On behalf of the author team, I would like to thank the two reviewers and the community comment received for their thoughtful, constructive and detailed review which will make this paper a stronger contribution to the literature.

Community comment: Pedro Roldán

This paper may be interesting for the discussion:

https://doi.org/10.5194/os-21-2283-2025

There we see the behavior of the AMOC up to 2300 in overshoot simulations of MRI-ESM2-0, CNRM-ESM2-1, IPSL-CM6A-LR and CanESM5. There is also a strong dispersion across these models.

Thank you for pointing towards this paper which is a valuable community resource. The most relevant results are from Figure 5a in Roldán-Gomez et al. (2025) which shows the ssp534-over Atlantic Ocean Heat Transport for four models to 2300. AOHT is closely related to AMOC so a comparison can be drawn. Our results are most similar to IPSL-CM6A-LR for NorESM2-LM which shows a weakening in AOHT, followed by an almost complete recovery around 2200, and a slight weakening thereafter; and CanESM5 for MPI-ESM1.2-LR which shows a complete recovery that is approximately stabilizing after 2200. There are two other models in Roldán-Gomez et al. (2025) that have behaviours that are not present in our results; CNRM-ESM2.1 that is persistently weakened after the point of peak warming (around middle of this century), and MRI-ESM2.0 which continues to weaken drastically into the future.

In section 3.3, added:

It should be noted that a diversity of Atlantic Ocean heat transport (closely related to AMOC) profiles is seen in other models run with CO$_2$ concentrations to 2300 in \emph{ssp534-over}, including a persistent weakened state from the middle of the 21st century, and a continued weakening post-overshoot akin to an AMOC collapse \citep{roldan-gomez_contribution_2025}. This highlights the importance of running simulations longer than to 2100.

For the discussion on the irreversibility of temperature and precipitation, this other paper may be also interesting:

https://doi.org/10.5194/esd-16-1-2025

Interestingly we do not see the same behaviour for NorESM2-LM for the equilibrium minus warming in ssp534-over (fig. 8d in our paper) compared to the multi-model mean in Roldán-Gomez et al (fig. 5a in theirs). We see a warmer Northern hemisphere ocean in the equilibrium phase and on the whole a cooler (but not significantly so, in most places) Southern hemisphere.

For precipitation in NorESM2-LM, we do see the same wettening in the Eastern Pacific South of the Equator in the equilibrium minus warming simulation (our fig. 9d comparing Roldan-Gomez's fig. 5b). However, elsewhere, the ICTZ follows the migration towards the warmer hemisphere (in the case of NorESM2-LM, towards the North) which is in contrast to the multi-model results in Roldán-Gomez.

This is attempting to match up the warming and equilibrium phases between the two papers noting that in Roldán-Gomez et al. the equilibrium phase is model dependent and, in the latter, the 2220-2239 period was chosen as the "equilibrium" phase (inferred from their fig. 2a). For MPI-ESM1.2-LR the direct comparison wasn't performed as we are not comparing the warming and equilibrium phases.

At the end of section 3.4.1, added

In contrast to NorESM2-LM, other CMIP6 models in the multi-model mean under \emph{ssp534-over} have a warmer Southern hemisphere and cooler Northern hemisphere in equilibrium compared with the warming phase at approximately the same GWL \citep{roldan-gomez_regional_2025} as a consequence of a North-to-South transport of heat that commences at approximately the time of peak warming and persists into the 23d century.

At the end of section 3.4.2, added

Comparisons can again be drawn with other (concentration-driven) CMIP6 models for NorESM2-LM. In general, owing to the warmer northern hemisphere in the stabilization phase compared to warming phase, the ITCZ is more northerly located during the stabilization period (fig. \cref{fig:pr_Ems-driven_results_cbar}d), which is in contrast to the CMIP6 model mean \citep{roldan-gomez_regional_2025}. However, NorESM2-LM shares the feature of increased precipitation in the eastern Pacific south of the equator with the CMIP6 model mean.

Reviewer 1 – Mitchell Dickau

GENERAL COMMENTS:

This manuscript by Smith et al. presents results from two Earth System Models (MPI-ESM1.2-LR and NorESM2-LM) run in emissions-driven mode until the year 2300 under three scenarios (SSP1-1.9, SSP2-4.5, and SSP5-3.4-over). These simulations allow for the analysis the carbon cycle and the climate responses to overshoot and net-negative emissions. By including SSP1-1.9 and SSP2-4.5, the study fills a gap in the literature, as previous emissions-driven experiments in CMIP6 were dominated by SSP5-8.5, representing a very high end of century forcing scenario, or SSP5-3.4-over scenario. Furthermore, the extension of these simulations to 2300 enables the examination of Earth system responses on multi-century timescales, revealing long-term hysteresis and irreversibility. The authors find that both models show similar carbon cycle responses in terms of distribution of carbon and the transition of carbon reservoirs from sources to sinks, similar irreversibility in sea-level rise and ocean deoxygenation, and similar precipitation responses to temperature change. In contrast, the two models diverge significantly in their AMOC responses, with NorESM2-LM exhibiting strong hysteresis and a secondary warming period driven by AMOC recovery and MPI-ESM1.2-LR showing a largely reversible AMOC response that is proportional to the global warming level. The authors show that these contrasting AMOC responses lead to diverging surface temperature changes.

Overall, this is a timely and valuable contribution to the literature. As the authors note, emissions-driven runs are rare in CMIP6, especially for scenarios widely accepted as being more socio-economically realistic. These runs are essential for understanding the long-term carbon cycle feedbacks that concentration-driven runs may miss, especially in the context of overshoot and net-negative emissions. The contrast between the two chosen models – one relatively reversible (MPI-ESM1.2-LR) and one showing complex hysteresis (NorESM2-LM) – provides a useful caution against relying on single-model outcomes for long-term adaptation planning and highlights the need for more emissions-driven Earth System Model experiments.

The manuscript is generally well-written and logically structured. With minor revisions to address the specific comments below, this paper would be a strong addition to the literature.

Thank you, Mitchell, for your comprehensive, thorough and thoughtful review and positive comments. We are pleased that you agree that this is a timely contribution.

SPECIFIC COMMENTS:

1. **Definition and Evidence of Zero Emissions Commitment (ZEC): In Section 3.1 (lines 173-175), the authors state that "Both models also show a negative zero emissions commitment evidenced by the emissions-temperature plot curving downwards after net zero (Koven et al., 2023), highlighted by the darker points in fig. 4, and confirmed by idealised CO2-only experiments in MacDougall et al. (2020)." While previous idealized experiments (e.g., ZECMIP) have established that these specific ESMs possess a negative ZEC, I question whether Figure 4 explicitly confirms this since ZEC is standardly defined by the temperature evolution when net-zero emissions are reached and maintained (MacDougall et al., 2020). In the scenarios presented here (esm-ssp119 and esm-ssp534-over), upon reaching zero (or net-zero) the first time, CO_2 emissions do not stabilize at zero but immediately transition to net-negative. If the authors are defining ZEC as when zero/net-zero CO_2 emissions is reached the second time (~2200 in esm-ssp-119 or ~2160 in esm-ssp-345-over), NorESM2-LM exhibits a warming trend which contradicts negative ZEC claim. The current text implies Figure 4 serves as proof of negative ZEC. I recommend the authors clarify how fig. 4 shows a response consistent with negative ZEC, perhaps by clarifying the definition of ZEC they are using, or remove the statement altogether.**

Thank you for this excellent comment. It was too much of a stretch to suggest that figure 4 is proof of negative ZEC in NorESM both because (1) our scenarios are not directly comparable to a ZEC experiment and (2) the long term behaviour of NorESM2 is indeed not a negative ZEC. In some models including NorESM, the behaviour of ZEC changes with time. This is not immediately obvious in the ZECMIP results. In MacDougall et al. (2020) fig. 2b, NorESM has a (if vou visually smooth out the variability) monotontically decreasing post-net zero temperature change over 100 years. However in Schwinger et al. (2022) (https://esd.copernicus.org/articles/13/1641/2022/) (fig. 1b & c) NorESM shows a decadal cooling to zero emissions but a centennial warming, so that ZEC is positive in the long term. Schwinger et al.'s fig. 1f shows qualitatively similar results to our global mean temperature projections for ssp119 and ssp534-over for their idealised overshoot scenarios. This again highlights the benefits of running scenarios further into the future than the next 100 years in order to better resolve some of these "surprises".

The rationale behind using figure 4 as a demonstration of negative ZEC is that the CDR phase in the cumulative emissions-temperature phase plots is below the increasing emissions phase. However, this could be a combination of both ZEC and an asymmetry in the TCRE and TCRR which is not separable in this experiment. Therefore we have weakened the language in section 3.1 to suggest that negative ZEC is "implied" and "on the decadal scale" for NorESM.

Original:

Both models also show a negative zero emissions commitment evidenced by the emissions-temperature plot curving downwards after net zero \citep{koven_much_2023}, highlighted by the darker points in fig. \ref{fig:temperature_v_emissions}, and confirmed by idealised CO$_2$-only experiments in \citet{macdougall_is_2020}.

Modified:

Both models imply a negative zero emissions commitment (ZEC) on the decadal timescale, evidenced by the cumulative emissions-temperature plot curving below the positive emissions phase in the first few decades after net zero \citep{koven_much_2023}, highlighted by the darker points in fig. \ref{fig:temperature_v_emissions}. The decadal timescale negative ZEC in these two models is also reported in idealised CO$_2$-only experiments to zero emissions in \citet{macdougall_is_2020}, though it should be highlighted that the comparison is not directly applicable as our scenarios go to net negative carbon emissions and include non-CO$_2$ forcers. However in NorESM2-LM the ZEC after 100 years reverses sign and becomes positive, and warming is also reported during net negative carbon emissions phases in idealised overshoot scenarios in this model \citep{schwinger_emit_2022}.

2. **Physical Mechanism of AMOC Overshoot: In Section 3.3, the authors attribute the rapid warming in NorESM2-LM in the late 22nd century to an AMOC recovery. The manuscript lacks a physical explanation for why the AMOC overshoots so strongly in this specific model. Adding a brief physical explanation for the strong AMOC recovery driving the reported secondary warming period in NorESM2-LM, either supported by a supplementary figure or a citation, would strengthen the manuscript.**

We agree that a brief explanation would help here, though to try and explain the full physical processes that are going on in this model would possibly be a paper in itself. In NorESM2-LM, as in many CMIP6 models, during the warming phase sea ice melts causing a freshwater flux into the North Atlantic, increasing surface buoyancy and reducing overturning circulation (Madan et al. 2024). The AMOC remains in a weak state during the negative emissions phase (fig. 4b, fig. 6i). In general, a reduced AMOC implies increased ocean heat uptake (e.g., Drijfhout 2015; Schwinger et al. 2022) due to a reduction of heat loss from the North Atlantic. In our simulations, in particular in esm-ssp534 and to a lesser extent in esm-ssp119, this is happening during a time of strong reduction of CO2 radiative forcing, resulting in an energy imbalance and consequential cooling. As the AMOC in NorESM2-LM recovers after around a century, surface temperature increases towards a value that is consistent with the new (reduced) state of ocean heat uptake under the now relatively constant radiative forcing. We see the same behavior in esm-ssp534-over and in esm-ssp119 as in the idealized overshoot experiments of Schwinger et al. (2022). We note that AMOC reduction in NorESM2-LM, compared to other CMIP models, is on the strong side, but the model is not an outlier (Madan et al. 2024, Schwinger et al. 2022, Weijer et al. 2020).

Schwinger 2022: Possibility for strong northern hemisphere high-latitude cooling under negative emissions | Nature Communications

Drijfhout 2015: Competition between global warming and an abrupt collapse of the AMOC in Earth's energy imbalance | Scientific Reports

Madan 2024: The weakening AMOC under extreme climate change | Climate Dynamics | Springer Nature Link

Weijer 2020: CMIP6 Models Predict Significant 21st Century Decline of the Atlantic Meridional Overturning Circulation - Weijer - 2020 - Geophysical Research Letters - Wiley Online Library

Added:

The AMOC reduction causes an increased ocean heat uptake, which happens at the same time that atmospheric CO$_2$ is reduced by the negative emissions. When AMOC picks up again at that time atmospheric CO$_2$ is approximately stabilized, ocean heat uptake decreases such that SAT increases again.

3. **Contextualizing Regional Hysteresis against Concentration-Driven Runs: In the Introduction (Line 114), the authors cite Pfleiderer et al. (2024) regarding regional climate signals in concentration-driven overshoot scenarios. However, this comparison is not revisited in the Results section. I recommend the authors explicitly compare their regional temperature and precipitation hysteresis patterns (Section 3.4) with those reported in Pfleiderer et al. (2024). Discussing similarities or differences would help clarify whether the inclusion of interactive carbon cycle feedbacks (emissions-driven) significantly alters regional reversibility compared to prescribed concentration pathways.**

This is a good point. Pfleider et al. (2024) fig. 3m can be compared with our fig. 8k for MPI-ESM1.2-LR for temperature and their fig. 10m with our fig. 8k for precipitation. Unfortunately, Pfleiderer et al. do not have results for NorESM2-LM. The comparison is not direct: differences between the studies include Pfleiderer using 30-year periods before and after peak warming in their presentation (where the global mean surface temperature may be different in the two periods, and is indeed reported to be 0.1 K lower on average in the cooling period across CMIP6 models), whereas we use regional patterns at the same global warming level. Pfleiderer et al. combine results for ssp534-over and ssp119 but did not have any simulations of ssp534-over available for MPI-

ESM1.2-LR so report the figure only for ssp119, whereas we show results for [esm-]ssp534-over. Despite this, we see the same patterns of surface temperature differences relative to the global mean between the studies; warm patches in Southern and South-East Asia, eastern China, North East and South East Pacific. The same general trend of the shift in the ITCZ is also seen, though the drying of the Sahel region in Pfleiderer is less prevalent in our results. On the whole, this would indicate that the temperature and precipitation responses are a physical rather than carbon-cycle mechanism and it does not matter to first order whether the scenarios are driven with emissions or concentrations to determine these physical responses.

Rather than individually describe the behavior for temperature and precipitation in sections 3.4.1 and 3.4.2, we felt it better to add a section in the Conclusions (renamed Discussion and Conclusions) highlighting this.

Added:

We find a similar pattern of regional temperature and precipitation response to periods before and after peak warming in the MPI-ESM1.2-LR model to concentration-driven scenarios in \citet{pfleiderer_limited_2024}, indicating that physical climate responses are likely not sensitive to whether scenarios are run with prescribed emissions or concentrations.

4. **Coupling the ITCZ Shift to AMOC Dynamics: In Section 3.4.2, the discussion on precipitation attributes the observed ITCZ shift to the "general hypothesis that the ITCZ moves towards the hemisphere with greater warming". I recommend explicitly linking the precipitation response back to the AMOC evolution. Since the strong AMOC reduction in NorESM2-LM is the primary driver of the Northern Hemisphere cooling, I would argue that it is the physical mechanism forcing the interhemispheric temperature gradient that shifts the ITCZ. Explicitly stating that the AMOC collapse drives the southward shift would provide a more cohesive mechanistic explanation for the NorESM2-LM results.**

Yes, good idea to include this. As described in Moreno-Chamarro et al. (2019), the weakening AMOC drives a negative anomaly in the NH-SH temperature gradient that is associated with a southward shift of the ITCZ. The text has been updated:

Original:

Again, the equilibrium minus cooling phase in NorESM2-LM is interesting (fig. \ref{fig:pr_Ems-driven_results_cbar}e), with the ITCZ shifted southwards reflecting the relatively warmer Southern Hemisphere when comparing these two periods, consistent with the results of \citet{steinert_irreversible_2025} for this model.

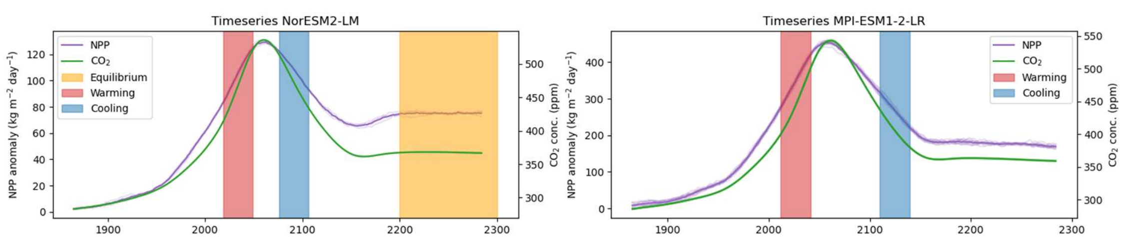
Modified:

Again, the equilibrium minus cooling phase in NorESM2-LM is interesting (fig. \ref{fig:pr_Ems-driven_results_cbar}e), with the ITCZ shifted southwards reflecting the relatively cooler Northern Hemisphere when comparing these two periods due to the weakened AMOC \citep{moreno-chamarro_linking_2020}. This results in a larger interhemispheric temperature gradient in the cooling phase in NorESM2-LM. This behaviour is consistent with the results of \citet{steinert_irreversible_2025} for NorESM2-LM.

Moreno-Chamarro et al. (2019): [Linking ITCZ Migrations to the AMOC and North Atlantic/Pacific SST Decadal Variability in: Journal of Climate Volume 33 Issue 3 (2019)]

5. **Substantiating the NPP atmospheric CO_2 Relationship: In Section 3.4.3 (lines 298-299), the authors state that "NPP more closely follows the evolution of atmospheric CO2 than temperature which is related to the fertilisation effect". The manuscript does not explicitly present data to verify this correlation for these specific simulations. I suggest supporting this claim by adding a figure to the Supplementary Material (e.g., a time-series overlay of Global NPP vs. Atmospheric CO2, or a scatter plot).**

Agreed, we did stated that NPP more closely follows temperature without actually showing it. We added a new Appendix figure A1 showing the comparison of NPP and atmospheric CO2 concentration.



6. **Nuancing the "Best Case" Scenario Framing: In the Conclusions (lines 342-345), the authors argue that these results represent a "best case" scenario because both models exhibit low climate sensitivity and negative ZEC. While this characterization may hold for the peak global temperature, it risks obscuring the severe regional risks identified in the study or other potential harmful Earth system responses not explored in the study. For instance, NorESM2-LM projects a severe AMOC collapse and significant regional cooling in Europe, which represents a challenging outcome for regional adaptation in the region rather than a "best case". In this example, Nor-ESM2-LM may very well present a much worse outcome of SSP5-3.4-over**

than a model that has higher climate sensitivity but exhibits less hysteresis in the AMOC response. I therefore recommend explicitly qualifying the "best case" statement. Since not all Earth system responses scale with global temperature, the authors should expand this paragraph to distinguish between "best case for global temperature" vs. "best case for earth system response and for implications for mitigation/adaptation" to avoid misinterpretation.

We agree that this is an important distinction that we overlooked by being too focused on global mean surface temperature, so we have revised the explanation.

<u>Original</u>:

From an adaptation planning perspective, the results presented in this paper probably represent a ` ` best case'' scenario. Both models have a (150-year Gregory regression-derived) climate sensitivity on the low side of the CMIP6 range, and have a strongly negative ZEC meaning that temperatures are expected to cool after net zero CO$_2$ is reached.

<u>Modified</u>:

From a peak global mean temperature perspective, the results presented in this paper probably represent a ` ` best case'' scenario. Both models have a (150-year Gregory regression-derived) climate sensitivity on the low side of the CMIP6 range, and have a strongly negative ZEC meaning that temperatures are expected to cool after net zero CO$_2$ is reached \citep{macdougall_is_2020}, notwithstanding the influence of non-CO$_2$ forcers. The \emph{esm-ssp119} simulations peak below 1.5°C in both models and are likely biased cool relative to historical GSAT change. The combination of low (Gregory) climate sensitivity, strong negative ZEC, and potential low-biased ensemble mean warming levels that the outcomes presented in the paper may underestimate the risks and challenges associated with overshoot scenarios. In addition, while on the cool side in terms of GSAT, the projections from NorESM2-LM suggest that large abrupt changes in AMOC, rapid phase of warming during the late 22nd century, and substantial regional changes such as cooling in Europe during the slowdown phase my pose more severe adaptation challenges than a model with higher peak warming but a more reversible regional climate profile.

TECHNICAL CORRECTIONS

- **Typo (page 16, line 300) "MPI-ESM2-LM" should be "MPI-ESM1.2-LR"**

Oops, thanks for spotting. Now fixed.

- **"hist-esm" is used in the figure title but "esm-hist" is used in the figure caption and text**

Excellent spot, thanks. Now fixed.

Reviewer 2

Review of “Overshoot and (ir)reversibility to 2300 in two CO2-emissions driven Earth System Models” by Smith et al.

This study uses two Earth System Models to run additional ensembles of emissions-driven simulations under higher and lower overshoot scenarios. The use of ensembles enables some robust identification of global and regional differences pre- and post-overshoot, albeit with model differences which are particularly evident on the local level.

This is a very nice study with insightful analysis, and it is well presented. I found the Conclusions and final remarks to be particularly well written, and the arguments put forward here are well backed up. I have a few comments and these are mostly around providing more context for the motivation for the study and the results.

Thank you very much for your positive comments. We are very pleased that you agree on the usefulness of this study.

Specific comments:

L9: Perhaps change “response to” to “climate response at”.

Changed.

Introduction: Overall, this is very comprehensive. The summary of how ScenarioMIP has worked previously and the benefit of emissions-driven simulations is particularly clear and useful. One thing I thought was missing was discussion of the work around emissions-driven ESM simulations more generally which helps to motivate your focus on long emissions-driven simulations. Most of these studies have used more idealised simulations, which highlights a benefit of the SSP-type emissions-driven simulations used here, but include a focus on low/net-zero emissions pathways. Relevant references include (Fyfe et al., 2021; King et al., 2024; Murphy et al., 2014; Sigmond et al., 2020).

Thanks for the positive comments on the introduction. The suggested studies are somewhat aligned with ours and provide a nice foundation. In every case, we feel this work is still a development on these previous papers:

Murphy et al. (2014) run three scenarios in CO2-emissions driven mode in a perturbed parameter ensemble, including RCP2.6 which could be classed as an overshoot scenario (at least by design), but scenarios were only run to 2100 so the long-term post-peak effects are not able to be determined in this study.

King et al. (2024) run a number of CO2 zero emissions commitment scenarios branched off from esm-ssp585 to determine stabilisation climate at different global warming levels. The stabilisation periods provide a nice counterpoint, however the experiments are idealised and do not follow any realistic socioeconomic transition.

Fyfe et al. (2020) focused on the near-term response following a reduction in emissions from COVID-19. Although they ran an emissions-driven version of SSP2-4.5 to 2100 (esm-ssp245) and the data is openly available, they do not mention how the long-term responses vary between the emissions- and concentrations-driven variants of the model in the paper and focus on the near-term response.

Sigmond et al. (2020), similarly to King et al. (2024), use long-term zero emissions projections to investigate stabilisation at different global warming levels. Again these are idealised but they are run for over 500 years for a few ensemble members.

Therefore, we added a summary sentence at the start of the second to last paragraph of the introduction:

Further studies using emissions-driven experiments have been undertaken in recent years, but realistic experiments may usually only be run to 2100 \citep{murphy_transient_2014,fyfe_quantifying_2021}, with longer term experiments tending to be more idealised scenarios such as immediate zeroing of CO$_2$ emissions \citep{sigmond_ongoing_2020,king_exploring_2024}.

L102-105: While Pfleiderer et al. (2024) is a relevant paper it is odd to pick out one when there are a few examples that could be raised. These include (Roldán-Gómez, De Luca, et al., 2025; Roldán-Gómez, Ortega, et al., 2025).

Thank you for pointing out these additional sources of literature which have been added; you will note that the community comment also suggested mentioning the two Roldán-Gómez papers.

<u>Original</u>:

In addition, the simulations are extended beyond 2100 until the year 2300. While \citet{pfleiderer_limited_2024} explored the responses in regional and extreme climate in overshoot scenarios in a multi-model context, and found that there was asymmetry in the responses before and after peak warming, they used an ensemble of CMIP6 models that ran only to 2100 and were driven with prescribed concentrations.

<u>Modified</u>:

\citet{pfleiderer_limited_2024} explored the responses in regional and extreme climate in overshoot scenarios in a multi-model ensemble context to 2100, and found that there was asymmetry in the responses before and after peak warming. \citet{roldan-gomez_regional_2025,roldan-gomez_contribution_2025} used extended simulations to

2300 available for four models in \emph{ssp534-over}, for which the longer term AMOC response exhibits a wide variety of behaviours. However, both studies used simulations with prescribed concentrations, meaning it is not possible to evaluate the behaviour of carbon sinks to overshoot.

L140-143: Similar behaviour is found in ACCESS-ESM-1.5 too (Chamberlain et al., 2024).

Added.

Figure 3: While this is generally very clear, the legends are odd and incomplete with none shown in (b).

Thanks for the feedback. The legends are not reproduced on every panel as the font size would be too small to be legible and there would be repetition. We believe there is enough information for unambiguous interpretation of the figure.

L161-164: Might be better to break this into two sentences for clarity.

Thanks for the suggestion. This has been implemented.

L175-179 and L214-215: A bit of a leap is made from GSAT change to AMOC change and a strong connection is drawn between the two. More discussion as to why AMOC change may strongly relate to GSAT change in the net-negative emissions phase would be useful, preferably with a reference.

The paragraph at the end of section 3.1 has been revised and no longer mentions AMOC. The sentence at the beginning of section 3.3 has been deleted since it no longer links back to this discussion.

L238-241: This is a similar finding to other studies including (Lacroix et al., 2024; Nauels et al., 2025).

Thanks for the suggestion. These references have now been added in:

Added:

Continued sea-level rise in overshoot scenarios has also been noted in previous studies with ESMs \citep{lacroix_persistently_2024} and sea-level emulators \citep{nauels_multi-century_2025}.

Section 3.4.1. This section is well written but could maybe benefit from noting that there is diversity in post-net zero regional temperature changes with some models showing more of a hemispheric difference than others (Cassidy et al., 2023; MacDougall et al., 2022). By using two models you're seeing some differences under net-negative emissions but one would expect there is a broad range of simulated changes in a larger ensemble.

Yes, true – both papers focus on ZECMIP rather than overshoot/CDR experiment but the point is valid.

Added:

While not directly comparable (analysing the stabilisation phase of an overshoot experiment relative to a zero-emissions commitment experiment), there is a diversity in hemispheric warming patterns post-net zero across the CMIP6 population \citep{cassidy_regional_2024,macdougall_substantial_2022} and therefore it is not surprising that the regional responses of the two models may differ.

Section 3.4.2. Again, this is a very nice section although feels a little brief. Some further context against other studies could be useful, including (Douglas et al., 2025; Kug et al., 2022).

Thank you for the comment. It is probably fair that some more positioning within the general behaviour of CMIP models from other studies is warranted.

Original:

In both models during the warming phase, the inter-tropical convergence zone (ITCZ) shifts northward (figs. \ref{fig:pr_Ems-driven_results_cbar}a,i), which is consistent with the general hypothesis that the ITCZ moves towards the hemisphere with greater warming (refer to figs. \ref{fig:tas_Ems-driven_results_cbar}a,i).

Updated:

In both models during the warming phase, the inter-tropical convergence zone (ITCZ) shifts northward (figs. \ref{fig:pr_Ems-driven_results_cbar}a,i), which is consistent with the general hypothesis that the ITCZ moves towards the hemisphere with greater warming (refer to figs. \ref{fig:tas_Ems-driven_results_cbar}a,i), and other (concentration-driven) overshoot simulations from CMIP6 models \citet{douglas_effects_2025,kug_hysteresis_2022}

…

Comparisons can again be drawn with other (concentration-driven) CMIP6 models for NorESM2-LM. In general, owing to the warmer northern hemisphere in the stabilization phase compared to warming phase, the ITCZ is more northerly located during the stabilization period (fig. \ref{fig:pr_Ems-driven_results_cbar}d), which is in contrast to the CMIP6 model mean \citep{roldan-gomez_regional_2025}. However, NorESM2-LM shares the feature of increased precipitation in the eastern Pacific south of the equator with the CMIP6 model mean.

L309-311: The Conclusions are very well written. I did wonder if some expansion on this comment about the number of ensemble members could be made. Could you even go as far as suggesting a minimum number to be run for relevant CMIP7 experiments? There is quite a big difference between running 10 or 3 as was done with the MPI and NorESM models respectively here.

Thank you for the positive comment.

Original:

Each ESM has run a large number of ensemble members for each scenario, which enables us to seperate the forced signal from internal variability of the models.

Updated:

Each ESM has run multiple ensemble members for each scenario, which enables us to separate the forced signal from internal variability. The number of ensemble members required depends on the phenomenon being investigated: for global and regional mean state variables reported in this paper (temperature, precipitation, NPP, carbon fluxes and stocks, AMOC strength, thermosteric sea-level rise and ocean oxygen content) three members is likely sufficient to determine significant differences, though extremes (not evaluated in this paper) would benefit from a larger ensemble.

References:

Cassidy, L. J., King, A. D., Brown, J., MacDougall, A. H., Ziehn, T., Min, S.-K., & Jones, C. D. (2023). Regional temperature extremes and vulnerability under net zero CO2 emissions. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/AD114A

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