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Interactive comment on "Increase in ocean acidity variability and extremes under increasing atmospheric CO_2" *by* Friedrich A. Burger et al.

Anonymous Referee #1

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General comments:

This is a nice manuscript that assesses extreme chemistry variability in ensemble projections of an Earth system model. The manuscript is both interesting and timely. My comments mainly relate to improvements I think the authors could make in understanding the different drivers of carbonate chemistry variability. Particularly, I'd like to see more on the physical processes driving the differences between the RCPs and the projected frequency/intensity/duration of extreme variability events.

Another general issue I think is how the authors choose to define extreme events. I would be more comfortable calling these "extreme variability events" given that mean trends have been removed. This is particularly an issue when they discuss saturation state and often give the impression that extreme events are projected to decline.

Finally, given that the carbonate chemistry decompositions apparently do not sum, I'm not convinced of their value. I suggest removing this analysis if it can't be properly validated.

Specific comments:

L21-23. This could be better explained. I suggest a sentence or two more, including a full definition of omega.

L43. I don't think Hofmann et al., 2011 is really relevant here as they don't assess organism adaptation/acclimation under variable chemistry regimes. Many other papers do, with mixed findings, for example see: (Rivest et al., 2017; Cornwall et al., 2020)

L45-48. The authors are being too concise here. Explain what you mean by undersaturation. I understand that you might have to refer to aragonite versus calcite but that should probably be already mentioned anyway.

L77. Its not very clear what "residual" means in this context, as it hasn't been defined yet.

L90. What is the depth of the first ocean level? This will useful to know, as it will be a major determinant of surface variability.

L120. What is potential vegetation? Are you referring to a coupled terrestrial carbon cycle? It is not clear what relevance this has.

L142. Do you mean that extremes that last over a change in year are split in two?

L143-145. It would be worth saying something about why this upper ocean region is so important e.g. location of most reef forming corals, calcifying phytoplankton etc.

Fig 1. Legend. This second line of this needs clarifying. I guess you're subtracting the ensemble mean change not the ensemble mean. You should say what reference years are used to calculate this ensemble mean change.

L160-165. The methods here are quite convoluted. An illustrative figure highlighting the different steps in the approach would really benefit readers. This could go in the main text or appendices.

L185-186. This suggests something is wrong with the decomposition. At any rate I'm not sure you can call this a decomposition if the separate terms don't sum. How far off summing is the decomposition? If it's not working its value is highly questionable and probably shouldn't be included.

L206-209. Has something like Table A1 been published elsewhere? I would move Table A1 into the main text. It's a nice finding that your observation-based product shows H+ seasonal amplitude increases and variable trends in omega seasonal amplitude. This forms a nice link between this work and the Landschützer et al., 2018 and Kwiatkowski & Orr, 2018 papers.

L239. What is meant by coherently here?

L255-256. Is this true? In Fig 3c/d this appears true under RCP8.5 but the opposite seems to occur under RCP2.6. Indeed the projections at 200m under RCP2.6 are very interesting and quite different across metrics. Any idea why the duration is so much more responsive? Some more detail here would be great. Are there reductions in stratification post 2040 in RCP2.6? I wonder if greater vertical mixing under mitigation might be driving the halt/slight decline in the duration of events and the difference in lags across metrics.

L275-279. More care needs to be made when making these sort of statements as the mean decline in OmegaA has been removed. I would call this variability/extreme variability not extreme events/extreme days.

L299-300. Could this be because the areas of upwelling are moving polewards in the model (see Rykaczewski et al., 2015)? Poleward of these grey regions there appears to be a general increase in extremes, which fits this narrative. Can you check upwelling

or some proxy of this in the model?

L313. Extreme "variability" events would perhaps be more accurate (here and elsewhere in the manuscript).

Section 3.4 As stated above, it's hard to have confidence in the decomposition if it doesn't sum to the model realisation. Maybe the authors would be better to focus on physical processes (upwelling/mixing/ice loss) and how they might explain changes in variability.

L394-395. Some further detail is needed here I think.

Section 4. I recommend dividing this into a few small subsections.

L411-414. But presumably once omega<1 is reached, the ocean spends a greater amount of time undersaturated when this reduced variability is taken into account. Can you comment on this?

Fig 11. This is an interesting figure.

L424-425. This is computationally a big ask. Maybe the community could get by with some daily statistics output at monthly resolution?

L448-449. This seems off topic.

L471. I think you need to clarify some of these definitions. To most people seasonal cycles are a form of sub-annual variability.

Technical comments:

L36. A reference is needed at the end of this paragraph. Some of those already cited in this paragraph would suffice.

L39. The formatting of multiple references here is different to elsewhere in the manuscript.

Fig 1. Legend. Mention that this is for the surface ocean.

L221-224. It would be clearer to discuss model performance at capturing mean seasonal cycles before discussing trends in seasonal cycles.

L272-273. I would rephrase this. 200m is not really the deep ocean.

Fig 5. Labels (extreme days/intensity/duration) on left of this figure would make it easier to read.

336. “during the” preindustrial

References

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