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

- 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

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- 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)
    - 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)
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

\[
\rho_{EV \cos\theta_{EARTH-SUN}} = \frac{4\pi^2 F(t, d) \sum_{i=0}^{3} c_i d n^i \ast d^2_{\text{VIIRS-SUN}} \times \int_{0}^{\infty} RSR(\lambda, t, d) d\lambda}{\text{RVS}(\lambda_B, \theta_{EV}) \times \int_{0}^{\infty} RSR(\lambda, t, d) \Phi_{\text{SUN}}(\lambda) d\lambda}
\]

\[
\text{RSR}(\lambda, t, d) \quad \text{Modulated RSR (S-NPP); prelaunch RSR (N-20)}
\]
VIIRS radiometric calibration

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

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

Improved with yaw and regular on-orbit data
• 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 $F(Moon)$

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

Solar azimuth angle

$\alpha_{RTA}$ and $\alpha_{H}$ 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

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

\[ \phi_v = 35.5^\circ \]
Performance of RSB #1: N-20 1/F-factors

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

\[ H_{RTA} = Func(H_{SDSM}, \alpha_{RTA}, \alpha_H) \]

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

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

Model parameters

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

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

- 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

Libya 4