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# Observing Clouds and Water Vapor with NASA's A-Train

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# Acknowledgements

- **The NASA Energy and Water-cycle Study (NEWS) project supports much of this work.**

- **The AIRS project supports the rest.**

- **This represents the work of many colleagues. Special thanks to:**

  **Brian Kahn, Baijun Tian, David Pierce, Duane Waliser, Joao Teixeira, Bjorn Lambrigtsen, Annmarie Eldering, Tim Barnett, Bill Read, Manuel de la Torre, Bill Irion, Evan Fishbein, George Aumann, Mous Chahine.**



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# *From*: The Second GEWEX Cloud System Study (GCSS) Science and Implementation Plan, 2000

"Certain intrinsic characteristics of the modeling and observing communities make it difficult to bring models and data together. **For the most part, observers are content to develop and (sometimes) apply retrieval algorithms to produce a data stream, and feel that their responsibility stops there. Modelers tend to want neat, gridded, averaged geophysical variables as data products, not wanting to hear about or think about either random errors or sampling biases."**



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# *From*: The Second GEWEX Cloud System Study Science and Implementation Plan, 2000 *Continued...*

**"To bridge the gap between what the data-collection community provides and what the modeling community needs, the task of *data integration* is absolutely essential. Unfortunately, it is always in danger of being ignored. Data integration consists of bringing together data from disparate instruments, and combining these data into a coherent physical description of what was observed, in a form suitable for use in the evaluation of the relevant models."**

**This is what we proposed to the NEWS project.**



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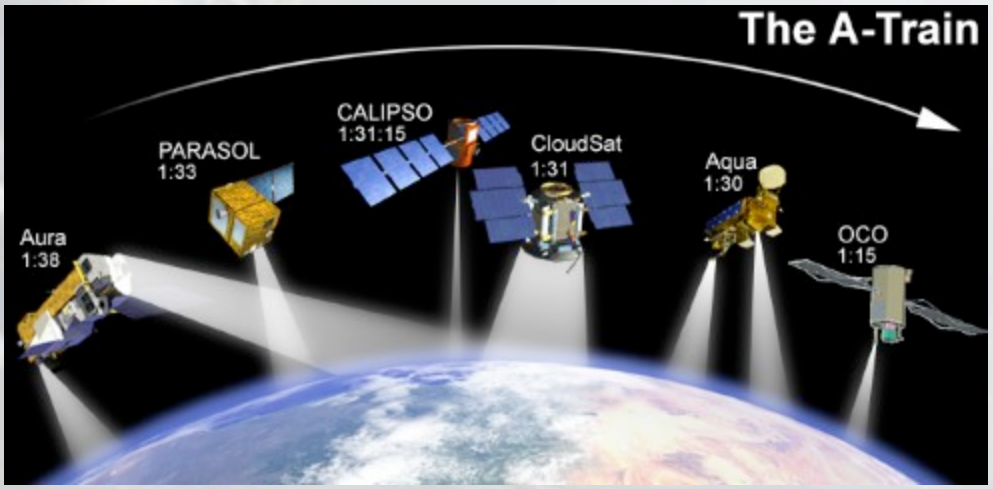
# The A-Train Satellites

- *Formation-flying NASA satellites.*
- *Several instruments measure atmospheric water substance*
  - *Aqua:*
    - *AIRS: Temperature, water vapor, cloud-top properties.*
    - *AMSR-E: Water vapor, cloud liquid water.*
    - *MODIS: Water vapor, temperature, cloud properties.*
  - *Aura:*
    - *MLS: Temperature, water vapor, cloud ice.*
  - *CloudSat/CALIPSO*
    - *CloudSat: Cloud flag.*
    - *Calypso: Not released.*



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# Today's Acronyms

- ***AIRS: Atmospheric Infrared Sounder***
  - **Combined infrared and microwave nadir sounder.**
  - **Profile quantities.**

- ***AMSR-E: Advance Microwave Scanning Radiometer for EOS***
  - **Nadir conical scanner.**
  - **Total water, cloud liquid water, SST over water.**

- ***MLS: Microwave Limb Sounder***
  - **Upper tropospheric water vapor and temperature.**

- ***MODIS: MODerate Resolution Imaging Spectroradiometer.***
  - **Cloud properties, T and q profiles.**



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# Combining A-Train Data Sets

## Strengths / Challenges

- **Strengths:**
  - ***The A-Train instruments provide nearly simultaneous, redundant observations.***
    - Like a downward-looking ARM site.
  - ***Large instrument teams are assessing individual data sets.***

- **Challenges:**
  - ***Unvalidated observations.***
  - ***Poorly characterized retrieval errors.***
  - ***Instruments not co-registered.***
  - ***Data set size and complexity.***
  - ***Scientific potential of*** individual ***data sets not fully realized.***



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# Our Analyses

- **Two general types of questions:**

1. ***How applicable are the satellite data?***
   - Traditional validation.
   - Intercomparison between different A-Train instruments.

2. ***What do the observations tell us about atmospheric processes?***



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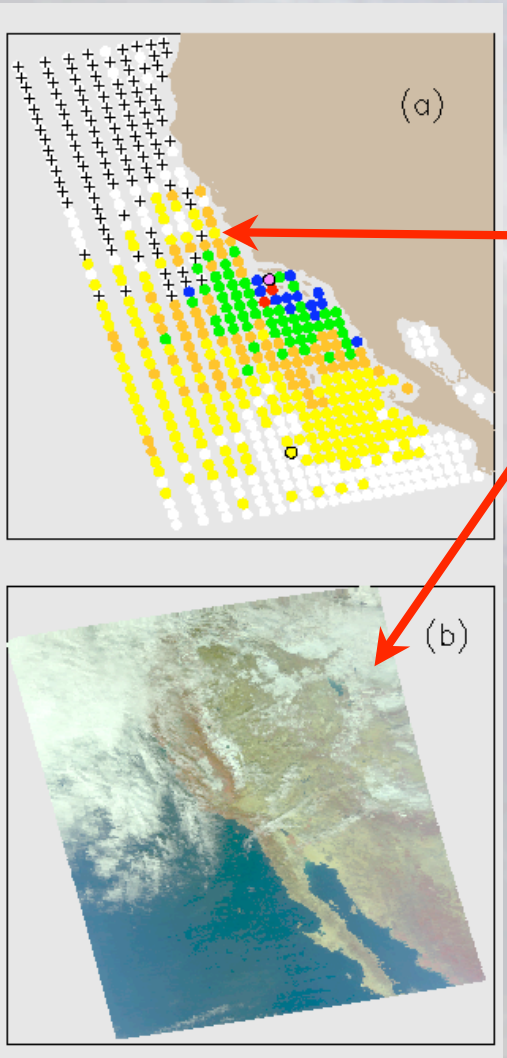
# A Study Relevant to This Group:

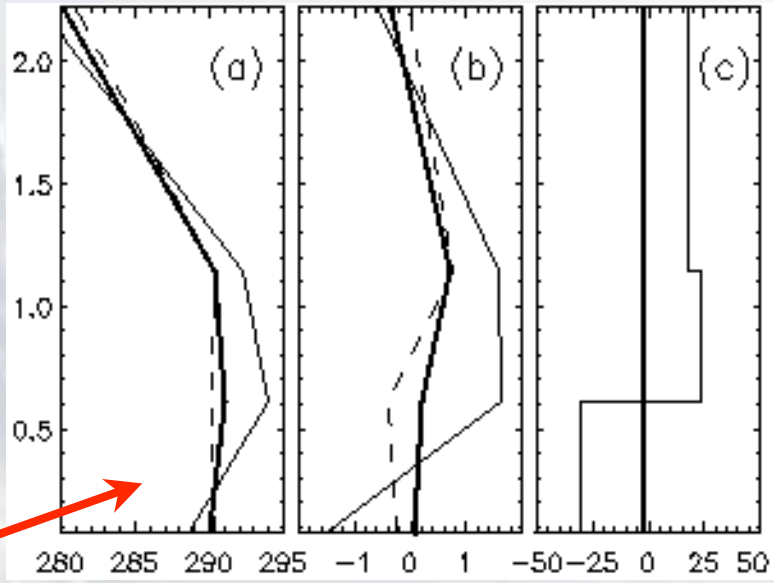
## *AIRS Detection of Near-Surface Temperature Inversions*




***Inversion locations- even under clouds***

***The Vis/NIR image***

***Mean T and q vs. ECMWF***




See:

E. Fetzer, J. Teixeira, E. Olsen, and E. Fishbein, 2004: Satellite remote sounding of atmospheric boundary layer temperature inversions over the subtropical eastern Pacific, *Geophys. Res. Lett.*, vol. 31, L17102, doi:10.1029/2004GL020174.



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# Occurrence Frequency of Temperature Inversions, and Water Vapor Distribution

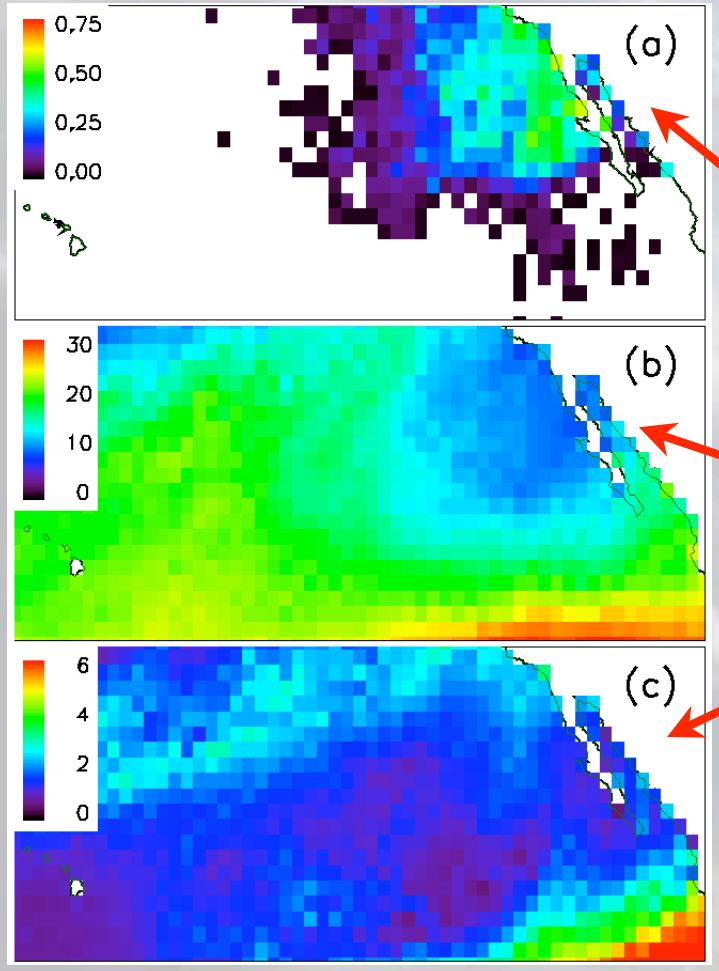


**Figure 3 from Fetzer et al. 2004**

**Frequency of temperature inversions 1-15 January 2003**

**1000-700 hPa water vapor (mm)**

**700-500 hPa water vapor (mm)**



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# Because sampling biases matter... *compare AIRS and AMSR-E*

- ***A basic premise***: **AMSR-E microwave observations are less affected by clouds than AIRS infrared observations**
  - ***Exploit this to understand biases in AIRS methodology.***

- **Part of a JGR special section on AIRS validation:**

  **Fetzer, E. J., et al., 2006: Biases in total precipitable water vapor climatologies from Atmospheric Infrared Sounder and Advanced Microwave Scanning Radiometer, *J. Geophys. Res.*, *111*, D09S16, doi:10.1029/2005JD006598.**



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# *Goals of This Study*

- **Show good agreement between AMSR-E and AIRS/AMSU/HSB somewhere, under some conditions**

- **Use AMSR-E to diagnose possible cloud-induced sampling biases in AIRS full retrievals.**
  - ***important implication for AIRS height-resolved water vapor climatologies (as in Fetzer et al. 2004...).***



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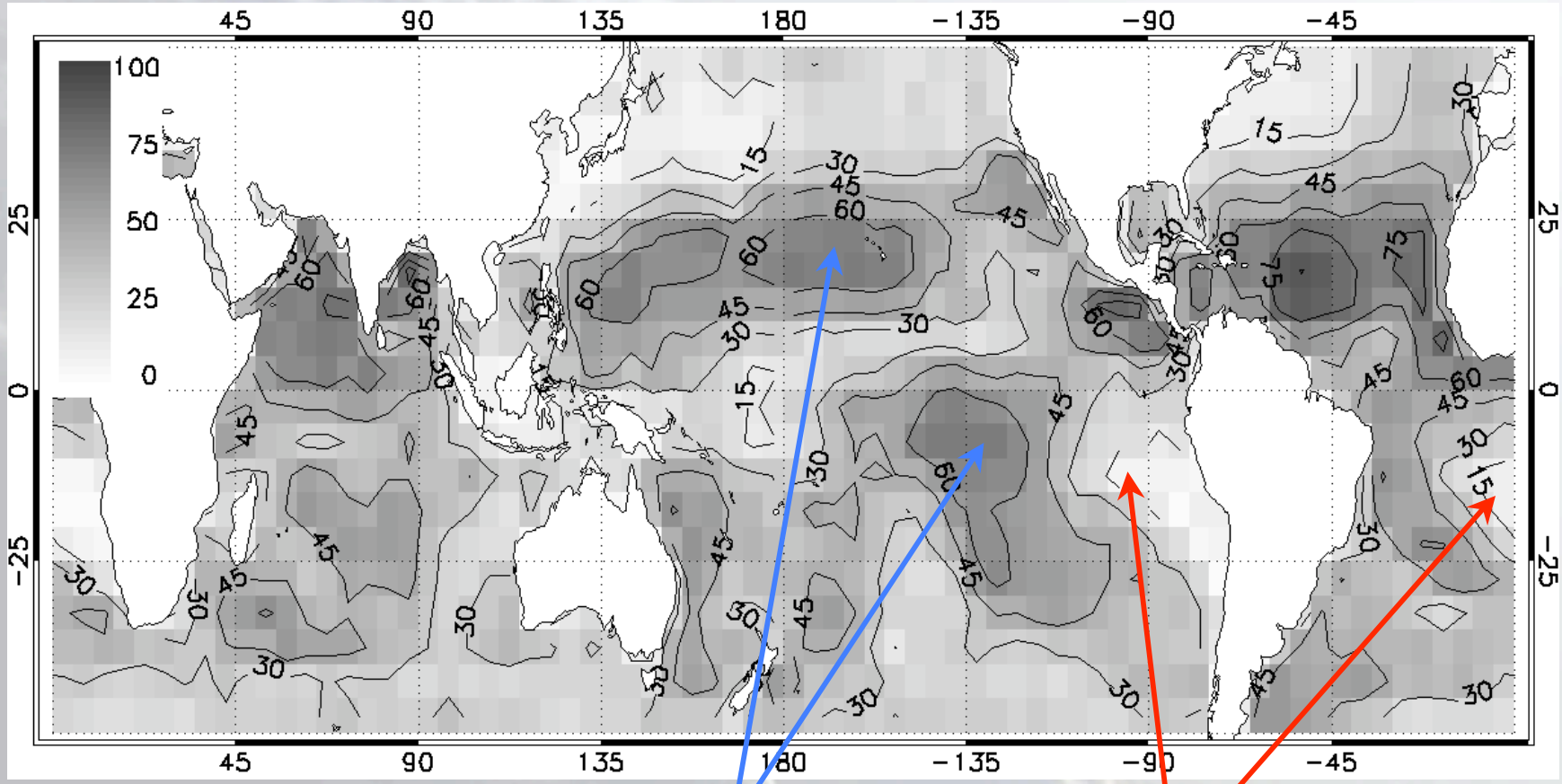
# AIRS retrieval yields vary with location

## *Fraction of 'good' retrievals (percent)*

### *25 Dec 2002 to 15 Jan 2003*




**AIRS works best in trade cumulus. Good news for GPCI studies & Fetzer et al. 2004.**

**Poorer coverage of stratocumulus; use with caution here.**



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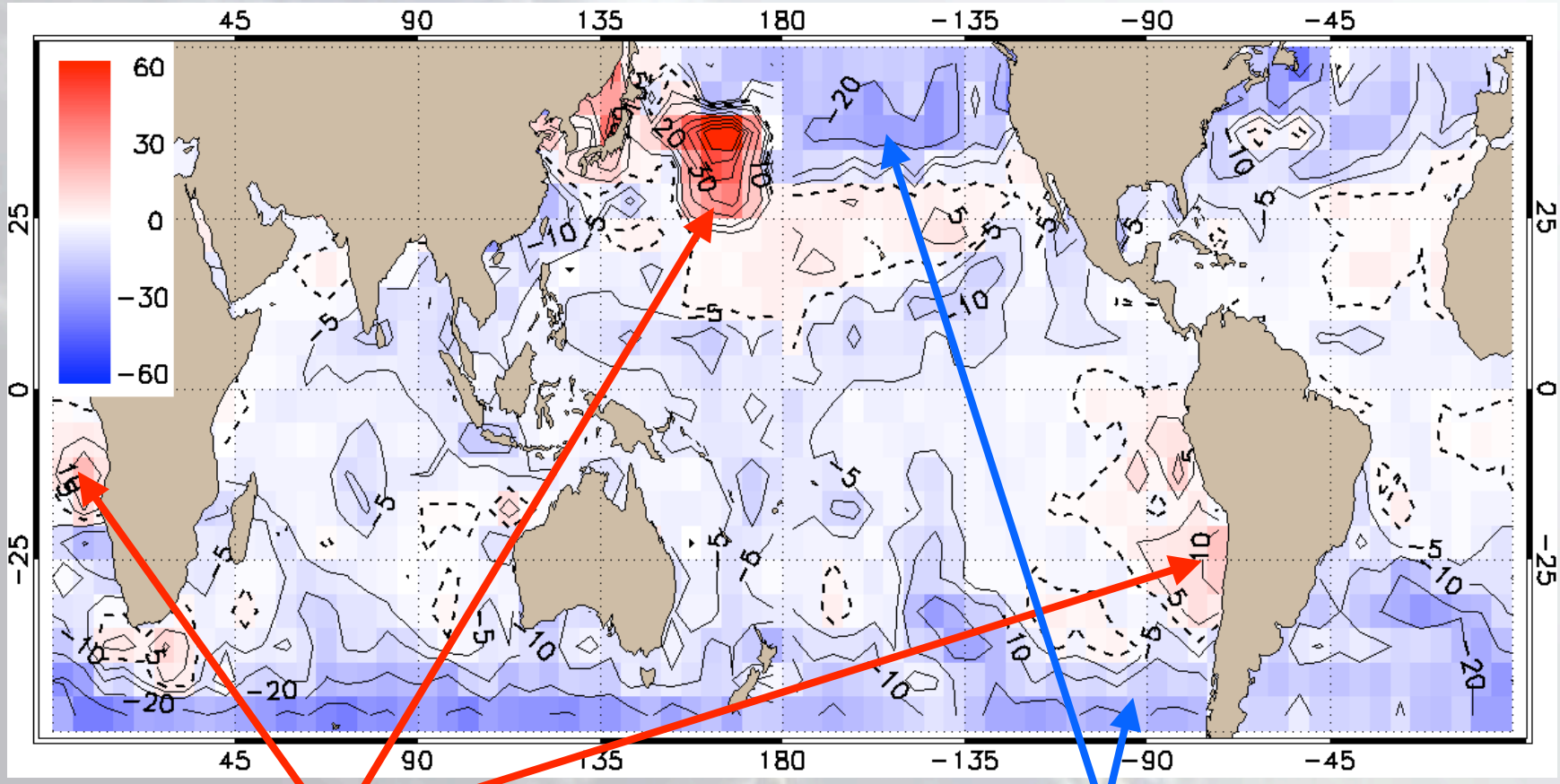
# *Full* AIRS & AMSR-E climatologies

## AIRS can be drier OR wetter

## *because of cloud-induced sampling effects*

### *25 Dec 2002 to 15 Jan 2003*




**AIRS climatology is**
***wetter*** **than AMSR-E in stratus regions**

**AIRS climatology is**
***drier*** **than AMSR-E at high latitudes**



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# Sampling biases in AIRS total water vapor
## *using AMSR-E as a diagnostic*

| Climate Regime | AIRS-AMSR-E total bias (%) | AIRS Full Retrieval yields (%) |
|---|---|---|
| Mid-latitude storm belts | -10 to -30 | 15 to 30 |
| Cold air outbreaks | +30 to +70 | <15 |
| Subtropical stratus | -5 to -15 | 15 to 50 |
| Trade wind cumulus | -5 to +5 | 50 to 90 |
| Tropical deep convection | -5 to +5 | 15 to 50 |

***From***: **Fetzer et al., 2006.**



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# *What does this say about subtropical boundary layer studies with AIRS?*

## *E. g. Fetzer et al. 2004 & future GPCI studies*

1. **Our inversion occurrence frequencies are overestimates**
   - ***Null solutions should be part of the climatology***
     - **"*I don't know*" is a legitimate answer.**

2. **Our mean water vapor depends on local climate**
   - **Overestimated in stratocumulus regions, but by 20% or less.**
   - **Correct in trade cumulus.**



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# The AMSR-E sampling bias study useful in other AIRS-related analyses

- **Water vapor in climate models are biased relative to AIRS.** ***Largest in trade cumulus belts -- where AIRS is most plausible.***
  - Pierce, D. W., et al., 2006: Three-dimensional tropospheric water vapor in coupled climate models compared with observations from the AIRS satellite system, *Geophys. Res. Lett., accepted.*

- **AIRS characterization of the MJO shows greatest differences with NCEP in clearer ("trade windy") areas.**
  - Tian, B., et al., (2006), Vertical moist thermodynamic structure and spatial-temporal evolution of the Madden-Julian oscillation in Atmospheric Infrared Sounder observations, *J. Atmos. Sci., in press.*



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# Some other studies now underway

- **Upper tropospheric water vapor comparisons with MLS**
  - ***Some surprising results, especially in the moist tropics***
    - MLS appears to have cloud-induced sampling biases (microwave scattering from ice particles).
  - ***Manuscript in preparation...***
- **Comparison of AIRS, MLS and MODIS clouds**
  - ***Two manuscript by B. Kahn submitted to JGR.***
- **First AIRS-CloudSat comparisons...**



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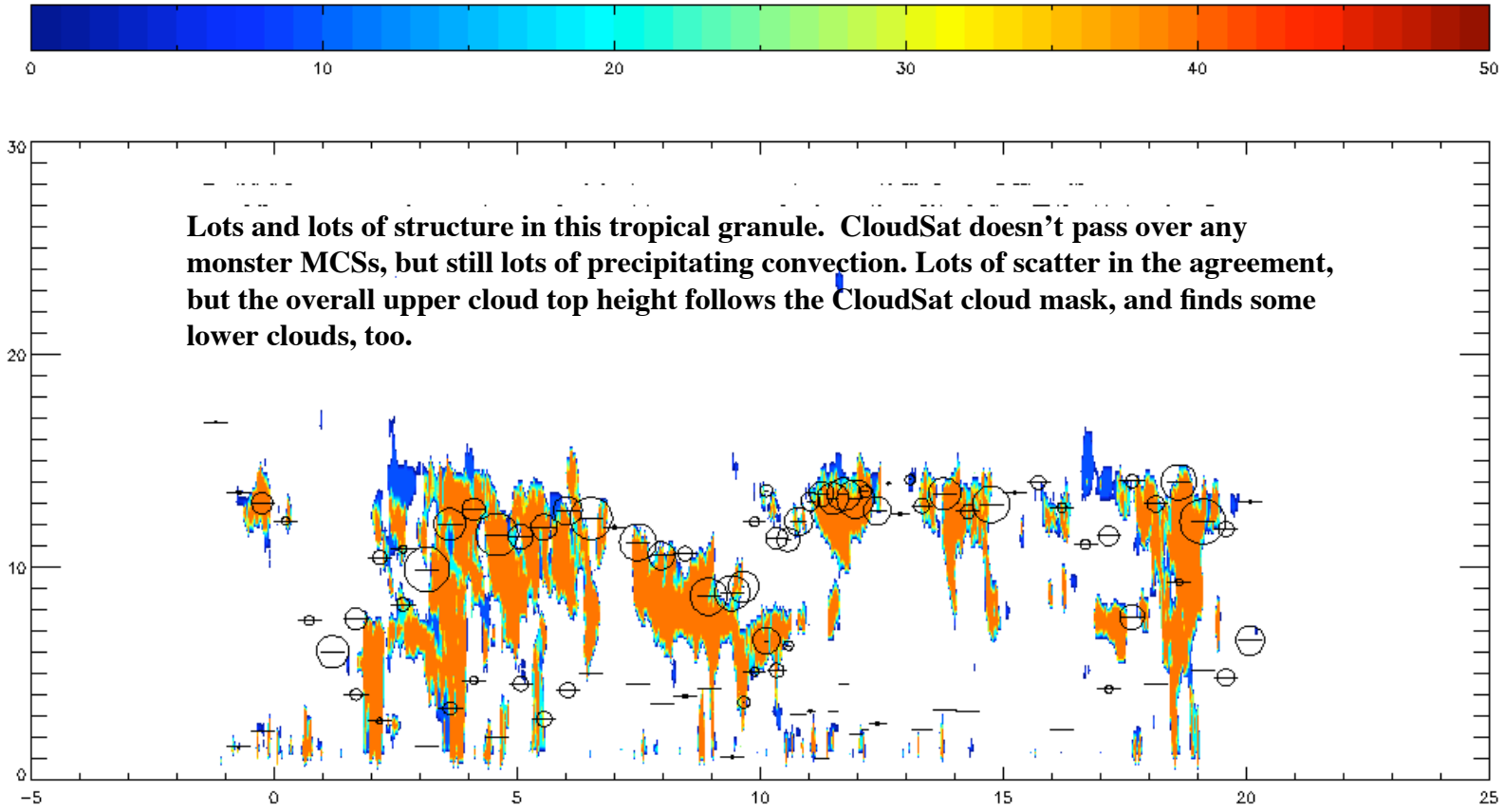
# Early AIRS-CloudSat comparison

## *Thanks to Brian Kahn*




**AIRS Granule 30, 07–20–2006, S. Atlantic Ocean; CloudSat granule 1205. CloudSat cloud mask intervals in color (Brian plotted everything > 0 here, and has looked at different cut-offs.**



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