Ocean carbon uptake and acidification: Can we predict the future?

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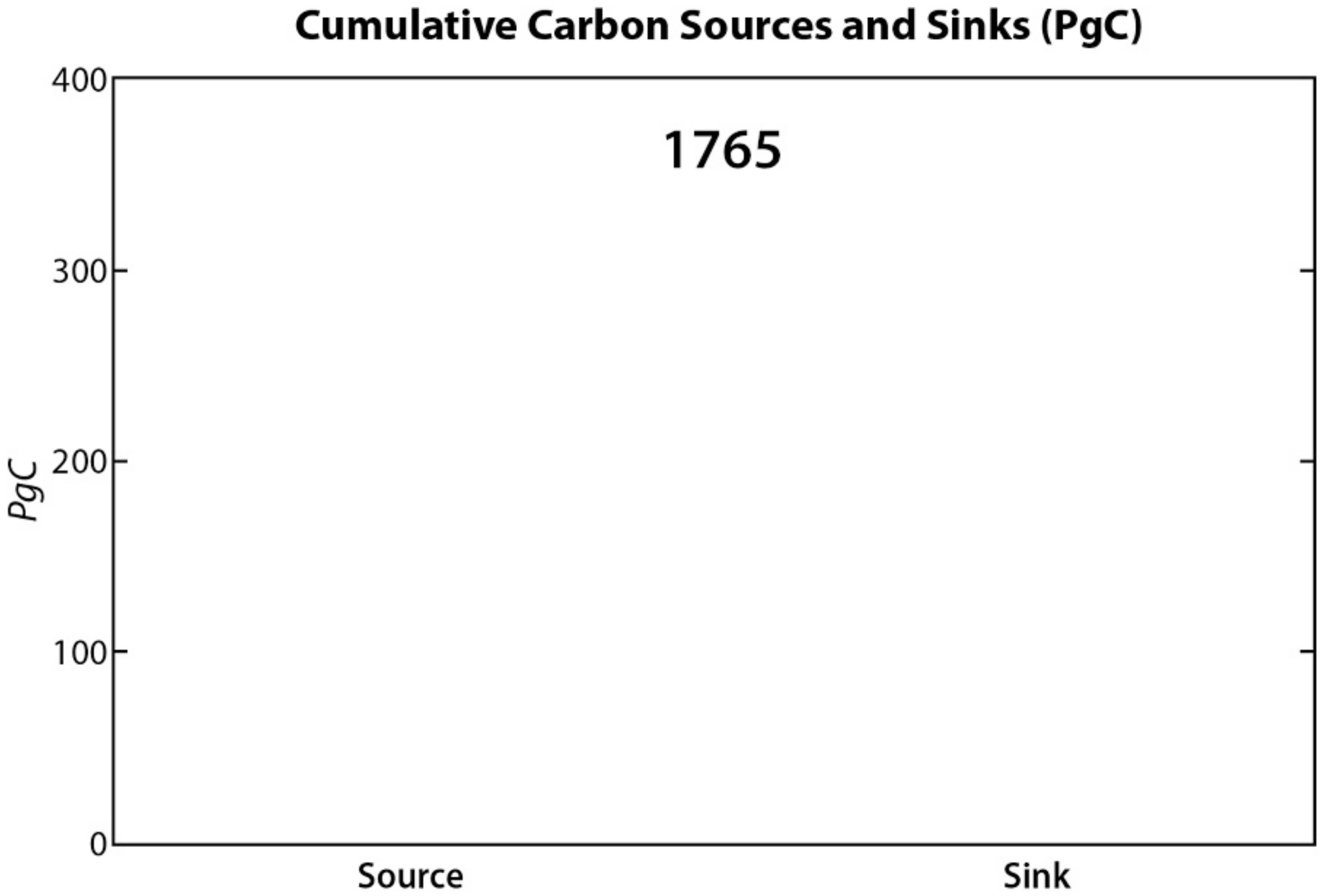
thanks to:

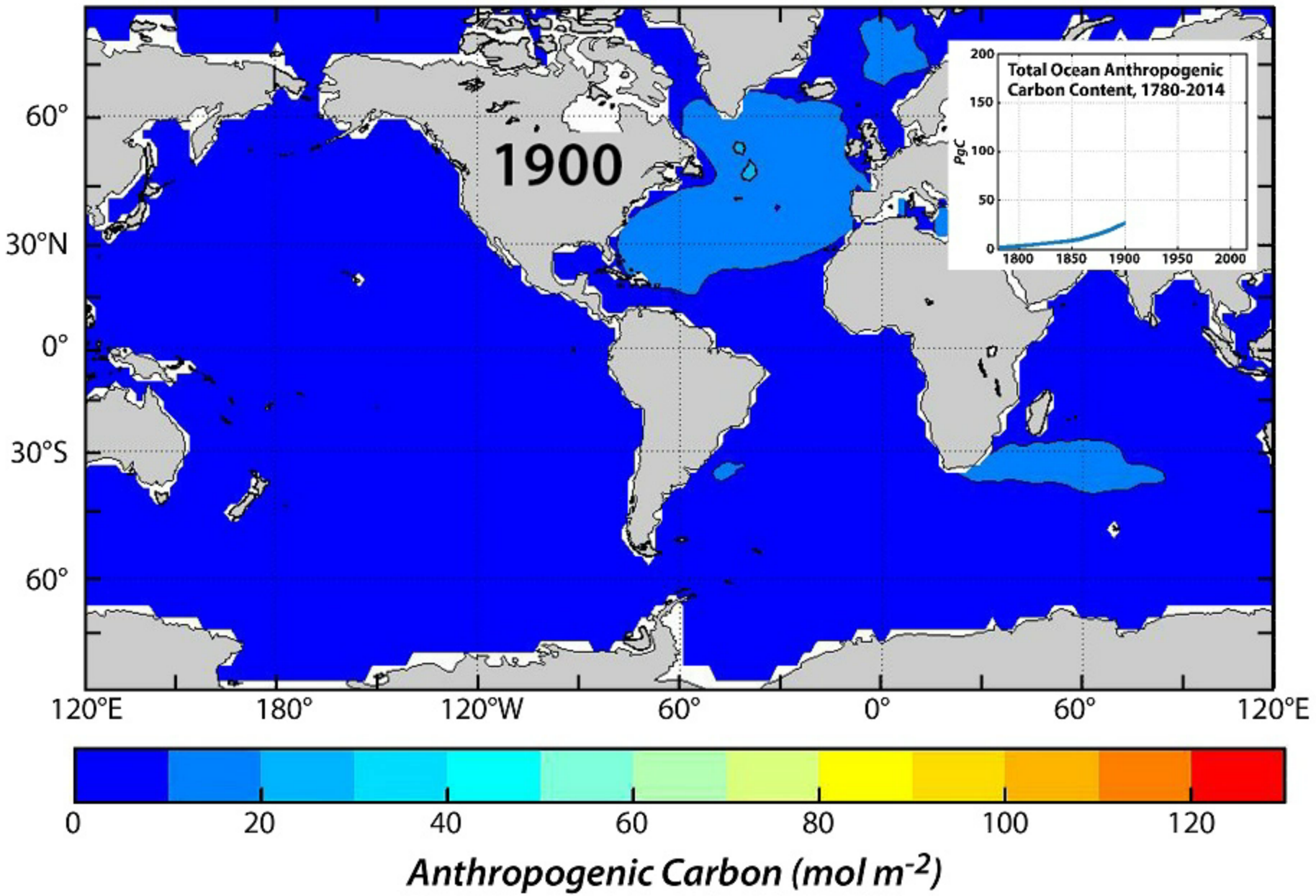
Galen McKinley & Amanda Fay at U. Wisconsin

Matt Long & Keith Lindsay at NCAR



Khatiwala et al. (2009,2013)

Anthropogenic Carbon Distribution in the Ocean



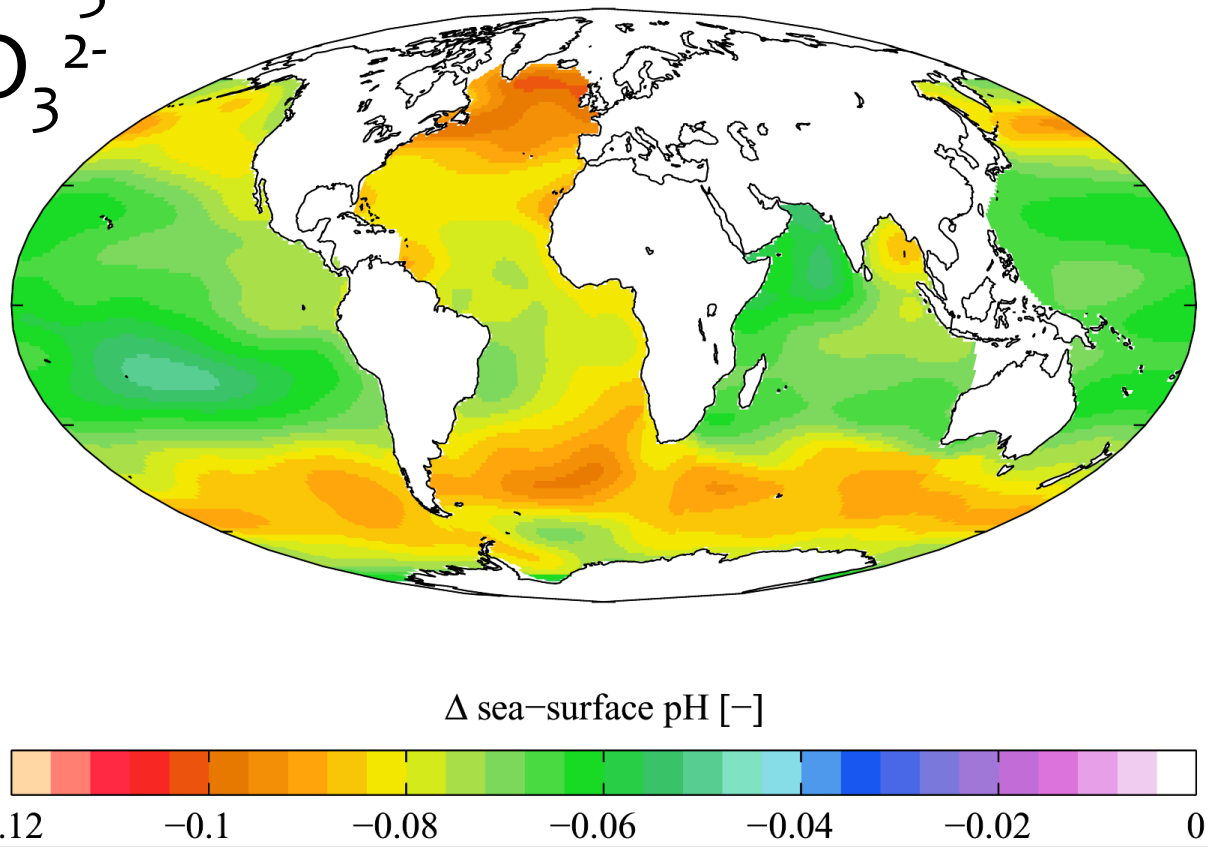
DeVries (2014)

Ocean carbon uptake leads to acidification

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$
$$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$
$$HCO3^- \leftrightarrow H^+ + CO_3^{2-}$$

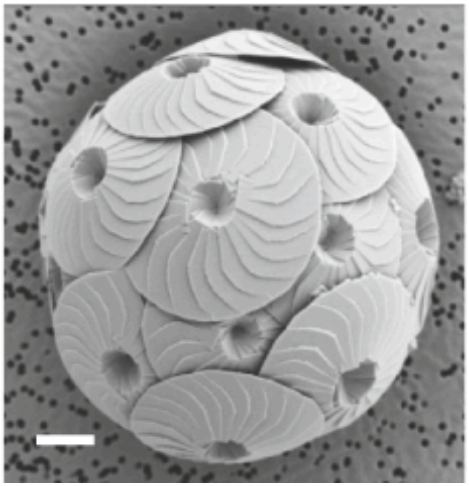
$$pH = -\log[H^+]$$

change in pH
1700s to 1990s

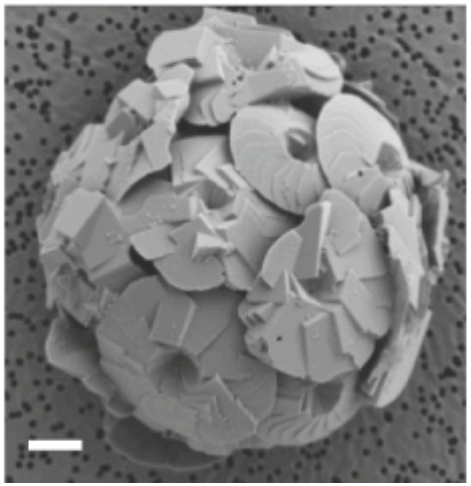


Acidification challenges shell-builders

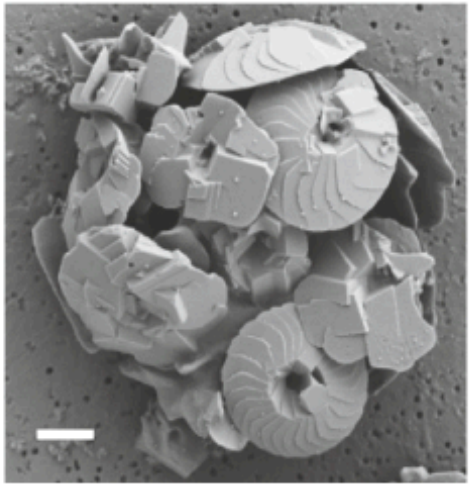
pH = 8.3



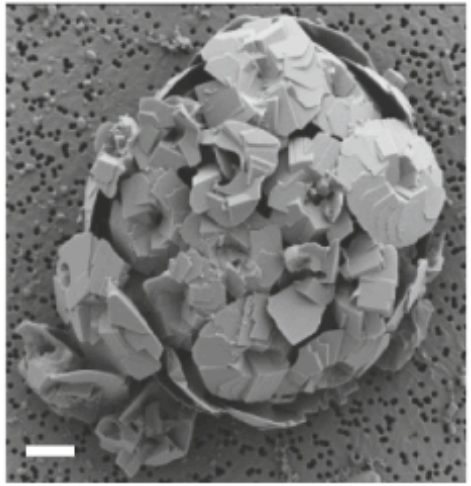
pH = 7.9

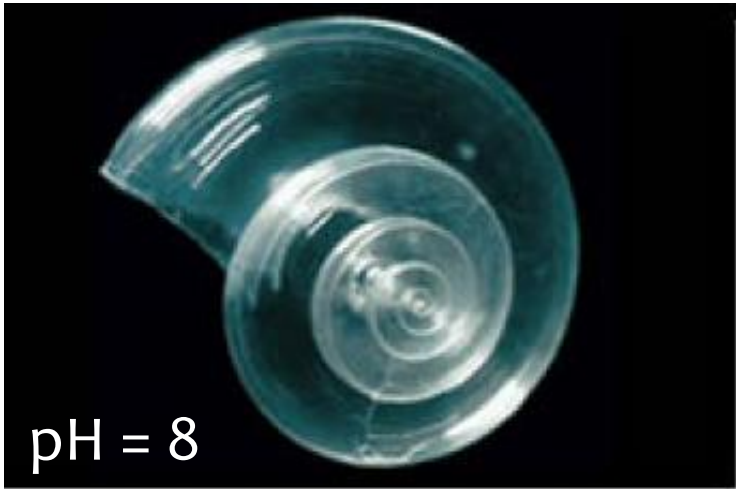


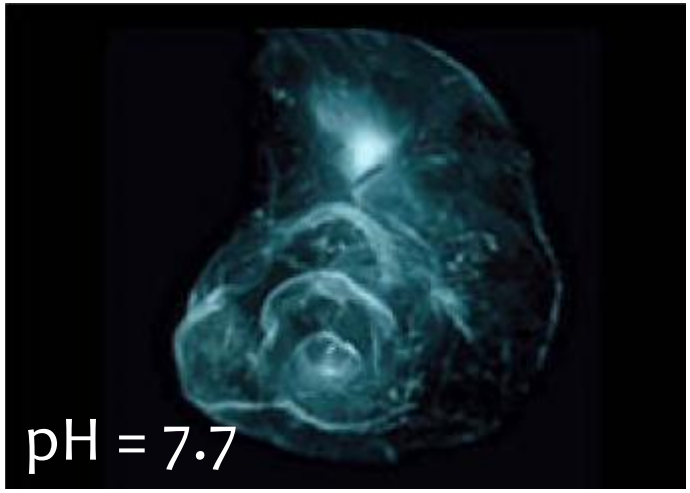
pH = 7.8



pH = 7.7

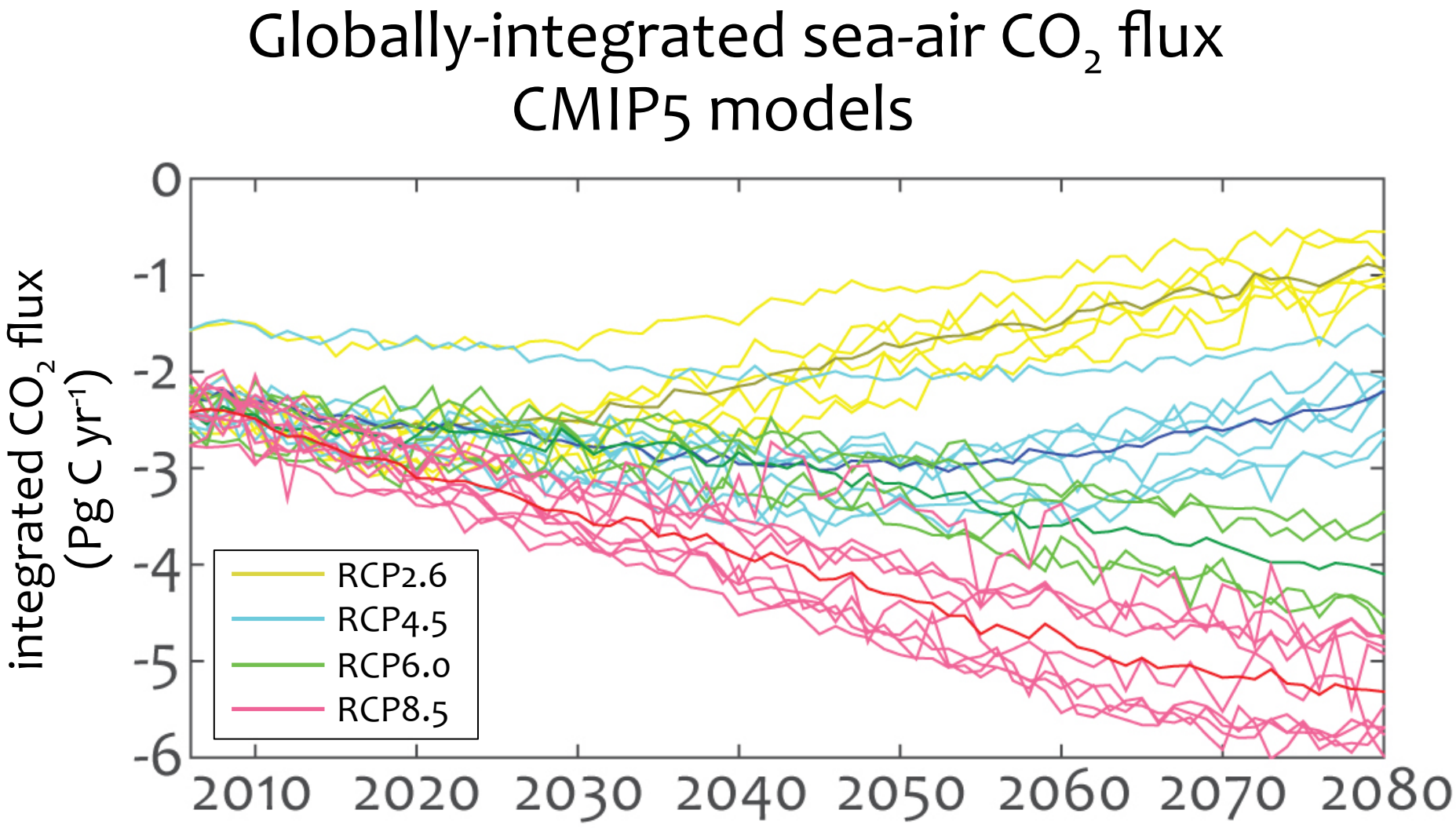






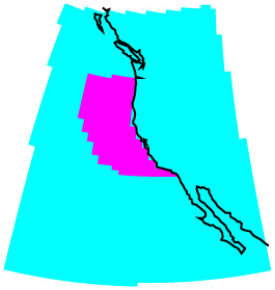
NOAA PMEL

How much CO_2 will the ocean absorb?

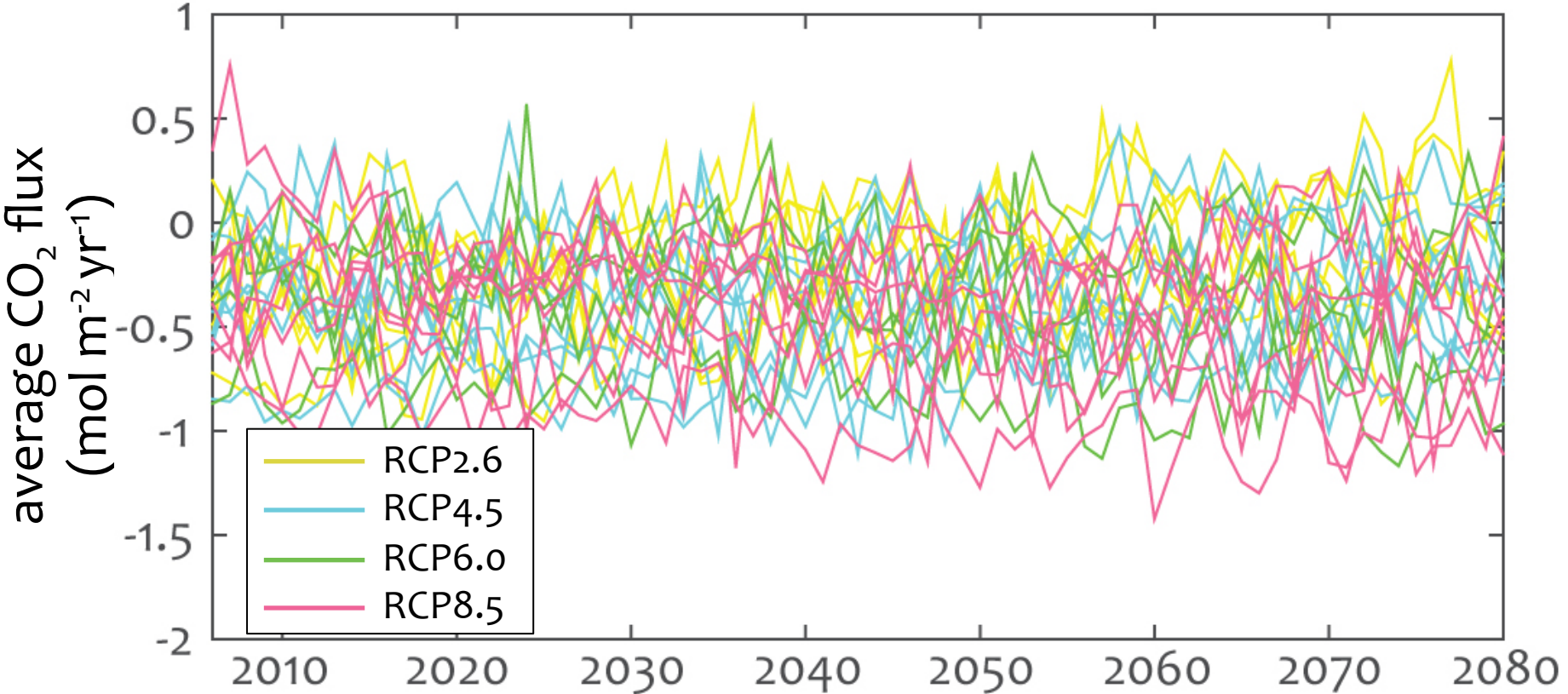


How much CO_2 will the ocean absorb?

California Current System average sea-air CO_2 flux

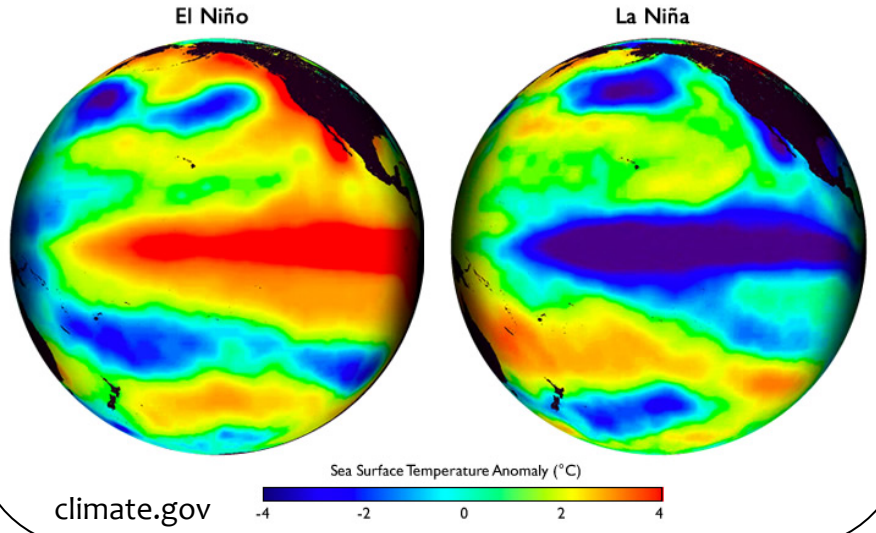


CMIP5 models



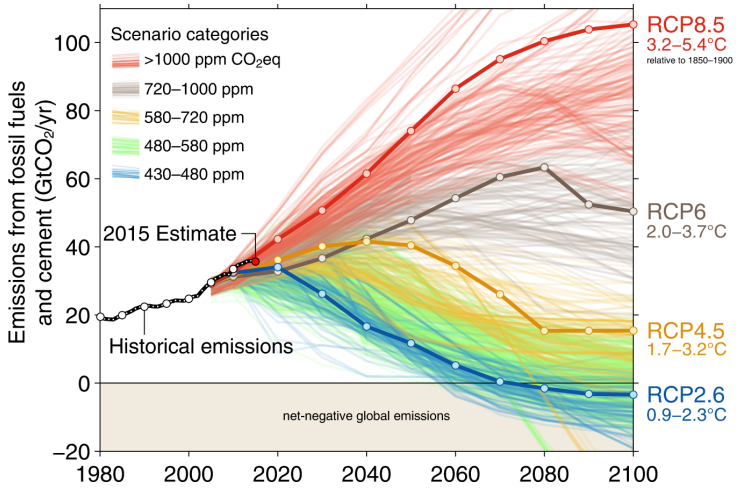
Sources of prediction uncertainty

Internal variability



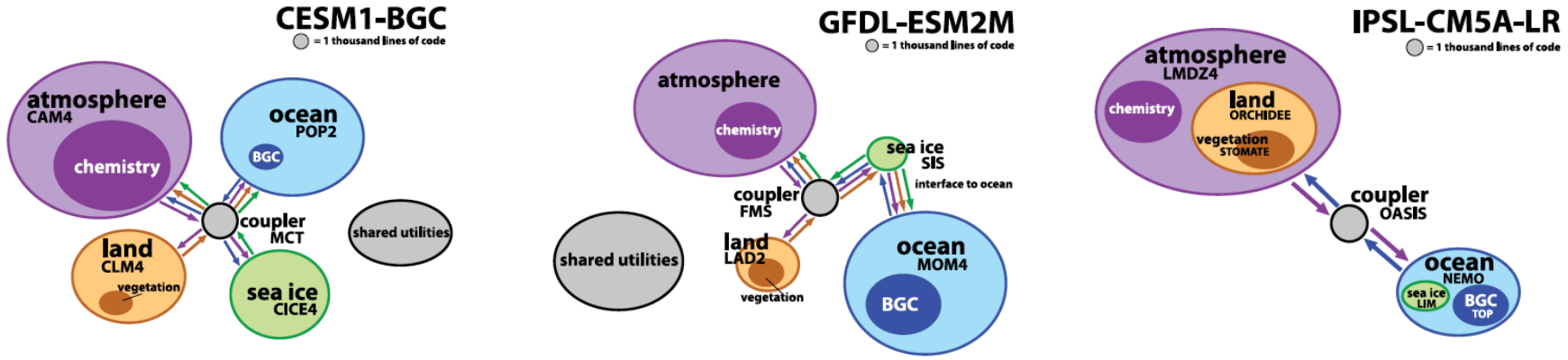
climate.gov

Emission scenario



Global Carbon Project

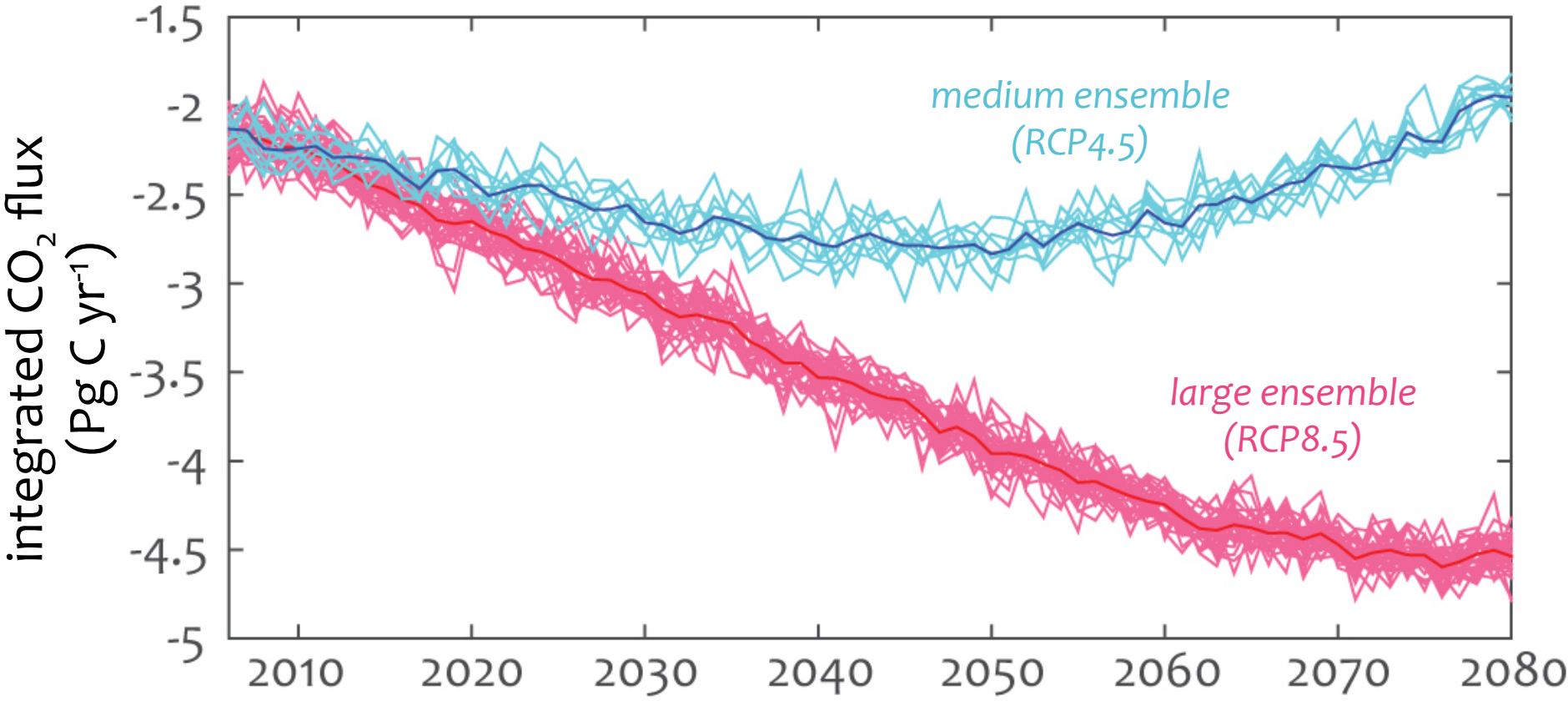
Model structure



Alexander and Easterbrook (2015)

CESM ensembles

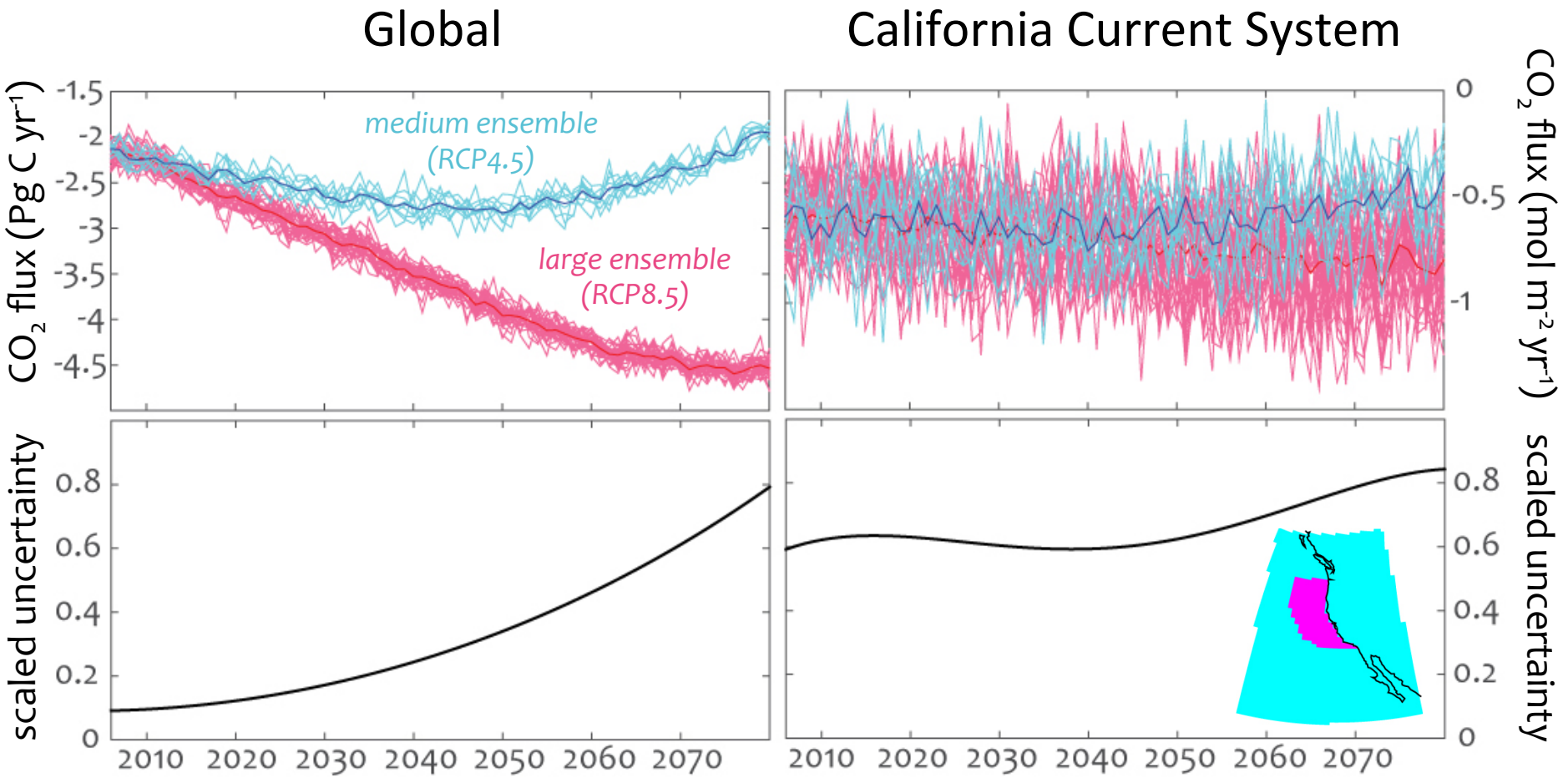
Globally-integrated sea-air CO_2 flux



Lovenduski et al. (in review)

How uncertain is our prediction?

CESM ensembles



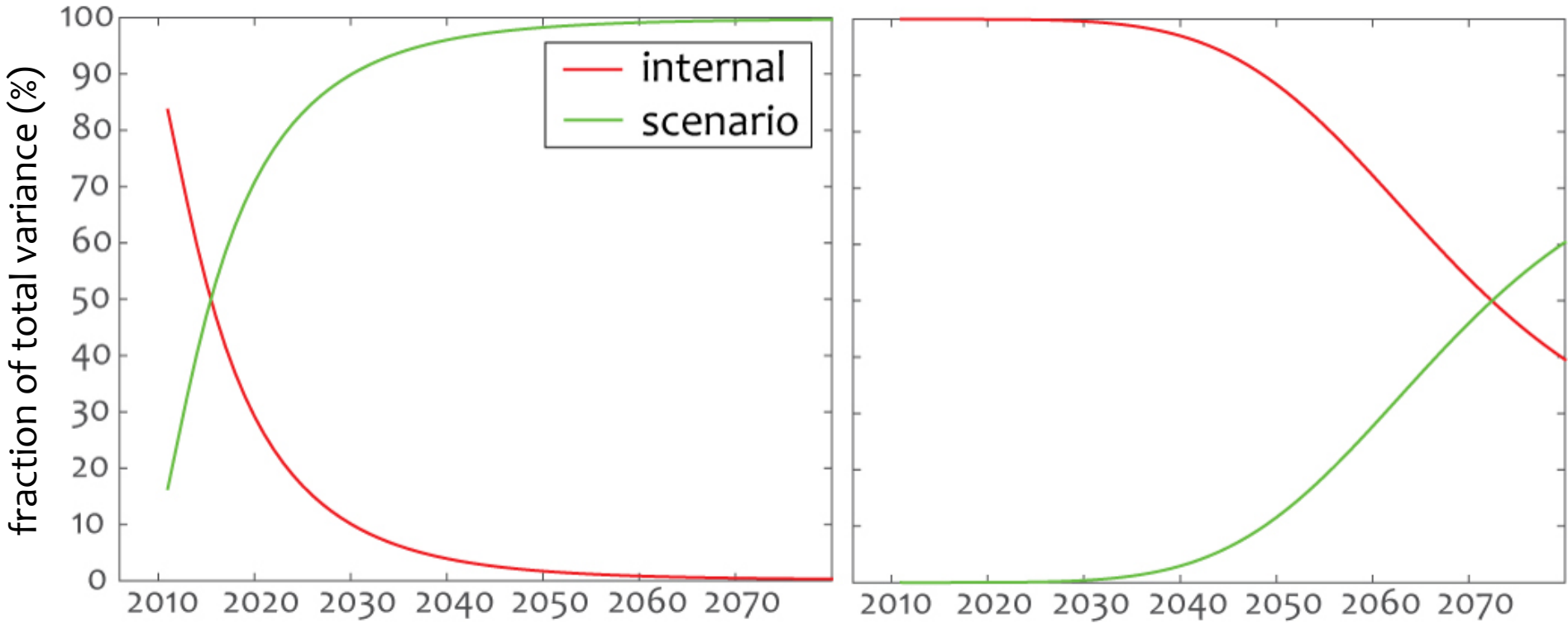
Lovenduski et al. (in review)

Evolving sources of uncertainty

CESM ensembles

Global

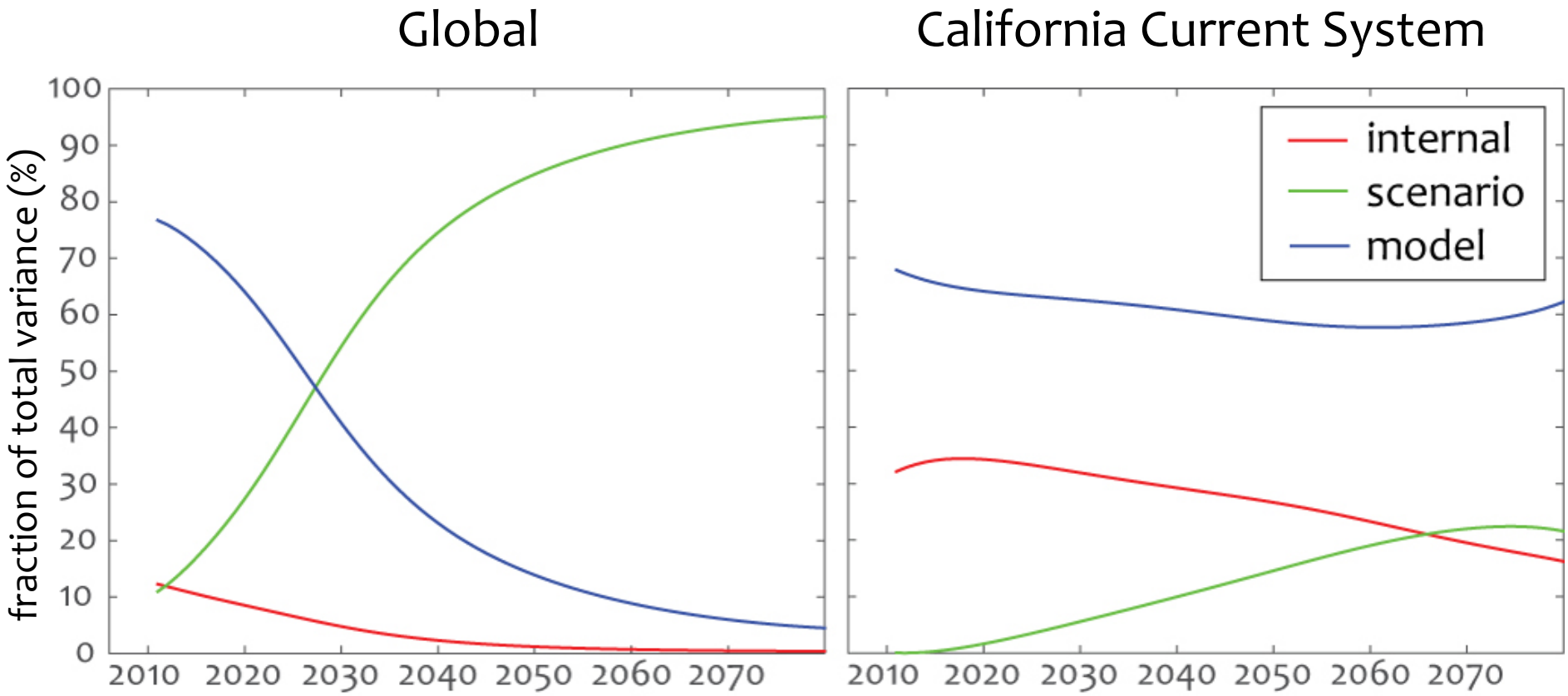
California Current System



Lovenduski et al. (in review)

Evolving sources of uncertainty

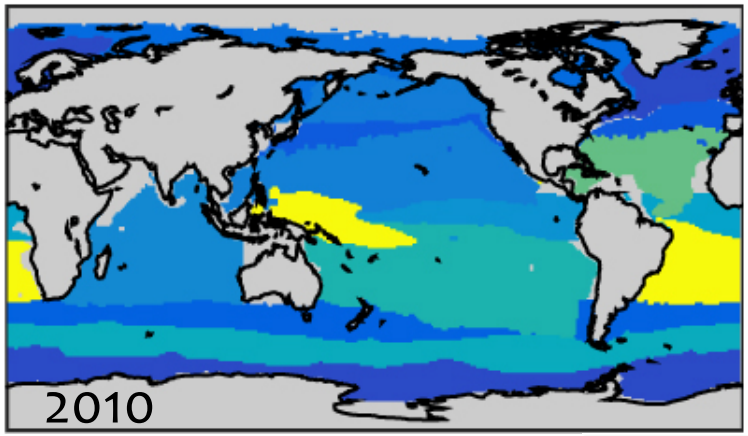
CMIP5

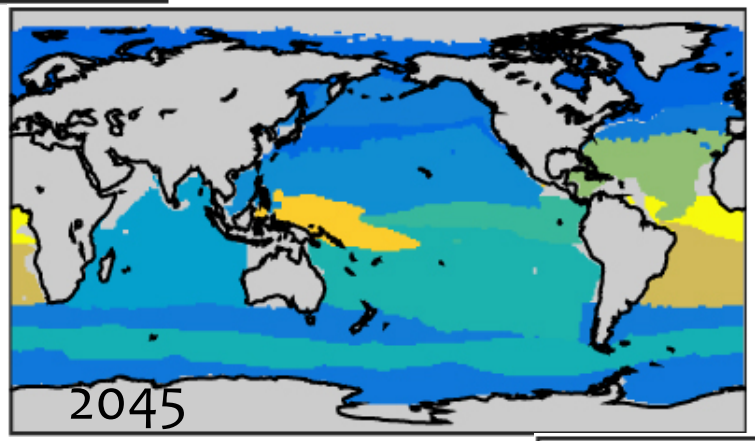


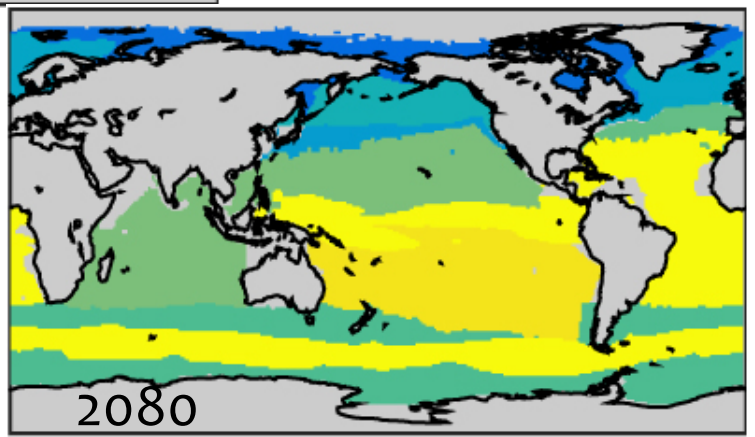
Lovenduski et al. (in review)

Uncertainty on the biome scale

CESM ensembles







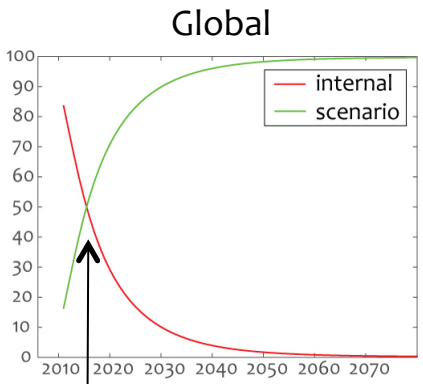
scaled uncertainty

0 0.2 0.4 0.6 0.8 1

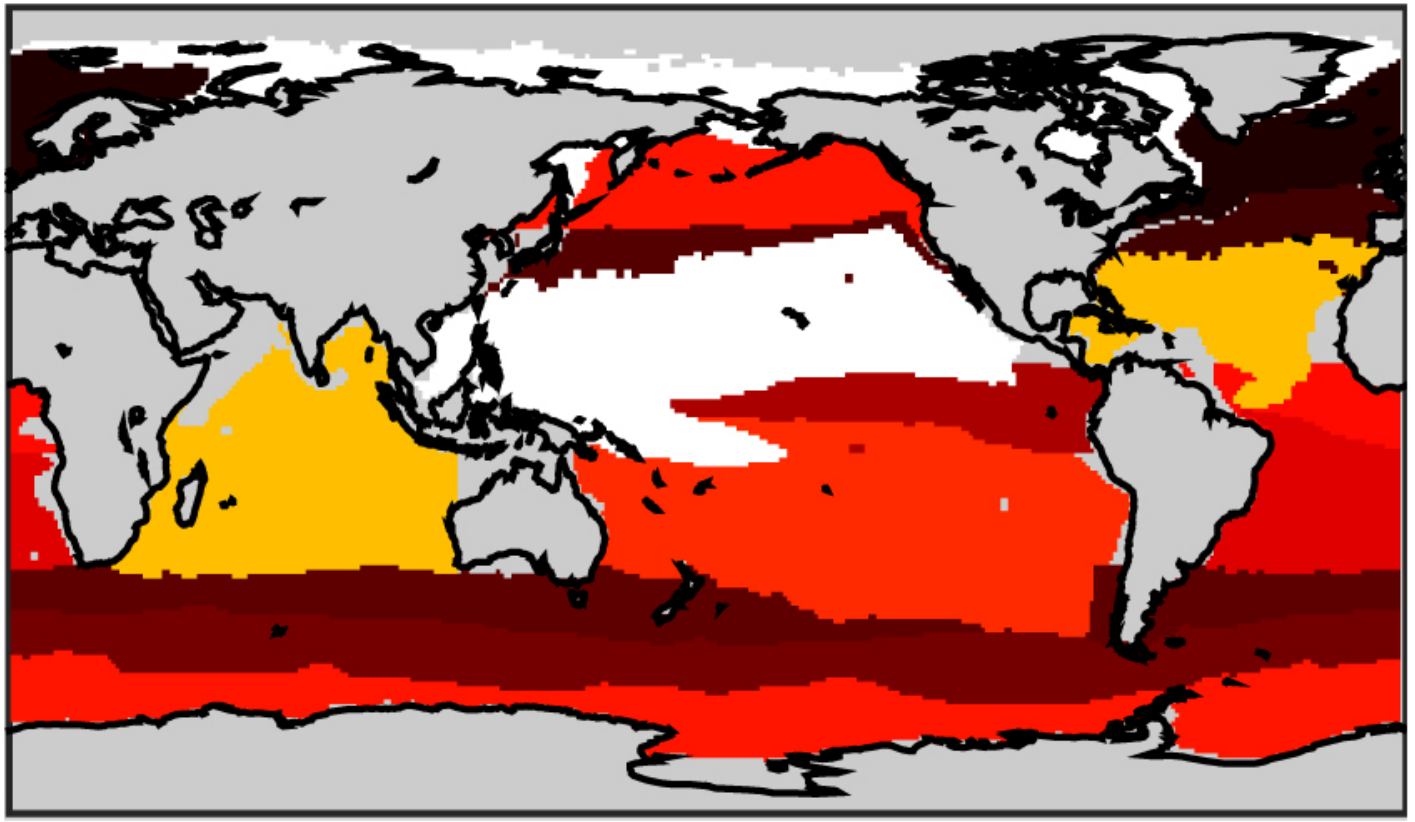
Lovenduski et al. (in review)

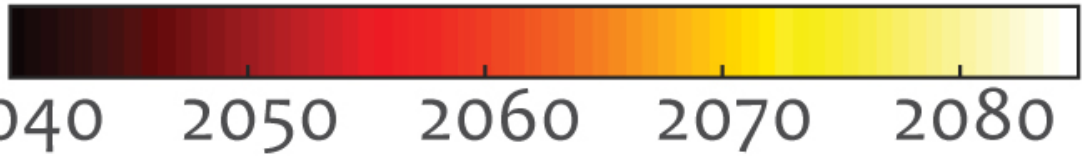
Internal variability is the primary source of uncertainty until…

CESM ensembles



When do the lines cross for each biome?





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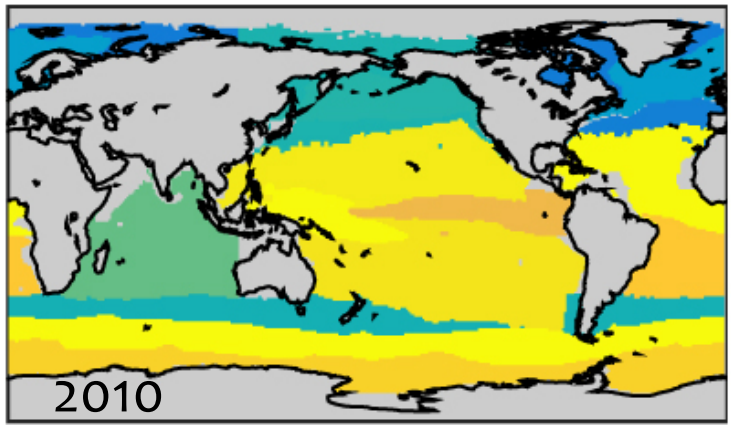
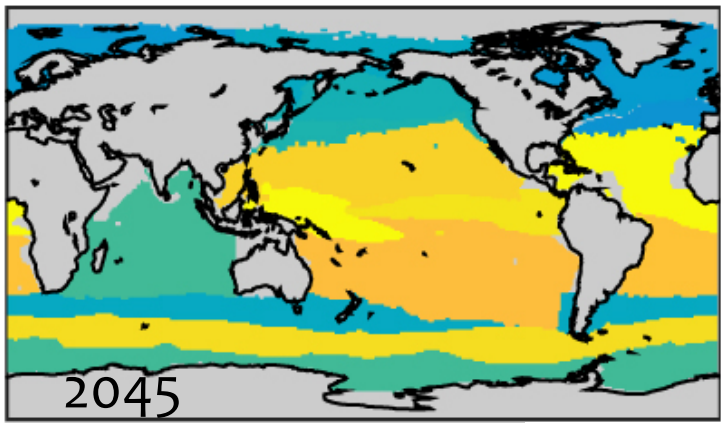
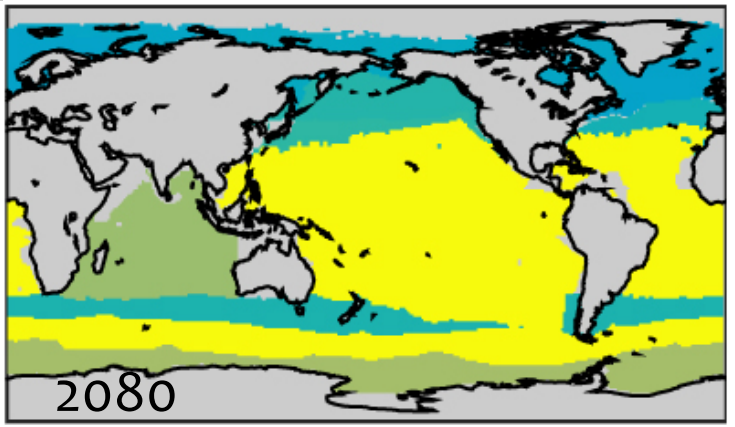
Uncertainty on the biome scale

CMIP5







scaled uncertainty

0 0.5 1 1.5 2

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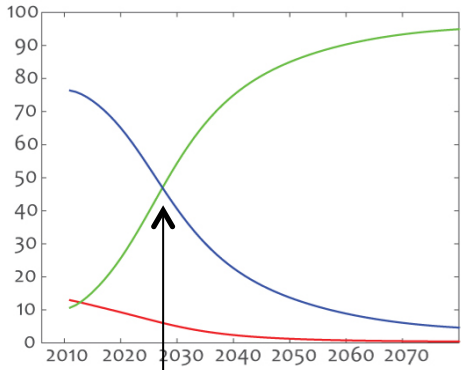
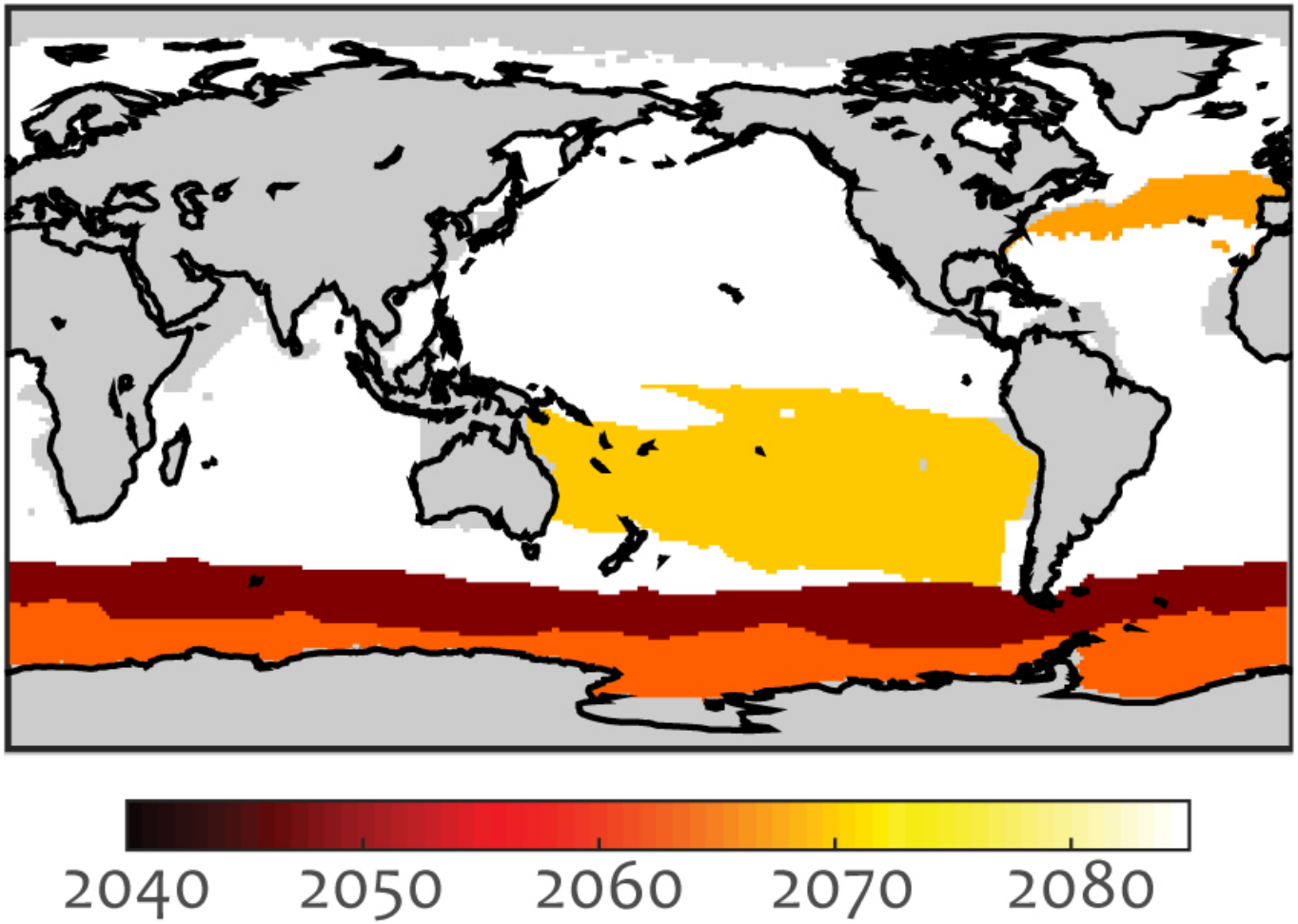
Model structure is the primary source of uncertainty until…

CMIP5

Global



When do the lines cross for each biome?



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Conclusions

- Predictions of the future ocean carbon sink are fraught with uncertainty, particularly at regional scales.
- The 3 sources of prediction uncertainty vary with time, spatial averaging scale, and from region to region.
- In order to produce reliable predictions on regional scales, we should invest in reducing model structure uncertainty.