "If each of the 6-hourly ventilation coefficients within one day is less than 6000 m2 s-1 , this day is counted as one weak ventilation day (WVD)". The threshold was cited from (Leung and Gustafson, 2005), a study of U.S. air quality, and was actually and firstly used by Pielke et al (1991). The question was that if the same threshold was reasonable for the recent haze pollution in China.**

**Pielke, R. A., R. A. Stocker, R. W. Arritt, and R. T. McNider (1991), A procedure to estimate worst-case air quality in complex terrain, Environ. Int., 17, 559– 574.**

*Reply*: The threshold is just used to indicate the intensity of ventilation, similar to that for precipitation or wind. The effect of ventilation on air pollutant may not change among different places. Thus, the value of less than 6000 $m^2 s^{-1}$ for ventilation coefficient was used not only in the U.S. (Leung and Gustafson, 2005; Trail et al., 2013), but also in other places such as India (Goyal and Rao, 2007; Manju et al., 2002), Athens (Kassomenos et al., 1995), and Thailand (Pimonsree, 2008).

Further, we conducted a sensitivity analysis to examine the relationships between WVD and haze days when different thresholds (3000, 5000, 6000, 7000, and 9000 $m^2 s^{-1}$) are used for the calculation of WVD. The result shows little change in their relationship under different thresholds (Fig. S4). Therefore, the threshold is reasonable for the analysis of this study.

Related clarification has been added in the second paragraph of section 2.2.

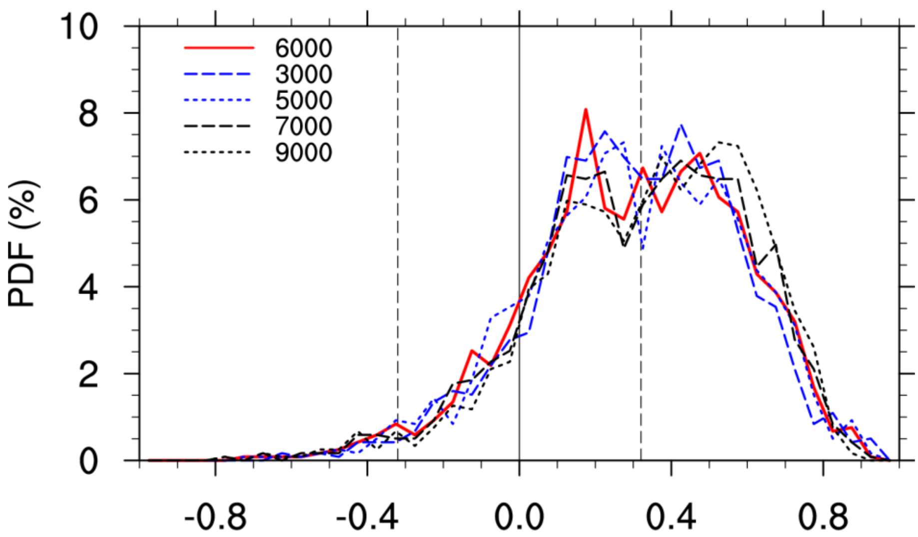


Fig. S4. Probability density function on the distribution of correlation coefficient between annual haze days and WVD. Different thresholds are used for the WVD calculation. Two dash lines indicate the 95% confidence level


Goyal, S., and Rao, C. C.: Air assimilative capacity-based environment friendly siting of new industries—A case study of Kochi region, India, J. Environ. Manage., 84, 473-483, 2007.

Kassomenos, P., Kotroni, V., and Kallos, G.: Analysis of climatological and air quality observations from greater Athens area, Atmos. Environ., 29, 3671-3688, 1995.

Manju, N., Balakrishnan, R., and Mani, N.: Assimilative capacity and pollutant

dispersion studies for the industrial zone of Manali, Atmos. Environ., 36, 3461-3471, 2002.
Pimonsree, S.: PM10 dispersion during air pollution episode in Saraburi, Thailand, Asia-Pacific Journal of Science and Technology, 13, 1185-1190, 2008.
Trail, M., Tsimpidi, A., Liu, P., Tsigaridis, K., Hu, Y., Nenes, A., and Russell, A.: Downscaling a global climate model to simulate climate change over the US and the implication on regional and urban air quality, Geoscientific Model Development, 6, 1429, 2013.

**4. The recent winter haze pollution in North China or BTH area was severest, but the bias of historical estimations in winter and in North China was very significant. Thus, the error bars or confidence intervals must be discussed.**

*Reply*: Similar to the contribution analysis in section 5, we applied the same method to investigate the contribution of different factors to the simulated AEC biases (Fig. S6). Overall, the simulation bias in boundary layer depth is the major factor for the simulated AEC bias over most parts of China (Fig. S6d). The related discuss is added in the first paragraph of section 3.

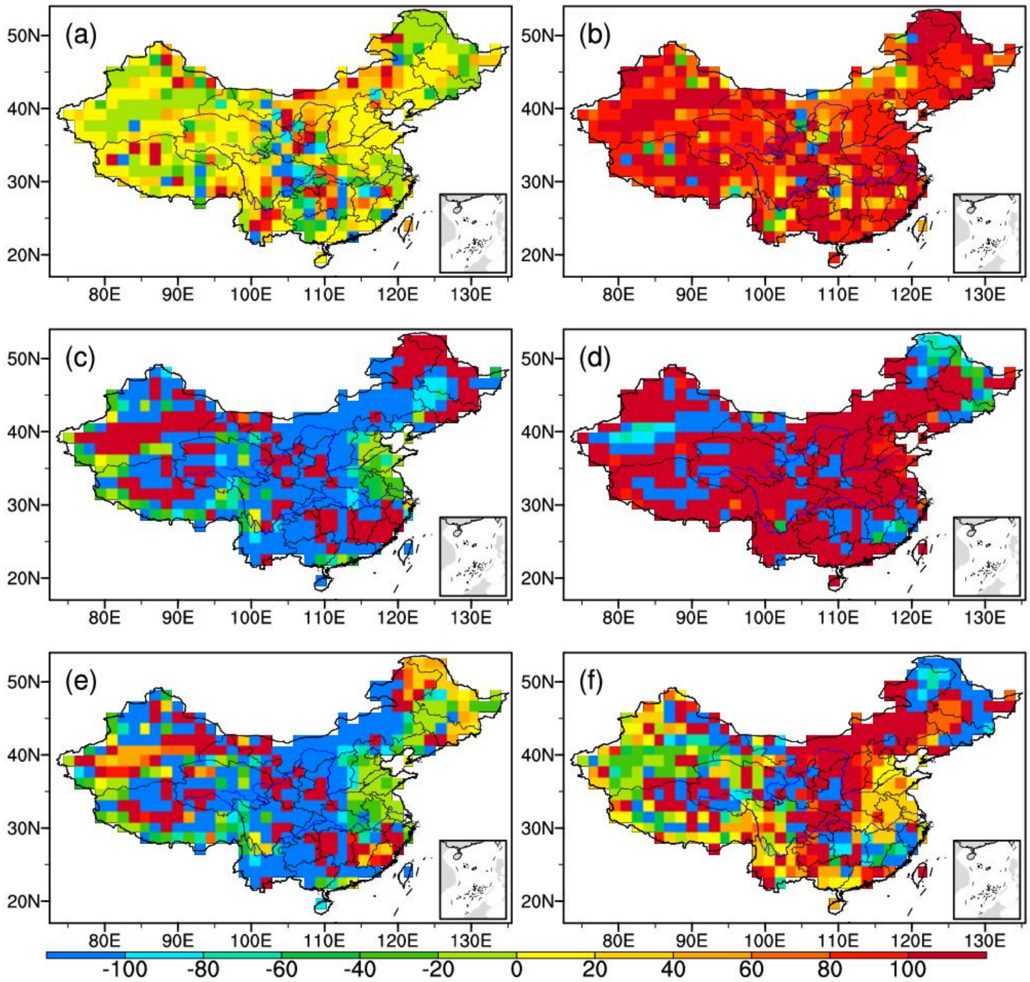


Fig. S5. Relative contributions (unit: %) of individual components to annual AEC biases based on the ensemble results. (a) precipitation, (b) ventilation, (c) wind speed averaged with the boundary layer, (d) boundary layer depth, (e) nonlinear term, (f) transient term.

**Specific Comments:**

**1. As well known, there were dozens of models in the CMIP5 project, so the reasons why only three models were selected should be supplemented. Furthermore, why did the authors only analyze two periods, i.e., 2046-2065 and 2080-2099?**

*Reply*: In CMIP5, ~20 GCMs provide the six-hourly outputs of wind speed, temperature, and humidity for dynamical downscaling. However, to drive RCM modeling, the ratio of the resolution between GCMs and RCMs should not exceed 6-8. So, only those GCMs with the resolution of 1~2 degree can be used to drive RegCM4 simulations. Due to the availability of CMIP5 GCMs and considering large volume of outputs for ~120-yr RegCM4 simulations, we just used these three GCMs for this study. This part has been added in section 2.1.

The periods 2046-2065 and 2080-2099 are commonly used to represent near-term and long-term in the CMIP5 projection, respectively (IPCC, 2013). This has been clarified in the first paragraph of section 4

**2. The definition of Beijing-Tianjin-Hebei region (BTH), Northeast China (NEC), Yangtze River Delta economic zone (YRD), and Pearl River Delta economic zone (PRD) must be illustrated clearly.**

*Reply*: A map has been added in the revised manuscript (Fig. S6, also see Fig. 1f in the manuscript).

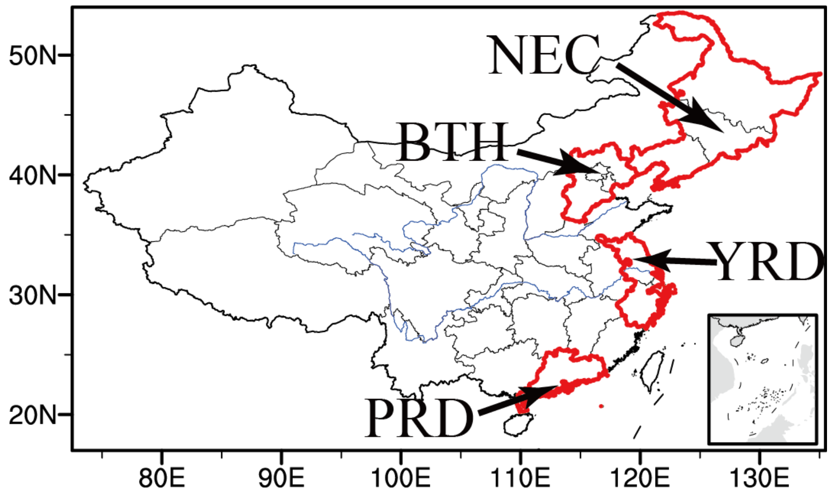


Figure S6. Four main economic zones of China, Beijing-Tianjin-Hebei region (BTH), Northeast China (NEC), Yangtze River Delta economic zone (YRD), and Pearl River Delta economic zone (PRD)

**3. In Figure 1–3, the resolutions of the observations was bad for evaluating the performance of Regcm4 downscaling. I noticed that the Era-interim used here was with the resolution 1.5*1.5°, and suggest that the data 0.5*0.5° should be**

**better.**

*Reply*: The native horizontal spatial resolution for the ERA-interim data is a T255 Gaussian grid, equivalent to a horizontal resolution of about 79 km or 0.75 $^{\circ}$. The data with other resolutions are bilinear interpolated from the native Gaussian grid (https://software.ecmwf.int/wiki/display/CKB/). So in the revised manuscript, 0.75$^{\circ}$ *0.75$^{\circ}$ grid data are used. The conclusions for the evaluation are not changed (see Table 1, Table 2 and the figures for the observation in the manuscript).