Response to referee comments on "A new indictor on the impact of large-scale circulation on wintertime particulate matter pollution over China"

We thank the reviewers for their valuable comments and suggestions. This document is organized as follows: the Referee's comments are *in italic*, and our responses are in regular text. The change of text is shown in blue. The page and line numbers refer to those in the revised manuscript with changes highlighted.

To Referee #1

This study develops a new metric - the Siberian High position index to examine the correlations between large-scale atmospheric circulation and air quality over China. This is a very interesting topic and should be of great interest to the community.

Q1. *p19279, L5-6, double check the uncertainty "±0.05±0.2×AOD" - whether the first "±" is needed.*

Response: The first number in the uncertainty equation represents the errors in theρ_s (surface reflectance) estimate and the second number represents systematic bias. The "±" sign in front of the first number is necessary because it can be positive or negative according to the MODIS retrieval algorithm (Kaufman et al., 1997). That is, +0.05+0.2×AOD indicates the upper boundary of the retrieval error, and -0.05-0.2×AOD indicates the lower boundary of the retrieval error (Remer et al., 2005; Chu et al., 2012).

Q2. *p19281, L8-9, climatology – climatological.*

Response: We have corrected it.

Q3. *p19295, Table 1, consider adding definition/description for high-SPHI VS low-SPHI winters so that the readers don't have to go back to the text to search for those info.*

Response: Description added. Please refer to the revised caption of Table 1: P27, L577-579.

Q4. *p19303, Figure 7 caption, wind fields –> wind direction (since wind fields would include both direction and speed).*

Response: The length of the vectors in figure 7 represents wind speed, so we still use wind fields in the caption. The shaded plot here also emphasizes the wind speed and makes it more explicit.

To Referee #2

This is a fairly focused study. I have a few questions and comments.

Q1. *There is a typo in "indictor" in the title; I believe it should be "indicator".*
Response: Yes, we have corrected it.

Q2. *Page19281, lines 18-21: Based on what was this point made? The two references, Lu et al. (2011) and Zhang et al. (2012), appear to be on SO_2, primary carbonaceous aerosols, and NOx emissions, which didn't really provide direct evidence for changes (or lack thereof) in AOD. The time series of key meteorological parameters during the study period should be examined to exclude potential effects of their changes. For instance, there appeared to be some sort of trend in SHI in Fig. 6a. It'd be more rigorous to exclude such possibilities before zeroing on anthropogenic emissions with such absolute certainty.*
Response: While AOD does not represent direct emissions, it is a proxy for the total abundance of aerosols within the atmospheric column. The aerosol sources over North China in winter are predominantly anthropogenic and secondary (Wang Y et al., 2013; Huang et al., 2014; Guo et al., 2014). SO_2 and NO_x are gaseous precursors of secondary inorganic aerosols which account for 40-70% of total aerosol mass over North China in winter (Yang et al., 2012; Wang Y et al., 2013). This is why we used the two references to indicate the increasing trends in those anthropogenic sources which will result in increasing aerosol abundance over China and hence increasing AOD. We examined the long-term trend of both SHI and SHPI during 2001-2013, and no significant ($p<0.05$) trend was found for either index. Thus, we conclude that the AOD trend is mostly likely caused by increasing anthropogenic emissions over this region. To further support this statement, we have added another reference (Streets et al., 2009) which examined the anthropogenic and natural contributions to regional trends in aerosol optical depth during1980-2006 and gave the same conclusion as ours.

Q3. *Page 19282, lines 28-29: See the comment above. It'd be more rigorous to demonstrate no trend in SHI before looking into the correlation between SHI and detrended AOD.*
Response: Yes, we have examined the trend of SHI and no significant trend is found. Please refer to the revised manuscript: P10, L214.

Q4. *Page 19286, line 27: "diffusion" should be replaced with "ventilation" or terms of the likes.*
Response: We have changed "diffusion" to "dispersion".

Q5. *Page 19287, lines 2-4. The first sentence is superfluous.*

Response: We have revised this sentence. Please refer to the revised manuscript: P16, L332-334.

Q6. *Page 19288, lines 19-20: A reference (or references) is needed for the statement that "SC has more cloud coverage than NC".*
Response: We have added a reference (Li et al., 2004) to support this statement.

References:

Chu, D. A., Kaufman, Y. J., Ichoku, C., Remer, L. A., Tanré, D., and Holben, B. N.: Validation of MODIS aerosol optical depth retrieval over land, Geophys. Res. Lett., 29, 1617, doi: 10.1029/2001 GL013205, 2002.

Guo, S., Hu, M., Zamora, M.L., Peng, J., Shang, D., Zheng, J., Du, Z., Wu, Z., Shao, M., Zeng, L., Molina, M.J., Zhang, R.: Elucidating severe urban haze formation in China, Proc. Natl. Acad. Sci. U.S.A., 111(49), 17373-17378, doi: 10.1073/pnas.1419604111, 2014.

Huang, R.J., Zhang, Y., Bozzetti, C., Ho, K.-F., Cao, J., Han, Y., Dällenbach, K. R., Slowik, J. G., Platt, S. M., Canonaco, F., Zotter, P., Wolf, R., Pieber, S. M., Bruns, E. A., Crippa, M., Ciarelli, G., Piazzalunga, A., Schwikowski, M., Abbaszade, G., Schnelle-Kreis, J., Zimmermann, R., An, Z., Szidat, S., Baltensperger, U., Haddad, I. E., and Prévôt, A. S. H.: High secondary aerosol contribution to particulate pollution during haze events in China, Nature, 514, 218-222, doi:10.1038/nature13774, 2014.

Kaufman, Y. J., Tanré, D., Remer, L. A., Vermote, E. F., Chu, A., and Holben, B. H.: Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer, J. Geophys. Res., 102, D14, 17051-17067, 1997.

Li, Y., Yu, R. C., Xu, Y. P., and Zhang, X. H.: Spatial Distribution and Seasonal Variation of Cloud over China Based on ISCCP Data and Surface Observations, J. Meteorol. Soc. Jpn., 82761-82773, doi: 10.2151/jmsj.2004.761, 2004.

Remer, L. A., Kaufman, Y. J., Tanré, D., Mattoo, S., Chu, D. A., Martins, J. V., Li, R.-R., Ichoku, C., Levy, R. C., Kleidman, R. G., Eck, T. F., Vermote, E., and Holben, B. N.: The MODIS aerosol algorithm, products, and validation, J. Atmos. Sci., 62, 947-973, doi: 10.1175/JAS3385.1, 2005.

Streets, D. G., Yan, F., Chin, M., Diehl, T., Mahowald, N., Schultz, M., Wild, M., Wu, Y., and Yu, C.: Anthropogenic and natural contributions to regional trends in aerosol optical depth, 1980-2006,

J. Geophys. Res., 114, D00D18, doi: 10.1029/2008JD011624, 2009.
Wang, Y. X., Zhang, Q. Q., He, K., Zhang, Q., and Chai, L.: Sulfate-nitrate-ammonium aerosols over China: response to 2000-2015 emission changes of sulfur dioxide, nitrogen oxides, and ammonia, Atmos. Chem. Phys., 13, 2635-2652, doi:10.5194/acp-13-2635-2013, 2013.
Yang, F., Tan, J., Zhao, Q., Du, Z., He, K., Ma, Y., Duan, F., Chen, G., and Zhao, Q.: Characteristics of $PM_{2.5}$ speciation in representative megacities and across China, Atmos. Chem. Phys., 11, 5207-5219, doi:10.5194/acp-11-5207-2011, 2011.