Review: ‘Marine Heatwaves in the Arabian Sea’ by Abhisek Chatterjee et al. submitted to Ocean Science

The authors of this manuscript apply a commonly used marine heatwave detection code to NOAA OISST satellite data to investigate marine heatwave (MHW) statistics in the Arabian Sea during 1982-2019. Furthermore they investigate the impact of a mean background warming trend vs. surface temperature variability in the region and also assess the role of dominant climate modes for the generation of marine heatwaves in the region. To further understand the physical drivers of the detected MHWs, a regional ocean model used to derive a mixed layer budget.

Studying MHWs in the Arabian Sea is very likely important given their potential impacts on ecosystems and economies and the regions dense population. While I am not an expert in this region’s oceanography, in my opinion, just presenting MHW statistics does not provide significant new insight. Many of the described sea surface temperature patterns and connections to climate modes are already well know in the literature. The definition of MHWs is a very useful construct to convey temperature changes/extremes, however, inherently no new insight is gained by calling something a marine heatwave. The focus of future MHW studies should lay on the depth-extent of these events and or biological/economical impacts as well as a more detailed discussion of the regional circulation and its variability (oceanic and atmospheric).

I believe it is acceptable to repeat certain analyses that have been only published in a global context, to set the scene for a regional study, however I encourage the others to change the focus of the study (more details below). While the motivation of the study is relevant, I am not convinced that the results presented here provide enough new relevant insight. Therefore, I recommend reconsidering publishing the manuscript after major revision.

General Comments

Papers like Oliver 2019 show already, using the same dataset and detection algorithm, regions where mean warming vs. variability change is dominant globally (see their figure 4), which even picks up the stronger warming in the northeastern Arabian Sea with the chosen colormap. Furthermore the Indian Ocean SST variability and response to climate modes such as ENSO, IOD etc, I believe has been well studied over the last decade. I understand that it can be important to compile these results with a truly regional focus. I wonder if the authors could present the first part of the paper more like a review and then include more discussion about actual impacts or regional details e.g.:

- Discuss absolute temperatures during MHWs and how that can impact the development and genesis of cyclones, which is done here only briefly.
- Discuss the observed patterns and variability in terms of the regional ocean circulation.
- I guess one main point to highlight is that the complex coupling with climate modes can can either dampen or exacerbate the impacts of a mean warming trend, thus significantly contributing to the observed interannual variability of MHW characteristics.
- What role does freshening in eastern Arabian Sea play for stratification change and ultimately SST?

In the second part of the study the model mixed layer budget part can be extended and discussed in more detail with respect to the actual physical mechanisms driving the individual terms. Part of this is done in the discussion at the end but it could be more detailed. Furthermore the model could be used to investigate some of the discussion points above.

In multiple passages the fact that patterns of MHWs coincide with warming SST patterns is presented as novel, however per MHW definition (using a fixed baseline) this is not surprising at all.

I think the manuscript would greatly benefit from a little more discussion when results are presented; e.g. L161-172 would be much more comprehensive if discussed in the light of already know SST responses to climate modes (see linebased comments below for more detail)

It is not clear to me why it makes sense to separate the pre-monsoon and summer monsoon season. It is mentioned that the SST trend is strongest during this time, however, I would appreciate a discussion with respect to e.g. different dynamics during these seasons.

I wish physical processes that could explain the described correlations between MHWs/SST and the climate modes would be discussed better.

Figures

Figure 2: It should be stated in the caption that the y-axis presents percentages. Would it be possible to rearrange the figure? Here the red/blue Nino index, which is repeated in each panel, dominates the figure while the actual MHW data is very small. I would suggest to make the panels larger at least and maybe apply some kind of transparency to the red and blue to take the focus away a little. Could the boxplots of NAS and SEAS for annual and each season be combined in one panel, thus having three instead of 6 subpanels? That way it would also be easier to compare NAS and SEAS. This should be possible since the panels can be stretched across the whole pagewidth, allowing two boxplots per year next to each other.

Figure 5: Add to caption what numbers in over bars mean

Figure 6: A correlation between MHW days and climate modes to my thinking just reflects the correlation between SST and climate modes. Again these patterns are fairly established in the region, e.g. Roxy et al. 2014 show SST composites for El Nino and La Nina

Figure 7: Abbreviations on captions should be consistent with panels, e.g. Q_v is SFX in a?

Figure 9: Would it be possible to plot two panels, one with previous and one with more recent cyclone tracks?

Line-based comments

L8: '...events that can cause a destructive…'
L9: change 'are' to 'is'?
L55: delete 'even'

L57: shows
L60/61: add citation?
L61/62: Impacts of increasing SST should be the same as MHW impacts since they are essentially the same thing

L64-66: Is there any data which implies changes in the catches over the recent warming decade?
L66: change ‘is’ to ‘are’
L129/130: This seems to be an important point regarding impacts on cyclones?
L131-133: Since MHWs are detected using a seasonal climatology, this reasoning is not plausible. The following sentence (L133/134) would be a better reasoning for focusing on the two chosen regions.

L135ff: I assume there would be significant circulation changes in these two seasons? How do these relate to the described spatial patterns? E.g. seasonal changes in the Somalia Current and the Northeast/Southwest Monsoon current?

L151-153: Complicated sentence. Instead just say something like: “This means that the duration of MHWs has increased rather than their frequency”.

L161: This can be due to both, a stronger warming from 2000 onward, as well as the choice of the baseline, which just means that mean temperatures get closer to the threshold.

L162/163: It would be helpful to just mention that these SST responses are well known, i.e. higher SST with +IOB and El Nino decay.

L174/175: Per MHW definition this is causation and should not be presented as a novelty.
L177/178: Not surprising due to know SST response to modes

L181: change ‘is’ to ‘has been’

L189/190: See comment to line 174/175. Furthermore, you can see this in Fig 6 in Oliver 2019, looking at the Arabian Sea.

L201-203: Rewrite these sentences as they are not clear. I suggest to delete the sentences or add something like “ It should be noted that the detection of MHWs is relative to a fixed baseline. If one were to use a moving baseline, warming SSTs would not necessarily lead a trend in MHW days. “

L208-211: Can this be explained by different forcing mechanisms associated with the monsoon?

L217ff: Again this shift around 2000 is likely determined by the used baseline.

L244/245: This is to be expected given the well know impacts of these modes on SST

L247/248: What physical processes can explain that pattern?

L266-268: This is no surprise since correlation maps for SST show that exact pattern with much weaker correlation in the northern Arabian Sea, e.g. Fig3a in Roxy et al., 2014

L276: Holbrook

L277: I would speak of **surface** MHWs here since more and more studies also investigate MHWs at depth which would not necessarily depend on mixed layer processes.

L290: Fig7 does not really show the maximum number of heatwave days?

L294: contributes

L294/295: Here it would be great to add a discussion sentence as to which physical processes are behind the describe terms.

L296 & 301: I am not sure I understand what is meant by 'persistent background warm conditions' or ' very warm precondition'. Aren't the warm SSTs a direct results of e.g. strong surface heat flux? In order to speak of background conditions or preconditioning I would expect to see all terms at different times, where one process drives warm SSTs and another one on top then drives a MHW.

L310/311: This connects to the previous comments and furthermore I don't think it is plausible to say that MHWs are driven by warm SST since one is defined by the other.

L338/339: I would make a point here that in these two years, on top of the mean warming trend, strong El Nino's lead to particular large and persistent SSTs.

L339-342: Both sentences seem to say the same thing.

L342ff: discuss with respect to fixed baseline and how this would change if a moving baseline was used.

L369-371: Is it really the heatwaves or the absolute temperature increase that cause the blooms?

Reference

Oliver, E. , 2019. Mean warming not variability drives marine heatwave trends. *Climate Dynamics* 53 (3-4), pp. 1653-1659, doi: 10.1007/s00382-019-04707-2