Suomi-NPP VIIRS Nighttime Environmental Products for Global Land Science and Disaster Response Applications

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(1) Devising effective emissions reduction strategies.
“Cities are brighter during the holidays than any other time in the year.”

– Time Magazine
You can see the glow from down the street. Now NASA can see it from space.
(2) Reducing energy poverty and increasing energy accessibility.
SUSTAINABLE DEVELOPMENT

Cote d'Ivoire - Emergency Infrastructure Renewal Project

Korhogo/Bouake/Yamoussoukro: 1-19-2012

Informal Settlements
Roads & Dense Residential Areas
Industrial & Commercial Areas

Count

Radiance [nW m⁻² sr⁻¹]

Korhogo, Population: 286,000
+B122%

Bouaké, Population: 536,000
+28%

Yamoussoukro, Population: 106,000
+30%

Budget: $200 million (USD) - Project Duration: 2012-2016
(3) Assessing social vulnerability and the cascading effects of disasters.
LANCE: NASA NEAR REAL-TIME DATA AND IMAGERY

Satellite Observations Monitor Outages From Superstorm Sandy

Molthan et al., 2013
Jeddah, Saudi Arabia
The Holy Month of Ramadan
“In the Middle East, some cities saw a 100% boost in illumination during the month of Ramadan compared to the rest of the year.”

– BBC News
Tel Aviv, Israel
Aleppo, Syria

“NASA Scientists can measure the EKG of a City”
– Smithsonian Magazine
New era of global energy cooperation requires new data and analytical tools.

**UN SDG-7:** Ensure access to affordable, reliable, sustainable, and modern energy for all.

**So What?**
Confluence of urban energy, development, and climate change agendas.

**Solutions?**
VIIRS is a step towards satellite-derived “energy intelligence”.

**Challenge?**

**Benefits?**

**Human-Centered Energy Research**

Message Box Handout: *Leopold Leadership Program at Stanford University*
VIIRS nighttime detection capabilities (a) with and (b) without lunar illumination.
Suomi–NPP VIIRS enables mapping of the economic, mobility, informational, and operational drivers that connect our cities to their surrounding landscape.
F/V Kiska Sea

Ice Edge

Crab Fleet

Dutch Harbor

Credit:
Eric Stevens
eric@gina.alaska.edu
• Correcting non-uniform brightness effects during first/third lunar quarter and reducing under-cloud-light glare in Enhanced NCC and comparing with other image products.

• Dynamic DNB (1st row) uses ‘erf-dynamic scaling’ (Seaman & Miller, 2015).

• Lunar Reflectance (2nd row) is scaled between 0 and 1.4 (the scale used in NOAA-CSPP CLAVR-X internal image implementation).

• The NCC (3rd row) and the Enhanced NCC (4th row) grayscale images scale the ‘pseudo albedo’ values between 0 and 1.

• Red sector shows the island of Sao Miguel (Azores Region, Portugal) at the edge of the swath. Correction in Enhanced NCC was able to bring out the city lights at Ponta Delgada.

• Yellow sector shows a city region around Gijón in Northern Spain. Enhanced NCC also reduces the light glare under thin clouds/fog, also making the image sharper.

(Credit: K. Brentzel and S. Dasgupta)
What is needed:

(1) Detailed Sun/Earth/Moon geometry prediction,
(2) Spectrally resolved lunar albedo and non-linear phase function
(4) Physical RT models of the underlying reflectance anisotropy (BRDF/Albedo/NBAR), aerosol, and cloud optical properties.
(5) Science data processing software, QA, and validation.
What Constitutes a Science-Quality Product?

1. Traceability and Heritage

**Earth's Future**

**B1. Correction of Surface Reflectance Anisotropy Effects**

\[
L_m (\lambda, \Omega_v, \Omega_m) = \frac{E_m(\lambda)}{\pi} \text{BRF}(\lambda, \Omega_v, \Omega_m) \cos(\theta_m)
\]

where \(\theta_m\) is the lunar zenith angle, and \(E_m(\lambda)\) (units of Watts m\(^{-2}\)) is the downwelling TOA sensor response function-weighted lunar irradiance derived from the MT2009 model:

\[
E_m(\lambda) = \int l_{MT}(\lambda) SRF(\lambda) d\lambda / \int SRF(\lambda) d\lambda
\]

**B2. Estimation of Nighttime Lights**

The surface upward radiance from artificial nighttime light sources, \(L_{\text{NTL}}\) (i.e., comprising nighttime lights from cities, suburban areas, rural villages, etc.) can be estimated using the following relationship [Johnson et al., 2013]:

\[
L_{\text{NTL}} = \left[ \frac{L_{\text{DNB}} - L_{\text{path}}}{T_s(\tau, \theta_v)} \right] \left[ 1 - a(\theta_m, \rho_a) \right] - L_m T_s(\tau, \theta_m)
\]

What Constitutes a Science-Quality Product?

1. Traceability and Heritage [VCM]

DOY 078, 2012, $\phi=129.4^\circ$
1. Traceability and Heritage [VCM]
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [VCM]
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [VCM]
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [Snow QA]

Winnipeg, Canada

DOY 039, 2012, $\phi=6.68^\circ$
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [Snow QA]

Fractional Snow Cover > 50%

“Cloudy” (false alarm)
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [Snow QA]

DOY 039, 2012, ϕ=6.68°

“Cloudy” (false alarm)
What Constitutes a Science-Quality Product?

1. Traceability and Heritage [Snow QA]

Take Away: **DNB products built on existing standard products have unique advantages in terms of heritage, provenance, and quality control.**
At 5,217 feet (1.59 km) Isfahan parallax effects are substantial

- **Terrain correction has significant impact** (note dramatic shift of Isfahan in the left-panel, in contrast to relative stability in the right panel.

*Note of caution:* clouds under-lit by cities will cause apparent shifts in city light locations, since the terrain correction is done with respect to the terrain elevation, not with respect to the cloud altitudes!!!
At 5,217 feet (1.59 km) Isfahan parallax effects are substantial
→ **Terrain correction has significant impact** (note dramatic shift of Isfahan in the left-panel, in contrast to relative stability in the right panel.

**Note of caution:** clouds under-lit by cities will cause apparent shifts in city light locations, since the terrain correction is done with respect to the terrain elevation, not with respect to the cloud altitudes!!!

**Credit:** Steve Miller (CIRA)
What Constitutes a Science-Quality Product?

2. Consistency and Stability [Temporal]

Miller and Turner (2009) Lunar irradiance model output, showing highly variable magnitude as function of lunar phase.
What Constitutes a Science-Quality Product?

2. Consistency and Stability [Temporal]

Miller and Turner (2009) Lunar irradiance model output, showing highly variable magnitude as function of lunar phase.
What Constitutes a Science-Quality Product?

2. Consistency and Stability [Temporal]

Comparison of 2015 annual composites of the VIIRS Day/Night Band Moon-Free composite approach (top-image) vs. the NASA Lunar BRDF-Corrected approach (bottom-image).

The Lunar BRDF correction removes a whole set of artifacts and extraneous light sources, including stray-light (red/orange blobs at high latitudes) and bidirectional reflectance (i.e., BRDF) effects (e.g., natural surfaces illuminated by airglow have disappeared from the Lunar BRDF corrected composite).

Straylight effects are contained to <15% of Lmin (3 nWatts/cm²·sr).
Lunar BRDF Correction of DNB (Cox-Munk Case)

Credit: Charles Gatebe, USRA

(from Gatebe and King, 2016)
3. Accuracy and Standardization

- Coordinate the quantitative validation of satellite-derived products, with an emphasis on:
- Validation across products from different satellite, algorithms, and agency sources.
- Establish the use of the LPV Validation Framework (seen here).

What Constitutes a Science-Quality Product?

http://lpvs.gsfc.nasa.gov/
Quantitative Analysis of VIIRS DNB Nightlight Point Source for Light Power Estimation and Stability Monitoring

Changyong Cao 1,* and Yan Bai 2

remote sensing
Puerto Rico’s Working Group on Light Pollution Field Campaign (May 23-27, 2016)
PROCEDIMIENTO ESTÁNDAR DE OPERACIÓN PARA RECOPILAR DATOS SOBRE BRILLANTEZ ATMOSFÉRICA UTILIZANDO EL SKY QUALITY METER (SQM) Versión: 6 de abril de 2016

Nombre del Procedimiento

Procedimiento Estándar de Operación para Recopilar Datos sobre Brillantez Atmosférica y Calidad de los Cielos Astronómicos Utilizando el Sky Quality Meter (SQM-L)

Figure 1: Map of PR's Light Pollution abatement Zones 1-8 (Regulation #8493 June, 27, 2014.)
With the SQM-L using the correct tools and analysis

- Beyond zenith luminance
- Average all-sky luminance
- Brightest sky luminance

Credit: National Park Service

- Vertical and horizontal illuminance from sky glow
- Light trespass from single sources
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<th>Product Name and ESDT series</th>
<th>Heritage MODIS</th>
<th>Product Status</th>
<th>Product Availability</th>
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<td>Snow Products VNP10</td>
<td>MxD10</td>
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Moving Forward

- Finalize implementation of ‘Intrinsic-IP Branch’ (using VIIRS-only BRDF approach) and ‘Nighttime Branch’ (Lunar BRDF correction) NRT PGEs.

- Incorporate feedback from GIBS-WV development team and key science users (e.g., Yale, NASA/SPoRT, UNOSAT).

- DNB Product suite is currently at ‘Provisional Stage’, with validation to CEOS/WGCV/LPV Stage 1 to be effective in early-2017 (pending acceptance of PR-WGLP campaign results in peer-review).
  - Finalize VIIRS DNB Level 1b/2 subsetter and conduct global assessment over 1,500 sites [ftp://ladsweb.nascom.nasa.gov/subsets/] -- AM = America; EU = Europe; EA = East China and Pacific; and AF = Africa and Middle East.
  - Conduct second PR-WGLP field campaign during the dry season (Dec, 2016 – Feb 2017), using enhanced measurement protocol and for planned Suomi-NPP Simultaneous Nadir Overpasses (SNOs).
Thanks to NASA’s SIF Fund. For more info:


Acknowledgements:

- Miller and Turner (2009), A Dynamic Lunar Spectral Irradiance Data Set for VIIRS DNB Nighttime Environmental Applications, IEEE-TGRS.
- Zhang et al., (2013), The Vegetation Adjusted NTL Urban Index: A new approach to reduce saturation and increase variation in nighttime luminosity, RSE.
- Johnson, et al., (2013), Preliminary investigations toward nighttime aerosol optical depth retrievals from the VIIRS DNB, AMTD.