Jun 20, 2025

Dear Editor and Reviewers,

Thank you for your insightful comments on this manuscript. We have carefully read each suggestion and given our point-to-point response to all the comments. We believe that the revisions have significantly improved the quality of the manuscript. The changes have been clearly marked in red in the revised version. We sincerely appreciate your efforts in reviewing our work again.

Best Regards,

Tian Feng, PhD

On behalf of all authors

Reply to Anonymous Referee #1

We thank the reviewer for the careful reading and helpful comments on our manuscript. We have revised the manuscript following the suggestion, as described below.

In this paper, the authors conducted an analysis of the O_3 observation and reanalysis data, employing WRF-Chem to quantify the contribution of CRI to O_3 generation during the 2022 warm season. Furthermore, potential future O_3 pollution risks are assessed based on the CMIP6. The manuscript's structure and the English expression is good. I would like to review the following major comments.

General Comments

1. This study focuses on the effect of CRI on O_3. Nevertheless, a paucity of relevant reviews exists regarding the effects of LCC, SSRD and CRI on O_3 production in the introduction. This deficiency hinders the comprehension of the significance of the work for readers, and consequently, the recommendation is made that relevant content should be incorporated.

Response: The other reviewer also comments that the introduction lacks of information on the influence of solar radiation on O_3 formation. Therefore, we address both comments together. We have rewritten the fourth paragraph of the Introduction and supplemented the original content, focusing primarily on how variations in cloud cover and solar radiation affect O_3 formation through altering photolysis rates. Unfortunately, we have not found references specifically addressing the impact of cloud–radiation interactions on O_3 formation. This is also the most significant contribution of our study. In addition to changes in cloud cover and solar radiation themselves, their interactions are also an important factor influencing O_3 concentration. This factor is closely related to climate change and is of increasing importance for future O_3 pollution control as well as related ecological and health studies.

The revised fourth paragraph is as follows: "*However, ground-level O_3 is inherently a photochemical product, and anthropogenic emissions are source drivers that determine its levels, while incident solar radiation acts as a trigger for photochemical reactions, dominating photolysis rates of O_3 production. Currently, there are few studies on the influence of changes in solar radiation on O_3 formation. Early studies reported that clouds have important impacts on tropospheric photochemistry, which increases global mean OH concentration by about 20% (Tie et al., 2003). It was also found that the* *prediction accuracy of clouds in the model would significantly affect atmospheric chemical composition near the surface layers, leading to an overestimation/underestimation of* O_3 *concentration (Pour-Biazar et al., 2007). During the Texas Air Quality Study II Radical and Aerosol Measurement Project, the influence of clouds on photolysis rate was evidently greater than that of aerosols (Flynn et al., 2010), and the total reduction in the photolysis rate caused by clouds and aerosols was almost linearly correlated with the reduction in the net* O_3 *production. These studies all indicates that changes in clouds and solar radiation significantly influence the photolysis conditions, which is of great importance to* O_3 *formation. In China, the decline in* $PM_{2.5}$ *concentration is considered one of the reasons for the increase in* O_3 *levels in recent years due to the weakened aerosol-radiation interactions (Yang et al., 2022). However, there are lack of field campaign evidences similar to those of the USA (Flynn et al., 2010), and only in recent years, fewer studies have qualitatively described the influence of solar radiation on* O_3 *concentration. For example, enhanced solar radiation during hot and dry weather can increase* O_3 *production (Mousavinezhad et al., 2021; Xia et al., 2022; Yin et al., 2019; Zhao and Wang, 2017). Some of these studies have also mentioned that cloud cover can alter solar radiation, thereby affecting* O_3 *formation (Xia et al., 2022; Zhao and Wang, 2017). Nonetheless, these studies are lack of quantitative analysis and systematic mechanism explanations of the contributions of clouds, solar radiation, and their variability to* O_3 *formation, and none of them further investigate the impact of cloud-radiation interactions (CRI) on* O_3 *formation. Moreover, with an increasingly persistent impact of climate change, how this factor may affect* O_3 *concentration remains unclear.*".

In addition, the framework of this study presented in the last paragraph of the Introduction has also been revised accordingly. The revised text is "*Using numerical models, we analyze the causes of high* O_3 *concentration and, in particular, assess the dependence of* O_3 *change on the variabilities of clouds, solar radiation and CRI. Furthermore, we project the potential impacts of these factors on high* O_3 *concentration under climate change.*".

The added references have been included in the reference list of the revised manuscript.

Flynn, J., Lefer, B., Rappenglück, B., Leuchner, M., Perna, R., Dibb, J., Ziemba, L., Anderson, C., Stutz, J., Brune, W., Ren, X., Mao, J., Luke, W., Olson, J., Chen, G.

and Crawford, J.: Impact of clouds and aerosols on ozone production in Southeast Texas, Atmos. Environ., 44(33), 4126–4133, 2010.

Pour-Biazar, A., McNider, R., Roselle, S., Suggs, R., Jedlovec, G., Byun, D., Kim, S., Lin, C., Ho, T., Haines, S., Dornblaser, B., Cameron, R.: Correcting photolysis rates on the basis of satellite observed clouds, J. Geophys. Res., 112, D10302, doi:10.1029/2006JD007422, 2007.

Yang, H., Chen, L., Liao, H., Zhu, J., Wang, W. and Li, X.: Impacts of aerosol–photolysis interaction and aerosol–radiation feedback on surface-layer ozone in North China during multi-pollutant air pollution episodes, Atmos. Chem. Phys., 22(6), 4101–4116, doi:10.5194/acp-22-4101-2022, 2022.

2. The authors conducted a comprehensive analysis of various factors leading to the abnormal increase in O_3 concentration in July 2022, and emphasized the importance of CRI in them. It is recommended that the authors undertake a comparative analysis of the contribution of CRI to O_3 change with that of other influencing factors, and incorporate a discussion on the relevant mechanism to enhance the clarity of the analysis.

Response: We have added a new figure (Figure S8 shown below) to specifically illustrate the contributions of different factors to O_3 change, and explained how CRI affects O_3 change by comparing its contributions with those of other factors. Figure S8 is based on Figure 3 and Figure 5c in the main text. The contribution of meteorological changes (orange bar in Figure S8) is calculated as the difference between the orange and green bars in Figure 3, while the contribution of emission changes (blue bar in Figure S8) is the difference between the orange and red bars in Figure 3. The contribution of CRI change (green bar in Figure S8) is the regional mean O_3 change in the YRD shown in Figure 5c.

We have included the related sentences in Lines 434-452: "*Such changes in LCC and SSRD can lead to variations in the CRI, resulting in significantly different impacts on O_3 production. Compared with the summer of 2021, the weaker CRI in the summer of 2022 leads to a widespread and substantial increase in O_3 change over the YRD, with the maximum increase exceeding 9 μg m^{-3} on a local scale (Figure 5c). This implies that a weakened CRI suppresses O_3 formation less effectively, thereby indirectly enhancing O_3 production, with a regional mean O_3 increase of 2.9 μg m^{-3} (Figure S8).*

Based on the above results, contributions of different factors to O_3 increase over the YRD in the summer of 2022 are shown in Figure S8. Changes in meteorological conditions including the reduction in LCC and the increase in SSRD lead to an increase of 9.2 μg m^{-3} in O_3 concentration. Thereinto, the weakened CRI due to the reduced LCC and increased SSRD contributes to 2.9 μg m^{-3}, accounting for 31.5% of the total O_3 increase caused by favorable meteorological conditions. In contrast, anthropogenic VOCs and NO_x emission reductions lead to a decrease of 1.5 μg m^{-3} in O_3 concentration, which is far less than the impact of the changes in photolysis conditions. This indicates that the reduction in LCC, the increase in SSRD, and the weakened CRI are the major drivers of the sudden increase in O_3 concentration over the YRD during the summer of 2022.".

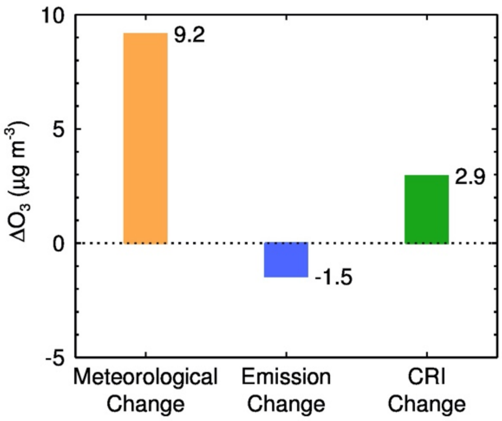

Figure S8 Contributions of interannual variability in various influence factors to ΔO_3. These factors include meteorological conditions, precursor emissions, and CRI. The changes in meteorological conditions also refer specifically to variabilities in LCC and SSRD.

3. As demonstrated in Section 3, the analysis indicates that CRI has been shown to contribute significantly to the abnormal increase in O_3 during the warm season of 2022. As the climate continues to warm in the future, lower LCC and higher SSRD are evident in CMIP6 products; however, the precise contribution of future CRI changes to future O_3 trends remains unclear. It is recommended that the authors incorporate a more explicit discussion.

Response: The major highlight of this study is that we identify the CRI intensity as a new factor to affect change in O_3 concentration, but we have to acknowledge that the precise contribution of future CRI changes to O_3 trends requires more studies for validation. To address the reviewer's comment, we would like to suggest that the interannual differences of summer SSRD and cloud cover under SSPs projections could reach or even exceed those observed between the summers of 2022 and 2021 (in this study, the interannual difference of SSRD more than 80 W m^{-2} and cloud cover difference reaching 0.09). This may indicate that the impact of interannual variation of CRI intensity on O_3 concentration change (ΔO_3) in the future could be no less than what was calculated in this study (ΔO_3 = 2.9 μg m^{-3}).

Related discussions have been added to the final paragraph of **Section 3.4** in Lines 523-530: "*Moreover, less clouds and more SSRD under SSPs will also weaken CRI and consequently aggravate O_3 pollution in the future. Based on SSPs projections, the interannual differences of summer SSRD and cloud cover could reach or even exceed those observed between the summers of 2022 and 2021 (the interannual differences in SSRD and LCC is 82.7 W m^{-2} and 0.09, respectively). It is reasonable to expect that the CRI interannual variability will likely exert an influence on O_3 changes that is no less significant than the calculation presented in this study.*"

Specific Comments

4. Page 2, Line 19-31 It is recommended that numerical descriptions be included to facilitate a more profound comprehension of the impact of CRI on O_3 among scholars.

Response: We have added the information on numerical experiments and rewritten parts of the Abstract, to make readers understanding the highlights more clearly. The revised text in Lines 20-31 is "*Here, we use a regional atmospheric chemistry model, along with 10-year ground-level O_3 measurements, and reanalysis data on low cloud cover (LCC) and surface downward shortwave radiation (SSRD) to investigate the impacts of variations in LCC, SSRD and cloud-radiation interactions (CRI) on O_3 production. We design six numerical experiments, and specifically modify parameters related to cloud radiation effects in the chemistry module to find out the underlying cause for O_3 increase during the warm season of 2022 in the Yangtze River Delta (YRD), China. Results show that O_3 production is strongly modulated by LCC and SSRD. The CRI plays a significant role in regulating O_3 concentration, i.e., reduced LCC, increased SSRD, and a weakened CRI are primarily responsible for the sharp increase in warm-season O_3 concentration observed in 2022 in the YRD, China.*".

5. Sect.2.2, Page 5, Line 174-175 Table S2 is recommended to be placed in the Figures to facilitate the reading process for the reader.

Response: We have moved Table S2 from to the Supplement to the main text and renumbered it as Table 1. Accordingly, the numbering of the other tables has been updated, and the original Table S3 is now Table S2. In addition, the reviewer suggested that CRI should be strengthened in scenario design by numbering scenarios with or without consideration of CRI separately (the last comment). Table 1 shown below has been revised according to the two specific comments.

Table 1 Setup of model experiments.

Experiment	Anthropogenic emission	Meteorology	Cloud-radiation interactions (CRI)
BS Exp._CRI	Emission 2022	Meteorology 2022	Yes
BS Exp._noCRI	Emission 2022	Meteorology 2022	No
CTRL Exp.1_CRI	Emission 2022	Meteorology 2021	Yes
CTRL Exp.1_noCRI	Emission 2022	Meteorology 2021	No
CTRL Exp.2	Emission 2021	Meteorology 2022	Yes
BG Exp.	No	Meteorology 2022	Yes

6. Sect.3.3, Page 10, Line 353-355 In order to enhance the clarity of the data, it is suggested that a greater emphasis be placed on the comparison of LCC and SSRD values.

Response: LCC and SSRD are indeed the most directly meteorological factors affecting O_3 formation, and more accurate model validation is therefore necessary. Unfortunately, LCC and SSRD are not routinely meteorological parameters observed at ground-level weather stations, and are difficult to obtain. As an alternative, we use reanalysis data to evaluate the performance of the model in simulating regional mean LCC and SSRD. To emphasize the comparison of LCC and SSRD, we have added a comparative analysis between observations and simulations in the revised version. We have supplemented the percentage deviations, and discussed how such biases may influence the assessment on the impacts of LCC and SSRD variabilities on O_3 formation.

We have added the sentences in Lines 390-395: "*These comparisons mean that the calculated interannual variability of LCC is approximately 22.2% lower than the observations, while SSRD variability is overestimated by about 1.0%. This may lead to a little underestimation of the impact of LCC and SSRD variabilities on O_3 formation. Generally, the model evidence confirms the observed linkage that an increase (decrease) in LCC and a decrease (increase) in SSRD can suppress (enhance) O_3 production (Figure S6).*".

7. In Table S2, the authors have devised a series of scenarios with the objective of quantifying the influence of different factors on O_3. Given the focus of this paper on the contribution of CRI to O_3 generation, it is suggested that CRI should be strengthened in scenario design, for example by numbering scenarios with or without consideration of CRI separately.

Response: The scenarios with and without the impact of CRI on O_3 formation have been assigned separate labels in Table 1 (Table S2 in the original manuscript). Table 1 has been shown above. The newly description have been added in **Section 2.2 Model and experiments**, and the related text is as follows: "*The BS_Exp. experiments with CRI considered or not are designated as BS_Exp._CRI and BS_Exp._noCRI, respectively, while the CTRL_Exp.1 experiments with and without CRI are designated as CTRL_Exp.1_CRI and CTRL_Exp.1_noCRI. The setup information for all simulation experiments is provided in Table 1.*".

Reply to Anonymous Referee #2:

We thank the reviewer for the careful reading and helpful comments on our manuscript. We have revised the manuscript following the suggestion, as described below.

General comments

The influences of emission changes, particularly the precursors, on ozone formation have drawn much attention in the science community, but few studies have focused on the photochemical condition related to solar radiation. Since the surface ozone is formed in photochemistry, the change in incident solar radiation is vital for ozone formation. The authors examine the crucial role of changing solar radiation, mostly perturbed by the appearance of clouds, in ozone formation in eastern China. Also, future scenarios of solar radiation and clouds are involved to present a projection of ozone pollution. The authors finally highlight that climate change will pose greater challenges for ozone pollution prevention and control in China. The manuscript is well organized with clear structure, and the language reads fluent. I still have some concerns in the introduction and future projections as shown in the major comments. The authors should address these issues soundly before its publication. Besides that, some technical revisions follow.

Major comments

1. The introduction on the current knowledge of the impacts of solar radiation on ozone formation is insufficient, although the authors have introduced the meteorological factors that affect ozone formation. More information and references are suggested to be included in the Introduction.

Response: The other reviewer also comments that the introduction lacks of information on the influence of LCC, SSRD and CRI on O_3 production, hindering the understanding on the significance of this study. We would like to address both comments together.

In the revised manuscript, we have rewritten the fourth paragraph of the introduction and supplemented the original content, focusing primarily on how variations in cloud cover and solar radiation affect O_3 formation through altering photolysis rates. Unfortunately, we have not found any reference specifically addressing the impact of cloud–radiation interactions on O_3 formation. This is the most significant contribution of our study. In addition to changes in cloud cover and solar radiation themselves, their interactions are also an important factor influencing O_3 concentration. This factor is closely related to climate change and is of increasing importance for future O_3 pollution control as well as related ecological and health studies.

The revised fourth paragraph is as follows: "*However, ground-level O_3 is inherently a photochemical product, and anthropogenic emissions are source drivers that determine its levels, while incident solar radiation acts as a trigger for photochemical reactions, dominating photolysis rates of O_3 production. Currently, there are few studies on the influence of changes in solar radiation on O_3 formation. Early studies reported that clouds have important impacts on tropospheric photochemistry, which increases global mean OH concentration by about 20% (Tie et al., 2003). It was also found that the prediction accuracy of clouds in the model would significantly affect atmospheric chemical composition near the surface layers, leading to an overestimation/underestimation of O_3 concentration (Pour-Biazar et al., 2007). During the Texas Air Quality Study II Radical and Aerosol Measurement Project, the influence of clouds on photolysis rate was evidently greater than that of aerosols (Flynn et al., 2010), and the total reduction in the photolysis rate caused by clouds and aerosols was almost linearly correlated with the reduction in the net O_3 production. These studies all indicates that changes in clouds and solar radiation significantly influence the photolysis conditions, which is of great importance to O_3 formation. In China, the decline in $PM_{2.5}$ concentration is considered one of the reasons for the increase in O_3 levels in recent years due to the weakened aerosol-radiation interactions (Yang et al., 2022). However, there are lack of field campaign evidences similar to those of the USA (Flynn et al., 2010), and only in recent years, fewer studies have qualitatively described the influence of solar radiation on O_3 concentration. For example, enhanced solar radiation during hot and dry weather can increase O_3 production (Mousavinezhad et al., 2021; Xia et al., 2022; Yin et al., 2019; Zhao and Wang, 2017). Some of these studies have also mentioned that cloud cover can alter solar radiation, thereby affecting O_3 formation (Xia et al., 2022; Zhao and Wang, 2017). Nonetheless, these studies are lack of quantitative analysis and systematic mechanism explanations of the contributions of clouds, solar radiation, and their variability to O_3 formation, and none of them further investigate the impact of cloud-radiation interactions (CRI) on O_3 formation. Moreover, with an increasingly persistent impact of climate change, how this factor may affect O_3 concentration remains unclear.*"

The added references have been included in the reference list of the revised manuscript.

Flynn, J., Lefer, B., Rappenglück, B., Leuchner, M., Perna, R., Dibb, J., Ziemba, L., Anderson, C., Stutz, J., Brune, W., Ren, X., Mao, J., Luke, W., Olson, J., Chen, G. and Crawford, J.: Impact of clouds and aerosols on ozone production in Southeast

Texas, Atmos. Environ., 44(33), 4126–4133, 2010.

Pour-Biazar, A., McNider, R., Roselle, S., Suggs, R., Jedlovec, G., Byun, D., Kim, S., Lin, C., Ho, T., Haines, S., Dornblaser, B., Cameron, R.: Correcting photolysis rates on the basis of satellite observed clouds, J. Geophys. Res., 112, D10302, doi:10.1029/2006JD007422, 2007.

Yang, H., Chen, L., Liao, H., Zhu, J., Wang, W. and Li, X.: Impacts of aerosol–photolysis interaction and aerosol–radiation feedback on surface-layer ozone in North China during multi-pollutant air pollution episodes, Atmos. Chem. Phys., 22(6), 4101–4116, doi:10.5194/acp-22-4101-2022, 2022.

2. The comparison between the scenarios in 2021 and 2022 suggests crucial impacts of solar radiation on ozone. This result has a background that the anthropogenic emissions change little for these two years. This is indeed right because the two years are so close that the emissions shall not change much. Yet, for the SSP scenarios in the 21st century, emissions are expected to vary largely during the long term. What will the ozone pollution be considering both the changes in emissions and solar radiation? I suggest the authors to include more discussion on it.

Response: Based on recent emission inventories, both VOCs and NO_x emissions in China have shown a decreasing trend. In this study, by comparison with emissions in the summer of 2021, VOCs and NO_x emissions in the summer of 2022 decreased by 4% and 5%, respectively, leading to a reduction in O_3 concentration by 1.5 μg m^{-3}. According to the current rates of emission reductions, using a simple linear extrapolation, in conjunction with China's carbon neutrality goal, we estimated that VOCs and NO_x emissions will have decreased by 31% and 37%, respectively, relative to 2021 levels by the 2030 carbon peak. By the 2060 carbon neutrality goal, the reductions are projected to reach 80% and 87%, respectively. Clearly, in reality, emission reductions may face challenges and are unlikely to follow a perfectly linear trend, and the O_3 response to precursor reductions is also nonlinear. Nonetheless, here we assume that, in accordance with this idealized scenario, the consequent reduction in O_3 concentrations by 2030 and 2060 are estimated to be reduced by 13.5 μg m^{-3} and 58.5 μg m^{-3}, respectively. Therefore, in the long term, on the decadal scale, the continued emission reductions are expected to effectively control O_3 pollution, leading to significantly lower O_3 concentrations compared to current O_3 levels.

Under three different SSPs, variabilities of clouds and SSRD in summer show a favorable environment for O_3 formation, with an increase rate of SSRD from 0.21 to 0.22 W m^{-2} per year, while interannual variability can reach several tens of W m^{-2}. In this study, interannual difference in SSRD between the summers of 2022 and 2021 is more than 80 W m^{-2}. According to the linear relationship between O_3 and SSRD shown in Figure 2, such differences in SSRD corresponds to a change of 28 μg m^{-3} in daytime O_3 concentration. According to the spatial distribution in Figure 4, the regional mean daytime O_3 change due to meteorological changes (including SSRD) is 9.2 μg m^{-3}. Thus, in the short term, on an interannual scale, the SSRD variability, particularly a sudden increase in SSRD, may partially offset the benefits of emission reductions. Given that coordinated VOCs and NO_x emission reductions are in the early stage, highly favorable photochemical conditions could not only counteract the effects of emission reductions, but may even lead to a rebound in O_3 concentrations.

In the last paragraph in **Section 3.4**, we added discussions on the possible changes in O_3 concentration caused by the changes in emissions and solar radiation, and the text is "*Fortunately, based on recent emission inventories, pollutants in China have shown a decreasing trend. In our study, by comparison with emissions in the summer of 2021, VOCs and NO_x emissions in the summer of 2022 decreased by 4% and 5%, respectively (Jiang et al., 2022; Li et al., 2024), leading to a reduction in O_3 concentration by 1.5 μg m^{-3}. According to these emission reduction rates, we use a simple linear extrapolation method, also in conjunction with China's carbon neutrality goal, to estimate VOCs and NO_x emissions in the future. By the 2030 carbon peak, VOCs and NO_x emissions will have been reduced by approximately 31% and 37%, respectively, relative to 2021 levels. By the 2060 carbon neutrality goal, the reductions are projected to reach 80% and 87%, respectively. Actually, emission reductions may face challenges and unlikely to follow such a perfect pathway, and the response of O_3 concentration to precursor reductions is also nonlinear. We thus assume that, if such an idealized scenario is followed, O_3 concentrations by 2030 and 2060 are estimated to be reduced by 13.5 μg m^{-3} and 58.5 μg m^{-3}, respectively, relative to the levels in 2021. Therefore, in the long term, on the decadal scale, the continued emission reductions are expected to significantly reduce O_3 concentration.*

However, on an interannual scale, the projected SSRD variability can reach several tens of W m^{-2}, which is consistent with this study. Our study shows that interannual *difference in SSRD between the summers of 2022 and 2021 is more than 80 W m^{-2}. Based on the linear relationship between O_3 and SSRD shown in Figure 2, such differences in SSRD corresponds to a change of 28 μg m^{-3} in daytime O_3 concentration. According to the spatial distribution in Figure 4, the regional mean daytime O_3 change due to meteorological changes (including clouds and SSRD) is 9.2 μg m^{-3}. Thus, a sudden increase in SSRD may partially offset the benefits of emission reductions. Given that coordinated VOCs and NO_x emission reductions are in the early stage, the increasing possibility of highly favorable photochemical conditions under climate change could not only counteract the effects of emission reductions, but may even lead to a rebound in O_3 concentrations in the short term.*".

3. We know that the SSP scenarios have large uncertainties. In Figure 6, the SSP scenarios are shown from 2025 to 2099 only. As the first quarter of the 21st century has past, are these SSP scenarios consistent with the variations in real-world Tmax, TCC, and SSRD? The ERA5 reanalysis may help.

Response: We have redrawn Figure 6 to include a comparison analysis between the SSPs projections and the ERA5 reanalysis data for the past 10 years (SSPs projections have been available since 2015). Although there is a noticeable deviation between the projections and observations (reanalysis datasets are generated by assimilating multi-source observation data), the SSPs projections can still provide meaningful information for predicting future ozone pollution trends.

We have added some discussions about the uncertainties of the SSPs scenarios in Lines 456-465: "*The projected climate change under each SSP deviates significantly from the ERA5 reanalysis data, particularly in terms of the interannual variability, which is remarkably larger in reality. This indicates that climate change is highly uncertain. Nevertheless, the projected trend of T_max is generally consistent with the ERA5. The TCC pattern also align well with the SSP2-4.5 projection in recent years, and the SSRD pattern also closely matches the SSP2-4.5 projection. This consistency roughly corresponds with the development pathway in China over the past decade. These comparisons suggest that the projections under different SSPs provide valuable information on understanding future climate change and its implications for O_3 pollution.*".

4. The model validation approach should appear in Data and Method.

Response: We have moved the model validation method from ***Section* Model validation** to ***Section* Data and Methods**, with minor revisions. The revised text is "*To evaluate the model performance, we use three common statistical indices involving mean bias (MB), root mean square error (RMSE), and index of agreement (IOA) (Willmott, 1981).* The formulas are as follows:

$$MB = \frac{1}{N}\sum_{i=1}^{N}(P_i - O_i) \quad (1)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2\right]^{\frac{1}{2}} \quad (2)$$

$$IOA = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - \overline{O}|+|O_i - \overline{O}|)^2} \quad (3)$$

where P_i and O_i represented the simulated and observed variables, respectively. N is the total sample number of the simulation, and $\bar{O}$ denotes the average of the observation. The IOA ranges from 0 to 1. The closer it is to 1, the better the simulation."

Minor comments

5. L45-48: need references, also for L48-49

Response: References have been added.

Lines 48-49 and Lines 50-51 present conclusions from the same reference of Xiao et al. (2022). In the revised manuscript, we have reorganized these two sentences into a single, cohesive statement as follows: "*Another notable aspect is that high O_3 concentration often coincides with high-temperature weather, and their co-occurrence frequency has increased at a faster rate than either alone in recent years (Xiao et al., 2022)*".

Reference

Zhang, Y. and Zheng, J.: Blue Book on Ozone Pollution Prevention and Control in China (2020) [in Chinese], edited by Li, M., Science Press, Beijing, China, 121 pp., ISBN 9787030716644, 2022.

6. L59: the temperature --> air temperature

Response: Revised.

7. L95: in particular, and --> and, in particular,

Response: Revised.

8. L227-235: The ozone variation during 2013-2021 is totally attributed to the emission changes in ozone precursors by the authors. Not any other contributors?

Response: Yes, from 2013 to 2021, the inter-annual variation of ozone concentration was influenced not only by emission changes of precursors, but also by meteorological conditions and $PM_{2.5}$ reductions. The meteorological conditions play an important but not dominant role in ozone trends (Li et al., 2020), and the continued $PM_{2.5}$ reduction weakens the aerosol uptake of hydroperoxyl (HO_2) radicals and enhances ozone production (Li et al., 2018). However, the ozone trend is primarily driven by emission changes (Liu et al., 2023; Liu and Wang, 2020). Our main purpose in citing multiple studies on the impact of emission changes on ozone trends is to demonstrate that the effect of emission changes on ozone trends could potentially be offset by changes in solar radiation conditions in the future (This is one of the main conclusions of our study).

To avoid the misunderstanding that O_3 variation is solely caused by changes in precursor emissions, we have revised and supplemented this section in Lines 263-278: *"Due to the Action Plan on Prevention and Control of Air Pollution since 2013, China's anthropogenic NO_x emissions were substantially reduced (Zhang et al., 2019), whereas VOCs emissions increased slightly during 2013-2017 (Zheng et al., 2018). The disproportionate emission reductions largely contributed to the continuous increase in O_3 concentration from 2013 to 2017 (Jiang et al., 2022; Wang et al., 2022; 2020). Since 2017, as VOCs emissions began to decline (Jiang et al., 2022; Simayi et al., 2022), along with the ongoing reduction in NO_x (Li et al., 2024; Zheng et al., 2018), O_3 concentration began to decline (Lu et al., 2019). In addition to precursor emissions, O_3 trends during this period were also influenced by meteorological conditions and $PM_{2.5}$ reductions. The meteorological conditions play an important but not dominant role in ozone trends (Liu et al., 2023; Li et al., 2020), and the continued $PM_{2.5}$ reduction enhances ozone production due to the weakened aerosol uptake of hydroperoxyl (HO_2) radicals (Li et al., 2019a). Nevertheless, O_3 trends was primarily driven by changes in precursor emissions (Wang et al., 2022a; Liu and Wang, 2020b)."*

In addition, to avoid the redundance with the revised text, we have slightly adjusted the beginning of the following paragraph. "*According to the principle of O_3 formation, it is influenced not only by changes in precursor emissions but also by the solar radiation intensity.*"

New citations have been also added in the reference list in the revised version.

Li, K., Jacob, D. J., Liao, H., Shen, L., Zhang, Q. and Bates, K. H.: Anthropogenic drivers of 2013–2017 trends in summer surface ozone in China, vol. 116, pp. 422–427. 2019a.

Li, K., Jacob, D. J., Shen, L., Lu, X., De Smedt, I. and Liao, H.: Increases in surface ozone pollution in China from 2013 to 2019: anthropogenic and meteorological influences, Atmos. Chem. Phys., 20(19), 11423–11433, doi:10.5194/acp-20-11423-2020, 2020.

Liu, Y., Geng, G., Cheng, J., Liu, Y., Xiao, Q., Liu, L., Shi, Q., Tong, D., He, K. and Zhang, Q.: Drivers of Increasing Ozone during the Two Phases of Clean Air Actions in China 2013-2020, Environmental Science & Technology, 57(24), 8954–8964, doi:10.1021/acs.est.3c00054, 2023.

Liu, Y. and Wang, T.: Worsening urban ozone pollution in China from 2013 to 2017 - Part 2: The effects of emission changes and implications for multi-pollutant control, Atmos. Chem. Phys., 20(1), 6323–6337, doi:10.5194/acp-20-6323-2020, 2020b.

9. L253-254: Revise the citation format

Response: Revised.

10. L289: decimal precision --> decimal fractions

Response: Revised. We have revised "*Additionally, ……without decimal precision*" to "*Additionally, ……, with no decimal fractions*".

11. L293-294: a should be an. I also see this typo in other lines of the text.

Response: We have corrected all similar misuses throughout the text.

12. L305: MB = -0.0 --> MB = 0.0

Response: Corrected. The MB is a negative number, and is approximately 0 after rounding to one decimal place. To indicate the direction of the deviation, a negative sign is included. We have removed the negative sign "-" in the revised version.

13. L365: Noticeably, the correlation between O_3 concentration and SSRD is more significant. Compare with what?

Response: Sorry, here is an error in the previous statement. The correct meaning is that the correlation between O_3 concentration and SSRD is less more significant than the correlations in Figures S6a and S6b.

We have corrected the sentence in Lines 402-406: "… *the correlation between* O_3 *concentration and SSRD is less more significant than the correlations in Figures S6a and S6b, with a confidence level exceeding 95% (whereas the first two panels show confidence levels exceeding 99.9%). The data are also distributed more dispersedly.*".

14. Figure 1, L759: remove 'map'; L764: the MEGAN --> MEGAN

Response: Removed.