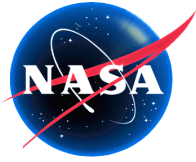# JPL Activities
Task 1: Sounder Science Status
Task 2.3: Boundary Layer Science

**Eric Fetzer, Joao Teixeira, Thomas Pagano
and Kevin Bowman**
**Jet Propulsion Laboratory/California Institute of
Technology**

**CLARREO Workshop
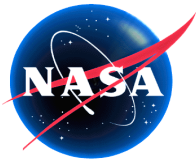Newport News, Virginia
May 1, 2008**

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Some Quotes

- "It's easy to find problems with climate models."
  - Anonymous Modeler

- "Models summarize our understanding of physical processes."
 - Phil Rasch

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Some soapbox thinking...

- *Process scales* are important. Why?

  1. Climate change over the coming decades will be at process scales.

  2. Climate models represent processes (see previous quotes).

- The largest uncertainties in climate prediction are cloud feedbacks (especially low clouds).

  – Cloud scales are much smaller than 100 km.

 – I'll use this as an example; similar arguments may hold for other feedbacks.
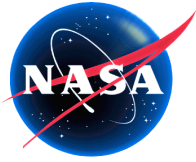
Eric.J.Fetzer@jpl.nasa.gov

Climate Science Using Sounder Observations

- Measurements proposed for CLARREO in Decadal Survey are similar to those of IR sounders.

- What questions are the sounders addressing today?

- What key questions remain for the hyperspectral infrared?

- The future.

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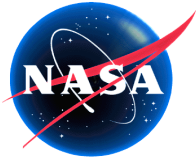
What issues are AIRS & TES addressing today?
(publication 1st authors)

- ## Climate processes and model validation
  - ## Water vapor, temperature:
    - **Hurricanes, deep convection** (Atlas, Wu, Wong, Holloway)
    - **Lower & upper trop hydration** (Worden, Dessler, Ray)
    - **Superstaturation** (Gettelman)
    - **IPPC models** (Pierce)
    - **Polar water cycle** (Ye, Gettelman)
    - **Climate feedbacks** (Su, Dessler)
  - ## Clouds
    - **Trends** (Sund)
    - **Microphysics** (Kahn, Nasiri)
   - **Inter-instrument consistency** (Kahn)

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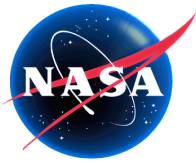
More issues AIRS & TES are addressing today

- Minor gases
  - **Ozone** (Bowman, Barnet)
  - **CO** (Osterman, McMillan)
  - **Methane** (Barnet)
  - **CO_2** (McNally, Morel, Chahine, Strow)
- Air-surface interaction
  - **Boundary layer over ocean** (Fetzer)
  - **Boundary layer over land** (Santanello)
- Radiative Balance
  - **IPCC models** (Huang)
  - **Water vapor radiative cooling** (Feldman)
  - **Cloud and aerosol longwave forcing** (Huang, de Souza)

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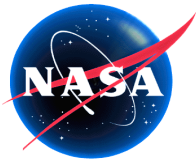
Hyperspectral Sounder Retrievals and Spectra for Climate Model Validation

- **Method 1: Data Products (L3)**
  - The models are drier than AIRS observations by 10%-25% in the tropics below 800 hPa.
 - The models are more moist by 25%-100% between 300 and 600 hPa, especially in the extra-tropics.

    David W. Pierce, Tim P. Barnett, Eric J. Fetzer, Peter J. Gleckler, Three-dimensional tropospheric water vapor in coupled climate models compared with observations from the AIRS satellite system, GRL, VOL. 33, L21701, doi:10.1029/2006GL027060, 2006
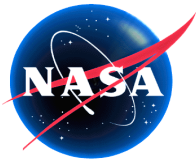
- **Method 2. Radiances (L1b)**
  - OLR Agrees with Models
  - Compensating Errors
  - Models dry in lower troposphere compensated by higher surface flux

    Huang et al. 2007.

Mean Model – AIRS

CCSM – obs, percent
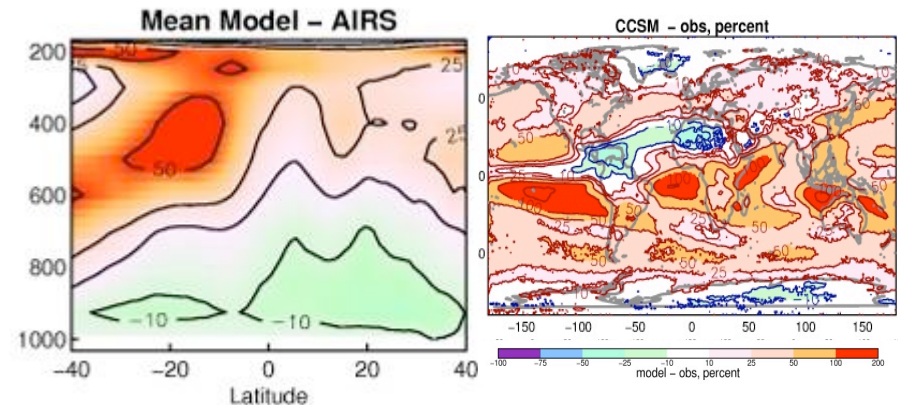
Unit: W m^{-2}	OLR		Window band	
	Total sky	Clear sky	Total sky	Clear sky
CERES	241.73	275.87	66.94	83.28
AM2	240.63	263.43	73.99	87.56
AM2-CERES	-1.10	-12.44	7.05	4.28
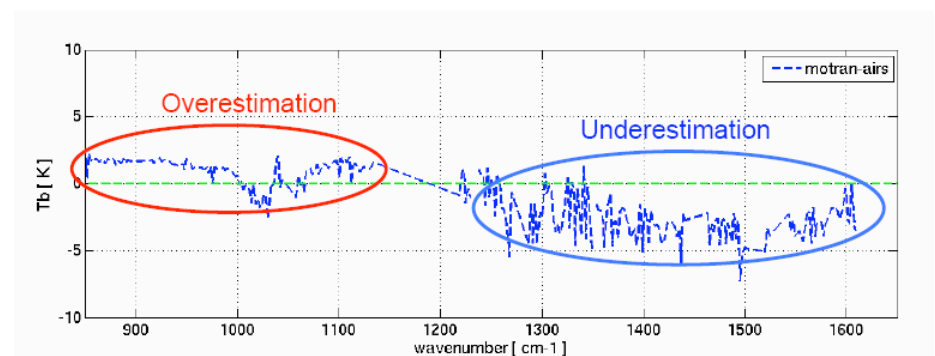
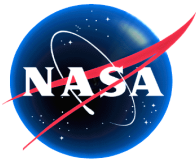Overestimation

Underestimation

IPCC model mean water vapor is biased
Similarly temperature (not shown).

Mean Climatologies of AIRS and 17 IPCC Models.
From Pierce et al. 2006, GRL
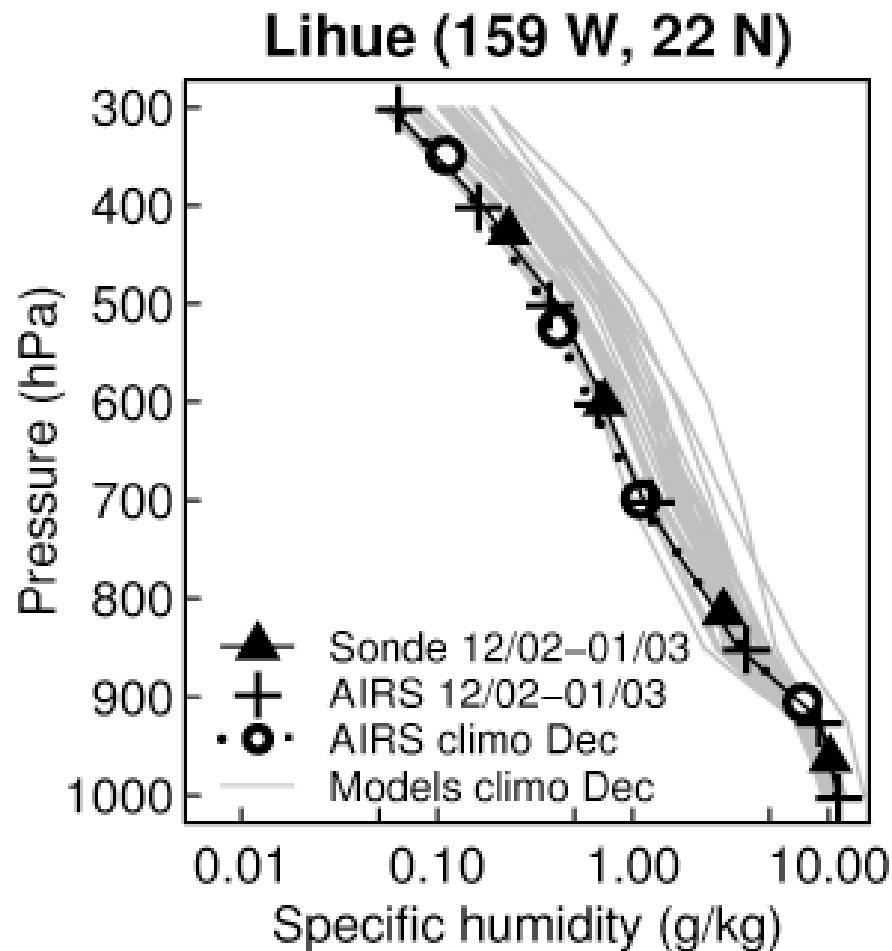
Lihue (159 W, 22 N)
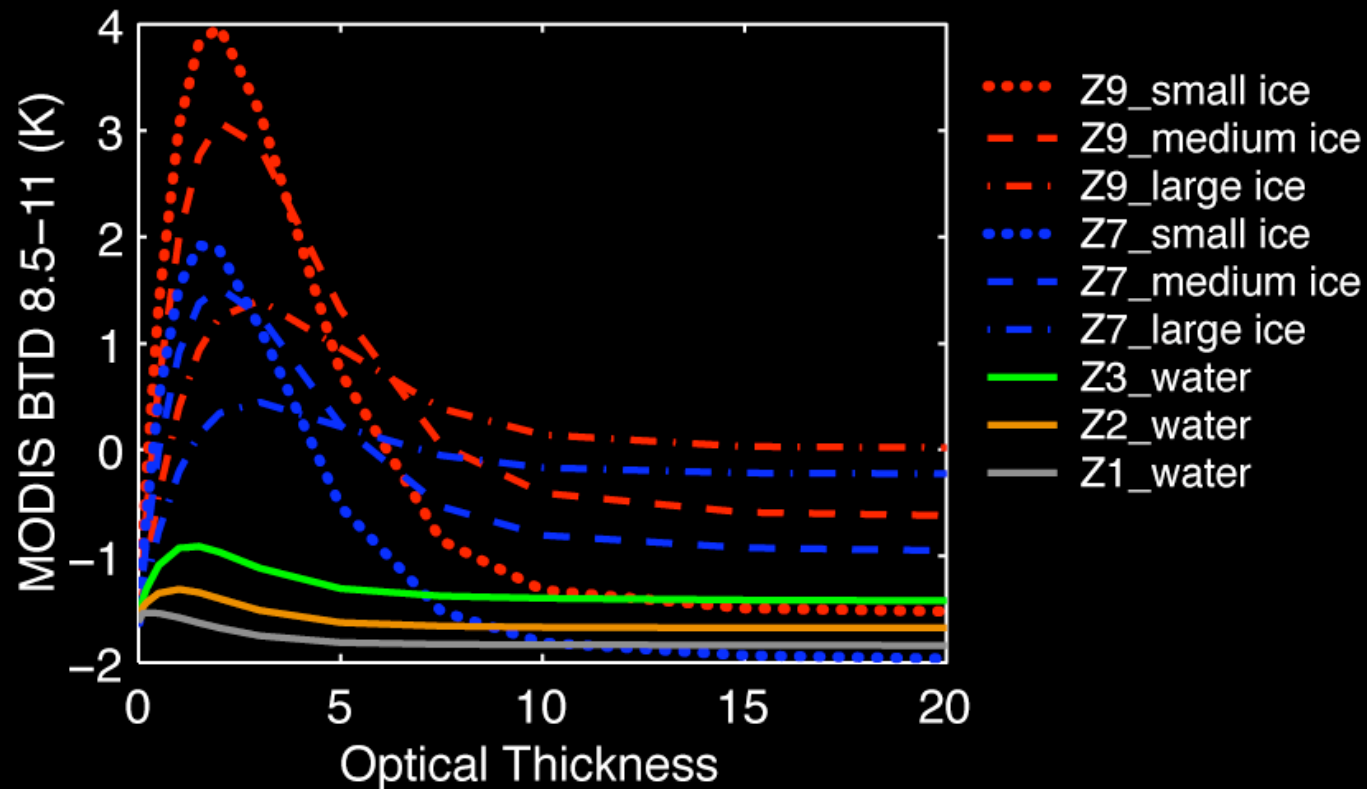
Sonde 12/02–01/03
AIRS 12/02–01/03
AIRS climo Dec
Models climo Dec

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MODIS cannot resolve High Ice Clouds over Low Water Clouds

Standard Simulations

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AIRS IR has cloud info
not available with MODIS.

Standard Simulations
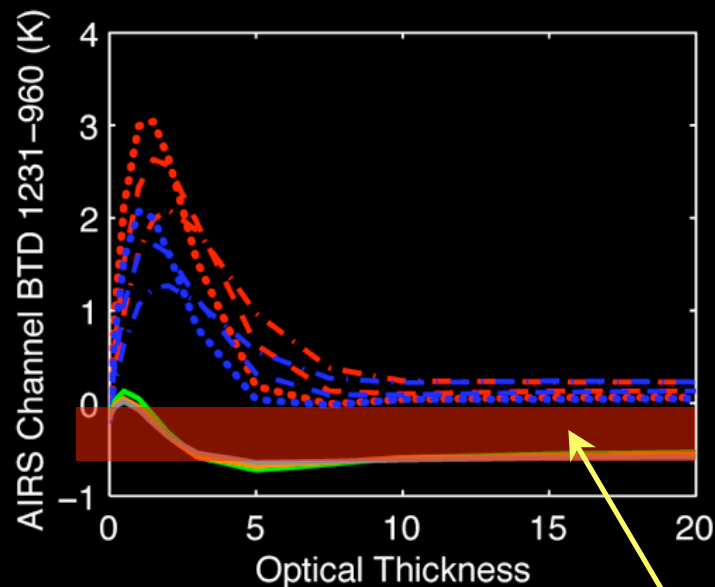
Potentially Mixed-Phase Simulations

Z9_small ice
Z9_medium ice
Z9_large ice
Z7_small ice
Z7_medium ice
Z7_large ice
Z3_water
Z2_water
Z1_water
Z5_small ice
Z5_medium ice
Z5_large ice
Z5_water
Z4_water
Z3_water
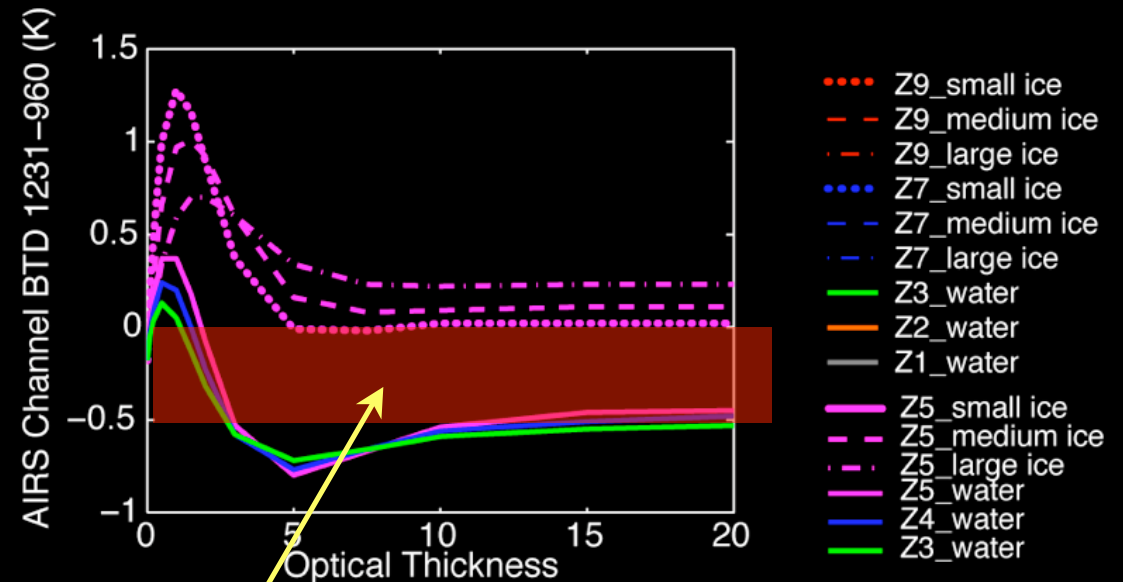
Water cloud curves are solid, ice cloud curves are dashed or dotted.

The biggest issue is the (large) 15 km scale of the AIRS footprint.
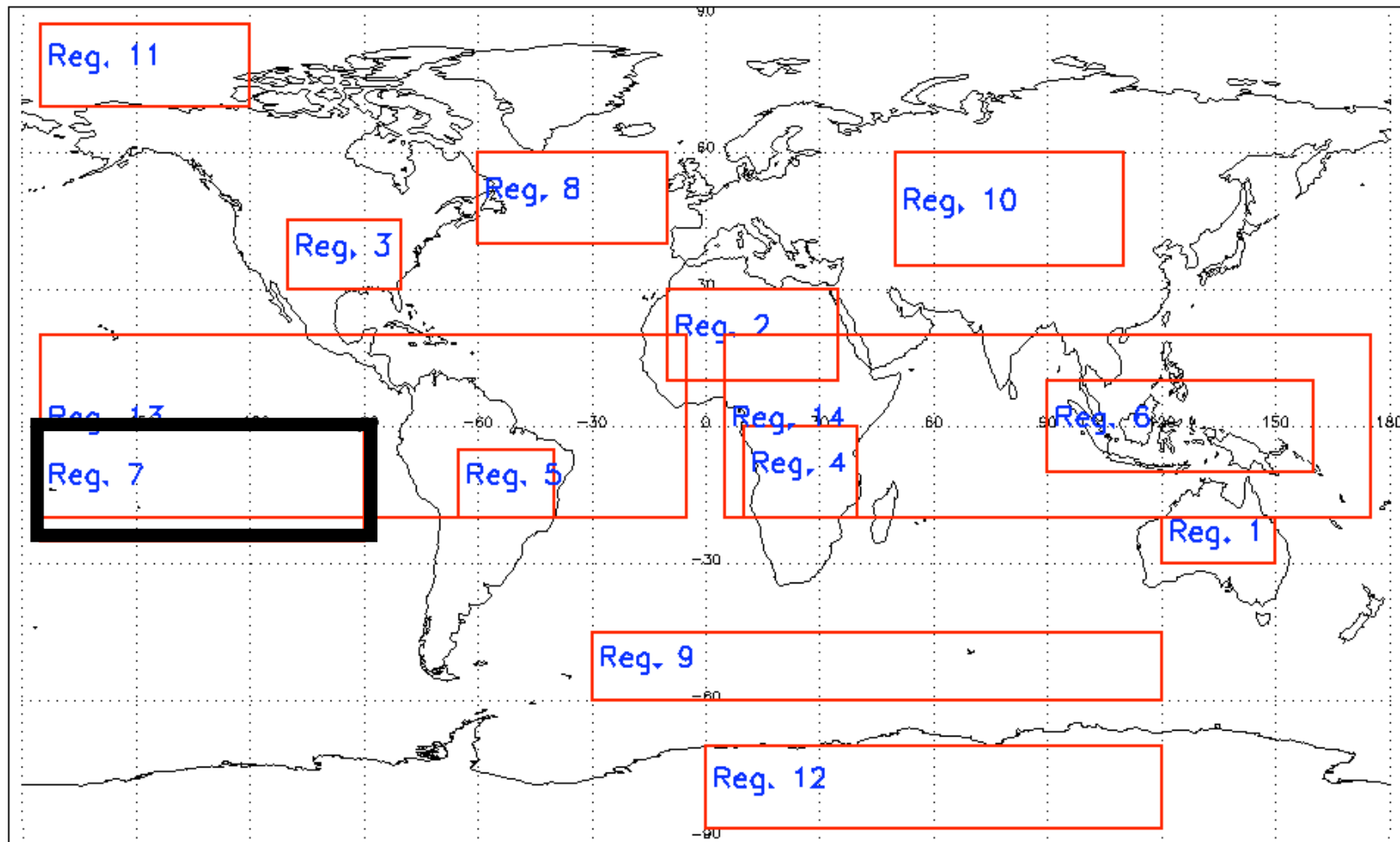"Borrowed" from Shaima Nasiri.

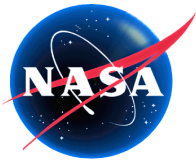~0.5 K phase separation

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AIRS data are mature enough to start deducing trends

SE Pacific

Weaker annual cycle with height.
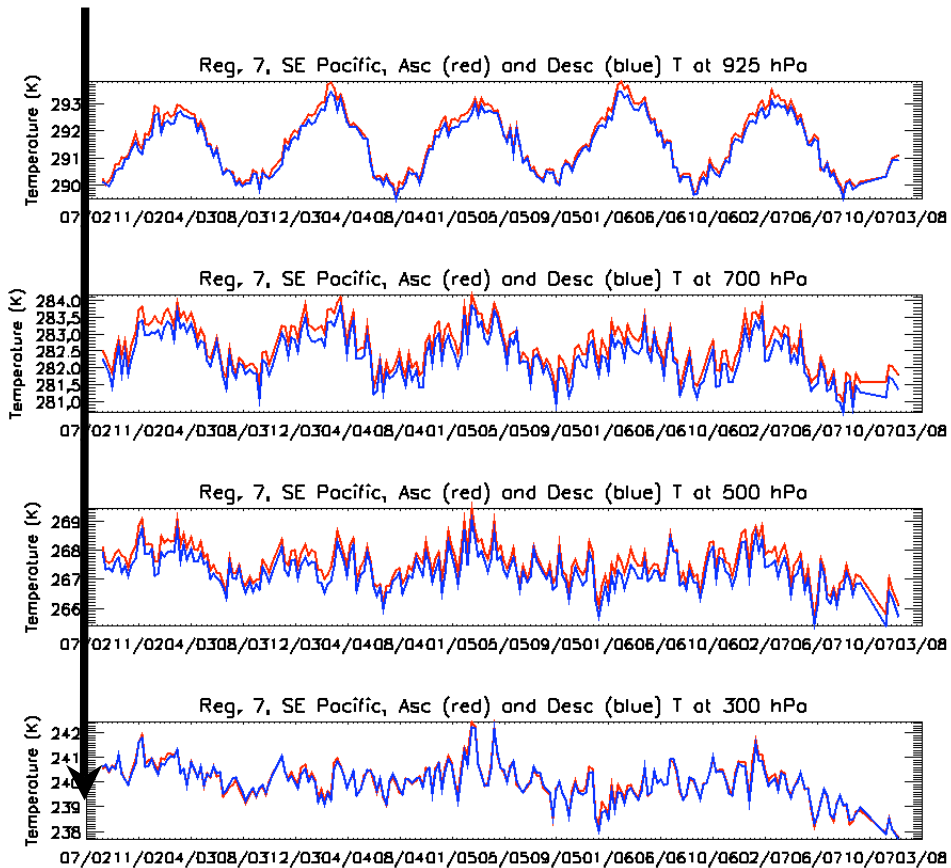
Strong annual cycle at all heights.

Temperature
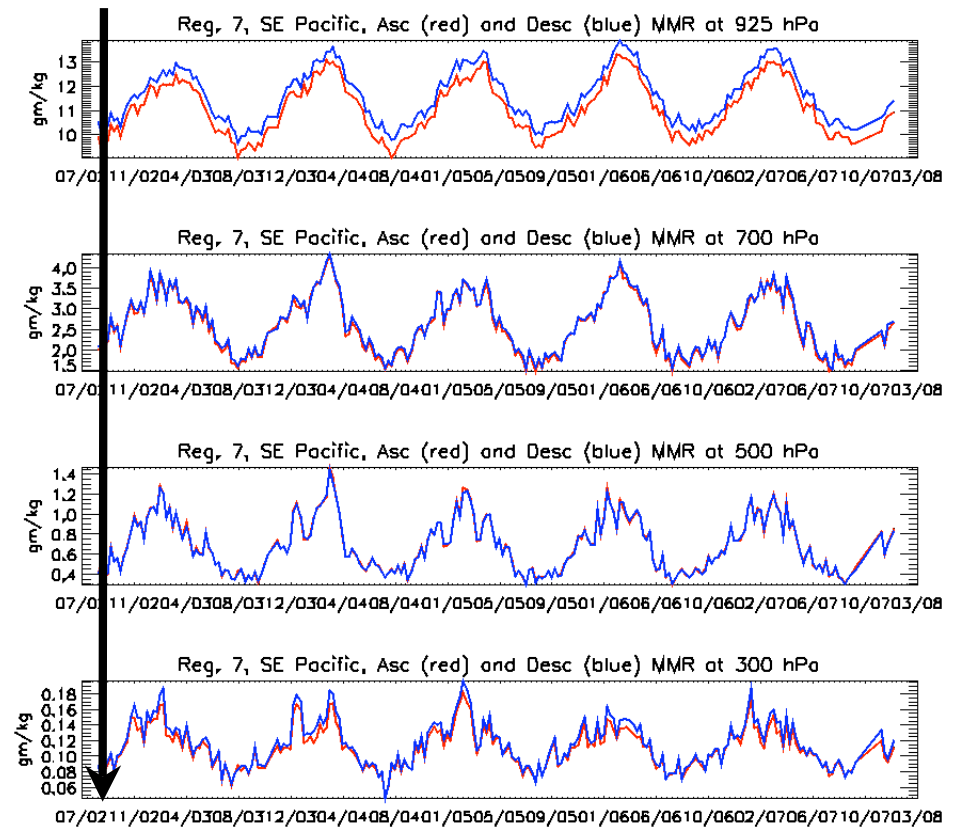
Water vapor

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AIRS CO$_2$ work continues to make progress

CO2 Trending using Spectra (Strow)

AIRS CO2 Product (Chahine)

AIRS Mid–Tropospheric CO2. July 2003, V5 Day 16 x 31
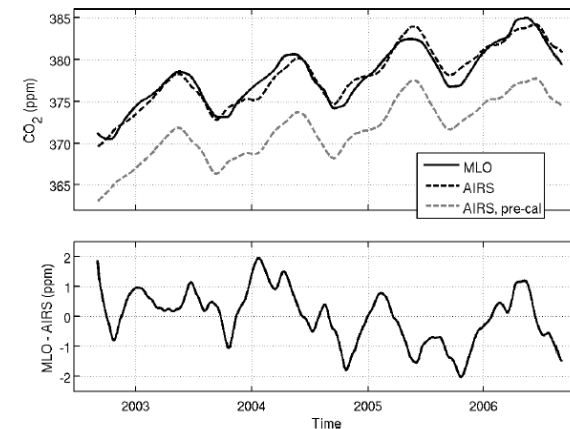
AIRS Zonal CO$_2$ Trends (Strow)
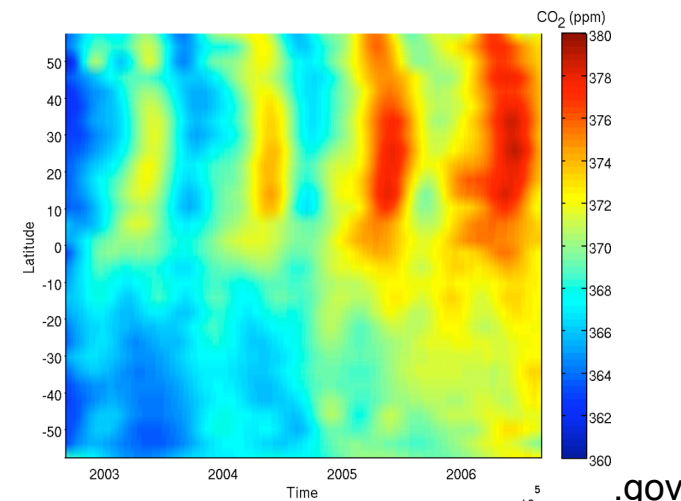
Demonstrates <10mK/year Stability

.gov

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Summary:
Hyperspectral Sounders

- Sounders observe key climate signatures, especially at scales >50 km.

- Many of these processes are poorly represented in models (or not analyzed, yet).

- Trending is only beginning.
  - Climate prediction will improve with record length.

- What additional questions will CLARREO answer?
  - especially given IPCC 2007 concerns with cloud feedbacks.

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Boundary Layer Science

- Why?

  – IPCC: "Cloud feedbacks remain the largest source of uncertainty."

  – Large uncertainties in the hydrologic cycle arise from poorly known land-surface interactions.

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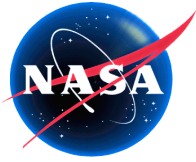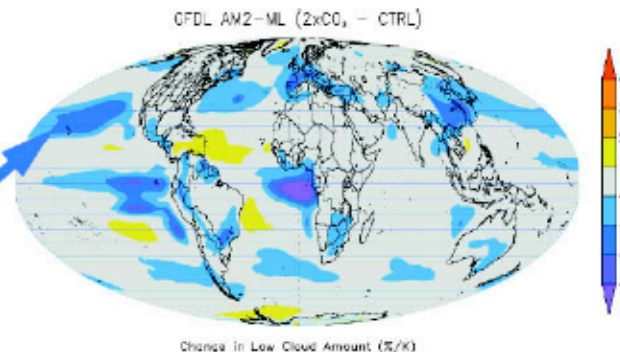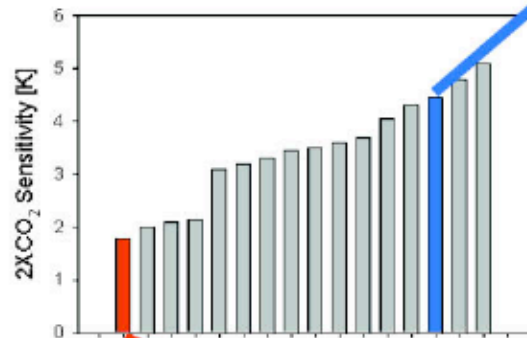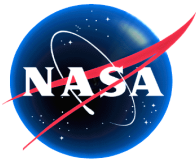# Low cloud climate feedbacks can be of opposite sign in IPCC models!

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
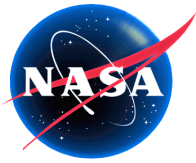
Models ranked by double CO_2 response.

GFDL AM2-ML (2xCO$_2$ − CTRL)

Change in Low Cloud Amount (%/K)

Fewer low clouds with warming

NCAR CAM2 (Year70 @1%CO$_2$/yr − CTRL)
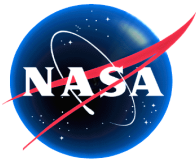
Change in Low Cloud Amount (%/K)
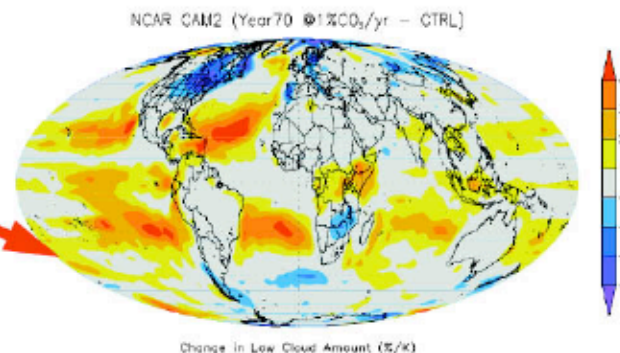
More low clouds with warming

B.Soden/G.Stephens

GFDL and NCAR have **_opposite_** low cloud cover sensitivity to CO_2 doubling
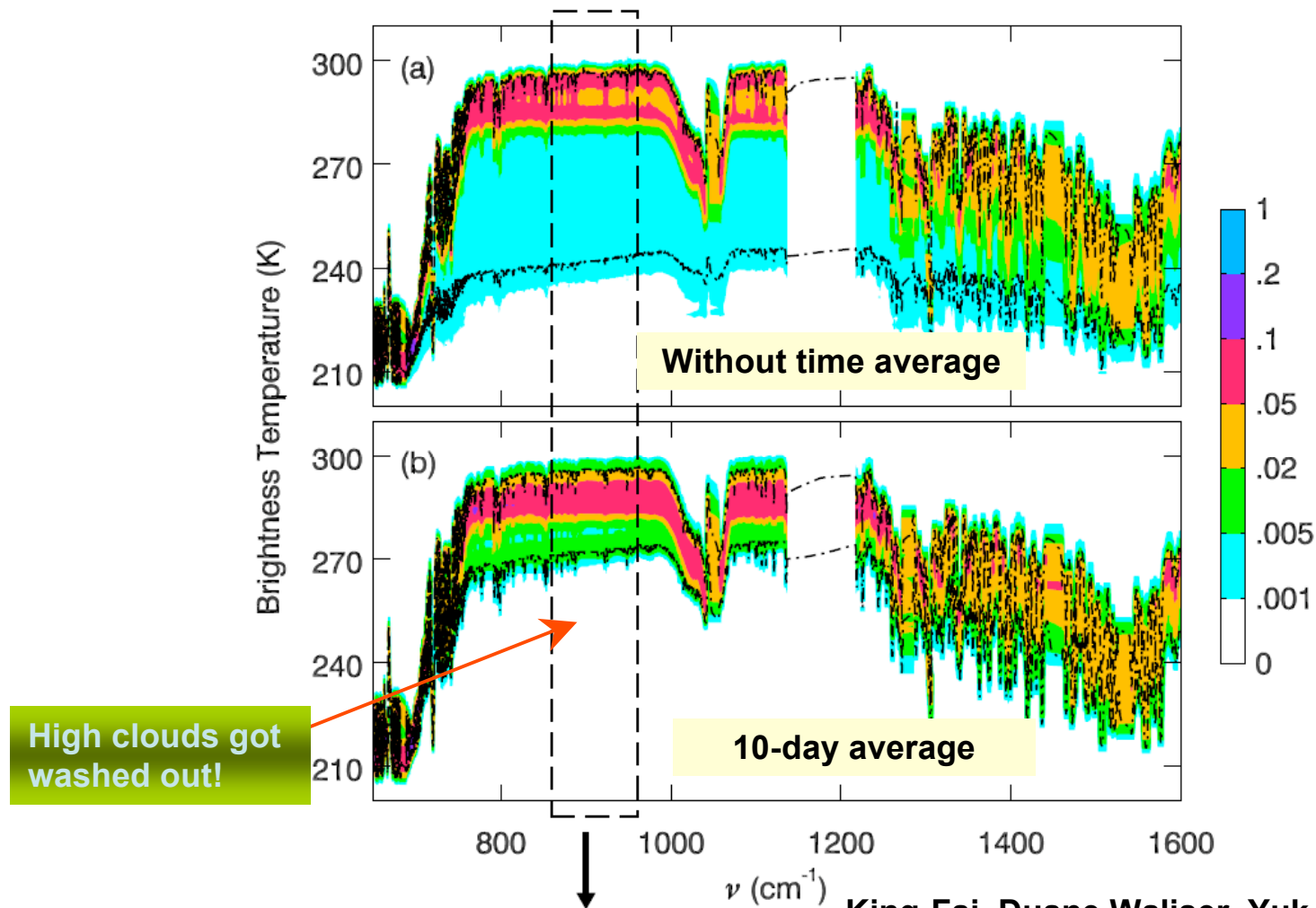
Eric.J.Fetzer@jpl.nasa.gov

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King-Fai, Duane Waliser, Yuk Yung, CalTech
Eric.J.Fetzer@jpl.nasa.gov
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What horizontal scales control stratocumulus clouds in the PBL?

GOES-10 VISIBLE IMAGE AND DETAIL
October 17 2001, 15:00 UTC

200 km

SHIP TRACK

10°S

20°S

90°W   80°W   70°W
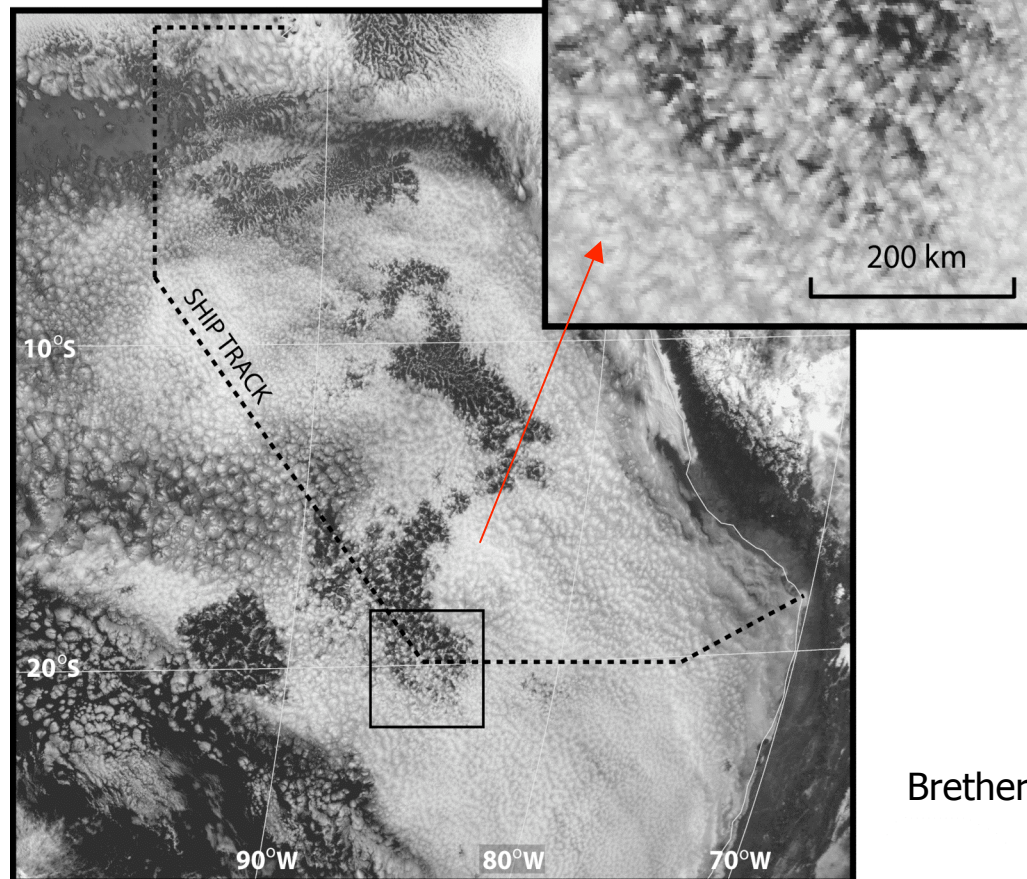
Bretherton et al (2004)

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Scales from 1 to 100 km probably play a significant role   18

Climate models will have very high resolution in 10 years

- Global Cloud Resolving Models (1-10 km) exist and produce realistic simulations of clouds.

- Chapter 9 of Decadal Survey calls for high spatial resolution climate models, especially regionally.

- CLARREO resolution should be commensurate.
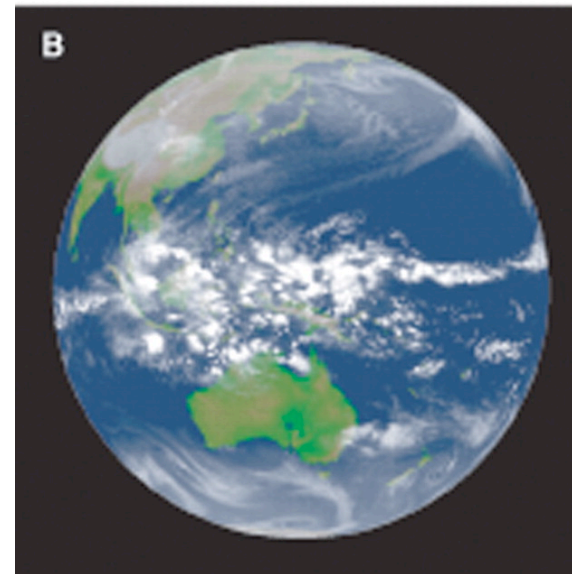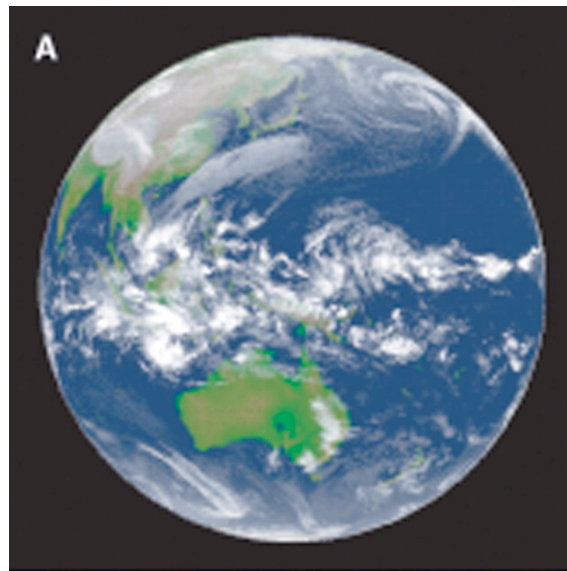
Miura et al. 2007

NICAM global model (3.5 km horizontal resolution):

(A) IR image; (B) model simulation

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Hyperspectral sounders have sufficient resolution for PBL T & q.

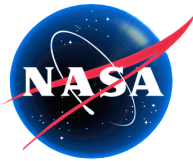*But... They do not observe at the scale of cloud processes.*
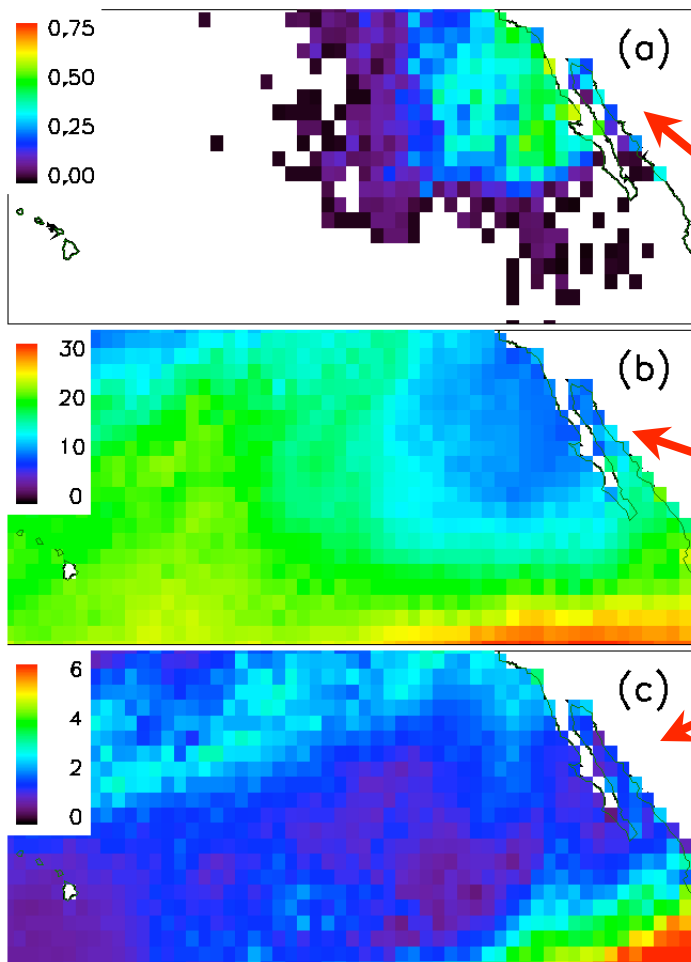
**Frequency of temperature inversions
1-15 January 2003**

1000-700 hPa water vapor (mm)

700-500 hPa water vapor (mm)

Occurrence Frequency of Temperature Inversions and Water Vapor Distribution from AIRS. Figure 3 from Fetzer et al. 2004

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Some Testable Hypotheses from increasing CO_2

- A shift in subtropical low clouds will occur over the next century, manifested at scales of 1-50 km.
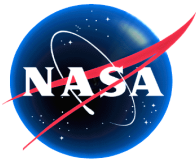 - The signal will be robust in the IR because of local changes in cloud microphysics.
  - The signal will be robust in the visible because of changes in local reflectivity.
  - The energetics will be much stronger than local CO_2 forcing.
  - Associate clouds feedbacks may dominate the climate change signal.

- Increased Walker Cell strength will lead to changes in the tropical Pacific subvisible cirrus.
  - The signal will detectable in the IR through cloud microphysics.
  - The energetics will be like local CO_2 forcing.

We think CLARREO should address the key issue in climate: Cloud Feedbacks
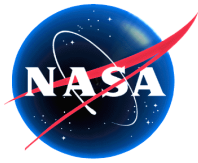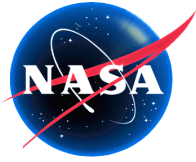
Eric.J.Fetzer@jpl.nasa.gov

Low Cloud Summary

1) Low cloud climate feedbacks are presently a key problem in climate change prediction

2) Stratocumulus clouds are the major players in cloud radiative forcing and are behind low-cloud climate feedbacks

3) Mesoscale physical processes (between 1 to 100 km) play a significant role in controlling existence of stratocumulus

4) High-resolution (1-10 km) models are becoming more frequent and are "intriguingly" realistic in stratocumulus simulations

5) Observations at these resolutions are necessary to understand low cloud climate feedbacks and to validate future models

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What We Will Do

- Examine spatial variability of radiances from TES, AIRS and MODIS associated with:
  - Stratocumulus
  - Water vapor
  - Cirrus

- Examine the same in high resolution models.
  - Start with WRF.

- What are the dominant scales CLARREO should observe?
  - to best exploit simultaneous, multispectral information.

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