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Interactive comment on "A zooplankton diel vertical migration parameterization for coastal marine ecosystem modeling" *by* Ariadna Celina Nocera et al.

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We address the points below, referee comments are in bold text.

General Evaluation

This study uses a 1-D NPZD model with a theoretical parameterization of the zooplankton diel vertical migration (DVM) to infer its impact on coastal ecosystem and carbon export. Simulations cover a wide range of parameters to analyse the sensitivity of the DVM and its impacts to model parameters (e.g. grazing rate, op-

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timal irradiance) and boundary conditions (e.g. winds conditions). The authors conclusion stress the importance of the grazing rate and the swimming speed to accurately represent the carbon export in coastal shallow marine ecosystems.

I found the objective of this study difficult to identify. What is the overall goal of the study ? While the experimental set up seems sound, results from previous model studies including a DVM parameterization are not discussed, which makes its impossible to identify new scientific inputs from the present study. Only one is really cited (the 1D model of Bianchi et al. 2013) and not thoroughly discussed. As an example, in the latter study, the optimal irradiance (Ic) chosen was 1.10-3 W.m-2, an Ic that is not even in the range of the tested parameters while the authors acknowledge its utmost importance in "accurately" reproducing DVM. What would be the added value to 3-D biogeochemical models (e.g. see Bianchi et al, 2013b; Aumont et al. 2018)?

We thank the reviewer for recognizing the qualities of our experimental set-up. We agree that the review of other modeling studies is not as thorough as it should. We will thus add text in our manuscript to fill that gap. Note that at the time the bulk of this work was done, Bianchi et al. (2013) was the only existing study. Since then, others have been published.

- The model of Bianchi et al. (2013) is the only existing model that explicitly simulate the migration of an Eulerian zooplankton compartment. Their parameterization is based, like ours, on the hypothesis that light is the main driver of DVM. They chose their isolume $I_c = 10^{-3}$ W m^{-2} in order to comply with observations of the migration depth, a value that is kept unchanged in all their simulations. Zooplankton migrates at a maximum speed $w_Z = 3$ cm s^{-1} $= 2592$ m d^{-1}, set constant everywhere except when approaching the isolume depth or the food maximum (the value of the maximum is not prescribed), in which case the speed decreases linearly to zero over a scale of 50 and 20 m, respectively. We recall here that our parameterization uses a vertical swimming speed that continuously scales as a function of the difference between the local irradiance and the optimal isolume I_c, and that zooplankton stops swimming when it encounters enough food, i.e. when the phytoplankton concentration is larger than P_{min}. Instead of assuming one value is representative of Nature, we carry a sensitivity analysis to explore how the ecosystem may respond if these parameters vary, which we think is a sound scientific approach to study highly complex systems with uncertain parameters. We stress that those two parameters are very seldom measured directly, but depend on indirect observations. Values we chose for the maximum swimming speed (i.e. animals are far from the preferred isolume) represent a maximum swimming speed of three body lengths per seconds for mesozooplankton ($\mathcal{O}10^2$ m d^{-1}). Parameters driving DVM in the study of Bianchi et al. (2013) have been chosen somewhat arbitrarily, as they claim themselves.

- Aumont et al. (2018) present a model, later used by Gorgues et al. (2019), that implicitly simulate DVM by assuming that zooplankton migrate instantaneously. This strategy is used because both the vertical resolution and the time step are quite large (the vertical grid spacing is 25 m near the surface and the time step is $\Delta t = 10\ 800$ s$= 3$ h) in order to limit the computational costs implied by the global domain and the biogeochemical model. Their choice of isolume is made according to a "quick" comparison with acoustic data and discrepancies are explained by an improper representation of light attenuation. Moreover, their implicit representation does not allow turbulence to affect the vertical movements of zooplankton, like it is the case in our explicit Eulerian framework.

The added value of our study is specifically to simplify the physical configuration in order to explore the range of parameters that may affect the plankton dynamics in the presence of DVM. There is no evidence in the relevant literature that a preferred representation of DVM exist with a defined set of parameter values.

Moreover, the choice of a coastal set up with shallow waters but with only surface turbulence considered would have required some justification, particularly if one of the main message of the study is referring to "benthic zooplankton". Coastal region where there is no tides or internal waves that will generate turbulence/mixing above the seafloor are so common?

Figure 1 (this reply) and the associated caption will clarify and justify the choice of our model configuration and to what type of coastal ocean does it apply or refer. See response on comment 22 of Referee #2. The proposed caption for Fig. 1 is: "Schematic illustration of the diel vertical migration in the context of a stratified marine environment. The left panel shows the relevant parts of the water column between the sea surface and the seabed. Wind forces turbulent mixing from the sea surface down to the pycnocline. The interior layer is characterized by low diffusivity ($K_z = 10^{-5}$ m s^{-2}) and the benthic layer is where detritus accumulates. Without DVM (central panel), zooplankton grows wherever there is food, which is predominantly phytoplankton in the euphotic layer, and detritus that accumulate near the seabed. With DVM (right panel), zooplankton swims toward a preferred light level, sometimes fighting against turbulence, with occasional pauses wherever phytoplankton is sufficiently abundant. One consequence of DVM is that it never ventures below a certain depth and can't develop near the seabed."

What is the rationale to justifiy the relationship between phytoplankton availability and DVM?

There is large set of data supporting the relationship between food (phytoplankton) and zooplankton migratory behavior (DVM) resulting in the hunger-satiation hypothesis (Pearre 2003). In the mentioned work, and supported by more literature (references therein), phytoplankton availability is the principal trigger to zooplankton "upward" movement, and light could be considered as a secondary factor. Accordingly, in our model zooplankton maximum depth is in close relationship with phytoplankton concentration, low phytoplankton availability driving upward migration to the surface where

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there is supposedly greater prey concentration.

Finally, the authors claim that "the zooplankton grazing rate and swimming speed parameters are particularly important for an accurate representation of the carbon export in coastal shallow marine ecosystems", but no observations whatsoever is given to backup this assertion. As a conclusion, "as is", this study is not put in the context of either modeling studies or observational studies. The parameterization chosen and the experimental set up is not really discussed either.

We think there is a lack of clarity in the text in this section from our side. The conclusion section is focused on the results obtained under this specific work, that is, for a 1D NPZD model representing a stratified marine environment (where tidal mixing is low). DVM effects could be quite different from those found in deeper ocean areas, but the associated patterns can match (Hamame and Antenaza 2009). We will rephrase this part of the section by putting an emphasis on how DVM affects biogeochemical interactions from a modeling point of view instead of concluding broadly on carbon export, which can't be easily deduced. We will further discuss other modelling exercises both in terms of the parameterization as well as on the results obtained in the respective modelling scenarios.

Specific points

p3 line 27: irradiance

Thanks.The typing error was fixed.

p8 line 9: Why restrict the analysis over a zooplankton biomass threshold?

We think there was a misunderstanding as the restrictive rule that we implemented for simulated zooplankton vertical migration was a phytoplankton minimum concentration threshold. This is described in the Equation 1 (DVM parameterization). The assumption that underlies this rule is the hunger-satiation hypothesis in vertical migration presented by Pearre (2003).

p9 line 18: On fig 4d the isolume is quite shallow (because of high phytoplankton concentration, I guess) therefore there is no need for zooplankton to go deep, isn't it ? Is this what you meant by this sentence :"The grazing rate is not sufficiently large to deplete phytoplankton, which remains abundant enough to provide zooplankton for a reason (with respect to the parameterization) to remain at this depth."?

(We've changed Figure 4 order as suggested by Referee #2, now is mentioned as Figure 5).

Yes, due to the chosen zooplankton grazing rate value = 0.5 d^{-1}, phytoplankton concentration never attain values below the imposed minimum concentration P_{min}= 1.4 mmol N m^{-3} that induces zooplankton to move. Thus zooplankton does not migrate following phytoplankton and their maximum concentration is confined during day and night between 15 and 25 m.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2020-10/bg-2020-10-AC3-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-10, 2020.

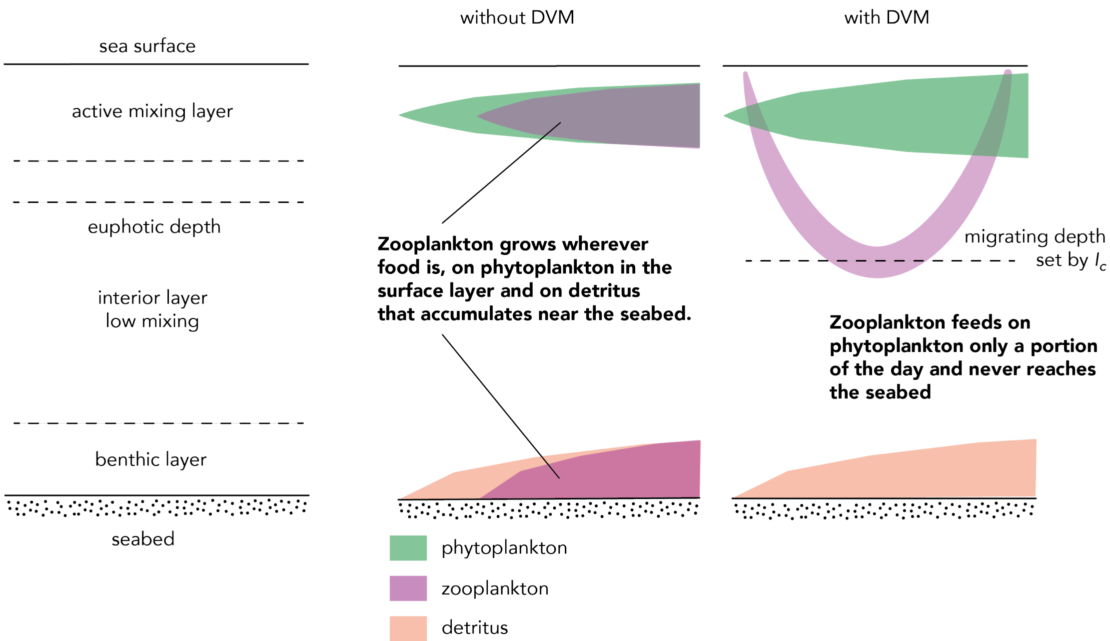

Fig. 1. Schematic illustration of the diel vertical migration in the context of a stratified marine environment.