Review #2

We are grateful to Referee #2's for his/her substantial efforts in reviewing the revised manuscript and for the constructive and valuable comments. We believe our paper has improved as a result of his/her comments. We highlight our responses to the general and specific comments and explain the revisions we have made to the paper accordingly. The reviewer's comments are shown below in italics writing while our response is marked in red.

# Comments on Revised Manuscript titled "Fast local warming is the main driver of recent deoxygenation in the northern Arabian Sea" by Zouhair Lachkar et al.

## General comments

*I find that the revised manuscript has undergone extensive changes and has significantly improved in its scientific content, with much cleaner analyses and illustrations compared to the original version. The authors have carefully addressed all my comments on the original version. While some improvements are still required in writing (presentation), I would recommend the manuscript be considered for publication after addressing some minor issues listed below.*

We thank the reviewer for the encouraging comment and for the positive assessment of the revised paper.

## Minor comments

*1. P6 L1: It should be S3 instead of S2.*

Corrected.

*2. Fig S1: Change 76W to 76E.*

Corrected.

*3. P9 L13: change "three" to "four".*

Corrected.

*4. P9 L14-24: Mention or mark the region over which the heat fluxes are set to climatological in $S_{hclim}$ and $S_{hclim\_AG}$. I presume (as inferred from your answer to my earlier comment # 3) that Gulf warming is not included in $S_{hclim}$. Similarly, provide precisely the region over which the winds have been modified in $S_{wclim\_JJAS}$ and $S_{wclim\_DJFM}$.*

Done. We now specifically mention that the climatological heat fluxes are prescribed across the entire domain for simulations $S_{hclim}$, $S_{wclim\_JJAS}$ and $S_{wclim\_DJFM}$, whereas for simulation $S_{hclim\_AG}$ (where Gulf warming is not included) the climatological heat fluxes are prescribed over the Arabian Gulf region only.
Please see lines 16-24, page P9, of the revised manuscript.

*5. What are the 0 contours in Figure 4b in most of the regions? The consistency between contours (last minus first five years) and color shading (trend) is unclear.*

The contour lines correspond to changes between the first five years [1982-1986] and the last five years [2006-2010] in O2 (in mmol/m3/decade). This is now explicitly stated in the revised caption of Fig4b. Although they are not exactly identical with the linear trends because of the interdecadal variability in the timeseries and the difference in the units, the general patterns of oxygenation/deoxygenation do correspond relatively well, especially in the northern Arabian Sea.

*6. P15 L10-12: "This is as oxygen…" - Not clear*

To clarify the statement, we changed it to: "Indeed, oxygen decreases in the northern AS by around 9% between 1982 and 2010 under climatological summer winds, a rate that is nearly 50% weaker than in the control run during the same period (Fig S20, SI)." (P15, line 10).

*7. P17 L11-13: I find that summer wind intensification occurs mainly south of 20oN in the AS (Figures 2c, S17d). Then how does the wind intensification drive shoaling of thermocline depth in the northern AS? This needs clarification.*

Although the summer wind intensification is stronger south of 20N as correctly pointed out by the referee, a strong negative wind stress curl (causing downwelling and thermocline deepening) dominates in the open ocean south of 20N as can be seen in the Ekman velocity and its trends included in our response to previous reviewer's comment #22. In contrast, open ocean upwelling and upwelling trends dominate north of 20N.

For more clarity, we have included the figure showing the average (and linear trends) in the Ekman suction velocity during the summer monsoon season in the Supp Information (new Fig S24).
We have also added the following statement:
"This suggests that summer monsoon wind intensification causes the thermocline depth to rise in the northern AS and deepen elsewhere (Fig 10). This is likely due to enhanced open ocean upwelling (Ekman suction) in the north and downwelling (Ekman pumping) in the south (Fig S24)." (P17, lines-13-14).

*8. P17 L31-32: Is it referring to Oschiles et al. (2019; Loss of fixed nitrogen causes net oxygen gain in a warmer future ocean)? May cite the paper.*

This statement was in reference to Fig S26. We have added the following statement with a reference to Oschlies et al. (2019) in the revised manuscript:
"[..], a process previously shown to be important for the oxygen budget on long timescales (Oschlies et al., 2019)". (P18, line 1).

*9. Fig S13: How are the trends computed with gaps in the data?*

These trends have been shown and included in response to Referee #1 comment. We do acknowledge that the substantial gaps in salinity data precludes extracting statistically significant trends as can be read in the manuscript text (page 8, lines 9-11):
"Yet, the highly sparse observational coverage (most of the observations coming from the last decade of the simulation) precludes extracting meaningful trends from the data to validate the simulated salinity long-term changes (Fig S14, SI)."

*10. Fig S14: Which box is referred to in the caption?*

The box is shown in Fig 4a. The caption was corrected.

*11. Fig S16 vs S8: Why different (SeaWiFs/OC-CCI) products are considered, though both are available during the period considered?*

We initially used the Ocean-Colour Climate Change Initiative (OC-CCI) product to evaluate the interannual variability in simulated chlorophyll in response to an explicit request made by Referee #1.
However, for more consistency with the seasonal chlorophyll variability analysis we have now replaced the OC-CCI dataset with the SeaWiFS product over the same period. This does not change the comparison dramatically and only slightly improves the correlation between simulated and observed interannual chlorophyll fluctuations (R=0.54 instead of R=0.48 with OC-CCI). Please see the new Fig S16.

*12. Fig S18: Mention it for the AS.*

Done.