

June 2021 CrIS J3 TVAC PFH Gas Cell ILS Tests

H. E. Motteler, L. L. Strow,
S. DeSouza-Machado,
S. Buczkowski
June 16, 2021

UMBC Atmospheric Spectroscopy Lab
Joint Center for Earth Systems Technology

Introduction

- We look at the CrIS J3 TVAC PFH Plateau 21 CO₂, CH₄, and CO gas cell ILS tests, and compare measured transmittances with calculated reference truth from LBLRTM and UMBC-LBL.
- Methods and results are overall similar to the PFL tests, and rather than examine each test in detail, we summarize the PFL and PFH metrology laser residuals in tabular form.
- We saw a significant wobble in the PFH CO test observed data. This was removed by using calibrated radiances for the 4-value transmittance ratio, and we discuss the steps in doing that.
- Although we don't dispute the merits of working with calibrated radiances for the transmittance tests, our current methods have worked fairly well, and should be fine for a first look at the remaining MN tests. Longer term, we will probably move to using calibrated radiances for all tests.

TVAC PFL and PFH absolute residual summary

PFL metrology laser absolute residuals by FOV, ppm

Test	1	2	3	4	5	6	7	8	9
5-19 s2 d0 CO2	-25.20	-22.61	-23.26	-0.65	3.23	3.23	20.03	23.26	23.90
5-19 s2 d1 CO2	-25.20	-23.26	-23.26	-0.65	3.23	3.23	19.38	23.26	23.26
5-25 s1 d0 CO2	-25.22	-24.58	-23.93	-1.29	4.53	2.59	20.70	21.99	23.93
5-25 s1 d1 CO2	-25.22	-23.93	-23.93	-1.94	3.88	1.94	20.05	21.34	23.28
5-26 s1 d0 CH4	-21.34	-21.34	-18.11	1.29	2.59	4.53	21.99	23.93	27.81
5-27 s1 d0 CO	-19.40	-20.70	-18.11	2.59	3.23	5.82	26.52	28.46	31.69

PFH metrology laser absolute residuals by FOV, ppm

Test	1	2	3	4	5	6	7	8	9
6-1 s1 d0 CO	-16.11	-19.34	-19.34	7.09	5.80	5.80	32.23	30.94	32.23
6-1 s1 d0 CH4	-18.69	-21.27	-22.56	6.45	5.16	3.22	28.36	27.72	27.07
6-2 s1 d0 CO2	-19.98	-20.63	-23.85	5.80	8.38	4.51	28.36	28.36	25.78
6-6 s2 d0 CO2	-23.18	-25.12	-25.76	2.58	4.51	0.64	24.47	25.12	21.90

The same value for Neon calibration, 703.44765 nm, is used for all tests.

TVAC PFL and PFH relative residual summary

PFL metrology laser relative residuals by FOV, ppm

Test	1	2	3	4	5	6	7	8	9
5-19 s2 d0 CO2	-28.43	-25.84	-26.49	-3.88	0.00	0.00	16.80	20.03	20.67
5-19 s2 d1 CO2	-28.43	-26.49	-26.49	-3.88	0.00	0.00	16.15	20.03	20.03
5-25 s1 d0 CO2	-29.75	-29.10	-28.46	-5.82	0.00	-1.94	16.17	17.46	19.40
5-25 s1 d1 CO2	-29.10	-27.81	-27.81	-5.82	0.00	-1.94	16.17	17.46	19.40
5-26 s1 d0 CH4	-23.93	-23.93	-20.70	-1.29	0.00	1.94	19.40	21.34	25.22
5-27 s1 d0 CO	-22.64	-23.93	-21.34	-0.65	0.00	2.59	23.28	25.22	28.46

PFH metrology laser relative residuals by FOV, ppm

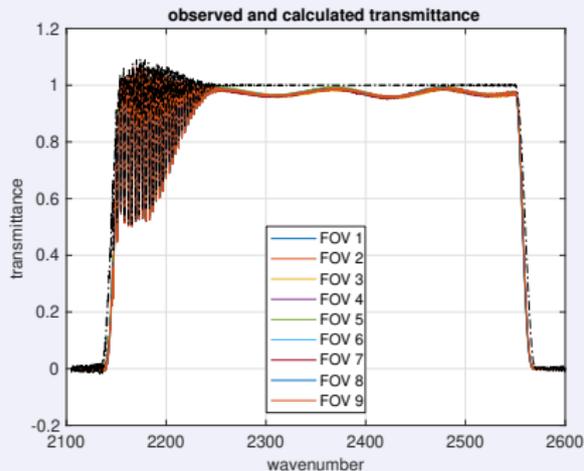
Test	1	2	3	4	5	6	7	8	9
6-1 s1 d0 CO	-21.91	-25.14	-25.14	1.29	0.00	0.00	26.43	25.14	26.43
6-1 s1 d0 CH4	-23.85	-26.43	-27.72	1.29	0.00	-1.93	23.20	22.56	21.91
6-2 s1 d0 CO2	-28.36	-29.00	-32.23	-2.58	0.00	-3.87	19.98	19.98	17.40
6-6 s2 d0 CO2	-27.69	-29.62	-30.27	-1.93	0.00	-3.86	19.96	20.61	17.39

The relative metrology laser residuals emphasize consistency among the tests.

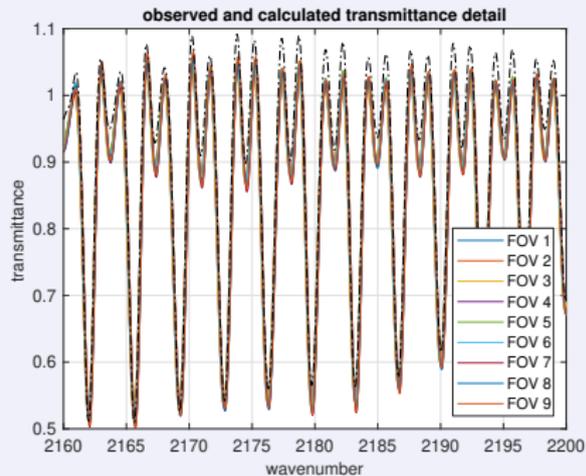
CO SW PFH side 1 test parameters

- PFL Plateau 21, 1 June 2021
- side 1, sweep direction 0
- fitting interval 2160 to 2240 cm^{-1}
- metrology laser 775.73301 nm, from neon 703.44765 nm
- ATBD default focal plane
- SA correction from ILS with periodic sinc at the sensor grid
- HTBB nominal T1 330 K, T2 320 K
- gas cell pressure 49.0 Torr
- gas cell temperature 18.5 C
- gas cell length 12.59 cm

CO PFH side 1 data before fitting

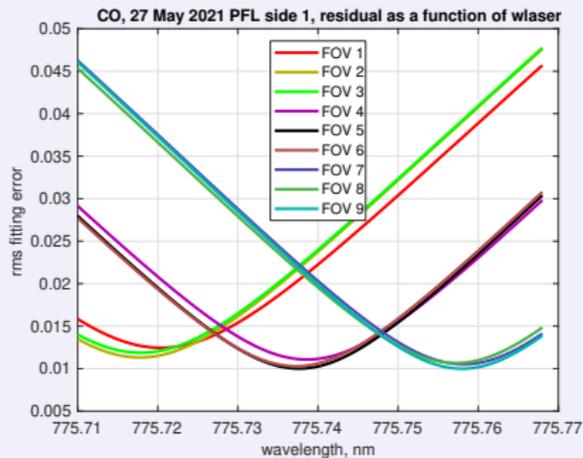


Observed and calculated transmittance, after the SA correction but before any fitting. We see a significant wobble in the observed data.

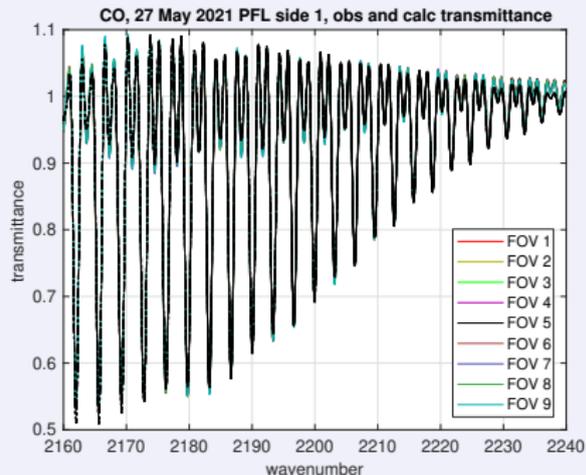


A detail from the previous plot. The wobble is noticeable even over the shorter spectral interval shown here.

CO side 1 fitting overview

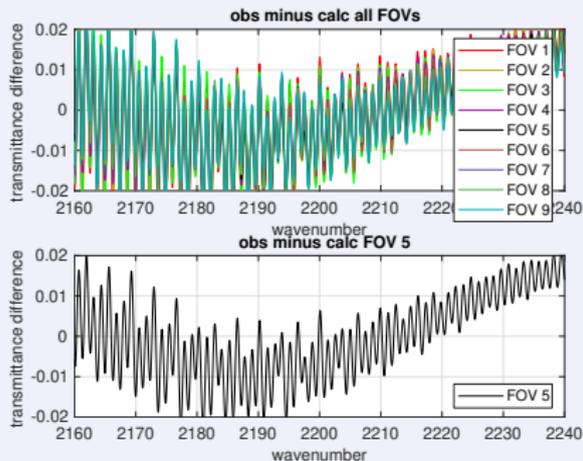


Residuals $\text{RMS}(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$
over the fitting interval as a function
of metrology laser wavelength.

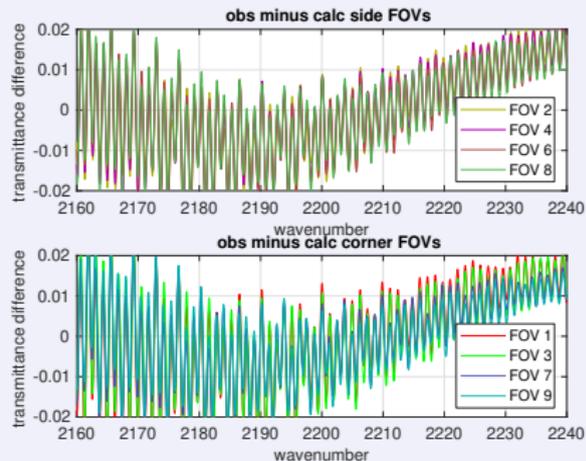


Fitted observed and calculated
transmittance, over the fitting interval.
The differences are reduced.

CO PFH side 1 obs minus calc breakouts



Fitted observed minus calculated transmittance for all FOVs and for FOV 5 alone, over the fitting interval. We see the wobble in the residuals.



Fitted observed minus calculated transmittance for side and corner FOVs, over the fitting interval. As before, we see the wobble in the residuals.

CO PFH side 1 tabulated residuals

metrology laser absolute residuals, ppm

32.23	7.09	-16.11	7	4	1
30.94	5.80	-19.34	8	5	2
32.23	5.80	-19.34	9	6	3

metrology laser relative residuals, ppm

26.43	1.29	-21.91	7	4	1
25.14	0.00	-25.14	8	5	2
26.43	0.00	-25.14	9	6	3

regression fitting weights and residuals

FOV	"a"	"b"	dmin	wmin	wfov
1	1.027	0.0025	0.0124	-16.11	775.7205
2	1.034	-0.0033	0.0113	-19.34	775.7180
3	1.040	-0.0051	0.0119	-19.34	775.7180
4	1.011	0.0146	0.0111	7.09	775.7385
5	1.006	0.0175	0.0100	5.80	775.7375
6	1.017	0.0095	0.0103	5.80	775.7375
7	1.000	0.0294	0.0105	32.23	775.7580
8	1.005	0.0240	0.0107	30.94	775.7570
9	0.998	0.0287	0.0100	32.23	775.7580

Transmittance from calibrated radiances

- The test data stream includes IT and SP looks that we can use to produce calibrated ES (gas cell) data. The calibration looks span the ES looks, the general pattern is IT, SP, ES, SP, IT.
- Let $\overline{ES} = \text{mean}(ES)$, $\overline{IT} = \text{mean}(IT)$, and $\overline{SP} = \text{mean}(SP)$, then we have calibrated radiances at the sensor grid as

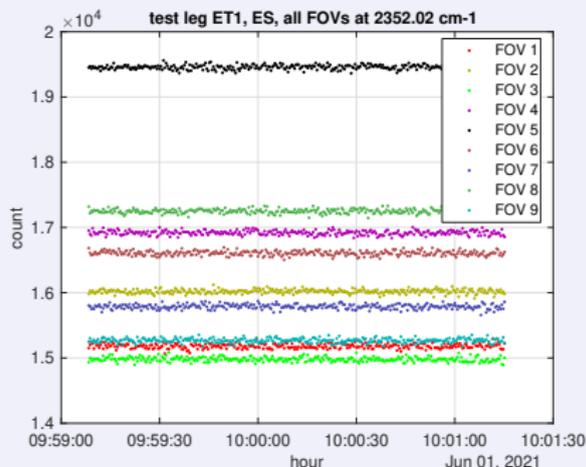
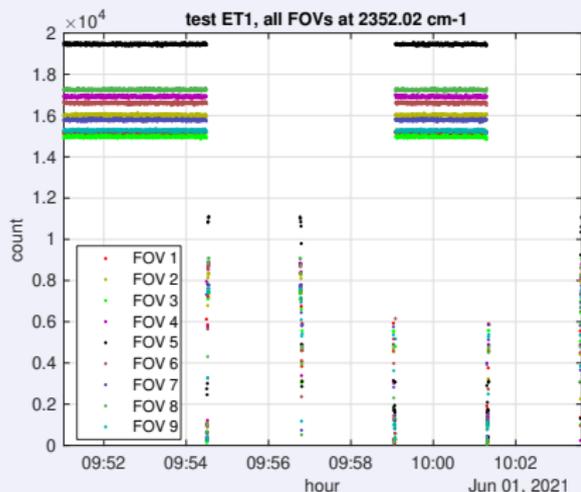
$$r_{ES}^{\text{sensor}} = r_{ICT}^{\text{sensor}} \cdot f_{\text{cos}} \cdot SA^{-1} \cdot f_{\text{cos}} \cdot \frac{\overline{ES} - \overline{SP}}{\overline{IT} - \overline{SP}} \quad (1)$$

- We do this for each test leg (ET1, ET2, FT1, and FT2), and get the gas cell transmittance, at the sensor grid, as the real component of

$$\tau = \frac{r_{FT2} - r_{FT1}}{r_{ET2} - r_{ET1}}. \quad (2)$$

- Expected transmittance values are also calculated at the sensor grid, for comparison purposes.

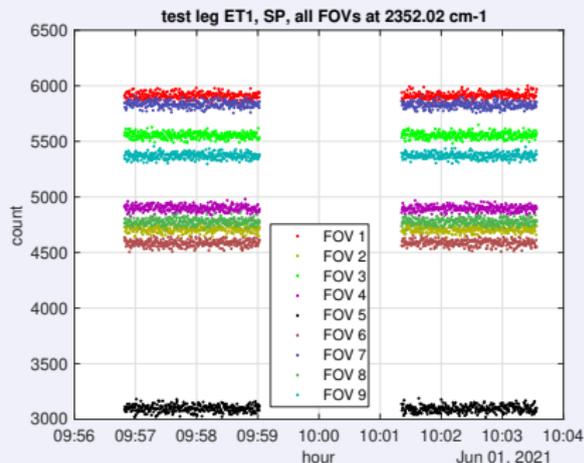
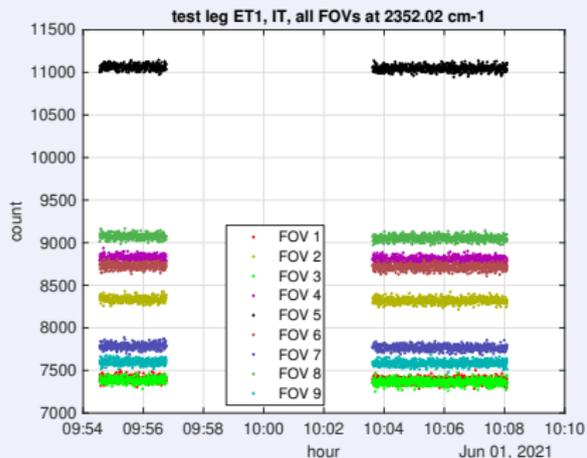
CO PFH ET1 ES (gas cell) looks



ES looks for the full ET1 test leg, as specified in the cmd files, before any trimming. The data block on the left may be some sort of warm up, and is not present in the other test legs.

The ES data block from the right, with both the left block and assorted outliers trimmed. All the ES looks need this sort of trimming.

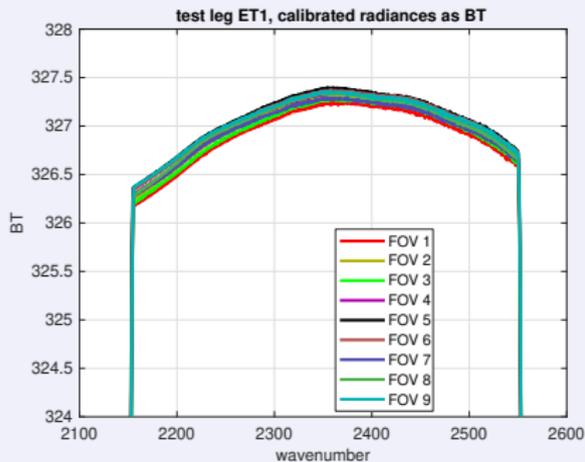
CO PFH ET1 IT and SP calibration looks



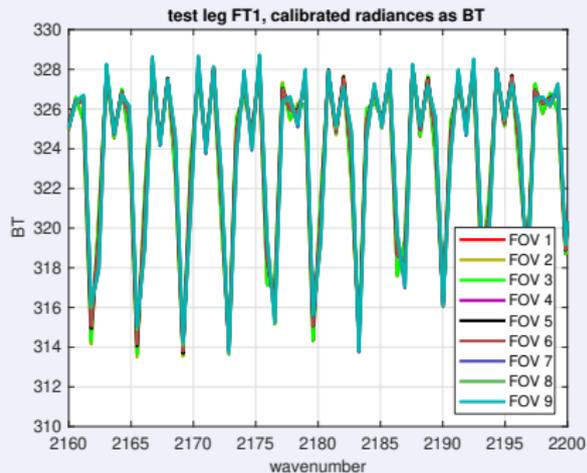
IT looks, spanning the SP data. No trimming was needed for the IT or SP looks, which greatly simplifies matters.

SP looks, spanning the ES data.

CO PFH ET1 and FT1 calibrated radiances

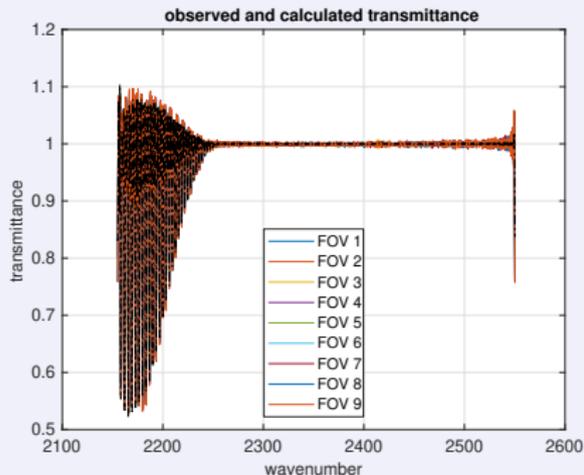


Calibrated radiances for the ET1 test leg. An improved focal plane model might bring the FOVs into better agreement.

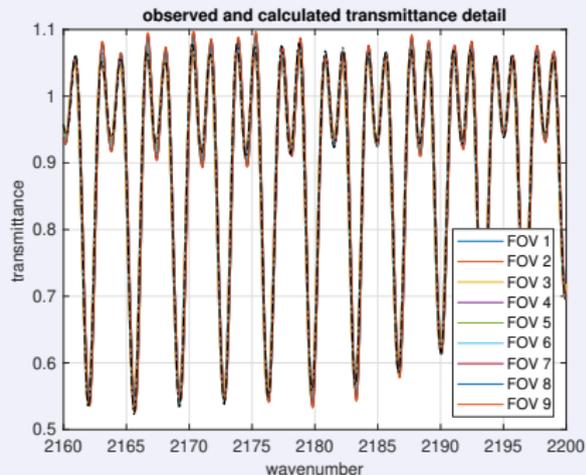


Detail of calibrated radiances for the FT1 test leg.

CO PFH transmittances from calibrated radiances

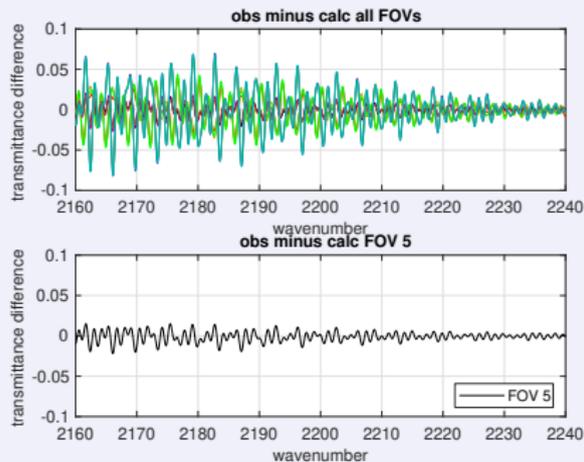


Observed transmittances from calibrated radiances, together with calculated transmittance. The wobble is gone.

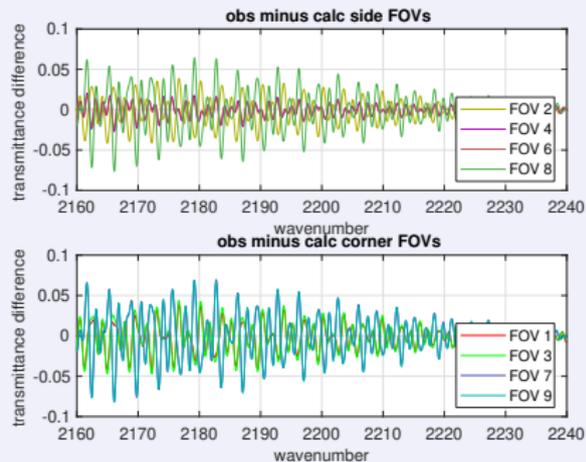


A detail from the previous plot. At this level of detail, observed and calculated transmittances are in good agreement.

CO PFH obs minus calc breakouts



Obs minus calc with transmittances from calibrated radiances, for all FOVs and for FOV 5 alone, before any fitting.



Obs minus calc with transmittances from calibrated radiances, for side and corner FOVs, before any fitting.

Conclusions

- Although the CO residuals on slide 15 are wobble free, except for FOV 5 they are larger than the CO residuals from slide 8. But the latter are taken after fitting; the comparable wobbly residuals before fitting would be much larger.
- We are not yet fitting transmittances from calibrated radiances, or using alternate measures of frequency difference, and so are not reporting met laser residuals. The fitting method, minimizing $\text{RMS}(a \cdot \tau_{\text{obs}} + b - \tau_{\text{calc}})$, where τ_{obs} is a function of the metrology laser wavelength, has been robust in the face of radiometric uncertainty, and we will probably continue to use it. But this requires extending the met laser parameter to each calibration test leg.
- In the meantime, we have done a preliminary analysis of PFH Plateau 21 CH₄, CO₂, and CO gas cell ILS tests, and compared these with calculated reference truth, and with the PFL tests. Overall, the results look quite good.