



# AIRS/AMSU Project Status and Applications

## IEEE GRSS Panel Event

“Fire and Water: How Are We Monitoring Natural Hazards in Southern California?”

Thursday, May 10, 2018, 5-7 PM

Northrop Grumman, Azusa

Prepared by Thomas S. Pagano

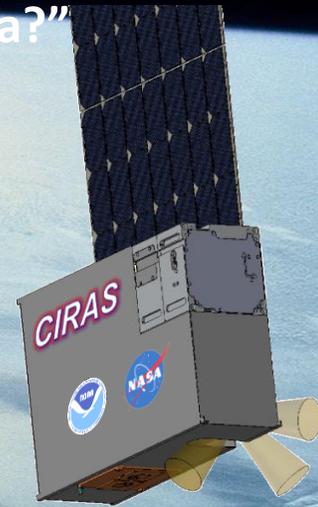
Jet Propulsion Laboratory, California Institute of Technology

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<http://airs.jpl.nasa.gov>

<https://www.jpl.nasa.gov/cubesat/missions/ciras.php>



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# NASA Earth Science Missions in Orbit

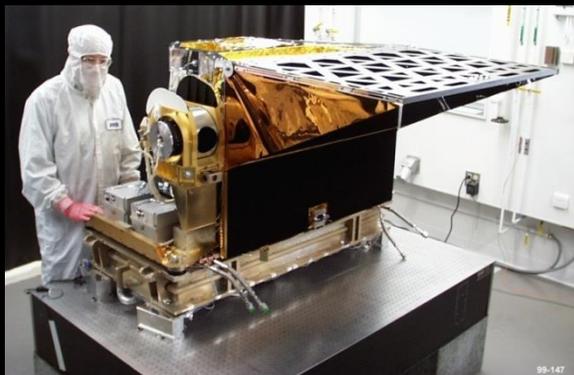




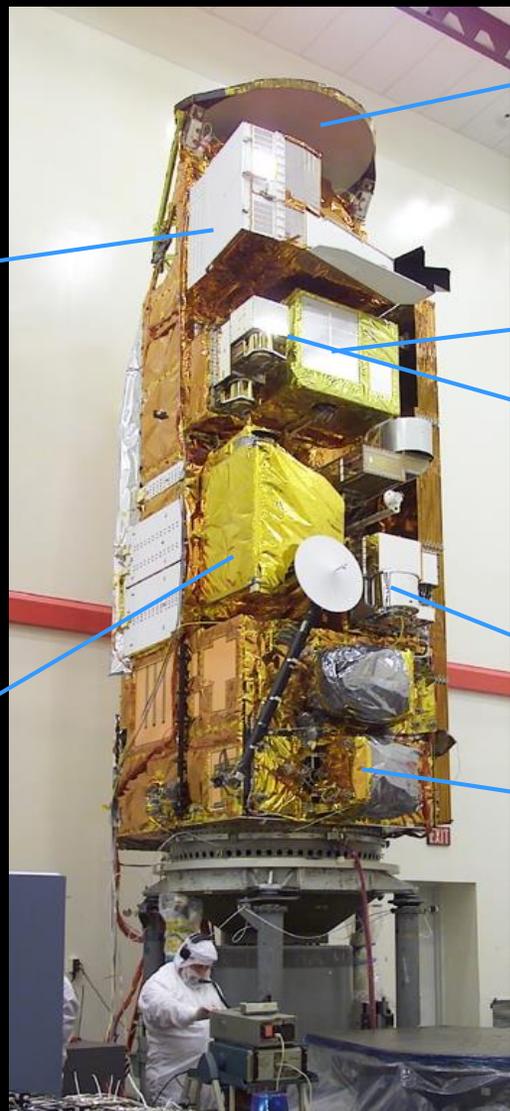
# The Aqua Spacecraft and Instruments



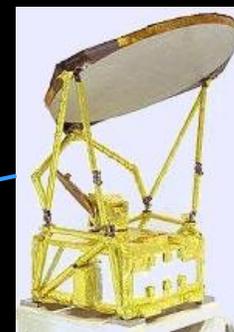
*Moderate Resolution Imaging Spectroradiometer (MODIS)  
GSFC/Raytheon*



*Atmospheric Infrared Sounder (AIRS)  
JPL/BAE SYSTEMS*



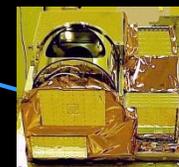
*AQUA Spacecraft  
GSFC/NGST*



*Advanced Microwave Scanning Radiometer (AMSR-E)  
MSFC/JAXA*



*Advanced Microwave Sounding Units (AMSU-A/B)  
JPL/Aerojet*



*Humidity Sounder from Brazil (HSB)  
JPL/Aerojet*

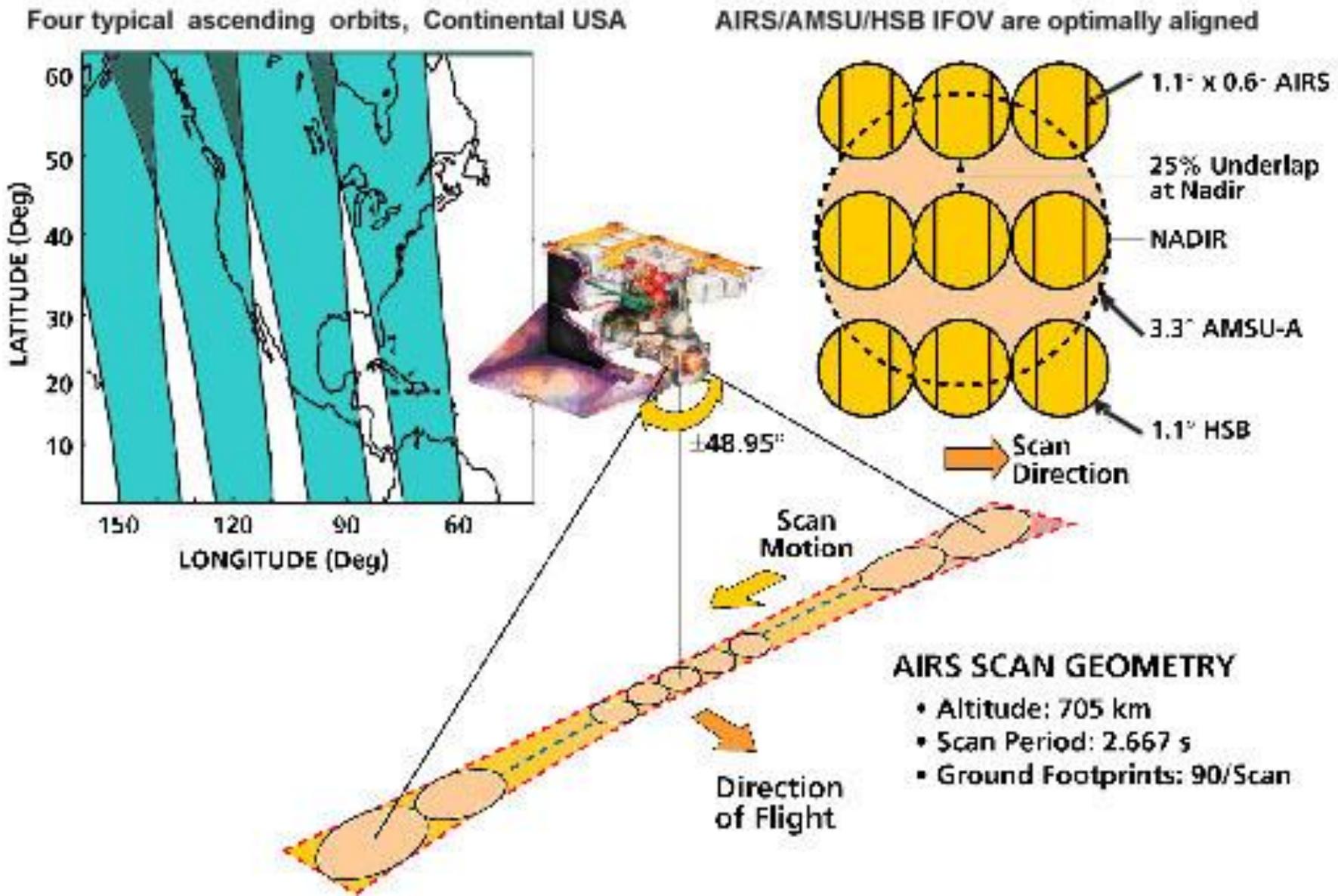


*Clouds and Earth Radiant Energy System (CERES)  
LaRC/NGST<sub>3</sub>*





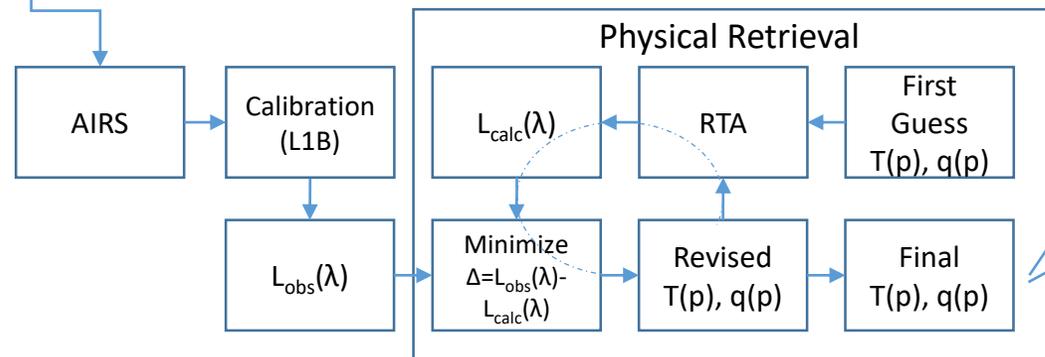
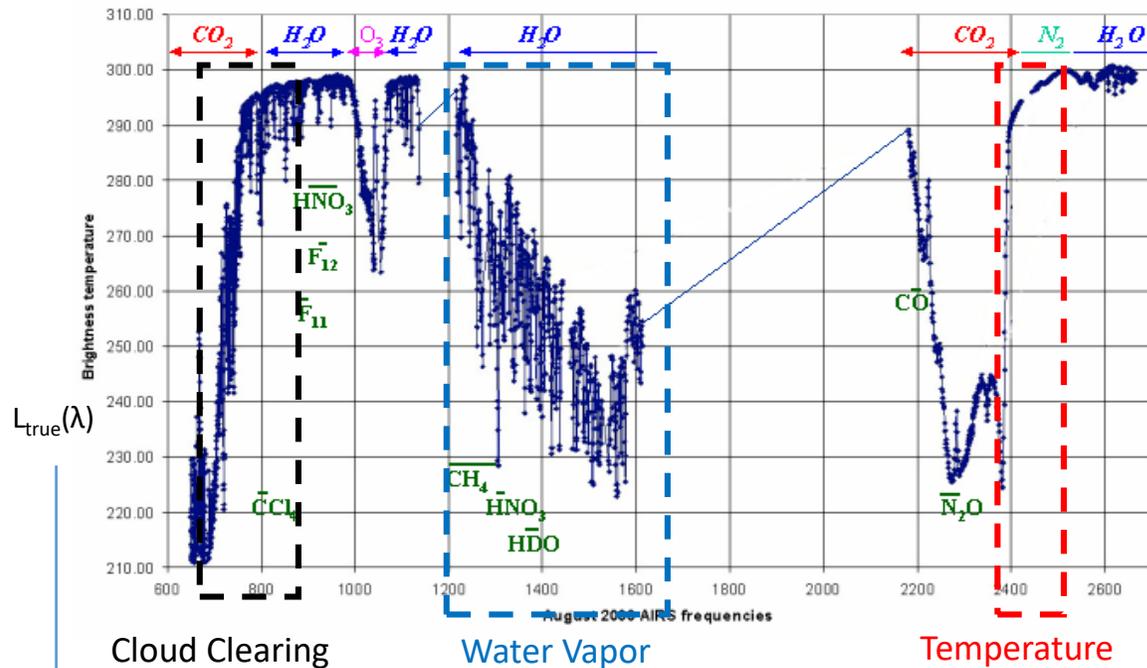
# AIRS and MODIS Have a Wide Swath to Provide Global Daily Coverage





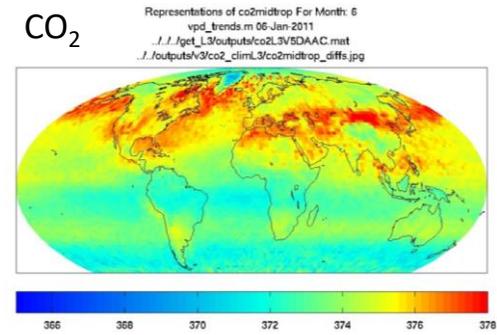
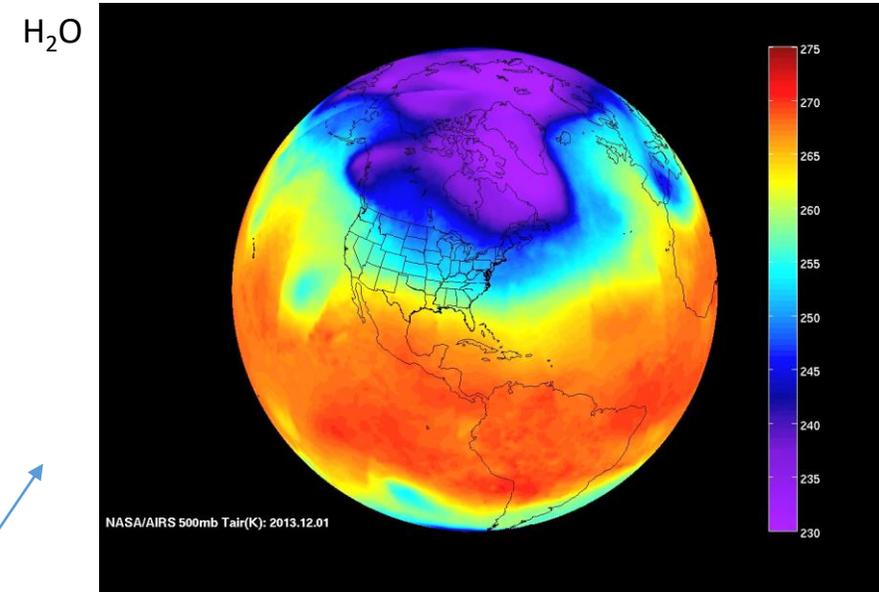
# IR Sounders Measure the Upwelling Earth Spectrum in the Infrared

### AIRS Channels for Tropical Atmosphere with $T_{surf} = 301K$ Full Spectrum



### AIRS Temperature at 500mb

Dec 4, 2013: Denver weather: Temperature hits minus 13 — record low for the date  
 Dec 24, 2013: Record Low Tied at Cedar Rapids This Morning | Iowa Weather Blog  
 Jan 6, 2014: Chicago Record Low Temperature: City Hits -16 Mark To Kick Off ...  
 Jan 29, 2014: Atlanta, Georgia, historic weather for the past week



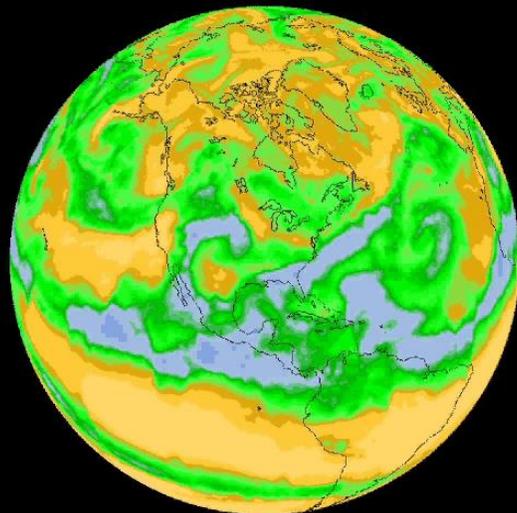
- Dr. Mous Chahine, 1935-2011
- AIRS Science Team Lead, 1991-2011
- Algorithms for Cloud Clearing, Temperature, Water Vapor and CO2 Retrievals



National Aeronautics and Space Administration  
 Jet Propulsion Laboratory  
 California Institute of Technology  
 Pasadena, California

H<sub>2</sub>O

500 mb Water Vapor (g/kg dry air)

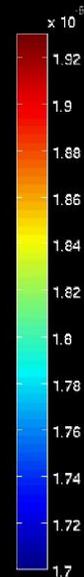
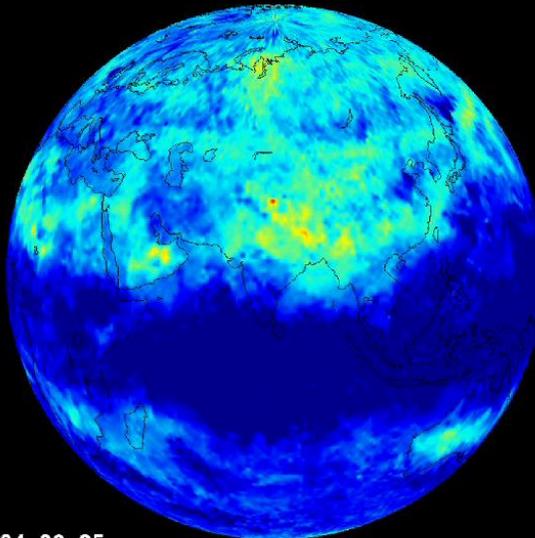


2005.08.01

AIRS Greenhouse Gases

CH<sub>4</sub>

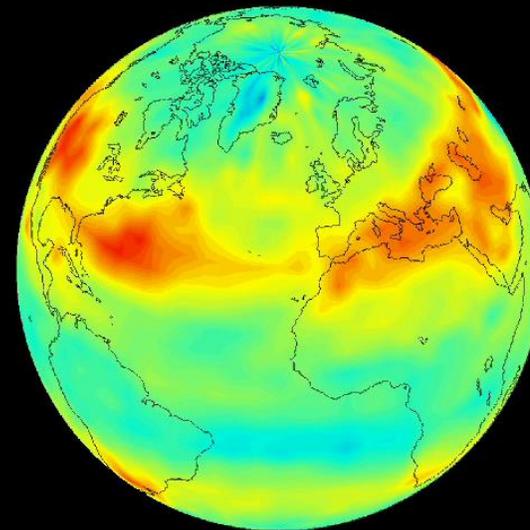
CH<sub>4</sub> VMR at 200 mb (ppm):



2004\_09\_25

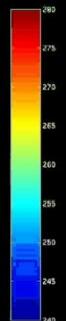
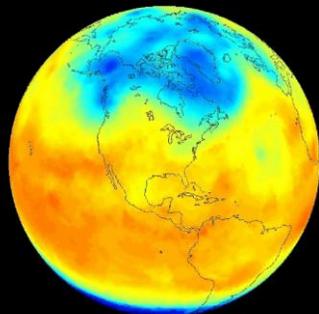
CO<sub>2</sub>

Mid-Tropospheric CO<sub>2</sub> (ppm)



Other AIRS Atmospheric Climate Products

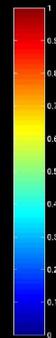
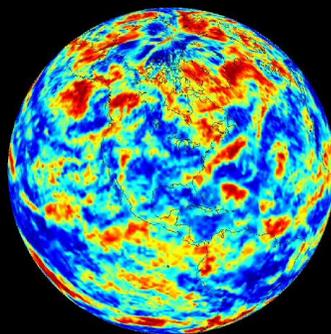
500 mb Temperature (K)



2005.08.01

Temperature

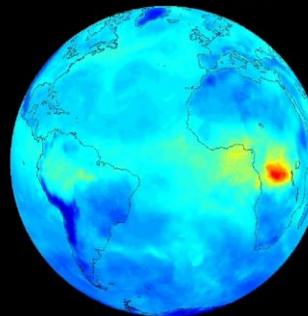
Cloud Fraction



2005.08.01

Clouds

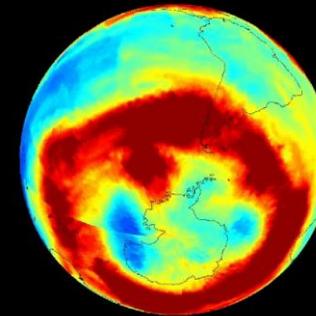
Total Column CO (molecules/cm<sup>2</sup>)



2005.08.01

CO

Total Column Ozone (DU)



2005.08.01

O<sub>3</sub>

Pagano, JPL, 2009

# Stronger Temperature Inversions Indicative of Polar Warming

- Arctic Region warming at twice the rate of the rest of the world
- Temperature inversions play a crucial role in mass and moisture flux
- AIRS data used to study frequency and strength of inversions
- Inversions of 2007 stronger than other years. Warming seen to 400mb

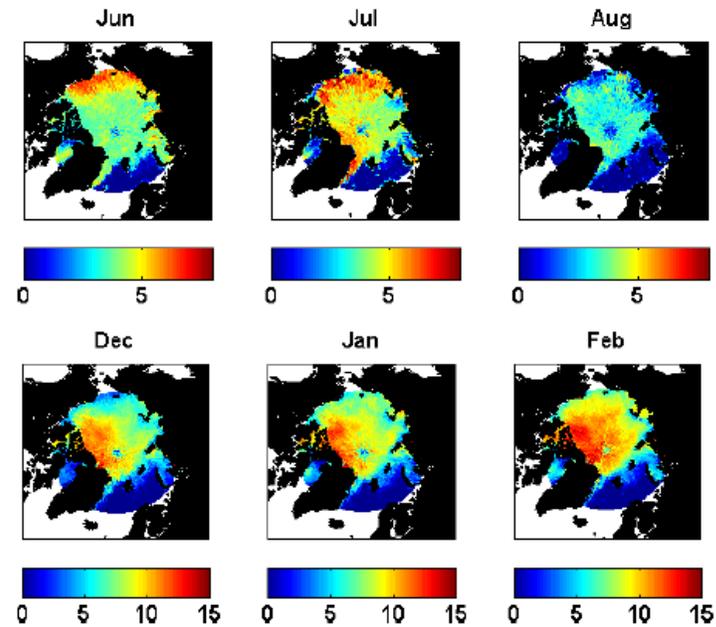
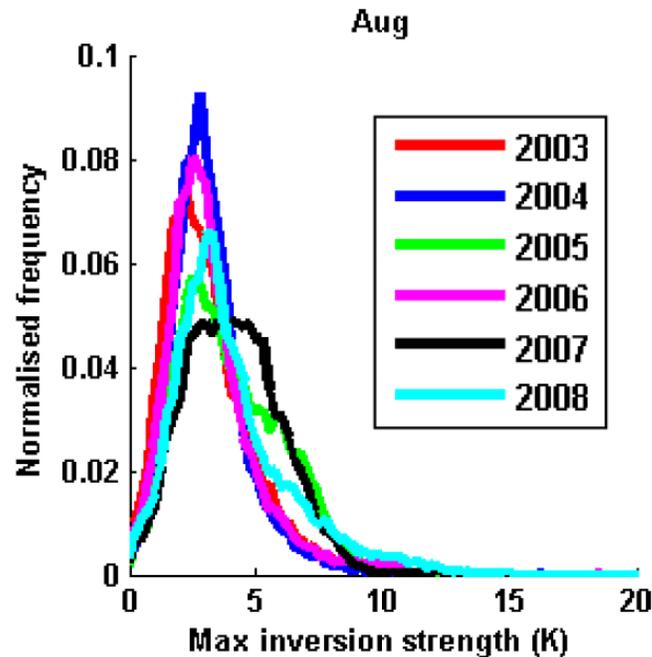


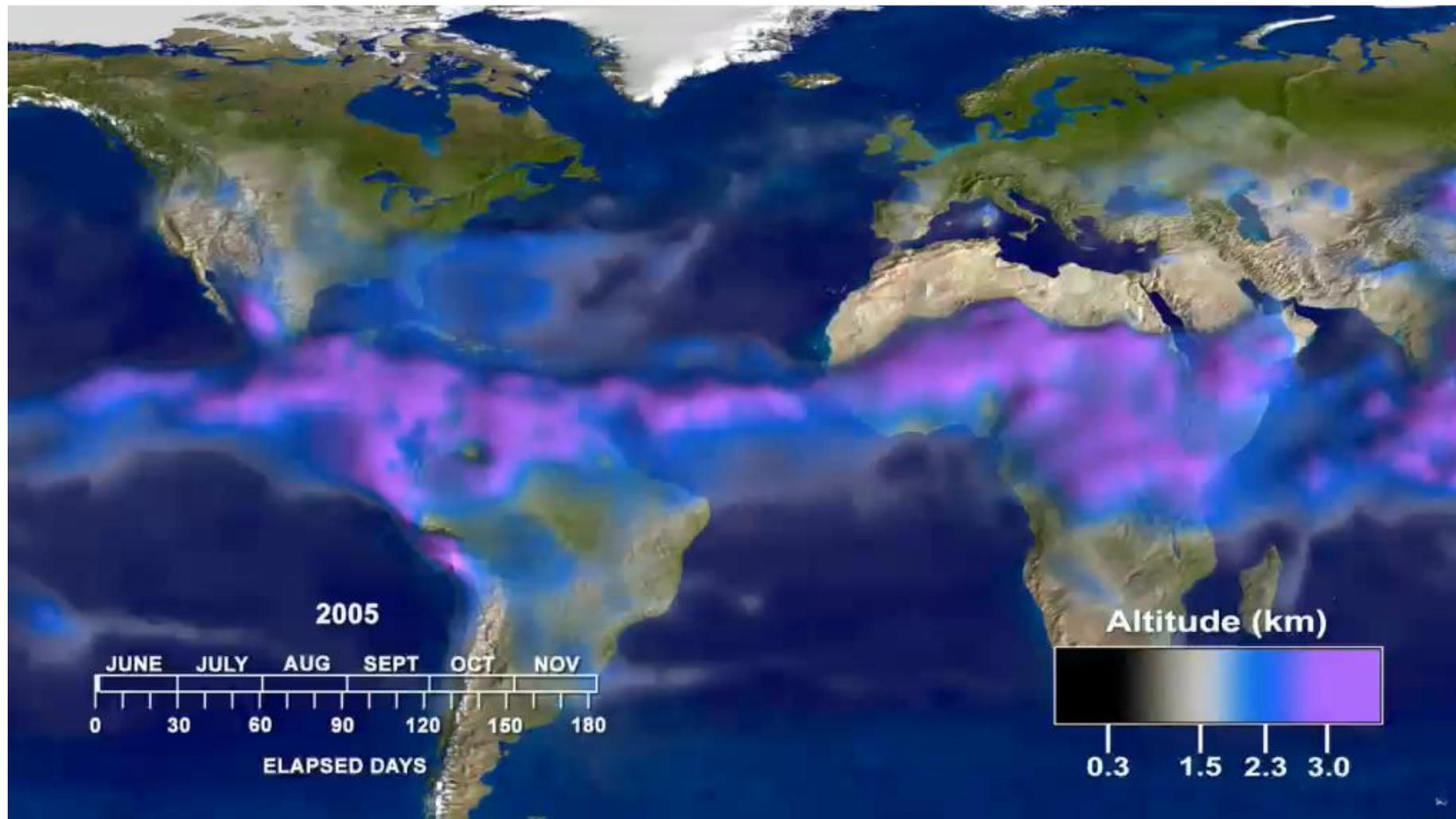
Fig. 5. The spatial pattern of inversion strength (in K) averaged over 2003–2008 for summer (top row) and winter (bottom row) months from the ascending passes. Note that the scale for the winter months is doubled.

A. Devasthale, U. Will'en, K.-G. Karlsson, C. G. Jones, "Quantifying the clear-sky temperature inversion frequency and strength over the Arctic Ocean during summer and winter seasons from AIRS profiles". *Atmos. Chem. Phys.*, 10, 5565–5572, 2010



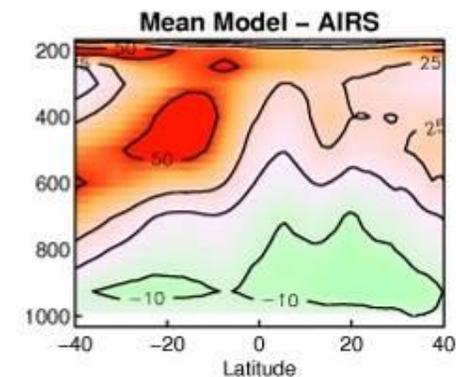
# AIRS Data Support Climate Research and Model Validation

## AIRS Used to Validate Water Vapor Transport

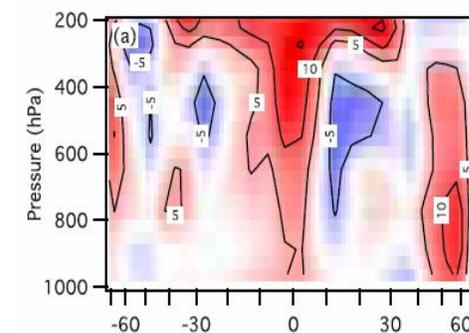


AIRS Water Vapor Isosurface (5kg H<sub>2</sub>O /kg Dry Air)  
V. Realmuto, C. Thompson, T. Pagano, S. Ray NASA/JPL

## Model Comparisons (Pierce, Scripps, 2006)

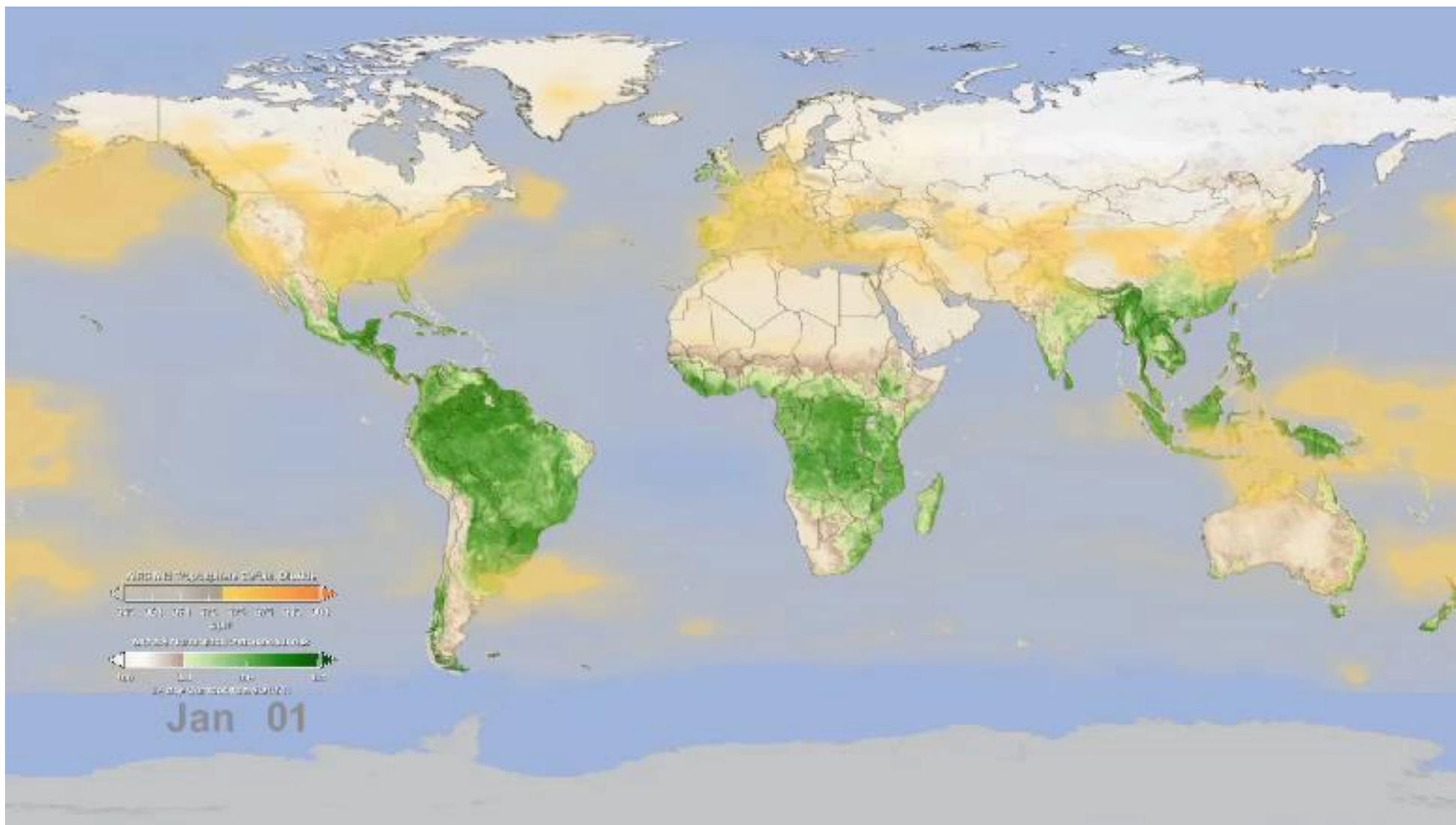


## Water Vapor Feedback (Dessler, Texas A&M, 2008)





# AIRS Mid-Trop CO<sub>2</sub> Drawdown Follows Regional Vegetation Cycle



Lori Perkins (NASA/GSFC Science Visualization Studio)  
T. Pagano, E. Olsen, S. Ray (JPL)

AIRS Mid-Trop CO<sub>2</sub> "Monthly Representation" + FRK  
MODIS EVI Monthly L3



# AIRS Applications Status

## WEATHER PREDICTION CENTERS

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### DROUGHT

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### USDM

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QuickDRI & VegDRI

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### FIRE

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Fire Danger Assessment System

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### HEALTH

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Influenza Forecast System  
(Zika/Dengue)

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## AVIATION, DISASTER RESPONSE

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Wash DC VAAC - SO2 alert

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SACS (EU) - daily global SO2 BT diff;  
SO2 load (BIRA/NILU Prata retrieval) &  
ash index, supports Toulouse VAAC

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NOAA Rapid Update Cycle Rapid  
Refresh Model - volcanic ash detection

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JPL Volcano Rapid Response

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## 2017 Earth Science Senior Review Subcommittee

AIRS data are of significant importance to  
FAA and the aviation community (sulfur  
dioxide, volcanic plumes).

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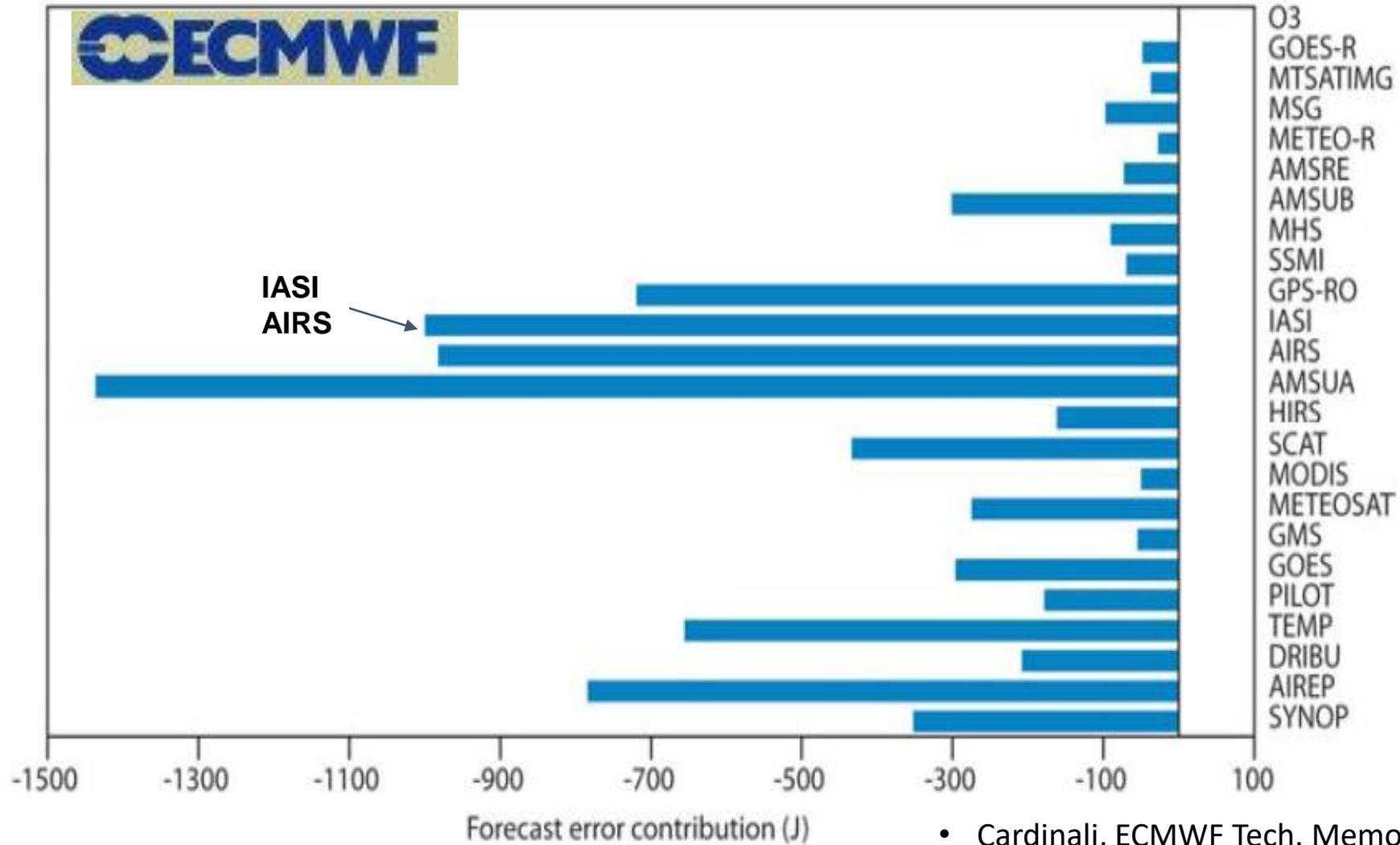
### AIRS ozone products (total column ozone, ozone anomaly) formerly in NAWIPS & AWIPS2

Were used by Ocean Prediction Center (high winds aloft - cyclogenesis), Aviation Weather Center (areas of turbulence) and WPC.

Emily Berndt, SPoRT — "We had to stop processing the AIRS ozone products due to the AMSU failure. The products were dependent on the L2 retrievals that utilized the paired AIRS/AMSU data. **What we demonstrated with AIRS we have been able to apply to CrIS/ATMS and IASI/AMSU retrievals"**



# IR Sounders Improve Weather Forecasts



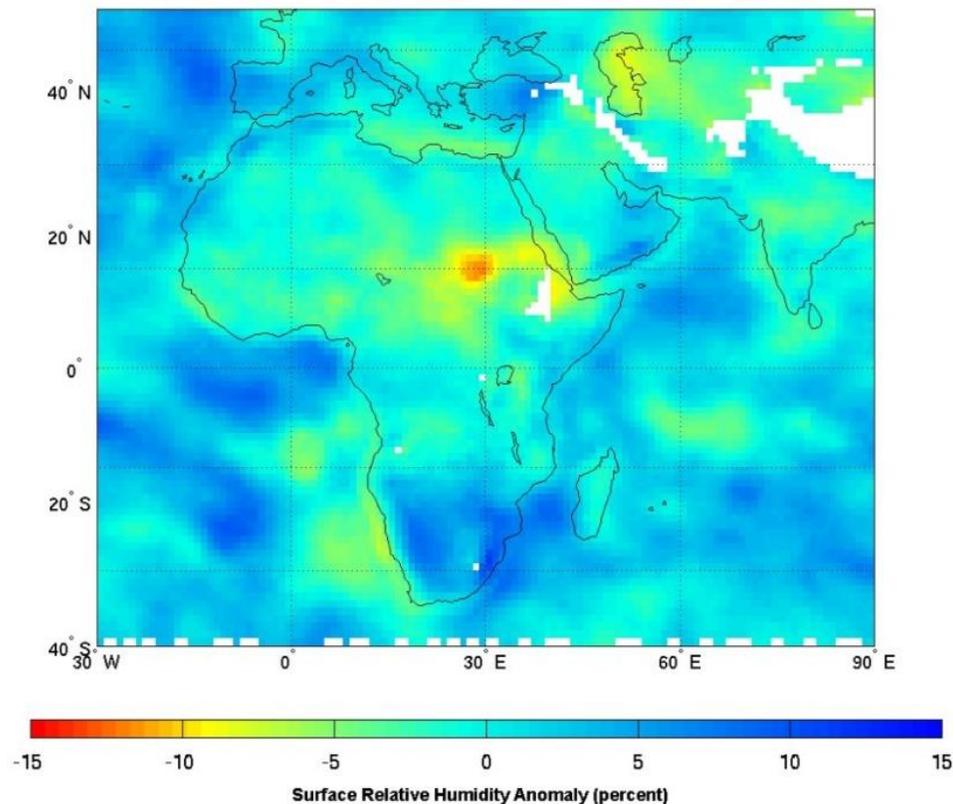
• Cardinali, ECMWF Tech. Memo. 599, 2009



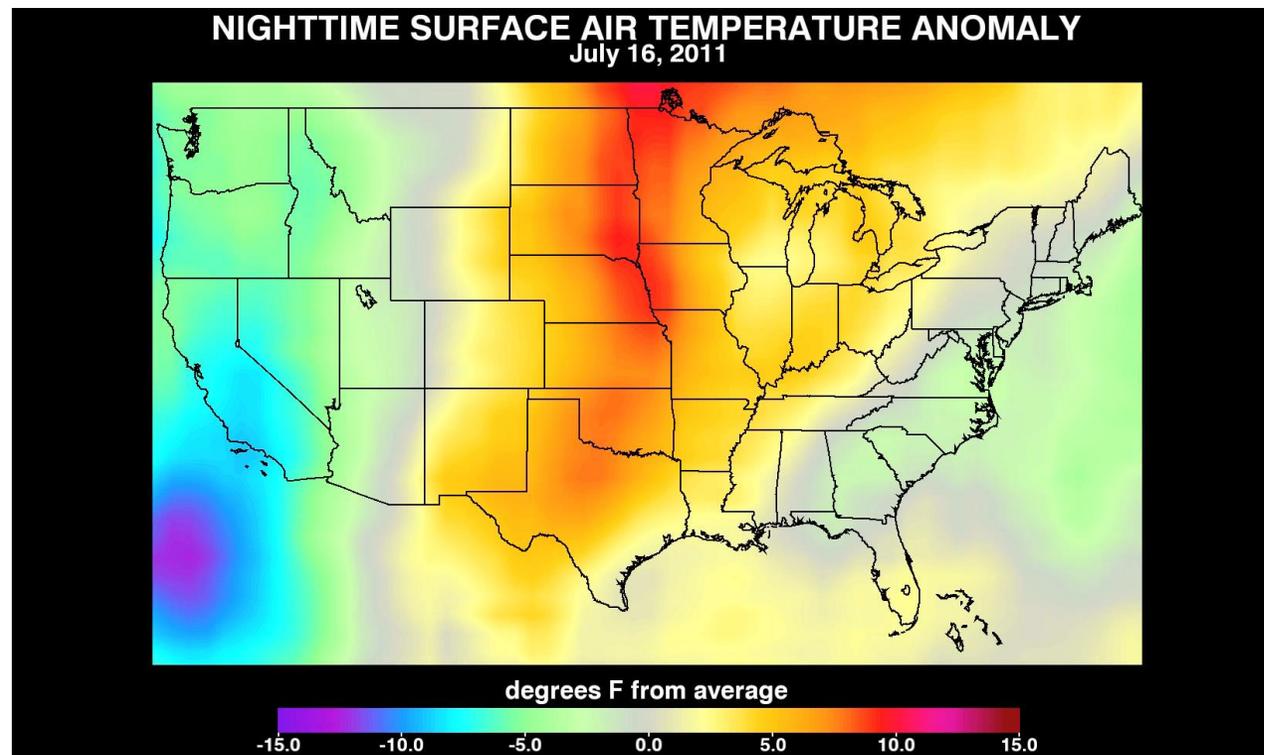
# AIRS Climatologies Enable Identification of Anomalous Weather and Climate Events

## Relative Humidity Anomaly Somalia Drought of July 2011

AIRS Relative Humidity at Surface JUL 2011 vs JUL mean from 2003-2010



## Surface Skin Temperature Anomaly Heat Wave of July 2011



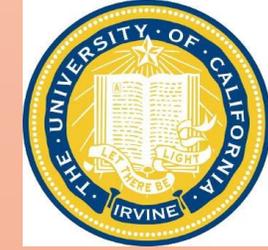
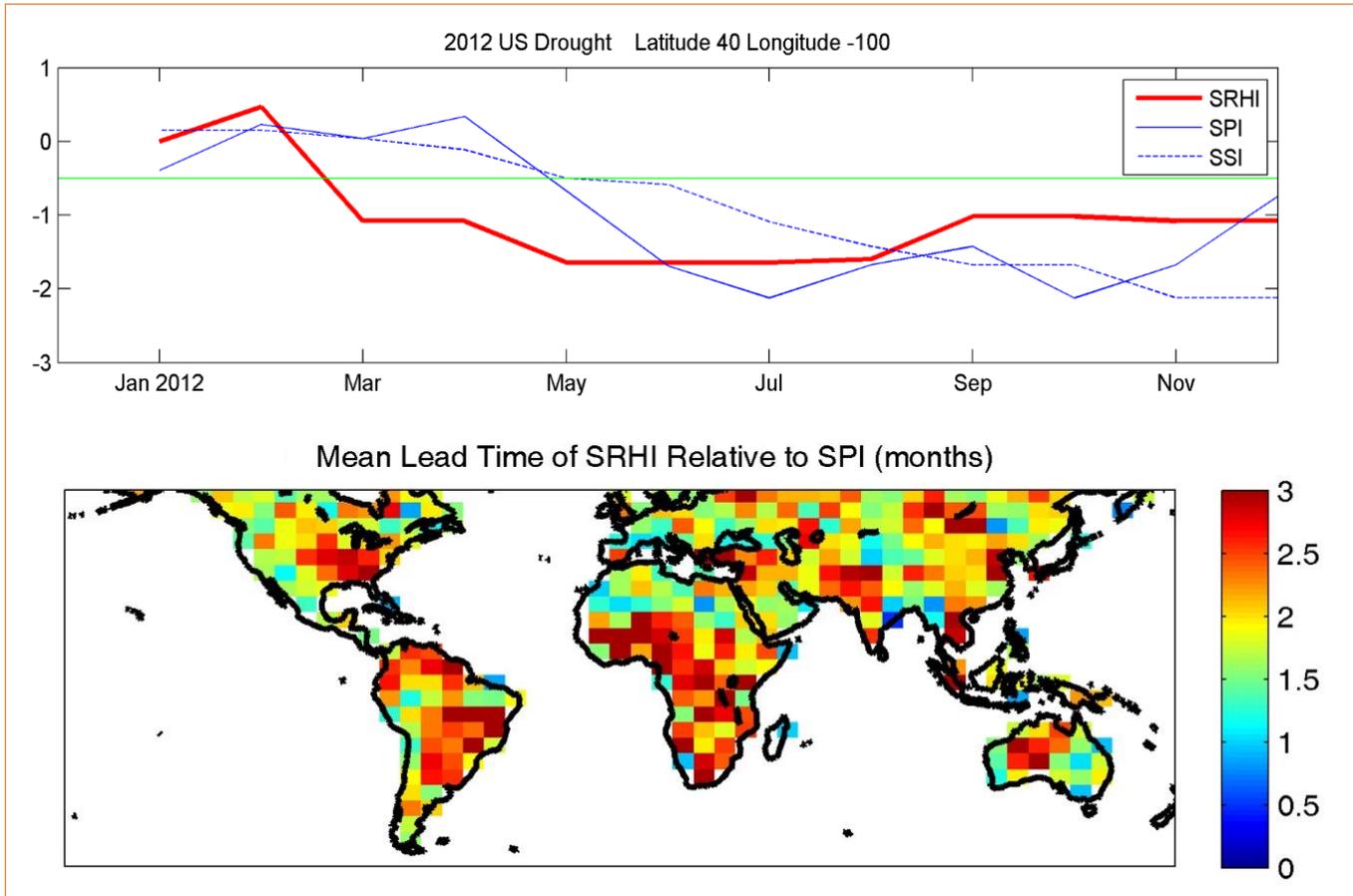
Additional Products Under Development:

- Mosquito Habitat Identification
- Temperature Inversion Identification (for Air Quality)



# AIRS Shows Skill in Early Drought Detection

Standardized Relative Humidity Index (SRHI) from AIRS near surface RH detects drought onset earlier than other indicators



Mean global AIRS-based SRHI lead time: **1.9 month**

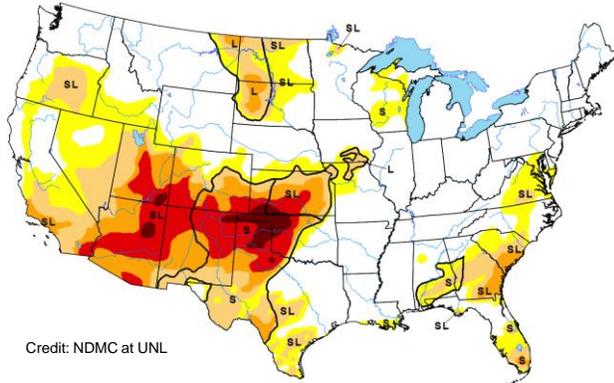
*Farahmand et al, 2015, A Vantage from Space Can Detect Earlier Drought Onset: An Approach Using Relative Humidity, Scientific Reports, 5, 8553; doi: 10.1038/srep08553.*



# AIRS Lower Trop Water Vapor Current and Future Applications

Map for April 12, 2018

Data valid: April 10, 2018 | Author: David Miskus, NOAA/NWS/NCEP/CPC

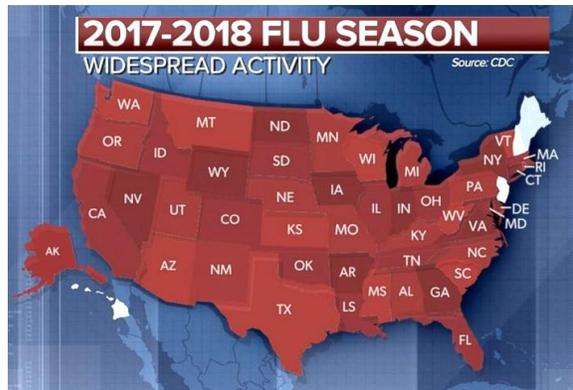


Credit: NDMC at UNL

## Drought Onset Detection

AIRS-derived drought products have shown early detection lead times of up to two months

July 2017 – AIRS Vapor Pressure Deficit, Relative Humidity, Surface Air Temperature included in U.S. Drought Monitor (probationary period)



Credit: ABC News

## Flu Forecasting

Flu forecasting system semi-operational

Has run on 2 flu seasons



Credit: Rick Ray

## Fire Danger Assessment System

Build formal relationship between JPL and operational fire science community for guidance/input

Create global fire-potential data product, make it publicly available

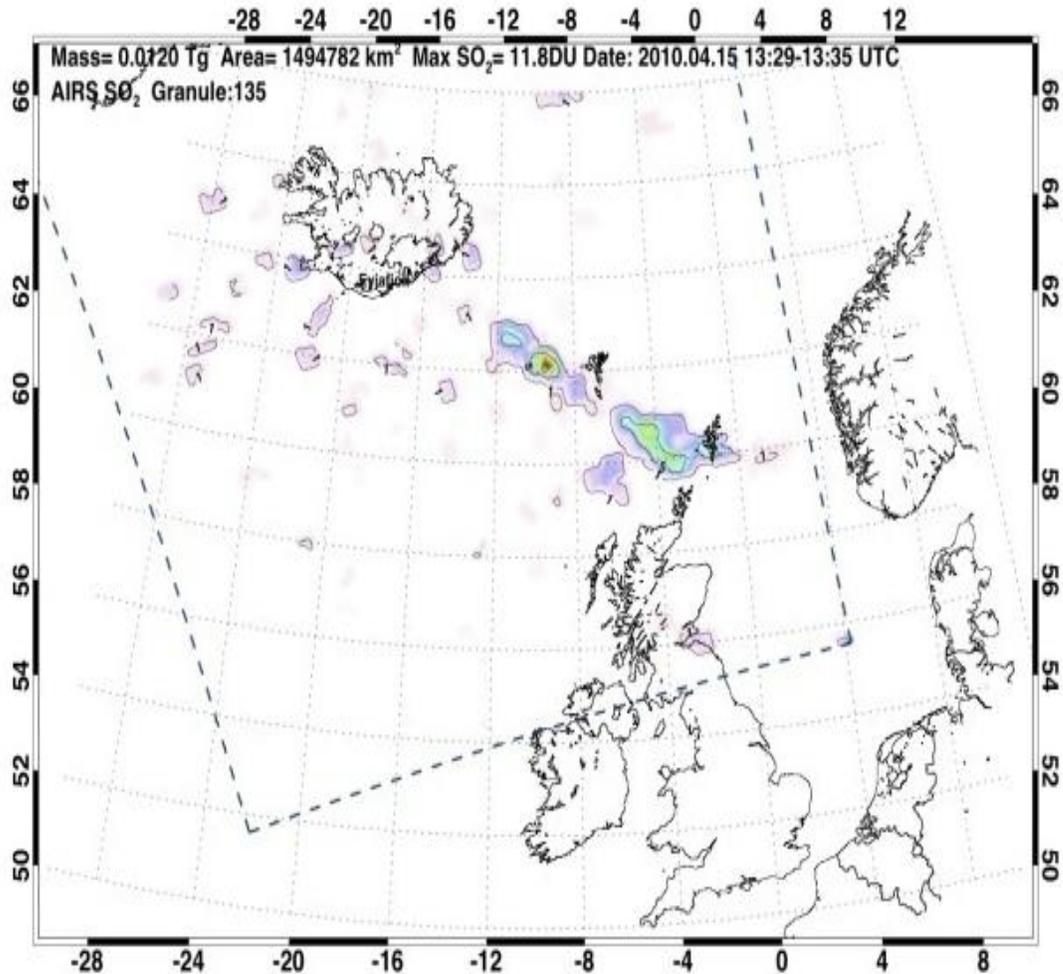
Can AIRS VPD-fire and the relationship between VPD, drought & fire contribute to determination of fire-risk?



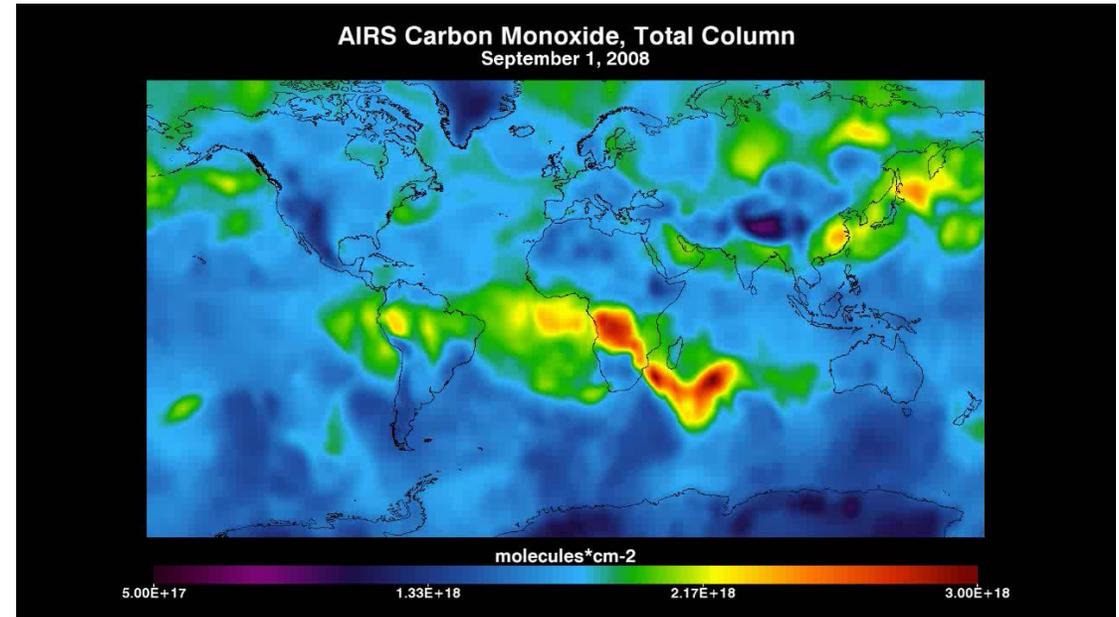
# AIRS Composition Products Support Aviation Hazards and Air Quality

## Sulfur Dioxide Alerts Aviation Warning

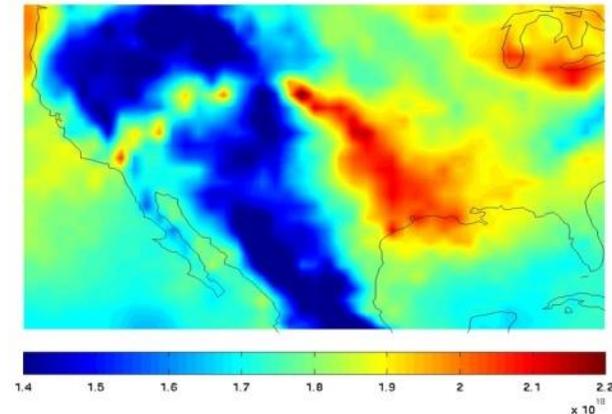
Ejyafyallajokul SO2  
Fred Prata NIAR, Norway



## Global Carbon Monoxide Transport (JPL, 2008)



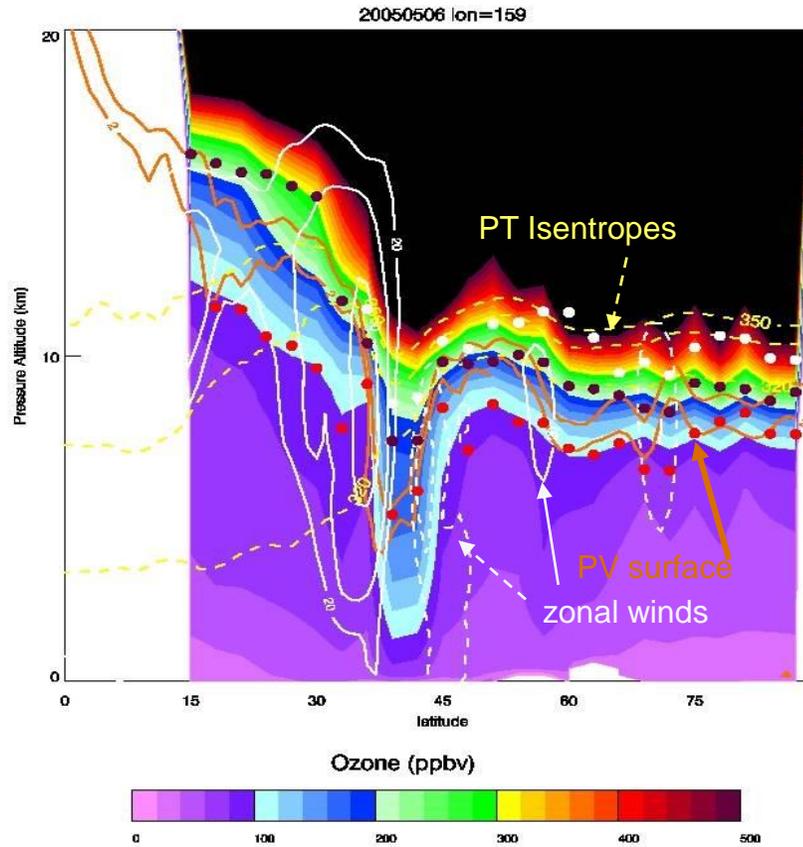
CO Total Column (mol/cm<sup>2</sup>): Aug 30-Sep 02, 2009 2009.09.02



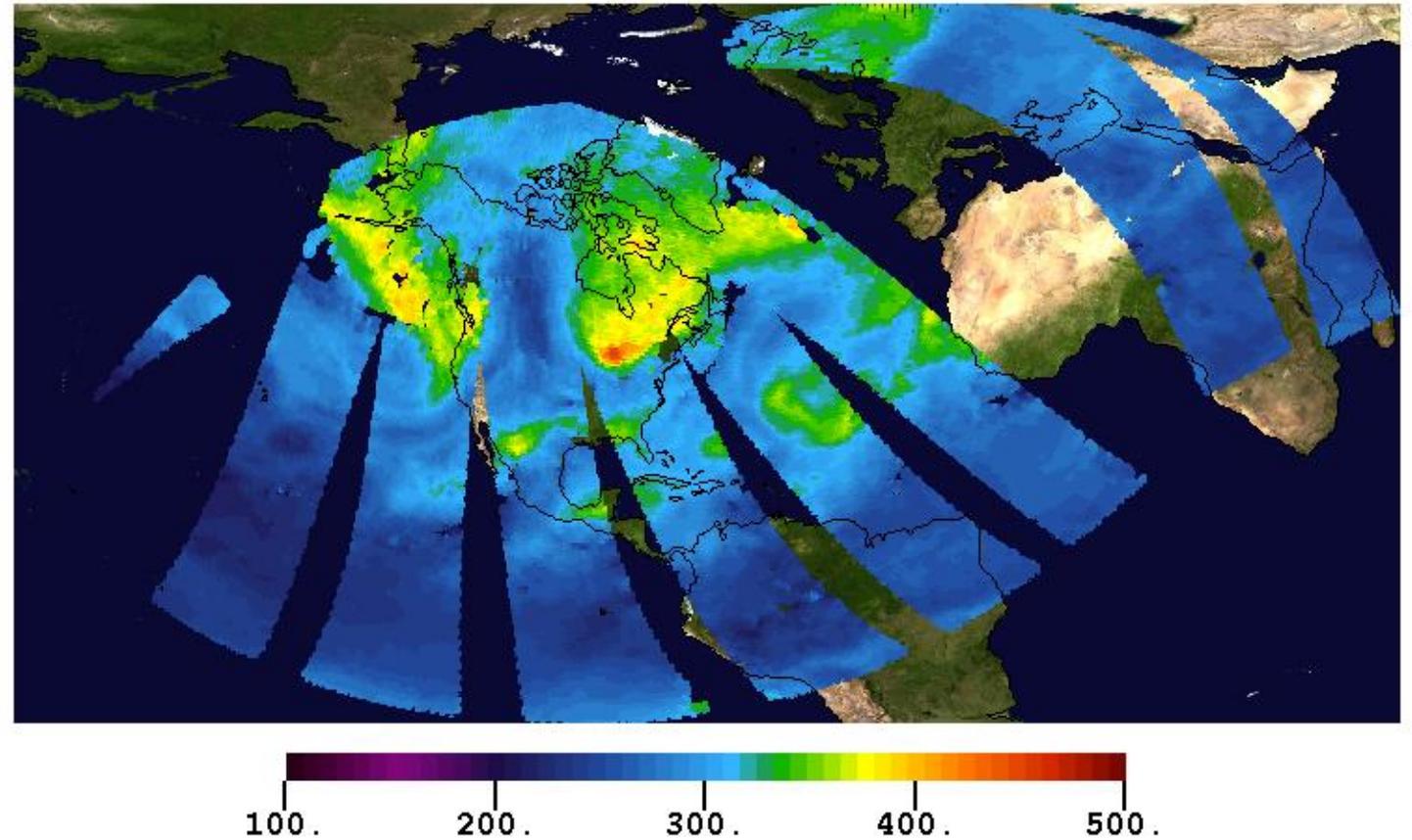


# AIRS Monitors Upper/Tropospheric-Stratospheric Ozone

## AIRS Identifies Stratospheric Ozone Intrusion, May 6, 2005 (Wei, 2008)



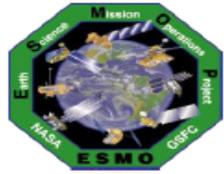
## AIRS Ozone Daily Global Imagery Enables Early Warning of Possible Poor Air Quality (7/19/07)



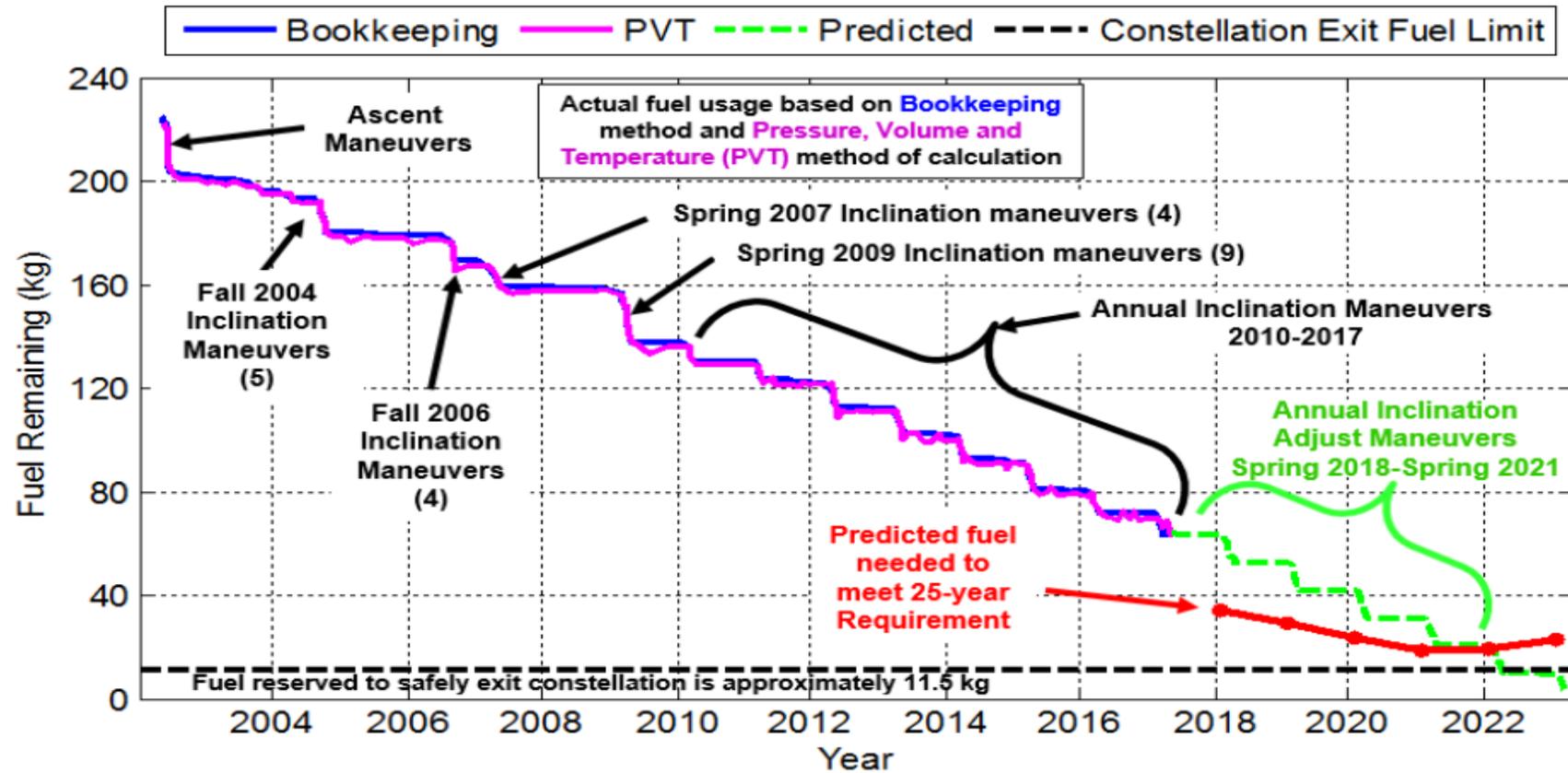
Pittman, J. V., L. L. Pan, J. C. Wei, F. W. Irion, X. Liu, E. S. Maddy, C. D. Barnet, K. Chance, and R.-S. Gao (2009), Evaluation of AIRS, IASI, and OMI ozone profile retrievals in the extratropical tropopause region using in situ aircraft measurements, *J. Geophys. Res.*, 114, D24109, doi:10.1029/2009JD012493



# AIRS Expected to Operate For Life of Spacecraft through 2022



## **No Changes** Fuel Usage: Actual & Predicted (November 2017)



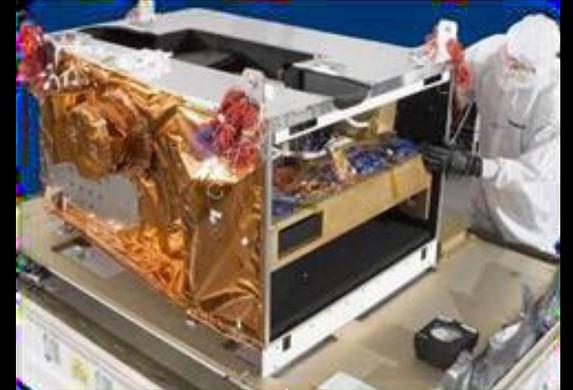
**ATMS**



**CrIS**



**VIIRS**



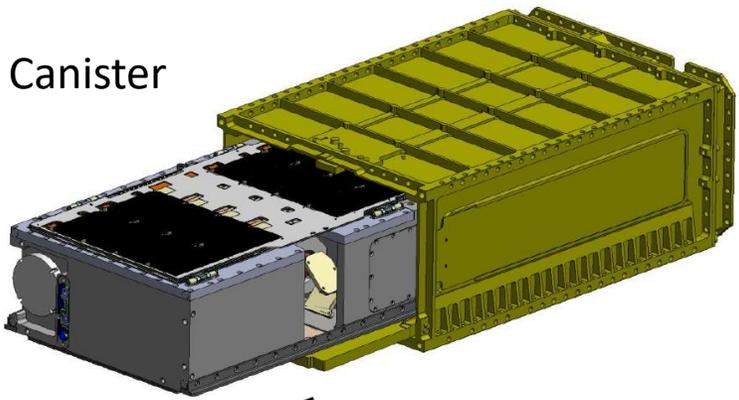
**OMPS**



**CERES**



PSC Canister



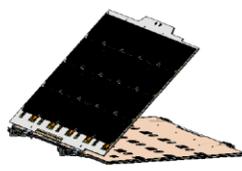
Deployment Direction



Stowed



1st Panel Released



1st and 2nd Panel Released



All panels Released



Fully Deployed



Solar Arrays

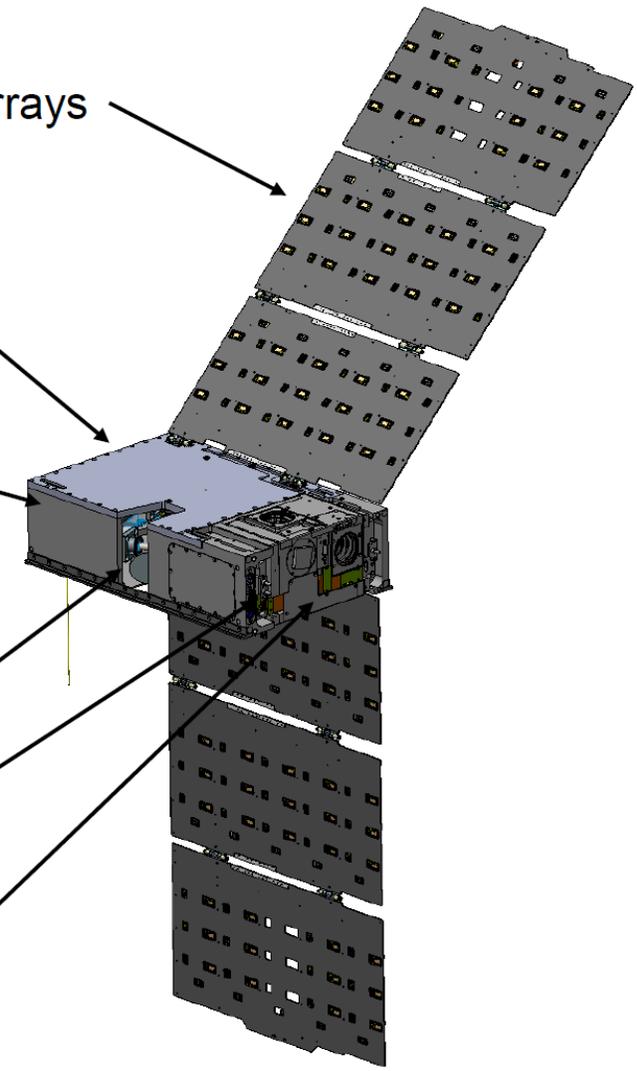
Instrument Panel

Main Chassis

Instrument Aperture

Sun Sensor

XB1 Avionics





# Summary and Conclusions

- NASA and NOAA Satellites Improve Weather Prediction and Support Earth Science
- Infrared Sounders including AIRS, CrIS and IASI have among the highest impact of all satellite instruments for improving weather forecast and are used widely for climate science
  - AIRS data assimilated by NWP centers worldwide
  - AIRS data used to validate climate models
  - AIRS data used to explore and understand processes affecting weather and climate
  - AIRS products help us understand the composition and chemistry of the atmosphere (e.g. O<sub>3</sub>, CO, CO<sub>2</sub>)
  - AIRS products used for applications to help decision makers: (e.g. SO<sub>2</sub>, Drought
- Microwave combined with infrared enable sounding in cloudy regions.
  - AMSU on Aqua and MetOp
  - ATMS on NPP and JPSS
- Aqua expected to run out of fuel by 2022. The NASA/NOAA Joint Polar Satellite System (JPSS) will continue AIRS type measurements into the late 2030's
- NASA and NOAA moving towards smaller satellites to save cost and complement existing satellites
- CubeSat technology now enables low-cost per satellite. Constellations are an alternative to GEO, provide global coverage of Temperature, Water Vapor, 3D Atmospheric Motion Vector Winds and Composition