Using VIIRS DNB SDRs to Generate Nighttime Lights Composites

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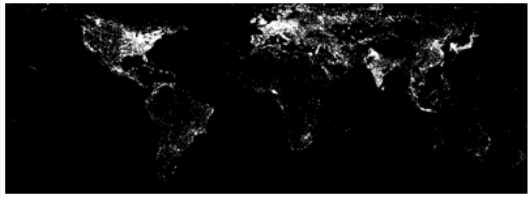
Nighttime Lights Composites

The EOG Group at NGDC has a long history of making global annual nighttime lights composites using DMSP-OLS data.

http://www.ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

Average Visible, Stable Lights, & Cloud Free Coverages						
Year\Sat.	F10	F12	F14	F15	F16	F18
1992	F101992	-------	-------	-------	-------	-------
1993	F101993	-------	-------	-------	-------	-------
1994	F101994	F121994	-------	-------	-------	-------
1995	-------	F121995	-------	-------	-------	-------
1996	-------	F121996	-------	-------	-------	-------
1997	-------	F121997	F141997	-------	-------	-------
1998	-------	F121998	F141998	-------	-------	-------
1999	-------	F121999	F141999	-------	-------	-------
2000	-------	-------	F142000	F152000	-------	-------
2001	-------	-------	F142001	F152001	-------	-------
2002	-------	-------	F142002	F152002	-------	-------
2003	-------	-------	F142003	F152003	-------	-------
2004	-------	-------	-------	F152004	F162004	-------
2005	-------	-------	-------	F152005	F162005	-------
2006	-------	-------	-------	F152006	F162006	-------
2007	-------	-------	-------	F152007	F162007	-------
2008	-------	-------	-------	-------	F162008	-------
2009	-------	-------	-------	-------	F162009	-------
2010	-------	-------	-------	-------	-------	F182010
2011	-------	-------	-------	-------	-------	F182011
2012	-------	-------	-------	-------	-------	F182012

F15 2003 Nighttime Lights Composite



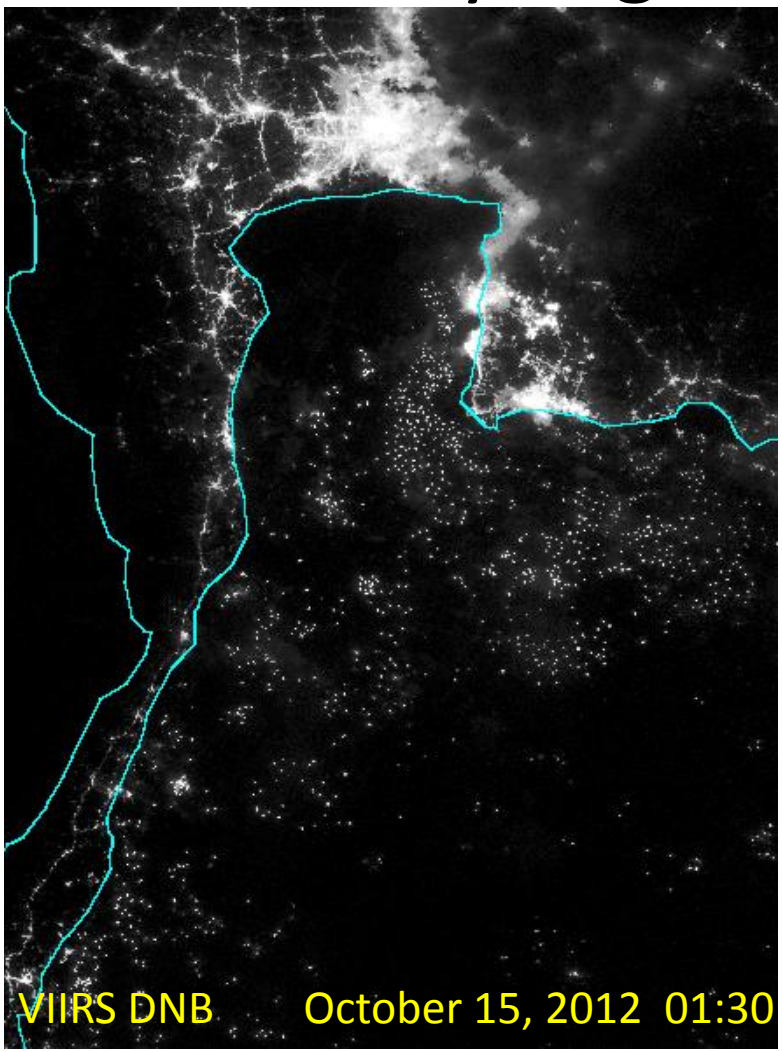
VIIRS Day-Night Band vs DMSP-OLS Spatial Resolution

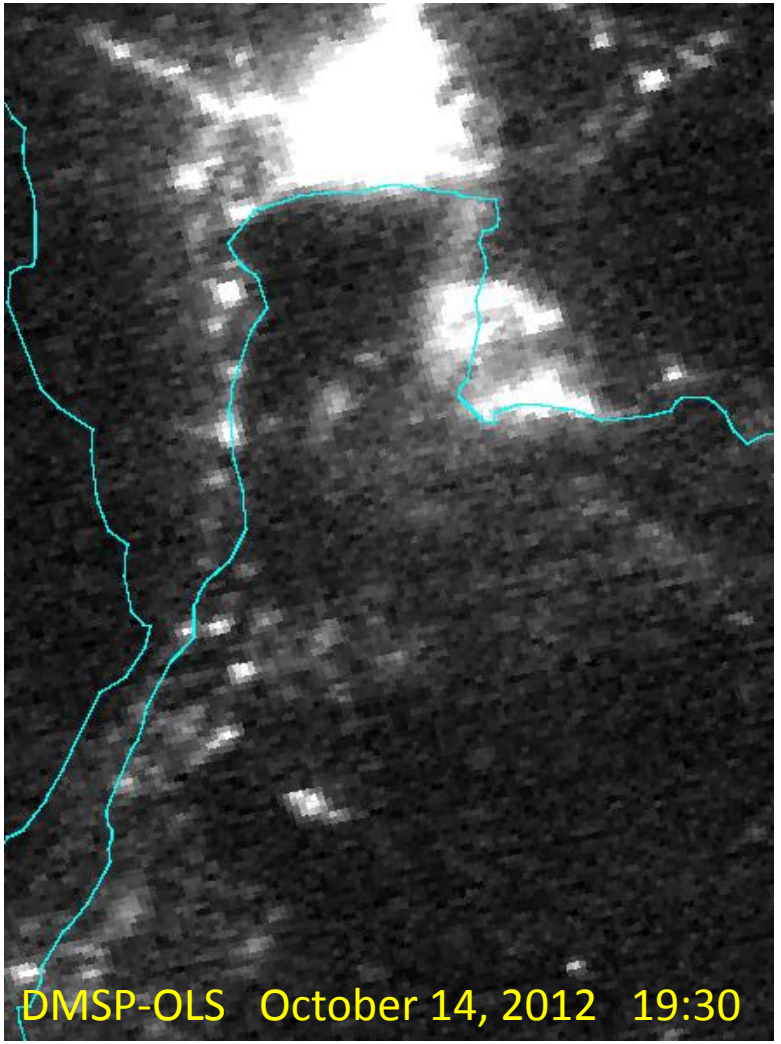
- The VIIRS DNB footprint is 45 times smaller than the nighttime DMSP-OLS pixel footprint!

VIIRS Day-Night Band vs DMSP-OLS

- ***Quantization:*** DNB is 14 bit versus 6 bit for OLS.
- ***Dynamic Range:*** Due to limited dynamic range, OLS data saturate on bright lights in operational data collections.
- **Lower Detection Limits:** DNB can detect dimmer lighting than OLS.
- ***Quantitative:*** DNB is calibrated, the OLS visible band has no in-flight calibration.
- ***Multispectral:*** VIIRS has additional spectral bands to discriminate combustion sources from lights and to characterize the optical thickness of clouds.

VIIRS Day-Night Band vs DMSP-OLS





Note the lack of DNB saturation in Bangkok. Also the increased spatial resolution and lower detection limits allow DNB to distinguish small roads and more isolated fishing boats.

Using VIIRS DNB for Nighttime Lights Composites

- **Some DMSP-OLS algorithms could be reused**
  - Day/night/twilight flagging
  - Zero lunar illuminance flagging
  - Stray light region flagging
  - Cloud algorithm (used M15 in place of OLS thermal band)
- **Some algorithms needed makeovers**
  - Light filter (to separate background from signal)
  - Lightning detector (to work on 16-line scan)
  - Terrain correction for geolocation
- **New algorithms**
  - Blurry lights filter (to remove reliance on cloud mask)
  - Fire removal (taking advantage of other VIIRS spectral bands)

VIIRS DNB Composites – First Attempt

- First prototypes made in Dec 2012 for low-moon nights in April and Oct 2012.
- Average radiance values were constructed on a 15 arc-second grid for data determined to be:
  - Cloud-free
  - Zero lunar-illuminance
  - Out of “stray light” region
- Composites weren’t as “sharp” as expected. We suspected either the cloud algorithm and/or errors in geolocation.

VIIRS DNB Composites – First Attempt

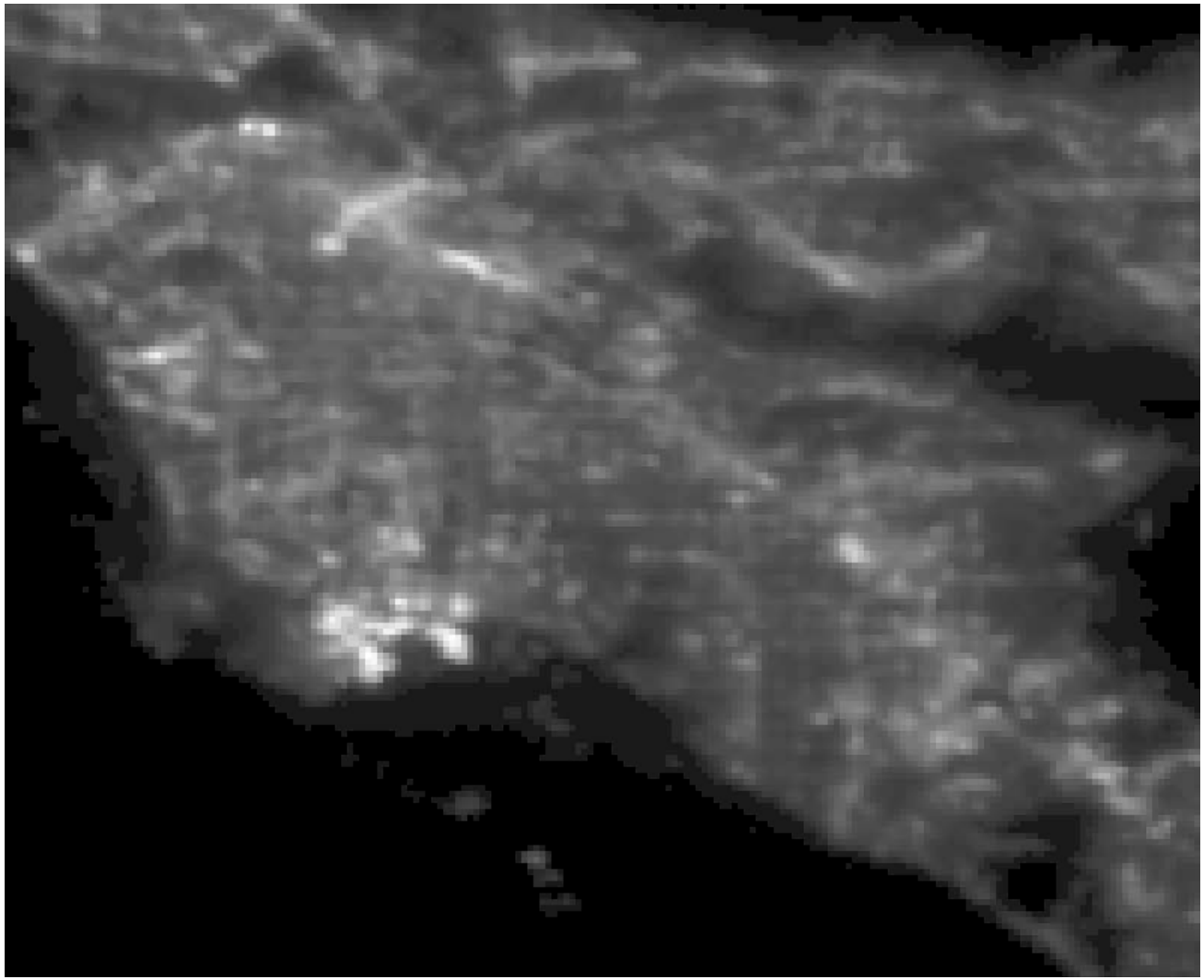
- Investigation revealed a known DNB pointing error. NGDC received a table of estimated pointing errors from L. Liao at Northrup Grumman, which were then matched with GEO LUT filenames recorded as an attribute in the DNB h5 files.
- Adding pointing error adjustment to terrain correction software made huge improvement in composite feature sharpness.
- It was decided to try using the VIIRS Cloud Mask for the next attempt to see if additional blurriness was reduced.

VIIRS DNB Composite (Oct 2012)
Before Pointing Error Correction

Close-up of Los Angeles Basin.

Toggle with next slide.

Notice westward shift and increased spread of lighting features due to pointing error.



VIIRS DNB Composite (Jan 2013)
After Pointing Error Correction

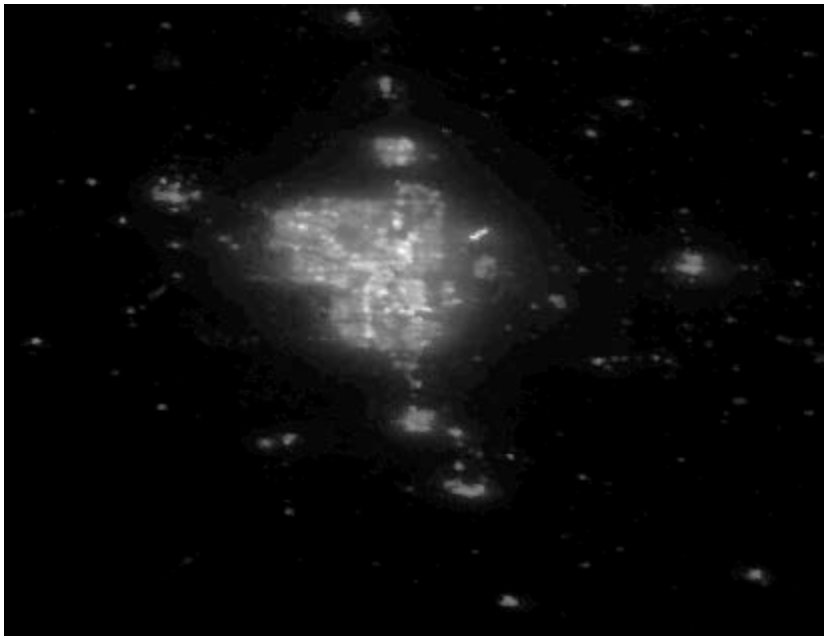
Close-up of Los Angeles Basin.

Toggle with prev slide.

Notice westward shift and increased spread of lighting features due to pointing error.

VIIRS DNB Composites – Second Attempt

- Second prototype made in April 2013 for all low-moon nights in Jan 2013.
- Composite still wasn't as "sharp" as expected in some regions of the world.
- The Jan 2013 composite used the VIIRS cloud-mask (VCM) to screen for clouds. Some clouds seem to be evading the cloud mask resulting in blurry lights.

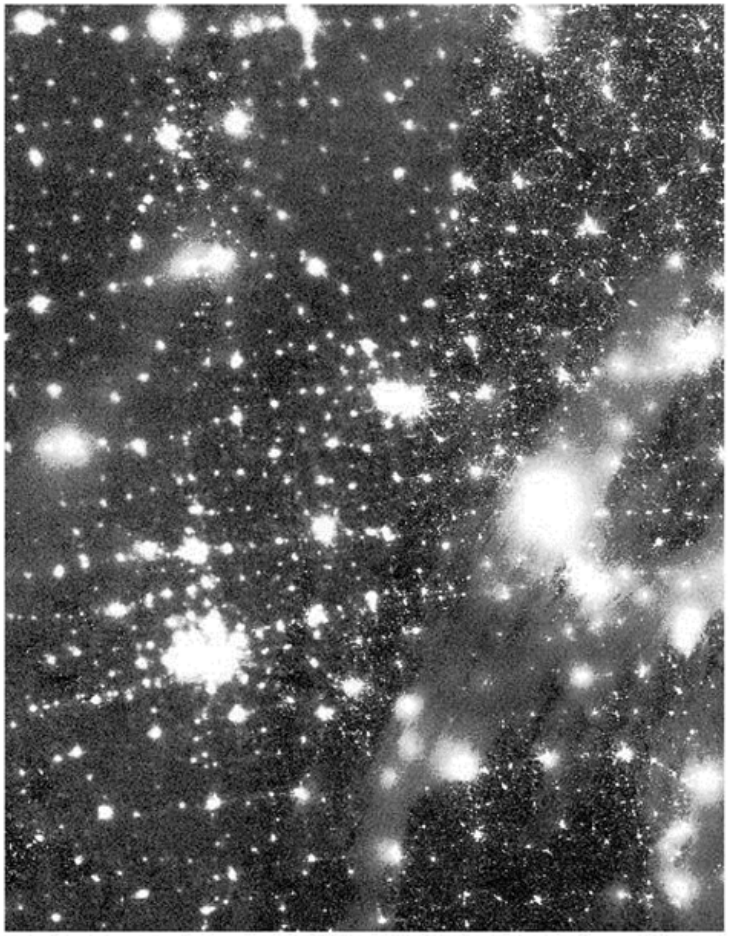


Calgary, Canada. Jan 2013 DNB Composite.

VIIRS DNB Composites – Current Run

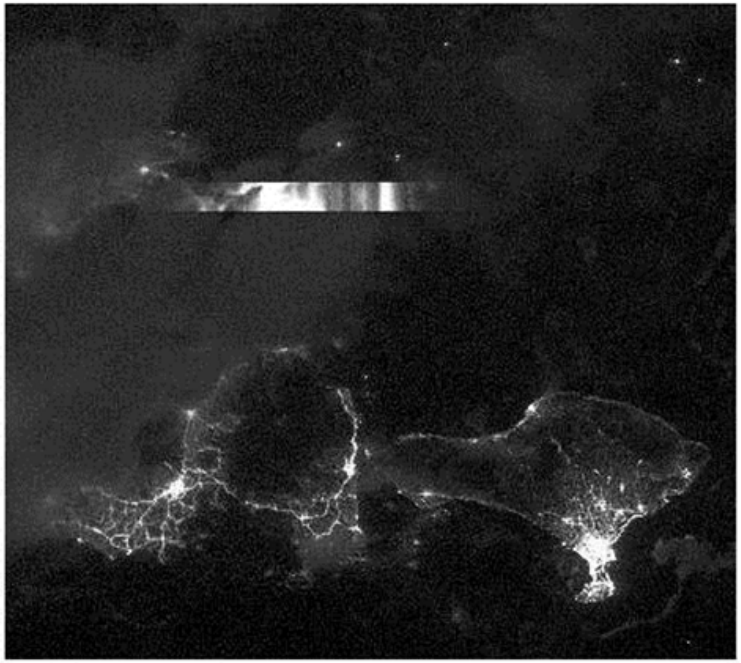
- Currently processing May 2014 data as it comes in.
- Additional algorithms being run are:
  - Blur Index (remove blurry lights without reliance on cloud mask)
  - Lightning filter
  - Light detection (separation of lights from background)

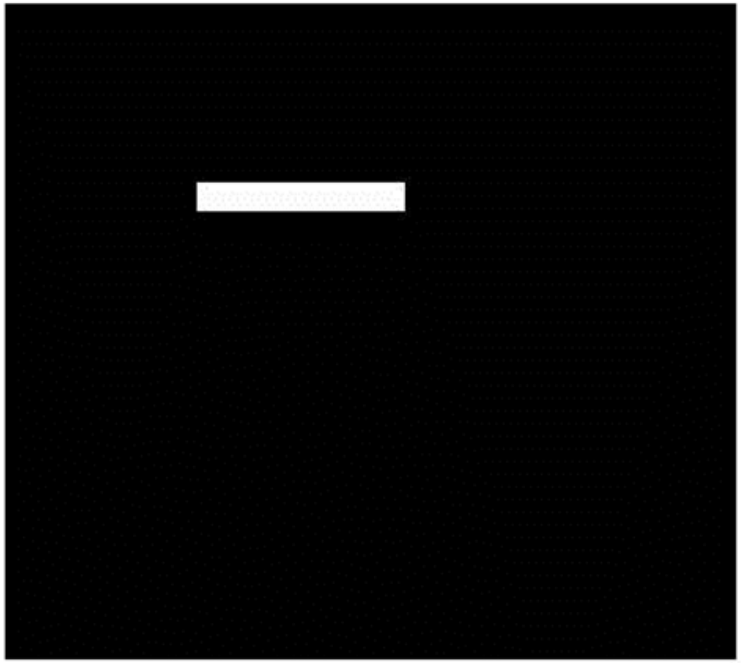
Blur Index



On the left is a DNB image showing areas with blur induced by clouds. On the right is the blur index image. Blurry areas are dark and sharp lights are bright. By applying a threshold on this index it will be possible to screen blurry areas from the composite.

Lightning Filter



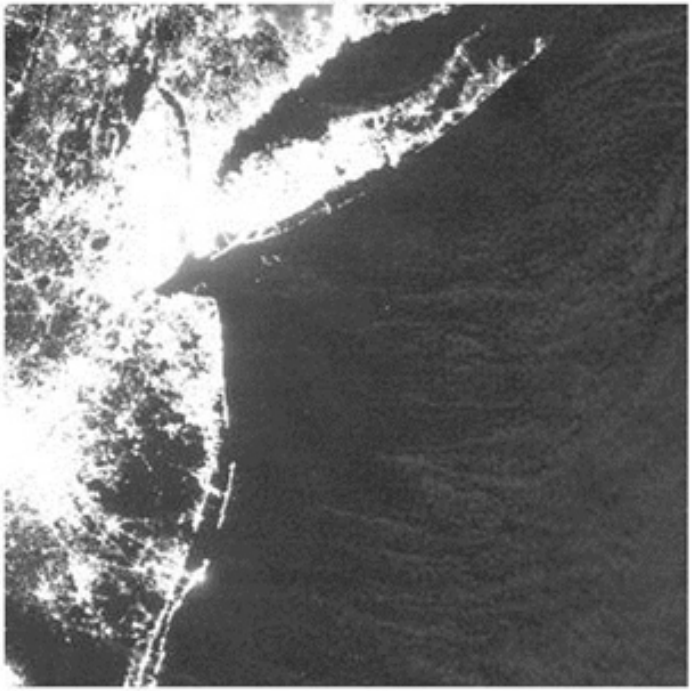


Example of lightning streaks detected by the DNB. The streaks are sixteen lines wide, arising from individual scans.

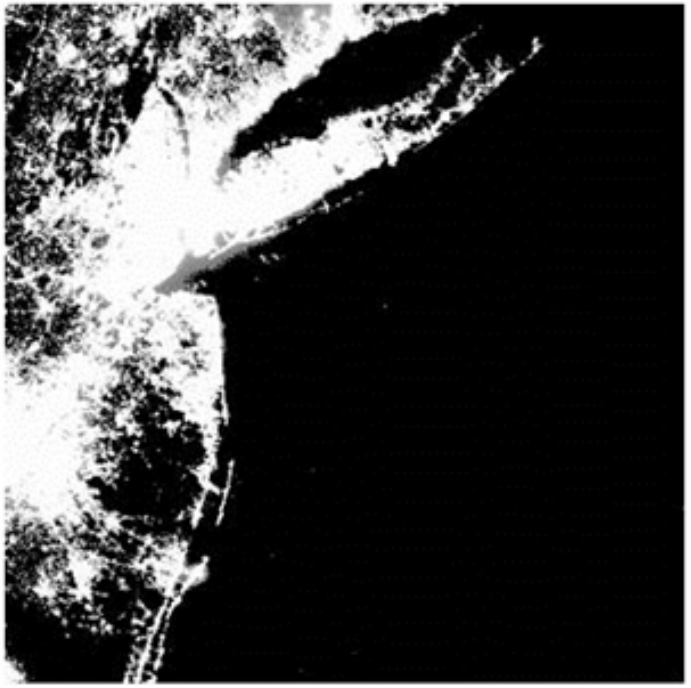
Removing reliance on a cloud-mask by using the blur index will make filtering for lightning signatures necessary for a clean DNB composite.

Light Detection

Raw DNB image



Background removed



A light detection algorithm is also being tested. It is designed for use on low lunar illumination DNB data.

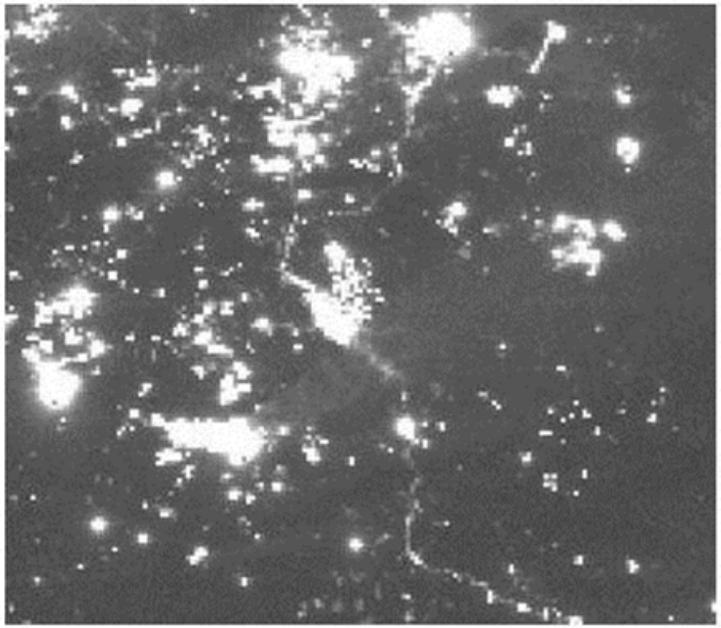
NGDC DNB Data Availability

- Monthly product generation started 5/1/14. The three preliminary products discussed are available at: http://ngdc.noaa.gov/eog/viirs/download_monthly.html
- NGDC also generates nightly mosaics in png and Google Earth Super-overlay formats http://ngdc.noaa.gov/eog/viirs/download_ut_mos.html

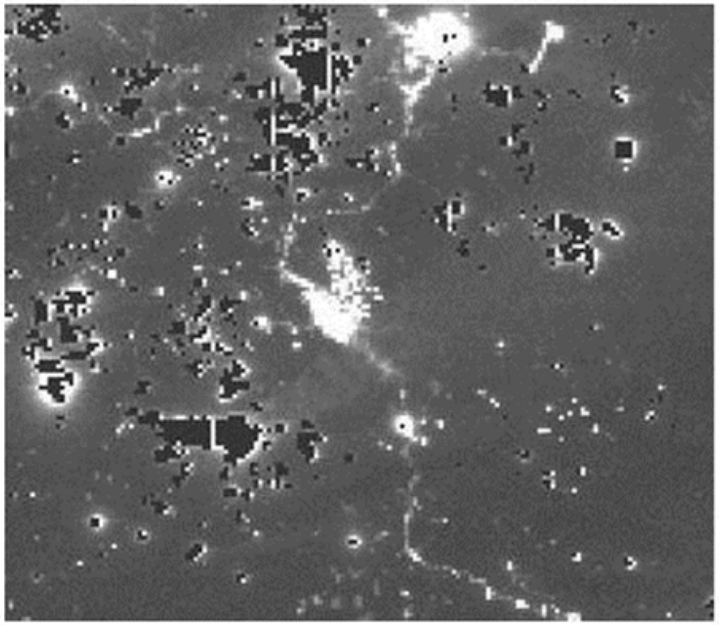
Next for VIIRS DNB Composites

- Still in algorithm development - R&D
  - Separating fires from lights using NGDC Nightfire product

Mixture of fires and towns



VNF fires masked out

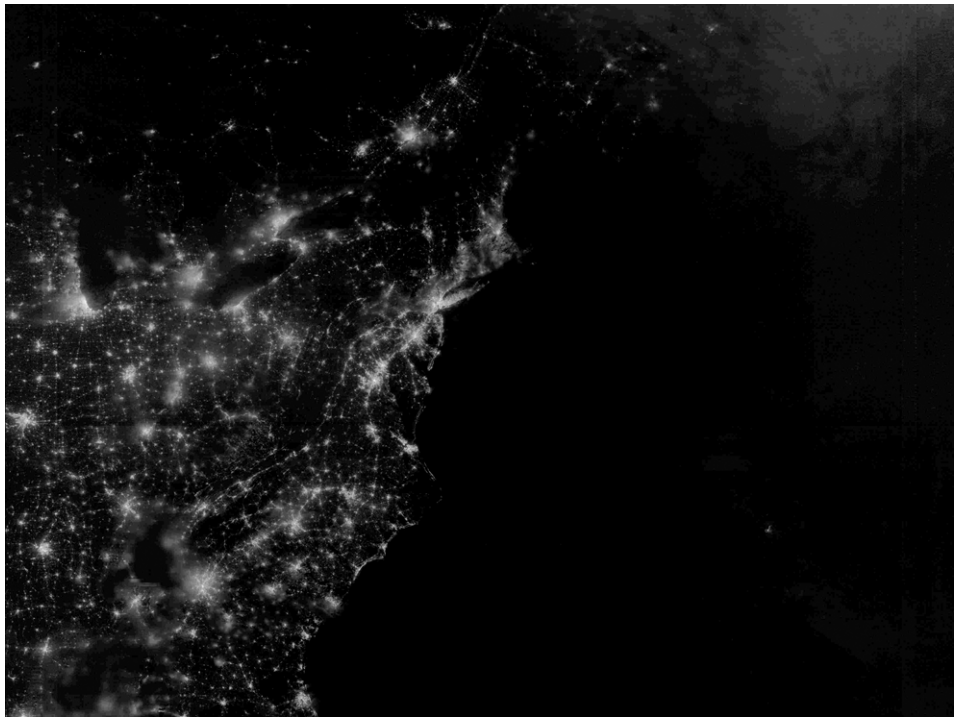


The image on the left is the raw DNB. The image on the right shows the masking of biomass burning pixels from the Nightfire (VNF) data.

DNB Atmospheric Correction
In development – R&D

- The loss of signal in the DNB due to atmospheric absorption and scatter is both substantial and highly variable, in the range of 15 to 60%.
- We are working on an atmospheric correction for the DNB that uses MODTRAN to estimate the transmissivity of the atmosphere in the DNB.
- We parameterize MODTRAN using atmospheric profiles generated from ATMS data, which are collected simultaneous to the VIIRS.
- Specifically, we will use atmospheric pressure, temperature and relative humidity profiles generated from ATMS data using the MIIRS processing package (NOAA, 2013).
- The MODTRAN runs are computationally intensive, therefore the correction will only be run on pixels that are entering the monthly composites.

Stray light correction algorithm from Northrup Grumman



This algorithm was implemented at the IDPS in August 21, 2013. We will likely need to implement the algorithm at NGDC and apply it to archive data acquired prior to that.

Publications

- VIIRS Nightfire: Satellite pyrometry at night http://www.mdpi.com/2072-4292/5/9/4423
- What is so great about nighttime VIIRS data for the detection and characterization of combustion sources? DOI: http://dx.doi.org/10.7125/APAN.35.5
- Using the short-wave infrared for nocturnal detection of combustion sources in VIIRS data. DOI: http://dx.doi.org/10.7125/APAN.35.6
- Why VIIRS data are superior to DMSP for mapping nighttime lights. DOI: http://dx.doi.org/10.7125/APAN.35.7
- Nighttime lights compositing using the VIIRS day-night band: Preliminary results DOI: http://dx.doi.org/10.7125/APAN.35.8