CAM6 patch experiments

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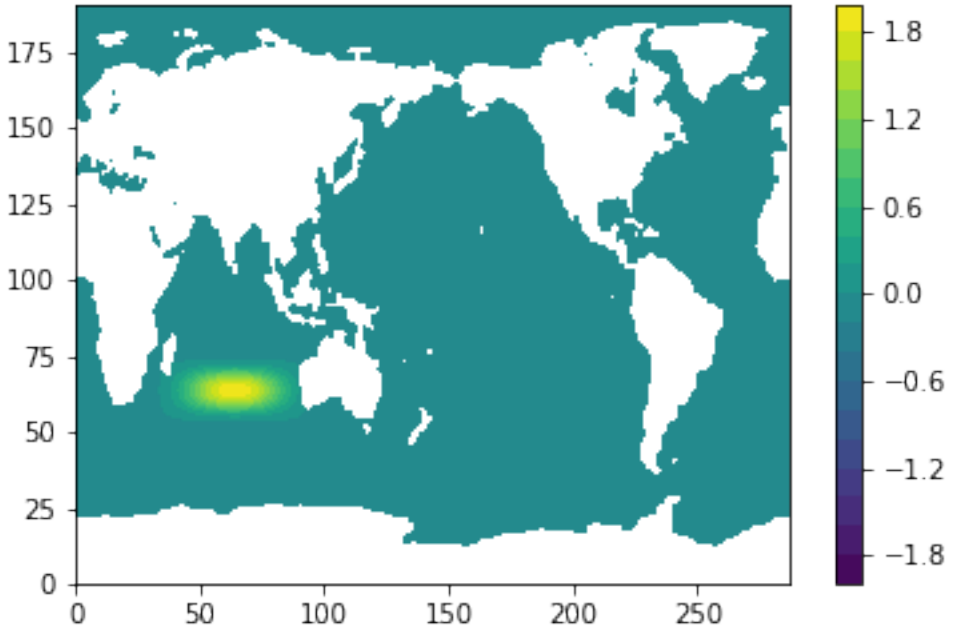
What are patch experiments?

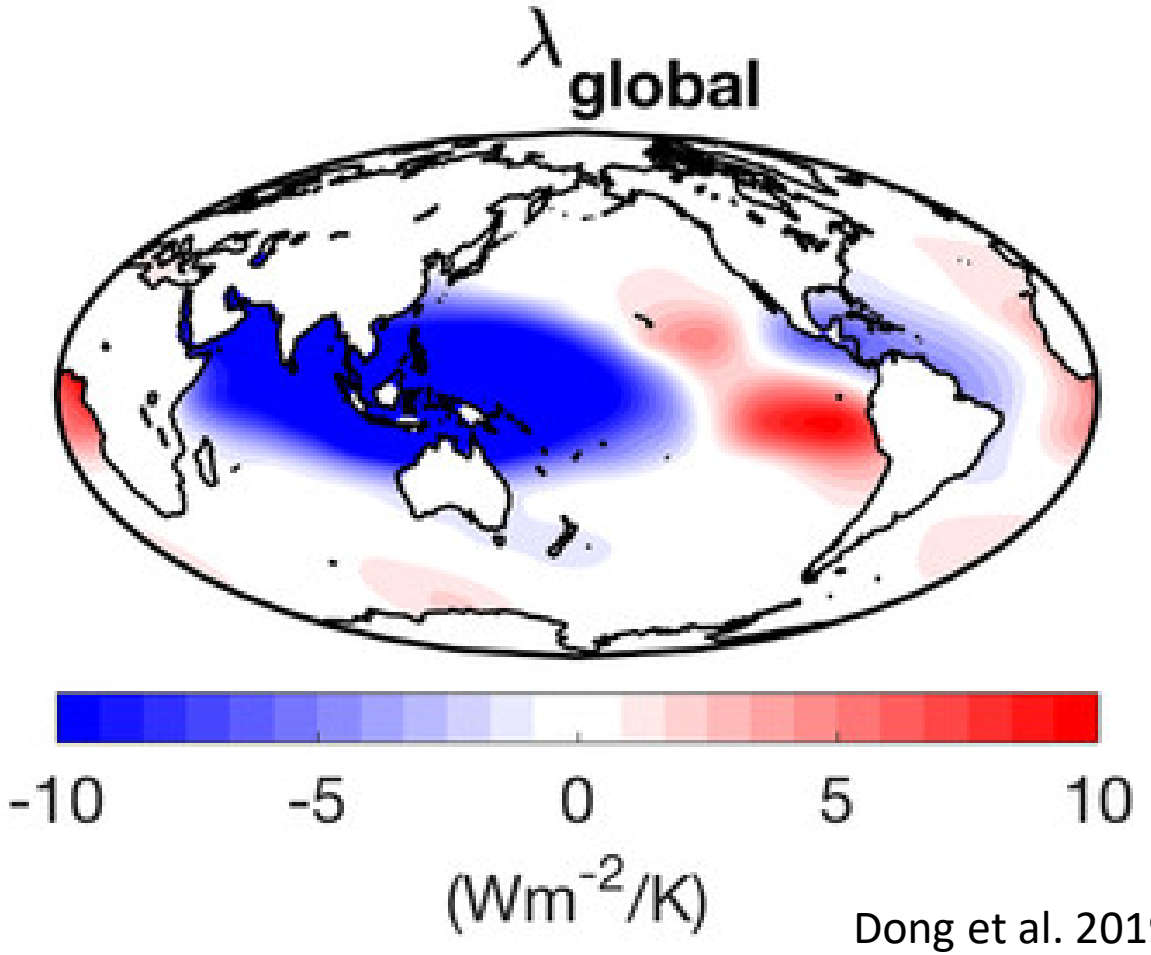
- An ensemble of atmosphere-only experiments which have imposed SSTs with patch shaped SST anomalies

- These experiments can be used to diagnose the response of the atmosphere to local SST change using a Green's function approach



Patch experiments have been used to study the **pattern effect**

The figure shows the *global mean radiative feedback* given SST warming at that location. The strong dependence of feedback on warming location explains why feedbacks are so sensitive to the *pattern of warming*.

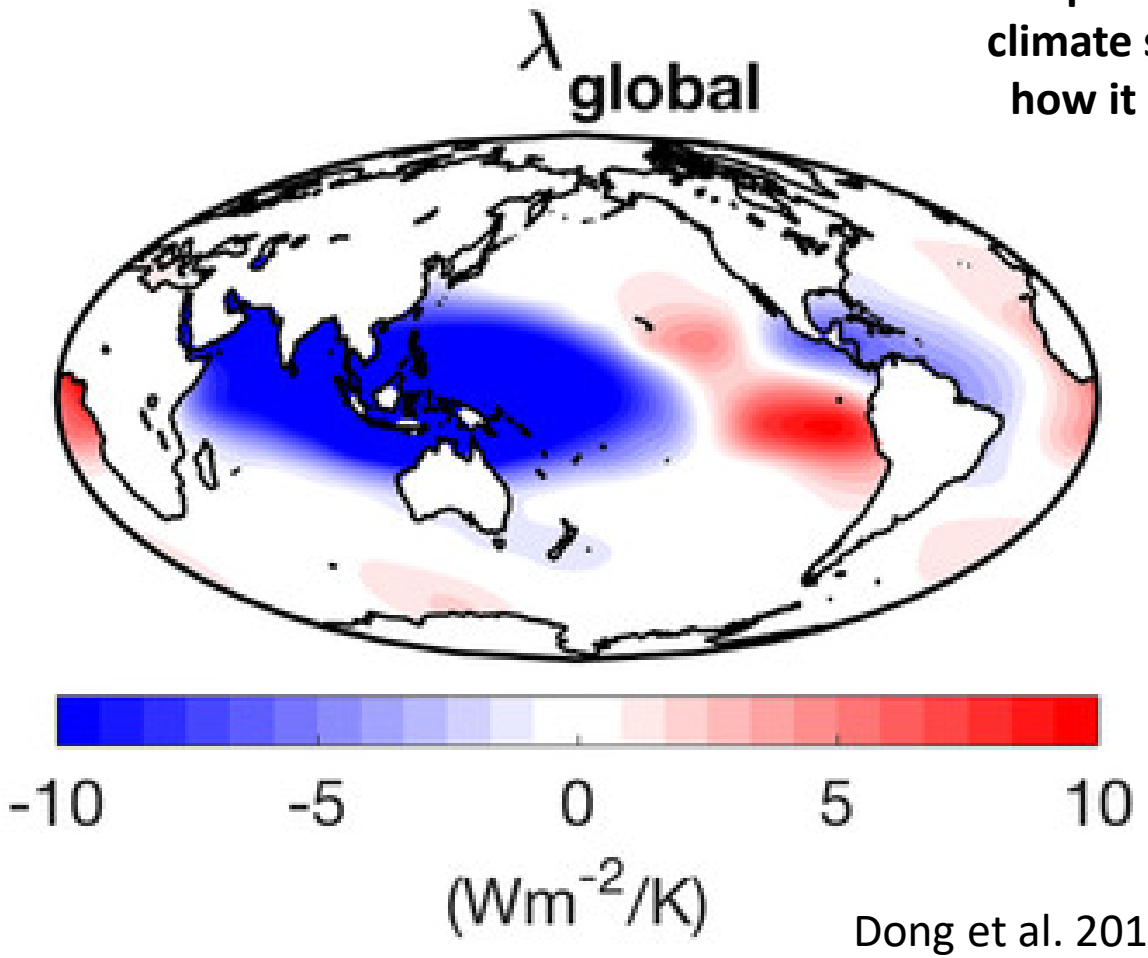


Dong et al. 2019, CAM4

Patch experiments have been used to study the **pattern effect**

The pattern effect has implications for the climate sensitivity and how it changes over time!

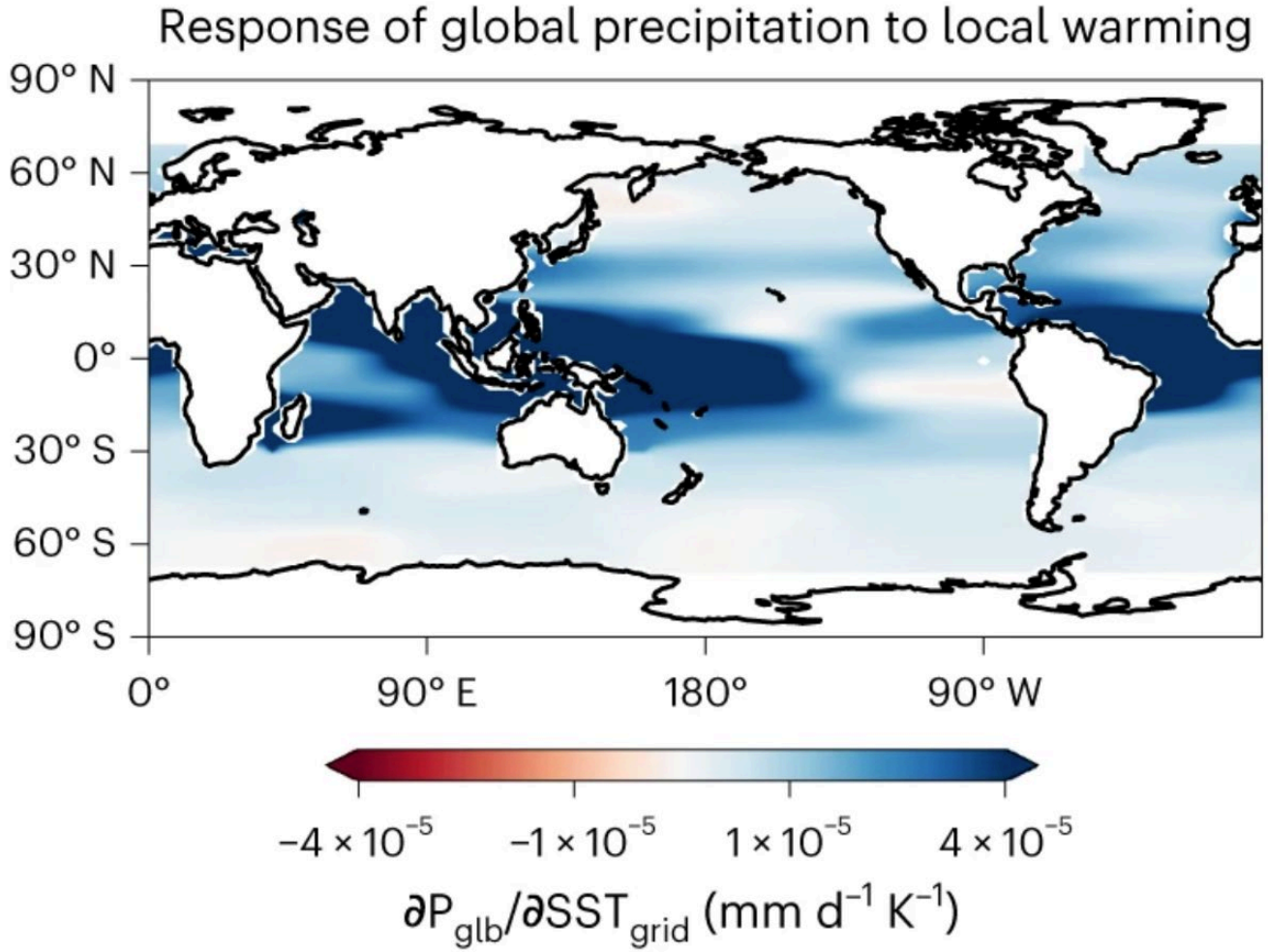
The figure shows the *global mean radiative feedback* given SST warming at that location. The strong dependence of feedback on warming location explains why feedbacks are so sensitive to the *pattern of warming*.



Dong et al. 2019, CAM4

and the response of precipitation to warming

The figure shows the *global mean precipitation response* given SST warming at that location.



Zhang et al. 2023

CAM6 patch experiments (almost) follow GFMIP protocol

cam6_3_026

The GFMIP Protocol

Control simulation (21 total simulation years)

Boundary conditions $\left(\{\overrightarrow{SST}_m\}_c, \{\overrightarrow{SIC}_m\}_c\right)$:	~~AMIP climatology (average of 1971–2020)~~ F2000climo
Forcing agents ($\{F\}_c$):	year 2000 values
Spinup:	$s_c = 1$ year
Post-spinup:	$y_c =$ ~~20 years~~ 11 years

Patch simulations (2180 total simulation years w/o spinup, 2398 w/spinup)

Spinup:	$s_p = 0$ years if branching from end of control simulation, 1 year otherwise
Post-spinup:	$y_p =$ ~~10 years~~ 7 years
perturbation:	$A_p = \pm 2$K
Size:	$\delta\phi_p = 20°$; $\delta\theta_p\left(\phi_p\right) = \begin{cases} 80° & \lvert\phi_p\rvert \le 30° \\ 80°/\cos\left(\phi_p\right) & \lvert\phi_p\rvert > 30° \end{cases}$
Locations (109 total):	$\lvert\phi_p\rvert \in \{0°, 20°\}$, $\theta_p \in \{180°\text{W, then every } 40°\}$
	$\lvert\phi_p\rvert \in \{10°, 30°\}$, $\theta_p \in \{160°\text{W, then every } 40°\}$
	$\lvert\phi_p\rvert \in \{40°, 60°, 80°\}$, $\theta_p \in \left\{180°\text{W, then every } 40°/\cos\left(\phi_p\right)\right\}$
	$\lvert\phi_p\rvert \in \{50°, 70°\}$, $\theta_p \in \left\{160°\text{W, then every } 40°/\cos\left(\phi_p\right)\right\}$
Patch shape:	sinusoidal (see Equation 1)

Diagnostic simulations (300 total simulation years per ensemble member; multiple members encouraged)

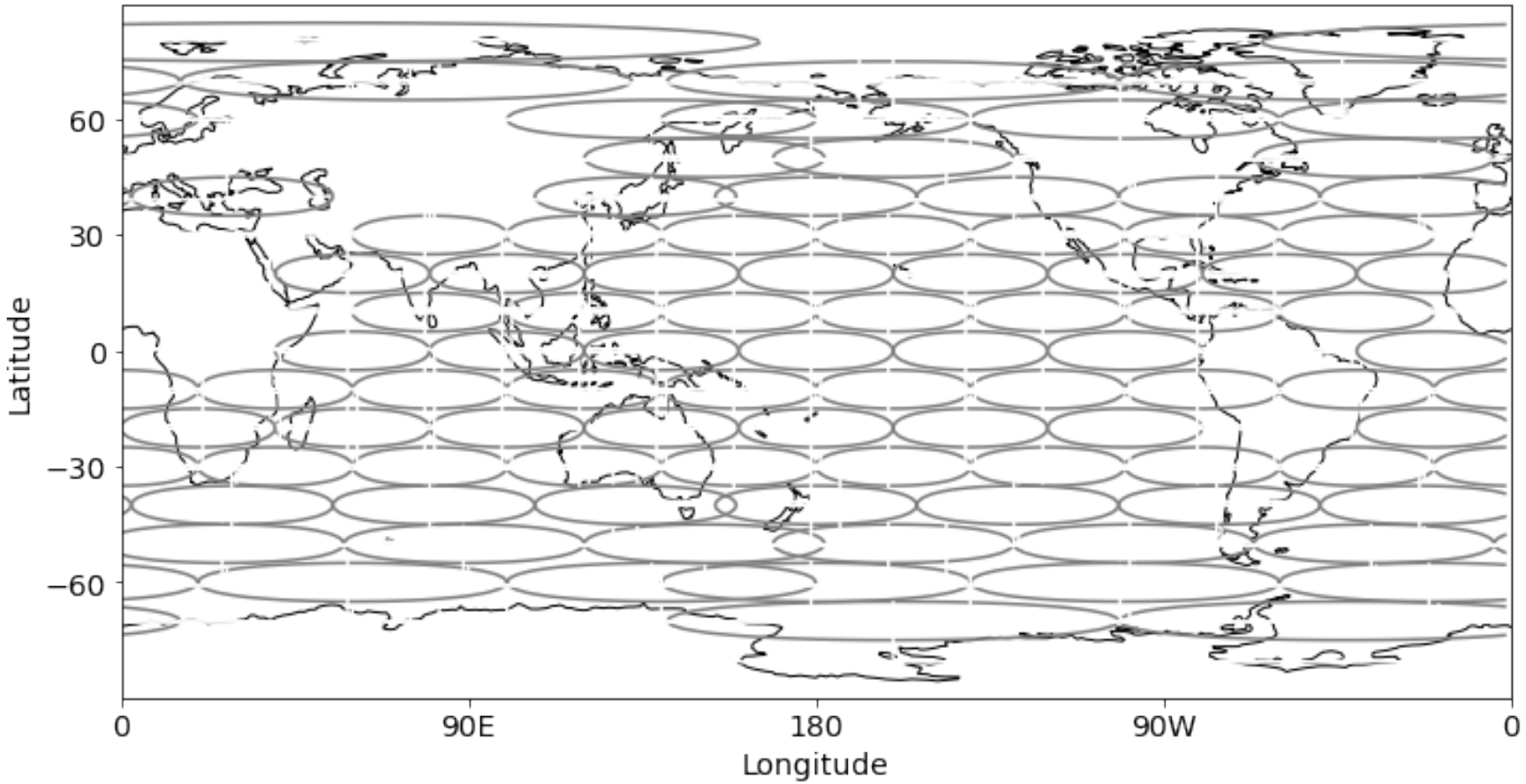
historical:	$\Delta\overrightarrow{SST}(t)$ from the AMIP time series, from 1871 to 2020
abrupt4x:	$\Delta\overrightarrow{SST}(t)$ from the CMIP6 multi-model-mean of abrupt4x (first 150 years)

Optional simulations

~~±4K patches:~~	~~same as patch simulations, but with $A_p = \pm 4$K~~
uniform perturbations:	same as patch simulations, but with uniform of $\Delta\overrightarrow{SST} = \pm$ 2K and ~~± 4K~~
~~modes of variability:~~	~~same as patch simulations, but with $\Delta\overrightarrow{SST}$ of modes of ENSO, PDO, IOD, and AMO~~

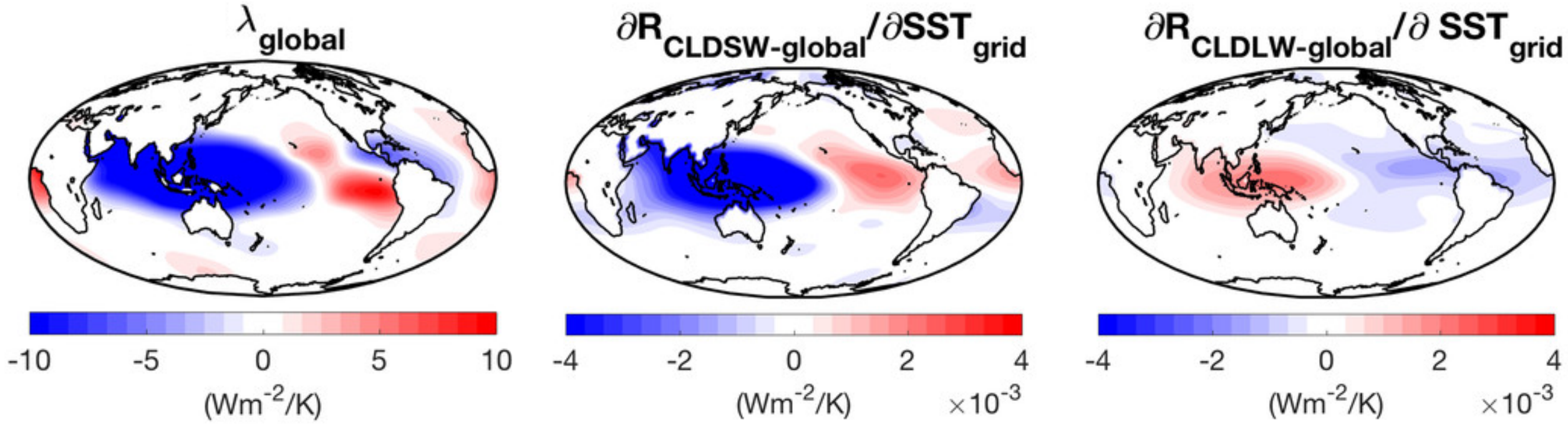
Note. All symbols are defined as in Figure 1. All simulations are run with atmosphere-only models, and with the same fixed climatological sea ice $\left(\{\overrightarrow{SIC}_m\}_c\right)$ and forcing agents ($\{F\}_c$) as the control simulation. Boundary conditions for all simulations are available for download at https://gfmip.org.

CAM6 SST patches



Now a little science

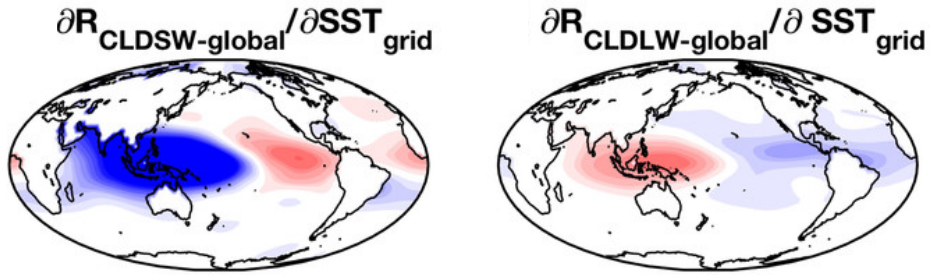
Much of the influence of SST on radiative feedbacks is via clouds



Dong et al. 2019, CAM4

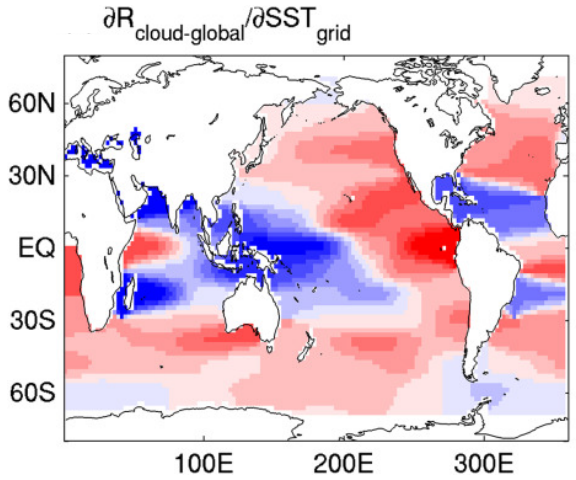
Cloud feedbacks in CAM4, 5, 6 patch experiments

CAM4



Dong et al. 2019

CAM5



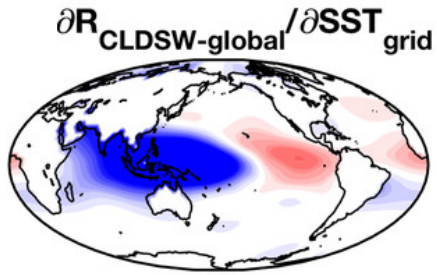
Zhou et al. 2017

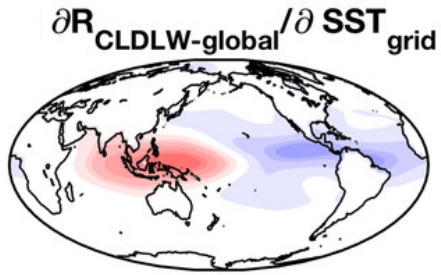
CAM6?

*The figure from the second slide is the total radiative feedback. This figure just shows cloud radiative feedback

Influence of SST on cloud feedbacks is similar across versions of CAM

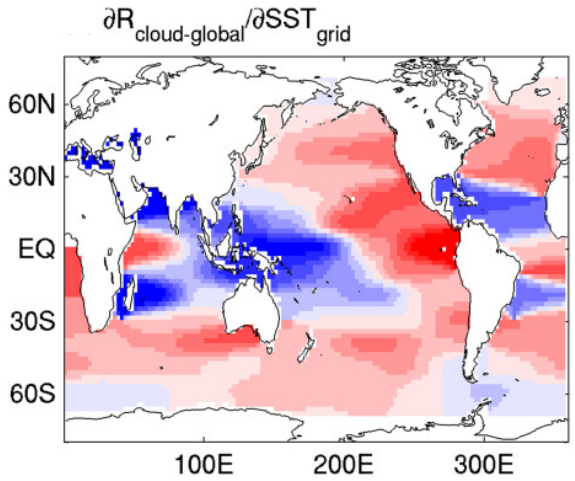
CAM4





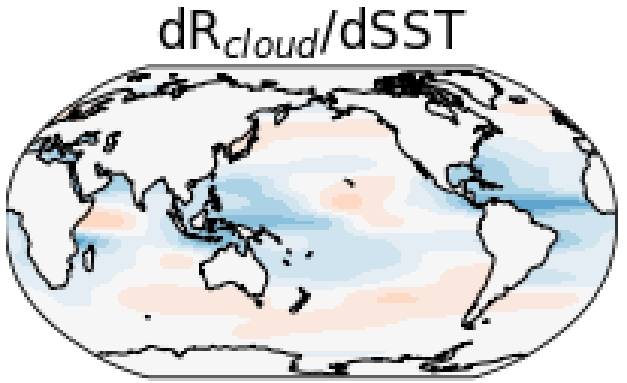
Dong et al. 2019

CAM5



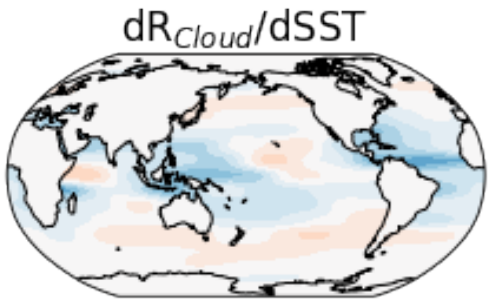
Zhou et al. 2017

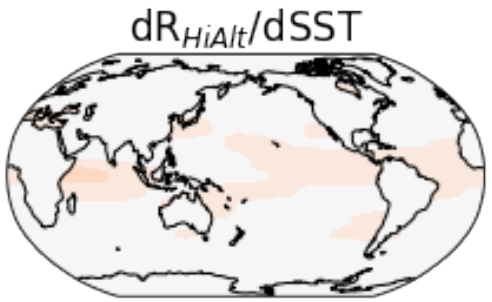
CAM6

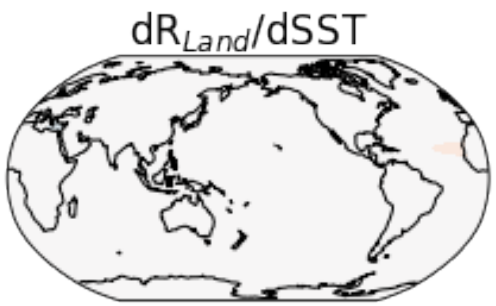


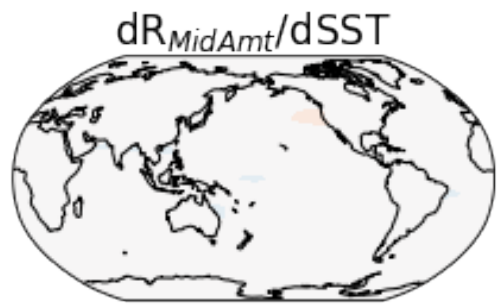
All three have different plotting conventions, for qualitative assessment only!

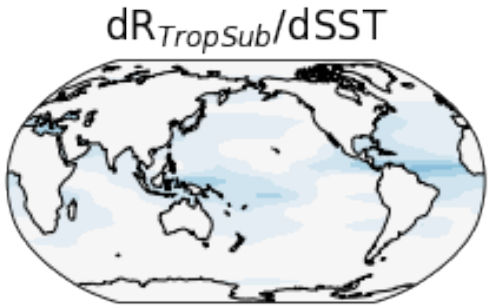
…but we can look at more cloud things in CAM6 than we could in earlier versions!

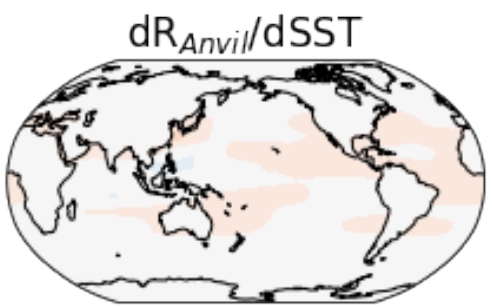


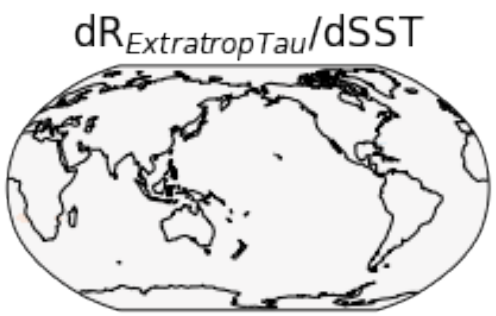


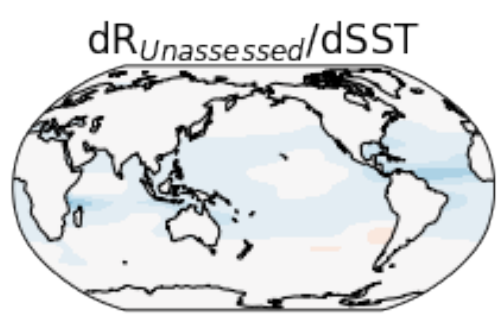




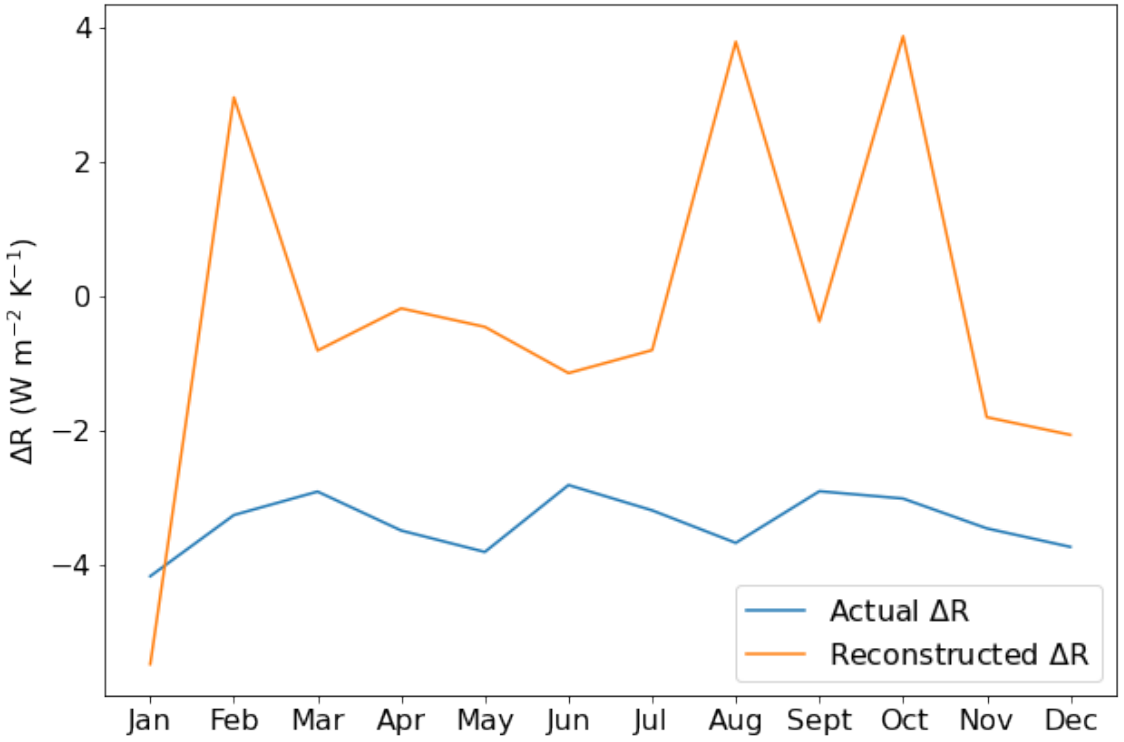








Caveat: nonadditivity

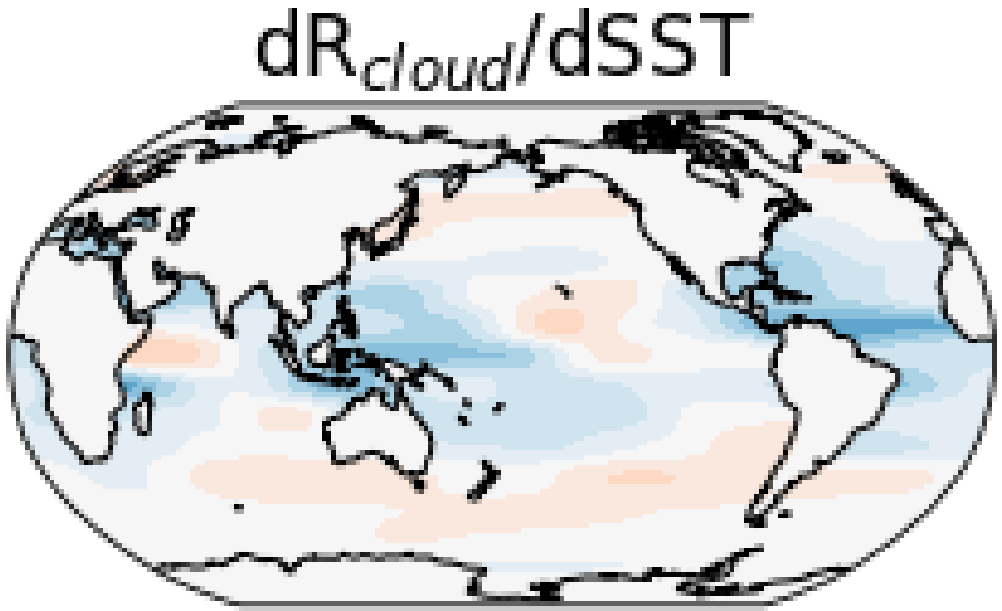


CAM6 patch experiments are available

- Control simulation: /glade/campaign/cgd/amp/mlduffy/control_timeseries
- Positive patch simulations and uniform +2K warming: /glade/campaign/cgd/amp/mlduffy/positive_timeseries
- Negative patch simulations and uniform -2K warming: /glade/campaign/cgd/amp/mlduffy/negative_timeseries
- Helpful info in: /glade/campaign/cgd/amp/mlduffy/patch_centers_*.nc

Summary

- **CAM6 patch experiments exist**!
- Preliminary results are broadly similar to CAM4 and CAM5
- Nonadditivity is a caveat



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