Steady expansion of global oxygen minimum volumes under climate change

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Oxygen minimum zones (OMZs) are regions of the ocean where dissolved oxygen levels are extremely low, significantly influencing biogeochemical cycles and challenging survival of some marine organisms. Despite their significance, yearly changes in OMZ volumes across different depths and regions remain poorly understood due to the limited observations. To explore the expansion and dynamics of OMZs in horizontal and vertical directions, we use comprehensive multi-source observations, a rigorous geostatistical modelling framework, and a spatially consistent Monte Carlo method to estimate the volumes of global ocean OMZs from 1960 to 2022, along with the associated uncertainties. We find that, since 1960, the volume of global OMZ60 (i.e., dissolved oxygen < 60 μmol/kg) expanded in both vertical and horizontal directions and by as much as 15 million km3, approximately comparable to the volume of the Arctic Ocean. It increased at a rate of 0.24 million km3 per year or 0.32% per year. This rate of expansion significantly exceeds previous estimates based on biogeochemical model predictions. Furthermore, our analysis implicates the increasing deep ocean temperature, due to anthropogenic climate warming as the primary driver of OMZ expansion. These findings not only highlight the need for targeted conservation and management strategies, but also call for a critical evaluation of current biogeochemical models in simulating OMZ dynamics so as to better predict the effects of OMZ expansion on marine ecosystems.