Author responses to Reviewers comments for the manuscript:

“Anomalous 2022 deep water formation and intense phytoplankton bloom in the Cretan area”

February, 2024

Reviewer #2

As the editor, I hereby provide a review of your submitted paper.

I do not find evidence in this paper that there actually was a phytoplankton bloom anomaly in the area in 2022; the existence of such an anomaly can only be demonstrated convincingly when based on observations. In fact, it is stated in the text that ocean colour satellite observations of the area appear to indicate that the bloom location and timing did not occur where the model predicted it to be.

We agree with the reviewer that the manuscript misses to clearly show that the event is anomalous (in terms of intensity and timing) considering the available observations. The comparison of the available observations with the OC climatology (Fig. R1 and R2) reveals higher-than-usual chlorophyll concentrations as well as an intense bloom that is spatially and temporally shifted with respect to the usual patterns observed in the Cretan area.

In particular, Fig. R1 shows that high chlorophyll concentrations are observed on 27 and 29 March and on 1 and 6 April. On these dates, observed chlorophyll concentration is higher than 0.5 mg m^{-3} (up to 3 mg m^{-3} on 29 March). Moreover, high chlorophyll concentrations are located in an area that differs (southwestern shifted) from the usual “Rhodes gyre” bloom regions, which in Fig. R1 is represented by the magenta contour identifying satellite climatology above 0.115 mg m^{-3} (half of the threshold used to define the event area; Fig 1 in the submitted manuscript). Further, it is worth to note that the area with climatological concentration above the threshold is largest at the beginning of March.

Additionally, an analysis of the deviation of OC observations with respect to the 1999-2020 climatology in the area under investigation demonstrates that on 27 March and 29 March, and on 1 and 6 april chlorophyll is 4 standard deviations higher than the mean (Fig. R2).

For sake of clarity and to include further comparison with observations, daily maps of model surface chlorophyll concentration are provided in Fig. R3. The simulated bloom started on 4 April, reached a peak between 8 and 9 April with concentration larger than 0.5 mg/m3 (i.e., similar values to the ones observed in satellite maps), and gradually extinguished from 11 April onward. On the other hand, from the analysis of satellite maps, it can be presumed that the event started somewhen around 27 March, maintained high concentration values on 29 March, 1 and 6 April and possibly ended between 8 and 9 April.

Even if the simulation shows a delay of 5-8 days, the use of modelled data have some clear advantages since the 3D products allowed to: (i) define the temporal and spatial boundaries of the event, (ii) tackle the sequence of physical and biogeochemical processes that are involved in the bloom dynamics. This second aspect will be strengthened by including additional figures as supplementary material, as proposed to Reviewer #1.

We believe that our contribution is a good example of the capability of an operational analysis and forecasting system to predict marine anomalous events and to provide a consistent and coherent picture of the processes involved using multiple information sources: atmospheric data, marine physical and biogeochemical modelling results, and observations.

Given the limits imposed by the State of the Planet Journal to the number of figures, we propose the following changes in the new version of the manuscript:

- Substitute old Fig. 4 with Fig. R1 to show the high chlorophyll values observed in OC and their temporal and spatial shift with respect to the area typically impacted by the Rhode gyre bloom.
- Include Fig. R2 and R3 and the explanation of the observed and simulated sequence of the event as supplementary material.
- Enrich the result section with a paragraph that highlights how the observations provide evidence of an anomalous event in the area as illustrated above.
- Enrich the discussion section on the mechanism driving late-winter/early-spring blooms in the Levantine basin also considering experimental and modelling studies (e.g., Habib et al., 2023; D'Ortenzio et al., 2021).

I would recommend that, instead of using NRT ocean colour products, that you look into time series of Chla from all ocean colour satellites merged together (such as the GlobColour satellite dataset). This will improve spatial and temporal coverage. If still plagued by too high cloud cover, use spatial and temporal averaging to analyse if the 2022 condition did (or did not) present a phytoplankton bloom anomaly.

We agree with the Reviewer about the need to use observations that provide the highest possible coverage and accuracy. In order to address the suggestion raised by the Reviewer, we updated the maps (new Fig. R1) using the reprocessed multi-year Copernicus Marine Service dataset, that uses better estimates of atmospheric variables with respect to NRT. Both the Copernicus Marine NRT product and the Copernicus Marine reprocessed one merge multi-sensor ocean colour datasets similarly to GlobColour. We also compared chlorophyll maps from GlobColour and Copernicus Marine products without finding relevant differences in the Mediterranean region in terms of spatial coverage. For instance, for the 29 March the two products (https://hermes.acri.fr/images/data/EURO/merged/day/2022/03/29/L3m_20220329__EURO_1_AVW-MODVIR_CHL1_DAY_00.png and https://data.marine.copernicus.eu/-/4ezccnprsg) have very similar spatial coverage and both show large chlorophyll concentration in the investigated area (up to 3 mg m^{-3}).

It is also worth to mention that the Copernicus Marine product used in the manuscript has the advantage of an algorithm specifically developed and tuned for the Mediterranean Sea (details are provided in the documentation at https://data.marine.copernicus.eu/product/OCEANCOLOUR_MED_BGC_L3_MY_009_143/d escription). For this and the above mentioned reasons, we will use the reprocessed Copernicus Marine chlorophyll product in the updated version of the manuscript (new Fig. R1 instead of Fig. 4 of the submitted manuscript), and we will specify that the product merges multi-sensor ocean colour datasets to obtain the highest possible spatial coverage.

I consider this issue a major problem and therefore recommend major revisions to your manuscript.

I look forward to seeing a revised version of your work.

Figures

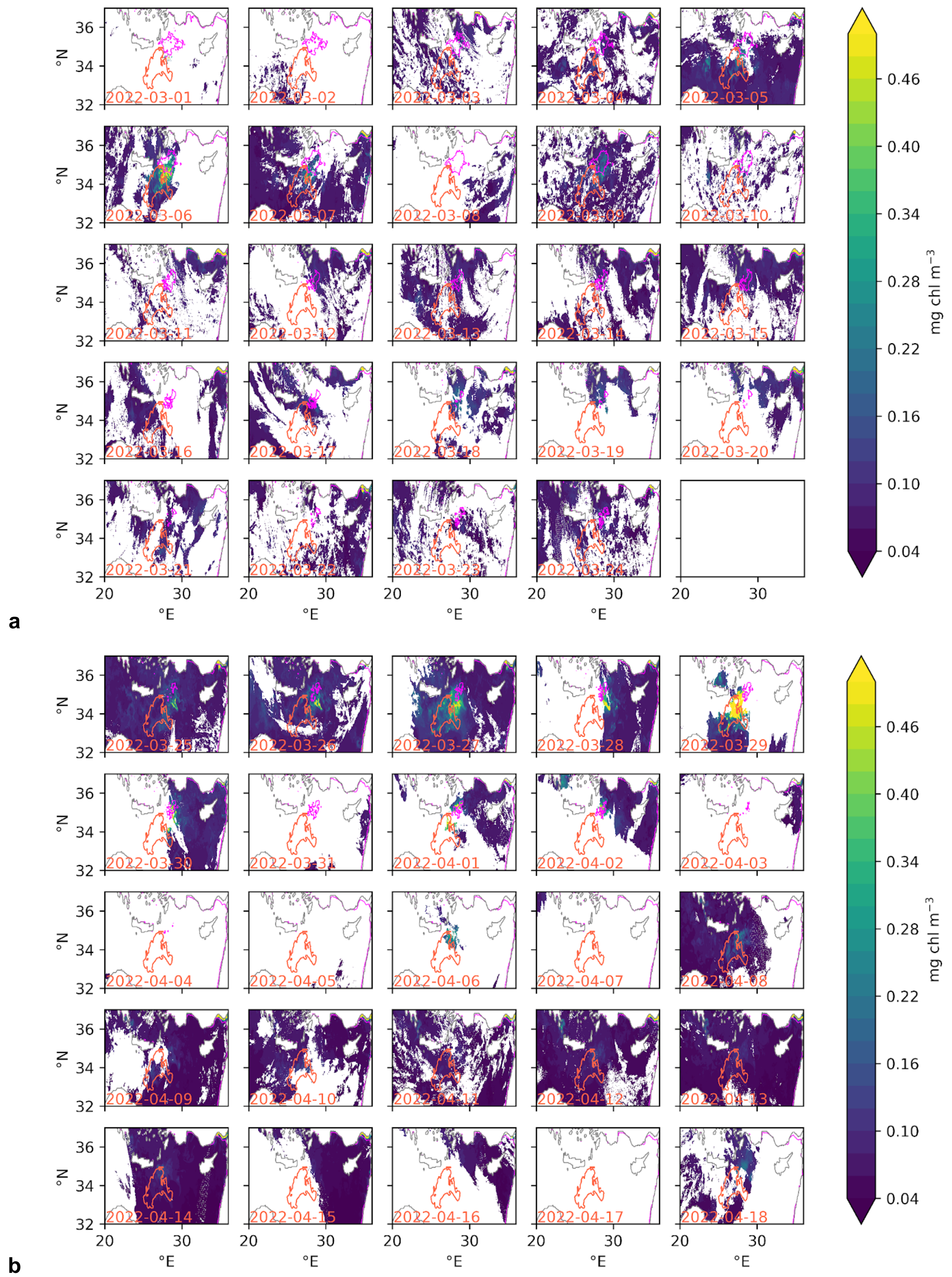
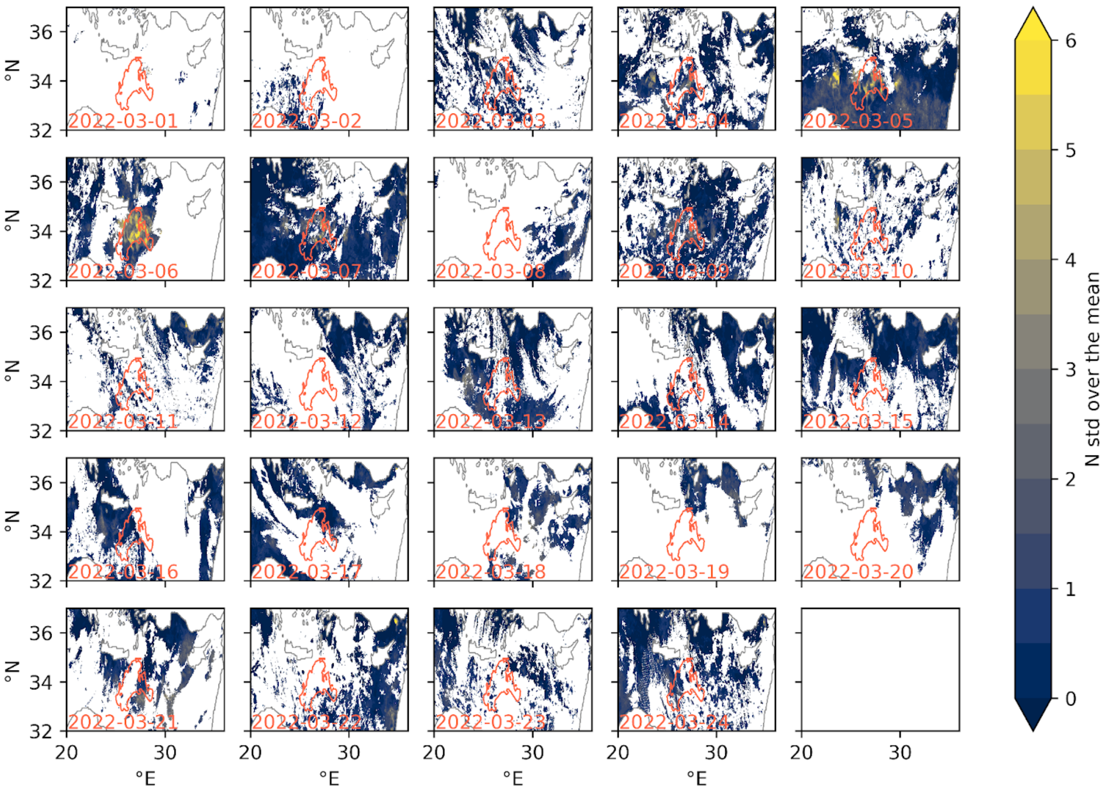
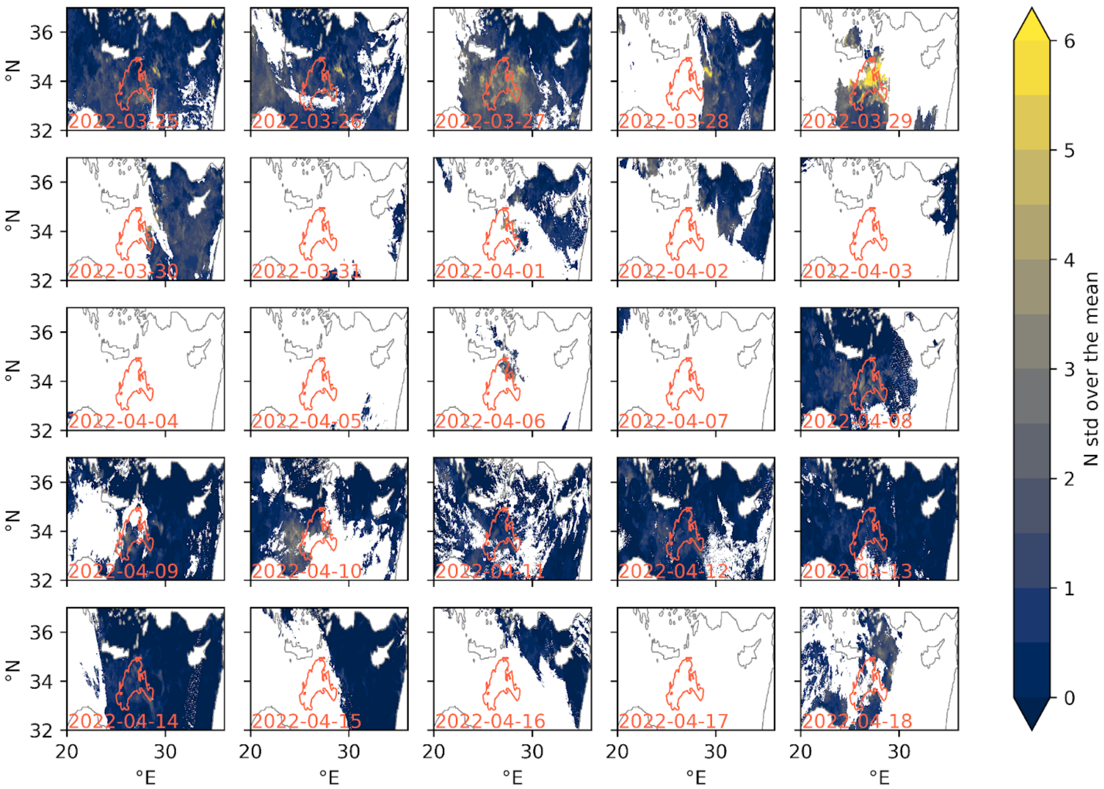


Fig. R1. Daily maps of satellite surface chlorophyll concentration [mg m^{-3}] from 1 March (a) to 18 April 2022 (b) with orange line contouring the event area as identified by the analysis and forecast model (Fig. 1 in the submitted manuscript) and magenta line contouring the usual winter blooms in the Rhode area (i.e., satellite chlorophyll climatology equal to 0.115 mg m^{-3}, half of the threshold used to delimit the event area; satellite data are from Copernicus Marine Service multi-year product).



a



b

Fig. R2. Daily maps of the number of climatology standard deviations over the climatology mean for satellite surface chlorophyll concentration [mg m^{-3}] from 1 March (a) to 18 April 2022 (b) with orange line contour of the event area (Fig. 1 in the submitted manuscript). Satellite climatology is from Copernicus Marine Service multi-year product.

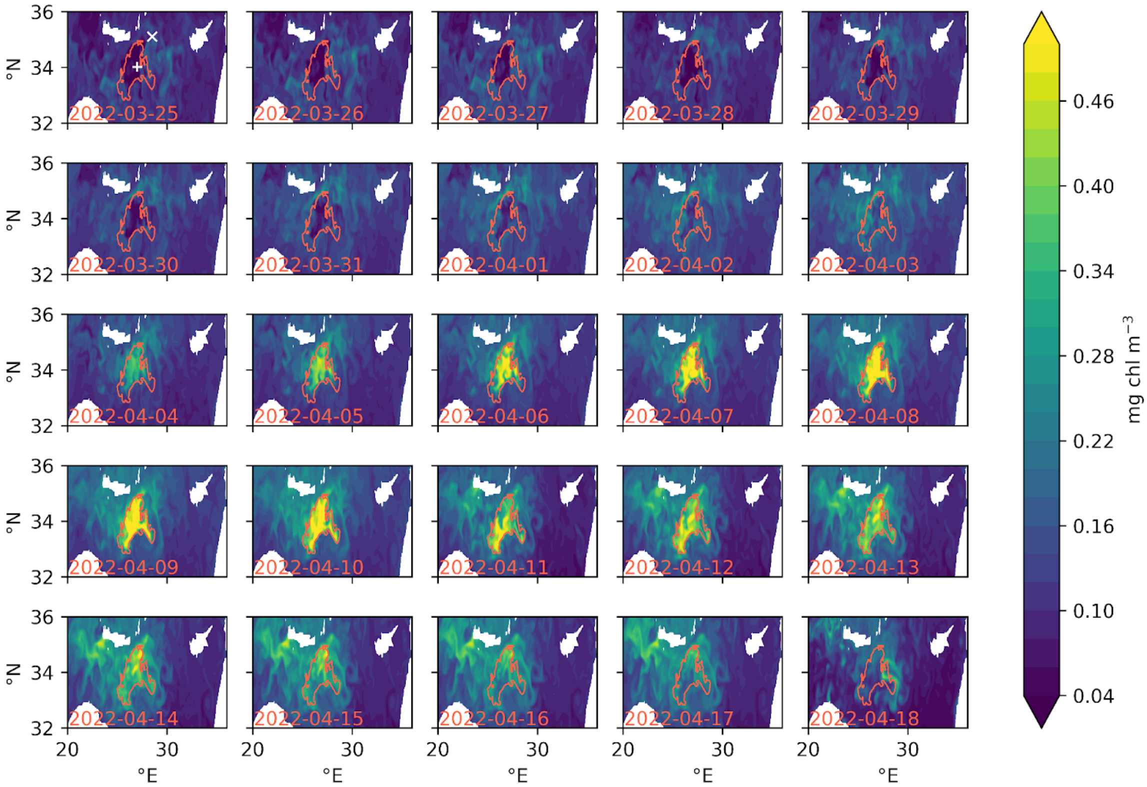


Fig. R3. Daily maps of model surface chlorophyll concentration [mg m^{-3}] from 25 March to 18 April 2022 with orange line contouring the event area (Fig. 1 in the submitted manuscript) and reference points (top left panel) inside ("+" marker) and outside ("x" marker) the event area.