S-NPP and N-20 VIIRS Reflective Solar Bands On-orbit Radiometric Calibration and Performance

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(presented by Ning Lei)

February 25, 2021

Objectives

1. Radiometric calibration improvements since last STM (Nov. 2019)
2. RSB radiometric performance update
3. Future works

What happened since STM 2019

S-NPP

- **Fit F(SD) to F(Moon), using a sliding window approach (remove long term drift timely between F(SD) and F(Moon))**
- **Linearly fit the most recent 1.5 years of F-factors to better predict future F-factors, reducing LUT delivery frequency from ~ once/6 weeks to ~ once/6 months (sets of LUTs delivered: 7 for C1.1 and 2 for C2.0)**
- **Delivered mission-long LUTs that have been used for L1B Collection 2.0**

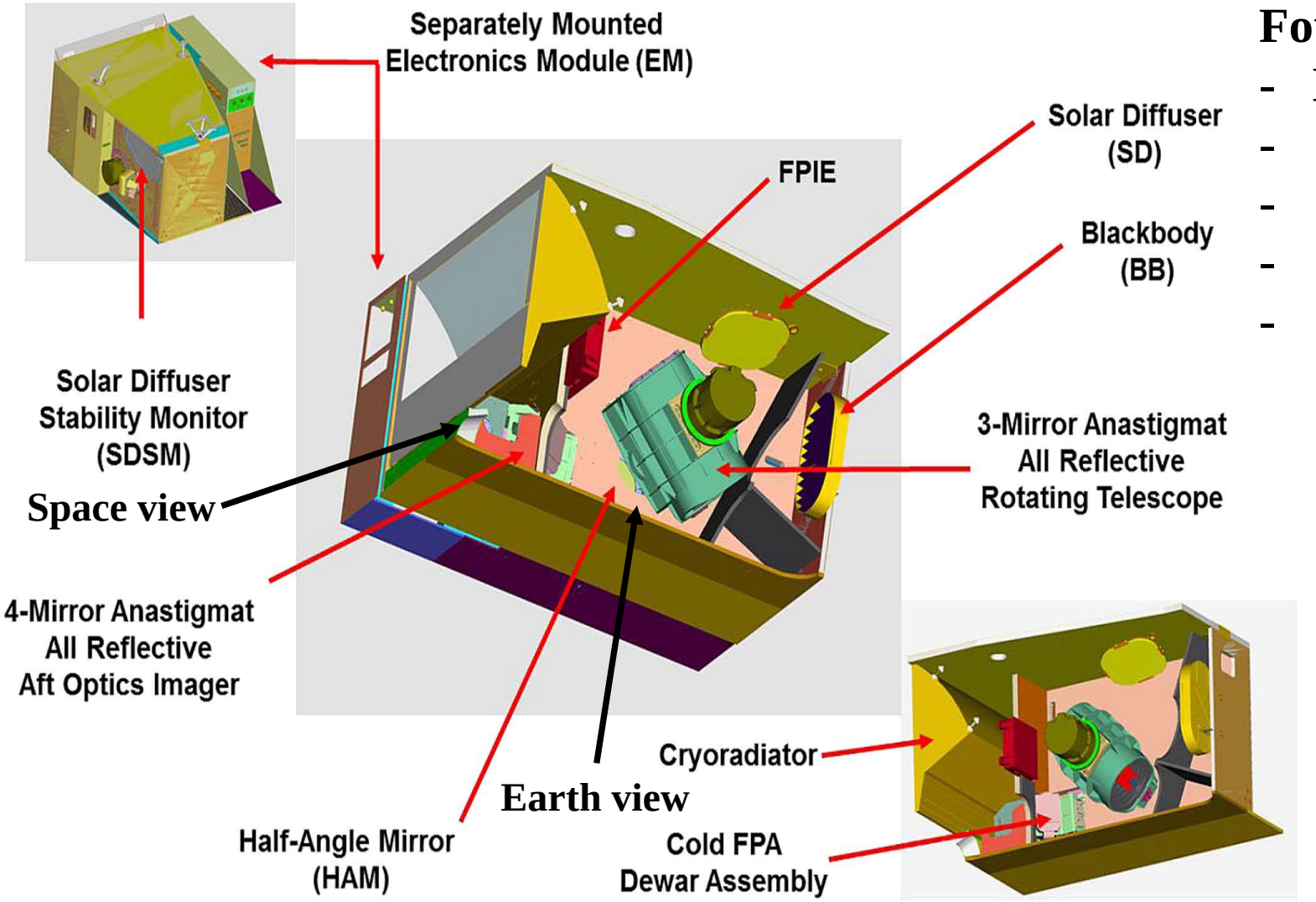
N-20

- **Linearly fit the most recent 1.5 years of F-factors to better predict future F-factors, reducing LUT delivery frequency from ~ once/6 weeks to ~ once/6 months (sets of LUTs delivered: 7 for C2.0)**
- **Replaced RVS LUT on July 30, 2020 (less than 0.1% impact on RSB L1Bs; more on TEBs)**

Instrument Event Highlights

- **S-NPP Instrument operations status Nominal. Events since Nov 1, 2019:**
  - Scan Sync Loss between RTA and HAM: 9 (latest #116 on 1/28/21)
  - Single Board Computer (SBC) Lock-up: None (latest #15 on 10/31/19)
  - Maneuvers
    - Roll: 7 lunar calibrations w/ roll, 5 w/o roll (latest on 2/23/21)
    - DMU: 3 (latest on 12/10/20)
    - IAM: 1 (on 9/24/20)
- **NOAA-20 Instrument operations status Nominal. Events since Nov 1, 2019:**
  - Scan Sync Loss between RTA and HAM: 5 (latest #57 on 12/19/20)
  - RTA stopped working: 20210214:19:15:54:7 to 20210215:01:12:57:6 (no Earth view data)
    - no meaningful impact on RSB radiometric performance
  - Maneuvers
    - Roll: 8 lunar calibrations w/ roll, 4 w/o roll (latest on 2/23/21)
    - DMU: 2 (latest on 9/29/20)
    - IAM: 1 (on 3/26/20)

VIIRS physical components



Fourteen Reflective Solar Bands (RSBs)

- **Narrow band widths: 15 – 80 nm**
- **Central wavelengths 0.412 – 2.25 μm**
- **Each band has an array of detectors**
- **M1-5, M7: dual-gain**
- **Three aggregation zones**

VIIRS RSB L1B products

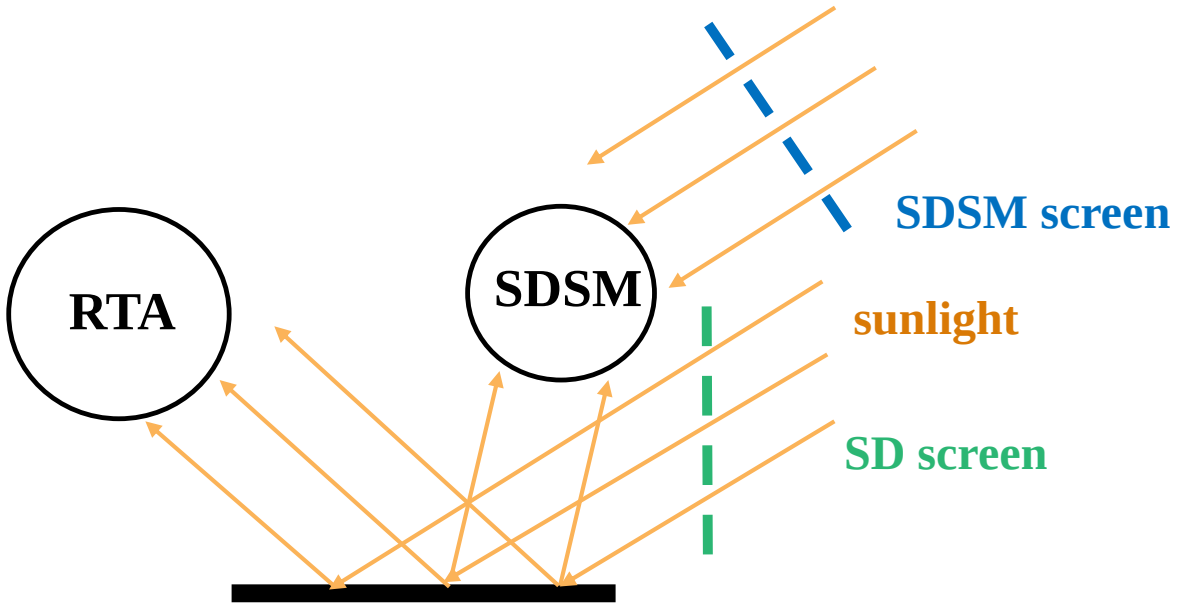
top-of-the-atmosphere (TOA) solar spectral reflectance

on-orbit calibrated

$$\rho_{\mathrm{EV}}\cos\theta_{\mathrm{EARTH-SUN}} = \frac{4\pi^2 F(t,d)\sum_{i=0}^{3} c_i dn^i * d^2_{\mathrm{VIIRS-SUN}} \times \int_0^{\infty} \mathrm{RSR}(\lambda,t,d)d\lambda}{\mathrm{RVS}(\lambda_{\mathrm{B}},\theta_{\mathrm{EV}}) \times \int_0^{\infty} \mathrm{RSR}(\lambda,t,d)\Phi_{\mathrm{SUN}}(\lambda)d\lambda}$$

$\mathrm{RSR}(\lambda,t,d)$ Modulated RSR (S-NPP); prelaunch RSR (N-20)

VIIRS radiometric calibration



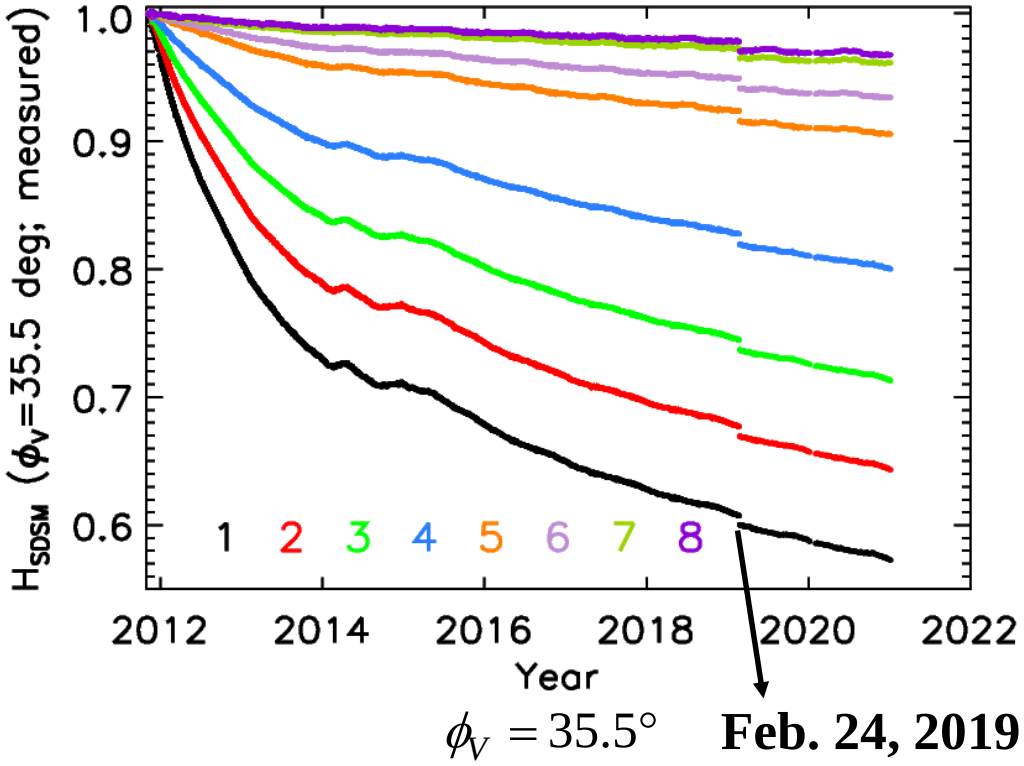
- τ_{SDSM} (relative)
- τ_{SD} BRDF(SDSM; relative)
- τ_{SD} BRDF(RTA; yaw)

Improved with yaw and regular on-orbit data

Solar Diffuser (SD): a calibration source; its BRDF change (H-factor) monitored by the SD stability monitor (SDSM)

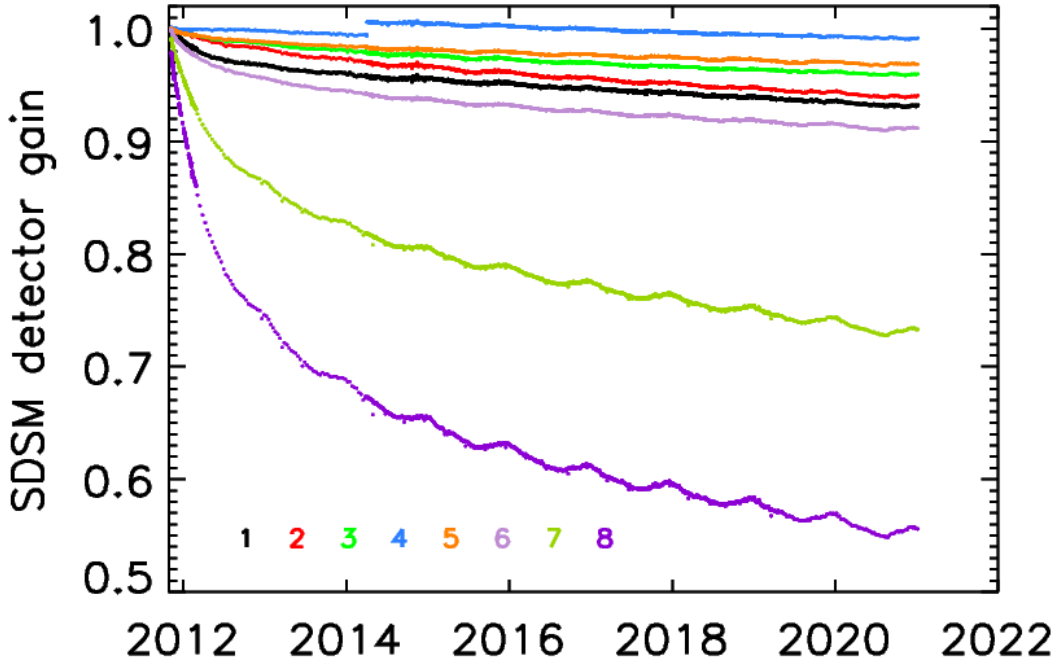
Performance of SD and SDSM: S-NPP

SNPP H-factors



$\phi_V = 35.5°$ **Feb. 24, 2019**

SNPP SDSM Detector Gains



- **SDSM detector gains trend normally**
- **H-factors dropped by about 1% due to the Feb. 24, 2019 event, impacting SD screen and/or SD**

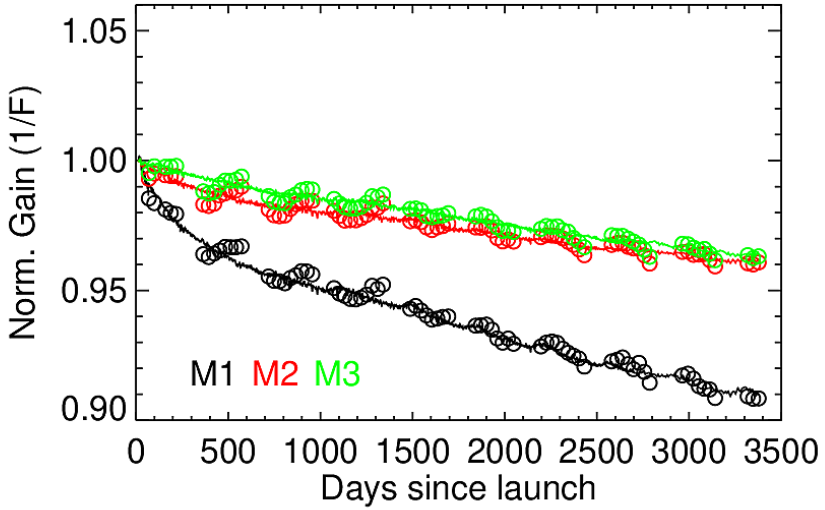
Calculate F(SD): using F(Moon)

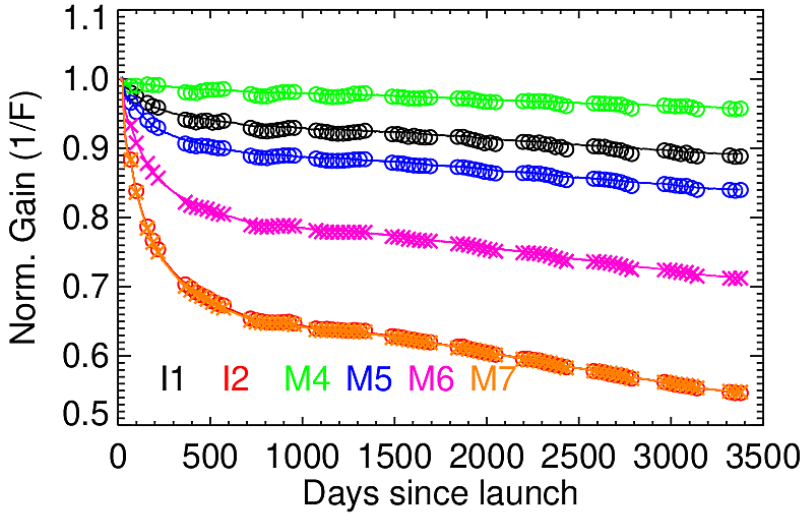
$$H_{\mathrm{RTA}} = H_{\mathrm{SDSM}} \times \frac{1 + \alpha_{\mathrm{RTA}}(\lambda) * (1 - H_{\mathrm{SDSM}})}{1 + \alpha_{\mathrm{H}}(\lambda) * (1 - H_{\mathrm{SDSM}}) * (\phi_{\mathrm{H,SD}}^{\mathrm{RTA}} - \phi_{\mathrm{H0}})}$$

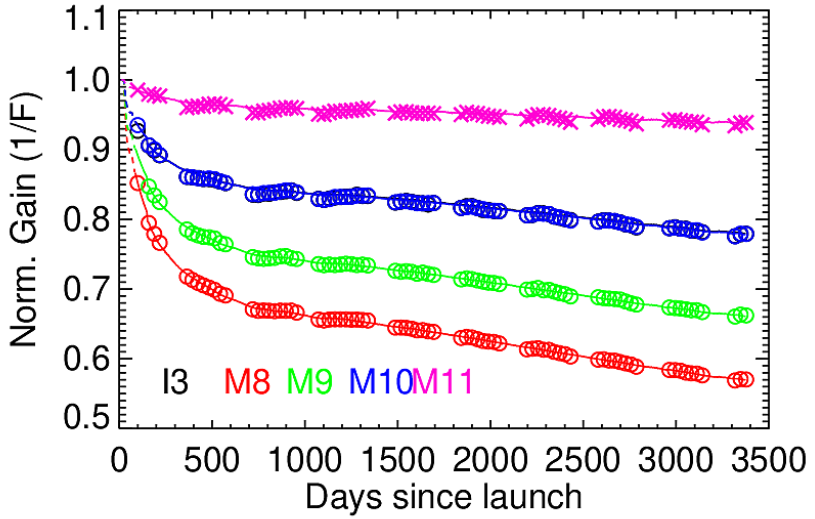
Solar azimuth angle

α_{RTA} and α_{H} obtained from fitting F(SD) to F(Moon)

Performance of RSB #1: S-NPP 1/F-factors





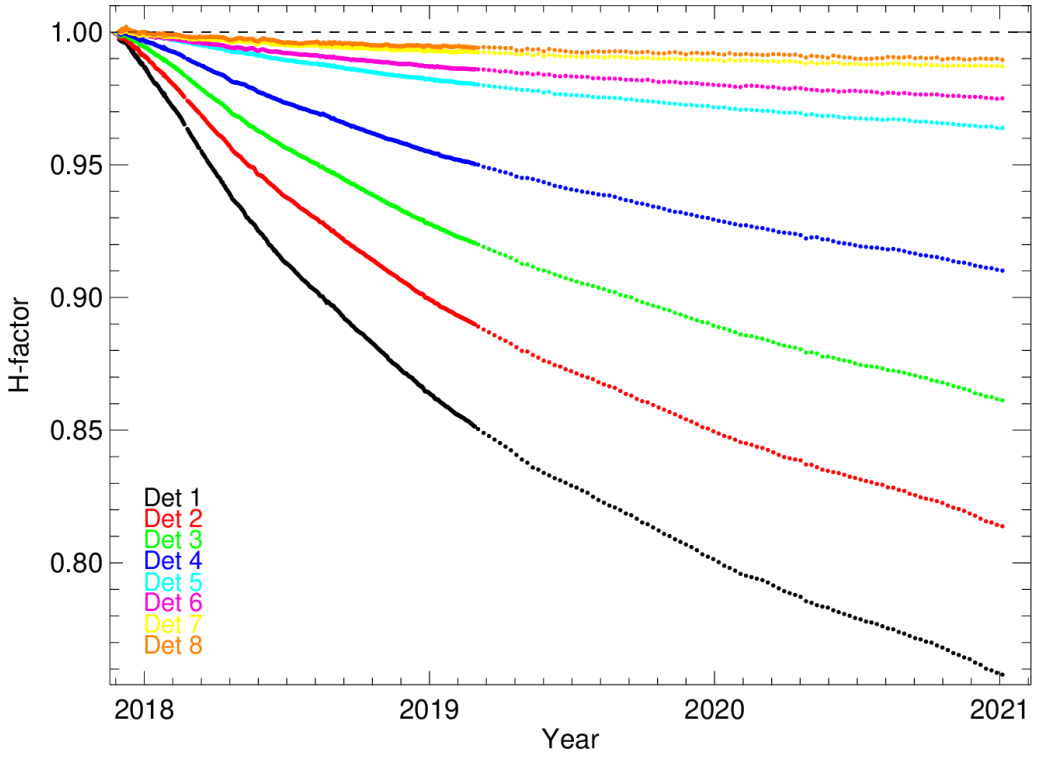


Solid lines: 1/F(SD)
Circles: 1/F(Moon)

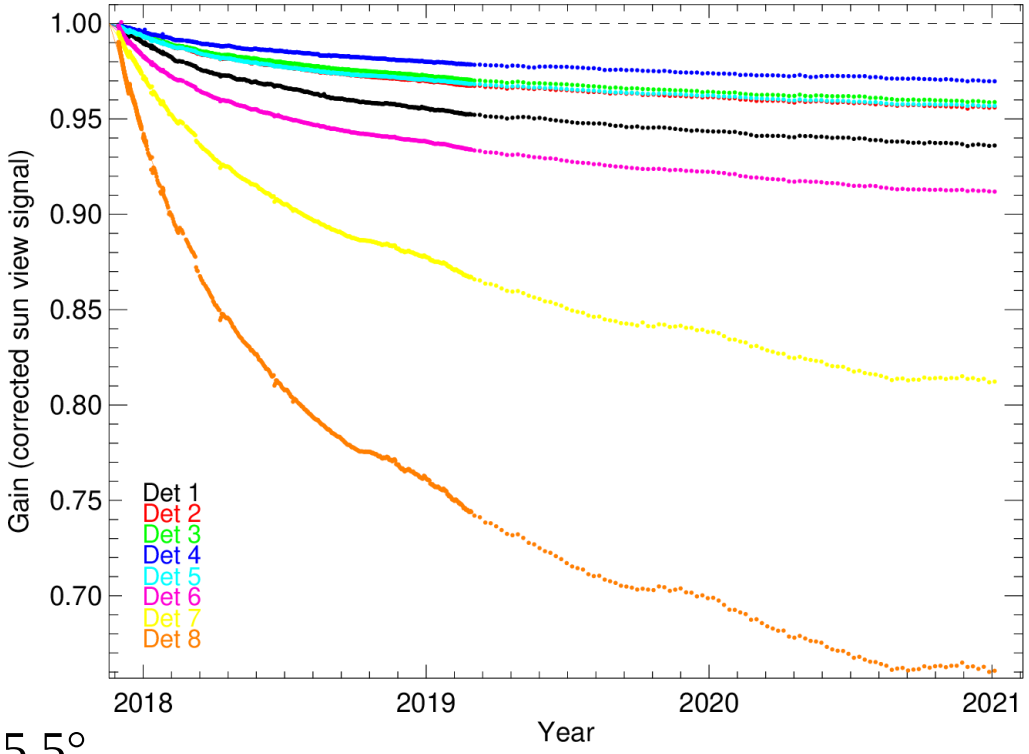
F(SD; C2.0) matches F(Moon) well

Performance of SD and SDSM: N-20

N-20 H-factors



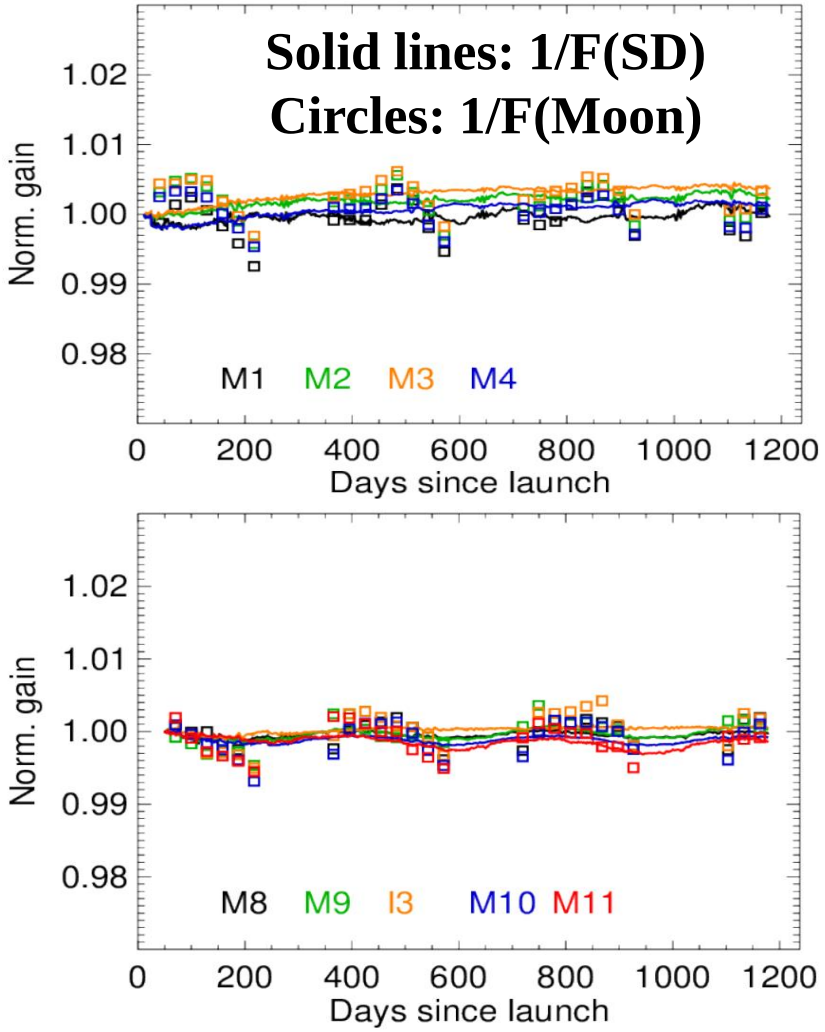
N-20 SDSM Detector Gains

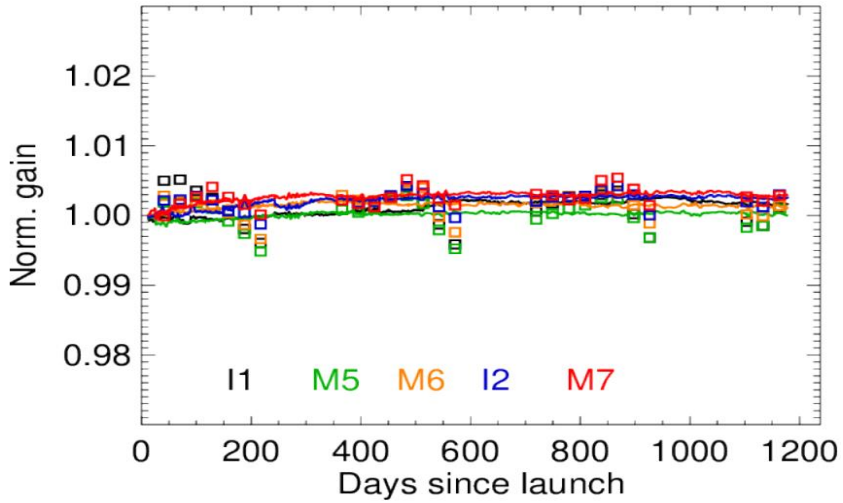


$\phi_V = 35.5°$

- **H-factors decrease at smaller rates than S-NPP H-factors**
- **SDSM gains decrease similarly to S-NPP**

Performance of RSB #1: N-20 1/F-factors



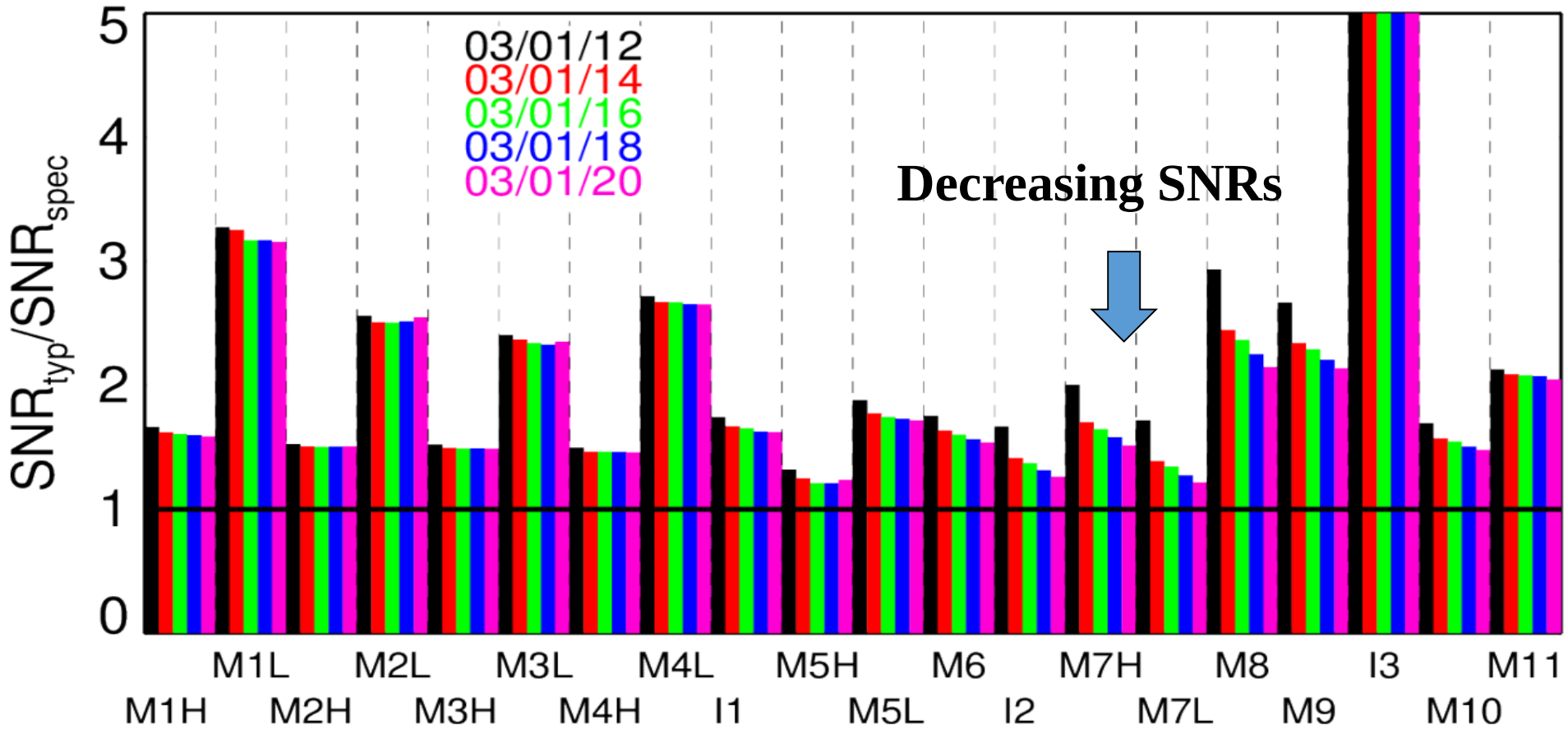


F(SD) matches F(Moon) well
F-factors are very stable over mission

$$H_{RTA} = Func\left(H_{SDSM}; \underbrace{\alpha_{RTA}, \alpha_H}\right)$$

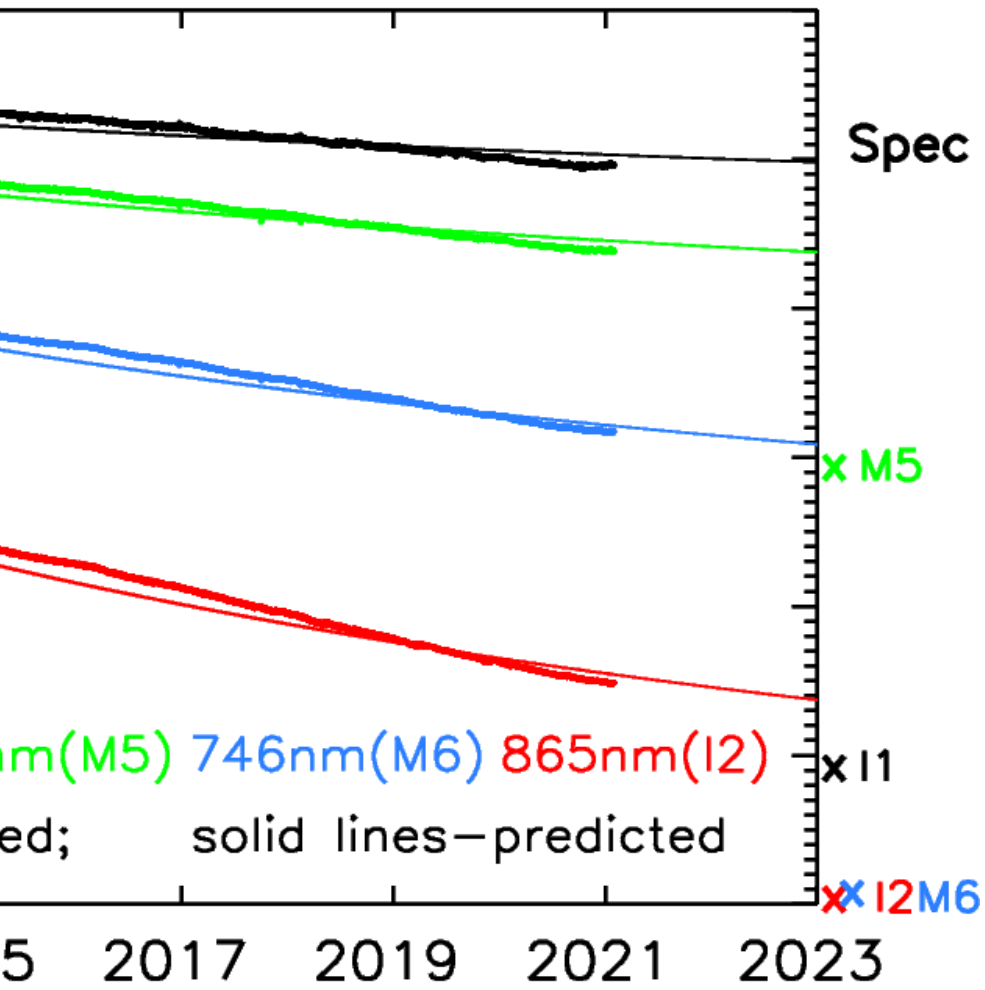
A fraction of S-NPP numbers

Performance of RSB #2: S-NPP SNRs



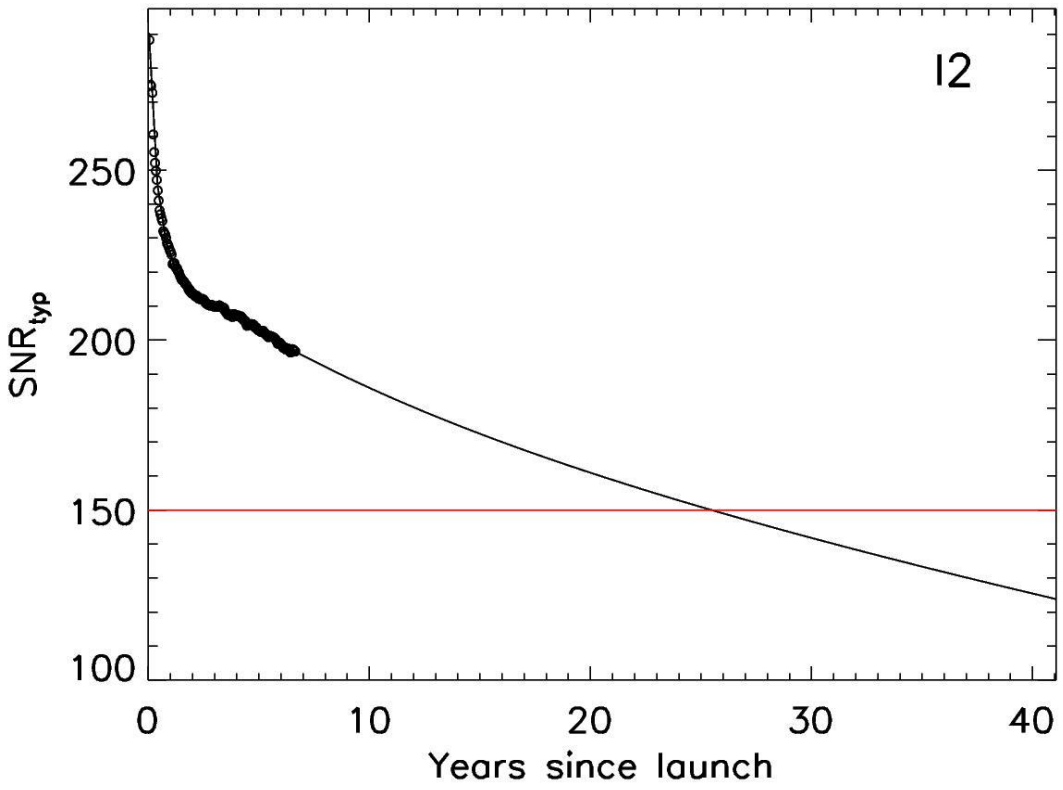
All SNRs satisfy requirements

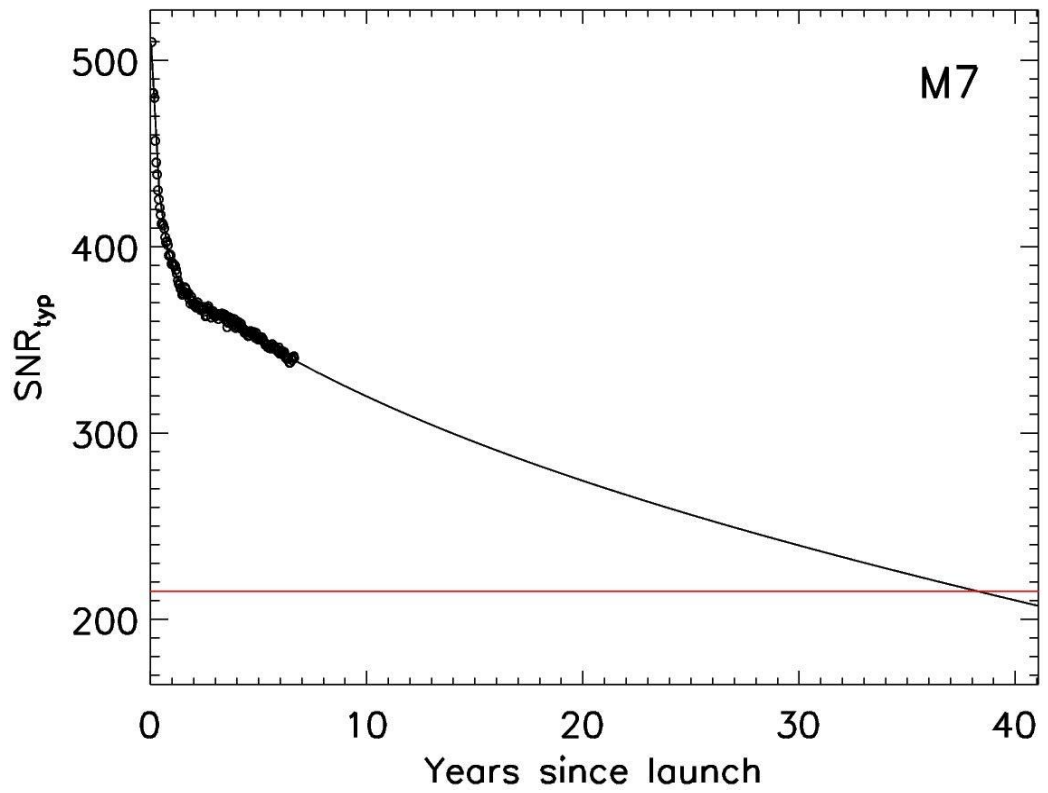
S-NPP VIIRS RSB gains: modeled vs measured



Gain (1/F) decrease is mainly due to RTA mirror contamination

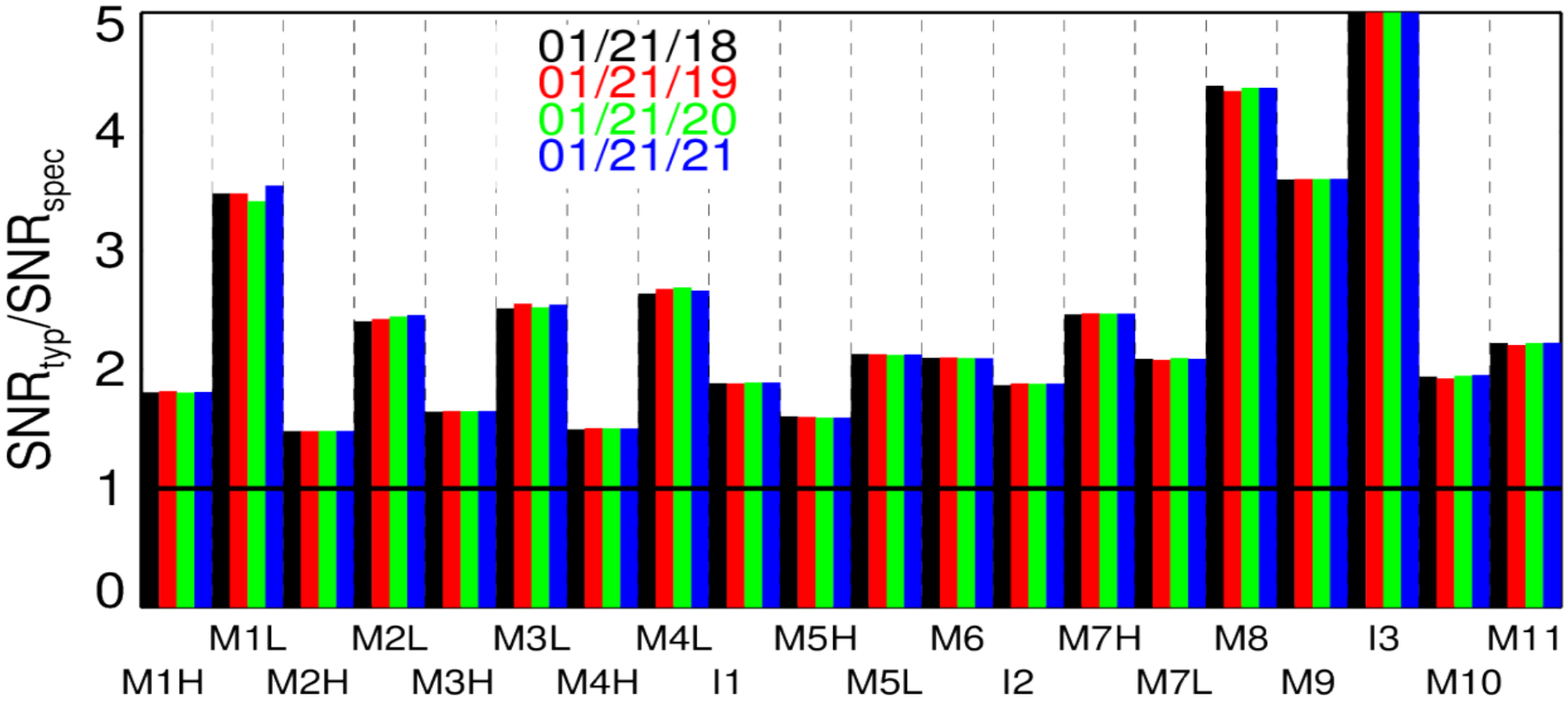
S-NPP RSB SNR predictions





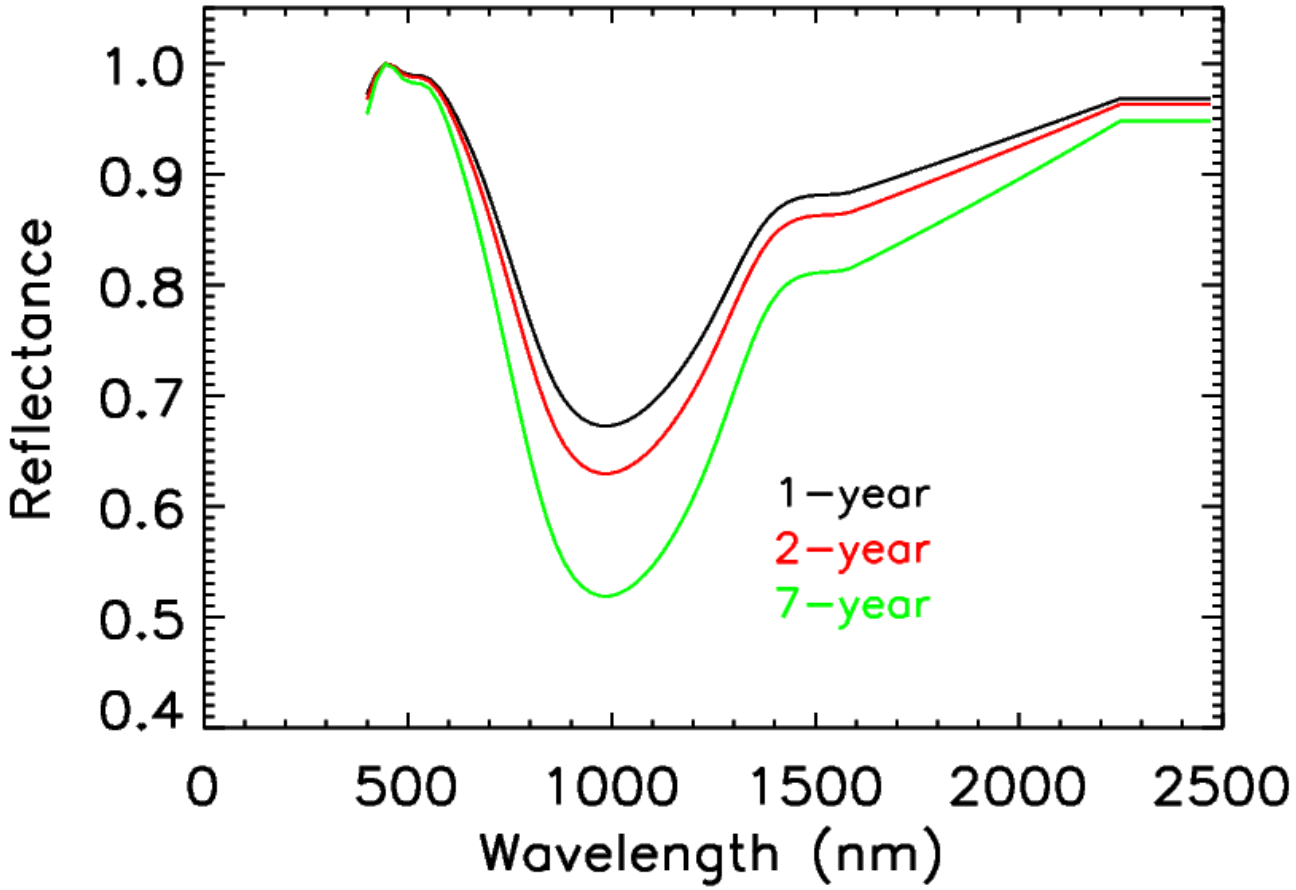
Needs more than 20 years for any S-NPP RSB SNR to go below requirement

Performance of RSB #2: N-20 SNRs



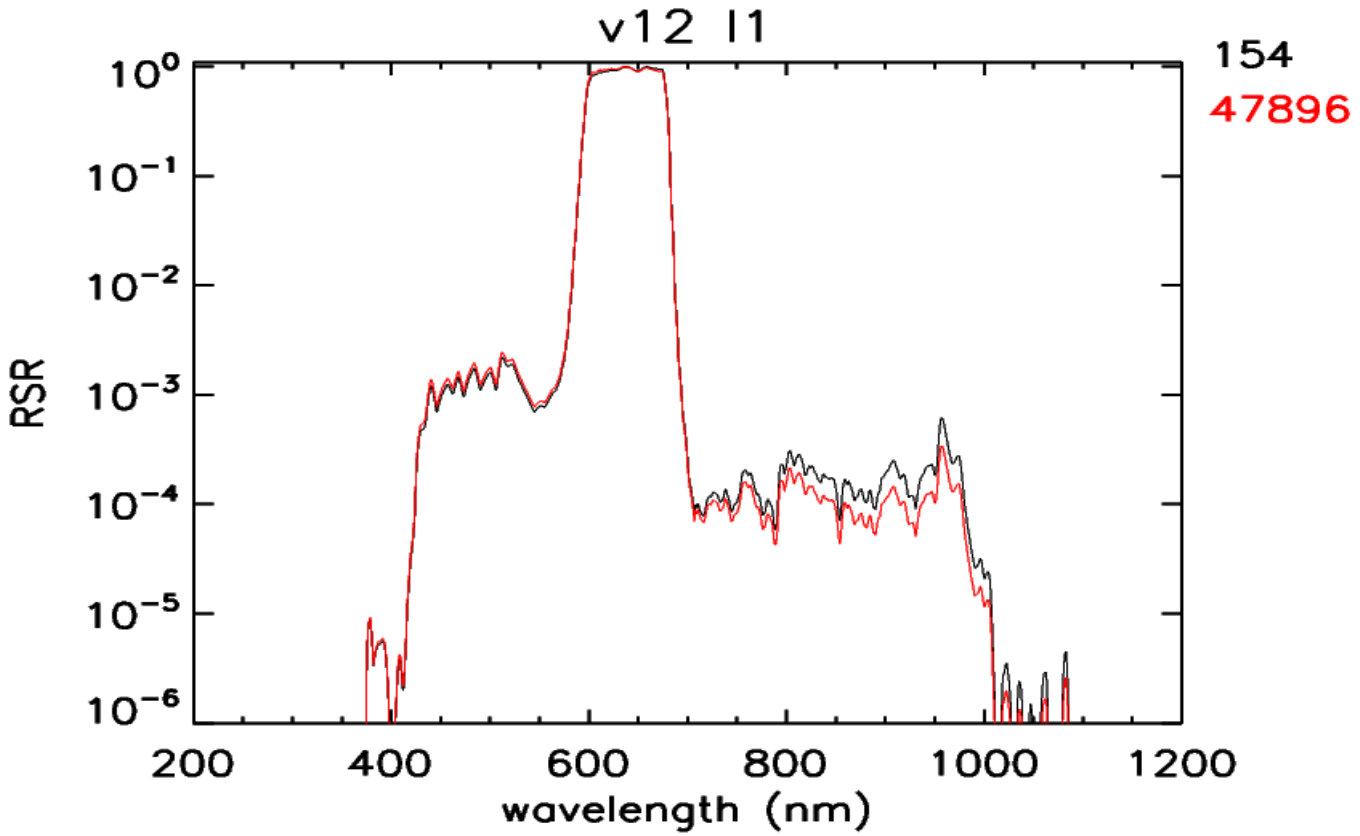
All SNRs are flat in time and satisfy requirements

Uneven RTA reflectance degradation in S-NPP



Uneven RTA reflectance degradation modulates RSRs

RSR modulated by uneven RTA degradation



Small impact on L1B reflectance (< 0.3%)
(but much larger impact on DNB products)

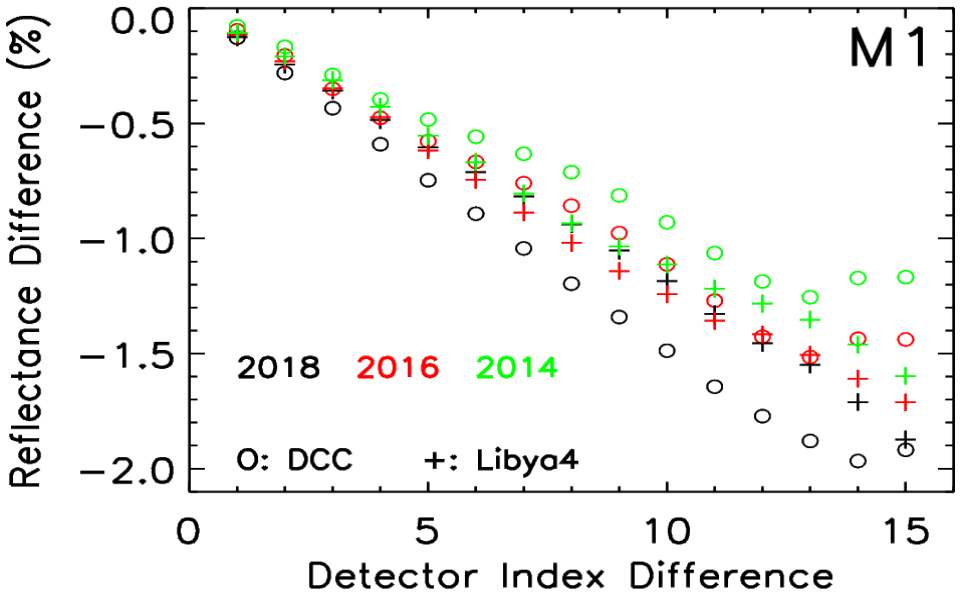
S-NPP H-factor SD positional dependence

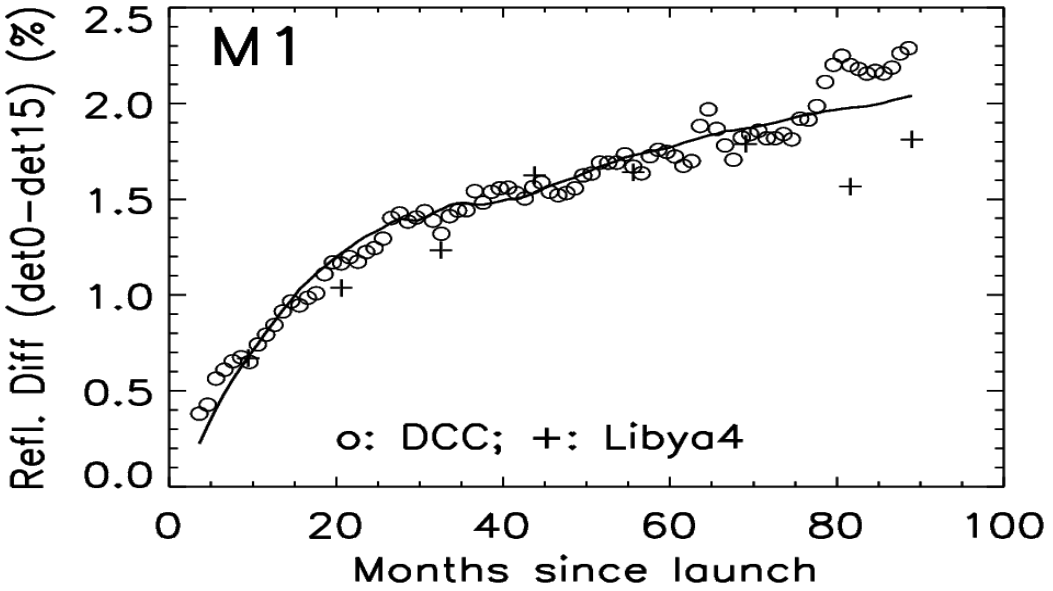
SD BRDF change factor (H-factor) can depend on SD position

model parameters

$$H_{\mathrm{RTA}}\left(\lambda, t, \phi^{\mathrm{RTA}}_{\mathrm{H,SD}}, \vec{r}_d\right) = H_{\mathrm{RTA}}\left(H_{\mathrm{SDSM}}(\lambda, t), \phi^{\mathrm{RTA}}_{\mathrm{H,SD}}\right) \times \left[1 + c_{d,1}(d - d_{\mathrm{mid}}) + c_{d,2}(d - d_{\mathrm{mid}}) \times \left(1 - H_{\mathrm{SDSM}}(\lambda, t)\right)\right]$$

detector array

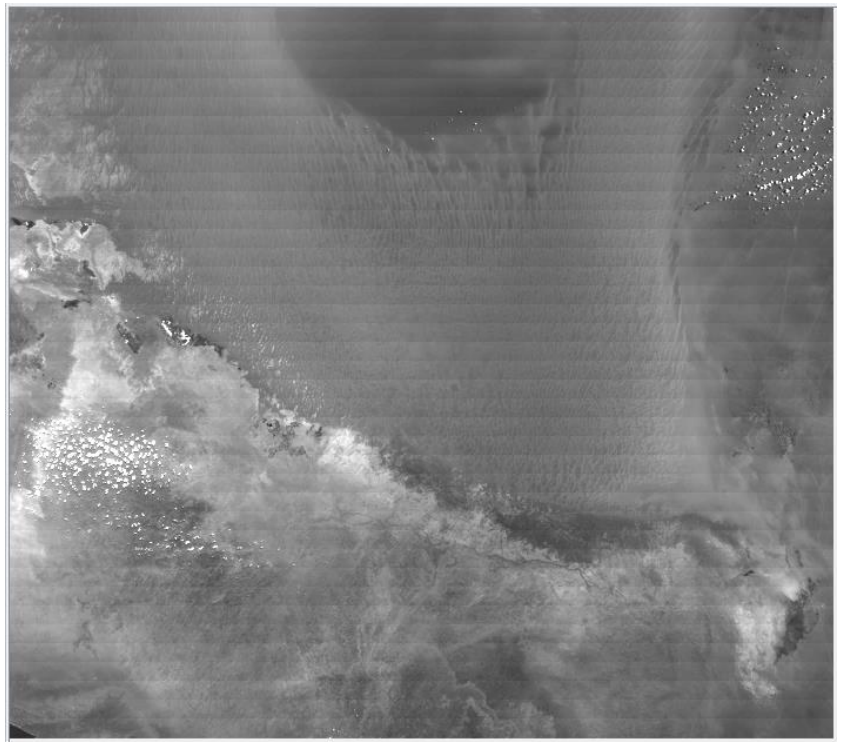


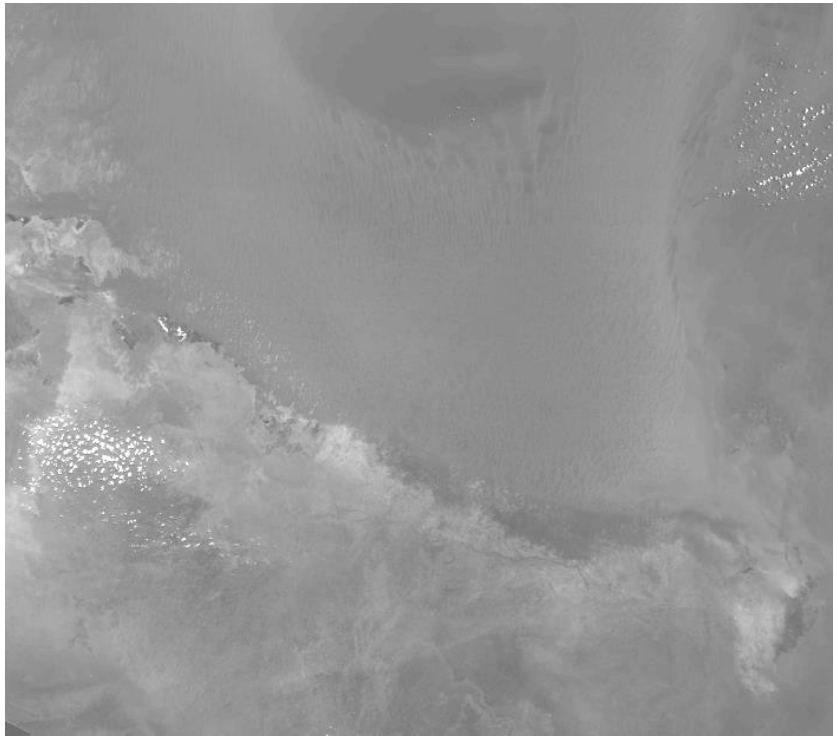


Linear relation wrt detector index

Performance of RSB #3: S-NPP TOA reflectance

M1 striping (C 1.1) **2019229** **M1 striping gone (C 2.0)**





Libya 4 image shows better quality with the new LUTs (striping is gone; largest improvement ~ 1.3%)

Performance of RSB #4: uncertainty of TOA reflectance

- **Derive reflectance uncertainty from definition**

$$\frac{\mathrm{var}(\rho_{\mathrm{EV}})}{\rho_{\mathrm{EV}}^2} = \frac{\mathrm{var}(dn_{\mathrm{EV}})}{dn_{\mathrm{EV}}^2} + \tan^2(\theta_{\mathrm{EARTH-SUN}})\,\mathrm{var}(\theta_{\mathrm{EARTH-SUN}}) + \frac{\mathrm{var}(H_{\mathrm{RTA}})}{H_{\mathrm{RTA}}^2} + \frac{\mathrm{var}(\tau_{\mathrm{SD}}\mathrm{BRDF}_{\mathrm{RTA}}(t=0))}{[\tau_{\mathrm{SD}}\mathrm{BRDF}_{\mathrm{RTA}}(t=0)]^2}$$

- **Reflectance comparison among instruments**
  - **For details of the current status of SNPP/N20/MODIS RSB L1B reflectance difference investigation results, please see Aisheng Wu's presentation tomorrow**

Future works

1. Yield more accurate DN saturation flagging (M6)
2. Establish L1B uncertainly index at pixel level
3. Improve SD F-factors for RSB low-gain stages
4. Directly use N20 F(Moon) for N20
5. Continue to improve on-orbit calibration algorithms
6. SNPP/N20 RSB difference investigation and mitigation
   - VCST-science teams joint meeting held on Dec. 18, 2020; potential future follow-up meetings

Summary

- **Both S-NPP and N-20 RSB gains perform well; recent N20 VIIRS RTA issue has no impact on N20 VIIRS RSB calibration**

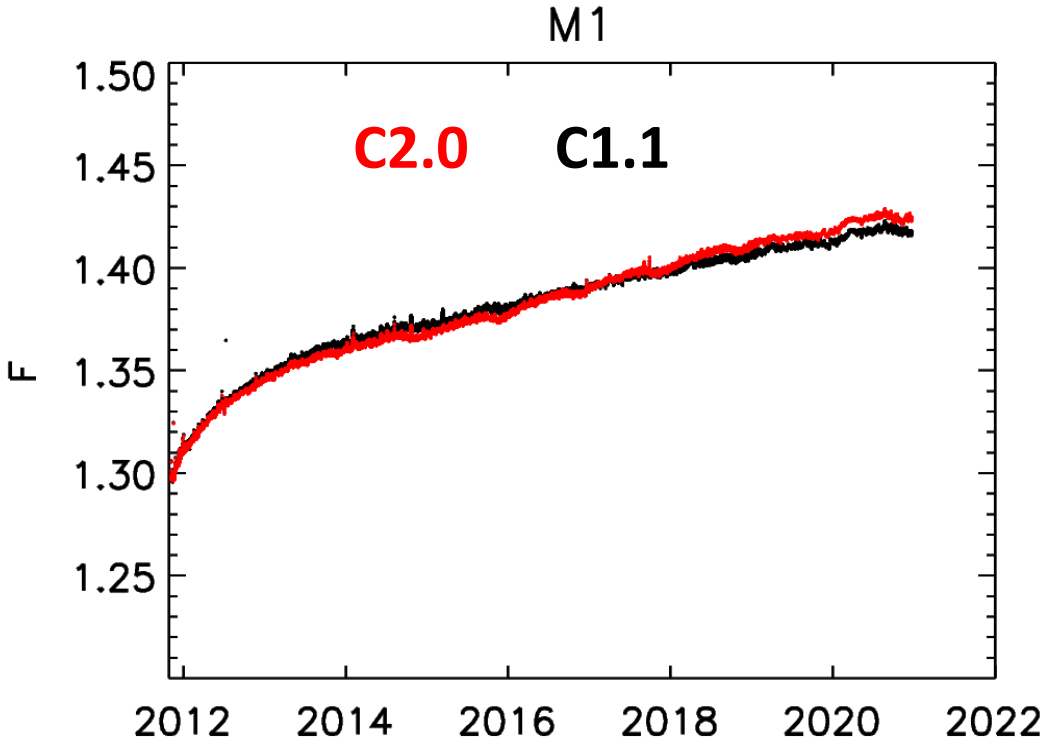
- **SNRs satisfy specifications and will remain above specifications for the foreseeable future**

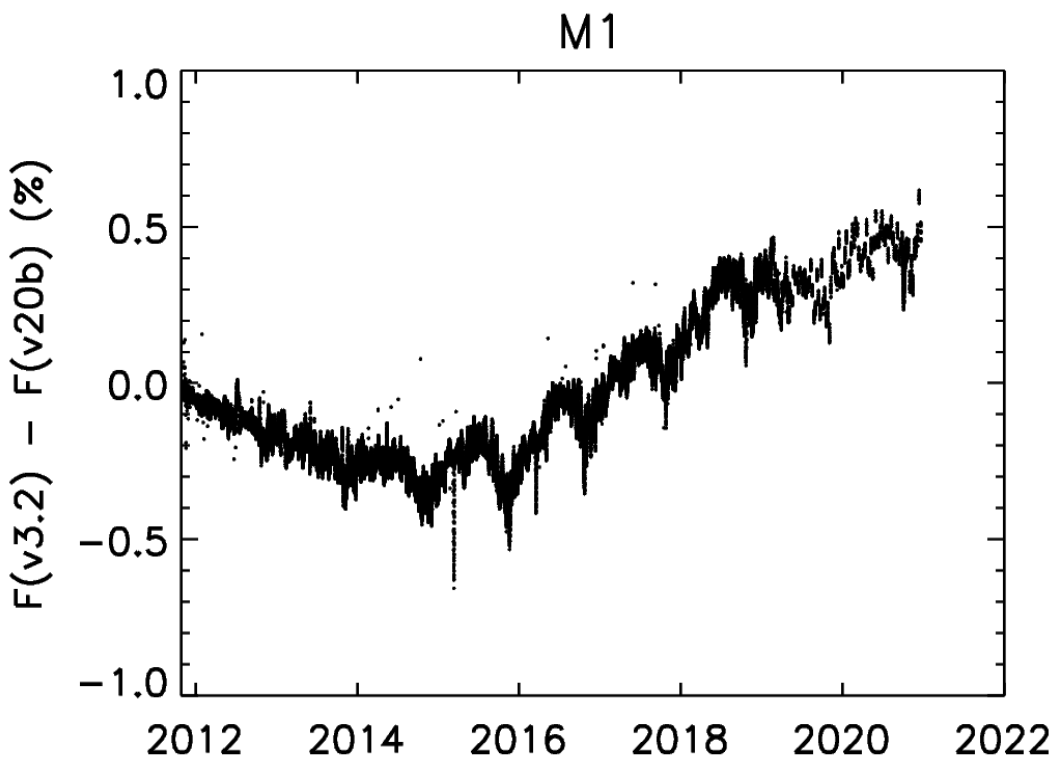
- **Performed a few improvements for S-NPP and N20 VIIRS RSBs**
  - sliding window fitting F(SD) to F(Moon) for S-NPP M1 & M2 bands (0.5%)
  - S-NPP H-factor SD positional dependence (1.3%)

- **Linearly fit the most recent 1.5 years of F-factors to better predict future F-factors, reducing LUT delivery frequency from ~ once/6 weeks to ~ once/6 months**

Backup Materials

S-NPP F-factor difference between C1.1 and C2.0





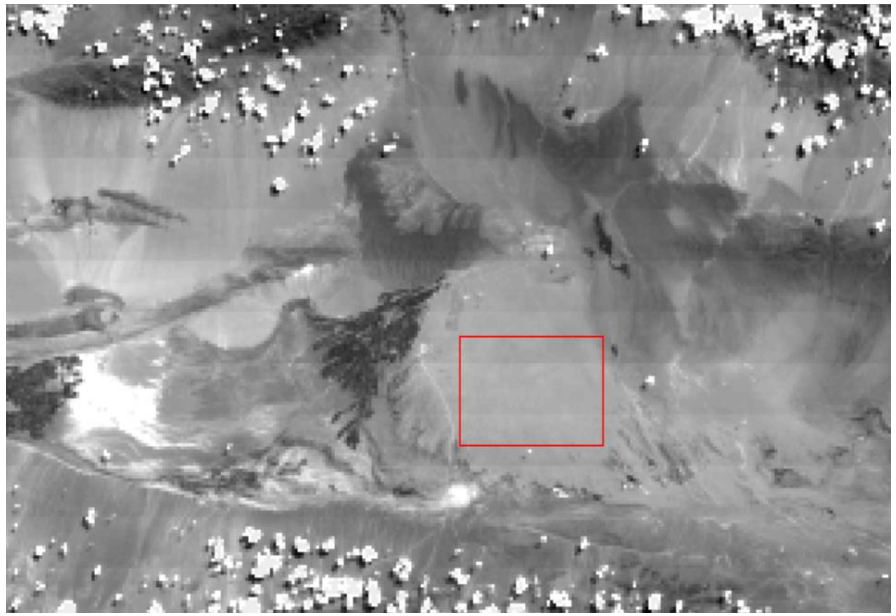
(Averaged over detectors; HAM A, high-gain)

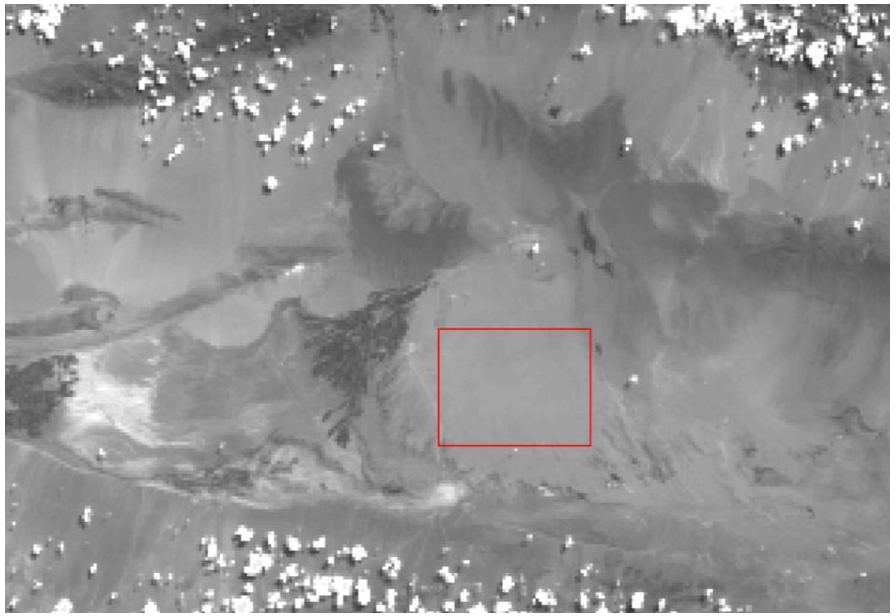
Small difference between two collections: mostly less than 0.5% in magnitude

(C2.0=v3.2; C1.1=v20b)

Dunhuang Images

M1 light striping (C 1.1) **Aug. 2020** **M1 striping gone (C 2.0)**





Dunhuang images show better quality with the new LUTs

TOA reflectance difference between SNPP and N20 VIIRS