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AIRS Mid-Tropospheric CO_2 Retrieval Results by method of Vanishing Partial Derivative (VPD) and Comparison with In Situ Measurements

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http://airs.jpl.nasa.gov

AIRS Science Team Meeting

April 16, 2008

California Institute of Technology

Pasadena, California

Overview

- Stability of VPD Solution
- Validation and Comparison with *In Situ* Measurements
  - Aircraft, Mauna Loa and Park Falls FTS
- Geospatial and Temporal Variability of CO_2
  - Impact of Weather and Stationary Sources
  - Comparison to Chemistry Transport Model
  - July 2003 5-Day Animation - Synoptic Variability
  - September 2002 through Dec 2005 Monthly Averages Demonstrating Seasonal and Interannual Variations

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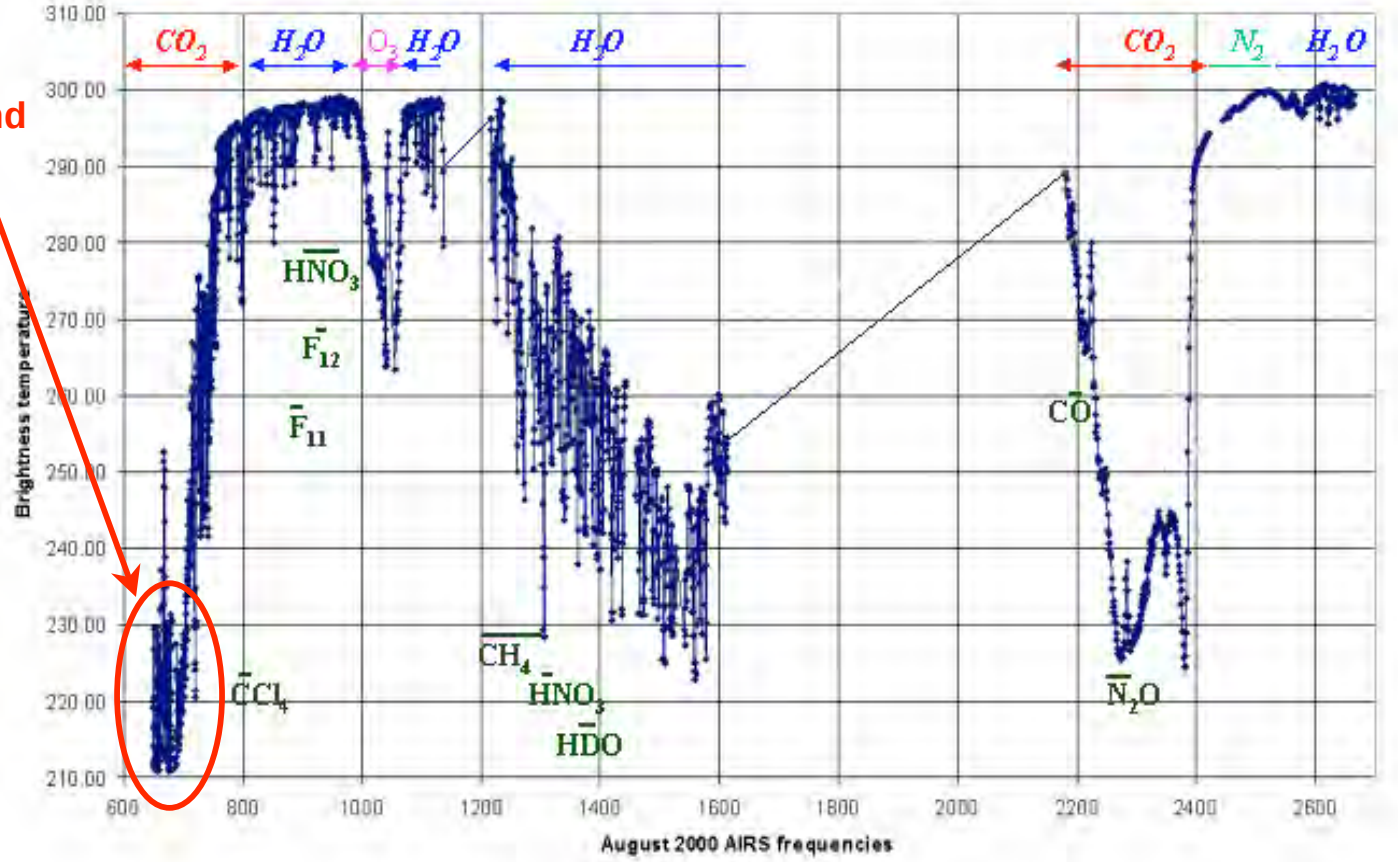
AIRS Infrared Spectrum

AIRS Channels for Tropical Atmosphere with T_surf = 301K

2378 channels - λ/δλ = 1200

15 μm band used by VPD



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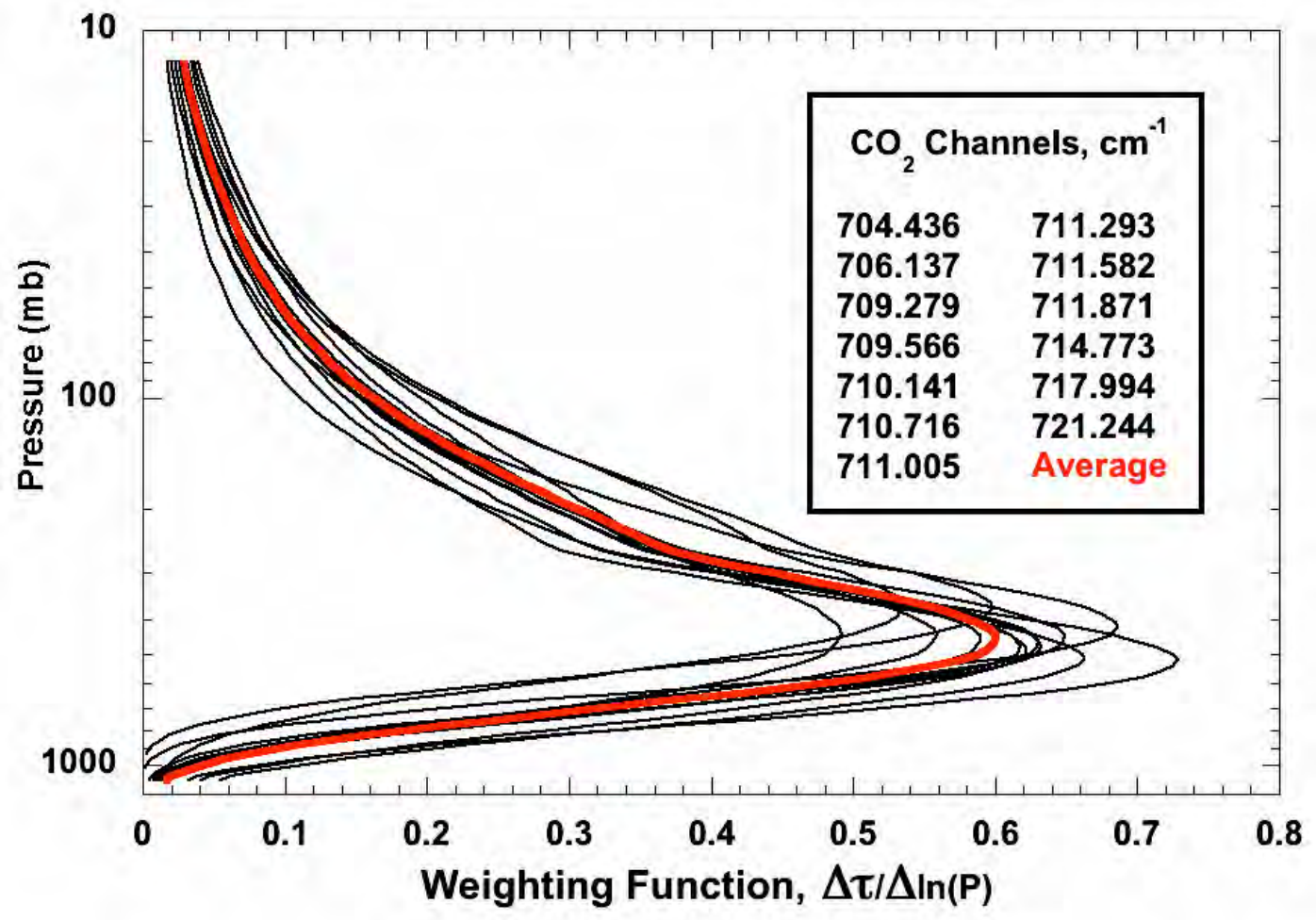
CO_2 Sounding Channels in the Mid-Troposphere



Peak Sensitivity: 450 hPa
Half-Peak span: 200->700 hPa

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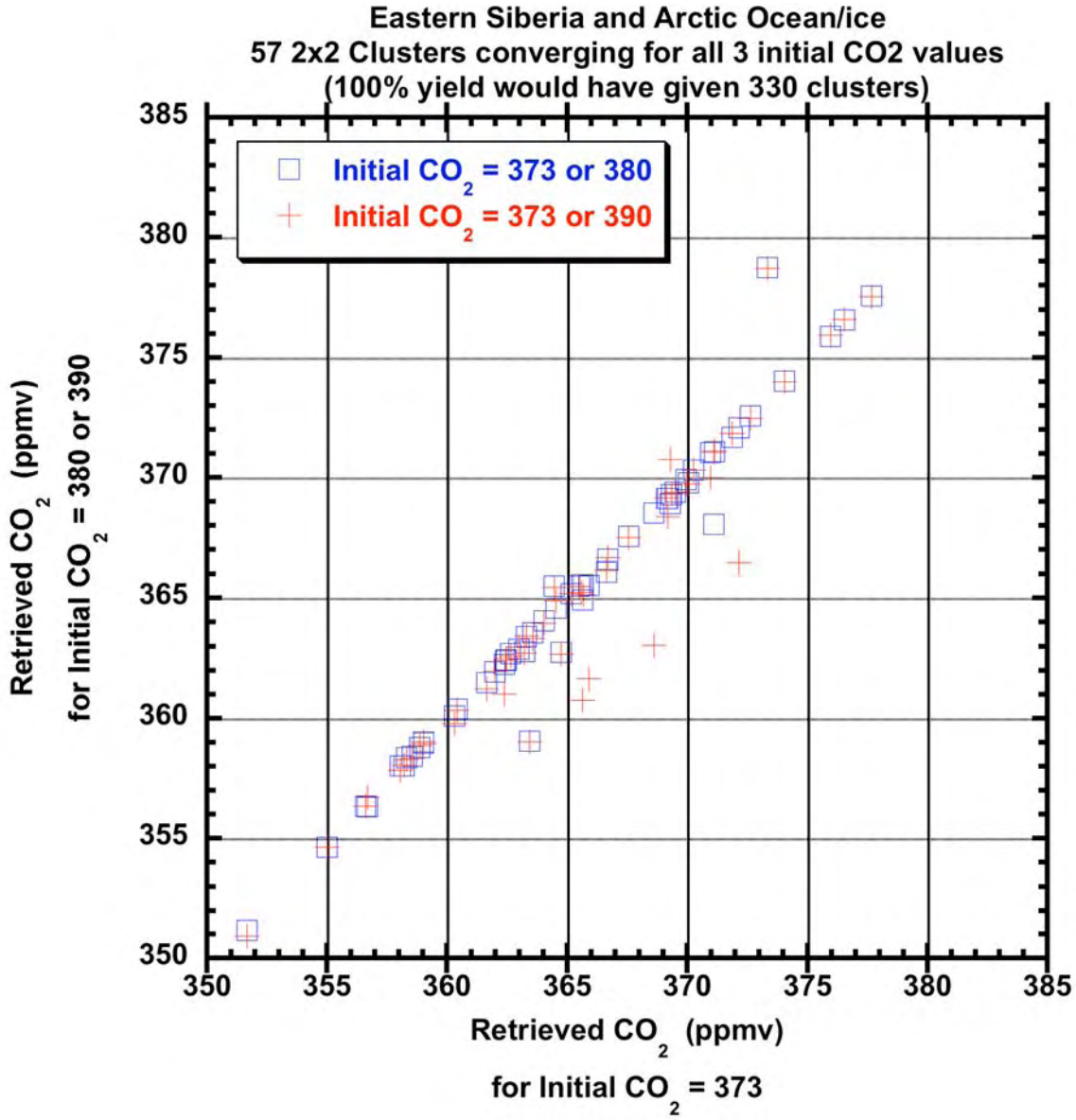
Independence of the Solution

from Initial starting value of the CO_2 Mixing Ratio assumed by the VPD algorithm

VPD retrieval result is independent of a wide range of initial assumption of CO_2 mixing ratio.

Only requirement is for the initial CO_2 that AIRS algorithm assumes to retrieve geophysical products to be within +/- 8% of the true value (nominally +/- 30 ppmv) to ensure that the rapid transmittance algorithm remains in the linear regime.



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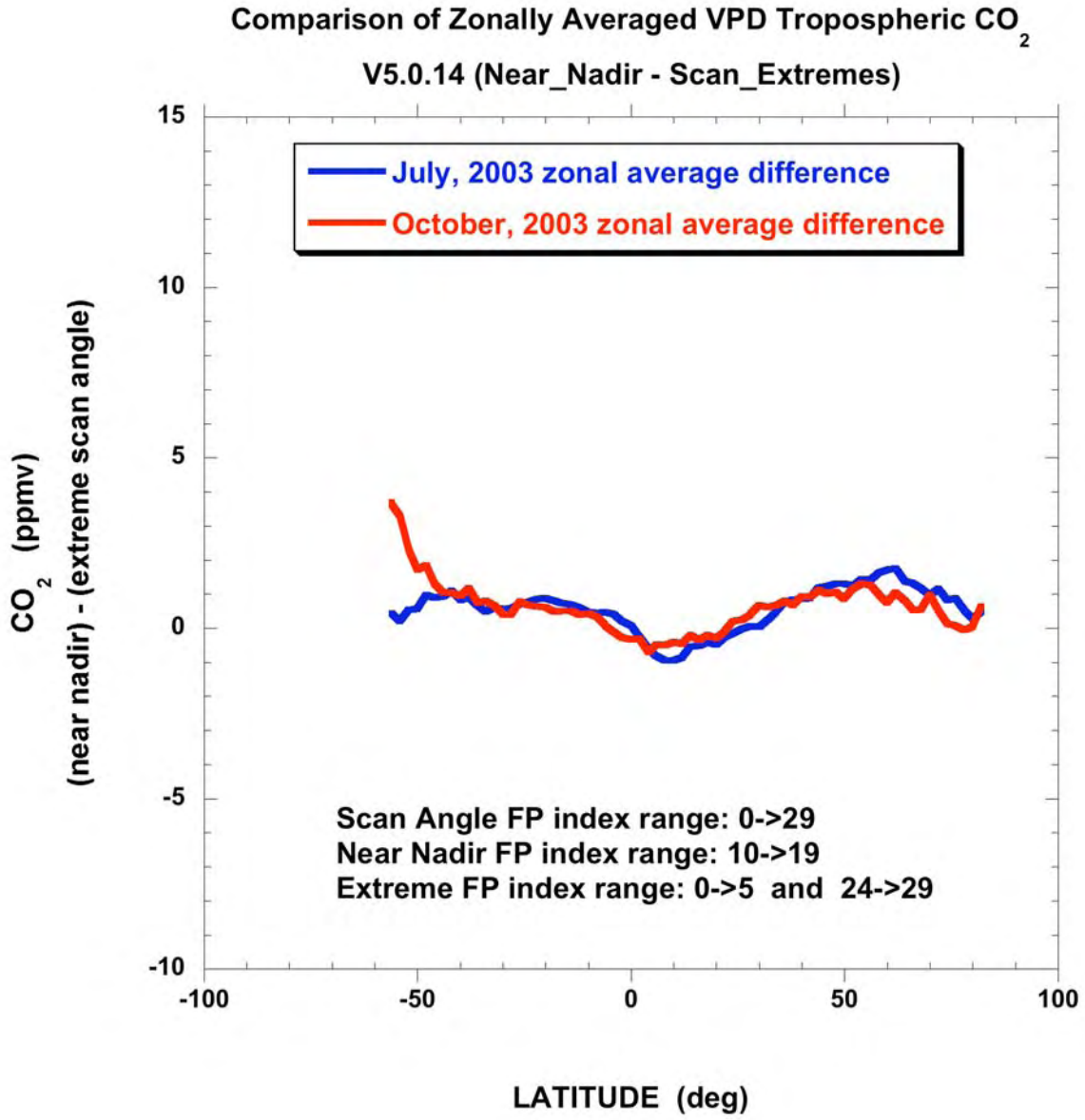
Independence of the Solution

With respect to scan angle

VPD retrieval result is independent of scan angle over the nearly entire globe.

Exception is high southern latitudes in October.



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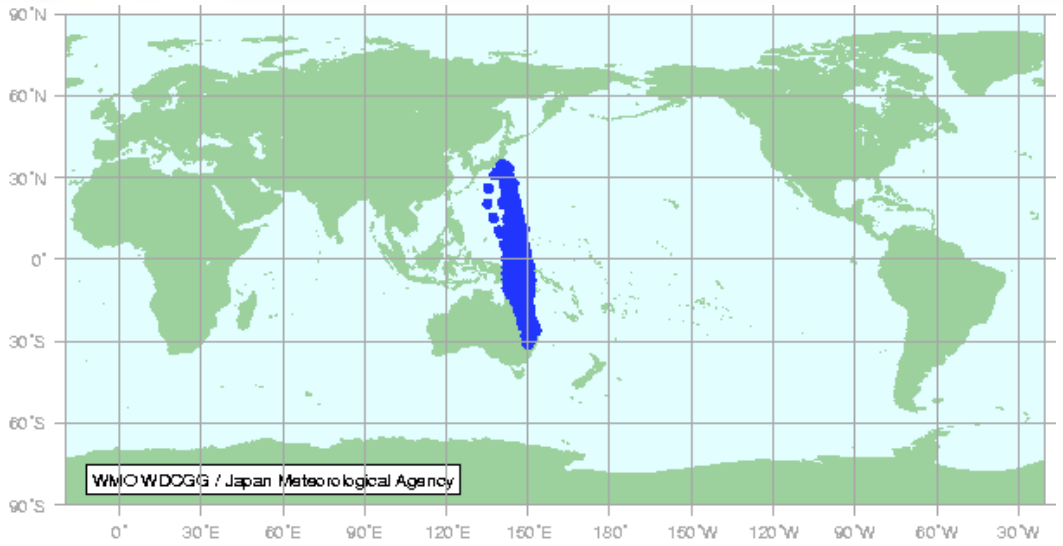
Validation

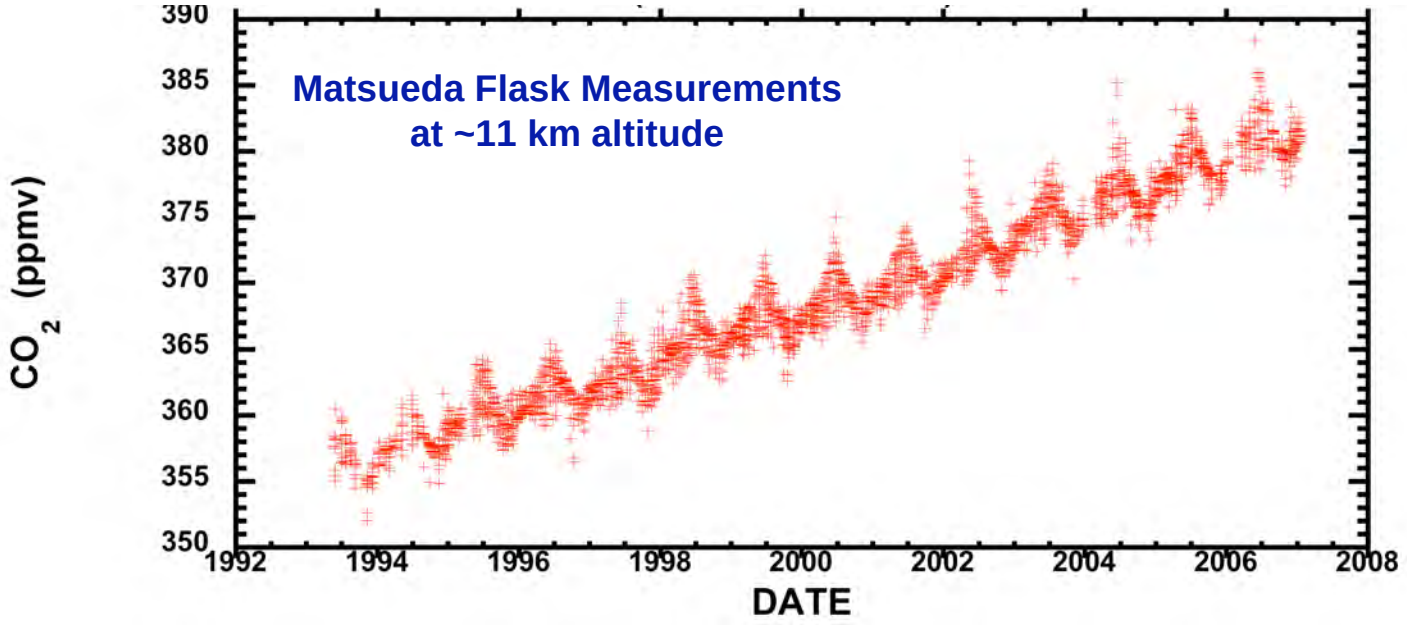
Matsueda Airborne Flask Measurements

CO_2 Measurements at 10.5 km altitude

JAL Flights
(every two weeks)



Most extensive high altitude aircraft measurements



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Evidence that VPD Retrieval Errors are Gaussian (Uncorrelated)

Over 18 months, 78 clusters of AIRS CO2 retrievals (731 retrievals total) collocated within ±4 hours and 150 km of Matsueda flask measurements

Standard Deviation = ±2.98 *ppmv*

The monthly averages

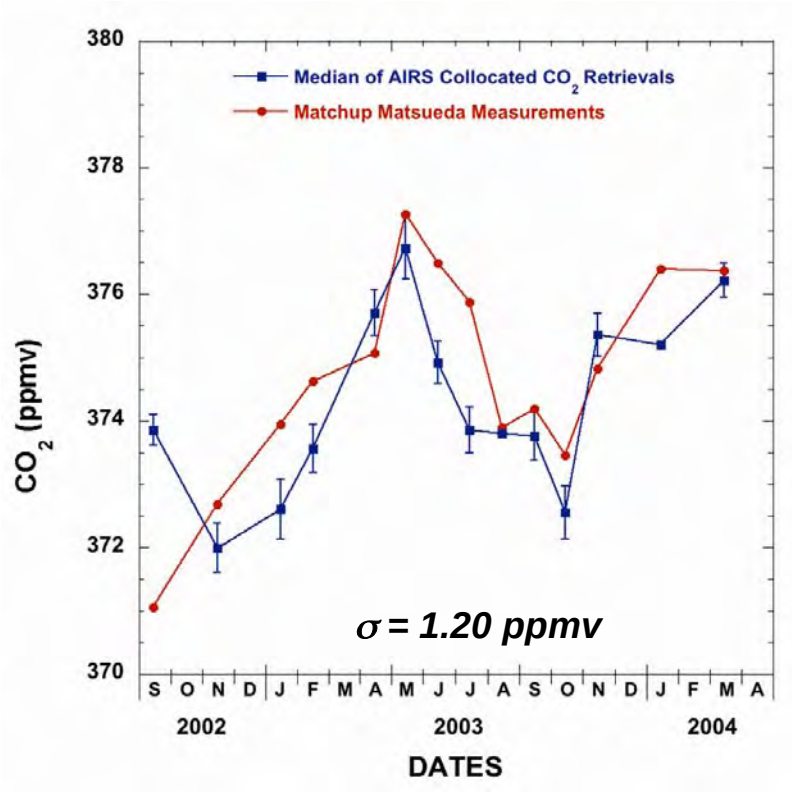
(5.6 clusters/month) yield

Standard Deviation = ±1.20 *ppmv*

$$\frac{2.98}{\sqrt{5.6}} = 1.26$$

Thus statistics are Gaussian and therefore the AIRS CO2 retrieval errors are uncorrelated and thus can be averaged to reduce the RMS errors.

True Validation via Collocated Data



CO_2 retrieved by Vanishing Partial Derivatives (VPD)
***M. Chahine, C. Barnet, E.T. Olsen, L. Chen and E. Maddy* [2005, GRL]**

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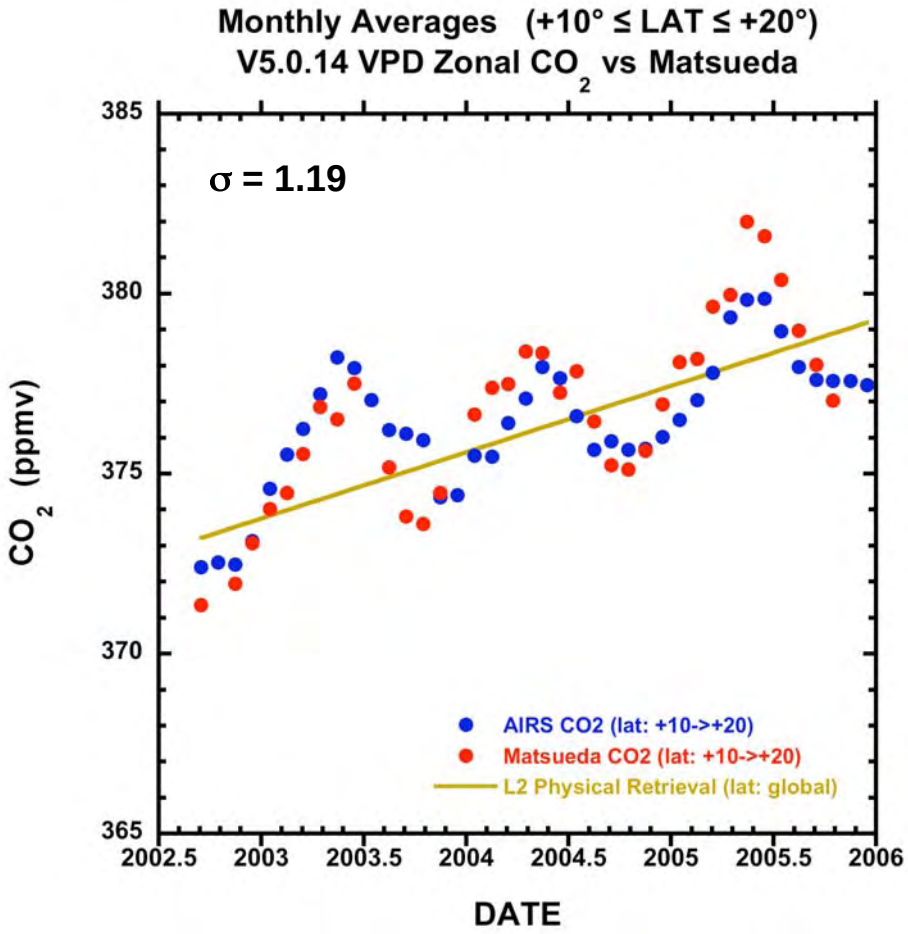
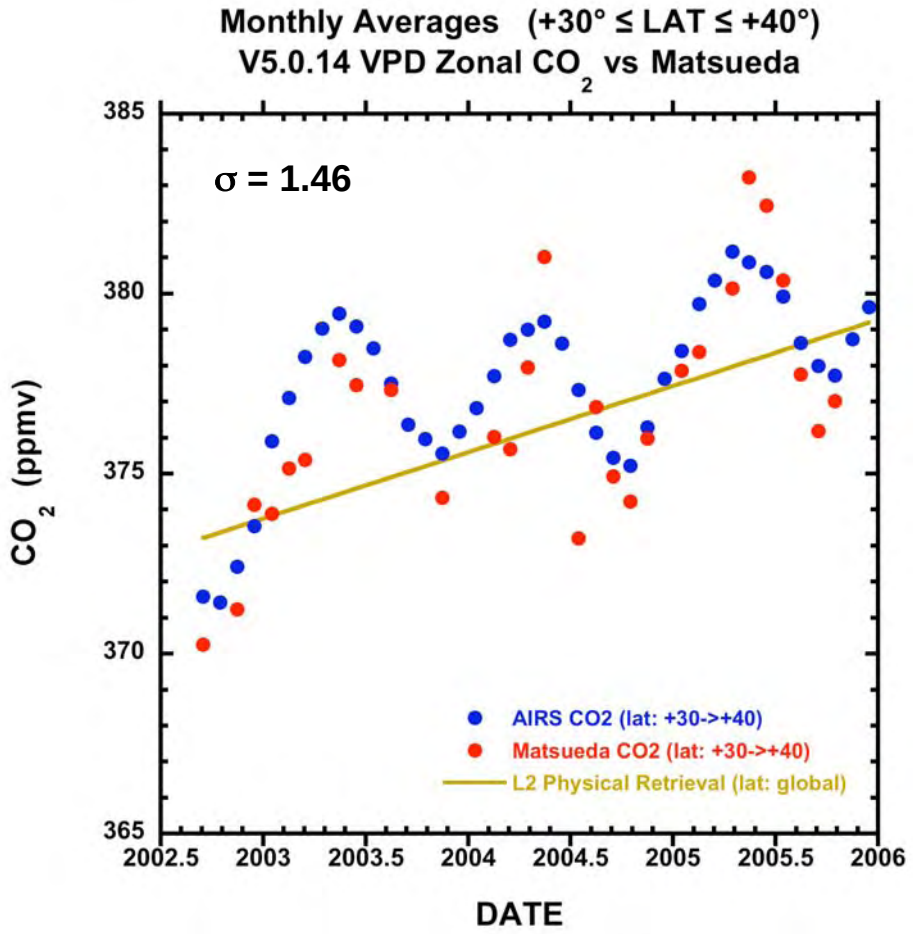
AIRS vs Matsueda Airborne over 3 years



+10° ≤ LAT ≤ +20°
AIRS averaged over all longitudes



+30° ≤ LAT ≤ +40°
AIRS averaged over all longitudes

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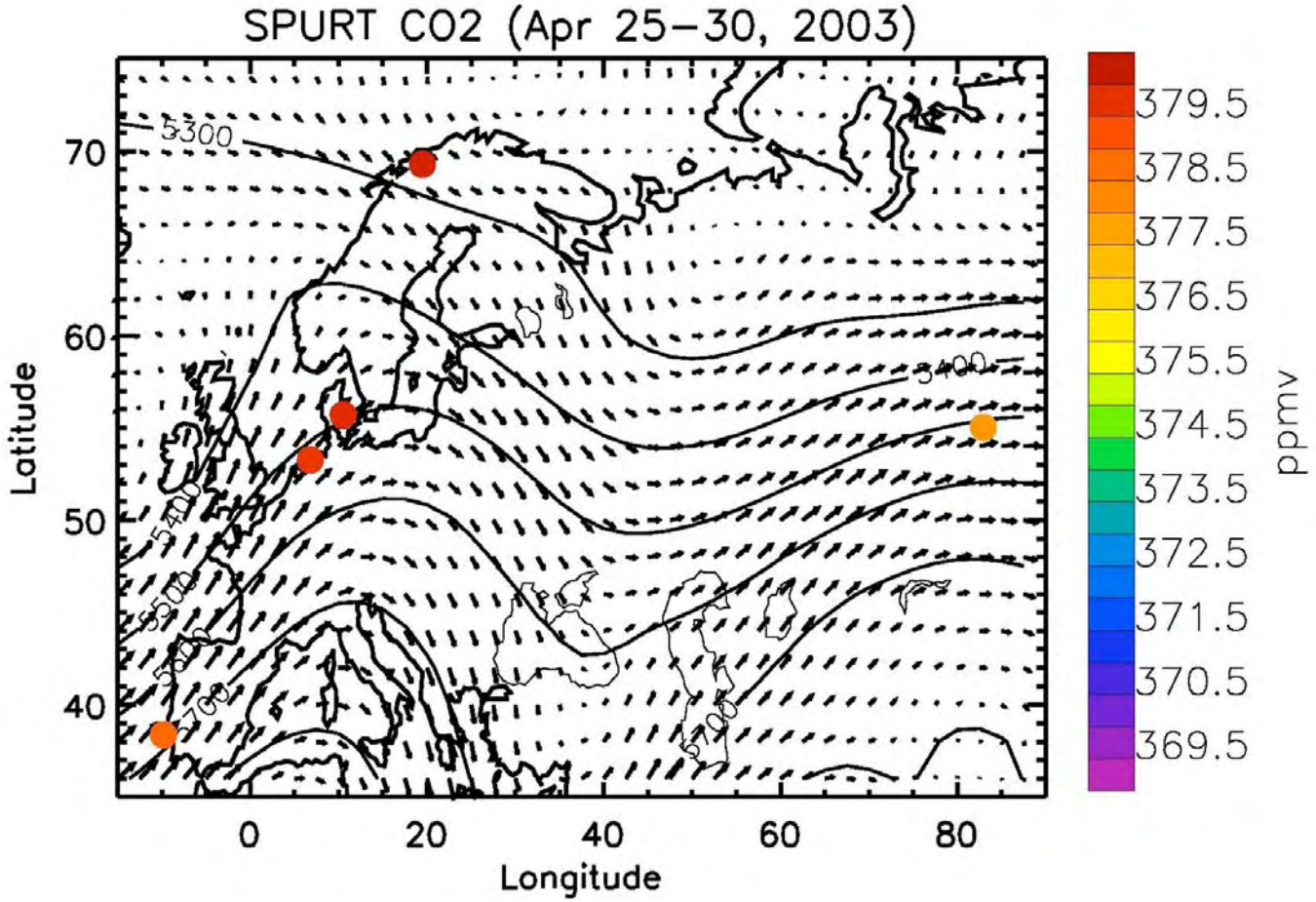
VALIDATION OF VPD CO_2 VIA AIRCRAFT CO_2 PROFILES at High Latitude



Dots: Aircraft CO_2 weighted by AIRS weighting function

Contour: NCEP2 GPH at 500 hPa; Vector: NCEP2 wind vector at 500 hPa

Courtesy of Peter Hoor for SPURT CO_2 [*Hoor et al*., 2004] and Dr. Michada for CO_2 at 55N, 83E

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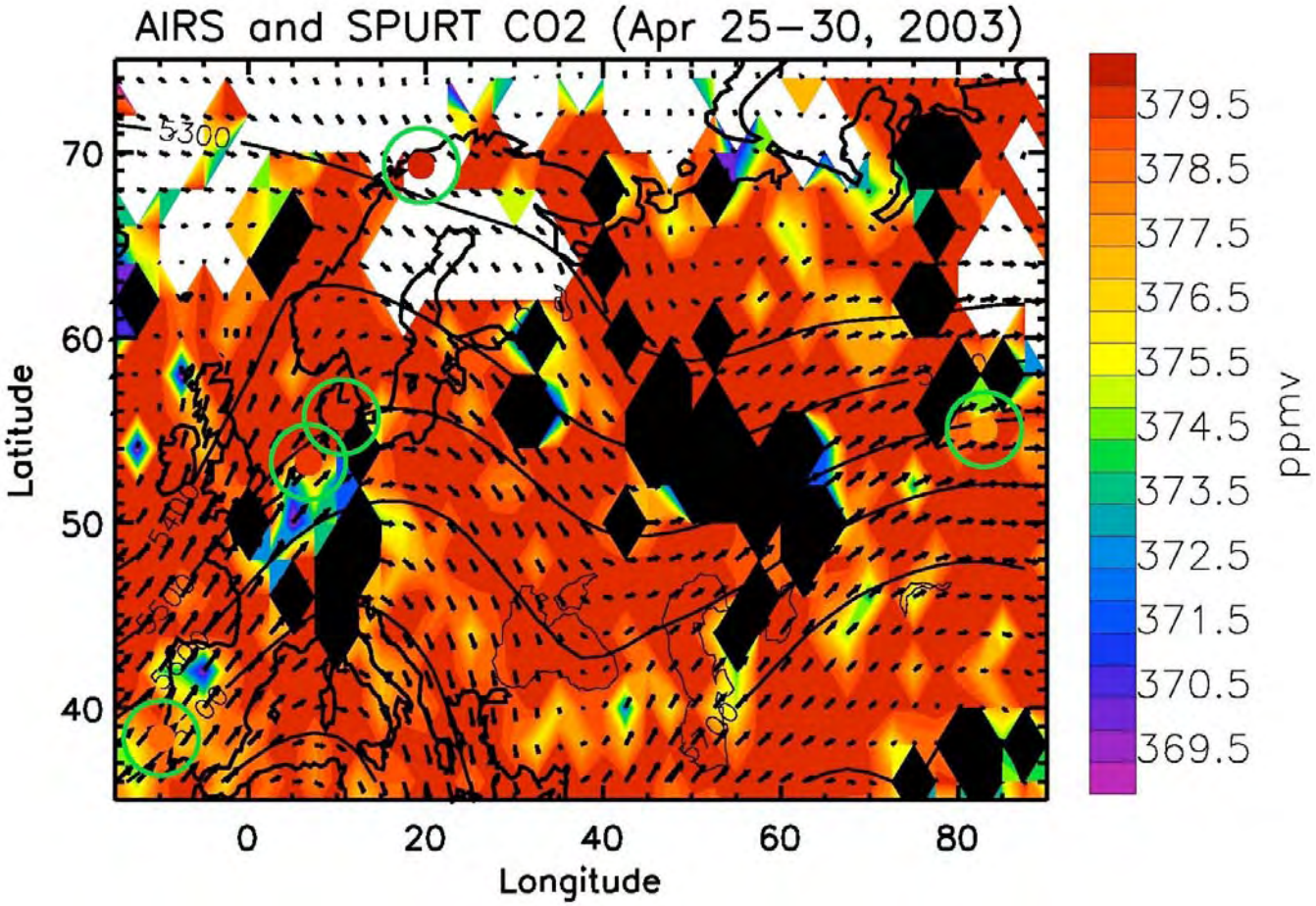

σ = *1.33 ppmv*

Dots: Aircraft CO_2 weighted by AIRS weighting function
Contour: NCEP2 GPH at 500 hPa; Vector: NCEP2 wind vector at 500 hPa

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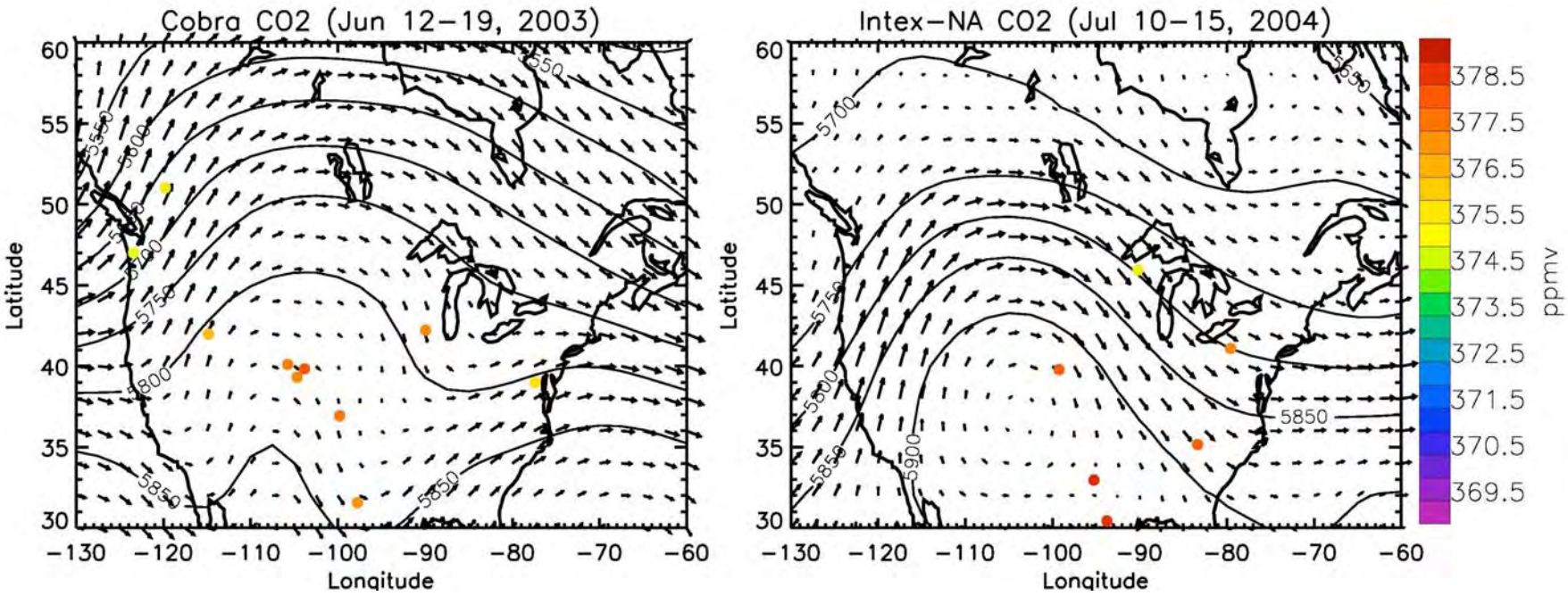
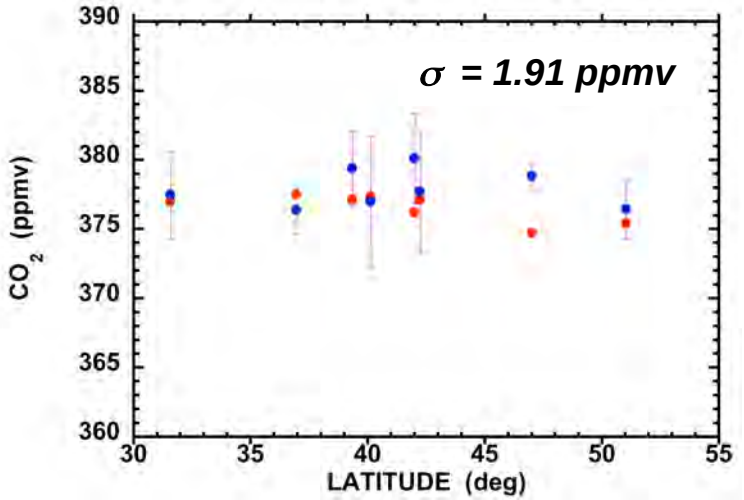
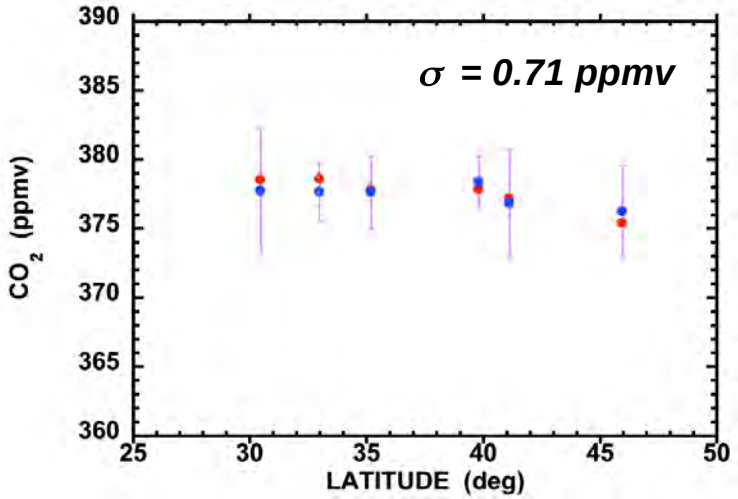
VALIDATION OF VPD CO_2 VIA AIRCRAFT CO_2 PROFILES OVER CONUS







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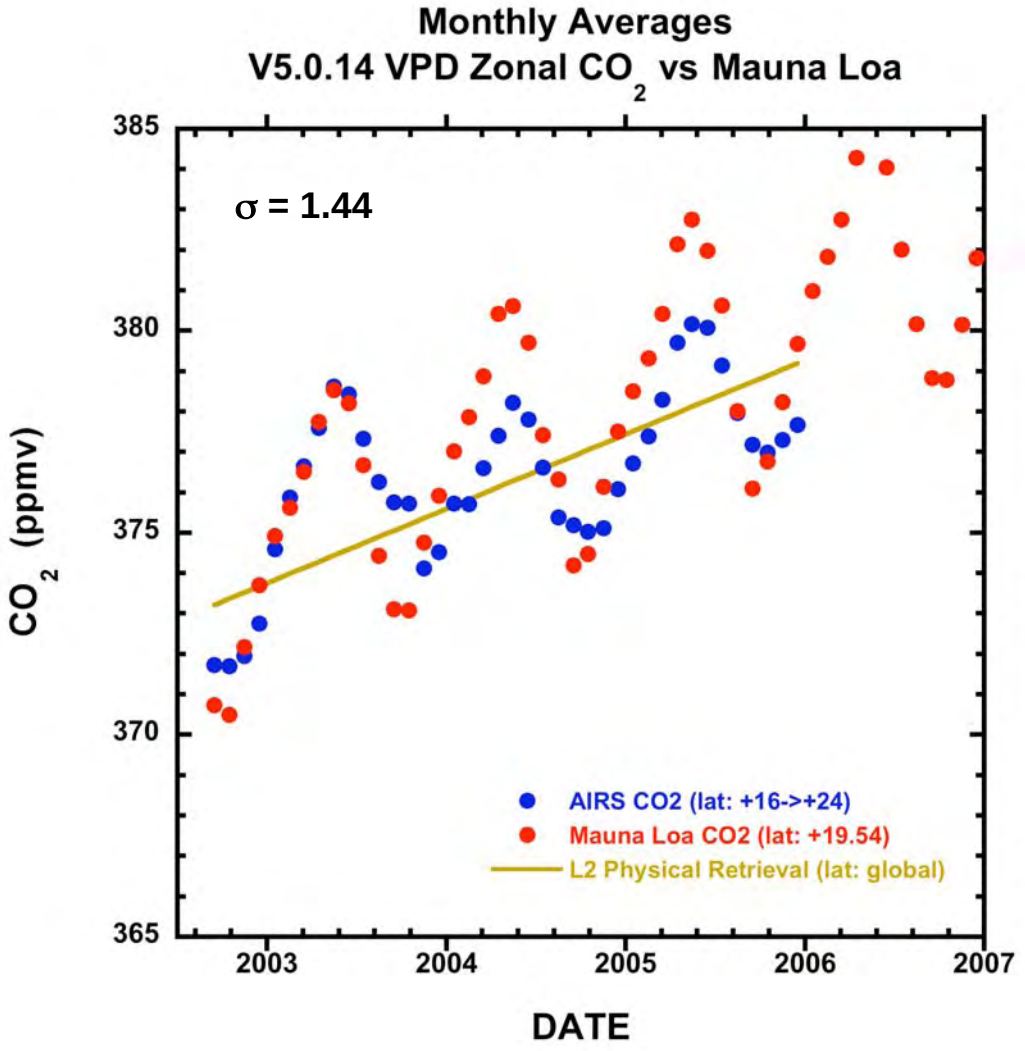
AIRS vs Mauna Loa over 3 years



Mauna Loa altitude is 3.4 km
AIRS peak sensitivity occurs at 6.3 km and half-peak spans 3 km to 12.5 km

Amplitude of seasonal variation at Mauna Loa is greater than in the mid-troposphere following 2003

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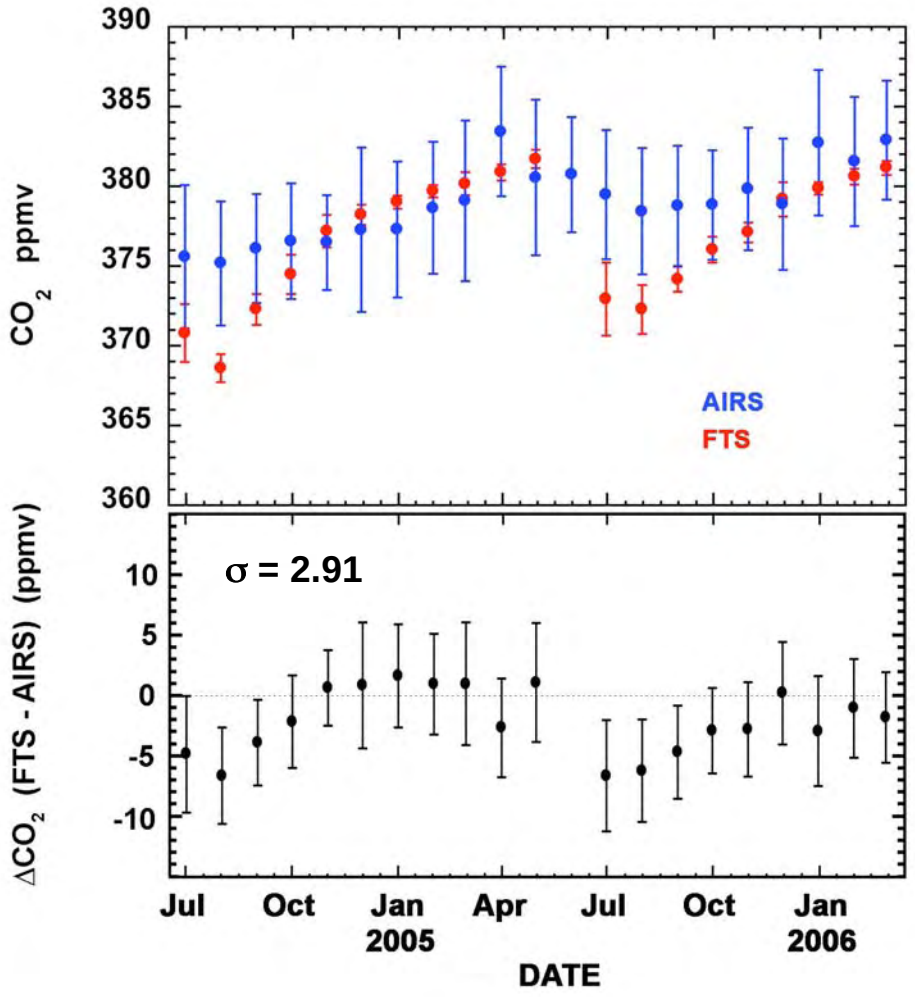
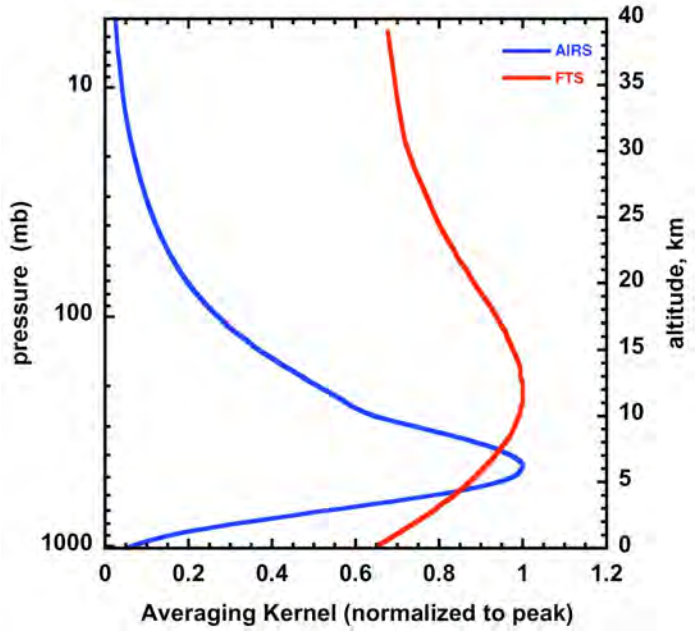
Comparison to Park Falls, WI Fourier Transform Spectrometer



- **Park Falls FTS (Paul Wennberg)**
  - Lat: +45.93 Lon: 90.27 W
  - total column measurement
  - clear sky observations
  - sensitive to boundary layer CO_2
- **AIRS**
  - CO_2 retrievals within 500km of Park Falls
  - clear & cloudy observations
  - insensitive to PBL CO_2
- **Result**
  - seasonal variation apparent in both
  - summer vegetative drawdown/buildup strongest in planetary boundary layer visible in Park Falls



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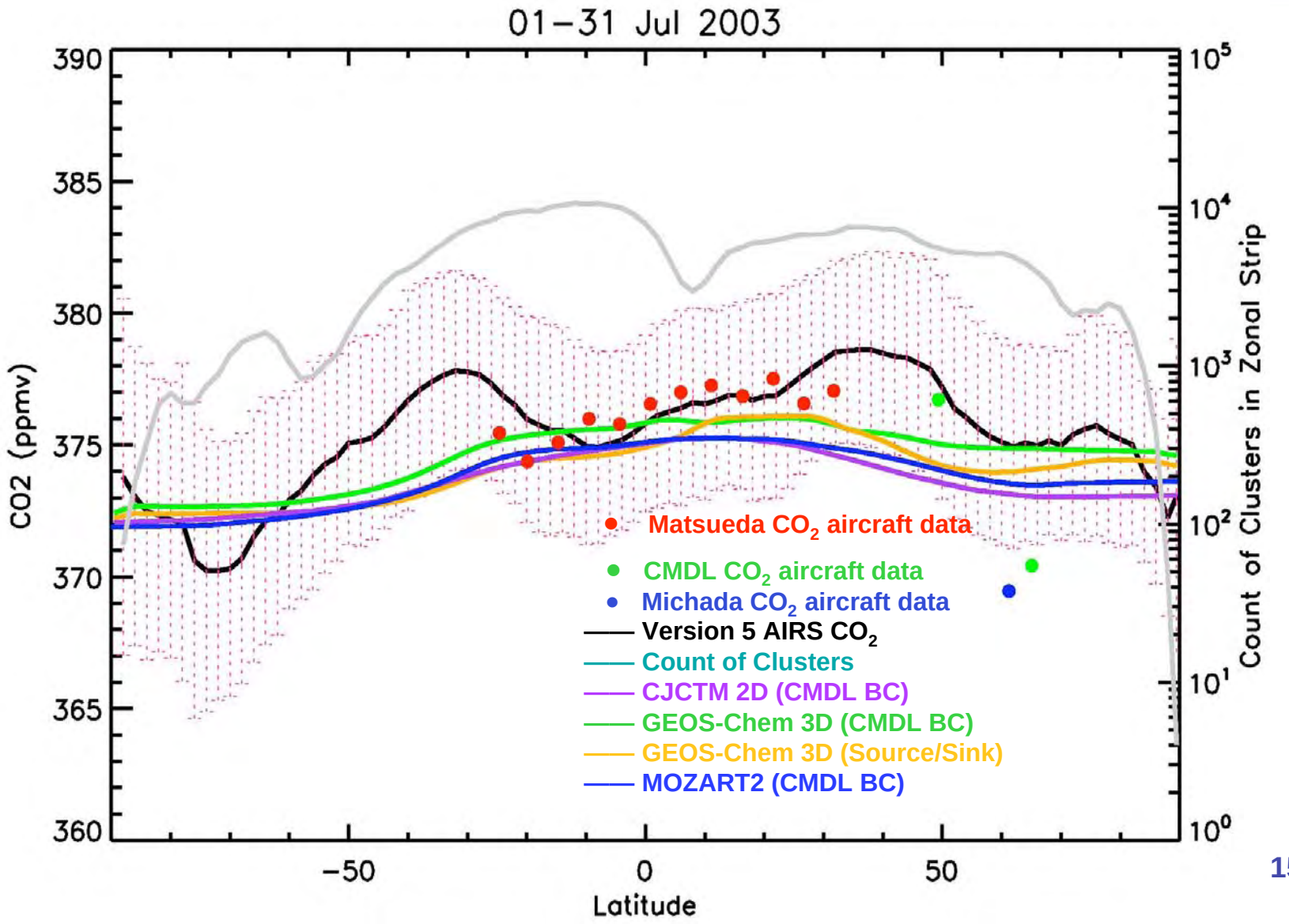
Zonal Variation of Observed and Modeled CO_2



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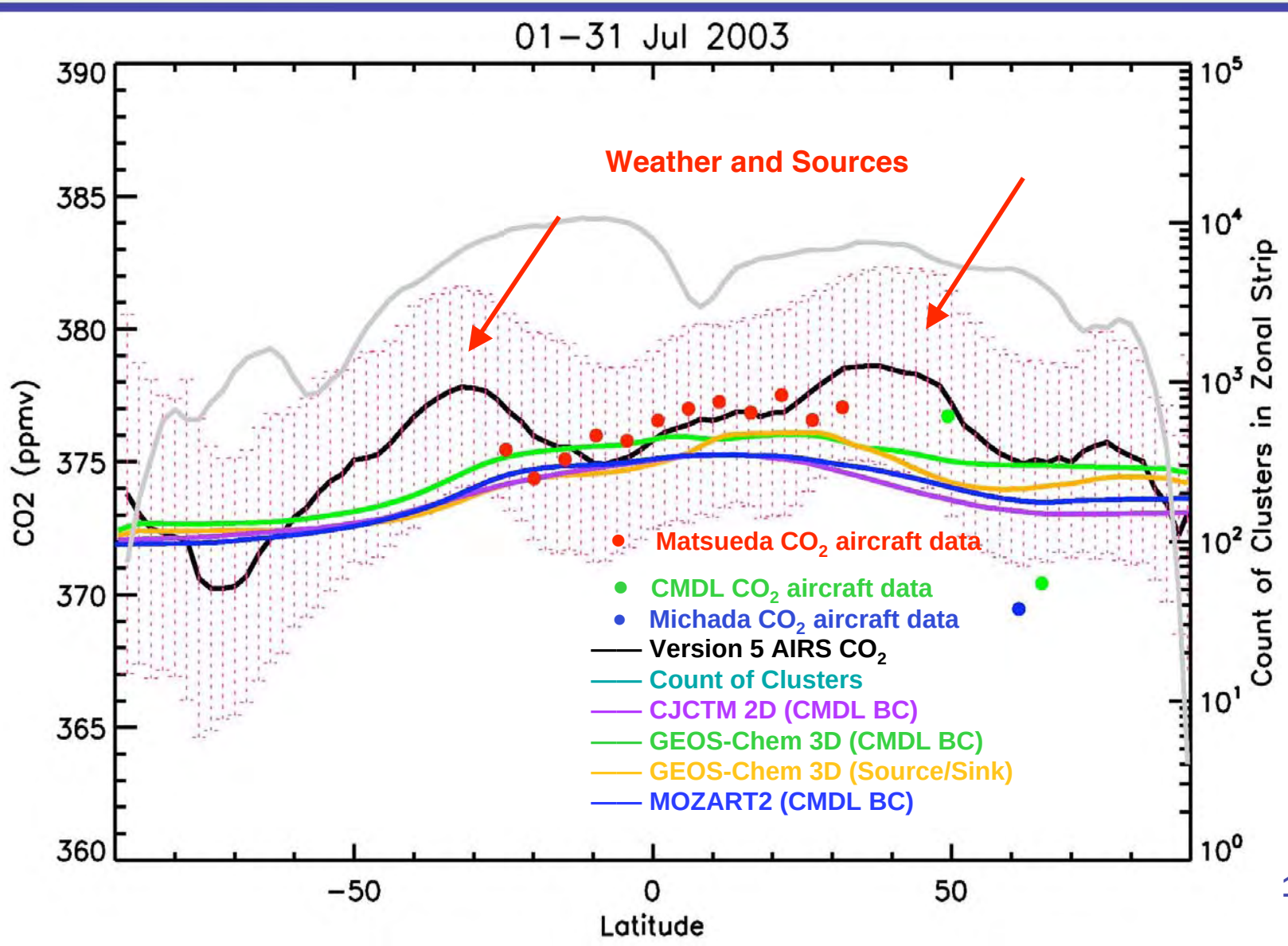

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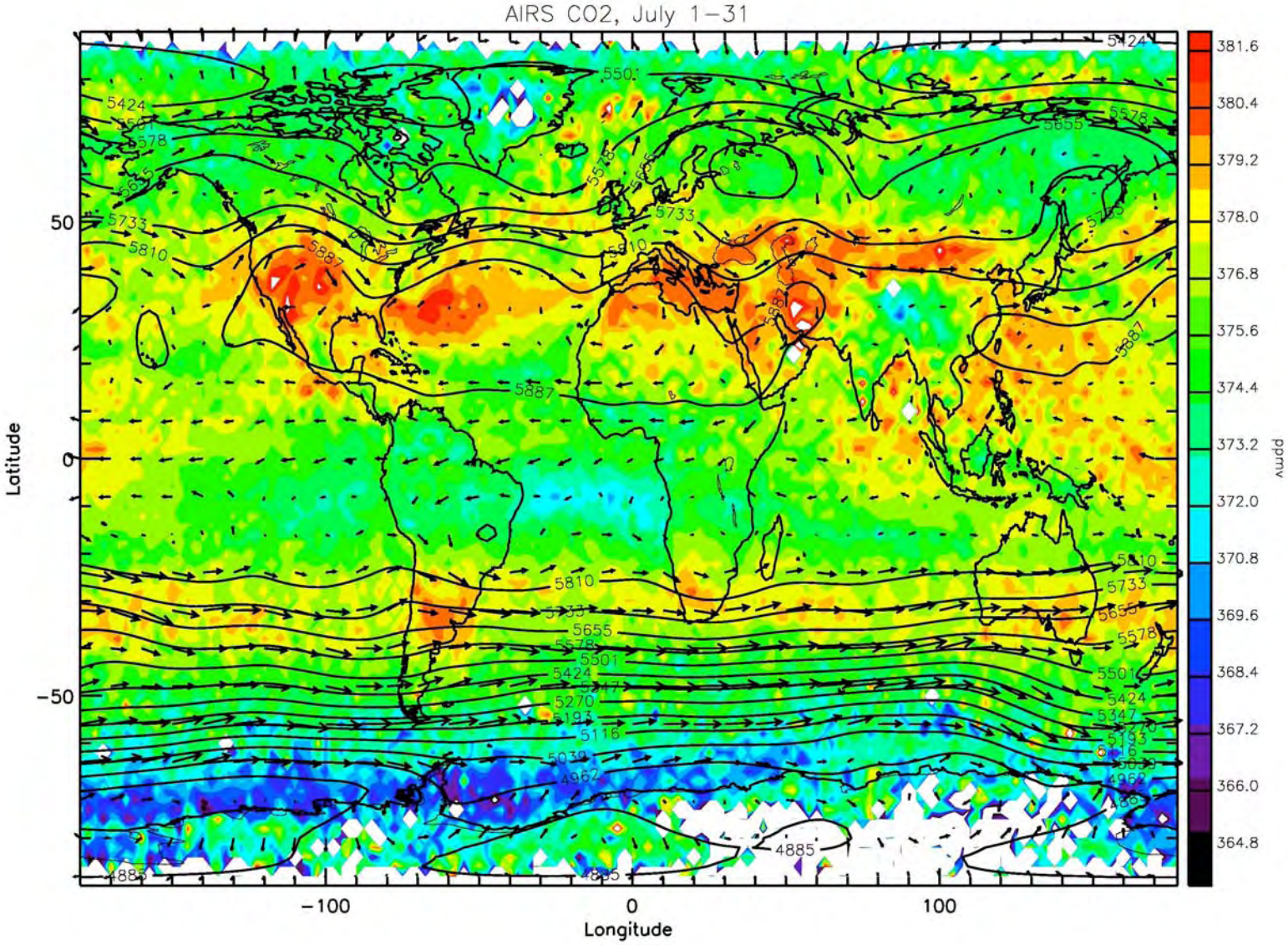
Monthly Average Spatial Pattern of CO_2

500 hPa geopotential heights & wind vectors from NCEP2 Reanalysis



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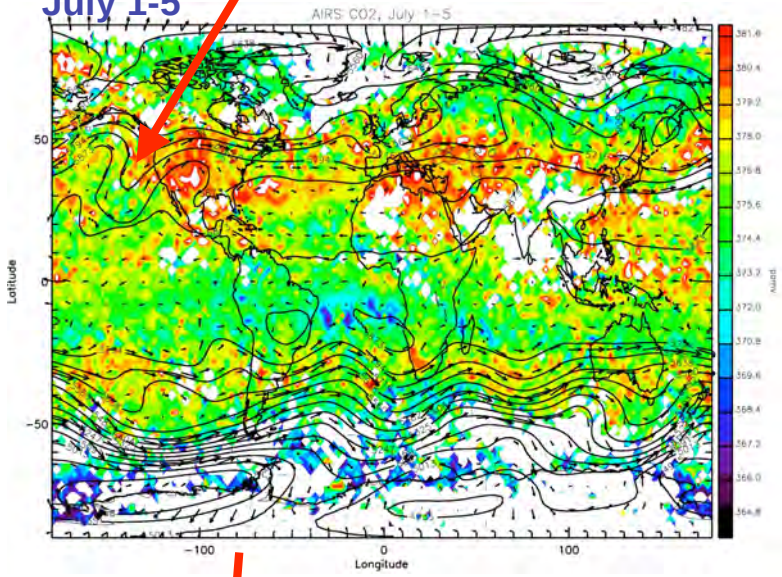
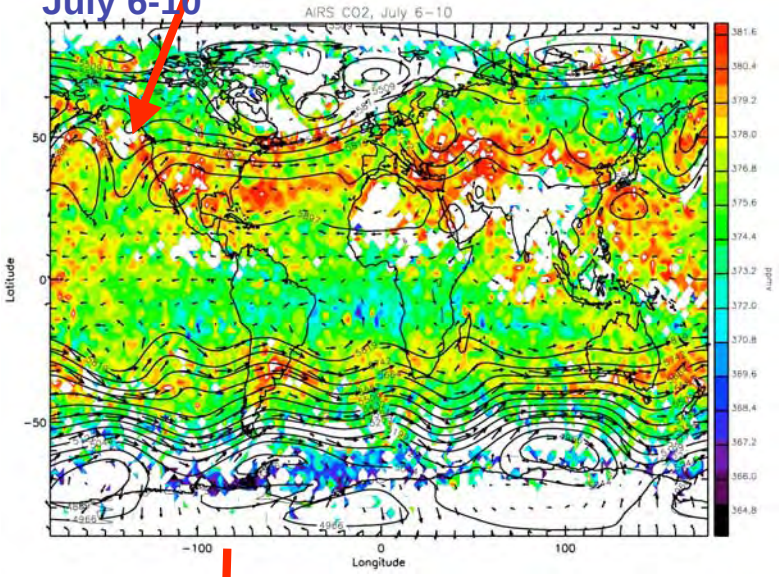
Effects of Weather on Mid Tropospheric CO_2

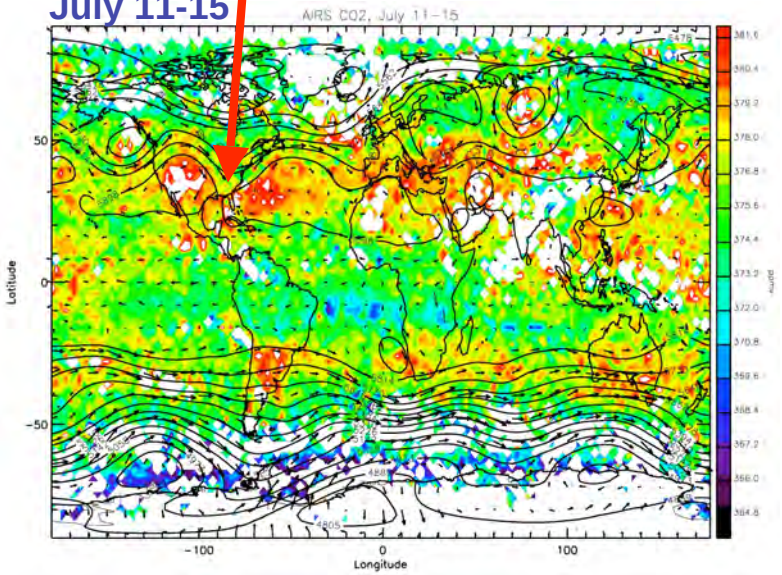
July 1-5



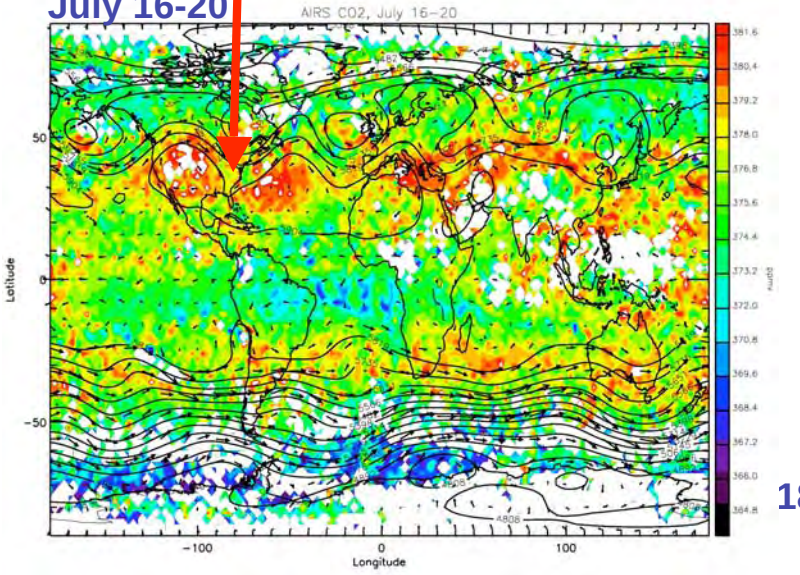
July 6-10



July 11-15



July 16-20



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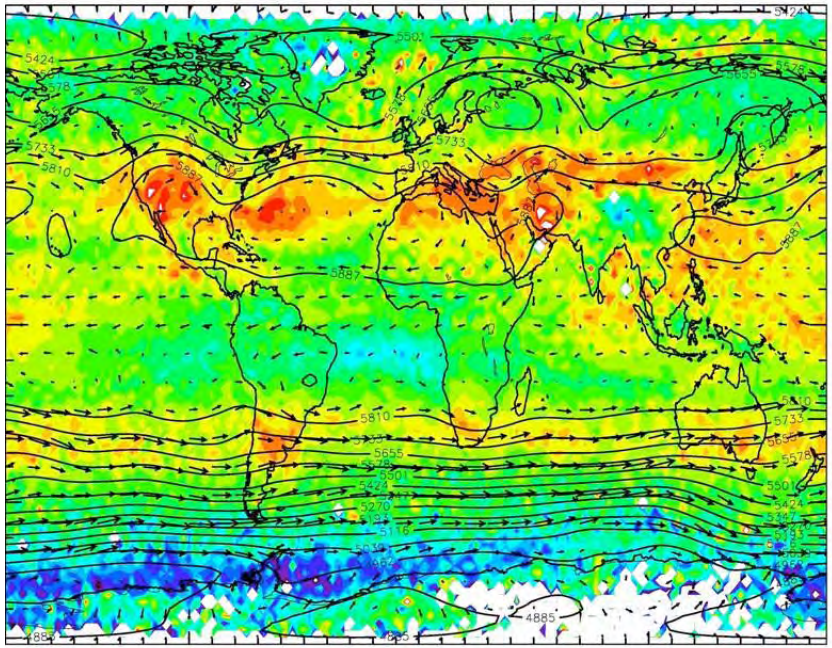
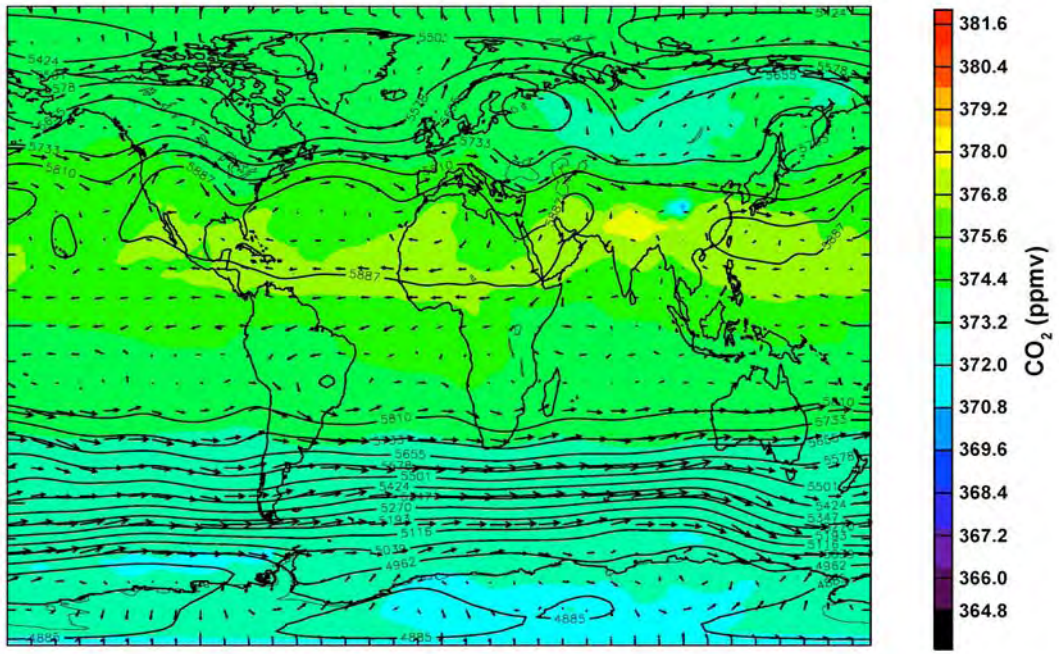
Models do not Capture the Impact of Weather and Surface Sources on mid-Trop CO_2

AIRS CO_2 for July 01–31, 2003



Model CO_2 for July 01–31, 2003



AIRS VPD Retrieval

GEOS-Chem Model

NH features muted

SH belt absent

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Large Stationary Sources of CO_2

Global distribution of large stationary sources of CO2

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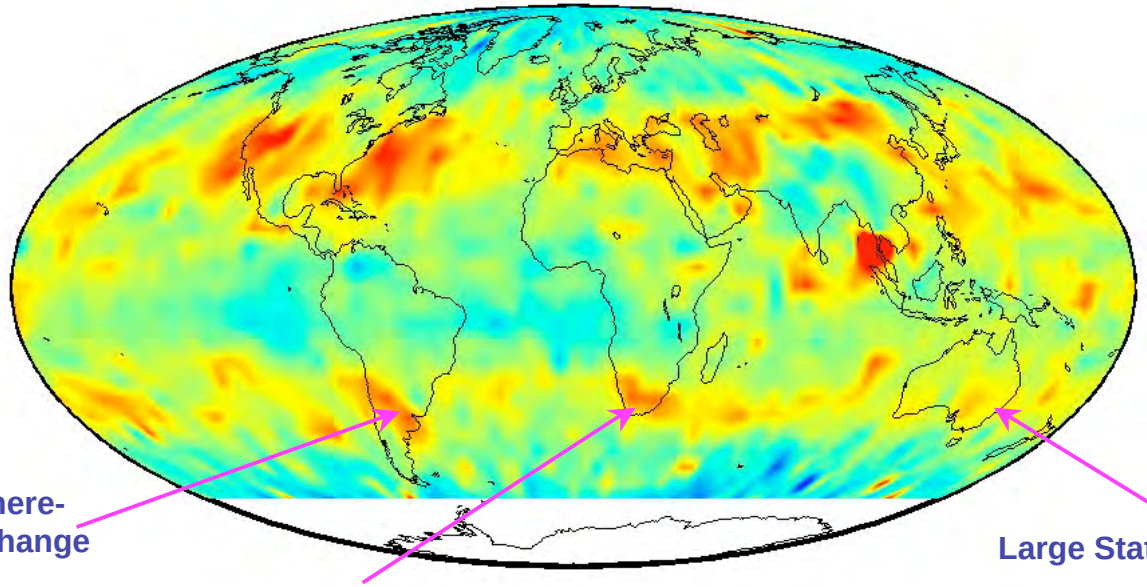
Impact of Weather and Large Stationary Sources on Mid-Tropospheric CO_2

July 24-28, 2003



Major Atmosphere-Biosphere Exchange

Major Stationary CO_2 Source

Large Stationary CO_2 Source

ppmv

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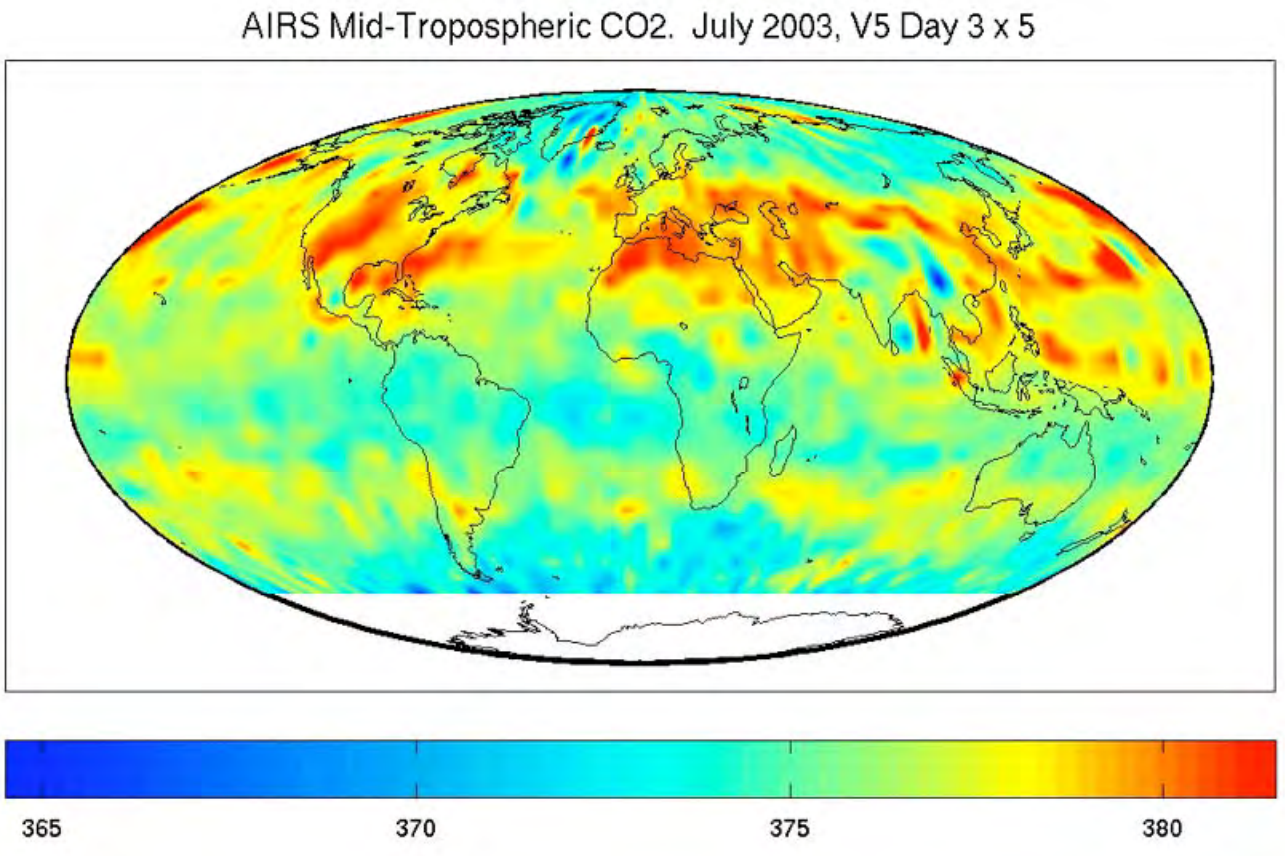
July 2003 CO_2 Time Series (5-Day Sliding Average)



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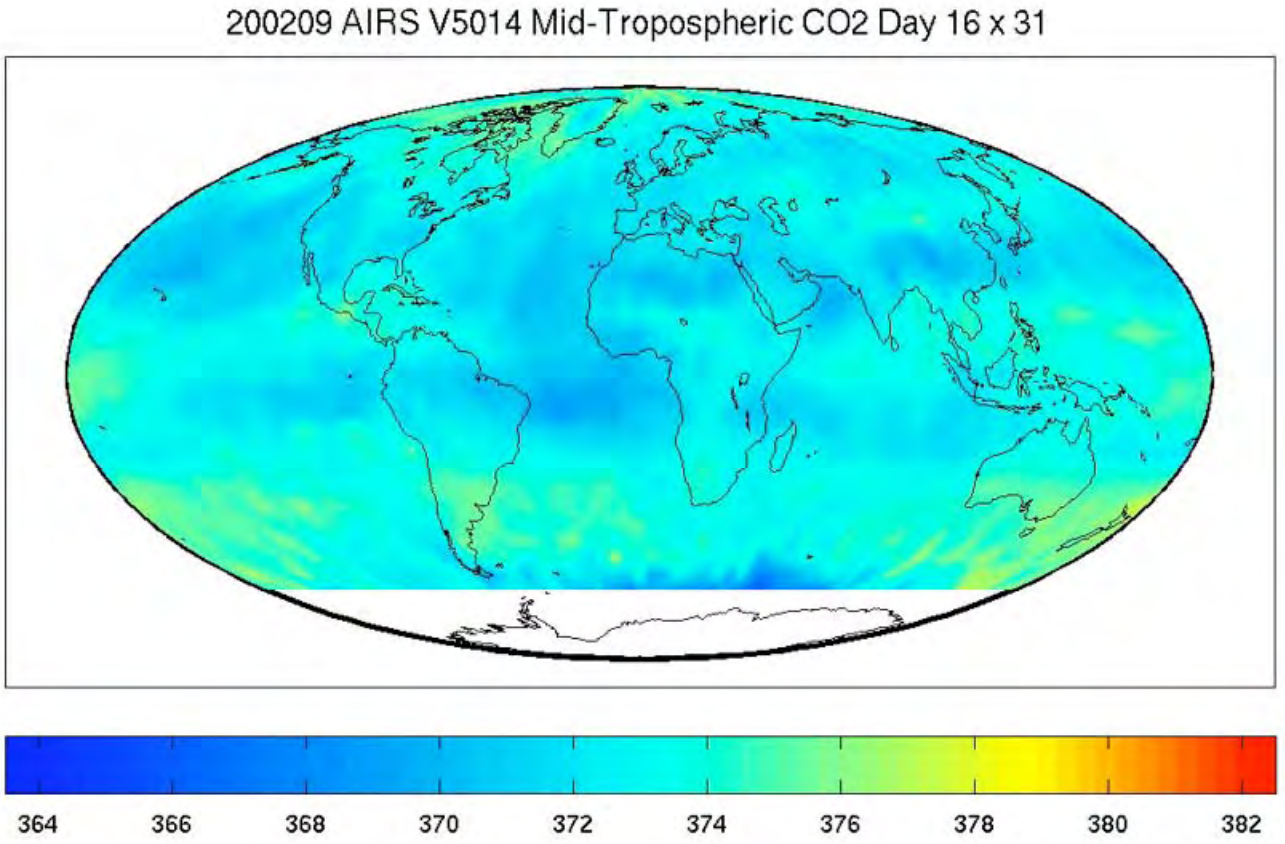
3-Year CO_2 Time Series (Monthly Averages)



Conclusions

- Method of Vanishing Partial Derivatives works well for retrieval of CO_2 is successful over the entire globe
- The AIRS VPD retrieved upper tropospheric CO_2 agrees reasonably well with in situ aircraft observations.
  - Additional high-altitude validation data are needed at high latitudes
- The rich time-varying spatial structure of CO_2 in the mid-troposphere is not capture by model.
  - Influence of mid-latitude jet streams is considerable
- Satellite retrieval of CO2 profiles provide a new tool to study the dynamics of the atmosphere

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The Future

Utilize AIRS Sensitivity to Retrieve the CO_2 Profile

Global Coverage

Daily - Day and Night

Pole-to-Pole

Land and Ocean

Cloudy and Cloud Free