Understanding Feedback Processes

Outline

- Definitions
- Magnitudes and uncertainties
- Geographic distributions and priorities
- Observational requirements

Climate Feedbacks

- Climate sensitivity is the equilibrium change in global mean surface temperature (ΔT) that results from a specified radiative forcing (ΔQ).

- The sensitivity is a function of the feedback factors (λ) .

$$\Delta T = \frac{\Delta Q}{\left(\lambda_{Planck} + \lambda_{wv} + \lambda_{cloud} + \lambda_{albedo}\right)}$$

Climate Feedbacks

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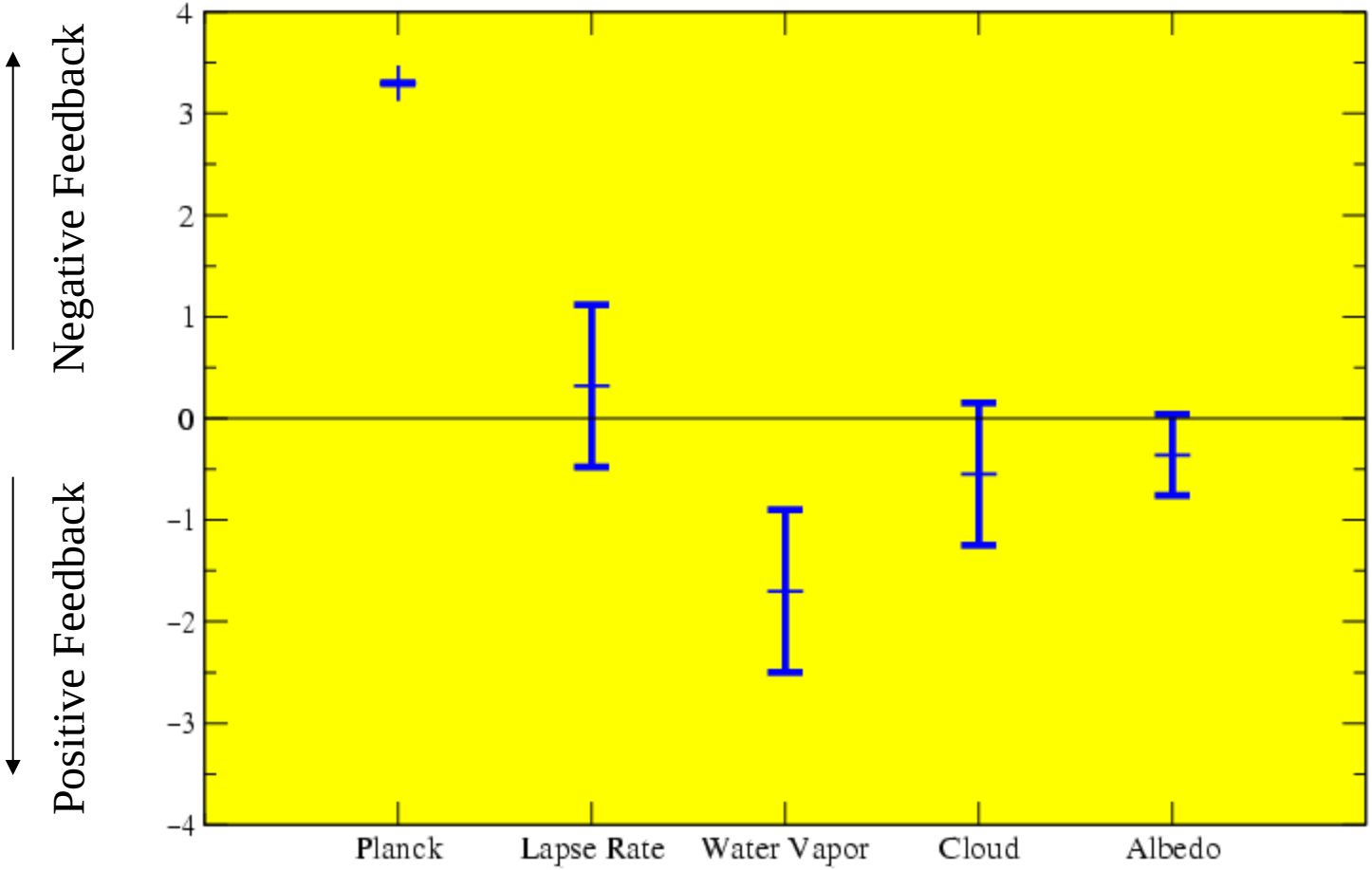
Radiative Forcing
4 W/m^2

$$\Delta T = \frac{\Delta Q}{\left(\lambda_{Planck} + \lambda_{wv} + \lambda_{cloud} + \lambda_{albedo}\right)} = 3\ \mathrm{K}$$

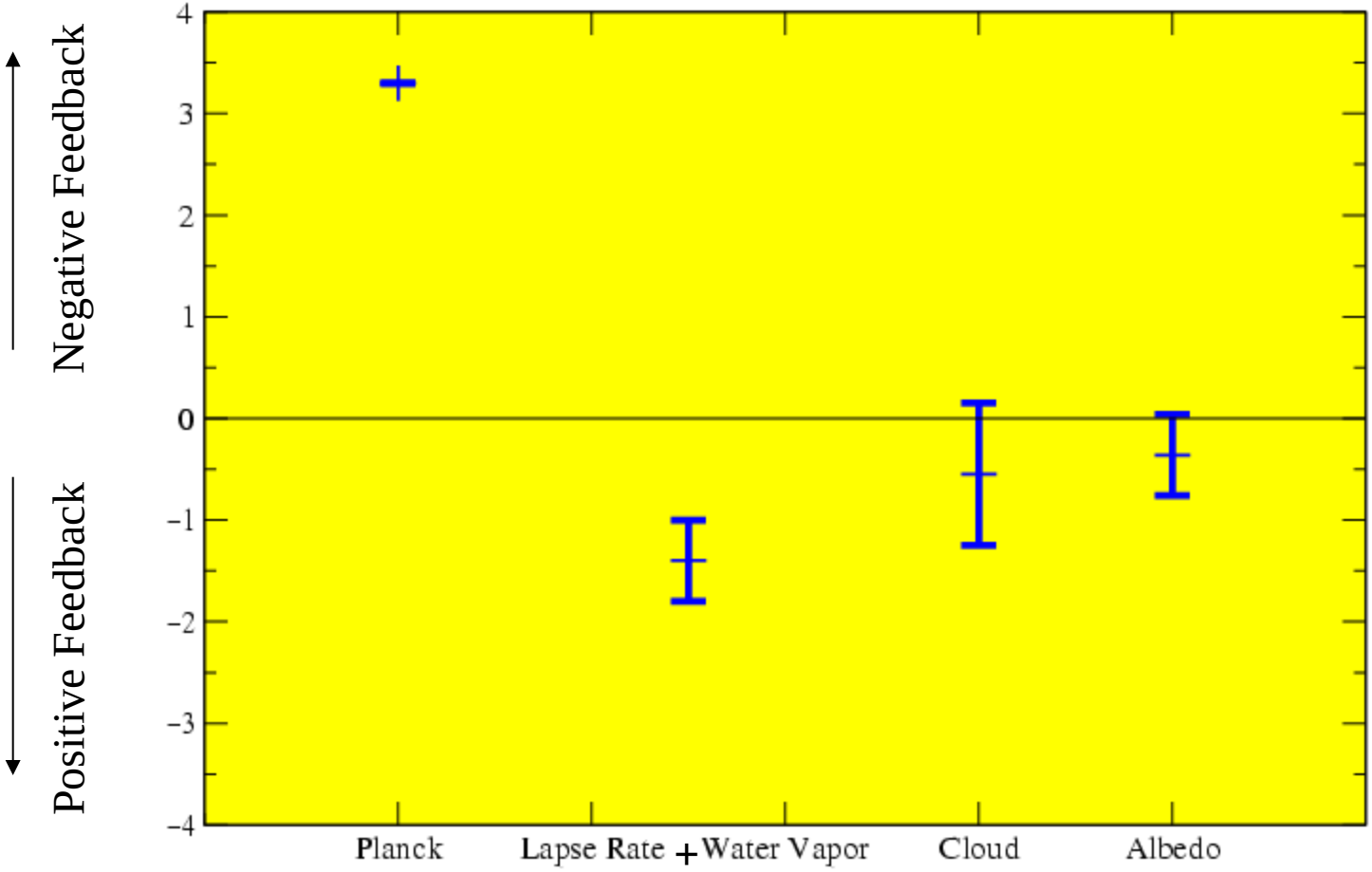
λ_{Planck}	λ_{wv}	λ_{cloud}	λ_{albedo}	
3.6	-1.6	-0.4	-0.3	W/m^2/K
Planck (temperature + lapse rate)	Water Vapor (mixing ratio)	Clouds (cloud amount, water path, particle size)	Albedo (snow, ice)	

Range of Model Feedbacks



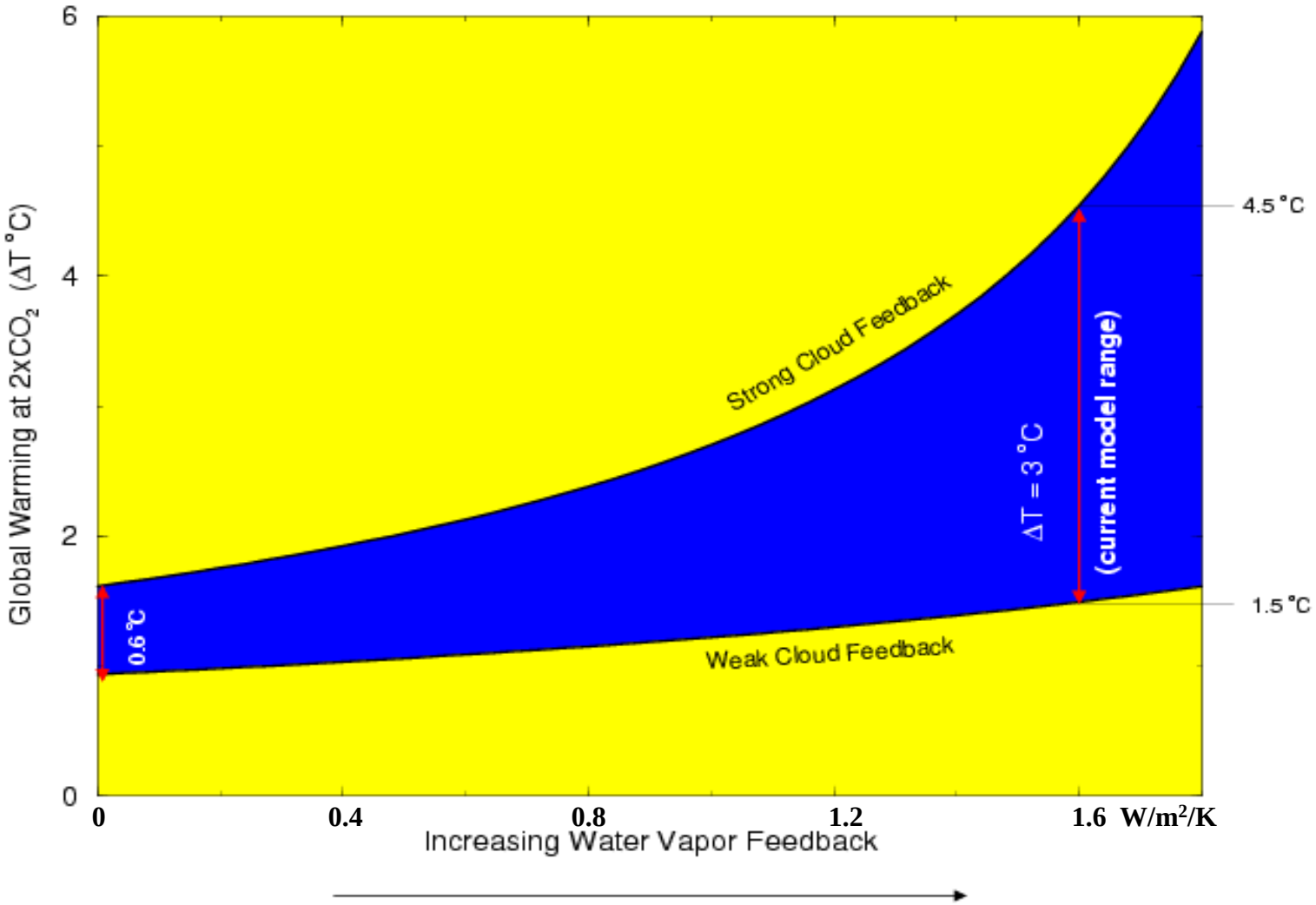
Colman (2003)

Range of Model Feedbacks

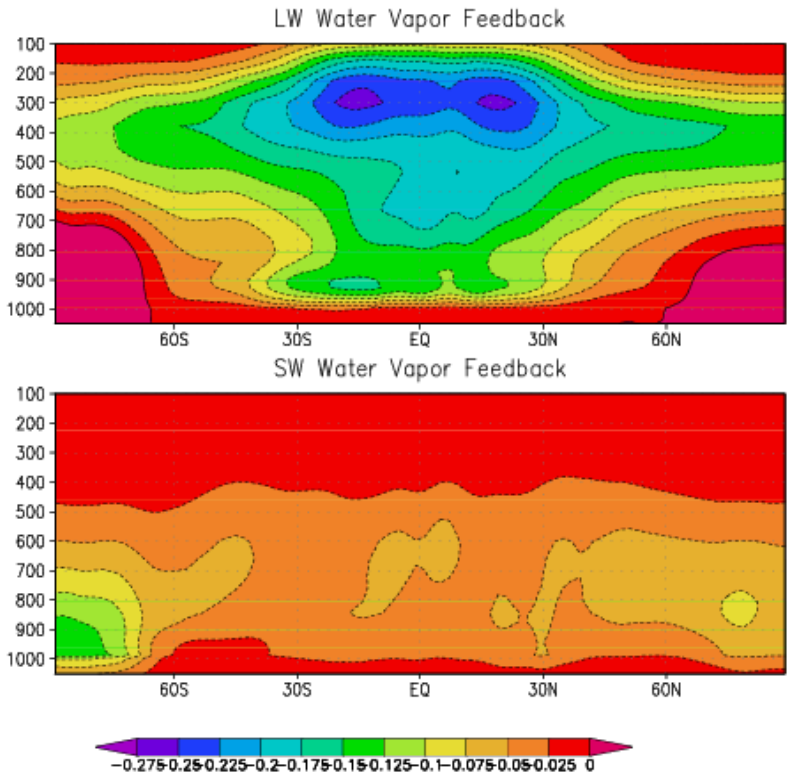


Colman (2003)

The Importance of Water Vapor Feedback



Distribution of Water Vapor Feedback



Stronger feedback

Weaker feedback

Vertical Contributions

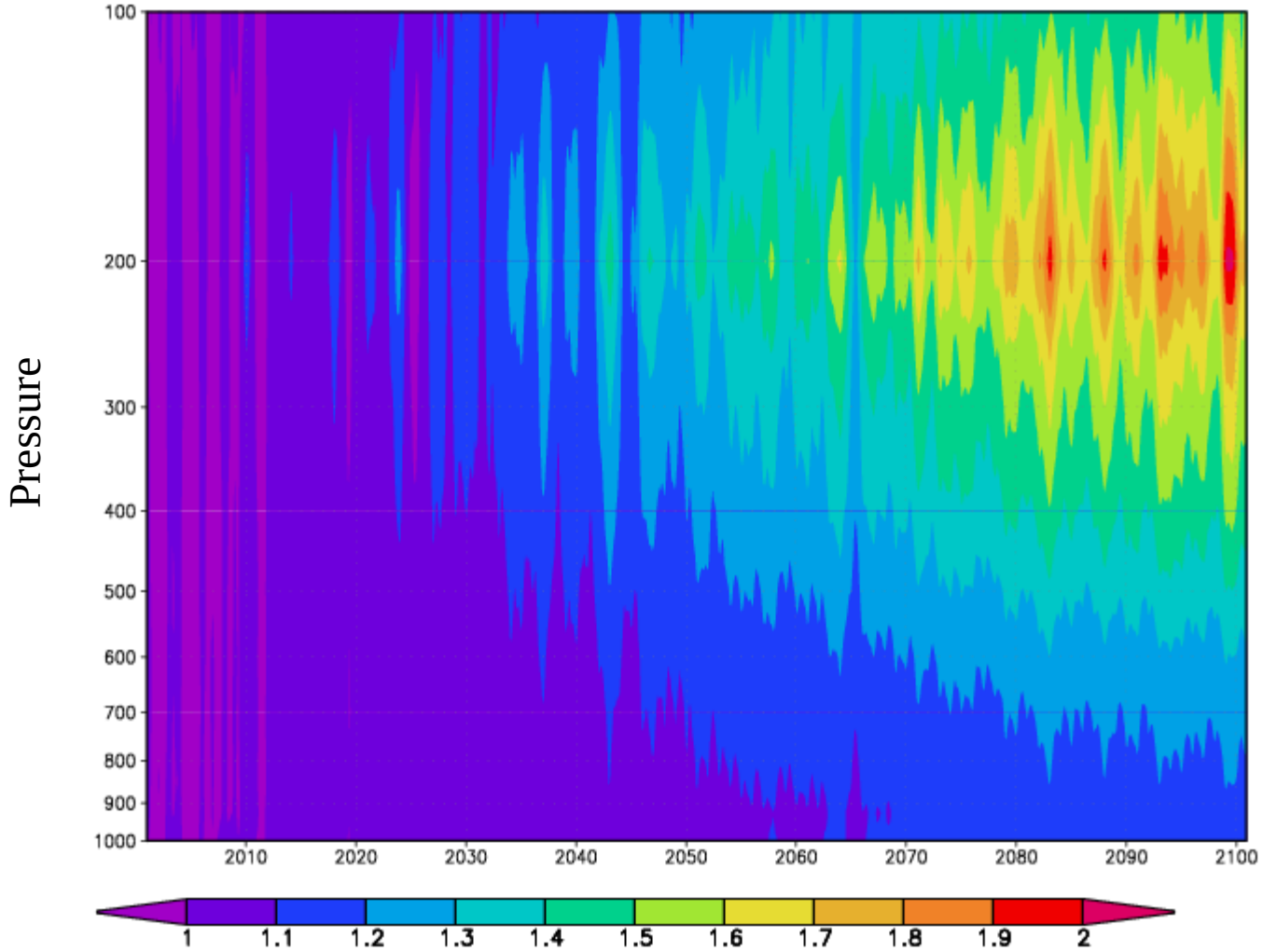
Boundary Layer	Upper Trop
(> 800 mb)	(< 600 mb)
~10%	~70%

Latitudinal Contributions

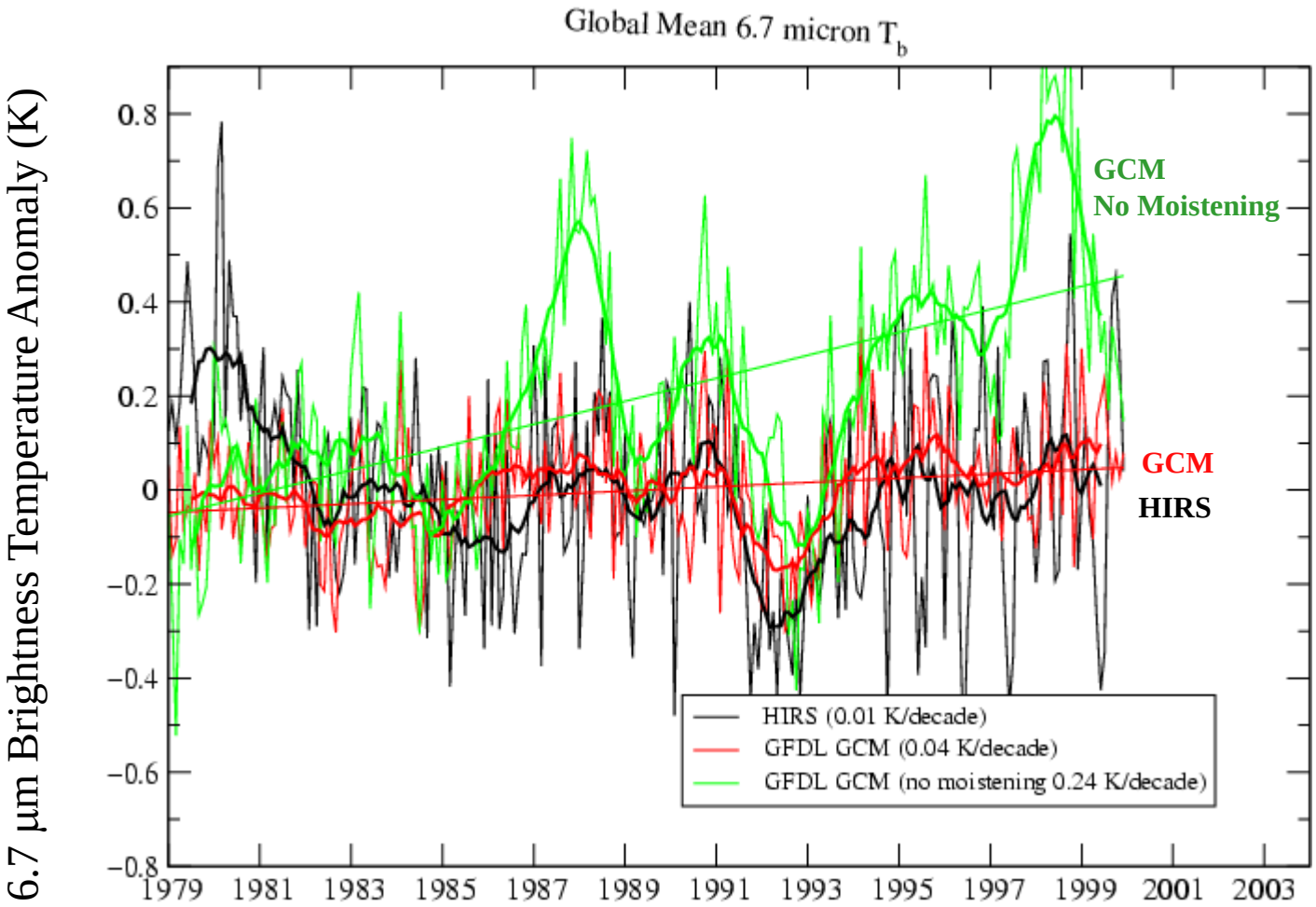
Tropics	Mid-Lat	Polar
~65%	~30%	~5%

Water Vapor Feedback

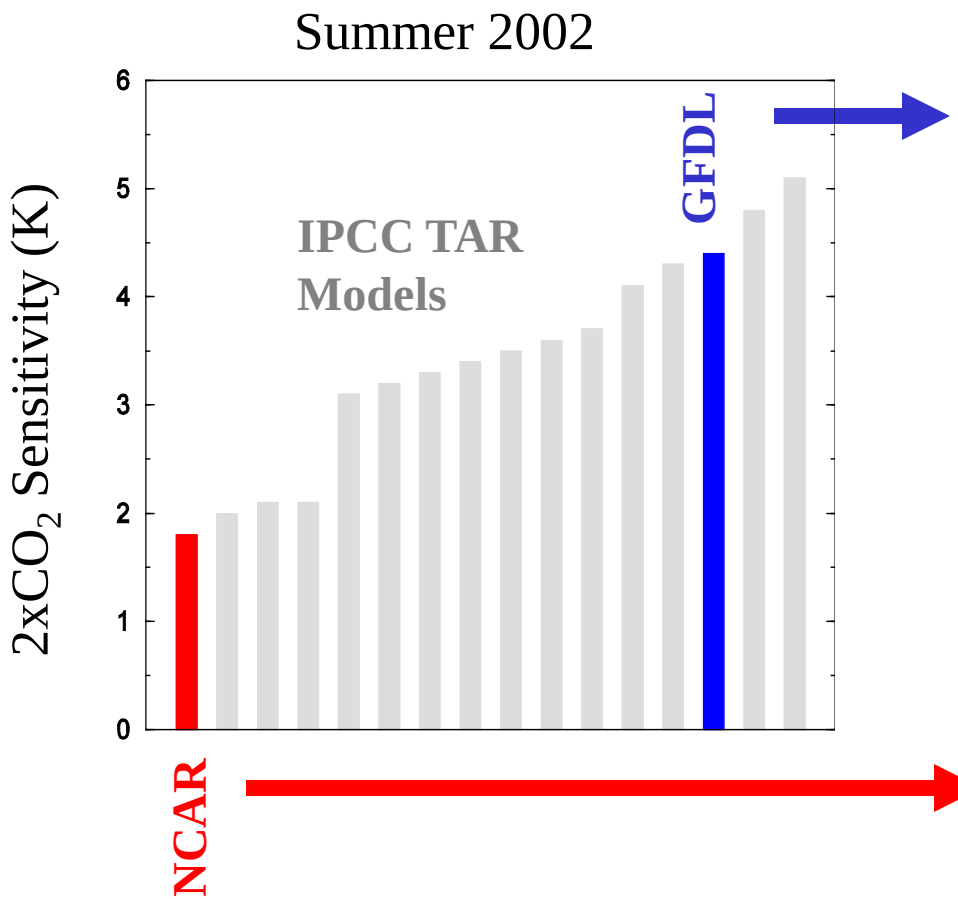
Fractional Change in Water Vapor Concentration: GFDL GCM (SRES A1B)

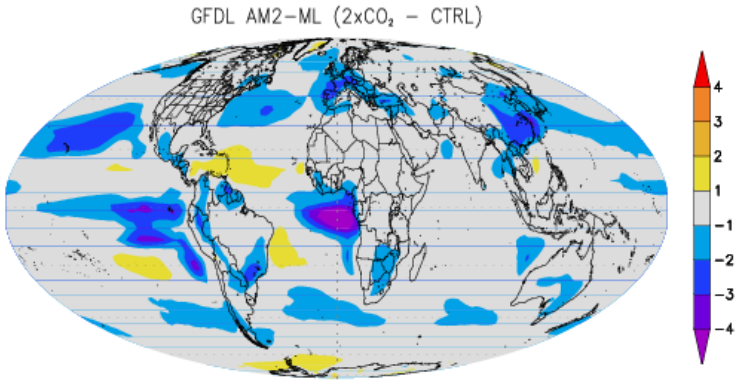


Water Vapor Trends

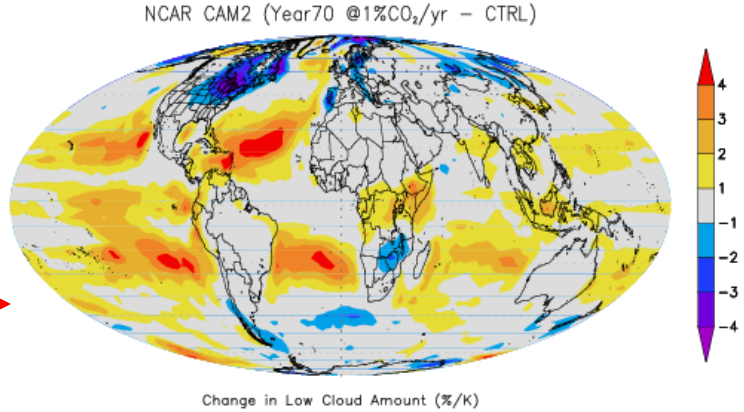


Cloud Feedback

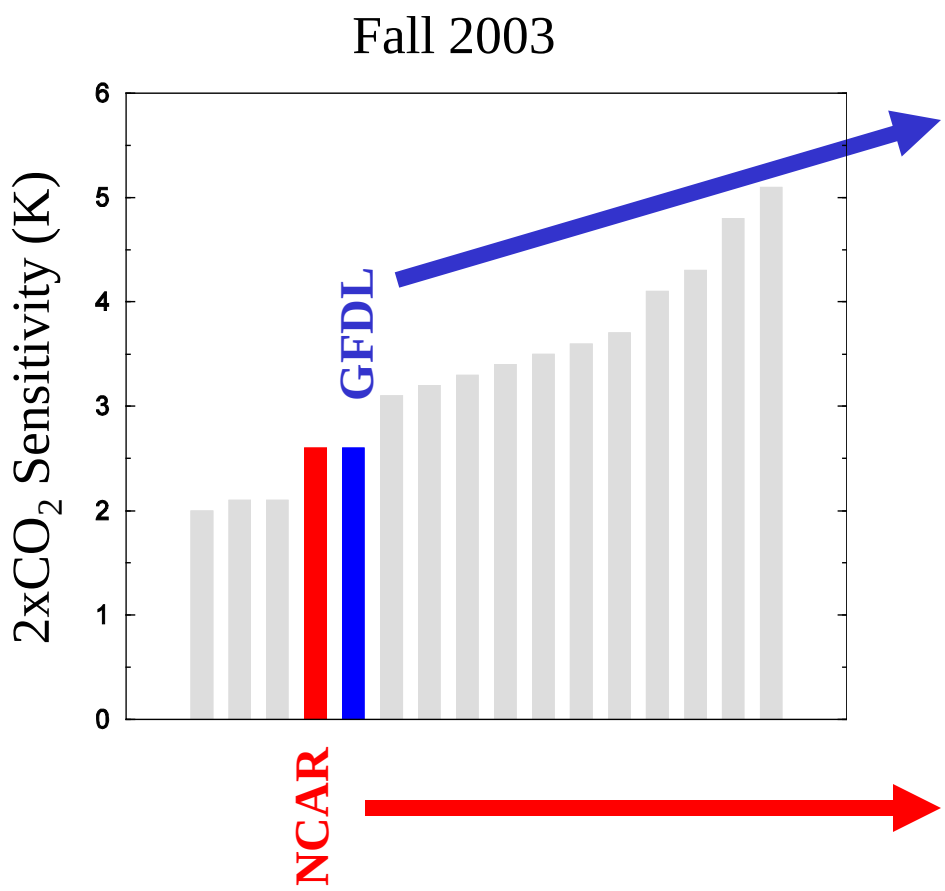


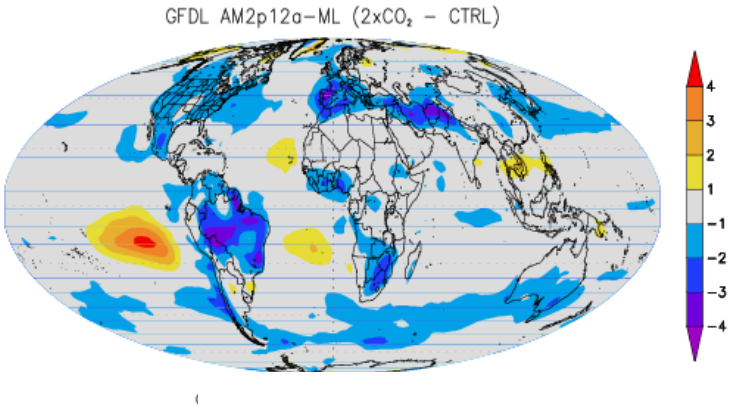


Change in Low Cloud Amount (%/K)



Cloud Feedback





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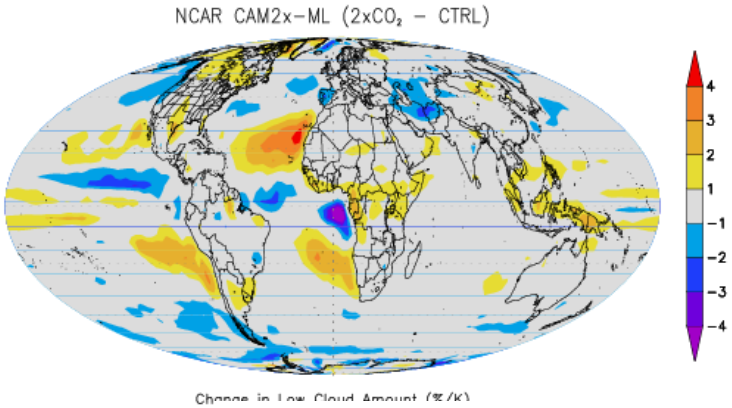
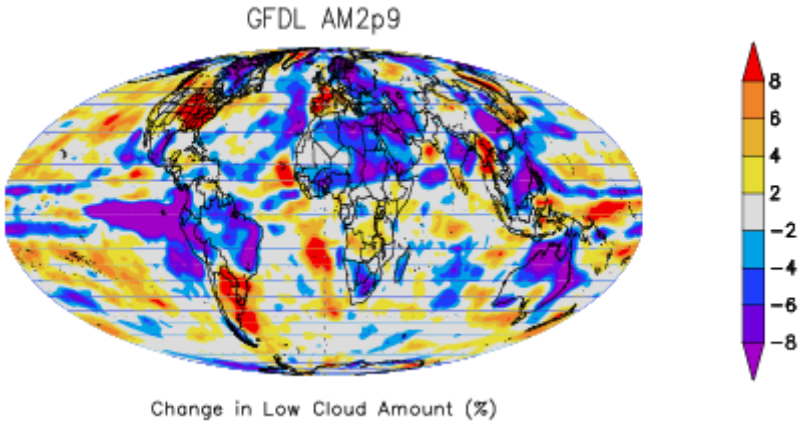
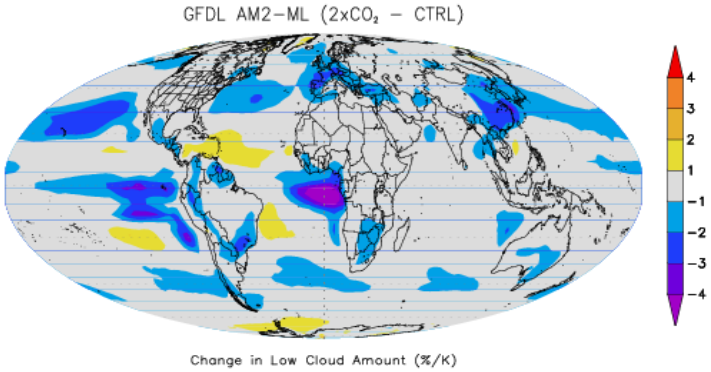


Cloud Feedback

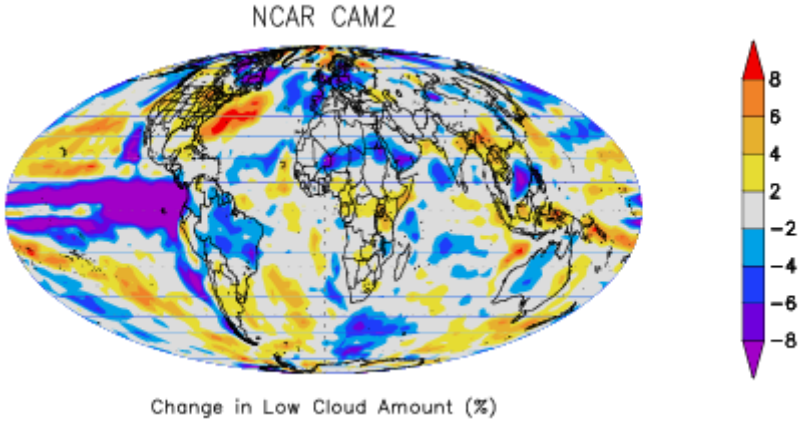
ENSO

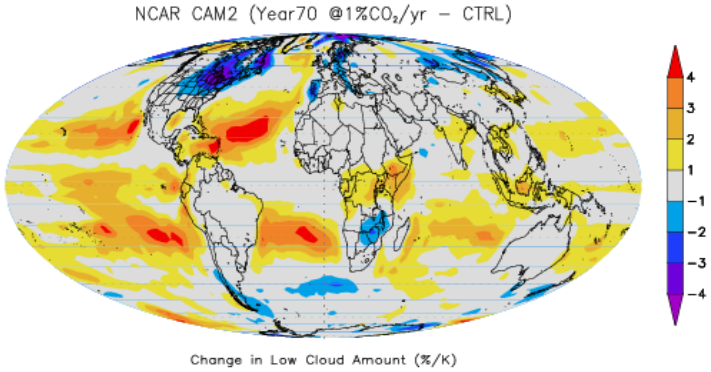
2x CO2





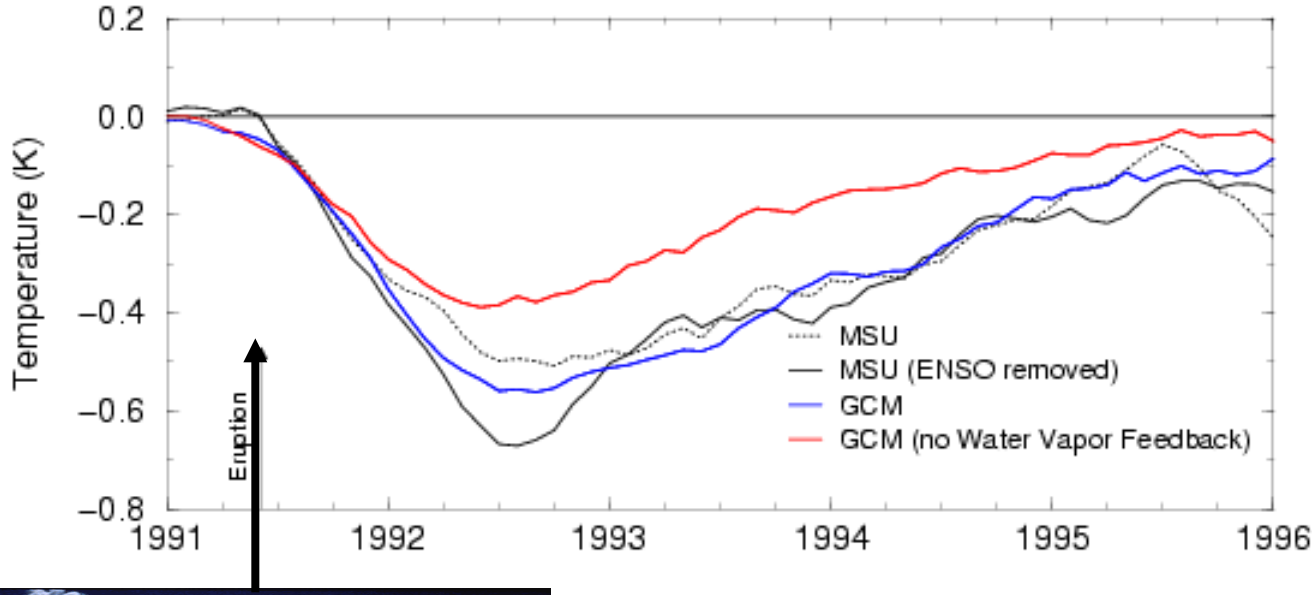
GFDL:
Strong positive <u>low</u> cloud feedback.





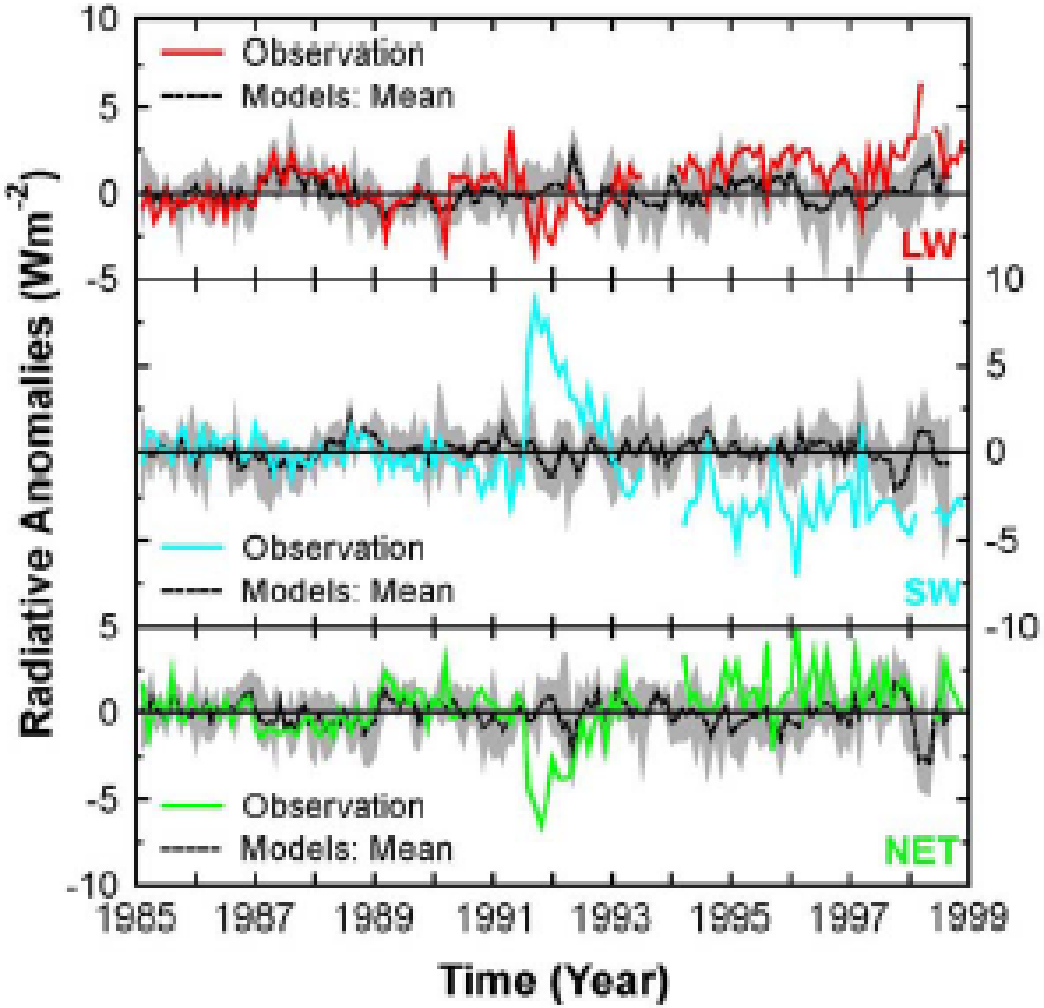
NCAR:
Weak negative <u>low</u> cloud feedback.

Response to Transient Forcings



Eruption of Mt. Pinatubo
June 1991

Cloud and Radiation Trends



Verification requires redundancy

Wielicki et al. (2002)

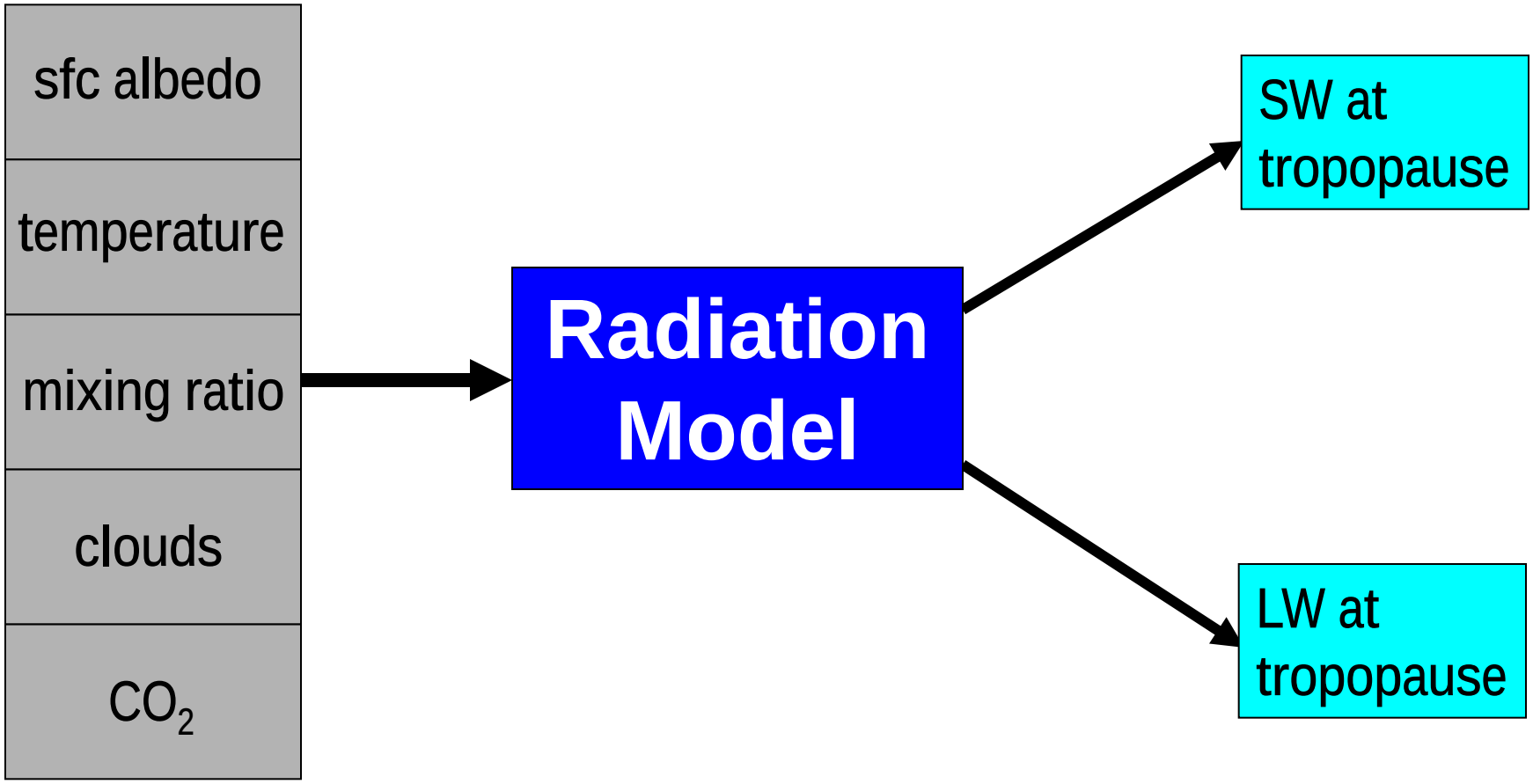
Priorities

- Free tropospheric temperature
- Tropical upper tropospheric water vapor (1%/dec, ΔZ=0.5 km)
- Low cloud cover (0.5%/dec, ΔZ=0.5 km)
- TOA radiative fluxes
- Redundancy

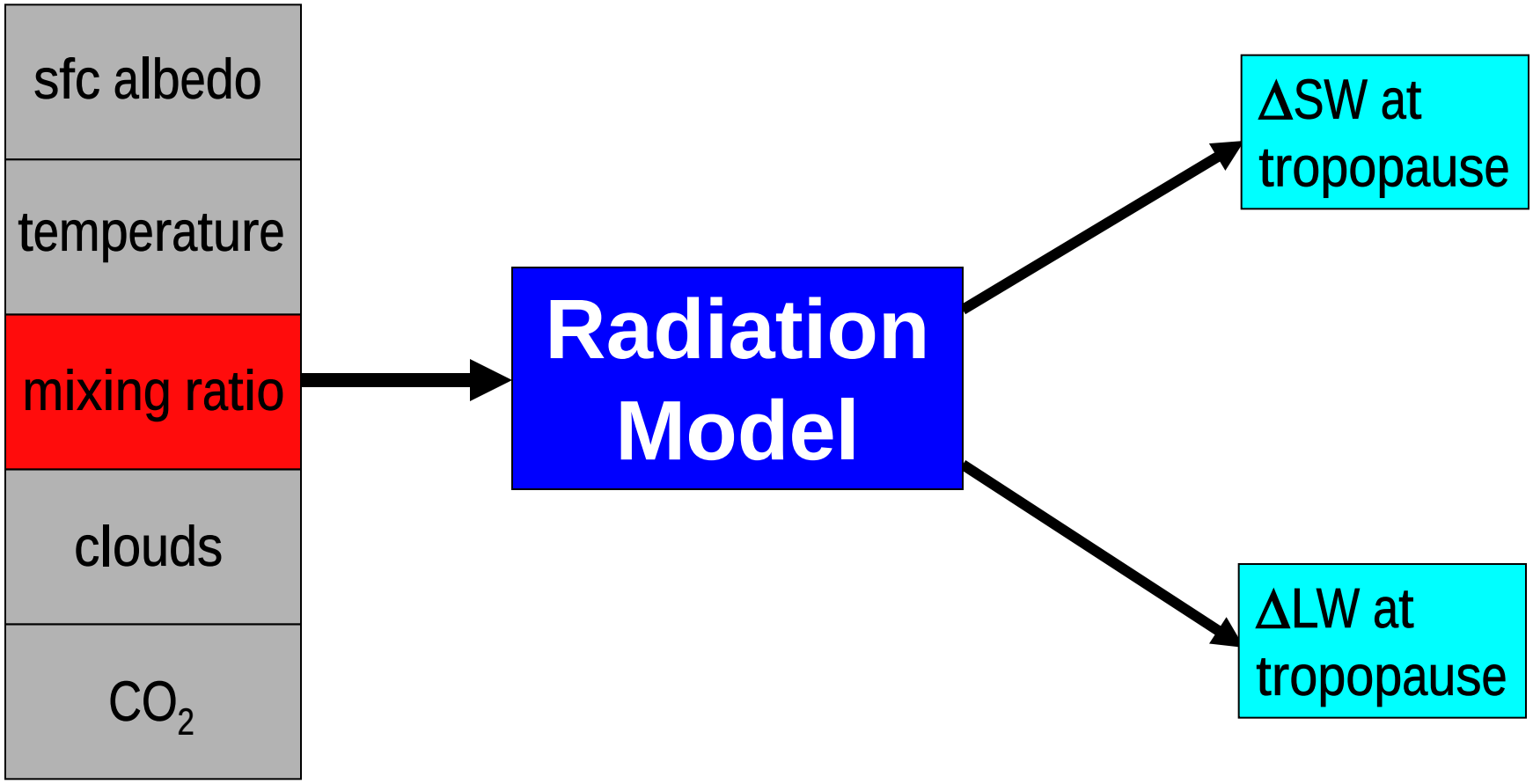
- Climate OSSE to guide system design and requirements

Extra Slides

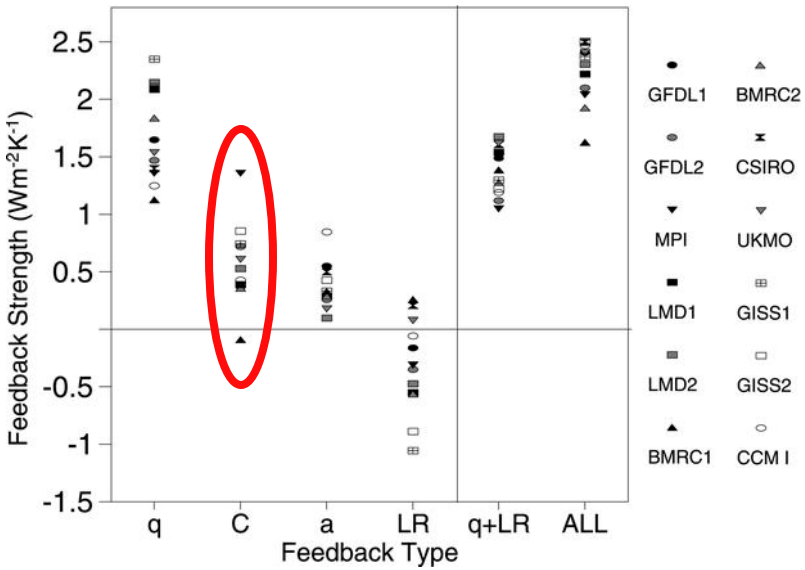
Calculation of Feedbacks: Control



Calculation of Feedbacks: Perturbation

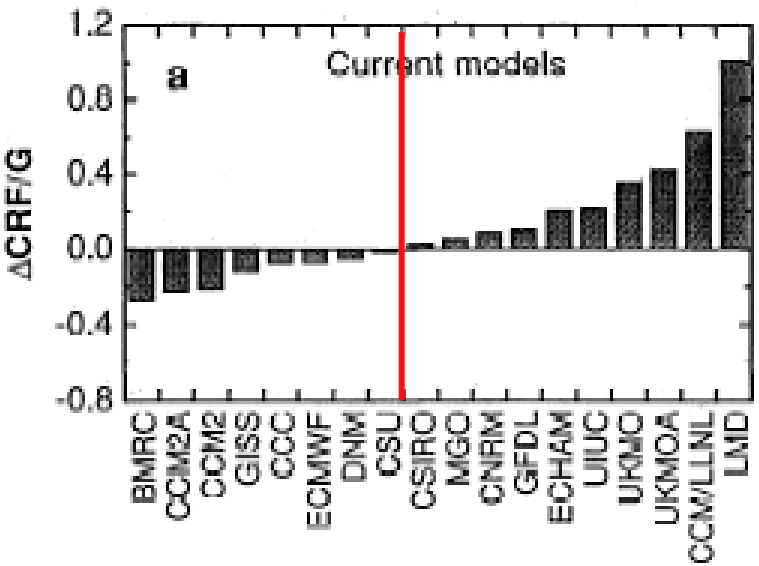


1 of 10 models has negative cloud feedback



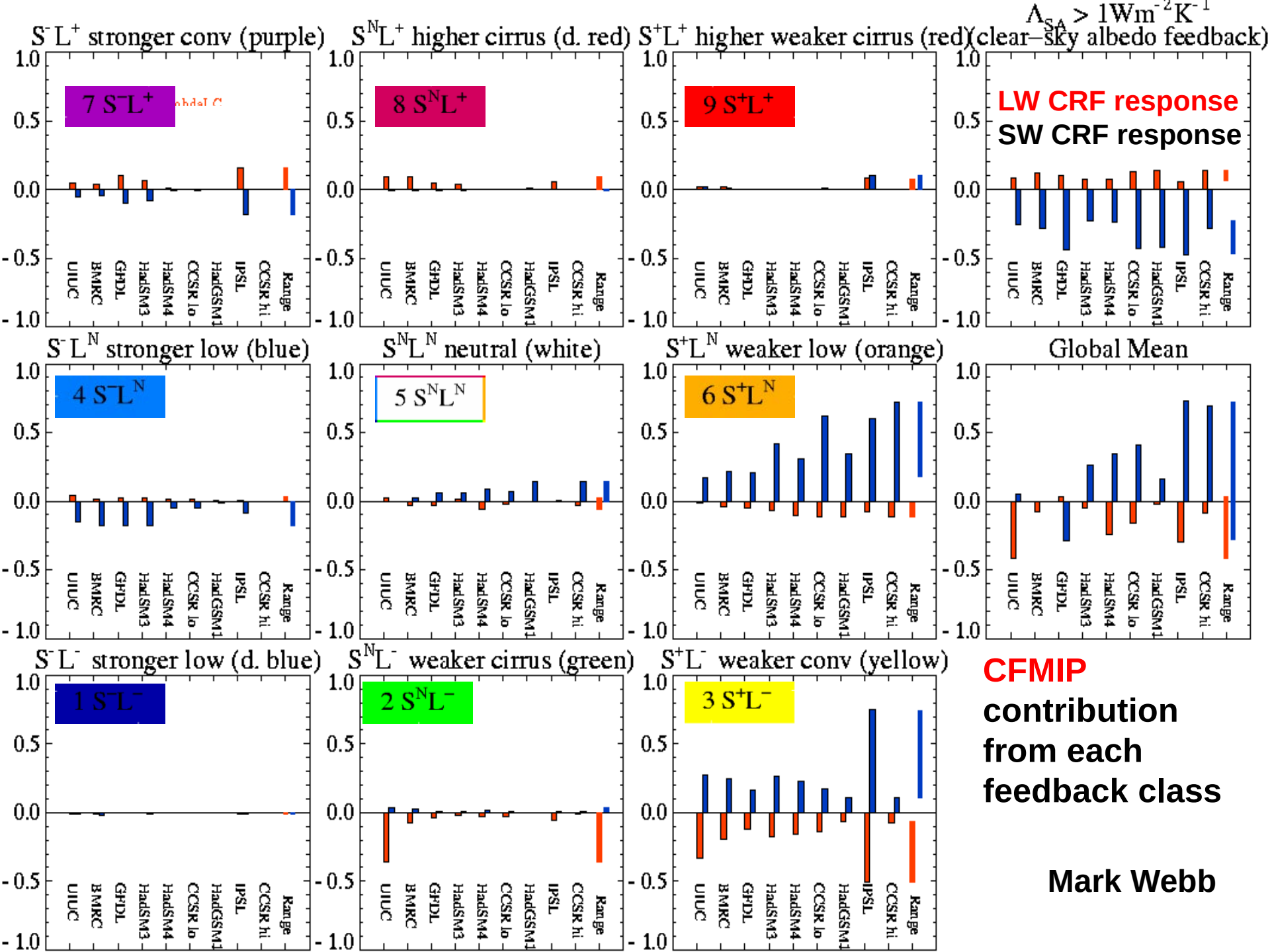
Colman (2003)
PRP Method

8 of 18 models have negative cloud forcing



Cess et al. (1996)
ΔCRF Method

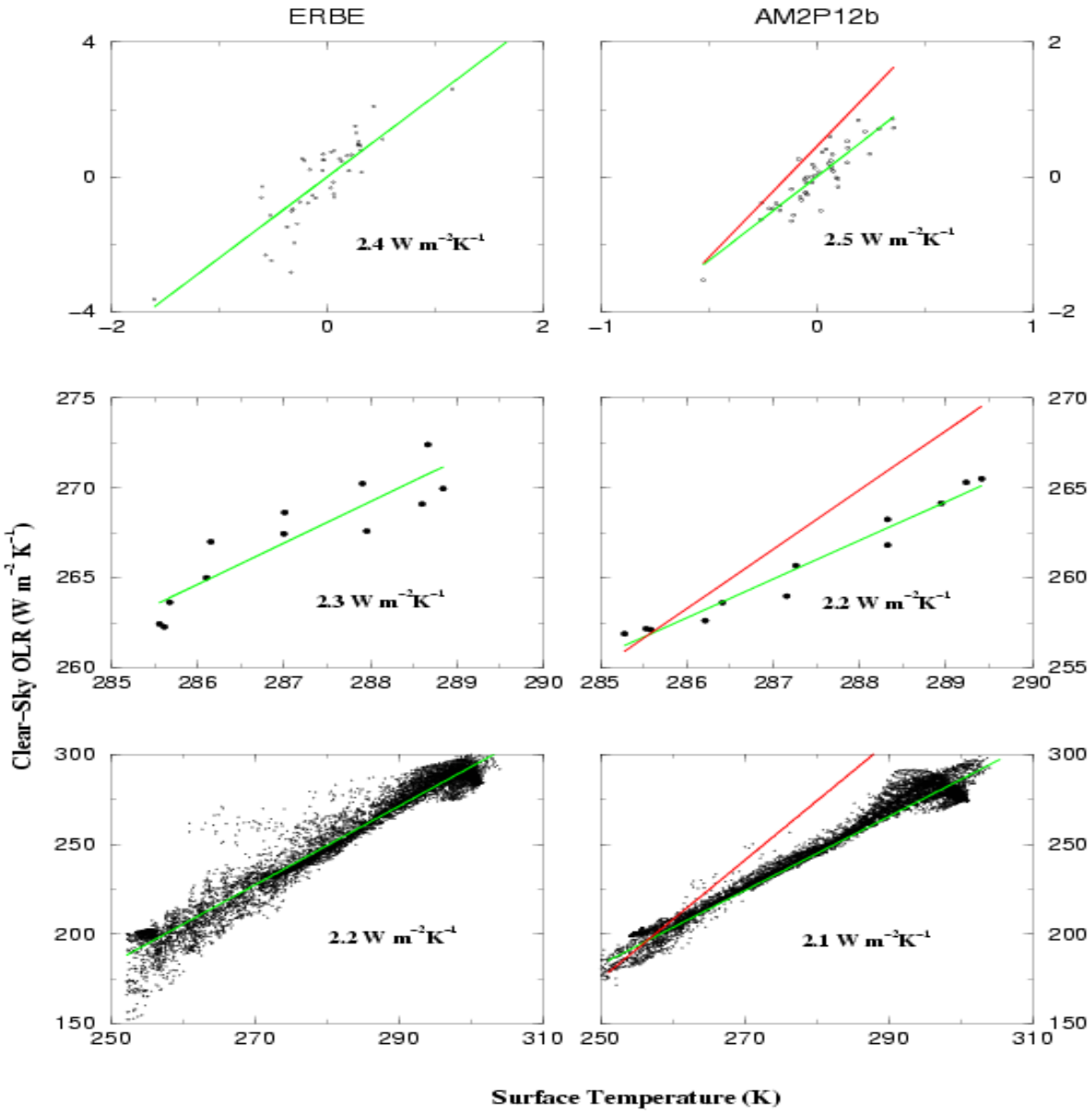
Soden, B. J., A. J. Broccoli, and R. S. Hemler, 2004: On the use of cloud forcing to estimate cloud feedback, *J. Climate*, in press.



CFMIP contribution from each feedback class

Mark Webb

Observable Radiative Damping Rates

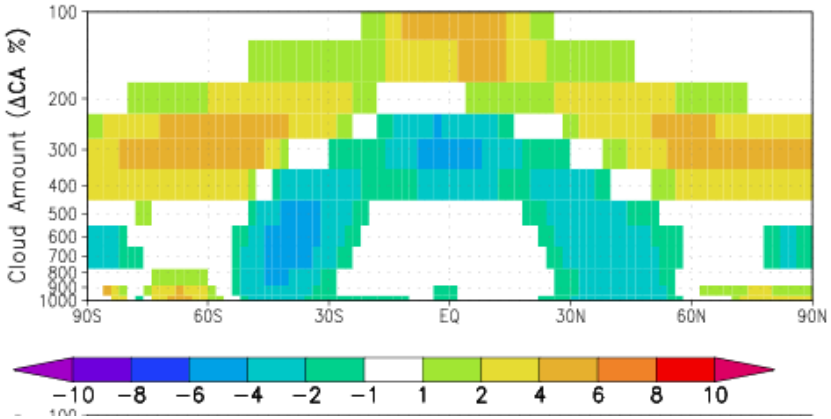


Interannual

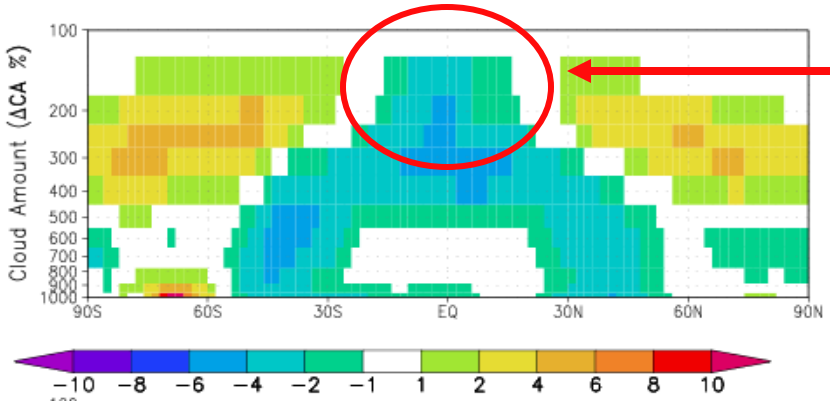
Seasonal

Regional

Cloud Changes in a Warmer Climate



AM2p5 – AM2p9:
Increased tropical high cloud amount.



AM2p10:
Reduced tropical high cloud amount. This weakens LW feedback and changes sign of SW feedback in model.