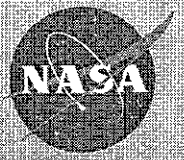

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Validation and Science Analyses of AIRS Quantities

Eric J. Fetzer, Brian Kahn, Annmarie Eldering and Stephanie Granger
Jet Propulsion Laboratory
California Institute of Technology

Stephen Leroy
Harvard University

AIRS Science Team Meeting
20 November 2004

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Overview of today's talk

- **Comparison with dedicate radiosondes**
  - ***-- Demonstrate 15% / 2 km in absolute humidity, 1 K / km in T.***
- **Comparison with AMSR-E total water vapor.**
  - ***-- No biases as a function of cloud fraction.***
- **Validating AIRS Clouds with MODIS**
- Some interpretation of AIRS water vapor.
  - *-- insight into phenomena is the ultimate validation*

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Validation with Dedicated Radiosondes

- **Three ARM sites and a few other locations.**
  - ***ARM uses Dave Tobin's best estimate fields***
- **Minimize mismatch in time**
  - ***Launch within ~1 hour of overpass***
- **NO mismatch in space**
  - ***Consider nearest retrieval to a given sonde***
- **Minimize scan angle effects**
  - ***Satellite always <30% from zenith.***
- **Use Vaisala RS90 sondes for sensitivity above 500 mb**
- **Use 20-100 sondes per site for statistical significance.**
- **Separate statistics by retrieval_type**
  - ***Is it microwave only or combined IR and MW?***

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Validation with Dedicated Radiosondes (Continued)

- **Examine profiles, time series, and height-dependent distributions.**
- **Report as height-dependent summaries of bias, RMS, etc.**

Upper tropospheric water vapor is a special case, the subject of a second talk.

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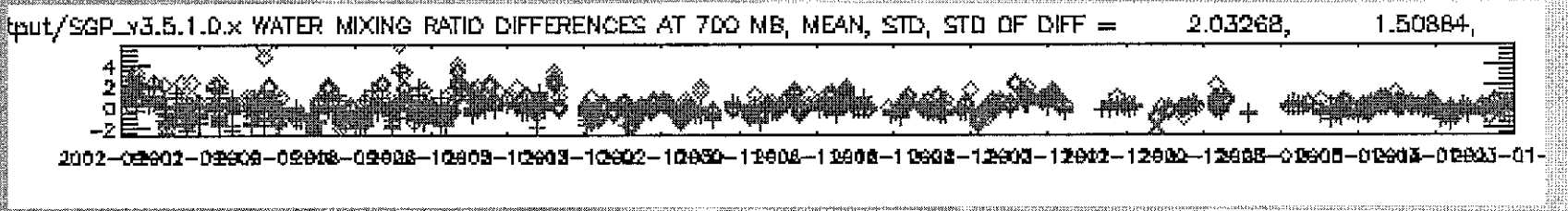
Warning: Water Vapor is Statistically Nonstationary and Highly Variable

AIRS (blue) and ARM Southern Great Plains Sonde (red) 700-600 mb mean mixing ratios



AIRS (blue) and Sonde (red) 700-600 mb mean mixing ratio differences

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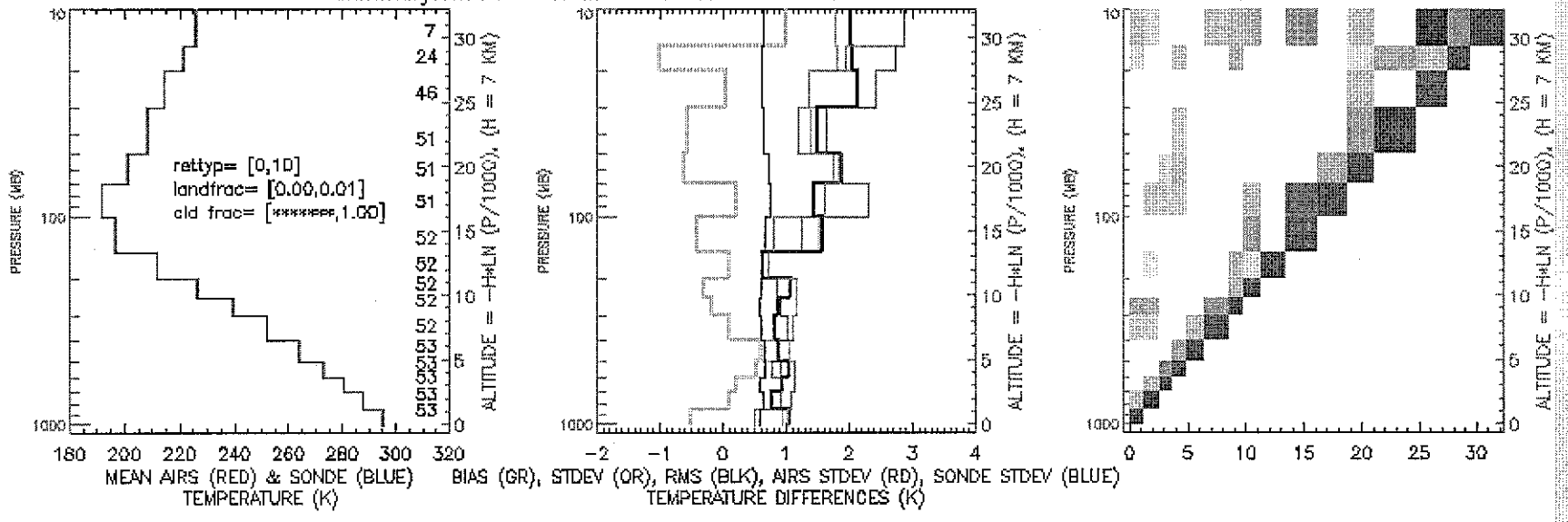
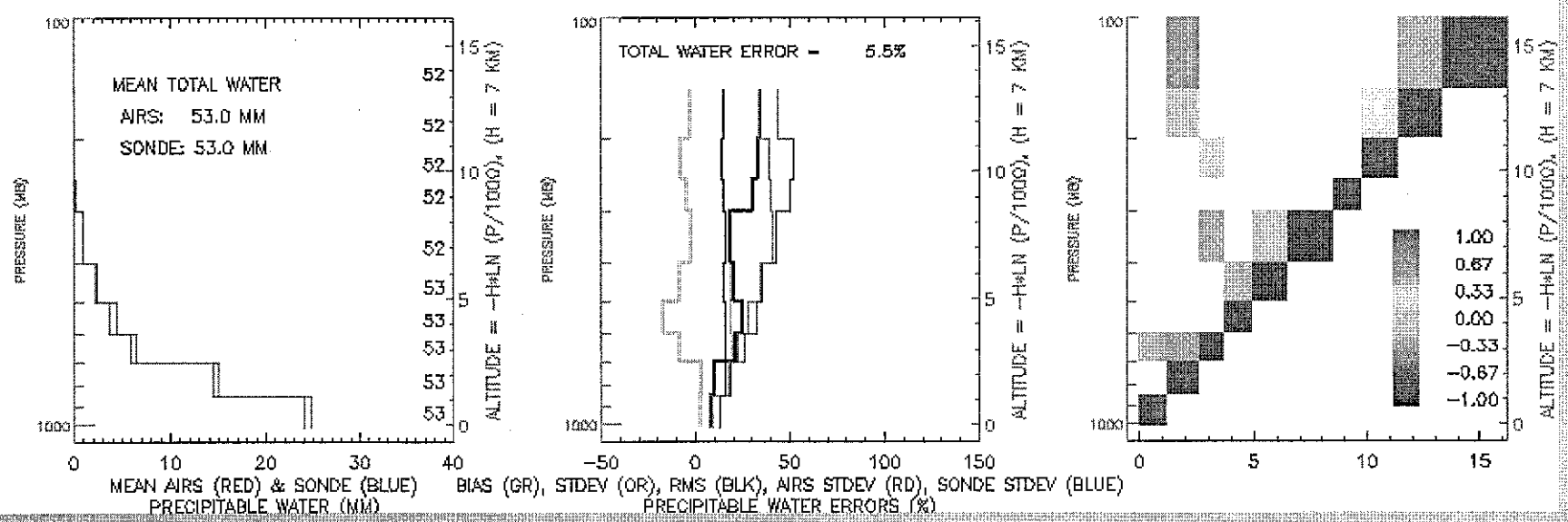
Full Retrieval Summary: ARM Tropical Western Pacific

Summary.TWP_v3.5.1.0.x.2002.09.15-2003.04.29.rt00-10:ind0-0.01:cld0.-1.1.bin





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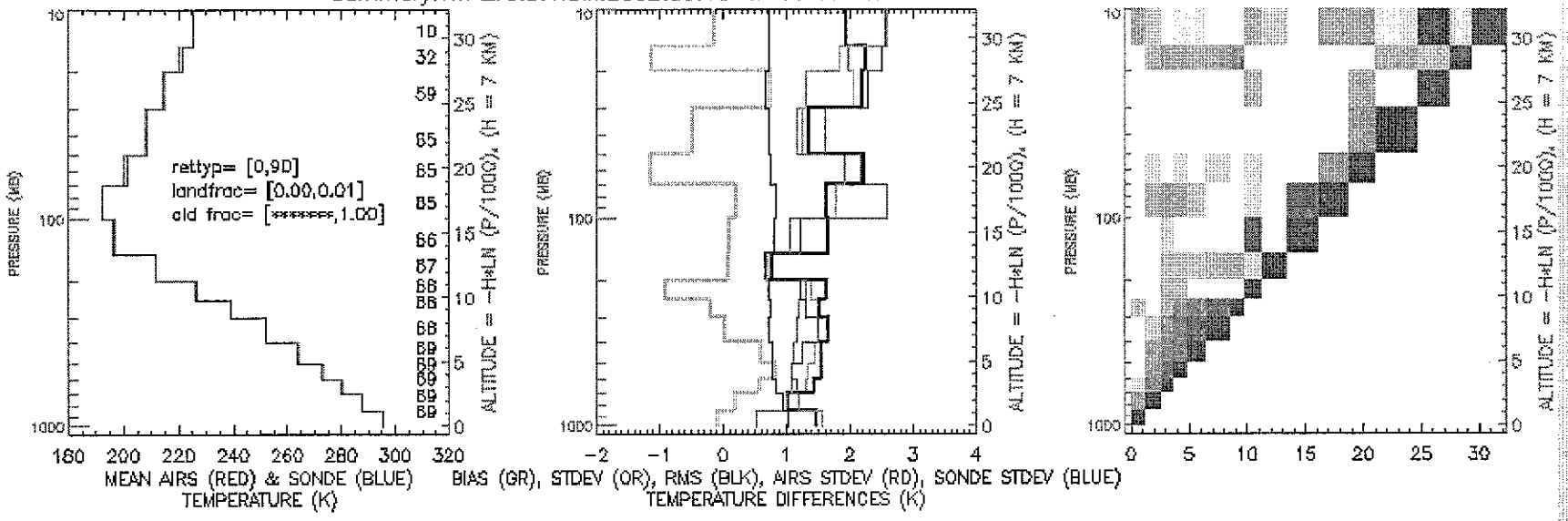
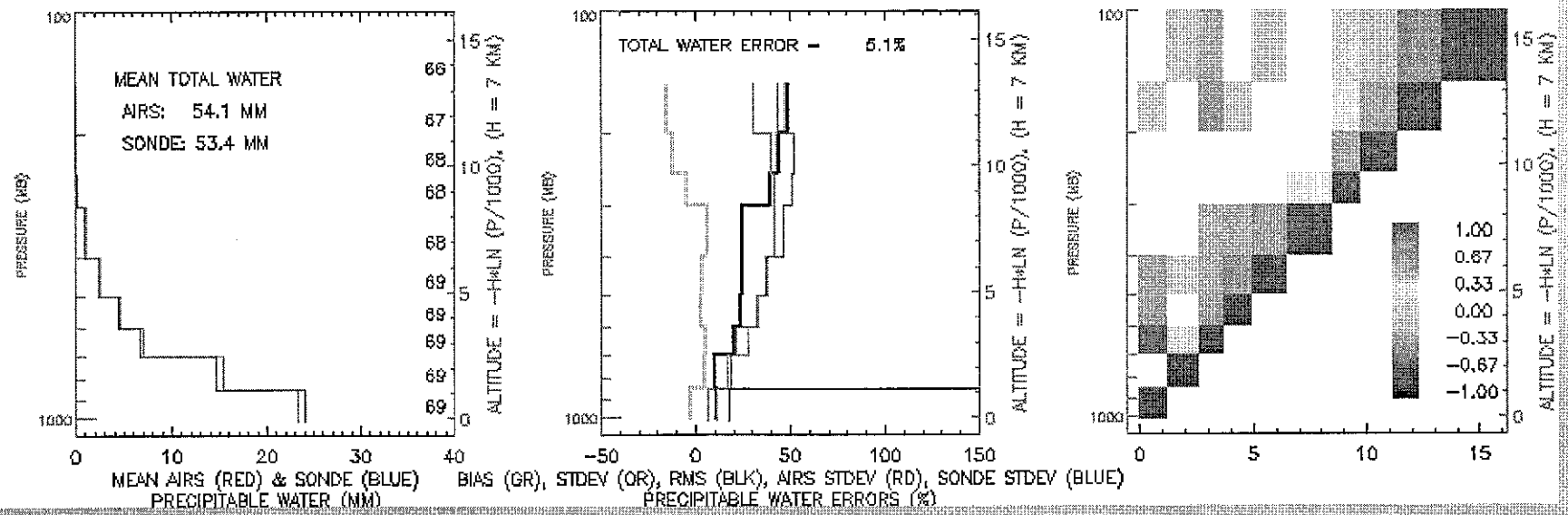
Full Retrieval Summary: ARM Tropical Western Pacific

Summary.TWP_v3.5.1.0.x.2002.09.15-2003.04.29.rt00-90:ind0-0.01:cld0.-1.1.bin





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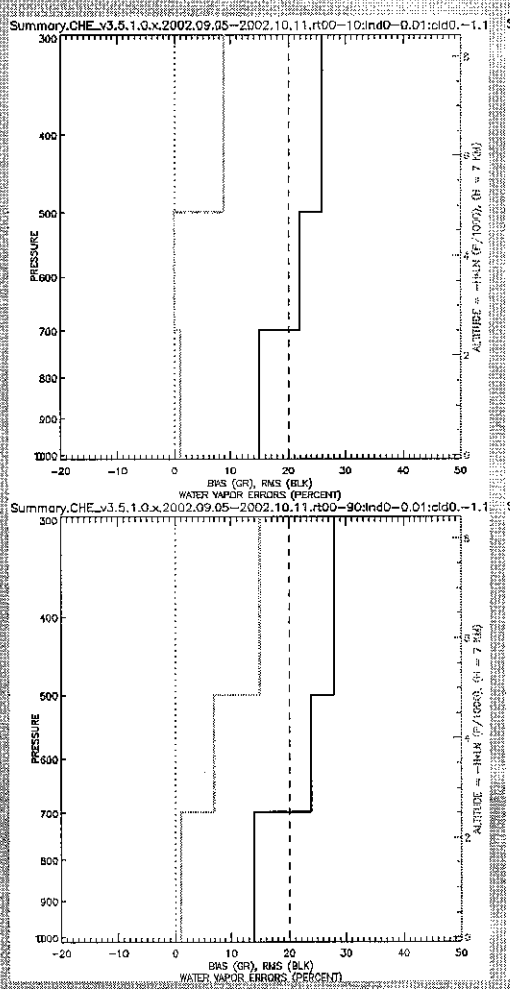
Water Vapor in 2 km layers

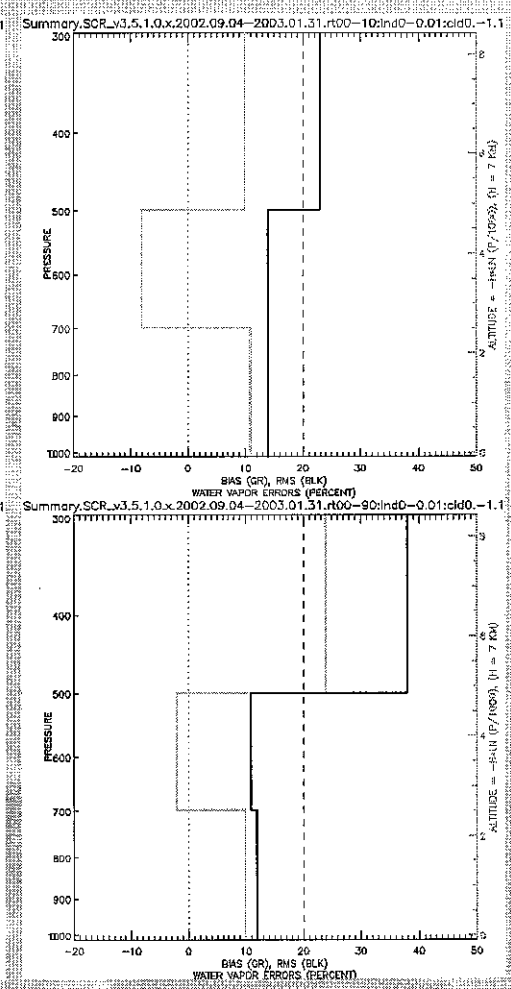
***Moral*: Good agreement suggests information at scales smaller than 2 km.**

Full Retrievals

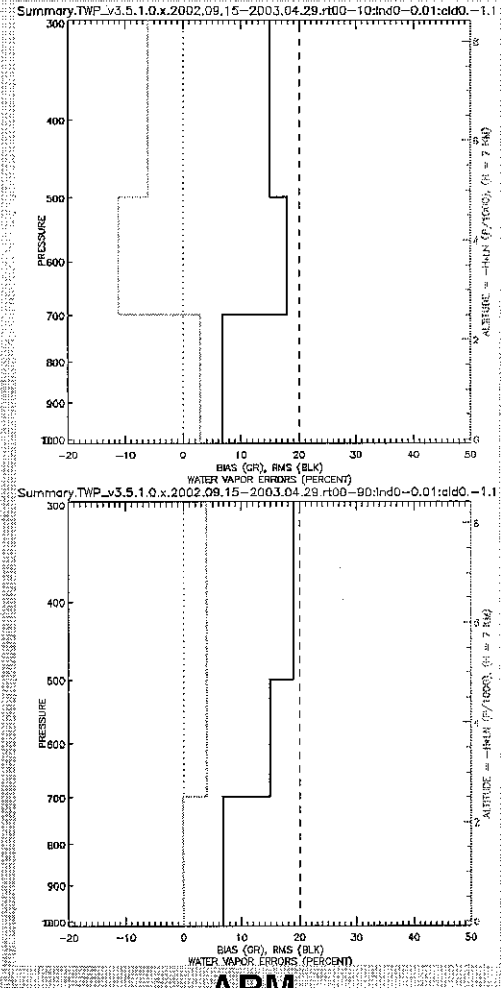
Microwave-only Retrievals



Chesapeake Light Platform



San Cristobal Galapagos



ARM Tropical Western Pacific

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Sonde Comparison Conclusions

- **AIRS is meeting 1 K in 1 km layers at oceanic sites**
- **AIRS is meeting 15% absolute humidity in 2 km at TWP.**
- **Be careful about conclusions at highly variable sites. Examples:**
  - ***ARM SGP is dominated by annual cycle***
  - ***High variability at Chesapeake Light Platform appears to contribute to larger differences.***

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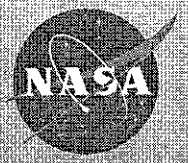

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AIRS - AMSR-E Comparisons
Approach and Methodology

- **Examine total water vapor**
  - ***Also SST -- not shown today***
- **6 September 2002**
- **Oceans only, ±50 degrees latitude**
- Two goals:
  1. *Look for global biases*
  2. *Look for biases as a function of AIRS retrieved cloud amount*

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Approach and Methodology (continued)

- **Footprint-by-footprint comparisons at AIRS retrieval horizontal resolution**
- **Match nearest AMSR-E neighbor to AIRS retrieval**
  - ***Data from http://www.ssmi.com/***
- **Generate separate statistics on retrieval_type**
  - ***Full retrievals: [0-10]***
  - ***MW-only retrievals: [20-50]***
- **Generate separate statistics for ascending and descending nodes.**

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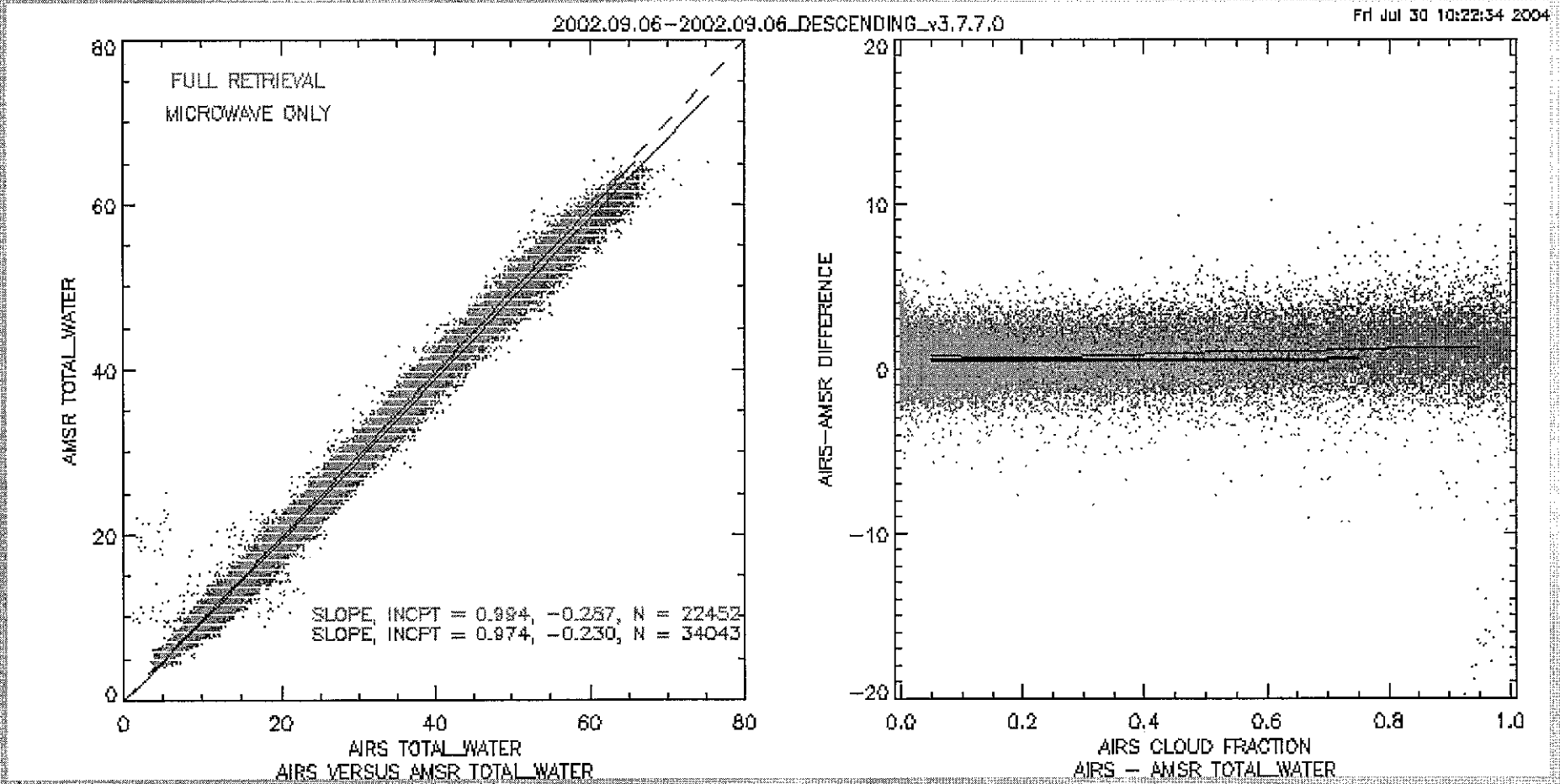
AIRS vs. AMSR-E
Total Water, Descending, v3.6.0



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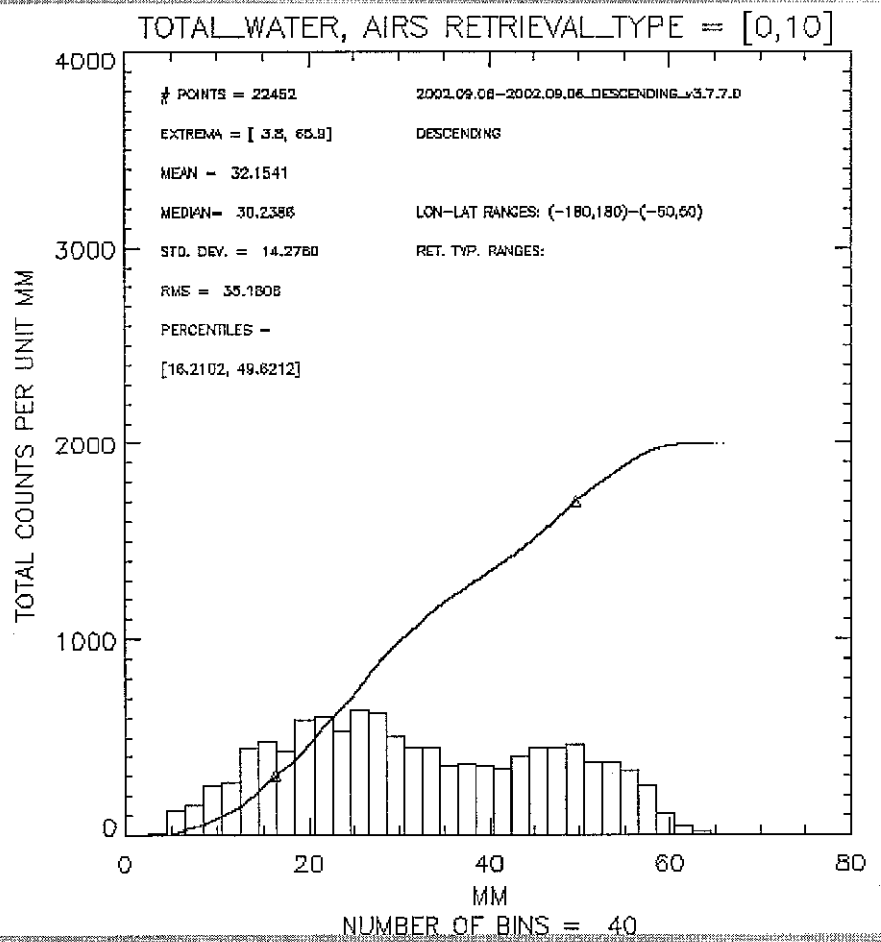
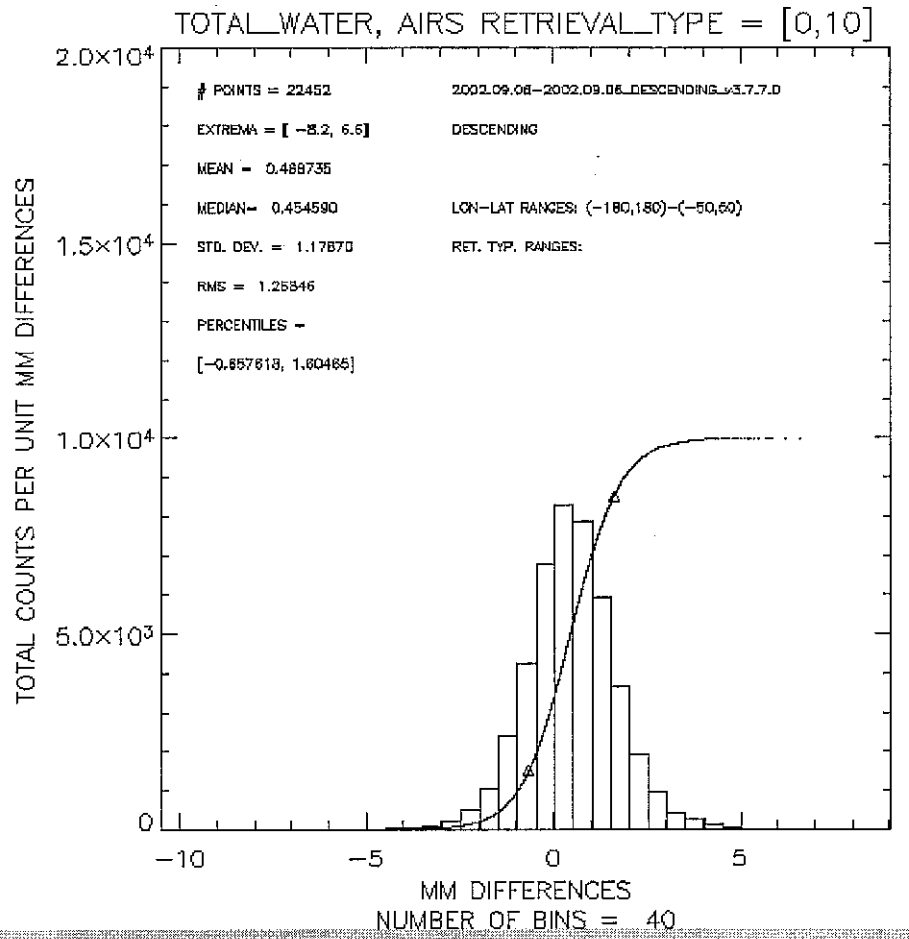
Distributions of AIRS and Differences

Total Water, Descending, Full retrievals





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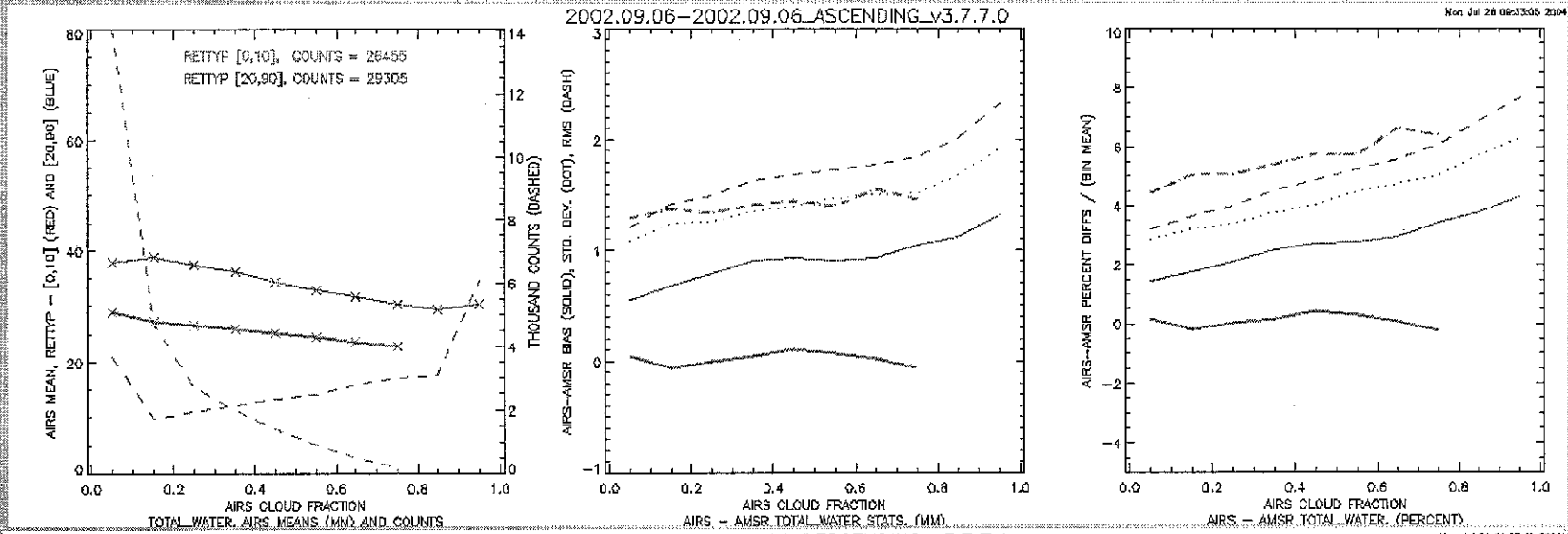
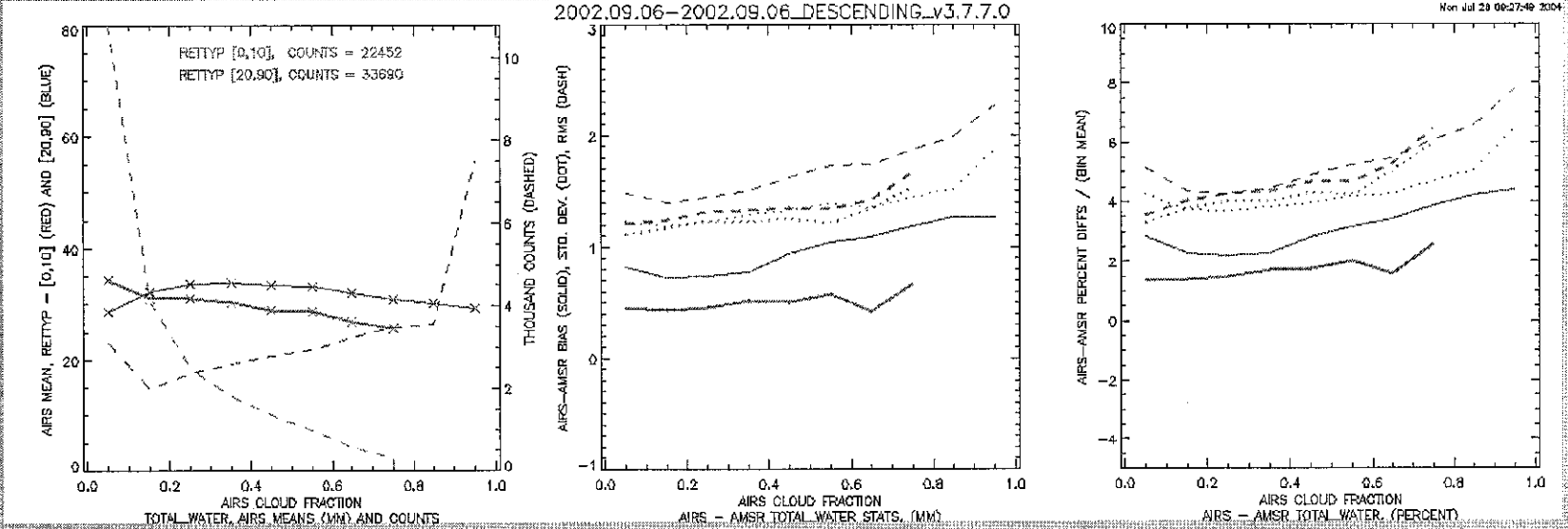
Differences as a function of retrieved cloud amount

Red: full retrievals; Blue: MW only

Ascending



Descending



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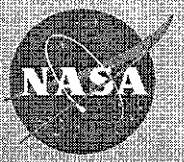

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Conclusions
Global Differences with AMSR-E Total Water

- **AMSR-E and AIRS total water are highly correlated for Full and MW-only AIRS retrievals.**
- **AIRS is wetter than AMSR-E by ~ 0.4 mm precipitable water at night; global mean AIRS = 32 mm.**
  - ***~1% bias at night***
  - ***no bias during daytime***
- **The distribution of differences is highly symmetric (gaussian?)**

Most Important:

- No bias with increasing cloud amount for full AIRS retrievals
- AIRS shows very slight negative bias for MW-only retrievals, approaching zero with cloud amount

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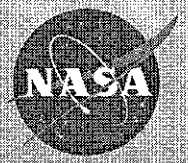

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Diagnosing The Effects of Clouds

Total Water, Ascending, Full retrievals

The basic premises:

1. **Errors in AIRS retrievals are scene dependent**
2. **Over-ocean scene variability is dominated by clouds.**

The basic conclusion:

- ***Understanding all AIRS products requires validating clouds.***

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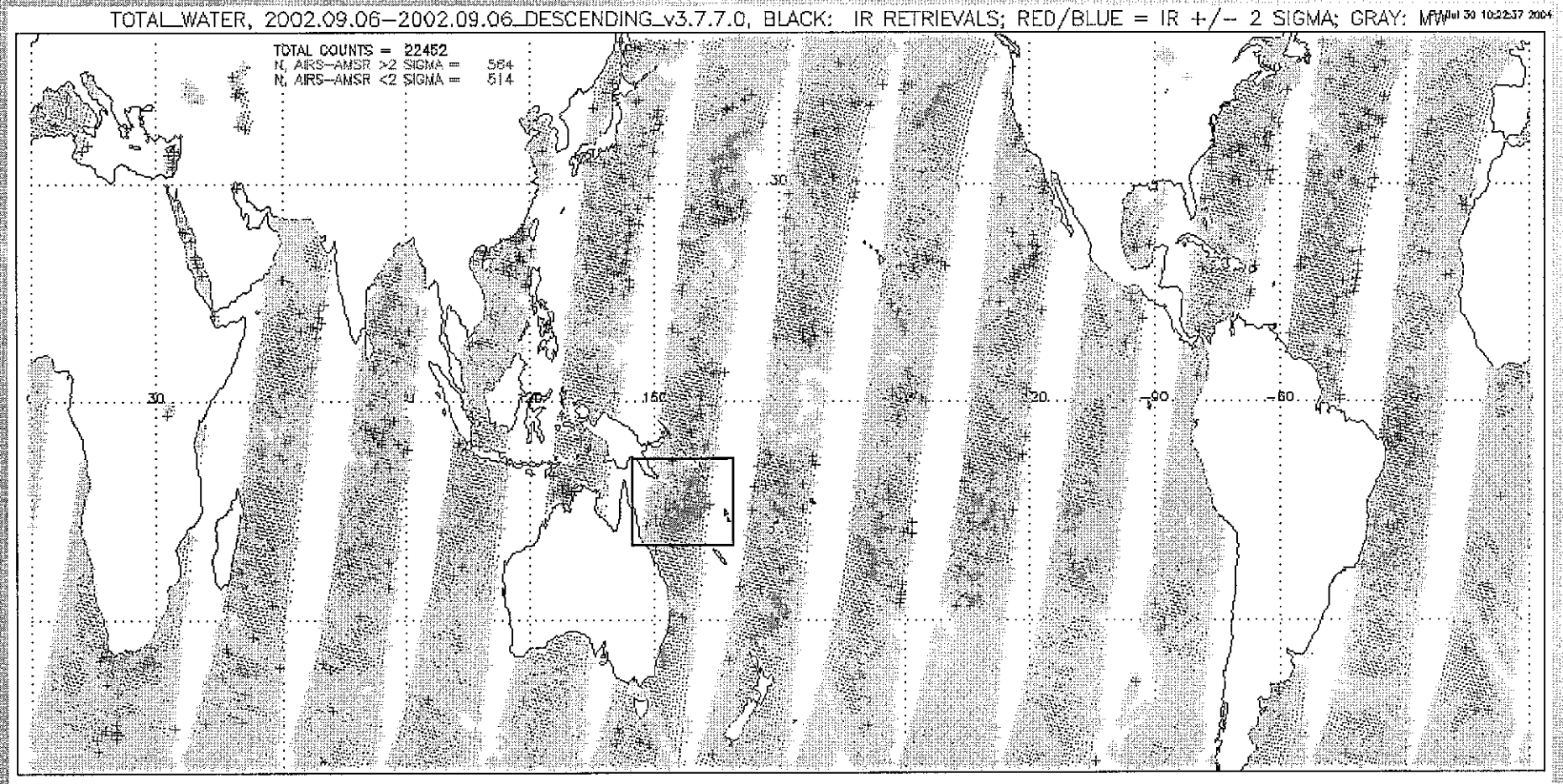
Differences Total Water with AMSR-E

Descending, Full retrievals



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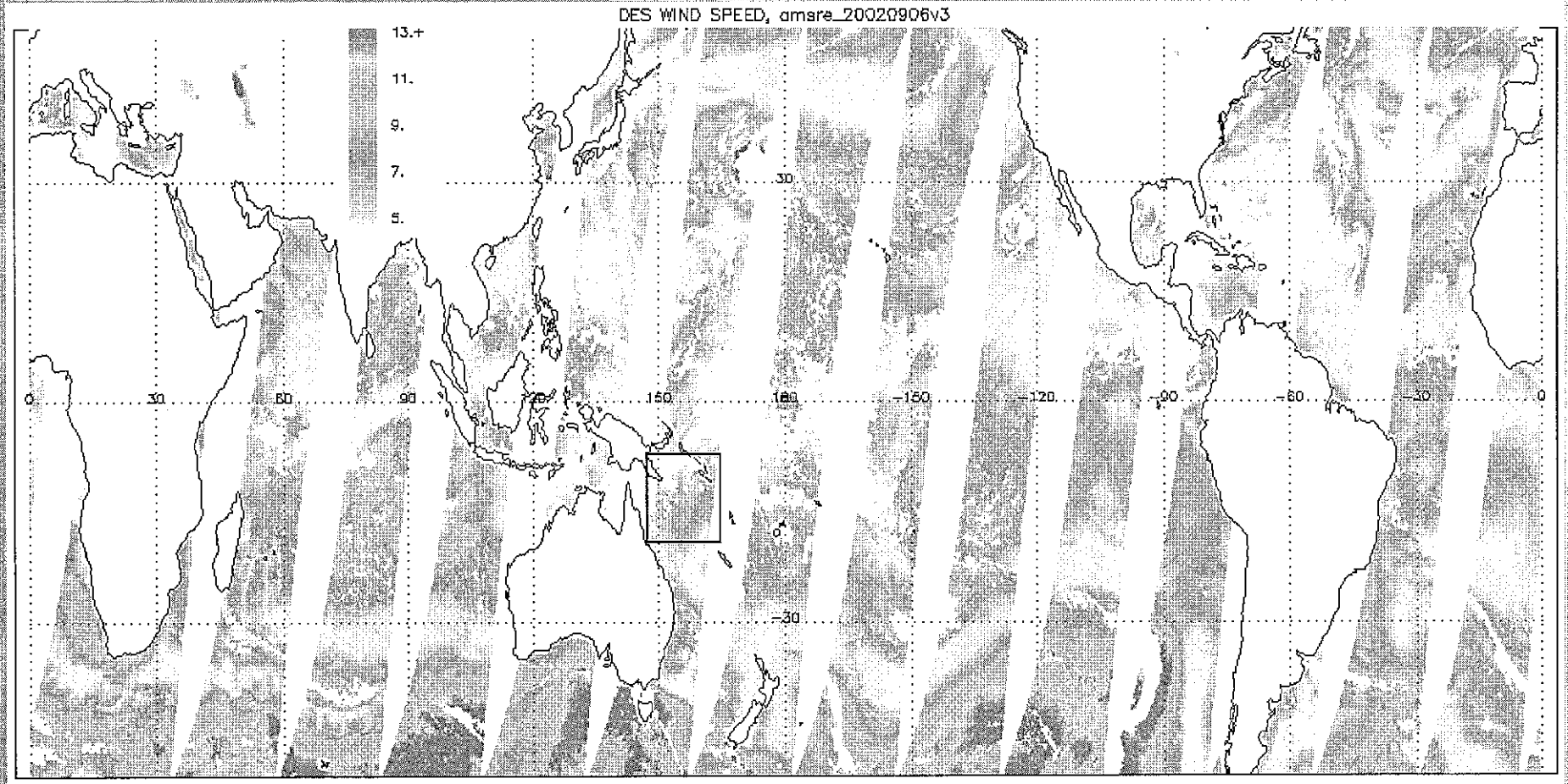
AMSR-E winds do not predict diffs in Total Q

=> *Don't blame surface wind effects*



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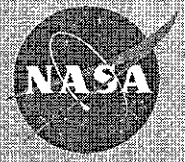

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Validating AIRS Clouds with MODIS

Work primarily by Brian Kahn

***Assumption*: Terra heritage means Aqua MODIS clouds are better understood than AIRS clouds**

=> AIRS-MODIS consistency is a good thing

Approach:

- **Use Liam Gumley's collocation code to match AIRS and MODIS.**
- **Compare averaged radiances first**
- **Dig deeper to understand causes of differences**
- **Look in the vicinity of ARM sites for ground truth.**

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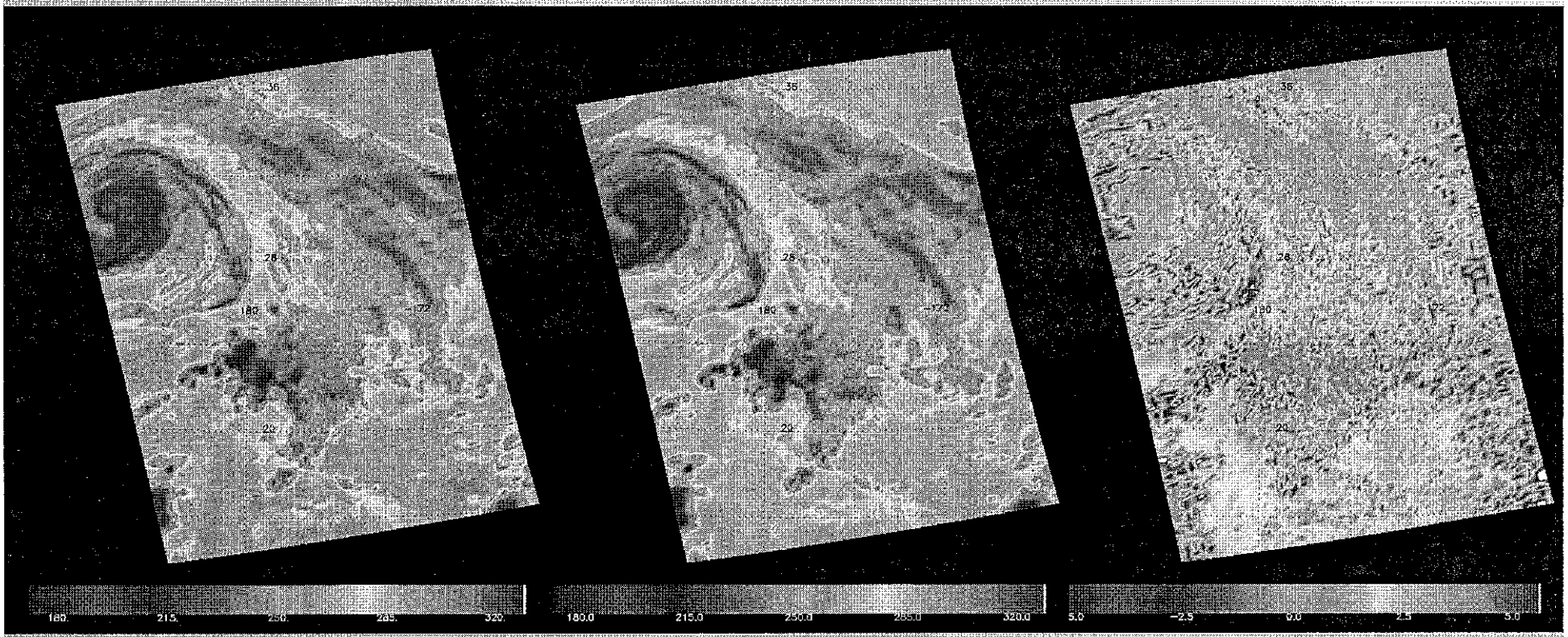
AIRS and MODIS, spatially and spectrally registered



AIRS BT spectrally-Avg'd to MODIS Chan. 31

MODIS Chan.31 spatially-avg'd to AIRS footprint

Difference of Two plots

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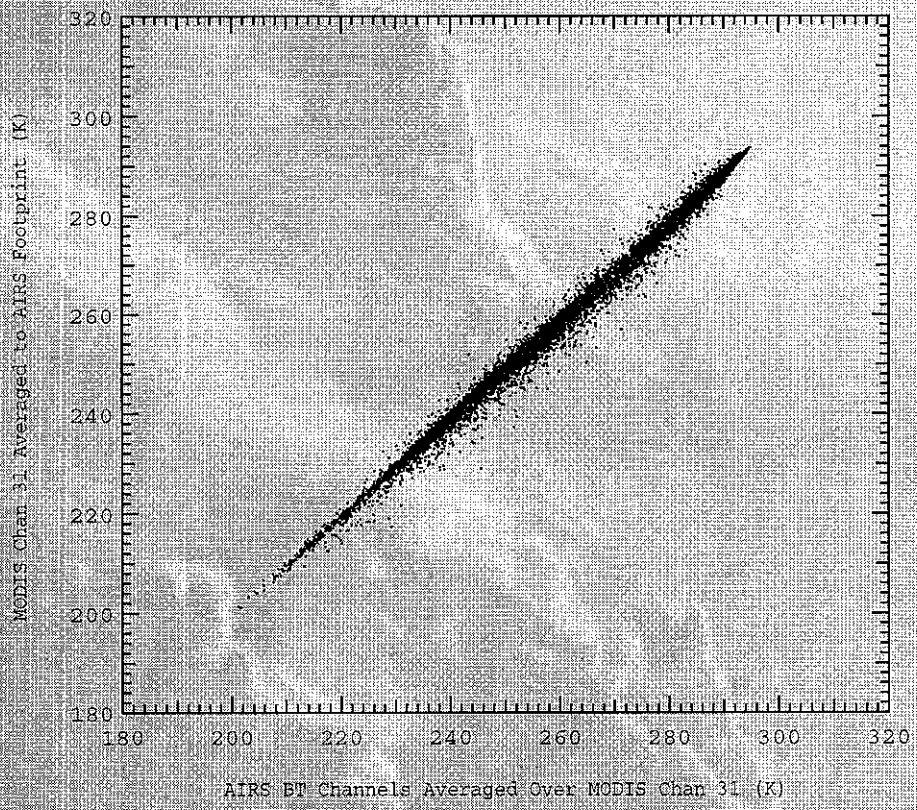
AIRS is Slightly Warmer



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Summary of Validation Results

- **AIRS is meeting 1 K / km in temperature and 15% / 2 km in water vapor**
- **Comparisons with AMSR-E show no cloud-dependent mean biases**
  - ***Locally biased, however.***
- **We a beginning to cross-compare AIRS and MODIS cloud properties to:**
  - ***Better understand scene-dependent biases.***
  - ***Demonstrate the usefulness of AIRS cloud parameters.***

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Some Science with AIRS Retrieved Products

Interpretation is the real validation exercise. Several examples today:

- **Subtropical temperature inversions and associated water vapor fields.**
- **Equatorial Kelvin Waves**
  - ***AIRS provides the first direct observations of temperature and humidity together.***
- **Upper tropospheric processes**
  - ***AIRS water vapor and ozone and proving useful in understanding stratosphere-troposphere exchange.***

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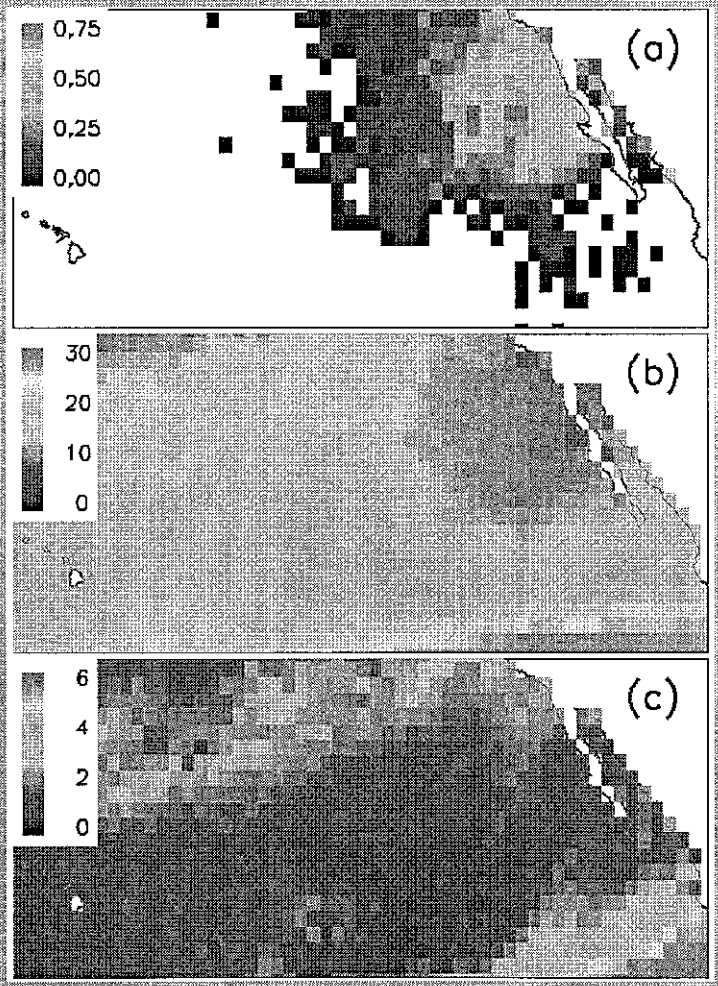
Occurrence Frequency of Temperature Inversions and Water Vapor Distribution

From 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.



Frequency of temperature inversions

1-15 January 2003

1000-700 hPa water vapor (mm)

700-500 hPa water vapor (mm)

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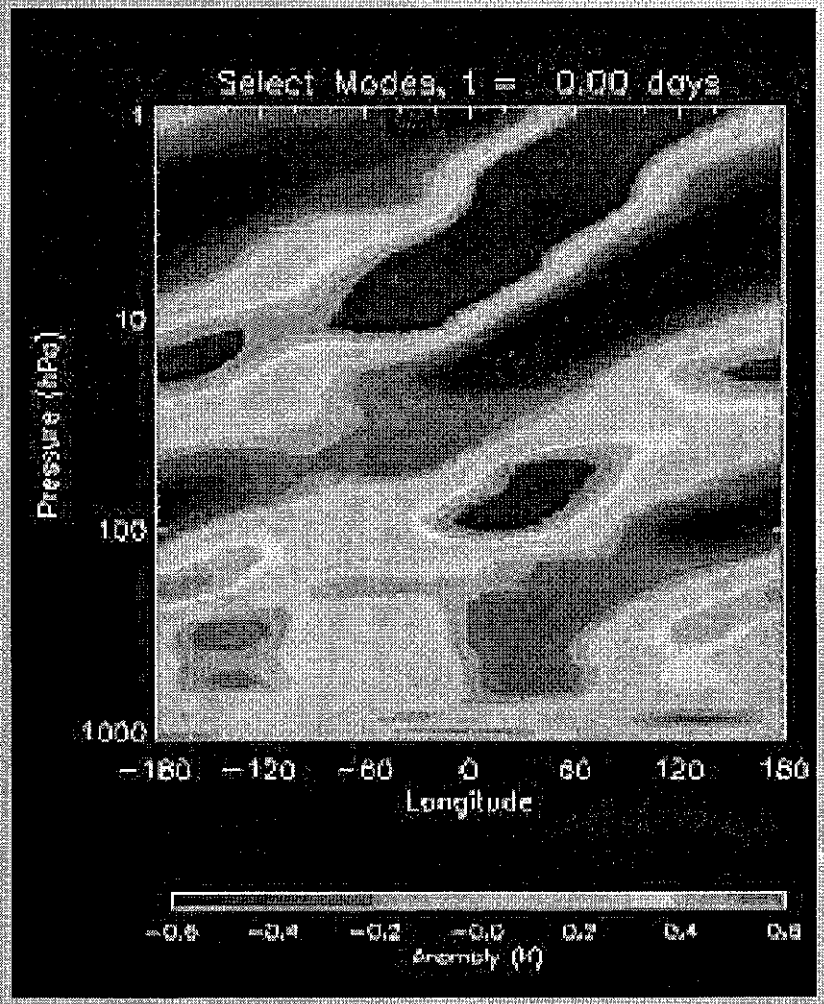
Tropical Kelvin Waves

See **S. S. Leroy, E. J. Fetzer and S. L. Granger, The interaction of Atmospheric Kelvin waves with humidity and convection as observed in AIRS data. Submitted to Journal of Geophysical Research, September 2004.**



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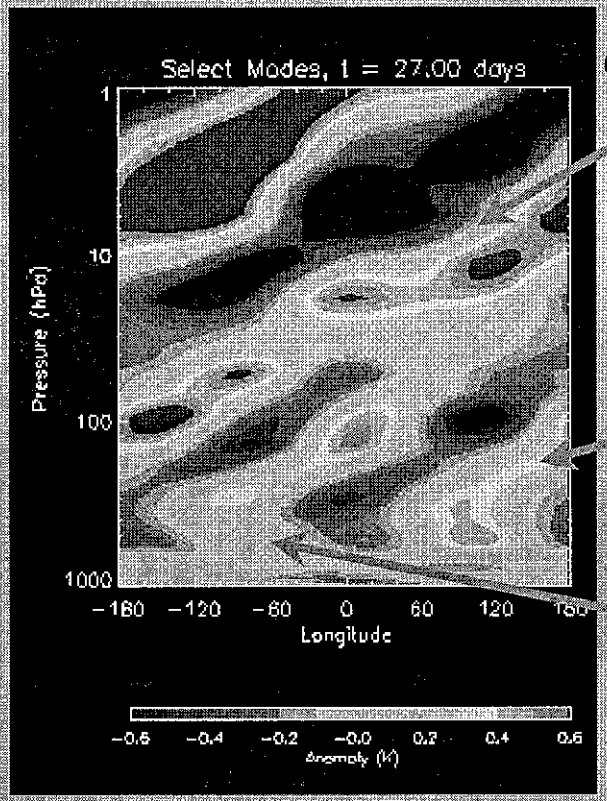
AIRS Kelvin Waves

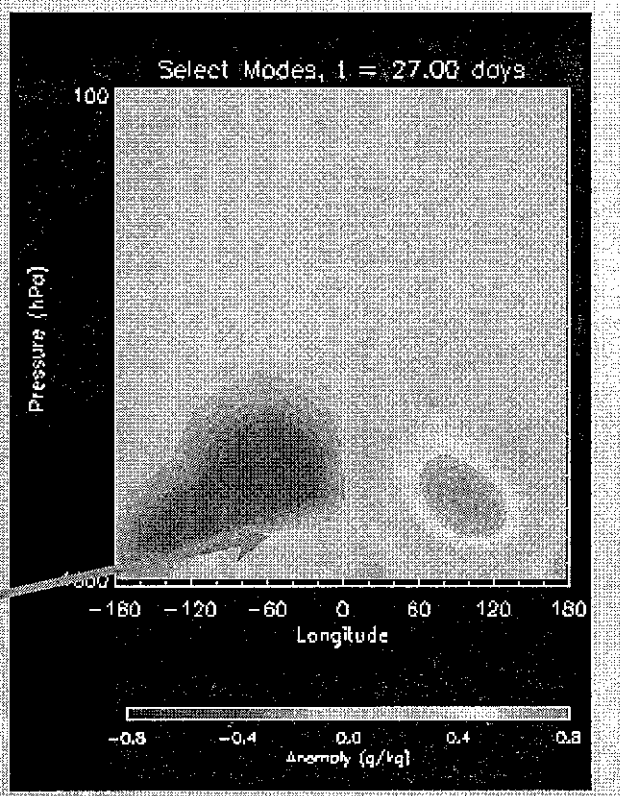
First Observations of Tropospheric Water Vapor Signal

Important Implications for Coupling Between Convection and Large Scales



Classic eastward phase tilt in T in middle atmosphere

Tropospheric T 'boomerang' (See Wheeler, Kiladas and Webster, J. Atmos. Sci. 2000)



T and q in phase in troposphere

Linear theory predicts phase quadrature!

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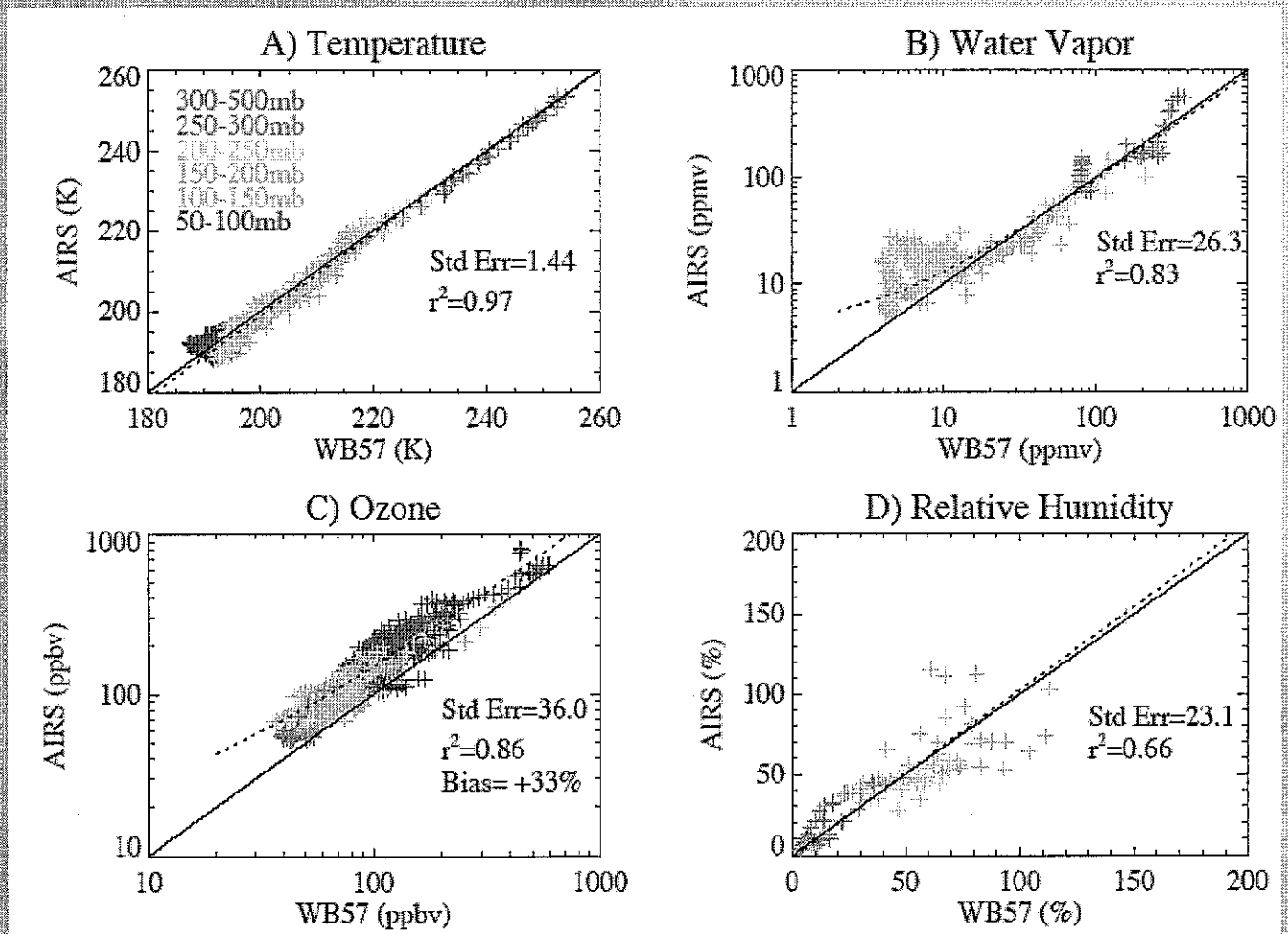
AIRS Upper Tropospheric Validation with Pre-Aura Validation Experiment aircraft data

From Gettelman, A., E. M. Weinstock, E. J. Fetzer, F. W. Irion, A. Eldering, E. C. Richard, K. H. Rosenlof, T. L. Thompson, J. V. Pittman,C. R. Webster and R. L. Herman, 2004, Validation of satellite data in the upper troposphere and lower stratosphere with in-situ aircraft instruments. *Geophys. Res. Lett.*, v. 31, L22107, doi:10.1029/2004GL020730.



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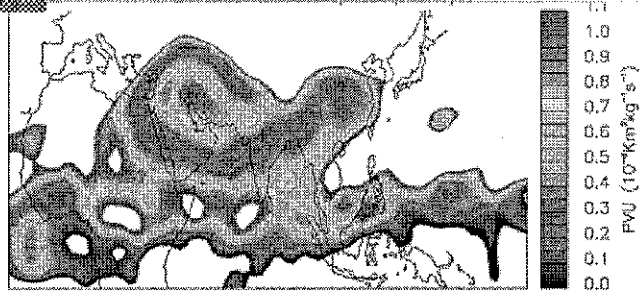
Relating AIRS Upper Trop Quantities to NCEP Potential Vorticity over Monsoon

Courtesy of Mijeong Park, NCAR

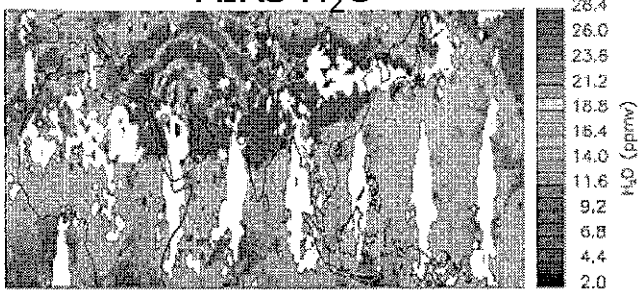
AIRS V3.0

JUL 12 2003

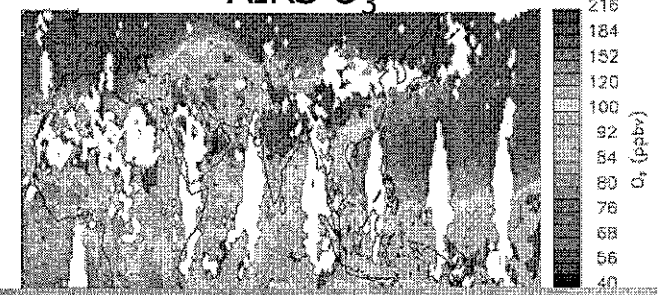
NCEP PV



AIRS H_2O

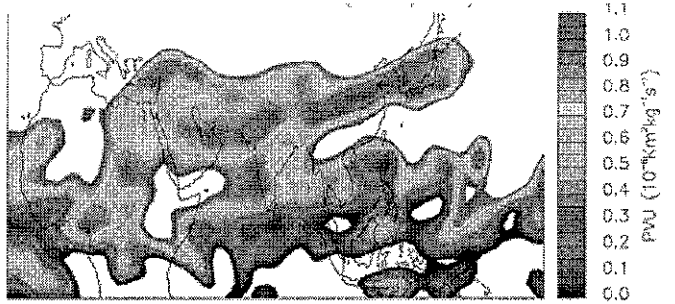


AIRS O_3

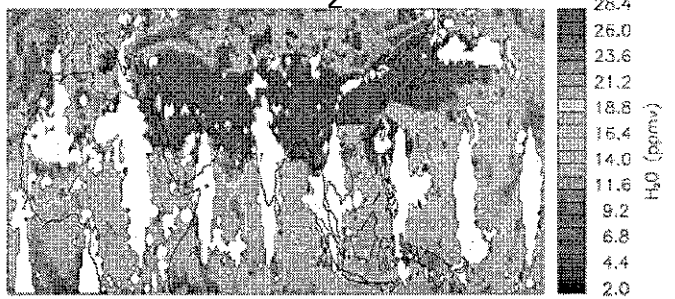


AUG 3 2003

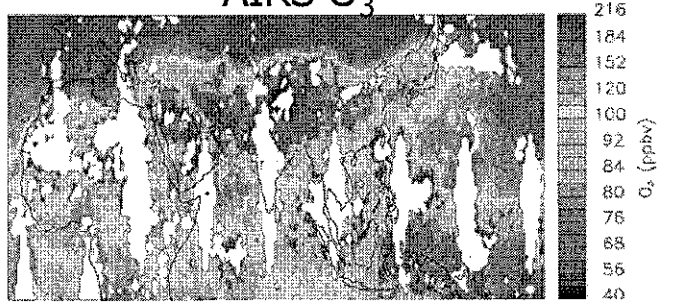
NCEP PV



AIRS H_2O



AIRS O_3



Potential temperature = 357 K;

p ~150-200 mb

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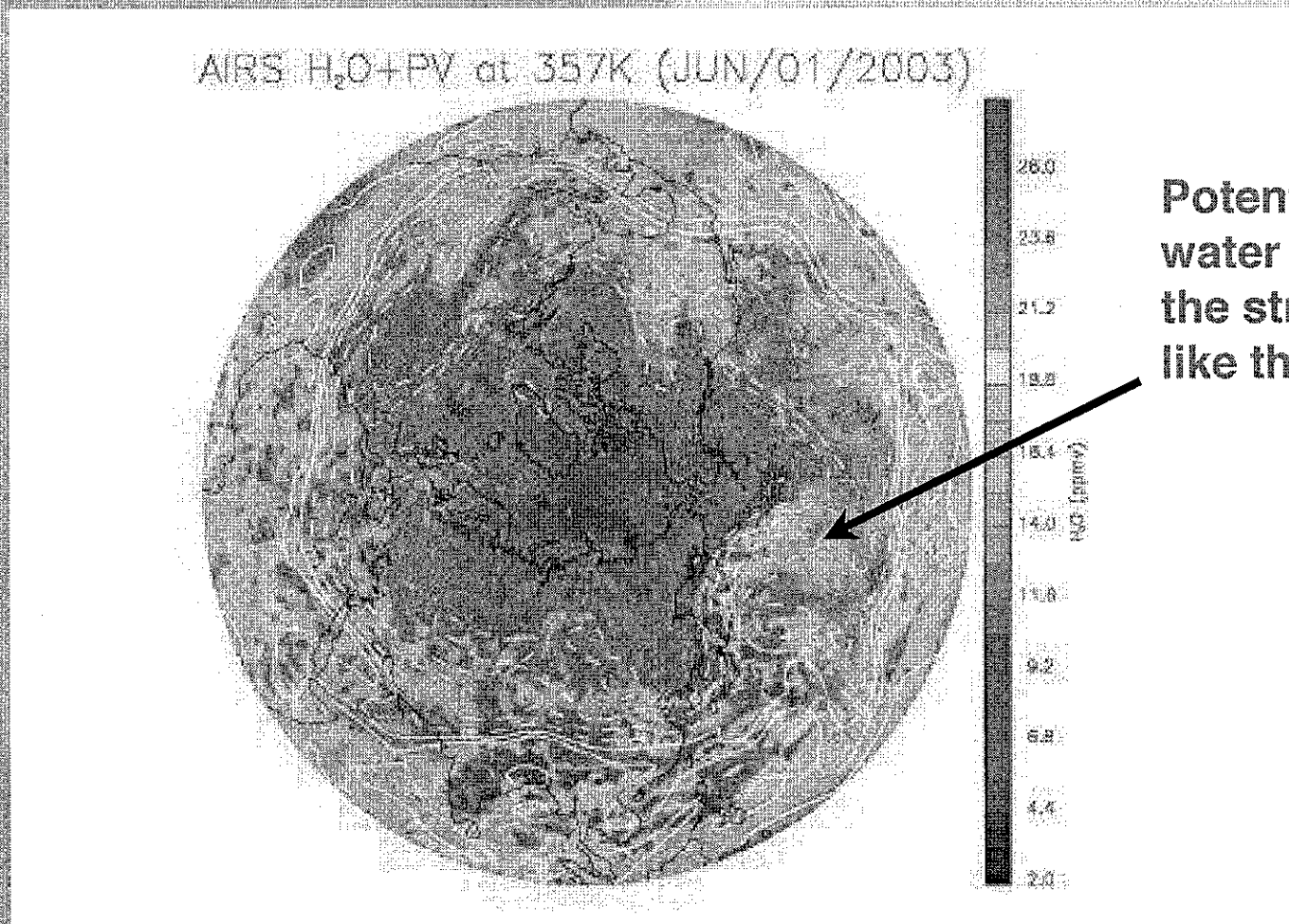
Stratosphere Troposphere Exchange of H2O? Still from a movie of June-October 2003

Courtesy of Mijeong Park, NCAR



Potential for quantifying water vapor transport into the stratosphere in events like this.

AIRS V3.0

Theta = 357 K

p ~150-200 mb

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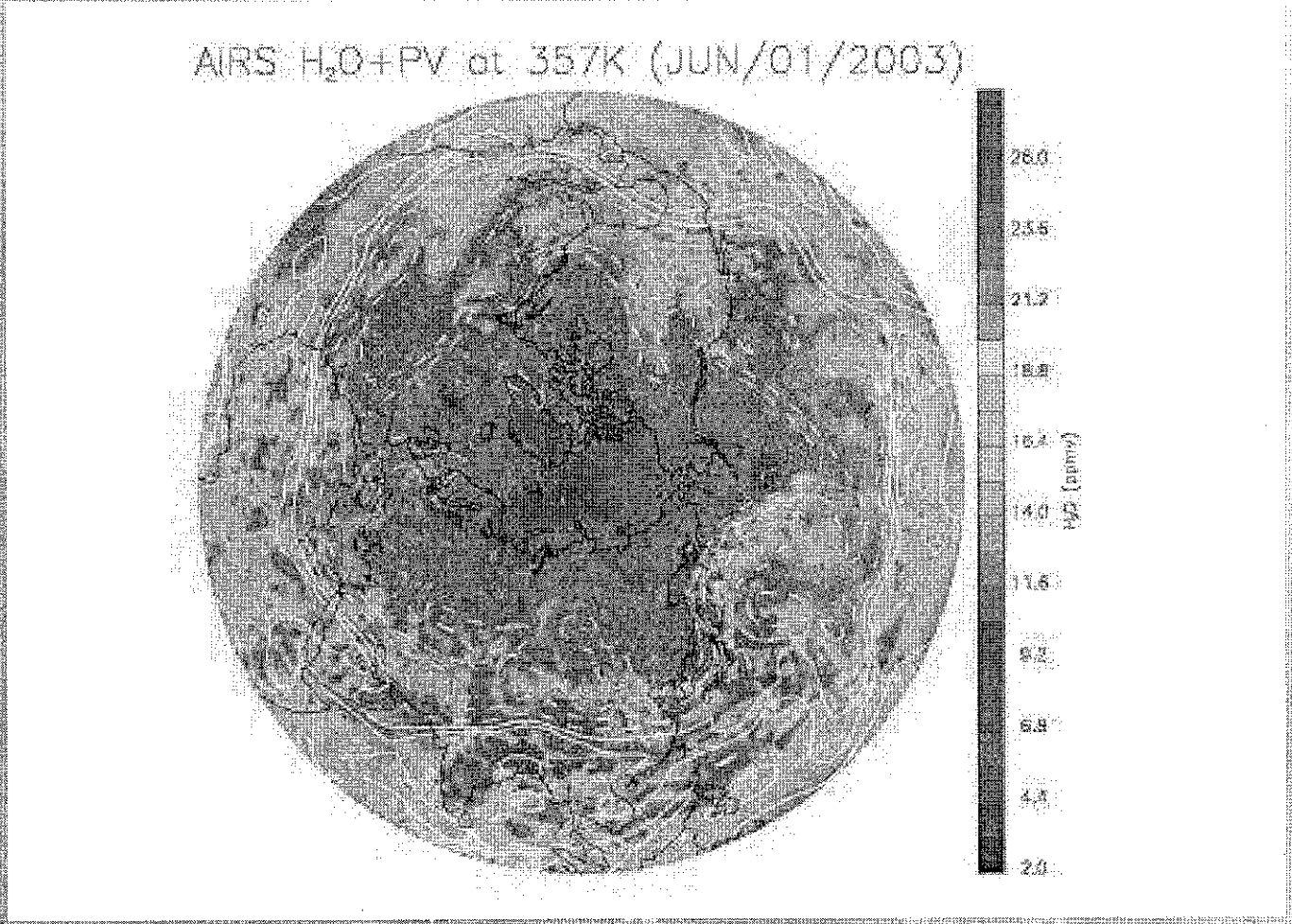
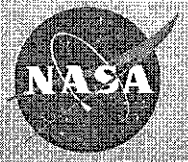
AIRS Upper Trop Water Vapor
Courtesy of Mijeong Park, NCAR



Eric.J.Fetzer@jpl.nasa.gov



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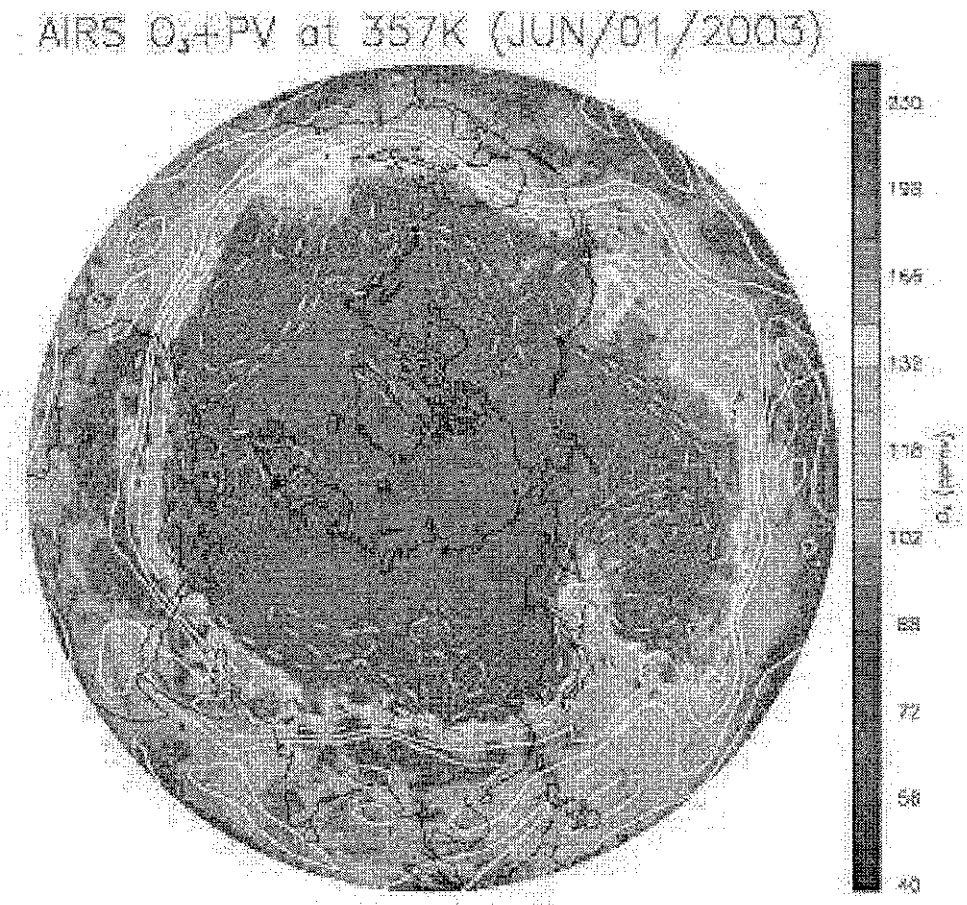
AIRS Upper Trop Ozone
Courtesy of Mijeong Park, NCAR



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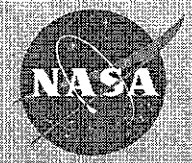

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AIRS 'Relative Humidity'
Courtesy Andrew Gettelman, NCAR

- AIRS Data has good error characteristics for T & Q in UT/LS
  Validation paper to in GRL
- Construct RH from T & Q data
  Use L2 data: each profile of T & Q
- Results indicate geophysical variability
  Seasonality as observed.
  Interesting differences from climate models
- Investigating RHi > 100%: Supersaturation
  Unprecedented ability to quantitatively examine UTH

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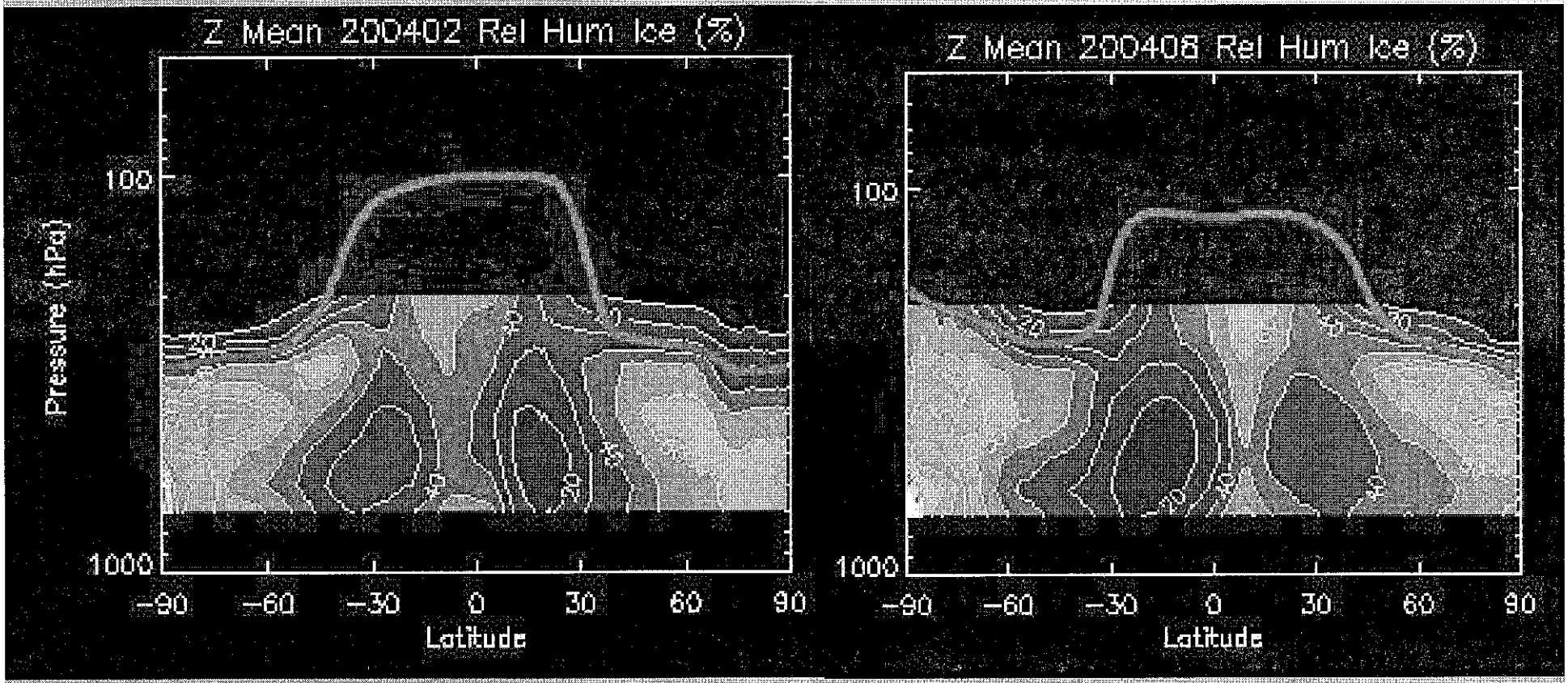
AIRS RHi Observations

Courtesy Andrew Gettelman, NCAR



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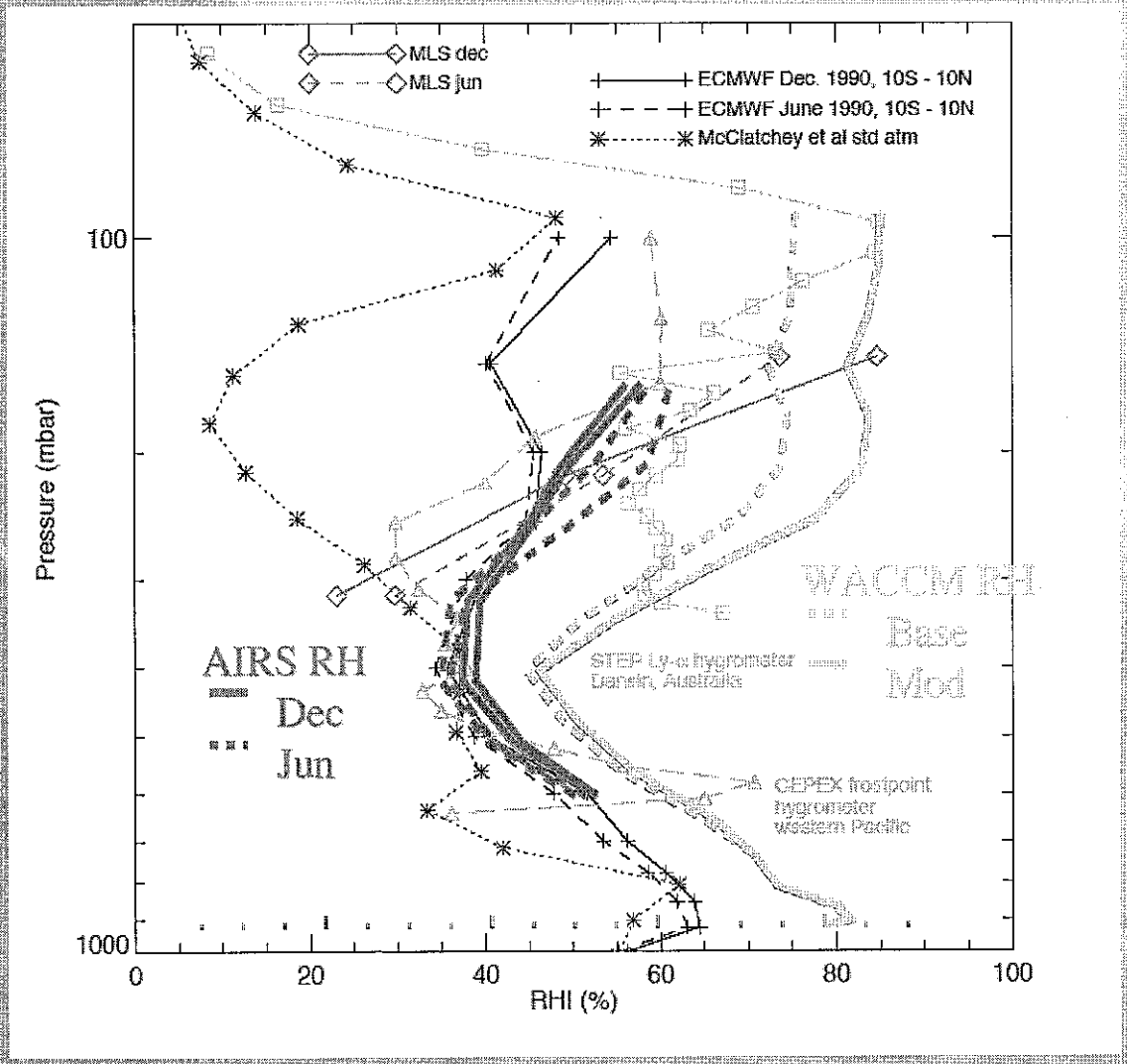
RH Comparison ±10 Lat (A. Gettelman, NCAR)

AIRS RH compares well to ECMWF & MLS; different than GCM



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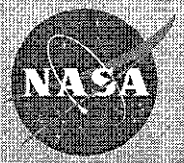

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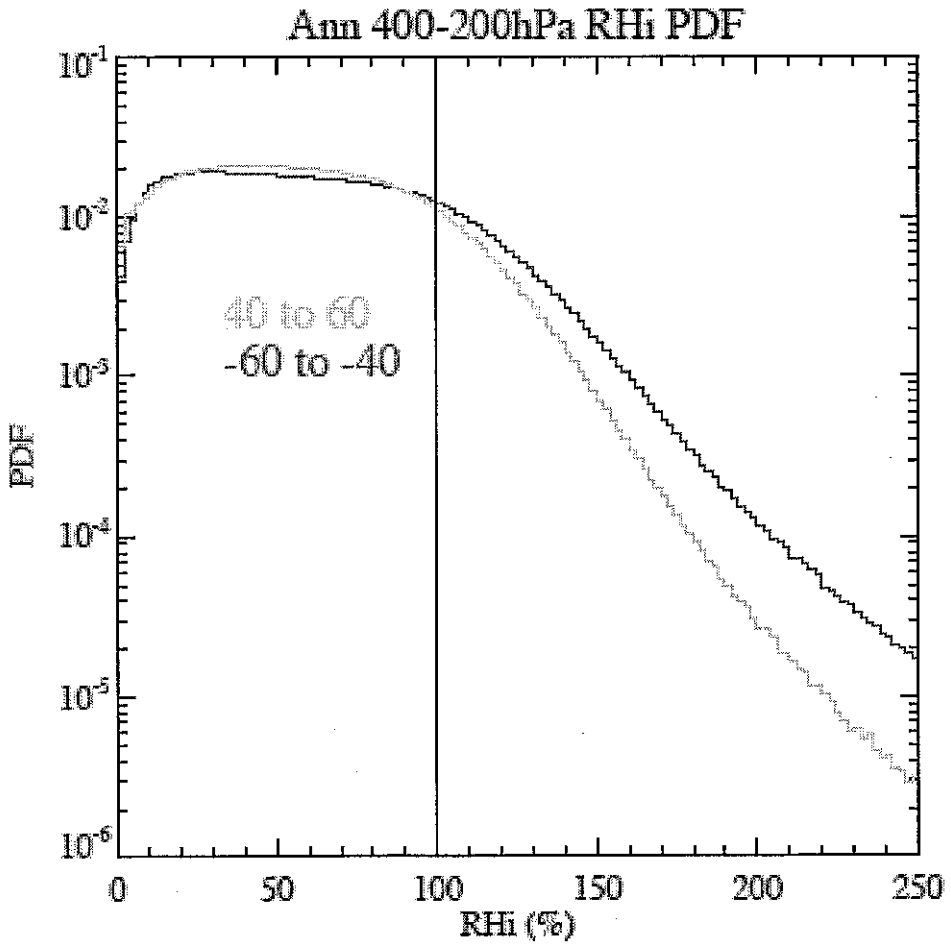
AIRS RHi Interhemispheric Differences

Courtesy Andrew Gettelman, NCAR

Consistent with aircraft observations



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