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 3

I agree that the introduction focuses more on climate change and TCs and less on upper ocean response. Please add literature and introductory comments on the expectation of upper ocean changes from the passing of hurricanes. An additional paragraph should suffice. Do not take out what you have - it is well written and supports the ideas. You need only add a little more. This will help the remaining parts of your paper pack more of an important "punch" if we are more aware of why it matters to be looking at Chl-a.

We have included the information below in Introduction in order to briefly describe the upper ocean changes to the passing of TCs (lines 47–58).

Over oceans, TC-induced wind forcing mixes the surface layer, deepens the mixed layer and uplifts the thermocline leading to a decreased upper ocean temperature and heat potential (Price, 1981; Shay and Elsberry, 1987; Trenberth et al., 2018). Vertical mixing and upwelling also lead to an increased abundance of surface phytoplankton due to entrainment of nutrient-rich waters from the nitracline to the ocean surface and/or entrainment of phytoplankton from the deep chlorophyll maximum (DCM) (Babin et al., 2004; Walker et al., 2005; Gierach and Subrahmanyam, 2008; Shropshire et al., 2016). The nutrient influx stimulates phytoplankton growth and can lead to phytoplankton blooms lasting several days after the TC passage in the oligotrophic oceanic waters (Babin et al., 2004; Hanshaw et al., 2008; Shropshire et al., 2016). Moreover, rainfall associated with these extreme meteorological phenomena modulates surface cooling and phytoplankton blooms since rainfall freshens the near-surface water increasing stratification and influencing vertical mixing (Lin and Oey, 2016; Liu et al., 2020). From satellite imagery, an increase in phytoplankton abundance is identified as elevated chlorophyll-a (chl-a) concentration. Distinguishing between mechanisms inducing changes in chl-a concentration is crucial to understanding the impact of storms on upper ocean oceanographic conditions.

Section 2.1. Please refer to Figure 1 as your "study area graphic", it will lead to your figure being moved up slightly which helps the reader identify the location.

We mentioned early in the manuscript (line 80, Materials and methods, Subsection 2.1. Study area) that Figure 1 shows our study area.

Did you do any assessment of other conditions of the atmosphere in the "pre-storm" week of Dorian? Meaning, did it rain at all during that time? Rainfall from minor to severe thunderstorms can alter your SSTs in the region and, without mention of it, I'm not sure that other atmospheric events might be biasing your results.

The oceanic response induced by a TC is determined by a combination of atmospheric and oceanic variables (Babin et al., 2004). So, we agree with this reviewer that the obtained results are influenced by atmospheric variables that are not directly considered in our study. For instance, as we mentioned in the revised version of the manuscript (lines 53–55), rainfall associated with TCs modulates surface cooling and phytoplankton blooms since rainfall freshens the near-surface water increasing stratification and influencing vertical mixing. However, given the strong impact of TC winds (mentioned in lines 47–48) and rainfall on vertical mixing, entrainment, and upwelling of the thermocline, which in turn modulate the post-storm SST and chl-a concentration response, we consider that through the assessment of the mixed layer depth and the 20 °C isotherm (D20) depth variability, we indirectly account for the effects of the above-mentioned atmospheric variables. We have included this information in the revised version of the manuscript (lines 190–199).

You mention TC Erin. Were there any other events? Please comment.

Thank you for this comment because we realized that, indeed, there was another TC crossing the western Sargasso Sea during our study period. In the revised version of the manuscript we included the trajectory of TC Jerry on Figure 2E. At the end of the third post-storm week and beginning of the fourth one, TC Jerry moved across the central northwestern Atlantic basin as a tropical storm and then weakened to a low-pressure system (Brown, 2019) (Figure 2E). In Figure 2E we can see a patch of considerable low SSTs to the left of Jerry's trajectory (centered at 31 °N and 70 °W approximately), which could have resulted from the combined effects induced by Humberto and Jerry. This patch of low SSTs was located to the right of Humberto's trajectory, who affected this area as a category 3 hurricane (Figure 1A) a week before the passage of Jerry (lines 213–218).

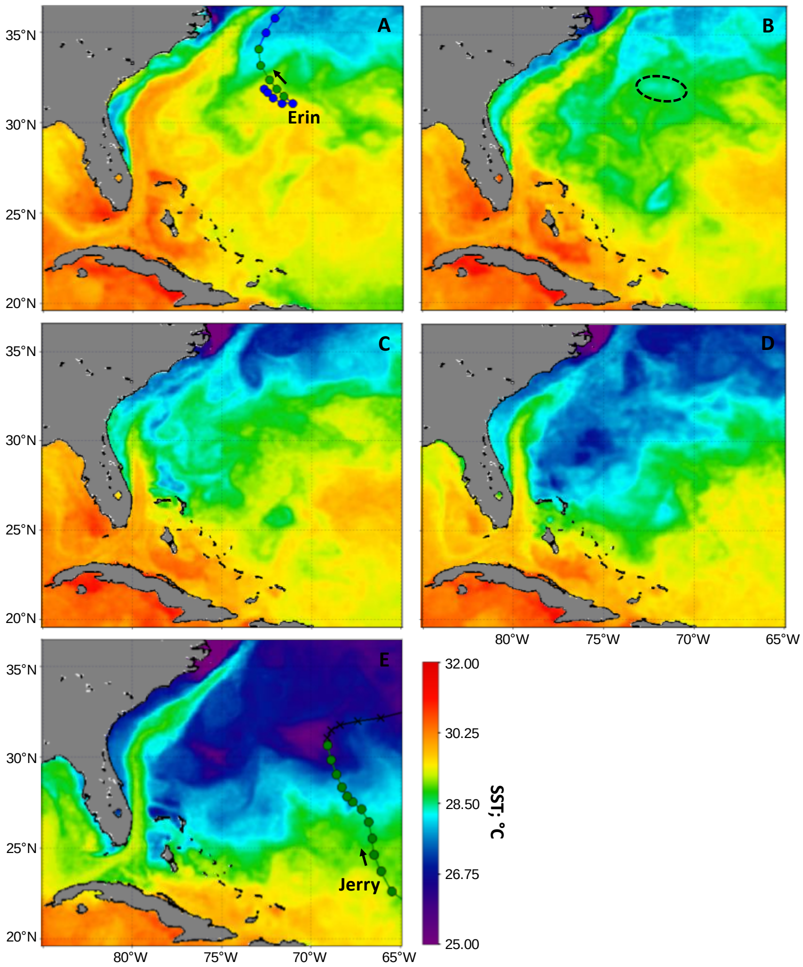

Figure 2. Weekly mean sea surface temperature (SST) in the (A) pre-storm week and (B) first, (C) second, (D) third and (E) fourth post-storm weeks of Dorian in the Sargasso Sea. The trajectories of Erin and Jerry are superimposed on (A) and (E), respectively, with colour coding as defined in Figure 1A and arrows indicating their forward movement. The dashed contours in (B) and (E) indicate the probable surface cooling induced by Erin and Jerry, respectively.

Paragraph including line 190: the way you worded the beginning of this paragraph is confusing. Please rephrase.

We have rephrased the beginning of the paragraph suggested above (line 219).

Great Figure 2. Really showcases what you are describing.

Thank you very much for your positive comment on Figure 2.

In paragraph with line 275, you bring it up yourself that the findings are similar with Ezer (2018) (or later, Foltz et al. 2015). So why is your study different? And, thus, why is it important that it is published? I think you need a stronger argument than you have presented here. Broader impacts related to your study can be helpful here.

The extensive surface cooling and the variability of the mixed layer depth found in our study agree with previous reports (e.g., Foltz et al. 2015, Ezer 2018, Ezer 2020) as was mentioned in the manuscript (lines 320–323, 349–350). We consider that the consistency of our results with the ones previously reported helps to confirm and consolidate the knowledge on the oceanic response to TCs in the region, which is needed in order to derive the general behavior of the upper ocean response to TCs. Moreover, the consistency of our results with those previously published confirms the suitability of the dataset used (i.e., a combination of satellite remote sensing and modelled data) to capture the ocean response to the passage of TCs (lines 497–498) since we used a dataset that is different from the ones used in previous studies. On the other hand, in the revised version of the manuscript we emphasized the novelty and main contribution of our study (lines 58–63, 427–429, 498–501, 518–524) on the basis of which we consider it is important to publish it. As we mentioned in Introduction, extensive and long-lasting SST cooling as well as intense post-storm phytoplankton blooms after the passage of consecutive TCs have been documented in the northwestern 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 Sargasso Sea (lines 58–63). Insights into the phytoplankton response to severe weather events are essential in order to ascertain the capacity of the oceans to absorb carbon dioxide through photosynthesis (Davis and Yan, 2004) (lines 67–68). Moreover, given that climate-driven processes affecting nutrient availability and phytoplankton primary production affect eel larval survival in areas with high spawning activity such as the Sargasso Sea, we consider that the assessment of the oceanic response to TCs in general, and the biological response, in particular, serves for future studies addressing the influence of climate variability on fishery oceanography in the region (lines 489–494).

I think your conclusion needs to be strengthened. While you provide a nice summary of what are interesting statistics, you need to relate it to a broader picture. Why does knowing this information help us in some way? Does it inform fisheries? Does it inform management practices? Why does it matter? (I believe it does, but you need to provide a stronger argument for it).

As we mentioned in Introduction, the assessment of the oceanic response to TCs has been a hot topic given its importance for studies on climate change, ecological variability and environmental protection (lines 65–66). Therefore, in Conclusions we mentioned the importance and application of our results in the research fields mentioned above. Overall, the oceanic response to the passage of Dorian and Humberto reported in our study gives insights into the oceanic implications of a simultaneous increase of both the frequency and intensity of TCs in the North Atlantic basin. Thus, together with a future increase of TC activity in the region, an increased oceanic response could also be expected. Moreover, considering that the TC-induced chl-a concentration changes may impact the survival rates of fish larvae and their recruitment to adulthood in the Sargasso Sea, the results presented here serve for future studies addressing the influence of climate variability on fishery oceanography in the region (lines 519–524).

References

Babin, S. M., Carton, J. A., Dickey, T. D., and Wiggert, J. D.: Satellite evidence of hurricane-induced phytoplankton blooms in an oceanic desert, Journal of Geophysical Research: Oceans, 109, C03 043, doi:10.1029/2003JC001938, 2004.

Brown, D. P.: Tropical cyclone report Hurricane Jerry, 17–24 September, 2019, National Hurricane Center, https://www.nhc.noaa.gov/data/tcr, 2019.

Davis, A. and Yan, X.-H.: Hurricane forcing on chlorophyll-a concentration off the northeast coast of the US, Geophysical Research Letters, 31, L17 304, doi:10.1029/2004GL020668, 2004.

Ezer, T.: On the interaction between a hurricane, the Gulf Stream and coastal sea level, Ocean Dynamics, 68, 1259–1272, 2018.

Ezer, T.: The long-term and far-reaching impact of hurricane Dorian (2019) on the Gulf Stream and the coast, Journal of Marine Systems, p.103370, doi:10.1016/j.jmarsys.2020.103370, 2020.

Foltz, G. R., Balaguru, K., and Leung, L. R.: A reassessment of the integrated impact of tropical cyclones on surface chlorophyll in the western subtropical North Atlantic, Geophysical Research Letters, 42, 1158–1164, 2015.

Gierach, M. M. and Subrahmanyam, B.: Biophysical responses of the upper ocean to major Gulf of Mexico hurricanes in 2005, Journal of Geophysical Research: Oceans, 113, C04 029, doi:10.1029/2007JC004419, 2008.

Hanshaw, M. N., Lozier, M. S., and Palter, J. B.: Integrated impact of tropical cyclones on sea surface chlorophyll in the North Atlantic, Geophysical Research Letters, 35, doi:10.1029/2007GL031862, 2008.

Lin, Y.-C. and Oey, L.-Y.: Rainfall-enhanced blooming in typhoon wakes, Scientific Reports, 6, 31310, doi:10.1038/srep31310, 2016.

Liu, F., Zhang, H., Ming, J., Zheng, J., Tian, D., and Chen, D.: Importance of precipitation on the upper ocean salinity response to Typhoon Kalmaegi (2014), Water, 12, 614, doi: 10.3390/w12020614, 2020.

Ning, J., Xu, Q., Feng, T., Zhang, H., and Wang, T.: Upper ocean response to two sequential tropical cyclones over the northwestern Pacific Ocean, Remote Sensing, 11, 2431, doi:10.3390/rs11202431, 2019.

Price, J. F.: Upper ocean response to a hurricane, Journal of Physical Oceanography, 11, 153–175, 1981.

Shay, L. K. and Elsberry, R. L.: Near-inertial ocean current response to Hurricane Frederic, Journal of Physical Oceanography, 17, 1249–1269, 1987.

Shropshire, T., Li, Y., and He, R.: Storm impact on sea surface temperature and chlorophyll a in the Gulf of Mexico and Sargasso Sea based on daily cloud-free satellite data reconstructions, Geophysical Research Letters, 43, 12 199–12 207, 2016.

Trenberth, K. E., Cheng, L., Jacobs, P., Zhang, Y., and Fasullo, J.: Hurricane Harvey links to ocean heat content and climate change adaptation, Earth's Future, 6, 730–744., 2018.

Walker, N. D., Leben, R. R., and Balasubramanian, S.: Hurricane-forced upwelling and chlorophyll a enhancement within cold-core cyclones in the Gulf of Mexico, Geophysical Research Letters, 32, doi:10.1029/2005GL023716, 2005.

Wang, T., Zhang, S., Chen, F., MA, Y., Jiang, C., and Yu, J.: Influence of sequential tropical cyclones on phytoplankton blooms in the northwestern South China Sea, Chinese Journal of Oceanology and Limnology, doi:10.1007/s00343-020-9266-7, 2020.

Wu, R. and Li, C.: Upper ocean response to the passage of two sequential typhoons, Deep Sea Research Part I: Oceanographic Research Papers, 132, 68–79, 2018.