Monitoring the VIIRS Reflective Solar Band Calibration Stability Using Deep Convective Clouds

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1. Introduction

The Visible and Infrared Imaging Radiometer Suite (VIIRS) onboard the Joint Polar Satellite System (JPSS) / Suomi National Polar-Orbiting Partnership (NPP) satellite has 22 spectral bands, with 14 Reflective Solar Bands (RSB), 7 Thermal Emissive Bands (TEB) and 1 Day Night Band (DNB). Onboard calibration of VIIRS is complex, especially for the RSBs and DNB, which are calibrated using a full-aperture solar diffuser (SD) and the degradation of SD is monitored by a solar diffuser stability monitor (SDSM). Significant SD degradations were observed in the visible and near-infrared spectrum. It is important to use independent validation time series to evaluate post-launch calibration stability of VIIRS RSBs and DNB.

Deep Convective Clouds (DCC) are extremely cold clouds that start from the planetary boundary layer and ascend to the tropical tropopause transition layer. The absorptions due to water vapor and other gases over DCCs are minimal. DCCs are bright targets and have nearly Lambertian reflectance . DCCs have been widely used as bright calibration targets for post-launch calibration and stability monitoring of radiometers in the visible and near-infrared spectrums for a variety of satellite instruments in the past decade. The purpose of this study is to investigate radiometric calibration stability of VIIRS RSB and DNB bands (M1-M5, M7-M11, I1-I3, and DNB) using the DCC technique.

2. VIIRS Dataset Used

- **Area of Interest**: Latitude -25° – 25°; Longitude: -150 ° – -60°
  An area also observed by GOES-East & GEOS-West
- **Bands Used**:
  RSB bands: M1-M5, M7-M11, I1-I3, DNB
  TEB bands: M15 (10.729 µm) & I5 (11.469 µm)
- **Time Period**: March 2012 – June 2015

Figure 1 Area of interest.

3. VIIRS DCC Identification Method

VIIRS DCC identification criteria (Wang and Cao 2014; 2015) :

1. **TB11 (M15 or I5) <= 205 K;**
2. **Standard deviation of TB11 of the subject pixel and its eight adjacent pixels <= 1K;**
3. **Standard deviation of VIS/NIR reflectance of the subject pixel and its eight adjacent pixels<= 3%;**
4. **Solar zenith angle (SZA) <= 40 degree;**
5. **View zenith angle (VZA) <= 35° (to avoid the bow-tie effect in VIIRS dataset);**
6. **DNB radiances were mapped to M15 lat/lons before DCC pixels were identified using M15 TB11.**

4. Monthly Probability Distribution Functions for VIIRS DCC

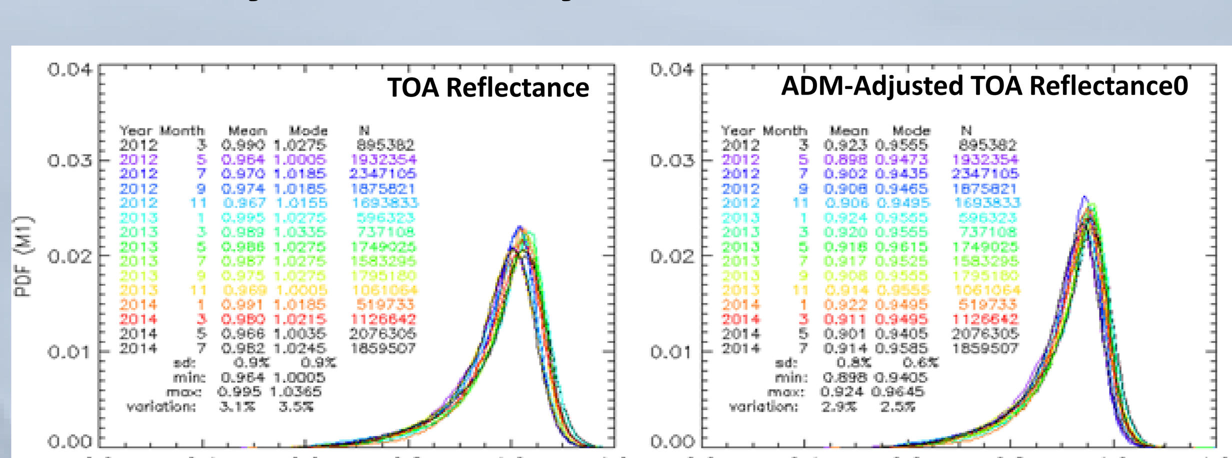
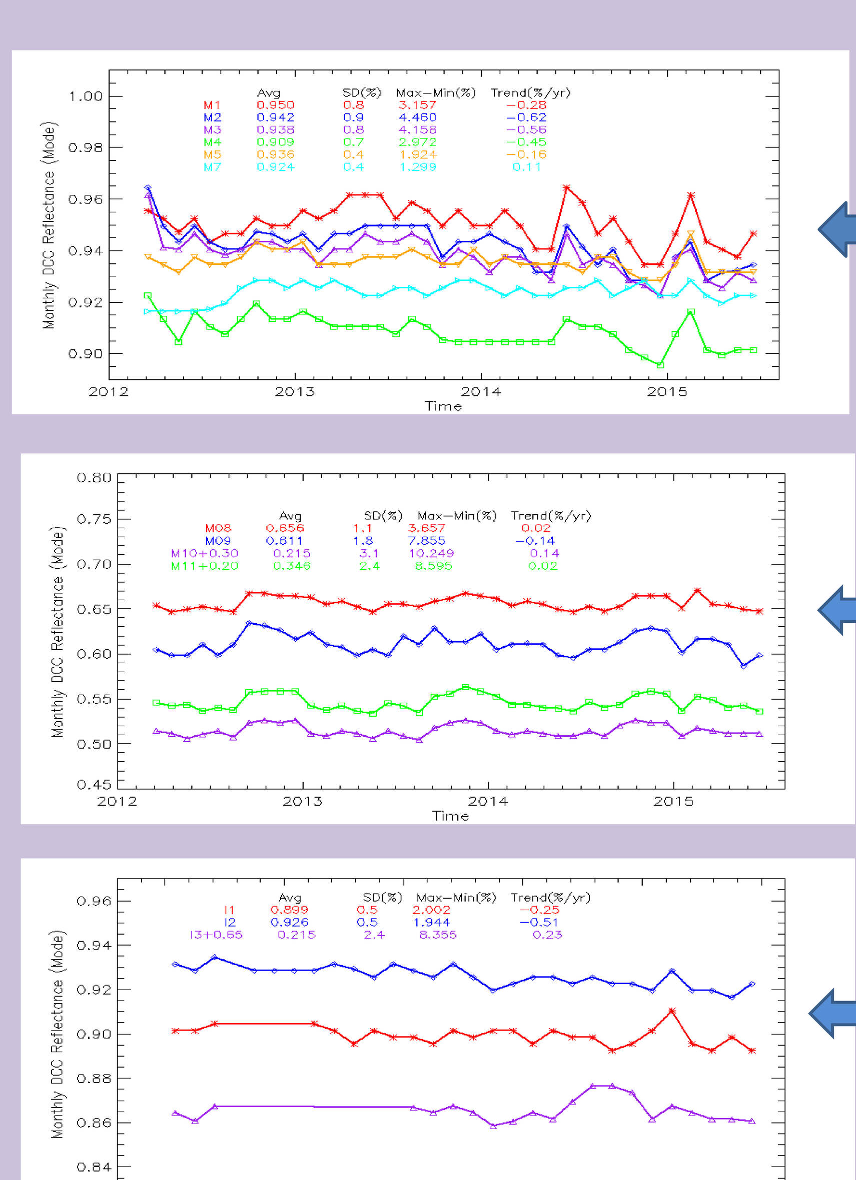


Figure 2 Monthly probability distribution functions (PDFs) of VIIRS DCC reflectance for before (left panel) and after (right panel) the correction of the anisotropic effects.

- **Anisotropic effect is corrected using Hu et al. (2004) Angular Distribution Model (ADM)**
- **Mean & mode of the monthly PDFs are two Important indices when using DCC for calibration**
- **Mode is used for individual bands calibration stability monitoring**
  -- **More stable than mean in the VIS/NIR spectrum**
- **Mean ratio is used for inter-channel relative calibration stability monitoring**
  -- **Mean ratio more stable than mode ratio**

5. DCC Time Series for Individual Bands Cal. Stability Monitoring



M1-M5,M7 (VIS/NIR 0.411 – 0.862 µm)

- **SD : <=0.9%**
- **Max - Min <=4.5%**
- **M5 & M7 are relatively more stable**
- **M6 saturated over DCCs, not considered**

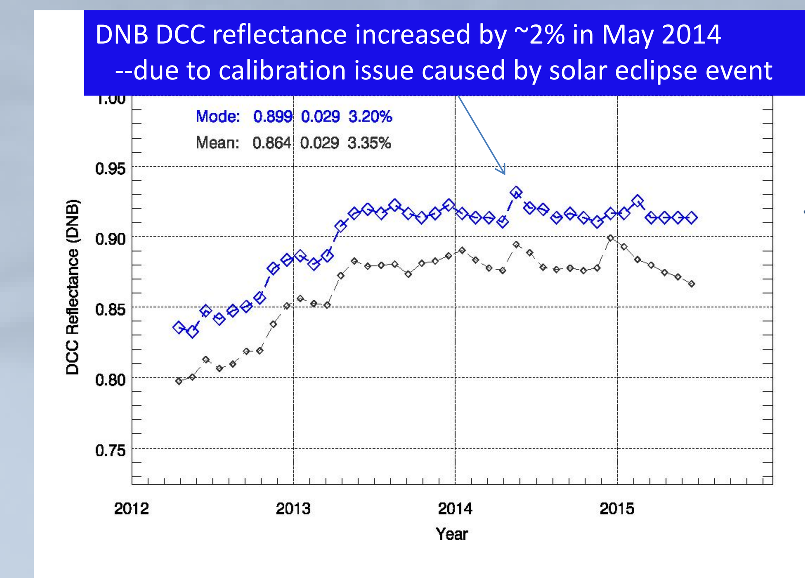
M8-M11 (SWIR 1.238 – 2.257 µm)

- **SD : 1.1 – 3.1 %**
- **Max – Min: 3.6 – 10.2 %**
- **M8 is relatively more stable**

I1, I2 & I3 perform similar as M5, M7, M10, respectively

Figure 3 Monthly DCC mode time series for M1-M5 & M7, M8-M11, and I1-I3

5. DCC Time Series for Individual Bands Calibration Stability Monitoring (Continued)



DNB (Daytime, Low Gain Stage)
- Generally stable since April 2013, after RSR update was implemented into operations.

Figure 4 Monthly DCC mode time series for DNB

6. Inter-Channel Relative Calibration Stability Monitoring Using DCC Mean Band Ratio Time Series

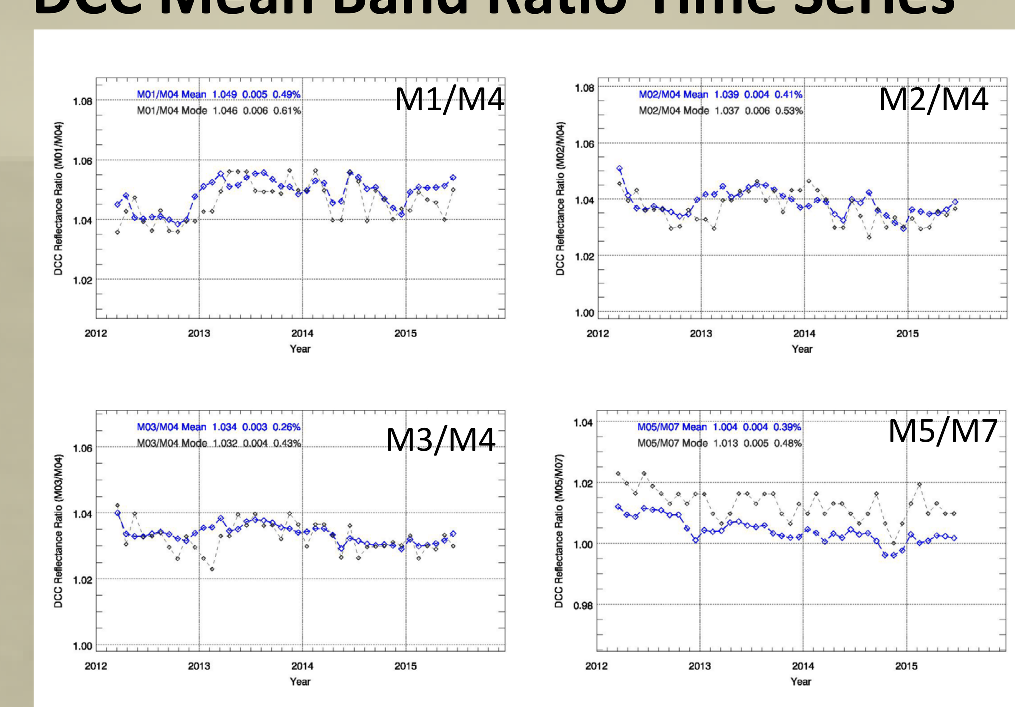


Figure 5 M1/M4, M2/M4, M3/M4, I5/I7 band ratio time series

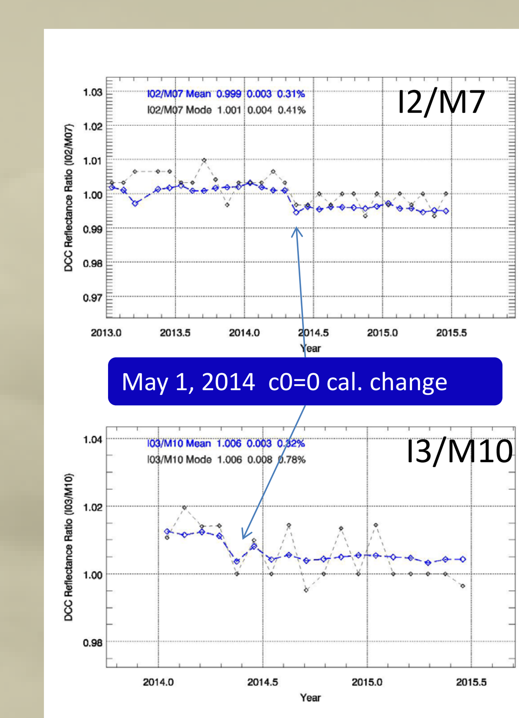


Figure 6 I2/M7, I3/M10 time series

- M1/M4 & M2/M4: 2012 & 2013 show different ratio patterns → coincident with OC group complains
- A downward trend is observed in the M5/M7 band ratio time times.

- I2 & M7 become less consistent after cal. change
- I3 & M10 become closer after cal. change

7. DCC Time Series vs. IDPS F-factor Time Series

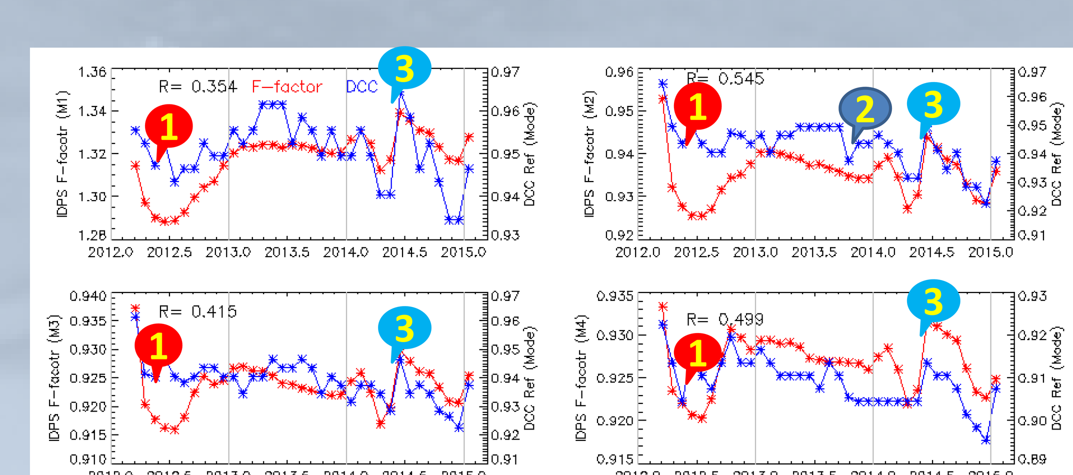


Figure 7 Comparing DCC mode and IDPS F-factor time series

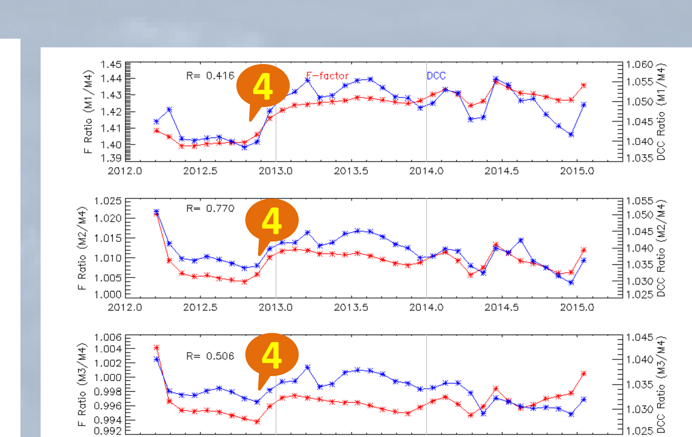


Figure 8 Comparing DCC mean band ratio and IDPS F-factor ratio time series

1. Apr 2012 IDPS code & LUTs changes
2. Oct 2013 SDSM misalignment
3. May 22, 2014 cal. Change
4. Nov 2012 SD processing param. change

DCC time series correlated with F-factor time series Correlations are stronger since Janunary 2014

8. Summary

- **STAR VIIRS SDR support team developed DCC time series for VIIRS calibration stability monitoring**
  - **https://cs.star.nesdis.noaa.gov/NCC/VSTS , update monthly**
  - **Completed M1-M5, M7-M11 & DNB (2012/03 – present)**
  - **Capable of capture calibration changes**
- **RSB calibration stability**
  - **M-Bands VIR/NIR Bands (M1-M5,M7)**
    --M1-M4 have large calibration changes
    --M5&M7 are relatively stable
    --M1/M4 & M2/M4 show different patterns in 2013 & 2014
  - **M-Bands SWIR Bands (M8-M11)**
    --M9-M10 large calibration changes
    --M8 is relatively stable
  - **I-Bands (I1-I3) perform similar as M5,M7,M10, respectively**
  - **DNB is relatively stable after April 2013**

References

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