

Biogeosciences Discuss., referee comment RC2
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Comment on bg-2021-301

Anonymous Referee #2

Referee comment on "Acidification, deoxygenation, and nutrient and biomass declines in a warming Mediterranean Sea" by Marco Reale et al., Biogeosciences Discuss.,
<https://doi.org/10.5194/bg-2021-301-RC2>, 2022

General comments:

This paper describes new high-resolution coupled (physic and biogeochemistry) simulations made under the RCP 4.5 and 8.5 scenarios for the Mediterranean Sea (MED). This work is in line with the studies that have been carried out over the last ten years to assess the effects of climate change on the circulation and biogeochemistry of the MED. The main improvement here is the use of a higher spatial resolution than the previous studies. I acknowledge the huge amount of work and computational time that is required to run such simulations and I do think that this study is a step forward to a better understanding of the effect of climate change on the MED. However, despite the overall good quality of this work, this paper could be improve.

The use of higher resolution simulations could significantly improve our understanding of the MED in the context of climate change, but the authors don't really highlight the interest of such high resolution in the manuscript. The authors propose an analysis based on two averaged integrated depths 0-100 m and 200-600 m for 8 Mediterranean sub-basins losing in my opinion the opportunity to fully take advantage of their model resolution. Furthermore, the discussion as proposed here lacks rigorous comparison and discussion with the existing literature which could emphasize more the importance of high resolution. I also have concerns about the methodology, for example (but not only) the choice of the reference periods (2005-2020) that have been taken into account including the beginning of the scenarios, and the choice of allowing only the dissolved inorganic carbon to change at Gibraltar Strait.

Specific comments :

Biogeochemical spin-up:

Some important information about the spin-up is missing for biogeochemistry. Please specify how you did the spin-up and how long it runs before being stable. It is briefly mentioned in section 3.1 but this should be presented before.

Boundary conditions:

The boundary conditions are kept constant except for the DIC. Why all the variables of the carbonate cycle aren't treated the same way? Furthermore, did you use boundary conditions from a global RCP 8.5 for the MED RCP 8.5 simulation and a global RCP 4.5 for the MED RCP 4.5 simulation?

Overall, this needs to be discussed as it could change the DIC / ALK ratio at Gibraltar Strait that might be important for pH variations in the MED. Please, specify how the DIC concentration evolves at Gibraltar Strait. A table representing nutrients and carbonate system variables for Gibraltar Strait and rivers will be appreciated.

Periods selection PRESENT MID and FAR:

A PRESENT period of 15 years was chosen and compared with MID and FAR periods of 20 years. How this could impact your results? Why don't you choose 20 years as well for the PRESENT period?

During PRESENT period (2005-2020), the simulations are already in scenarios mode, as the RCP scenarios start in 2005. Therefore, the PRESENT period encompasses change linked to climate change which could lead to bias for evaluating the effect induced by climate change. Indeed, major differences between the 2 simulations considering the 2 RCP scenarios may appear during the PRESENT period, as observed for zonal stream function on your figure 4. Usually, the reference period is chosen among the hindcast part of the simulation to avoid those issues (Richon et al. 2019; Pages et al. 2020b, and others). Did you run a hindcast part before the scenarios? Please, at least, discuss your choice of the reference period and how it may affect your results.

Statistical significance:

There is no indication in the text about the significance of the differences obtained for comparison between the MID and FAR periods. The word 'significant' is used but without

statistics. In order to evaluate whether the numeric differences are substantial, it is necessary to calculate some parameters such as the t-student (See line 517 as an example) and to indicate if the variations are significant in the text and in the figures.

Some temporal correlations are indicated over the manuscript, for example between oxygen concentration and decrease of MLD, but any values are given (r and p-value) to assess the results. Please add some statistics.

Model validations:

Please add more quantitative validations with for example a Taylor diagram.

The model is validated based on 2005-2020 averages made with the CTRL simulation forced with RCP scenario. As mentioned before, it is not well suited to use that for model validations because the scenarios already have an impact. Could you discuss the potential implications?

Discussion limitations:

The discussion is interesting overall but there is a lack of links between the paragraphs and some parts could be more detailed.

Line 718, it is indicated that the signals are in agreement with the previous literature. This is not exact at least for the NPP as Macias et al. (2015) pointed out a decrease of the primary production rates in the Western Basin and an increase in the Eastern Basin, and Pages et al., 2020 a general decrease of the NPP. Please, address the variables one by one, the differences between the models results are a strength if they are discussed.

The use of 1/16 resolution grid is one of the strengths of this study but I think this needs to be more discussed as said in the General comments section. This point has been highlighted in the introduction and is supposed to be the main improvement of this study. However, in the current state of the discussion, it seems that the same conclusions may have been reached with a lower resolution.

Could you accentuate the discussion around the difference observed between the RCP 8.5 and the RCP 4.5 ?

Mixed layer depth:

How did you define the mixed layer depth? Please add this information to the manuscript.

NPP :

The effects of the model equations on the NPP trends could be more discussed. This is an important difference between the models which needs to be addressed. Your model equations assume that the planktonic community will remain the same over the next century without adaptation to warmer temperatures, which is unlikely. Furthermore, O'Connor et al., (2011) is cited to explain particulate organic matter decrease despite NPP increase. This paper focuses on terrestrial plants and herbivores which are very different from phytoplankton. Please, add other more appropriate references.

Nutrients :

A nutrients peak is obtained with the RCP 4.5 simulation between 2055 and 2075 (figure S7) and described in lines 455-456. How do you explain this peak? At Gibraltar's Strait the nutrient concentrations are supposed to be fixed, so did the surface water flux change? Could you explain why?

To the best of my knowledge, the Atlantic inflow is hypothesized to increase a bit over the next century due to stronger evaporation in the eastern basin that will increase the SSH gradient. Might this strong peak (and the even higher peak in 2095) be related to model instability?

Could you also explain why we didn't observe the peak in the RCP 8.5 simulation where the effect of climate change should be even stronger?

This is concerning as this nutrient input affects the response of the WMED (see for example your figure 12 where a peak is visible for the organic matter).

Vertical stratification affects the sinking velocity of particles:

It is suggested that vertical stratification affects the sinking velocity of particles (lines 544-545). To my knowledge, even if stratification might impact the downward flux of particles, most of the models didn't take that into account. Could you please explain how it is taken into account in BFM?

DIC and pH :

Line 626: "Disentangle the temperature and DIC contributions ..." how did you do this?

Figures :

There are 18 figures in the manuscript and 14 in SM which is a lot.

The figures like figure 5 (14 are concerned) presented in the supplementary material could be sum-up in a table. The manuscript will become easy to read (mostly the result section) with fewer references to the supplementary material.

In general, there are issues with the figures. The captions are generally not detailed enough and need to be re-written. The units need to be on the figure and not only in the captions. There are cosmetic issues on the figures. Here are a few random examples (more are given in the minors comments section) :

- Figure 3 the labels are too small, units for temperature?

- Figure 4 units? and please, add a map showing the location of the transect

- Figure 16, there is no label for the year, and apparently, you give twice the WMED, d,e,f should be EMED

- Figure S7, the y-axis label is too stretched, use scientific notation you will have more space.

- Figure S8 (S9) the size of both color bars seems to be different.

Technical corrections :

Figure 1: Please highlight extend of the Atlantic buffer zone in the figure. In general, I would like to see the unit below the scale/color bar of a figure, this comment applies to all the figures of the manuscript.

Line 75: "all focusing on high emission..." replace all by "mostly" as Macias et al., 2015 use the RCP 4.5 that is not a high emission scenario.

Line 76: A1B climate change: please explain

Line 83: A2 emission scenario: please, relate to the RCP scenarios used here

Lines 94-95: "Moreover, the work also projected ..." change by "Moreover, Solidoro et al 2020 also ... "

Line 109, line 115: same paragraph as before

Line 116: You say 70 vertical levels and later (line 150) you say 72 please correct that.

Line 118: You need to define the acronym you use MFS16 and OGSTM-BFM and add citations for both.

Line 138: Same thing as before for OPA this time.

Line 145: Same for NEMO.

Line 153: Same for CMCC-CM. I will not continue to list those errors, please be sure that every acronym is defined as it is first used.

Line 188: chemical reactions

Line 191-192: CaCO₃

Lines 294- 276: I think this is an interesting

approach but this paragraph is difficult

to read. Could you try to make it a bit more clear? I think that bringing the S1 figure here could be helpful for the reader.

Line 297: Specify the periods of the satellite climatology.

Line 310 - 315: The spin-up information needs to be completed and added before in the manuscript.

Figure 2: Please add the units on the figure for the profiles, and the map. This remark applies to all the figures of the manuscript.

Figure 2 Add the source of the dataset cited in the caption.

Figure 3 : The font size of "Year" is too small, this applies to other figures that show time series. If I understand correctly, the variables that you show here are corrected from the CTRL bias ($X_{anom}(k)_{scen}$), please mention it in the caption. Those comments apply to the other times series of the manuscript.

Furthermore, why did you apply a 10-years running mean here and not in figure 7?

This 10-years running mean is not mentioned in the manuscript (unless I miss it) so it is confusing.

Line 338: Give more citations here.

Line 348: remove "Fig. S2 in the supplementary material" by (Fig. S2 and S3). The "in the supplementary material" is not necessary and you are not using it all the time, so, remove it everywhere in the manuscript.

Line 360: replace "increased freshwater deficit" by "decreasing freshwater discharge"

Figure 4: I would like the unit near the color bar. You need to show the location of this zonal stream function over a map.

Figures 5: Again, place the units near the color bars. For the caption, there is not enough information to understand the figure. What are the values in green squares? What is the MID-FUTURE/ FAR-FUTURE ? The unit given is just for the 4 top figures. Please change the caption to take this into account. This comment is valid for all the other figures in the manuscript and in the supplementary material that looks like figure 5.

Line 384: Define EMT.

Line 418: Fig.S6 add space.

Line 507 : (Fig. 12) should be Fig. 11

Line 555 : (both phyto- and zoo-) remove the -

Line 658: Should be Figure 17

Line 724: change Pages et al 2020 for Pages et al 2020b. This applies to all the manuscript.

Line 856: in the bibliography, certain references format are not coherent. For example at line 856 all the authors aren't listed there is an et al. This is the same for lines 890, 902,916, 933, 1006, 1080, 1103.

Line 902: Punctuation is wrong

Line 982: Format issue