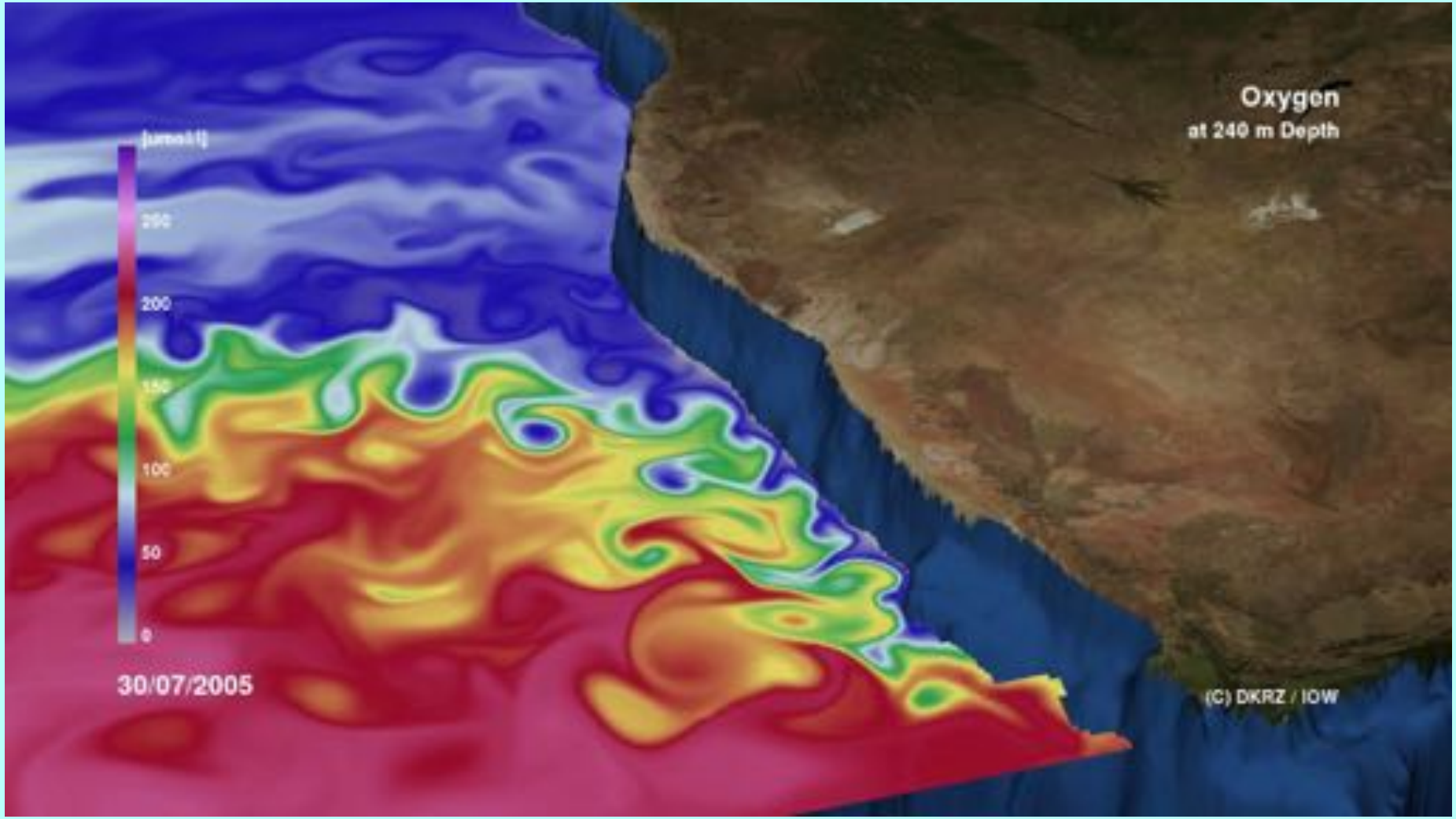
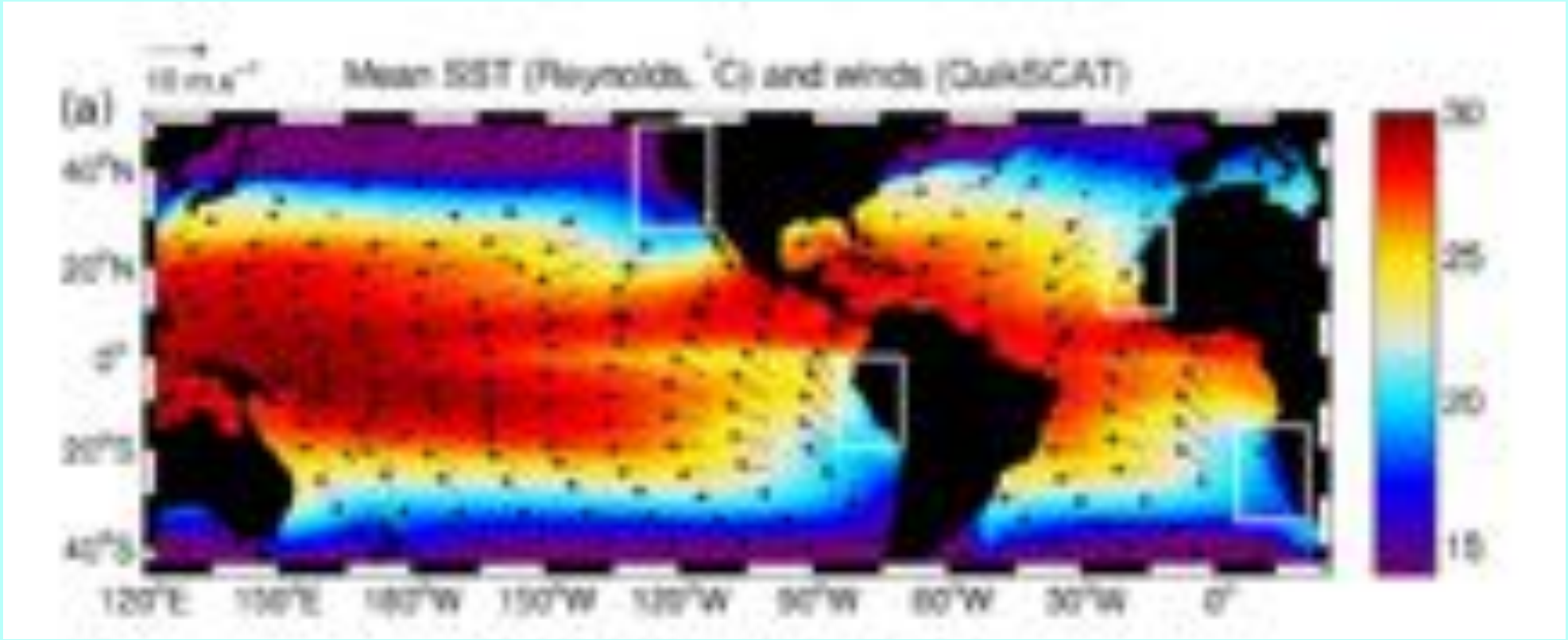
Marine Biogeochemistry of the Benguela Upwelling Region

COESSING 2019 at RMU



GenusPodcast, https://www.youtube.com/watch?v=8C9p6_qxgEI

Eastern boundary current upwelling regions

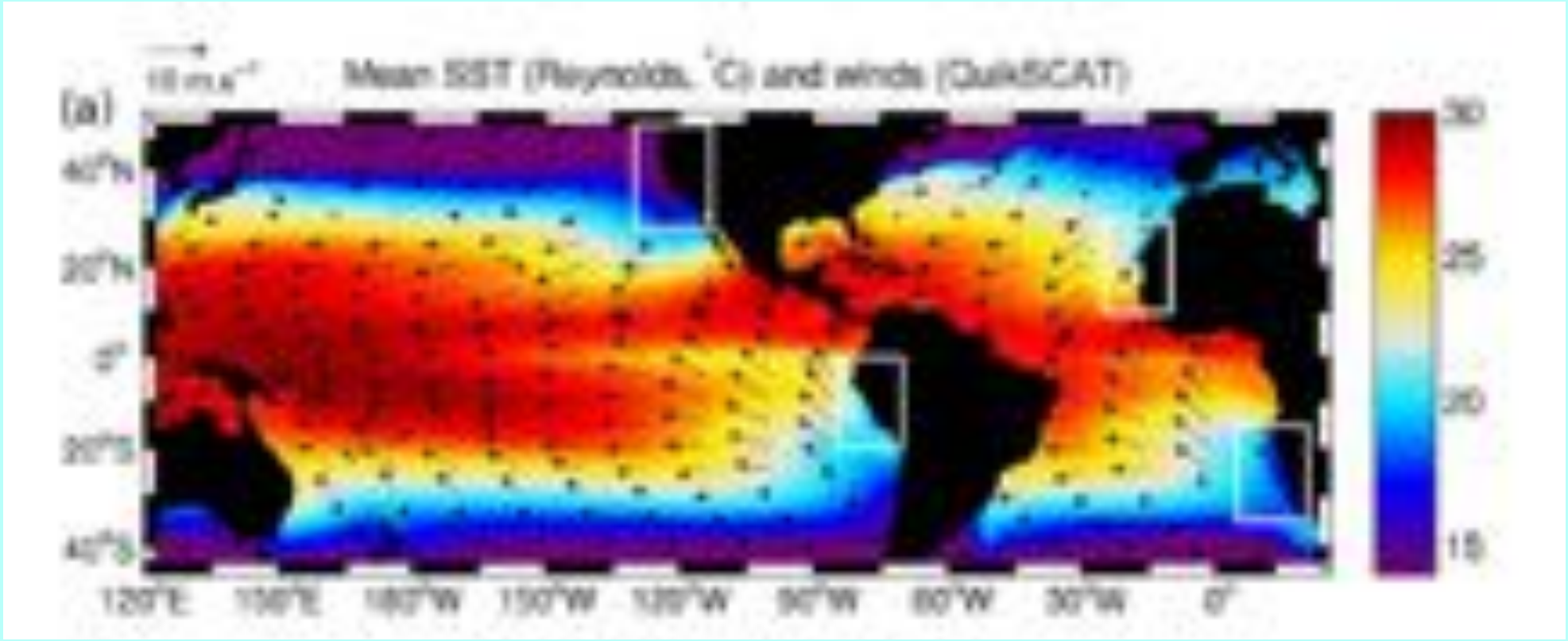


Chavez & Messie, 2009

Outline

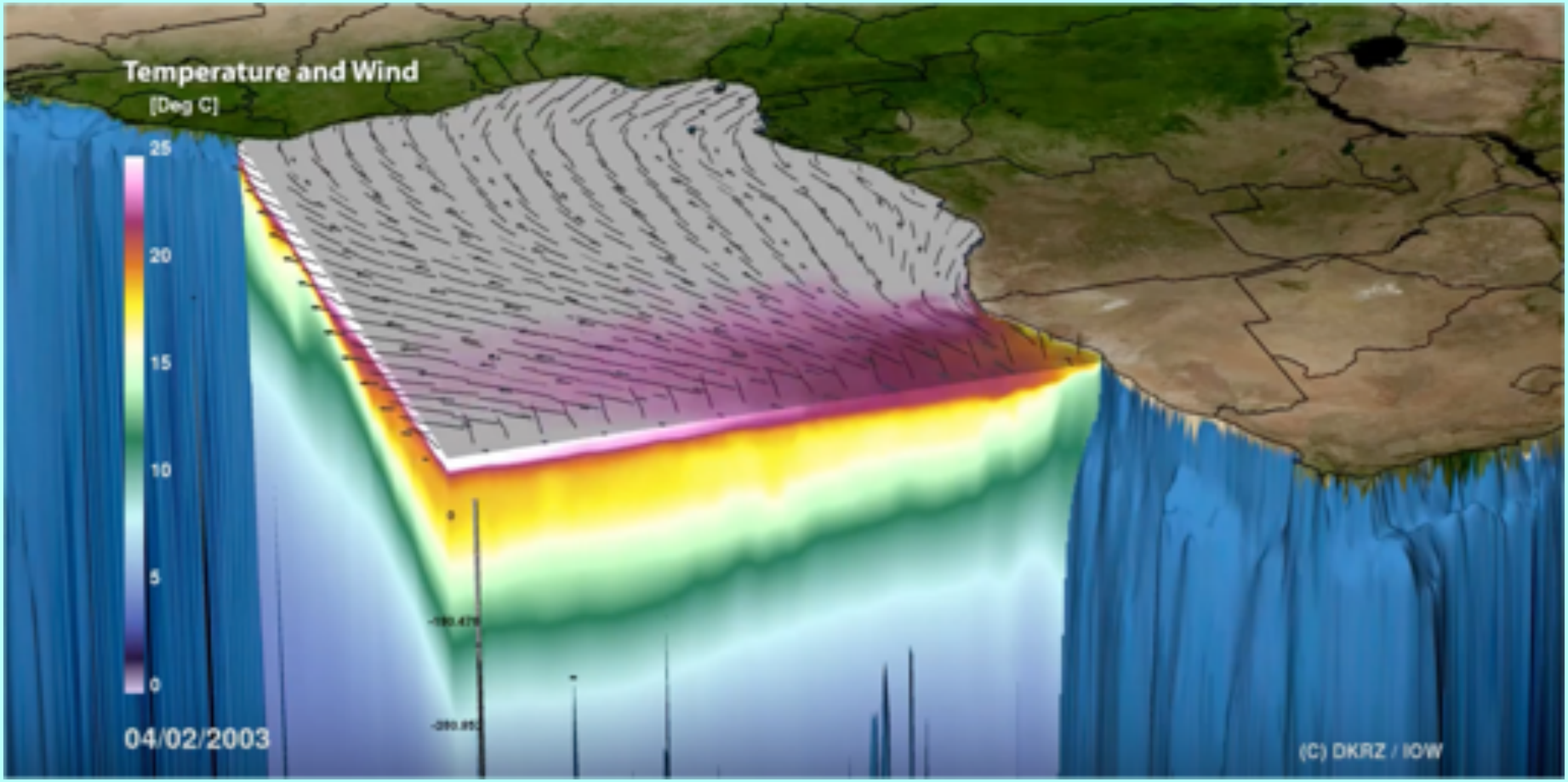
- Benguela upwelling region and its Oxygen Minimum Zone (OMZ)
- Marine nitrogen cycle in the OMZ
- Sulfur cycling in the OMZ
- OMZ expansion in a warming climate

Focus on the Benguela Upwelling but these geochemical process apply to all these regions



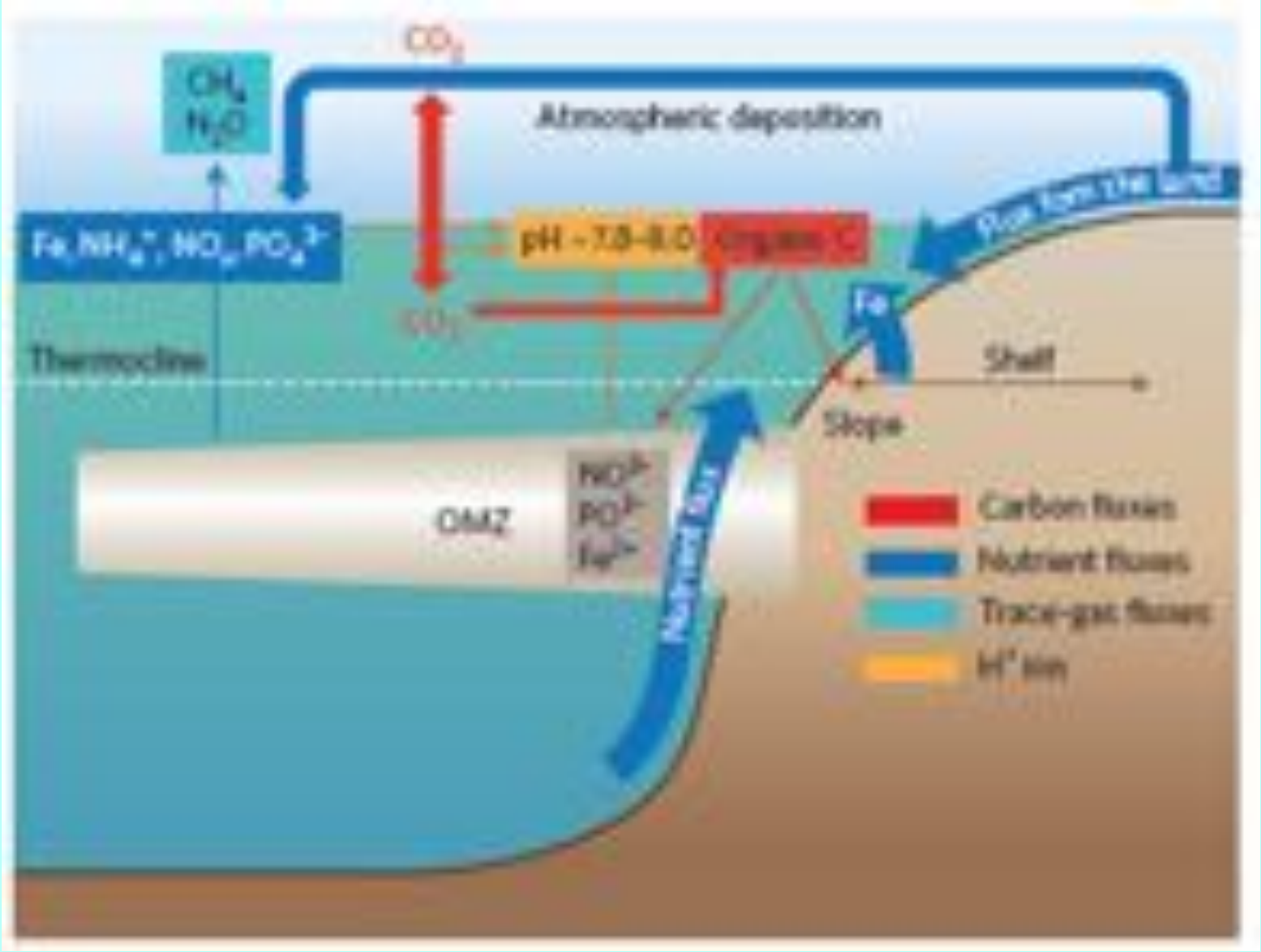
Chavez & Messie, 2009

Benguela Upwelling



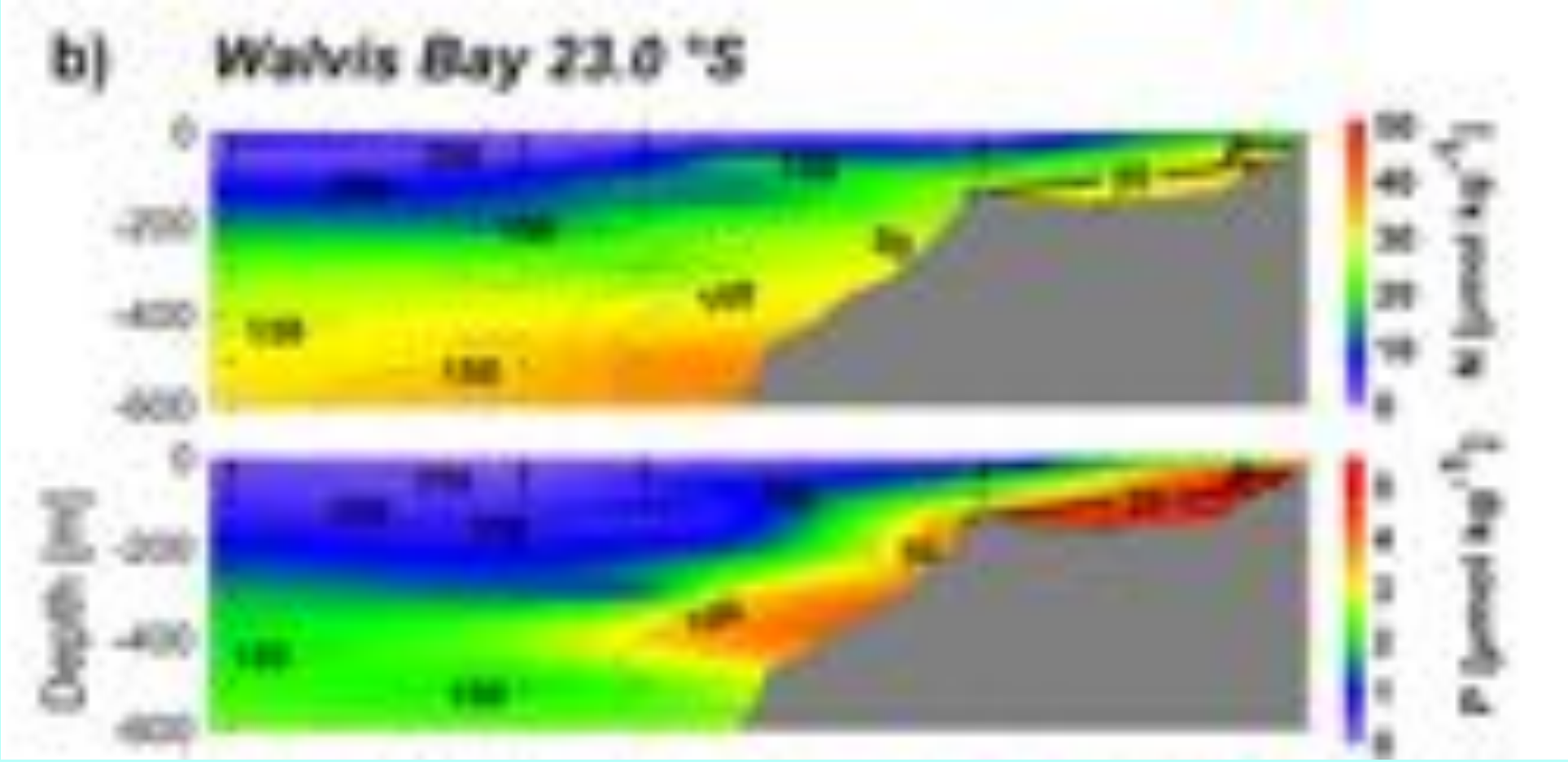
GenusPodcast, https://www.youtube.com/watch?v=8C9p6_qxgEI

Upwelling system



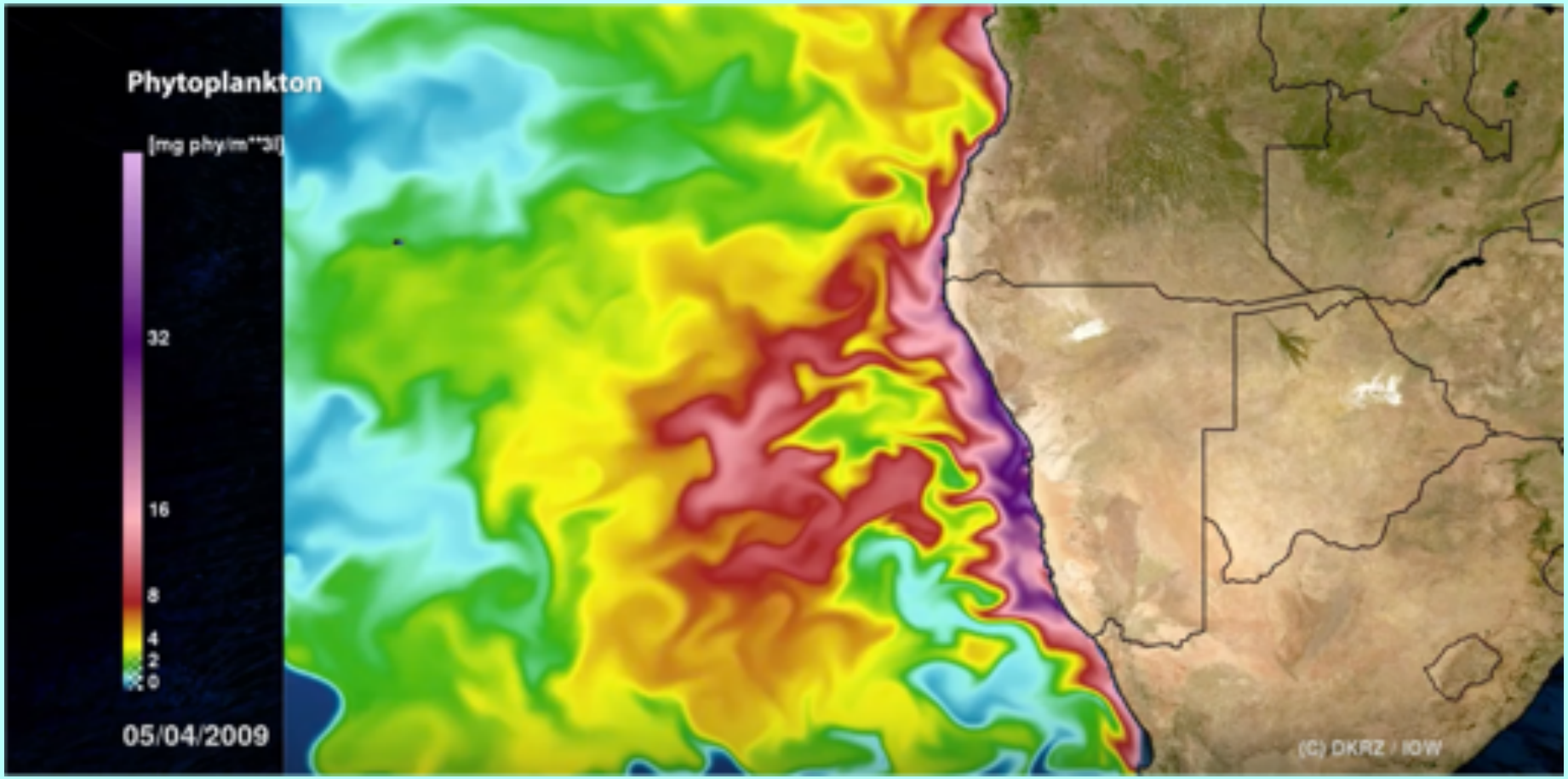
Capone & Hutchins, 2013

Upwelling delivers nutrients to the surface



Flohr et al., 2014

Increased primary productivity results from these upwelled nutrients

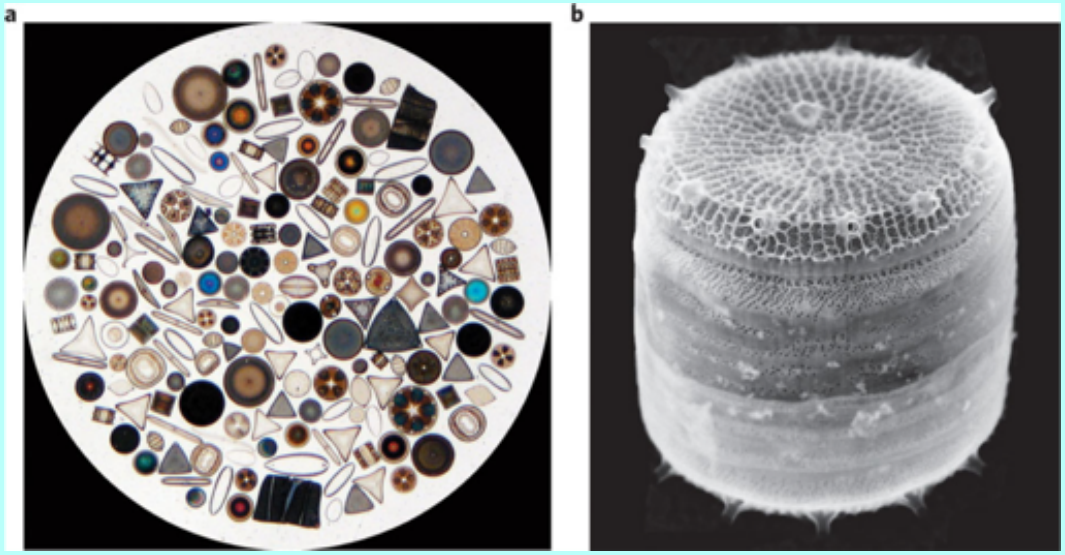


GenusPodcast, https://www.youtube.com/watch?v=8C9p6_qxgEI

Carbon fixation: $CO_2 + H_2O \rightarrow CH_2O + O_2$

Blooms are made up of phytoplankton such as Diatoms and Coccolithophores

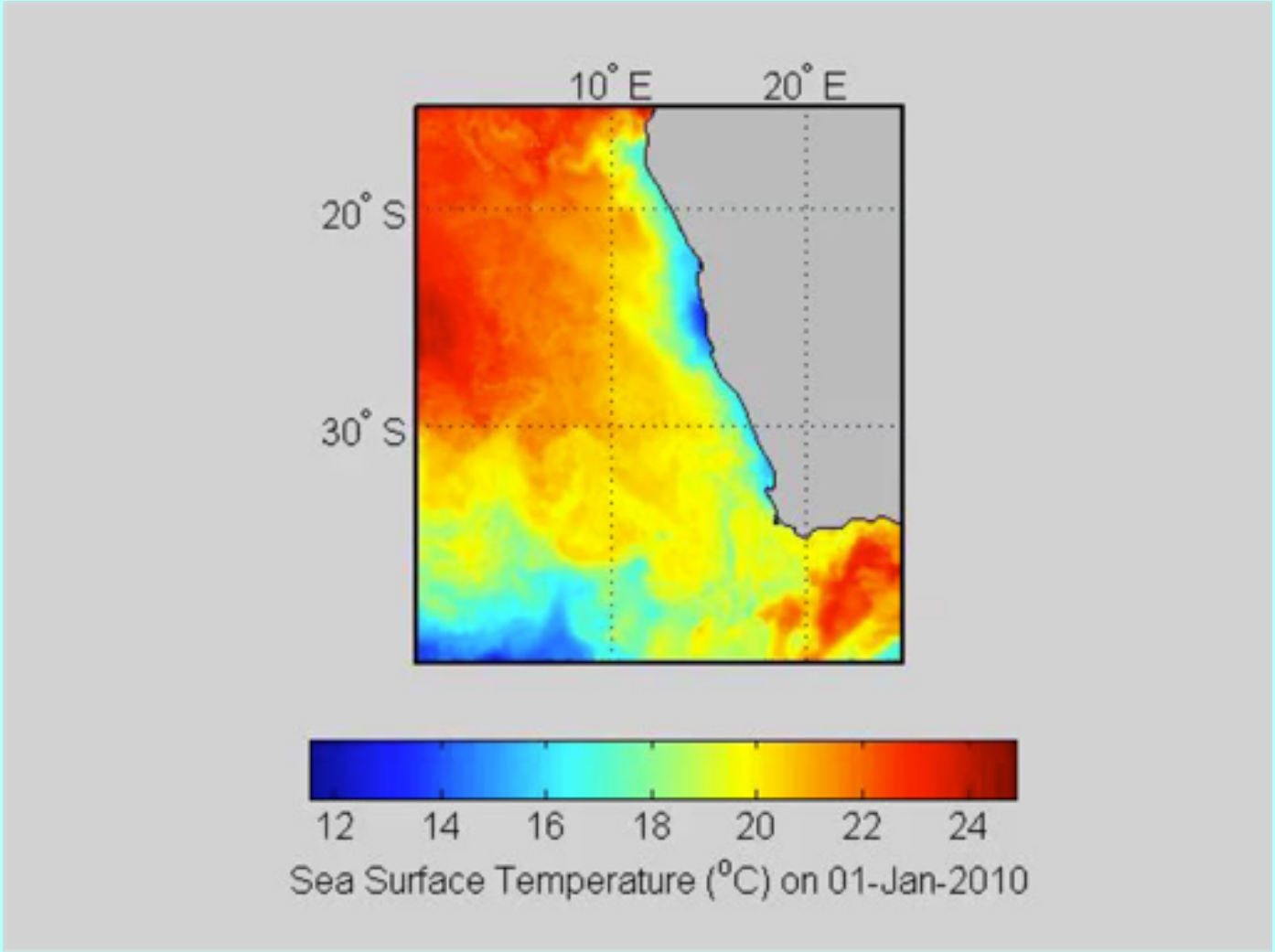
Diatoms



Möller & Hoose, 2011

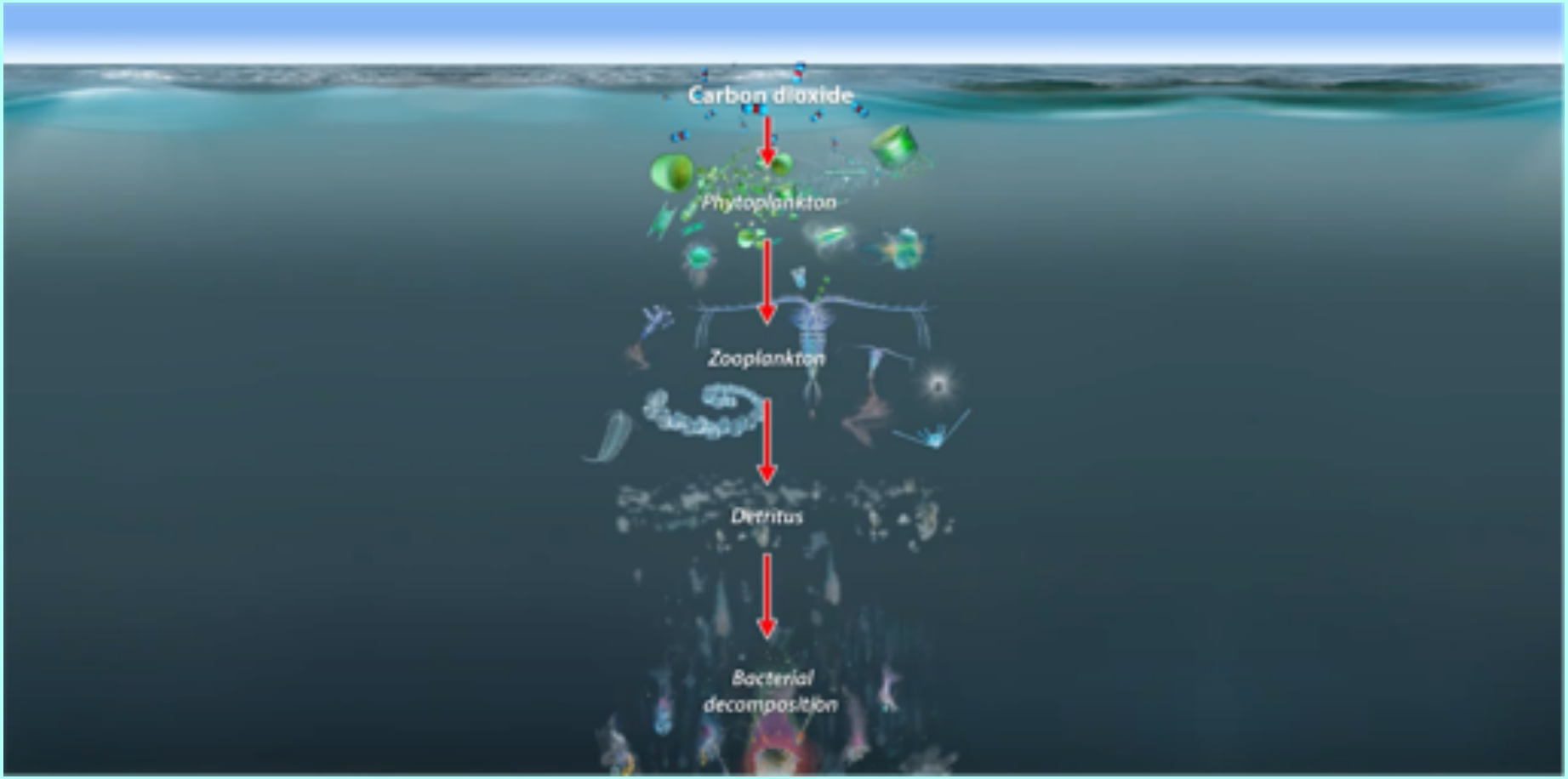
Coccolithophore

Seasonality of the Benguela upwelling



https://oceancurrents.rsmas.miami.edu/atlantic/benguela_2.html

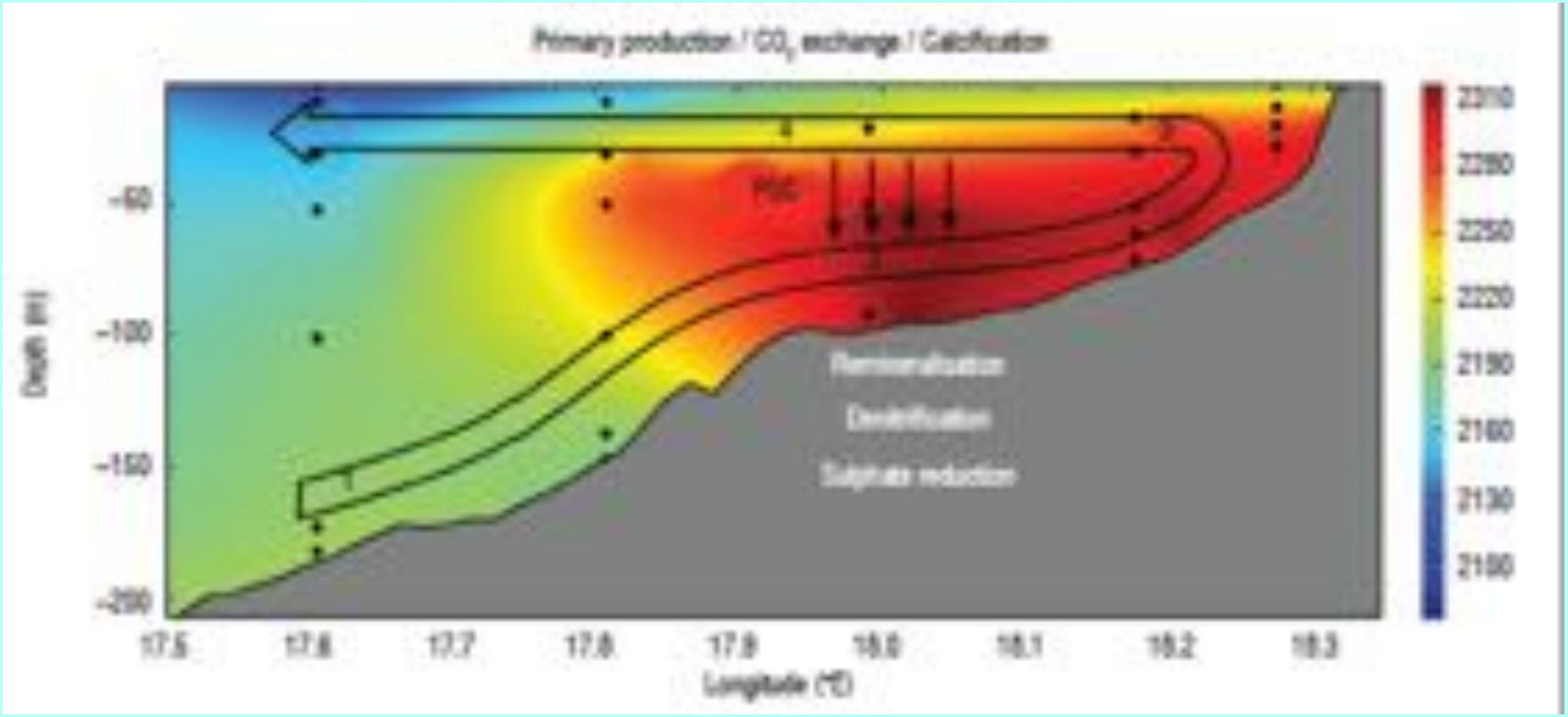
As phytoplankton and zooplankton die and sink they are degraded by heterotrophic prokaryotes



GenusPodcast, https://www.youtube.com/watch?v=8C9p6_qxgEI

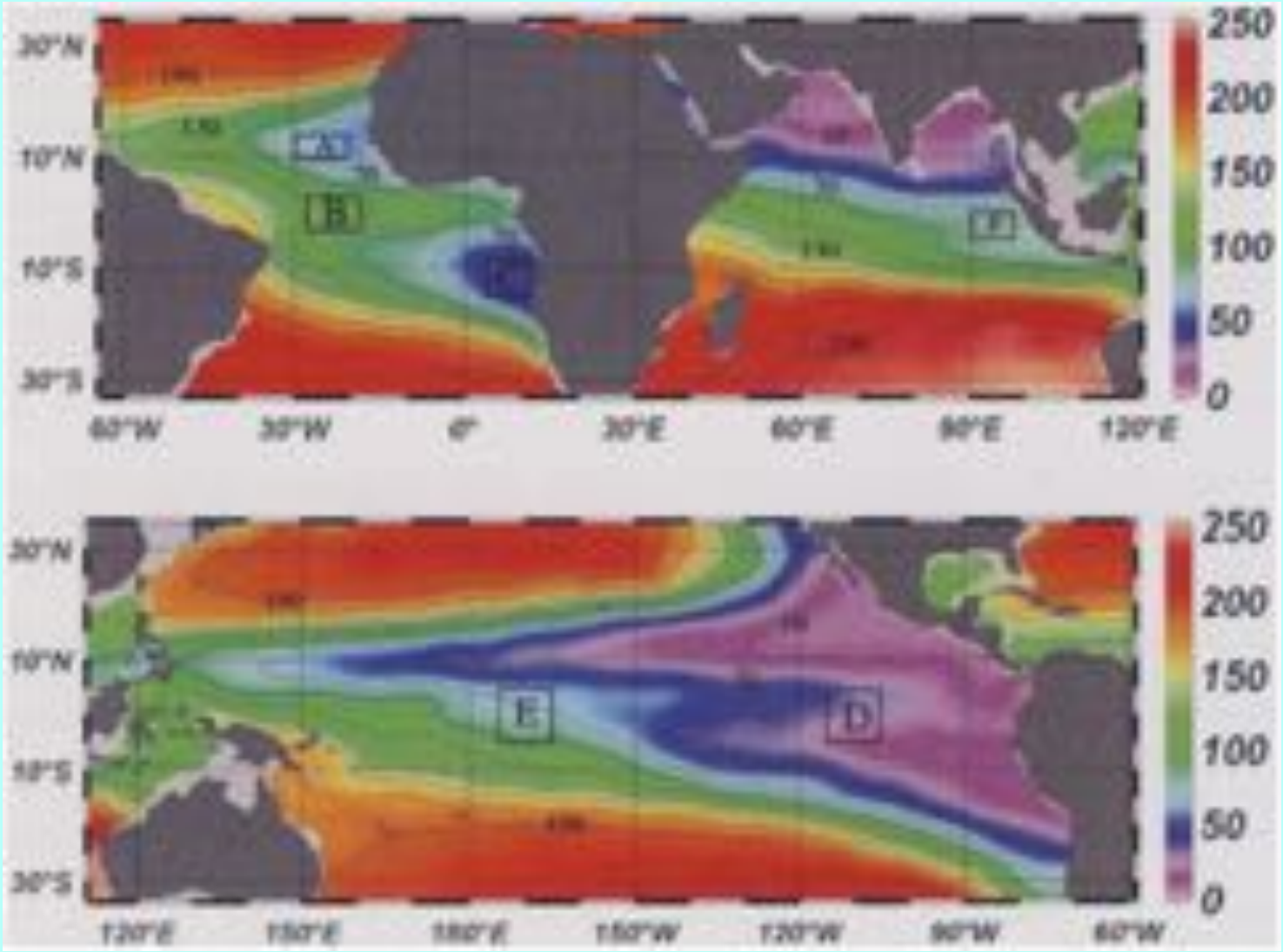
Increased dissolved inorganic carbon concentrations are indicative of remineralization by heterotrophic microbes

Remineralization: Organic Matter + Electron Acceptor (O_2) -> Simple nutrients + H_2O + CO_2



Gregor & Monteiro, 2013

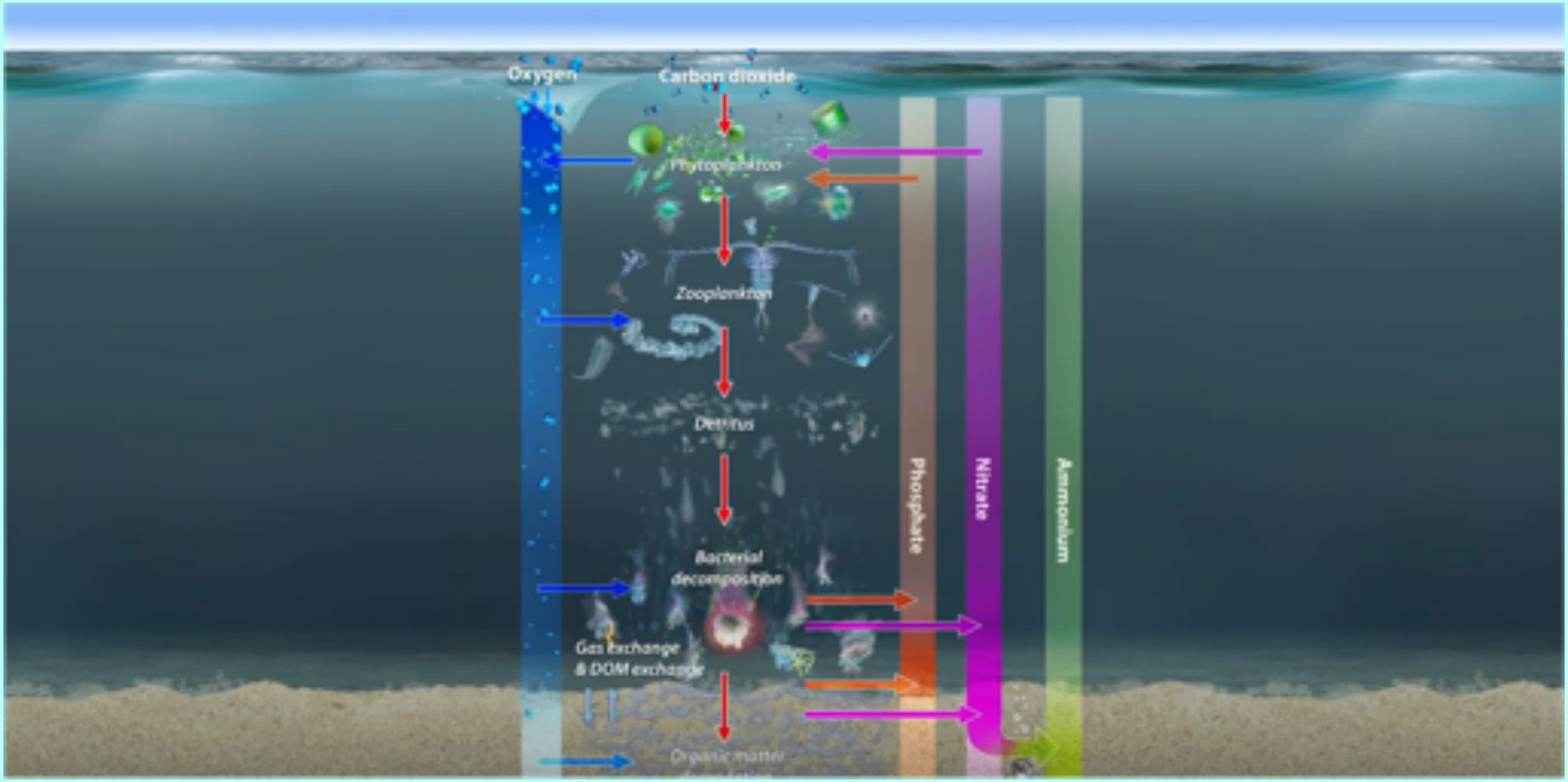
Oxygen minimum zones are created in these upwelling regions



Depth:
400 m

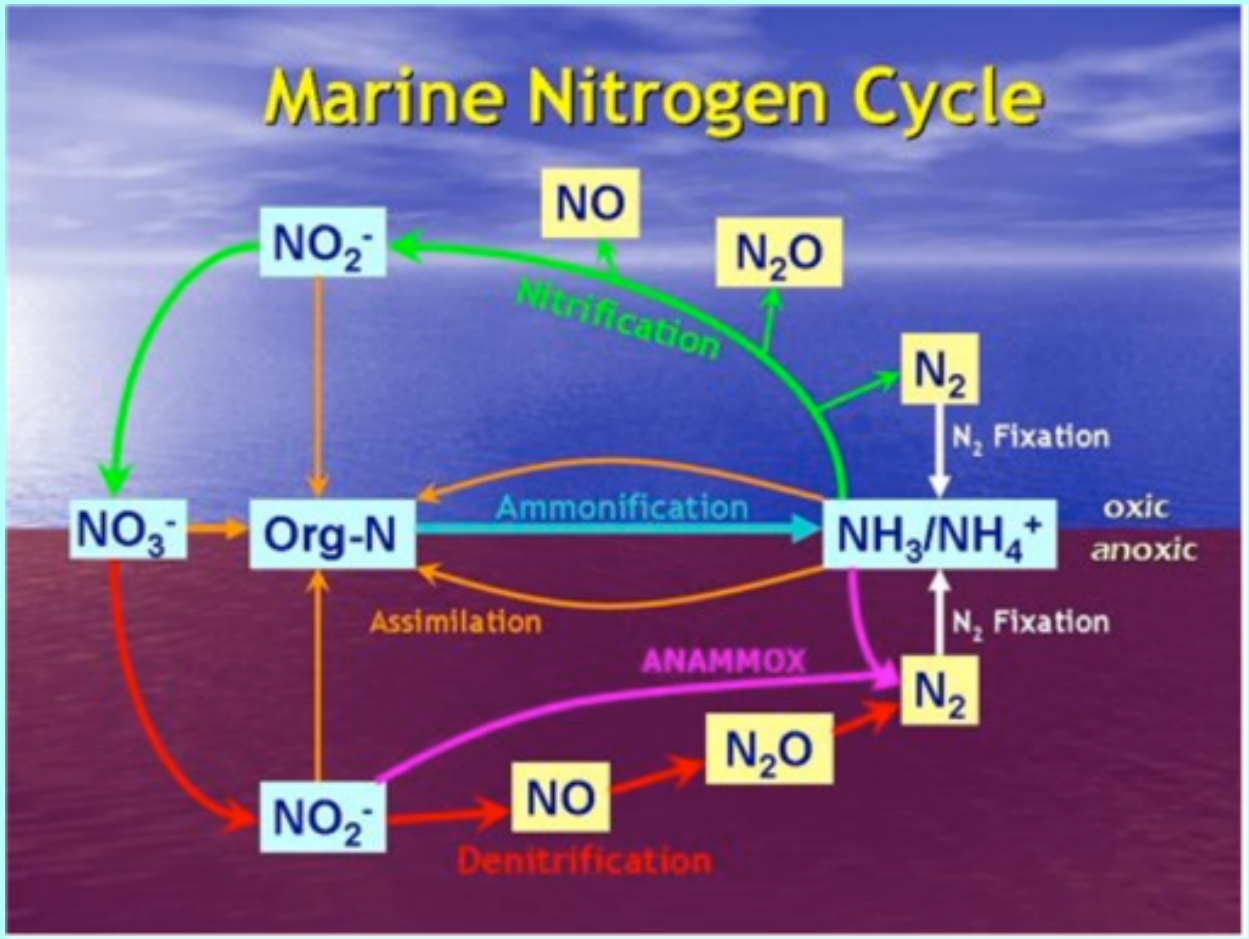
Stramma et al., 2008

In oxygen minimum zones unique biogeochemical processes occur



GenusPodcast, https://www.youtube.com/watch?v=8C9p6_qxgEI

30-50% of fixed nitrogen lost from the ocean occurs in OMZs



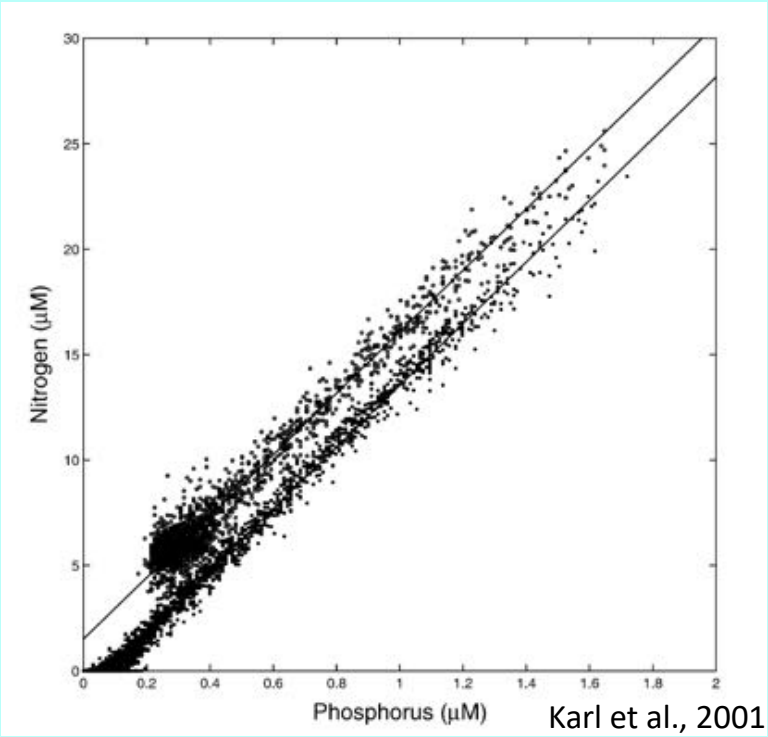
https://wordsinmocean.com/2012/09/18/challenger-2012-selected-keynote-lectures-phyllis-lam-max-planck-institute-microbial-nitrogen-cycling-in-oxygen-minimum-zones/

Redfield Ratio

C:N:P 106:16:1

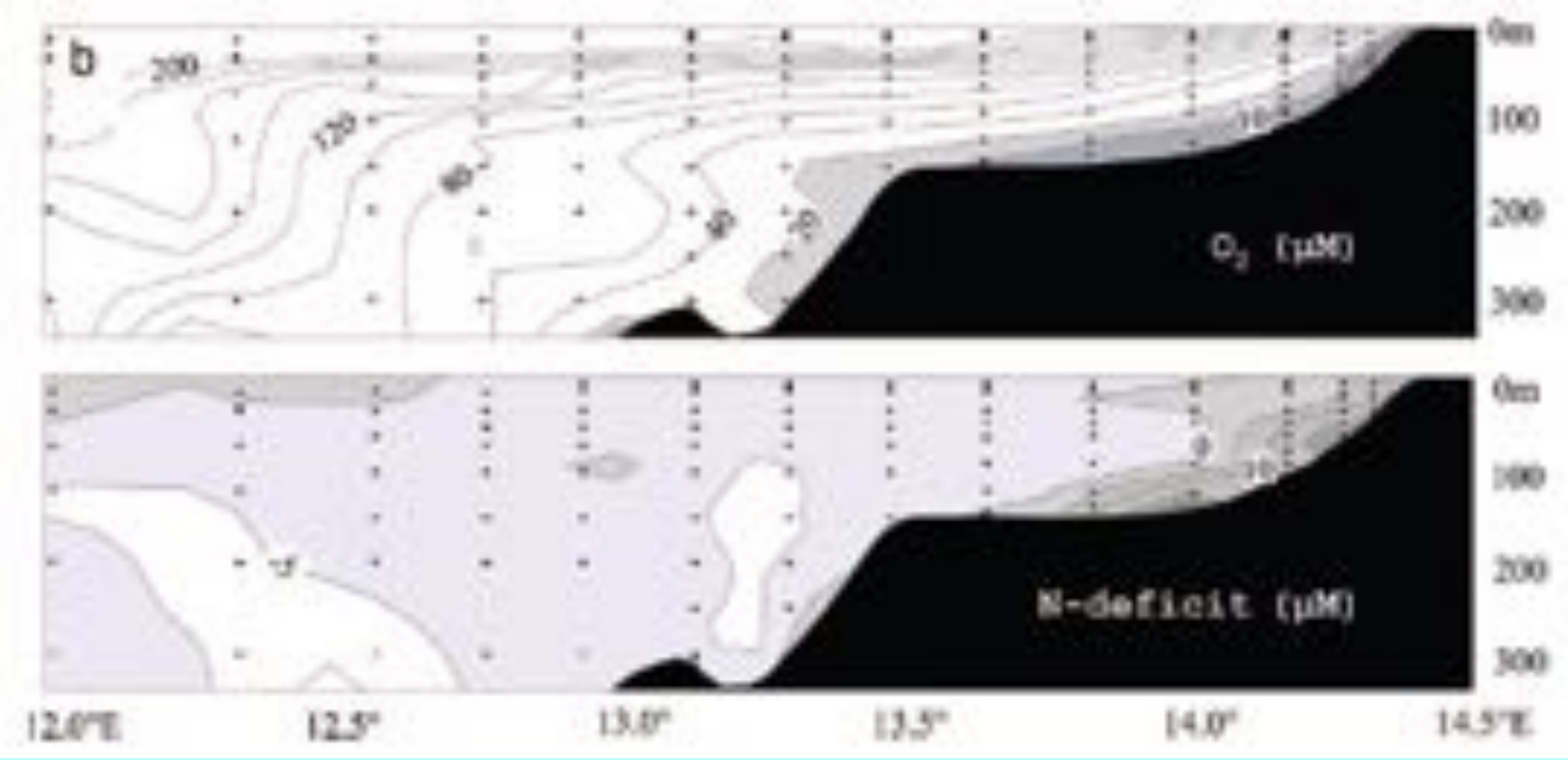
-Average molar ratio of primary elements in living material

-This ratio reflects the ratio of inorganic nutrients in the ocean, the ratio of uptake of these elements by living organisms, as well as the ratio in living cells



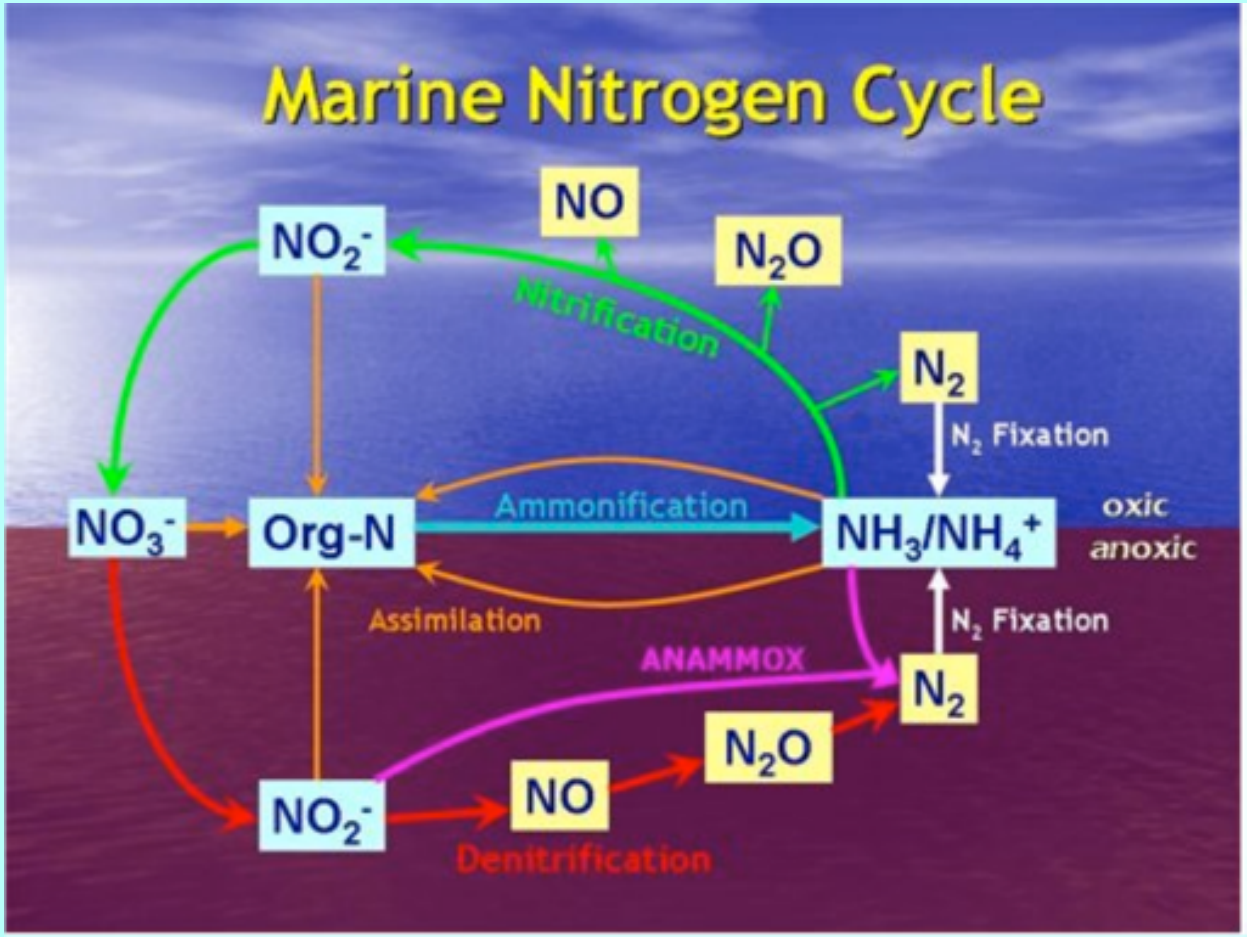
Karl et al., 2001

Evidence of fixed nitrogen removal



Kuypers et al., 2005

Two mechanisms for loss of fixed nitrogen from the ocean



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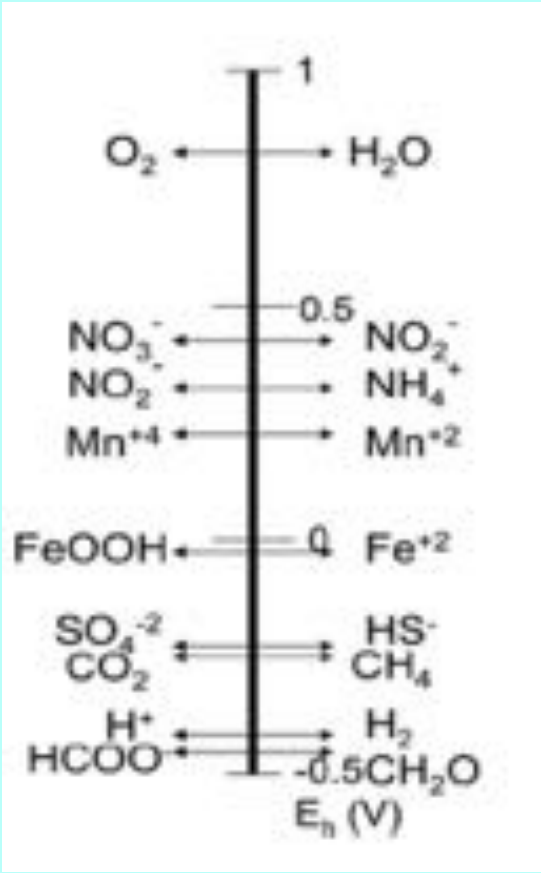
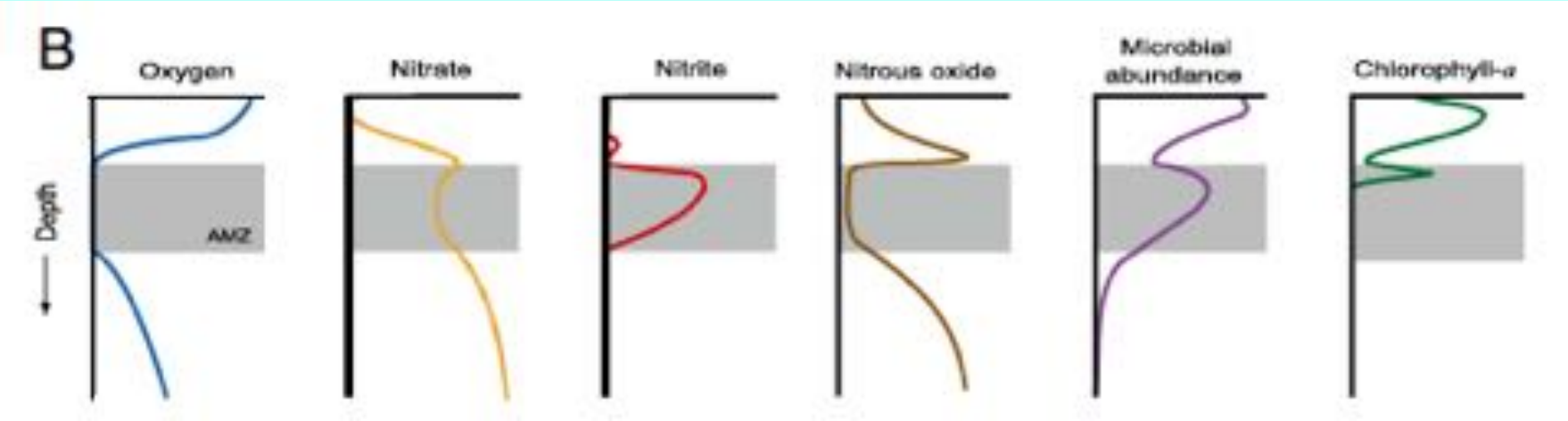
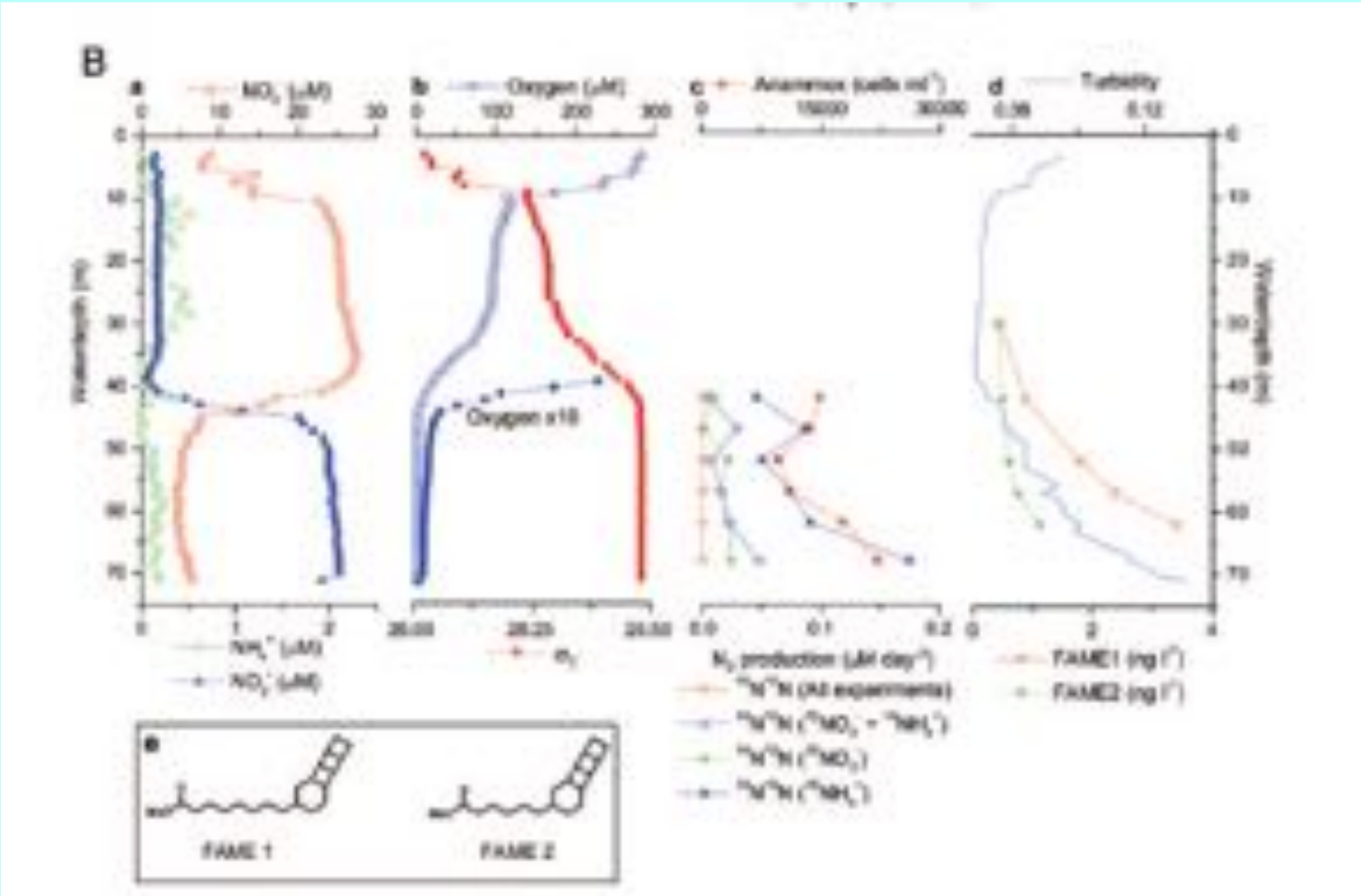


Characteristic biogeochemical profiles in an OMZ



Ulloa et al., 2012

Chemical profiles in the Benguela OMZ



Kuypers et al., 2005

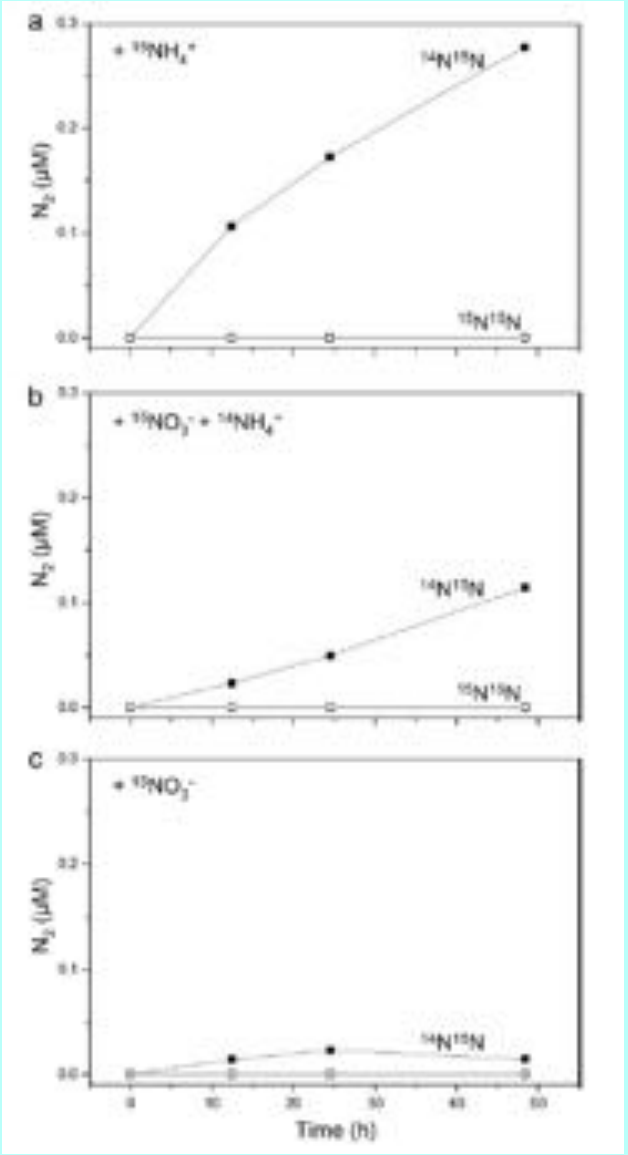
Identification of Anammox in the Benguela Upwelling

Annamox:

$NO_2^- + NH_4 \rightarrow N_2$

Denitrification:

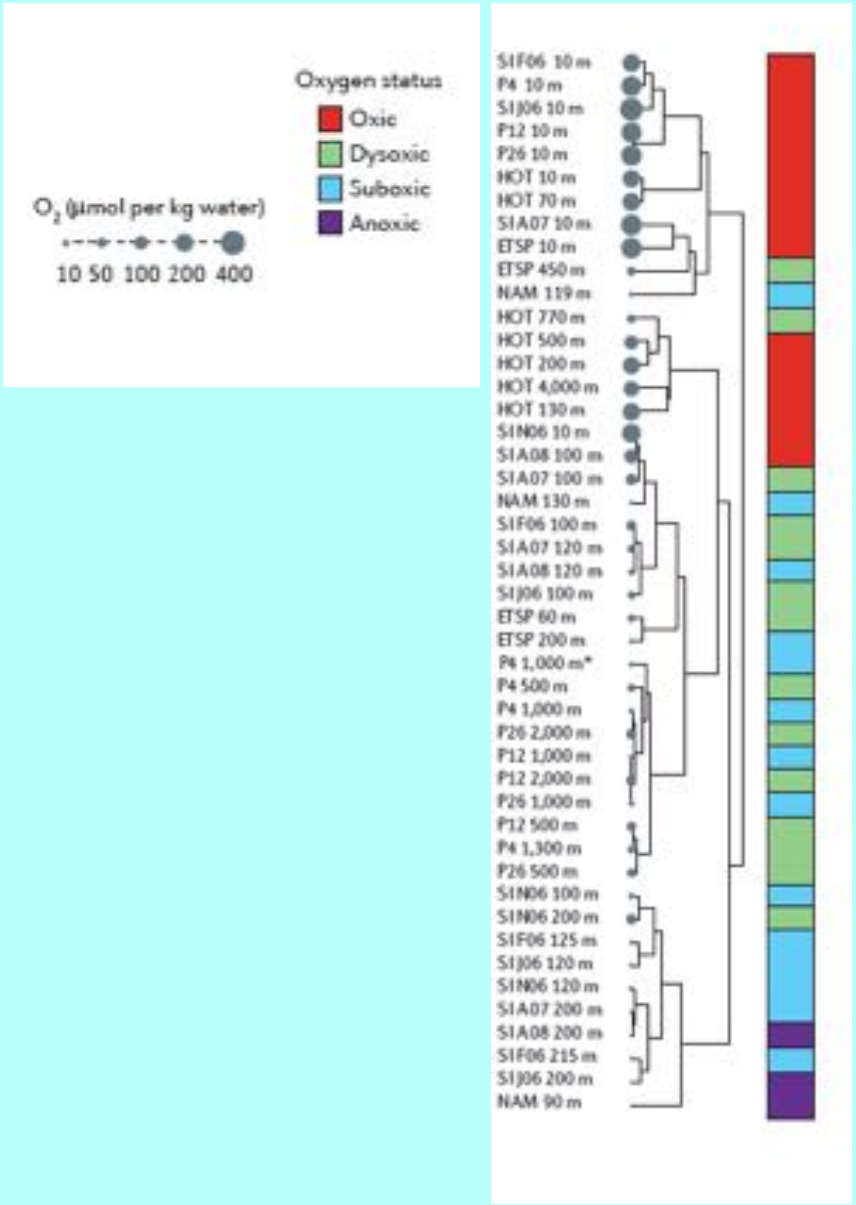
$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$



68 m

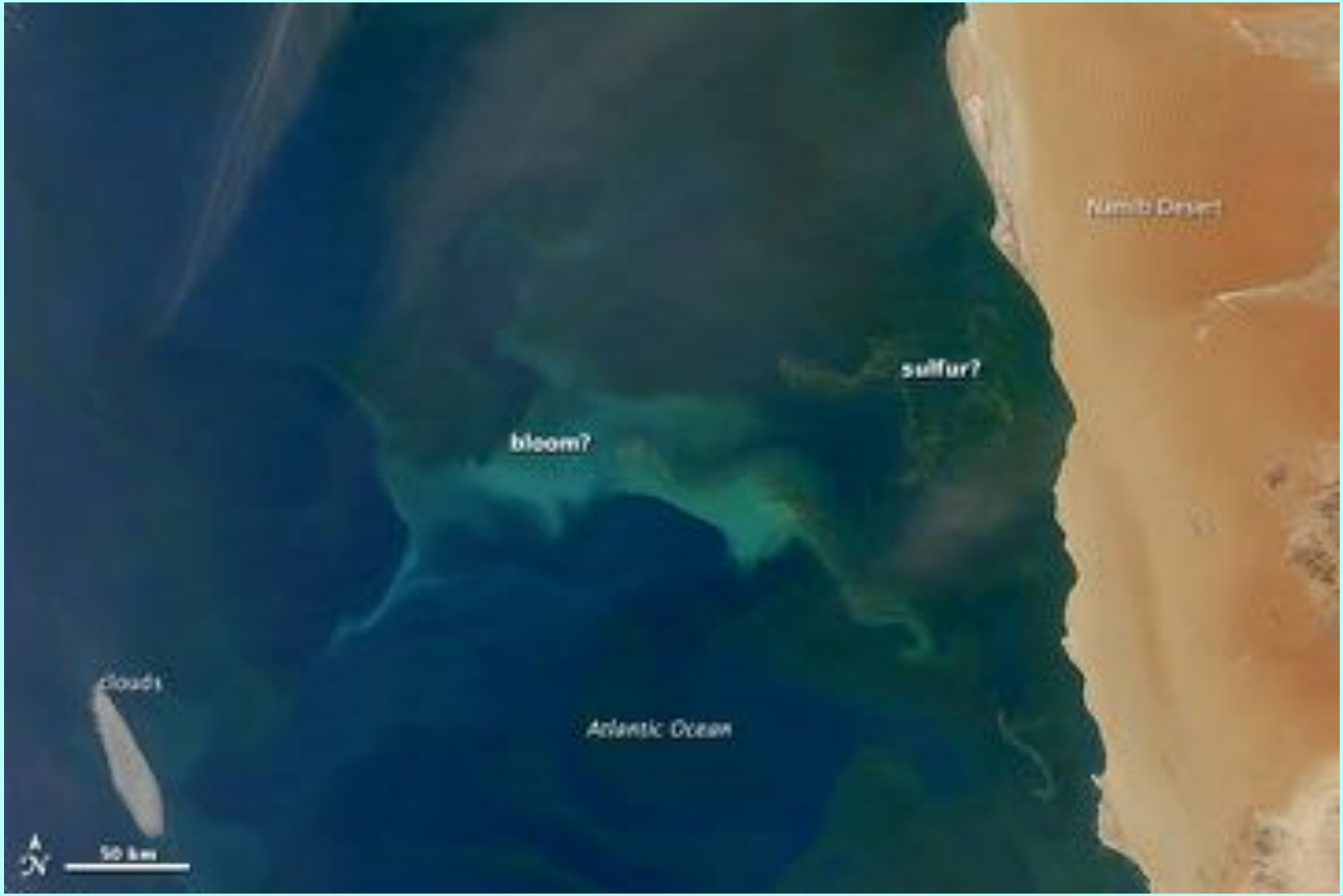
Kuypers et al., 2005

Distinct microbial community in OMZs responsible for these processes



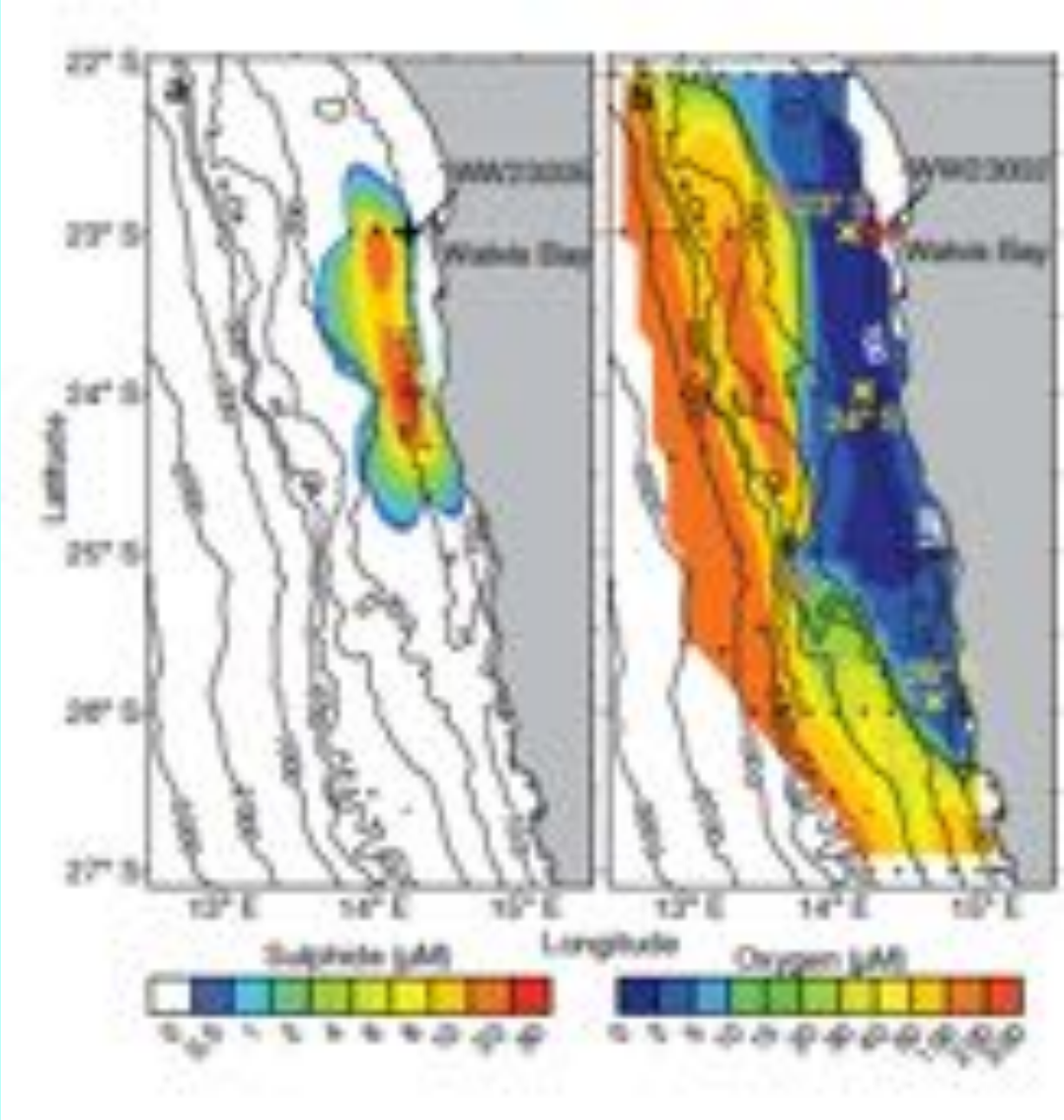
Wright et al., 2012

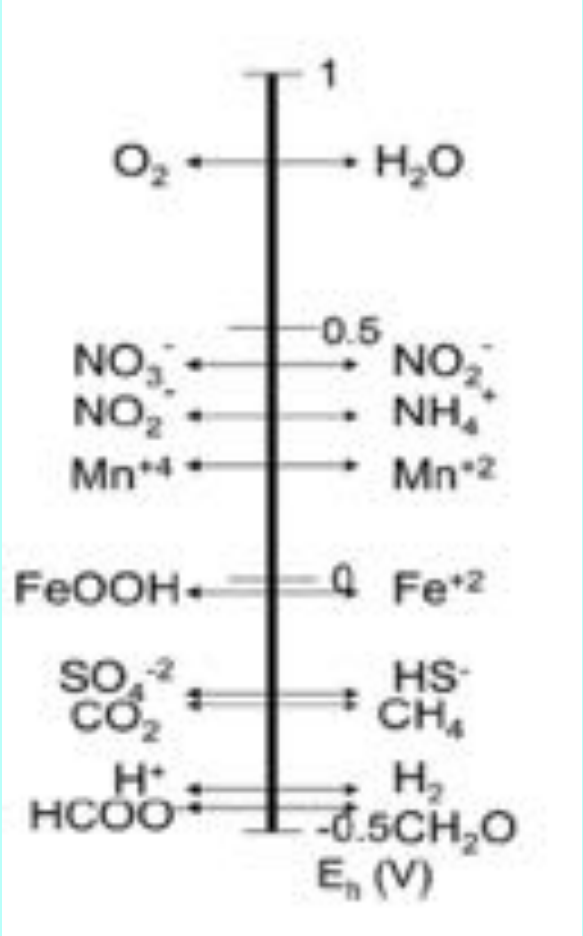
Sulfur cycling: plumes of sulfur emerge during upwelling and OMZ formation



NASA

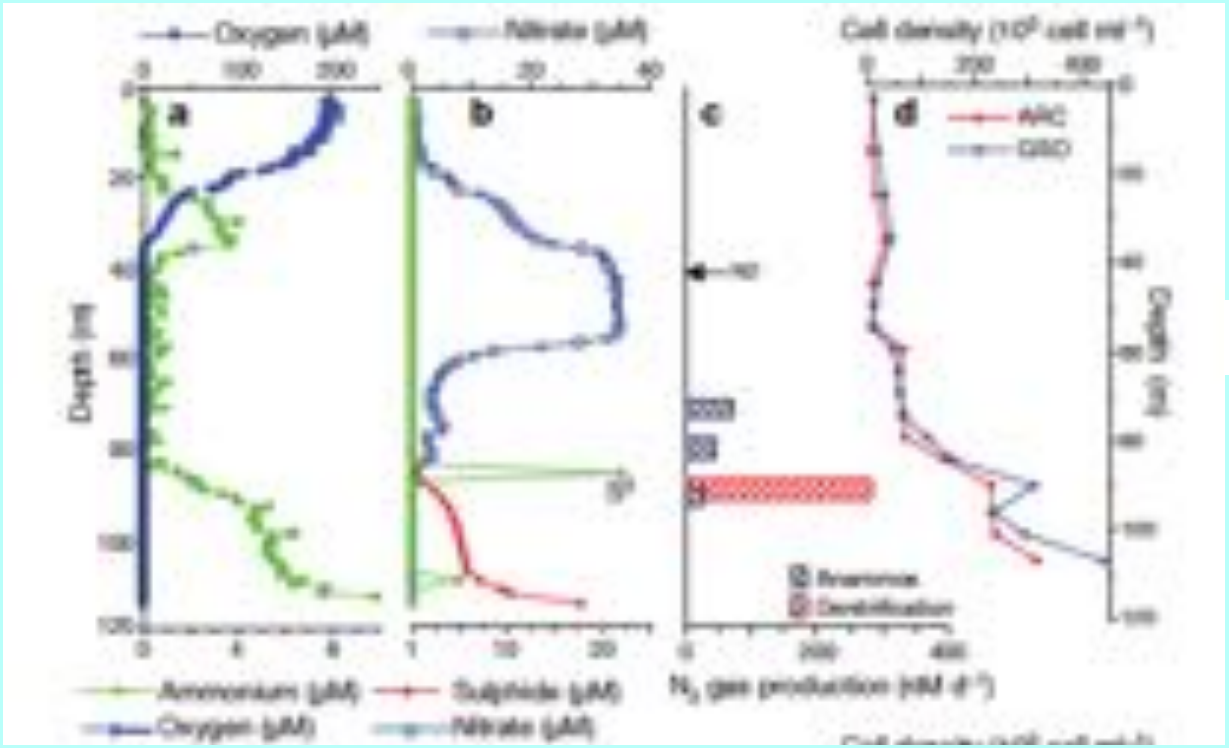
Sulfide production in the OMZ





Lavik et al., 2009

Sulfate can also be used as an electron acceptor

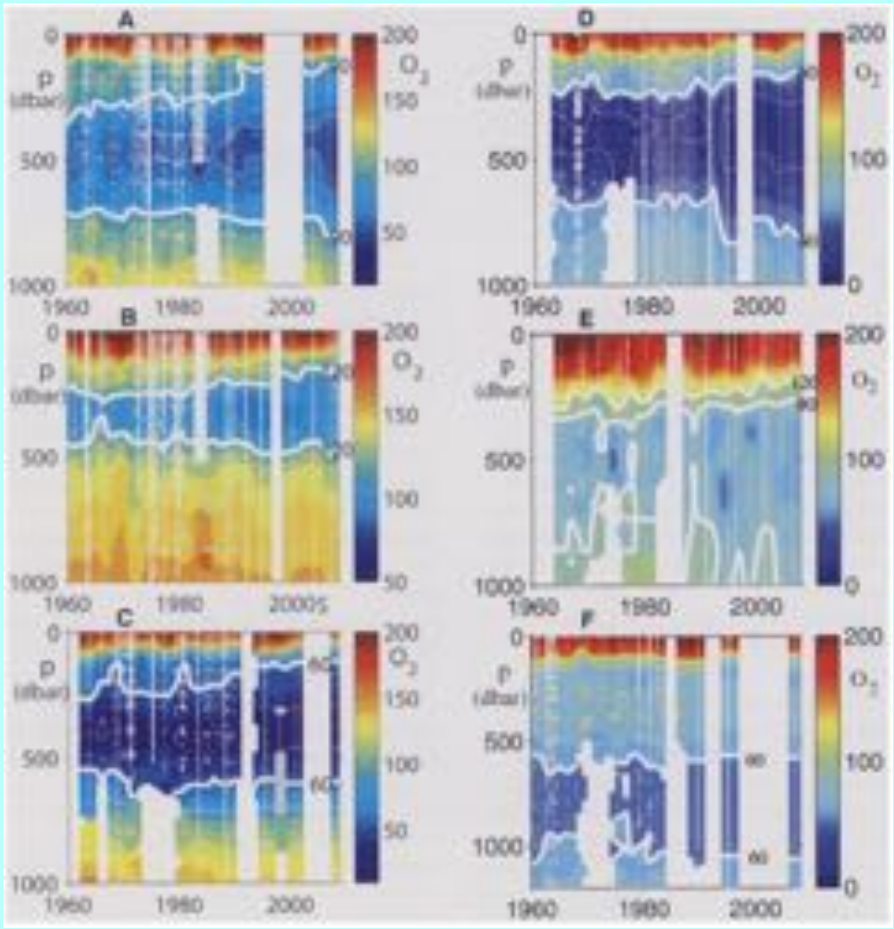


Lavik et al., 2009

Coupling nitrate reduction to sulfide oxidation:

$$2NO_3^- + 5HS^- + 7H^+ \rightarrow N_2 + 5S^0 + 6H_2O$$

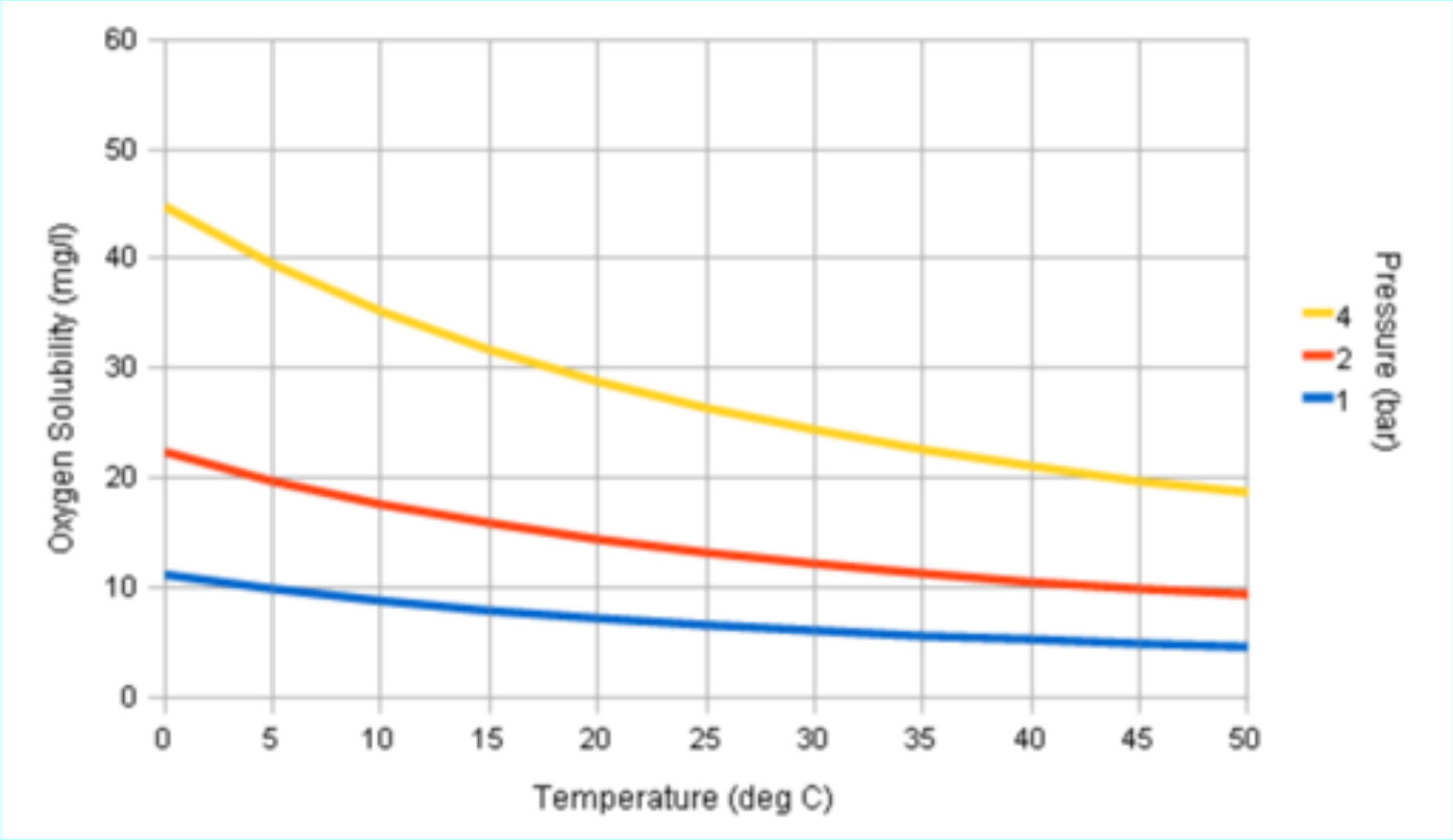
OMZs may expand as global temperatures increase due



Ocean areas (Fig. 1)	Temperature trend (°C year^{-1})	Oxygen trend (μmol kg^{-1} year^{-1})	Integrated oxygen loss (mmol m^{2} year^{-1})
Area A	+0.009 ± 0.008	−0.34 ± 0.13	136
Area B	+0.005 ± 0.008	−0.19 ± 0.12	74
Area C	+0.002 ± 0.011	−0.17 ± 0.11	74
Area D	−0.001 ± 0.009	−0.13 ± 0.32	49
Area E	−0.010 ± 0.008	−0.19 ± 0.20	74
Area F	+0.005 ± 0.007	−0.09 ± 0.21	37
N. Pacific, 100 to 400 m depth (11)	+0.005 to +0.012	−0.39 to −0.70	165

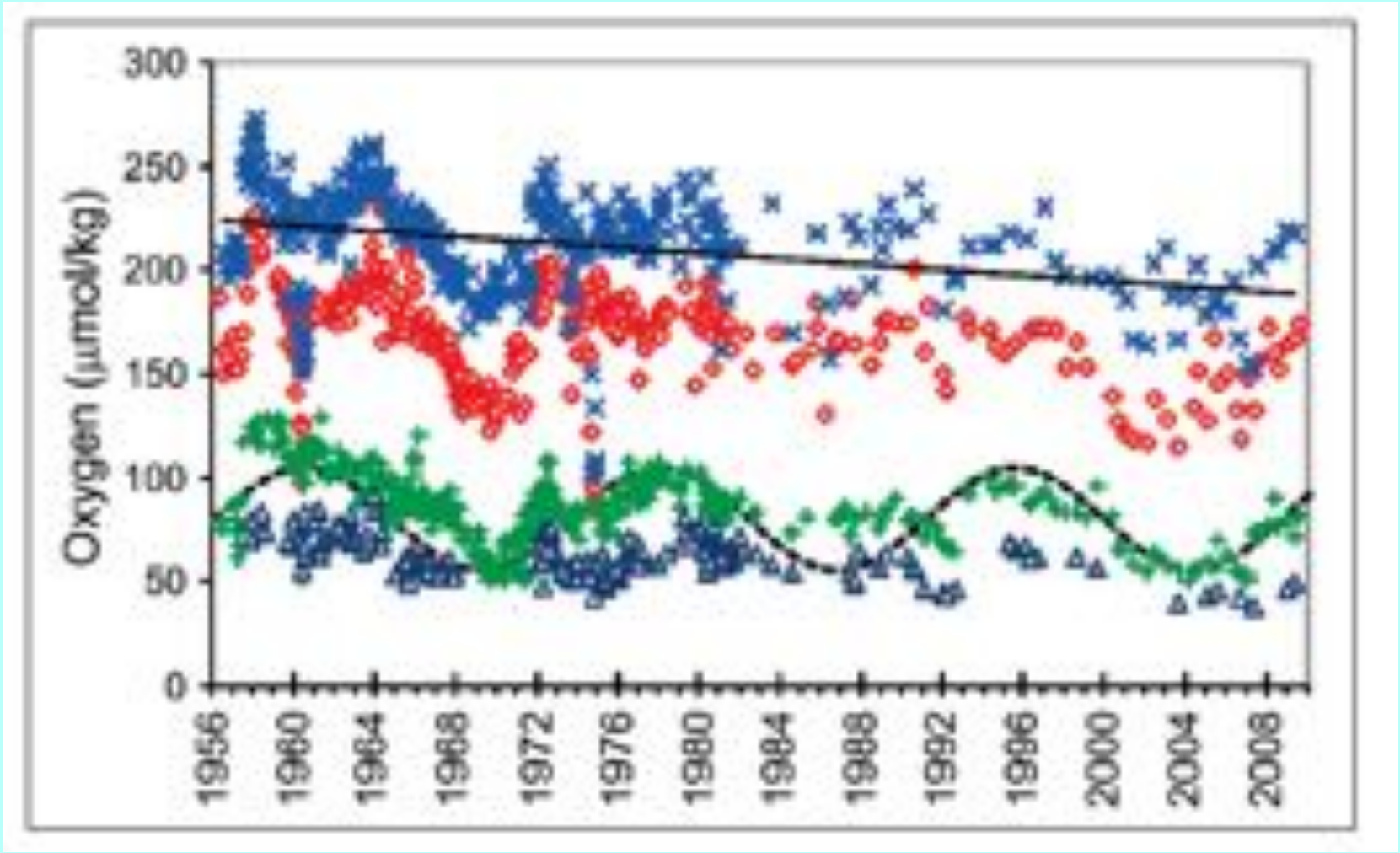
Stramma et al., 2008

Oxygen solubility decreases with increasing temperature



engineeringtoolbox.com

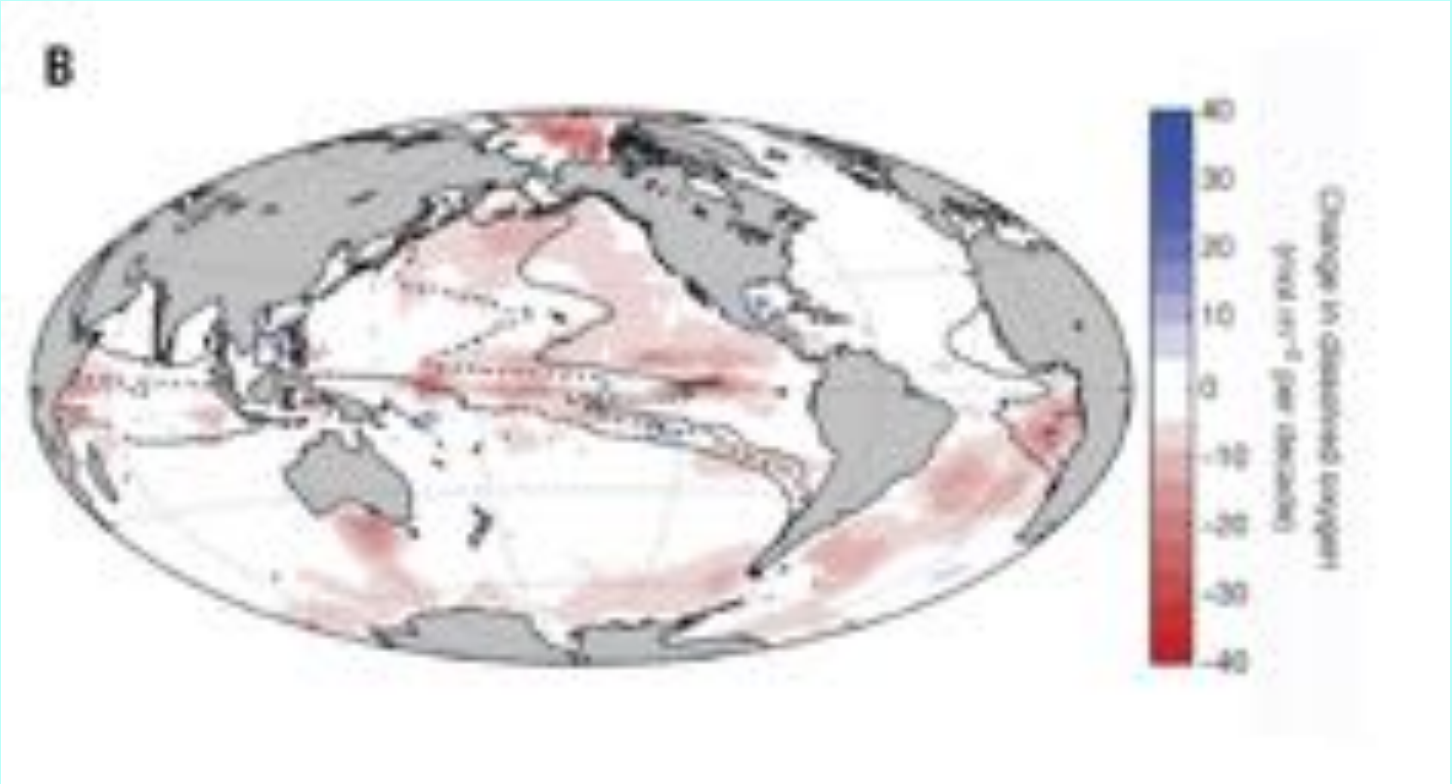
Oxygen is being lost from many ocean regions



NASA Astrobiology Institute

How might global balances of nitrogen and sulfur species shift as oxygen minimum zones expand?

Questions?



Breitburg et al., 2018