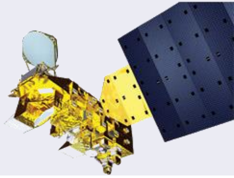
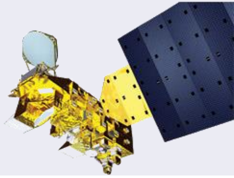


Radiometric Accuracy Improvements for Version 7

T. Pagano, S. Broberg, E. Manning, H. Aumann
California Institute of Technology / JPL

June 27, 2017

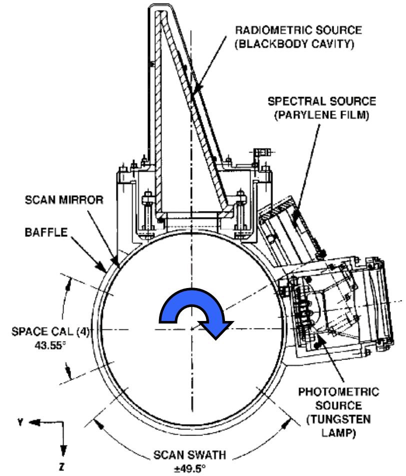
Preliminary



AIRS Designed for High Spectroradiometric Resolution, Accuracy and Stability

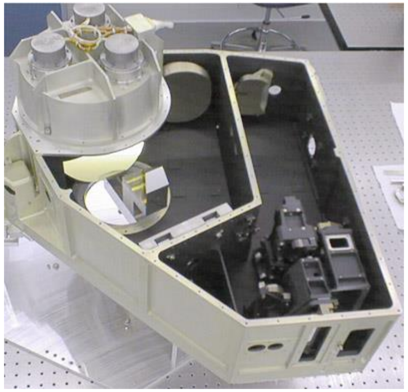
AIRS Features

- Orbit: 705 km, 1:30pm, Sun Synch
- Pupil Imaging IFOV : 1.1° x 0.6° (13.5 km x 7.4 km)
- Scanner Rotates about Optical Axis (Constant AOI on Mirror)
- Full Aperture OBC Blackbody, ε>0.998
- Full Aperture Space View
- Solid State Grating Spectrometer
- Temperature Controlled Spectrometer: 158K
- Actively Cooled FPAs: 60K
- No. Channels: 2378 IR, 4 Vis/NIR
- Mass: 177Kg,
  Power: 256 Watts,
  Life: 5 years (7 years goal)



Isolated Scan Cavity

Temperature Controlled Instrument



Grating Spectrometer

IR Spectral Range:
3.74-4.61 μm, 6.2-8.22 μm, 8.8-15.4 μm
IR Spectral Resolution:
≈ 1200 (λ/Δλ)
No. IR Channels: 2378 IR

Active Detector Cooling

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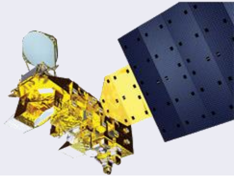
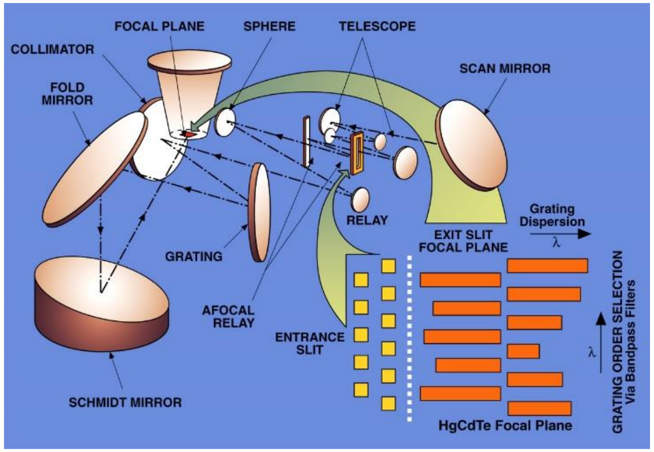
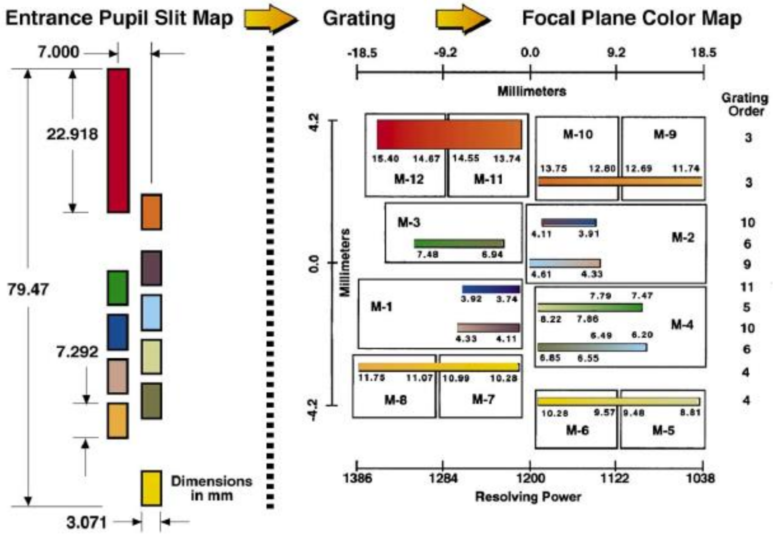
AIRS Spectral Bands Defined by 11 Entrance Apertures and 17 Detector/Filter Modules



AIRS Module Spectral Band Limits					
		λ1	λ2	v1	v2
		(µm)	(µm)	(cm^{-1})	(cm^{-1})
1	M1a	3.752	3.934	2541.9	2665.2
2	M1b	4.127	4.348	2299.8	2422.8
3	M2a	3.891	4.088	2446.2	2569.8
4	M2b	4.301	4.584	2181.5	2325.0
5	M3	6.930	7.473	1338.2	1443.1
6	M4a	6.196	6.489	1541.1	1613.9
7	M4b	6.549	6.848	1460.3	1527.0
8	M4c	7.469	7.786	1284.3	1338.9
9	M4d	7.858	8.217	1217.0	1272.6
10	M5	8.798	9.469	1056.1	1136.6
11	M6	9.558	10.269	973.8	1046.2
12	M7	10.264	10.974	911.2	974.3
13	M8	11.065	11.744	851.5	903.8
14	M9	11.731	12.670	789.3	852.4
15	M10	12.790	13.735	728.1	781.9
16	M11	13.728	14.543	687.6	728.4
17	M12	14.663	15.394	649.6	682.0





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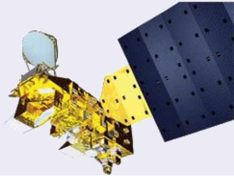
AIRS Radiometric Transfer Equations Used to Identify Error Terms



Radiometric Transfer Equations

$$N_{sc,i,j} = \frac{a_o(\theta_j) + a_{1,i}(dn_{i,j} - dn_{sv,i}) + a_2(dn_{i,j} - dn_{sv,i})^2}{1 + p_r p_t \cos 2(\theta_j - \delta)}$$

$$a_o(\theta_j) = P_{sm} p_r p_t [\cos 2(\theta_j - \delta) + \cos 2\delta]$$

$$a_{1,i} = \frac{N_{OBC,i}(1 + p_r p_t \cos 2\delta) - a_o(\theta_{OBC}) - a_2(dn_{obc,i} - dn_{sv,i})^2}{(dn_{obc,i} - dn_{sv,i})}$$

$N_{sc,i,j}$ = Scene Radiance (mW/m^2-sr-cm^{-1})
Psm = Planck radiation function
$N_{OBC,i}$ = Radiance of the On-Board Calibrator Blackbody
i = Scan Index, j = Footprint Index
θ = Scan Angle. θ = 0 is nadir.

dni,j = Raw Digital Number in the Earth View
dnsv,i = Space view counts offset.
ao = Radiometric offset. a1,i = Radiometric gain.
a2 = Nonlinearity
prpt = Polarization Factor Product
d = Phase of the polarization

Radiometric Accuracy Equation

$$\partial N_{SC}^{\,2} = \left(\frac{\partial N_{SC}}{\partial p_r p_t}\Delta p_r p_t\right)^2 + \left(\frac{\partial N_{SC}}{\partial \delta}\Delta \delta\right)^2 + \left(\frac{\partial N_{SC}}{\partial T_{sm}}\Delta T_{sm}\right)^2 + \left(\frac{\partial N_{SC}}{\partial \theta}\Delta \theta\right)^2 + \left(\frac{\partial N_{SC}}{\partial \varepsilon_{OBC}}\Delta \varepsilon_{OBC}\right)^2 + \left(\frac{\partial N_{SC}}{\partial T_{OBC}}\Delta T_{OBC}\right)^2 + \left(\frac{\partial N_{SC}}{\partial a_2}\Delta a_2\right)^2 + \left(\frac{\partial N_{SC}}{\partial dn}\Delta dn\right)^2$$

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

4

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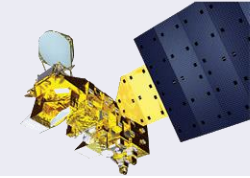
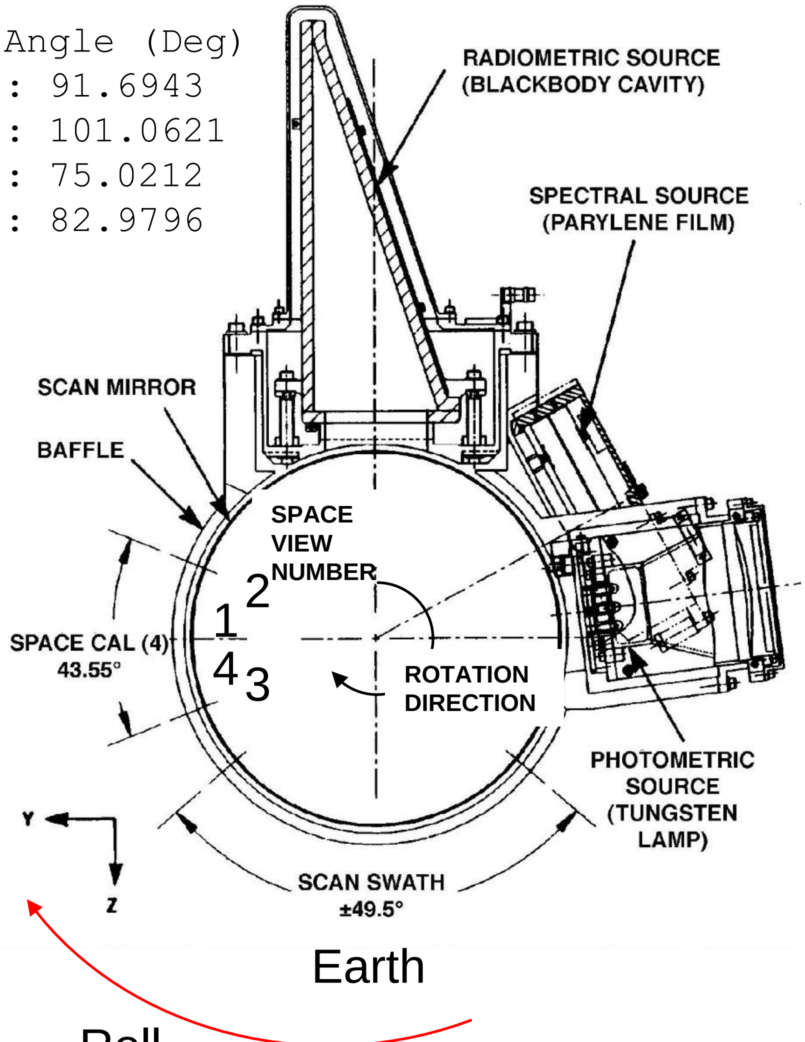
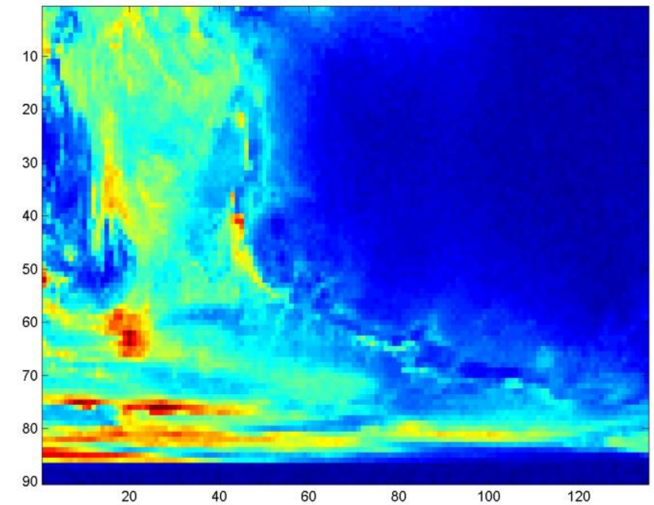
4 Spaceviews Enable Calibration of Mirror Polarization. Roll provides Validation.



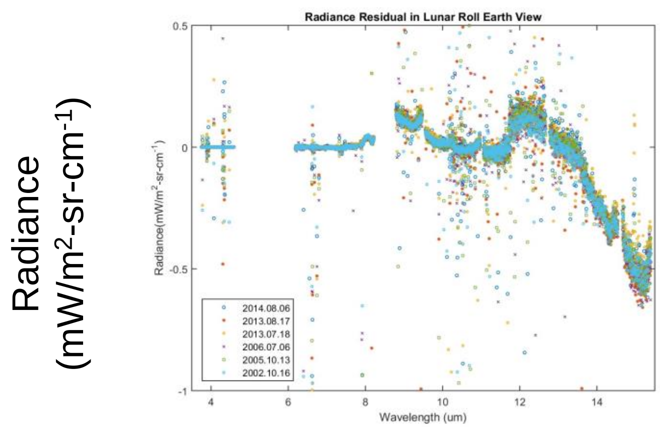
SV Angle (Deg)
SV1: 91.6943
SV2: 101.0621
SV3: 75.0212
SV4: 82.9796



BT Ch 2333, 2616 cm^{-1}



Earth View – Space View Radiance



$$(dn_x - dn_{s1})a_1 = -P_{sm}p_r p_t[cos2\delta cos2\theta_x + sin2\delta sin2\theta_x + cos2\delta]$$

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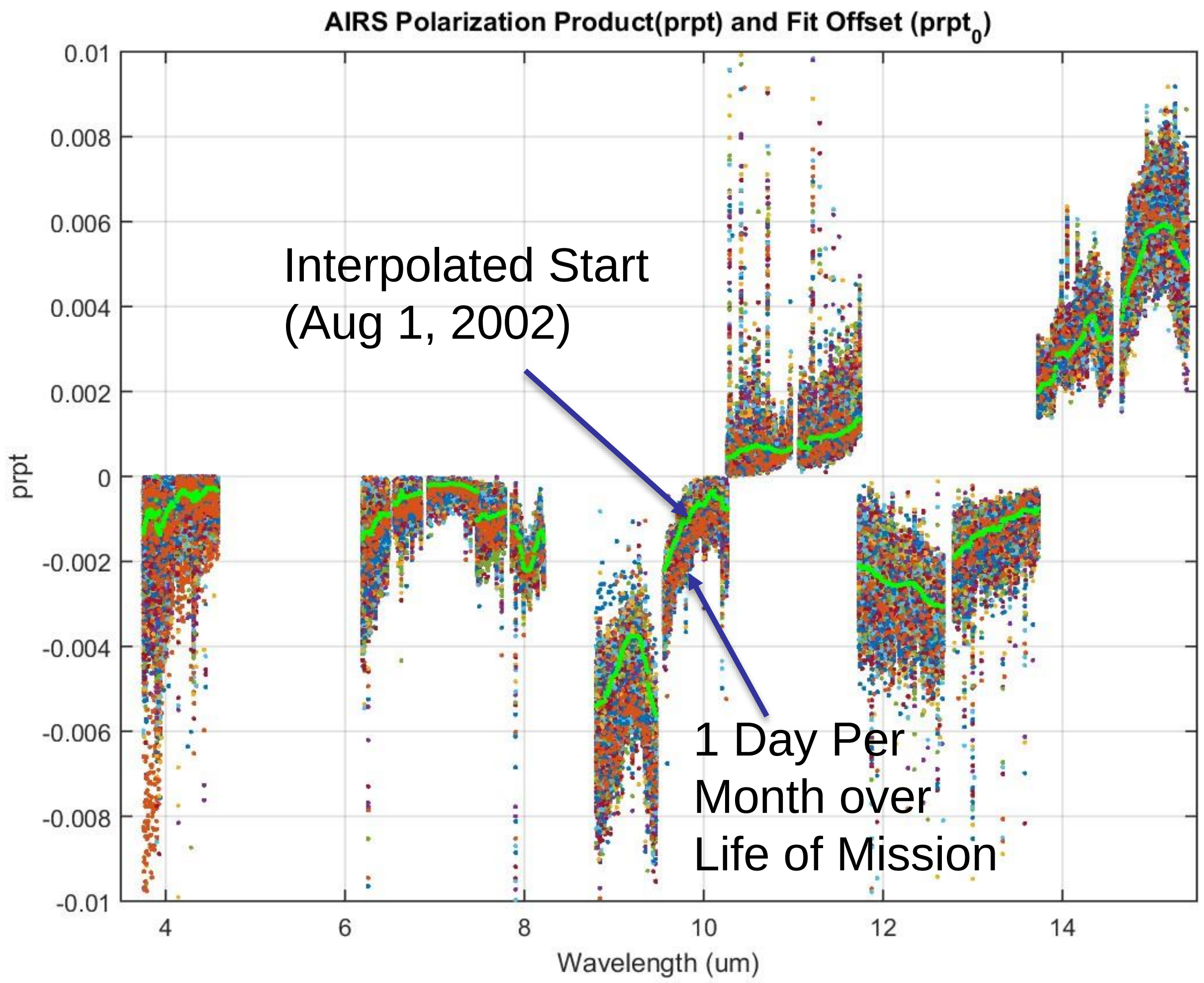
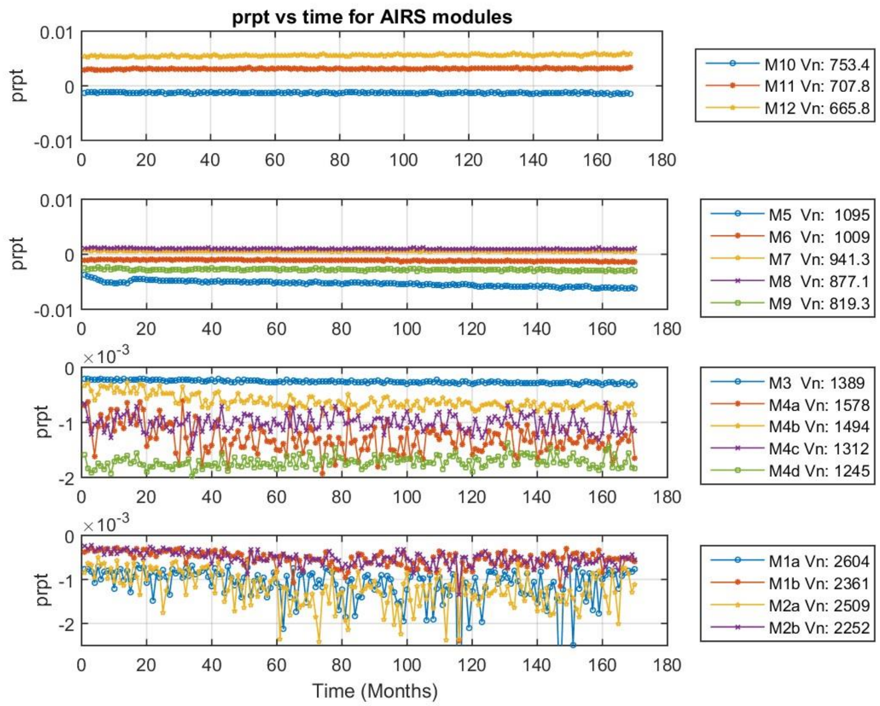
Polarization and Phase Derived from SV Data over Entire Mission



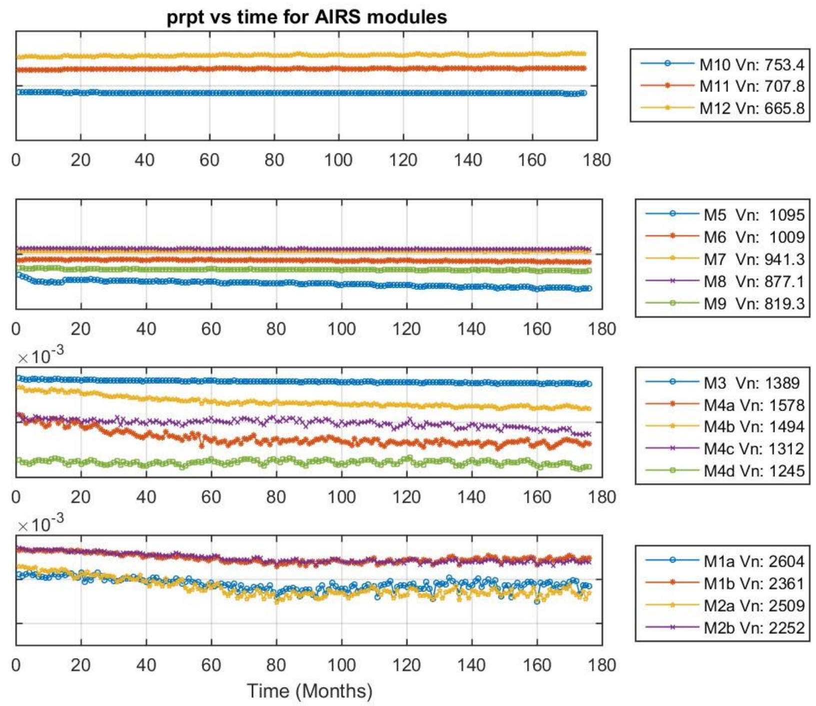
Preliminary

30d Average Improves In-orbit Characterization of AIRS Mirror Polarization Trends

One Day Per Month



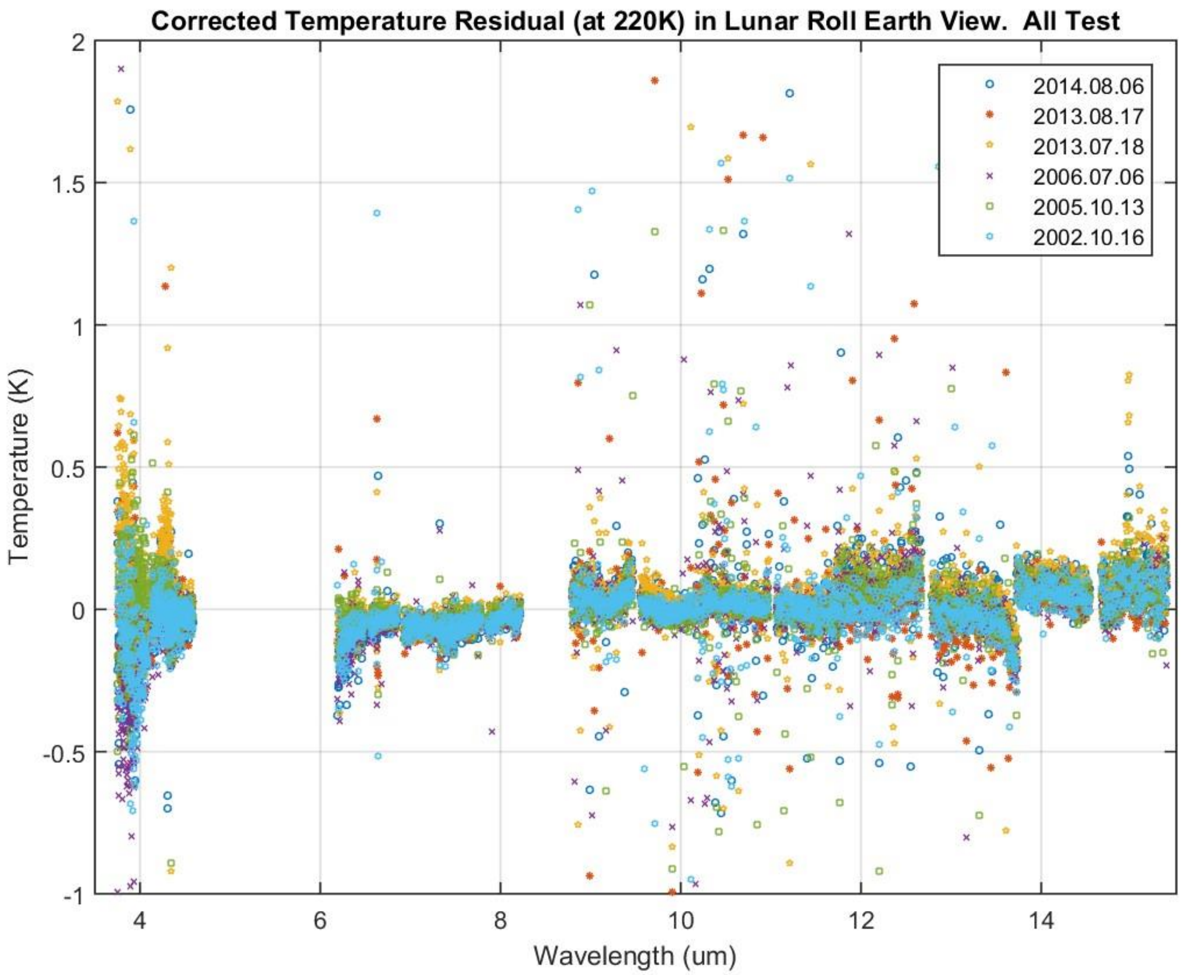
30d Average Day Per Month



Preliminary

Coefficients derived from space views applied to roll test produce low errors

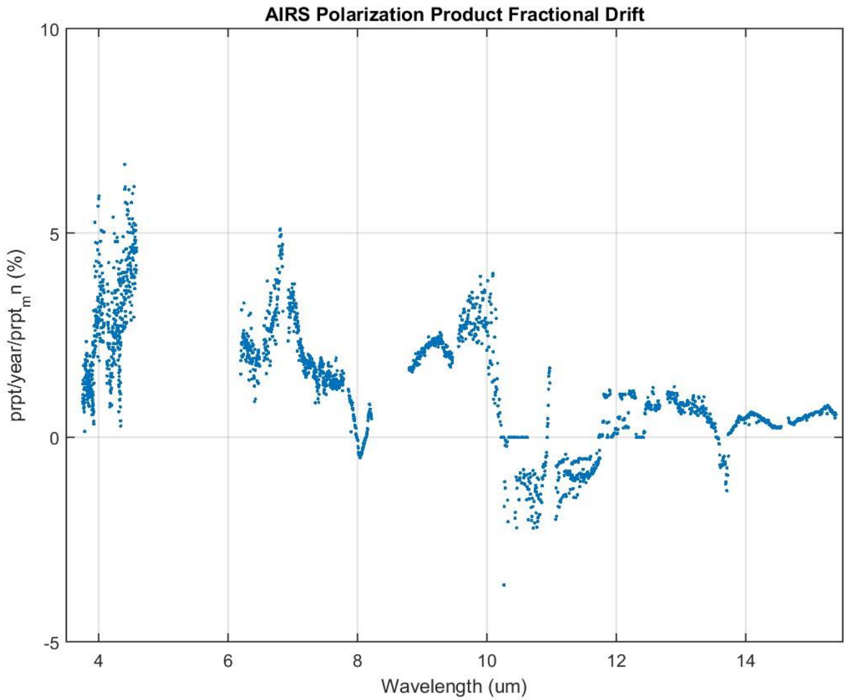
Derived radiance in Earth Viewport of deep space (spacecraft roll maneuver) expressed in terms of temperature at 220K



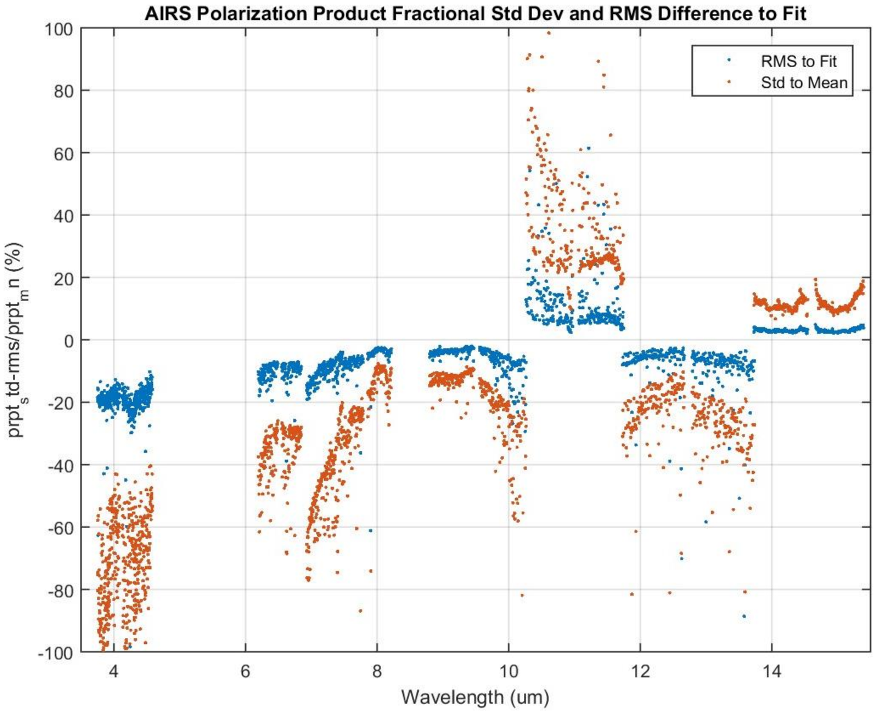
Preliminary

Linear fit gives annual trend. Time dependent polarization reduces errors.

Trend in polarization is up to 5% of nominal per year

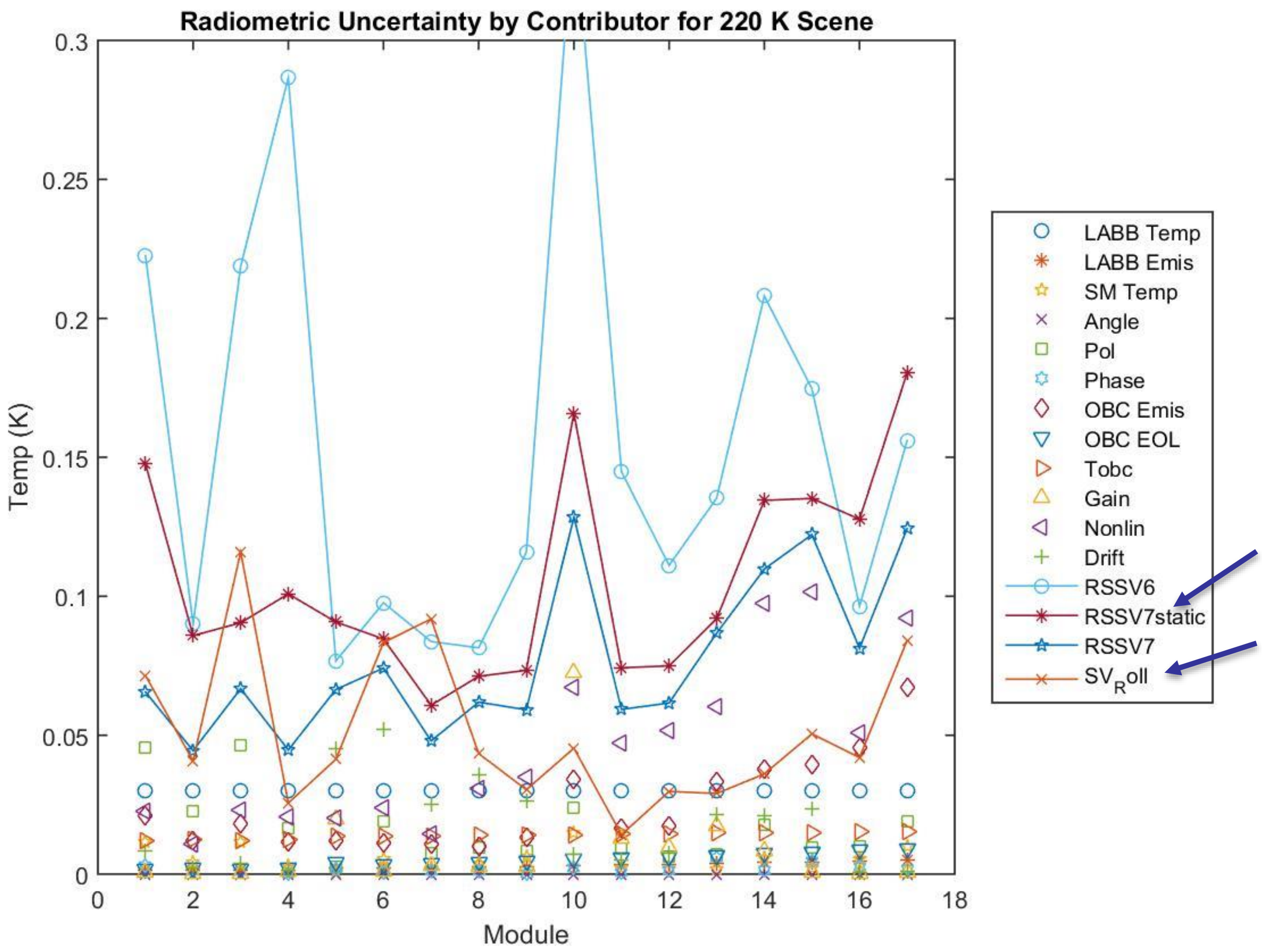


Time dependent polarization fit (blue) reduces errors compared to static (red)



Preliminary

Contributors to radiometric error at 220K and totals compared to prior versions



- Improvement in accuracy of more recent versions attributed to better polarization amplitude and phase estimates
- V7 coefficients applied to space view roll

Preliminary

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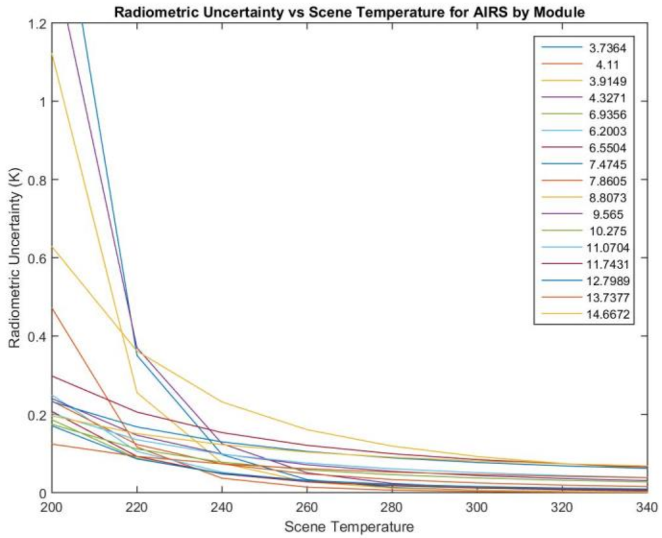
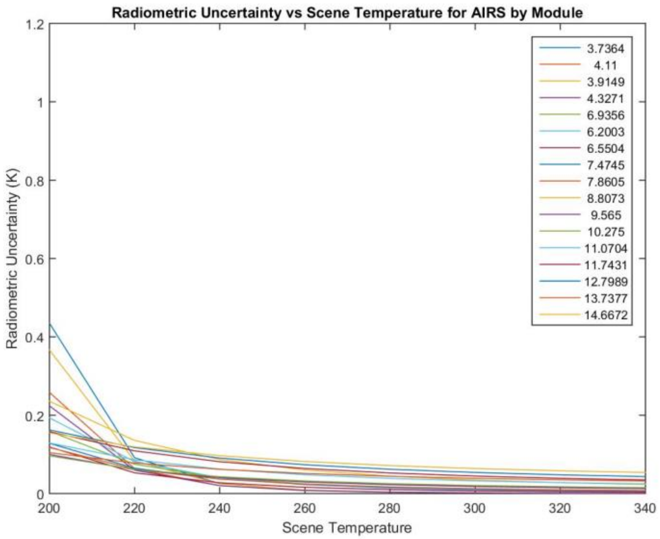
Radiometric accuracy expected to be better for low scene temperatures in Version 7

v6



v7



V7	AIRS Module	λ1(μm)	T(K) 200	T(K) 220	T(K) 240	T(K) 260	T(K) 280	T(K) 300	T(K) 320	T(K) 340
1	**M1a**	**3.752**	0.435	0.091	0.025	0.009	0.003	0.002	0.001	0.000
2	**M1b**	**4.127**	0.258	0.064	0.020	0.008	0.003	0.002	0.001	0.001
3	**M2a**	**3.891**	0.367	0.083	0.025	0.009	0.004	0.002	0.001	0.001
4	**M2b**	**4.301**	0.224	0.060	0.020	0.008	0.004	0.002	0.001	0.001
5	**M3**	**6.930**	0.159	0.075	0.041	0.025	0.016	0.011	0.008	0.006
6	**M4a**	**6.196**	0.193	0.081	0.040	0.022	0.014	0.009	0.006	0.005
7	**M4b**	**6.549**	0.119	0.053	0.027	0.016	0.010	0.007	0.005	0.004
8	**M4c**	**7.469**	0.128	0.065	0.037	0.024	0.016	0.012	0.009	0.007
9	**M4d**	**7.858**	0.118	0.062	0.037	0.024	0.017	0.012	0.010	0.008
10	**M5**	**8.798**	0.236	0.136	0.087	0.060	0.045	0.035	0.028	0.023
11	**M6**	**9.558**	0.100	0.061	0.041	0.030	0.023	0.018	0.015	0.013
12	**M7**	**10.264**	0.096	0.062	0.043	0.032	0.025	0.021	0.017	0.015
13	**M8**	**11.065**	0.129	0.086	0.063	0.048	0.039	0.033	0.028	0.025
14	**M9**	**11.731**	0.158	0.109	0.081	0.064	0.053	0.045	0.039	0.035
15	**M10**	**12.790**	0.162	0.117	0.091	0.074	0.062	0.054	0.048	0.043
16	**M11**	**13.728**	0.104	0.078	0.062	0.051	0.044	0.039	0.035	0.032
17	**M12**	**14.663**	0.155	0.119	0.097	0.082	0.071	0.064	0.058	0.054

Preliminary

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AIRS Radiometric Uncertainty Status

- AIRS radiometric accuracy at low temperatures driven by knowledge of the mirror polarized emission ($p_r p_t$ and delta)
- View of space during normal scanning operations enables in-flight derivation of polarized emission
- Terms applied to earth view during spacecraft roll show low residual errors
- Significant improvement over v6 errors
- Worst problem (biggest improvement) at short wavelengths and cold temperatures.
- Next Steps:
  - Test: Examine sample and ACDS data sets compared to prior versions
  - Validate:
    - Check trends on Deep Convective Clouds
    - Revisit validation of polar regions
  - Cross-compare
    - Compare with IASI and CrIS