Reviewer 1:

The manuscript provides a comprehensive review and discussion point about how the biogeochemical coupled hydrodynamic could be used in an Ocean Alkalinization experiments.

The manuscript lays out all the processes and questions any project about OAE should explore. It provides a Guide to Best Practices.

I found the manuscript well written, with only a few points of discussion that could be added, listed below.

Response: We appreciate the constructive comments and positive review.

A few dotted points related to the manuscript:

- Any OAE experiment will require the modelling exercise to be complete as soon as the experiment is underway (near real-time) or, even better, in a forecast mode. There are many operational systems available at the global scale but few at the scale of OAE (regional to sub-regional). This is an essential point as the availability of forcing data initial conditions are crucial elements to any modelling system.

Response: We agree and added the following statement in section 2.1.2:

" In this context, model simulations are particularly useful if available in near-real time or in forecast mode. This requires specification of lateral boundary conditions and atmospheric forcing up to the present and into the future. Global 1/12th-degree nowcasts and 10-day forecasts of ocean conditions are available from the Copernicus Marine Service (CMEMS 2023) and atmospheric forcing up to the present and 10 days into the future are available from the European Centre for Medium Range Weather Forecasts (ECMWF 2023)."

References

ECMWF 2023. European Centre for Medium-Range Weather Forecasts (ECMWF) IFS CY41r2 high-resolution operational forecasts (Accessed on 06-10-2023).

CMEMS 2023. Global Ocean Physics Analysis and Forecast. E.U. Copernicus Marine Service Information (CMEMS). Marine Data Store (MDS). DOI: 10.48670/moi-00016 (Accessed on 06-10-2023)

- In Section 2.2.3. I would add the resuspension due to waves as a significant process in representing the sediment-water exchange. While it only applies to particles, resuspension can be crucial in enhancing carbonate particle dissolution. (Eyre, B. D., Cyronak, T., Drupp, P., De Carlo, E. H., Sachs, J., & Andersson, A. J. (2018). Coral reefs will transition to net dissolving before end of century. *Science*, *359*(6378), 908–911. https://doi.org/10.1126/science.aao1118)

Response: We are not aware of evidence that resuspension enhances carbonate dissolution. The reference provided makes no mention of resuspension.

- In section 2.3, I would add a point about the development of unstructured model mesh. Using unstructured mesh allows increasing resolution in a specific area while retaining the ability to have a lower resolution elsewhere to capture larger-scale processes. It can act as an alternative strategy to multiple model nests.

Response: We had already mentioned unstructured grid models (line 204) and native grid-refinement (line 551). We have modified the latter sentence as follows to explicitly use the term unstructured grids (new text in bold):

*"Native grid-refinement**, e.g. via unstructured grids,** is another approach that may be pursued to effectively support OAE research."*

- The discussion about the use of DA in OAE could be simplified. While there is room to develop news DA technic to assist OAE, I don't see DA as a major player in OAE.

Response: We feel that DA is needed to achieve the most accurate model simulation possible and would like to point to the first comment by the reviewer, where they call for forecast simulations for OAE. We would like to emphasize that forecasts will be more accurate if they involve DA. In section 3.3, we explain (text bolded here for emphasis):

*"Data assimilation (DA) **is the process of improving the dynamical behavior of models** by statistically combining them with observations."*

and

*"Application of DA for ocean models is typically applied for one of two purposes: (1) **to systematically optimize model parameters**, e.g., phytoplankton growth and nutrient uptake or rates of background dispersion, and (2) **to estimate the ocean state**, e.g., distributions of temperature, phytoplankton biomass, alkalinity"*

For separation between OAE signals and natural variability, more accurate, data-assimilative simulations will be much more useful than simulations that display a lot of unconstrained natural variability. Time of emergence, as is commonly used in climate change projections, is likely too imprecise for quantification and verification of OAE impacts. Application of DA will enable more precise attribution. We added the following sentence to tried to improve on this aspect by adding the following text in section 3.3 to articulate this important point:

*"**State estimation offers the potential to constrain variability such that OAE-induced perturbations of carbonate system parameters can be documented even if they are smaller than the natural variability in the study region.**"*

Furthermore, DA methods provide a useful framework for uncertainty quantification, as described in section 3.4.

In the Introduction we modified the text as follows to better explain why DA is helpful and likely needed (new words in bold font):

*"Applications of realistic models rely on them being skillful and accurate, requiring that they include parameterizations of the relevant processes, and that they are constrained by observations that contain sufficient meaningful information **(what is sufficient depends on the application and research question)**. Methods **for constraining models by observations through statistically optimal combination of both** are available. Application of such methods is referred to as data assimilation and provides the most accurate estimates of biogeochemical properties and fluxes."*

- On the other hand, the author could discuss the use of DA in the optimisation phase of any OAE, for example, some of the DA machinery could be used to optimise the amount of Alkalinity being released to maximise the impact area.

Response: In our experience, this type of analysis can be done efficiently as a sensitivity analysis. DA feels like overkill in this context.