Geostationary Lightning Mapper On-Orbit Sources of False Events

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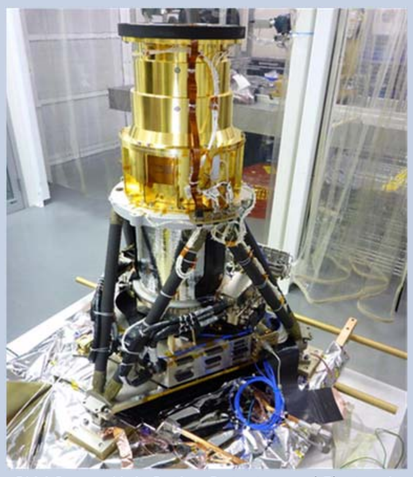
Abstract

The first Geostationary Lightning Mapper (GLM) was launched aboard the GOES-R Spacecraft (now GOES-East) on November 19, 2016 and is now fully operational. GLM uses a high-speed camera and on-board video processing to detect the optical emission of lightning for the full disk observed from the geostationary orbit. During the Post Launch Test period the instrument and ground processing algorithms (GPAs) were tuned to optimize the tradeoff between detection efficiency and false event rate. False events, those not due to lightning, arise from a variety of sources. A primary function of the GPAs is to remove false events prior to assembling events into groups and flashes for use by weather forecasters and scientists. Effective discrimination of false events depends on understanding the phenomenology of the various sources of false events.

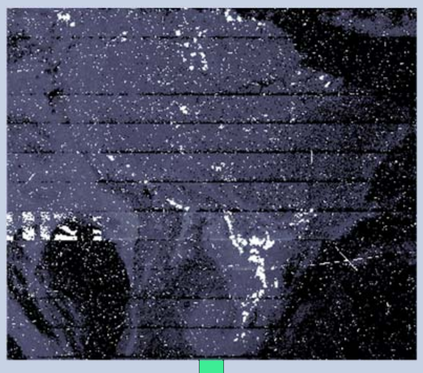


GLM Sensor Unit Optics, Detector, and Electronics

What is an Event?

An event is an exceedance in one pixel detected above the running average of the background plus a selectable detection threshold. GLM detects approximately 10,000 events per second, most of which are noise. Keeping the threshold for detection low allows detection of faint lightning, but requires that false events be filtered out of the data on the ground. The GLM ground processing algorithms remove events found to not be lightning, and the rest are passed on to become part of the GLM data products.

GLM Raw Events



Ground Processing Algorithm Event Filters

Data Burst 0.3%

Blooming 1.0%

Overshoot 2.4%

Crosstalk 0.003%

Second Level Threshold 7.4%

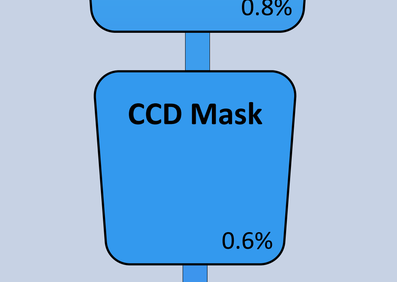
Radiation 0.8%

CCD Mask 0.6%

Coherency 68.6%

Contrast Leakage 0.2%

Events after GPA Filters



Digital video link from GLM Sensor Unit

Data formatter bursts occur when the framing characters present in the digital video stream are corrupted in transfer, causing the event processor state machine to interpret framing characters as valid video data. This anomaly causes the event detection logic to generate a sudden burst of false events in a single frame.

Blooming of the CCD

The CCD will bloom under two circumstances. First is when Sun glints off ocean, lakes, and rivers and generates a specular reflection to the instrument that produces photo charge on the CCD that exceeds the charge capacity of a pixel. The second circumstance is during solar intrusion events when stray light from the Sun intrudes on the CCD.

Analog readout circuitry in GLM Sensor Unit

The CCD output electronics cause overshoot, where a sudden rise in the signal from one pixel to the next can cause following pixels to register false events. The overshoot false events can be thought of as a "tail" of false events that can appear subsequent to a real event, when considering the order in which the pixels are read out of the electronics.

CCD output amplifier stages in GLM Sensor Unit

When a large event occurs in a given pixel, the amplitude of this event can induce crosstalk onto the same pixel in adjacent event processors and beyond. When this crosstalk event amplitude is large enough to exceed the threshold setting, the signal will be processed as an event and transmitted to ground.

CCD noise during exposure

The 2nd level threshold filter is designed to remove false events from "hot pixels". It applies individual threshold tables on a pixel by pixel basis versus having all pixels within a specific RTEP processed through the same threshold levels.

Radiation tracks during exposure

Energetic particles impacting the CCD or the RTEP background pixel memory cause false events. For CCD impacts, the number of false events detected by the instrument depends on the incident angle of the particle and the CCD. Particles impacting the CCD at or near zero degrees produce a "track" of false events.

Noise in non-sensitive pixels during exposure

The masked pixel locations are determined during instrument calibration. These pixels are non-responsive to light because they are located in regions of the CCD that were not thinned during processing.

Random noise generated throughout signal chain

False events can be caused by shot noise, electronics noise, and radiation. Noise-produced false events are characterized by low amplitudes and random occurrences in time and location, whereas lightning events are characterized by high coherency in time and space (multiple pixels are illuminated in a single frame and the same pixels continue to be illuminated over the duration of the lightning flash). Thus lightning events are "coherent" whereas false events are random.

During CCD exposure, due to spacecraft jitter

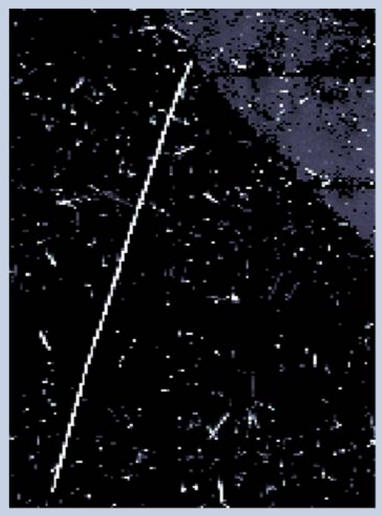
Near cloud edges, coastlines, snowfields, or other bright/dark edges on the surface of the earth, false events caused by spacecraft jitter may occur. Generation of these false events are minimized by the exquisite stability of the GOES-R spacecraft. Events due to jitter are also suppressed during spacecraft maneuvers by optimizing background tracking parameters.

Events remaining after GPA Filters are lightning

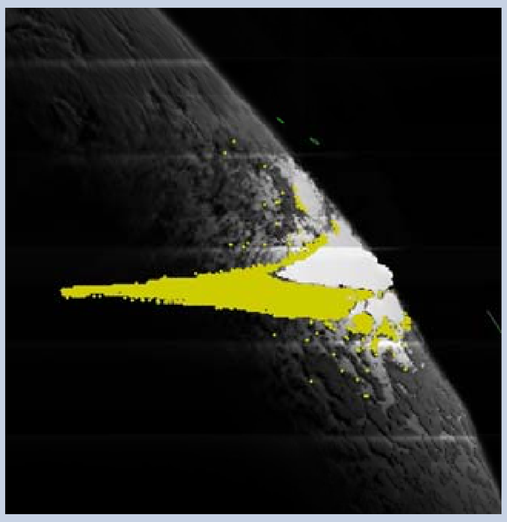
Key performance achieved:

- **Detection Efficiency >80%**
- **False Alarm Rate < 2%**
- **Navigation Error < 90 µ radians 3σ**

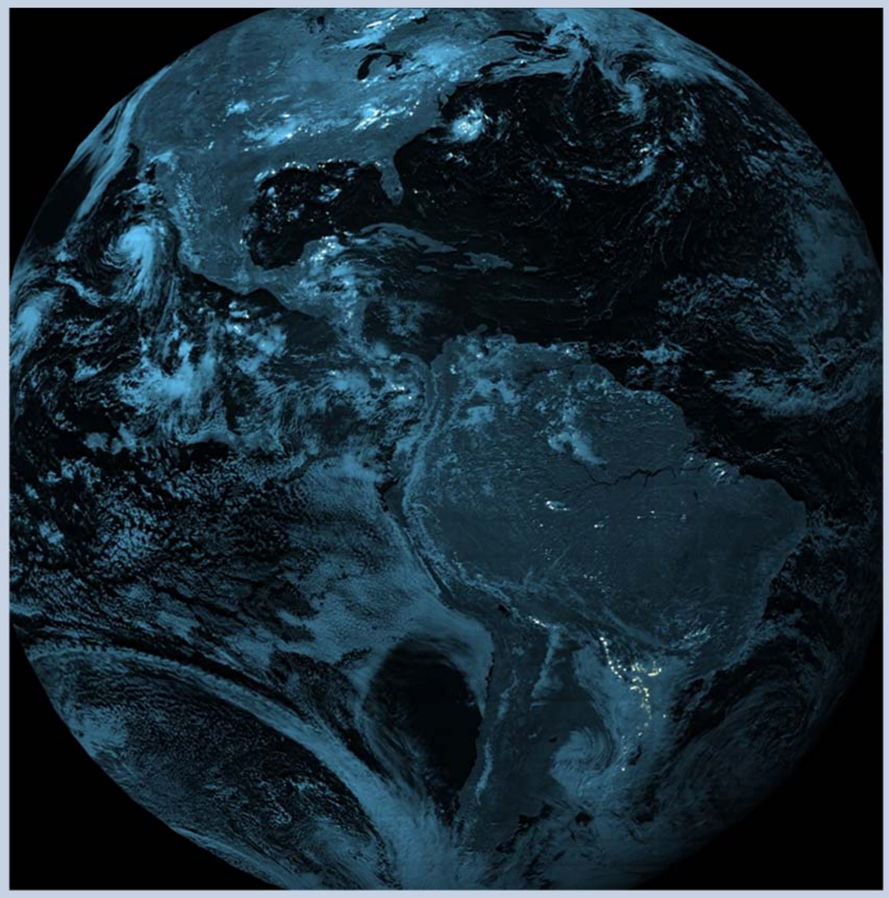
GLM Full Disk
Events Prior to GPA Processing



Radiation streaks



Blooming at sunrise



GLM Full Disk Image
Background plus Lightning after GPA Processing