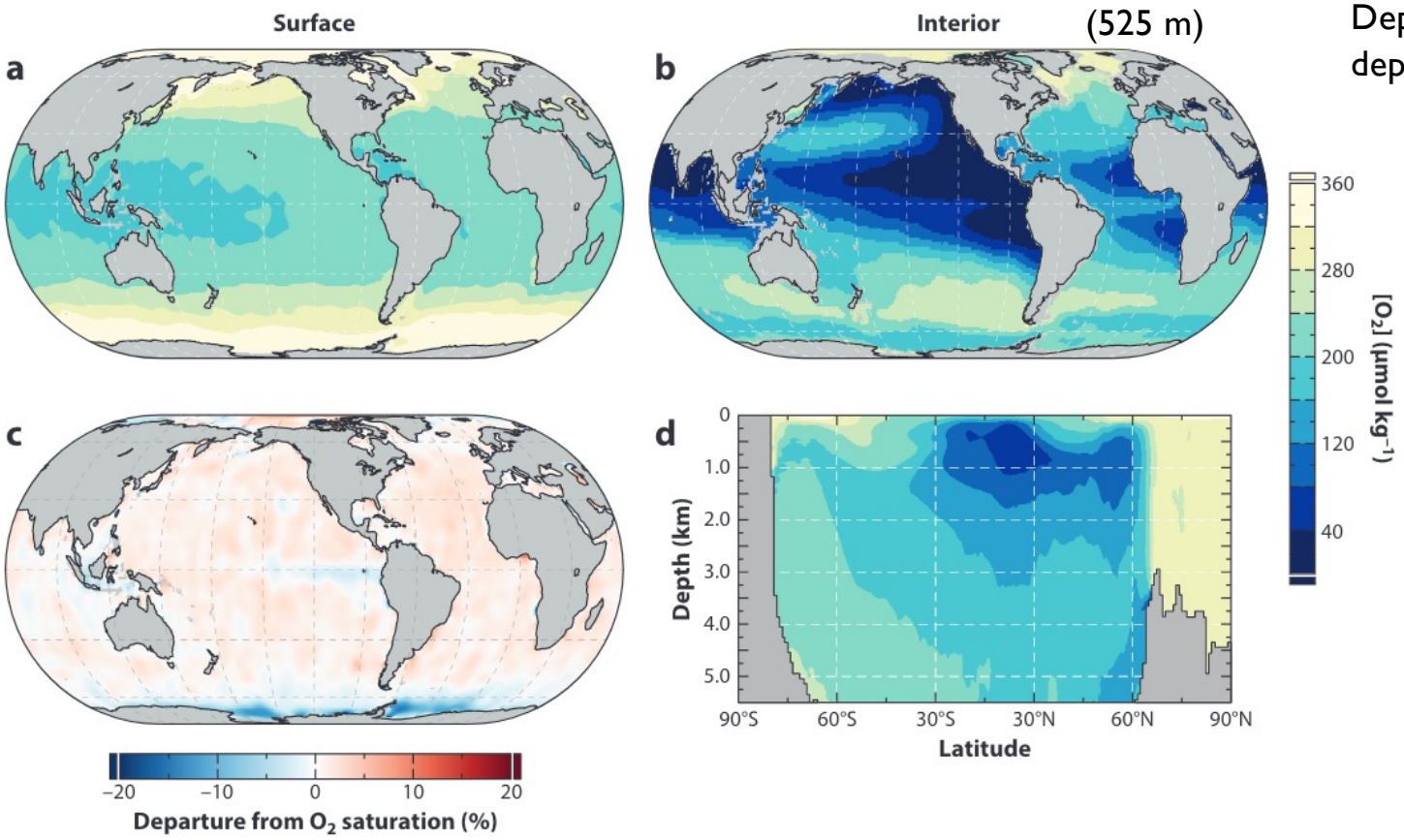
Oxygen in the Ocean: Where did it come from, where did it go?

Oxygen in the ocean today:

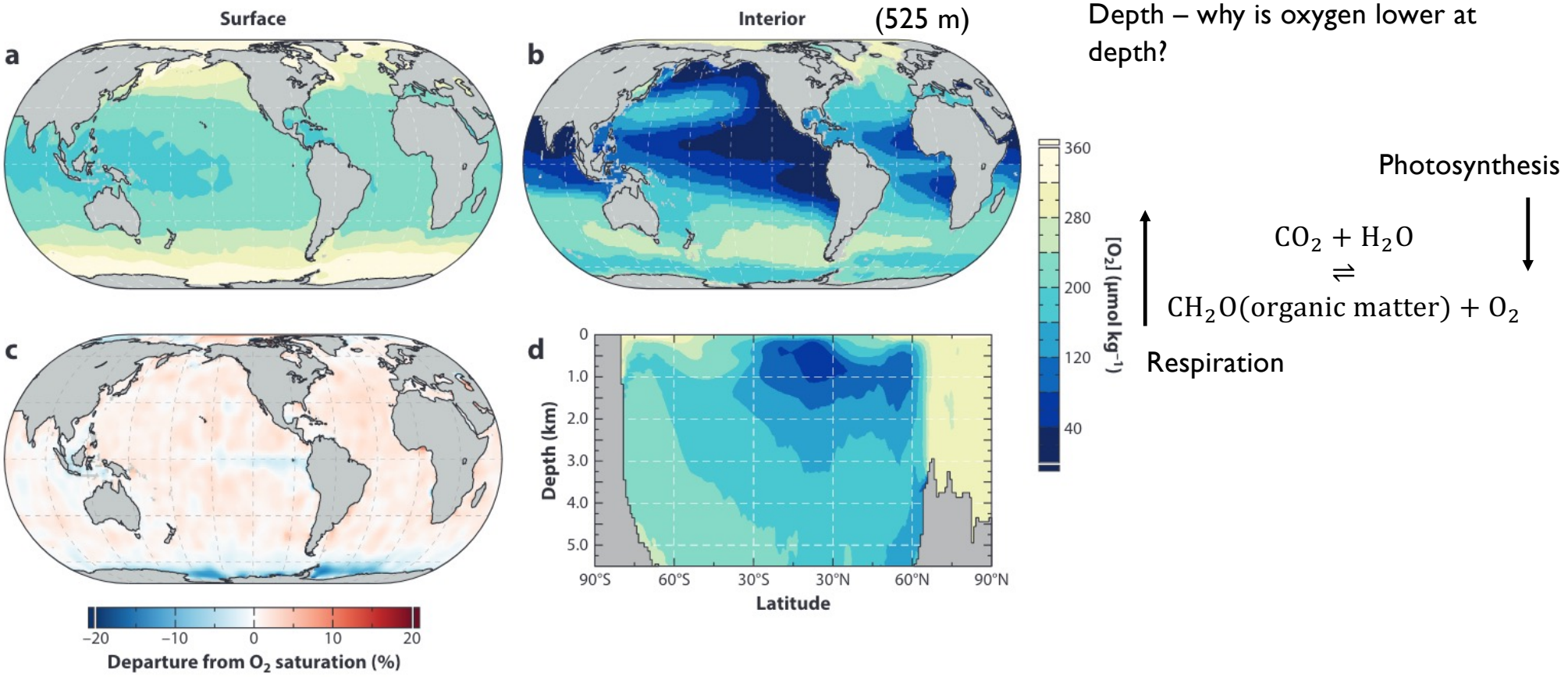
Surface – higher in cold areas, lower in warm areas (solubility!)

Depth – why is oxygen lower at depth?



Reinhard and Planavsky 2022

Oxygen in the ocean today:



Reinhard and Planavsky 2022

Surface – higher in cold areas, lower in warm areas (solubility!)

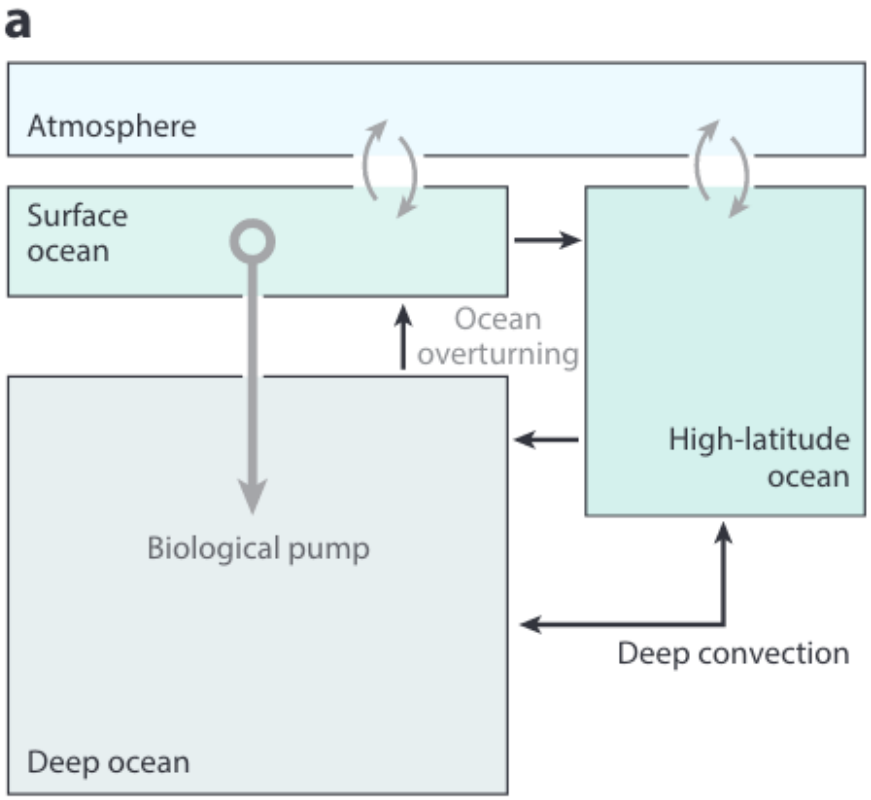
Depth – why is oxygen lower at depth?

Photosynthesis

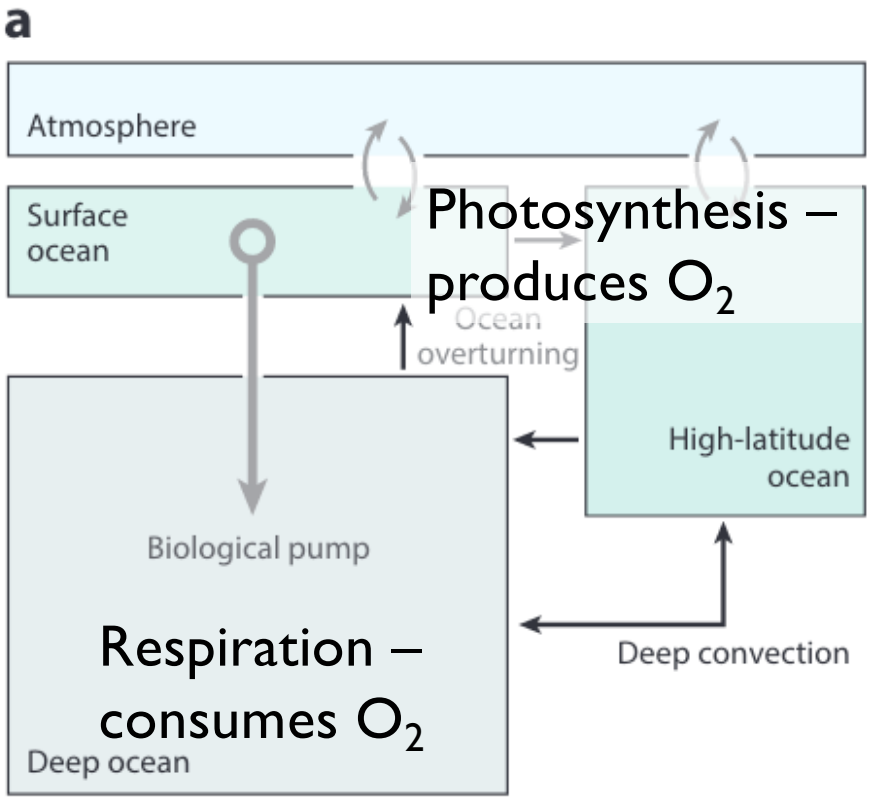
$$CO_2 + H_2O \rightleftharpoons CH_2O(\text{organic matter}) + O_2$$

Respiration

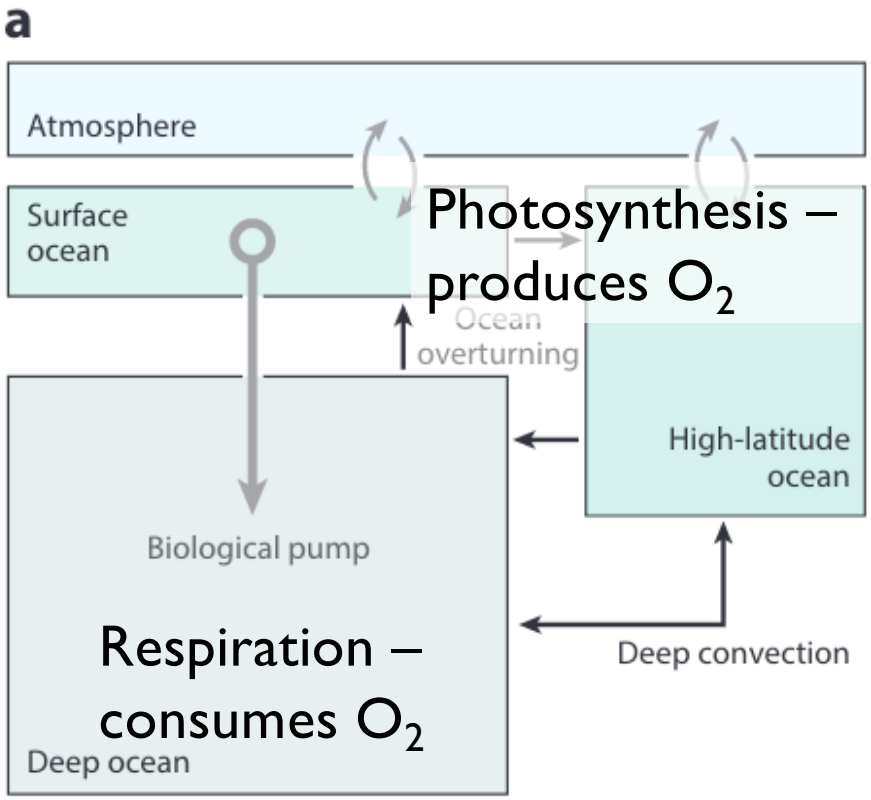
Oxygen cycling through the ocean and atmosphere

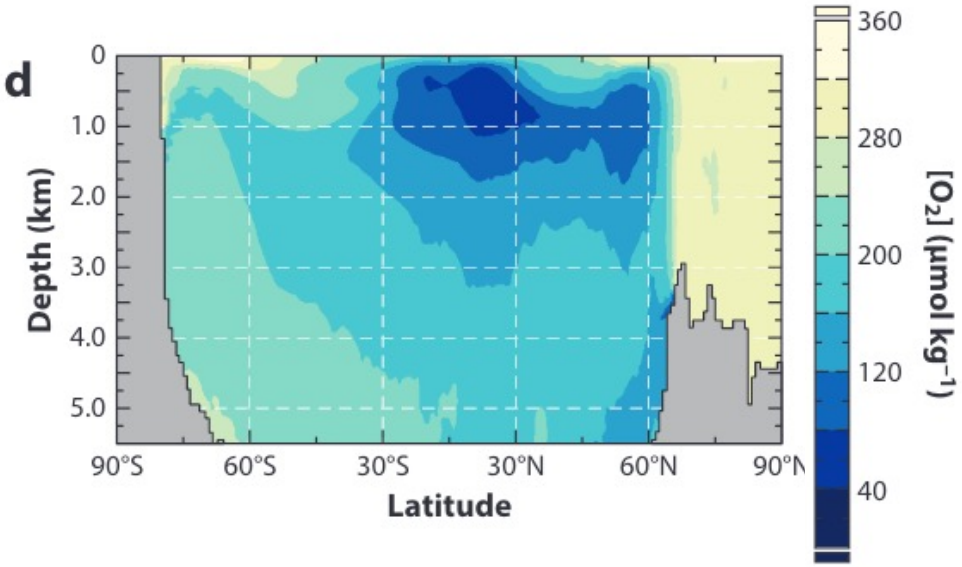


Oxygen cycling through the ocean and atmosphere

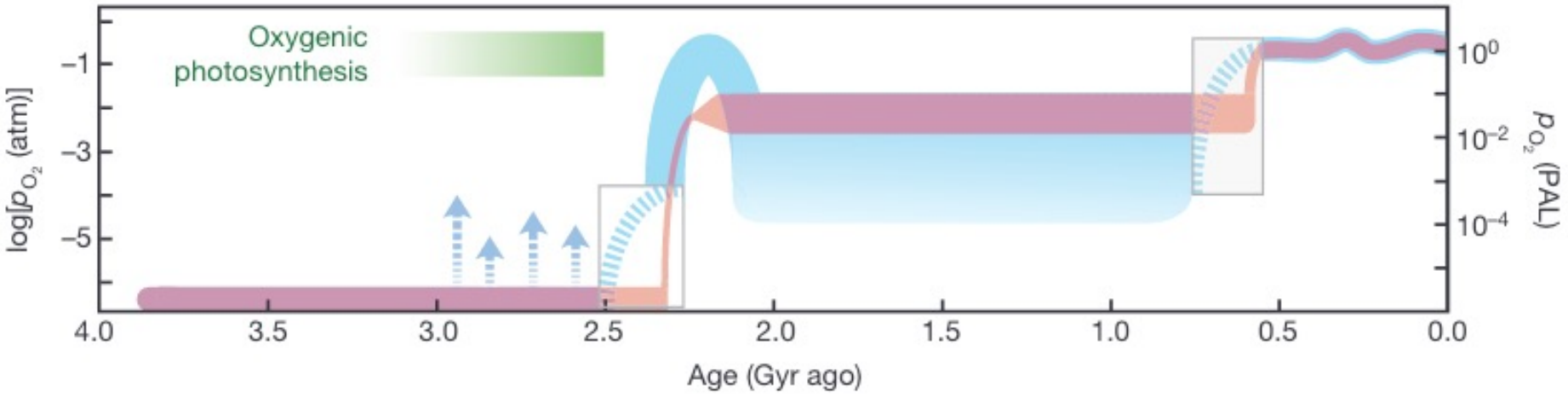


Oxygen cycling through the ocean and atmosphere





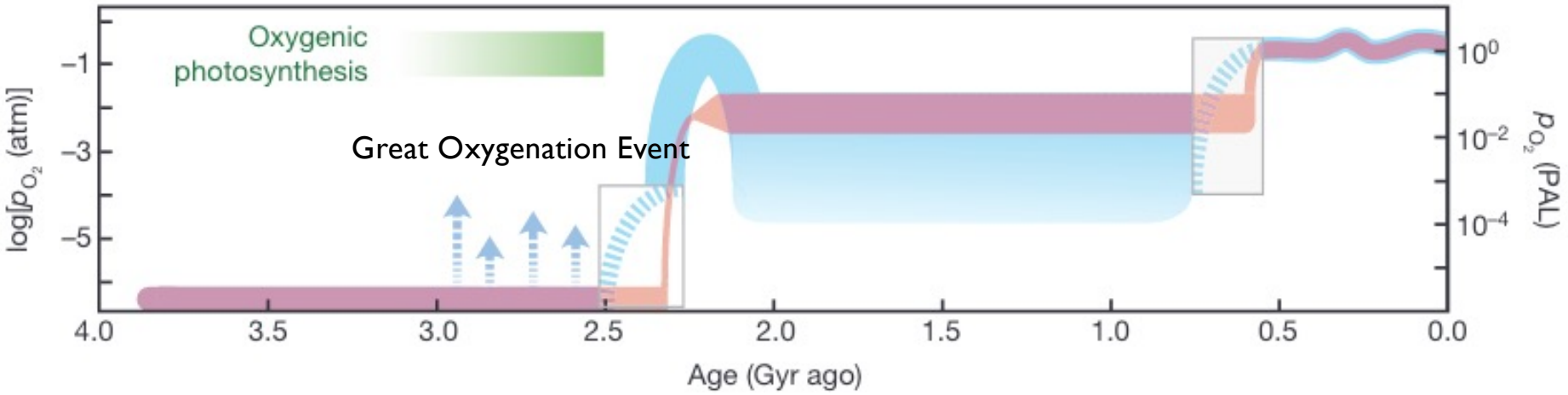
History of oxygen in the ocean:



pO_2 – oxygen partial pressure
PAL – Present Atmospheric Level

Lyons et al. 2014

History of oxygen in the ocean:



pO_2 – oxygen partial pressure
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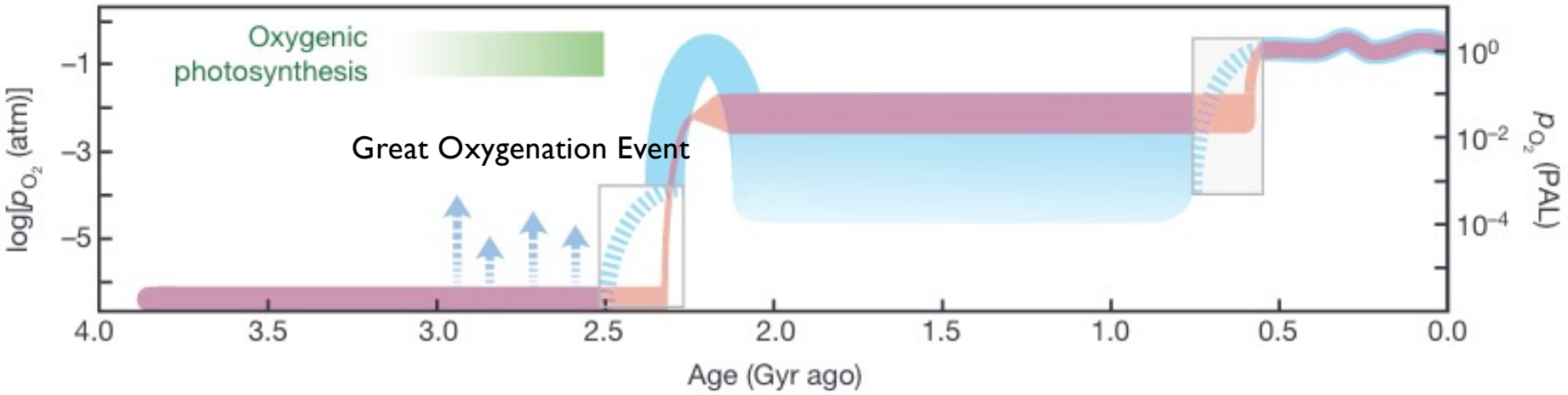
$$CO_2 + H_2O \rightleftharpoons CH_2O(\text{organic matter}) + O_2$$

Lyons et al. 2014

History of oxygen in the ocean:

Rise of vascular plants on land



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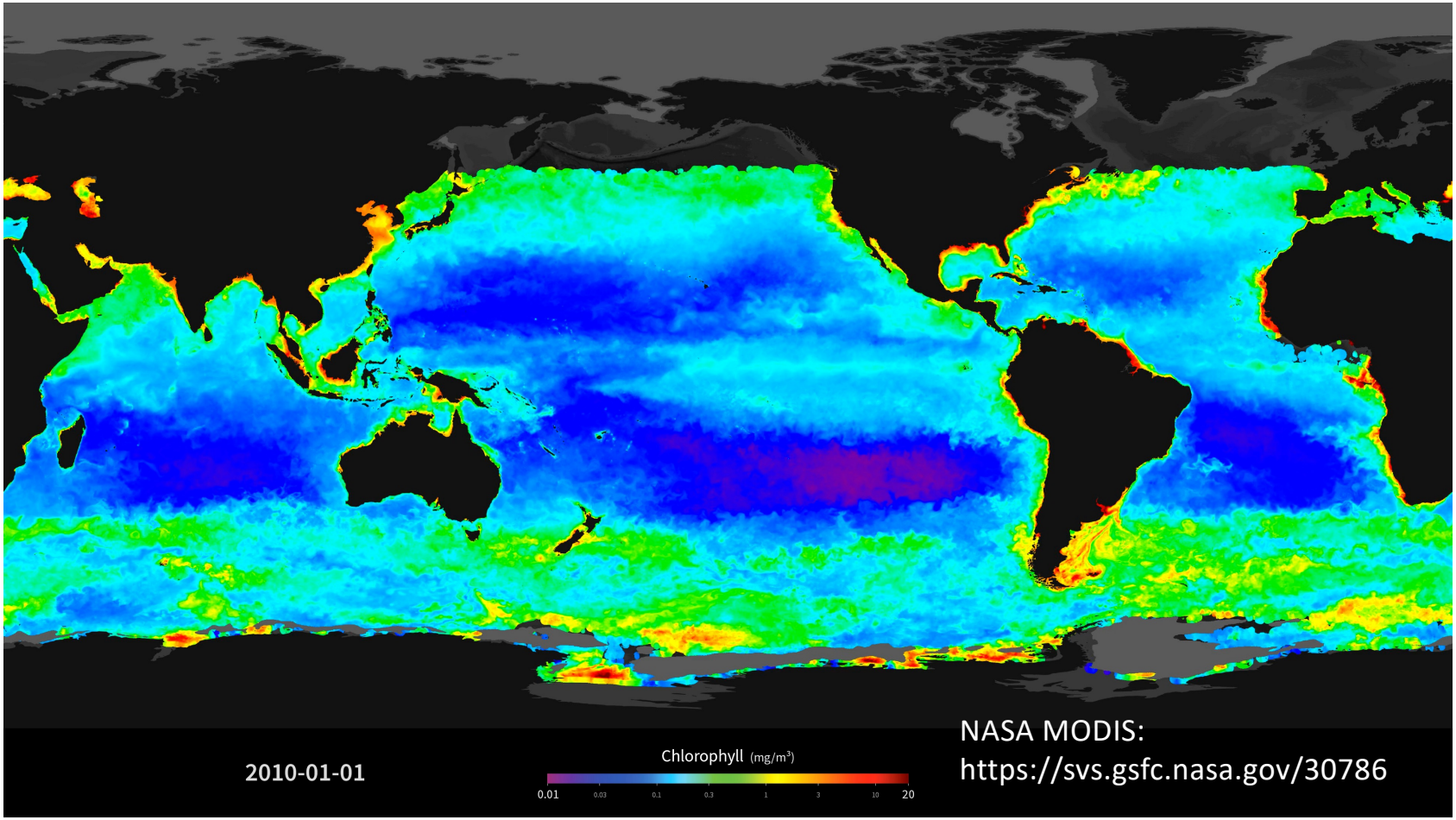
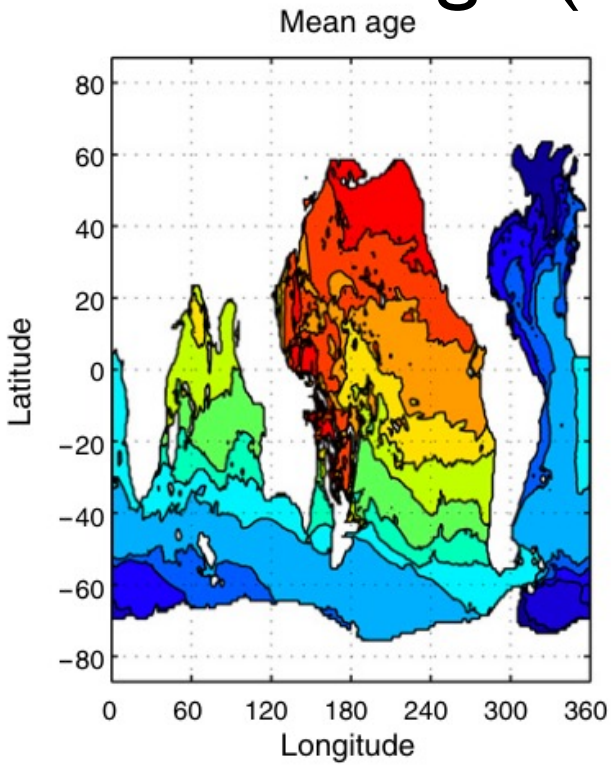
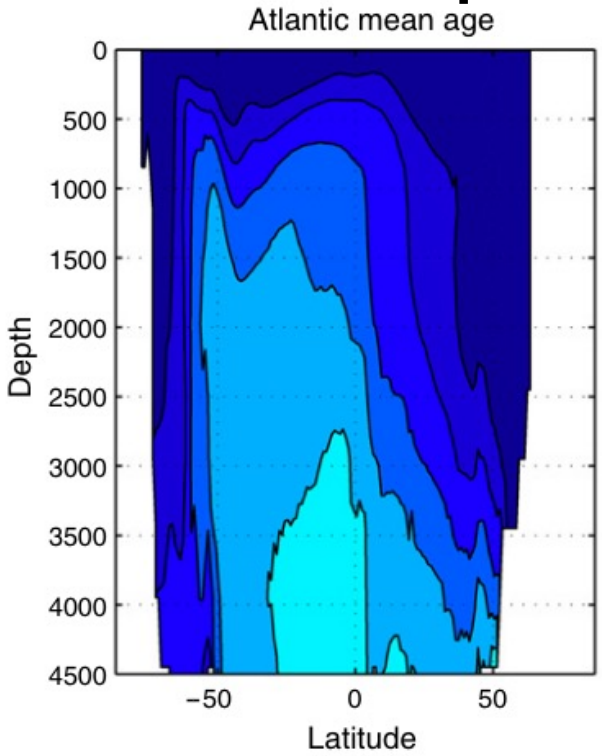
Lyons et al. 2014

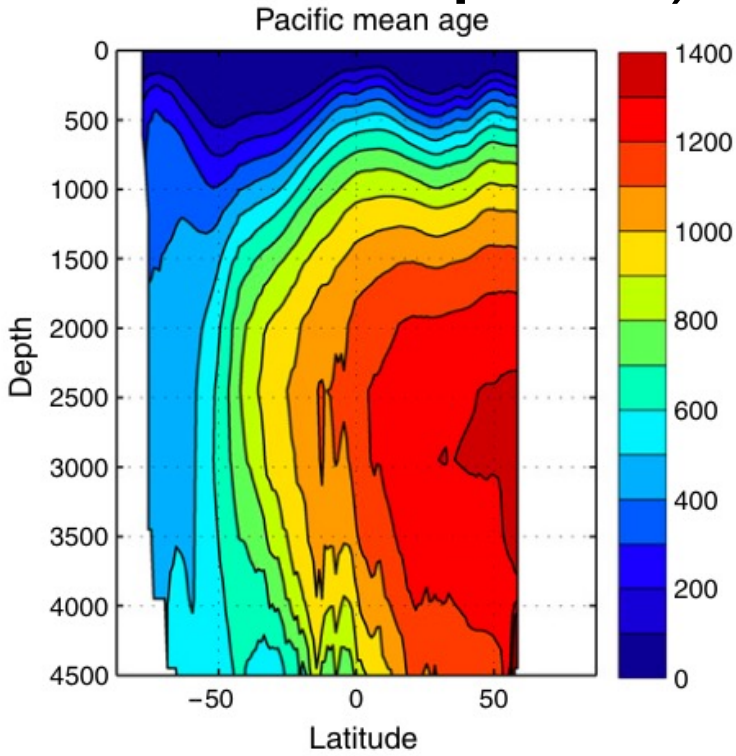
Surface ocean chlorophyll from satellites



Water age (time since exposure to atmosphere)

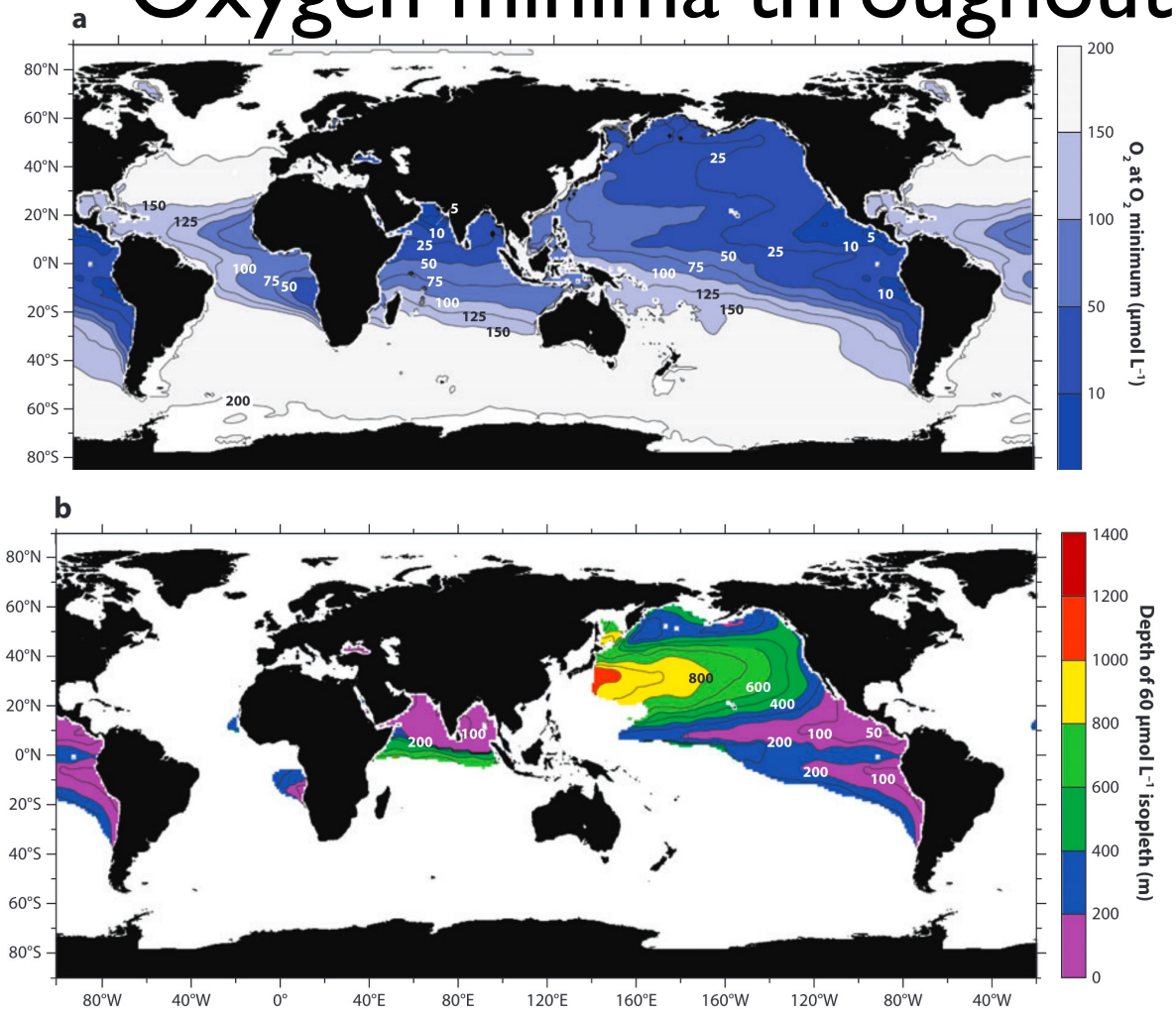






Khatiwala et al. 2012

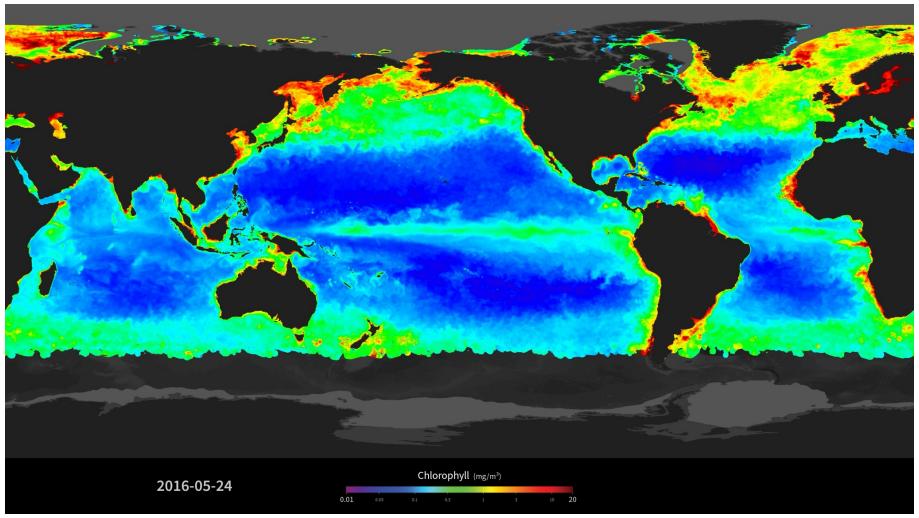
Oxygen minima throughout the ocean



Where do the lowest oxygen minima occur?

Keeling et al. 2010

Oxygen minima throughout the ocean



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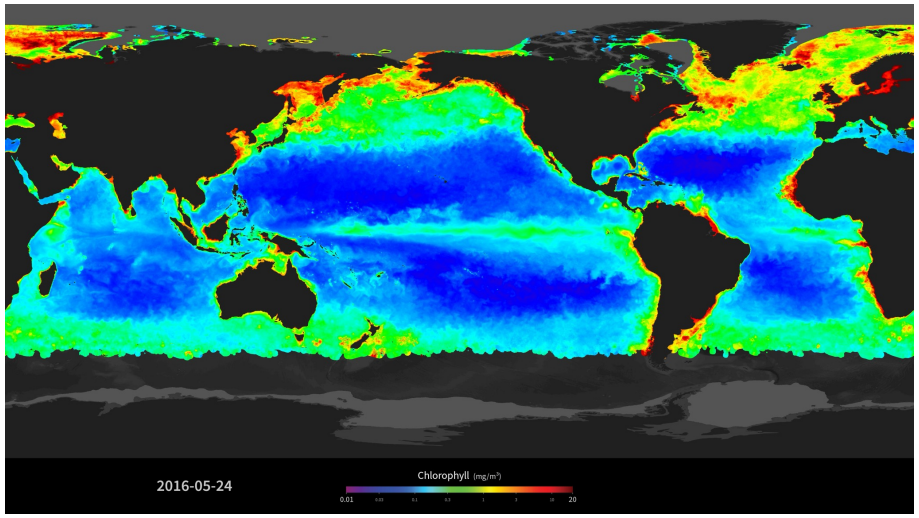
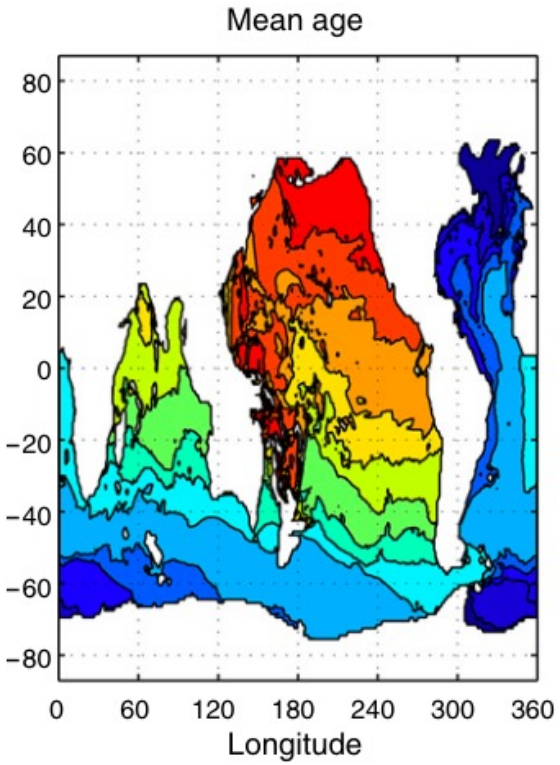
Oxygen minima throughout the ocean





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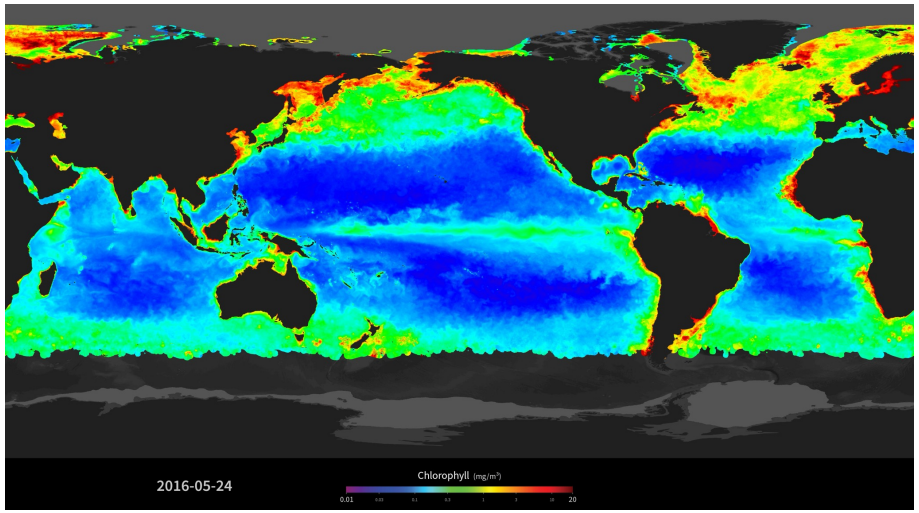
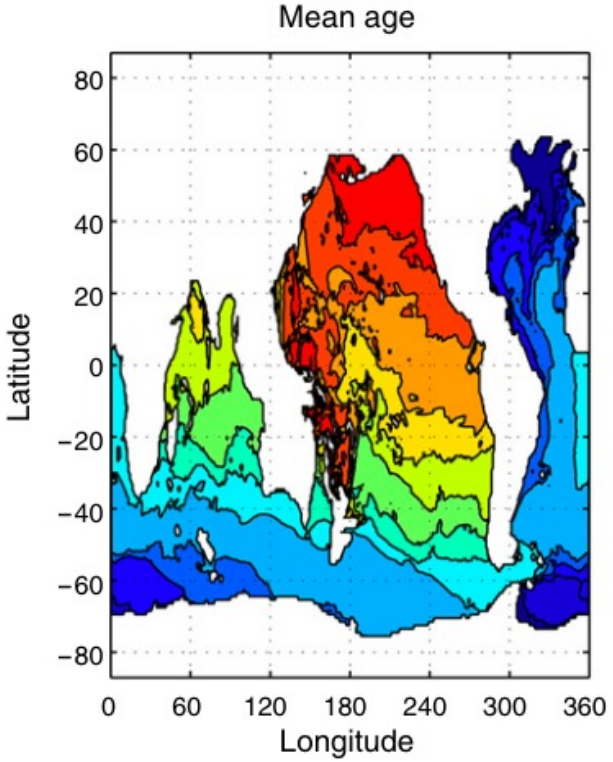
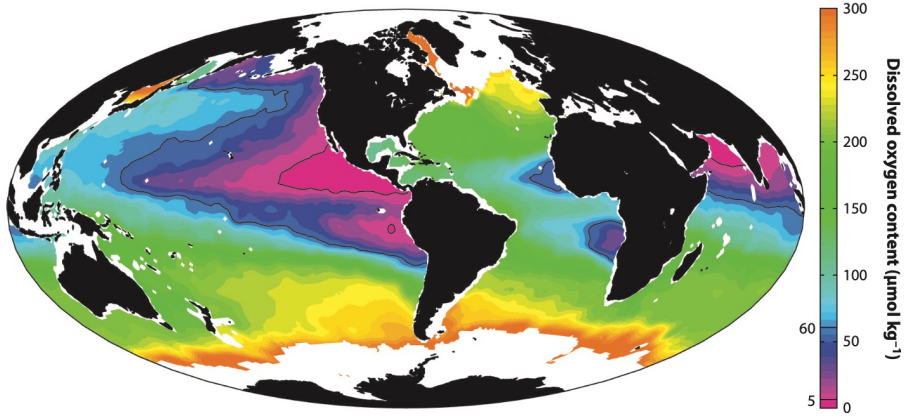
Oxygen minima throughout the ocean

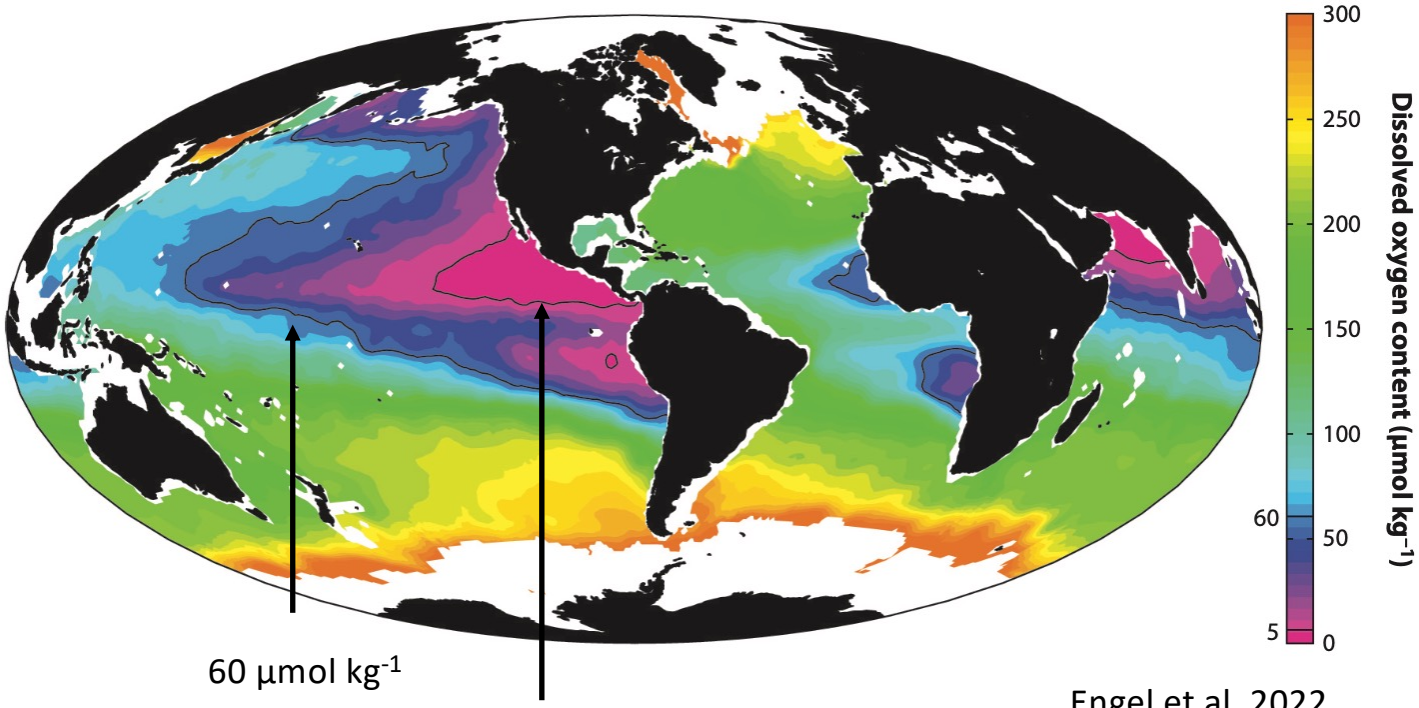






Where do the lowest oxygen minima occur?

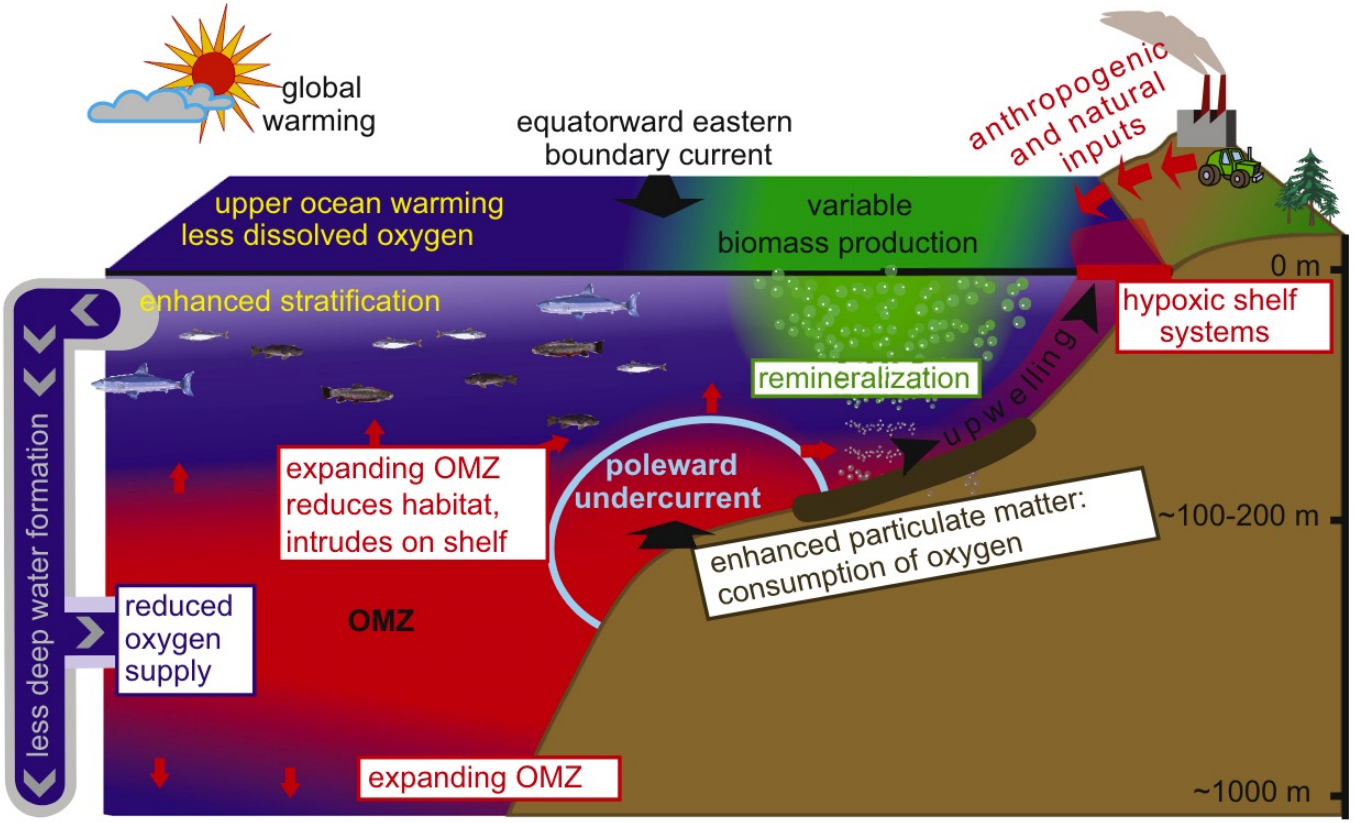
Oxygen minimum zones globally



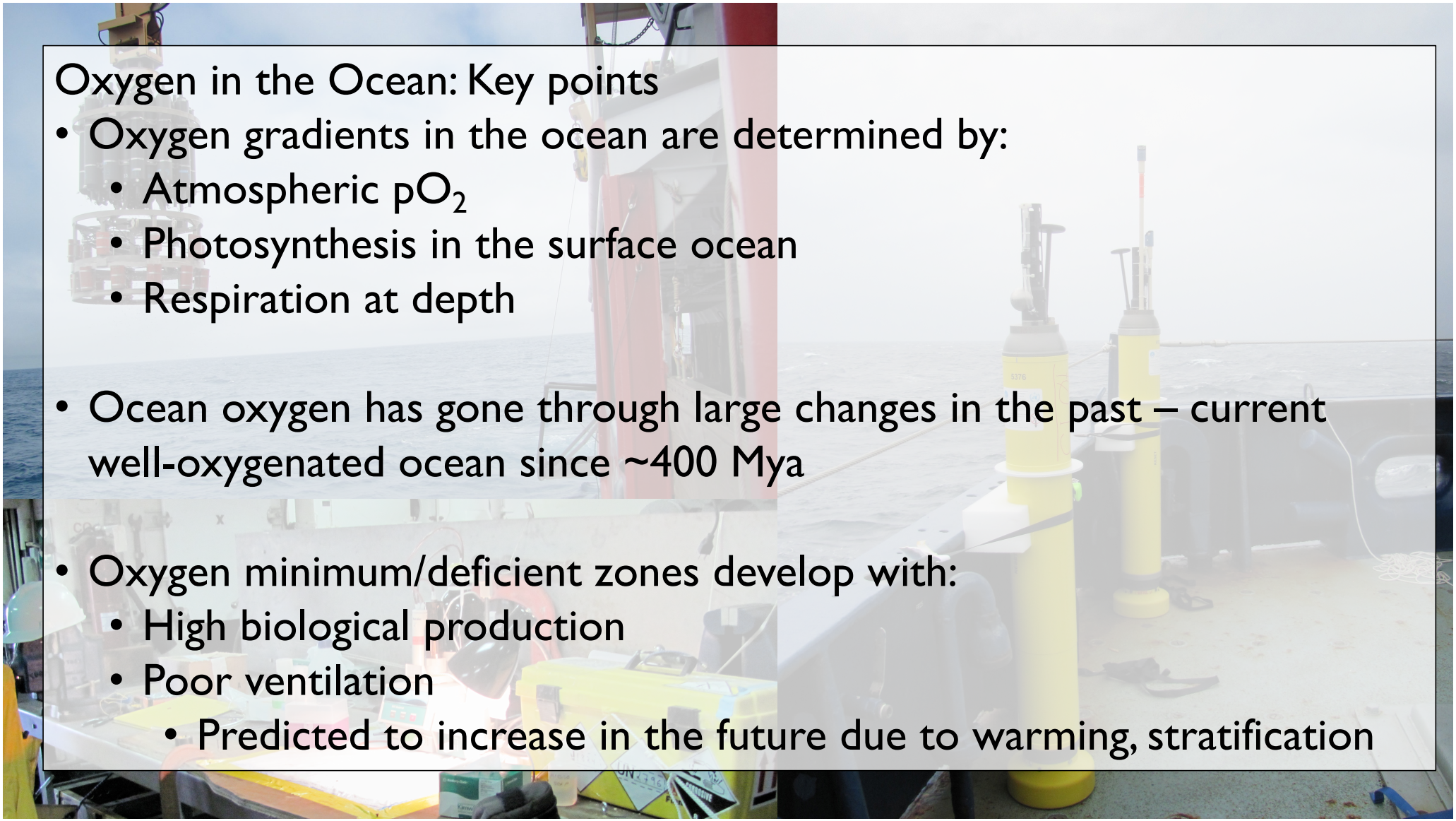
Engel et al. 2022

Oxygen concentration at 27.05 kg m^{-3} isopycnal

Oxygen minimum (deficient) zones: Future changes



Stramma et al. 2010



Oxygen in the Ocean: Key points

- Oxygen gradients in the ocean are determined by:
  - Atmospheric pO_2
  - Photosynthesis in the surface ocean
  - Respiration at depth

- Ocean oxygen has gone through large changes in the past – current well-oxygenated ocean since ~400 Mya

- Oxygen minimum/deficient zones develop with:
  - High biological production
  - Poor ventilation
    - Predicted to increase in the future due to warming, stratification