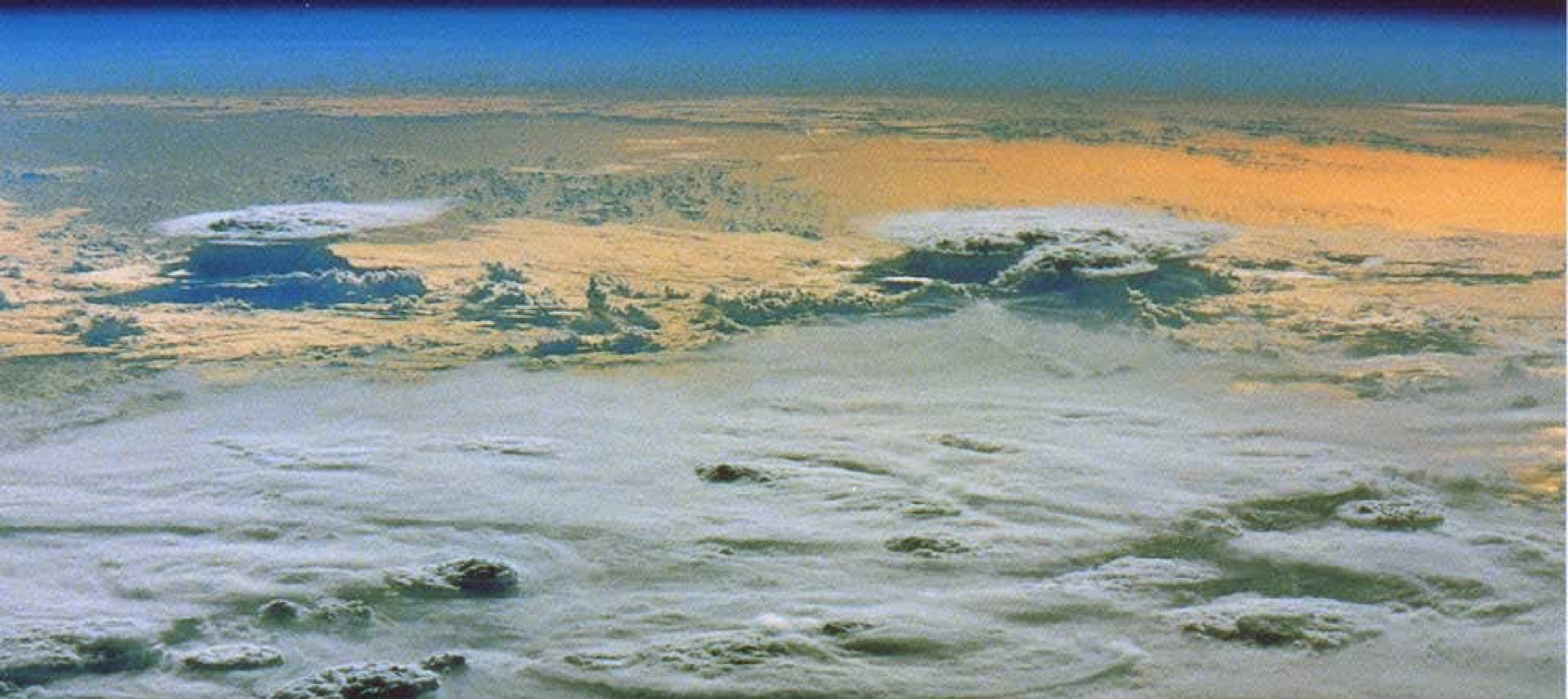
Observational Needs for Testing Global Model Parameterizations



Andrew Gettelman, NCAR

Thanks to: J. Kiehl, W. Collins, P. Rasch

Motivation

- Get the ‘Right answer’ for the ‘Right reasons’
- Climate variability (all scales)
- Climate Changes
- Understanding Key Processes
- Representing Feedbacks (processes interacting)

My Biases:

- Global models & big (climate) picture
- Upper/Free Troposphere critical

Outline

- Examples from NCAR CAM3
- Key Processes & Parameterizations
- Testing with observations
- Confidence in observations
- Future Requirements

Key Global Model Processes

- NCAR/CAM Architecture
  - ‘State of the Art’ General Circulation Model
  - Can be coupled (Ocean, Land, Sea Ice)
  - Deep ocean to lower thermosphere
  - Chemistry, Aerosols, Biogeochemistry, etc
- Focus on Condensation/Microphysics
  - Hydrologic Cycle
  - Climate Feedbacks (UTH, Clouds)
  - Aerosol radiative effects and Clouds
- Measurement issues cut across processes

CAM3 microphysics

- Bulk condensation scheme conserves H_2O
- Condense, Advect, Evaporate, Sediment
- Cloud/Condensate Particle Size = f(T)
- Cloud Fraction = f(RH) [Sundquist, Slingo]
- Clouds not affected by aerosol scheme (yet)
- Radiation is dependent on clouds (overlap)

Key Science Questions to Test

- What are key biases in the model?
  - Tropopause, Double ITCZ
- How does UTH vary and change?
  - H_2O feedbacks
- How do we handle supersaturation (ice)?
- Aerosol impacts on cloud particles
  - Aerosol indirect effects?
- How do process interactions affect model biases?

Observational Requirements

- Need validated data: either in-situ or remote
  - Need to know error characteristics
- Process studies
  - Detailed in-situ data, off line testing
  - Column models, box models & trajectories
  - Multiple scale models (cloud resolving, mesoscale)
- Derived quantities and effects
  - Remotely sensed (cloud particles, radiation)
  - Mean & Variability (many scales)

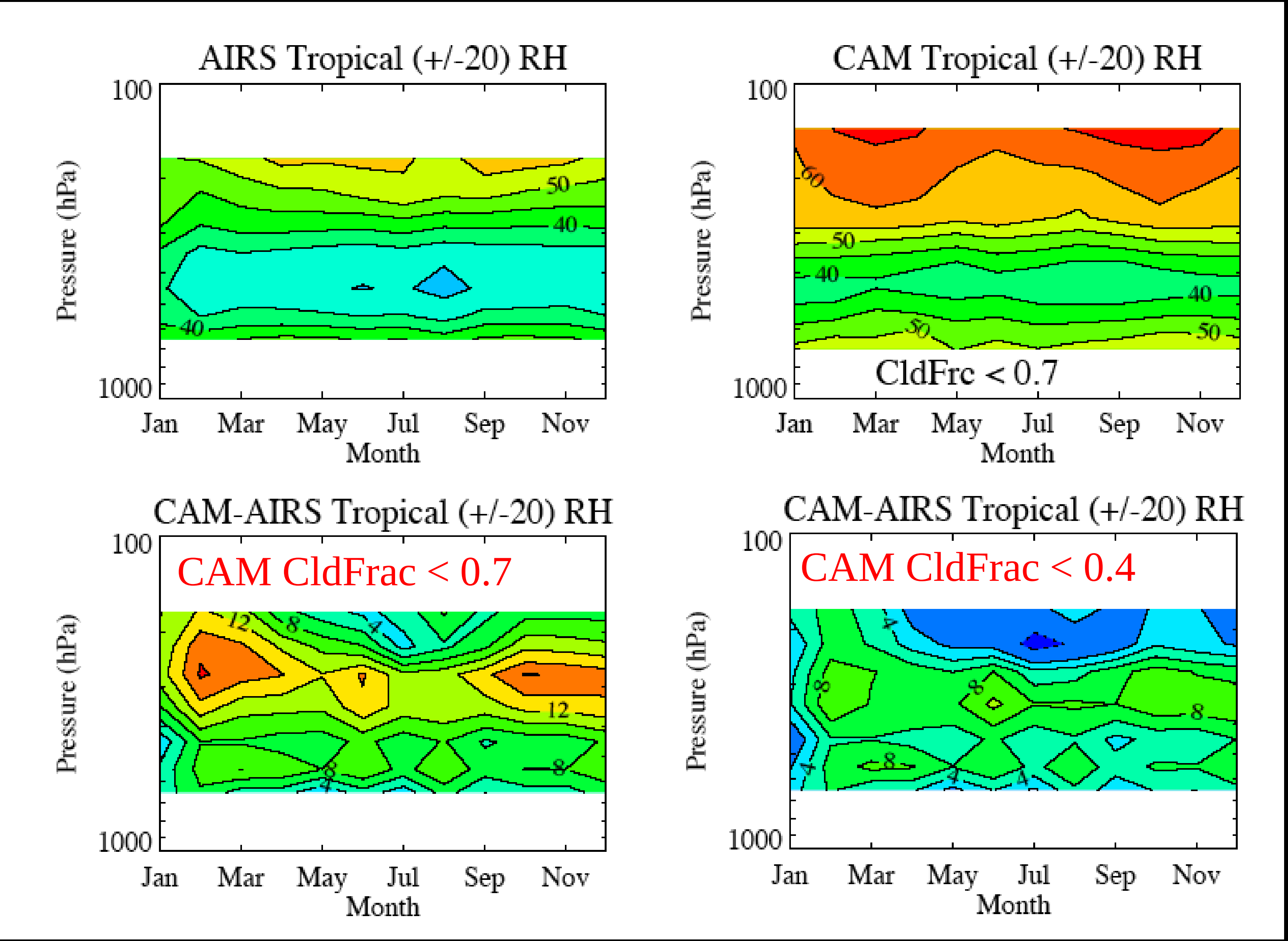
How do we test Parameterizations?

1. Climatology (mean)
2. Monthly, Seasonal, Interannual Variability
3. High Frequency Variability
4. Data Assimilation

Focus: RH, Cloud particle sizes, Transport

Also: Chemistry, Radiation

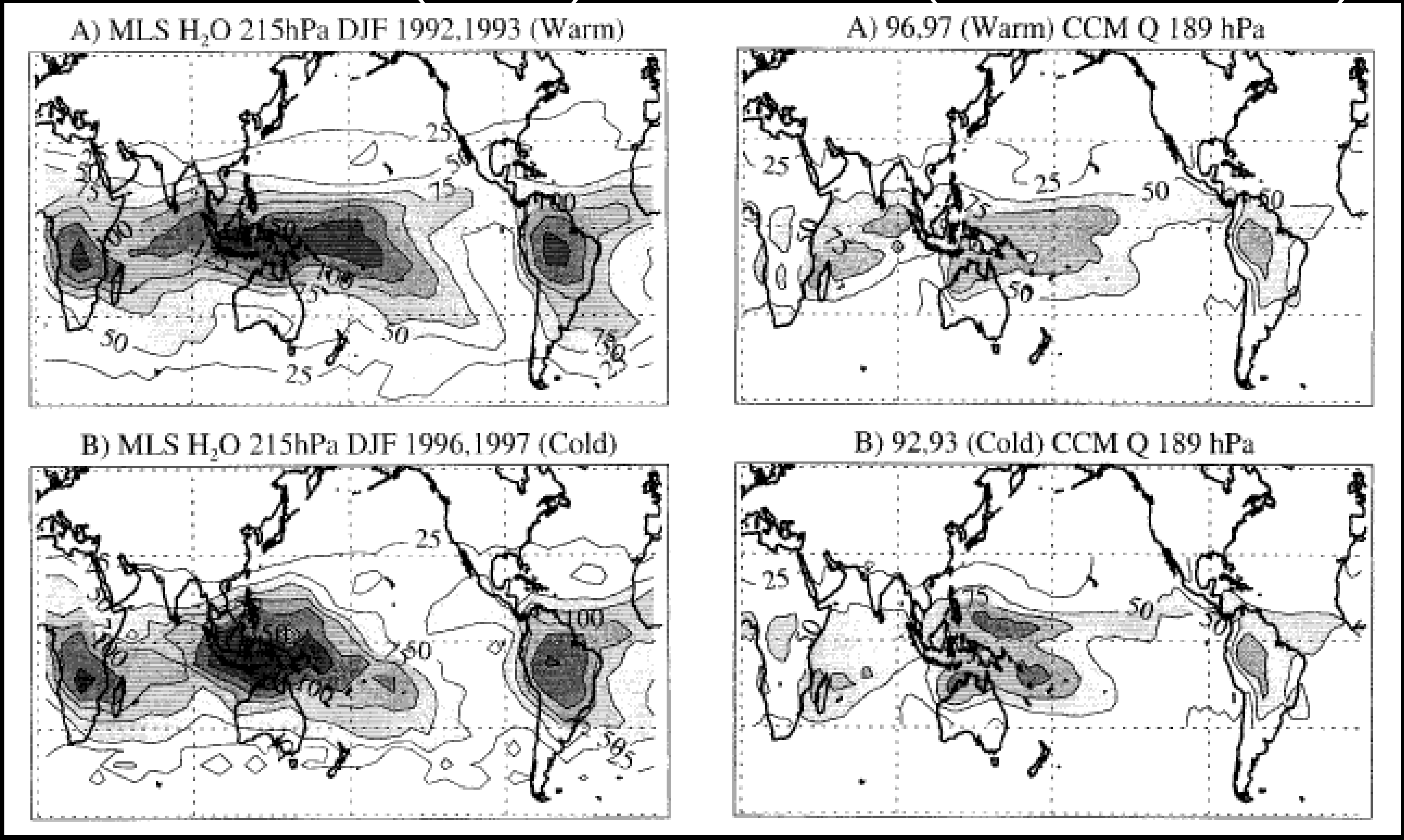
The Mean: AIRS v. CAM3 RH



Variability: ENSO

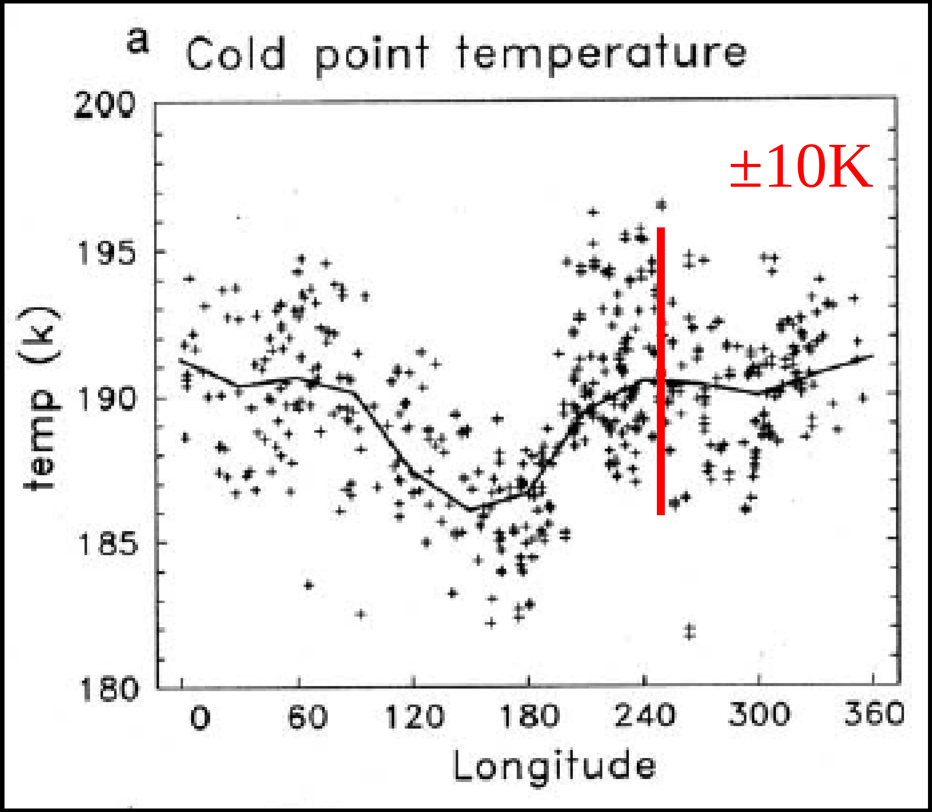
DJF H_2O (Q)

Observations (MLS) Model (observed SSTs)



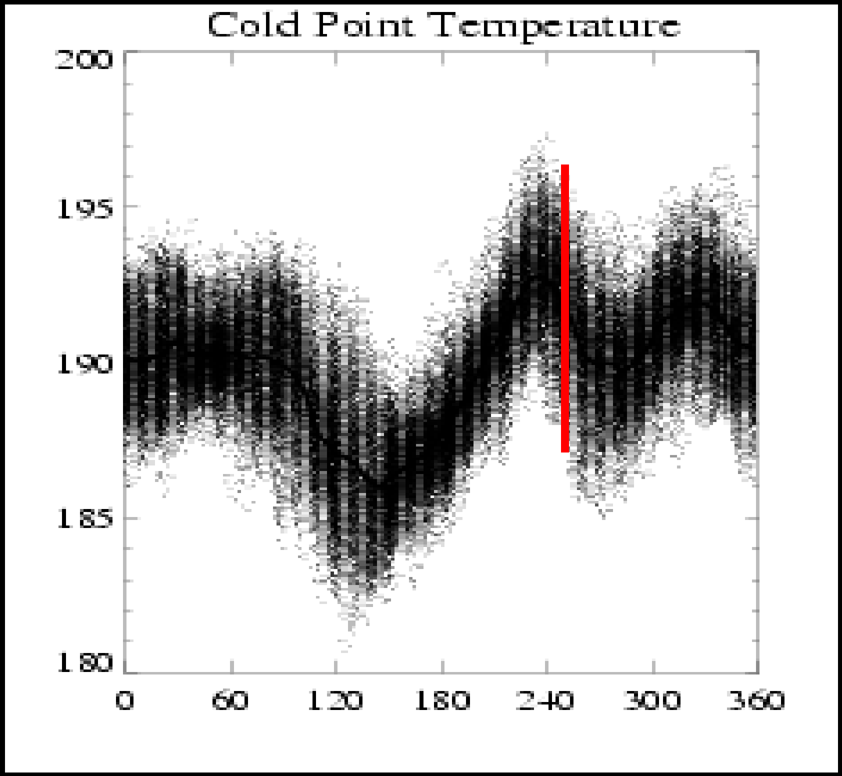
High Frequency: The Tropopause

Can we reproduce all scales of variability?



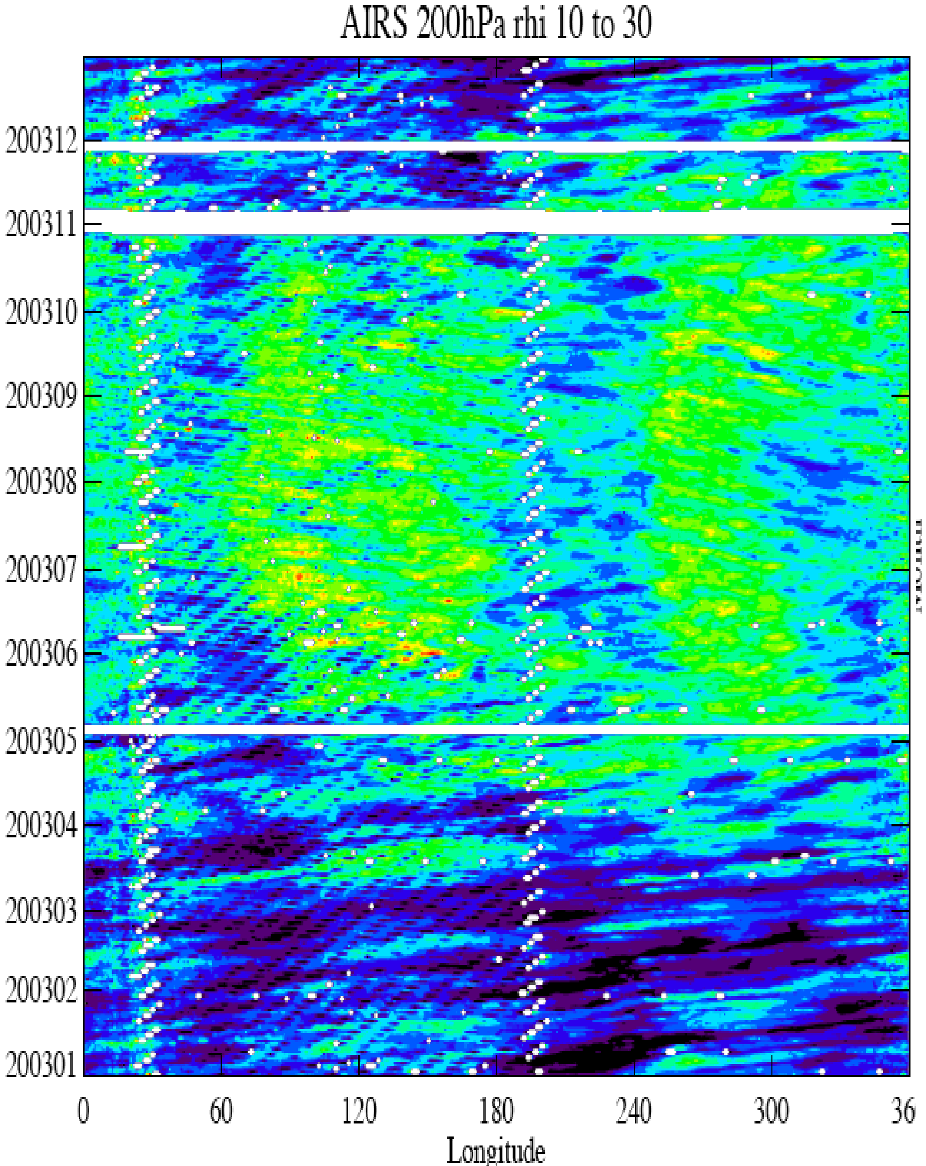
GPS Data: DJF 1996-7

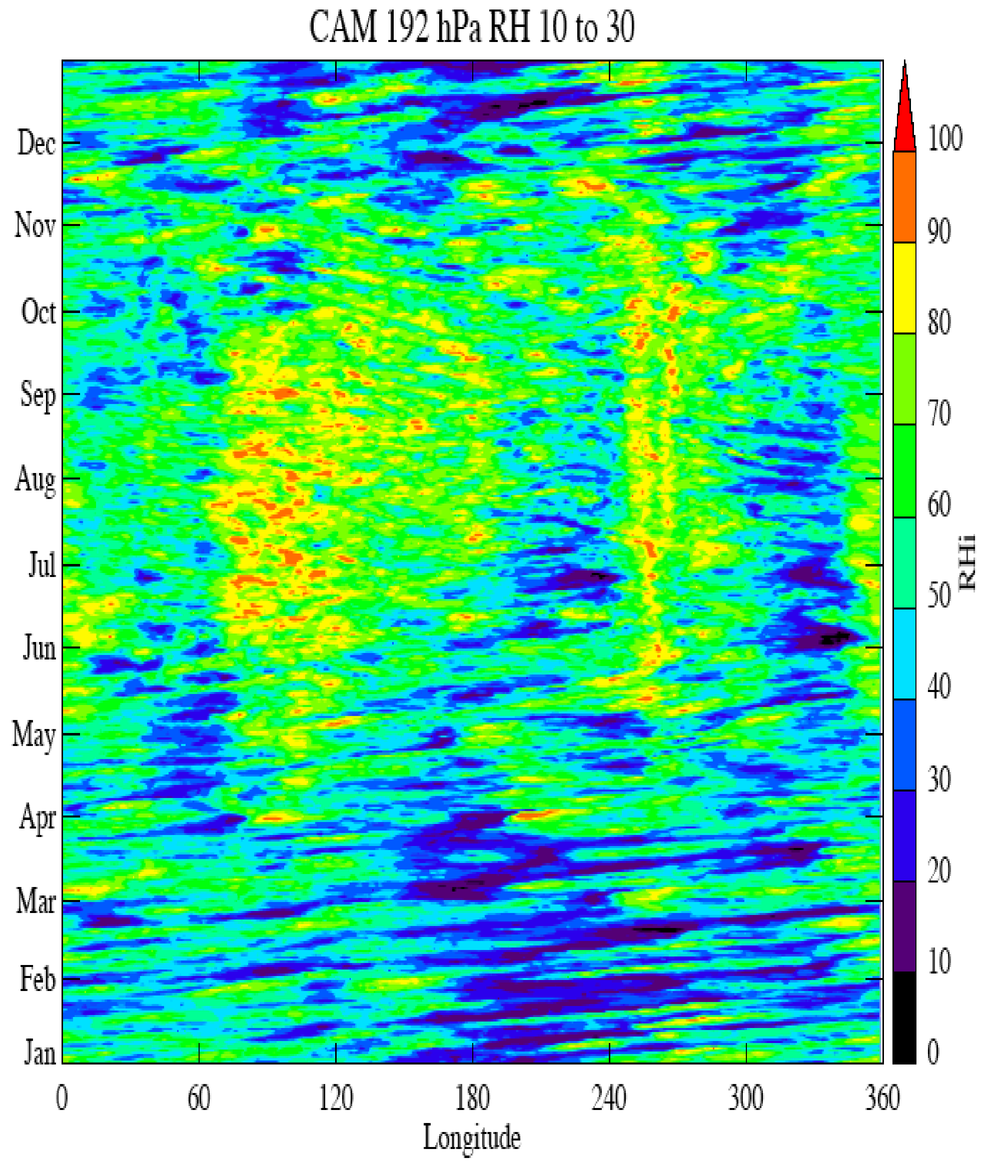
(Randel et al 2003, Fig 4)



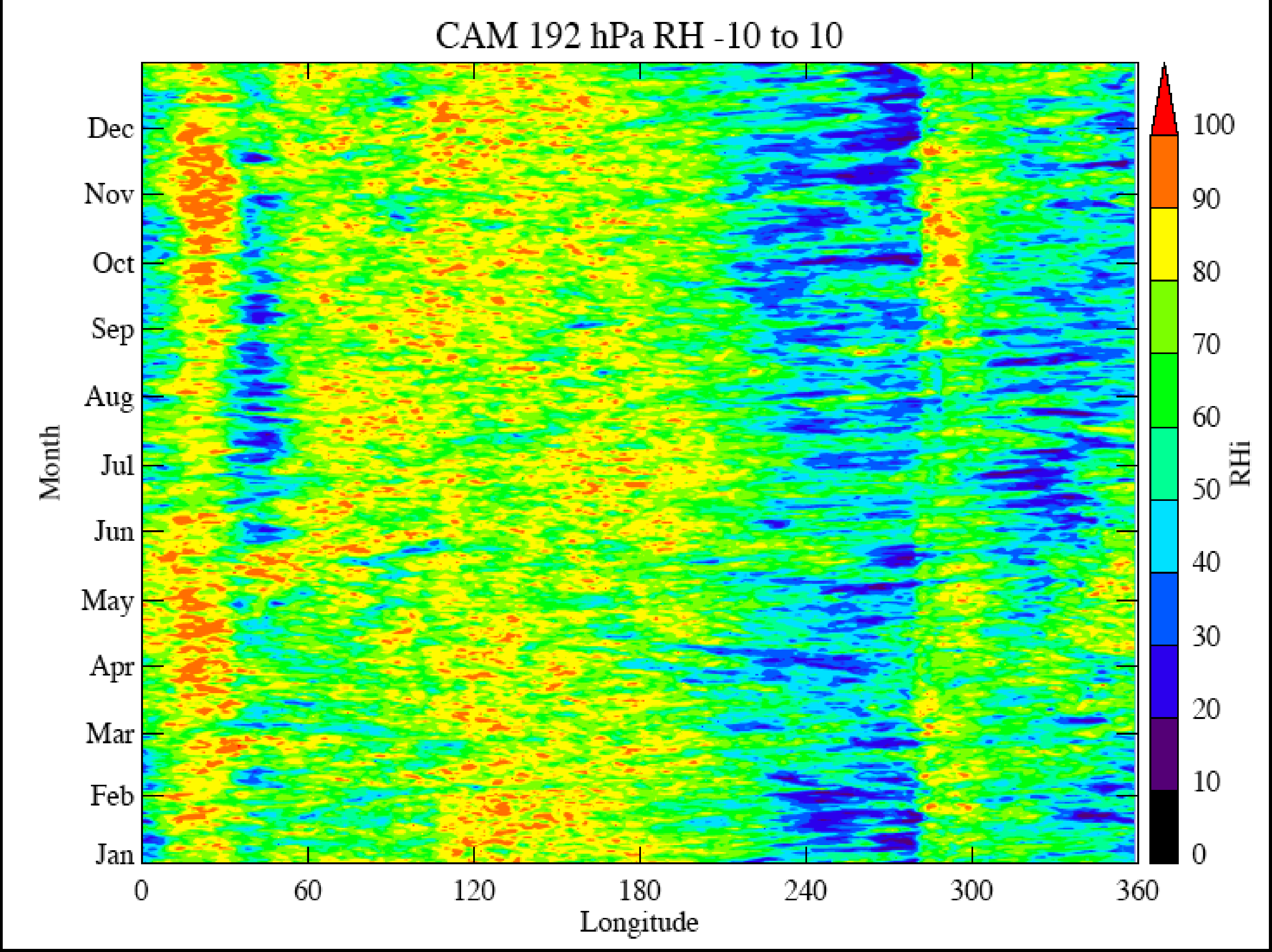
WACCM2: Jan-Feb

Daily Subtropical 200hPa RH



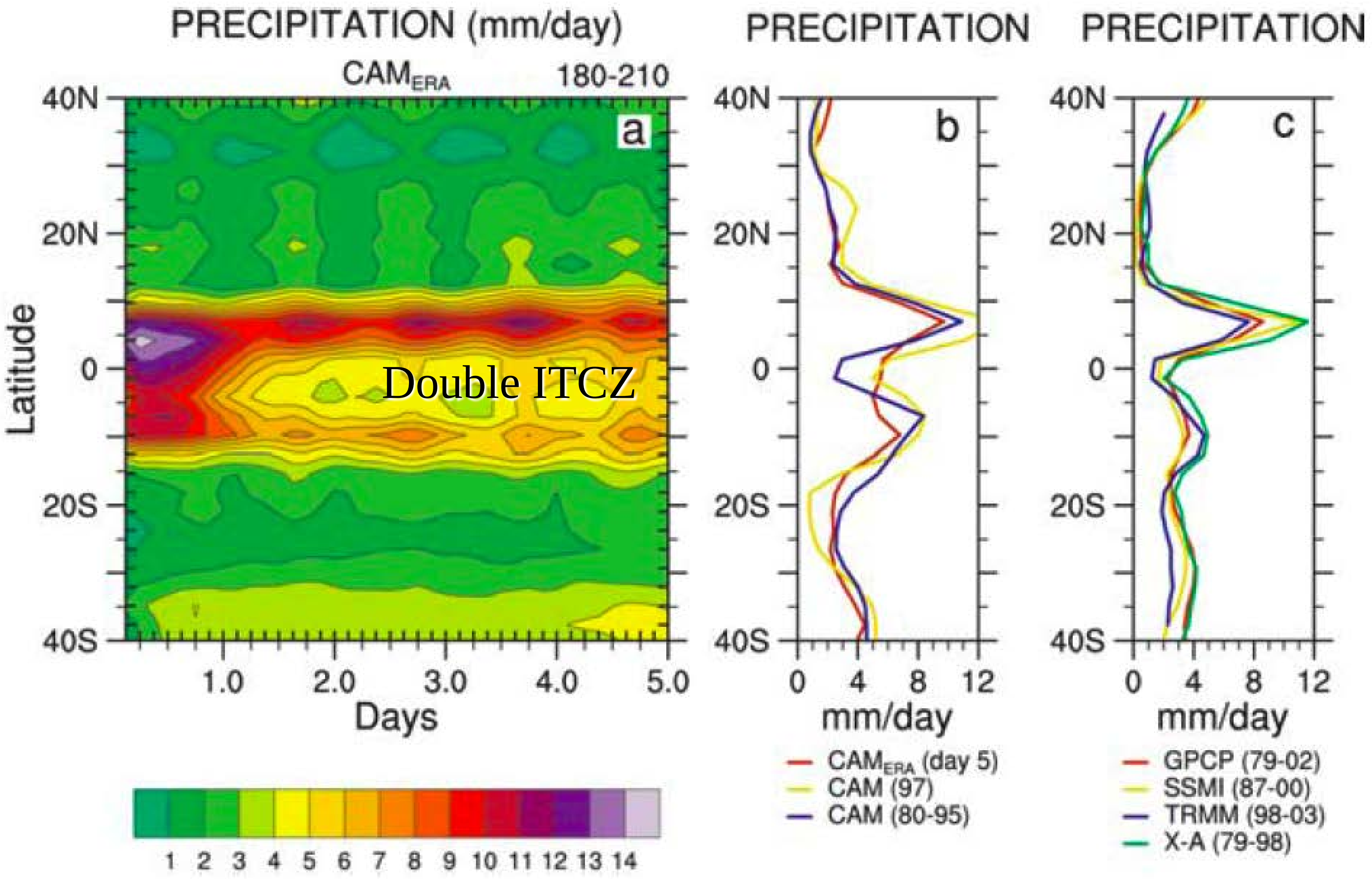


CAM Tropical 192hPa RH



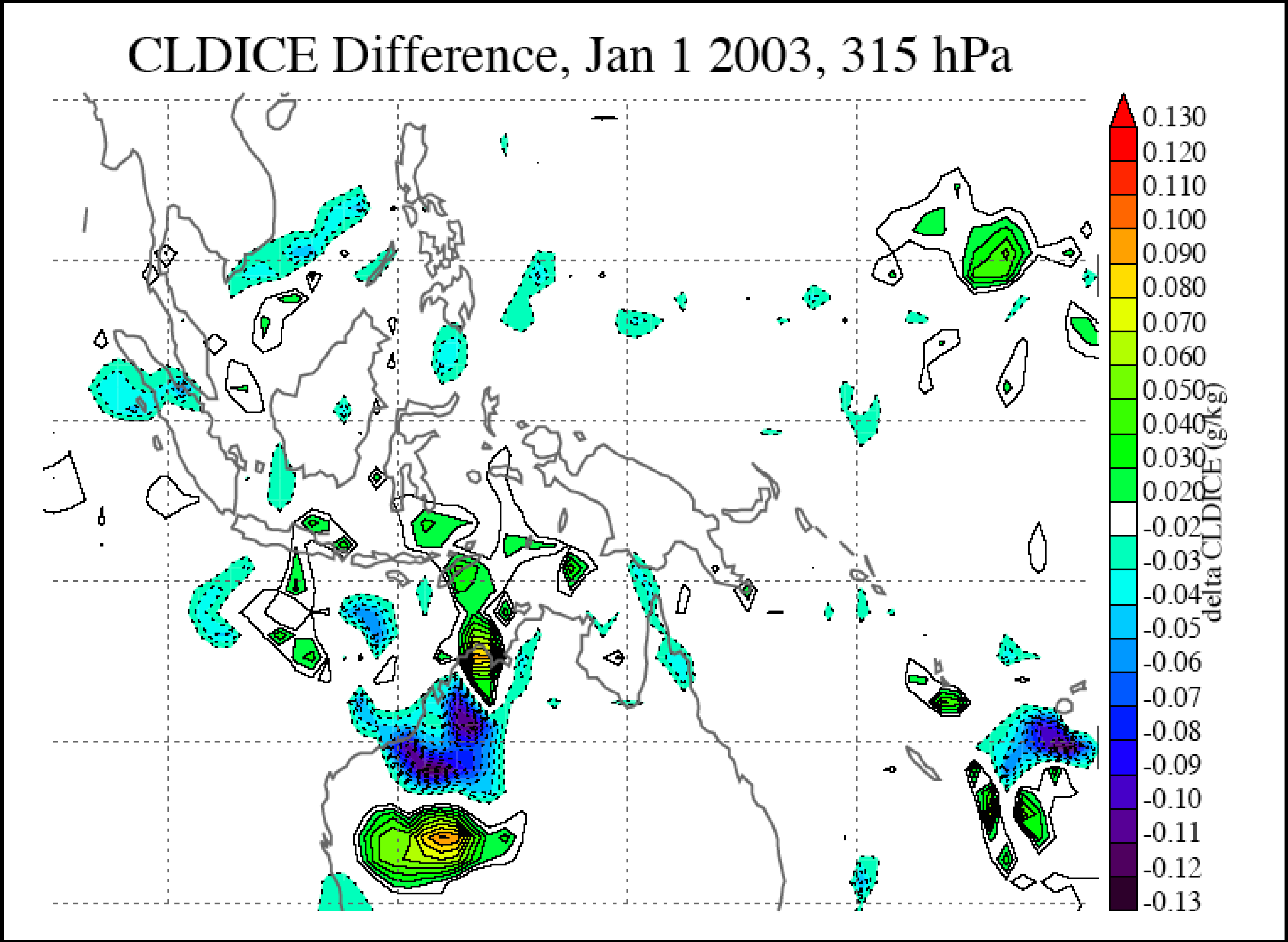
Forecasting to Evaluate Models

Phillips et al, BAMS, 2004



Data Assimilation

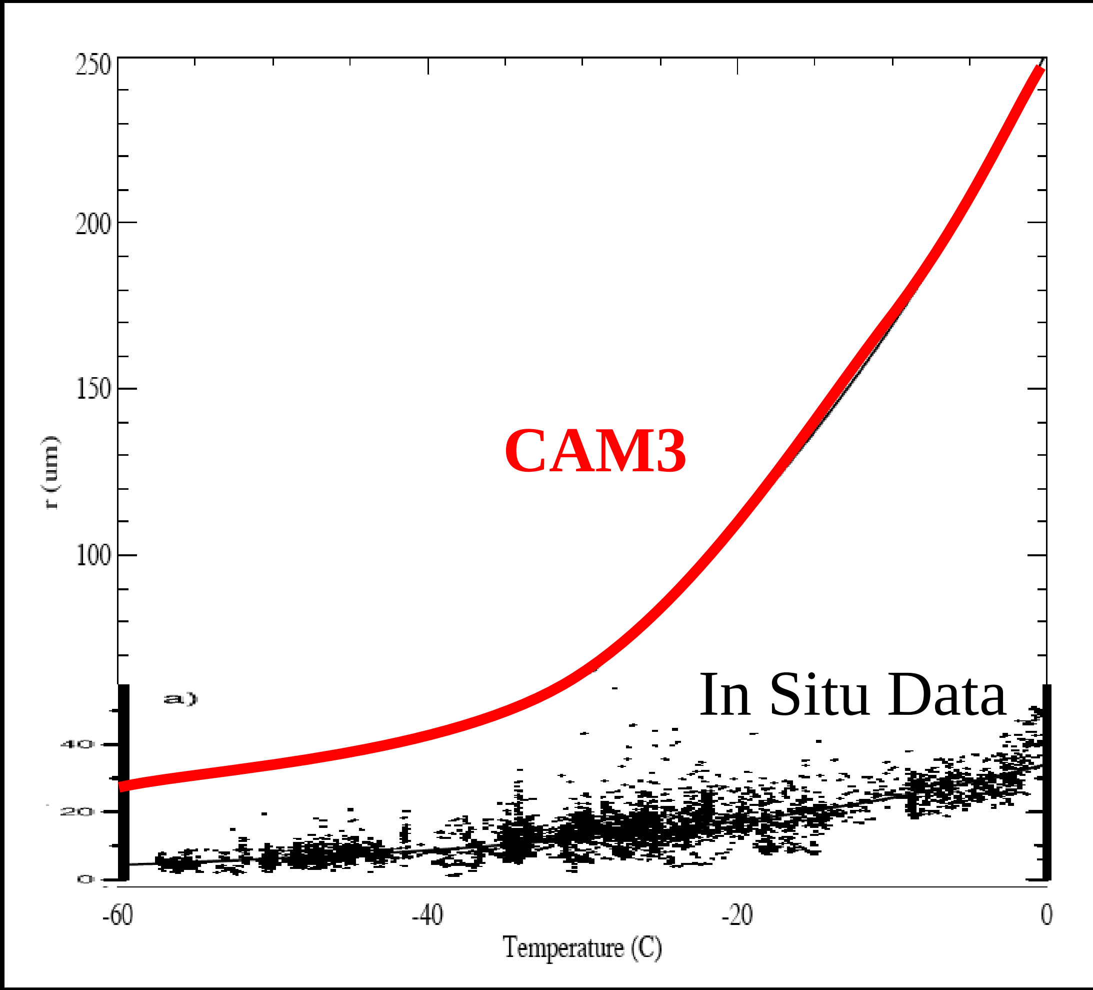
Assimilation - Forecast after 6 hours



Where assimilation affects model: compare to cloud obs

Derived Quantities: Particle Size

Variation of Effective Radius (r_e) v. Temperature

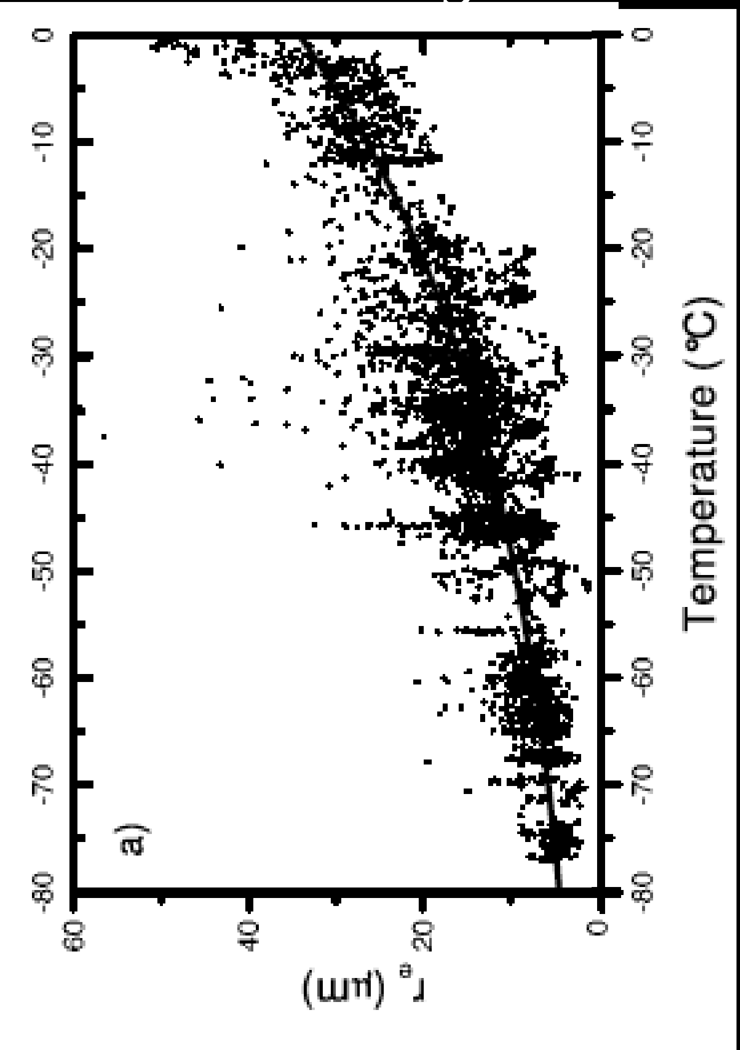


Data: Garrett 2003, GRL, Figure 1

Derived Quantities: Particle Size (2)

Variation of Effective Radius (r_e) v. Temperature

MODIS gets basic shape, but strong peak @~30um



<-- Garrett 2003, GRL, Figure 1

MODIS (L2 subset), Jan 30, 2004

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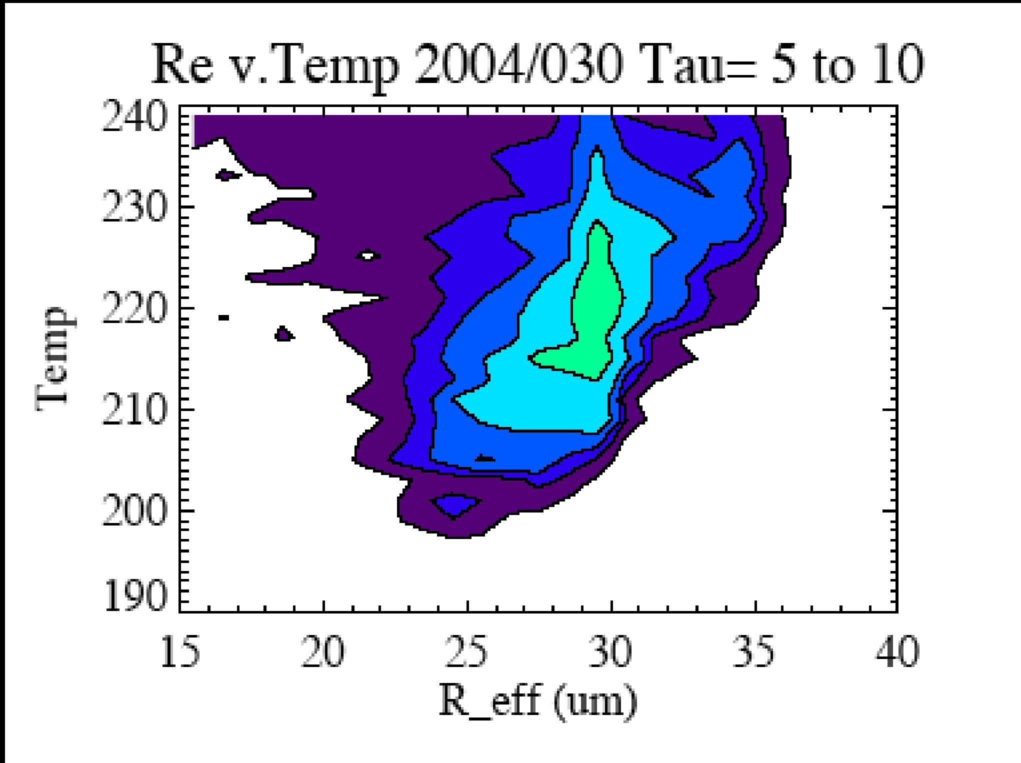
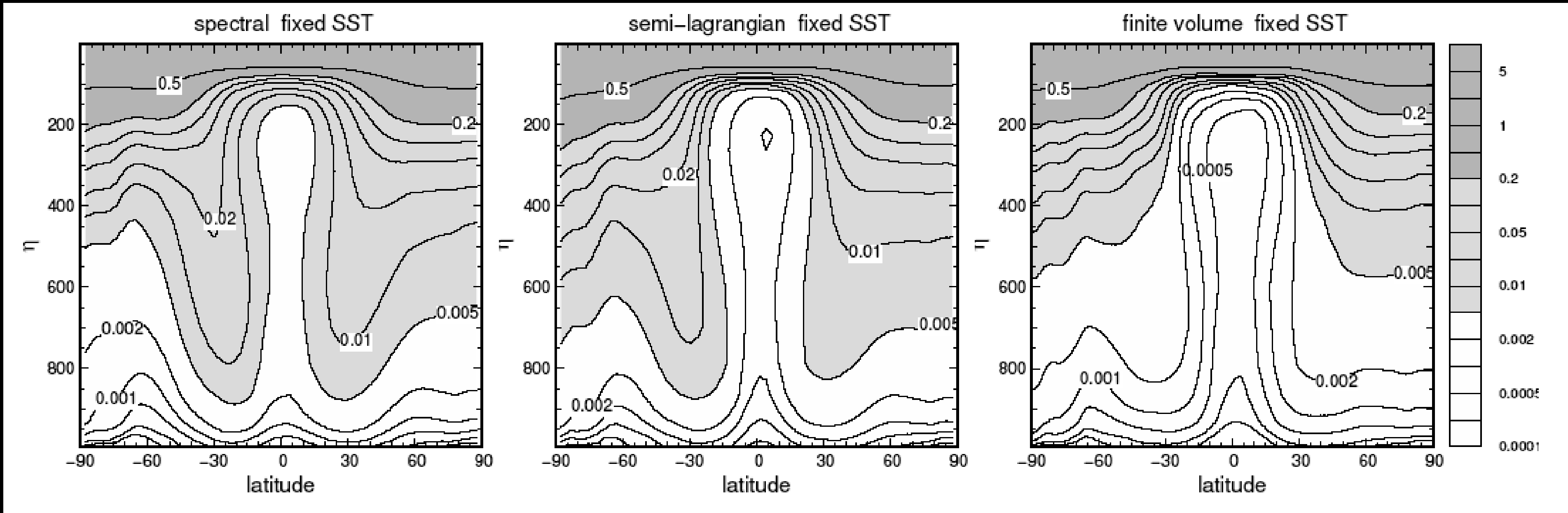


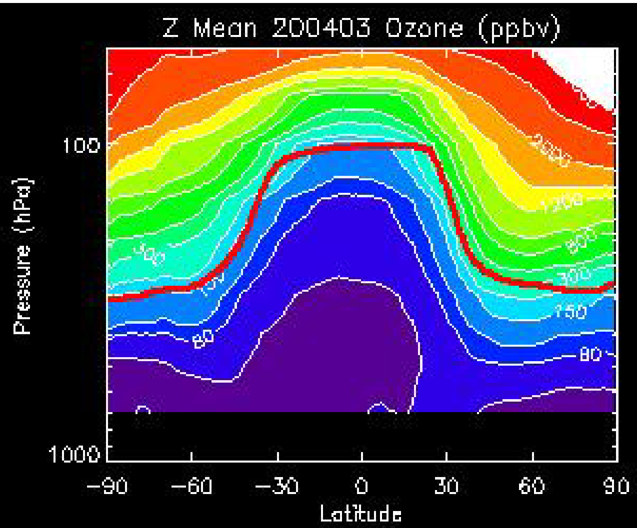
Transport & Chemistry

3 Transport Schemes for ‘Ozone’ in CAM3



Rasch et al, in Prep

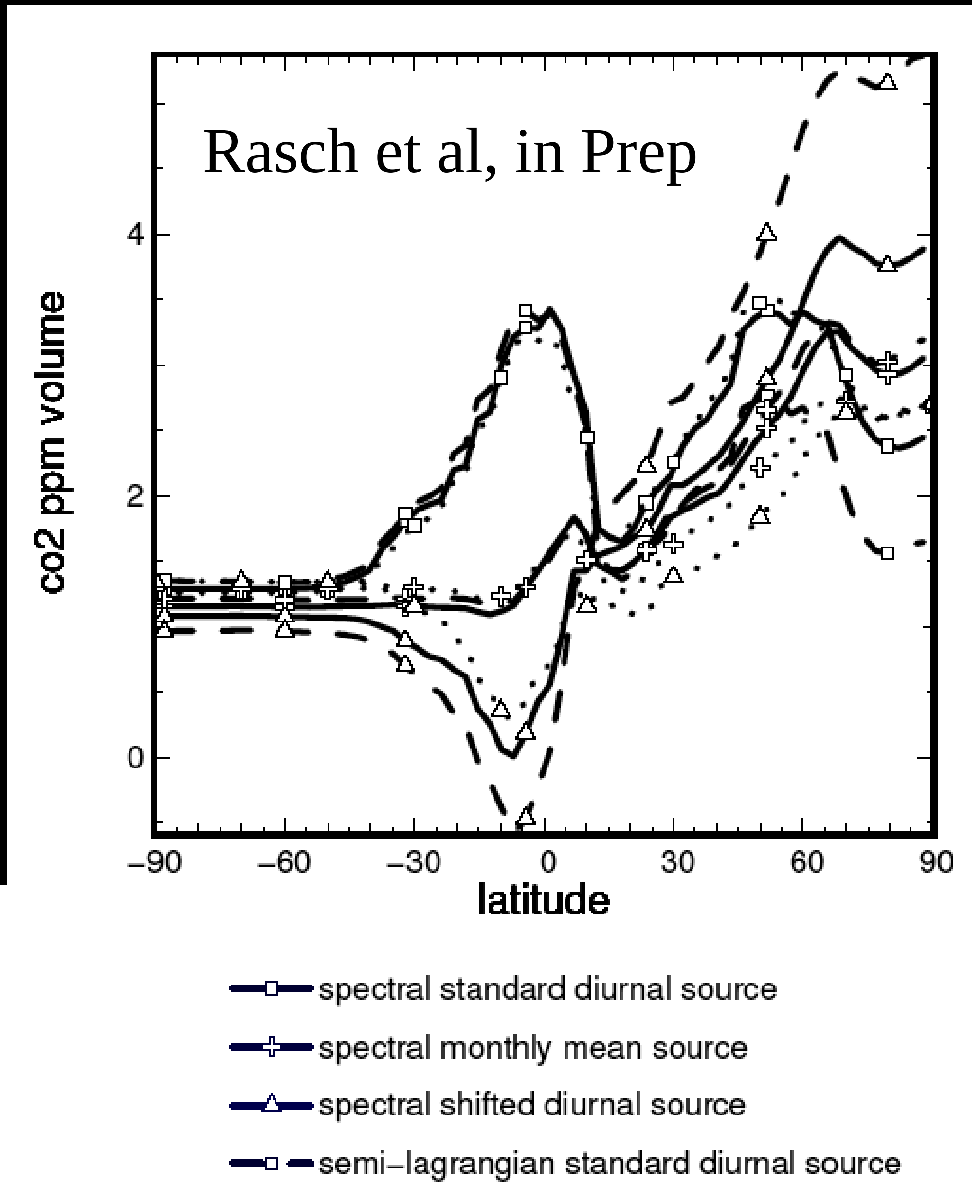
AIRS O_3
(March 2004)



Climate & Transport

Biogenic CO_2 transport:

1 model, 3 transport schemes & diurnal cycle spans range of variability from TransCom intercomparison

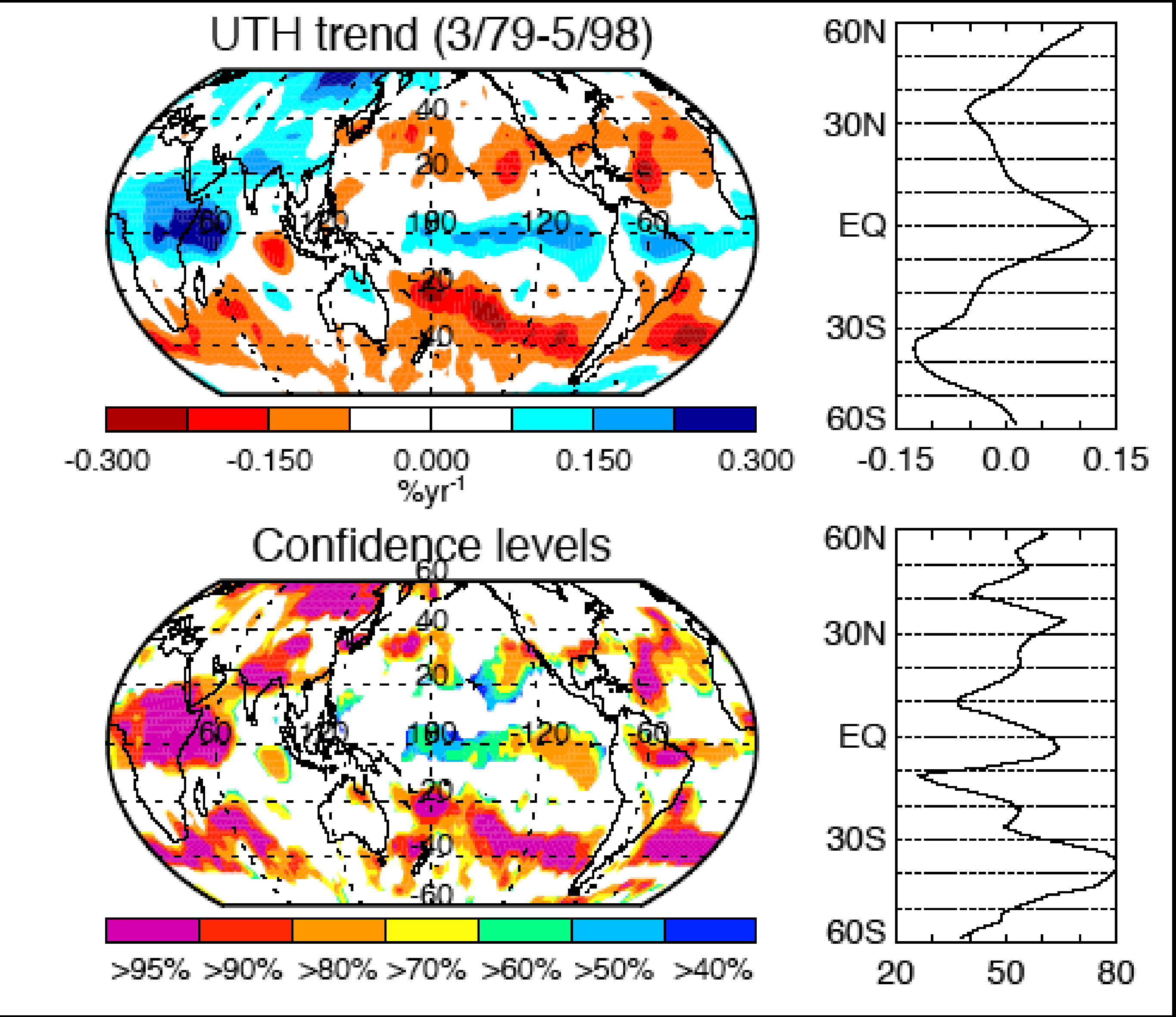


Specifics (1): T & H_2O

- H_2O ± 20% single precision, <5% average
  - This is : 1-10ppmv in UT/LS
  - Daily necessary, probably will need 2-4 x daily soon
- T ± 0.25K UT/LS, 0.5K elsewhere
  - 2x Daily, probably 4x daily (forecasts), more (GW)
- RH ± 5% (sampling as for H_2O)
  - This means: 5-10ppmv H_2O UT, 0.5 ppmv LS,
  - T ± 0.25K at tropopause, 0.5K UT
- Long term (decadal +) changes:
  - RH< 2% H_2O <5% T<0.2K

Long Term UTH trends

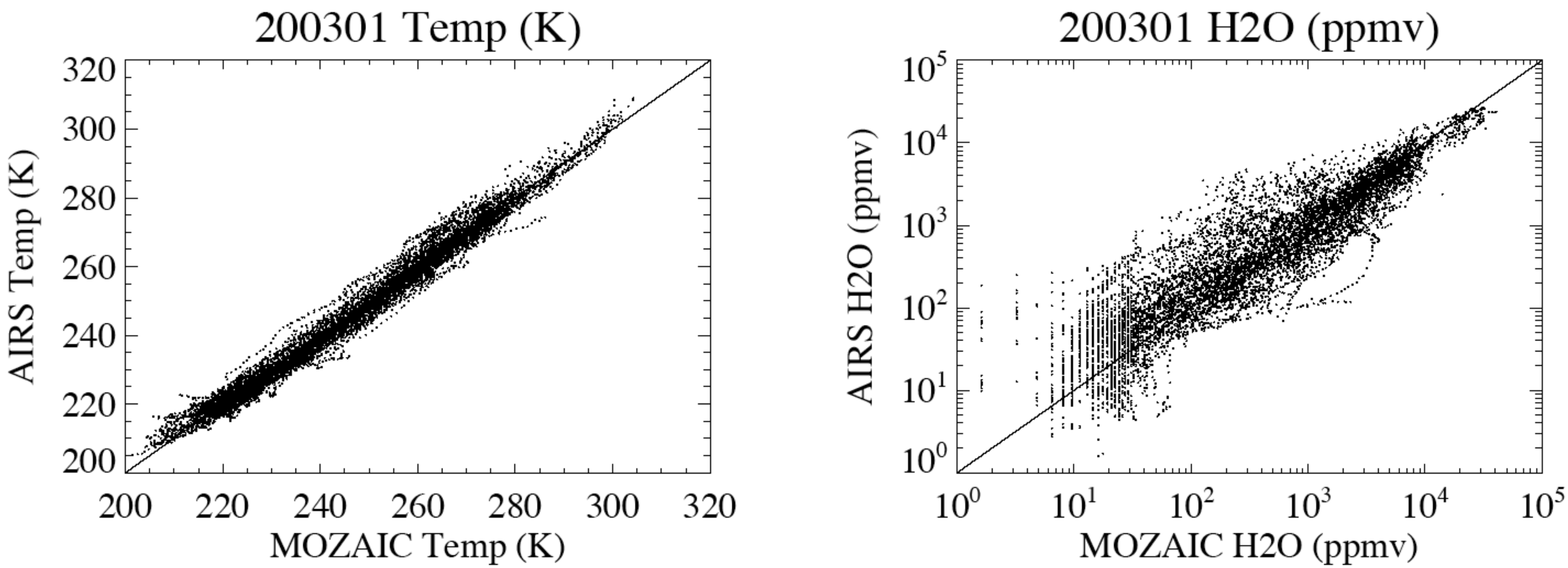
HIRS/TOVS trends



Bates & Jackson 2001, GRL

T & Q: Possible from Space

AIRS v. MOZAIC (in situ Aircraft) T & H_2O



Need more validation!

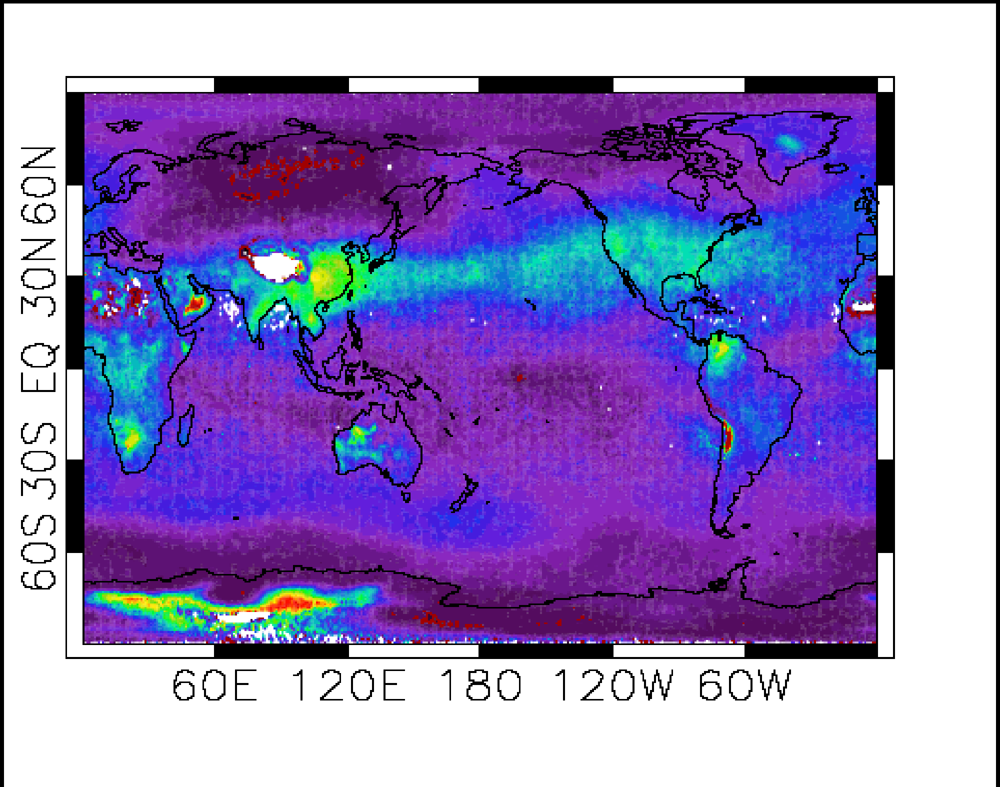
Specifics (2): Clouds, Rad, Chem

- Cloud Optical Properties, LWP/IWC: settle for the right variations, ±50%. Sub-daily sampling
  - Assimilation will be key
- Radiation: Spectrally resolved (aerosol extinction) & broadband
  - H2O continuum at low T & P important for climate
- Key Chemical Constituents: H_2O, O_3, CO, NOx
  - 10%, daily, global. Diurnal cycles eventually
  - This is possible to do from space!

Upper Air Chemistry from Space

700mb March 2003 O_3

O_3 (AIRS)



Need the right sensors, retrievals, validation

Where we are going

- Atmospheric Models are more demanding now
  - Increased complexity
- Asking tougher questions
  - aerosols, particle sizes, feedbacks, chemistry
- Techniques more advanced
  - Assimilation => need for error analysis
  - BETTER validation critical for testing models
- Questions will get tougher
  - hourly resolution for global process studies
  - More derived and interlinked quantities

Recommendations

- Validation of Climate Products critical
  - Need uncertainties (for Data Assimilation)
  - Don’t cut calibration (especially radiation)
  - Need in-situ validation (balloons, aircraft)
- Need a ground based Reference Network
  - Clouds, Wind (remote), T, H_2O, O_3
- NPOESS is losing its climate mission
  - Almost there with EOS clouds, chemistry
  - NPOESS may be repeating past mistakes