Global satellite observations of surface lighting: From DMSP to VIIRS

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Lights At Night!

Cities and human settlements
Industrial Sites

Gas Flares

Boats

Fires
The NASA/NOAA Visible Infrared Imaging Radiometer Suite (VIIRS) primary mission is weather. The sensor is flown on polar orbiting satellites and have a 3000 km swath, capable of collecting a complete set of day and night images every 24 hours.
The meteorologist had a requirement for visible imagery of clouds at night, to augment the thermal imagery. This required specialized low light imaging sensors, with detection limits low enough to detect moonlit clouds.
FORERUNNER SYSTEMS

The original sensors collecting low light imagery were flown by the U.S. Air Force Defense Meteorological Satellite Program (DMSP). The collections started in 1971 from SAP (Sensor Aerospace vehicle electronics Package). This was followed by the Operational Linescan System (OLS) in 1976. Data were brought down in digital format and written to film for interpretation. A film archive was established at the University of Colorado. A large part of the film archive was digitally scanned under NOOA’s Climate Data Modernization Program. EOG has a copy of the scans.
1970’s DMSP low light imaging capabilities were revealed


1989 First global nighttime lights map - derived from DMSP film data

DMSP Digital Archive

• In 1992, following the end of the “cold war”, the U.S. military relaxed the DMSP data distribution policy and provided several years of funding to establish a digital archive at the NOAA National Geophysical Data Center (NGDC) in Boulder, Colorado.

• Initially NGDC was authorized to distribute DMSP data outside the U.S. government after the data were 72 hours old.

• In 2000 the data hold dropped to three hours.
1994 Elvidge and Baugh began work with digital DMSP data at NOAA’s National Geophysical Data Center, Boulder, Colorado.

We wrote algorithms to detect and geolocate lights from DMSP images. Our first map was made with data from 29 orbits over the USA. We recognized a lot of lights were missing, probably due to cloud cover.
1995 - We developed a cloud detection algorithm and with 236 orbits came up with this product of the USA

We collected data at low, medium, and high gain data to overcome the dynamic range and quantization limitations of the OLS.

The standard DMSP global nighttime lights products had saturation in urban centers and with brightness levels reported as “digital numbers”. The Air Force agreed to collected fixed gain data at low, medium and high settings during new moon periods.
1998 First global radiance nighttime lights products with the gain controlled OLS data

These were the data that made it possible to produce the early global maps of artificial sky brightness.

2011 VIIRS launched – providing major improvements

- 45 times smaller pixel footprint
- 14 bit quantization (OLS has six bit)
- Lower detection limits
- Better geolocation
- In flight radiometric calibration
- Continuity - There will be a total of five VIIRS instruments flown – assuring data continuity for the next two decades.
June 28, 2019 VIIRS vs OLS Singapore
VIIRS low light imaging at night: DNB detects electric lighting, fires and flares. M7-11 detect combustion sources.
Three global product lines

https://payneinstitute.mines.edu/eog/

- **VIIRS nighttime lights (VNL):** Nightly mosaics, monthly cloud-free composites and annual nighttime lights.
- **VIIRS boat detections (VBD):** Nightly locations with radiances, monthly and annual summary grids.
- **VIIRS nightfire (VNF):** Nightly locations with temperature, source size, and heat output. Monthly and annual summary grids.
VIIRS Nighttime Lights (VNL) 2015 Myanmar

Raw cloud-free composite

Outlier removed

Nighttime lights
VIIRS boat detection (VBD)

Boats in Java Sea

Jakarta
Algorithms run on images, output points, vast data volume reduction.

VIIRS day/night band (DNB) nighttime

Boat detection data (points)
Single Night of Detections (June 9, 2017)

Standard is four hour temporal latency, with files available at 06:00 local time
For gas flares – the nighttime is the right time!
Bakken Oil Field, North Dakota

Shortwave infrared (1.63 um) day

Same band, same area, next night

Gas flare peak radiant emissions are near 1.63 micrometers. The flare radiance is lost during the day due to sunlight.
Why Multispectral?

To get at the Planck curves!

Daily files are in csv and kmz formats
EOG produces annual inventories of gas flaring location and flared gas volume estimates:
https://ngdc.noaa.gov/eog/viirs/download_global_flare.html
What we discovered with VIIRS regarding light pollution sources

• There are vast numbers of heavily lit fishing vessels operating throughout Asia and several other areas. These have not been considered in sky brightness mapping and most studies of lighting impacts on the environment. There is now a solid record of these extending back to 2012.

• The most intense sources of light pollution are gas flares. With zero shielding a single large flare can light up the sky like a city. There is now a solid record of flare locations and intensities back to 2012.

• DMSP-OLS is back! Crude – but long lived. EOG will continue the DMSP time series with pre-dawn OLS data collected by satellites F15 and F16. We plan to study the diurnal behavior of lights using DMSP F18 from 20:00, VIIRS from 01:30 and DMSP F15 from 03:00.
We thought 2013 was the last year where a global nighttime lights product could be made with DMSP data.
Those lights do get around!
Summary

• The history of satellite observations of lights at night extends back to the 1970’s. Data recorded on film.
• Scientific utilization was expanded when a digital archive was established in 1992.
• The first high quality global nighttime lights products were produced in 1995.
• The first radiance nighttime lights products were produced in 1998 and made it possible to model artificial sky brightness.
• The quality of the observation took a major step forward with the advent of VIIRS data in 2012.
• EOG developed VIIRS nightfire in 2012 and has produced a time series of annual gas flaring inventories – significant for night sky studies.
• In 2014 EOG developed a vessel detection product – providing locations and brightness of maritime light pollution sources.
• EOG produces nightly, monthly and annual nighttime lights from VIIRS.
• EOG plans to extend the DMSP time series using pre-dawn OLS data to study the diurnal patterns of electric lighting and to build a bridge between DMSP and VIIRS.
• VIIRS data collections expected to continue for another 20+ years.