Reply letter to the anonymous Referee #1

Received and published: 12 September 2016

General Comments:

The paper entitled “Seasonal prediction of winter haze days in the north-central North China Plain” selected seven predictors based on the analysis, and then used them to establish two statistical schemes for the prediction of the winter haze days over the north-central North China Plain. The two prediction models were demonstrated to have good ability to capture the interannual and interdecadal trends and the extremums of the haze days over the north-central North China. Thus, this study provides a good basis for the prediction of the haze days. I recommend the manuscript a minor revision before it be published in the journal.

Specific Comments:

(1) As is known, the human activity, especially the energy consumption, is the first driver for the increasing of the haze days in North China in recent years, while the climatic conditions may be the second driver. So, how to take the human influence into account in the current prediction models? Some discussions about this issue are suggested to be included in the study.

Reply:

There was no doubt that the human activities were the first driver and contributor for the increasing of haze days in China and should be taken into account, but it was quite difficult to gather the associated dataset. Our studies based on the assumption (or compromise) that the socio-economic component varied slowly between the current and previous year. Thus, the socio-economic terms could be neglected in the DY approach and were contained again by adding the previous measurement. Although the assumption was rough and simple, it indeed supports a way to the seasonal prediction of haze days. This compromise might be unsuitable in certain years when this pollutant emission proportion varied dramatically. Fortunately, the climate factors also contributed significantly and the developed models showed good

performance. In the last section, following the kindly advice of the referee, we discussed the ideal scheme that used the preceding autumn energy consumption as a predictor.

Revision in the last paragraph:

……At the same time, if the SPM_{MLR} performed well in some years, the SPM_{GAM} also showed good ability in these years, and *vice versa*. One possible reason could be that some useful factors, most notably the human activities, were not included here. There is no doubt that the human activities, especial the energy consumption, was the first driver for the increasing of haze pollution. In this paper, we simply assumed that the difference in pollutant emissions between current and previous years was very small and that the socio-economic component of WHD_{NCP} varied slowly. This assumption could support the seasonal prediction of haze days in most of the years, but still was a compromise. In certain years, especially the recent years, this pollutant emission proportion varied rapidly that needed to be taken into account. The preceding autumn energy consumption should be a good choice, but difficult to be measured, and its DY could be introduced into the developed models directly to improve the predictive skill.

(2) The predictors are selected mainly based on the correlation analysis. The correlations may indicate some relations (phenomena) but do not really imply causality (reason). To confirm the reliability of the selected predictors for the prediction models, the physical mechanisms underlying their relationships are suggested to be presented.

Reply:

Actually, the studies about the associated physical mechanism, i.e., how the external forcings influenced haze pollutions, were new and still insufficient. In this paper, we selected 7 predictors and could not present the physical mechanism that each external forcing stimulated such associated circulations. Following the suggestions, we cited the latest reference about the impact of Pacific and Atlantic SST and the ASI on haze

pollution, and also added some content and Figures about the way that the associated circulations impacted the WHD_{NCP} DY. Finally, we pointed out that the underlying physical mechanism about the external forcing needed further and deeper studies and some useful hints could be found in this paper.

Revision for each predictor:

For Predictor x_1, the following contents were revised:

The features of negative EU and positive WP pattern could be identified clearly and the anomalous cyclone over South China and South China Sea was significant in the circulations associated with predictor x_1 ($\times -1$) (Figure 3). Although the associated land-air interaction, especially in the DY field, was complicate and still unclear, according to the analysis of Figure 1, the horizontal and vertical diffusion of pollutant particles would be restricted efficiently.

For Predictor x_2, the following contents were revised and Figure 5 was replaced:

Chen et al. (Chen et al. 2015) found that the severe winter haze events in the North China were closely related with the weaker and northward EAJS. The positive SST DY around the Alaska Gulf could induce obviously anomalous cyclone over eastern China and the adjacent ocean, and the stimulated easterly weakened the core of EAJS. Furthermore, there was significantly anomalous southerly at the high latitude that restricted the cold activities from their source region and intensified the haze pollution over NCP (Figure 5).

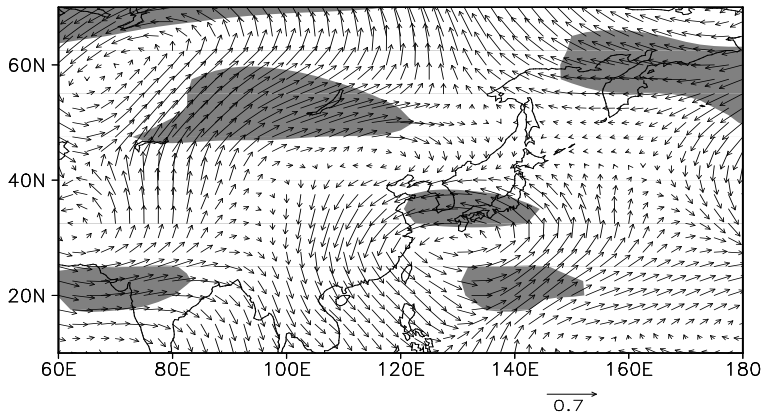

Figure 5. The CC between predictor x_2 and wind vector DY at 200 hPa in winter from 1980 to 2013. The shade indicates that the CC between the zonal wind DY and x_2 exceeded the 95% confidence level.

For Predictor x_3, the following contents were revised, Figure 7 was replaced and a latest reference was cited:

Xiao et al (Xiao et al. 2015) proved the SST anomalies over the North Atlantic from summer to the following winter exhibit a significant relationship with winter haze days on both decadal and interannual timescale.

The most obvious DY atmospheric circulations related with predictor x_3 ($\times -1$) were the positive WP pattern, whose south center linked with a subtropical high (Figure 7). The continental high and marine low was both weakened by the anomalous geopotential height form the lower to middle layer that led to weaker EAWM and weaker cold air. The pressure gradient over the east coast of China also resulted in significant southerly anomalies, indicating smaller surface wind and more moisture and resulting in more WHD_{NCP}.

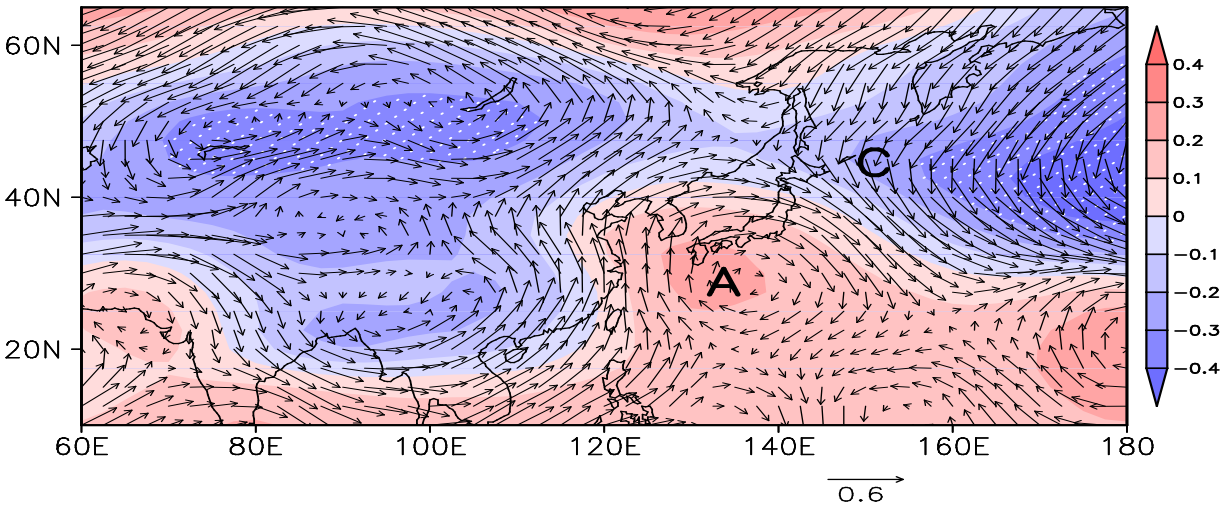

Figure 7. The CC between predictor x_3 ($\times -1$) and Z500 DY (shade)/850 hPa wind DY (arrow) in winter from 1980 to 2013. The dots indicate that the CC exceeded the 95% confidence level. A and C represent anti-cyclone and cyclone, respectively.

For Predictor x_4, the following contents were revised:

Thus, the EAJS was weakened by the induced easterly and shifted northward that illustrated less cold activities over NCP (Yang et al. 2002) and generated more haze days.

For Predictor x_5, the following contents were revised:

Following SST, the soil moisture is another important factor for seasonal prediction (Guo et al. 2007). The WHD_{NCP} was closely correlated with the moisture conditions due to the hygroscopicity of the atmospheric particles (Yin et al. 2015a). ……Being specific to local circulations, the cyclone over South China and the anti-cyclone over NCP and West Pacific stimulated significant southeaster between them (Figure omitted) that transported more moisture but decelerated the surface wind in the NCP.

For Predictor x_6, the following contents and Figure 13 were revised:

The anomalous geopotential height was distributed zonally at high latitude indicating that the meridional circulations that transported cold air were weak. The positive high over NCP could confine the vertical motion and the vertical diffusion of atmospheric particles and intensify the haze pollution over the NCP.

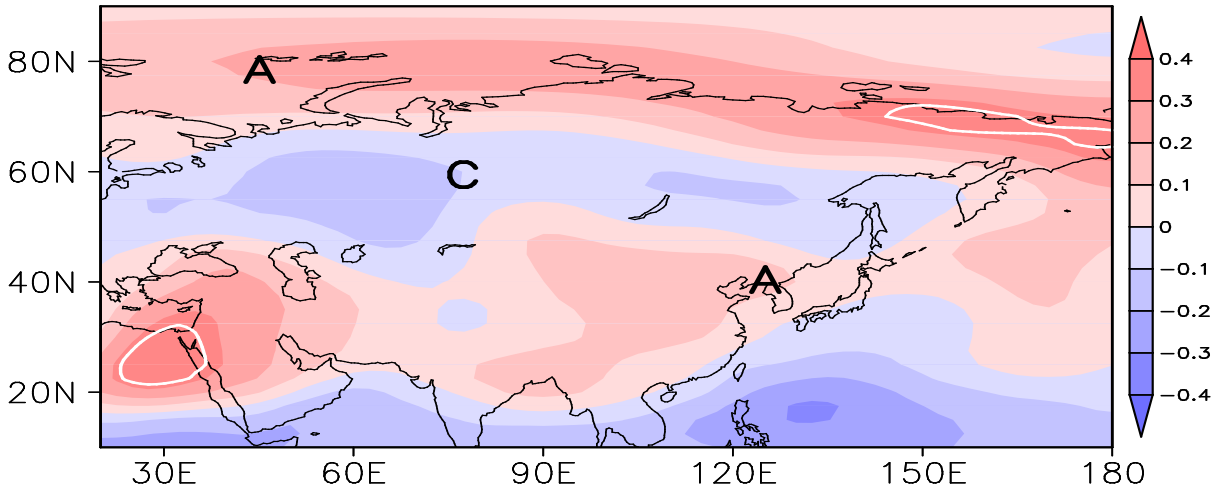

Figure 13. The CC between predictor x_6 and Z500 DY in winter from 1980 to 2013. The white curves indicate that the CC exceeded the 95% confidence level. A and C represent anti-cyclone and cyclone, respectively.

For Predictor x_7, the following contents and were revised:

……The anomalous anti-cyclone over NCP and adjacent ocean not only led to stable atmosphere but also resulted in small wind and high humidity…….

(3) There are far too many acronyms. This made me very confused when reading this paper. So, how can the authors expect the readers to remember all these acronyms in reading through the paper?

Reply

Yes, too many acronyms make the article difficult to read.

Revision in the last paragraph:

We have deleted the acronyms that used less than (including) thrice, such as Z, SWP, PSS, TBO, CPC, GLM and EV.

(4) The writing are needed to be further improved, and some sentences are needed to be rephrased to make them more clear. At several places, I cannot understand what is being conveyed. For example, "some new climatic finding have been helpful seasonal. . .", "soil moisture is an important . . . but only after SST", and so on. Please re-edit before submitting

Reply

We have re-edited and improved the writing sentence by sentence, including the issues mentioned here and some others.

Revision related to the issues mentioned here, and the other revisions were addressed in the manuscript.

Some new climatic studies should be helpful for diagnosing seasonal predictors of winter haze days over the NCP (WHD_{NCP})

Following SST, the soil moisture is another important factor for seasonal prediction (Guo et al. 2007).

(5)Some references are cited in the text but not listed in the Reference section. Please check throughout the manuscript.

Reply

We checked throughout the manuscript and added the missed and some latest references.

Revisions:

The accessorial references were listed below.

Czaja A, Frankignoul C. 1999. Influence of the North Atlantic SST onthe atmospheric circulation. Geophys. Res. Lett. 26: 2969 –2972

Huang Y Y, Wang H J, Fan K. 2014. Improving the Prediction of the Summer Asian-Pacific Oscillation Using the Interannual Increment Approach. J. Climate, 27: 8126—8134, doi: http://dx.doi.org/10.1175/JCLI-D-14-00209.1

Yang S, Lau K M, Kim K M. 2002. ariations of the East Asian Jet Stream and Asian–Pacific–American Winter Climate Anomalies. Journal of Climate, 15(3): 306—325

Yee T, Mitchell N. 1991. Generalized additive models in plant ecology, Journal of Vegetation Science, 2(5): 587—602

Xiao D, Li Y, Fan S J, Zhang R H, Sun J R, Wang Y. 2015. Plausible influence of Atlantic Ocean SST anomalies on winter haze in China. Theor. Appl. Climatol, 122: 249—257