Reply to anonymous reviewer

General comments

The paper is a valuable extension of the global analysis of carbon cycle feedbacks (Arora et al., 2020) and presents a useful framework that uses changes to the interior ocean carbon pools to help infer the first-order mechanisms contributing the magnitudes of regional and, thus, global ocean carbon cycle feedback parameters. The focus is primarily on how and why the strengths of the ocean carbon cycle feedback parameters vary at the basin-scale. The authors use diagnostics of the saturated, regenerated, disequilibrium carbon to help interpret these basin-scale variations. The also include a detailed mechanistic analysis of the relationship between AMOC on the feedback parameters. I particularly appreciated i) the thorough theoretical explanation for the evolution of the global ocean feedback parameters based on the contribution from the diagnosed saturated, disequilibrium, and regenerated carbon pools, and ii) the use of the box models to explore the response of these carbon pools to different AMOC scenarios.

We thank the reviewer for their positive view and constructive comments.

1) The global analysis of the evolution of the carbon cycle feedback parameters based on contributions from the different carbon pools (figure 2 with explanations rooted in fundamental chemistry) is rigorous and informative, but it would be easier to follow if this analysis were shifted and consolidated in a dedicated results section (details below).

Agreed, we will re-write/re-organise sections 2 and 3 (please see reply to comment 5 below).

2) I would have liked to see a basin-scale analysis similar to the global analysis of the evolution of the carbon cycle feedback parameters based on relative contributions from the different carbon pools. Why did you not use the same approach and figure presentation? Was it too difficult to interpret presented this way?

We agree and we will add this information for the different ocean basins (Atlantic, Pacific, Indian, Southern, and now Arctic ocean). Specifically, we will extend Figure 2 to include the 5 basins and split it into 2 figures: Figures R1 and R2 below. These figures and the evolution of the carbon cycle feedback parameters based on relative contributions from the different carbon pools for the global ocean and the different ocean basins will be presented and discussed in the updated section 3.2 (please see proposed structured in comment 5 below).

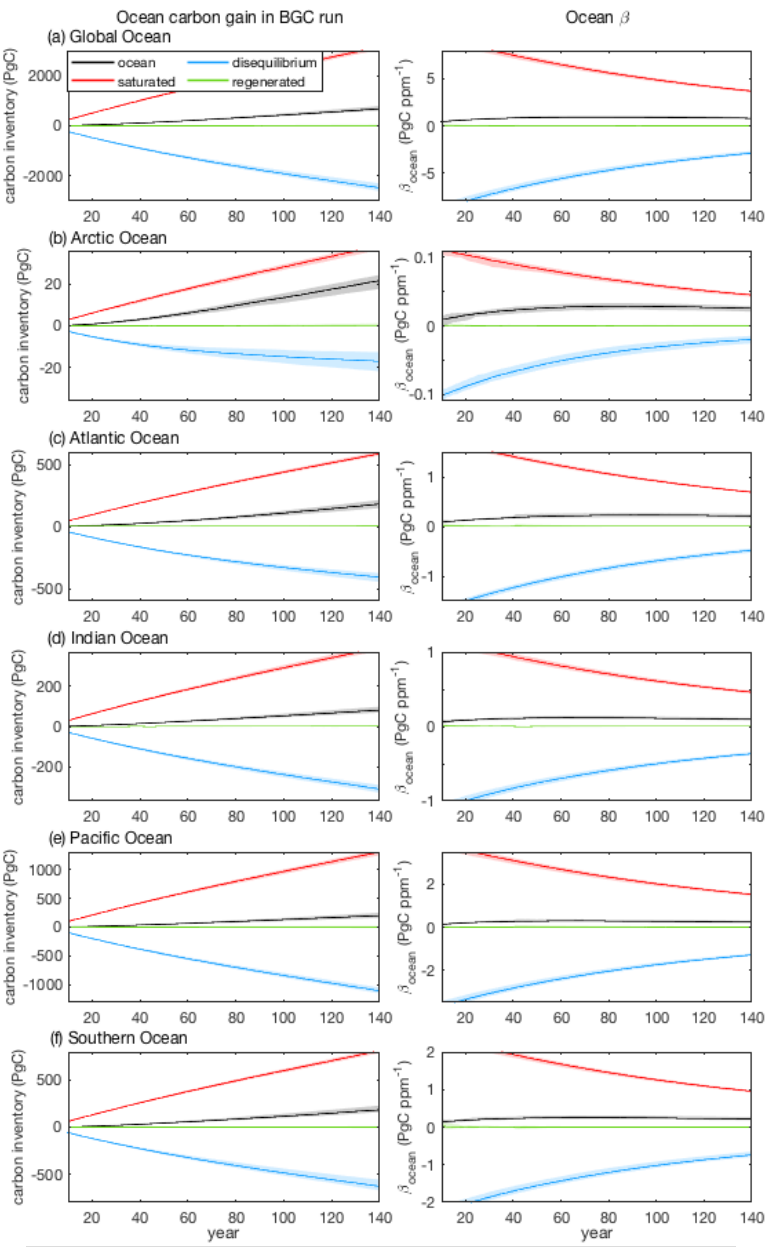

Figure R1. Ocean carbon inventory changes relative to the pre-industrial in the biogeochemically coupled simulation (BGC) (left panels) and ocean carbon-concentration feedback parameter, β (right panels), along with the contribution from the saturated, disequilibrium and regenerated carbon pools in CMIP6 Earth system models: (a) global, (b) Arctic, (c) Atlantic, (d) Indian, (e) Pacific and (d) Southern Oceans. The solid lines show the model mean and the shading the model range. Note this is an extension of Figure 2 in the original manuscript.

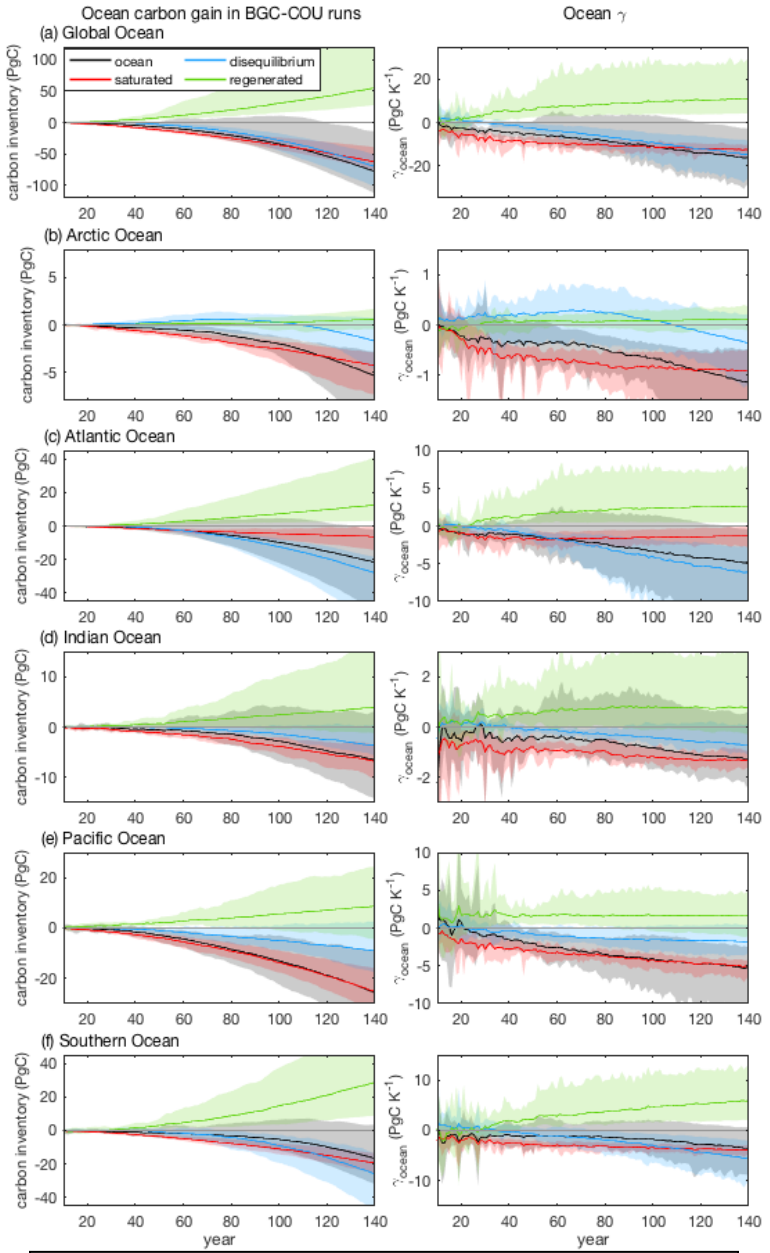

Figure R2. Ocean carbon inventory changes in the fully coupled simulation (COU) relative to the biogeochemically coupled simulation (BGC) (left panels) and ocean carbon-climate feedback parameter, γ (right panels), along with the contribution from the saturated, disequilibrium and regenerated carbon pools in CMIP6 Earth system models: (a) global, (b) Arctic, (c) Atlantic, (d) Indian, (e) Pacific and (d) Southern Oceans. The solid lines show the model mean and the shading the model range. Note this is an extension of Figure 2 in the original manuscript.

3) This paper focuses mostly on the regional feedback parameters calculated from the changes to carbon storage in the ocean interior. The ocean carbon cycle feedback parameters derived from air-sea CO2 fluxes are not analysed much here. Globally the feedback parameters based on the air-sea flux and storage approaches are very similar, but—as the authors note—differences emerge at regional scales, largely because of the influence of transport. I think it is important to introduce the reader to the strengths and limitations of these complementary approaches. For example, basin-scale feedback parameter calculated using changes in the inventories of interior carbon pools, aggregates many spatially and temporally varying processes over large ocean basins, which has it's limitations in terms of deciphering the driving mechanisms since it is integrating DIC changes that are driven by different and often compensating processes within the region and from outside the region itself (particularly in the Southern Ocean). But, on the other hand, even if the exact sources of the changes are more difficult to pinpoint, the interior carbon pools provide an integrated picture of the first order controls on changes in carbon storage in the different basins. Furthermore, we can use the diagnosis of the various carbon pools to help interpret the mechanisms behind these changes.

We will add discussion about the differences, the strength and limitation calculating feedbacks from carbon storage vs carbon flux in the proposed new section 2.2. We will also introduce new equations and symbols for the regional beta and gamma estimated based on cumulative flux versus estimated based on carbon inventory in the new section 2.1. Please see reply to comment 5 below for the new sections.

4) Here the analysis of the processes (ocean carbonate chemistry, physical ventilation, and biological processes) driving changes in the carbon cycle feedback parameters are diagnosed from changes to the saturated, disequilibrium and regenerated DIC pools. So that the reader, can better evaluate the results presented from this part of the study an honest appraisal of the strengths and limitations of this approach would also be a valuable addition.

i) For example, interpreting changes in the distributions of the different carbon pools is not always straightforward as you might hope (see spatial complexity in Arora et al., 2020). Nevertheless, basin-scale changes in carbon storage provide a natural integration of a spatially complex air-sea CO2 flux pattern.

We agree with this point and this complexity is reflected in the regional maps for beta and gamma (Figure 3). We will introduce and discuss a new supplement figure with regional maps for the saturated, disequilibrium and regenerated component of beta and gamma in the spirit of Figure 3.

ii) Even using this approach it is not possible to completely separate the various processes. For example, the regenerated component combines both biological and ventilation changes because the strength of the biological pump is also dependent on the ventilation. It seems that describing the changes in terms of their impacts on the different carbon pumps could be helpful.

We agree that the regenerated component depends on changes in the ventilation as we describe in lines 214-217 and lines 253-255, and this dependence leads to a significant correlation between gamma_regenerated and AMOC in the Atlantic Ocean as described in lines 438-440. We incorporate this effect of the changes in the ventilation on the biological carbon pool to biological processes (lines 214-217 and 253-255), since in the absence of biology this effect would be zero. We will add text to clarify that the regenerated component corresponds to the biological pump and the preformed component to the solubility pump. We then go on to split

the preformed component into two idealised pools: a saturated and a disequilibrium pool, such that we split the global solubility pump into a chemical and physical component in terms of the carbon uptake and transfer. We prefer to discuss the changes in terms of physical, chemical, and biological processes rather than in terms of biological and solubility pump, but we will clarify that the biological processes include the effect of physical ventilation to the biological carbon pool.

iii) Basin-scale variations in the change in carbon storage can't be interpreted directly as the importance of the region to the global carbon cycle feedbacks, because the source (and mechanism) of change could have been from outside the region.

The regional carbon cycle feedbacks estimated based on regional carbon inventory includes the effect from the source and the effect from the transport on carbon storage, as illustrated in Figure 3, Figure A1 and discussed in lines 270-289. We will extend the discussion in lines 270-289 to clarify this issue (please see reply to comment 3). Even for the feedbacks defined by the air-sea fluxes, separating the local from the far-field control is still problematic as the local air sea fluxes include influence from transport of carbon or other tracers like temperature and nutrients from outside the region. Here, we are using a framework to provide insight on the basin-length effect of different processes (biology, chemistry, physical ventilation) on the carbon cycle feedbacks no matter if those processes are of local or remote origin. As we briefly discuss in lines 527-530, but we will further extend in the revised manuscript, estimates of the contribution from the different carbon pools in a dynamically based density space rather the geographical space may provide further insight.

5) My main recommendation is to reorganise several sections of the paper to help clarify the methodology and distil some of the main results—in particular for the analysis of the contribution of the various carbon pools to the regional carbon cycle feedback parameters (detailed suggestions are given below).

We agree with the recommendation to restructure part of the manuscript. Following the reviewer's comments, we plan to re-organise the paper in the following manner:

1. **Introduction**
2. **Regional ocean carbon cycle feedbacks analysis in CMIP6 models**
   - **2.1 Methodology**
     Derivation of global and regional beta and gamma (equations 1-5, equations 22-23, new equations for the distinction between feedback estimates from air-sea fluxes vs ocean carbon inventory and relevant text)
   - **2.2 Regional beta and gamma in CMIP6 models: estimates based on carbon storage vs carbon uptake**
     Differences due to carbon transport: maps in Figure 3, new supplement figure showing explicitly the effect of transport (see Figure R3), expanded discussion in lines 272-293 of the original manuscript, strength/limitation of the two approaches. Refer to Appendix A for the net effect of carbon transport to the carbon storage on the different ocean basins.
3. **Processes controlling the ocean carbon cycle feedbacks in CMIP6 models**
   - **3.1 Methodology**
     Derivation of the contribution from different carbon pools on the carbon cycle feedbacks (equations 6-11, equations 17-21).

3.2 Contribution from different carbon pools to global and regional beta and gamma

3.2.1 Insight from theory

Material/text linked to equations 12-16 and Figure 2 but now modified to include results for the global ocean and the different basins (please see response to comment 2 and Figures R1 and R2).

3.2.2 Quantitative contribution from the different carbon pools

Material/text on the relative contribution from the different carbon pools to the feedbacks in terms of magnitude and uncertainty for a quadrupling of atmospheric CO2 (Figure 4 and Table 2). A new supplement figure with regional maps for the saturated, regenerated and disequilibrium component in the spirit of Figure 3.

3.3 Contribution from different ocean basins to the global ocean beta and gamma

Material associated with Figure 5 and subsection 3.2 of the original manuscript.

4. Dependence of the carbon cycle feedbacks on the Atlantic Meridional Overturning circulation

4.1 Insight from an idealised climate model with a meridional overturning

Material from section 4.1 of the original manuscript

4.2 Results from CMIP6 models

Material from section 4.2. of the original manuscript

5. Discussion and Summary

5.1 Regional ocean carbon cycle feedbacks

Material from section 5.1 of the original manuscript

5.2 Effect of the Atlantic Meridional Overturning Circulation

Material from section 5.2 of the original manuscript

Appendix A: Effect of ocean transport on the carbon storage in different basins (Figure A1 and material from Appendix A of the original manuscript)

Our new structure draws on the reviewer's recommendations, but sections 2 and 3 are separated in terms of themes rather than in terms of methods and results, which we think is more intuitive and easier to follow.

6) It is difficult to see the relative contribution of saturated, disequilibrium and regenerated carbon pools to the basin-scale feedback parameters. I would suggest adding (or modifying) a figure dedicated to the relative contributions of saturated, disequilibrium and regenerated carbon pools to the basin-scale feedback parameters. Although, Figure 4 contains this information, it can be difficult to read this information off the figure.

We will add and discuss Figures R1 and R2 to complement Figure 4 (please see reply to comment 2 above).

7) Related to the last comment, the author often presents the volume integrated quantities, which makes it more difficult to appreciate:

i) where a feedback is stronger or weaker than expected based on volume alone (Figure 5 shows this well, but sometimes it is lost in the text),

Agreed, we will re-write/re-organise section 3 and text related to Figure 5.

and ii) what processes (diagnosed using the changes to the carbon pools) dominate the magnitudes of each carbon cycle feedback parameter in each basin (not always easy to see in the Figures and tables).

We will add and discuss Figures R1 and R2 (please see reply to comment 2 above) to complement Figure 4.

8) The authors suggest they will account for the impact of carbon transport. This influence is transport is not presented in much detail, and would require a more thorough comparison of regional air-sea CO2 flux and storage feedback parameters. Therefore I would either i) elaborate on this in a dedicated section or ii) simply remove and include some reference to the impact of transport in the methodology where the relative merits of flux and storage approaches are discussed.

The direct influence of the carbon transport to the feedbacks as defined by the carbon storage is captured by the difference between the feedbacks estimated from the cumulative carbon fluxes (Figure 3.b) and the carbon inventory (Figure 3.a), and by the deficit between the black and red lines in Figure A1. We will add a supplement figure (see Figure R3 below) that explicitly shows the difference between panels a and b in Figure 3 and further discuss the regional distribution of this effect of the carbon transport on the carbon storage. We will also clarify that here we discuss the effect of the carbon transport to the carbon storage, but we do not separately estimate and isolate the effect of the transport of carbon and other tracers (e.g., temperature, salinity, nutrients) on the regional source of carbon itself, which will need further analysis.

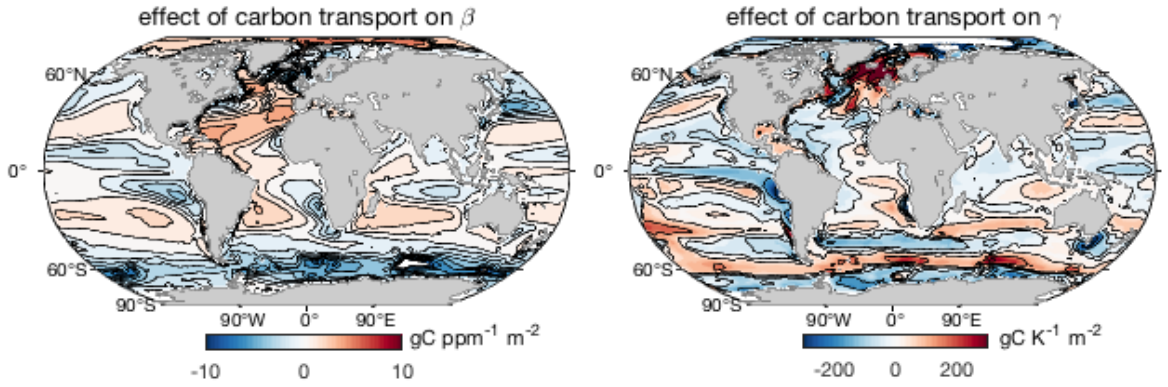

Figure R3: Geographical distribution of the effect of carbon transport on the beta and gamma based on carbon storage, as estimated from the difference between the CMIP6 intermodel mean regional ocean carbon inventory changes and the CMIP6 intermodal mean regional cumulative ocean carbon uptake from the atmosphere.

9) Several time the authors comment on the beta having less uncertainty (intermodel variability) than the gamma. This is misleading, because the uncertainty in each is mapped disproportionately onto the uncertainty in carbon storage (i.e. gamma is multipled by only > 4 deg C , while beta is multiplied by the > 700 ppm change in atmospheric CO2) .

We will clarify that the uncertainty of gamma is larger than the uncertainty of beta in relative terms (variability in relation to the mean as described by the coefficient of variation) but that beta has more uncertainty in absolute terms for the carbon storage (variability in PgC).

Specific comments

Abstract

10) On beta: “The Atlantic, Pacific and Southern Oceans contribute equally to the carbon-concentration feedback, despite their different size.” I think a better emphasis is that the Atlantic storage increase more and Pacific storage increases less than expected in relation to their size. Then mention why. Also the Southern Ocean beta is low despite the strong air-sea CO2 flux here, because it transported out of the region. what about the Indian? Summarise on the controls on beta for each basin

Agreed, we will modify the abstract.

11) On gamma: Similarly, I would summarise the dominant controls for each basin, merging the conclusions from the carbon pools and AMOC parts of the analysis.

We will modify the abstract to summarise dominant controls for each basin. We prefer to keep the AMOC part of the analysis separate rather than merging it with the controls for each basin in the abstract.

Introduction

12) lines 25 –28: Given the central importance of these feedbacks in this papers, this introduction to carbon cycle feedback parameters could be a little more comprehensive. It also a bit awkward to read. Perhaps merge the name and description of each feedback. And then finish with "These two carbon cycle feedbacks have been extensively used to...."

Agreed, we will re-write this part.

13) lines 74–79: rework section description to reflect any changes made to the sections.

Agreed, we will re-write to reflect the changes to the sections (please see reply to comment 5 for the proposed new sections).

Ocean carbon cycle feedbacks and their control by different processes

14) The beginning of this section reads like part of the introduction. I think it should be clear to the reader from the onset that this is where you will present the approach used in this paper.

I would start this section introducing your methodology and how the methodology compares to previous studies, particularly Arora et al., 2020. Something along the lines of “here we extend the analysis of the carbon cycle feedbacks diagnosed in the CMIP6 models (Arora et al., 2020)….” and then introduce what part of the analysis is identical and what parts have been modified or extended.

The beginning of the section will be modified to reflect changes/re-organisation of the section (please see response to comment 5 above). We will also clarify that our methodology is a regional extension of the methodology for the effect of different carbon pools on the carbon cycle feedbacks introduced in Williams et al., 2019 and used in Arora et al., 2020 for CMIP6.

15) I recommend separating the methodology into two parts: 2.1 Ocean carbon cycle feedback analysis, 2.2 Diagnostics of processes controlling carbon cycle feedbacks.

We will re-organise section 2 (please see reply to comment 5 above).

16) Move the results and discussion of the contribution of the global saturated, disequilibrium, and regenerated carbon pools (and the associated Figure 2) to the global carbon cycle

feedback parameters to section 3. It is very interesting and thorough and deserves a dedicated results section.

Agreed, we will move this discussion in the new section 3 (please see reply to comment 5).

17) For improved clarity, the ocean cycle carbon cycle feedbacks (e.g. recommended Section 2.1) should consolidate all the feedback methodology from other sections and include some missing elements:

We will re-organise section 2 (please see reply to comment 5 above)

(i) Clearly present and give distinguish between the feedback parameters and the carbon inventories calculated from the i) air-sea CO2 fluxes and ii) interior carbon inventories. In regional analyses this distinction becomes very important (as the authors explain). For example, you could use 'betaf' and 'If' and 'betas' and 'Is' for beta and carbon inventories calculated from carbon fluxes and carbon storage respectively.

Agreed, we will introduce terms and equations to distinguish the feedbacks estimated based on cumulative air sea flux and based on the carbon storage in the new section 2.1.

(ii) Please include a discussion of the merits/limitations of the flux vs storage approaches and their complementarity.

Agreed, we will discuss limitation and strength of the two approaches, particularly in terms of regional feedbacks in the new section 2.2 (please see response to comments 3 and 4.iii above).

(iii) Move the regional calculation of the feedback parameters (263–274) to this section.

Agreed.

(iv) The basins have not been defined. Please provide the precise boundaries used for the basin-scale analysis show boundaries on the maps in Figure 3.

Agreed, we will provide bounds in terms of latitude and/or characteristic regional features (e.g., south edge of Africa) for the basin separation in the main text and include a map that shows this separation in a supplement figure (see Figure R4 below). Note that we will also update the manuscript (figures, tables, and text) to include a separate Arctic ocean basin.

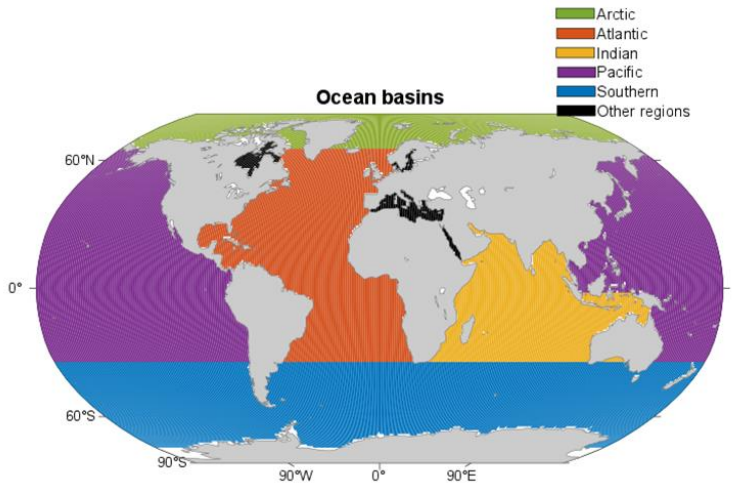

Figure R4. Geographical definition for the different basins used in our analysis. Other regions include semi-enclosed seas that are not included in any of the 5 main ocean basins.

18) For the section (e.g. recommended section 2.2) presenting the methodology for diagnosing the ocean processes contributing the carbon cycle feedbacks (based on calculations of saturated, disequilibrium, regenerated carbon pools)

(i) Start this section with something like your line 115. “To gain insight …”

(ii) Include detail here on the how the various carbon pools are used to diagnose ocean processes (ventilation, biology…) and the limitations of this approach.

(iii) I assume methodology used to calculate the carbon pools is identical to that used in Arora et al., 2020? Please elaborate. If so, it would be useful to inform the reader.

(iv) Include here only the methodology used to calculate the changes in the carbon pools and leave the theoretical explanations that are used to better understand their evolution to section 3.

We will restructure sections 2 and 3 (please see response to comment 5 above). The methodology for separating the contribution into different carbon pools follows the methodology of Williams et al., (2019) that was then used in CMIP6 analysis in Arora et al., (2020) (lines 115-117 of the original manuscript) (please see reply to comment 14 above).

19) line 81–84: this essentially repeats introductory section above (lines 25–28) and doesn’t need to be repeated here.

We disagree. Repeating this text in the methodology summarises the fundamental view of the carbon cycle feedback framework and is helpful for readers not familiar with this framework

20) line 106: this does not “exclude” all model biases because the initial biases continue to impact their evolution, but it does help reduce them. Either replace “To exclude” by “To reduce” or “To partially exclude”.

Agreed, we will revise the text to ‘reduce’.

21) line 251: replace “suggesting” with “indicating”

Agreed.

22) line 253: replace “act to reduce” with “reduce”

Agreed.

Regional carbon cycle feedbacks in CMIP6 Earth system models

23) To make the paper easier to follow, this section should consolidate the global and basin-scale analyses of the contribution of the carbon pools to the carbon cycle feedback parameters

Agreed, we will re-write and re-organise section 3. Please see reply to comment 5 above for the new structure and Figures R1 and R2.

24) You could rename the title of this section “3 Processes controlling the carbon cycle feedback parameters” and subsections “3.1 Global analysis” and “3.2 Basin-scale analysis”. Maybe there is no need for subheadings.

We plan to restructure section 3. Please see reply to comment 5 above for our new structure and title of sections and subsections.

25) The section starting on line 275 touches on the impact of carbon transport on the feedback parameters and on line 291 mentions that the study will account explicitly for the ocean

transport of carbon. Since there there is little discussion of the impact of transport on the feedbacks in the paper and the main results are added to an Appendix, these paragraphs seems out of place here. Two suggestions:

(i) Either include a more detailed examination of the impact of transport on regional betas and gammas in a dedicated results& discussion section including the figures in the Appendix. This would be interesting if it extends our understanding beyond what is presented in Frolicher et al., (2015).

(ii) Or, the spatial distribution of the ocean carbon-cycle feedbacks in figure 3 could be moved into and discussed in the methodology section where the air-sea CO2 flux and carbon storage feedback parameters are introduced and compared. Here the figures could be discussed in terms of the complementarity of the flux and storage approaches.

We will move this part of the study into the new section 2.2 and include discussion about the differences, the strength and limitation calculating feedbacks from carbon storage vs carbon flux. Please see reply to comment 5 (for the proposed new structure), and reply to comments 3 and 8, and Figure R3. We still prefer to keep Figure A1 and discuss it in an appendix such that this information is available to the reader but the new section 2.2. is kept sharp.

26) There are some places—particularly in the interpretation of the changes in the global and regional carbon pools and their contributions to the feedback parameters—where the language used to associate the changes to mechanisms, reads as if these are mechanisms have been determined rather than diagnosed. I think care needs to be taken to word the results and conclusions in light of an honest appraisal of the confidence we have in the mechanisms diagnosed using this approach (probably in the methodology).

Agreed, we will update the text to reflect that the mechanisms are diagnosed rather than determined.

27) lines 263 –271: As mentioned earlier, move this methodological detail to section 2.

Agreed, please sea reply to comment 5 above for the updated structure of the manuscript

Global analysis

28) For the Global analysis I would recommend moving the global analysis of the contributions of the various ocean carbon pools to the carbon cycle feedback parameters (I.e. associated with Figure 2) into a dedicated section, which includes the following text: the presentation of the theoretical analysis that helps us interpret the evolution of the global feedback parameters: saturated component (lines 148–196), regenerated (lines 208 – 217), and disequilibrium (lines 225–238 starting with the rise in atmospheric CO2….).

Agreed, subsection 3.2.1 will be dedicated to this insight from the theoretical analysis (please see reply to comment 5 for the updated structure).

Basin-scale analysis

29) I feel this section of the paper needs some polishing. The figures and the discussion don't always clearly separate the impact of the strength of the feedback (i.e. volume-normalised) from the volume-integrated impact. Consequently, it can be difficult to clearly see the relative contributions of the saturated, disequilibrium and regenerated carbon pools to the basin-scale parameters. This was done well for the global analysis.

We will re-organise section 3 and the text associated with the basin scale analysis (please see reply to comment 5 for the updated structure). We will also extend Figure 2 into two figures and include information for the basin-length analysis (please see reply to comment 2 above and Figures R1 and R2).

30) I find the separation between section 3.1 and 3.2 confusing. Only a short discussion of the contribution of different basins to global carbon cycle feedback parameters is needed here (the main results are already in Figure 1). The main focus should be i) the relative strengths of the carbon cycle feedbacks relative to their volumes and ii) on the analysis of the mechanisms controlling the differences between the basin-scale carbon cycle feedback parameters (volume-normalised) by accounting for the contributions from the different carbon pools.

We will re-organise this section (please see reply to comment 5 for the updated structure).

31) I would start section on the relative strengths of the feedbacks by discussing Figure 5, which is better suited for this than figure 4. For example, for beta, It is easy to see that the Atlantic takes up more and the Pacific less relative to their volumes

In the new manuscript (see reply to comment 5 for the new structure) Figure 5 will be discussed in terms of contribution of each of the basins to the global carbon cycle feedbacks. Figure 4 along with Figures R1 and R2 (please see reply to comment 2 above) will be discussed in terms of contribution of the different carbon pools to the basin-length feedbacks:

(i) the opposing or complementary effect of the saturated, disequilibrium and regenerated part on the basin-length carbon cycle feedbacks.
(ii) the magnitude and uncertainty of the contribution of the different carbon pools to the basin-length feedbacks in the CMIP6 models,

32) A figure is missing that is dedicated to the relative contributions of saturated, disequilibrium and regenerated carbon pools to the basin-scale feedback parameters. For example, you want to be able to easily see what mechanisms is responsible for the Atlantic taking up more and Pacific taking up less carbon relative to it's volume or what process dominates the carbon-climate feedback in each basin. Although, Figure 4 contains this information, since the feedbacks parameters are i) not volume-normalised and ii) the components of the feedback parameter for each region are not presented side-by-side, it can be awkward to read this information form the figure. Maybe Figure 4 could be reworked by :

We will introduce Figures R1 and R2 showing the contribution of the different carbon pools to the basin-length feedbacks as described in the reply to comment 2 above, to complement Figure 4.

(i) either grouping the contributions from each carbon pool into a plot for each basin rather than for each component.

The grouping in terms of basins rather than carbon pool components does not work well for beta in Figure 4 that focus on magnitude and range, as the total, the saturated, the disequilibrium and regenerated are different orders of magnitude (see Figures 4 and R1). However, we now introduce figures R1 and R2 that in our opinion show well the contribution from each carbon pool for each basin.

(ii) or presenting the contribution of each component to the basin-scale feedback parameters as percentage contributions, so that it is easy to clearly see how the relative contributions of the different components to the total feedback vary between the regions.

The contribution for the saturated, disequilibrium, and regenerated components to each basin or to the global ocean cannot be meaningfully presented as percentage as these different components have a positive or negative contribution (opposing each other, see Figures 4 and R2).

In contrast, the contribution of each basin to the different components (saturated, disequilibrium and regenerated) can be presented as percentages, since on average the different components are of the same sign for all the basins and for the global ocean: e.g., the contributions of the regenerated component to gamma is on average positive for all basins for a quadrupling of atmospheric CO2, while the contribution of the saturated and disequilibrium components to gamma is on average negative for all basins for a quadrupling of atmospheric CO2 (see Figures 4, R1 and R2).

33) It would be informative to see the geographical distributions of the saturated, disequilibrium, and regenerated components to help with the interpretation of the basin-scale changes and to complement the depth sections presented in Arora et al., (2020).

Agreed, we will add a supplement figure with the maps/geographical distribution for the saturated, disequilibrium and regenerated component and relevant discussion in the new section 3.2 (please see reply to comment 5 for the new structure).

Discussion and Summary

34) line 163: In "The transport effect acts to decrease the carbon-concentration feedback parameter" it is important to mention increase relative to what. That is, the carbon-concentration parameter calculated from the air-sea CO2 fluxes.

Agreed, we will clarify following the reviewer's suggestion.

35) line 473: again the intermodel variability in beta may seem small, but the impact of this intermodel variability on carbon storage is not.

Agreed, please see reply to comment 9 above.

36) line 479: "consistent with previous studies" here mention consistent with the spatial patterns of gamma diagnosed from the air-sea CO2 fluxes in the last two generations of ESMs (i.e. spatial patterns of the feedback parameters in Roy et al., 2011 and in the CMIP5 models in the IPCC WG1 assessment report Ciais et al., 2013).

Agreed, we will reference these studies here.

37) line 490: It would be useful to reference consistency with previous analyses of the drivers of the carbon-concentration parameter distributions here even if they were based on the CO2 air-sea flux carbon cycle feedbacks "as was shown in a CMIP5-generation model…. and is consistent with analyses of the carbon-climate feedback distributions from previous generation models (Roy et al., and Ciais et al., 2013)"

Agreed, we will reference these studies here.

Figures

38) Figure 4: Does not include the multimodel mean (or median). I think it would be most informative to overlay the median and IQR.

Agreed, we will add the mean (rather than the median to be consistent with the estimates in our tables), and the interquartile range in Figure 4.

39) Figure 5: It looks like some of the parts of the ocean have not been included here. I suppose there is meant to be an 'Other regions' category (inland seas and arctic?) to make each column sum up to 100%. Please explain in the caption.

Yes, this is meant to be other regions including the Arctic.

Why were these other regions left out? They contribute a substantial amount to global gamma.

The Arctic has a high contribution, and we will revise the manuscript to now introduce a separate Arctic ocean basin. We will keep only the semi-enclosed seas like the Mediterranean Sea, Hudson Bay and Red Sea in the 'other regions'.

40) ## Technical comments

There are a few places where the English needs a little work. I have picked up a bunch of them, but someone should give the document another once over.

Agreed.

Abstract

line 4: Change ". The contribution from different ocean basins to the carbon cycle feedbacks and its control by the ocean carbonate chemistry, physical ventilation and biological processes is explored in diagnostics of 10 CMIP6 Earth …." to ". The contribution from different ocean basins to the carbon cycle feedbacks and the processes that control them are explored using diagnostics of ocean carbonate chemistry, physical ventilation and biological processes in10 CMIP6 Earth …."

We will re-write this text.

line 5: Change "mechanist" to "mechanistic"

Agreed.

line 15: change "on global scale" to "at the global scale"

Agreed.

Introduction

Line 21: change "refer" to "referred"

Agreed

Line 22: change "lapse rate" to "tropospheric lapse rate"

Agreed

Line 24: change "land and ocean" to "land and ocean reservoirs".

Agreed

Line 34: change "feedback is about 3 times stronger over land than the ocean on centennial " to "feedback is about three times stronger over ::the:: land than the ocean on centennial "

Agreed

Line 55: I would remove “hence” because it implies you are going to focus on both heat and carbon in this study.

Agreed

line 56: Replace “Hence, our motive is to explore the mechanisms that lead to this regional variation in the carbon storage and the carbon cycle feedbacks for the different ocean basins…” with “Our ::motivation:: is to explore the mechanisms that lead ::these:: regional variations in the carbon storage and the carbon cycle feedbacks ::in:: the different ocean basins…”

Agreed

line 71: changes “insight for” to “insight into”

Agreed

line 72: This sounds odd. Please replace “Our aim is to provide insight for the relative contribution from different ocean basins to the ocean carbon cycle feedbacks, and the processes that drive this relative contribution and its uncertainty amongst CMIP6 " by “Our aim is to provide insight ::into:: the relative contribution of different ocean basins to the ocean carbon cycle feedbacks and the processes that drive this regional partitioning in the CMIP6 models”.

Agreed, we will re-write this text.

line 73: it reads as if you will exploring the controls of the AMOC. Please replace by something like “the control of the AMOC on the carbon cycle feedbacks”.

Agreed, we will re-write this text.

Line 76: replace “processes” by “diagnostics of processes”.

Agreed.

Ocean carbon cycle feedbacks and their control by different processes

Line 81: comma between “CO2 which”

Agreed.

Line 82: change”At the same time the increase in atmospheric CO2 modifies the physical climate system, such as for example leading to ocean warming and increase in stratification“ change to “At the same time the increase in atmospheric CO2 modifies the physical climate system, leading to changes such as ocean warming and increased stratification…. “

Agreed.

Line 84: change “ocean carbon uptake” “change in ocean carbon uptake”

We will rephrase to ‘the ocean carbon gain due to anthropogenic carbon emissions …’.

line 110: you don’t need the subscript ocean for Equation 5. I would save the subscript position for discriminating between feedback parameters calculated using air-sea CO2 fluxes vs carbon storage.

We prefer to keep the subscript ocean for clarity as we refer to ocean carbon cycle feedback parameters rather than including the contribution from land. We will however introduce notation to separate the calculations based on air-sea CO2 vs carbon storage.

line 111: choose to either capitalise or not the word “earth” in the document.

Agreed, we will use Earth consistently.

Line 115: “To gain insight for the driving mechanisms of the carbon cycle feedbacks and their uncertainty “ “To gain insight ::into:: the driving mechanisms of the carbon cycle feedbacks and their uncertainty “

Agreed

line 125: replace “extend” by “extent”.

Agreed

line 125: replace “contemporary CO2” with “contemporary CO2 concentration”.

Rather than use contemporary that has led to confusion, we will explicitly define DICsat and DICdis in terms of the departure from a full chemical disequilibrium with the given atmospheric CO2 at the same time.

Line 126: include symbol and units for carbon inventory (I.e. deltaI, PgC) for consistency with unit conversion listed below. (Odd to have unit conversion when no units have been listed as yet).

Agreed

line 127: for consistency, include units of DIC pools.

Agreed

line 128: Again you don’t need the subscript ocean here. Save it for inventory calculated using carbon storage.

We prefer to keep the subscript ocean but we will introduce notation for the difference between estimates using carbon storage vs air-sea flux.

line 132: Again no ocean subscript needed, use symbol to symbol to specify we are talking about betas calculated from carbon storage.

We prefer to keep the subscript ocean but we will introduce notation for the difference between estimates using carbon storage vs air-sea flux.

line 135: Rather than “can be expressed as” it would be more direct to write “were diagnosed” to clarify that this is what you do in this study.

Agreed

line 155: “contemporary atmospheric CO2”. Maybe I have misunderstood something here. But, I would have thought this refers to projected atmospheric CO2? Could you please clarify.

‘contemporary atmospheric CO2’ will be altered to ‘atmospheric CO2 taken at the same time’.

Regional carbon cycle feedbacks in CMIP6 Earth system models

line 263: replace “into contribution” with “into contributions”

Agreed

line 266: replace “non-linearity of ocean carbon cycle feedbacks” with “non-linearity of ocean carbon cycle feedbacks (see Equation 4)”

Agreed. We will re-organise this text and modify equations 22 and 23 following the description of the global carbon cycle feedbacks in equations 4 and 5 to avoid any confusion.

line 266: replace “n notes” by “n denotes”

Agreed.

line 305: or that the region dominating the the carbon cycle feedback differs between the models.

Agreed, we will add the suggested text.

Control of the Atlantic Overturning circulation to the carbon cycle feedbacks

The title seems back-to-front. Suggestions: "Relationship between carbon cycle feedbacks and the Atlantic Meridional overturning circulation" or "Control of the carbon cycle feedbacks by the Atlantic overturning circulation"

We will change the title for this section to ‘Dependence of the carbon cycle feedbacks on the Atlantic Meridional Overturning Circulation’

Discussion and Summary

line 494: Similarly “control of the Atlantic Meridional Overturning circulation” is not the right title. You are talking here about the control of the feedbacks by the AMOC, not the controls on the AMOC itself.

We will change the title for this subsection to ‘Effect of the Atlantic Meridional Overturning Circulation’