Initial Analysis of CrIS TVAC MN Gas Cell Tests

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October 22, 2014

overview

- preliminary analysis of the CO, CH_4, and NH_3 TVAC MN gas cell tests for the three CrIS bands shows good agreement with calculated data
- the metrology laser residuals are generally consistent for all three bands
- the observed and directly measured cell pressures are now much closer
- calculated spectra are from UMBC line-by-line software by S. DeSouza-Machado, convolved to the CrIS sensor grid
- for each test, the fitting interval was chosen to include significant spectral detail

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

$$\tau = \frac{FT_2 - FT_1}{ET_2 - ET_1}$$

  gives a good approximation of the gas cell transmittance.

- τ is then compared with calculated transmittance, to verify instrument calibration

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 $\tau_{\mathrm{obs}} = f \circ \mathrm{SA}^{-1} \circ f((\mathrm{FT}_2 - \mathrm{FT}_1)/(\mathrm{ET}_2 - \mathrm{ET}_1))$
- ▶ compare observed and calculated transmittance spectra at the sensor grid

This process is embedded in a search where we minimize $\mathrm{RMS}(a \cdot \tau_{\mathrm{obs}} + b - \tau_{\mathrm{calc}})$ 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

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 measured pressure 40.5 torr
- gas cell calculated pressure 41 torr
- gas cell temperature 17 C
- gas cell length 12.59 cm
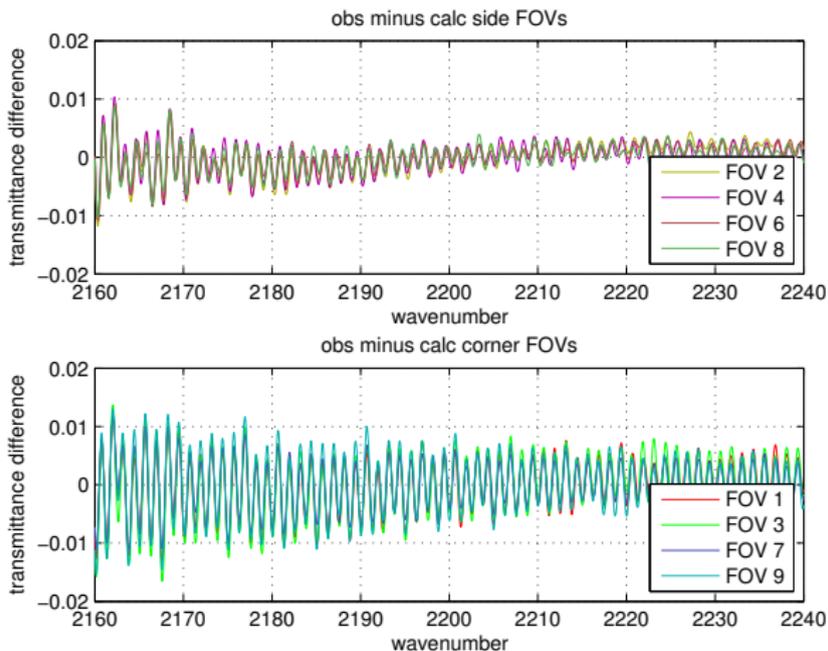- HTBB nominal T1 335 K, T2 320 K

CO obs and calc
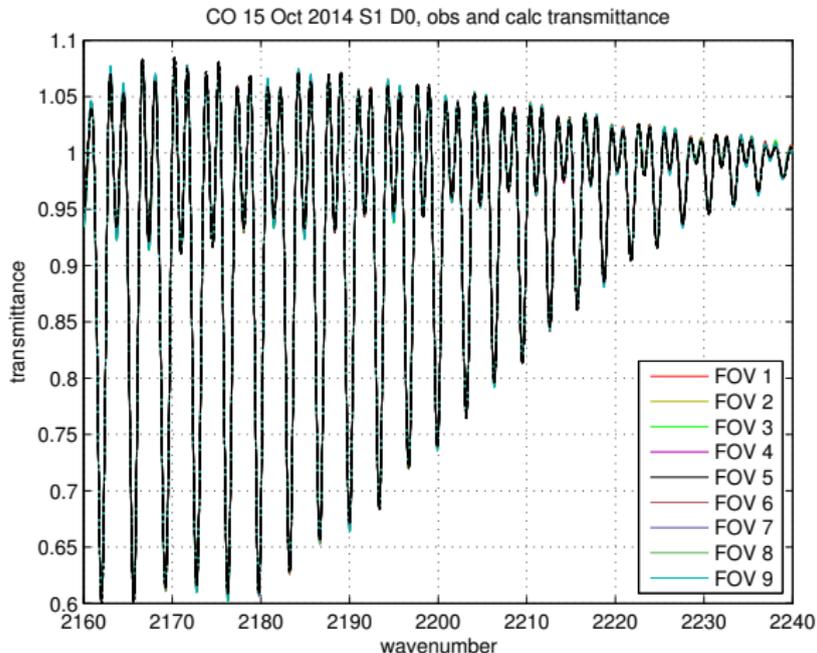
Observed and calculated transmittance for all FOVs, over the fitting interval. At this level of detail we see all values are very close.
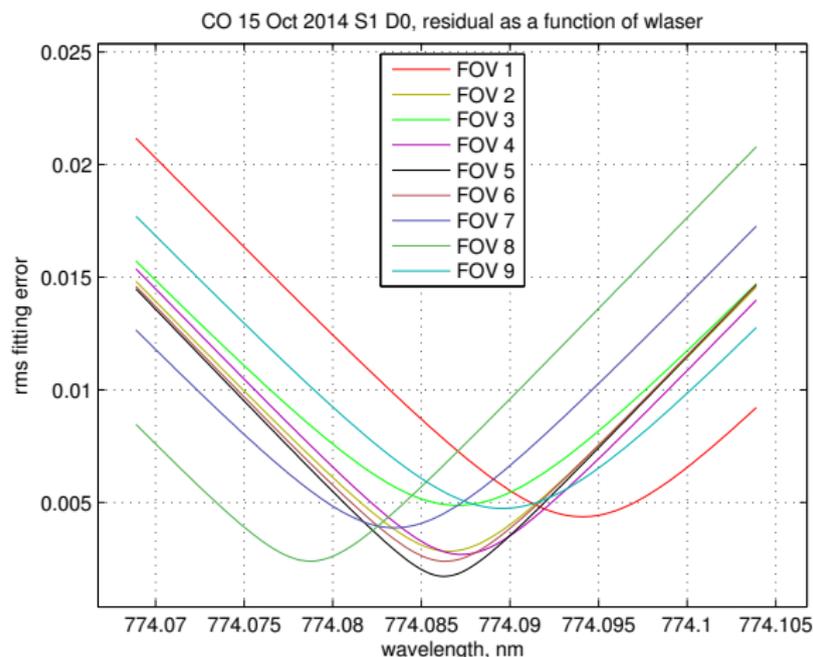
CO obs minus calc
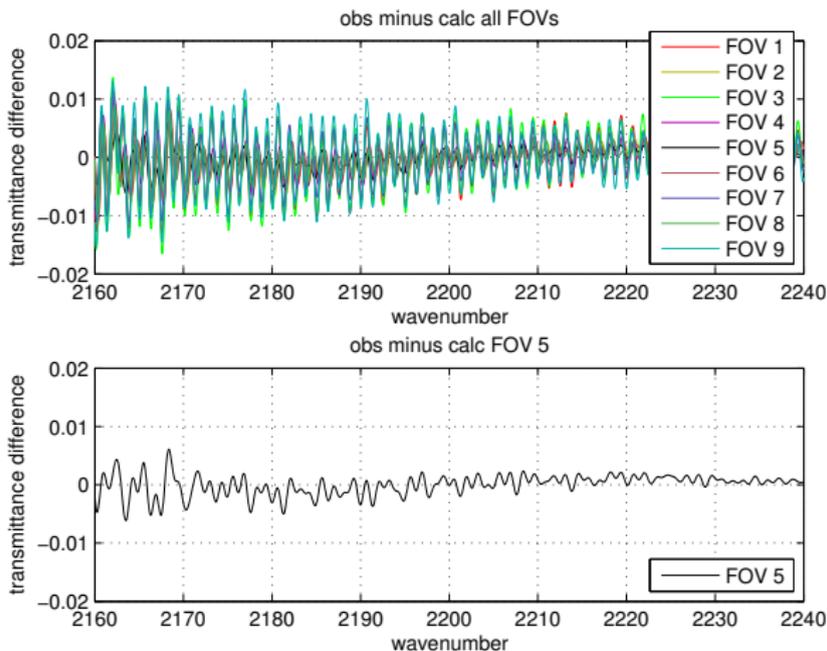
Observed minus calculated transmittance for all FOVs and for FOV 5 alone, over the fitting interval.

CO obs minus calc

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

CO fitting residuals

CO 15 Oct 2014 S1 D0, residual as a function of wlaser

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

CO tabulated residuals

metrology laser relative residuals, PPM

−3.6172	1.2918	10.0764	7	4	1
−9.8181	0	0.2584	8	5	2
4.1339	0	1.0335	9	6	3

regression fitting weights and residuals

| FOV	"a"	"b"	dmin	wmin	wfov
1	0.993	0.0125	0.0044	13.18	774.0941
2	1.003	0.0020	0.0028	3.36	774.0865
3	0.997	0.0079	0.0049	4.13	774.0871
4	1.001	0.0014	0.0027	4.39	774.0873
5	0.992	0.0090	0.0017	3.10	774.0863
6	0.997	0.0038	0.0024	3.10	774.0863
7	0.999	0.0011	0.0039	−0.52	774.0835
8	1.005	−0.0056	0.0024	−6.72	774.0787
9	0.985	0.0129	0.0047	7.23	774.0895

CO summary

- results are similar to the previous TVAC CO test, where the cell pressure was estimated to be 26 torr
- the metrology laser residuals are within 2 or 3 ppm of the corresponding residuals from the previous TVAC CO test
- the a and b weights are close to 1 and 0, suggesting our estimate of 41 torr CO is in reasonable agreement with the measured value of 40.5 torr.
- the FOV 1 a weight in the previous CO test was about ten percent too high. The new value is much closer to 1.
- the breakouts by side and corner FOVs show the residuals are only slightly greater for the corner FOVs. This is significant for the high res SW band, which has the strongest SA correction

CH$_4$ test parameters

- fitting interval 1220 to 1380 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 measured pressure 39.4 torr
- gas cell calculated pressure 40 torr
- gas cell temperature 16.9 C
- gas cell length 12.59 cm
- HTBB nominal T1 360 K, T2 320 K
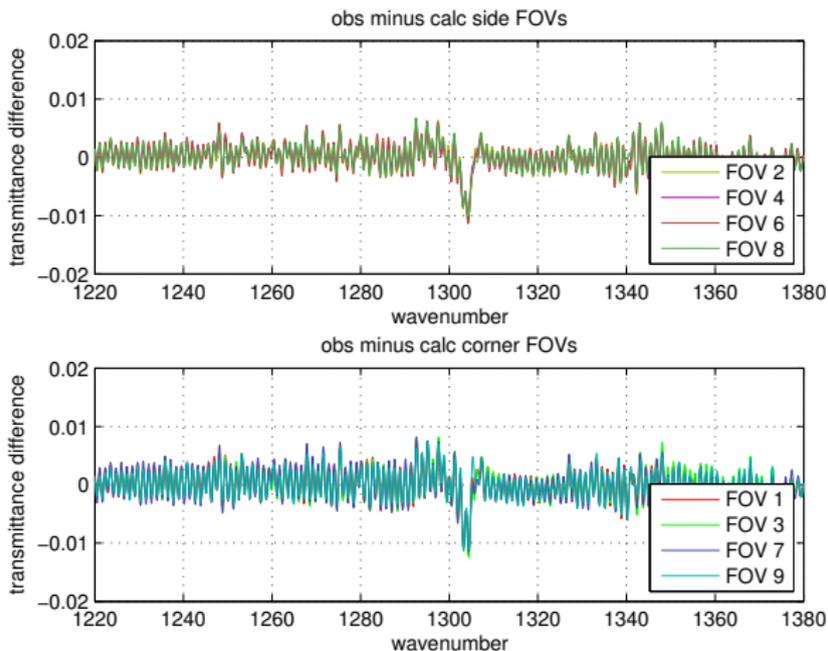
CH$_4$ obs and calc
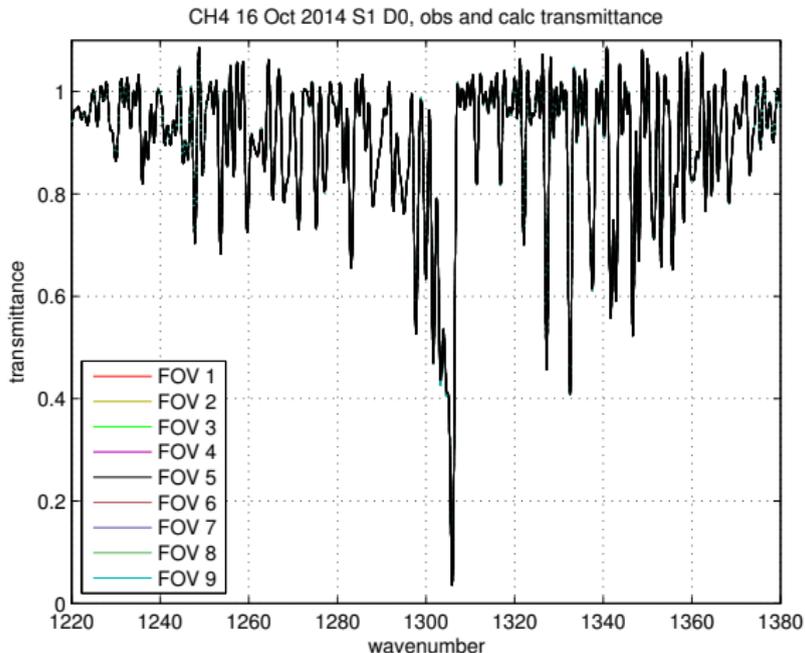
Observed and calculated transmittance for all FOVs, over the fitting interval. At this level of detail we see all values are very close.

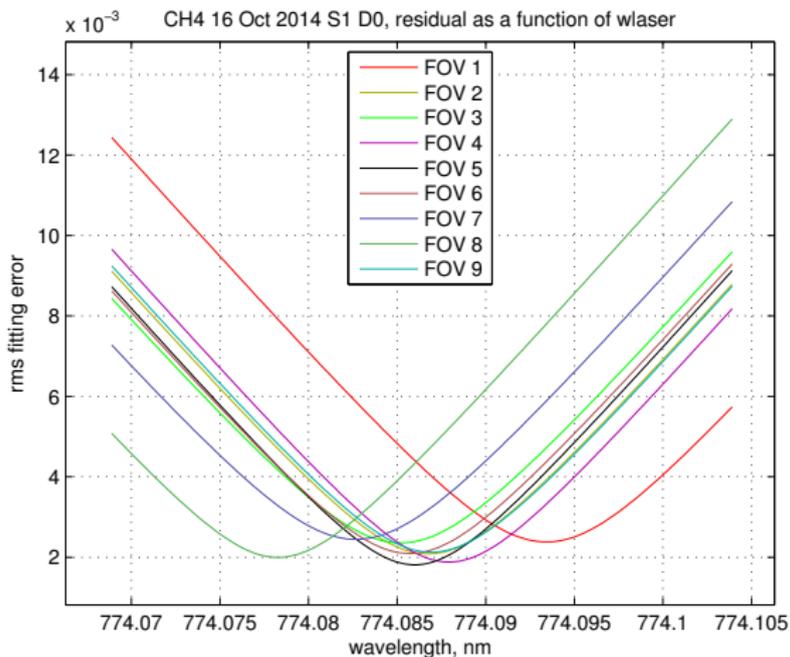# CH$_4$ obs minus calc
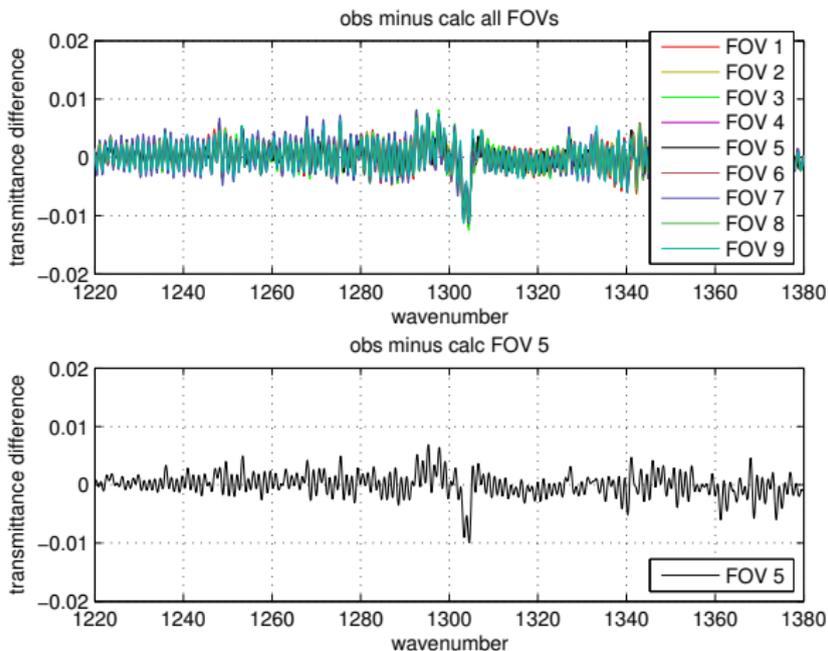
Observed minus calculated transmittance for all FOVs and for FOV 5 alone, over the fitting interval.

CH$_4$ obs minus calc

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

CH$_4$ fitting residuals

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

CH$_4$ tabulated residuals

metrology laser relative residuals, PPM

−4.3923	2.3253	9.5597	7	4	1
−10.0764	0	0.7751	8	5	2
1.0335	−0.5167	−1.2918	9	6	3

regression fitting weights and residuals

| FOV	"a"	"b"	dmin	wmin	wfov
1	1.006	−0.0163	0.0024	12.40	774.0935
2	1.007	−0.0171	0.0021	3.62	774.0867
3	1.009	−0.0186	0.0024	1.55	774.0851
4	1.011	−0.0202	0.0019	5.17	774.0879
5	1.008	−0.0175	0.0018	2.84	774.0861
6	1.014	−0.0227	0.0021	2.33	774.0857
7	1.011	−0.0196	0.0024	−1.55	774.0827
8	1.012	−0.0200	0.0020	−7.23	774.0783
9	0.991	−0.0031	0.0021	3.88	774.0869

CH$_4$ summary

- overall, the results are very good
- the metrology laser residuals are within 2 or 3 ppm of the CO residuals. The consistency between bands is significant.
- the *a* and *b* weights are close to 1 and 0, suggesting our estimate of 40 torr CO is in reasonable agreement with the measured value of 39.4 torr
- the plotted residuals (obs minus calc) are slightly smaller than for the corresponding CO values
- the breakouts by side and corner FOVs show the residuals are only slightly greater for the corner FOVs.

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 measured pressure 39 torr
- gas cell calculated pressure 37 torr
- gas cell temperature 17 C
- gas cell length 12.59 cm
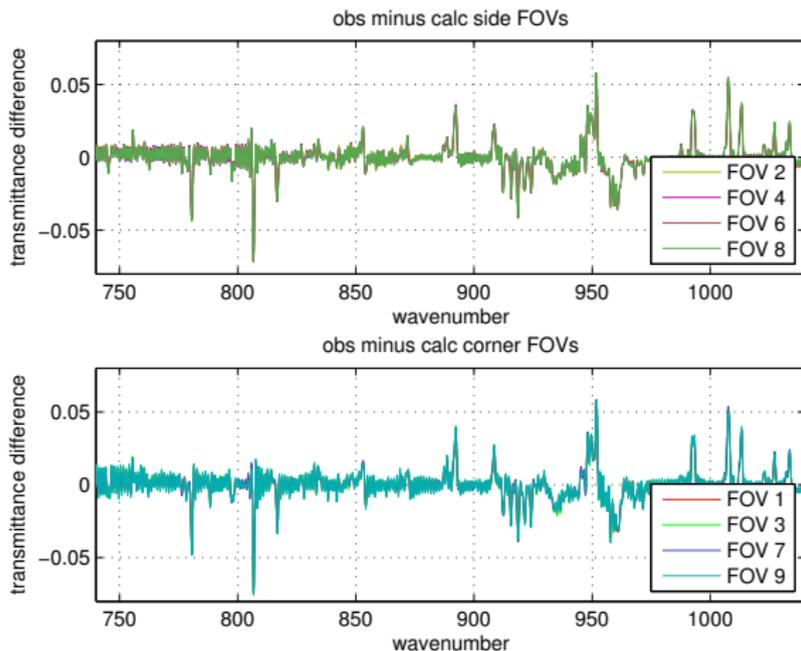- HTBB nominal T1 360 K, T2 320 K

NH₃ obs and calc
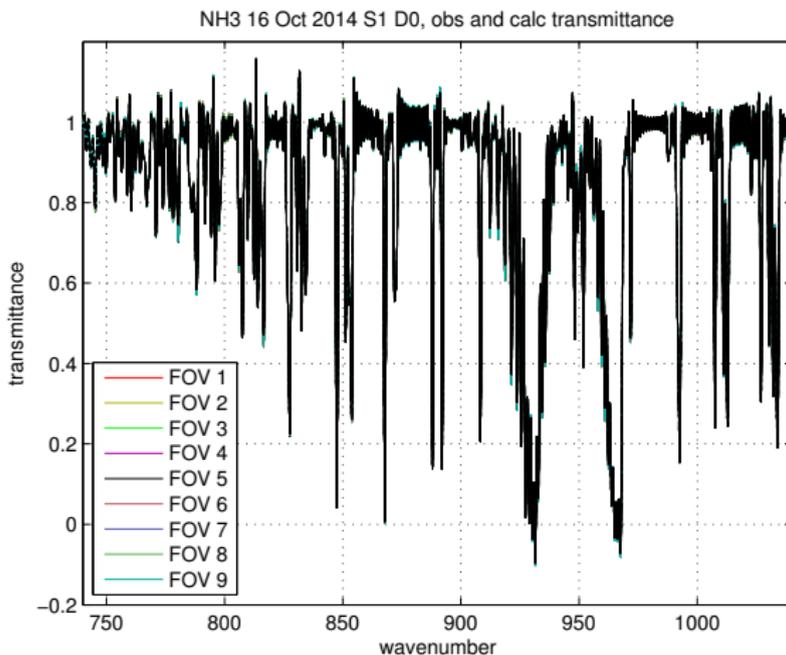
NH3 16 Oct 2014 S1 D0, obs and calc transmittance

Observed and calculated transmittance for all FOVs, over the fitting interval. At this level of detail we see all values are close.
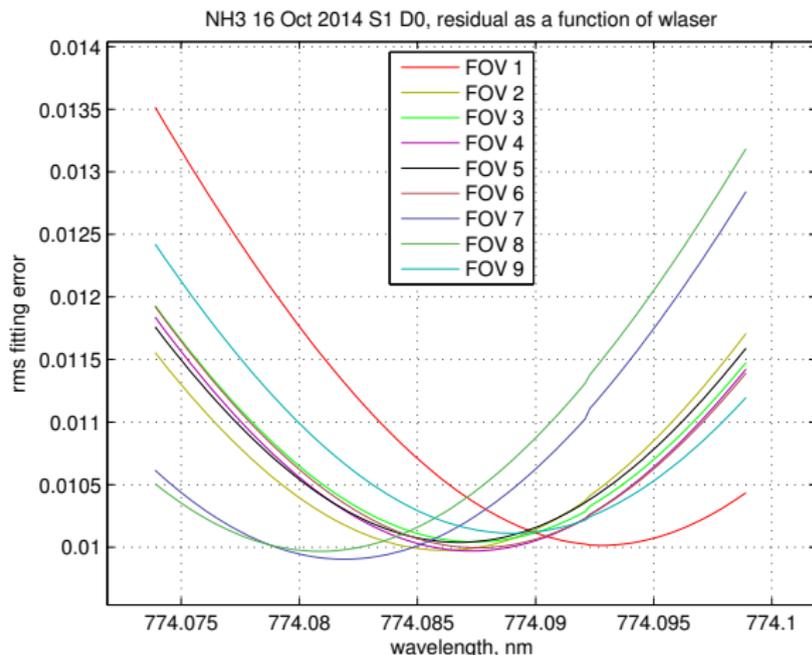
NH$_3$ obs minus calc
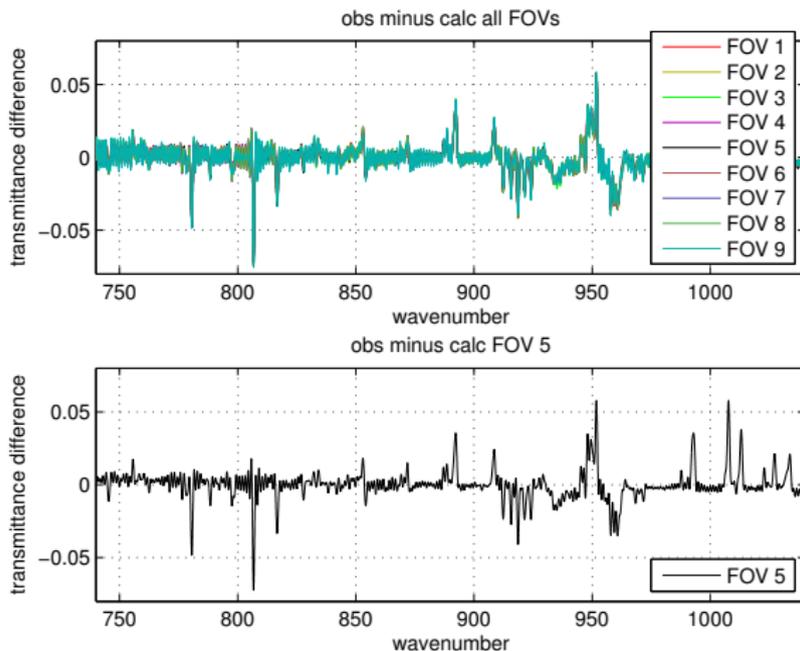
Observed minus calculated transmittance for all FOVs and for
FOV 5 alone, over the fitting interval.

NH₃ obs minus calc

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

NH$_3$ fitting residuals

NH3 16 Oct 2014 S1 D0, residual as a function of wlaser

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

NH$_3$ tabulated residuals

metrology laser relative residuals, PPM

−6.2009	0.7751	7.7511	7	4	1
−7.4927	0	−0.7751	8	5	2
3.1004	1.0335	1.0335	9	6	3

regression fitting weights and residuals

FOV	"a"	"b"	dmin	wmin	wfov
1	1.000	−0.0002	0.0100	11.37	774.0927
2	1.000	−0.0009	0.0100	2.84	774.0861
3	1.002	−0.0023	0.0100	4.65	774.0875
4	0.998	−0.0002	0.0100	4.39	774.0873
5	0.979	0.0117	0.0100	3.62	774.0867
6	1.004	−0.0044	0.0100	4.65	774.0875
7	1.002	−0.0032	0.0099	−2.58	774.0819
8	1.000	−0.0020	0.0100	−3.88	774.0809
9	1.004	−0.0049	0.0101	6.72	774.0891

NH$_3$ summary

- the metrology laser residuals are within 2 or 3 ppm of the CO and CH$_4$ residuals. The consistency among bands is good
- the *a* and *b* residual weights are closer to 1 and 0, in comparison with the previous NH$_3$ test
- the plotted residuals (obs minus calc) are larger but so is the absorption at 37 torr vs 7 torr, in comparison with the previous NH$_3$ test
- the *a* and *b* residual weights are very close to 1 and 0, suggesting our estimate of 37 torr NH$_3$ partial pressure is correct