

*Authors: We thank Dr. He and Dr. Savelli for the time and effort that they took in reviewing our manuscript. We appreciate their attention to detail and their suggestions for improvement. We are confident we have addressed their criticisms, and provide a revised draft following their feedback, along with point-by-point responses to each comment.*

## **RC 1**

line 36, Earth system ->Earth System

*Authors: Change made*

line 53, oceans -> cryosphere

*Authors: Change made*

line 63, remove "the impacts"

*Authors: Change made*

line 70, it is not clear with "observations of climate and ecological dynamics". I would suggest just keep "observations".

*Authors: Change made*

line 79, may need to rephrase to make it clear.

*Authors: insert/confirm applied*

line 85, "the exchanges of CO2 from sources to sinks" -> "the flux of CO2". -> "in particular the flux into the oceans"

*Authors: Change made*

line 96, "simulated variables and parameters" -> "simulated dynamics and parameterised processes"

*Authors: Change made*

line 179, "be of use to both" -> "be used for"

*Authors: Change made*

Section 4. Maybe add a title and short overview description for section 4?

*Authors: The missing Section 4 title was inserted in the manuscript and reads as "4. Earth System opportunities included in the CMIP7 Data Request"*

Line 525 and 539, the AMOC acronym has already been defined in the introduction.

*Authors: Change made*

Line 649, "and-use" -> "land use"

*Authors: Change made*

Table A1, ID 23, delete the duplicate words.

*Authors: The text was revised accordingly*

## RC 2

Table format

I would suggest adding an accessible version of existing variables in a Table format, as the authors did for new variables in Annex 2, and not only json format available in Zenodo. It will make it easier and more accessible to keep track of variables and additions in the future CMIP iterations.

*Authors: According to the shared indications provided by the Data Request (DR) Task Team on the thematic manuscripts, only new variables or relevant corrections/recommendations to those existing in the CMIP6 DR were reported in Annex 2. This choice mainly aimed to avoid overlaps with information already reported in previous CMIP6 publications. We added a statement about this at the beginning of Section 4. In addition, the introduction of Annex 2 was complemented with a link to the latest Data Request Airtable update ([https://bit.ly/CMIP7-DReq-v1\\_2\\_2\\_3](https://bit.ly/CMIP7-DReq-v1_2_2_3)), which represent a more accessible platform for users willing to navigate throughout the database. The content of the Airtable data correspond to that of the json file stored in the Zenodo catalog. Please note that we updated also the reference to the latest minor release to v1.2.2.3 (see 'Code and data availability' section) and modified the related reference to Anstey et al. (2025).*

Geoengineering and CDR.

Also, going through the data request, I identified several mentions of geoengineering and CDR. Can this be a separate opportunity in the future?

*Authors: We have added text in the discussions making this point: "As efforts to better represent CDR processes continue to improve in ESMs (e.g., Sanderson et al., 2024), it will be critical to update data requests so that assessment of the realism of these processes, as well as consistency between ESMs and the IAMs used to generate scenarios, can be assessed. This will require sustained efforts of the CDR community to identify key variables relevant to CDR processes alongside new model developments. "*

GAP: perspective section on cross-sphere feedback,

Finally, as a key gap, I would add more words in the perspective section on cross-sphere feedback, especially between land and ocean. How will the ocean biogeochemistry change with terrestrial runoff? The connection and especially the biogeochemical transformation across the aquatic continuum need to be better represented in models.

*Authors: This connection has now been briefly mentioned in the introduction (albeit only briefly as the introduction is already a little long).*

Minor comments

Going through the manuscript, I identified a couple of typos (see below). I recommend doing a thorough review to correct those. Even in the tables of Annex 1 and 2.

L60: fulfil -> fulfill, check for rest of the text

*Authors: Change made*

L68: fulfilment -> fulfillment, check for rest of the text

*Authors: Change made*

L74: just removal? I would add emission/release

*Authors: Change made*

L85: I think the open ocean is not an issue. Representation of the coastal ocean is more challenging.

L90: I would add a word on the transformation of elements when connecting reservoirs. Especially in the land-to-ocean aquatic continuum.

*Authors: In response to the two above comments: we now mention coastal processes the introduction but leave it largely as is given that we feel that it contains the appropriate level of specificity. However, in order to acknowledge that the reviewer raises an important point, we have added the following text to the discussion of still-existing gaps in ES modeling capabilities.*

*“Coastal processes, which have highly heterogeneous carbon flux dynamics, are not well-represented in global climate models (Laruelle et al. 2018; Dai et al. 2022). Increased spatial resolution and improvements in biogeochemical modules may reduce uncertainty surrounding land-ocean transport, and clarify the unique features of the ocean carbon pump in coastal regions (Bourgeois et al. 2016; Friedlingstein et al. 2025).”*

L44: missing a period.

*Authors: Change made*

L90: Yes and no.

Some ESMs does not solve specific mechanisms that could cause tipping points.

*Authors: We were unclear as to the exact reference the reviewer was making, since L90 doesn't involve tipping points. However, we have updated the question section to state: "What are the critical thresholds for these regime shifts to occur, and how consistent are these across different models? How consistently do different models represent the feedback mechanisms leading to tipping points?", and provided a better overview of the representation of tipping elements in earlier CMIP models in section 4.7.*

## Scientific Questions

I like the scientific questions, but I would also insist on or emphasize on how CMIP6 led to these questions. Just one sentence in the introductory paragraph of subsection 1.2 to make the connection with everything mentioned in subsection 1.1. The reader will appreciate that these questions are laid in CMIP's perpetual cycle of model improvement/understanding.

*Authors: We agree with the point raised by the reviewer on adding a short sentence to recall the role played by previous CMIP cycles. The beginning of Section 1.2 now reads as "The substantial knowledge on Earth System dynamics is built on the incremental progress made in previous CMIP iterations, leading to the current potential to predict natural systems evolution and its connections with human activities under manifold scientific dimensions."*

1) Cycles and 2) Ecosystems: like for Energy, it is also important to look at the transformation of elements (carbon, nutrients) across realms. I don't know if these scientific questions are still up for change, though. It is actually mentioned in subsection 1.3 Scope of the data request 'The CMIP7-ES theme deals primarily with Earth system cycles and interactions across domains' so maybe it is worth adding this notion of across domains in Questions 1 or 2.

*Authors: We have edited this section to include additional questions following the reviewer comment.*

*1) Cycles: How do the global carbon and other biogeochemical cycles respond to and feedback into changes in radiative forcing, and how does carbon cycle uncertainty contribute to uncertainty in projected warming? Which are the biogeochemical compounds that are still lacking or being underrepresented in the exchanges and flows across ESMs realms"*

*2) Ecosystems: How will climate change and/or climate mitigation influence the ocean biological carbon pump, and how will marine ecosystems be affected? What dynamics and feedbacks govern the prevalence of fire on a global scale, and how do changing fire regimes alter the terrestrial carbon cycle? What viable model solutions exist to map flows of matter and energy, and monitor trophic regimes under future climate evolution.*

*3) Energy: How does energy move across realms (ocean, land, cryosphere, atmosphere), and can we optimize model output of the Earth's energy budget in a way that can be compared to*

*observations? Can we keep track of the energy fluxes represented in water as it transfers between phase states and domains? How is energy stored and propagated between the atmosphere and oceans systems to produce internal climate variability on daily to decadal timescales, and can model hindcasts be used to improve multi-annual to decadal-scale predictability and the prediction of extremes?*

*4) Thresholds Under what climate forcing scenarios could major tipping points within the Earth system be reached? What are the critical thresholds for these regime shifts to occur, and how consistent are these across different models? How consistently do different models represent the feedback mechanisms leading to tipping points?*

L236:

I would consider non-profit organizations as a non-academic audience, too. Some organizations have the expertise to download and analyze model outputs from CMIP. Open science is essential in the framework of CMIP and these organizations need data to advocate for specific questions. They usually start the initiative and bring it to the government level for planning and policy-making.

*Authors: Change made*

Description of the methodology in Sections 2 and 3 is really appreciated but I would try to shorten it as much as possible. Table 1 is the main highlight. I would consider moving the rest to Supporting Information.

*Authors: In coordination with the DR Task Team, these sections were specifically proposed to elucidate the effort made in redesigning the DR toward a community driven approach. The scope is to recognize the need to transparently describe the progressive steps that were taken in the identification of scientific opportunities, specifically toward the ES author team decisions workflow and the broad DR cross community exchanges. Beyond the ES Authors and DR Task Team, the remarkable engagement effort of the broad scientific community showed to be a promising exercise to up-level the CMIP exercise. For the above motivations, we prefer to maintain Sections 2 and 3 in their current form.*

L290: CO<sub>2</sub>, please check the rest of the text for subscript formatting.

*Authors: The text was revised by applying the correct subscript formatting to the term "CO<sub>2</sub>".*

L300:

"their Fig. 5 (land carbon cycle) and Fig. 6 (ocean carbon cycle)" Please make sure that you refer to the correct figures describing variables for land and ocean. For example, figures concerning ocean carbon start at Fig 13 in their paper.

*Authors: The correct reference to the ocean carbon cycle Figure 13 from Jones et al., (2016) was added in the revised manuscript.*

Table 3:

For each set of variables in 4.2, I would mention that these variables should directly match what is observable or closely related. I even suggest adding one sentence in the associated paragraph on making sure that models output variables that are directly or closely comparable with observations. Sometimes models are too advanced compared to observations. Not as relevant for this manuscript, we would also need better ways to compare model outputs with observations, as the latter come with temporal discontinuity and different spatial coverage.

*Authors: The text of section 4.2 was complemented with a short sentence that reads as “In particular, tier1 variable groups include metrics from diverse ES realms that would enable for a direct or as close as possible comparison with available observations.”*

L356:

Just out of curiosity, is the change in runoff and associated solids and solutes considered in “cross-sphere feedbacks between fire and various Earth system components”? It would be relevant in 4.4.

*Authors: Yes. Changes in runoff and associated dissolved and particulate carbon and nitrogen, as well as their downstream impacts on marine ecosystems (related to Sec. 4.4), are considered as part of the cross-sphere feedbacks between fire and multiple Earth system components in FireMIP for CMIP7 (Li et al., 2025; <https://doi.org/10.5194/egusphere-2025-6115>). This citation has been added in section 4.3.*

L377:

Air-sea CO<sub>2</sub> flux is not directly output by models? Why is only abiotic carbon cycling mentioned here? How about the biological pump?

*Authors: The biological pump is introduced below, in section 4.4.3.*

In 4.4,

it would be important to mention the need to identify the variables that would allow to better constraining the role of the ocean carbon sink and then its trajectory in different scenarios.

*Authors: The following sentence has been added to section 4.4. “The new variables requested will provide additional constraints on the ocean carbon pump both historically and under climate scenario projections.”*

L399:” for potential future studies of deep-sea organisms and processes” and L406:

*Authors: The sentence was more specific as originally written, and therefore we have opted to leave it as is.*

In 4.7, I would mention if any previous CMIP6 experiments managed to capture a tipping point in the Earth System.

*Authors: Added the following to include CMIP6 instances of tipping points: “There is empirical evidence from CMIP6 simulations of the existence of critical thresholds in Earth System Models (ESMs), for example in rapid cooling events in the North Atlantic subpolar gyre (Swingedouw et al., 2021), decay and shutdown of the Atlantic meridional overturning circulation (Drijfhout et al., 2025), and dieback events in the Amazon rainforest (Parry et al., 2022), as well as more general abrupt shift events which could correspond to various tipping points (Terpstra et al., 2025). These phenomena were also reported in CMIP5 models by Drijfhout et al. (2015). Significant uncertainty remains around the mechanisms behind these regime shift events, as well as the critical thresholds that would trigger them once crossed.”*

L558, please rephrase this sentence.

*Authors: Now reads “The ES author team identified the model variables needed to fully represent the carbon cycle and achieve greater clarity surrounding how changes in radiative forcing propagate through the Earth system.”*

L602, sentence is missing a period.

*Authors: The typo was corrected*

L649: “Carbon fluxes associated and-use change” -> Carbon fluxes associated land-use change

*Authors: The typo was corrected*

*Authors note: we have also added additional clarification on variables listed in Annex 2 following a public comment made on the DR Github page: <https://github.com/CMIP-Data-Request/Harmonised-Public-Consultation/issues/109>*

*And we have updated the citations to reference the other CMIP7 special issue publications.*