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Ocean deoxygenation in the Arabian Sea: quantifying the recent trends and exploring their drivers

Zouhair Lachkar (1), Muchamad Al Azhar (1,4), Marina Levy (3), Shafer Smith (1,2)

(1) New York University (NYU) in Abu Dhabi, Center for Prototype Climate Modeling (CPCM), NYUAD research institute, Abu Dhabi, United Arab Emirates (zouhair.lachkar@nyu.edu), (2) Courant Institute of Mathematical Sciences, New York University, New York, United States of America, (3) Sorbonne Universite (CNRS/IRD/MNHN), LOCEAN-IPSL, Paris, France, (4) Plymouth Marine Laboratory, Plymouth, United Kingdom

The Arabian Sea hosts one of the most intense oxygen minimum zones (OMZs) in the world. Observations suggest a decline of O_2 in the northern Arabian Sea over the recent decades accompanied by an intensification of the suboxic conditions there and a shoaling of the hypoxic boundary in the western Arabian Sea. Yet, the magnitude and the spatial patterns of these changes are still largely unknown due to the scarcity of observations, while their drivers and biogeochemical implications remain unexplored. Here, we reconstruct the evolution of dissolved ocean in the Arabian Sea from 1982 through 2010 using hindcast simulations performed with an eddy-resolving ocean biogeochemical model forced with observation-based winds and heat and freshwater fluxes. We find a significant thermocline deoxygenation in the northern and western Arabian Sea and an increase of O_2 off the West Coast of India (WCI). At 100m depth, the oxygen dropped by up to 10 and 8 mmol m^{-3} decade^{-1} in the Gulf of Oman and the western Arabian Sea, respectively. In contrast, O_2 increased by 4 to 8 mmol m^{-3} decade^{-1} along the WCI at the same depth. These changes are associated with a statistically significant increase of the volume of suboxia (O_2 < 4 mmol m^{-3}) by up to 20% over the study period, resulting in an increase of denitrification by 30-50% north of 20°N. Our analysis indicates that the increase of O_2 off the WCI is essentially caused by a deepening of the thermocline associated with the increase of summer monsoon winds over the study period while the deoxygenation seen in the northern and western Arabian Sea is associated with a combination of surface warming and weakening of the winter monsoon winds that led to a reduced winter convection and a shoaling of the thermocline depth there. We also show that the deoxygenation trend in the Gulf of Oman is further amplified by the recent fast warming of the Arabian Gulf. Our findings confirm that the Arabian Sea OMZ is strongly sensitive to upper-ocean warming and concurrent changes in the Indian monsoon winds. Finally, our results also demonstrate that changes in the local climatic forcing play a key role in regional dissolved oxygen changes and hence need to be properly represented in global models to reduce uncertainties in future projections of deoxygenation.