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Reply on RC1

Liliane Merlivat et al.

Author comment on "Physical mechanisms for biological carbon uptake during the onset of the spring phytoplankton bloom in the northwestern Mediterranean Sea (BOUSSOLE site)" by Liliane Merlivat et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-315-AC1, 2022

Review of "Physical mechanisms for biological carbon uptake during the onset of the spring phytoplankton bloom in the northwestern Mediterranean Sea (BOUSSOLE site)" by Merlivat et al.

This manuscript addresses the question of what mechanisms trigger the start of the spring phytoplankton bloom and associated DIC drawdown in the Northwest Mediterranean Sea. To do this they used a suite of autonomous at sea and satellite data (2016-2019). They argue that reduced wind stress and positive air-sea heat flux leads to stratification and elevated mixing layer irradiance levels, which leads to growth of previously light-limited phytoplankton (nutrients assumed to be replete due to prior deep winter mixing). Whilst I do not believe this is an especially novel finding, a nice ¢dataset is nevertheless brought together. My main recommendation is addition of calculated light data where possible (i.e., calculating and presenting average mixing layer irradiance) – further details provided within the comments below

Calculations, an update of the figure 2 and a new figure (attached) have been made.

Lines 46–55 of the introduction would benefit from supporting references.

We will revise the introduction, add references and update the abstract.

Lines 57–59: I think it would be beneficial here to outline the mechanism by which atmospheric forcing is important for bloom initiation (i.e., by regulation of the mixed/mixing layer depth and thereby light availability).

It is now written: " the timing of the initiation of the surface spring phytoplankton bloom depends in particular on atmospheric forcing.The physical processes of wind stress, heat flux and vertical mixing control the depth of the mixed/mixing layer and thus the availability of light [Siegel et al, 2002, Chiswell, 2011; Taylor and Ferrari, 2011; Brody and Lozier, 2015; Enriquez and Taylor, 2015, Rumyantseva et al, 2019]. "

Lines 60–61: I think the justification for hourly-daily timescale observations should be expanded on a little; for example, bloom initiation might be rapid and the bloom duration transient, therefore stressing why driving factors need to be observed at high frequency

The formation of organic matter from phytoplankton at the surface occurs a few days before the accumulation of phytoplankton biomass integrated at depth, as indicated by the chlorophyll distribution observed in 2016 (Fig. 2e). This is a rapid phenomenon caused by the decrease in wind stress and change in sign of the heat flux associated with intermittent mixing and restratification events . For this reason, atmospheric driving factors must be observed at high frequency.

Lines 77–80: I think this sentence needs adjusting – the 'variability' in atmospheric forcing is not the factor leading to deep convection, rather the combination of atmospheric cooling and strong winds?

The sentence has been changed. It is written: « Intense convection resulting from repeated high wind events in winter or early spring when atmospheric temperatures are low bring nutrients to the surface layer [Andersen and Prieur, 2000; Antoine et al., 2008b; Marty et al., 2002; Pasqueron de Fommervault et al., 2015]."

Lines 143–144: Provide here the mixed layer depth criterion that was used in Holte and Talley (2009)?

The mixed layer depth was estimated using the potential density algorithm.

Line 164: Suggest 'sunlight-induced fluorescence quenching' rather than 'quenching' alone

This has been modified.

Line 199-200: How did the authors objectively define the 'onset period of the bloom'?

We define the fist day of the onset period when DIC decreases and temperature increases during identified periods of stratification when vertical mixing events are negligible. For these identified periods, biological production and air-sea exchange are the dominant processes responsible for daily changes in DIC (cf the figure below). Similarly, an increase in surface chlorophyll is observed simultaneously with the decrease in DIC.

Figure : From March 6 to April 5, (a) DIC and Chla, (b) PAR and average mixing layer irradiance. The vertical dotted black line indicates the onset of the bloom on March 18. On (a), the purple line indicates the 3 days biological diurnal DIC changes during the period considered to compute NCP. The blue and orange lines indicate the surface Chla when the glider was at a distance of less than 5 km (blue) and less than 20 km (orange) respectively from the Boussole buoy.

Figure 3. Can satellite chlorophyll-a concentration be added to these plots (e.g., 8-day averages

Over the period 2017 to 2019, GlobColour merged Chla products based on satellite observations with a resolution of 25 km, and a binning period of 8 days (http://www.oceancolour.org) were used . As a limited number (~ 7) of measurements are available during the studied period, in panels g, h, i of figure 3, only the depth of the euphotic layer is indicated (the orange line). It is

calculated as a function of Chla based on the equation of Morel and Berthon (1989):

Zeu = 34 (Chla) -0.39 (equation 2)

The objective is to compare the euphotic layer depth to the mixing layer depth over the studied period.

The labels are also cut off from panels ‘a’ and ‘g’. Also a ‘red dotted line’ is

mentioned in the figure caption, but I cannot see it in the figure? `

The figure has been corrected. The red dotted line indicates the change of sign of the net heat flux from negative to positive values on panels d,e,f. This is now indicated in the figure caption.

Figure 4: I don’t understand panel b: How is the euphotic depth being added on, with an x-axis of wind stress? How does wind stress increase with water depth? Or is the y-axis “Mixed layer depth” or ‘Euphotic depth”? If so, better to add both these labels on, otherwise it is confusing!

In the caption of figure 4, it is indicated that the blue dots correspond to the period March 14-17 and the red dots to the period March 18-21 respectively. On panel b, blue and red dots represent the mixing layer depth over these 2 periods. It is exact that the euphotic depth (purple line) does not depend of the wind stress. The depth of the euphotic layer is shown to illustrate that it varies little throughout the period March 14-21, but is shallower than the mixing layer in the period before the onset of bloom (blue dots) and the opposite thereafter (red dots).

Lines 275–289: Please can the authors calculate the average mixing layer irradiance and show this on Figures 2 and 3? This will be a function of the incident irradiance, the mixing depth, and the diffuse attenuation coefficient (see e.g., Behrenfeld et al. 2005 Section 2.1; Venables and Moore, 2010 Eq. 2). The diffuse attenuation coefficient can be estimated from surface chlorophyll-a concentrations. It is difficult to imagine how average mixed layer irradiance is changing (i.e., if this is increasing as the authors imply) without doing and presenting the results of this calculation. This is also needed to support the final statement in lines 288–289. It is also relevant for how the problem is framed in the abstract.

We have calculated the average mixing layer irradiance, I, which is a function of the incident irradiance, PAR, mixing layer depth, h, and the diffuse attenuation coefficient, Kd, estimated from surface chlorophyll-a concentrations (Venables and Moore, 2010).

K_d=0.05+0.057 □Chla□^(0.58)

I= PAR/(K_d h) (1-e^(-K_d h))

The results are shown in figure 2d of the manuscript . In 2016, the start of the increase in irradiance from March 15 precedes the increase in PAR by 3 days as a result of the decrease of the mixing layer depth observed only after 18 March (see the above figure which will be inserted in the manuscript). For the period between 2017 and 2019, only satellite chlorophyll-a concentrations with a binning period of 8 days were available, which is too large to calculate the average mixing irradiance as it is highly variable on a daily scale.

Concluding remarks section: It would be nice if the authors could use their findings to make a comment on the relative support of the different mechanisms proposed for initiation of the spring boom discussed in the introduction (i.e., from the perspective of surface DIC drawdown, whereas other studies have mostly focussed on chlorophyll).

We will add:

-we outline that in our paper we focus on the role of physical drivers to control the start of DIC decrease, and the concomitant surface phytoplankton growth which develop in shallow weak stratification of the mixed layer that appears once deep-mixing ceases.

- we have shown that the onset of the surface phytoplankton, identified by a simultaneous initial decrease in DIC and an increase in surface Chla, precedes by a few days the surface and depth integrated chlorophyll maximum detectable from space by satellites with a binning period of 8 days. This time span does not allow to identify precisely the contribution of atmospheric drivers to trigger the onset as the formation of phytoplankton biomass as it occurs on a daily basis.

References

Behrenfeld, M.J., Boss, E., Siegel, D.A. and Shea, D.M., 2005. Carbon based ocean productivity and phytoplankton physiology from space. Global biogeochemical cycles, 19(1).

Venables, H. and Moore, C.M., 2010. Phytoplankton and light limitation in the Southern Ocean: Learning from high nutrient, high chlorophyll areas. Journal of Geophysical Research: Oceans, 115(C2).

Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2021-315/bg-2021-315-AC1-supplement.pdf