OB24D-0490
Title below

Oceanic oxygen 'gO_2ing'; but where?

Oxygen is not a 'climate-insignificant atmospheric gas, of immense abundance' - (total) 1,080,000GT. (est.).

Atmospheric oxygen is in equilibrium with, thus regulates, oceanic oxygen (total) 7,700GT. (est.); only a **portion** of which, is in the relevant upper ocean / atmospheric contact exchange layers, thus, magnifying the immediate impact, of anthropogenic atmospheric oxygen depletion.

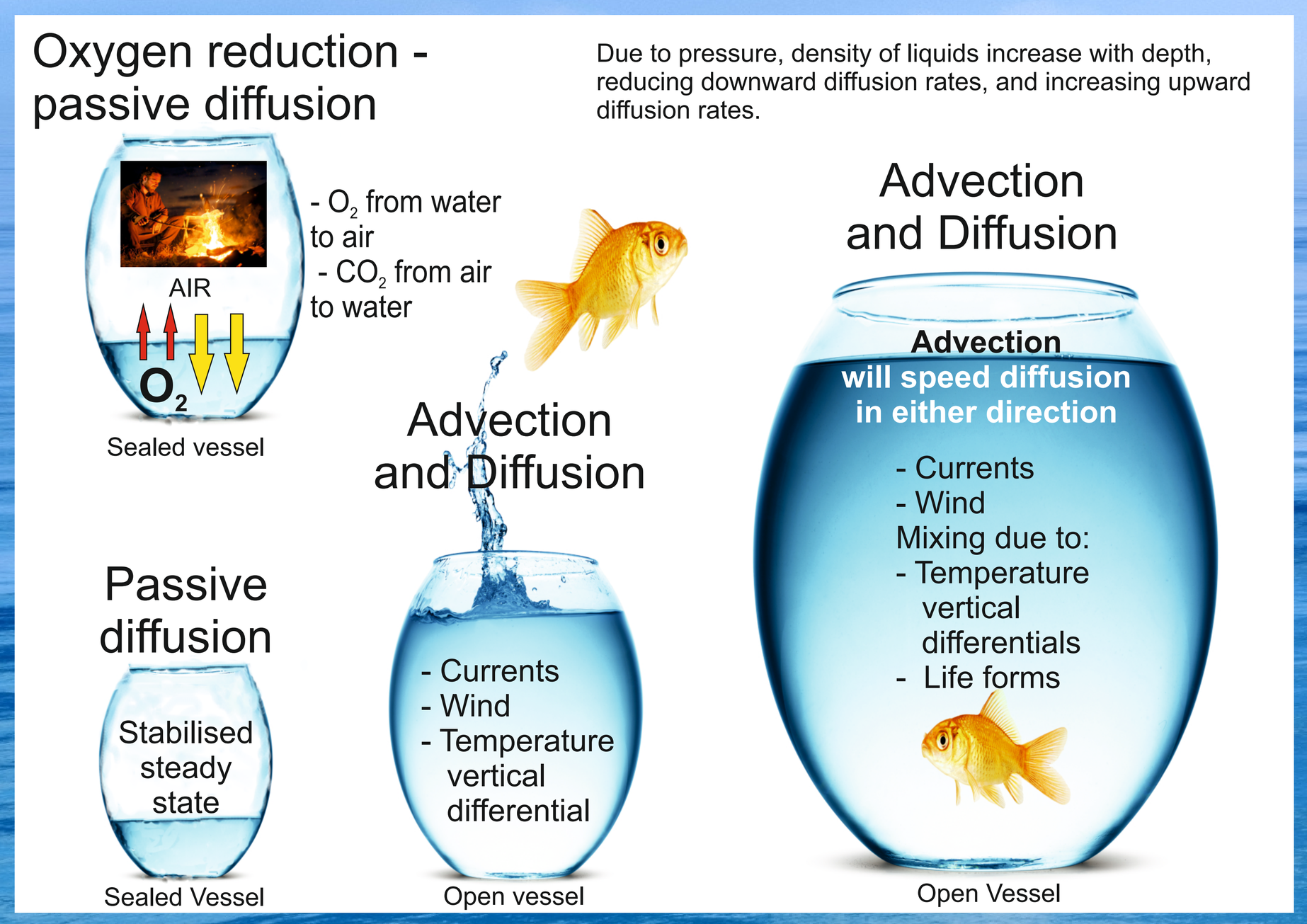
Fossil fuel, and other O_2 use, diminishes oceanic oxygen ...

"Climate change is not just about carbon"

Henry's law ('constant')
and Graham's law

Henry's Law - "At constant temperature, the amount of a given gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid."

Graham's law: "the rate at which gas molecules diffuse is inversely proportional to the square root of its density at constant temperature."



Theory

Oceanic oxygen is buffering atmospheric oxygen loss? Why would it not?

140-150 times as much oxygen in the atmosphere as in the ocean

"The Ocean is Losing its Breath"
1-2% loss, 77-154 gigatons (GT) of total oceanic oxygen (O_2) 7,700GT (est.), over the last 50 years.
https://unesdoc.unesco.org/ark:/48223/pf0000265196

"15% of global oxygen decrease can be explained by a warmer mixed-layer reducing capacity to store oxygen".
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2011GL049513

'Fixed Observatories and LongTime-series of Dissolved Oxygen Measurements: Good Quality Data is a Challenge'
DOI: 10.1109/OCEANSE.2019.8867385

"We find that in about 35% of the thermocline anthropogenic O2 depletion emerges before anthropogenic warming."
https://www.researchgate.net/publication/335587788_Is_deoxygenation_detectable_before_warming_in_the_thermocline

"increase in biological consumption is an unlikely explanation for oxygen decreases over these large spatial scales" IPCC.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2011GL049513

"However, current models . . . generally simulate only about half the oceanic oxygen loss inferred from observations."
https://www.nature.com/articles/s41561-018-0152-2

"Current models may underestimate deoxygenation because of unresolved transport processes, unaccounted for variations in respiratory oxygen demand, or missing biogeochemical feedbacks."
https://www.nature.com/articles/s41561-018-0152-2

"Tuna as well as billfish fish habitat shrank by 15 percent from 1960 to 2010, due to lack of oxygen".
https://www.scientificamerican.com/article/the-ocean-is-running-out-of-breath-scientists-warn/

The 'ocean Skin' will have own characteristics, which will logically determine gas exchange diffusion rates, if it remains relatively saturated, diffusion will continue, as long as replenished from oxygen below, hence the depletion effect.

Ocean 'surface skin' dynamics are complex; but does evaporation based cooling, create greater inherent skin density, thus dissolved oxygen density, so impacting oxygen diffusion driving higher atmospheric partial pressure? 'Salting-out' would increase oxygen release.

Upper surface layer oxygen

Unstable in solution - will tend to diffuse upwards due to mixing, and high relative pressure differential per vertical metre, resulting in local degassing and upward movement, facilitating surface saturation, and exchange into atmosphere despite rising oxygen minimum zones.

Reasons for declining ocean oxygen:

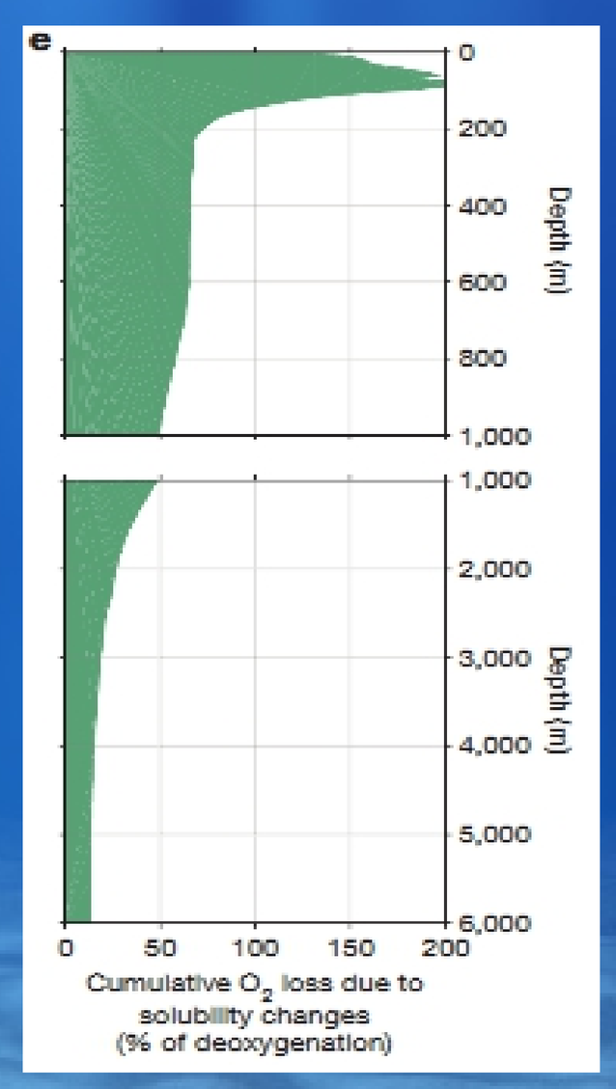
- Rising temperature
- Thermoclines
- Eutrophication
- Henry's law - atmospheric replenishment of anthropogenic oxygen use by oceans

Oxygen in upper ocean layers 0-1000m 50??% of 7,700GT ≈ 3,850GT

Atmospheric O_2 usage 30-50GT. ≈ 1% O_2 upper ocean content.

Large uncertainties ~ delays in system response ~ significant possible consequences.

"70% of the observed rate of deoxygenation at 300 m depth"
"Due to rapid air–sea gas exchange, surface waters continuously approach oxygen saturation."
DOI: 10.1038/s41561-018-0152-2



'Decline in global oceanic oxygen content during the past five decades'
Abstract Fig.2 with many thanks - doi:10.1038/nature21399

What is the decline in the oxic boundary in the Black Sea telling us? Were a significant sulphidic H_2S event to occur results might include - asphyxiation - acid rain - extensive damage to ozone layer = an extinction event mechanism?
Anoxia and extinction DOI: 10.5061/dryad.5j8321f
https://www.sciencedaily.com/releases/2005/02/050223130549.htm

How much atmospheric oxygen is used by anthropogenic activity? How much is buffered by Oceans?

26 - 33% (or more?) CO_2 emissions absorbed by oceans
https://scripps.ucsd.edu/programs/keelingcurve/2013/07/03/how-much-co2-can-the-oceans-take-up/
https://www.ecowatch.com/oceans-absorb-co2-2631712140.html
May 2018-2019 3.5 ppm rise atmospheric CO_2 ≈ 27 GT, but 37GT. emitted by fossil fuels alone (1ppm = 7.8 GT CO_2)
https://earthsky.org/earth/atmospheric-co2-record-high-may-2019

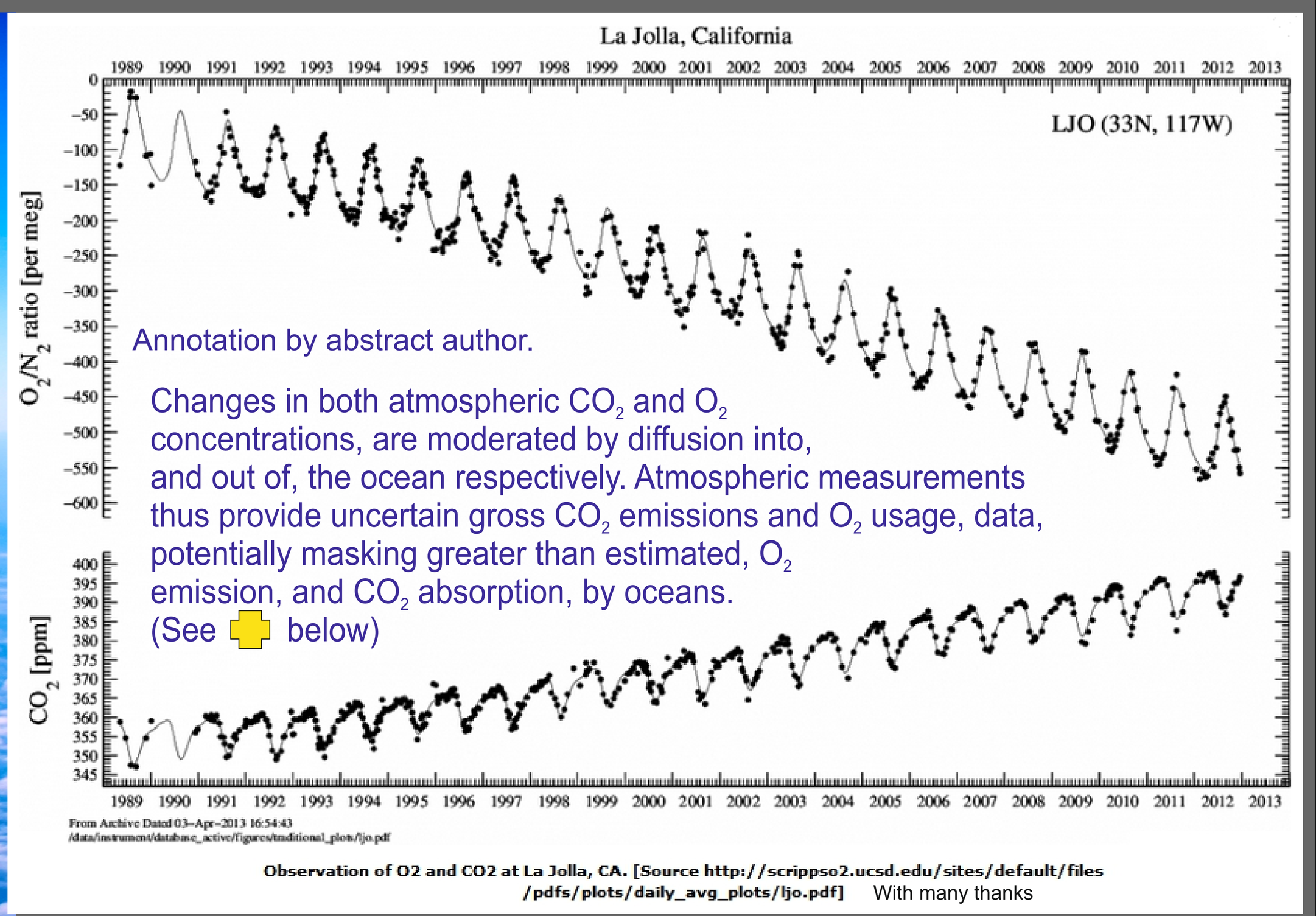
Oxygen usage ~		GT. pa.
	Humans (fuelled by plants)	3.1
	Live-stock	2.5
	Eutrophication	?
	Soil carbon loss	3.0
	Tundra carbon loss	1.0
	Crop burn-off / fuel	6.0
	Forest Fire (wild)	1.5
	Fossil Fuels	27.0
	Waste to Heat	??
(Less) Offset 'Plant' carbon capture		(?)
Total oxygen usage GT		30 to 45GT.

30-45 GT % ocean oxygen upper layer ≈ 1%
See also https://www.earth-syst-sci-data-discuss.net/essd-2019-36/essd-2019-36.pdf

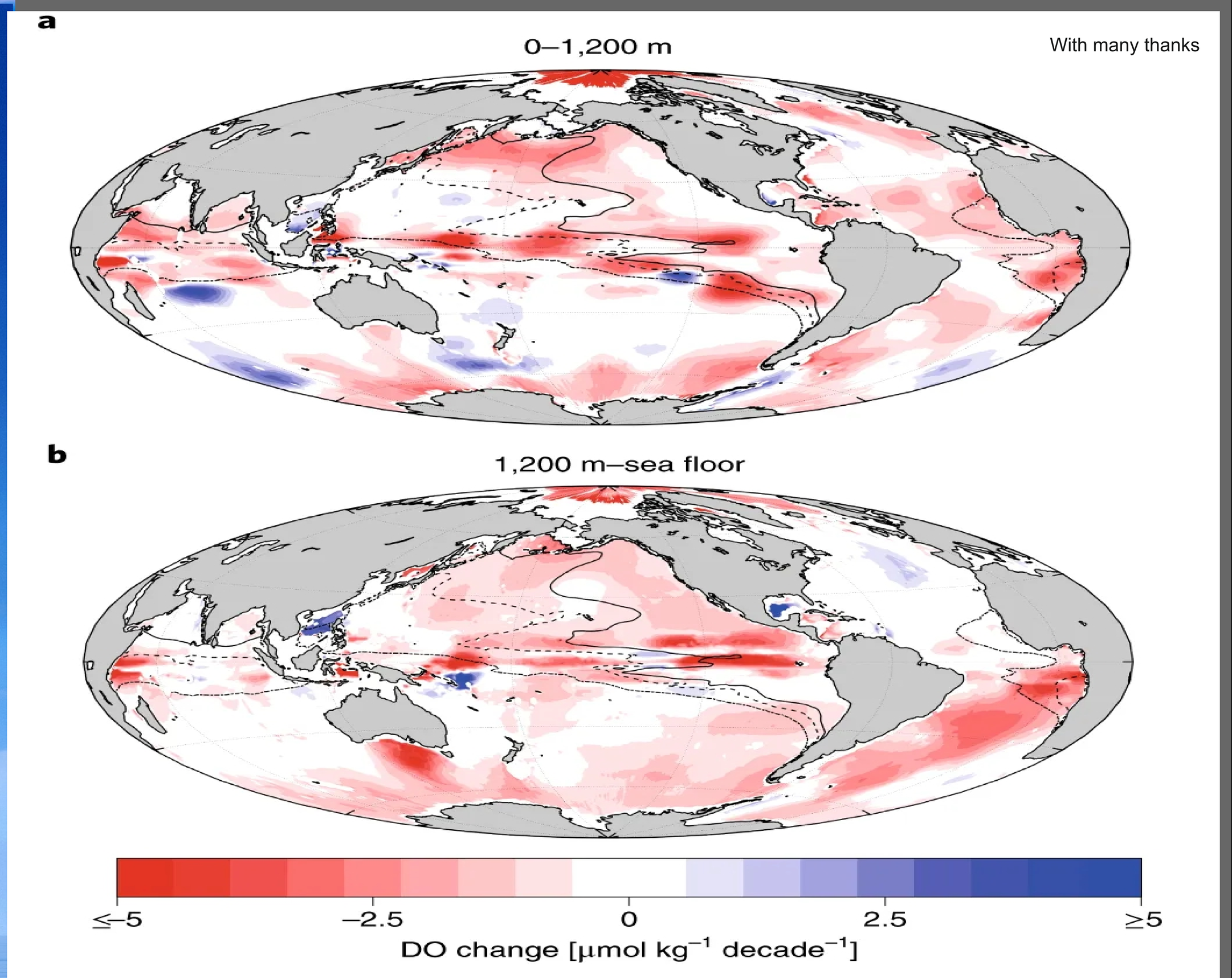
Deep water oxygen

Relatively stable in solution; low relative pressure differential per vertical metre

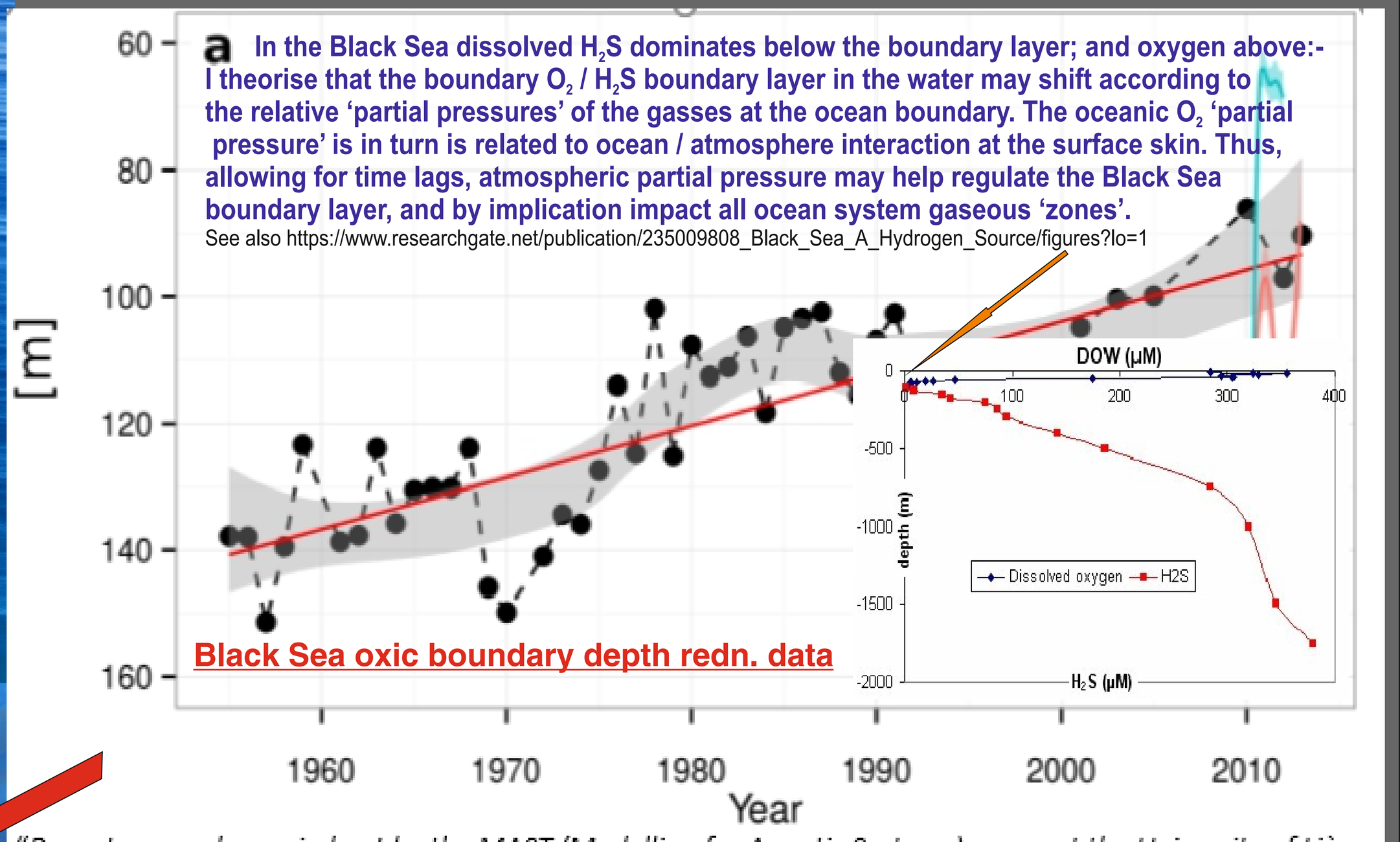
Oxygen in deep ocean 1000-6000 m 50%? of 7700GT



Observation of O2 and CO2 at La Jolla, CA. [Source http://scrippso2.ucsd.edu/sites/default/files/pdfs/plots/daily_avg_plots/ljo.pdf] With many thanks



a,b, Observational estimate of the 50-year (1960 to 2010) oxygen change in the upper (a: 0–1,200 m) and deep (b: 1,200 m–sea floor) ocean in μmol kg^{-1} per decade. Data are taken from ref. 1. Lines indicate boundaries of OMZs with less than 80 μmol kg^{-1} oxygen anywhere within the water column (dashed/dotted), less than 40 μmol kg^{-1} (dashed) and less than 20 μmol kg^{-1} (solid). DO, dissolved oxygen. https://www.nature.com/articles/s41561-018-0152-2/figures/3



"Recent research, carried out by the MAST (Modelling for Aquatic Systems) group at the University of Liège, has shown that this oxic boundary shoaled from 140 to 90 metres between 1955 and 2015.
Lecrenier P, Cameron A. The Black Sea has lost more than a third of its habitable volume. 2016. Phys.org
https://phys.org/news/2016-09-black-sea-lost-habitable-volume.ht
With many thanks

Oxygen usage pa. ~ Humans ~ 3.1GT?
Pre-humans, with natural fires and volcanoes, atmospheric oxygen levels oscillated within stable boundaries.
'The global oxygen budget and its future projection'
https://doi.org/10.1016/j.scib.2018.07.023 With many thanks

Oxygen usage pa. ~ Livestock ~ 2.5 GT?
The global oxygen budget and its future projection
https://doi.org/10.1016/j.scib.2018.07.023

Oxygen usage pa. ~ Eutrophication ~ GT? in fresh and salt water systems

Oxygen usage pa.~ Soil C loss respiration ~ 3GT?
Figure could be much higher or lower - estimated at 1 ton per hectare on 4 billion cultivated hectares

Oxygen usage pa. ~ Tundra defrost, and Fire ~ 1GT??
"carbon dioxide emissions of 1.7 billion tonnes a year are about twice as high as previous estimates" (gross).
https://www.cbc.ca/news/technology/permafrost-climate-change-1.5330144
"The conversion to CO2 is going much faster than previously thought," "because permafrost is such a rich potential source of the greenhouse gas. If all the world's permafrost melted, it could double the amount of heat-trapping carbon dioxide in the atmosphere" https://www.scientificamerican.com/article/melting-tundra-releases-carbon-dioxide-quickly/

Oxygen usage pa. ~ Crop burnoff / fuel wood ~ 6 to 15GT?.
https://www.ncbi.nlm.nih.gov/pubmed/17734705
'Biomass Burning In the Tropics: Impact on Atmospheric Chemistry and Biogeochemical Cycles.'
"Biomass containing 2-5 petagrams of carbon is burnt annually"
Includes: fuel wood, savanna - shifting agriculture and related deforestation - With many thanks.

Oxygen usage pa. ~ Forest Fire ~ 1.5 - 2.1GT?
"Biomass burning events in forests have released approximately 2–3 Pg C yr−1, mostly in the form of CO_2" From Estimation of CO2 Emissions from Wildfires Using OCO-2 Data https://www.mdpi.com/2073-4433/10/10/581/htm
With many thanks - estimates vary greatly including as to which types of fires are included

Oxygen usage pa. ~ Fossil Fuels ~ 25GT.
The global oxygen budget and its future projection
https://doi.org/10.1016/j.scib.2018.07.023
Figures for 1990 - 2005
2019 - 37Gt CO_2 - 27GT O_2, - 10GT C

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Oceanic oxygen 'gO_2ing'; but where? - 'Henry's Law': is oceanic oxygen buffering atmospheric oxygen loss? - An extinction risk?

R A Brown, The McCarrison Society, McCarrison.com. Funding - self funded - Conflicts of interest - none

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