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Interactive comment on "Seasonal variability of the circulation in the Arabian Sea at intermediate depth and its link to the Oxygen Minimum Zone" *by* Henrike Schmidt et al.

Henrike Schmidt et al.

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Interactive comment on "Seasonal variability of the circulation in the Arabian Sea at intermediate depth and its link to the Oxygen Minimum Zone" by Henrike Schmidt et al.

Anonymous Referee #2 Received and published: 8 March 2020

General Comments The manuscript addresses important concerns relating to the oxygen minimum zone in the Arabian Sea, but could benefit from a more complete comparison of the model output to observational data, including acknowledgement of existing

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observational publications.

Reply to reviewer #2 We would like to thank the reviewer for taking the time and for providing constructive and very specific comments, which helped to improve the manuscript considerably. We rearranged the order of figures and included two completely new figures (Figs. 6 and 11). We also rewrote some parts of the manuscript to make the results and the discussion easier to follow. We have carefully addressed his/her comments. The point-by-point responses to the specific comments follow below.

Specific comments 1) It is not clear to me how "intermediate" depth is defined. On Page 2 Line 7 the OMZ is stated as 200-700 m depth, and Fig 3 has particle paths spanning from 200-800 m depth, so I assume this must be the range, but it should be stated more clearly in the text (maybe in parenthesis behind the first reference to "intermediate depth)

This is a good point. We included the definition of "intermediate" depth now more clearly in the manuscript. Abstract: "... to investigate the advective pathways of Lagrangian particles into the Arabian Sea OMZ at intermediate depths between 200 and 800 m." Section 2.2: "...OMZ by performing backward trajectories and to draw inferences of the basin wide spread of oxygen at intermediate depth (200 – 800 m)."

2) Page 4 Lines 26-29 not necessary

We would like to keep the paragraph. It might not be necessary but we consider it as helpful for the reader.

3) Page 5 line 21+ say model output were validated using YoMaHa data, but no detail is provided other than stating it "agrees very well."

We added a carefully description of the near-surface circulation obtained from YoMaHA07 as well as HYCOM. Additionally, we refer to the analysis of near-surface circulation in the northwestern Indian Ocean based on drifter data by Vitale et al. (2017).

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“The complex circulation pattern at the near-surface, which is strongly affected by the seasonal Asian monsoon (Schott et al., 2009) is well described by the HYCOM data reflecting all (reversing) currents that are relevant for the AS. During the winter monsoon, the Somali Current (SC) flows southwestward along the coast of Somalia (Fig. S1a, b). The Northeast Monsoon Current (NMC) sets westward at the southern tip of India and supplies the West Indian Coast Current (WICC), which is flowing northward along the coast of India (Figs. 1a, b). During the summer monsoon, the Somali Current (SC) and the Ras al Hadd Jet (RHJ; also called East Arabian Current (Vitale et al., 2017)) flow northeastward along the coast of Somalia and Oman (Fig. S1c, d). A strong gyre, the Great Whirl (GW), can be identified, which generally develops off the coast of Somalia during the summer monsoon season (Figs. S1c, d). In accordance to observations, the West Indian Coast Current (WICC) flows southward along the coast of India and feeds the Southwest Monsoon Current (Figs. 1c, d). The comparison of the near-surface circulation obtained from HYCOM and ARGO agrees very well during the winter and summer monsoon (see supplement Fig. S1). Additionally, an analysis of seasonal surface velocities in the AS (Vitale et al., 2017; their Figs. 2a, 3a), which is based on a drifter climatology including data from March 1995 to March 2009 (Lumpkin and Pazos, 2006) also confirms the good representation of the near-surface velocity from HYCOM data.”

4) The manuscript states a lack of observational data, but several circulation studies have been done in this region that are not acknowledged in this manuscript. The manuscript would benefit from a more detailed description of how model output compare to both YoMaHa observations as well as previously published observations. Suggestions here: Zhankun Wang et al 2014 (Deep Sea Research) Seasonal and annual variability of vertically migrating scattering layers in the northern Arabian Sea. Zhankun Wang et al 2013 (Deep Sea Research) High salinity events in the northern Arabian Sea and Sea of Oman. Sarah Stryker Vitale et al 2017 (Dynamics of Atmospheres and Oceans) Circulation analysis in the northwest Indian Ocean using ARGO floats and surface drifter observations, and SODA reanalysis output

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Thanks for pointing out these publications. The analysis of near-surface circulation in the northwestern Indian Ocean based on drifter data by Vitale et al. (2017) is used now for the validation of the HYCOM velocity data. “Additionally, an analysis of seasonal surface velocities in the AS (Vitale et al., 2017; their Figs. 2a, 3a), which is based on a drifter climatology including data from March 1995 to March 2009 (Lumpkin and Pazos, 2006) also confirms the good representation of the near-surface velocity from HYCOM data.” Zhankun Wang et al., 2013 and 2014 are now acknowledged in the introduction and the discussion. "In the northwestern part of the basin where the Gulf of Oman merges with the AS, PGW about constantly runs out throughout the year (Fig. 10c, d). Observations confirm the small seasonal variations of the PGW outflow (Johns et al., 2003), which can be influenced by cyclones (Wang et al., 2013).“ “The seasonal changes significantly influence biogeochemical cycles, biological activity and ecosystem response (Hood et al., 2009; Resplandy et al., 2012; Brewin et al., 2012; Wang et al., 2014).” “Lagrangian particles cross regions with high primary production during the long-distance advection while looping around the northern part of the basin. A study of seasonal vertically migrating scattering layers reveals a rapid increase of biomass in the northern Arabian Sea in the layer between 250 and 450 m depth during the period of June to November (Wang et al., 2014).”

5) Page 9 Line 17- state approximate depths of isopycnals (here and elsewhere) in the text so the reader does not have to refer to the figure throughout

As the depth of the isopycnal surfaces are variable, we decided to refer to the density in the text, because this is the more precise information. To make it easier for the reader to follow, we now added the depth of the isopycnal surface at a few passages in the text: We added the approximate depth in the manuscript where you suggested it: “Lagrangian trajectories were calculated on basis of the daily HYCOM reanalysis velocities on the isopycnal surface of 27 kg/m3 lying in the depth range of 450 to 500 m.” We also added the depth to the caption of Fig.2 for better reading: “Mean seasonal velocity for the Arabian Sea based on HYCOM data on the isopycnal surface of σ=27 kg/m3 in the depth range of 450 to 500 m for. . .” Further we changed Fig. 3 so that the density layers are directly in the figure. We hope that makes it easier for the reader to follow.

6) The last sentence of the conclusion is not clearly written.

Thank you for that comment, we changed the last paragraph to: “The seasonal variability of advective pathways into the ASOMZ agrees well with the weak seasonal oxygen cycle and shows clear differences between the eastern and western basin. Still the oxygen content of advected water masses is strongly influenced by the strength and seasonality of biogeochemical processes in the AS. Nonetheless, we conclude that the advection of water mass plays a crucial role for the eastward shift of the ASOMZ and might also be responsible for the maintenance of low oxygen in the ASOMZ throughout the year. However, we cannot state whether physical or biogeochemical processes play the dominating role for the seasonal variability of the ASOMZ based on this method.”

Technical Comments 7) Page 4 line 12 “it's” should be “its” Thank you for noticing that. We changed that.

8) Page 8 Line 25- Not clear to me what “lack of 3 month” means- typo?

We apologise the misunderstanding. Lack of 3 month was meant to describe a temporal offset in time. We hope it is better to understand with the new sentence: “Seasonal differences in particle movement around the release locations can be predicted by starting the calculations with a temporal offset of 3 month within the same year (January, April, July and October).”

9) Page 14 Line 27- “weak” misspelled Thanks, we changed that.

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2020-9/os-2020-9-AC2-supplement.pdf

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2020-9, 2020.

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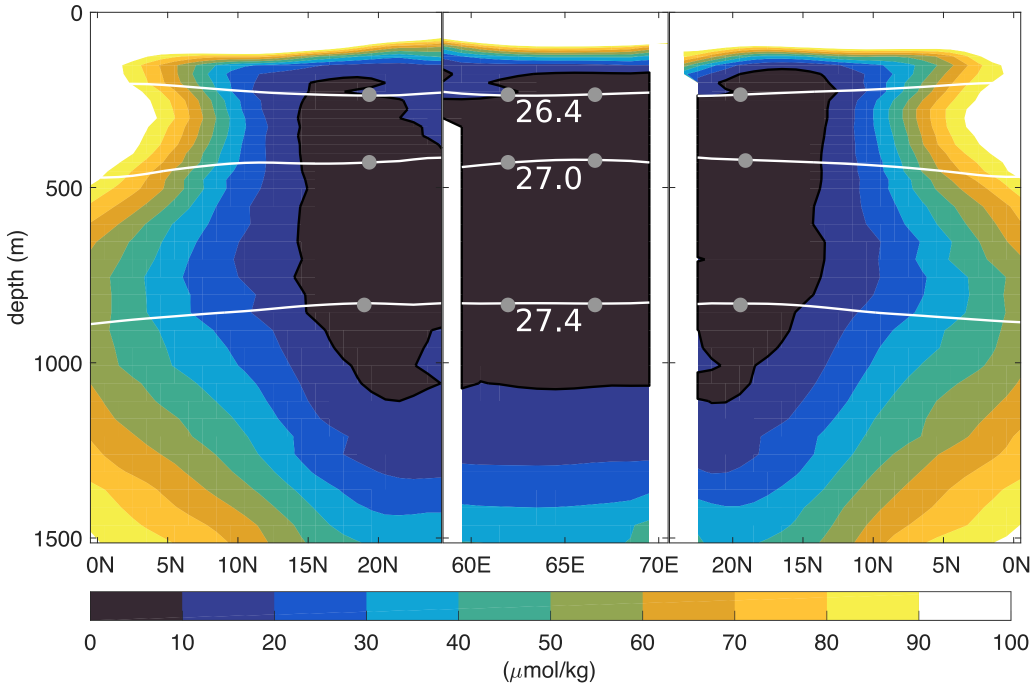

Fig. 1. Figure 3: Annual mean of dissolved oxygen concentration along 62°E (left), 66.5° E (right) and 19° N (middle) from the WOA 13 climatology (see Figure 1). Advective pathways from Lagrangian particles a

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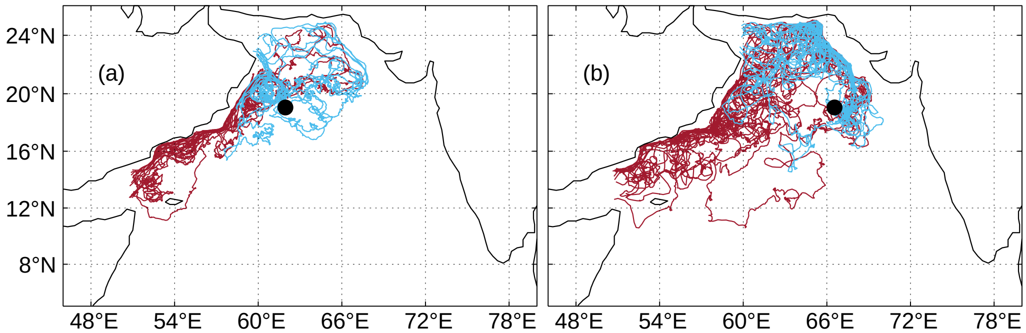

Fig. 2. Figure 6: Exemplary advective Lagrangian pathways connecting the Persian Gulf (blue) and the Red Sea (red) with the (a) western release (WR) and the (b) eastern release (ER) locations marked in black.

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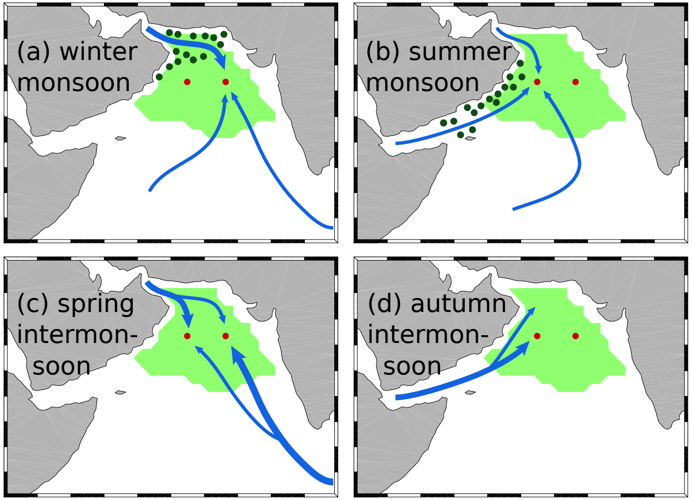

Fig. 3. Figure 11: Schematic of the main advective pathways of the water masses for the a) winter, b) summer, c) spring inter- and d) autumn inter-monsoon seasons. See also Figure 1. The dark green dots indic