Response to Editor

General comment

"I find that you demonstrate quite robustly the impact of this tropical cyclone on the Black Sea physics and in particular on the intensity of the western gyre upwelling and Rim Current. However, the demonstration of the impact of this extreme event on the ecosystem is by far less robustly addressed and less convincing. In particular, the exceptional character of the coccolithophore bloom and on its dominance over other groups need to be more convincing. The reviewer also questions the algorithm that has been used to estimate the Chla and the abundance of coccolithophores. She/he underlines that the MODIS level 2 product is indeed not appropriate for Case2 waters and the Kubryakov et al (2019b) equation considers that the reflectance is due to coccolithophores only. Then, she/he asks to use specific algorithms 1) for case 2 waters for retrieving chla and 2) to retrieve TSM and then to clearly differentiate the contribution of coccolithophores to the Rrs. He/she made suggestions about algorithms that can be used.

I think that it is an important request that needs to be addressed because the novelty of this manuscript is the impact of the cyclone on the biology (and not on the physics since it has already been published). I am convinced that it would strengthened your message (please see the full review for details).

She/he also requires a deeper investigation of the mechanisms that explain the dominance of coccolithophores during the event. I agree that as it is now it is still quite generic and that the absence of other species during this event (e.g. diatoms) needs to be better justified.

Then I would like that you address very carefully all the comments of the reviewer and that you provide a point by point answer to each comment with a clear explanation on how you plan to address them in a revised version. I have also provided a short review of your work here below. As said above, I urge you to give strong evidences of the impact of this cyclone on the biology. In a lot of places in the manuscript, this impact is described based on features that are not specific to this cyclone. A robust justification also requires an excellent data set on which the interpretation will be based.

In a lot of places, the manuscript is not clearly written and would strongly benefit from a careful reading and english editing. I am not a native speaker but I have tried to provide some suggestions (I realized that some suggestions that I made on the first version were not taken into account, so please check carefully)".

Authors answer. We would like to thank the Editor for such detailed and useful comments. In the new version of the manuscript, we significantly revised the discussion on the mechanism driving the observed anomalous bloom. We extended a discussion on the used methods and satellite products according to the comments of Reviewer 1. We also carefully checked English and corrected it throughout the text.

Editor comment (EC)

EC1. "Line 40 "Tropical cyclones mostly are observed at latitudes less than 30°". A reference is needed. Then, I will say "…an anomalous atmospheric cyclone..." and not "the".

Answer EC1. We corrected the text (lines 47-49): "Tropical cyclones (or typhoons) are usually originated at latitudes less than 30° (see the review in Emanuel, 2003). However, an anomalous atmospheric cyclone formed over the Black Sea basin at 40°E on 25-29 September (Fig. 1a) had all the characteristic features of the tropical cyclones."

Emanuel, K. (2003). Tropical cyclones. Annual review of earth and planetary sciences, 31. Vol. 31:75-104 https://doi.org/10.1146/annurev.earth.31.100901.141259.

EC2. "Lines 44-46: "Later, detailed statistics of cyclones of the basin on the base of the regional atmospheric model showed that eddies with similar intensity were detected over the Black Sea only 3 times over 30-year period 45 (Efimov et al., 2009)". This sentence is not clear. What do you mean by "detailed statistics of cyclones of the basin" which regional atmospheric model? What do you mean by "eddies"?"

Answer EC2. We corrected this phrase for clarity (lines 52-54): "Later, a detailed statistical study of the characteristics of the atmospheric cyclones over the Black Sea (Efimov et al., 2009) showed that cyclones with such large intensity were detected over the Black Sea only 3 times during 30-year period."

EC3. "Line 58: Please give the units of N and Bbp".

Answer EC3. Lines 67-71: the sentence is rewritten as "In the areas of coccolithophore bloom, their cell concentration (N, cell l^{-1}) can be estimated on the base of backscattering or R_{rs} data (see Gordon & Balch, 1999). In this paper, we use the equation

$$N=0.8\cdot10^{9}\cdot b_{bp}(700)^{1.21} \quad (1)$$

and the linear relationship between $R_{rs}(555)$ and backscattering coefficient (b_{bp}, m^{-1}) $b_{bp}(700)$ – $R_{rs}=0.7\cdot b_{bp}(700)$ – to give an estimate of coccolithophores concentration on the base of satellite data."

EC4. "Lines 60-61: "According to the used parameterization, the concentration value is more than 1.0·106 cells l-1, i.e. bloom conditions, corresponds to the value of Rrs=0.005 sr-1. ". This sentence is not clear. Do you mean that the condition for having a bloom is a cell abundance higher than 106 cells/l which means, according to the parameterization linking Rrs and the cells abundance, a Rrs larger than 0.005sr-1?"

Answer EC4. We rewrote this paragraph for clarity: "The phytoplankton bloom is usually subjectively defined as the conditions when N exceeds 10^6 cells l^{-1}. According to Equation 1, it corresponds to the value of $R_{rs}=0.005$ sr^{-1}."

EC5. "Line 66: I would suggest to use v (and not □) in vectoral form".

Answer EC5. We corrected the equation.

EC6. "Line 67: please add a complete reference of the product."

Answer EC6. We added the complete reference to the text: "The satellite altimeter data (product identifier: SEALEVEL_BS_PHY_L4_REP_OBSERVATIONS_008_042) is made freely available by the Copernicus Marine Environmental Monitoring Service (ftp://my.cmems-du.eu/Core/SEALEVEL_GLO_PHY_L4_REP_OBSERVATIONS_008_042/)."

EC7. "Line 87: "A quasi-tropical atmospheric cyclone…" why do you use "A" and not 'The atmospheric cyclone…' are you referring to the cyclone you are investigating in this manuscript? Or is it a generality of the effect of atmospheric cyclone? If this is the case then, a reference is needed."

Answer EC7. We agree. Here it should be "The atmospheric cyclone." The text is corrected.

EC8. "Line 92: "Such a divergence causes the compensating upward vertical motions and intense entrainment of cold waters from deep layers to the surface..." I find this sentence confusing. First, upwelled waters are not coming from deep waters but from waters located at ~50-100 m depth (please specify) For a reader who does not know very well the Black Sea this needs to be clarified. Then, from what is written above (lines 87-90), the enhanced upwelling in the central part is created by Ekman pumping generated by the wind shear stress associated to the cyclone. Please clarify".

Answer EC8. We agree. We corrected this paragraph for clarity. We also excluded this sentence in the revised version of the manuscript.

EC9. "Lines 102-103: please be more specific. Why may? Do you have evidence that it happens? If yes, please gives a concrete example".

Answer EC9. Thank You. We rewrote this paragraph for clarity (lines 119-122): "Nutricline in the Black Sea is relatively shallow, and its upper border is located at a depth of 50-60 m (Konovalov and Murray, 2001; Tuğrul et al., 2015). The euphotic zone in the Black Sea in September is about 40-50

m (Kubryakov et al., 2020). Thereby the impact of QTC caused an uplift of nutricline on 30-40 m to the euphotic zone, accompanied by its erosion driven by strong wind mechanical mixing".

EC10. "Line 109-110: I would say that it is the enhanced sea level anomaly gradient between the western central basin and the coast that intensified the Rim Current".

Answer EC10. We corrected this phrase (lines 130-131): "The rise of sea level gradients caused a strong intensification of the large-scale cyclonic circulation of the Black Sea – the Rim Current."

EC11. "Lines 114-115: This delay in the response of the current to an intensification of the wind curl has also been evidenced in "...and is related to..." and **EC12.** "Lines 116-118: please reformulate".

Answer EC11 and EC12. We corrected this paragraph (lines 134-137): "The maximum intensity of the geostrophic velocity was observed about 2 weeks after the action of the cyclone on 6-10 October (Fig. 3, black line). This delay is related to the time needed for the sea level to adjust to the changes in ekman transport. Such time estimated from altimetry data is 1-2 weeks (Grayek et al., 2010; Kubryakov et al., 2016), which is in close agreement with the time lag observed in the present case."

EC13. "Line 133: Before the passage of the atmospheric cyclone..."
Answer EC13. Corrected.

EC14. "Line 131: Chl as defined in the intro".
Answer EC14. It is changed as "Impact of quasi-tropical cyclone on Chl."

EC15. "Line 141: ...after the action of the atmospheric cyclone..."
Answer EC15. Corrected.

EC16. "Line 146: "…which suggests the mainly mechanical nature of its increase…". Please explain what is meant here".

Answer EC16. We corrected the text (lines 163-166): "However, on the next MODIS 8-daily map (Fig. 4c), Chl in this zone decreased to the pre-storm values. One of the possible reason of such rise of Chl is entrainment of phytoplankton from its summer subsurface maximum, which cause its rapid but short-period increase in surface layers (Babin et al., 2004; Kubryakov et al., 2019c)."

EC17. "Line 245: the number of cells associated with the maximum Rrs is still much lower than the value of 30 106 cells/l given in the introduction".

Answer EC17. $30*10^6$ is an absolute record of cell concentration detected only by one author in 1993 (Mihnea, 1997). Usually, cell concentration during the strongest early summer bloom is about 2-6 mln cells l^{-1} and in the winter period is only about 1-2 mln cells l^{-1}. We corrected the Introduction for clarity (see lines 37-44): "Usually, the cell concentration (N) during summer blooms in the Black Sea is ~$2\text{-}6\cdot10^6$ cells l^{-1} (Mikaelyan et al., 2005, 2011, 2015; Pautova et al., 2007), but in certain years it can reach very high values N=$10\text{-}30\cdot10^6$ cells l^{-1} (Korchemkina et al., 2014; Mihnea, 1997; Yasakova and Stanichny, 2012). Weaker blooms are detected in the winter period (Hay et al., 1990; Kubryakov et al., 2019c; Kubryakova et al., 2021; Mikaelyan et al., 2020; Sorokin, 1983; Stelmakh et al., 2009; Stelmakh, 2013; Sukhanova, 1995; Türkoğlu, 2010; Yasakova et al., 2017). Recent Bio-Argo (Kubryakov et al., 2019c) and satellite studies (Kubryakova et al., 2021) showed that winter blooms usually start in December with a peak in January and are observed almost every year. N is usually lower in winter than in summer (N=$0.5\text{-}2\cdot10^6$ cells l^{-1}) (Kubryakov et al., 2019c; Stelmakh et al., 2009; Stelmakh, 2013)".

We added this information to the discussion (see lines 360-365): "The coccolithophore blooms usually occupy the upper mixed layer, which in winter is 2-3 times larger than in summer, which suggests that the total cell amount in the water column is similar in the winter and summer period (Kubryakov et al., 2019b). In October 2005, we observed very high surface values of R_{rs} reaching 0.018 sr^{-1}, which correspond to the estimated N reaching $10\cdot10^6$ cells l^{-1}. The mixed layer in October is usually about 2 times higher than in early summer, which suggests that the intensity of the observed autumn

coccolithophore bloom in October 2005 was comparable to the record blooms detected in the summer of 1993 (Mihnea, 1997) and 2012 (Yasakova and Stanichny, 2012)".

EC18. "Lines 296: please reformulate".
Answer EC18. This sentence is reformulated.

EC19. "Line 301: the intense denitrification".
Answer EC19. Thank you. We corrected this phrase (lines 312-313): "Low N/P is caused by intense removal of nitrates by denitrification process in the suboxic layer of the basin (Konovalov et al., 2008; Tuğrul et al., 2014)."

EC20. "Lines 307-308: I am confused. Do you think that there was photoinhibition in early October after the passage of the cyclone? Do you think that it was the photo-inhibition that could explain a (eventual) dominance of coccolithophores during this period of the year, especially after the passage of a cyclone that, as you show in the manuscript, considerably extended the mixed layer depth?"
Answer EC20. We agree and decided to exclude this phrase from the manuscript.

EC21. "Line 309: do you mean heterotrophic dinoflagellates?"
Answer EC21. The phrase is corrected (lines 333-334): "The grazing pressure on the diatoms or dinoflagellates by zooplankton usually is higher than on coccolithophores (Nejstgaard, 1997; Stelmakh, 2013)…"

EC22. "Lines 340-344: I do not understand the link between these 4 lines and the cyclones passage. This seems to be a generality about the occurrence of coccolithophores blooms in the Black Sea and in other areas. Please clarify the link or remove."
Answer EC22. We removed this paragraph from the text.

EC23. "Line 340: I would say clacifiers or coccolithophores instead of calcified phytoplankton."
Answer EC23. We corrected on "coccolithophores."

EC24. "Line 356: correct the units."
Answer EC24. Corrected.

EC25. "Lines 347-351: I would insist on the particular conditions associated with the passage of the cyclone that led to this anomalous boom. Here what is mentioned in (1) also happens when there is no cyclone. I would insist on the unusual Ekman transport that generated unusual upwelling, …"
Answer EC25. We agree and rewrote the Conclusion part (see lines 368-372): "Satellite data showed that the bloom was caused by intense upwelling driven by ekman pumping during the action of QTC. The upwelling was maximum in the western cyclonic gyre of the Black Sea, where isopycnals were uplifted to the surface. After QTC, SST in this area decreased to 10°C, which was on 10-13°C lower than surrounding waters, indicating intense vertical entrainment of nutrients in the euphotic layer. This process led to the increase of Chl, which was followed by strong bloom of coccolithophores."

EC26. Figure 2: could you please add a legend for the arrow (length and velocity)? + give the source of the Seal level data in the legend.
Answer EC26. The magnitude of the currents is shown by the color scale (on the right side of the Fig. 2c, d). For example, green color defines values of velocity 25-35 cm/s. This is more convenient for the reader because it is hard to compare the length of one arrow with another visually. We added this information to the Fig. 2 caption. "Velocity magnitude in Fig. 2c, d is shown by color scale."

EC27. Figure 3: I would reformulate the legend. "Temporal evolution during the passage of the cyclone of the SST, .., western cyclonic gyre .. extension of the coccolithophore bloom. Please specify

what is meant by western cyclonic gyre (the black circle in Figure 2) same with the south continental slope (indicate on Figure 2 the region of averaging).

Answer EC27. Thank You. We corrected the figure caption as Temporal evolution of SST (°C, blue line), R_{rs} (sr^{-1}, purple), Chl (mg/m^3, green) averaged in the central-western part of the basin (see black rectangles in Fig. 5c, d); area of coccolithophore bloom (km^2, red); geostrophic velocity over the south continental slope in the point 41.9375N and 28.4375E, see white star in Fig. 2d (m/s, black).

EC28. Figure 4: Chl

Answer EC28. "Chlorophyll a" is replaced by "Chl".

EC29. "Figure 6: Instead of showing the RRs in December I would like to see snapshot in October because the coccolithophore bloom is usually observed at the end of summer (see e.g. Sur et al., 1994)."

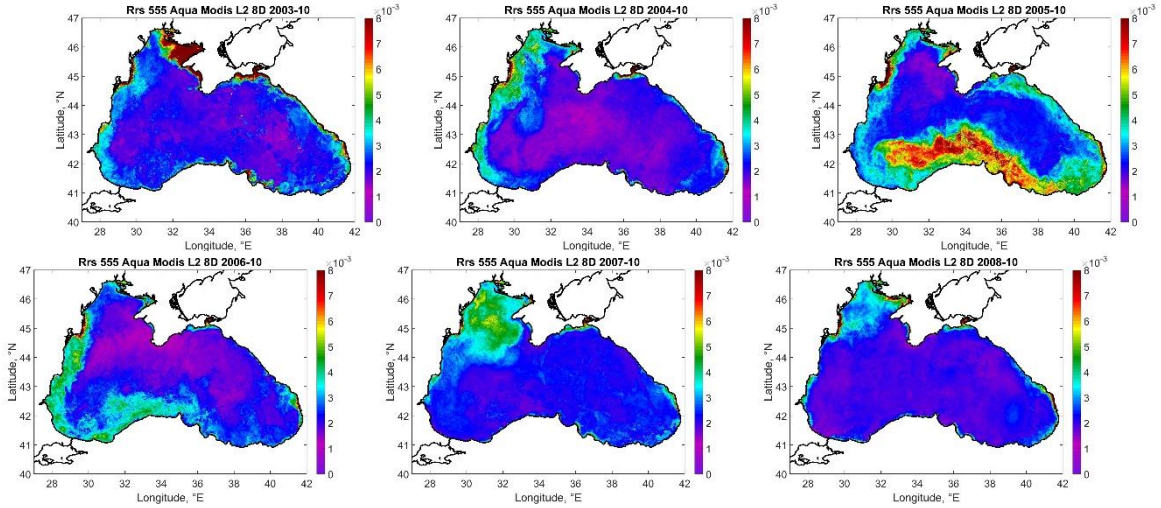
Answer EC29. Modern MODIS data shows that usually there are two seasonal blooms of coccolithophores: first, in the early spring (May-June and rarely July), and second, winter bloom in December-February. We added this information to the Introduction.

Usually, in August, there are no signs of coccolithophore blooms. One probable exception was a very cold period in the beginning of 1990, with anomalously intense coccolithophore bloom detected in some early studies. After that, such blooms were not observed.

Below, we show R_{rs} maps for October 2003-2019. Analysis of R_{rs} variability in 2003-2019 showed that this situation was unique for the early autumn period, when R_{rs} usually is low (< 0.002 sr-1, see Fig. 6b). Only in rare cases – in October of 2006 and 2014, we observed the increase of R_{rs} up to 0.005 sr^{-1}, which was two times lower than 0.01 sr^{-1} in 2005. As it is seen from this figure, the case of 2005 was exceptional. The magnitude of the bloom at this time reach the highest values, which is related to the action of the very strong and anomalous quasi-tropical cyclone in September 2005.

In the winter period (Kubryakova et al., 2021) showed that strong storms might trigger the winter coccolithophore blooms. Several examples of similar blooms in the south part of the Black Sea are presented in Fig. 6c, d. However, such blooms usually are observed later in a year (December in this case) and also are less intense.

We added this information to the paper (see lines 287-289): "Analysis of R_{rs} variability in 2003-2019 showed that this situation was unique for the early autumn period, when R_{rs} usually is low (< 0.002 sr^{-1}, see Fig. 6b). Only in rare cases – in October of 2006 and 2014 – we observe the increase of R_{rs} up to 0.005 sr^{-1}, still two times lower than 0.010 sr^{-1} in 2005."



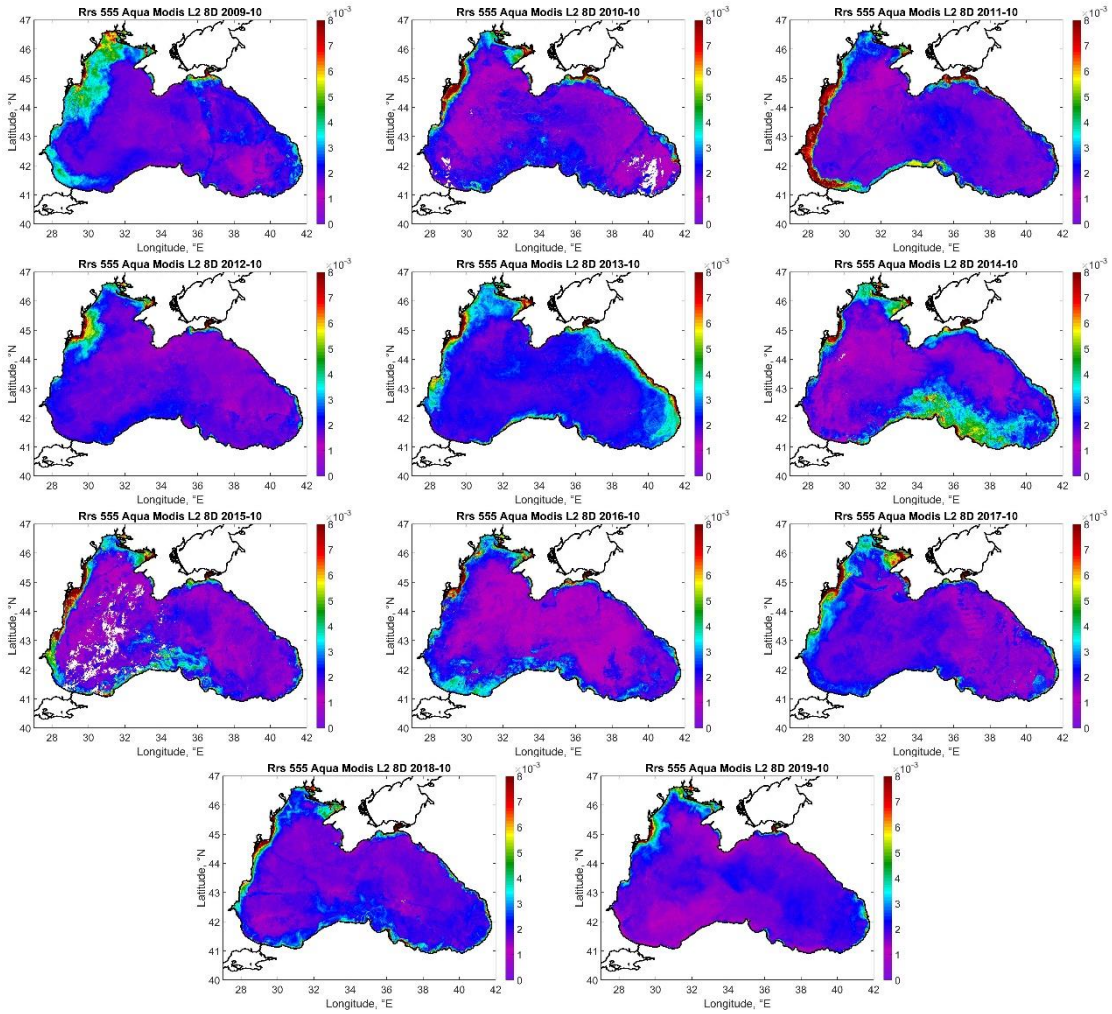


Fig. R1. Monthly maps of R_{rs} in October of 2003-2019 from MODIS data.

English editing (EE)

You use a mix of simple past, present perfect and preterit. Please check the manuscript and use consistently the same tense.

Answer. We carefully corrected the English grammar in the revised version of the text. We also changed the time throughout the text to a simple past.

EE1. "Line 8: I would say "..causing a decrease in sea surface temperature of 15°C and an acceleration of the cyclonic .."

Answer EE1. Thank you. Line 8: the part of the sentence is rewritten as "… causing a decrease in sea surface temperature of 15°C and an acceleration of the cyclonic…".

EE2. "Line 10: "Baroclinic instabilities of the plume boundary caused …"

Answer EE2. Thank you. Line 10: the part of the sentence is rewritten as "Baroclinic instabilities of the plume boundary caused intense…"

EE3. "Line 11: "These processes triggered .." please use the same tense everywhere".

Answer EE3. Thank you. It is rewritten.

EE4. "Line 37: "Weaker blooms are also observed in the cold period of the year .. "

Answer EE4. Corrected.

EE5. "Line 38: Kubryakov et al., 2019a."

Answer EE5. It is corrected.

EE6. “Line 40: “Tropical cyclones are mostly observed at latitudes less than 30° E.”
Answer EE6. It is corrected.

EE7. “Line 41 “This cyclone had..”
Answer EE7. It is corrected.

EE8. “Line 47: which led”
Answer EE8. It is corrected.

EE9. “Line 86: what is nitrocline? Please define. Is it nutricline or nitracline?”
Answer EE9. It is corrected on “nutricline”.

EE10. “Line 91: rose by and dropped by.”
Answer EE10. It is corrected.

EE11. “Line 94: “.. for September of..”
Answer EE11. It is corrected.

EE12. “Line 95: felt”.
Answer EE12. It is corrected.

EE13. “Line 96: “which was 13-15°C lower than the surrounding water SST (23-25°C) ..”
Answer EE13. It is corrected.

EE14. “Line 96: The isotherm 10°C in the Black Sea in September was located ..”
Answer EE14. It is corrected.

EE15. “Line 98: into the sea surface.”
Answer EE15. It is corrected.

EE16. “Line 99: period of the year”.
Answer EE16. It is corrected.

EE17. “Line 100: Nitroclyne? Check the whole manuscript”.
Answer EE17. It is corrected all over the manuscript.

EE18. “Line 110: the Rim Current.”
Answer EE18. It is corrected.

EE19. “Line 119: was about.”
Answer EE19. It is corrected.

EE20. “Line 135: spread of the Danube plume.”
Answer EE20. It is corrected.

EE21. “Line 145 part of the sea.”
Answer EE21. It is corrected.

EE22. “Line 148: transported.”
Answer EE22. It is corrected.

EE23. “Line 151: Rim Current or Rim current? Please choose and use it consistently throughout the manuscript.”

Answer EE23. Thank you. “Rim current” is replaced by “Rim Current”.

EE24. “Line 159: caused.”

Answer EE24. It is corrected.

EE25. “Line 184: remove however.”

Answer EE25. It is corrected.

EE26. “Line 193: climatological values.”

Answer EE26. It is corrected.

Response to Reviewer

"The study reports on anomalous coccolithophores bloom detected by satellites in the Black Sea in October 2005 after a quasi-tropical cyclone in September 2005. The authors analyse physical (mainly) and biological mechanisms explaining the observed phenomenon.

The study definitely deserves publishing. Additional revision, however, might still improve the presentation. I realize that some justifications are challenging given the information the authors have on hands (although sounds plausible). Below I list several suggestions the authors might want to consider to further improve the manuscript".

Answer. First, we would like to thank the anonymous Reviewer for valuable comments and recommendations.

General comments

GC 1. "Indeed, the coccolithophores is the phytoplankton group that due to light scattering by its coccolith (a distinct from other phytoplankton groups feature) can be detected from satellite images. The authors referred to several regional (developed for the Black Sea) empirical algorithms.

The paper would benefit from introducing a bit more insights on the satellite algorithms used, with an emphasis on how backscattering from algal and non-algal particles are treated. The algorithm exploited in this study for coccolithophores cell concentration (Ncoc) is based on empirical relation to the light backscattering (bbp) and via bbp to remote sensing reflectance (Rrs) at 555 nm (Rrs555). Following Kubryakov et al. 2019b, the relationship was obtained in the assumption that all backscattering is attributed to scattering by coccoliths, when regionally calibrating the algorithm only in situ measurements from the areas not influenced by non-algal particles were considered. Are there any limitations because of this assumption when applying the algorithm for whole domain? (State it when introducing the method, whether/how or not/why it will impact the analysis).

As input information the authors use MODIS standard Level 2 data on chlorophyll-a concentration (Chl), Rrs and bbp. The standard algorithm does not work for turbid conditions (case 2 waters) and provide (strongly) overestimated Chl (as the authors briefly mentioned). However, the conditions discussed in the study are quite turbid and one could expect backscattering by suspended matter (total suspended matter, TSM) along the cast especially in the river (not only Danube) inflow areas (Kopelevich et al. 2014).

To support the discussion on the origin of the coccolithophores bloom (and the statement that Danube plume and Rrs on 5th October in Fig 5b are TSM free) estimates of Ncoc based on the algorithms accounting and diagnosing also non-algal backscattering (Kopelevich et al. 2014) would be of a help. Alternatively, it would be possible to consider TSM retrievals that could be obtained with Polymer (https://www.hygeos.com/polymer) or SNAP (https://step.esa.int/main/toolboxes/snap/), working with MODIS Level 1 and Level 2 products. These packages would allow to use algorithms for case 2 water and obtain more accurate estimates of Chl if required (Currently as far as I understood the authors use this "artificially" high Chl to trace the Danube plume).

I have to state that this additional information will not, of course, cancel the fact of the observed coccolithophores bloom, but might support the discussion on mechanisms involved".

Answer GC1. We absolutely agree that regional algorithms will be useful for better interpretation of the data obtained, and, especially, quantitative estimates given in the manuscript. The presented algorithm of the estimation of cell concentration can be used only in the areas of coccolithophore bloom and has several limitations. Particularly, in the shelf zone, the lithogenic particles give a major contribution to R_{rs}. In our paper, we give a brief description of the sources of lithogenic particles in Section 3.3 and Fig. 6b. The high concentration of CDOM and lithogenic particles in the plume (Case 2 waters) can affect the Chl estimates in the coastal zone.

To decrease the effect of these errors for the quantitative estimates in our paper (given, e.g. in Fig. 3), we use only data in the deep part of the Black Sea. Values of cell concentration (N) were used to estimate the maximum observed N, which was detected in the central part of the basin Sea (43°E, 34°N). We also use N to the estimated area of the bloom. However, for this task, we use only pixels

located in the deep part of the basin (depths more than 500 m) to exclude the impact of lithogenic particles on the shelf. Temporal evolution of the Chl and R_{rs} data in Fig. 3 was obtained on the base of the data in the central-western gyre, which was not affected by plume waters (see Fig. 5d).
We added this information to the text and also significantly extended the methods section to give appropriate information on the possible errors in estimating the coccolithophore concentration (lines 62-82): "In the deep part of the Black Sea, the rapid growth of R_{rs} is mainly caused by scattering on coccoliths during the coccolithophore bloom (Cokacar et al., 2001, 2004; Kopelevich et al., 2014). Another strong source of backscattering and the reflectance increase in the enclosed Black Sea is lithogenic particles originating from the river discharge; due to coastal erosion; resuspension of bottom sediments. These processes mainly occur in the shelf area of the basin (see more details in Section 3.3). In the areas of coccolithophore bloom, their cell concentration (N, cell l^{-1}) can be estimated on the base of backscattering or R_{rs} data (see Gordon & Balch, 1999). In this paper, we use the equation

$$N=0.8\cdot10^{9}\cdot b_{bp}(700)^{1.21} \quad (1)$$

and the linear relationship between $R_{rs}(555)$ and backscattering coefficient (b_{bp}, m^{-1}) $b_{bp}(700)$ – $R_{rs}=0.7\cdot b_{bp}(700)$ – to give an estimate of coccolithophores concentration on the base of satellite data. It should be noted that this formula is very approximate and gives only rough estimates of N. The backscattering during coccolithophore bloom represents a mixture of the signals from the plated coccolithophores and detached coccoliths. The number of coccoliths per cell can vary strongly. In this paper, we use an average value of 30 coccoliths per cell. However, this value can change from 10 (Balch et al., 1991) to more than 50 (Mikaelyan et al., 2005). In the coastal areas, R_{rs} represents the mixture of signals from riverine particles and coccoliths (Kopelevich et al., 2014). These signals can be separated using a two-parametric model (Kopelevich et al., 2014), which is based on the data on absorption coefficient of yellow substance (a_g) and R_{rs}. Unfortunately, we do not have data on the a_g in September-October 2005. That is why, in our study, we used a more simple approach (Equation 1) to give only approximate estimates of the maximum observed N and the area of a bloom. The phytoplankton bloom is usually subjectively defined as the conditions when N exceeds 10^6 cells l^{-1}. According to Equation 1, it corresponds to the value of $R_{rs}=0.005$ sr^{-1}. The area of coccolithophore bloom was estimated as a total area with values of $R_{rs}\geq0.005$ sr^{-1}. To exclude the impact of lithogenic particles on the shelf, we used only pixels located in the deep part of the basin (depths more than 500 m)".

GC2. "The main difficulty (but not a limitation for publishing) of the study is a lack off in situ measurements nutrients and phytoplankton composition, suspended matter during the investigated event. Are there any similar conditions/mechanisms explaining the discussed exceptional coccolithophores bloom event in October 2005 and more regular event like summer (June) or late-autumn bloom observed or monitored more frequently and complemented by in situ measurements of other quantities? Intercomparison of such events would also support the discussion with respect to phytoplankton composition and shifts in phytoplankton compositions. Generally, the authors provide consistent discussion on the coccolithophores trait allowing it to dominate among other phytoplankton groups (e.g. diatoms) under certain (discussed) environmental conditions. (I would just comment on general affinity of coccolithophores for nutrients, which according to Paasche 2001 high for phosphate to a larger extent than for nitrogen, that makes them strongly competitive even under condition with low phosphate concentration). The discussion could be further improved with explaining the October 2005 event given the phytoplankton composition information from well-understood events clearly presented as a background (What about the December events the authors present in Figures 6c and 6d?)".

Answer GC2. Unfortunately, currently there is no in-situ microscopic information about coccolithophores and, especially, their time evolution after intense atmospheric storms (as well as another phytoplankton group).

Statistical information and detailed evolution of several winter coccolithophore blooms were presented in the recent study of (Kubryakova et al., 2021) on the base of MODIS data in 2003-2019. Authors, particularly, showed that winter coccolithophore blooms, including December cases in Fig. 6d,

also are often observed 1-2 weeks after intense storm action. This is in agreement with our results and evidence that wind-driven upwelling and mixing is an important mechanism of coccolithophore blooms in both winter and autumn. However, usually the winter blooms are significantly less intense and are observed later (in December-February). The action of quasi-tropical cyclone in September 2005 caused an exceptional situation for the Black Sea ecosystem – a very strong bloom of coccolithophores, anomalous both by its intensity and timing.

In the new version of the manuscript, we also significantly revised the discussion on the possible mechanisms driving the coccolithophore blooms (see lines 310-357). We pointed out more clearly the possible driving factors on the observed anomalous coccolithophore blooms. These are huge amounts of nutrients, entrained to the surface after the upwelling; increase of Chl preceding rise of coccolithophores; ability of coccolithophores to utilize dissolved organic nitrogen; grazing pressure by zooplankton, which has its seasonal peak in autumn month.

A similar situation is usually observed in the Black Sea in spring, when winter convection is followed by intense spring bloom of diatoms in March and then by May-June coccolithophore blooms (Mikaelyan et al., 2015; Kubryakov et al., 2019a). The hypothesis of the observed diatom-coccolithophore sequence in the Black Sea was proposed in (Mikaelyan et al., 2015) and is supported by in-situ chemical and biological data of (Mikaelyan et al., 2015; Silkin et al., 2009).

The results of this study showed that intense atmospheric processes could impact significantly on the taxonomic composition of the phytoplankton and deserved a specialized in-situ investigation. In our plans, it is to do an in-situ survey after the intense storm and to obtain the characteristics of phytoplankton (and, particularly, coccolithophores), which grow after the storm. This is rather a difficult task, as phytoplankton response to the storm is delayed (see Fig. 3), and many different conditions can alter its taxonomic composition. Also, it worth noting that it is very hard to obtain data on the time evolution of the bloom from the in-situ survey for enough continuous-time (several weeks). The cyclone discussed in this paper was unique in its intensity. According to (Efimov et al., 2009), such cyclones are observed only one time in 10 years. Therefore, we can expect a weaker response of the phytoplankton community on the usual storms.

Detailed information about the response of the phytoplankton community to short-term physical processes can be provided only on the base of continuous data of the taxonomic composition of phytoplankton, based, e.g. on the measurements of moored flow cytometers, or validated biogeochemical numerical models. We are already working with a numerical Biogeochemical Flux Model (BFM), which probably can reproduce such features of the ecosystem. However, a lot of work still needs to be done.

We added this information to the manuscript.

GC3. "Unfortunately, it is most probably not straight forward to get now satellite information on diatom over the considered period of time. To my knowledge, there is no algorithm regionally developed for retrieving phytoplankton groups in the Black Sea. The global algorithm OC-PFT by Hirata et 2011 (further developed by Soppa et al., 2014) could provide information on diatoms but not necessarily suits the Black Sea. It could be one of the sources of the additional information on diatoms. However, it is worth remembering that the quality of the retrievals depends also on the quality of total Chl retrievals. There is a diatom (among other phytoplankton group) product based on the study by Xi et al. (2020) and available from https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_082

Please check with respect to the Black Sea, original Xi et al. (2020) study did not present this basin.

Hirata, T., Hardman-Mountford, N. J., Brewin, R. J. W., Aiken, J., Barlow, R., Suzuki, K., Isada, T., Howell, E., Hashioka, T., Noguchi-Aita, M., and Yamanaka, Y.: Synoptic relationships between surface Chlorophyll-a and diagnostic pigments specific to phytoplankton functional types, Biogeosciences, 8, 311–327, https://doi.org/10.5194/bg-8-311-2011, 2011.

Soppa, M. A., Hirata, T., Silva, B., Dinter, T., Peeken, I., Wiegmann, S., and Bracher, A.: Global Retrieval of Diatom Abundance Based on Phytoplankton Pigments and Satellite Data, Remote Sensing, 6, 10 089–10 106, https://doi.org/10.3390/rs61010089, 2014.

Xi, H., Losa, S.N., Mangin, A., Soppa, M.A., Garnesson, P., Demaria, J., Liu, Y., d'Andon, O.H.F., Bracher, A., 2020. Global retrieval of phytoplankton functional types based on empirical orthogonal functions using CMEMS GlobColour merged products and further extension to OLCI data, Remote Sensing of Environment, 240, 111704. doi:10.1016/j.rse.2020.111704".

Answer GC3. Thank You for these interesting references. According to Your advice, we analyzed this product (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_082) for the Black Sea. It also contains information about haptophytes (coccolithophores). Below we showed October 2005 maps of diatoms and haptophytes. Unfortunately, this product has only monthly resolution, which does not allow to trace the discussed bloom evolution.

On the monthly-maps, we see that diatoms prevailed in the area of the Danube plume (Fig. R1). It is hard to conclude from available data whether or not the product was able to captured diatom dominated areas in the basin. It also showed a high concentration of haptophytes on the offshore zone of the Danube plume (Fig. R1 – center). However, it does not reveal the coccolithophore blooms over the continental slope of the basin. We also checked another period with known data on coccolithophores (June 2012), when in-situ measurements showed very intense coccolithophore blooms reaching 10-20 mln cells/l in the Black Sea (Yasakova, Stanichny, 2012; Korchemkina et al., 2017; Yasakova et al., 2017). The product showed that haptophytes concentration in June 2012 was 5-10 times lower than in October 2005 (Fig. R1 – right), which is unlikely because one of the record coccolithophore bloom was detected in June 2012.

This is possibly related to the complexity of the Black Sea water, which contains a lot of CDOM due to intense river discharge. We agree with Your comment that this product needs additional regional validation in the Black Sea. Such a product can be very valuable for our studies. Thank You for this reference. We added a short comment concerning the importance of the development of such satellite algorithms (lines 392-394): "These data are crucial for the validation of satellite algorithms for phytoplankton species detection (such as Xi et al., 2020) and biogeochemical numerical models, which will help to provide more insights on the mechanisms of the ecosystem response on intense atmospheric forcing."

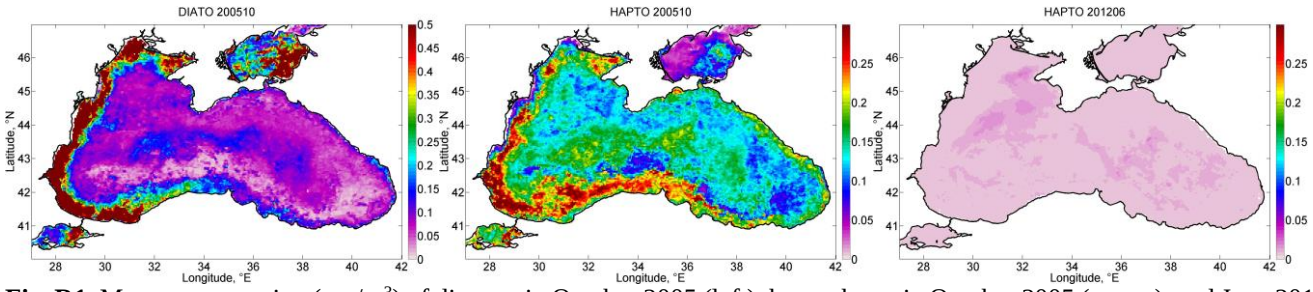


Fig. R1. Mass concentration (mg/m^3) of diatoms in October 2005 (left), haptophytes in October 2005 (center), and June 2012 (right) according to satellite product of (Xi et al., 2020).

GC4. "In the conclusion, additionally, could be a highlight on why the identified physical processes induce the bloom of coccolithophores not other phytoplankton groups over the considered period of time".

Answer GC4. Thank You for this advice. We added such a paragraph to the conclusion in the revised version of the paper (lines 380-383): "We hypothesize that the possible reasons for domination of coccolithophores in the observed case were: a) higher grazing pressure on the other phytoplankton (such as diatoms) by zooplankton, which have its seasonal maximum in September-October; b) ability of coccolithophores to use osmotrophy and utilize organic nitrogen; c) low N/P ration in the Black Sea nutricline, which led to the fast depletion of nitrates for diatoms blooms."

Minor comments (MC)

MC1. "line 58: introduce backscattering coefficient bbp and and coccolithophores cell concentration N".

Answer MC1. Lines 67-72: the sentence was rewritten as "… In the areas of coccolithophore bloom, their cell concentration (N, cell l^{-1}) can be estimated on the base of backscattering or R_{rs} data (see Gordon & Balch, 1999). In this paper, we use the equation

$$N=0.8\cdot10^{9}\cdot b_{bp}(700)^{1.21} \quad (1)$$

and the linear relationship between $R_{rs}(555)$ and backscattering coefficient (b_{bp}, m^{-1}) $b_{bp}(700)$ – $R_{rs}=0.7\cdot b_{bp}(700)$ – to give an estimate of coccolithophores concentration on the base of satellite data."

MC2. "line 163 -167: very nice description of the Danube plume distribution (any relation to CDOM and TSM?)".

Answer MC2. The regional satellite algorithm for the reconstruction of the TSM in the Black Sea on the base of channels 443, 488, and 555 was developed in our recent studies.

See please

- Kremenchutskiy, D.A., Kubryakov, A.A., Zav'yalov, P.O., Konovalov, B.V, Stanichniy, S.V. and Aleskerova, A.A., 2014. Determination of the Suspended Matter Concentration in the Black Sea Using to the Satellite MODIS Data, Ecological Safety of Coastal and Shelf Zones and Comprehensive Use of Shelf Resources. Sevastopol: ECOSI-Gidrofizika. Iss. 29, pp. 5-9 (in Russian).
- Appendix in Kubryakov, A. A., Aleskerova A. A., Goryachkin, Yu. N., Stanichny, S. V., Latushkin, A. A., and Fedirko A. V.: Propagation of the Azov Sea waters in the Black sea under impact of variable winds, geostrophic currents and exchange in the Kerch Strait, Prog. Oceanogr., 176, 102119, https://doi.org/10.1016/j.pocean.2019.05.011, 2019. (in English).

However, total suspended matter includes both lithogenious particles and coccoliths, which are also carbonate suspended particles for optical measurements. So, the map of TSM is very similar to the map of R_{rs} (see an example in Fig. R2 below and Fig. 7d in the manuscript). The quantification of the CDOM in the Danube plume is a very important problem for the ecosystem of the Black Sea. Unfortunately, at the moment, there are no regional algorithms for the reconstruction of CDOM and its characteristics in the Black Sea Case 2 waters.

However, the goal of this paper is to describe the anomalous coccolithophore blooms in the Black Sea due to the extreme impact of the small-scale atmospheric cyclone. To quantify the characteristics of this bloom, we use only data in the deep part of the Black Sea, which allows us to, at least partly, avoid the impact of the Danube plume (please see more details in response to GC1 above).

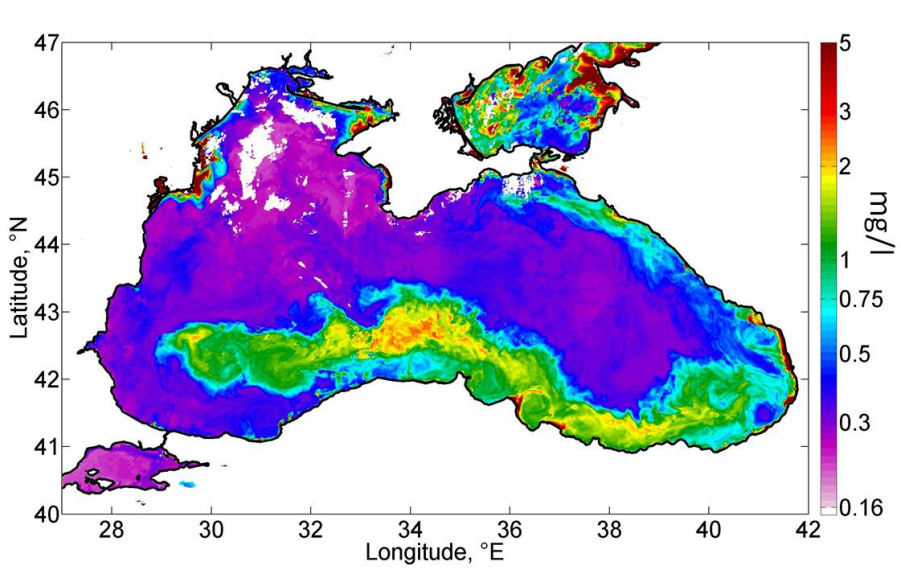


Fig. R2. MODIS Map of TSM reconstructed using regional algorithm of (Kremenchutskiy et al., 2014, Kubryakov et al., 2019) for October 2020.

MC3. "line 230, 236: - nutrient rich conditions are not necessarily required for coccolithophores".

Answer MC3. We rewrote this phrase as "This frontal zone is a subject of the intense horizontal mixing between brackish nutrient-rich plume waters and saline waters of the central part, which may be one of the possible triggers of phytoplankton bloom."

MC4. "Line 297: "low nitrogen and high phosphate conditions" also low phosphate conditions"; "Line 297, 305 and 306: "low nitrogen and high phosphate conditions", "relatively high phosphate "generally, coccolithophores has high affinity for phosphate, can grow in low phosphate conditions. The main precondition is that as the authors wrote there are still nutrients not consumed by others (diatoms) and grazing presser on other phytoplankton groups".

Answer MC4. We rewrote the discussion Section in the revised version of the manuscript to more clearly represent the possible mechanisms driving the observed coccolithophore blooms.

MC5. "Line 307: "Second.." combine with previous paragraph, "Third, …" as well".

Answer MC5. We corrected this paragraph in the revised version of the manuscript.

MC6. "Line 552-554: belongs to introduction".

Answer MC6. We agree and rewrote this sentence (lines 384-386): "…extreme atmospheric events can play an important role in the observed interannual variability of the coccolithophores and related carbonate fluxes in many other ocean areas, such as the Northern Atlantic and the Southern Ocean, where storms are significantly more frequent…".

Typos (T)

T1. "line 38: please mind space after "Kubrykov" -> "Kubrykov et al. 2019a".

Answer T1. Thank you. It is changed.

T2. "line 59: delete comma after Kubryakov".

Answer T2. It is changed.

T3. "Line 290: please replace "that" by "than".

Answer T3. Line 292: it is replaced.