

# Comparison of SPCCSM4 cloud feedbacks with SST+4K and 4xCO<sub>2</sub> SPCAM4 simulations

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# Simulations

SPCCSM4: coupled ocean

Control run spun up with present-day CO<sub>2</sub>

Step 4xCO<sub>2</sub> branched from control at yr. 0, run out 150 yrs

SPCAM4: SST, sea ice based on AMIP specs (per CFMIP2)

CTL: 1xCO<sub>2</sub>, AMIP SST, run out 30 yrs

4CO<sub>2</sub>: 4xCO<sub>2</sub>, AMIP SST, run out 10 yrs

update of Wyant et al. 2012 with SPCAM3 -> SPCAM3.5, longer runs

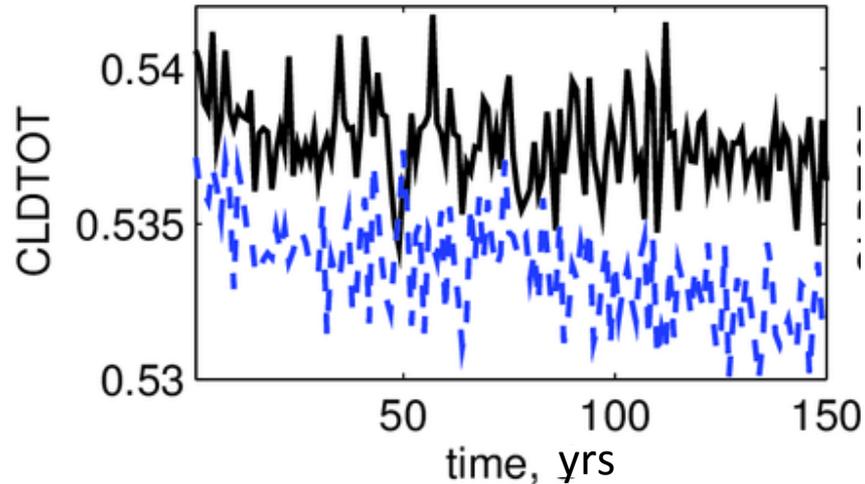
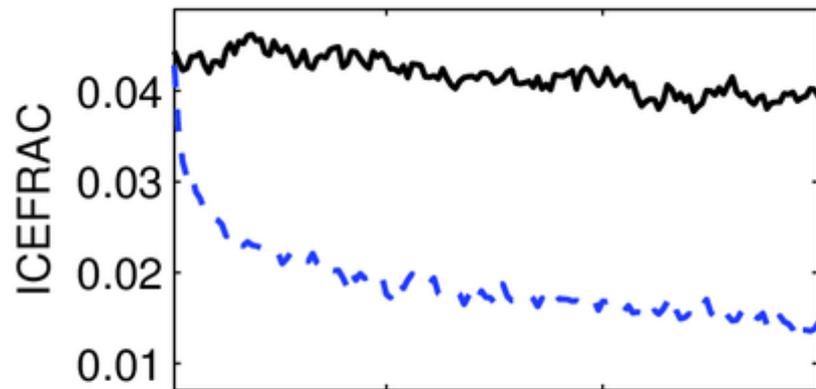
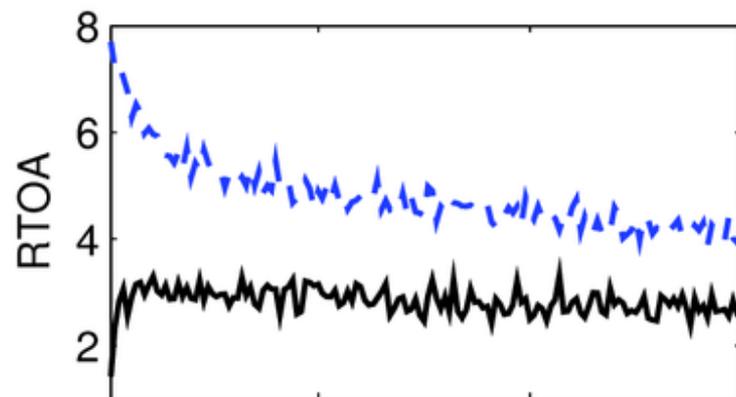
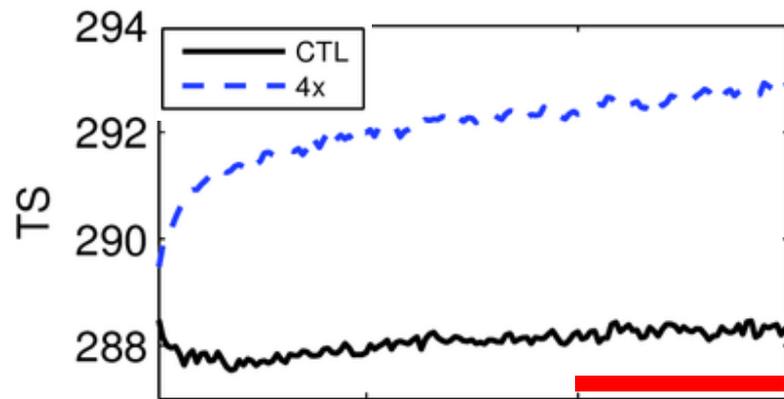
P4: 1xCO<sub>2</sub>, AMIP SST + 4 K, run out 10 yrs

update of Wyant et al. 2006, 2009 with SPCAM3 -> SPCAM3.5, longer runs

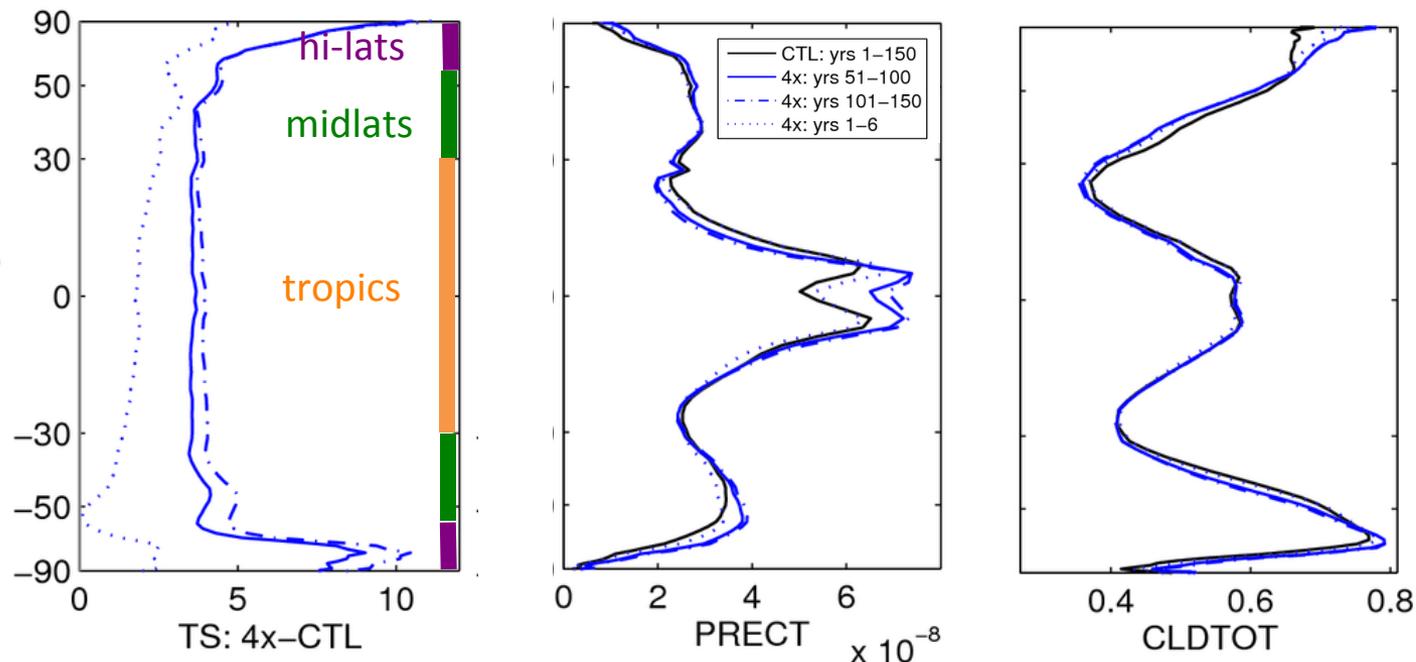
## Goals:

1. Do 4CO<sub>2</sub> and P4 capture rapid and SST-mediated features of the coupled 4CO<sub>2</sub> step response?
2. Do 4CO<sub>2</sub> and P4 behave like Wyant et al. SPCAM3 results?

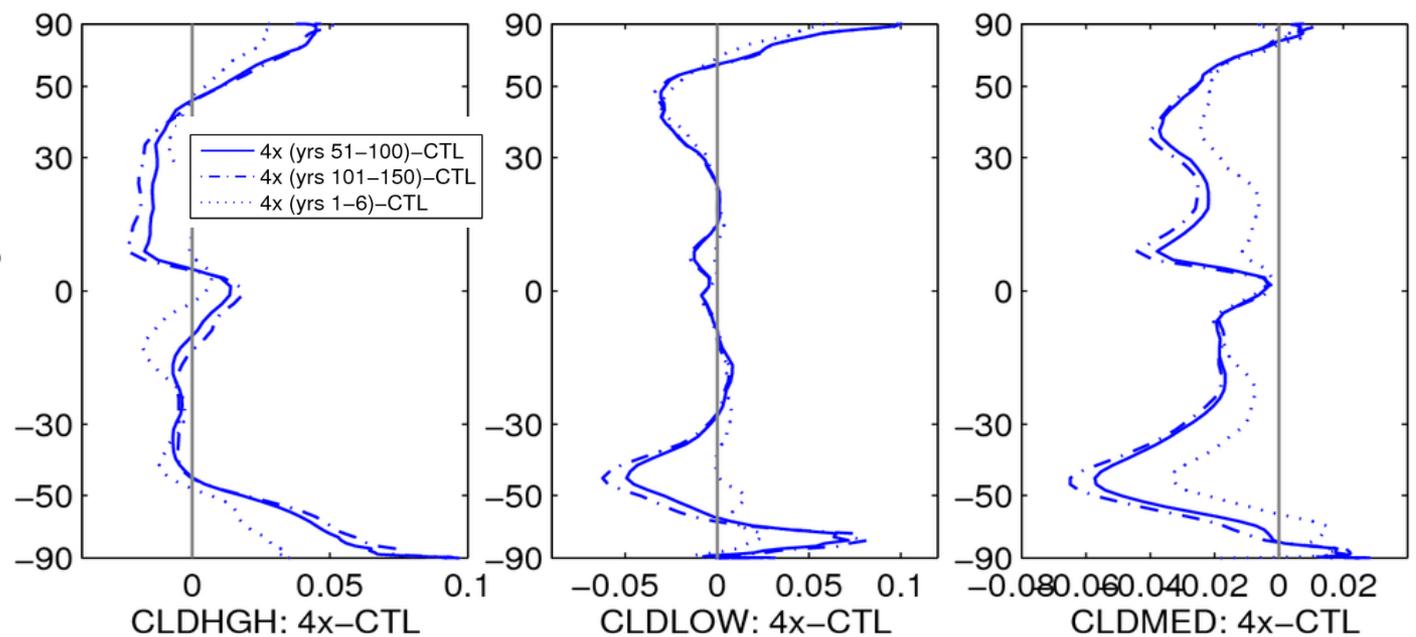
# SPCCSM response to step 4xCO<sub>2</sub>



# Zonal mean responses



4K warmer  $|lat| < 60$ .  
 More ITCZ, hi-lat prec  
 Less mid-lat,  
 more hi-lat cld



Less mid-lev cld  
 Poleward low-cld shift  
 More polar high cld  
 Less subtrop high cld

# Linearity of cloud trends

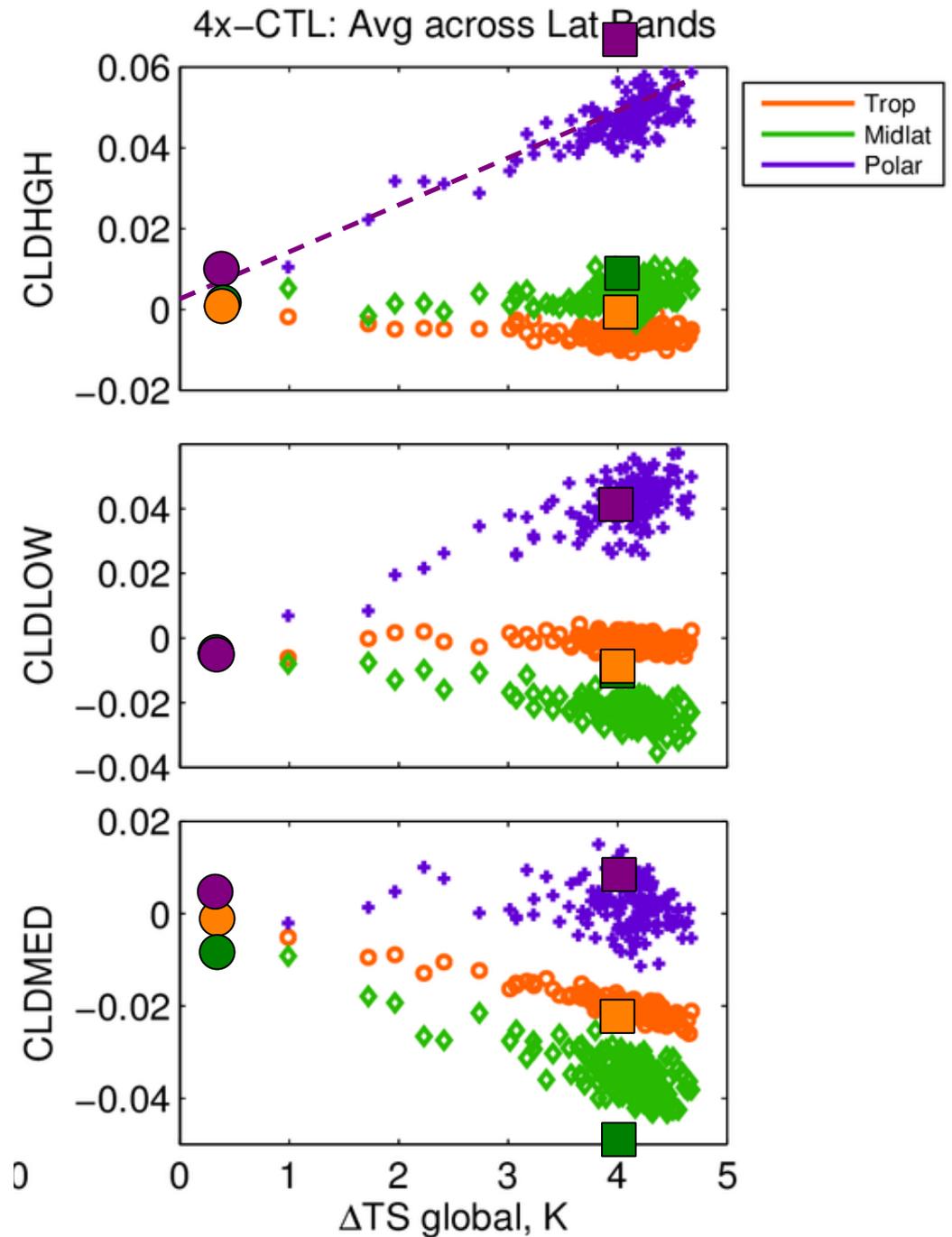
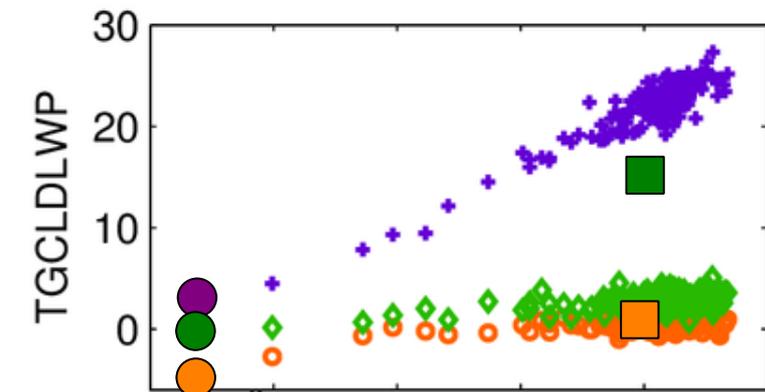
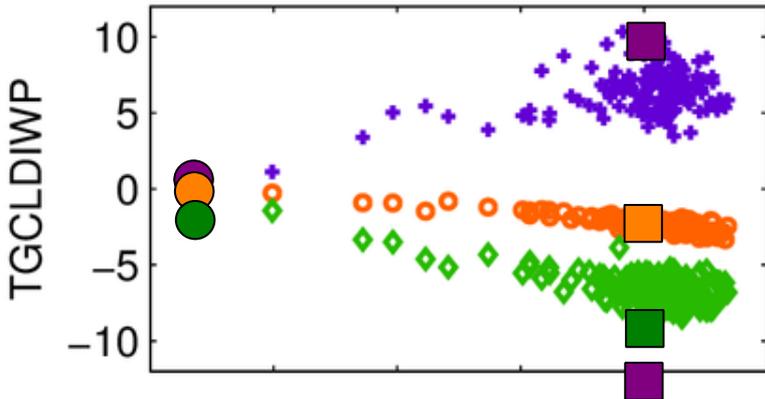
Y-intercept of fit line  $\sim 4\text{CO}_2$  fixed SST

Slope of fit line  $\times 4\text{K} \sim +4\text{K}$  SST

Filled circles =  $4\text{XCO}_2$

Filled squares =  $4\text{XCO}_2 + \text{P4}$

Polar cloud increase/thickening



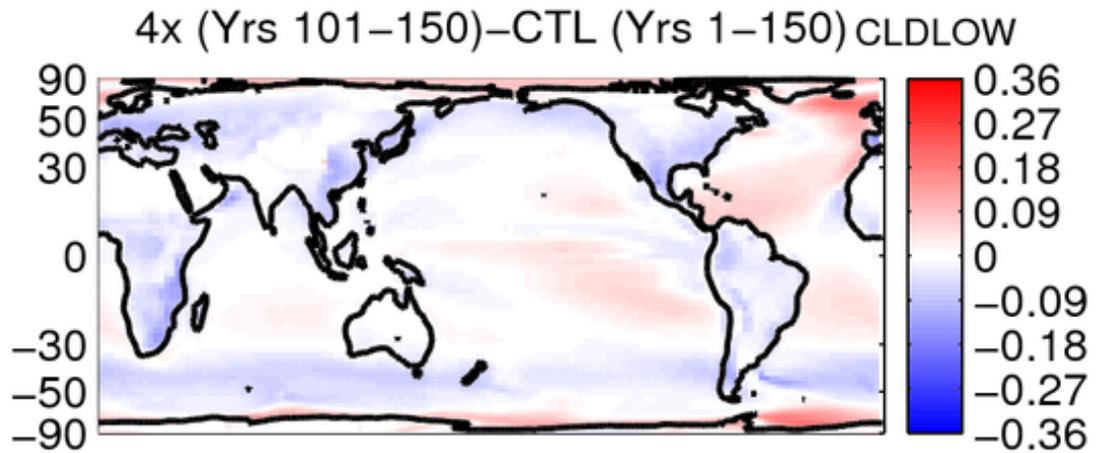
Are coupled cloud responses predicted by 4CO<sub>2</sub> and P4 runs?

Relatively small zonal-mean 4CO<sub>2</sub>-induced fast cloud response ✓

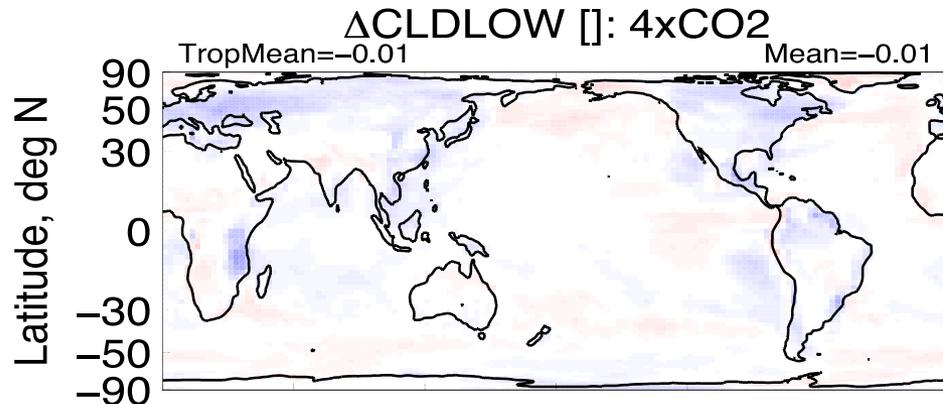
Midlevel warming-mediated cloud decrease ✓

High-latitude warming-mediated cloud increase ✓

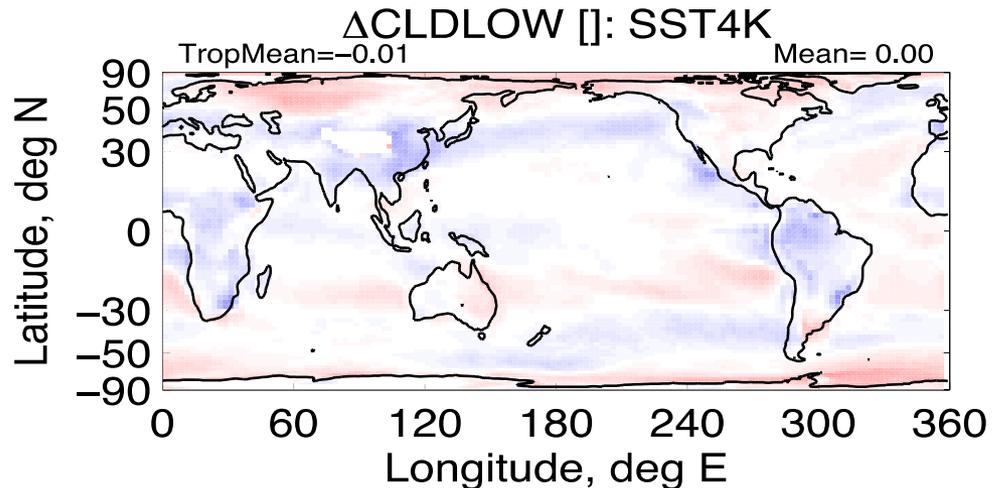
Low cloud decrease over land in coupled run



4xCO2 adjustment small except in NH hi lats

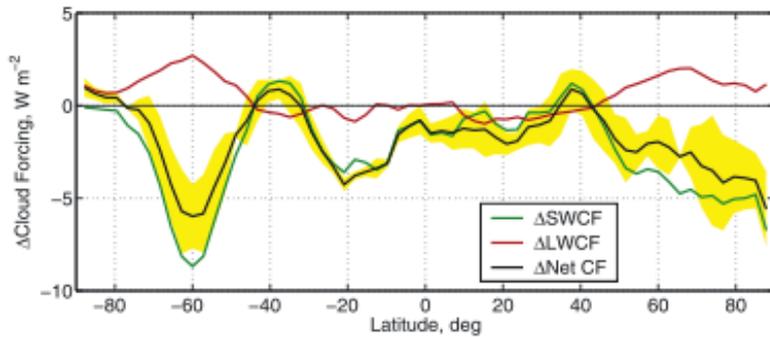


SST+4K explains more of the coupled signal



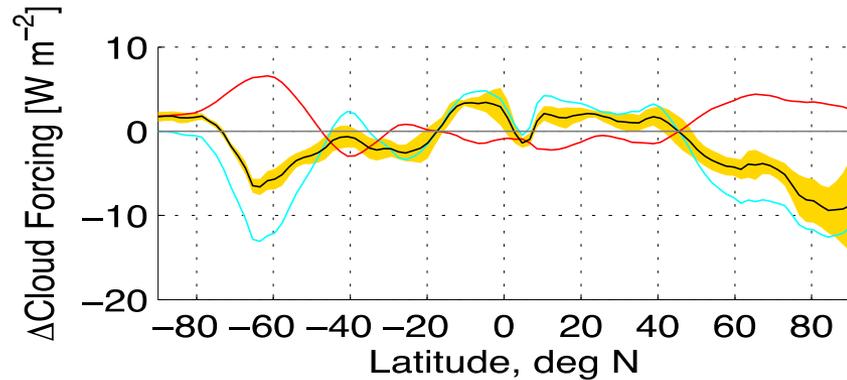
# Comparison with Wyant et al. 2006 P2 SPCAM3 run

In SPCAM3 with +2K SST, W06 found more negative (stronger) net CRE at 50-70 S, 50-90 N and 30 S-30 N



**Figure 1.** The annual zonal-mean changes in *SWCF* (green), *LWCF* (red), and net cloud forcing (black) of SPCAM between the +2 K and control runs. The interannual standard deviation of the mean net cloud forcing change (see text) is plotted in yellow.

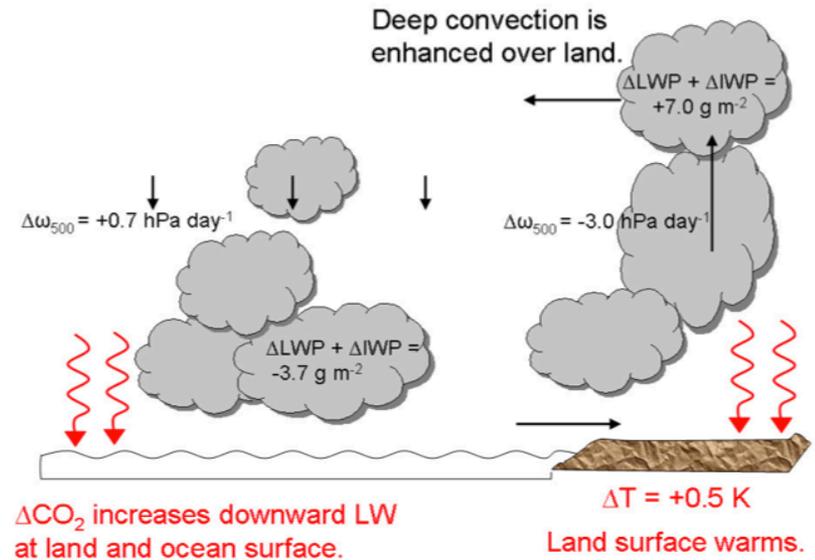
In SPCAM4 with +4K SST, we find fair agreement at high lats but net CRE is near-zero at low lats.



# Comparison with Wyant et al. 2012 SPCAM3 4xCO2 run

W12: 4xCO2 induces rapid shift of deep cloud, rain from tropical ocean to land in SPCAM3.

SPCAM4: Similar results, more precision. Low cloud decreases over tropical ocean and land.



	30S-30N	Low	Med	High	Rain
SPCAM3 W12 2yrs	CTL	27%	7%	17%	3.3 mm/d
	Δland	0.56%	0.57%	2.03%	0.25
	Δocean	-0.11%	-0.32%	-0.42%	-0.25
SPCAM4 4XCO2 10yrs	CTL	31%	11%	28%	3.6 mm/d
	Δland	-0.93%	1.27%	2.18%	0.14
	Δocean	-0.39%	-0.61%	-0.81%	-0.32

Grey = insignificant change given interannual variability

# Conclusions

- SPCAM4 AMIP 4CO<sub>2</sub> and SST+4K runs can rationalize broad features of SPCCSM4's coupled cloud response:
  - less midlevel cloud
  - more Arctic cloud
  - less low cloud over land

They suggest this response is mainly induced by global warming rather than fast adjustment to increased CO<sub>2</sub>
- The 4xCO<sub>2</sub> and P4 cloud responses are qualitatively similar but quantitatively different than previously published, much shorter SPCAM3 runs.
- These new runs will be a useful comparison with the CFMIP2 runs done with CMIP5 GCMs.