Version 7 Level 1B Radiometric Calibration Updates

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AIRS Science Team Meeting

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Overview

- AIRS radiances are of high value to the scientific community
  - AIRS measures the upwelling Earth's hyperspectral infrared radiances with high precision and accuracy and global daily coverage
  - AIRS data have been nearly continuous in time, beginning in September 2002 and continuing to the present
  - AIRS data are used for climate benchmarking and radiance trending
  - AIRS is a cross-calibration reference sensor in GSICS
  - AIRS data are assimilated into reanalysis models
- Radiometric Calibration Coefficients Updated
  - The current operational version uses coefficients derived pre-flight
  - Updates provided to polarization, emissivity, nonlinearity (V7.1)
- V7.1 differences from V5:
  - Reduced L/R Assymetry in Cold Scenes
  - Lower radiometric uncertainty

AIRS Radiometric Calibration Equations

Scene Radiance

$$L_{ev} = L_o(\theta) + \frac{c_1'(dn_{ev} - dn_{sv}) + c_2(dn_{ev} - dn_{sv})^2}{[1 + p_r p_t cos2(\theta - \delta)]}$$

Mirror Polarization Contribution

$$L_o(\theta) = \frac{L_{sm} p_r p_t [cos2(\theta - \delta) - cos2(\theta_{sv,i} - \delta)]}{[1 + p_r p_t cos2(\theta - \delta)]}$$

Gain Term

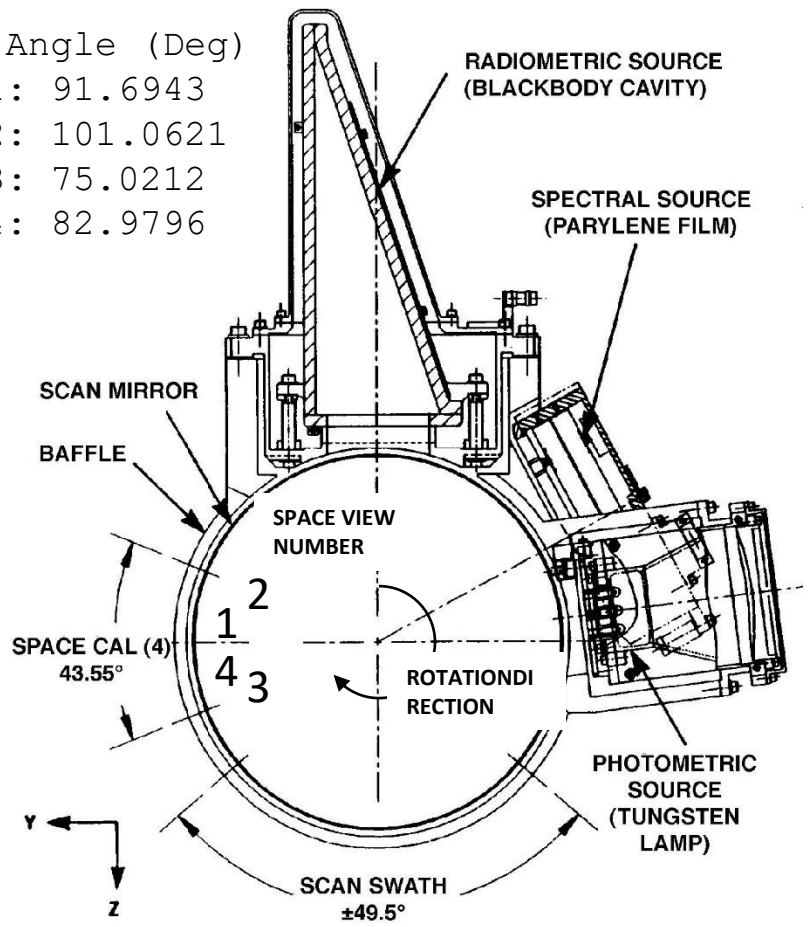
$$c_1{}' = \frac{[\varepsilon_{obc} P_{obc} - L_o(\theta_{obc})][1 + p_r p_t cos2\delta] - c_2(dn_{obc} - dn_{sv})^2}{(dn_{obc} - dn_{sv})}$$

- T. Pagano et al., "Reducing uncertainty in the AIRS radiometric calibration", Proc. SPIE 10764-23, San Diego, CA (2018)
- T. Pagano et al., "Pre-Launch and In-flight Radiometric Calibration of the Atmospheric Infrared Sounder (AIRS)," IEEE TGRS, Volume 41, No. 2, February 2003, p. 265
- T. Pagano, H. Aumann, K. Overoye, "Level 1B Products from the Atmospheric Infrared Sounder (AIRS) on the EOS Aqua Spacecraft", Proc. ITOVS, October 2003

L_{ev} = Spectral Radiance in the Earth Viewport (W/m2-sr-μm)
L_{sm} = Spectral Radiance of the Scan Mirror for Unity Emissivity at T_{sm} (W/m^2-sr-μm)
L_o = Spectral Radiance Correction for Scan Mirror (W/m^2-sr-μm)
c_1 = Instrument gain (W/m^2-sr- μm-counts)
c_2 = Instrument nonlinearity (W/m^2-sr- μm-counts^2)
dn_{ev} = Digital counts while viewing Earth for each footprint and scan (counts)
dn_{sv} = Digital counts while viewing Space for each scan (counts)
$p_r p_t$ =Product of scan mirror and spectrometer polarization diattenuation (unitless)
θ = Scan Angle measured from nadir (radians)
δ = Phase of spectrometer polarization (radians)
P_{obc} = Plank Blackbody function of the OBC blackbody at temperature T_{obc} (W/m^2-sr-μm)
T_{obc} = Telemetered temperature of the OBC blackbody (K) with correction of +0.3K.
ε_{obc} = Effective Emissivity of the blackbody
dn_{obc} = Digital number signal from the AIRS while viewing the OBC Blackbody

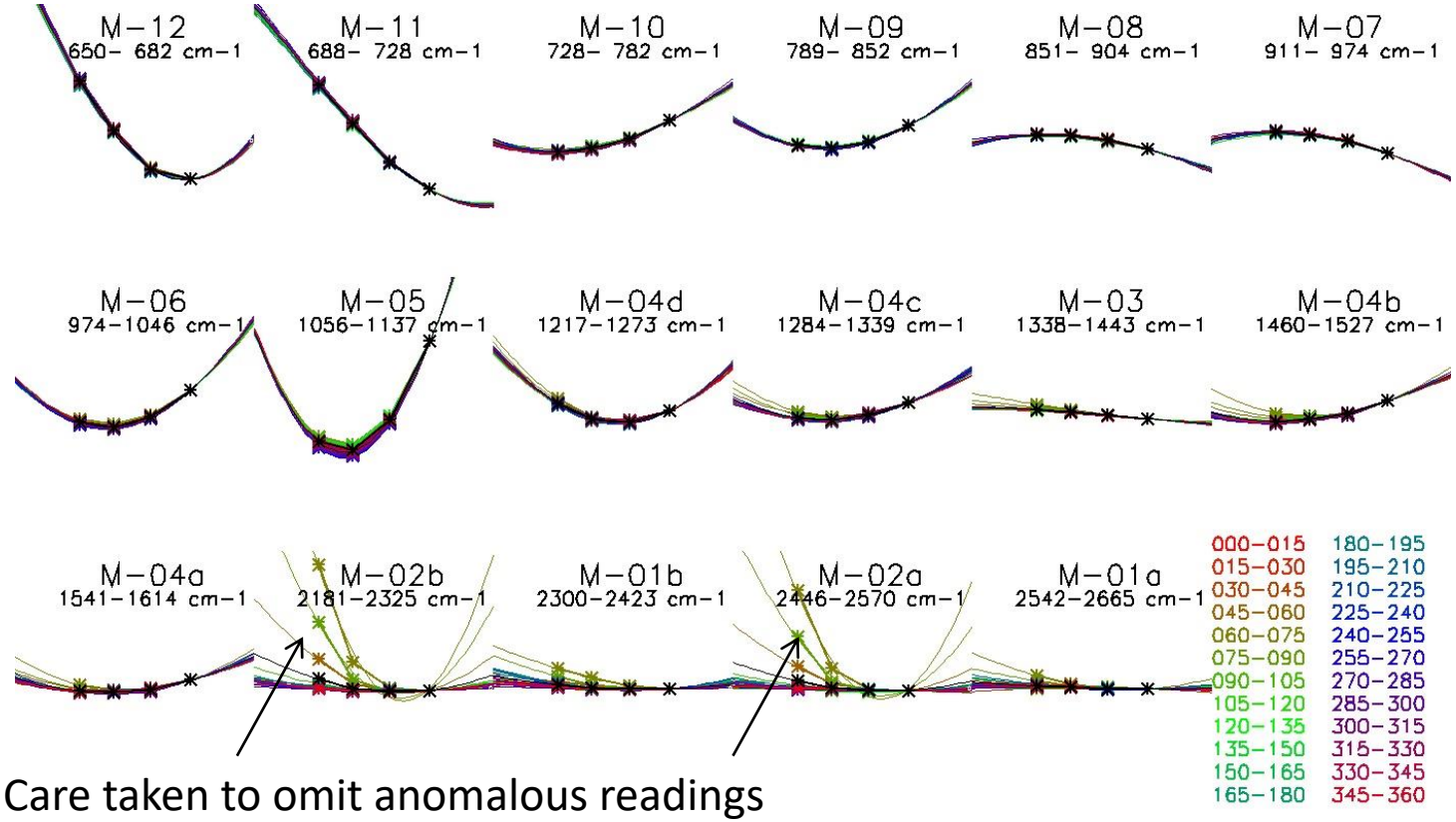
V7.1 Uses Space Views to Compute Polarization Terms

SV Angle (Deg)
SV1: 91.6943
SV2: 101.0621
SV3: 75.0212
SV4: 82.9796



Earth

- Regression of polarization response to every space view in the mission between 2003-2017 (171 mo)
- Plots and Data from Evan Manning

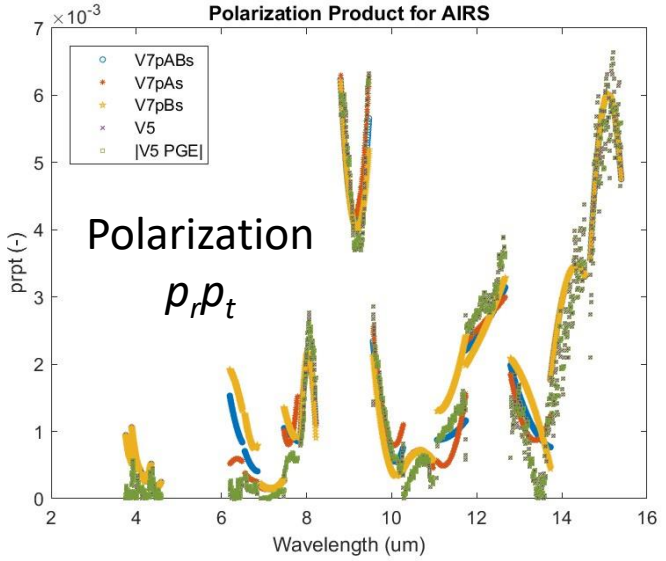


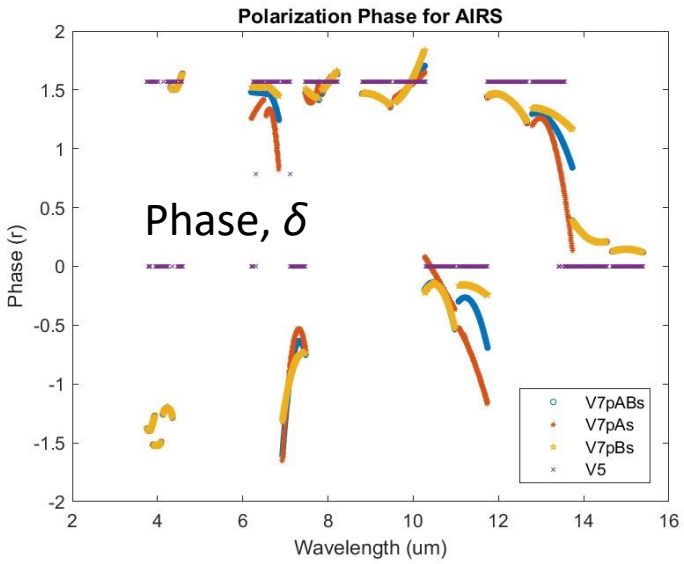
Care taken to omit anomalous readings

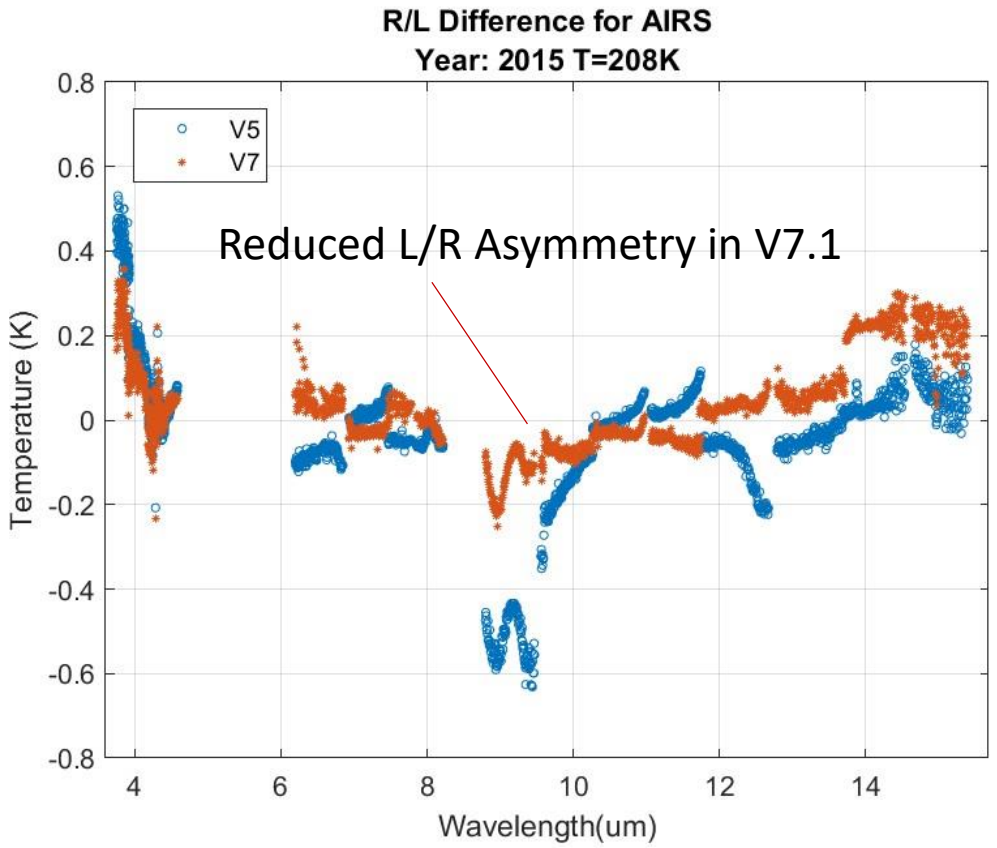
$$(dn_{sv,i} - dn_{sv,1})c_1' = -L_{sm}p_r p_t\left[cos2\theta_{sv,i}cos2\delta + sin2\theta_{sv,i}sin2\delta + cos2\delta\right]$$

V7.1 Polarization Coefficients improve L/R Asymmetry

- Polarization Amplitude Similar to V5
- V7.1 AB Side Dependent
- V7.1 Polarization Amplitude Time Dependent (Mostly only affects M5)
- V5 Phase binary due to use of sign on $p_r p_t$ rather than true phase
- V7.1 Phase channel and time Dependent



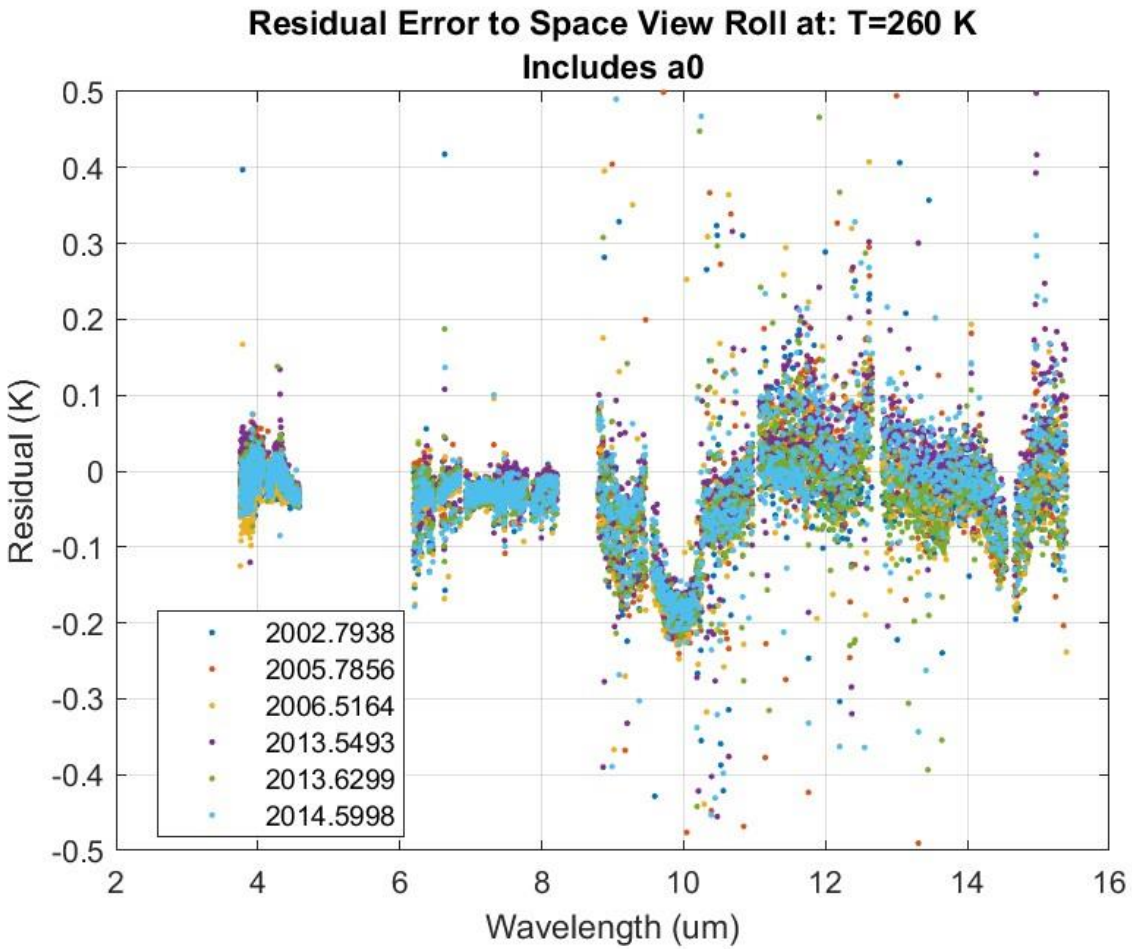




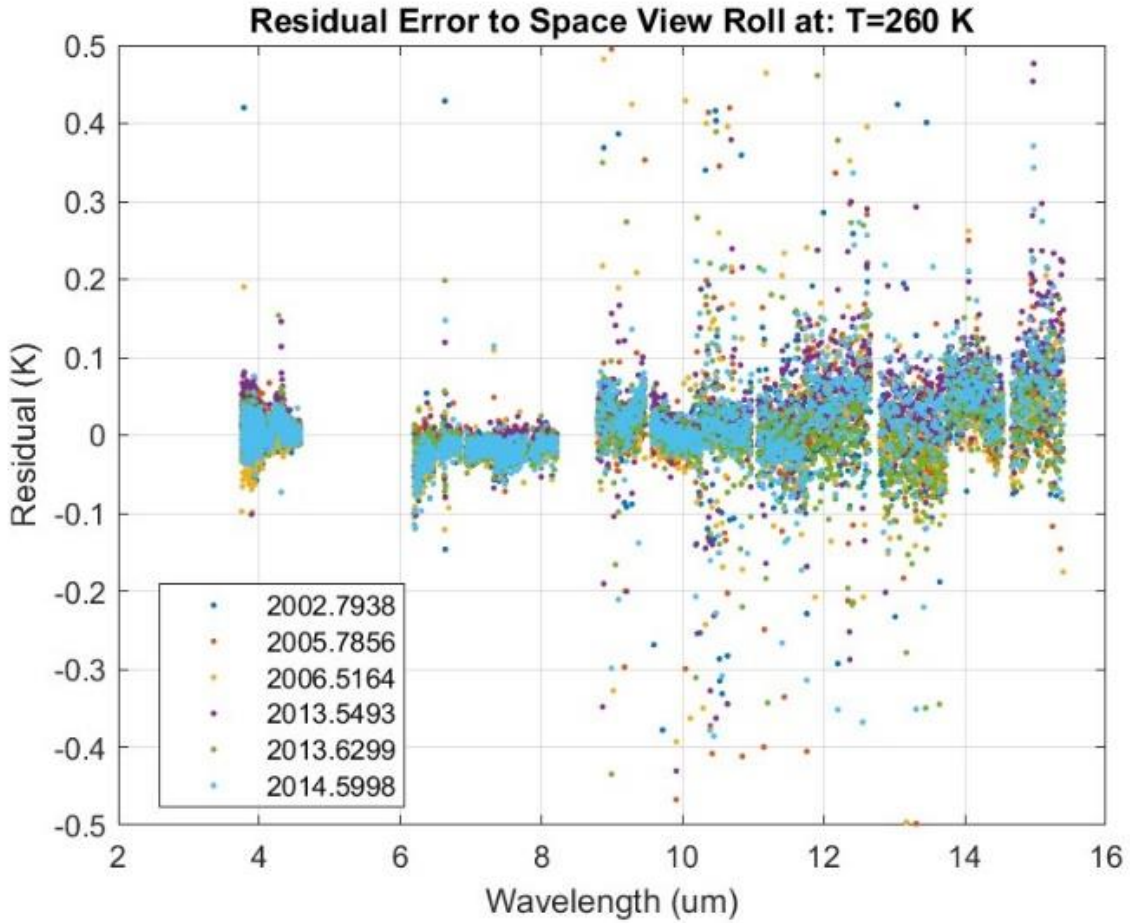
- AIRS Cal Subset: AIRXBCAL for V5
- 50S to 50N, Tsc < 210K
- 1/3 of Scan Right – 1/3 of Scan Left
- V7.1 Curve produced using ez_rad_conv (V5 to V7)
- Data from E. Manning

Space View Roll Test Confirms a0=0

Residual Radiance (with a0)

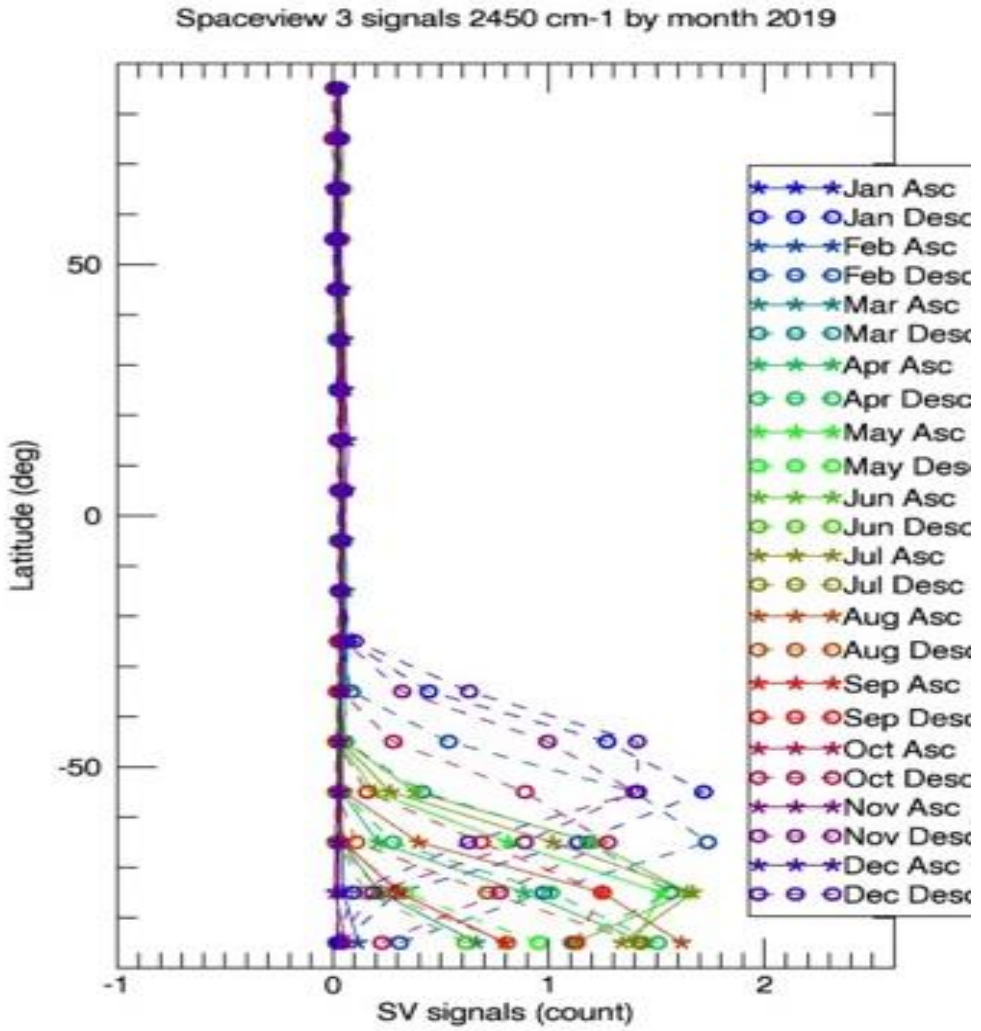


Residual Radiance (a0 = 0)



L1B v7.1 spaceview handling update

- In addition to the coefficient changes, v7.1 L1B will modify the logic which combines observations from the four space view ports to estimate the zero-signal level (offset)
  - The spaceviews will be adjusted to a common level to compensate for small polarization-related biases
  - The spaceviews closest to Earth will not be used for a region near the south pole where an extraneous signal has been observed.



E. Manning

V7.1 Coefficients use more pre-flight test data than V5

- V5 based on Test Number 1 and 2
- V7.1 based on Tests 1-14
- V7.1 Radiometric Coefficients derived using V7.1 Polarization Coefficients

V5

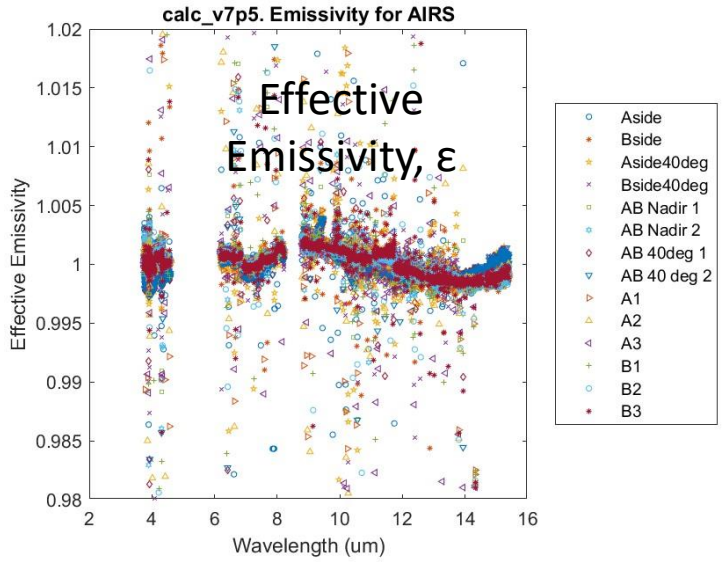
V7.1

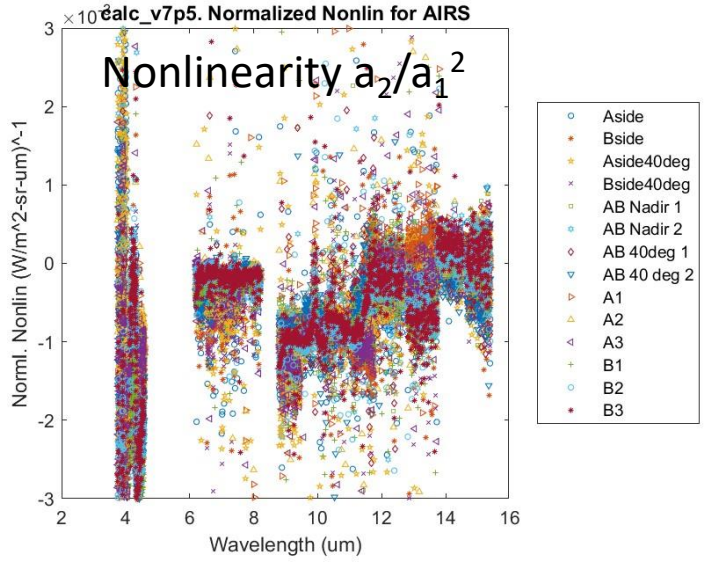
Post Field Stop

Number	Side	AOI	200 K	205 K	220 K	230 K	240 K	250 K	265 K	280 K	295 K	310 K		
1	A	N		1687	1692	1693	1698	1704	1710	1718	1719	1727		
2	B	N		1688	1689	1696	1697	1705	1706	1715	1720	1726		
3	A	40	1827*	1830	1841	1844	1849	1852	1857	1860	1865*	1872		
4	B	40	1828*	1829	1842	1843	1850	1851*	1858	1859	1866	1871		
	Side	AOI	200 K	205 K	220 K	230 K	240 K	250 K	265 K	280 K	295 K	310 K		
5	AB	N		1685	1690	1694	1699	1702	1708	1716	1721	1724		
6	AB	N		1686	1691	1695	1700	1703	1709	1717	1722	1725		
7	AB	40	1825*	1832	1839	1845	1848	1853	1855	1861	1864	1869		
8	AB	40	1823*	1831	1840	1846	1847	1854	1856	1862	1863	1870		

Pre-Field Stop

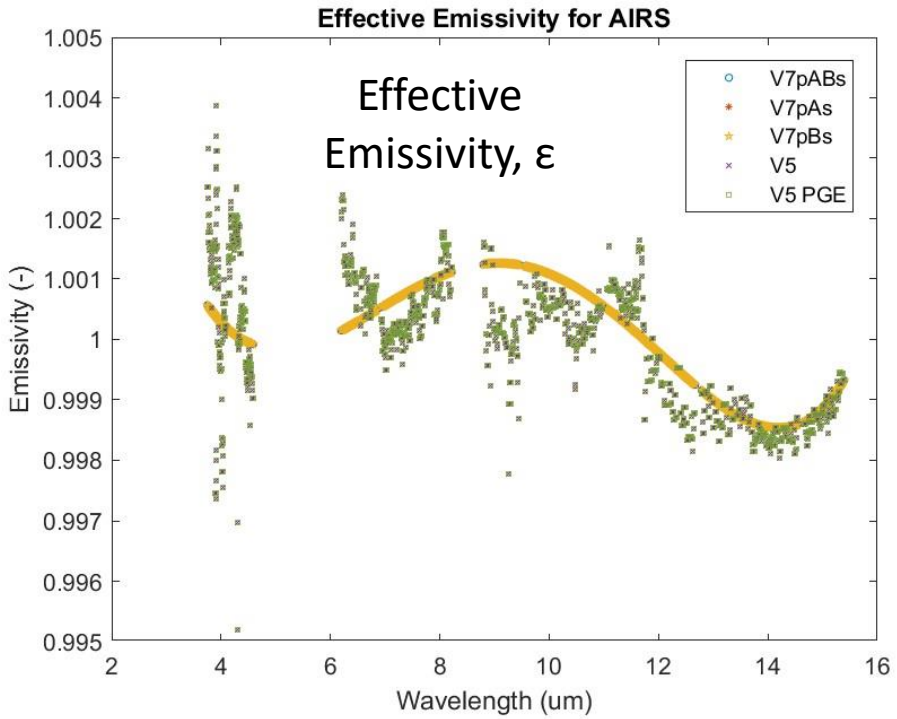
	Side	AOI	197 K	207 K	221 K	235 K	250 K	265 K	280 K	295 K	310 K	325 K	340 K	357 K
9	A	N	528	534	540	548	554	560	569	575	581	587	593	599
10	A	N	530	537	542	551	556	563	571	577	582	588	594	601
11	A	N	533	539	545	551	559	565	572	578	584	590	596	602
12	B	N	529	535	541	549	555	561	568	574	580	586	592	598
13	B	N	531	536	543	550	557	562	570	576	583	589	595	600
14	B	N	532	538	544	550	558	564	573	579	585	591	597	603

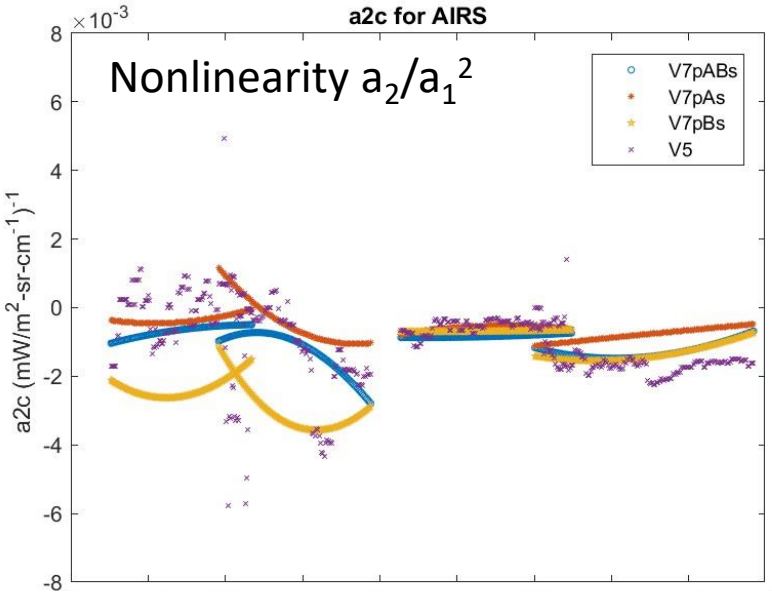


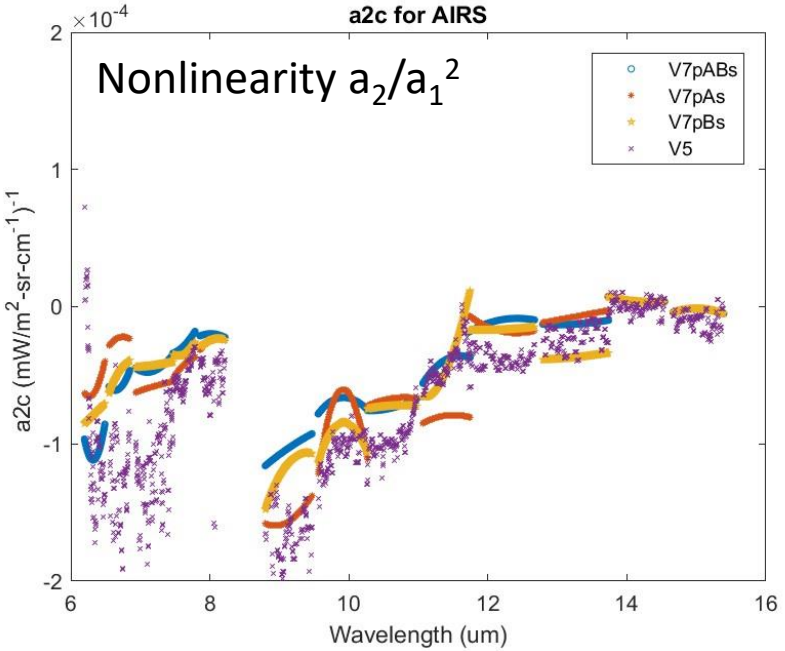


V7.1 Coefficients very close to V5

- Effective Emissivity Smoothed over Modules
- No A/B Dependence
- Nonlinearity Smoothed Within Each Module
- Nonlinearity AB Side Dependent
- Deviation from fit taken as ‘uncertainty’ on per ch. basis



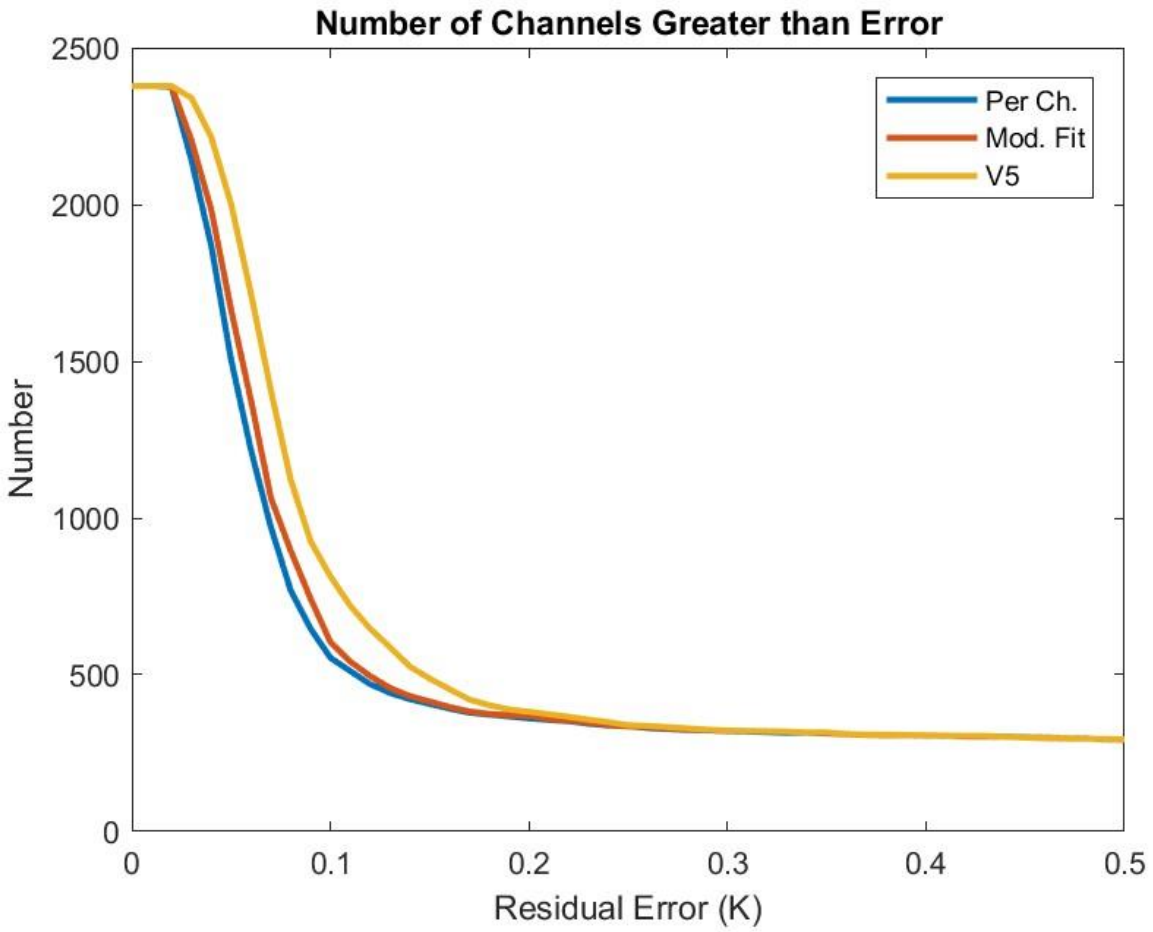




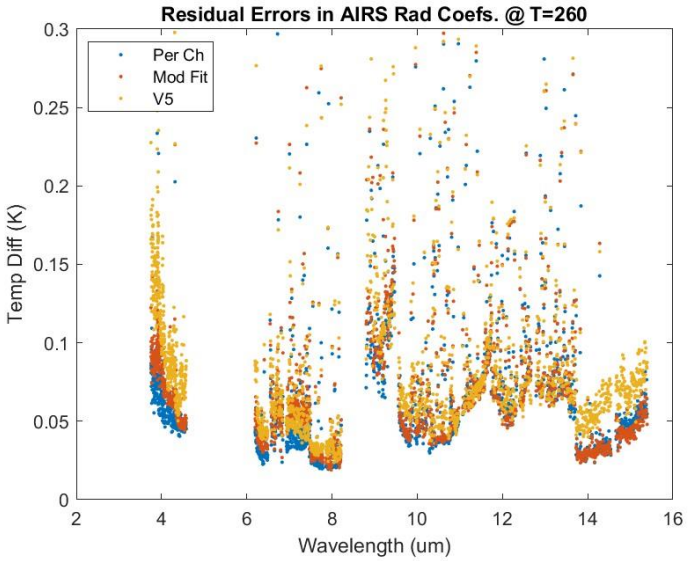
T. Pagano, Candidate Coefficients for V7 L1B: V7p, JPL Internal Memorandum, AIRS Project Office, ADF 1006, May 11, 2020

V7.1 has lower residuals than V5 to pre-flight test data

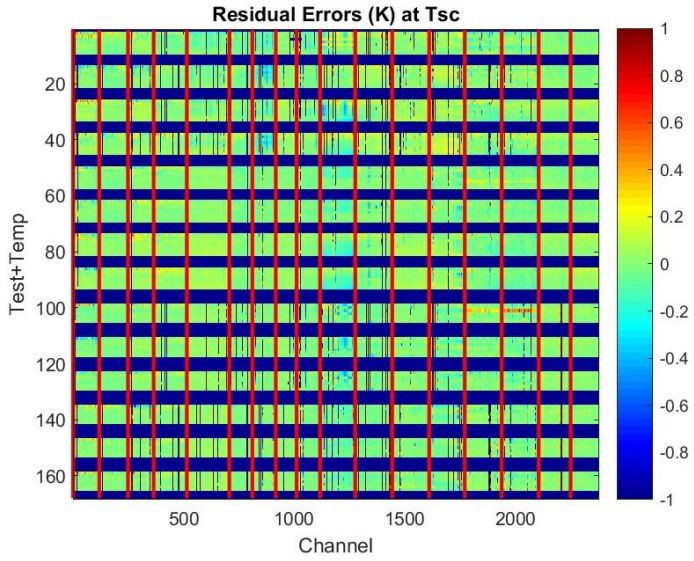
V7.1 Residual Errors for All Test



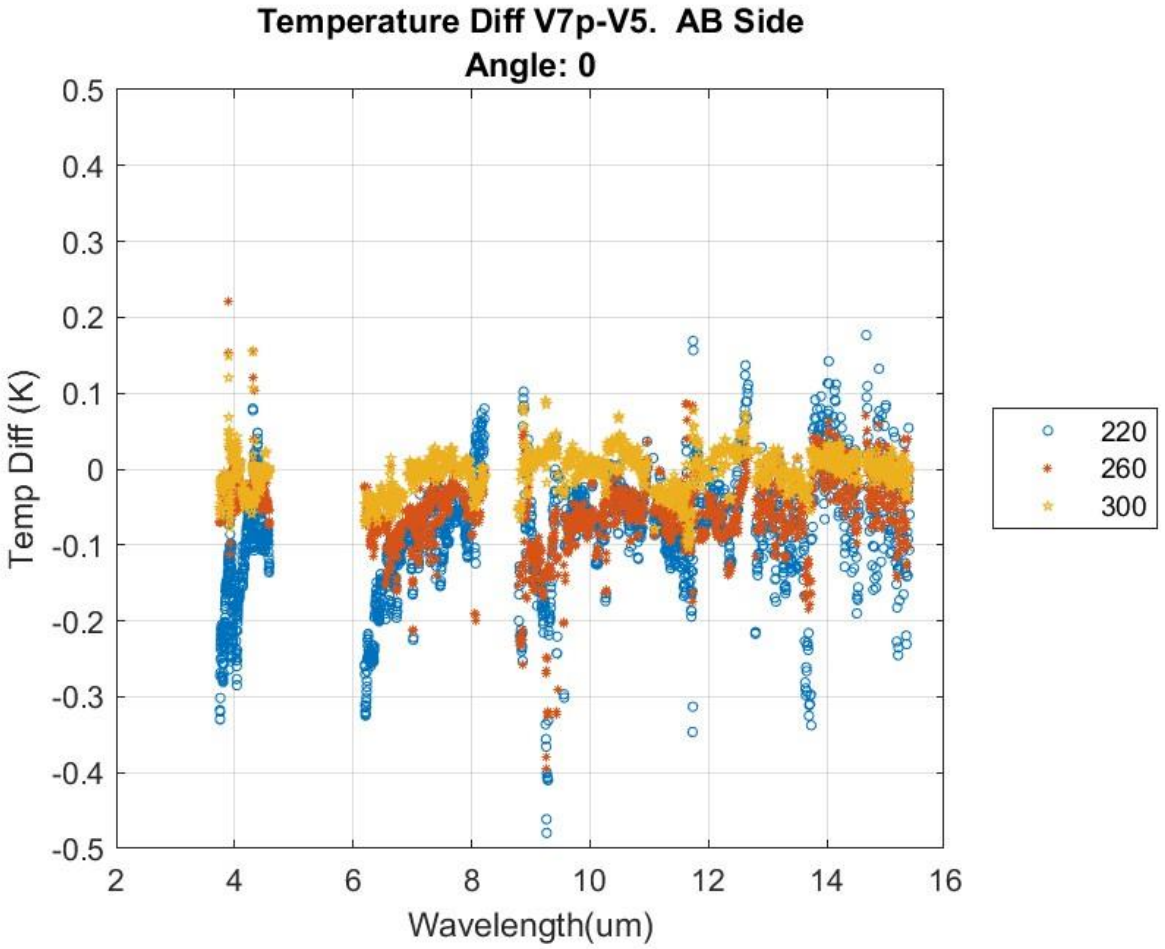
V7.1 RMS Error over all Tests

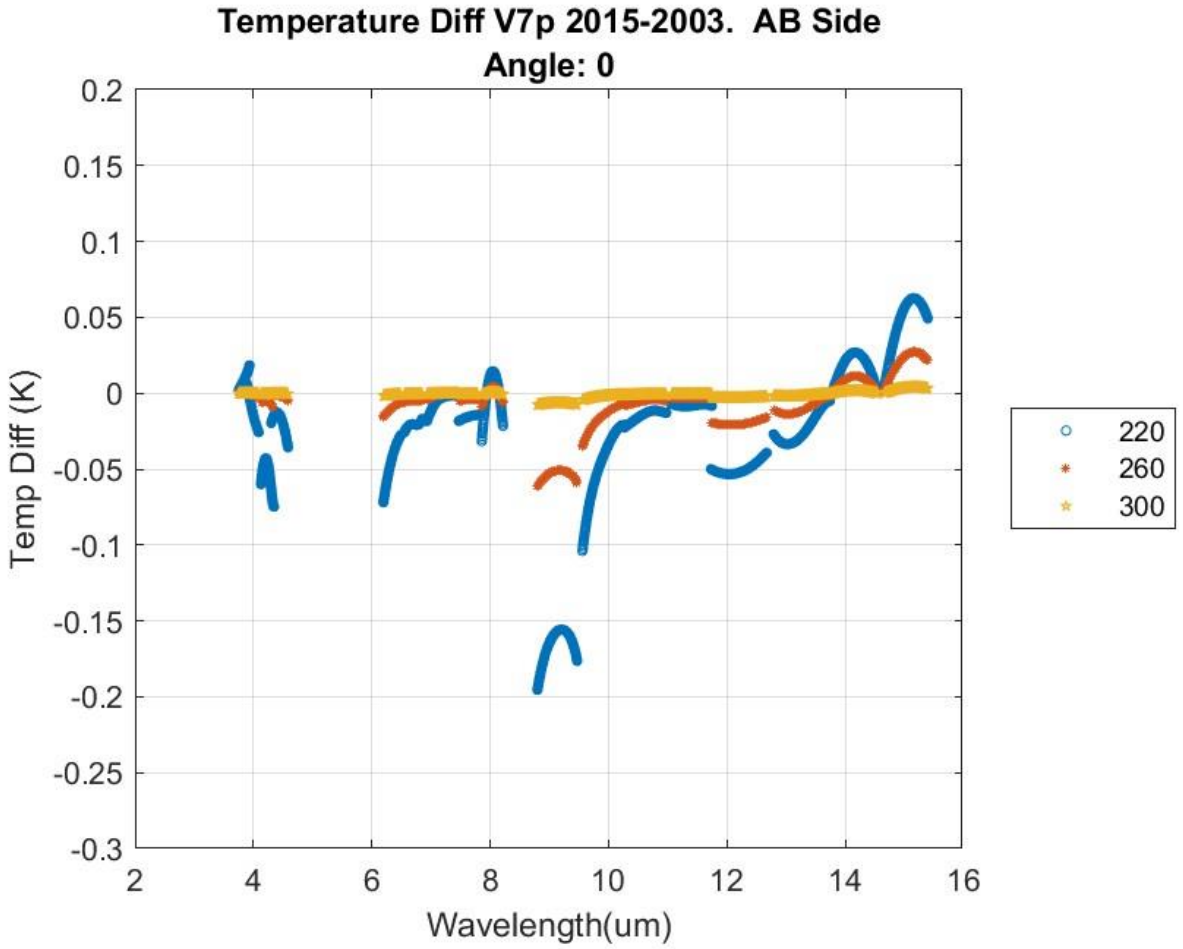


V7.1 Residuals for Individual Tests

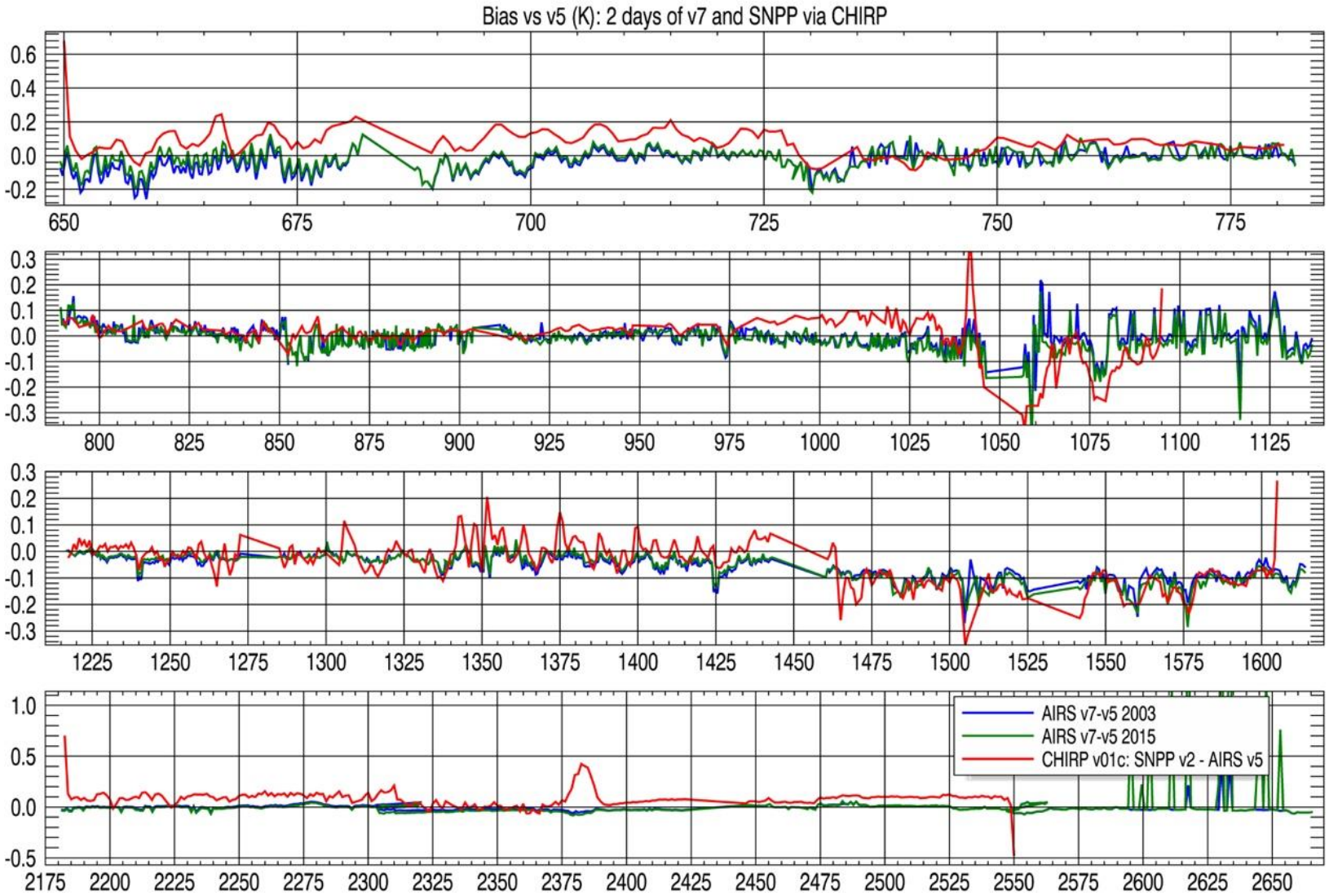


V7.1-V5 Greatest at cold scenes. V7.1 has slight time dependence





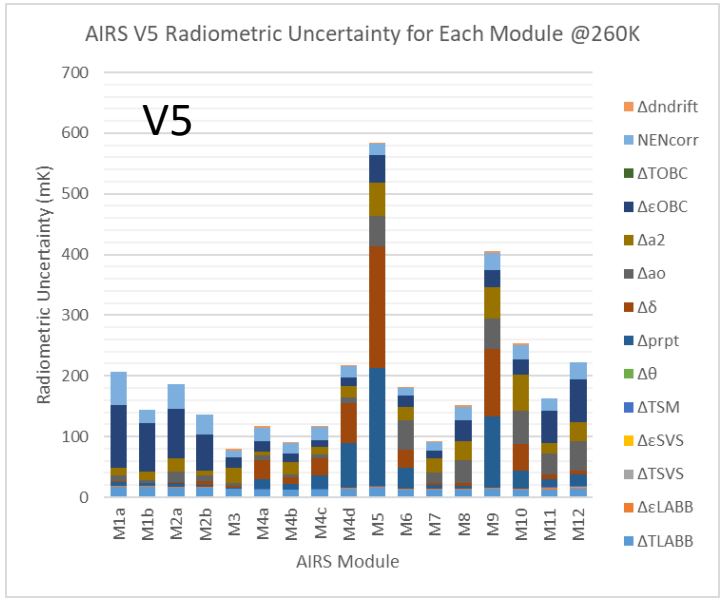
AIRS V7.1-V5 Compared to CHIRP L1C Biases

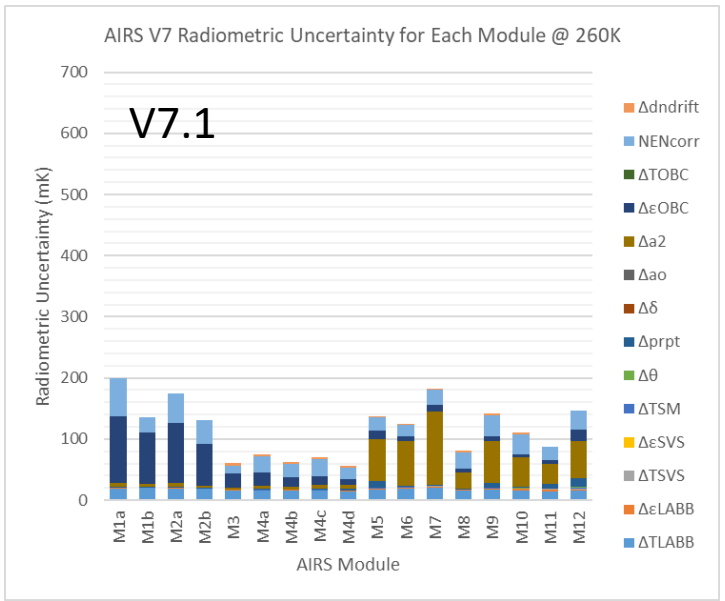


E. Manning, 'ADFM: v7 changes to v5 compared to CHIRP CrIS SNPP vs v5 biases', ADF TBD, 10/5/20

AIRS Radiometric Accuracy Improved in V7.1

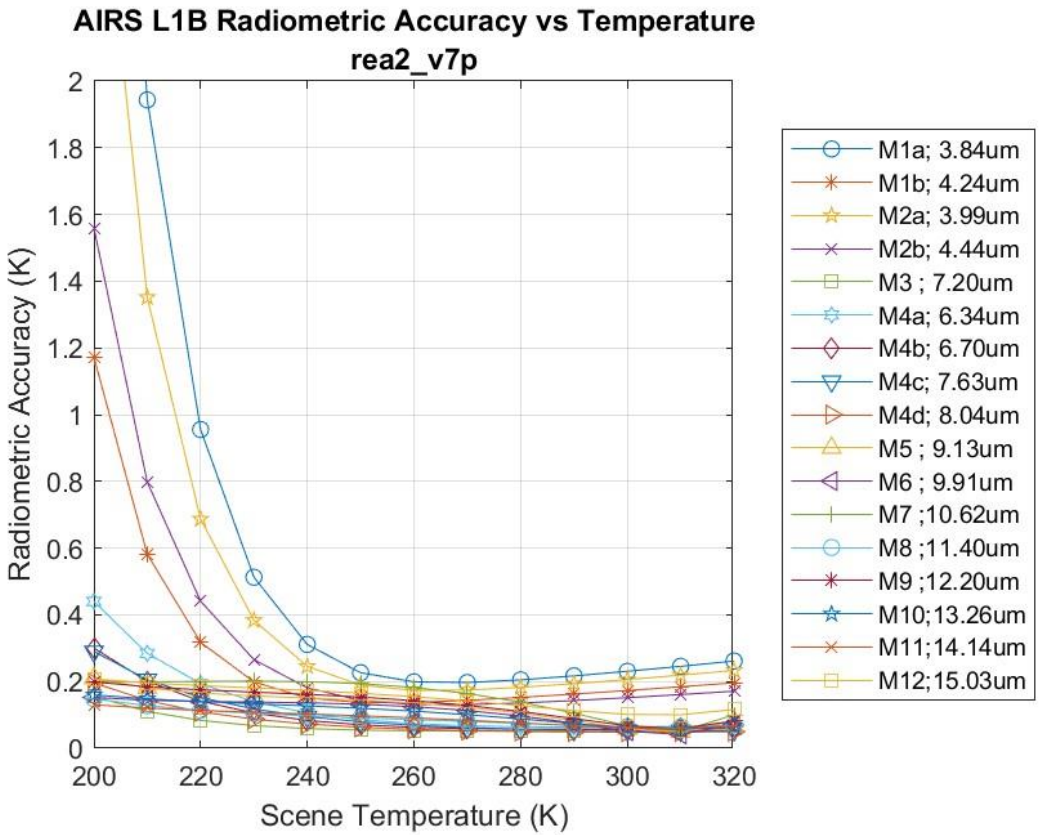
Errors at 260K by Contributor





- All Errors are 1-sigma and RSS of contributors
- Height of contributors within each bar is percentage of total
- V5 errors dominated by polarization uncertainty
- V7.1 errors dominated by Nonlinearity and OBC Emissivity
- V7.1 Results are Preliminary

V7.1 Temperature Dependence



Pagano, T.S., H. Aumann, S. Broberg, C. Canas, E. Manning, K. Overoye, R. Wilson, "SI-Traceability and Measurement Uncertainty of the Atmospheric Infrared Sounder Version 5 Level 1B Radiances", Remote Sens. 2020, 12, 1338; doi:10.3390/rs12081338

Summary and Conclusions

- Modest improvements to the AIRS Level 1B calibration coefficients have been made based on a better under understanding of pre-flight and in-flight measurements. No impact to trends except M5
- Polarization changes verified to L/R Asymmetry
- Space views corrected two ways
  - Remove stray signals at poles
  - Offset by median relative to SV1 to remove polarization bias amongst SV's
- Radiometric coefficients updated. Use more pre-flight data than V5
- Improved knowledge of nonlinearity and role of a0
- V7.1 Differences with V5 mostly at cold scenes and less than 200 mK
- V7.1-V5 differences compare favorably in some modules with biases seen in AIRS L1C-CHIRP
- Radiometric Uncertainty in V7 expected to be better in M5 and M9, M10 due to better knowledge of polarization