

Interactive comment on “Oxygen and nutrient trends in the Tropical Oceans” by Lothar Stramma and Sunke Schmidt

Anonymous Referee #1

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This is a very interesting and potentially significant paper for documenting important long term environmental changes in the ocean. The authors have amplified and extended the time coverage of their previous work with data from the 1950's to the present day and with additional parameters and wider geographic coverage. This paper is especially interesting for demonstrating the association of trends with the various climate indices pertinent for different oceanic regions. Sub-dividing the climate indices into their modes and separating the environmental trends by mode (in addition to the overall trend) was a novel approach that illuminated some of the complexities of tracking and interpreting these changes. This will be an important contribution to our understanding of global climate change effects in the ocean. Specific comments and suggestions are below.

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Abstract: The abstract begins with a reference to the “vertical expansion of the intermediate-depth low-oxygen zones”, a topic developed in the earlier Stramma et al. (2008) paper. The present manuscript does not really discuss “vertical expansion” and I suggest modifying this introductory abstract sentence so that it focuses on the present paper.

Methods: I am not a specialist with the statistical methodology (a limitation discussed in advance by email with the editor). However, many readers of this paper are likely to also be non-specialists in this regard. In order to make this paper more comprehensible to the broader global change community, a simple non-technical summary paragraph of how the data were chosen and assembled to get a single point representing 1 year per depth zone and area, and the limitations of the dataset and methodology, would be valuable and would prevent mis-interpretation. Although I read the referenced methods in Schmidt et al. (2017), I still have questions (and most general readers would probably not refer back to that reference).

Some methodological questions that could be addressed in a summary paragraph include:

Were only individual bottle sample data used or were data from continuous electronic sensors from the last few decades included (vertical profiles from the many oceanographic instruments that include CTD sensors)? If electronic profiles were used, how were they condensed into 1 value for that depth interval? Were any data from Argo floats used since temporal and geographic coverage is expanding (although extended geographical oxygen coverage is only just beginning with the Biogeochemical Argo floats)? If these various electronic profilers were not used, a major source of modern data was ignored, and this limitation should be acknowledged. The discussion could include suggestions about how these continuous profiles might be applied to future trend calculations.

How many individual data points (or specific CTD casts) were included for each year?

C2

This is especially important for interpreting the earliest records. Could this be included in a supplementary table?

The authors do discuss how they accounted for chemical measurement improvements over this time period. However, since the 1950's, there have also been substantial improvements in location (satellite-based) and depth (electronic sensor) data. Was there any consideration for those sampling changes and uncertainty of those parameters in earlier data? That should at least be mentioned.

The authors mention standard vertical depth levels (line 126). What are the depths and how were they used? As someone who deals with the small-scale vertical and temporal variability of oxygen through some of these depth strata, I remain confused about how that single value was derived, what it represents, and how robust that calculated value is. Is this supposed to be an indicator of the concentration of oxygen in the OMZ? Small changes in depth (and location and time) within their indicated depth zones can have quite different oxygen concentrations, as we now know from continuous profiling sensors and short-term replicated profiles. Since many of the long-term trends are slight, small changes in this value (for example from bottles offset by < 10 m or taken a few hrs apart) could have large consequences for the calculated trends. In the discussion, the authors should include more about the uncertainty associated with these issues, how to account for that, and how to improve future predictions.

Results and Figures

Tables 1 and 2. It would be helpful to have more space between items or some other font indicator (bold?). It took several readings to notice the year listing since this blended in with the other numbers.

Fig. 2 and 3. The plots should be labelled A, B, C etc. There should be bigger tick marks for the decadal divisions on the x axis so those are visually differentiated from the climate index modal divisions. The caption should include a sentence noting that the X's in the plots represent an annual value (one X per year). There should also be

C3

a sentence to point out that the Y axes for oxygen (and nitrate in Fig. 4) differ in each plot.

Fig 5. First line of the caption should delete "oxygen" and its units since this figure shows different variables in each graph.

It would be very interesting to see all the overall trend lines for a particular variable (oxygen in the two depth zones, nitrate) plotted on a single graph (one graph for each variable) with a single Y axis range. This would allow a visual comparison of the geographic variability in the strength of these trend lines. This could be a supplemental figure.

Discussion This paper provides strong support for the trend of increasing deoxygenation worldwide at mid ocean depths. Many interesting possibilities are discussed to explain the trends in the different ocean areas and the interactions of different variables with regional physical oceanography, the climate modes, and each other. However, this also becomes confusing with details. It would be helpful to have some summary conclusions, perhaps a numbered list by geographic area. I would also like to see more discussion about the broader implications of these trends especially for ocean biology and human impacts. The authors could also bring in some mention of how their results could contribute in the future to some of the major climate change discussions and documents (IPCC report, UN Ocean Decade, etc.)

Minor wording comments: Line 47: sinking, transport, and subduction into the deep ocean (the biological pump includes more processes than sinking) Line 73: extent Line 74: biologically Line 97: despite the fact that the low Line 434: nutrients Line 441: agrees with Line 443: sentence? Line 452: adding Line 463: trend-line; Line 478: areas. Hence, Line 484: appear Line 485: ocean; therefore, Line 495: inverse Line 496: observed; however, Line 519: fisheries