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Comment on bg-2021-97

Sarah Schlunegger (Referee)

Referee comment on "Deep chlorophyll maximum and nutricline in the Mediterranean Sea: emerging properties from a multi-platform assimilated biogeochemical model experiment" by Anna Teruzzi et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-97-RC1, 2021

Referee comments on "**Deep chlorophyll maximum and nutricline in the Mediterranean Sea: emerging properties from a multi-platform assimilated biogeochemical model experiment**" by Teruzzi et al., currently in discussion at Biogeosciences.

Teruzzi et al presents the results from a data-assimilating biogeochemical model of the Mediterranean Sea. This work provides a novel case-study of the dual use of remotely-sensed (ocean color) and *in situ* (BGC-Argo) biogeochemical constraints in reconstruction of one year of the biogeochemical state of the Mediterranean Sea. Firstly, the data-informed model solution demonstrates fidelity with observations for a number of surface and depth-resolved biogeochemical metrics, such as the vertical position and longitudinal gradients of the deep chlorophyll maximum and its co-variance with the nutricline. Secondly, the study presents compelling evidence for the synergistic benefits of assimilating estimates of remotely-sensed chlorophyll concentrations in tandem with in situ, depth-resolved estimates of chlorophyll. Thirdly, the study discuses some of the nuanced differences between the impacts of assimilating satellite versus BGC-Argo chlorophyll upon the model solution. The most striking difference discussed is the strong seasonal signatures the different observational streams have upon the solution, with remotely-sensed chlorophyll providing stronger constraint during winter months, and in situ chlorophyll providing stronger constraint during summer months. Finally, implications for optimized sampling strategies, such as the recommendation that BGC-Argo increase sampling frequencies during the 'influential' summer season, are discussed.

This work represents a timely contribution to the underway community efforts towards optimizing the design of a global, autonomous biogeochemical observing network for use in constraining reconstructions of the evolving ocean state. I recommend this manuscript for publication after a few minor clarifications and elaborations are incorporated, as I outline below.

Points of clarification:

- The model setup describes the biogeochemical model as being coupled offline to the dynamical model. Coupled implies two-directional influence, i.e. that the biogeochemistry is both impacted by and impacts the dynamical fields. Is this the case?
  - If it is the case that the model set up is "coupled" in the true sense of the word, then the impact on the dynamical fields should also be presented.
  - If it is not the case, and in fact the biogeochemical model or assimilation of biogeochemical fields does not feed-back or modulate the underlying dynamical fields, then a more appropriate term to use is "forced" or "driven" – i.e. Line 135 should read "the MedBFM was forced or driven offline with output from MENO3.4-OceanVar…"
- To improve accessibility, an additional paragraph of description or context of Eq. 1 should be included. This would involve, for instance, expalaination of the "innovation" term (Line 159), and discussing the significance or intuitive purpose of the different covariance vectors.
- Regarding the "Impact indicator" metric:
  - (a) It needs to be explained that the impact indicator given by Eq 2, although it does not contain an explicit 'directionality' of the impact (i.e. towards better or worse agreement with the data-constraints), that the assimilation methodology works to push the model solution towards the data, therefore any non-zero value of I(t) represents a nominal improvement in model-data fit. From the equation alone, and without sufficient prior understanding of the methodology, this is not obvious, making it difficult to interpret if the additional streams of assimilated data are merely influencing or in fact improving the solution.
  - (b) The maps of Fig. 6 and Fig. 7 present a very derived / abstract metric. These figures present the 50th and 90th percentile 'impact' of assimilated the given field during the given season. Interpretability of this abstracted metric would improve if an additional subpanel was included in each figure which showed a representative distribution of the impact-indicator for a single grid-cell (or averaged over a region), with markings at the 50th and 90th percentile. This could also provide opportunity to contrast the summer vs. winter distributions of the indicator. For instance, for chlorophyll, the winter distribution of the indicator would be shifted toward "1" while the summer distribution would be closer to "zero". See a mock-up below. This will help orient the reader as to what the maps are presenting.

- The conclusions section would benefit from a final sentence that poses the significance of the study within the context of future advances in biogeochemical data assimilation within basin and global domains, i.e. something like " The multi-platform assimilation yielded improvements in model representation of large-scale (hundreds to thousands of kilometers) bio-dynamical features and is suggestive of the applicability of this advancement to reconstructions of other ocean regions and the global domain."

Minor editorial and stylistic suggestions:

L7-10: Rewrite to something like: "Data assimilation has lead to **advancements in biogeochemical modelling and scientific understanding of the ocean**. The recent operational availability of data from BGC-Argo floats, which provide valuable insights into key vertical biogeochemical processes, **stands to** further **improve** biogeochemical

modelling through assimilation schemes that include observations **from floats** in addition to traditionally assimilated satellite data." (bold is new)

L16: "maximum depth**,** intensity and nutricline depth" (added a comma and removed the first 'and')

L39: Add the following reference, which also provides motivaiton for the direct use of optical properties in data assimilation:

Dutkiewicz, Stephanie, Anna E. Hickman, Oliver Jahn, Stephanie Henson, Claudie Beaulieu, and Erwan Monier. 2019. "Ocean Colour Signature of Climate Change." *Nature Communications*. 10 (1). https://doi.org/10.1038/s41467-019-08457-x.

L40: Ocean-colour observation assimilation takes advantage of the frequent, large-scale satellite observations of **ocean properties related to the microbial biology of the upper ocean.**

L42: "deeper ocean layers requires approximations **and assumptions.**"

L45: "localization" – what does this mean?

L66: "ideal" – replace with "suitable" or "appropriate" – as it could be easily argued that a region with less coastal margins and more open-ocean conditons, where ocean color is more reliable, would be a more 'ideal' location to do a multi-platform assimilation.

L348: "In our results, this **hypothesis** was **supported** by higher nutrient uptakes in the western…"

L409: Remind readers of what Vv means, i.e. " Vv (vertical co-varience error)"

L415: Remind readers of what Vb means, i.e. " Vb (biogeochemical co-varience error)"