Responses to the reviewer's comments point by point

We thank the reviewer for his/her comments, and we do think the comments and suggestions improved our manuscript considerably. Our point-by-point replies to the comments are given below. The replies are in blue font, the revisions in the revised manuscript and the responses with red font, and important statements are of bold.

General Comments:

My two main concerns deal with the need for improved referencing of previous work, and more details and motivation are needed regarding the ozone forecast equations. The standard of English is quite good, but there are many instances of grammatical errors or awkward phrasing. The paper should be revised for English prior to publication.

Reply:

Thanks for the comment. Referring to your comments, we have reconsidered the references in the article; revised the problems in the section of the ozone forecast equations and the language problems with the help of native speaker. Language modification is not marked in the revised manuscript in red font.

Major comments:

1. The title should be modified so that is uses the term "circulation pattern" rather than "circulations". Circulation pattern is defined by the Glossary of the American Meteorological society, while circulations is not defined: http://glossary.ametsoc.org/wiki/Circulation_pattern

Also, variability is a better word choice than variations. Therefore, the title should be: "Quantifying the impact of synoptic circulation patterns on ozone variability in North

China from April-October, 2013-2017" Throughout the paper "synoptic circulation pattern" should be the preferred term.

Reply:

Thanks for the comment. **We reconsidered the terms 'circulation pattern' and 'weather type' and revised them in our paper. Based on previous references, we think the best term to describe the Lamb weather typing technique in the entire revised manuscript is 'weather types,' and in other instances, we used 'circulation pattern.' we also replaced 'variation' with 'variability.'.**

2. The Introduction does a very poor job of referencing relevant papers in support of the claims made in the text:

2) the papers by Liu et al [2007; 2012] focus on PM2.5 and are not authoritative papers for explaining ozone photochemistry. Instead see Monks et al [2009; 2015].

3) Line 51: please provide a reference for APAPPC

4) Line 58: references are need for the impact of climate on ozone. Jacob and Winner is appropriate, as is Lu et al. [2019].

5) Regarding the background on the association between transport patterns and air pollution, this paper is missing some key references (listed below), such as Moody et al. [1998] and Cooper et al. [2001]. Also, Section 4.4 of Monks et al. [2009] provides a very good summary of the early work (through 2008) on the relationship between synoptic patterns and air pollution transport. An important paper for China is Wang et al., 2009.

Reply:

Thank you very much for your valuable suggestion. According to your suggestion, we revised the references in this article.

On comment 3), We revised as shown in lines 55-56, as follows: 'the Action Plan for Air Pollution Prevention and Control (www.gov.cn/zwgk/2013-09/12/content_2486773.htm) was implemented.'

3. I have many questions regarding Section 3.4:

1) The authors need to explain why they developed the equations to forecast ozone. Is this just an academic exercise to see if its's even possible? Has this method been requested by air quality managers? Is it an alternative to atmospheric chemistry models that have not performed well?

Reply:

In this section, we did not express our meaning clearly. The reason for establishing this equation is to quantify the effect of synoptic weather patterns changes on day-to-day ozone concentration and then to establish the ozone potential forecast model. Therefore, we changed the title of 3.4 as shown in lines 363-364, as follows: '**Quantifying the impact of weather patterns on day-to-day ozone concentration and forecasting daily ozone concentration.**'

The primary motivation of this study is to provide a comprehensive and quantitative understanding of how weather influences ozone pollution in Northern China; thus, we aim to quantify the impacts of synoptic weather patterns and local meteorological factors on daily variations of surface ozone in Northern China. We also want to search for a linkage between the daily variation of surface ozone and the local and synoptic meteorological factors statistically. To better reflect this view, we added the following sentences in lines 86-89 of the revised manuscript: **'Quantifying the contribution of local meteorological factors to the day-to-day variation in ozone will a provide scientific basis and guidance for reasonable ozone reduction measures, and clarifying and quantifying the relationship between meteorological factors and ozone is vital for daily ozone pollution potential forecasts.'**

Multiple linear regression (MLR) is an effective and widely used way to describe the relationship between meteorology and air quality and thus to aid in the prediction of air quality (Shen et al., 2015; Otero et al., 2016; Li et al., 2019). Compared to atmospheric chemistry models, the potential forecasting model of ozone is reliable and requires a low computational burden, which means the potential ozone could be assessed quickly and accurately in the short term or even

in the medium/long term against the background of global climate change, which has been done in some regions (Cheng et al., 2007; Demuzere and van Lipzig, 2010a).

2) How would this method work in operational mode? Would a weather forecast model be run to identify the synoptic circulation pattern for the next day, and then for a given city, select the equation that predicts ozone for that particular synoptic circulation pattern? Does Figure 9 show results for each city, using all five major synoptic circulation patterns?

Reply:

We intend to use the results of numerical weather model (e.g., WRF) to determine day-to-day weather patterns. **Since the Lamb weather classification method is not limited by the sample size, the weather classification results can be obtained as long as there is a predicted sea level pressure field. Therefore, we can easily determine the predicted weather type.** Other meteorological factors also depend on the results of the numerical weather model. Referring to the views of Reviewer 1, we reconsidered that TCC can be obtained indirectly from the model; however, considering the complexity of indirect computation and its influence on ozone in the prediction model, we do not consider TCC anymore and rebuilt the ozone potential prediction models in 14 cities.

We realized that we did not emphasize the percentage of the modeled data and validated data in Section 2.5. We added the following description (also as shown in lines 180-182 of the revised manuscript): **'Notably, in this research, after excluding the missing data and disordering the time sequences, 80% of these days were used to build the potential forecast equations and the remaining 20% were used to validate the accuracy of the equations.' Therefore, Figure 9 shows the validation of the remaining 20% of the data (not input into the model) by the modeling equation for each city. For validation data, the prediction of ozone concentration obtained by inputting the meteorological factors into the corresponding weather category's simulated formula of specific city; therefore, composite validation**

datasets indicate the prediction ozone concentrations of five categories are integrated (as shown in lines 394-397).

3) The authors provided some summary statistics in the Supplement (Table S4) to describe the performance of the forecast equations, but these results are not very intuitive or easy to understand. It would really help if the authors can select a typical city and then report the predicted ozone values for the five major synoptic circulation patterns, and then report the range of values that were actually observed. For example, if the model predicts Beijing will have ozone of 160 ug m-3 tomorrow under Cyclonic conditions, but the observations show a range of 140 +/- 50 ug m-3 (where the uncertainty is 2 standard deviations) , the reader might conclude that the while the equation predicts a high ozone day there is a wide range of uncertainty.

Reply:

In order to better illustrate the accuracy of the predicted results, we added in the supplement a comparison figure between the simulated results and the measured results from April to October 2013-2017. The added description is shown in the fourth paragraph of Section 3.4.

The results reveal that most of the validation data are within the acceptable error range within the 2:1 and 1:2 ratio lines, and the scatters are distributed evenly around the 1:1 line. **For example, the comparison of the observed and predicted ozone in Beijing during our study period is shown in Fig. S10. This also indicates that the segmented synoptic-regression approach is practicable to construct the ozone potential forecasting model in most cities in North China.** (as shown in lines 400-403)

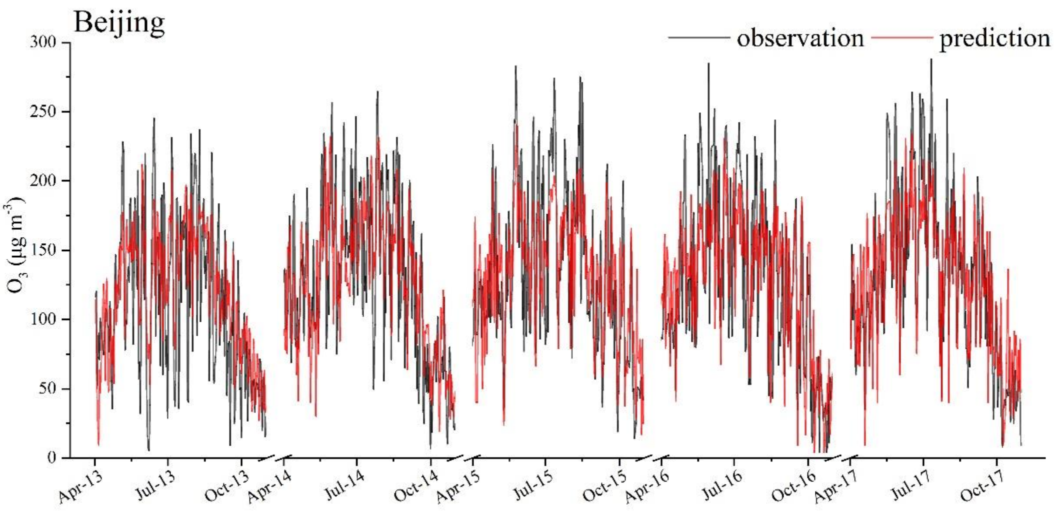

Fig. S10. Comparison of the observed and predicted values in Beijing from April-October 2013-2017

4) Are the forecasts from these equations any better than the forecasts from an atmospheric chemistry model?

Reply:

The MLR method used in this study is based on the synoptic weather patterns; thus, it is called as a segmented synoptic-regression analysis approach. **This method is superior to the traditional simulation only using local meteorological factors and can more accurately quantify the impact of meteorological conditions on day-to-day ozone concentration (Eder et al., 1994; Demuzere and van Lipzig, 2010b).**

The prediction model of ozone concentration established by the synoptic-regression method is a potential prediction model based on meteorological factors. **Its function is not to accurately predict the concentration of ozone but to predict the possible concentration of ozone under certain weather conditions in the future. This method is simple and rapid in assessing future ozone concentrations for short-range or even mid- and long-term forecasting.**

Minor Comments:

Line 63-65 This sentence is not well written. A better form would be: A given synoptic circulation pattern represents a particular range of meteorological conditions, therefore synoptic classification is a useful method for gaining insight into the impact of meteorology on ozone levels on the regional scale.

Reply:

Thank you. We have replaced this statement with the previous description, as shown in lines 65-67.

Line 182 Please explain how the exceedance ratio is calculated

Reply:

Thank you. We added the sentence as shown in lines 193-194 of revised manuscript, as follows: ‘exceedance ratio which means the proportion of days exceeding the standard (160 μg m^{-3}).’

Line 186 Beijing is a city, is it not? Or is “Beijing” referring to a large urban region that contains smaller cities?

Reply:

Beijing refers to an administrative division.

Line 208 These references are not authoritative when describing the impacts of stratospheric ozone on China. A good overview is provided by Stohl et al., and a recent model analysis that quantifies the impact of the stratosphere on ozone above China is Verstraeten et al., 2015.

Reply:

Thank you. We added these references as shown in line 221 of revised manuscript.

Line 209 It’s not clear to me how the results of Tang et al. differ from your results. Please clearly state the results from Tang et al. and then show how your results are different.

Reply:

Thank you. We added the sentence as shown in lines 221-225 of revised manuscript, as follows: ‘Notably, this conclusion is different from that of Tang et al. (2012) , ,who reported that the concentration in July was higher than that in May in North China during 2009-2010. However, as our study shows that the domain-averaged MDA8 O3 in May was even higher than in July, the concentrated pollution episode occurred earlier, especially in 2017.'

Line 216 Not all of these references are authoritative. A good review of the relationship between ozone and temperature is Pusede et al., 2015.

Reply:

Thank you. We added the reference as shown in line 230 of revised manuscript.

Lines 256-259 These ozone fluctuations in relation to cold fronts have been reported for the eastern USA: Cooper et al., 2001 and Cooper et al., 2002

Reply:

Thank you. We added the references as shown in line 274 of revised manuscript.

Figure 1. The blue boxes around some of the cities are very difficult to see. Please make the lines thicker.

Reply:

Thank you. We repainted the figure as follows:

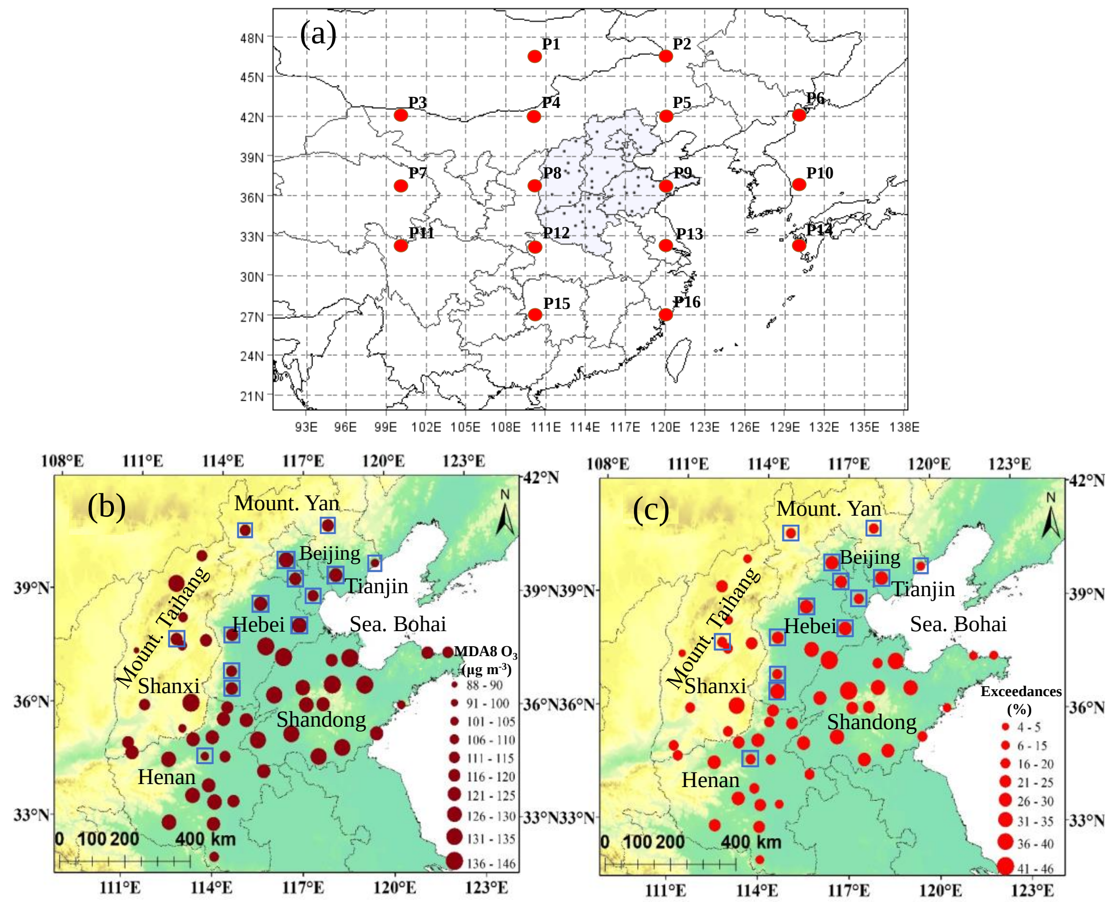

Fig. 1. Location of North China (shaded area), all cities (black spots) and sea level pressure grids (a). The 16 red points show the locations of the 5°×10° mean sea level pressure grids used for the Lamb-Jenkinson weather type classification. The spatial distributions of the maximum daily 8-h running average O_3 (MDA8 O_3) concentration (b) and exceedance ratios (c) for 58 cities. Statistics for 2013-2017 are shown with blue boxes; the other boxes are those for 2015-2017. The base map is topography; the elevations of the Taihang Mountains are more than 1200 meters, and the Yan Mountains range from 600 to 1500 meters.

Figure 4. The panels in this figure are far too small to be seen. This figure needs to fill an entire page, so that the reader can clearly see the information. Likewise, Figure S8 is impossible to read.

Reply:

Thank you. In order to see the information of Fig. S8, we repaint Fig. S8 into two figures, Fig. S8 and Fig. S9, as shown below:

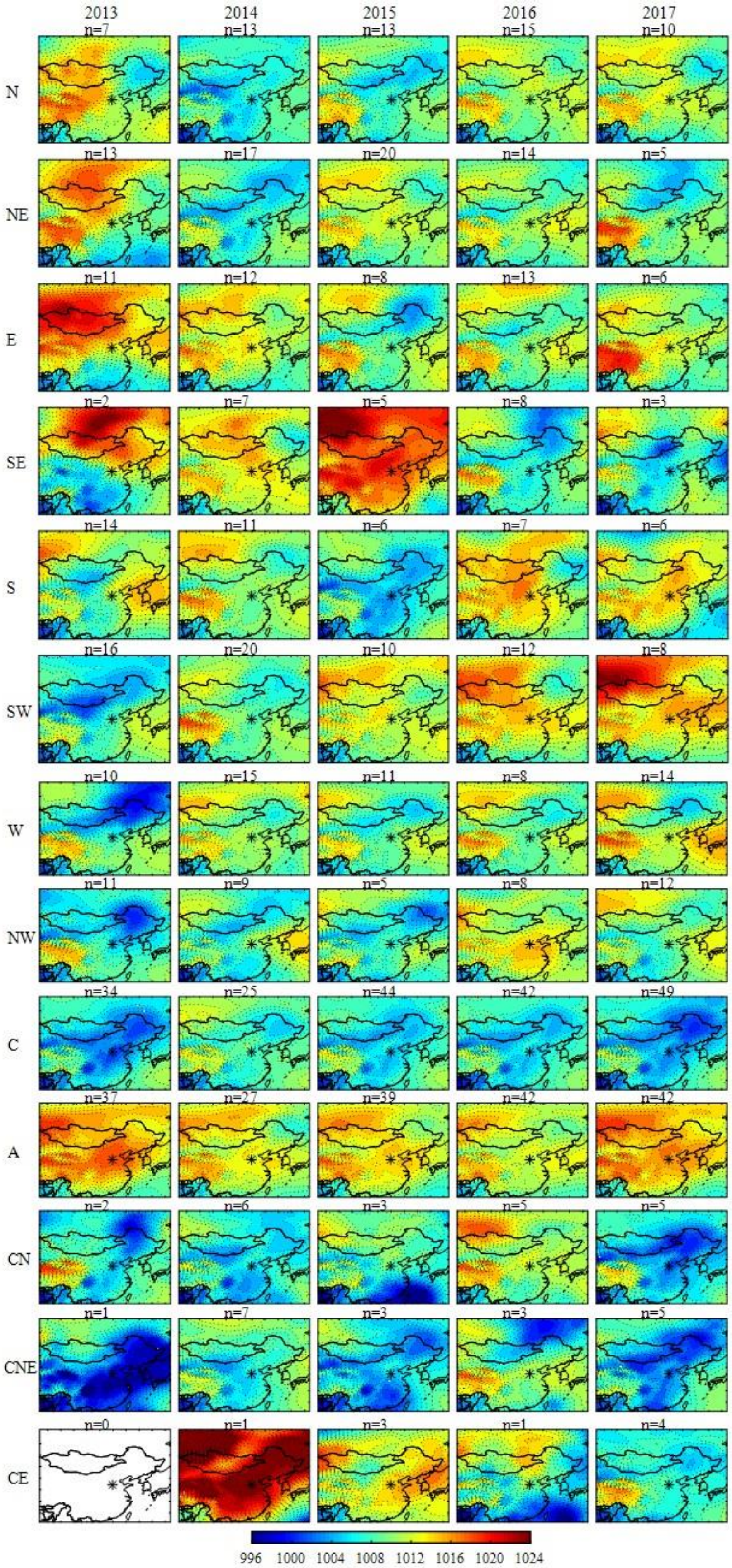

Fig. S8. Pressure field characteristics and occurrence days (n) of weather type N to CE in 2013-2017.

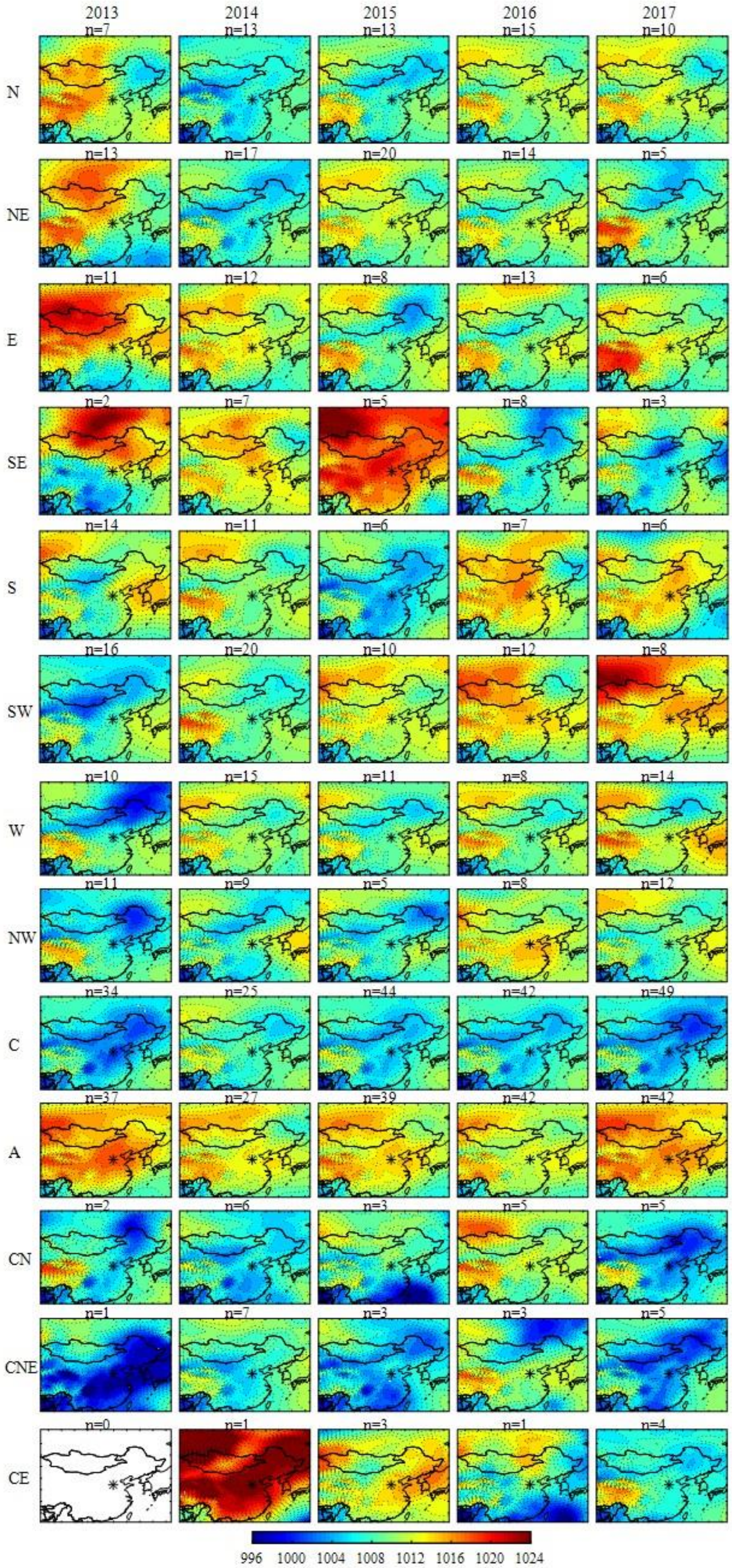

Fig. S9. Pressure field characteristics and occurrence days (n) of weather type CSE to ANW in 2013-2017.

References

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