Initial Analysis of CrIS TVAC NH_3 and CO tests

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overview

- preliminary analysis of the NH_3 and CO TVAC gas cell tests show good agreement with calculated data.
- we describe our test procedures and compare calibration equations for gas cell and regular CrIS processing.
- there was some uncertainty about gas cell pressures. the values we used are chosen (to the nearest torr) to minimize residuals.
- the high resolution CO measurements are used to compare self-apodization corrections with periodic and regular sinc.

test methods

- the test places a gas cell between the instrument and a black body. Four measurements are made—cell full with BB at T_1, cell full with BB at T_2, cell empty with BB at T_1, and cell empty with BB at T_2.
- let FT_1, FT_2, ET_1 and ET_2 be the corresponding on-axis count spectra. Then

$$\tau = \frac{\mathrm{FT}_2 - \mathrm{FT}_1}{\mathrm{ET}_2 - \mathrm{ET}_1}$$

  gives a good approximation of the gas cell transmittance.
- calculated spectra are from the UMBC line-by-line software by S. DeSouza-Machado, convolved to the CrIS sensor grid

test methods

The main steps in analyzing the test data are

- read the CCSDS data packets
- take interferograms to count spectra
- take the mean of spectra over stable test intervals
- find $\tau_{\text{obs}} = f \circ \text{SA}^{-1} \circ f((\text{FT}_2 - \text{FT}_1)/(\text{ET}_2 - \text{ET}_1))$
- compare observed and calculated transmittance spectra at the sensor grid

This process is embedded in a search where we minimize $\text{RMS}(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$ as a function of metrology laser wavelength. From this we get both a conventional residual and the difference of wavelength at the minima from the neon calibration value.

test methods

- note the close parallel between our expression for transmittance

$$\tau_{\text{obs}} = f \cdot \text{SA}^{-1} \cdot f \cdot \frac{\text{FT}_2 - \text{FT}_1}{\text{ET}_2 - \text{ET}_1}$$

  and our default CrIS calibration equation

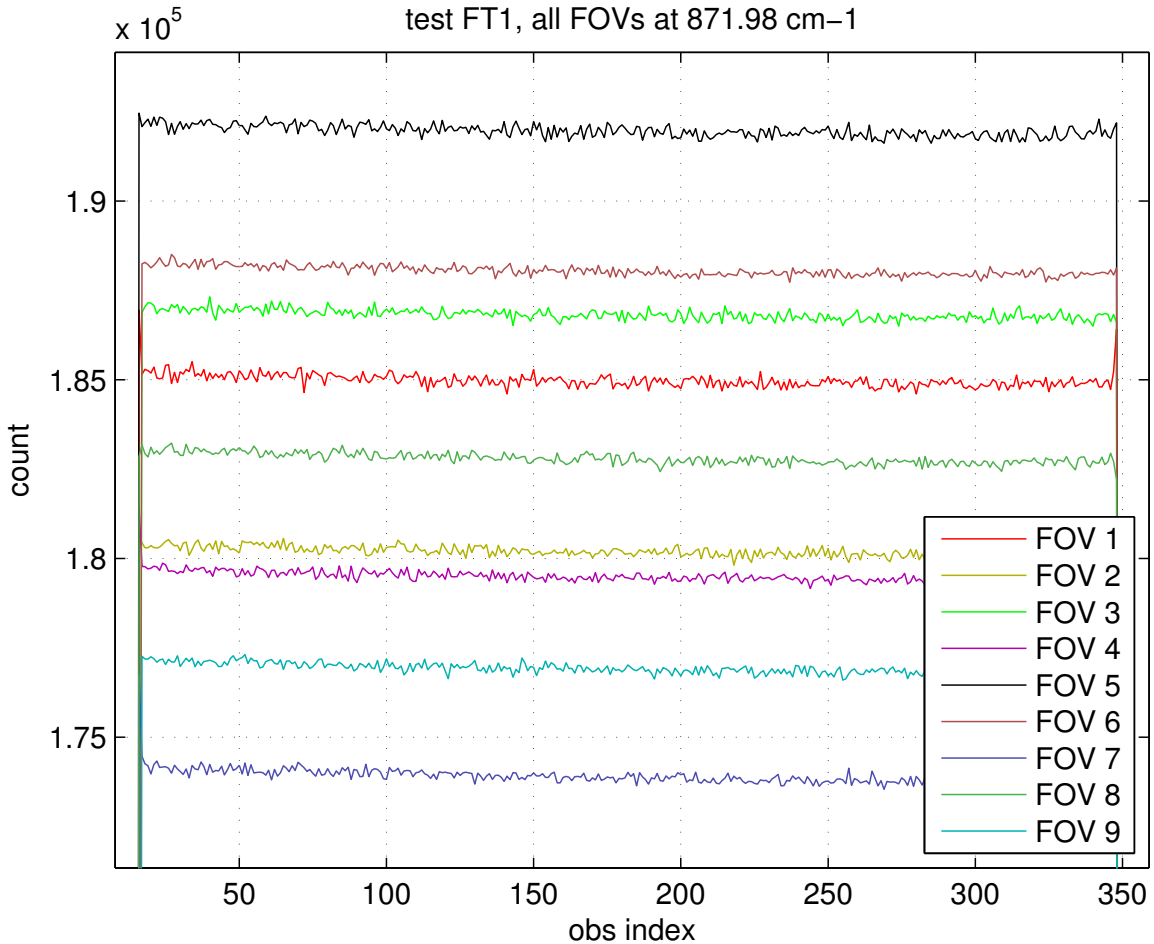
$$r_{\text{obs}} = F \cdot r_{\text{ICT}} \cdot f \cdot \text{SA}^{-1} \cdot f \cdot \frac{\text{ES} - \text{SP}}{\text{IT} - \text{SP}}$$

- here f is a raised-cosine bandpass filter, SA^{-1} the inverse of the ILS matrix, r_{ICT} is expected ICT radiance at the sensor grid, and F is Fourier interpolation from sensor to user grid.
- the same f is applied to the line-by-line transmittances before convolution to the CrIS sensor grid

NH_3 test parameters

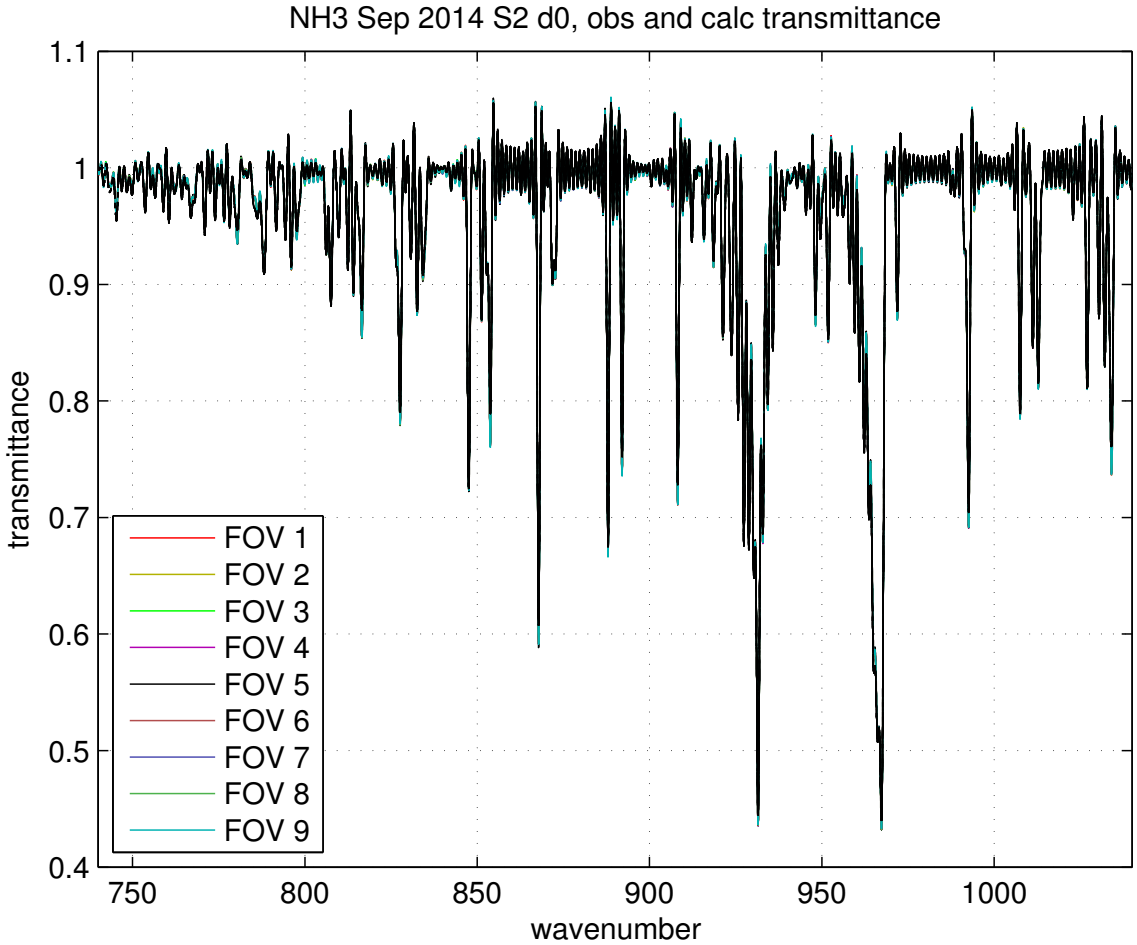
- fitting interval 740 to 1040 cm^{-1}
- metrology laser wavelength from neon cal
- Oct 2013 Exelis side 1 focal plane values
- ILS with periodic sinc wrap at the sensor grid
- 330 observations in each test leg
- gas cell nominal pressure 39 torr
- gas cell NH_3 partial pressure 7 torr
- gas cell temperature 18.2 C
- gas cell length 12.59 cm
- HTBB nominal T1 360 K, T2 320 K

NH_3 test data



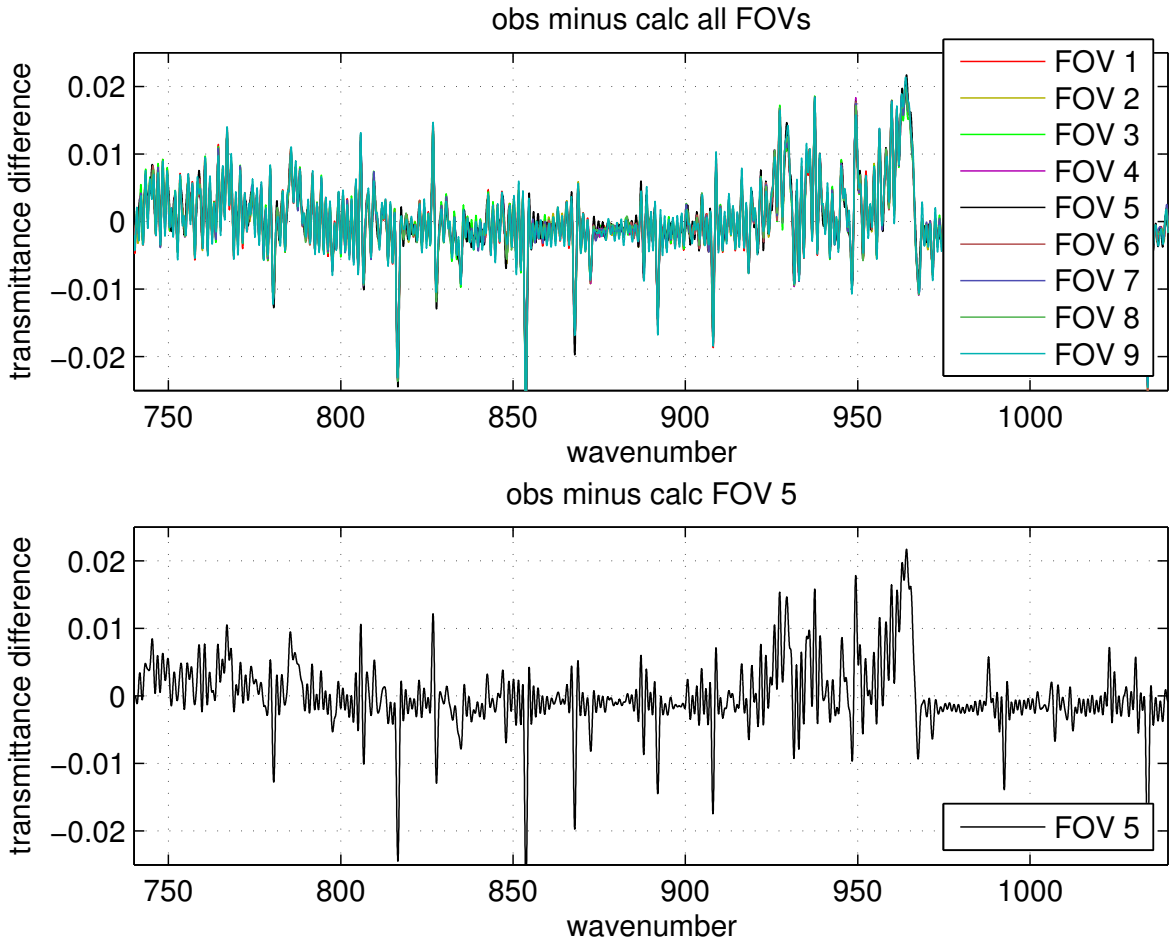
A midband count spectra channel, showing each FOV over the course of the FT1 test segment

NH_3 obs and calc



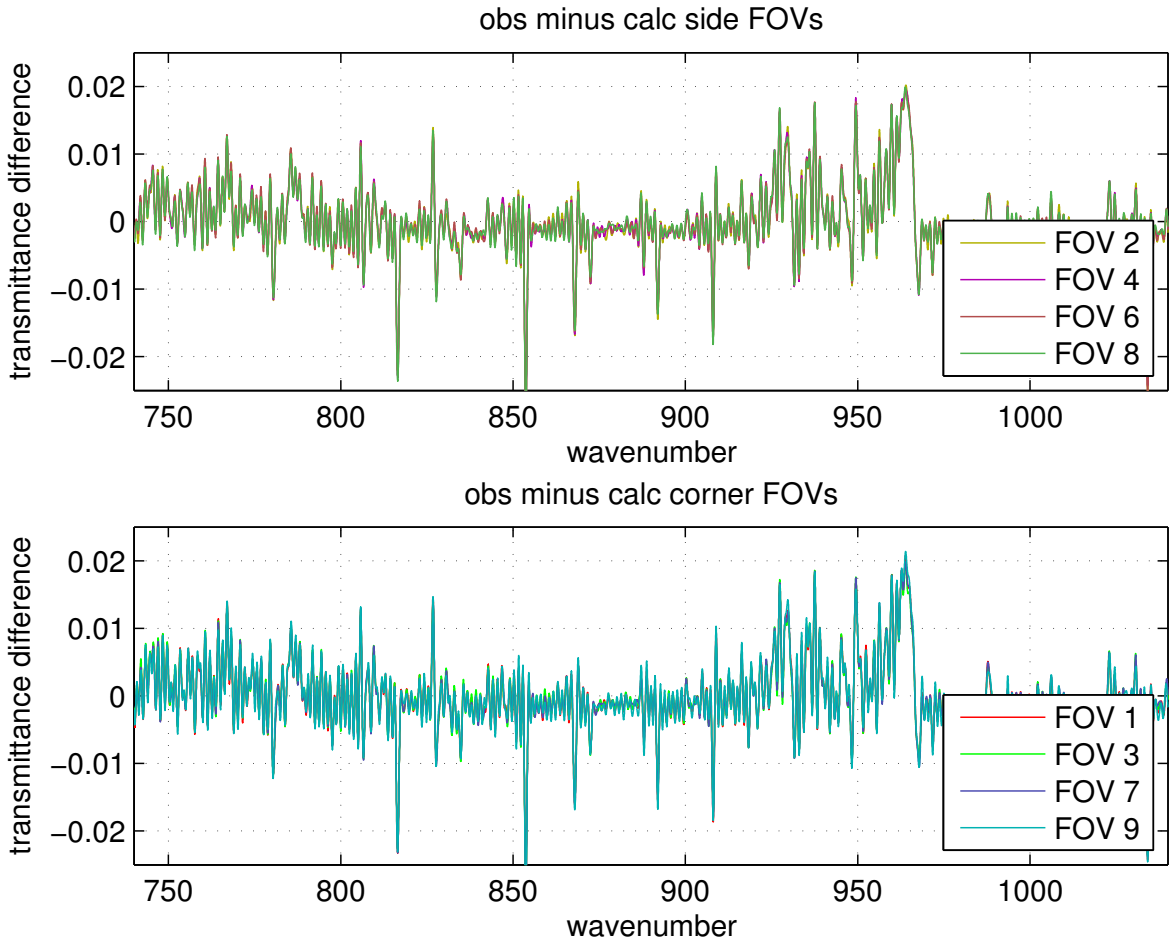
Observed and calculated transmittance for all FOVs, over the fitting interval. At this level of detail we see all values are very close.

NH_3 obs minus calc



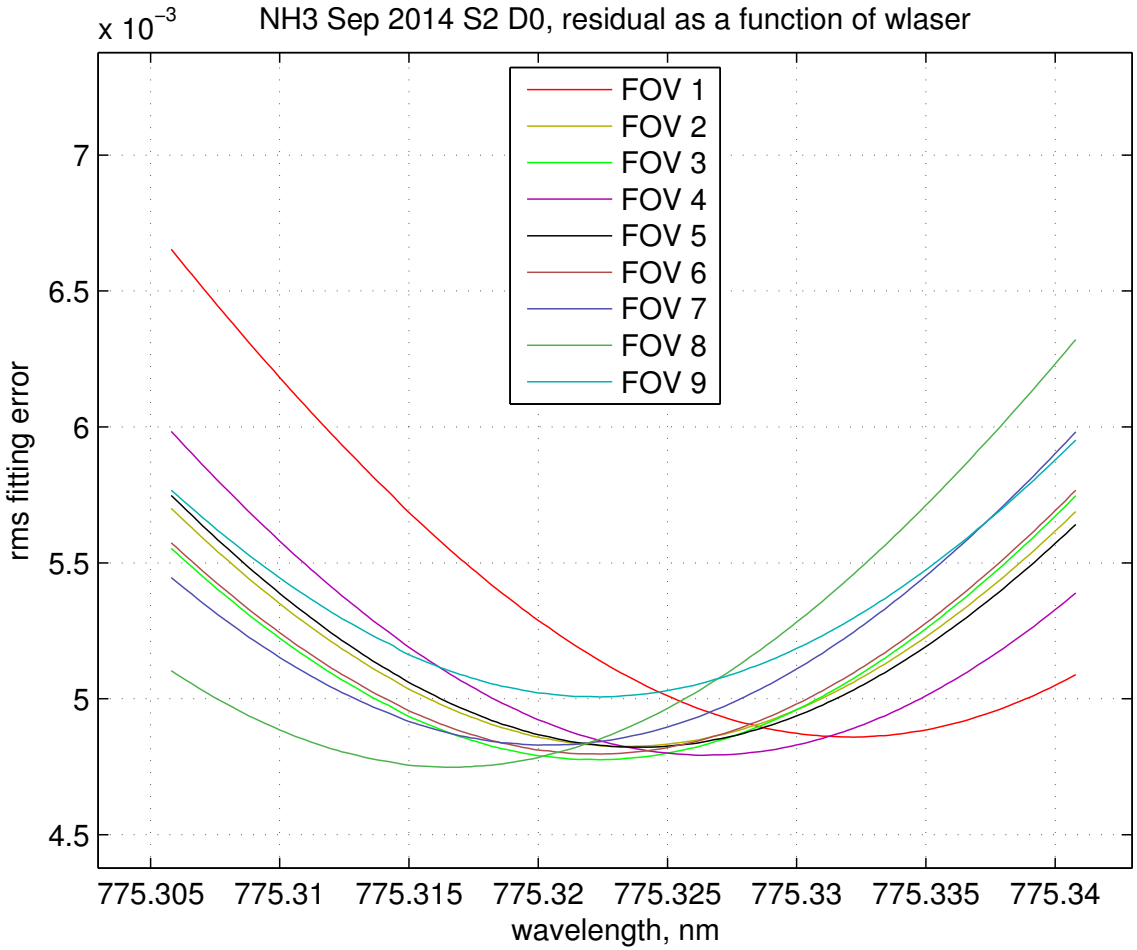
Observed minus calculated transmittance for all FOVs and for FOV 5 alone, over the fitting interval.

NH_3 obs minus calc



Observed minus calculated transmittance for side and corner FOVs, over the fitting interval.

NH_3 fitting residuals



Fitting residuals RMS$(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$ as a function of metrology laser wavelength, for each FOV.

NH_3 tabulated residuals

metrology laser relative residuals, PPM

-5.4171	2.8376	10.3184	7	4	1
-9.8025	0	-1.2898	8	5	2
-2.3216	-2.3216	-2.3216	9	6	3

regression fitting weights and residuals

FOV	"a"	"b"	dmin	wmin	wfov
1	1.019	-0.0182	0.0049	21.15	775.3322
2	1.017	-0.0165	0.0048	9.54	775.3232
3	1.024	-0.0226	0.0048	8.51	775.3224
4	1.020	-0.0195	0.0048	13.67	775.3264
5	1.001	-0.0031	0.0048	10.83	775.3242
6	1.024	-0.0233	0.0048	8.51	775.3224
7	1.026	-0.0242	0.0048	5.42	775.3200
8	1.022	-0.0212	0.0047	1.03	775.3166
9	1.022	-0.0213	0.0050	8.51	775.3224

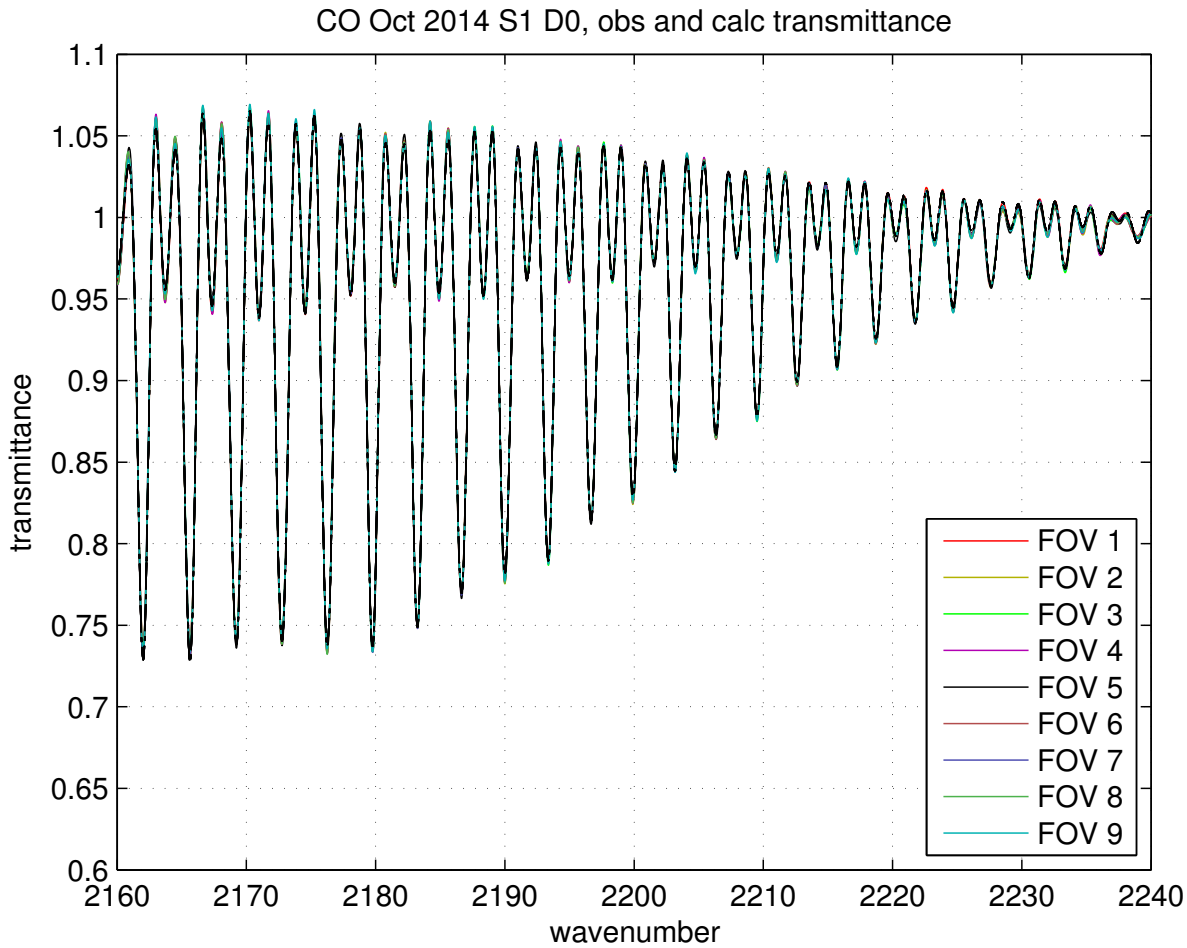
NH_3 summary

- the fitting interval was chosen to include significant spectral detail
- the *a* and *b* residual weights are close to 1 and 0, suggesting the estimate of 7 torr NH_3 partial pressure is not too far off.
- although this was a side 2 test, we got better results with the Fall 2013 Exelis side 1 focal plane, and that is what is shown here
- the metrology laser residuals are good, but can probably be reduced significantly with small adjustments to the focal plane model
- the residual plots are very similar for all FOVs

CO test parameters

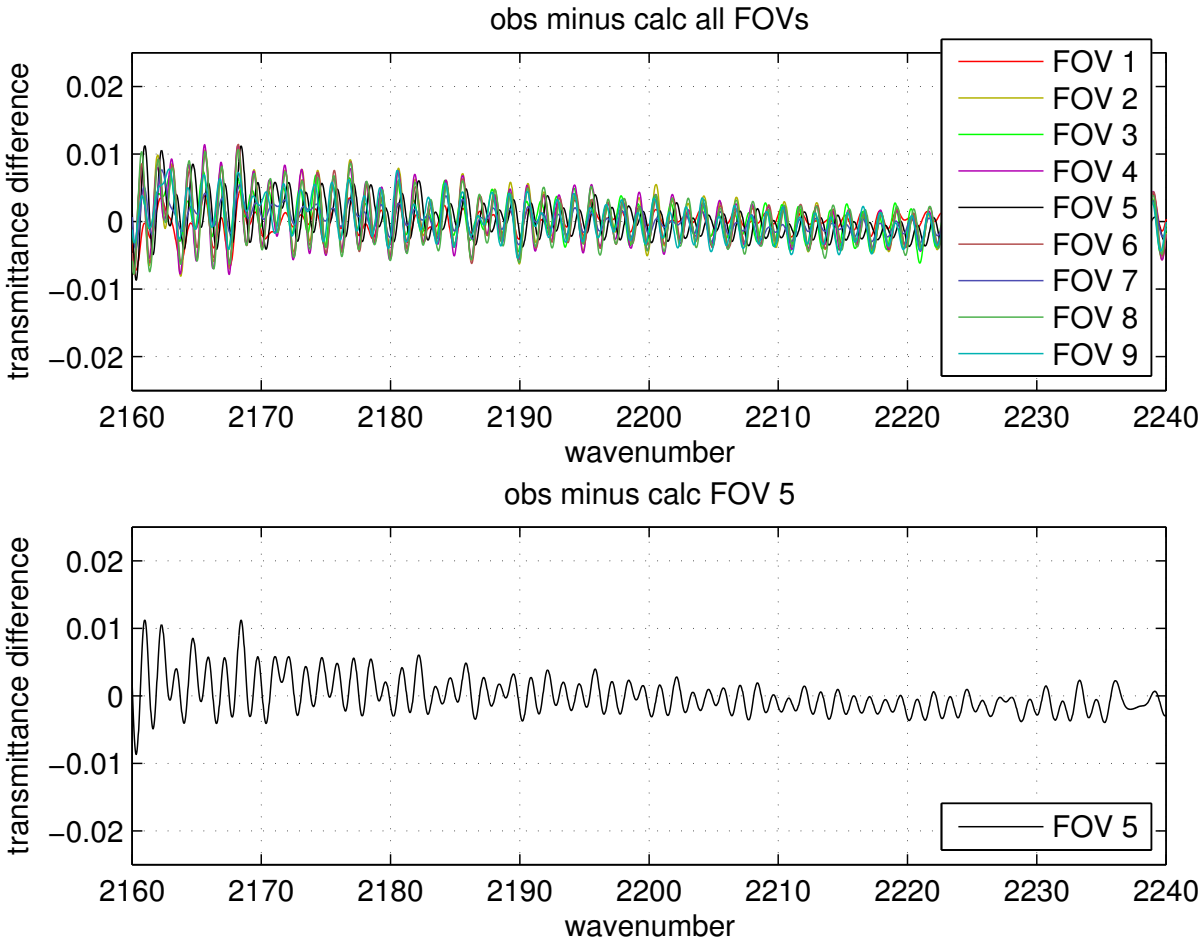
- fitting interval 2160 to 2240 cm^{-1}
- metrology laser wavelength from neon cal
- Oct 2013 Exelis side 1 focal plane values
- ILS with periodic sinc wrap at the sensor grid
- 330 observations in each test leg
- gas cell nominal pressure 40 torr
- gas cell CO partial pressure 26 torr
- gas cell temperature 17.7 C
- gas cell length 12.59 cm
- HTBB nominal T1 335 K, T2 320 K

CO obs and calc



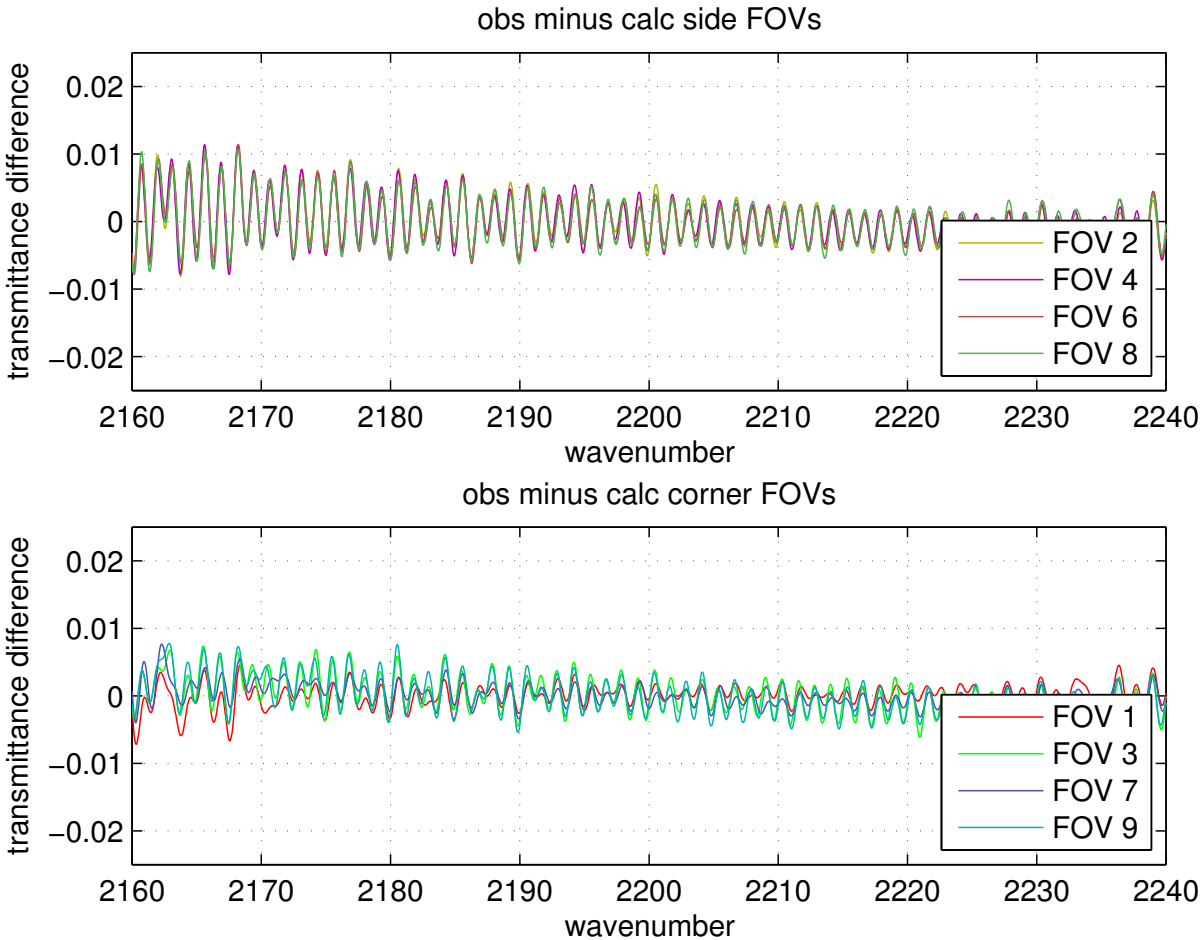
Observed and calculated transmittance for all FOVs, over the fitting interval. At this level of detail we see all values are very close.

CO obs minus calc



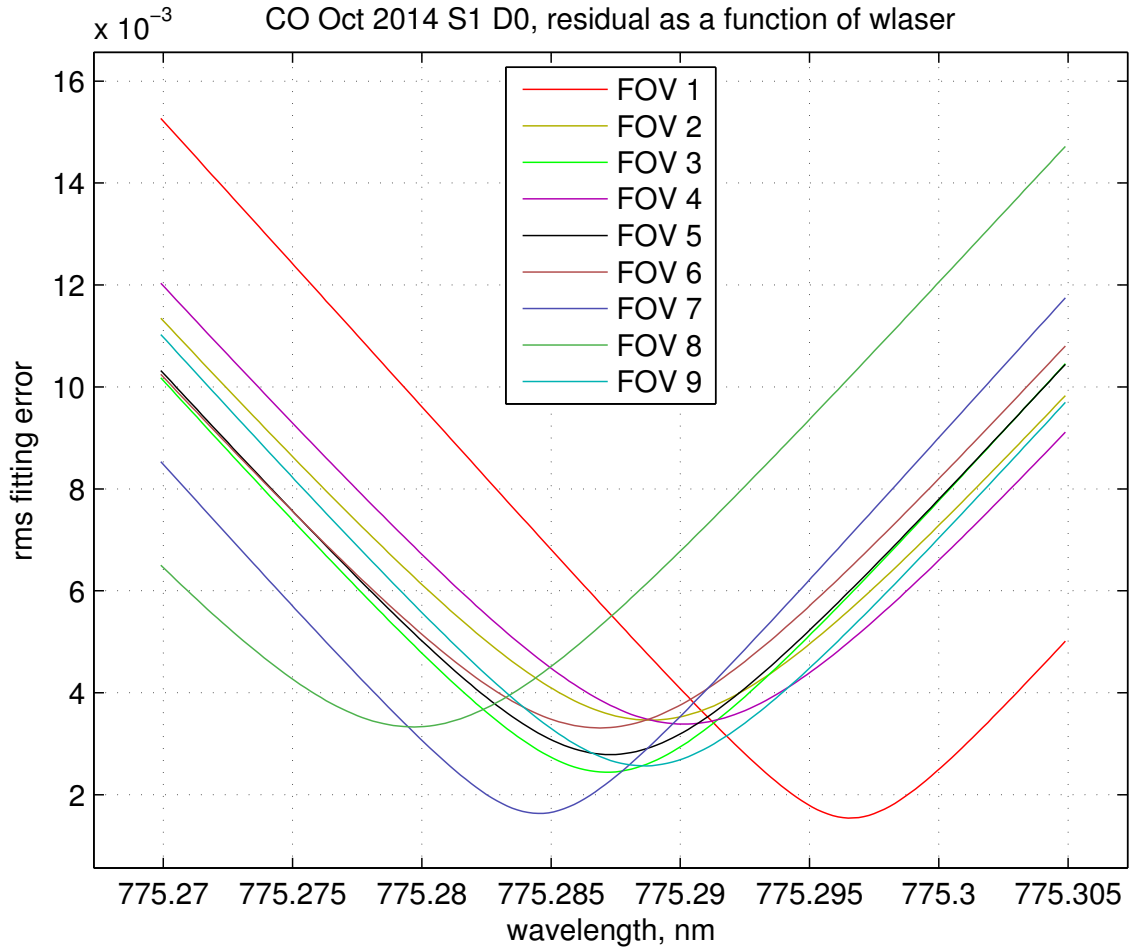
Observed minus calculated transmittance for all FOVs and for FOV 5 alone, over the fitting interval.

CO obs minus calc



Observed minus calculated transmittance for side and corner FOVs, over the fitting interval.

CO fitting residuals



Fitting residuals RMS$(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$ as a function of metrology laser wavelength, for each FOV.

CO tabulated residuals

metrology laser relative residuals, PPM

-3.6116	3.6116	11.8666	7	4	1
-9.8028	0	2.0638	8	5	2
1.8058	-0.5159	-0.2580	9	6	3

regression fitting weights and residuals

FOV	"a"	"b"	dmin	wmin	wfov
1	1.107	0.0063	0.0015	14.96	775.2965
2	1.007	-0.0096	0.0035	5.16	775.2889
3	1.005	-0.0078	0.0024	2.84	775.2871
4	1.003	-0.0084	0.0034	6.71	775.2901
5	0.999	-0.0029	0.0028	3.10	775.2873
6	1.007	-0.0110	0.0033	2.58	775.2869
7	1.000	-0.0088	0.0016	-0.52	775.2845
8	1.008	-0.0161	0.0033	-6.71	775.2797
9	0.987	0.0049	0.0026	4.90	775.2887

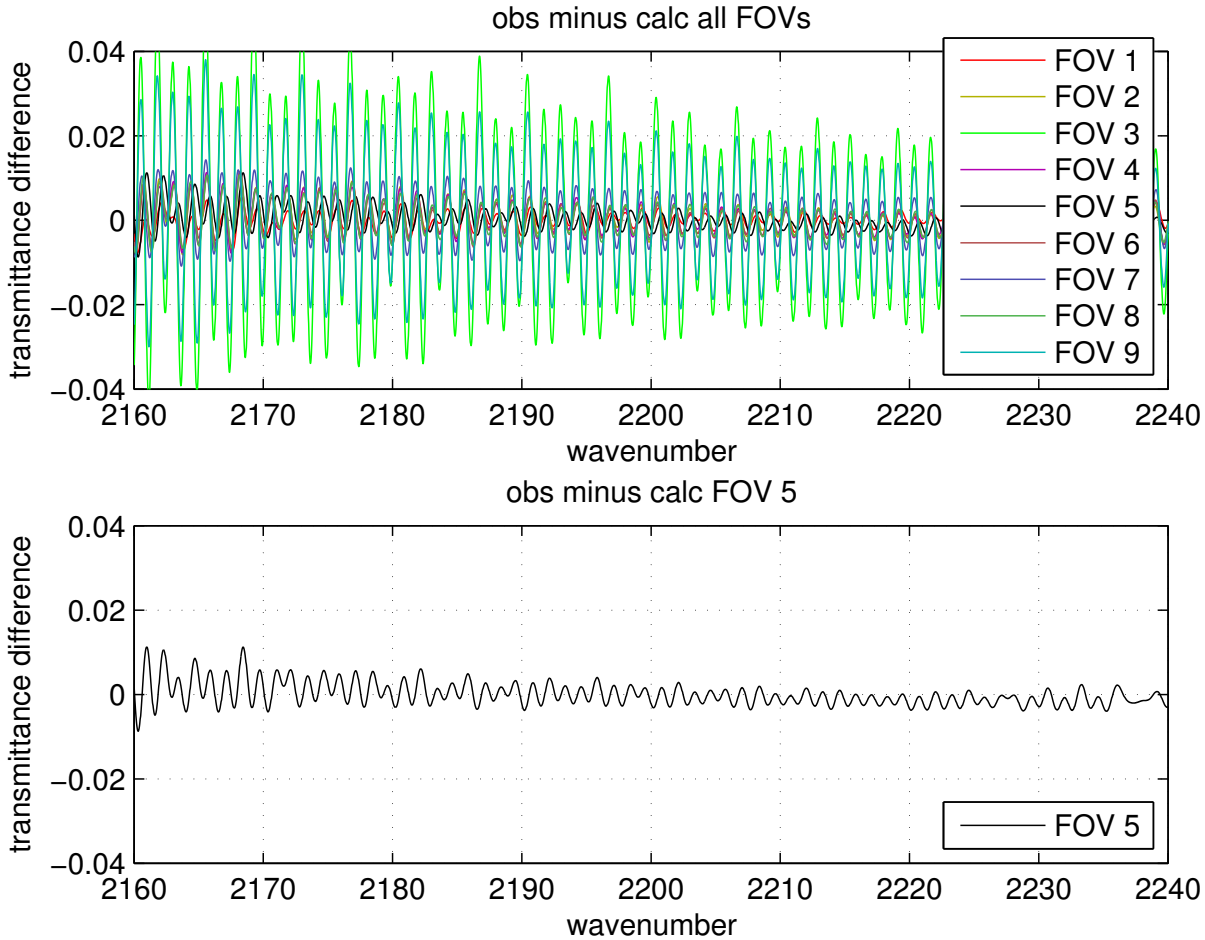
CO summary

- the fitting interval was chosen to include significant spectral detail
- the *a* residual weight for FOV 1 is significantly greater than 1. (*a* is a scaling factor and *b* an offset applied to the observed data.)
- aside from FOV 1 the *a* and *b* weights are very close to 1 and 0, suggesting our estimate of 26 torr CO partial pressure is close.
- as with NH_3 the metrology laser residuals are good, but can probably be reduced significantly with small adjustments to the focal plane model
- note that the residual plots are very similar for all FOVs. This is significant for the high res SW band, which has the strongest SA correction

CO with regular sinc

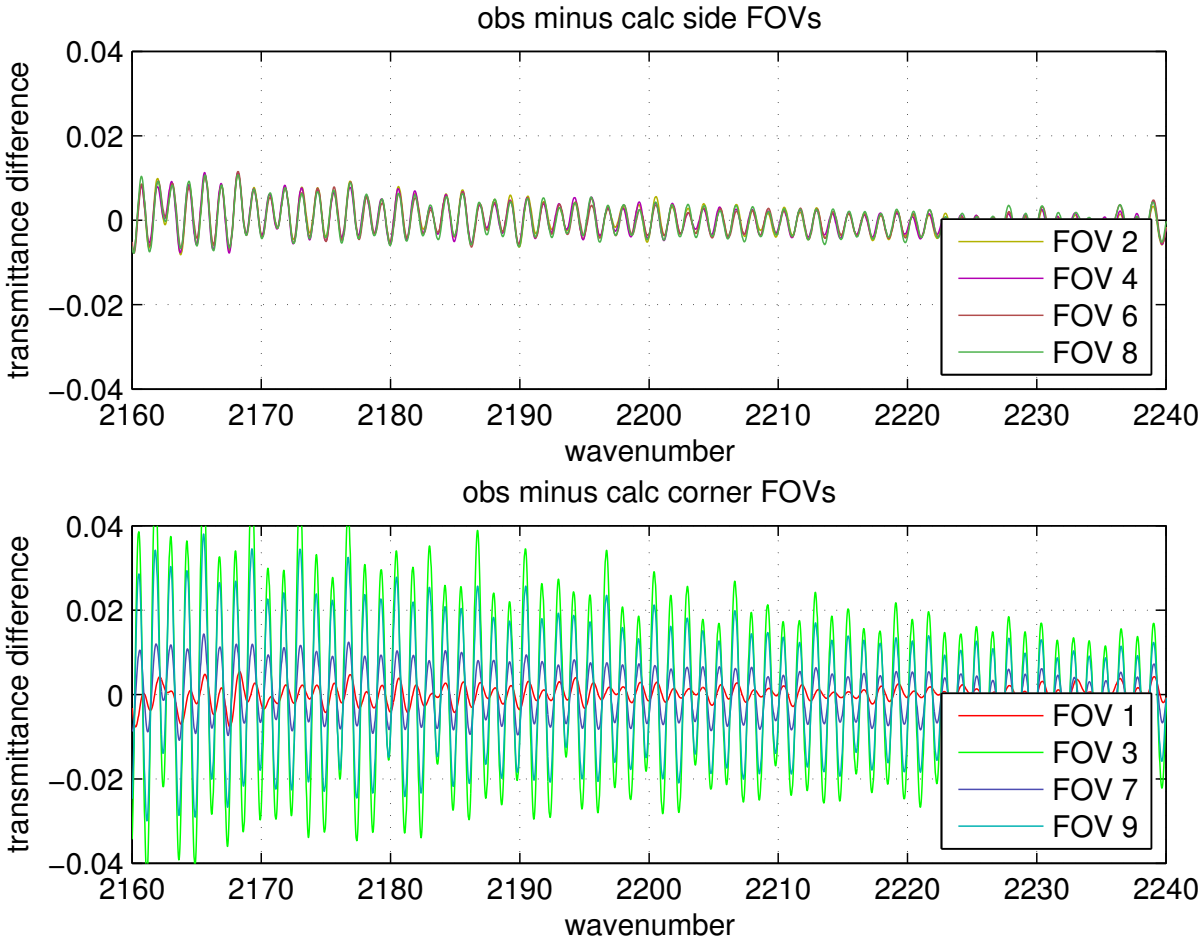
- the CO test above was done with ILS functions using
  1. periodic sinc with the wrap at the decimated sensor grid
  2. periodic sinc with the wrap at the undecimated sensor grid
  3. regular sinc
- we have shown results for (1), and did not find any difference between (2) and (3). We present results for (3), regular sinc.
- note that since our tests are done at the sensor grid, the ILS is only present in the SA correction

sinc obs minus calc



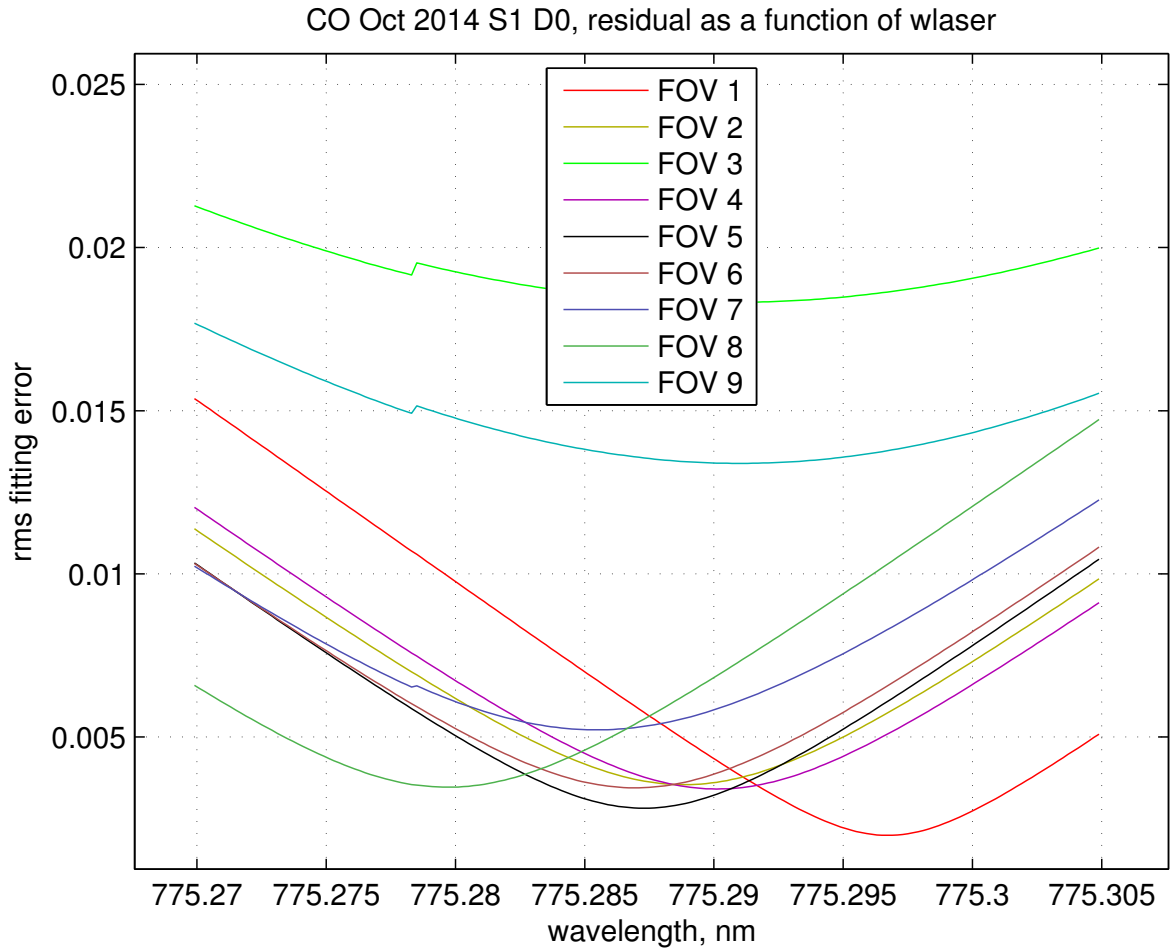
Observed minus calculated transmittance for all FOVs and for FOV 5 alone, with sinc ILS

sinc obs minus calc



Observed minus calculated transmittance for side and corner FOVs, with sinc ILS.

sinc fitting residuals



Fitting residuals RMS$(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$ as a function of metrology laser wavelength for each FOV, with sinc ILS

sinc tabulated residuals

metrology laser relative residuals, PPM

-2.5797	3.6116	12.1246	7	4	1
-9.8028	0	2.0638	8	5	2
4.9014	-0.5159	4.1275	9	6	3

regression fitting weights and residuals

FOV	"a"	"b"	dmin	wmin	wfov
1	1.108	0.0061	0.0020	15.22	775.2967
2	1.007	-0.0095	0.0035	5.16	775.2889
3	0.942	0.0532	0.0183	7.22	775.2905
4	1.003	-0.0084	0.0034	6.71	775.2901
5	0.999	-0.0029	0.0028	3.10	775.2873
6	1.006	-0.0107	0.0034	2.58	775.2869
7	0.995	-0.0039	0.0052	0.52	775.2853
8	1.008	-0.0159	0.0035	-6.71	775.2797
9	0.954	0.0368	0.0134	8.00	775.2911

sinc observations

- the residuals RMS$(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$ for corner FOVs 3 and 9 are significantly greater with regular sinc
- the same residuals for corner FOVs 1 and 7 are slightly greater with regular sinc

FOV	psinc	sinc
1	0.0015	0.0020
3	0.0024	0.0183
7	0.0016	0.0052
9	0.0026	0.0134

- this is suggestive but not conclusive, due to the large variation among the corner FOVs with regular sinc.
- although the FOV 1 sinc residual is greater than the psinc, it is smaller than any of the other sinc residuals.