Response to the comments from reviewer 2

We thank the reviewer for carefully going through the manuscript and offering insightful and constructive suggestions. The manuscript has been revised, taking all comments of the reviewer into account. Detailed replied to each of the comments are given below. Reviewer's comments are marked in **BOLD** font and the responses are in normal text.

General comments

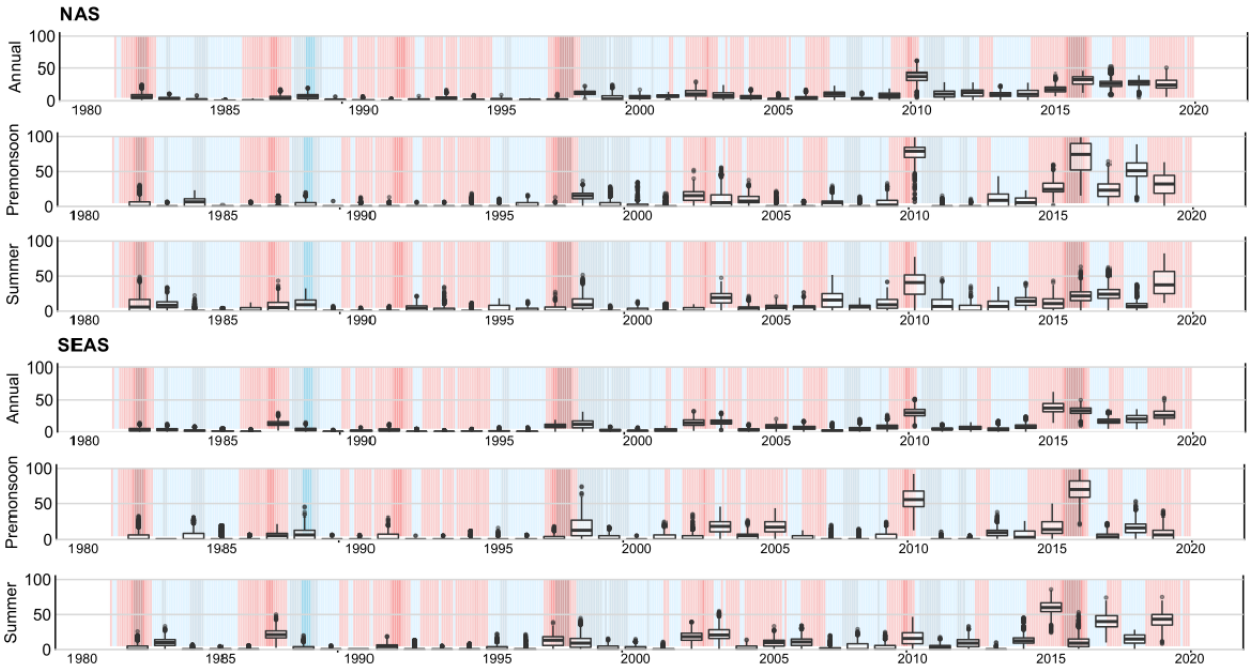
This article examines the history of marine heatwaves (MWHs) in the Arabian Sea over approximately the past 40 years. The authors are motivated by the fact that few studies of MHWs in the Arabian Sea have been carried out, yet they have significant impacts on marine ecosystems and fisheries. The paper is well organized, interesting and informative. It may be worthy of publication subject to revision, especially with regard to the first three points below.

Response: We would like to thank the reviewer for appreciating the work and pointing out some of the overall issues with the original manuscript. The point-by-point response to each of the comments is given below.

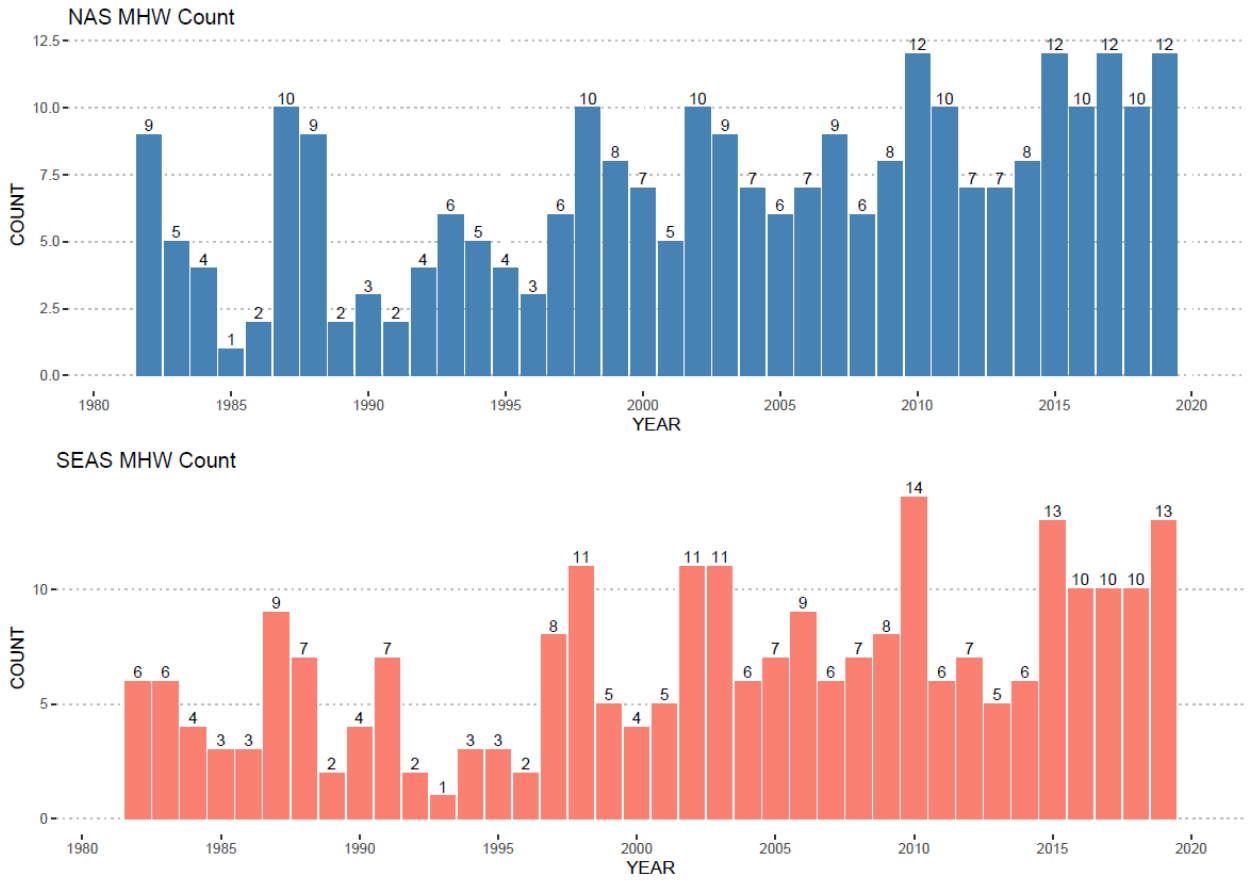
1) I don't get a sense of what a marine heat wave looks like in the Arabian Sea. Statistics are presented in terms of trends, correlations, and time series. For the three stated metrics (frequency, duration, amplitude), please make a table that compares these for the period before and after 2000. Also, provide a description of one exemplary heat wave after 2000 (spatial structure, time history, etc).

Response: In order to provide a sense of how a heatwave event would like in the Arabian Sea, we have modified the "Dynamical mechanisms" section by including a detailed discussion on the heatwave observed during the year 2010 as a case study. This event was the longest and one of the most intense heatwaves observed since the availability of satellite observation. We have shown its spatio-temporal evolution and discussed the dynamics behind its generation, peak and decay using a mixed layer heat budget. Also, relate these processes to the known climate responses whenever possible.

As the heatwave metrics vary from one grid to the other, it was not possible to include a table listing these metrics year-wise. However, to improve the readability we have modified the boxplots showing the percentage of heatwave days across the years in the northern Arabian Sea (NAS) and the southeastern Arabian Sea (SEAS). Also, we included a bar plot to show the maximum observed number of heatwave events for the above mentioned two regions in each year in the revised manuscript. The figures are given below for reference.



Caption: Boxplots of percentage of heatwave days using OISST experienced during annual, pre-monsoon and summer monsoon season for the north Arabian Sea (NAS) and the southeastern Arabian Sea (SEAS). The shading represents the Niño3.4 index.



Caption: Maximum number of heatwave events observed in each year for the NAS and SEAS.

2) The heat balance analysis is misleading because it is only an analysis of MWHs when they last an entire season, which is rare (only 2016 according to Figure 2). It is an analysis of the background conditions on which MWHs develop, but the MHW itself may arise through different processes that are not same as occur in a seasonal mean heat balance. This point needs to be clearly articulated.

Response: The reviewer is rightly pointed that the seasonal evolution may not necessarily lead to heatwaves as they are generally shorter than the seasonal cycle. So, each event needs to be looked at separately and therefore, a statement based on seasonal average may be misleading.

In order to resolve this issue, we have dropped the entire original discussion of the original manuscript. Instead, we have now provided a detailed discussion on the heatwave observed during the year 2010 as a case study. This event was the longest and one of the most intense heatwaves observed since the availability of satellite observation. We have shown its spatio-temporal evolution and discussed the dynamics behind its generation, peak and decay using a mixed layer heat budget. Also, relate these processes to the known climate responses whenever possible.

3) Line 109-110. The model has been validated for other purposes than the study of MHWs. Please quantify the level of agreement between observed and modeled SSTs in Figures 7 and 8. Also, how sensitive are results to use of different flux forcing products?

Response: In the revised manuscript, we have compared the evolution of observed SST with the model SST in Figure 8, 9 and 10. They show that the model could faithfully reproduce the observed SST patterns and the time evolution, except that the model shows ~0.5^{o}C negative bias. Since, for a heatwave, we are interested in anomaly rather than the absolute temperature, this negative bias in the model doesn't impact our conclusions.

Regarding different flux product, yes, we believe that any change in the atlospheric fluxes would impact the model simulation. For example, scatterometer winds allow better intraseasonal simulations than the Tropflux or reanalysis products. Since, here we intend to run the simulation for a longer period, we preferred to use tropflux product which is available from the year 1979 to 2018.

Other comments:

Abstract, line 10. "The Indian Ocean received almost no attention..." This statement is not correct. The term "marine heatwave" was coined to describe the Ningaloo Nino that occurred off Western Australia in 2011. More appropriately, the Arabian Sea has not received much attention.

Response: We have corrected this statement in the revised manuscript and now reads as follows:

"The north Indian Ocean received almost no attention in this regard despite the fact that this ocean basin, particularly the Arabian Sea, is warming at the most rapid pace among the other tropical basins in recent decades."

Related to the comment above, somewhere in the discussion in lines 34-52, Ningaloo Ninos, and the mechanisms responsible for them, should be mentioned (Feng et al, 2013).

Response: We have added a statement in the introduction section to incorporate this fact in the revised manuscript and it reads as follows:

"These extreme warm SST conditions was first coined to describe the Ningaloo Niño off the western coast of Australia during spring 2011 (Feng et al., 2013)."

Line 177. "...coincide with the El-Niño year or the year next to the El-Niño year..." This is confusing. El Nino events typically span two calendar years, e.g. 2015-16. So it is not clear what El Nino year (singular) means. Likewise, the second year of an El Nino is part of the same El Nino.

Response: We agree with the reviewer. We have modified this statement as follows:

"Further, most of the intense heatwave years also coincide with the El-Niño years suggesting an important role of climate modes in modulating these extreme events in this region which is in agreement with what is observed in other regional seas across the world ocean (Oliver et al., 2019)."

Further, we have provided more clarity when discussed climate modes such as El Nino, IOD and IOBM in Section 5. Included more background studies and known responses of these climate modes in the SST of the north Indian Ocean.

Lines 260-62. It needs to be mentioned here that the IOBM is often forced by ENSO via the atmospheric bridge, so that the results for the IOBM automatically contain ENSO effects.

Response: We agree with the reviewer. In the revised manuscript, we have expanded Section 5 to include more discussion on these climate modes and their linkages.

Lines 270-74. Same point as immediately above: the IOD is often forced remotely by ENSO.

Response: Please see the response to the above comment.

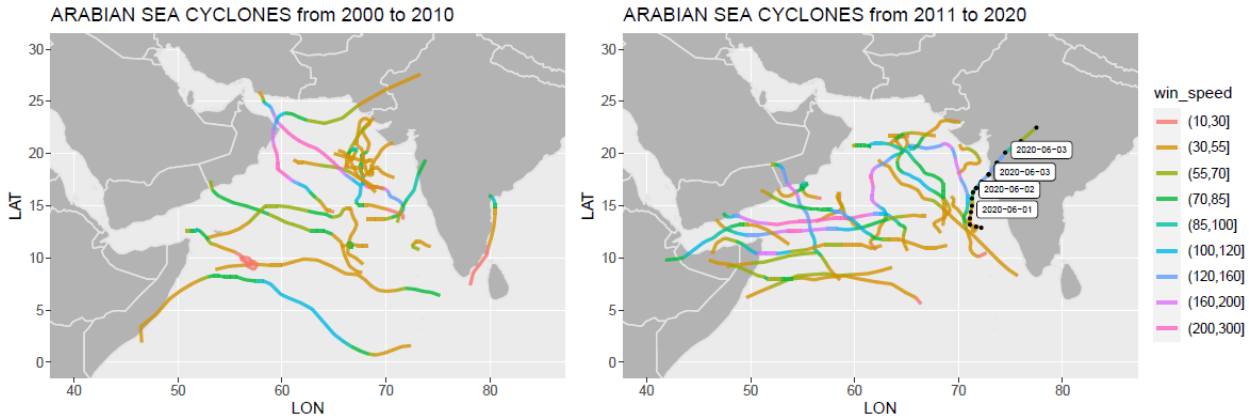
Figure 1. Say over what period the trends are computed.

Response: Corrected.

Figure 9. Identify in some way (different color?) the track of the storm in panel (a) that is highlighted in panel (b).

Response: We have given a marker to the cyclone referred to in the other panel (Figure 13 in the revised manuscript). Note also that we have now modified this figure to show the contrast in tracks between 2000-2010 and 2011-2020 period (Figure 13 of the revised manuscript). We have also expanded the discussion on the relation between cyclones and heatwaves.

The revised figure is given below. Note that the event line plot for the cyclone Nisagra is shown as a separate plot (Figure 14 of the revised manuscript). Overall, three test cases are discussed in this manuscript when a tropical cyclone is involved in terminating long heatwave events.



Caption: Cyclones tracks during 2000-2010 (left) and 2011-2020 (right). The cyclone track of Nisagra which made landfall off Mumbai in 2020 is marked with the dates.

There is need for editing. For example, "makes this regions remained unexplained" (line 331), "wracked" (line 376), "stapling" (Figure 1 and 6 captions) are incorrect words or grammar.

Response: Corrected.