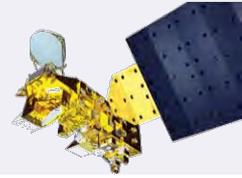


# AIRS V6 CO<sub>2</sub> Interim Product Testing and Plans for Future Development

**Edward Olsen, Stephen Licata**  
Jet Propulsion Laboratory, California Institute of Technology

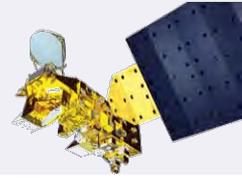
**NASA Sounder Science Team Meeting**  
**30 Sep - 2 Oct 2014**

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US Government sponsorship acknowledged*



- **Released V5 CO2 Product**
  - 2002 – 2010 ingest AIRS/AMSU Level 2 product
  - 2011 – present ingest AIRS-Only Level 2 product
- **Interim Product Testing (V6 L2 product ingest)**
  - **Comparison of V6R107, V6R108 and V6 for 1 January 2007**
    - SARTA V107 – uses fixed “at launch” coefficients
    - SARTA V108 – uses fixed coefficients derived after 28 Oct 2003 CME forced Aqua shutdown and the subsequent AIRS recovery cool down
    - V6 – uses interpolated coefficients incorporating scan-dependent Doppler shifts and orbit-dependent module shifts
  - **Profile Analysis Tool for Optimal Channel Selection**
    - Ingests models and AIRS L2 products
    - Computes 100-layer profiles of Jacobians, Contribution Functions and Weighting Functions for all AIRS channels using any of the 3 RTAs
  - **V6R108 Product Testing**
    - Zonal comparison of V6R108 and V5 product to collocated airborne in situ measurements
- **Plans for Future Development**
- **Summary**

# Current Released AIRS CO2 Products (V5 AIRS-Only vs V5 AIRS/AMSU)



**Shift from AIRS/AMSU to AIRS-Only**  
**V5 CO2 based on AIRS/AMSU radiances**  
 Sept 2002 through Dec 2010  
**V5 CO2 based on AIRS-Only radiances**  
 Jan 2011 through current date  
 (By mid-year 2011 the progressive degradation of AMSU channel 5 reached the point that CO2 product yield was noticeably impacted)

Left Column:

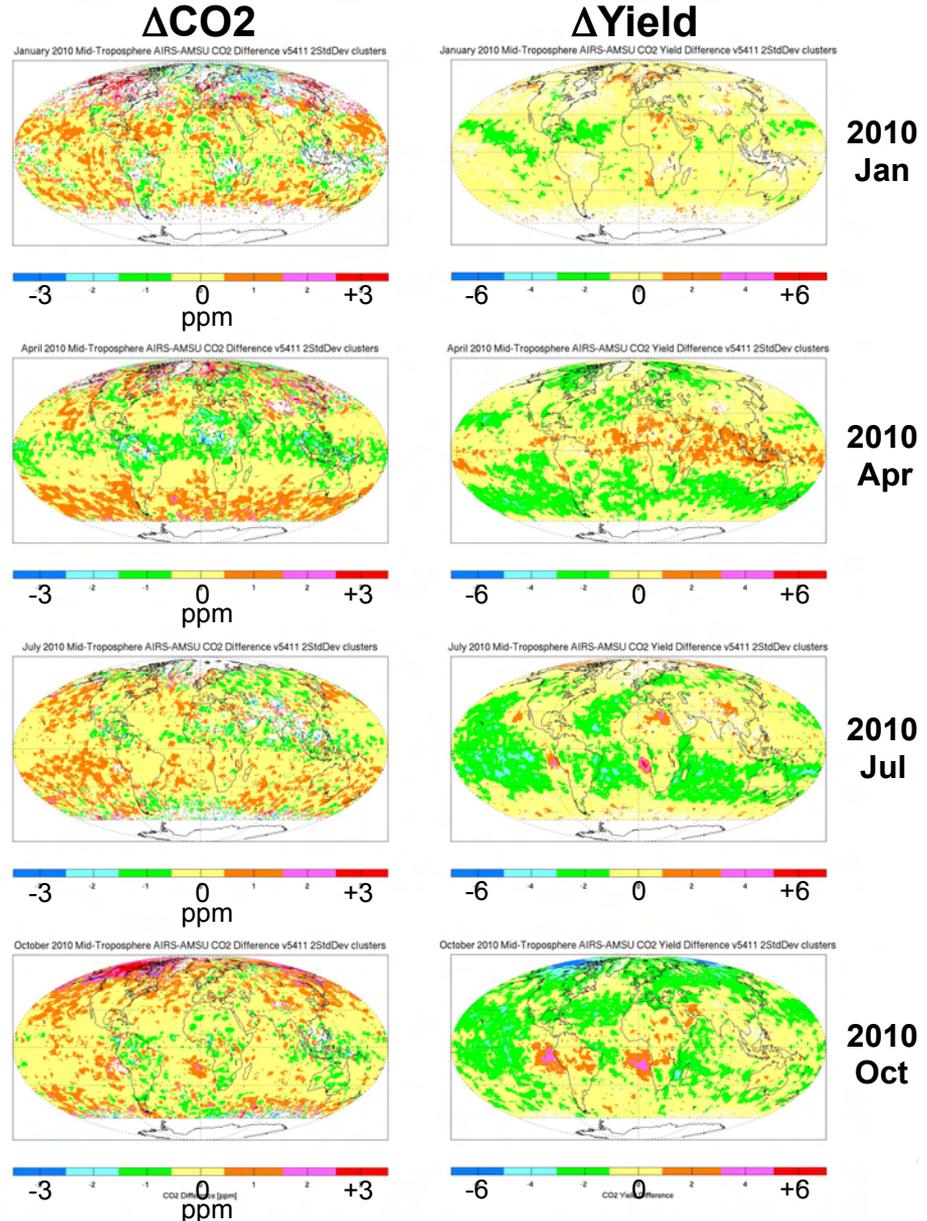
Retrieved CO2 difference  
 (AIRS\_Only – AIRS\_AMSU)  
 in 1°x1° grid smoothed to 5°x5°

- Differences are small except at the highest northern latitudes

Right Column:

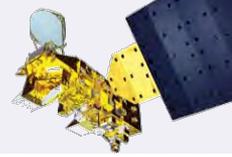
CO2 retrieval yield difference  
 (AIRS\_Only – AIRS\_AMSU)  
 In 1°x1° grid smoothed to 5°x5°

- Increased yield for AIRS\_Only in areas dominated by low stratus (off West coasts of North & South America and Africa) indicates that additional cloud filtering is advisable for the CO2 retrieval algorithm when operating in AIRS\_Only mode

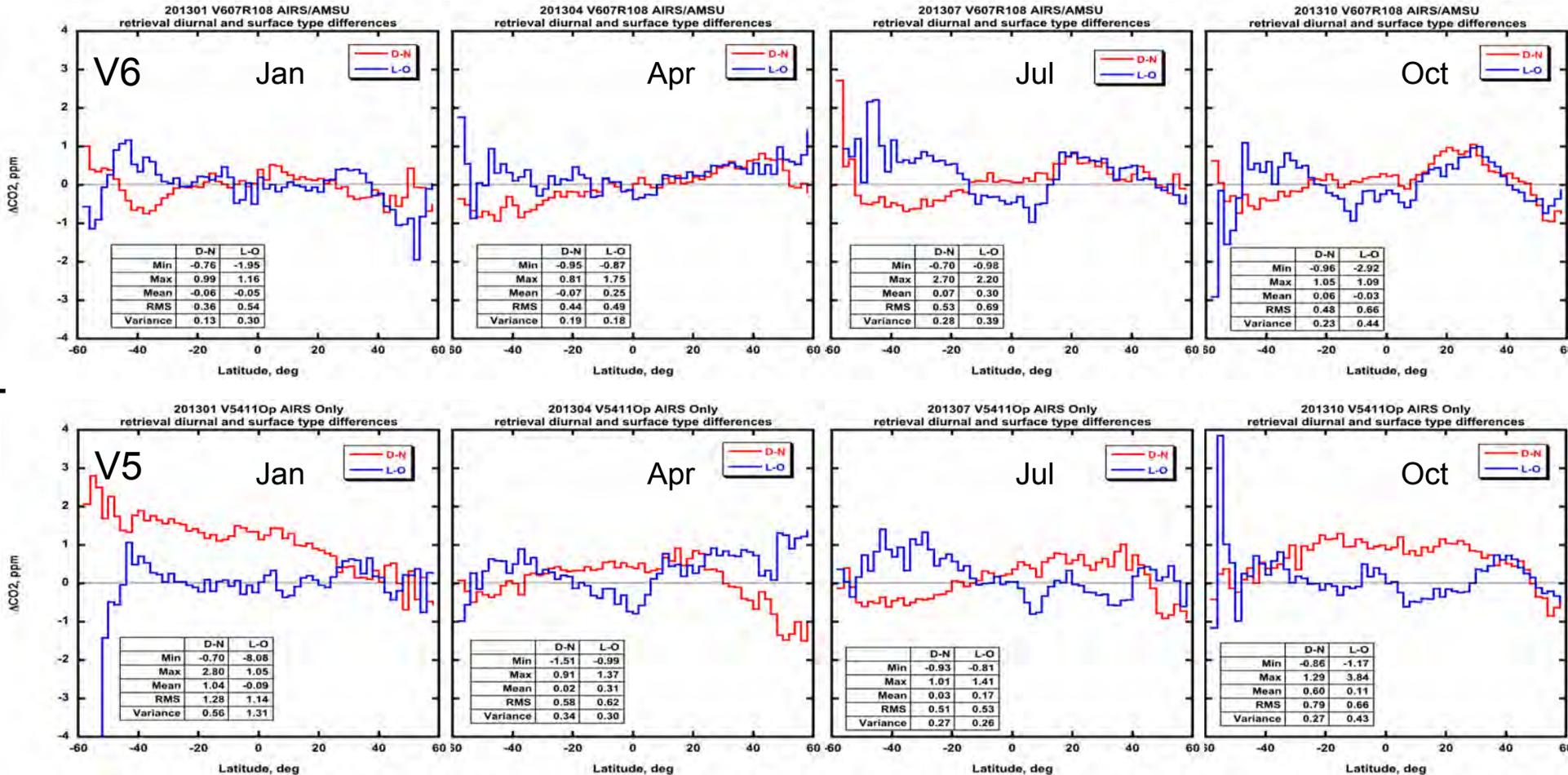




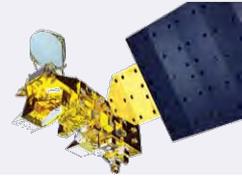
# V6R108 vs V5 Retrieved CO2 Zonal Variation



## 2013 Monthly Average Diurnal and Land vs Ocean

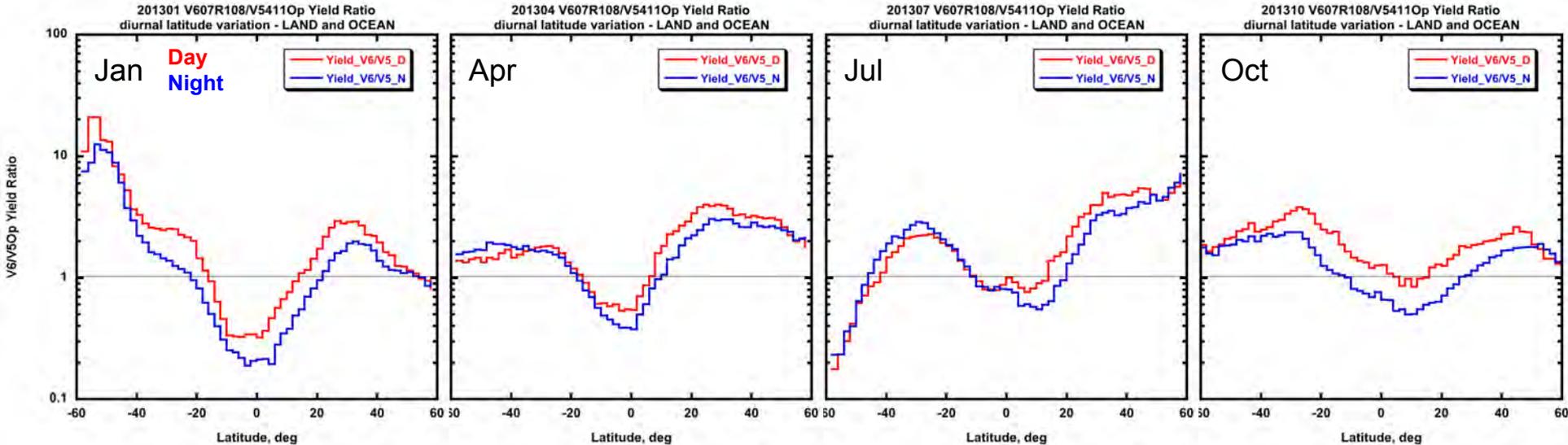


- Compared to V5 (AIRS-Only) Operational Product, V6R108 mid-trop product exhibits:
  - Reduced variation with latitude
  - Smaller diurnal contrast
  - Smaller contrast between land and ocean



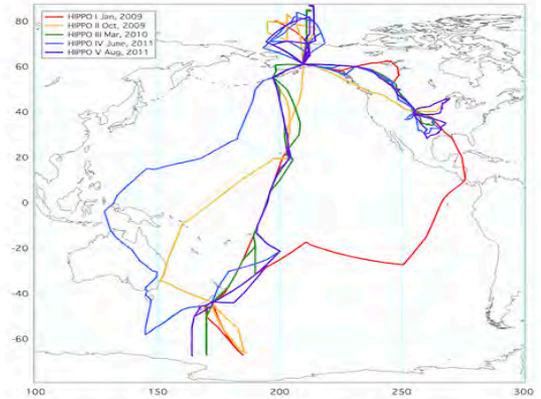
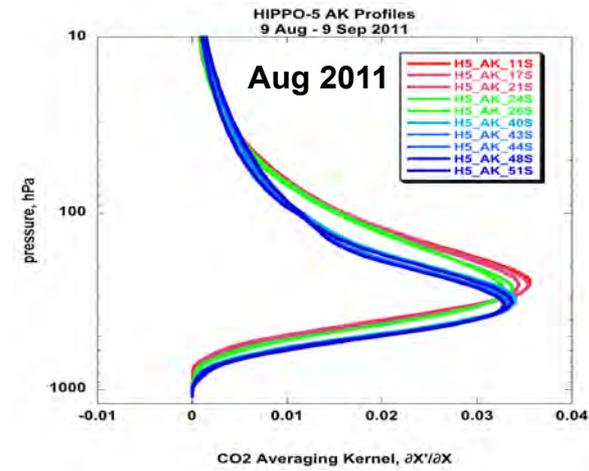
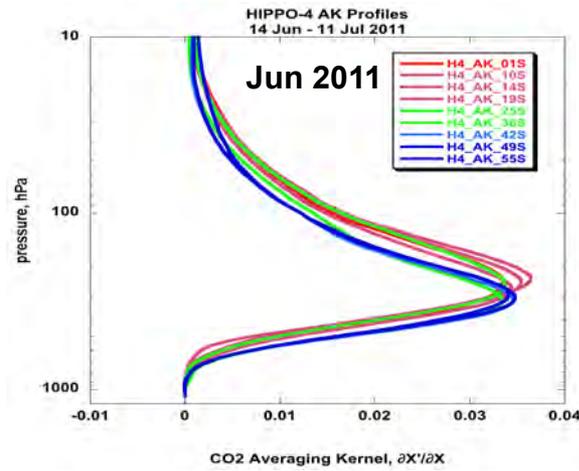
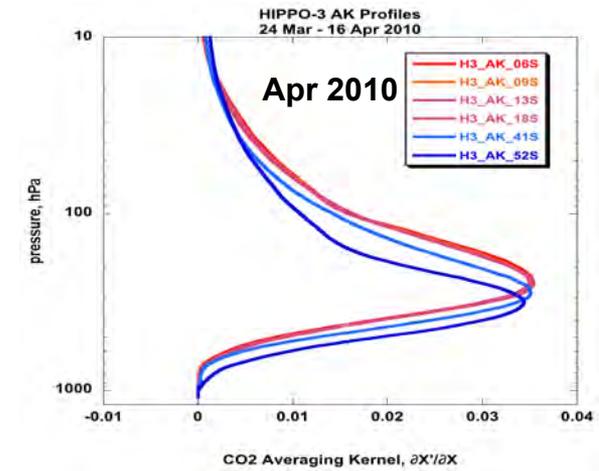
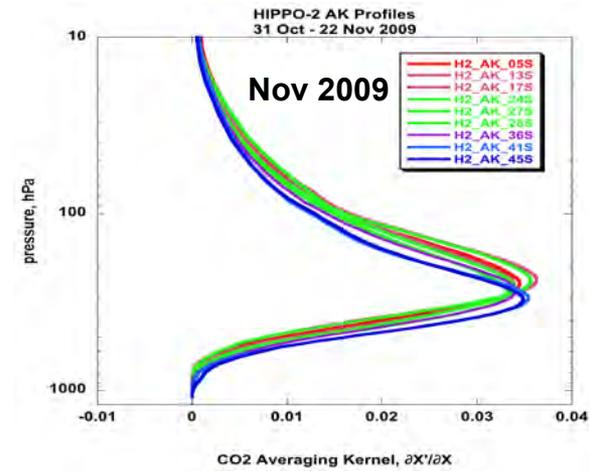
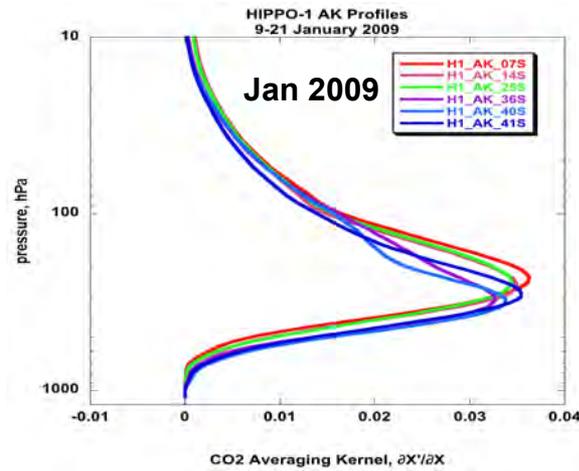
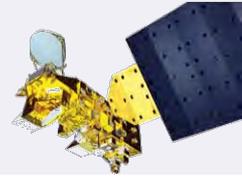
## 2013 Monthly Average Diurnal Yield Combined Land and Ocean

### RATIO of V6R108 Yield to V5 Yield



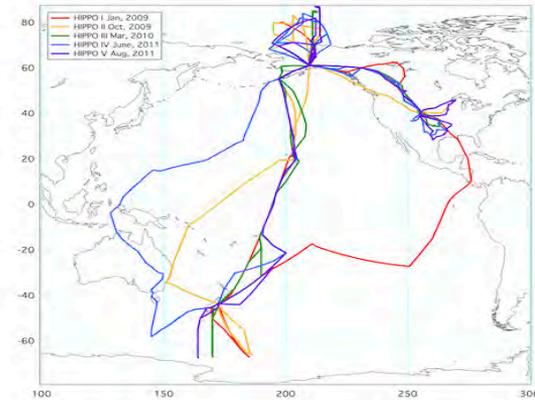
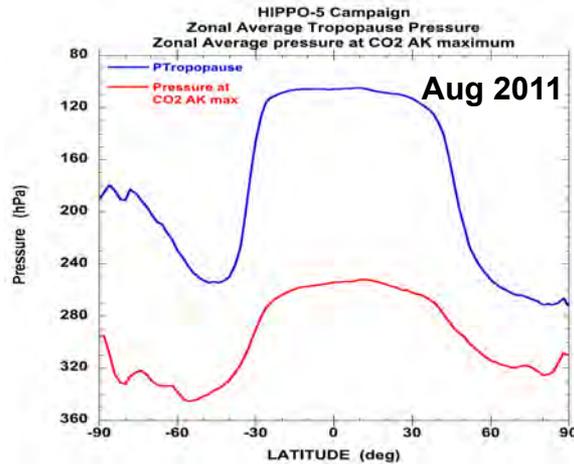
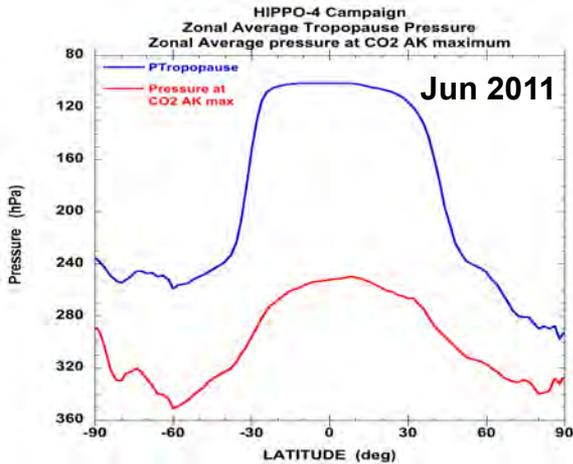
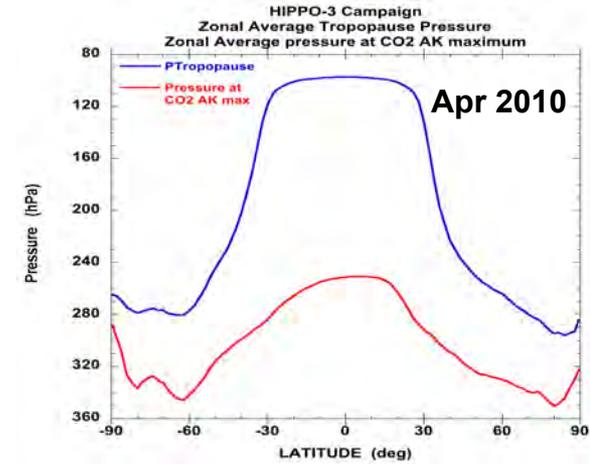
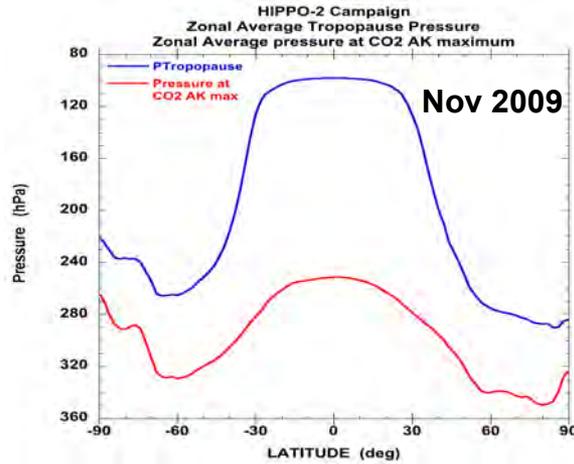
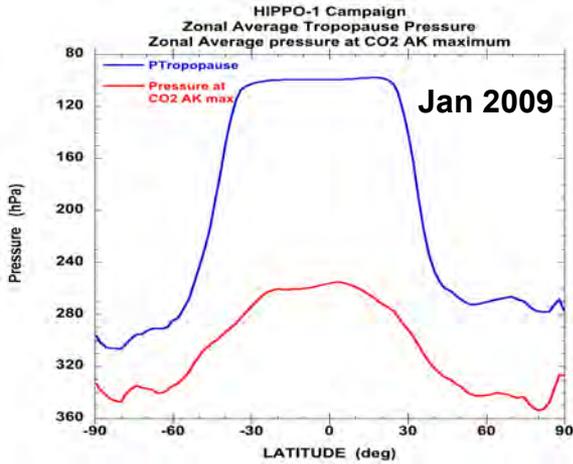
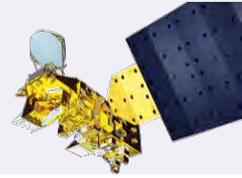
- V6R108 combined land/ocean yield is greater than that of V5 AIRS-Only, except in the tropics**
  - High altitude (~300 hPa) thick clouds predominate in the tropics
  - V5 AIRS-Only has excessive yield compared to V5 AIRS/AMSU in areas where low stratus predominates (low mid-lats, west of North and South America, and Africa)
- Daytime V6R108 yield enhancement over V5 generally greater than at nighttime**

# AIRS CO<sub>2</sub> Averaging Kernels in SH During HIPPO Campaigns (2009-2011)



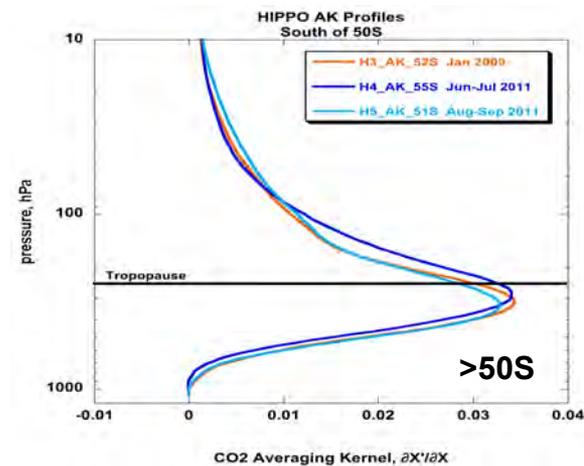
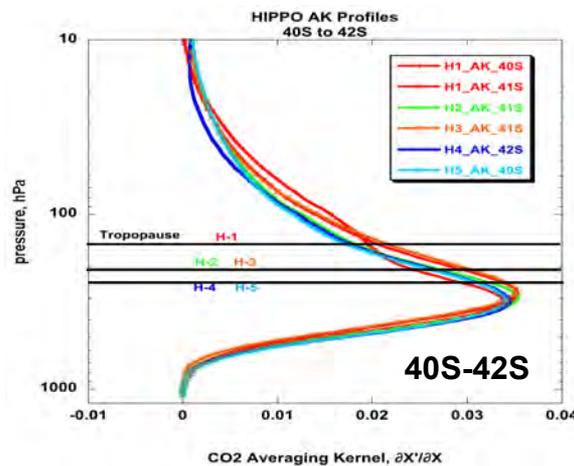
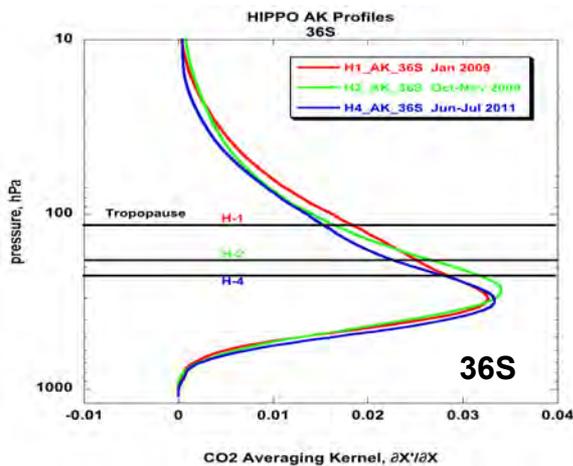
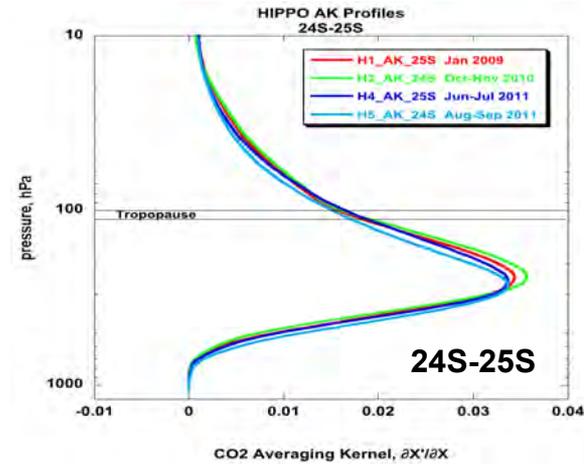
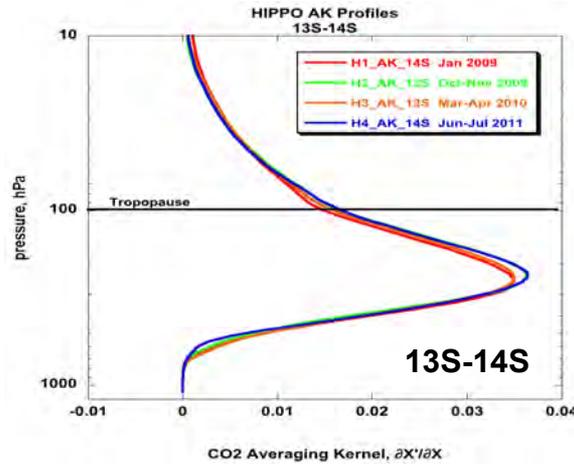
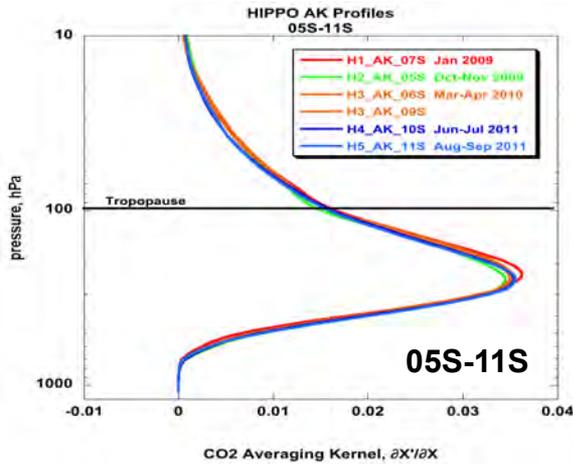
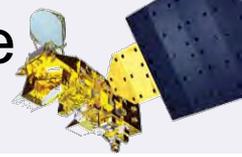
- The 5 HIPPO campaigns flew roughly equivalent latitude ranges over the mid-Pacific, but at different seasons
- AIRS AK profiles hardly change location in column or magnitude with season north of 60S
  - The shape of the AIRS AK profiles and location of peak sensitivity in column do change with latitude 6

# V5 AIRS/AMSU CO<sub>2</sub> AK and Tropopause During Months of HIPPO Campaigns



- On the other hand, the pressure at which the tropopause occurs changes with both latitude and season
- AIRS AK peak sensitivity is well separated from the tropopause in the tropics
  - At high latitudes, the separation is much less and is a strong function of season

# AIRS CO<sub>2</sub> Averaging Kernels and Tropopause by Latitude in SH During HIPPO Campaigns



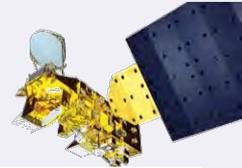
Validating collocated AIRS retrieved CO<sub>2</sub> with HIPPO measured CO<sub>2</sub> profiles is thus complicated because:

- AIRS AK tails extend well above the highest altitude of HIPPO in situ measurements
- Tropopause shifts closer to pressure of AK maximum at higher latitudes
  - More so in the SH winter time at the mid-latitudes
- Tropopause pressure is very close to that of AK peak for  $|\text{lat}| > 45^\circ$

Thus measured profile must be augmented with model data above highest altitude attained for accurate comparison

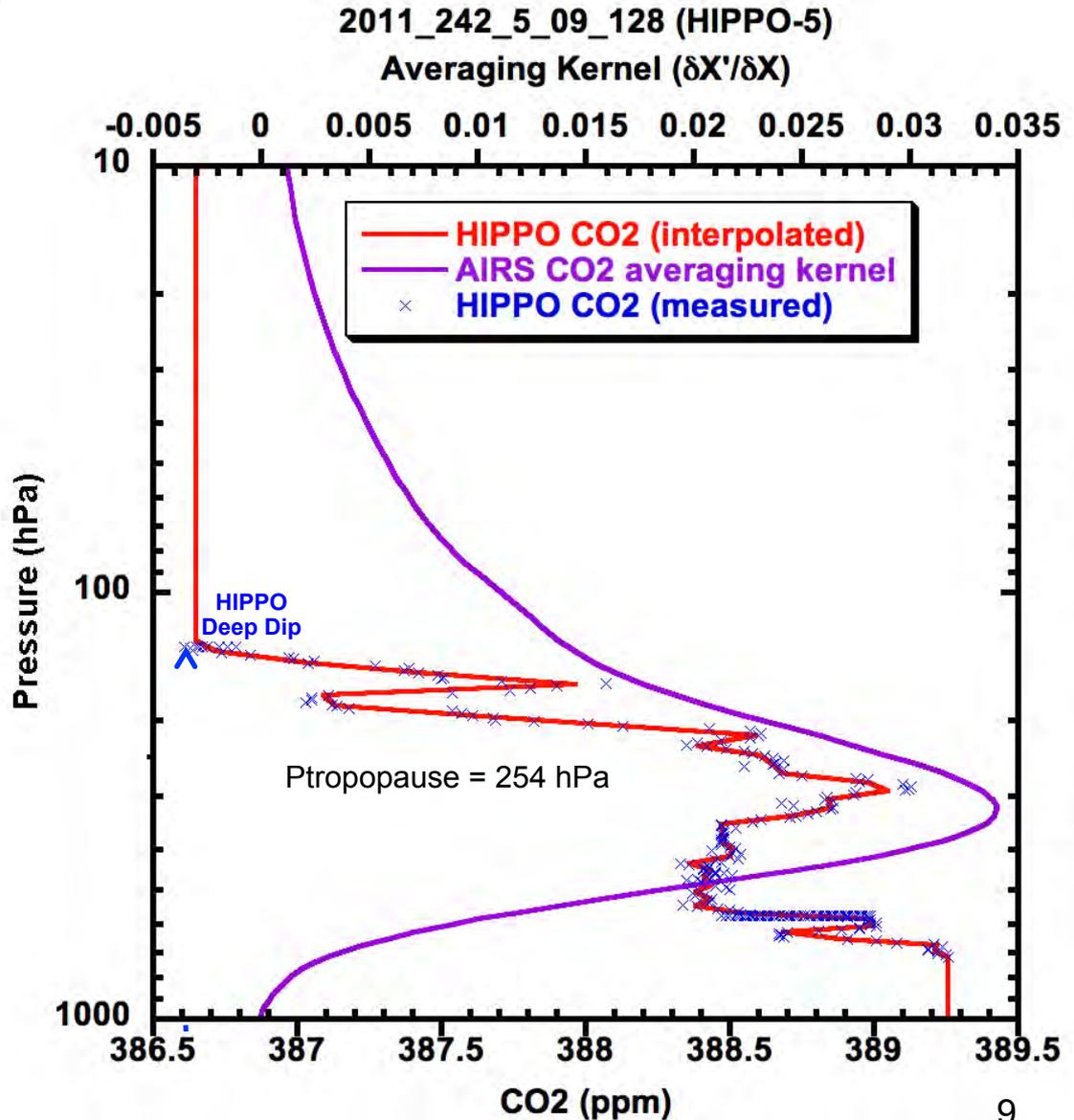
# HIPPO Profile and AIRS Averaging Kernel

(simple extension into high altitude tail)

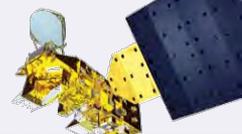


## Example

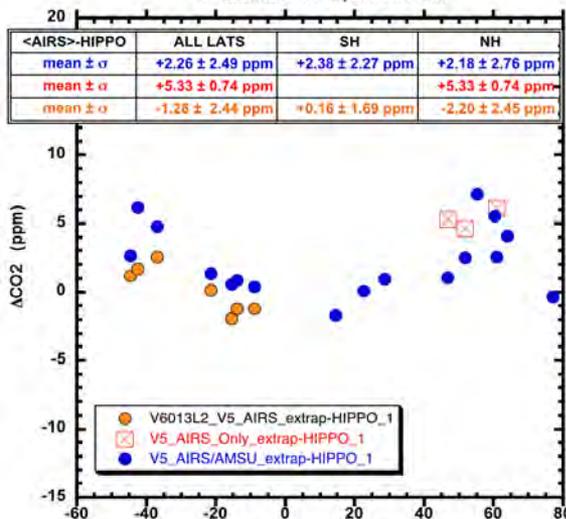
- Interpolate HIPPO measurements over range of aircraft altitude to AIRS support pressure levels
- Fill profile above highest altitude point
- Fill profile below lowest altitude point
- Convolve profile with AIRS sensitivity function to arrive at a value to compare to collocated AIRS retrieved value
- **Extension of HIPPO “Deep Dip” profile at high altitude results in a calculation overestimate for HIPPO comparison of  $\leq 3$  ppm depending upon season and latitude**
- Developing realistic profile fill including stratospheric fall-off using model forecast (MACC-II)



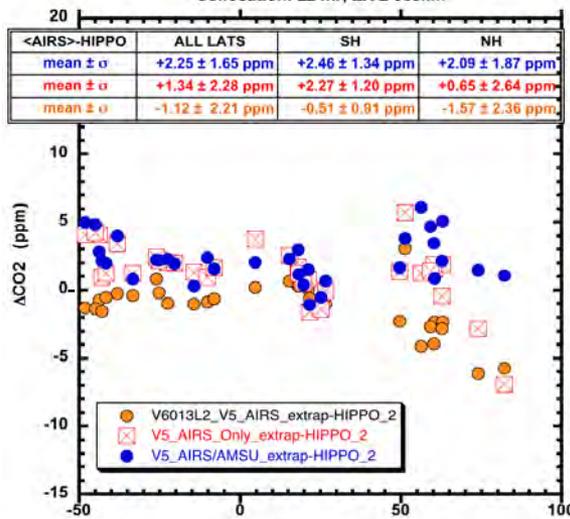
# V6R108 AIRS and V5 AIRS vs HIPPO



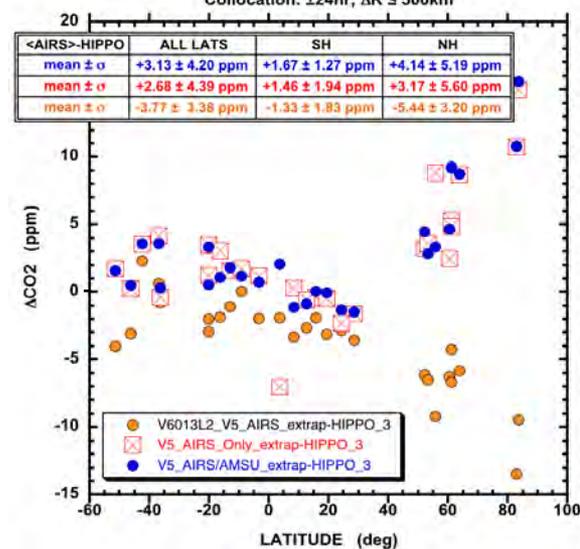
V5 AIRS/AMSU - HIPPO-1  
V5 AIRS-Only - HIPPO-1  
V6013L2\_V5\_AIRS/AMSU - HIPPO-1  
9 Jan - 22 Jan, 2009  
Collocation:  $\pm 24$ hr;  $\Delta R \leq 500$ km



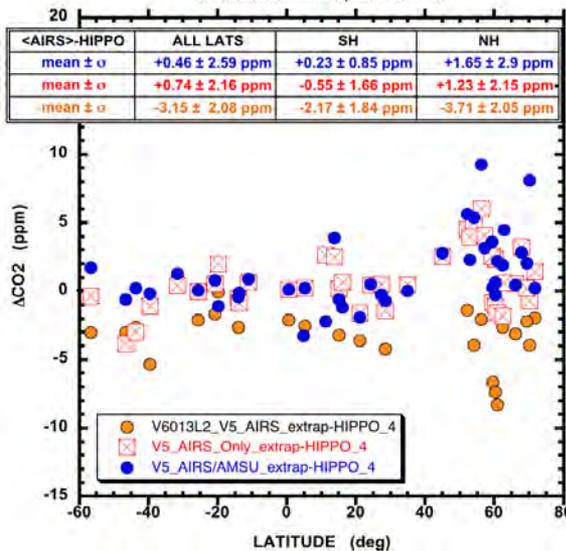
V5 AIRS/AMSU - HIPPO-2  
V5 AIRS-Only - HIPPO-2  
V6013L2\_V5\_AIRS/AMSU - HIPPO-2  
30 Oct - 22 Nov, 2009  
Collocation:  $\pm 24$ hr;  $\Delta R \leq 500$ km



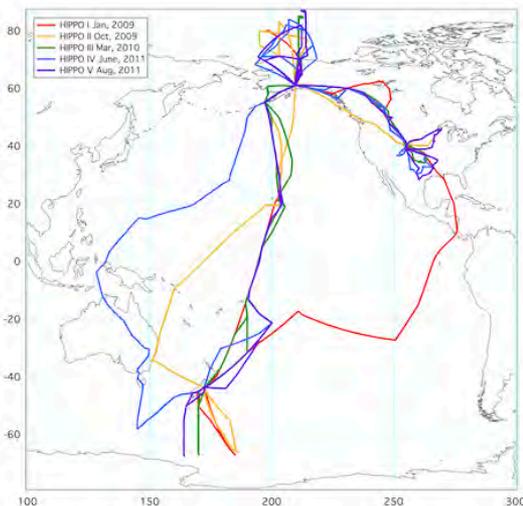
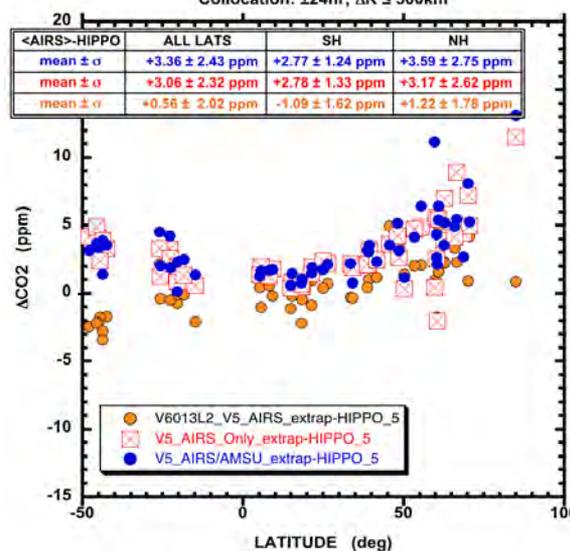
V5 AIRS/AMSU - HIPPO-3  
V5 AIRS-Only - HIPPO-3  
V6013L2\_V5\_AIRS/AMSU - HIPPO-3  
23 Mar - 16 Apr, 2010  
Collocation:  $\pm 24$ hr;  $\Delta R \leq 500$ km

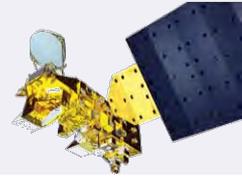


V5 AIRS/AMSU - HIPPO-4  
V5 AIRS-Only - HIPPO-4  
V6013L2\_V5\_AIRS/AMSU - HIPPO-4  
13 Jun - 30 Jun, 2011  
Collocation:  $\pm 24$ hr;  $\Delta R \leq 500$ km



V5 AIRS/AMSU - HIPPO-5  
V5 AIRS-Only - HIPPO-5  
V6013L2\_V5\_AIRS/AMSU - HIPPO-5  
8 Aug - 10 Sept, 2011  
Collocation:  $\pm 24$ hr;  $\Delta R \leq 500$ km

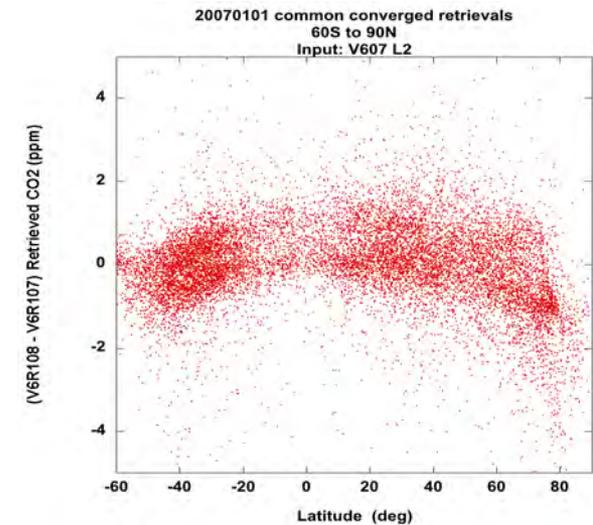
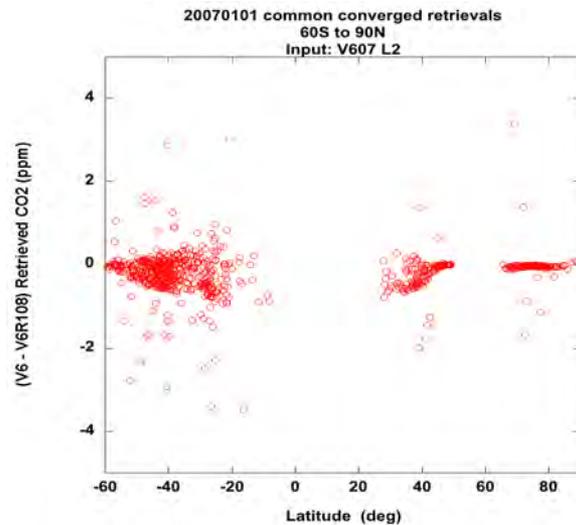
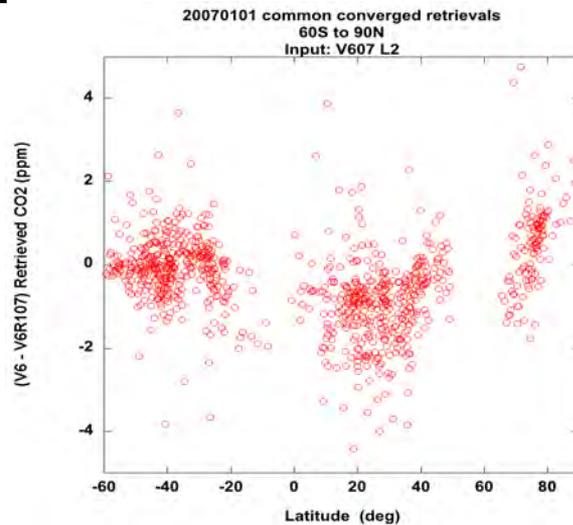
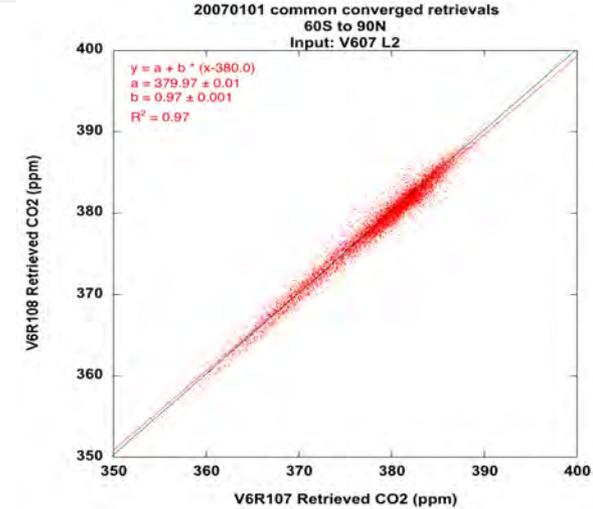
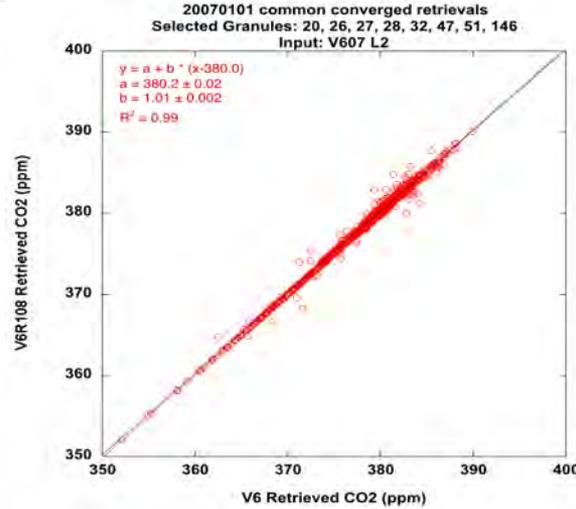
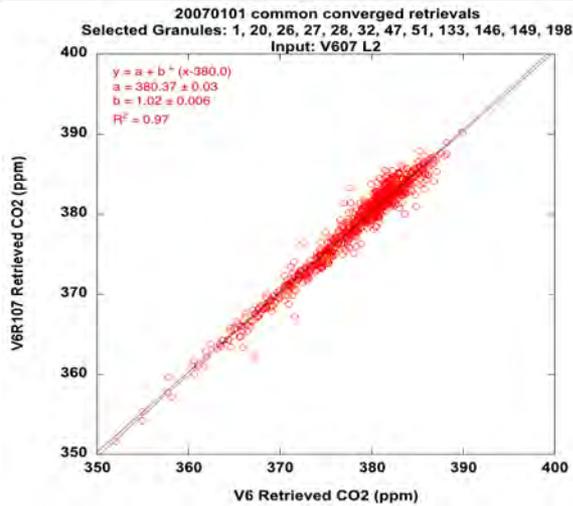
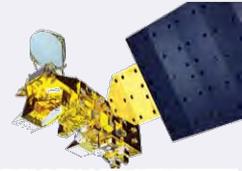




- **Operationalize V6 mid-trop PGE and Release**
  - Top priority is to reduce execution time using SARTA V6
    - V6 execution time
      - ~ 5 minutes/granule using SARTA V107 and SARTA V108 (same as V5 execution time)
      - ~2.5 hours/granule using SARTA V6
        - » Due to reinterpolation of all coefficients for 2378 channels for each call to SARTA
  - Test V6 SARTA operation against V108 SARTA operation
    - Seasonal analysis over globe (Jan/Apr/Jul/Aug)
    - Validate against collocated HIPPO measurements
  - Document and release to operational team
- **Optimal channel selection for sensitivity lower in troposphere**
  - Select channel sets based on Jacobians (for T,q,O3, CO2)
  - Test and refine selection to quantify/minimize impact of surface temperature bias
- **Test retrievals lower in the troposphere**
  - Validate against collocated HIPPO/CARIBIC measurements
    - Extend in situ profiles with MACC-II model data
  - Quantify impact of biased CO2 prior
  - Adjust channel sets and QA as found necessary

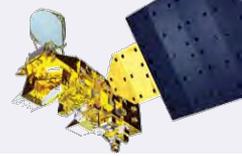
# V6 vs V6R107 and V6R108 CO<sub>2</sub>

## 1 January 2007



- V6R107 RTA coefficients are fixed “at launch” set, valid before the 29 Oct 2003 Coronal Mass Ejection forced Aqua shutdown
- V6R108 RTA coefficients are the fixed post-CME set, valid after instrument temperature stabilized
- V6R108 is more consistent with the full V6 results, but does not include Doppler and orbital variations of coefficients

# Profile Analysis Tool



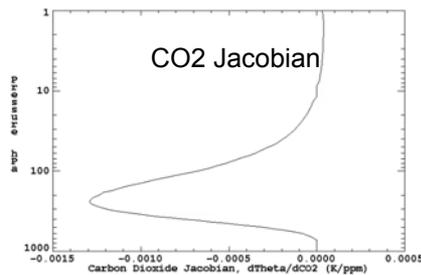
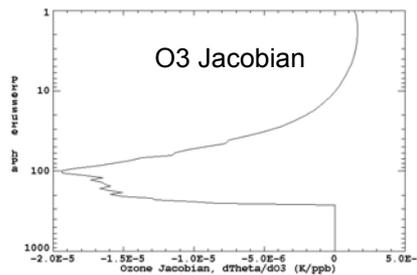
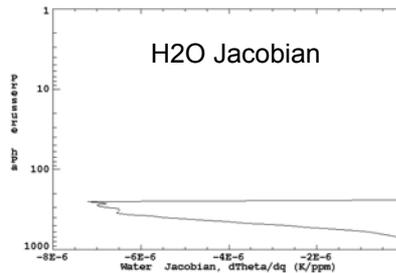
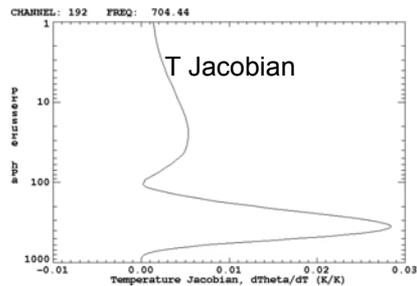
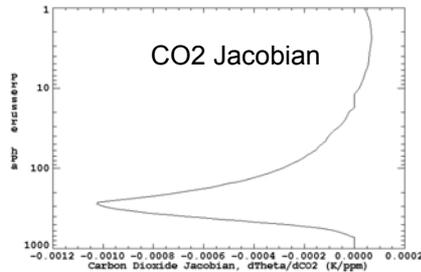
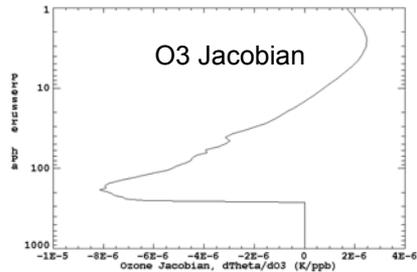
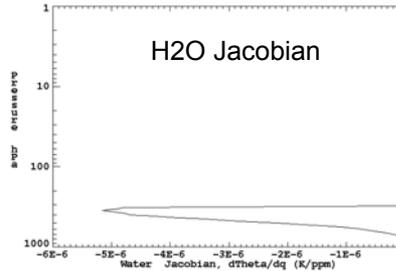
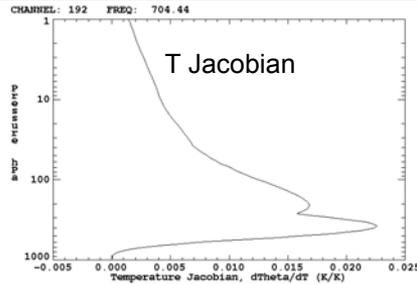
## Profile Analysis Tool

### Input:

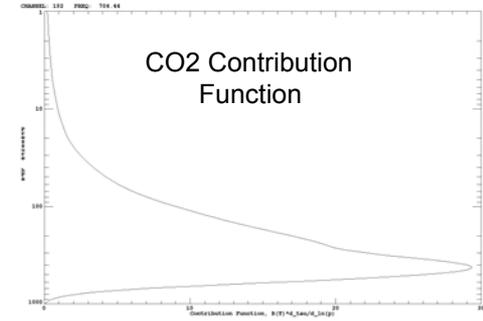
- Standard models
- AIRS L2 profiles

### Output for all AIRS channels:

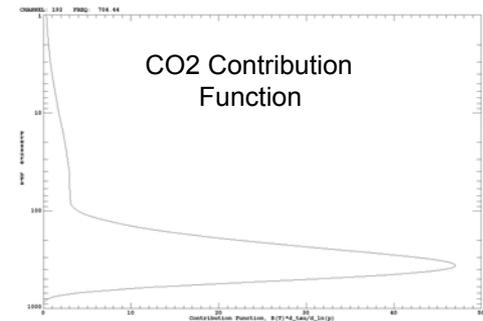
- Weighting Functions
- Contribution Functions
- Jacobians
- Fractions of TOA radiances
  - From surface
  - From troposphere
  - From stratosphere



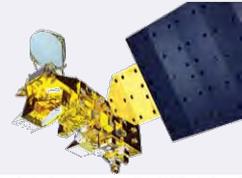
Polar



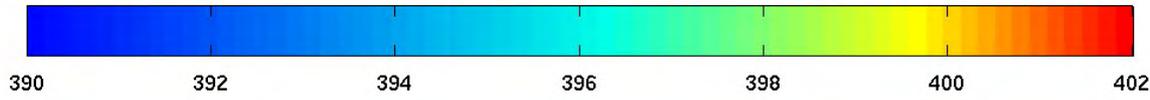
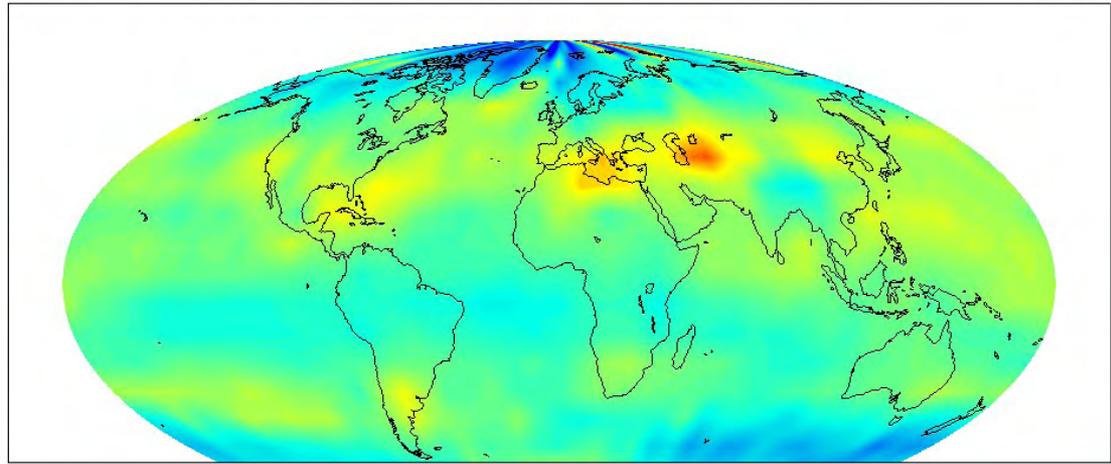
Tropical



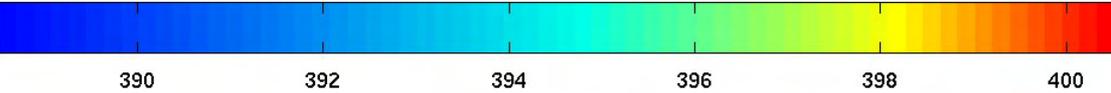
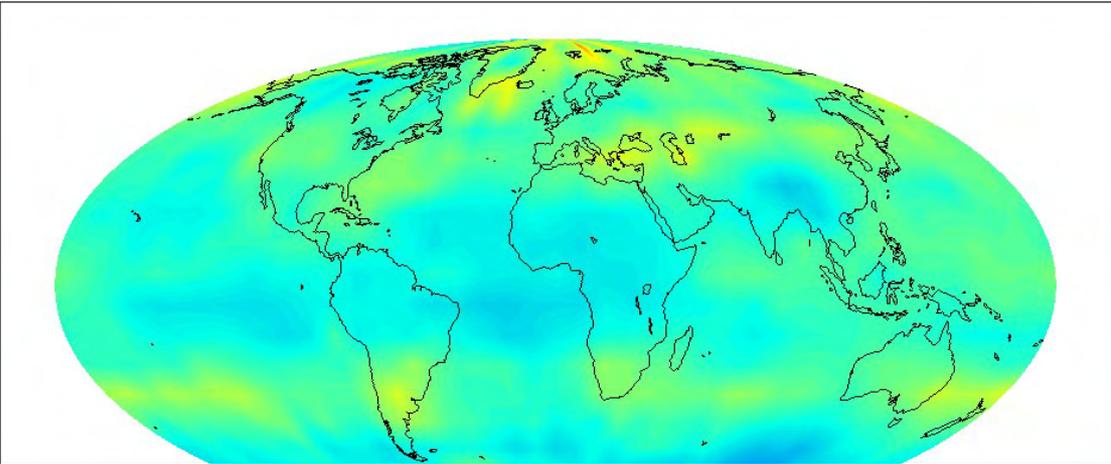
# AIRS V5 Global CO2 July/August 2014

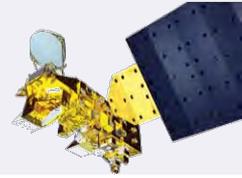


**July, 2014**



**August, 2014**

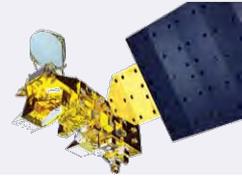




# Summary-1

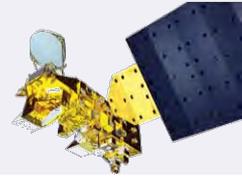
- **V5 AIRS-Only CO<sub>2</sub> product is current public release**
  - Retrieved CO<sub>2</sub> differences from V5 AIRS/AMSU small except at the highest northern latitudes
  - Yields differences small except in areas where extensive low stratus cloud cover is present
- **V6 code**
  - Code designed for rapid conversion to PGE
    - Execution options set via environmental variables
      - Channel lists, priors, SARTA version, QA filtering rules and thresholds
  - Capable of ingesting V5 and V6 AIRS L2 products
  - Capable of using three RTA versions (V107, V108 or V6)
  - Supports multiple channel sets for separate partial column retrievals
  - Plan to operationalize V6.0 Retrieval when V6 RTA speedup task and final tests are completed
    - Seasonal analysis of global yield and retrieval (Jan/Apr/Jul/Oct)
    - Validation against HIPPO
    - Document and release

# Summary-2



- **V6 retrieval testing**
  - **V6 execution in V5 mode (ingest V5 L2 and RTA V107) yields identical result as the V5 Operational PGE**
    - End-to-end validation of V6 interim processing code
  - **V6 execution time**
    - ~ 5 minutes/granule if using SARTA V107 and SARTA V108 (same as V5 execution time)
    - ~2.5 hours/granule if using SARTA V6
      - Due to necessary reinterpolation of large coefficient arrays for all 2378 channels for each call to SARTA
        - » Currently testing methods to bring execution time down to that for SARTA V108
  - **V6 externalized near surface partial layer temperature profile tweak due to intrusion of topography**
    - Yields result identical to that leaving it active in RTA for current channel set
    - Required for iterative solution using channels sensitive lower in the atmospheric column
  - **V6 retrievals using same channel set and RTA V108 are consistent with V5 for  $|\text{lat}| < 50^\circ$** 
    - V6 does not require V5 radiance bias correction
  - **V6 Yield**
    - Enhanced over V5 everywhere and for all seasons except in tropics
      - Possibly due to V5 AIRS-Only yield being artificially high in areas where low stratus predominates
    - Daytime yield enhancement usually larger than that at nighttime everywhere and for all seasons
    - Land scene yield enhancement generally larger than ocean scene enhancement, everywhere and for all seasons
  - **V6 Retrieved CO<sub>2</sub> diurnal variation**
    - Over ocean is smaller than V5; constant to within 0.5 ppm over latitude range  $|\text{lat}| < 60^\circ$
    - Over land shows more variation than V5 with latitude, changing with season
      - Greatest amplitudes are in the mid-lat of the summer hemisphere
        - » Convection, or RTA108 (i.e., w/o Doppler and variable module offsets in RTA V6) effect?
    - Nighttime land/ contrast lower than V5
    - Daytime land/ocean contrast higher than V5 and shows variation with latitude

# Summary-3



- **V6 retrieval testing (continued)**
  - **Validating against in situ measured profiles**
    - **HIPPO Profiles**
      - Initial validation completed
      - Future extension of profiles with MACC-II model forecast
    - **CARABIC Profiles**
      - Data in hand
      - Create readers to allow use with current analysis codes
    - **Plan is to have a standard set of in situ measurements for test and validation of incremental changes to V6 CO<sub>2</sub> retrieval**
      - Quantify impact of biased CO<sub>2</sub> prior