Response to Reviewer 1

Major comments

Major comment 1: Clarify the motivation and relevance of overshoot and SAI scenarios for Africa

Reviewer comment: *The manuscript addresses an important topic; however, the motivation connecting climate overshoot scenarios to SAI and their relevance for Africa needs to be strengthened.*

- Scientific justification of scenarios: The authors should better explain why studying high-end overshoot and SAI scenarios is valuable despite their lower likelihood under current mitigation pathways. These scenarios can serve as stress tests to understand potential climate risks, reversibility, and adaptation challenges under extreme forcing conditions.

- Positioning within existing literature: Statements implying that African climate impacts are largely unexplored should be revised. While regional research gaps remain, there is an expanding body of work investigating African climate change impacts. The authors should acknowledge these efforts and clarify what specific knowledge gap this study addresses.

Response: We agree that the original framing understated existing African climate research and did not connect overshoot clearly enough to SAI. The Introduction now identifies the specific comparison: African responses to a common 1.5°C SAI objective on two different background pathways, with an additional 2.0°C overshoot experiment. It acknowledges prior Africa-focused studies, including Pinto et al. (2020) and Egbebiyi et al. (2025). We describe these scenarios as idealised stress tests rather than likely forecasts. They allow assessment of regional climate trajectories through a warming peak and of differences between temperature and hydrological responses. They do not establish reversibility of ecosystem impacts or isolate injection amount from all background-state effects.

Major comment 2: Improve the regional framework for interpreting impacts

Reviewer comment: *The manuscript evaluates impacts using geopolitical regions; however, the study focuses on agriculture, ecosystems, and water resources, which may be better represented through climate and ecological zones.*

- Use of agro-ecological regions: The authors should consider whether an agro-ecological classification (e.g., Sahara, Sahel, savanna, tropical forest regions) would provide a more physically meaningful interpretation than political boundaries.

- Link to impacts: Such a framework would allow more targeted discussions of SAI impacts on vulnerable systems, since climate responses are strongly controlled by factors such as aridity, vegetation, soil properties, and hydrological regimes.

Response: We appreciate this suggestion. We did not change the regional classification or repeat the analysis using agro-ecological zones. The revised manuscript retains the five broad African subregions, North, West, Central, East, and Southern Africa, to remain consistent with the regional masks used throughout the analysis and figures. We agree that these broad regions do not resolve the climatic and ecological variation within them, and we have made that limitation explicit. Nevertheless, it is important to mention that the regional classification gives an important overview of the major climate classification of the African continent and has also been used in different studies (e.g. Oloniyo et al., 2026) over the region

Major comment 3: Clarify interpretation of the surface moisture budget and water availability

Reviewer comment: *The manuscript appears to equate changes in (P-E) with changes in surface water availability, which may overextend the conclusions.*

- Distinguish moisture budget from water availability: The surface moisture budget provides information about precipitation inputs relative to evaporative losses but does not directly quantify available water resources.

- Consider missing hydrological processes: Surface water availability also depends on runoff, infiltration, groundwater recharge, soil moisture storage, drainage, and human water use. Therefore, conclusions regarding preservation of water availability should be qualified.

- Clarify the role of runoff: Neglecting runoff may be acceptable for a climatological atmospheric moisture analysis; however, the authors should acknowledge that a complete terrestrial water balance involves terms such as (P-E-R-D).

Also, the moisture budget analysis requires additional methodological clarification.

- Resolve inconsistencies in reported values: The manuscript reports moisture budget values of approximately 1-1.5 mm/day, while seasonal decomposition shows peaks of 4-4.5 mm/day. The authors should clarify whether these represent different quantities, averaging periods, or units.

- Define seasonal decomposition: The authors should explain whether values represent daily means, monthly averages, seasonal totals, or outputs from a decomposition method.

- Provide quantitative trends: Statements describing increasing or decreasing trends should be supported with numerical trend values, particularly where differences between SSP and SAI scenarios are difficult to discern.

Response: We agree. Throughout the revision, we define the surface moisture budget as precipitation minus actual evapotranspiration (P - ET). It does not directly quantify accessible water in soils, rivers, reservoirs or aquifers. A full terrestrial balance requires storage changes, runoff, subsurface drainage and relevant management fluxes, with terms defined to avoid double counting. We removed the original claim that SAI preserves surface water availability. ET is derived from actual latent heat flux, not an estimate of evaporative demand.

The seasonal analysis uses calendar-day-weighted mean daily rates in mm day^{-1}. It is a climatological seasonal average, not a decomposition algorithm. An individual wet-season mean can exceed the annual mean because lower or negative values in other seasons reduce the annual average. For the no leap calendar, annual = (90 DJF + 92 MAM + 92 JJA + 91 SON) / 365. This identity was checked for all 180 member-region-scenario-component rows; the largest numerical residual is 1.78×10^{-15} mm day^{-1}. Table S1 provides the regional surface moisture budget means, and Figure 6 states the units and averaging convention.

We also replace qualitative trend language with Theil-Sen slopes over the complete 2040-2099 window (Table S2). In West Africa, mean slopes are −0.0617, −0.0535, −0.0309, +0.0004 and −0.0305 mm day^{-1} per decade for SSP5-8.5, SSP5-3.4-OS, SSP585_1.5 SAI, SSP534OS_1.5 SAI and SSP534OS_2.0 SAI. We report member ranges as descriptive ensemble spread, not confidence intervals or trend-significance tests. Missing 2029 observations prevent complete three-member full-century summaries for the two 1.5°C SAI histories; the complete later window avoids that omission.

Major comment 4: Better highlight the novelty and strengths of the study

Reviewer comment: *The manuscript provides a detailed discussion of limitations, but the methodological strengths and unique contributions are less clear.*

- Highlight contributions: The authors should emphasize what aspects of the modelling framework, scenario design, or analysis provide new insights compared with previous studies.

- Balance limitations with strengths: A stronger discussion of the study's methodological advantages would improve the positioning of the manuscript and ensure that the contribution is recognized beyond the limitations discussed.

Response: The Discussion now explains the contribution after the limitations paragraph. The framework compares two forcing backgrounds at a common target, separates reference-period changes from same-period SAI effects, and calculates nonlinear indices for each member before averaging. Combining precipitation with actual evapotranspiration reveals compensating contributions that precipitation metrics alone would miss. Consistent regional weighting and explicit seasonal reconciliation strengthen internal interpretation. We avoid claiming that the design uniquely isolates aerosol amounts, that a small ensemble proves robustness, or that the analysis establishes new crop or water-resource outcomes. See Discussion section, pages 29 - 30, lines 343 - 413

Specific comments

Lines 51 to 65

Reviewer comment: *The authors comment on climate overshoot; however, how are they tying it in to SAI and its impacts? The paragraph seems somewhat disjointed from the next paragraph.*

Response: Despite the policy relevance of overshoot scenarios, their regional climate impact, particularly over Africa, is not yet fully understood. Comparing these scenarios allows continued warming to be contrasted with a warming peak followed by cooling. The later decline does not remove the period of elevated warming, during which changes in climate extremes may affect agriculture and water resources. SAI has therefore been proposed as a means of limiting peak warming during an overshoot. Its implications for Africa must be assessed from both the temperature response and the accompanying changes in precipitation and the surface moisture budget. See page 1, lines 61-65

Line 63

Reviewer comment: *Despite the policy …" I think this is not an accurate description of the current state of the science. There are quite a number of researchers working to understand this topic over the region. The expertise may not be from the region, but there are definitely quite a number of research studies being conducted over the region. This should be acknowledged.*

Response: The statement has been revised to: " Despite the policy relevance of overshoot scenarios, their regional climate impact, particularly over Africa, is not yet fully well understood". See Page 1, lines 61 - 62.

Line 80

Reviewer comment: *Change to Pinto et al. and Egbebiyi et al. demonstrated that …*

Response: The sentence has been revised as "Pinto et al. (2020) and Egbebiyi et al. (2025) demonstrated that while SRM significantly reduces mean and extreme temperatures across the continent, its effect on precipitation is less linear and varies markedly across different parts of Africa, particularly between East and West Africa." See Pg. 3, lines 79 - 81

Line 88

Reviewer comment: *"These studies collectively underscore the need for targeted…" - more targeted assessments. There are some studies, but more would be better.*

Response: "targeted assessments" has been changed to "more targeted assessments". The sentence has now been revised as "These studies collectively underscore the need for more targeted assessments of how SAI interacts with specific emission pathways and warming trajectories, particularly under overshoot conditions that represent increasingly plausible future scenarios. ". See Pg. 3, lines 88

Lines 93 to 95

Reviewer comment: *The authors should further clarify the relevance and applicability of this work for the African region, particularly given that the scenarios considered may represent relatively unlikely future pathways under current mitigation trajectories. The manuscript would benefit from a stronger discussion of the rationale for examining these high-end overshoot and SAI scenarios. Specifically, the authors should emphasize that, despite their lower likelihood, such scenarios provide valuable insights into the potential magnitude, spatial variability, and reversibility of climate impacts under extreme*

forcing pathways, serving as important stress tests for climate resilience, adaptation planning, and risk assessment.

Response: The scenarios are framed as conditional stress tests for temperature changes and regional hydrological responses, rather than forecasts. Their usefulness lies in comparing demanding forcing trajectories and intervention objectives relevant to identifying questions for adaptation and impact assessment. We avoid asserting that they bound every possible African impact.

Line 112

Reviewer comment: *The authors do a good job of localizing the analysis by considering geopolitical regions. However, given that the study focuses on climate impacts relevant to agriculture, water resources, and ecosystems, it may be more appropriate to consider a subdivision based on agro-ecological zones rather than, or in addition to, geopolitical boundaries. An agro-ecological framework would likely provide a more physically meaningful basis for interpreting regional responses, as climate impacts and vulnerabilities are strongly tied to environmental characteristics such as aridity, vegetation type, and hydrological regimes. This approach would also allow the authors to make more targeted statements regarding the implications of SAI, for example, distinguishing responses in the Sahara, Sahel, savanna, and humid tropical regions rather than broader regions such as North Africa. This could improve the clarity and relevance of the discussion for climate adaptation and resource management.*

Response: We appreciate the suggestion. We did not change the regional classification or repeat the analysis using agro-ecological zones. The five-region framework was retained for consistency with the existing masks, analysis, and figures. We have instead acknowledged that the broad regions do not resolve within-region agro-ecological differences.

Lines 153 and 155

Reviewer comment: *L153: b should not be capitalised. L155: b should not be capitalised.*

Response: We changed the bold "b" to lowercase and unbolded it. See lines 153 and 155

Line 165

Reviewer comment: *ETCCDI is already defined elsewhere before this.*

Response: ETCCDI is defined at the first occurrence in the Introduction and abbreviated subsequently (See Page 2, lines 50). The methodological citation is Zhang et al. (2011), and we distinguish the additional temperature indices from standard ETCCDI indices. See Page 7, line 169

Line 214

Reviewer comment: *Correct "indices plateau begin".*

Response: We revised the sentence to state that, under SSP5-3.4-OS, the temperature indices level off and subsequently decline. We also removed the statement implying that WSDI extends through 2099. The revised Figure 1 and its caption show that the WSDI series end in 2091 under SSP5-8.5 and 2087 under SSP5-3.4-OS because of incomplete daily maximum-temperature records. See Page 9; lines 198-201

Lines 284 to 285

Reviewer comment: *The statement that SAI shifts tropical rainfall patterns through stratospheric heating and suppresses evaporation requires further clarification and stronger support from the cited literature. The cited study (e.g., [DOI: 10.1029/2019GL085758]) appears to primarily discuss circulation and seasonal changes at higher latitudes rather than directly demonstrating tropical rainfall shifts or evaporation suppression. Therefore, this statement may overstate the current evidence. I suggest revising this discussion to provide a more general overview of the potential impacts of SAI rather than attributing the specific changes observed in this study to these mechanisms without further analysis. At present, the extent to which SAI modifies tropical rainfall distributions or suppresses evaporation remains uncertain and may depend on the background climate state, regional processes,*

and also the model in use. Additionally, the phrase "shift tropical rainfall patterns" is ambiguous. Please clarify whether this refers to changes in the spatial location of precipitation, changes in seasonal timing (e.g., onset/cessation), or changes in rainfall intensity and variability.

Response: We agree and have revised the Discussion to avoid directly attributing the simulated rainfall changes to stratospheric heating or reduced evaporation. The revised text presents changes in the energy balance and atmospheric circulation only as possible explanations reported in previous studies and makes clear that these mechanisms were not isolated in our analysis. We also removed the ambiguous phrase "shift tropical rainfall patterns" and now describe the simulated changes directly in terms of precipitation magnitude and spatial pattern.

Line 286

Reviewer comment: *Niemeier and Simpson citations are absent from the references.*

Response: Complete references for Niemeier et al. (2013) and Simpson et al. (2019) have been added to the reference list.

Lines 295 to 299

Reviewer comment: *What would this mean for precipitation? Does it mean SAI could lead to higher rainfall/extreme rainfall days compared to the other climate scenarios? The sentence implies that SAI would preserve surface water availability through the century. Is this good or bad? Also, the final sentence appears to extend beyond what is directly supported by the analysis. While the surface moisture budget provides valuable information on the balance between atmospheric water inputs and losses, it does not directly quantify surface water availability, which is additionally controlled by processes such as runoff, infiltration, groundwater recharge, soil moisture storage, and human water use. Therefore, the conclusion that SAI could preserve surface water availability appears stronger than the evidence presented. The authors should either qualify this statement or provide additional analyses or supporting literature that establish a clear link between changes in P-E and surface water availability, particularly in West Africa. Given that this is a climatological analysis, neglecting runoff (R) may be reasonable for evaluating broad atmospheric moisture balance; however, it should be acknowledged that actual surface water availability depends on the full hydrological balance, including terms such as runoff and drainage (P-E-R-D).*

Response: No direct inference about extremes or available water follows from a higher surface moisture budget value. We remove the preservation claim and discuss precipitation indices separately. For example, same-period continental Rx5day decreases by 8.7, 5.5 and 2.6 mm in the three SAI experiments, while the regional surface moisture budget can increase. In West Africa, the positive mean surface moisture budget differences are primarily associated with increased P: ΔP is +0.105, +0.257 and +0.308 mm day^{-1}, while ΔET is -0.005, +0.075 and +0.085 mm day^{-1}. These contrasts do not establish whether particular local rainfall extremes increase, or whether the balance change is beneficial for a given crop or catchment.

Lines 301 to 303

Reviewer comment: *Can the trend values be quantified? It is hard to see the "increasing trend" for some of the scenarios like SSP3.4-OS and the SAI scenarios.*

Response: Table S2 gives the mean and range of member-specific Theil-Sen slopes for all four regions over 2040–2099. For the nearly flat West African overshoot SAI 1.5°C case, the mean is +0.0004 mm day^{-1} per decade and the member range is –0.0140 to +0.0188. We no longer describe every West African scenario as declining, or infer significance from the apparent sign of a smoothed curve.

Line 304

Reviewer comment: *Are these monthly averages, monthly totals, seasonal totals or daily averages? The seasonal decomposition results appear to be inconsistent with the values presented earlier in the manuscript. Specifically, the moisture budget is reported to range between approximately 1.0 and 1.5*

mm day⁻¹, yet the JJA seasonal values are stated to peak at approximately 4.0-4.5 mm day⁻¹. If these represent seasonal means of the same variable, such values would not be mathematically possible, suggesting either a difference in the quantity being analyzed (e.g., seasonal accumulation versus seasonal mean), a change in units, or a different processing methodology. Please clarify how the seasonal decomposition was performed, what quantity is being presented, and whether the reported units are correct. If these values are derived from a decomposition algorithm rather than a simple seasonal average, this should also be explicitly stated to avoid confusion.

Response: Both figures present the surface moisture budget in mm day⁻¹. Figure 4 shows a smoothed annual time series, whereas Figure 5 shows seasonal means for 2060-2079. An individual seasonal mean can therefore be higher or lower than the annual mean. We verified the annual values using the day-weighted mean of the four seasons over the same period and clarified this calculation in the Methods.

Figure 6 units

Reviewer comment: *Check the units.*

Response: We checked and corrected the vertical axis. The seasonal surface moisture budget and SAI-effect figures use mm day⁻¹, while Figure A3 reports seasonal precipitation totals in mm season⁻¹.

Lines 331 to 332

Reviewer comment: *Beneficiary relative to what?*

Response: We removed "greatest beneficiary" and now compare each SAI experiment with its corresponding simulation without SAI over the same period. The revised text reports the changes in the surface moisture budget without describing them as benefits.

Lines 371 to 373

Reviewer comment: *citation needed "From an agricultural perspective".*

Response: We added Sultan and Gaetani (2016) to support the discussion of agricultural sensitivity to changes in temperature and water availability. We also clarified that the indices analysed here do not directly estimate crop yields, as other factors such as soil type and farm management practices are also major contributors.

Lines 393 to 395

Reviewer comment: *The higher moisture levels… This work does not show this result, hence the authors would need to back up this claim.*

Response: We removed the unsupported claim and now report only the simulated changes in the surface moisture budget and its precipitation and evapotranspiration components. We also clarify that the surface moisture budget does not directly measure water availability.

Lines 401 to 409

Reviewer comment: *This paragraph appropriately discusses the methodological limitations of the study, which provides useful context for interpreting the results. However, it would also be valuable for the authors to highlight the methodological strengths and innovations that underpin the contribution of this work. In particular, the manuscript would benefit from a discussion of what aspects of the experimental design, modeling framework, or analytical approach provide new insights beyond existing studies. Placing such a discussion after the limitations paragraph would help balance the presentation by emphasising not only what the study cannot address, but also the robustness of the framework and the unique contributions it makes to understanding climate responses under overshoot and SAI scenarios. This would strengthen the positioning of the manuscript and better convey its novelty and significance.*

Response: We added a paragraph highlighting the comparison of SAI experiments across two background scenarios, the calculation of indices for individual ensemble members and the combined analysis of precipitation, evapotranspiration and the surface moisture budget.

References

Reviewer comment: *Alphabetise the reference list.*

Response: The reference list has been arranged alphabetically.

Figures 2, 5, A1 and A3

Reviewer comment: *The font size of legends and labels is too small. Also, the figures pixelate when zoomed in for details.*

Response: We have regenerated the figures at a final width of 7.15 inches and 450 dpi, with fonts sized for readability at the final page width.