S-NPP VIIRS Thermal Emissive Band (TEB) Validation Update

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with contributions from
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Thanks to all VIIRS SDR team partners in this work

Suomi NPP SDR Science and Products Review
December 18-20, 2013
College Park , MD

Outline

- VIIRS On-orbit TEB Evaluation
  - VIIRS-CrIS Comparisons
  - VIIRS-IASI Comparisons
  - Aircraft (NASA ER-2) Based Comparisons
  - VIIRS-MODIS Comparisons
  - Lake Tahoe Surface Network Comparisons
- Path Forward
- Summary

Objective: <u>understand</u> TEB SDR performance

"On-orbit sensor performance characterized and calibration parameters adjusted accordingly".

Top Level: VIIRS TEB Progress since Provisional Maturity

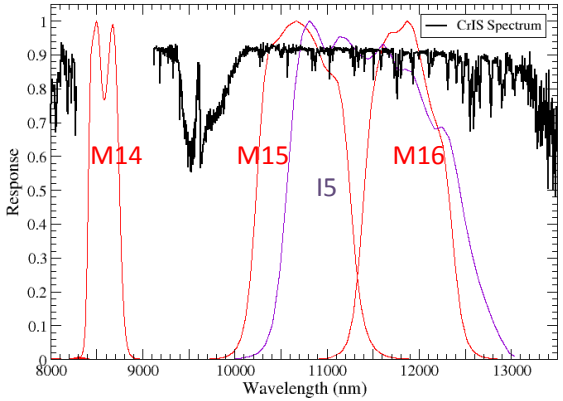
➢**VIIRS TEB performing well since provisional**; no new major issues. All spectral bands appear to be radiometrically stable and to meet performance requirements. Validated maturity is achieved.

➢**The SDR team is focused on detailed minor items** with the goal to further enhance the VIIRS TEB instrument performance. Several studies have been performed:

- M15 bias at cold temperatures relative to CrIS (DR 7414)
  - The STAR and U. Wisconsin team coordinating with the CrIS SDR team to diagnose root cause of the cold scene bias.
  - CrIS SDR team has recently tuned the CrIS calibration (Mx8.1), reducing the bias slightly (~0.1K).
  - About 0.4K bias at ~200K remains. VIIRS SDR team performed in-depth analysis (see Dave Moyer, Chris Moeller studies)
  - Impact of bias at 205k on DCC calibration for RSB investigated (journal paper in progress)
- TEB band range limit discrepancies between BT and Radiance investigated, working closely with the Fire team. Similar issues are under study for the RSB. DR is currently being evaluated.
- Comparisons with MODIS at SNOx are being performed.
- SST and M15/M16 striping studies: atmosphere vs. detector stability (see presentation by F. Padula)
- M12 striping due to difference in geometric azimuth angles
- VIIRS calibration dependence on OBC temperature.
- VIIRS M13 low gain calibration assessment
- VIIRS TEB gains remain relatively stable

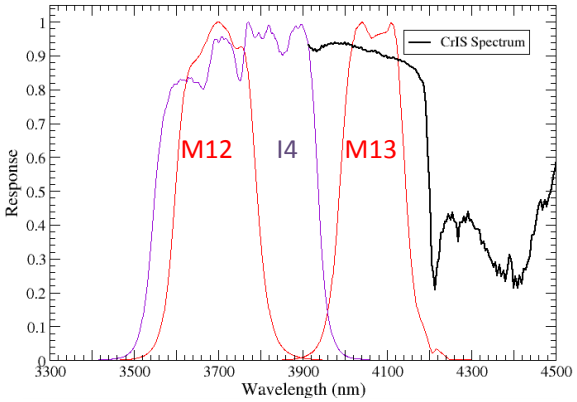
VIIRS Imagery Gallery Enhancement (https://cs.star.nesdis.noaa.gov/NCC/GalleryPage04)

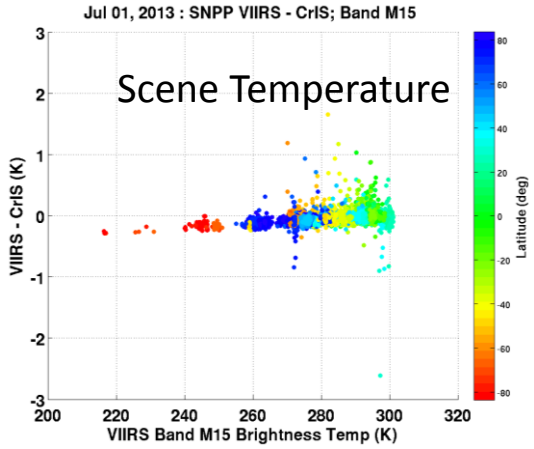
VIIRS-CrIS SDR Comparisons



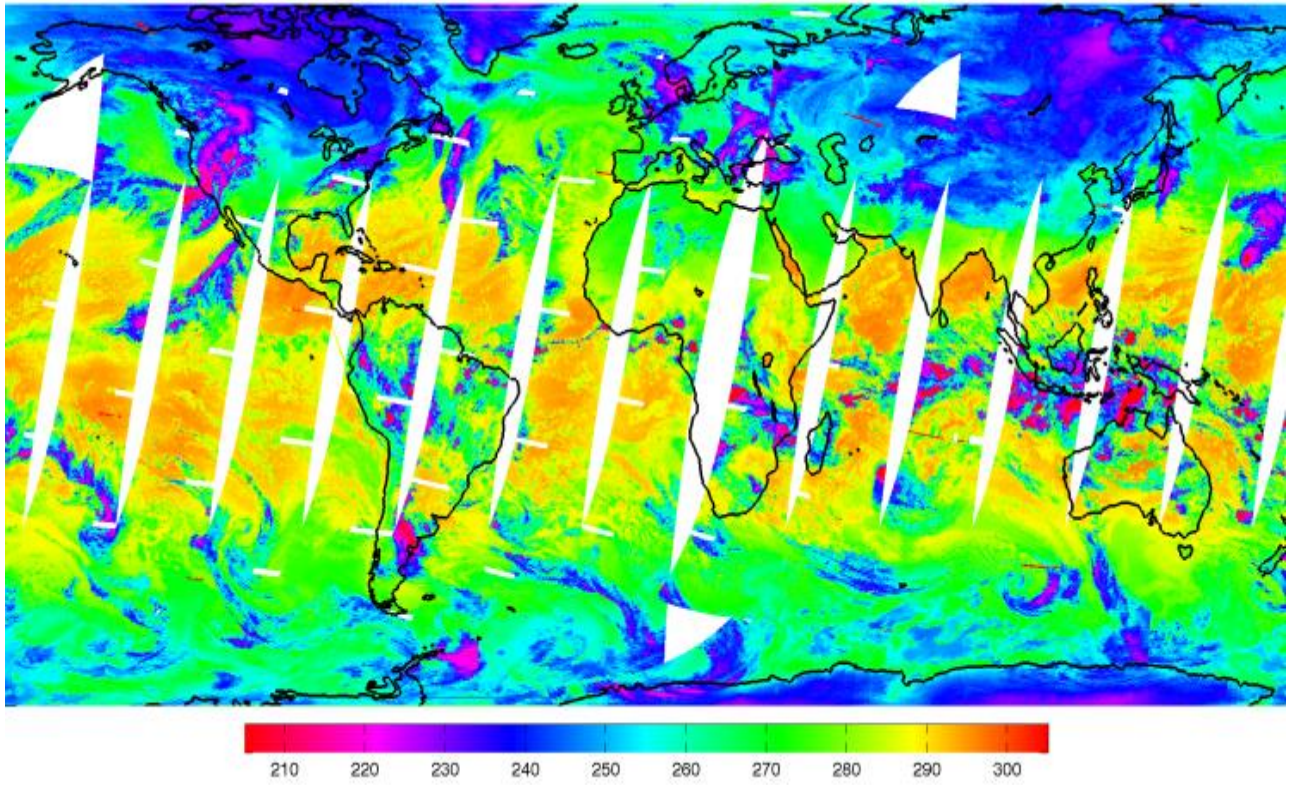
- VIIRS SDR accuracy/stability plus RVS performance
- Global; 2.9 million matchups daily from SNPP platform
- CrIS radiances anticipating Mx8.1
- In-band spectral radiance for M13, M15, M16 and I5
- Long term high quality data record to assess stability

CrIS spectrum covers VIIRS M13, M15, M16, and I5 but does not include OOB response in M15 and M16

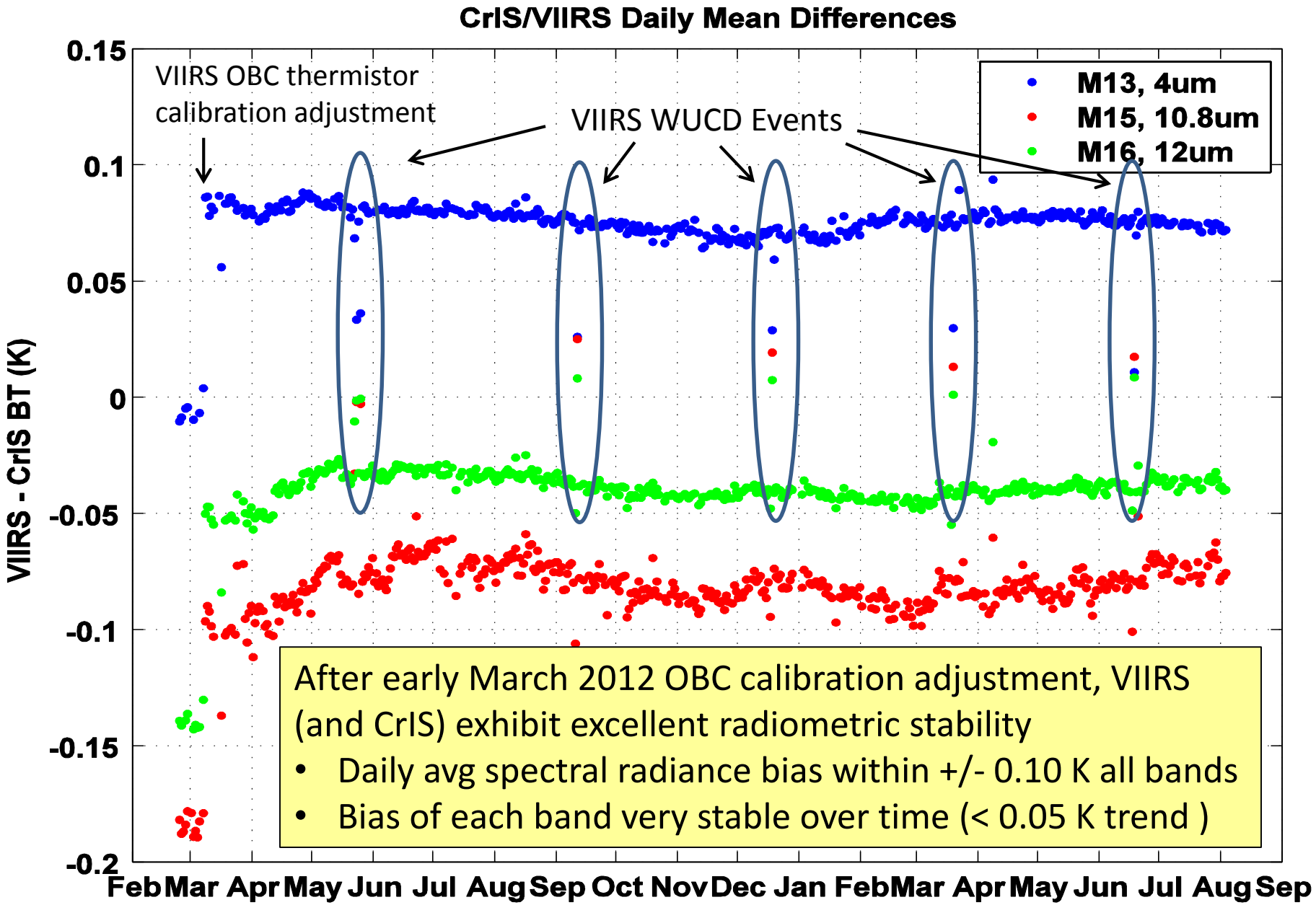




CrIS convolved with VIIRS SRF **VIIRS mean within CrIS FOVs**

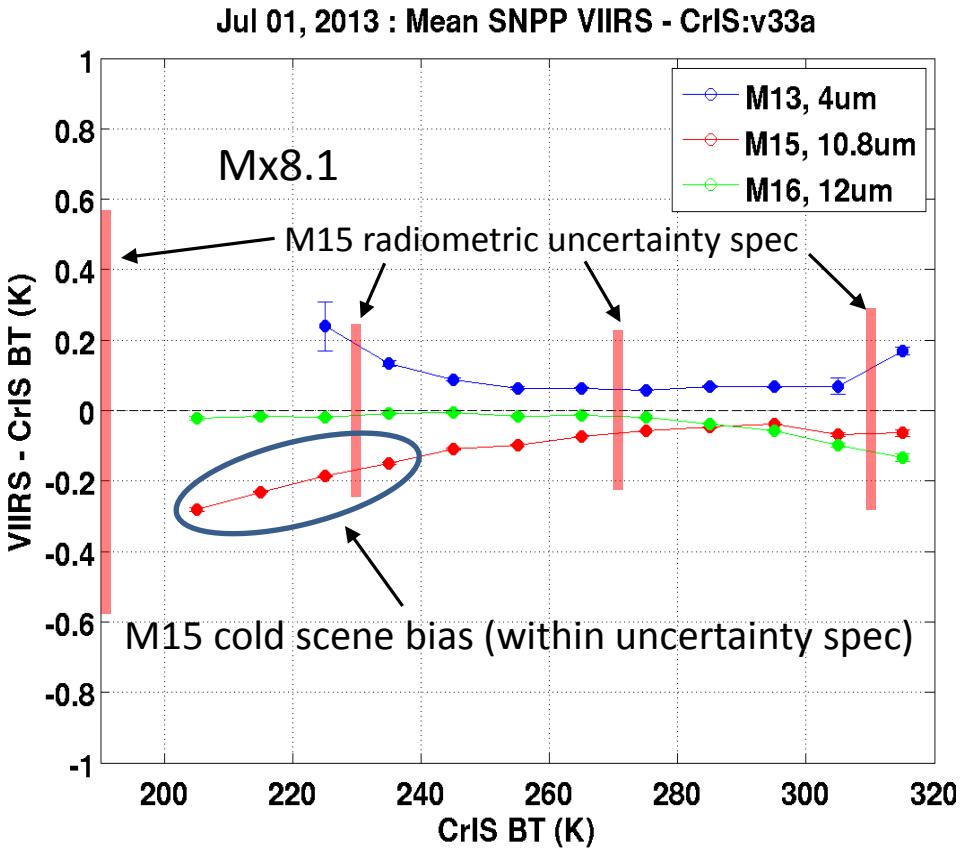


VIIRS-CrIS SDR Comparisons

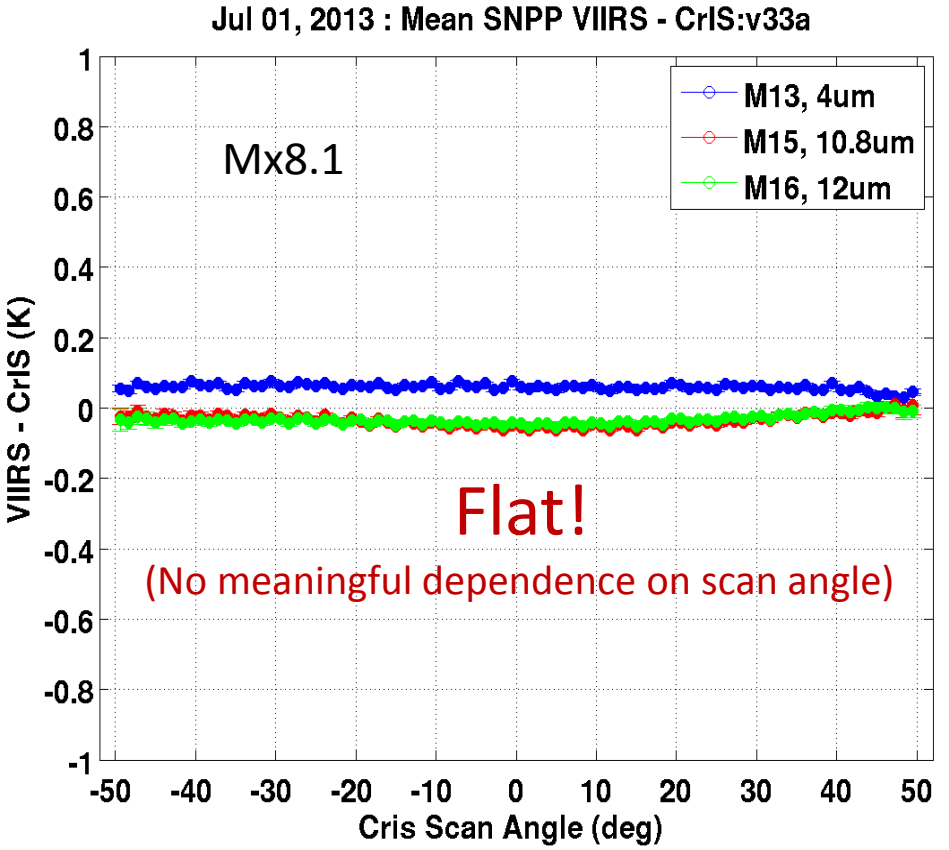


VIIRS-CrIS (Mx8.1)

- Scene temperature provides insight on calibration coefficient performance.
- Scan angle provides insight on HAM RVS characterization quality.
- Data shown for July 1, 2013 is typical of all days. CrIS calibration Mx8.1.

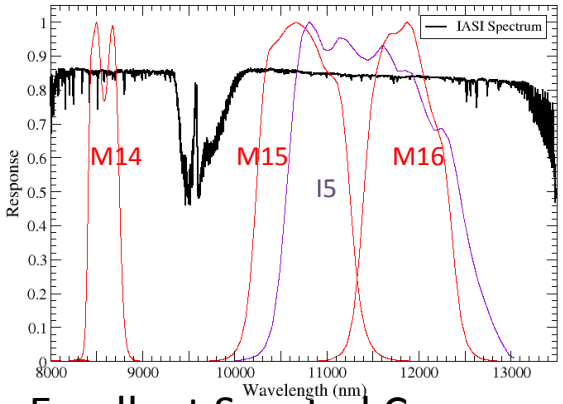


- M15 bias (above) has <u>minor cold scene dependence</u>, less so for M13. Suggests that C_0 coefficient may not be optimally set. Note: this dependence has been reduced by Mx8.1 CrIS calibration.
- Minimal dependence of bias on scan angle (right). <u>TEB RVS well characterized</u>.

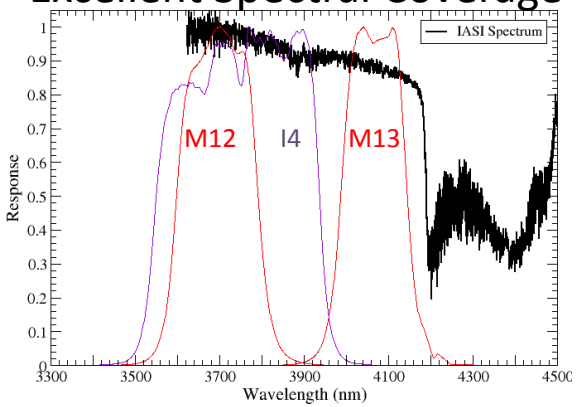


VIIRS-IASI SDR Comparisons

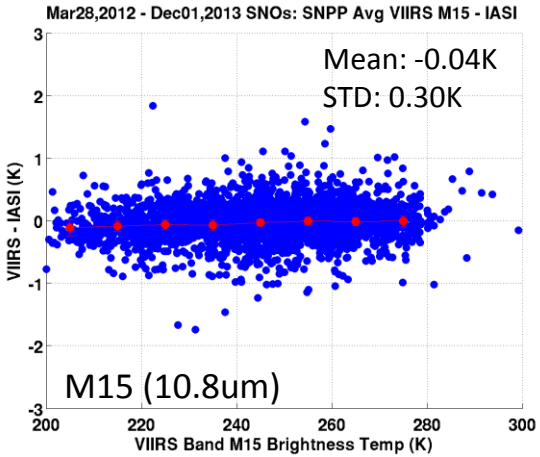
- Evaluate VIIRS SDR accuracy and OOB impact
- High latitude SNOs; limited data sample
- All FOVs inside 50 km radius around each SNO are retained:14-16 IASI FOVs and >10,000 VIIRS 1 km FOVs
- 10 minute tolerance on SNO occurrence
- IASI spectral coverage of VIIRS M13-M16, I5; nearly complete spectral coverage of M12 (85%) and I4 (81%)



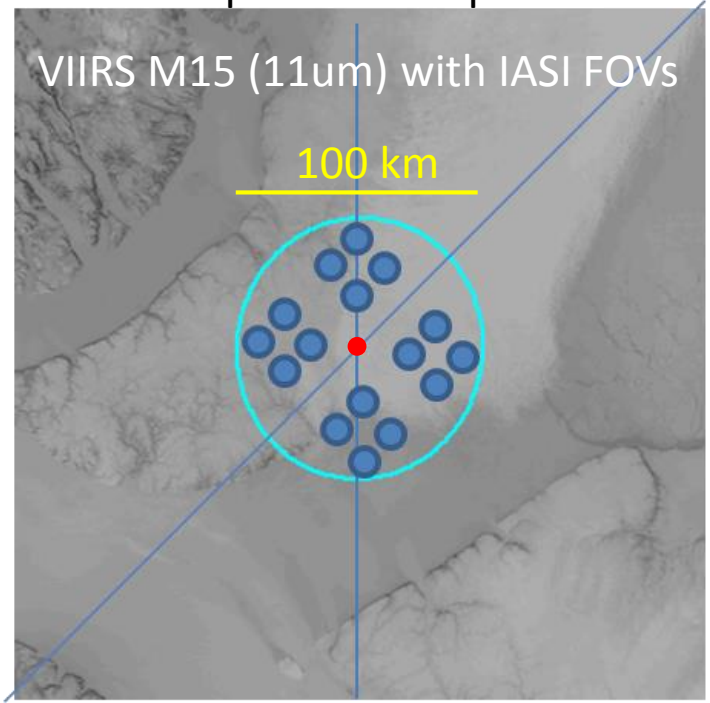
Excellent Spectral Coverage



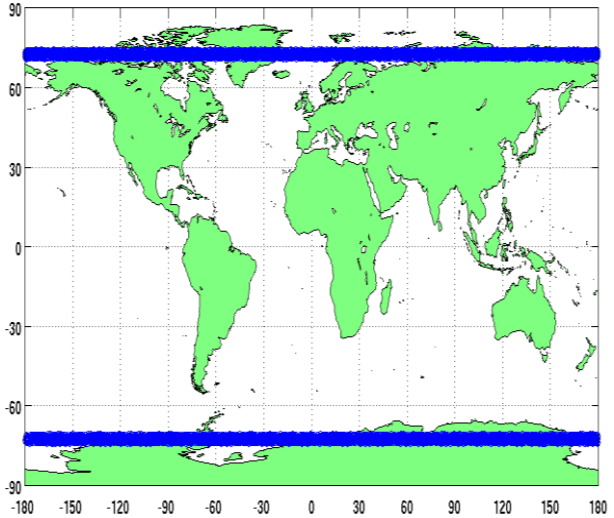
Difference as a function of scene temperature

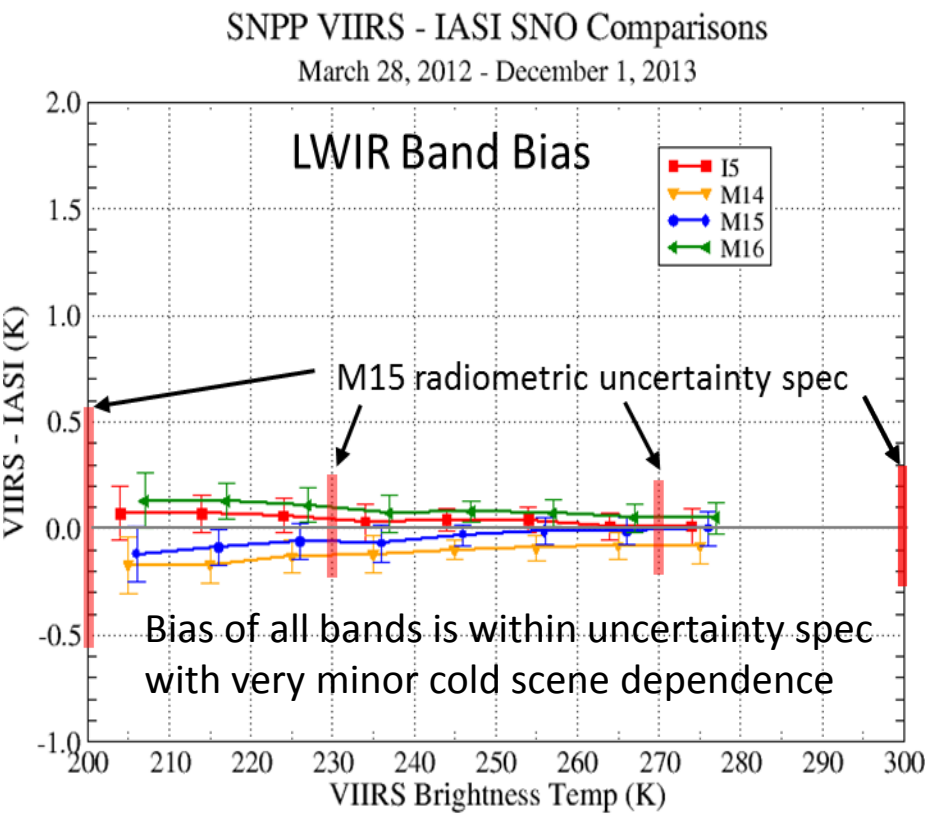


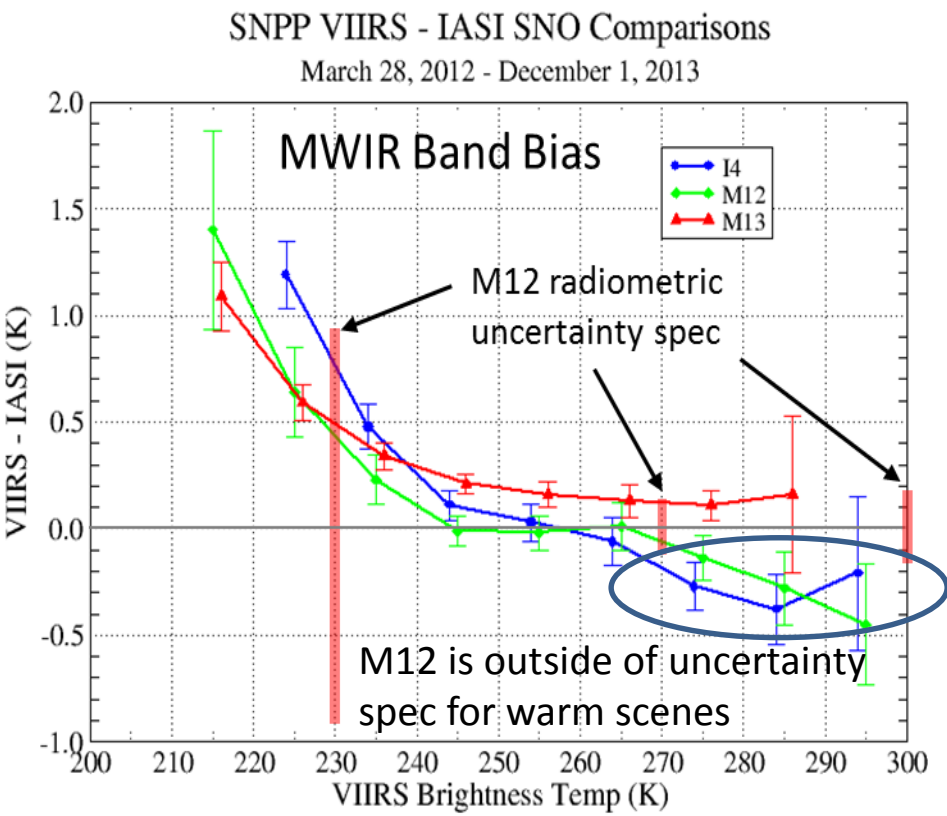
+/-10 minute tolerance on overpass of SNO point

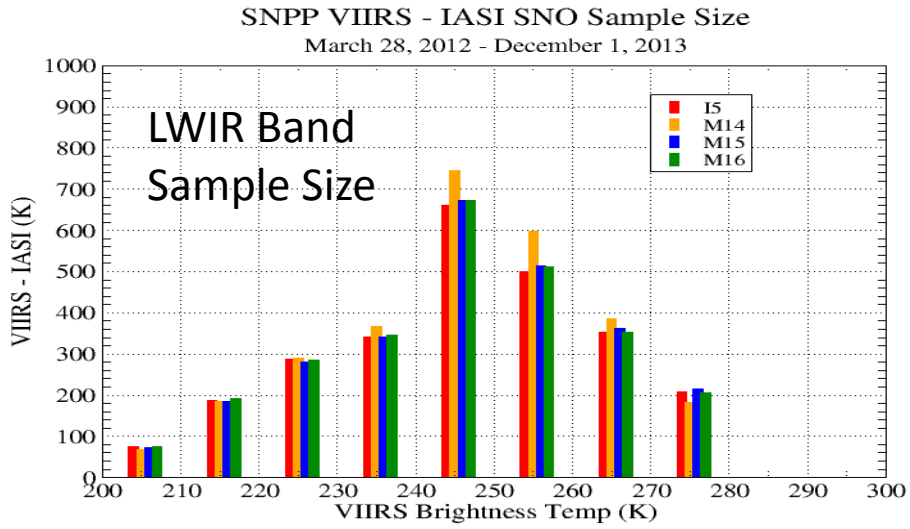


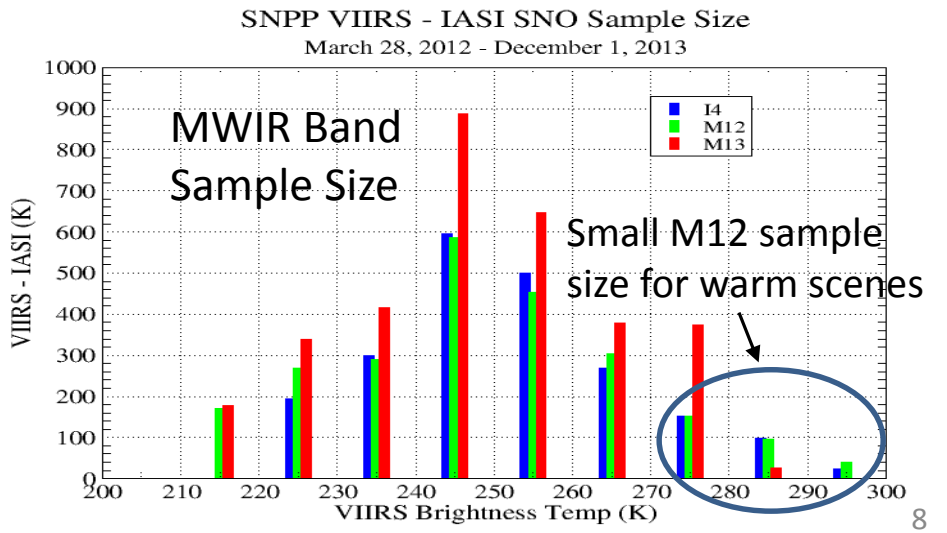
S-NPP/MetOp-A SNOs occur exclusively at polar latitudes



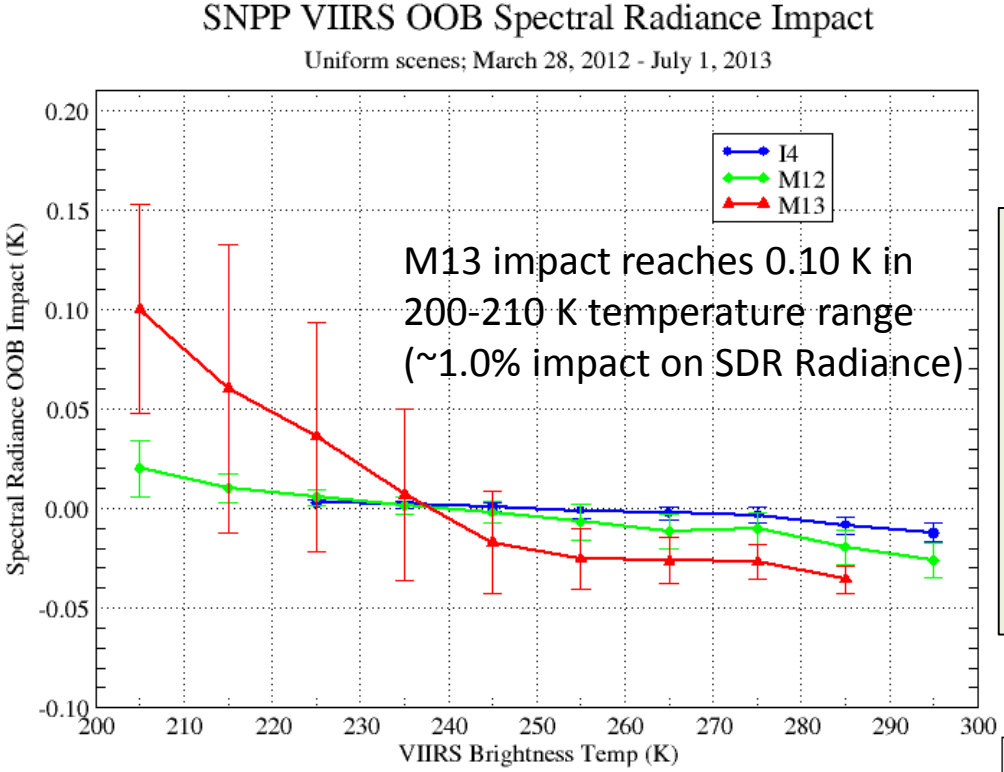

SNPP VIIRS - IASI SNO Comparisons
March 28, 2012 - December 1, 2013
LWIR Band Bias
I5
M14
M15
M16
M15 radiometric uncertainty spec
Bias of all bands is within uncertainty spec
with very minor cold scene dependence
VIIRS - IASI (K)
VIIRS Brightness Temp (K)


SNPP VIIRS - IASI SNO Comparisons
March 28, 2012 - December 1, 2013
MWIR Band Bias
I4
M12
M13
M12 radiometric
uncertainty spec
M12 is outside of uncertainty
spec for warm scenes
VIIRS - IASI (K)
VIIRS Brightness Temp (K)


SNPP VIIRS - IASI SNO Sample Size
March 28, 2012 - December 1, 2013
LWIR Band
Sample Size
I5
M14
M15
M16
VIIRS - IASI (K)
VIIRS Brightness Temp (K)

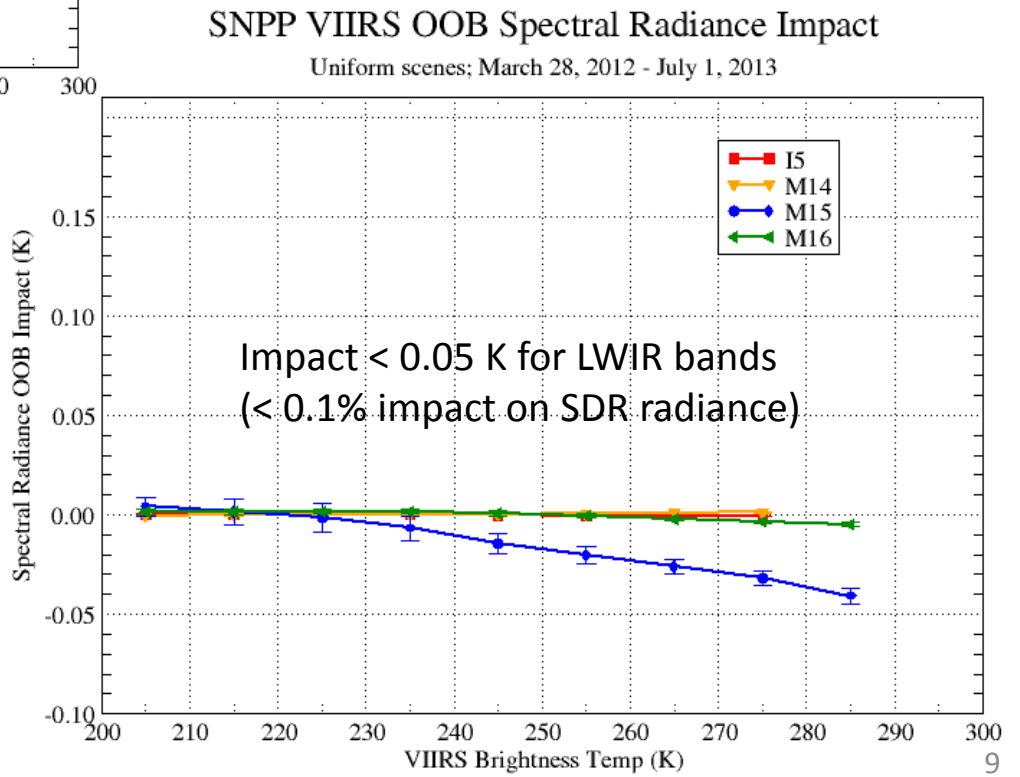

SNPP VIIRS - IASI SNO Sample Size
March 28, 2012 - December 1, 2013
MWIR Band
Sample Size
I4
M12
M13
Small M12 sample
size for warm scenes
VIIRS - IASI (K)
VIIRS Brightness Temp (K)

Out-of-Band Impact based on SNOs



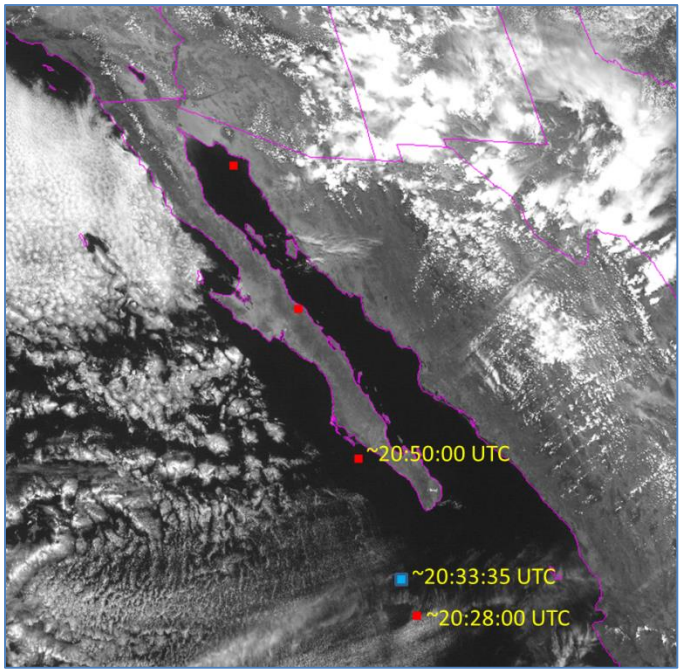
- Compare In-band+ OOB signal to In-band-only signal.
- Pre-launch measurements indicated possible non-compliance in M15 and M16 (see yellow boxes lower left)
- But, < 0.05 K impact except for M13 which reaches 0.10 K only at cold scenes

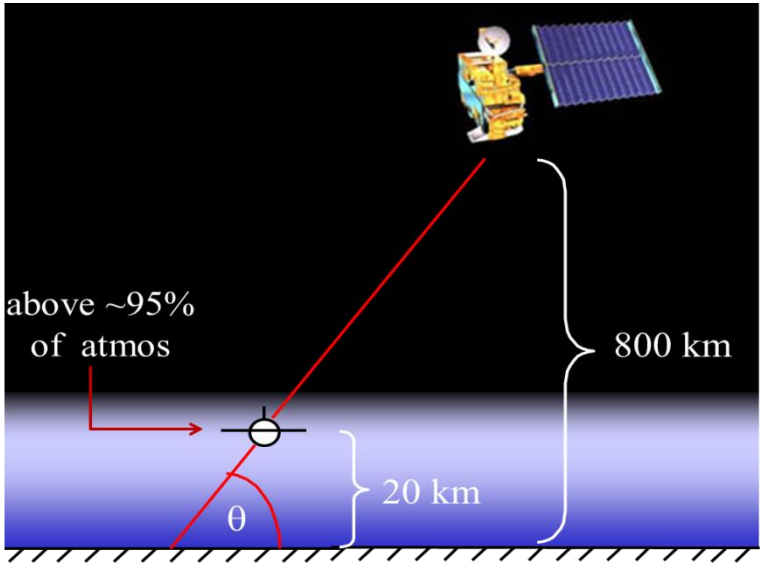
Band	Band Center (nm)	Bandwidth (nm)	Extended Bandpass (nm)	Integrated OOB % (spec)
M12	3694.6	193.2	3515.3 – 3890.5	0.34 (1.1)
M13	4065.7	158.2	3900.4 – 4240.8	0.35 (1.3)
M14	8577.4	341.0	8332.2 – 8875.5	0.21 (0.9)
M15	10740.9	1014.5	9916.2 – 11650.2	0.40 (0.4)
M16A	11859.9	912.8	11068.4 – 12668.1	0.39 (0.4)
M16B	11867.1	920.6	11072.7 -12676.6	0.37 (0.4)
I4	3743.3	386.8	3472.5 - 4009.3	0.16 (0.5)
I5	11500.9	1880.4	10170.2 - 13035.5	0.06 (0.4)



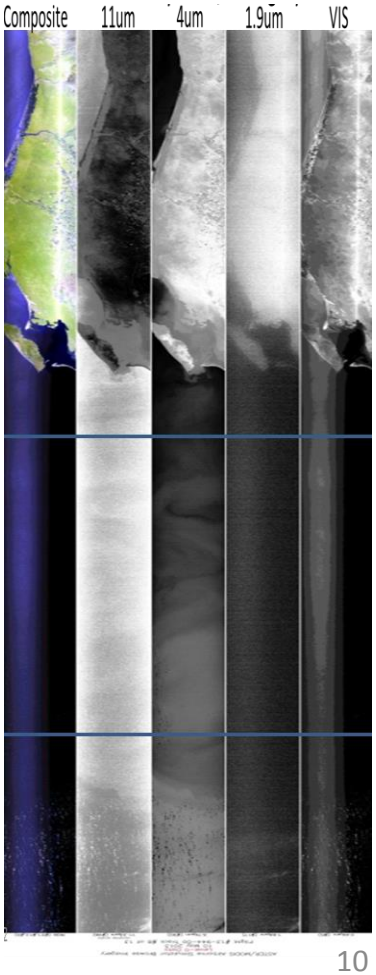
NASA ER-2 Underflights of S-NPP

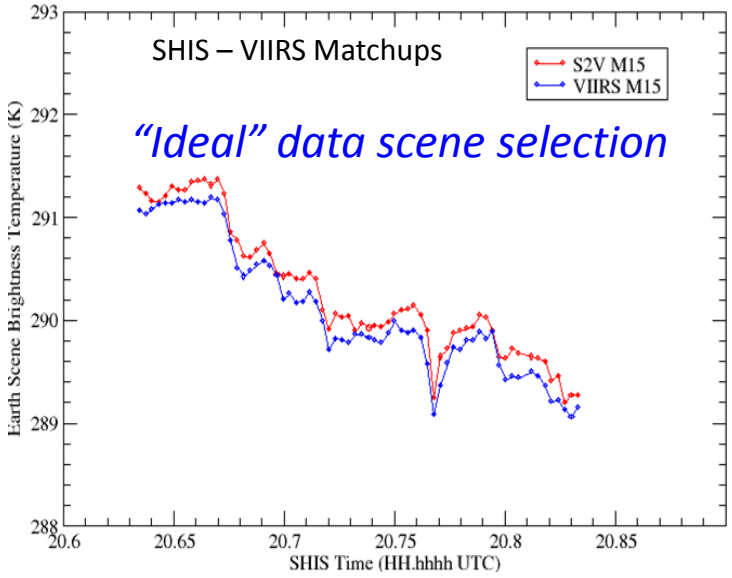
- VIIRS SDR accuracy evaluation
- SHIS (NIST-traceable blackbody source, 0.1 K)
- MASTER (50 m spatial resolution mapping)
- 3 excellent flights under S-NPP (8 total)

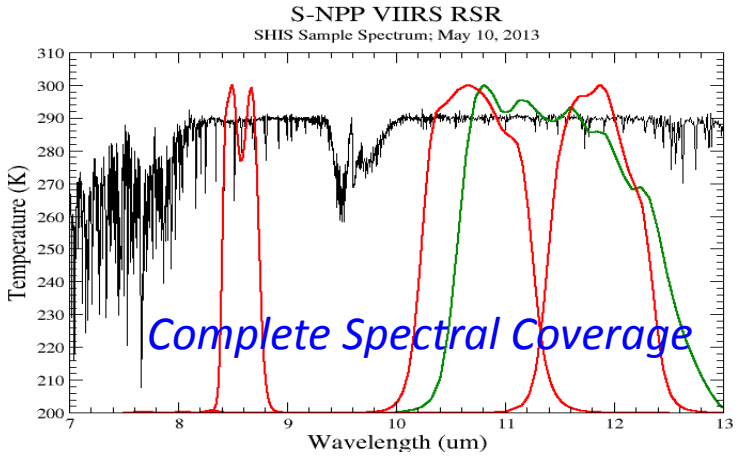




MASTER Q/L Imagery

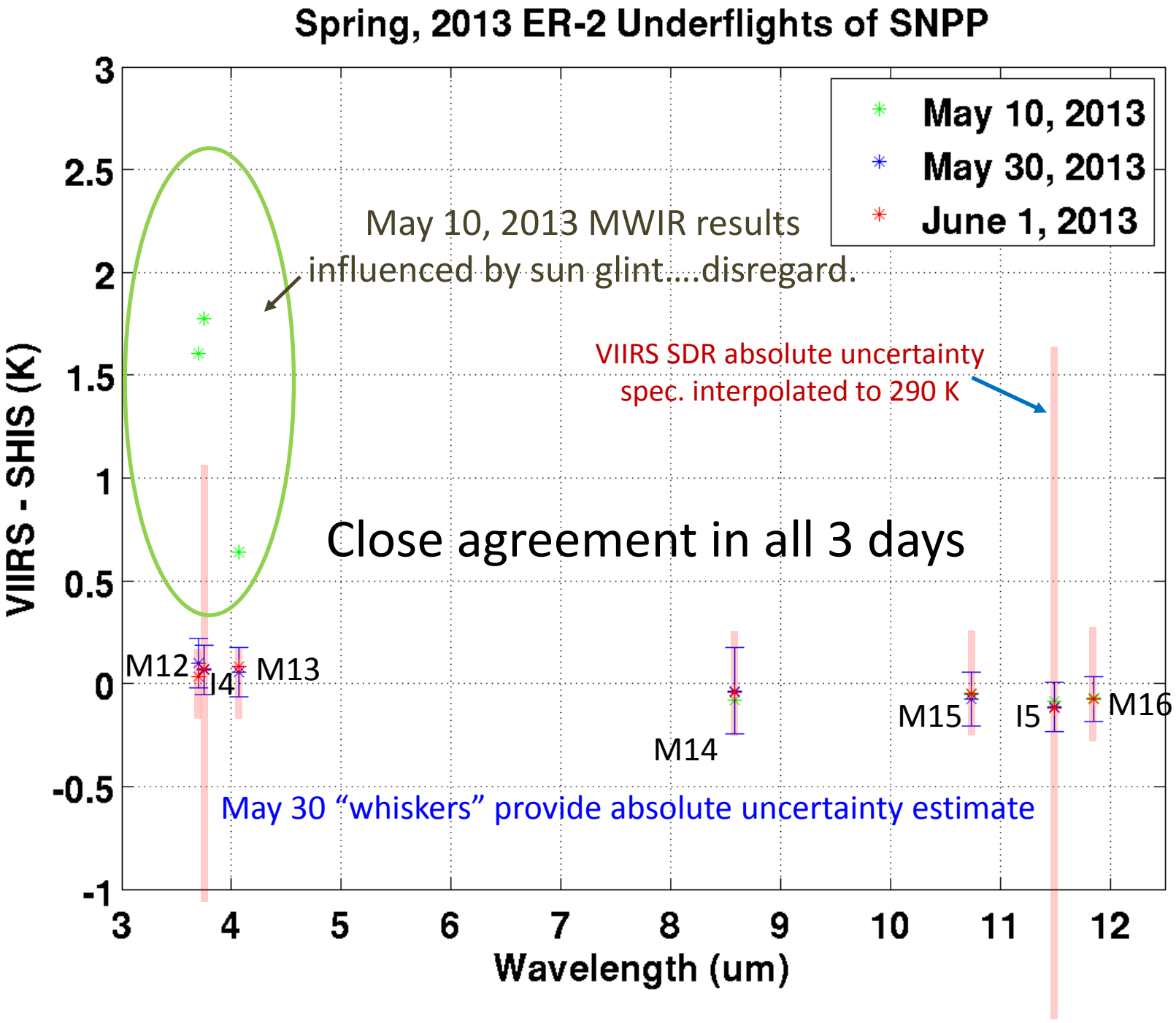




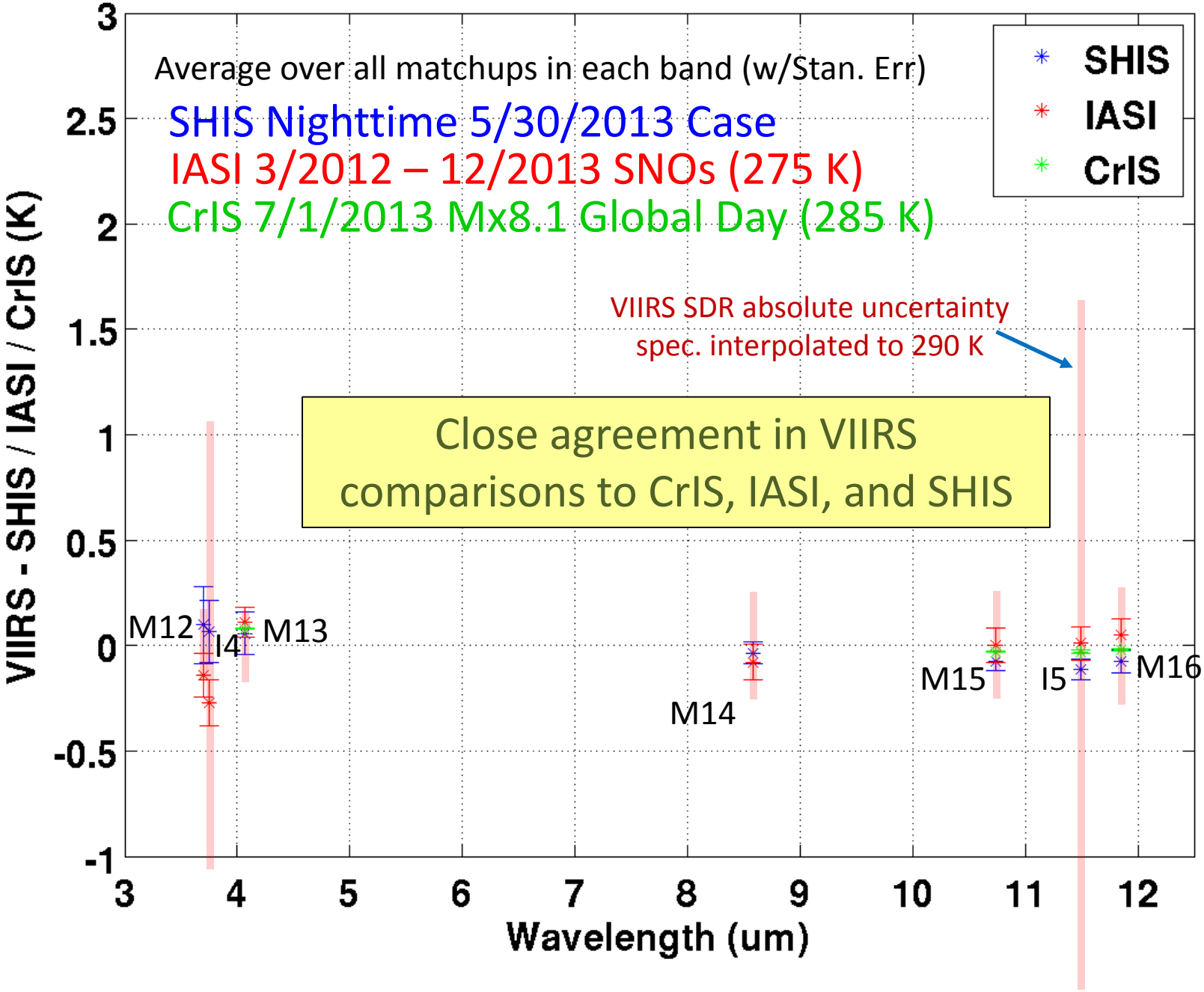


VIIRS-SHIS Absolute Uncertainty Sources and Estimates

- Spatial Matchup (geolocation) Error
  - < 0.01 K (ensemble)
- Temporal Offset
  - .07, .05, .06, .05 K for M14, 15, 16, I5, resp.
  - Actual is expected < 50% of above numbers because above numbers reflect 30-50 minute difference between repeat SHIS coverage. Actual difference of SHIS and VIIRS is 4-16 minutes.
- SHIS Radiometric Uncertainty
  - ~0.1 K @ 290 K for all bands
- Altitude Temperature Correction
  - 50% of correction:
  - I4 0.18 0.02 K I5 0.06 0.03 M12 0.02 0.01 M13 0.01 M14 M15 M16
- RSS Total Uncertainty Estimate
  - **~0.12 K** (I4, I5, M12, M13, M15, M16)
  - **0.21 K** (M14)


Spring, 2013 ER-2 Underflights of SNPP
May 10, 2013
May 30, 2013
June 1, 2013
May 10, 2013 MWIR results
influenced by sun glint….disregard.
VIIRS SDR absolute uncertainty
spec. interpolated to 290 K
Close agreement in all 3 days
M12
I4
M13
M14
M15
I5
M16
May 30 "whiskers" provide absolute uncertainty estimate
VIIRS - SHIS (K)
Wavelength (um)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
3
4
5
6
7
8
9
10
11
12

VIIRS Warm Scene Comparisons to SHIS, IASI, and CrIS:v33a



Path Forward

- TEB SDR research items
  - C_0 calibration coefficient impact on VIIRS SDR product
  - Response of VIIRS SDR to changes in the OBC operating temperature
  - Striping in TEB SDR
- Continue monitoring TEB SDR performance
  - Intra- and inter-satellite comparisons
  - Additional aircraft campaigns (cold scenes?)

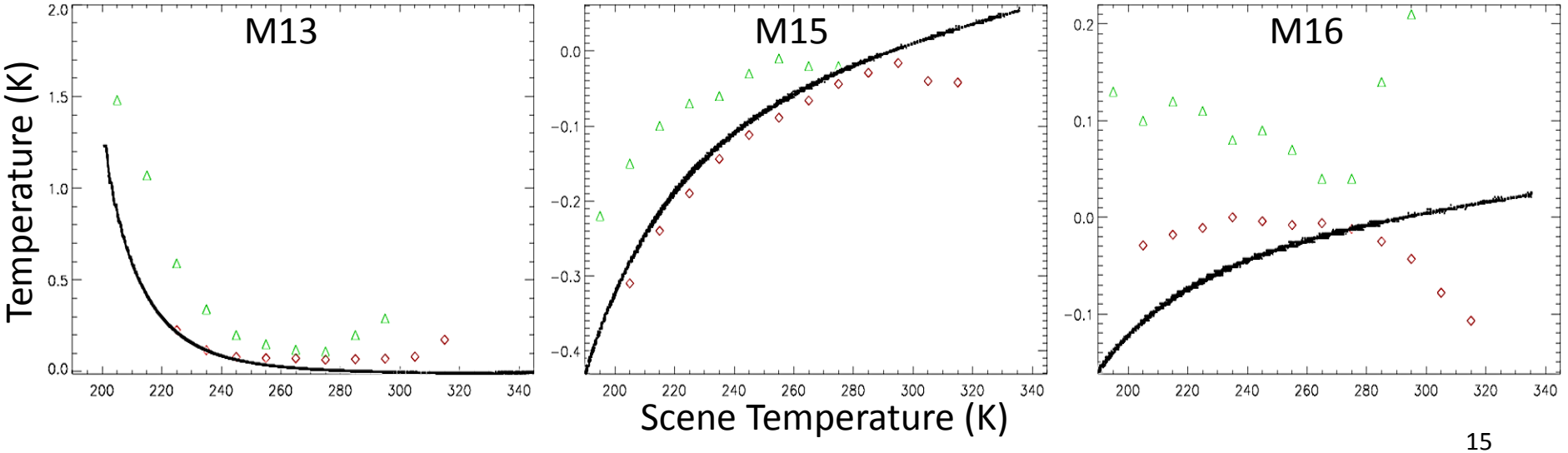
VIIRS C_0 Calibration Coefficient Modification

- Modify the VIIRS TEB delta C LUT to change the VIIRS cold brightness temperatures to better match CrIS and IASI on-orbit cold scene performance (brightness temperature).
- Preserves VIIRS detector-to-detector, HAM side and temperature relative "shape" in prelaunch tables.
- Latest testing uses CrIS calibration planned for Mx8.1.

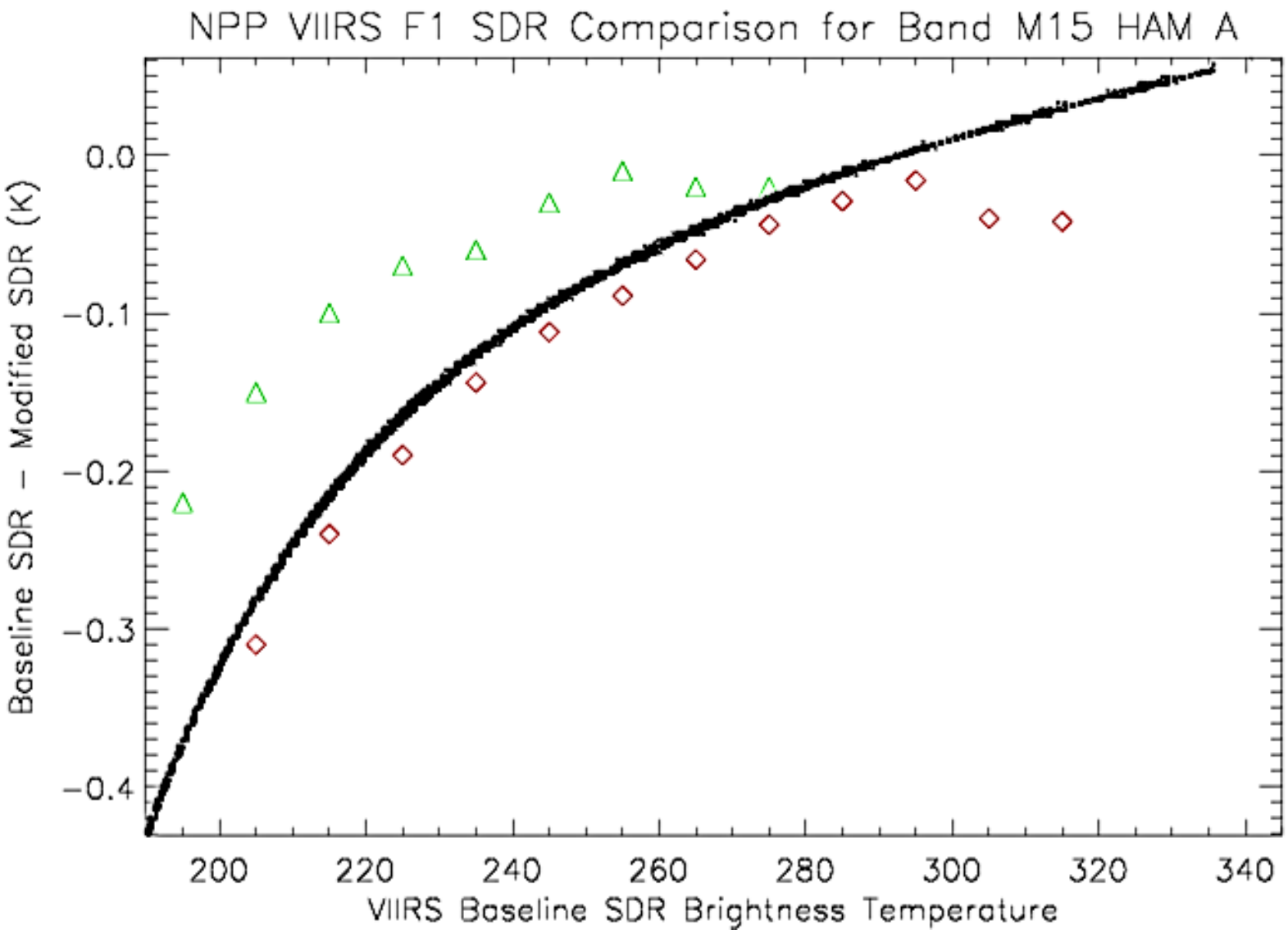
Residual Background Emission

Calculated Radiance

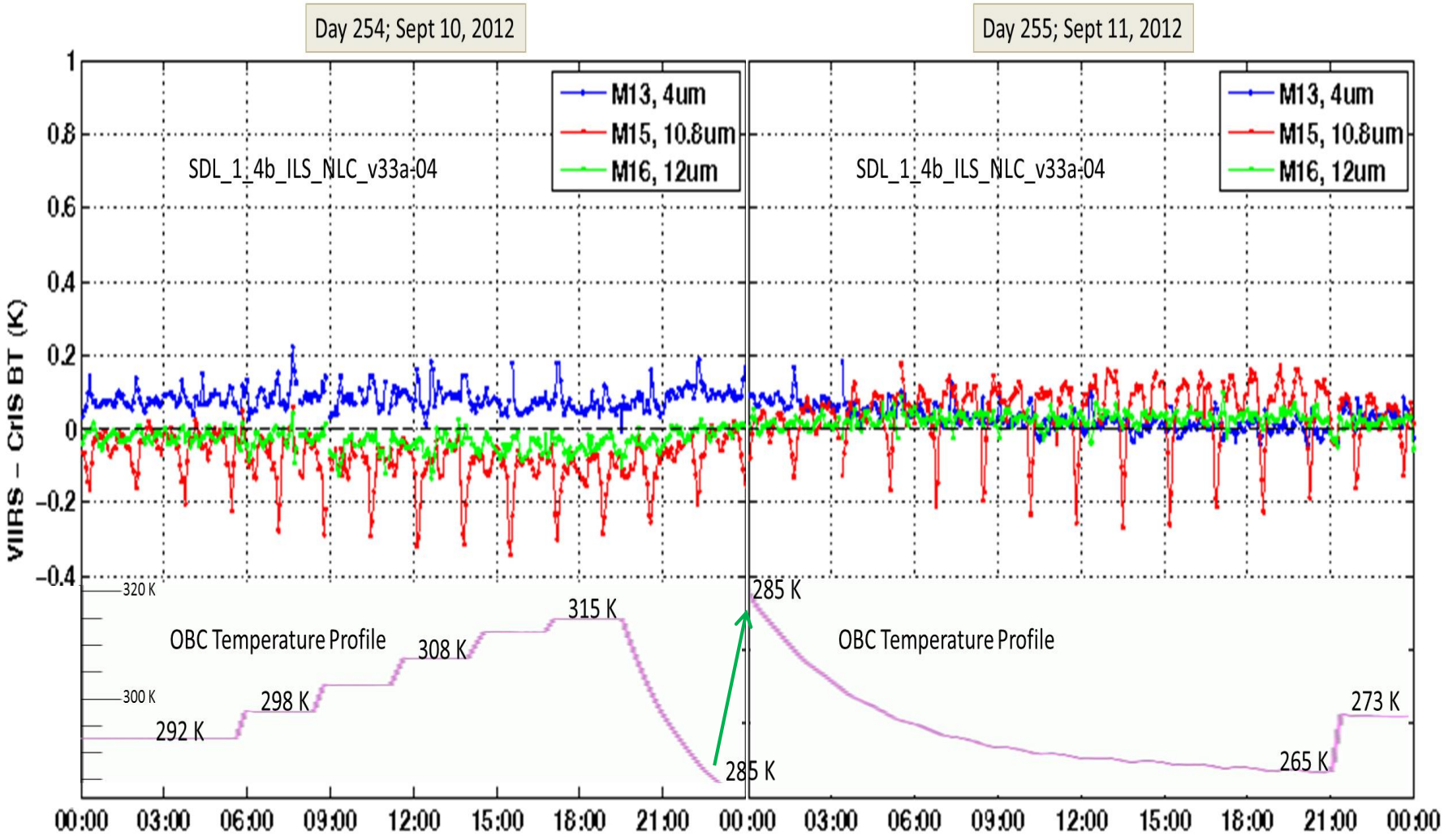
$$L_{ap}(RVS_{EV}) = \frac{(RVS_{SV} - \mathrm{RVS}_{EV}) \cdot \left[\frac{(1-\rho_{rta}) \cdot L(T_{rta}) - L(T_{ham})}{\rho_{rta}} \right] + F \cdot \left(c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^{\ 2} \right)}{\mathrm{RVS}_{EV}}$$



VIIRS C_0 Calibration Coefficient Modification



VIIRS-CrIS Comparisons During VIIRS WUCD: Mx8.1



TEB SDR Performance Summary

- No significant new issues since Provisional status.
- VIIRS TEB on-orbit SDR comparisons demonstrate high quality, stable performance. Adjustments since launch have been effective; TEB calibration is well understood.
- NIST traceable SHIS comparisons show SDR compliance in warm scenes for all TEB.
- Future minor adjustments under consideration, e.g.
  - M15 cold scene performance
  - Minor dependence of calibration on OBC temperature
  - SST band striping
- Cold scene calibration is most challenging portion of dynamic range to validate.

Backup

VIIRS SDR Absolute Uncertainty

SRV0545: “For the bands specified as moderate resolution and emissive, the radiometric calibration uncertainty of spectral radiance shall be equal or less than the percentages specified in Table 17.”

Band	λ_c (μm)	Scene Temperature				
		190K	230K	270K	310K	340K
M12	3.7	N/A	7.0% 0.92 K	0.7% 0.13 K	0.7% 0.17 K	0.7% 0.21 K
M13	4.05	N/A	5.7% 0.81 K	0.7% 0.15 K	0.7% 0.19 K	0.7% 0.23 K
M14	8.55	12.3% 2.51 K	2.4% 0.75 K	0.6% 0.26 K	0.4% 0.23 K	0.5% 0.34 K
M15	10.763	2.1% 0.56 K	0.6% 0.24 K	0.4% 0.22 K	0.4% 0.28 K	0.4% 0.34 K
M16	12.013	1.6% 0.48 K	0.6% 0.26 K	0.4% 0.24 K	0.4% 0.31 K	0.4% 0.37 K
I4*	3.74	5.0% 0.90 K				
I5*	11.45	2.5% 1.40 K				

*Note: Imager bands I4 and I5 requirements only at scene temperature of 267 K.