

Using ocean-only models to study the role of the ocean in climate change

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2. Studying CRFs using ocean-only models

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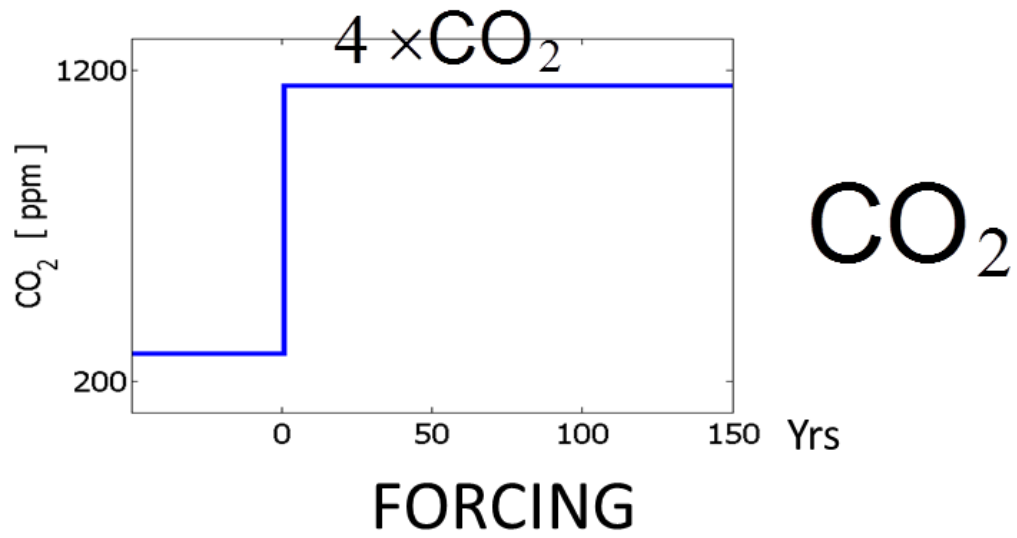
1. Climate Response Functions (CRFs)

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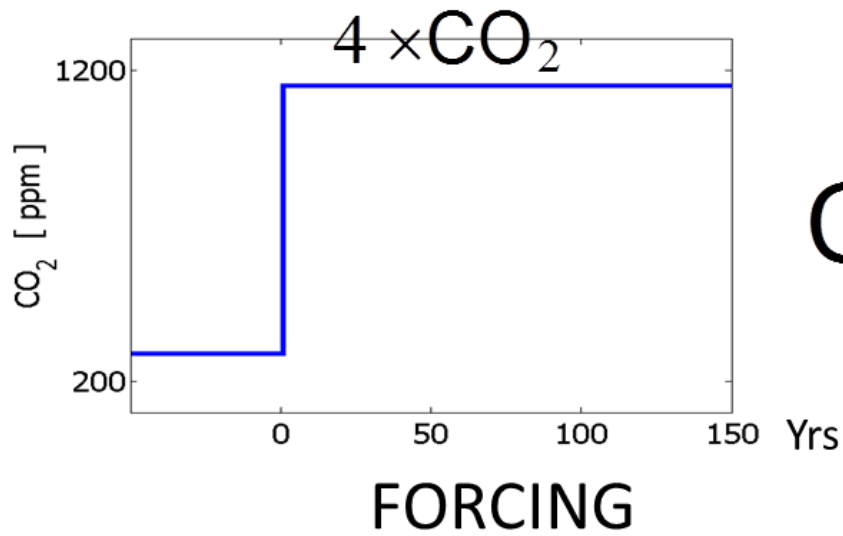
3. Proposal for a CORE follow-on:

explore/isolate the role of ocean dynamics in setting the form of CRFs but in an ocean-only context

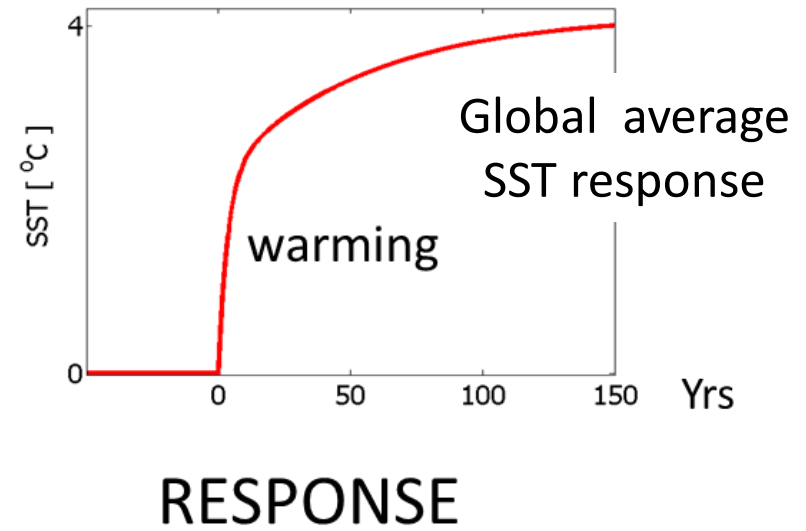
Climate Response Functions



Climate Response Functions



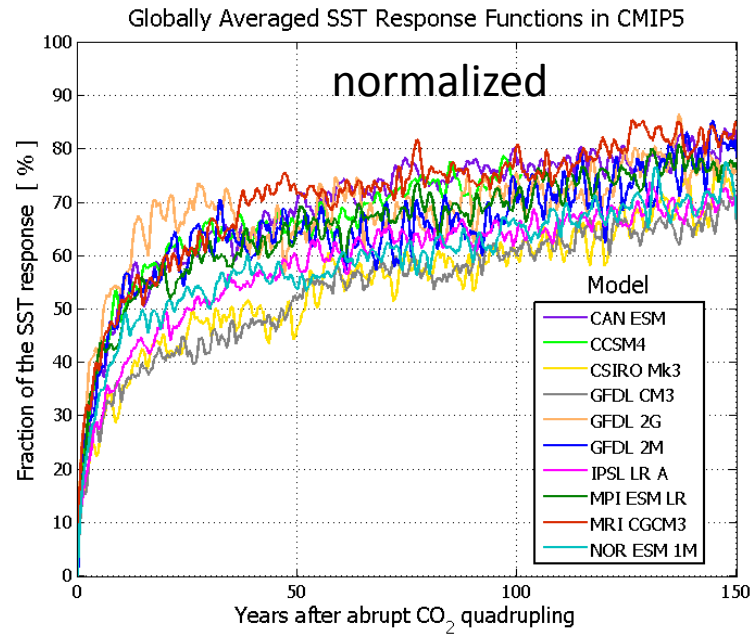
CO₂



GHG Response Functions

Run out coupled A-O-ICE climate model to equilibrium.

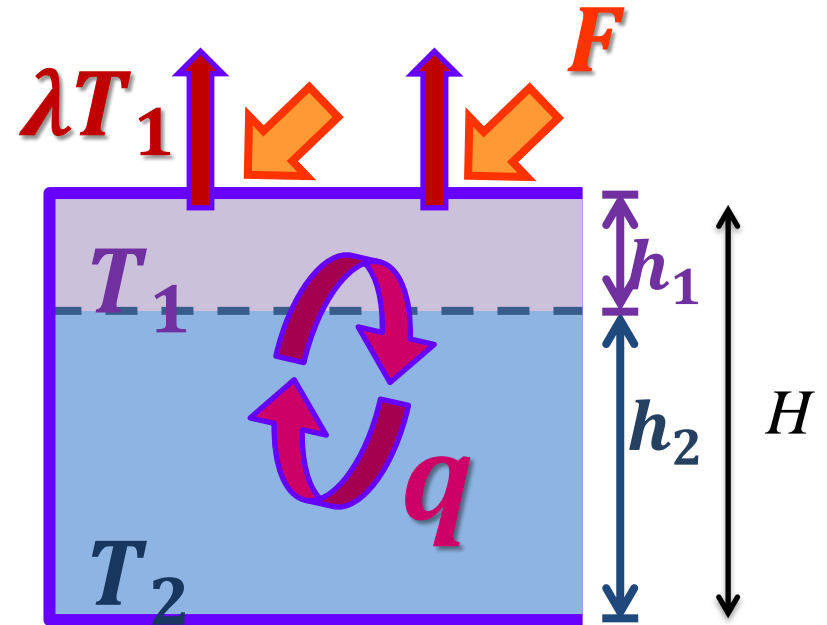
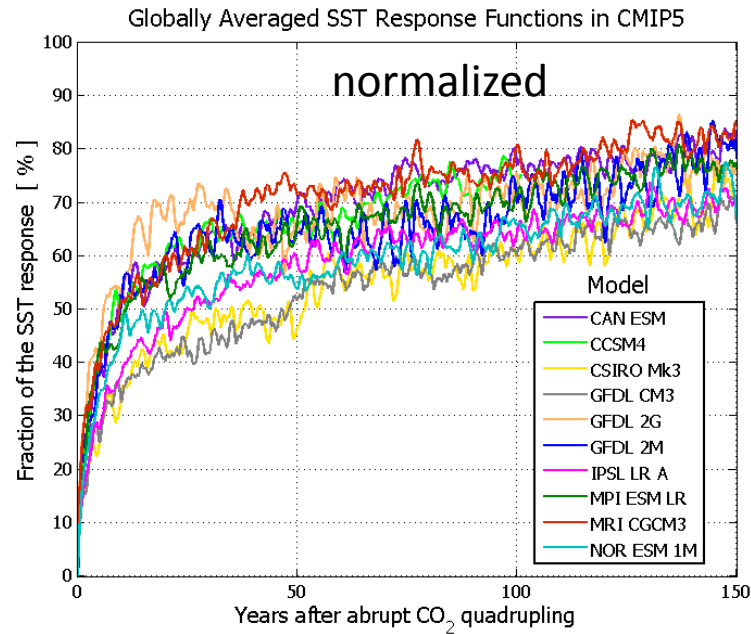
Then instantaneously perturb GHG forcing and study evolution to new equilibrium



GHG Response Functions

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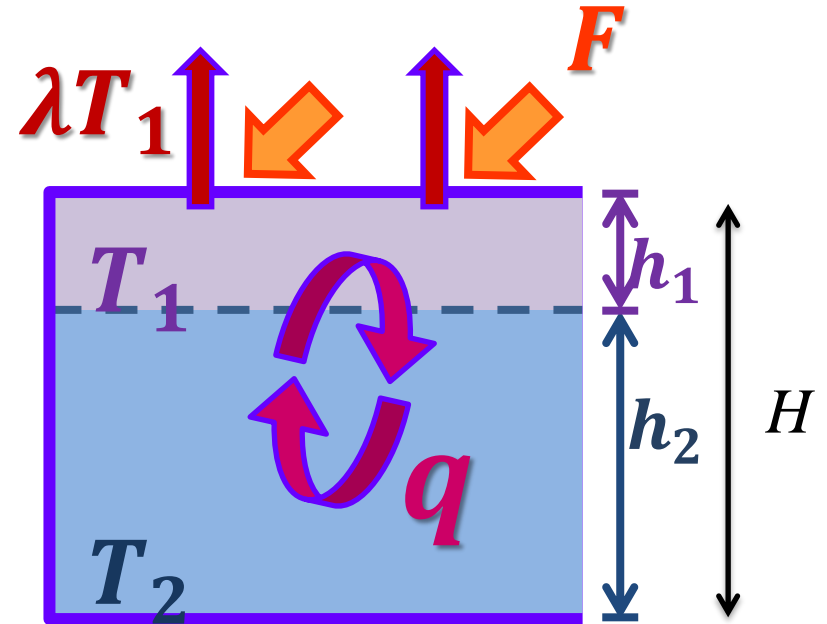
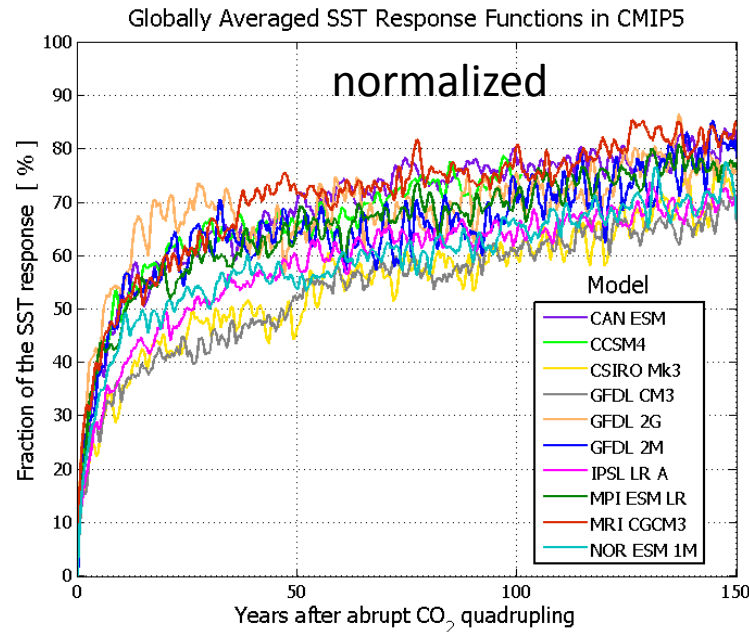
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GHG Response Functions

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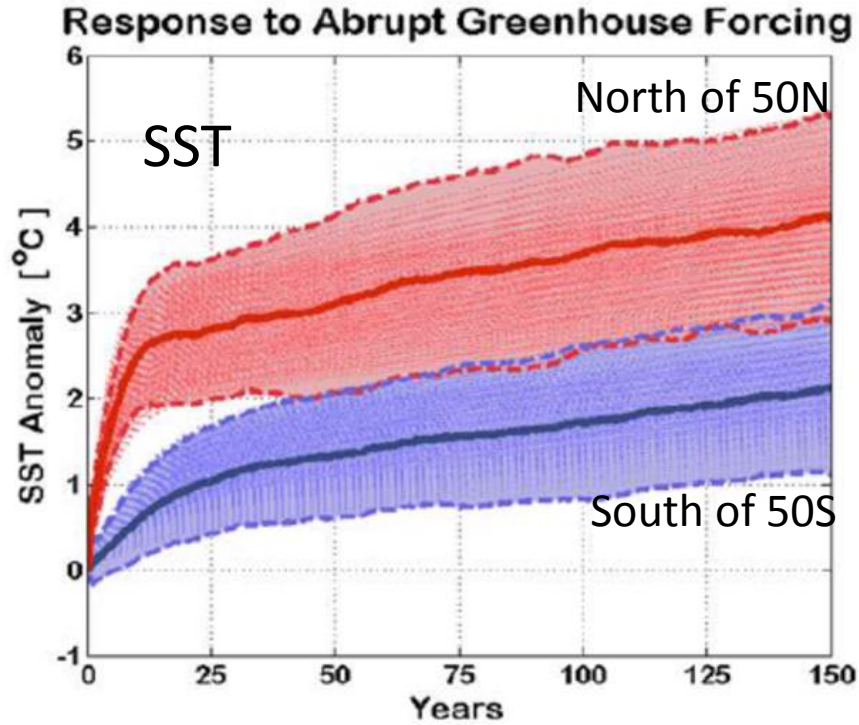


Gregory, 2000; Winton et al, 2012; Kostov et al, 2014

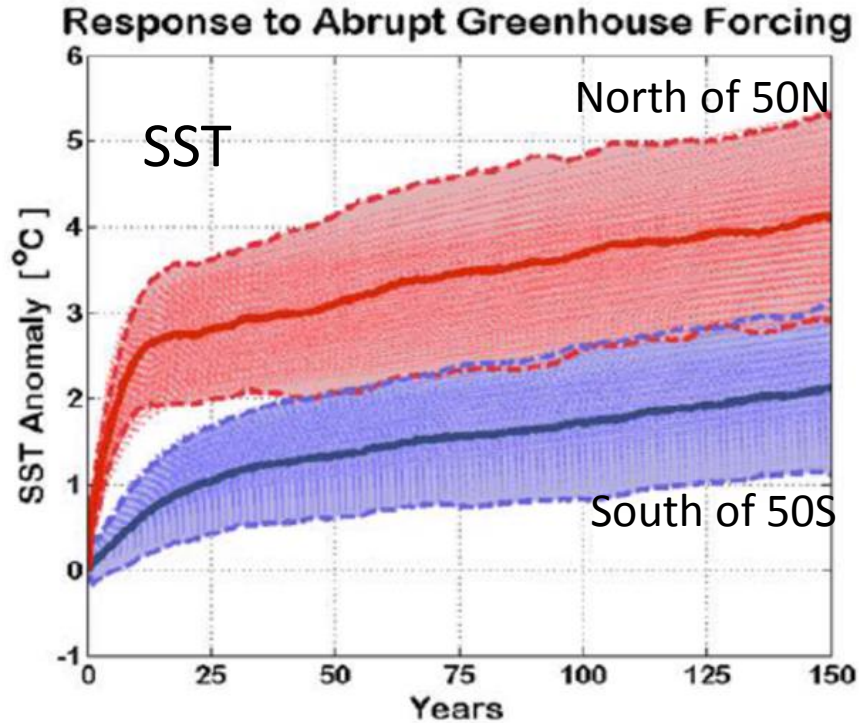
Fast timescale $\tau_1 \approx \lambda + Q$ - few years

Slow timescale $\tau_2 \approx \lambda Q r / (\lambda + Q)$ - decades

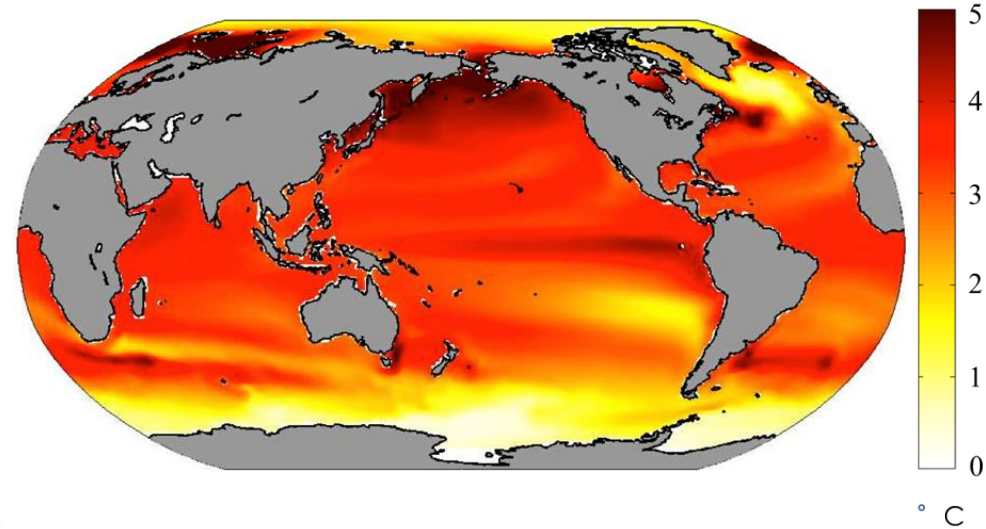
Regional GHG response functions



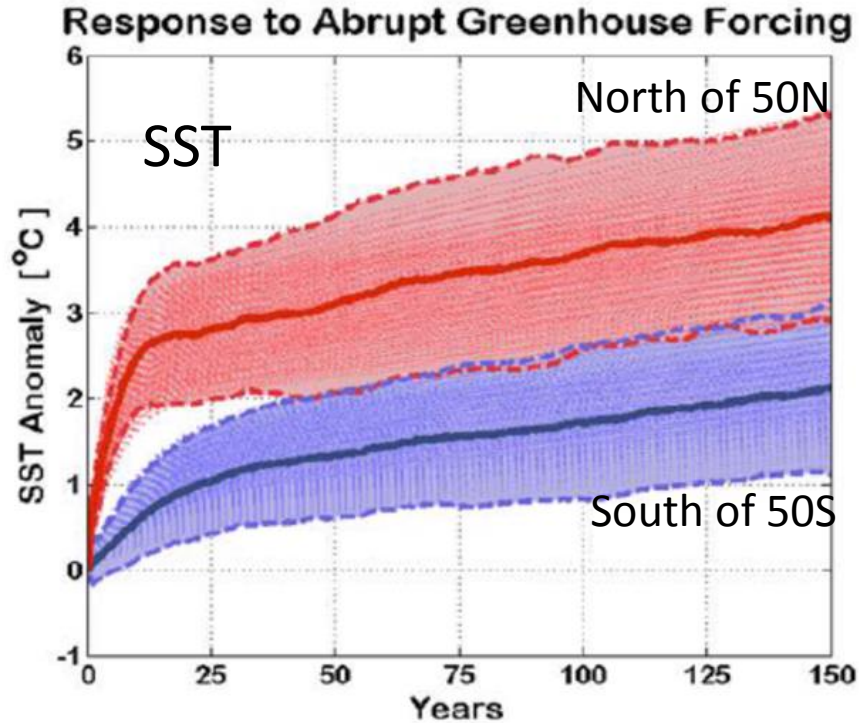
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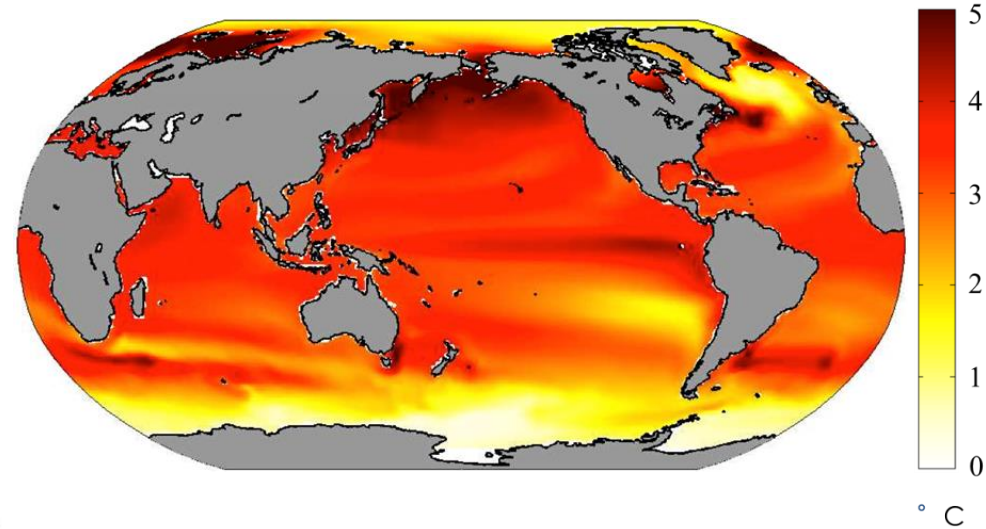
CMIP5 ensemble
(15 models, abrupt 4xCO₂)



Regional GHG response functions



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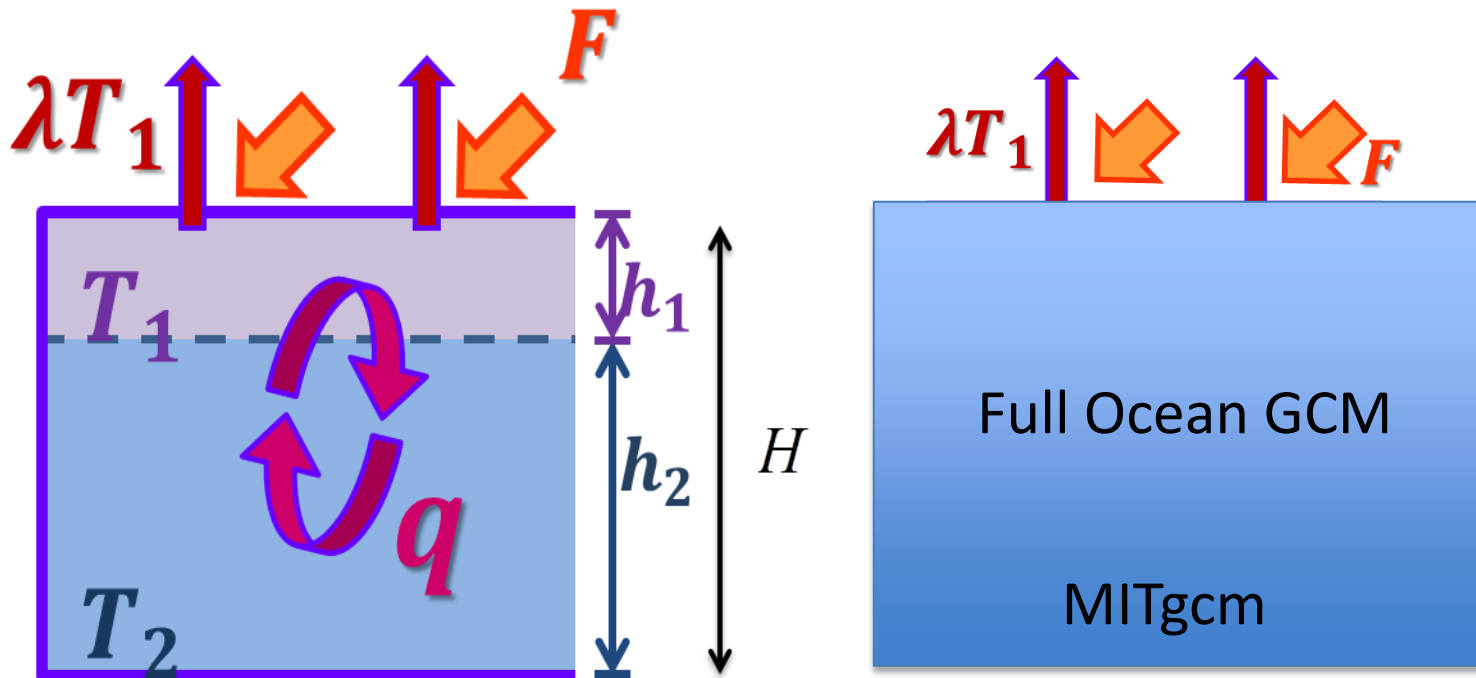
Delayed warming in the SH, accelerated warming in NH

Ocean-only calculation

Replace 2-box model with full ocean GCM driven following CORE1 protocol following Griffies et al (2009)

Carry out a 'climate change' experiment:

- Abrupt, uniform surface forcing of $F = 4 \text{ W/m}^2$ everywhere
- Spatially-invariant radiative feedback of $\lambda = 1 \text{ Wm}^{-2} \text{ K}^{-1}$

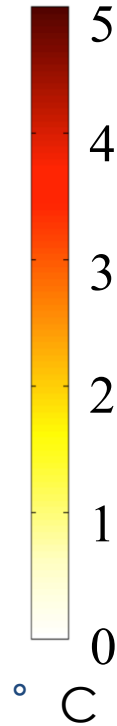
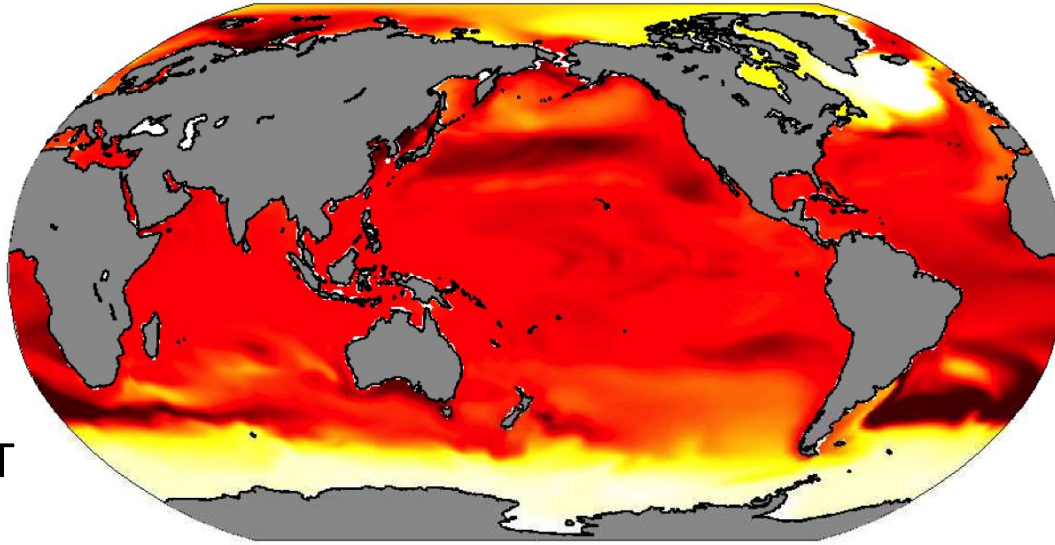


Spatial pattern of warming

Temperature change (°C) after 100 years

Ocean-only
MITgcm

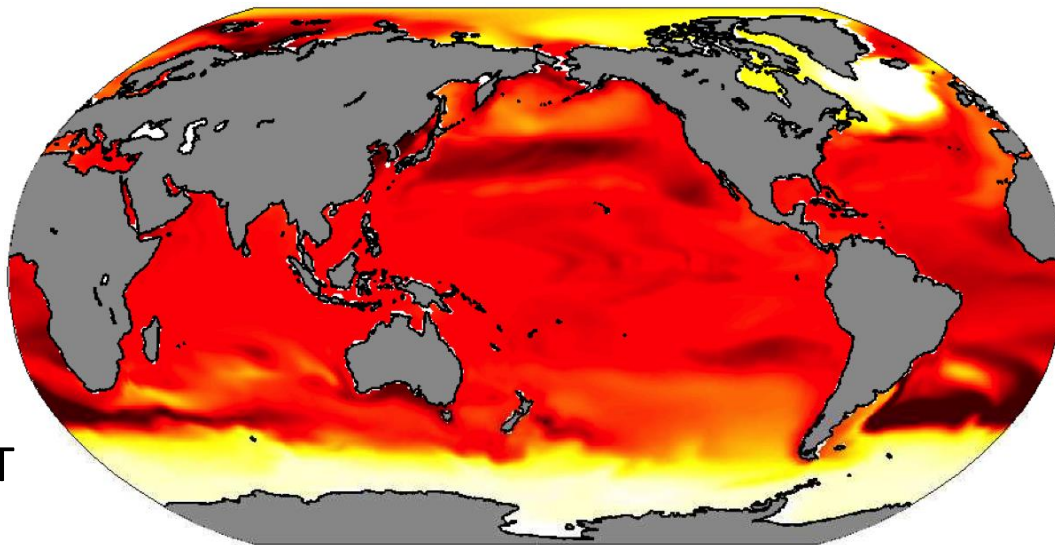
Jeff Scott &
Kyle Armour, MIT



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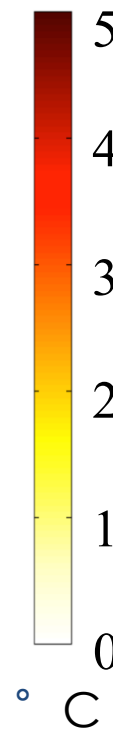
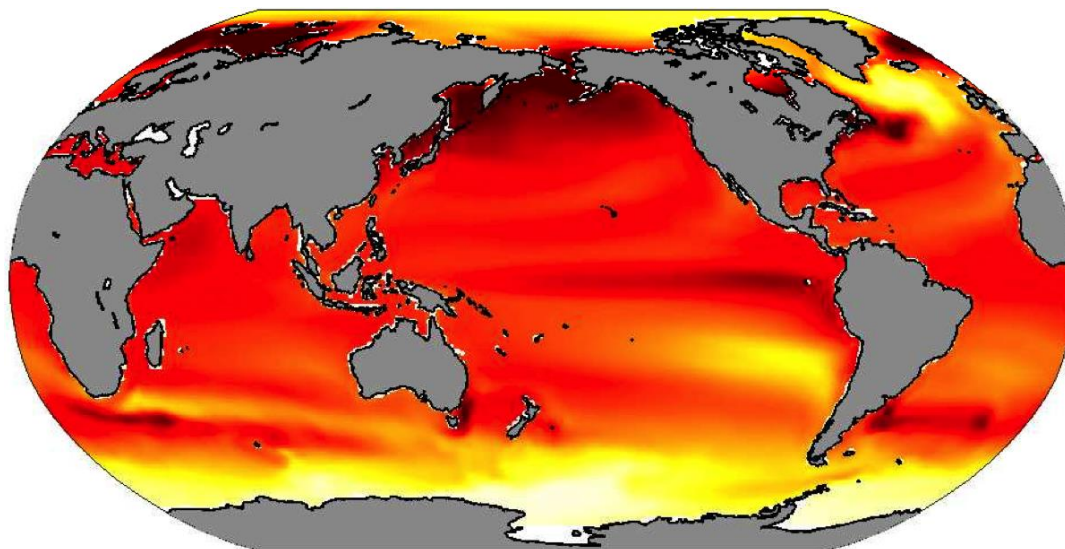
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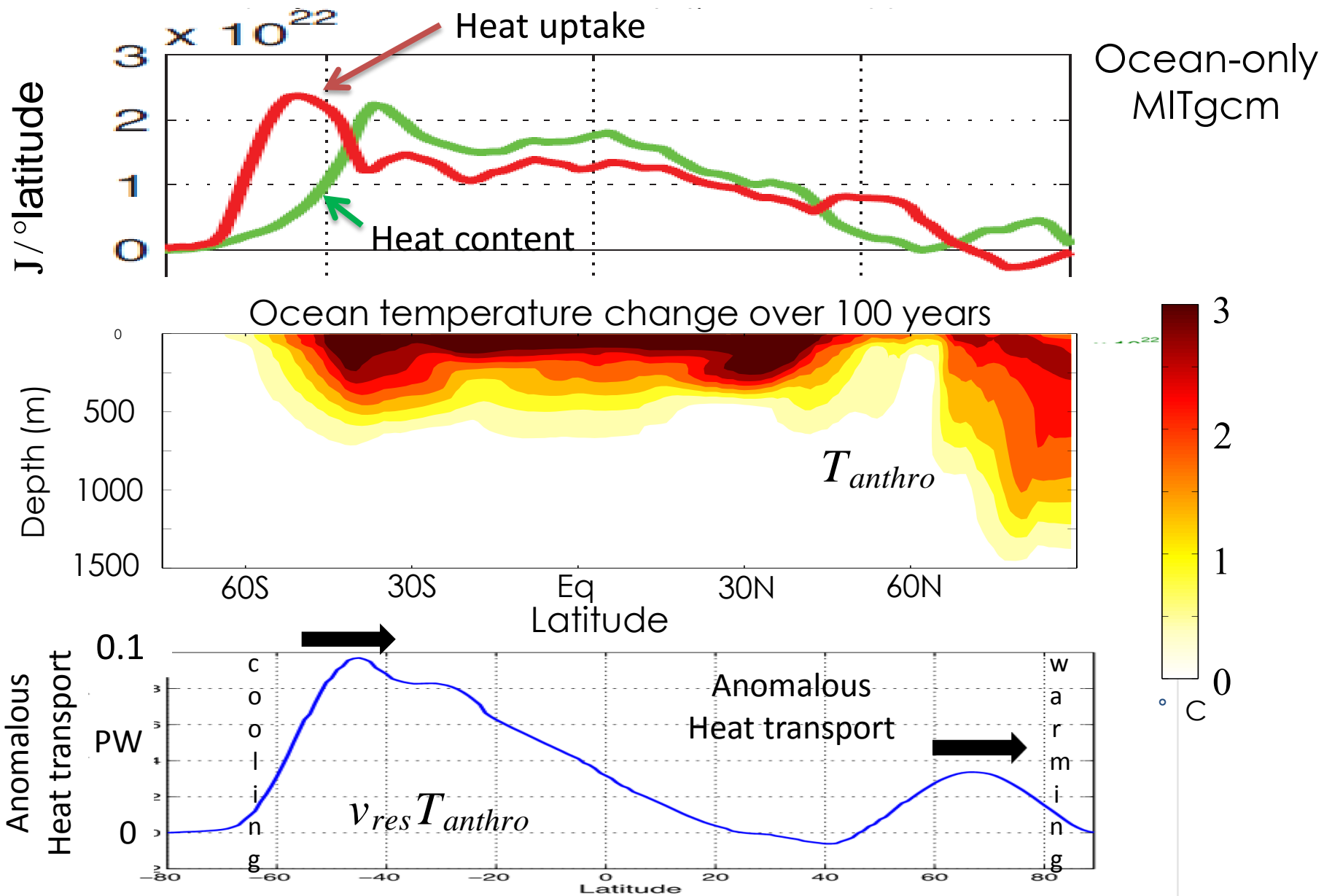
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CMIP5
ensemble

(15 models,
abrupt $4\times\text{CO}_2$)

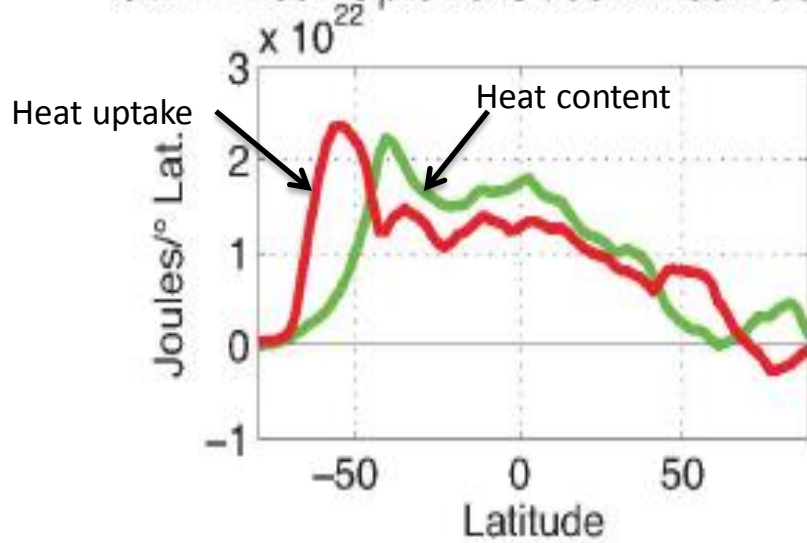


Energy accumulation, ocean storage & transport

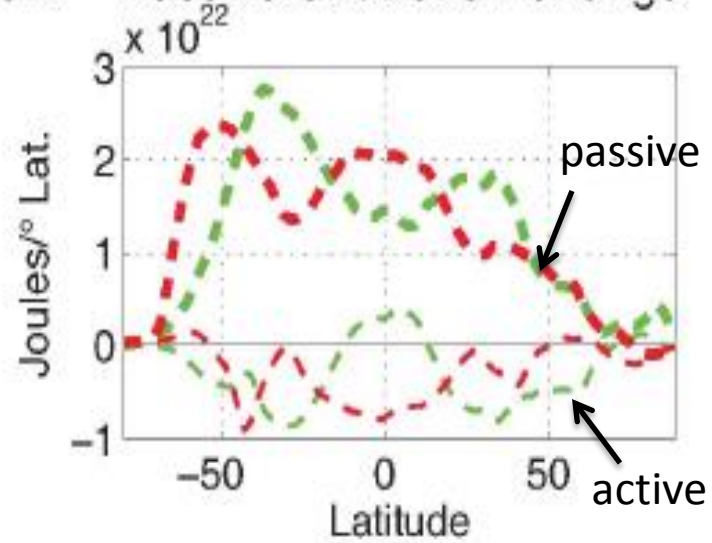


Active vs Passive

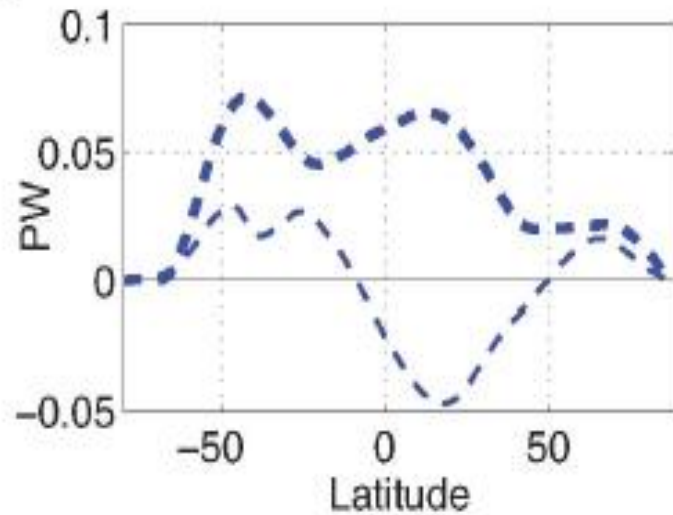
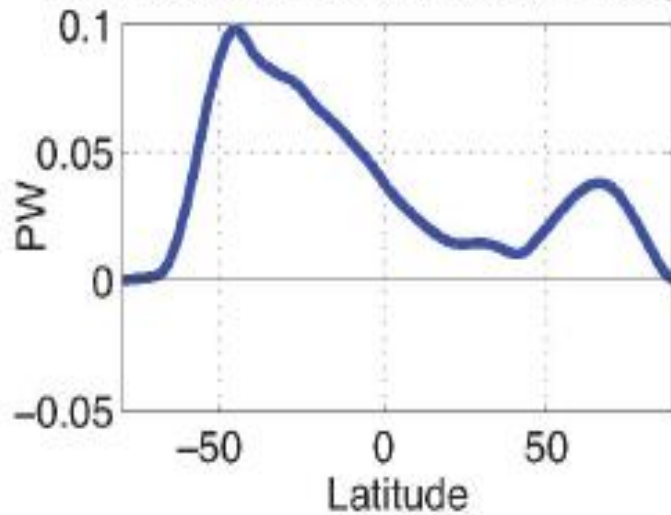
Cum. Heat Uptake/Ocean Heat Content



Passive/Circulation Change

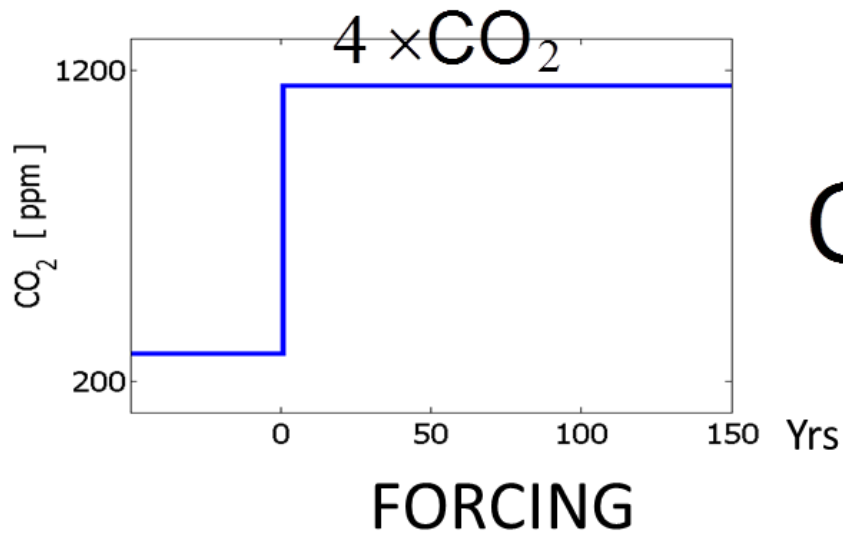


Anomalous Ocean Heat Transport

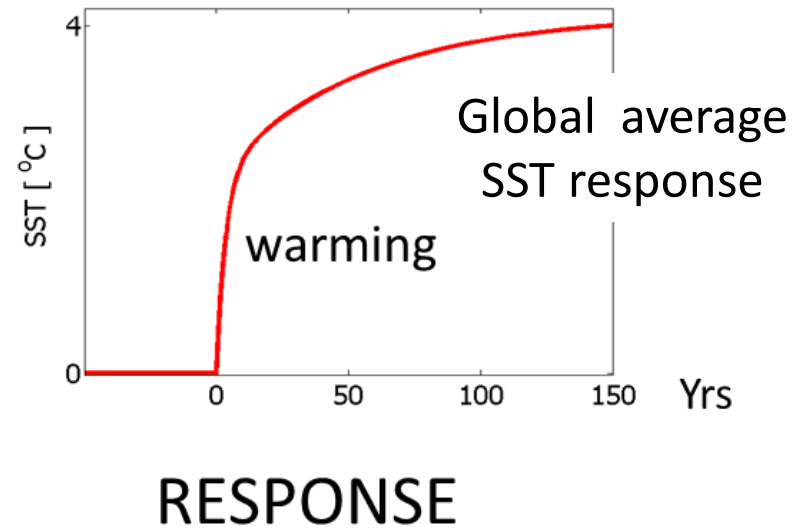


Other kinds of forcing

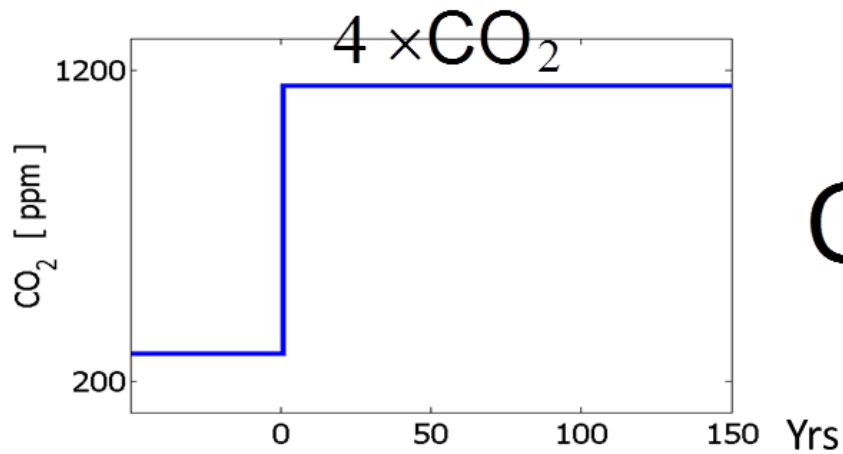
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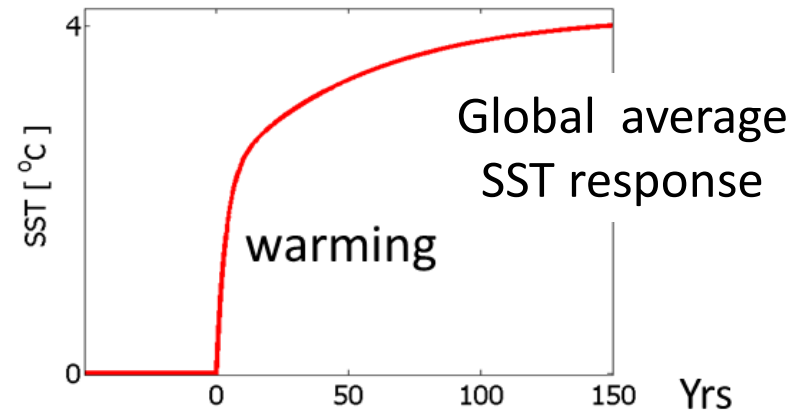
CO₂



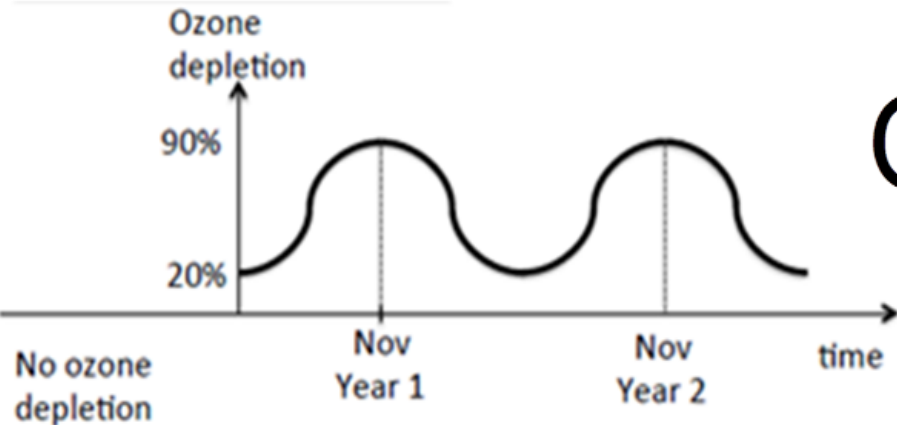
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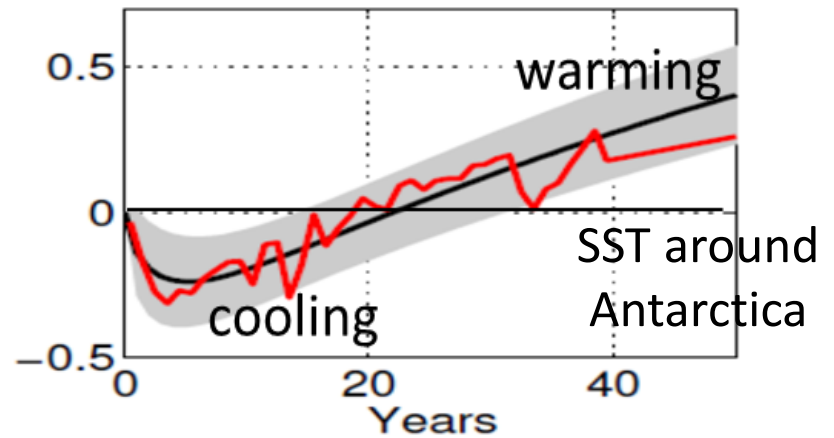
FORCING



RESPONSE

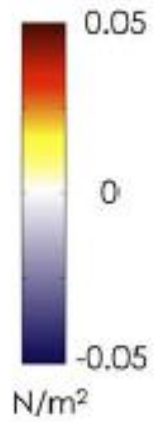
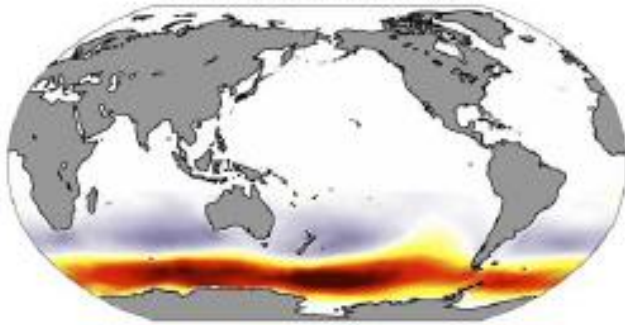


O₃

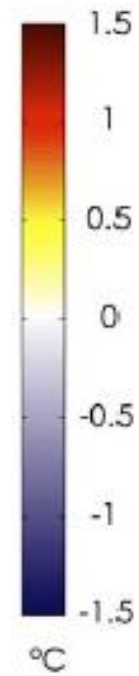
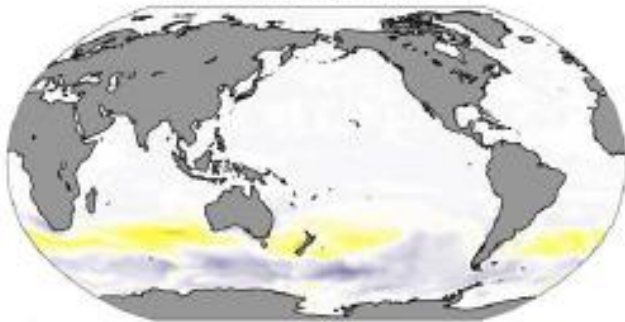


Wind forcing

Wind stress anomaly

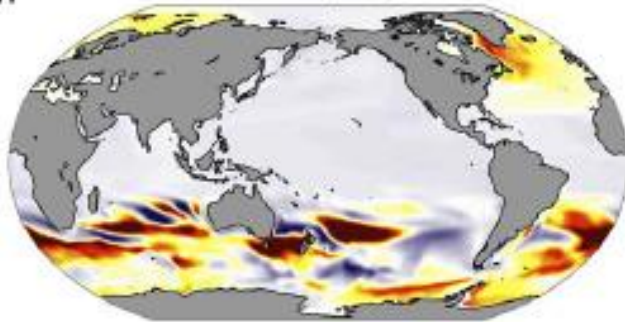


SST anomaly in year 1



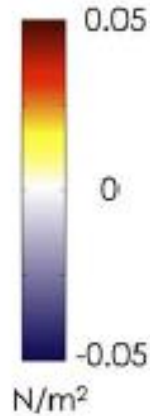
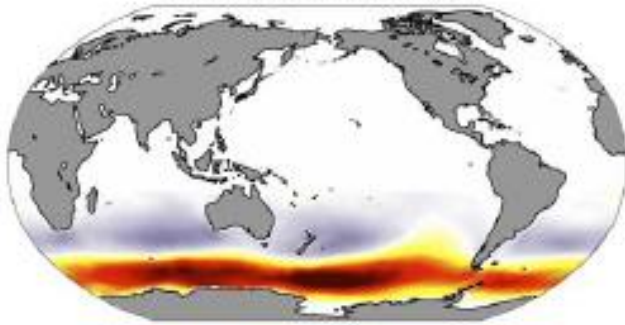
Ocean-only
MITgcm

SST anomaly in year 50

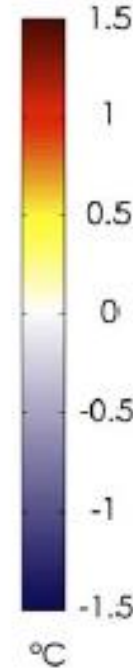
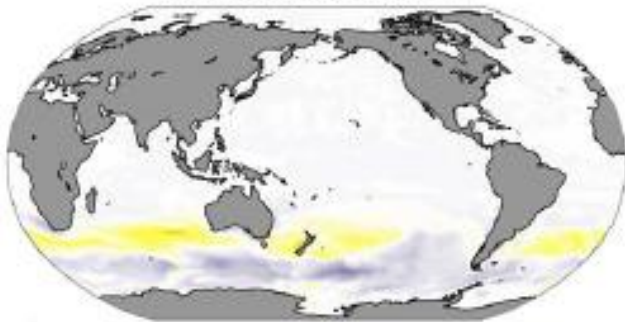


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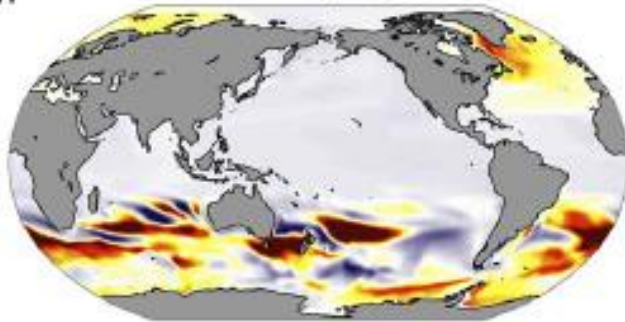


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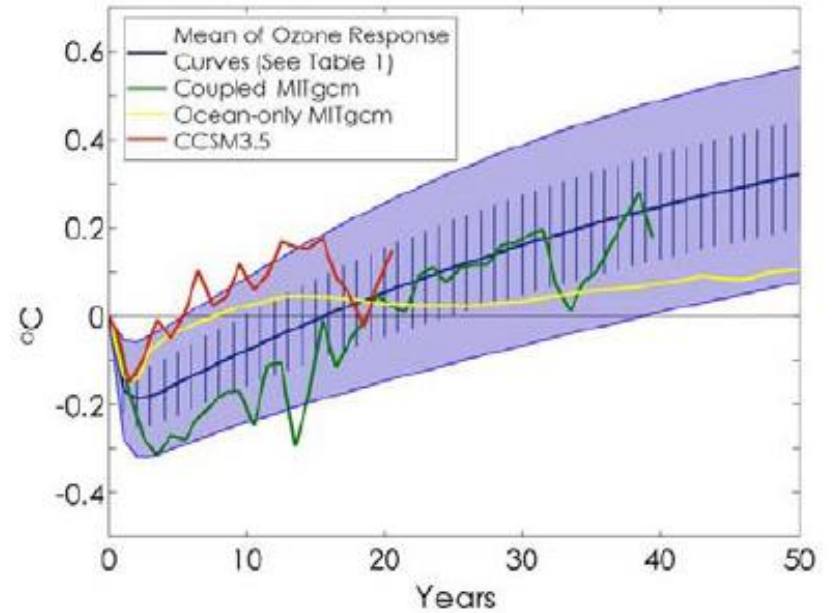


Ocean-only MITgcm

SST anomaly in year 50



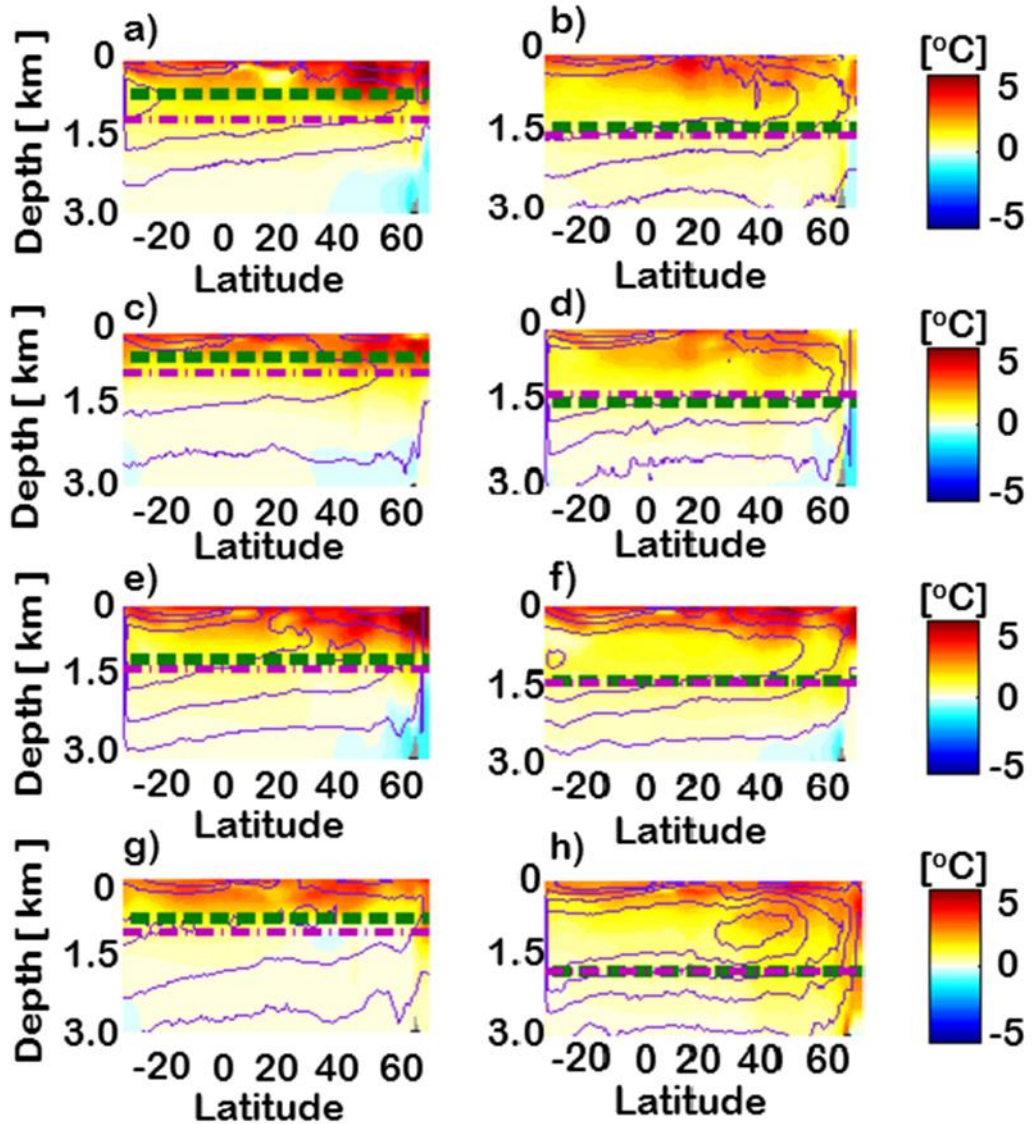
Response to Abrupt Ozone Forcing



Ozone hole response functions

How can we explore/isolate the role of ocean dynamics in setting the form of CRFs but in an ocean-only context?

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Heat uptake and AMOC in coupled models

A Proposed CORE Protocol for “Radiative Forcing” scenarios

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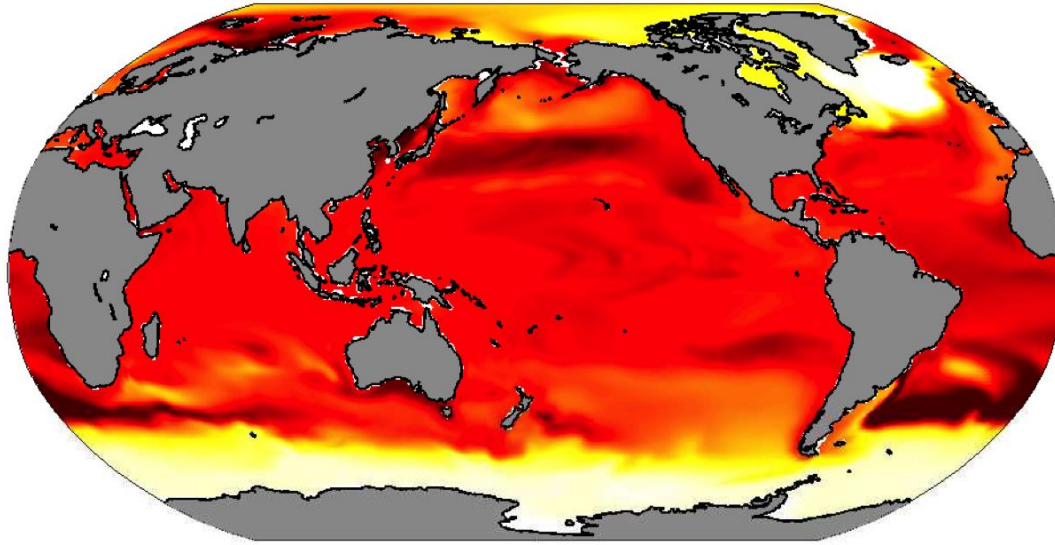
4. Damp SST anomalies at a rate set by a climate feedback parameter.

$$\frac{D_{res}}{Dt} (T_c + T_{anthro}) = Q (\mathcal{H}_c + \mathcal{H}_{anthro}) - \gamma (SST - SST_c)$$

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(15 models,
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