

Response to the reviewers

We thank the reviewer Prof. Claudine Hauri for her very helpful and constructive comments. In the following we address the comments point by point.

Terhaar et al., use 14 Earth System Models from CMIP6 to assess Arctic Ocean acidification and how these CMIP6 results compare to earlier results from the CMIP5 generation models. The CMIP6 models project a reduced uncertainty in aragonite and calcite saturation states compared to CMIP5, which is mainly due to compensation of over or underestimation of Ca^{2+} through over or underestimation of freshening and reduction of alkalinity. Overall, CMIP6 models improved on simulating max. sea surface densities and therefore better simulate the transport of Ca^{2+} into the Arctic Ocean. The manuscript is well written. There were a few sections that need some clarifications (see comments below), but in general I think this manuscript can be accepted with minor revisions.

1.1 — Page 1: Lines 35 – 37: I think this sentence should be rephrased. This could be misinterpreted to “freshening reduces the difference in a way that carbonate ion concentration will be zero”

Reply: This has now been changed to:

“ As freshwater AT and CT concentrations are generally similar, freshwater fluxes into the ocean typically act to reduce the difference between AT and CT, decreasing marine CO_3^{2-} concentrations and ocean pH (Waldbusser and Salisbury, 2014; Wanninkhof et al., 2015; Xue and Cai, 2020; Bates et al., 2009; Bates and Mathis, 2009; Yamamoto-Kawai et al., 2011). In the Arctic Ocean, projected freshening...”

1.2 — Page 2, Line 48. There are two Bates et al., 2009 references in this manuscript, so it is not clear which one the authors refer to with Bates et al., 2009. Also, I doubt Bates is the right reference here since he is a biogeochemist and not a mammal biologist.

Reply: The Biogeoscience LaTeX template formats the two citations of Bates in 2009 in two different ways: “Bates et al., 2009” and “Bates and Mathis, 2009”. If we can distinguish these two citations in a better way, we will do so.

We will remove the reference to Bates et al., 2009 here as suggested by the referee and replace it with Jay et al., 2011 and AMAP, 2018.

1.3 — Page 2, Line 49: delete “ocean”

Reply: “ocean” will be deleted as suggested.

1.4 — Page 3, Lines 55- 61. This first paragraph could be used to explain emergent constraints a bit better. It becomes clear on lines 66 -69, but readers who are not familiar with this methodology could be easily lost in this section.

Reply: The introduction and description of emergent constraints will be expanded in the revised manuscript as suggested.

1.5 — Lines 69 and 70: This is confusing. I thought emergent constraints were already applied to CMIP5 models in a previous publication (Terhaar et al., 2020a)?

Reply: Emergent constraints were indeed applied in a previous publication. That publication (Terhaar et al., 2020a) constrained C_{ant} and acidification. Both applications are important for the Introduction and therefore mentioned in the Introduction. We have decided not to add the reference again in order to improve readability.

1.6 — Page 4, Lines 110 – 112: Was the difference based on annual means, monthly means? Would be good to clarify here.

Reply: The difference is based on annual means. The sentence will be changes in the revised manuscript to as follows:

“ C_{ant} was defined as the difference between annual means of dissolved inorganic carbon in the historical (1850–2014) simulations merged with the respective Shared Socioeconomic Pathway (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) (2015–2100) (Riahi et al., 2017), and the concurrent pre-industrial control simulations of each model.”

1.7 — Page 5: Line 137: How were historical atmospheric CO₂ concentrations refined? Reference?

Reply: In CMIP6, the historical global annual mean CO₂ concentrations were updated with additional data available since CMIP5. Furthermore, global CO₂ concentrations were additionally provided as monthly latitudinally resolved concentrations with model groups free to choose the forcing files they use. This will be detailed in the revised manuscript with the appropriate reference provided.

1.8 — Overall, I think the methodologies would become clearer if the authors included a more detailed explanation on how emergent constraints were used on the CMIP6 models. I realize that there was a section on emergent constraints in the introduction, but 1) I found this section hard to follow, and 2) it wasn't clear whether this was only applied to CMIP5 or also CMIP6.

Reply: We will try to make this introductory section on emergent constraints easier to follow. In addition, the following details on how we applied emergent constraint techniques will be added to the Methods in the revised manuscript:

“To calculate the emergent constraint, first an ordinary least squares regression was calculated between the simulated present-day maximum sea surface density and the Arctic Ocean C_{ant} inventory in 2100 for each ESM of the CMIP6 model ensemble. The uncertainty range was estimated using the $1-\sigma$ prediction interval. In a second step the probability density functions (PDFs) from the observations was convoluted with the PDF from the linear regression, assuming a Gaussian distribution in both cases. The convolution of both PDFs is the constrained projection of the Arctic Ocean C_{ant} inventory following previous studies (Cox et al., 2013; Wenzel et al., 2014; Kwiatkowski et al., 2017).”

1.9 — Page 7, Lines 177 -183: Since results from the historical simulation were compared to CMIP5 it might make sense to compare the 21st century results to CMIP 5 as well? Or even better all together move this comparison to the section dedicated to CMIP5 and CMIP6 comparison later on (see comment below)

Reply: This will be moved as suggested by the referee.

1.10 — Page 10, Line 201: “the upper 1000m of the Arctic Ocean” does not make sense. This could be interpreted horizontally or vertically. It also needs to be clarified whether it is from the surface or bottom.

Reply: This will be changed in the revised manuscript from “the first” to “the upper 1000 m”.

1.11 — Line 209: reword “first 1000 m”

Reply: This will be changed in the revised manuscript to “the upper 1000 m”.

1.12 — Line 212: maybe change to “between 100 and 1000 m from the surface”

Reply: This will be changed as suggested.

1.13 — Page 11, section 3.3 Since you are comparing CMIP5 and CMIP 6 results here, I would get rid of the comparison you do at the beginning of the results to avoid repetition and simplify everything.

Reply: This will be changed as suggested by the referee.

1.14 — Page 17, line 360: first comma does not seem necessary

Reply: The comma will be deleted.

1.15 — Line 378: “area” does not seem necessary in combination with refugia.

Reply: “area” will be deleted in the revised manuscript.

1.16 — Line 380: As mentioned earlier, I’m not sure Bates is the right reference here.

Reply: We will remove the reference to Bates et al., 2009 here as suggested by the referee and replace it with Jay et al., 2011 and AMAP, 2018.