

Interactive comment on “The fate of upwelled nitrate off Peru shaped by submesoscale filaments and fronts” by Jaard Hauschildt et al.

Anonymous Referee #2

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The authors present a study that combines observations and modeling in order to assess the role of submesoscale filaments and fronts in the lateral and vertical redistribution of the upwelled nutrients. They use ship data collected both along shore and cross shore transects off the coast of Peru to study the structure of upwelling filaments and their role in the nutrient transport and subduction, and its impact on primary production. Further, they use a coupled CROCO+PISCES simulation to strengthen these findings and expand their analysis through lagrangian experiments that allow them to follow the biogeochemical transformations of upwelled particles. They find that submesoscale filaments advect upwelled nutrients offshore, while also subducting them, therefore limiting production.

The paper is interesting and contains relevant in situ data on these submesoscale

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structures. I appreciated the Lagrangian approach to study biogeochemical transformations and the fate of the upwelled particles. The results are interesting: they strengthen previous claims regarding the importance of filaments and fronts for the offshore transport, while clarifying better the role of these structures in the enhancement of subduction (rather than submesoscale upwelling). The writing is good, with a few typos and some potential for improving the paper structure (see comments below).

I have two major comments that I'm listing below, plus a few minor/detailed comments following. My main concerns regard: lack of a thorough model evaluation, lack of a clear description of the biogeochemical model and therefore of the meaning of certain processes the authors refer to to draw conclusions. I also have a few concerns regarding the paper structure, which I am listing in the detailed comments as they refer to some specific sections. I suggest that the paper is published after revisions are done.

MAJOR COMMENTS

1) Model evaluation

In my opinion, the paper lacks of a thorough model evaluation. Was this exact model setup and run used in a previous publication, where a full evaluation can be found? Is there an appendix or supplementary material that I missed containing more information in this regard? If this is not the case, I strongly encourage the authors to provide a better evaluation of the model, as the current information doesn't seem enough to me. The only figures that provide some comparison between model and observations are Figure 2, 3, 4. However, these images refer to specific days (April 14 2017 and April 5 2017 respectively in observations and model), and they seem to show pretty large biases in the temperature and salinity fields in the model, especially in the upwelling area. These are accompanied by very high nutrient levels, suggesting a high bias in the upwelling fluxes overall. Both the physical and biochemical tracer biases can have important repercussions on the lateral and vertical fluxes and transformations which require to be discussed in the paper discussion section as they may impact the results

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of the Lagrangian analysis. No longer term mean evaluation of the model is explicitly provided (even though the model was run for several years). Also, the discussion of the model performance in the paper text is too qualitative and scattered throughout the text, while it would be worth having a dedicated subsection. I strongly suggest that the authors include in the paper some difference plots (SST, SSS, MLD, velocities, EKE, CHL, nutrients) and/or use a Taylor diagram to summarize the performance of the model in the region of study in order to be able to assess its limitations in the discussion.

2) Biogeochemical model

Throughout the text, the authors refer to key biogeochemical processes resolved by the model PISCES. However, these processes are never well defined in terms of what other modeled processes and variables they depend upon, and which quantities drive and regulate them in the model. Sometimes assumptions are made regarding modeled biogeochemical processes, when the way they work should be known from the model equations. Please, include an explicit description of the few relevant model processes in your methods section, and clarify to the reader how they relate to each other, providing fundamental knowledge regarding the characteristics of the employed biogeochemical model. Example 1: in page 15, lines 10-16, the authors discuss the fact that chlorophyll and production relate differently to each other in model and observations; this depends on the model code, which is known, and therefore the question is: how does PP relate to CHLA in the model? Can you explain these differences using the model equations, since they can be checked, and is it worth suggesting any amendment to the processes represented by the model given what you find in the observations? Since this process is of interest, the authors should include more information on the model representation of these processes in the methods. Example 2: page 15, lines 29-30: The authors talk about modeled primary production and nitrate uptake, however no information was provided to understand how the two relate to each other in the model. What processes contribute to nitrate uptake in PISCES?

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Introduction/Discussion: Please, include the following relevant literature and discuss how it compares to your findings

FILAMENTS STRUCTURE

- Bettencourt, J. H., Rossi, V., Hernández-García, E., Marta-Almeida, M., and López, C. (2017), Characterization of the structure and cross-shore transport properties of a coastal upwelling filament using three-dimensional finite-size L yapunov exponents, *J. Geophys. Res. Oceans*, 122, 7433– 7448, doi:10.1002/2017JC012700.

IMPACT OF MODEL RESOLUTION ON VERTICAL FLUXES

- Zhong, Y., and Bracco, A. (2013), Submesoscale impacts on horizontal and vertical transport in the Gulf of Mexico, *J. Geophys. Res. Oceans*, 118, 5651– 5668, doi:10.1002/jgrc.20402.

- Zhong, Y., Bracco, A., Tian, J. et al. Observed and simulated submesoscale vertical pump of an anticyclonic eddy in the South China Sea. *Sci Rep* 7, 44011 (2017). <https://doi.org/10.1038/srep44011>

SUBDUCTION BY FRONTS

- Stukel, M.R., Song, H., Goericke, R. and Miller, A.J. (2018), The role of subduction and gravitational sinking in particle export, carbon sequestration, and the remineralization length scale in the California Current Ecosystem. *Limnol. Oceanogr.*, 63: 363-383. doi:10.1002/lno.10636

- Michael R. Stukel, Lihini I. Aluwihare, Katherine A. Barbeau, Alexander M. Chekalyuk, Ralf Goericke, Arthur J. Miller, Mark D. Ohman, Angel Ruacho, Hajoong Song, Brandon M. Stephens, Michael R. Landry *Proceedings of the National Academy of Sciences* Feb 2017, 114 (6) 1252-1257; DOI: 10.1073/pnas.1609435114

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DETAILED COMMENTS

Page 2, line 10-11: This sentence is too long, please split it in two parts.

Page 2, line 34: Please add the following modeling study for the filament transport in the Canary Upwelling System: Lovecchio, E., Gruber, N., & Münnich, M. (2018). Mesoscale contribution to the long-range offshore transport of organic carbon from the Canary Upwelling System to the open North Atlantic. *Biogeosciences*, 15(16), 5061-5091.

Page 3, line 6-7: Please rephrase the following sentence “For instance, if nitrate uptake by PP occurred much faster than subduction, then mainly organic matter produced in the surfacelayer would be subducted, whereas if it were slower, nitrate would be subducted.”

Page 3, line 9: What does “process studies” mean?

Page 3, line 23: Is 2.5 km resolution enough to resolve submesoscale? I thought one needed at least 2km, if not 1 km. Could you please refer to literature to confirm your statement what 2.5 km is enough?

Page 3, line 26, point nr.1: As I stated, I don't think the paper answers this question, because the model evaluation in the paper is extremely limited and restricted to a few specific simulated events rather than the mean state of the system and its dynamics. Also this is more of a model evaluation problem than a scientific question. I wouldn't include question nr 1 here, I would only leave questions nr 2 and 3.

Subsection 2.5: Please provide here a description of how the relevant processes discussed in the paper are represented by the biogeochemical model PISCES. Please, specify what is the time resolution of your model output.

Subsection 3.1: The structure of this subsection is confusing, as it alternates results

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from the observations (paragraphs 1 and 3) and results from the model which actually in great part is a model evaluation. Please, move out the model evaluation from here and create a proper section that focuses on it, in order to refer to it also in the discussion when considering the limitations of the model. Also, please list first all the results obtained from the observations, and then those obtained from the model, without switching from one to the other in each paragraph.

Page 11, line 7: “The variability of biogeochemical fields is similar to observations”. Please, avoid using generic terms such as “similar”.

Page 11, line 21-24: Please, remove this summary: these results are expected in any upwelling region, so it doesn't really add much information.

Figure 3 and Figure 4: What do the model output sections represent? Is this still a single instance such as Figure 2 (April 5th 2017)? Or is this some longer term mean? Please, state this in the captions. Also, how was the specific day for the model analysis and plots chosen? Currently, some explanation is given in page 14 lines 31-35, however some of the plots have already been introduced before this paragraph. Also, I would assume there are several events that may resemble the observations in the many years of model run, why was only a specific event chosen rather than using an ensemble of suitable events? Please, explain your rationale for the choice of day either in the captions or in the Methods.

Page 14, line 21: The paper provides a discussion of PP and how differently it relates to CHL in model and observations. Therefore, why is PP not plotted in Fig 3 and 4 if it's a variable of interest? Would it make sense to add it?

Page 14, line 31-32: Please, rephrase the first sentence as it's not good English.

Page 14, line 33: Please rephrase here with “We therefore picked simulated filaments...”

Page 15, line 10: Please, substitute similar with similarly

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Page 15, line 17-27: This paragraph is not very useful and sounds like a repetition. It could be removed.

Page 15, line 29-30: I don't understand this first sentence. Since one can actually determine the simulated rate of nitrate uptake in the model, why should one "assume" something about it?

Page 17, line 14-24: This section belongs to the Methods, not the Results.

Page 17, line 24-26: Why should this implicit assumption be reasonable? Could you please provide some reason? Also, what is the definition of "subducted" - below what depth (this should be defined in the methods)?

Page 16, line 10: This initial sentence about the importance of SST remarks that it's crucial to include a good evaluation of the temperature gradient in the model.

Figure 7: The x-axis labels and ticks overlap in the subplots.

Page 19, line 1-13: Wouldn't it be necessary to also discuss how the general model performance changes changing the resolution? What about the effects linked to the change in resolution of the forcing such as the wind stress, which is known to influence both upwelling and small scale flow? This paragraph compares two runs, but none of them was thoroughly evaluated.

Page 19, line 20: Please add "is" in "during one season and is less..."

Page 19, line 31-32: Please rephrase better the sentence "Further offshore..."

Page 20, line 1: Who are "they"?

Page 20, line 2: Please substitute "a nitrate increase is found" with "nitrate increases"

Page 20, line 3-4: Why is this a "plausible explanation"? Too short and speculative, this needs to be expanded and explained better, possibly in the discussion.

Page 23, line 7: Is this measurement from 1985 the only available measurement?

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Page 20, line 5-15: This entire paragraph belongs to a model evaluation.

Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2020-112>, 2020.

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