Response to the referees of the manuscript "An energetic perspective on the impact of the Atlantic Multidecadal Variability on the West African Monsoon"

Dear co-editor,

Please find below the detailed point-by-point response to the comments of all referees of the manuscript. We provide our response to each of their comments and specify the changes made to the manuscript to address them. To ease the identification of the changes, we specify the line numbers in the marked-up manuscript where they can be found. We would like to thank the three reviewers for their careful reading and constructive comments, which have helped improve our manuscript.

Comments from reviewer 1.

General
The authors study the influence of Atlantic Multidecadal Variability (AMV) on the West African Monsoon (WAM) in a suit of simulations. The main findings are a an intensification of WAM in response to the positive phase of AMV, driven by a northward shift of the African ITCZ associated with energetic constraints on the position of the ITCZ, and a weakening and northward shift of the shallow meridional circulation over the Sahara, which supports the intensifcation of WAM by reduced dry air intrusions into the deep-convective region. The paper is well organized and well written, and the results are overall well supported. I do have a couple of concerns regarding the energetic constraints and regrading the attribution of the surface heat anomalies associated with AMV with the WAM response. I would therefore recommend accepting the paper after addressing these concerns. Additional minor comments are listed below by line number.

We thank the reviewer for the careful reading and constructive comments on our manuscript. In the following, we provide a point-by-point response to the points raised in the comments and the modifications made in the manuscript to address them.

Comments
1. The energetic constraints are no more than a balance condition, and I was not convinced that the heat anomalies in the north Atlantic are a direct driver of the WAM response — especially considering that the regional energy balance is not closed (i.e., due to zonal energy fluxes). For example, moisture transport from the tropical Atlantic into the Sahel would induce a similar result, in which case, the northward shift of the ITCZ would yield a similar change to the energy transport fields, rather than be a a response to the imposed energetic imbalance. Given that the authors explain the northward shift of the WAM ITCZ as a direct response to the energetic imbalance, I would

expect better support (e.g., see the comment below) for this claim and better description of the limitations of this hypothesis.

We thank the reviewer for this insightful comment. We agree that the energetic framework adopted here primarily describes a balance constraint and does not, by itself, establish a unique causal pathway. We also acknowledge that processes not explicitly quantified in our analysis, such as zonal energy fluxes and atmospheric energy storage, may contribute to the regional energy budget. In addition, we recognize that, as proposed by the reviewer, a northward shift of Sahel precipitation could arise from changes in moisture transport from the tropical Atlantic.

While the analyses we can perform are constrained by the available model output (see below), we would like to emphasize the following points:

1. The experimental setup imposes SST anomalies over the North Atlantic (including both tropical and extratropical regions), which induce a regional energy perturbation. Part of this excess energy is locally radiated to space, but a substantial fraction is redistributed through changes in the atmospheric circulation. In this context, negative NEI anomalies developing in the South Atlantic act to enhance the interhemispheric energy contrast, as noted by the reviewer, but are best interpreted as part of the atmospheric adjustment to the imposed North Atlantic forcing, rather than as an independent driver of the response. The resulting anomalous moist static energy flux exhibits a southward component at Sahel longitudes (Fig. 4a), which is consistent with a northward displacement of the ascending branch of the monsoonal circulation and the associated precipitation. We interpret this adjustment as being physically consistent with and, in fact, a necessary response to the imposed energy perturbation. At the same time, we acknowledge that it involves coupled dynamical and thermodynamical processes and does not uniquely isolate a single causal mechanism.
2. We further acknowledge that the vertically integrated moist static energy fluxes shown in Fig. 4a do not allow us to disentangle the relative roles of different processes contributing to the anomalous energy transport. In particular, they do not distinguish between contributions from the mean circulation and transient eddies, nor between latent and sensible components, or between different vertical levels of the atmosphere. As a result, our analysis cannot rule out that enhanced moisture transport from the tropical Atlantic may play an important role in linking the imposed North Atlantic energy perturbation to the Sahel precipitation response. The presence of a westerly component in the anomalous energy flux over the Sahel is consistent with this interpretation (Fig.4a). A more detailed process-level attribution would require high-frequency, vertically resolved model output, which is not available for the simulations analyzed here.
3. While we do not have the necessary output to verify that in the analyzed simulations, on seasonal time scales, atmospheric storage tendency is about one order of magnitude smaller than NEI in ERA5 data (Fig. R1). In addition, there is no strong inter-hemispheric gradient in the storage tendency. This confirms a good correspondence between NEI and MSE flux divergence, hence justifying our neglect of the storage term.

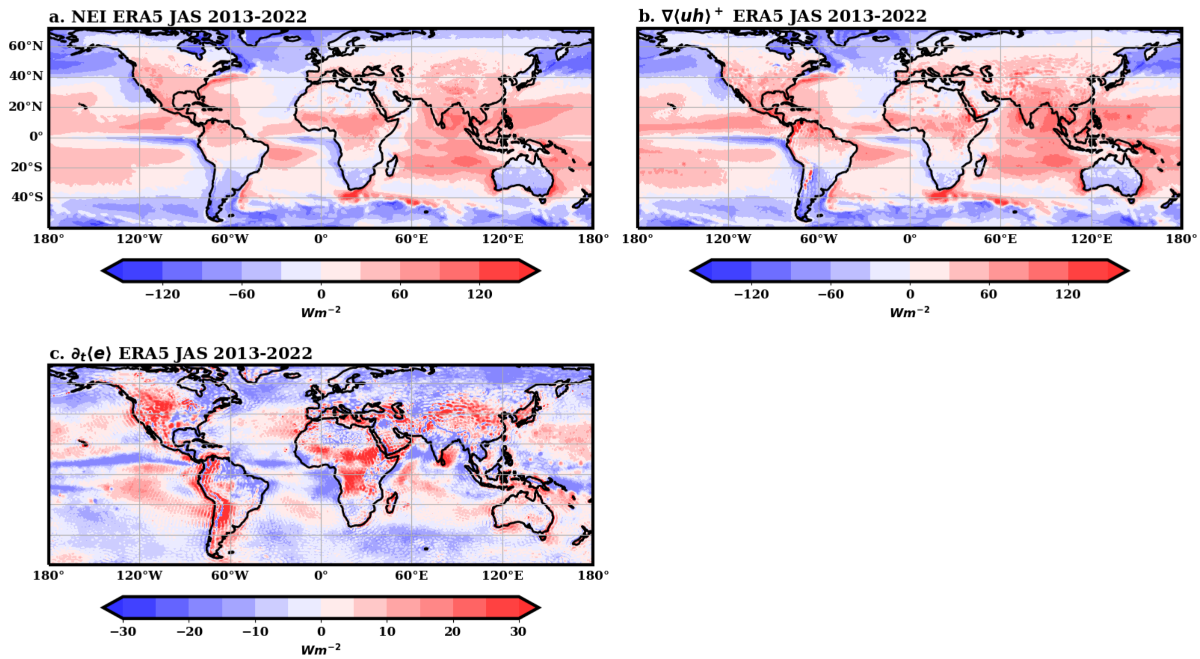

Fig. R1: a) Net energy input (NEI) calculated from ERA5 (Hersbach et al., 2020) energy imbalances at TOA and the surface averaged for the July to September season for the 10-year period of 2013-2022 (shaded, W m^{-2}); b) Mass-consistent divergence of the vertical integral of total energy flux (Mayer et al. 2021) averaged for the same season and period; c) time tendency of the mass-weighted vertical integral of moist enthalpy calculated as the residual between NEI and the mass-consistent divergence of the vertical integral of total energy flux averaged over the same season and period. Note the different colorscale.

To address these concerns, we have made the following changes in our manuscript:

a. Removal of the word “direct” on Line 243, to acknowledge that the response may arise through an intermediate chain of processes. Also include a new sentence with a reference to the South Atlantic negative anomalies in lines 245-247:

   “These adjustments also include changes in NEI in regions remote from the primary forcing, such as the Atlantic south of the equator, where negative NEI anomalies develop (Fig. 4a) and further strengthen the inter-hemispheric energy gradient.”

b. Inclusion of a more thorough discussion of the limitations of the energetic framework in lines 430-442:

   “Some methodological limitations also need to be emphasized. First, our energetic framework neglects atmospheric energy storage, assuming that the divergent component of the vertically integrated energy flux is balanced by the mean NEI (Eq. 1), which might not be the case for seasonal means (Donohoe et al., 2013). While the limited available model output does not allow us to verify the validity of this assumption in our simulations, a comparison of these terms using ERA5 reanalysis (Hersbach et al., 2020; Mayer et al., 2021)

suggests this is a robust approximation for a 10-year summer mean (see Fig. S13 in the supplementary material). Second, the vertically integrated MSE fluxes (Fig. 4a) do not uniquely identify the specific chain of intermediate physical links driving the WAM adjustment to the AVM forcing. In particular, these integrated fluxes do not allow us to disentangle the relative contributions of the mean circulation and transient eddies, nor the specific roles of latent and sensible energy transport. Consequently, our results do not preclude, and are indeed consistent with, the hypothesis that enhanced moisture transport from the tropical Atlantic acts as a primary causal link between North Atlantic warming and the northward Sahelian ITCZ shift. The presence of a westerly component in the anomalous MSE flux over the Sahel (Fig. 4a) supports this interpretation. High-frequency and vertically resolved model output (not currently available for this ensemble) would be necessary to further attribute these changes to specific process-level dynamics."

c. This previous discussion is complemented with the addition of Fig. R1 to the Supplementary material as Fig. S13.

2. DCPP includes experiments where the tropical and extratropical components of AMV are separated (Boer et al. 2016). Examining the sensitivity of the response to this decomposition can be very helpful in attributing the WAM response to specific processes (e.g., tropical moisture transport vs. inter-hemispheric asymmetric heating). I would like for the authors to analyze these experiments or at the very least explain why were these not examined.

We thank the reviewer for this suggestion. To address this, we analyzed the three models in our ensemble (IPSL-CM6A-LR, CNRM-CM6-1, and HadGEM3-GC31-MM) that performed these specific DCPP-C experiments (tropical vs extratropical AMV forcing). Our analysis led us to exclude these results from the final manuscript for the following reasons:

1. The Sahel rainfall response is highly inconsistent across these three models. For example, in CNRM-CM6-1, the response is driven by the tropical component, whereas in HadGEM3-GC31-MM, it is significant only in the extratropical experiment (see Figs. R2 and R3 in this reply).
2. Even when SST restoration is restricted to the extratropics (north of 30ºN), positive SST anomalies are communicated to the tropical Atlantic via coupled air-sea feedbacks (e.g., Zhang et al., 2019). This precludes the clean attribution of the WAM response to specific latitudinal bands that the reviewer was suggesting.
3. Only 3 of our 11 models performed these experiments. Including results from such a small subset would undermine the robust multi-model consensus that is the focus of our study.

In addition, we note that in the full AMV experiments analysed in the manuscript, both contributions, tropical and extratropical NEI, are relevant, and their combination explains more inter-model variance of Sahel rainfall than any of them separately (Fig. R4).

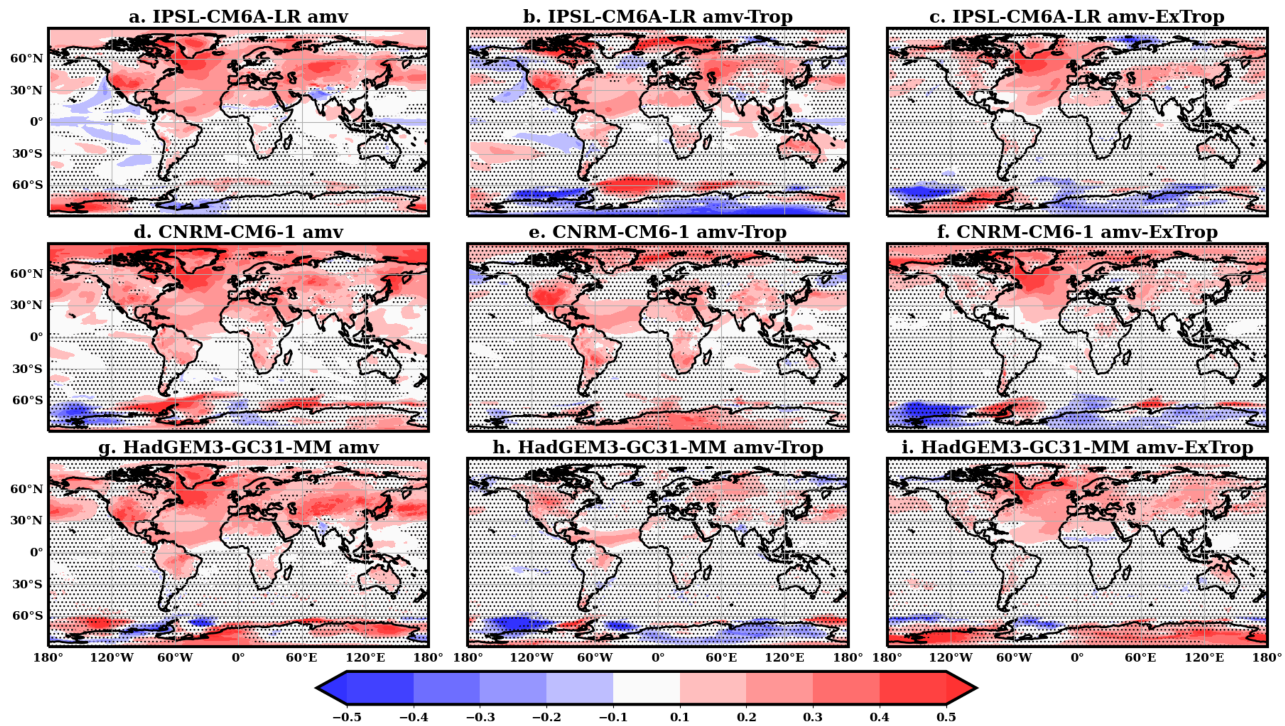

Fig R2: Multimodel mean AMV+ minus AMV− change in JAS surface temperature (◦ C) for the simulations where the SSTs where restored in the whole North Atlantic (left column, plots a, d and g), only in its tropical region (central column, plots b, e and h) and only in its extratropical region (right column, plots c, f and i) for the IPSL-CM6A-LR (first row, plots a to c), CNRM-CM6-1 (second row, plots d to f) and HadGEM3-GCM31-MM (third row, plots g to i) models. Dots mark regions where anomalies are not statistically significant ($p<0.05$) according to the parametric t-test for differences in means, assuming a Gaussian distribution for the samples and independence of the different ensemble members.

To address the reviewer's concern, we added a comment on the relevance of both tropical and extratropical NEI contributions in the North Atlantic, and how their combination explains more of the inter-model variance of Sahel rainfall than either contribution separately (lines 258-260):

"*Note that both the tropical and extratropical portions contribute to the North Atlantic NEI, and their combination explains more inter-model spread of Sahel rainfall changes than either contributor separately (Fig. S6 in the supplementary material).*"

We also included Fig. R4 in the supplementary material as Fig. S6.

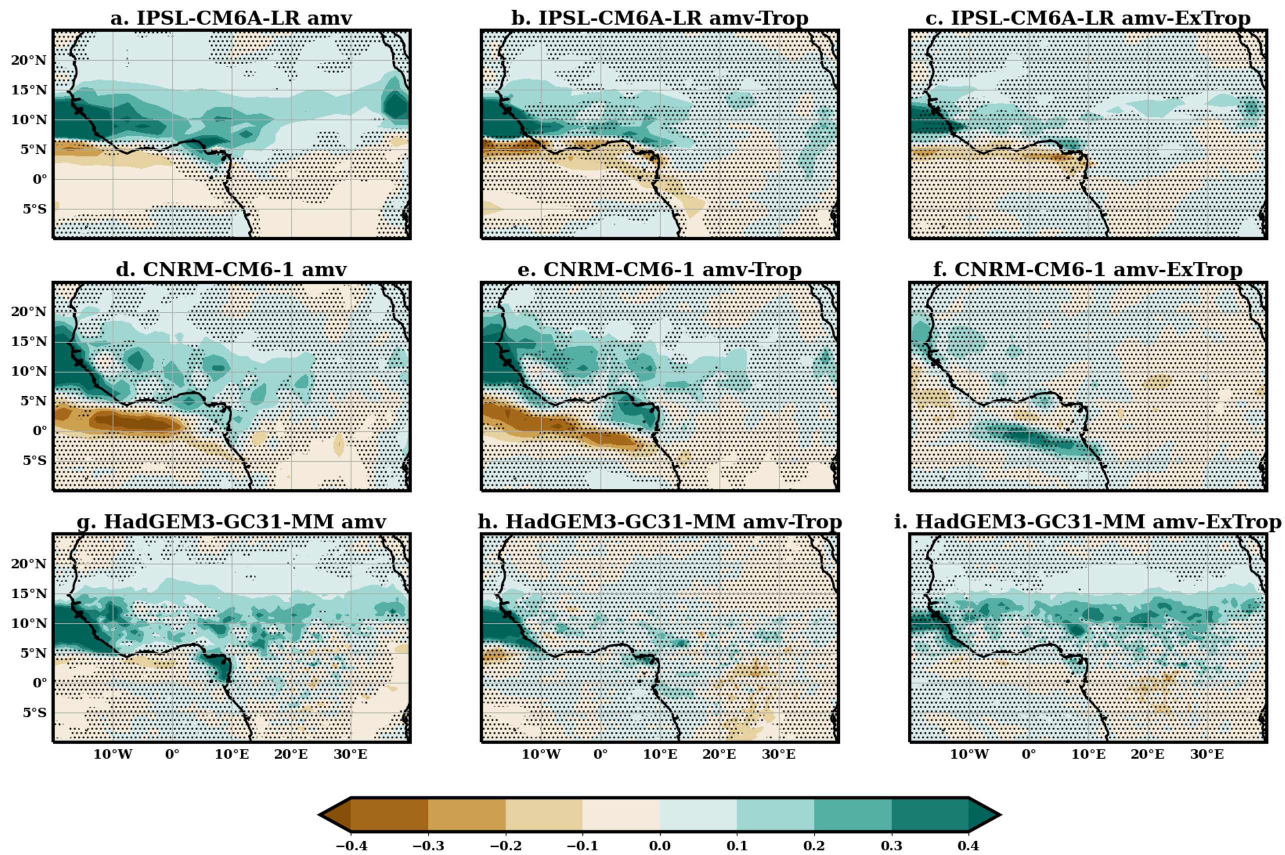

Fig. R3: as in Fig. R2 but for changes in JAS precipitation (mm·day^{-1}).

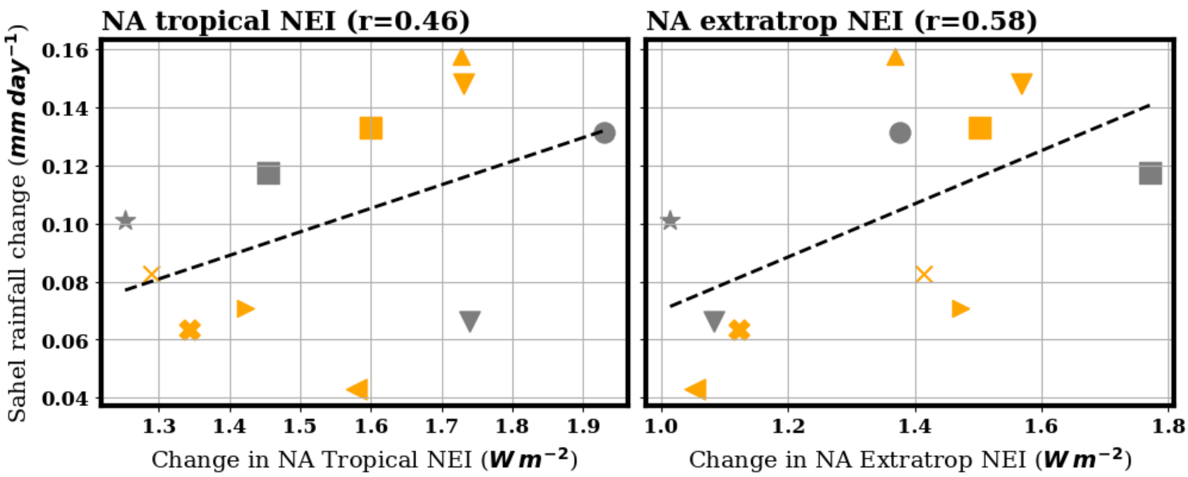

Fig. R4: Scatter plots of averaged Sahel rainfall change (mm day^{-1}) and: a) NEI averaged over the tropical North Atlantic (W m^{-2}, using the orange box in plot 4c from the equator to 30ºN) and b) NEI averaged over the extratropical North Atlantic (W m^{-2}, using the orange box in plot 4c only north of 30ºN).

Line-by-line comments:

Comments by line number

74—76 It would be helpful to show the AMV pattern to which are you relaxing the model, and not have to refer to Boer et al. (2016).

We agree that explicitly showing the restoration region is helpful. Figure R5 shows the AMV positive pattern to which SSTs were restored in the AMV+ simulations. We included this figure in the supplementary material as Fig. S1 and updated the text (lines 76-79) to point directly to this figure and clarify the region where the restoration is performed.

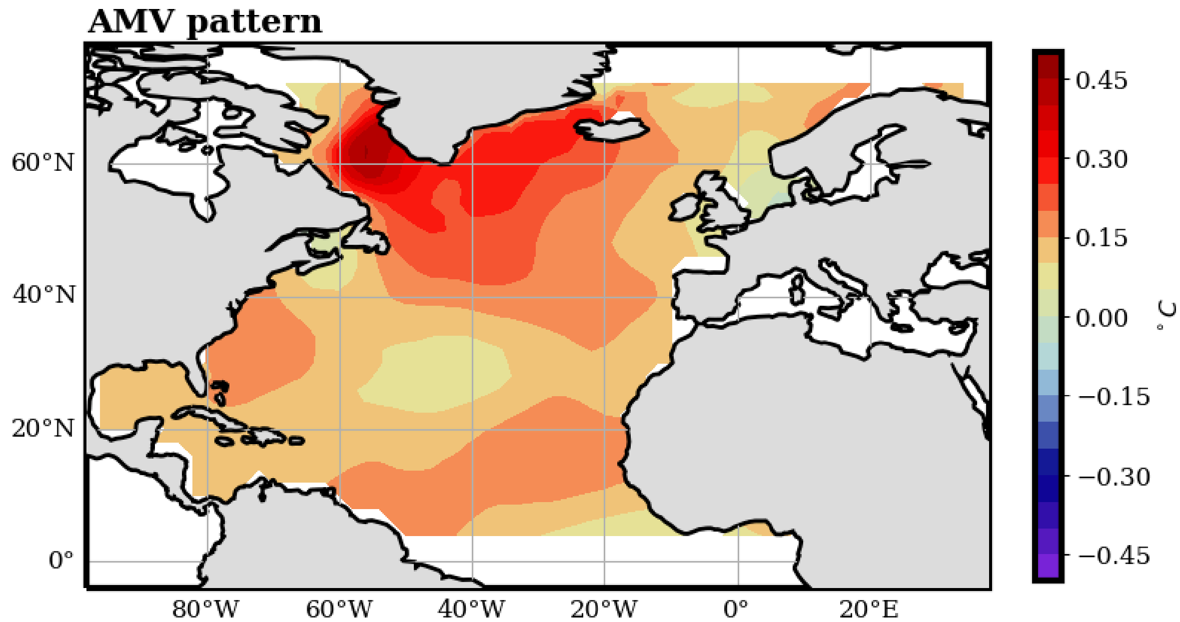

Fig. R5: Full AMV+ pattern (ºC). SSTs are restored to follow the pattern between 10ºN and 65ºN. The AMV anomalies to which SSTs are restored are gradually reduced in an additional buffer zone 8º to the north and south of this box.

84—85 The context of this sentence is not clear. Do you mean that for interpretation of the results (which show the positive phase), we assume that the negative phase response in equal and opposite?

Yes, that is correct. To clarify this for the reader, we removed this sentence from lines 92-94 and moved it up in the text (lines 88-90), so that the new description reads:

"Changes associated with a positive AMV phase are estimated by subtracting the negative experiment from the positive one ($AMV^{+} - AMV^{-}$). Since this estimation assumes linearity, the changes associated with a negative AMV phase can be obtained by reversing the sign of the anomalies."

102-103 Not clear what you mean by that. Since you use monthly data, the calculation neglects transient eddies. Or are you using monthly means of covariant fields?

We appreciate the opportunity to clarify this. While we use monthly mean fields for NEI, our methodology infers the divergent component of the MSE flux by assuming the energy budget is closed and storage is negligible. Under these assumptions, the inferred term implicitly includes the effects of the entire atmospheric circulation, including the time-mean circulation and transient eddies. We revised Section 2.2, removing potentially confusing language regarding the "small contribution" of eddies (lines 100-101), and, after removing the less detailed explanation in lines 114-115, added a clearer explanation of how the inferred term accounts for the "total" energy transport in lines 122-124:

"Note that even though NEI calculation is performed with monthly mean values, the inferred divergent component of the mass-weighted vertical integral of the MSE flux is inclusive of time means and transient eddies."

231—232 This is speculative. The energetic balance mandates that northward shifts of the ITCZ are associated with southward cross-equatorial energy fluxes. Specifically, is seems like the dominant NEI contribution in from the tropical Atlantic, west of the Sahel. I am therefore not convinced that excess heating of the north Atlantic as a whole is a well supported interpretation of the results. Moreover, negative NEI just south of the equator in the WAM sector might prove to be as important to the energetic contrast driving the WAM ITCZ shift. Similarly, changes in equatorial atmospheric NEI (at the orange rectangle in panel 4b), which determine the extent of ITCZ migrations in response to hemispherically asymmetric heating, may also contribute to the shifts of the WAM ITCZ (cf. Adam et al. 2019). As an alternative hypothesis, could it be that heating of the tropical Atlantic supports increased moisture transport to the WAM region leading to anomalous precipitation?

We refer the reviewer to our detailed reply to their Major Comment 1. Regarding the specific role of equatorial NEI, which could act as a sensitivity factor for ITCZ shifts in response to a hemispherically asymmetric heating, we find no evidence of a consistent relationship between changes in equatorial NEI at Sahel latitudes (in the box in plot 4b) and Sahel precipitation (see Fig. R6).

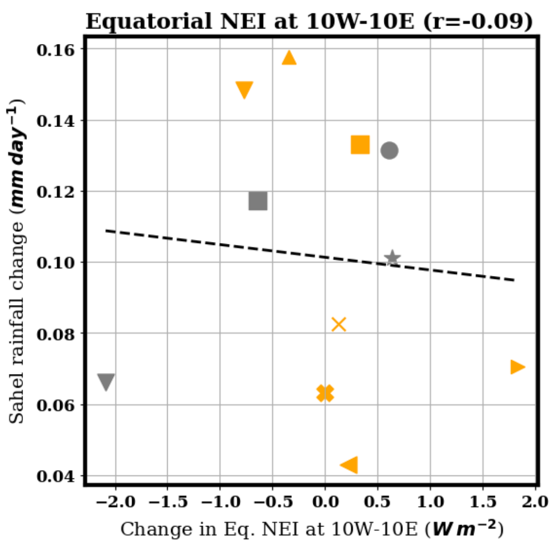

Fig R6: Scatter plots of averaged Sahel rainfall change (mm day^{-1}) and NEI changes averaged over the equator at Sahel longitudes (W m^{-2}, see orange box in plot 4b).

244 This formulation neglects the temperature difference between the atmosphere and surface, which can lead to some error (cf. Siler et al. 2019)

We thank the reviewer for this remark. We acknowledge that our formulation involves approximations that are not clearly stated in the text. In particular, (i) near-surface wind speed is estimated from monthly mean zonal and meridional components at 1000 hPa, and (ii) near-surface relative humidity is approximated as the ratio between near-surface specific humidity and saturation specific humidity at the surface. The latter approximation makes our formulation consistent with Siler et al. 2019 (their eq. 2).
These approximations introduce some errors. In particular, neglecting the temperature difference between the surface and near-surface air can lead to errors in our estimation of the relative humidity changes. However, scaling arguments following Siler et al. (2019) indicate that, for typical temperature differences and their simulated changes, the resulting error in fractional relative humidity remains small (on the order of a few percent), and does not affect the qualitative interpretation of Fig. 5.

To clarify this point, we revised the text to explicitly state these approximations. Specifically, we modified lines 269–272 to:

"In Fig. 5, we present these terms for the surface, except for the wind speed, which is estimated from monthly mean zonal and meridional components at 1000 hPa, and RH, which is calculated as the ratio between near-surface specific humidity and saturation specific humidity at the surface. These represent approximations to near-surface wind speed and relative humidity."

247 (and elsewhere where relevant) relative —> fractional
We thank the reviewer for this correction. We have replaced all instances in the manuscript following the reviewer's suggestion (lines 266, 267, 268, 276, 277, and caption of Fig. 5)

261—263 Also, consider the negative and positive feedbacks discussed in Karnauskas (2022) and Ganguly et al. (2024)

We thank the reviewer for highlighting these feedbacks. Due to the experimental setup, the atmosphere and ocean are partly decoupled in the Atlantic north of 2ºN. This prevents the full realization of Wind-Evaporation-SST (WES) feedbacks in the North Atlantic. This comment has, however, brought to our attention that this effective decoupling was not clearly explained in the previous version of our manuscript. We believe that the inclusion of figure R5 to the supplementary material and the clarification of where the SST restoration is performed will help clarify this. In addition, we updated text (lines 283-286) to:

"*This yields a dipole in surface wind speed anomalies (negative north of 10°N, positive to the south; Fig. 5c), which in turn suppresses latent heat flux to the north and increases it to the south, consistent with the pattern in Fig. 5a. Note that in this region, the experimental setup prevents full atmosphere-ocean coupling, such that* *positive and negative Wind-Evaporation-SST feedbacks (e.g. Karnauskas 2022; Ganguly et al. 2024) are hindered."*

272—274 This is hardly the rising branch of the Hadley circulation, not is it "the" ITCZ, which are both zonal mean constructs. Perhaps a better way to describe these regional dynamic changes would be by treating them as changes in the the monsoonal Hadley-like circulation in the African sector.

We thank the reviewer for this suggestion. We adopted the reviewer's suggested terminology, referring to the monsoonal Hadley-like circulation in the African sector and the main rainfall band rather than the global ITCZ so that the new sentence reads (lines 295-297):

"In the African sector, this flux is accomplished by a northward shift of the monsoonal Hadley-like circulation's ascending branch and is thus associated with a corresponding northward shift of the main rainfall band, ultimately leading to enhanced rainfall over the Sahel."

300—303 If we explain the easterly jet based on the thermal wind, isn't this response a simple and obvious result of the northward shifted heated region over WAM?

We agree that the AEJ response is a consequence of the shifted thermal gradient. We revised this paragraph to clarify that increased soil moisture from enhanced rainfall promotes evaporative cooling, which alters the latitudinal temperature gradient and, via thermal wind balance, shifts the AEJ northward, so that it now reads (lines 325-331):

"Models with stronger rainfall change over the Sahel are also those that show a stronger northward shift of the AEJ (Fig. 6e). We speculate this link to be a consequence of the surface response to enhanced rainfall (see Fig. S8 in the supplementary material): increased soil moisture in the latitudinal band between 10ºN and 15°N following enhanced precipitation promotes evaporative cooling of the surface by changing the balance between latent and sensible heat fluxes, which alters the surface temperature latitudinal gradient and, through thermal wind balance (Cook, 1999), enhances the AEJ to the north and reduces it to the south."

Figure 5 caption ECMWF surface specific humidity can be readily calculated with surface pressure and 2m dew point temperature. No reason to exclude these models (e.g., https://forum.ecmwf.int/t/how-to-calculate-hus-at-2m-huss/1254).

We thank the reviewer for this tip. However, we have not been able to find near-surface dew point temperature in the data catalogue at ESGF for these models and experiments. Near-surface specific humidity and near-surface relative humidity were also missing for ECMWF-IFS-HR and ECMWF-IFS-LR models for PRIMAVERA amv-pos and amv-neg experiments in the ESGF catalogue. For this reason, they remain excluded from Fig. 5.

Comments from reviewer 2.

General comment:

The paper is logically organized and well written. The description is like a textbook, and readers who encounter the West African Monsoon for the first time may learn the related dynamics very efficiently through this paper. However, I have multiple minor concerns, especially regarding the details related to the energetic constraint on the ITCZ over the Sahel. I'm happy to review it again after these concerns are addressed.

We thank the reviewer for the careful reading of the manuscript and the constructive comments and suggestions to improve it. In the following, we provide a point-by-point response to the concerns raised in their comments and the modifications we propose to address them.

Major concern: Energetic variable in Fig. 4g is too arbitary

L231–241: Fig. 4f–h implies that NEI over the North Atlantic (over the box in Fig. 4c; 70°W–0°) causes the southward cross-equatorial energy transport anomaly over 10°W–10°E, leading to the northward ITCZ shift and hence the Sahel precipitation enhancement over the same longitude range. However, the selection of the North Atlantic box for averaging NEI looks too arbitrary. In particular, the longitude range used for averaging NEI and that used for calculating the ITCZ shift are quite different. What is the rationale for your selection of the NEI averaging box for Fig. 4g?

We thank the reviewer for this comment. The NEI averaging domain in Fig. 4c over the North Atlantic was chosen as a compromise between covering the region with strong NEI anomalies and maintaining a simple geometric definition (Eq-70ºN, 70ºW-0) that minimizes the inclusion of continental land masses. To ensure robustness of our results and to address the reviewer's concerns, we have tested several alternative definitions:

- We recalculated NEI within the original domain (Eq-70ºN, 70ºW-0) after masking all land points. This does not strongly modify our results (Fig R7a).
- We expanded the domain eastward (Eq-70ºN, 70ºW-10ºE), while maintaining the ocean-only mask. This broader domain yields a very similar correlation (Fig R7b).

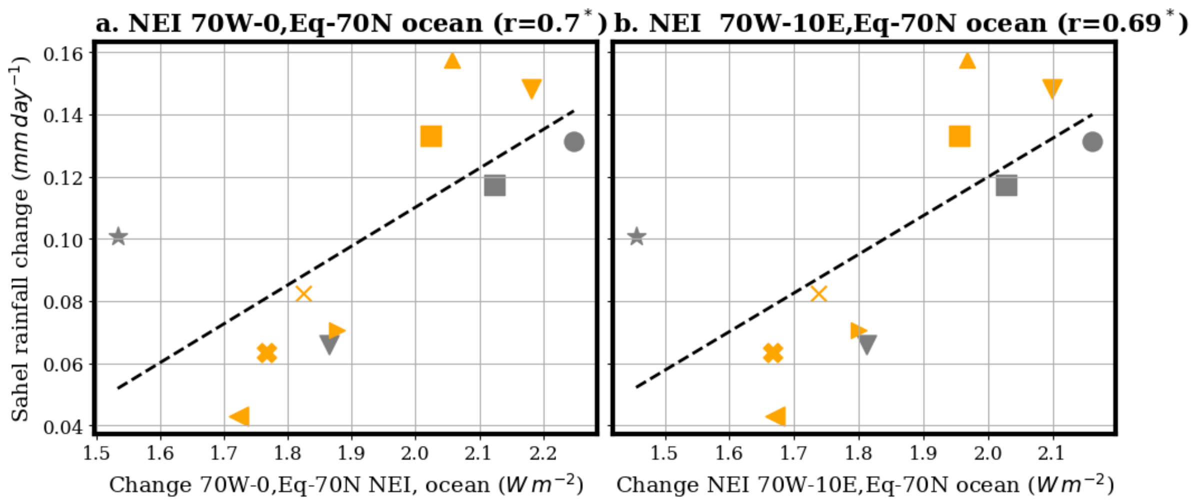

Figure R7: Scatter plots of averaged Sahel rainfall change (mm day^{-1}) and NEI changes (W m^{-2}) averaged over taking only ocean points in the longitude-latitude boxes of: a) 70ºW-0, Eq-70ºN (see orange box in plot 4c in the original manuscript); and b) 70ºW-10ºE, Eq-70ºN.

To address the reviewer's concern, we added a clarification at lines 256-257 regarding the selection of the NEI domain:

"*A similar relationship emerges when comparing Sahel rainfall changes with the NEI or surface energy imbalance averaged over the North Atlantic, where strong NEI anomalies develop (Fig. 4g,h): models with higher atmospheric energy input through surface fluxes tend to produce stronger southward cross-equatorial energy transport and greater Sahel rainfall anomalies.*"

In addition, it seems that the NEI maximum is over the tropics, not in the extratropics where the AMV forcing exists. There are also negative NEI anomalies over the tropical southeastern Atlantic. The reason for this tropical NEI gradient—favorable for the southward energy transport over Sahel longitudes—is not clearly explained. The authors partly attempt to address this by analyzing latent heat flux in Fig. 5, but to me, the wind speed increase in Fig. 5c is too narrow to explain the broad positive NEI over the northern tropical Atlantic.

Perhaps this tropical NEI pattern could be the emergence (or feedback) of the Atlantic ITCZ shift itself, as author speculated with Fig. 5c. Then, we may say that the ITCZ shift over the Sahel can be shaped by energetic imbalance caused by the oceanic ITCZ shift. But, all of these concerns can seem to be too specific. The author can improve the description for the flawless science, albeit current analysis still looks reasonable for the usual publication.

We agree with the reviewer that NEI anomalies in Fig. 4a are locally stronger over the tropical Atlantic than over the extratropics. However, both tropical and extratropical NEI are important and, notably combined, they explain more of the inter-model variance of Sahel rainfall (r=0.70 when considering the North Atlantic Ocean, Fig. R7) than either contribution does individually (Fig. R8; r=0.48 when considering only the tropical North Atlantic Ocean and r=0.59 when considering only the extratropical Atlantic Ocean).

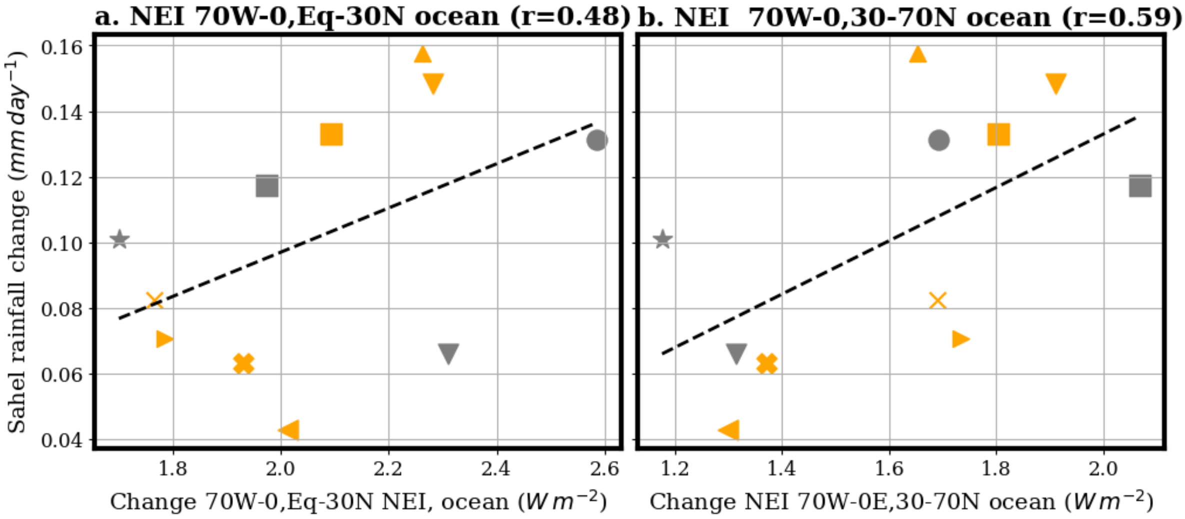

Fig. R8: Scatter plots of averaged Sahel rainfall change (mm day^{-1}) and: a) NEI averaged over the tropical North Atlantic (W m^{-2}, using the orange box in plot 4c from the equator to 30ºN) and b) NEI averaged over the extratropical North Atlantic (W m^{-2}, using the orange box in plot 4c only north of 30ºN). Only points over the ocean were used in the average calculation. This figure can be compared to the one provided in the reply to reviewer 1 (fig. R4, for which all points, including land ones, were used).

As for the NEI negative anomalies in the South Tropical Atlantic, approximately between the Equator and 10ºS, these appear to be small compared with those in the North Atlantic and do not seem to be relevant to the intermodel spread of Sahel rainfall anomalies (Fig. R9).

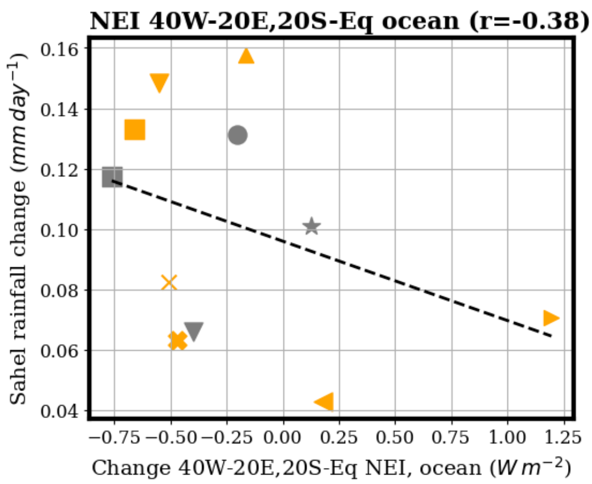

Fig. R9: Scatter plots of averaged Sahel rainfall change (mm day^{-1}) and NEI averaged over the South Tropical Atlantic (W m^{-2}, 40ºW-20ºE from 20ºS to Eq).

We also agree with the reviewer that the localized wind speed increases (Fig. 5c), which are largely restricted to the south of 10ºN, do not account for the broad NEI anomalies in the tropical Atlantic. While latent heat anomalies account for most of the positive NEI across the North Atlantic (85 %), they cannot explain the surface energy imbalance where surface winds weaken in response to a positive AMV phase (e.g., 60ºW-20ºW and 10ºN-20ºN, see Fig. 5c in the manuscript). In this specific region, the positive surface energy anomaly is primarily due to cloud-radiative feedbacks linked to the northward shift of the oceanic ITCZ (Fig. R10). The increased cloud cover leads to a reduction in surface downwelling shortwave radiation (Fig. R10f), and a corresponding increase in reflected shortwave radiation at the TOA (Fig. R10k) over the approximate box 50ºW-15ºW and 5ºN-15ºN. This term, in turn, is mostly balanced by reduced OLR (Fig. R10l).

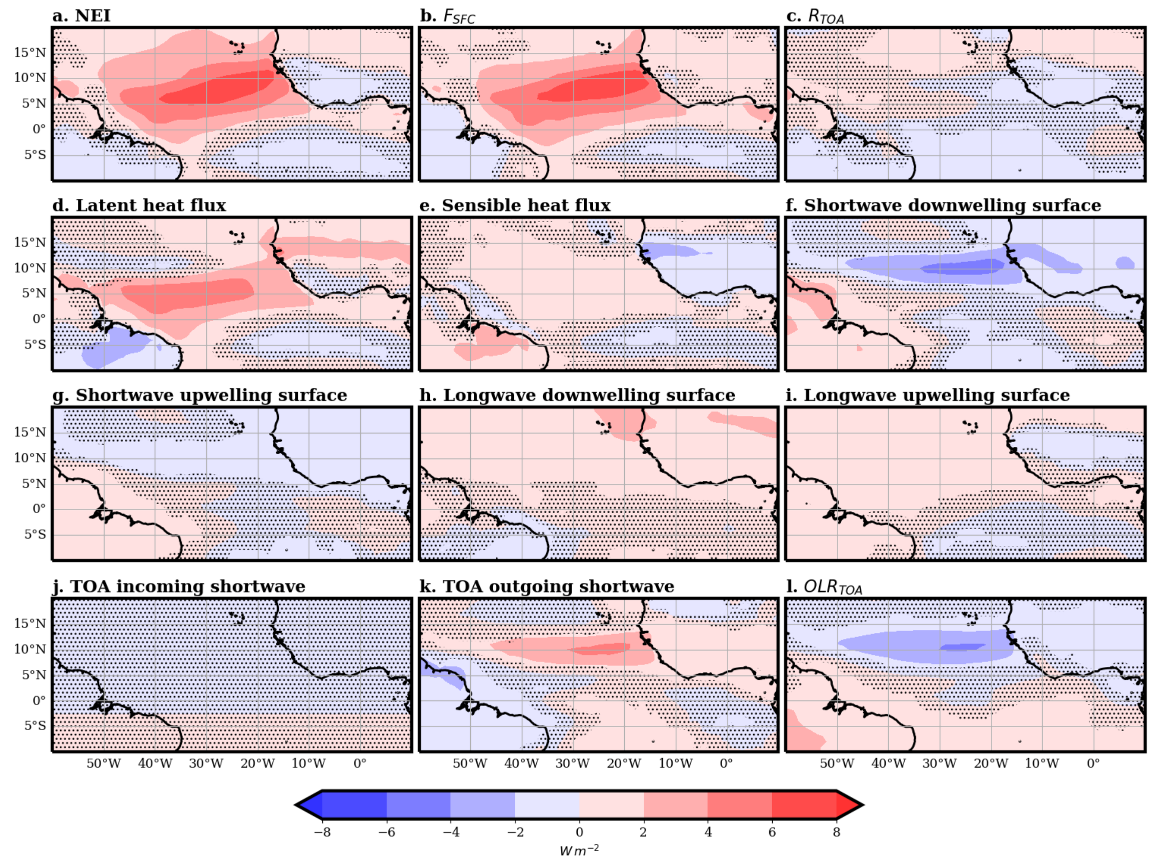

Fig. R10: Multimodel average changes in AMV+ minus AMV− in JAS for: a) net energy input (NEI) into the atmospheric column; b) energy imbalance at the surface (F_{SFC}); c) energy imbalance at TOA (R_{TOA}); d) latent heat flux; e) sensible heat flux; f) surface downwelling shortwave radiation; g) surface upwelling shortwave radiation; h) surface longwave downwelling radiation; i) surface longwave upwelling radiation; j) TOA incident shortwave radiation; k) TOA outgoing shortwave radiation; l) TOA outgoing longwave radiation. All units are Wm^{-2}. Positive values in panels f, h, k and l imply energy loss for the atmospheric column. Positive values in all other panels imply energy gain for the atmosphere. Dots mark regions where fewer than 80% of the models agree on the sign of changes.

To address the reviewer's concern, we introduced the following modifications:

- We included figure R10 in the supplementary material as Fig. S5 and added a short explanation of the NEI changes in the approximate box 50ºW-15ºW and 5ºN-15ºN (lines 250-253):

  "*A notable exception to the dominance of latent heat fluxes in the NEI pattern is the northern flank of the tropical NEI maximum (approximately between 60ºW-20ºW and 10ºN-20ºN). In this specific region, the positive surface energy anomaly is primarily due to cloud-radiative feedbacks linked to the northward ITCZ shift (Fig. S5 in the supplementary material).*"

- As commented above, we included Fig. R4 in the supplementary material as Fig. S6, and added in lines 258-260 a comment on the relevance of both tropical and extratropical NEI contributions in the North Atlantic, and how their combination explains more of the inter-model variance of Sahel rainfall than either contribution separately.

Minor comment:

L56–57: Kang et al. (2008) is one of the original papers on the energetic constraints on the ITCZ. Please add it as a reference.

Kang, S. M., Held, I. M., Frierson, D. M. W., & Zhao, M. (2008). The Response of the ITCZ to Extratropical Thermal Forcing: Idealized Slab-Ocean Experiments with a GCM. Journal of Climate, 21(14), 3521–3532. https://doi.org/10.1175/2007JCLI2146.1

We thank the reviewer for this suggestion. We added the reference in the suggested sentence (lines 56-61).

L84–85: "Since this estimation assumes linearity, the changes associated with a negative AMV phase can be obtained by reversing the sign of the anomalies."

→Is this description referring to the forcing itself? The current sentence is difficult to understand.

We apologise for the confusing phrasing. The sentence was referring to the estimation of the changes associated with a positive phase of AMV: we estimate this impact by subtracting the negative experiment from the positive one (AMV^{+}-AMV^{-}). There could be non-linearities in the impact of AMV, which we cannot account for without a control simulation. To clarify this, we moved this explanation up in the text, to line 89-90, so that the new paragraph reads:

"Changes associated with a positive AMV phase are estimated by subtracting the negative experiment from the positive one ($AMV^{+} - AMV^{-}$). Since this estimation

assumes linearity, the changes associated with a negative AMV phase can be obtained by reversing the sign of the anomalies."

L111-112:"Assuming that energy storage is negligible over seasonal and long-term averages (denoted by overbars)"

→In Fig.4 of Donohoe et al. (2013), at the monthly timescale, there are non-negligible contributions from the storage term for the hemispheric asymmetry of the atmospheric energy budget. Therefore, I do not think you can say "seasonal" here. Strictly speaking, you would need to demonstrate that the storage term does not matter for your analysis by calculating it and comparing it with the other terms. However, the strong correlation between the NEI proxy and rainfall in Fig. 4g may be sufficient for a first-order application.

Donohoe, A., Marshall, J., Ferreira, D., & Mcgee, D. (2013). The Relationship between ITCZ Location and Cross-Equatorial Atmospheric Heat Transport: From the Seasonal Cycle to the Last Glacial Maximum. Journal of Climate, 26(11), 3597–3618. https://doi.org/10.1175/JCLI-D- 12-00467.1

We thank the reviewer for this remark and the reference. While we do not have the necessary output to verify that the energy storage is negligible over the JAS season in the analysed simulations, we highlight that the atmospheric storage tendency is about one order of magnitude smaller than NEI in ERA5 data (Fig. R1). In addition, there is no strong inter-hemispheric gradient in the storage tendency. This confirms a good correspondence between NEI and MSE flux divergence, hence justifying our neglect of the storage term.

To address the concern raised by the reviewer, we added Fig. R1 as supplementary Fig. S13 and included a more thorough discussion of the limitations of the energetic framework. In particular, the discussion regarding the assumption of negligible energy storage now reads (lines 430-435):

"*Some methodological limitations also need to be emphasized. First, our energetic framework neglects atmospheric energy storage, assuming that the divergent component of the vertically integrated energy flux is balanced by the mean NEI (Eq. 1), which might not be the case for seasonal means (Donohoe et al., 2013). While the limited available model output does not allow us to verify the validity of this assumption in our simulations, a comparison of these terms using ERA5 reanalysis (Hersbach et al., 2020; Mayer et al., 2021) suggests this is a robust approximation for a 10-year summer mean (see Fig. S13 in the supplementary material).*"

L222–224:"Such enhanced southward energy transport is typically realised through a northward displacement of the ascending branch of the Hadley circulation (Donohoe et al., 2014)."

→This is generally true when the gross moist stability (GMS; the efficiency of energy transport by the circulation) remains the same. How can you ensure

that this assumption holds in this case as well? The strong correlation in Fig. 4g may indicate that variations in GMS do not play a major role here. However, I think it would be better to explicitly state this underlying assumption—namely, fixed GMS—somewhere in the text.

We thank the reviewer for this suggestion, which we follow by modifying the sentence to explicitly state this assumption to (lines 234-236):

"*Provided gross moist stability does not change (Raymond et al. 2009), such enhanced southward energy transport is typically realised through a northward displacement of the ascending branch of the Hadley circulation (Donohoe et al., 2014)*."

L291-292: "These negative anomalies are linked to the surface cooling induced by increased soil moisture following increased precipitation."

→Would it be clearer to say "evaporative cooling" instead of "surface cooling"? The underlying physical process is somewhat obscured in the current wording.

We thank the reviewer for the suggestion. We modified the text as suggested. Particularly:

- Lines 314-318: *"These negative anomalies are linked to the surface evaporative cooling induced by increased soil moisture following increased precipitation (see Fig. S9 in the supplementary material). The resulting surface evaporative cooling modifies the meridional temperature gradients, reducing them south of the climatological maximum and strengthening them to the north, which favours a northward shift of the African Easterly Jet (AEJ), consistent with thermal wind balance (Cook, 1999)."*
- Lines 326-331: *"We speculate this link to be a consequence of the surface response to enhanced rainfall (see Fig. S8 in the supplementary material): increased soil moisture in the latitudinal band between 10ºN and 15°N following enhanced precipitation promotes evaporative cooling of the surface by changing the balance between latent and sensible heat fluxes, which alters the surface temperature latitudinal gradient and, through thermal wind balance (Cook, 1999), enhances the AEJ to the north and reduces it to the south."*

L315: In the energy budget equation, the MSE flux term in Eq. (1) is decomposed into a horizontal advection term and a vertical advection term. How is the vertical advection term derived? The continuity equation may provide the explanation, but the reader would benefit from a more explicit description.

We thank the reviewer for this suggestion. Indeed, we need the continuity equation to reach the equation shown. To make this more explicit, we expanded this explanation in the following way (lines 340-349):

"Taking time averages, again assuming negligible atmospheric energy storage ($\partial_t\langle e\rangle \approx 0$) and decomposing the total transport in mean and eddy components, the energy budget can be written as:

$$\overline{NEI} - \langle \nabla_h \cdot (\overline{\boldsymbol{u}}\overline{h}) \rangle - \langle \nabla_h \cdot (\overline{\boldsymbol{u}'h'}) \rangle = 0 \quad (2)$$

where overbars denote time averages, and primes denote deviations from the time averages. Together with the continuity equation ($\partial_p \overline{\omega} + \nabla_h \overline{\boldsymbol{u}} = 0$, where ω is the vertical velocity in pressure coordinates), the second term in the left-hand side of equation (2) can be written as:

$$\langle \nabla_h \cdot (\overline{\boldsymbol{u}}\overline{h}) \rangle = \langle \overline{\boldsymbol{u}} \cdot \nabla_h \overline{h} \rangle - \langle \overline{h} \partial_p \overline{\omega} \rangle = \langle \overline{\boldsymbol{u}} \cdot \nabla_h \overline{h} \rangle + \langle \overline{\omega} \partial_p \overline{h} \rangle$$

This provides the following expression for the column-integrated energy balance:

$$\overline{NEI} - \langle \overline{\boldsymbol{u}} \cdot \nabla_h \overline{h} \rangle - \langle \overline{\omega} \partial_p \overline{h} \rangle - \langle \nabla_h \cdot (\overline{\boldsymbol{u}'h'}) \rangle = 0"$$

L329–332: "Consequently, the vertical advection term ($-\langle \omega \partial_p h \rangle$) becomes more negative. Given the tropical MSE vertical structure, this implies a change from a shallower convection regime to a deeper convection regime with a first-baroclinic mode structure (Hill et al., 2017). This interpretation agrees with the horizontal divergence anomalies in Fig. 6c, which show reduced divergence at mid levels and stronger divergence aloft."

→This is a beautiful explanation, but I think an explicit visualization related to the vertical advection term would be helpful. How about adding changes and climatology of ω, as well as changes and climatology of MSE (h), as supplementary vertical profiles similar to Fig. 6a–c? If shallower convection transitions to deeper convection, this should be identifiable through stronger upward motion in the mid-to-upper troposphere. The MSE profile may also help explain the details of the ω changes under the constraints imposed by NEI and the horizontal advection term. This point may be somewhat secondary, but it would strengthen the mechanistic explanation in this study.

We thank the reviewer for this suggestion. Fig. R11 shows the plot recommended by the reviewer. As expected, the positive phase of AMV induces reduced ascent in the lower levels and enhanced ascent in the mid-to-upper troposphere, above approximately 675 hPa (Fig. R11a) in our reference box (10ºW-10ºE, 10-20ºN). In turn, moist static energy is enhanced throughout the troposphere, driven by changes in moisture in the lower-to-mid troposphere and by changes in temperature in the upper troposphere (Fig. R11b). The enhancement is stronger in the lower troposphere, which, together with the climatological ascent, provides a thermodynamic contribution towards an increased vertical import of moist static energy throughout the atmosphere (see term $\omega\boldsymbol{\delta}(\partial_p h)$ in Fig. R11c). This import is counterbalanced by the dynamical contribution: the change from a shallower convection regime to a deeper convection regime acting on the climatological profile of moist static energy provides enhanced vertical export of moist static energy throughout the troposphere (see term $\boldsymbol{\delta}(\omega)\partial_p h$ in Fig. R11c). These changes promote enhanced vertical export of moist static energy (a more negative vertical advection term, $-\boldsymbol{\delta}(\omega\partial_p h)$) in the mid-to-upper troposphere, and a more modest vertical import of moist static energy in the lower levels.

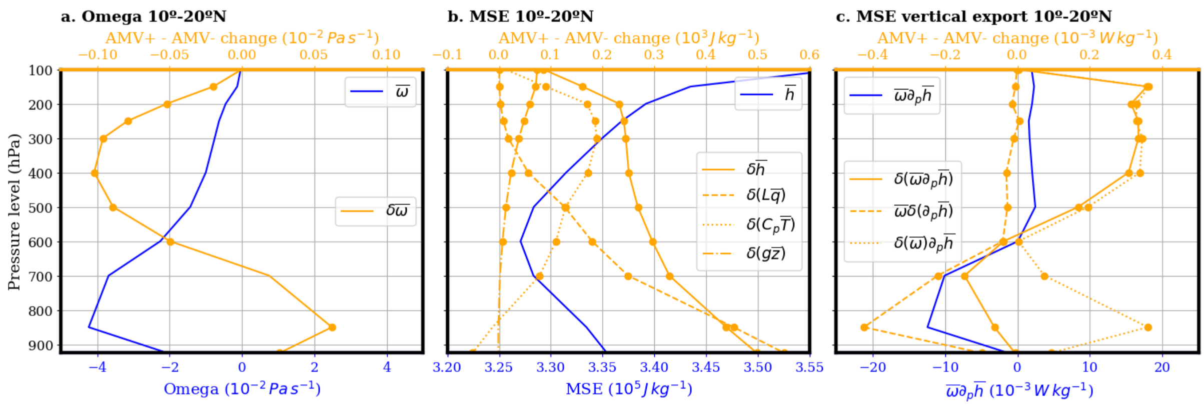

Fig. R11: Profiles of AMV$^+$ minus AMV$^-$ differences (orange, top axis) and climatological values (blue, bottom axis) in the Sahel box defined as 10ºW-10ºE,10ºN-20ºN (see purple box in figure 2b of the manuscript) of: a) omega (ω, Pa s^{-1}); b) moist static energy (MSE, J kg^{-1}) and c) vertical export of moist static energy ($\omega\partial_p h$, W kg^{-1}). Changes in moist static energy in panel b are further partitioned into the potential energy (gz, dashed dot line), sensible ($c_p T$, dotted line) and latent enthalpy (Lq, dashed line). The vertical export of moist static energy in panel c is decomposed into its thermodynamic ($\omega\boldsymbol{\delta}(\partial_p h)$, dashed line) and dynamic ($\boldsymbol{\delta}(\omega)\partial_p h$, dotted line) components. Models EC-Earth3P-HR and EC-Earth3P in the PRIMAVERA protocol were not used to calculate the multi-model mean omega, as we could not find this variable for these models. In addition, model EC-Earth3 in the DCPP-C protocol was also excluded from the vertical profile analysis because too few vertical levels were available in its outputs. Dots in the orange lines mark changes for which at least 80% of the models agree on the sign.

Following the reviewer's advice, we included this figure in the supplementary material as Fig. S12 and updated the text accordingly (lines 364-366):

"Given the tropical MSE vertical structure, this implies a change from a shallower convection regime to a deeper convection regime with a first-baroclinic mode structure (see Fig. S12 in the supplementary material)."

Figure 3 caption: "c and d)" -> "c) and d)"

We thank the reviewer for the correction. We implemented the suggested change in the new version of the manuscript (line 5 in the caption of Fig. 3).

Comments from reviewer 3.

Review of “An Energetic Perspective on the Impact of the Atlantic Multidecadal Variability on the West African Monsoon”

This study employs a large set of SST-restoring simulations to investigate the mechanisms by which the Atlantic Multidecadal Variability (AMV) influences the West African Monsoon and Sahel rainfall. From an energetics perspective, this paper argues that the positive AMV SST anomalies induce a northward shift of the Atlantic ITCZ and the monsoon circulation, thereby intensifying Sahel rainfall through circulation compensation of cross-equatorial atmospheric heat transport.

Overall, I find the paper well written and the results clearly presented. I have only some general questions that I hope will help further improve the paper.

We thank the reviewer for the careful reading and constructive suggestions made to improve it. In the following, we provide a reply to them and the modifications we propose to address them.

1. It would be very helpful if the authors could expand the simulation description (section 2.1). Currently, the manuscript only states that in the simulations, “North Atlantic SSTs are restored to follow a fixed, idealized anomalous pattern of the AMV”. I assume this means that the models are run in the fully-coupled configuration (as hinted in Table 1), and that some sort of SST nudging approach is applied. How exactly is the SST restoring implemented - by adjusting surface heat fluxes? Also, how are the targeted SST anomalies derived from observations? I assume they are defined in the two projects cited in this study, but for readers who may not be familiar with those projects, a more detailed description of the simulation design would be very helpful.

We thank the reviewer for this suggestion. The details of the experimental design are provided in three separate technical reports (https://www.wcrp-esmo.org/projects-and-panels/dcpp/dcpp-resources, last accessed 26 March 2026), which were summarised in the paper by Boer et al. (2016).

Regarding the SST pattern used as target, it is derived from observations following the procedure documented in Ting et al. (2009) and using ERSSTv4 observational-based data set (Huang et al. 2015). First, estimates of the externally forced signal are obtained using a signal-to-noise maximizing EOF analysis applied to global, annual-mean SSTs derived from the multi-model ensemble of the historical experiment in CMIP5. Second, once the time series of the principal component associated with the leading EOF is obtained, the observed annual-mean SSTs are regressed onto it, and the result is subtracted from the original field. The resulting residual SST field represents the estimation of the internal component of the observed SST variability. Third, the AMV index is defined as the spatial average of the annual SST residual field over the North Atlantic (0ºN-60ºN, excluding Mediterranean and Baltic Seas), which is then low-pass filtered with a cutoff period of 10 years to focus on the decadal timescale. Finally, the SST pattern for AMV is obtained by regressing the residual SST field on the AMV index over the 1900-2013 period.

Regarding the implementation of the SST restoring, the recommendation is to alter the non-solar total heat flux by adding the term $\gamma_T(SST_{MODEL}-SST_{TARGET})$, where SST_{MODEL} and SST_{TARGET} are the simulated and target SSTs, respectively, and γ_T is a feedback coefficient (Haney 1971). To avoid spurious alterations, the recommendation is to use a weak restoring value of γ_T=-40 $Wm^{-2}K^{-1}$, which is equivalent to a restoring time scale of about 60 days for a 50-meter mixed layer depth. Most models follow this recommendation (Ruprich-Robert et al. 2021; Hodson et al. 2022). Another method to constrain SSTs is to directly add the following Newtonian damping term in the temperature equation at the first level of the ocean model: $\lambda(SST_{MODEL}-SST_{TARGET})$, where λ is the inverse of the relaxation time scale. IPSL-CM6A-LR uses this latter approach with a restoring term that depends on the mixed layer depth as described in Ortega et al. 2017.

Following the reviewer’s suggestion, we included a more detailed explanation of the target SST pattern, a new figure showing the pattern in the supplementary material (Fig. R5, which is now Fig. S1), and further explanation of how the SST restoring is performed. The first part of the first paragraph in section 2.1 (lines 74-83) now reads as follows:

“We use two sets of sensitivity experiments, consisting of 10-year runs with global coupled models in which North Atlantic SSTs are constrained to follow a fixed, idealised anomalous pattern of the AMV in its positive (AMV+) and negative (AMV−) phases, respectively. The anomalous pattern (see supplementary Fig. S1) is derived from an estimation of the internal component of the observed SST variability, following the procedure proposed by Ting et al. (2009) and using the ERSSTv4 dataset (Huang et al. 2015). The SST AMV signal is imposed in the North Atlantic, from 10ºN to 65ºN, with an additional 8º buffer zone in which the amplitude of the AMV anomaly is reduced. Within this region, SSTs are constrained either through

alteration of the surface fluxes or through a Newtonian SST nudging. Hereinafter, we will jointly refer to these adjustments as SST restoring. Further details on how the AMV pattern is obtained and on how the models' SST is constrained can be found in Boer et al., (2016) and the technical notes for AMV simulations (https://www.wcrp-esmo.org/projects-and-panels/dcpp/dcpp-resources, last accessed 26/03/2026)."

We also checked the text for coherence with the way in which we refer to the SST restoring and made the following changes:

- Line 69: " *… SST pattern characteristic of the AMV through flux adjustment (Boer et al. 2016).*"--> " *… SST pattern characteristic of the AMV through SST restoring (Boer et al. 2016).*"
- Line 181: "*The flux restoring imposes …*" → "*The SST restoring imposes …*"
- Line 273: "*In response to the imposed flux restoring …*" → "*In response to the SST restoring …*"

2. Perhaps related to the point above, my second question is regarding the energetics diagnosis. The authors argue that the warm SST anomalies drive positive atmospheric energy input in the North Atlantic, which subsequently induces circulation anomalies to compensate for the energy imbalance. This seems somewhat expected, as the AMV simulations are essentially forced by surface heat flux to restore specific SST anomalies (if I'm correct about the restoring approach). However, I wonder if this mechanism (atmospheric energy anomalies in response to SST forcing) also holds in other fully coupled scenarios, where the atmospheric heat budget and SSTs evolve interactively rather than through a one-way coupling in which SSTs drive the atmospheric response. This may be addressed by analyzing AMV composites from fully-coupled piControl simulations. The authors could test if the fully-coupled models without SST restoring would also produce similar patterns of atmospheric energy and precipitation changes associated with positive and negative AMV anomalies.

We agree with the reviewer that the SST restoring performed in the North Atlantic can alter energy exchanges, and this represents one of the limitations of our approach: the extent to which the experimental setup can represent the effect of the AMV in observations. We also agree that the comparison between SST-restored and fully coupled simulations could shed light on this issue. And in fact, this is the approach taken by O'Reilly et al. (2023), who investigate this potential problem in depth by focusing on the relation of surface heat fluxes (which are the relevant ones according to our Fig. 4) and SST anomalies in the subtropical and midlatitudes of the North Atlantic for decadal timescales (see their Figs. 2 and supplementary Fig. 3). Their results suggest that the SST-surface heat flux relationship in the AMV experiments is consistent with that of fully coupled models and observations for the midlatitudes. However, discrepancies appear in the subtropical North Atlantic between the SST-restoring experiment, where the relation is positive, meaning heat fluxes tend to respond to SSTs and damp them, and the observations and fully coupled models, where the relation is weakly negative, suggesting heat fluxes might drive SST changes. Nevertheless, for the subtropical region, there is a seasonal dependence in the SST-surface heat flux relationship for the observations and fully coupled models: the negative relationship in observations and fully coupled models is restricted to the winter months, while for the boreal summer months, the relationship is positive (their supplementary figure 12). Thus, the AMV experiments are more consistent with the fully coupled runs and with observations during the boreal summer months, which is the season under study in our analysis. The analysis by Kim et al. (2020) of the AMV in a fully-coupled simulation also suggests that the surface heat fluxes in the tropical Atlantic could be responding to ocean processes only during the summer months (their Figs. 5 and supplementary figure S5, allowing for a change of sign of the heat fluxes taken as positive into the ocean in this study).

As the analysis suggested by the reviewer was already undertaken by O’Reilly et al. (2023), we refrain from adding the proposed test in our manuscript and resort to discussing our results in light of those of O’Reilly et al. (2023) and Kim et al. (2020). In fact, this limitation of our study was already discussed in section 4. We extended the discussion further to (lines 410-414):

“Nevertheless, the potential issues associated with SST restoring for surface heat fluxes are likely smaller during boreal summer, our season of interest. A comparison of fully-coupled and SST-restoring simulations suggests the latter are more realistic during boreal summer, when surface heat fluxes tend to dampen SST anomalies also in the tropical and subtropical regions (Kim et al. 2020; O’Reilly et al. 2023)”

3. While the study focuses on regional precipitation and circulation (within a narrow longitude range in the Atlantic), the key mechanisms invoke the zonal-mean energetics constraint on ITCZ shift and the associated cross-equatorial heat transport. Since the positive AMV surface temperature anomalies extend across much of the northern hemisphere, it raises the question of whether there is also evidence for a zonal-mean ITCZ shift and corresponding changes in MSE and rainfall. In other words, is the mechanism proposed for the Sahel region part of the broader zonal-mean energetics constraint?

We thank the reviewer for this suggestion. The zonal-mean changes in rainfall and MSE meridional transport are indeed suggestive of a broader ITCZ shift (Fig. R12a) and a consistent zonal-mean southward anomalous energy transport (Fig. R12b).

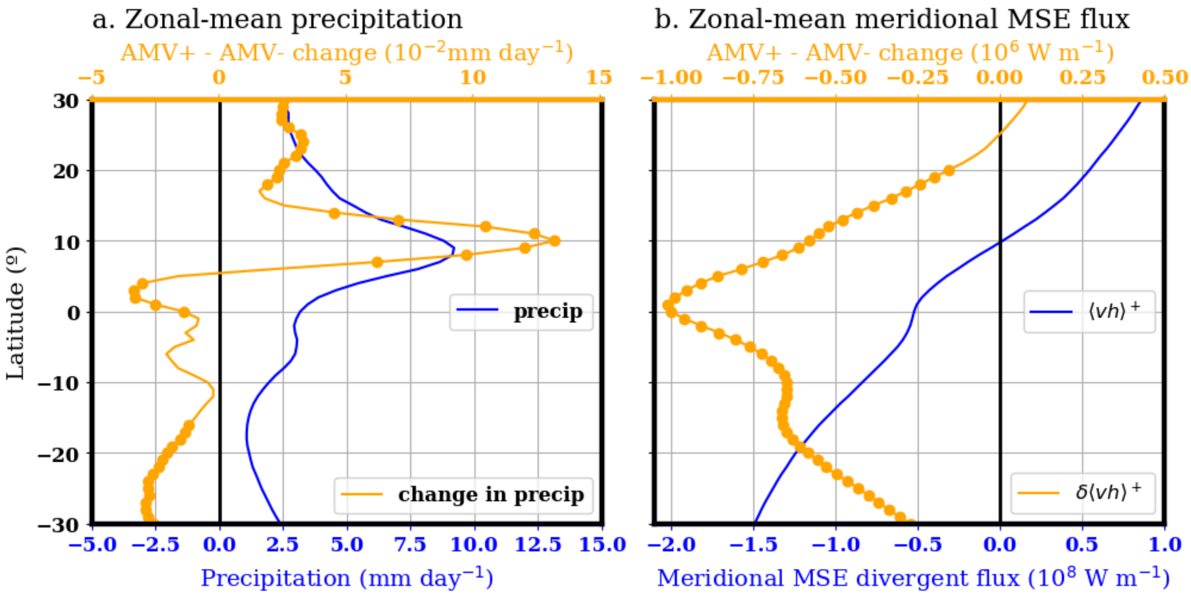

Fig. R12: AMV^+ minus AMV^- changes (orange, top axis) and climatological values (blue, bottom axis) of zonal-mean (a) precipitation (mm day^{-1}), and (b) meridional column-integrated moist static energy (MSE) flux (<vh>$^+$, W m^{-1}). Dots in the orange lines mark changes for which at least 80% of the models agree on the sign.

Away from the Atlantic and African longitudes, the northward ITCZ shift is contributed to by enhanced precipitation over the Indian subcontinent and the Bay of Bengal, the northern shift of the rainband over the eastern Pacific and the rainfall decrease in the southtropical central Pacific (Fig. R13).

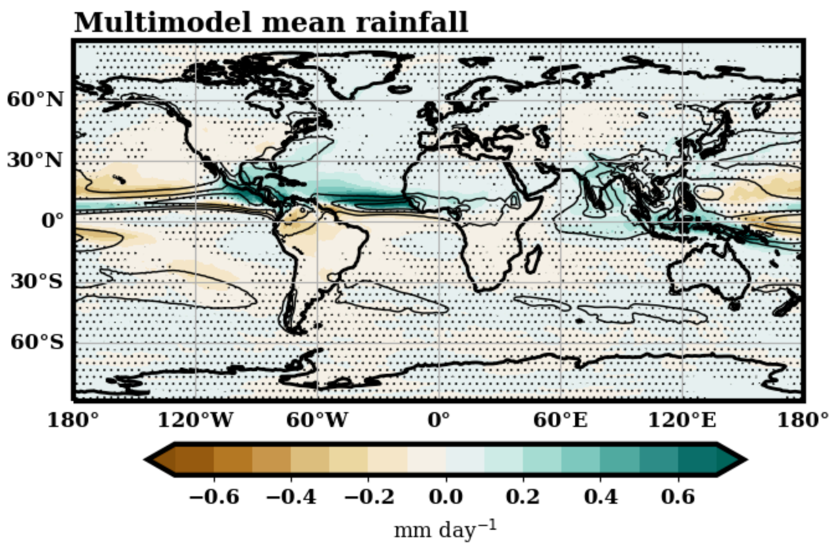

Fig. R13: Multimodel mean AMV^+ minus AMV^- change in JAS for rainfall over West Africa (mm day^{-1}). Dots mark regions where less than 80% of the models (less than 9 out of 11) agree on the sign of changes. Contours show multimodel mean JAS rainfall (grey contours are drawn every 4 mm day^{-1} with the starting black contour at 4 mm day^{-1}).

Following this remark from the reviewer, we included Fig. R12 in the supplementary material as Fig. S4 and modified the sentence in lines 232-234 to include the zonal-mean analysis:

"*In response to a positive AMV, a robust anomalous southward cross-equatorial column-integrated MSE flux develops in the Atlantic and along African longitudes (*$\langle vh \rangle^{+}$*, with meridional wind v, Fig. 4b), and is also observed at the global scale in the zonal mean (Fig. S4 in the supplementary material).*"

Minor comment:

The anomalous results from the MPI models seem confusing, especially that the discrepancies are mainly in tropical surface temperature responses (Fig. 1d). Although I understand that fully elucidating the behavior of these models is beyond the scope of this study, it would be interesting to show the global surface temperature and precipitation response maps from individual models in the Supplement Information.

We thank the reviewer for this suggestion. Figs. R14 and R15 show the global plots of the surface temperature and precipitation response to the positive phase of AMV for individual models, including the MPI-ESM1-2-HR and MPI-ESM1-2-XR.

Following the reviewer's suggestion, we added Figs. R14 and R15 to the supplementary material as Figs. S2 and S3, respectively, and refer to them in section 3.1 in the manuscript:

- Lines 185-187: *"Conversely, MPI-ESM-2-HR and MPI-ESM-2-XR exhibit highly anomalous behaviour. In response to warm North Atlantic SST anomalies, these models cool over the simulated period, especially over the tropical ocean regions (Fig. 1d, and Fig. S2 in the supplementary material)."*
- Lines 189-190: "In addition, these models present a strong response in Sahel rainfall (see Fig. S3 in the supplementary material), characterised by a positive and statistically significant trend throughout the simulation (Fig. 1e)."

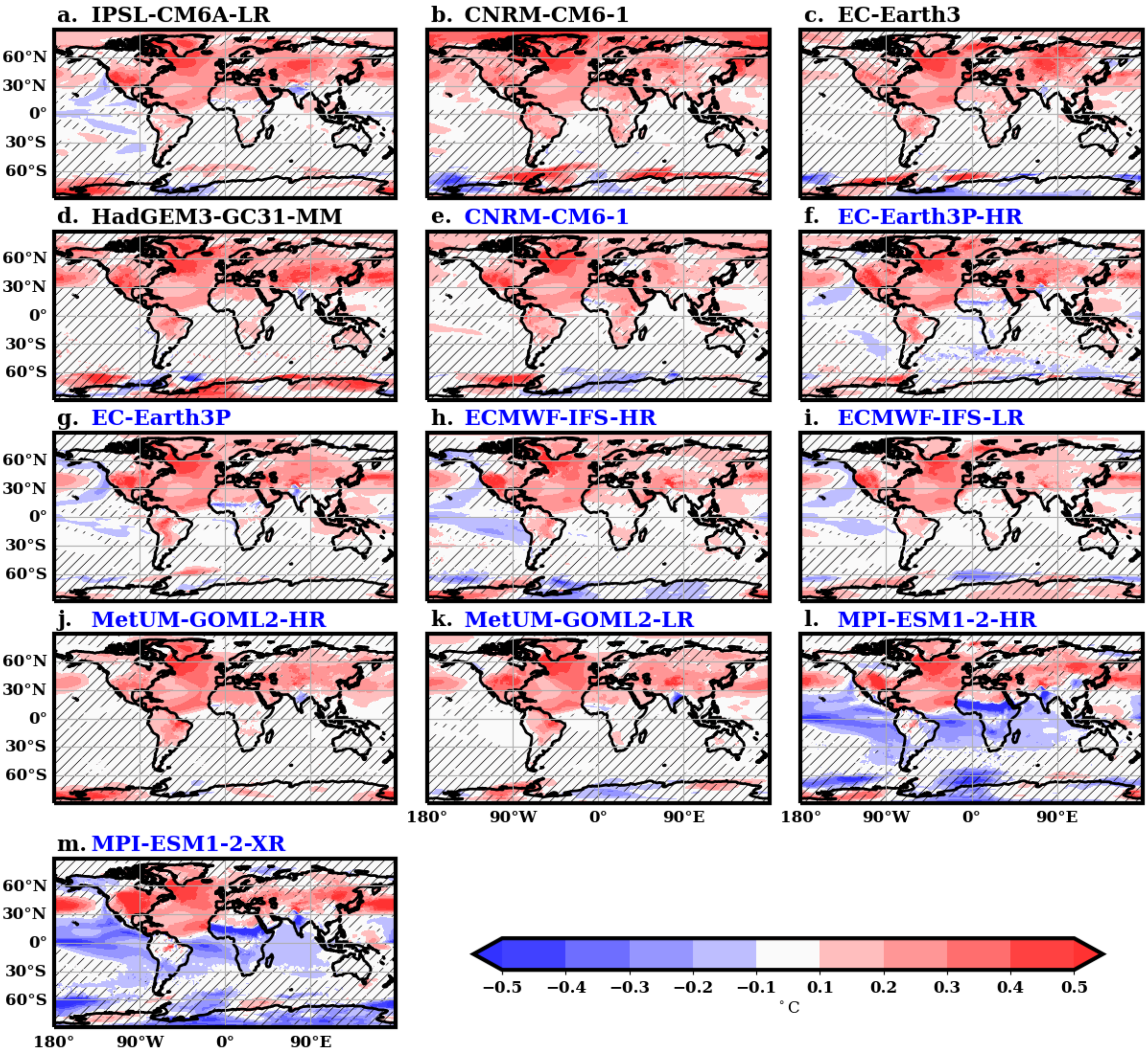

Fig. R14: Difference in mean JAS seasonal surface temperature between AMV⁺ and AMV⁻ experiments (shaded; ºC). For simulations under the PRIMAVERA protocol (marked blue in the model name labels), only half the anomalous values are shown. Regions where differences are not statistically significant ($p < 0.05$) according to the parametric t-test for differences in the means under independence, assuming a Gaussian distribution for the samples, are hatched.

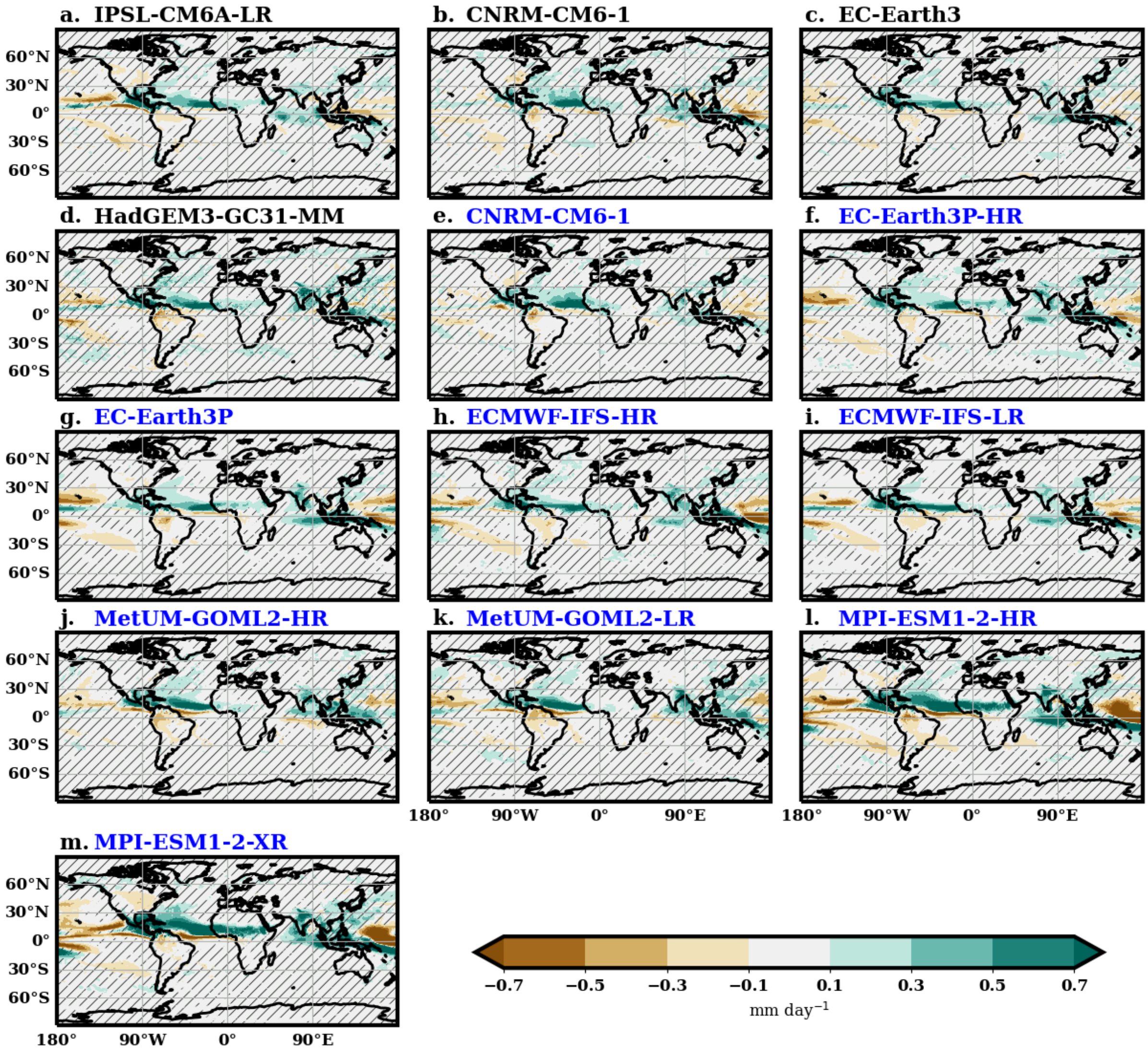

Fig. R15 Difference in mean JAS seasonal rainfall between AMV$^+$ and AMV$^-$ experiments (shaded; mm day^{-1}). For simulations under the PRIMAVERA protocol (marked blue in the model name labels), only half the anomalous values are shown. Regions where differences are not statistically significant ($p < 0.05$) according to the parametric t-test for differences in the means under independence, assuming a Gaussian distribution for the samples, are hatched.

Additional modifications.

We checked the manuscript for readability and coherence and made the following modifications:

- Line 2: "*We investigate this connection …*" → "*We investigate the AMV-WAM connection …*"

- Line 4: "*Results show that a positive AMV phase (warmer North Atlantic) …*" → "*Results show that a positive AMV phase (anomalously warm North Atlantic) …*"
- Line 126: "*... Saharan heat low …*" → "*...SHL…*"
- Line 176: "*We evaluate the stability of the simulations …*" → "*We evaluate the potential drifts of the simulations …*"
- Line 227: "*... to a positive phase of AMV …*" → "*... to a positive phase of the AMV …*"
- Lines 240-242: "*When scaled to the entire latitude circle, this corresponds to (-1.6±1.0*)◦ per PW. This estimate is in close agreement with those reported by Donohoe et al. (2014) for the observed interannual variability of the zonally averaged ITCZ position*." → "*When scaled to the entire latitude circle, this corresponds to (-1.6±1.0*)◦ per PW, an estimate in close agreement with those reported by Donohoe et al. (2014) for the observed interannual variability of the zonally averaged ITCZ position*"
- Line 281: " … AMV- …" → "... AMV+ …"
- Line 292: "*... in response to the positive AMV, …*" → "*... in response to the positive AMV phase, …*"
- Line 313: "*... Saharan Heat Low ...*" → "*... SHL …*"
- Lines 333-335: "*Conversely, neither the intermodel spread of the strength nor of the shift of the Saharan Heat Low structure is related to the change in Sahel rainfall (see Fig S1 and S2 in the supplementary material).*" → "*Conversely, the intermodel spread of neither the strength nor of the shift of the SHL structure is related to change in Sahel rainfall (see Fig S7 and S8 in the supplementary material).*"
- Line 353: "*... and hence lower MSE, air …*" → "*... and hence, lower-MSE air …*"
- Line 368: "*... horizontal MSE export in a temperature …*" → "*... horizontal MSE export in temperature …*"
- Line 387: "*... Saharan Heat Low …*" → "*... SHL …*"
- Line 445: "*... Saharan Heat Low (SHL)…*" → "*... SHL …*"
- Line 479: "*... Saharan heat low …*" → "*... SHL …*"
- Line 486: "*... Saharan heat low …*" → "*... SHL …*"
- Line 509: "*Simona Bordoni and Elsa acknowledge …*" → "*Simona Bordoni and Elsa Mohino acknowledge …*"
- Line 3 in the caption of Fig. 1: "*... loosing …*" → "*… losing …*"
- Line 3-4 in the caption of Fig. 2: "*Scatter of Sahel …*" → "*Scatter plot of Sahel …*"
- Line 3 in the caption of Fig. 4: "*... with v meridional wind …*" →"*... with meridional wind v…*"
- Lines 5-6 in the caption of Fig. 4: "*... strength of the meridional component of the divergent column integrated MSE flux …*" → "*... strength of the divergent component of the column integrated meridional MSE flux …*"
- Line 8 in the caption of Fig. 4: "*For plot a, anomalies …*" →"*For plot a), anomalies …* "
- Line 1 in the caption of Fig. 5: "*Multimodel average relative changes …*" → "*Multimodel mean of fractional changes …*"

- Line 4 in the caption of Fig. 5: "*... first calculating the saturated vapour pressure …*" → "*... first calculating the saturation vapour pressure …*"
- Lines 6-7 in the caption of Fig. 5: "*Changes are relative to …*" → "*Fractional changes are expressed relative to …*"
- Caption in Fig. 7 was corrected for the mathematical expressions of the different components of the MSE export.

We also updated the reference section and revised the citation to figures in the supplementary material.

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