Recent Improvements in S-NPP VIIRS DNB Calibration

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Outline

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- DNB major calibration updates timeline
- Improvement in low light radiance accuracy
  - Airglow contamination and impacts
  - Airglow removal from dark offset
- Reprocessing-led Improvements
- LCRI based automated straylight correction
- Summary

Introduction

- Suomi NPP VIIRS is equipped with day/night band (0.5-0.9um) capable to view earth in visible spectrum both during day and night.
- Wide dynamic range (specification: 7 orders magnitude) is made possible by using 3 gain stages (LGS/MGS/HGS).
- DNB HGS detectors are highly sensitive to detect faint emission from airglow.
- Why characterizing airglow is important for DNB?
  - DNB dark offset is primarily determined by viewing the Pacific Ocean during new moon.
  - Presence of airglow overestimates the dark offset which has direct impact on DNB SDR (calibrated radiance) and EDR such as near constant contrast (NCC) imagery.
- Analyzed how the absolute accuracy of low light radiance can be improved using airglow free dark offset.
- In addition, reprocessing at STAR results in entire DNB archive with improved and consistent calibration.
- Recently, an automated technique for straylight LUT has been developed that removes manual work involved in current operational straylight LUT generation.

NOAA IDPS: DNB Major Calibration Updates

<u>March 2012</u>
1st calibration update using VROP

- *Updated both onboard and ground offset tables and gain ratio*
- *Improved the radiometric accuracy of esp. for HGS data.*

<u>April 2013</u>
DNB RSR LUT updated with modulated RSRs

- *Accounts for the RTA degradation impact on RSRs*
- *Improved the radiometric accuracy of all gain stages*

<u>August 2014</u>
Straylight correction implemented

- *Characterize and correct the straylight*
- *improves the data quality*

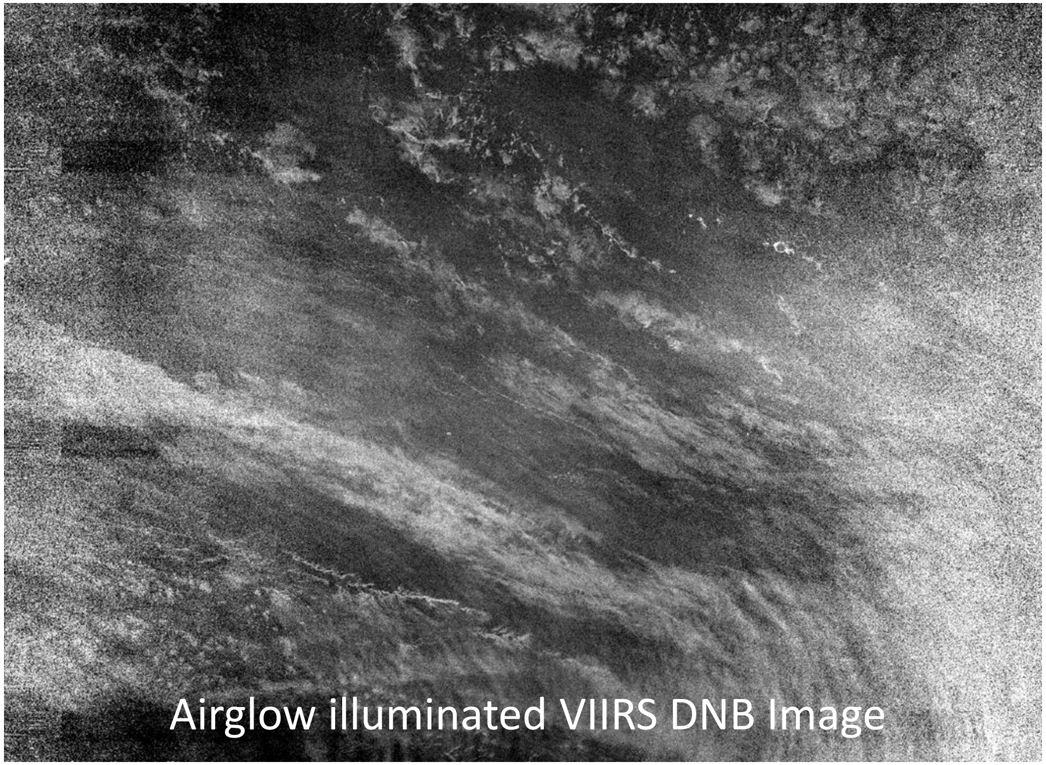
<u>May 2015</u>
DNB terrain correction implemented

- *Improves the geolocation accuracy (accuracy from few pixels (over high altitudes such as Tibet) to sub-pixel level)*

<u>January 2017</u>
Deep space based DNB dark offset (DN0)

- ***Removes airglow from dark offset***
- ***Improves the radiance accuracy by more than 10% at low radiance.***

New Moon Night over Ocean



HGS granule taken on 22 Sep 2014 between 11:47:052 and 11:52:46 UTC, during a new moon in the region over the South Pacific Ocean. The plotting range from black to white is from -8.3×10^{-11} to 4.2×10^{-10} W cm^{-2} sr^{-1}.

Airglow profile

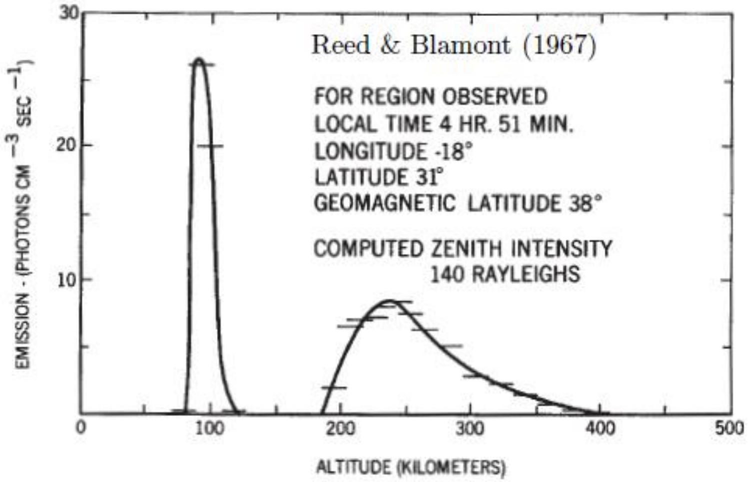
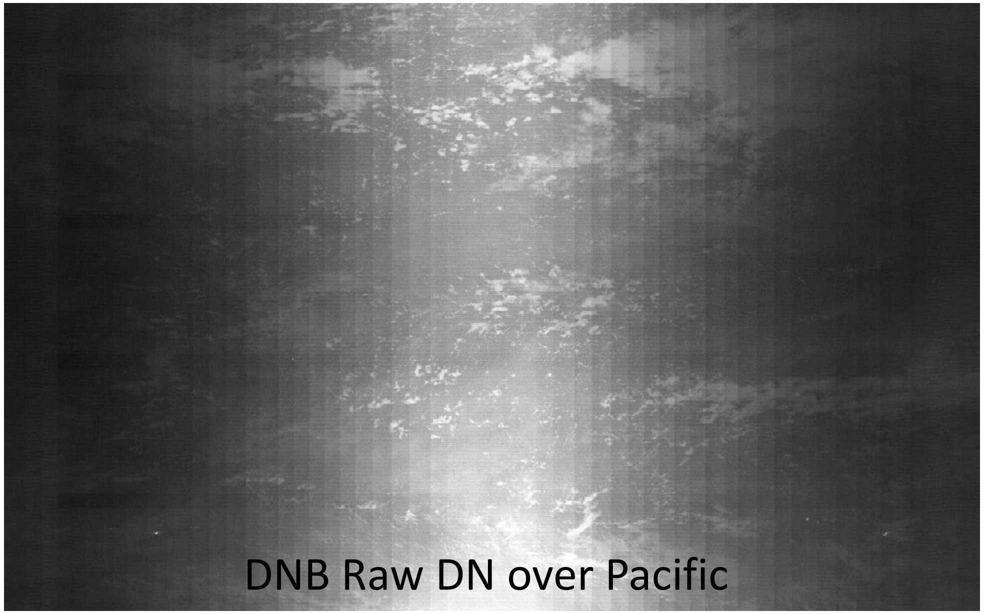


Fig. 1. A typical height profile of airglow volume emission (satellite OGO II). The peak near 90 km is due to OH emission, the extended peak at higher altitudes to [OI] emission at 630 nm (Leinart et al., 1998)

Nighttime illumination of earth during new moon is dominated by airglow. A part of illumination also comes from star lights.

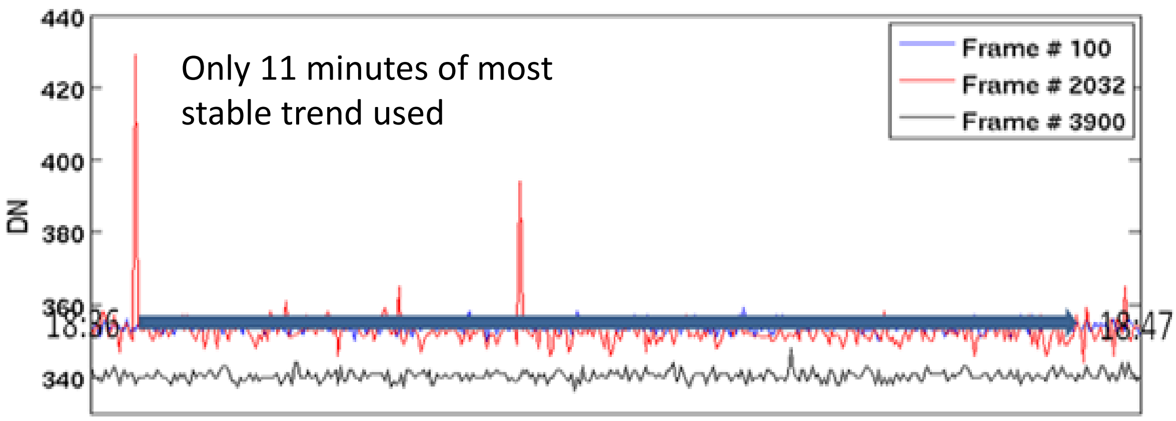
Airglow Impact in DNB Calibration



- *DNB HGS Radiance = (Raw DN – Dark offset) * Gain_Ratio*$_{LGS/HGS}$ * *Gain*$_{LGS}$
- Airglow impact on Gain$_{LGS}$ and Gain_Ratio$_{LGS/HGS}$ are negligible
- Dark Offset over pacific Ocean during new moon: True dark offset + airglow
- **Airglow Impact**:
  - *Increase in dark offset*
  - *Underestimation in DNB radiance*
  - *Results in plenty of negative radiance pixels in SDR*
- *Is it possible to get airglow free DNB data to estimate dark offset?*

DNB Deep Space Observation

- On Feb. 20, 2012 SNPP had a pitch maneuver for instruments to collect deep space data.
- Deep space measurement is not contaminated by airglow. However, it can still have some faint light from stars.
- Airglow free deep space data results in dark offset values that are smaller than the one using dark ocean.
- Airglow free dark offset can be scaled using onboard calibrator data to estimate the temporal trend required for long term calibration.



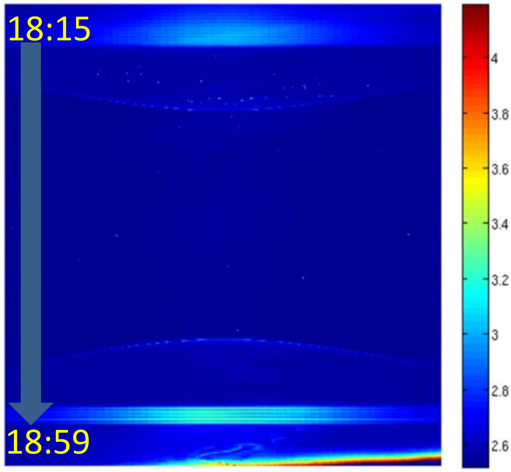


Figure 3. Pitch maneuver based deep space view data for 3 samples as a function of time. Raw digital counts are higher near nadir. Few large spikes are due to bright stars.

Airglow Contamination in Dark Offset

- VIIRS on-orbit dark offset
  1. determined for the 1st time using observations over Pacific on Feb. 21, 2012.
     - Airglow contaminated
  2. determined once using deep space data collected on Feb. 20, 2012.
     - No airglow
- Difference between above two offsets provide estimation on the airglow contamination.
- Figure shows zenith dependency with magnitude at the edge more than twice than that at nadir (~0.2 nW/[cm^2-sr]).
- ***Impact of airglow on SDR product varies as a function of scan angle and the magnitude of absolute radiance of a pixel.***

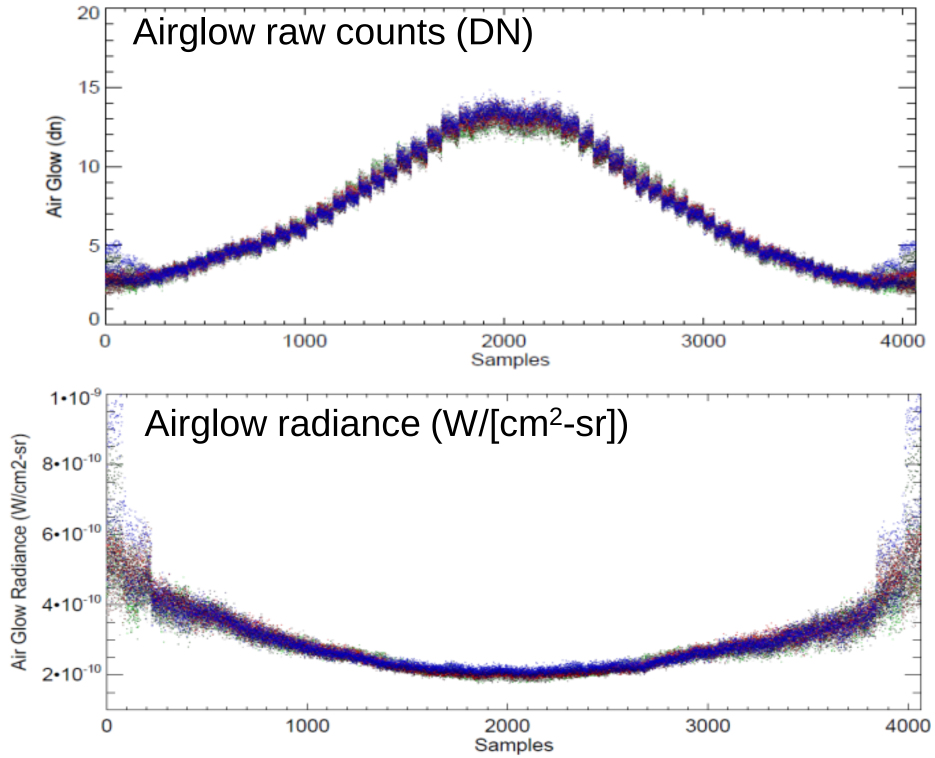


Figure 5. Airglow contamination in Dark Offset

Quantify Impact of Airglow

- Figure shows the DNB radiance difference (%) for a nighttime granule calibrated using dark offset with/without airglow.
- Impact of airglow contaminated dark offset on radiance
  - increases with increase in scan angle and
  - decreases with increase in pixel radiance.

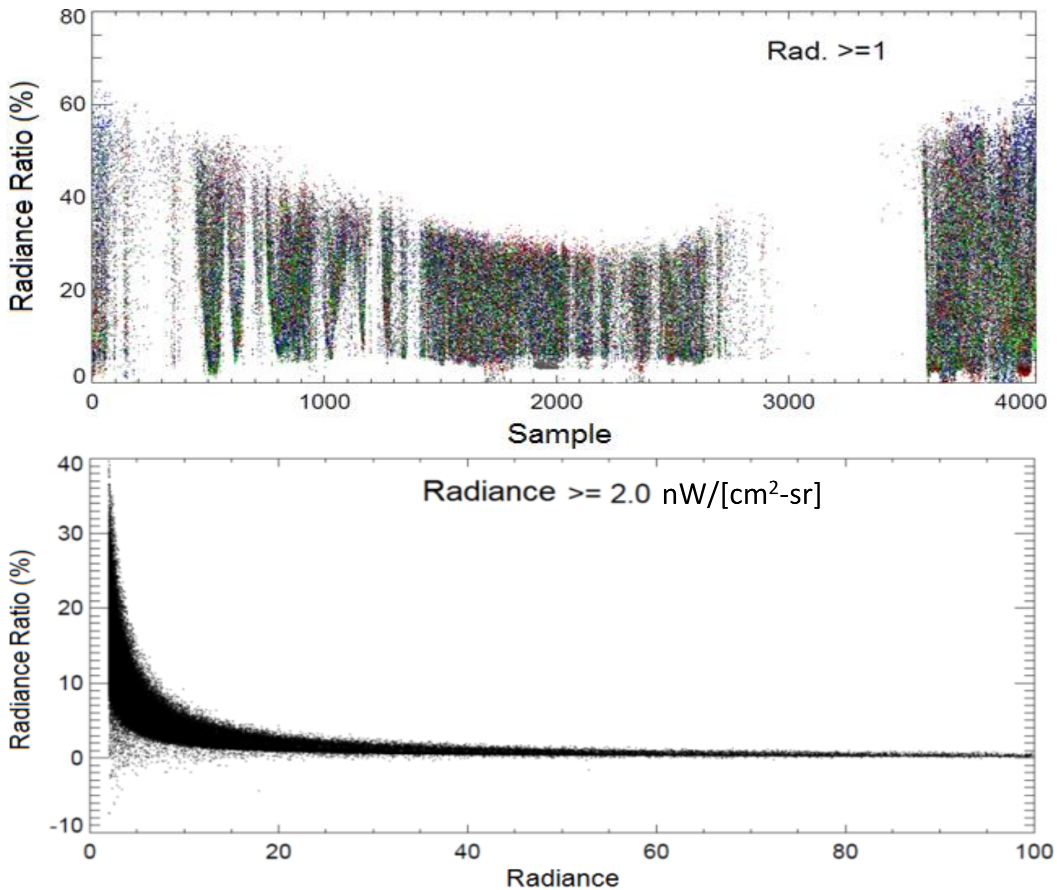
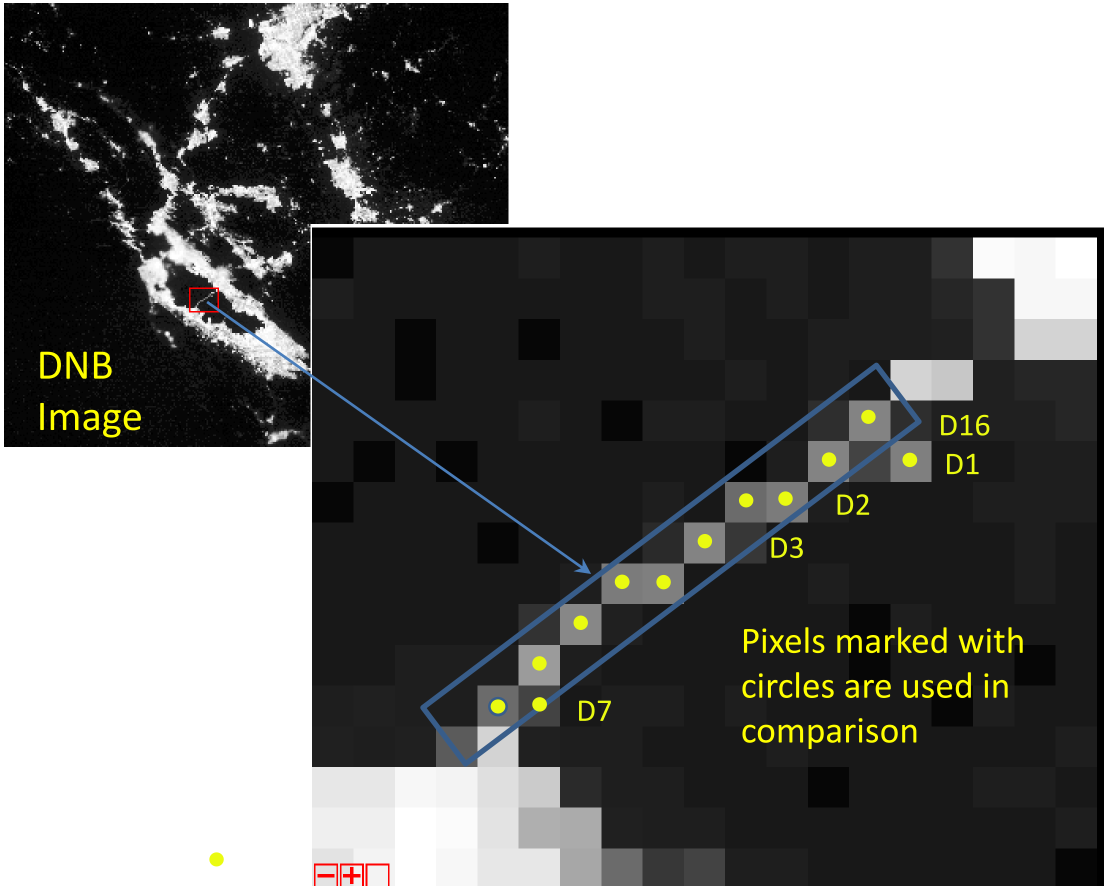


Figure. Ratio of radiance granules calibrated using dark offsets based on a) deep space data and b) dark ocean observation

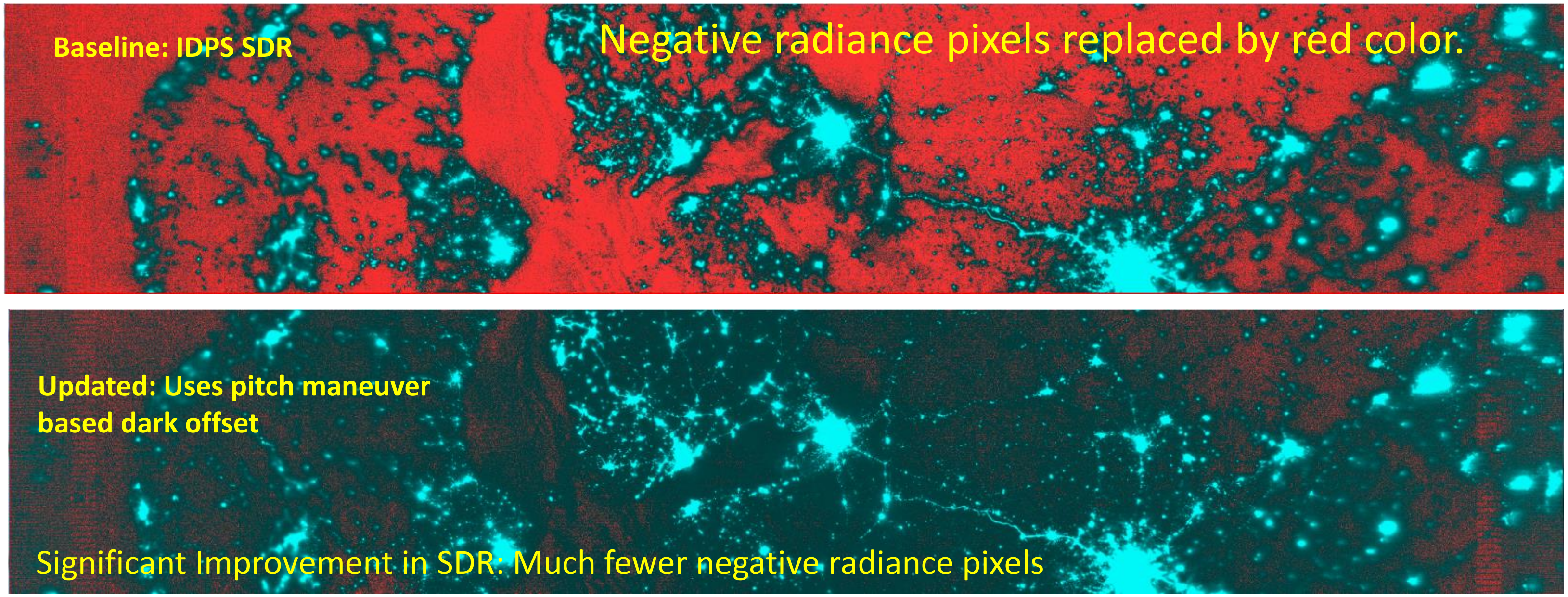
A Case Study over San Mateo Bridge



~10% discrepancy in radiance is consistent with previous study (Cao et al. 2015).

- Majority of radiance for bridge pixels (yellow dots) ranges from 3-4 nW/[cm^2-sr].
- ~10% increase in radiance near nadir after using dark offset without airglow.
- The impact increases with decrease in absolute pixel radiance or the increase in scan angle.

Benefit of Airglow Free Dark Offset: Reduction in Negative Radiance Pixels



Data acquired: 01/03/2017 @00:31 UTC

- Presence of airglow results in large percentage of negative radiance pixels in operational DNB data esp. over clear sky region near new moon nights.
- Negative radiance pixels in a night granule reduced mostly by more than 70% near nadir and by more than 40% near edge after using airglow free deep space view based dark offset.

Update in Operational Calibration

Note to user community

- *NOAA operational IDPS started to use airglow free dark offset since Jan. 12, 2017*
- *Reprocessed DNB data at NOAA STAR uses airglow free dark offset.*

Reprocessing-led Improvements in DNB SDR

- IDPS has only one update in DNB RSR LUT (April 05, 2013).
  - Reprocessing uses **time dependant DNB RSRs** for entire archive.
- IDPS offset table is generated using Earth View (EV) data that is contaminated by air glow.
  - Reprocessing uses deep space based **airglow free dark offset**.
- IDPS DNB SDR data before 03/20/2012 has poor calibration due to absence of on-orbit based offset and gain ratio.
  - Reprocessing uses **on-orbit based offset and gain ratio for entire DNB SDRs**.
- DNB straylight light correction went operational in IDPS in August 2014.
  - Reprocessing implements **straylight correction for entire DNB archive**.
- DNB terrain correction (TC) went operational in IDPS in May 2015.
  - Reprocessing produces **terrain corrected geolocation** data for all DNB SDRs.
  - Geolocation accuracy improved from few kms at high altitude to sub-pixel level (few hundred meters).

Recent Improvement in DNB Straylight Correction Processing

- Current operational stray light correction for VIIRS DNB at IDPS is based on monthly stray light correction Look-up-Table (LUT).
- Granules with stray light around new Moon are visually inspected for minimum light contamination such as artificial light, aurora or other light sources and then are selected for stray light correction LUT generation.
- After May 2015, LUTs accumulated over past one year have been annually recycled and applied to operational stray light correction
- Developed a light contamination ranking index (LCRI)-based algorithm to automate DNB granule selection and stray light correction LUT generation

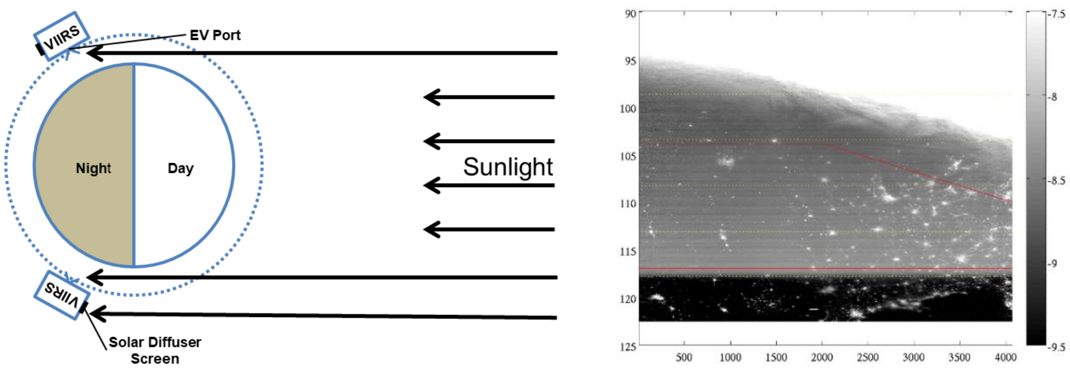
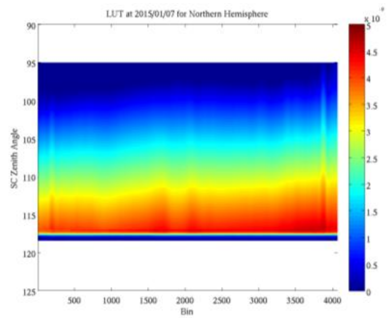
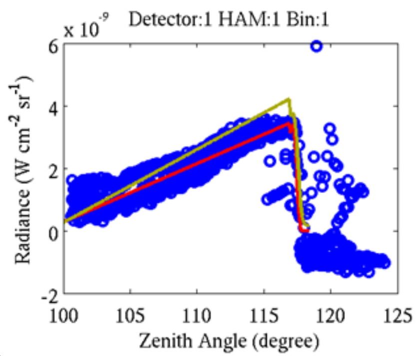


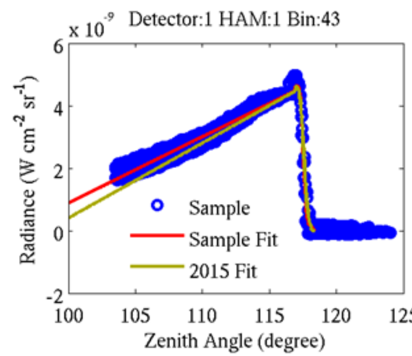
Figure 1: Left: Paths of sunlight illumination onto VIIRS as sources of stray light for DNB in northern and southern hemisphere. Right: Typical northern hemisphere DNB image with stray light contamination.

LCRI-based Method for Automating DNB Stray Light Correction



Northern hemisphere DNB stray light correction LUT Using LCRI method





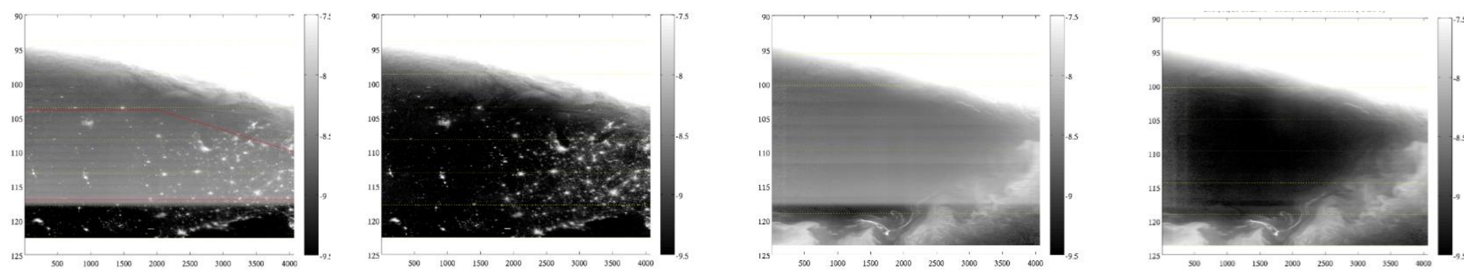


Figure 8: Example of DNB images over northern hemisphere before (Panel #1 and #3) and (Panel #2 and #4) after applying stray light correction LUT generated with LCRI method. Effectiveness of stray light correction in revealing artificial light and aurora can be clearly seen.

Ref. Shao et al. (2017)

Summary

- Major improvements in VIIRS DNB operational calibration by using airglow free dark offset:

  1. significant improvement in the absolute accuracy of low light radiance
     - *Pixels with ~3 nW/[cm^2-sr] radiance suggest accuracy improvement by more than 10% at nadir.*
  2. significant reduction in negative radiance pixels in SDR
     - *Negative radiance pixels in a night granule reduced mostly by more than 70% near nadir and by more than 40% near edge.*

- Reprocessed VIIRS DNB data at STAR results in entire data archive with improved and consistent radiometric and geometric calibration.

- Developed a light contamination ranking index (LCRI)-based algorithm to automate DNB granule selection and stray light correction LUT generation.