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Atmospheric Infrared Sounder

# 7.5 Years of AIRS Mid-Tropospheric AIRS CO<sub>2</sub> Release, Validation and Applications

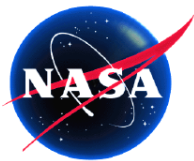
Edward Olsen<sup>1</sup>, Moustafa Chahine<sup>1</sup>, Luke Chen<sup>1</sup>,  
Xun Jiang<sup>2</sup>, Thomas Pagano<sup>1</sup> and Yuk Yung<sup>3</sup>

<sup>1</sup> Science Division, Jet Propulsion Laboratory, Caltech

<sup>2</sup> Department of Earth & Atmospheric Sciences, Univ. of Houston

<sup>3</sup> Division of Geological & Planetary Sciences, Caltech

NOAA/ESRL Global Monitoring Conference, May 18-19, 2010



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# The Atmospheric Infrared Sounder on NASA's EOS Aqua Spacecraft

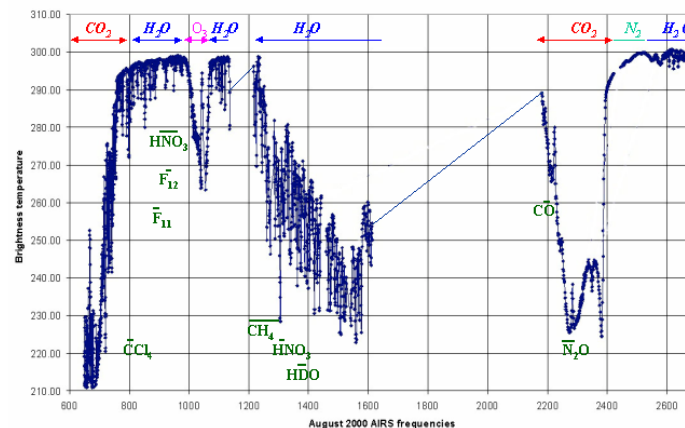
## AIRS

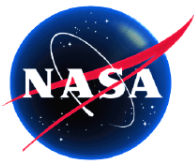
- AIRS Characteristics
- Launched: May 4, 2002
- Orbit: 705 km, 1:30pm, Sun Synch
- IFOV :  $1.1^\circ \times 0.6^\circ$   
(13.5 km x 7.4 km)
- Scan Range:  $\pm 49.5^\circ$
- Full Aperture OBC Blackbody,  $\epsilon > 0.998$
- Full Aperture Space View
- Solid State Grating Spectrometer
  - IR Spectral Range:  
3.74-4.61  $\mu\text{m}$ , 6.2-8.22  $\mu\text{m}$ ,  
8.8-15.4  $\mu\text{m}$
  - IR Spectral Resolution:  
 $\approx 1200 (\lambda/\Delta\lambda)$
  - # IR Channels: 2378 IR
- VIS Channels: 4
- Mass: 177Kg,  
Power: 256 Watts,  
Life: 5 years (7 years goal)



## AIRS Spectra

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





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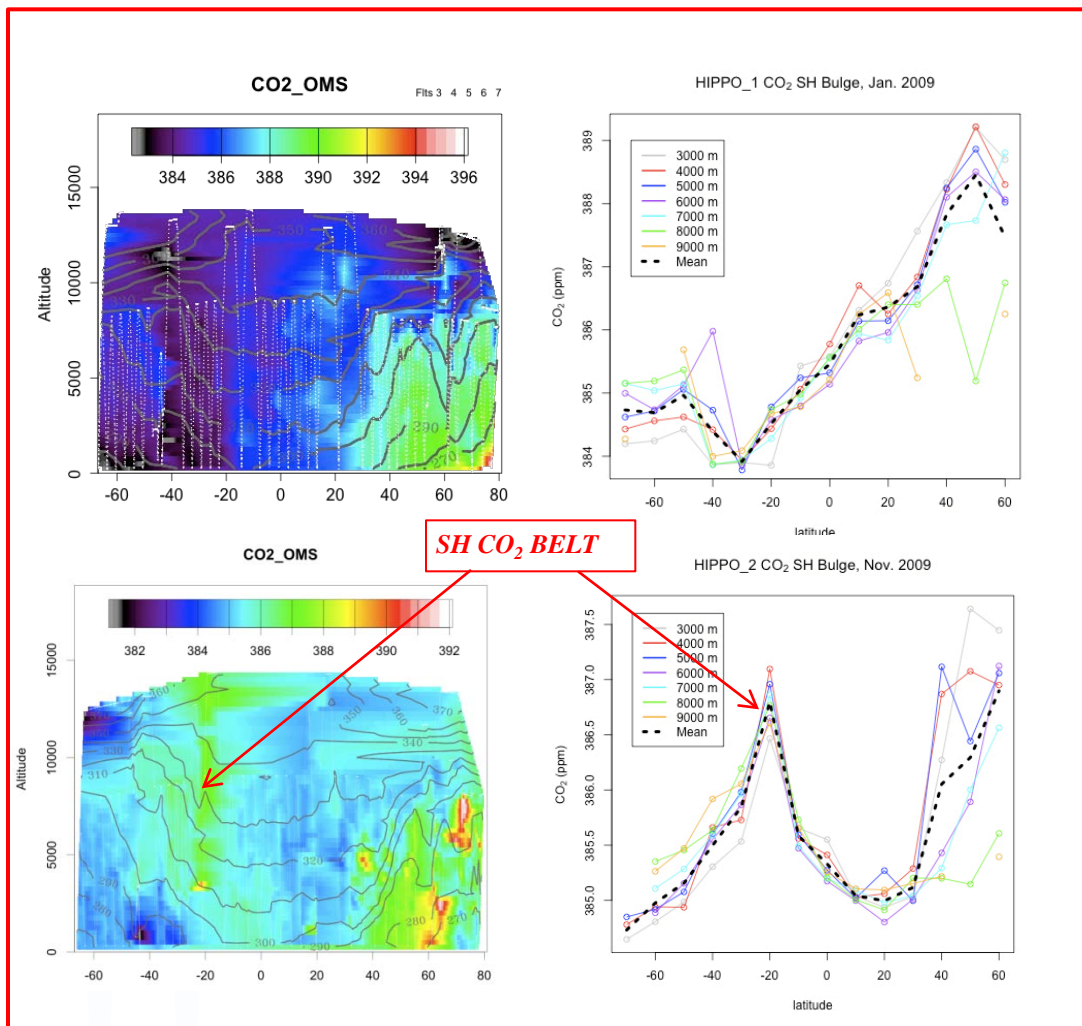
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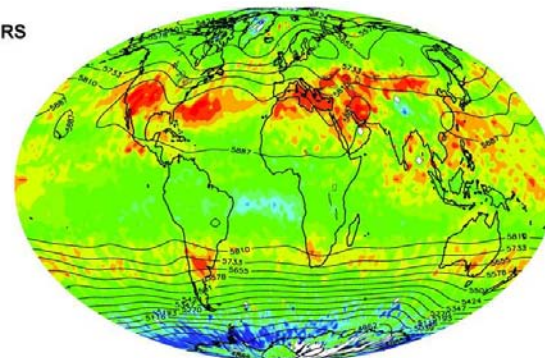
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# In-Situ Confirmation of Seasonally Variable Southern Hemisphere Belt

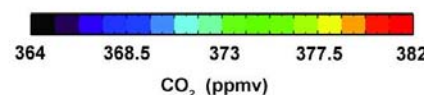
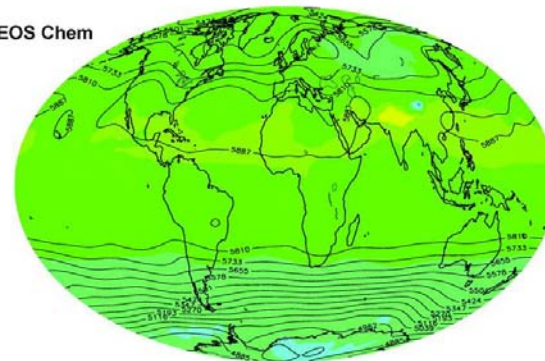
AIRS has Observed the SH CO<sub>2</sub> Belt Since 2003



AIRS

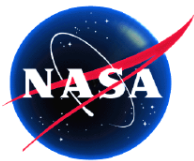


GEOS Chem



Steve Wofsy (Harvard) HIPPO Campaign -2009

Chahine, et al., Satellite remote sounding of mid-tropospheric CO<sub>2</sub>, Geophys. Res. Lett., 35, L17807, doi:10.1029/2008GL035022.



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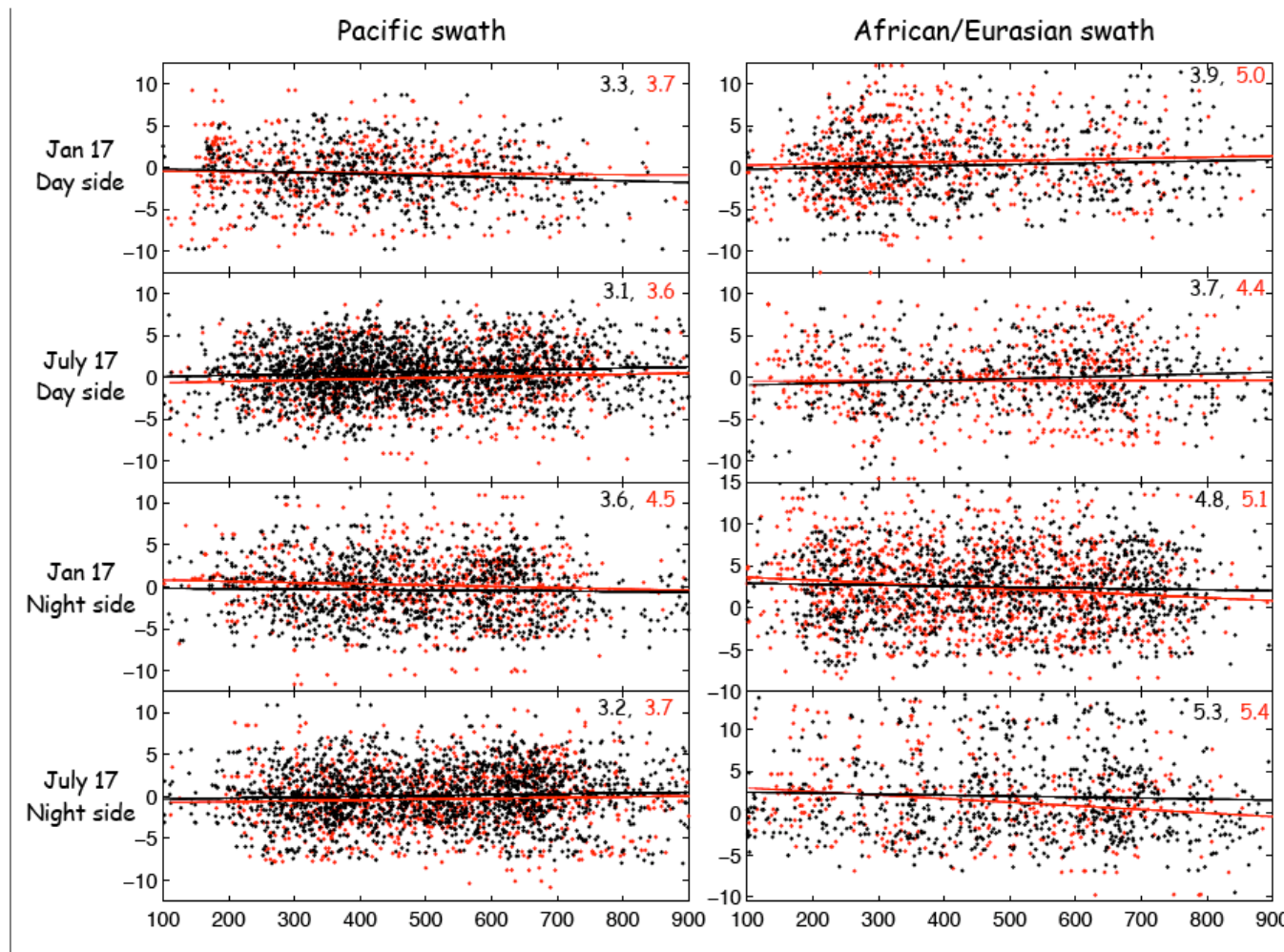
# AIRS CO<sub>2</sub>: No Cloud-top Dependent Bias Compared to Carbon Tracker

Carbon Tracker-AIRS difference (ppm)

Black: Standard Products

Red: Support Products

Analysis by:  
David Baker, CSU



Cloud Top Pressure (hPa)



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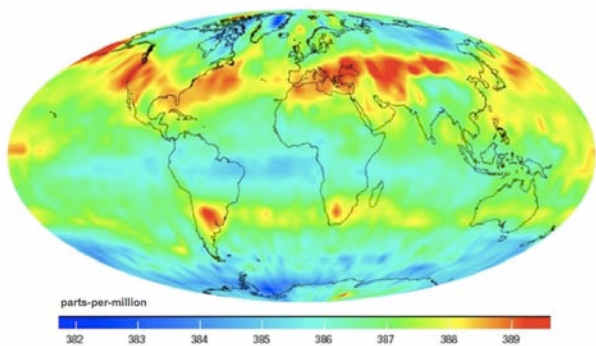
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# Release of AIRS CO2 Data Products

## [http://airs.jpl.nasa.gov/AIRS\\_CO2\\_Data](http://airs.jpl.nasa.gov/AIRS_CO2_Data)

### AIRS Level 2 and Level 3 Mid-Tropospheric CO2 Data Release



Monthly average of carbon dioxide in the mid-troposphere made from data acquired by AIRS during July 2009.

September 2002 - April 2010

Latitude Range: 60°S to 90°N

#### Level 2

- includes averaging kernels
- nadir resolution: 100km x 100km

#### Level 3

- spatial grid: 2° x 2.5° (lat/lon)
- time periods: 1d,8d,calendar month

Contact: [Edward.T.Olsen@jpl.nasa.gov](mailto:Edward.T.Olsen@jpl.nasa.gov)  
phone: 818-354-7604

#### Access to AIRS Tropospheric CO2 Product Files

The AIRS CO2 product files may be freely downloaded from the Goddard Earth Sciences (GES) Data and Information Services Center (DISC). The links listed below will give you access to all the AIRS carbon dioxide data products.

The URL providing links to all methods of access to AIRS Data Products:

<http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings>

Links on this web page may be used to search for and subset all AIRS data products by type, geospatial location, and time and to download them via ftp or directly via links on web pages.

URLs for access via Mirador to the Level 2 (standard, support) CO2 Data Products:

<http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=airx2stc>  
<http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=airx2spc>

URLs for access via Mirador to the Level 3 CO2 (daily, 8-day, monthly) Data Products:

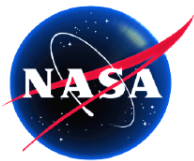
<http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=airx3c2d>  
<http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=airx3c28>  
<http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=airx3c2m>

Corresponding URLs for access via the Web Portals:

[http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/airsL2\\_Stc](http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/airsL2_Stc)  
[http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/airsL2\\_Spc](http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/airsL2_Spc)  
<http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/AIRX3C2D>  
<http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/AIRX3C28>  
<http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings/by-data-product/AIRX3C2M>

The sample L2 swath and L3 grid data readers provided with the AIRS V5 documentation package are available at the URL:

<http://disc.sci.gsfc.nasa.gov/AIRS/documentation>



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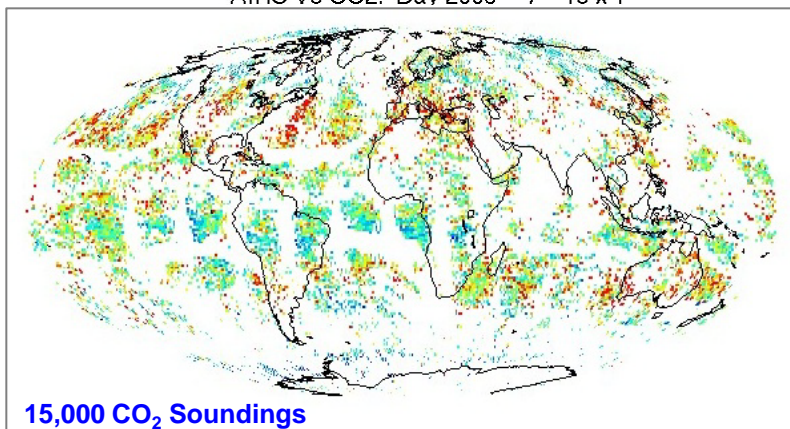
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# Global Yield of AIRS Level 2 Mid-Tropospheric CO<sub>2</sub>

**AIRS Daily CO<sub>2</sub> Yield**  
**1°x1° Spatial Resolution**

AIRS V5 CO2: Day 2003 7 15 x 1

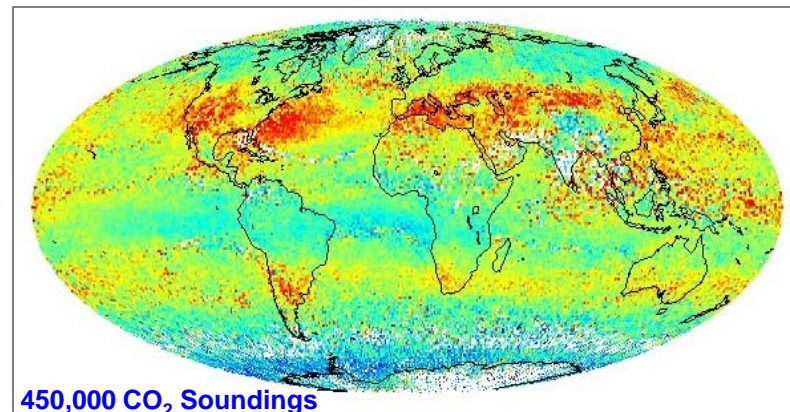


15,000 CO<sub>2</sub> Soundings

365 370 375 380

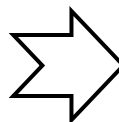
**AIRS Monthly CO<sub>2</sub> Yield**  
**1°x1° Spatial Resolution**

AIRS V5 CO2: Day 2003 7 15 x 30



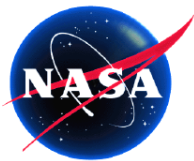
450,000 CO<sub>2</sub> Soundings

365 370 375 380



**AIRS Level 2 Mid-Tropospheric CO<sub>2</sub> retrieval yield is controlled by requirement for highest quality temperature and water vapor AIRS Level 2 products in 2x2 array of adjacent FOVs**

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



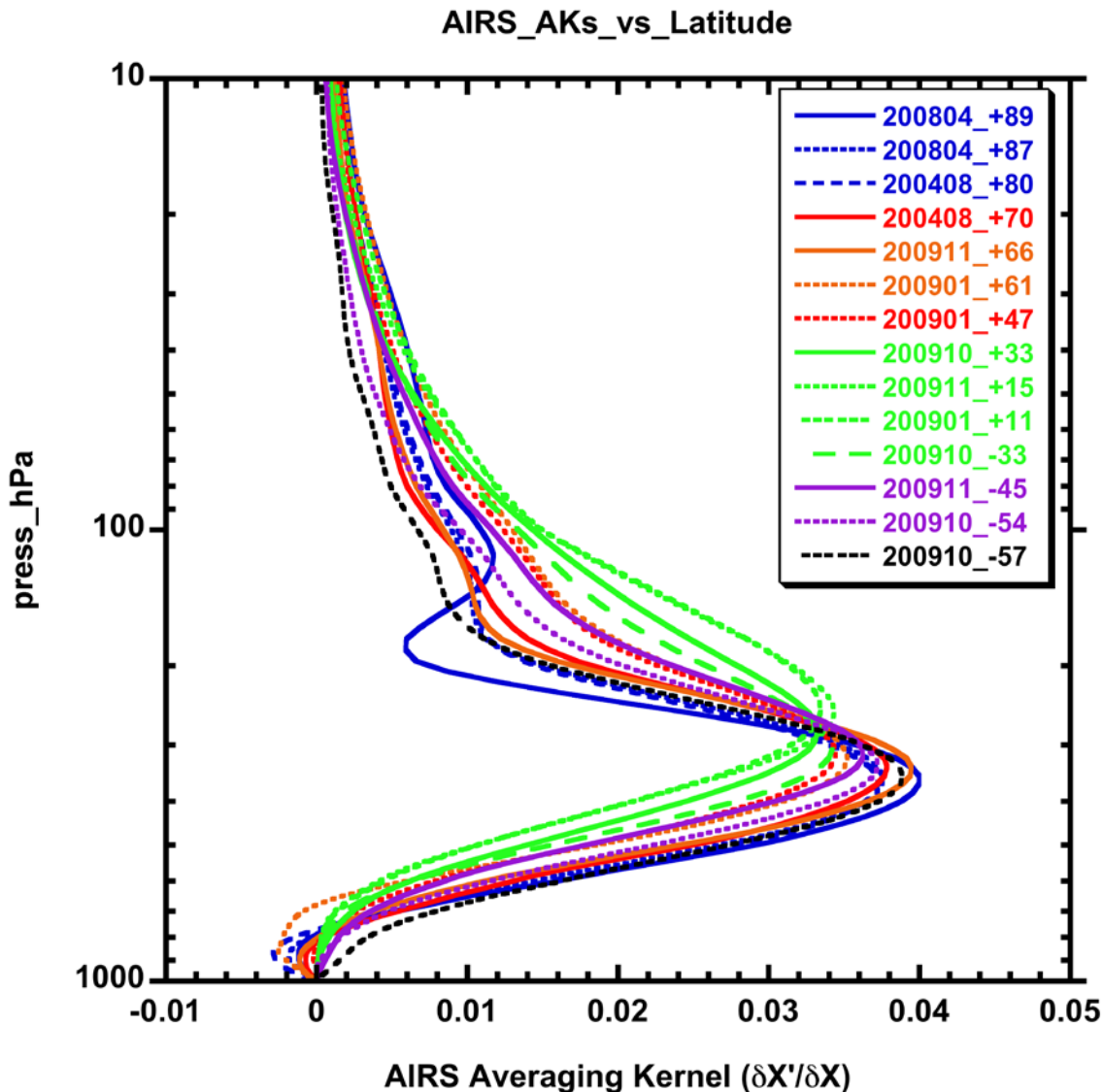
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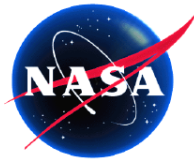
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# Representative AIRS Mid-Trop CO<sub>2</sub> Averaging Kernels



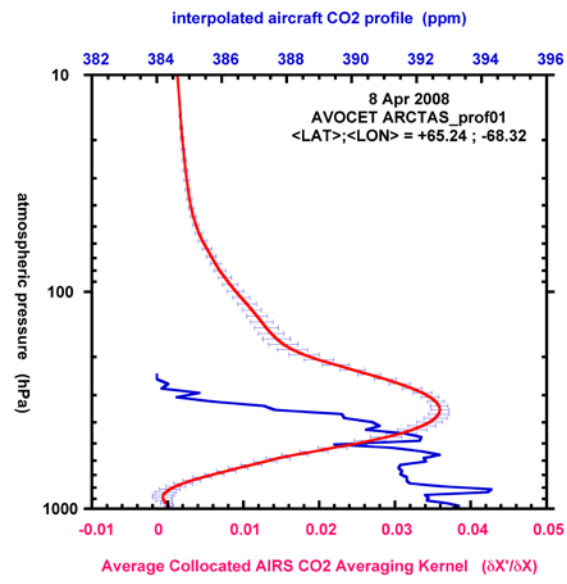
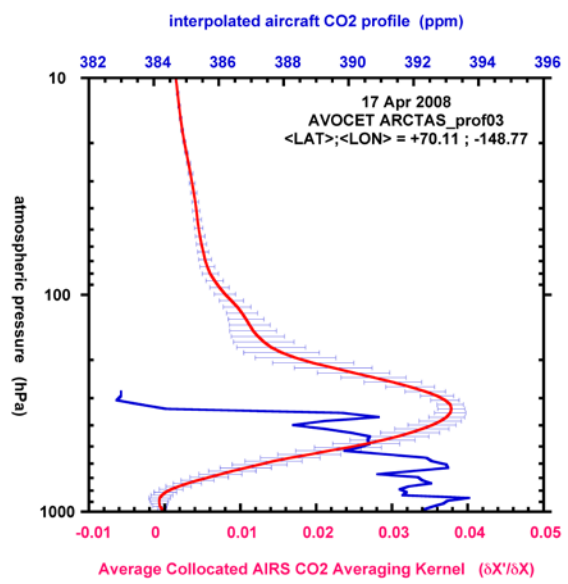
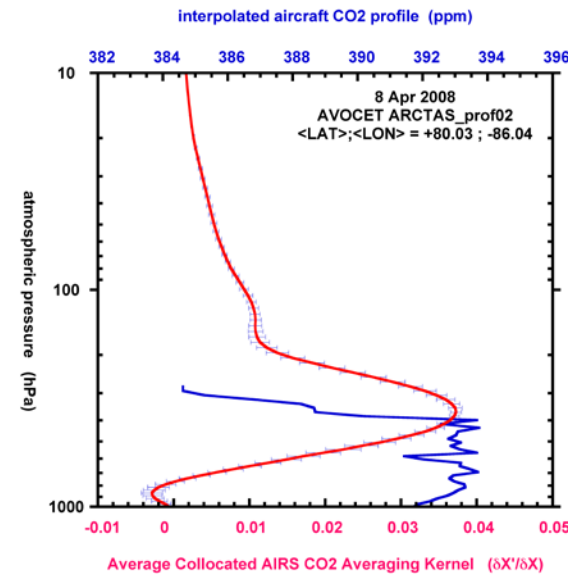
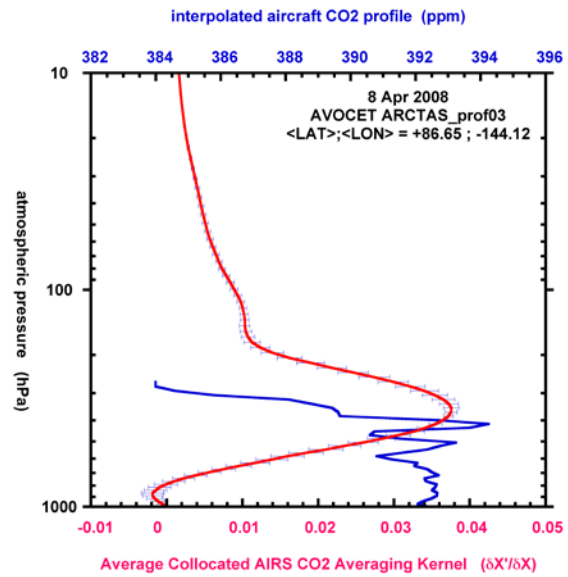
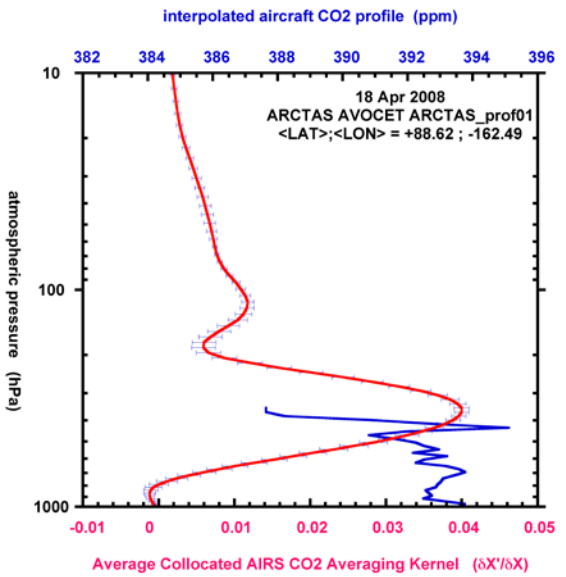


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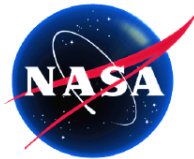
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# Average Collocated AIRS CO<sub>2</sub> AKs and AVOCET ARCTAS CO<sub>2</sub> Profiles for Various Latitudes in April 2008







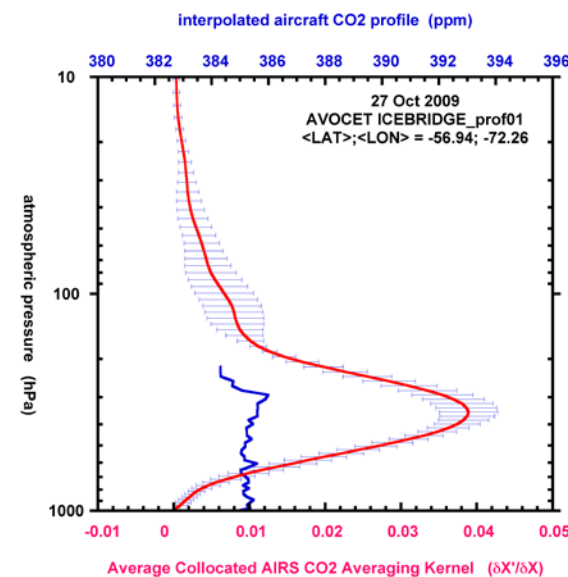
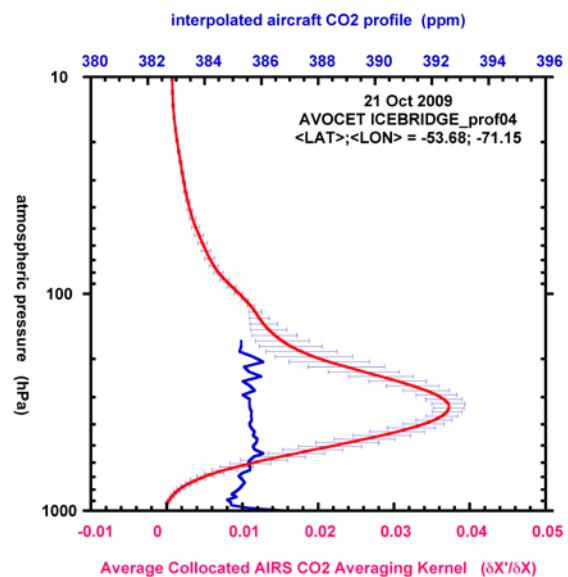
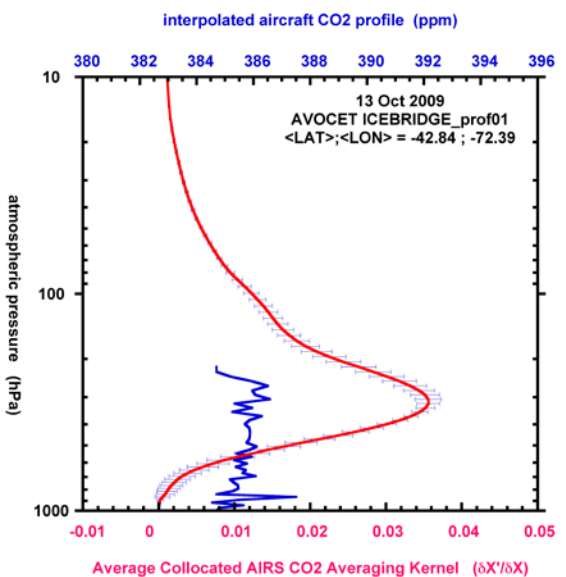
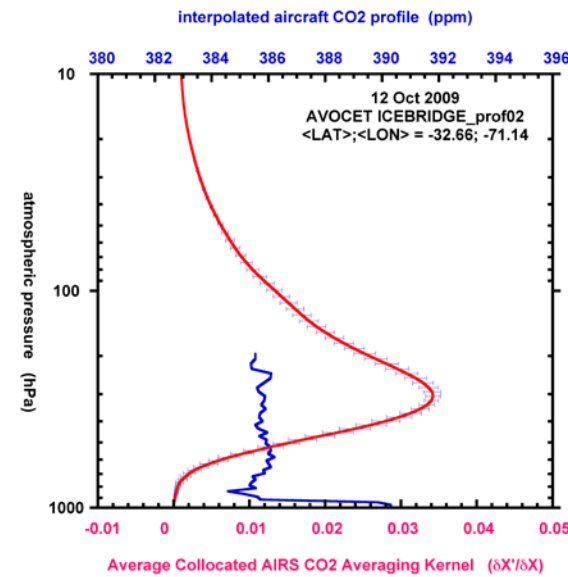
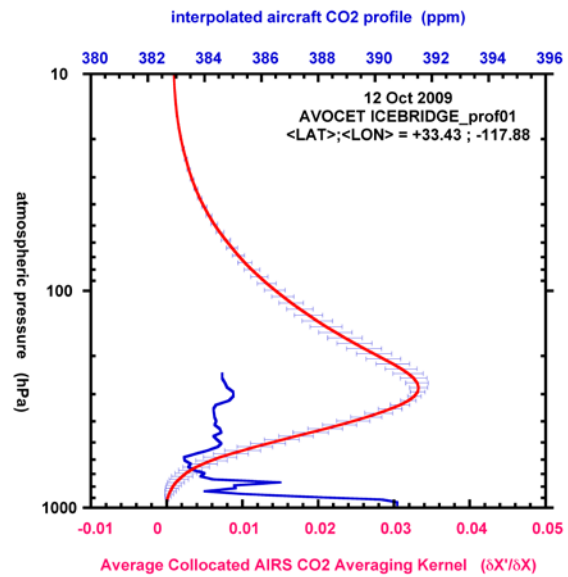
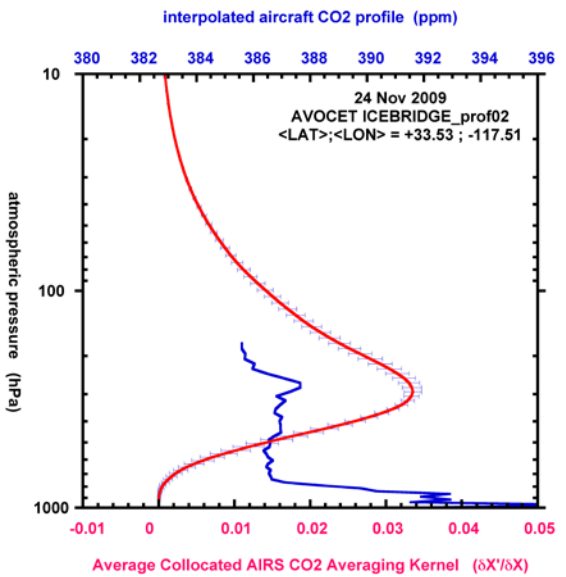
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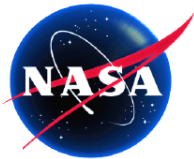
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# Average Collocated AIRS CO<sub>2</sub> AKs and AVOCET ICEBRIDGE CO<sub>2</sub> Profiles for Various Latitudes in October 2009





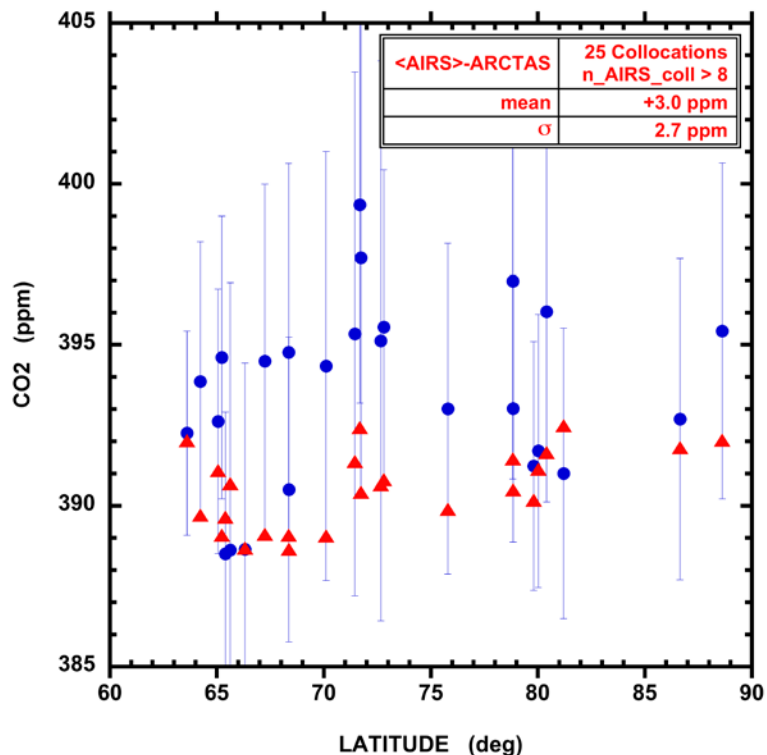
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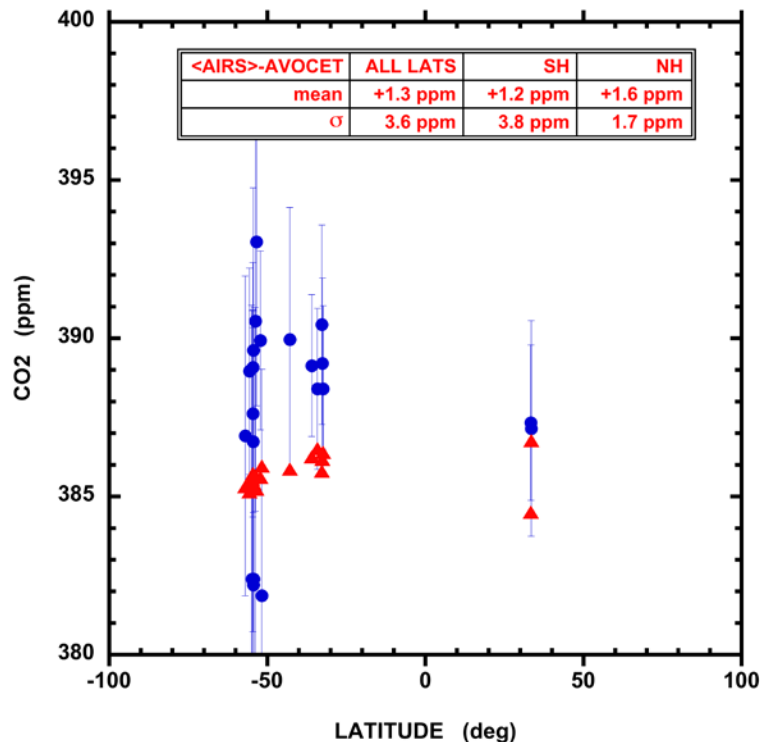
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# Comparison of AIRS CO<sub>2</sub> Retrievals with “deep dip” AVOCET Data from 2008 ARCTAS and 2009 ICEBRIDGE Campaigns for profiles ranging from near surface to p ≈ 200 hPa

2008 April Comparison of AIRS and ARCTAS-1 CO<sub>2</sub>  
ARCTAS-1 profiles weighted by <AIRS Collated Averaging Kernels>  
AIRS collocated within 500 km radius and ± 1 day of ARCTAS  
ARCTAS sensor CO<sub>2</sub> convolved with AIRS AK



2009 Oct Comparison of AIRS and ICEBRIDGE-1 CO<sub>2</sub>  
ICEBRIDGE-1 profiles weighted by <AIRS Collated Averaging Kernels>  
AIRS collocated within 500 km radius and ± 1 day of ICEBRIDGE  
ICEBRIDGE sensor CO<sub>2</sub> convolved with AIRS AK



AVOCET CO<sub>2</sub> vertical profile profile data column averaged with average of collocated AIRS Averaging Kernels



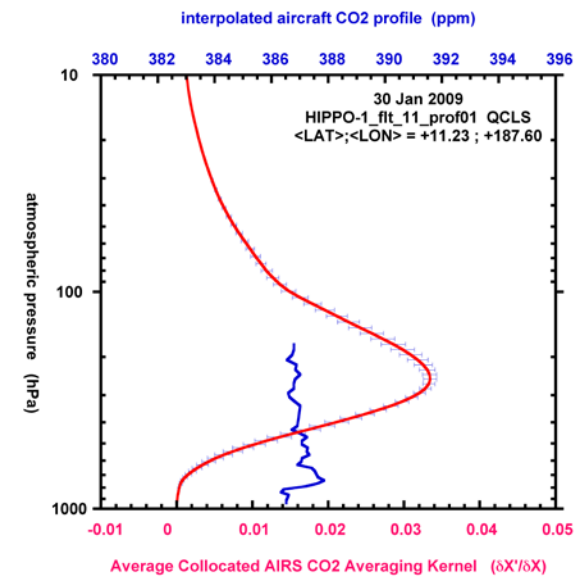
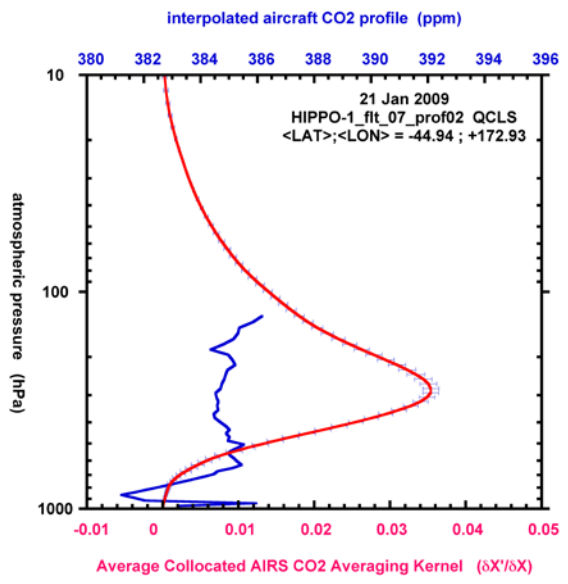
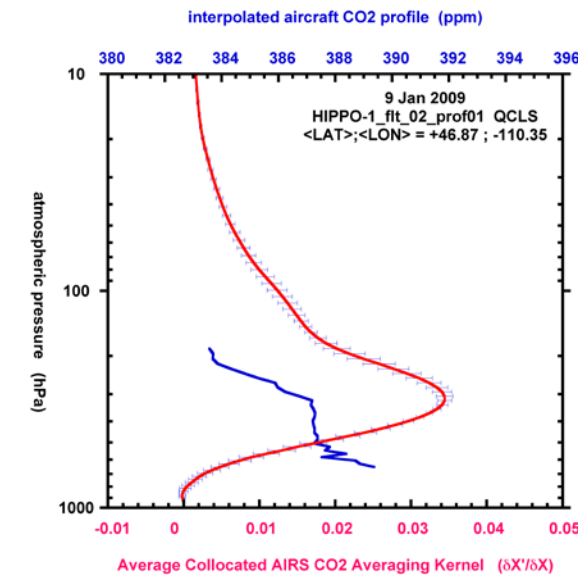
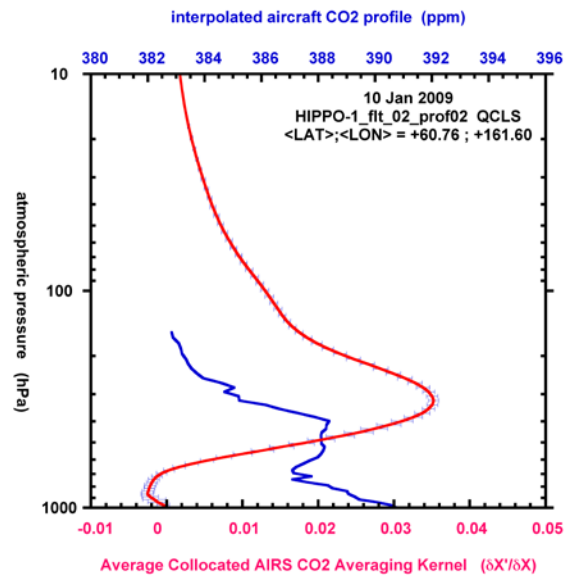
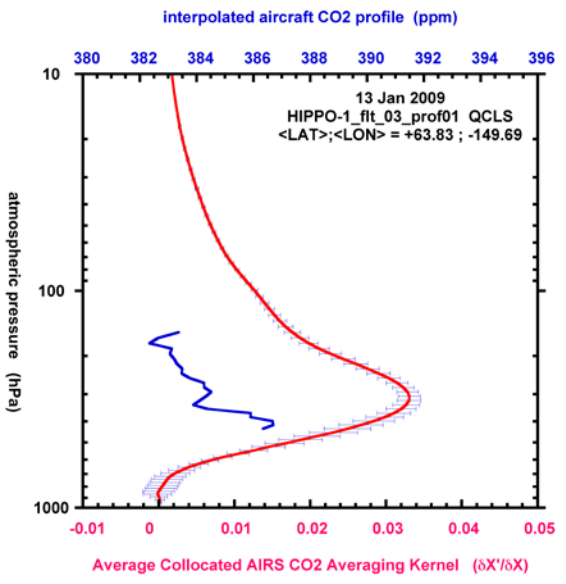
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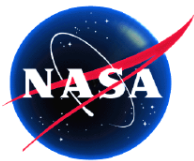
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# Average Collocated AIRS CO<sub>2</sub> AKs and HIPPO-1 QCLS CO<sub>2</sub> Profiles for Various Latitudes in January 2009





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# Comparison of Collocated AIRS CO<sub>2</sub> Retrievals with “deep dip” January 2009 HIPPO Data for profiles ranging from near surface to p < 200 hPa

2009 Jan Comparison of AIRS and HIPPO-1 CO<sub>2</sub>

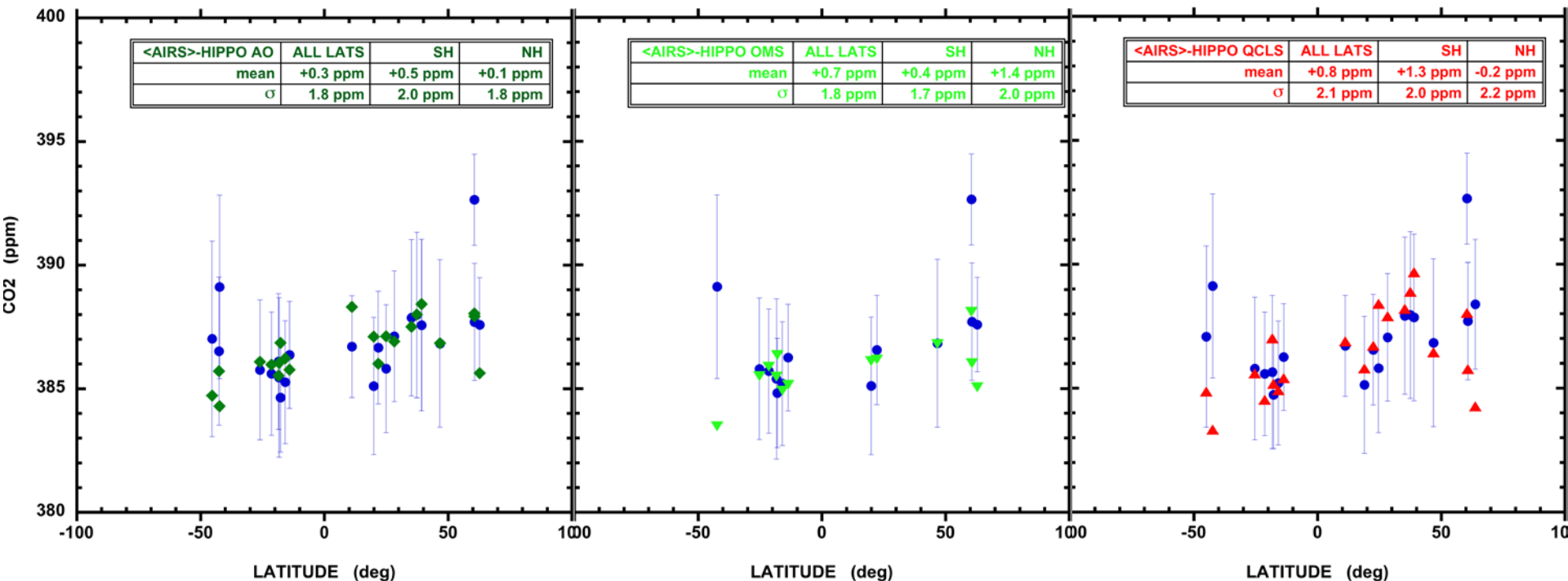
HIPPO-1 profiles weighted by <AIRS Collated Averaging Kernel>  
AIRS collocated within 500 km radius and ± 1 day of AO  
HIPPO AO sensor CO<sub>2</sub> convolved with <AIRS AK>

2009 Jan Comparison of AIRS and HIPPO-1 CO<sub>2</sub>

HIPPO-1 profiles weighted by <AIRS Collated Averaging Kernel>  
AIRS collocated within 500 km radius and ± 1 day of OMS  
HIPPO OMS sensor CO<sub>2</sub> convolved with <AIRS AK>

2009 Jan Comparison of AIRS and HIPPO-1 CO<sub>2</sub>

HIPPO-1 profiles weighted by <AIRS Collated Averaging Kernel>  
AIRS collocated within 500 km radius and ± 1 day of QCLS  
HIPPO QCLS sensor CO<sub>2</sub> convolved with <AIRS AK>



HIPPO CO<sub>2</sub> vertical profile profile data column averaged with average of collocated AIRS Averaging Kernels



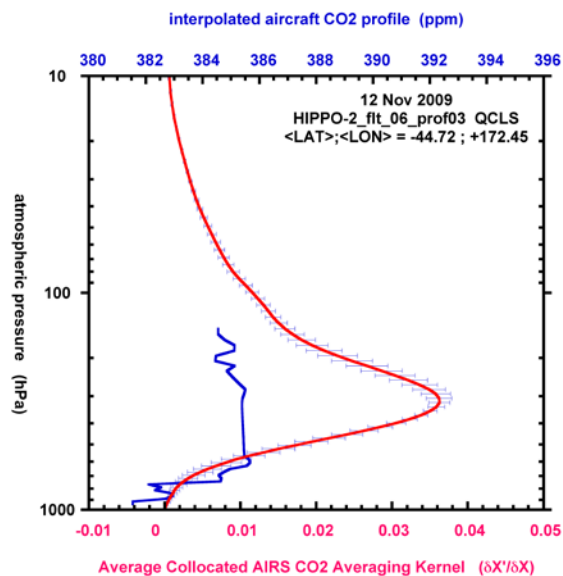
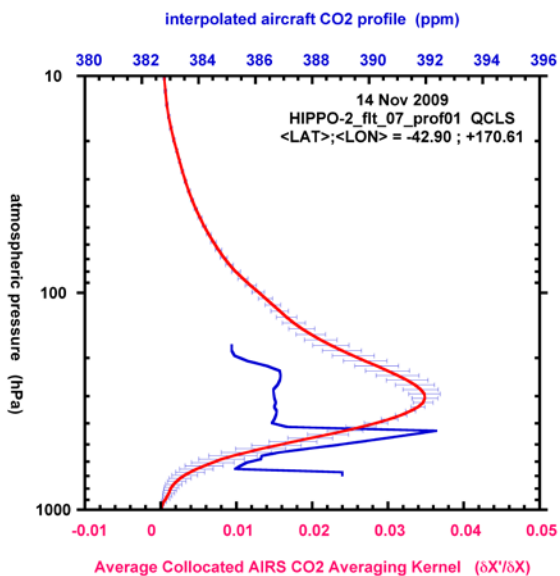
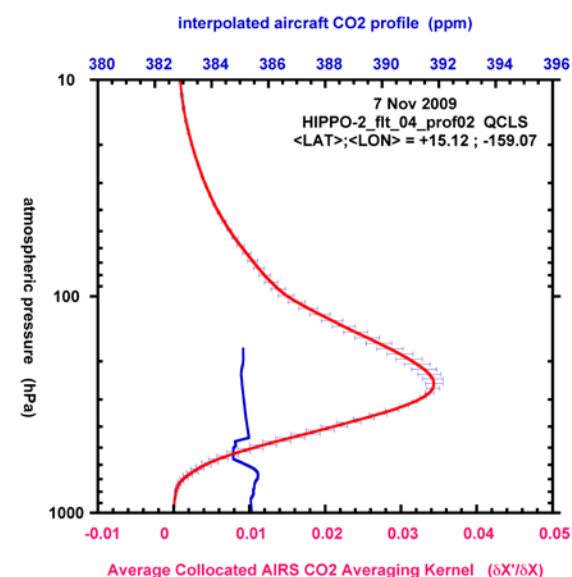
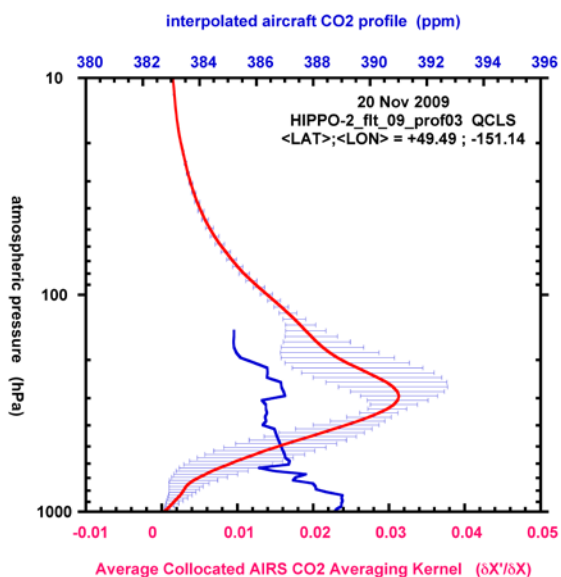
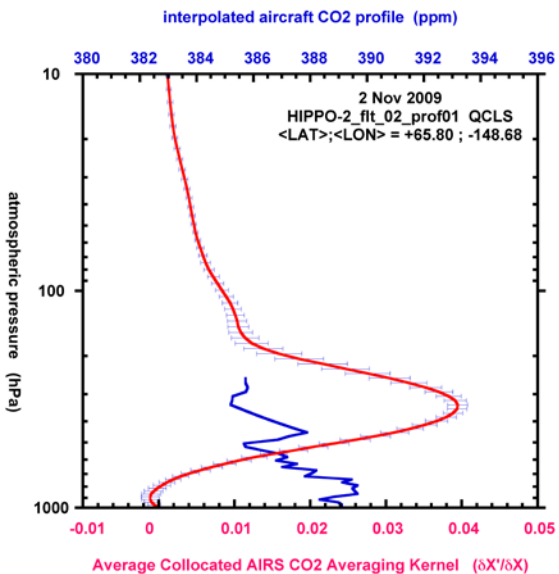
National Aeronautics and Space Administration

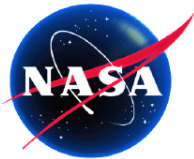
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# Average Collocated AIRS CO<sub>2</sub> AKs and HIPPO-2 QCLS CO<sub>2</sub> Profiles for Various Latitudes in November 2009





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# Comparison of Collocated AIRS CO<sub>2</sub> Retrievals with “deep dip” November 2009 HIPPO Data for profiles ranging from near surface to p < 200 hPa

2009 Nov Comparison of AIRS and HIPPO-2 CO<sub>2</sub>

HIPPO-2 profiles weighted by <AIRS Collocated Averaging Kernel>

AIRS collocated within 500 km radius and ± 1 day of AO

HIPPO AO sensor CO<sub>2</sub> convolved with <AIRS AK>

2009 Nov Comparison of AIRS and HIPPO-2 CO<sub>2</sub>

HIPPO-2 profiles weighted by <AIRS Collocated Averaging Kernel>

AIRS collocated within 500 km radius and ± 1 day of OMS

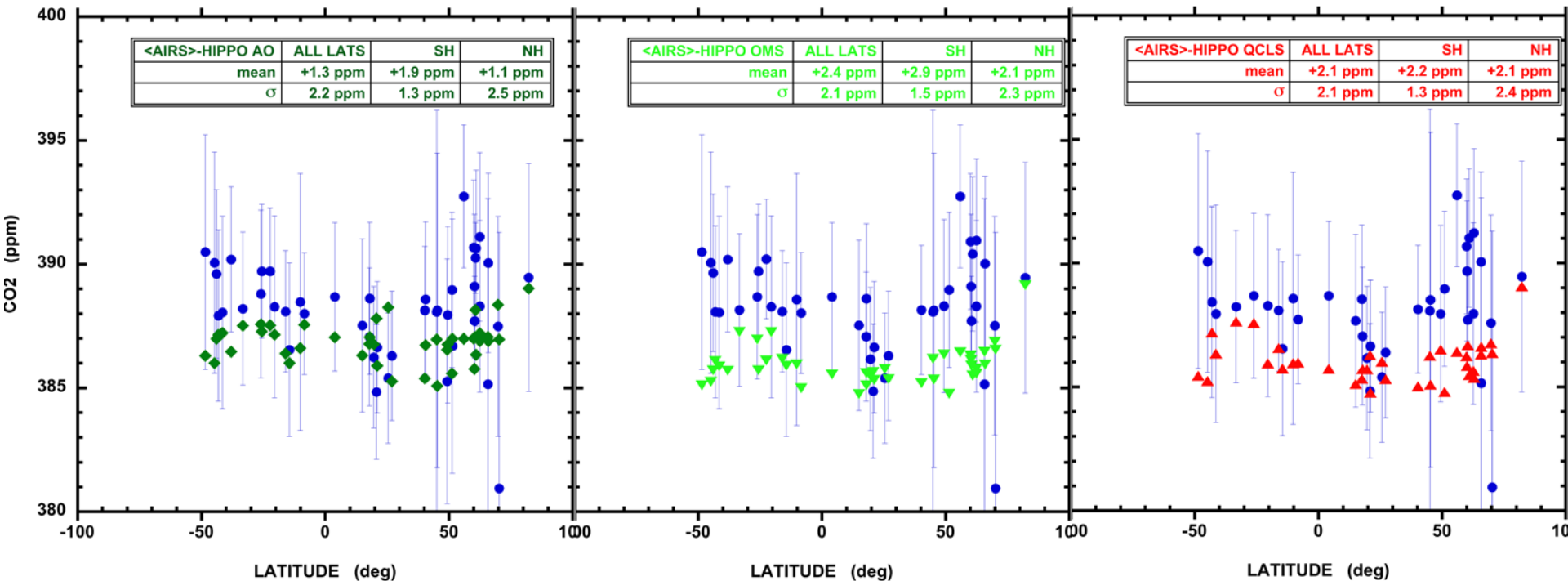
HIPPO OMS sensor CO<sub>2</sub> convolved with <AIRS AK>

2009 Nov Comparison of AIRS and HIPPO-2 CO<sub>2</sub>

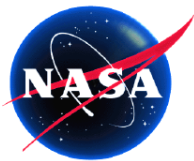
HIPPO-2 profiles weighted by <AIRS Collocated Averaging Kernel>

AIRS collocated within 500 km radius and ± 1 day of QCLS

HIPPO QCLS sensor CO<sub>2</sub> convolved with <AIRS AK>



HIPPO CO<sub>2</sub> vertical profile profile data column averaged with average of collocated AIRS Averaging Kernels



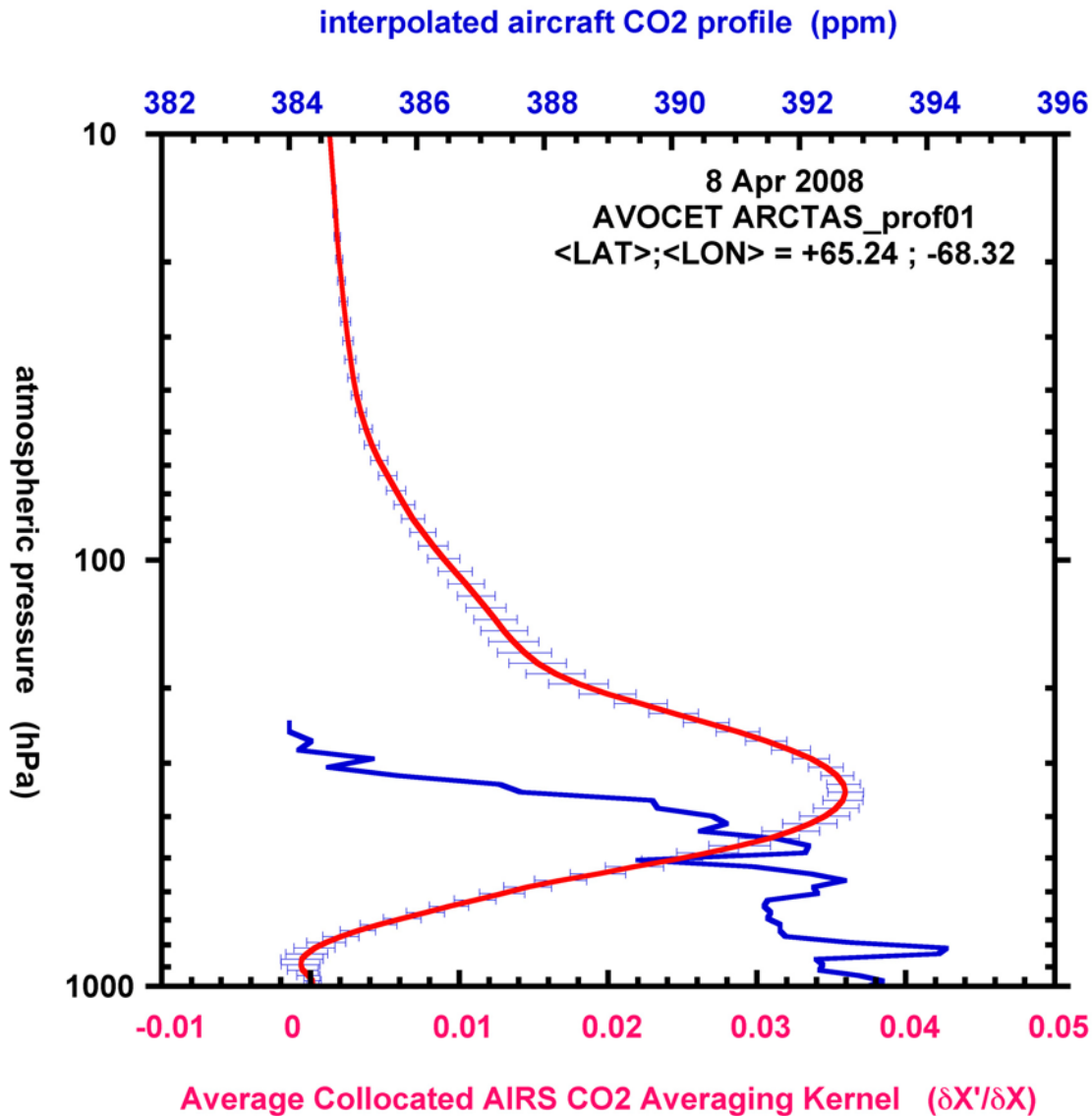
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# Comparison of Collocated AIRS CO<sub>2</sub> AKs and Aircraft CO<sub>2</sub> Profiles for 66°N





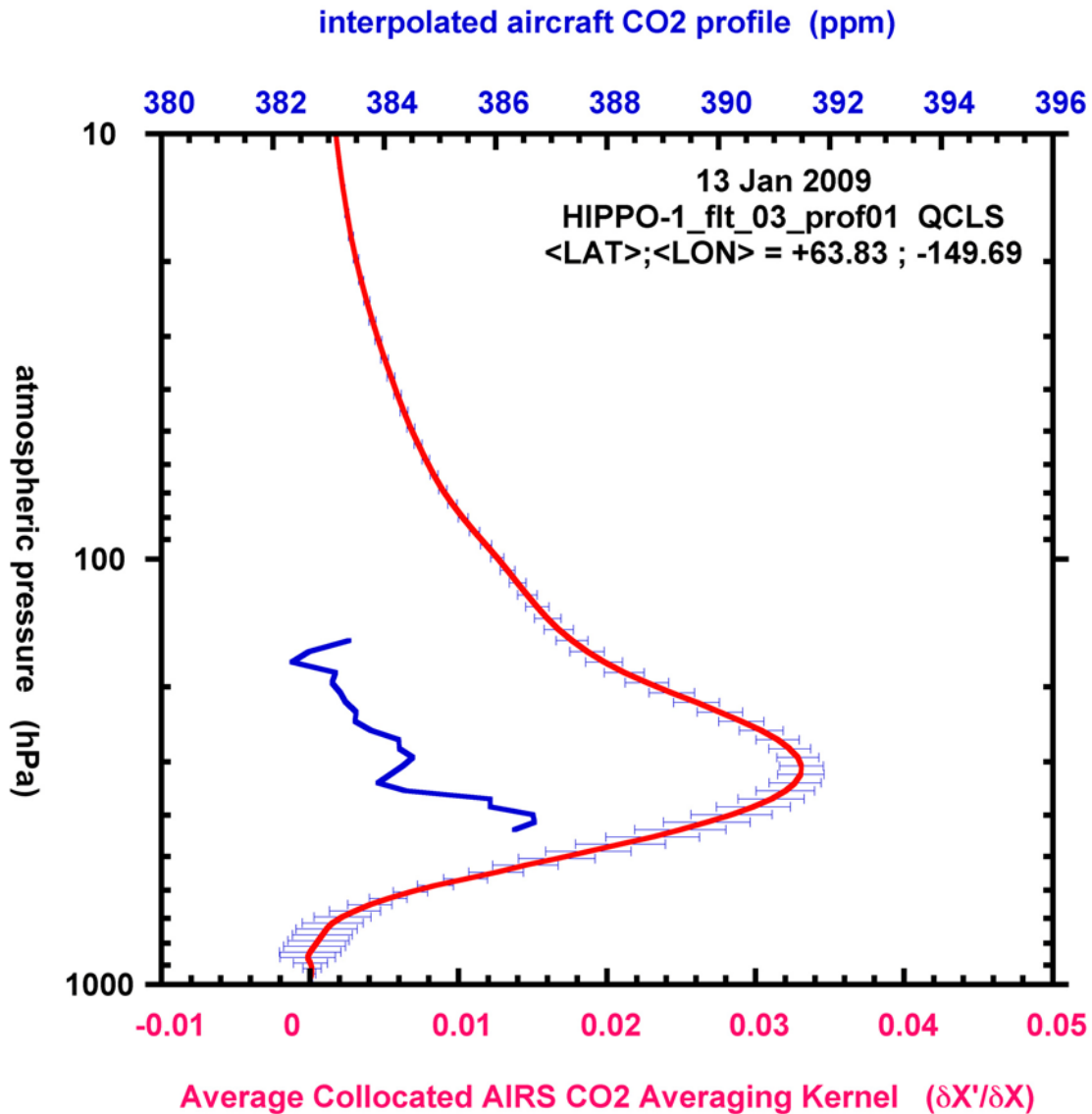
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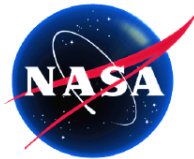
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# Comparison of Collocated AIRS CO<sub>2</sub> AKs and Aircraft CO<sub>2</sub> Profiles for 66°N







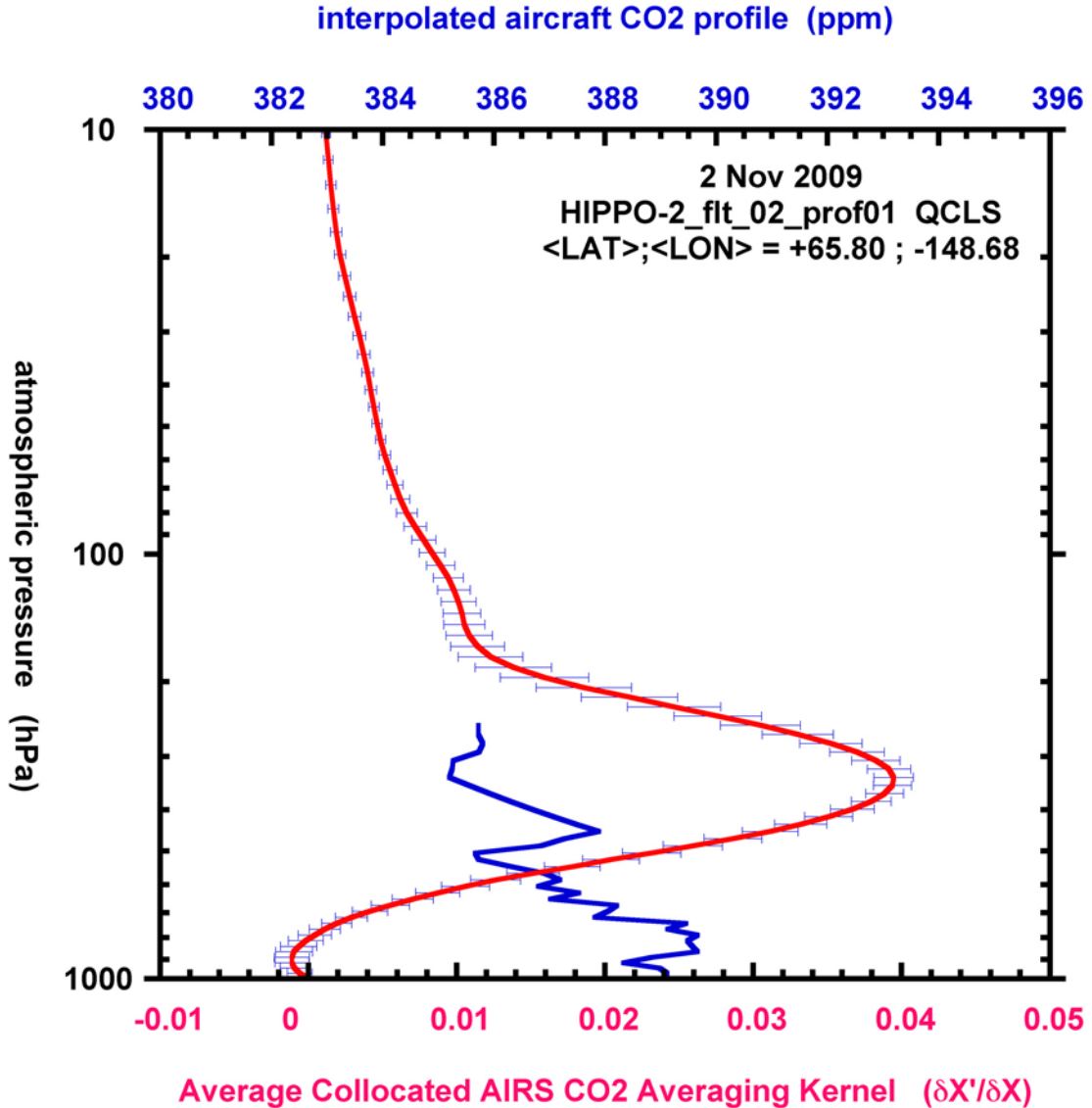
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Jet Propulsion Laboratory  
California Institute of Technology

Pasadena, California

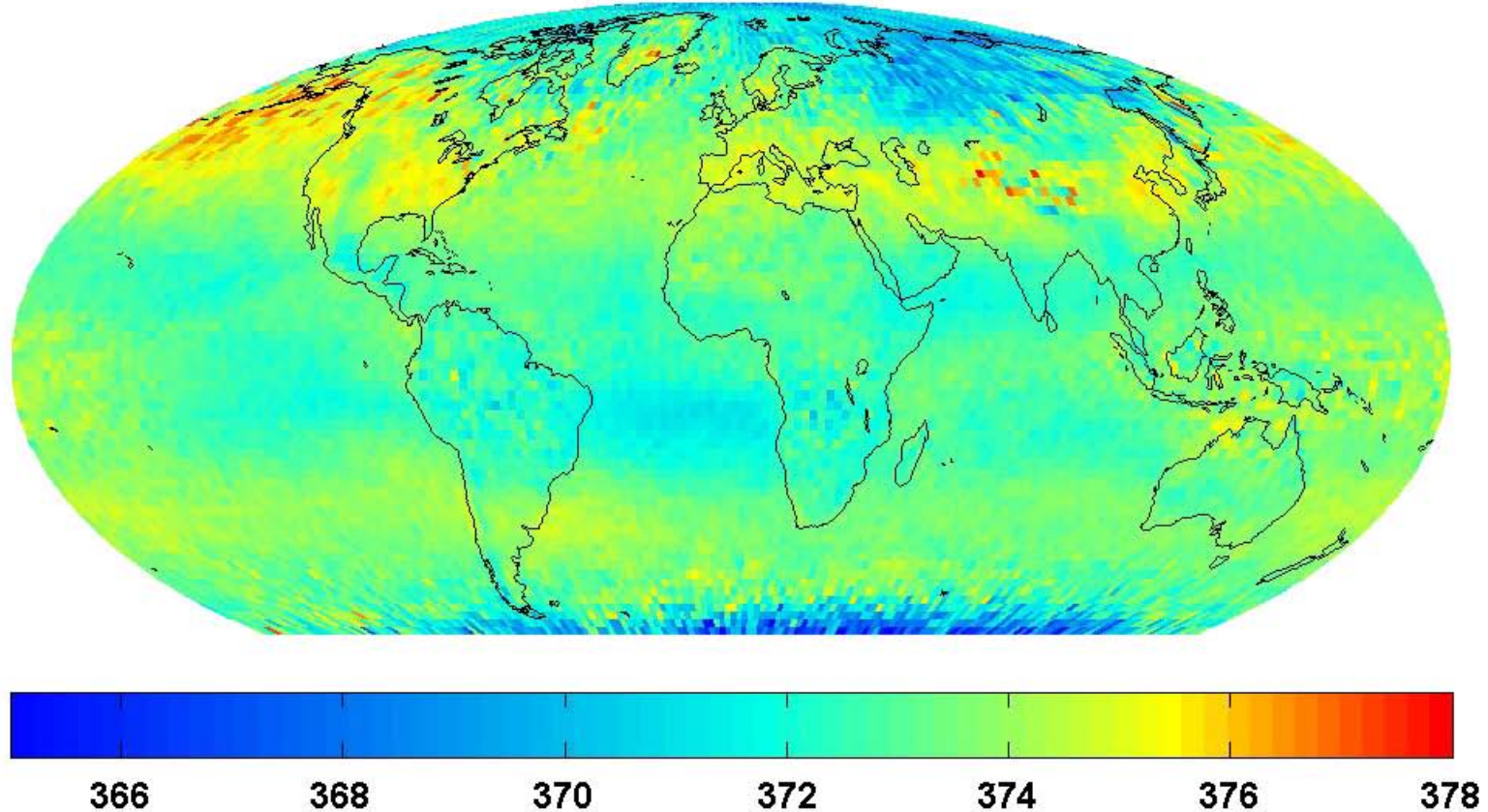
Atmospheric Infrared Sounder

# Comparison of Collocated AIRS CO<sub>2</sub> AKs and Aircraft CO<sub>2</sub> Profiles for 66°N

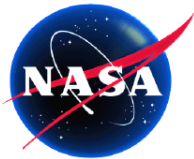


# Monthly Average Detrended Mid-Tropospheric CO<sub>2</sub>

JAN AIRS CO2 Climatology



Monthly Average Data binned at 2°x2° spanning January 2003 to December 2009 detrended at 2.1 ppm/yr, then individual months (all Jans, all Febs, etc) averaged



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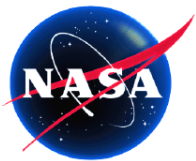
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## 7.5 - Years of AIRS Mid-Trop CO<sub>2</sub>

### What Processes have we Observed/ Studied So Far?

1. Seasonally variable belt of CO<sub>2</sub> in the Southern Hemisphere
2. Vegetation uptake over Park Falls
3. Seasonal Cycle and Trend well captured in AIRS Data  
(Comparison with Independent in-situ Aircraft Data)
4. Intraseasonal and Interannual Variability  
(Semi- annual Oscillation in AIRS CO<sub>2</sub>; Influence of Polar Vortex on AIRS CO<sub>2</sub>)
5. Stratospheric-Tropospheric exchange  
(SSW Event - increased O<sub>3</sub> & decreased CO<sub>2</sub> in the Troposphere)
6. Influence of ENSO on CO<sub>2</sub> during El Nino Event  
(More CO<sub>2</sub> in the Central Pacific and Less in the Western Pacific)
7. Direct Assimilation of AIRS CO<sub>2</sub> Retrievals using the Ensemble Kalman Filter  
(EnKF)



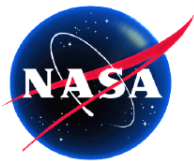
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**Thank You**



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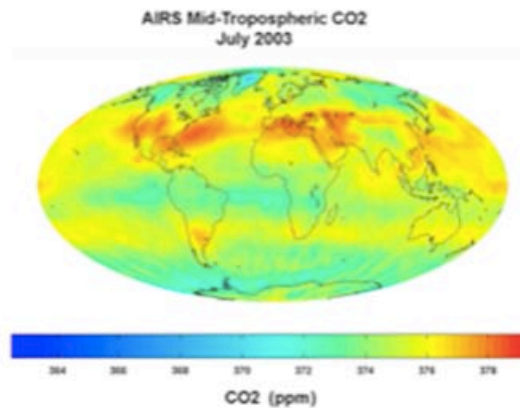
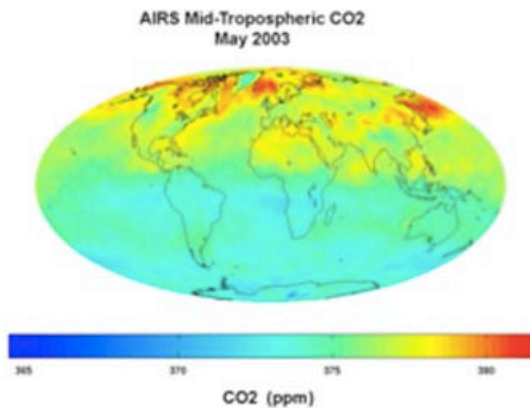
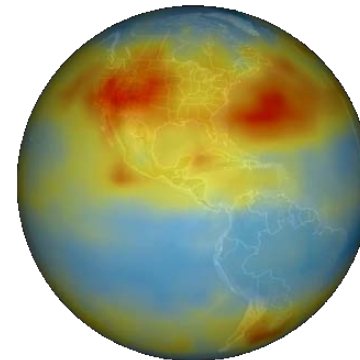
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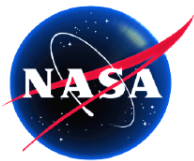
Atmospheric Infrared Sounder

## 7.5 - Years of AIRS Mid-Trop CO<sub>2</sub>

### What have we Observed/Learned?

1. CO<sub>2</sub> is NOT Horizontally Well Mixed in the Trop.
  - Driven by Weather Patterns (Jet Stream)
2. Complexity of the Southern Hemisphere Carbon Cycle
  - Calls for Expanded Validation Efforts and Analysis





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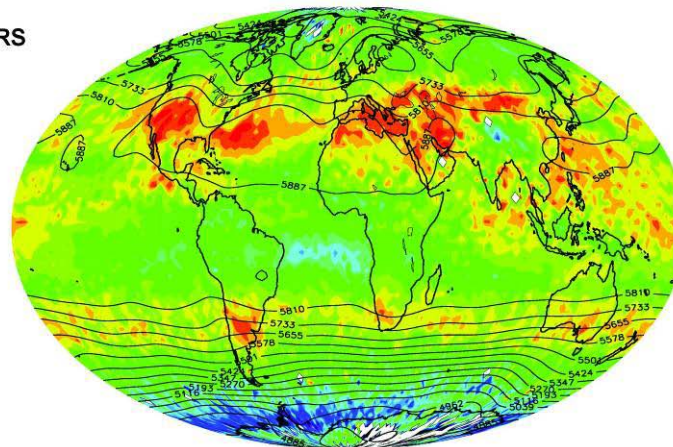
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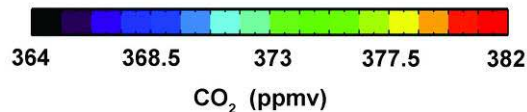
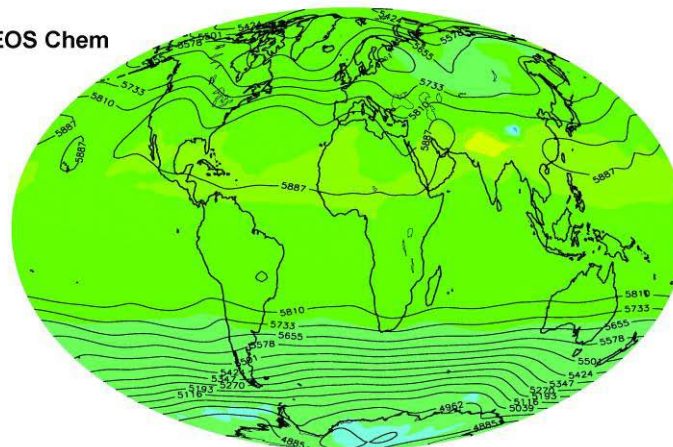
# AIRS CO<sub>2</sub> Compared to Models

**Current Models of  
Global Distribution  
of CO<sub>2</sub> do not  
capture observed  
spatial and temporal  
variability**

AIRS



GEOS Chem



Chahine, M. T., L. Chen, P. Dimotakis, X. Jiang, Q. Li, E. T. Olsen, T. Pagano, J. Randerson, and Y. L. Yung (2008),  
Satellite remote sounding of mid-tropospheric CO<sub>2</sub>,  
**Geophys. Res. Lett.**, **35**, L17807,  
[doi:10.1029/2008GL035022](https://doi.org/10.1029/2008GL035022).