Response to Referee #1:

We are grateful to the referees for their time and energy in providing helpful comments and guidance that have improved the manuscript. In this document, we describe how we have addressed the reviewer's comments. Referee comments are shown in black and author responses are shown in blue text.

Summary:

Li et al. use CMIP6 simulations (SSP3-7.0 and SSP3-lowNTCF, part of AerChemMIP) to compare the impacts of increasing emissions of greenhouse gases+aerosols (SSP3-7.0) as opposed to reduced emissions of aerosols (Near-Term Climate Forcers, or NTCFs) and continued emissions of greenhouse gases (SSP3-lowNTCF, which is an idealized simulation that implements future air quality standards that do not reduce GHG emissions). The authors first compare global impacts of SSP3-7.0, SSP3-lowNTCF, and the difference between the two experiments (under the assumption that studying the difference isolates the climate impact of reduced non-methane NTCFs), then specifically South/East Asia. The authors report changes in Effective Radiative Forcing (ERF) and increased climate extremes. I found this paper to be generally well written and the text easy to follow, and the results are interesting and potentially important if policymakers implement short-term air pollution controls only (without reducing any greenhouse gas emissions). My main concerns are outlined below, followed by specific line comments.

Before I continue my review, I should note that I am relatively new to the research area of NTCF simulations, but I have more experience in the area of population exposure, CMIP ensemble analysis, and climate impacts of emissions. I am not a statistician or climate extremes expert, so I have focused my comments on the overall scientific quality of the paper, novelty of the work, clarity of the writing/figures, and overall climate impacts assessed.

- Thank you for your positive evaluations. All the questions and concerns have been carefully answered and the paper has been revised accordingly.

Main Concerns:

1. I am less familiar with the literature related to AerChemMIP, so I went back to re-read a few of the papers Li et al. cite in the introduction. Specifically, I read Allen et al. (2020), who conducted a very similar analysis (compared SSP3-7.0 to SSP3-lowNTCF simulations) and parts of the IPCC AR6 WG1 Chapter 6.

My main concern is that many of the results presented here are either quantitatively or qualitatively similar to those in Allen et al.: Allen et al. compare CMIP6 SSP3-7.0 and SSP3-lowNTCF, and already make the main points this manuscript makes- specifically, climate extremes (temperature, precipitation) are intensified with reduced aerosol forcing, and this change in extremes is strongly felt over parts of southern and eastern Asia. Some (but not all) of the climate extreme indices are even already presented in Allen et al.

I do recognize that there is some new material here because Li et al. assess a wider range of climate extreme indices, examine population-weighted climate impacts, and focus on Asia. However, I didn't notice any outstanding new findings, but instead more details on findings similar to those already published. The authors simply acknowledge that Allen et al. examine 'trends', but don't really acknowledge very much beyond that, and even re-present similar information (e.g., changes in ERF), but using a slightly different method (change in means over two time periods instead of trends, etc).

Response: Thanks for your constructive comments! As suggested, we clarified our motivation and discussed the novelty of this study compared with Allen et al. (2020) in the revised paper. The following information are added in Introduction and Discussion sections:

(i) "However, there were some limitations in that study. First, Allen et al. (2020) only considered three extreme indicators including hottest day, wettest day, and consecutive dry days to examine the effects of future non-methane SLCF reductions on climate extremes. These three indicators were not enough to represent climate extremes, especially the lack of some indicators related to human health. For example, tropical night (TR) usually occurs in combination with extended periods of heat (particularly in extra-tropical regions) and have been suggested to be problematic for human health (Weisskopf et al., 2002; Patz et al., 2005) and the maximum consecutive 5-day precipitation (RX5day) can be used as an indicator of flooding and related hazards (Frich et al., 2002; Sillmann et al., 2013). Second, climate extremes pose a serious threat on human body (Bras et al., 2021; Tellman et al., 2021). Quantifying avoided population exposure to climate extremes associated with future non-methane SLCF reductions is valuable for future policymaking on climate change mitigation and adaptation, especially in these densely populated and industrially developed regions of Asia, which is lacked in Allen et al. (2020)." Lines 84-93

(ii) "Compared with previous assessment by Allen et al. (2020), our study provides some new insights for the effects of future non-methane SLCF emissions on regional climate change. Firstly, although extreme temperature indices are all increasing in the future due to the reduction of non-methane SLCFs, TX90p and WSDI vary spatially opposite to TXx, indicating that the warming of future temperature extremes is greater at higher latitudes, while the increase in the frequency and duration of extreme temperature occurrences is more pronounced at lower latitudes. As for extreme precipitation, changes in both R10 and R95p in some areas are contrary to previous results considering only aerosol reduction, revealing the importance of considering aerosol and ozone interactions. More importantly, we analyze the changes in TR and RX5day. The former represents the variation of nighttime temperature extremes that are important for human health. The latter is usually used as an indicator of flooding, suggesting that heavy precipitation associated with natural disasters will be aggravated in the future due to non-methane SLCFs reduction. Secondly, population exposure can provide a well assessment of future climate change risk. The reduction of non-methane SLCFs will result in the exposure of millions of people to extreme events, and up to tens of millions in densely populated areas, such as northern India, which is an indicator of human health risk and also valuable for future policymaking on climate change mitigation and adaptation, Thirdly, Allen et al. (2020) used nine models, including five Aer+O_3 models and four Aer-only models, but we used seven Aer+O_3 models. The more Aer+O_3 models may better reflect the effect of considering the combined aerosol and ozone changes simultaneously. Finally, Pendergrass et al. (2019) have shown that the response of extreme precipitation to warming varies widely in climate models, especially in the tropics. The rate of response increases with warming is not linear but non-linear (Pendergrass et al., 2019), as shown in Allen et al. (2020) that some of the extreme indices were not well fitted. Freychet et al. (2019) suggested that radiation-driven aerosol emission impacts on local surface temperature and precipitation were not linear and could be mitigated or cancelled by the local dynamics. Our method of subtracting the mean between two periods may, to some extent, provide a more intuitive representation of the changes in the extreme indices in absolute terms." Lines 426-446

2. A critique of how this experiment (SSP3-lowNTCF) is analyzed and presented here: there seems to be a history of 'idealized emissions reduction modeling' experiments that have led to misconceptions related to the impacts of aerosol reductions in the scientific literature and in the public/media (e.g., see Shindell and Smith, 2019, Nature, who argue against the realism of immediate 'zero emissions' and the associated spike in warming).

Admittedly, SSP3-lowNTCF is a more 'realistic' scenario that doesn't implement immediate 'zero emissions' – However, I went back to the IPCC AR6 WG1 Chapter 6.6 and 6.7, and the IPCC specifically states that SSP3-lowNTCF is 'an idealized simulation of a very ambitious air-quality policy where the maximum technical potential of existing end-of-pipe technologies is explored'. How realistic is it that nations will only implement air quality, and absolutely no GHG reductions? And how are the results presented here to be interpreted (esp. by policymakers, the public, and/or the media)? I understand that there is scientific value in distinguishing among GHG vs aerosol reductions, but how is this information to be used, and what is the context?

I bring these issues up because I think the Discussion/Conclusion could be strengthened by at least a qualitative comparison with SSP1 (which in my understanding is where the reduced aerosol emissions come from in the SSP3-lowNTCF experiments)- what are the benefits of reducing both GHG+NTCF emissions instead of reduced NTCF emissions alone? Without context, the results presented here make me think 'Air pollution reductions are harmful- they will worsen climate extremes'- Is this the takeaway the authors intend?

IPCC AR6 Chapter 6.7 ends with some discussion of the contextualization of these idealized results in comparison with SSP1 (see for example, Shindell and Smith, 2019, Nature, or how Allen et al. also contextualizes the changes in extremes with the reduced air pollution exposure, etc.).

Response: Thanks for your constructive suggestions! As suggested, we discussed the realism of SSP3-lowNTCF scenario and added some qualitative comparison with SSP1 in the revised paper as follows:

"Notably, GHGs share many common sources with SLCFs, such as the combustion of fossil fuels. Emission reductions for shorter-lived GHGs, such as methane, can partially mask or offset the warming caused by emission reductions of non-methane SLCFs over decades, providing benefits for both climate change mitigation and air quality on nearly all decadal to centennial time scales (Allen et al., 2021; Shindell and Smith, 2019). Increasing and accumulating anthropogenic GHG emissions are the main driving factor in shaping the increase and intensification of extreme high temperatures globally and regionally. By the end of the century, the differences in temperature and precipitation between the different aerosol reduction scenarios are negligible in the context of ambitious CO_2 reductions (Hienola et al., 2018; Wilcox et al., 2020), and global warming is significantly less under strong mitigation scenarios with both climate policies and air quality controls (i.e., SSP1-1.9 and SSP1-2.6) than under the SSP3-7.0-lowNTCF scenario with only strong air quality control measures (Naik et a., 2021). Even if the impact of non-methane SLCFs is negligible on centennial time scales, they may be important for regional and global climate in the coming decade, especially for Asia where aerosol has played an important role in historical changes, in particular for precipitation (Wilcox et al., 2020). The important impact of SLCFs on climate change in the short term does not mean that reducing air pollutants is harmful to the climate, but rather that it generates additional warming to the climate, amplifying the temperature and extreme precipitation caused by GHGs changes (Wang et al., 2016; Luo et al., 2020). In the short term, the differences in regional climate change under different future emission scenarios depend strongly on changes in emissions of SLCFs, especially before net CO_2 emissions (and co-emitted aerosol emissions) become very low in the first half of this century (Hienola et al., 2018; Wilcox et al., 2020). Warming is most obvious in the strong mitigation scenarios (i.e., SSP1-1.9 and SSP1-2.6) because of the rapid reduction in aerosols. In the SSP3-7.0 scenario, aerosols do not decrease until mid-century, but increases in methane and ozone contribute to the net warming in 2040. The warming is similar in magnitude to the SSP1 scenario, where aerosol reductions are the primary driver (Wilcox et al. 2020; Naik et al. 2021). Also, the conclusion of Shindell and Smith (2019) that there is no conflict between climate and air quality objectives may not hold when using a full coupled global climate model and when investigating changes beyond global mean temperature (Wilcox et al., 2020). Although it is difficult to improve air quality alone without reducing GHGs in reality, this is the case for some air quality policies, such as flue gas desulfurization in coal-fired power plants, denitrification, restaurant grease pollution control, and improved vehicle emission standards. These advanced end-of-pipe control measures may involve only the reduction of air pollutants (Rafaj et al., 2014; Hordijk and Amann, 2007). For example, European countries have taken specific measures to reduce air pollutant emissions, especially through the application of advanced end-of-pipe emission control technologies, resulting in a significant decline in SO_2 and NOx emissions in Western Europe after the 1970s, compared to a constant growth rate of CO_2 emissions (Rafaj et al., 2014; Hordijk and Amann, 2007). For China, the State Council implemented the Air Pollution Prevention and Control Action Plan in 2013 and the Three-Year Action Plan to Win the Blue Sky Defense War implemented in 2018 both introduced a series of aggressive industrial clean air policies (Zheng et al., 2018; Cheng et al., 2019). The reality in China's air pollution prevention and control policies in recent years is that China's treatment is still dominated by end-of-pipe measures, as source treatment often requires large investments to ensure energy efficiency and is not conducive to maintaining the competitiveness of Chinese industry (Wu et al., 2019), in which case it may only result in rapid reductions in air pollutants. Besides, emissions reductions aimed at achieving global carbon neutrality will inevitably result in further reductions in SLCF emissions, as demonstrated in the SSP1-1.9 and SSP1-2.6 scenarios (Gidden et al., 2019), which may lead to greater impacts of SLCFs on climate. The maximum technical potential in SSP3-7.0-lowNTCF scenario refers to the currently existing end-of-pipe technologies, with faster technological progress and stronger air quality action, greater emission reductions may also be possible, which may cause greater impacts on climate. Additionally, cleaner air may already has increased the warming effect of CO_2 emissions over the past two decades, and this will get worse as air pollution continues to be controlled (Quaas et al., 2022; McKenna et al., 2021). Finally, large biases may exist in SLCF emissions at the regional scale in global emissions scenarios due to insufficient consideration of local environmental policies (Tong et al., 2020). For example, the SSP-RCP global emissions scenarios used in CMIP6 do not fully consider the rapid pollution controls enacted in China since 2013 under the Air Pollution Prevention and Control Action Plan. Consequently, the emissions trends in the SSP scenarios after 2014 differ significantly from actual conditions in China (Wang et al., 2021; Tong et al., 2020), which may lead to underestimation of the impact of SLCF emissions reductions in China. This study highlights the importance of reductions in emissions of non-methane SLCFs for future climate change and population exposure risk in eastern and southern Asia in the short term and suggests that current and future policy decisions about air pollution emissions have the potential for a large near-term impact on temperature and precipitation extremes. What policymakers, the public or the media need to know is that air pollution is dangerous to human health, and there is no doubt that we need clean air, but more importantly efforts to reduce GHGs need to be doubled in order to simultaneously mitigate climate change and improve air quality (Quaas et al., 2022; McKenna et al., 2021)." Lines 447-498

3. Clarity of figures:

In several figures showing time series, there are no y axis labels or x axis labels (e.g., Figure 4, others). Also, there are acronyms in the figure subplot titles that are not defined in the figure caption- it is difficult to find what these are without searching through the text/tables, so please define all acronyms in the caption. I understand the extremes are defined in a table, but it would be helpful to not have to flip back and forth to determine what they are.

Response: In the revised paper, we added axis labels and defined all acronyms in the captions.

In many of the maps showing changes, the same colormap is used to show changes over time and differences among experiments in the same figure, which is visually confusing.

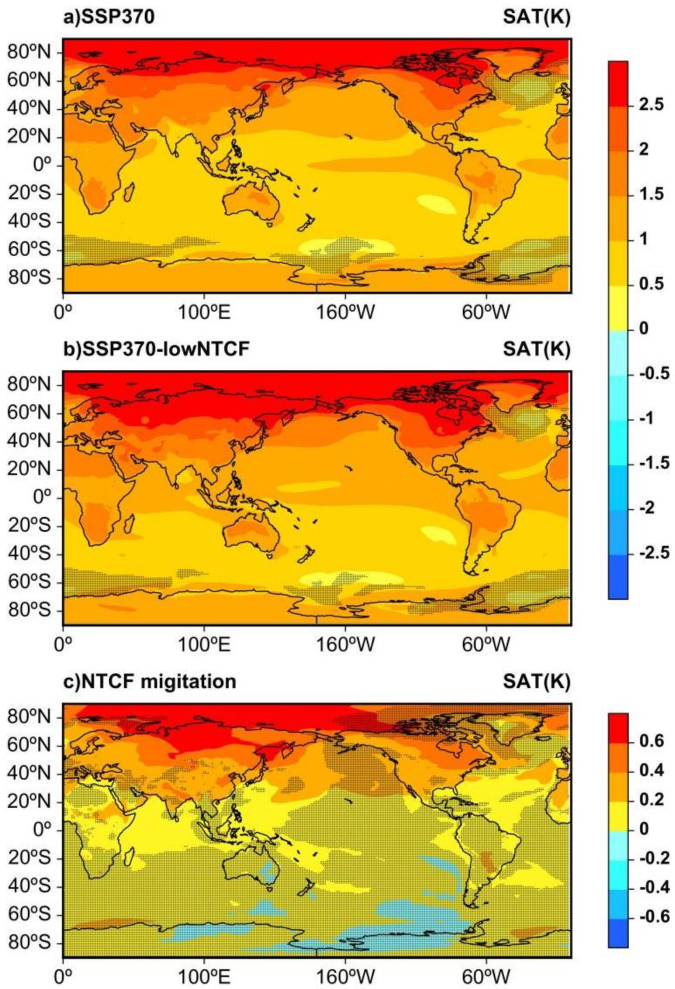
Response: In the revised paper, we used different colormap, makes it look more visually appealing in terms of magnitude.

Several figures showing time series include red and green lines, which will be indistinguishable for a red/green colorblind reader.

Response: As suggested, the green lines were replaced with gray lines in Figure 1, Figure 4 and Figure 7 in the revised paper.

Several of the figures with maps show dots/stippling at locations where >60% of models 'agree on sign of change'. I don't find stippling 'significant' locations in this case to be particularly helpful visually because the dots cover almost all of the map (yes, CMIP6 models show the globe warms under SSP3- why is this stippled when this is my default expectation, and has been reported before?). Perhaps more importantly, the stippling obscures the colors underneath so the reader cannot easily interpret the colors. Can the authors stipple throughout where there is disagreement?

Response: As suggested, the dotted regions indicate that the warming is not significant in Figure 3 in the revised manuscript.



Showing that CMIP6 models agree on sign of change for global warming is a frankly low bar/not a robust metric, as is the low >60% agreement threshold. Can the authors choose a more robust method (e.g., agree on magnitude of change, using something like coefficient of variation- e.g., Buzan and Huber, 2020: https://www.annualreviews.org/doi/abs/10.1146/annurev-earth-053018-060100), or at least where 75% or 90% or 95% of the models agree on sign?

Response: As suggested, we used a higher threshold (six out of seven models for SAT, four out of five models for the extreme temperature indices and five out of six models for the extreme precipitation indices) to estimate whether the changes of climate extremes are robust. All related figures were updated in the revised paper.

CMIP6 model validation in terms of climate extremes: I was surprised to see an evaluation of CMIP6 model results without any (as far as I could tell) mention/citation of an assessment of model performance- how well do these models simulate temperature + precipitation extremes if we are to rely of their projections of future extremes?

Response: As suggested, we added new Figure 2 to evaluate the performance of the CMIP6 MME in simulating temperature and precipitation extremes in the historical period (1995-2014). The following information are added in the revised paper:

"To evaluate the performance of the models, a gridded daily maximum and minimum temperature and daily precipitation dataset obtained from the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) is used here. This dataset was constructed using optimal interpolation methods based on approximately 16,000 station and satellite observations (Chen et al., 2020b). It spans the period from 1979 to the present and has a high level of resolution of 0.5 ° × 0.5 °. All model outputs as well as observations were interpolated into a common grid (1 ° × 1 °) through bilinear interpolation except precipitation data, which used first-order conservative interpolation." Lines 148-153

"We compared the simulated results with the observational climate extremes during 1995–2014 (Fig. 2). In general, the CMIP6 MME can reasonably reproduce the observed spatial distribution of extreme temperature and precipitation indices. For the extreme temperature indices, the maximums obtained from both the CMIP6 MME and observations are found in eastern China and southern Asia, especially for the simulated absolute extreme indices (TXx, TR) (Figs. 2a, 2b, 2e and 2f), which are generally consistent with the observations in spatial distribution with limited difference in magnitude. Relative to the absolute extreme indices, the percentile and duration indices show large differences between the CMIP6 MME and observation (Figs. 2c, 2d, 2g and 2h). Previous studies also shown that both CMIP5 and CMIP6 perform relatively unsatisfactorily in simulating spatial patterns of the duration and percentile indices (Fan et al., 2020; Guo et al., 2021). For R10, RX5day and R95p, the climatological mean is well captured by CMIP6 MME, although it tends to produce overestimates especially over southeastern Qinghai-Tibet Plateau and the Indo-China Peninsula (Figs. 2i-n). In addition, the CMIP6 MME underestimates the CDD in northwest China and along Mongolia (Figs. 2o and 2p), which is consistent with previous studies (Zhu et al., 2021; Kim et al., 2020). Although the CMIP6 MME produce some regional biases with respect to observation, such biases will be significantly reduced when considering the difference between the two segments of time (Sillmann et al., 2013; Chen et al., 2020). In this study, we focused on the changes in the future (2031–2050) relative to the reference period (1995–2014), so the results of the CMIP6 MME can be considered representative." Lines 155-169

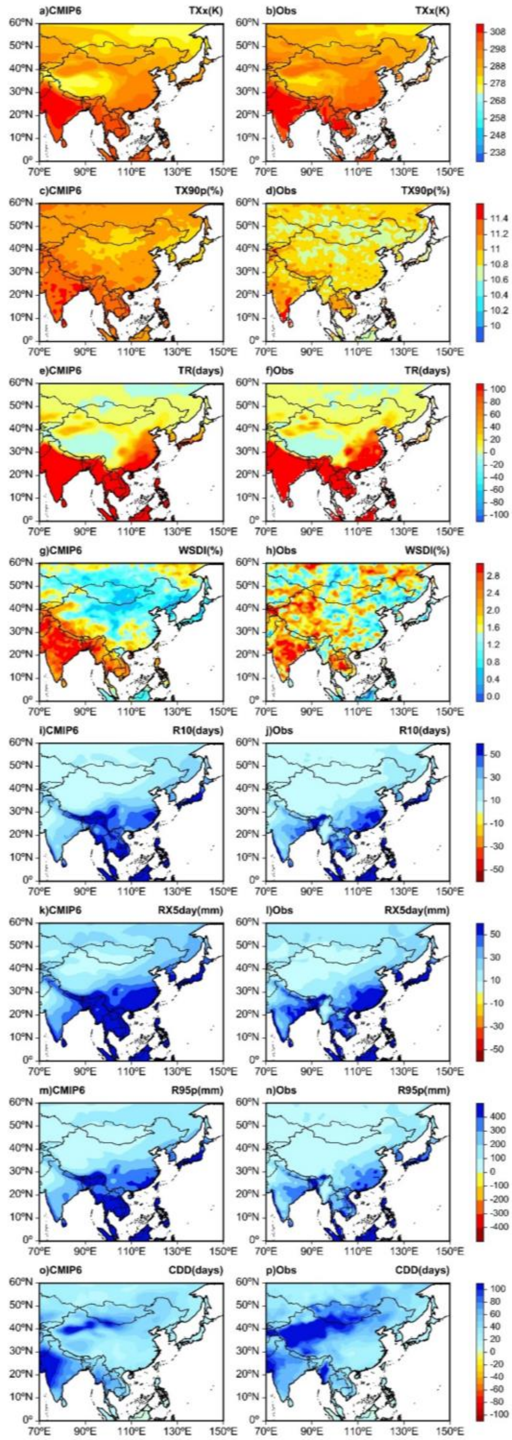


Figure 2: The annual mean of the hottest day (TXx), warm days (TX90p), tropical nights (TR), warm spell duration (WSDI), heavy precipitation (R10), maximum consecutive 5-day precipitation (RX5day), total wet-day precipitation (R95p), and consecutive dry days (CDD) over study area during 1995-2014 for CMIP6 multi-model mean (left column) and gridded observations (right column).

CMIP6 multi-model ensemble averaging: From my reading of the paper, the authors seem to have just averaged across an ensemble of CMIP6 models- should the models be selected/weighted according to performance, or perhaps according to independence (see for example Brunner et al., 2020: https://esd.copernicus.org/articles/11/995/2020/ who suggest that equally weighting CMIP6 models does not produce the same results as weighting them based on independence/performance)? Or are there too few models? Some mention/justification of simple ensemble averaging could be helpful.

Response： Thanks for your suggestion.

(i) In the revised paper, we clarified as follows:

"At present, there are few models carrying out both SSP3-7.0 and SSP3-7.0-lowNTCF experiments, thus, we directly used the CMIP6 multi-model ensemble (MME) mean to investigate the changes of climate extremes in response to future SLCFs emission reductions." Lines 145-147

(ii) In the revised paper, we added new Figure 2 to evaluate the performance of the CMIP6 MME and found that the CMIP6 MME can well capture the spatial pattern of temperature and precipitation extremes in the historical period (1995-2014). For detailed descriptions, please refer to the above response.

The authors have an ensemble of model simulations, so they should have a range of results in terms of changes in climate extremes, but the main results presented in the text and Abstract are presented as one number (e.g. 'regional average temperature on the hottest days (TXx) by 0.3 K)'- isn't there some range/spread in the results? This range is shown in the figures and mentioned occasionally in the text, but this nuance/uncertainty does not come out in the Abstract or in much of the results, where one mean/median number, with no range/uncertainty is presented. It would seem to me that the range or 1 or 2 sigma should be presented next to all of the mean/median results.

Response： As suggested, we added one sigma range to all of the mean results in the Abstract and Conclusions in the revised paper. For example, "The additional warming caused by the non-methane SLCF reductions increases the hottest days (TXx) by 0.3 ± 0.1 K, the percentage of warm days (TX90p) by 4.8 ± 2.2 %, the number of tropical nights (TR) by 1.7 ± 0.8 days………." Lines 16-25

Line/Specific Comments:

Lines 11-15: 'Stringent…climate'- the authors mention that SLCF emissions reductions have been implemented, then in the next sentence state that they examine future impacts. The naïve reader could assume that the SSP3-lowNTCF simulations are realistic and are simply a continuation of past air quality/climate policy. Is this the case?

Also, this sentence conveys to me the idea that emissions reductions have already happened, but the next sentence claims to study future emissions reductions. I think some clarification could be helpful here.

Response: In the revised paper, we modified this sentence as follows:

"Future stringent SLCF emissions controls to mitigate air pollution will substantially impact regional climate change." Lines 9-10

Line 13: 'in Asia'- the boxes in the main text seem to be a sub-section of eastern/southern Asia, not all of Asia.

Response: Thanks for your suggestion. We have changed the title into "Impacts of reductions in non-methane short-lived climate forcers on future climate extremes and the resulting population exposure risks in eastern and southern Asia". In the revised paper, we defined the latitude and longitude of our chosen study area in Figure 2 as follows:

"The scope of eastern and southern Asia in this study is defined as 0-60 °N, 70-150 °E." Line 115

Line 14: 'SSP' – please define this acronym (authors define all other acronyms in Abstract, why not this one?).

Response: As suggested, we defined "SSP" as "shared socioeconomic pathway (SSP)" in the revised paper. Line 12

Lines 16-18: 'The MME results…': The authors report a change in ERF that seems to be half the magnitude of that presented in the Allen et al. paper cited in the Introduction (0.44 W/m2 over the entire time period in Allen et al.). Why the difference? And also, most of the paper is not about ERF, but climate extremes, so why is this part of the focus in the Abstract? Or is this necessary to explain why changes are observed? I don't understand why the authors need to re-report changes in ERF that were recently published unless they show something significantly new/different.

Response: Our ERF estimates of 0.23 was smaller than 0.44 in Allen et al. (2020), which is likely attributed two aspects: (i) The units are different in two studies. Allen et al. (2020) represents trend change with the unit of Wm^{-2} $decade^{-1}$, but this study represents mean change of two periods with the unit of Wm^{-2}. (ii) The number of climate models are different in two studies. The ERF trend of 0.44 Wm^{-2} $decade^{-1}$ in Allen et al. (2020) is the average result of all models, including both the five Aer+O_3 models and the four AER-only models. But in this study, the results are averaged from the seven Aer+O_3 models. SLCFs affect climate by perturbing the balance of radiative energy balance at the top of the Earth's atmosphere, and ERF is a useful measure of the extent to which forcing elements affect climate.

Line 16: 'Regional average temperature'- please remind reader which region (transitioned from global ERF in previous sentence)

Response: As suggested, we defined "regional mean" as the entire study area in the revised paper. Line 17

Line 24: 'predicted'- here and elsewhere in the manuscript, isn't 'projected' the preferred term for changes in climate based on changes in boundary conditions/forcing?

Response: As suggested, we modified "predicted" as "projected" in the revised paper. Line 23, Line 256, Line 266 and Line 405

Lines 58-59: 'on future climate change has been limited to the effect of aerosol forcing associated with incomplete interactive tropospheric chemistry schemes in global climate models' - except in Allen et al., who used CMIP6 ESMs, like in this study.

Response: As suggested, we added some other studies for this sentence in the revised paper. Lines 60-63

Lines 74-75: 'focused on trends of climate variables, and its assessment of regional climate changes, particularly climate extremes, was insufficient.' – this seems subjective- the extreme indices they assessed showed qualitatively similar results to the ones presented here. The time series presented in Allen et al. also show similar information, so what makes this 'insufficient'?

Response: As suggested, we clarified our motivation in the revised paper as follows:

"However, there were some limitations in that study. First, Allen et al. (2020) only considered three extreme indicators including hottest day, wettest day, and consecutive dry days to examine the effects of future non-methane SLCF reductions on climate extremes. These three indicators were not enough to represent climate extremes, especially the lack of some indicators related to human health. For example, tropical night (TR) usually occurs in combination with extended periods of heat (particularly in extra-tropical regions) and have been suggested to be problematic for human health (Weisskopf et al., 2002; Patz et al., 2005) and the maximum consecutive 5-day precipitation (RX5day) can be used as an indicator of flooding and related hazards (Frich et al., 2002; Sillmann et al., 2013). Second, climate extremes pose a serious threat on human body (Bras et al., 2021; Tellman et al., 2021). Quantifying avoided population exposure to climate extremes associated with future non-methane SLCF reductions is valuable for future policymaking on climate change mitigation and adaptation, especially in these densely populated and industrially developed regions of Asia, which is lacked in Allen et al. (2020)." Lines 84-93

"Compared with previous assessment by Allen et al. (2020), our study provides some new insights for the effects of future non-methane SLCF emissions on regional climate change. Firstly, although extreme temperature indices are all increasing in the future due to the reduction of non-methane SLCFs, TX90p and WSDI vary spatially opposite to TXx, indicating that the warming of future temperature extremes is greater at higher latitudes, while the increase in the frequency and duration of extreme temperature occurrences is more pronounced at lower latitudes. As for extreme precipitation, changes in both R10 and R95p in some areas are contrary to previous results considering only aerosol reduction, revealing the importance of considering aerosol and ozone interactions. More importantly, we analyze the changes in TR and RX5day. The former represents the variation of nighttime temperature extremes that are important for human health. The latter is usually used as an indicator of flooding, suggesting that heavy precipitation associated with natural disasters will be aggravated in the future due to non-methane SLCFs reduction. Secondly, population exposure can provide a well assessment of future climate change risk. The reduction of non-methane SLCFs will result in the exposure of millions of people to extreme events, and up to tens of millions in densely populated areas, such as NIN, which is an indicator of human health risk and also valuable for future policymaking on climate change mitigation and adaptation. Thirdly, Allen et al. (2020) used nine models, including five Aer+O_3 models and four Aer-only models, but we used seven Aer+O_3 models. The more Aer+O_3 models may better reflect the effect of considering the combined aerosol and ozone changes simultaneously. Finally, Pendergrass et al. (2019) have shown that the response of extreme precipitation to warming varies widely in climate models, especially in the tropics. The rate of response increases with warming is not linear but non-linear (Pendergrass et al., 2019), as shown in Allen et al. (2020) that some of the extreme indices were not well fitted. Freychet et al. (2019) suggested that radiation-driven aerosol emission impacts on local surface temperature and precipitation were not linear and could be mitigated or cancelled by the local dynamics. Our method of subtracting the mean between two periods may, to some extent, provide a more intuitive representation of the changes in the extreme indices in absolute terms." Line 427-447

Line 76: Yes, the IPCC AR6 does present mostly a global overview in terms of temperature impacts (figure 6.23 in AR6 WG1), but Allen et al. already report that impacts are most intense in parts of Asia.

Response: As suggested, we clarified our motivation in the revised paper. Please see the response to the above comment.

Lines 137-139: ‘Gridded population datasets for 2000 and 2040 under SSP3 were used to represent the population during the reference and future periods, respectively.’ – which dataset? GPWv4 and SSP projections? Citation?

Response: As suggested, we added citation and clarified as follows:

“Gridded population datasets for 2000 and 2040 under SSP3 were used to represent the population during the reference and future periods, respectively (Jones and Oneill 2016).” Lines 178-180

Figure 2 and other figures with maps: see main comment about stippling significance, which covers information/colors presented on maps. Also, please use separate colormap to show differences in time periods vs differences among experiments to visually distinguish, unless there is a specific reason to use the same colormap in both.

Response: In the revised paper, we used different colormap, makes it look more visually appealing in terms of magnitude.

Lines 145-149: I am more familiar with attempting to distinguish among causes of impacts (changing climate or changing population) by assessing changes in population-weighted impacts using static (present) population, and comparing to results using dynamic population. Does this produce the same result as the equation/method here?

Response: The changes of future population exposure were attributed to the changes in population, climate, and population-climate interaction, which is well illustrated in Equation 1. We have revised the description. The difference of results using present and dynamic population only represents the contribution of population change to changes of population exposure.

Line 180 ‘3.2 Changes in temperature extremes in Asia’ – I was a bit surprised not to notice a mention of how well these models simulate observed frequency etc of past, observed extremes. The authors jump straight into projected extremes- are there papers showing that these temperature and precipitation extreme indices are well captured by the climate models used here? See for example (Li et al.: https://journals.ametsoc.org/view/journals/clim/34/9/JCLI-D-19-1013.1.xml, Kim et al., 2020: https://www.sciencedirect.com/science/article/pii/S2212094719302439; Yang et al., 2021: https://link.springer.com/article/10.1007/s00376-021-0351-4).

Related to this, Yang et al. (above) report that not all models perform equally well in terms of simulation of temperature extremes over China, and choose to analyze projections from a sub-selection of models that better simulate observed climate- have the authors considered doing this?

Response: At present, there are few models carrying out both SSP3-7.0 and SSP3-7.0-lowNTCF experiments, thus we directly used the CMIP6 multi-model ensemble (MME) mean to investigate the changes of climate extremes in response to future SLCFs emission reductions." Lines 145-147

In the revised paper, we added new Figure 2 to evaluate the performance of the CMIP6 MME and found that the CMIP6 MME can well capture the spatial pattern of temperature and precipitation extremes in the historical period (1995-2014). For detailed descriptions, please refer to the above response.

Figure 4: where is the region that the average encompasses? I don't think the region boxes are shown until Figure 6. How are these sub-regional boxes chosen? Are these SREX regions? Or did the authors just choose boxes to maximize signal after they ran the analysis? Also, the regional maps (like Figure 5) could be easier to interpret if the authors include country borders.

Response: (i) In the revised paper, we defined our study area in Figure 2. The regional mean time series in the entire study area were shown in Figure 4.

ii) We selected sub-regional boxes with the large signal, high emission, and population density.

iii) Accepted, we have added country borders in all regional maps.

Figure 7: Here and previous figure showing time series: please do not include red and green for red-green colorblind readers (why not red, blue, grey?).

Response: As suggested, the green lines were replaced with gray lines in Figure 1, Figure 4 and Figure 7 in the revised paper.

Line 245: 'the extreme precipitation changes are more significant' – how is significance determined? Do the authors mean 'larger' or something similar?

Response: Yes, the description "significant" were revised as "large" in the revised paper. Line 295

Line 250: Here and Figure 8: drawing boxes outlining the regions of interest on the anomaly maps would be helpful to determine where spatially the location is that the authors are discussing in the text.

Response: As suggested, we added the boxes in Figure 8 to represent the four selected sub-regions.

Line 293: 'future precipitation distribution in SC could be more heterogeneous under high SSP scenarios.' Spatial distribution or PDF distribution? Please be more specific, as I wasn't sure what a 'heterogeneous distribution is' if it's a histogram/PDF.

Response: It means the PDF distribution. A decrease in light rainfall and increase in heavy rainfall will lead to simultaneous increases in CDD and extreme precipitation, and this phenomenon may be even more pronounced under high SSP scenarios.

Figures 11/12: Typo in figure 'climte'

Response: Corrected as suggested.

Lines 329-333: 'climate factors under both the SSP3-7.0 and SSP3-7.0-lowNTCF scenarios in the four selected regions (Fig. 11). This result suggests that climate change is the primary driver of population exposure to extreme temperature events, followed by changes in the climate population interaction factor, with population change contributing the least.'

I am a bit confused about the wording here- how are we to distinguish SLCF from climate? I think a clarifying phrase and breaking up some long sentences could be helpful as authors explain.

Response: As suggested, we modified this sentence as "This result suggests that climate change caused by non-methane SLCFs is the primary driver of population exposure to extreme temperature events." Lines 385-386

Lines 346-347: 'in increases in extreme temperature and precipitation events' – this is relative to the background increases already experienced in SSP3-7.0, correct? Please clarify.

Response: Yes, we modified as this sentence as "…… resulting in increases in extreme temperature and precipitation events compared to the standard SSP3-7.0 scenario." Lines 402-403

Lines 368-378: See my main comment above: can the authors benchmark/qualitatively compare previously published findings of reductions of both GHG+NTCF under SSP1-2.6 or a similar experiment? What are the benefits of reducing both vs just reducing NTCFs, or the combined impacts? And I think a further discussion/emphasis of the realism of NTCF reductions only would be helpful- are countries going to only reduce SLCFs? Have they already? How realistic are these results in a real-world context?

Response: In the revised paper, we discussed as follows:

"Notably, GHGs share many common sources with SLCFs, such as the combustion of fossil fuels. Emission reductions for shorter-lived GHGs, such as methane, can partially mask or offset the warming caused by emission reductions of non-methane SLCFs over decades, providing benefits for both climate change mitigation and air quality on nearly all decadal to centennial time scales (Allen et al., 2021; Shindell and Smith, 2019). Increasing and accumulating anthropogenic GHG emissions are the main driving factor in shaping the increase and intensification of extreme high temperatures globally and regionally. By the end of the century, the differences in temperature and precipitation between the different aerosol reduction scenarios are negligible in the context of ambitious CO2 reductions (Hienola et al., 2018; Wilcox et al., 2020) and global warming is significantly less under strong mitigation scenarios with both climate policies and air quality controls (i.e., SSP1-1.9 and SSP1-2.6) than under the SSP3-7.0-lowNTCF scenario with only strong air quality control measures (Naik et a., 2021). Even if the impact of non-methane SLCFs is negligible on centennial time scales, they may be important for regional and global climate in the coming decade, especially for Asia where aerosol has played an important role in historical changes, in particular for precipitation (Wilcox et al., 2020). The important impact of SLCFs on climate change in the short term does not mean that reducing air pollutants is harmful to the climate, but rather that it generates additional warming to the climate, amplifying the temperature and extreme precipitation caused by GHGs changes (Wang et al., 2016; Luo et al., 2020). In the short term, the differences in regional climate change under different future emission scenarios depend strongly on changes in emissions from SLCFs, especially before net CO2 emissions (and co-emitted aerosol emissions) become very low in the first half of this century (Hienola et al., 2018; Wilcox et al., 2020). Warming is most obvious in the strong mitigation scenarios (i.e., SSP1-1.9 and SSP1-2.6) because of the rapid reduction in aerosols. In the SSP3-7.0 scenario, aerosols do not decrease until mid-century, but increases in methane and ozone contribute to the net warming in 2040. The warming is similar in magnitude to the SSP1 scenario, where aerosol reductions are the primary driver (Wilcox et al. 2020; Naik et al. 2021). Also, the conclusion of Shindell and Smith (2019) that there is no conflict between climate and air quality objectives may not hold when using a full coupled global climate model and when investigating changes beyond global mean temperature (Wilcox et al., 2020). Although it is difficult to improve air quality alone without reducing GHGs in reality, this is the case for some air quality policies, such as flue gas desulfurization in coal-fired power plants, denitrification, restaurant grease pollution control, and improved vehicle emission standards. These advanced end-of-pipe control measures may involve only the reduction of air pollutants (Rafaj et al., 2014; Hordijk and Amann, 2007). For example, European countries have taken specific measures to reduce air pollutant emissions, especially through the application of advanced end-of-pipe emission control technologies, resulting in a significant decline in SO2 and NOx emissions in Western Europe after the 1970s, compared to a constant growth rate of CO2 emissions (Rafaj et al., 2014; Hordijk and Amann, 2007). For China, the State Council implemented the Air Pollution Prevention and Control Action Plan in 2013 and the Three-Year Action Plan to Win the Blue Sky Defense War implemented in 2018 both introduced a series of aggressive industrial clean air policies (Zheng et al., 2018; Cheng et al., 2019). The reality in China's air pollution prevention and control policies in recent years is that China's treatment is still dominated by end-of-pipe measures, as source treatment often requires large investments to ensure energy efficiency and is not conducive to maintaining the competitiveness of Chinese industry (Wu et al., 2019), in which case it may only result in rapid reductions in air pollutants. Besides, emissions reductions aimed at achieving global carbon neutrality will inevitably result in further reductions in SLCF emissions, as demonstrated in the SSP1-1.9 and SSP1-2.6 scenarios (Gidden et al., 2019), which may lead to greater impacts of SLCFs on climate. The maximum technical potential in SSP3-7.0-lowNTCF scenario refers to the currently existing end-of-pipe technologies, with faster technological progress and stronger air quality action, greater emission reductions may also be possible, which may cause greater impacts on climate. Additionally, cleaner air may already has increased the warming effect of CO2 emissions over the past two decades, and this will get worse as air pollution continues to be controlled (Quaas et al., 2022; McKenna et al., 2021). Finally, large biases may exist in SLCF emissions at the regional scale in global emissions scenarios due to insufficient consideration of local environmental policies (Tong et al., 2020). For example, the SSP-RCP global emissions scenarios used in CMIP6 do not fully consider the rapid pollution controls enacted in China since 2013 under the Air Pollution Prevention and Control Action Plan. Consequently, the emissions trends in the SSP scenarios after 2014 differ significantly from actual conditions in China (Wang et al., 2021; Tong et al., 2020), which may lead to underestimation of the impact of SLCF emissions reductions in China. This study highlights the importance of reductions in emissions of non-methane SLCFs for future climate change and population exposure risk in eastern and southern Asia in the short term and suggests that future and current policy decisions about air pollution emissions have the potential for a large near-term impact on temperature and precipitation extremes. What policymakers, the public or the media need to know is that air pollution is dangerous to human health, and there is no doubt that we need clean air, but more importantly efforts to reduce GHGs need to be doubled in order to simultaneously mitigate climate change and improve air quality (Quaas et al., 2022; McKenna et al., 2021)." Lines 448-499

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