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 #1:

Review of "Impact of western pacific subtropical high on ozone pollution over eastern china"

General: This paper examines how much impact the variability of Western Pacific Subtropical High (WPSH) have on the surface ozone over East China. A combined modeling and observational approach reveal the impact quantitatively as well as the involved chemical and physical processes. The manuscript is clear and well written, and I believe that the quantitative analysis is very important for a better understanding of summertime air quality in China. However, there are some major points which have to be clarified and discussed further, as described below.

Major points: In this study, the budget analysis of PBL ozone are performed using the diagnostics calculated in the GEOS-Chem model to investigate how and how much the variability of WPSH induces the changes in the summertime ozone over East China. However, the relationships with the meteorological conditions are not fully investigated, as pointed out below. Further analysis and discussions are needed.

1) **The ozone dry deposition process should be also taken into consideration for the budget analysis, because the variability of the WPSH influences not only the four processes diagnosed here (i.e. chemistry, transport, mixing and convection) but more or less the dry deposition process.**

Thanks for pointing out this problem. We acknowledged that dry deposition is also an essential process in tropospheric ozone pollution. However, as we used the non-local PBL scheme in our simulation, the dry deposition is included in the "mixing" term of the budget analysis. We have explained this problem in the main text. We also added the diagnosis of dry deposition flux and dry deposition velocity in the supplementary.

[Main text, Lines 211-218]:

Dry deposition is not separately discussed in the budget diagnosis, as this process is included in mixing when using the non-local PBL mixing scheme. However, as it is an important process for ozone removal, we show the dry deposition flux and velocity at the surface level in the supplementary (Figure S2). It is found that dry deposition velocity appears spatially correlated with precipitation, i.e., higher precipitation generally corresponds to higher dry deposition velocity, whereas dry deposition flux is proportional to the change in ozone concentrations (Figure 2).

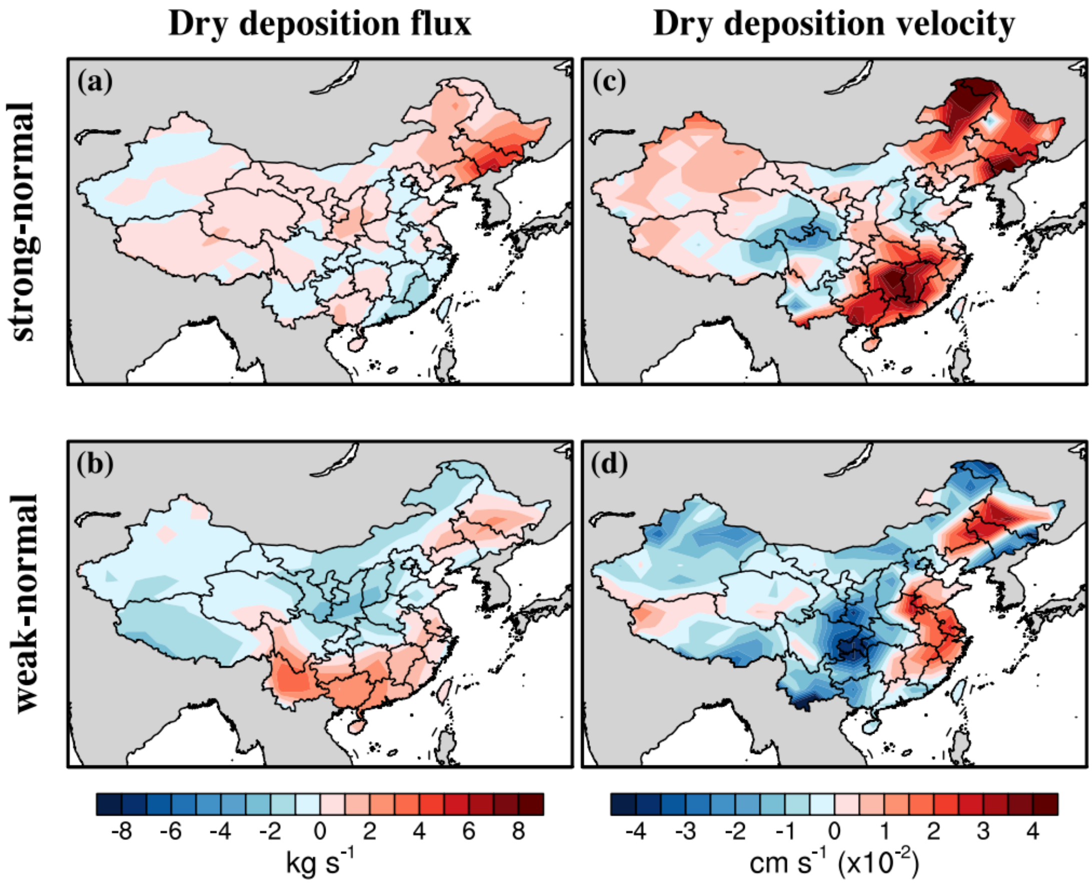

Figure S2. The changes in dry deposition flux and dry deposition velocity at the surface level in GEOS-Chem model. The first row shows the differences between strong and normal WPSH conditions, and the second row shows those between weak and normal WPSH conditions.

2) **There is lack of quantitative analysis to clarify which meteorological variables (solar radiation, temperature, RH. . .) are key factors that lead to the changes in ozone chemistry (i.e. chemical production/loss of ozone). Further analysis is needed to clarify this point.**

Thanks for pointing out this problem. In this paper, our primary focus is the impact of the coordinated change of the entire meteorological field induced by the variation of the WPSH weather system on ozone. As we mentioned in the introduction (Line 71-72), the meteorological variables are interrelated. For example, an increase in cloud cover is associated with reduced solar radiation, it is thus difficult to isolate and to quantify the contribution of each variable separately. However, we admitted that it is important to investigate which meteorological variables are the key factors. We therefore attempt to address this problem by correlation analysis of ozone and each meteorological variable to explain this problem to our best extent, as shown in Figure S3.

[Main text, Lines 281-290]:

Among these meteorological variables, RH, solar radiation, temperature, and meridional wind are mostly closely related to surface ozone concentrations (Figure S3). In particular, for Northern China, the highest correlation (positive) is found between ozone and temperature. For Central Southern China along the Yangtze River basin, ozone is most highly correlated with RH. Whereas for Southern China, wind speed and meridional winds seem to play the dominant role. The latter variable also shows reversed relationship with ozone for Northern (positive) and Southern China (negative), highlighting the different characteristics in regional transport of ozone pollution. The results of our correlation analysis are also consistent with previous studies (Jeong and Park, 2013; Zhang et al., 2015; Gong and Liao, 2019).

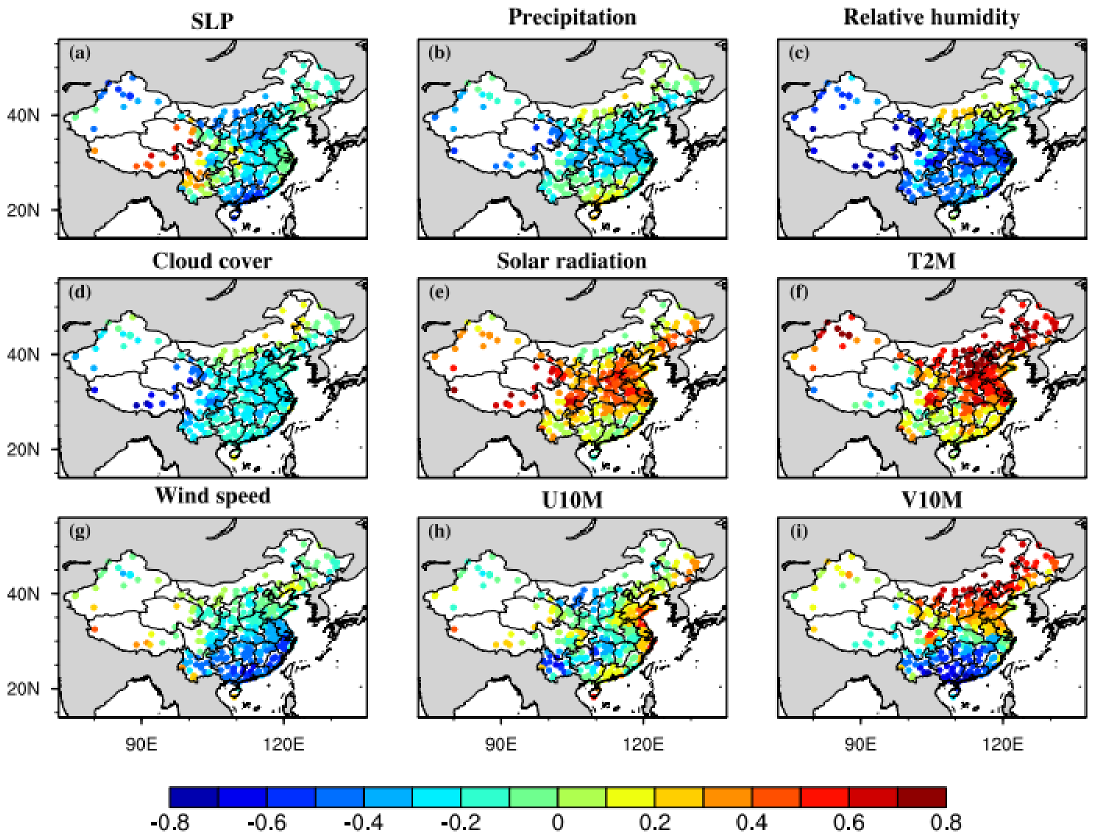

Figure S3. Correlation coefficients, between simulated daily MDA8 ozone concentrations and meteorological variables including SLP, precipitation, relative humidity, cloud cover, solar radiation, 2 m temperature, wind speed, 10 m U wind, and 10m V wind calculated for the summer periods from 2014 to 2018.

3) Intensities of convective activities associated with WPSH variation are supposed to be very large. However, the large differences in convective activities between weak and strong WPSH only induces the small differences in PBL ozone, as you pointed out (Figure 4). It is required to explain the mechanism.

Thanks for pointing out this lack of clarity. We added a few sentences to explain this mechanism.

[Main text, Lines 416-427]:

Convection only induces minor modulation to the total changes, generally less than ±1 kg s^{-1} and negligible for some cases (Figure 4l&m). There are two possible reasons for this insignificant change. On the one hand, as ozone is insoluble in water, the large changes in convective activities associated with the WPSH variation may only exert minor effect in the ozone concentration through wet scavenging. Instead, it *influences ozone concentration by the vertical transport of ozone as well as its precursors, but the average magnitude of convective transport is about one order smaller than that of chemistry. On the other hand, previous studies show that the effect of convective transport of ozone alone is to reduce the tropospheric column amounts while the convective transport of the ozone precursors tends to overcome this reduction (Wu et al., 2007; Lawrence et al., 2003). As a result, changes in ozone are neutralized and the net effect is weak.*

4) **In Figure 1c, the absolute differences in the WPSH-index between weak and normal WPSH days (purple and green dots) are several times larger than those between strong and normal WPSH days (red and green dots). It is required to discuss how this asymmetry affects the later composite analysis.**

Thanks for pointing this out. We did notice this asymmetry. However, the meteorological changes associated with strong and weak WPSH appear much more symmetric. Therefore, this feature should not affect the ozone response much. We added the following discussions about this asymmetry in WPSH index.

[Main text, Lines 355-360]:

Although the WPSH index exhibits an asymmetric feature, with the difference between weak and normal days much larger than that between strong and normal days, the responses of meteorological variables appear more symmetric (Figure 3). This thus leads to the more symmetric change in ozone concentrations (Figure 2). Therefore, we consider this asymmetric behavior in WPSH strength has negligible effect in the response of ozone pollution.

Minor comments:

- L103 to L106: If there are a reference paper or technical report on the observation data used here, it should be cited.

Thanks for pointing out this problem, we cited the Chinese standard document for ozone observation data.

[Main text, Lines 109-112]:

The ozone data follows the standard released by the Chinese standard document HJ 654-2013 (MEP, 2013) and the pollutant concentration data is available at https://quotsoft.net/air/. We downloaded hourly surface ozone concentration data for all sites from 2014 to 2018.

- L114: should “for 2014-2018” -> “for 1979-2018”? (see Figure 1a and 1b).

We are sorry for this confusion. Here the GEOS_FP meteorological fields are from 2014 to 2018. The timespan for ozone analysis is from 2014 to 2018. However, in section 2.2, in order to define the WPSH index, we used SLP data from 1979 to 2018 to calculate its climatological mean state and the standard deviation (Figure 1a&b). This SLP data comes from the ERA5 reanalysis rather than GEOS_FP. We added explanations to make it clear. We also added a citation and acknowledgment of the ERA5 dataset.

[Main text, Lines 131-134]:

We first used the long-term ERA5 reanalysis SLP data (Hersbach et al., 2019; https://cds.climate.copernicus.eu/) to determine the climatology and variability of SLP over the northwestern Pacific. Figure 1a shows the multi-year averaged summertime SLP field from 1979 to 2018, and Figure 1b shows its standard deviation.

- L114 to L115: If there are a reference paper or technical report on the "GEOS-FP database", it should be cited.

Thanks for your advice. We cited the "File Specification for GEOS-5 FP" here.

[Main text, Lines 118-121]:

Meteorological fields for 2014-2018 were obtained from the Goddard Earth Observing System Forward Processing (GEOS-FP) database (GEOS-FP file specification document, Version 1.0 (11 Jun 2013)), which is the current operational met data product from the Global Modeling and Assimilation Office (GMAO).

[Main text, Lines 684-685]:

Lucchesi, R., 2013: File Specification for GEOS-5 FP. GMAO Office Note No. 4 (Version 1.0), 63 pp, available from http://gmao.gsfc.nasa.gov/pubs/office_notes.

-L158: should "Cloud convection" -> "Vertical transport due to convective transport"?

Yes, thanks for pointing this out. We have revised it accordingly.

-L178: I suppose that "MEGAN and soil NOx emissions turned off" means "BVOC and soil NOx emissions are set to zero". Is it right?

Yes, HEMCO has a list of emission extensions and the GEOS-Chem users can decide whether these emissions should be used or not. There are logical switches for all datasets listed in HEMCO_Config.rc to facilitate turning different datasets on/off.

"MEGAN and soil NOx emissions turned off" here means that these two emissions datasets are not read in. We rephrased our expression to make it clear.

[Main text, Lines 203-206]:

We also performed another set of simulations with MEGAN and soil NOx emissions turned off to explore the contribution of natural emissions; in this case, these two emission datasets are not read in during the simulation.

-L209: What is the ratio of "cities with significant differences"? This information should be described.

Thanks for pointing it out. We added the ratio in the main text.

[Main text, Lines 250-259]:

Quantitatively, 45% and 31% of the cities show significant differences (p-value< 0.05) in Student's t-test for the strong and weak WPSH relative to normal days, respectively. During strong WPSH days, the average MDA8 increased by 10.7 ppbv (+19%, Figure 2a&c) in Northern China and decreased by 11.2 ppbv (-24%, Figure 2a&c) in Southern China. Under weak WPSH conditions, the average MDA8 decreased by 10.2 ppbv (-17%, Figure 2b&d) in Northern China and increased by 4.6 ppbv (+10%, Figure 2b&d) in Southern China. This dipole change of ozone is also confirmed by a regression analysis of surface ozone against the WPSH index (Figure 2e),in which 71% cities show significant signals (p-value< 0.05) with positive coefficients over Northern China and negative values in Southern China.

-L251 to L252: "high-pressure center in Northwest Pacific is . . . shifted slightly southward (Figure 3b)". The readers cannot know which the southward shift is slight or not, because the difference in SLP between strong (weak) and normal WPSH days is only showed in Figure 3a (3b). The SLP composite under strong (weak) WPSH days should be also depicted in Figure 3a (3b).

We are sorry for this confusion. What we want to express is the difference of the SLP between normal and weak WPSH. We rephrased this sentence to eliminate this ambiguity.

[Main text, Lines 304-305]:

Under the weak WPSH condition, it shows a negative anomaly center in the Northwest Pacific Ocean and to the southeast of China coast (Figure 3b).

- L257: Does "abnormal changes" mean "asymmetric changes" in L254? Is it an appropriate expression in the context?

The “abnormal changes” here correspond to “solar radiation decreased and total precipitation increased in Guangdong province”. We acknowledge that “asymmetric changes” is a more appropriate expression and we now used this word instead.

[Main text, Lines 309-311]:

However, these asymmetric changes in meteorology well match the observed decrease of ozone in Guangdong province.