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Interactive comment on "A two-decades (1988–2009) record of diatom fluxes in the Mauritanian coastal upwelling: Impact of low-frequency forcing and a two-step shift in the species composition" *by* Oscar E. Romero et al.

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A two-decades (1988-2009) record of diatom fluxes in the Mauritanian coastal upwelling: Impact of low-frequency forcing and a two-step shift in the species composition (bg-2020-336) Authors = Oscar E. Romero, Simon Ramondenc and Gerhard Fischer

Response to Referee 2's comments

As required by BG, the response to the Referees is structured in the following sequence: (1) comments from Referee 2 (RC2) and (2) authors' comments (AC).

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Comments from Referee #2 RC2: (Frankcombe et al., 2010) with the presented dataset the authors can only check on how major shifts between positive and negative states of AMO, occurred within the period of this record, affect the Canary Upwelling system, but not its fully and longterm effect on the system. However, the NAO index of atmospheric circulation over Europe has a periodicity in the order of 7-8 years (Knut Lehre Seip et al., 2019) and the work of (Yamamoto and Palter, 2016) shows a clear relation between the NAO and the AMO, with northerly winds associated to a positive state of AMO and zonal winds to a negative state of AMO. As such, it would be interesting to verify the relation of your data with NAO variability, since upwelling is indeed a response to an atmospheric process. It would also have been nice to have a comparison with the upwelling index or northerly wind strength. Maybe through another statistical approach, something like cross-correlation?

AC: We provide an additional analytical test that supports our interpretation. Indeed, we performed a correlation analysis with samples' score resulting from CA (Dim.1, Dim.2 and Dim. 3, which discriminates the diatom communities), climatic indexes (ENSO, NAO, AMO), diversity index (Shannon diversity) and fluxes (total diatom flux, freshwater diatom flux, Opal flux). As suggested by Reviewer 2, the correlogram shows a significant negative relationship between AMO and NAO. However, the goodness of fit between climatic indexes was low (R2 around 0.2). The correlogram also shows that the samples' score of first CA axis (Dim. 1, which discriminates the benthic from the other diatom groups) seems also impacted by the NAO, although with an exceptionally low R2. However, the statistical tests (clustering, boxplot and the Kruskall Wallis approach) performed in the first submission do not show any relationship between diatom groups and the NAO. Conversely to the correlogram, our statistical approach analyses each community independently and does not compare one group with the others. Although both statistical approaches are correct, we believe that the correlogram method could induce some misunderstanding, leading to a certain degree of overestimation of NAO impact. We conclude that AMO have a stronger impact on diatom communities off Mauritania than NAO. The significant NAO impact observed in correlogram is indirectly linked to communities via AMO, which is himself impacted by the NAO. We will comment on the possible impact of NAO on the diatom community at site CBmeso and discuss the publications suggested by Referee 2.

RC2: On which respects the effect of warming climate on the upwelling system and its primary production, you depart from the different conclusions reached by different studies, as presented in your introduction, to the proposal that your data is a different way of approaching the question. However, you conclude that your diatom data might be instrumental in distinguishing between climate-forced and intrinsic variability of the population of primary producers. I have trouble with this statement, intrinsic variability is related to the basic needs of the organisms, so they will most probably change in function of the changes imposed on the system both by global and regional processes that in the end will also react to climate forcing!

AC: indeed, this sentence is not as clear as we thought it was. We will rephrase it as follows: Our 1988-2009 data set contributes to distinguish the impact of low-frequency climate forcings and will be especially helpful for establishing the scientific basis for forecasting and modelling future states of the Canary EBUE and its decadal changes.

RC2: Furthermore, although it is very important to understand the process behind your stunning increase in benthic diatoms, your record does not allow you to verify what happens in terms of the plankton production and assemblage evolution during this 20yr. Or does it? Can you deduce the effect of the benthic flux that obscures the total record, and explore the 20yr variability of the planktonic diatom flux and assemblages 'composition that reach the trap?

AC: It is true that the dramatic shift in the species-specific composition of the diatom assemblage in May 2001 does not imply any dramatic change in the absolute values of the total diatom concentration nor it translated into any significant changes of the biogenic silica (=opal) flux (see also Romero et al., 2017, Prog. Oceanogr. 159, 131). This observation also matches previous work at CBmeso (Fischer et al., 2016, Biogeosciences 13, 3203).

RC2: There is a general problem with the way references are listed in the text they do not follow an alphabetical order nor the year of publication.

AC: The citation of articles and book chapters follow BG Instructions to Authors. We will check all quoted references again before re-submission.

RC2: What is the reason to use the term pelagial rather than pelagic? Although used for lakes I have not seen any paper that defends/justifies its use for the ocean environment.

AC: we will rephrase accordingly and use pelagic instead of pelagial throughout the MS.

RC2: The use of satellite images (composites for the n_ of years considered for each specific time interval / diatom phase) for comparison would also be important to verify the variability on the surface water and upwelling conditions.

AC: three pictures of chlorophyll a concentration have been added to Figure 1 (attached). They depict the average concentration of chlorophyll a for three winters (1997, 2002 and 2008), gained with SeaWIFs and MODIS (https://oceancolor.gsfc.nasa.gov/cgi/l3, details will be provided in the revised version of the MS). The high interannual variability is clearly recognized.

RC2: Different depths of trap deployment at some time intervals (Table 1) may influence the diatom assemblage encountered as a result of a different catching area and the different contribution of particles transported by intermediate nepheloid layers. This needs to be acknowledged and discussed especially because one of the periods coincides with the ENSO period.

AC: This issue was also raised by R1 and is addressed in the replies to Referee 1's comments.

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RC2: Are you assuming that the intensification of the shelf and slope poleward current favors an increase in production of the benthic community and maintenance of the means of downslope transport, or the existence of a stronger poleward current gives rise to a stronger suspension of the benthic forms and their downslope transport in higher quantities? This needs clarification and discussion.

AC: The benthic diatoms found in the CBmeso trap samples predominantly thrive in shallow coastal waters, not deeper than 50 m water depth, within the sunlit layer along the Mauritanian coast. Its occurrence in the hemipelagic CBmeso trap represents a lateral transport signal. As a possible explanation for the dramatic increase of benthic diatoms in the hemipelagic environment, we speculate that the intensification of the shelf and slope poleward transport upon deeper waters. It is well-known that the dynamic Mauritanian coastal waters serve as a jet for cross-shore particle transfer and it produces sporadic particle clouds, which are advected hundred kilometres offshore within intermediate and bottom-near nepheloid layers (Nowald et al., 2015) toward the hemipelagic of the low-latitude NE Atlantic (Fischer and Karakaş, 2009). This transport occurs within weeks (Karakaş et al., 2006, 2009). Subsurface waters (200 to 300 m depth) might be the place of mixing processes of older, laterally-advected materials from the shelf by giant filament activity, with relatively fresh material derived from the open ocean surface (Fischer et al., 2009). In addition to the nepheloid layer-mediated transport, the dynamics of water masses related to the existence of the canyon system off Mauritania might have contributed to the enhancement of transport from shallow water upon the trap site CBmeso.

RC2: Pg. 3, Ln. 78 – The authors suggest that a different approach for the characterization of multiyear to interdecadal upwelling intensity in EBUEs is by assessing fluxes of particulates and microorganisms as captured by continuous sediment trap experiments."

AC: As stated in the paragraph of our first submitted version (l. 66-77), a vast majority of the previous studies on the long-term variability of productivity and upwelling intensity along the north-western African margin follows different approaches than the one applied in our study. Approaches previously used for the description of interannual upwelling variations are velocity and directions of winds, annual wind stress, and Ekman transport. With the sentence written in last paragraph of the Introduction, we intended to emphasize that observational data based on interannual trap experiments are uncommon and represent a different approach to the study of possible links between variability of the microorganisms community, upwelling variations and the impact of low-impact climate and oceanographic forcing.

RC2: Although you can assume that the flux of planktonic organism blooming in surface waters as a result of upwelling intensity, we are also aware that the nutrient content of the upwelling water is determinant for the size of the blooms as well as for the type of phytoplankton community. As such, bloom size and consequently microorganism fluxes could also reflect shifts in the upwelling source water associated with latitudinal shifts for example, rather than variations in upwelling intensity. In fact, in this study besides the physical setting it is important to also consider the chemical (nutrient) and biological setting.

AC: it is true that the occurrence of diatom populations (or those of any other organisms) at the CBmeso site is the result of the interaction of several processes acting in different timescales. The fact that the shift in the species-specific composition of the diatom assemblage in May 2001 is not paralleled by either an increase or decrease of total diatom and/or biogenic silica flux suggests that the intensity of upwelling per se did not significantly change after 2001, nor an increase in DSi availability occurred after May 2001 in waters overlying site CBmeso.

RC2: Pg. 6, Ln. 103 – The SACW occurs in layers between 100 and 400 m depth at the Banc d'Arguin and off Mauritania.

AC: the sentence will be accordingly corrected.

RC2: Pg. 8, Ln 250-252 – ENSO appears to be modulated by AMO, check Levin et al,

(2017) or Chen et al., 2019 or Zhang et al., (2019).

AC: these three papers will be discussed in the revised version.

RC2: Pg. 9. Ln. 301 – 302 – The list of species presented do correspond to marine plankton forms that although not thriving in the highly productive and colder coastal upwelling systems, and more likely to be found in warmer waters, they are also not characteristic or real oligotrophic waters.

AC: in addition to other peer-reviewed publications, we base the grouping of diatom species found in the CBmeso trap samples on our almost 20 year continuous research of the temporal dynamics of diatom populations and their biogeographical occurrence. Throughout the years, we have learnt that the species listed as 'open-ocean taxa' are typical of ocean waters of low content of dissolved silica (DSi). The term 'low' here is sued in comparison to the high content of DSi in coastal waters of EBUEs, which is at least five to ten times higher than in open-ocean waters of the mid-latitude North Atlantic. From this point of view, we are confident in characterizing the open-ocean diatoms (as listed in Table 2 of our MS) as typical of oligotrophic waters. In addition to the papers quoted in out MS, we have studied trap-gained diatom assemblages from different setting from mid- and low latitudes all around the world. These studies have largely helped to characterize the biogeography of marine diatoms and their ecology (e.g., Romero et al., 2000, Deep Sea Research Part II: 47(9): 1939; Romero et al., 2002, Journal of Plankton Research 24: 1035; Romero et al., 2009, Deep Sea Research I 56: 571; Romero and Armand, 2010 in: The Diatoms, Applications for the Environmental and Earth Sciences, Ed.: Smol and Stoermer, Cambridge University Press: 373; Romero et al., 2016, Progress in Oceanography 147, 38).

RC2: Pg. 10, Ln. 323- 324 - The impact of the environmental variables on diatom communities was investigated by simple comparison using the samples clustering and the forcing values associated (Fig 4). You are not using the forcing values, but rather the value of an index that is considered to define the coherent mode of natural variability occurring in the north Atlantic. Changes in this mode will have an impact on the circulation at your study site and be considered a forcing factor for your specific process.

AC: We agree with Referee 2 in that we used climate indexes, which is a proxy of the direct environmental forcing. We did not use highly-resolved environmental data (e.g., DSi content) because they are not available for the complete time serie.

RC2: Pg. 10, Ln. 329 – Please specify tendency of the gradient.

AC: it has been re-phrased and reads as follows: In addition, a gradient in the Shannon diversity index of the diatom populations (Fig. 4c) is observed with predominant low values (1.7-2.5) corresponding to benthic (=group 4), intermediate values (2.7-3) for coastal planktonic (=group 3) and high values (3.1-3.45) in samples dominated by coastal upwelling and open-ocean populations (=groups 2/1) (pairwise Wilcoxon rank sum test; p-value<0.05).

RC2: Pg. 10, Ln. 335 – Mentioned figure should be included as a supplementary figure.

AC: Figure 3 highlights our statistical approach to define which diatom communities dominate our samples and the time series of their respective dominance instead of doing it visually. Since this figure is also causally related to Figure 4, we do believe that Figure 3 should be kept as part of the MS figures and does not need to be transferred to Supplement

RC2: Pg. 10, Ln 337 - the benthic diatom D. surirella decreased the diversity, although it also seems to be promoted determined by AMO strengthening. In the same way, the second CA axis samples scores are positively correlated with TDF, which confirms that coastal upwelling diatoms seems to promote define the TDF.

AC: it has been re-phrased and reads as follows: 'Given that the first CA is positively driven by the benthic group, this confirms the outstanding dominance of the benthic diatom D. surirella after May 2001, which also appears linked to the strengthening of AMO. In the same way, the second CA axis is positively correlated with total diatom flux also confirms that coastal upwelling diatoms deliver a large numbers of diatom valves.'

RC2: Pg.11, Ln 352 - Based on outstanding shifts in the species-specific composition of the diatom assemblage occurred throughout the study interval (Fig. 2b).

AC: it has been re-phrased and reads now: 'Based on outstanding shifts in the species-specific composition of the diatom assemblage occurred throughout the study interval (Fig. 2b), we propose three main intervals in the multiyear evolution of populations and discuss them in view of mayor environmental forcings:...'

RC2: Pg. , Ln. 360 - Based on the long-term trends of our data and their statistical analysis (Figs. 2-5), we suggest that the proposed intervals were the response of the diatom populations to the impact of low frequency forcing on the Canary upwelling system. To be correct, the upwelling system is the one that responds to the low frequency forcing. Diatom assemblages reflect hydrographic and nutrient availability brought up by the upwelled source waters.

AC: It is true that the upwelling in the Canary EBUE responds to low-frequency climate impact. By studying the diatom populations, we did not, however, directly characterize long-term variability of upwelling intensity off Mauritania as studies quoted in the Introduction of our first submitted version did (L. 66 th 77). Therefore, we believe that the sentence as written is correct.

RC2: Figure 4: Comparison of (a) clusters extracted from multivariate analysis with the environmental forcing variables (a1: Total diatom flux; a2: AMO; a3: Shannon diversity). Besides being too small and difficult to see, total diatom Flux and Diversity are not forcing variables. They all reflect the community adaptation to the regional conditions resulting from the forcing factor(s).

AC: we will rephrase this accordingly. NAO, AMO, ENSO and the diversity index

Shannon-Weaver are indices while the total diatom flux is a variable. This was wrongly described in the original submission. The file resolution of Fig. 4 will be enlarged.

RC2: References Chen, S., Song, L. & Chen, W.: Interdecadal Modulation of AMO on the Winter North Pacific Oscillation-Following Winter ENSO Relationship. Adv. Atmos. Sci. 36, 1393– 1403, 2019. https://doi.org/10.1007/s00376-019-9090-1 Frankcombe, L. M., Heydt, A. v. d., and Dijkstra, H. A.: North Atlantic Multidecadal Climate Variability: An Investigation of Dominant Time Scales and Processes, Journal of Climate, 23, 3616-3638, 2010. Levine, A. F. Z., M. J. McPhaden, and D. M.W.Frierson: The impact of the AMO on multidecadal ENSO variability, Geophys. Res. Lett., 44, 3877–3886, 2017. doi:10.1002/ 2017GL072524. Knut Lehre Seip, Øyvind Grøn and Hui Wang: The North Atlantic Oscillations: Cycle Times for the NAO, the AMO and the AMOC. Climate, 2019, 7, 43; doi:10.3390/cli7030043 Yamamoto, A. and Palter, J. B.: The absence of an Atlantic imprint on the multidecadal variability of wintertime European temperature, Nature Communications, 7, 10930, 2016. Zhang, W., X. Mei, X. Geng, A. G. Turner, and F. Jin: A Nonstationary ENSO– NAO Relationship Due to AMO Modulation. J. Climate, 32, 33–43, 2019. https://doi.org/10.1175/JCLI-D-18-0365.1. AC: we are grateful for these references. These peer-reviewed publications will be accordingly discussed in the revised version.

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Figure 1
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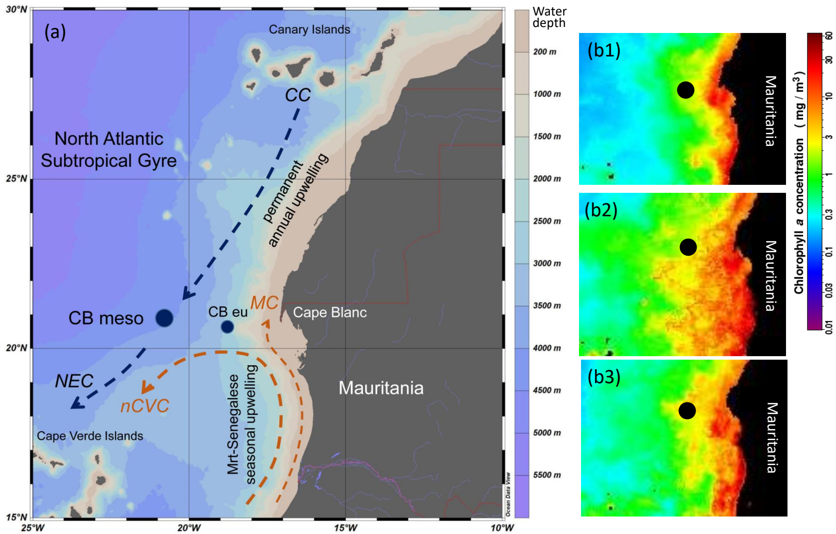

Fig. 1. Figure 1 revised

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