S-NPP, N-20, and N-21 VIIRS Reflective Solar Bands
On-orbit Radiometric Calibration and Performance

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Objectives

1. Radiometric calibration improvements since last STM (Feb. 2021)

2. RSB radiometric performance update

3. Future works
What happened since STM 2021

**S-NPP**
- Safe mode occurred in July 2022 led to F-factor trending change for many RSBs
- Developed TOA reflectance factor uncertainty algorithm
- Improved L1B pixel saturation detection

**N-20**
- Sliding window (in time) approach, using F(moon): same approach employed by S-NPP
- Improved L1B pixel saturation detection

**N-21**
- Launched on Nov. 10, 2022
- First mission RSB F-factor LUTs delivered with screen functions derived from calibration data collected on yaw maneuver orbits
VIIRS RSB calibration

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

\[ F(t, d) \sum_{i=0}^{3} c_i dn^i \]

on-orbit calibrated

Spectral radiance
Performance of S-NPP SD and SDSM

- SDSM detector gains trend normally
- H-factors dropped by about 1% due to the Feb. 24, 2019 event
- Recently, H-factors trend upwards (det 1-5), because of unusual solar activity impact on SD, also occurring for N20 and MODIS SDs
Calculate $F(SD)$

**S-NPP and N-20**

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

$\alpha_{RTA}$ and $\alpha_H$ obtained from fitting $F(SD)$ to $F(Moon)$

Use a sliding window (in time) approach, fit $F(H_{RTA})$ to $F(Moon)$ to find $\alpha_{RTA}$ and $\alpha_H$

**N-21**

Not enough $F(Moon)$ available to fit; choose to use the measured $H_{SDSM}$ (no deconvolution)
Solid lines: 1/F(SD); Circles: 1/F(Moon)

F decreases with time, because of telescope mirror surface tungsten oxide contamination
**Performance of N-20 SD and SDSM**

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

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**N-20 H-factors**

- $\phi_v = 35.5^\circ$

**N-20 SDSM Detector Gains**

- $G_{\text{DSM}} = 5.35 V_f$

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- **Det 1**
- **Det 2**
- **Det 3**
- **Det 4**
- **Det 5**
- **Det 6**
- **Det 7**
- **Det 8**
Solid lines: 1/F(SD); Circles: 1/F(Moon)
F-factors are very stable over mission
Performance of N-21 SD and SDSM

- H-factors decrease faster than N-20 and similarly to S-NPP H-factors
- SDSM gains decrease similarly to S-NPP and N-21
- Undulation in the H mainly from screen function errors (will be improved later this year)
Performance of N-21 RSBs: F-factors

- VISNIR bands: $F(\text{SD, with measured } H_{\text{SDSM}})$ has a downward trend
- SWIR bands: $F(\text{H}=1)$ trends upwards, likely because of ice accumulation on focal plane
SNRs

All SNRs satisfy requirements, except N-20 I3 band detector 29 (noisy detector)
S-NPP H-factor SD positional dependence

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

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

Model parameters:
- \( H_{\text{RTA}} \)
- \( H_{\text{SDSM}} \)
- \( c_{d,1} \)
- \( c_{d,2} \)
- \( d \)
- \( d_{\text{mid}} \)

Detector array model parameters.
S-NPP TOA images

2019229
M1 striping (C1.1)

2019229
M1 striping gone (C2.0)

March 2023
No striping seen (C2.0)

H-factor SD positional dependence algorithm (2017) and results (2018) are still good
Uncertainty of TOA reflectance factor

- Derive reflectance factor uncertainty from definition

\[
\frac{\text{var}(\rho_{EV}\cos\theta_{EARTH-SUN})}{\rho_{EV}^2(\cos\theta_{EARTH-SUN})^2} = \frac{\text{var}(dn_{EV})}{dn_{EV}^2} + \frac{\text{var}(H_{RTA})}{H_{RTA}^2} + \frac{\text{var}(\tau_{SD}BRDF_{RTA}(t=0))}{[\tau_{SD}BRDF_{RTA}(t=0)]^2} + \text{var} \left[ \frac{RVS(\theta_{SD})}{RVS(\theta_{EV})} \right] \\
+ \text{var}(c_{2,1})(dn_{EV} - dn_{SD})^2 + \frac{\text{var}(\cos(\theta_{SUN-SD}))}{\cos^2(\theta_{SUN-SD})}
\]

- Uncertainty LUTs are generated for L1B code for S-NPP and N-20

Reference: VCST_TECH_REPORT_2022_009
Use neighboring band radiance as a reference, in addition to its own radiance

Future works

1. N-20 RSB striping mitigation

2. Improve N-21 screen functions with data collected at both yaw maneuvers and regular orbits

3. S-NPP M6 saturation flagging
Summary

• S-NPP, N-20, and N-21 VIIRS RSBs perform normally with SNRs satisfying specifications (except N-20 I3 detector 29) and will remain above specifications for the foreseeable future

• Used N-20 RSB F(moon) to find $H_{RTA}$ from $H_{SDSM}$, instead of using S-NPP $H_{RTA}$ results, a sliding window approach

• Developed L1B reflectance uncertainty algorithm, delivered uncertainty LUTs

• Improved saturation detection algorithm