VIIRS Nighttime Lights Algorithm Development 2015

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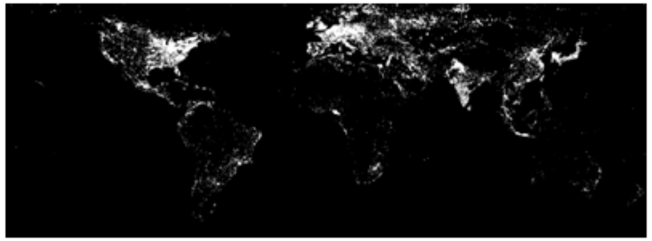
Nighttime Lights Composites
(Historical OLS Products)

The EOG Group at NCEI has a long history of making global annual nighttime lights composite products 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
2013	-------	-------	-------	-------	-------	F182013

F15 2003 Nighttime Lights Composite



Nighttime Lights Composites
What are they?

- A nighttime lights composite is made to serve as a baseline of persistent light sources.
- Composites are made as an average of the highest quality nighttime lights imagery over desired time period – usually monthly or annually.
- “Stable Lights” composites have ephemeral light sources and non-light (background) areas are removed from a composite.
- EOG group is producing current monthly cloud-free/no-moon DNB nighttime lights composites and is doing algorithm development to turn these in to Stable Lights composites.

Nighttime Lights Composites
What goes in?

- Only the “highest quality” nighttime data gets averaged into a composite
- Currently this is defined as DNB data that is:
  - Cloud-free (using the VIIRS cloud-mask (VCM) product)
  - Nighttime with solar zenith angles greater than 101
  - Not affected by moonlight (lunar illuminance < 0.0005 lux)
  - Middle of swath (DNB has increased noise at edge of scan)
  - Free of lights from lightning
  - Free of “lights” from South Atlantic Anomaly

Nighttime Lights Composites
(Monthly DNB Products)

- Monthly DNB nighttime lights composites are available online
- Globe is cut into 6 tiles to reduce individual file sizes
- These products still contain ephemeral lights and non-lights (background).

http://www.ngdc.noaa.gov/eog/viirs/download_monthly.html

Sources of Nighttime Lights

Cities and human settlements

Aurora

Lightning

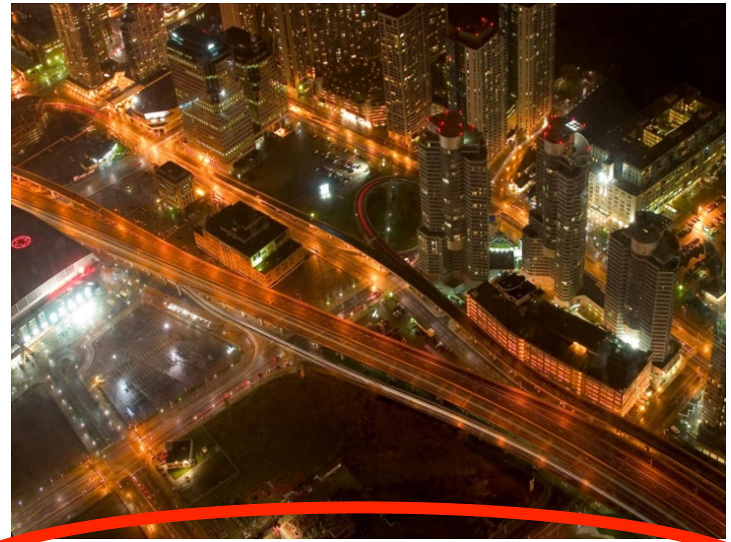
Boats

Gas Flares

Industrial Sites

Fires

Stable Sources of Nighttime Lights



Cities and human settlements

Aurora

Lightning

Boats

Gas Flares

Industrial Sites

Fires

DNB Image Artifacts

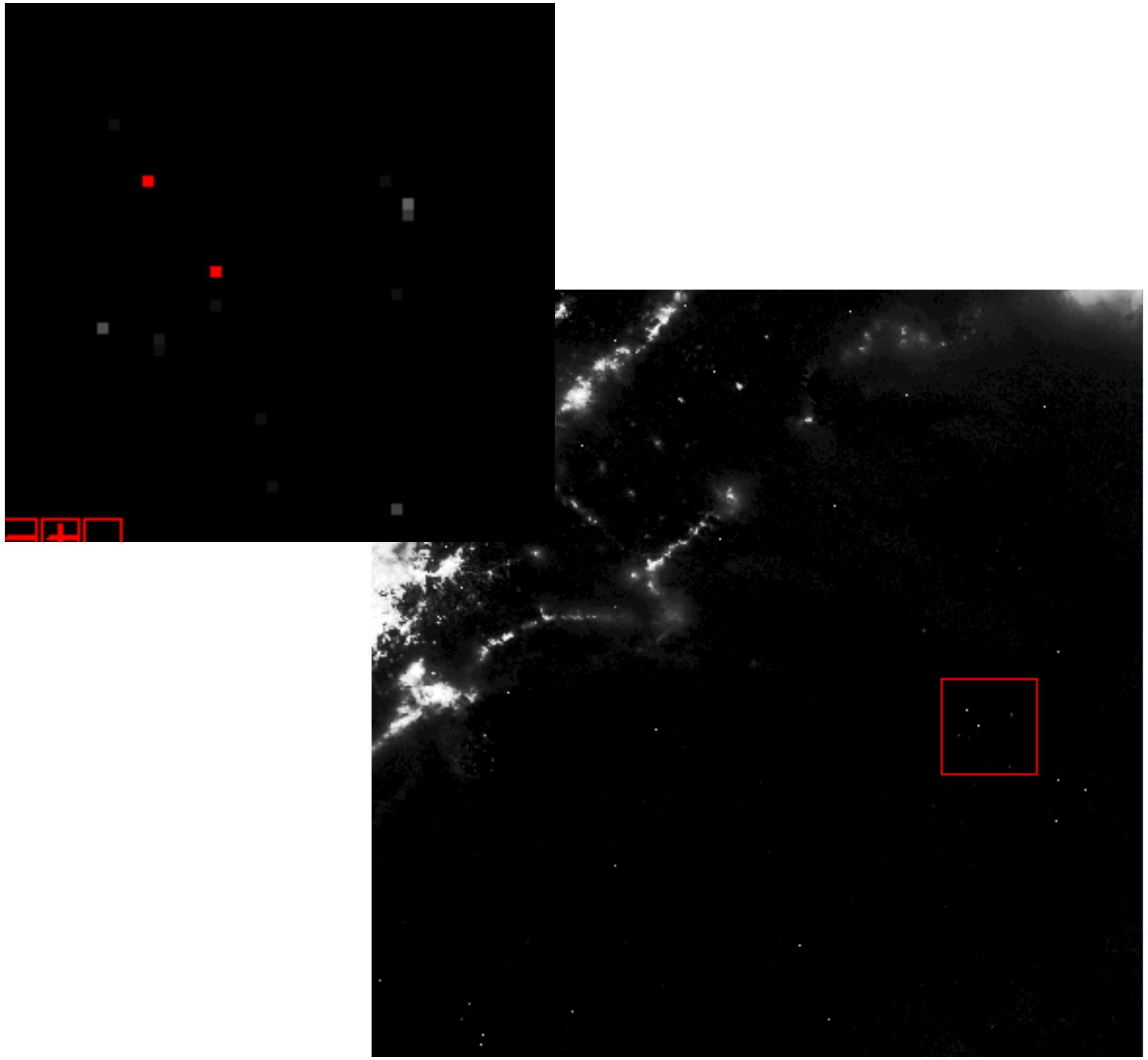
- In addition to ephemeral lights, there are sensor specific image artifacts that need to be removed.
- The four most troublesome artifacts:
    - Stray Light
    - High energy particle hits to detector – most common in South Atlantic Anomaly (SAA) region
    - Cross talk – across lines within a scan when imaging very large gas flares
    - DNB aggregation zones 29-32

DNB Image Artifacts: Stray Light

- Northrup Grumman algorithm was implemented at the IDPS in August 2013.
- Does a good job of mitigating stray light effects for visual interpretation.
- Some issues for algorithm development within the stray light corrected region:
  1) Can under/over-correct, especially at transition into stray light and in Southern hemisphere
  2) Variance of data across scan is altered
  3) Correction quality is dependent on time from correction lookup table generation
- Stray light corrected regions are identified and processed separately

DNB Image Artifacts: SAA Hits

- Example of high values in DNB due to high energy particles in South Atlantic Anomaly region.
- Red pixels were labelled as SAA hits because they exceeded the average of neighboring pixels by more than 99.5%
- This algorithm removes **most** of the SAA noise
- In prototype composites, there appears to be remaining SAA noise with low radiance values. Further investigation is warranted.

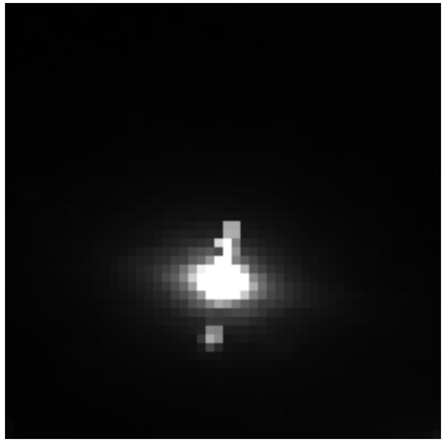


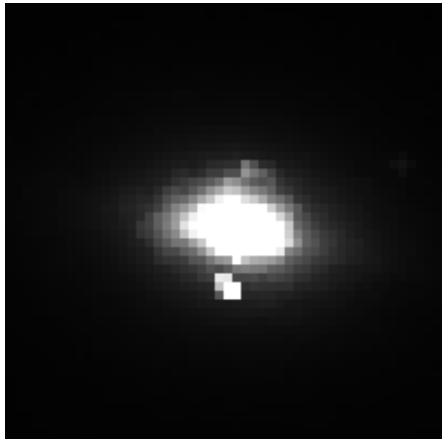
March 31, 2012 – off coast of Brazil

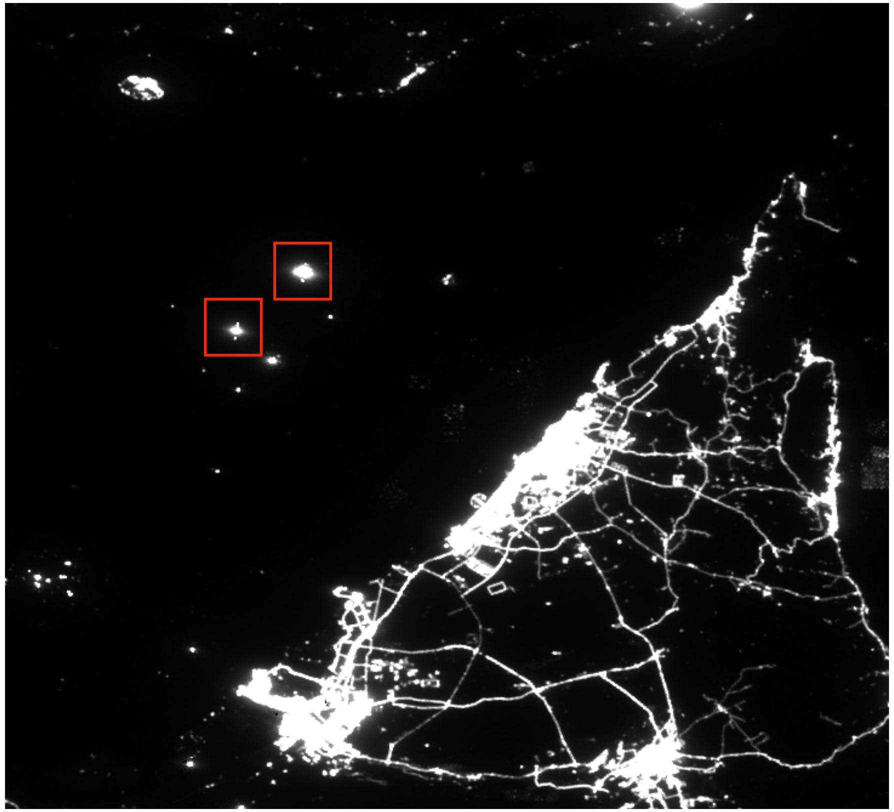
DNB Image Artifacts: Crosstalk

- Crosstalk is only an issue in High Gain State (HGS) DNB data
- Crosstalk manifests as spurious signal in the same sample position in other detectors within the scan.
- Crosstalk is seen mainly (only?) over large gas flares
- Both positive and negative crosstalk occurs
- Algorithm for detection of crosstalk events is TBD

Crosstalk shows up as pairs of small “lights” around large gas flares in Persian Gulf DNB composite.



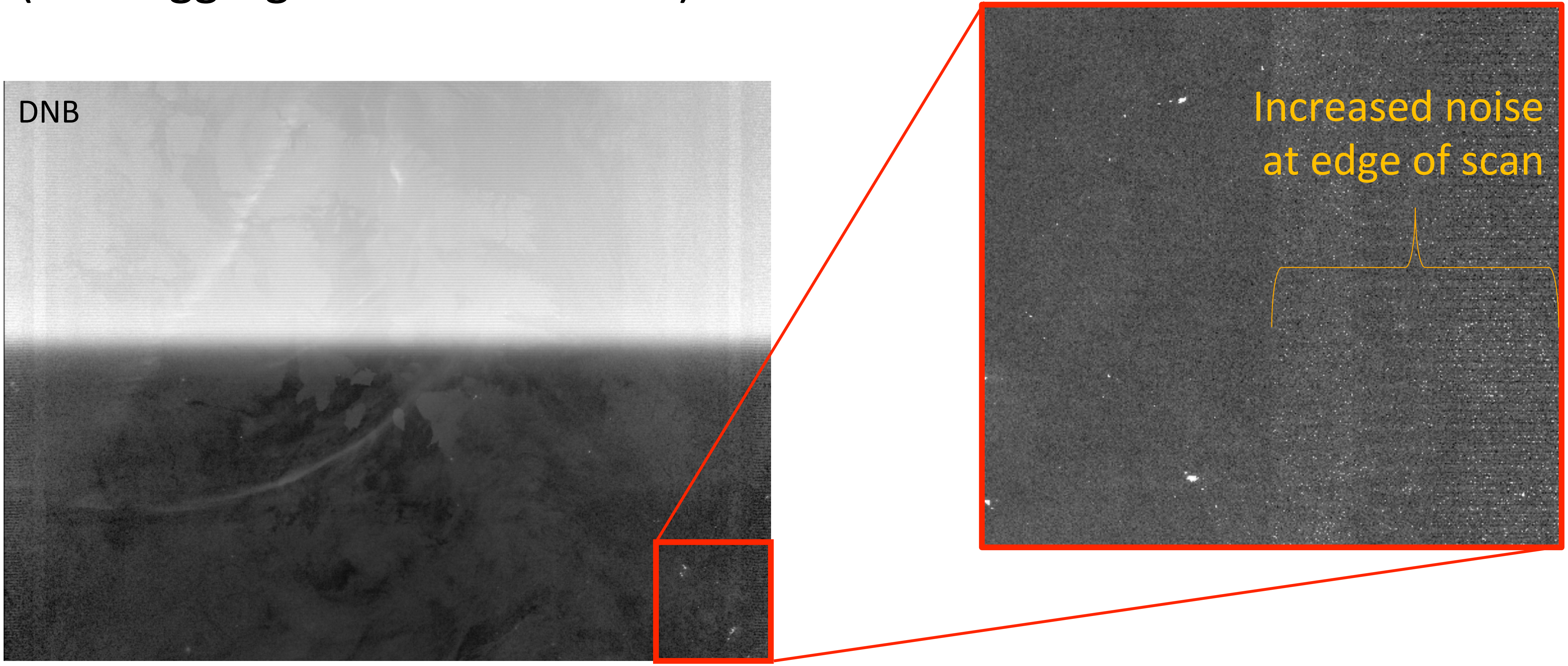




May 2014 average DNB composite

DNB Image Artifacts: Agg. Zones 29-32

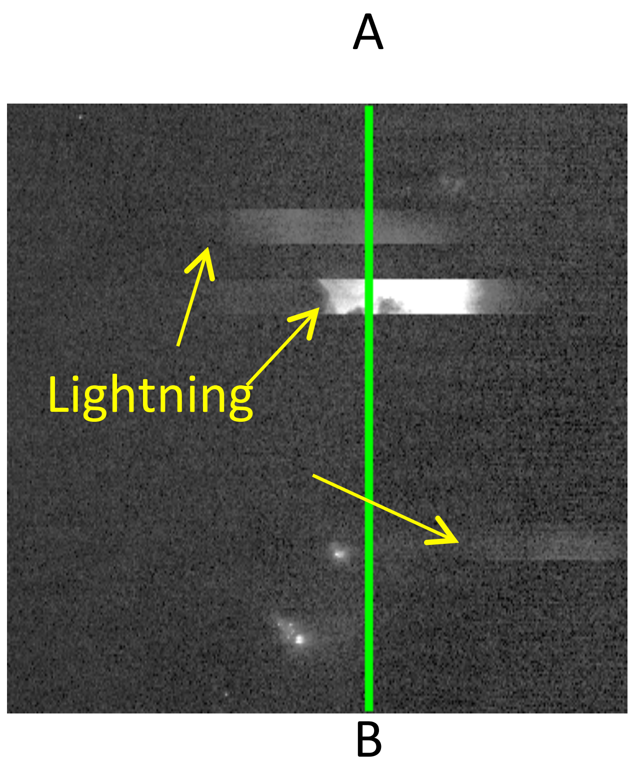
Edge-of-swath pixels are discarded due to increased noise (DNB aggregation zones 29-32).

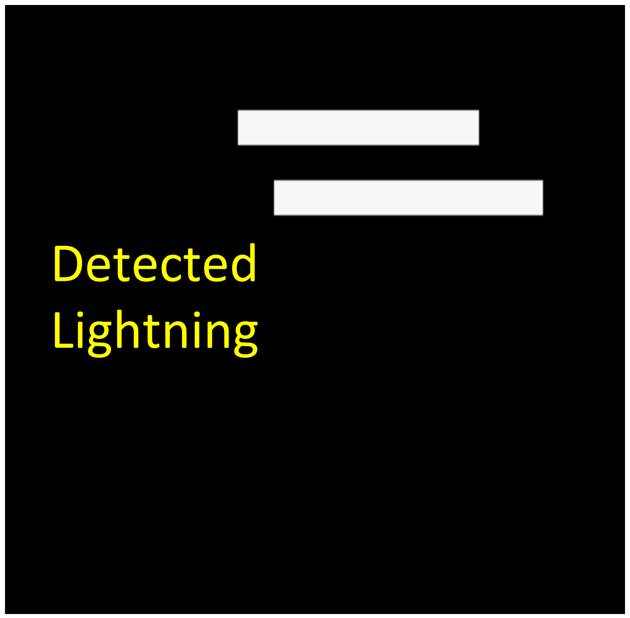


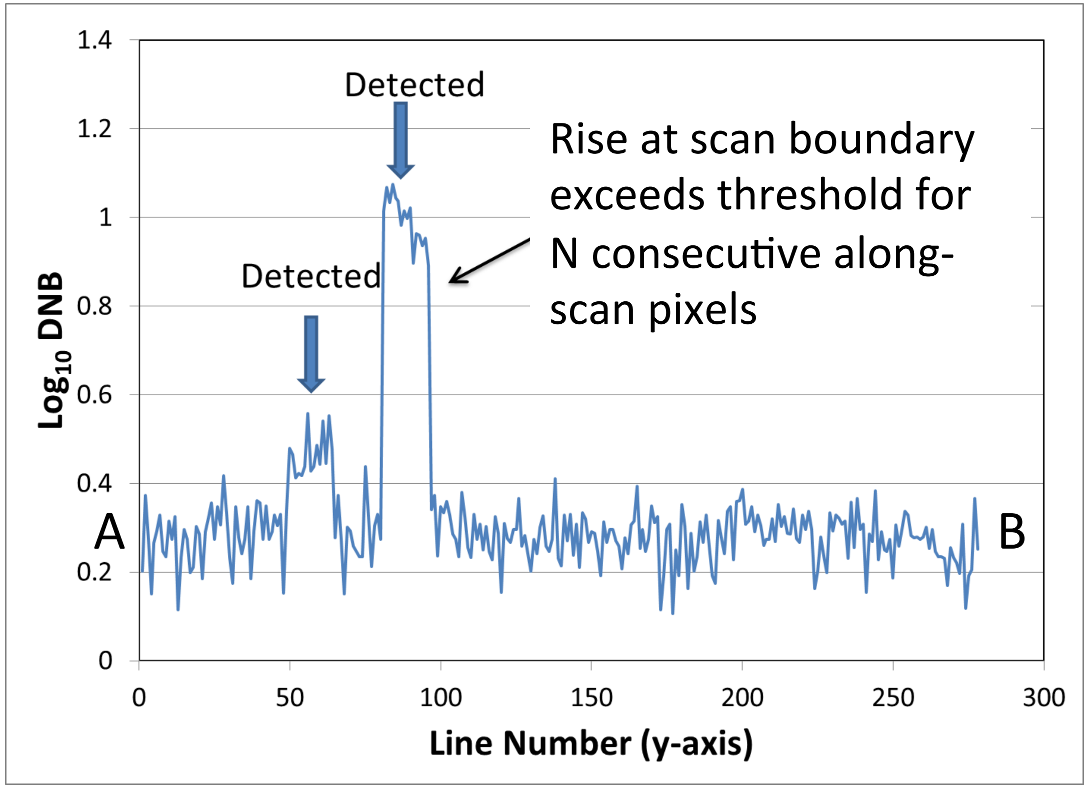
Aggregate SVDNB_npp_d20121018_t0749150_e0754554_b05050_c20121018135455638495_noaa_ops.h5

DNB Ephemeral Lights: Lightning

- Lightning appears in DNB imagery as horizontal ribbons of lighting.
- These features are generally one scan (16 lines) wide.
- When lightning features are in adjacent scans, they are generally offset and the brightness values differ, so algorithm still holds.



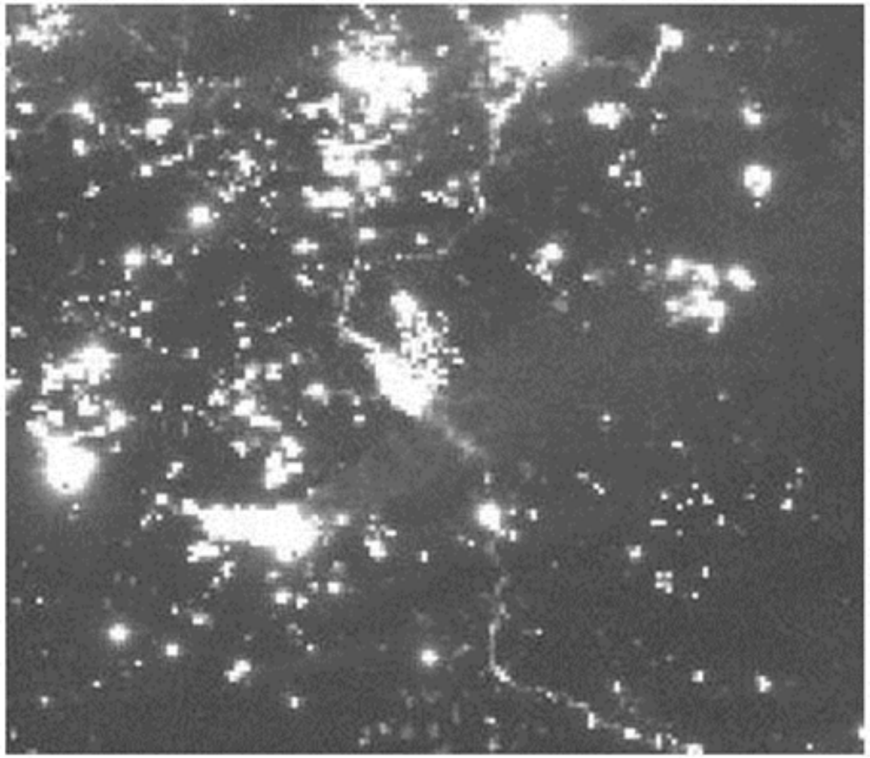




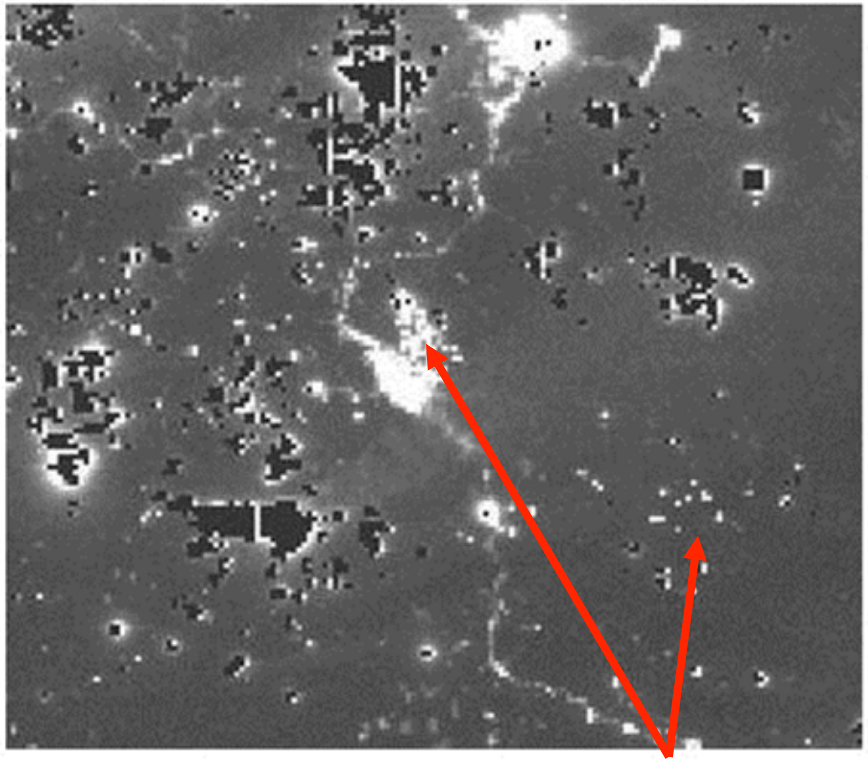
DNB Ephemeral Lights: Fires/Flares/Volcanos

- First approach:
  - Separate fires from lights using VIIRS NightFire (VNF) product
  - VNF algorithm uses VIIRS M-band data, collected simultaneously with DNB

Mixture of fires and towns



VNF fires masked out



Some fires not detected by VNF

Issues:

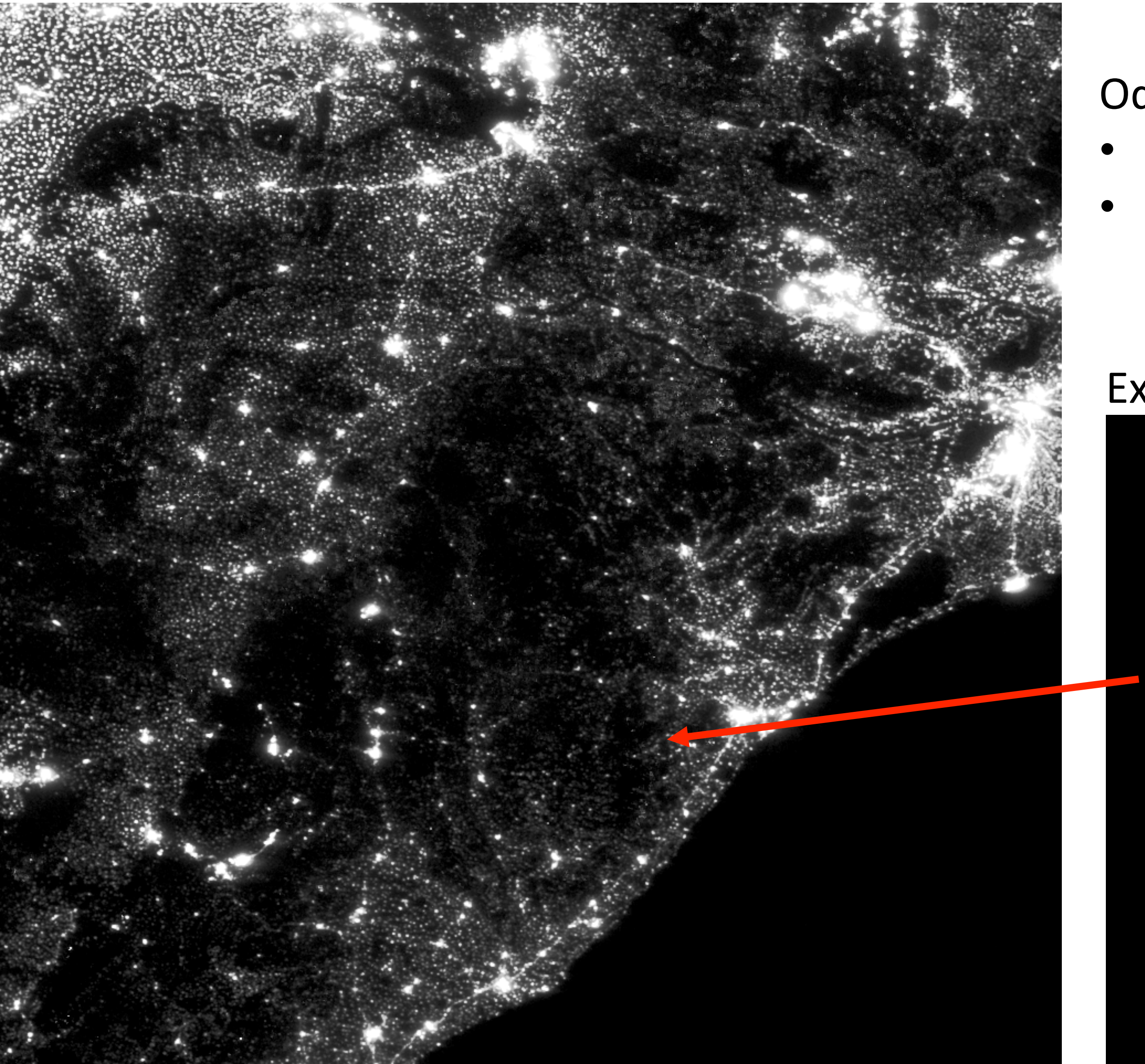
1) Remaining glow around VNF detections need to be addressed.

2) DNB has lower detection limits than the M-bands and picked up some fires that VNF did not detect.

DNB Ephemeral Lights

- Second approach:
  - Create histograms of DNB radiances using an extended time series (annual)
  - Use histograms to identify and remove outliers
  - Similar to algorithm developed for DMSP-OLS Stable Lights
  - Advantages: This algorithm removes ANY outliers, including fires, boats, unfiltered-SAA, crosstalk, …
  - Disadvantages: Persistent flares and volcanic activity can remain. Method requires long time-series of data.

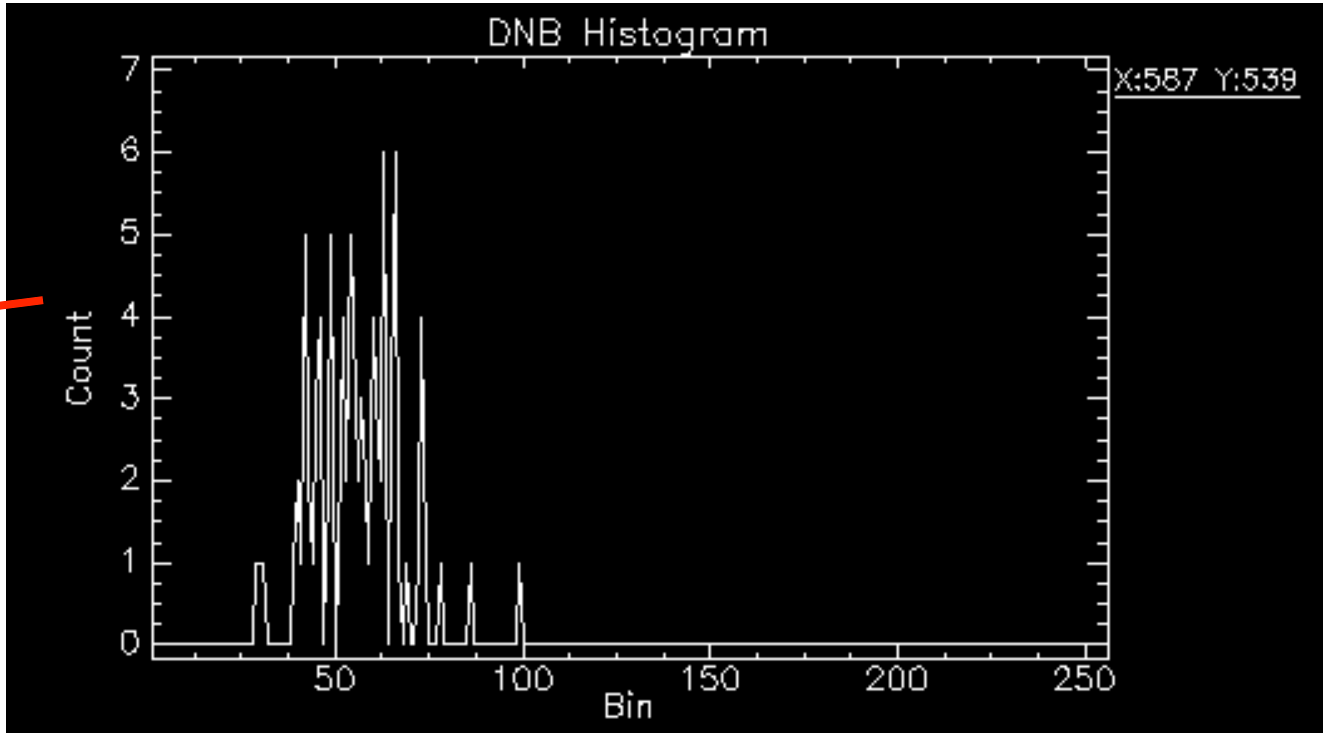
DNB Ephemeral Lights: Outlier Removal



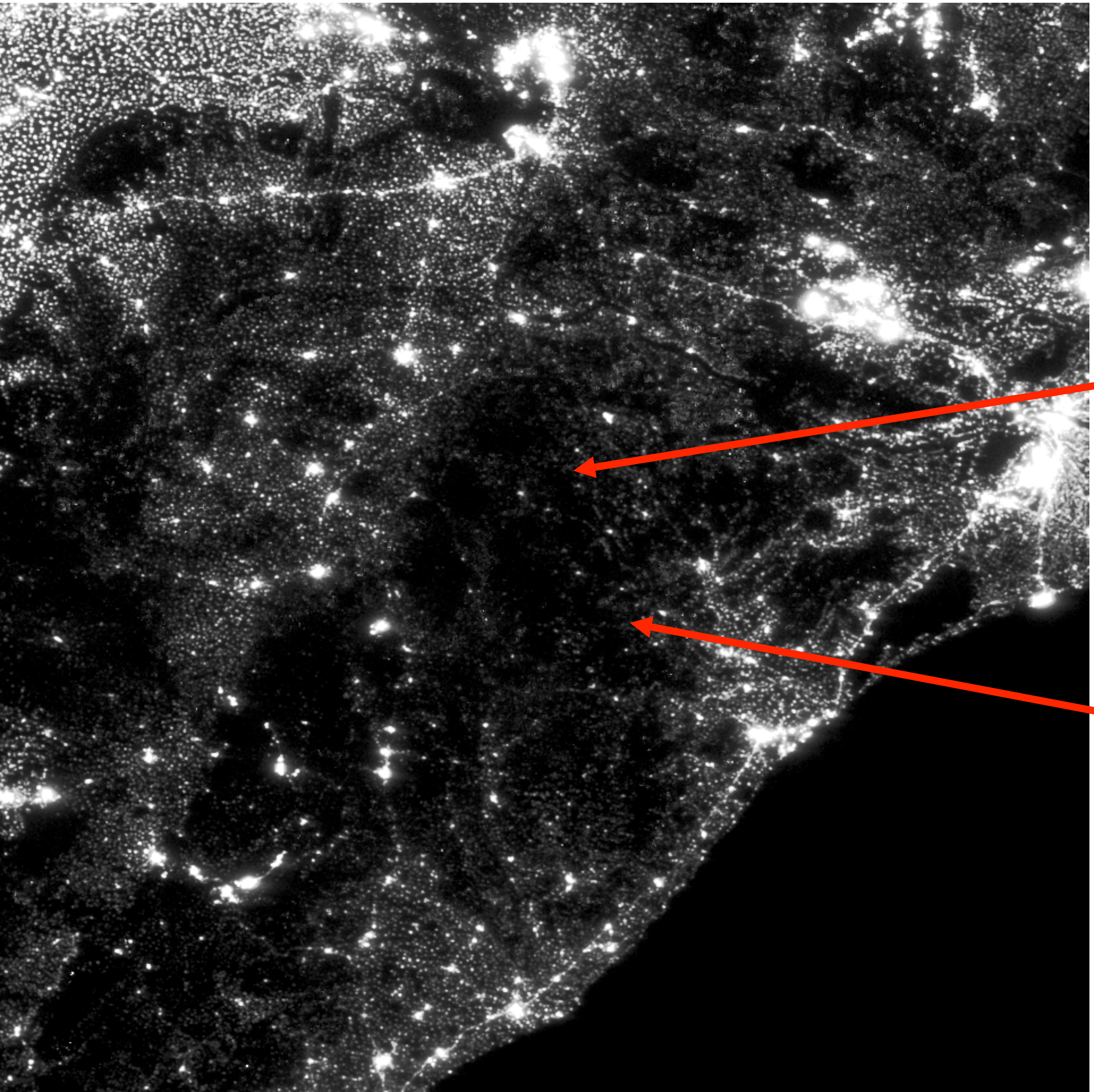
Odisha, India 2014 DNB Composite

- Histograms are made for each grid cell in composite
- DNB radiance values are placed in discrete bins based on log transform. Bin=floor(100*(log(1E9*Rad+1.5))

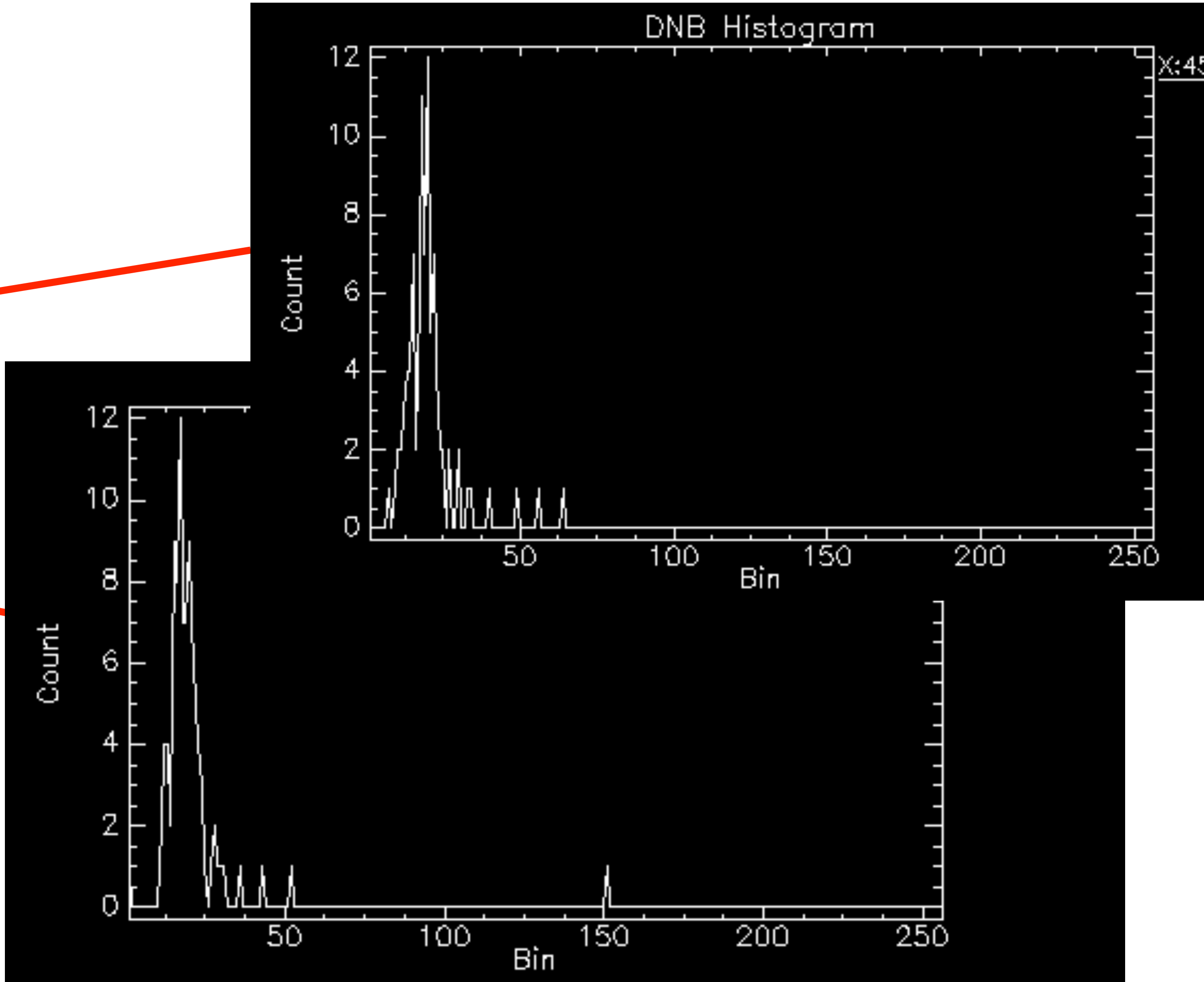
Example histogram of small village



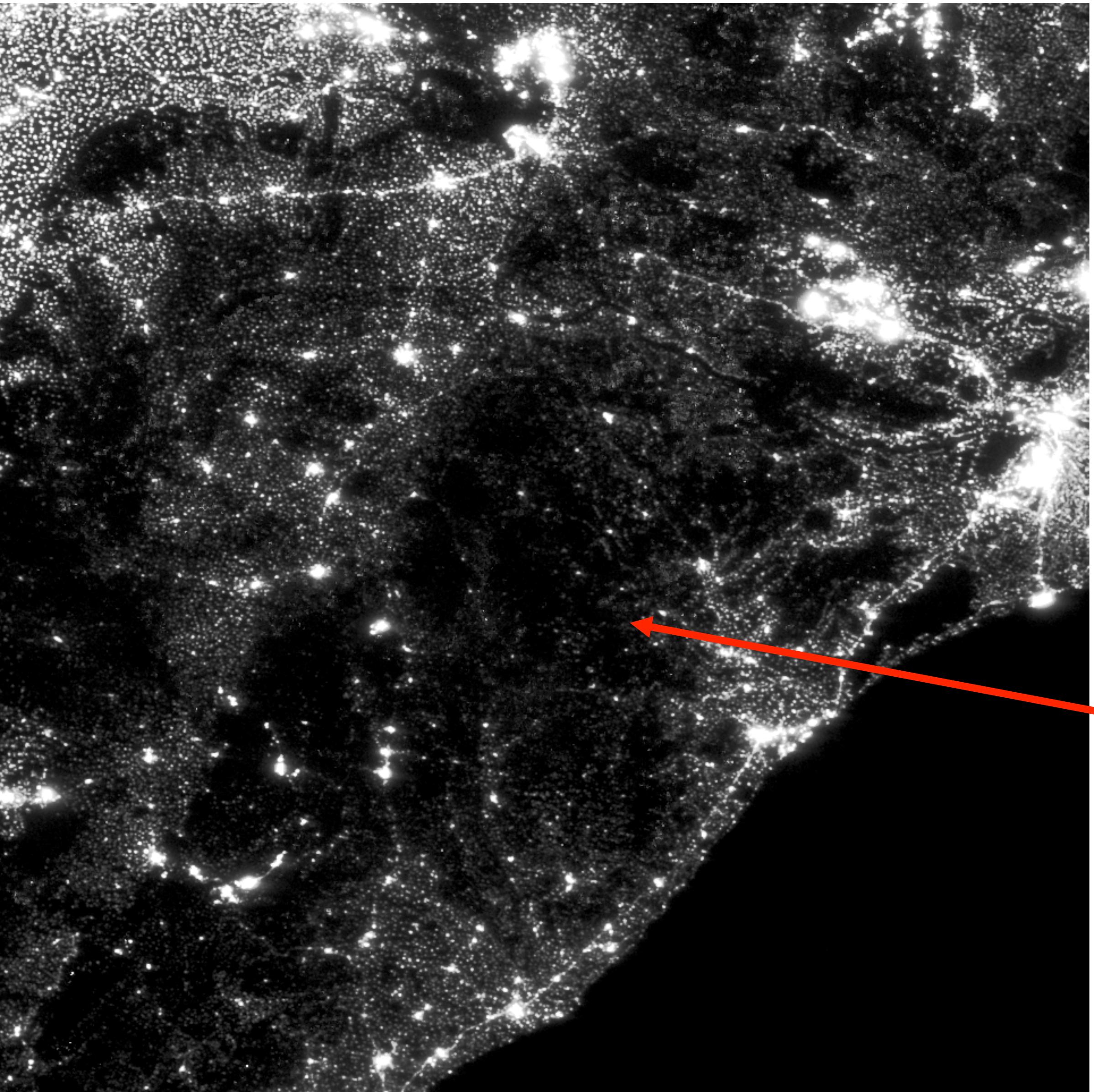
DNB Ephemeral Lights: Outlier Removal



Example histograms of grid cells containing fires

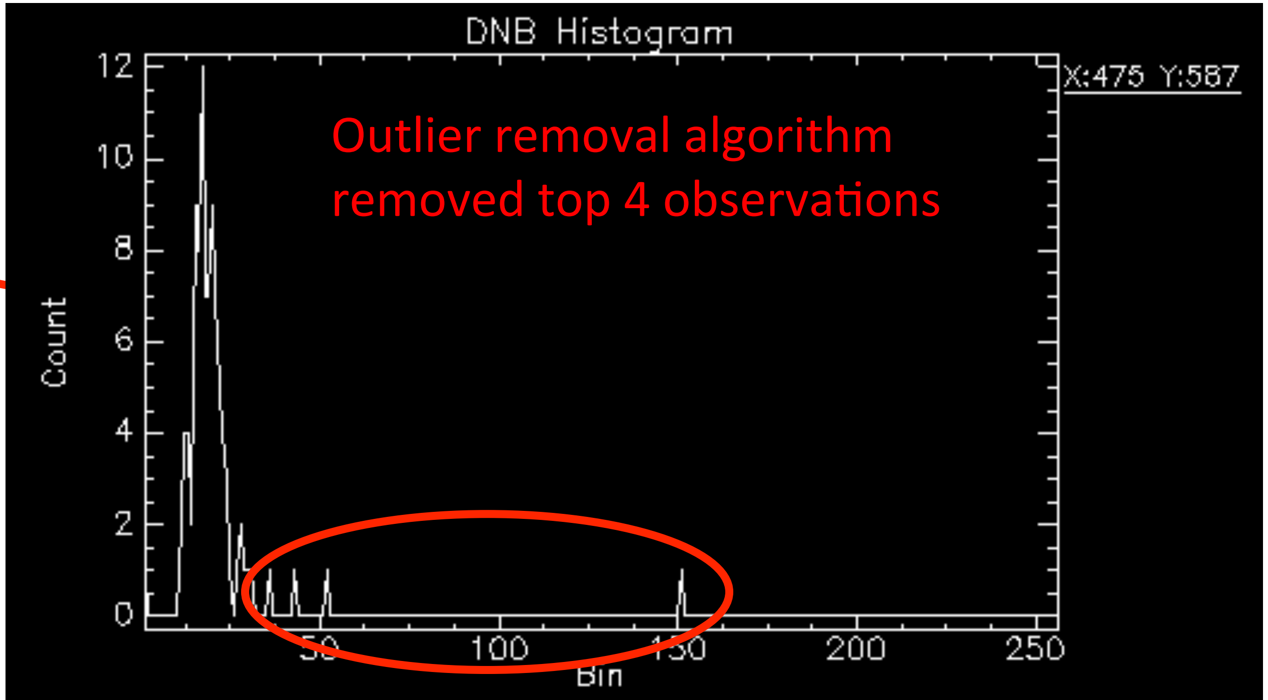


DNB Ephemeral Lights: Outlier Removal



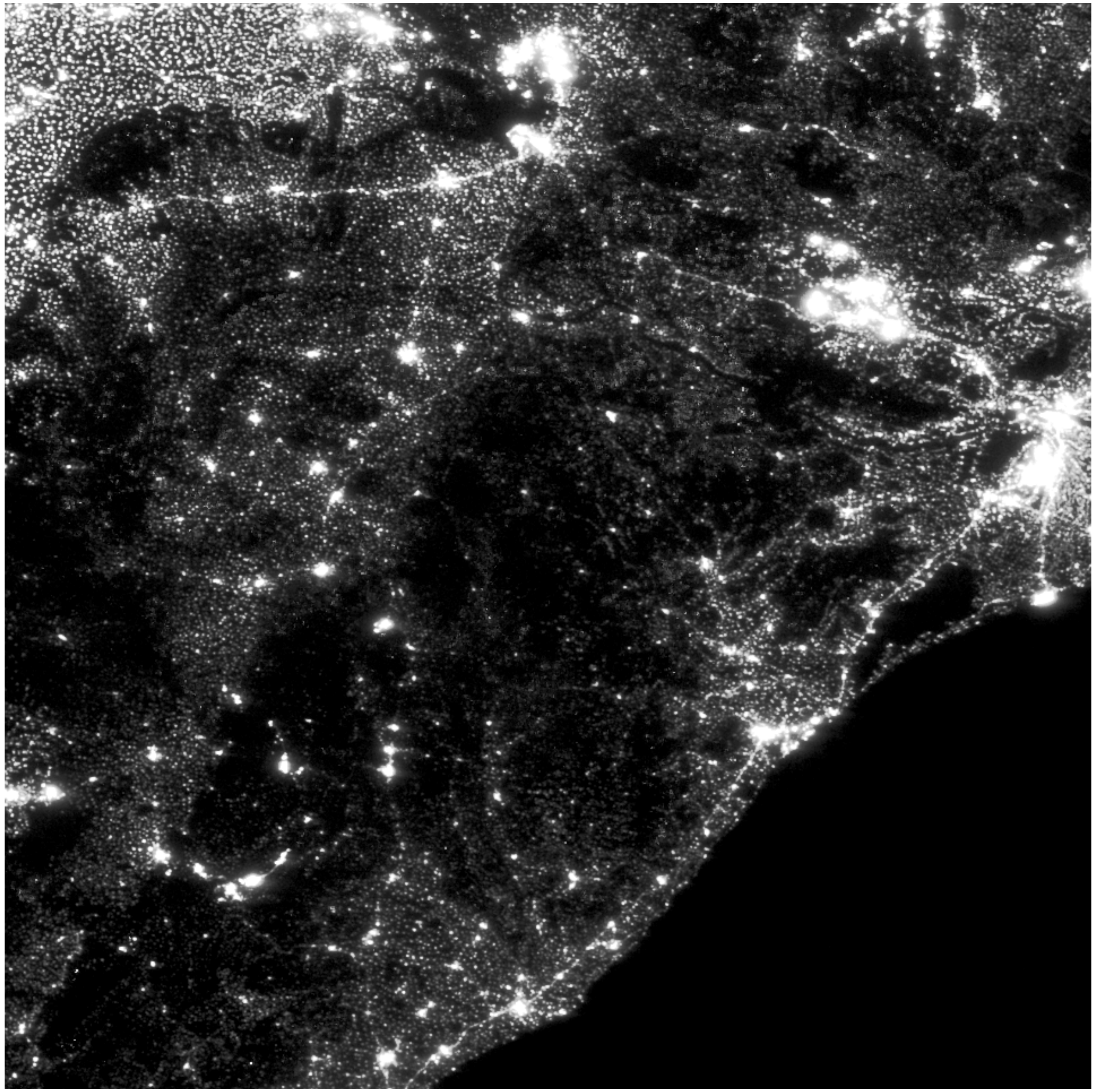
Algorithm:

1) Compute standard deviation of observations
2) Remove highest observation
3) Re-compute standard devation
4) Repeat steps 2-3 if difference in standard deviations > threshold
5) Re-compute average of remaining observations



DNB Ephemeral Lights: Before Outlier Removal

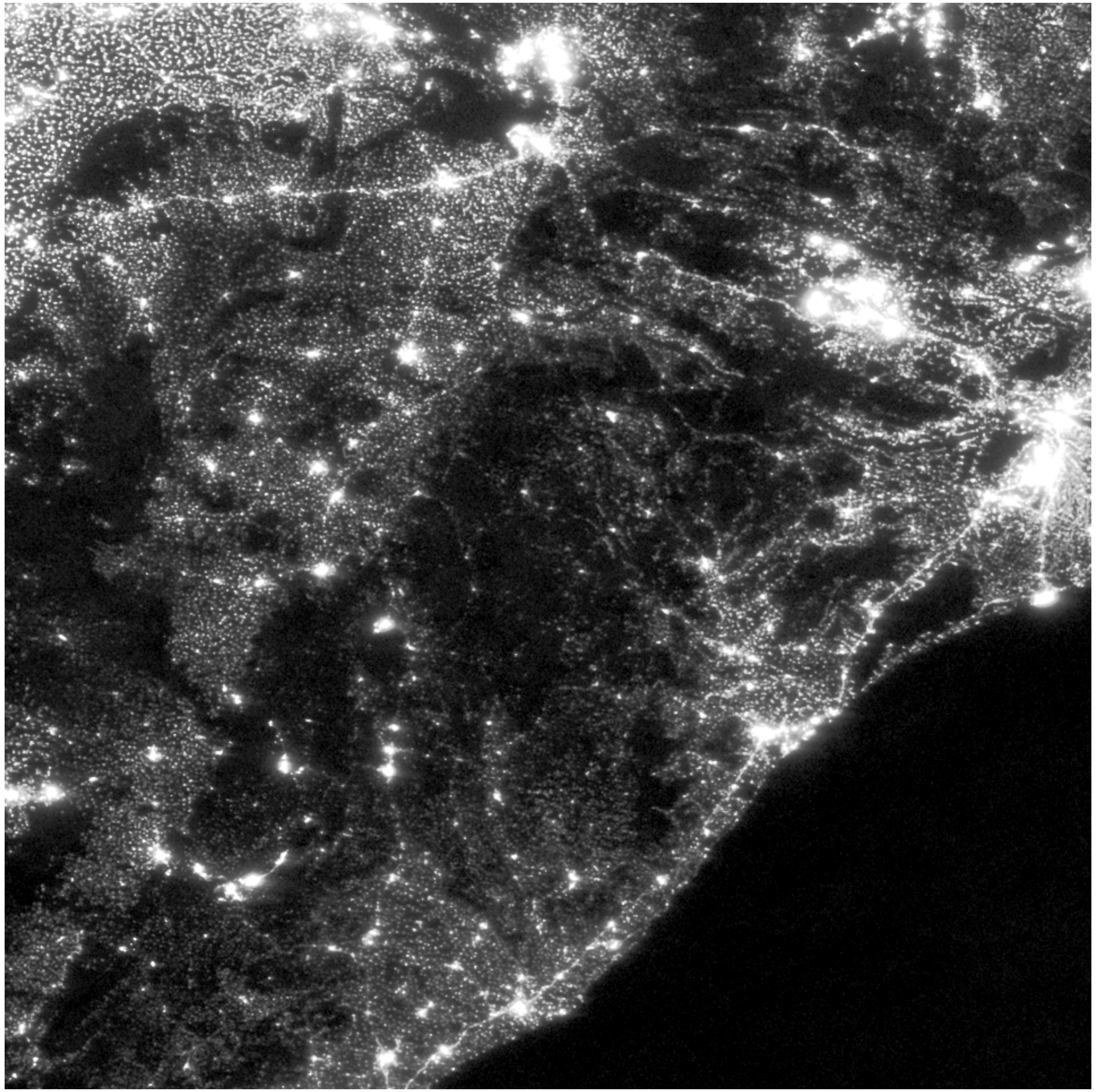
Toggle with next slide



Notice how regions with fire activity return to background radiance levels after outlier removal

DNB Ephemeral Lights: Before Outlier Removal

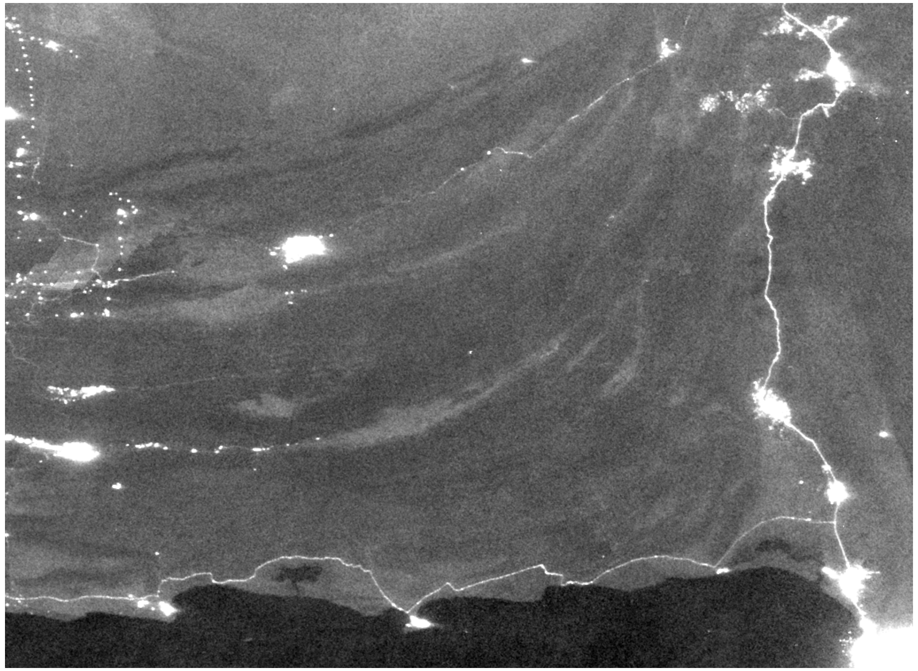
Toggle with previous slide



Notice how regions with fire activity return to background radiance levels after outlier removal

DNB Background Removal

- The DNB's detection limits are low enough, that even without moonlight present, nocturnal airglow can light up terrain and high albedo surfaces, making it challenging to separate dim lights from high albedo surfaces.



2014 DNB Composite over Southern Pakistan – some road features have lower average radiance values than no-light areas with high albedo

2014 DNB Composite over Himalayas – snow-covered peaks have higher average radiances than some of the villages

DNB Background Removal

- Current approach:
  - Create 5X5 pixel histograms of DNB radiances after outlier removal using an extended time series (annual)
  - Analyze histograms for existence of a “pure background” grid cell using mean and standard deviation.
  - For each composite grid cell, get “closest” pure background grid cell. Remove its background and re-average to get lights-only average.
- Foreseen challenges
  - Known discontinuities in offsets of DNB calibration (monthly?)
  - SRF changes in DNB over time could affect this work
  - Defining “closest” in terms of which background grid cell to use

Nighttime Lights Composites: Next Steps

- Finalize background characterization/removal algorithm
- Test outlier removal algorithm on aurora
- Add in Nightfire detections to identify locations of persistent flares and volcanos
- Apply atmospheric correction algorithm to DNB radiances

Questions?

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Backup Slides

VIIRS Nighttime Lights Composite – 2015/01

Excluding Stray Light Corrected Areas

VIIRS Nighttime Lights Composite – 2015/01

Including Stray Light Corrected Areas