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Biogeosciences Discussions

Interactive comment on "A mathematical modelling of bloom of the coccolithophore *Emiliania huxleyi* in a mesocosm experiment" *by* P. Joassin et al.

P. Joassin et al.

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Dear reviewer,

We do thank you for the time you spent to read our manuscript. Your comments will indubitably help us to improve our work. Here below, you will find our answers to all your comments taken one by one (in italics).

Reviewer: “The discussion tends to focus on whether the data fits the observations of this particular experiment”

The mesocosm experience focused on the impact of the varying pCO2 on different Ehux cellular activities able to participate to an export of carbon, i.e. primary produc-

tion, calcification and production of TEP. The main goal of this model developed in the scope of that mesocosm experience was to represent conjointly all these three cellular processes. As you underlined it, the model achievement described in the manuscript is the first stage of the application of the model as a predictive tool regarding impact of pCO2 variations on Ehux physiology. Prior to appreciate the reaction of the model in particular pCO2 conditions, one should appreciate the capacity of the model to take into account the specific conditions imposed by the mesocosm environment. This requirement motivated the consideration of particular process like the enhanced Ehux mortality due to viral lysis in a confined environment. Actually, the present work does not intend to focus its discussion on the predictive capabilities of the model but focuses on the gathering in the same conceptual structure of formulations representing such different processes like primary production, calcification and TEP production. A good matching of the model results with the data of the present-day pCO2 conditions should be underlined as it reflects the coherence of the mesocosm experimental data set and the reliability of the formulations used. Beyond that first stage, the model may be suitable for further applications in higher pCO2 conditions.

It must also be recalled that this mesocosm experiment had offered a unique diversified data set to test conjointly several formulations about cellular processes. In our knowledge, this is the first time that a dynamic model of coccolithophores disposes of such a diversified data set to be calibrated. Indeed, alkalinity and DIC data allow for instance the validation of the representation of the calcification process. Data on DOC, DIC and TEP allow the validation of the representation of DOC extra-excretion and TEP formation. Nitrate, Ammonium and phosphate data allow testing the formulation of inorganic nutrients uptakes by coccolithophores. Data on DIC, nutrients and chlorophyll allow assessing the uncoupling of carbon and nitrogen dynamics. All these mathematical formulations were revealed to be consistent with the whole set of observations. This global approach singularises our model as far as the validation of existing models of coccolithophores dynamics may be quite crude. Indeed, the validation of many models including coccolithophores resides only in satellite-derived concentrations in chloro-

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phyll or phytoplankton abundances. In those cases, the absence of data for alkalinity, DIC, PIC and DOC does not allow testing formulations concerning calcification or TEP production.

Finally, it should be noted that we did not limit our discussion to the analysis of the matching between model results and observations. We used the model in order to provide carbon and nitrogen budgets. These flows have not been measured and the model provided quantification for them (see figure nr.6 in the manuscript). Doing so, the model showed the presence of 3 to 4 particular periods in the bloom chronology. At last, the model underlined the importance of the choice for an unbalancing growth between carbon and nitrogen.

Reviewer:” With no grazing control on bacterial biomass, the model probable has no steady state with mineral nutrient limited bacterial growth rate“

In order to avoid an excessive complexity, the model has to go throughout simplifications for several aspects concerning the representation of the ecological environment. Among them, we do agree that the consideration of grazing and the implication of phytoplankton species other than Ehux are the most subject to debate. Giving the fact that experimentalists affirmed that grazing was not a significant mortality cause for Ehux in the mesocosm experiment; a reasonable assumption may consider that the mortality caused by micro and mesozooplankton grazing is a constant fraction of the Ehux carbon biomass. Following this assumption, the mortality due to grazing can be considered as included in the constant mortality term applied to Ehux carbon biomass in the model. This option might be safer rather than an explicit representation of zooplankton grazers while there is no experimental data concerning zooplankton usable for any validation of added zooplankton state variables. Concerning the bacterial biomass, it is sure that a retro-control due to grazing would have refined the representation of bacterial growth. But once again, the absence of data concerning grazers would have brought the model to an upper level of complexity without having the possibility to verify its relevance with the experimental observations. In any case, the results of the model

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for the bacterial growth are fairly good regarding the fact that the model is not properly dedicated to the study of bacterial dynamics. However we do agree with your comment suggesting that the discussion shall be extended concerning the competitive behaviour of the bacterial pool for inorganic nutrients. Following model results, bacteria are actually never competitive with Ehux for inorganic nutrients: an excretion of ammonium is sustained by bacteria through the whole simulation.

Reviewer:” Competition between Ehux and other flagellates in the same size class in particular “

Another simplification resided in the fact the model does not take into consideration the presence of other phytoplankton species belonging to the same size class, i.e. Micromonas specie. This phytoplankton specie indeed realises a bloom in the beginning of the experiment, which was observed and measured through the Micromonas enumeration. However, the impact on nutrients stocks due to this Micromonas bloom is not significant. The nitrates consumption imputable to Micromonas does not give a remarkable signal on the nitrates time-series (see the nitrate observed time-series in figure 3). Moreover, it must be observed that following the measurements of chlorophyll, the Micromonas bloom intensity is quasi 10 times weaker than the one realised by Ehux. Changing the initial conditions was not a solution to avoid the eventual sidestep due to the bloom of Micromonas. If the model started at day 10, the time given to the simulation is not enough to leave the coccolithophores blooming in phase with the observations.

Reviewer:” The whole data set is used for fitting, i.e. there is no validation part of this work“

Most of parameters are taken from literature sources. The values used for these parameters remain within the extremes of the sourced values withstanding that these extremes offer sometimes a great range of choice. To be a reliable tool to study the impact of particular pCO2 conditions, the model has to demonstrate its ability to rep-

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resent the whole set of experimental variables for the present-day pCO2 conditions taking into account the specific conditions imposed by the mesocosm environment. This requirement motivated that some parameters were derived from certain variables of the experimental dataset (only issued from the present pCO2 conditions), as far as the calculated values remained acceptable regarding values proposed in literature source. The coherence of the data set, provided by the same mesocosm experiment, and the various biochemical variables followed during the experimental duration allows considering that a validation of the model is actually performed as far as most of the measured variables remained unused to obtain the calculated parameters. It should be underlined that the model promotes a representation of several cellular processes highly interdependent: calcification is partly function of primary production, and TEP production depends on cellular C:N ratio which controls also the uptakes of DIC and so the primary production. The global matching of all these modelled processes to the correspondent observations should confirm the reliability of the set of parameters applied in the model.

Reviewer:” This model is likely to be used as a module“

As you underlined it rightly, the model needs to deal with final practical applications. This first stage of its development provided a mathematical tool fitted with reliable formulations for a conjoined representation of key processes like primary production, calcification and production of TEP. Among these applications, we find of course the confrontation of the model with future higher pCO2 conditions. Beside, we do follow your opinion about the fact that the model should be considered as a module to be included in larger ecological model. From that point of view, the model should learn about the mandatory processes required to correctly represent the dynamics and the interactions of Ehux with a larger biogeochemical environment. To our opinion the major outputs of our work are as follows: - The model indeed learns about certain simplifications of Ehux mathematical representation. One of them concerns indubitably the state variables of free calcite and attached calcite. Following model results, it was observed

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that the molar calcite to organic carbon ratio of an Ehux cell remains quasi unchanged between values of 0,55 to 0,57. Regarding that fact, and within the condition that the model is applied in environmental conditions where there cannot occur any dissolution of calcite, the model economises both state variables of free and attached calcite. - The model demonstrates that the unbalanced growth model is duly requested to represent Ehux. The decoupling between DIC and DIN uptakes is certainly requested if the model aims to represent the TEP production, which is basically driven by the evolution of the cellular C:N molar ratio. - As said before, mathematical representation of important processes affecting coccolithophores were thoroughly validated with the diversified data set (see first point of our answers).

In future applications, we will use results of this study to represent the dynamics of coccolithphores in the Black Sea. We will represent this group by two boxes: carbon biomass and nitrogen biomass assuming that the Ca:C ratio is constant. All the mathematical formulations of processes will be kept unchanged as well as the parameters set. Then, we will assess whether a re-calibration of the model is necessary using available data (that are unfortunately very scarce: only a few DIC, alkalinity profiles and some punctual measurements of coccolithophores biomass).

Reviewer:” English language in the title does not seem perfect“

We do agree that English language of the title is not correct. Several other corrections concerning grammar and syntax have been brought to the text.

Interactive comment on Biogeosciences Discuss., 5, 787, 2008.