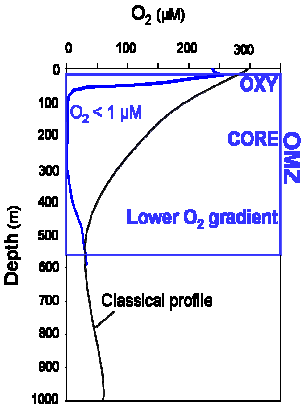
The Oxygen Minimum Zones (OMZs)

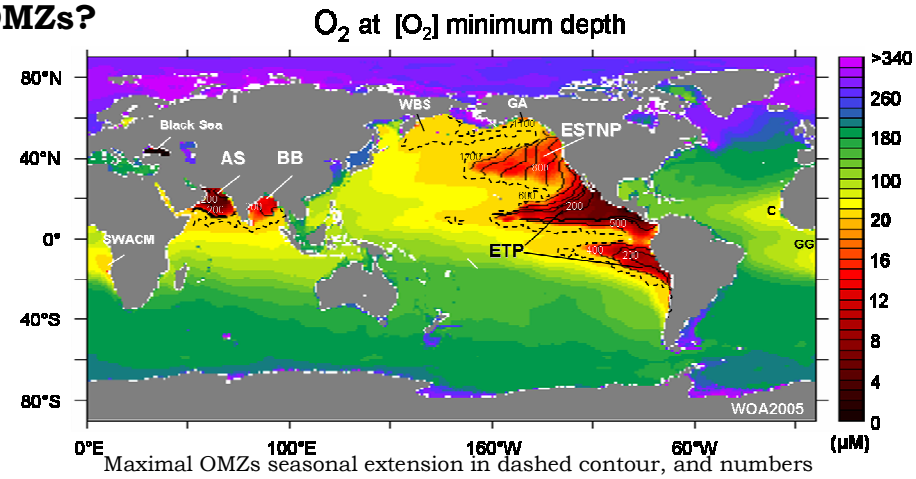
Aurélien PAULMIER and Véronique GARCON

As upwelling regions of high productivity, OMZs are playing a fundamental role on climate (e.g. greenhouse effect through N_2O) and on ecosystems (e.g. respiratory « barrier », nitrogen loss).

• What and where are the OMZs?

The OMZs O_2 profiles are different from those classically reported in all oceans by a minimum: i) ~5 times shallower, inducing a strong O_2 gradient, the oxycline (OXY); ii) ~50 times more intense.



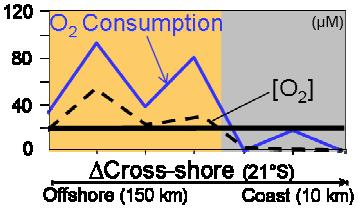


Maximal OMZs seasonal extension in dashed contour, and numbers correspond to the depth in meters of the OMZ CORE upper limit

Permanent OMZs cover ~8% of the total oceanic surface (Paulmier and Ruiz-Pino, 2008): i) in subsurface, focused in the tropical oceans: North and South Eastern Pacific (ETP); Arabian Sea (AS) and Bay of Bengale (BB) in the Northern Indian Ocean; les intense in the eastern Atlantic (SWACM, C, GG); ii) deeper in the subtropical eastern Pacific (ESTNP). In addition, 2 seasonal OMZs at high latitudes have been identified in the West Bering Sea (WBS) and in the Gulf of Alaska (GA).

• How are the OMZs working?

The formation/maintaining of so intense O_2 minima results from both dynamical (low ventilation, "shadow zone", undercurrents of poor O_2 water, stratification) and biogeochemical (O_2 consumption) mechanisms. Locally, all biogeochemical anomalies (e.g. subsurface N_2O peak, carboncline) and activity (e.g. aerobic remineralization, nitrification-denitrification) focused near the OXY and the upper part of the OMZ CORE, associated with a potential co-existence of bacterial processes which usually occur at different depths. This high specific OMZ activity appears to be intermittent and controlled by the oxygenation (e.g. Paulmier et al., 2006) and the organic matter (Paulmier et al., 2009).

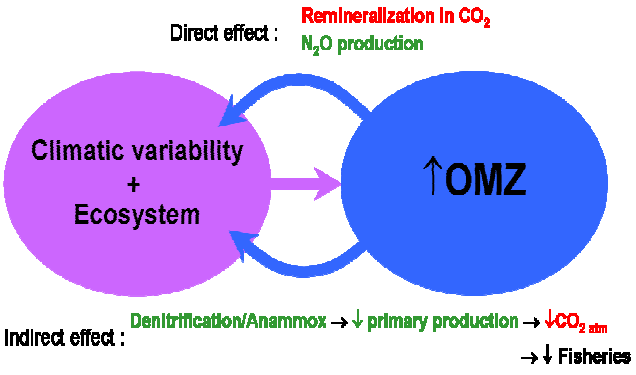


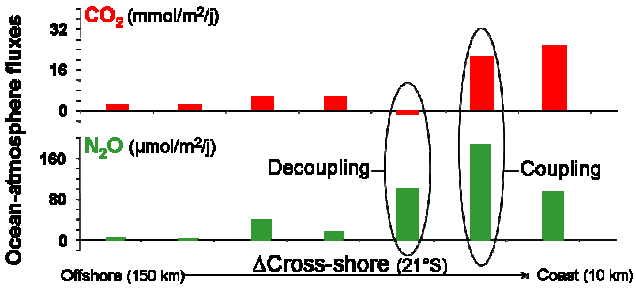
$[O_2]$	OMZ
⊕	*Thickening/formation*
⊖	*Established/in destruction*

Ilustrated on a transect in the OMZ off Chile, the consumption and concentration of O_2 are concomitantly variable (Paulmier et al., 2006).

• What are the impacts associated with the OMZs?

1) Expansion of the OMZs in response to: i) global warming: less ventilation mainly due to higher stratification, but also to lower O_2 solubility; ii) the perturbations of the ecosystems: higher O_2 consumption due to human activitties (ocean fertilization and eutrophication through nutrient inputs in the rivers or atmospheric deposition)
2) Complex feedback effects on climate and the ecosystems: i) direct: e.g. N_2O production or on CO_2 sequestration due to OMZ remineralization mechanisms; ii) indirect: e.g. nitrogen loss through denitrification/anammox.





Ilustration of the complex OMZ feedback effect for 2 greenhouse gases in the OMZ off Chile: intense but variable source of N_2O and CO_2, with coupled and decoupled situations (Paulmier et al., 2008).

Paulmier, A., Ruiz-Pino, D., Garçon, V., and L. Farías (2006) Maintaining of the Eastern South Pacific Oxygen Minimum Zone (OMZ) off Chile. Geophys. Res. Letters 33, L20601, 2006.
Paulmier, A., and D. Ruiz-Pino(2008) Oxygen Minimum Zones (OMZs) in the modern ocean. Progress In Oceanography, doi:10.1016/j.pocean.2008.08.001.
Paulmier, A, Ruiz-Pino, and V. Garçon (2008) The Oxygen Minimum Zone (OMZ) off Chile as intense source of CO_2 and N_2O. Continental Shelf Research 28(20), 2746-2756.
Paulmier, A., Kriest, I., and A. Oschlies (2009) Stoichiometries of remineralisation and denitrification in global biogeochemical ocean models. Biogeosciences 6, 923-935.