SNPP VIIRS Reflective Solar Bands On-orbit Radiometric Calibration Performance and Improvements

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VIIRS RSB On-orbit Calibration

TOA spectral hemispherical reflectance is estimated by (Eq. 81, ATBD vF)

\[
\rho(\lambda_B) = \frac{\pi F(B) \times \left( c_0 + c_1 d_{EV} + c_2 d_{EV}^2 \right)}{RVS(\theta_{EV}, B) \cos \theta_{sun-earth} E_{sun}(\lambda_B, d_{sun-viirs})} 
\]

(1)

Focus: correctly calculate \( F \) (correction factor)

\[
F = \frac{\int RSR(\lambda, B, t) \times L_{SD}(\lambda, t, \phi)}{\left( c_0 + c_1 d_{SD} + c_2 d_{SD}^2 \right) \times \int RSR(\lambda, B, t) d\lambda}
\]

(2)

\( L_{SD} \): improved \hspace{1cm} \text{RSR}(\lambda, B, t): \text{slightly improved}
Improved Calculated Sunlit SD Spectral Radiance

\[ L_{SD} = E_{sun}(\lambda) \cos(\theta_{SD-sun}) \tau_{SAS} \text{BRDF}_{RTA}(\lambda, t = 0, \phi) H_{RTA}(\lambda, t, \phi) \]  (3)

★ \( H_{RTA}(\lambda, t, \phi) \) (SD BRDF degradation factor): biases removed and screen transmittances are more accurate
(computed from \( H_{SDSM} \))

\[ \tau_{SAS}(\lambda, \phi) \text{BRDF}_{RTA}(\lambda, t = 0; \phi) : \text{one bias removed, 0.05\% along solar azimuth direction} \]
Improvements on $H_{SDSM}$: part 1

(1) SDSM screen transmittance is more accurately calculated
   use both yaw maneuver and a small portion (~3-month) of regular data

SDSM screen coord.
(2) Improved relative $\tau(\text{SD}) \ast \text{BRDF}(t=0; \text{SDSM})$

use both yaw maneuver and a small portion of regular data

and remove bias from the angular dependence of $H_{\text{SDSM}}$
Solar angular dependence of SD BRDF degradation factor

$H_{SDSM}$ depends on solar vertical angle
- the dependence is stronger with smaller $H_{SDSM}$
(3) Rescale $H_{SDSM}$ effectively move up $H_{SDSM}$ at the wavelength of 412 nm (M1) by about 1.0%
(4) Model $H_{SDSM}$ at SWIR band wavelengths
originally $H_{SDSM}(\text{SWIR wavelength}) = 1$

$$1 - H(\lambda, t) = \frac{\alpha(t)}{\lambda^{4.07}} \quad \alpha(t) = \left\langle (1 - H(\lambda, t)) \times \lambda^{4.07} \right\rangle$$

$$\lambda = (\lambda_{\text{det 5}}, \lambda_{\text{det 6}}, \lambda_{\text{det 7}}, \lambda_{\text{det 8}})$$

![Graph showing changes in $H$ over wavelength and days since launch.](image-url)
Improved $H_{\text{SDSM}}$ (SDSM SD view)

$H_{\text{SDSM}}$ can be precisely measured with a relative error mainly in the mid to low 0.0001
Improvements on $H_{RTA}$: part 1

(1) $H_{RTA}$ dependence on solar azimuth angle $\phi_H$

**non-observable dependence on $\phi_H$**

$$F \propto 1 + \beta(\lambda) \times \left( H_{SDSM, \text{mean RSR }}(t_{mid}) - H_{SDSM, \text{mean RSR}} \right) \times (\phi_H - 48.0^\circ)$$ (4)
Improvements on $H_{RTA}$: part 1

(1) $H_{RTA}$ dependence on solar azimuth angle $\phi_H$

$$F_1 = F \left[ \frac{1}{1 + \beta(\lambda) \left( H_{\text{SDSM, mean RSR}}(t_{\text{mid}}) - H_{\text{SDSM, mean RSR}} \right)} \left( \phi_H - 48.0^\circ \right) \right]$$

Diagram:

- plus: lunar F
- dot: SD F
(2) $H_{RTA}$ from $H_{SDSM}$: match scaled lunar results through least-squares fitting

\[ F_2 = F_1 \times [1 + \gamma(\lambda) \times (1 - H_{SDSM})] \quad \text{update RSR} \]

\[ H_{RTA} = H_{SDSM} \times \frac{[1 + \gamma(\lambda) \times (1 - H_{SDSM})]}{1 + \beta(\lambda) \times (1 - H_{SDSM}) \times (\phi_H - 48.0^\circ)} \]

plus: lunar $F$
dot: SD $F$
Calculated Detector Gain

gain := \frac{1}{F}
Calculated Gain: new vs old

Old (last version)  New (current version)
$F$ Precision Estimation

M1: 0.07%, M2: 0.07%, M3: 0.06%, M4: 0.04%, I1: 0.06%, ..., M11: 0.05%
Summary

• *F* calculation accuracy has been improved
  (1) removed yearly detector gain undulations (as large as 0.5% for M1)
  (2) removed biases (originally observed as large as 1.5% for M1) relative to lunar observations
  (3) removed bias due to incorrect $H_{SDSM}$ normalization at $t=0$ (~1% for M1)
  (4) removed bias in the original $\tau_{SD}^{BRDF_{RTA}}(t=0) (>0.05\%$; yaw)
  (5) removed bias for the calculated SWIR band throughput (0.4% for M8)
  (6) improved accuracies in $\tau_{SD}^{RBRDF_{SDSM}}(t=0)$ and $\tau_{SDSM}^{R}$ (yaw+non-yaw)

  $H_{SDSM}$ precision of 0.0003 to 0.0007

• *F* precisions are around 0.05% on a per satellite orbit basis
  (M1:0.07%, M2:0.07%, M3:0.06%, M4:0.04%, I1:0.06%, …, M11:0.05%)