American Meterological Society (AMS)
92nd Annual Meeting
January 24, 2012

Dr. Hugh Christian, 256.961.7828
GLM Phenomenology
Lockheed Martin

Karen M. Gheno, 650.424.2714
GLM Deputy Program Manager
Lockheed Martin

GOES-R
Geostationary Operational Environmental Satellite R-Series

A collaborative mission between NOAA and NASA

Geostationary Lightning Mapper

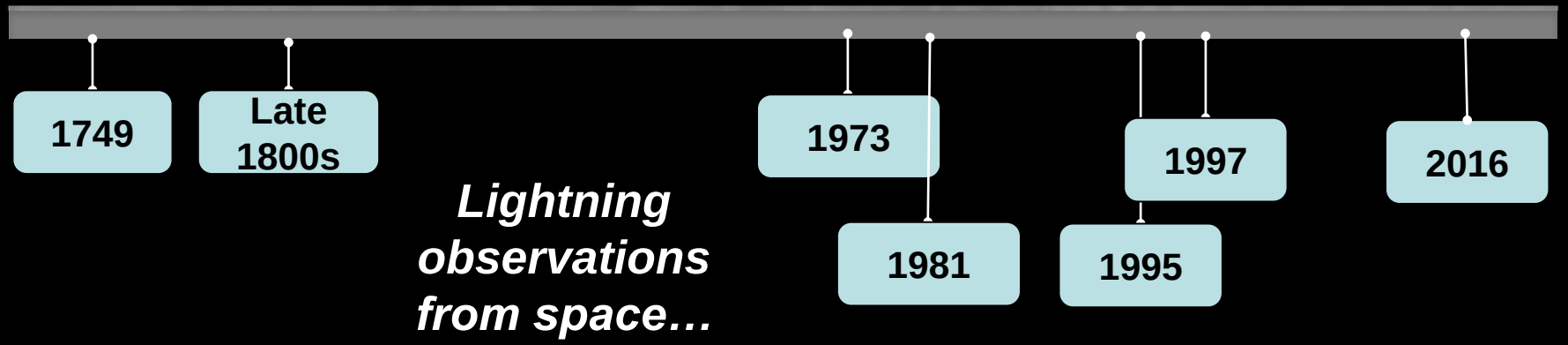
Provides early indication of sever weather

The GOES-R Geostationary Lightning Mapper (GLM) detects and maps total lightning (in-cloud and ground-to-ground) and provides early indication of storm intensification and severe weather events.

Tuscaloosa, Alabama

Credit: NOAA

Lightning rod invented



Lightning observations from space…

Photography and spectroscopic tools available

Credit: NASA

Lightning Phenomenology
Value of Remote Sensing

- Most of the electrical energy generated by a thunderstorm is dissipated by lightning – lightning flash rate is quantitatively related to the electrical energy generation

- The electrical generator is active during the updraft - lightning activity mirrors thunderstorm development

- Electrical energy is generated during ice production - amount of lightning is quantitatively related to the amount of ice

Maximizing the Value of GLM Data

- A major application of GLM will be using trends in lightning flash rate to infer storm intensification
  - Assumes that the flash rate is invariant with the charging current and that all flashes are basically equal
    - We know the latter is not true and suspect that the % of electrical energy dissipated by lightning may change with storm type and conditions
- GLM provides stroke rates and optical energy which may be helpful in determining variances
  - Strokes are more numerous than flashes – faster trending
  - Optical energy additional information

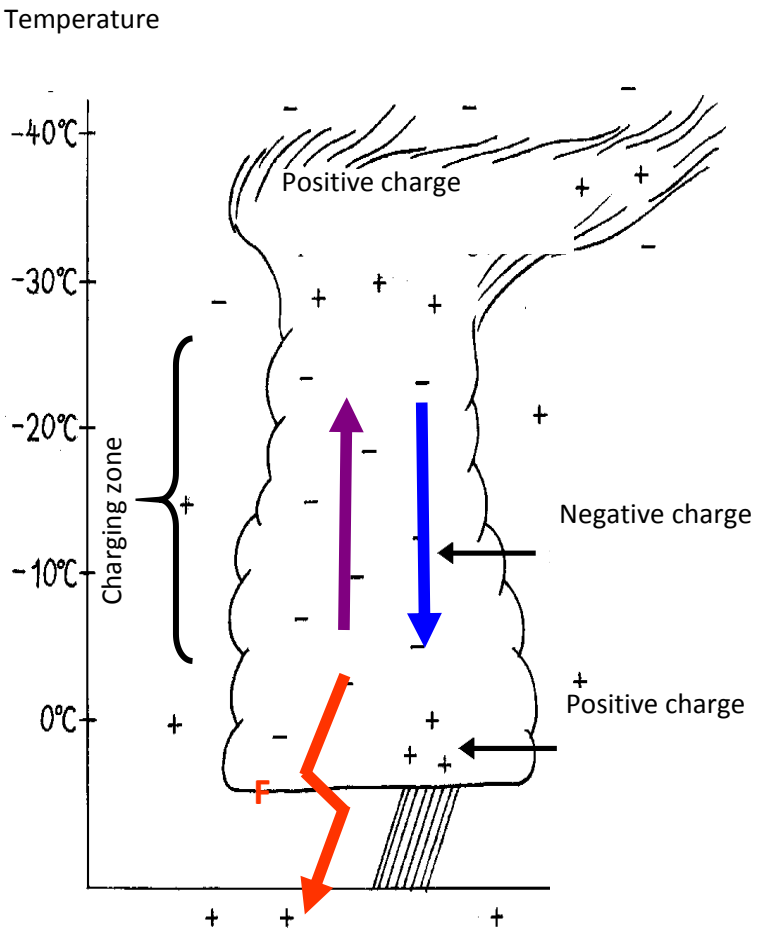
- Using a newly developed ground based electric field change meter array:
  - Determine charge location and electrostatic energy dissipated by each stroke
  - Determine the charging (Maxwell) current
  - Thus can estimate the electrical energy dissipated by lightning and its % of the total electrical energy generation for different storm types and conditions
  - Hopefully to improve GLM data value

Example: Electrification, thus Lightning is controlled by ice production

Hypothesis: Lightning frequency (F) proportional to product of upward non precipitation ice mass flux (I) and precipitation ice mass flux (p)

$$F = c*p*I$$

Supported by simple calculations (Blyth et al. 2001) and lightning model results (Baker et al. 1995, 1999).



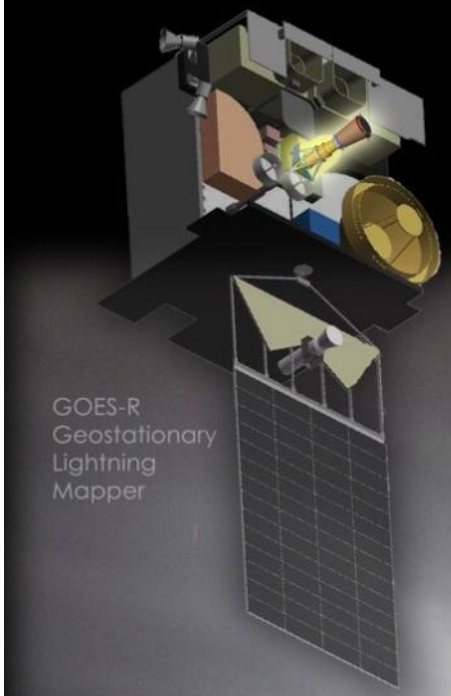
UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

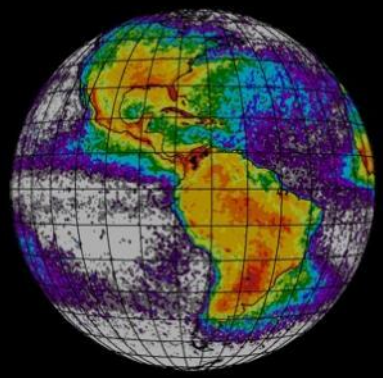
Fundamental question for operation:

What attribute of lightning is most useful?

Fundamental question for validation:

What is the best way from the ground to characterize what GLM “sees?”

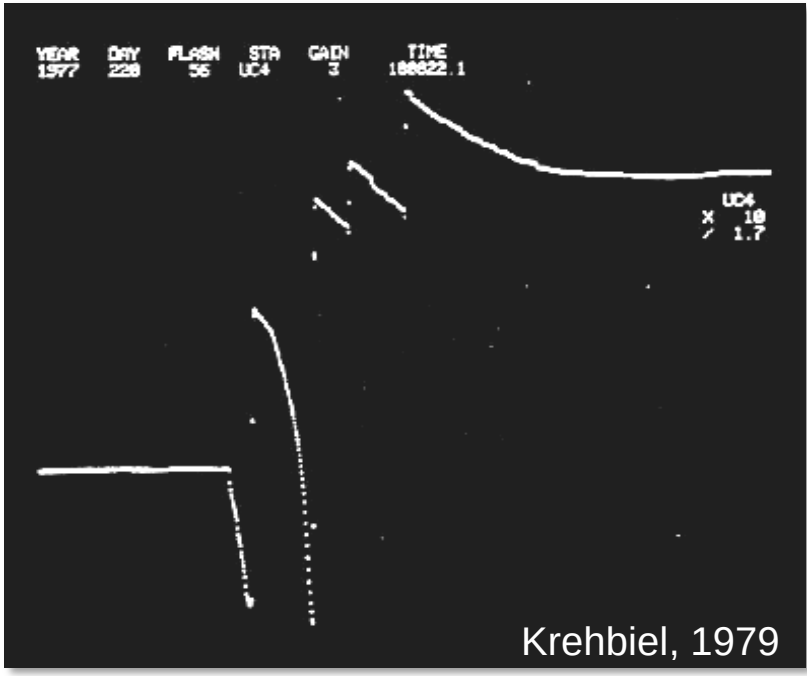




Why this new array?

- Underlying assumption: the energetics of a lightning process is tied to the "net charge involved"
- So, although lightning can be measured in various ways, in order to measure the energetics, we need to measure the electric field change due to a stroke/flash
- Others have measured electric fields
  - e.g., arrays of instruments that focus only on the electrostatic component of radiated electric field (e.g. KSC, NMT)
  - single station fast antennas

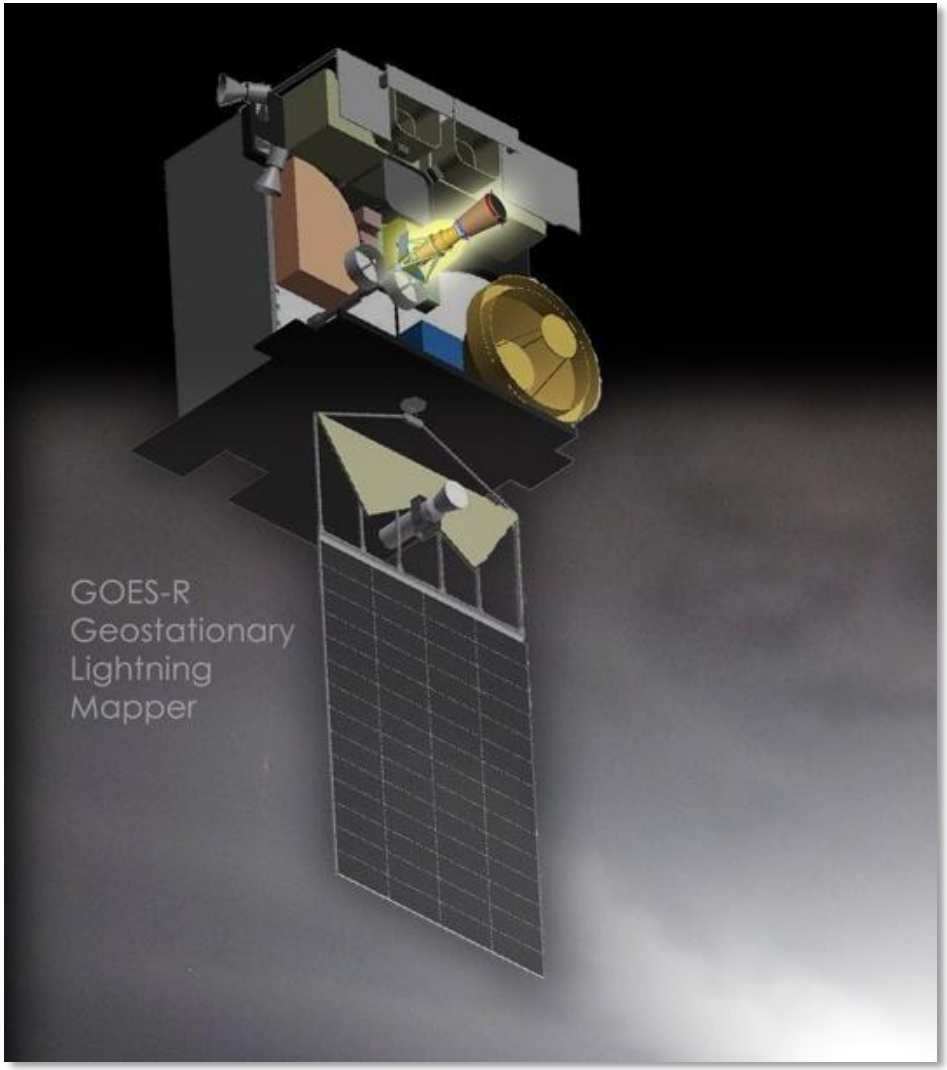
What if we design an array that can measure all components of the radiated electric field?

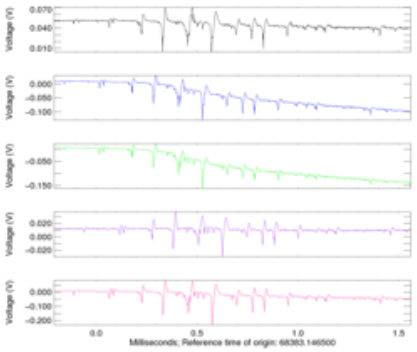


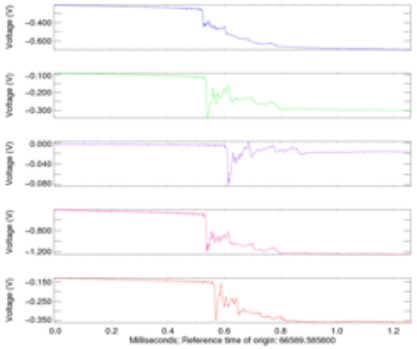
Krehbiel, 1979

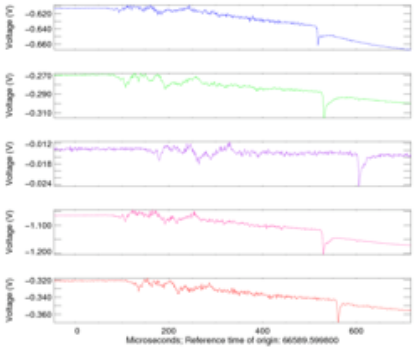
“Low hanging fruit”

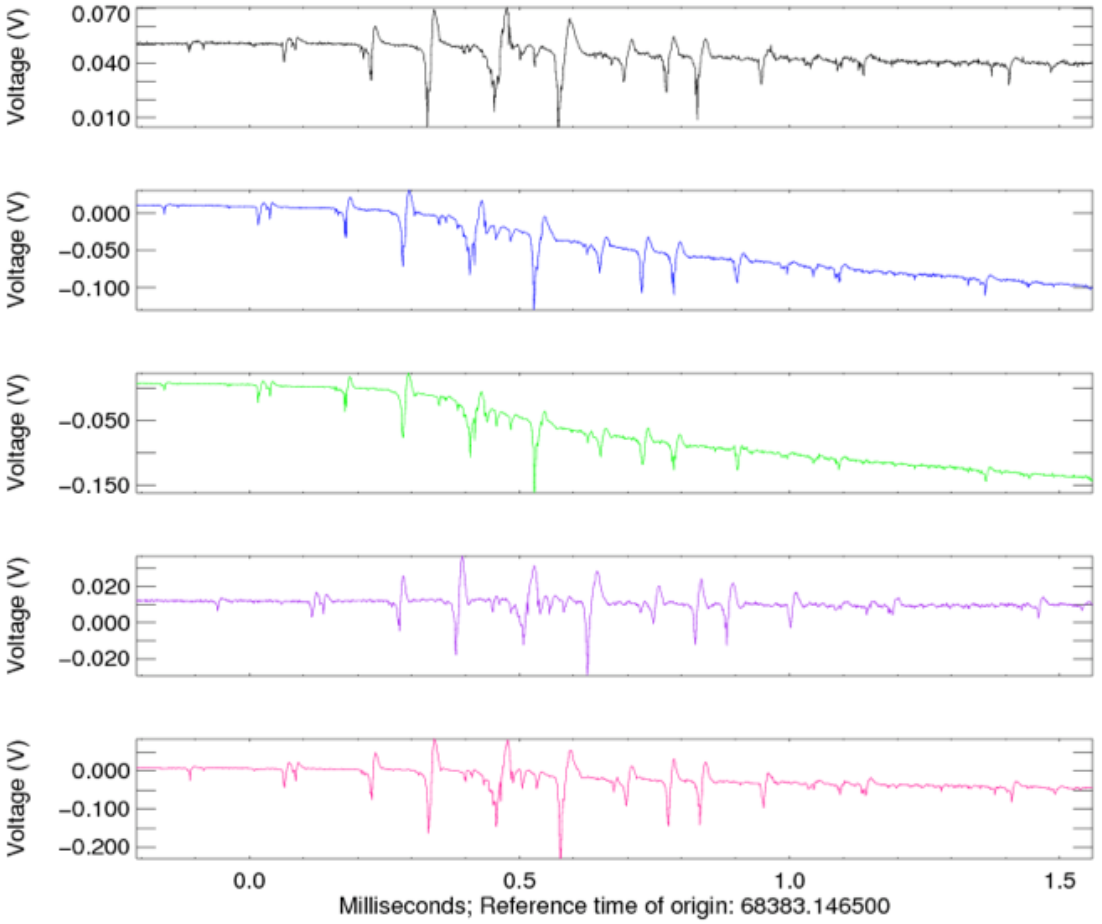
- Ground truth for space-based measurements
  - LMA is great at detecting lightning, but can LMA yield any energetic information?
  - Could use NLDN, but it’s notoriously bad at measuring ICs



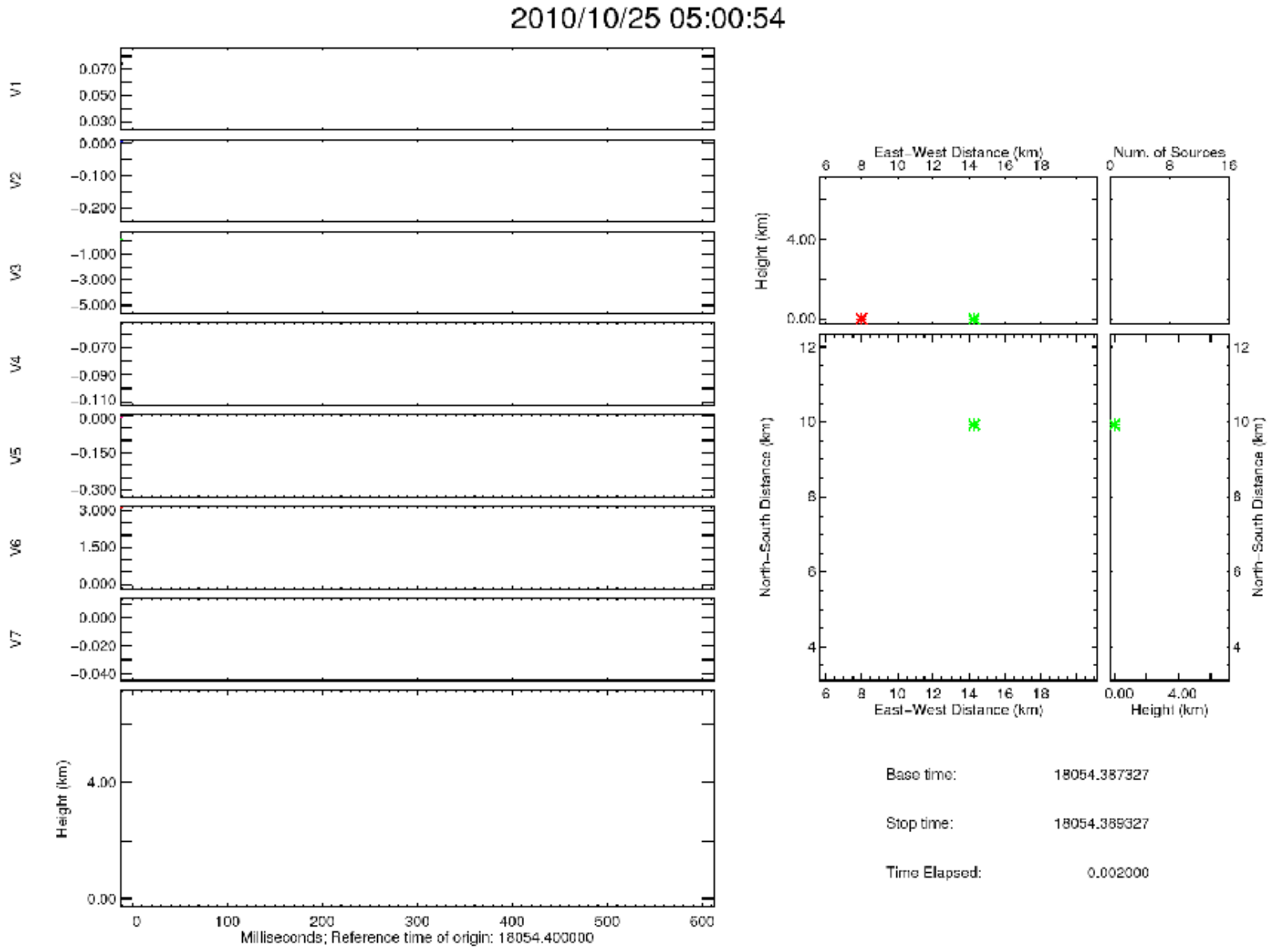




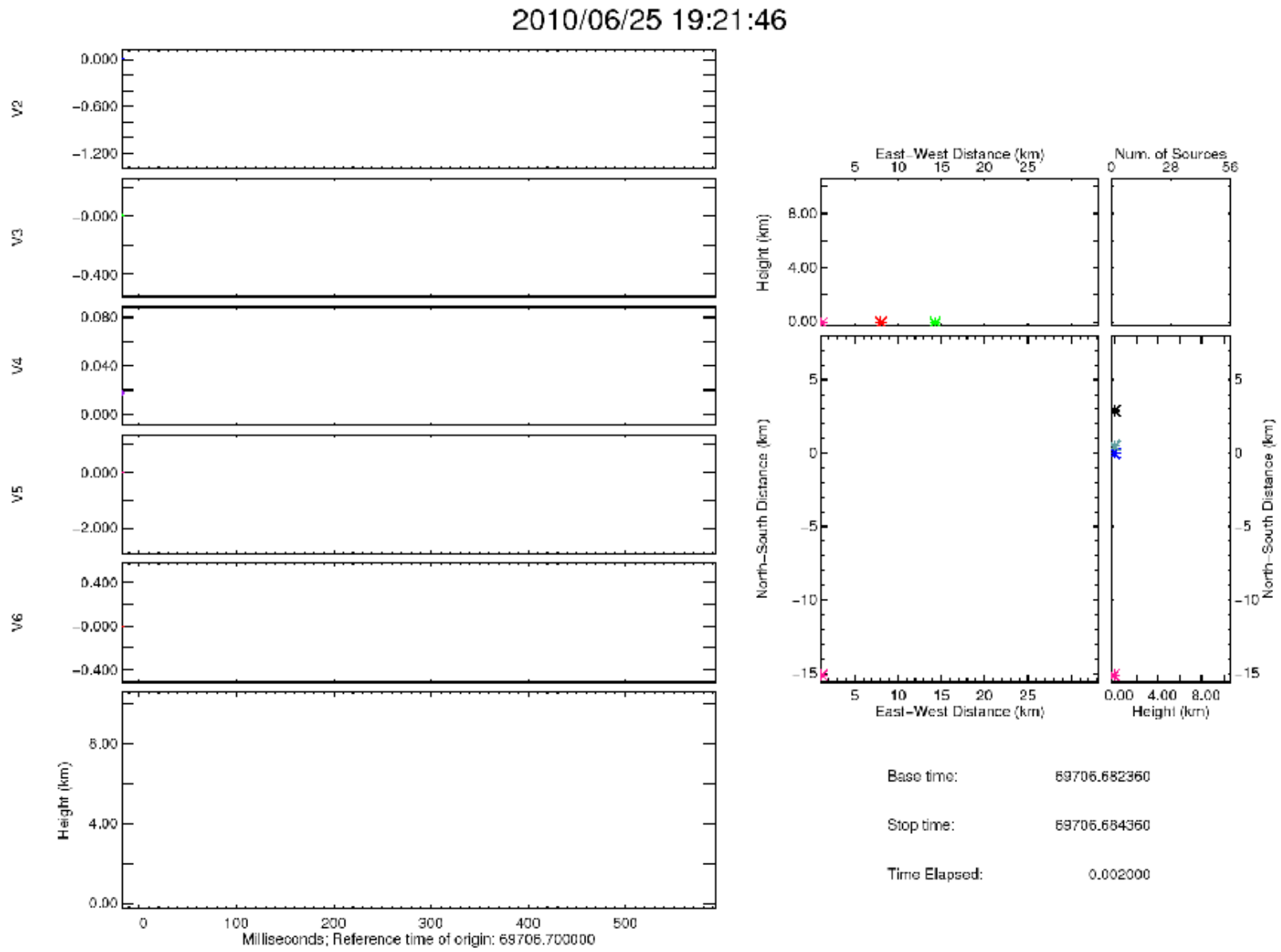




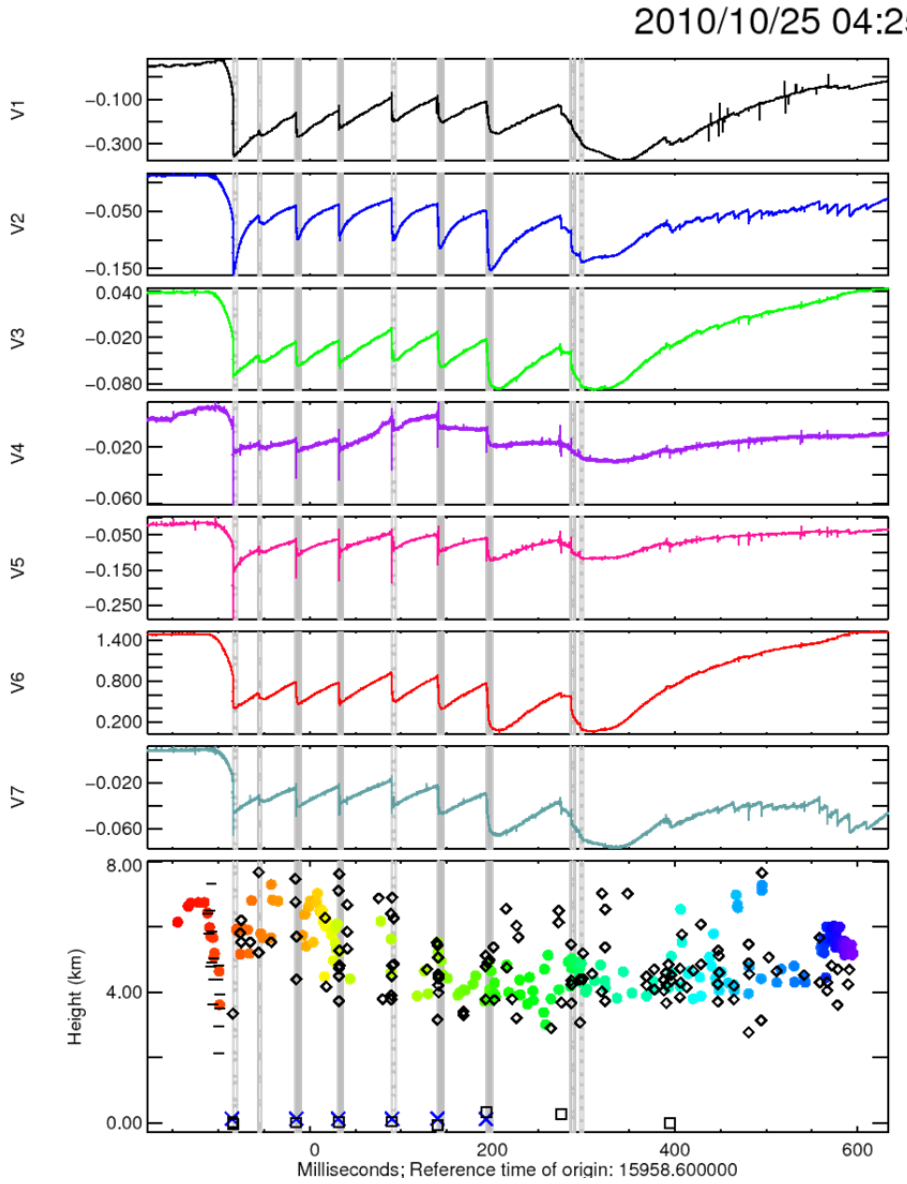
Case 1

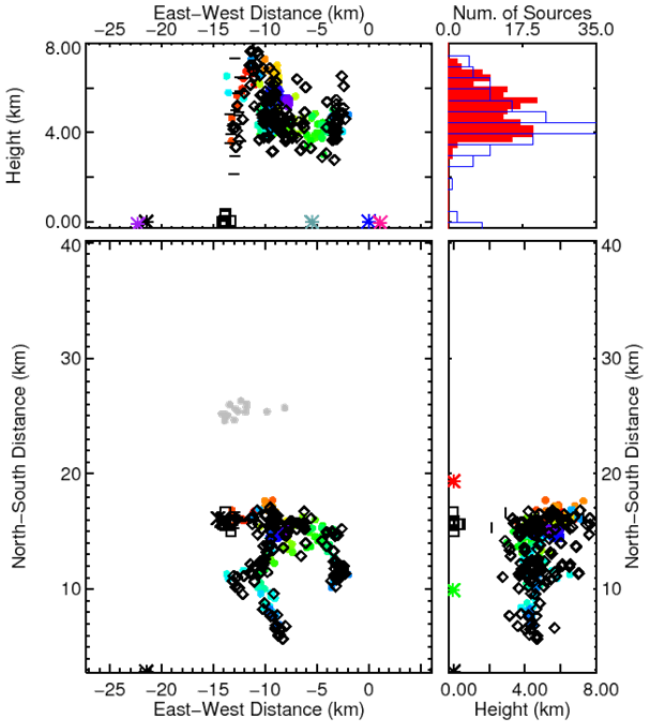

2010/10/25 05:00:54
V1
V2
V3
V4
V5
V6
V7
Height (km)
Milliseconds; Reference time of origin: 18054.400000
East–West Distance (km)
Num. of Sources
North–South Distance (km)
Height (km)
Base time: 18054.387327
Stop time: 18054.389327
Time Elapsed: 0.002000

Case 2


2010/06/25 19:21:46
V2
V3
V4
V5
V6
Height (km)
Milliseconds; Reference time of origin: 69706.700000
East–West Distance (km)
Num. of Sources
North–South Distance (km)
Height (km)
Base time: 69706.682360
Stop time: 69706.684360
Time Elapsed: 0.002000

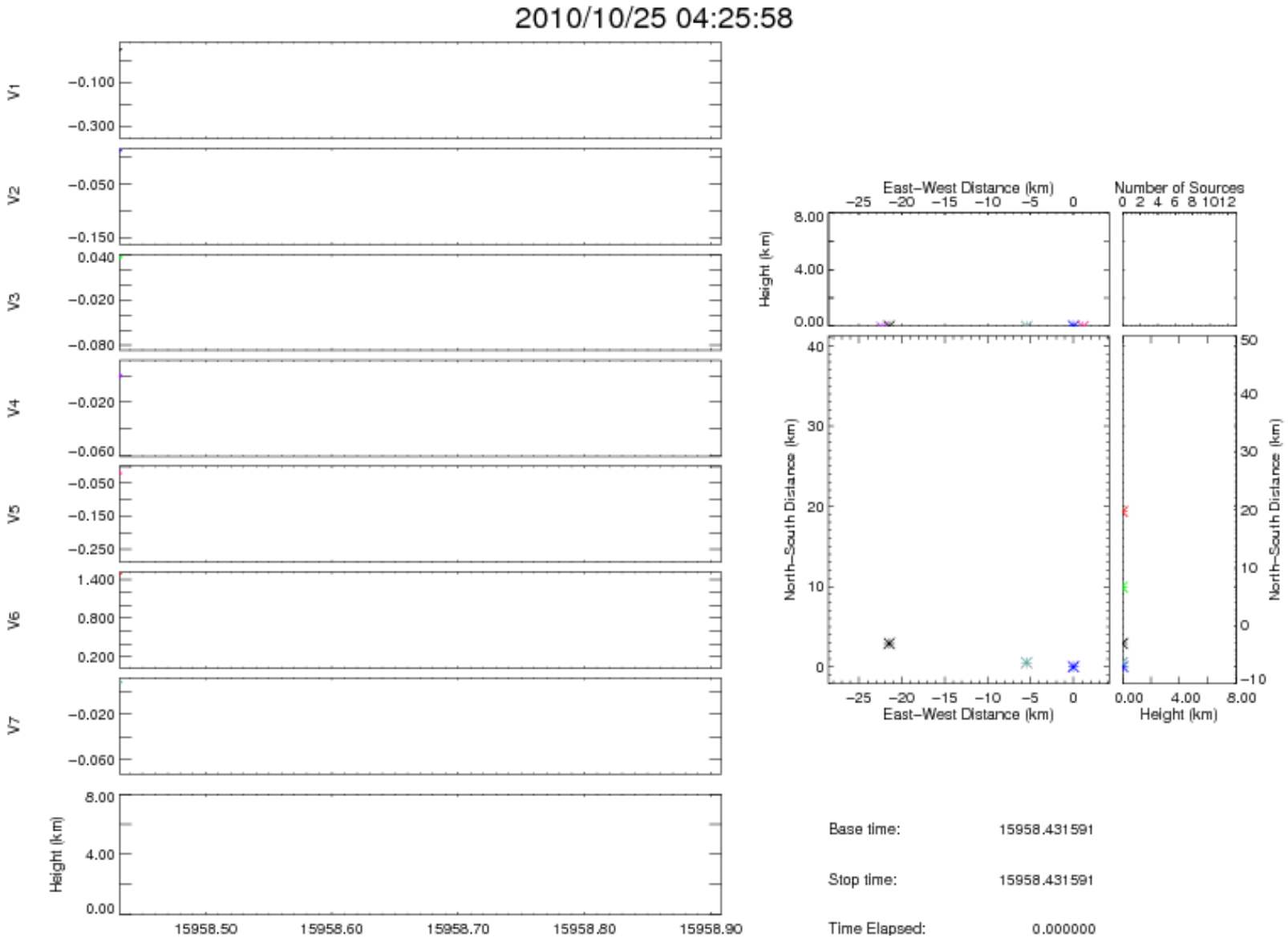
HAMMA vs. LIS
Detections & Locations





Base time:	15958.422249
Stop time:	15959.233089
Time Elapsed:	0.810840

Case 3

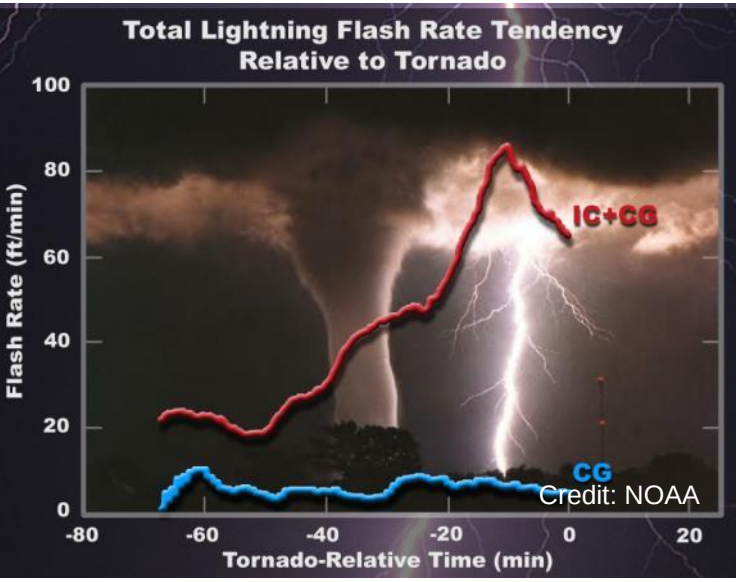

2010/10/25 04:25:58
V1
V2
V3
V4
V5
V6
V7
Height (km)
15958.50
15958.60
15958.70
15958.80
15958.90
East–West Distance (km)
Number of Sources
North–South Distance (km)
Height (km)
Base time: 15958.431591
Stop time: 15958.431591
Time Elapsed: 0.000000

GLM Key Driving Requirements & Mission Objectives

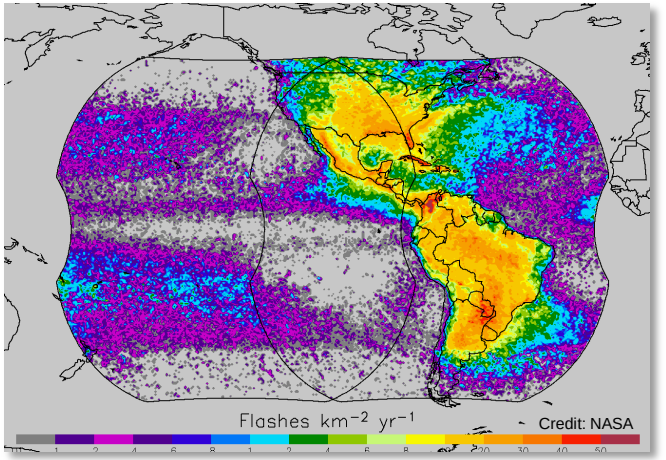
- Top-Level Requirements
  - Capture 70% of the lightning flashes
  - False alarm rate less than 5%

- GOES-R GLM Mission Objectives

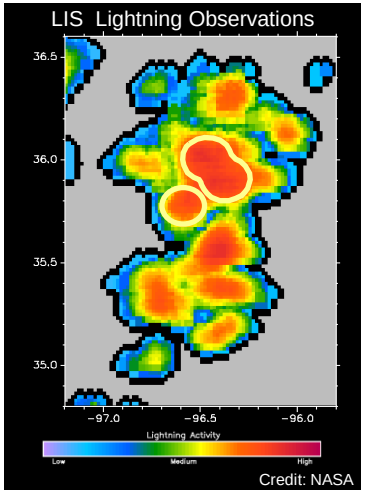
Longer tornado warning time



Decadal lightning data



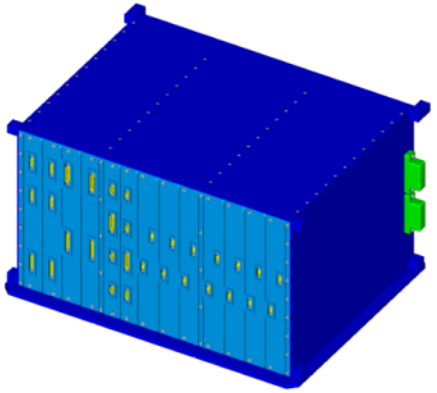
Storm cell tracking



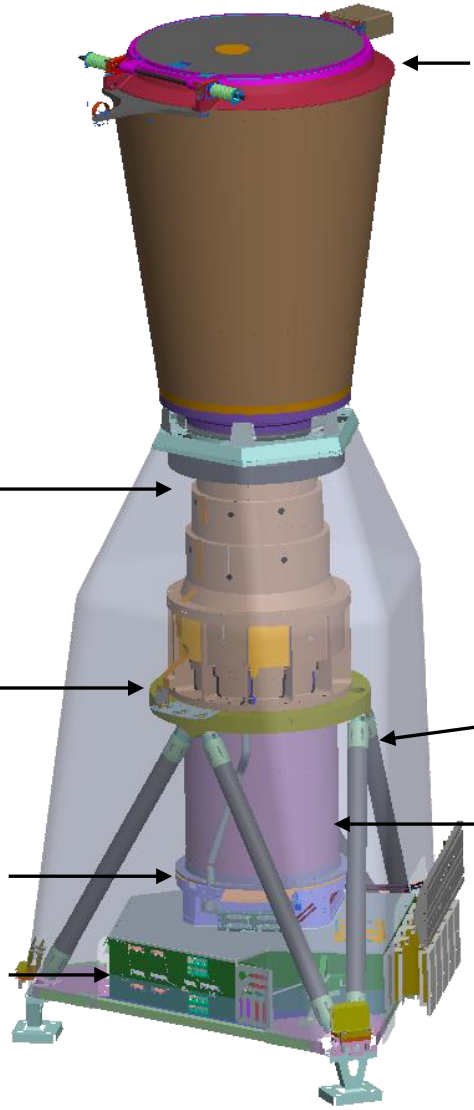
Real-time lightning data is key to early tornado warning

GLM Instrument Overview

Electronics Unit

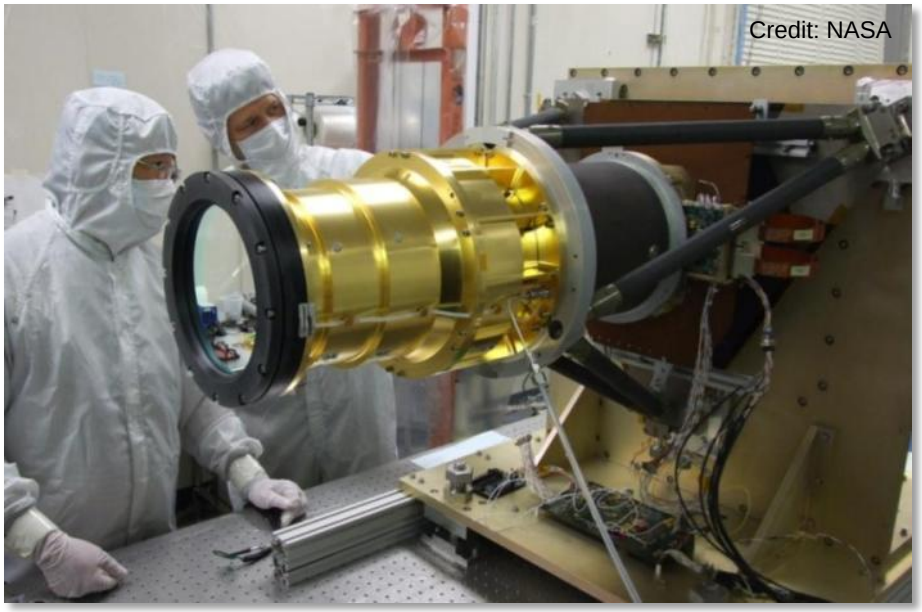


Sensor Unit



Optical assembly, Support Structure, and Metering Tube

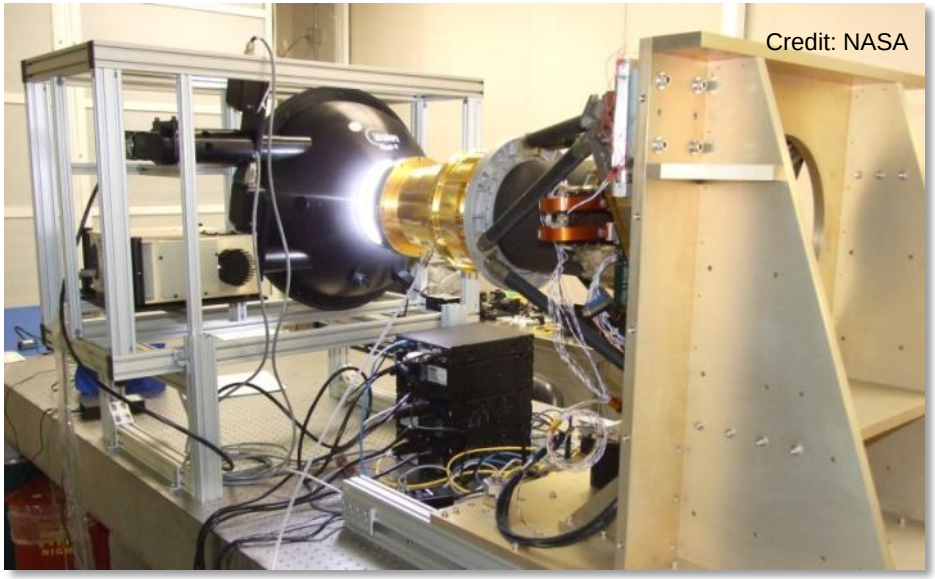
GLM Instrument Overview



GLM is a near-IR detector that continuously maps in-cloud & cloud-to-ground lightning with near uniform spatial resolution

GLM Characteristics

- CCD event detector
  - 777.4 nm wavelength
  - 2 ms frame rate
  - 7.7 Mbps downlink rate
- Near uniform spatial resolution
  - 8 km (nadir) – 14 km (edge of FOV)
  - 70-90% flash detection
- Product availability <10 sec total latency



GLM EDU and Flight Development Status

Engineering Development Unit

- Completed System CDR (Dec 2010)
  - Completed Electronics Unit Electronics Δ-CDR (Apr 11) and Sensor Unit Electronics Δ-CDR (Aug 2011)
- Completed development and testing of ground processing algorithms
- Development hardware (thru Nov 2011)
  - Completed EDU optical assembly throughput and filter testing
  - Completed EDU door and baffle vibration testing
  - EDU structure with high fidelity mass models assembled and completed qualification vibration testing
  - Completed EDU instrument EMI/EMC chamber testing

Flight hardware in fabrication and test

- Thermal subsystems in flight fabrication
- Flight detectors completed fabrication and back-side thinning
- Received majority of EEE flight parts; distribution to flight board fabrication vendors in process
- Completed flight fabrication and test of flight filters; met or exceeded requirements
- FM1 Optical assembly testing (thermal, vibration, and optical) (1Q 2012)
- FM1 structure fabrication (1Q 2012)
- Electronics board- and box-level flight fabrication (1Q 2012)

GLM: The next generation of space-based lightning detection

- GLM's total lightning data will have immediate applications to aviation weather services, climatological studies, and severe thunderstorm forecasts and warnings

Thunder is good, thunder is impressive;

but it is lightning that does the work.

~ Mark Twain

Credit: NOAA