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Atmospheric Infrared Sounder  
Pasadena, California

# Validation of AIRS Retrievals of CO<sub>2</sub> via Comparison to *In Situ* Measurements

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

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# Overview

- **AIRS on Aqua: 2002- present**
  - Expected to continue operation to 2011 and beyond
  - Background: spectrum, weighting functions, initialization
- **Comparison with Aircraft and FTIR Measurements**
  - Matsueda (CONTRAIL) JAL flask measurements
  - Park Falls, WI FTIR
  - Bremen, GDR
  - Spitsbergen, Norway
- **AIRS Retrievals over additional FTIR Sites**
  - Darwin, AU
  - Lauder, NZ
- **Mid-Tropospheric CO<sub>2</sub> Weather and Contribution from Major Surface Sources**



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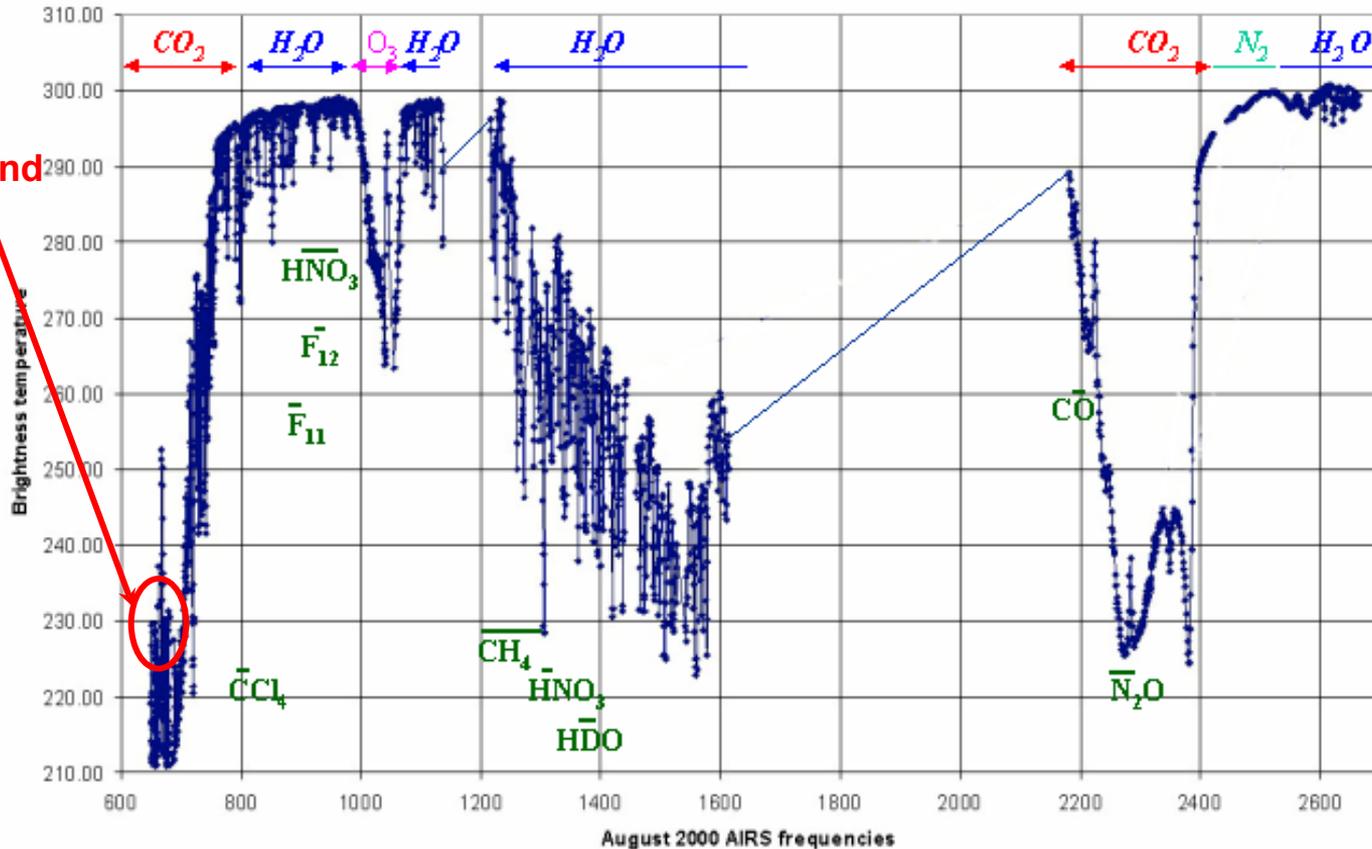
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# Typical AIRS Infrared Spectrum

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

2378 channels -  $L/\lambda_L = 1200$

15  $\mu$ m band



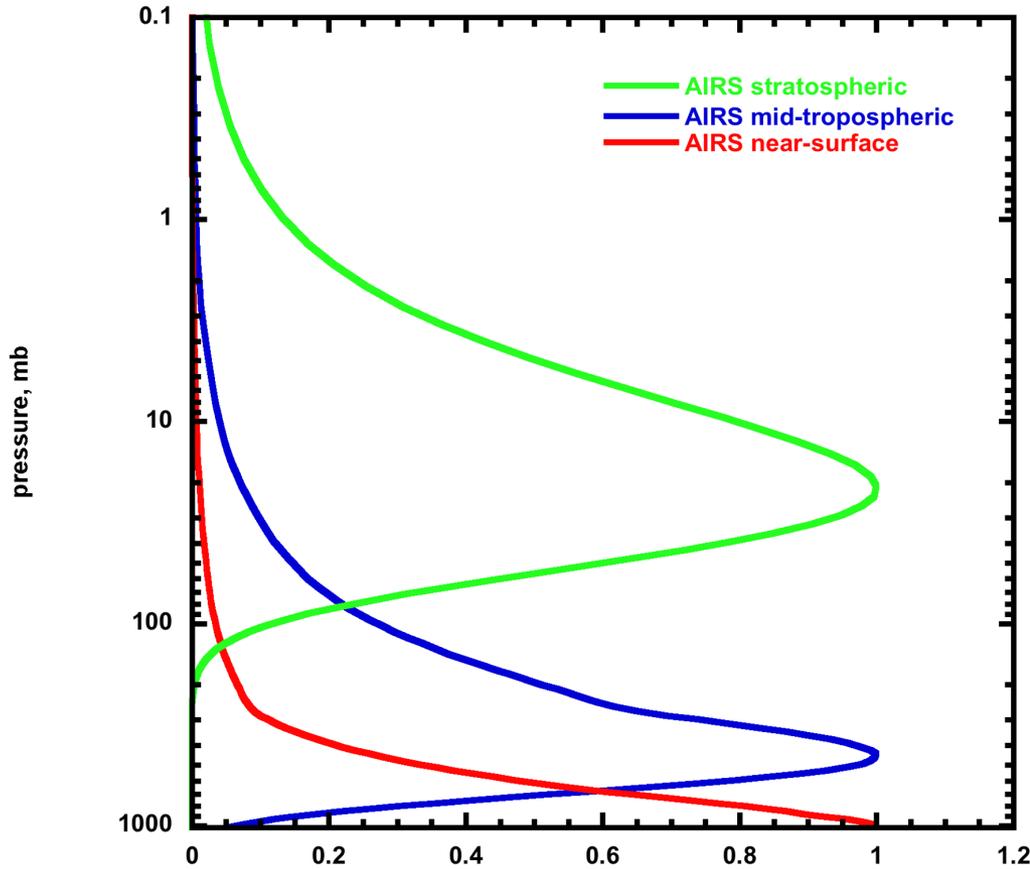


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# AIRS sensitivity for retrieving CO<sub>2</sub> profiles



Average Weighting Function,  $\Delta\tau/\Delta\ln(p)$  (normalized to maximum)

## AIRS is capable of retrieving CO<sub>2</sub> in 3 layers

- Mid-troposphere (Completed)  
2002 to present  
Accuracy 1 -> 2 ppmv
- Stratosphere (2009)
- Near-Surface (2010)



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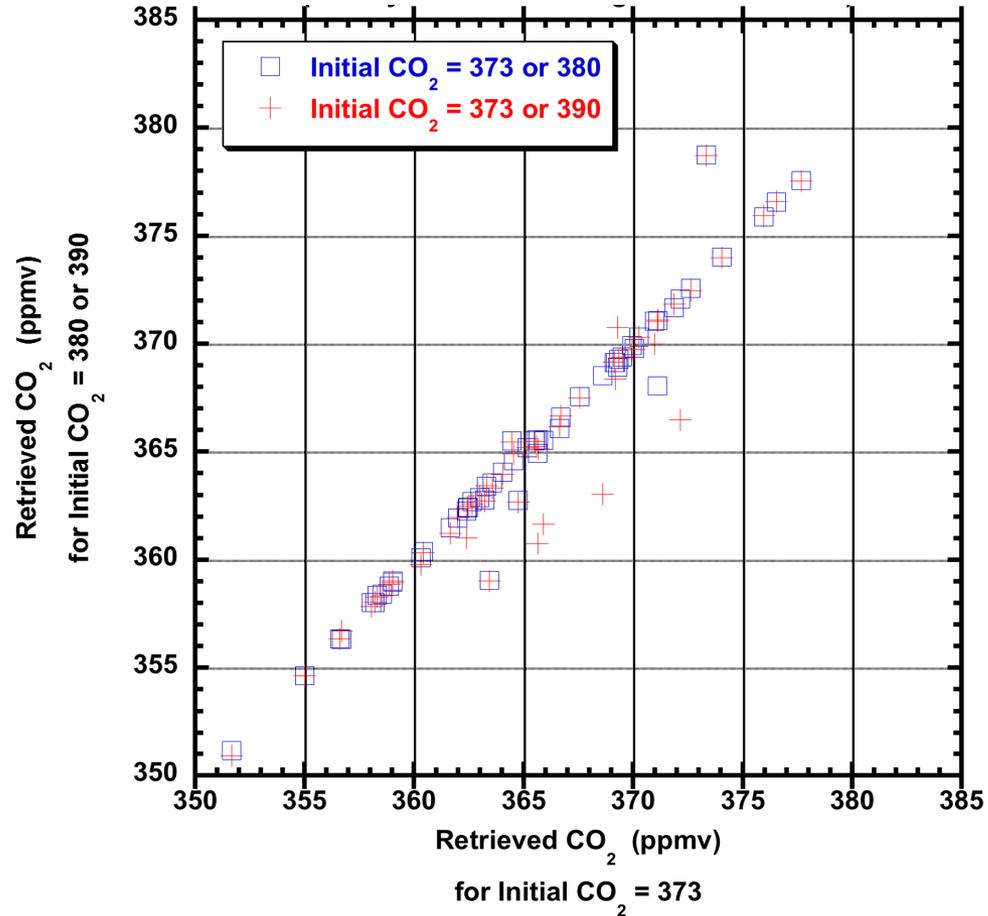
# Independence of CO<sub>2</sub> solution with respect to the initial guess

For derivation of Level 2 products, the AIRS V5 retrieval algorithm assumes a simple linear variation of CO<sub>2</sub> with time in order for the RTA to remain in the linear domain with respect to perturbation. A single value for CO<sub>2</sub> is assumed over the entire globe at any time:

$$\text{CO}_2(t) = 371.92 + 1.84 \times (t - t_0)$$

Where  $t_0 = \text{Jan 1, 2002}$

The VPD retrieval assumes this same initial value for consistency. In addition, our tests have demonstrated independence of solution to assumed initial CO<sub>2</sub> for the year 2003 over the range: 330 ppmv to 390 ppmv



*Our VPD CO<sub>2</sub> retrieval errors are independent  
thus retrievals can be averaged to reduce the RMS errors.*



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# Available *in situ* measurements for validation and comparison

## ➤ Aircraft CO<sub>2</sub> Profiles

- Closest we can come to a true validation of AIRS CO<sub>2</sub> retrievals
- Sparse dataset, especially for profiles reaching up to 12 km altitude

## ➤ CONTRAIL (Matsueda) Flask Measurements

- Affords long-term, seasonal and interannual comparison 30S to 30N
- Narrow range of altitude: 11 km  $\pm$  1 km
- Over ocean

## ➤ TCCON FTIR Sites

- Continuous daily observations
- No nighttime, thus long gaps for high latitude sites during polar winter



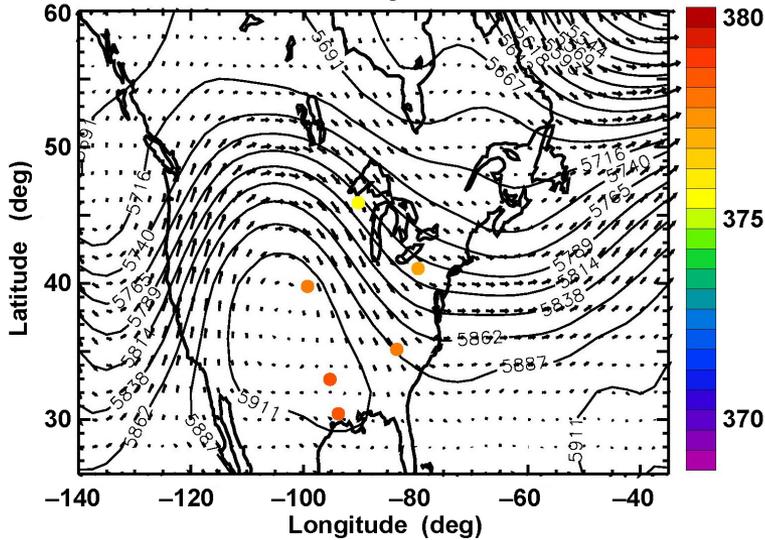
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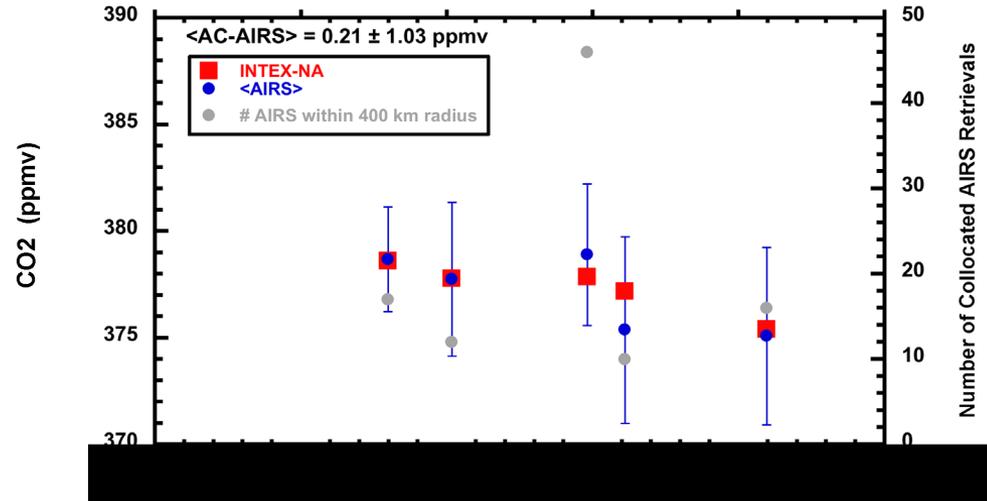
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# Comparison of Collocated V1.5x AIRS CO<sub>2</sub> (N\_coll ≥ 9) with INTEX-NA and SPURT

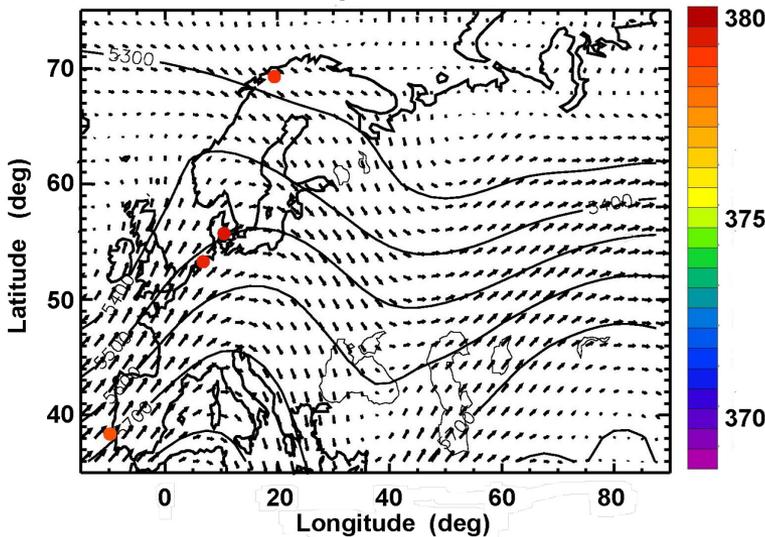
INTEX-NA July 10-15, 2004



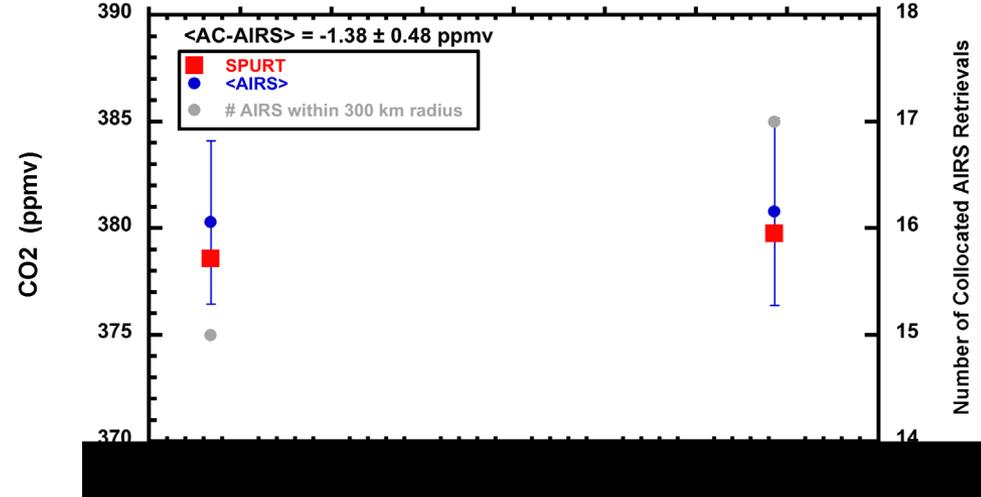
Aircraft data from Stephanie Vay (LaRC)



SPURT April 25-30, 2003



Aircraft data from Peter Hoor et al.



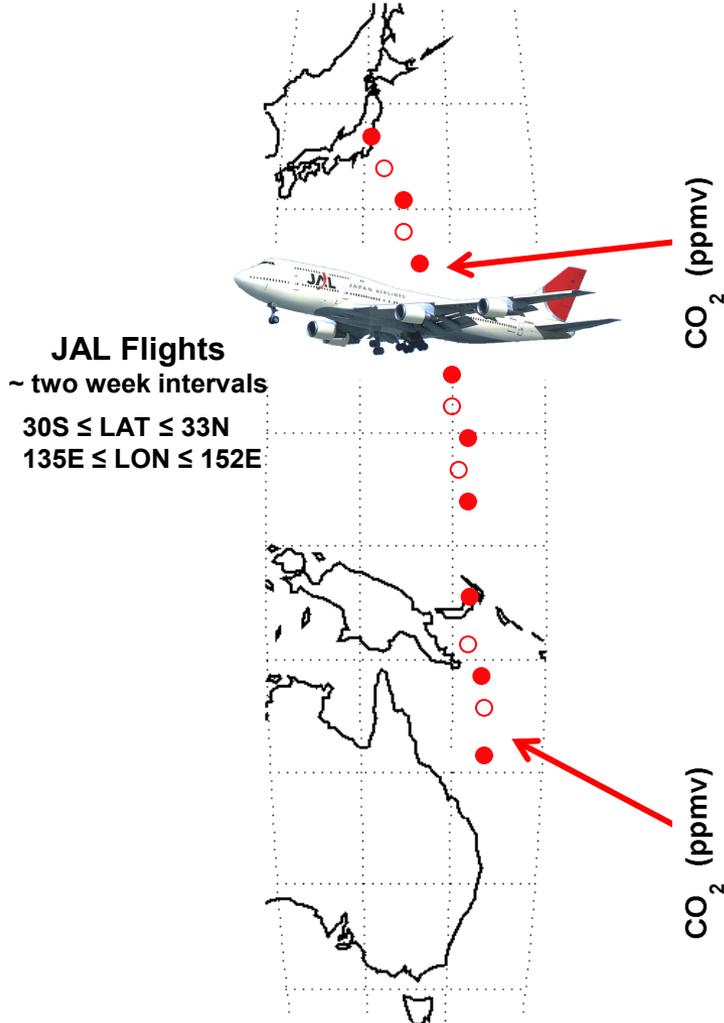


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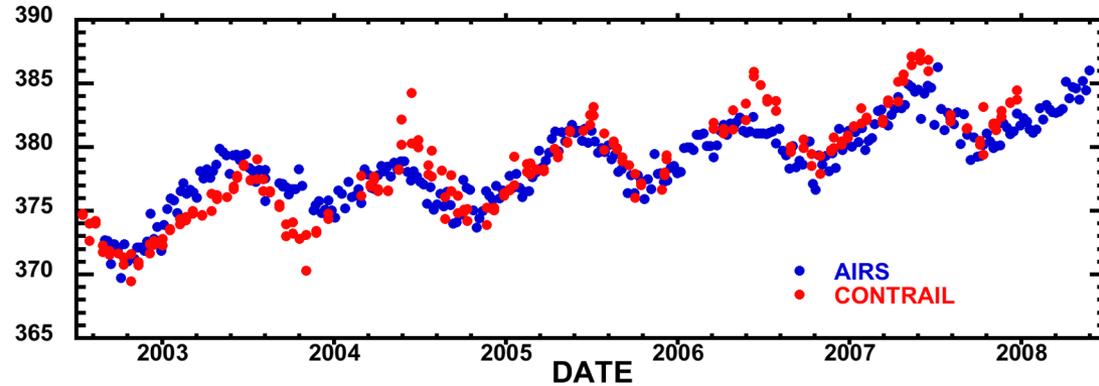
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# Comparison of V1.5x AIRS CO<sub>2</sub> in 10°x10° Areas and CONTRAIL (Matsueda) Airborne Flask Measurements (flying at 10 km to 12 km altitude in 10° latitude zones)



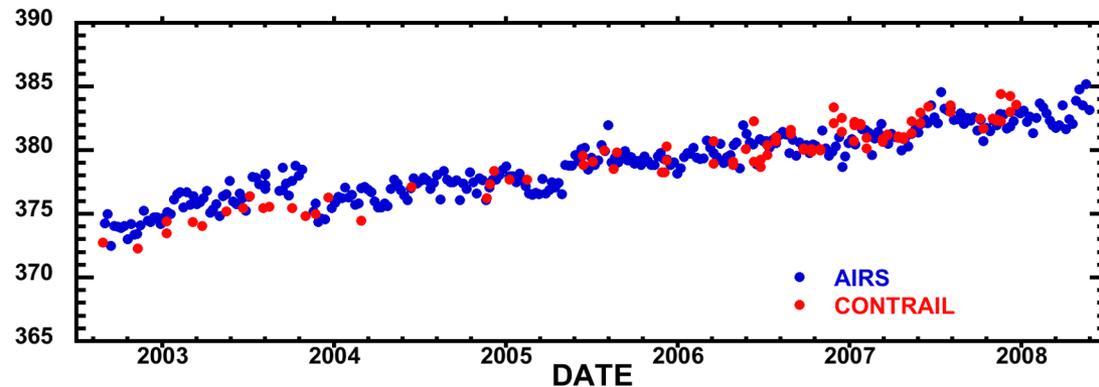
7-day averages of AIRS retrievals: LAT= +25° ± 5° LON = 143° ± 5°

CONTRAIL individual flask measurements: LAT = +25° ± 5°



7-day averages of AIRS retrievals: LAT= -25° ± 5° LON = 143° ± 5°

CONTRAIL individual flask measurements: LAT = -25° ± 5°



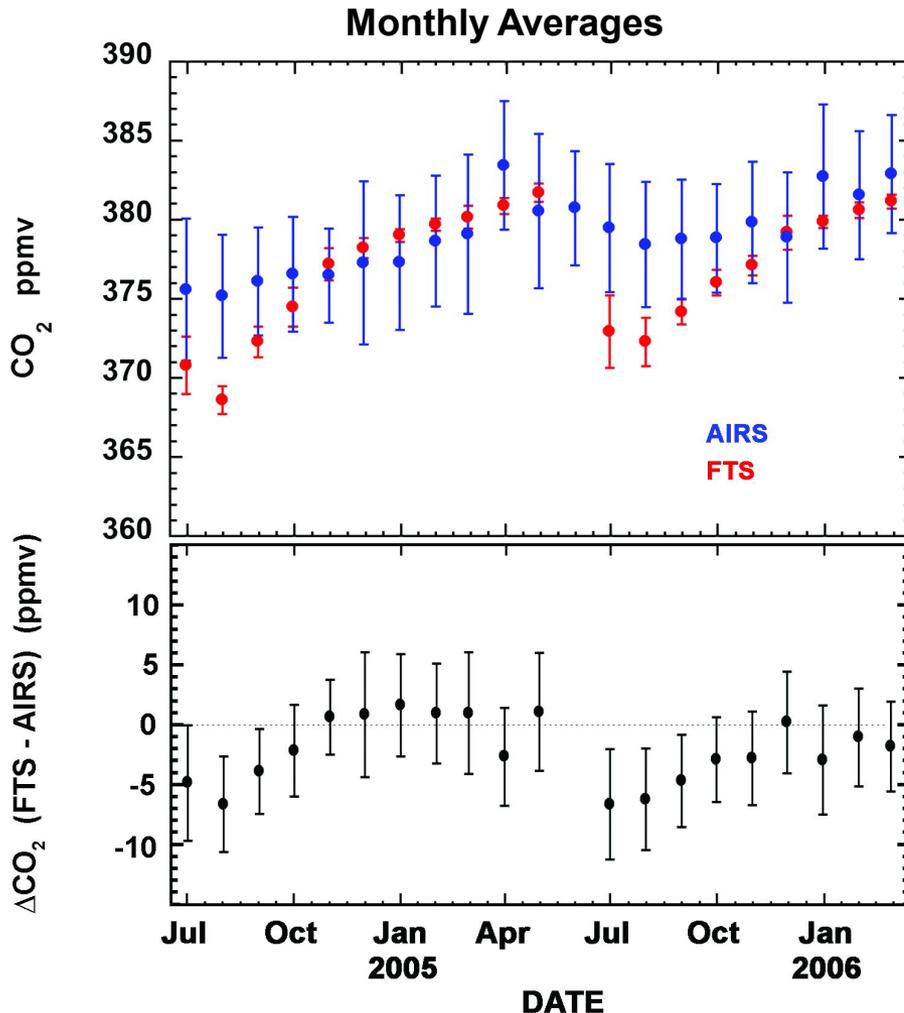


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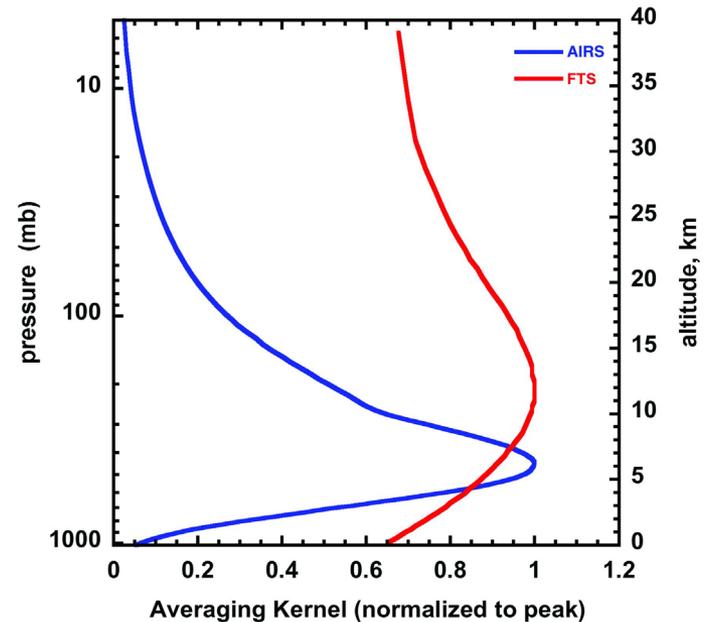
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# Comparison of V1.5x AIRS CO<sub>2</sub> to Park Falls, WI Fourier Transform Spectrometer



- **Park Falls FTS (*Paul Wennberg*)**
  - Lat: 45.93 N Lon: 90.27 W
  - clear sky observations
- **AIRS**
  - Within 250km radius of Park Falls
  - clear & cloudy observations
- **Vegetation uptake during growing season**
  - 6->7 ppmv departure in June 2004/2005



Washenfelder. R. A., et al. (2006), J.Geophys. Res. 111, D22305, doi:10.1029/2006JD007154.



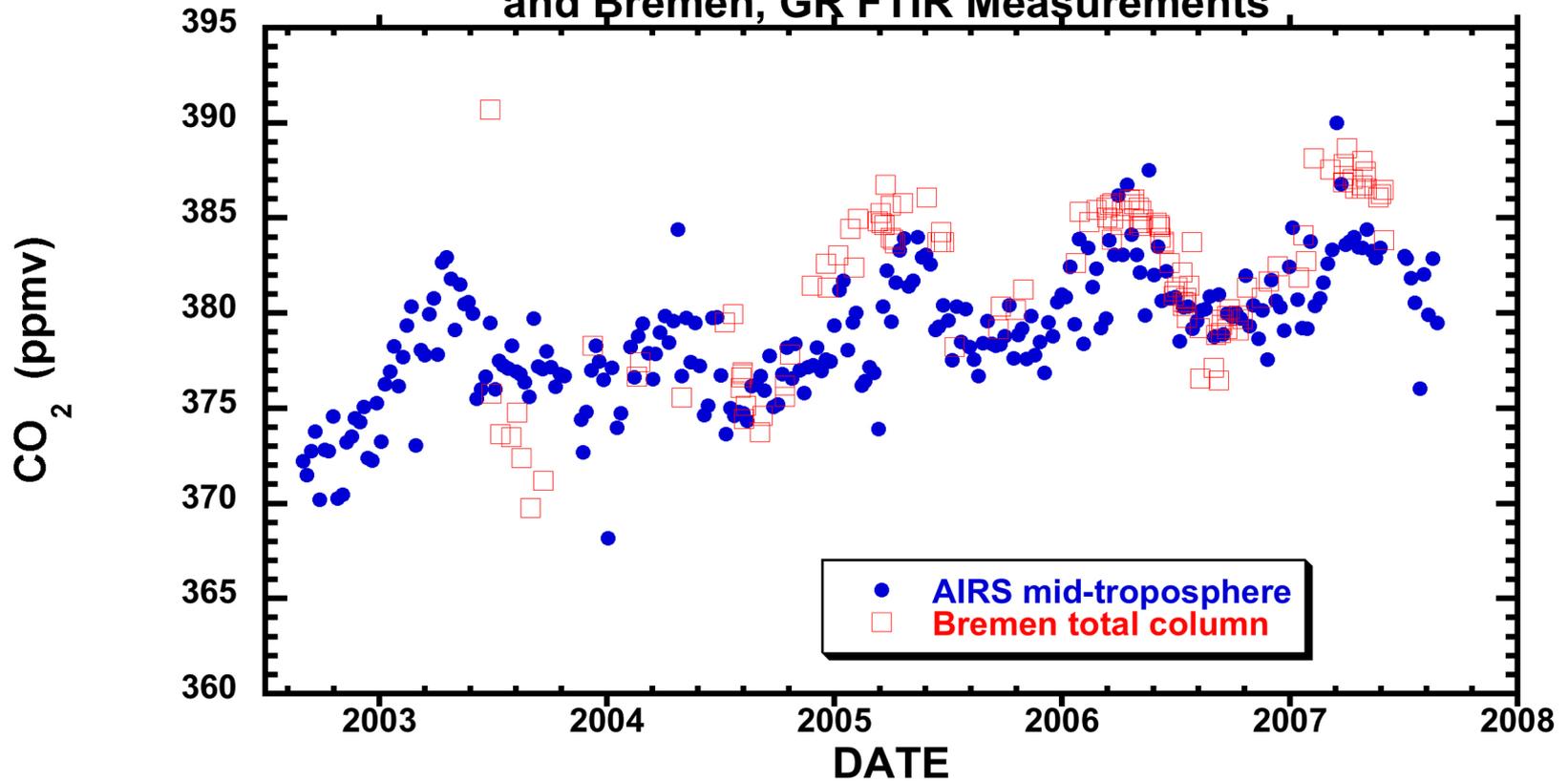
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# Comparison of V1.5x AIRS CO<sub>2</sub> seasonal cycle and trend to Bremen FTIR (53.1N; 8.9E)

## 7-Day Averages of AIRS Retrievals within 250 km of Bremen and Bremen, GR FTIR Measurements



Bremen FTIR data provided by Prof. Dr. Justus Notholt, University of Bremen



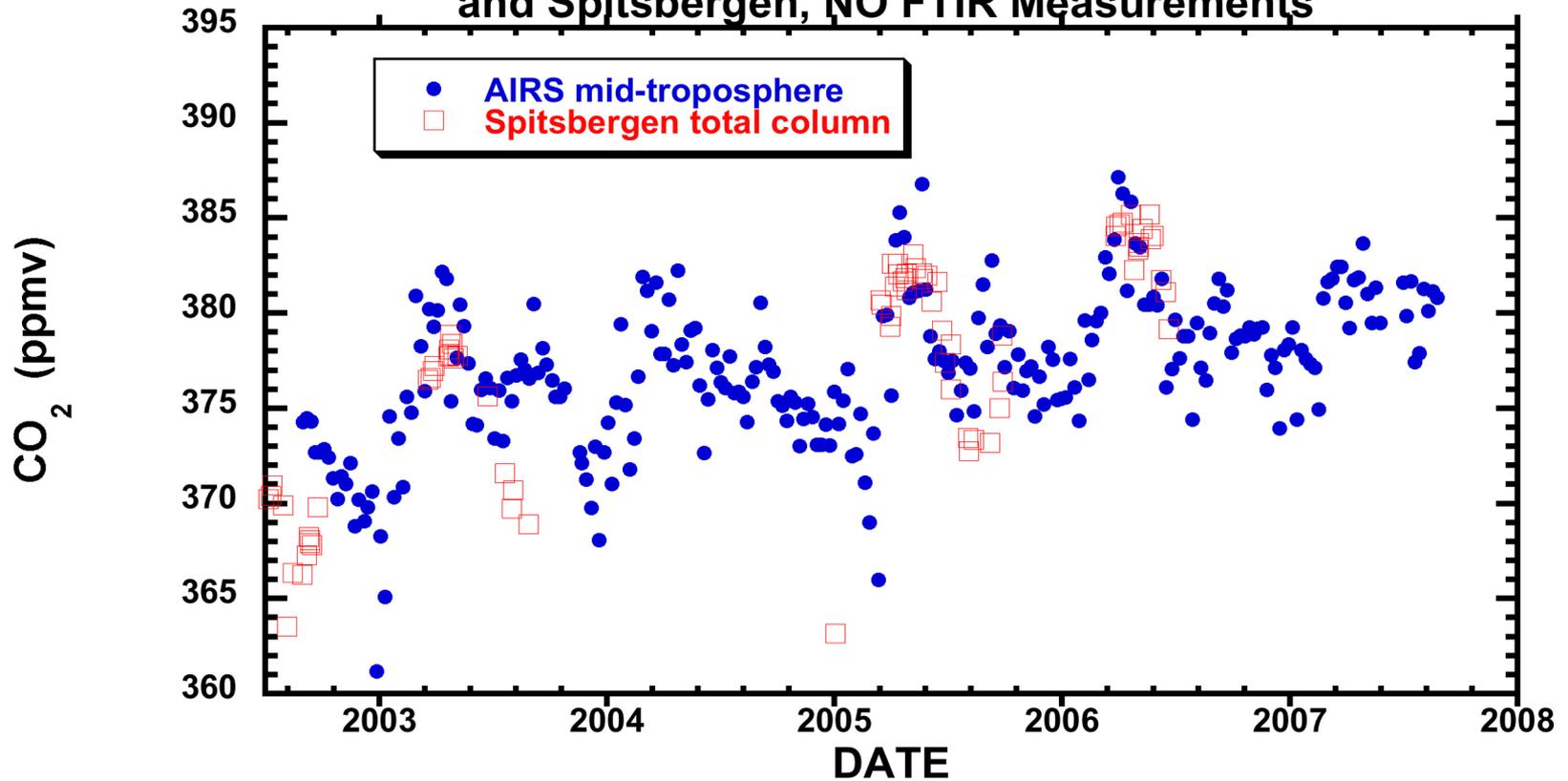
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# Comparison of V1.5x AIRS CO<sub>2</sub> seasonal cycle and trend with Spitsbergen(78.9N; 12.4E)

## 7-Day Averages of AIRS Retrievals within 250 km of Spitsbergen and Spitsbergen, NO FTIR Measurements



Spitsbergen FTIR data provided by Prof. Dr. Justus Notholt, University of Bremen



# Summary and Conclusions

- **We have carried out comparisons with independent measurements between 30°S and 80°N**
  - **Excellent agreement with aircraft and FTIR as a function of season and latitude**
- **TCCON network provides opportunity for frequent comparison of AIRS mid-tropospheric CO<sub>2</sub> retrievals with high-quality measurements of Column CO<sub>2</sub>**
  - **Combined observations offer possibility of tracking the large-scale variation of CO<sub>2</sub> in the boundary layer**
- **AIRS allows monitoring of distribution of global CO<sub>2</sub> in the free troposphere on a weekly basis**
  - **Significant spatiotemporal variability is apparent and appears to be strongly influenced by large-scale circulations such as the middle-latitude jet streams and synoptic weather systems**



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## Pre-Release of Version 2.0

- **AIRS V2.0 CO<sub>2</sub> monthly average, gridded data**
  - **Time Period: Sept 2002 through Dec 2004**
  - **Global Coverage: 60°S to 90°N**
  - **Geospatial Resolution: 2° x 2.5° (lat x lon)**
  - **Averaged in time for each calendar month**
- **Access**
  - **DISC GES**
    - **<http://disc/gsfsc/nasa/gov/AIRS>**
  - **Data Format**
    - **HDF-EOS Point**



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***BACKUP***



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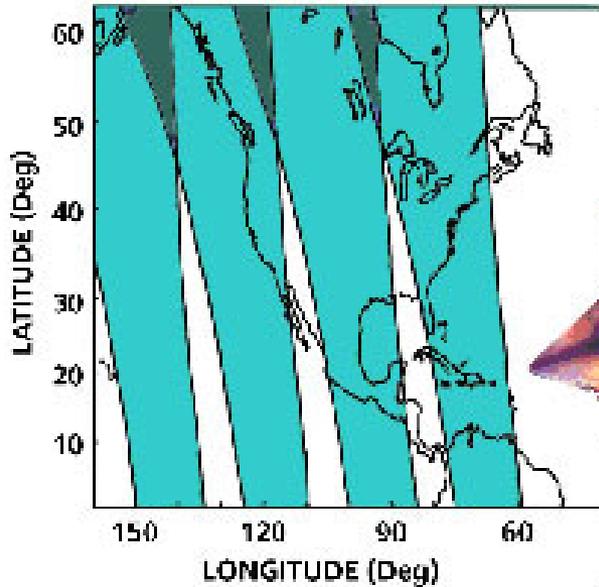
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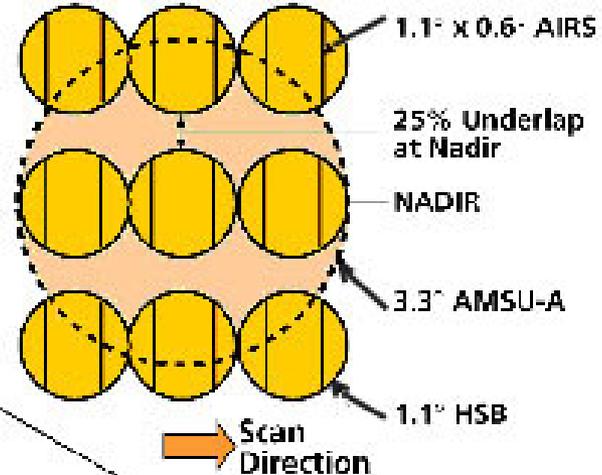
# AIRS AMSU-HSB Scan Patterns

*"There no such thing as cloud-free...It is just cirrus"*  
GEWEX-ISCCP

Four typical ascending orbits, Continental USA



AIRS/AMSU/HSB IFOV are optimally aligned



$\pm 48.95^\circ$

Scan Motion

Direction of Flight

See Box on page 915  
*Bul. Am. Met. Soc*  
June 2006

## AIRS SCAN GEOMETRY

- Altitude: 705 km
- Scan Period: 2.667 s
- Ground Footprints: 90/Scan



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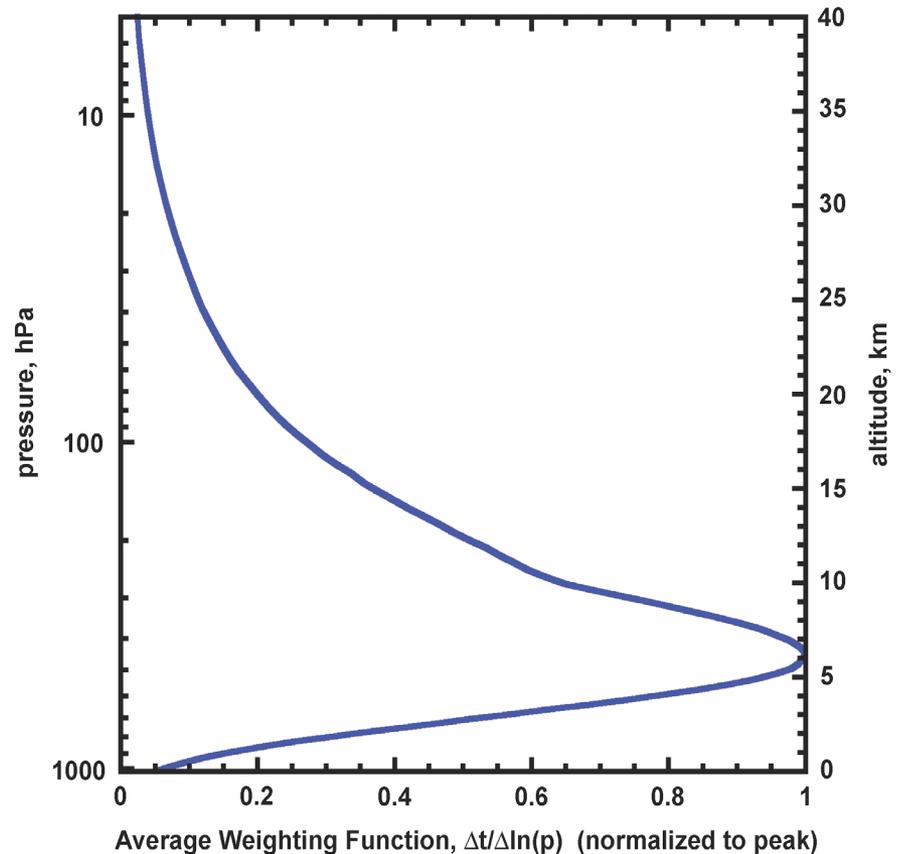
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# AIRS Sensitivity Function for mid-Tropospheric CO<sub>2</sub>

**Average weighting function for  
13 selected CO<sub>2</sub> channels in 15  $\mu$ m  
band**

- Peak sensitivity occurs  
at 450 hPa (6.2 km)
- Width at half-maximum spans  
700 hPa (3 km) to 200 hPa (12 km)
- Sensitivity to surface emission  
limited to less than 0.05 K radiance  
contribution





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# AIRS mid-Tropospheric CO<sub>2</sub> Sensitivity Function for tropical, mid-latitude and polar regions

Average weighting function for  
13 selected CO<sub>2</sub> channels in 15  $\mu$ m  
band

