V6 CO2 Retrieval Development

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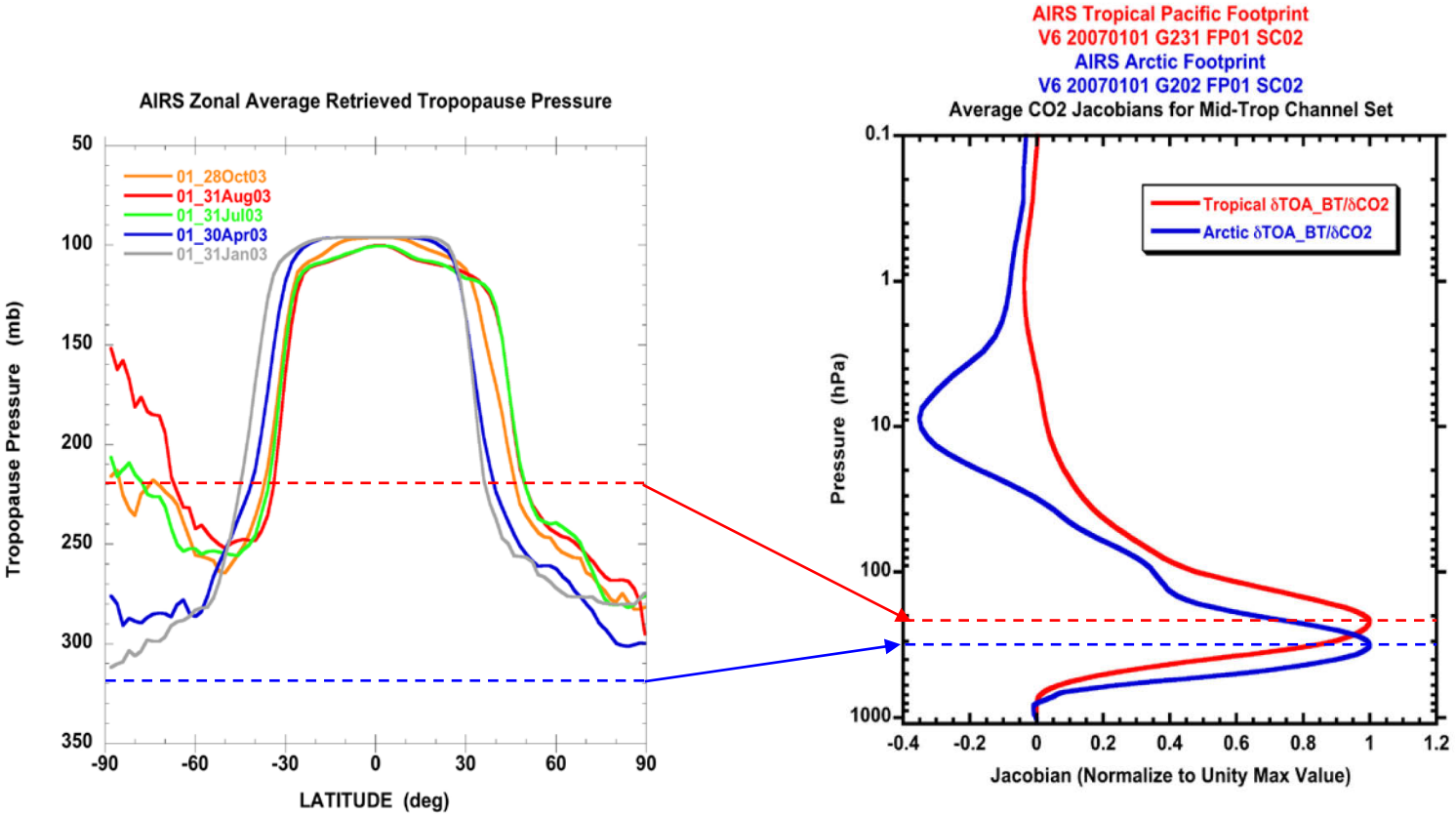
Activities – V6 CO2 Development

- **Channel selection**
  - Developed tools to support optimization of channel subsets to better constrain the partial columns of the atmosphere which they represent
    - Common library of software modules shared with optimized retrieval code
    - Ingest model atmospheres and AIRS V5 and V6 PGE output
    - Compute channel-by-channel profiles of weighting functions, contribution functions and Jacobians
    - Sensitivity analysis to optimize channel sets continues in collaborative effort with Paul Dimotakis, Zhijin Li and Ilana Gat
- **V6 PGE-compatible multi-layer unified CO2 retrieval code**
  - Developed a single post-processing CO2 retrieval PGE capable of retrieving CO2 in one or more partial columns of the atmosphere independently
    - Execution options chosen via environmental variables
      - Channel lists, priors, SARTA version, QA filtering rules and thresholds
    - Mid-troposphere and mid-stratosphere codes implemented
    - Future addition of lower-troposphere easily accommodated
    - Capable of ingesting V5 and V6 physical retrievals and L1B/L2 CC radiances
    - Can use SARTA V107, V108 or V6
  - V5/SARTA V107 mode output digitally identical to V5 Operational PGE output
- **V6 testing**
  - Currently using V6.0.2 AIRS L2 data for Jan/Apr/Jul/Oct 2003/2007/2011
  - Optimizing channel set selection/latitude weighting and QA filtering

Channel Selection Issues

(sensitivity analysis collaborators: Dimotakis, Li and Gat)

- **Sensitivity analysis reveals pressure layer of Jacobian peak of V5 VPD tropospheric CO2 channels is a function of latitude. In addition, the movement of the high latitude tropopause to lower altitudes in January/April increases fraction of TOA radiances in CO2 channels function contributed by stratosphere**
  - **Solution: modify channel set to shift sensitivity peak lower and minimize stratospheric tail structure; weight channels according to location of Jacobian peaks to maintain pressure level position in atmospheric column**



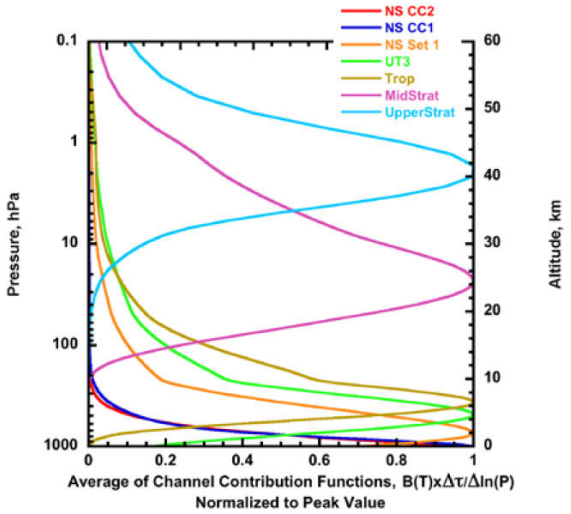
Channel Selection Analysis

(sensitivity analysis collaborators: Dimotakis, Li and Gat)

- **Channel Sets**
  - **Mid-Trop**
    - Jacobians of V5 operational channel set peaks higher in troposphere than contribution functions, hence connection to surface CO2 flux weaker than initially believed
    - Preliminary channel set resulting from Jacobian sensitivity analysis results in increased sensitivity to ΔCO2
    - Now optimizing set so Jacobian peaks occur lower in the troposphere and in the same pressure layer for all latitudes (requires latitude dependent channel weighting)
  - **Mid-Strat**
    - Jacobians of initial test set identified via contribution functions not well localized
    - Preliminary channel set based on Jacobian sensitivity analysis results in increased sensitivity to ΔCO2 that is more localized in atmospheric column
  - **Lower Trop**
    - Channels chosen using contribution functions exhibit Jacobians whose peaks occur higher in the troposphere than desired
    - To Do: identify and optimize channel set(s) to shift Jacobian peaks as near to the surface as feasible

Note:

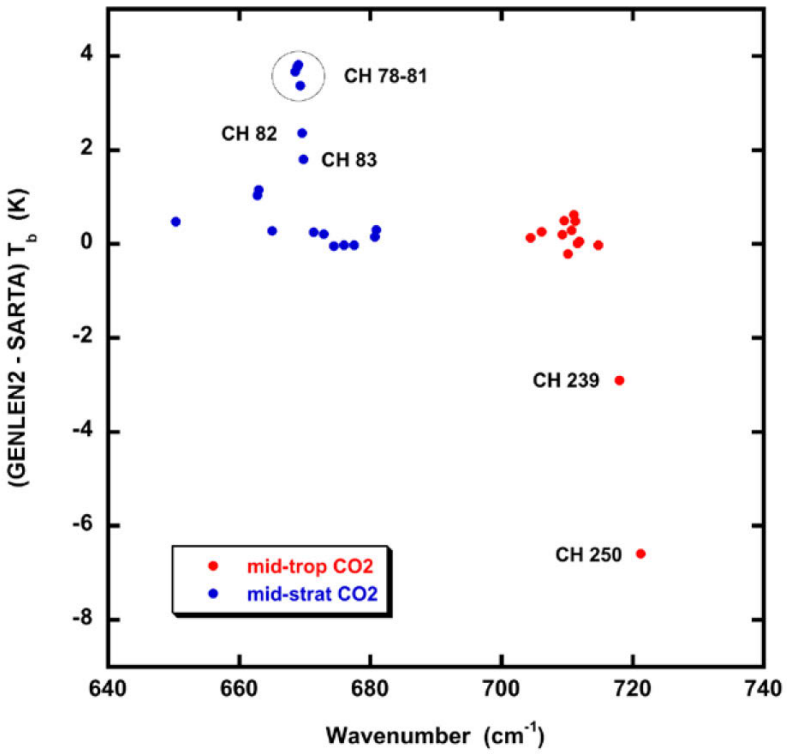
- VPD algorithm gives full weight to the measured radiances
  - Therefore channel contribution functions were employed as the channel selection criteria
  - VPD seeks to minimize the difference between an atmospheric state and the radiances
  - Averaging kernels/Jacobians provide ΔCO2 sensitivity information desired by customers studying surface flux
  - Therefore channel selection must primarily be carried out via Jacobian sensitivity analysis



Additional Channel Selection Issue

- SARTA and GENLN2 calculated TOA radiances for same atmospheric state are inconsistent for some channels
  - mid-trop CO2 retrieval channels:
    likely due to GENLN2 line mixing problem at the 721 cm^{-1} Q-branch
  - mid-strat CO2 retrieval channels:
    likely due to GENLN2 errors in the 670 cm^{-1} R-branch
- Additional line-by-line analysis to ensure no problematical channels are used for retrieval

channels used to retrieve CO2



RTA Selection - Analysis & Decision

- **RTA Selection**
  - **V6 CO2 retrieval code executes all SARTA versions: V107, V108 and V6**
    - **Operational V5 CO2 retrieval using V107 SARTA execution time = 5 min/granule/CPU**
    - **Optimized V6 CO2 retrieval using V108 SARTA execution time = 3 min/granule/CPU (this will be the delivered operational CO_2 RTA)**
    - **Optimized V6 CO2 retrieval using V6 SARTA execution time = 2.5 hr/granule/CPU (this will be revisited in future to develop a workaround)**
  - **Challenge of V6 SARTA**
    - **Dynamic recalculation for all 2378 channels, once for every profile passed to the V6 SARTA**
      - **Updates y-axis offset, due to dynamically changing Doppler shift and module baseline drift**
      - **Addition of channel-specific deltas from A/B weights table**
      - **Executed for every perturbation of T, q, O3, CO2 in each iteration step of VPD (300 to 500 times/cluster CO2 retrieval depending upon number of iterations required to converge)**
  - **Compromise choice: V108 SARTA**
    - **Forward calculated radiances differ from V6 by ≤ 1 %**
    - **Test results: CO2 retrievals differ from those which result using V6 SARTA by 0.1 ppm to 0.5 ppm**

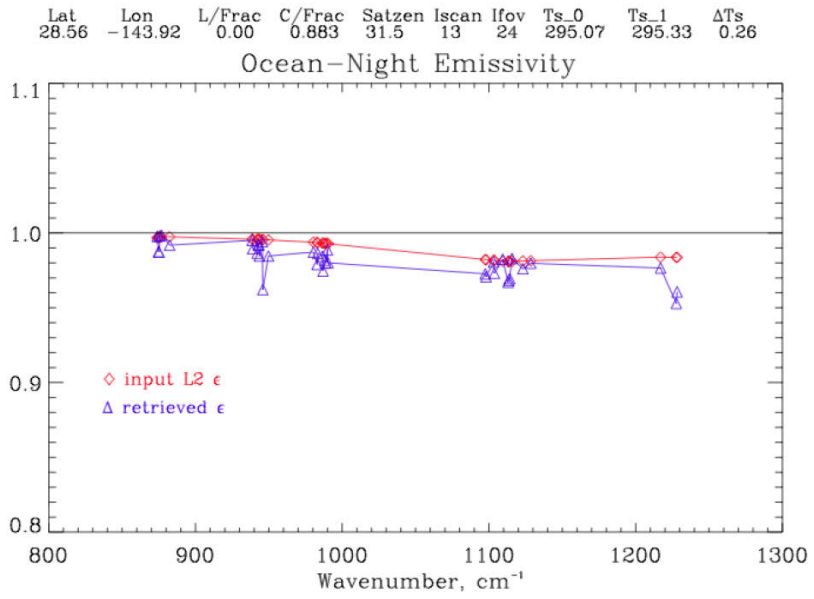
V6 CO2 Retrieval Status and Testing

- V5/SARTA V107 mode assimilating V5 L2 data
  - Compared against operational code retrievals at each step of restructuring/consolidation of PGE to ensure digitally identical output
- V6/SARTA V108 mode assimilating V6 L2 data
  - Supports calculation of Jacobians as well as of averaging kernels
  - Expanded QA for enhanced dynamic filtering and quality control
    - Uses expanded QA and error reporting provided in V6 L2 products
    - Extracts additional information from SARTA
      - Example: fraction of TOA radiance arising from surface, troposphere, stratosphere
  - Radiance bias correction applied in CO2 V5Op is unnecessary in V6 CO2 retrieval
    - Bias trend of L2 physical retrieval Tair against radiosondes present in V5 has been substantially mitigated in V6
  - Initial retrieval results assimilating V6.0.2 Level 2 data products
    - Error in QA filter implementation drastically reduced yield --- Oops!
    - V6 CO2 retrievals agree well with Matsueda and V5Op retrievals for $|lat| \leq 40^{\circ}$
      - Deviation at high northern latitude greater in Jan/Apr (-5 ppm to -10 ppm) than Jul/Oct (-2 ppm to -5 ppm)
      - CO2 discrepancy between V5Op and V6 at high northern latitude is under study
        - Currently rerunning with correct QA filter implementation to regain yield
        - Next: optimize channel set and install weighting as a function of latitude to minimize change in location of retrieved layer in the atmospheric column from equator to pole

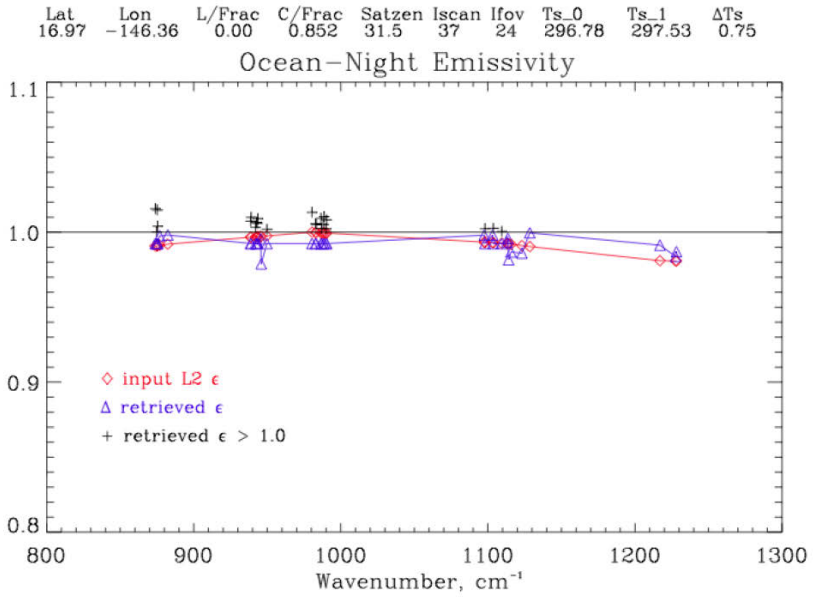
V6 VPD Surface Emissivity Retrieval Development

- **Accurate accounting of surface contribution required in the lower troposphere CO2 retrieval algorithm. V6 L2 surface emission better than that of V5, but its solution must be included in VPD**
  - **A module solving for the surface emissivity is being developed**

Some Retrievals are Successful



Some Retrievals are Problematical



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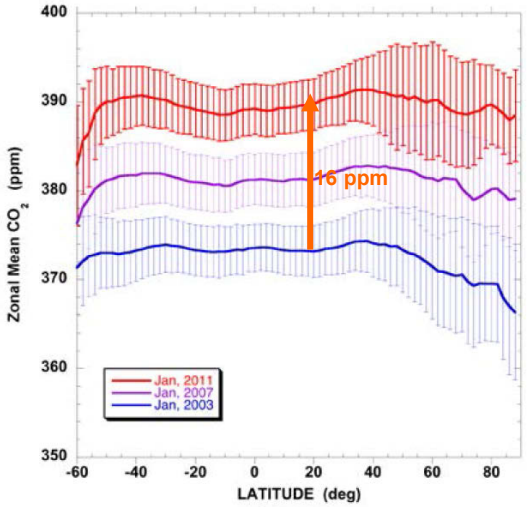
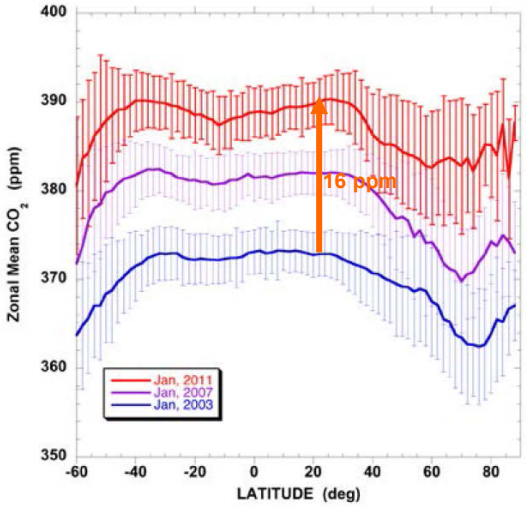
Atmospheric Infrared Sounder

January 2003/2007/2011
Zonal Average V5Op and V602 CO2 and Yield
(note: Global Average DCO2 2003->2011 = 16 ppm)

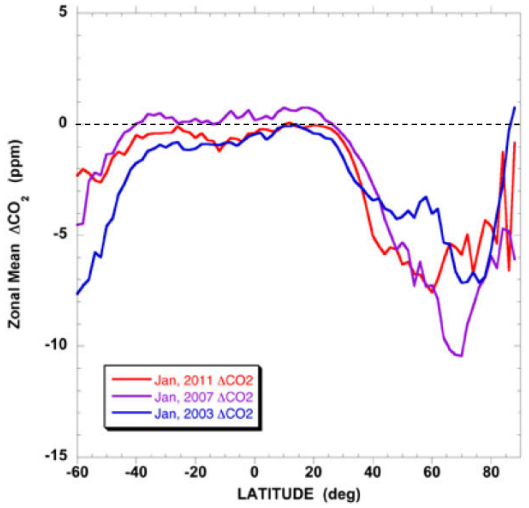
V5Op CO_2



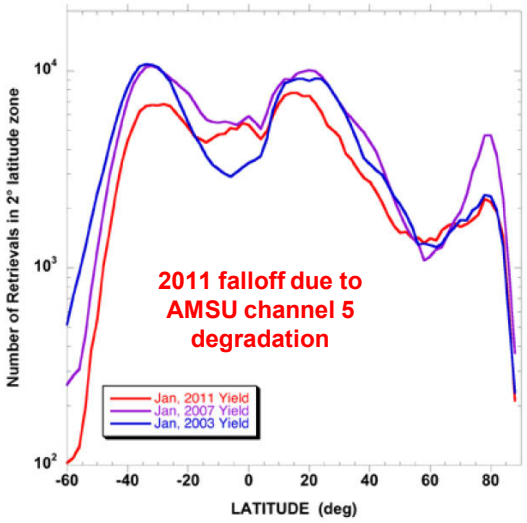
V602 CO_2



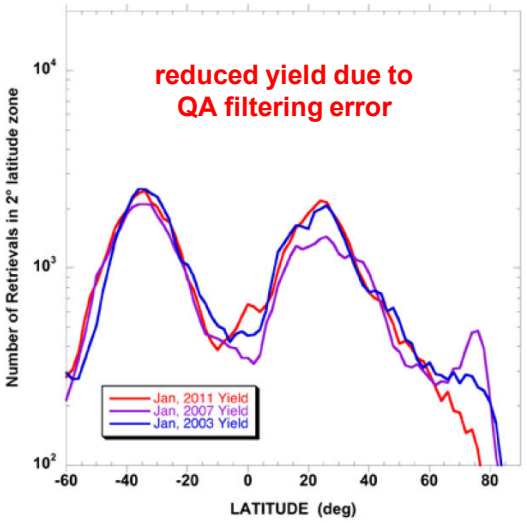
(V602-V5Op) CO_2



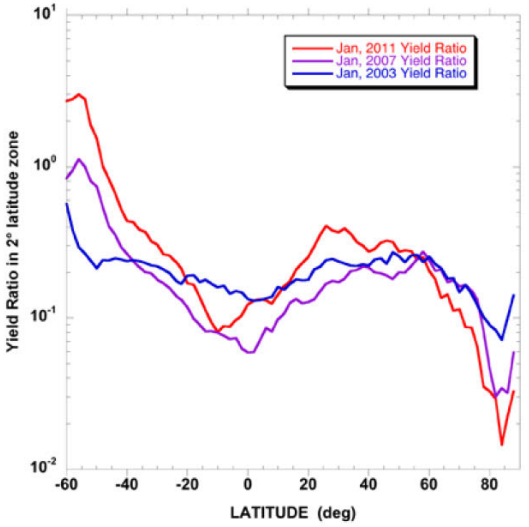
V5Op Yield



V602 Yield



(V602 Yield)/(V5Op Yield)



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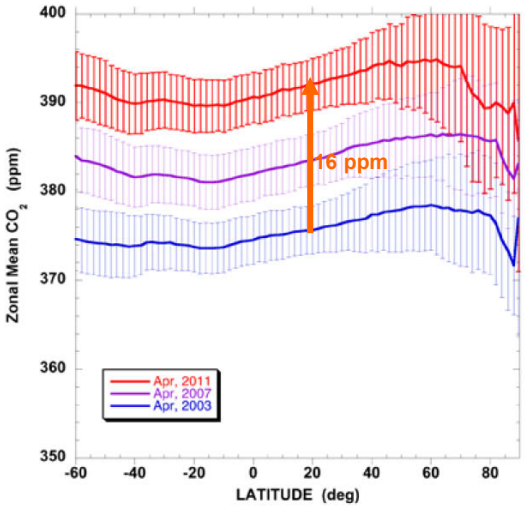
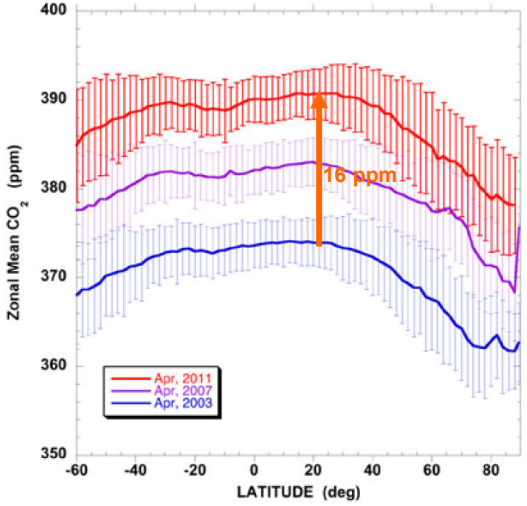
Atmospheric Infrared Sounder

April 2003/2007/2011
Zonal Average V5Op and V602 CO2 and Yield
(note: Global Average DCO2 2003->2011 = 16 ppm)

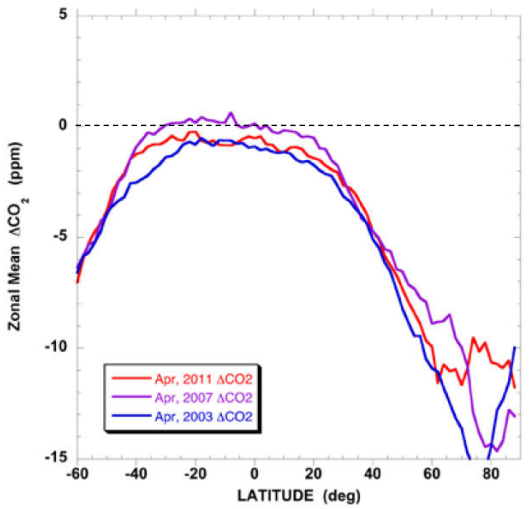
V5Op CO_2



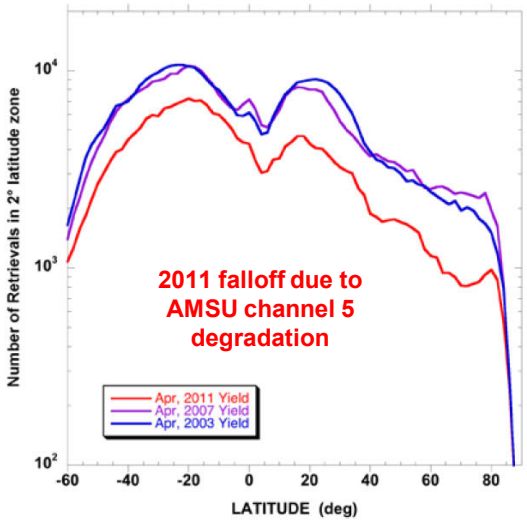
V602 CO_2



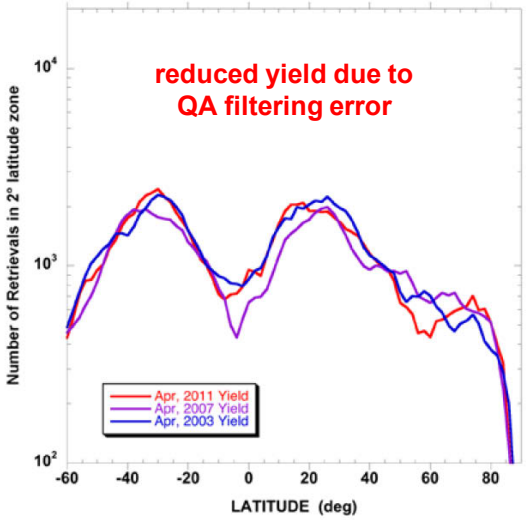
(V602-V5Op) CO_2



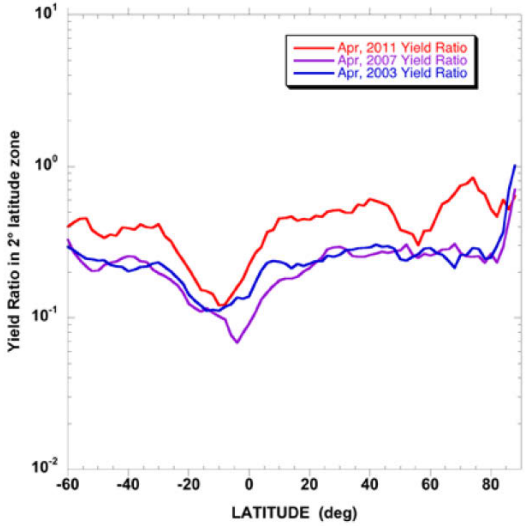
V5Op Yield



V602 Yield



(V602 Yield)/(V5Op Yield)



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Atmospheric Infrared Sounder

July 2003/2007/2011
Zonal Average V5Op and V602 CO2 and Yield
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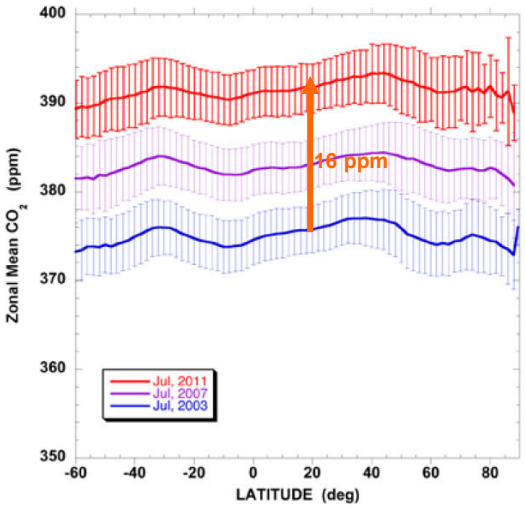
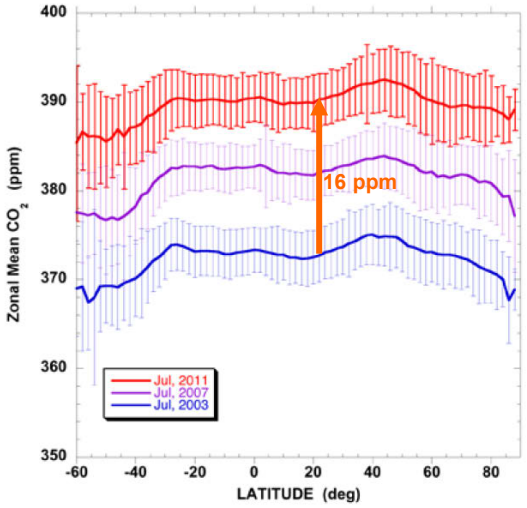
V5Op CO_2



V602 CO_2



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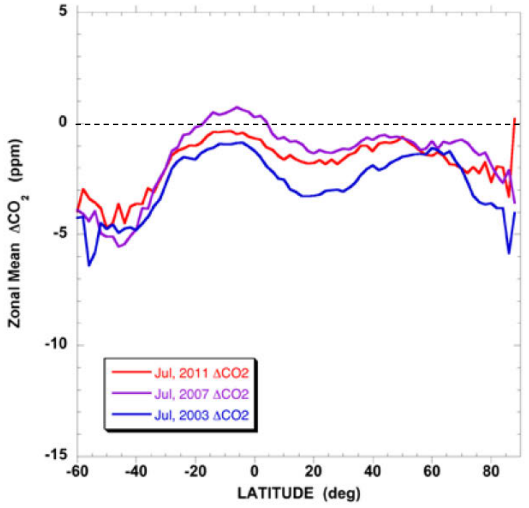
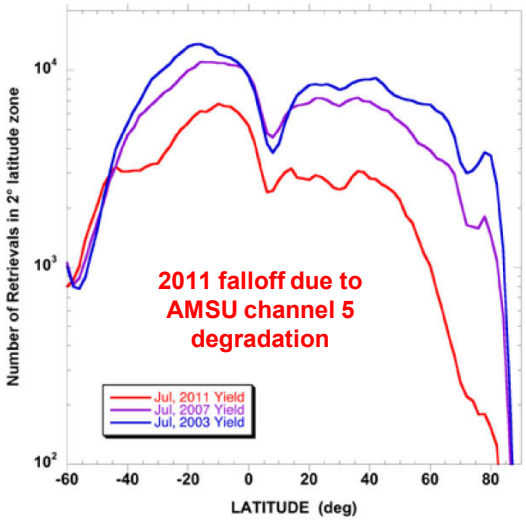
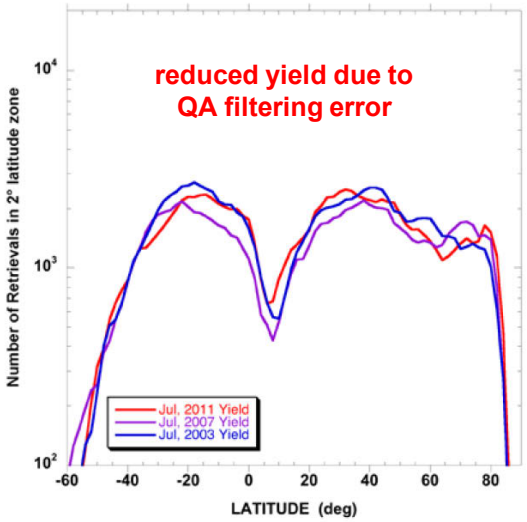


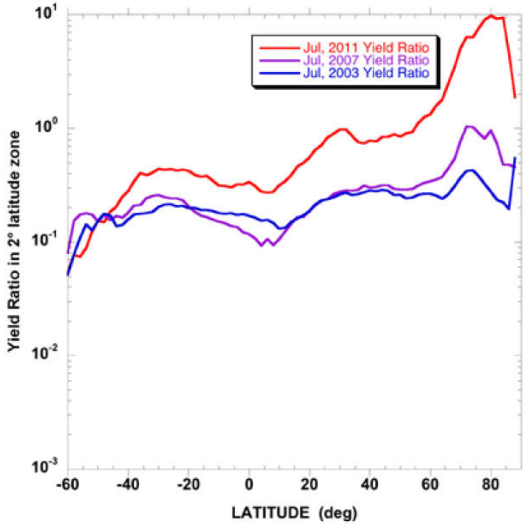
V5Op Yield



V602 Yield



(V602 Yield)/(V5Op Yield)



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October 2003/2007/2011
Zonal Average V5Op and V602 CO2 and Yield
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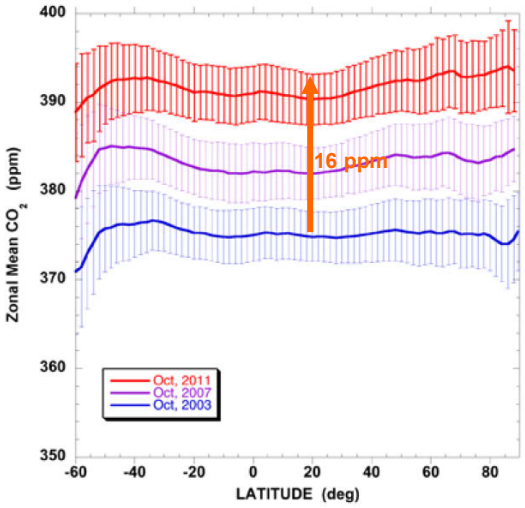
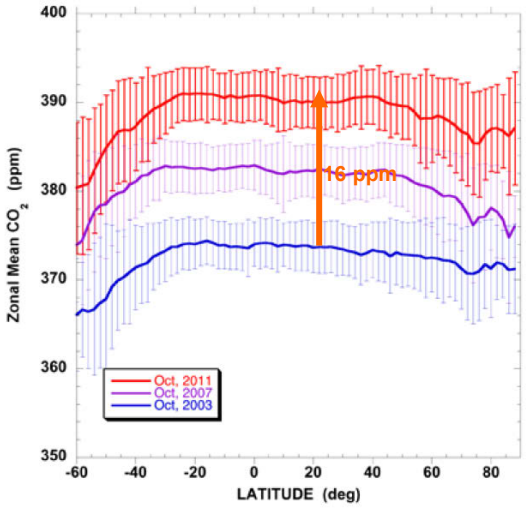
V5Op CO_2



V602 CO_2



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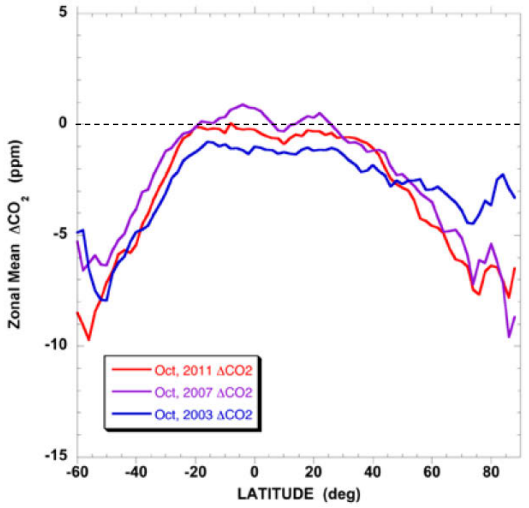
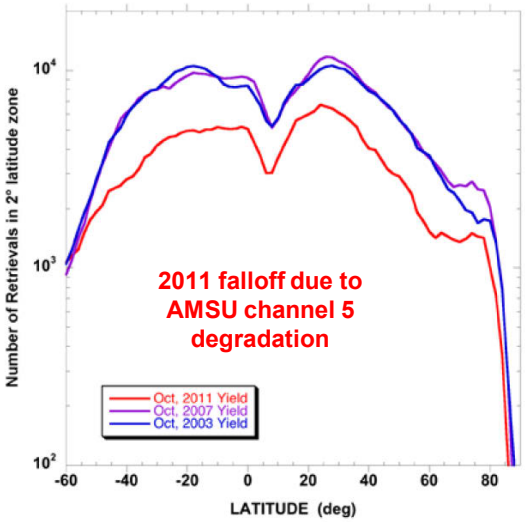
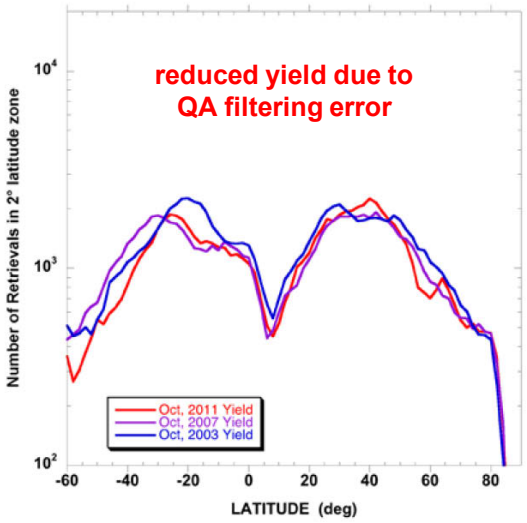


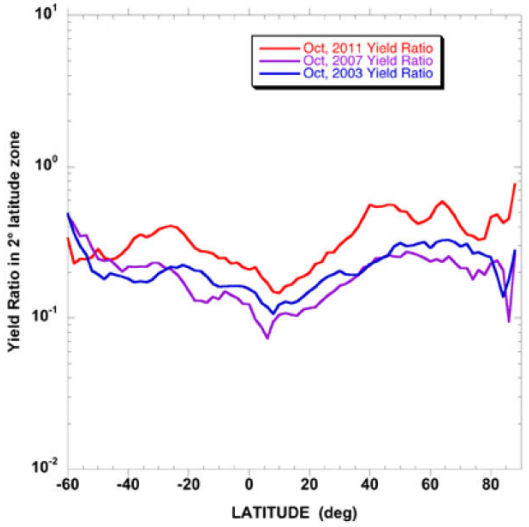
V5Op Yield



V602 Yield



(V602 Yield)/(V5Op Yield)



FY 2013 Plan

- V6 VPD CO2 PGE staged delivery
  - Mid-Troposphere
    - Validation runs against aircraft campaigns: INTEX, COBRA, ARCTAS, HIPPO
    - Deliver operational mid-trop V6 CO2 retrieval February, 2013
    - Will contain early version of mid-strat code, which will not be executed for production
  - Mid-Stratosphere
    - Validation run against SCIAMACHY
    - Deliver operational mid-strat V6 CO2 retrieval upgrade May, 2013
    - Allows PGE to be operated in strat CO2 retrieval mode
  - Lower Troposphere
    - Develop new channel set and QA
    - Develop ocean surface emission module
    - Incorporate into operational V6 CO2 PGE code and perform initial validation study against HIPPO
    - Deliver research version in V6 Op CO2 PGE for assessment September, 2013