A Ground Reference Method For Suomi-NPP VIIRS Day-Night Band And M Bands Performance Validation

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Introduction

- SNPP was launched on Oct. 28th, 2011, Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the five onboard instruments
- VIIRS DNB and M bands characteristics (Table 1)
- DNB and M bands RSRs (Figure 1)
- Calibration reference sites
  Libya 4 and Dome C sites (Figure 2)

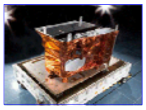


Table 1. List of characteristics of VIIRS DNB and M bands within DNB wavelength range.

VIIRS Band	Central wavelength (µm)	Band width (µm)	Wavelength Range (µm)	Band Explanation	Spatial Resolution at nadir (m)
DNB	0.7	0.4	0.5-0.9	Visible/Reflective	750 across full scan
M4	0.555	0.02	0.545-0.565	Visible/reflective	750
M5	0.672	0.02	0.662-0.682		750
M6	0.746	0.015	0.739-0.754	Near IR	750
M7	0.865	0.039	0.846-0.885		750

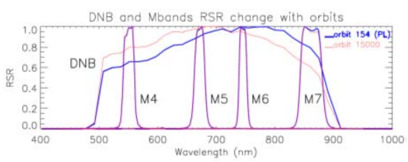


Figure 1. DNB and M bands prelaunch RSRs and modulated RSRs.

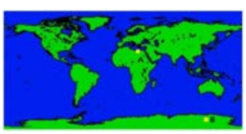


Figure 2. Geolocation of (A)-Libya 4 and (B) Dome C sites.

Data

- Solar irradiance LUT and the modulated RSR LUTs
- SCIAMACHY spectral data
- The DNB and M bands SDR products:
  Interface Data Processing Segment (IDPS)
  NASA Land Product Evaluation and Algorithm Testing Element (PEATE)
- Nadir overpass, cloud free, 32x32 pixel standard deviation of radiance < 0.0001
- 32x32 pixels mean radiance and reflectance for DNB; same geolocation pixels for M bands

Methodology

- Libya 4 DNB radiance and reflectance calculation

$$L_{normalized} = \frac{L_m * d^2}{\cos(\theta)} \quad (1)$$

$L_{normalized}$ =Measured solar radiance after E-S distance and solar zenith angle correction (W·cm-2·Sr-1)

L_m =Measured solar radiance provided by the DNB product (W·cm-2·Sr-1)

d =Earth-Sun distance (astronomical units)

θ =Solar zenith angle

$$\rho_{TOA} = \frac{\pi * L_m * d^2}{\cos(\theta) * ESUN_\lambda} \quad (2)$$

ρ_{TOA} =Top of atmosphere reflectance with Earth-Sun distance correction (%)

$ESUN_\lambda$ =band dependent mean solar irradiance (W·m-2·nm-1).

$$ESUN_\lambda = \frac{\sum(RSR_\lambda * SolarIrradiance_\lambda * \Delta\lambda)}{\sum(RSR_\lambda * \Delta\lambda)} \quad (3)$$

RSR_λ =wavelength dependent relative spectral response of band λ

$\Delta\lambda$ =wavelength spectral interval (nm)

$SolarIrradiance_\lambda$ =Solar spectral irradiance from VCST LUT (W·m-2·nm-1)

M bands radiance and reflectance data are calculated by using the scaled integer (SI), scale, and offset values provided by the SDR products.

Modulated TOA reflectance is calculated using SCIAMACHY spectral data:

$$\rho_{TOA\_model} = \frac{\sum(\rho_{SCIAMACHY} * SolarIrradiance_\lambda * RSR_\lambda * \Delta\lambda)}{\sum(RSR_\lambda * SolarIrradiance_\lambda * \Delta\lambda)} \quad (4)$$

- Libya 4 integrated DNB radiance calculation

$$R_{mi} = \frac{\int RSR(Mband)_\lambda * RSR(DNB)_\lambda * \rho_\lambda * d_\lambda}{\int RSR(DNB)_\lambda * \rho_\lambda * d_\lambda} \quad (5)$$

$$W_{mi} = \frac{R_{mi}}{R_{m4} + R_{m5} + R_{m7}} \quad (6)$$

$$DNB_{bandwide} = \int RSR(DNB)_\lambda * d_\lambda \quad (7)$$

$$Integral_{Mbands} = (W_{m4} * L_{m4} + W_{m5} * L_{m5} + W_{m7} * L_{m7}) * DNB_{bandwide} \quad (8)$$

R_{mi} are weight parameter for M bands 4, 5, and 7, respectively. W_{mi} are the weights that contained the scale for making all weights' sum as 1. The Integral M bands radiance, $Integral_{Mbands}$, are calculated using the L_{mi}, which are the M bands radiance normalized with solar zenith angle and Earth-Sun distance. $DNB_{bandwide}$ is the DNB RSR band wide parameter.

- Dome C DNB radiance and reflectance calculation

$$L_{normalized\_dis\_esr} = \frac{L_m * d^2}{F_{ESUN}} \quad (9)$$

$$F_{ESUN} = \frac{ESUN_t}{ESUN_{t0}} \quad (10)$$

F_{ESUN} is the ratio of ESUN between the data collection time t and the reference time t0

$$L_{normalized\_dis\_esr} = f_0 + f_1 * \theta \quad (11)$$

$$F_{brdf} = \frac{f_0 + f_1 * \theta_r}{f_0 + f_1 * \theta_0} \quad (12)$$

The ratio factor, F_{brdf}, is calculated based on linear fit parameters and θ_0 is reference angle (60 degree), θ_r is the collected data's solar zenith angel.

$$L_{normalized\_dis\_brdf} = \frac{L_m * d^2 * F_{brdf}}{\cos(\theta_r)} \quad (13)$$

$$\rho_{TOA\_DomeC} = \frac{\pi * L_m * d^2 * F_{brdf}}{\cos(\theta_r) * ESUN_\lambda} \quad (14)$$

Results

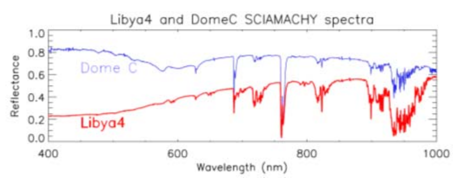
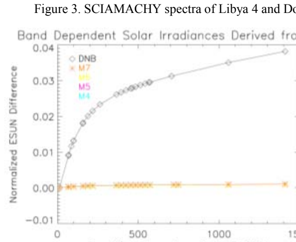


Figure 3. SCIAMACHY spectra of Libya 4 and Dome C.



In the first 3.5 years

DNB 3.8%
M7 0.1%
M6 0.065%
M5 0.095%
M4 0.1%

Figure 4. Normalized DNB and M bands ESUN values derived from modulated RSRs.

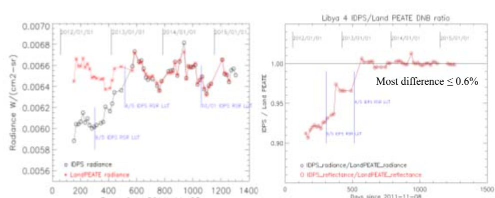
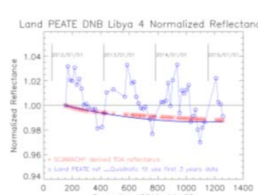


Figure 5. Libya 4 DNB radiance and reflectance of IDPS and Land PEATE data at 32x32 pixels area.



In the past 3.5 years

1.2% decrease in SCIAMACHY

1.3% decrease in Land PEATE

Figure 6. Libya 4 DNB Land PEATE and SCIAMACHY comparison.

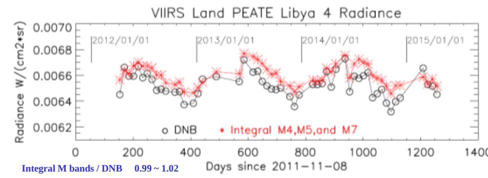
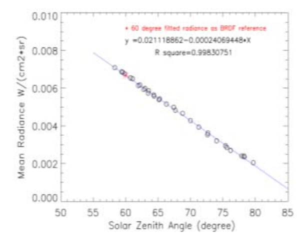


Figure 7. Libya 4 DNB and integral M bands radiance for overlap areas.



Use first year data in 2012. Each data point represents mean radiance of 32x32 pixels at site after Earth-Sun distance and RSR normalization.

Figure 8. Dome C DNB BRDF linear fit.

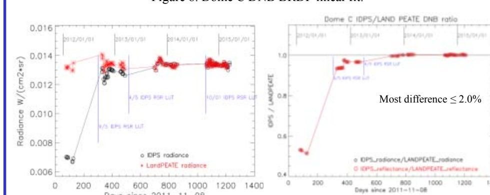


Figure 9. Dome C DNB radiance and reflectance of IDPS and Land PEATE data at 32x32 pixels area.

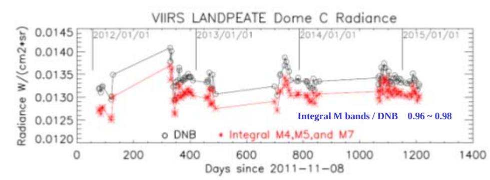


Figure 10. Dome C DNB and integral M bands radiance for overlap areas.

Conclusions

- DNB modulated RSR introduced about 3.8% increase at band dependent solar irradiance, M4-M7 bands have 0.1% or less increase.
- After excluding data before 2013 April, IDPS to Land PEATE data ratio in both radiance and reflectance are consistent (Libya ≤0.6%, Dome C ≤2.0%). The difference in early data collection period are caused by the inconsistent calibration LUTs.
- At Libya 4 site, the TOA reflectance from SCIAMACHY indicates 1.2% decrease and the Land PEATE data has 1.3% decrease. The significant RSR changes cause reflectance changes even though the ground target is same.
- The difference of Land PEATE integrated M bands radiance to DNB radiance trends are small (Libya 4 ≤2%, Dome C ≤4%). This demonstrate the consistent quality of DNB and M band calibration.
- We suggest using the IDPS DNB data after 2013 April 5th for long term change detection which contain better quality LUTs. The Land PEATE DNB, M4,M5,M7 data have stable radiometric calibration in operation period.

Acknowledgment

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Reference: X. Chen et al., Validation of S-NPP VIIRS Day-Night band and M bands performance using ground reference targets of Libya 4 and Dome C. SPIE, Earth Observing Systems XX, San Diego, (2015)