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Standard and Research Products from the AIRS and AMSU-A on the EOS Aqua Spacecraft

Thomas S. Pagano*, Moustafa T. Chahine, Hartmut H. Aumann, Bjorn H. Lambrigtsen, Eric J. Fetzer, Frederick W. Irion, Edward T. Olsen, Stephanie Granger, Sung-Yung Lee, Thomas Hearty, Vincent J. Realmuto, Michael Gunson

NASA Jet Propulsion Laboratory

(*Current Employer: Optical Physics Corporation, Calabassas, CA)

L. Larrabee Strow, Wallace McMillan

University of Maryland Baltimore County

Joel Susskind

NASA Goddard Space Flight Center

Outline

- **AIRS Project Overview**
- **AIRS Core Products**
  - ***Validation***
- **Weather Forecasting**
- **Supporting Climate Modeling**
- **Research Products**
  - ***Atmospheric Trace Gas Composition***
  - ***Aerosols***

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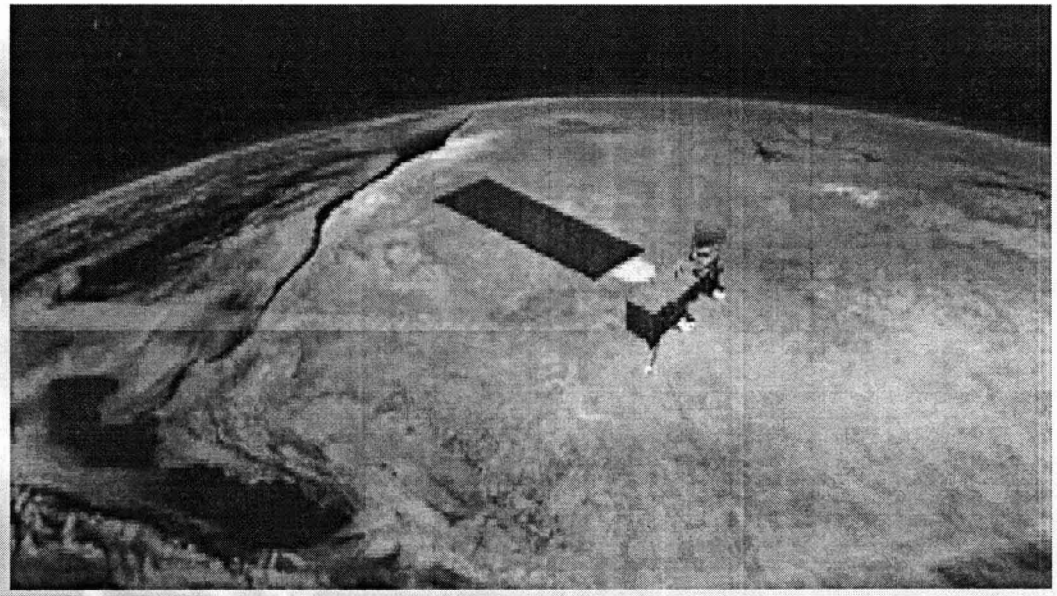
AIRS/AMSU/HSB Project Overview



Spacecraft:	EOS Aqua
Instruments:	AIRS, AMSU, HSB,
	(MODIS, CERES, AMSR-E)
Launch Date:	May 4, 2002
Mission Life:	5 years (Nominal)
Team Leader:	Mous Chahine

AIRS Project Objectives

1. Weather Forecasting: AIRS Already Achieved 6 hours in 6 days improvement in NH with NCEP Operational Model (JCSDA)
2. Climate Studies: Atmospheric Hydrology Cycle
3. Tropospheric Composition: O_3, CO, CO_2, CH_4, ...

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AIRS/AMSU/HSB Standard Products

Radiance Products (Level 1B)	RMS Requirement	Current Estimate
AIRS IR Radiance	3%*	<0.2%
AIRS VIS/NIR Radiance	20%	10-15%
AMSU Radiance	0.25-1.2 K	
HSB Radiance	1.0-1.2 K	N/A
Standard Core Products (Level 2)		
Cloud Cleared IR Radiance	1.0 K	<1.0 K
Sea Surface Temperature	0.5 K	0.8 K
Land Surface Temperature	1.0 K	TBD
Temperature Profile	1 K / km	1K / km
Humidity Profile	15% / 2 km	15% / 2km
Total Precipitable Water	5%	5%
Fractional Cloud Cover	5%	TBD
Cloud Top Height	0.5 km	TBD
Cloud Top Temperature	1.0 K	TBD

*Absolute Relative to NIST

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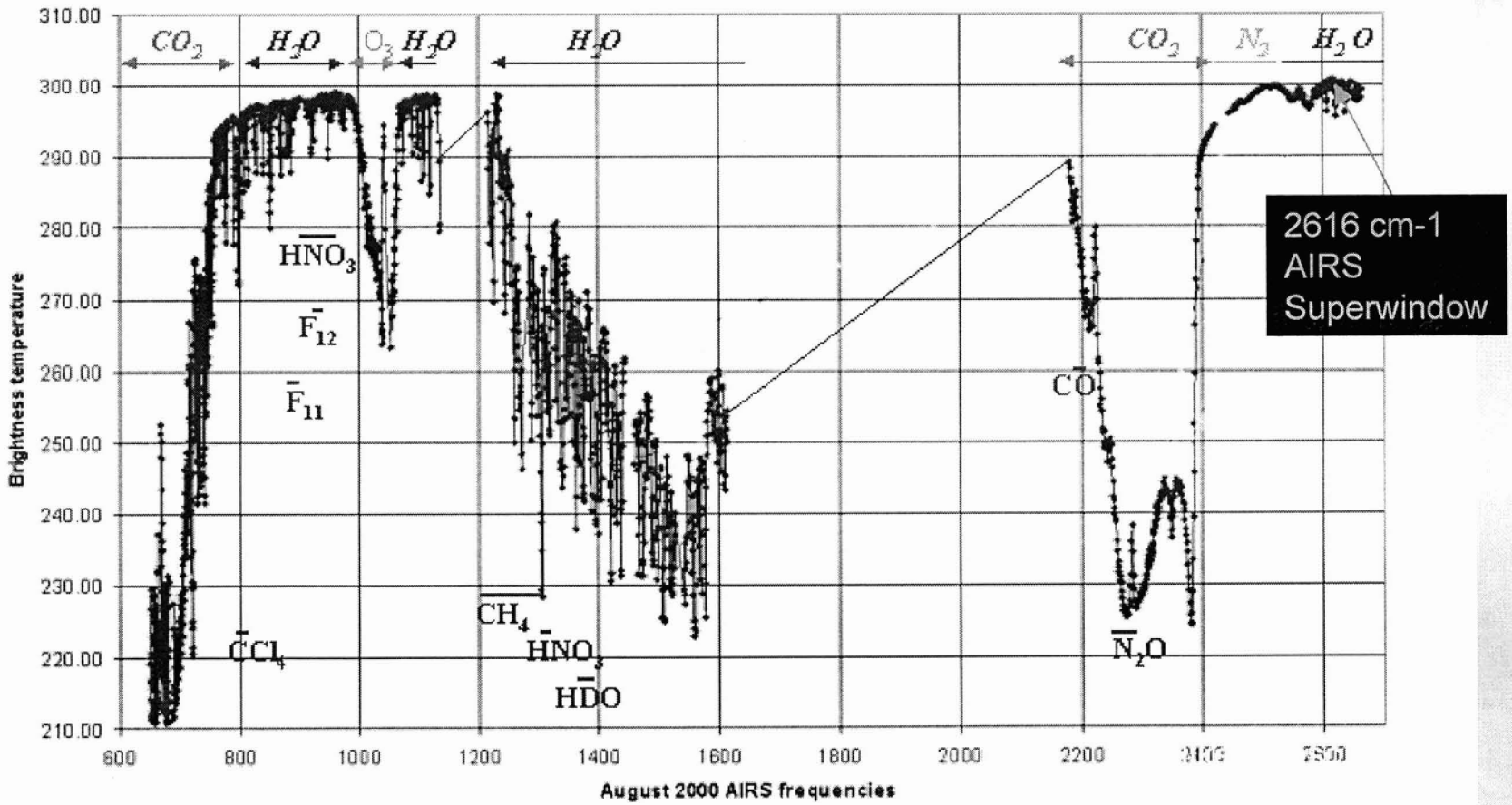
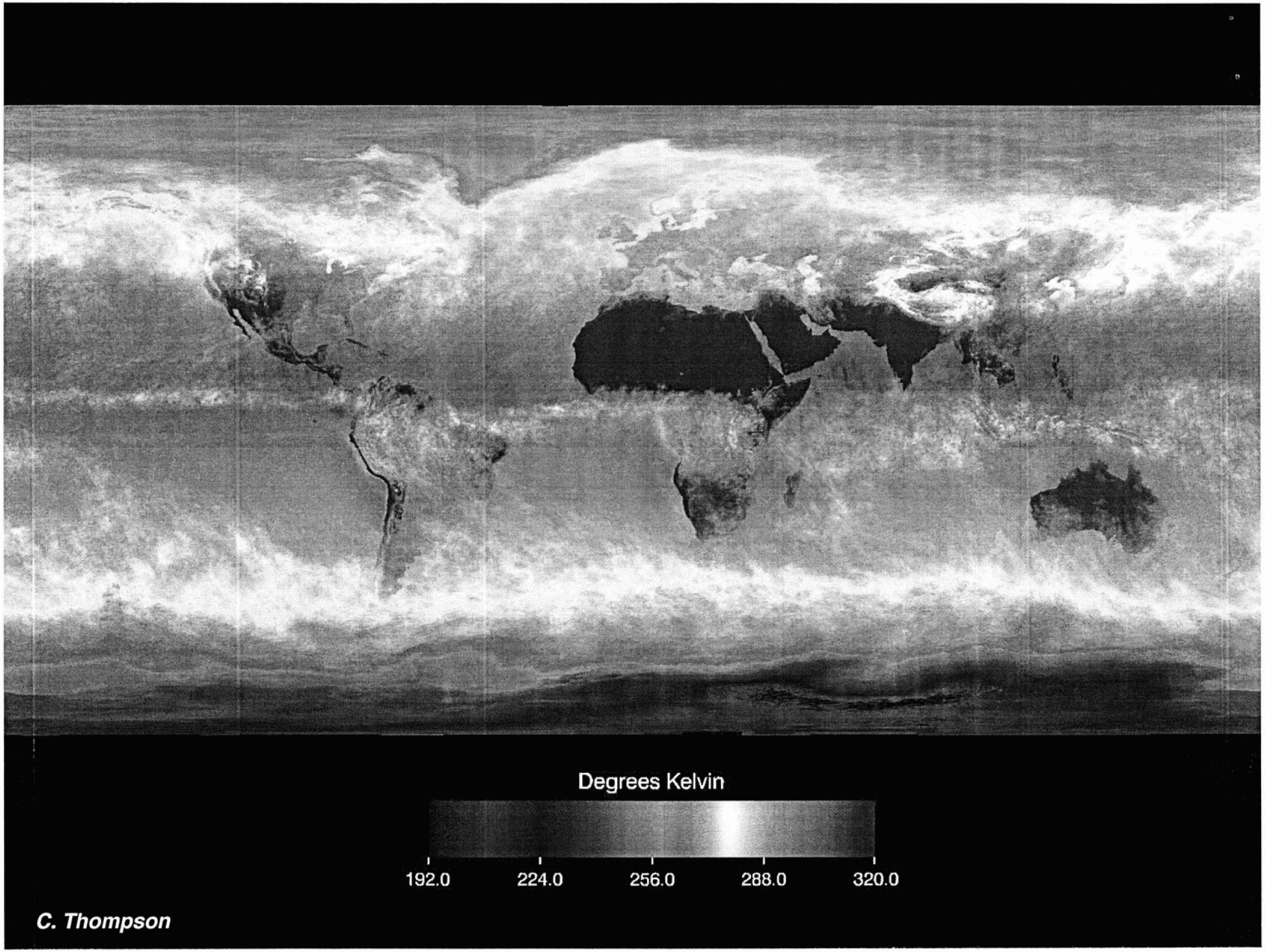
AIRS Spectrum Reveals State and Composition of the Atmosphere

AIRS Channels for Tropical Atmosphere with T_surf = 301K

Full Spectrum




Degrees Kelvin
192.0
224.0
256.0
288.0
320.0
C. Thompson

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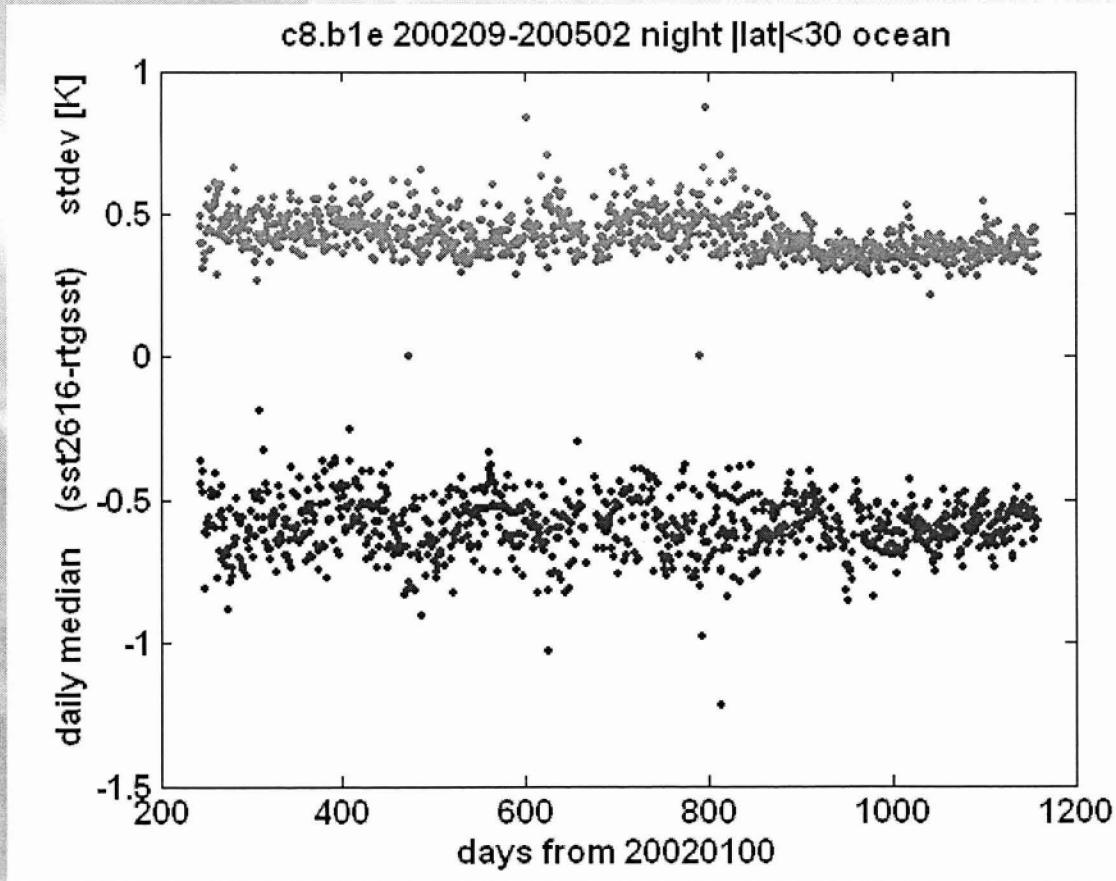
Infrared Radiances Stable and Accurate

- **AIRS 2616 cm^{-1} compared to RTG SST**
  - ***Bias (cold) -0.6K***
    - 0.3K because
      - *AIRS measures skin temperature*
      - *RTG is a bulk temperature about 2 meters below surface*
    - Another 0.3K due to residual clouds in "clear" footprints used in the analysis
  - ***Reduced scatter after day 900 (May 2003) due to RTG improvement***

AIRS Radiometric Performance: Stable to <8mK/Y – H. Aumann (JPL)



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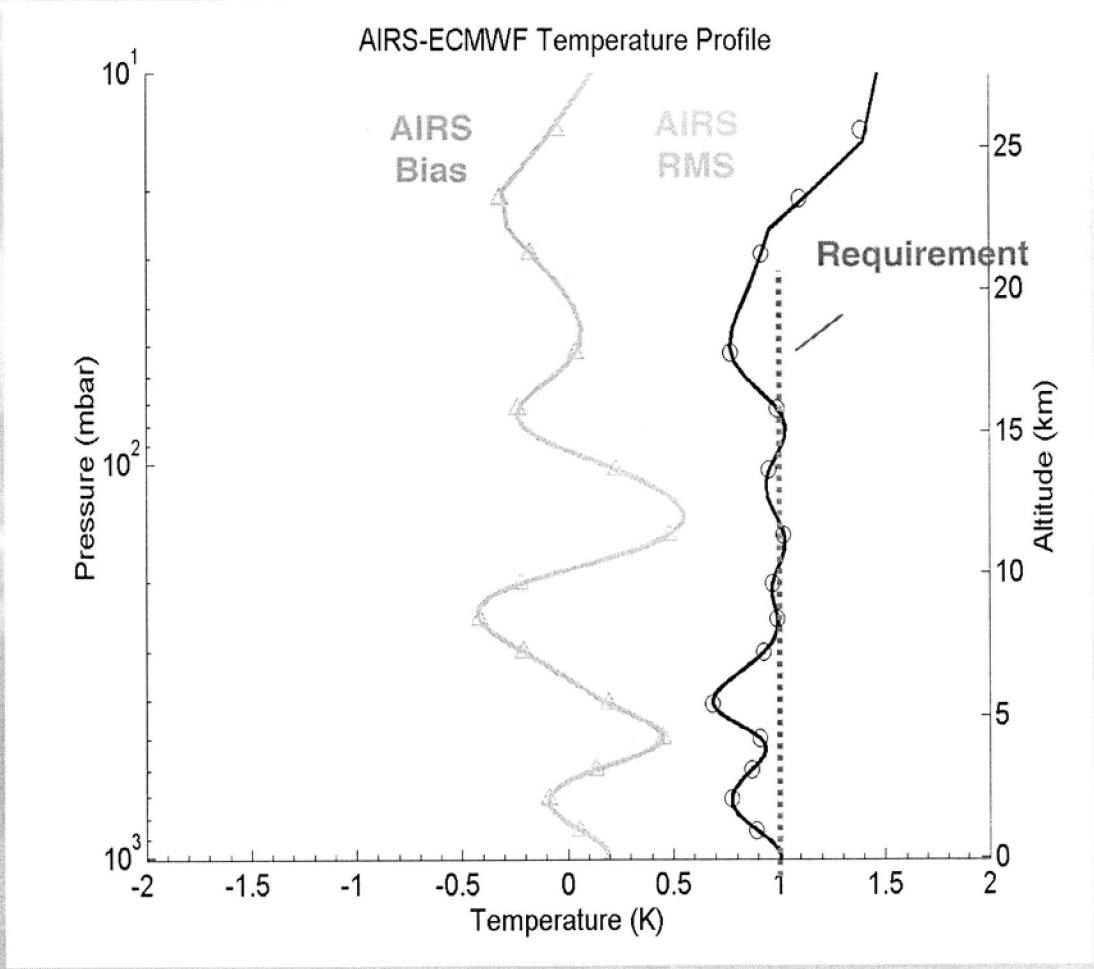
AIRS Temperature Profiles Validated

Temperature Profiles Accurate to 1K/km to 30 mb

Ocean, Mid Latitude vs ECMWF

- AIRS/AMSU-A generate 100,000 valid profiles per day
- Radiosondes produce only 4,000 per day
- Accurate soundings can be achieved for up to 80% cloud cover



(T. Hearty/JPL)

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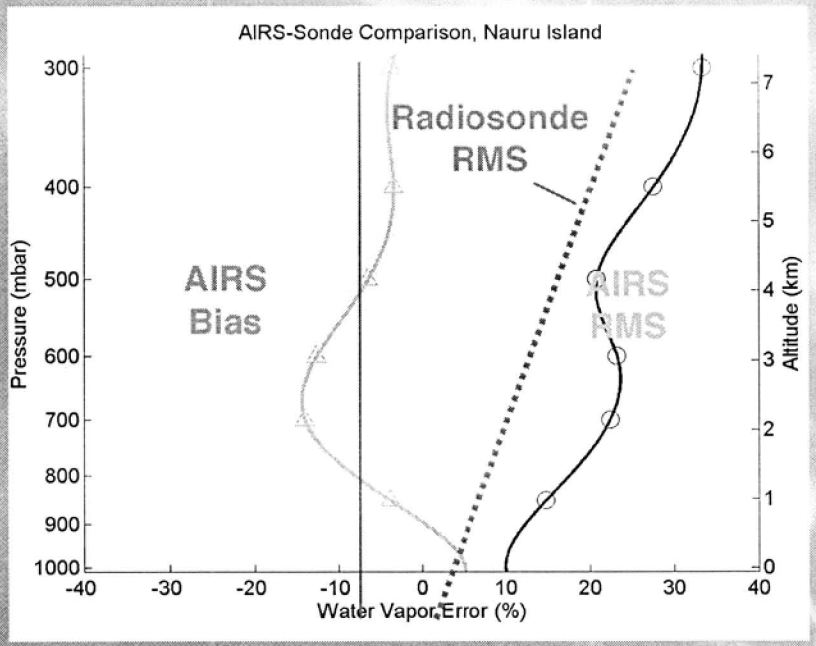
AIRS Shows High Accuracy and Horizontal Resolution of Water Vapor

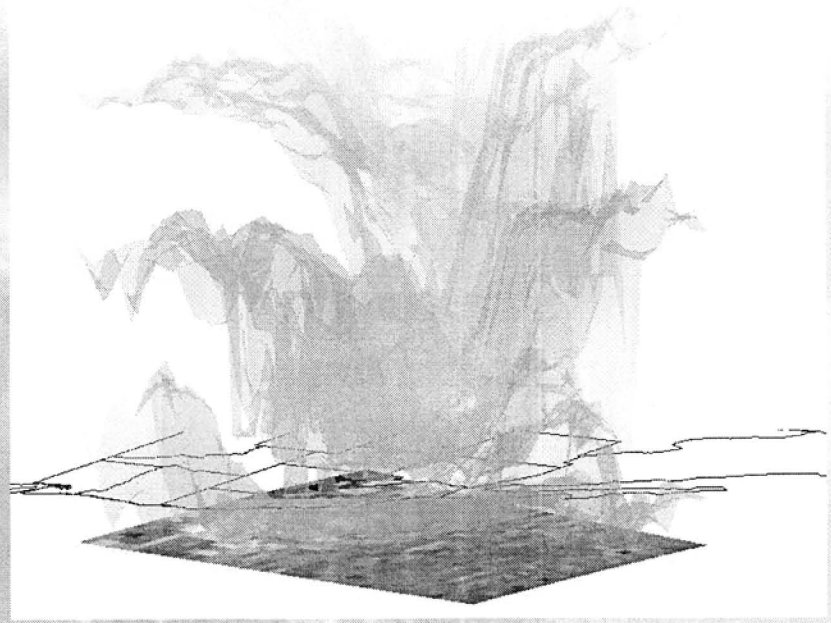
Water Vapor Profiles Match Radiosondes

Nauru Island Radiosondes



(E. Fetzer/JPL)

Isohyets Show Good Horizontal Resolution



T. Pagano (JPL)

Weather Forecasting Using AIRS Data

- **Several weather prediction centers around the world are studying the assimilation of AIRS/AMSU-A data for their forecasts**

- **At JCSDA (NOAA, NASA, and DoD Joint Center for Satellite Data Assimilation), AIRS radiance data have been assimilated in trials using the operational NCEP Global Forecast System (GFS)**

  - *Significant positive impact on forecast accuracy were observed*

  - *AIRS data will go into the operational forecast after the next NCEP upgrade*

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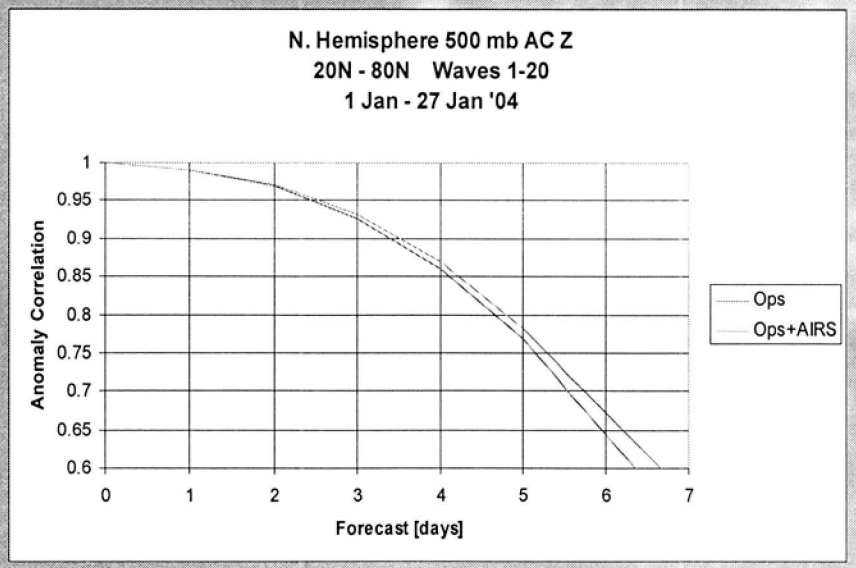
Assimilation of AIRS Radiances Improves Forecast Accuracy

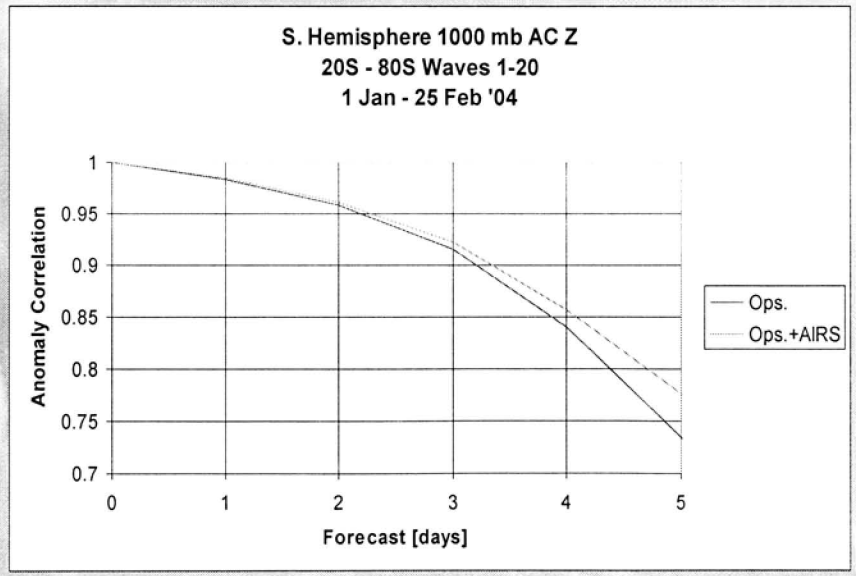
Joint Center for Satellite Data Assimilation (JCSDA)
NCEP Operational Model

"A several hour increase in forecast range at five or six days normally takes several years to achieve at operational weather centers" and "This magnitude of improvement is quite significant when compared with the rate of general forecast improvement over the last decade". **John Le Marshall** in EOS, March 15 2005, Vol 86, No 11

Northern Hemisphere (6 hrs on 6 Day Forecast)



Southern Hemisphere (8 hrs on 5 Day Forecast)



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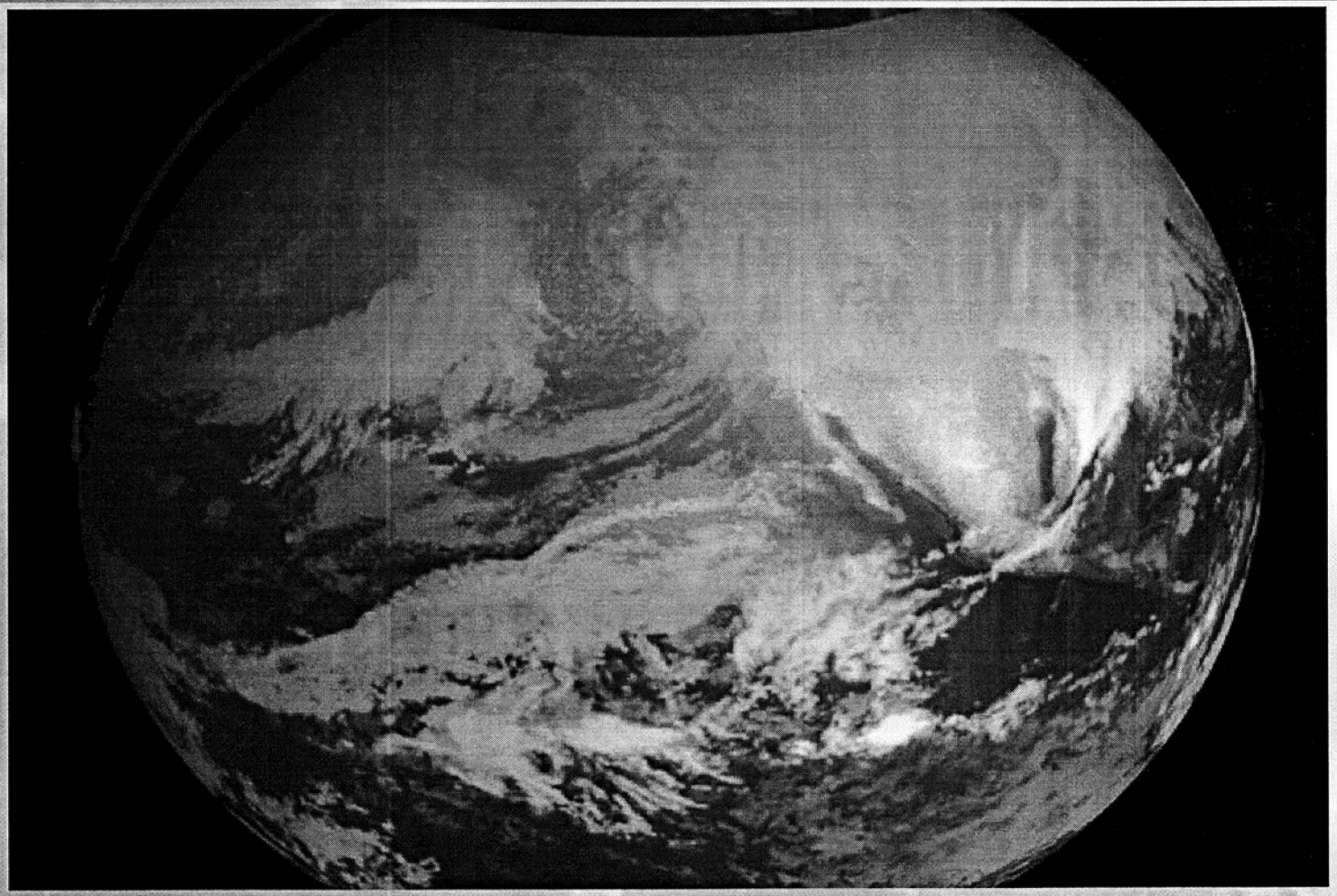
AIRS Water Vapor Expected to Enhance Weather Prediction



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Science Visualization Studio

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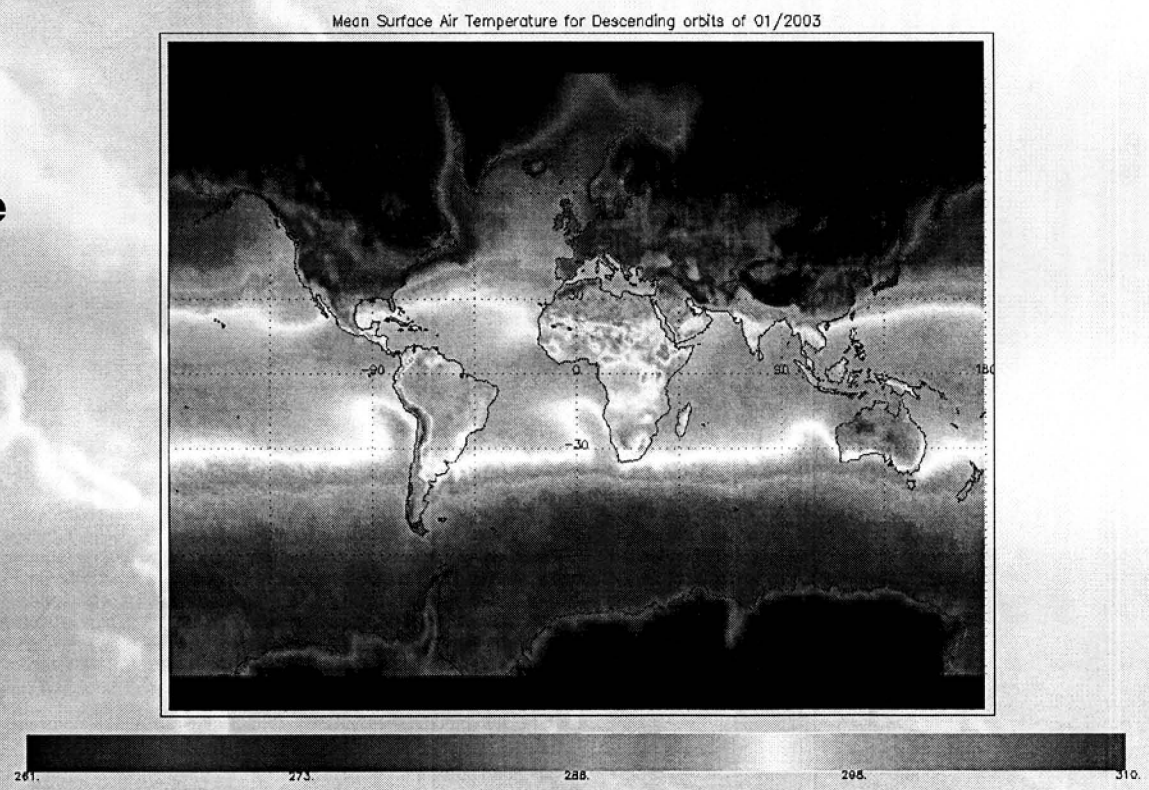
AIRS L3 Products

- Temperature Profile
- Temperature Profile MW
- Geopotential Height
- Water Vapor Profile
- Ozone
- Total Column Water
- Surface Air Temperature
- Surface Skin Temperature
- Vis Cloud Fraction
- Cloud Height
- Cloud Fraction
- OLR
- MW Surface Emissivity
- IR Emissivity

- Daily: 1°x1°
- 8-Day: 1°x1°
- Monthly: 1°x1°



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AIRS L3 Surface Air Temperature (July 2003)

C. Thompson, E. Olsen (JPL)

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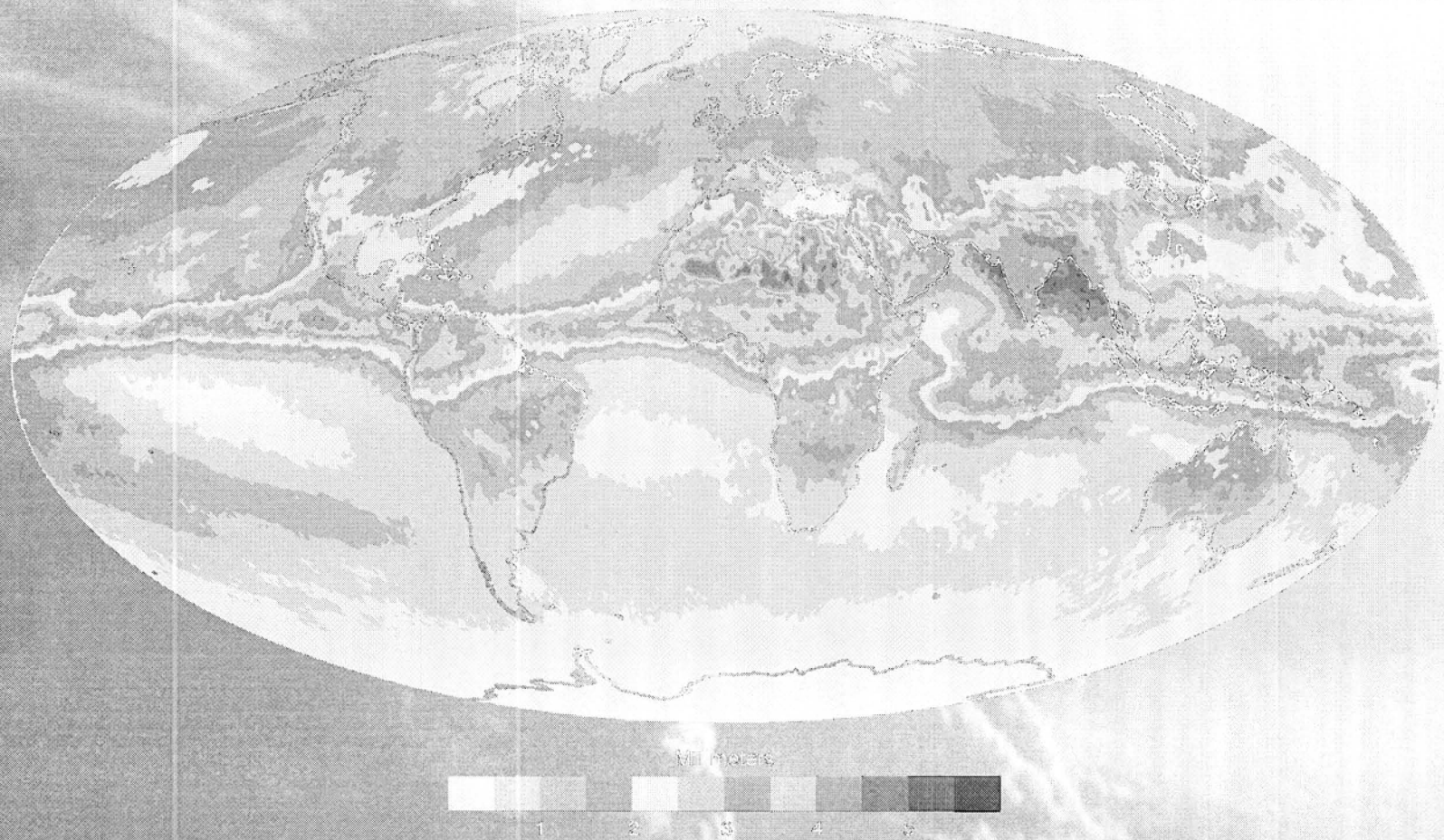
AIRS L3 Upper Atmospheric Water Vapor (July 2003)



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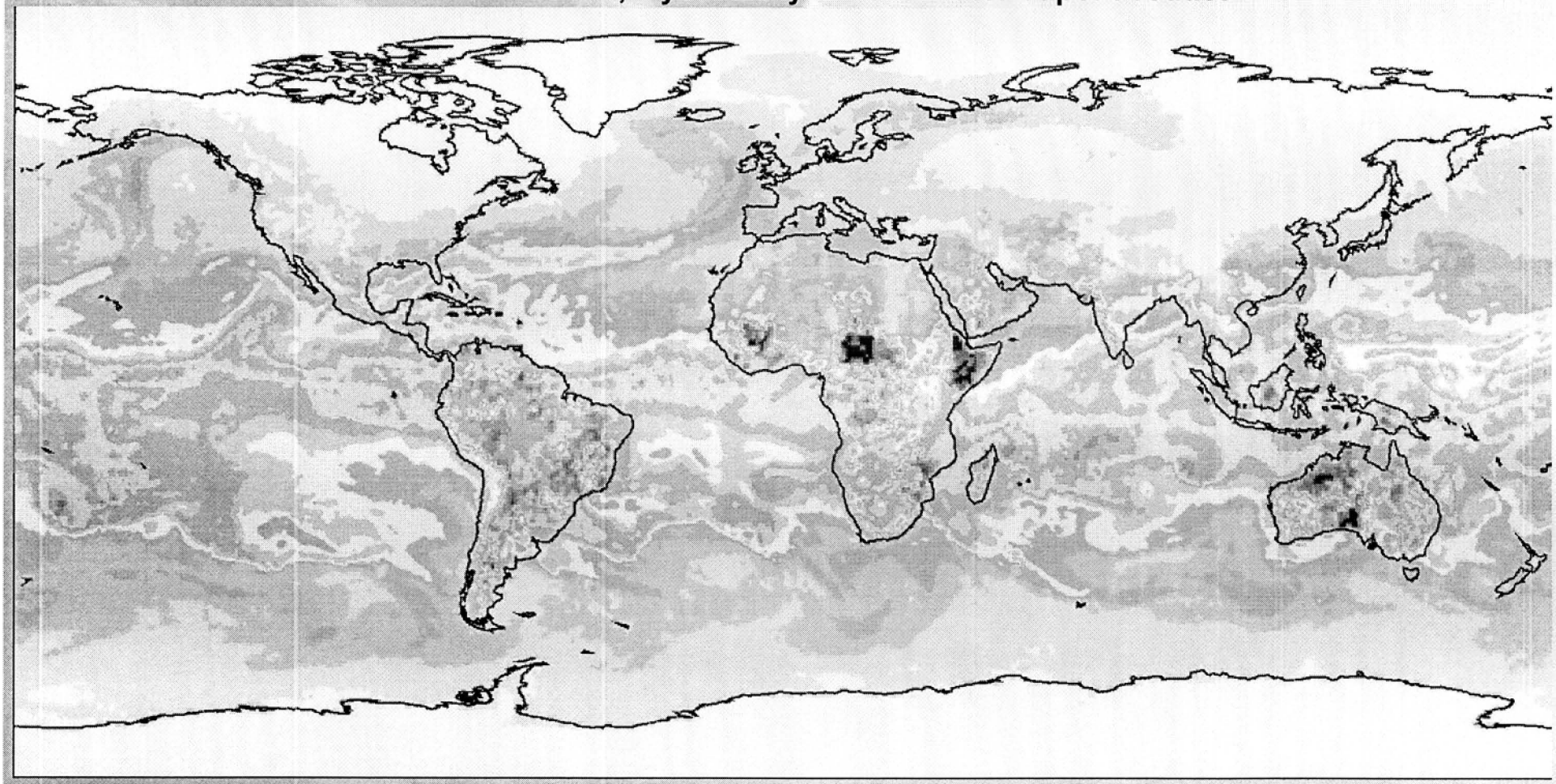
AIRS Provides Long Term Daily Record of Layer Water Vapor

700 mb – 900 mb, 2 year Daily Level 3 Water Vapor Product



S. Granger (JPL)

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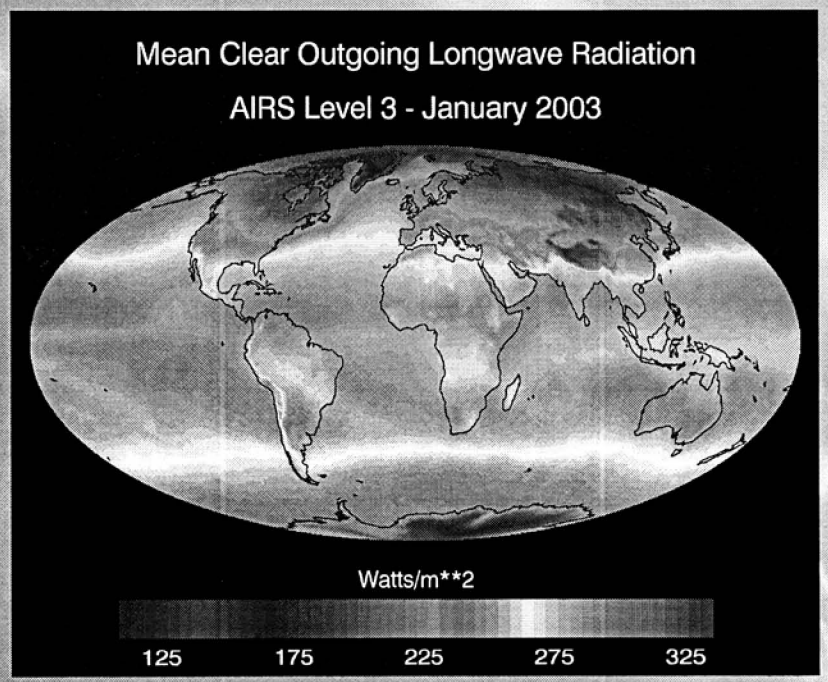
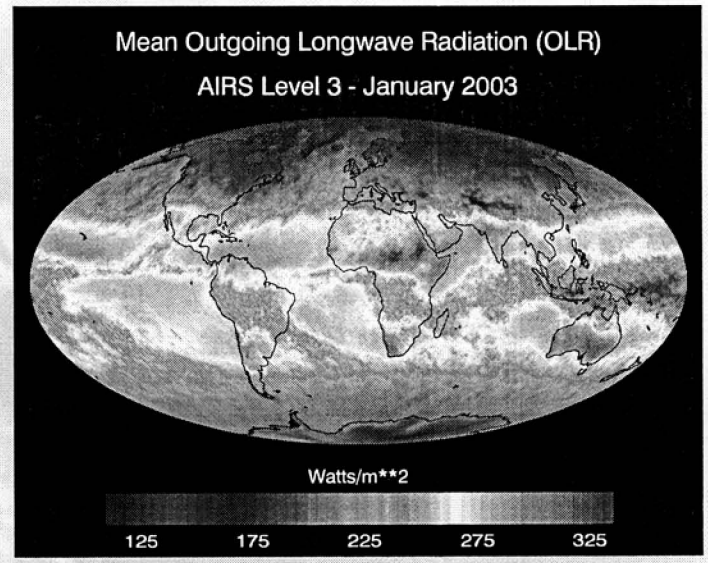
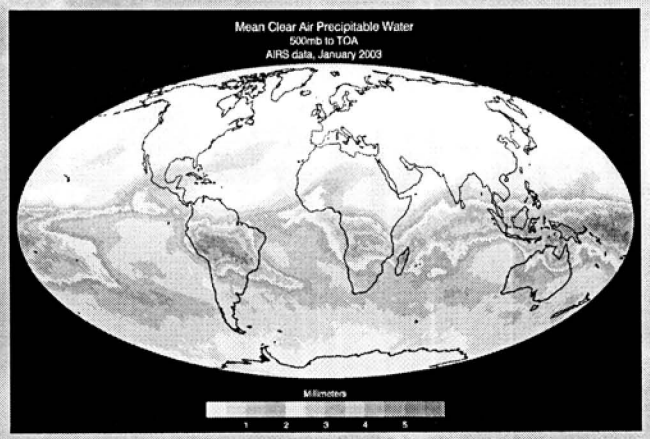
AIRS L3 Clear Sky OLR is New Product







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Climate Processes Observed by AIRS

- **Phenomena poorly represented in numerical models**
  - ***Upper Tropospheric Water Vapor Distribution***
  - ***The Madden-Julian Oscillation***
    - A phenomenon that affects billions of lives
      - *Monsoon onset and breaks closely tied to MJO*
      - *Modulates rainfall in California*
    - MJO is not realistically represented in numerical models
      - *Significantly limits extended-range (2-3 weeks) tropical forecasts.*
  - ***Cirrus Clouds***
    - Cirrus clouds are poorly represented in numerical models
    - AIRS high spectral resolution promises better sensitivity to thin clouds
    - Validation results are very encouraging

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Atmospheric Composition Research Products Under Development

- O_3
  - *Match TOMS to better than 5% except over ice.*
  - *Achieved Day or Night, Globally*
- SO_2
  - *AIRS distinguishes ash cloud from SO2 gas*
- CO
  - *Good horizontal resolution and coverage*
- CH_4
  - *First retrievals show expected behavior*
- CO_2
  - *Seasonal and annual trends match expectations*
- Aerosols
  - *Silicate signatures allow dust detection*

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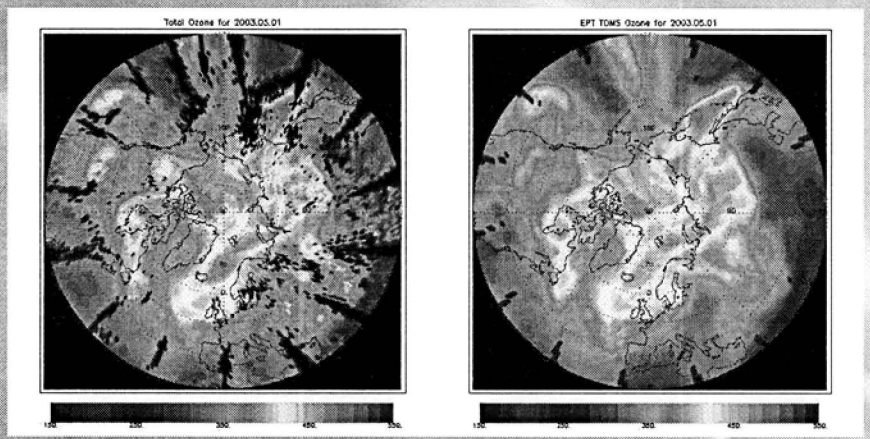
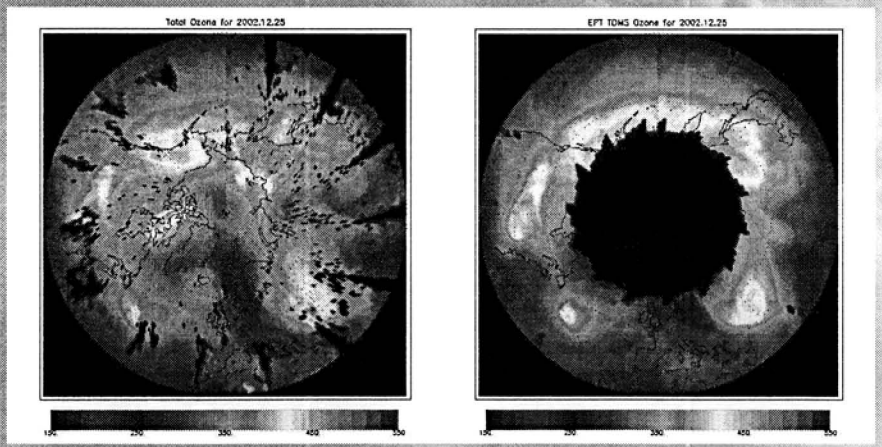
AIRS Ozone Distribution

North Pole
AIRS vs TOMS
Acquired Day and Night

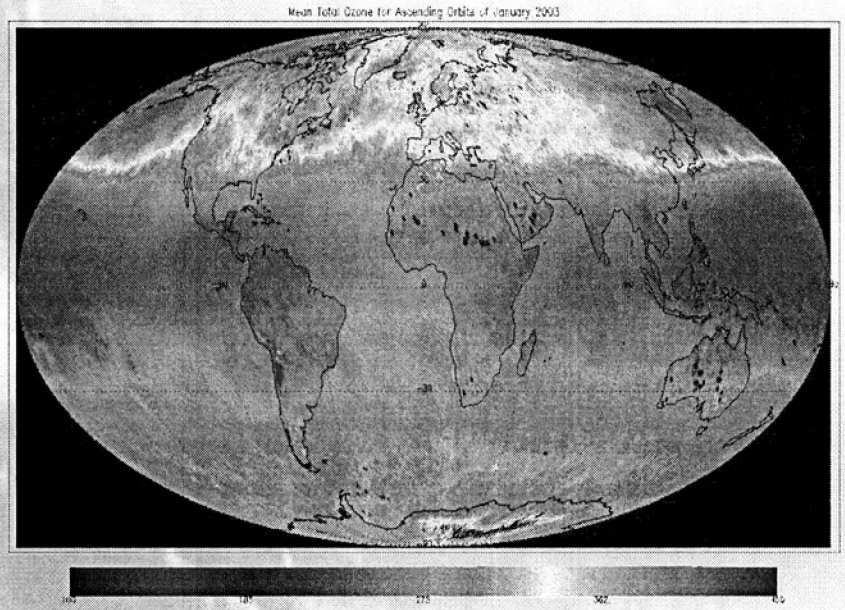
AIRS **May** **TOMS**



AIRS **December** **TOMS**



AIRS Monthly Ozone Product



Images by Sung-Yung Lee (JPL)

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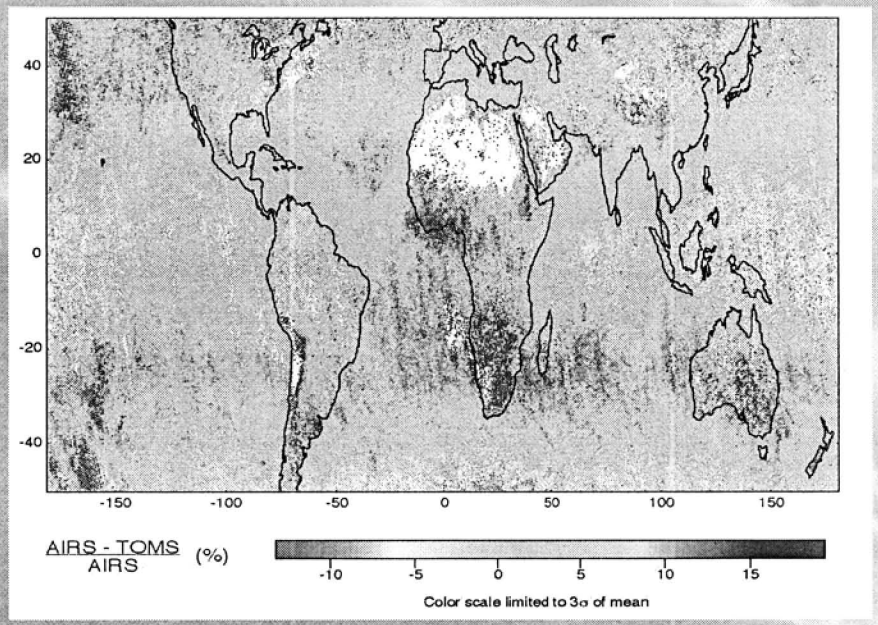
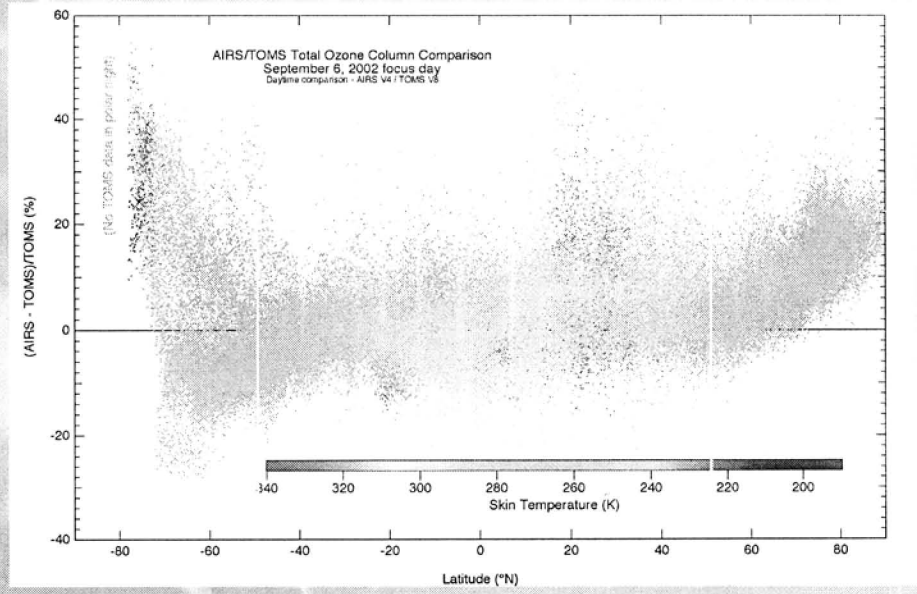
AIRS Ozone Compares Well with TOMS

AIRS Ozone Compared to TOMS



AIRS Total Ozone Agrees with TOMS
Mean = +2, -4% with σ = 7%



Fredrick W. Irion (JPL)
Collaborators: Michael Newchurch, Sunmi Na, Mohammed Ayoub (UAH),
Mike Gunson (JPL)

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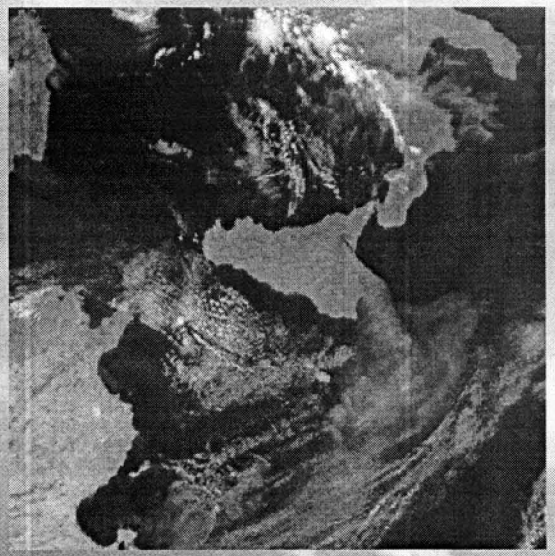
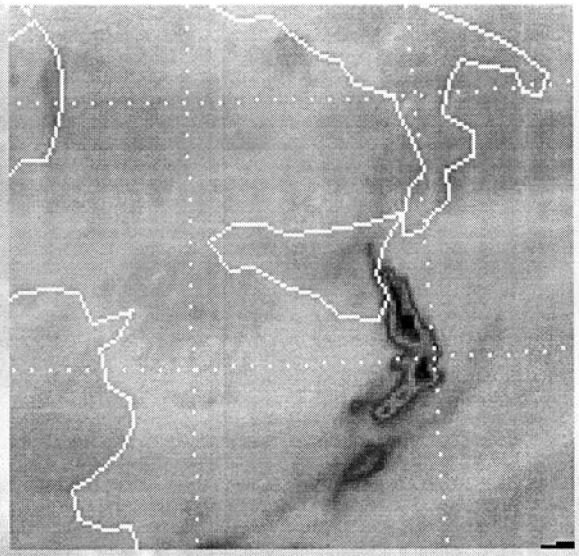
AIRS Images Volcanic SO2

Mt. Etna (AIRS Vis)

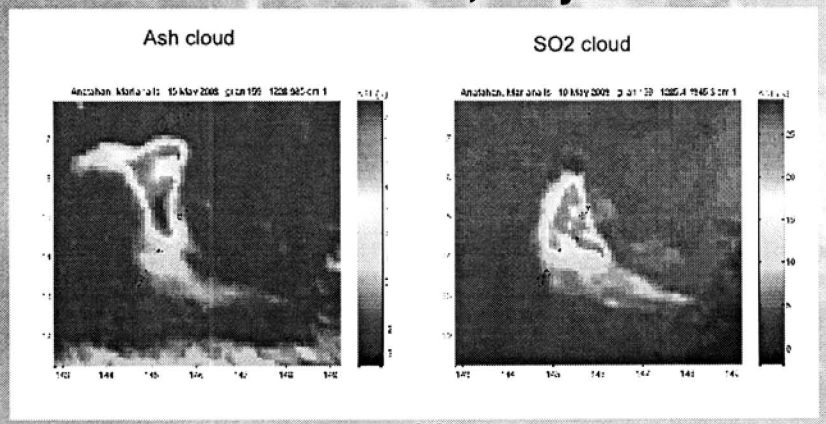


SO_2 Extraction



(S. Lee/JPL)

Anatahan Island, May 2002



(L. Strow/UMBC)

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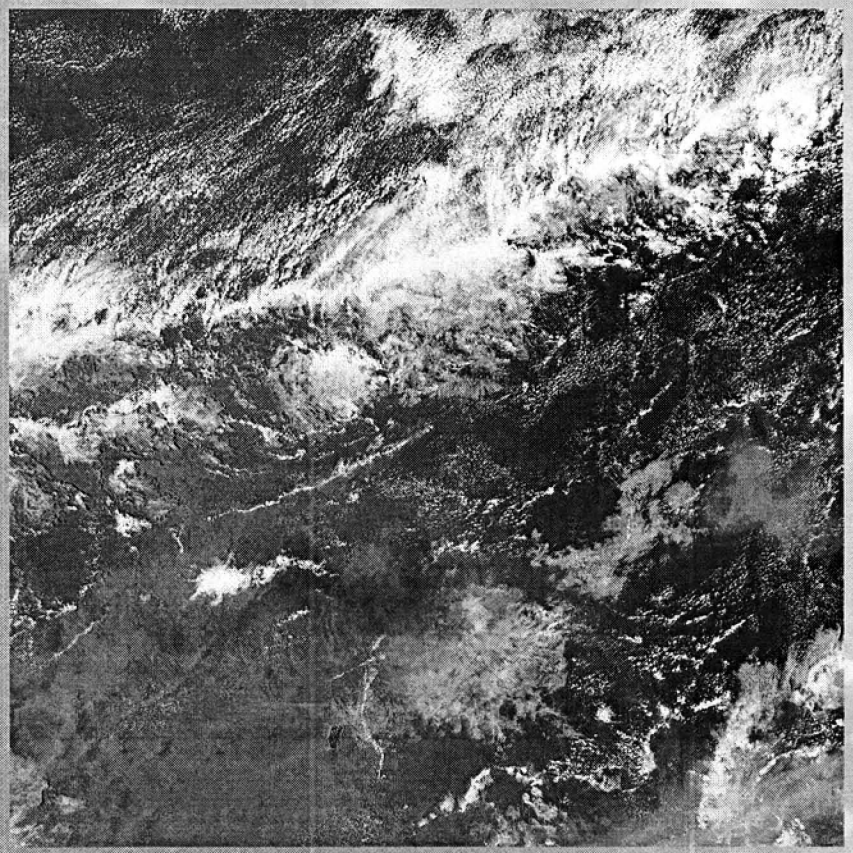
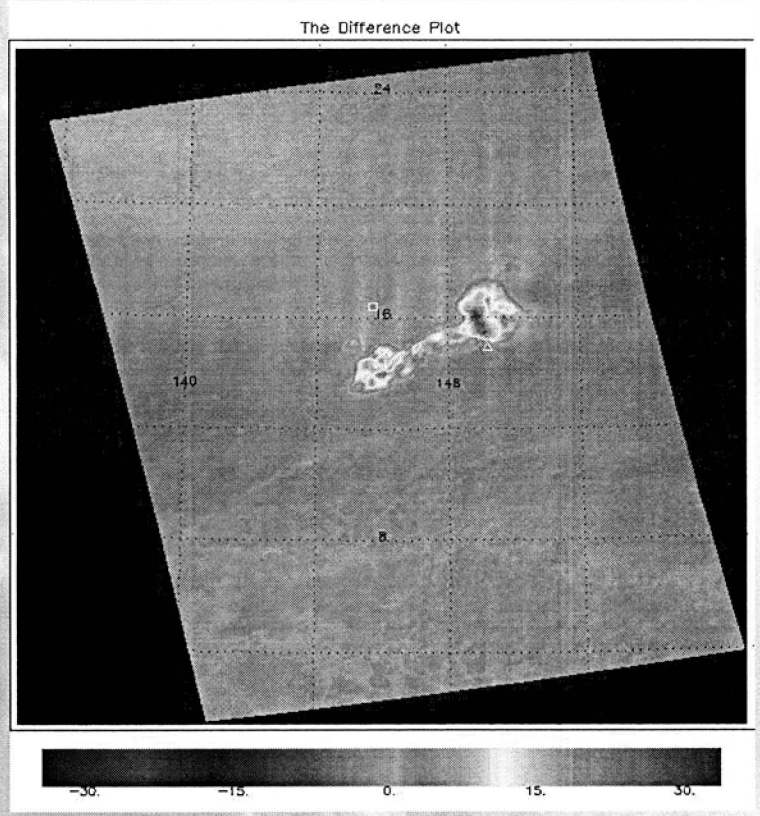
Recent Eruption of Anatahan
April 6, 2005

MODIS



AIRS SO2 Channel Difference



(S. Lee/JPL)

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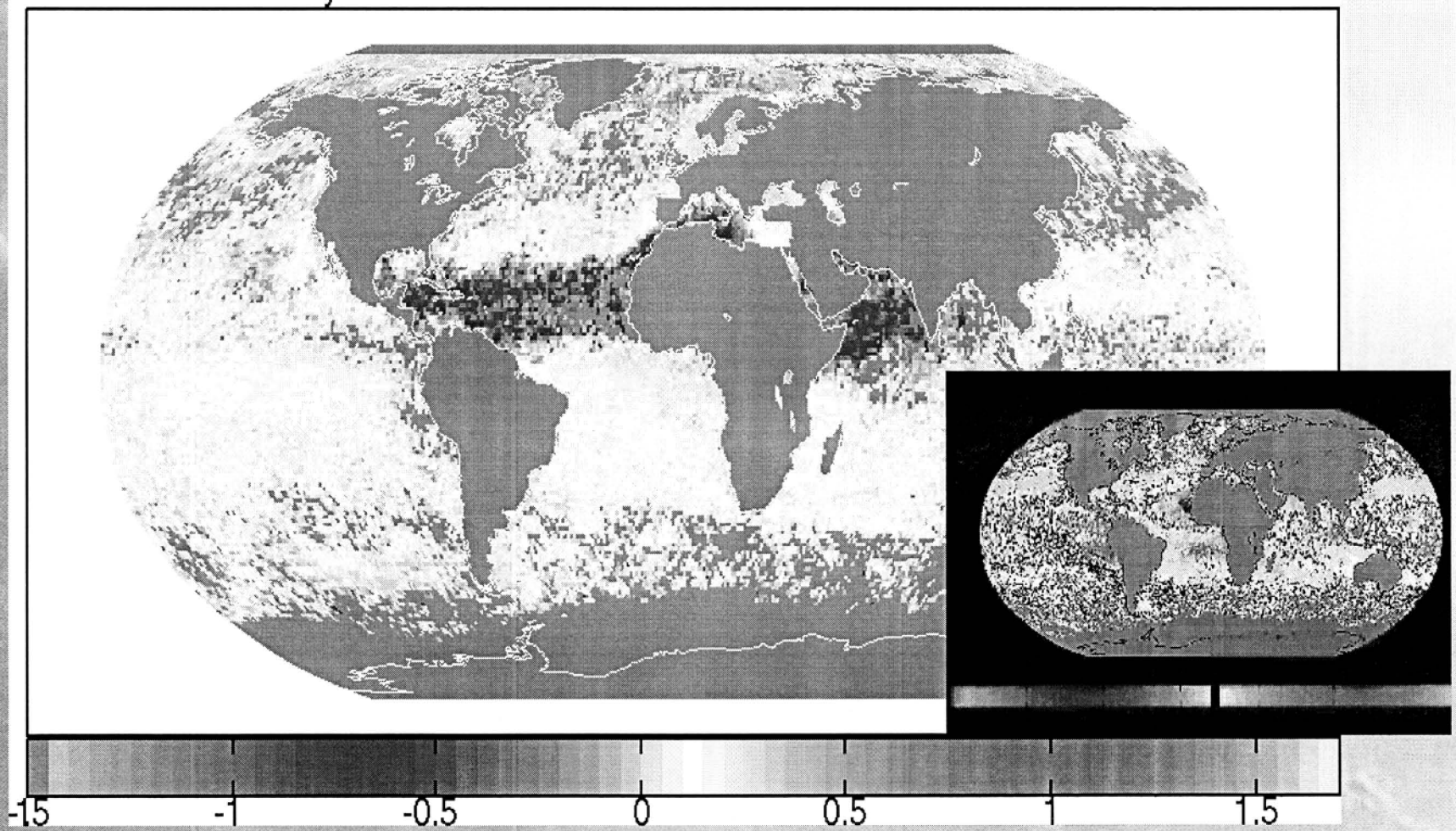
AIRS Aerosols for July 2003

July Dust Detection: 961 - 1232 cm^{-1} Bias Difference



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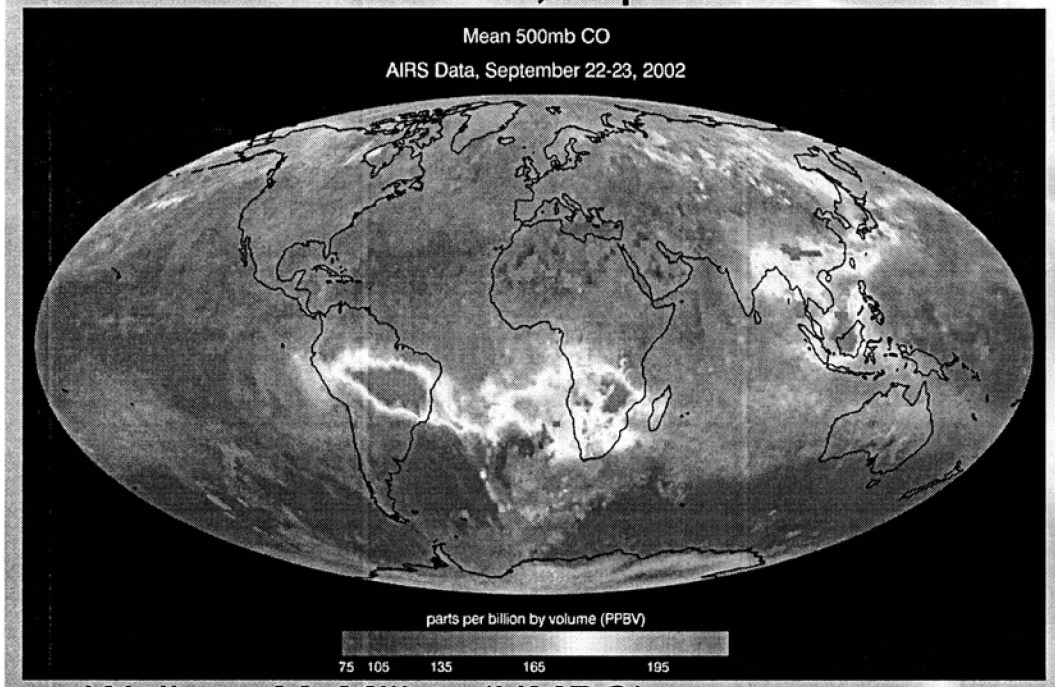
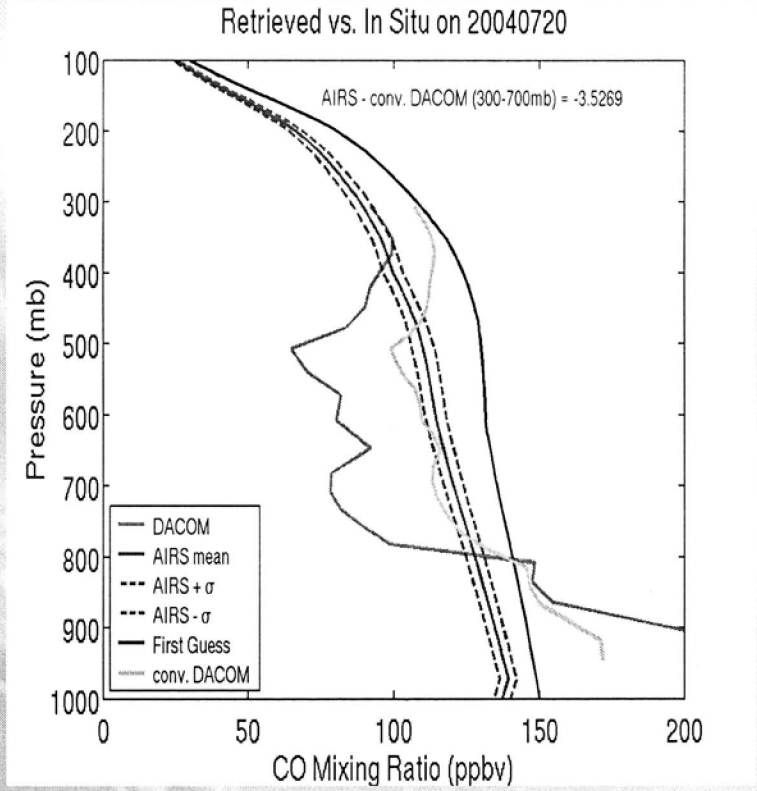
AIRS CO

AIRS 1 Week CO, September 2002





Wallace McMillan (UMBC)

Collaborators: C. Barnet (NOAA), L. Strow (UMBC), J. Warner (UMBC), Glen Sachse (LaRC)

AIRS Tropospheric CO sensitivity peaks near 500 mb; accuracy better than 15%.

Validation underway with data from NASA's INTEX-A field experiment

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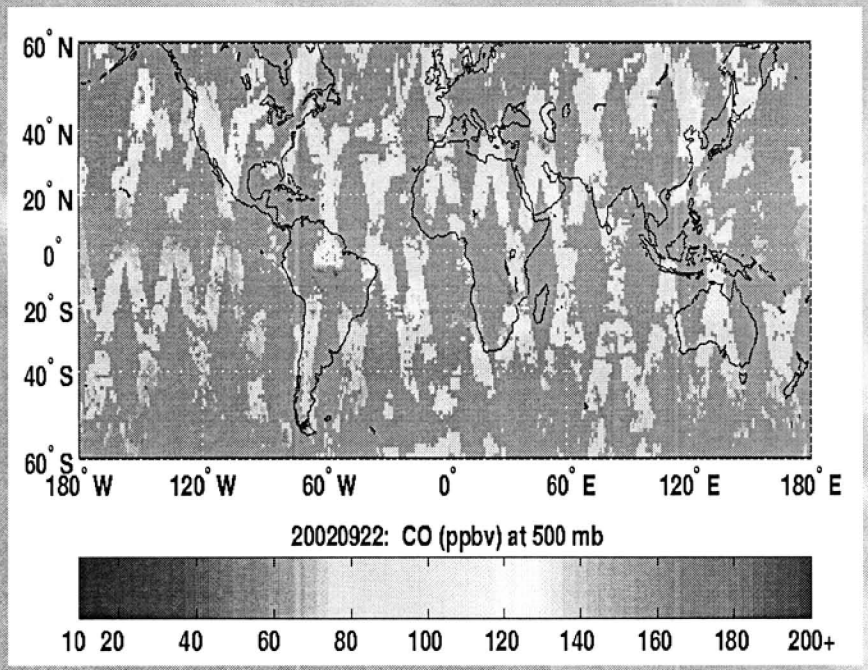
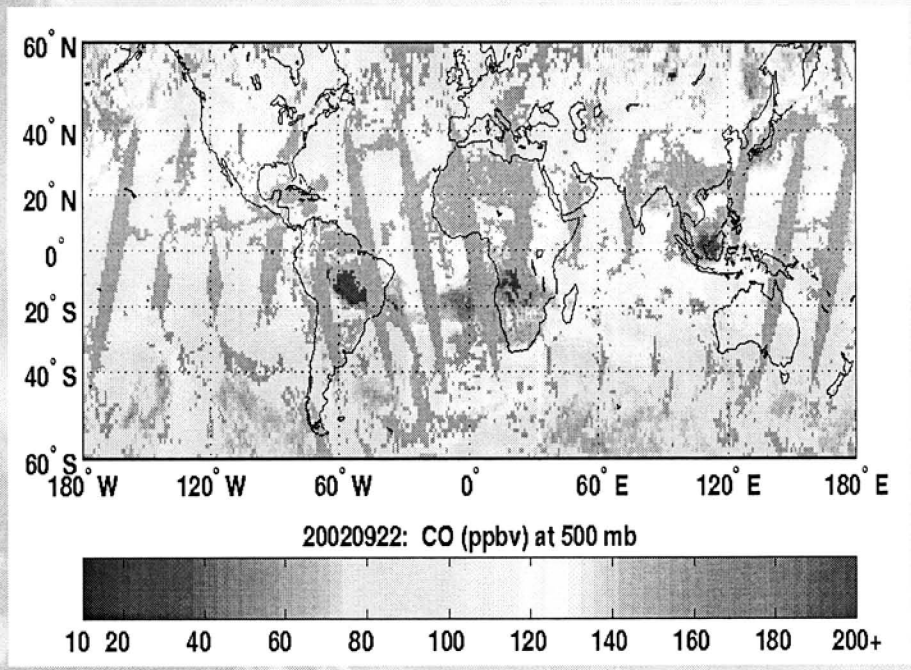
AIRS Has Daily Global Coverage of 95% of the Earths Surface

MOPITT CO



AIRS Global CO Produced Daily



(W. McMillan/UMBC)

AIRS daily CO coverage is more than twice that of MOPITT on the Terra with comparable accuracy, but somewhat lower vertical resolution.

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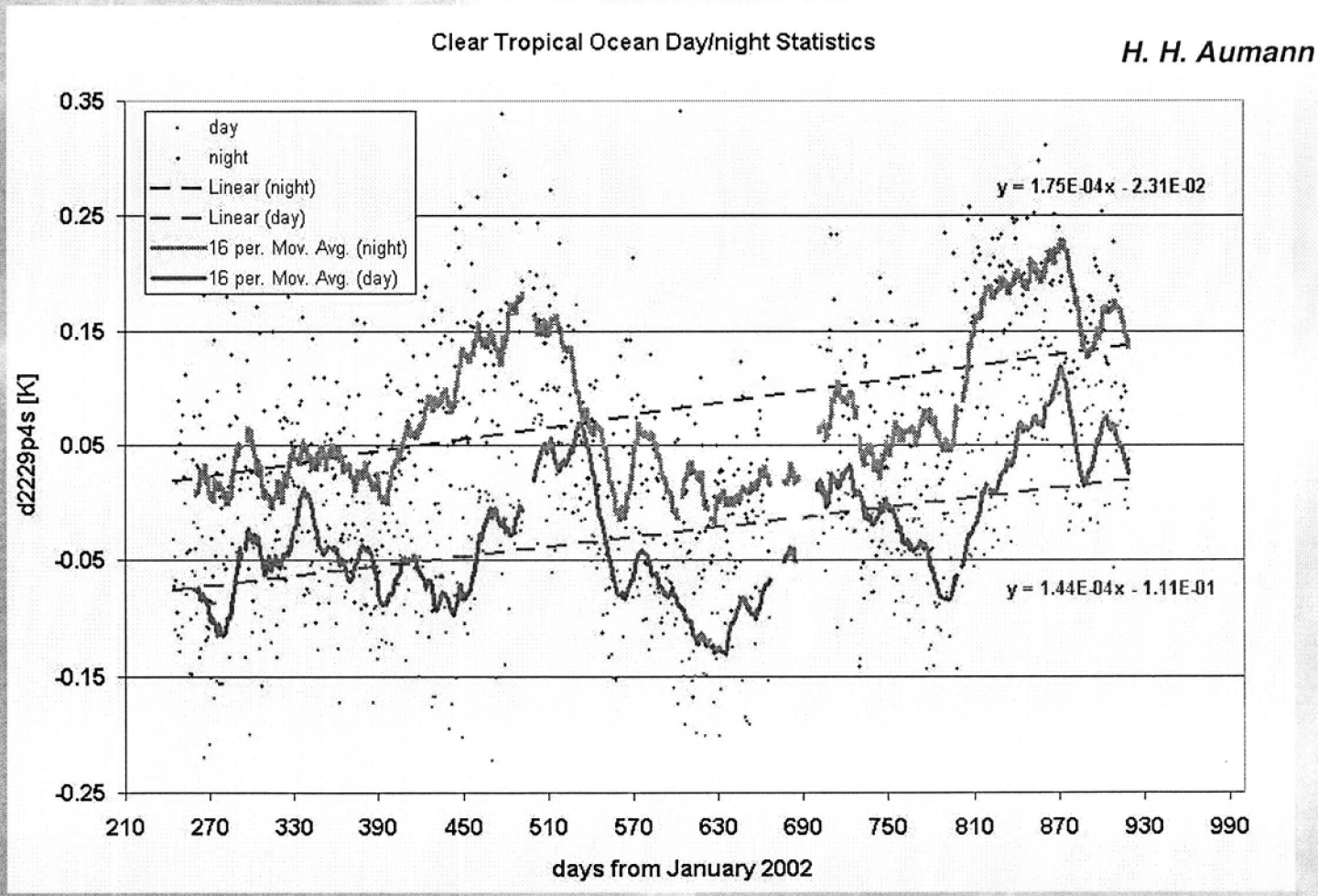
AIRS Sensitivity to CO_2 in the lower troposphere (Surface to 5km)



Difference between channels 2388 cm^{-1} and 2229 cm^{-1} reveals the seasonal characteristics of CO_2 – H. Aumann

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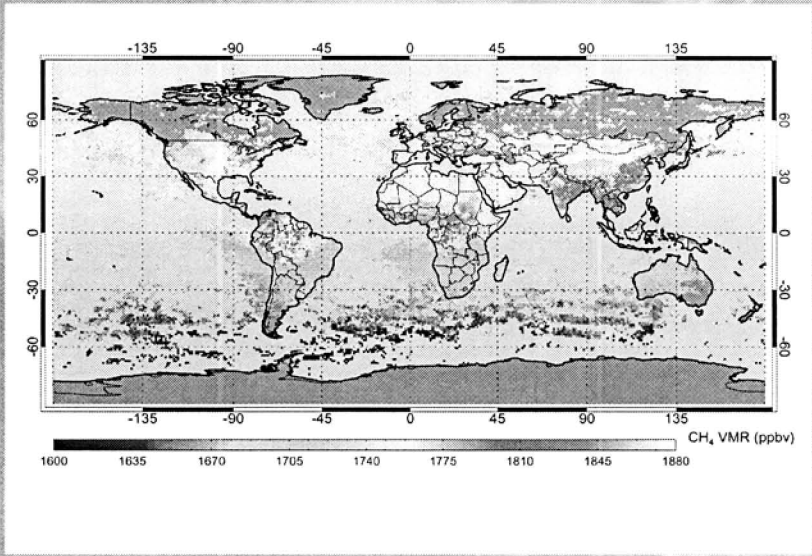
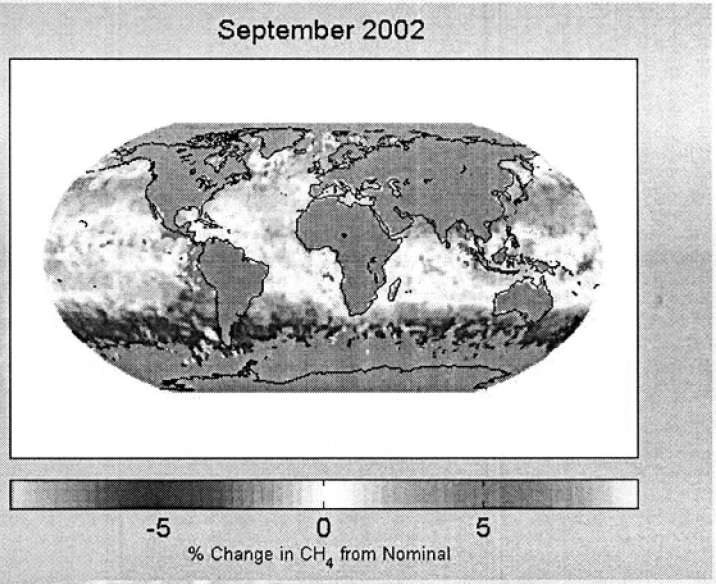
AIRS Methane vs SCIAMACHY

SCIAMACHY August – November 2003



AIRS Monthly



Larrabee Strow (UMBC)
Collaborators: C. Barnet (NOAA), W. McMillan (UMBC)
Validation in progress
AIRS daily CH_4 analysis currently limited to oceans

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AIRS Upper Tropospheric CO_2 (5-15km) (Cloud Free Conditions)

Average CO_2=371.04 ppm
First iteration
January 1-6, 2003

PRELIMINARY

Eric Maddy
NOAA/QSS

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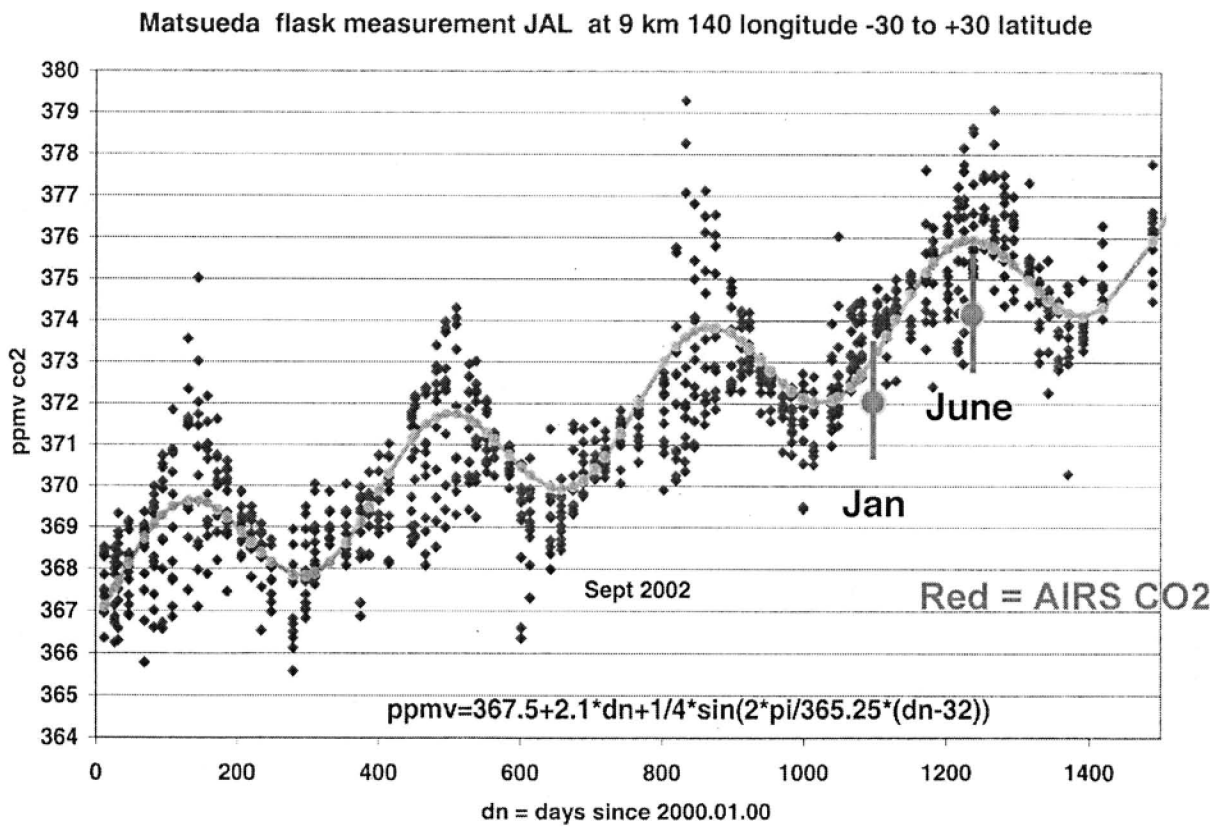
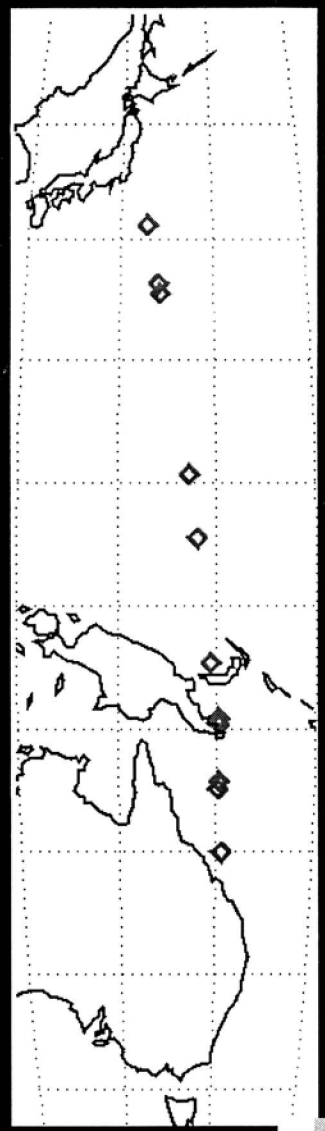
AIRS CO_2 Comparison with Matsueda Under Cloudy Conditions



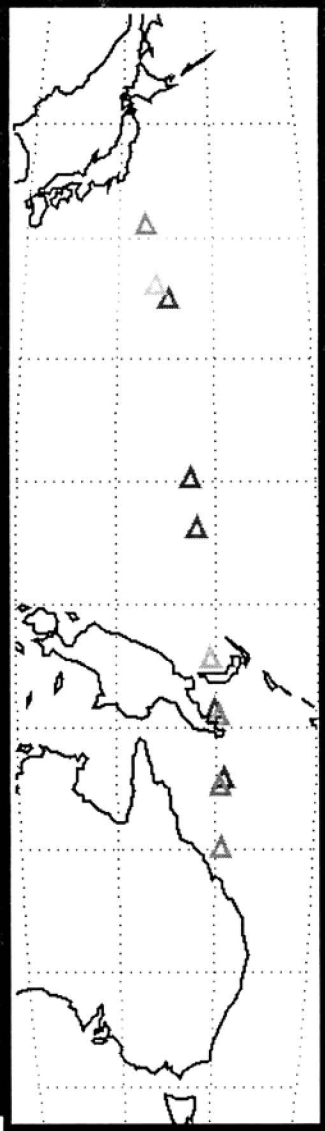
AIRS Carbon Dioxide Retrievals

Cloudy Conditions (cloud-cleared)

Matsueda Airborne Flask

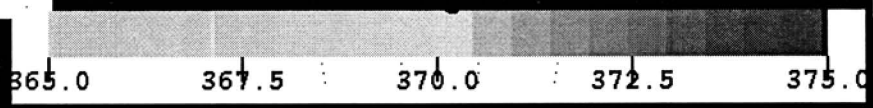


Collocated AIRS



-2.37 ppmv

1.46 ppmv



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Summary

- **AIRS has been shown to be a source of highly accurate, high spectral resolution infrared radiances**
- **These radiances are now being assimilated by weather prediction centers worldwide**
- **The accuracy and stability of the IR radiometric calibration permit AIRS data to be used in climate studies, improving the fidelity of climate models**
- **AIRS IR spectra contain a gold mine of information about atmospheric constituents such as CO, CO_2, CH_4, O_3, SO_2, and aerosols**
- **AIRS provides information on the global three-dimensional distribution of water vapor in the atmosphere**
  - ***Weather forecasting***
  - ***Climate modeling***