

First, we would like to thank Julien Palmiéri for his careful evaluation of our manuscript and his interesting comments which we believe will help us to improve it. Please, find hereafter our response to these comments.

Major comments

1) First, the reason of the choice is not given. I understand it is greatly needed for developments like adding the mixotrophs in Eco3M. It's a huge task that require such lightweight configuration to test, verify that nothing is broken, and make sure the fluxes between each element of the model are reasonable. So, this choice is easily explained for the part 1, but less for this one.

We agree with this point. The use of a 0D configuration may seem more justified for the first part of our study as adding mixotrophs required many tests.

We chose to also use a dimensionless configuration for the part II as we wanted to provide a reliable representation of the carbonate system, which consider mixotrophs organisms, in the simplest way possible. In other words, we wanted to provide a tool which is easy to use, easy to adapt to other coastal area (by modifying the environmental forcings and the AT-S correlation) and give reliable results in a short amount of time.

Another reason to use a dimensionless configuration rather than a 3D configuration was the possibility to compare Eco3M_MIX-CarbOx to Eco3M-CarbOx in the same type of implementation. By comparing the models, we can answer several questions and especially: How mixotrophs affect carbonate variables ? Does adding them provide a more accurate representation of these variables ? and then build further relevant simulation strategies for 3D.

Considering these reasons, this dimensionless configuration can be seen as a laboratory to test and then build further relevant simulation strategies for 3D.

To justify the use of a 0D configuration, we first clarified the aim of the study at the end of the introduction (l.79):

[Here we try to provide a more realistic representation of carbonate system variables in the BoM. As a starting point, we used the concept of the dimensionless Eco3M-CarbOx model (Lajaunie-Salla et al., 2021), which aims to represent a small volume of surface water (i.e., 1 m^3) in the BoM. We developed a planktonic ecosystem model which contains, among others, mixotrophic organisms, modified the carbonate module described by Lajaunie-Salla et al. (2021) and added it to our newly developed planktonic ecosystem model to obtain the Eco3M_MIX-CarbOx model (v1.0). We implemented two types of TA formulation and compared the simulation results to in situ observations to identify which formulation was capable to deliver the more realistic results: (i) a formulation that only considers biological processes (referred to as autochthonous formulation) and (ii) a new TA formulation that depends only on salinity (referred to as allochthonous formulation). Furthermore, we simulate air-sea CO_2 fluxes to determine whether the BoM act as a sink or a source of CO_2 and provide a detailed analysis of drivers of seawater $p\text{CO}_2$ variations for two specific hydrodynamic processes typical for the BoM: (i) Rhône River intrusion and (ii) summer upwelling events. **With this study, we aim to provide a new tool which allow to obtain a reliable representation of the carbonate system in the simplest way as possible: by using a dimensionless configuration which is easy to use, adapt and give results in a short amount of time.]**

And we gave a justification of this choice in the Section 2.2 (l.111):

[In this study, we used the Eco3M_MIX-CarbOx model (v1.0) which was developed to represent the dynamics of the seawater carbonate system and mixotrophs in the BoM and was implemented using the Eco3M (Ecological Mechanistic and Molecular Modelling) platform (Baklouti et al., 2006a, b). **Eco3M_MIX-CarbOx is a dimensionless model (0D): we consider a volume of 1 m³ of surface water at SOLEMIO station, in this volume the state variables only vary over time as the model is not coupled with a hydrodynamic model. We chose to use a 0D configuration as this configuration has several advantages, especially, calculation times are low (around 45 minutes in our case). It allows us to make several test simulations to better understand the biogeochemical functioning of the BoM and its possible reactions to environmental forcings.]**

In the introduction, it's made mention of the need for high resolution model for coastal regional study, and the next sentence announce the use of a dimensionless (0D hereafter) configuration.

We understand that these sentences can be confusing. We add a sentence to make a better link between 3D introduction and use of 0D (l.65).

[Most modelling approaches to investigate carbonate system variables typically employ 3D coupled physical-biogeochemical models and focus on larger coastal areas (e.g., Artioli et al., 2014; Bourgeois et al., 2016). If the focus is on smaller areas this requires higher spatial and temporal resolution to correctly represent the relevant processes (Bourgeois et al., 2016). **However, higher spatial and temporal resolution often result in a significant increase of the calculation time which make more difficult the repetition of numerical experiments, an important step to better understanding the global functioning of the area and its reaction to environmental forcings. A solution to avoid important calculation times is to use a dimensionless model. This type of model allows to conduct large amount of test in short amount of time. For instance,** Lajaunie-Salla et al. (2021) used the dimensionless Eco3M-CarbOx model, which contains a carbonate module performing the resolution of the carbonate system based on total alkalinity (TA) and dissolved inorganic carbon (DIC). Even if the DIC, oceanic partial pressure of CO₂ (pCO₂) and total pH (pH_T) representations look reliable, Eco3m-CarbOx tends to minimize the range of TA variations during the year, resulting in a near constant TA (Lajaunie-Salla et al., 2021).]

2) A second point is that this 0D brings more questions than answers. Because it is a surface box, the model does not represent advection and mixing. The physics variable/forcing come from observations and hence include annual cycle and external forcing, including specific phenomena like summer upwellings or the Rhône waters passing by. But what about the nutrients ?

We agree that hydrodynamic processes, especially upwelling and Rhône River intrusions in the BoM are associated with nutrients inputs. In Eco3M_MIX-CarbOx, upwellings are only represented by strong variations of temperature and Rhône River intrusions are only represented by strong variations of salinity and TA inputs when allochthonous TA formulation is used. In other words, we do not consider the possible inputs of nutrients associated with these events and assumed that nutrients are fully the result of autochthonous biological processes (due to 0D configuration) which means that they are modelled based on the following state equations :

$$\frac{\partial \text{NO}_3}{\partial t} = \text{Nitrif}_{\text{NO}_3}^{\text{NH}_4} - \sum_{i=1}^2 \text{Upt}_{\text{NO}_3}^{\text{PhyN}_i} - \text{Upt}_{\text{NO}_3}^{\text{CMN}_i}$$

$$\frac{\partial \text{NH}_4}{\partial t} = \text{Excr}_{\text{NH}_4}^{\text{COPN}} + \text{Excr}_{\text{NH}_4}^{\text{NCMN}} + \text{Remin}_{\text{NH}_4}^{\text{BACN}} - \sum_{i=1}^2 \left(\text{Upt}_{\text{NH}_4}^{\text{PhyN}_i} \right) - \text{Upt}_{\text{NH}_4}^{\text{CMN}} - \text{Upt}_{\text{NH}_4}^{\text{BACN}} - \text{Nitrif}_{\text{NH}_4}^{\text{NO}_3}$$

$$\frac{\partial \text{PO}_4}{\partial t} = \text{Excr}_{\text{PO}_4}^{\text{COPP}} + \text{Excr}_{\text{PO}_4}^{\text{NCMP}} + \text{Remin}_{\text{PO}_4}^{\text{BACP}} - \sum_{i=1}^2 \left(\text{Upt}_{\text{PO}_4}^{\text{PHY}_{\text{P}_i}} \right) - \text{Upt}_{\text{PO}_4}^{\text{CMP}} - \text{Upt}_{\text{PO}_4}^{\text{BACP}} \quad (\text{Eq. S1})$$

Nitrate concentration results from nitrification and phytoplankton and CM uptakes. Ammonium concentration results from copepods and NCM excretion, bacterial remineralisation, heterotrophic bacteria, phytoplankton, and CM uptakes and losses from nitrification. Finally, phosphate concentration results from copepods and NCM excretion, bacterial remineralisation and heterotrophic bacteria, phytoplankton, and CM uptakes.

What are the external forces driving the biology of the model ?

Biology is impacted by temperature and/or irradiance. Depending on the biogeochemical process considered, both or only one of them can have an impact and this impact could be direct or indirect. Nitrification which is performed by nitrifying bacteria (organisms not considered explicitly in the model) depends on temperature and modelled dissolved oxygen concentration:

$$\text{Nitrif}_{\text{NH}_4}^{\text{NO}_3} = \text{tx}_{\text{NITRIF}} * \text{NH}_4 * f_{\text{Q}_{10}, \text{nitrif}}^T * \frac{\text{O}_2}{\text{O}_2 + \text{K}_{\text{O}_2}}$$

$$f_{\text{Q}_{10}, \text{nitrif}}^T = Q_{10, \text{nitrif}}^{\frac{T-10}{10}} \quad (\text{Eq. S2})$$

where $\text{tx}_{\text{NITRIF}}$ represents the fraction of NH_4^+ used for nitrification, K_{O_2} is the dissolved oxygen half saturation constant and $\text{Q}_{10, \text{nitrif}}$ is the temperature coefficient for nitrification.

We detailed the modelling of planktonic organisms in the companion paper (Barré et al., 2023a). To sum up, heterotrophic bacteria processes are directly impacted by temperature. Phytoplankton and CM processes are directly impacted by temperature (all processes) and irradiance (photosynthesis and grazing). Copepods and NCM processes are indirectly impacted by temperature and irradiance through the consumed preys.

This is not explained until the discussion, what is extremely frustrating, as we don't really understand what the model sees and feels or not, until the very end, when the author reveals some of the experiment limitations.

We provided all the balance equations, detailed formulations of biogeochemical processes and parameters values in the companion paper (Barré et al., 2023a). For organisms, we did not find relevant to provide them again. However, we understand the necessity of adding explanations about the nutrients in the manuscript. We decided to add a subsection in Section 2.2.1, in which we detail the modelling of nutrients and organic matter.

[2.2.1 Nutrients and organic matter representation in the model

As we use a dimensionless configuration, we assume that nutrients are fully the result of autochthonous biological processes. In other terms, we do not consider allochthonous inputs of nutrients (i.e., from rivers or atmosphere as instance). For all the simulations, nutrients dynamics are represented by the following state equations:

$$\frac{\partial \text{NO}_3}{\partial t} = \text{Nitrif}_{\text{NO}_3}^{\text{NH}_4} - \sum_{i=1}^2 \text{Upt}_{\text{NO}_3}^{\text{Phy}_{\text{N}_i}} - \text{Upt}_{\text{NO}_3}^{\text{CM}_{\text{N}_i}}$$

$$\begin{aligned}
\frac{\partial \text{NH}_4}{\partial t} &= \text{Excr}_{\text{NH}_4}^{\text{COP}_N} + \text{Excr}_{\text{NH}_4}^{\text{NCM}_N} + \text{Remin}_{\text{NH}_4}^{\text{BAC}_N} - \sum_{i=1}^2 \left(\text{Upt}_{\text{NH}_4}^{\text{PHY}_{N_i}} \right) - \text{Upt}_{\text{NH}_4}^{\text{CM}_N} - \text{Upt}_{\text{NH}_4}^{\text{BAC}_N} - \text{Nitrif}_{\text{NH}_4}^{\text{NO}_3} \\
\frac{\partial \text{PO}_4}{\partial t} &= \text{Excr}_{\text{PO}_4}^{\text{COP}_P} + \text{Excr}_{\text{PO}_4}^{\text{NCM}_P} + \text{Remin}_{\text{PO}_4}^{\text{BAC}_P} - \sum_{i=1}^2 \left(\text{Upt}_{\text{PO}_4}^{\text{PHY}_{P_i}} \right) - \text{Upt}_{\text{PO}_4}^{\text{CM}_P} - \text{Upt}_{\text{PO}_4}^{\text{BAC}_P}
\end{aligned} \tag{1}$$

The concentration of NO_3^- results from nitrification and phytoplankton and CM uptakes. Ammonium concentration results from copepods and NCM excretion, bacterial remineralisation, heterotrophic bacteria, phytoplankton, and CM uptakes and losses from nitrification. Phosphate concentration results from copepods and NCM excretion, bacterial remineralisation and heterotrophic bacteria, phytoplankton, and CM uptakes.

Such as nutrients dynamics, organic matter (dissolved and particulate) dynamic is only the result of autochthonous biological processes (Eq. 2 and 3).

$$\begin{aligned}
\frac{\partial \text{DOC}}{\partial t} &= \sum_{i=1}^2 \left(\text{Exu}_{\text{DOC}}^{\text{PHY}_{C_i}} \right) + \sum_{i=1}^2 \left(\text{Exu}_{\text{DOC}}^{\text{MIX}_{C_i}} \right) + \text{Excr}_{\text{DOC}}^{\text{COP}_C} + \text{Mort}_{\text{DOC}}^{\text{BAC}_C} - \text{BP}_{\text{DOC}}^{\text{BAC}_C} \\
\frac{\partial \text{DON}}{\partial t} &= \sum_{i=1}^2 \left(\text{Exu}_{\text{DON}}^{\text{PHY}_{N_i}} \right) + \sum_{i=1}^2 \left(\text{Exu}_{\text{DON}}^{\text{MIX}_{N_i}} \right) + \text{Mort}_{\text{DON}}^{\text{BAC}_N} - \text{Upt}_{\text{DON}}^{\text{CM}_N} - \text{Upt}_{\text{DON}}^{\text{PICO}_N} - \text{Upt}_{\text{DON}}^{\text{BAC}_N} \\
\frac{\partial \text{DOP}}{\partial t} &= \sum_{i=1}^2 \left(\text{Exu}_{\text{DOP}}^{\text{PHY}_{P_i}} \right) + \sum_{i=1}^2 \left(\text{Exu}_{\text{DOP}}^{\text{MIX}_{P_i}} \right) + \text{Mort}_{\text{DOP}}^{\text{BAC}_P} - \text{Upt}_{\text{DOP}}^{\text{CM}_P} - \text{Upt}_{\text{DOP}}^{\text{PICO}_P} - \text{Upt}_{\text{DOP}}^{\text{BAC}_P}
\end{aligned} \tag{2}$$

The concentration of dissolved organic carbon (DOC), nitrogen (DON) and phosphorus (DOP) depends on phytoplankton and mixotrophs exudation, copepods excretion, heterotrophic bacteria mortality (natural mortality) and CM, PICO and heterotrophic bacteria uptake.

$$\begin{aligned}
\frac{\partial \text{POC}}{\partial t} &= \text{E}_{\text{POC}}^{\text{COP}_C} + \text{Predation}_{\text{POC}}^{\text{COP}_C} - \text{BP}_{\text{POC}}^{\text{BAC}_C} \\
\frac{\partial \text{PON}}{\partial t} &= \text{E}_{\text{PON}}^{\text{COP}_N} + \text{Predation}_{\text{PON}}^{\text{COP}_N} - \text{Upt}_{\text{PON}}^{\text{BAC}_N} \\
\frac{\partial \text{POP}}{\partial t} &= \text{E}_{\text{POP}}^{\text{COP}_P} + \text{Predation}_{\text{POP}}^{\text{COP}_P} - \text{Upt}_{\text{POP}}^{\text{BAC}_P}
\end{aligned} \tag{3}$$

The concentration of particulate organic carbon (POC), nitrogen (PON) and phosphorus (POP) depends on copepods egestion, predation by higher trophic levels on copepods (closure term of the model) and heterotrophic bacteria production and uptake. POM particles are large enough to sink, however, we do not consider a term to represent their removal from the surface box by sinking. In our case, the POM, such as the DOM, stay in the box and is constantly recycling.

A detailed description and formulations of processes can be found in Barré et al. (2023a). Processes notation description can be found in Table A1 (Appendix A).]

We modified the manuscript consequently (l.111):

[In the following, we provide a detailed description of the carbonate module. **We also give a brief description of nutrients and organic matter representation.** A detailed description of other compartments, especially of mixotrophs compartment can be found in Barré et al. (2023a).]

Appendix A:

[Table A1: Description of state equation processes.

Notation	Process
Copepods	
$\text{Excr}_{\text{NutX}}^{\text{COPX}}$ $\text{NutX} \in [\text{NH}_4^+, \text{PO}_4^{3-}]$ $X \in [\text{N}, \text{P}]$	Excretion of nutrient X by copepods
$\text{Excr}_{\text{DOC}}^{\text{COPC}}$	DOC excretion by copepods
$\text{Resp}_{\text{DIC}}^{\text{COPC}}$	Copepods respiration
$\text{E}_{\text{POX}}^{\text{COPX}}$ $X \in [\text{C}, \text{N}, \text{P}]$	Copepods egestion
$\text{Predation}_{\text{POX}}^{\text{COPX}}$ $X \in [\text{C}, \text{N}, \text{P}]$	Predation by higher trophic levels on copepods
Mixotrophs (Mix $\in [\text{NCM}, \text{CM}]$)	
$\text{Exu}_{\text{DOX}}^{\text{MixX}_i}$ $X \in [\text{C}, \text{N}, \text{P}]$	DOX exudation by mixotrophs
$\text{Resp}_{\text{DIC}}^{\text{MixC}}$	Mixotrophs respiration
$\text{Photo}_{\text{DIC}}^{\text{MixC}}$	Mixotrophs photosynthesis
$\text{Excr}_{\text{NutX}}^{\text{NCMX}}$ $\text{NutX} \in [\text{NH}_4^+, \text{PO}_4^{3-}]$ $X \in [\text{N}, \text{P}]$	Excretion of nutrient X by NCM
$\text{Upt}_{\text{NutX}}^{\text{CMX}}$ $X \in [\text{N}, \text{P}]$ $\text{NutX} \in [\text{NO}_3^-, \text{NH}_4^+, \text{PO}_4^{3-}]$	Uptake of nutrient X by constitutive mixotrophs
$\text{Upt}_{\text{DOX}}^{\text{CMX}}$ $X \in [\text{N}, \text{P}]$	Uptake of DOX by constitutive mixotrophs
Phytoplankton (Phy $\in [\text{NMPHYTO}, \text{PICO}]$)	
$\text{Resp}_{\text{DIC}}^{\text{PhyC}}$	Phytoplankton respiration
$\text{Photo}_{\text{DIC}}^{\text{PhyC}}$	Phytoplankton photosynthesis
$\text{Upt}_{\text{NutX}}^{\text{PhyX}}$ $\text{NutX} \in [\text{NO}_3^-, \text{NH}_4^+, \text{PO}_4^{3-}]$	Uptake of nutrient X by phytoplankton
$\text{Exu}_{\text{DOX}}^{\text{PhyX}}$ $X \in [\text{C}, \text{N}, \text{P}]$	DOX exudation by phytoplankton
$\text{Upt}_{\text{DOX}}^{\text{PICOX}}$ $X \in [\text{N}, \text{P}]$	Uptake of DOX by picophytoplankton
Heterotrophic bacteria	
$\text{BP}_X^{\text{BACC}}$ $X \in [\text{DOC}, \text{POC}]$	Bacterial production
$\text{BR}_{\text{DIC}}^{\text{BACC}}$	Bacterial respiration
$\text{Upt}_{\text{POX}}^{\text{BACX}}$ $X \in [\text{N}, \text{P}]$	POX uptake by heterotrophic bacteria

$\text{Exu}_{\text{DOX}}^{\text{PhyX}_i}$
 $X \in [\text{C}, \text{N}, \text{P}]$

DOX exudation by phytoplankton

$\text{Remin}_{\text{BACX}}^{\text{NutX}}$
 $\text{NutX} \in [\text{NH}_4^+, \text{PO}_4^{3-}]$
 $X \in [\text{N}, \text{P}]$

Remineralisation of nutrient X by heterotrophic bacteria

$\text{Mort}_{\text{DOX}}^{\text{BACX}}$

Heterotrophic bacteria natural mortality

Dissolved inorganic matter (DIM)

$\text{Diss}_{\text{DIC}}^{\text{CaCO}_3}$

CaCO_3 dissolution

$\text{Prec}_{\text{DIC}}^{\text{CaCO}_3}$

CaCO_3 precipitation

Nitrif

Nitrification

Aera_{DIC}

Air-sea CO_2 gas exchanges (aeration)

]

Also, we propose to add the figure 2, which resumes the hypothesis used in this study and allows to visualize the OD concept, at the end of part 2.2.2 (2.2.3 in the revised manuscript).

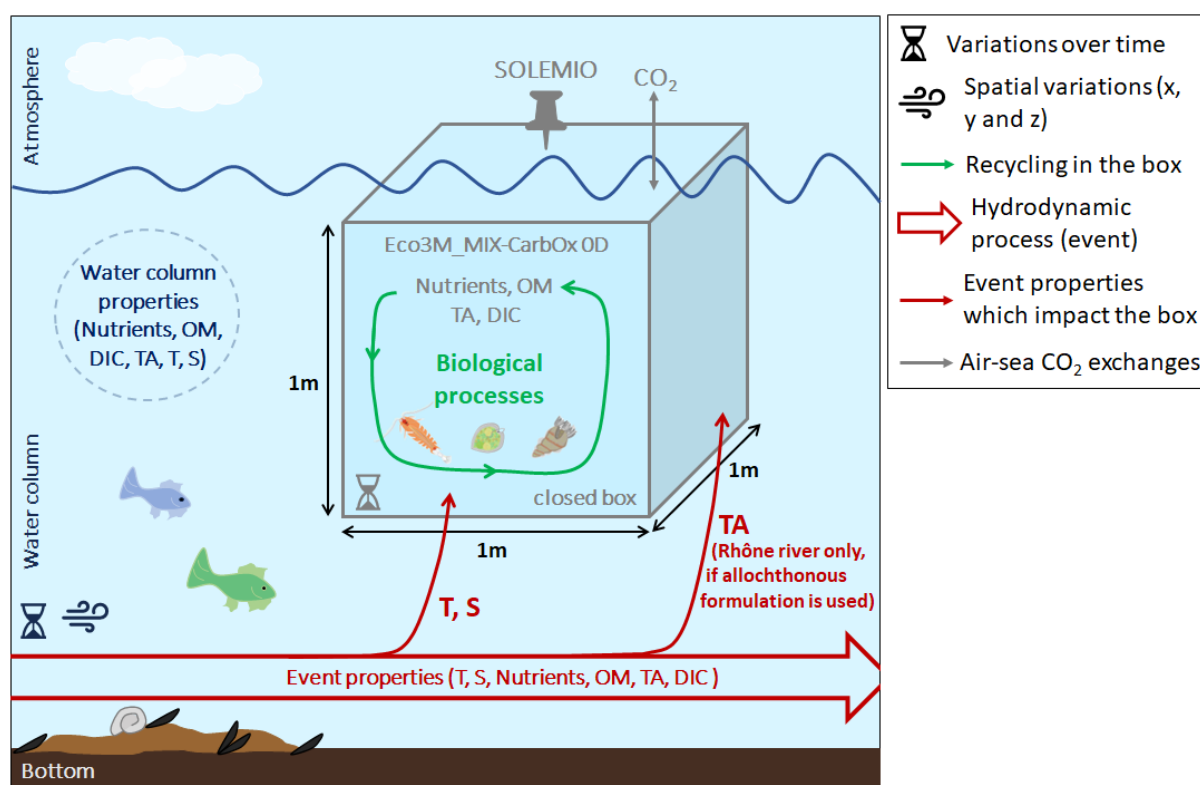


Figure 2: Schematic representation of OD concept and summary of the hypotheses used in this study with Eco3M_MIX-CarbOx. T: temperature, S: Salinity and OM: Organic matter.

We modify the manuscript consequently:

(l.181): Figure X illustrates the concept of OD and summarize the hypothesis used in this study with Eco3M_MIX-CarbOx.

3) Still about the OD, what happens to the POM ? Do they sink ? Are they removed from the surface box ? Or do they float there and are slowly remineralized (as if the bay is mixed enough to keep the particles around) ? This is important as it has an impact on TA and DIC and all other nutrients concentration.

In the model, the POC, PON and POP dynamics result from copepods egestion, higher trophic level predation on copepods (closure terms of the model) and heterotrophic bacteria uptake (Eq. S3). They do not sink and are constantly recycling in the surface box using the processes indicated above.

$$\begin{aligned}\frac{\partial \text{POC}}{\partial t} &= E_{\text{POC}}^{\text{COPc}} + \text{Predation}_{\text{POX}}^{\text{COPx}} - \text{BP}_{\text{POC}}^{\text{BACc}} \\ \frac{\partial \text{PON}}{\partial t} &= E_{\text{PON}}^{\text{COPN}} + \text{Predation}_{\text{PON}}^{\text{COPN}} - \text{Upt}_{\text{PON}}^{\text{BACN}} \\ \frac{\partial \text{POP}}{\partial t} &= E_{\text{POP}}^{\text{COPp}} + \text{Predation}_{\text{POP}}^{\text{COPp}} - \text{Upt}_{\text{POP}}^{\text{BACp}}\end{aligned}$$

(Eq. S3)

Using these state equations, the POM compartment is balanced (Fig. S1) which is why we do not consider a term to represent their removal from the surface box by sinking.

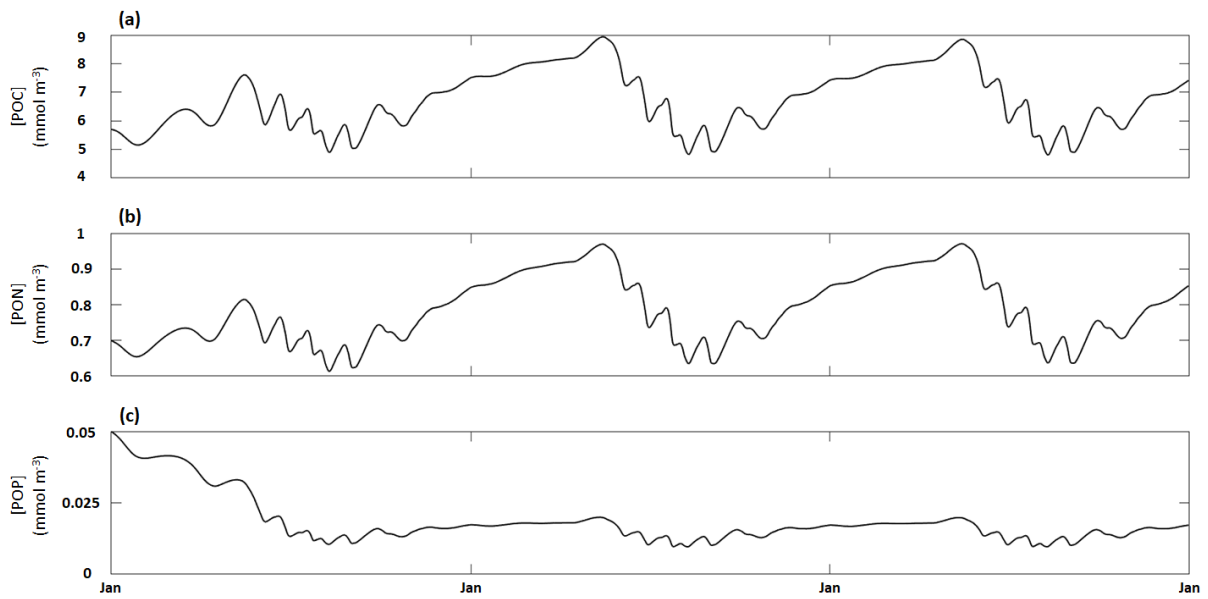


Figure S1: Time-series of daily averaged (a) POC, (b) PON and (c) POP for the three years of simulation (repetition of 2017 three times) for the reference simulation (SIMCO, Table 2 of the manuscript).

We hope that adding the part 2.2.1 (see point 2) which contains a description of dissolved and particulate organic matter representation in the model will clarify this point.

4) Somehow it looks like (and I am sorry to say that, but I am sure you agree with me) the work you've done here (changing from autochthonous TA formulation – what is what you ideally want to use – to the abiotic, allochthonous formulation) is a way to fix a problem due to the configuration choice, that is not done for this kind of study. Your conclusion (you need to switch from 0D to 3 or at least 1D) should have been one of Lajaunie-Salla et al. 2021's study.

We agree, by changing the formulation of TA from autochthonous to allochthonous, our aim was to correct a bias due to the configuration choice.

By implementing an allochthonous formulation of TA in Eco3M_MIX-CarbOx, we first wanted to explain the result obtained by Lajaunie-Salla et al. (2021) and make sure that this result was not due to a poor representation of a biological process that could affect TA dynamics. Then, with the results obtained in our study, we could confirm that the lack of variation in the AT representation of Lajaunie-Salla et al.

(2021) is explained by the fact that the 0D configuration does not allow (at first sight) the consideration of allochthonous contributions and especially of the Rhône River which is the main source of TA variations in the area.

Nevertheless, the 0D configuration has several advantages, including its short calculation time which allowed us to provide a detailed analysis of drivers of seawater $p\text{CO}_2$ variations, particularly during specific hydrodynamic processes typical for the BoM. This type of study is still uncommon in the area, as few of them investigated the carbonate system dynamics, especially the $p\text{CO}_2$ variations drivers (reference study: Wimart-Rousseau et al., 2020) and would have been more difficult to conduct in 3D. That is why we chose to keep working on the 0D configuration (therefore, looking for a way to better represent the TA on which $p\text{CO}_2$ calculation depends) and present the results obtained with this configuration as we think that, even if some points deserve to be reworked in 3D, the 0D already allows to obtain interesting results.

5) Before publication I would require the author to better explain the choice and implications of the 0D in the method section, so that the reader can really understand the experiments and the results.

- How are the nutrients managed (initialized with annual average value)?

Nutrients dynamics are the results of biological processes which take place in the box only, please see point 2 for details.

- Are total N, P, Si, Fe, Alk supposed to be conserved within the box ? Or are they allowed to fluctuate with some external sources and sinks from/to outside the box, apart from the air-sea CO_2 flux?

We do not consider Si and Fe in our model. Total N, and P are supposed to be conserved within the box as we do not consider any external source or sink from/to the water column (Fig. S2).

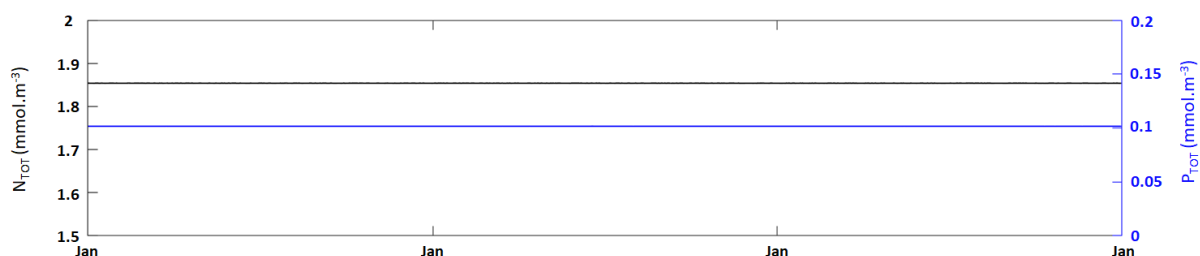


Figure S2: Time-series of daily averaged total nitrogen (N_{TOT}) and phosphorus (P_{TOT}) for the three years of simulation (repetition of 2017 three times) for the reference simulation (SIMC0, Table 2 of the manuscript).

When TA calculation is based on autochthonous formulation, TA is supposed to be conserved in the box. However, when we repeat the year 2017 three times, we observe a decreasing trend for TA ($-16\mu\text{mol kg}^{-1}$ in three years) (Fig. S3). This decrease is explained by the prevailing of precipitation compared to dissolution. For the bay of Marseille, this result seems consistent as other studies (Bensoussan & Gattuso, 2007 ; Wimart-Rousseau et al., 2020) suggest a net calcifying system, however, in our case, it means that TA is not conserved in the box.

When TA calculation is based on allochthonous formulation, the TA result is the balance between Rhône River TA sources and sinks due to the net calcifying system.

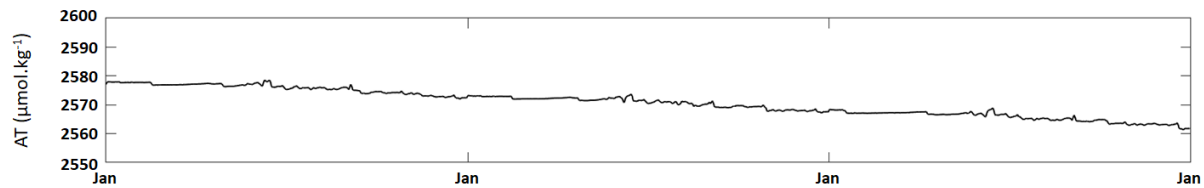


Figure S3: Time series of daily averaged TA for the three years of simulation (repetition of 2017 three times) for the reference simulation (SIMC0, Table 2 of the manuscript).

- What happens to all sinking materials ? Even if they stay in the box, we need to know.

Sinking materials (POM, organisms larger than CM and CaCO_3 in our case) stay in the box. They are constantly recycled by the biogeochemical processes which impact them (see point 3).

I ask for major revision, just to be sure this part is improved.

We hope that our responses, especially adding 2.2.1 and the figure 2 to the manuscript, clarify these points.

For the rest I cannot ask you to re-do everything in 1 or 3D, this will most probably be your next paper anyway.

Indeed, we plan to study carbonate system variables dynamics in the BoM using a 3D coupled model and to present the results of this study in another manuscript.

Modifications in the text:

The English might need some rewording. I am not an english native, so I cannot help much for that, but I would recommend a second read. For example, you make an extensive use of the word “yielding”. It is a nice word, but you should replace some of them with relevant synonyms.

As we are not native speakers, we have sent our manuscript to a native speaker before submission. So, the version provided to you was already corrected and rephrased by a native speaker, however, we took into account your suggestion and minimize the use of “yielding”.

I.140: We rephrased [As a last term we included the mixotrophic uptake of nutrients which yields the following state equation for TA] to [As a last term we included the mixotrophic uptake of nutrients. **TA is calculated as follows:**]

I.288: We modified [Both simulations yield a strong decrease of $p\text{CO}_2$ on March 15th , in response to a Rhône River intrusion in the BoM.] to [**For both simulations a strong decrease of $p\text{CO}_2$ is modelled on March 15th , in response to a Rhône River intrusion in the BoM.**]

I.301: We deleted [Regarding the coast function, simulations yielded $\text{CF} < 2$ for all variables which is considered very good ($\text{CF} < 1$) or good ($1 \leq \text{CF} < 2$) (Table 3).].

I.306: We modified [Furthermore, SIMC1 produced the best TA representation yielding the lowest values for CF, %BIAS and RMSD (Table 3).] to [Furthermore, SIMC1 produced the best TA representation **resulting in** the lowest values for CF, %BIAS and RMSD (Table 3).]

I.430: We changed [In contrast, the allochthonous formulation yielded a much high variability in TA that was close to in situ observations.] to [In contrast, the allochthonous formulation **produced** a much high variability in TA that was close to in situ observations.]

I.439: We modified [Having neglected other allochthonous drivers seems to be justified by the results which yielded a close match to observations and a generally better representation of the other carbonate system variables since DIC, $p\text{CO}_2$ and pH_T are all closely related to TA (Fig. 4 and Table 3).] by [Having neglected other allochthonous drivers seems to be justified by the results which **showed** a close match to observations and a generally better representation of the other carbonate system variables since DIC, $p\text{CO}_2$ and pH_T are all closely related to TA (Fig. 4 and Table 3).]

I.531: We changed [The reason for this discrepancy may be related to the fact that our model overestimates seawater $p\text{CO}_2$ during winter, yielding a sea-air difference close to zero (Fig. 5d). As a result, despite strong winds and low temperatures which would favour CO_2 absorption (Middelburg, 2019), the winter CO_2 sink is not well represented.] to [The reason for this discrepancy may be related to the fact that our model overestimates seawater $p\text{CO}_2$ during winter, **resulting in** a sea-air difference close to zero (Fig. 5d). As a result, despite strong winds and low temperatures which would favour CO_2 absorption (Middelburg, 2019), the winter CO_2 sink is not well represented.]

Page2 line 25 : add some “-” or () : “model – consistent with observations – predicted....”

Done.

P3-L65 : You need to add something here about the reason for 0D.

We added (I.65):

[Most modelling approaches to investigate carbonate system variables typically employ 3D coupled physical-biogeochemical models and focus on larger coastal areas (e.g., Artioli et al., 2014; Bourgeois et al., 2016). If the focus is on smaller areas this requires higher spatial and temporal resolution to correctly represent the relevant processes (Bourgeois et al., 2016). **However, higher spatial and temporal resolution often result in a significant increase of the calculation time which make more difficult the repetition of numerical experiments, an important step to better understanding the global functioning of the area and its reaction to environmental forcings. A solution to avoid important calculation times is to use a dimensionless model. This type of model allows to conduct large amount of test in short amount of time. As instance, Lajaunie-Salla et al. (2021) used the dimensionless Eco3M-CarbOx model, which contains a carbonate module performing the resolution of the carbonate system based on total alkalinity (TA) and dissolved inorganic carbon (DIC). Even if the DIC, oceanic partial pressure of CO_2 ($p\text{CO}_2$) and total pH (pH_T) representations look reliable, Eco3m-CarbOx tends to minimize the range of TA variations during the year, resulting in a near constant TA (Lajaunie-Salla et al., 2021).]**

P5-table1: You only fill the time resolution information for the wind. Does that mean they’re all the same ? It seems from the text that some data are daily. You should feel them all, or tell in the table description why the other data have no time resolution information.

All data cited in Table 1 are hourly measurements. To avoid confusion, we fill all the lines of the table.

[Table 1. Data types and their sources used to drive the environmental forcing during the 2017 model run (based on Barré et al., 2023a).

	Data type	Location	Time resolution
Sea surface temperature	Measurements	Planier station	Hourly
Salinity	Measurements	Carry buoy	Hourly
Wind	WRF model results	SOLEMIO station	Hourly
Irradiance	WRF model results	SOLEMIO station	Hourly

Atmospheric pCO ₂	Measurements	Cinq Avenues station	Hourly
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P6-L124 to 126. “ In addition to ...”. what you say there sounds obvious, but BGC-model not including mixotroph represent reasonable TA and DIC. Do you have a Reference paper for this statement ?

We added the reference Mitra et al., (2014): In this article, authors show why it is important to consider a mixotrophs compartment and how not consider it can lead to a failure to capture the true dynamics of the carbon fluxes. (Mitra, A., Flynn, K. J., Burkholder, J. M., Berge, T., Calbet, A., Raven, J. A., Granéli, E., Glibert, P. M., Hansen, P. J., Stoecker, D. K., Thingstad, F., Tillmann, U., Våge, S., Wilken, S., and Zúrov M. V.: The role of mixotrophic protists in the biological carbon pump, Biogeosciences, 11, 995-1005, <https://doi.org/10.5194/bg-11-995-2014>, 2014.

P7-equation1 : You should specify that all terms are define in the appendix A.

Thank you for pointing this out, we added it l.144: [where i represents the number of organisms. [Processes description can be found in Table A1 \(Appendix A\) and formulations are available in Barré et al. \(2023a\)](#). In this formulation, TA only depends on biogeochemical processes (i.e., TA riverine inputs are excluded).] and l.170: [where i represents the number of organisms. [Processes description can be found in Table A1 \(Appendix A\) and formulations are available in Barré et al. \(2023a\)](#). As an additional modification, we use a more recent version of the gas transfer velocity calculation introduced by Wanninkhof (2014).].

P7- equ2 and 3 : You can specify the unit at the end of the equation, and remove the following sentence.

Done.

I might be wrong but, shouldn't the “photo” terms be more like uptake terms ? Phyto absorbs more DIC than the only ones used for the photosynthesis. Isn't this equation missing the remineralization terms as a source of DIC ?

Thank you for this interesting comment. We are aware that phytoplankton can absorb more DIC than the one associated with photosynthesis process. However, in Eco3M_MIX-CarbOx, we made the choice to consider only the DIC uptake used through photosynthesis (photosynthetic organisms only use the DIC they need for photosynthesis, surplus is released through respiration process).

The term $Photo_{DIC}^{ORG_i}$ (with $ORG \in [PHYC, MIXC]$), when apply to the DIC, represents the DIC uptake linked to photosynthesis, by phytoplankton and mixotrophs. When The term $Photo_{DIC}^{ORG_i}$ is applied to phytoplankton or mixotrophs, it represents the biomass increase associated with photosynthesis. Both processes are identical, they have the same formulation (photosynthesis based on Geider et al. ,1998) except that when the process is applied to DIC, the biogeochemical flux applied is negative (positive when applied to phytoplankton and mixotrophs). We then used the same notation to be consistent.

In Eco3M_MIX-CarbOx, we consider DIC remineralization through respiration process. Especially, the DIC which comes from bacteria respiration is actually the result of POC and DOC remineralization.

P8-equ5 and L179-181 : I don't understand why you define Aera being negative when the CO₂ flux is toward the sea. In Equ 4, $\partial DIC / \partial T$ increases with Aera being positive, what means CO₂ flux toward the sea, and $pCO_{2,sw} > pCO_{2,atm}$. There's a discrepancy here you might want to correct.

Thank you for pointing this out. We corrected the balance equation for DIC (l.167, Eq.4):

$$\frac{\partial \text{DIC}}{\partial t} = \sum_{i=1}^2 \left(\text{Resp}_{\text{DIC}}^{\text{Phyc}_i} \right) + \sum_{i=1}^2 \left(\text{Resp}_{\text{DIC}}^{\text{Mix}_{C_i}} \right) + \text{Resp}_{\text{DIC}}^{\text{COP}_c} + \text{BR}_{\text{DIC}}^{\text{BAC}_c} + \text{Diss}_{\text{DIC}}^{\text{CaCO}_3} - \sum_{i=1}^2 \left(\text{Photo}_{\text{DIC}}^{\text{Phyc}_i} \right) - \sum_{i=1}^2 \left(\text{Photo}_{\text{DIC}}^{\text{Mix}_{C_i}} \right) - \text{Prec}_{\text{DIC}}^{\text{CaCO}_3} - \text{Aera}_{\text{DIC}}$$

Equation 5 of the manuscript remains unchanged. We still consider that negative aeration values ($p\text{CO}_{2,\text{atm}} > p\text{CO}_{2,\text{sw}}$) are associated with CO_2 fluxes toward the sea and an increase of DIC, which is now consistent with the DIC balance equation.

P11-L237 : “the first three terms of Eq.(10)”, I think you refer to Eq.11, not 10.

Thank you for pointing this out, we modified: [The first three terms of the Eq. (10) can be calculated as follow:] by [The three terms of Eq. (11) can be calculated as follow:].

P14-Table3 : just to mention, comparing pH is tricky. Comparing pH change or bias in pH unit can be misleading. Best practice is to compare H^+ concentration. See Kwiatkowski and Orr, 2018 (<https://www.nature.com/articles/s41558-017-0054-0>).

Thank you for pointing this out. We take into account your suggestion and propose to add in Appendix the statistical indicators calculation for H^+ concentration:

[Appendix C: Statistic indicators calculation for H^+ concentration]

Table C1: Comparing the different model results to surface observations at SOLEMIO station for H^+ concentration. N represents the number of observations. Mean, SD, AE, AAE and RMSD are in the same unit than the considered variable, i.e.: mmol m^{-3} for H^+ concentrations. % BIAS is without unit.

[H ⁺]		
N	Observations	20
Mean ± SD	Observations	$8.08 \times 10^{-9} \pm 5.52 \times 10^{-10}$
Mean ± SD	SIMC0	$8.89 \times 10^{-9} \pm 2.91 \times 10^{-10}$
	SIMC1	$8.39 \times 10^{-9} \pm 4.06 \times 10^{-10}$
	CarbOx	$8.52 \times 10^{-9} \pm 2.80 \times 10^{-10}$
%BIAS	SIMC0	-5.33
	SIMC1	-3.91
	CarbOx	-5.47
AE	SIMC0	-4.30×10^{-10}
	SIMC1	-3.15×10^{-10}
	CarbOx	-4.42×10^{-10}
AAE	SIMC0	6.45×10^{-10}
	SIMC1	6.05×10^{-10}
	CarbOx	6.36×10^{-10}
RMSD	SIMC0	6.98×10^{-10}
	SIMC1	7.14×10^{-10}
	CarbOx	6.93×10^{-10}

]

Please, note that based on Referee 2 suggestions we modified the statistical indicators calculated. We replaced CF which was not sensitive enough by average error (AE) and average absolute error (AAE):

$$\text{AE} = \frac{\sum_{i=1}^N (\text{O}_i - \text{M}_i)}{n}$$

(Eq. S4)

$$AAE = \frac{\sum_{i=1}^N (|O_i - M_i|)}{n}$$

(Eq. S5)

Where O represents the observations and M the model results, calculations are based on Stow et al. (2009).

And we modified the text accordingly (l.301):

[For statistical indicators, %BIAS values are systematically lower than 10 %, with the highest values obtained for pCO_2 with ~6 % while the remaining variables had values < 1 %. Similarly, pCO_2 had the highest RMSD, AAE and AE which suggests that this parameter is not as well represented in the model as the other variables. Furthermore, SIMC1 produced the best TA representation resulting in the lowest values for %BIAS, AE, AAE and RMSD (Table 3). Moreover, SIMC1 produced an annual mean-TA that was closest to the observations. While the SIMC0 and Eco3m-CarbOx results are fairly similar. SIMC0 produced a slightly better representation of TA compared to Eco3m-CarbOx (%BIAS, AE, AAE and RMSD slightly lower). For pH_T , SIMC1 outperformed SIMC0 based on %BIAS (Table 3), however, AE, AAE and RMSD values are similar for the three simulations. We then performed the calculation of statistical indicators on H^+ concentration as, according to some authors (Kwiatkowski & Orr, 2018), comparing H^+ concentrations is a better practice than comparing pH. Results are available in Appendix C. Based on Table C1, SIMC1 also outperformed SIMC0 based on AE and AAE. For studying DIC and pCO_2 , the situation is less clear as the simulations performed differently for different indicators, making it difficult to pick a clear winner. Still SIMC1 shows the best AAE and RMSD values for DIC, and the best %BIAS, AE, and AAE for pCO_2 . In conclusion, SIMC1 shows the best overall indicator values for the examined variables (more specifically, it outperformed the other simulations in 13 of 20 indicator comparisons when including H^+ concentrations comparison).]

P15 -Fig 5 : the e,f,g and h panels are not useful. There is no additional information, and it's not even zoomed-in. Instead, I would remove them, make the picture slightly bigger, and highlight the SUP like you do in Fig. 6 with a shading or something similar.

Done. We modified the caption and the text accordingly.

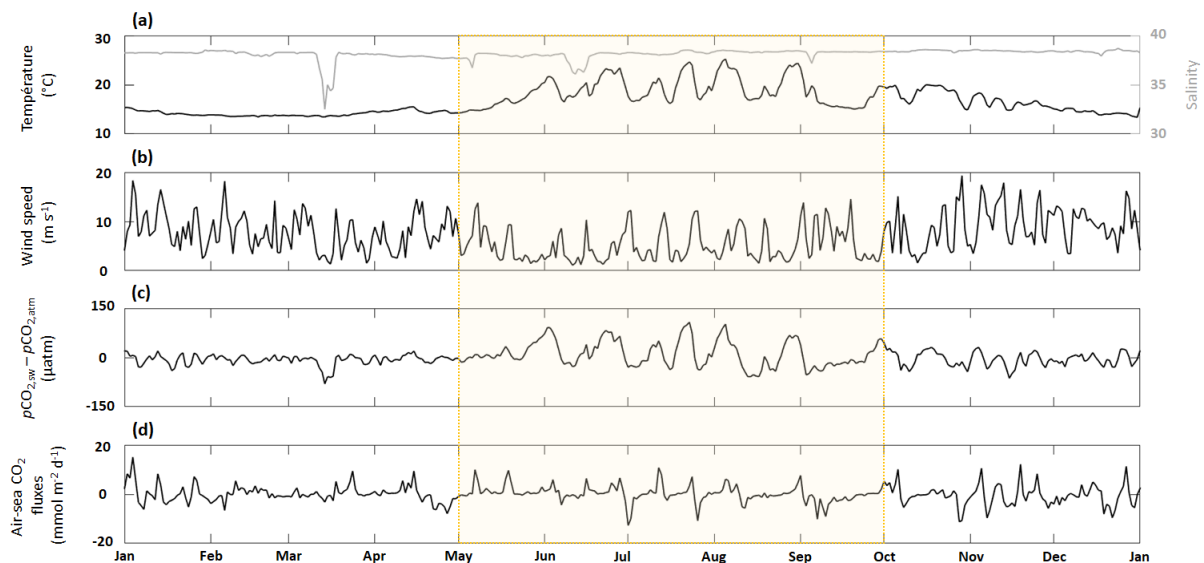


Figure 5: Time series of (a) in situ daily average sea surface temperature (black line) and salinity (grey line) (b) SIMC1 daily average wind speed (c) the difference between SIMC1 daily average seawater $p\text{CO}_2$ and in situ daily average atmospheric $p\text{CO}_2$ (d) SIMC1 daily average air-sea CO_2 fluxes (aeration process). The summer upwelling period (from 1 May to 1 October) is highlighted in yellow.

P16-Fig 6 : The panel d is quite difficult to look out, it can be quite difficult to differentiate the different blue lines (especially nTA and nDIC have very similar colours). Plus, most of the time the curves in this panel are between -100 to +100 μatm , while the y-axis goes from -600 to +600 μatm . Apart from the big events, it's quite difficult to see what's happening there. Maybe take the whole page for this picture ?

We agree. We changed the colour used for nTA representation in figure 6d. If necessary, we also propose to add an appendix which includes the enlargement of figure 6d.

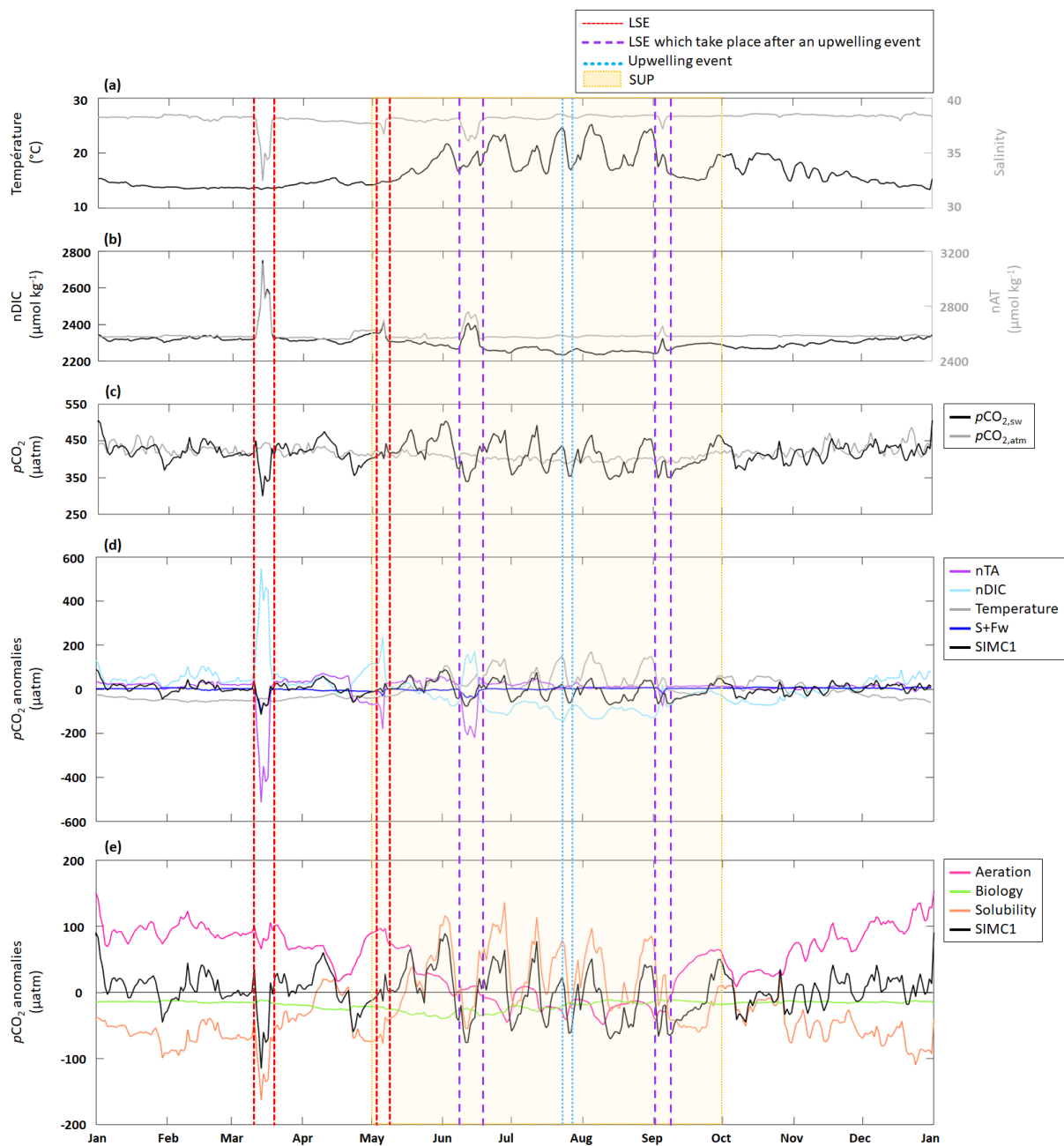


Figure 6: Time series for 2017 of daily average (a) in situ temperature and salinity (b) modelled nDIC and nTA (c) modelled seawater and in situ atmospheric $p\text{CO}_2$ (d) $p\text{CO}_2$ anomalies generated by DIC, TA, Fw+S and temperature based on the approach in Lovenduski et al. (2007) (Note: the dark blue line is sometimes obscured by the black line, especially in March. [An enlargement of the panel d is available in Appendix X.](#)) (e, j) $p\text{CO}_2$ anomalies generated by aeration, solubility, and biological processes based on the approach in Turi et al. (2014). LSE and an upwelling event have been highlighted. The summer upwelling period (SUP) is indicated by yellow shading.

[Appendix X: Time series of daily average $p\text{CO}_2$ anomalies generated by DIC, TA, Fw+S and temperature based on the approach described in Lovenduski et al. (2007), for 2017. Enlargement of the panel d of the figure 6.

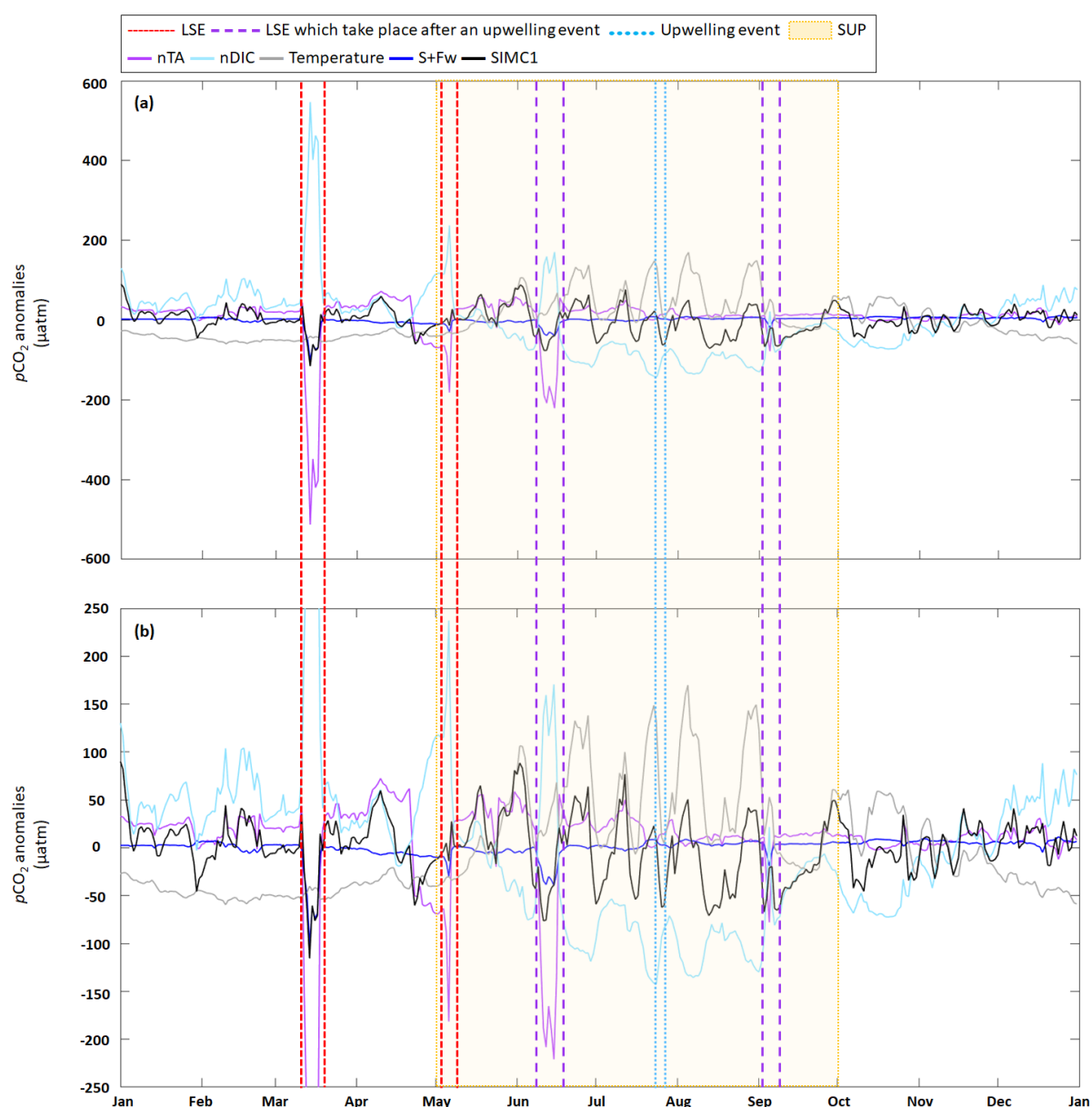


Figure C1: Time series for 2017 of daily average (a) $p\text{CO}_2$ anomalies generated by DIC, TA, Fw+S and temperature based on the approach in Lovenduski et al. (2007) (Note: the dark blue line is sometimes obscured by the black line, especially in March), (b) Enlargement of the panel a between -250 and 250 μatm . LSE and an upwelling event have been highlighted. The summer upwelling period (SUP) is

indicated by yellow shading.

]

P17-L365 to 370 : You forgot to refer to Fig. 6e somewhere in this section.

We added it (l.365-370). [The four LSE are also visible in the solubility-generated anomalies generating strong decreases (Fig. 6e). However, only two LSE are easily identifiable (15 March with a drop from -41 μatm to -163 μatm and 6 May with a drop from 8 μatm to -75 μatm) while the other two appear to be obscured by temperature-related counter-movements. Since aeration- and solubility-generated anomalies show opposite seasonality, they partly cancel each other out. While aeration seems to dominate from November to May, (apart from LSE), solubility appears to dominate from May to November and during LSE. Biological processes are never the dominant driver of $p\text{CO}_2$ variations as they are systematically smaller (by a factor of 2 to 3) than aeration and solubility-generated anomalies (Fig. 6e). Biology-induced anomalies are always negative, providing evidence that biological processes always decrease $p\text{CO}_2$.]

P19-L445 : “we could (not cloud) provide”.

Thank you for pointing this out, we corrected it.

P20 – L477-8 : “While we only considered TA inputs” (only in the allochthonous formulation, I guess), “Rhône River intrusion can also bring nutrient”. This is never explained till now. I already said it in the first part of the review, but you have to be clear about this. The reader cannot fully understand your results otherwise. The model biology only feels the environment changes/variations through the physical forcing only (T, S and light). The biology reacts to the Rhône water only because it is fresher, or to the upwelling because it is colder, but not because of the associated nutrient changes (that do not occur). It is important to tell it because the biology can react in the opposite way than otherwise expected and explain that because it is a 0D model you probably don’t have much choice (as I understand it). Knowing that, I am surprised by the DIC variations Fig. 3, that are surprisingly good.

P21-L482-4 : same remark than just above.

We hope that adding 2.2.1 and the figure 2 to the manuscript clarifies this point. However, we also modified this paragraph to better emphasize that only changes in temperature, salinity and AT are considered by the model during these events (l.477 to 482):

[In all four LSE, biological processes did not have any significant impact on $p\text{CO}_2$ variations (Fig. 6e). To interpret this result, it is important to consider the assumptions used by Eco3M_MIX-CarbOx (section 2.2). Rhône River intrusion can significantly modify the biogeochemistry of the bay as they are typically associated with temperature and salinity changes and TA, DIC and nutrients inputs (Gatti et al., 2006; Fraysse et al., 2014; Lajaunie-Salla et al., 2021). Due to its 0D configuration, Eco3M_MIX-CarbOx only represents temperature and salinity changes and TA inputs (only if the allochthonous formulation is used for the latter). Lajaunie-Salla et al. (2021) showed that nutrient inputs associated to Rhône River intrusion in the BoM led to an increase in chlorophyll concentration. This phytoplankton growth leads to further decrease in $p\text{CO}_2$, which means that by neglecting nutrient inputs we possibly underestimated the importance of biological processes, and especially of autotrophic processes during Rhône River intrusions. Moreover, the high DIC concentrations observed in Rhône River waters (2995 $\pm$ 575 μM on average, Sempere et al., 2000) could also affect $p\text{CO}_2$ variations by increasing the nDIC contribution during intrusion events which counteract the overall of $p\text{CO}_2$ that is typically observed during these events.]

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