NOAA-20 CrIS SDR Beta Maturity Status Report

January 25, 2018

CrIS SDR Team

With contributions from NOAA/STAR, NASA/GSFC, Harris, UW/SSEC, UMBC, UMD/CICS, SDL/USU, MIT/LL, Logistikos, Raytheon

Outline

- Algorithm Cal/Val Team Members
- NOAA-20 CrIS Cal/Val Time Line
- NOAA-20 CrIS First Global Coverage Image
- CrIS Instrument Performance
  - On-orbit NEdN
  - DA Bias Tilt
  - Metrology Laser Set Optimization
  - Gain Setting
  - Bit Trim/Impulse Noise Mask Check
  - On-Orbit Torque Null Position Update for In-Track Angles
- CrIS SDR Performance
  - Radiometric Calibration Accuracy
  - Spectral Calibration Accuracy
  - Geolocation Accuracy
- Summary and Path Forward

Cal/Val Team Members

PI	Organization
Changyong Cao (acting)	NOAA/STAR
Dave Tobin	U. of Wisconsin (UW)
Larrabee Strow	U. of Maryland Baltimore County (UMBC)
Deron Scott	Space Dynamic Lab (SDL)
Dan Mooney	MIT/LL
Dave Johnson	NASA Langley
Lawrence Suwinski	Harris
Joe Predina	Logistikos
Deirdre Bolen	JPSS/JAM
Wael Ibrahim	Raytheon

- **Big thanks for the dedicated and hard work of each of the contributing organizations**
- **Team work has been and continues to be exceptional**

NOAA-20 CrIS SDR Cal/Val Timeline

	Flight Activity	Ground Activity
L + 0 (11/18/17)	JPSS-1 Launch	
L + 11 (11/29/17)	Begin Outgassing	
L + 46 (1/3/18)	End Outgassing; Deploy Cooler Door; Initial Cal Table upload(v112) Instrument Stable	
L + 47 (1/4/18)	First Earth view science data available	Science Data Available (L+48)
		CrIS Diode Temp, IR Gain Check, BTM, Impulse Noise Mask Check, Jitter Performance, etc
L + 60 (1/17/18)	Second Cal Table (v113) upload with PGA gain and new Neon Wavelength and ILS parameters	
		SDR data available (Beta Maturity L+68), Spectral Cal/Laser Stability, Detector Noise/Linearity, Full Res Diagnostic, Geolocation a2, ILS parameters Delivered w/STAR input (L+85)
L + 90 (2/16/18)	Third Cal Table Upload v114	Provisional Maturity

Beta Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

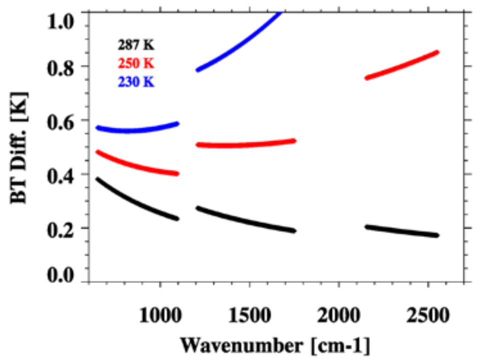
- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

NOAA-20 SDR Calibration Uncertainty Specifications

Normal Spectral Resolution

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN @287K BB mW/m^2/sr/cm^{-1}	Radiometric Uncertainty @287K BB (%)	Spectral (chan center) uncertainty ppm	Geolocation uncertainty Km (Nadir)
LW	650-1095	713	0.625	30	9	**0.14**	**0.45**	**10**	**1.5**
MW	1210-1750	433	1.25	30	9	**0.06**	**0.58**	**10**	**1.5**
SW	2155-2550	159	2.5	30	9	**0.007**	**0.77**	**10**	**1.5**

Radiometric uncertainty specification converted to Brightness Temperature (BT)

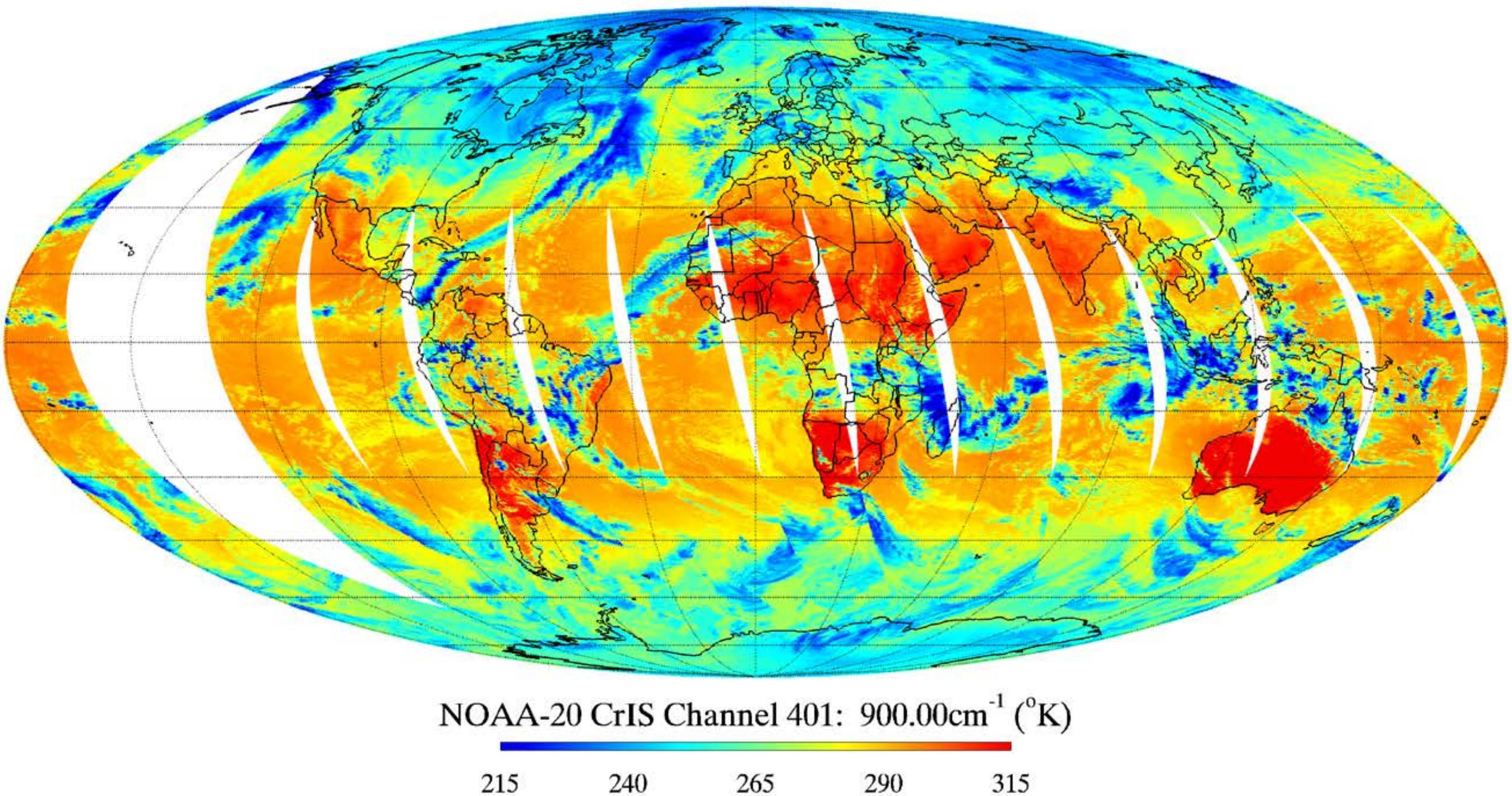


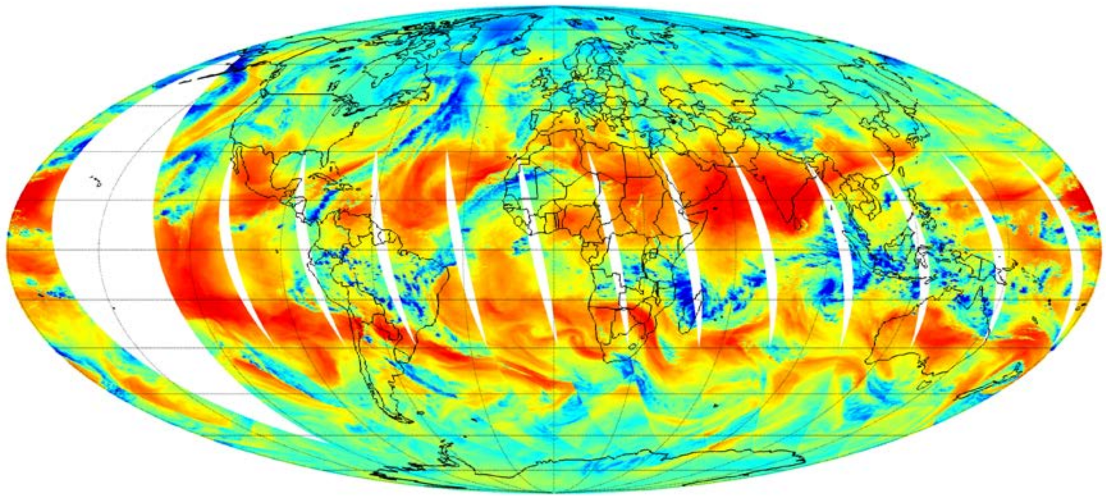
Full Spectral Resolution

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN @287K BB mW/m^2/sr/cm^{-1}	Radiometric Uncertainty @287K BB (%)	Spectral (chan center) uncertainty ppm	Geolocation uncertainty Km (Nadir)
LW	650-1095	713	0.625	30	9	**0.14**	**0.45**	**10**	**1.5**
MW	1210-1750	865	0.625	30	9	**0.084**	**0.58**	**10**	**1.5**
SW	2155-2550	633	0.625	30	9	**0.014**	**0.77**	**10**	**1.5**

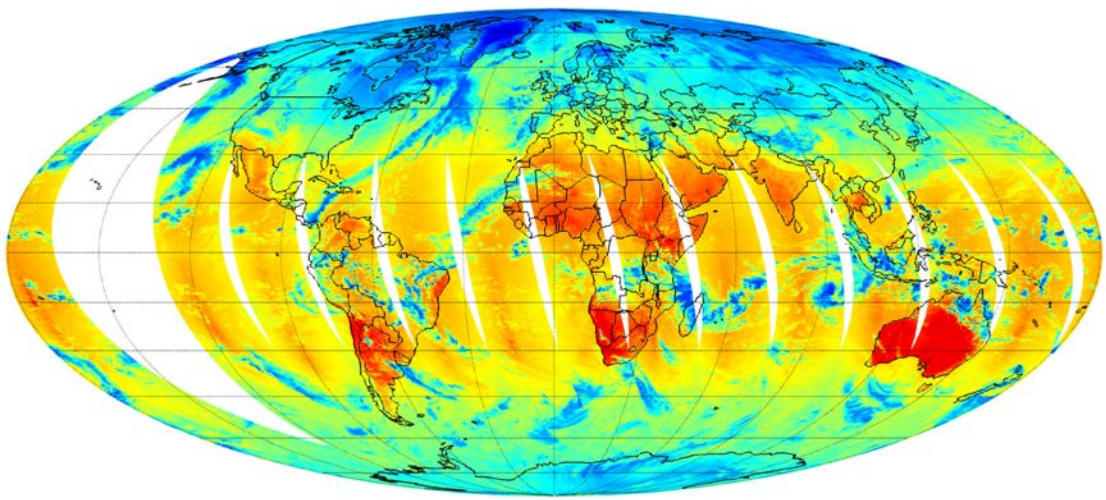
NOAA-20 CrIS First Light Images

- On Jan 5, 2018, forty-eight days after NOAA-20 was launched into Earth orbit, it sent back its first Cross-track Infrared Sounder (CrIS) science data.
- All three bands are working nominally, IDPS successfully generated both Normal Spectral Resolution (NSR) and Full Spectral Resolution (FSR) SDR data.





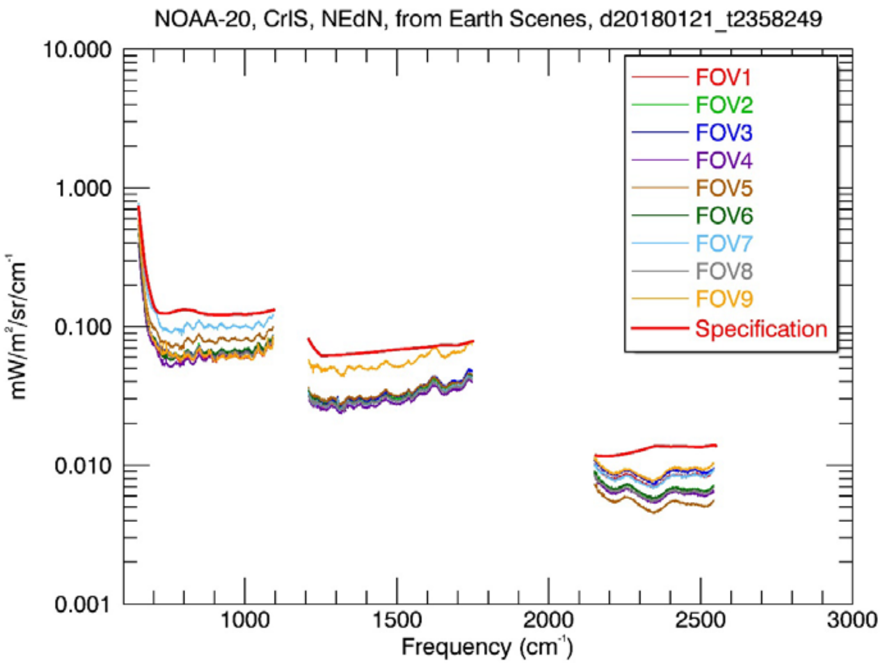
NOAA-20 CrIS Channel 1025: 1598.75cm^{-1} (^{o}K)



NOAA-20 CrIS Channel 1267: 2455.00cm^{-1} (^{o}K)

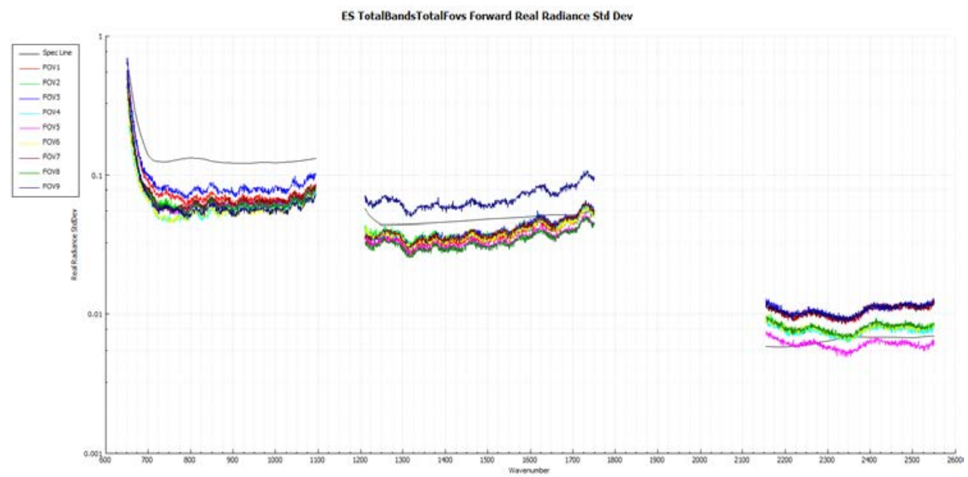
220 245 270 295 320

Earth view data on 01/21/2018, from 23:40:16 to 23:59:28



ECT TVAC

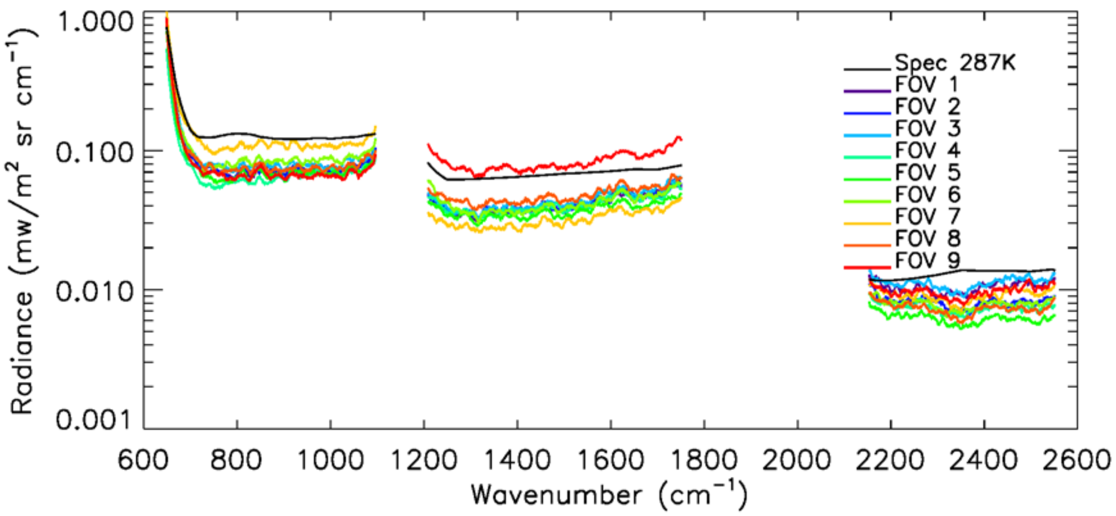
(Specification using NSR, need to times 1.4 and 2.0 for FSR data for MWIR and SWIR, respectively)



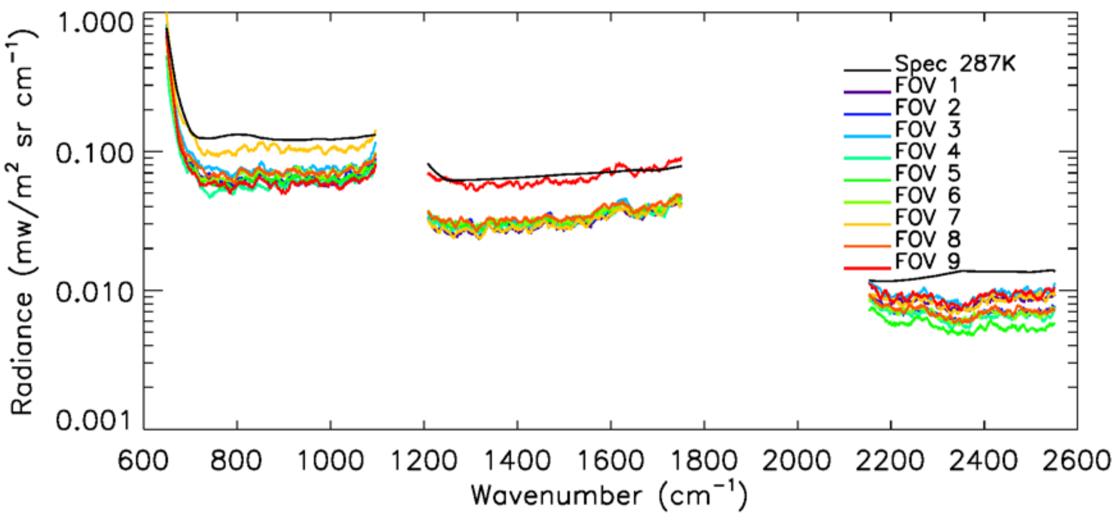
- MW9 NEdN elevated as expected from prelaunch TVAC measurements but within specification
- LW7 NEdN elevated (high noise had been seen once before during EMI test phase)
- NEdN calculated on 1-8 is very similar to prelaunch TVAC test results
- NOAA-20 NEdN are comparable to S-NPP

ICT NEdN Become Better after Instrument Temperature Stable

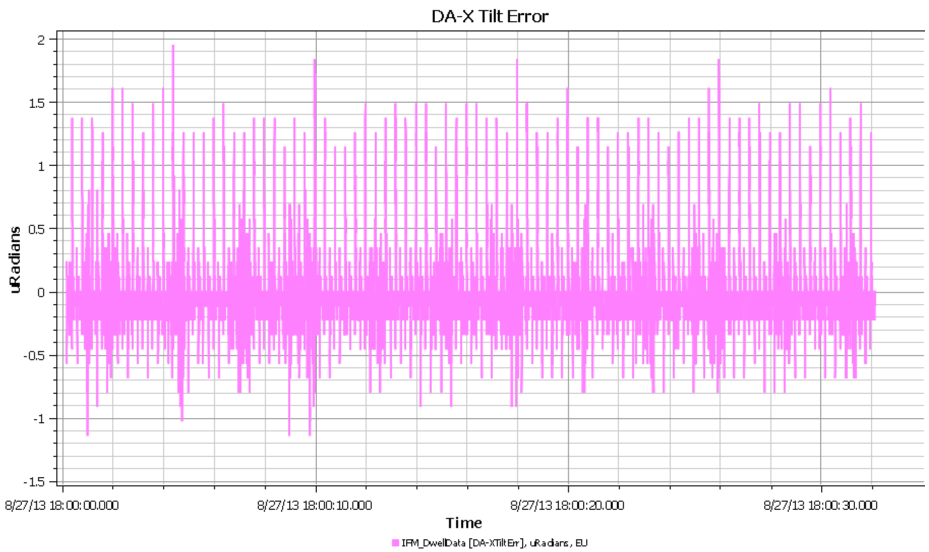
ICT NEdN on 01/05/2018

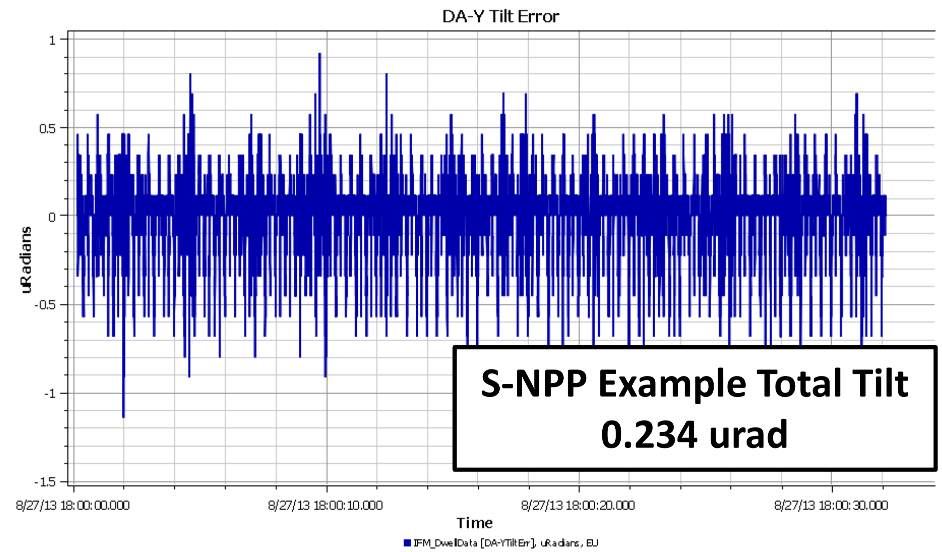


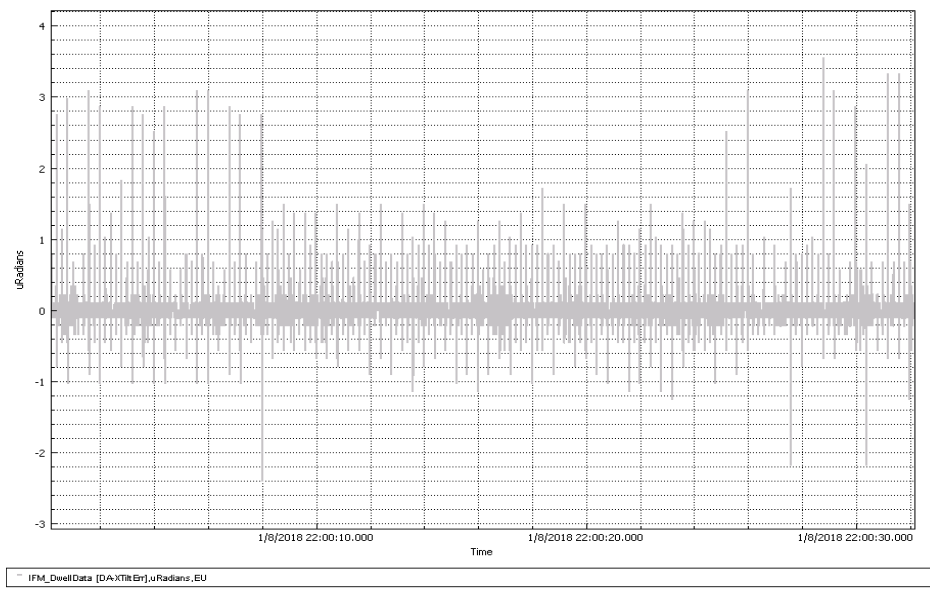
ICT NEdN on 01/21/2018

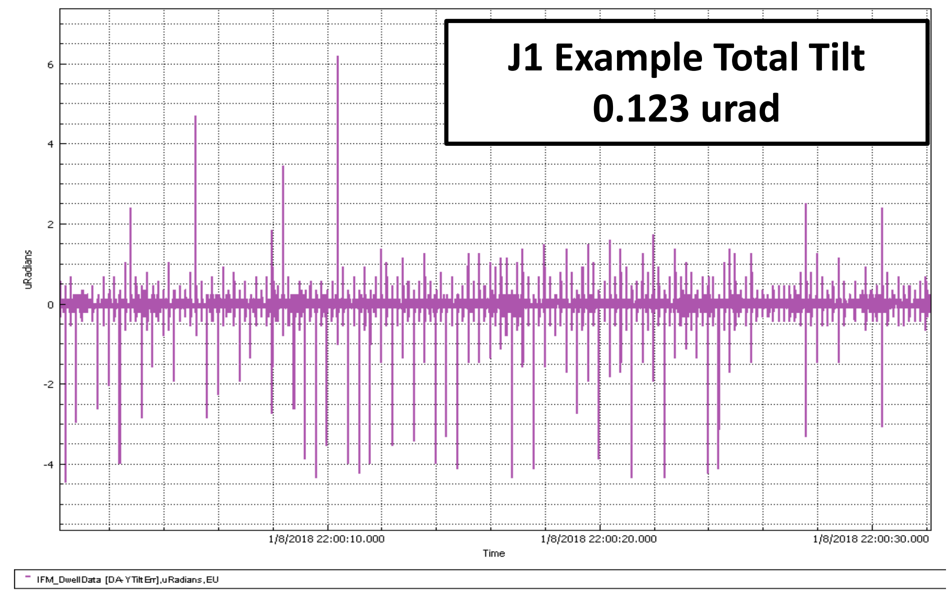


DA Tilt Time History
Total Tilt Value Better than S-NPP

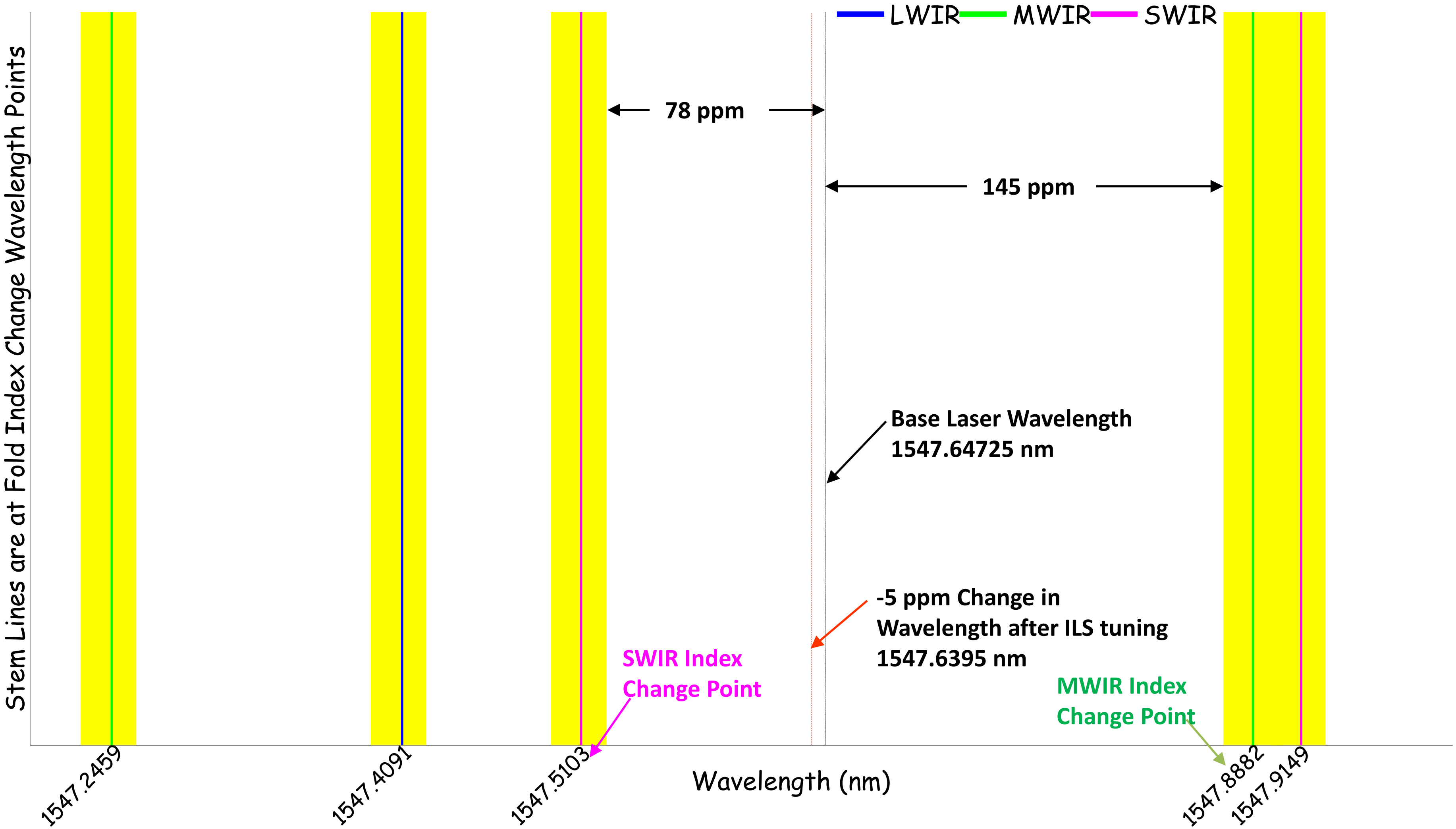








Current Laser Wavelength is Well Outside keep-out Zones

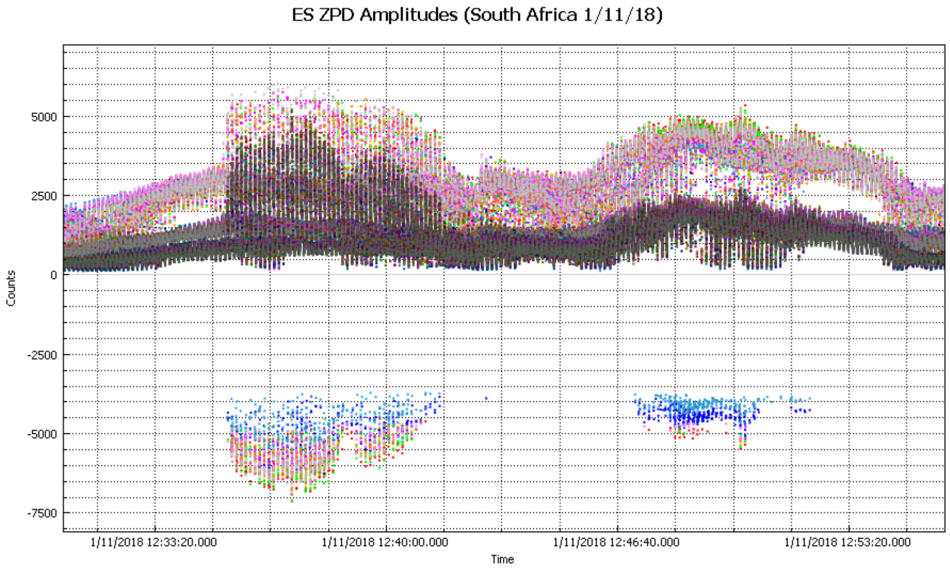


Gains Verified with Hottest Scene & Trended Over Several Days for Additional Confirmation

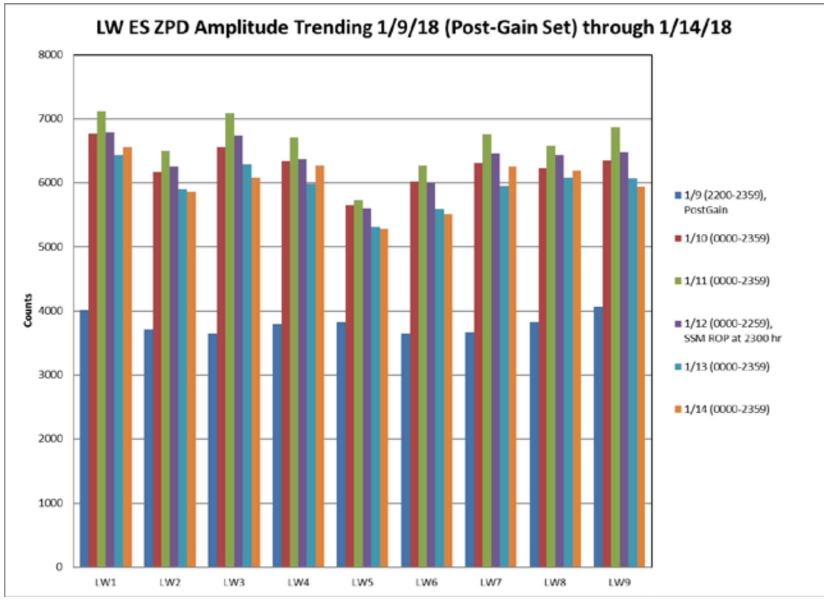
Earth Scene ZPD Amplitude trending confirmed gain setting is final

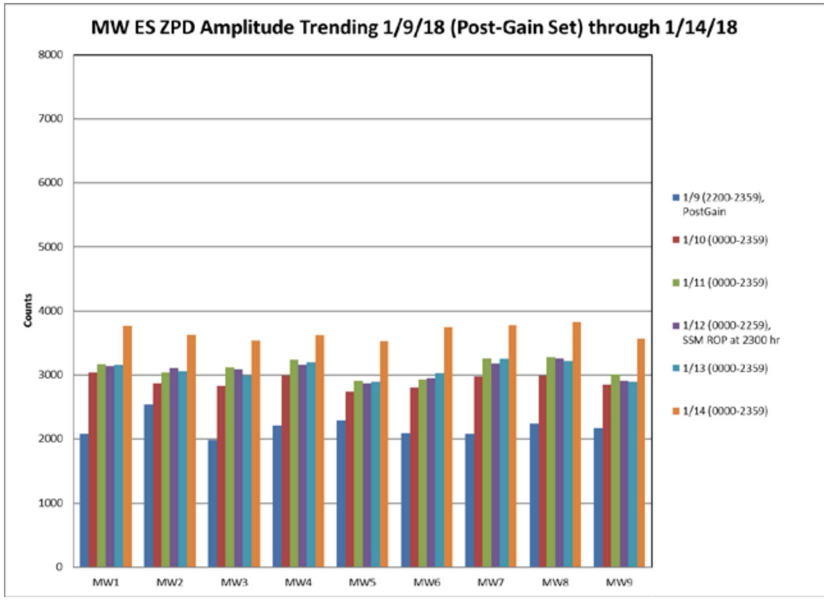
- Gain setting on 1/9 (during 21:00 GMT) provides margin for bands/FOVs
- ES ZPD amplitudes trended from 1/9 (post gain set) through 1/14
- Hottest scene observed from South Africa pass on 1/11 (12:00-13:00 GMT)
  - Actual pass is 12:35:45 – 12:39:15 (~ 32°42'S & 18°42'E to 22°41'S & 14°32'E)
  - Corresponds to apparent brightness temperature of about 336.7K
  - Max absolute ES ZPD Amplitudes for the pass shown below

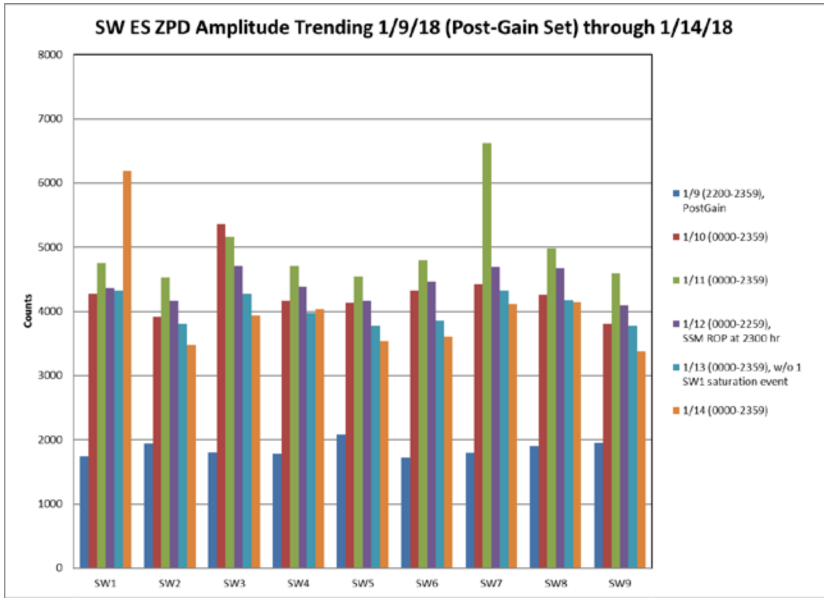
Band	LW	MW	SW
FOV1	7120	3168	4752
FOV2	6496	3040	4528
FOV3	7088	3120	5152
FOV4	6704	3232	4704
FOV5	5728	2912	4544
FOV6	6272	2928	4800
FOV7	6752	3264	5200
FOV8	6576	3280	4976
FOV9	6864	3008	4592
Max	**7120**	**3280**	**5200**



ES ZPD Trending







- ES ZPD trending show gain set provides margin against max 8192 counts
- Occasional high or saturated single sample in SW FOVs from sun glint are not considered for gain or bit trim setting.
- Need future investigation why the MW ES ZPD gain so low

NOAA-20 Bit Trim and Impulse Mask

Bit Trim Mask and Impulse Mask assessed with the hot scene data

1. Full Spectral Resolution Bit Trim Mask launched with instrument is sufficient
   - Includes the extended samples for LW and SW
   - No change to data rate
2. NOAA-20 impulse now at same levels as S-NPP
   - Open at ZPD and 1 bit down elsewhere

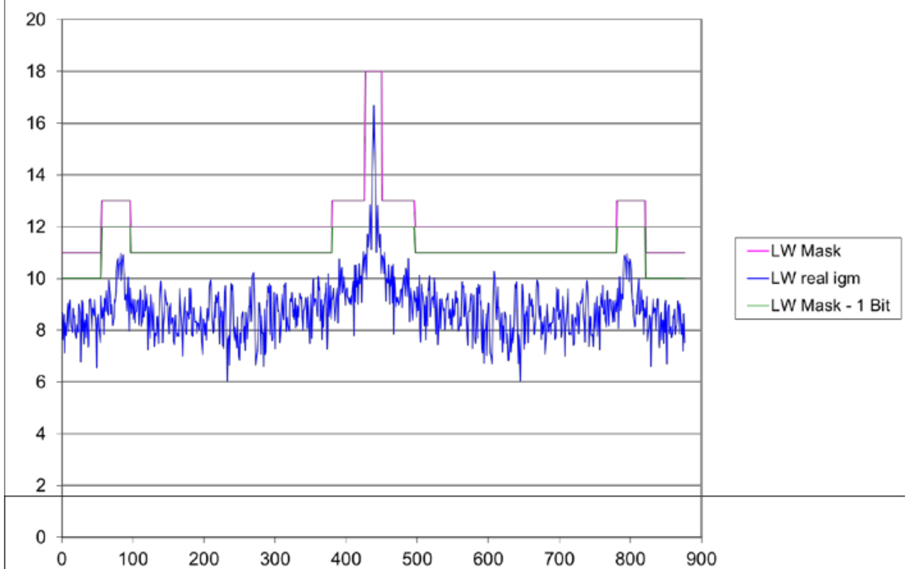
J1 FSR LWIR Bit Trim Table		
Start Sample Index*	***End Sample Index****	***Bits Remaining***
1	55	11
56	96	13
97	380	12
381	426	13
427	450	18
451	496	13
497	780	12
781	821	13
822	876	11

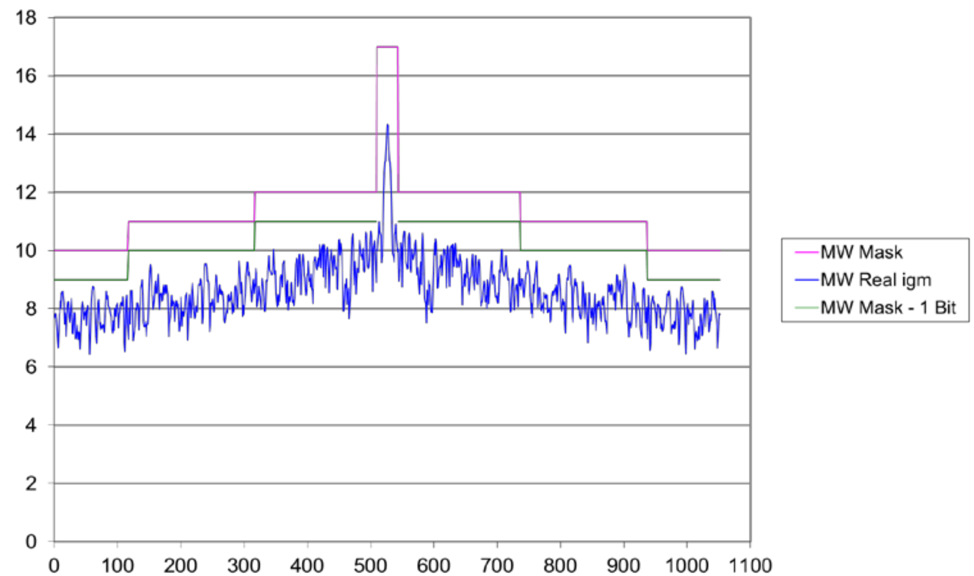
J1 FSR MWIR Bit Trim Table		
Start Sample Index*	***End Sample Index****	***Bits Remaining***
1	116	10
117	316	11
317	507	12
508	509	12
510	543	17
544	545	12
546	736	12
737	936	11
937	1052	10

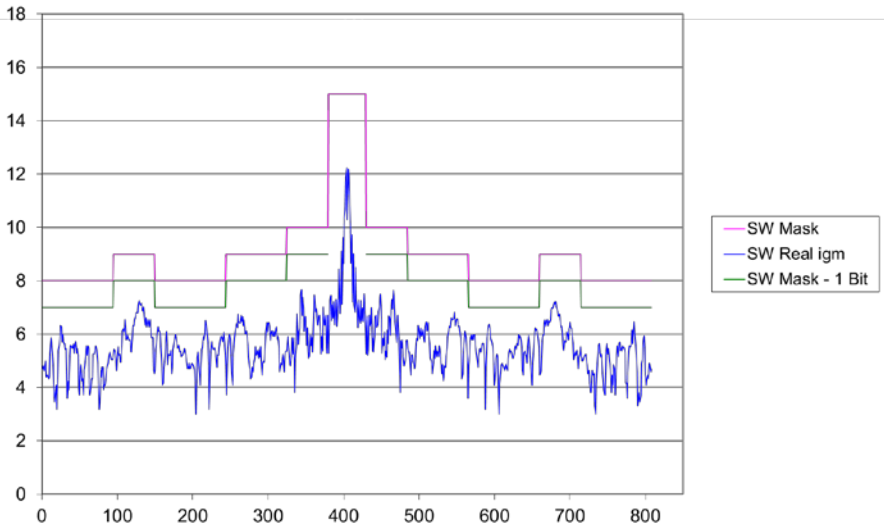
J1 FSR SWIR Bit Trim Table		
Start Sample Index*	***End Sample Index****	***Bits Remaining***
1	94	8
95	149	9
150	243	8
244	324	9
325	377	10
378	379	10
380	429	15
430	431	10
432	484	10
485	565	9
566	659	8
660	714	9
715	808	8

* After Decimation.

Bit Trim Mask for NOAA-20







- Real component for hottest scene: South Africa Pass 1/11/18 12:00-13:00 GMT
- Imaginary component also within the mask – 1 bit (for sign) levels

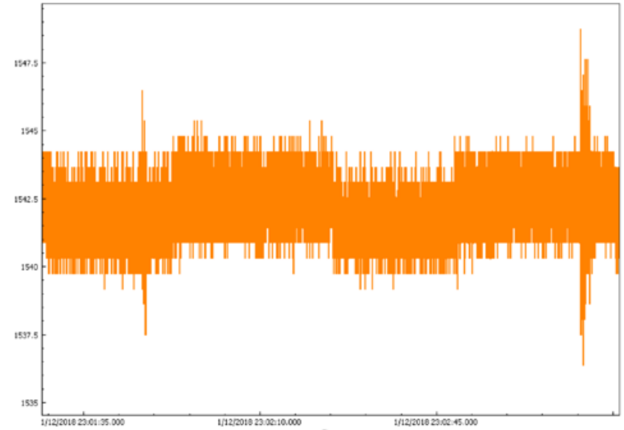
SSM Geolocation ROP performed on 1/12 during 23:00 hr GMT

- SSM Velocity and Motion Compensation disabled
- SSM Commanded In-Track Position set to zero

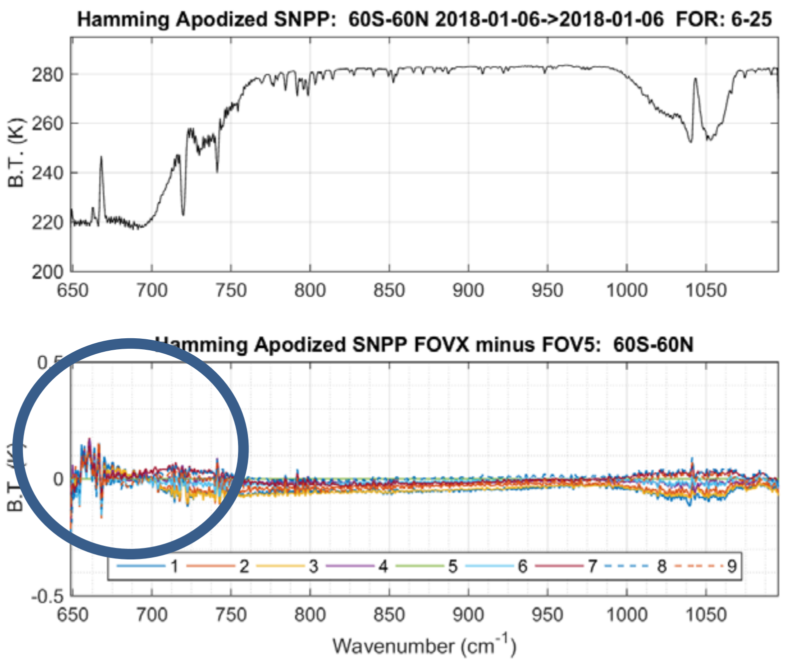
Null Torque value is the In-Track offset position

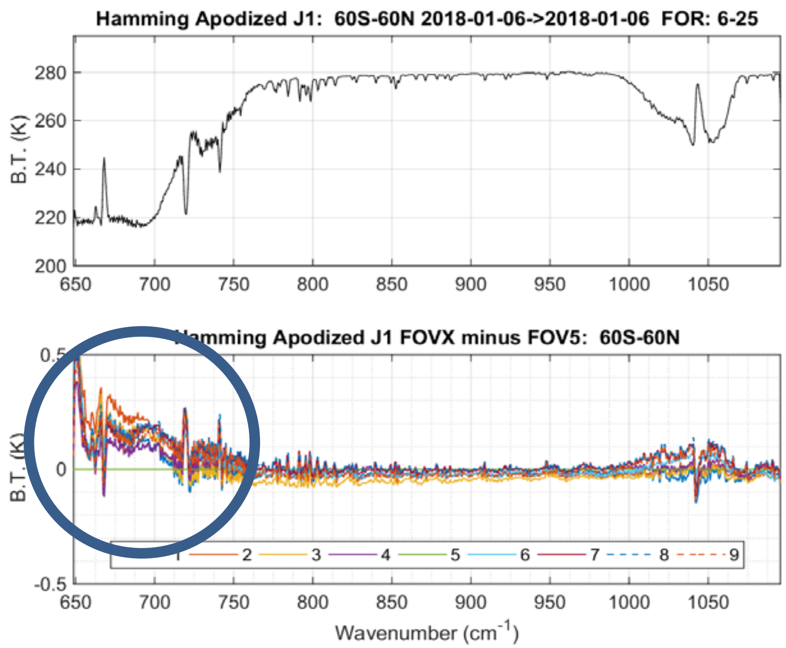
- Some cross-coupling seen in IT from movement of the CT going from ES10 to Space to ICT during test (48 sec collects)

Position	Collection Start
ES 10	23:00:26
DS	23:02:00
ICT	23:03:34



- Zoom in of flat portion shows an average value of ~1542.4 urad vs. 1666 urad ground test value
- In-Track angles decrease by ~0.062 mrad in v113 eng pkt (uploaded 1/17) relative to v112 (uploaded 1/3)
- ~1 mrad offset remains between CrIS and VIIRS
- Mapping angles in the engineering packet can be updated to resolve CrIS and VIIRS offset, though CrIS already meets its geolocation specification.



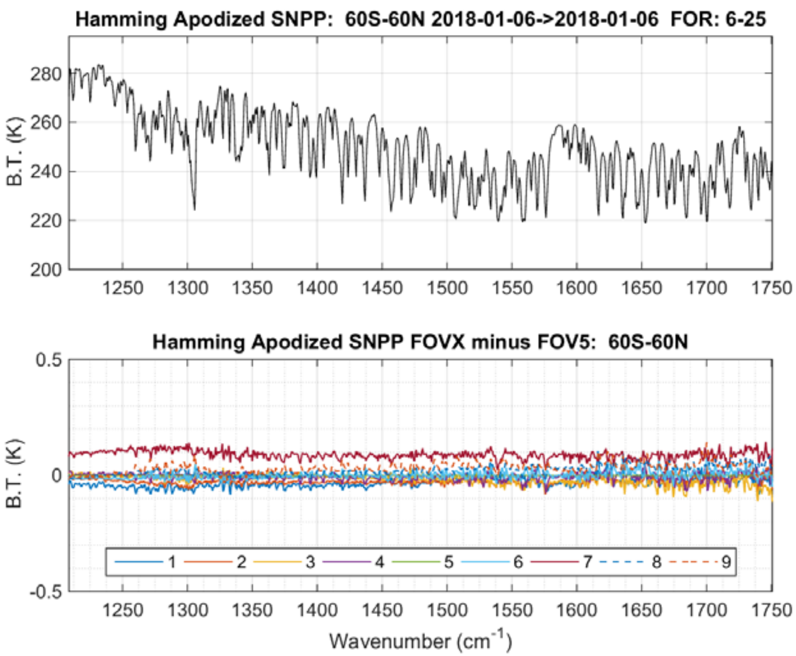


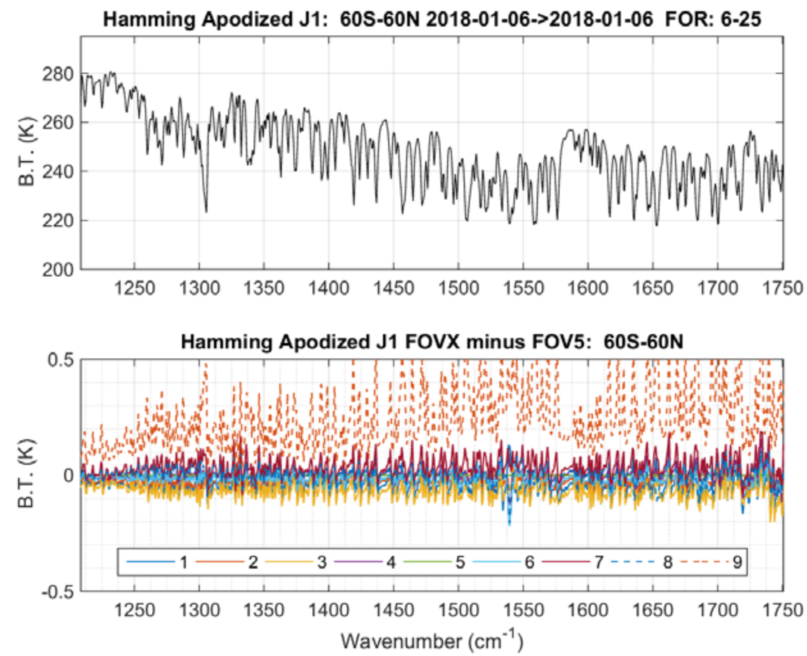
S-NPP LW agreement < 0.15 K

- S-NPP nonlinearity parameters were set during the S-NPP checkout phase in January 2012 but still remain valid six years later.

NOAA-20 LW bias wrt FOV5 ~ 0.2K

- Initial NOAA-20 flight data suggests a small post-launch adjustment to the NOAA-20 LW FOV5 a2 parameter
  and perhaps some minor refinements of the other FOVs.





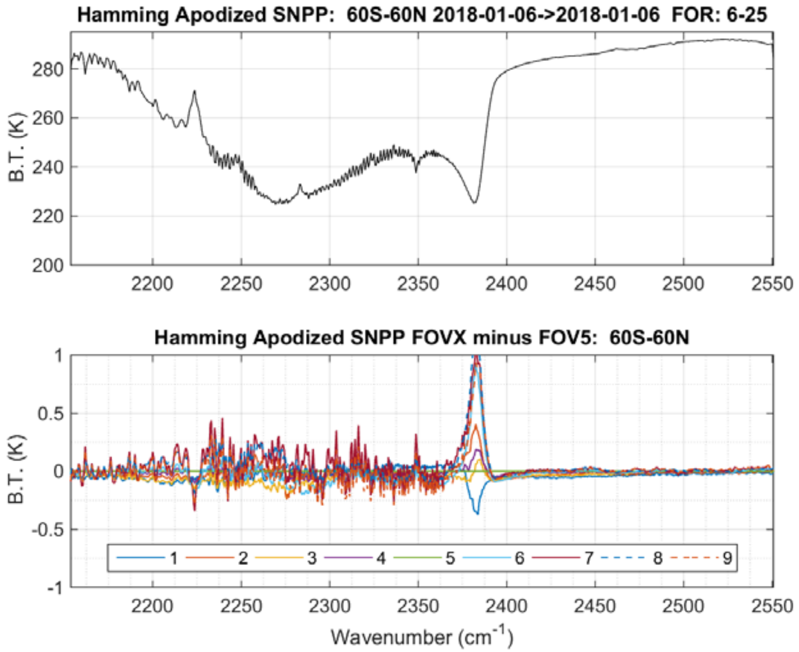
S-NPP MW FOV7 has highest nonlinearity

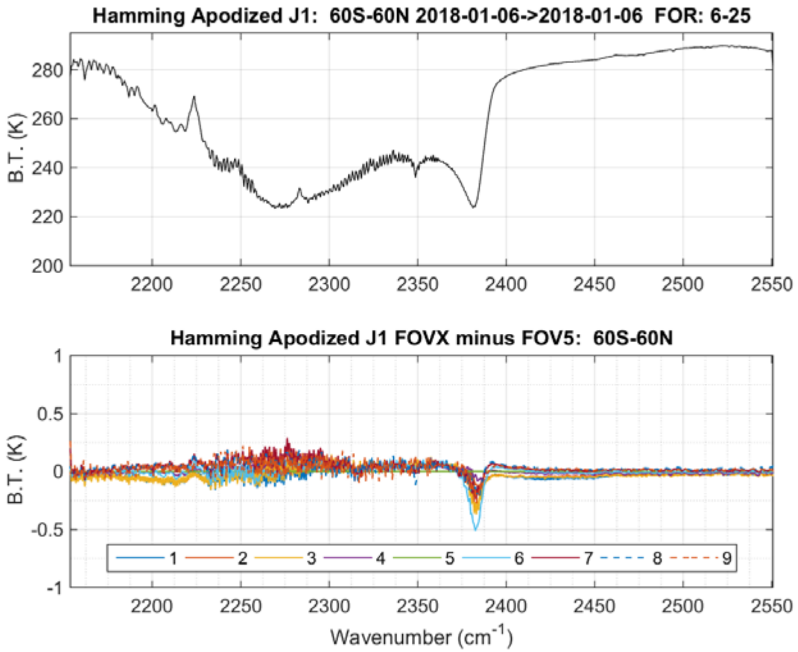
- S-NPP MW nonlinearity was adjusted to remove the line structure in FOV7
  however a small systematic bias of 0.1K remains.

NOAA-20 MW FOV9 has highest nonlinearity

- NOAA-20 MW nonlinearity needs to be adjusted to remove the line structure in FOV9,
  however a small offset may remain similar to that seen in SNPP FOV7.

Relative Radiometric Calibration (FOVX – FOV5)





S-NPP SW FOV7 & 9 are out-of-family

- S-NPP SW has some issues on spectral lines for FOVs 7 & 9.
  This is more apparent in unapodized spectra. (Apodized shown here)

NOAA-20 SW looks better

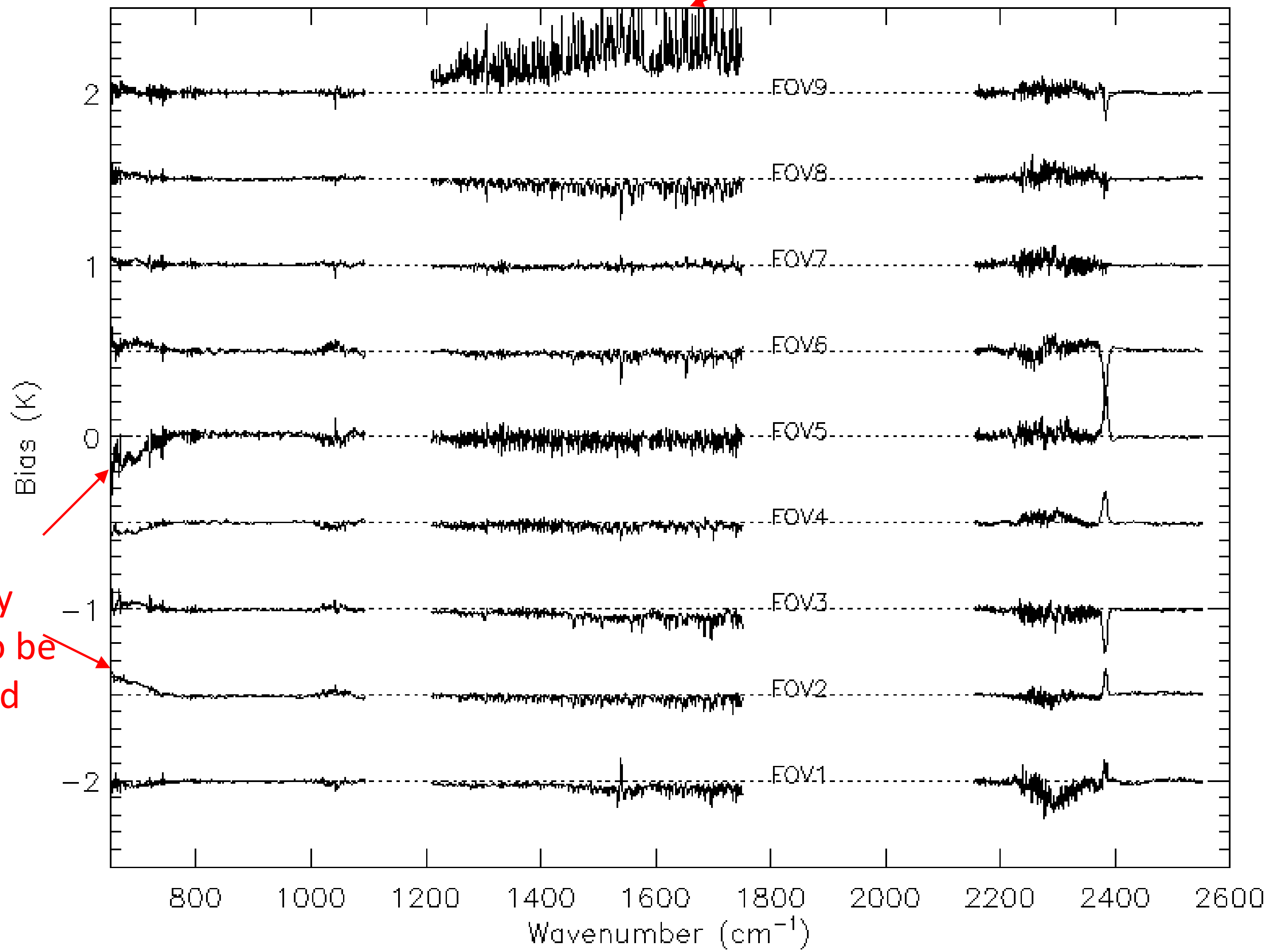
- NOAA-20 SW band looks very good

FOV-2-FOV Radiometric Consistency

NOAA-20 on 01/05/2018

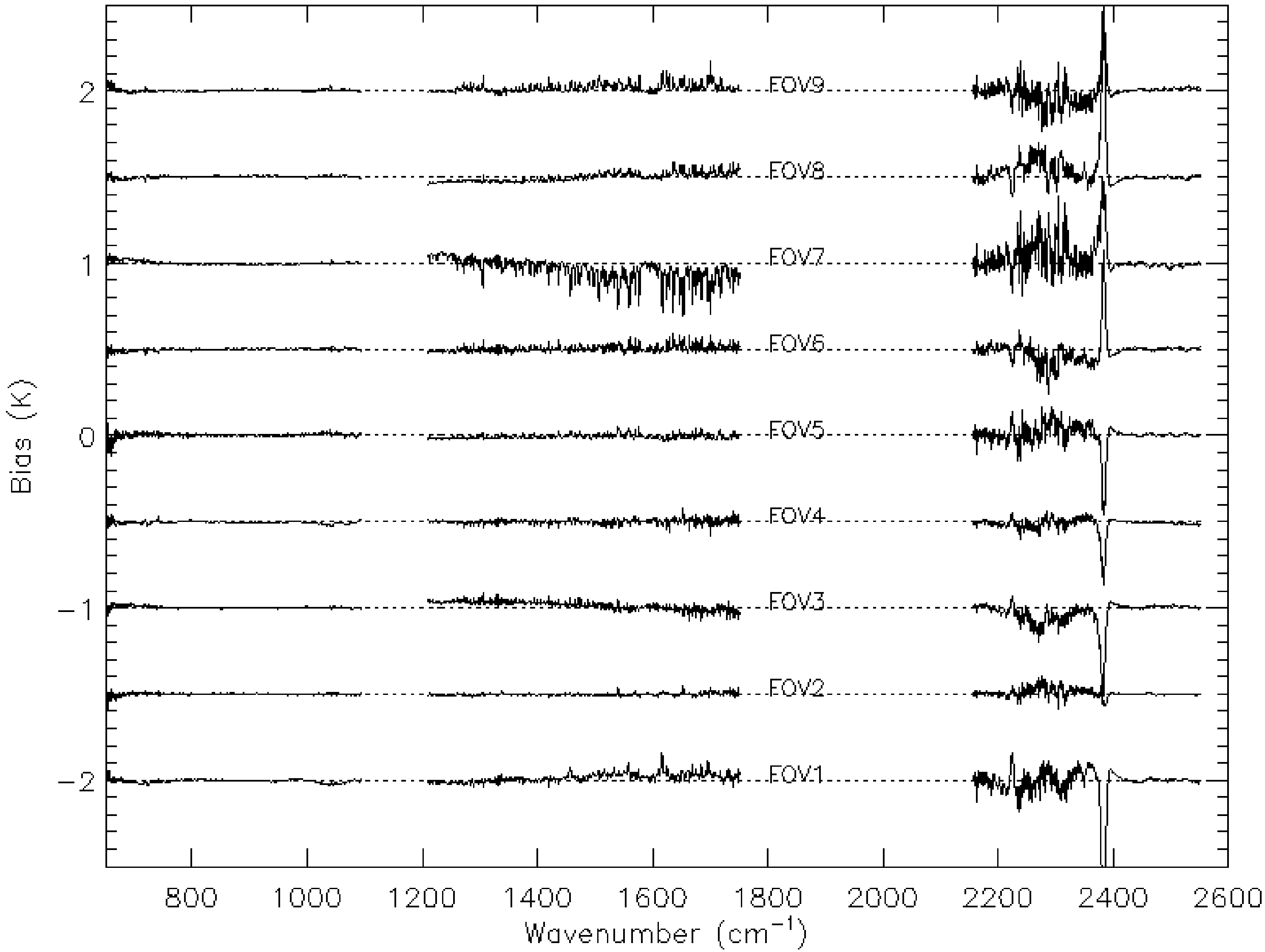
MWIR FOV 9 out of family

Non-linearity need to be adjusted



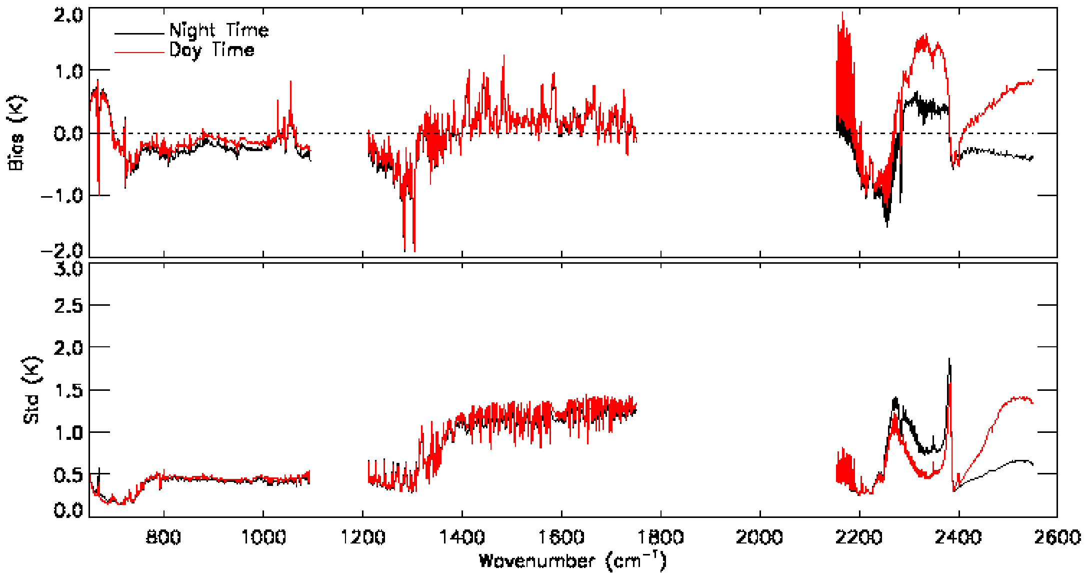
FOV-2-FOV Radiometric Consistency

S-NPP on 01/05/2018

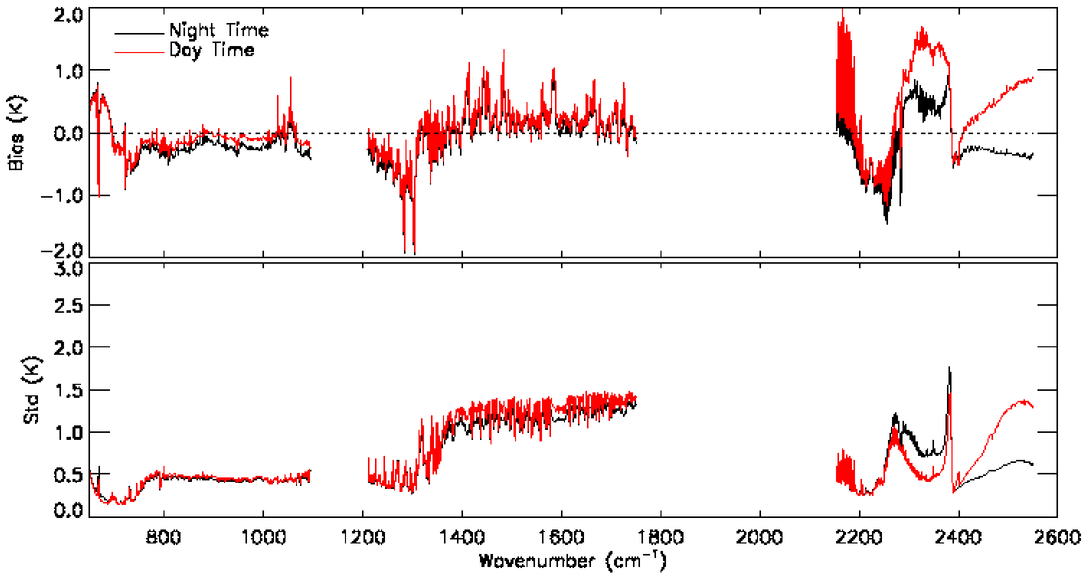


Radiometric Accuracy Compared to Simulation

NOAA-20
On 01/05/2018



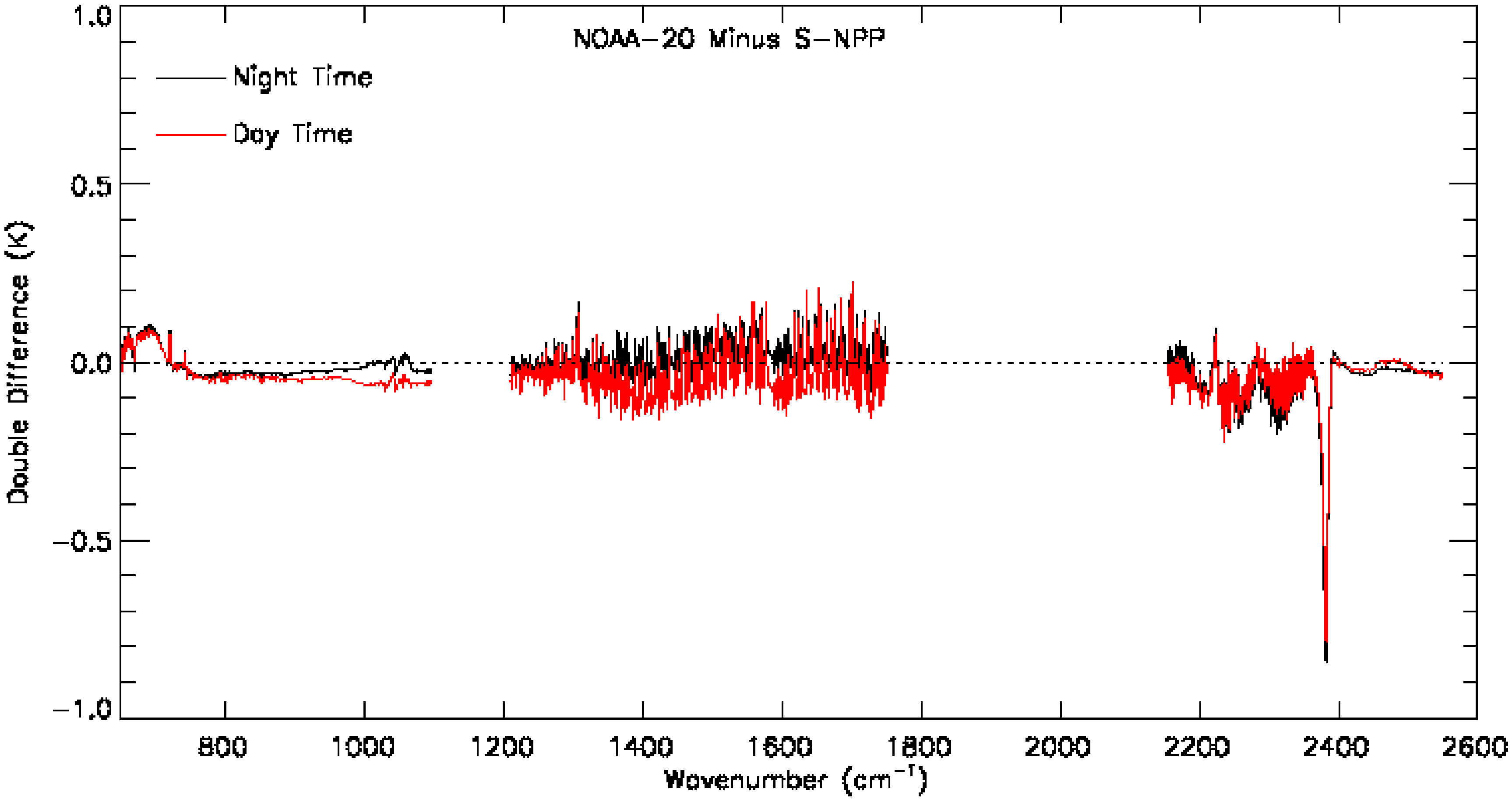
S-NPP



Radiometric Accuracy
Double Difference

Data on 01/05/2018

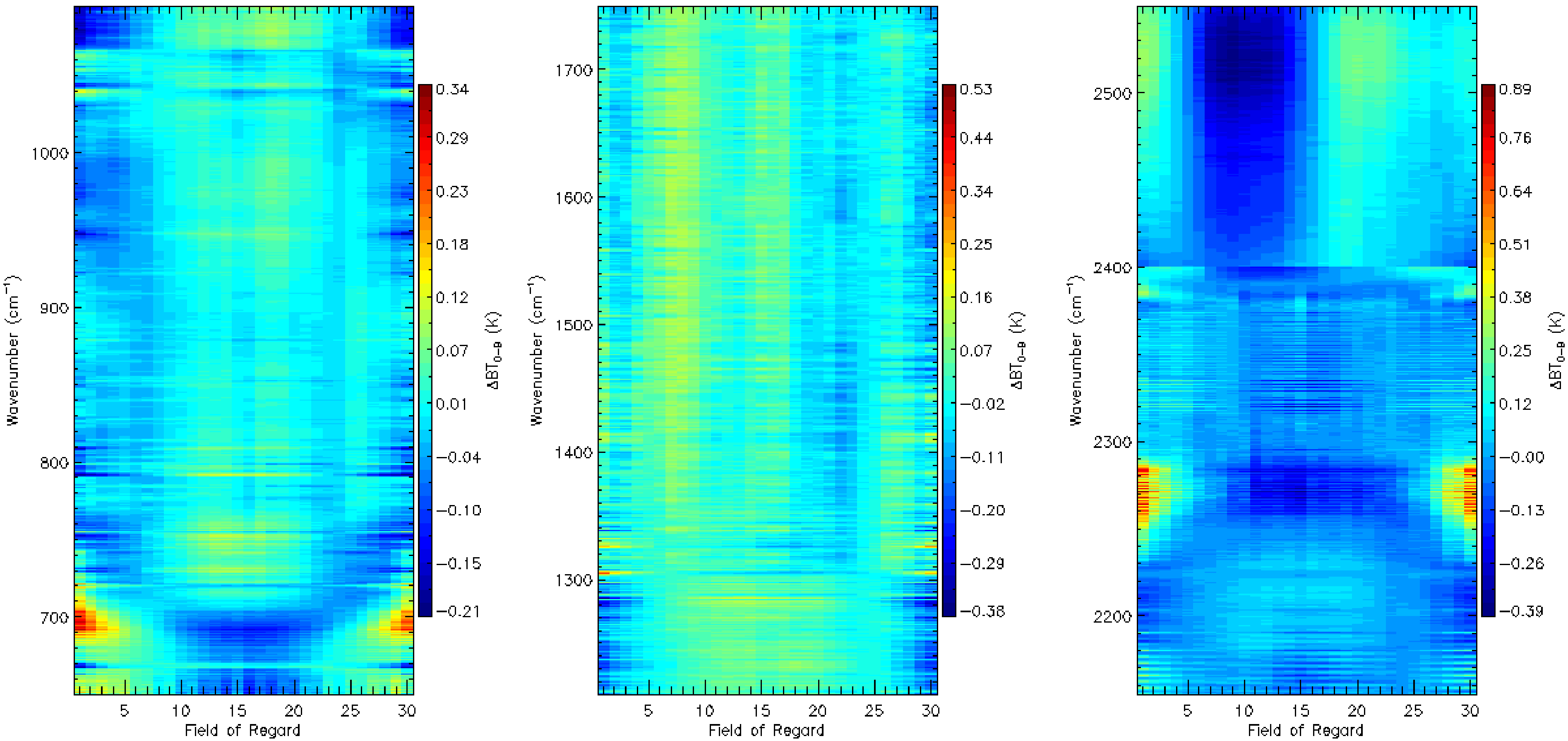
$$(BT - BT_{crtm})_{n20} - (BT - BT_{crtm})_{npp}$$



All channels (except one) are with ±0.2 K with S-NPP

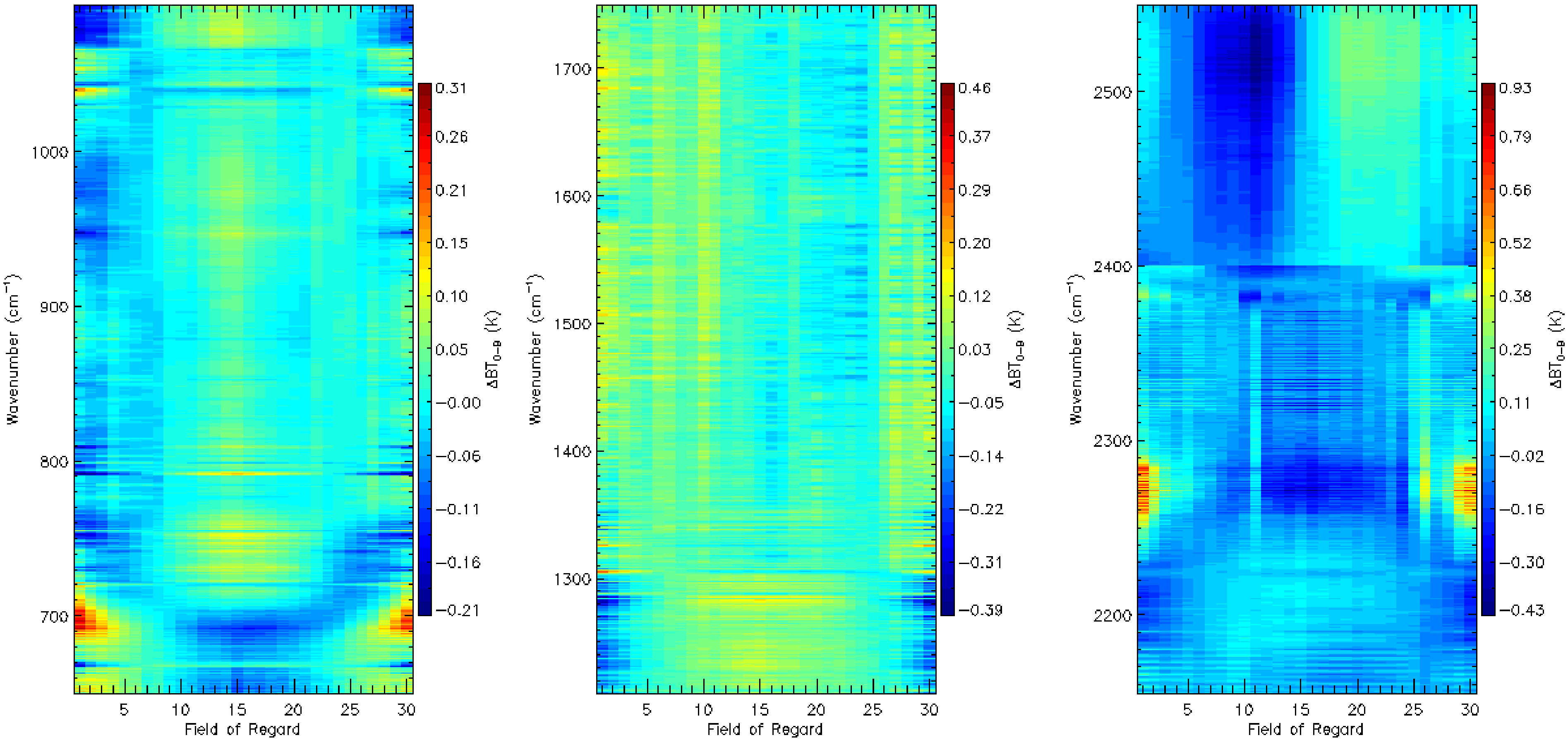
Data on 01/05/2018

S-NPP



Data on 01/05/2018

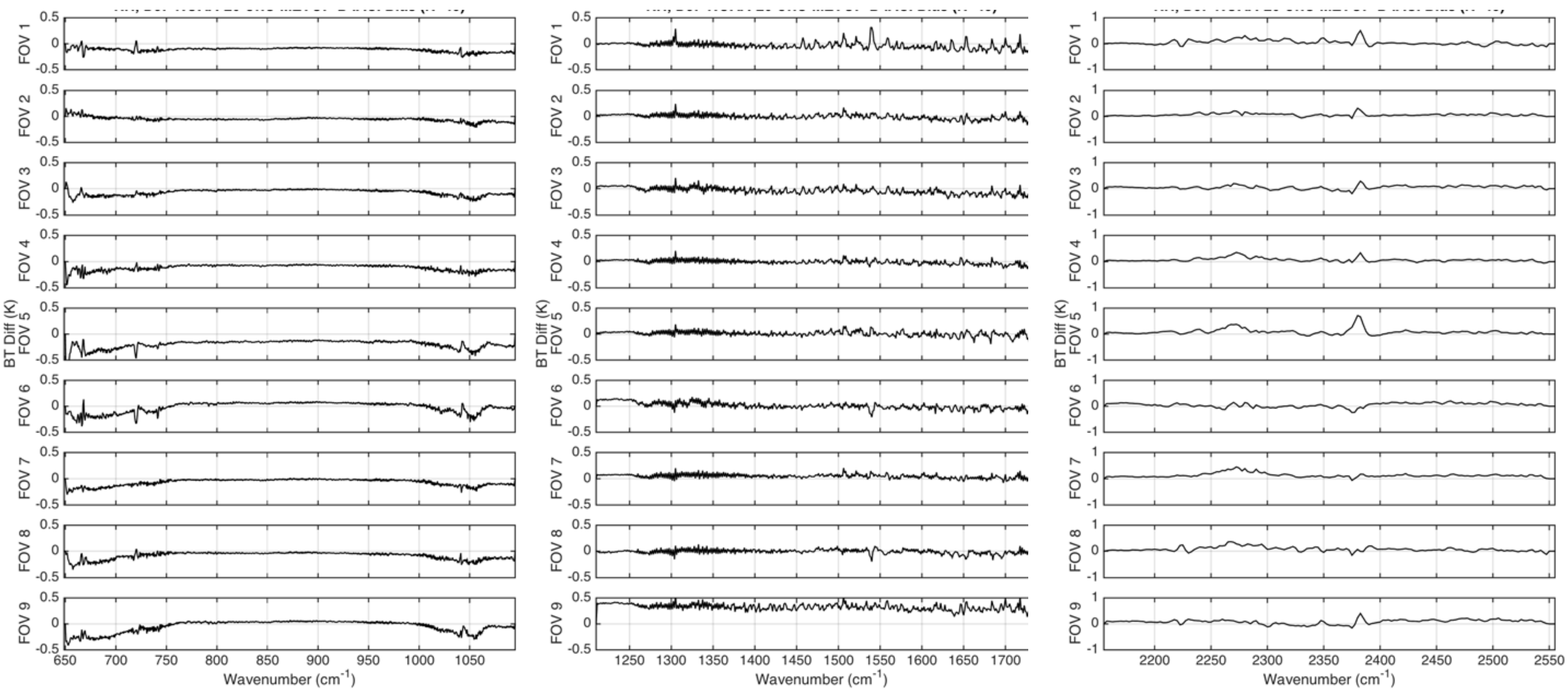
NOAA-20



Preliminary IASI-B/CrIS SNOs

Northern Hemisphere SNOs, Hamming Apodized CrIS – IASI Bias (CrIS using EP v112)

- Variation of results among FOVs in LW CO2 regions
- MW FOV9 out-of-family among FOVs
- Mean differences generally less than ~0.5K

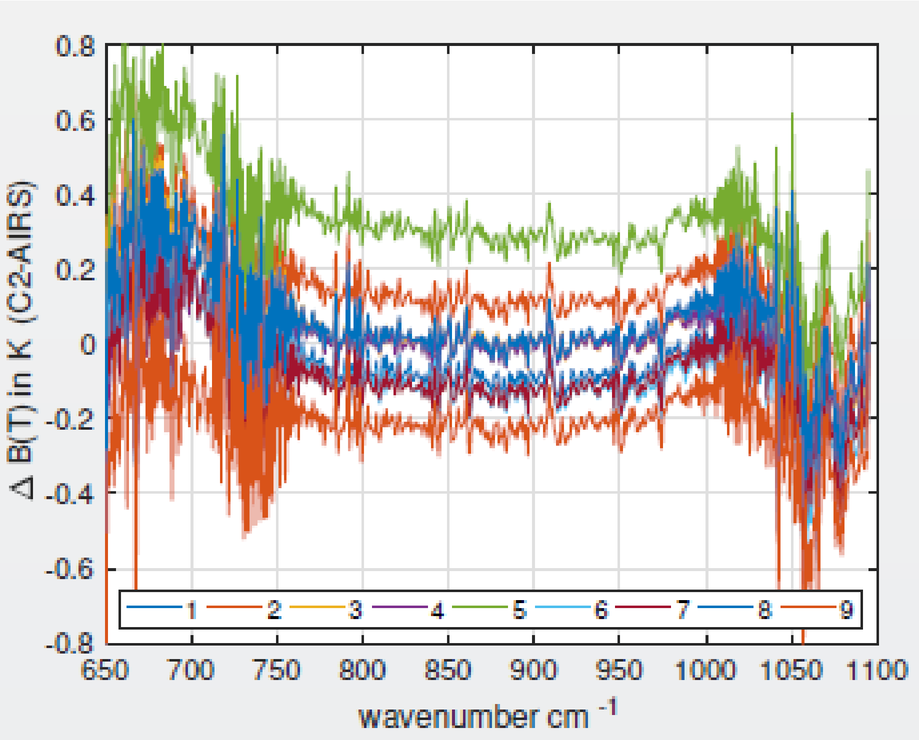


LW MW SW

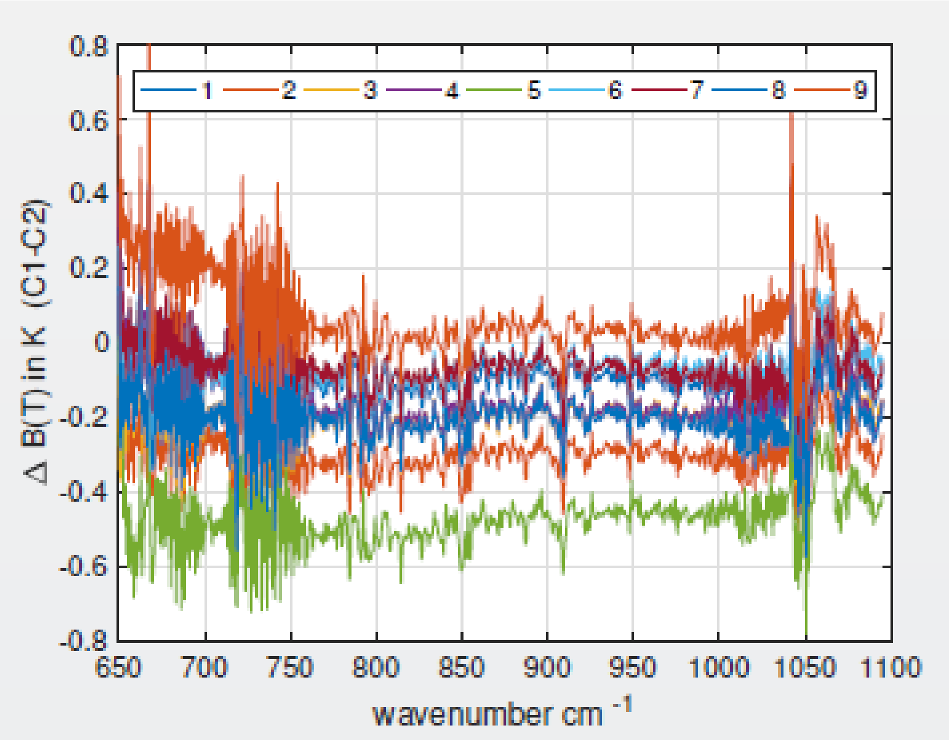
Preliminary AIRS/CrIS SNOs

Use AIRS as a transfer standard between S-NPP (CrIS-1) and NOAA-20 (CrIS-2)

- Convert AIRS L1c to CrIS ILS (AIRS2CrIS)
- Find CrIS-1 and AIRS2CrIS SNOs and difference: C1-ARIS
- Find CrIS-2 and AIRS2CrIS SNOs and difference: C2-AIRS
- (C1-AIRS) minus (C2-AIRS) radiometric differences



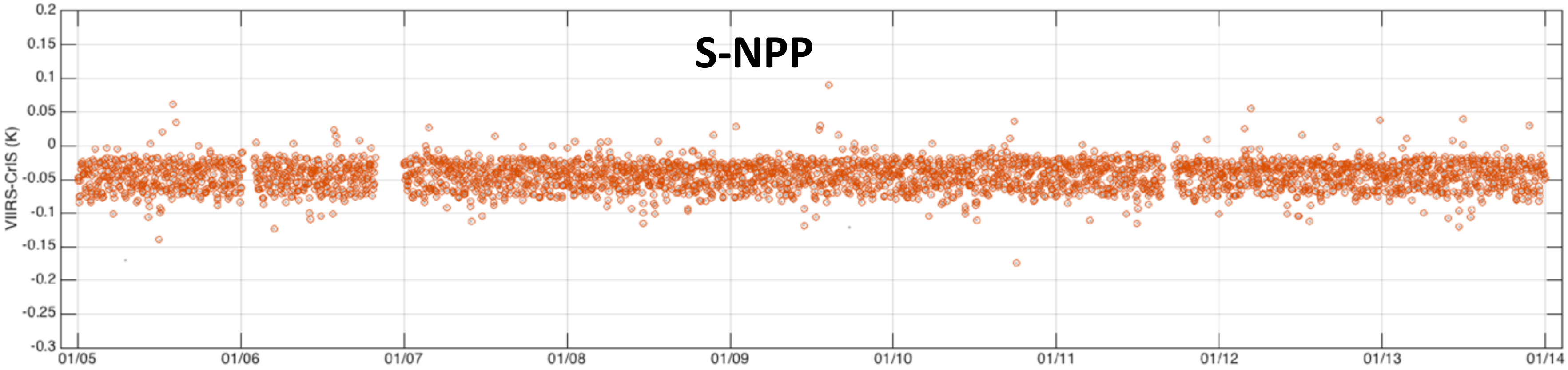
CrIS-2 minus AIRS SNOs

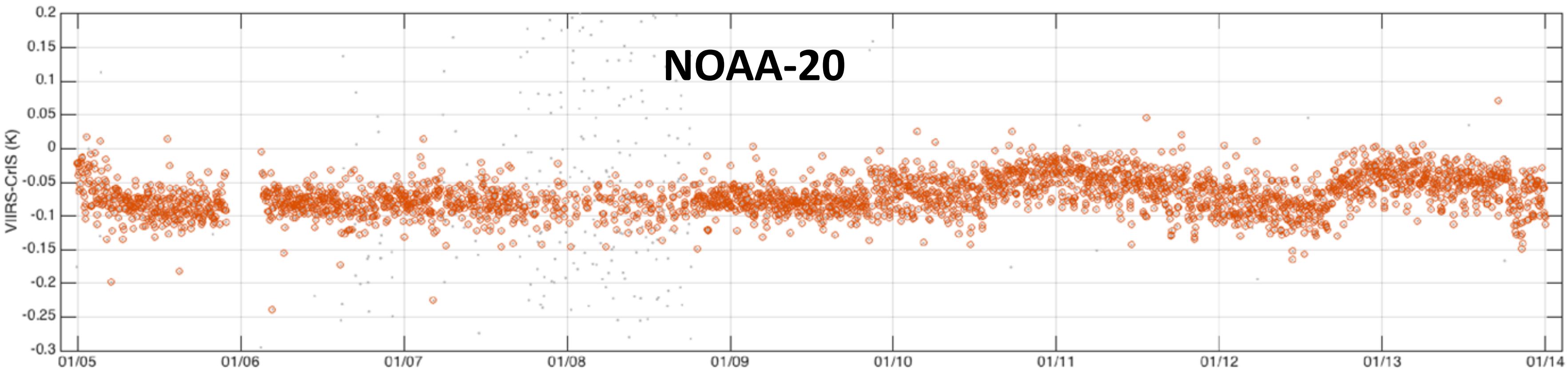


(C1- AIRS) - (C2-AIRS) = (C1- C2)

Preliminary CrIS/VIIRS Comparisons

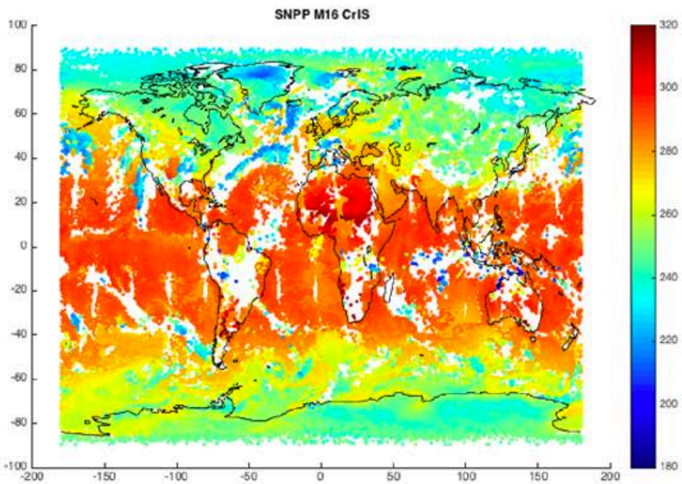
M16 (~11.8 micron) time series. 4 minute time averages

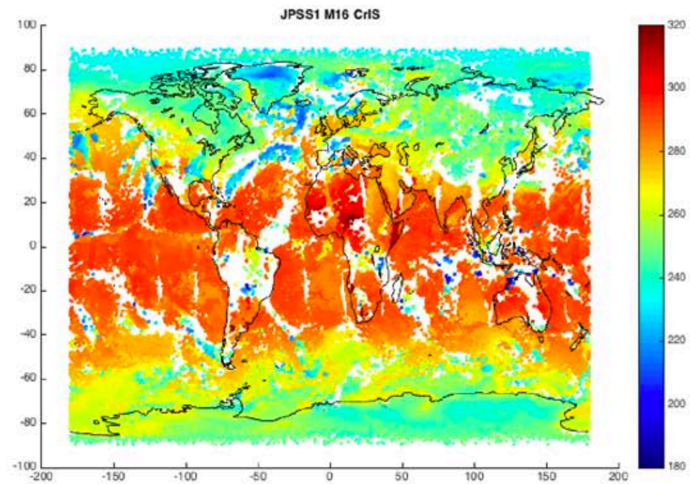




Preliminary CrIS/VIIRS Comparisons

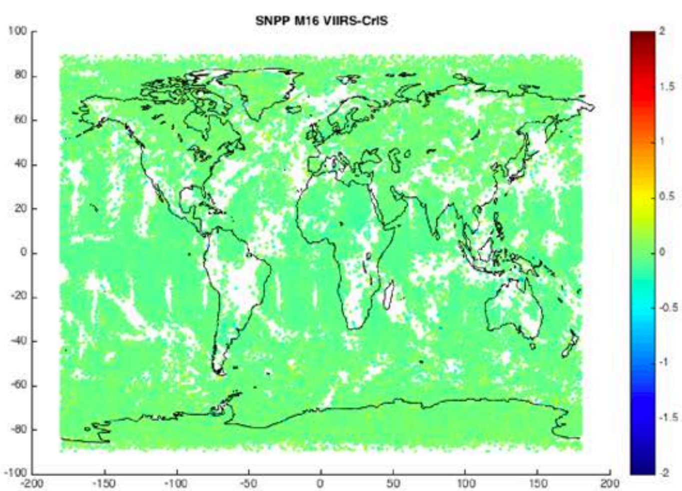
M16 (~11.8 micron) on January 7th

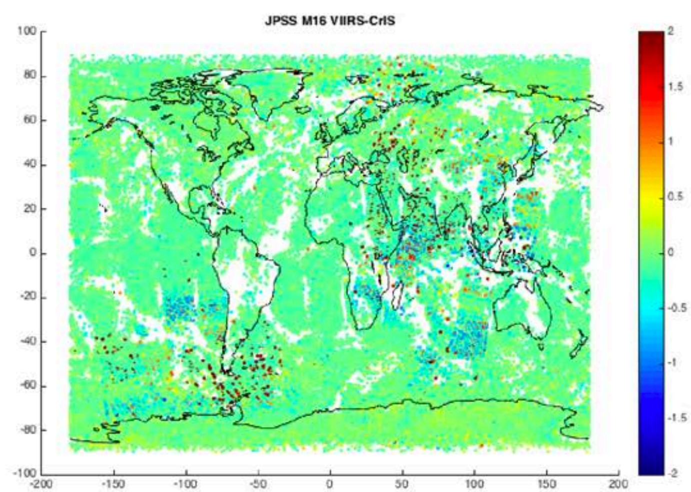




S-NPP

NOAA-20

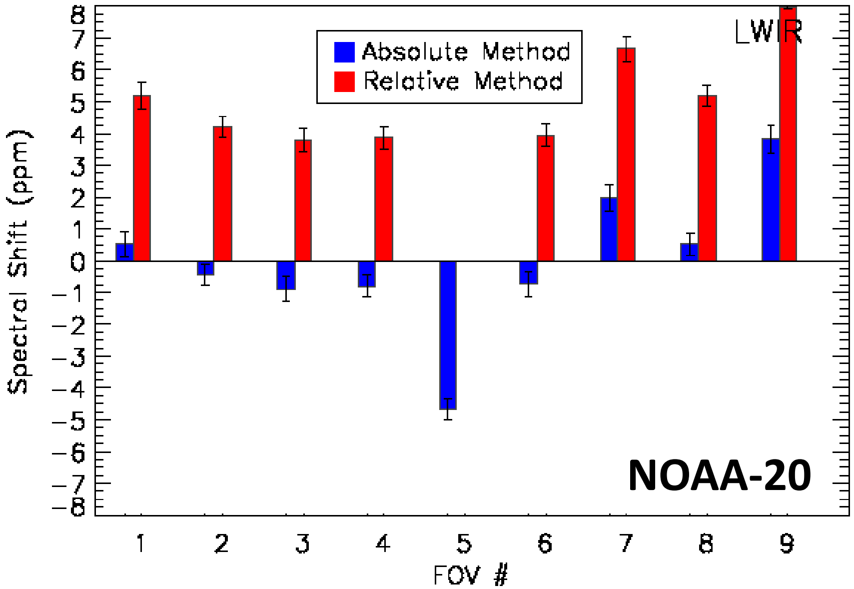


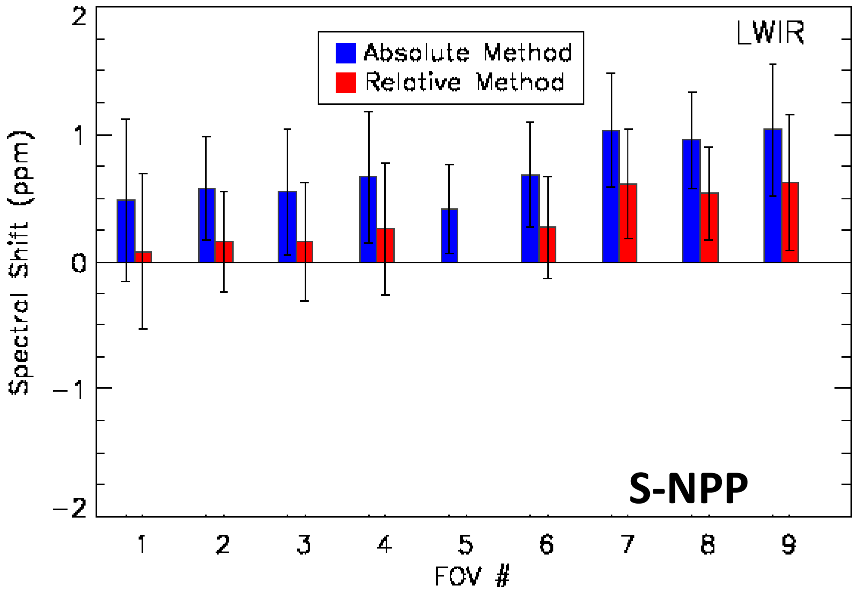


Spectral Accuracy at LWIR Relative and Absolute (Meet Specification)

Data on 01/05/2018

- Absolute spectral shift
  FOV 5: **-5** ppm
  FOV 7: **+2** ppm
  FOV 9: **+4** ppm
  Other FOVs: within ± 1 ppm
- Need to adjust FOVs 5, 7 and 9 ILS parameters

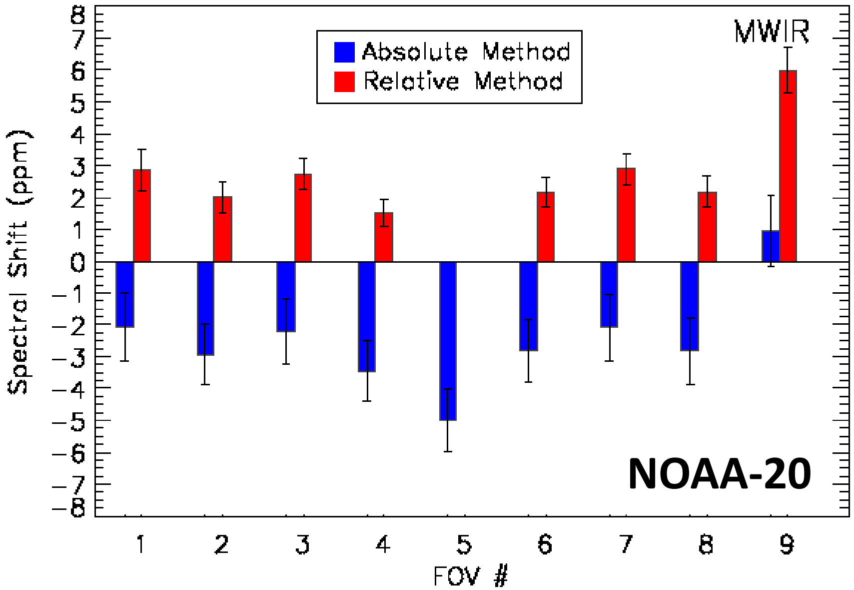


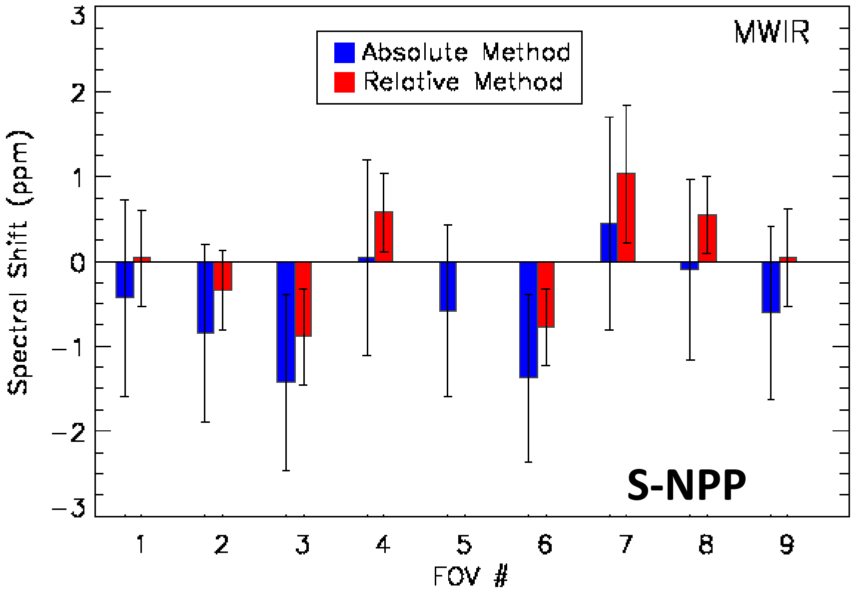


Spectral Accuracy at MWIR Relative and Absolute (Meet Specification)

Data on 01/05/2018

- Absolute spectral shift
  FOV 5: **-5** ppm
  FOV 9: **+1** ppm
  Other FOVs: negative **2** to **3** ppm
- All FOVs ILS parameters need to be adjusted to within 1 ppm



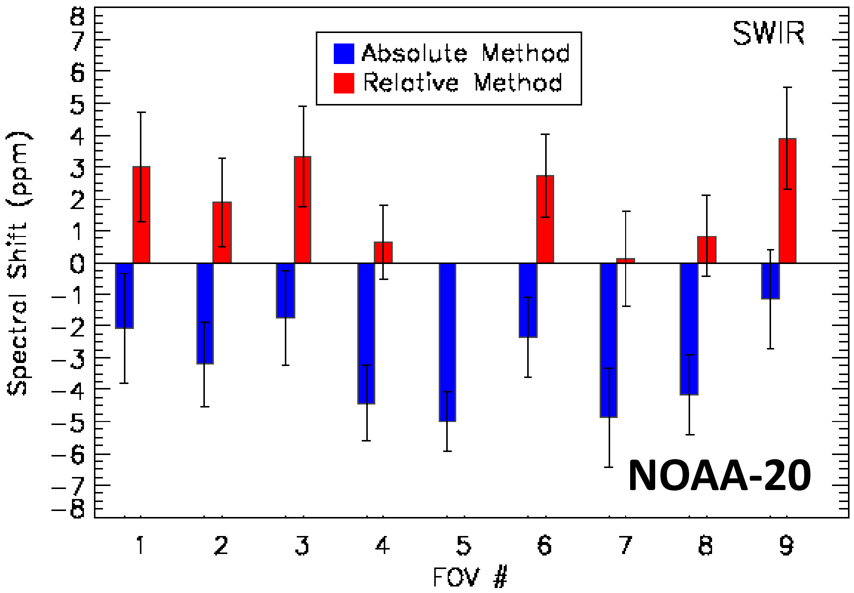


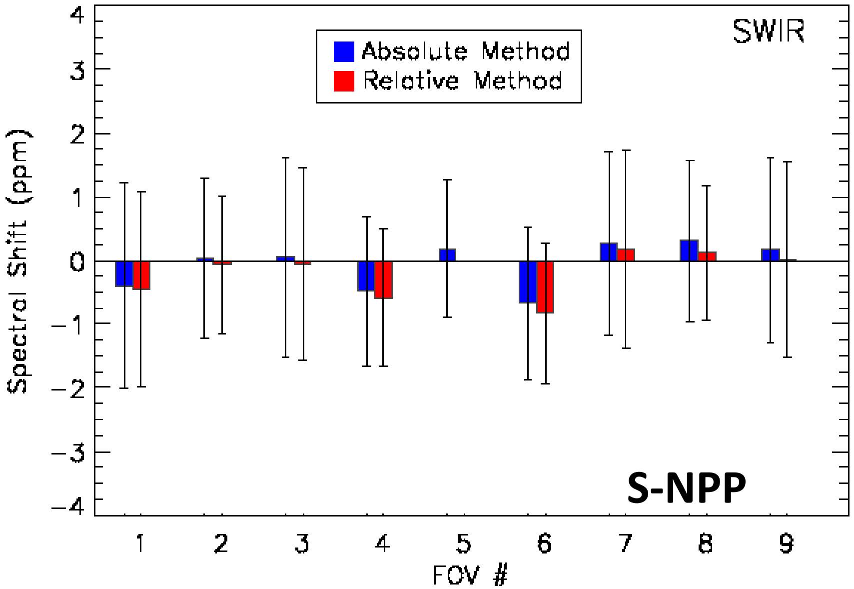
Spectral Accuracy at SWIR Relative and Absolute (Meet Specification)

Data on 01/05/2018

- Absolute spectral shift
  FOV 5: **-5** ppm
  FOVs 4, 7, and 8: -4 to -5 ppm
  Other FOVs: negative **2** to **3** ppm
- All FOVs ILS parameters need to be adjusted to within 1 ppm

All on axis FOV 5 in three bands have about 5 ppm shift, which indicate that the true Neon Wavelength is lower than the value current used in the spectral calibration system. Recommended to adjust the Neon Wavelength in the EngPkt v113

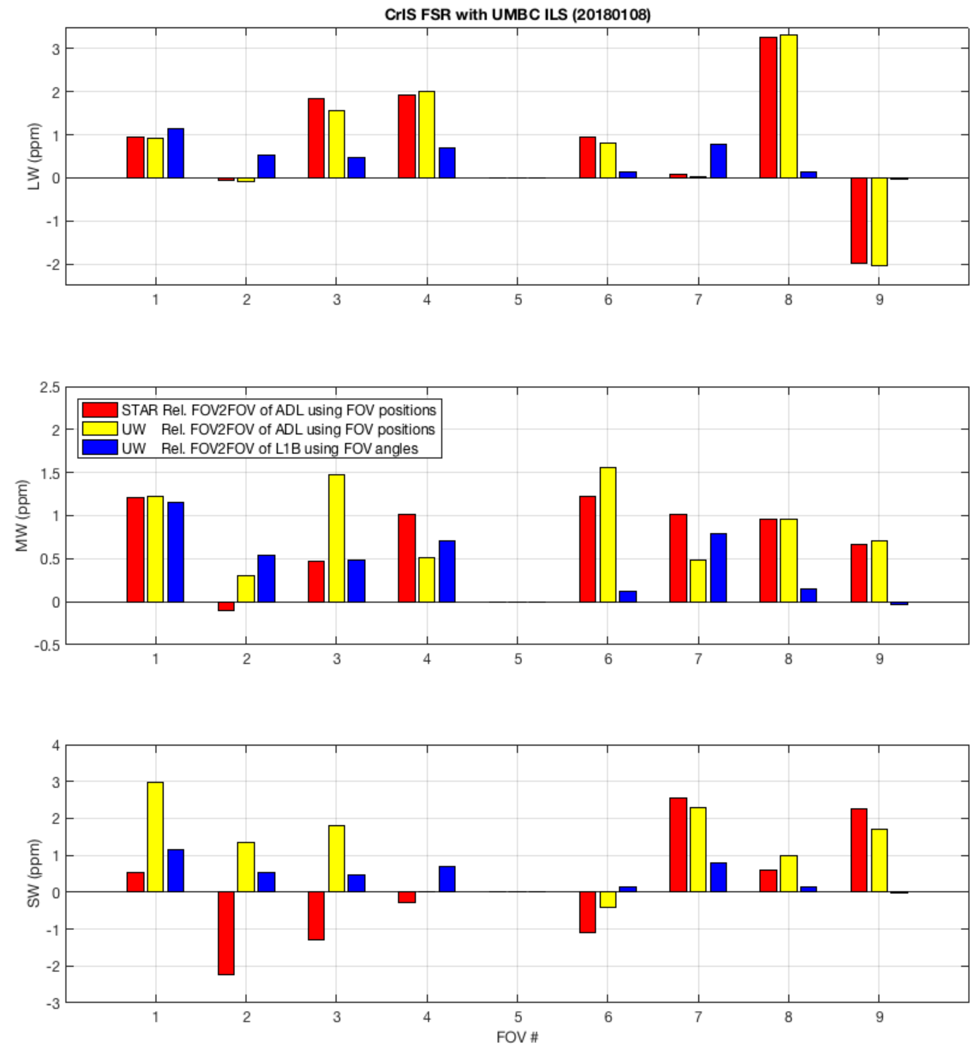




FOV-2-FOV Spectral Calibration Analysis Using ILS Parameters in EngPkt v113

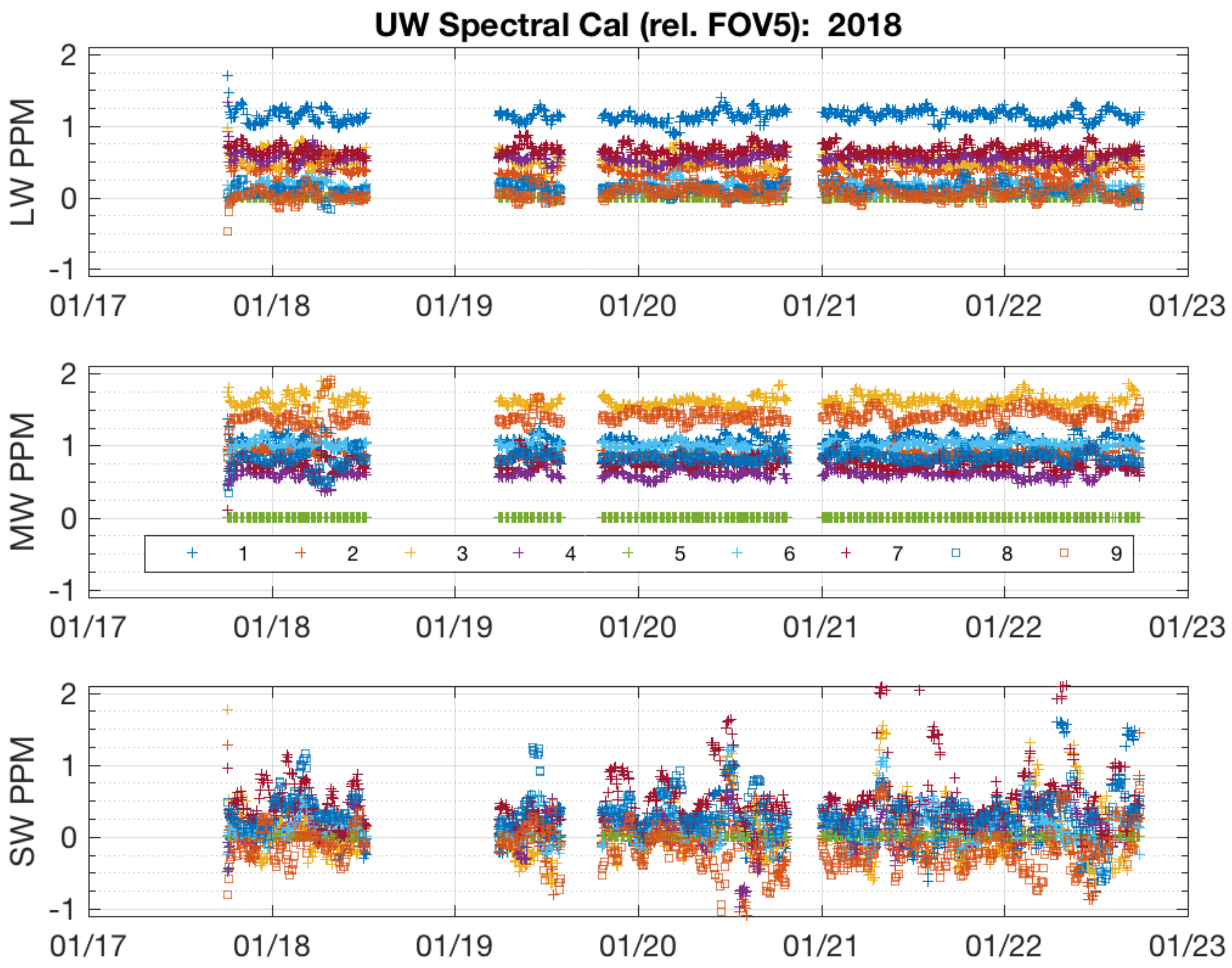
1) For the ADL FSR SDRs generated by STAR for the case study of 08 Jan 2018, the UW analysis of relative FOV2FOV agrees well with the STAR FOV2FOV analysis, with the notable exceptions of SW FOVs 1, 2, and 3.

2) For radiances generated using the UW matlab cal code (which uses FOVangles generated from the prescribed v113 EP ILS parameters), the relative FOV2FOV behavior is improved over the ADL SDRs.

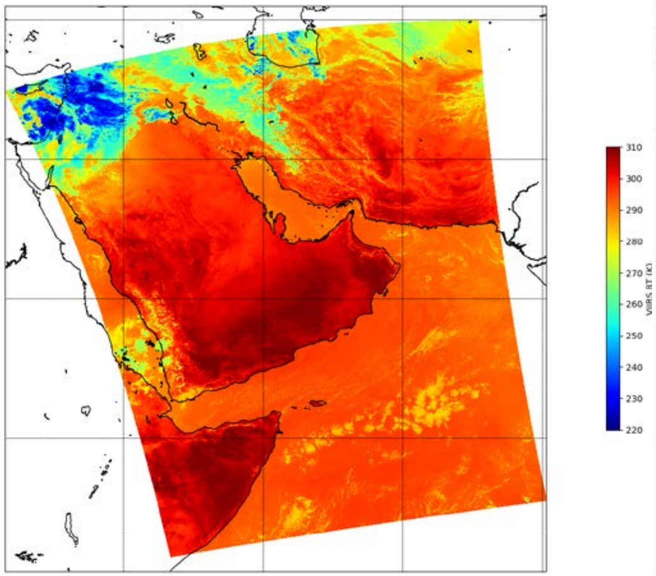


Future Improvement: FOV-2-FOV Spectral Calibration Analysis

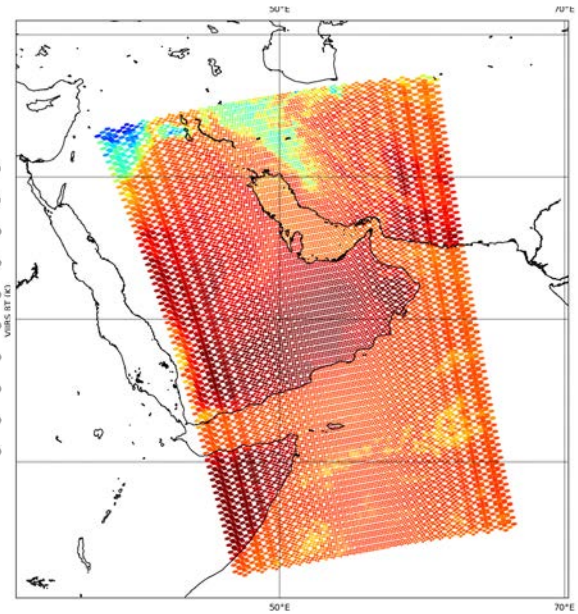
UW L1B Radiance w/ UMBC FOVangles



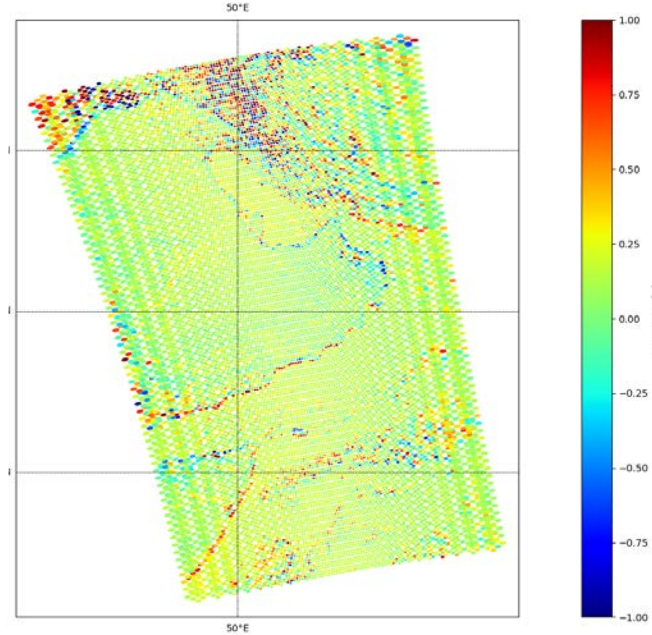
Geolocation Accuracy



VIIRS M15



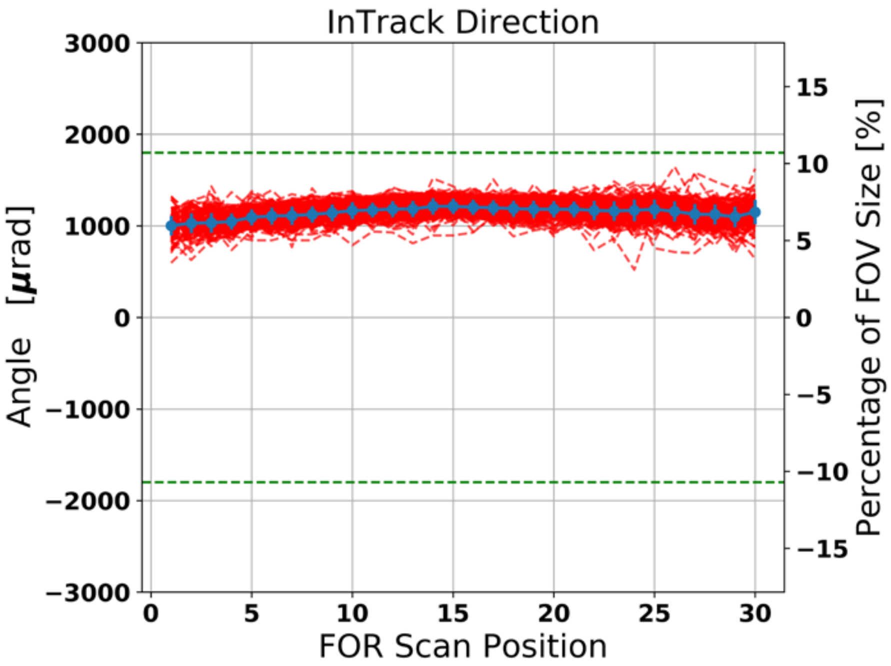
CrIS at 900.0 cm-1

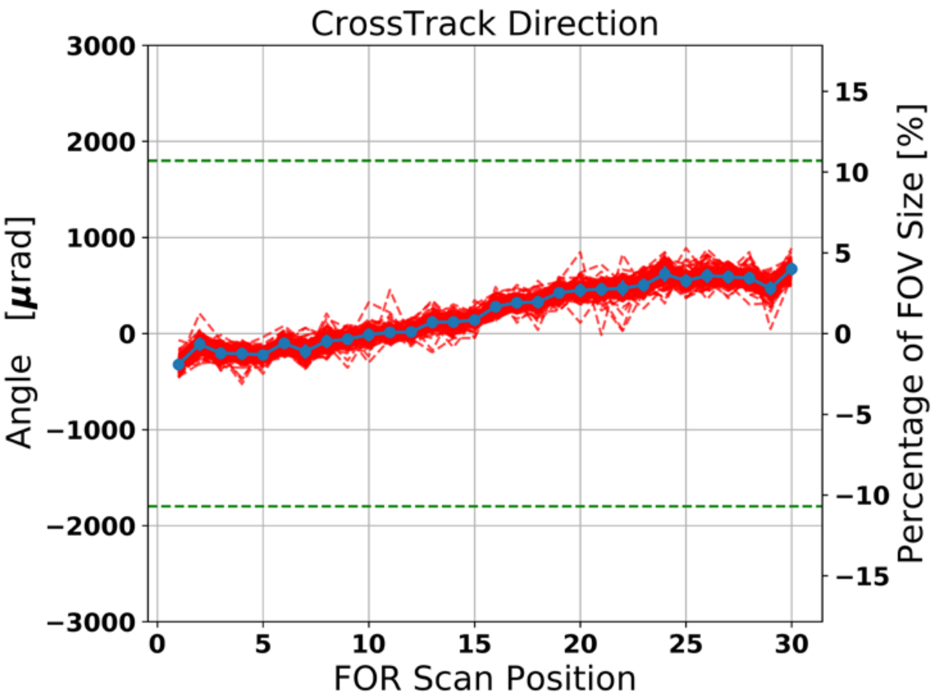


CrIS –VIIRS BT Diff.

Collocated CrIS and VIIRS images

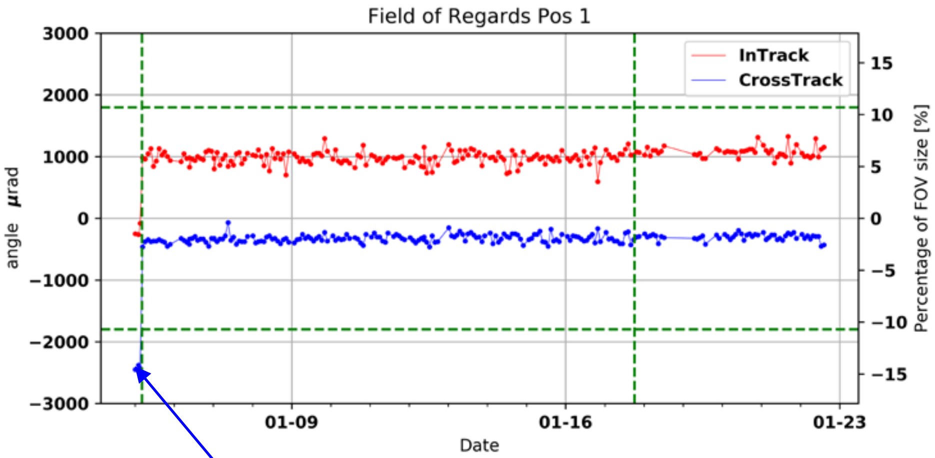
Results indicate some sub-pixel level difference, relative to VIIRS

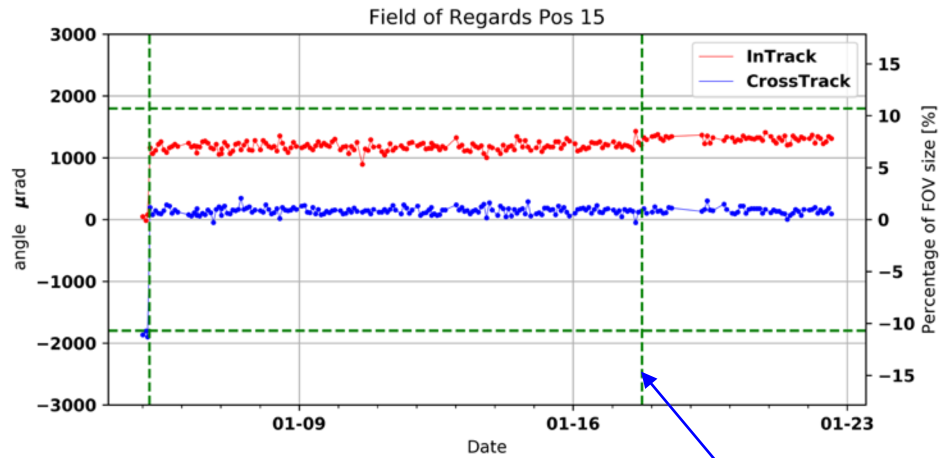




Data after EngPkt v113

Geolocation Accuracy (Meet Specification)



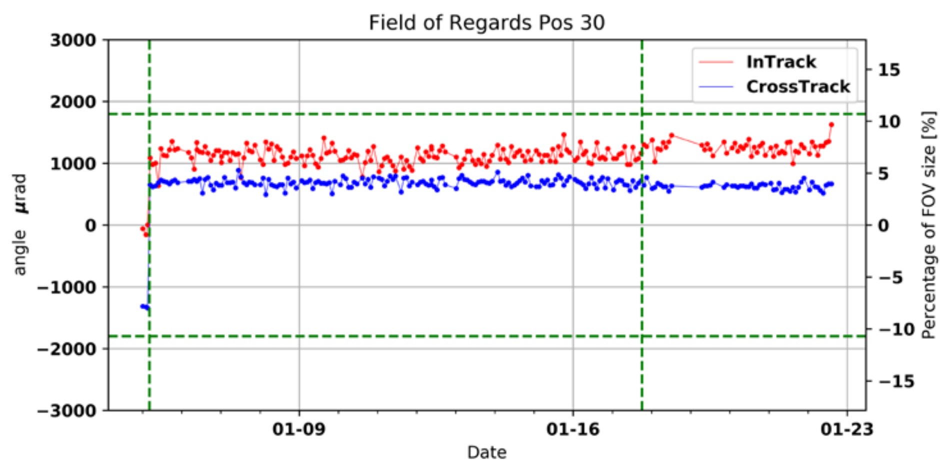


VIIRS geolocation update at 0413 UTC on January 5, 2018

EngPkt v113 upload

Overall performance for CrIS geolocation for all FOV positions:

- it already meets the specifications (1.5 km at nadir - 11% of FOV size for all scan positions)
- In-track geolocation having up to about 6% FOV size error, which can be resolved by updating the mapping angles using VIIRS geolocation as reference



Summary

- NOAA-20 CrIS SDR data well meet and exceed the beta maturity: NOAA-20 CrIS SDR data can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose
- Major NOAA-20 CrIS SDR data Performance:
  - NEdN: all FOVs and bands within the specification, comparable well to S-NPP
  - Radiometric uncertainty: within the specification, all channels (except one) are with ±0.2 K with S-NPP (global averaged), showing very good agreement with VIIRS, AIRS, and IASI (less than 0.5 K)
  - Spectral uncertainty: within the specification, FOV 5 absolute spectral shift within 1 ppm, relative shift within 3 ppm for all bands after EngPkt v113
  - Geolocation uncertainty: within the specification, in-track geolocation having up to about 6% FOV size error
- NOAA-20 CrIS SDR data are available from 01/04/2018. The data gaps are due to CrIS PLTs or spacecraft maneuvers. Other than that, IDPS ground process can successfully generate the CrIS SDR data

Path Forward

- The CrIS SDR team will continue performing the cal/val with NOAA-20 CrIS towards Provisional status milestone by mid February, 2018
  - Radiometric uncertainty: Non-linearity coefficients adjustment, especially for LWIR and MWIR FOV 9
  - Spectral uncertainty: Fine tuning the ILS Parameters in focal plane to reduce the relative spectral shift among FOVs
  - Geolocation uncertainty: updating the mapping angles using VIIRS geolocation as reference to reduce in-track uncertainty

- Initial feedback from EDR team are very positive. Look forward to further collaborations