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

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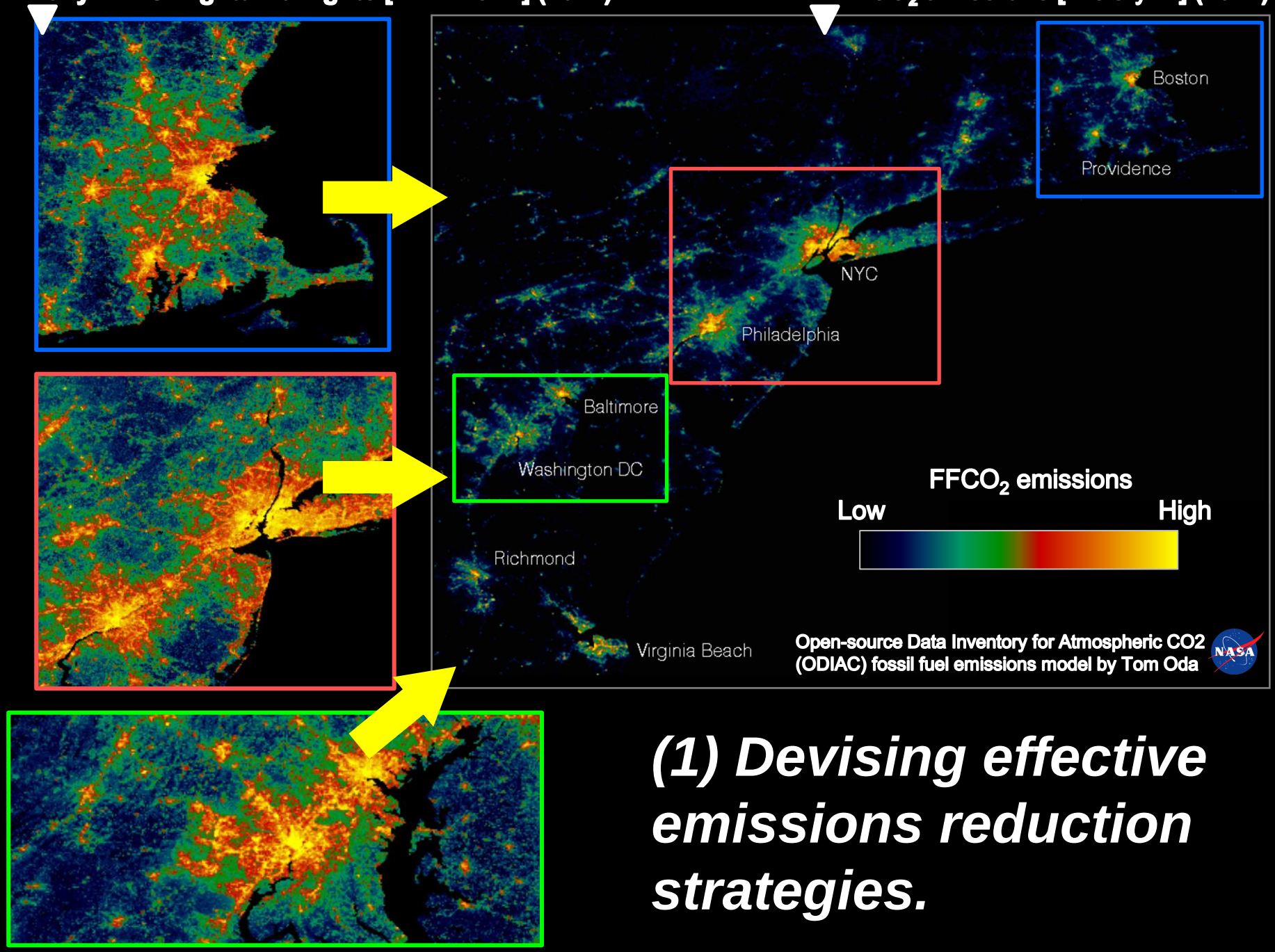
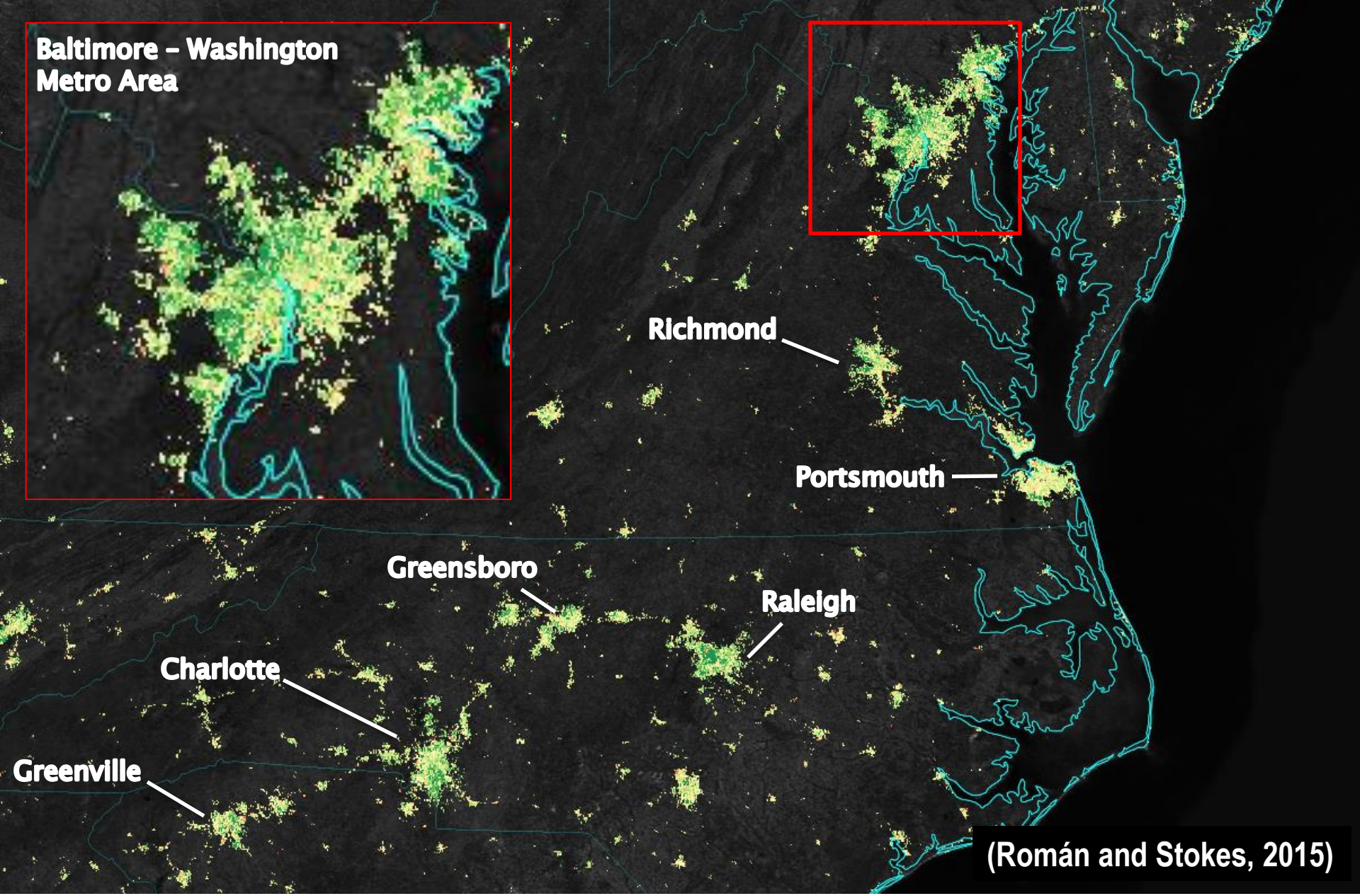
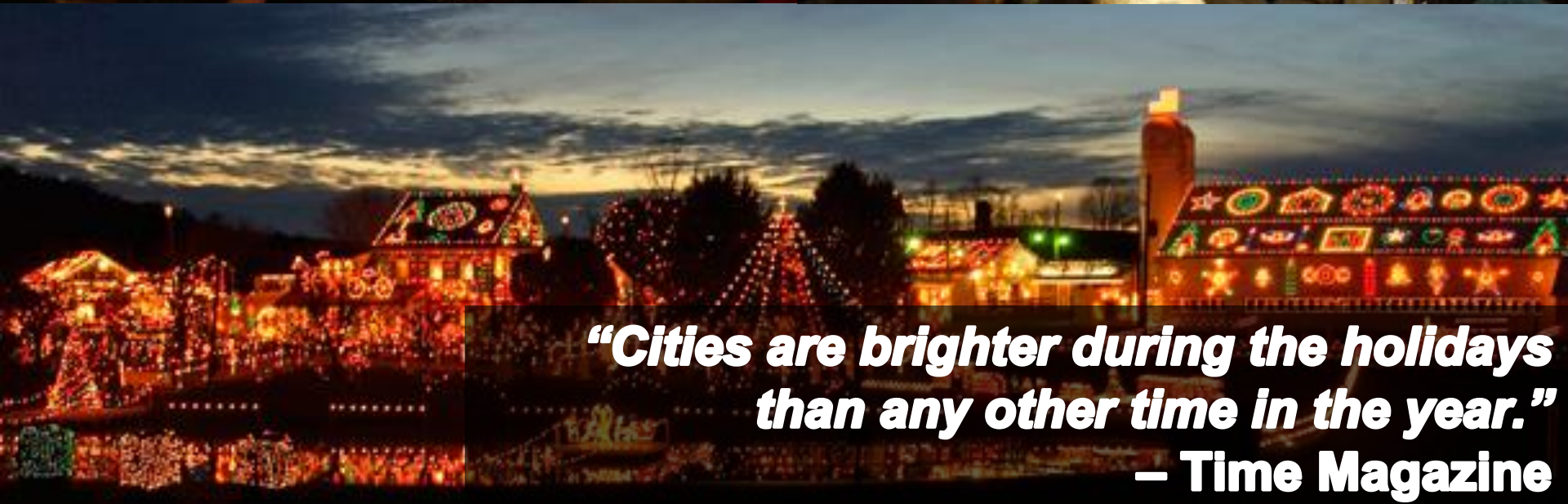
Zhuosen Wang[2], Virginia Kalb[1], Eleanor Stokes[3], Karen Seto[3], Gary Lin[4], Robert Wolfe[1], Sadashiva Devadiga[4], Carol Davidson[4], Sudipta Sarkar[4], Jeffrey Schmaltz[4], Ryan Boller[1], George Riggs[4], José A. Pou[5], Olga Ramos[6], Elizabeth Padilla[7], Andrew Molthan[8], Tony Cole[8], Crystal Schaaf[9], Eric Vermote[1], Steven Miller[10], Charles Gatebe[1], Swarvanu Dasgupta[1], and Kelvin Brentzel[1]

[1]NASA/GSFC, [2]UMD/ESSIC, [3]Yale/FES, [4]SSAI, [5]PR-EQB, [6]UFS, [7]PLN, [8]NASA/MSFC/SPoRT, [9]UMB, [10]CIRA



(1) Devising effective emissions reduction strategies.


Baltimore – Washington
Metro Area
Richmond
Portsmouth
Greensboro
Raleigh
Charlotte
Greenville
(Román and Stokes, 2015)
Change in Outdoor Lighting
less
equal
more
NASA
Goddard
SPACE FLIGHT CENTER



"Cities are brighter during the holidays than any other time in the year."

– Time Magazine

EARTH *RIGHT* NOW

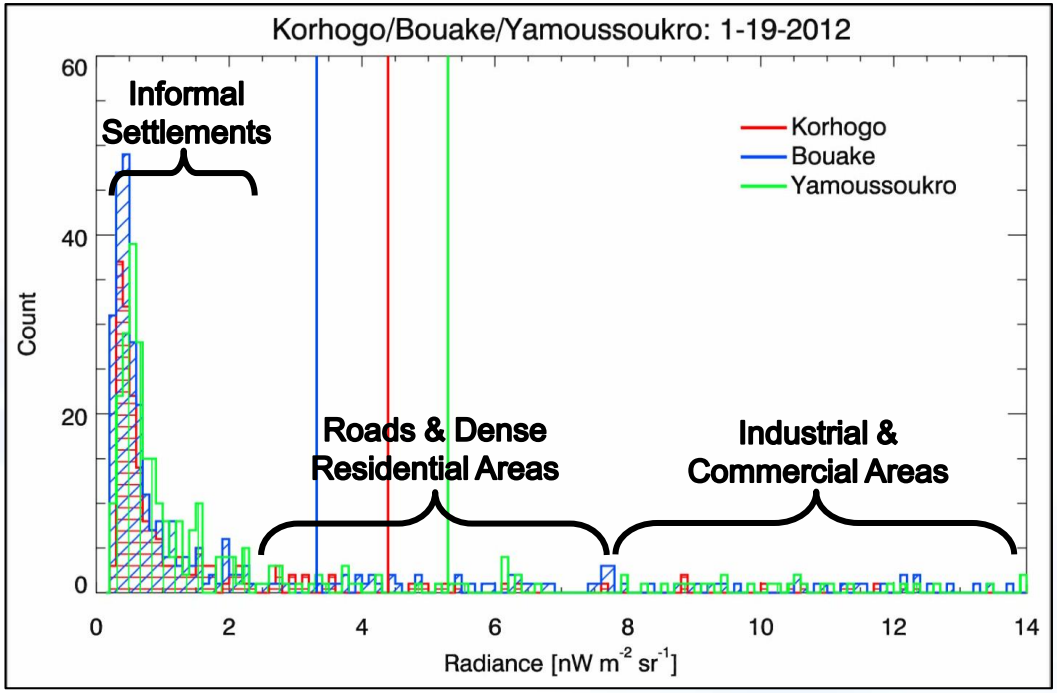
www.nasa.gov/earthrightnow

(2) Reducing energy poverty and increasing energy accessibility.

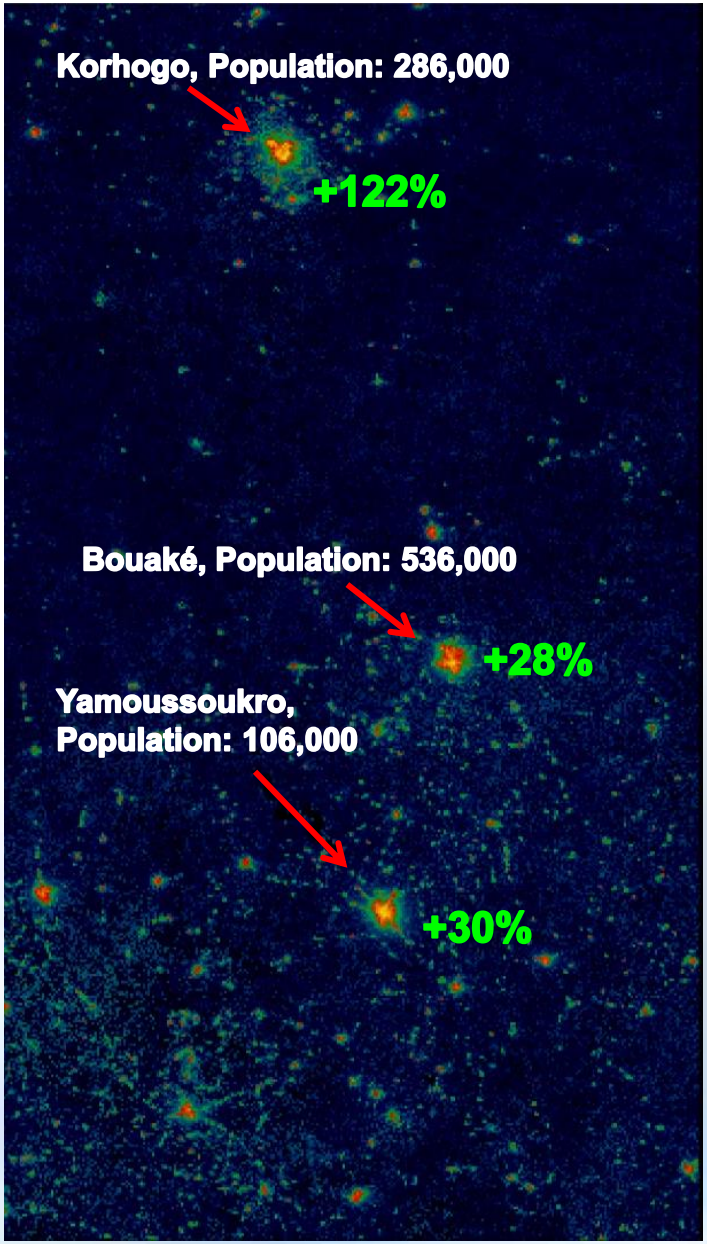
Tracking Rural Energy Access and Electrification

SUSTAINABLE DEVELOPMENT

Cote d'Ivoire - Emergency Infrastructure Renewal Project



Budget: $200 million (USD) **- Project Duration: 2012-2016**



(3) Assessing social vulnerability and the cascading effects of disasters.

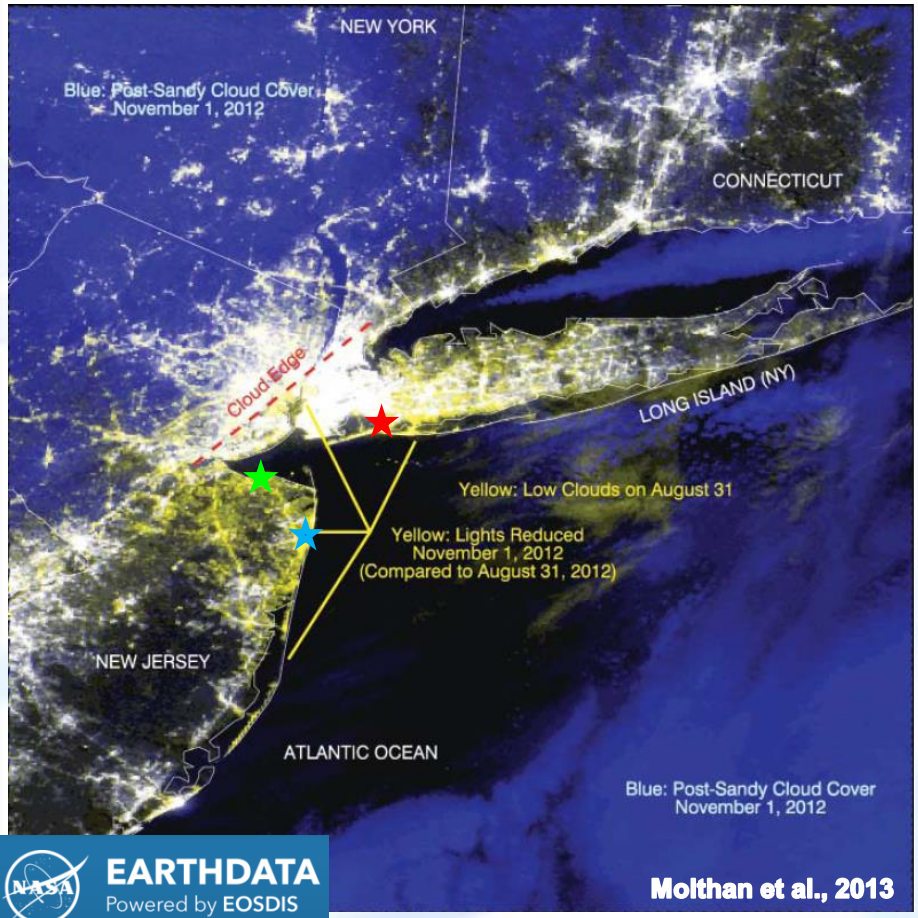
LANCE: NASA NEAR REAL-TIME DATA AND IMAGERY

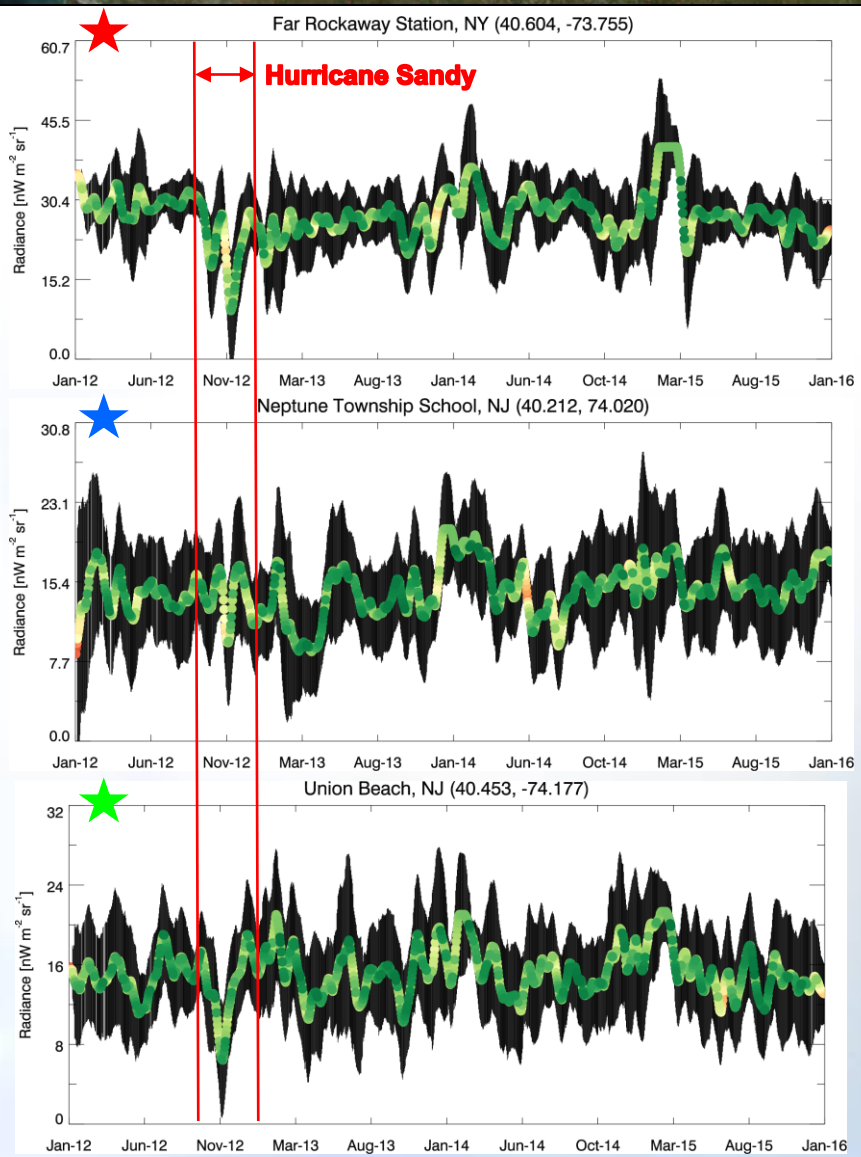
EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

SPORT

Satellite Observations Monitor Outages From Superstorm Sandy

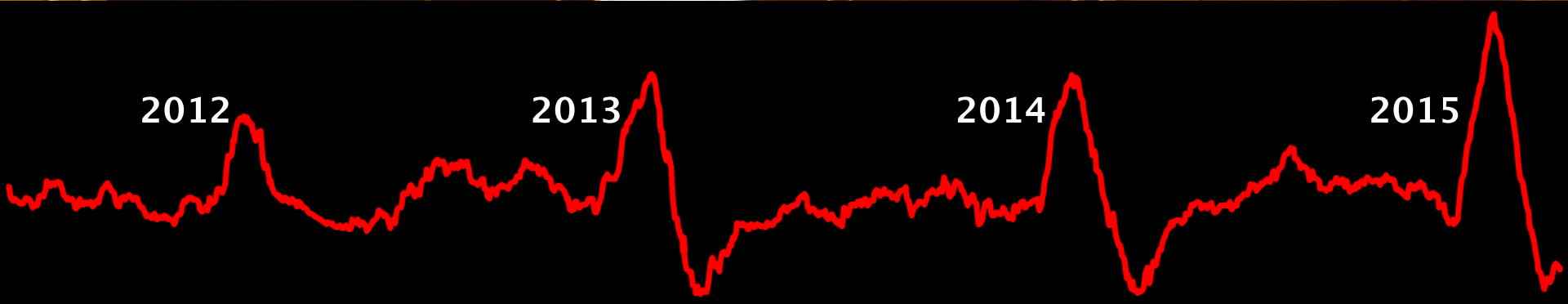




Low Confidence — High Confidence

EARTHDATA
Powered by EOSDIS

Jeddah, Saudi Arabia



The Holy Month of Ramadan

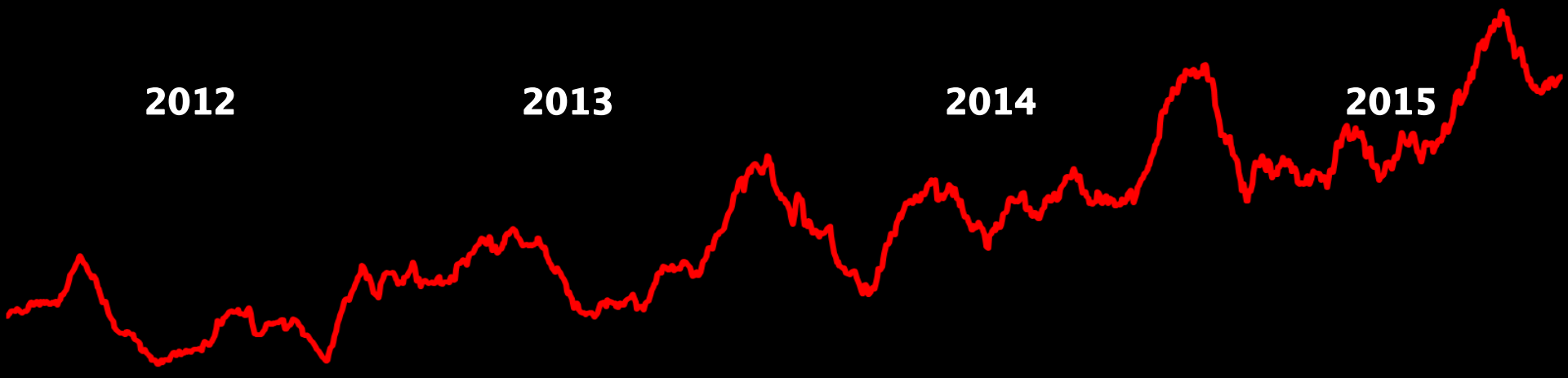
"In the Middle East, some cities saw a 100% boost in illumination during the month of Ramadan compared to the rest of the year.

– BBC News

Tel Aviv, Israel

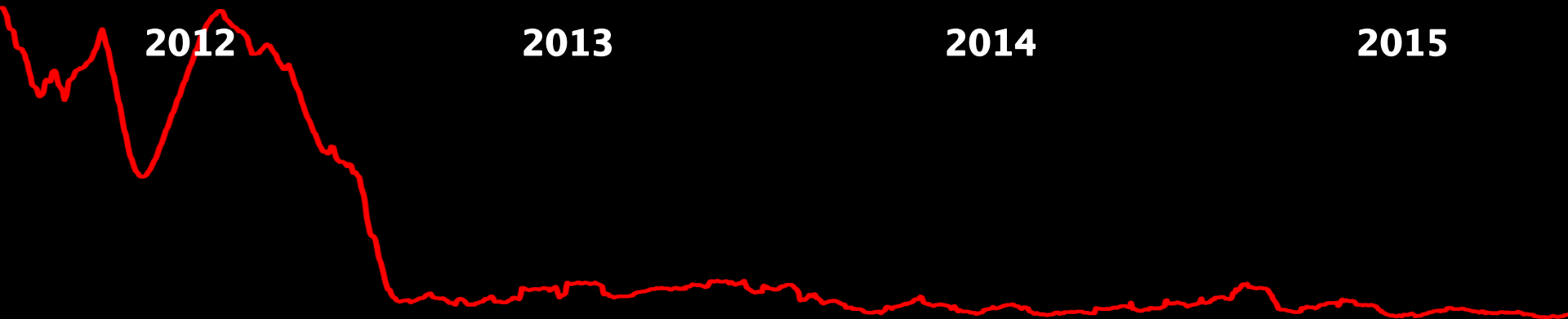
2012 2013 2014 2015

Basrah, Iraq



Aleppo, Syria

"NASA Scientists can measure the EKG of a City"
– Smithsonian Magazine



Challenge?

New era of global energy cooperation requires new data and analytical tools.

Benefits?

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

Human-Centered Energy Research

So What?

Confluence of urban energy, development, and climate change agendas.

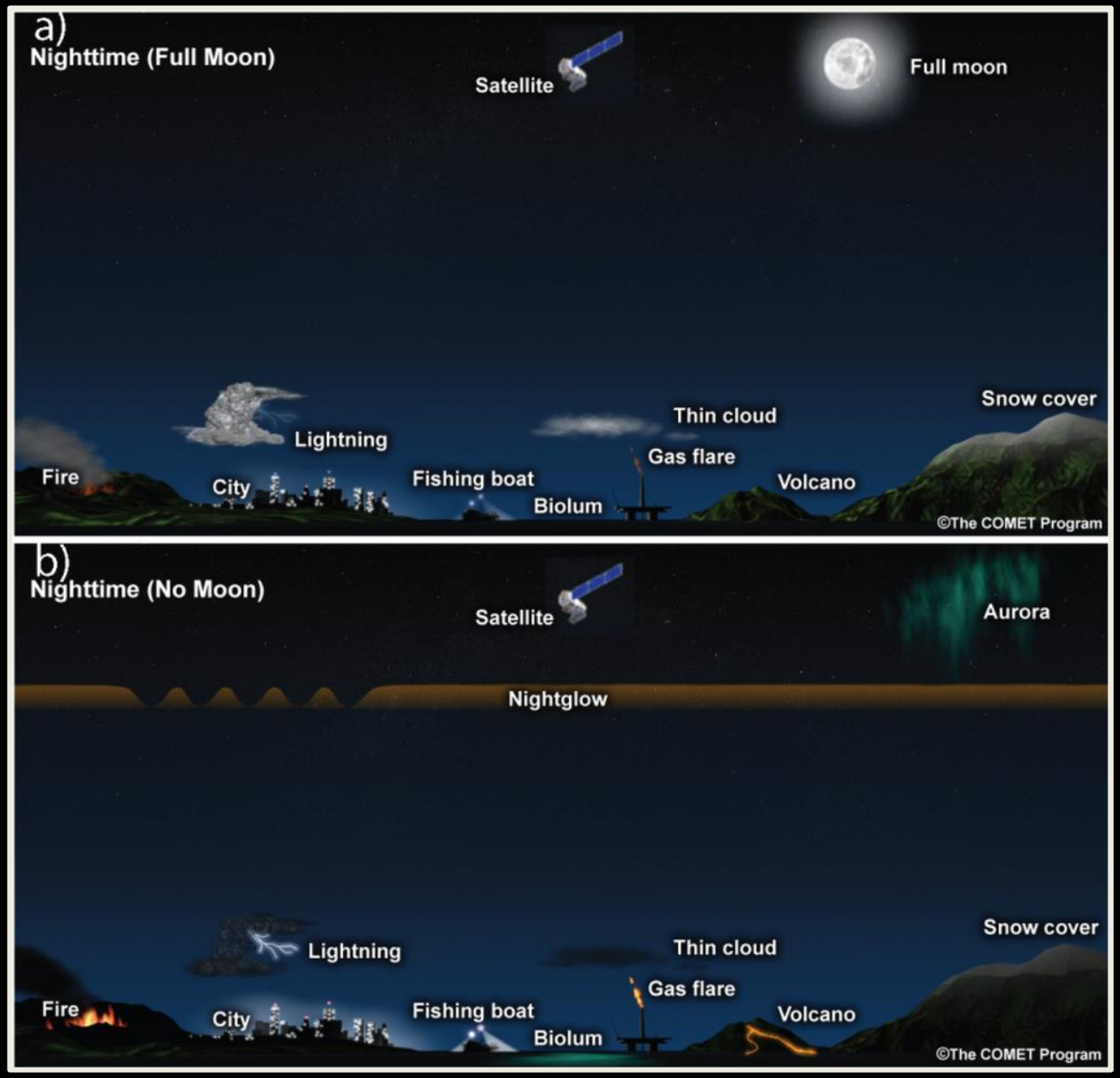
Solutions?

VIIRS is a step towards satellite-derived "energy intelligence".

Message Box Handout:
Leopold Leadership Program at Stanford University

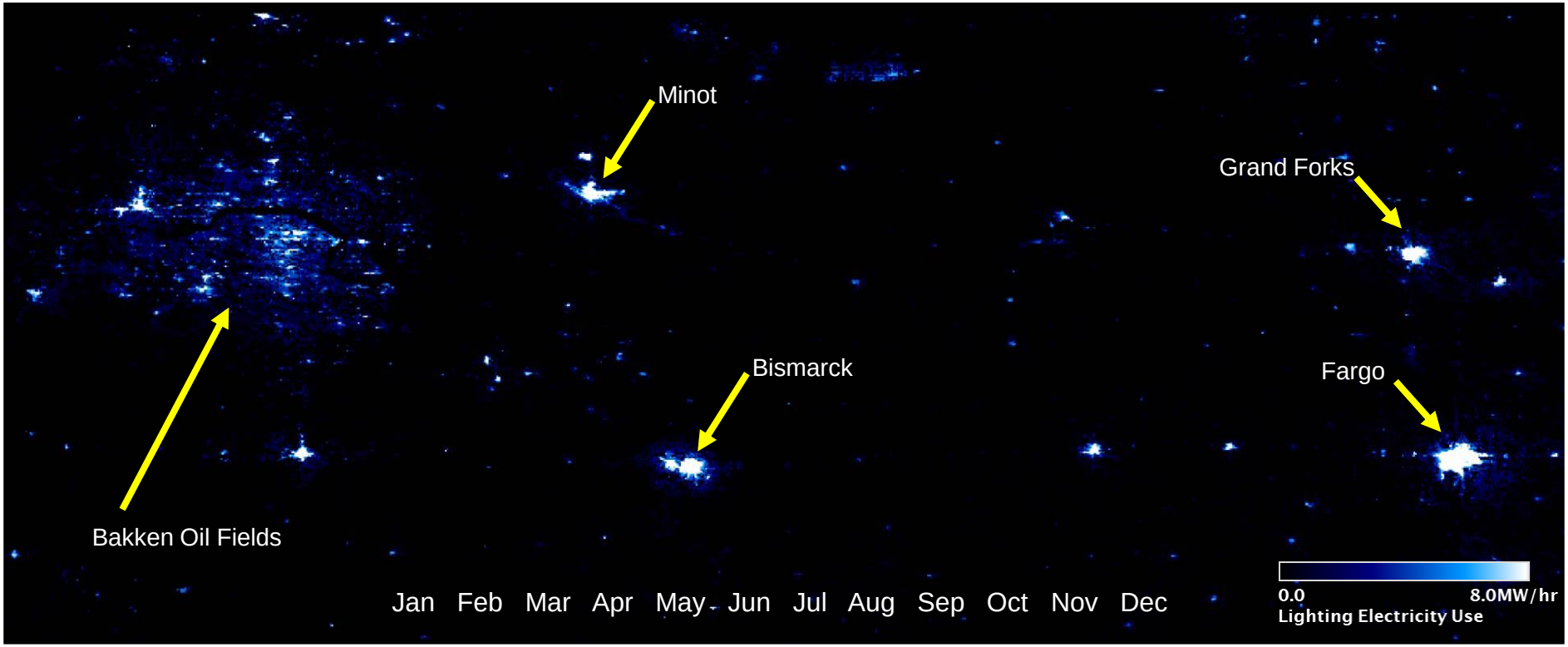
NASA Goddard SPACE FLIGHT CENTER

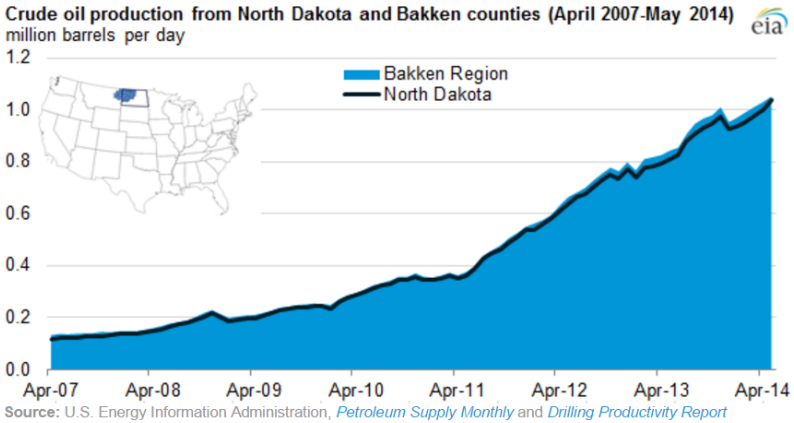
VIIRS nighttime detection capabilities (a) with and (b) without lunar illumination



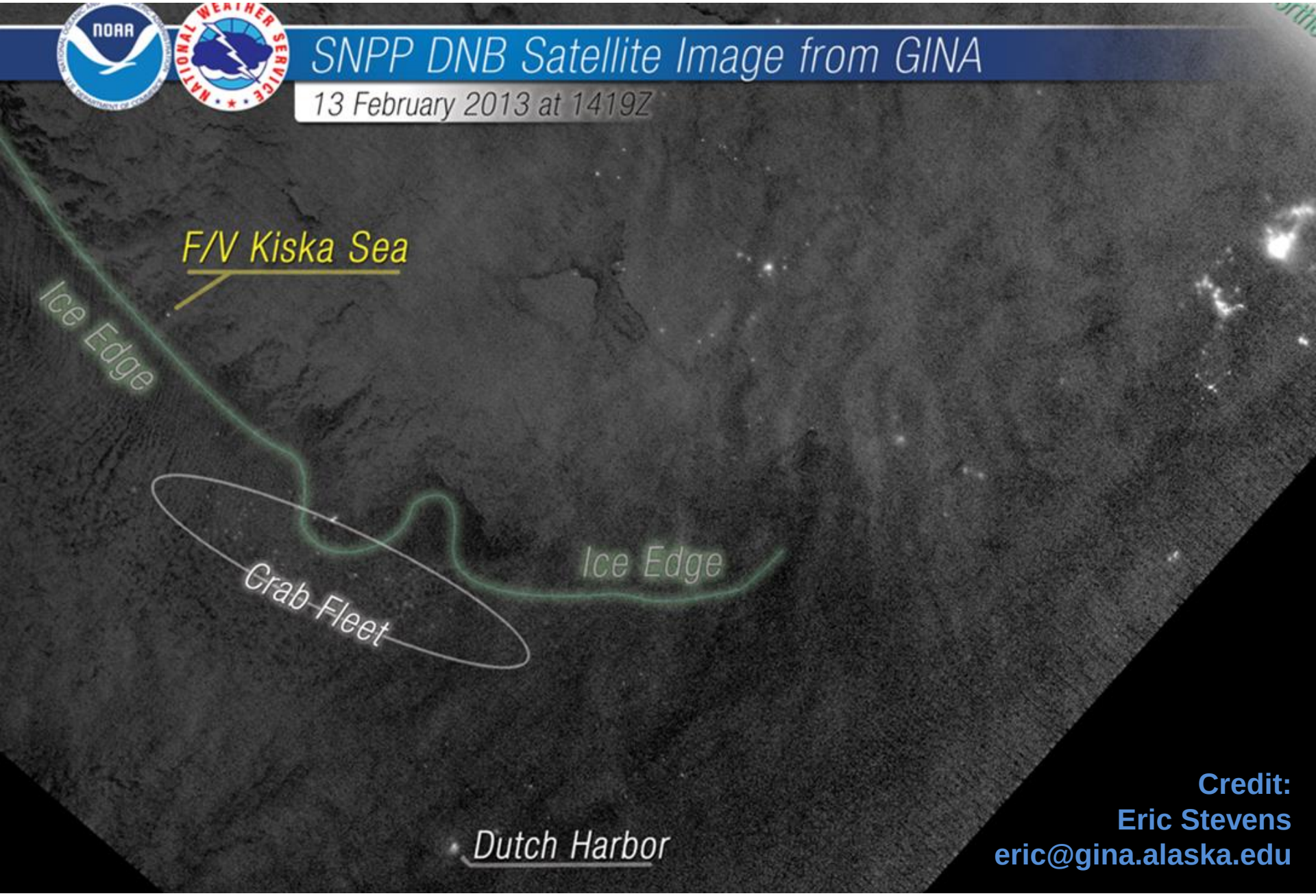
Miller et al., (2013) *Remote Sens. 2013, 5(12), 6717-6766; doi:10.3390/rs5126717*

Understanding Drivers of Future Urban Growth:
from NASA-GSFC brief to Sen. Heidi Heitkamp (D-ND)

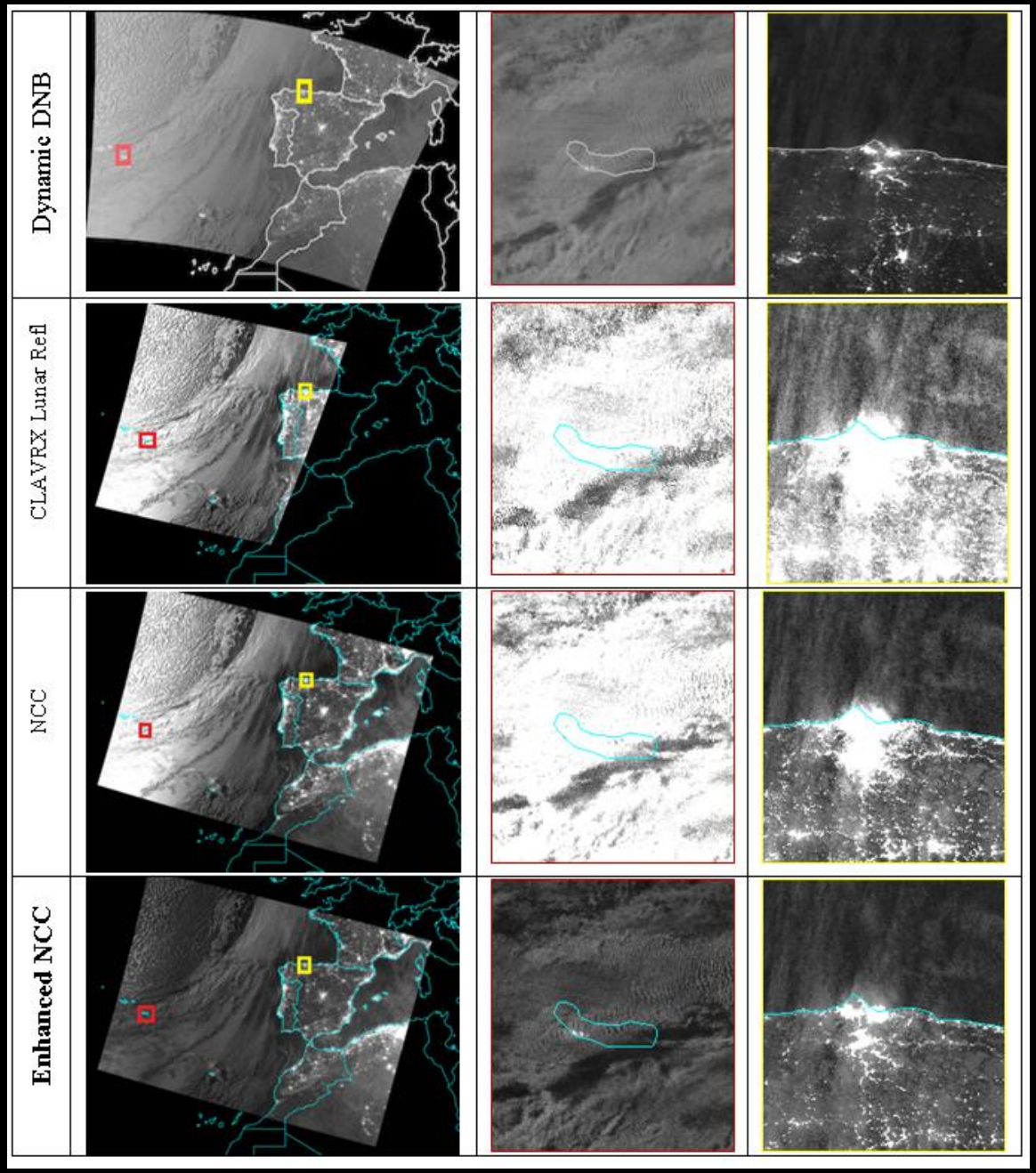




Suomi-NPP VIIRS enables mapping of the economic, mobility, informational, and operational drivers that connect our cities to their surrounding landscape.


SNPP DNB Satellite Image from GINA
13 February 2013 at 1419Z
F/V Kiska Sea
Ice Edge
Ice Edge
Crab Fleet
Dutch Harbor
Credit:
Eric Stevens
eric@gina.alaska.edu

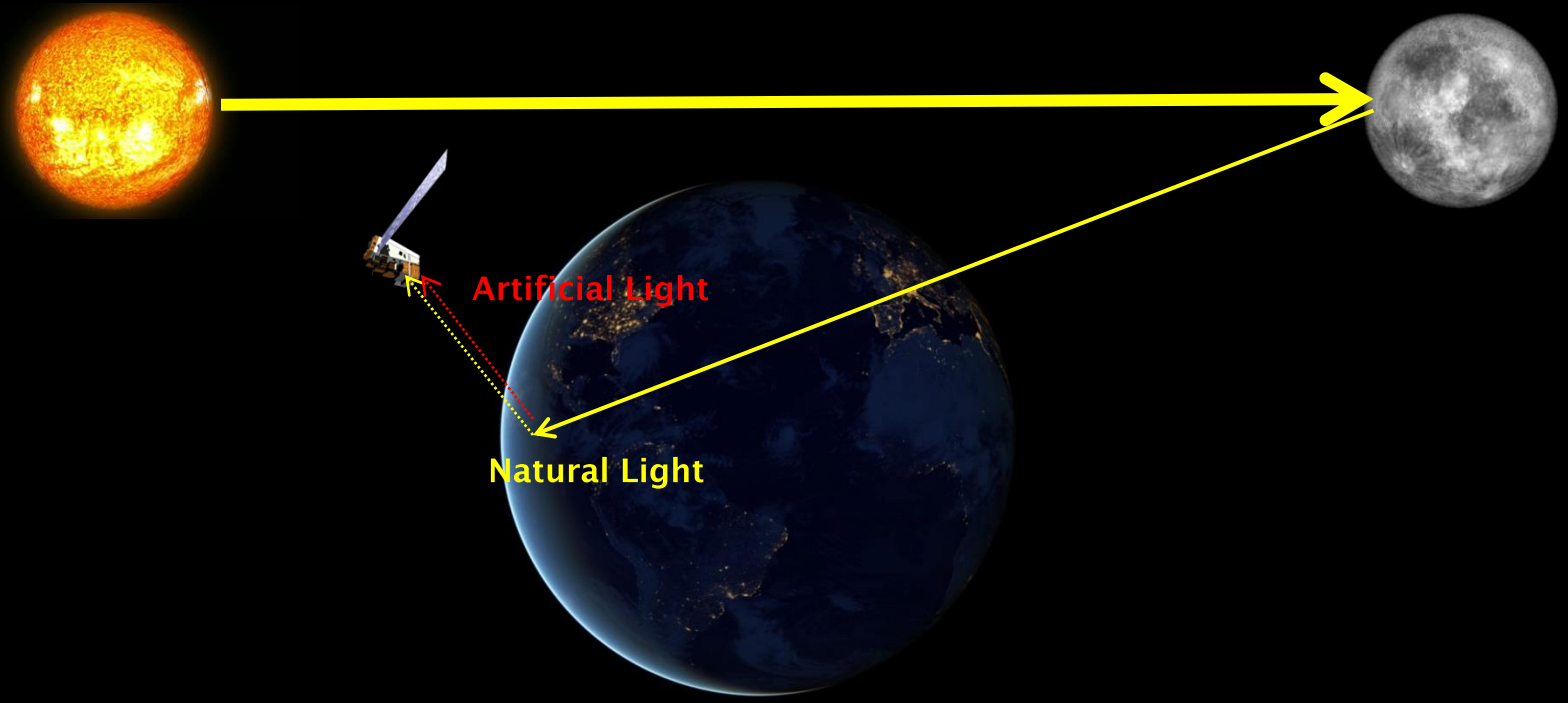
(FROM TUESDAY) NASA DRL Enhanced Near Constant Contrast Imagery



- **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)

Quantitative Nighttime Remote Sensing Principles



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

AGU PUBLICATIONS

Earth's Future

B1. Correction of Surface Reflectance Anisotropy Effects

$$L_m\left(\lambda, \Omega_v, \Omega_m\right) = \frac{E_m(\lambda)}{\pi} \mathrm{BRF}\left(\lambda, \Omega_v, \Omega_m\right) \cos\left(\theta_m\right)$$

where θ_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:

$$E_m(\lambda) = \int I_{MT}(\lambda)\, SRF(\lambda)\, d\lambda \Big/ \int SRF(\lambda)\, d\lambda$$

B2. Estimation of Nighttime Lights

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

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

from **Román and Stokes (2015)**, *Earth's Future, 3: 182–205. doi:*[10.1002/2014EF000285](10.1002/2014EF000285)

What Constitutes a Science-Quality Product?

1. Traceability and Heritage [VCM]

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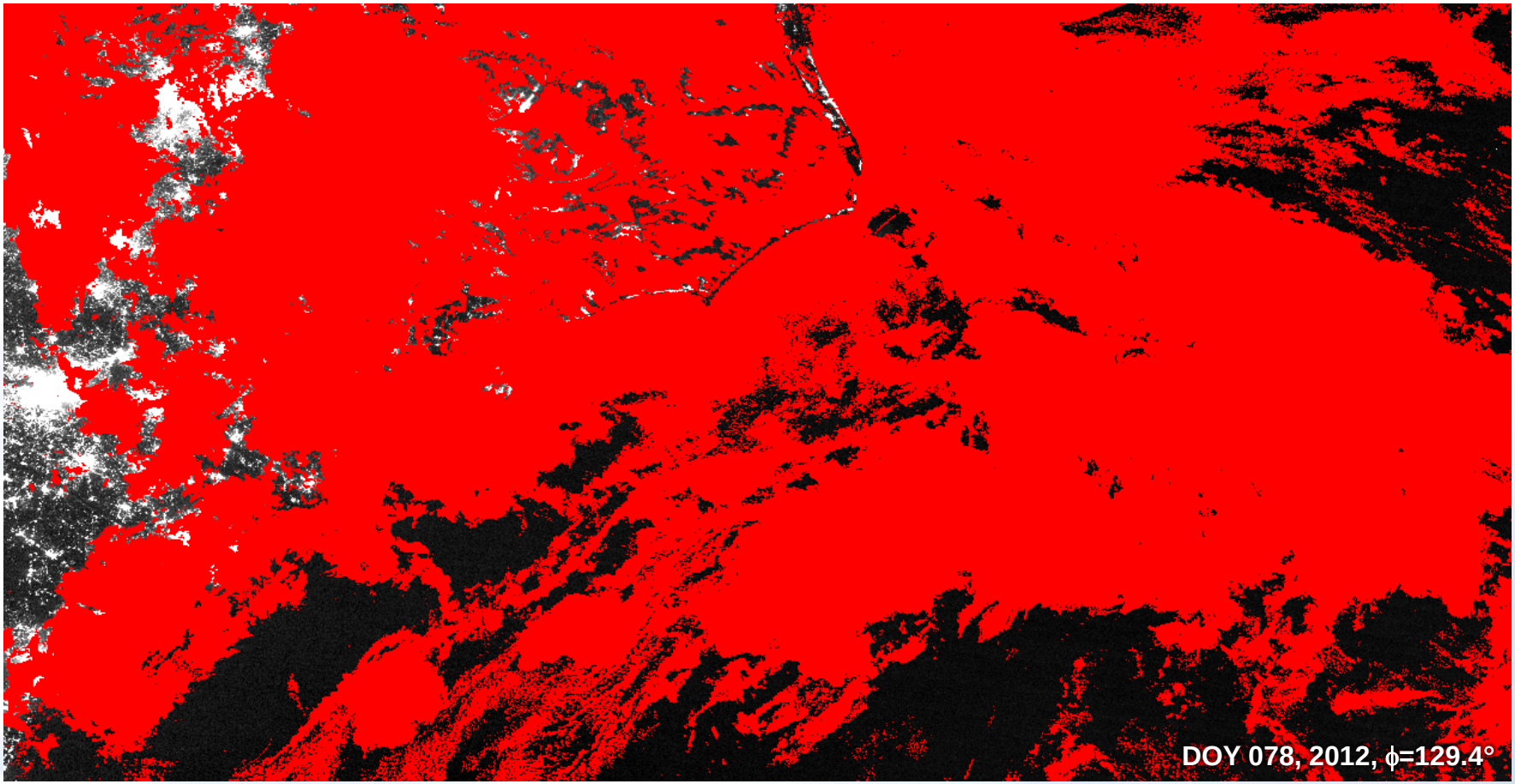

Cloudy

What Constitutes a Science-Quality Product?

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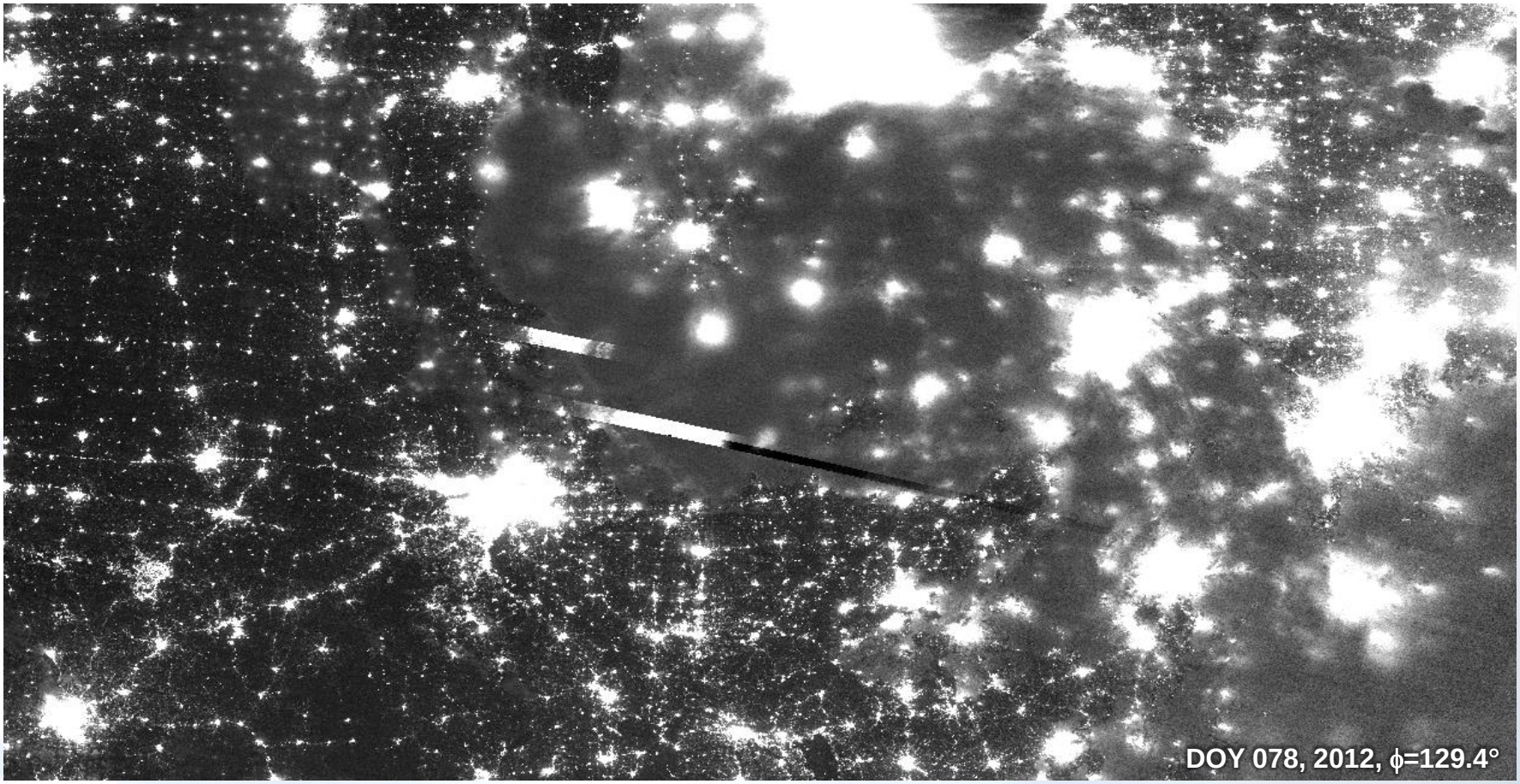

What Constitutes a Science-Quality Product?

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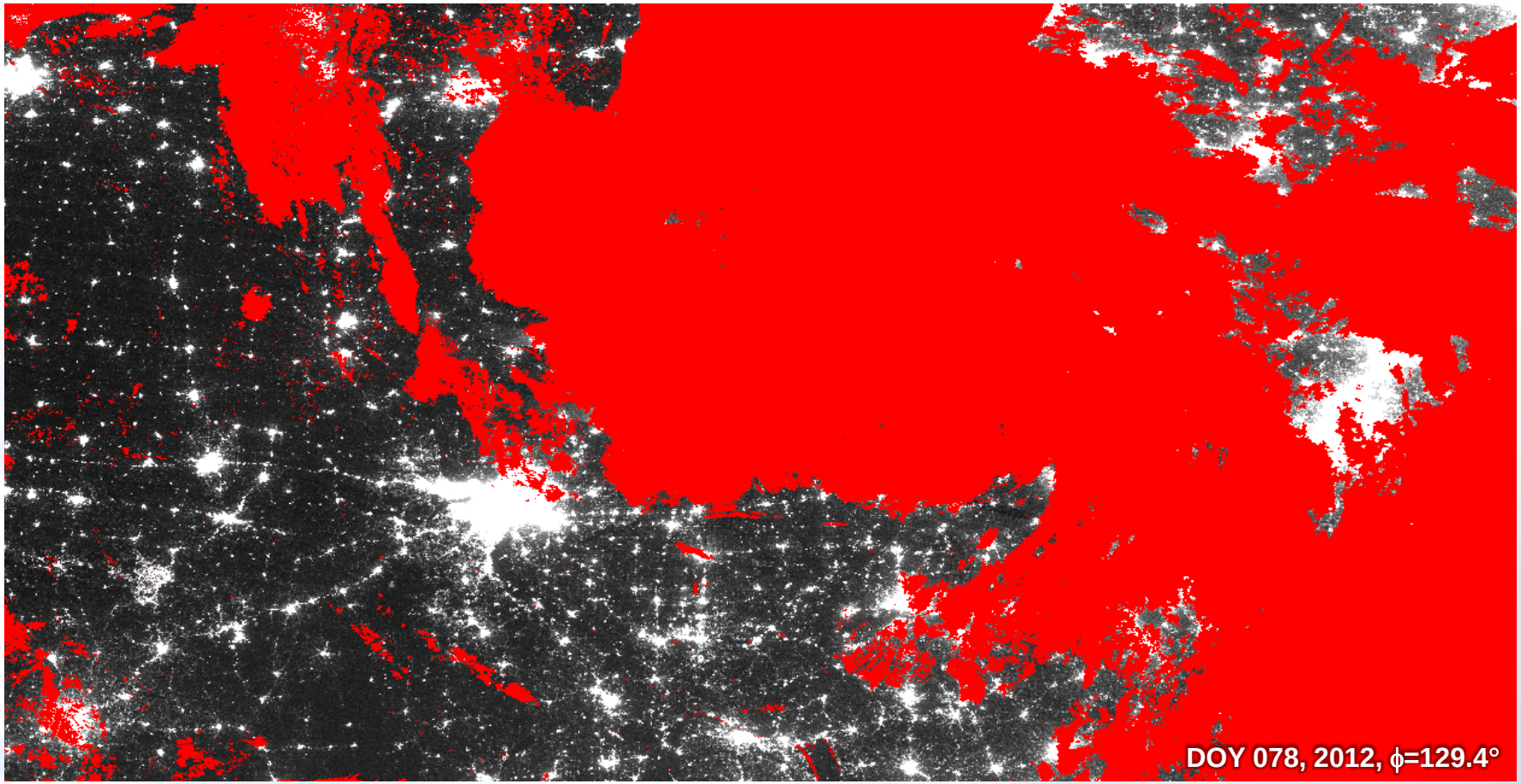
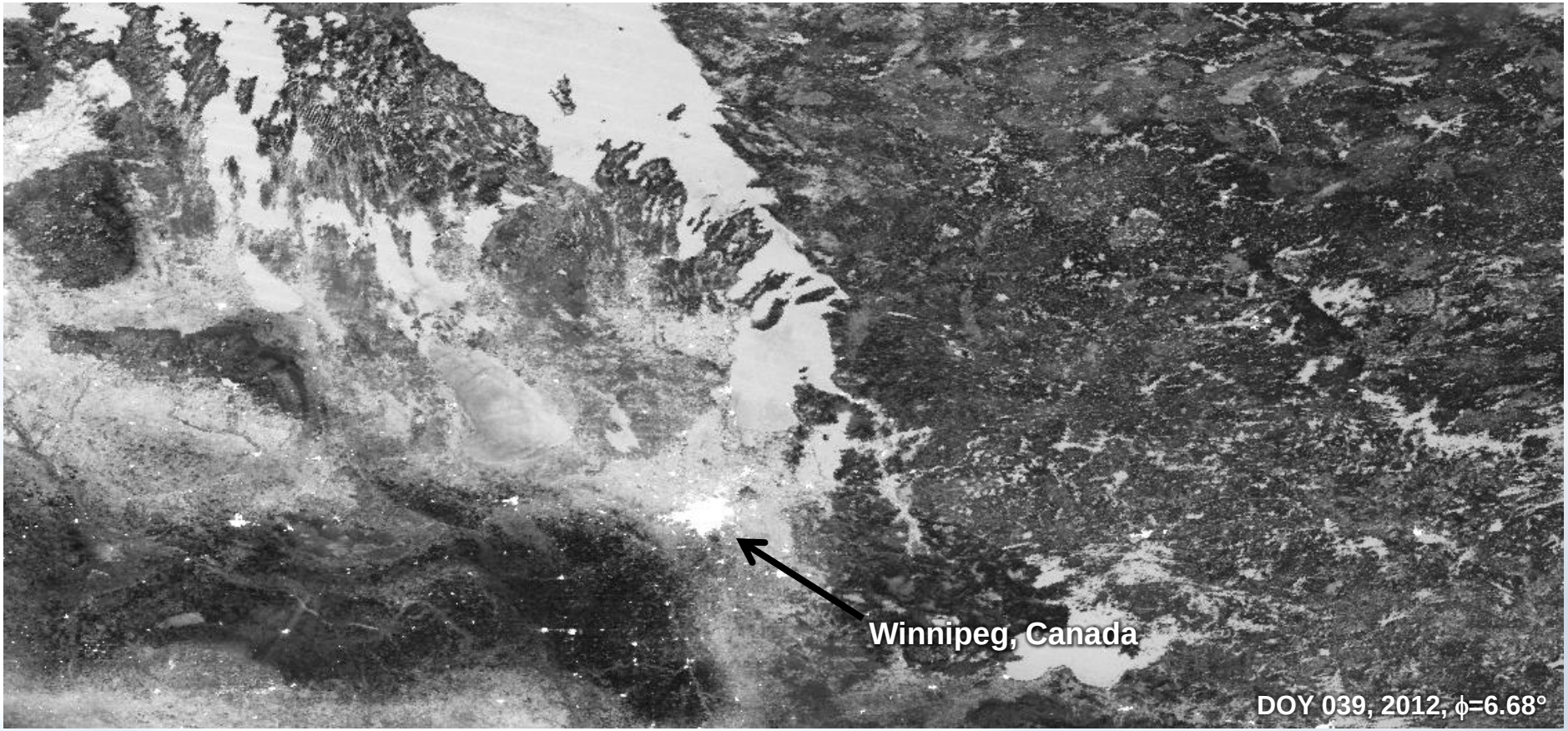


Cloudy

What Constitutes a Science-Quality Product?

1. Traceability and Heritage [Snow QA]



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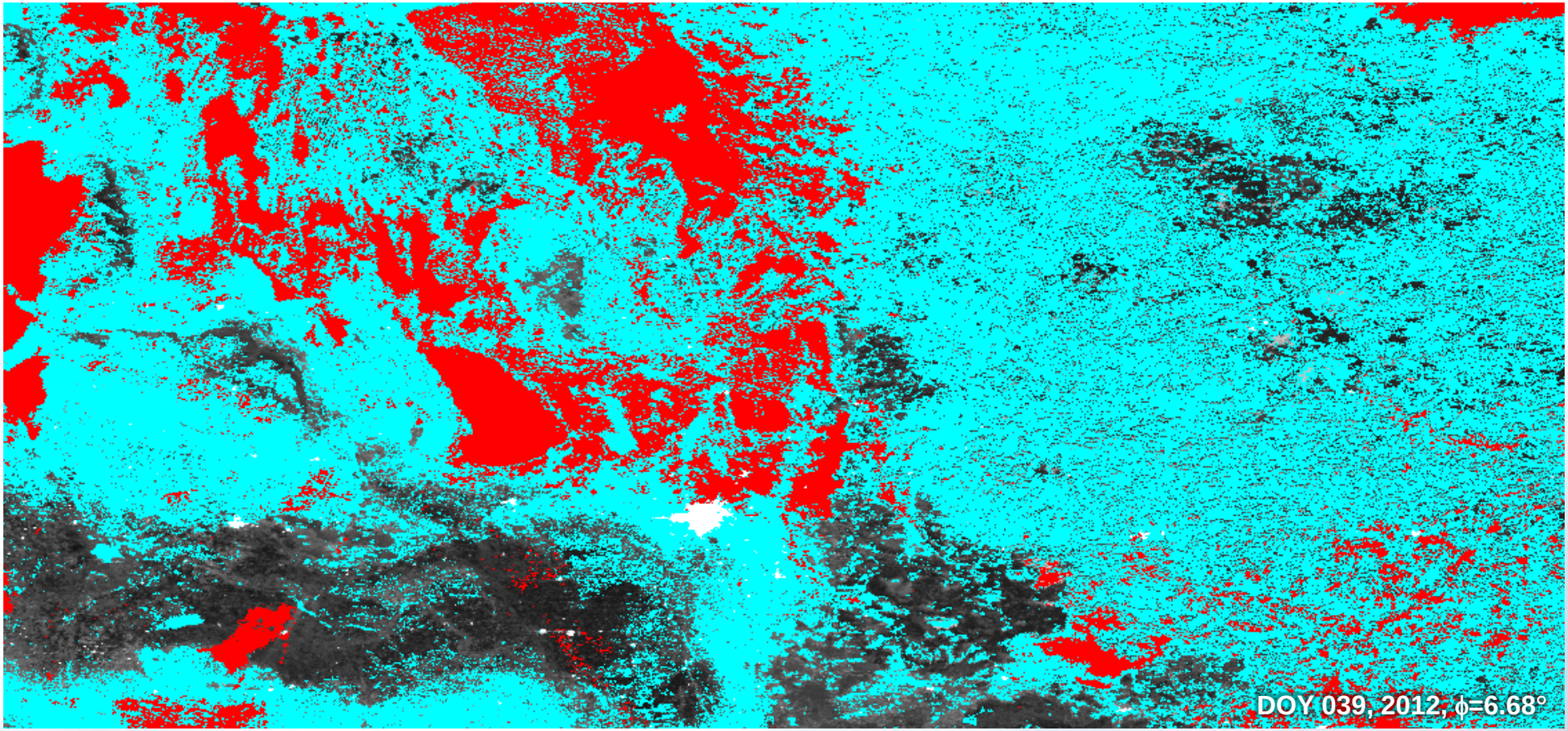

Fractional Snow Cover > 50%

"Cloudy" (false alarm)

What Constitutes a Science-Quality Product?

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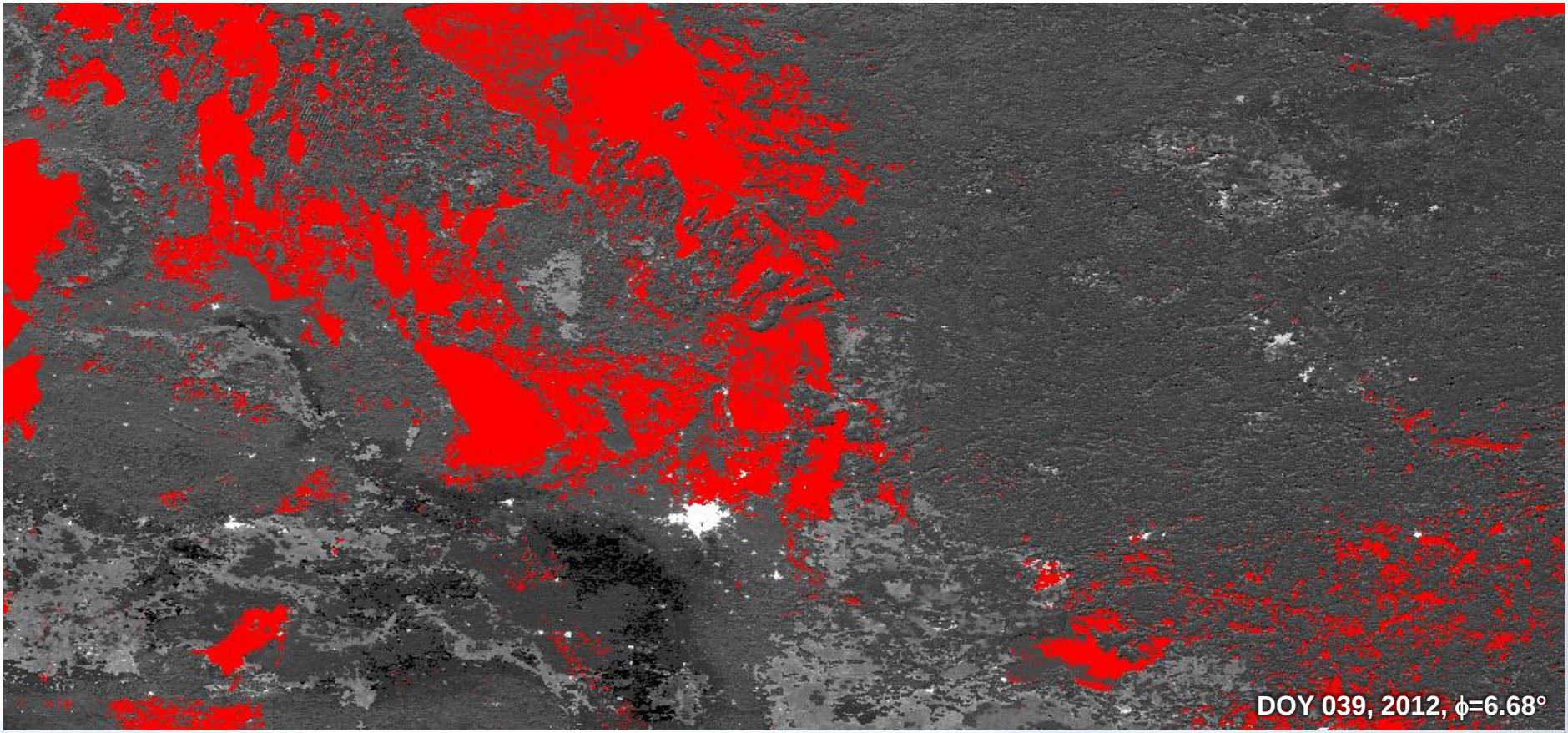

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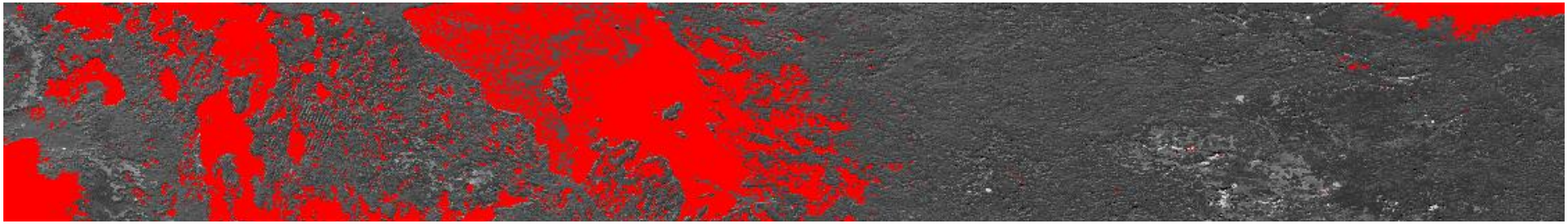
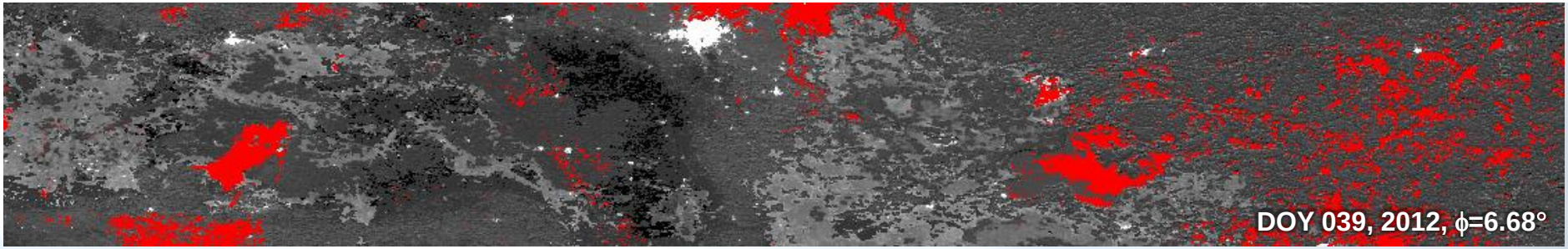


Take Away: *DNB products built on existing standard products have unique advantages in terms of heritage, provenance, and quality control.*



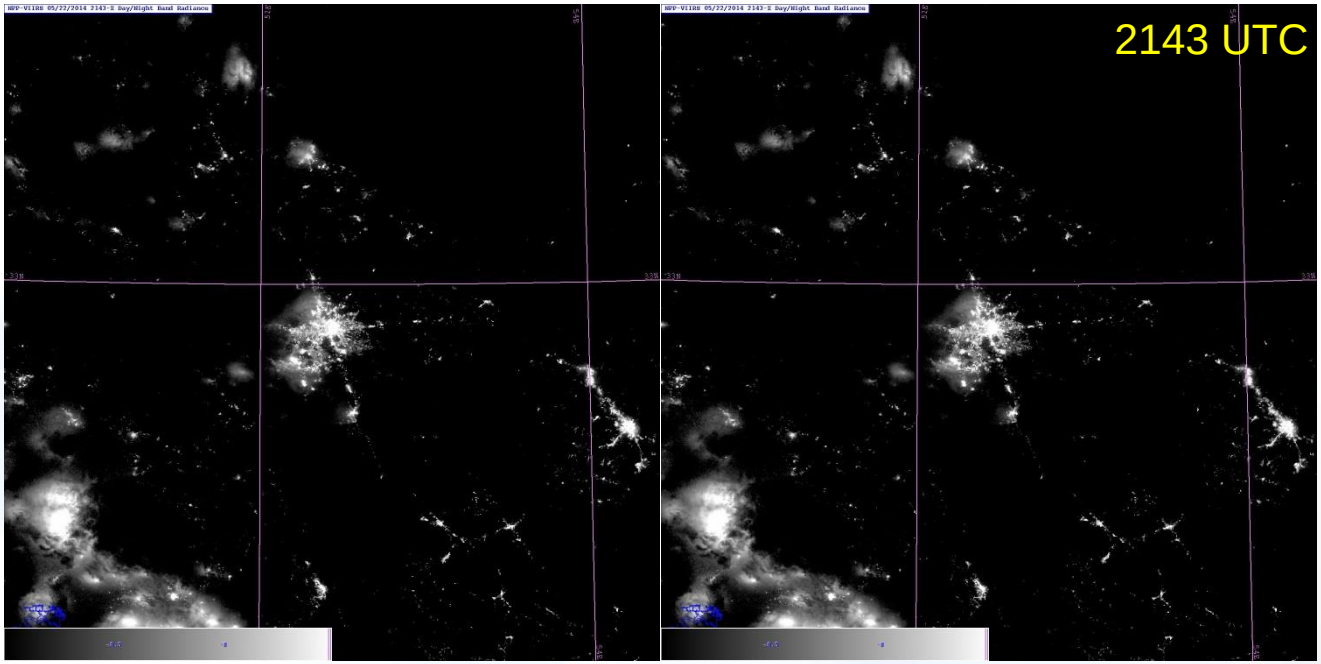
"Cloudy" (false alarm)

What Constitutes a Science-Quality Product?

2. Consistency and Stability [Spatial]

Isfahan (32.63˚N, 51.65˚E, 1.59 km)

No Correction | Terrain Correction



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)

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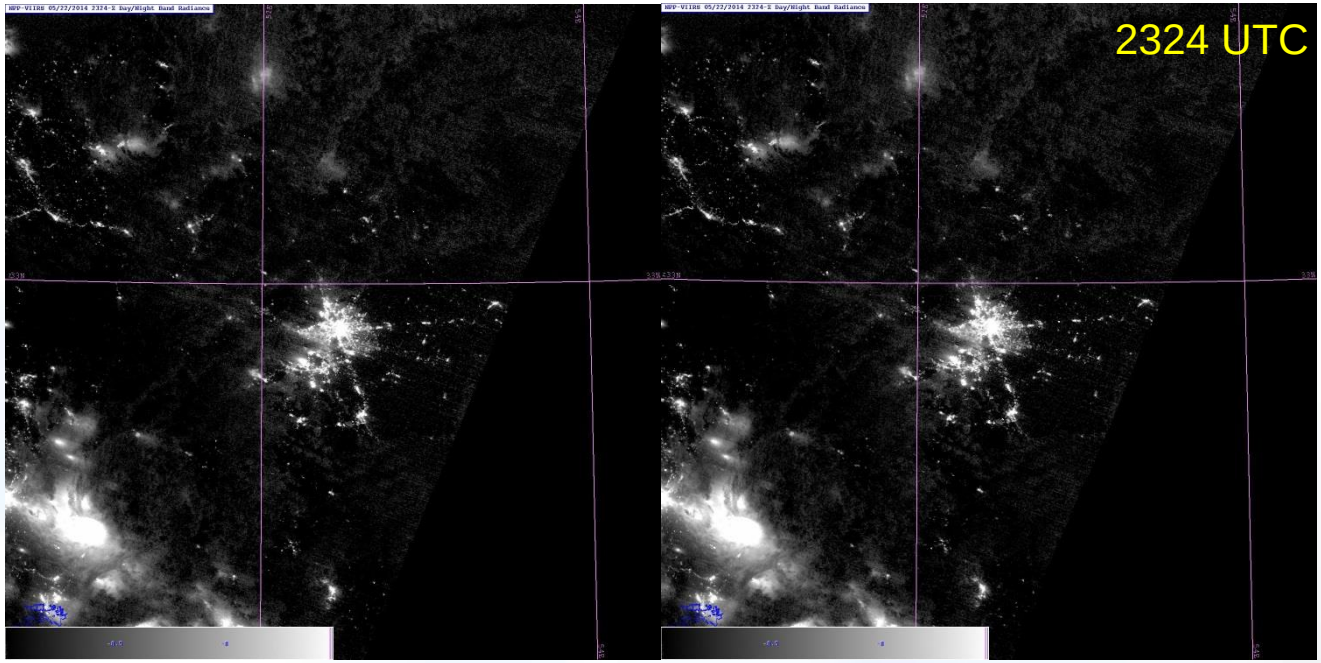

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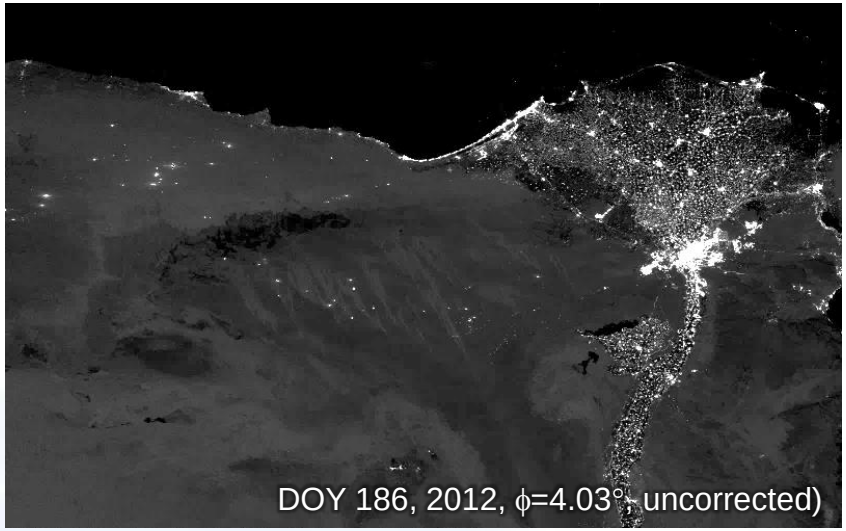
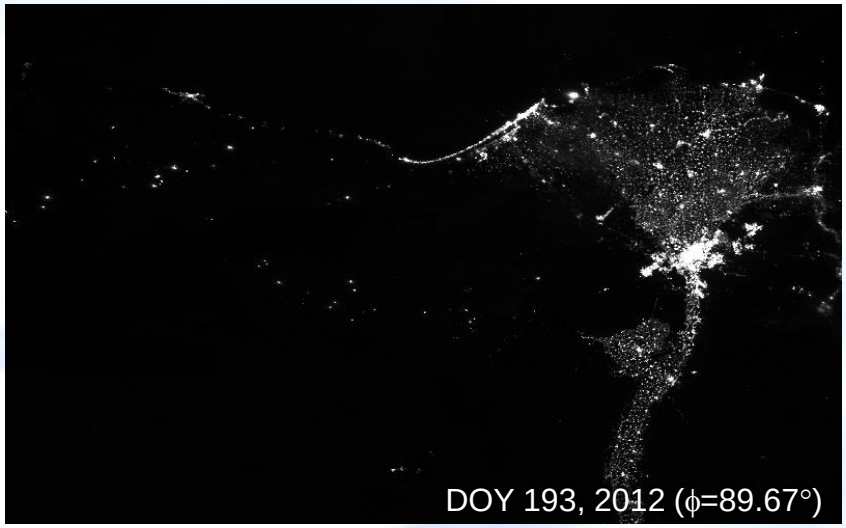
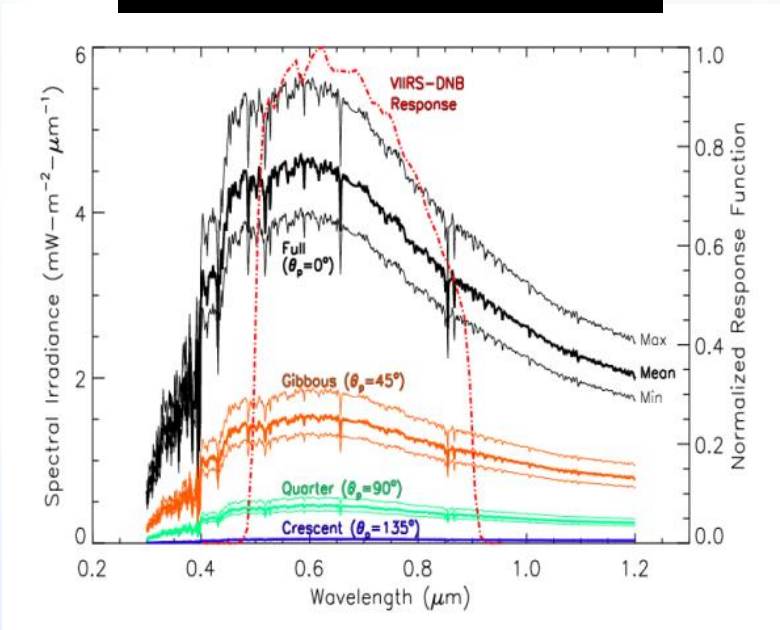
What Constitutes a Science-Quality Product?

2. Consistency and Stability [Temporal]



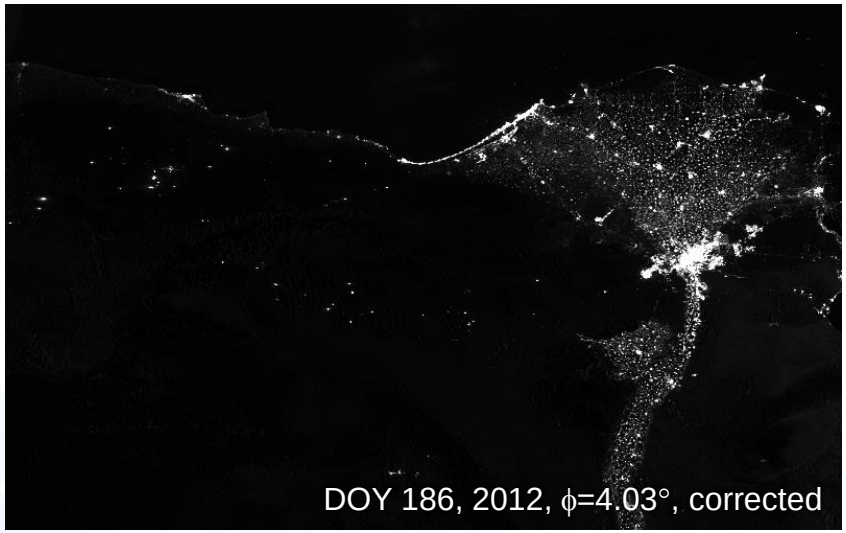


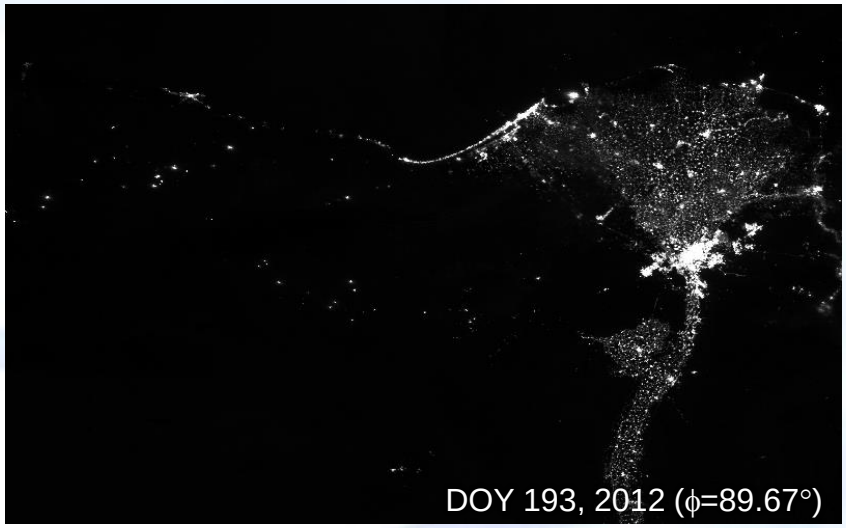


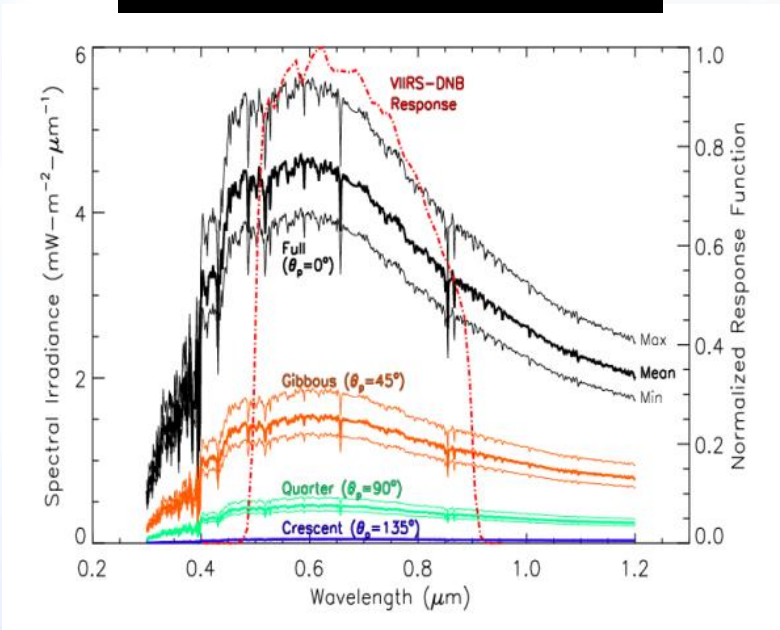
Miller and Turner (2009) Lunar irradiance model output, showing highly variable magnitude as function of lunar phase.

What Constitutes a Science-Quality Product?

2. Consistency and Stability [Temporal]







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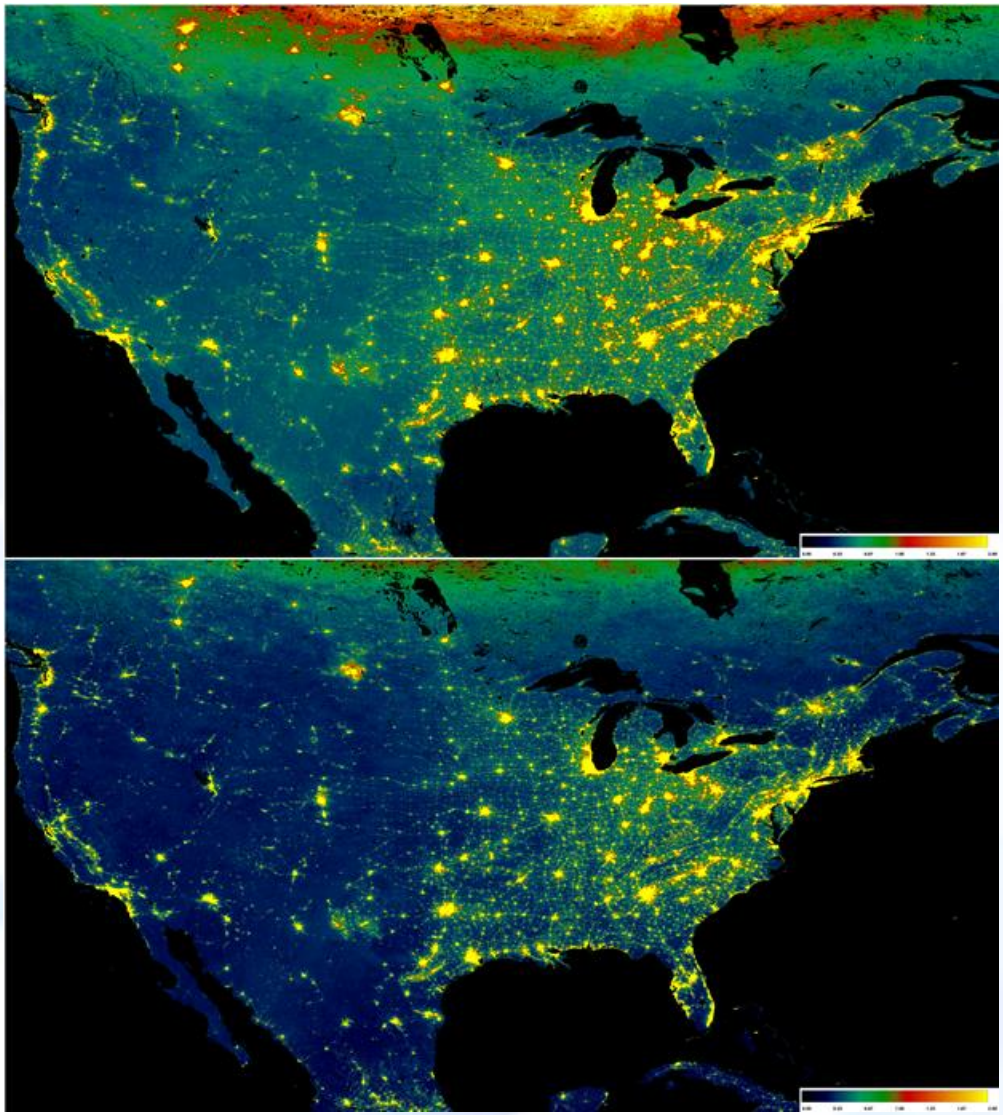
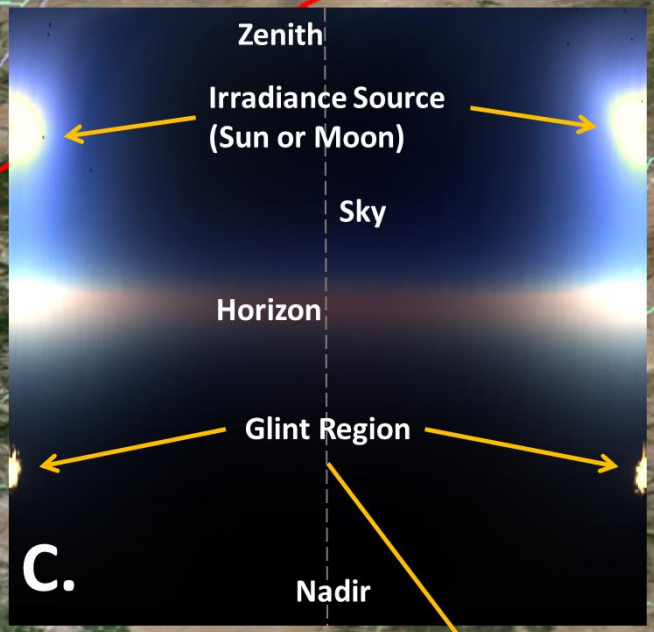


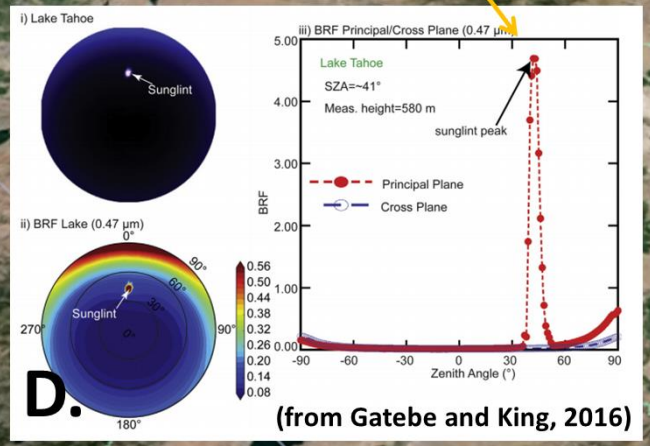
Comparison of 2015 annual composites of the VIIRS Day/Night Band Moon-Free composite approach (top-image) vs. the NASA Lunar BRDF-Corrected approach (bottom-image).

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/cm^2•sr).

Lunar BRDF Correction of DNB (Cox-Munk Case)





Truckee

Lake Tahoe

South Lake Tahoe

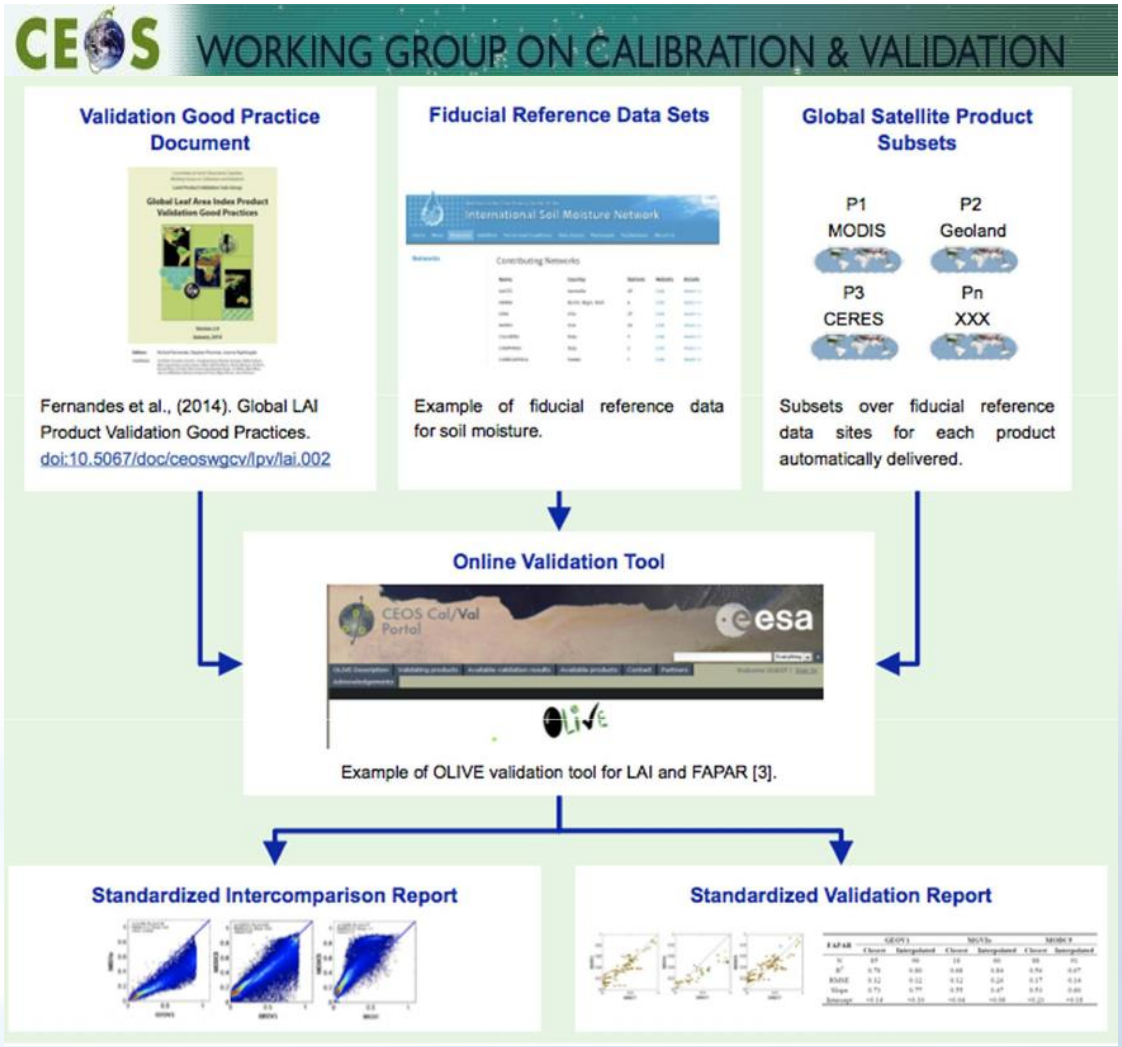
Alpine

(Credit: Charles Gatebe, USRA)

What Constitutes a Science-Quality Product?

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).

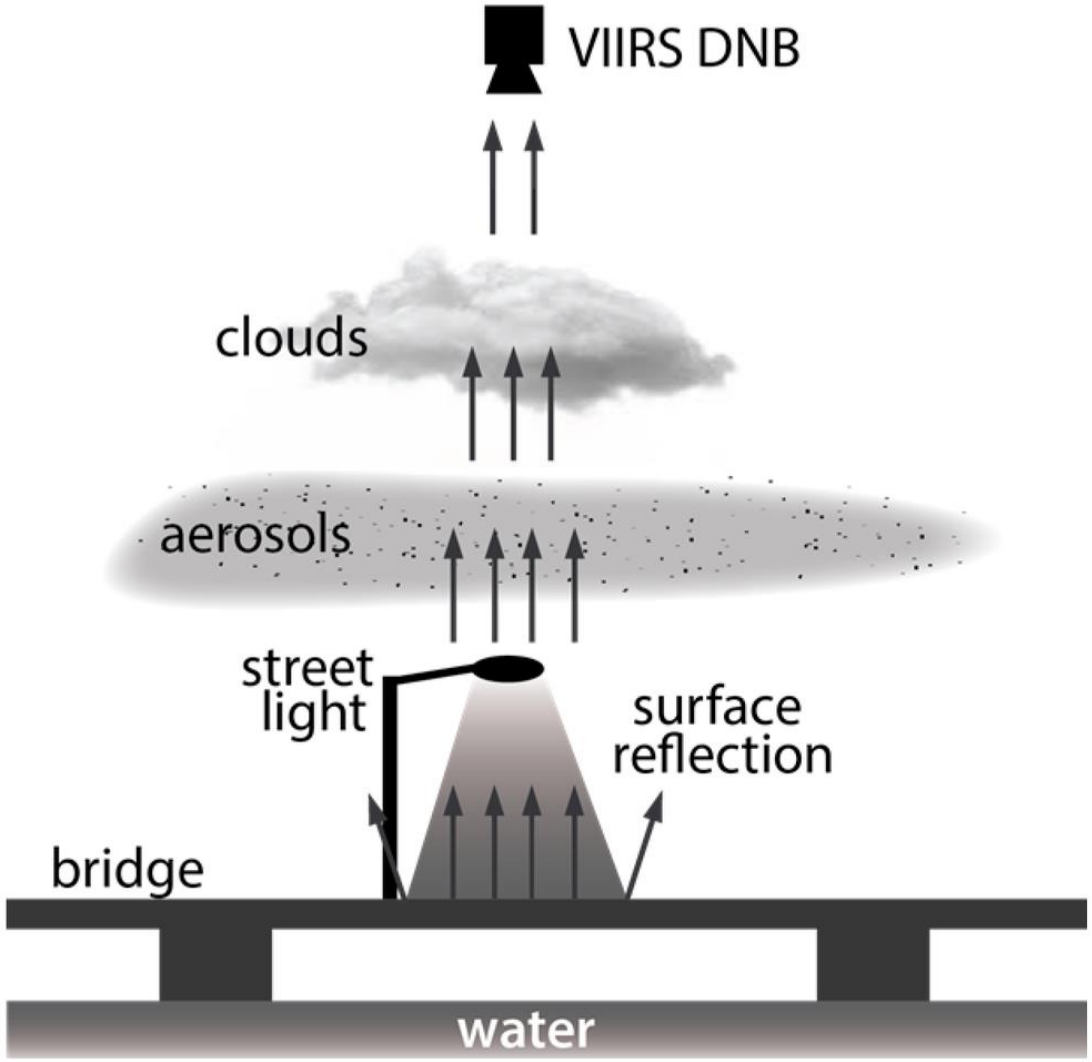


http://lpvs.gsfc.nasa.gov/

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)

para la Naturaleza

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

JCA
JUNTA DE CALIDAD AMBIENTAL
ESTADO LIBRE ASOCIADO DE PUERTO RICO

NASA

UPR

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)

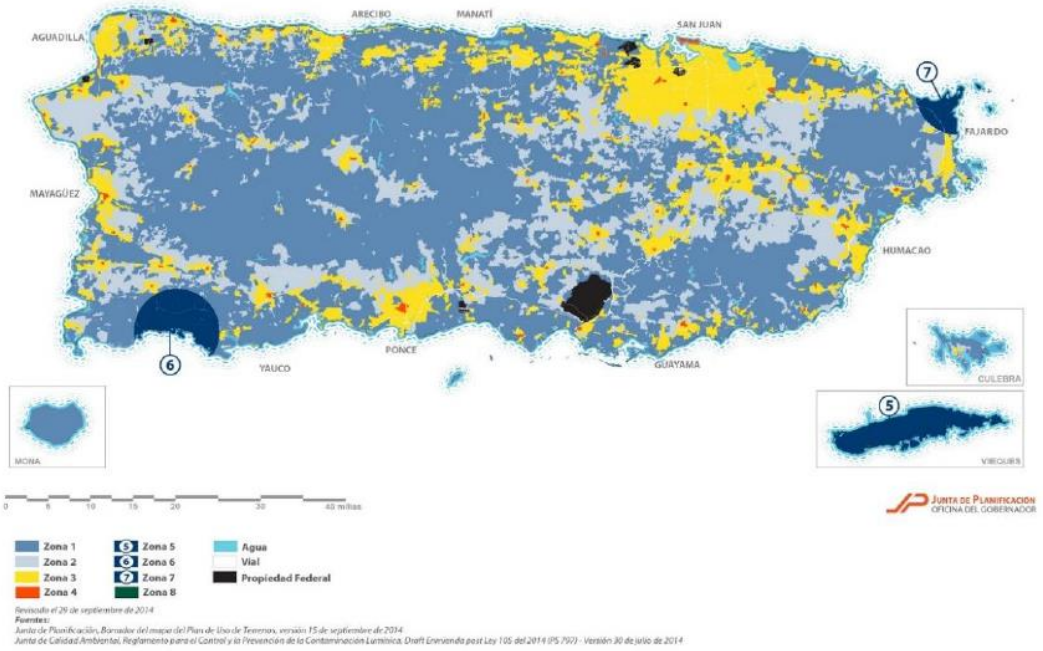


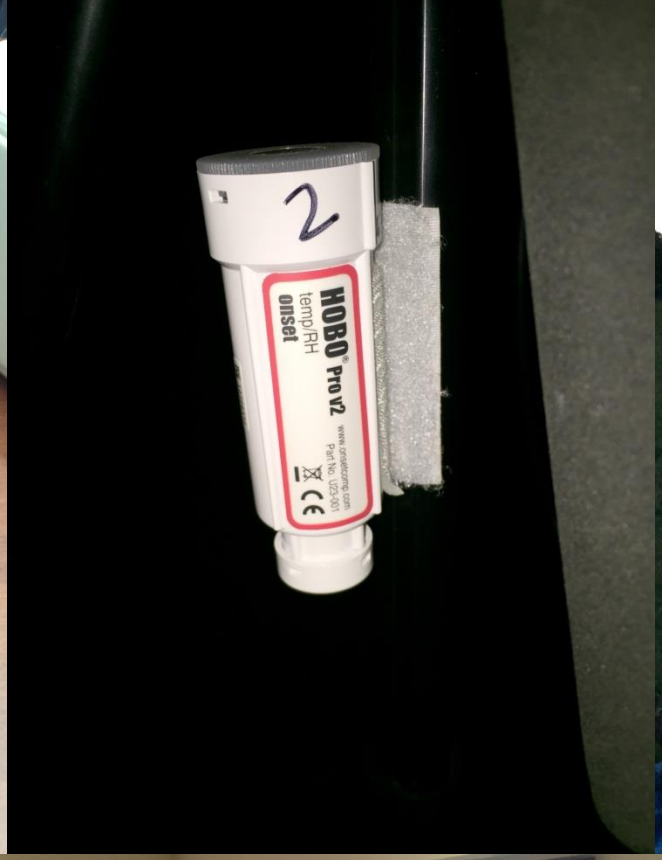
Figure 1: Map of PR's Light Pollution abatement Zones 1-8 (Regulation #8493 June, 27, 2014.)

Credit: National Park Service

With the SQM-L using the correct tools and analysis

- Beyond zenith luminance
- Average all-sky luminance
- Brightest sky luminance
- Vertical and horizontal illuminance from sky glow
- Light trespass from single sources


Canon
Canon
Sky Quality Meter
mags
arcsec²
Start
16 17 18 19 20 21
www.unihedron.com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V1 Forward Processing and Reprocessing: Schedule

Land Products: Schedule and Status

Product Name and ESDT series	Heritage MODIS	Product Status	Product Availability
Surface Reflectance VNP09	MxD09	Science code delivered and transitioned to operations	July 2016
LAI/FPAR VNP15	MxD15	Science code delivered and undergoing testing	August 16
Snow Products VNP10	MxD10	Science code delivered and undergoing testing	July 16
MAIAC VNP19	MCD19	Science code under development at SCF	October 2016
BRDF/Albedo VNP43	MCD43	Science code delivered and undergoing testing	August 2016
Burned Area VNP64A1	MCD64A1	Science code under development at SCF	March 2017
Active Fires VNP14	MxD14	Science code delivered and transitioned to operations	August 2016
Vegetation Index VNP13	MxD13	Science code under development at SCF	August 2016
LST & E VNP11(VNP21)	MxD11 (MxD21)	Science code delivered and undergoing testing	December 2016
Ice Products VNP29/VNP30	MxD29	Science code under development at SCF	November 2016
Phenology VNP12Q2	MCD12Q2	Science code under development at SCF	April 2017
Day/Night Band	None	Science code delivered and undergoing testing	April 2017

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:

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