NOAA-20 VIIRS SDR
Beta Maturity
Status Report

January 22, 2018

VIIRS SDR Team

With contributions from NOAA STAR, NASA/VCST, The Aerospace Corp., and U. of Wisconsin

VIIRS Beta Maturity

- **Beta maturity definition:**
  - 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, exist.

- **Justifications for declaring VIIRS SDR data products beta maturity:**
  - VIIRS SDR for all four major categories (RSB, TEB, DNB and GEO) were checked;
  - All calibration related parameters were checked;
  - Initial On-orbit NEΔT and SNR are characterized;
  - On-orbit SDR bias was characterized based on preliminary comparisons with Suomi NPP and Aqua MODIS;
  - All major SDR/GEO quality flags were checked;
  - Errors and artifacts in the data products were documented. Solutions have been proposed and evaluated, but not necessarily implemented.
  - NOAA STAR Ocean Color, SST, Fire, Imagery, and other teams have performed an initial assessment of the SDR and EDR data and are generally positive about the data quality.

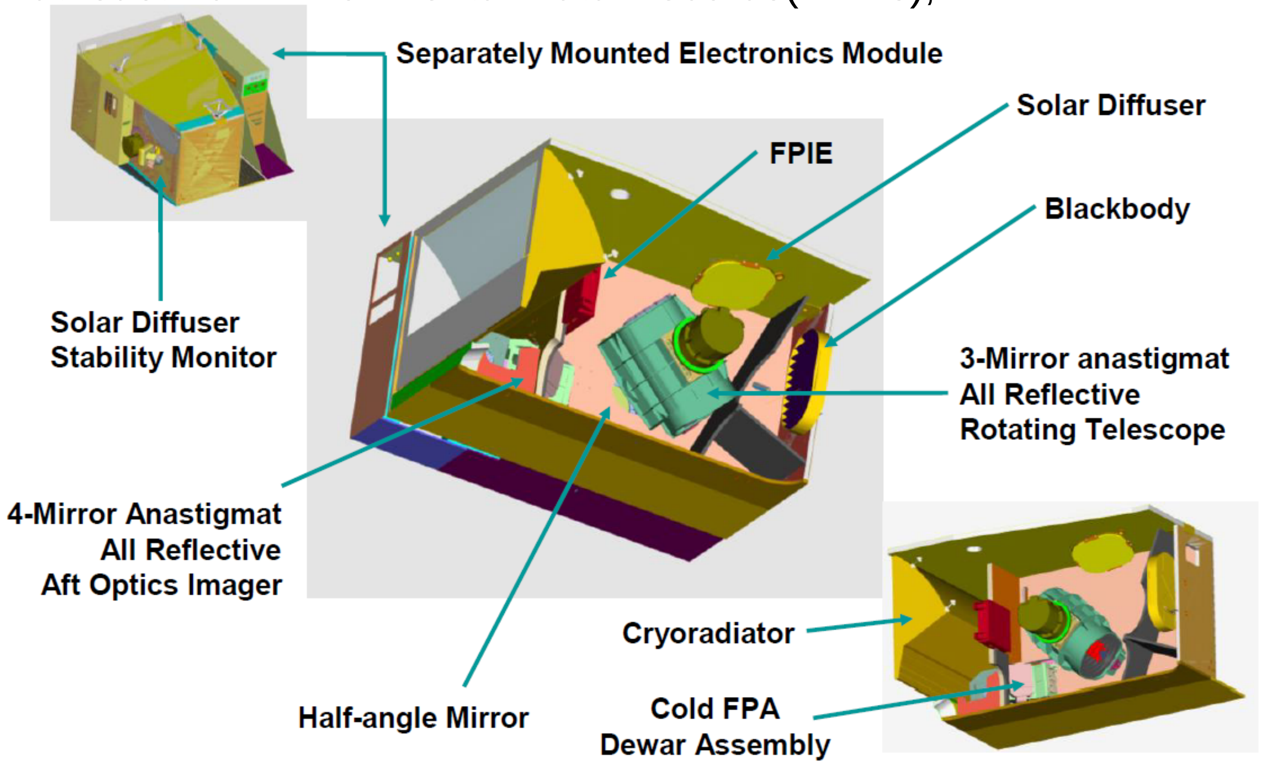
Outline

- Introduction
- NOAA-20 VIIRS performance
  - Reflective Solar Bands
  - Day/Night Bands
  - Thermal Emissive Bands
  - Radiometric vs. Imaging bands
- Summary and path forward

NOAA-20 VIIRS Instrument

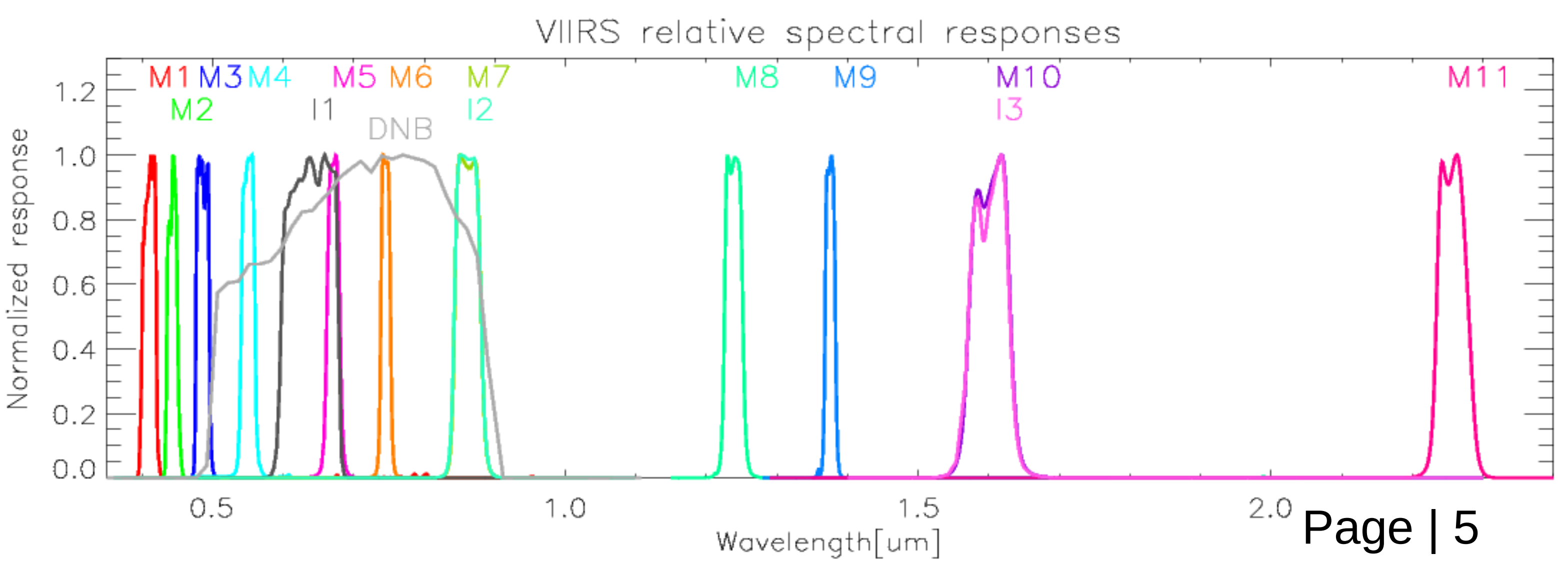
VIIRS is a scanning imaging radiometer onboard Suomi NPP and JPSS satellites that produces global imagery and radiometric measurements of the land, atmosphere, cryosphere, and oceans in the visible and infrared bands with moderate spatial resolutions and 22 spectral bands;

The operationally produced VIIRS data are widely used globally to monitor hurricanes/typhoons, measure cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, active fires, and Earth's albedo. The VIIRS data support the operational production of at least 26 Environmental Data Records(EDRs);



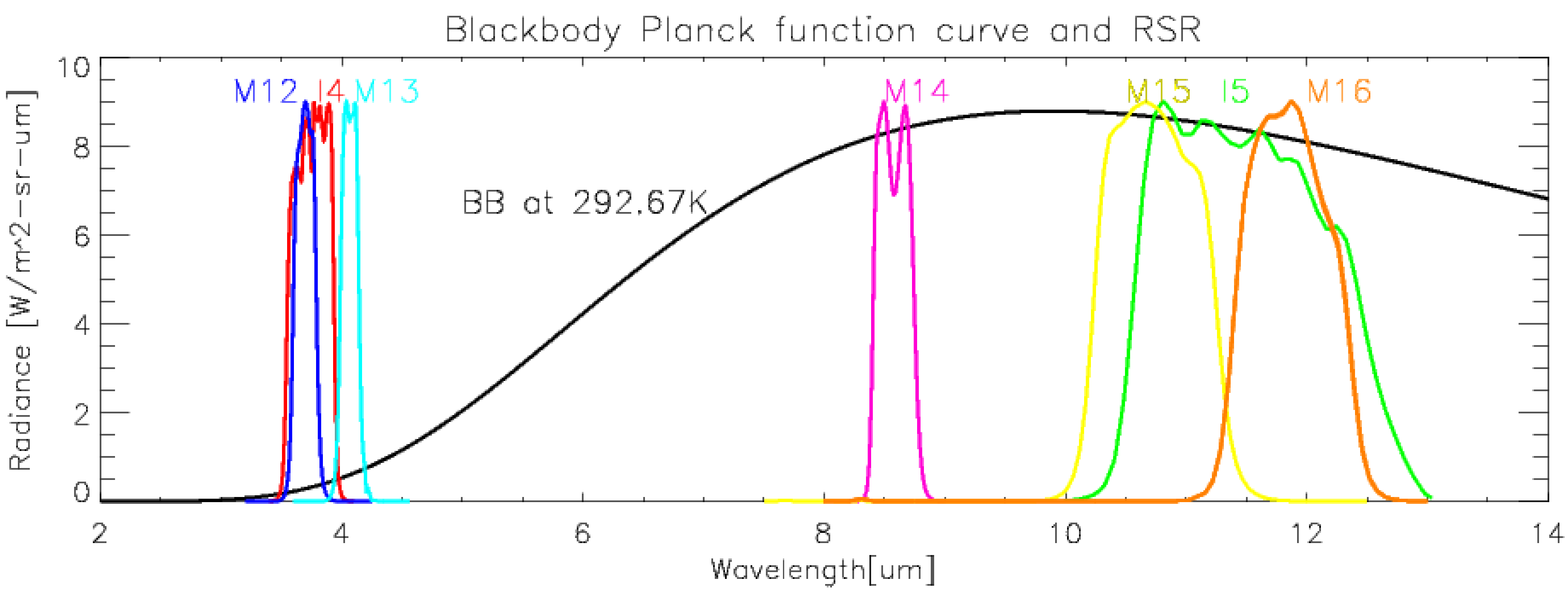
VIIRS Spectral Bands (RSB/DNB)

- Spectral Bands of the VIIRS RSB
  - RSB cover a spectral range from 0.412 μm to 2.25 μm.
  - There are 14 RSB with 3 image bands (I1-I3) and 11 moderate bands (M1-M11).
  - RSB band calibration is dependent on Solar Diffuser (SD) and Solar Diffuser Stability Monitor (SDSM) observations.
  - The required RSB calibration uncertainty is 2 percent.



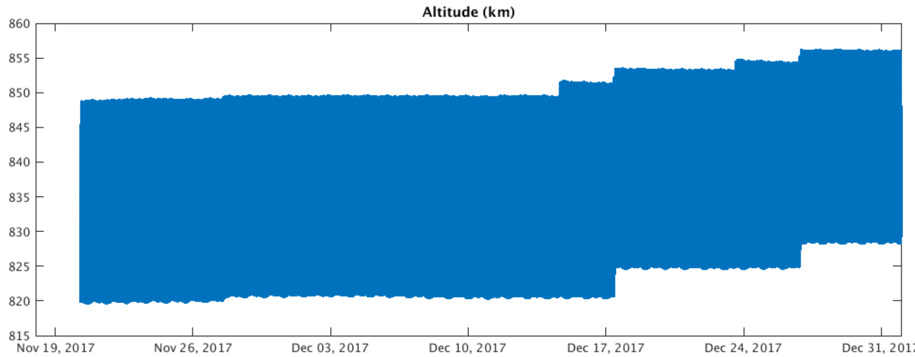
VIIRS Spectral Bands (TEB)

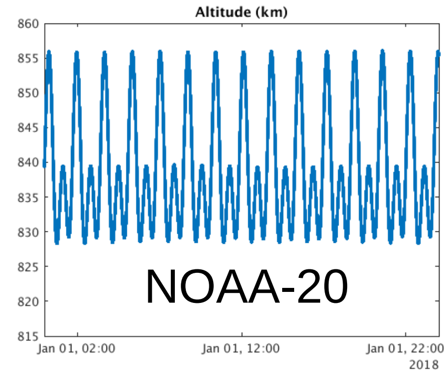
- Spectral Responses of the VIIRS TEB
  - There are 7 bands with 2 image band (I4, I5) and 5 moderate bands (M12-M16)
  - Calibration sources are Onboard Blackbody (BB) with six thermistors and space view.

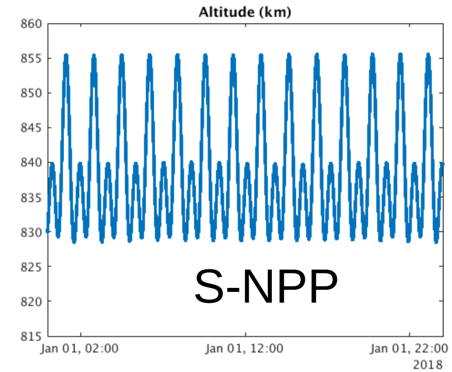


Spacecraft Ephemeris and Attitude

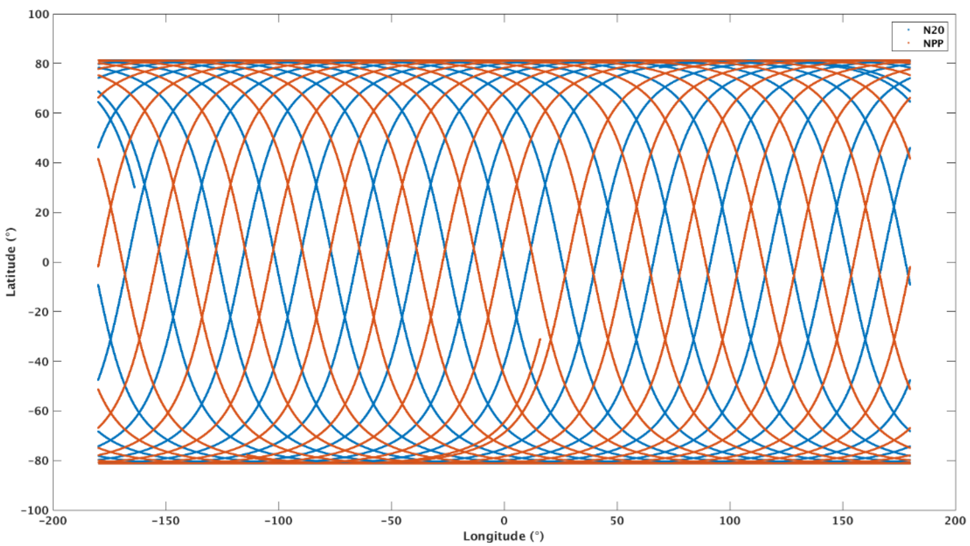
- NOAA-20 orbit phasing with S-NPP completed after orbit raising increased the N20 spacecraft altitude to match NPP: final “trim” of the N20 orbit on January 6, 2018

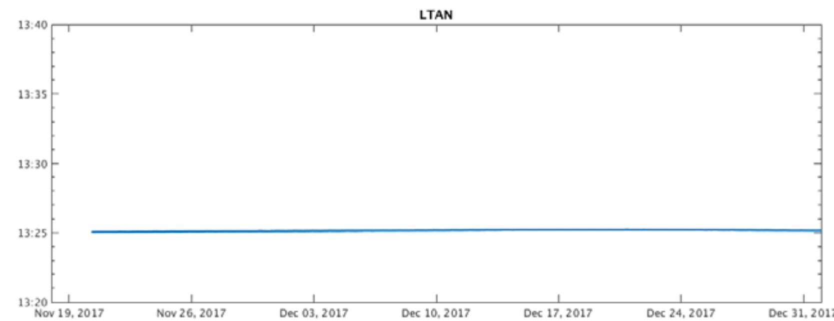






NOAA-20 and Suomi NPP ground tracks interleave as planned





NOAA-20 orbit has LTAN (local time of equator crossings from South to North) set according to the mission requirements of 13:30 ± 10 min., with the current goal set to 13:25 ± 1 min.

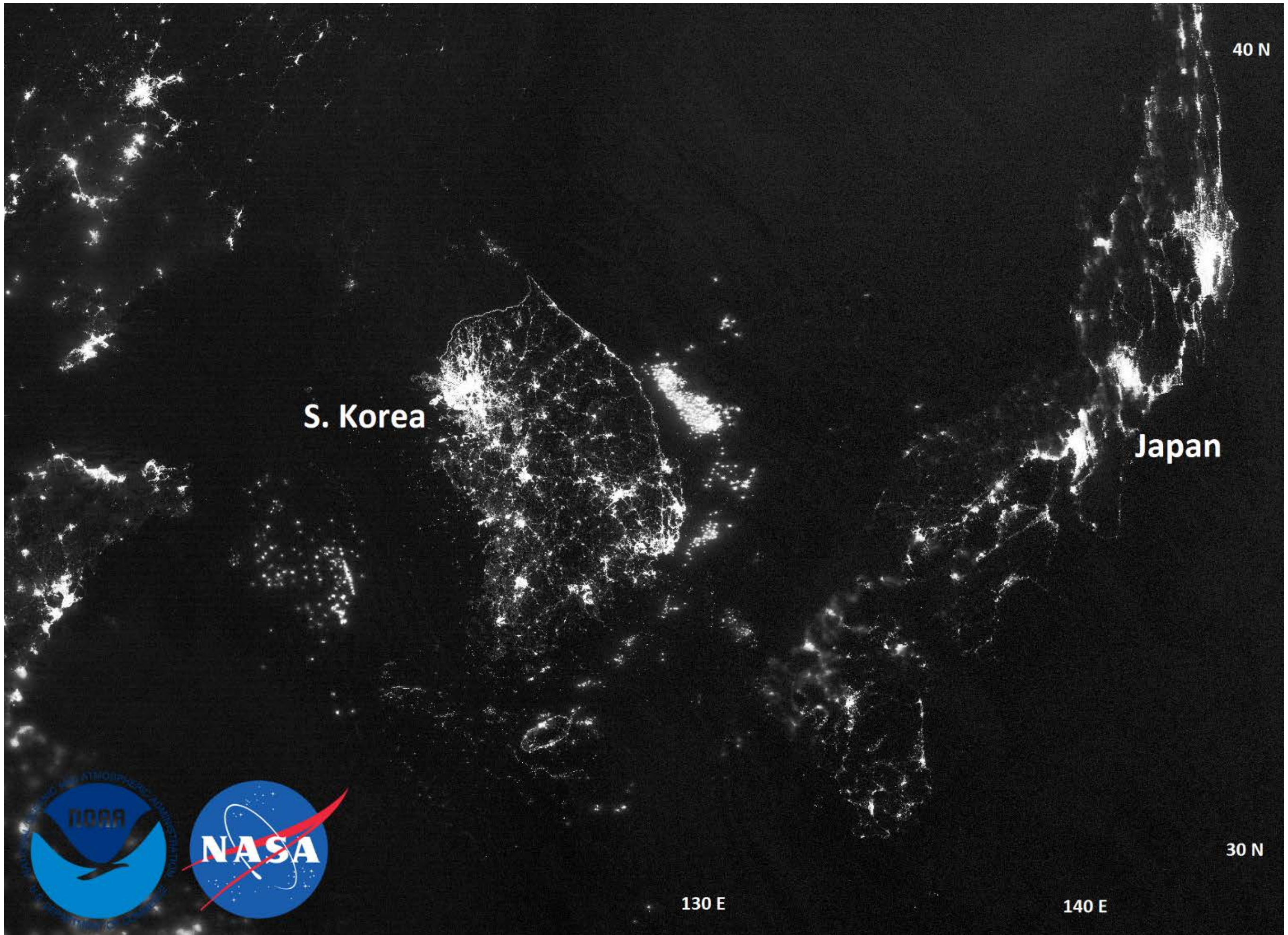
NOAA-20 VIIRS First Light Images: VisNIR Bands

- Earth observations from NOAA-20 VIIRS started on December 13, 2017 with the granule acquired at 16:51 UTC
- Continuous IDPS production of VisNIR SDR Earth data began on December 20, 2017 with the granule acquired at 13:29 UTC

Bands M5, M4, M3 shown as RGB

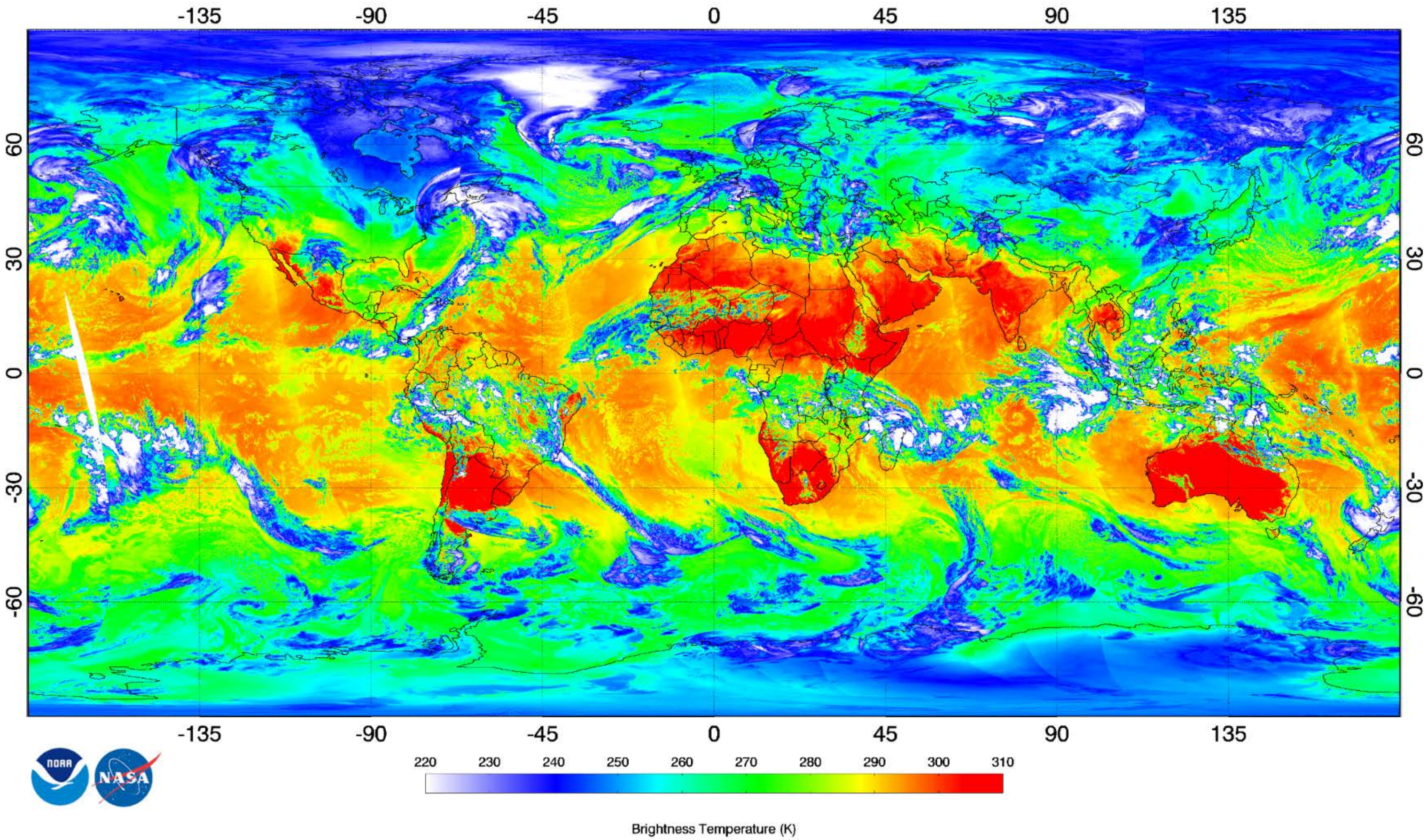
First Light Images: Day Night Band

- While NOAA-20 VIIRS DNB images have been acquired since December 13, 2017, DNB detectors reached operational temperature around 6:00 UTC on January 4, 2018



First Light Images: Thermal Emissive Bands

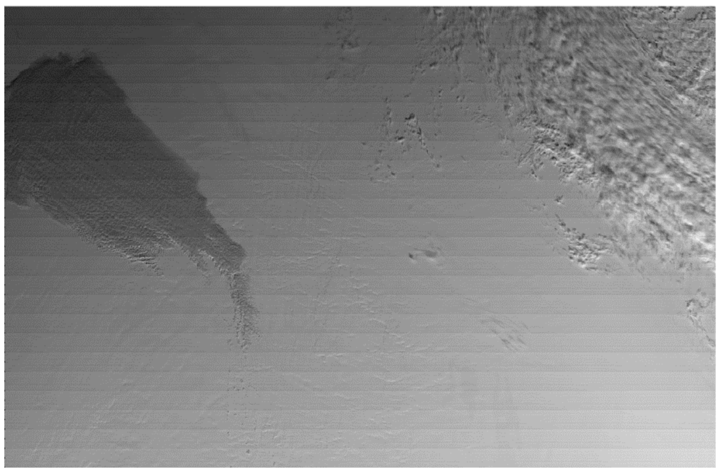
- NOAA-20 VIIRS S/MWIR and LWIR bands CFPA (I3 to I5 and M8 to M16) reached operational temperature around 8:30 UTC on January 5, 2018
- All thermal bands are working nominally, except that I4 and I5 radiance/brightness temperature products from IDPS are currently often replaced with fill values due to electronics temperature below a LUT threshold: update in progress (ADRs 8559-8561)



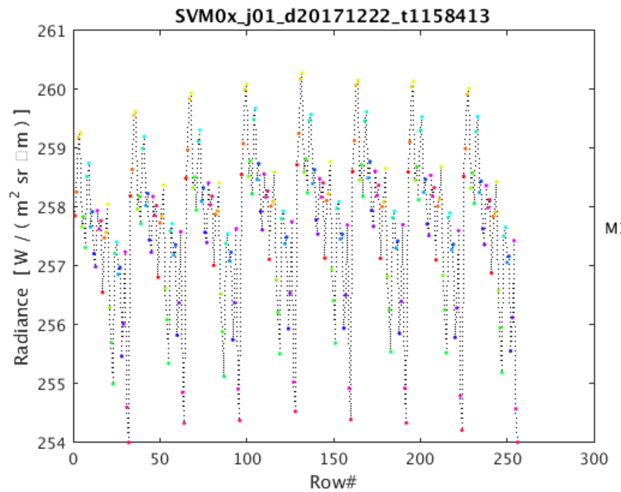
Band M15

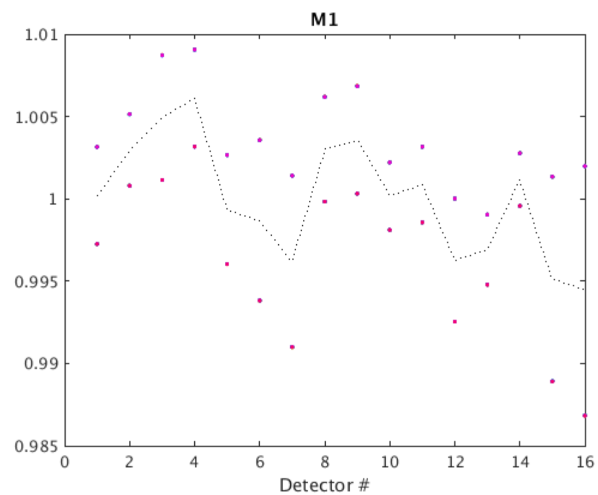
Image Quality

- No image artifacts, such as echoes or ghosts, have been detected in the NOAA-20 VIIRS SDR images
- Minor striping may still be present despite updated radiometric calibration



An example of striping observed in an Antarctic scene for band M1 from SDR data reprocessed with the updated F-PREDICTED LUT





M1

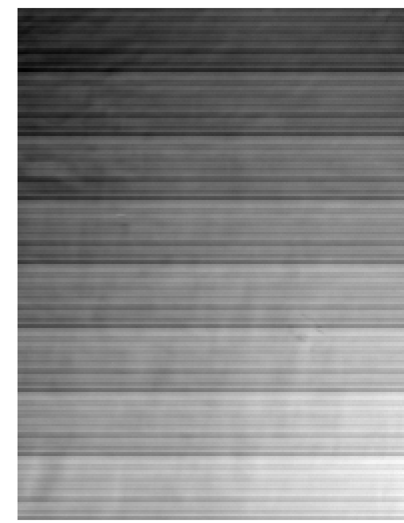
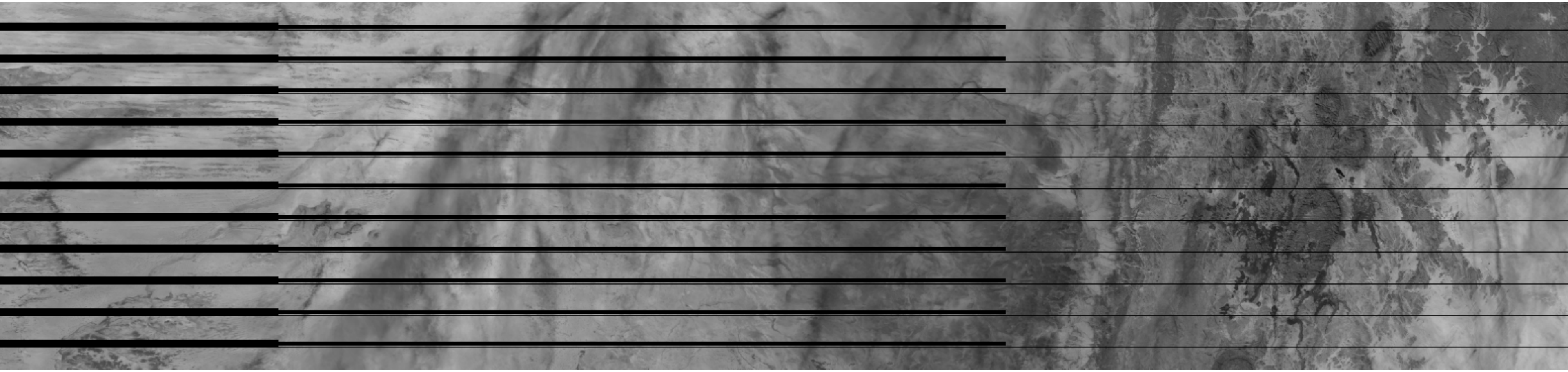


Image Quality: SWIR Bands

Bands M11, M10, M8 shown as RGB

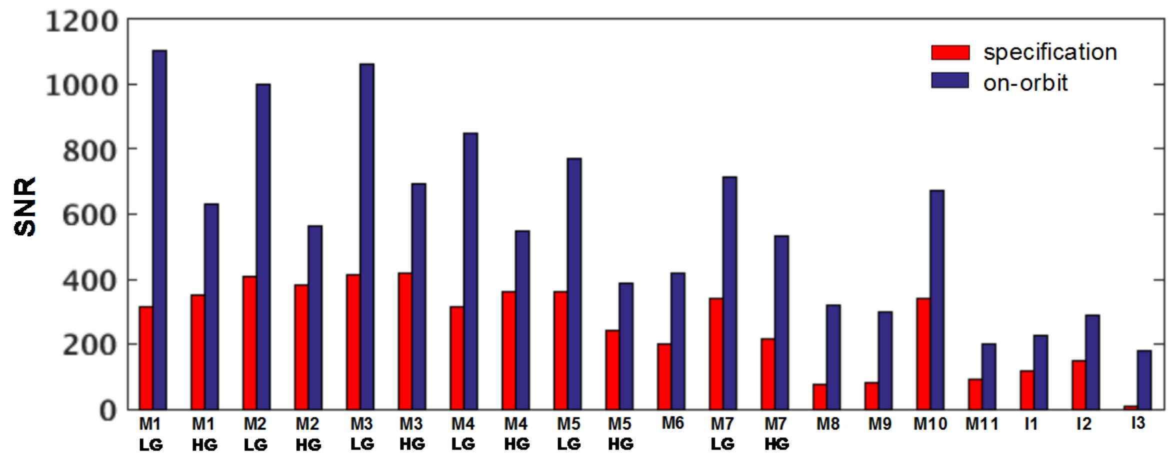
- **One detector (#29) for band I3 is inoperable:** will be replaced with fill values in IDPS products; this was a known issue before launch but the performance is worse than predicted in prelaunch

Band I3



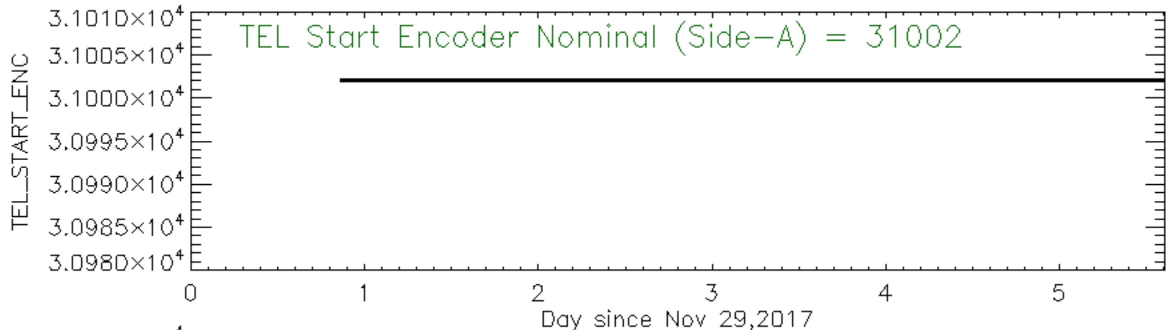
RSB Noise/SNR

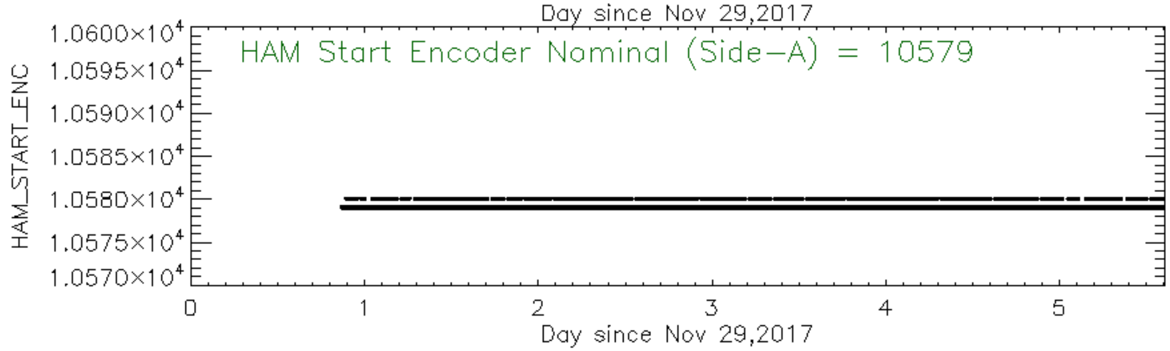
Band	L_{typ}	SNR spec	SNR on-orbit
M1 LG	155	316	1102
M1 HG	44.9	352	631
M2 LG	146	409	998
M2 HG	40	380	564
M3 LG	123	414	1061
M3 HG	32	416	693
M4 LG	90	315	848
M4 HG	21	362	549
M5 LG	68	360	774
M5 HG	10	242	385
M6	9.6	199	417
M7 LG	33.4	340	715
M7 HG	6.4	215	532
M8	5.4	74	321
M9	6	83	297
M10	7.3	342	673
M11	1	90	199
I1	22	119	225
I2	25	150	286
I3	7.3	6	180

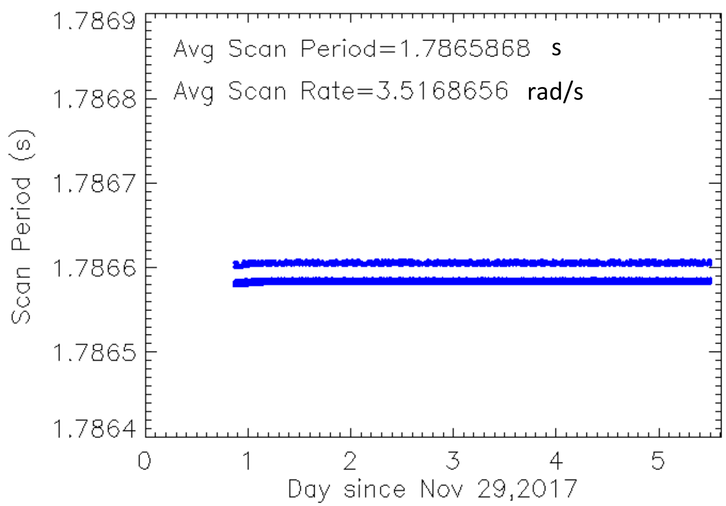


- L_{typ} unit: W/m^2-sr-µm
- SNR on-orbit of a given band is average over all detectors of the band
- The SNR requirement is met for all RSBs except for detector 29 of I3
- Detector 29 of I3 was excluded from the I3 on-orbit SNR calculations
- On-orbit SNR for I3 detector 29 is only about 1.2: detector will be designated as inoperable

Earth Scan Monitoring







- Start-of-scan encoder values are stable and in agreement with prelaunch values
- Occasional **losses of synchronization** between the rotating telescope and the half-angle mirror have been observed: each lasted about 2 minutes
- Scans affected by the sync loss events are flagged in SDR and erroneous data are replaced with fill values (same as in S-NPP products)

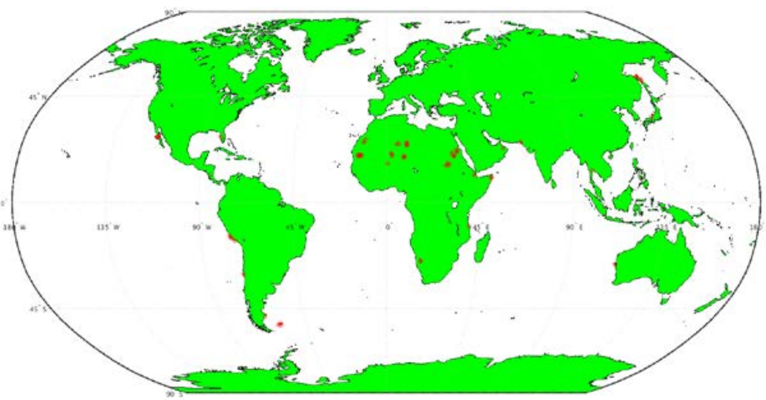
Scan Period = time difference between two consecutive start-of-scan timestamps

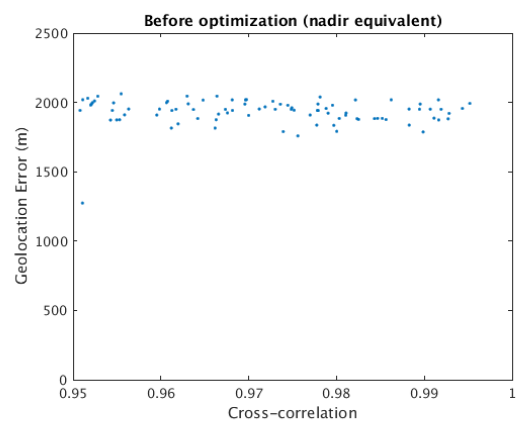
Scan Rate = 2π / Scan Period

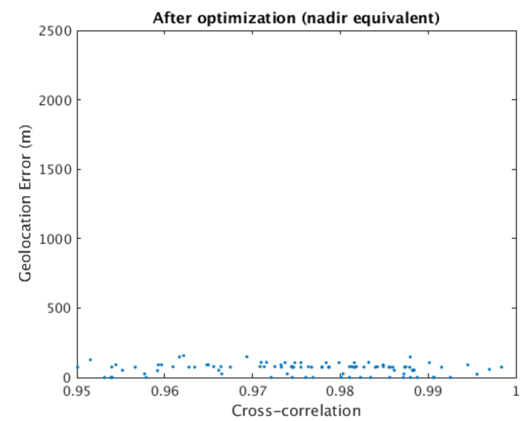
Scan period and scan rate appear to be stable, consistent with prelaunch values

Geolocation Accuracy

- Preliminary evaluations based on Landsat matchups have shown that initial uncertainty of NOAA-20 VIIRS geolocation products was larger than mission requirements: approximately 2 km (3-sigma or CE95)
- Optimization of the instrument-to-spacecraft mounting matrix allowed for reduction of the geolocation uncertainty to within requirements: approximately 100 m
- Updated LUTs that improve geolocation accuracy have been deployed in IDPS for the SDR production starting with the granule acquired at 4:13 UTC on January 5, 2018

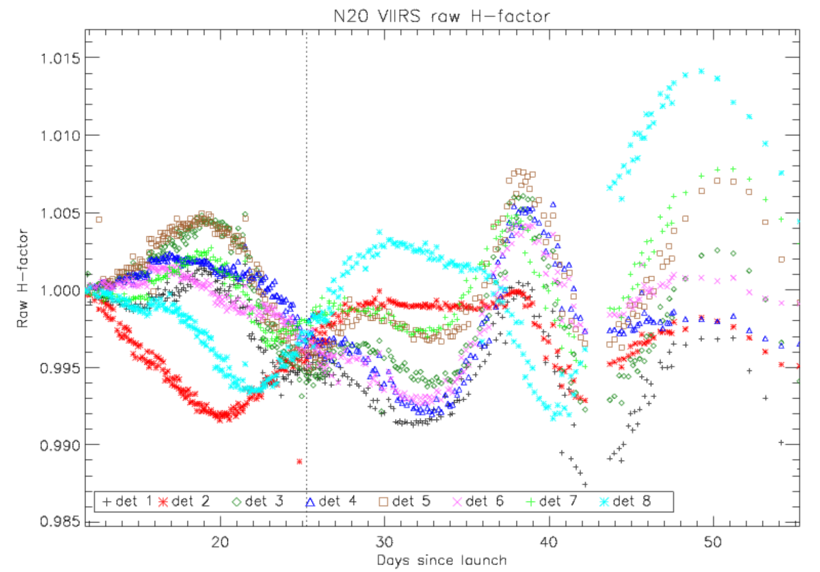


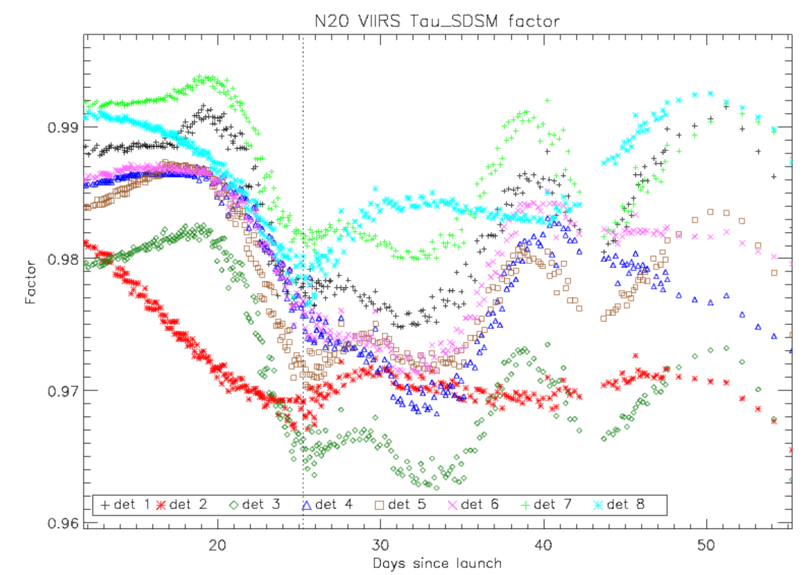




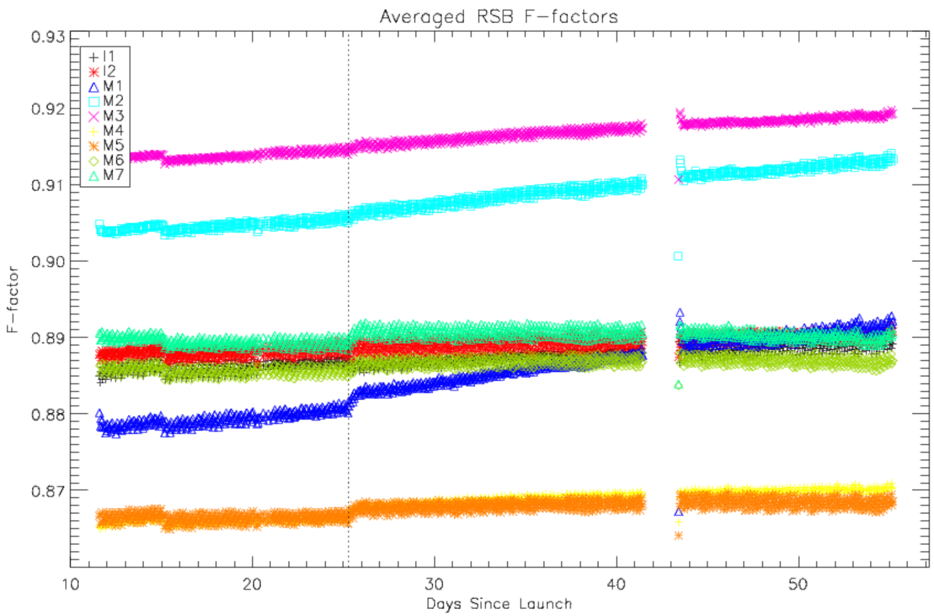
Solar Diffuser Monitoring

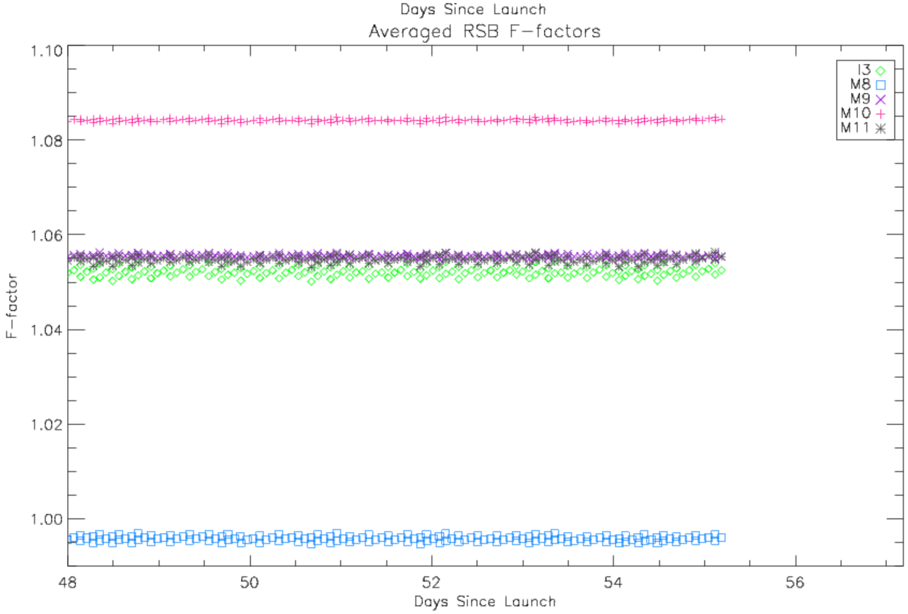
- SDSM measurements taken on every orbit from #166 to #374
- Switched to every other orbit from #376
- Change to once per day SDSM collects on January 5, 2018
- Initial calculations of the H factors (solar diffuser BRDF vs. orbit #0) indicate potential problems with prelaunch transmission and BRDF LUTs (mainly the SDSM sun view screen transmission LUT, as shown on the graphs)
- Improvements are expected after analysis of data from the yaw maneuvers (scheduled for Jan 25-26, 2018)
- Assuming **H = 1** for the F LUT update on Dec 22, 2017, with linear trends added for bands affected by solar diffuser degradation (details on the following charts)





RSB Radiometric Calibration



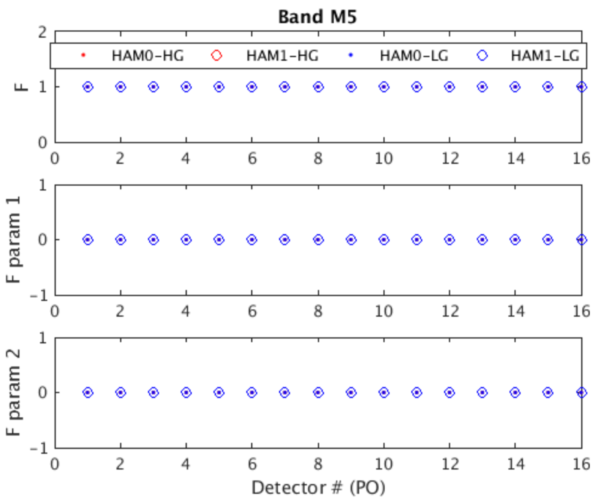


- F factor values for VisNIR bands have displayed stable trends since the nadir doors opening on day 26, except for the safe mode event
- After cryo-radiator door opening, SWIR band F-factors become available, and they are quite stable near unity, but also indicate change of radiometric calibration from prelaunch values
- Non-linearity of SWIR band radiometric response is corrected for bands M8 to M11, but not for band I3

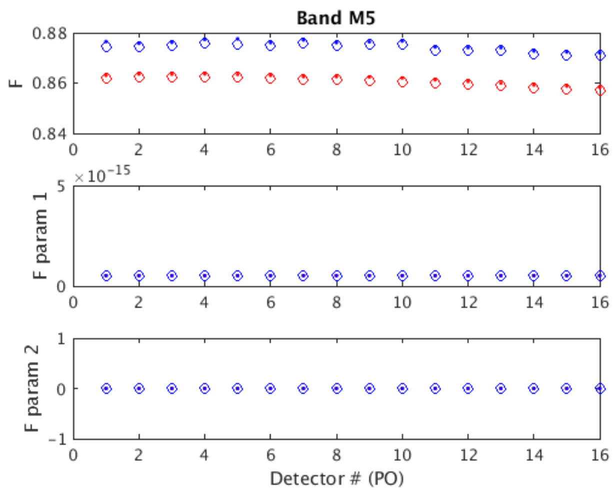
VisNIR Radiometric Calibration

- Changes of radiometric calibration versus the prelaunch values (the F factors) have been calculated for every orbit since VIIRS activation on day 11 after launch
- Solar diffuser degradation estimates from SDSM measurements are currently not included in the F factor calculations due to unexpected variability, but the degradation is accounted for by linear regression of the F factor time series
- Initial F factor values quite different from 1, by about 10%
- Stable trends have been observed after Earth observations started: averaged F factors (with trends added) since day 26 were used to calibrate current SDR products from IDPS since January 5, 2018 (granule 4:13 UTC) (example for band M5 shown below)

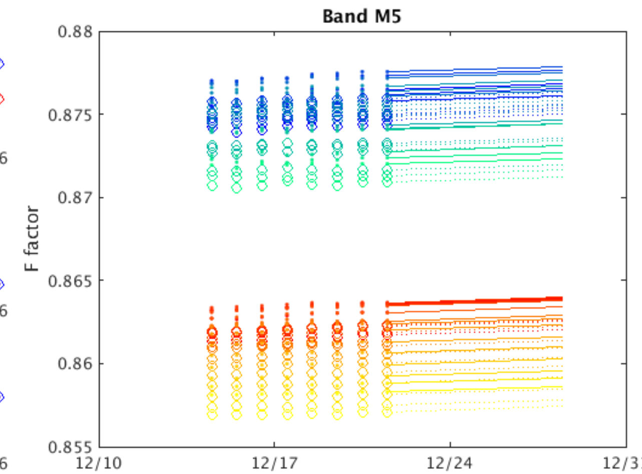
Prelaunch



Updated

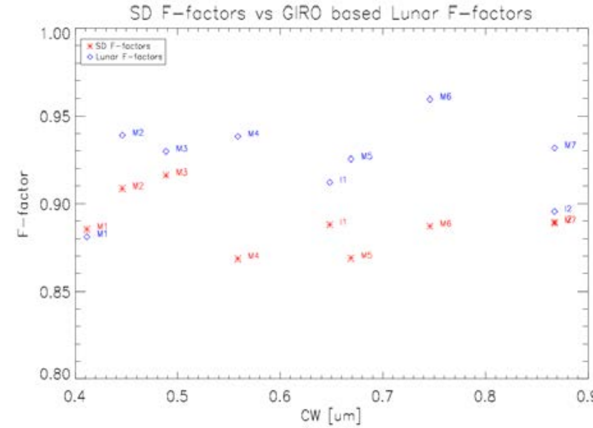


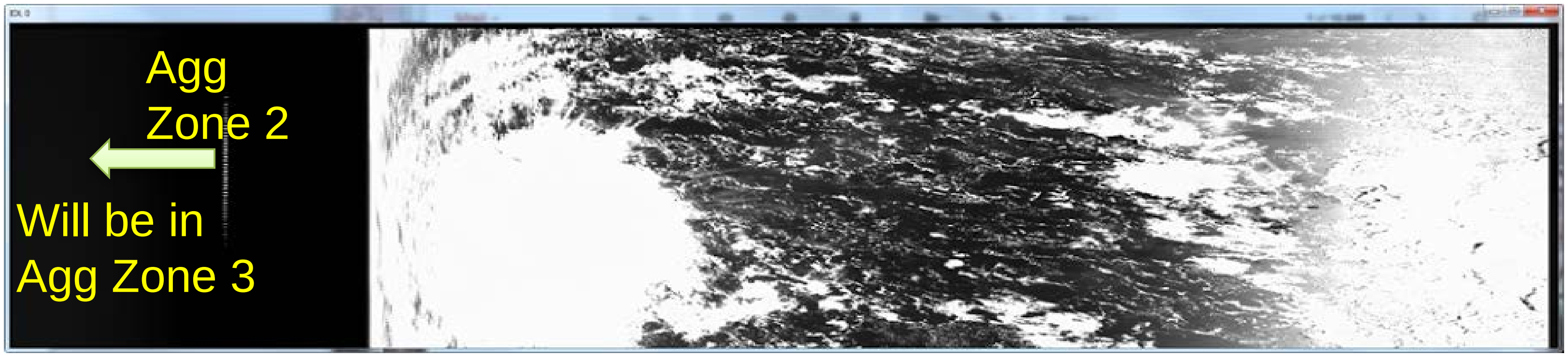
Prediction

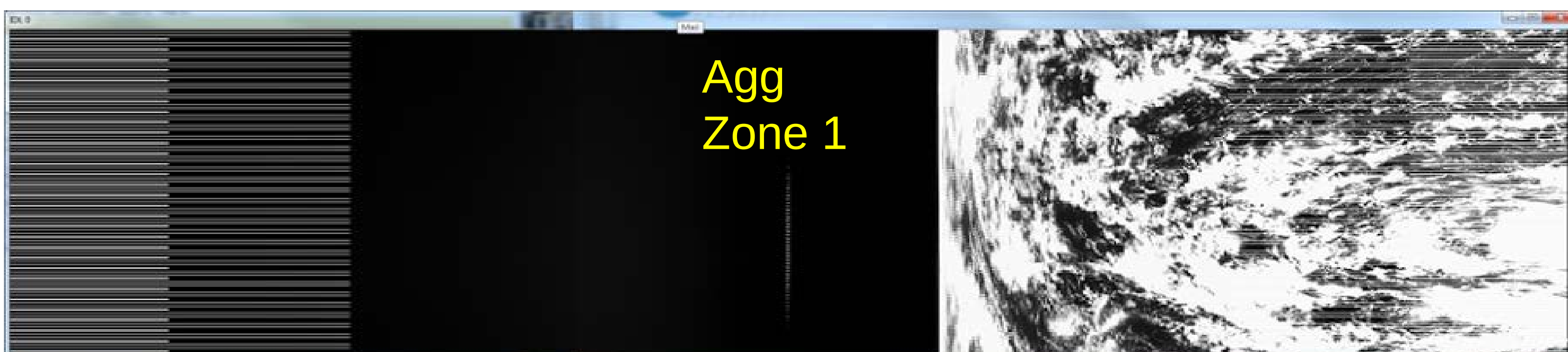


Lunar Calibration

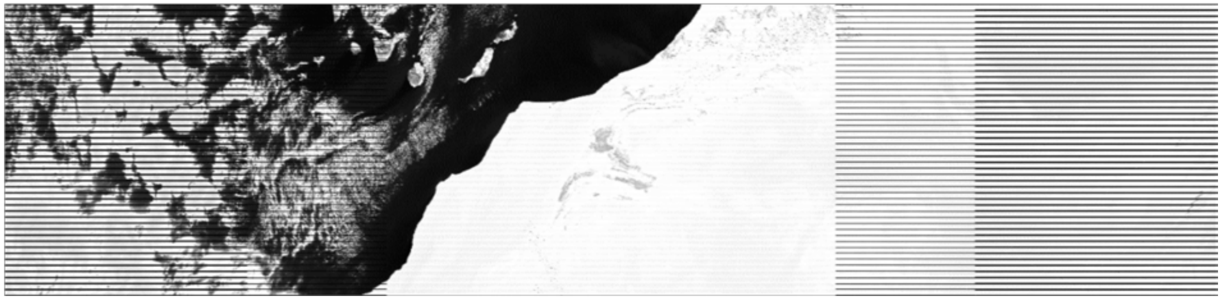
- The first NOAA-20 VIIRS lunar calibration was successfully scheduled and conducted on December 29, 2017 around 10:03:32 UTC
- Preliminary lunar F-factors are closer to one than solar F-factors, and they are lower for I-bands than for M-bands, except for band M1



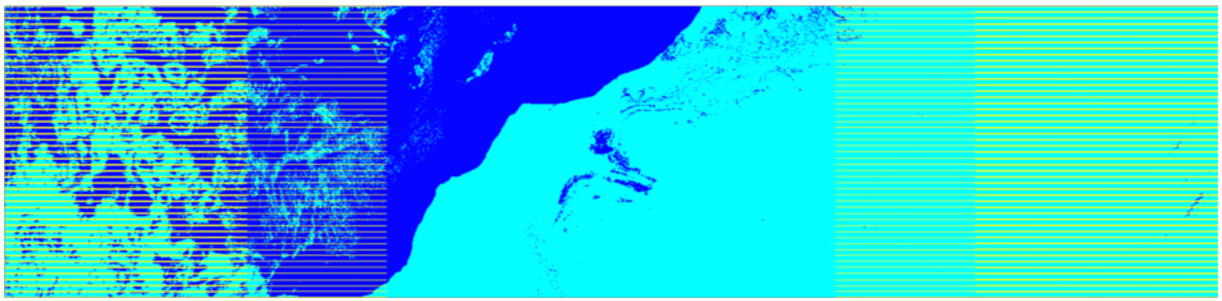




Dynamic Range



M6 Radiance



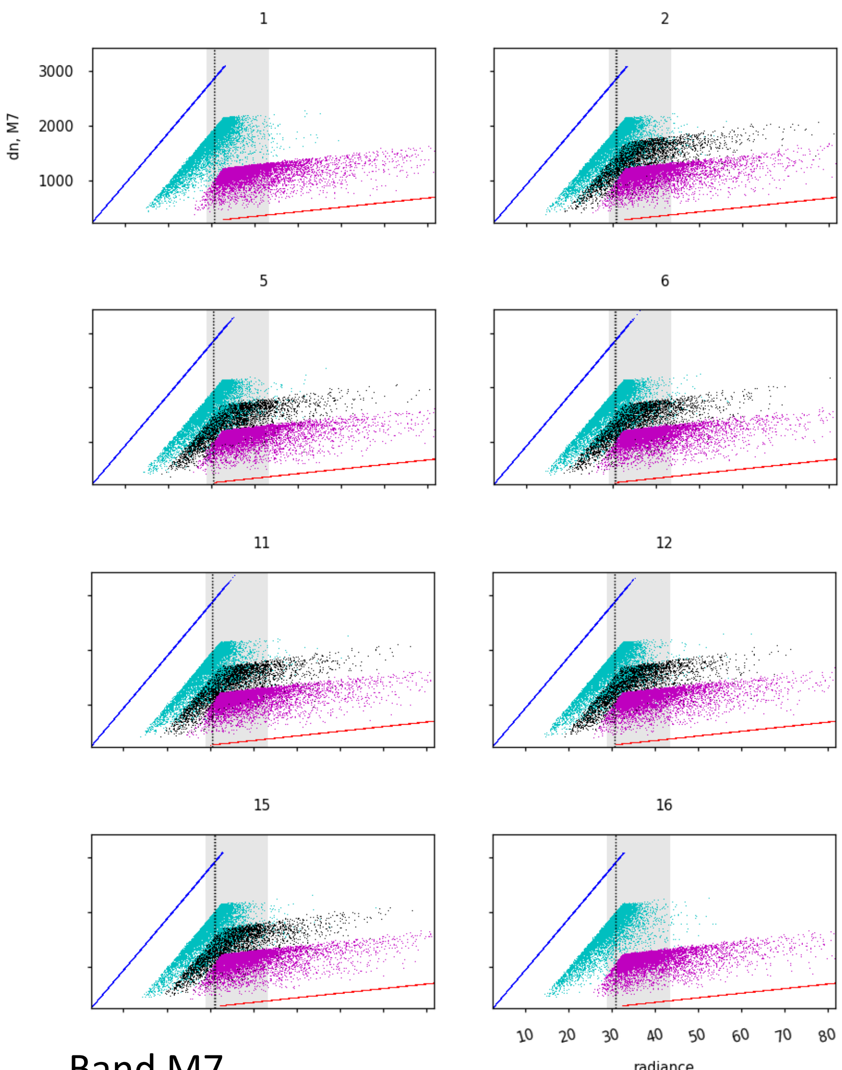
M6 Quality Flag

M6 Out-of-Range Flag

- Dynamic range of all bands, except M6, appears to agree with specifications and prelaunch measurements
- M6 products are affected by “roll-over”: many radiance measurements above approximately 30 W/m^2-sr-µm are incorrect
- Currently, only some of the erroneous pixel values are flagged as poor quality and out-of-range
- Because NOAA-20 VIIRS telescope has higher throughput than on S-NPP (no tungsten oxide contamination), the “roll-over” occurs at lower radiance values, and the NOAA-20 M6 images appear darker than those from S-NPP

Further analysis is need for bands with waivers such as M8

Dual Gain Transition

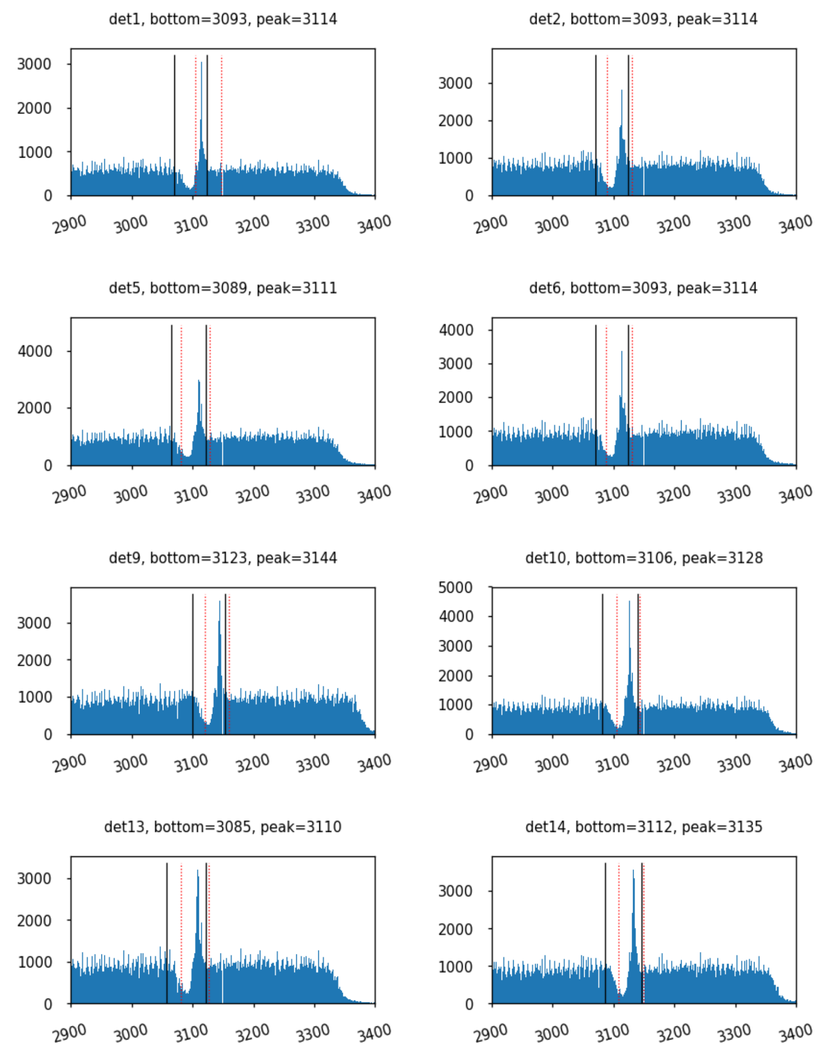


Band M7

- Analyses of on-orbit data have shown that transitions between high gain and low gain for bands M1 to M5 and M7 occur at radiance values that agree with the specifications (100% to 150% high-gain L_{max})
- An example for select band M7 detectors is shown:
  - o Blue: high gain pixels
  - o Red: low gain pixels
  - o Cyan, black, magenta: aggregated pixels with mixed gains (*dn* is not aggregated, but radiance is)
  - o Gray: specification limits (upper end of the blue "line" must overlap with the low end of the red "line", and both must be within the gray area)

Graphs provided by NASA VCST

Dual Gain Anomaly



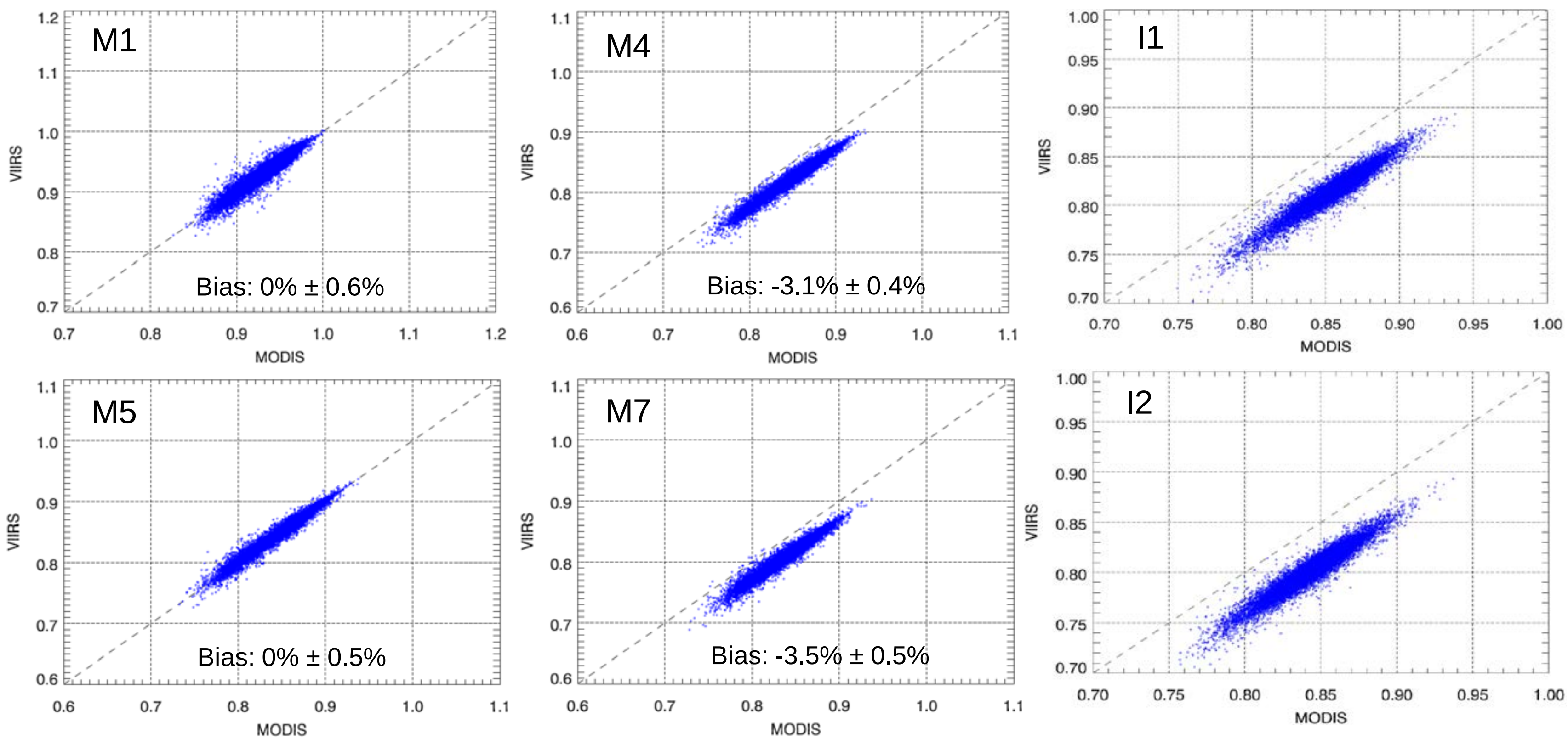
Band M7

Graphs provided by NASA VCST

- Dual Gain Anomaly (DGA) can be seen in DN histogram as a deficit of pixels for a small range of DNs and a spike in the number of pixels with adjacent, higher DNs
- Pixels affected by DGA may have significant errors in the SDR radiance/reflectance products, thus, pixels in the predefined DN ranges are flagged as “poor quality”
- DN histograms from the on-orbit NOAA-20 VIIRS data indicate that the DGA ranges agree with the prelaunch estimates implemented in the current DGA LUT (dotted red lines on the sample graphs shown on the left)
- Therefore, the prelaunch DGA LUT has not been updated yet

Preliminary RSB Comparison with Aqua MODIS

SNO	Date	Time (NOAA-20)	Time (Aqua)	Lat,Lon (NOAA-20)	Time Diff (s)
	1/7/2018	15:20:09	15:18:58	-77.46, 14.51	71



- Agreement between reflectance products for some VIIRS and MODIS VisNIR bands (M1, M5) improved after the F-PREDICTED LUT update on January 5, 2018, but differences for other bands (M4, M7, I1, I2) can still be observed

Preliminary RSB Comparison with S-NPP VIIRS

- Used double differencing with MODIS to compare NOAA-20 and S-NPP VIIRS since SNO doesn't exists between N20 and NPP
- Top table shows the bias of both NPP VIIRS and N20 VIIRS relative to MODIS
- Difference in bias (bottom table) shows N20 VIIRS and NPP VIIRS radiometric consistency

Bias Relative to MODIS (5 SNO events)	M1	M4	M5	M7	I1	I2
N20 VIIRS Bias	-0.11 ± 0.74	-3.04 ± 0.62	-0.06 ± 0.67	-3.44 ± 0.69	-4.52 ± 0.65	-4.81 ± 0.65
NPP VIIRS Bias	-1.30 ± 0.89	-0.58 ± 0.82	3.31 ± 0.84	0.65 ± 0.87	-2.21 ± 0.89	0.47 ± 0.96

Bias= (VIIRS – MODIS)*100%/MODIS

N20 VIIRS bias relative to NPP VIIRS	**M1**	**M4**	**M5**	**M7**	**I1**	**I2**
	1.19 ± 1.34	**-2.46 ± 1.05**	**-3.37 ± 1.15**	**-4.09 ± 1.23**	**-2.31 ± 1.21**	**-5.28 ± 1.34**

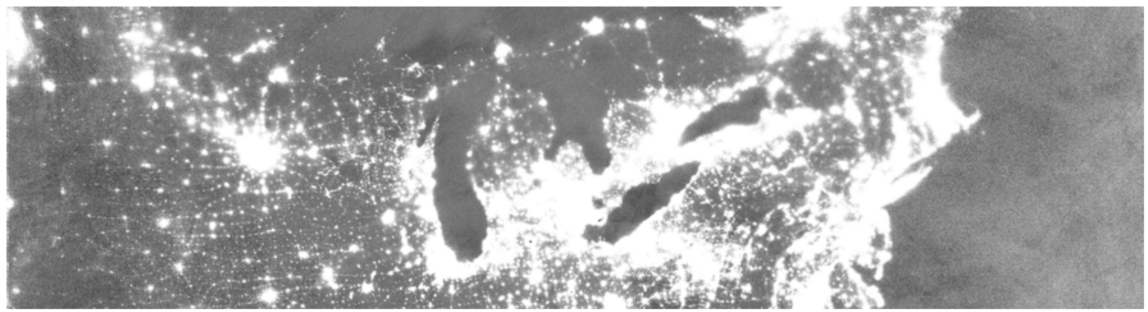
- This preliminary SNO study suggests that N20 VIIRS calibration is underestimated for M4, M5, M7, I1 and I2 as compared to NPP VIIRS ranging from nearly -2.5% to more than -4%

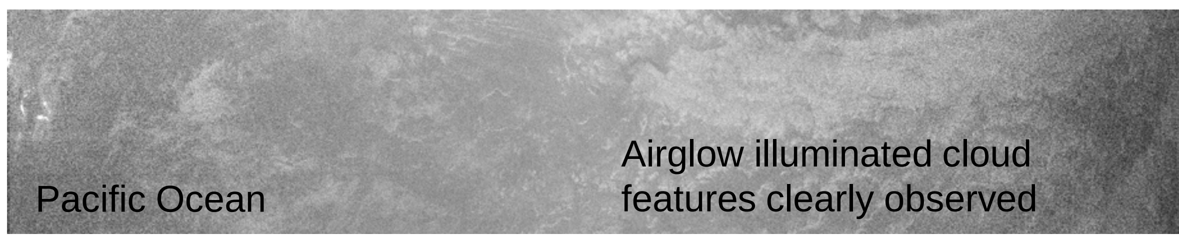
DNB Image Quality

IDPS SDR: using prelaunch calibration coefficients (including dark offsets and gain ratios)

Reprocessed SDR: using new moon based gain ratios, DN0, and on-orbit LGS Gains:

- Banding and striping artifacts are removed



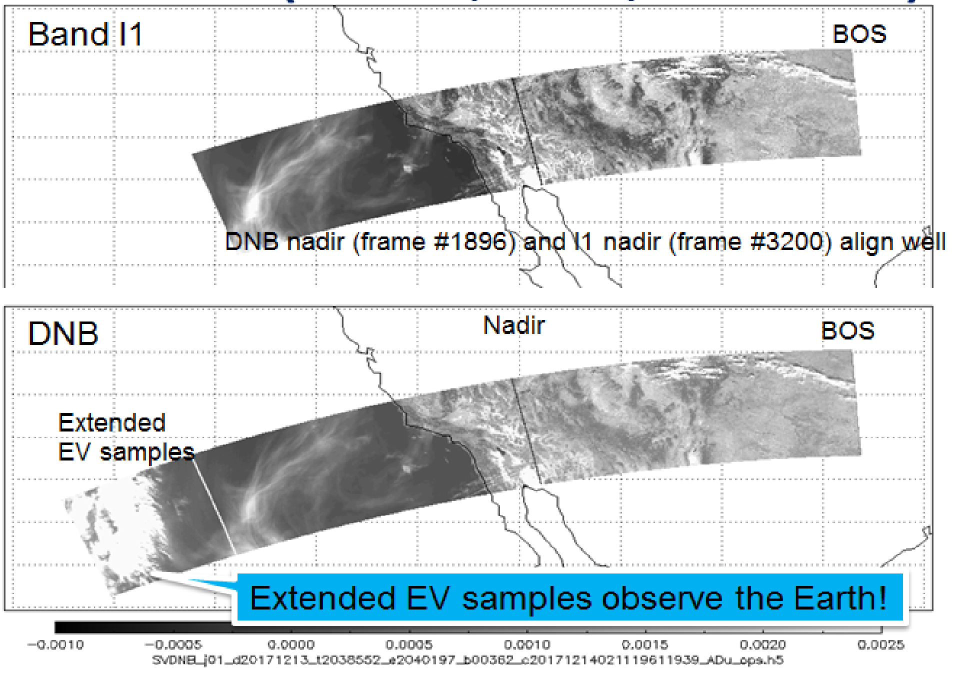


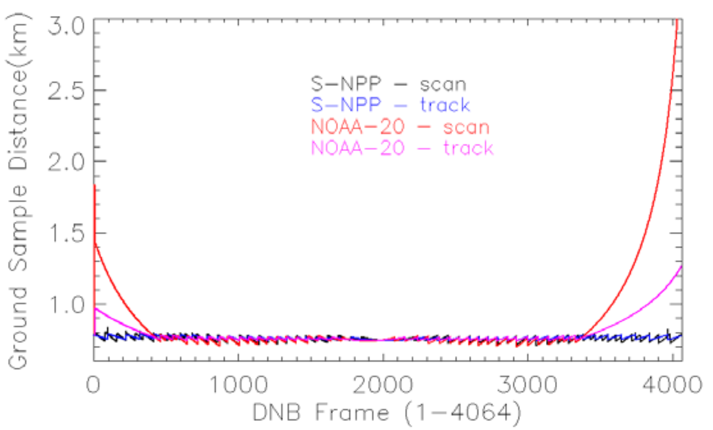
- Successfully generated first set of VIIRS DNB offset and gain ratio LUTs from on-orbit measurements
- New moon based LUTs clearly improve the DNB image quality
- These LUTs were derived before cryo-radiator door opening: The offset values have changed after the DNB CCD temperature became controlled, and thus these LUTs have not been implemented in IDPS

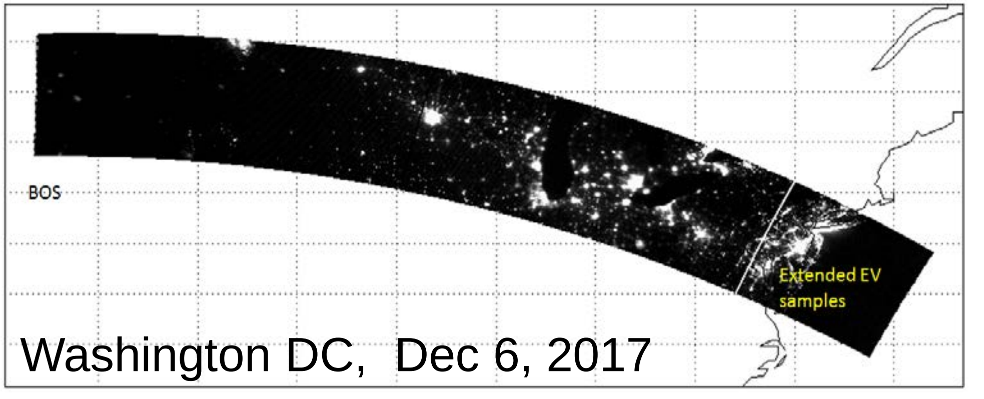
Verification of DNB Agg. Mode Change

- NOAA-20 DNB adopts Agg. Mode Op21, different from S-NPP (Op32)
  - To mitigate high non-linearity at high scan angles
- Prelaunch VIIRS geo code change performs well based on preliminary on-orbit verification results
- Extended EV sample observed the Earth, providing ~600 km extra data compared to S-NPP DNB

NOAA 20 (Dec 13, 2017, California)

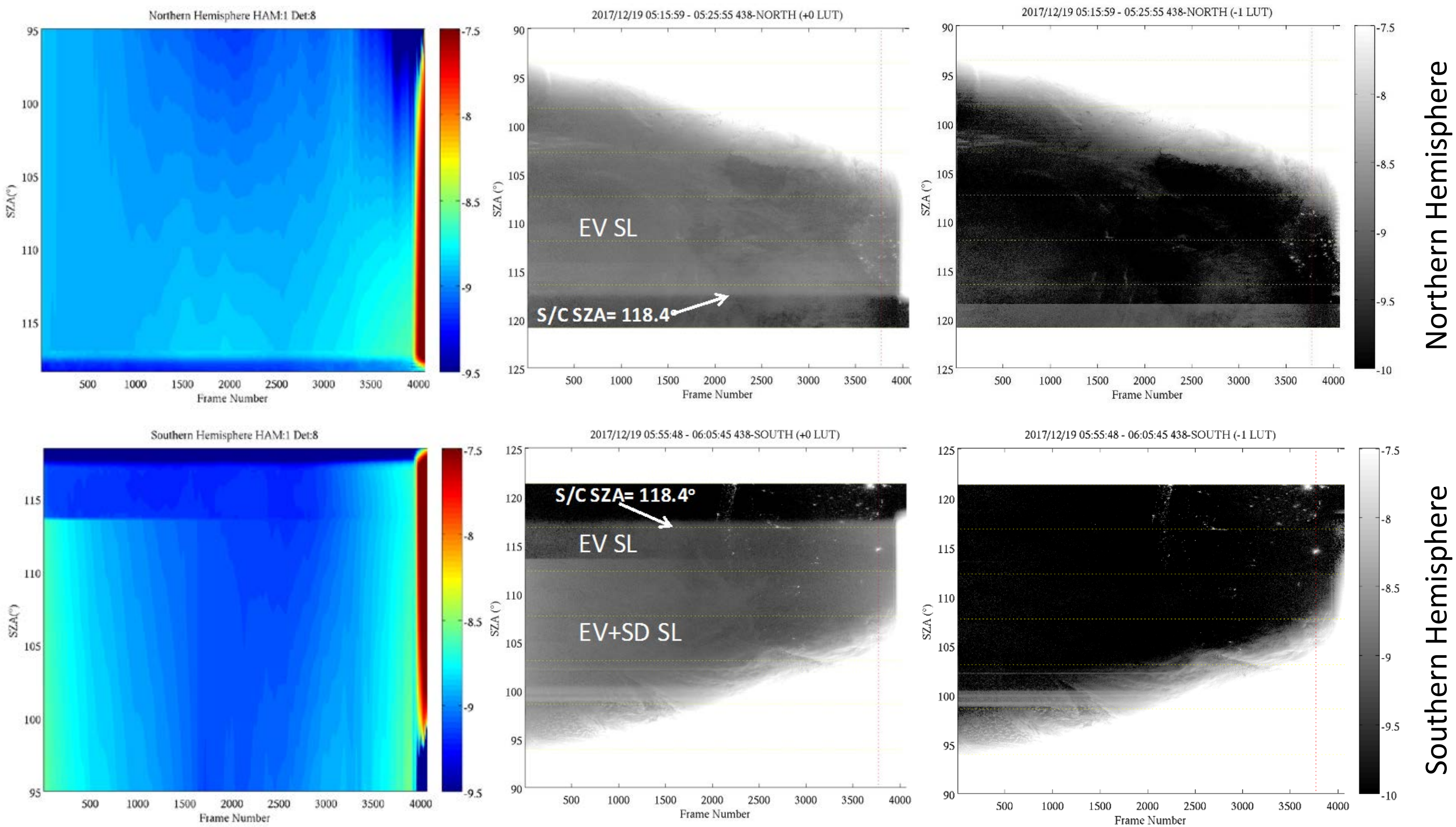






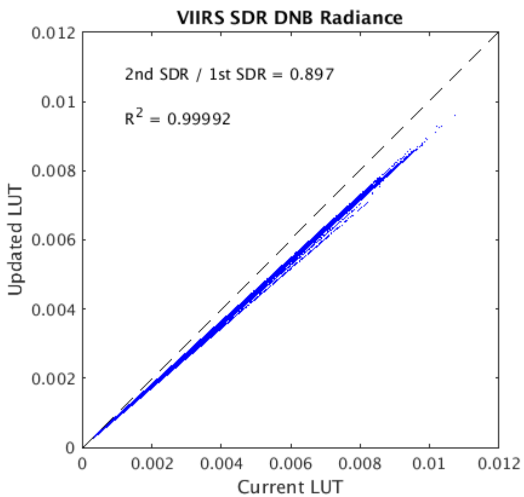
DNB Stray Light

Stray Light Correction LUT | Without Correction | With Correction

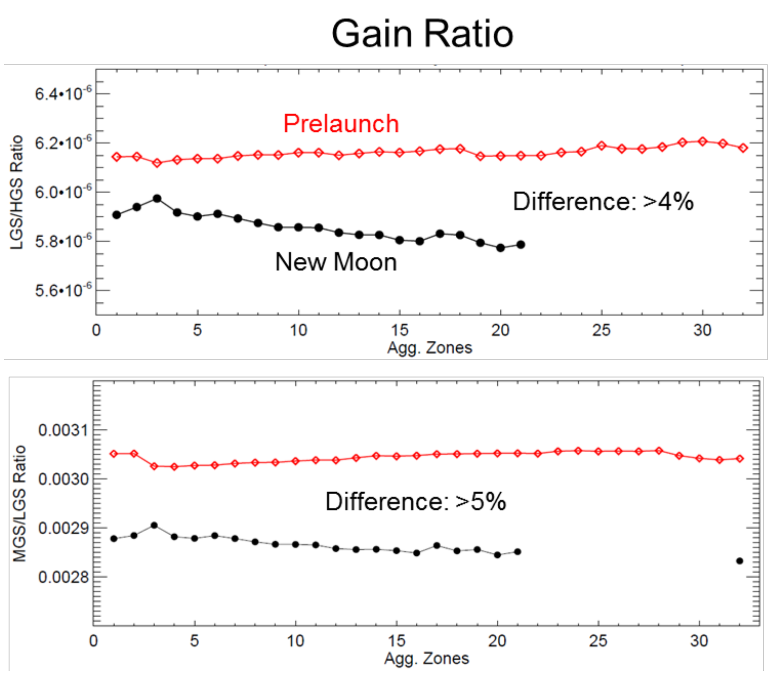


- NOAA-20 VIIRS DNB stray light patterns are similar to S-NPP
  - New feature: strong and rapidly rising stay light in the extended Earth View (EV)
  - S-NPP stray light correction has been adopted, but not applied yet in NOAA-20 SDR production

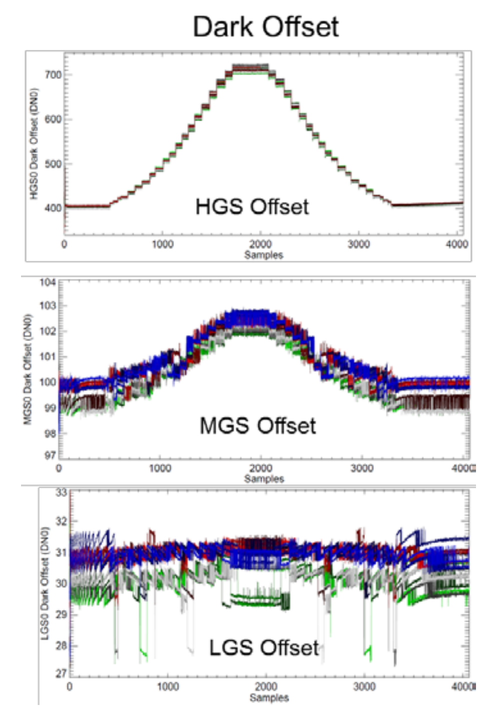
DNB Calibration



- DNB radiometric calibration ("LGS Gains") has been derived from the on-orbit solar calibration measurements for all aggregation modes (1 to 21)
- About 10% change has been observed from the prelaunch calibration
- The updated LGS Gains were applied in the DNB SDR products from IDPS starting with the 4:13 UTC granule on January 5, 2018

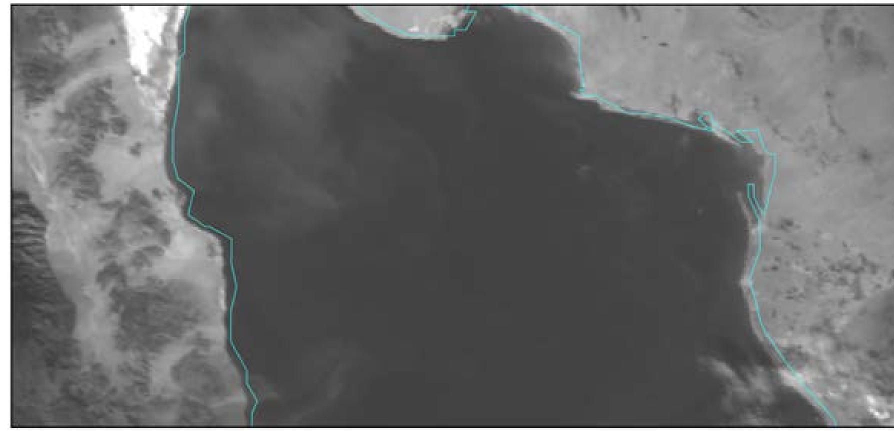


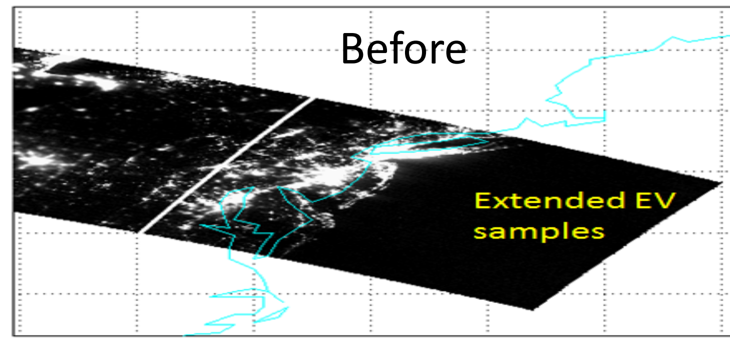
- DNB Dark Offsets and Gain Ratios have been evaluated, but the LUTs for the SDR production in IDPS will be updated only after the January 17, 2018 New Moon calibrations

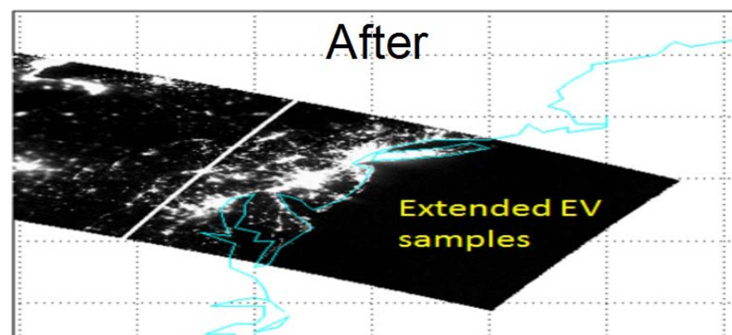


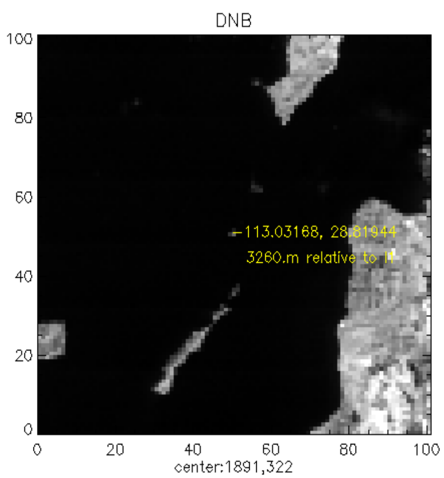
DNB Geolocation Accuracy

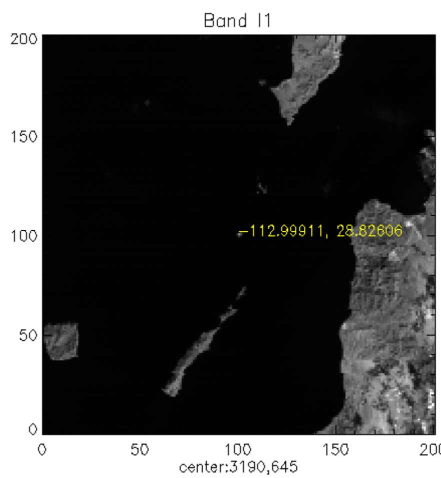
- Assessed by visually comparing DNB obs. with coastlines, small islands, and nighttime point sources, and I1
  - Nadir: ~ +5 km (scan); -1 km (track)
  - Comparable to S-NPP
- After 1st on-orbit GEO parameters LUT (Jan 5, 2018), DNB geolocation errors:
  - < 200 m
  - Extended EV samples: ~ 1 km











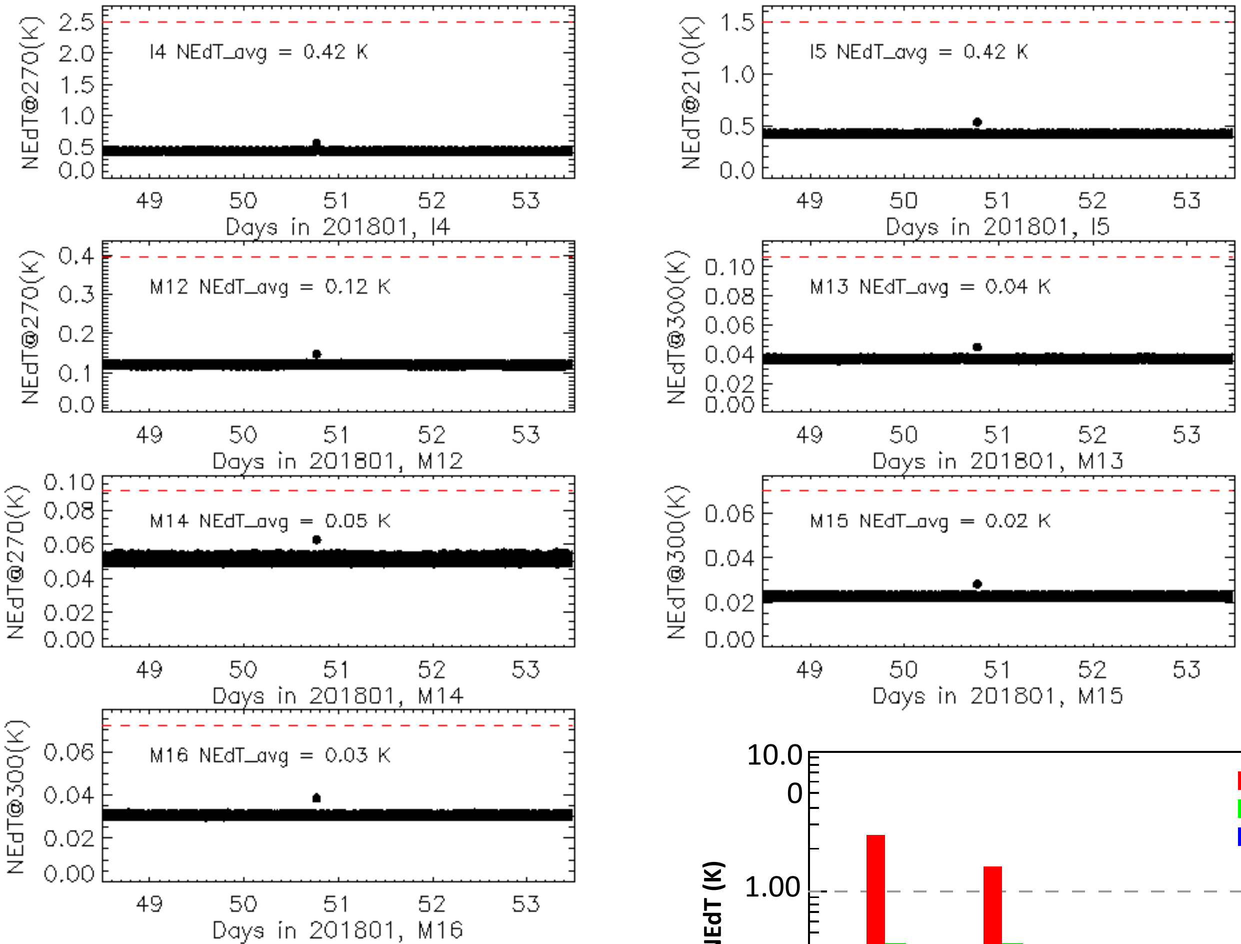
California
Dec 13, 2017

d20171213_t2037294_e2038539

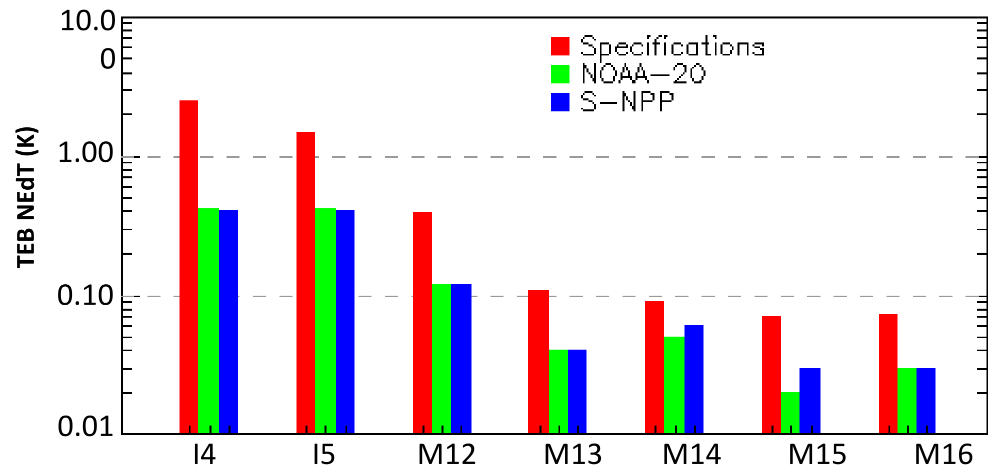
NOAA-20 VIIRS TEB Performance

- Blackbody temperature is very stable, uniformity 30 mK
- Cryo-cooler door opened on January 3, 2018, LWIR CFPA and S/MWIR CFPA temperatures have been stabilized since January 5, 2018 8:30 UTC
  - LWIR CFPA temperature: 80.47 K
  - S/MWIR CPA temperature: 80.23 K
  - LWIR heater power ~125 mW, better than expected
- TEB F-factors are generally stable
  - M14 detector 6 jumped by ~0.1% for a few days, but recovered on Jan 9
  - M13 shows some anomalies, but their magnitude is small
- NEdTs are well bellow specifications for all TEB bands

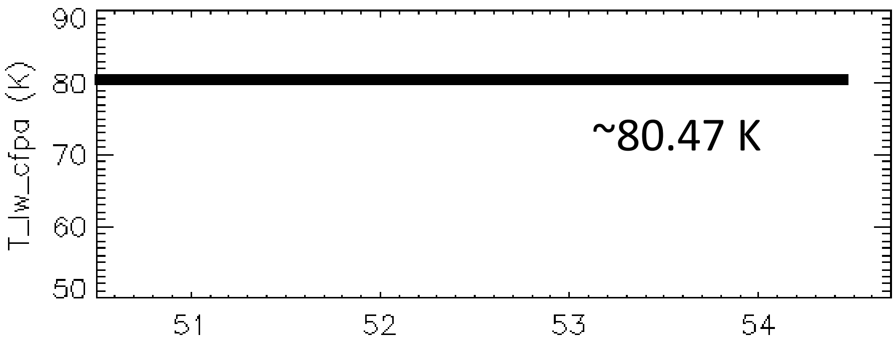
TEB Noise/NEdT

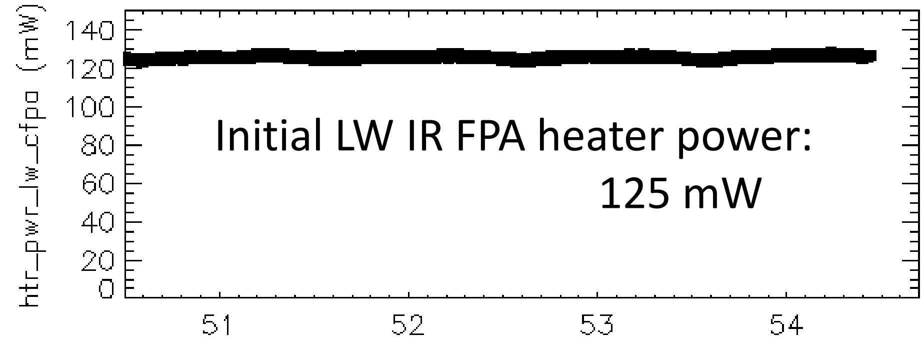


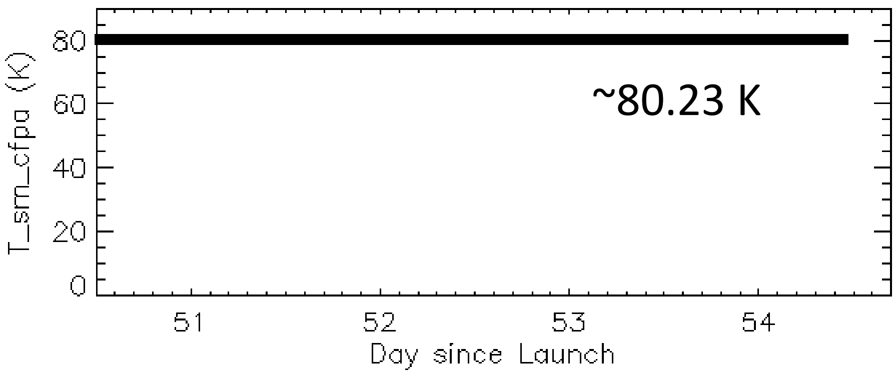
- NOAA-20 VIIRS TEB on-orbit NEdTs are comparable to S-NPP
  - ➢ all far below specifications

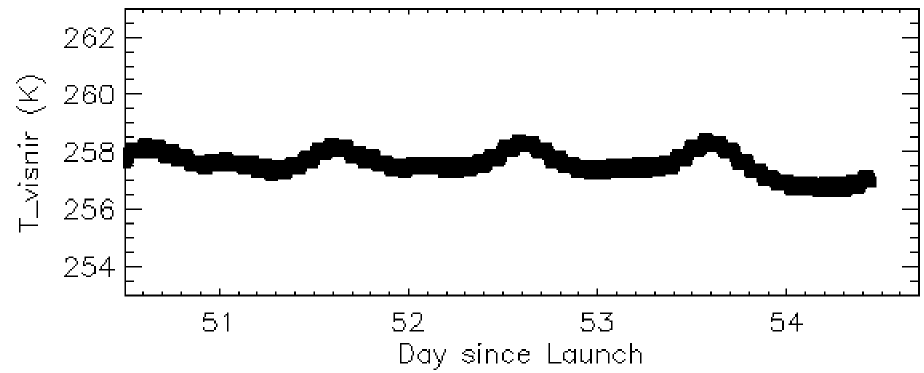


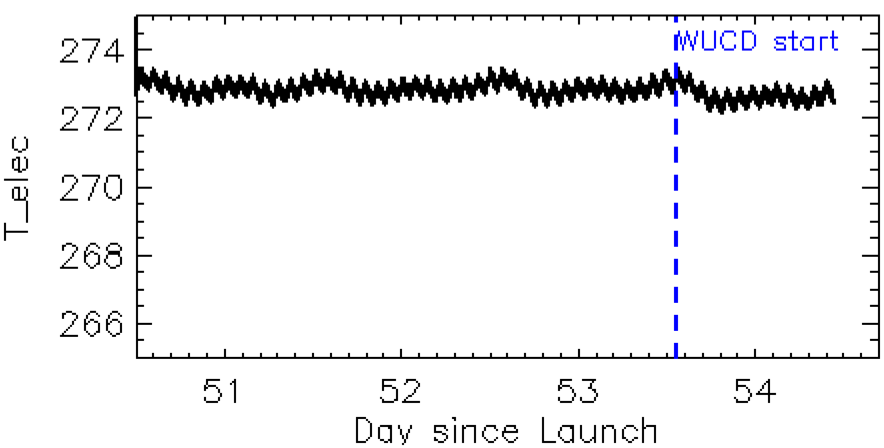
Instrument Temperature Telemetry

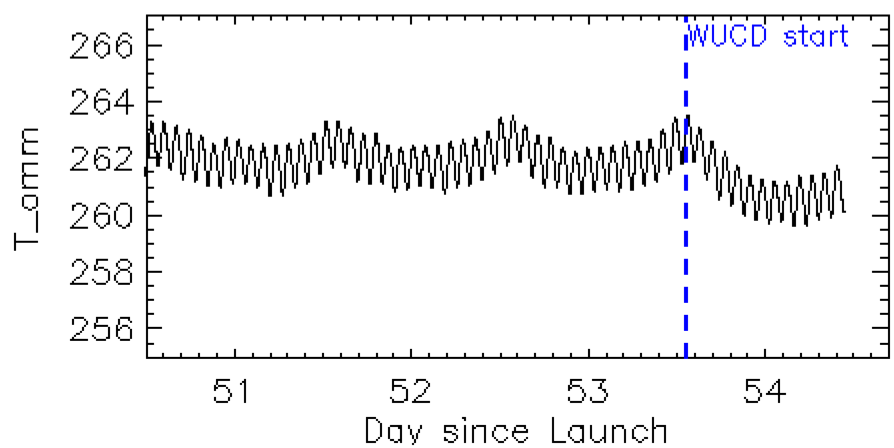




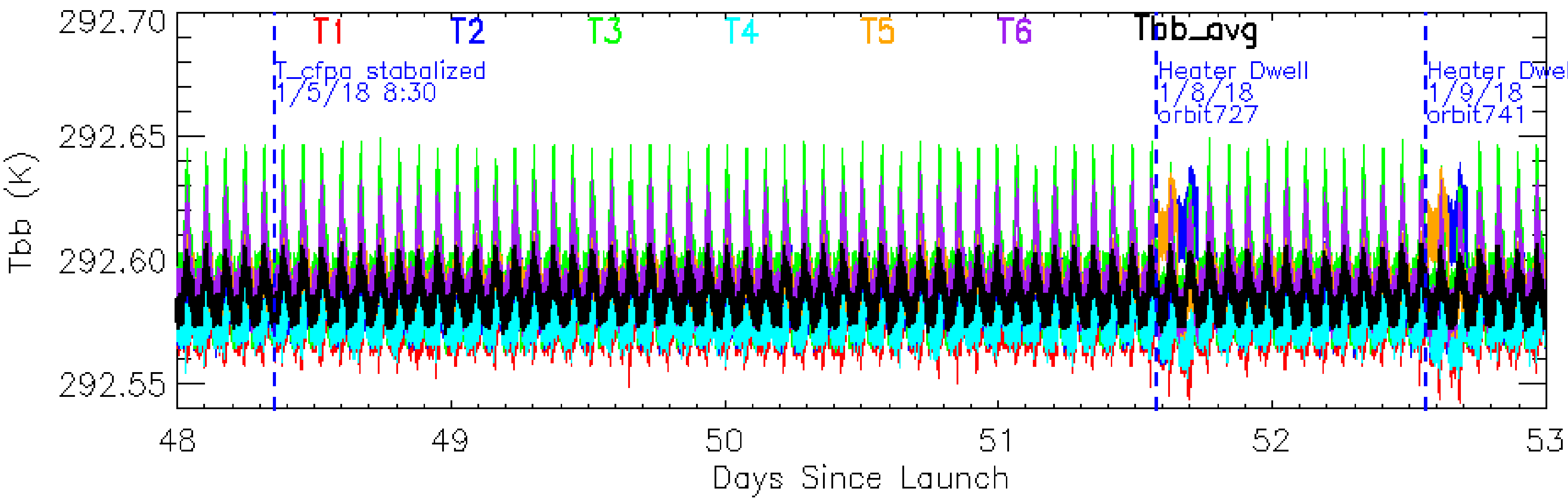


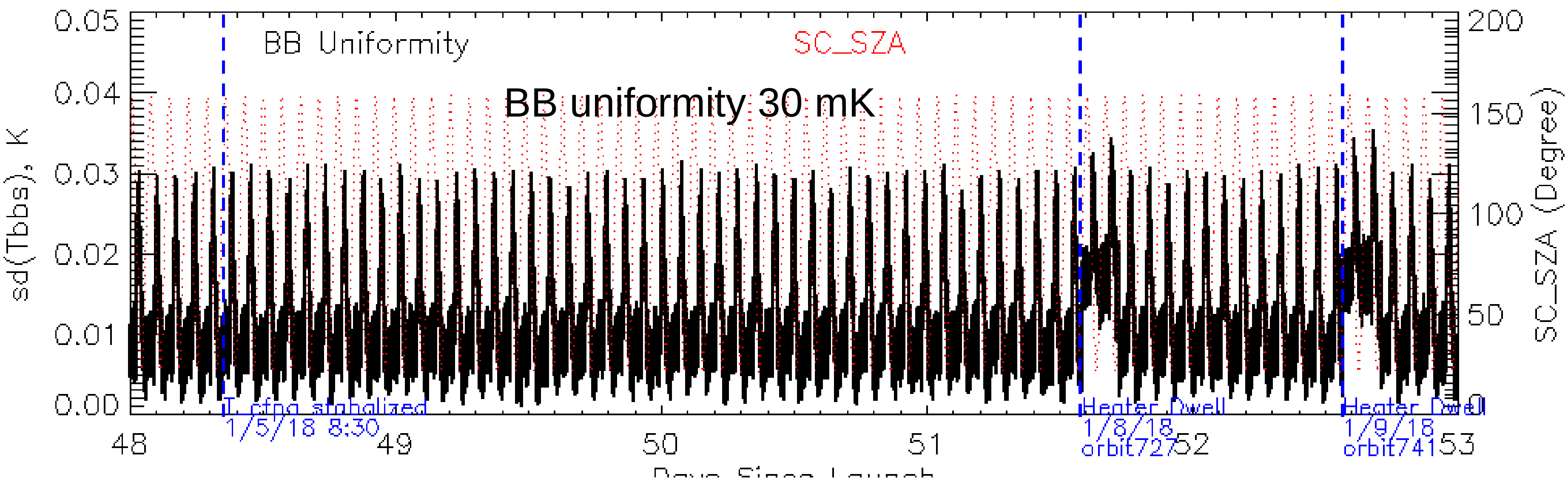






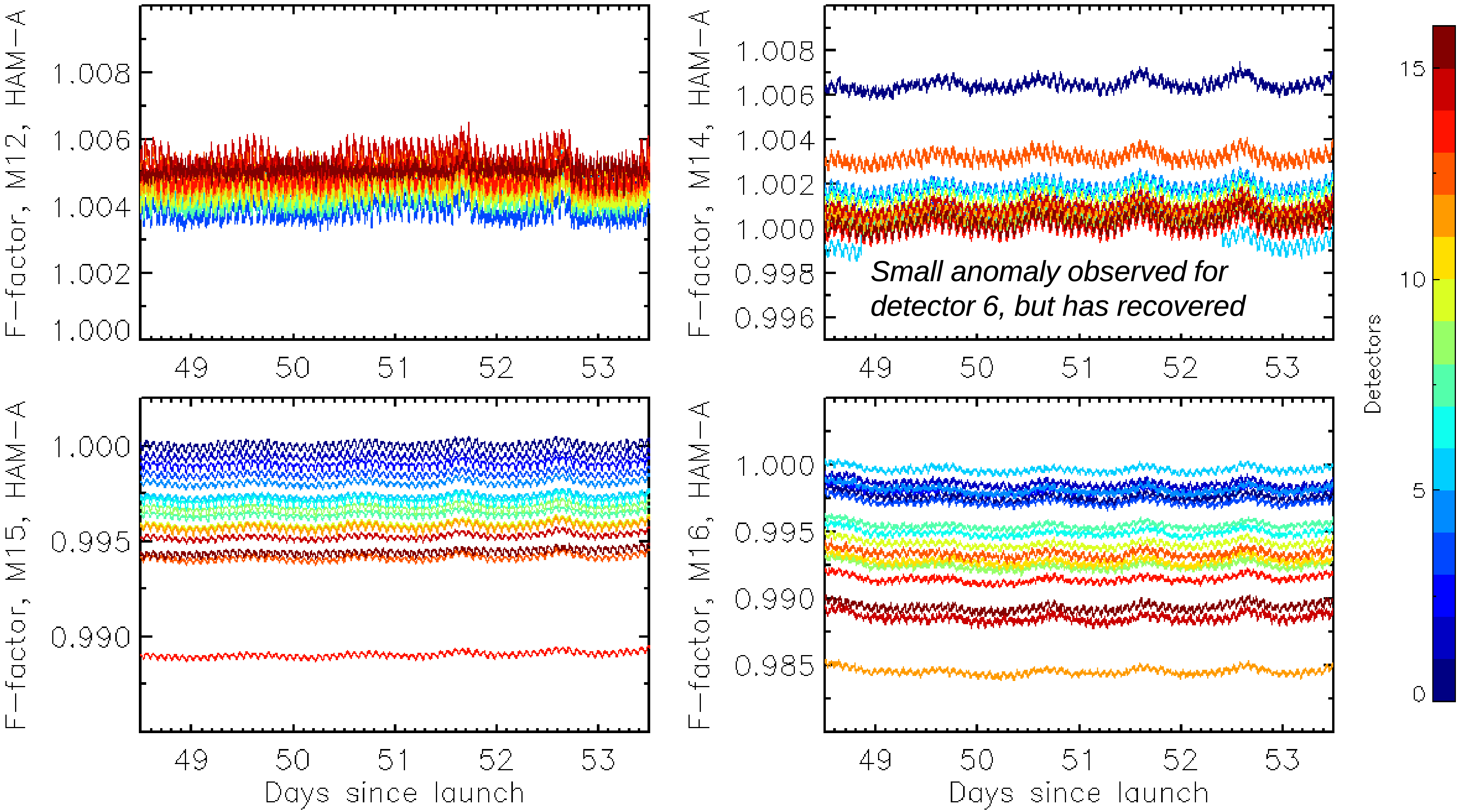
OBC BB Temperature and Uniformity



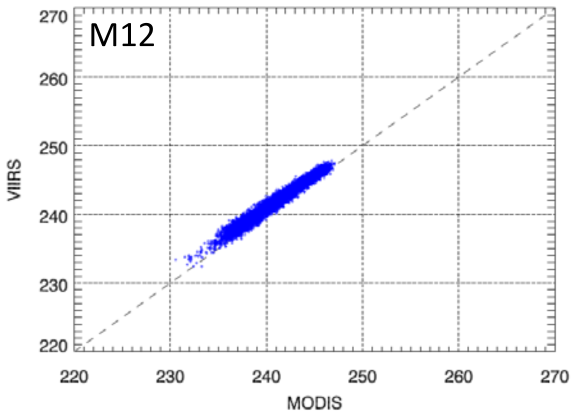


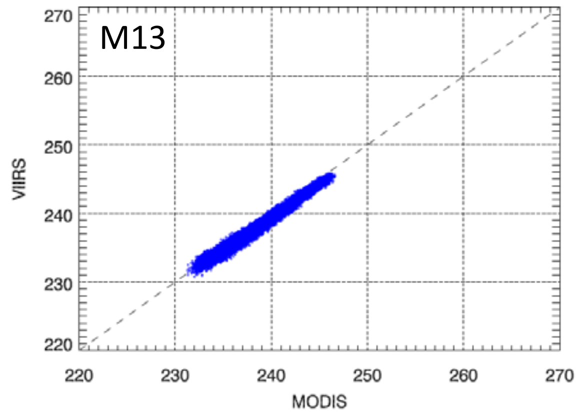
TEB Radiometric Calibration

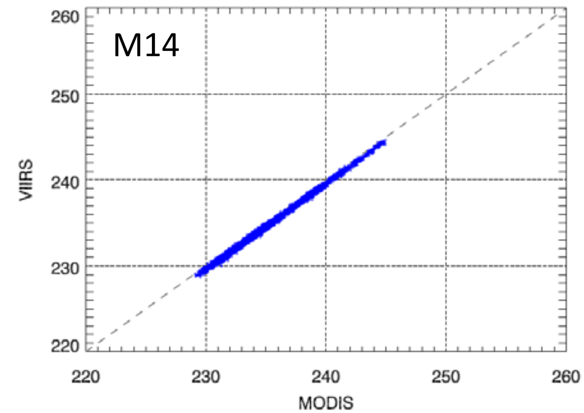
TEB F factors are generally stable during nominal operations

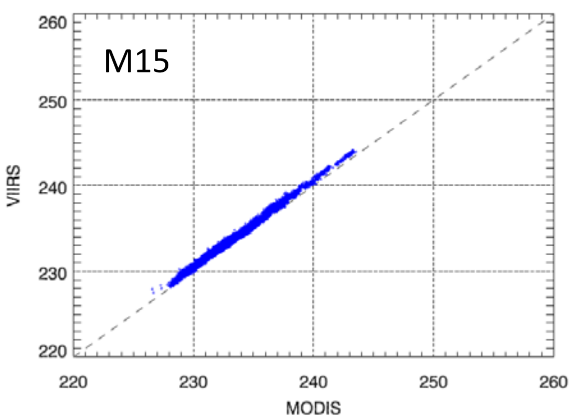


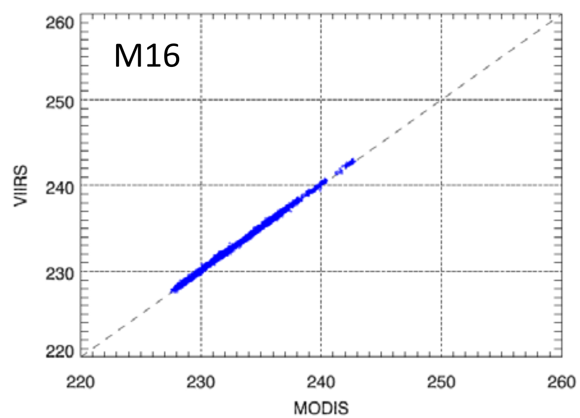
TEB Comparison with Aqua MODIS











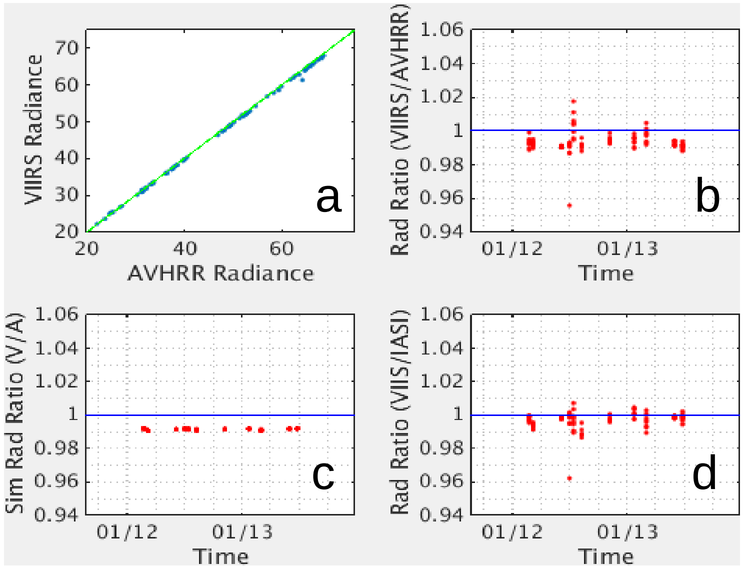
Bands	Bias (K)
M12	0.853 ± 0.527
M13	-0.592 ± 0.484
M14	-0.441 ± 0.174
M15	0.478 ± 0.273
M16	0.122 ± 0.156

SNO Location: Greenland (Night)

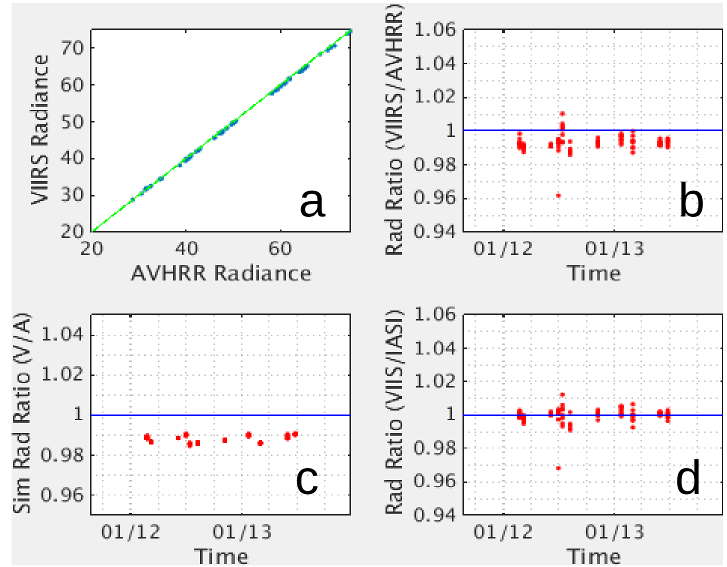
- Preliminary SNO comparisons for the NOAA-20 bands M12 to M16 show good agreement with MODIS

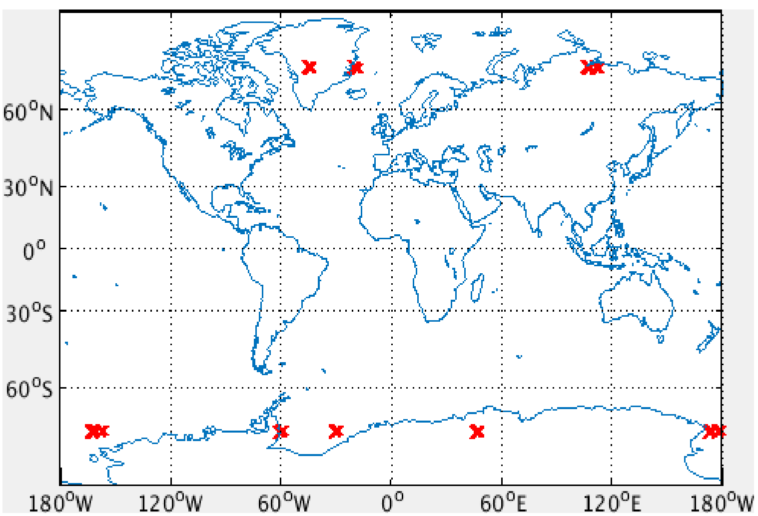
TEB Comparison with AVHRR

VIIRS M15 vs AVHRR CH4



VIIRS M16 vs AVHRR CH5



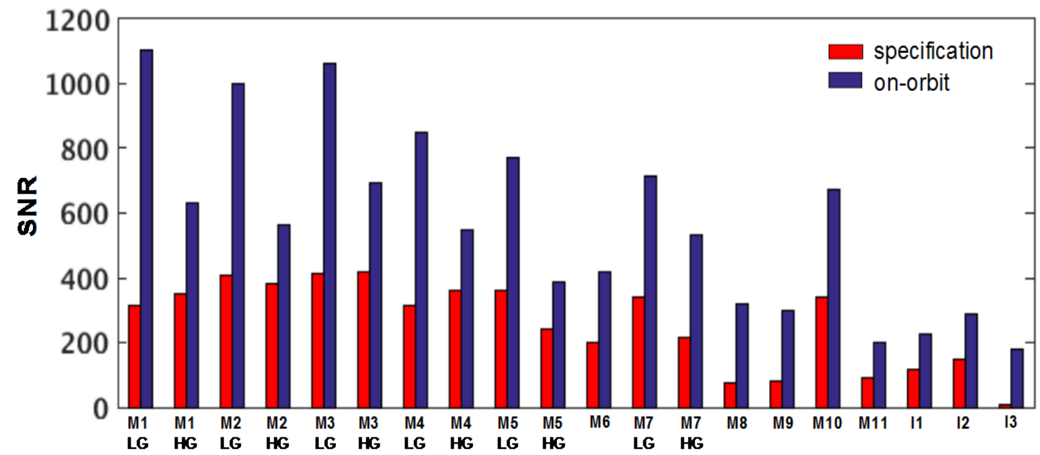


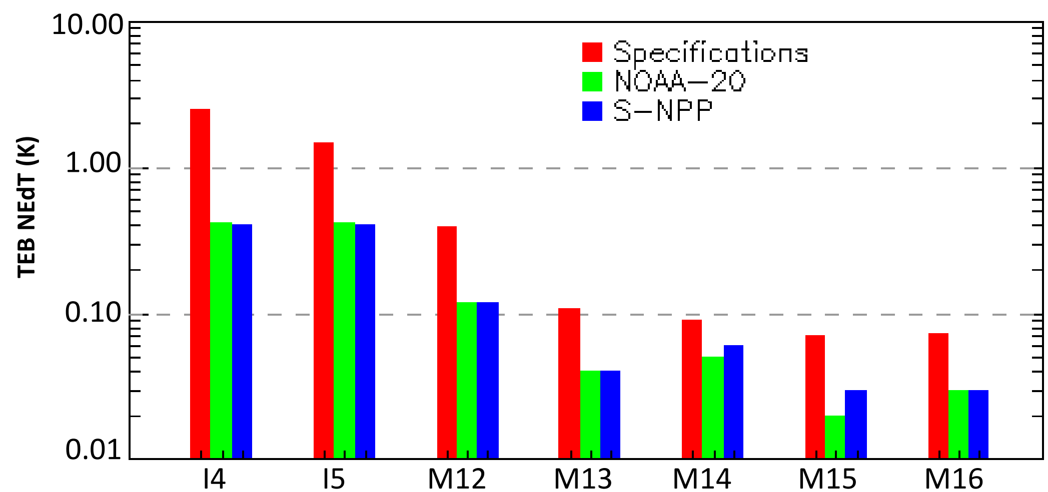
- NOAA-20 and Metop-B SNO occurred on January 11-13, 2018: comparison is done in IASI FOV over SNOs
- Spectral response convolution with IASI shows the simulated VIIRS radiance is generally less than AVHRR (c)
- Scatter plots and time series show the VIIRS radiance is less than AVHRR radiance by around 1% (a,b)
- Simulated VIIRS IASI agrees well with IASI (d)

NOAA-20 VIIRS SNR/NEDT (1/18/2018)

Band	L_{typ}	SNR spec	SNR on-orbit
M1 LG	155	316	1102
M1 HG	44.9	352	631
M2 LG	146	409	998
M2 HG	40	380	564
M3 LG	123	414	1061
M3 HG	32	416	693
M4 LG	90	315	848
M4 HG	21	362	549
M5 LG	68	360	774
M5 HG	10	242	385
M6	9.6	199	417
M7 LG	33.4	340	715
M7 HG	6.4	215	532
M8	5.4	74	321
M9	6	83	297
M10	7.3	342	673
M11	1	90	199
I1	22	119	225
I2	25	150	286
I3	7.3	6	180

Band	T_typ	NEDT Spec	NOAA-20 (on-orbit)	S-NPP (on_orbit)
M12	270	0.396	0.12	0.12
M13	300	0.107	0.04	0.04
M14	270	0.091	0.05	0.06
M15	300	0.07	0.02	0.03
M16	300	0.072	0.03	0.03
I4	270	2.5	0.42	0.4
I5	210	1.5	0.42	0.4





Summary

- NOAA-20 VIIRS SDR data can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose
- NOAA-20 VIIRS has been performing well since the nadir door opened. Overall VIIRS performance meets specifications. Extensive cal/val work by the VIIRS SDR team has improved the data quality and will continue to do so.
- Known issues:
  - RTA/HAM sync losses
  - I3 band “bad” detector
  - Low instrument component temperature causing issues with LUTs and in data production (fixed delivered to the operations for I-band TEB)
  - New straylight in the DNB extended view
- The VIIRS SDR team will continue performing the cal/val with NOAA-20 VIIRS towards Provisional status milestone by mid February, 2018
- Initial feedback from selected EDR teams are very positive. Look forward to further collaborations.