

## Deoxygenation of the ocean

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The amount of oceanic oxygen has varied on time scales of millennia to seasons. For recent decades, as well as for the future, a rather rapid change in dissolved ocean oxygen (DO) is shown in observations and numerical models respectively. Subsurface low oxygen layers – oxygen deficient zones (ODZ) – exist in all ocean basins. In recent decades tropical [1] and subtropical DO decreased in most regions of the world ocean [2]. These DO trends are a combination of long-term trends superimposed with (multi-) decadal and short-term variability. The expansion of ODZs reduces the available habitat of pelagic fishes [3] and strongly effects the coastal ecosystems [4] and species distribution. Observed nutrient changes seem to be related to oxygen changes modified by local and eddy processes. An oxygen budget of available oxygen measurements revealed a world ocean oxygen loss of about 2% over the last 50 years [5]. While the exact processes at play remain elusive, causes of the oxygen variability involve climate-change related ocean warming, variations in the supply paths of oxygen-rich water via zonal current bands, changes in the expansion and speed of the subtropical gyres, and climate related signals like the Pacific Decadal Oscillation (PDO). On the large scale the observational results are consistent with model results which predict a further oxygen decline in the future. However, causes of discrepancies on local scales between observed and modelled oxygen changes are still unresolved. For the year 2100 a further decrease in the total ocean inventory of dissolved oxygen is projected [6] which is likely caused by global warming. In case of continuing deoxygenation ecological impacts as described for the geological past [7] are expected with consequences for fisheries [8] and coastal economics.

[1] Stramma *et al.* (2008), *Science* **320**, 655-568. [2] Keeling *et al.* (2010), *Annu. Rev. Mar. Sci.* **2**, 199-229. [3] Stramma *et al.* (2012) *Nature Clim. Change* **2**, 33-37. [4] Vaquer-Sunyer and Duarte (2008) *PNAS*, **105**, 15452-15457. [5] Schmidtko *et al.* (2017), *Nature* **542**, 335-339. [6] Cocco *et al.* (2013), *Biogeosciences* **10**, 1849-1868. [7] Benton & Twitchett (2003), *Trends in Ecology and Evolution* **18**, 358-365. [8] Cheung *et al.* (2013), *Nature Clim. Change* **3**, 254-258.