AIRS Retrieval of Atmospheric CO_2 in Three Layers (progress toward satellite retrieval of a profile)

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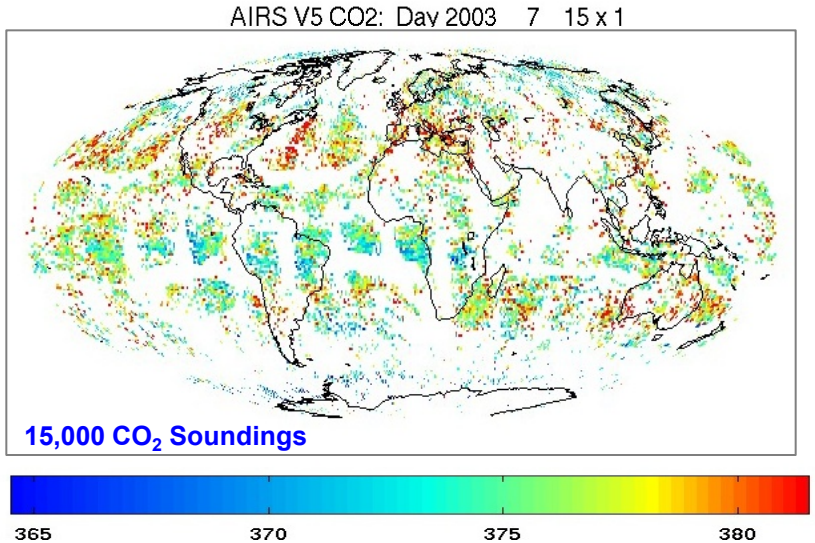
AIRS Operational Product
Mid-Tropospheric CO_2
(8 - 10 km)
Publically Released Dec 2009
and Extended Monthly

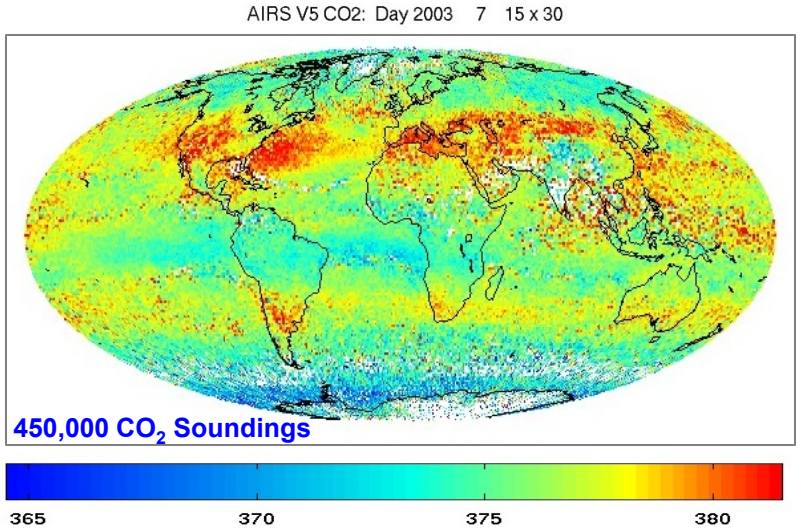
http://airs.jpl.nasa.gov/get_airs_co2_data

Global Yield of AIRS Level 2 Mid-Tropospheric CO_2

AIRS Daily CO_2 Yield
1°x1° Spatial Resolution



AIRS Monthly CO_2 Yield
1°x1° Spatial Resolution



AIRS Level 2 Mid-Tropospheric CO_2 retrieval yield is controlled by requirement for highest quality temperature and water vapor AIRS Level 2 products in 2x2 array of adjacent FOVs

Yield is expected to increase in V6 Release

Day/Night, Pole-to-Pole, Land/Ocean/Ice, Cloudy/Clear

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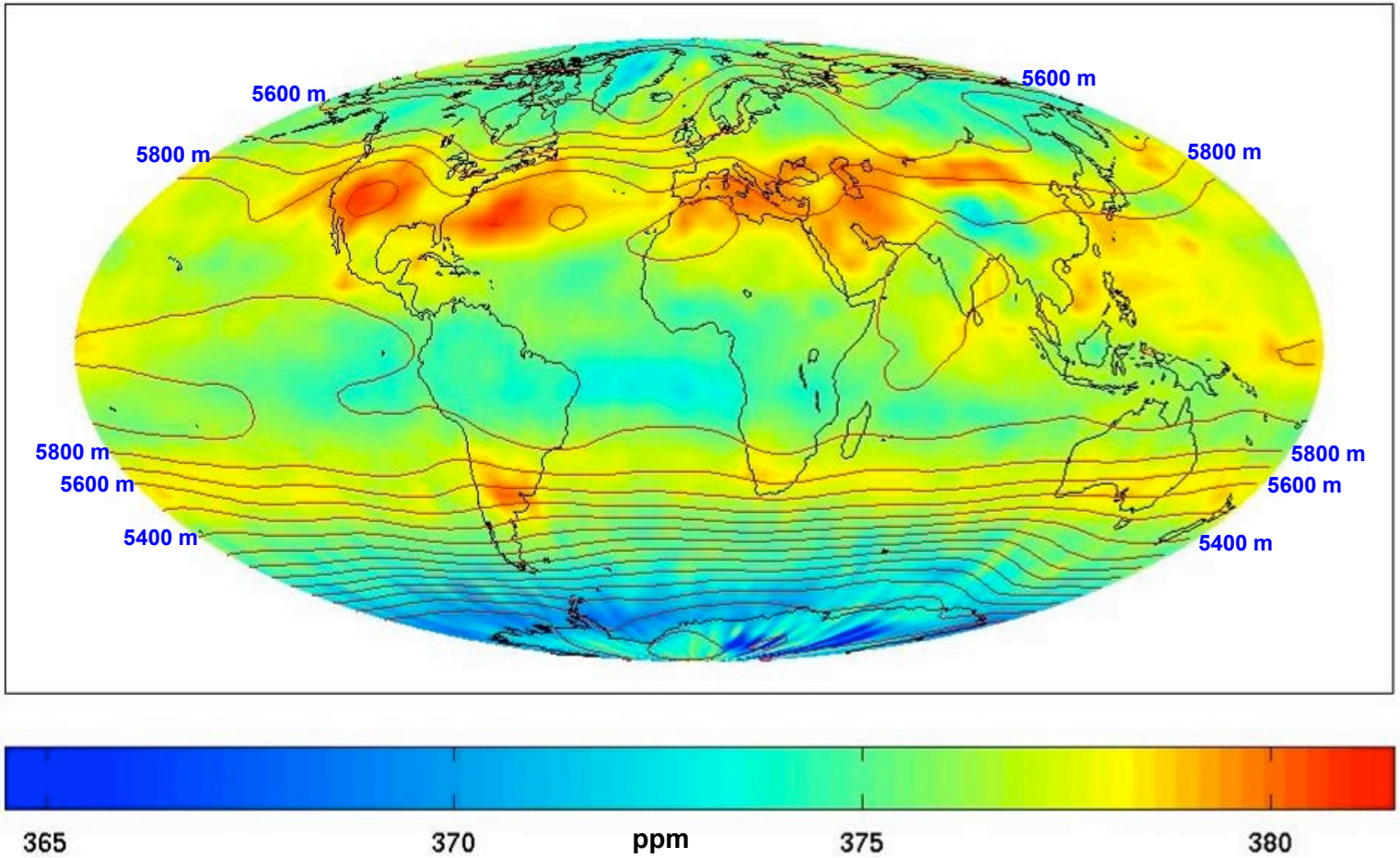
Atmospheric Infrared Sounder

AIRS Data Show CO_2 is not well mixed in Mid-Troposphere

July 2003 AIRS mid trop CO_2 (5° smoothing) with 500 hPa gph contours



CO_2 is <u>NOT</u> Well Mixed in the mid-troposphere

- **Driven by synoptic-scale phenomena (polar/subtropical jet streams)**
- **Complexity of the Southern Hemisphere not present in models**
- **AIRS mid-trop data will facilitate modeling of vertical & horizontal transport**

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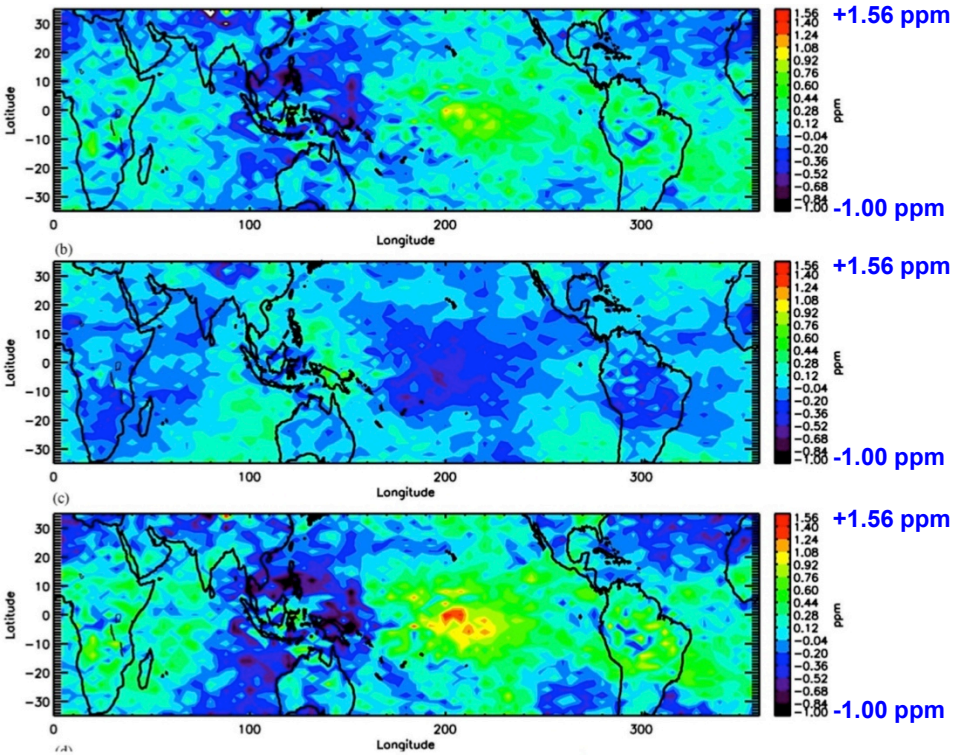
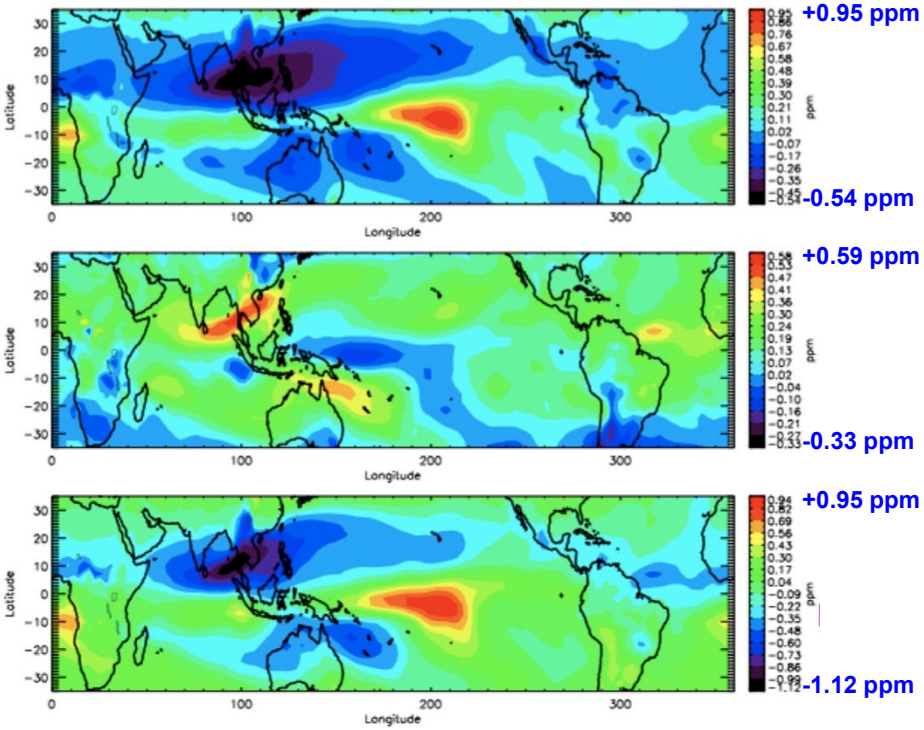
Atmospheric Infrared Sounder

UofH/JPL Study Finds Influences of El Niño in Mid-Tropospheric CO_2 Levels observed by AIRS Agrees with Walker Circulation





TOP: AIRS detrended and deseasonalized CO_2 anomaly averaged for 11 El Nino months (high CO_2 in Central Pacific)

MIDDLE: AIRS detrended and deseasonalized CO_2 anomaly averaged for 17 La Nina months (low CO_2 in Central Pacific)

BOTTOM: AIRS CO_2 anomaly difference (El Nino – La Nina) (Consistent with change in Walker Circulation)

TOP: MOZART-2 CO_2 anomaly during El Nino

MIDDLE: MOZART-2 CO_2 anomaly during La Nina

BOTTOM: MOZART-2 CO_2 Difference (El Nino – La Nina) (signal is smaller than observed by AIRS)

Jiang, X., M. T. Chahine, E. T. Olsen, L. L. Chen, and Y. L. Yung (2010), Interannual variability of mid-tropospheric CO2 from Atmospheric Infrared Sounder, Geophys. Res. Lett., 37, L13801, doi:10.1029/2010GL042823

NOTE: MOZART-2 results are preliminary. The boundary condition is a climatology and does not include interannual variability

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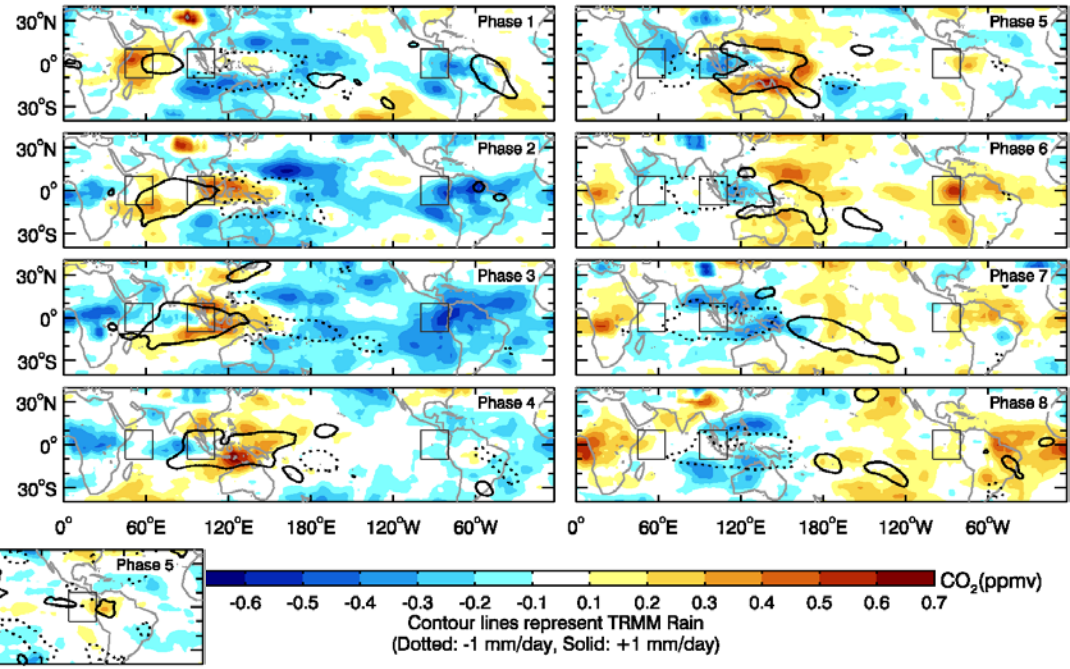
MJO-related AIRS Mid-Tropospheric CO_2 Anomaly
Intraseasonal CO_2 variability across the global tropics

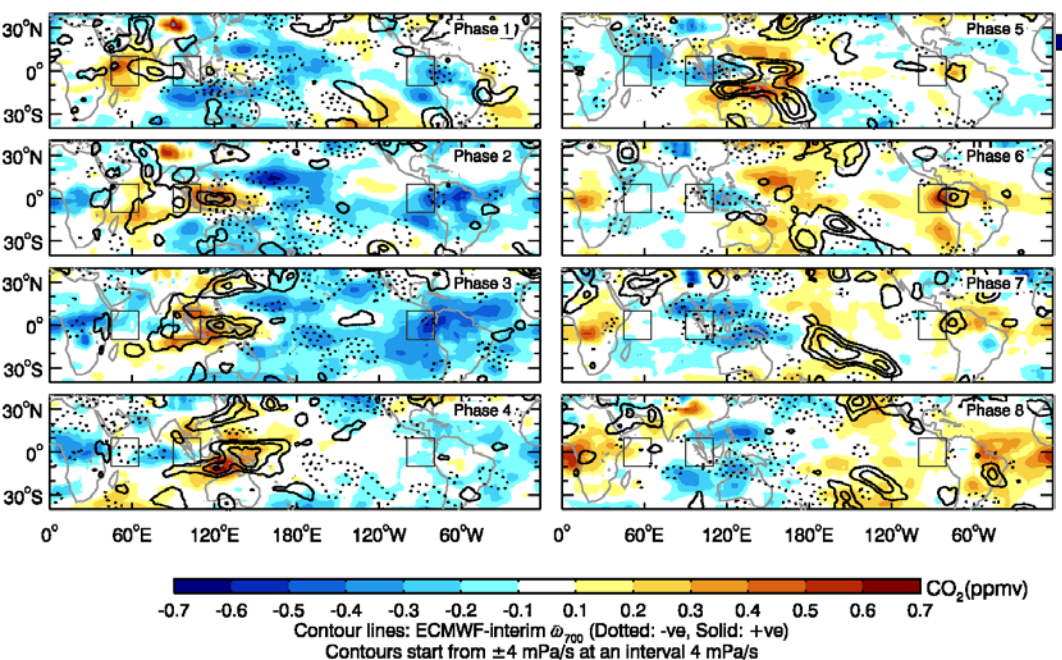
King-Fai Li, Tian, B., Waliser, D.E. and Yung, Y.L. (2010), Tropical mid-tropospheric CO2 variability driven by the Madden-Julian Oscillation, PNAS, 107 (45), 19171-19175, doi: 10.1073/pnas.1008222107

MJO has previously been studied via its impact on atmospheric winds, pressure, temperature, moisture and rainfall.

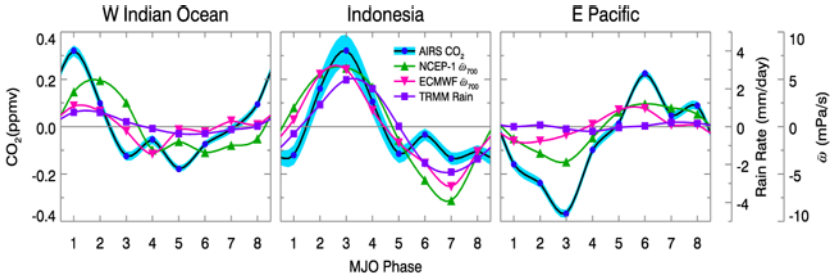
Its impact upon mid-tropospheric CO_2 has now been detected.

This provides a new window of study of this planetary-scale zonal overturning circulation anomaly.



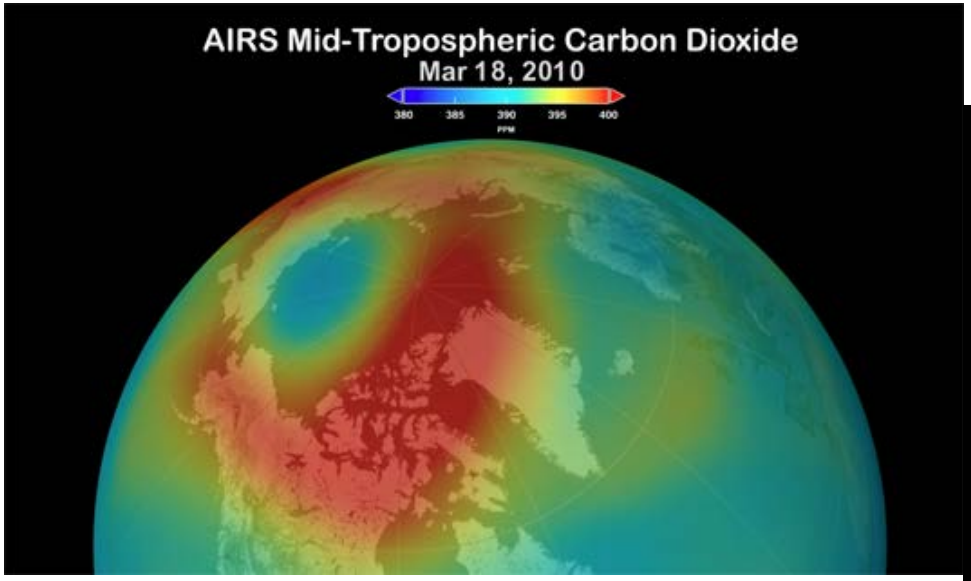


The CO_2 anomaly is driven by the eastward-propagating vertical circulation of the MJO and implies that CO2 values are higher at the surface than in the upper troposphere.
This intraseasonal CO_2 variability provides a robustness test for chemical transport models.

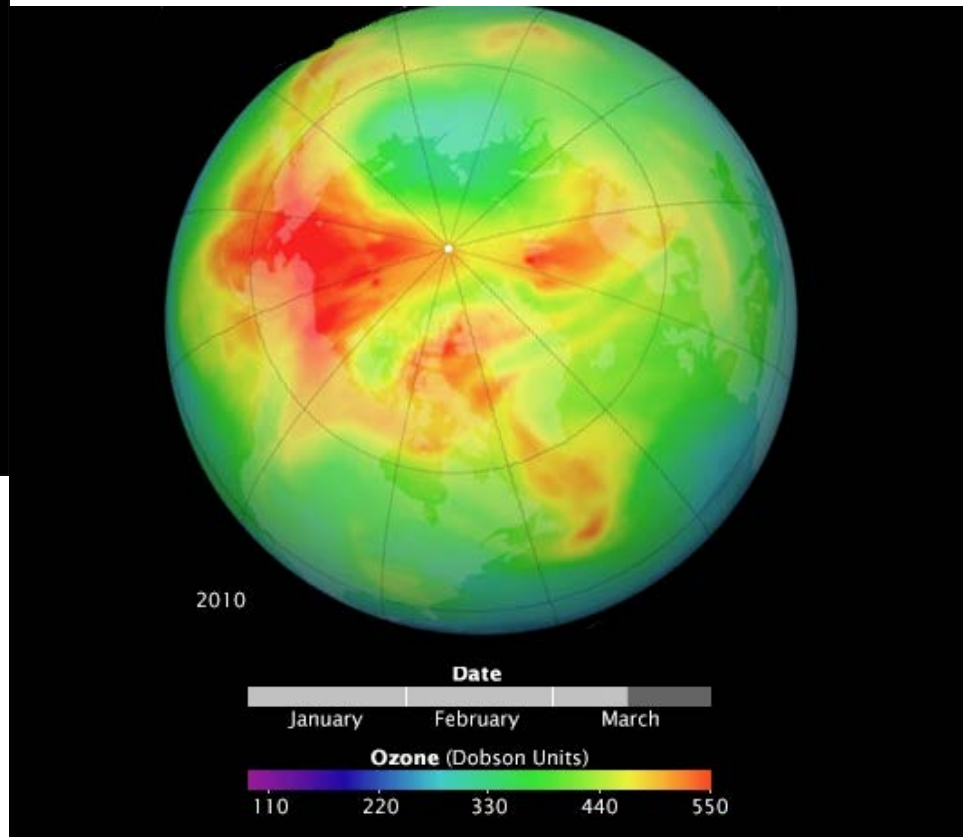


18 March 2010 AIRS Mid-Trop CO_2 and OMI O_3

AIRS



OMI



OMI image from movie at
http://earthobservatory.nasa.gov/IOTD/view.php?id=49874

AIRS image from movie at
http://svs.gsfc.nasa.gov/vis/a000000/a003800/a003812/index.html

AIRS Development Product
Mid-Stratospheric CO_2
(25 km)

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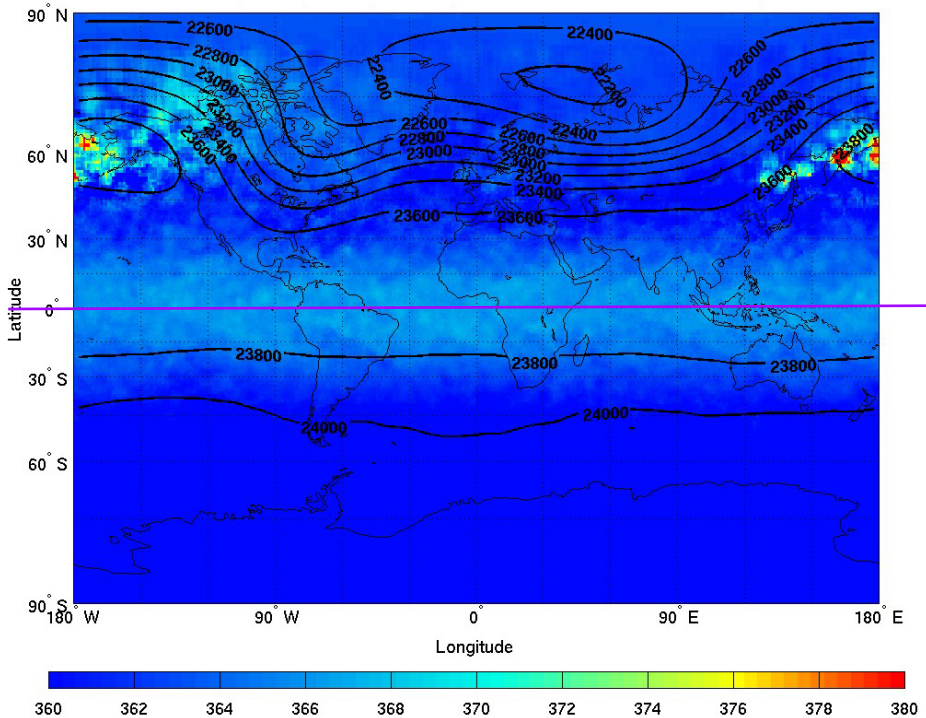
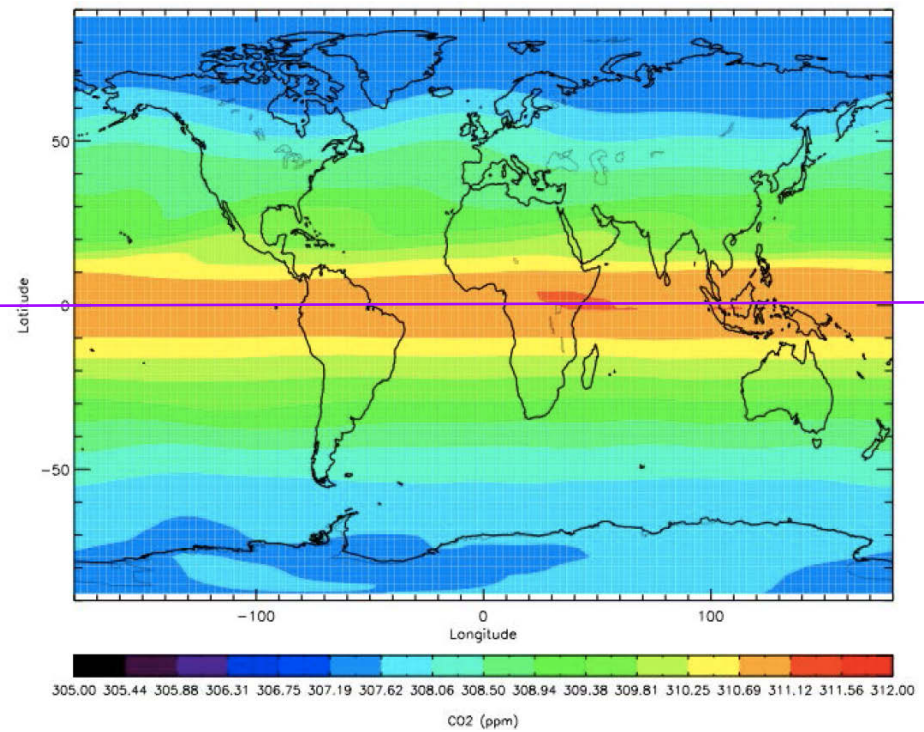
Jan 2003 Stratospheric CO_2 Retrieval Compared to Models

(AIRS Stratospheric Contribution Function Applied to Models)

AIRS Retrieved CO_2



3-D IMATCH CO_2



360 **Contours are 30 hPa GPH** **380**

305 **Model profile weighted by AIRS sensitivity function** **312**

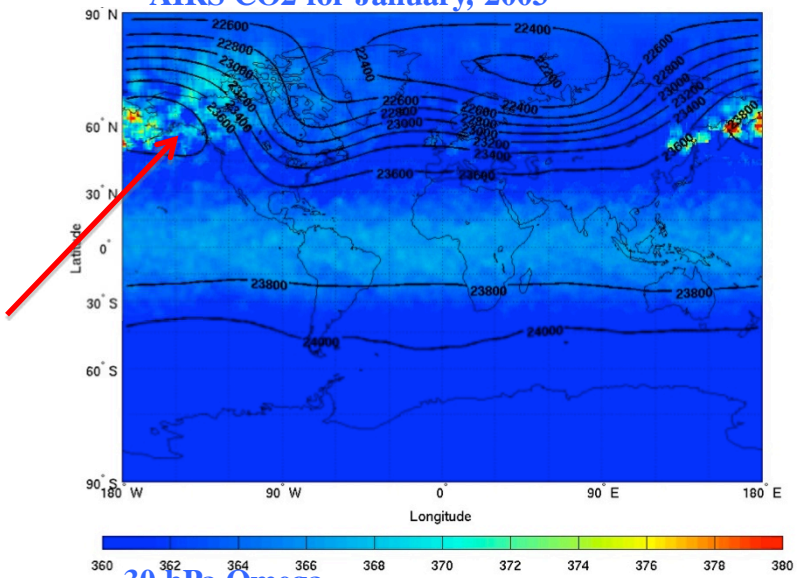
PRELIMINARY

Both AIRS and models show presence of tropical pipe
- **AIRS shows greater variation with latitude (~15 ppm vs ~4 ppm)**
- **AIRS shows additional troposphere intrusion at high latitude**

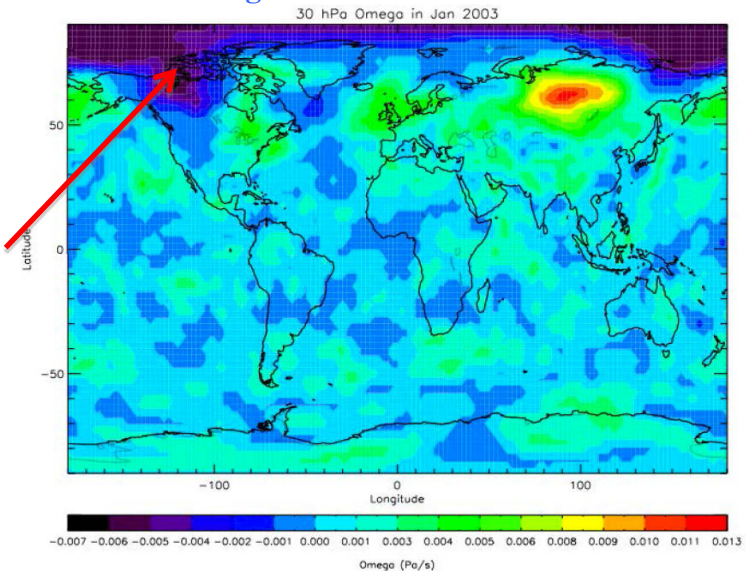
Model Runs by Xun Jiang, University of Houston

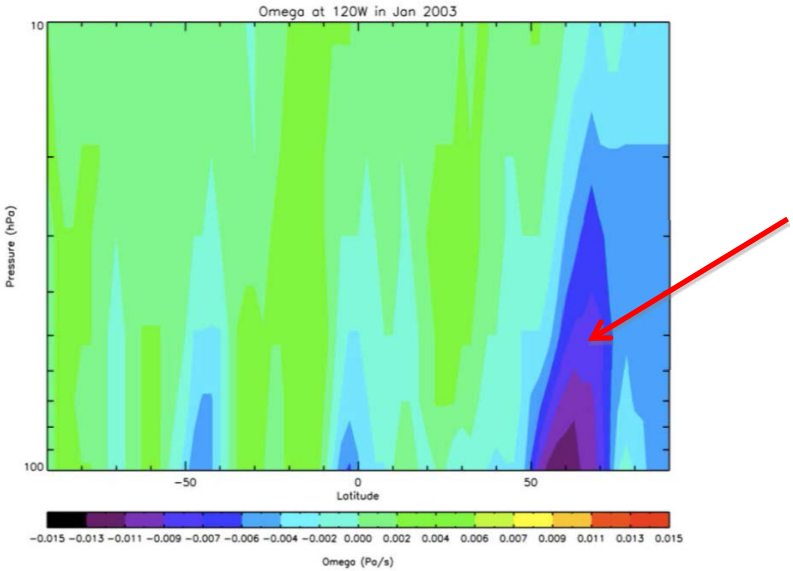
AIRS Stratospheric CO_2 (tropospheric CO_2 intrusion/vertical wind)

AIRS CO2 for January, 2003



30 hPa Omega





Vertical velocity (dP/dt) at 120°W in January 2003 (NCEP2 Reanalysis)
Negative (positive) value represents upward (downward) motion. Units are Pa/s.

Omega = dP/dt at 30 hPa (NCEP2 Reanalysis)
Negative Omega --- Upward motion;
Positive Omega --- Downward motion

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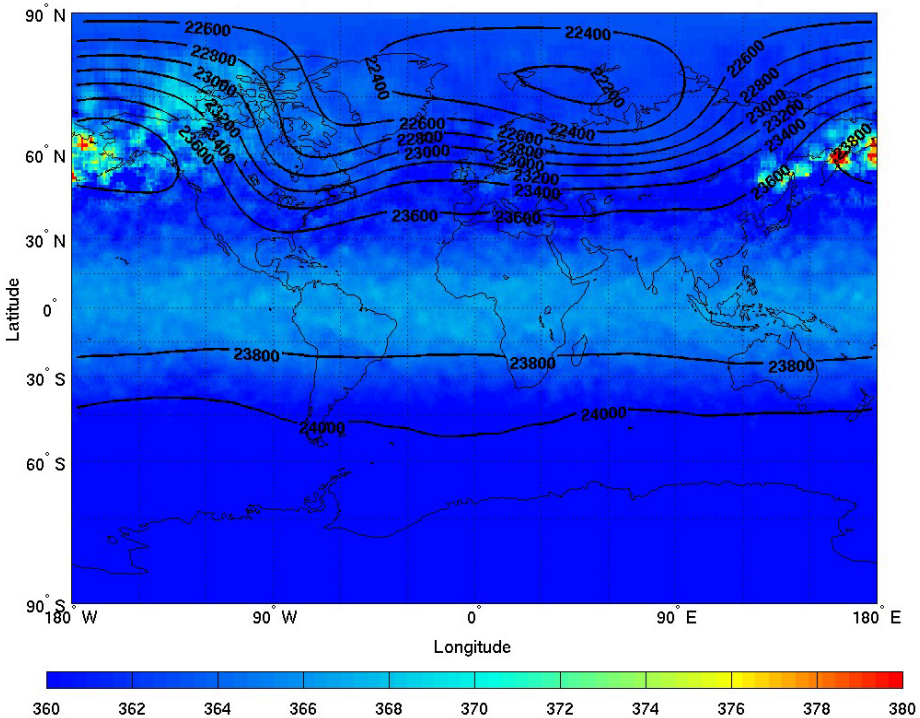
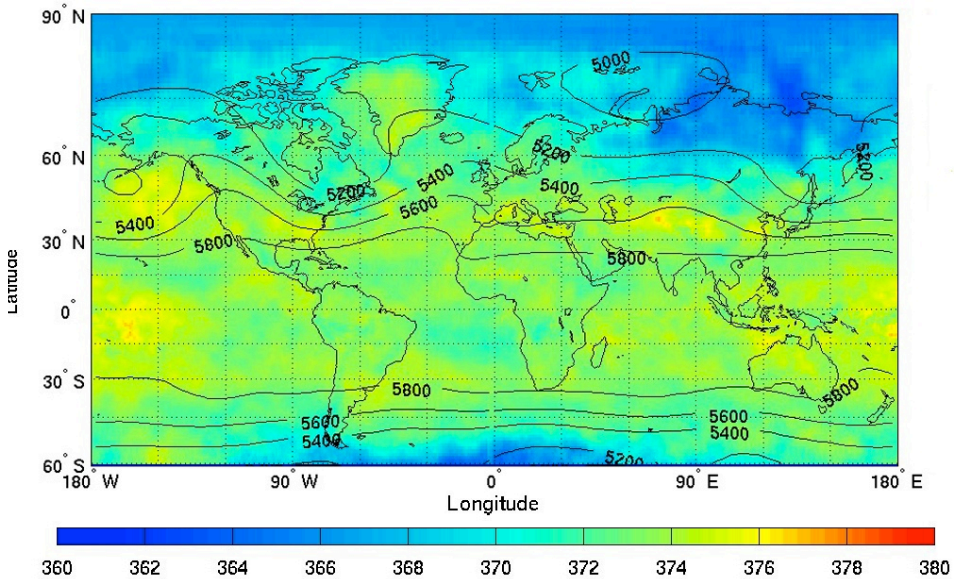
Jan 2003 Mid-Strat CO_2 Retrieval Compared to Mid-Trop CO_2 Retrieval

AIRS Stratospheric Retrieved CO_2



360 Contours are 30 hPa GPH(m) 380

AIRS Mid-Trop Retrieved CO_2



360 Contours are 500 hPa GPH(m) 380

PRELIMINARY

Average age of Tropical AIRS Mid-Strat CO_2 = 3.75 years (assuming 2 ppm/yr increase)

- **AIRS average Mid-Strat CO_2 for $|LAT| \leq 10^\circ$ = 366.1 ppm**
- **AIRS average Mid-Trop CO_2 for $|LAT| \leq 10^\circ$ = 373.6 ppm**

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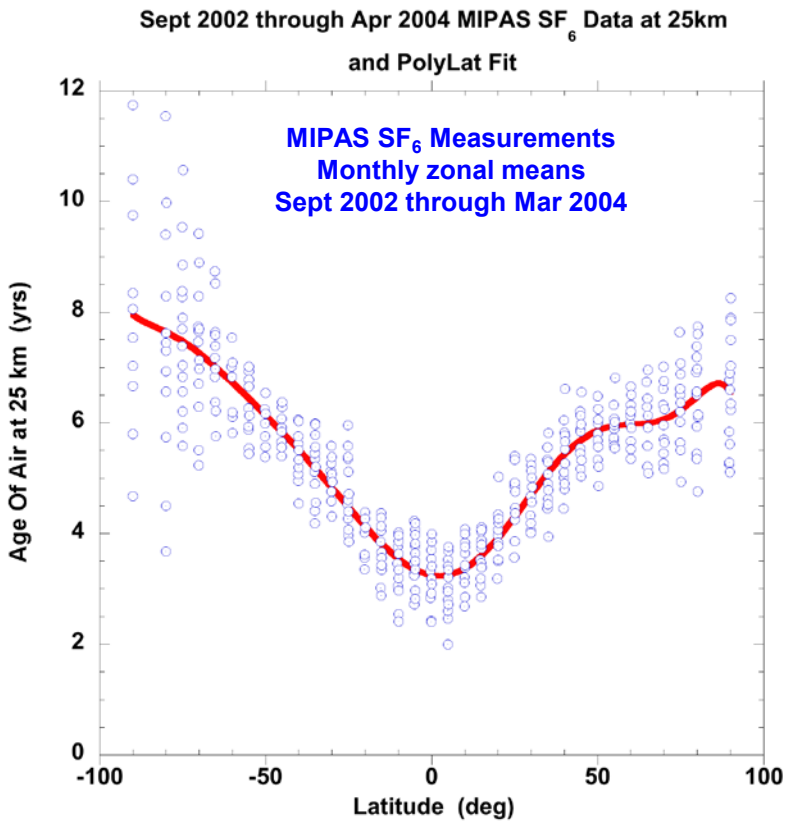
Jan 2003 AIRS Mid-Stratospheric CO_2 Age of Air

Prior is Jan 2003 Mid-Trop Tropical Average (|lat| ≤ 10°) = 373.6 ppm
Retarded by Latitude-Dependence of Age of AIR at 25 km from MIPAS

MIPAS SF_6 Data

and polynomial fit for latitude dependence

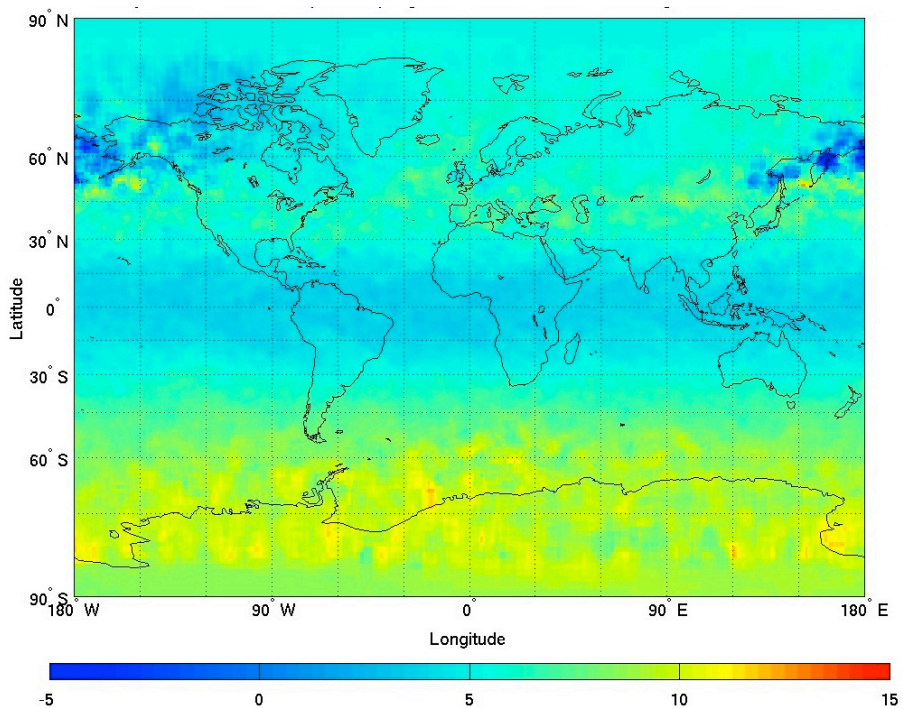


Stiller et al (2007), Global distribution of mean age of stratospheric air from MIPAS SF6 measurements, Atmos.Chem.Phys.Discuss., 7,13653

AIRS CO_2 Mid-Stratospheric Age of Air

Assuming 2 ppm/yr increase

(relative to Mid-Trop Tropical @ 450 hPa)



Age(yr) ≡ (373.6_ppm – stratCO2ret_ppm)/(2 ppm/yr)

Range: -2 to +13 years

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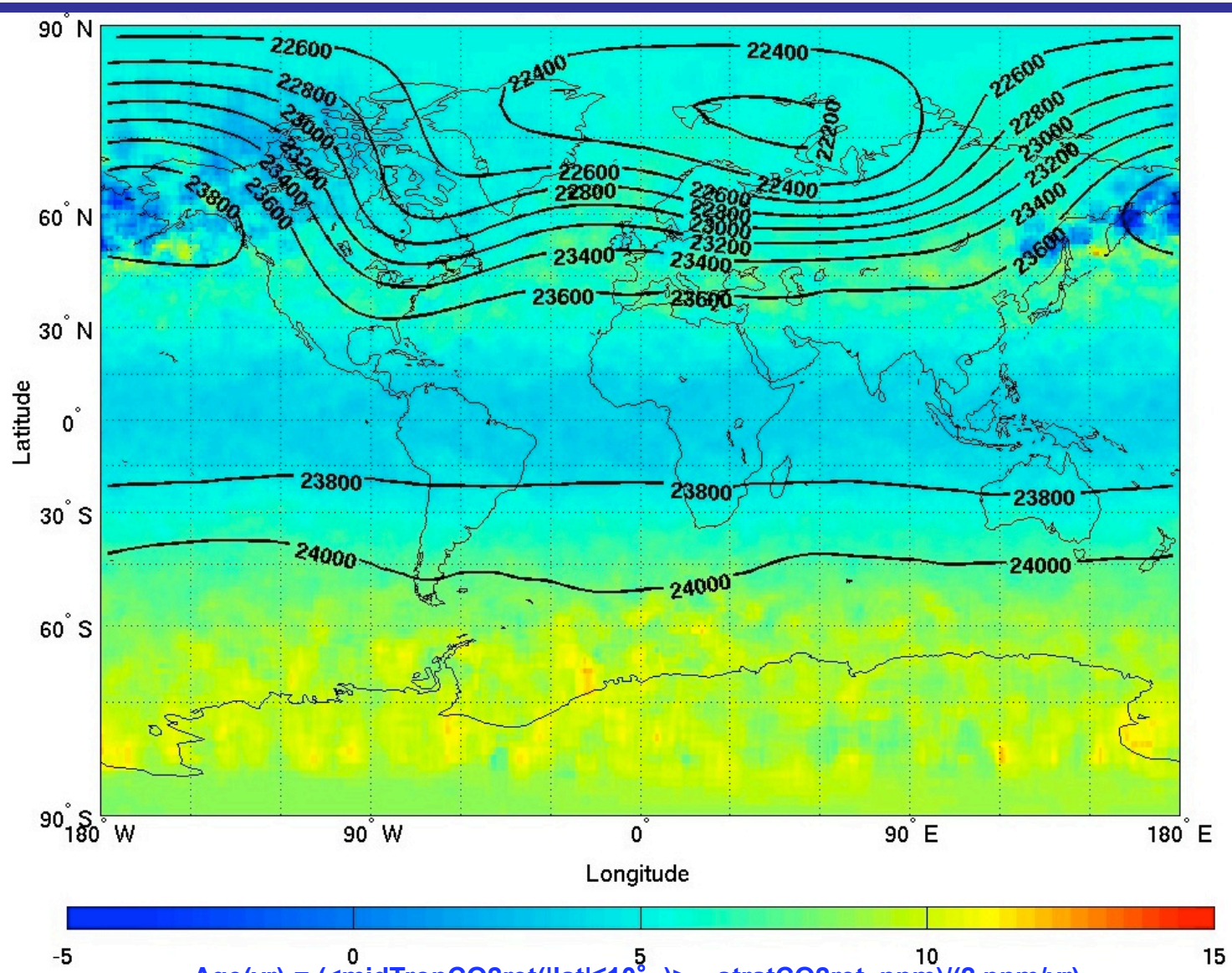
Jan 2003 AIRS CO_2 Mid-Stratospheric Age of Air

(relative to Mid-Trop Tropical @ 450 hPa)

Contours are 30 hPa GPH (m)



Age(yr) ≡ (<midTropCO2ret(|lat|≤10°)> – stratCO2ret_ppm)/(2 ppm/yr)

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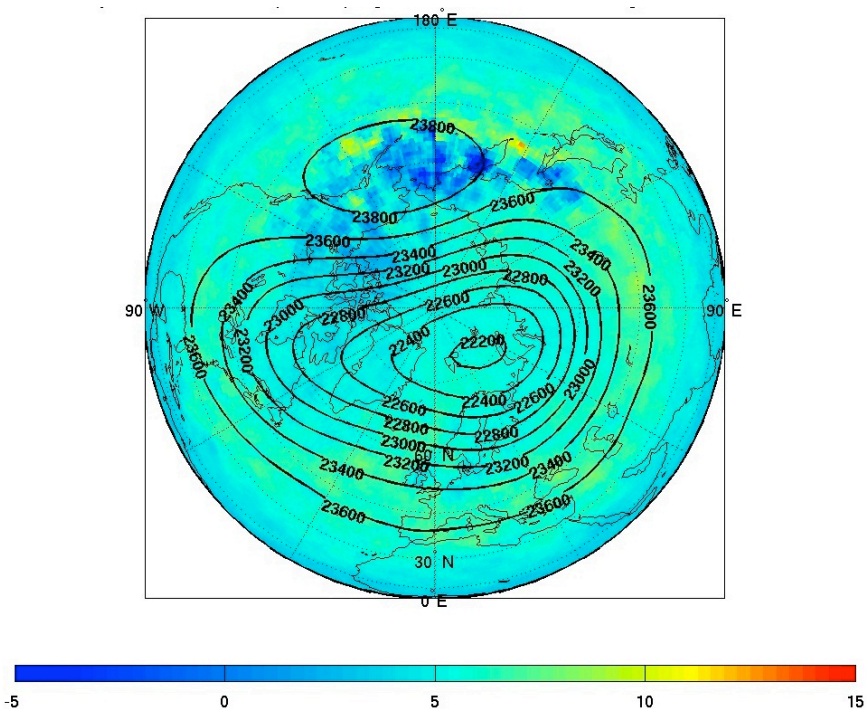
Jan 2003 AIRS CO_2 Mid-Stratospheric Age of Air

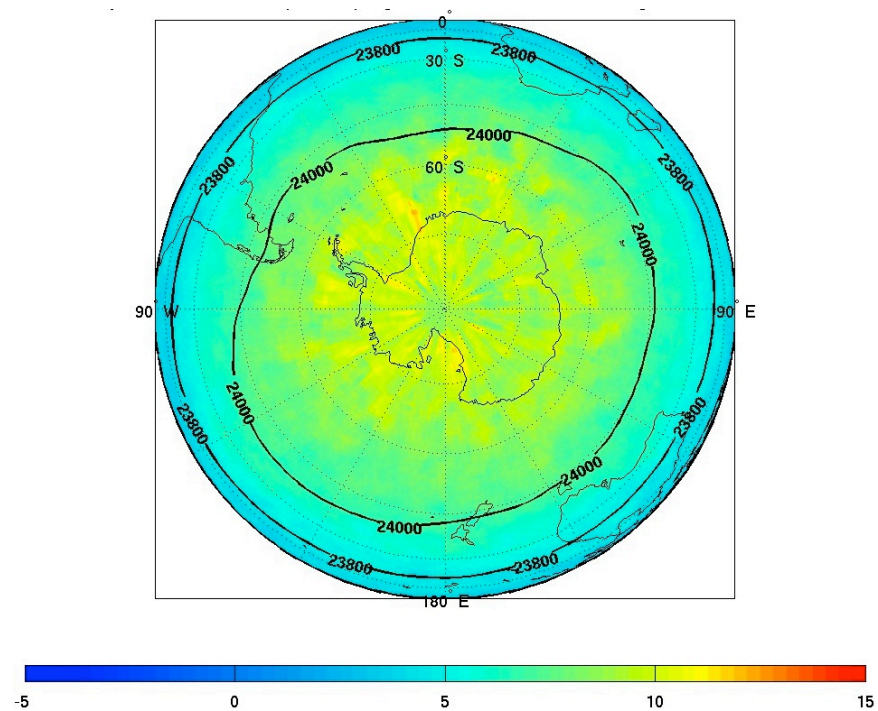
(relative to Mid-Trop Tropical @ 450 hPa)

Contours are 30 hPa GPH (m)

North Pole



South Pole



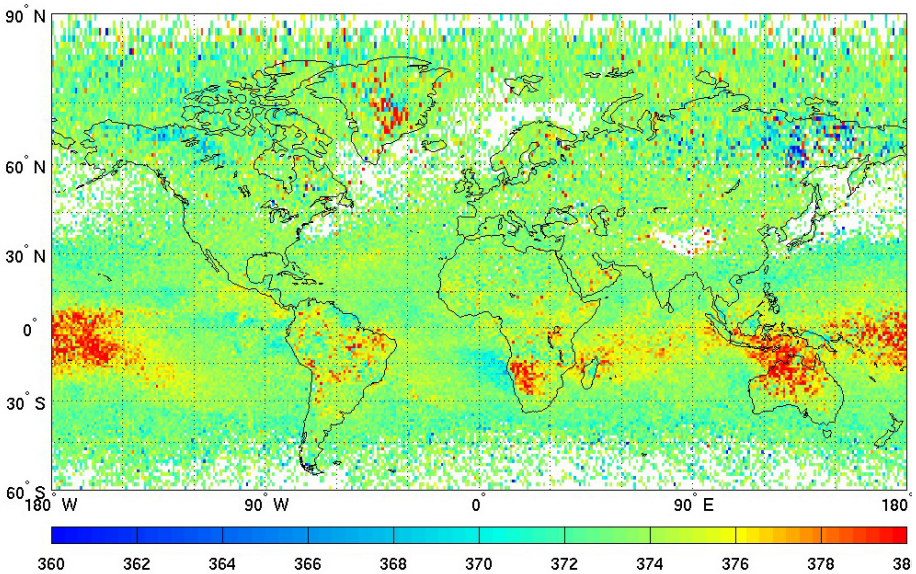
Age(yr) ≡ (<midTropCO2ret(|lat|≤10°)> – stratCO2ret_ppm)/(2 ppm/yr)

AIRS First Results
Lower-Tropospheric CO_2
(2.2km)

AIRS Lower-Tropospheric (2.2km) CO_2

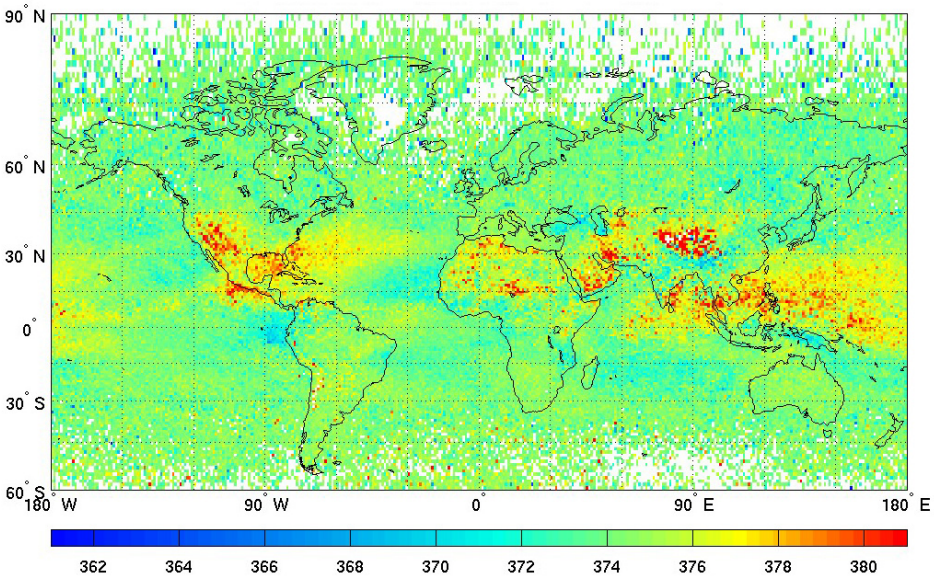
(preliminary results – channel set not yet optimized and surface emission module not yet implemented)

January 2003
AIRS Lower Tropospheric CO2 Retrievals



PRELIMINARY

July 2003
AIRS Lower Tropospheric CO2 Retrievals



PRELIMINARY

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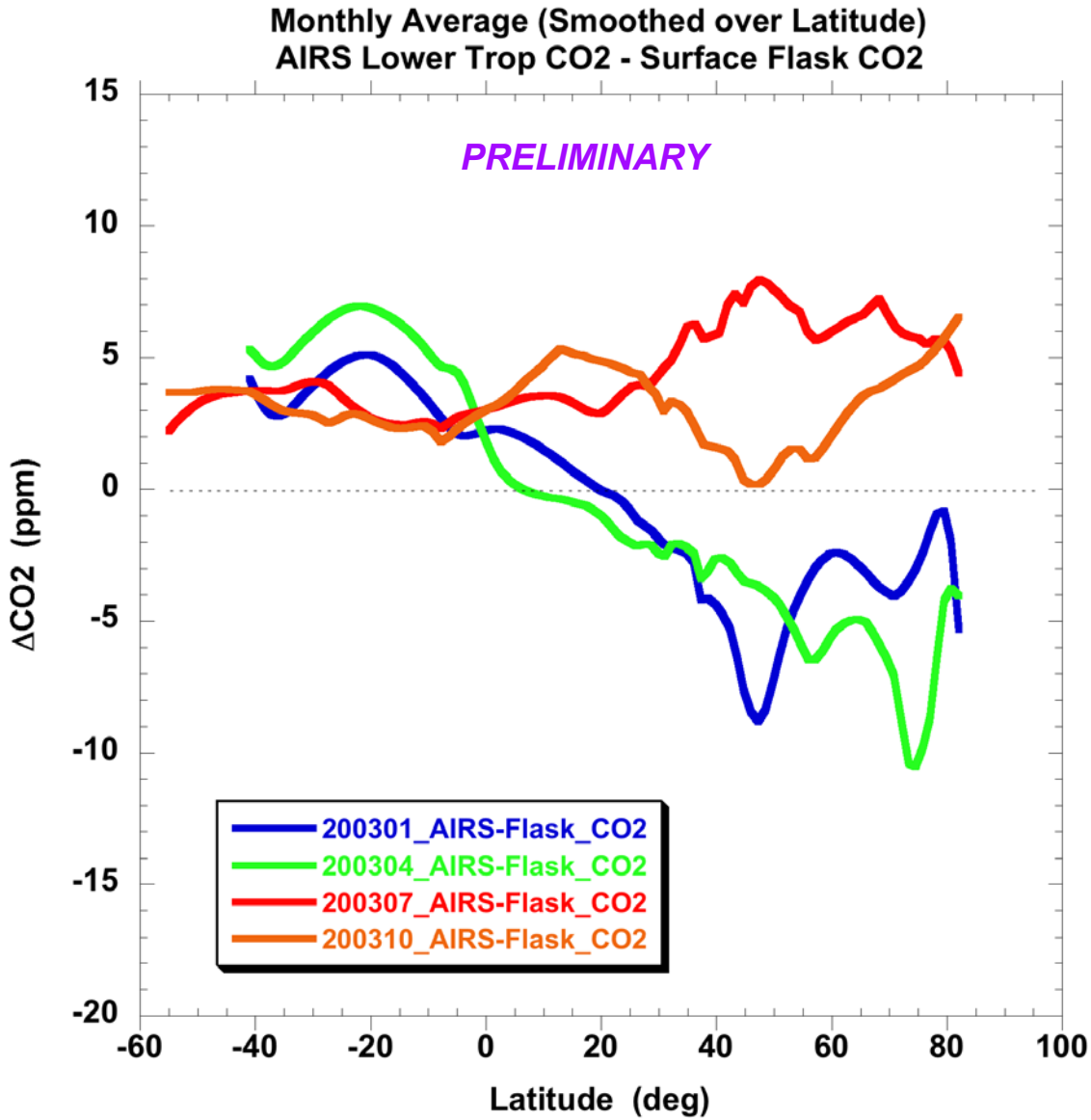
Prelim AIRS Lower-Tropospheric (2.2km) CO_2

(comparison to collocated surface flask locations)

(Flask monthly averages; monthly average and std dev for AIRS retrievals within 250km)



Latitude dependence of seasonal variation of (AIRS-Flask) appears reasonable:

Strong NH seasonal variation apparent
- **Respiration at surface greatest Jan-Apr**
- **Vegetative drawdown at surface greatest Jul-Oct**

When calculation of lower troposphere averaging kernels for AIRS retrievals are implemented, analysis comparison to aircraft profiles will be carried out

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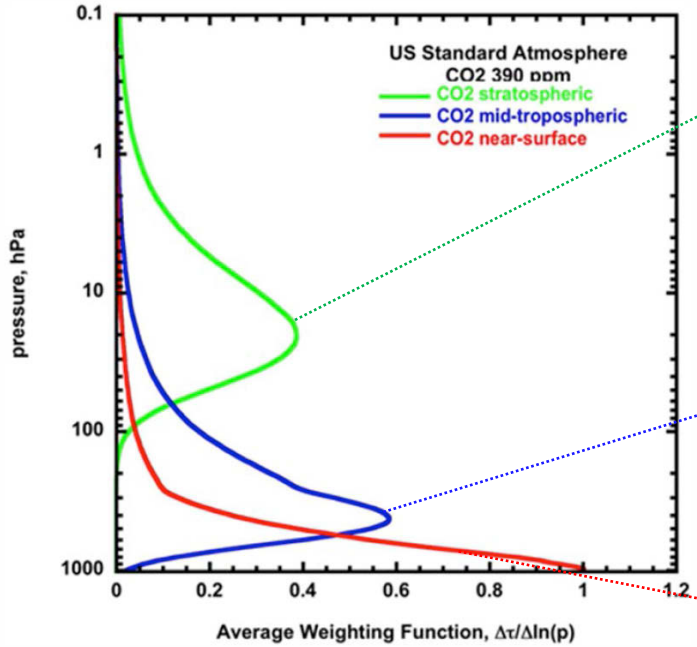
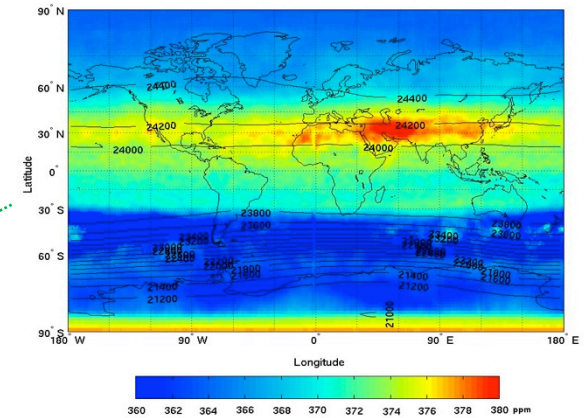
3 Layers of CO_2 Derived from AIRS July 2003

AIRS CO2 Weighting Functions



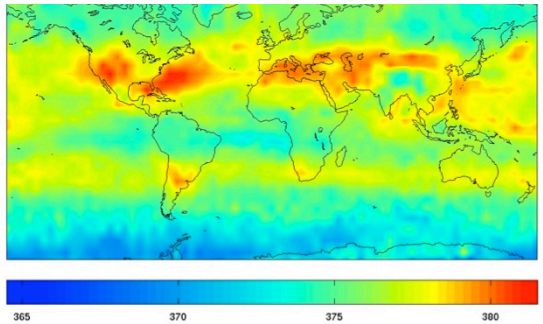
Sensitivity of AIRS Channels to CO2

Stratosphere



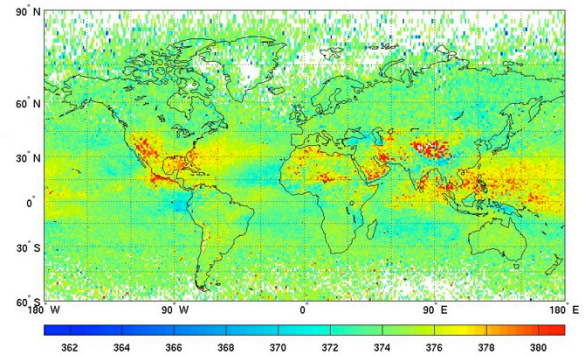
Preliminary

Mid-Troposphere



Validated
Sept 02 - Present

Lower Trop



Preliminary

M. Chahine et. al. (JPL)

Moustafa T. Chahine
1935 - 2011

A Brilliant Scientist
A Great Visionary
A Caring Mentor
A Good Friend
Whose door was always open

Leave comments at
http://blogs.jpl.nasa.gov/2011/03/in-memory-of-dr-moustafa-t-chahine-1935-2011/
they will be collected and presented to his family

END

PS: I invite you to access Eyes on the Earth at this URL
http://climate.jpl.nasa.gov/Eyes
To see visual globes of satellite data in near real time as well as from past dates