Response to the review of "Impact of western pacific subtropical high on ozone pollution over eastern china":

We thank the referee for the detailed and constructive comments. We respond to each specific comment below. The referee's original comments are shown in blue. Our replies are shown in black. The corresponding changes in the manuscript are shown in *Italic black*.

Anonymous Referee #2:

This study presents a combined modeling and observational investigation of how meteorological conditions associated with the western pacific subtropical high (WPSH) affect surface ozone. The manuscript tells a nice story, with each piece of analysis following on from the previous. Their approach does represent a broader (temporally and spatially) and more coherent analysis than previous studies, particularly Zhao and Wang (2017). The manuscript is well written and leads the reader through the analysis in a very clear manner, particularly the introduction. Observational analysis is backed up convincingly by a modeling study which seeks to determine the effect of natural emissions on ozone variability. This modeling study further demonstrates the importance of physical and chemical mechanisms during different phases of the WPSH.

Main comments:

1) **My main comment is about what this manuscript presents that isn't already published. To me it seems as if the manuscripts novelty is in the modeling, and improved understanding about the processes that alter the ozone budget under the WPSH regimes. However, in the conclusion and abstract much of the text is dedicated to drawing conclusions about ozone changes driven by meteorology, which is very similar to the work of Zhao and Wang (2017). I do note that the authors do point out that their study considers and observational record two years longer than Zhao and Wang. The paper provides useful insights from the modeling approaches, though my opinion is that these insights should be the focus of the paper.**

Thank you very much for pointing out this problem. We revised the abstract and conclusion to emphasize our focus in modeling and diagnosis of the phsycial processes.

[Abstract, Lines 18-39]:

Surface ozone is a major pollutant in Eastern China, especially during the summer season. The formation of surface ozone pollution highly depends on meteorological *conditions which are largely controlled by regional circulation patterns, which can modulate ozone concentrations by influencing the emission of the precursors, the chemical production rates, and regional transport. Here we show that summertime ozone pollution over Eastern China is distinctly modulated by the variability of West Pacific Subtropical High (WPSH), a major synoptic system that controls the summertime weather conditions of East Asia. Composite and regression analyses indicate that positive WPSH anomaly is associated with higher than normal surface ozone concentration over Northern China but lower ozone over Southern China. Stronger than normal WPSH leads to higher temperatures, stronger solar radiation at the land surface, lower relative humidity, and less precipitation in Northern China, favoring the production and accumulation of surface ozone. In contrast, all meteorological variables show reverse changes in Southern China under stronger WPSH. GEOS-Chem simulations reasonably reproduce the observed ozone changes associated with the WPSH and support the statistical analyses. We further conduct budget diagnosis to quantify the detailed contributions of chemistry, transport, mixing, and convection processes. Results show that the changes of ozone is primarily attributed to chemical processes. Moreover, the natural emission of precursors from biogenic and soil sources, a major component influencing the chemical production, accounts for ~30% of the total surface ozone changes.*

[Main text, Lines 482-511]:

In this study, we highlight the role of weather systems like WPSH on surface ozone pollution in China interpreted with a comprehensive mechanism analysis. Statistical analysis of surface observation reveals a dipole-like ozone change associated with the WPSH intensity, with stronger WPSH increasing surface ozone concentration over Northern China but reducing it over Southern China, and a reversed pattern during its weak phase. This phenomenon is associated with the change of meteorological conditions induced by the change of WPSH intensity. Specifically, when WPSH is stronger than normal, dry, hot south winds from inland area serves to increase temperature in Northern China but decrease relative humidity, cloud cover, and precipitation, creating an environment that is favorable for surface ozone formation. In Southern China, the changes of meteorology and ozone are reversely symmetric to the north. Opposite changes are found during weaker WPSH conditions.

This dipole pattern of surface ozone changes is well reproduced by the GEOS-Chem model simulations, which not only confirms the impact of meteorology on ozone concentrations, but also allows the diagnosis of the processes involved in ozone change, namely chemistry, transport, mixing, and convection processes. Our results show that chemistry and transport processes play more important roles than mixing and convection. The transport budget confirms the pattern and quantifies the magnitude of regional transport indicated by the wind anomalies in the meteorological fields. The enormous change in the chemistry budget shows that chemical production serves as the leading process determining the direction of the *ozone change. As the anthropogenic emission is fixed, the chemistry process is influenced by the changes in natural emission and chemical reaction rates associated with WPSH variations. By comparing the GEOS-Chem simulations with the MEGAN and soil emissions turned on and off, we determined that ozone changes caused by natural emissions (including BVOCs and soil* NO_x*) account for ~30% of the total ozone changes. The GEOS-Chem simulations in our study serve as a useful tool to provide more quantitative insights and analysis, which compensate for the statistical analysis results in previous studies (Zhao and Wang, 2017; Yin et al., 2019).*

2) The use of north and south China does not seem consistent throughout the manuscript. At L205 north/south is demarcated at 32N. Later, at L333, north and south regions are defined 36-42N and 26-32N respectively. Some clarity would be beneficial. The choice of the north and south region (L333) seems somewhat arbitrary and need more rationale, as many conclusions in section 3.4 rest on this choice, particularly those surrounding the contributions of BVOCs, soilNOx etc in figures 6(i-n).

Thank you for pointing out this problem. The different definition is mainly due to the difference spatial representation of site observation and model grids. We added the following explanations to clarify this issue.

[Main text, Lines 227-235]:

Regarding the region definition in this study, because in section 3.1 and section 3.2 the calculations are all site-based (city-average), we applied a single latitude division line of 32°N to separate Northern and Southern China and a longitude division line of 100°E as a boundary for a rough definition of Eastern China (green lines in Figure 2a). In section 3.3 and later, the paper mainly focused on the model result analysis, which is gird-based (region-average); thus, we used a north region and a south region with the same size and shape to ensure their comparability. The principle we chose the north and south region is based on the principle of avoiding the influence of coastline and covering as much land area as possible.

Minor comments:

-L137 Is this definition of weak, normal, strong conditions common? If not, more rationale about these percentile choices is warranted.

Thanks for pointing out this problem. We added explanations about the choice of this division standard.

[Main text, Lines 149-157]:

Specifically, days with WPSH-index exceeding the 90th percentile of its distribution are classified as strong WPSH days, the 45th -55th percentile as normal WPSH days, and those below the 10th percentile as weak WPSH days (Figure 1c). There are two main reasons for the setting of this division standard: 1) using the 10% percentile range ensures that we have the same number of days during the summer from 2014 to 2018 for each type and enough sample (46 days for each type) for the composite analysis and statistical test; 2) the chosen of the percentile threshold is to maximize the difference between strong, weak and normal WPSH conditions in the time span of our study.

-L229-233 This paragraph and the accompanying graphs really clearly and nicely demonstrate the meteorological effects. However, I don't agree that figure 3c shows a decrease in precipitation over northern china, at least not significantly. Figure 3c shows very little change to me.

Thanks for pointing out this problem. We agree that the decrease in precipitation over northern China is not significant. We changed the expression as below. However, relative humidity shows a coherent reduction over Northern China, so our conclusion remains intact.

[Main text, Lines 272-277]：

As a result, Northern China exhibits a decrease in relative humidity (Figure 3e) and an increase in temperature (Figure 3k). Although the precipitation does not show significant changes, the decrease in cloud cover (Figure 3g) increases the near-surface solar radiation (Figure 3i) and can further change the photochemical reaction rates, which partly explains the increase of ozone concentrations here (Jeong and Park, 2013; Gong and Liao, 2019).

-L283 Are the modelled strong/normal/weak values calculated from the same days as the observations? A direct comparison as seen in Figure 2 would require this, but it is not clear to me that this is the case.

Thank you for pointing out this lack of clarity. The modeled strong/normal/weak values were calculated from the same days as the observations. We added an explanation to make it clear.

[Main text, Lines 344-347]：

Figure 2 (filled contours) shows the simulated MDA8 changes during strong/weak WPSH days with respect to normal days (a&b) and their relative changes (c&d). The simulated strong/normal/weak values were calculated from the same days as the observations.

-Figure 1c requires an axis label dependent on your normalization procedure. It is not apparent what form of normalization has been performed.

Thank you for pointing out this lack of clarity. We added explanations to make it clear.

[Main text, Lines 141-145]:

Here we adopted the same method to calculate the geopotential height anomaly and divided the anomaly time series according to its standard deviation to obtain a normalized WPSH index. Then we used this index to represent the strength and variability of the WPSH (Figure 1c).

-Other figures. The quality of the figures is excellent, if a little small.

Thank you for pointing out the size problem. We acknowledge that some figures are a bit small, which is also our concern. However, as we want to show different variables or processes together to facilitate comparison, it's not easy to enlarge it due to the large number of subplots. We provided a landscape version for figure 4 and figure 6 to make them appear larger.

Technical corrections:

-L72 'some led' -> 'some that led'

Revised as suggested. Thank you.

-L103 should 'since' -> 'in'?

Revised as suggested. Thank you.

-L110 Should 'following' -> 'preceding'?

Thank you for pointing out this lack of clarity. The "following calculation" here does not refer to the preceding quality control but to the calculations in sections 3.1 and 3.2. We now moved it to the end of section 2 and discussed the calculations we did in more detail.

[Main text, Lines 227-235]:

Regarding the region definition in this study, because in section 3.1 and section 3.2 the calculations are all site-based (city-average), we applied a single latitude division line of 32°N to separate Northern and Southern China and a longitude division line of 100°E as a boundary for a rough definition of Eastern China (green lines in Figure

2a). In section 3.3 and later, the paper mainly focused on the model result analysis, which is gird-based (region-average); thus, we used a north region and a south region with the same size and shape to ensure their comparability. The principle we chose the north and south region is based on the principle of avoiding the influence of coastline and covering as much land area as possible.

-L114 was -> were

Revised as suggested. Thank you.

-L235 ‘temperatures, less’ -> ‘temperatures and less’

Revised as suggested. Thank you.

-L429 ‘much’ -> ‘more’?

Revised as suggested. Thank you.