

ISIMIP3b paper: review comments 3, 4

Reviewer 3:

Summary

The authors present the climate forcings for the ISIMIP3b, groups 1 and 2, simulations, and describe the generation of these forcing in some detail. This paper aims to provide primary guidance for impact modelers with respect to which climate forcing should be used for particular experiments.

Overall response

This paper seems to meet its goals (given that I am not an impact modeler who would be using these data), although the relationship between the specific climate-forced simulations and the experimental goals of ISIMIP are not entirely clear. While section 2 is comprehensive and fairly clear, section 1 is a bit confusing because of the conflation of ‘simulation’ and ‘experiment,’ and also the redundancy in the text and in table 2. I suggest revising table 2 to make it more tractable (see comments below) and reorganizing section 1 around the target experiments that refer to the simulations defined in table 2. An experiment in this context is the comparison of simulation outputs to address a particular question. Each individual simulation is not an experiment in and of itself. There are also a couple of sections that seem irrelevant and could be removed.

Response: Thank you very much for the hint to the potentially confusing use of the term ‘experiment’! Section 1 is dedicated to a short introduction of the different simulation set-ups covered by the ISIMIP3b protocol. Each paragraph describes the simulation set-up and the reasoning why it has been included in the protocol, i.e. which research questions can be addressed based on the associated impact simulations.

Throughout the text, simulation set-ups are also called ‘experiments’ as commonly done in the model intercomparison projects e.g. comprising CMIP (see Table on CMIP6 Experiments in the [CMIP Model and Experiment Documentation](#)) and also following a longer tradition within ISIMIP. So ‘simulation set-up’ and ‘experiment’ are used as synonyms. We clearly state that at the beginning of the introduction now:

“This is the second paper of a series of three papers describing the experiments of the third simulation round of the Inter-Sectoral Impact Model Intercomparison Project ISIMIP ([isimip.org](#)). The project provides a common scenario framework for cross-sectorally consistent climate impact simulations. Here, the term ‘experiment’ is used as synonym for ‘scenario-setup’, i.e. the specification of the impact model simulations in terms of the applied input data or additional assumptions determining the simulations. This is following the use of the term within other model intercomparison projects such as the Coupled Model Intercomparison project CMIP ([CMIP Model and Experiment Documentation](#)) and a longer tradition within ISIMIP.”

We hope that this is more consistent and clearer now also based on the adjustments made in response to your individual comments below.

Specific comments and suggestions

Typos, etc.

line 147: lightning?

Response: Yes! Corrected!

line 224: ‘..data are derived...’

Response: Yes! Corrected!

Text organization/clarity

line 78: Are these also group I simulations?

Response: Only the pre-industrial and historical part of the simulations forced by the pre-industrial climate forcing belong to the group I simulations as indicated by the color coding in Table 2. The separation is also explicitly mentioned in the description of the pre-industrial reference simulations (first set of simulations described in section 1.1):

“The complete pre-industrial reference runs are divided in two parts. Only the first parts from the start until 2014 belong to group I (grey fields in **Table 2**), while the second parts covering the period 2015-2100 belong to group II (red parts of **Table 2**).”

However, you are absolutely right that these explanations come quite late. Therefore, we have introduced the group I and II definition in Figure 1 by labeling the associated parts of the time axis. In addition we now clearly mention that the group I simulations only cover the pre-industrial and historical time period:

“In a first set of experiments covering the pre-industrial (1601-1849) and historical period (1850-2014) (ISIMIP3b, group I) the CMIP6-based CRFs for the historical period are combined with historical observation-based DHF also considered in ISIMIP3a (e.g. land use patterns, water and agricultural management, and fishing efforts).”

and we also mention the ‘future part’ of the pre-industrial reference simulations in the description of the group II simulations in the abstract now:

“The second group of experiments (ISIMIP3b, group II) comprises future projections assuming constant observational direct human forcings at 2015 levels to estimate the impact of climate change given today’s direct human influences for the low emission scenario SSP1-2.6, the high and the very high emission scenarios SSP3-7.0, SSP5-8.5, and reference simulations based on pre-industrial CRF, respectively.”

Lines 243-245: This is awkward. Try departing into 2 sentences.

Response: Done. The part now reads:

“The reference simulations represent large samples (at least 250 years) of impact distributions based on stable pre-industrial CRFs (picontrol) and constant DHFs (see ‘picontrol + 1850soc’, ‘picontrol + 2015soc’, and ‘picontrol + nat’ experiments in Table 2). Compared to the often used much shorter historical reference periods, this allows for a more robust fitting of extreme value distributions such as Gumbel distributions to simulation of e.g. annual maximum discharge to estimate reference 100 year return levels.”

Lines 253-255: This is the case for all simulations, not just pi-control. I suggest moving this info to the beginning of this section.

Response: The pre-industrial reference experiment is specific in the sense that the climate forcing does not change from the historical to the future period. It is all based on the CMIP picontrol runs. That is why we consider it important to mention it here. The general separation between the group I and group II simulations is now already introduced earlier (see adjustments made in response to your previous comments).

Lines 257-265: This is out of place. It should go into an ‘experiment’ section after the simulations are described. This section is simply describing the simulations.

Response: Section 1.1 and section 1.2 are dedicated to the introduction of the different experiments considered within ISIMIP3b group I and group II, respectively. Each paragraph describes both the simulation set-ups as well as the reasoning why this set-up has been selected to be part of the ISIMIP3b protocol, i.e. which type of analyses could be done based on the associated impact simulations. The lines 257-265 belong to that introduction of the pre-industrial reference experiments. It may have appeared too separate by the blank line. We have deleted that line. In addition, we have changed the order of the paragraph on the ‘hist-nat’-based experiments and the discussion of the spin-up. The discussion of the ‘hist-nat’-based experiments contributed to the discussion of the primary reference experiments as it also highlights the restrictions of the associated impact simulations. In addition, even given our definition of the term ‘experiment’, the use of the term in the first sentence is not correct. We have changed that and have also modified the paragraph to clarify the aspects above:

“Comparing these reference simulations to the scenario simulations using historical CRFs (historical + histsoc, historical + 2015soc, historical + 1850soc, historical + nat; default (see below)) allows for the estimation of the effects of simulated historical climate change conditional on the assumed DHF. The historical CRF (‘historical’) starts from the pre-industrial climate simulation in 1850, i.e. the ‘picontrol’ and ‘historical’ simulations have a common starting point. As some impact indicators may have ‘internal’ trends not necessarily forced by external drivers (e.g. re-growth of forests), the comparison of the 1850-2014 impact simulations forced by the ‘historical’ CRF to parallel simulations using the ‘picontrol’ CRF is more appropriate to estimate the effects of historical climate change than comparing an early period of the historical impact simulation to the end of the historical period. The comparison of the simulations assuming ‘historical’ CRF with the reference simulations based on ‘picontrol’ CRF does not allow for a separation of the impacts of the natural and anthropogenic historical climate forcing. To allow for a quantification of the effects of the *anthropogenic* CRFs, we also support historical reference simulation accounting for the natural CRF only (‘hist-nat’ experiment

within the Detection and Attribution Model Intercomparison Project (DAMIP) as sub-MIP of CMIP6, (Gillett et al., 2016) While this set-up is not an official part of the ISIMIP3b protocol, we provide the associated bias-adjusted CRF as secondary climate input data (Lange et al., 2023).”

Lines 272-276: This does not seem relevant. It is unclear why this is included. If there are extra data like this, maybe mention it in a special section at the end of the paper.

Response: The additional ‘hist-nat’-based CRF have been provided on request by certain modelling teams interested in the attribution of historical impacts to anthropogenic climate forcing. We consider it meaningful to discuss this extension here as these additional experiments represent an alternative to the reference experiments discussed in the paragraph. It also allows us to highlight the limitation of the primary reference experiments to avoid misinterpretations when assessing the associated simulations.

Lines 284-288: Another experiment description vs a simulation description

Response: The text has been adjusted to be fully in line with our understanding of the term ‘experiment’ as ‘simulation set-up’:

“Standard historical simulations based on historical climate-related forcing and observed changes in direct human forcing (historical + histsoc; default): This experiment covering the historical period (1850-2014) is determined by historical (‘historical’) CRFs and DHFs evolving according to observations (ISIMIP3a ‘histsoc’ DHF). The ISIMIP3b ‘historical + histsoc’ experiment is comparable to the default ‘obsclim + histsoc’ experiment considered within ISIMIP3a but based on simulated CRFs. The simulated climate is different from the observed realisation due to differences in the internal variability of the observed and simulated historical climate and potential deficits in the climate model simulations or the observational data. A comparison between the default ISIMIP3b ‘historical + histsoc’ impact model simulations to the associated ISIMIP3a results allows for a quantification of the effects of the discrepancies between the observed and simulated CRFs on the considered impact indicators. The simulations can be initialised from the spin-up of the associated pre-industrial reference simulation in case a spin-up is needed.”

This is consistent with providing a short description of the experiment (simulation set-up) and the motivation for the associated simulations (why the experiment has been included into the protocol) and in line with the title of the section (‘Experiments and underlying rationale’).

Lines 312-317: More experiment description

Response: See above. We have slightly adjusted the text to harmonize the use of the term ‘experiment’: “This experiment is introduced as a companion experiment to the ‘obsclim + nat’ experiment of ISIMIP3a.”

Line 355 and 359: Simulations, not experiments

Response: See above. The text has been changed to:

“This experiment represents an expansion of the group I ‘historical + histsoc’ experiment based on fixed 2015 DHF for the future. Note that this experiment is different from the experiment with fixed 2015 DHF for the future where the associated impact simulations start from the ‘historical + 2015soc’ group I simulations (see description below).”

Lines 365-367: Experiment info

Response: Here the text is in line with our interpretation of the term ‘experiment’ and has only been slightly adjusted for a clearer distinction of the ‘experiment’ and the associated simulations:

“These experiments have been introduced to describe the impacts of different scenarios of changes in the climate-related systems on today’s natural systems and societies, i.e. assuming present day population levels and distributions, land use patterns, water, and agricultural management measures etc.. [...] To be able to separate natural trends from the effects of changing CRFs, the associated impact simulations can be compared to reference impact simulations with pre-industrial CRF forced with the same DHF (‘picontrol + 2015soc-from-histsoc’, see description in group I section).”

Lines 821-853: If the sea level data are not ready yet, then this section is not needed. If the method changes a bit, then this section will be wrong. It is better to leave it out. You have already stated that these data are forthcoming.

Response: Yes, the data set does not exist yet. However, we also use the paper to announce the provision of certain data sets. Protocol papers such as this one always have the problem that they require a review of decisions that are already taken because they document the results of an extended discussion process. However, where possible we would like to also let people know that there is a concrete plan on how to generate one of the missing data sets (future coastal water levels accounting for sea level rise and bias-adjusted ocean data) or ask for input if such a process does not exist yet (e.g. lightning flash rates for all climate change scenarios). That enables feedback either in the review process but also afterwards that could still improve the approach. Meanwhile the paper describing the basic approach for the long term sea level projections has been published. The text has been adjusted accordingly such that readers can get a clear idea of the first step towards the provision of the data set that has already been taken (see section 2.3).

Line 862: These have already been created, correct?

Response: No, this dataset does not exist yet. The sentence refers to the ‘Climate-Related Forcings for the ‘de-biased’ sensitivity experiment’ that are announced in Table 1 under ‘Global oceanic forcings’. We have adjusted the sentence and the entry in Table 1 to make clear that this is an announcement. See arguments above.

In Table 1: “These data sets have not been generated yet. However, in section **2.4.2** we propose an approach to de-bias the oceanic forcings based on the ocean biogeochemistry model NEMO-PISCES forced by a de-biased version of the IPSL-CM6A-LR-based atmospheric forcing as an option to fulfil the demand for de-biased ocean data we would like to follow.”

In line 862: “However, in order to mitigate potential biases in global impact model simulations stemming from biases in raw oceanic forcing data, we plan to provide a de-biased version to be used in a sensitivity experiment (see **Table 2**).”

The different aspects of the method itself have already been tested in other contexts such that we are confident that the proposed approach will work.

Line 946-960: It is unclear which ocean simulations are which in this paragraph. It seems that there are intermediate simulations for the bias correction and then the simulations that provide the final data. The first sentence includes ‘another set of ocean model simulations.’ Then there is the ‘forced ocean biogeochemistry model for historical and future simulations.’ Then there is the ‘direct flux into the ocean model,’ (which one?) and the climate change fluxes into the NEMO-PISCES model. Please clarify the workflow here and indicate the final output data referred to in the next paragraph.

Response: We have revised this paragraph to better explain the workflow, and to clarify that there is only a single ocean model involved (NEMO-PISCES); and also to clarify a question by reviewer #4 about SST-dependent surface fluxes. The revised paragraph reads as follows:

“The 3-hourly surface fluxes, constructed as described above, then serve as input for another set of NEMO-PISCES ocean model simulations which produce the final, bias-adjusted historical and future forcings for the marine ecosystem models. Since these ocean model simulations are driven directly with surface fluxes (instead of bulk formulae), they enable an online implementation of the surface heat flux feedbacks triggered by climate change, which is important for realistically representing the effects of global warming (Lengaigne et al., 2025). As described by Lengaigne et al. (2025), climate change alters surface fluxes both directly through the effect of greenhouse gases on atmospheric characteristics, such as wind speed or humidity; and through feedback effects related to changes in SST. For our bias-adjustment procedure, to maintain physical consistency, the part of the anomalous surface fluxes that directly depends on climate change-induced SST warming is separated from the part that does not. For bias-adjustment, the part of the anomalous surface fluxes that directly depends on climate change-induced SST warming is separated from the part that does not. Only the latter part is used as a direct flux input to NEMO-PISCES, while the former is implemented within NEMO-PISCES as an online relaxation to the warming signal from the debiased historical and future simulations using a spatially and seasonally variable feedback damping coefficient. This SST feedback coefficient, derived from observed surface variables, represents the Newtonian cooling negative feedback related to latent heat fluxes through the Clausius-Clapeyron relationship and the negative feedback related to upward long-wave radiation through Stefan’s law (Zhang & Li, 2014), and the positive downward longwave radiation feedback related to increasing temperature (Shakespeare & Roderick, 2022). Application of this approach to the NEMO-PISCES ocean model effectively reproduces the global SST changes simulated by CMIP6 models, as demonstrated in (Lengaigne et al., 2025).”

Line 972-973: Is this describing the overall data, or the additional data? If it is the overall data, then it seems out of place.

Response: The sentence refers to the data that will be generated for all GCMs, not to the additional observational data already provided for the historical period. So we have moved it to end of the paragraph above that is on the general approach:

“[...] Depending on data availability for the relevant monthly fluxes, this de-biasing procedure can be applied to any climate model. The set of variables included in the de-biased dataset (**Table 9**) will be a subset to the one in the raw GCM dataset (see **Table 8**).”

Tables and figures

Table 2:

There is a lot of repeated text and slight variations that make this table unwieldy and too large. I suggest creating more columns for the configuration options (e.g., rcp, co2, dhf, crf, bias, etc.) and listing which one for each simulation row. Or Use one general description of what the selections mean, either in the caption or in a special row.

Answer: Table 2 follows the standard ISIMIP format that has already been applied in other modelling rounds. It is identical to the scenario Tables included in the sector specific online protocols, where the Tables may be reduced according to the selection of experiments relevant for the sector. As this format is established in the community it would be more confusing to change it to a version that looks different from the one in the protocol. The design of the Table follows the way the simulations will be done: The impact model simulations will be transient runs starting in 1601 and ending in 2100 corresponding to one pair of the rows in the Table (one specifying the Climate-Related Forcings and one determining the Direct Human Forcing) with different specifications of the CRF and DHF for the different time periods. As the specification of the experiment in one time period depends on the combination of the DHF and the CRF it would not fit into the format to introduce additional columns that are dedicated to the different time periods. So as an impact modeller you can go through the individual rows and directly see how the provided forcing data sets have to be combined to do the simulations in the most convenient way.

Reviewer 4

General comments:

The paper describes the construction of model scenarios for the third round of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP). The authors describe the climate related forcings (CRF) and direct human forcings (DHF) used for the different scenarios. The experiments in group I cover a range of historical and counterfactual scenarios, while the experiments in group II describe a range of future scenarios with SSP scenarios for CRF and fixed DHF at different levels. Group II also includes scenario descriptions for sensitivity simulations such as CO₂ (fixed at 2015, and high CO₂ levels), future lightning and "de-biased" simulations for the marine ecosystems and fisheries sector.

The paper is well written but would improve in comprehensibility by providing more context for certain aspects of it. I suggest the following additions:

Define CRF and DHF in greater detail. Understanding the paper greatly depends on the reader understanding why these two forcings are separated. What are the scientific questions that are being addressed by these scenarios. This may have been addressed in detail by a previous paper but would improve the current paper if stated here in brief.

For DHF, please give examples. For CRF, while they are defined by the SSP/ RCP scenarios, please describe in text form what is included in your definition of CRF. Especially, what is included in "atmospheric climate forcing" when GHG concentrations are listed independently of that.

Response: Thank you very much for the hint. We introduce both terms in the introduction now:

“Within ISIMIP the experiments are determined by the underlying set of CRFs and DHF. The CRF is different from the ‘climate forcing’ considered within climate models. For the impact models the associated climate change represents the forcing. In addition, some of the impacts (e.g. changes in natural vegetation and crop yields) also directly depend on CO₂ concentrations (CO₂ fertilization effect, increased water use efficiency). Others (coastal infrastructure models) need information about sea level rise as input. Following the terminology of the IPCC AR6, where climate-related systems are defined as the “climate system including the ocean and the cryosphere as physical or chemical systems” (B. O’Neill et al., 2022), we label this group of forcings as Climate-Related Forcings (CRF) that cover all the inputs listed in Table 1. This group is distinguished from the Direct Human Forcing induced by socio-economic development, mitigation strategies or human adaptation measures such as land use changes, changes in agricultural and water management, population and assets distributions. While this paper only introduced the CRF for the ISIMIP3b, group I + II experiments a list of inputs belonging to this second group of forcings can be found in Frieler et al. (2024).”

Typos, typography, style, etc.

153: first mention of GCM, please define it here instead of in line 224.

Response: Ah yes! Has been adjusted!

158: "and to provide of a long" -> "and to provide a long"

Response: Thank you very much for spotting! Text has been changed!

235: missing space between CRF and opening bracket

Response: Thank you very much! Space has been introduced!

243: Gumble -> Gumbel

Response: Corrected!

462-465: Are multiple fonts/ font sizes being used here? If this is done to make the variable names stand out, cursive may be more efficient at achieving this.

Response: That was unintended. The size has been adjusted.

498: being better/ worse -> showing better/ worse model performance

Response: Has been adjusted.

578 vs 590: inconsistent use of dash for "pseudo future" vs "pseudo-future"

Response: We have adjusted the text to consistently use 'future pseudo-observations' throughout the paper.

621: Typo in citations: Themeßl not hemeßl, I assume.

Response: Yes! Has been corrected!

625: inconsistent use of fonts

Response: Has been corrected!

719 & 220: inconsistent use of brackets: Both the Cucchi and the Adler-citation should not be in brackets if I understand the sentence structure correctly. Where does the bracket before WFDE5 close?

Response: We have added the missing bracket closing after the Cucchi reference. The brackets around the citation within the outer brackets are automatically inserted by the referencing tool but will be gone after the final type setting.

743: remove comma between MIT and approach

Response: Done!

768 inconsistent use of brackets: What does the closing bracket belong to?

Response: Closing bracket has been deleted.

777: missing closing bracket

Response: Missing closing bracket has been added:

“CHAZ (Lee et al., 2018) seed disturbances are also initialised randomly, but, in contrast to the MIT model, the global seeding rate and the local probabilities are derived from two versions of a TC genesis index (TCGI, (Tippett et al., 2011)) (genesis module) and intended to represent the environmental conditions instead of being adjusted to produce a prescribed number of TCs.”

805: by a global reanalysis data -> by global reanalysis data

Response: Corrected!

806: cyclone risk at Mumbai -> cyclone risk in Mumbai OR "for Mumbai"?

Response: Changed to 'for Mumbai'.

819: 200m -> 200 m

Response: Corrected!

829: longer-term -> long-term. If you speak of short-term, not shorter-term, you should just use long-term instead of longer-term as well.

Response: Yes, corrected!

928: are the added -> are then added

Response: Corrected!

1002: simulations by -> simulations of

Response: Corrected!

1009: Please keep using present tense as you've done for the rest of the method description.

Response: Has been corrected to present tense.

Text organization/clarity

94: It would be beneficial for the general understanding of the scenarios and the whole paper if you would explain what CRF and DHF mean beyond spelling out the term. What is included in each forcings, give examples and explain the rationale behind separating those two.

Response: In addition to the text above explaining what CRF and DHF mean, we have added the following explanations to the abstract:

“This paper describes the climate-related forcings (CRFs), i.e. change in climate comprising the atmosphere and the ocean, coastal water levels, and atmospheric composition (CO₂ and methane concentrations), provided as input data within the ‘b’ part of the third simulation round of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b).”

“While ISIMIP3a comprises historical impact models simulations forced by observational Direct Human Forcings (DHF), such as changes in population and asset distributions, land use, fishing efforts, agricultural and water management driven by socio-economic development or climate protection strategies, and observational CRF, the ISIMIP3b CRFs are based on climate model simulations generated within the sixth phase of the Coupled Model Intercomparison Project (CMIP6).”

In addition, we explicitly refer to Table 1 in the ISIMIP3a protocol paper listing all the DHF provided and Table 1 of this ISIMIP3b, group I + II protocol paper listing all the CRF that is or will be provided within ISIMIP3b already at the beginning of the introduction:

“In its third round it covers i) model evaluation and climate impact attribution experiments based on observation-based CRF and DHF (ISIMIP3a, Table 1 of associated protocol paper (Frieler et al., 2024)), ii) climate impact simulations driven by simulated CRFs based on climate model simulations generated within the sixth phase of the Coupled Climate Model Intercomparison Project (CMIP6) (see **Table 1**, this paper) assuming ISIMIP3a observational DHF in the historical period and fixed 2015 DHF for the future simulations (ISIMIP3b, group I+II, this paper), and iii) an upcoming set of CMIP6-based future projections where DHF vary according to given Shared Socioeconomic Pathways (SSPs) (no adaptation scenarios) and in response to climate change impacts (adaptation scenarios) (ISIMIP3b, group III). So while this paper only describes the ISIMIP3b CRF, the first paper described the historical DHF used within ISIMIP3b, and the third paper will only address the future DHFs for group III that are still under development while the CRF of the group III simulations will be identical to the future CRF described here.”

121: for i) what's the update from ISIMIP2b - was it CMIP5 data before?

Response: Yes, ISIMIP2b is CMIP5-based. We now explicitly say that:

“Compared to the CMIP5-based ISIMIP2b, the ISIMIP3b CRF represent the following updates: i) climate forcing data based on phase 6 of the Coupled Model Intercomparison Project (CMIP6) (Eyring et al., 2016) and post-processed by an improved bias adjustment and statistical downscaling method (see section 3.2), and ii) provision of large ensembles of potential realisations of tropical cyclone tracks, wind and precipitation fields derived from two different modelling approaches assuming CMIP6 boundary conditions, while in ISIMIP2b only one approach was used and precipitation fields were not included.”

165: While the 8.5 scenario may be criticised for being too high, is the 2.6 not too low? Has Earth's radiative forcing not surpassed 2.6 W/m² increase already? By now that's more of a "what could have been" than a "what may happen" scenario.

Response: Yes, radiative forcing may have exceeded 2.6 W/m² already (IPCC estimate: "Human-caused radiative forcing: 2.72 [1.96 to 3.48] W/m² in 2019 relative to 1750). However, even in RCP2.6 that level is exceeded and only reached again at the end of the century after an overshoot. Also regarding the impacts of climate change, the actual extent of climate change matters more than the underlying radiative forcing. Here, at least measured in global mean temperature change, at least part of the ISIMIP models exceed the projections of the lowest (up to 2100) scenario (VLLO) that will be considered within CMIP7-ScenarioMIP (see Figures below from van [Vuuren et al., GMD, 2025](#)). The associated projections start from 2025, i.e. they account emissions and forcings already reached so far. The VLLO warming is still only estimated by the simple climate model FAIR, as the actual simulations by the GCMs still have to be started. However, based on these projections we do not consider RCP2.6 as too low yet.

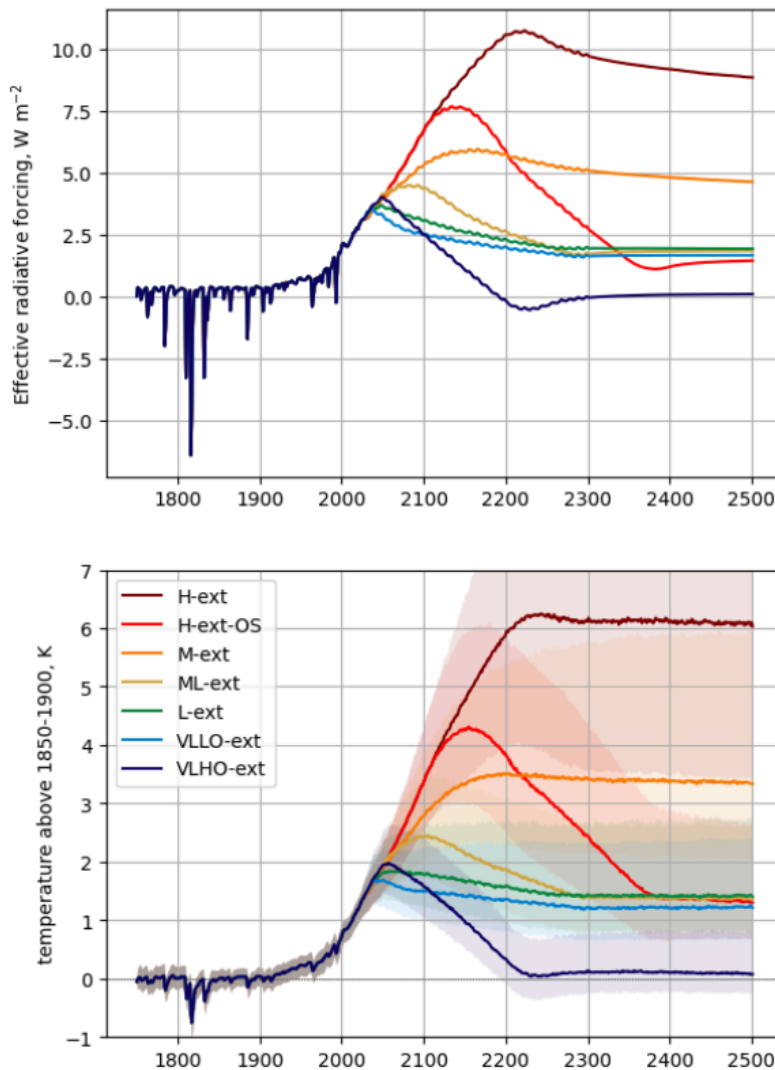


Fig 1: Part of Figure 2 of van Vuuren et al., 2025.

268: What does "copy as often as needed" mean? Taking i) as an example, do I understand it correctly that for simulations starting at 1850, the picontrol CRF for 1850 should be used for spin-up, and that if multiple model years are needed for spin-up the year 1850 should be repeated as often as needed?

Response: Many vegetation / land surface models require a spin-up which is longer than our picontrol time series. In this case, it is not just one year of the CRF that should be copied as often as required but the entire time series of picontrol forcing provided within ISIMIP3b. Otherwise, the spin-up may be built on the particular conditions of only one year which could for example be extremely warm. We have slightly adjusted the sentence now saying: "For the spin-up all years of the 'picontrol' CRF should be copied as often as needed."

309: The description of the purpose of the scenario as described here helps the reader gain a better understanding why the scenarios are constructed the way they are. It would be beneficial for the

reader if the authors could add similar descriptions to the other scenarios described in this section.
E.g. the scenario in L298 - what does this scenario allow quantifying for?

Response: We have added the motivation of these experiments to the paragraph:

“The ‘historical + 1850soc, default’ impact model simulations allow for the quantification of the ‘pure effect of climate change’ over the historical period. In contrast, the comparison of the ‘historical + 1850soc, default’ impacts simulations to the ‘historical + histsoc’ simulations allows for the quantification of the ‘pure effect of historical changes in DHF’.”

377: "an as large as possible ensemble" -> an ensemble of [...] with as many members as possible

Response: Yes! The sentence has been changed accordingly.

395: effect of CO₂ only or effect of CO₂ plus other greenhouse gases? Please clarify.

Response: It is the effect of CO₂ only, because CO₂ concentrations have strong direct effect on the impacts (through CO₂ fertilisation which is a highly uncertain process in vegetation models). The experiment is designed to separate the climate effects from the CO₂ fertilisation effect. The experiment is only done for CO₂ as many models in the biomes, water, fire, crop modelling sector account for these direct impacts. Many other climate forcings (such as other GHG or aerosols loadings) do not have such a direct impact on the considered systems or the impacts are only captured in individual models (such as direct impacts of atmospheric CH₄ concentrations on CH₄ uptake of soils). This is explicitly said in the text now:

“To separate the effects of increasing atmospheric CO₂ concentrations (in particular the CO₂ fertilisation effect on vegetation) from the effects of other changes in the climate-related systems, the ISIMIP3b protocol includes sensitivity experiments where atmospheric CO₂ concentrations are held constant at 2015 levels.”

404: Not sure I understand this correctly? The future lightning data is only available for one GCM, namely UK-ESM. Is that correct? That means simulations of the future including the impact of future changes in lightning can only be done using atmospheric input data from one GCM? Assuming lightning statistics are closely related to the GCMs internal dynamics and lightning parametrisation scheme and that the lightning data should match the atmospheric data used for a consistent simulation.

Response: Yes, unfortunately that is true. We fully agree that the lightning data should match the atmospheric data. However, the required densities (strokes per km² day⁻¹) are simply not provided for the ISIMIP3b GCMs within CMIP6 except for UKESM. As we consider this a critical and avoidable limitation we particularly mention this aspect in the conclusion as one we hope to overcome in ISIMIP4.

407: What exactly does "without accompanying changes in climate" mean? To avoid confusion here, it may be useful to define CRF in more detail in the introduction section: Name the atmospheric forcings considered in CRF, e.g. GHG concentration, solar forcing, stratospheric aerosols, SSTs/SICs, ozone concentrations, etc.

Response: The climate-related forcing for ISIMIP does not correspond to the climate forcing in the climate model simulations. For the considered impact models the climate forcing (GHG concentration, solar forcing, stratospheric aerosols, SSTs/SICs, ozone concentrations) relevant in the GCM simulations does not necessarily have a direct impact on the considered natural and human systems. Instead, the associated changes in the climate system including the atmosphere and the ocean are used as input. CO₂ and CH₄ are additionally provided because of direct impacts on natural and human systems (e.g. direct effects of CO₂ fertilization or higher water use efficiencies on crop yields and natural vegetation and direct effect of atmospheric CH₄ concentrations on soil CH₄ uptake at least considered by individual impact models). All considered CRF are listed in Table 1.

In the considered sensitivity experiment, modellers are asked to combine the relatively low levels of climate change associated with the SSP1-2.6 scenario with the high atmospheric CO₂ concentrations considered within SSP5-8.5. As the climate variables and the CO₂ concentrations are separate inputs to the impact models, it is possible to run them for such an artificial combination of inputs.

407: What is the purpose of this scenario? Why is isolating the impact of changes in CO₂ concentrations from other anthropogenic climate forcings useful? Is this to estimate the capacity of peatland to store CO₂?

Response: The experiment was introduced on request by the ISIMIP peat sector to complement the experimental design of a planned paper. In that paper, simulations using ssp126 and ssp585 climate and CO₂ and ssp585 with constant CO₂ (2015co₂ setting) are used to isolate climate and CO₂ effects in peat models. To complement the CO₂ sensitivity experiment with a low level of climate change but high CO₂, this “climate sensitivity under high CO₂ concentration experiment” was introduced to better isolate the climate effect from CO₂-effects in that specific paper. A comparison of the default simulations assuming high levels of climate change and atmospheric CO₂ concentrations to the simulations associated with the proposed sensitivity experiment allows for testing to what degree the strength of the direct impacts of CO₂ forcing (CO₂ fertilization and increased water use efficiencies) depend on different levels of climate change. The experiment is not introduced to quantify the separate effects of CO₂ forcing on climate and then on the impacts of climate change. The ISIMIP3b atmospheric climate and ocean climate forcing is always based on the full set of climate forcings considered in the standard ‘picontrol’, ‘historical’ and ‘ssp126’, ‘ssp370’, and ‘ssp585’ experiments within CMIP. This also applies to this sensitivity experiment within ISIMIP3b. The experiment is only done for CO₂ as many models in the biomes, water, fire, crop modelling sector account for these direct impacts. Many other climate forcings (such as other GHG or aerosols loadings) do not have such a direct impact on the considered systems or the impacts are only captured in individual models (such as direct impacts of atmospheric CH₄ concentrations on CH₄ uptake of soils).

426: Is CO2 not an atmospheric forcing as well? Again, defining what you include in (other) atmospheric forcings may help avoid confusing the reader.

Response: In the line we said:

“Here the climate-related forcings are only described by the climate (oceanic and atmospheric) and CO₂ forcings as we do not provide coastal water levels yet.”

To clarify the situations we now say:

“Here, the CRF are only described by the climate (oceanic and atmospheric) forcings and the assumed CO₂ and CH₄ concentrations that have a direct influence on the simulated impacts independent of climate. Coastal water levels are not mentioned in the description as we do not provide the associated input data yet.”

447: Meaning the picontrol runs are time-slice runs?

Response: No, the picontrol simulations from CMIP represent continuous GCM simulation. However, the attached time axis (see original start and end year of the selected part of the picontrol runs in column 4 of Table 4) is arbitrary as there is no reference to e.g. the timing of the historical forcing. This means the time axis can be flexibly shifted to 1601–2100 as done for ISIMIP3b to allow for picontrol reference simulations that are in parallel to the scenario runs. The text has been adjusted to:

“For the pre-industrial conditions, 500 years of picontrol output data are used and harmonised across GCMs with respect to the time range they cover. This is possible because picontrol data only carry nominal year labels without historical reference points (see original nominal start and end years in Table 4). We changed the GCM-specific picontrol time ranges listed to 1601–2100.”

514: Not sure I understand the meaning - Are the atmospheric and ocean components independent of each other within each model, i.e. not one of them is a coupled atmosphere - ocean model but rather use prescribed SSTs/SICs for modelling the atmospheric component? MPI-ESM has a coupled ocean model, though.

Response: The GCM all represent a coupled atmospheric and ocean component. The paragraph is about the dependence of these components across the different GCMs. The GCMs participating in CMIP often build on oceanic or atmospheric components that have been developed from the same source.

739: define TC

Response: Introduced already in the abstract now!

768-774: should the licensing not be under "Data availability"?

Response: The paper only provides a documentation of the data sets (included variables, formats, sources, covered time period) but does not display or discuss them contentwise. As such they are not a ‘result’ of the paper. The data availability statements refers to the data that are analysed and discussed in the paper. This has been decided after iteration with the executive editor.

810-816: move licensing to "Data availability" section.

Response: See above.

828-853: Since you mention that the method for the coastal water levels will be described in an upcoming paper, should this section be removed from the current paper and put into the upcoming one?

Response: Meanwhile the paper describing the basic approach that will be used for the projections is published. We consider it helpful to announce the data set that potential users are informed and still get an opportunity to give feedback by contacting us.

869: What is the reference level here? Is this the historical period used as reference (ref)? Does it mean you calculate the future value $X(\text{future})$ as $X(\text{OBS, ref}) + X(\text{mod, future}) - X(\text{mod, ref})$?

Response: The reference years are given in **Table 10** in **section 2.4.3** where the delta approach is also described: "The adjustment is based on the delta approach where simulated and observational forcing data X_{sim} and X_{obs} are averaged across a given historical reference period to determine the bias $\Delta = \text{mean}(X_{\text{sim}}) - \text{mean}(X_{\text{obs}})$ that is then subtracted from the simulated forcing data."

897: The use of GCM here is confusing. Not every GCM has an interactive oceanic component, only a subset of them do. When referring to GCMs with an online ocean model, one usually refers to them as atmosphere-ocean GCMs (AOGCMs). As far as I could find, Eyring et al. (2023) do not speak of GCMs when mentioning model performance of oceanic variables, but rather of "climate models" or "CMIP6 models". I would suggest using a similar phrasing in your text to avoid confusing the reader.

Response: We use the term as the most general umbrella term. All the ISIMIP3b GCM are actually even Earth System Models not only representing an interactive ocean, but also including a representation of the carbon cycle. However, for CMIP6 they were run in concentration driven mode.

944: Why would there be gaps? If an atmospheric model is set to output a variable at a 3-hourly frequency, one would assume there should be no gaps (provided no data is lost). Are you saying that under the CMIP6 protocol the 3-hourly output is not requested and therefore not available for all models and scenarios?

Response: Yes, the data is not available for all models and scenarios. We have changed the text to: "In addition, the 3-hourly input from the GCMs is not available for all scenarios."

951: Which part depends on climate change, which does not? Do you mean historical vs future? Please clarify.

Response: We do not mean historical vs future. What we mean is that climate change alters surface fluxes both directly through the effect of greenhouse gases on atmospheric characteristics, such as wind speed or humidity; and indirectly, through changes in sea-surface temperature (SST). If the altered fluxes simulated by ESMs would be applied to the ocean model with no correction, then

these latter, indirect effects - from the SST-related feedbacks - would be double-counted. Therefore it is necessary to isolate the direct, SST-independent flux anomalies from the SST-dependent flux anomalies. This can be done through calculations described by Zhang & Li (2014) and Shakespeare & Roderick (2022), and synthesized by Lengaigne et al. (2025). We do not reiterate these relatively complicated calculations here but instead refer to these papers for detail.

We have extended the discussion in the paper to clarify (also responding to questions by reviewer #3):

“The 3-hourly surface fluxes, constructed as described above, then serve as input for another set of NEMO-PISCES ocean model simulations which produce the final, bias-adjusted historical and future forcings for the marine ecosystem models. Since these ocean model simulations are driven directly with surface fluxes (instead of bulk formulae), they enable an online implementation of the surface heat flux feedbacks triggered by climate change, which is important for realistically representing the effects of global warming (Lengaigne et al., 2025). As described by Lengaigne et al. (2025), climate change alters surface fluxes both directly through the effect of greenhouse gases on atmospheric characteristics, such as wind speed or humidity; and through feedback effects related to changes in SST. For our bias-adjustment procedure, to maintain physical consistency, the part of the anomalous surface fluxes that directly depends on climate change-induced SST warming is separated from the part that does not. For bias-adjustment, the part of the anomalous surface fluxes that directly depends on climate change-induced SST warming is separated from the part that does not. Only the latter part is used as a direct flux input to NEMO-PISCES, while the former is implemented within NEMO-PISCES as an online relaxation to the warming signal from the debiased historical and future simulations using a spatially and seasonally variable feedback damping coefficient. This SST feedback coefficient, derived from observed surface variables, represents the Newtonian cooling negative feedback related to latent heat fluxes through the Clausius-Clapeyron relationship and the negative feedback related to upward long-wave radiation through Stefan’s law (Zhang & Li, 2014), and the positive downward longwave radiation feedback related to increasing temperature (Shakespeare & Roderick, 2022). Application of this approach to the NEMO-PISCES ocean model effectively reproduces the global SST changes simulated by CMIP6 models, as demonstrated in (Lengaigne et al., 2025).”

981: Calibrating regional marine ecosystem models with observed variables leads to biases in historical simulations? I'm not sure that is what you want to convey here. In L982 you mention the models being driven by modelled data (not observed as mentioned before). I can't quite figure out what you want to say here. Are those models mostly driven by observed data but sometimes by modelled data and the latter leads to biases?

Response: Thank you for the question. We have adjusted this sentence to clarify:

“However, despite this calibration, biases may still occur in the ecosystem model’s historical simulations when it is forced by - potentially biased - climate model data instead of observational data.”

985: Is this the same delta method as used above? I suggest moving this explanation to the first mention of the method.

Response: Yes, this is the explanation of the delta approach mentioned in the introduction of section 2.4. As we already refer to subsection 2.4.3 for an explanation we would leave it there. We have instead decided to delete the following short version of the explanation from the intro as it seems more confusing than helpful.

994: What is the EwE model? And the Atlantis model? Please add references if appropriate.

Response: Sorry for providing these model names without explanation. EwE stands for Ecopath with Ecosim, see Christensen et al. (2014); the Atlantis model is documented by Ortega-Cisneros et al. (2017). To refer readers to documentation of these and other regional models (including the Mizer model also mentioned in the table), we have amended the Table caption:

[“EwE: Ecopath with Ecosim. See Ortega-Cisneros et al. \(2025\) for details about this and other ecosystem models mentioned.”](#)

1026-1038: should be move to the introduction

Response: The discussion of the reasons to select SSP5-8.5 and SSP3-7.0 and associated limitations are already discussed at the beginning of section 1 which seems to be the best place to do so. We have only lightly modified the description there to be more concrete on the differences between SSP3-7.0 and the other scenarios as we were in the conclusion:

“Based on these discussions, the ‘medium to high end of the range of future forcing pathway’ SSP3-7.0 (B. C. O’Neill et al., 2016) has been added to the ISIMIP3b scenario set-up. While this scenario is described as ‘average no climate protection policy’ by (Hausfather & Peters, 2020), we highlight that we explicitly do not describe it as a ‘business as usual scenario’ and that this was not the framing within ScenarioMIP either. Instead SSP3-7.00 differs from the other scenarios with regard to particularly high aerosol emissions and high decreases in forest areas going beyond the assumptions in the other scenarios. So it has been shown that the increase of global mean precipitation with global warming is much weaker in SSP3-7.0 than in the other scenarios (Shiogama et al., 2023).”

The associated part has been removed from the conclusion while we keep only the first lines of the paragraph as an intro of the conclusions and a short summary of the paper.

1051: should v) not be iv)?

Response: Yes! Corrected accordingly!

Figures and Tables

204 - Figure 1: what's the meaning of the variability of the scenarios? Assuming the y-axis is related to radiative forcing - the amplitude of the variability seems very strong and implies a strong multi-decadal pattern. Should the variability look more like in Fig. 3?

Response: There is no intention to depict a realistic variability. The lines even represent a whole group of different variables (see Table 1 for the CRF and Table 1 of Frieler et al. 2025 for the DHF). The depicted variability is only used to show that the groups of forcings are subject to shorter term variabilities at all.

227 - Table 1:

[Tropical cyclone...] - future runs starting in 2061 - what's the significance of that year?

Response: The MIT-TC data have originally been created for diverse purposes outside of the ISIMIP context. The provided data set represents a collection of these data. That explains its fragmentation. The year 2061 for example does not have any specific significance within the general ISIMIP3b context, but simply represents the starting year of the time window for which we can provide TC tracks based on associated ssp126 climate projections from the four listed ISIMIP3b GCMs.

[Atmospheric composition or fluxes] - no fluxes are listed in this section, only concentrations

Response: Yes! 'or fluxes' has been deleted.

426 - Table 2:

Maybe the table header for Experiment could be amended to explain the contents of the cells better: E.g. CRF scenario name - DHF scenario name - priority? I'm not sure why one of the experiment names is bold while the other is not?

Response: We have changed the header of the first column. In addition, the CRF and the DHF specification are now both shown in bold as they are equally important. Instead the priority is no longer indicated in bold. Based on other modifications of Table 2 based on other comments, it is hopefully much more consistent now.

missing description for column "Period: pre-industrial" row "pre-industrial control 1st priority" - The cell only contains the letter "s"

Response: The cell could be deleted.

CO2 sensitivity (related to comment on L395) So it's not only CO2, but also CH4? Does that mean when CO2 was mentioned in previous scenario descriptions, CH4 was meant as well? What about other GHGs?

Response: The experiments are included to separate the CO2 fertilization effect on vegetation from the CO2-effect driving climate change. It only refers to CO2 because of its direct effect on vegetation.

To this end the impact model simulations are forced by the SSP1-2.6, SSP3-7.0, and RCP5-8.5 GCM simulations describing the climate change accounting for the full set of climate forcings associated with these scenarios (including CO₂, CH₄ and others), but the atmospheric CO₂ concentrations, which is an additional input for the impact models, is held constant at 2015 levels. It represents an artificial scenario as in this case the fixed level of atmospheric CO₂ concentration is not consistent with the considered level of climate change. However, the associated simulations (and the comparison to the default simulations accounting for climate change and CO₂ fertilization) allow for a separation of the effects of climate change from the direct effects of CO₂ fertilization. The direct effects of atmospheric CH₄ concentrations are only represented in a very limited number of impact models (2-3). That is why we have not included an associated CH₄ sensitivity experiment. Within the described CO₂ sensitivity experiment atmospheric CH₄ concentrations and all other CRF should simply be assumed to vary as in the associated default experiments. That is how the sensitivity has been generally been introduced at the beginning of section 1:

“Optional forcing data could be used but is not mandatory. In addition, the protocol includes a set of sensitivity experiments that are described as deviations from the default runs and labelled by the baseline CRF and DHF settings and a third specifier indicating the deviation from this default setting.”

"simulated SSP1-2.6 changes in the climate-related systems but fixed 2015 CO₂ concentrations"

What are climate-related systems?

Response: We follow the IPCC definition as introduced in chapter 16 of the WGII contribution to the IPCC AR6: “climate-related systems, defined here as climate system including the ocean and the cryosphere as physical or chemical systems.” The definition is now also provided in the introductions. However, we shortened the description in Table 2:

“Simulated historical CRF, CO₂ and CH₄ concentrations as observed in the historical period, then simulated SSP1-2.6-based CRF but fixed 2015 CO₂ concentrations”

The analogous changes have been applied to the other entries in the second column of Table 2.

Where are fixed CO₂ levels used and where SSP1-2.6 values?

Response: In the default experiments CO₂ concentrations change according to the SSP1-2.6, SSP3-7.0, or SSP5-8.5 scenarios, but in the CO₂ sensitivity experiments only climate changes according to these scenarios while the atmospheric CO₂ concentrations (which are a separate input for a range of impact models) are held constant at 2015 levels over the entire future period starting in 2015.

RCP8.5 1850 soc "described above" is superfluous, not used in other cells either

Response: All entries in the fourth column of Table 2 have been shortened accordingly.

Figure 4: x axis description should be month, not day of year.

Response: The displayed data is daily data. So the label 'day of the year' is correct. The letters only indicate the start of the individual months. We now also indicate the associated number of the day.

There were several inconsistencies in spelling and scientific notation that I shortly summarise here:

Citation: <https://www.geoscientific-model-development.net/submission.html#references>

Parenthetical citation is used throughout the text even when narrative citation should be used. Also, when citing multiple journals they should be in the same bracket (L782)

Response: This was due to an issue with the citation manager, indeed. We corrected it throughout the manuscript.

Please use superscript for "day-1" etc throughout the text (including tables), same for m-3.

Response: Has been corrected throughout the text!

Inconsistent use of subscript for CO₂, see Table 1

Response: Has been corrected throughout the text!

For temperature, please follow SI notation rules: there should be a space between the number and the unit °C: e.g. 2.6 °C. This error occurs throughout the text, e.g. Figure 4, L444, L519-535.

Response: Has been corrected throughout the text!

Inconsistent use of hyphen and m-dashes for date ranges. GMD prefers n-dashes (as correctly done in L554), please correct e.g. in L558, L763-764.

Response: Has been corrected throughout the text!

Lightning is misspelled as lighning/ lighting multiple times (e.g. L147, and for varlightning in L998, L1016)

Response: Has been corrected throughout the text!

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