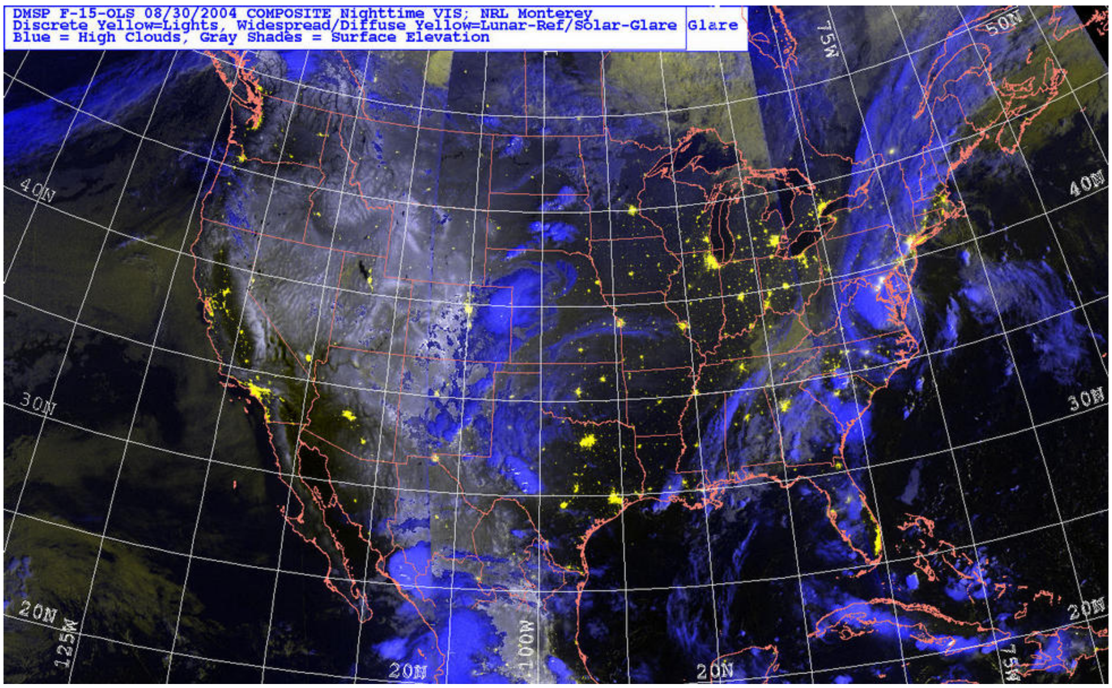
Satellite Product Tutorials:

Nighttime Lights



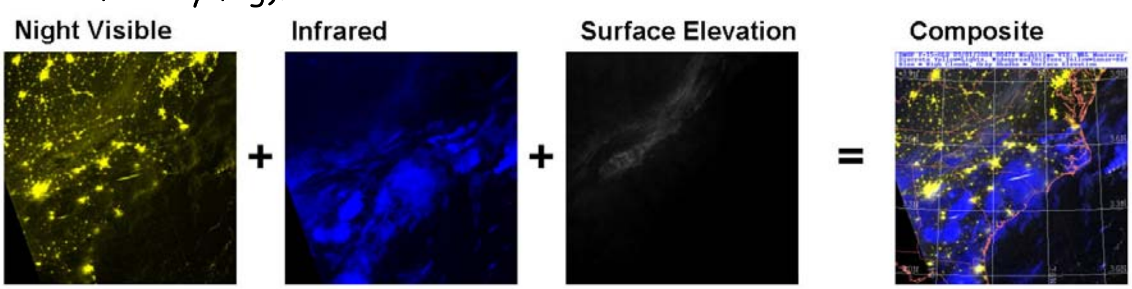
Above: The nighttime lights product is based on a low-light detection instrument (the Operational Linescan System, or "OLS") operating aboard the Defense Meteorological Satellite Program (DMSP). Lights from various large cities across the country appear as yellow dots (among the clearly noted in the above example are Miami, Chicago, Dallas, and the greater Los Angles area), high clouds (including thunderstorms) are blue, low cloud cover are diffuse yellow, and topography shown in gray-scale (for example, the Rockies, with higher elevation terrain in white). Designed to detect the moonlight reflection off clouds and snow cover, its extreme sensitivity to all varieties of visible light emission enables the OLS to also detect urbanized areas (city lights, highways, etc.), fishing boats, lightning flashes, fires, and even auroras. Here, illuminated regions are depicted as yellow, high clouds are coded as blue, and surface elevation has been added in grey/white to provide topographic context.

Why We're Interested…

Low light sensors offer a unique opportunity to literally cast light on to the often-difficult problems surrounding nighttime satellite products. Due to its lack of calibration on the OLS day/night band (like a mercury thermometer without temperature graduation marks drawn on the glass), we cannot apply the data in a quantitative way (for example, we couldn't deduce cloud properties, or match observed city brightness to electrical consumption). In many ways this has limited the scope of research applications of this band. Perhaps the most notable research surrounding the day/night band deal with demographics studies based on extended time series of OLS observations. Additional topics that do not necessarily require calibration are the validation of low cloud distribution and snow cover under full moonlit skies, and assessment of storm electrification in conjunction with surface-based lightning detection systems.

How This Product is Created…

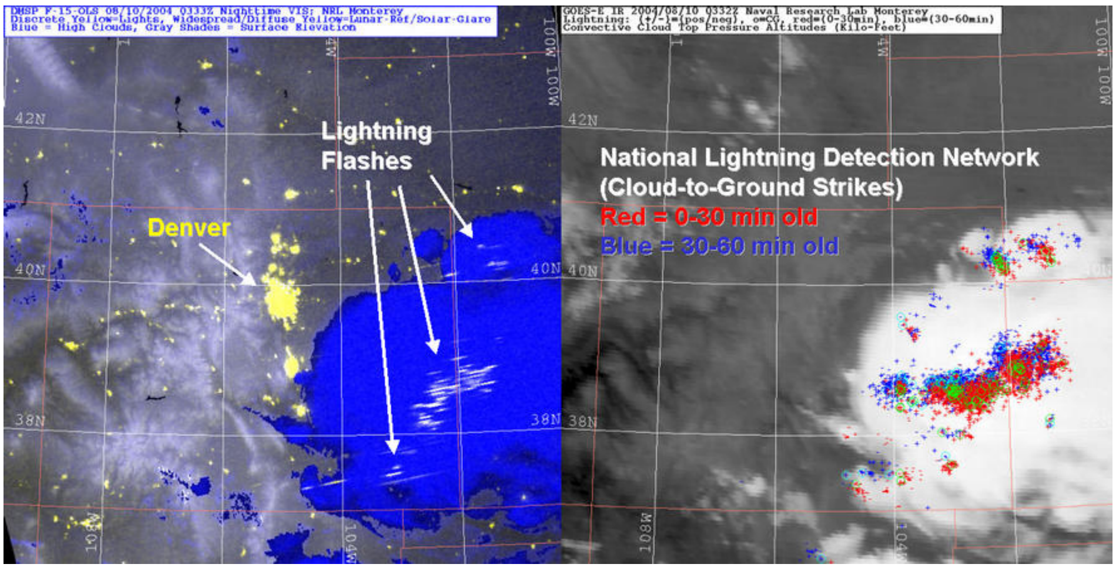
Three pieces of information that go into forming the current nighttime lights product: the OLS day/night visible band, the OLS infrared band, and a high-resolution topography database. The day/night visible band provides information on any light sources or moonlight reflection in the scene as mentioned previously. The infrared data enables the depiction of clouds. The surface elevation information enables placing observed low cloud features in the context of surrounding terrain (for example, identifying areas of valley fog).



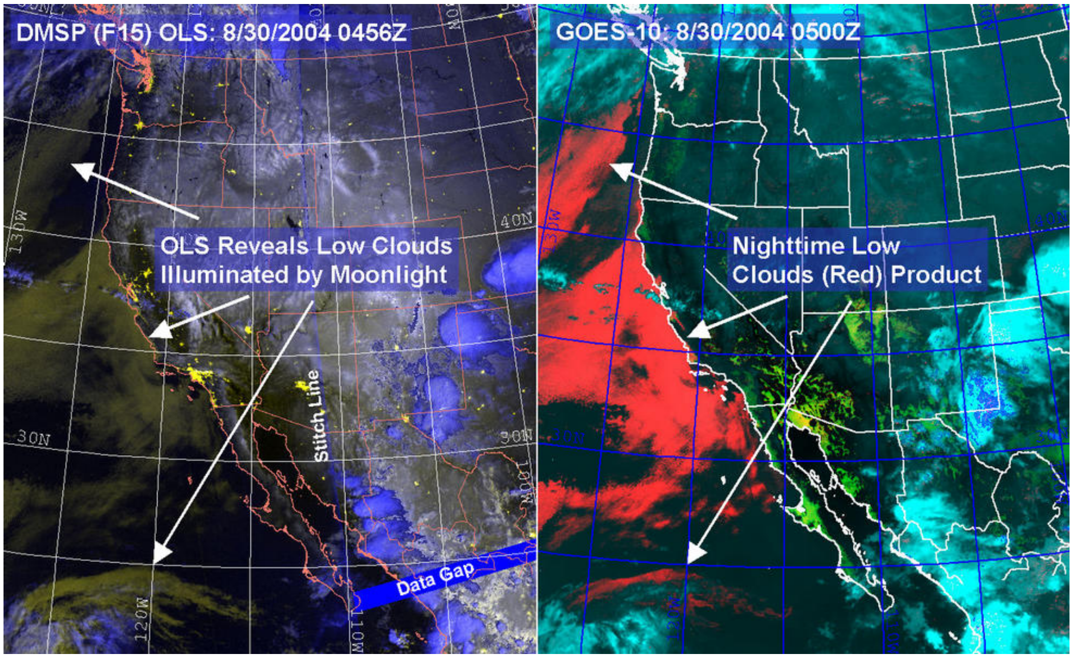
These three pieces of information are combined into a false-color enhancement depicting terrain features in black/white, surface lights as yellow, and high cold clouds as blue, as shown in the illustration above. Low cloud cover is only detectable when there is sufficient lunar illumination. The OLS scans in a "back and forth" pendulum motion across the earth's surface. If by chance it crosses over a thunderstorm during a lightning flash (which is often observable at cloud top as a brief and diffuse illumination of the parent cloud) the OLS will record that flash as a light source. Combined with the cold cloud top signal, the yellow (lights) + blue (cloud) color combination yields a white depiction for these detected strikes.

How to Interpret…

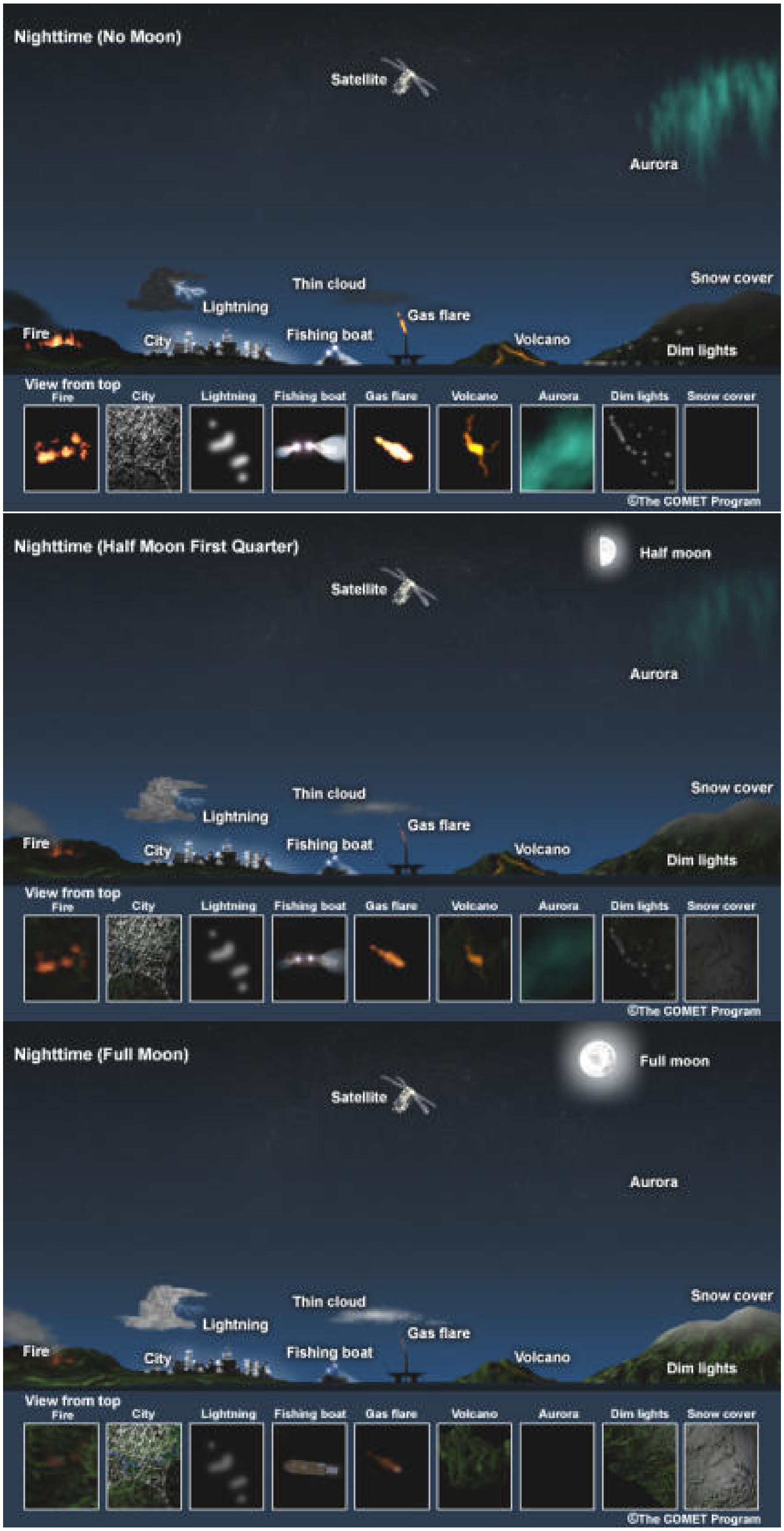
What to look for:



In the example above, centered over Colorado during August 2004, a large thunderstorm complex is making its way eastward across the plains. At left is the nighttime visible product, which reveals major metropolitan areas as yellow clusters, and major interstate highways appear almost a string of pearls (with each "pearl" being a small roadside town). Lightning flashes embedded within the deep blue convective clouds appear as streaks, owing to the sweeping scanning pattern of the sensor and the sustained flickering of multiple lightning strikes within the clouds. The image at right is the corresponding lightning detection network product, indicating strikes over the last 60 minutes. The OLS catches a small component of this flash history as it scans nearly instantaneously over these thunderstorms.

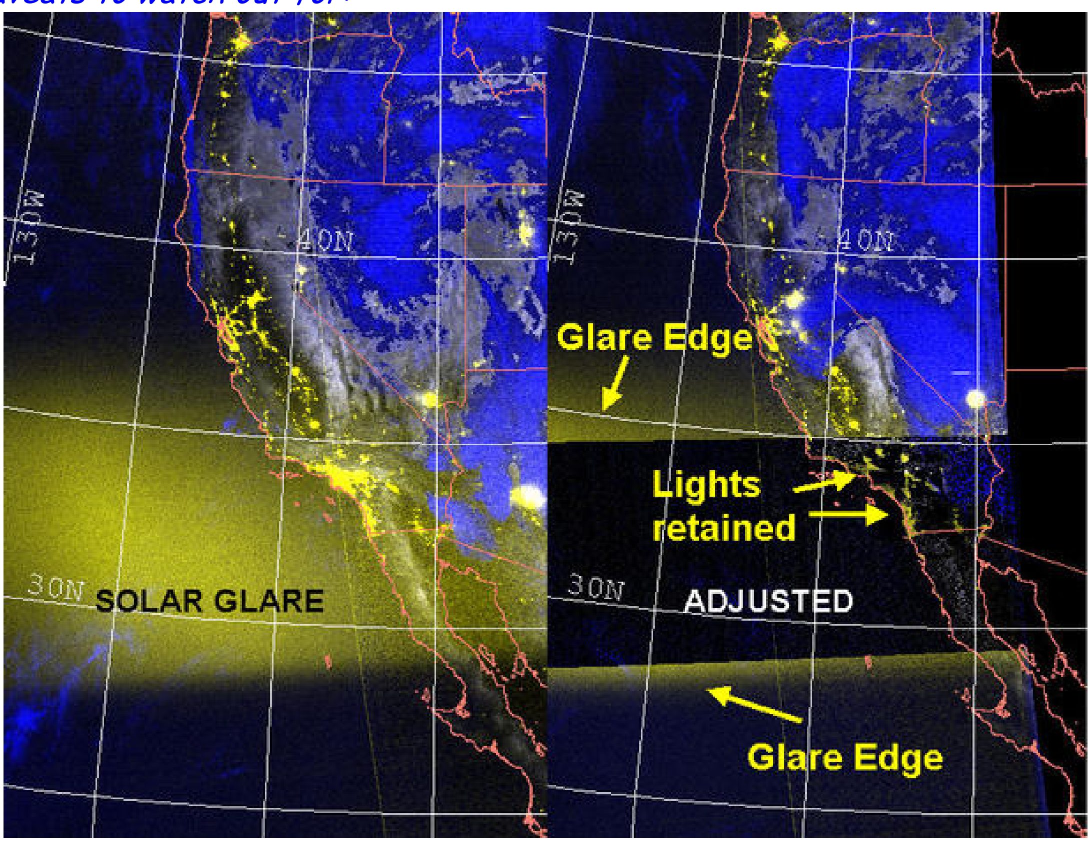


Presented above is an example of how the nighttime visible product can be used to validate the low cloud at night (infrared channels only) technique. As pointed out particularly over the oceans, lunar illumination readily highlights extensive decks of marine stratocumulus against the otherwise dark ocean background. Also shown in the OLS nighttime visible example are various imagery artifacts that occasionally appear in these products. The "data gap" noted arose from a drop-out in satellite information over a short duration, and the "stitch line" corresponds to the interface between imagery from two adjacent orbits of the same satellite (here, we paste together multiple passes in producing a composite image over a large domain). Through co-registration of products, NexSat enables one-to-one comparisons between the various sensor capabilities in cases where the observations are reasonably close in time.


Nighttime (No Moon)
Satellite
Aurora
Thin cloud
Lightning
Snow cover
Gas flare
Fire
City
Fishing boat
Volcano
Dim lights
View from top
Fire
City
Lightning
Fishing boat
Gas flare
Volcano
Aurora
Dim lights
Snow cover
©The COMET Program
Nighttime (Half Moon First Quarter)
Half moon
Satellite
Aurora
Thin cloud
Lightning
Snow cover
Gas flare
Fire
City
Fishing boat
Volcano
Dim lights
View from top
Fire
City
Lightning
Fishing boat
Gas flare
Volcano
Aurora
Dim lights
Snow cover
©The COMET Program
Nighttime (Full Moon)
Full moon
Satellite
Aurora
Thin cloud
Lightning
Snow cover
Gas flare
Fire
City
Fishing boat
Volcano
Dim lights
View from top
Fire
City
Lightning
Fishing boat
Gas flare
Volcano
Aurora
Dim lights
Snow cover
©The COMET Program

The responses of the nighttime visible band to the many possible light sources in the scene are depicted in the cartoon (courtesy of the COMET program) on the previous page for the case of new moon, half moon, and full moon illumination. The general response as moonlight is increased is for terrestrial light sources (for example, city lights and fires) to fade and for reflecting objects (for example, clouds and snow cover) to increase in brightness. Another important consideration is how high the moon is above the horizon at the time of the satellite overpass. A partial moon that is higher in the sky will produce higher illumination and reflection than a full moon that has just risen.

Caveats to watch out for:



During certain times of the year, the satellite is oriented in such a way that sunlight enters directly into the OLS telescope during part of its orbit across the nighttime side of the earth. In these instances, the visible signals we are trying to detect from the earth are washed out by the sunlight contamination. This contamination is referred to as "solar glare" and we make some modest attempts here to mitigate these effects. The correction looks for low variability elevations in the brightness along an entire scan line. If it finds such regions, it attempts to salvage any discrete jumps in brightness (presumed to be city lights) before subtracting off the elevated mean signal. If the brightness is too high, we assume that we are in a significant glare zone and the data is blacked-out. Unfortunately, it is easy for the new user to excitingly mistake glare features for the aurora borealis (a.k.a. "Northern Lights") phenomenon. Usually be discriminated by their consistent structure (always oriented along satellite scan lines, similar location over several days time, and repeated pattern between adjacent satellite passes). Auroras will appear as broad regions of brightness, but typically have a more meandering structure, are not necessarily in the glare-pattern orientation, and will vary across the scene.

Note on product availability: The DMSP is a constellation of polar orbiting satellites. Currently there are 5 satellites in this constellation, numbered F12 through F16. Most of these are placed in orbits near the sunrise/sunset terminator. Since the nighttime lights product works best when there is little or no sunlight present, the F15 satellite (with its 9 PM local crossing time) offers the best year-round information. Approaching wintertime, F14 and F16 (with 7-8 PM local crossing times) also begin to provide useful nighttime visible imagery thanks to shorter days and longer nights. F12 and F13 have 5:30-6:30 PM orbits, and may be less useful in this regard with the exception of high latitudes in the wintertime hemisphere.

Looking Toward the NPOESS Era…

Unlike the DMSP-OLS instruments, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) VIIRS instrument will be calibrated and situated with several other channels besides just 11.0 micron infrared. This opens the door for a wide range of applications, including cloud microphysics and cloud/snow at night. Higher quality data with less instrument noise is also anticipated, making for cleaner and more precise products. Will maintain nearly constant spatial resolution along scan.

Did You Know…?

The DMSP series, which began in 1965, was a classified program until 1970. Even today, imagery from OLS cannot be released to the public until 3 hours after the raw data is collected.

Want to Learn More?

Learn more about the Defense Meteorological Satellite Program

Obtain DMSP/OLS data from the National Geophysical Data Center

Learn more about plans for the VIIRS Day/Night Band

Elvidge, C. D., K. E. Baugh, E. A Kihn, H. W. Kroehl, and E. R. Davis, 1997: Mapping city lights with nighttime data from the DMSP Operational Linescan System, Photogrammetic Engineering & Remote Sensing, Vol. 63, No. 6, June 1997, pp. 727—734.

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