Comparison of the NOAA and NASA VIIRS DNB Stray Light Correction Methods

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1. Introduction

The VIIRS onboard the Suomi National Polar-Orbiting Partnership (SNPP) satellite provides a panchromatic Day/Night Band (DNB, 500 – 900 nm) that can detect signals from very dim nighttime scene. DNB data have been applied in many areas such as city lights with power assumption, urban expansion, fishing boats, air glow, aurora, and lighting. However, DNB observations at high latitude are affected by stray light, which is detector, HAM side, scan angle, and spacecraft solar zenith angle and azimuth angle dependent. Two methods have been developed by NOAA and NASA to remove stray lights from the affected regions. The purpose of this study is to compare the two DNB stray light correction methods to investigate potential improvements to the NOAA method.

2. NOAA Operational VIIRS DNB Stray Light Correction

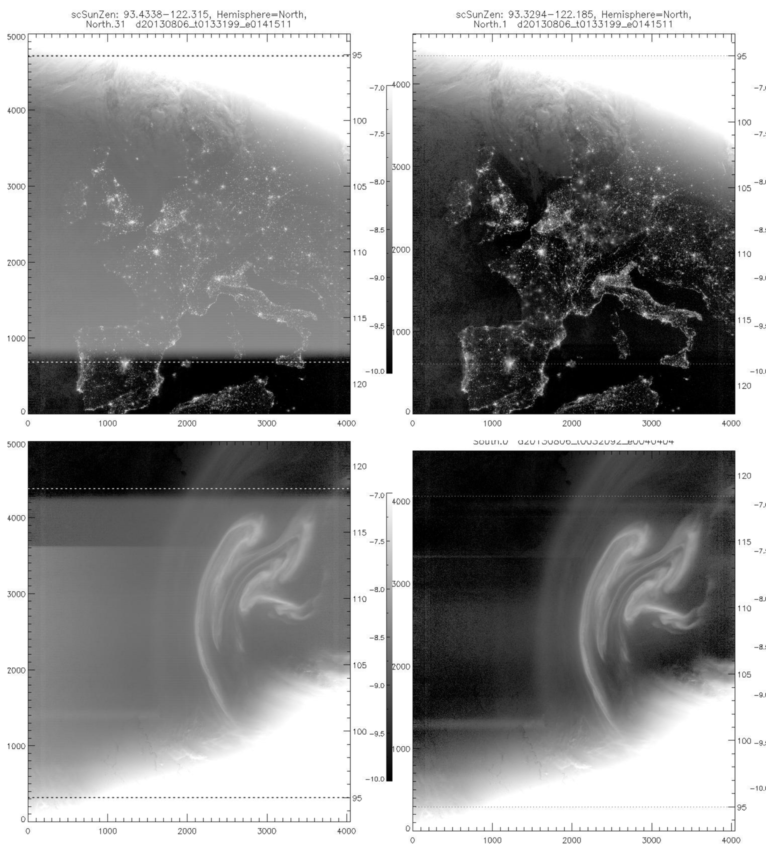


Fig.2-1 VIIRS DNB observations for before (left panel) and after (right panel) the NOAA operational stray light correction.

- NOAA operational processing adopted a method initially developed by NG (Liao et al., 2013; Mills et al., 2013) which uses manually staged stray light contaminated earth view data during 3-day of new moon period. Detector, HAM side, scan angle, and spacecraft solar zenith angle dependent stray light correction look-up table (LUT) is fitted using the selected data for each month. 20-30 granules are usually selected per month for each hemisphere.
- 12 LUTs were developed using 1 year of new moon data (July 8, 2013 – May 28, 2014). Overall, the correction can be reused. IDPS has been recycling the 12 LUTs since June 2014.
- STAR successfully transitioned the SNPP DNB Stray Light correction from NG to STAR in late 2014
- STAR has been supporting operational stray light LUT updates with solar vector error correction since January 2015.

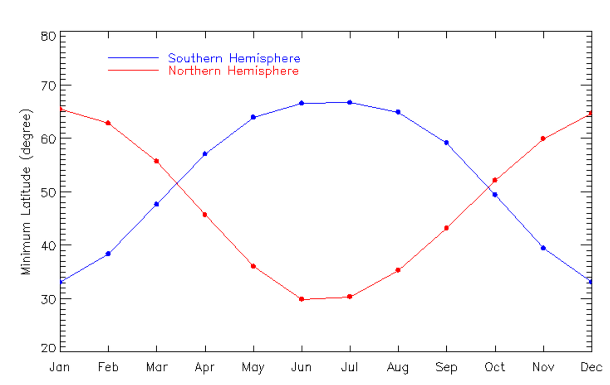


Fig. 2-2 Seasonal variation of the lowest latitudes that are affected by stray light, estimated using one year of DNB new moon data. During summer, stray light can affect regions as south as 30° latitude in the Northern Hemisphere.

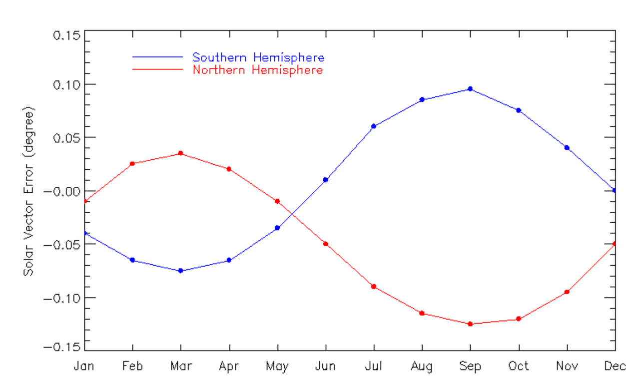


Fig.2-3 Impact of solar vector error on SC solar zenith angle.

3. Comparison of NOAA /NASA DNB Stray Light Corrections

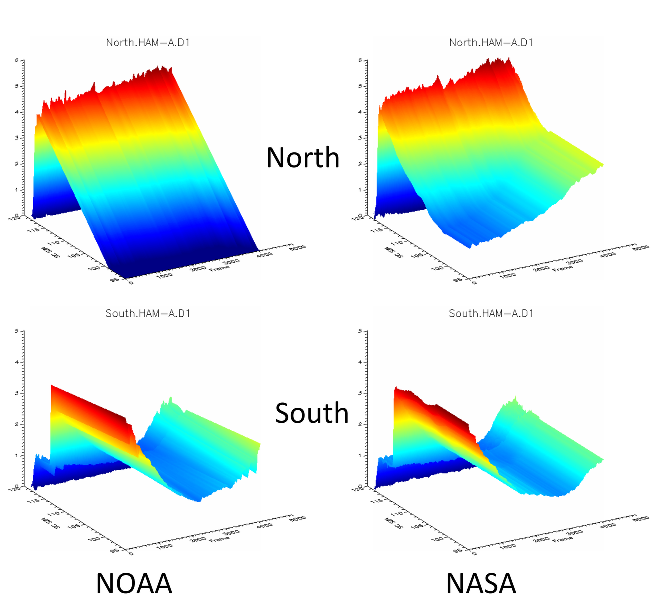


Fig 3-1. Comparing NOAA versus NASA stray light correction LUTs (20130806 new moon date).

- NASA VCST team follows the same principle as the NOAA method and developed a statically-based method that automatically generates monthly stray light correction LUT using one day of earth view data during the new moon without the fittings (Lee et al., 2014).

NOAA & NASA stray light LUTs share many common features:

- Stray light contamination is stronger in the Northern Hemisphere
- NASA and NOAA LUTs are generally consistent for the Southern Hemisphere
- NASA and NOAA LUTs show similar detector-dependent patterns
- Differences between HAM-A and HAM-B are both small in NOAA and NASA LUTs.

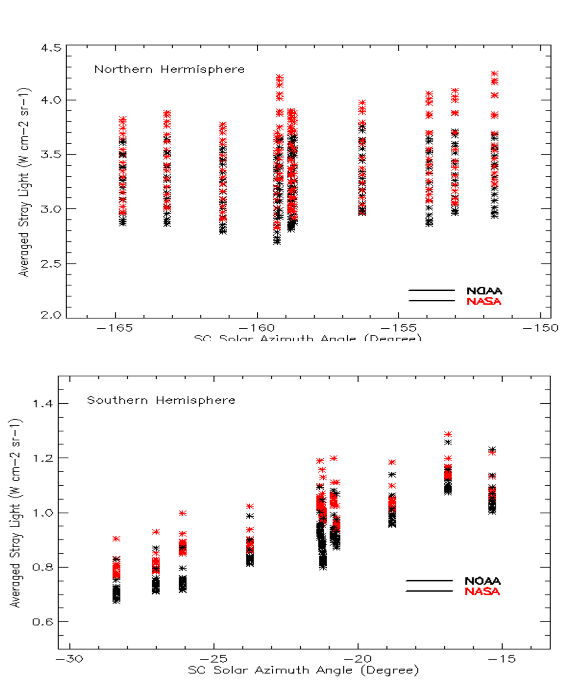


Fig 3-2. Relations between stray light and SC solar azimuth angle for 16 detectors (near nadir, 110°<SC solar zenith angle<118.4°)

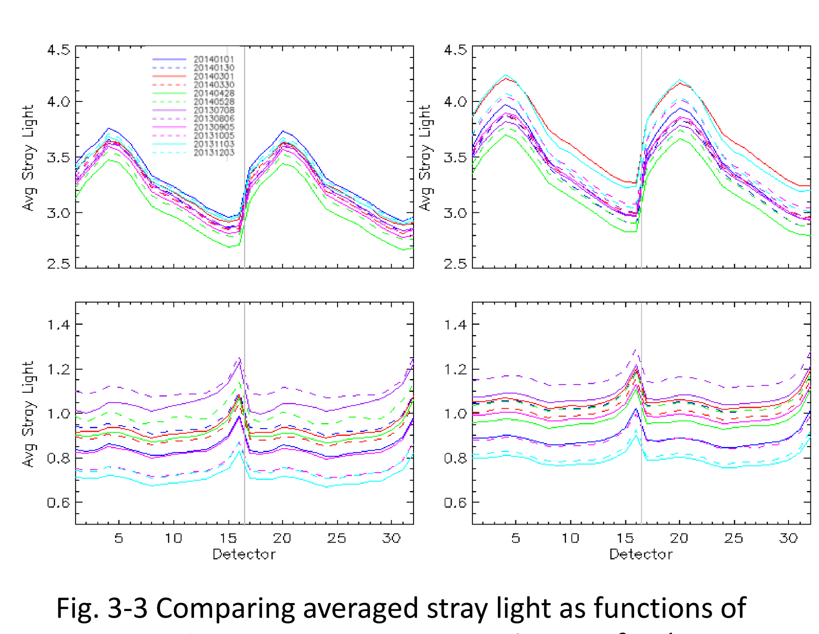


Fig. 3-3 Comparing averaged stray light as functions of detectors for NOAA and NASA LUTs (nW cm^{-2} sr^{-1}, near nadir, 110°<SC solar zenith angle<118.4°). Stray light is highest for Detector 4 (D4) and lowest for detector 16 (D16) in the Northern hemisphere. The detector level variations in the Southern Hemisphere is much smaller.

- **Northern Hemisphere**: larger detector-dependent stray light variations exist;
- **Southern Hemisphere**: detector-dependent stray light variations are small; stray light is strongly correlated with SC solar azimuth angle (R>0.9).

- NASA LUTs are generally smoother due to the use of more data to generate a LUT than the NOAA(NG) method; The less smooth NOAA LUTs may cause more striping.
- NASA LUTs show larger monthly variations compared to those from NOAA in the Northern Hemisphere.

4. Arctic DNB Striping Case Study

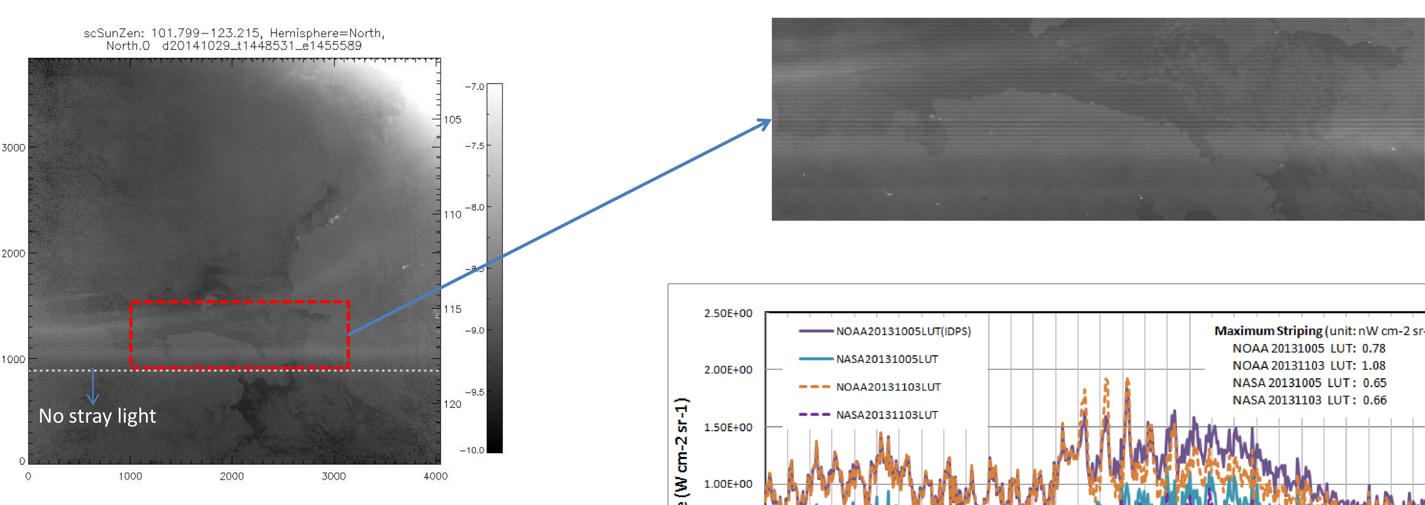


Fig. 4-1 October 29, 2014 STAR operational DNB granules over the Arctic. Significant striping is observed after operational stray light correction (using 20131005 LUT), especially near the penumbra zone. No obvious striping is observed in the stray light free region, indicating that the striping is due to imperfect stray light correction.

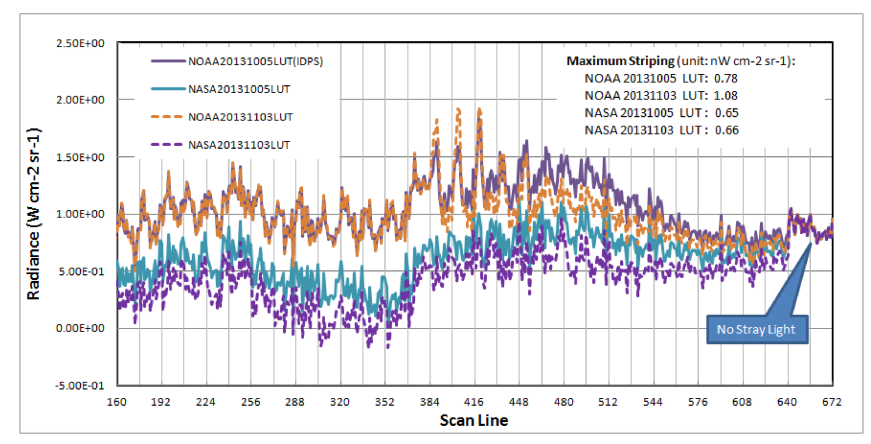


Fig. 4-2 Comparing the performance of NOAA and NASA LUTs at nadir (sample 2032). Results using NASA LUTs have smaller striping.

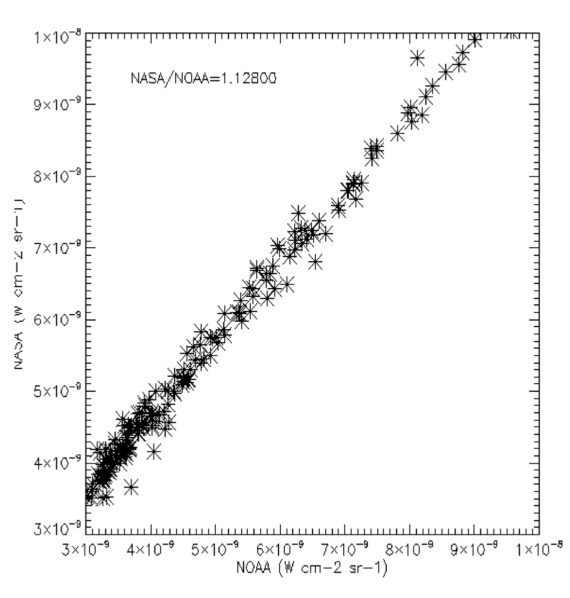


Fig. 4-3 Radiometric calibration difference between NOAA and NASA DNB radiance is less than 13% based on radiance ratio using data from no stray light region. The differences in striping is much larger than that for calibration.

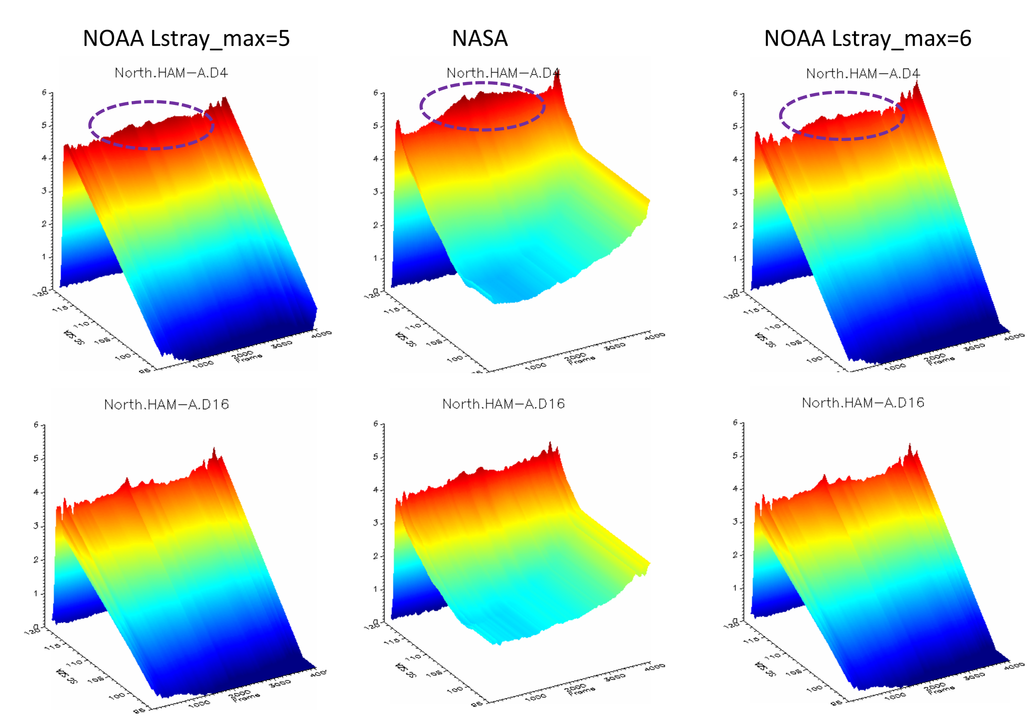


Fig. 4-4 Comparing NOAA and NASA 20131005 stray light LUTs. Stray light effect is highest for D4 and lowest for D16 (see Fig. 3-3). After increasing Lstray_max threshold from 5.0 to 6.0 nW cm^{-2} sr^{-1} for the NOAA LUT, D4 stray light values increase, while values for D16 remain unchanged.

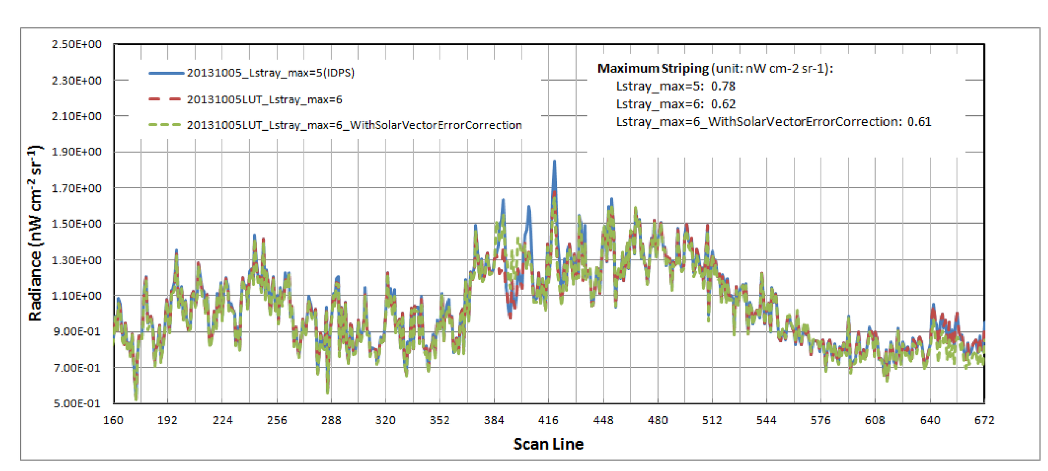
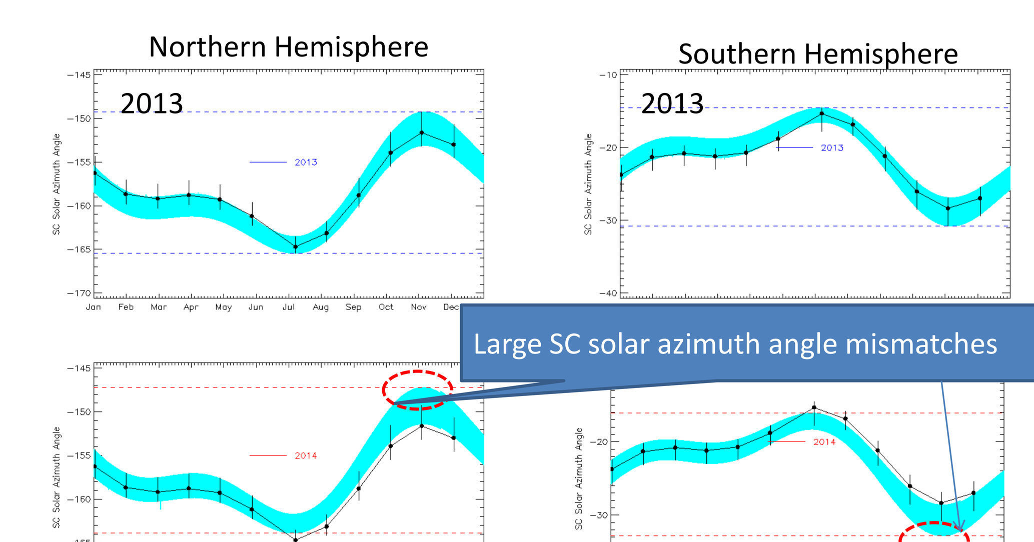


Fig. 4-5 Comparing the performance of NOAA 20131005 LUTs with higher Lstray_max threshold and solar vector error correction. LUT developed with higher Lstray_max threshold (red dash line) reduces striping. Solar vector error correction (green dash line)also helps reduce striping, however, its impacts are small. However, detector-dependent striping still exists in some regions. More new moon data may b required to better characterize stray light.



The SC solar azimuth angle mismatch between October 2014 DNB observations and 2013 stray light LUTs due to 2014 SNPP orbital change may also cause striping. This issue will be studied in the future.

Fig. 4-6 Mismatch between the SC SAA in the DNB new moon data used to generate the 12 NOAA LUTs (black color, min/mean/max) and SC solar azimuth angle variations for the 2013/2014 stray light affected regions (cyan color).

4.Summary and Future Work

- The NOAA and NASA DNB stray light correction methods were analyzed using 12 LUTs developed based on July 2013 – May 2014 new moons:
  - Stray light characterizations for the Southern Hemisphere are generally consistent;
  - Larger differences exist for the Northern Hemisphere between the two methods.
- Based on the Arctic DNB striping case study, increasing Lstray_max threshold may reduce striping in the NOAA operational DNB nighttime product in the Northern Hemisphere.
- NASA LUTs are smoother than those from NOAA, indicating more new moon data need to be used in order to improve the NOAA LUTs;
- Solar vector error correction may also reduce striping, but its impacts are small.
- More work is needed to investigate the impact of the Oct/Nov 2014 SC solar azimuth angle mismatch on NOAA operational stray light correction.

References

1. Mills, S., S. Weiss, et al. (2013). VIIRS day/night band (DNB) stray light characterization and correction. Proc. SPIE 8866, Earth Observing Systems XVIII, 88661P, San Diego.
2. Liao, L. B., S. Weiss, et al. (2013). "Suomi NPP VIIRS day-night band on-orbit performance." Journal of Geophysical Research: Atmospheres 118(22): 2013JD020475.
3. Lee, S., C. Sun, et al. (2014). An overview of NASA VCST SNPP VIIRS day/night band on-orbit calibration methodology. Proc. SPIE 9218, Earth Observing Systems XIX, 921808, San Diego, CA.