AIRS V6 CO2 Retrieval Development

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Activities – AIRS V6 CO2 Development

- **V6 PGE-compatible multi-layer CO2 Retrieval Code**

  Objective is to have a single post-processing CO2 retrieval PGE stripped of development and test code fragments capable of processing either V5 or V6 data to retrieve CO2 at one or more levels of the atmosphere independently.

- **Channel selection**

  Objective is to optimize channel subsets by analyzing their contribution functions over the globe using AIRS L2 retrievals for Jan/Apr/Jul/Oct of 2003/2007/2011 to better constrain the partial columns of the atmosphere which they represent.

- **V6 Testing**

  Initial test using V5 implementation

  L2 is from early V6 (V5.9.12 ZBT) – Jan/Apr/Jul/Oct 2003/2007/2011

  Currently implementing V6 RTA to support full V6 testing using V6.0.2 L2 data sets

AIRS V6 CO2 PGE Development

- V6 CO2 retrieval post-processing PGE reorganized for maintainability
  - Combines four separate research codes into one PGE
  - Legacy research code fragments and stubs removed
  - Code modularized and heavily commented
  - Implements both mid-trop and mid-strat capability
    - Common code modules
    - Switch between mid-trop and mid-strat by environmental variable controlling:
      - Channel lists
      - QA filtering rules
      - Priors
    - Validated that execution mode results in the same output as earlier runs of the four separate research codes
  - Allows easy addition of lower-trop capability
  - Supports choice of V5 or V6 RTA
    - Allows processing of V5 data as well as V6 data
    - Implements V6 Doppler/orbital/seasonal spectral shifts (new)
    - We learned a lot about V6 RTA while developing the Weighting Function and Contribution Function Tools

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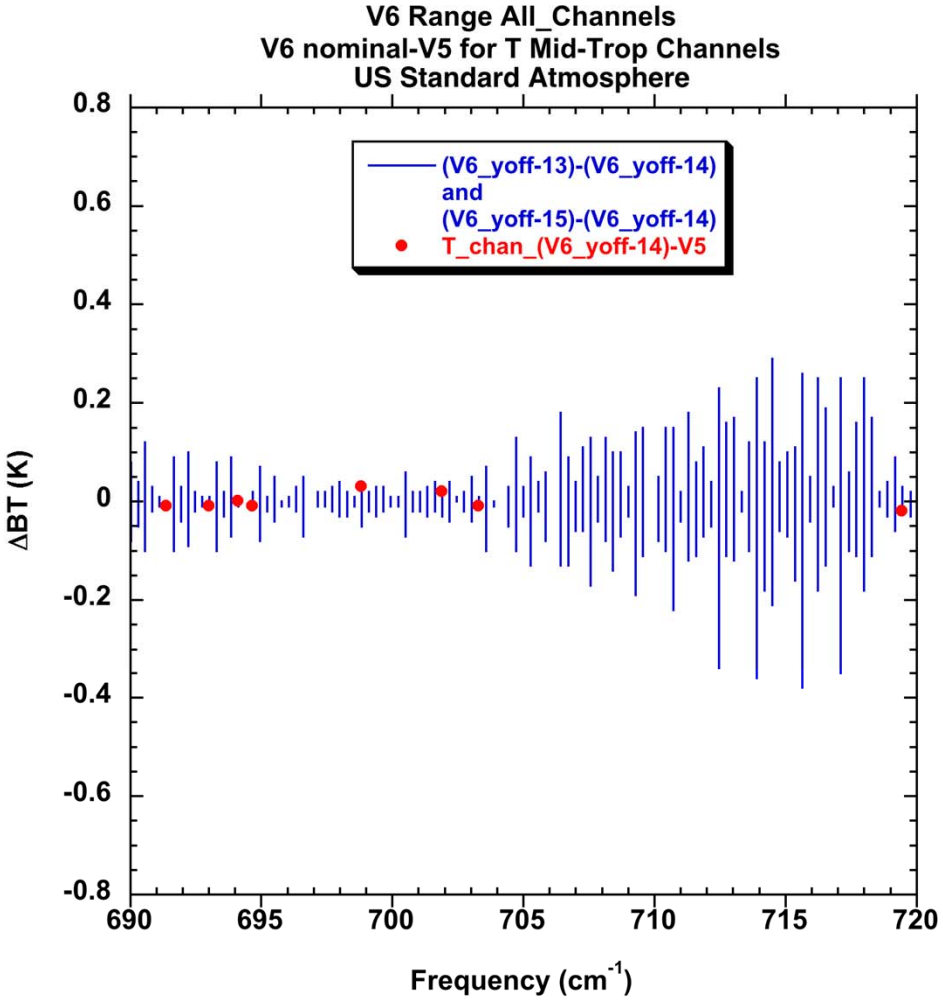
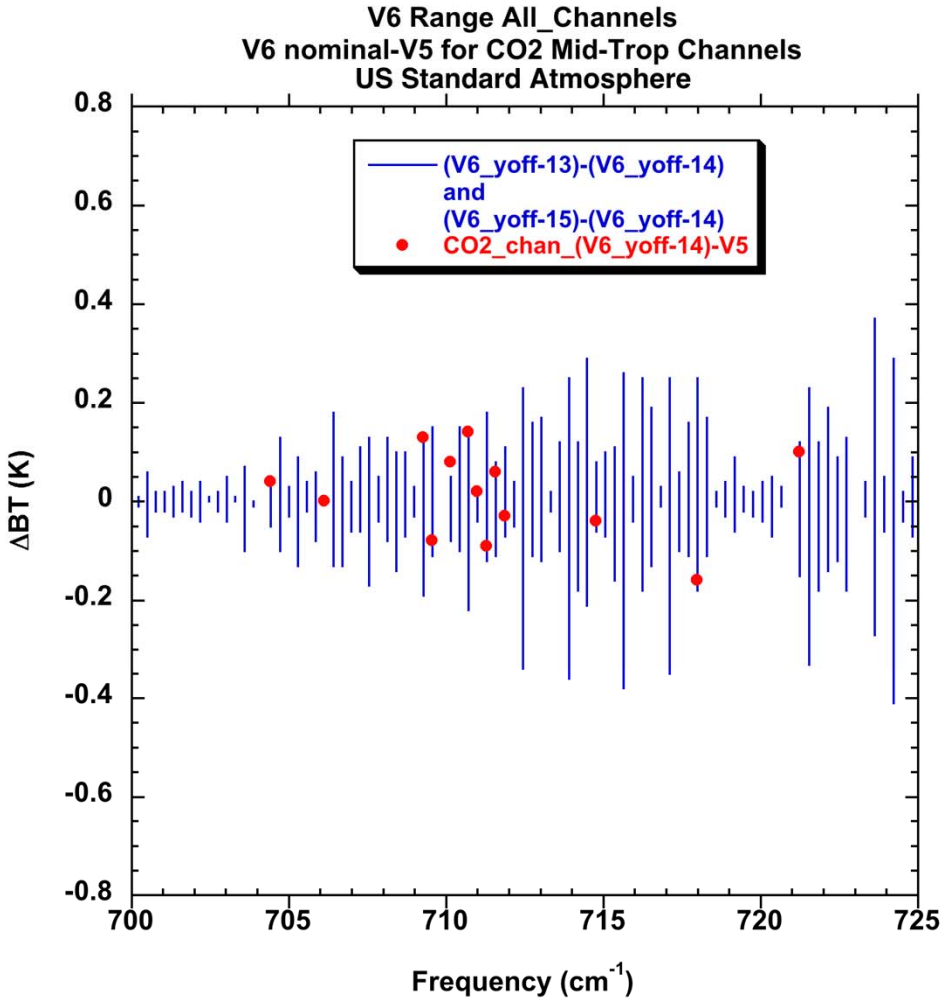
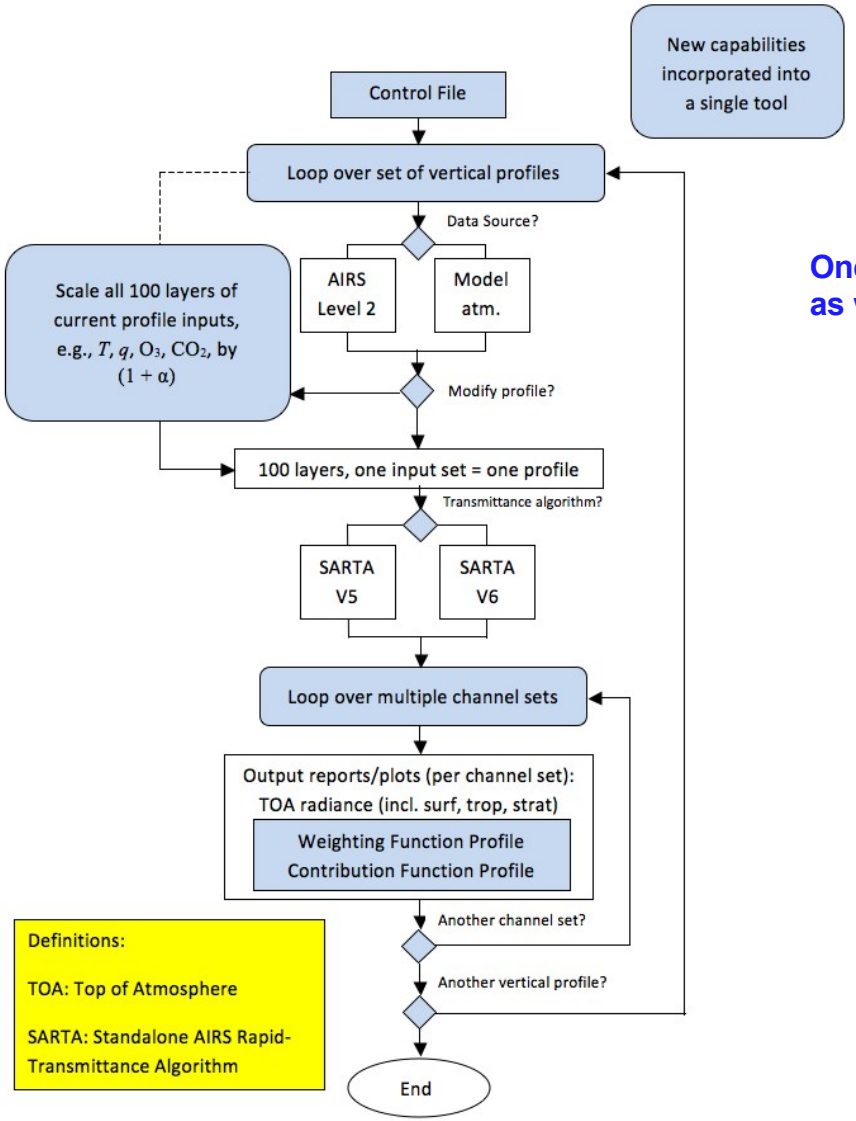
Expected V6 Spectral Shift Range and Offset of V5 from V6 Nominal Shift for VPD Mid-Trop Tair and CO2 Channels





Note:
Maximum spectral shift on the focal plane is expected to be ± 1 μm after adding up contributions of Doppler, orbital, seasonal and long-term contributions (1 μm ≈ 8.4 ppmf)

WgtFnc/CntFnc Tool Flow Diagram For Channel Selection Analysis



One of several tools developed as wrappers for V5 and V6 RTAs

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Example Report for AIRS L2 Arctic Footprint (Output profiles encompass all 100 layers)

```
Output_Product_Name: cnt-2007-01-01_G202_FP01_SC02_v6_unperturbed-mid_trop_co2_ops-381ppm
Input_Instructions: /home/eto/WTG_TOOL/inputs/20070101_G202_Arctic/wtg_20070101_G202_co2_v6_unper.inp
SARTA_Library: /raid5/slicata/co2/wtg_sartav6/sartaV108_ext/lib/libsarta.so
Profile_Data_Source: /archive/AIRSOps/airs/gdaac/v5/2007/01/01/airx2sup/AIRS.2007.01.01.202.L2.RetSup.v5.0.14.0.G07193090333.hdf_Footprint[0-29]_01_Scanline[0-44]_02
Reference_Data_Source_(Observed): /archive/AIRSOps/airs/gdaac/v5/2007/01/01/airi2ccf/AIRS.2007.01.01.202.L2.CC.v5.0.14.0.G07193090333.hdf
Profile_Surface: PSurfStd_1008.85_mb_TSurfStd_248.04_K_LandFrac_0.00
Topography: Lat=74.86_deg_Lon=-178.39_deg_Elev=0.0_m_PGood=1008.85_mb_PBest=931.52_mb
Channel_Number_Set: mid_trop_co2_ops
Average_of_peak_pressure_levels_of_13_channels:  488.55
Standard_deviation_of_peak_pressure_of_13_channels:   58.48
Peak_pressure_of_the_curve_made_from_averages_of_13_channels:  487.21

CH_____________: X  X  X       192       198       209       210       212       214       215       216       217       218       228       239       250
cm-1___________: X  X  X    704.44    706.14    709.28    709.57    710.14    710.72    711.00    711.29    711.58    711.87    714.77    717.99    721.24
TOA_obs_rad____: X  X  X   39.2500   40.5000   42.8750   43.7500   43.0000   42.1250   44.8750   43.3750   43.5000   43.7500   45.2500   47.2500   39.0000
TOA_obs_rad_err_: X  X  X    0.1406    0.1250    0.2109    0.2422    0.1641    0.1562    0.2656    0.1797    0.2656    0.1875    0.2656    0.3281    0.1211
TOA_obs_Tb_K___: X  X  X    216.87    218.51    221.54    222.54    221.77    220.86    223.92    222.31    222.48    222.79    224.74    227.21    218.47
TOA_obs_Tb_err_K: X  X  X      0.16      0.14      0.23      0.27      0.18      0.18      0.29      0.20      0.29      0.21      0.28      0.34      0.14
TOA_calc_rad___: X  X  X   39.0579   40.2056   42.9581   43.4143   42.7110   42.3345   44.7162   43.3053   43.2927   43.2646   45.1995   46.9680   39.3267
TOA_calc_Tb_K__: X  X  X    216.64    218.17    221.63    222.17    221.45    221.10    223.75    222.24    222.26    222.26    224.69    226.92    218.85
contrib_peak_mb_: X  X  X    374.72    424.47    496.63    515.72    477.96    496.63    535.23    515.72    496.63    515.72    535.23    575.52    390.89
FWHM_mb________: X  X  X    423.32    394.95    411.25    411.03    407.27    564.66    425.19    432.06    428.30    426.75    447.07    469.28    489.87
surf_calc_rad__: X  X  X    0.0001    0.0024    0.0407    0.0502    0.0306    0.0933    0.1932    0.0805    0.0547    0.0775    0.4484    0.8567    0.0845
surf_calc_Tb_K__: X  X  X     58.57     70.71     88.30     89.97     86.25     95.28    102.24     94.04     90.83     93.77    112.03    120.88     95.41
trop_calc_rad__: X  X  X   15.4037   21.2214   23.2184   23.9033   23.9303   18.9752   29.4923   22.4332   21.6559   24.0378   27.1782   29.7764   14.2032
trop_calc_Tb_K__: X  X  X    180.88    192.01    195.68    196.80    196.91    188.59    205.22    194.64    193.39    197.29    202.38    206.43    180.33
strat_calc_rad_: X  X  X   23.6542   18.9818   19.6990   19.4609   18.7501   23.2660   15.0307   20.7916   21.5821   19.1492   17.5729   16.3350   25.0390
strat_calc_Tb_K_: X  X  X    195.80    188.06    189.73    189.34    188.11    195.92    180.89    191.88    193.26    189.05    186.46    184.41    199.94

layer  pressure  T_Air_K      theta        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt        cnt_avg
000 1085.3611  -9.99900E+03 0.000E+00     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
001 1056.4771  -9.99900E+03 0.000E+00     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
002 1027.9924  -9.99900E+03 0.000E+00     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
003  999.9099   2.48143E+02 2.470E+02     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
004  972.2318   2.48838E+02 2.491E+02     0.0000     0.0506     0.5488     0.6704     0.4258     0.9461     1.9509     0.8668     0.6517     0.9086     2.9736     5.2100     0.4790     1.2063
005  944.9604   2.50063E+02 2.526E+02     0.0000     0.1008     0.9350     1.1346     0.7451     1.5001     3.0922     1.4044     1.0901     1.5067     4.4276     7.6075     0.7040     1.8652
006  918.0980   2.50566E+02 2.557E+02     0.0000     0.1701     1.3332     1.6068     1.0934     1.9817     4.0881     1.9050     1.5217     2.0836     5.4920     9.2568     0.8598     2.4148
007  891.6464   2.50647E+02 2.578E+02     0.0303     0.2750     1.8335     2.1936     1.5454     2.5340     5.2282     2.4996     2.0496     2.7804     6.6227    10.7815     1.0263     3.0308
008  865.6077   2.50788E+02 2.602E+02     0.0550     0.4353     2.4840     2.9488     2.1426     3.2018     6.6009     3.2398     2.7109     3.6469     7.9414    12.5613     1.2198     3.7837
009  839.9835   2.50819E+02 2.625E+02     0.0978     0.6755     3.3292     3.9193     2.9205     4.0148     8.2696     4.1699     3.5563     4.7346     9.4585    14.6152     1.4631     4.7096
010  814.7755   2.50488E+02 2.647E+02     0.1688     1.0237     4.3913     5.1239     3.9084     4.9691    10.2200     5.2968     4.5897     6.0412    11.2169    16.8641     1.7520     5.8128
011  789.9849   2.49611E+02 2.664E+02     0.2807     1.5041     5.6474     6.5286     5.1197     6.0210    12.3498     6.5752     5.7744     7.5245    13.0775    19.0766     2.0898     7.0438
012  765.6133   2.48528E+02 2.675E+02     0.4471     2.1284     7.0337     8.0530     6.4596     7.1031    14.5061     7.9263     7.0903     9.0869    14.8652    21.0188     2.4530     8.3209
013  741.6616   2.47651E+02 2.689E+02     0.6923     2.9467     8.6275     9.7836     8.0141     8.2944    16.8337     9.4339     8.5398    10.8263    16.7523    22.9690     2.8874     9.7385
014  718.1309   2.46792E+02 2.705E+02     1.0472     4.0079    10.4909    11.7789     9.8538     9.6330    19.4111    11.1655    10.2155    12.8638    18.8292    25.1163     3.4162    11.3715
015  695.0221   2.46288E+02 2.720E+02     1.5361     5.3120    12.5246    13.9266    11.8932    11.0282    22.0304    13.0085    12.0196    14.9640    20.9330    27.1909     4.0334    13.1077
016  672.3358   2.45601E+02 2.745E+02     2.2415     7.0409    15.0770    16.6012    14.4296    12.7693    25.2698    15.3285    14.2801    17.5727    23.6214    29.9937     4.8646    15.3146
017  650.0724   2.44148E+02 2.756E+02     3.1208     8.9577    17.5051    19.0899    16.9170    14.3239    28.0340    17.4689    16.3886    19.9299    25.8659    32.1166     5.7172    17.3412
018  628.2324   2.42572E+02 2.765E+02     4.1722    10.9725    19.6727    21.2626    19.1967    15.6398    30.1754    19.2995    18.2463    21.9256    27.5346    33.3270     6.6161    19.0801
019  606.8161   2.40953E+02 2.774E+02     5.4238    13.1354    21.7293    23.2767    21.4047    16.8676    32.0179    21.0156    19.8892    23.7580    28.9714    34.2134     7.6608    20.7203
020  585.8234   2.39197E+02 2.783E+02     6.8647    15.3722    23.5993    25.0674    23.4579    17.9691    33.5025    22.5596    21.4682    25.3576    30.1130    34.7637     8.7582    22.2195
021  565.2542   2.37333E+02 2.790E+02     8.4233    17.5358    25.1119    26.4581    25.1833    18.8343    34.4345    23.7871    22.7494    26.4335    30.8304    34.7860     9.8584    23.4174
022  545.1084   2.35416E+02 2.796E+02    10.0807    19.5872    26.2866    27.4873    26.5842    19.5176    34.9010    24.7254    23.7830    27.2861    31.1914    34.4112    10.9341    24.3674
023  525.3855   2.33404E+02 2.802E+02    11.7702    21.4468    27.0888    28.1253    27.6152    20.0000    34.9255    25.3569    24.4603    27.7771    31.1920    33.6732    11.9765    25.0314
024  506.0849   2.31355E+02 2.807E+02    13.3974    22.9919    27.4396    28.3098    28.1859    20.2086    34.4429    25.6013    24.7867    27.8481    30.7568    32.5164    12.9286    25.3395
025  487.2058   2.29423E+02 2.813E+02    14.9373    24.2354    27.4431    28.1506    28.3888    20.2565    33.6020    25.5550    24.8333    27.6115    30.0170    31.1123    13.7807    25.3787
026  468.7474   2.27646E+02 2.821E+02    16.4145    25.2797    27.2784    27.7929    28.4005    20.2326    32.6404    25.3902    24.7536    27.2412    29.1848    29.7151    14.6038    25.3021
027  450.7087   2.25923E+02 2.831E+02    17.7817    26.1003    26.9527    27.3298    28.2341    20.1445    31.5665    25.1110    24.5489    26.7497    28.2770    28.3293    15.3911    25.1167
028  433.0883   2.24170E+02 2.841E+02    18.9543    26.6036    26.3847    26.6442    27.7945    19.9055    30.2893    24.6370    24.1403    26.0567    27.1942    26.8364    16.0159    24.7274
029  415.8850   2.22357E+02 2.851E+02    19.8489    26.7049    25.5415    25.6966    27.0389    19.5300    28.7739    23.9209    23.4883    25.1218    25.8911    25.1907    16.4846    24.0948
030  399.0971   2.20513E+02 2.861E+02    20.4199    26.4550    24.4278    24.4998    25.9821    18.9851    27.0440    22.9630    22.5914    23.9572    24.3780    23.4622    16.7362    23.2232
031  382.7230   2.18714E+02 2.871E+02    20.7113    25.8667    23.1418    23.1456    24.7127    18.3065    25.2089    21.8409    21.5275    22.6512    22.7462    21.6162    16.7844    22.1738
032  366.7607   2.16994E+02 2.883E+02    20.7549    25.0718    21.7961    21.7448    23.3546    17.6295    23.3872    20.6601    20.3953    21.3089    21.1106    19.8321    16.7122    21.0583
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034  336.0634   2.13674E+02 2.910E+02    20.1850    22.9733    19.0309    18.8987    20.4923    16.0782    19.8696    18.2077    18.0133    18.5964    17.9330    16.4700    16.2118    18.6892
035  321.3239   2.12019E+02 2.924E+02    19.5837    21.6905    17.6045    17.4420    18.9837    15.2241    18.1528    16.9229    16.7514    17.2128    16.3648    14.9479    15.7411    17.4325
036  306.9871   2.10503E+02 2.939E+02    18.7909    20.3177    16.1834    15.9943    17.4645    14.3378    16.4905    15.6264    15.4735    15.8411    14.8355    13.4506    15.1512    16.1506
037  293.0504   2.09179E+02 2.958E+02    17.9957    19.0247    14.9764    14.7831    16.0984    13.5441    15.0354    14.4742    14.3308    14.6215    13.5108    12.1629    14.5874    15.0050
038  279.5108   2.08042E+02 2.980E+02    17.1838    17.7788    13.8463    13.5305    14.8463    12.8051    13.7343    13.4264    13.2834    13.5124    12.3286    11.0456    14.0220    13.9495
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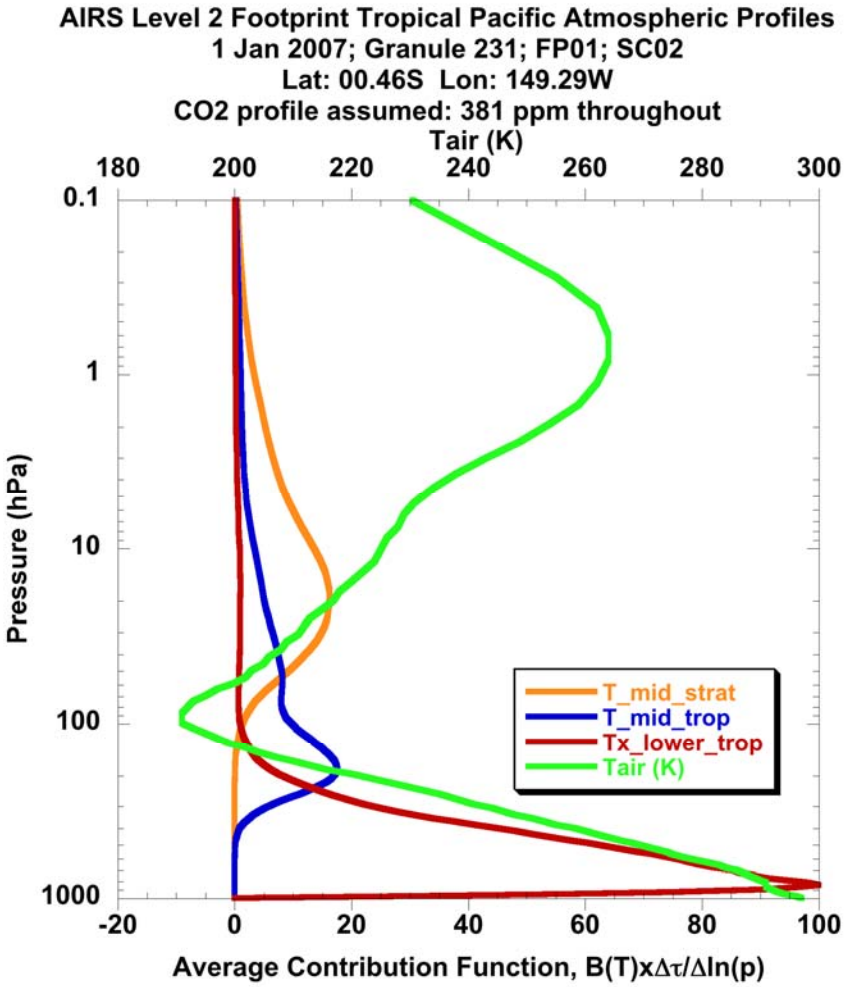
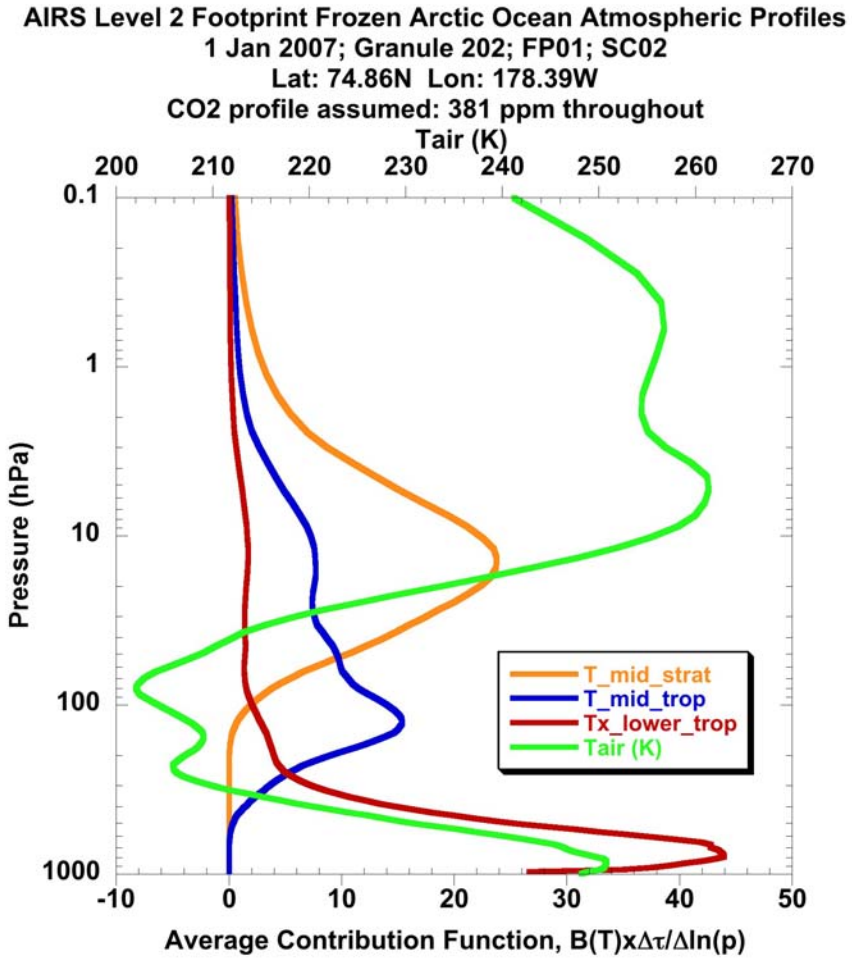
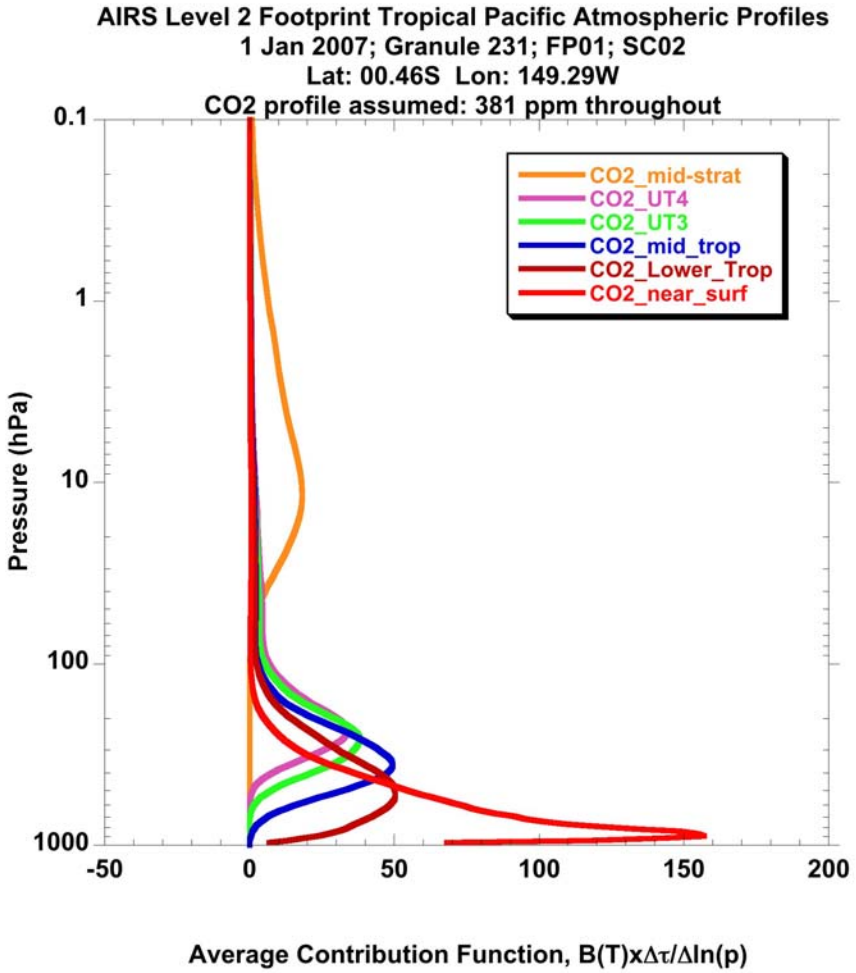
Contribution Functions/Temperature Profiles V5 VPD T_{air} Auxiliary Groups using V6 RTA

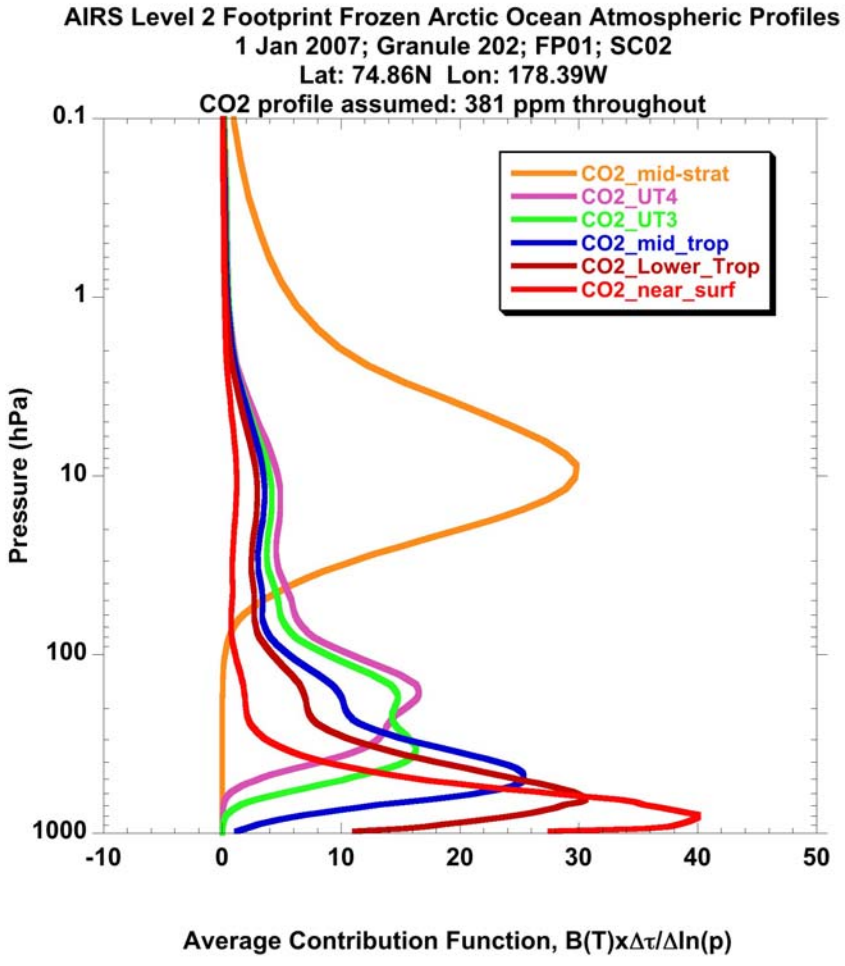




Mid-Trop channel set at high latitude likely requires optimization

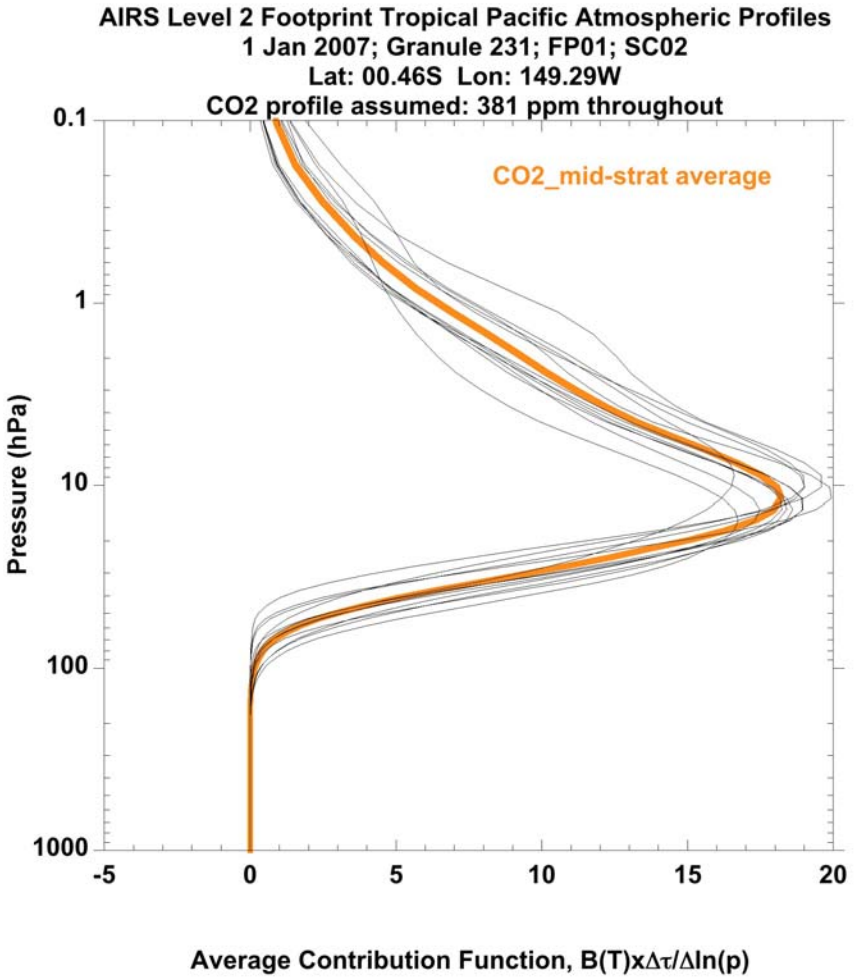
Contribution Functions/Temperature Profiles V5 VPD CO2 Groups using V6 RTA

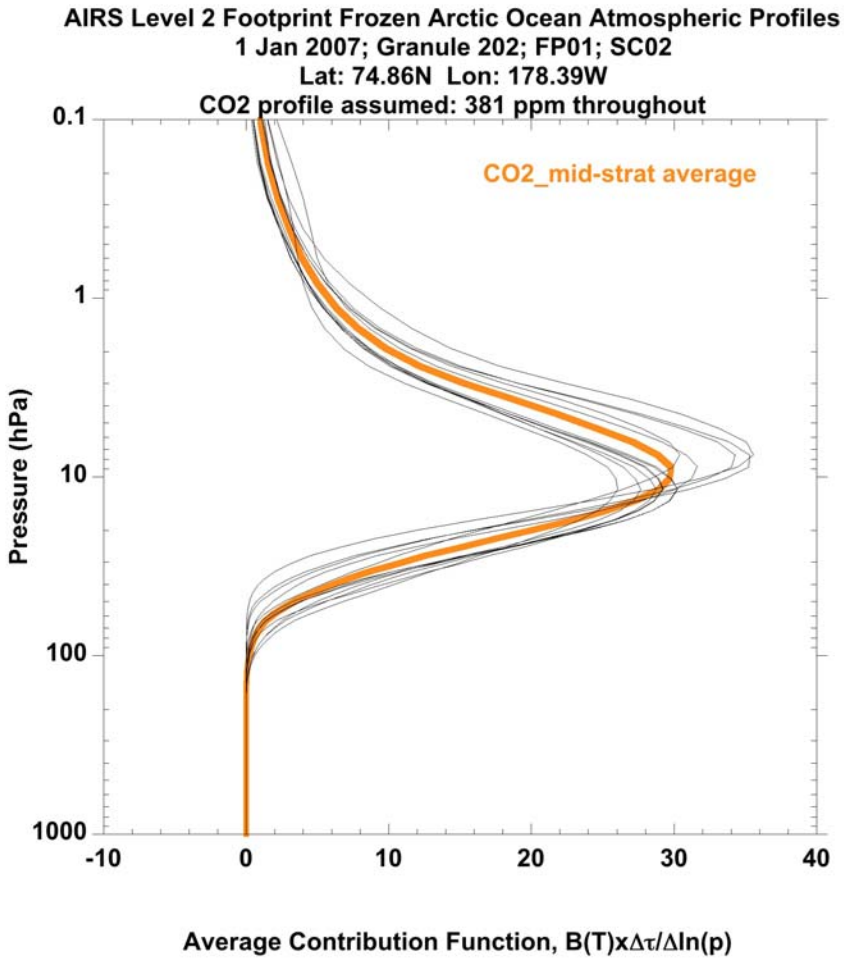




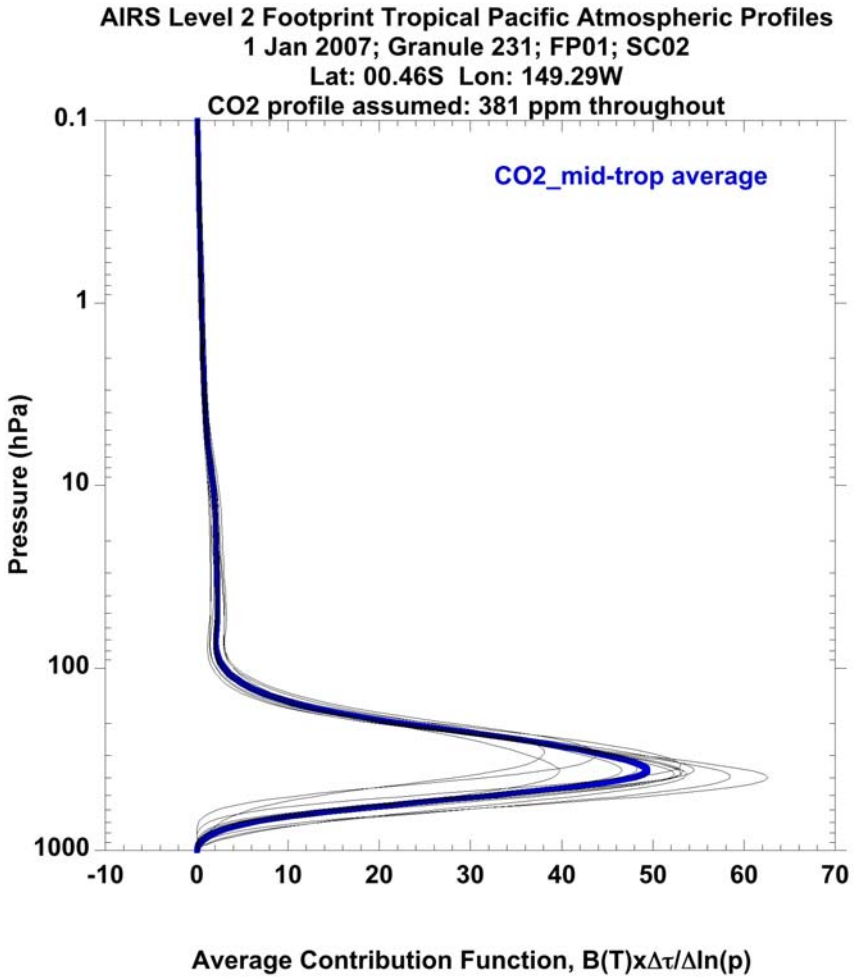
Mid-Trop/Upper-Trop channel sets at high latitude likely require optimization

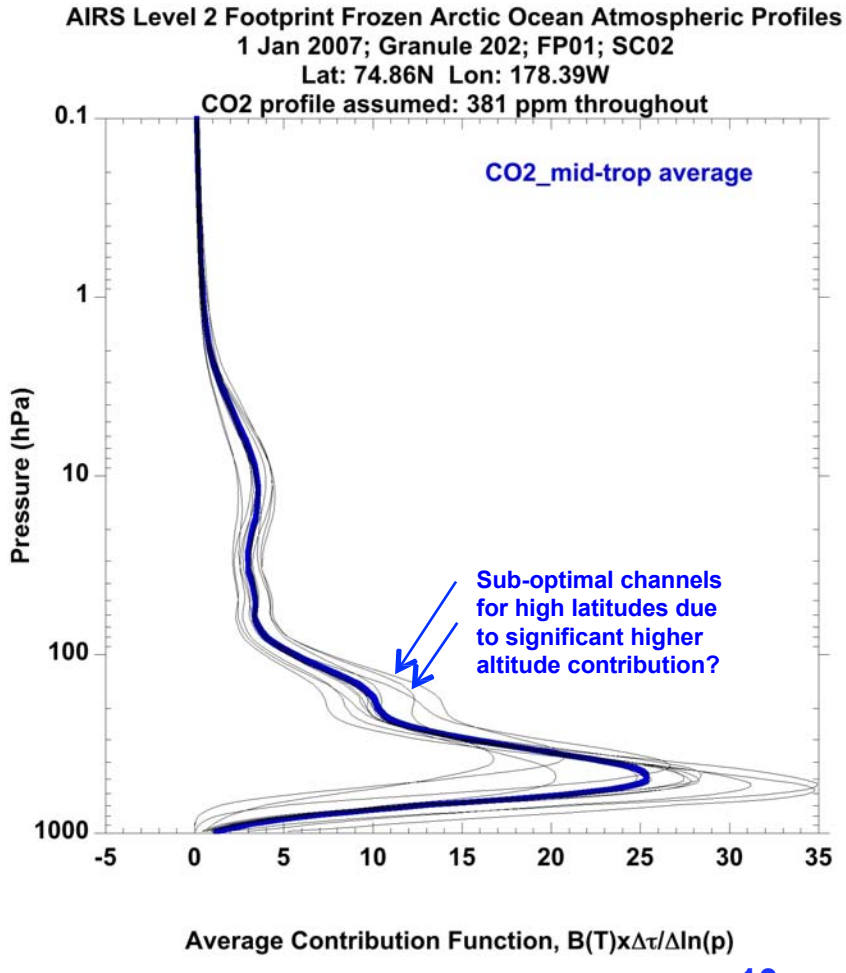
Contribution Functions
Initial CO2 Mid-Strat Channel Set using V6 RTA



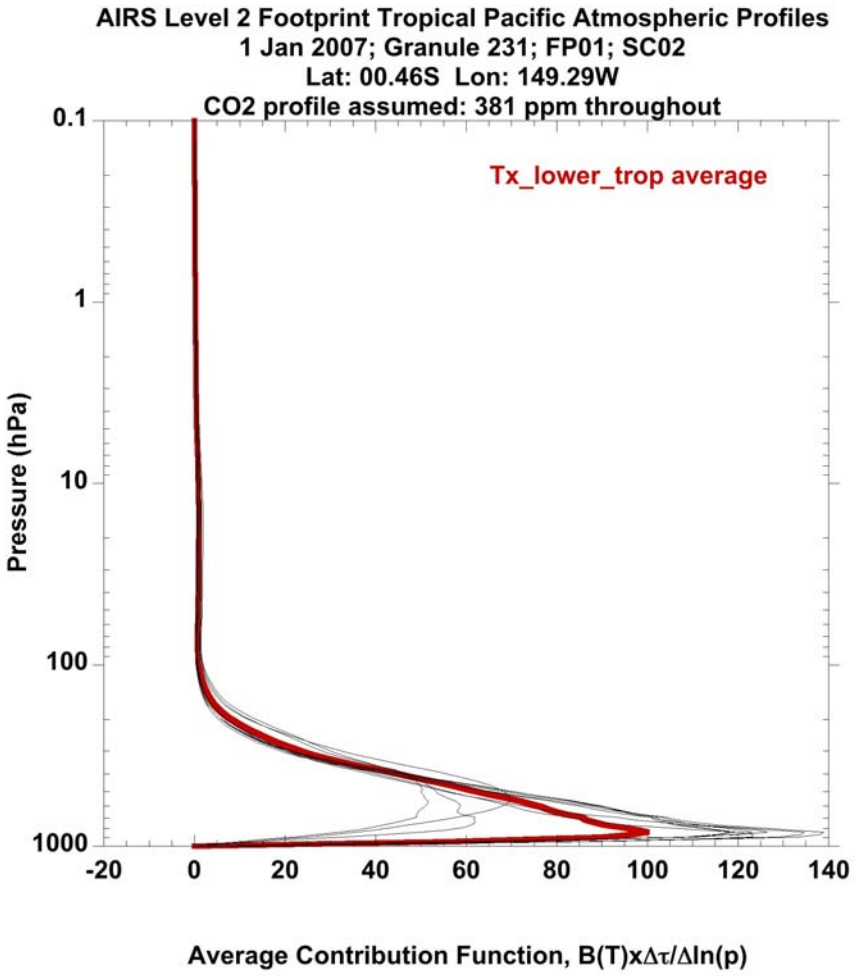


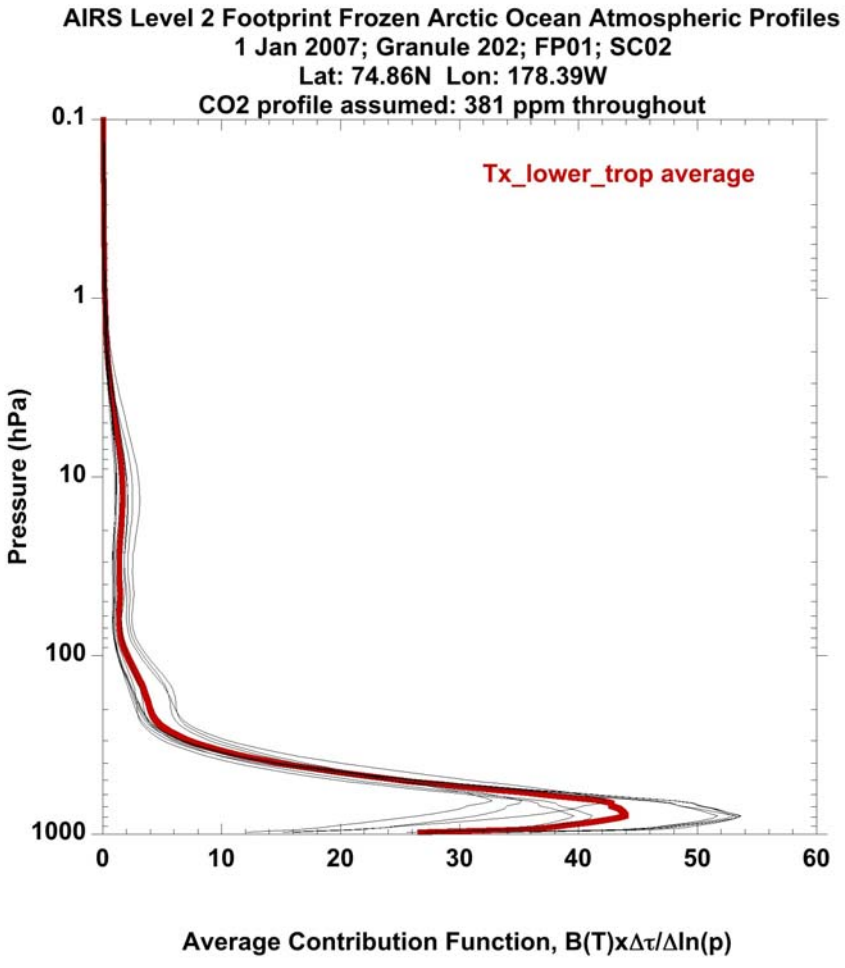
Contribution Functions
Initial CO2 Mid-Trop Channel Set using V6 RTA



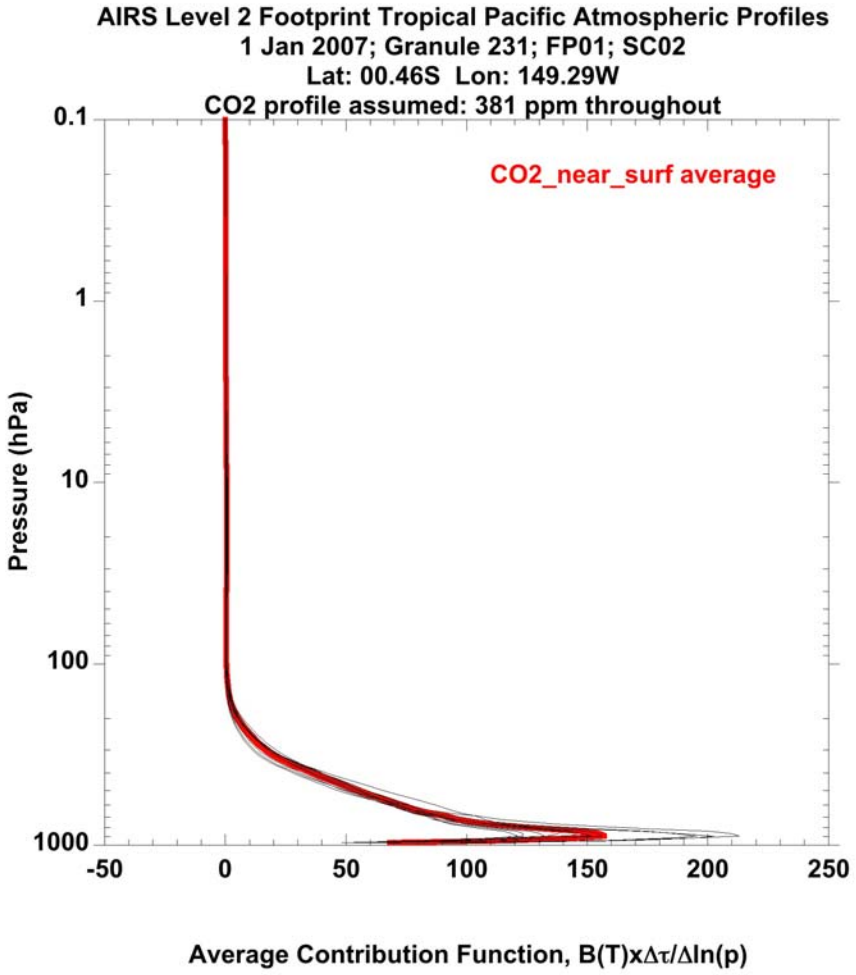


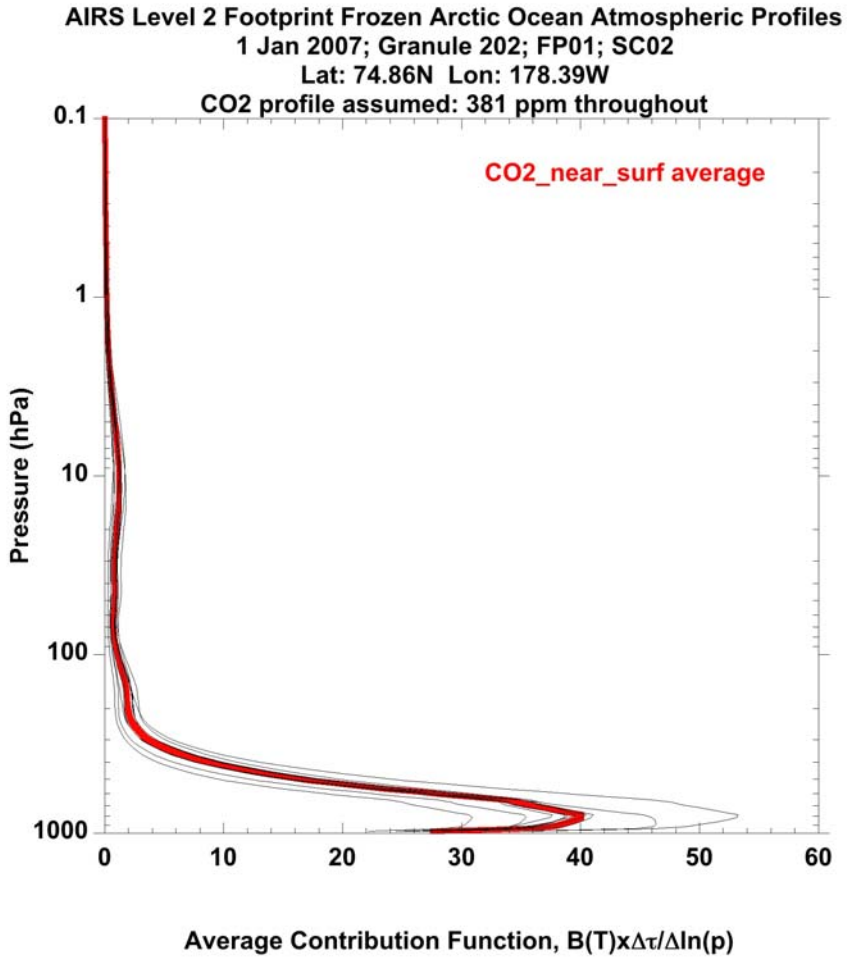
Contribution Functions
Initial Tair Lower-Trop Channel Set using V6 RTA





Contribution Functions
Initial CO2 Near-Surf Channel Set using V6 RTA





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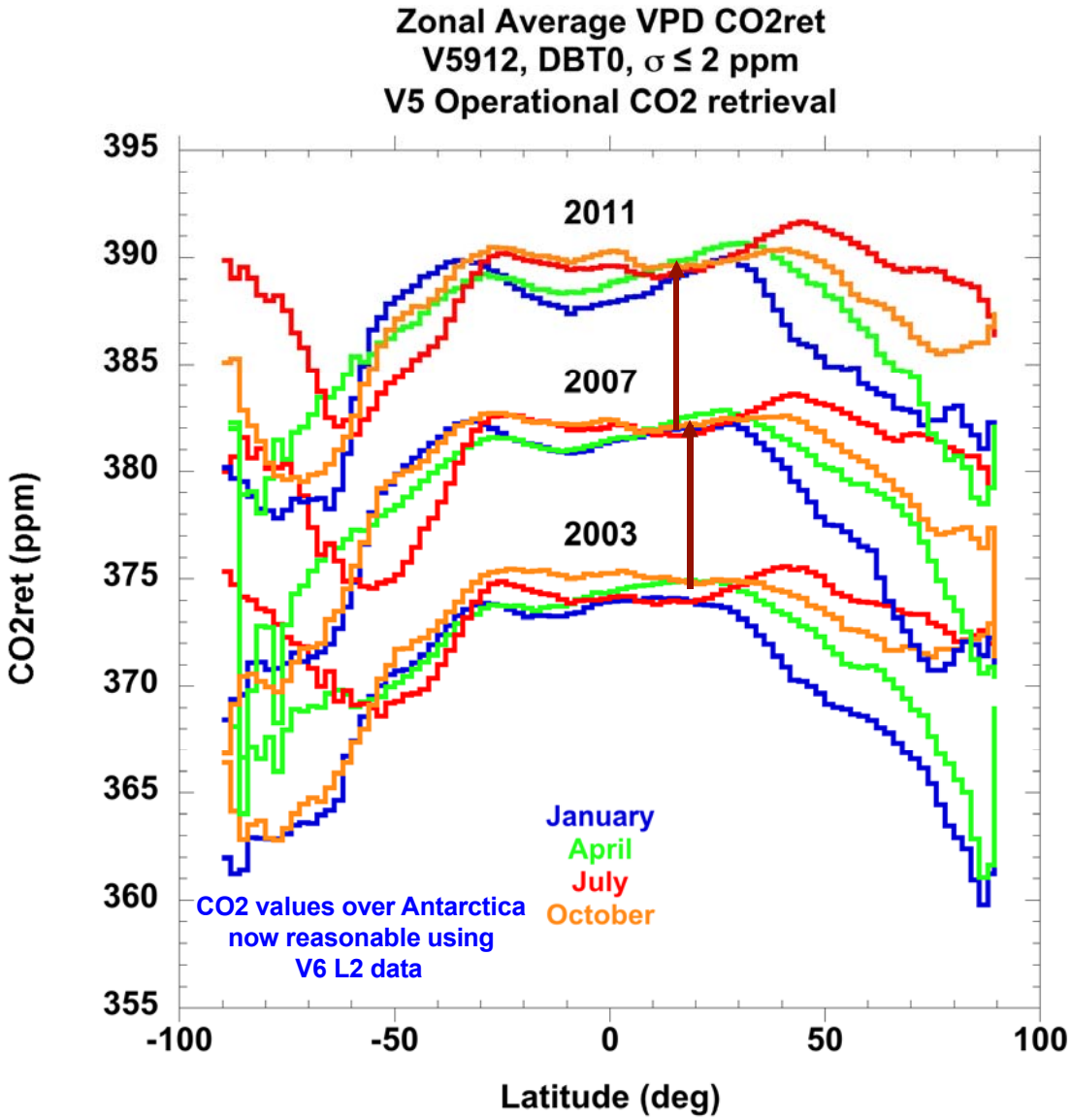
Interannual and Seasonal Variations Retrieved Mid-Trop CO2 Early V6 L2 Data; Unoptimized V5 Operational VPD

interannual variation is reasonable

expected 8 ppm interannual variation at 2 ppm/yr



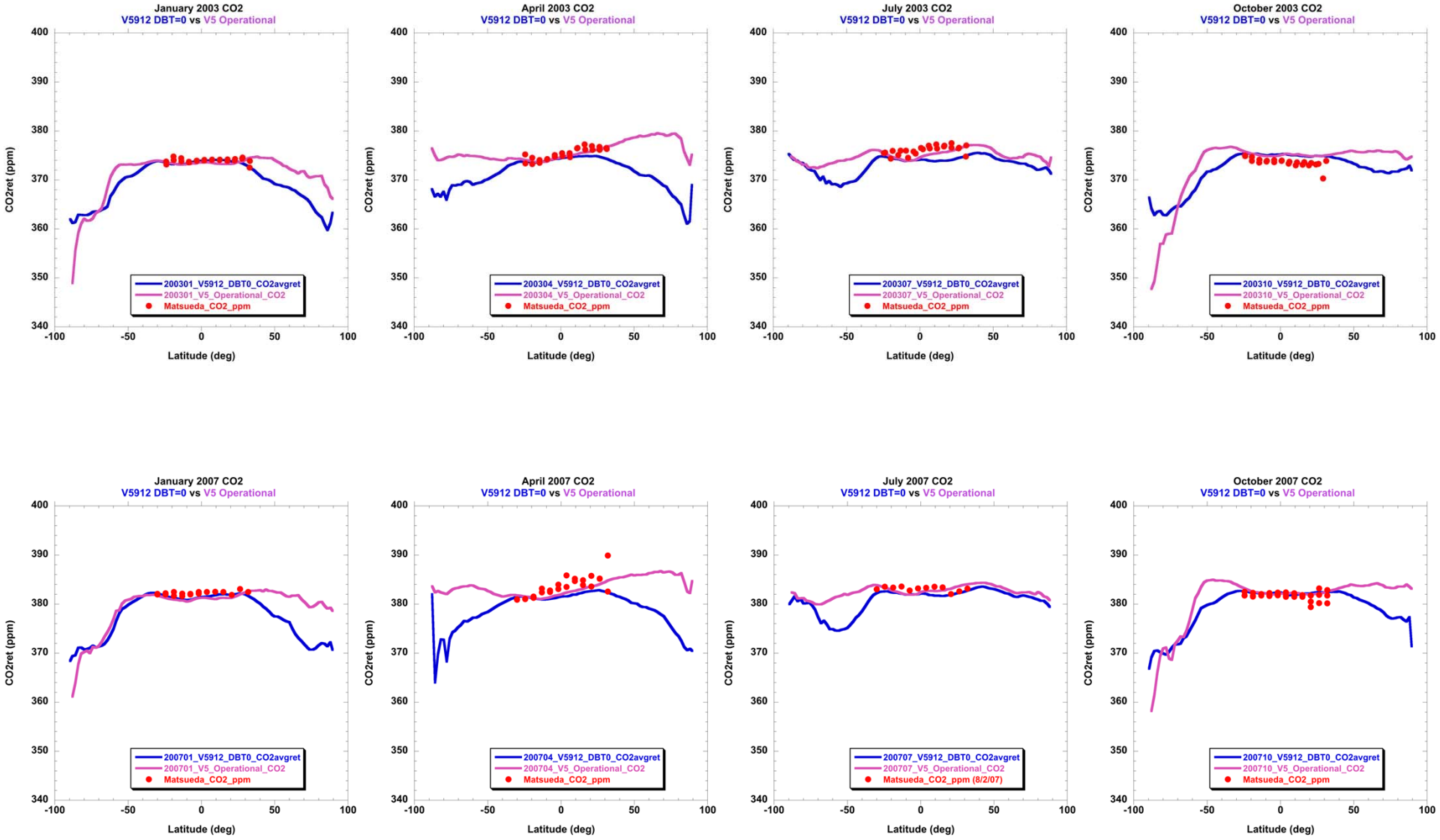
high NH latitude variation may be impacted by suboptimal channels (too great a contribution from low stratosphere)

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Atmospheric Infrared Sounder

Zonal Average of Retrieved Mid-Trop CO2 Early V6 L2 Data; Unoptimized V5 Operational VPD Compared to Matsueda In Situ Measurements and Zonal Average of V5 Operational Retrieval



National Aeronautics and Space Administration

Jet Propulsion Laboratory
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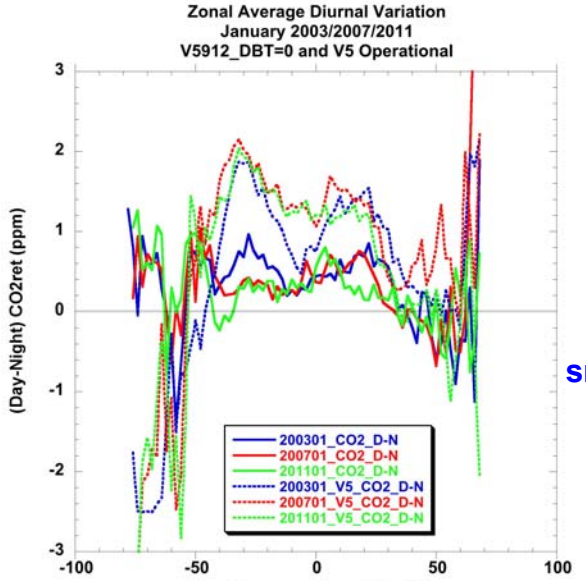
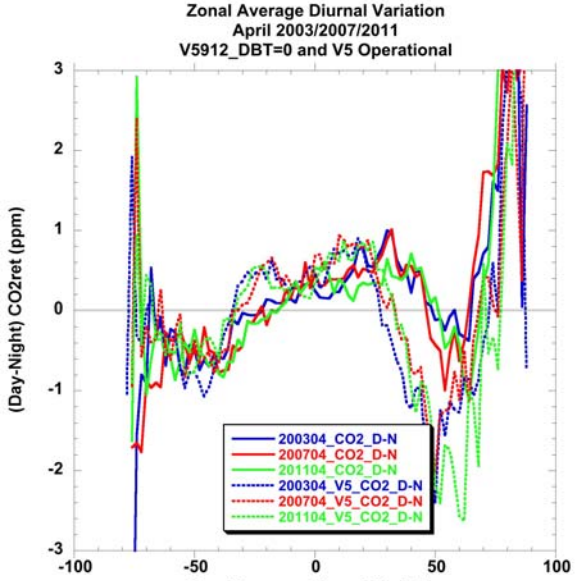
Atmospheric Infrared Sounder

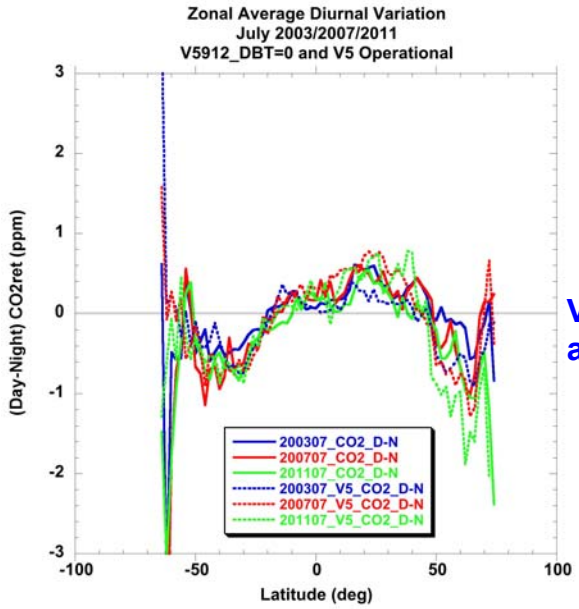
V6/V5 Diurnal Variation Comparison



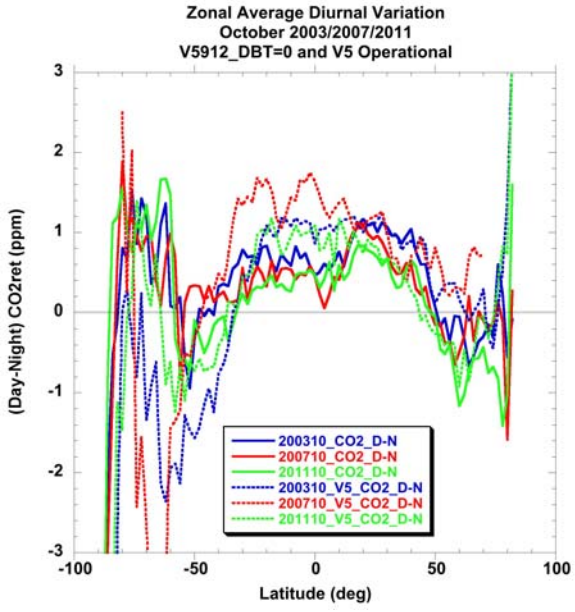
January
V6 diurnal
about 1 ppm
smaller than V5



April
V6 diurnal
0.5 - 1 ppm
smaller than V5

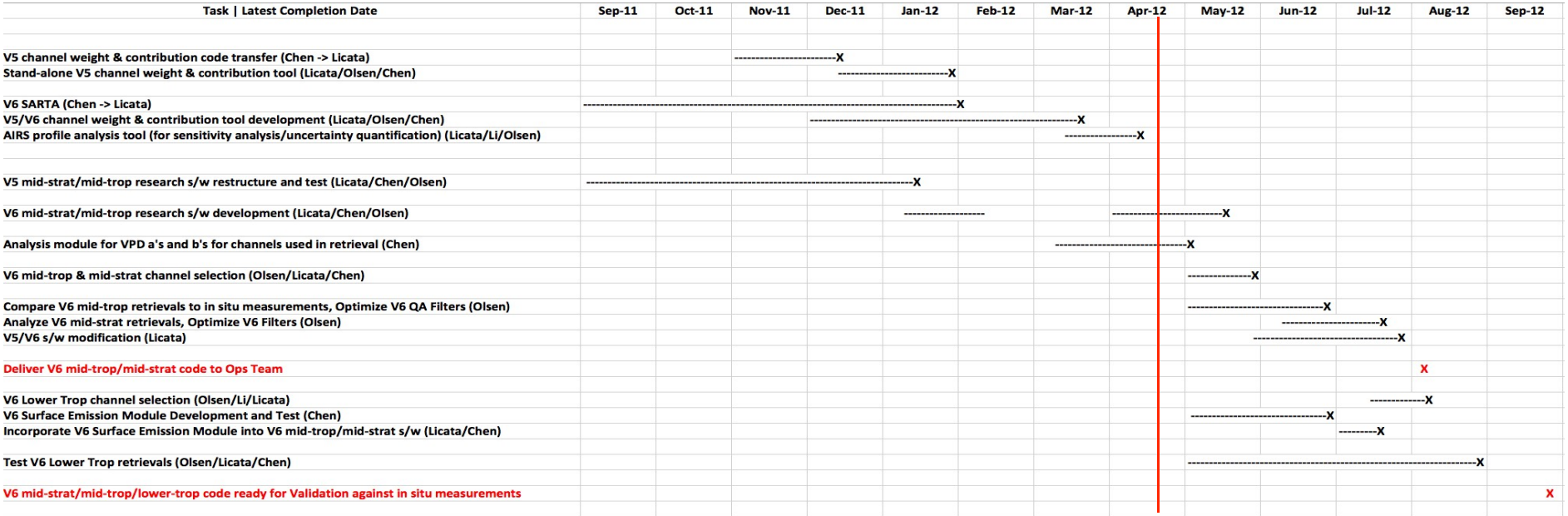


July
V5/V6 diurnal
about the same



October
V6 diurnal
0.5 – 1 ppm
smaller than V5

Schedule


Task | Latest Completion Date
Sep-11
Oct-11
Nov-11
Dec-11
Jan-12
Feb-12
Mar-12
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
V5 channel weight & contribution code transfer (Chen -> Licata)
Stand-alone V5 channel weight & contribution tool (Licata/Olsen/Chen)
V6 SARTA (Chen -> Licata)
V5/V6 channel weight & contribution tool development (Licata/Olsen/Chen)
AIRS profile analysis tool (for sensitivity analysis/uncertainty quantification) (Licata/Li/Olsen)
V5 mid-strat/mid-trop research s/w restructure and test (Licata/Chen/Olsen)
V6 mid-strat/mid-trop research s/w development (Licata/Chen/Olsen)
Analysis module for VPD a's and b's for channels used in retrieval (Chen)
V6 mid-trop & mid-strat channel selection (Olsen/Licata/Chen)
Compare V6 mid-trop retrievals to in situ measurements, Optimize V6 QA Filters (Olsen)
Analyze V6 mid-strat retrievals, Optimize V6 Filters (Olsen)
V5/V6 s/w modification (Licata)
Deliver V6 mid-trop/mid-strat code to Ops Team
V6 Lower Trop channel selection (Olsen/Li/Licata)
V6 Surface Emission Module Development and Test (Chen)
Incorporate V6 Surface Emission Module into V6 mid-trop/mid-strat s/w (Licata/Chen)
Test V6 Lower Trop retrievals (Olsen/Licata/Chen)
V6 mid-strat/mid-trop/lower-trop code ready for Validation against in situ measurements

Summary – AIRS V6 CO2 Development

- V6 CO2 retrieval post-processing PGE reorganized for maintainability
  - Legacy research code segments/stubs removed
  - Code modularized and heavily commented
  - Implements both mid-trop and mid-strat capability
    - Choice: channel lists, priors and QA filtering rules; code modules are common
    - Allows easy addition of lower-trop capability
    - Choice of V5 or V6 RTA to allow V5 or V6 data processing
      - Implements V6 Doppler/orbital/seasonal spectral shifts
- Revisiting channel selection – tools developed
  - Analyzing channel sensitivity over globe using V5 and V6 L2 & RTA
  - Identifying sub-optimal channels
  - Optimizing selection criteria and QA filters for V6
- Early V6 results (V5.9.12 ZBT)
  - V5 retrieval PGE for Jan/Apr/Jul/Oct of 2003/2007/2011
    - Interannual variation consistent with global growth of CO2
    - Diurnal variation is small fraction of 1 ppm
    - Lower NH high latitude winter mid-trop CO2 in V6 may be due to sub-optimal channel contribution tails extending into lower stratosphere
    - Reasonable mid-trop CO2 over Antarctica likely due to better temperature profiles over that continent

AIRS V6 CO2 Development

Thank You!