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Intensification of the Arabian Sea oxygen minimum zone driven by warming of the Red Sea and the Arabian Gulf

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Due to their landlocked nature and strong sensitivity to local climates, semi-enclosed seas are prone to amplified warming under future climate change. This is particularly true for the Red Sea (RS) and the Arabian Gulf (AG) due to their small volumes and relatively limited exchange with the surrounding Indian Ocean as well as their proximity to the fast warming Arabian Peninsula. While the predicted rapid warming of the two marginal seas is expected to challenge their local ecosystems already subject to extreme temperatures, its potential consequences for the biogeochemistry of the Indian Ocean at large remain poorly understood. In particular, the effects of such changes on the oxygen minimum zone (OMZ) of the Arabian Sea are unclear. Here we show that a warming of the RS and AG that is consistent with future (2100) projections under the "business as usual" RCP8.5 emission scenario can lead to a substantial intensification of the OMZ and increase of denitrification in the northern Arabian Sea. To this end, we performed a series of eddy-resolving regional simulations of the Arabian Sea and its marginal seas using the Regional Ocean Modeling System (ROMS) coupled to a nitrogen-based nutrient-phytoplankton-zooplankton-detritus (NPZD) ecosystem model. We show that when a uniform surface warming of +4C is applied to the RS, the volume of suboxic water in the Arabian Sea increases by 20% while denitrification increases by 16%. A similar surface warming of the AG increases the Arabian Sea suboxic volume and denitrification by 15% and 11%, respectively. The intensification of the Arabian Sea OMZ is even stronger in the (top 200m) epipelagic zone with an increase of the suboxic volume by 25% and 45% in response to warming of the RS and AG, respectively. The intensification of the hypoxic conditions near the surface induces important habitat compression with potentially detrimental effects on the regional fisheries. A full oxygen budget for the region reveals that the intensification of the OMZ results from a reduction of the ventilation of the intermediate layers in the northern Arabian Sea by the RS and AG waters that gain buoyancy and lose oxygen due to surface warming. These results stress the need for improving the representation of the RS and the AG in the current generation of climate models, as these marginal seas can be crucial in shaping the Arabian Sea OMZ and modulating the large-scale marine nitrogen budget.