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Interactive comment on "Oxygen minimum zones in the tropical Pacific across CMIP5 models: mean state differences and climate change trends" *by* A. Cabré et al.

Anonymous Referee #2

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Cabre et al examine 11 Earth System Models with respect to their representation of present Oxygen Minimum Zones (OMZs), and their projection of OMZs and oxygen inventory. For the mean state, they find considerable discrepancies between models and observations in pattern and extent of OMZs. They identify potential reasons for the mismatch between simulated and observed oxygen and OMZs in the mean state, among them model physics (in particular: representation of the equatorial dynamics, ventilation pathways) as well as biogeochemistry (particularly sinking and remineralization of POC). Cabre et al. further examine projections of changes in OMZ, and compare the long-term changes to the effects of interannual variability on AOU, oxygen concentration and saturation in different domains.

The paper is a very comprehensive and thorough analysis of Earth System Models, and about their skill in representing oceanic oxygen dynamics. I am convinced it will contribute to future model analysis and development. I particularly appreciated the examination of the mean state, which covers so many different angles of model analysis: physical and biogeochemical diagnostics (including a very useful metric), as well a structural analysis of the different model components. I definitely recommend this paper for publication. I have just a few, minor comments, which perhaps could help to fine-tune and streamline the paper a bit.

Generally, I think the analysis of the mean state (section 3.1) could be a bit more connected to sections 3.2 (Oxygen changes in the Pacific from 1990-2090) and 3.3 (interannual variability vs long-term changes). Further, a few words about the relevance of different criteria for OMZ definition and their relevance for organisms (e.g., Hofmann et al., 2013, Kinetic bottlenecks to respiratory exchange rates in the deep-sea – Part 1: Oxygen. Biogeosciences, 10, 5049–5060; Seibel, 2011, Critical oxygen levels and metabolic suppression in oceanic oxygen minimum zones, Jour. Exp. Biol., 214, 326-336) may illustrate the effects of these assumptions onto organisms (the "real world"). Likewise, some few sentences about the effect of (model parameterizations of) DOM on simulated OMZs may complete the discussion about biogeochemistry and errors in OMZ.

Minor specific comments: ————————-

p 6527, lines 10 and 13: "Karstensen"

p 6527, line 17: "northern tropical Pacific" or "Northern Tropical Pacific"

p 6528, lines 8-10: The models by Kriest et al (2010, 2012) did not include explicit denitrification, but a more recent one (Kriest and Oschlies, 2015, Geosci. Model Dev. Dev. Discuss., 8, 1945–2010) does and examines this with focus on OMZ - skip "denitrification" or refer to the more recent reference?

p. 6529, line 18 ff: What was the reason for choosing 1960-1999 - because there are observations available for this period? Would results look very different if 1860-1899 was chosen as reference period?

p. 6530, line 5: what was the criterion for "equilibrium"?

Section 3.1: It would help the reader if there were more specific references to panels in the figures. (E.g., Fig 1, panel a).

p. 6532, line 5: point "(a)" is difficult to see from figure 2.

p. 6533, lines 15-18: As far as I can see from Fig 3, IPSL-CMA5 has approximately 1 uM PO4 around 100m, while the observations show around 2 uM. Could this be really limiting/the reason for the underestimation? IPSL-CMA5 also shows far too high oxygen at that depth - could that be another reason for the underestimation in subsurface OMZ?

p. 6536, lines 14-26: Could another reason for the overestimate in deep oxygen by some models be due to errors in biogeochemistry / too little remineralization having taken place in these waters? (Instead of "only" errors in physics.)

p. 6538, line 1 "[...] having the same biogeochemical module (MPI-ESM and NorESM1-ME) [...]" - do they really have the SAME module, or just "similar" ones? (E.g., same equations, but different parameters?)

p. 6541, lines 2-4: Does this mean that in this model decay of organic matter continues without using oxidants (oxygen, nitrate, sulfate, ...)? It may be too much for this paper, but: would it help / wouldn't it be interesting to also examine the models with respect to how they treat (a) "oxidant conservation", and (b) "DOM" dynamics (which may affect formation and persistence of OMZs particularly in the equatorial Pacific).

p. 6543, lines 4ff: This seems to be a really informative and helpful metric!

Just a suggestion: In section 3.2 I first had some problems following the authors' train

of thought. It helped a bit to see Fig 10 (afterwards), because I assume the distinction among the different domains in that figure and in section 3.2 seems to be roughly the same. If this is indeed the case, it might help to refer to Fig 10 earlier.

p. 6545, lines 21-22 "decrease age (Fig 8l) and increase AOU (Fig 8i)": where (at what depth level) exactly is this happening?

p. 6546, line 4 "Karstensen"

p. 6547, lines 1-2 "The trends in both AOU and O2sat are consistent across models (Fig. 8f and i)" - For AOU (8i) there seem to be many unhatched areas in intermediate low latitude depths.

p. 6547, lines 15-28 and Fig 9: I find the spread of projected OMZ volume quite considerable, even when disregarding the two most extreme outliers (IPSL and HadGEM2). Including the variability, for the very low thresholds (<5 uM) the remaining models seem to encompass -10% to +20%. Perhaps discuss this a bit more (if only briefly), as these are the ranges/thresholds only a few organisms will be able to cope with, and where most likely denitrification sets in. Further, in Fig 7 the authors have already used varying thresholds for model skill assessment - perhaps discuss these findings, and there implications for assessment of future development a bit more at this point?

p. 6548, line 27 "expected response" - what is this?

Section 3.3: This section/analysis seems to focus on a region (10S-10N, east of 115W) that has not been examined before, in the very careful analysis of model mean state. The closest analysis would be Fig 3 (5S-5N, 80-100W). Would it make sense to harmonize this a bit more? This also takes up on the very important finding from that first part, namely that most models have problems representing the bimodal structure of the eastern tropical Pacific OMZ. I'd suggest to refer to that section a bit more.

p. 6552, line 20 "would not trigger denitrification so easily" - do you really mean "denitrification", or rather "remineralization"?

p. 6552, line 23-25: "We recommend ..." - Sediment models, and their exchange with the water column, would have to be calibrated and their skill be examined, too. Be a bit more cautious here?

p. 6553, line 20: what is "oxygen behavior"?

Fig 1 (as well as other figures below): I found it very difficult to distinguish some line colours. If possible, could the black and grey lines (observations and model means) be a bit thicker? Further, instead of distinguishing the different variants of models by different shades (e.g., purple and pink for IPLS; light and dark green for MPI; light and dark blue for GFDL), maybe one colour, but with straight and dashed lines could be easier to see?

Fig 2 (as well as other figures below): I am a bit undecided about the vertical log-scale: although it helps a lot to see the fine structures at the surface, it is somehow difficult to translate these plots into something that is of significance on a global scale. E.g., an underestimate of oxygen from 1000 m to the bottom would have a huge impact on global model inventory, but not show up strongly in these plots. I don't want to actually recommend changing the scale to a linear, but just note, that these may be somehow difficult to interpret.

Fig 9: This is an interesting plot, but the two lines for each model are a bit confusing: Is there any way to plot this with mean plus/minus 1 SD, e.g. as horizontal bars, or with transparent shades? Alternatively, the mean with bold lines, and plus/minus one SD as thin dashed lines (if it does not become too crowded).

Fig. 10: I really like this informative and comprehensive figure and analysis.

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