Climate Change Impacts on the Global Ocean

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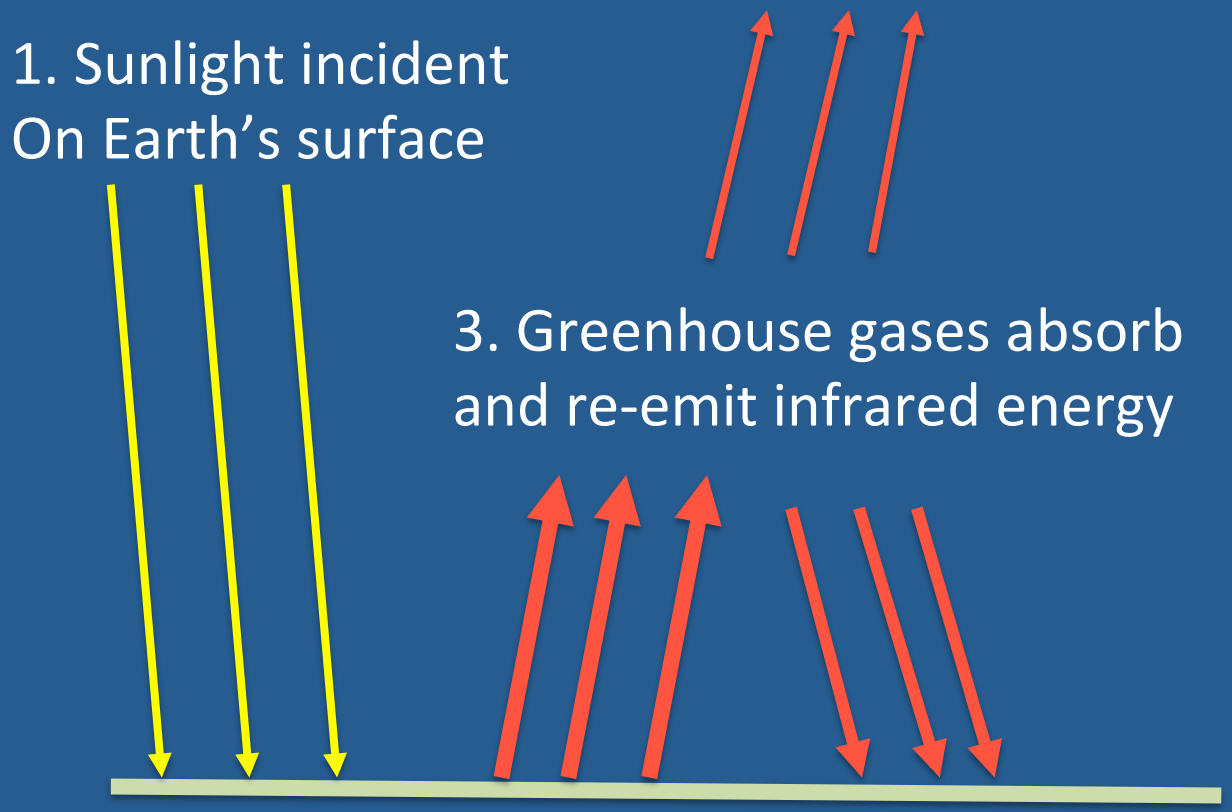
Outline

- The greenhouse effect, CO_2 and global warming
- Observed ocean warming and acidification
- Projected ocean warming and acidification
- Projected changes in ocean primary production

Note – not a comprehensive review; highlighting several impacts of high ecosystem-relevance

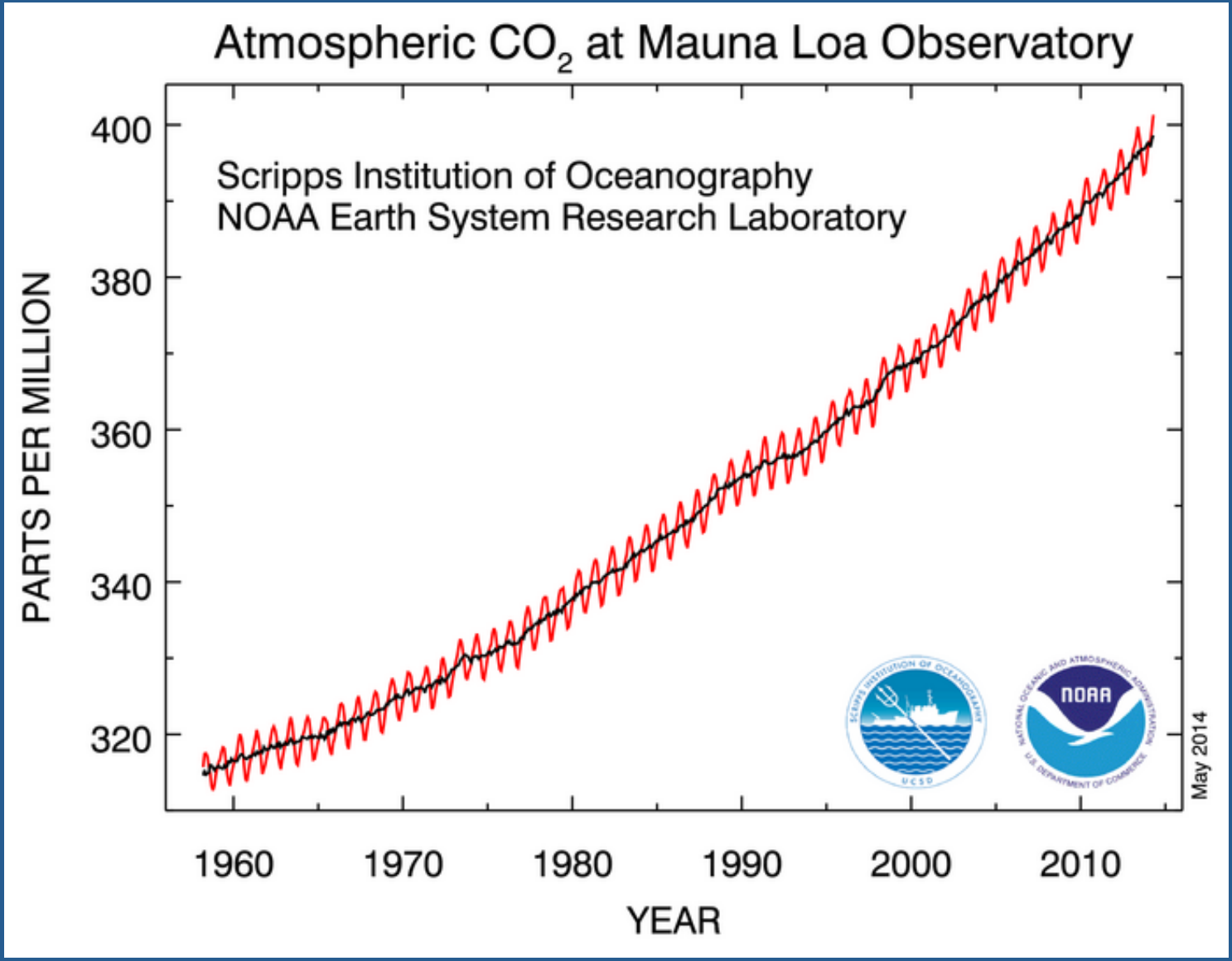
The insulating effect of greenhouse gases (a simplified view)



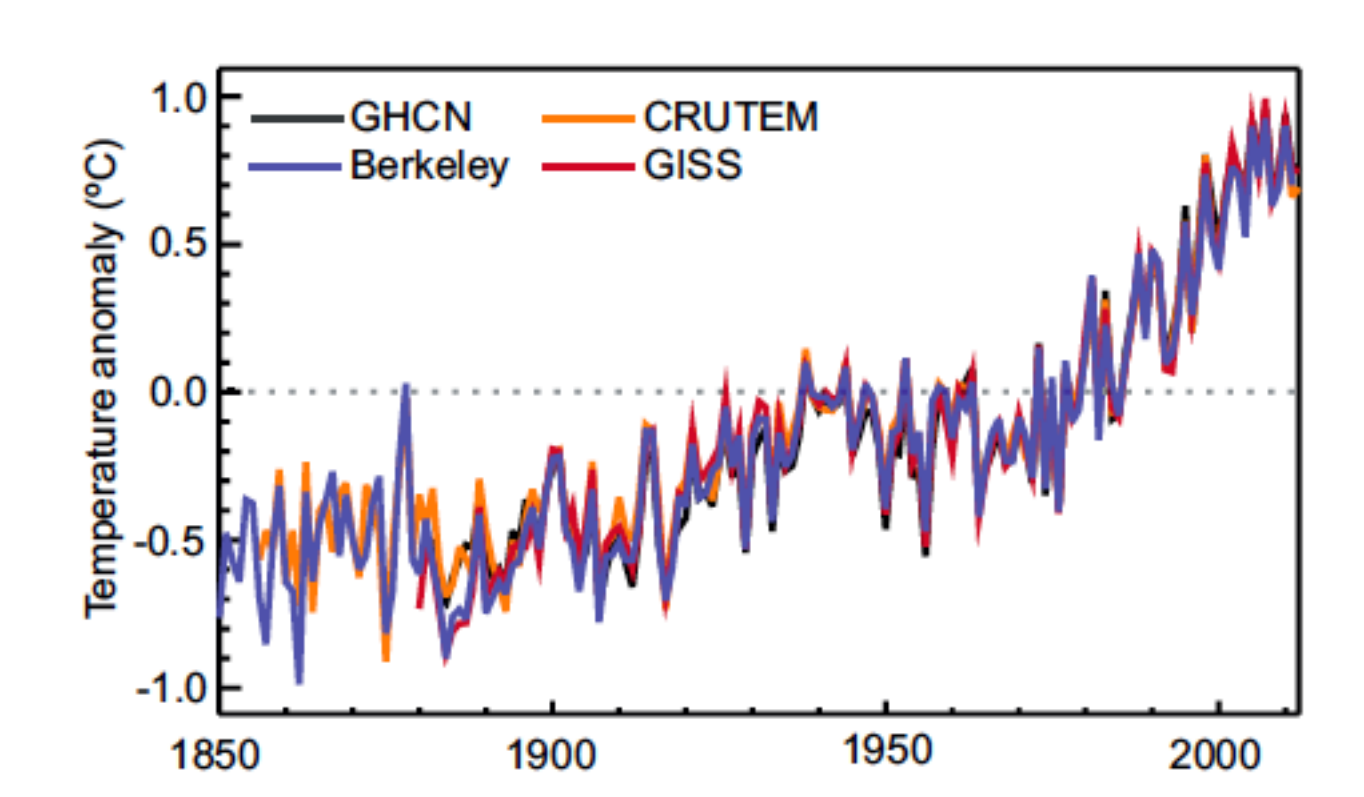
Were it not for the greenhouse effect, the average surface temperature on earth would be -19 degrees Celsius

Le Treut and Somerville, IPCC-AR4, WG1, Chapter 1

Increasing CO_2 and other greenhouse gases due to human activity



Land surface air temperature (LSAT) has been increasing

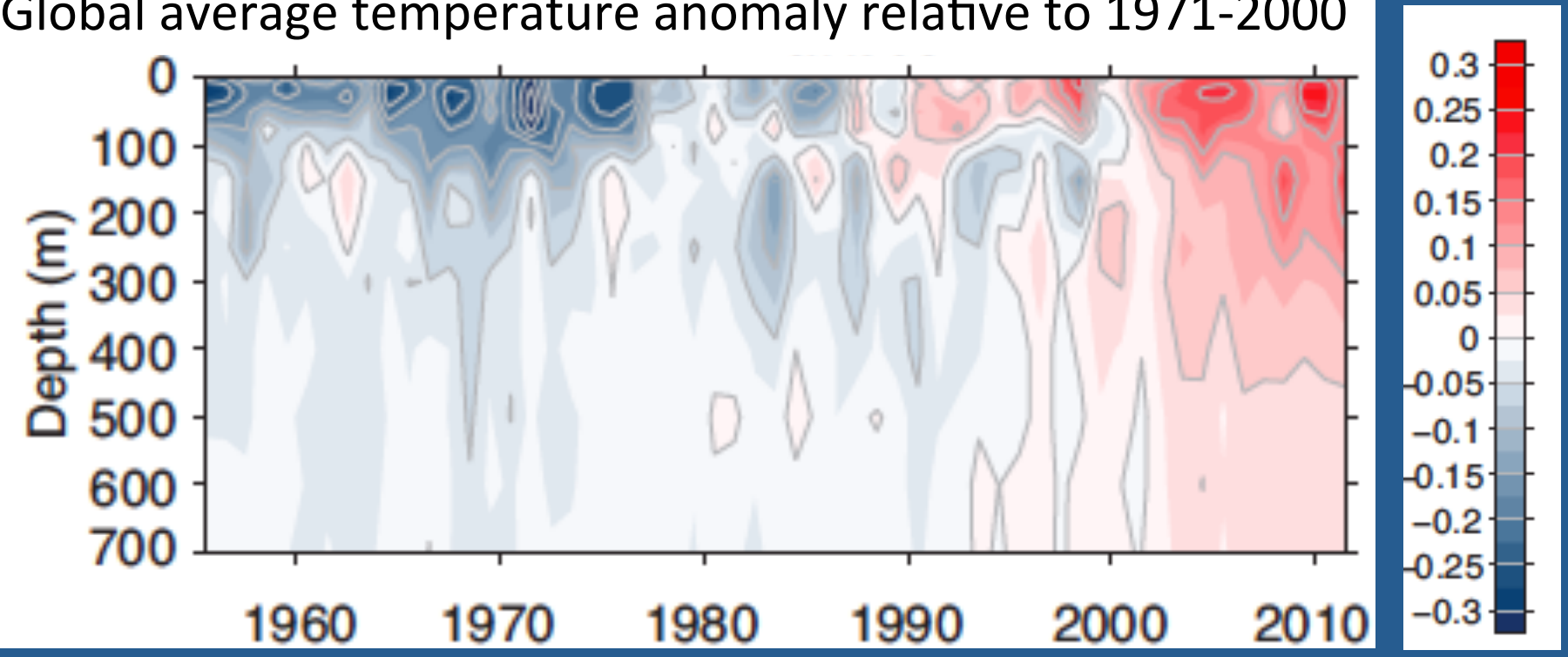


"It is certain that globally averaged LSAT has risen since the late 19th century"

(IPCC-AR5 WG1 Report, Chapter 2, Figure 2.14)

The ocean's surface is warming despite its tremendous heat capacity

Global average temperature anomaly relative to 1971-2000

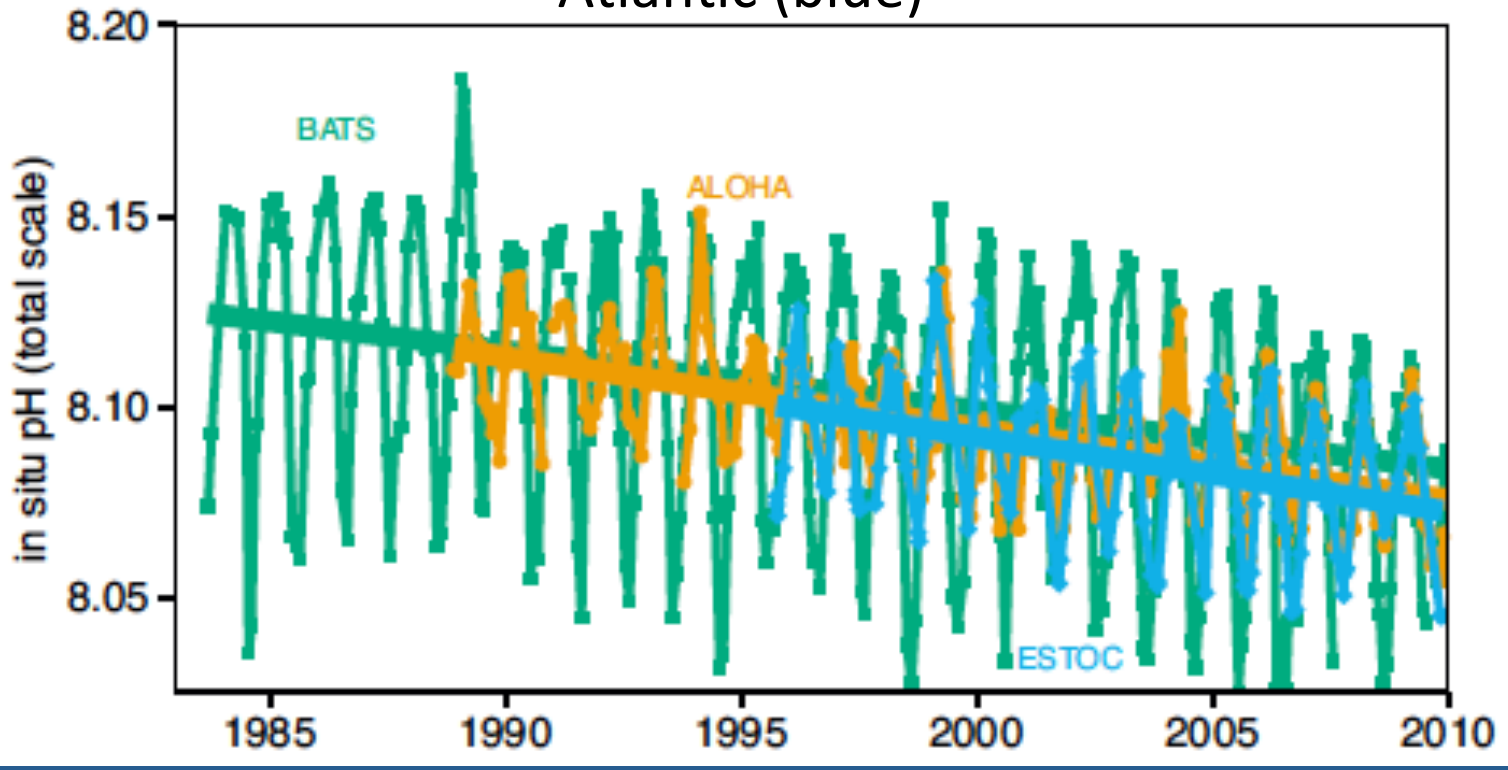


"It is virtually certain that the upper ocean (0-700m) heat content increased during the period from 1971-2010"

(IPCC-AR5 WG1 Report, Chapter 3, Figure 3.1c)

The ocean absorbs significant anthropogenic CO2, but becomes more acidic as a result

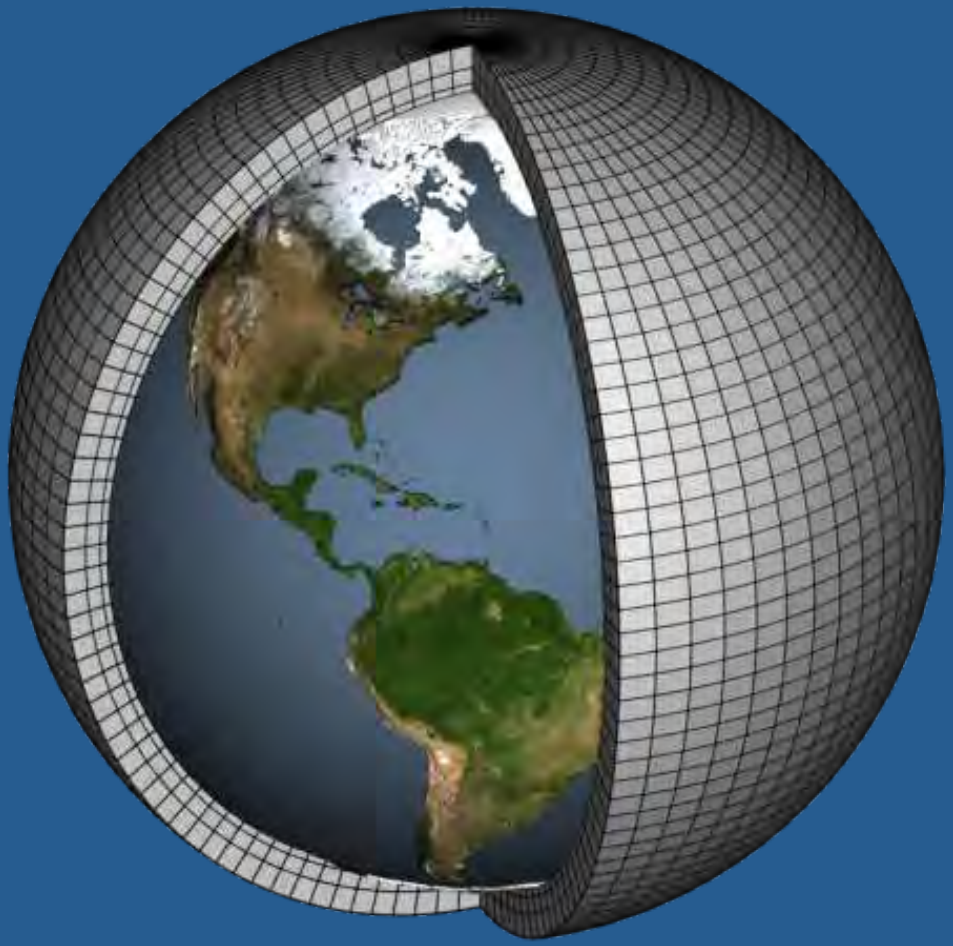
pH trends at Bermuda (green), Hawaii (orange), NE Atlantic (blue)



There is high confidence that the pH of surface seawater has decreased by 0.1 since the beginning of the industrial era

(IPCC-AR5 WG1 Report, Chapter 3, Figure 3.18)

What might the future hold?

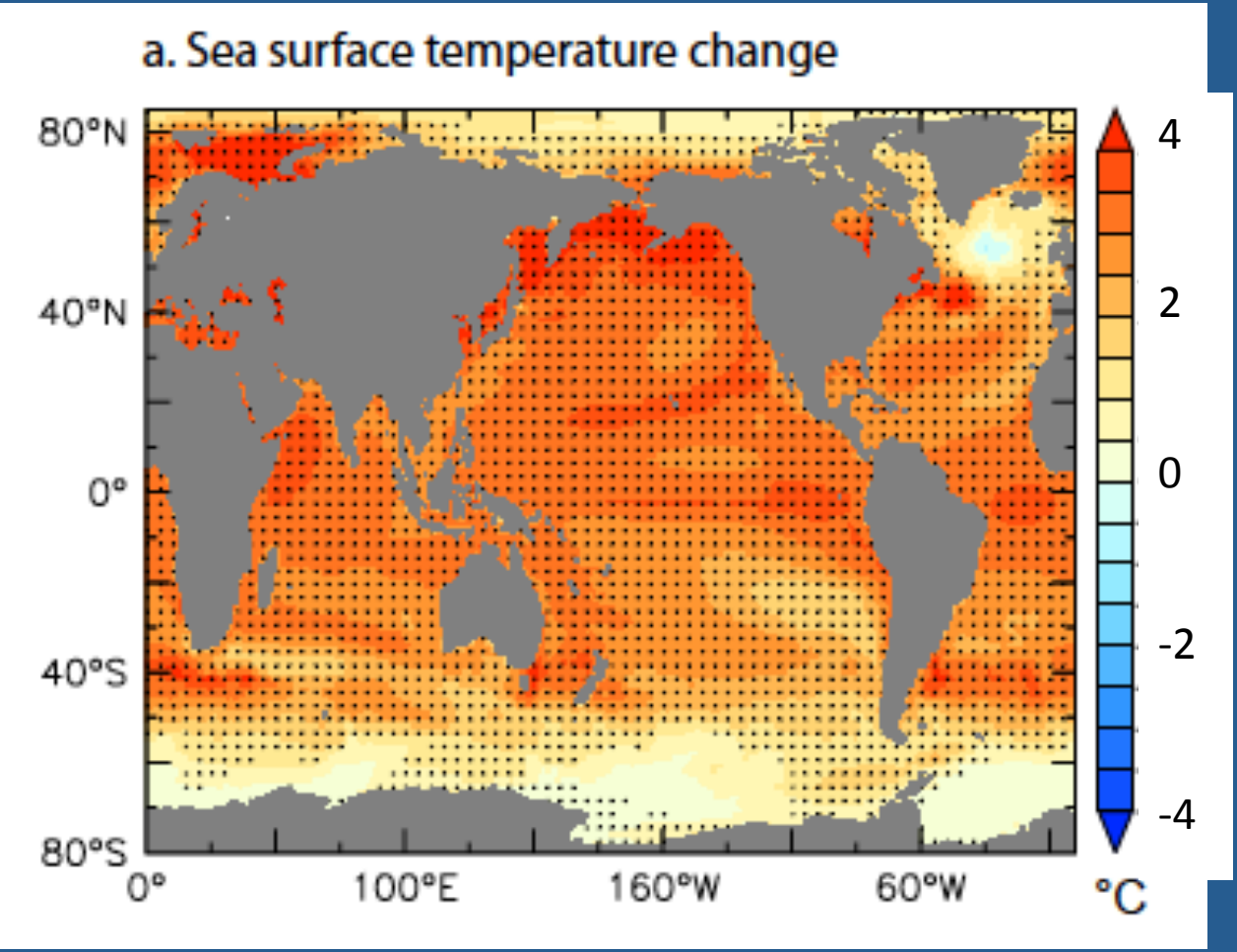


Global climate models are mathematical representations of the coupled atmosphere, ocean, land and ice system. Confidence in projections rests on:

1. Foundation on accepted physical principles
2. Ability to reproduce observed features of current climate and past climate changes

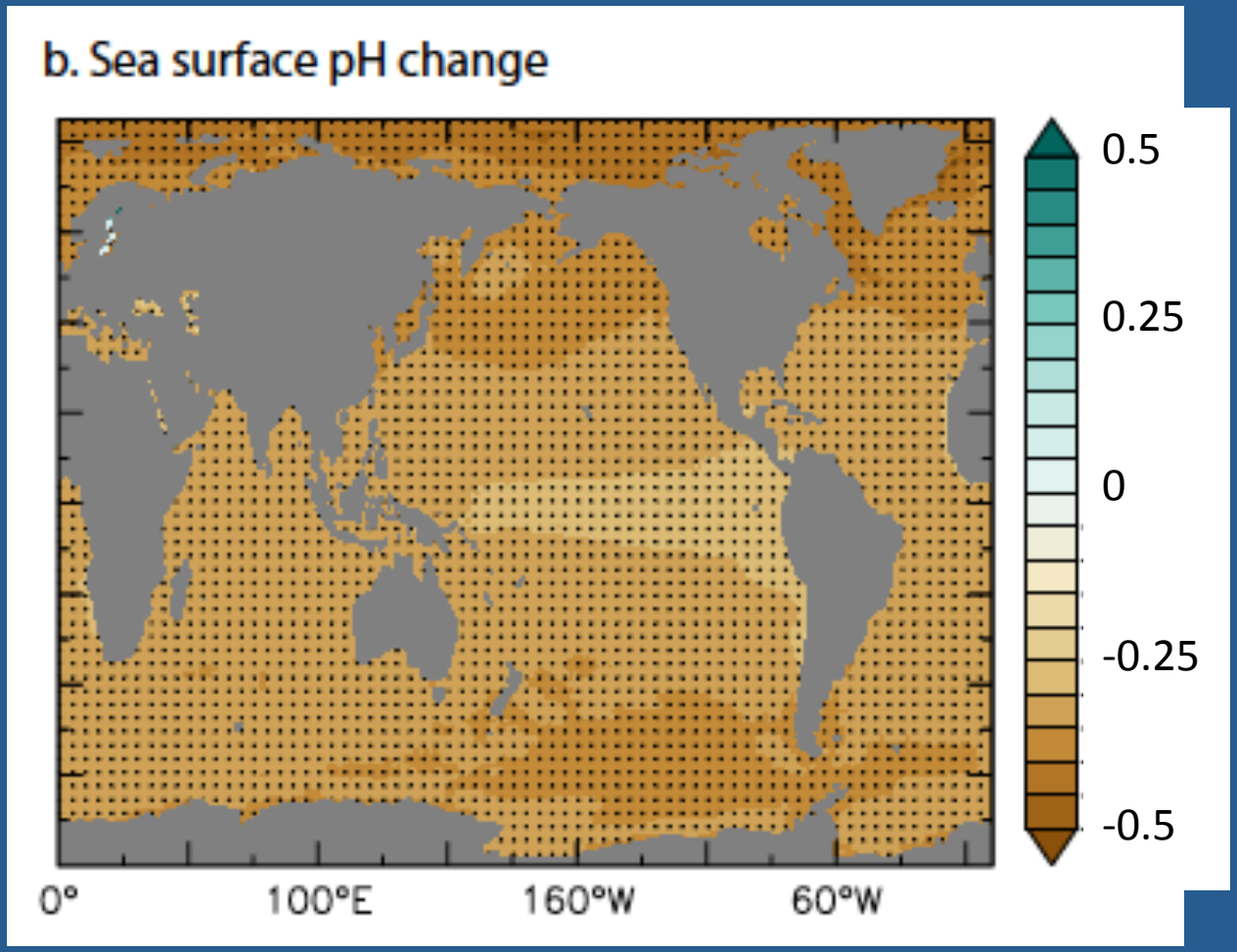
(Randall and Wood, IPCC-AR4, Chapter 8, WG1 Report)

Projected 2-4 deg. C increase in SST by 2091-2100 for high emissions scenarios



Bopp et al., 2013, Biogeosciences, 10, 6225-6245

Projected 0.2-0.4 decrease in pH by 2091-2100 under high emissions scenario



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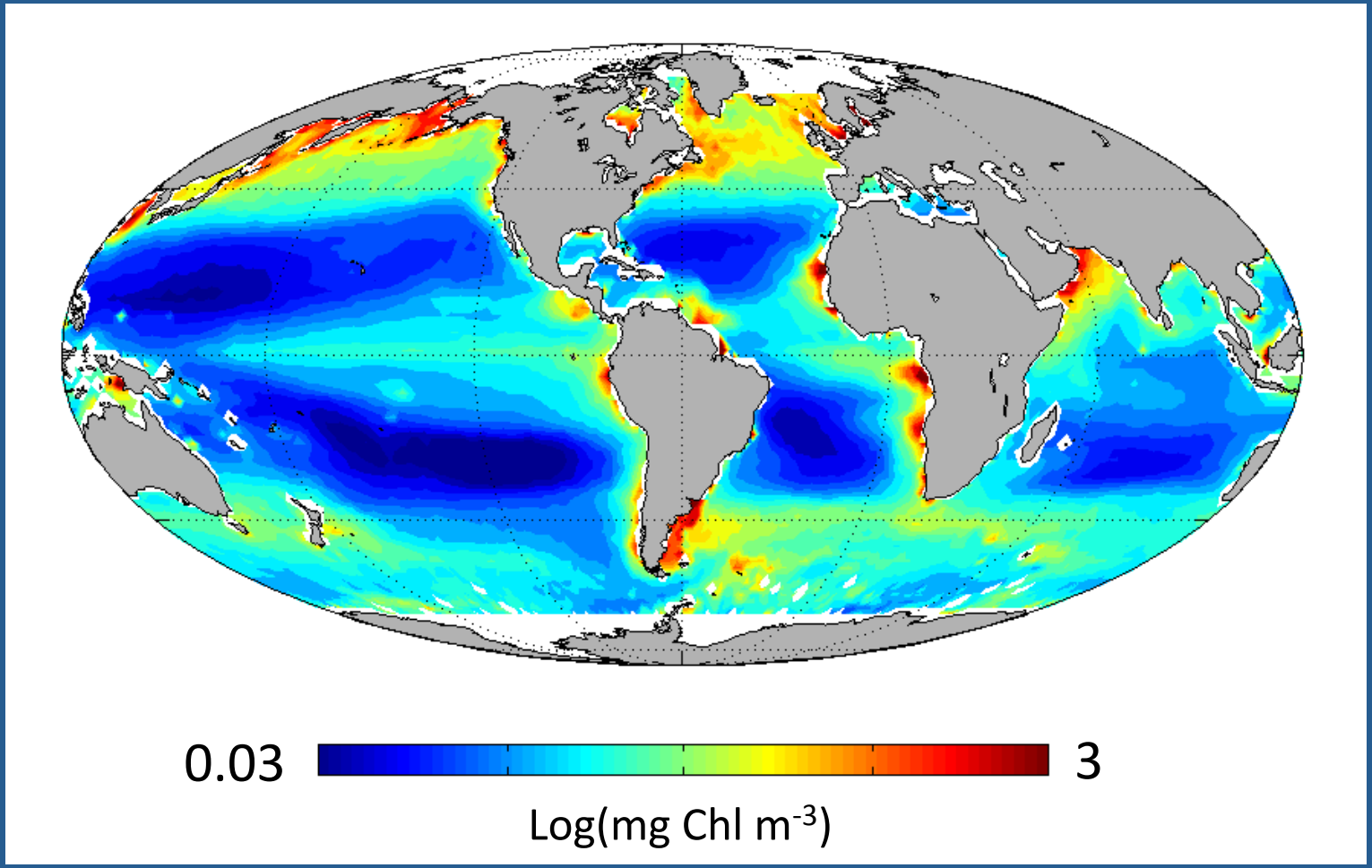
Primary production by photosynthetic phytoplankton supports nearly all life in the ocean

CO_2+ nutrients + water--> organic matter + oxygen

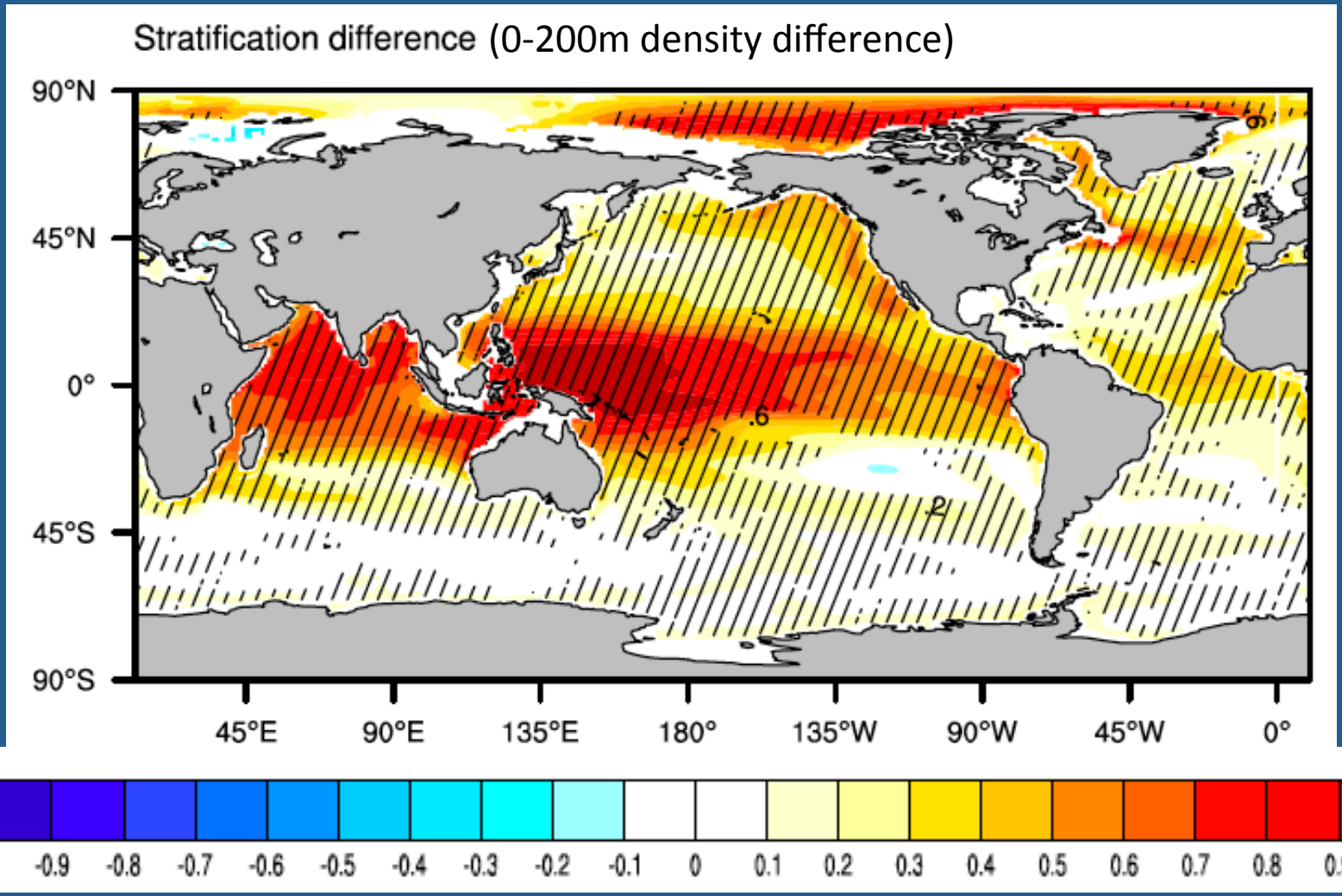
Nutrients

Confluence of nutrients and light can be seen in global observed satellite chlorophyll fields



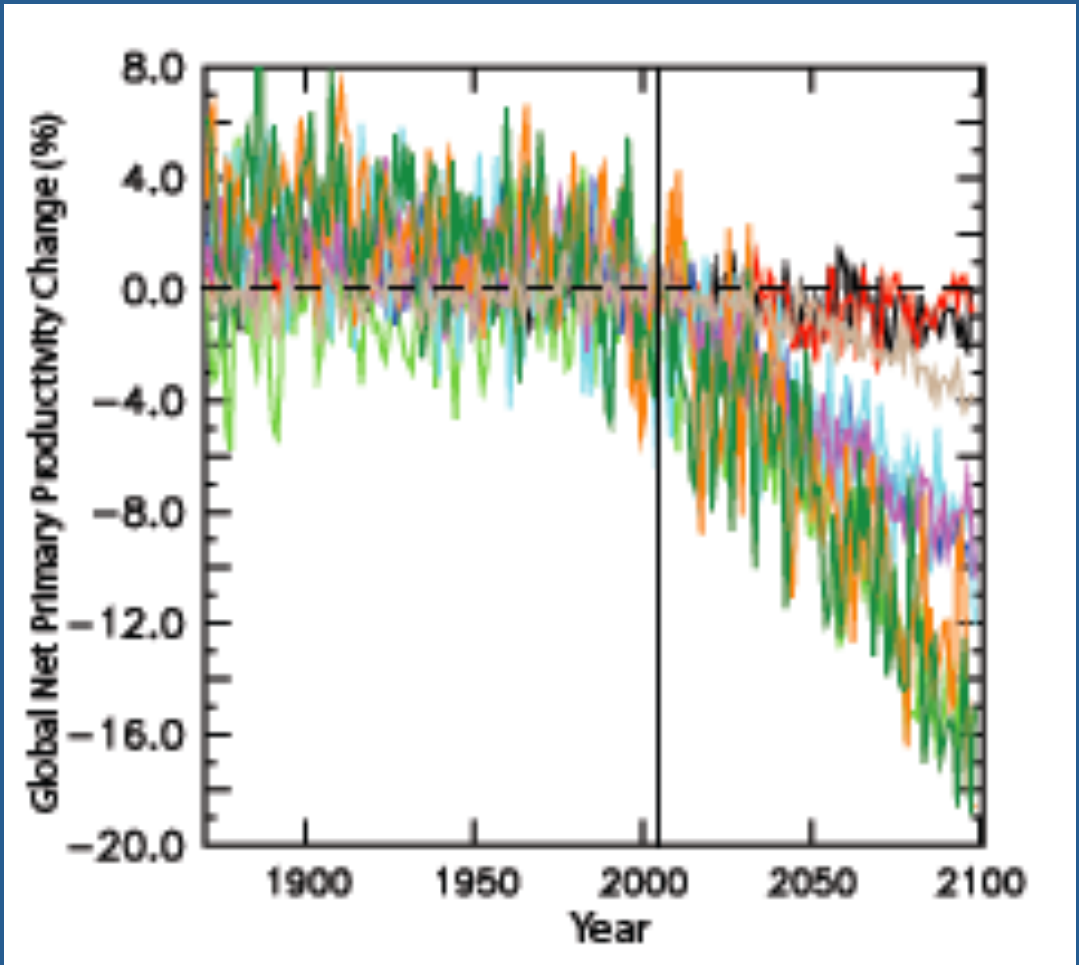
SeaWiFS, 1998-2004 average

Projected strengthening stratification inhibits transport of deep nutrients to he ocean surface



Capotondi et al., 2012, Journal of Geophysical Research, 117

Modest to moderate projected declines in global primary production under high emissions

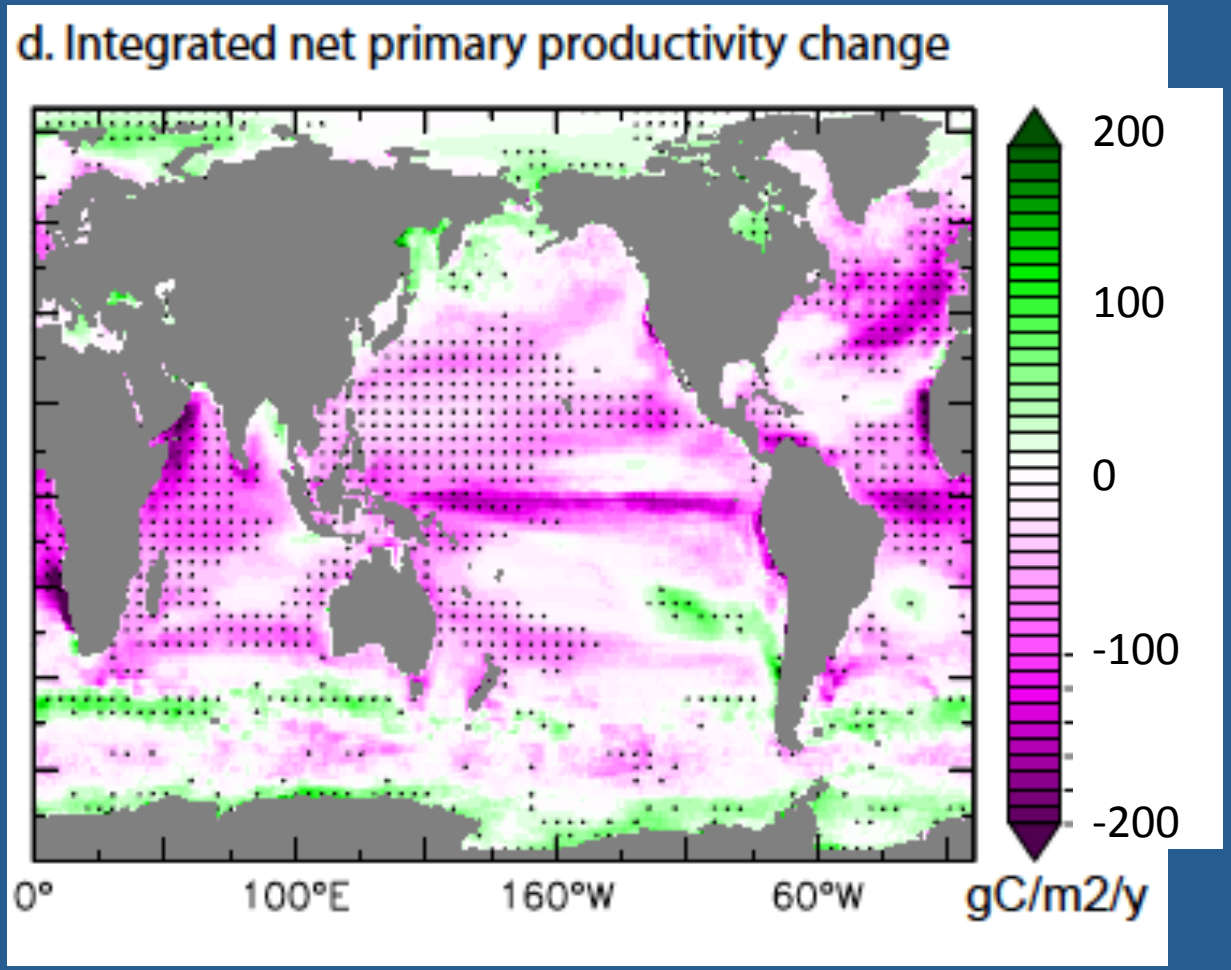


Medium confidence in the direction of change; low confidence in the magnitude

(IPCC-AR5, WG2, Chapter 6)

Bopp et al., 2013, Biogeosciences, 10, 6225-6245

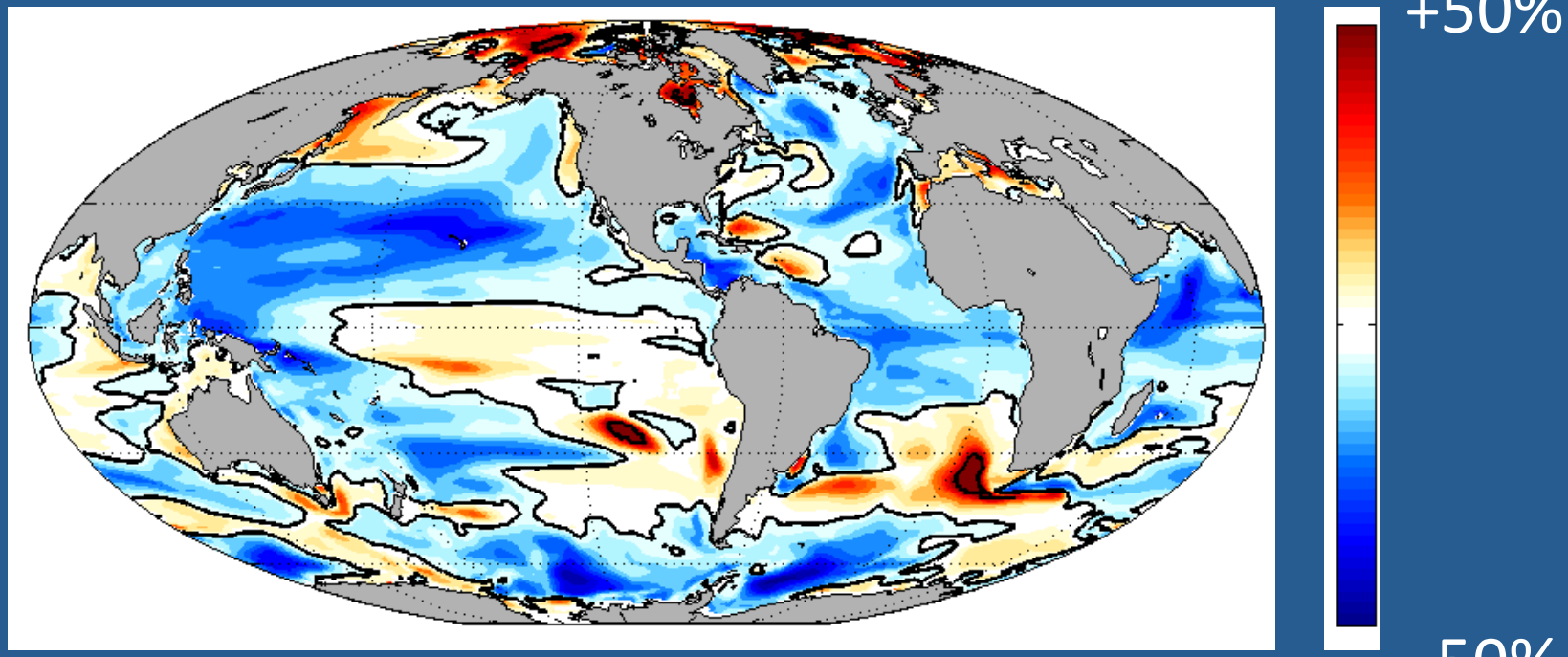
Evidence for latitudinal shift in Prim. Prod. change, but marked regional variation across models



Bopp et al., 2013, Biogeosciences, 10, 6225-6245

Individual projections suggest potential for regional PP changes of ~25-50%, but limited consensus on magnitude and direction

% change, primary prod



Stock et al., in prep, Biogeosciences

Summary

- The ocean baseline for marine resources is changing and will continue to do so through the next century.
- Under high emissions scenarios:
  - 2-4 deg. C increase in SST (high confidence)
  - 0.2-0.4 decline in pH (high confidence)
  - Increased stratification (high confidence)
  - Decline in global NPP (medium confidence in direction, low in magnitude) with potential for more pronounced regional changes