Assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations

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Abstract

The low gain stage of VIIRS Day/Night Band (DNB) on Suomi-NPP is calibrated using onboard solar diffuser. The calibration is then transferred to the high gain stage of DNB based on the gain ratio determined from data collected along solar terminator region. The calibration transfer causes increase of uncertainties and affects the accuracy of the low light radiances observed by DNB at night. Since there are 32 aggregation zones from nadir to the edge of the scan and each zone has its own calibration, the calibration versus scan angle of DNB needs to be independently assessed. This study presents preliminary analysis of the scan-angle dependence of the light intensity from bridge lights, oil platforms, power plants, and flares observed by VIIRS DNB since 2014. Effects of atmospheric path length associated with scan angle are analyzed. Other effects such as light changes at the time of observation are also discussed. The methodology developed will be especially useful for JPSS J1 VIIRS due to the nonlinearity effects at high scan angles, and the modification of geolocation software code for different aggregation modes. It is known that J1 VIIRS DNB has large nonlinearity across aggregation zones, and requires new aggregation modes, as well as more comprehensive validation.

Introduction

The Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the key instruments on the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite designed primarily to observe clouds and earth surface variables. Among the twenty-two bands of VIIRS onboard the NPP satellite, the Day/Night Band (DNB) represents an unprecedented night observation capability. It is superior to its predecessor, the Operational Line Scanner (OLS) on the Defense Meteorological Satellite Program (DMSP), in both spatial and radiometric performance because it has a finer spatial resolution of constant 742 m across the three thousand kilometer scan. The Day/Night band (DNB) is also the first to utilize onboard calibration [1].

The VIIRS DNB uses advanced onboard aggregation techniques to achieve constant spatial resolution across scan with 32 aggregation zones. Since each zone has its own calibration, it is not easy to validate the calibrated radiances across the zones. It is also found that in J1 VIIRS prelaunch testing, a large nonlinearity exists in the higher aggregation zones, which would lead to a significant bias across zones along scan. This study attempts to evaluate the response versus scan by using point sources [2] such as bridge lights, oil platforms, and flares to potentially quantify the effect. The challenges in this work are also discussed.

Methodology

To evaluate the DNB radiometric response versus scan angle, we select ground based night light sources. Ideal sources should be stable over time and spatially isotropic (or radiating equally in all directions). However, not many targets are truly stable due to fluctuations of power supplies, and atmospheric changes. Analysis of night lights from DNB led us to focus on bridge lights, oil platforms and gas flares. We are mostly interested in the lights over water because this greatly reduces lunar reflection from the surrounding areas, which would complicate the analysis.

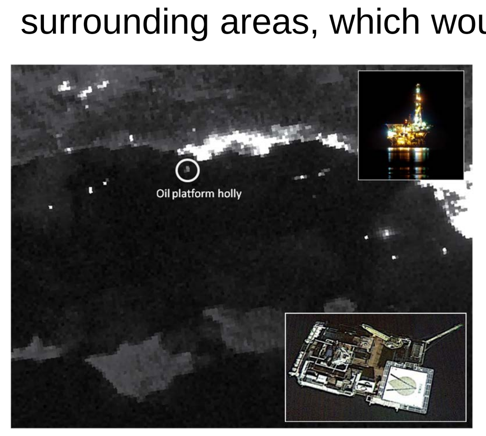

Figure 1. DNB image of the oil platform Holly

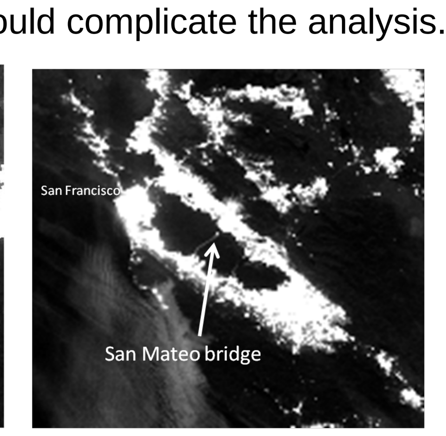

Figure 2. DNB image of the San Mateo bridge

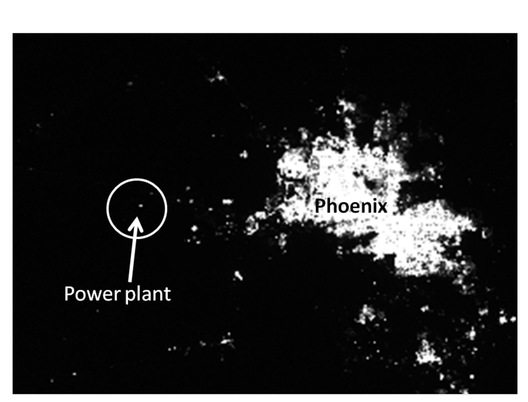

Figure 3. DNB image of the the power plant near Phoenix, Arizona

Figure 1 shows an example of night lights from the oil platform Holly located near Los Angeles. It is about 50 meters long and 29 meters wide over the water. The lights appear to be always on at night and are relatively stable as a point source for DNB radiance and geolocation analysis. Although oil platforms have lights on overnight, their stability long term is not well known. For example, some lights on the platform may be turned on and off at a given schedule. This increases the uncertainties for radiance validation.

The San Mateo bridge in San Francisco (Figure 2) is another point source over the water. In comparing with the oil platform holly, the bridge has more points and they are assumed to be more stable over time since the lights are turned on over night as a requirement for transportation safety. Some of the bridge lights have been replaced with LEDs which are extremely stable.

Figure 3 shows the power plant located on the west about 40 miles away from Phoenix AZ, which is a good candidate for a ground based night light source. Although there is little light around the power plant, and also Arizona has more clear sky at night, the ground lunar reflection may affect the stability of DNB radiance and geolocation.

Finally, gas flares are assumed to be on all the time, but the stability is unclear. Furthermore, it is not clear how gas flare intensity is related to oil production volume, and whether there is a daily schedule. In this study, we also tested using gas flares in the mid-east region. Despite the challenges, we believe that by using multiple sites and multiple types of light source, the uncertainties in those factors can be reduced.

Other uncertainties include the atmospheric effects, which may have a different attenuation at different view angles. In addition, the sensor spatial response (aka MTF or point spread function) is different at different aggregation zones.

In this study, we use the following procedure to analyze the DNB response at different scan angles:

1. The DNB observations at nadir are collected at 16 day orbital repeating cycles to evaluate the stability of the night light source. [3]
2. The DNB observations at different scan angles for all days are collected and plotted against the scan angle to study the response vs. scan angle.
3. The results are analyzed in relation to various factors to estimate the effect of the scan angle or frame
4. The potential use of this method for J1 DNB aggregation (Figure 4) evaluation is assessed.

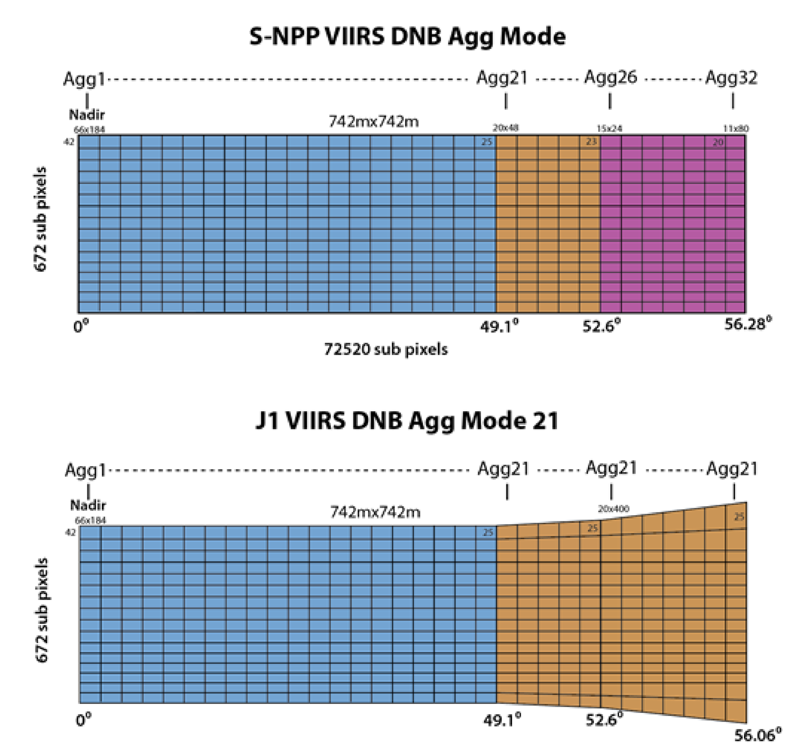

Figure 4. VIIRS DNB aggregation scheme for NPP and J1 (Notional drawing, not to scale, subject to change)

Data Sets and Analysis Results

The data set we used for the analysis is VIIRS DNB SDR data with geolocation/terrain correction for Suomi NPP.

- The data sets used are from time period 2014 and 2015 (Table1).
- The max radiance vs. frame number for San Mateo bridge, platform Holly, power plant in AZ and Bahrain passport control are shown in Figure 5.

Table 1. Data sets used in the study

Location	**Time series**
San Mateo bridge (San Francisco)	12/04/2014 – 04/02/2015
Oil platform holly (Los Angeles)	12/15/2014 – 04/06/2015
Power plant (AZ)	12/11/2014 - 04/12/2015
Bahrain passport control	12/02/2014 - 04/13/2015

Figure 5 shows that there appears to be a scan angle dependent radiance bias across scan. At nadir, the radiance is lower than those at the beginning and end of the scan. The magnitude of the radiance variation over different scan angle for the east end of the bridge is about 1e-8 to 4e-8 w/cm^2-sr, which is a change of about 4x time (or from 3e-9 to 1.5e-8 w/cm^2-sr for the middle site). Note that this pattern is consistent for the two sites used, one on the east end of the bridge and the other is in the middle of the bridge.

There are several possible causes for the scan angle dependent bias. First of all, it is possible that there is a radiometric bias across the aggregation zones. This was not extensively studied for Suomi NPP VIIRS DNB, although more attention was paid during the J1 VIIRS DNB prelaunch testing. If this is the case, then the plot here would be very useful for comparing with J1 VIIRS DNB once it is launched, since it is known that J1 VIIRS DNB has a much larger effect in scan dependent bias.

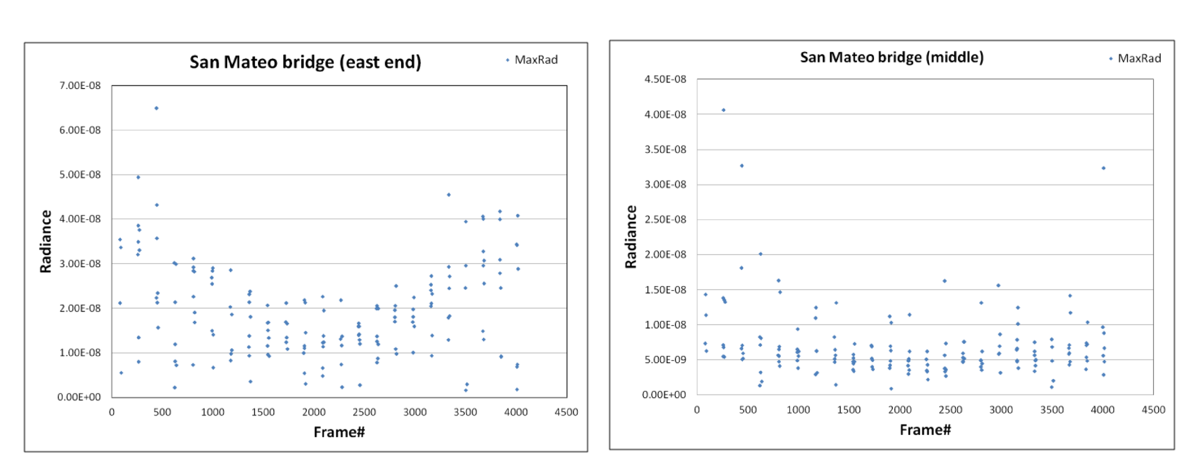

Figure 5. Radiance vs. scan angle for San Mateo bridge (left: east end; right: middle of bridge)

Other causes include atmospheric path length and scattering, response versus scan (RVS) angle, the point spread function changes from nadir to end of scan, time of the observation due to traffic lights, calibration bias across aggregation zones. Finally, air glow [4] may have an impact but the magnitude is on the order of 1.0e-9 which cannot explain the pattern in Figure 5.

Figure 6 shows the response vs. scan for the oil platform holly located on the west coast near Los Angeles. A similar scan angle dependent bias is also found here. At nadir, the radiance of 5e-9 w/cm^2-sr is much lower than those at the end of the scan (Compared to the lights on the San Mateo bridge, it seems that the radiance from the oil platform Holly is not as stable).

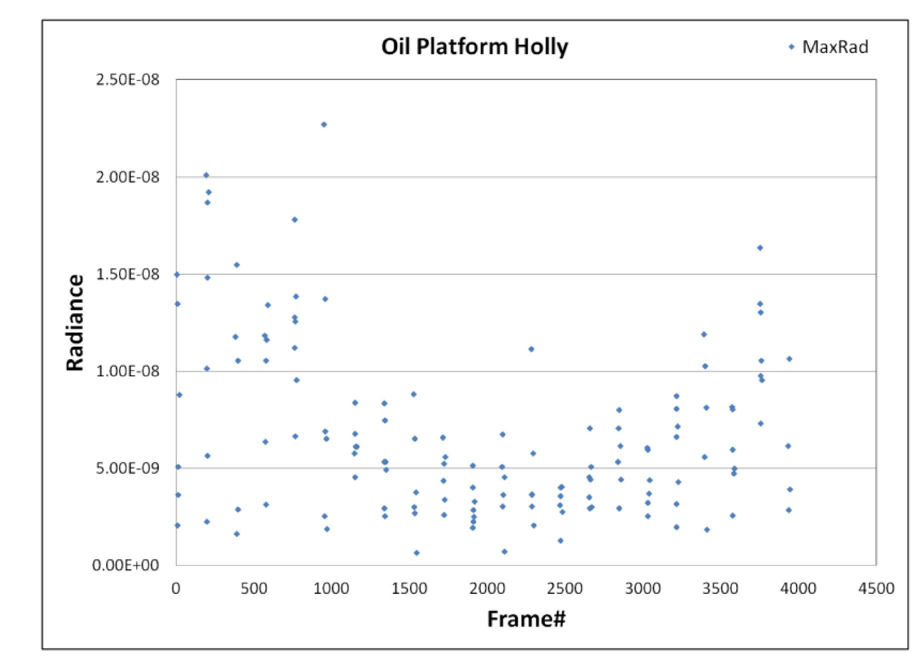

Figure 6. Radiance vs. scan angle for Oil Platform Holly

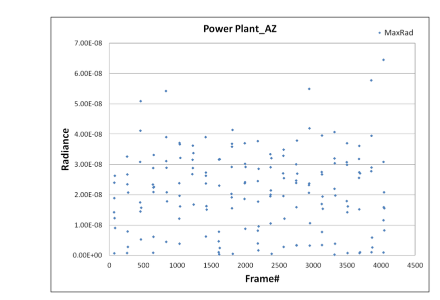

Figure 7. Radiance vs. scan angle for the power plant in Arizona

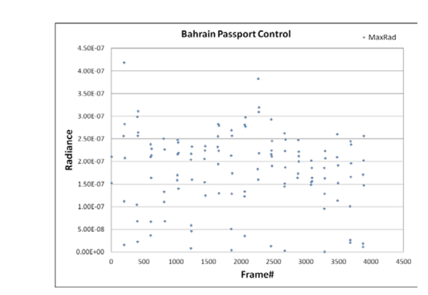

Figure 8. Radiance vs. scan angle for the passport control of Bahrain

The power plant in Arizona and the passport control of Bahrain are the ground base point sources. In comparison with Figure 5 and Figure 6, the pattern for Figure 7 and Figure 8 are not very clear. It might be due to the effect of the ground lunar reflection which may have disrupted the pattern. Also it can be due to ground reflection of street light.

Conclusion

Preliminary analysis of the scan-angle dependence of the light intensity from bridge lights, oil platform, power plants, and flares observed by VIIRS DNB since 2014 are presented in this study. Results show that there appears to be a scan angle dependent radiometric bias, with a low radiance at nadir while gradually increases towards edge of the scan. This pattern is found in both the San Mateo bridge and the oil platform holly samples, although it is less clear for the Arizona power plant and Bahrain cases. It is possible that this effect is due to the VIIRS DNB aggregation zones on Suomi NPP VIIRS, which would also help study the effect of J1 VIIRS DNB nonlinearity at high scan angles, which requires the use of new aggregation modes. However, the results are preliminary and more analysis is needed to get a better understanding of this effect. Other effects such as atmospheric path length and light on/off schedule as well as traffic volume may also contribute to this pattern. We found that the point sources over water have the clear advantage than the ground base point sources for the radiance and geolocation validation analysis since there is little reflection from the water and this reduces the uncertainties compare with the ground point source.

References

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