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Interactive comment on "Differences between coastal and open ocean distributions of N_2O in the oxygen minimum zone off Peru" *by* A. Kock et al.

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We would like to thank the reviewers for their useful suggestions to improve our manuscript. We carefully revised our manuscript according to the reviewers' remarks. We included a description of the hydrographic settings and a TS-diagram in the revised manuscript, as suggested by reviewer 1, and re-structured some paragraphs of the manuscript to emphasize the main findings of the manuscript. Please find a detailed reply to the reviews below. Line references refer to the revised manuscript in the original manuscript format.

R1: "Firstly, the title of the work is confusing. The authors should distinguish the difference between distribution in coastal and open waters."

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We changed the title to: “Extreme N2O accumulation in the coastal oxygen minimum zone off Peru”

R1: “I also expect to see an oceanographic analysis of how the authors distinguish between coastal and oceanic region. Since this region is subjected to coastal upwelling the areas should be separated, taking into account, for example, of Rossby ratio.”

We agree with the reviewer that objective criterion is needed to distinguish between coastal and open ocean stations. As suggested by the reviewer, we used the first baroclinic rossby radius as defined by Chelton et al. (1998) to determine open ocean and shelf stations. Stations with a distance to the shelf break (2000 m isobath) shorter than the rossby radius were classified as “coastal” whereas samples with a larger distance were classified as “offshore”. This classification was used to create Figure 5 and 6 (the newly added TS diagrams), and the stations shown in Figure 4 were colorcoded according to this classification.

Chelton, D. B., DeSzoeke, R. A., Schlax, M. G., El Naggar, K., and Siwertz, N.: Geographical variability of the first baroclinic Rossby radius of deformation, Journal of Physical Oceanography, 28, 433-460, 10.1175/1520-0485(1998)028<0433:gvotfb>2.0.co;2, 1998.

R1: “I feel that in order to interpret the observed results, the study lacks an analysis of distribution and mixing of water masses. For ejemple the presense of the emblematic equatorial subsurface water (ESSW) is omitted. Also, the study region is characterized by different zones (the occurrence of shelf and coastal upwelling), and by an intricate regional oceanography that is influenced by equatorial dynamics.”

We included a brief description of the hydrographic setting of the ETSP in the introduction section and an additional figure showing the TS-diagrams of the offshore and onshore stations. These are discussed in detail in the results and discussion section to further assess the oceanographic influence on the N2O distribution in our study area (lines 101-112).

R1: "The paper does not touch on any of these regional oceanographic aspects, nor aspects regarding the temporal variability of ENSO (El Niño, or coastal trapped wave of intraseasonal frequency), even though the sampling strategy considered different years. Despite the several years of analysis carried out for this study, part of the variability could be caused by temporal scales or by mesoscale phenomena previously described for the same study area. This can be clearly observed when the authors present the latitudinal distribution along 86 _W (Fig. 2), temporary differences, for example, are observed (between cruise M77-4 and M90) that result in different spatial structures (for example see the peak of nitrite and maximum observed in nitrous oxide)."

We disagree with the reviewer that the differences observed in the M77-4 and M90 sections shown in Figure 2 can be interpreted as an indication for strong temporal differences between these cruises. At the oxygen concentrations present in the OMZ, the nitrous oxide and nitrite distributions are highly sensitive to marginal changes in the oxygen concentrations. The differences could be furthermore be the result of the rather coarse depth resolution of our sampling which leaves the opportunity that sharp maxima in N2O or nitrite were undersampled. On the contrary, the similarities in the oxygen distributions along 86°W and the very similar ΔN2O/AOU relationships observed during M77-4 and M90 indicate rather similar conditions between the measurement campaigns in 2008/2009 and 2012/2013. This is supported by Southern Oscillation Indices that indicate El Niño conditions for both sampling periods. We nevertheless agree with the authors that the discussion of influence of ENSO on the hydrographic settings in the ETSP is a useful addition to our manuscript. We therefore included a paragraph on the influence of ENSO on the variability and the conditions prevalent during the measurements in the introduction and methods sections (lines 115-120 & 126-129).

R1: "Furthermore I am concerned with the explanation about the distribution and that it is "ventilation or re-ventilation" of the water; this is both discussed and concluded as a key issue. In truth, under the context in which it is referred to, I find that this term is not clear or is not correctly used. First the authors should clarify precisely what they mean by the term “ventilation”, as it is not very obvious to myself, nor I believe to other Oceanographers; for example, coastal upwelling is properly not a ventilation process, on the contrary has the reverse effect as vertical advection dominates. [. . .] I think that there are many diapycnal mixing processes, as well as vertical and lateral advection, that is likely to cause the observed heterogeneity.”

In the context of our manuscript we used the terms “ventilation” and “re-ventilation” for processes that irreversibly increased the oxygen concentrations in a certain water parcel, i. e. (diapycnal or isopycnal) mixing or the direct exchange of the waters with the atmosphere. To avoid confusion we exchanged the term “ventilation” by the more precise term “(re)-oxygenation.

R1: “A further point to consider is that the biogeochemical processes which cause accumulation and consumption of N2O are not suitably addressed, and they even fail to consider the relationship between AOU and nitrite and nitrate (only AOU vs. N2O, Figure 5).”

We disagree with the reviewer that we did not sufficiently address the biogeochemical processes that influence N2O production and consumption.

We used N’ (([NO3-]+[NO2-])-16[PO4-]) to colorcode the scatterplots in Figure 5. The argumentation that extreme N2O accumulation was found in samples that were also depleted in inorganic N is an integral part of our argumentation, and we thoroughly discussed the processes that could lead to both, N depletion and N2O accumulation. We also discussed the relationship between N2O and nitrite distribution and argued that nitrite accumulation coincided with N2O depletion, but no relationship between N2O and nitrite accumulation was observed.

We do not think that showing the relationship between AOU and nitrate and nitrite would significantly improve our understanding of the processes that lead to N2O accumulation in this area.

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R1: “On analysing Figure 5, the coast and the open ocean are not very different, except for the fact that is seems there is even greater dispersal in the coastal zone.”

The greater dispersal of delta N2O values in the coastal data is indeed the main finding of our manuscript. An increase of delta N2O with AOU similar to our offshore observations has been observed in different oceanic areas and has frequently been used to parameterize N2O concentrations from oxygen in oceanic modeling (see e.g. (Nevison et al., 2003;Zamora et al., 2012)). One of the main findings of our manuscripts is that this approach does not account for the extreme N2O accumulation over the Peruvian shelf which would lead to a significant underestimation of the N2O emissions from this area.

Nevison, C., Butler, J. H., and Elkins, J. W.: Global distribution of N2O and the Delta N2O-AOU yield in the subsurface ocean, Global Biogeochemical Cycles, 17, 1119 10.1029/2003gb002068, 2003.

Zamora, L. M., Oschlies, A., Bange, H. W., Huebert, K. B., Craig, J. D., Kock, A., and Loscher, C. R.: Nitrous oxide dynamics in low oxygen regions of the Pacific: insights from the MEMENTO database, Biogeosciences, 9, 5007-5022, 10.5194/bg-9-5007-2012, 2012.

R1: “So, when the authors conclude that the coastal upwelling off the Peruvian shelf causes conditions that lead to the extreme accumulation of N2O, what would these conditions be? Are the authors referring to benthic processes?

Assuming that the reviewer refers to the last sentence of the abstract, we specified the conditions leading to extreme N2O accumulation there. We think that the main factors that influence the N2O concentrations are higher rates of N cycle processes due to the strong remineralization on the shelf in conjunction with strong mixing processes that lead to frequent transitions from anoxic to oxic conditions. Benthic processes may have only an indirect influence on the N2O production.

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