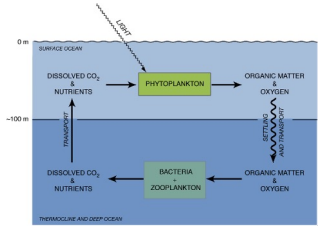
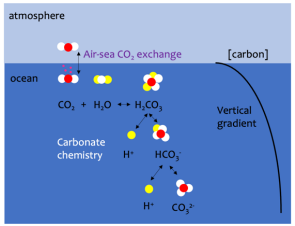
Impacts of Marine Heatwaves on Ocean Biogeochemistry

Nikki Lovenduski
University of Colorado Boulder

What will you learn in this lecture?

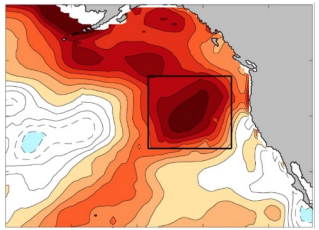


Biological activity and circulation set the mean distribution of chemicals in the ocean



Gases and chemistry in the ocean

- Solubility
- Carbonate chemistry



Marine heatwaves impact multiple ocean biogeochemical processes

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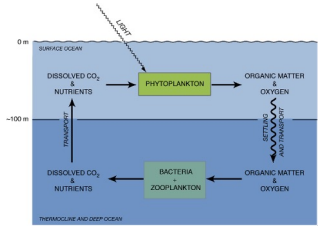

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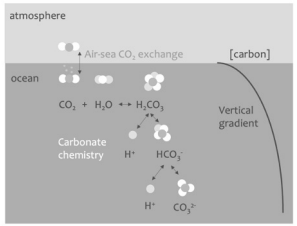

Gases and chemistry in the ocean

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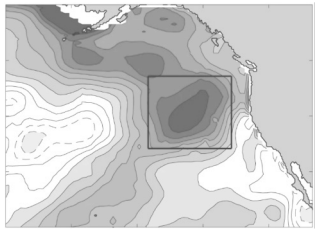


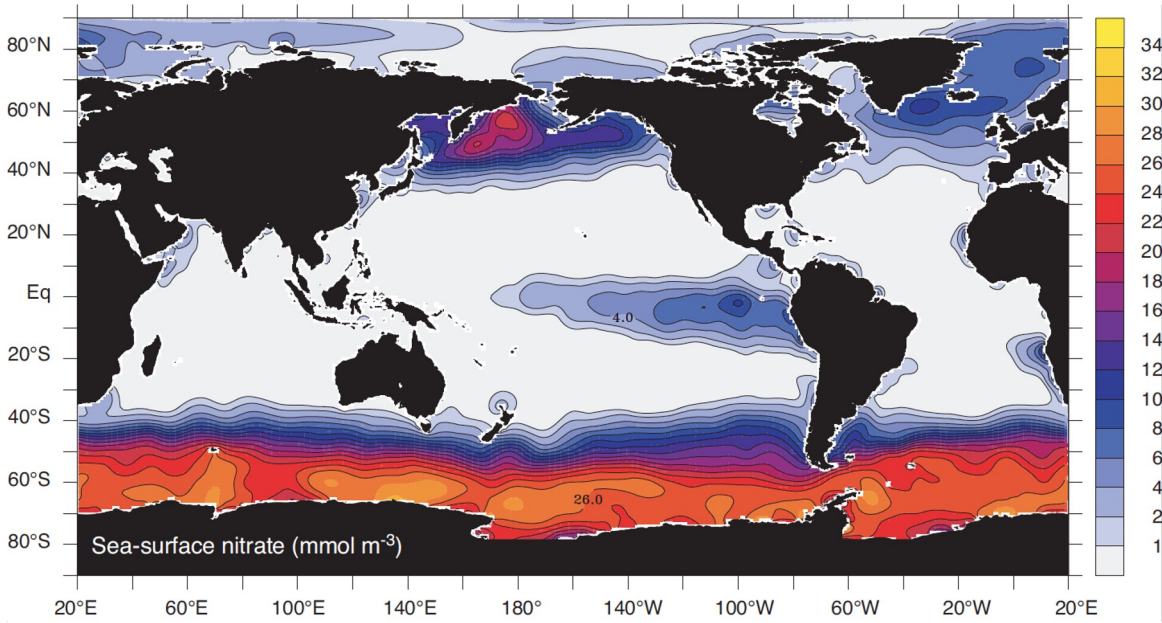
Marine heatwaves impact multiple ocean biogeochemical processes

Breakout question (in groups of 4 - 5 people)

This map shows the annual-mean surface ocean nitrate concentration [NO_3^-].

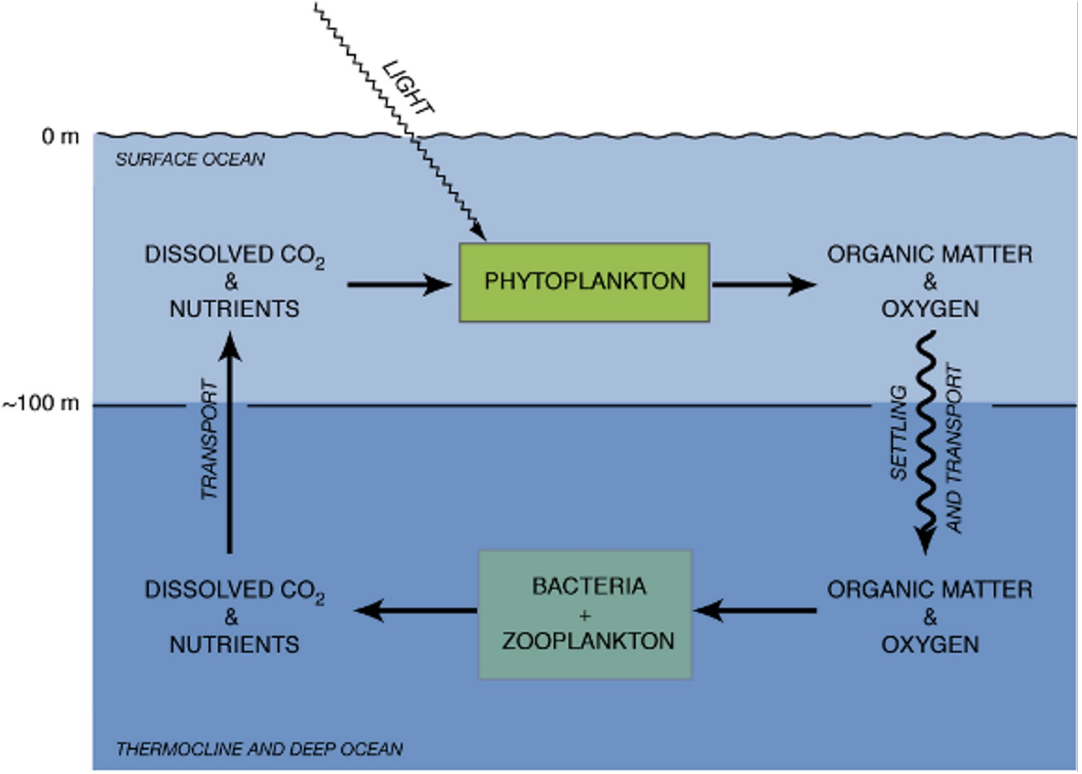
1. Why are the tropical Pacific and subpolar regions characterized by such high nitrate concentrations?

2. Why are the subtropics characterized by near-zero nitrate concentrations?



Sarmiento and Gruber (2006)

The role of biology



Sarmiento and Gruber (2006)

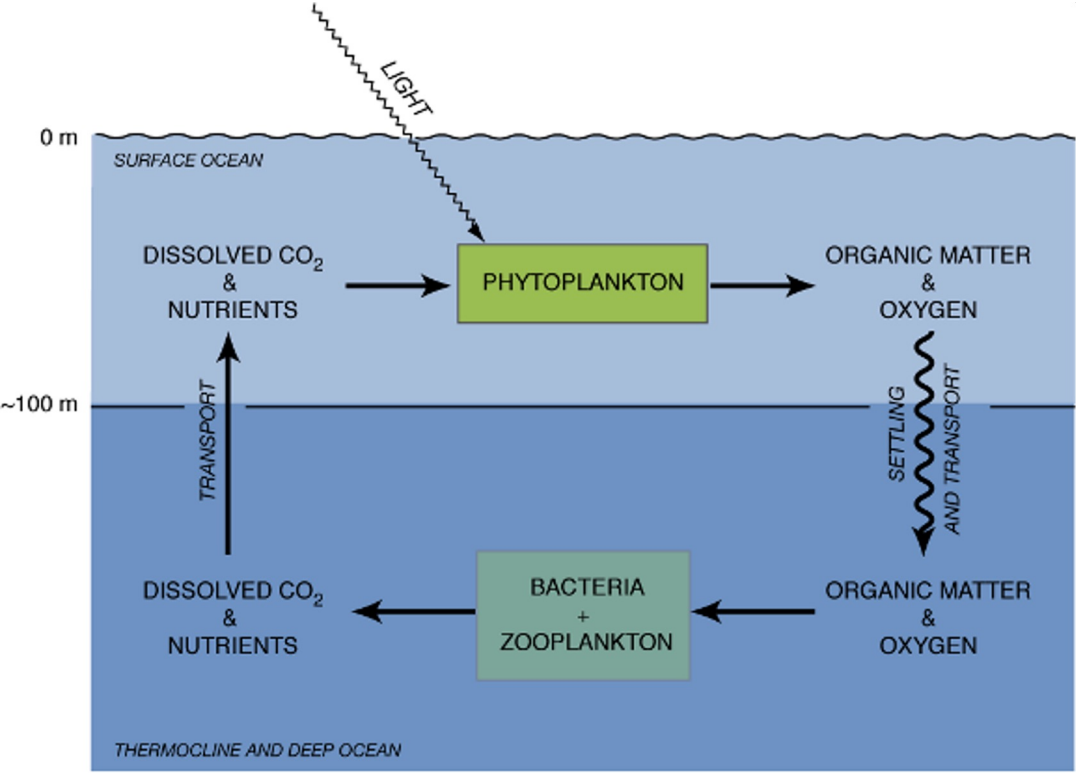
Photosynthesis

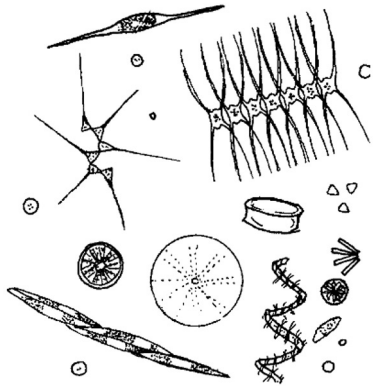
$106\ CO_2 + 16\ HNO_3 + H_3PO_4$
$\rightarrow$organic matter + $150\ O_2$

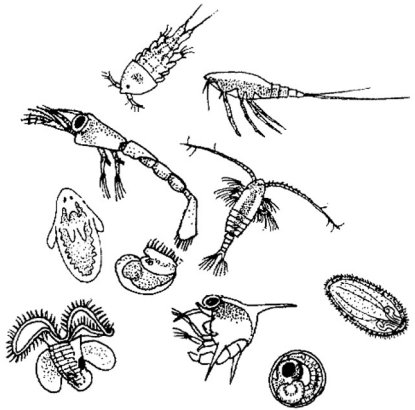
Remineralization

organic matter + $150\ O_2$
$\rightarrow 106\ CO_2 + 16\ HNO_3 + H_3PO_4$

The role of biology

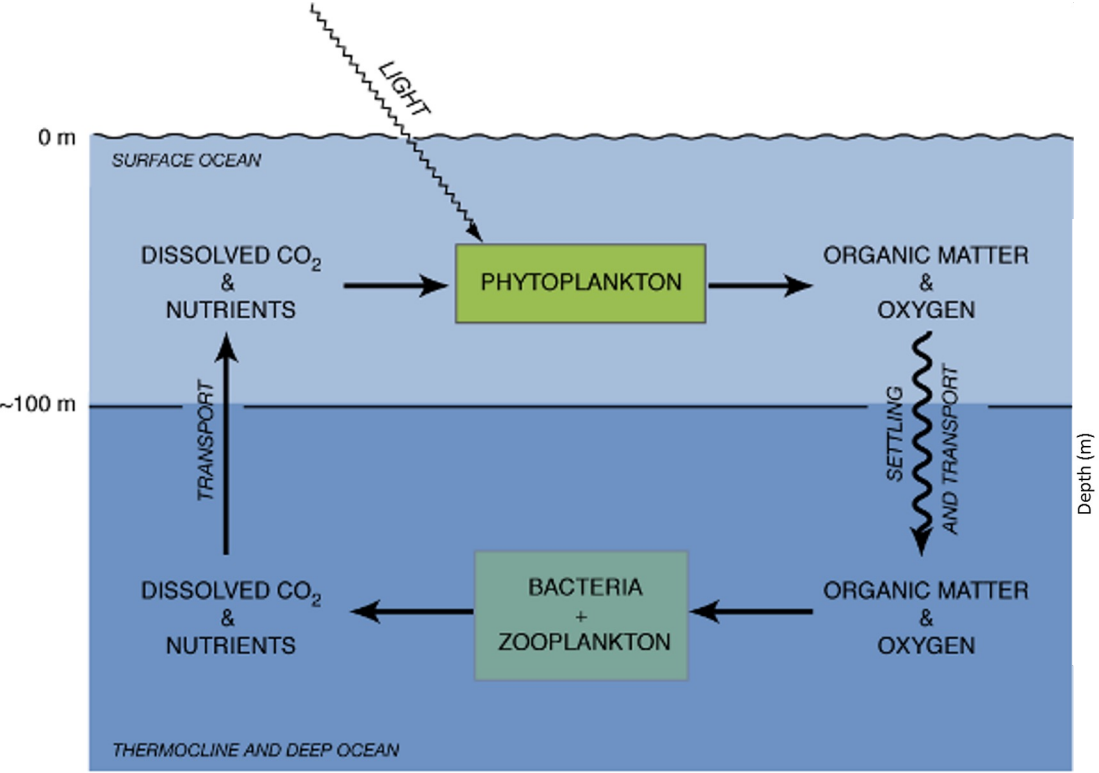


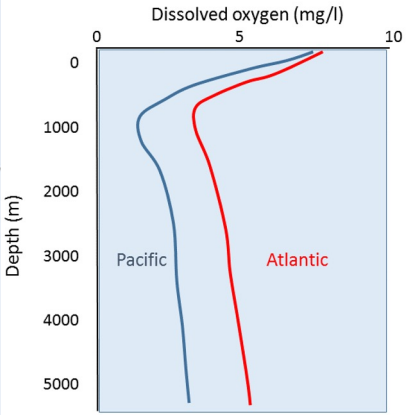


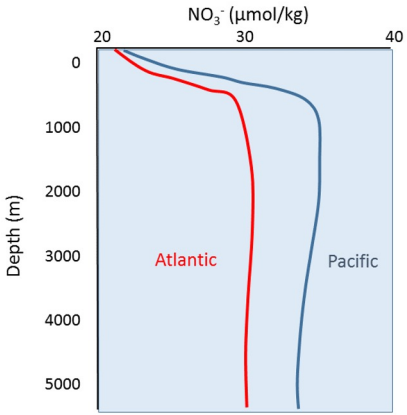


Sarmiento and Gruber (2006)

The role of biology

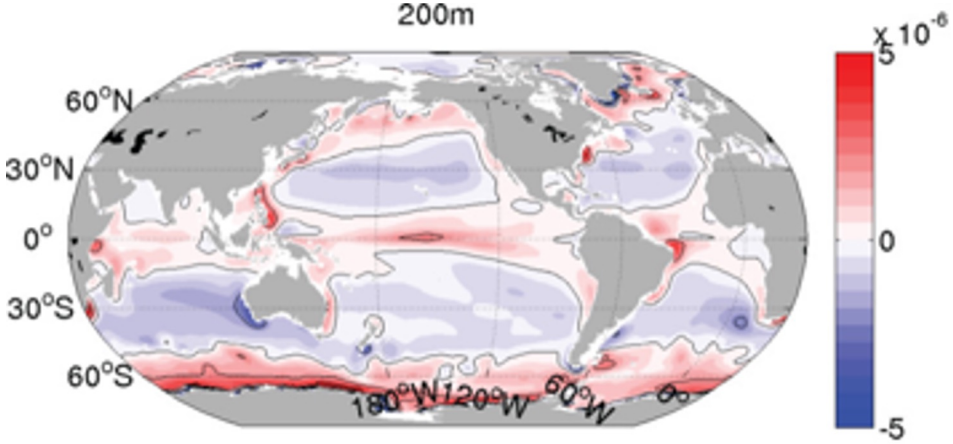


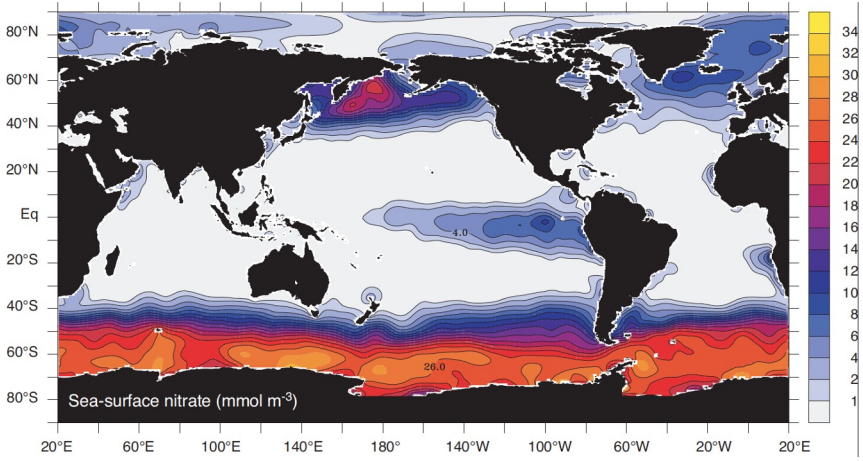


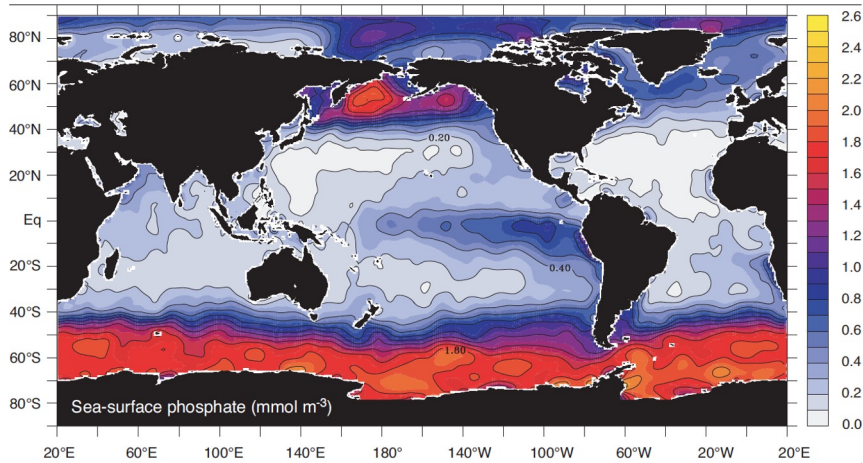


Sarmiento and Gruber (2006)

Nutrient upwelling



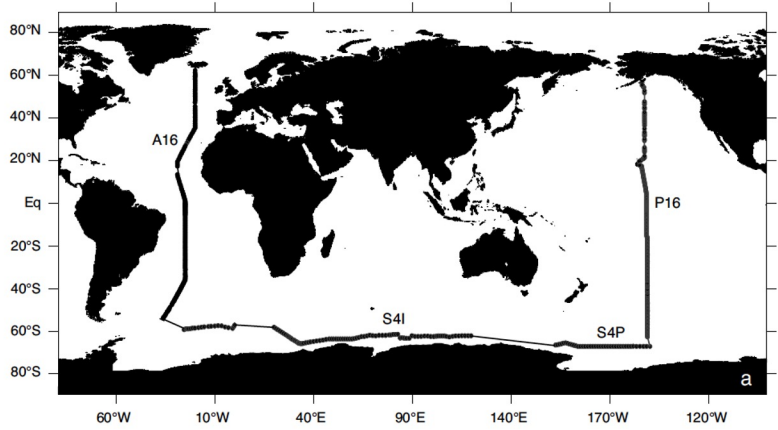




Liang et al. (2017)

Sarmiento and Gruber (2006)

The cruise you would never want to go on

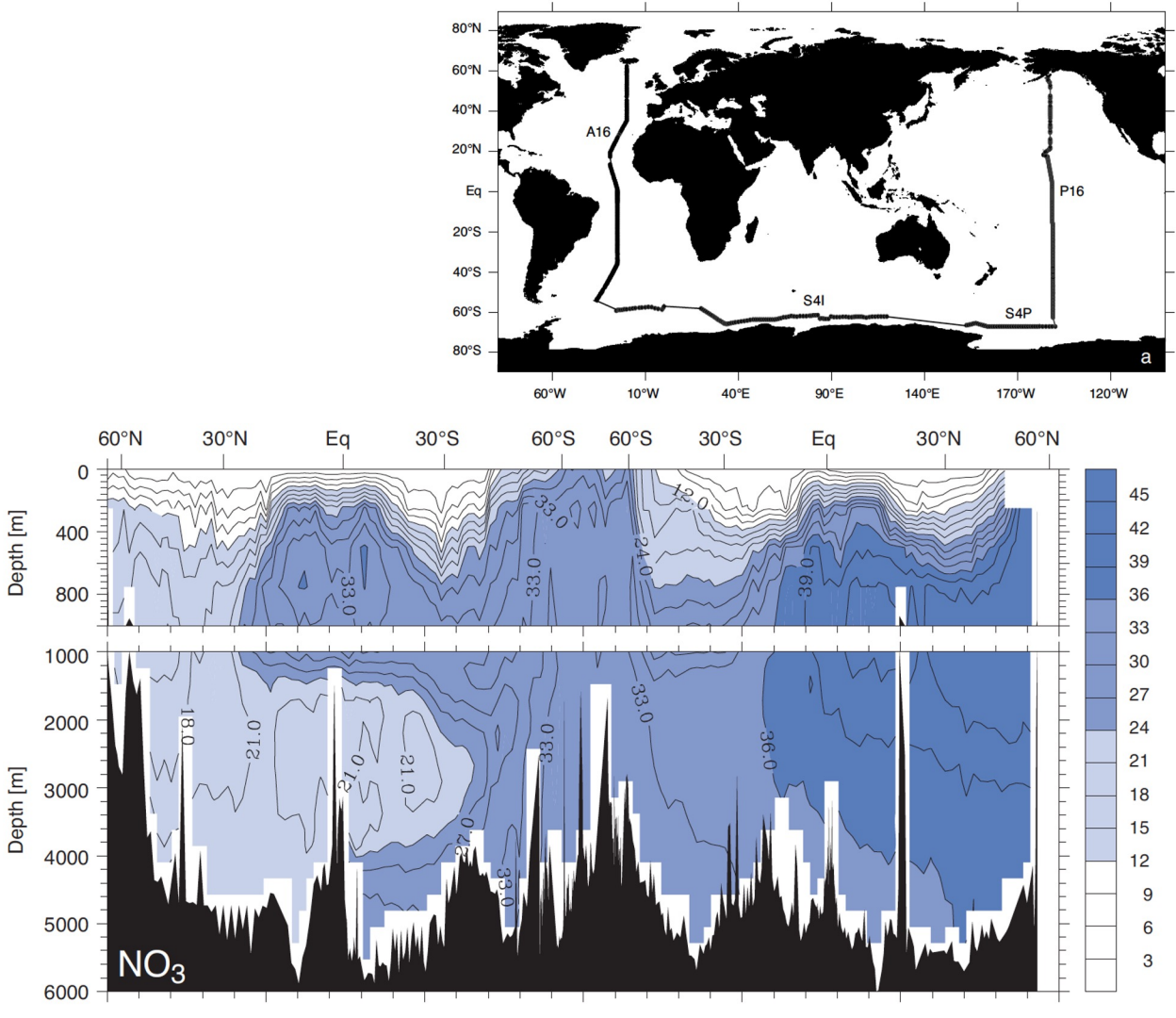


Sarmiento and Gruber (2006)

Breakout question

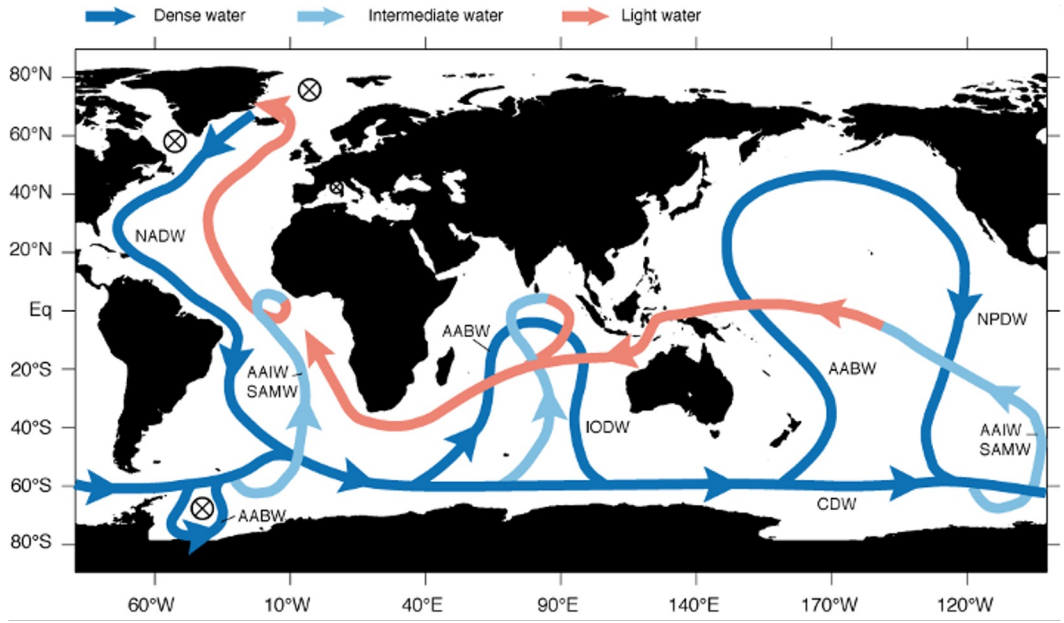
This figure shows the nitrate concentration [NO_3^-] on the cruise you would never want to go on.

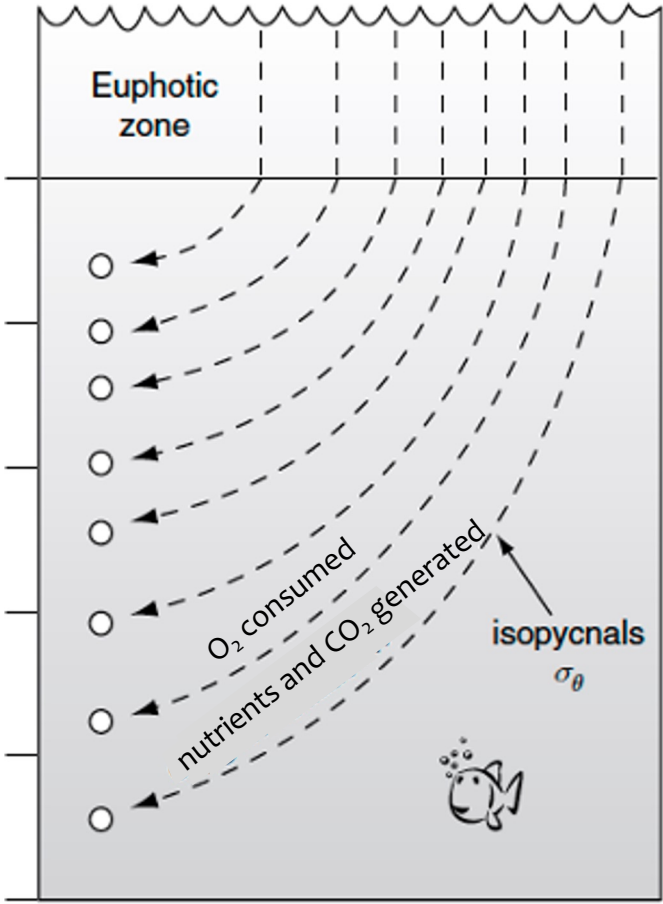
Why is [NO_3^-] so elevated in the deep North Pacific?



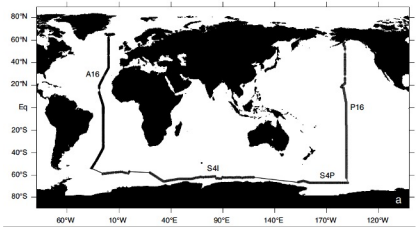
Sarmiento and Gruber (2006)

Signatures of remineralization in the thermohaline circulation

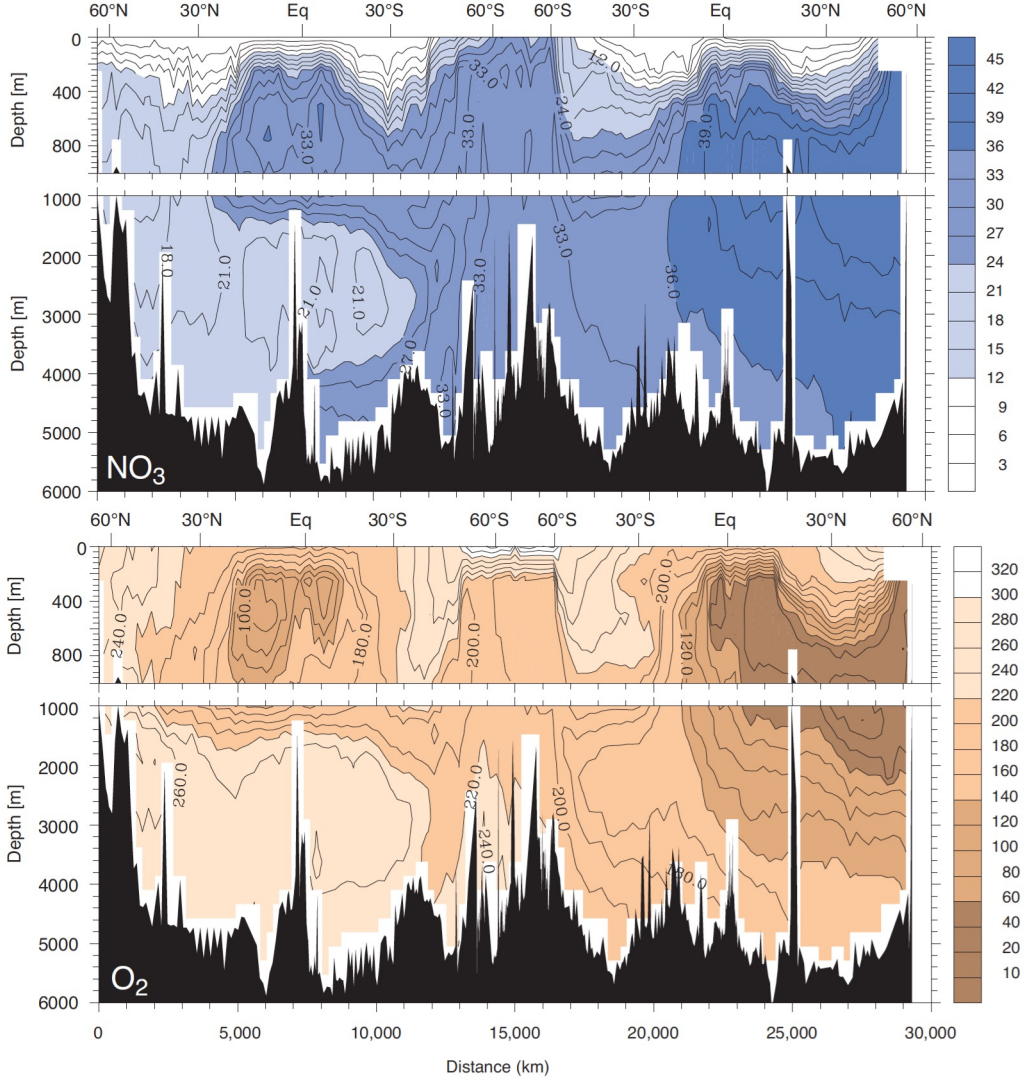




Sarmiento and Gruber (2006); Emerson and Hedges (2008)

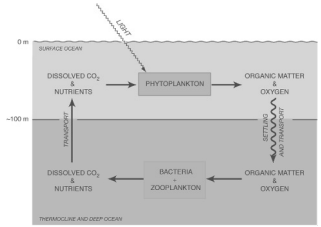


The North Pacific subsurface is characterized by the highest nutrient and carbon concentrations and the lowest oxygen concentrations in the global ocean.

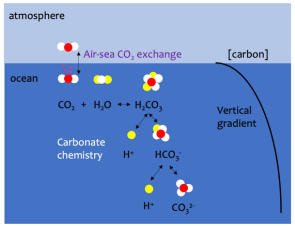


Sarmiento and Gruber (2006)

What will you learn in this lecture?

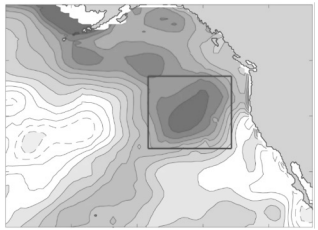


Biological activity and circulation set the mean distribution of chemicals in the ocean



Gases and chemistry in the ocean

- Solubility
- Carbonate chemistry



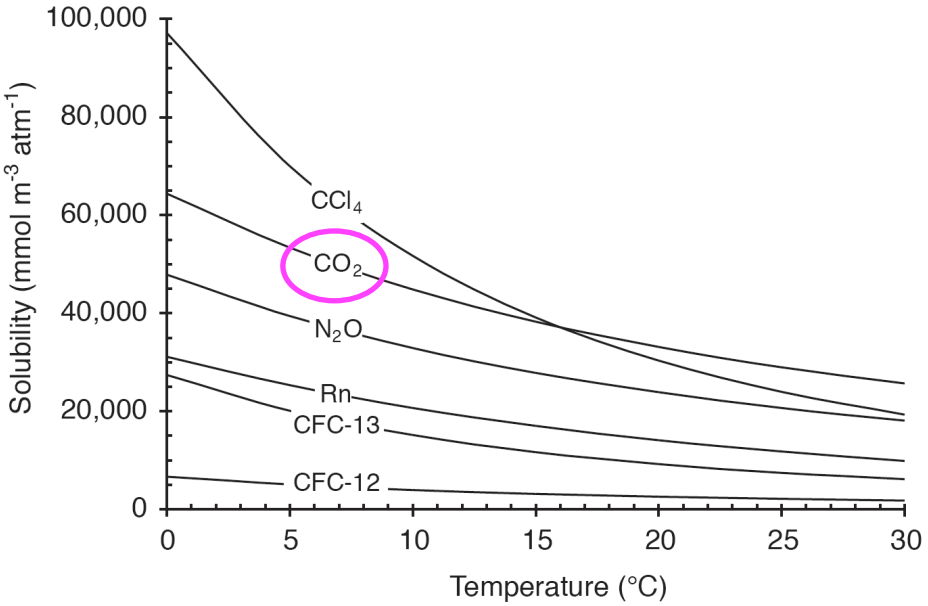
Marine heatwaves impact multiple ocean biogeochemical processes

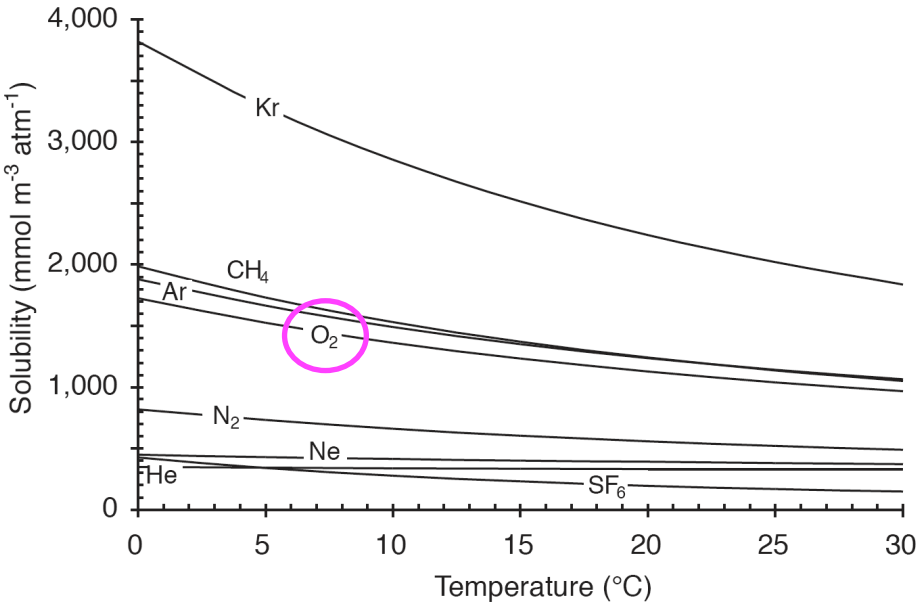
Breakout question

1. If you open a can of soda and leave it out, it will eventually go “flat”. Why does this happen?

2. If you wanted to prevent it from going flat, would you put it on the warm countertop or in the cold refrigerator?

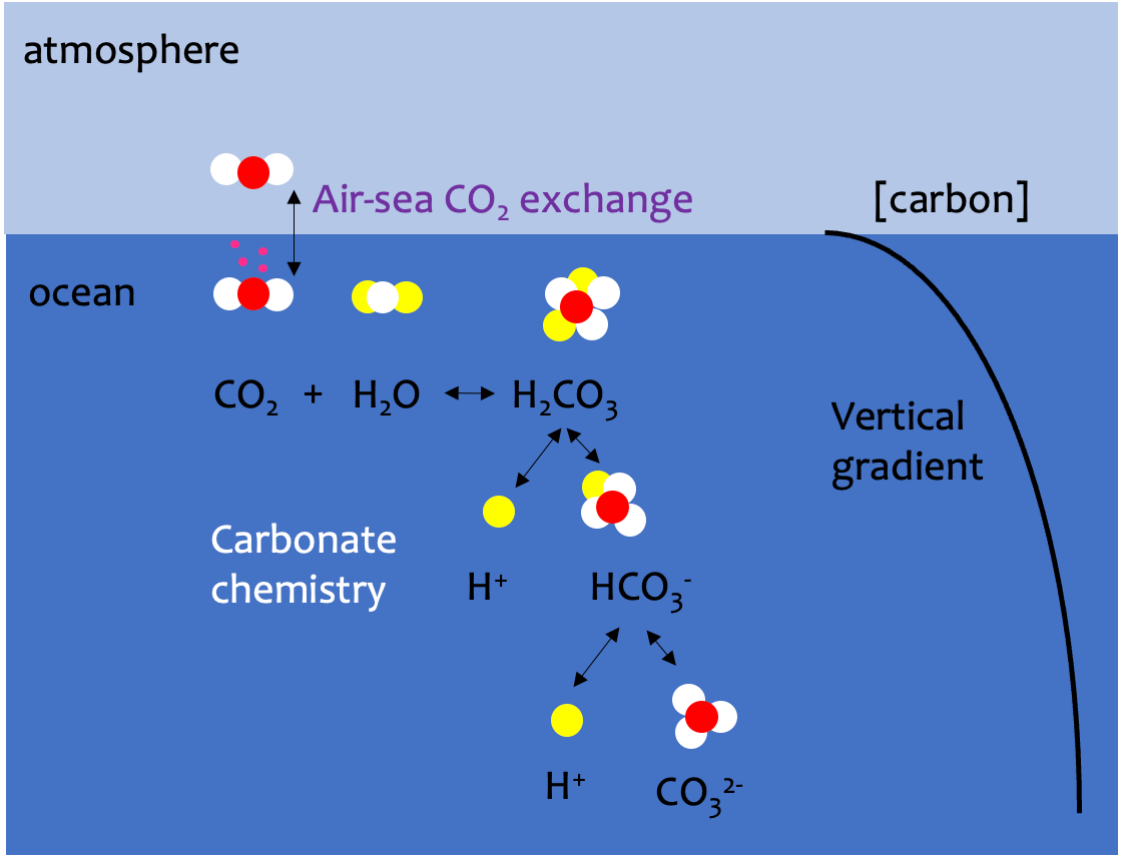
Gas solubility is a function of temperature



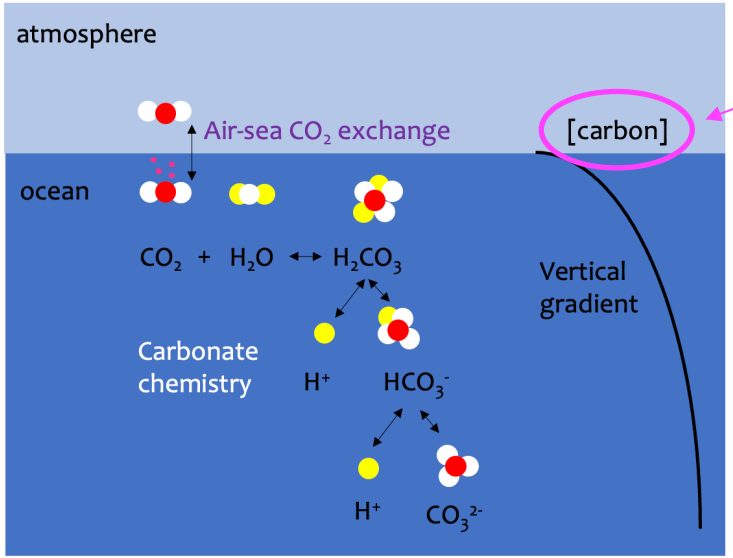


Sarmiento and Gruber (2006)

Carbonate chemistry



Dissolved Inorganic Carbon

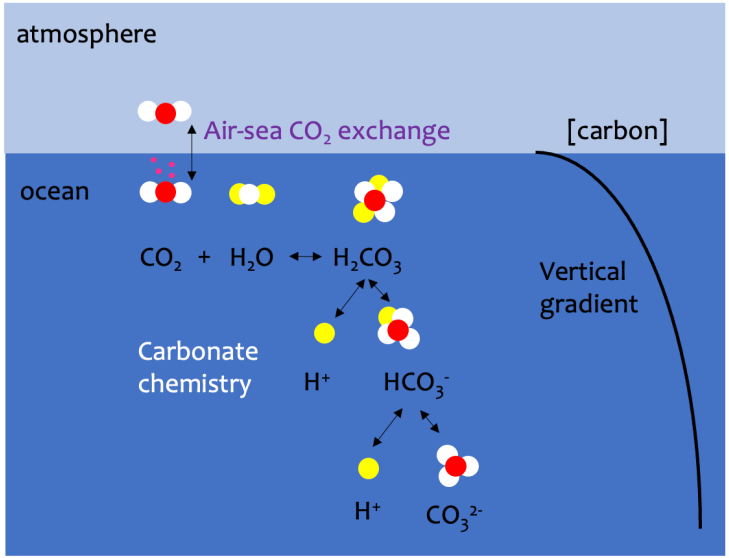


<u>Dissolved Inorganic Carbon (DIC)</u>

DIC is the sum of the concentrations of all the inorganic carbon species in the ocean

$$DIC = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$$

Breakout question



Dissolved Inorganic Carbon (DIC)

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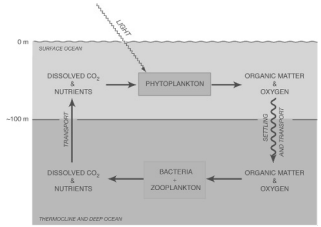
$$DIC = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$$

If the ocean absorbs anthropogenic CO_2 from the atmosphere,

- Does DIC increase or decrease?
- Does $[H^+]$ increase or decrease?

What will you learn in this lecture?



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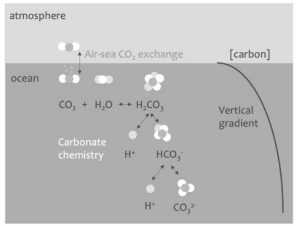

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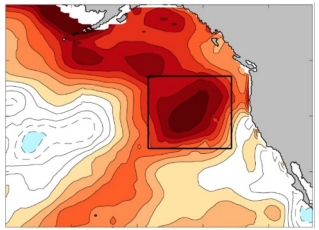
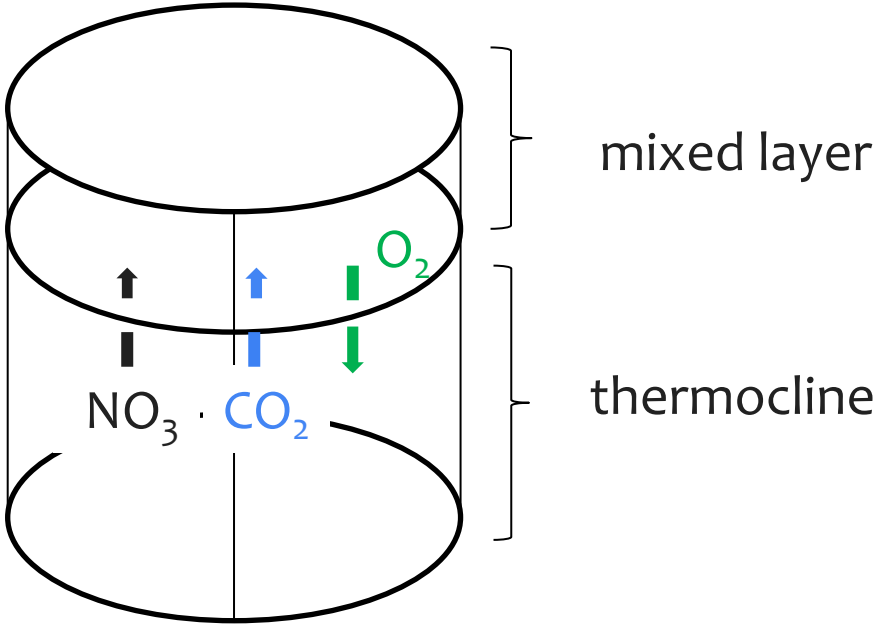
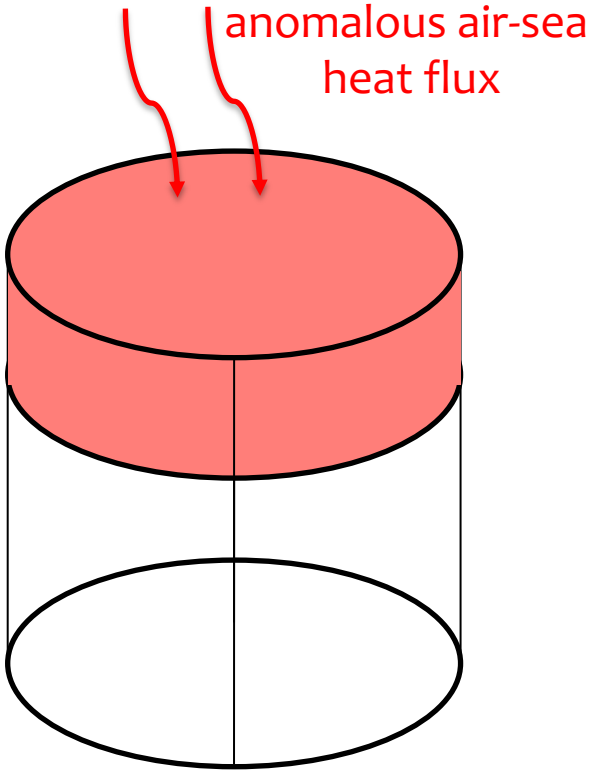
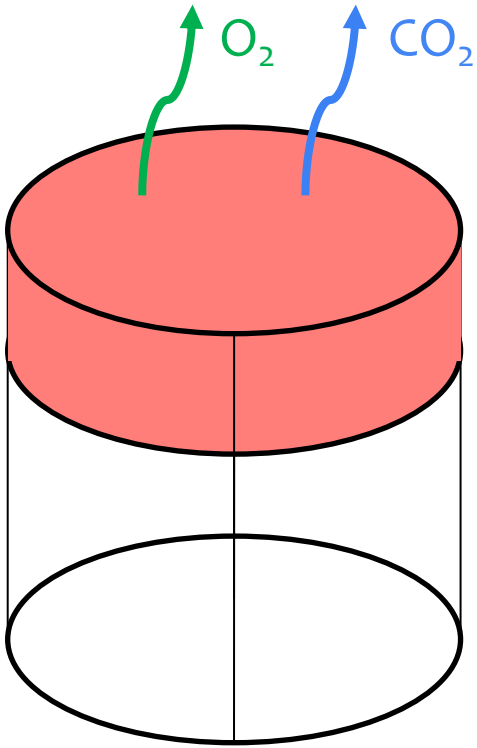


Marine heatwaves impact multiple ocean biogeochemical processes

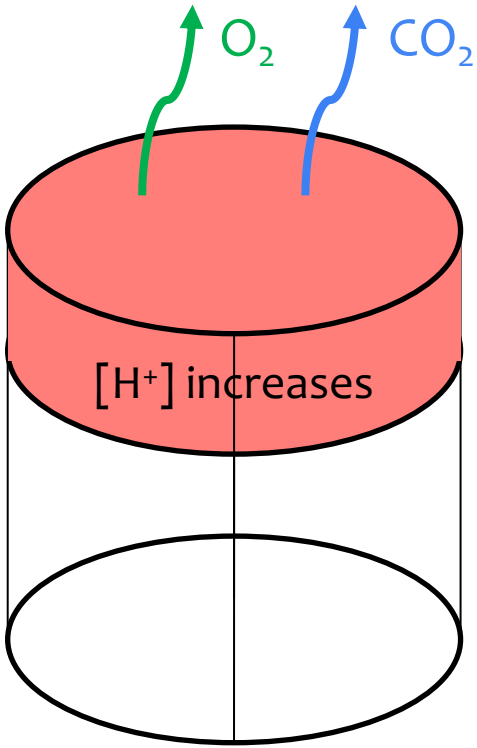
Schematic illustration of possible MHW impact on BGC



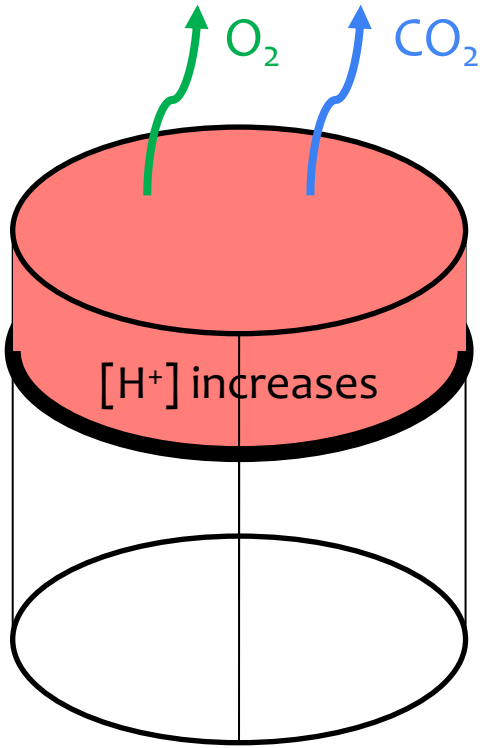

anomalous air-sea
heat flux



gas solubility decreases

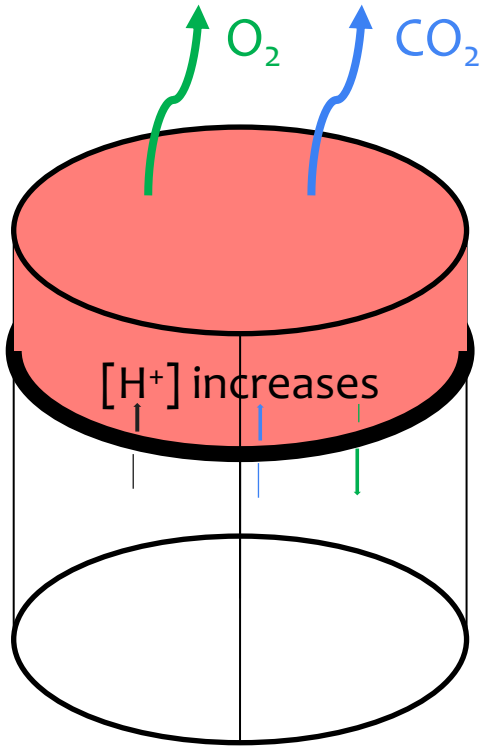


gas solubility decreases



gas solubility decreases

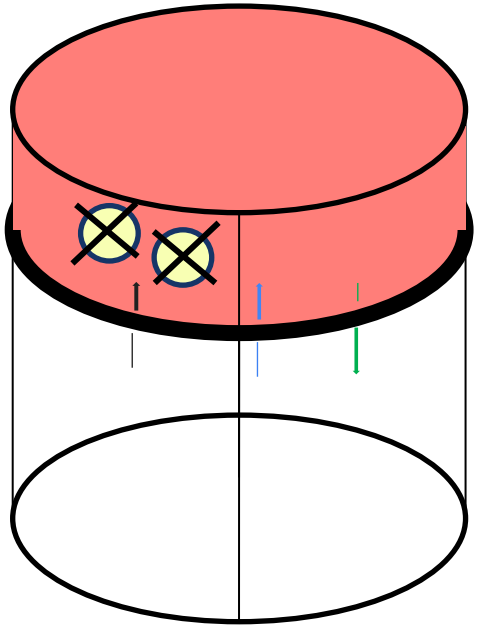
stratification increases



gas solubility decreases

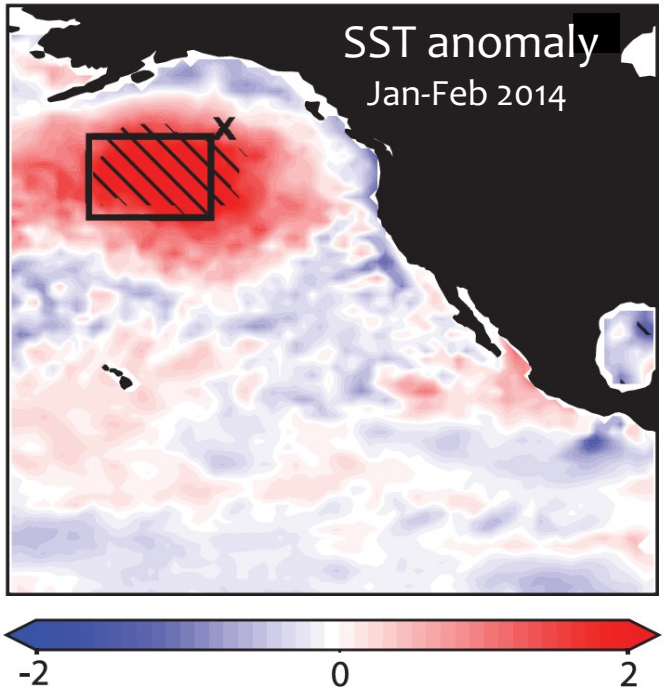
stratification increases

vertical exchange of NO_3, CO_2, and O_2 decreases



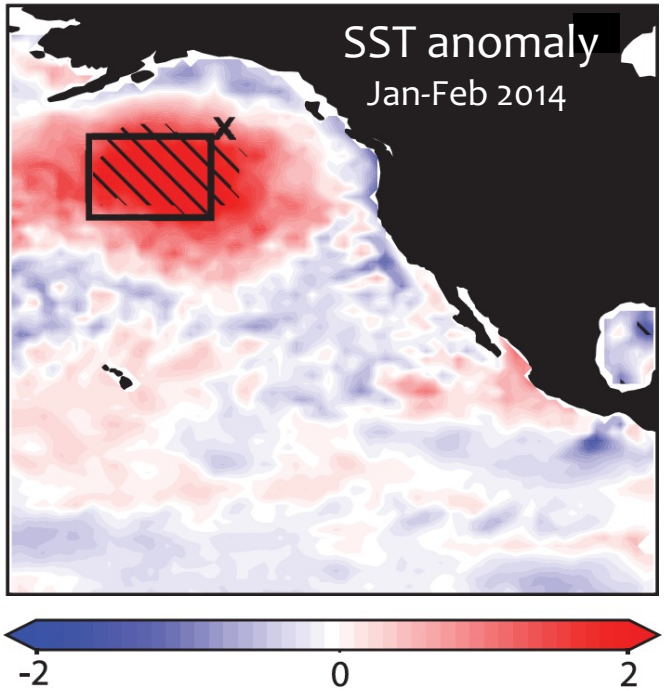
phytoplankton
abundance decreases

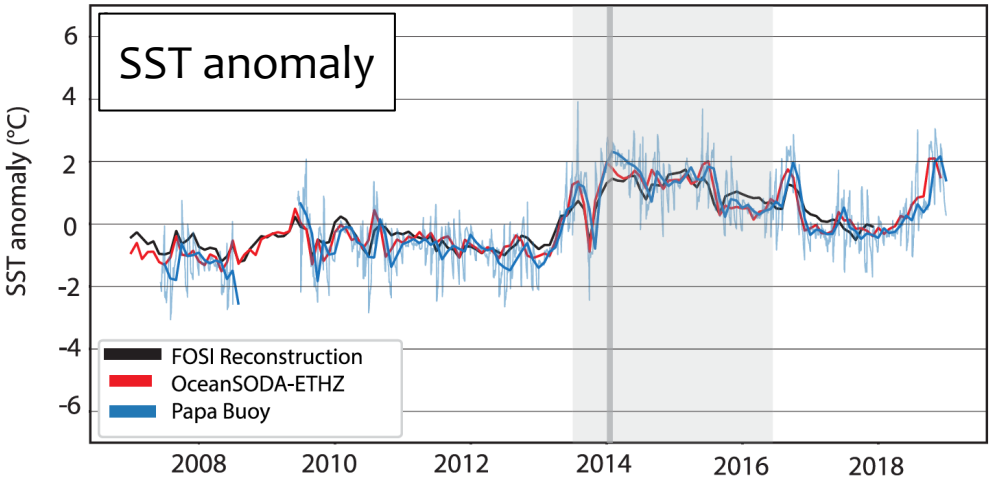
An example: The Blob



Mogen et al. (2022)

An example: The Blob





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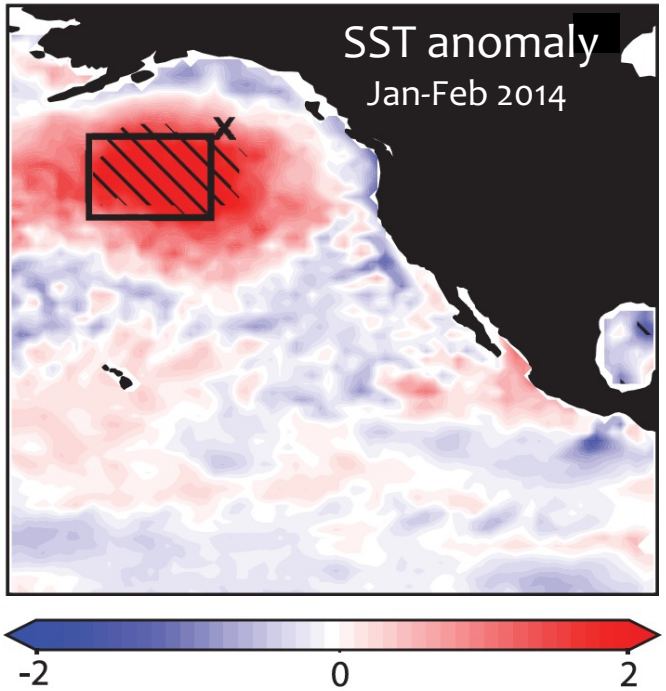
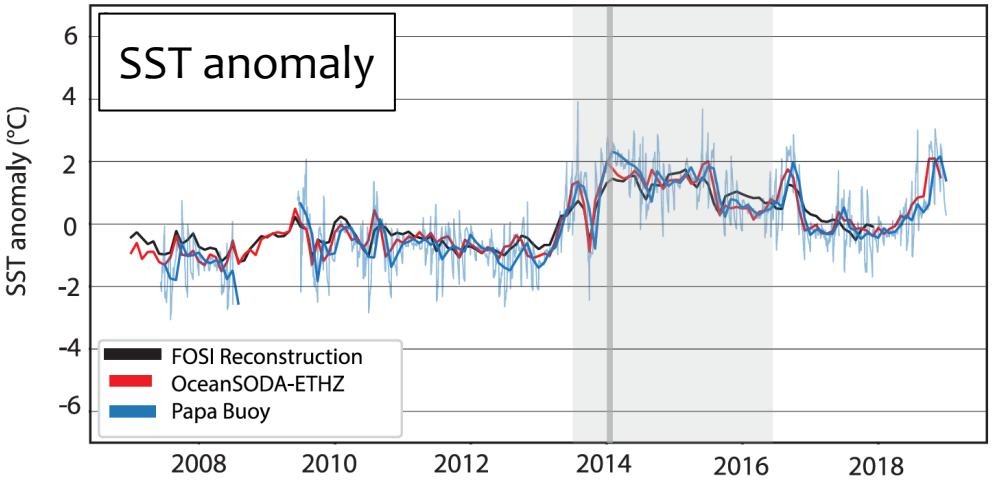
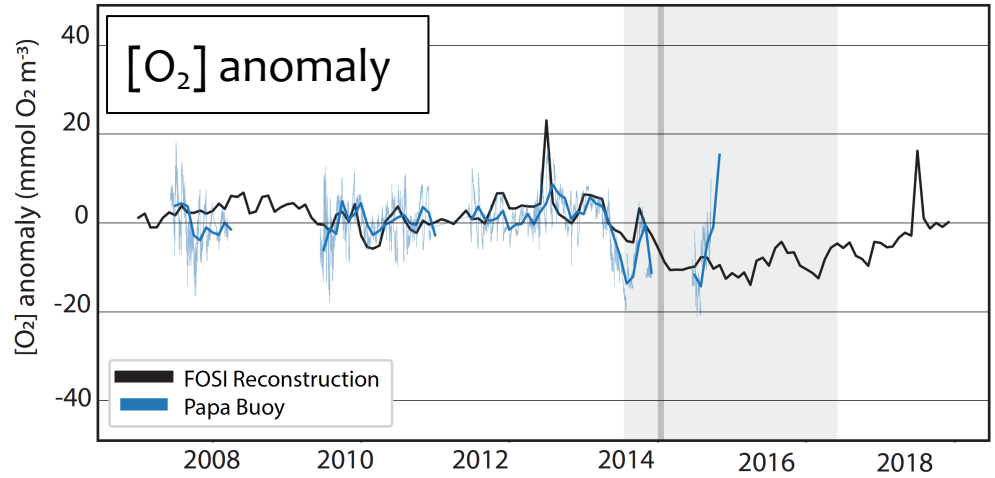
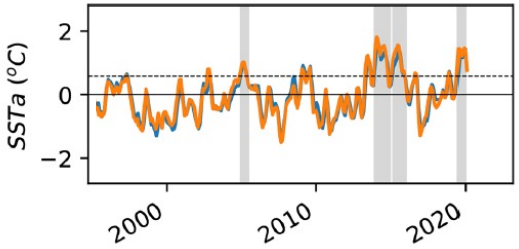




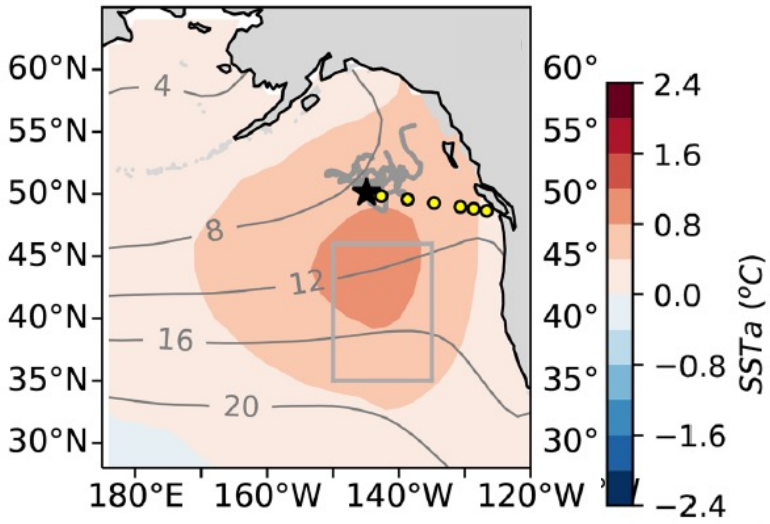


Mogen et al. (2022)

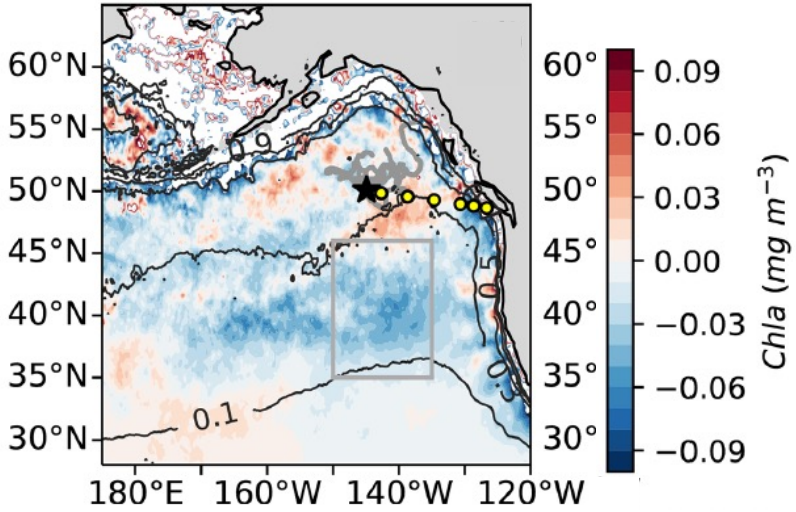
Warm events



SST anomaly

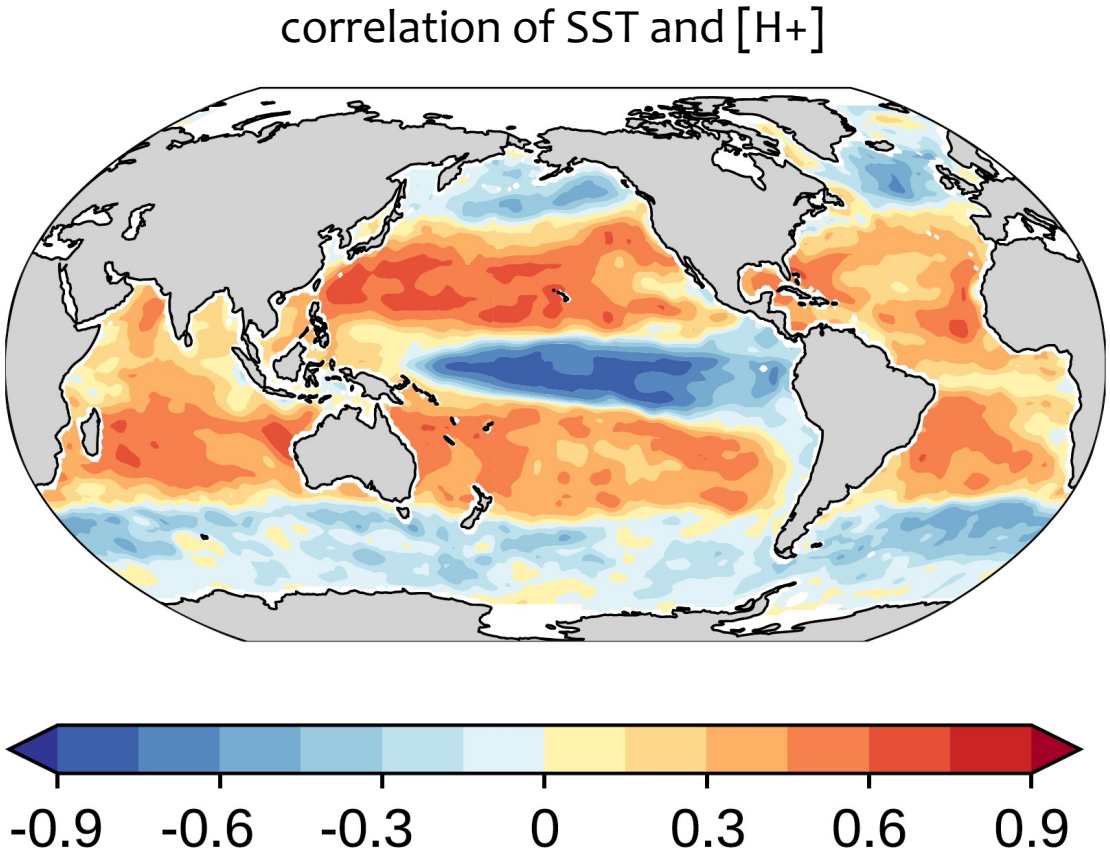


chlorophyll anomaly



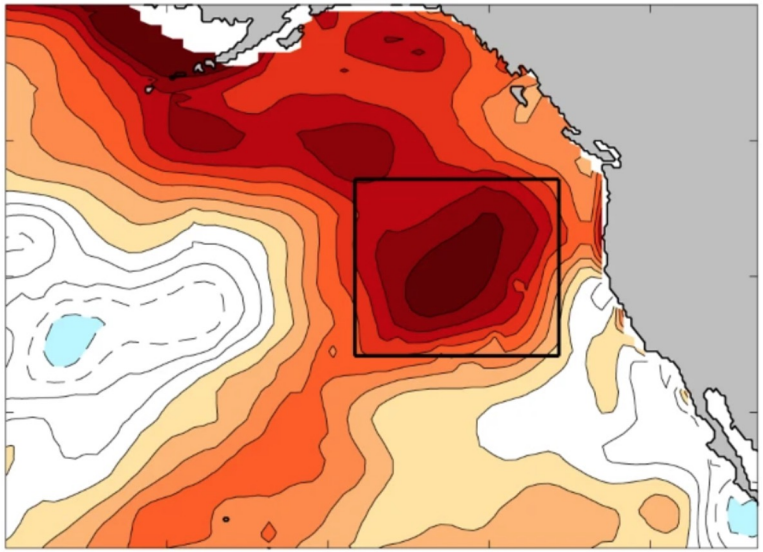
Wyatt et al. (2022)

Compound extremes



Burger et al. (2022)

Breakout question



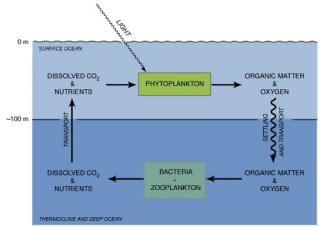
This afternoon, we will do a ‘hands on’ activity wherein we quantify the changes in biogeochemistry associated with ‘Blob 2.0’.

Make a prediction
How will Blob 2.0 impact…

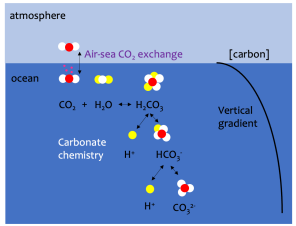
- Surface ocean oxygen
- Surface ocean carbon (DIC)
- Phytoplankton biomass (chlorophyll)

??

What did you learn in this lecture?

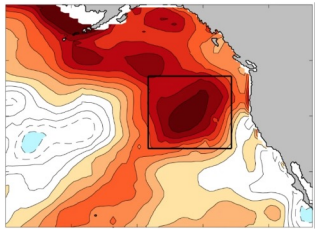


Biological activity and circulation set the mean distribution of chemicals in the ocean



Gases and chemistry in the ocean

- Solubility
- Carbonate chemistry



Marine heatwaves impact multiple ocean biogeochemical processes