Reply to Referee 1

We are grateful to the referee for the encouraging comments and careful reviews which helped to improve the quality of our paper. In the following we quoted each review question in the square brackets and added our response after each paragraph.

[Review Comment: In this paper, the observational and modeling studies show a relationship between the haze events over CEC and Tibetan Plateau (TP). I think it is a very interesting paper. It provides a new perspective to investigate the causes of the haze pollution in China. I believe this manuscript is appropriate for publication in Atmospheric Chemistry and Physics and would recommend publication subject to primarily minor revisions outlined below.]

Reply 1: Thank you for the encouraging comments.

[1. In this paper, which are the simulation results? Which are the observed results? Please comment on these.]

Reply 2: Following this comment, we have added a paragraph at the beginning of the revised Section 3 (Results and discussion) with following sentences:

"In this Section, we identify the contributions of pollutant emissions and climate change to interannual haze variations（in Sect. 3.1）, reveal a climatological "susceptible region" for haze formation in China (in Sect, 3.2), analyze the relationships between TP's thermal forcing and haze over CEC (in Sect, 3.3) and investigate the TP-warming inducing favorable meteorology for CEC's haze (in Sect. 3.4) based on the meteorological observations. In order to more convincingly demonstrate the observed results, Section 3.5 presents the results of a sensitivity simulation experiment about impacts of the TP's thermal forcing on CEC's aerosol variations."

[2. How to separate the time series into three phases in Fig.1? How to define the haze event in the figure? Please comment on these.]

Reply 3: In response to the referee's questions, we have clarified the statements in the revised manuscript as follows:

"In accompany with an unceasing increase in the Chinese pollutant emissions during recent decades, the significant interannual variations of haze occurrences in CEC over recent decades could be separated into three interdecadal phases with the trends of slow ascending (4.6d/10a) from the 1960s to 70s, less changing (1.7 d/10a) during the 1980s–1990s and sharply rising with a trend reaching 13.0d/10a going into the 21st century (upper panel of Fig. 1). Although of a continuous increasing trend in the pollutant emissions over the recent decades, the haze variations in CEC have evolved with the different trends of slow, less and sharply ascending over three interdecadal periods," (Please see the second paragraph of Sect. 3.1).

"This study adopts a widely-used comprehensive haze definition using surface in-situ observations of visibility, relative humidity and weather phenomenon. The observed relative humidity of less than 90% is used to distinguish haze from fog under the visibility <10km, (Schichtel et al., 2001; Doyle and Dorling, 2002; Ding and Liu, 2014)." (Please see the first paragraph of Sect. 2).

References:

Schichtel, B. A., Husar, R. B., Falke, S. R. and Wilson, W. E.: Haze trends over the United States 1980–1995, Atmos Environ, 35,5205–5210, 2001.

Doyle. M. and Dorling, S.: Visibility trends in the UK 1950–1997, Atmos Environ, 36,3161–3172, 2002.

[3.Please give us the more detailed information about CO2 emission.]

Reply 3: In the revised manuscript, we have added "The Chinese CO2 emission data over 1961-2012 are downloaded online from the website (http://cdiac.ornl.gov/CO2_Emission/timeseries/national)" in the first paragraph of Section 2, and "the Chinese CO_2 emission data source: http://cdiac.ornl.gov/CO2_Emission/timeseries/national" in the caption of Fig. 1.

[4. "In accompany with an unceasing increase in the Chinese pollutant emissions in recent decades, the significant interannual variations of haze occurrences in CEC have evolved with the trends of slow ascending from the 1960s to 70s, less changing during the 1980s–1990s and sharply rising with a trend reaching 13.0d/10a going into the 21st century (upper panel of Fig. 1), implying that climate change could also play an important role in the variations of haze events in CEC apart from the anthropogenic dimension of pollutant emission sources related to the rapid industrialization of China." I think this conclusion looks a little messy. You need to give us more evidence to prove this point.]

Reply 4: Following the suggestions, we have clarified that conclusion in the revised manuscript as follows (in Sect. 3.1):

"In accompany with an unceasing increase in the Chinese pollutant emissions during recent decades, the significant interannual variations of haze occurrences in CEC over recent decades could be separated into three interdecadal phases with the trends of slow ascending (4.6d/10a) from the 1960s to 70s, less changing (1.7 d/10a) during the 1980s–1990s and sharply rising with a trend reaching 13.0d/10a going into the 21st century (upper panel of Fig. 1). Although of a continuous increasing trend in the pollutant emissions over the recent decades, the haze variations in CEC have evolved with the different trends of slow, less and sharply ascending over three interdecadal periods, implying that climate change could also play an important role in the variations of haze events in CEC apart from the anthropogenic dimension of pollutant emission sources related to the rapid industrialization of China. A steady decline of East Asian monsoon winds is negatively correlated to haze occurrences in the CEC with the coefficient of determination, R2=0.6419 passing the confidence level of 99.9% (lower panel of Fig.1), indicating a consequence of East Asian monsoon climate change to CEC haze pollution.”

[5. Fig.3: Surface wind speed or wind speed at 10 m? Please check it.]

Reply: Yes, it is wind speed at 10 m. It has been corrected in the caption of Fig.3.

[6. Could you give us the information about pollutant emission in lower TP’s Q1 (1996,2002) and higher TP’s Q1 (1998,2003)?]

Reply: The haze variations are generally controlled by pollutant emissions and meteorological conditions. In order to more convincingly demonstrate the contribution of the TP-warming to the haze frequency over CEC, a sensitivity simulation by employing the global air quality model GEM-AQ/EC is designed to isolate the emission influence on interannual variations of aerosols, where the monthly data of anthropogenic emissions by fossil fuel and biomass burning as well as the sulfate emissions compiled using EDGAR2.0 (Gong et al., 2012) are introduced without any interannual changes from 1995 to 2004. As designed in the sensitivity simulation, the pollutant emissions in lower TP’s Q_1 (1996,2002) and higher TP’s Q_1 (1998,2003) are same used in the simulation with the emission inventory dataset EDGAR2.0.

In the revised manuscript, we have added the above-discussions in Sect. 2 (the last paragraph) and in Sect. 3.5 (lines 348-349; lines 360-362) .

[7. As we known, dust is one of the absorbing aerosols in the atmosphere, which can influence the climate directly by modulating the radiation budget, affect the microphysical properties of clouds, and alter the surface albedo of the ground covered by snow or glacier. TP dust could impact on regional and global climate (e.g., Lau et al., 2006,2010; Huang et al., 2007; Chen et al., 2013). Could you consider the climatic

effects of the TP dust in this paper? I am wondering whether there is a relationship between TP dust and haze over CEC.

References:

1. Lau, K. M., M. K. Kim, and K. M. Kim (2006), Asian summer monsoon anomalies induced by aerosol direct forcing: The role of the Tibetan Plateau, Clim. Dyn., 26(7-8), 855–864, doi:10.1007/s00382-006-0114-z.

2. Lau, W. K. M., M. K. Kim, K. M. Kim,and W. S. Lee (2010), Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols, Environ. Res. Lett., 5, 025204, doi:doi:10.1088/1748 9326/5/2/025204.

3. Huang, J., P. Minnis, Y. Yi, Q. Tang, X. Wang, Y. Hu, Z. Liu, K. Ayers,C. Trepte, and D. Winker (2007), Summer dust aerosols detected from CALIPSO over the Tibetan Plateau, Geophys. Res. Lett., 34, L18805,doi:10.1029/2007GL029938, 2007.

4. Chen, S., J. Huang, C. Zhao, Y. Qian, L. R. Leung, and B. Yang, Modeling the transport and radiative forcing of Taklimakan dust over the Tibetan Plateau: A case study in the summer of 2006, J. Geophys. Res. Atmos., 118,2013.]

Reply: Many thanks for the referee's discussion. We agree with all the suggestions. We have added these in Section 1: Introduction (lines 120-130) as follows:

"Aerosol transport and deposition have been increasingly dirtying and even melting the snow- and ice-dominated wintertime TP (Ramanathan and Carmichael, 2008;Xu et al., 2009). This process leads to decreases in the snow and ice albedos, which could be largely responsible for climate change in the TP region (Hansen and Nazarenko, 2004). As one of the absorbing aerosols in the atmosphere, dust can influence the climate directly by modulating the radiation budget, affect the microphysical properties of clouds, and alter the surface albedo of the ground covered by snow or glacier TP dust could impact on regional and global climate (Lau et al., 2006,2010; Huang et al., 2007; Chen et al., 2013; Liu et al. ,2008). "

We have accordingly cited the following articles in the revised manuscript:

Chen, S., Huang, J., Zhao, C., Qian, Y., Leung, L. R., and Yang, B.:Modeling the transport and radiative forcing of Taklimakan dust over the tibetan plateau: a case study in the summer of 2006, J.Geophys. Res.-Atmos., 118, 797–812, doi:10.1002/jgrd.50122, 2013.

Lau, K. M., Kim, M. K., and Kim, K. M.: Asian summer monsoon anomalies induced by aerosol direct forcing: the role of the Tibetan Plateau, Clim. Dynam., 26, 855–864, doi:10.1007/s00382-006-0114-z, 2006.

Lau, W. K. M., Kim, M. K., Kim, K. M. and Lee, W. S.: Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols, Environ. Res. Lett., 5, 025204, doi:10.1088/1748 9326/5/2/025204, 2010.

Liu, Z., Liu, D., Huang, J., Vaughan, M., Uno, I., Sugimoto, N., Kittaka, C., Trepte, C., Wang, Z., Hostetler, C., and Winker, D.: Airborne dust distributions over the Tibetan Plateau and surrounding areas derived from the first year of CALIPSO lidar observations, Atmos. Chem. Phys., 8, 5045-5060, doi:10.5194/acp-8-5045-2008, 2008.

Huang, J., Minnis, P., Chen, B., Huang, Z., Liu, Z., Zhao, Q., Yi, Y., and Ayers, J. K.: Long-range transport and vertical structure of Asian dust from CALIPSO and surface measurements during PACDEX, J. Geophys. Res., 113, D23212, doi:10.1029/2008JD010620, 2008.

Wang, H.-J., Chen, H.-P. and Liu J.-P.: Arctic sea ice decline intensified haze pollution in Eastern China, Atmos. Oceanic Sci. Lett., 8(1), 1-9, doi: 10.3878/AOSL20140081, 2015.

Zhang, R. H., Li, Q. and Zhang, R. N.:Meteorological conditions for the persistent severe fog and haze event over eastern China in January 2013, Science China: Earth Sciences, 57, 26–35, doi: 10.1007/s11430-013-4774-3, 2014.

Yan, L. and Liu, X..: Has climatic warming over the Tibetan Plateau paused or continued in recent years?, Journal of Earth, Ocean and Atmospheric Sciences, 1, 13-28, 2014.

Duan, A. , Wu, G. X., Zhang, Q., Liu, Y,: New proofs of the recent climate warming over the Tibetan Plateau as a result of the increasing greenhouse gases emissions, Chinese Science Bulletin,51(11), 1396-1400, 2006.

Liu, X. and Chen, B.: Climatic warming in the Tibetan Plateau during recent decades, Int. J. Climatol. 20, 1729-1742, 2000.