Response to Reviewer 2:

We would like to thank the reviewer for the positive and constructive feedback, which helped us to improve our manuscript. Our responses are provided in blue below.

1. The authors should provide a clear overview of the experiments. Please list greenhouse gases, ODS, TSI/SSI, ocean and sea-ice configuration, initialization, spin-up, equilibrium criterion, and analyzed years for four experiments.

The description of the model and experimental setup will be thoroughly revised with respect to the reviewerd comments in the revised version of the manuscript.

2. The authors apply EOF decomposition to the R10mm anomaly field and retain the leading ten PCs. They then use the observed temperature and precipitation anomaly as predictors to construct individual multiple linear regression models for each of the ten PCs. But the manuscript lacks details on the cross validation, explained variance, and predictor stability criteria.

For the reconstruction of the summer (JJA) R10mm index, we used observed (E-OBS) summer anomalies of the R10mm index over the period 1950–2020. First, the observed R10mm data were linearly detrended, and anomalies were calculated relative to the 1950–2020 mean. The resulting R10mm anomaly field was then decomposed into spatial patterns using empirical orthogonal function (EOF) analysis.

Global gridded observations of surface temperature (T) and precipitation (PP) over the same period and season (JJA) were also linearly detrended and normalized. These fields were used to select predictors for each R10mm principal component (PC) based on the stability correlation criteria described in Rimbu et al. (2025).

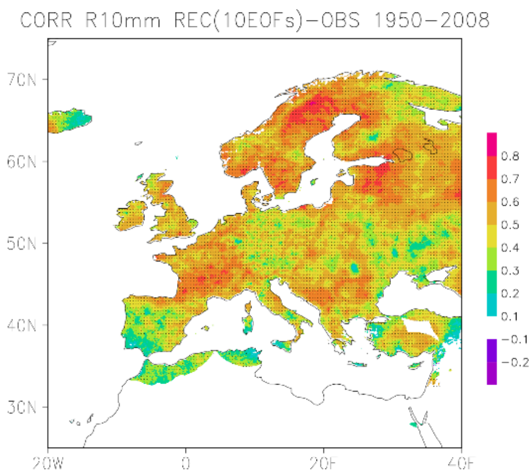

Figure 1 (review process only): Correlation observed-reconstructed R10mm field using neofs=10, lw=21 years, ct=0.2 , window perct=70%. The correlation pattern is not sensitive to reasonable changes in these parameters.

For the reconstruction, we retained the first 10 EOFs (neof = 10) of the R10mm anomaly field, which together explain approximately 55% of the total field variance. We used a correlation window of 21 years (lw = 21), a correlation threshold of 0.2 (ct = 0.2), and a percentage threshold of 70% (perct = 70%). The prediction model for each PC was constructed using T and PP anomaly time series from grid points for which the absolute correlation exceeded 0.2 in at least 70% of the 21-year windows over the period 1950–2020.

The PC prediction models calibrated using the observational data were subsequently applied to surface T and PP anomalies from the ModE-RA paleo-reanalysis dataset to reconstruct the R10mm PCs. Sensitivity tests show that the resulting R10mm reconstruction is robust with respect to changes in the number of EOFs used to decompose the predictand field (neof), as well as changes in the correlation stability criteria (lw, ct, and perct).

As described in the manuscript, the reconstruction was validated using observed gridded data and climate indices. During the overlapping period between E-OBS and ModE-RA (1950–2008), the reconstructed and observed R10mm fields show highly statistically significant correlations at most grid points (Fig. 1), providing confidence in the ability of the reconstruction approach to reproduce the observed spatial and temporal variability of the R10mm index.

3. I believe the vertical response of ozone to GSM is also important. The ozone vertical profiles should be included in the supplementary.

Thank you for this comment. The scope of our manuscript is already quite broad, and we would prefer not to broaden it further. In addition, while we agree that the vertical distribution of ozone is interesting, we do not think that it provides substantial additional information in the context of the present study, as the described distribution of local temperature anomalies is closely related to the total column ozone response. Nevertheless, for completeness and to address the reviewer's comment, we provide the vertical ozone distribution here for review purposes.

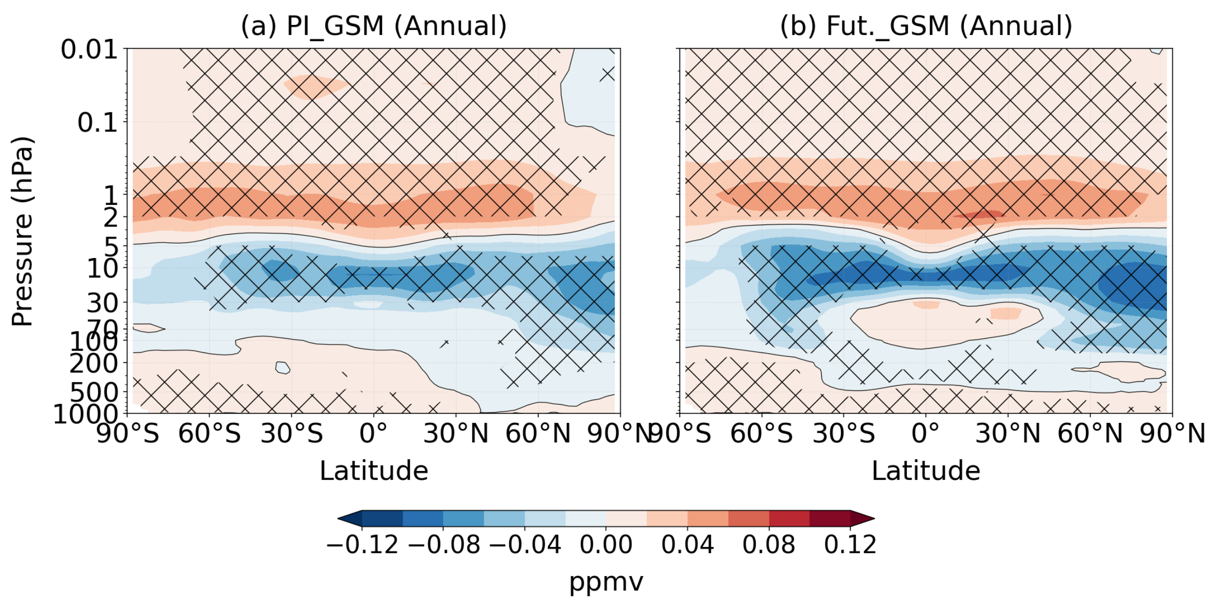

Figure 2 (review process only): Annual mean O3 anomalies for the PI GSM and Future GSM scenarios.

The figure reveals well-known features of the solar imprint on ozone, with the strongest negative response occurring around 10 hPa, where ozone concentrations are highest. In contrast, positive ozone anomalies occur in the upper stratosphere and mesosphere, consistent with findings from numerous previous studies investigating ozone responses to Grand Solar Minima and the 11-year solar cycle. These positive anomalies are associated with a weakening of the HOx catalytic ozone destruction cycle under reduced solar activity and and substantial reduction in solar UV radiation in the Lyman-α and Schumann–Runge part of the solar spectrum.

4. The explanation of the physical mechanism remains somewhat incomplete. Please provide the reduced solar forcing impact on ozone, temperature gradient through monthly evolution.

The reviewer is correct. We now also include the anomalies of the meridional temperature gradient and total column ozone (TCO) on a monthly basis.

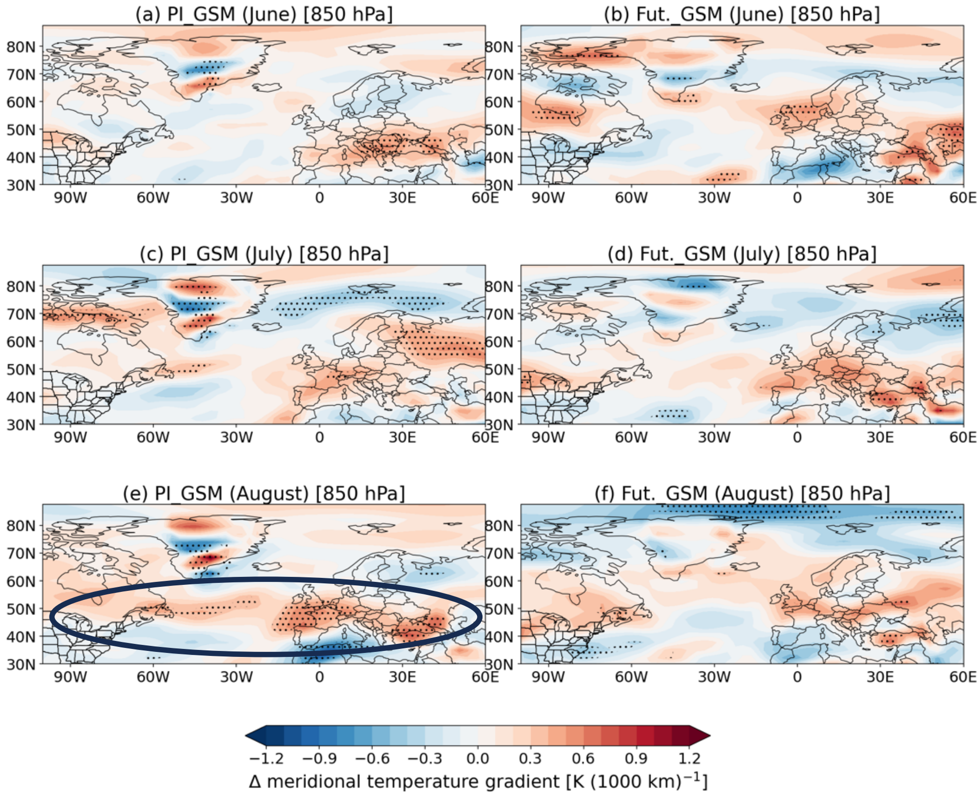

Figure 3 (to be included in the revised version of the manuscript): Anomalies of the meridional temperature gradient for the PI and Future GSM experiments.

As the reviewer can see, the meridional temperature gradient is significantly reduced in a continuous band extending from North America across the North Atlantic into central and southeastern Europe under PI GSM conditions in late summer. Since the meridional temperature gradient ($\partial T/\partial y$) is generally negative in the Northern Hemisphere mid-latitudes because temperature decreases towards the north, positive anomalies indicate that the gradient becomes less negative and therefore correspond to a weakening of the meridional temperature gradient. This spatial pattern is consistent with our analysis of the jet stream response and the associated changes in extreme precipitation. In contrast, no similarly coherent and statistically significant pattern can be found under future climate conditions, consistent with the weaker and less structured responses found for the other meteorological variables.

We will also include the TCO anomalies for all individual months in the revised manuscript. As the reviewer can see, and as already discussed in the manuscript, strong negative TCO anomalies generally correspond to regions of weaker surface cooling. This relationship is particularly evident in the spatial patterns. However, TCO anomalies are clearly not the only factor shaping the surface temperature response, and additional dynamical and radiative processes also contribute to the resulting temperature anomalies.

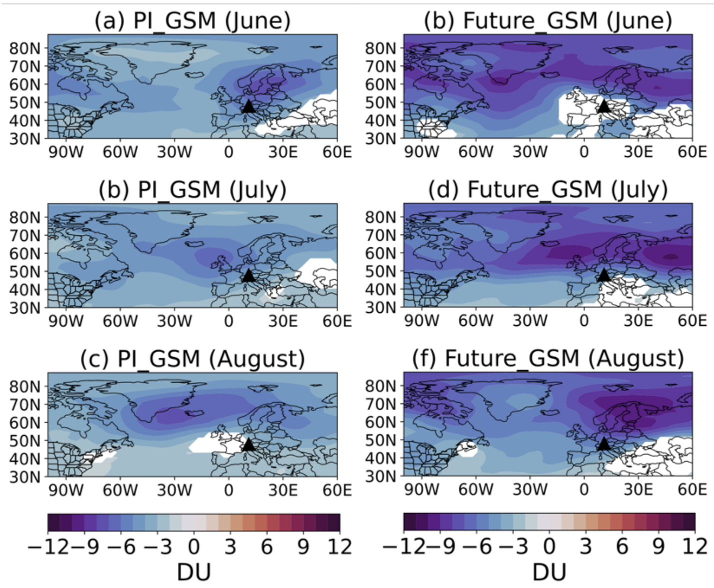

Figure 4 (to be included in the revised version of the manuscript): Anomalies of the total column ozone for the PI and Future GSM experiments.

5. The discussion of Holocene population dynamics and detectability of the 11-year solar cycle since the 1930s appears speculative relative to the four idealized constant-forcing experiments. These passages should be shortened and framed as hypotheses.

We will phrase this passage more cautiously in the revised manuscript.

6. The conclusion part covers many discussion points, I suggest changing the heading to "Conclusion and discussion", and restructuring the content into several well-organized subsections to improve clarity.

The „Conclusions and discussion“ section will be streamlined in the revised version of the manuscript.

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