Reply to Reviewer #1

REPLY: We grately appreciate the reviewer for reviewing our manuscript very carefull and providing constructive comments. Here, we would like to reply to the comments point-by-point and will upload the revised manuscript following these comments. Please note that any revisions in the manuscript will be given in **blue-color font** for easy-tracking and line numbers are for the revised manuscript.

General comments

This study evaluate the implications of physical biases on the simulated marine biogeochemical processes in the tropical Atlantic Ocean for 4 different version of a ESM. The models used are different versions of NorESM, an earth system model with different components, with an increasing degree of complexity and resolution. The different results are compared to a base solution, NorESM1, taken as the benchmark.

The main improvement was to decrease the bias of annual mean of SST, giving rise to a realistic development of the Atlantic Cold Tongue (in geographical location and timing), and hence the marine primary production in the Equatorial Atlantic ocean. This shows the clear link between the physical cycles and the biological ones. Consequence of the improvements in the physical representations of the system, is also the improvement of the carbon cycle representations, discussed in the manuscript mainly in terms of air-sea C02 fluxes.

The development of the manuscript start by a broad review of the oceanography of the tropical Atlantic ocean, including it's links with coastal phenomena (river inputs), the circulation in neighboring tropical systems, and characteristics phenomena of variability in the region (Atlantic Niño's), and the consequences in terms of anthropogenic and global change effects. The role of ESM is also introduced as key tools, as well as the importance of the physical phenomena on the biogeochemical cycles. Their biases in the physical components clearly decreases its performance downstream regarding the biogeochemical cycles (primary and secondary, oxygen, carbon).

Within this problematic issues, the present manuscript introduce the physical, biological and chemical components of the several versions of the NorESM configurations, and analyze the improvements with relation to the base model, concerning the mean annual, the seasonal and inter-annual time scales.

The NorESM model contributes to CMIP (5 and 6), which provide a degree of general quality and confidence on the results. However, for someone not necessarily familiar with global scale model analysis and its limitations, the large bias reported, even in the most recent (with better performance) versions,

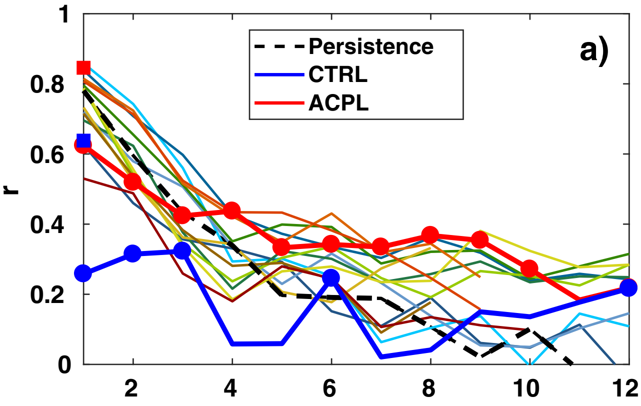
give reasons for some degree of concern regarding the confidence for simulations for the recent past / present and mainly the future scenarios.

The structure of the results starts from the comparison with climatological standard data, and the reasons to induce so large bias, primarily associated to wind stresses and air-sea fluxes in the atmospheric components. The improvements of the different versions justify its application, in terms of horizontal and vertical distributions (Figures 1 and 2).

The seasonality is analyzed along the equator in terms of SST, primary production and PCO2 when compared to the climatological values, (Fig 3) and a thorough analysis (although a bit 'too verbose') of the differences and the improvements was done in the manuscript.

The next step was to analyze the interannual variability, dominated by Atlantic Niño/Niña phenomena. One wonders if the models are able (or not) to reproduce the actual Niño/a's years in the recent pass (I think that the response is probably not), as the forcing used in the most advanced models should include the atmospheric mechanisms (wind stress anomalies) to start Niño/a(s). I think that some comment should be done around this issue.

REPLY: We grately appreciate the reviewer for reviewing our manuscript very carefull and providing constructive comments. In terms of reproducing the general characteristic of the observed Atlantic Niño/Niña, the reviewer is correct that even state-of-the-art prediction models still have numerous challenges to overcome. However, as Fig.R1 shows (obtained from Counillon et al., 2021) that physical bias correction, which was also employed in our study (ACPL) has a potential to alleviate the low prediction skill of Atlantic Niño index in the equatorial Atlantic (please note that our models are identical with Counillon et al., 2021). In this prediction system, sea surface temperature anomaly is initialized.



FigR1. Prediction skill of ATL3 index (20W-0 and 3S-3N) performed by NorESM1-CTL (blue) and NorESM1-AC (red). Obtained from Counillon et al. (2021). Values close to one indicate high predictive skills. X-axis denotes leading time (month).

While the paper showed the improventment in predictive skill, May-initialized prediction has relatively lower improvement, indicating that the prediction of Atlantic Niño/Niña and the corresponding marine biogeochemical processes is far from satisfactory. We added this discussion in the **Summary and Discussion**. Please see lines at 490-492.

The analysis centered the attention around the STD of several fields, (Fig 6), composite anomaly differences in the horizontal (Fig 7) and in vertical sections (Fig 8 and 9) for different variables. It seems to me a too technical and specialized explanation section for modelers, while I would expect some comments within the discussion section about this important issue.

REPLY: The motivation for the analysis is (1) because the state-of-the-art ESMs like CMIP6 still have big issues in not only climate state, but also inter-annual variability in the tropical Atlantic, it is important to investigate the variability in different model configuration and (2) because recent studies show impacts of the Atlantic Niño on marine biogeochemical processes like Chrolophyll (Cheniatt et al, 2021) and sea-air CO_2 flux (Koseki et al., 2023), it is really important to assess the model performance in terms of marine biogeochemical response to the Atlantic Niño. Because it seems that we did not clearly mention part of this motivation in the manuscript, we added the motivation in the beginning of the Section 3.2. Please see lines at 307-309 and 310-312.

Otherwise the manuscript are well organized and well written, and deserves to be published in my opinion.

REPLY: Again, thank you very much for the reviewer's constructive comments and positive reviewing.

Specific comments

The description of the different versions of NorESM model is rather difficult to follow for someone that does not know the NorESM* system, and a table containing the four versions and main features would help to the reader better identify the common points and differences between models.

REPLY: Thank you very much for this suggestion. We have added a table of four configiuraitons of NorESM we used in this study as shown below. This table is added as Table 1 and description of it has been added in the **Section 2.2: Model configurations**. Please see lines at 135-136.

	Atmosphere	Ocean	Bias Correction	New Paramerization / Updates	Ensemble Number	Historical Period
NorESM1-CTL	CAM4 (143x96)	MICOM (319x384)	No	No	5	1990-2019

NorESM1-AC	CAM4 (143x96)	MICOM (319x384)	Anomaly Coupling (Toniazzo and Koseki, 2018; Counillon et al., 2021)	No	5	1990-2019
NorESM2-LM	CAM5 (143x96)	BLOM (319x384)	No	Ocean mixig layer (Ilicak et al., 2009) Ocean eddy diffusion (Eden et al.,2009) Atmospheric angular momemtum (Toniazzo et al.,2020) More details, Seland et al. (2020)	3	1990-2014
NorESM2-MM	CAM5 (287x192)	BLOM (319x384)	No	Ocean mixig layer (Ilicak et al., 2009) Ocean eddy diffusion (Eden et al.,2009) Atmospheric angular momemtum (Toniazzo et al.,2020) More details, Seland et al. (2020)	3	1990-2014

Table 1. List of four different configurations of NorESM simulation.

From my point of view the way how the Figure 4 , containing Taylor diagrams of the SST, PP and CO2 fluxes was done, should be better explained.

REPLY: Thank you very much for this comments. We improve the description and explanation of the Fig.4. Please see lines at 255-259 and 260-264.