Interactive comment on "Oceanic response to the consecutive Hurricanes Dorian and Humberto (2019) in the Sargasso Sea" by Dailé Avila-Alonso et al.

The reviewer is thanked for his/her positive and constructive comments on the manuscript.

REVIEWER 2

The study describes the response of the ocean to two consecutive hurricanes in 2019, looking at various aspects, including temperature change, heat content and chlorophyll. The paper is well written and interesting, though the results are not unexpected or especially new. It should be noted though that studies of consecutive hurricanes in this region are not new - the authors may have not been aware for example of some recent studies (that should be cited) of the impact of consecutive hurricanes on the same region, including Todd et al. (2018) on the 2017's hurricanes and Ezer (2020) who studied the same Dorian and Humberto hurricanes of this study! However, the aforementioned papers focused mostly on the impact of hurricanes on coastal sea level and ocean currents (and the Gulf Stream in particular), while here the additional analysis of biological impacts and chlorophyll is an interesting new kink that worth publication.

We agree with the fact that studies on consecutive hurricanes in this region are not new since, for instance, the articles suggested by this reviewer (cited in lines 39, 44, 320, 324, 327, 465, 480 in the revised version of the manuscript) address the impact of consecutive hurricanes on ocean circulation in the western Sargasso Sea. However, as we mentioned in the manuscript, studies on the effects induced by consecutive TCs have been much less documented as compared to the response to individual TCs (Wu and Li, 2018; Ning et al., 2019) (lines 58–63), mainly because the occurrence of hurricanes following similar trajectories within a short period of time is uncommon. In the manuscript we cited several articles assessing the SST and chl-a concentration response to the passage of consecutive typhoons in the western Pacific Ocean (e.g., Wu and Li, 2018; Ning et al., 2019; Wang et al 2020). However, to the best of our knowledge there are no previous studies assessing the biological response to consecutive TCs in the western Atlantic Ocean (lines 60–63).

With regards to ocean dynamics, it would be useful to add a little more discussion - the study area is strongly influenced by the Gulf Stream which was significantly weakened during Dorian (Ezer, 2020) and this had implications for mixing and advection, since a weakened GS could also contribute to relative cooling downstream when advection of warm tropical waters slows down.

7. Lines 305-312- When discussing the dynamics and mixing processes, may be add something about the role of the Gulf Stream, as in Ezer (2020).

In the revised version of the manuscript we included the information below in order to discuss the influence of the Gulf Stream on the observed post-storm cooling and mixing (lines 320–329).

The extensive surface cooling observed to the right of Dorian's trajectory (Figure 2B and C) was also reported by Ezer (2020). Besides, this extensive cooling was consistent with the one observed after the passage of Hurricane Matthew (2016) (who followed a similar trajectory as Dorian) and results from the interaction between a hurricane and the core of the Gulf Stream flow and its associated eddy field (Ezer, 2018). Dorian induced a disruption of the Gulf Stream flow, disconnecting the upstream Florida Current from the downstream Gulf Stream and weakening the Gulf Stream flow by almost 50% (Ezer, 2020). This direct effect on surface currents was followed by intense surface cooling largely determined by the reduced flow of warm tropical waters being advected downstream Gulf Stream as well as mixing of the upper oceanic layer (like during the Hurricane Matthew) (Ezer et al., 2017; Ezer, 2020). Overall, the interaction of hurricanes with the Gulf Stream induces a considerable vertical mixing and reduction of the stratification frequency (Kourafalou et al., 2016). Consequently, it has been reported that vertical mixing drove cooling of the upper 50 m after the passage of Matthew across the Sargasso Sea (Ezer, 2018).

It would have been interesting also to extend the study period to see the timescale of recovery after the storm and the role that the GS plays in this recovery.

We assessed the oceanic response during a month after the passage of Dorian in agreement with the methodology followed in previous studies assessing climatological responses to the passage of hurricanes (line 123), which allowed us to compare the retrieved temporal evolution of SST and chl-a concentration anomalies with the ones reported in Menkes et al. (2016) for all TC-prone regions around the world (e.g., lines 431–432, 434–435, 468–470). On the other hand, the analysis of four post-storm weeks allowed us to compare the individual response induced by Dorian in the first and second post-storm weeks with the one induced by the combined effects of Dorian and Humberto in the third and fourth post-storm weeks since the main purpose of our study is to highlight the increased oceanic response to the passage of consecutive TCs. We agree that it would be interesting to analyse the timescale of recovery after the storm and the role that the Gulf Stream plays in this recovery. However, this is out the scope of our research. We consider that a thorough study is needed in order to accurately assess the timescale of the decay of the oceanic response induced by these TCs.

Extending the study period can add uncertainties related with the real environmental drivers governing the retrieved oceanic variability. Oceanic variability within a few days (and weeks) after the passage a hurricane can certainly be associated with the perturbations induced by this atmospheric phenomenon. However, extending the study period increases the probability to account for additional drivers influencing the observed oceanic variability, such as those governing the actual seasonal variability of the analysed variables. It has been reported that TCs occurring in the first half of the hurricane season (at global scale) disrupt the seasonal warming trend, which is not resumed only 20–30 days after the cyclone passage, while cyclone occurrences in the last half of the season lead to an SST decrease from which the ocean does not recover due to the seasonal cooling cycle (Dare and McBride, 2011). On the other hand, Haakman et al. (2019) reported on the basis of climatological analysis that strong cold anomalies induced by a hurricane in the North Atlantic basin need around 50–60 days to (almost) disappear and recover the climatological mean values.

We computed anomalies of SST and chl-a concentration two months after the passage of Dorian (Figure R1). The additional almost 30 days essentially account for October 2019. During this period, SST kept a decreasing trend showing the most negative anomalies of the entire study period. In agreement, chl-a concentration anomalies in the square study area at this time showed the most positive values of the entire analysed post-storm period. We consider that in order to correlate the oceanic variability in October 2019 with the probable long-lasting effects induced by Dorian and Humberto, a climatological analysis would be needed in order to discard the influence of the seasonal cycle of these variables in the study area. This new analysis would extend our study too much. We consider that, definitively, further studies are needed in order to accurately assess the recovery timescale after the passage of consecutives hurricanes in the western Sargasso Sea.

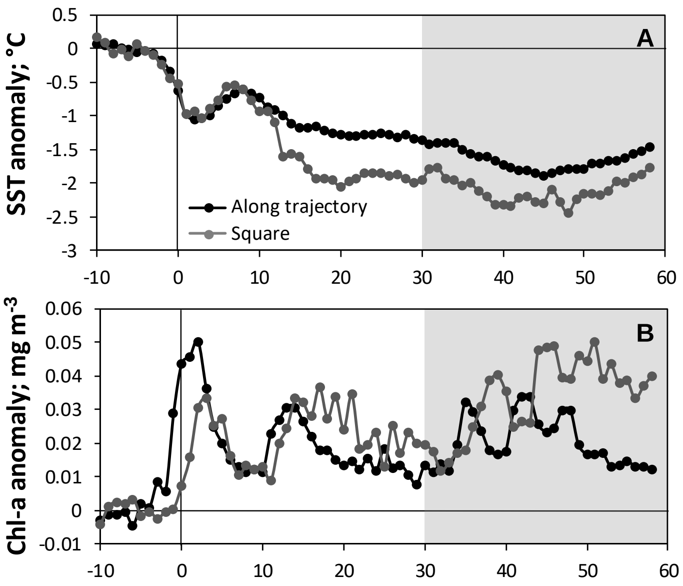

Figure R1. Daily mean evolution of anomalies of (A) sea surface temperature (SST) and (B) chlorophyll-a (chl-a) concentration in the Sargasso Sea before, during and after the passage of Dorian and Humberto. The grey-shaded areas depict the extended period of analysis corresponding to October 2019.

Specific Comments:

2. Abstract- Sentence starting "Overall, : : :" (line 7) and ending ": : :post-storm weeks, respectively." (line 12) is too long, cumbersome and needs separating to shorter sentences and rephrasing.

In the revised version of the manuscript, we have rewritten this sentence as follow: Overall, anomalies of sea surface temperature, ocean heat content and mean temperature from the sea surface to a depth of 100 m were a 50, 63 and 57% smaller (more negative) in the third/fourth post-storm weeks than in the first/second post-storm weeks of Dorian (accounting only for Dorian effects), respectively. For what concerns the biological response, we found that surface chlorophyll-a (chl-a) concentration anomalies, the mean ch-a concentration in the euphotic zone and the chl-a concentration in the deep chlorophyll maximum were 16, 4 and 16% higher in the third/fourth post-storm weeks than in the first/second post-storm weeks, respectively (lines 7–12).

3. Introduction- The discussion is mostly about climate change and hurricanes, and not enough on the actual topic of the study, i.e., the processes involved in the impact of storms on the upper ocean.

In the revised version of the manuscript we have included a little more discussion and analyses related with the processes associated with the impact of storms in the upper ocean (e.g., lines 320–329, 436–480). New analyses were performed to make clearer the contribution of consecutive hurricanes superimposing effects on the ocean in the study area as was suggested by the first reviewer. We assessed the individual response induced by Humberto (lines 436–455) and we compared the oceanic response induced by Dorian and Humberto with the one induced by an individual hurricane (Irene 2011) and other consecutive hurricanes (Dennis and Floyd 1999) in the study area (lines 456–476). However, we acknowledge that further studies are needed in order to get a deeper understanding on the processes driving the upper ocean response to the passage of consecutive hurricanes in the study area (lines 516–518).

4. Line 35- I suggest deleting "In agreement", its awkward to start a paragraph this way.

In the revised version of the manuscript, we have deleted "In agreement" (line 36).

5. Lines 38-39- Maybe add citation to Todd et al. (2018) who studied the same mentioned hurricanes, and when discussing Dorian (lines 42, 62, etc.) may cite Ezer (2020).

We added the suggested citations in several lines in the manuscript (lines 39, 44, 320, 324, 327, 465, 480).

6. Figures 6a and 11a- It is unclear how they were done and what they represent- how can one compare a hurricane at a particular year and a particular week to past years?, and what does the clear trend represents. It seems that there is much more information in these figures than described and the interpretation is unclear.

In the revised version of the manuscript, we reformulated the information in lines 248–255 to clarify the procedure followed to create the time series of the weekly anomalies shown in Figures 6A and 11A. Moreover, we have rewritten the results derived from these figures (lines 255–259, 308–311). Overall, we mentioned that the actual third and fourth post-storm weeks of Dorian in the square study area were the ones of 19–26 September 2019 and 27 September–4 October 2019, respectively, so, we assessed the SST and chl-a concentration variability during these weeks in the previous years for which satellite observations were available, i.e., 1982–2018 for SST and 1998–2018 for chl-a concentration. We refer to these weeks as the *third and fourth post-storm weeks of Dorian* regardless of the analysed year, and to indicate the actual oceanic response induced by Dorian and Humberto we specified this was the one in 2019.

On the other hand, the positive trend observed in time series of SST anomalies (Figure 6A in the manuscript) accounts for the ocean surface warming in the region as previously reported (Bulgin et al 2020) (lines 261–262). In the revised version of the manuscript we present a new analysis and results (lines 260–267) since we removed the positive trend in order to compare anomalies in 2019 with the ones in the previous years on the same basis, i.e., without considering the effect of ocean warming in the region. From the detrended time series (Figure 6B), we observe that SST anomalies in 2019 were the coldest ones in the climatological record except for the ones in 1984 and 1999 confirming the considerable cooling induced by the combined effects of Dorian and Humberto.

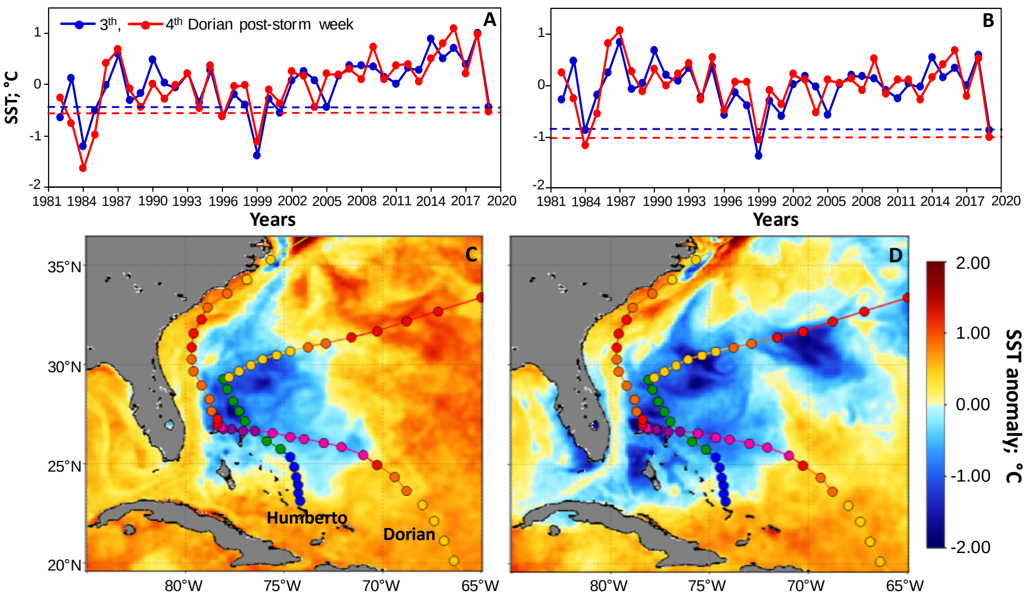

Figure 6. (A) Time series of weekly mean sea surface temperature (SST) anomalies during the third and fourth post-storm weeks of Dorian in the square study area shown in Figure 1B. (B) Detrended time series of SST anomalies. The dashed lines mark anomalies in 2019 for comparison with the previous years. (C) and (D) Spatially

explicit SST anomalies (Dorian+Humberto (2019) induced effects – Climatology (1982–2018)) in the third and fourth post-storm weeks of Dorian, respectively.

8. Fig. 12c- Are those absolute geostrophic velocity? or velocity anomaly? Anomalies do not tell us much, maybe also show the absolute SSH and velocity to indicate the hurricane track relative to the mean flow of the subtropical gyre and the GS.

The main purpose of Figure 12 is to depict that in some cases, maximum surface cooling and high chl-a concentration occurred over areas with low values of sea surface height (SSH) and oceanic cyclonic circulation, which largely correspond to cold-core eddies (lines 330–331). In the first version of this manuscript we had used an image of sea surface height anomaly (SSHA) considering that this 'anomaly' preserves seasonal signals since it accounts for the difference between the best estimate of the sea surface height and a mean sea surface derived from long-term observations from satellite altimeters (Muller-Karger et al 2015). For this reason, we can see in Figure R2 that both SSHA and SSH images show a similar spatial distribution of low values of the sea level in the central Sargasso Sea basin. Thus, and considering the suggestion made by this reviewer, we used the image of absolute SSH in the revised version of the manuscript (Figure 12C in the manuscript). We also specified that the vectors of marine currents displayed in Figure 12C represent absolute geostrophic velocity (Figure 12 caption).

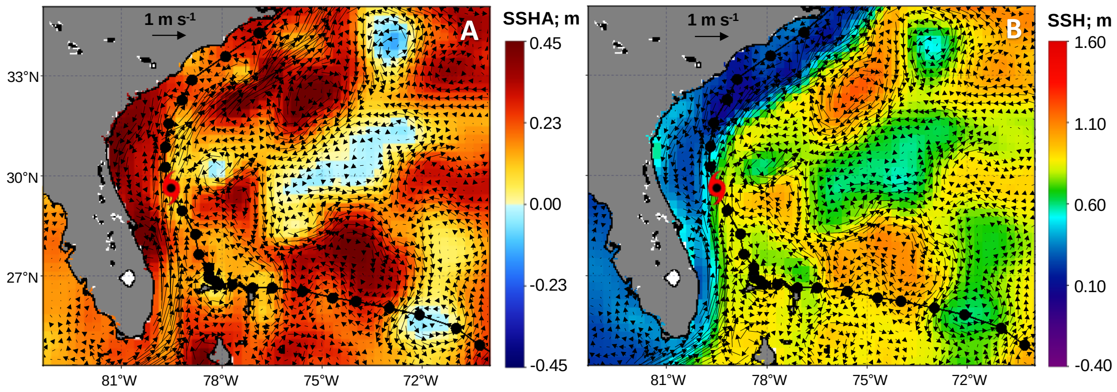

Figure R2. (A) Sea surface height anomaly (SSHA) and (B) sea surface height (SSH) with the absolute geostrophic velocity vectors superimposed (data derived from Salto/DUACS gridded multimission altimeter at 0.25 × 0.25 spatial resolution). The trajectory of Dorian and a hurricane symbol indicating its estimated position are superimposed on all imagines.

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