Response to comments #3

RC3 comments:
Li et al ("Surface ozone impacts on major crop production in China from 2010 to 2017") quantifies the crop production and economic loss from surface ozone (O_3) in China over several years. Overall, the method used is sound and has been used by many studies previously. However, significant improvements must be made to the description of results, discussion and implications for this to be a meaningful scientific paper worth of publication in ACP.
Response: We thank the reviewer's very positive comments of our study. We have revised the paper to take those comments into account. We provide detailed responses below (reviewers' comments in plain font, our replies in blue), and very much appreciate the reviewers' time.

Sections 3.2-3.4 should be simplified and reorganized (together or separately) to better highlight the main results, rather than list many values that can be found in tables and figures. Increase comparing/contrasting of different crops and regions and tie these to an improved discussion section.
Rsesponse: Response: We thank the reviewer's suggestion. We now add one topical sentence in each from section 3.2 to 3.4:
Line 158:
"The accumulated AOT40 values vary among the four crops, mainly determined by the seasonality of ozone concentrations."
Line 186:
"From equation 3, we expect that the spatial distribution of CPL among the four crops would be different from their RYLs."

The current discussion section is largely a restating of the intro, methods and results. Instead, expand the final paragraph to speak more about the implications of the work. Include discussion of the seasonal cycle of O_3 that is carried through to the cropping season differences. Add more about the chemistry and policies throughout China that causes the results. For example, why O3 increases when PM regulations were successful. This section should also include discussion of the uncertainties in the model O_3 concentration, AOT40 metric and economic valuation.
Response: We appreciate the reviewer's comment about the discussion. We now rewrite the discussion. In the new Discussion section, we talked about the decreasing trend of ozone-induced crop yields losses in China after 2013, the future climate and population changes on crops, and also the uncertainties for our study originating from the model, the emission inventories and the concentration-response function we used. We also rewrote the Results and Summary section to show the results only.
"4 Discussions

Surface ozone emerged as an important environmental issue in China, and were shown increasing trend in major megacities for the past few years using both modelling and observation data (Lu et al., 2018, 2019; 2020; Li et als., 2020; Liu and Wang, 2020a,b; Ni et al., 2018; Wang et al., 2020), though strict clean air regulations have been implemented after 2013. Exposure to high concentrations of surface ozone not only poses threat to human health, but also cause damages to crop. Our study presented a comprehensive analysis on the impact of surface ozone exposure on four major crop production loss in China, including wheat, rice (double early and late rice, single rice), maize (north maize and south maize), and soybean. Unlike the surface ozone trend, we showed that the national crop yields for major crops in China usually peaks in 2014 or 2015, shortly after the strict clean air regulations after 2013. The decreasing trend of crop yield losses associated with surface ozone exposure was mainly explained by the fact that the surface ozone in China were increasing in urban areas, while decreasing in the rural areas (Li et al., 2022), where the major crops are planted. Nonetheless, the relatively higher ozone, especially compared with developed countries, such as United States and Japan (Lu et al., 2018), are still posing great threats to crop productions in China. Combing the annual crop production from the Statistical Yearbook of China, we estimated that the surface ozone in China could cause an average of 26.42 million metric tons losses (Mt) of wheat production from 2010 to 2017. These losses are even comparable to the annual average wheat production during the same period in Paris, which is the fifth largest wheat production in the world (http://www.fao.org/faostat/en/#data/QC, accessed December 12, 2021). We also estimated that the surface ozone exposure could cause 18.58 Mt losses of rice production in China, comparable to the annual rice production in Philippines, the world's 8^{th} largest rice production. Transferring to economic values, we estimated the surface ozone exposure could cost more than 20 billion $ losses, representing more than 0.20% of annual average Gross Domestic Product (GDP) in China from 2010 to 2017. The latest edition of the State of Food Security and Nutrition in the World estimated that between 720 and 811 million people in the world faced hunger in 2020, with 161 million increasing compared with 2019, and nearly 2.37 billion people did not have access to adequate food, with no regions spared (FAO, 2021). Therefore, reducing surface ozone pollution could not only bring the benefits of reducing ozone-related premature deaths, but also bring the benefits of control the global hunger and malnutrition issues, thus helping to reach the Sustainable Development Goal 2 of "Zero Hunger". Meanwhile, Chinese population are projected to continue to increase and peak around 2025 under all the shared socioeconomic pathways (SSPs, Chen et al., 2020), making it more urgent to improve the crop productions by all means.

Uncertainties exist in the design of our study, including the coarse resolution of the global transport model we used, the regional emission inventories, as we as the concentration-response functions. From the model evaluation, we learnt that our model tends to overestimate the annual MDA8 O_3 concentration in China. However, through sensitivity experiences, Wang et al. (2022) showed that model biases in ozone were likely to have a relatively small impact on estimated production losses. The uncertainties from the changes in growing seasons, and the concentration-response functions tend to have larger effects. We propose that further studies, using high-resolution bias-corrected ozone concentration data and region-specific response functions, need to be carried out to quantify the negative effects of surface ozone on crops. In our study, we also did not consider the possible climate changes on the crop productions. However, previous studies have demonstrated that temperature increases could significantly reduce the crop productions as well (Asseng et al., 2015; Wiebe et al., 2015; Liu et al., 2016; Zhao et al., 2016, 2017). Despite these limitations and uncertainties, our study strives to estimate the long-term negative effects from surface ozone exposure in China before and after the clean air action in China. These estimations could provide the government and policy-makers useful references to be taken into account of the detrimental effects of ozone exposure on crop productions in China when making regional-specific ozone control policies."

More specific comments/suggestions are listed below:

Line 74: Add at least the direction of adjustment. Increased due to vertical gradient near surface?

Response: Thanks for the comments. We now rephrase this sentence in line 82-85:
"We then adjusted the model simulated surface ozone from lowest grid box height (usually above 30 meters) to the crop height (usually 1 meter at the ambient observation sites), which usually reduce the simulated ozone concentrations by 30-50% (Van Dingenen et al., 2009; Zhang et al., 2012)."

Line 77: Why compare model AOT40 and not model concentrations? AOT40 has also not yet been introduced.
Line 80: A figure showing the observed-model concentration comparison would be helpful, especially the expected seasonal cycle, despite the bias. Do the patterns match?
Response: We thank the reviewer pointing this out. These are really good questionss! Since they are related, we put our responses together here.
We evaluated the modelled ozone concentration from 2013 to 2017 in our earlier paper using the same set of simulations, which was just published in the same journal (section 3.1 in Zhang Y. et al., 2021: *Impacts of emission changes in China from 2010 to 2017 on domestic and intercontinental air quality and health effect*). In Zhang et al., 2021, we evaluated the model's performance in simulating annual average maximum daily 8 h average (MDA8) O_3 by comparing with hourly surface observations retrieved from the China National Environmental Monitoring Center (CNEMC) network (http://106.37.208.233:20035/) from 2013 to 2017, since the data prior to 2013 are not available. From the comparison, we concluded that our model overestimates the annual MDA8 ozone in China, with mean bias of 5.7 ppbv and normalized mean bias of 13.7% for 5-yr average. However, the AOT40 comparison showed that our model simulated AOT40 values, after adjusting the model simulated ozone concentration at crop height, were lower than the observation. Reducing the sampling height from the lowest grid box center (~30m) to 1 crop height (1-3 m) on average decreases the AOT40 by half (Van Dingenen et al., 2009). To make it clear, we now rewrite this paragraph to show the model evaluations of the annual MDA8 O_3 from line 86 to line 93:

"We first evaluated the model's performance by comparing the model simulated annual average maximum daily 8-hr average (MDA8) O_3 with the surface observation from 2013 to 2017, which were downloaded from National Environmental Monitoring Center (CNEMC) Network (http://106.37.208.233:20035/). It collects at least 100 million environmental monitoring data from 1497 established air quality monitoring stations annually for national environmental quality assessment. The ozone observation data before 2013 were not available (Lu et al., 2018, 2020). In general, our model captures spatial patterns of the ozone distribution in China (Fig. S6 in Zhang et al., 2021), but overestimates the annual MDA8 O_3 concentration, with mean bias of 5.7 ppbv and normalized mean bias of 13.7% for 5-yr average from 2013 to 2017 (Table 1 in Zhang et al., 2021)."

Reference:
Van Dingenen, R., Dentener, F. J., Raes, F., Krol, M. C., Emberson, L. and Cofala, J.: The global impact of ozone on agricultural crop yields under current and future air quality legislation, Atmos. Environ., 43(3), 604–618, doi:10.1016/j.atmosenv.2008.10.033, 2009.

Zhang, Y., Shindell, D., Seltzer, K., Shen, L., Lamarque, J.-F., Zhang, Q., Zheng, B., Xing, J., Jiang, Z., and Zhang, L.: Impacts of emission changes in China from 2010 to 2017 on domestic

and intercontinental air quality and health effect, Atmos. Chem. Phys., 21, 16051–16065, https://doi.org/10.5194/acp-21-16051-2021, 2021.

Line 85: Should "matrixes" be "metrics"?
Response: We now change to "metrics"

Line 87: Why not use other metrics such as M12/M7 or others instead of or in addition AOT40?
Response: AOT40 metric is the European standard for the protection of vegetation, and widely used in both America and Asia (Tang et al., 2013; Lefohn et al., 2018; Lin et al., 2018). The AOT40 metric is also considered as more accurate at high levels of ozone concentration (Tuovinen, 2000; Hollaway et al., 2012), which is the case for ozone pollution in China (Lu et al., 2018, 2020). To clarify this, we modify the sentence in line 97-99:

"In this study, we adopted the ozone metric of AOT40 which is the European standard for the protection of vegetation, and also the commonly used and reliable indicator in both America and Asia for crop yield assessment (UNECE, 2017; Tang et al., 2013; Lefohn et al., 2018; Lin et al., 2018; Feng et al., 2019a,b). The AOT40 metric is also considered as more accurate at high levels of ozone concentration (Tuovinen, 2000; Hollaway et al., 2012), which is the case for China (Lu et al., 2018, 2020)."

Line 126: Is this the global price from FAOSTAT?
Response: We thank the reviewer's question. The purchase price in each country is considered as market price according to FAOSTAT (FAOSTAT, 2020; Feng et al., 2019a), and the price in line 126 is the price in China. To avoid confusion, we changed "purchase price" to "market price" through the paper, and also modify the sentence 138-140 to make it clearly:
"where $Crop\ Price_p$ stands for the annually markets price in China for each crop with unit of USD/Mt. Crops markets prices were acquired from the FAOSTAT (http://www.fao.org/faostat/, last accessed 26th, March, 2s020; Feng et al,, 2019a)."

Reference:
FAOsSTAT, 2020, http://www.fao.org/faostat/, last accessed 26th, March, 2020

Feng, Z., De Marco, A., Anav, A., Gualtieri, M., Sicard, P., Tian, H., Fornasier, F., Tao, F., Guo, A. and Paoletti, E.: Economic losses due to ozone impacts on human health, forest productivity and crop yield across China, Environ. Int., 131(February), 104966, doi:10.1016/j.envint.2019.104966, 2019a.

Lines 134-135: This section uses the annual values to show the general trends and distribution, not because of the varying growing seasons.
Response: We thank the reviewer pointing this out. We now rewrite the sentence in line 147-149:
"Since the surface ozone in China has a distinct seasonal variation, thus making the direct comparison of the accumulated AOT40 values between the four crops impossible (Table 1), here we present the temporal and spatial distribution of annual accumulated AOT40 in China from 2010 to 2017."

Line 185: "later" than?
Response: We changed to "later than 2014". Thanks for pointing out.

Line 192: This is actually due to the seasonal cycling / varying O_3 between the growing seasons, not the difference in calculation of the growing season itself

Response: We agree with the reviewer and revised the sentence in line 200 below:

"The CPL for double early and late rice both peak in 2014, but with different years for the lowest values (Tables S9 and S10), highlighting the seasonal variations of O_3 concentration between different growing seasons (Table 1)."

Figure 5: What is the a) and b) each referring to? Missing from the caption.
Figures 5-6: There are too many bars, with the variation between crops in many provinces roughly the same. Consider simplifying to highlight main points.

Response: We appreciate the reviewer's comments about the Figures 5 & 6. Since these two questions are related, we address them together.

Fig. 5 a) & b) shows the wheat production loss by magnitude for all the province in China. We agree with the reviewer that both the Figs 5-6 have too many bars (as also pointed out by reviewer 2), so we revised these two plots to show only the top 5 provinces with the largest crop loss. The province-level results are kept in the Tables S7-S12 in the supporting material.

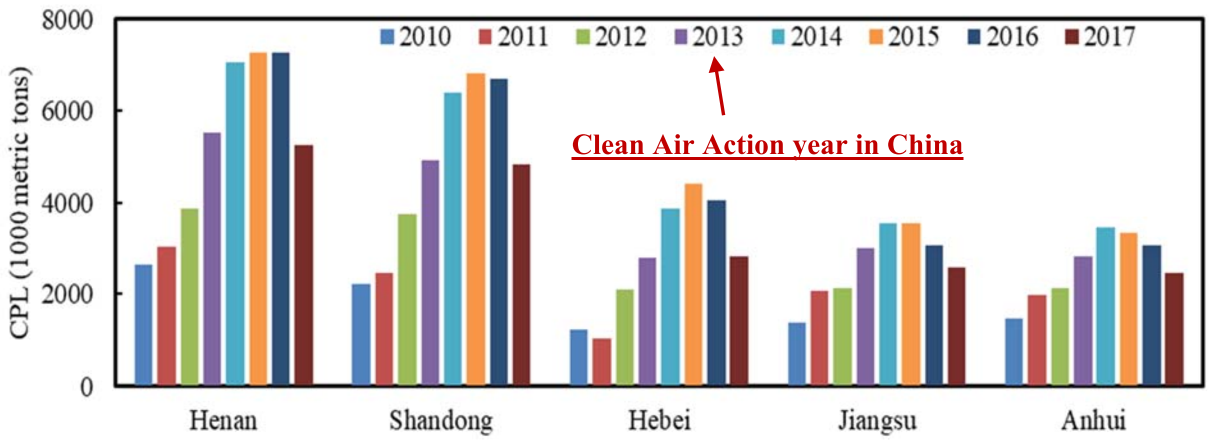
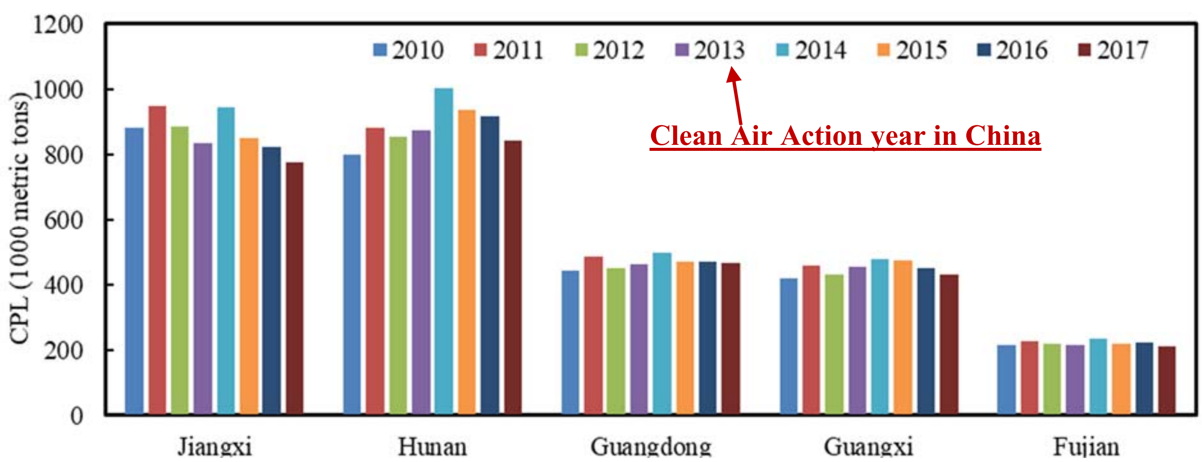


Figure 5: Annual wheat production loss by province from 2010 to 2017 (1000 metric tons) due to surface ozone exposure.



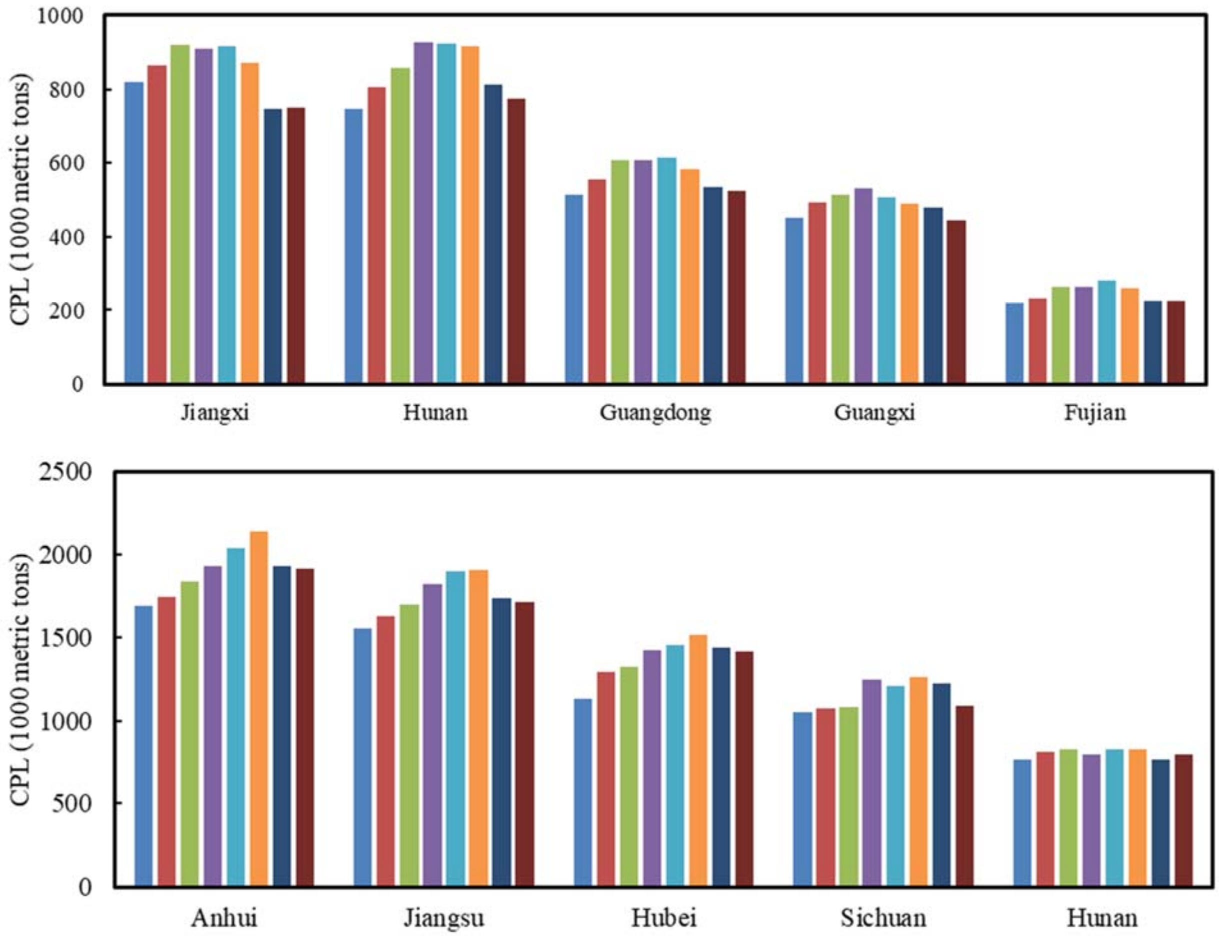


Figure 6: The production losses for rice, including double early rice (a), double late rice (b), and single rice (c) in all the China provinces. Units of thousands metric tons.