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 italics and author responses are shown in blue regular text.

Reviewer #2

There are some interesting things in this study. The authors have computed a drought index and collocated it with demographic/economic data, which I have never seen done before. I do question whether this is the best suited for ACP, but I'll leave that up to the Editor to decide.

- We sincerely thank you for these insightful comments. While Atmospheric Chemistry and Physics (ACP) indeed places a strong emphasis on the physical and chemical processes of the atmosphere, it does not exclude policy-oriented studies related to atmospheric problems, such as climatic extremes and air pollution. For example, we found the following studies that focus on economic and/or health impacts:
  (1) Lee, J., Mast, J. C., and Dessler, A. E.: The effect of forced change and unforced variability in heat waves, temperature extremes, and associated population risk in a CO2-warmed world, *Atmos. Chem. Phys.*, 21, 11889-11904, 10.5194/acp-21-11889-2021, 2021.
  (2) Li, C., Hu, Y., Zhang, F., Chen, J., Ma, Z., Ye, X., Yang, X., Wang, L., Tang, X., Zhang, R., Mu, M., Wang, G., Kan, H., Wang, X., and Mellouki, A.: Multi-pollutant emissions from the burning of major agricultural residues in China and the related health-economic effects, *Atmos. Chem. Phys.*, 17, 4957-4988, 10.5194/acp-17-4957-2017, 2017.
  (3) Xu, J. W., Lin, J., Tong, D., and Chen, L.: The underappreciated role of transboundary pollution in future air quality and health improvements in China, *Atmos. Chem. Phys.*, 23, 10075-10089, 10.5194/acp-23-10075-2023, 2023.
  (4) Zhao, W., Zhao, Y., Zheng, Y., Chen, D., Xin, J., Li, K., Che, H., Li, Z., Ma, M., and Hang, Y.: Long-term variability in black carbon emissions constrained by gap-filled absorption aerosol optical depth and associated premature mortality in China, *Atmos. Chem. Phys.*, 24, 6593-6612, 10.5194/acp-24-6593-2024, 2024.

I am not entirely sure what to recommend for this paper. There are many descriptions that are lacking and many others that need to be changed. The next version of this paper will be so different that it's hard to make a determination.

- In this revision, we have made the following major changes in response to the referees' comments to improve the clarity and scientific merits of the study:
  (1) Added more quantitative and attribution analyses of SAI impacts on climate in both GeoMIP6 and GLENS;
  (2) Compared drought responses between GeoMIP6 and GLENS and explained the underlying physical causes;
  (3) Clarified the specific periods and scenarios used for comparisons;
  (4) Provided more detailed explanations of methods (e.g. the calculation of scPDSI).

My biggest complaint is that there are numerous places where the description is not careful, leading to some over-claims. For example, while the results are potentially important for climate justice, actual considerations of justice should take numerous variables into account, as well as adaptive capacity (like irrigation, or countries that experience less drought could pay countries that experience more drought). Lines 331-332 are another example – you're looking at GDP and population correlated with the Human Development Index. You are not actually looking at "human societal development". It would be very easy to argue about these different data sources and how relevant they are for society, and entire fields of study do exactly that. The scenarios and strategies that you looked at are quite narrow and not designed to affect drought indices, yet you make broad conclusions about what SAG would do in general. The point being, you should be careful to stick to discussing what you actually did.

- Thank you for your suggestions. In this revision, we have toned down some overstatements and adopted a more conservative approach in our conclusions. For example, in the Abstract, we concluded that "These findings suggest that the current SAI strategies in GeoMIP6 and GLENS may induce the risk of unintentionally worsening regional hydroclimatic disparities." (Lines 35-37). In the Result section, we emphasized that our results are influenced by inter-model uncertainties: "It is important to note that under both SRMs, the exposure of the

GDP and population for the low HDI countries varies to a certain extent among models. However, most models project elevated risks, suggesting that these nations may remain highly vulnerable." (Lines 422-425). We also removed some sentence to avoid possible biases: "~~This similarity suggests that the choice of injection strategy does not substantially alter the major conclusions, which highlight the increased spatial heterogeneity in drought responses under the SAG implementation.~~"

Another major concern is that you only looked at the frequency of extreme drought (lines 139-140). There are other forms of drought that are still important. While this doesn't need to change your analyses, your descriptions should be more careful.

- We have gone through the paper and changed ambiguous terms like 'drought' to 'extreme drought' as suggested. In addition, we investigated the changes of other drought indexes as a comparison: "Additionally, we compute other drought indices for comparisons, including the PDSI, Palmer Modified Drought Index (PMDI), Palmer Hydrological Drought Index (PHDI), and Palmer Z Index (Z-index)." (Lines 226-228)

  "For this study, we used scPDSI due to its clear physical meaning, adaptive climatic responses, and specific criteria for drought extremes (Wells et al., 2004). As a comparison, we checked other drought indices such as PDSI, Palmer Modified Drought Index (PMDI), Palmer Hydrological Drought Index (PHDI), and Palmer Z Index (Z-index). Projections using these indices showed similar patterns to scPDSI though with spatially varied magnitude (Fig. 11), suggesting that our main conclusions are not affected by the selection of the drought index." (Lines 496-502)

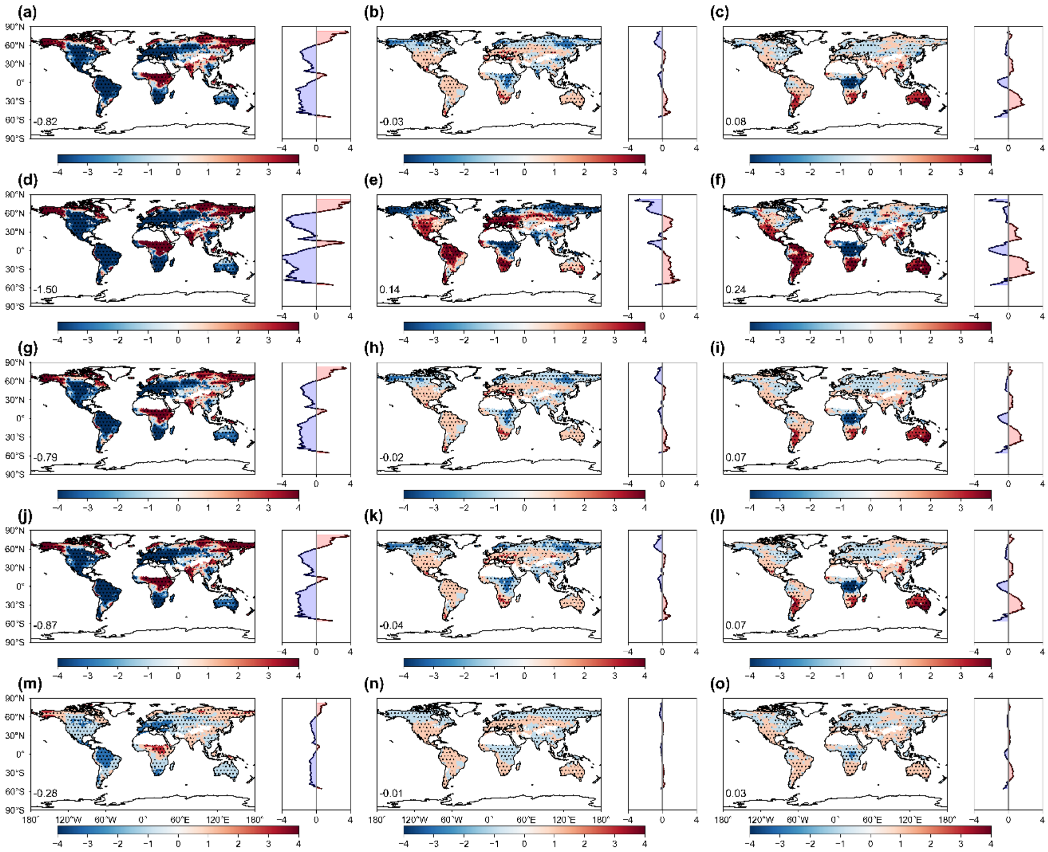

Figure 11. Change of drought status indicated by different indices. Results shown are the changes of drought indices (a, d, g, j, m) at 2081-2100 under SSP5-8.5 scenario relative to the historical period of 1995-2014, as well as that under (b, e, h, k, n) G6solar and (c, f, i, l, o) G6sulfur scenarios relative to SSP5-8.5 both at 2081-2100. Drought indices include (a, b, c) self-calibrating Palmer Drought Severity Index (scPDSI), (d, e, f) PDSI, (g, h, i) Palmer Modified Drought Index (PMDI), (j, k, l) Palmer Hydrological Drought Index (PHDI), and (m, n, o) Palmer Z Index. The latitudinal distribution of the changes is shown on the right side of each panel. The dotted areas indicate regions where at least four out of five models show changes with the same signs.

The reporting of the results is quite biased. One of the major conclusions of the paper is that low HDI countries have a large increase in drought exposure under SAI. But looking at the results in Figure 4, the error bars are enormous. This indicates a strong model-dependence of the results, which is hardly mentioned by the authors. The authors could easily be accused of cherry-picking evidence to make SAG look bad.

➢ Thank you for your questions. In the revised paper, we have acknowledged the limitations of our analyses and removed any statements that could be considered overstated.

"It is important to note that under both SRMs, the exposure of the GDP and population for the low HDI countries varies to a certain extent among models. However, most models project elevated risks, suggesting that these nations may remain highly vulnerable." (Lines 422-425)

We removed the following statement in the original paper: "~~This similarity suggests that the choice of injection strategy does not substantially alter the major conclusions, which highlight the increased spatial heterogeneity in drought responses under the SAG implementation.~~"

And finally, the writing needs to be substantially improved. Many descriptions are simply glossed over, for example how the scPDSI is defined. Also, your descriptions of percentage change are confusing – are these relative or absolute changes?

- In the revised paper, we have provided a more detailed description of the scPDSI calculation as follows:

  "The calculation of PDSI requires the use of P, PET, and AWC to calculate eight variables related to soil moisture based on the water balance: evapotranspiration (ET), recharge (R), runoff (RO), loss (L), potential evapotranspiration (PE), potential recharge (PR), potential runoff (PRO), and potential loss (PL) (Webb et al., 2000). These variables are then used to calculate the Climatically Appropriate For Existing Conditions' (CAFEC) precipitation ($\hat{P}$):

$$\hat{P} = \alpha PE + \beta PR + \gamma PRO - \delta PL \tag{4}$$

  Here, α, β, γ and δ are the water-balance coefficients, which are derived from ET, R, RO, and L divided by their potential values, respectively. The difference between P and $\hat{P}$ is defined as moisture departure (d):

$$d = P - \hat{P} \tag{5}$$

  The d is scaled to a moisture anomaly index (Z index) using climatic characteristic (K):

$$Z = dK \tag{6}$$

  K can be calculated by potential evapotranspiration, recharge, runoff, precipitation, loss and moisture departure:

$$K_i' = 1.5\log_{10}\left(\frac{\frac{\overline{PE_\iota} + \overline{R_\iota} + \overline{RO_\iota}}{\overline{P_\iota} + \overline{L_\iota}} + 2.8}{\overline{D_\iota}}\right) + 0.5 \quad (7)$$

$$K_i = \frac{17.67}{\sum_j^{12} \overline{D_j} K_j'} K_i' \quad (8)$$

Where $\overline{D}$ is the average monthly moisture departure, 17.67 is an empirical constant. The PDSI for a given month is calculated using the Z index and empirical parameters:

$$PDSI_i = 0.897 PDSI_{i-1} + \left(\frac{1}{3}\right) Z_i \quad (9)$$

The duration factors (0.897 and 1/3) are empirical parameters obtained by Palmer from previous studies (Alley, 1984). The original drought index, PDSI, is calculated using fixed climatic thresholds that are not comparable across different climatic regions. To address such limitation, the scPDSI employs dynamic climatic characteristic and duration factors based on the regional environment, offering the advantage of both spatial and temporal comparability (Wells et al., 2004; Dai, 2011; Van Der Schrier et al., 2013). In the calibration of PDSI, monthly K was adjusted using local climate statistics to ensure that extreme drought events (PDSI ⩽ -4.0) and wet periods (PDSI ⩾ 4.0) occur at frequencies of approximately 2%. The duration factors were derived from linear regression analyses of accumulated Z-index values during extreme drought and wet conditions, thereby enhancing sensitivity to regional climate variability." (Lines 190-220)

➢ We used absolute changes for the extreme drought frequency: "The frequency of drought extremes for a given scenario is calculated as the fraction of extreme drought months out of a 240-month period. The absolute changes of such frequency are compared among scenarios and SAI strategies." (Lines 223-225). However, we use relative changes for socioeconomic exposures by defining Mitigation Potential (MP) in Equation 10.

I will also encourage the authors to ensure that all of the elements in the supplemental material are referenced in the main text.

➢ In this revision, we have incorporated all supplementary materials into the main text and provided appropriate references.

Lines 26-27: These numbers are scenario-dependent (as you say later in the paper). You need to be more specific.

- Corrected as suggested: "By 2100, the frequency of extreme droughts is projected to increase by 7.33% under the high-emission Shared Socioeconomic Pathways 5 (SSP5-8.5) scenario relative to present day. SAI reduces this increase by 1.99% in GeoMIP6, and by 1.80% in GLENS compared with Representative Concentration Pathways 8.5 (RCP8.5)." (Lines 24-28)

Lines 30-31: See my general comment above. You looked at one index in three scenarios. It is very difficult to conclude anything about what people "should" do to promote climate justice.

- We revised the abstract with more specific scenarios and conservative implications: "These findings suggest that the current SAI strategies in GeoMIP6 and GLENS may induce the risk of unintentionally worsening regional hydroclimatic disparities." (Lines 35-37)

Lines 67-70: These are not the only regional effects. Why are you focused on these regions?

- We agree that the impacts of SAI may vary across regions depending on the type of SAI. In the revised paper, we have modified these sentences to present a general map rather than focusing on a specific region: "Region-specific analyses suggest that specific SAI deployment strategies may mitigate extreme drought risks under the Shared Socioeconomic Pathways 5 (SSP5-8.5) scenario. For instance, in Cape Town, South Africa, model ensembles indicate a potential 90% reduction in extreme drought risk when applying the GLENS injection protocol (Botai et al., 2017; Odoulami et al., 2020). However, these benefits are highly contingent upon the specific implementation strategy: different SAI designs or distinct greenhouse gas background conditions (e.g., SSP2-4.5) could result in neutral or adverse outcomes (Du et al., 2025)." (Lines 75-83)

Lines 73-74: Yes/no questions are not particularly interesting. Without doing any research, I can tell you that the answers to the questions as posed are yes and no, *respectively. Can you rephrase these?*

- In the revised paper, we have modified these objectives as follows: “In this study, we use ensemble simulations from both GeoMIP6 and GLENS to assess 1) how SRM strategies alter the magnitude and spatial distribution of extreme drought risk under high-emission scenarios, and the climatic mechanisms that govern these changes; and 2) how the magnitude of SRM-derived drought exposure reduction varies across countries with different levels of socioeconomic development.” (Lines 85-89)

Line 82: You explore _some_ uncertainties.

- We revised this sentence as follows: “We explore uncertainties associated with different SAI strategies, including the fixed equatorial injection approach adopted in G6sulfur (GeoMIP6) and the multi-latitude aerosol placement used in GLENS.” (Lines 97-98)

Lines 219-221: This is only true if the equation is linear. Otherwise your description needs to be more careful.

- We agree that the assumption of linear additivity does not strictly hold for scPDSI due to the inherent nonlinearities in its calculation and the interactions among climate variables. The main purpose of this attribution is to identify the dominant drivers of scPDSI changes. In the Discussion section, we have acknowledged the limitations of this attribution analysis: “However, variations of drought involve complex relationships between temperature and precipitation, leading to nonlinear responses of drought to the perturbations in these climatic variables. For instance, the sum of the contributions of individual climatic factors is not fully equal to the total changes in drought extremes under the SSP5-8.5 and two SRM scenarios (Figs 4 and 6).” (Lines 463-467)

Line 233: Models?

- Corrected as suggested.

Lines 255-256: The cooling should not be uniformly distributed. I think this is an artifact of your choice of color bar.

➢ We appreciate your concern regarding to the potential biases in the color bar. Here, we chose a finer colorbar to highlight the differences in the amount of cooling in different areas (Fig. R1). In addition, we calculated the average temperature changes and standard deviations for different climate zones (tropical, temperate, and polar) in Fig. R2. The recalculations confirmed that cooling was not spatially uniform in G6solar. The tropical zone exhibits weaker cooling (mean ΔT = -2.3°C ± 0.36°C) than temperate (-2.76°C ± 0.6°C) and polar (-2.78°C ± 0.98°C) zones (Fig R2). As a result, we revised this sentence to "Reduction of the solar constant in G6solar causes an <u>intense</u> cooling worldwide" (Lines 303-304)

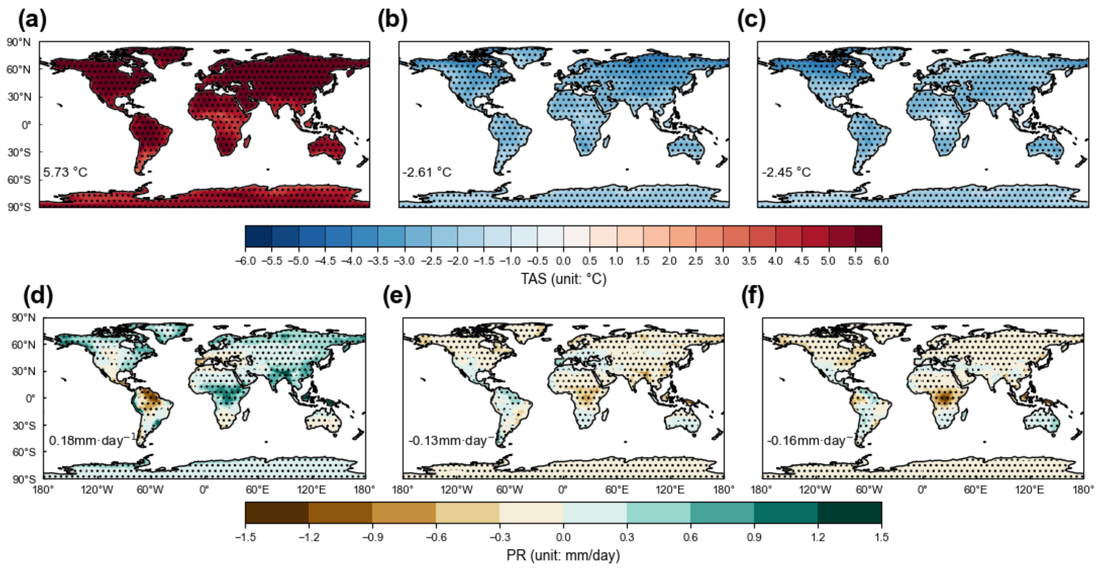

Fig. R1. The same as Fig.2 but with different colorbars.

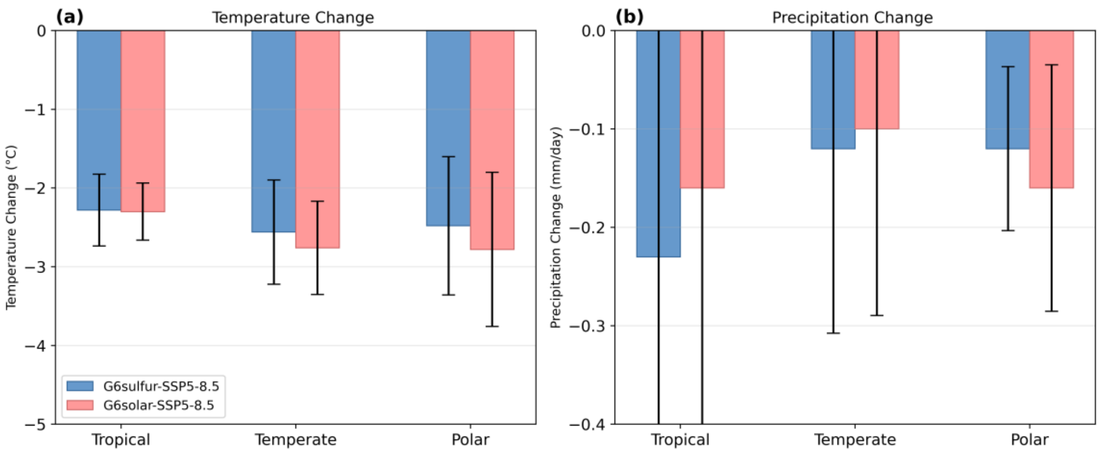

Fig. R2. Results shown are the average temperature (a) and precipitation (b) change under G6solar (Red) and G6sulfur (Blue) relative to SSP5-8.5 scenarios both at 2081-2100 across three climate regions (Tropical, Temperate, and Polar). The error bars showing the standard deviation to indicate the variability of temperature in different regions.

Lines 333-336: You need to be much more specific about your assumptions. Very very small differences in the population growth rate can lead to differences of billions of people by the end of the century.

- We agree that absolute GDP and population exposure values may be sensitive to SAI implementation and socioeconomic assumptions. However, the absolute numbers are not our focus. Instead, we define the Mitigation Potential (MP) to quantify the extent to which SRM could offset the increased drought exposure caused by climate warming. For the uncertainty tests in Figures 12 and 13, we replaced future GDP and population with present-day values. Comparisons (Fig. 8 vs. Fig. 12 and Fig. 10 vs. Fig. 13) show that the spatial distribution of MP remains highly consistent, regardless of whether future or present-day GDP and population values are utilized in the analysis.

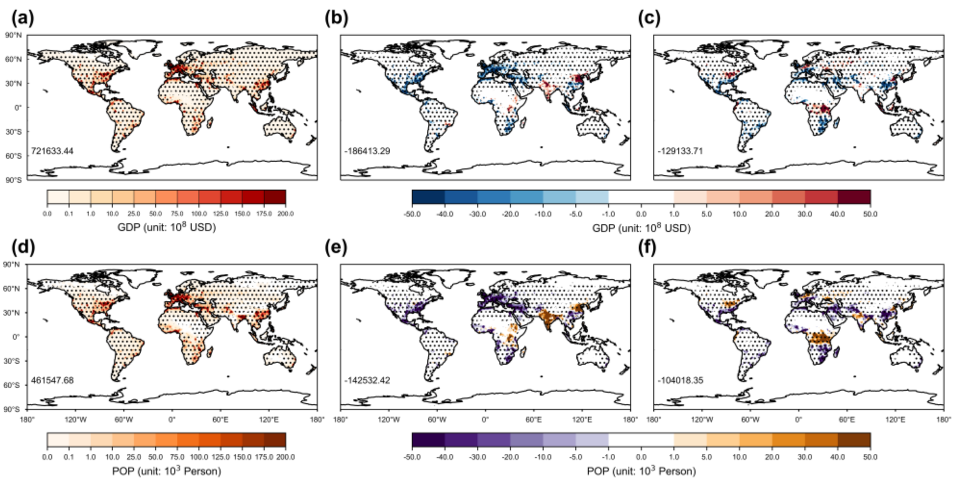

Figure. 8. Changes in GDP and population exposure to drought extremes. Results shown are the changes of (a, b, c) GDP and (c, d, f) population (POP) exposure to drought extremes at 2081-2100 (a, d) under SSP5-8.5 scenario relative to the historical period of 1995-2014, as well as that (b, e) under G6solar and (c, f) G6sulfur scenarios relative to SSP5-8.5 both at 2081-2100. The dotted areas indicate regions where at least four out of five models show changes with the same signs. The global sum value of the difference is shown at the lower-left of each panel.

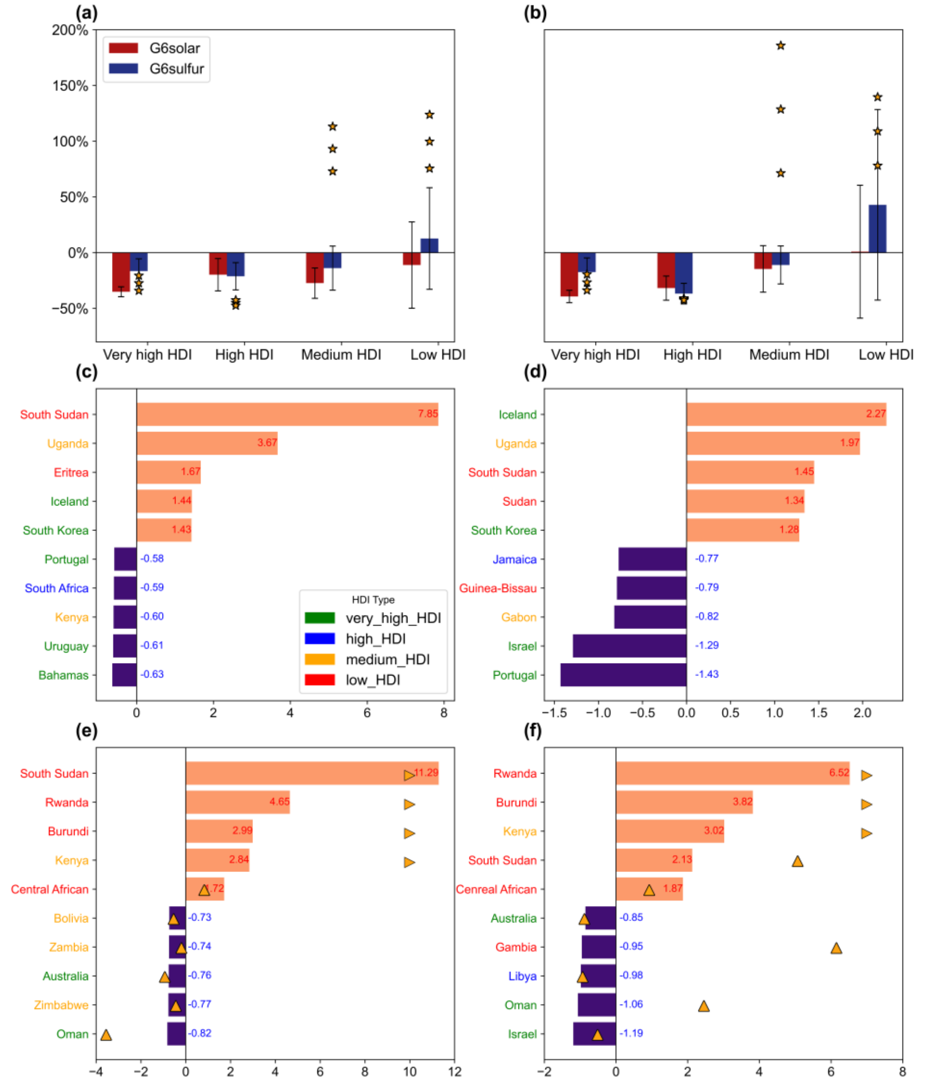

Figure. 10. Changes in GDP and population exposure to drought extremes by HDI. For each of four HDI groups, changes in (a) GDP or (b) population exposure to drought extremes for 2081-2100 in G6solar (blue) and G6sulfur (red) relative to SSP5-8.5 are normalized by the differences under SSP5-8.5 relative to 1995-2014. The bars represent the mean changes from five models with errorbars indicating one standard deviation for inter-model spread. Yellow stars represent results from three members of GLENS. The mitigation potential (MP, see Methods) is also calculated for individual countries, and the top 5 countries with the greatest mitigation (violet) or aggravation (orange) of (c, e) GDP and (d, f) population exposures to drought extremes are shown for (c, d) G6solar and (e, f) G6sulfur, respectively. The MP values (ratios of changes) are denoted for those top countries. Yellow triangles denote GLENS outcomes (right-aligned for values exceeding axis limits).

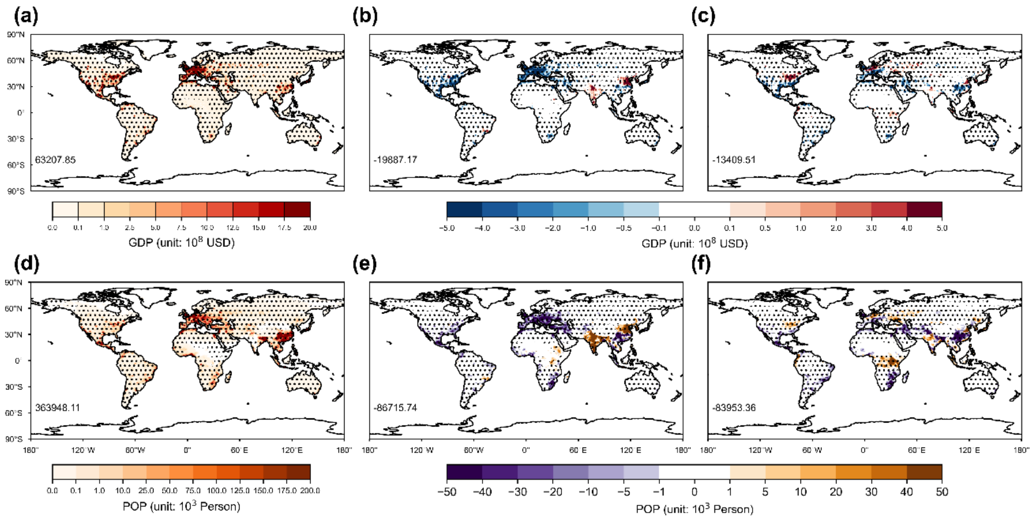

Figure 12. The same as Figure 8 but present-day GDP and population is applied.

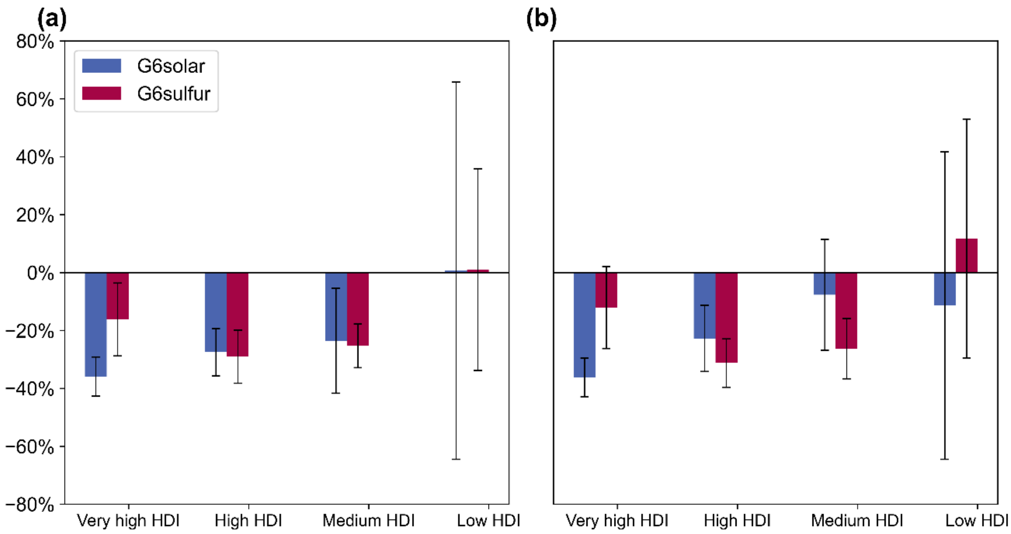

Figure 13. The same as Figure 10 but present-day GDP and population is applied.

Lines 357-358: Exposure is not risk. https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf

➢ Corrected as suggested.

Lines 371-372: This is a strawman argument. These scenarios were not designed to *alleviate drought extremes, so it's unsurprising that they have limited effectiveness in alleviating drought extremes.*

- Thank you for your comment and we have removed this statement in the revision.

Lines 373-374: This isn't necessarily rainfall enrichment. It's a rainfall increase. The increase might be in the form of severe storms, which isn't good either.

- Corrected as suggested: "For example, the SAI in G6sulfur mitigates only 42.8% of the SSP5-8.5 warming (Fig. 2c) but offsets 88.9% of the rainfall increase under SSP5-8.5 (Fig. 2f)" (Lines 443-445)

Lines 409-410: This narrow set of simulations does not cover all possible strategies. You can't make this conclusion.

- We have removed this conclusion in the revised paper.

Reference

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