On-orbit Testing of GOES-16 and GOES-17 GLM payloads from 2 NASA SLR sites with collocated laser beacons

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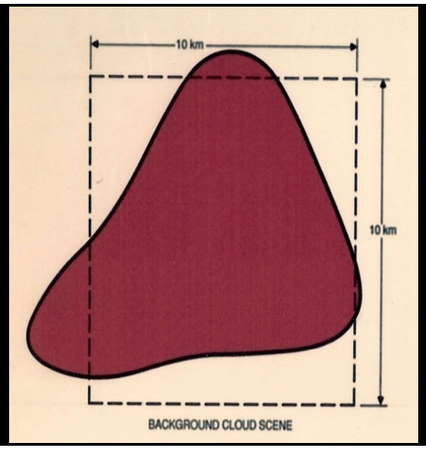
Optical Lightning - Detection

1. **Lightning from Space:** Lightning appears like a pool of light on the top of the cloud.
2. **Daytime Challenge:** During day, sunlight from cloud top dominates the lightning signal.

Spatial

Optimal sampling of lightning scene relative to back-ground scene.

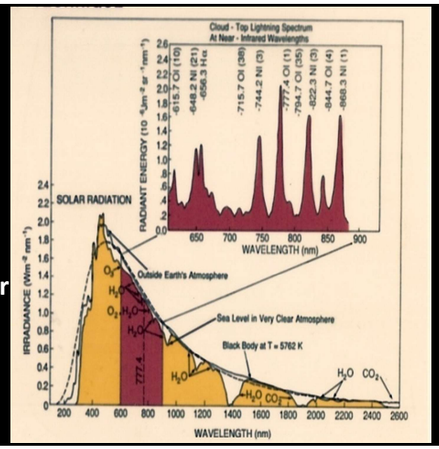
Pixel field-of-view 4-10 km.



Spectral

Optimal sampling of lightning signal relative to back-ground signal.

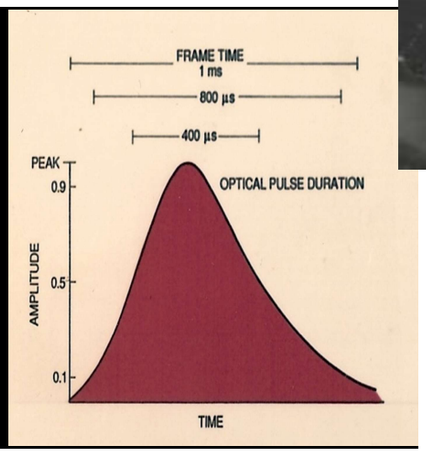
GLM uses 1nm filter at 777.4 nm.



Temporal

Optimal sampling of lightning pulse relative to back-ground signal .

GLM uses 2 ms frame rate.

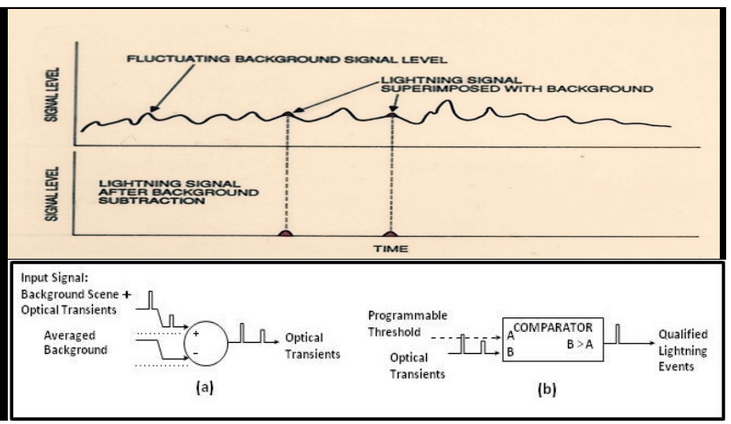


a. Even with spatial, spectral and temporal filters, background can exceed lightning signal by 100 to 1;
b. Frame-by-frame background subtraction to produce a lightning only signal.
c. Filtering results in 10^5 reduction in data rate requirements while maintaining high detection efficiency for lightning.

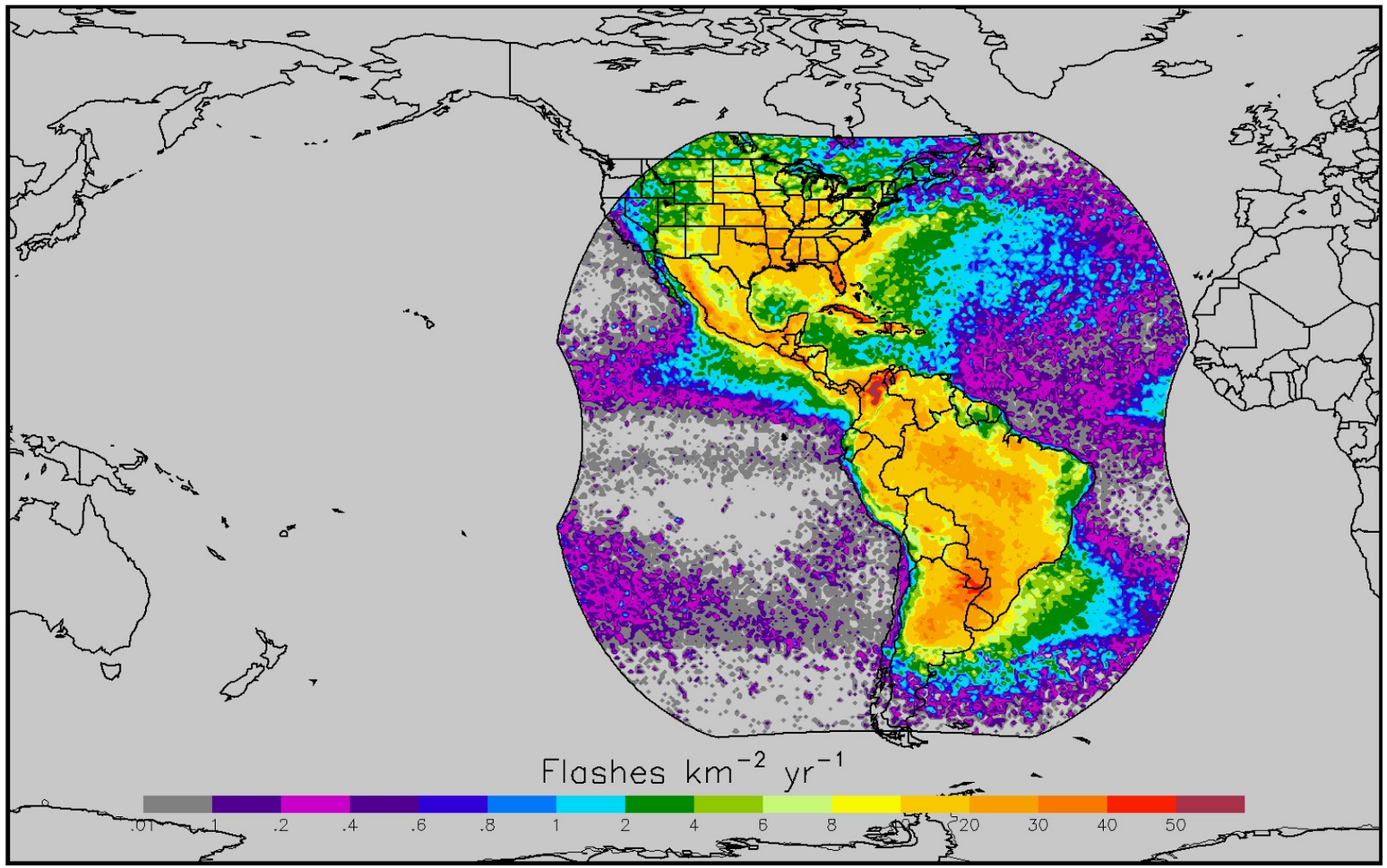
Background Subtraction

Optimal subtraction of background signal levels at each pixel.

Transient events selected for processing.

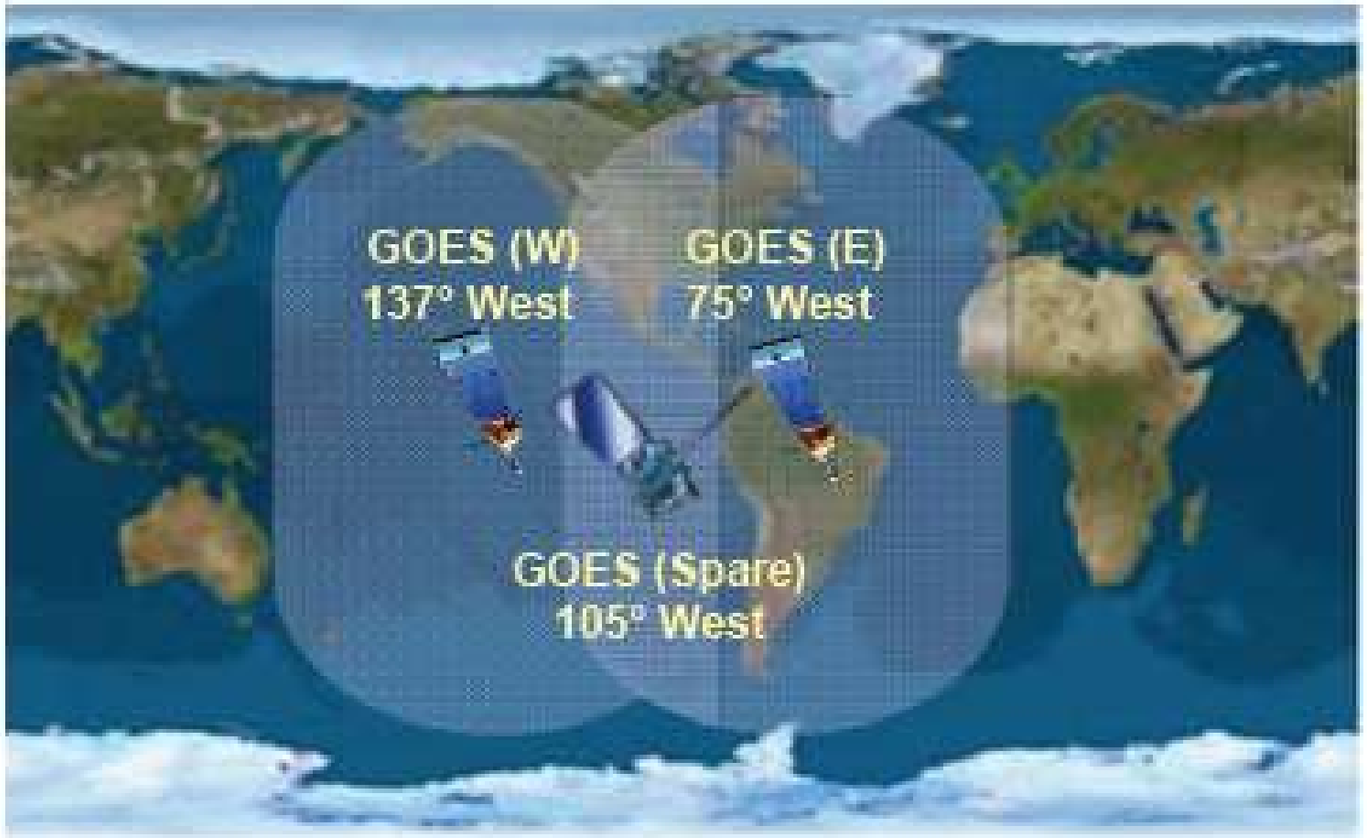


Lightning Flashes in the Americas



Lightning flash plot based on the LIS/OTD yearly climatology data

GOES R series footprint



Two operational satellites and on-orbit spare

1. GOES-16, was launched in Nov, 2016 and GOES-17 in March 2018.

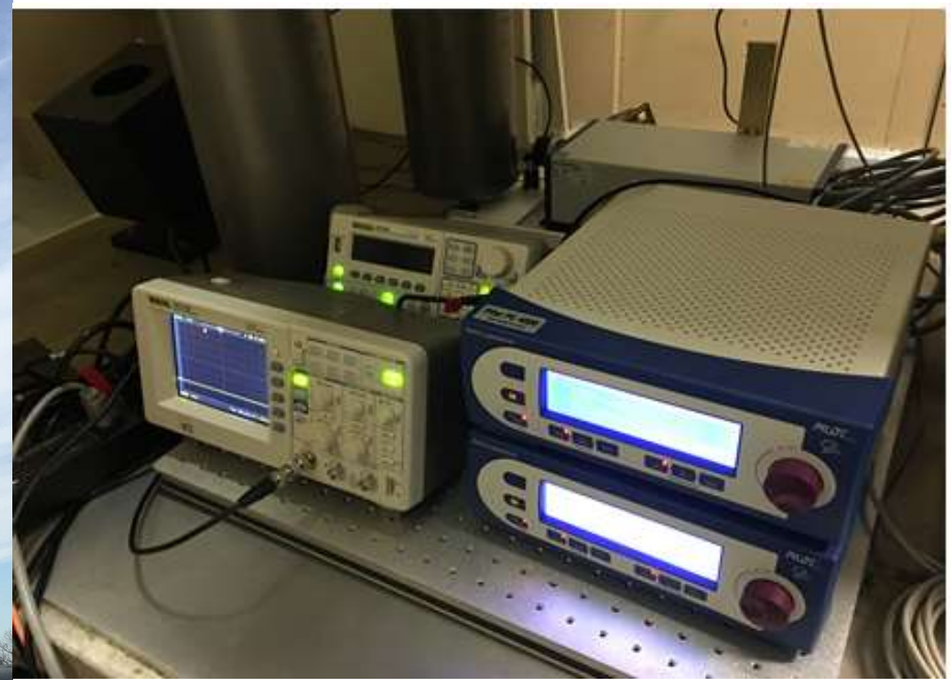
GLM – Rationale for Laser beacon

1. GLM needs accurate mapping of its sensor pixels to geo-spatial coordinates. This is needed day and night
2. GPA uses the background images to determine the offset wrto nadir position of the S/C based on a 7 day average.
3. The instrument geospatial accuracy depends on:
    1. Diurnal and thermal dependencies;
    2. “Cloudtop” model;
    3. Sensor’s “overshoot” correcting digital filter;
    4. Dither, Equinox, Yaw Flip related changes;
    5. Baseline for future.

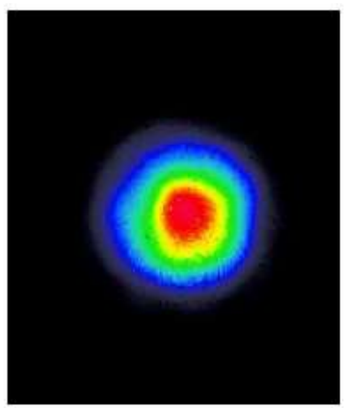
GLM - Laser Beacon & Auxiliary optics

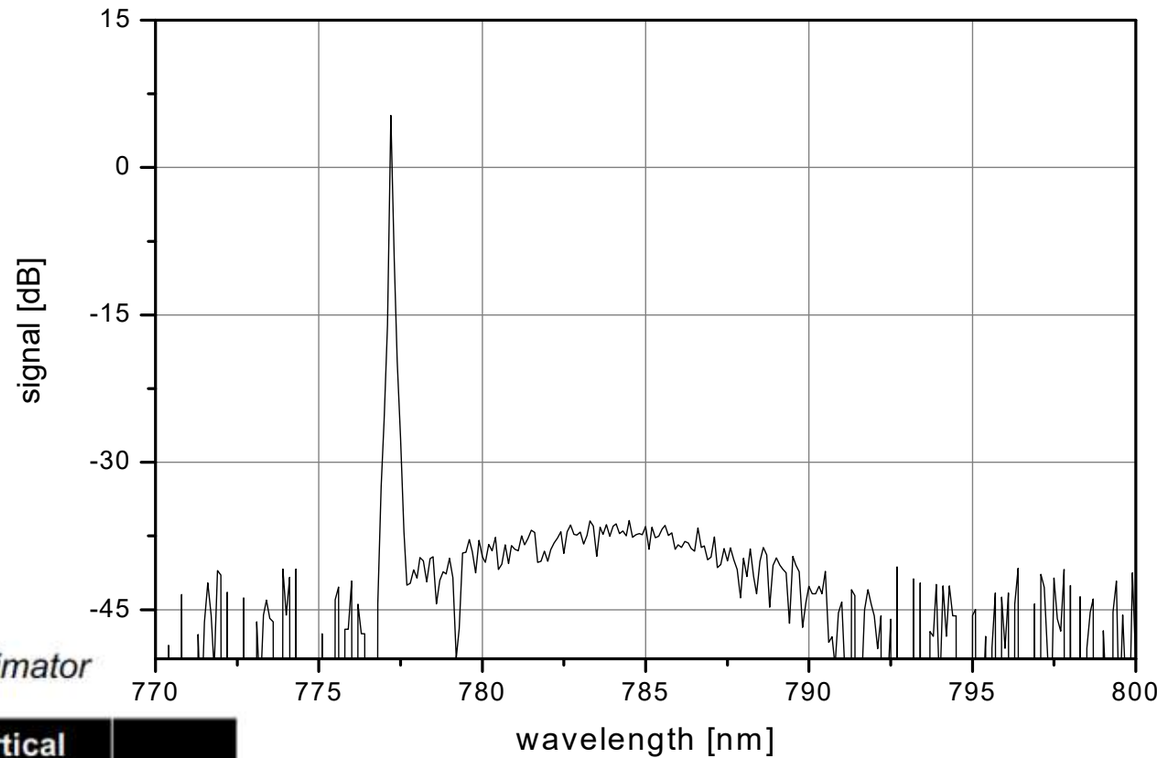
1. A semiconductor MOPA diode laser at 777.2 nm wavelength;
2. Electronically modulated to produce a 0.5-1.5 ms pulse;
3. Wavelength tuning within 20pm;
4. Laser at a PRF=50Hz;
5. An auxiliary refractive optics telescope + a single mode fiber coupler
6. Piggybacked to the main telescope and co-integrated;
7. Safety system with the added logic for a SINGLE LASER ONLY firing at a time.

Laser beacon – SLR mounted payload + laser Controls



GLM laser – Key attributes

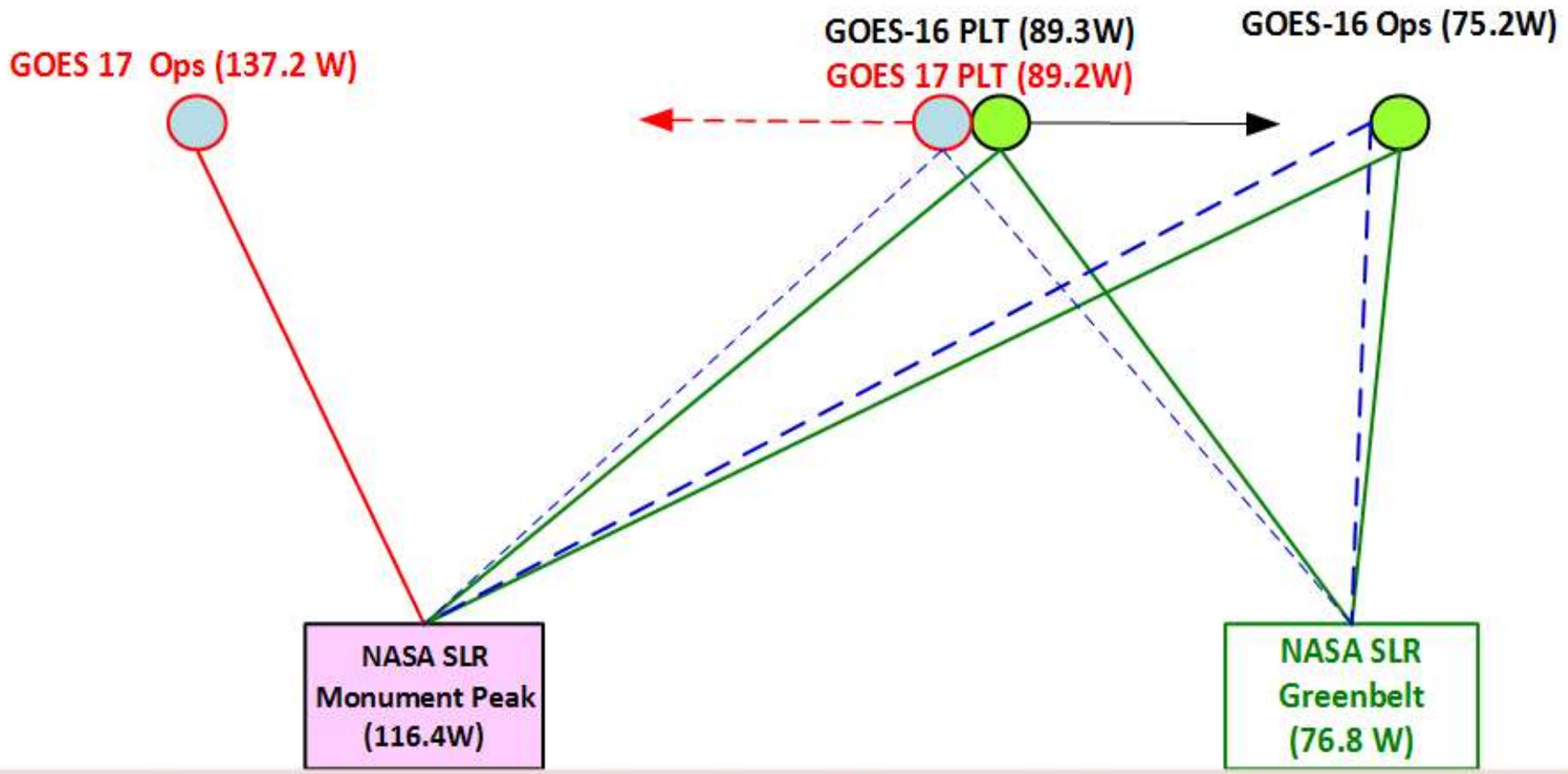




Data collected behind fiber collimator

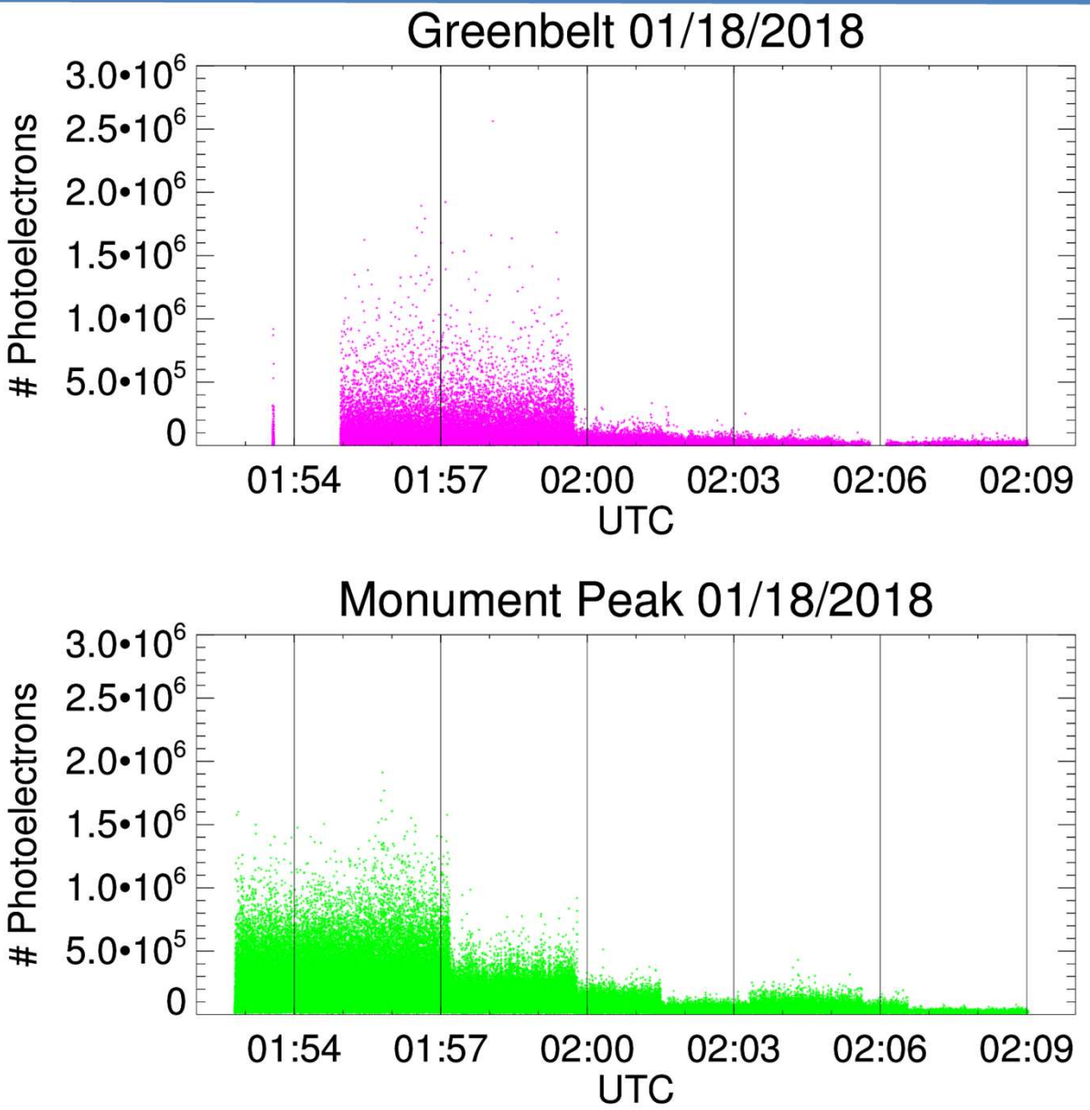
		horizontal	vertical	
Beam quality	M^2	1.03	1.07	
Astigmatism				1.2%

Intercomparison Test - Satellites and Sites



Green line – data already taken by GOES-16 at the PLT(=89.5W) and Ops slots (=75.2W);
Blue dotted line – Proposed GOES-16 and GOES-17 near simultaneous data collection;
Red line - Data to be taken from the GOES-17 Operational slot; **GB** = Greenbelt;
MP= Monument Peak;

Laser Beacon Results: Time Series



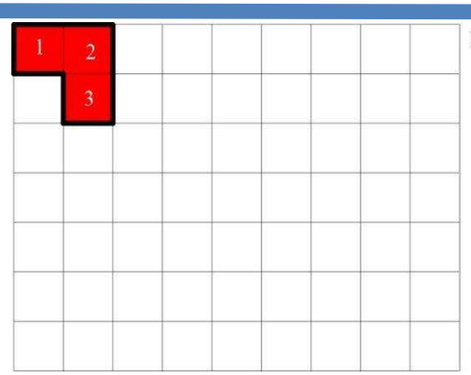
Magenta for Greenbelt;

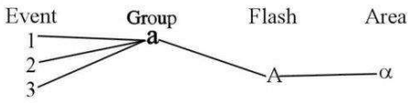
Green for Monument Peak;

Raw Data: Near simulataneous sensor data from 7105 and 7110 sites with >1E+5 pe;

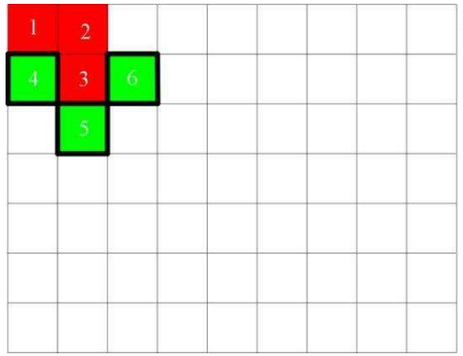
adequate for a robust centroid estimation of the pixel location;

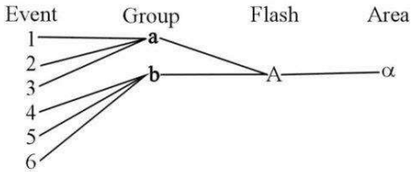
Data Analysis - Events to Groups to Flashes



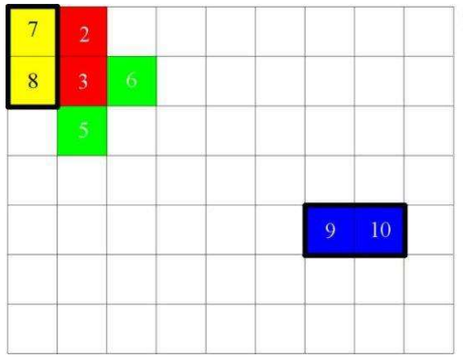


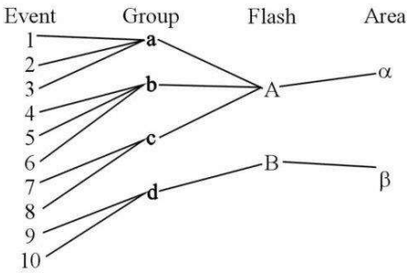
Time = 0 ms





Time = 100 ms





Time = 350 ms

Groups - Events that occur at same frame time in adjacent pixels

Flashes – Groups that occur close together in space and time

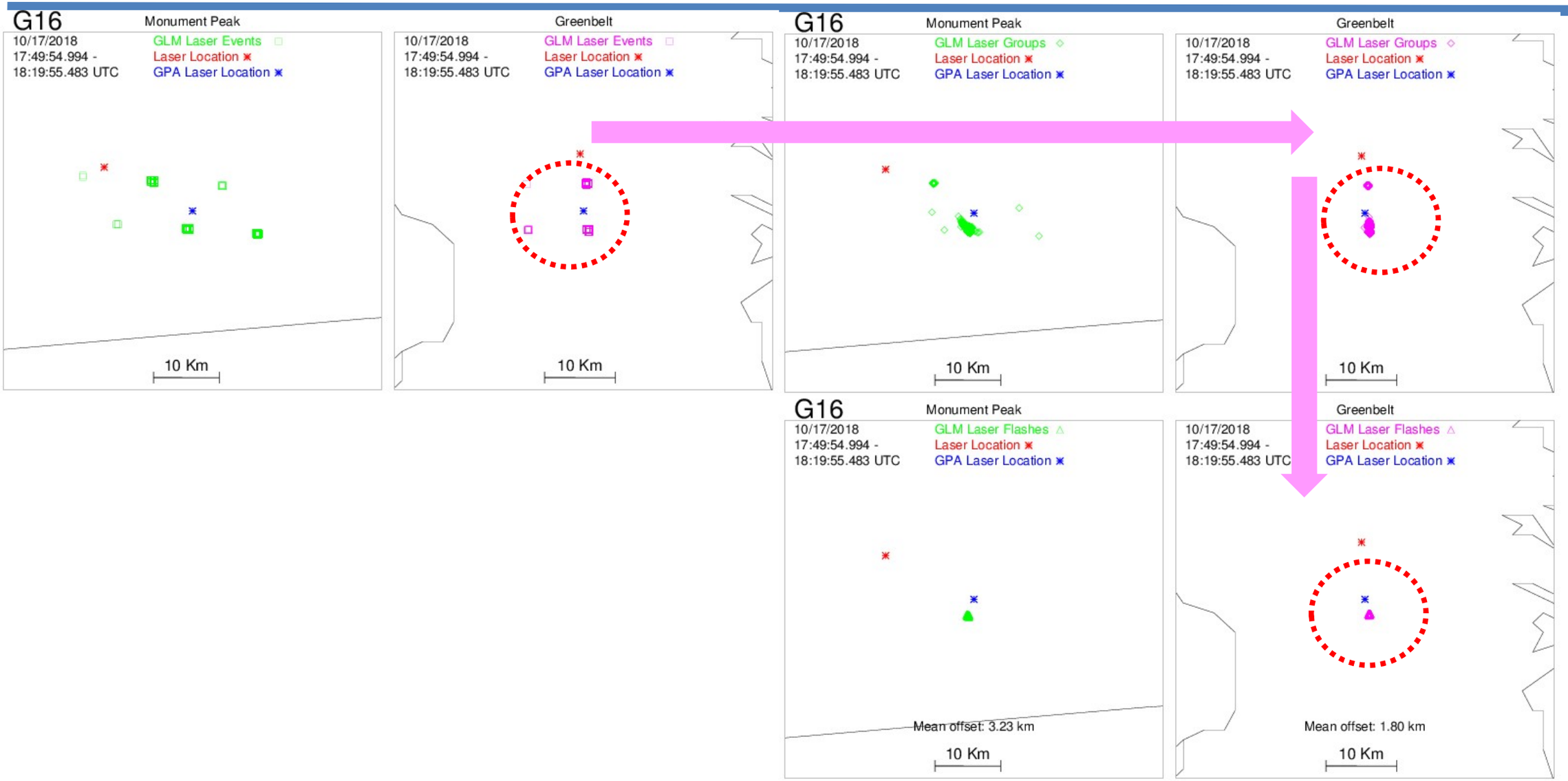
A flash is considered ended when no nearby groups occur for **1/3 s**.

Event geolocation – pixel latitude, longitude assuming specified cloud top height

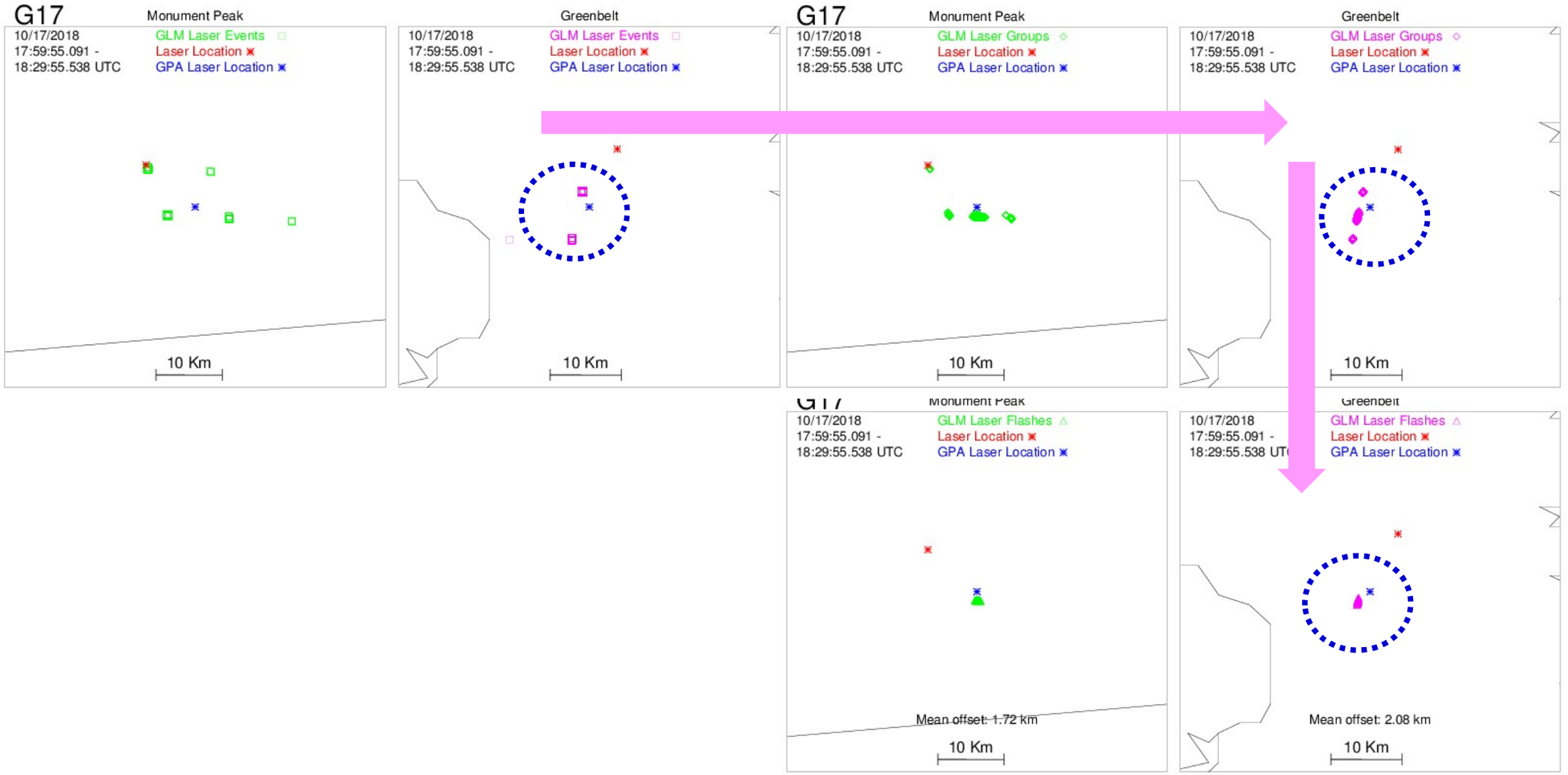
Group geolocation – Radiance weighted mean event location

Flash geolocation – Radiance weighted mean group location

G16 - Beacon Data Analysis: Events to Groups to Flashes



G17- Beacon Data Analysis: Events to Groups to Flashes



Summary

1. The laser beacons from the 2 SLR sites took GLM data during Apr 2017- Oct 2018.
2. SLR site coordinates provided precise location for data translation to the cloudtop.
3. Unlike natural lightning, the laser beacon delivers a fixed PRF, allowing correlation of L0, L1b, and L2 time series.
4. Data taken under varying diurnal conditions, S/C dither, eclipse, and yaw flip.
5. Measured values agrees with refined preliminary models to <2km, exceeding the 5km requirement;
6. Expects the last phase of the 2 satellite tests during the 3rd-4th week of November