Verifying the water vapor feedback using ENSO

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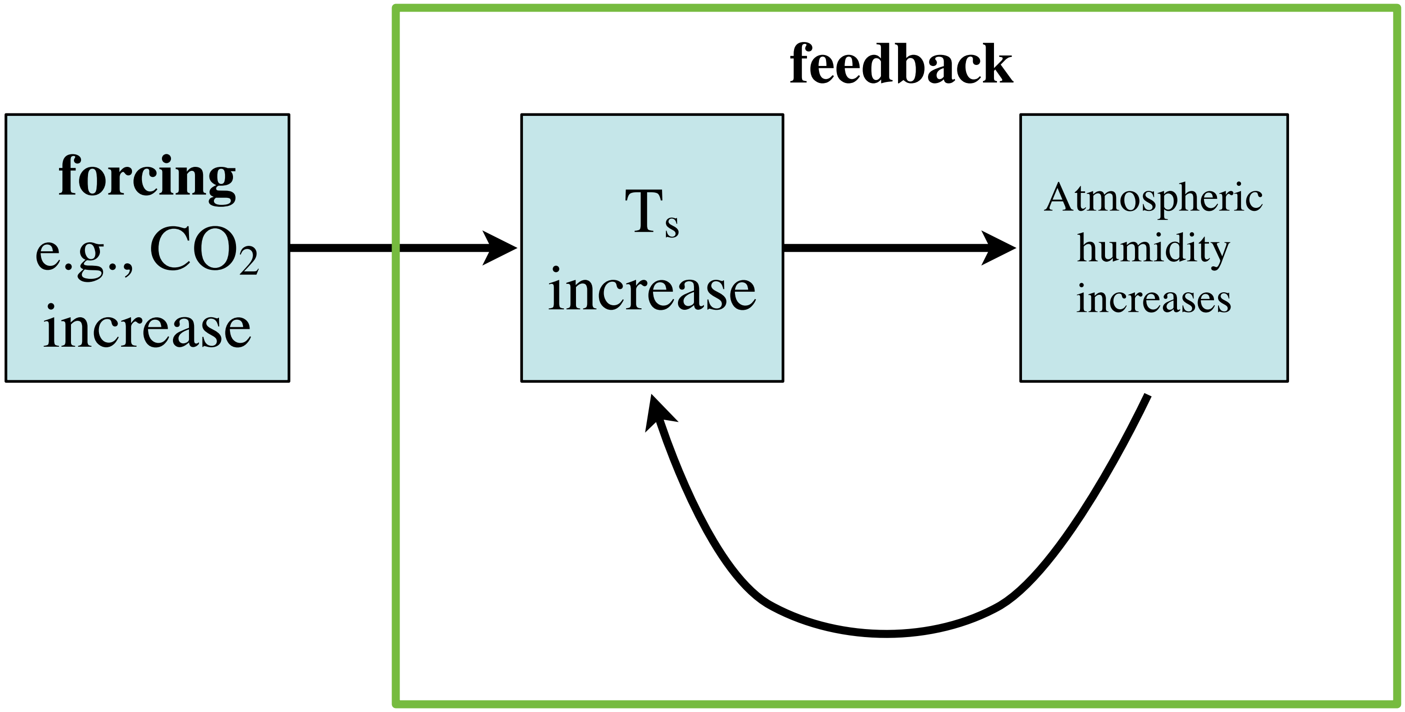
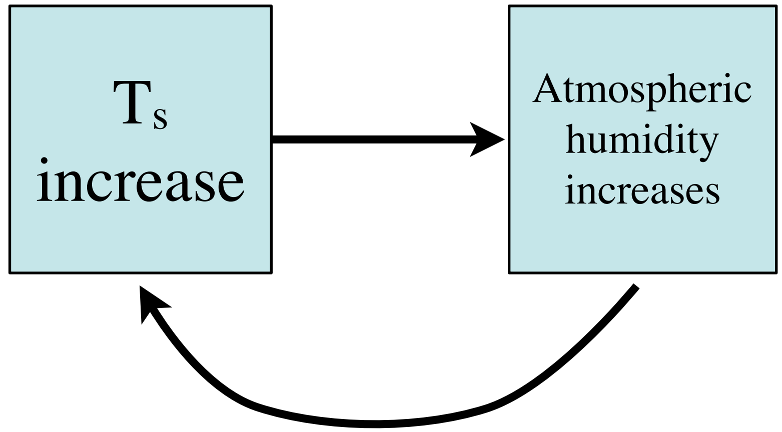
How can we measure this?





Volcano
ENSO+interannual
seasonal cycle
decade-scale warming

Constant Relative Humidity
Partial Radiative Perturbation

Observational tests of the water vapor feedback

Volcano	Soden et al., 2002; Forster and Collins, 2004
ENSO+interannual	Soden, 1997; Dessler et al., 2008; Minschwaner and Dessler, 2004; Gettelman and Fu, 2008;
seasonal cycle	Inamdar and Ramanathan, 1998; Wu et al., 2008
decade-scale warming	Hall and Manabe, 1999; Soden et al., 2005

Partial Radiative Perturbation

T_{s-a} ⟷ T_{s-b}

q_a ⟷ q_b

T_{atm-a} ⟷ T_{atm-b}

ice_a ⟷ ice_b

Wetherald and Manabe, 1988
Colman, 2003; Forster and Collins, 2004;
Soden and Held, 2006

TOA net flux R_a

↑

T_{s-a}

q_a

T_{atm-a}

ice_a

new TOA net flux R_b

↑

T_{s-b}

q_b

T_{atm-b}

ice_b

Wetherald and Manabe, 1988?
Colman, 2003; Forster and Collins, 2004;
Soden and Held, 2006

ΔR = change in global average TOA flux due to Δq

ΔT_s = change in global avg. surface temperature change ($T_{s\text{-}b}$-$T_{s\text{-}a}$) associated with Δq

new TOA net flux R_b

$T_{s\text{-}a}$	$T_{s\text{-}b}$
q_a	q_b
$T_{atm\text{-}a}$	$T_{atm\text{-}b}$
ice_a	ice_b

Wetherald and Manabe, 1988?

Colman, 2003; Forster and Collins, 2004; Soden and Held, 2006 the water vapor feedback

$$\lambda = \frac{\Delta R}{\Delta T_S}$$

$$T_s = \frac{-G}{\lambda_o + \lambda_1 + \lambda_2 + \cdots}$$

ΔR = change in global average TOA flux due to Δq between two climate states

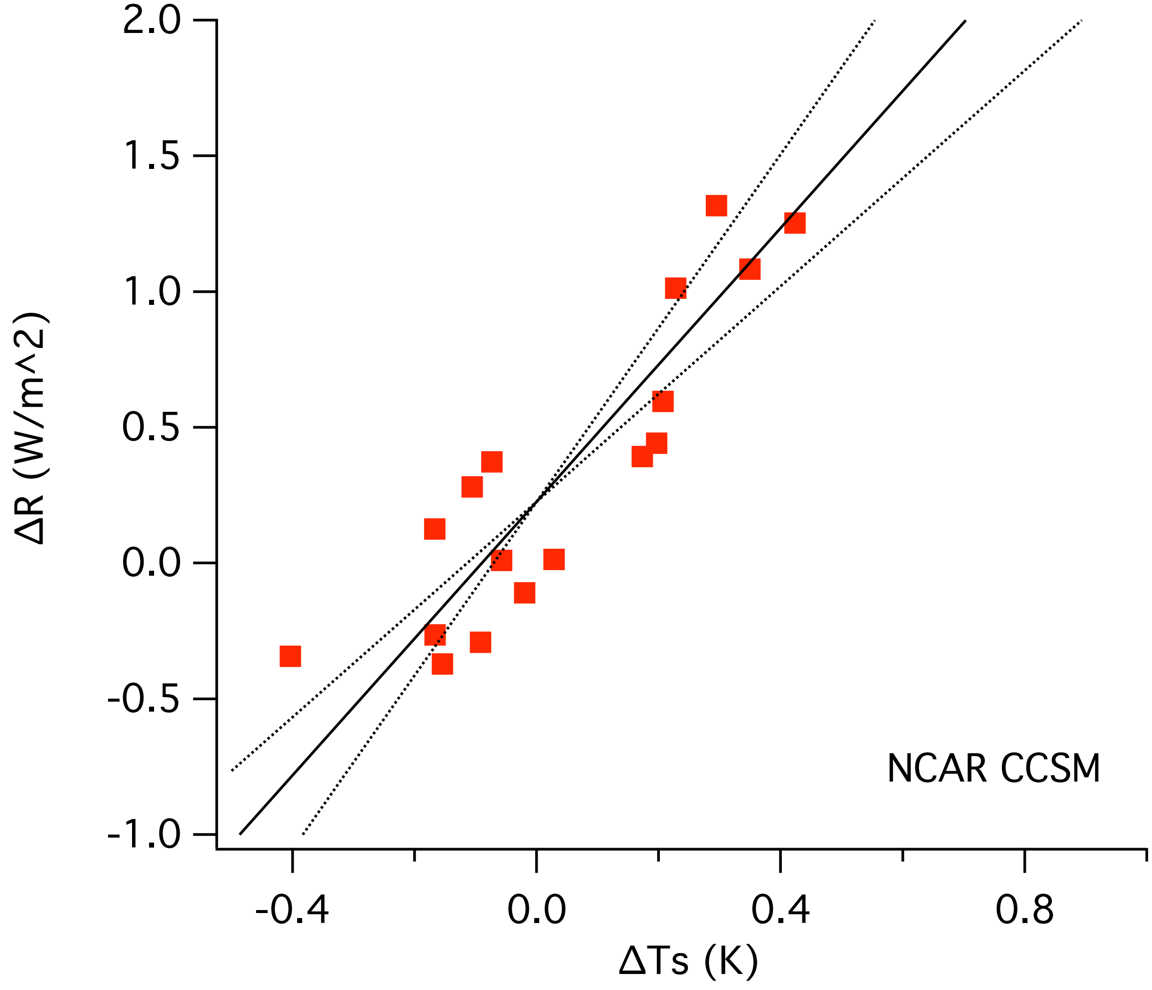
ΔT_s = change in global avg. surface temperature change ($T_{s\text{-}b}$-$T_{s\text{-}a}$) associated with Δq

Wetherald and Manabe, 1988?
Colman, 2003; Forster and Collins, 2004; Soden and Held, 2006

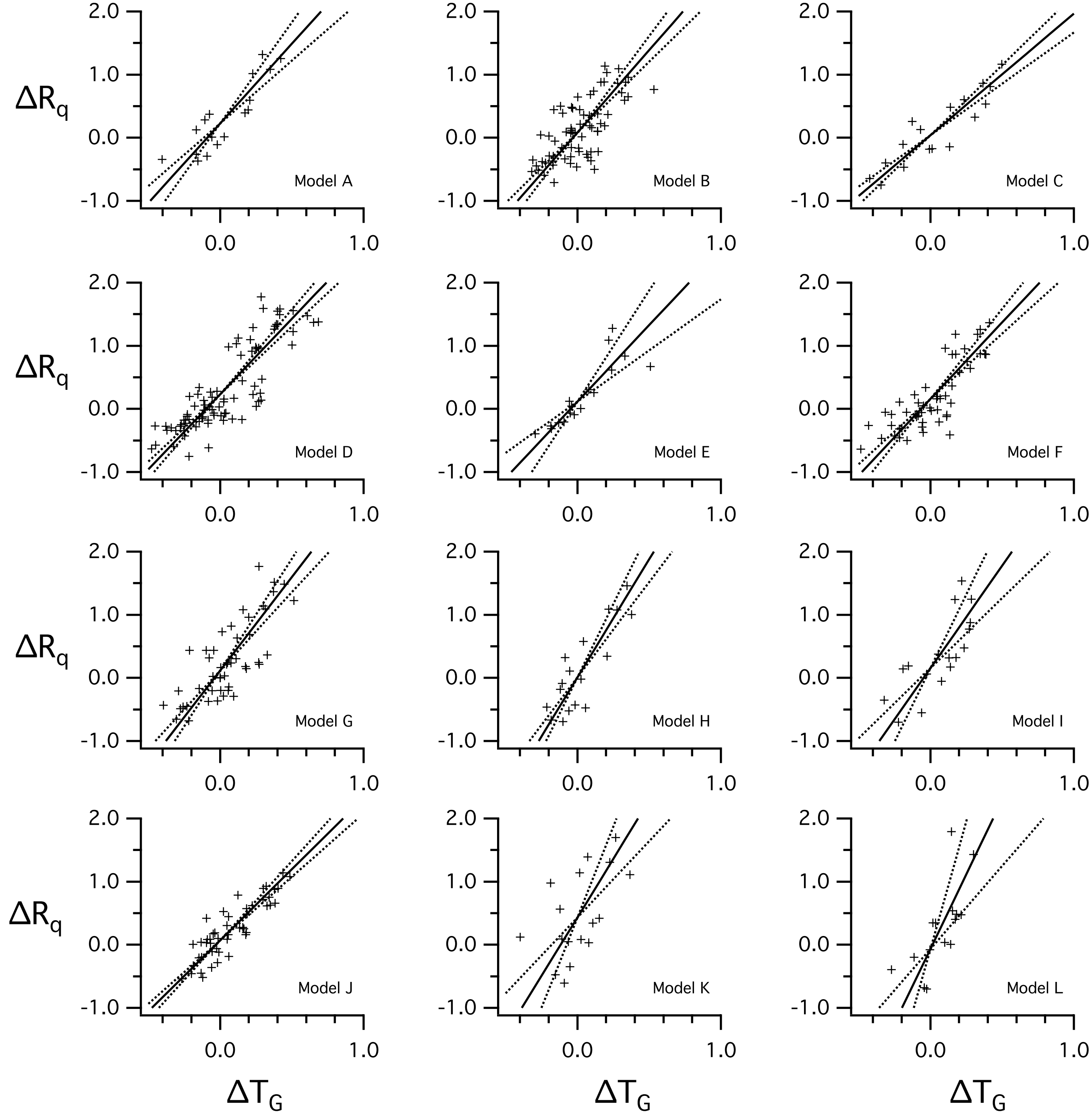
Method

- AMIP models from the PCMDI archive
- Reanalysis: ERA40 & MERRA
- For each strong DJF ENSO month (e.g., Jan. 1983), calculate ΔR and ΔT_s between that month and the long-term average for all Januaries in the model run
- Obtain one estimate of ΔR and ΔT_s for every strong ENSO month

$$\lambda = \frac{\Delta R}{\Delta T_S}$$

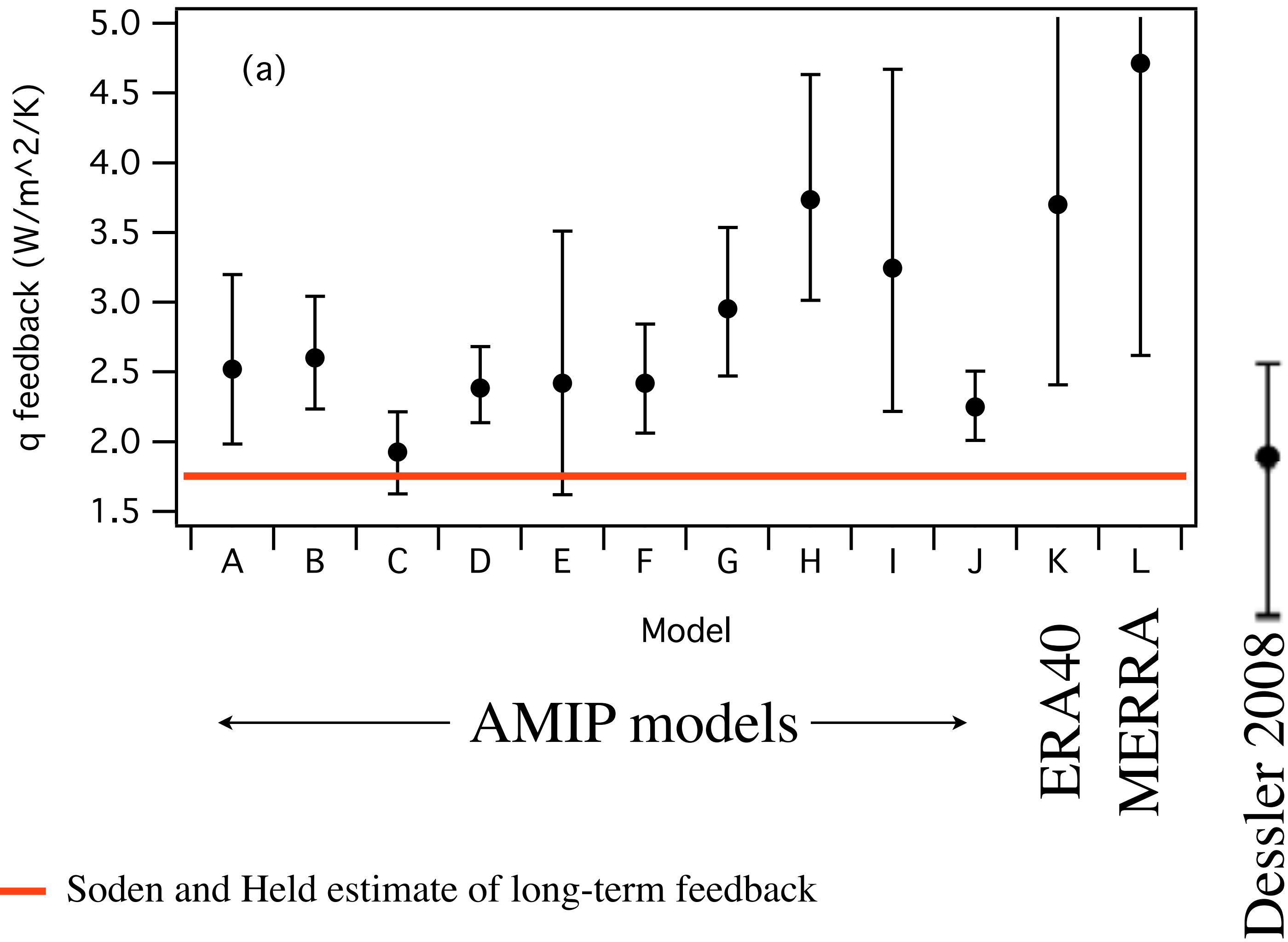


Each point is a strong ENSO DJF



ΔRq
ΔTG
2.0
1.0
0.0
-1.0
0.0
1.0
Model A
Model B
Model C
Model D
Model E
Model F
Model G
Model H
Model I
Model J
Model K
Model L

$$\lambda = \frac{\Delta R}{\Delta T_S}$$



Soden and Held estimate of long-term feedback

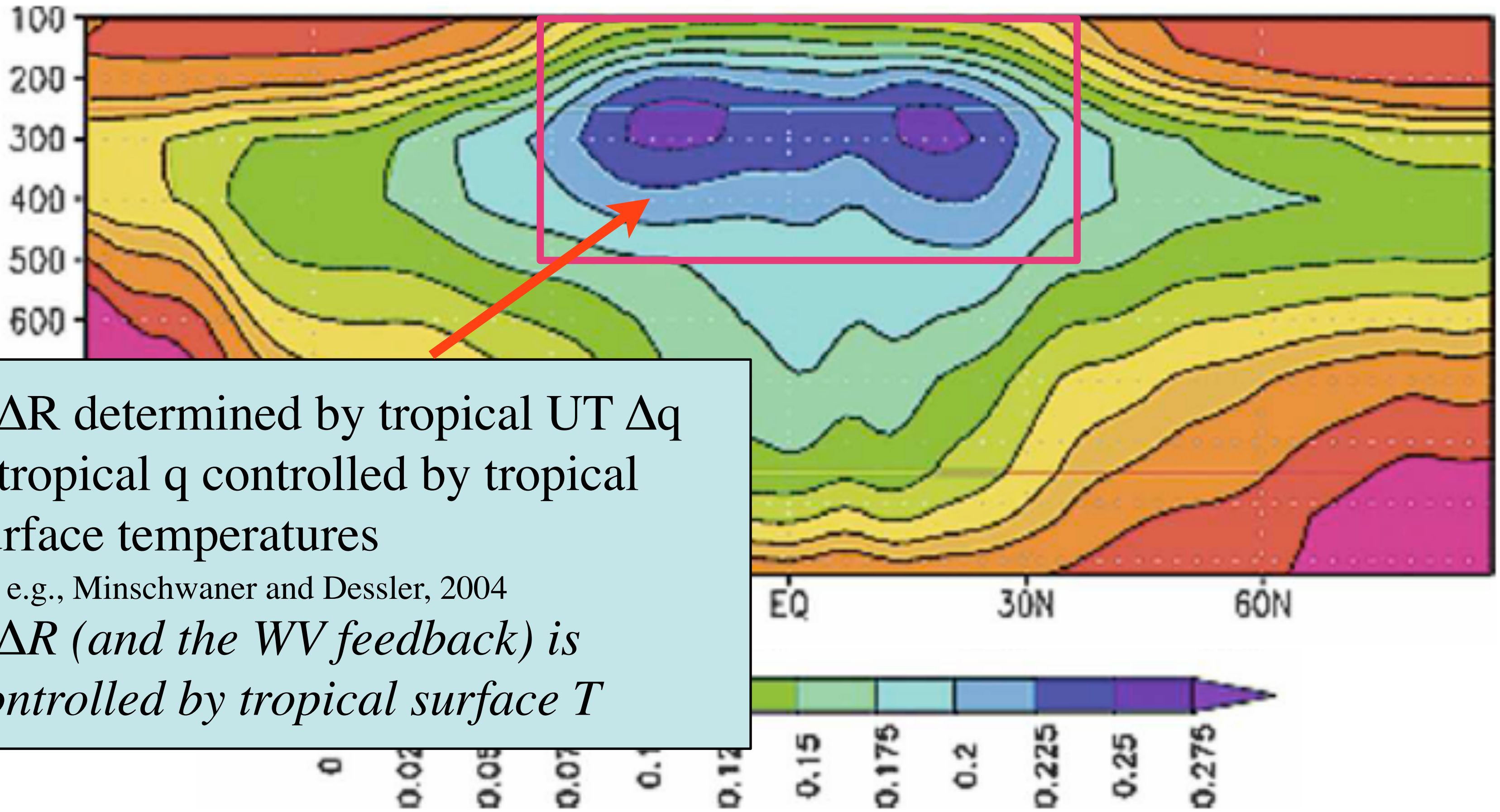
Conclusions 1

- Models, reanalysis, and pure obs. agree that the feedback is positive and strong
- Reanalysis is larger than the models
  - if reanalysis is correct, then models are *underestimating* the feedback
  - uncertainties generally overlap
- ENSO WV feedback larger than in response to long-term warming (e.g., Colman, Soden and Held)

Questions for the rest of the talk

- What is the source of disagreements among the models and between the models and reanalyses?
- Speculation: Why is the ENSO feedback larger than the feedback in response to long-term warming?

Water vapor feedback is primarily a "tropical" phenomenon

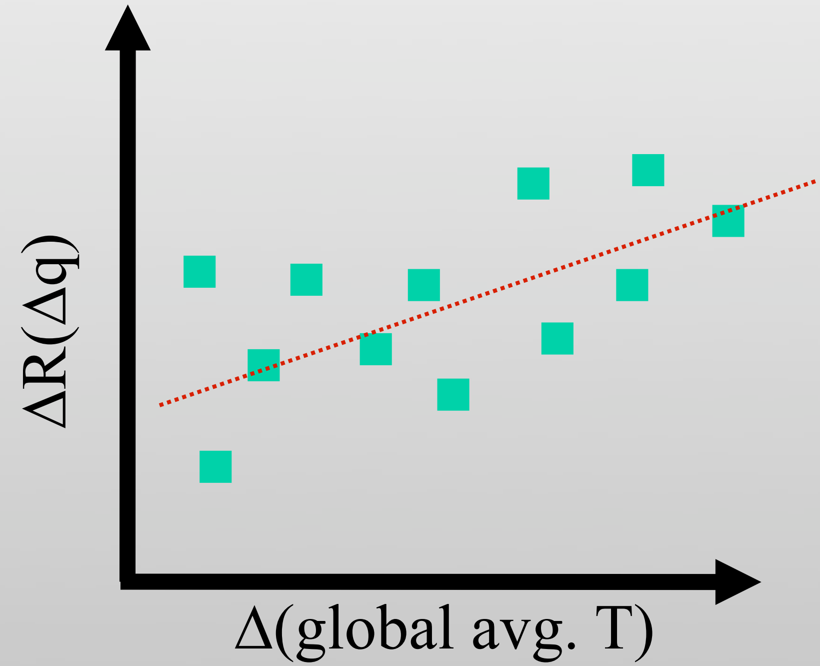


* ΔR determined by tropical UT Δq
* tropical q controlled by tropical surface temperatures
  e.g., Minschwaner and Dessler, 2004
* *ΔR (and the WV feedback) is controlled by tropical surface T*

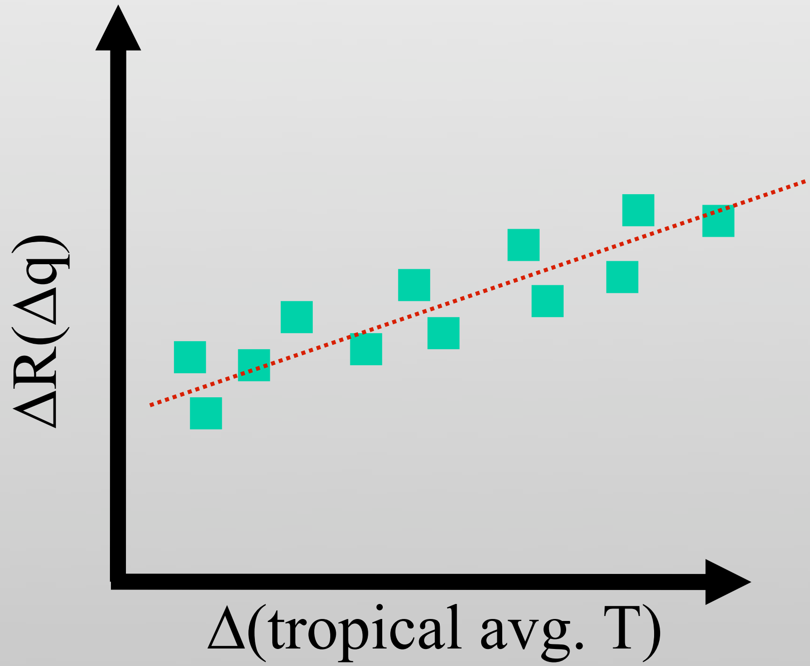
Change in R per unit change in q(x,y,z): ΔR/Δq(x,y,z)

Fig. 2 of Soden et al., 2008

Regress ΔR vs. *global* surface temperature

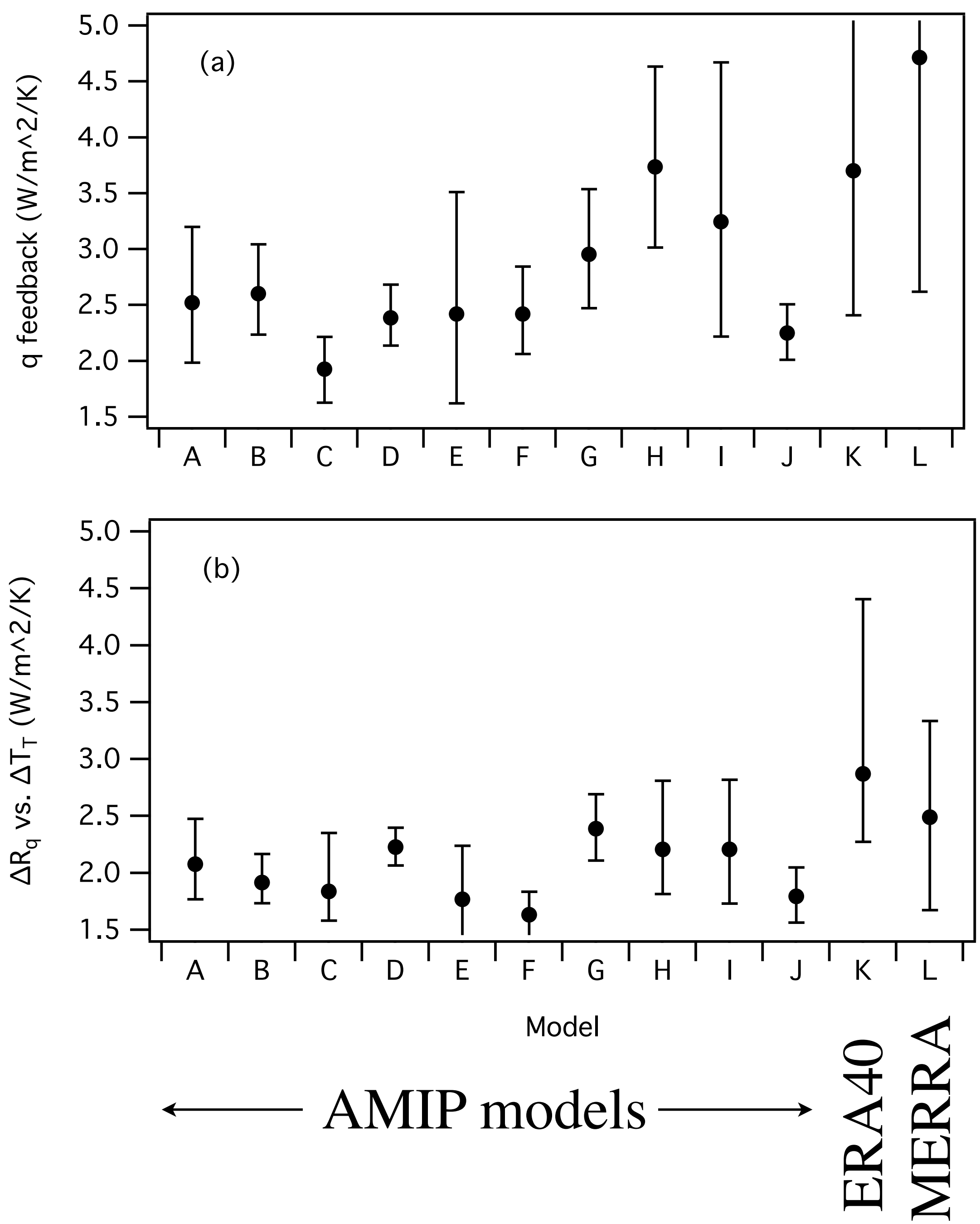


Regress ΔR vs. *tropical* surface temperature



$$\frac{\Delta R}{\Delta T_S}$$

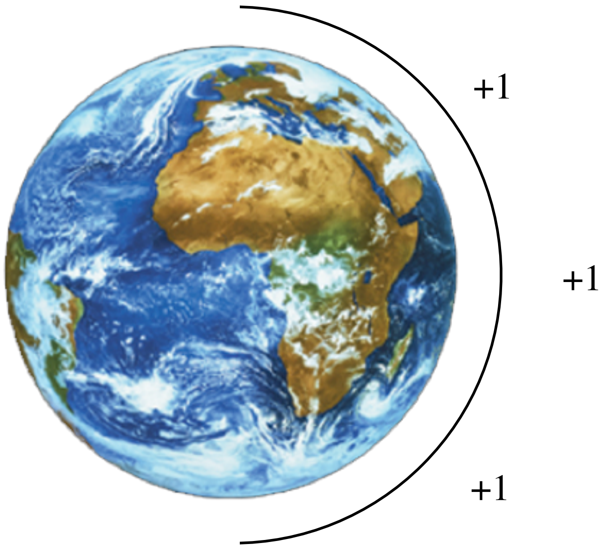
$$\frac{\Delta R}{\Delta T_T}$$



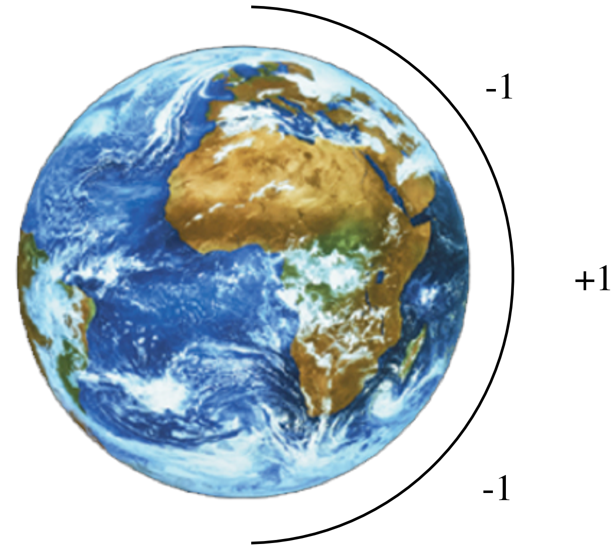
What does this mean?

- A consistent relationship exists between tropical surface ΔT_T and the radiative response to water vapor ΔR
  - GCMs
  - reanalyses
  - pure obs.

$$\lambda = \frac{\Delta R}{\Delta T_S}$$



smaller feedback

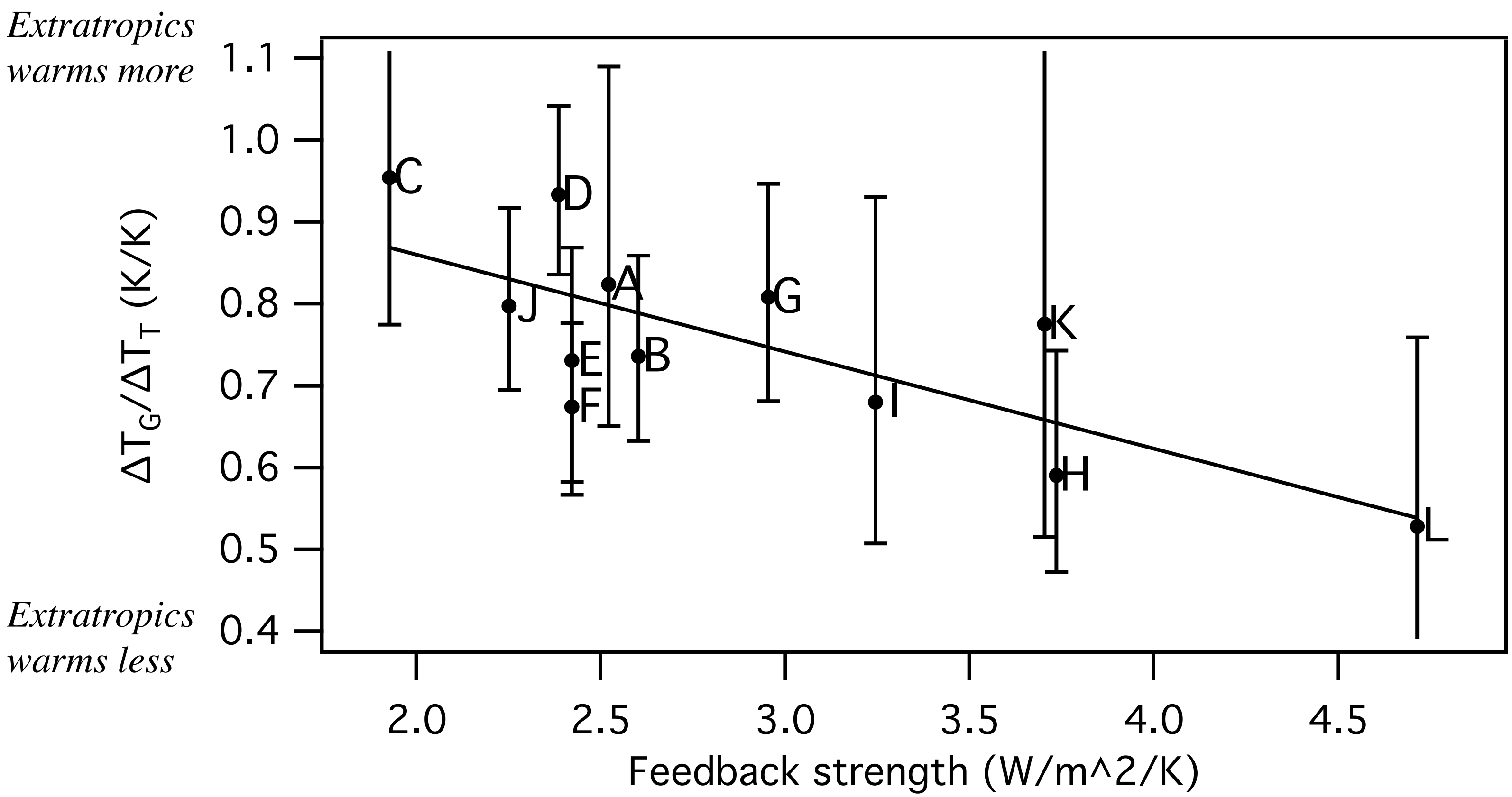


larger feedback

ΔR for these two worlds is the same

ΔT_s is different

$$\lambda = \frac{\Delta R\left(\Delta q\left(\Delta T_T\right)\right)}{\Delta T_G}$$



Summary

- In response to ENSO climate change, models, reanalysis, and pure obs. show a strong and positive water vapor feedback
- Models, reanalysis, and pure obs. show that the radiative response to WV between two climate states is determined by change in the tropical surface T
  - WV feedback determined by tropical UT water
  - Tropical UT water is controlled by surface T described by Minschwaner and Dessler [2004] (see me for reprints)
- Differences among models and between models and reanalyses are due to differing estimates of extratropical surface T changes --- they are NOT due to the radiative response of WV
- This work is in press at *J. Climate*. See me for preprints.