Necessary but not sufficient conditions for constraining water vapor feedbacks

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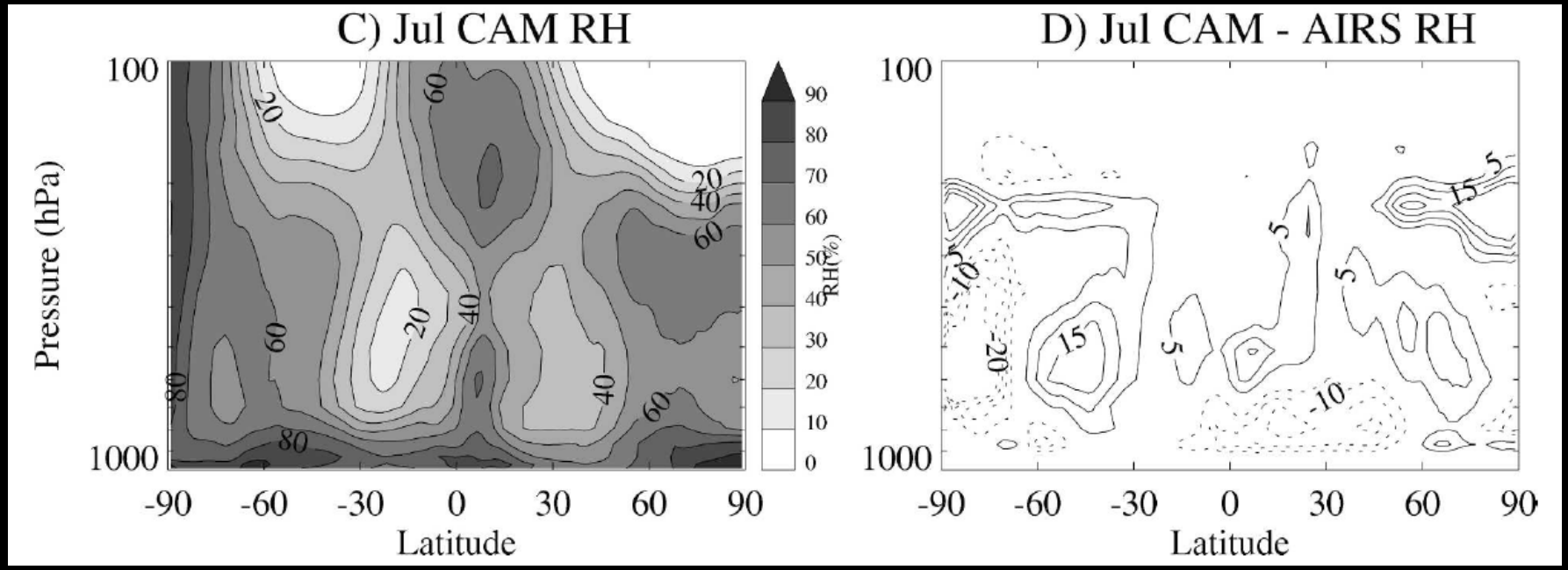
Outline

- GCM Humidity
  - H_2O & RH simulations v. AIRS
- Vertical Structure of H_2O Feedbacks
  - AIRS & GCM
- Questions & Thoughts
- Observations

GCM H_2O: 'Not Bad'

CAM v. AIRS: AIRS sorted for Clouds

Some biases in sub-tropics

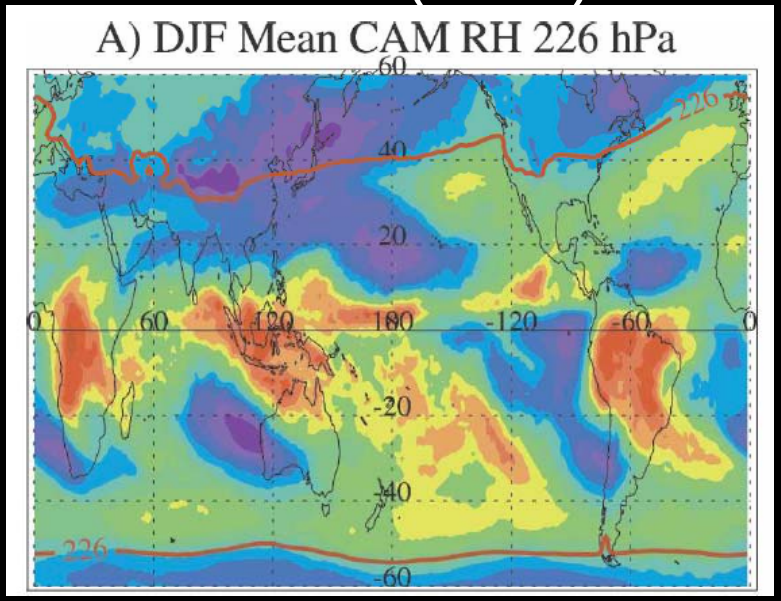


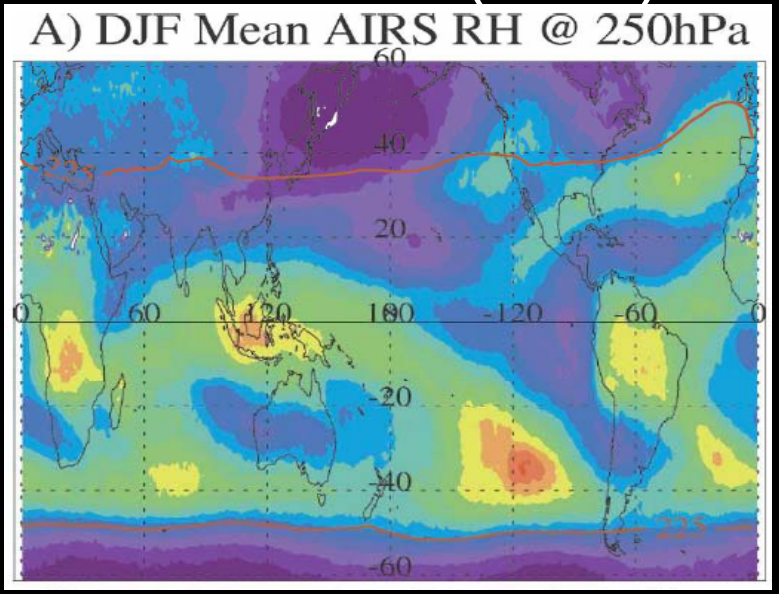
Water Vapor (RH)

Simulation (CAM)

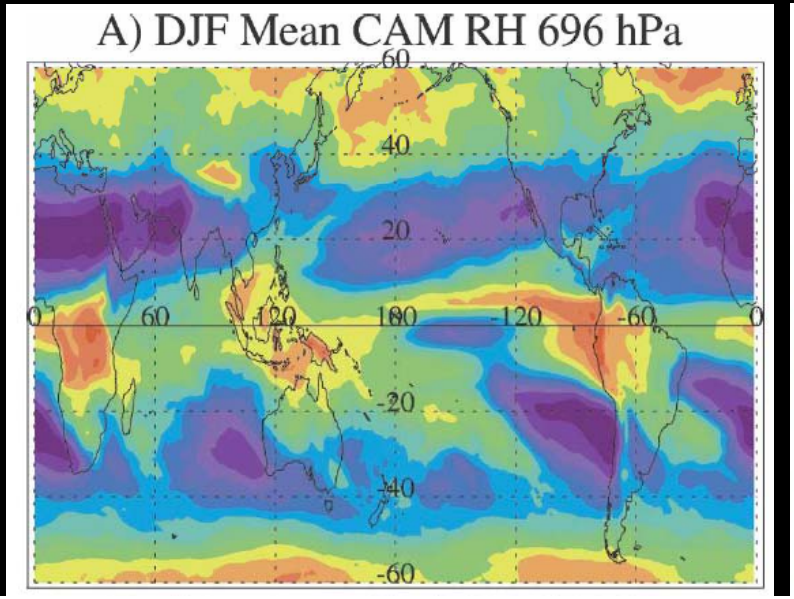
Observations (AIRS)

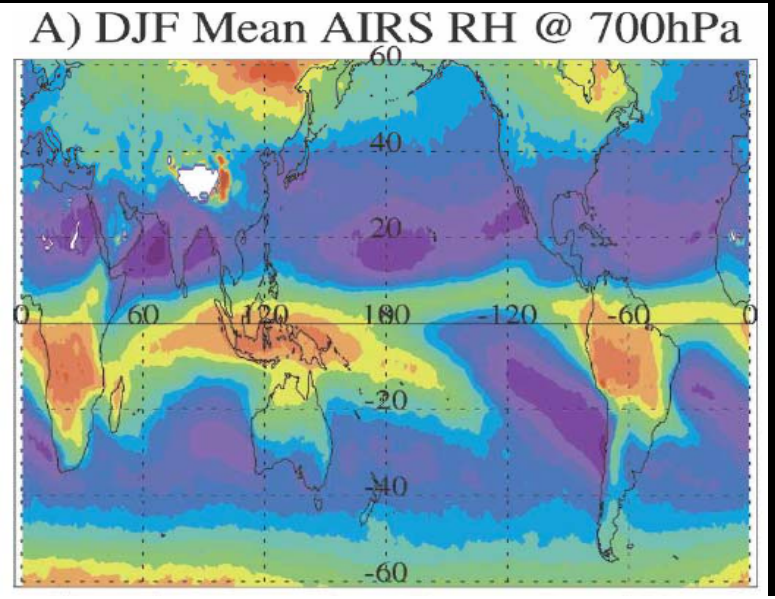
250 hPa





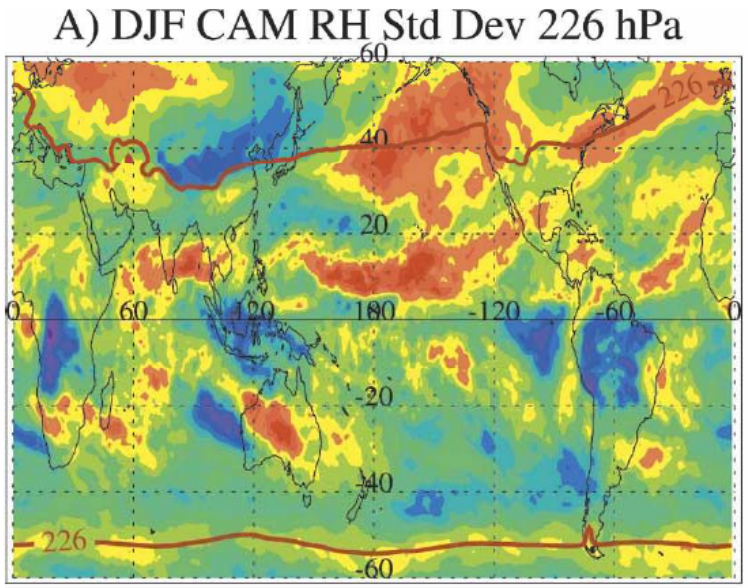
700 hPa

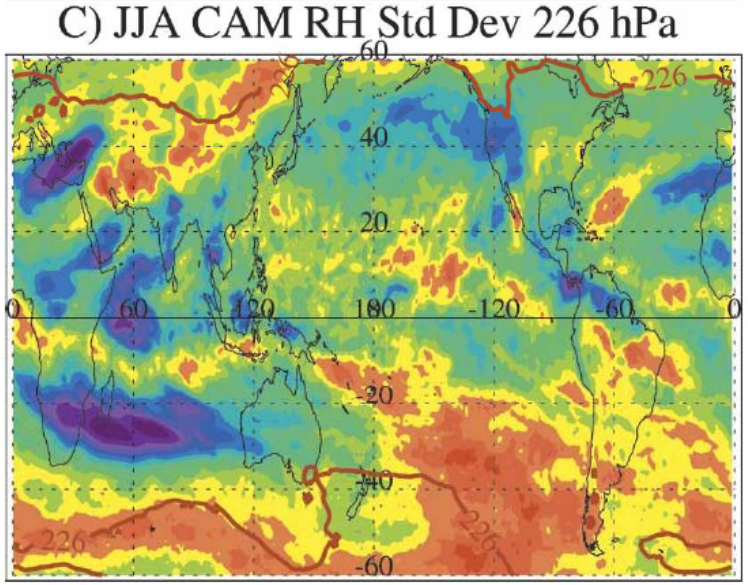




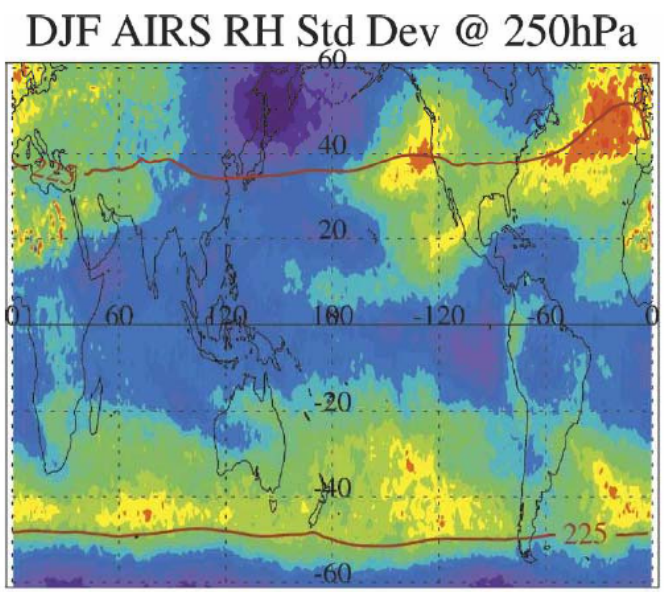
Standard Deviations

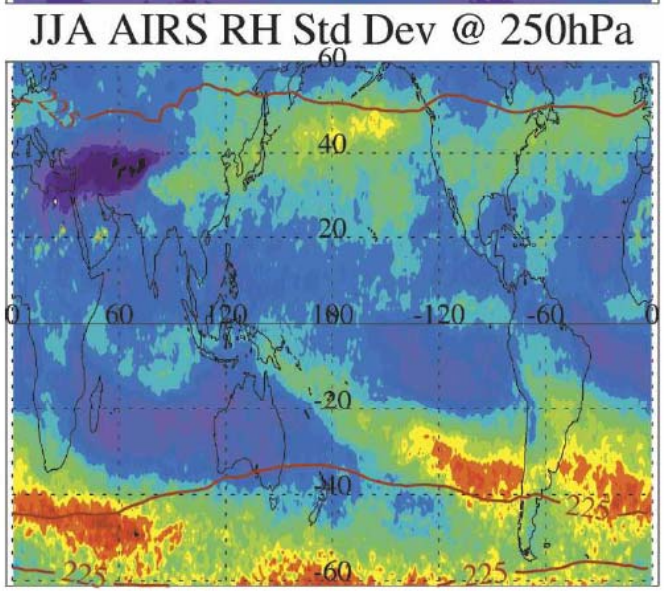
Simulation (CAM)

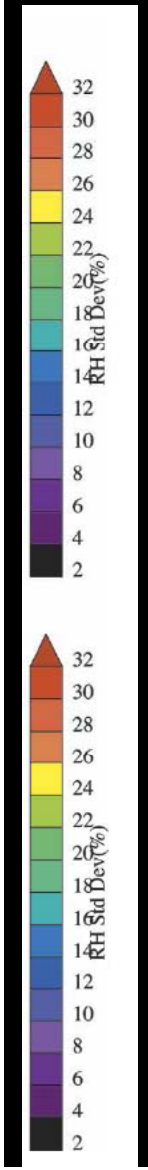




Observations (AIRS)



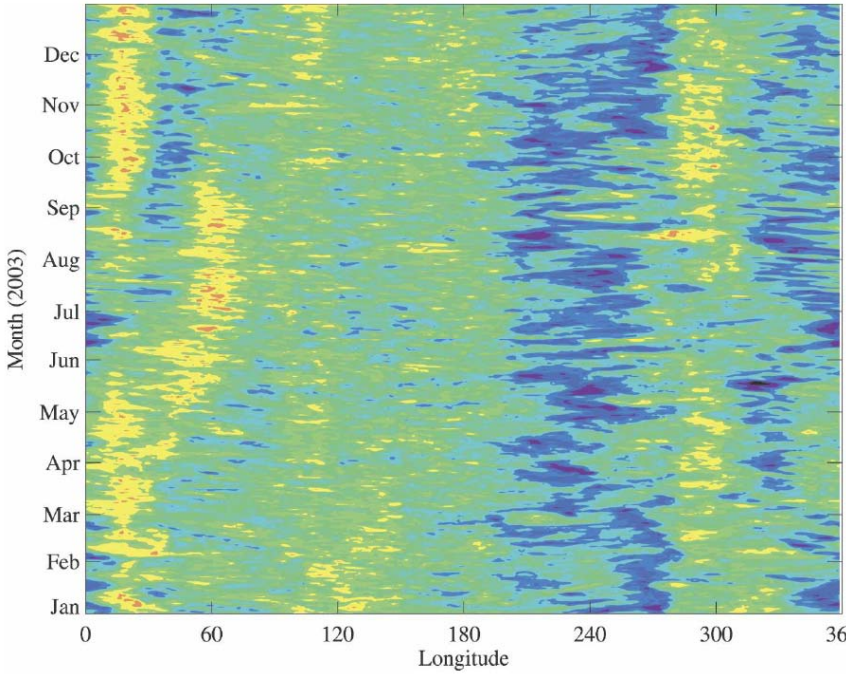




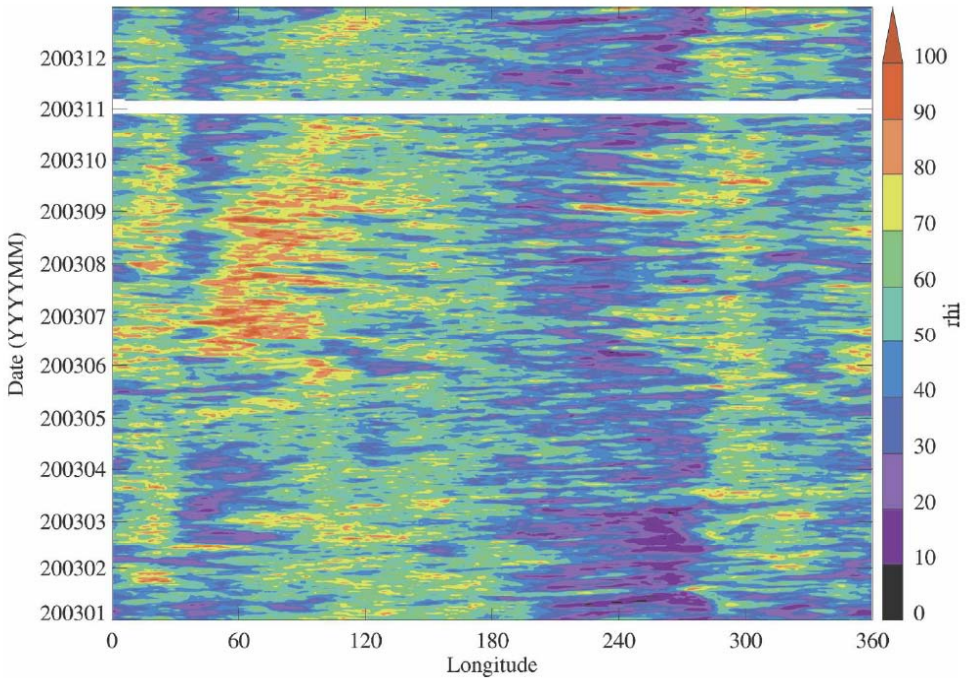
Convective Clouds: Organization

225hPa Relative Humidity (10S-10N)

Model



AIRS



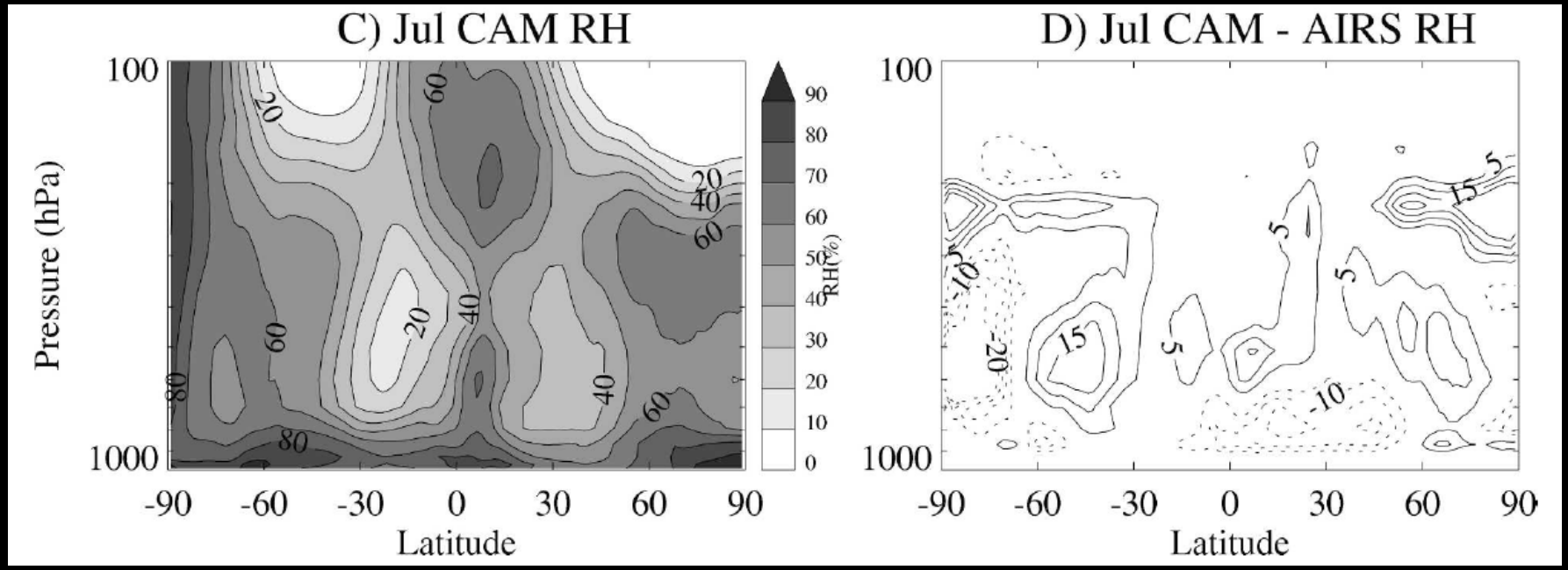
Not enough simulated RH variability: wrong cloud organization

Simulating Humidity

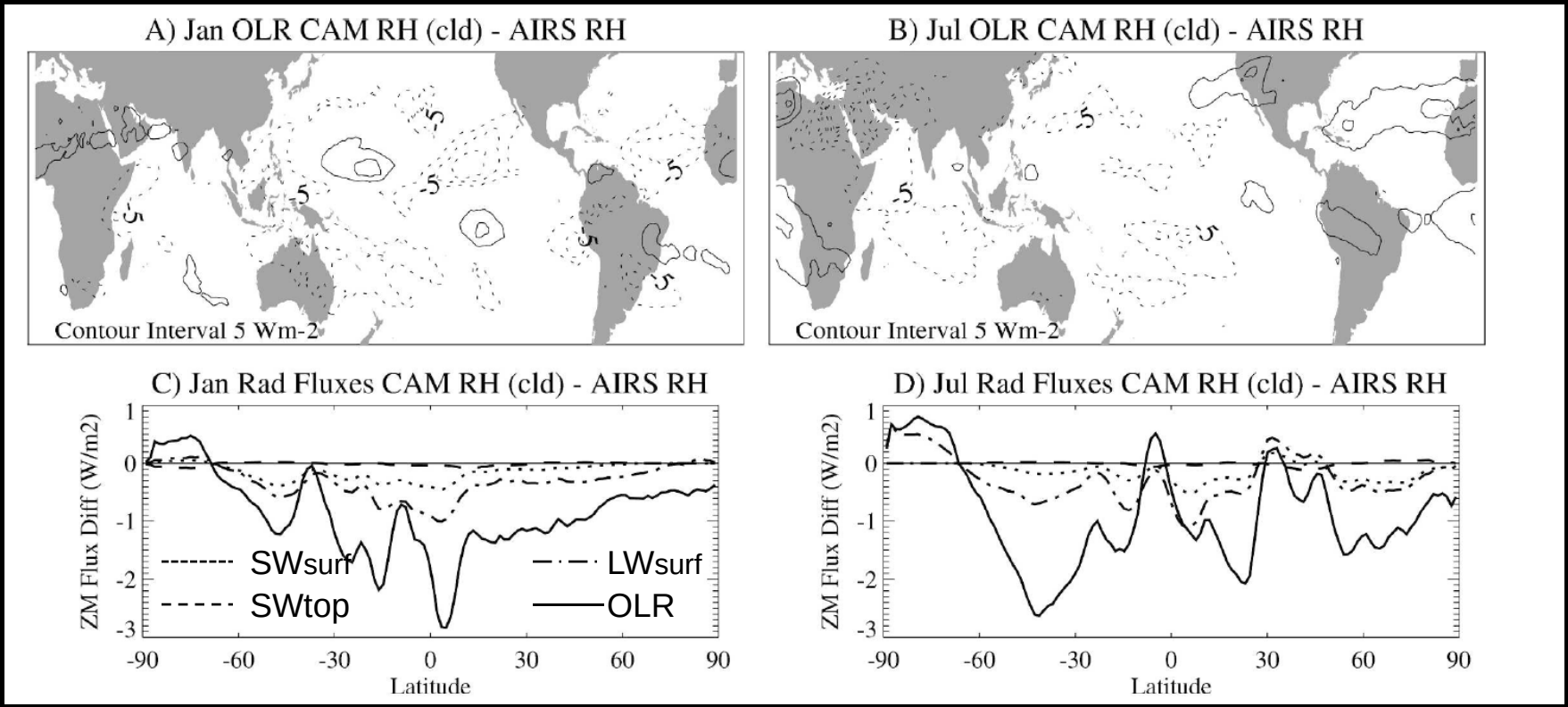
- GCM's have 'generally correct' H_2O distributions
  - Objections?
- "Last Saturation" models work qualitatively
- But: the subtropics are often too moist
- Uncertainties in Observed humidity
  - upper tropical troposphere & high latitudes (ice supersaturation)
- Many scales of variability are not resolved
- These deficiencies may matter for feedbacks
  - Definitely clouds, possibly H_2O

Radiative Impacts of H_2O

Differences in Relative Humidity result in differences in radiative fluxes



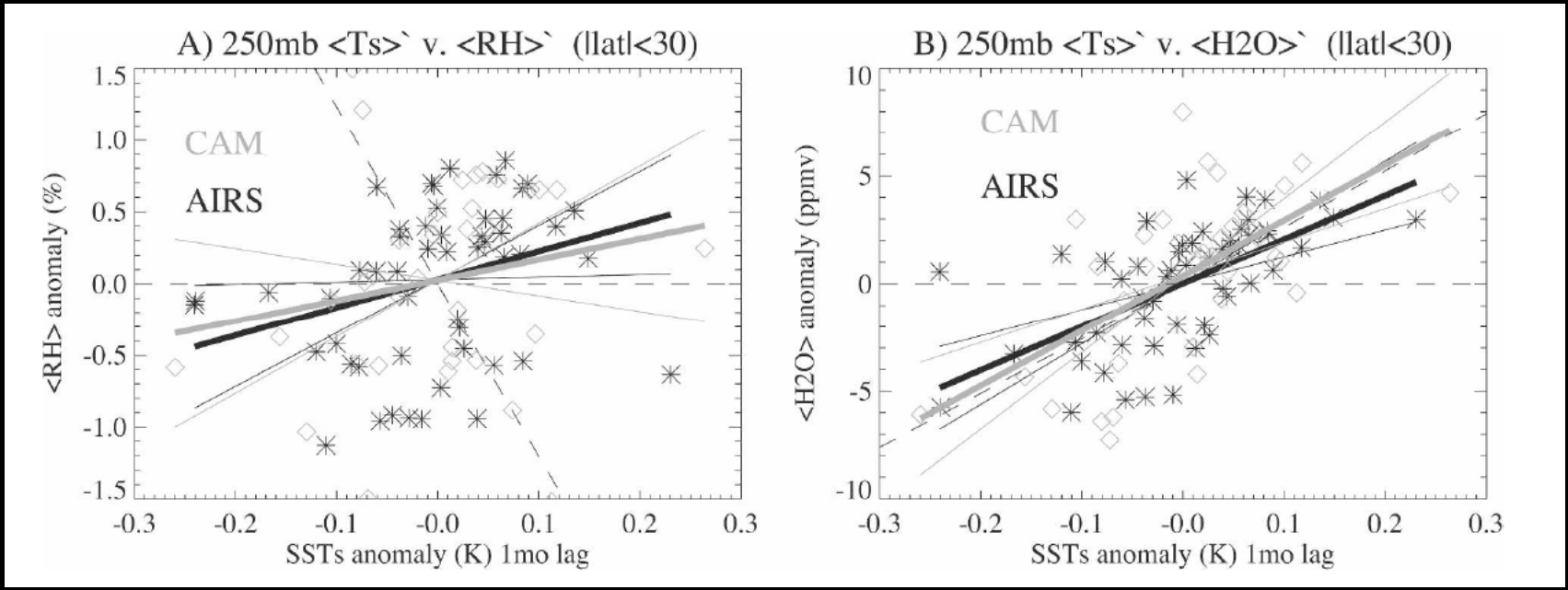
Radiation (2)



Impact of humidity differences: globally about 1Wm^{-2}, locally 5-15Wm^{-2}

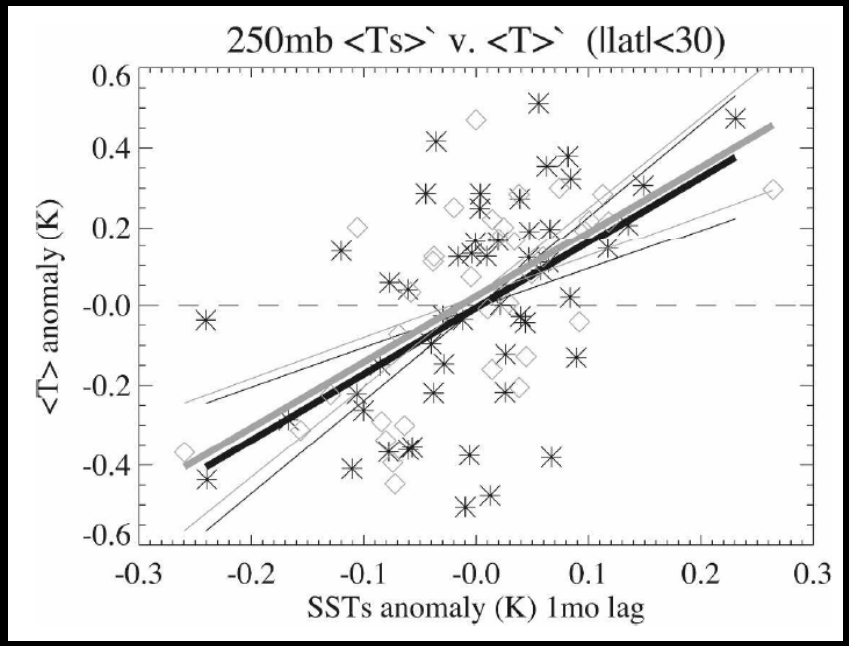
Largest impact in subtropics

Water Vapor Feedbacks

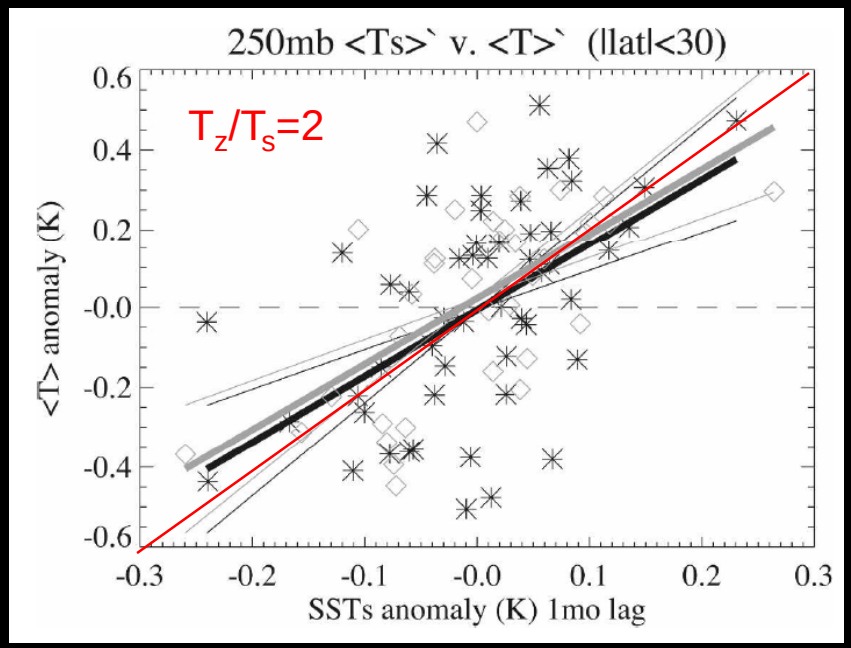


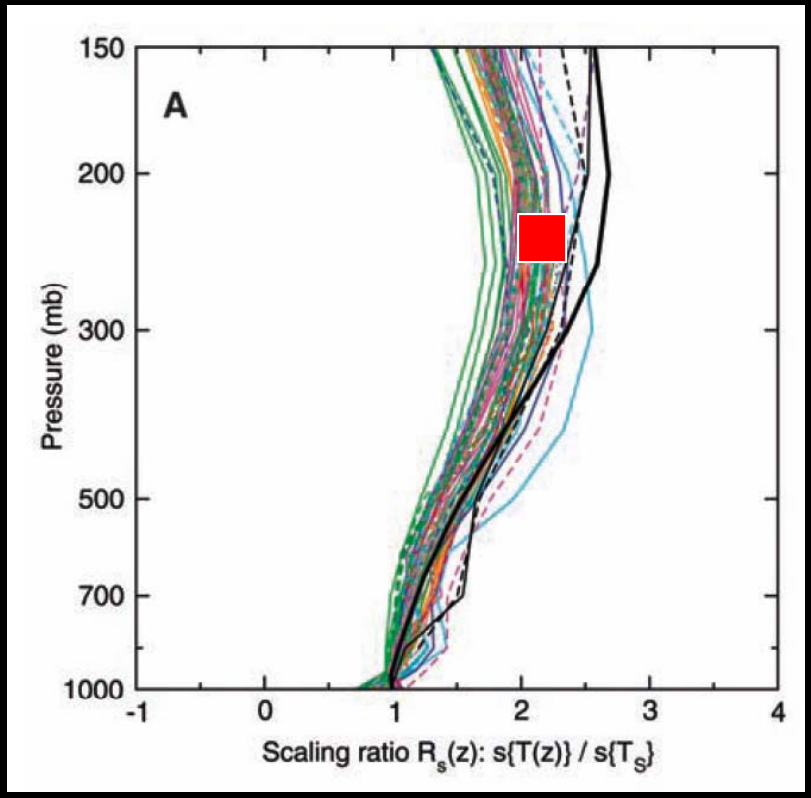
Response of upper troposphere RH and H_2O to surface T
Model (CAM) and observations (AIRS) are similar
Both are 'not inconsistent' with constant RH hypothesis
(Gettelman & Fu, 2008)

Note: $dT > dT_s$


250mb <Ts>` v. <T>` (|lat|<30)
<T> anomaly (K)
SSTs anomaly (K) 1mo lag
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.3
-0.2
-0.1
-0.0
0.1
0.2
0.3

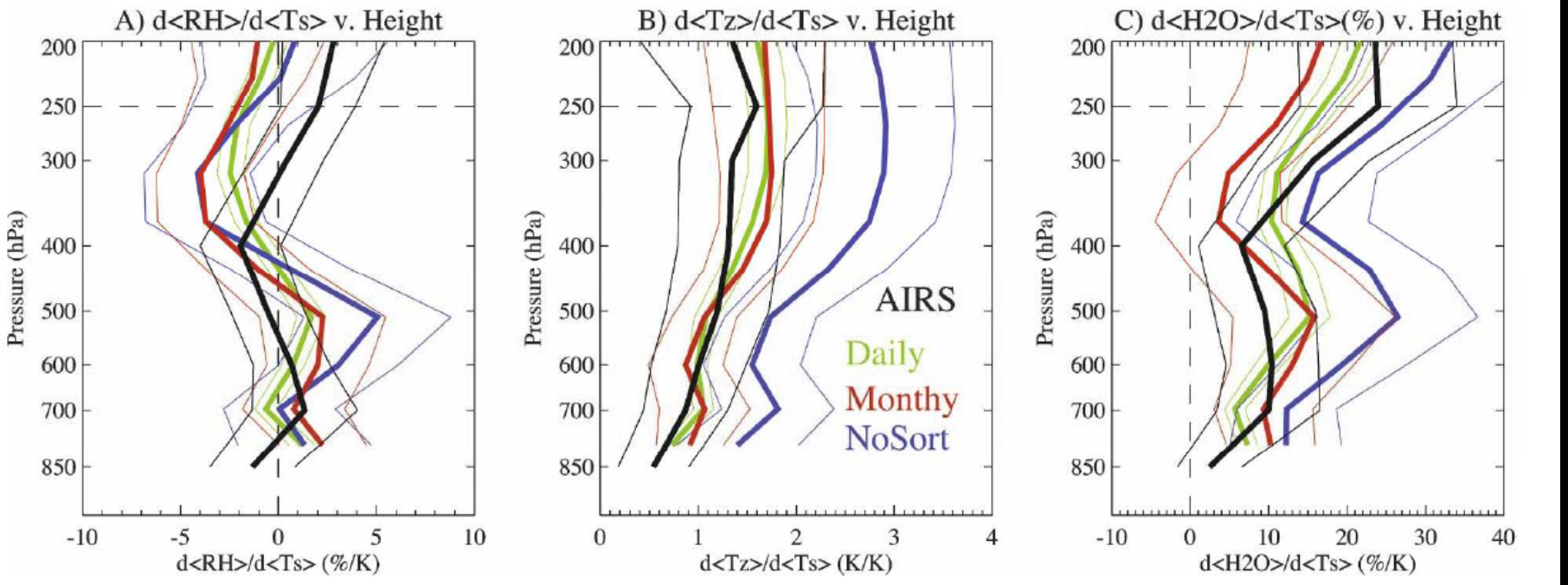
Note: $dT_z > dT_s$





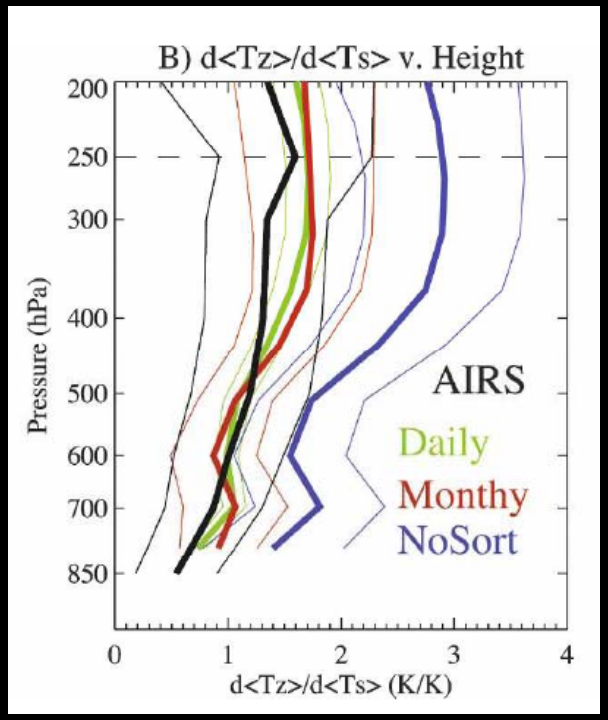
Not surprising (Santer et al 2005, Science)

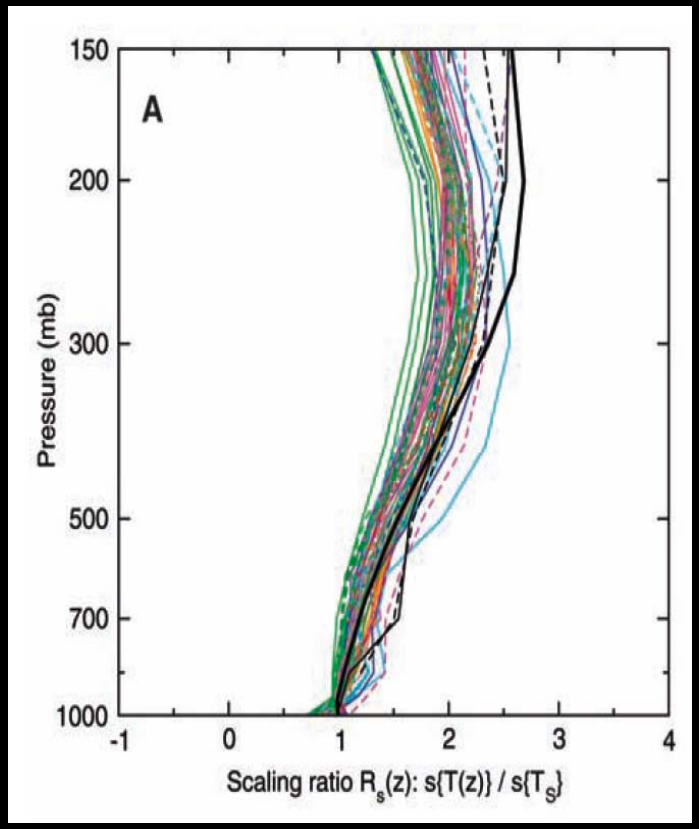
Vertical Structure



- Note changes with height
- Better agreement with AIRS when the model is sorted for cloud fraction < 0.7

Vertical Structure

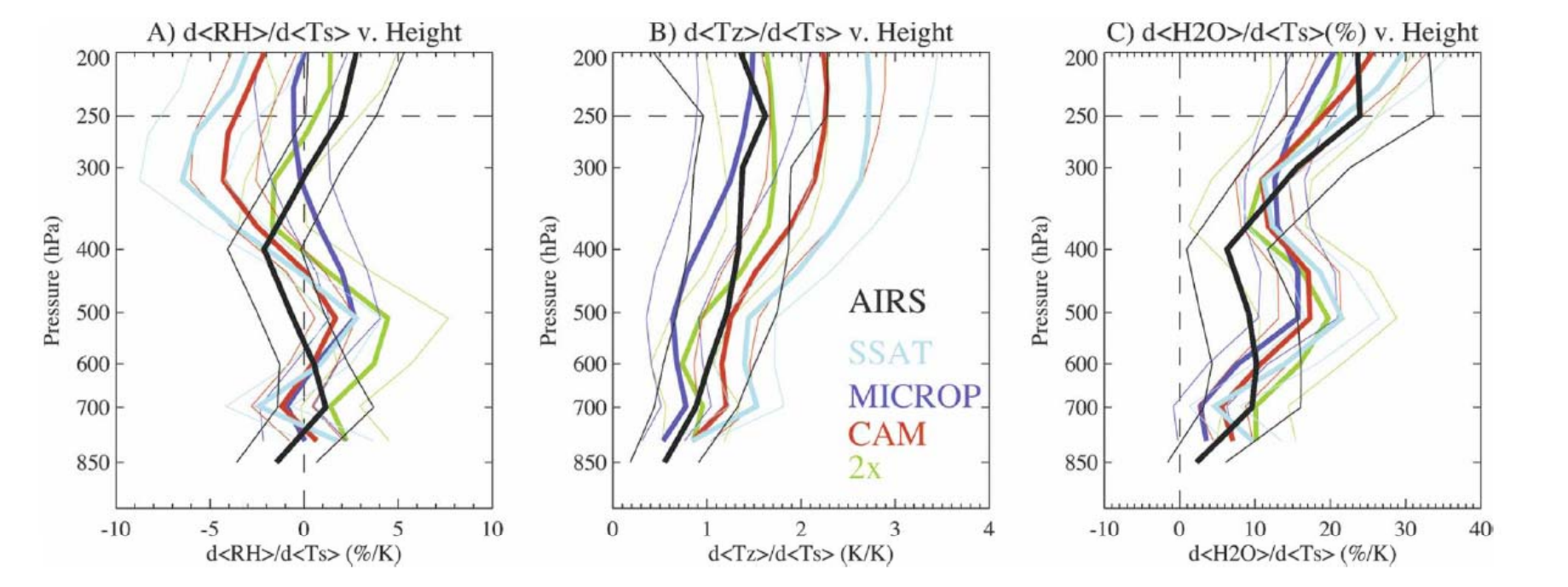




- Similar to moist adiabatic lapse rate, and other models

Water Vapor Feedbacks (2)

Model (CAM) agrees with observations (AIRS) in vertical



Significant differences with parameterization

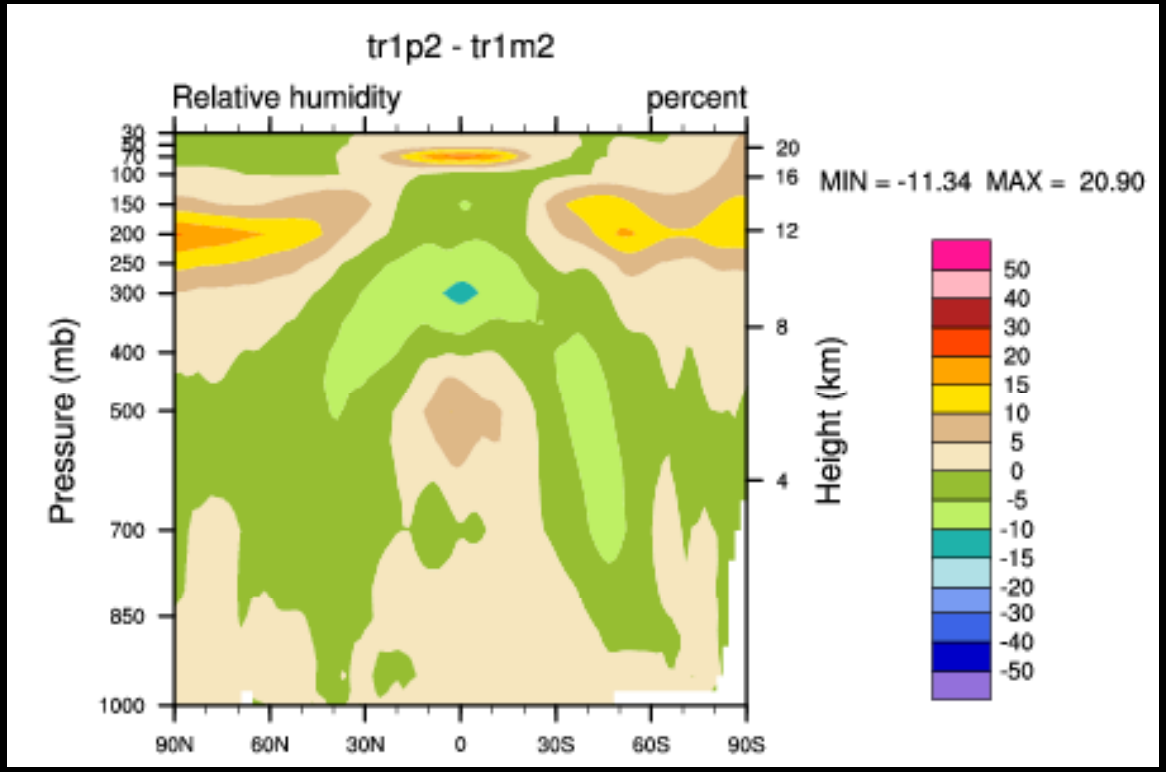
Analogs for climate change?

- Are observed perturbations (monthly means, ENSO, Pinatubo) analogs for climate change?
- Do circulation changes make feedbacks qualitatively different?
- Try something else: Cess experiments

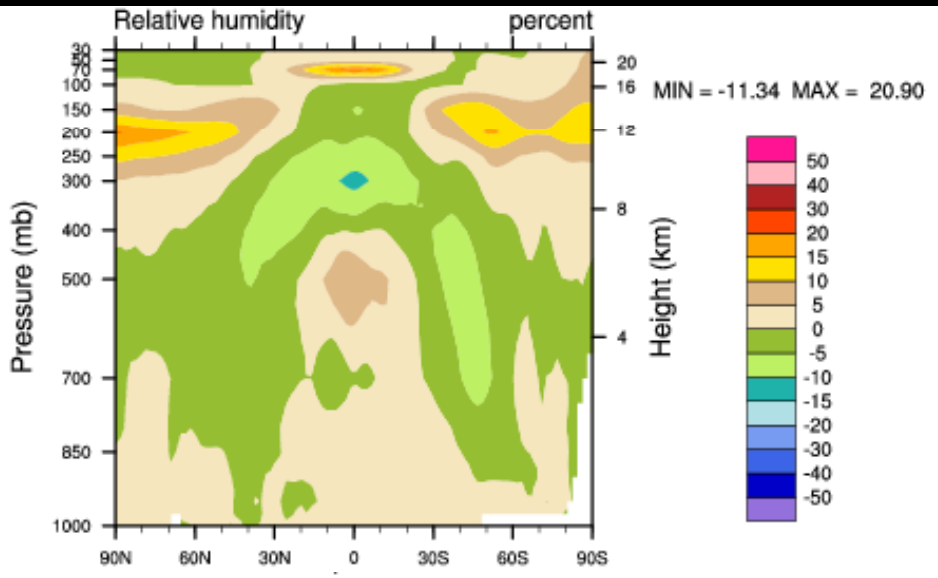
  +2K v. -2K SST changes

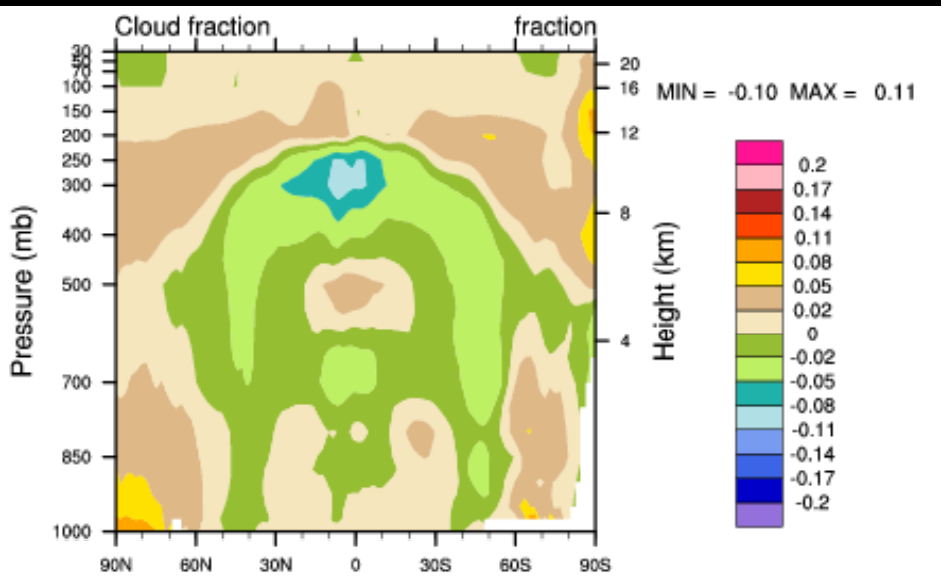
Vertical Structure: Cess Exp

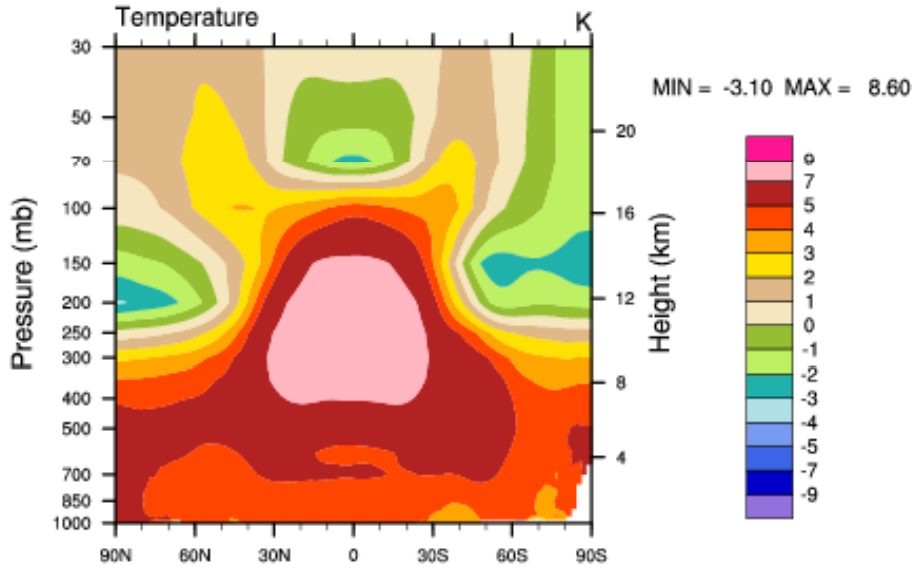
- +2K v. -2K SSTs (Cess Experiments)
- Similar vertical structure with imposed climate change



Vertical Structure: Cess Exp







What is happening?
- clouds coupled to RH
-dT > dH_2O @ 300hPa
- or, maximum 700-500hPa

Cause?

- See H_2O signal in AIRS & CAM
  - Monthly perturbations & Cess experiments
- RH increases are not monotonic
- What processes are responsible?
  - Convection?
  - H_2O sources? Detrainment?
  - Shallow cumulus?
  - Larger change because it is drier in mid-troposphere?
- I do not know the answer!

Questions

- Other than moist convective adjustment, is there any theory we can draw on to constrain water vapor feedbacks?
- Is any theory necessary?
  - Is ‘slightly less than constant RH’ good enough?
- Where is the ‘sufficient condition’?

- Relation to cloud feedbacks?
  - Humidity sources through detrainment?

Questions (2)

- Are these reasonable analogs for climate change?
- How will tropical circulations respond?
- Do we know the H_2O feedback ‘well enough’?
- How does water vapor interact with cloud feedbacks?

Observations(1): Quantification

How to improve quantification/attribution?

- Do we have enough spectral resolution?
- CLARREO and diurnal cycles?
  - overall radiative constraints: TOA balance, cloud forcing, etc
  - we are still lacking some basic absolutes!
- Better vertical resolution for T & H_2O
  - Key for vertical structure
- Better precision on H_2O

Observations(2): ‘Climate’ Records

How to improve long term records?

- What can we learn from previous efforts?
  - MSU (T), HIRS (H_2O)?
- Continuity of AIRS/IASI through CrIS
  - Very Good start: worried about NPOESS CrIS
  - Cloud observations? Diurnal cycle?
- Who handles climate in the US?
  - Satellites: NASA, NOAA
  - Other: DOE, NSF

Cloud Effect

- Clouds modify the water vapor feedback (seen above)
- Also: Soden et al 2008: Radiative Kernels

H2O “Radiative Kernels”

All Sky

Clear