

Response to reviewers' comments

We would like to thank both the reviewers for their constructive comments throughout the review process. Here, we have responded to each point-by-point comment from both the reviewers. Sometimes, we have also included texts from the revised version within the quotes. The line number referred to in these responses are based on the revised manuscript. Reviewer's comments are marked in **BOLD** font, and the responses are in normal text.

Response to the comments from reviewer 1

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 replies to each of the comments are given below.

L32/33: Replace 'These extreme warm SST conditions were' with 'The term "marine heatwave" was'

Response: Corrected

L38: Replace 'it's' with 'their' as MHWs is plural here

Response: Corrected.

L46: replace 'responsible' with 'to be a major driver' as other can also play a role for Ningaloo Nino

Response: Corrected.

L60: delete 'Unfortunately' at beginning of sentence

Response: Corrected.

L71: delete 'also'

Response: Corrected.

L133-150: I think the additional information provided with respect to the physical processes in the two seasons is generally useful but might be slightly too detailed out of context at this point where no results have been shown yet. I would instead add explanatory sentences regarding the circulation when the actual MHW trend pattern in the different seasons is described. For example add a short discussion at the end of the paragraph finishing at L172.

Response: The introductory paragraphs of Section 3 are now re-arranged as suggested.

L143: modify '...via advected by the coastal currents...' e.g ; 'Intrusions of freshwater via the coastal current' or 'freshwater advected by the coastal current'

Response: Corrected.

L164: This still leaves 40% for other seasons which is a non-negligible amount.

Response: Yes, winter months also show a considerable number of marine heatwaves. However, we haven't studied them in this study as we intend to investigate these extreme events when the north Indian Ocean warms rapidly to form the large part of the Indo-Pacific warm pool and cause severe stress to the corals and ecology.

L182: '..turned much prolonged...' is still not correct use of language. Why not just say 'the duration of heatwaves has increased in the recent decade'?

Response: Corrected.

L192-193: add that El Nino and +IOBM alter the background state to warmer temperatures thus potentially explaining these exceptions. This may be a personal style but as a reader I find this kind of information at this point very helpful.

Response: We have added a statement in the revised manuscript that reads as follows (Line no 174-175 of the revised manuscript):

"The warmer than usual SST during El-Niño and positive phase of IOBM thus potentially explains these exceptions."

L206/207: Delete 'Interestingly' and rephrase if necessary. As mentioned in the first round of revision "Per MHW definition this is causation and should not be presented as a novelty". It is fine to state the connection as the authors draw the correct conclusion in the next sentence that this increase in MHWs is likely driven by an increase in mean SST.

Response: Corrected.

L225ff: change to "The use of a fixed climatological baseline in this (and other) studies inherently means that a rapid warming in the recent decade shifted the mean SST towards the heatwave threshold"

Response: Corrected.

L242: you mean 2016 was the second largest or strongest event? 'most' does not make sense here.

Response: We wanted to mean "second strongest" to refer the 2016 event. The same is corrected in the revised manuscript.

L326: Consider changing the section title to something like: 'Dynamical mechanisms inferred from a case study'

Response: We have now modified the section title as suggested.

L344: Do you imply that the onset of summer monsoon clouds reduce the shortwave radiation and thus contribute to decreasing temperatures/ a termination of the MHW? If so, add that explanation.

Response: We have now added a statement in line nos. 318-319 of the revised manuscript and reads as follows:

"The onset of summer monsoon clouds reduce the shortwave radiation, thus contribute to the decreasing temperature and termination of the heatwave."

Further, detailed explanations of the underlying processes are discussed in the following paragraphs.

L400: 'The warming peaks in late April to early May' which plot are you referring and are you only talking about the model now in this paragraph?

Response: Yes, this statement is based on the MLD budget. We have now added referring figure followed by this statement for clarity.

L406: delete 'was'

Response: Corrected.

L405ff: So does the model exactly reproduce the cyclone? I.e. is it included in the forcing as discrete event? It would maybe be helpful to state in the methods which temporal resolution the atmospheric forcing of the model has. Do you think the MHW contributed to the generation of the cyclone? Somewhere here it might be helpful to mention the absolute temperatures and conditions that are needed for a cyclone. Also is this the peak season for cyclones as the temperatures reach their maximum in June?

Response: Yes, the model could reproduce the oceanic response to the cyclone. Note, however, that the response is expected to be weaker than the observation due to the coarser (spatial and temporal) forcing used to force the model. The details about the forcing fields are given in the methodology section.

We certainly feel that the MHWs have a definite impact on the cyclones. In the discussion section we have corroborated the same. However, we noted that further study is required to understand the dynamical links between heatwaves and associated atmospheric conditions to the observed enhanced cyclogenesis of this region.

Yes, pre-monsoon season shows strong cyclonic activity over the Arabian Sea.

L411: Is it really the cyclone or the shift into the summer monsoon season and an associated change in winds/circulation? I guess both.

Response: The sharp drop in SST in fact due to the cyclone Phet. However, summer monsoon winds gradually cool the surface as the winds peak up in the western Arabian Sea and over its fetch.

L419: adjust to the fact that you are doing a case study now instead of a general budget.

Response: Corrected.

L458/459: So this suggest that generally the onset of summer monsoon winds is a mechanism that terminates MHWs in the pre-monsoon region? I think it is an interesting and important discussion if the strong seasonality associated with the monsoon is a limiting factor for the duration of MHWs in each season?

Response: Yes, as the summer monsoon winds peak up, the western Arabian Sea is bound to cool and therefore, will cause termination of any ongoing heatwaves. However, in the east, particularly in the southeastern Arabian Sea, other physical factors play a role.

L469: In terms of cyclogenesis, would it make sense to come up with a new metric such as an X amount of days above a certain absolute temperature?

Response: As we have mentioned in our discussion section, the relationship between heatwaves and the cyclogenesis may not have a linear relation. The other atmospheric factors are also important. Therefore, we are not in a position to tell if a metric as suggested by the reviewer will be helpful. Further study is required to understand these processes.

Figure 8 Are these snapshots of SST or weekly averages? This should be stated in the caption

Response: The panels show daily averages. The caption is now suitably revised for clarity.

Figure 10 Would it make sense to also show the modeled climatology or threshold?

Response: The climatological threshold for the OISST is for the period 1982-2011. Since the model simulation is only available from 1990, we have not attempted to create a similar

threshold. The model simulation was only used for the MLD budget for the heatwave event during 2010.

Figure 15 There is a (b) label in the figure but not panel (a)

Response: Corrected.

Response to the comments from reviewer 2

The paper is much improved from the original submission and I recommend publication. I think it would be worthwhile though to elaborate a little more on the 2010 heat wave for which the heat balance is featured. In particular, it is noteworthy that the 2009-10 El Nino is the strongest central Pacific (CP) El Nino in at least the past 40 years (Lee and McPhaden, 2010, GRL). CP El Ninos have a greater impact on subsidence over the Indian Ocean than eastern Pacific (EP) El Ninos and therefore also on summer monsoon rainfall (Krishna Kumar et al, 2006, Science). I believe—the authors can verify this—that 2010 was a significant drought year in India. More generally, with ENSO and IOBM forcing of the Indian Ocean regions, other environmental hazards (drought for example, over the Indian subcontinent) will co-occur with MWHs. Therefore, adaptation strategies will potentially need to account for the societal impacts of multiple co-occurring environmental stressors on land and in the ocean related to climate variability and change.

Response: We would like to thank the reviewer for recommending this manuscript for publication. We are also thankful for the reviewers' constructive comments throughout the review process, which have helped in improving this manuscript.

Regarding the 2009-2010 El-Niño, we have added a few statements in the revised manuscript (line nos. 387-394) and read as follows:

"It is noteworthy here that the longest heatwave event in the Arabian Sea is noted during spring 2010, which is also coincided with the strongest central Pacific El-Niño in the recent decades (Lee and McPhaden, 2010). In fact, the central Pacific El-niños seem to have a greater impact over the Indian Ocean and, therefore, on the Indian monsoon rainfall (Krishna Kumar et al., 2006). The severe drought during the summer of 2009 is one such example. More generally, with ENSO and IOBM forcing of the Indian Ocean regions, other environmental hazards (for example, droughts over the Indian subcontinent) will co-occur with MWHs. Therefore, adaptation strategies will potentially need to account for the societal impacts of multiple co-occurring environmental stressors on land and in the ocean related to climate variability and change."