An Introduction to the GOES-R Geostationary Lightning Mapper

Steven J. Goodman
GOES-R Program Senior Scientist, NOAA/NESDIS

http://www.goes-r.gov

The fact that lightning could be seen from high altitudes was noted in anecdotal form by the early U-2 pilots, and more focused observations were reported by the Apollo and early Space Shuttle flights. Simple camera systems were used to record what they saw.

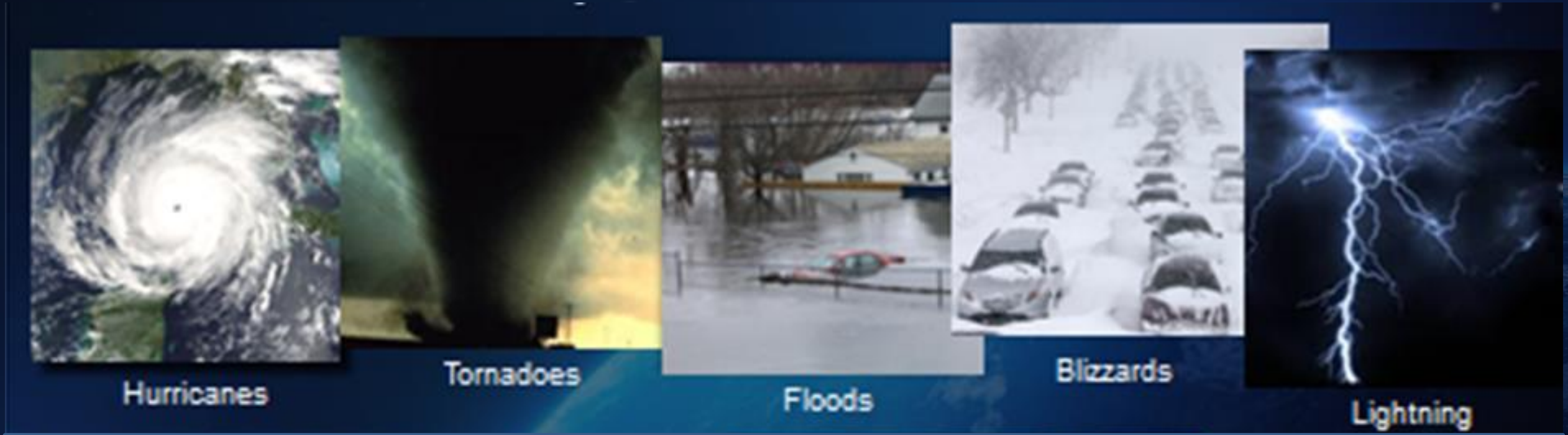
Lightning Storms from Uganda to Zanzibar Island

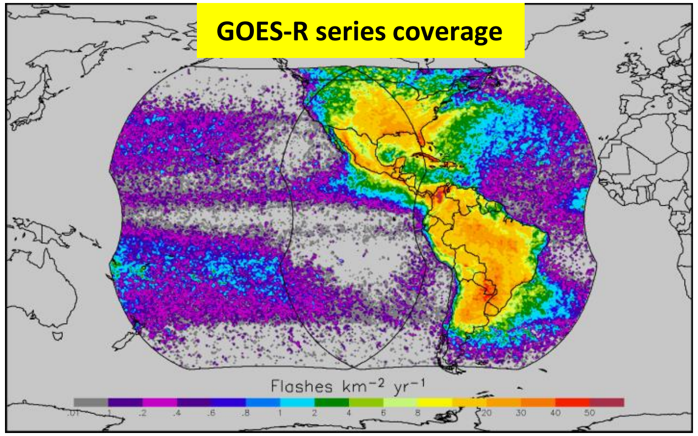
Videos produced by the Crew Earth Observations group at NASA Johnson Space Center

For replication and crediting information, please see our guidelines on our main video page.

GLM Science Team and Partners

Weather Impacts on Society: Lightning





GOES-R Warning Products

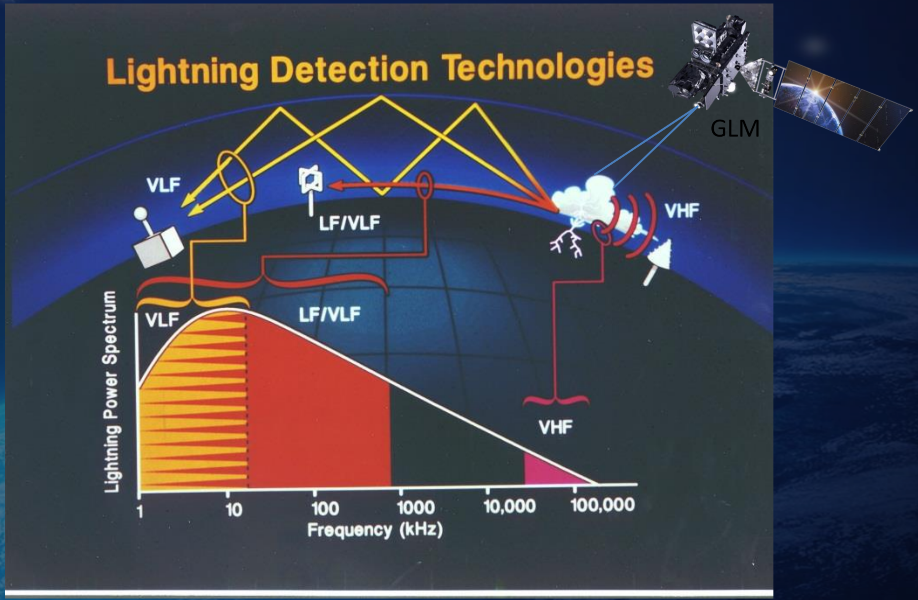
Initial focus on products that offer NWS near-real time Warning Related utility.

Products:

- Severe Storm Warning Lead Time
- Hurricane Intensity
- Lightning Detection
- Rainfall Rate / QPE
- Fire Ignition
- Air Transport Safety and Efficiency
- Convective Turbulence
- Volcanic Eruptions
- Convective Initiation

Lightning Observing Systems

Available information as input to weather forecasting models (data assimilation), nowcasting systems, and decision support systems



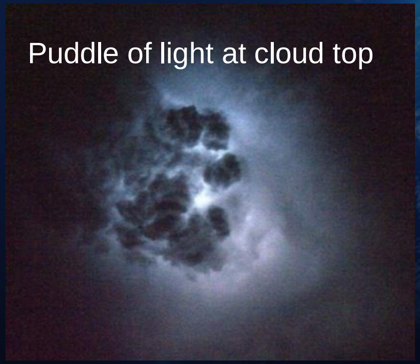
Lightning Detection and Mapping

- Local electric field mill networks
- High speed digital video cameras, all-sky cameras
- Short-range VHF in-cloud lightning mapping (60-180 MHZ)
- National cloud-to-ground lightning mapping (LF, 500 kHZ)
- International long range sferics networks (VLF, 10 kHZ)
- Sub-orbital: planes, balloons, UAVs (electrical, magnetic, optical)
- Lightning optical imagers orbiting Earth (GEO, LEO)

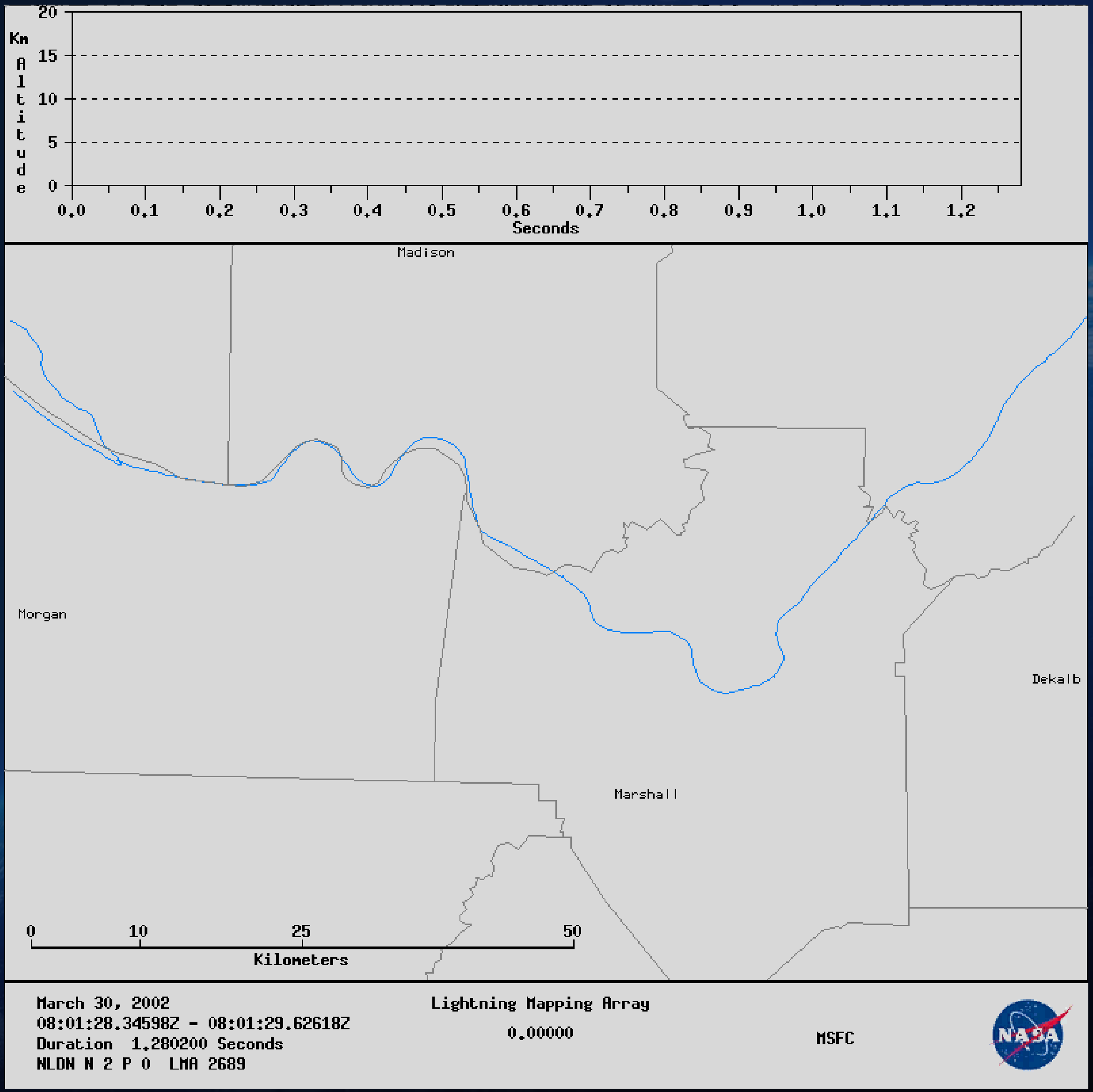
Key Performance Measures- Detection Efficiency, Location Accuracy, Flash Type, Stability, Consistency

High Speed Digital Video
Lightning Flash 7500 fps

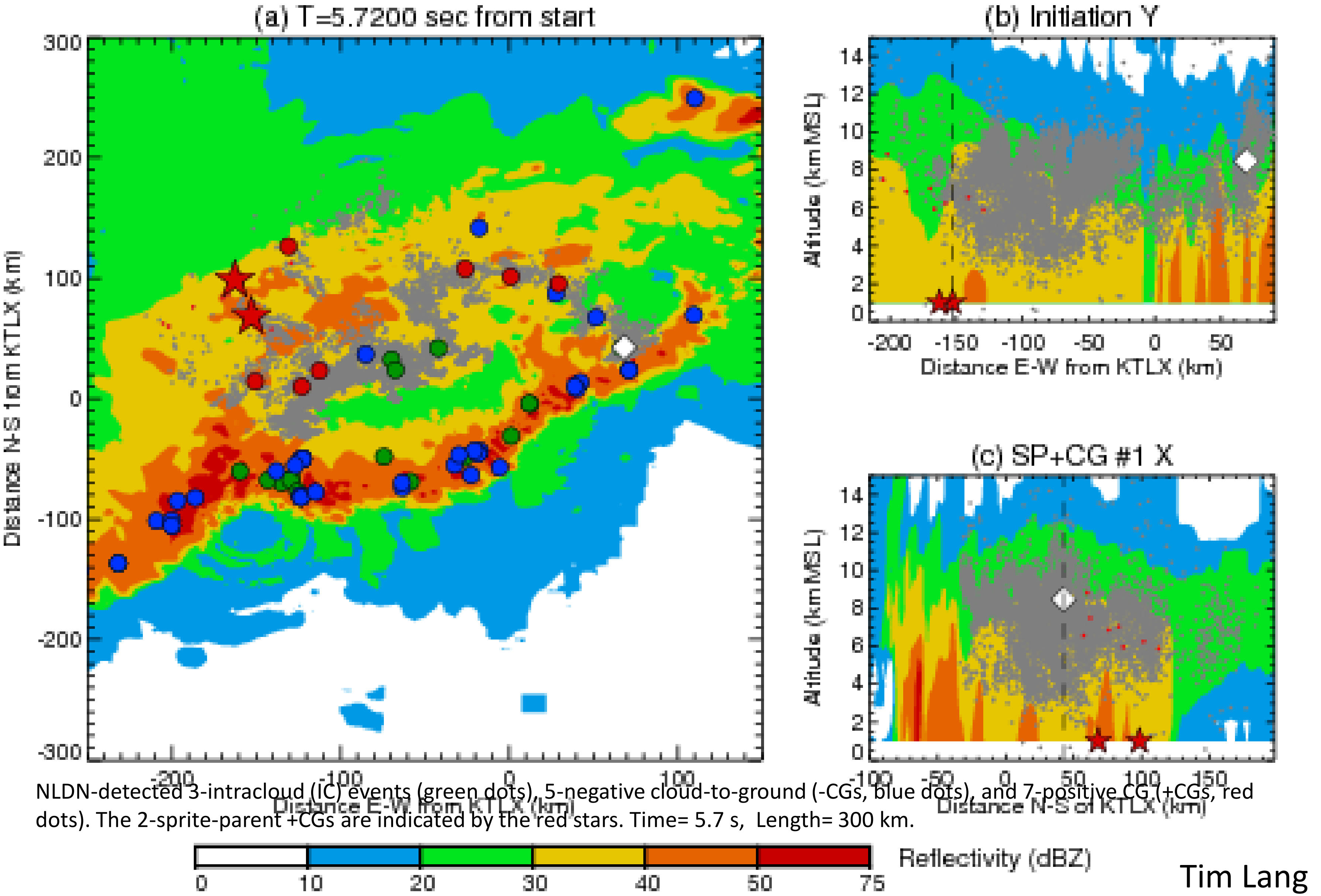
The GLM



What Goes On Inside the Cloud Before Lightning Strikes



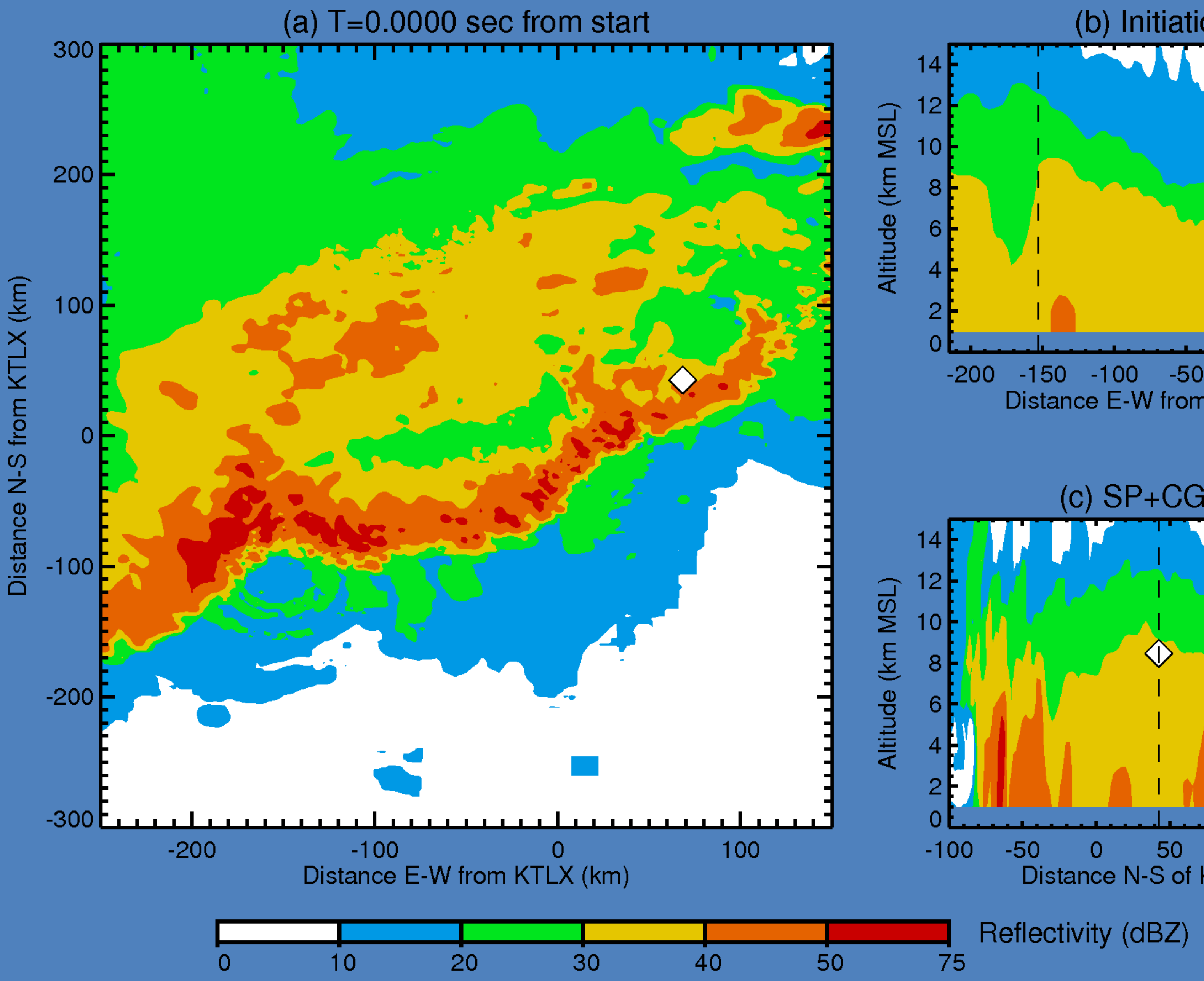
Lightning Flash 300 km in horizontal extent



NLDN-detected 3-intracloud (IC) events (green dots), 5-negative cloud-to-ground (-CGs, blue dots), and 7-positive CG (+CGs, red dots). The 2-sprite-parent +CGs are indicated by the red stars. Time= 5.7 s, Length= 300 km.

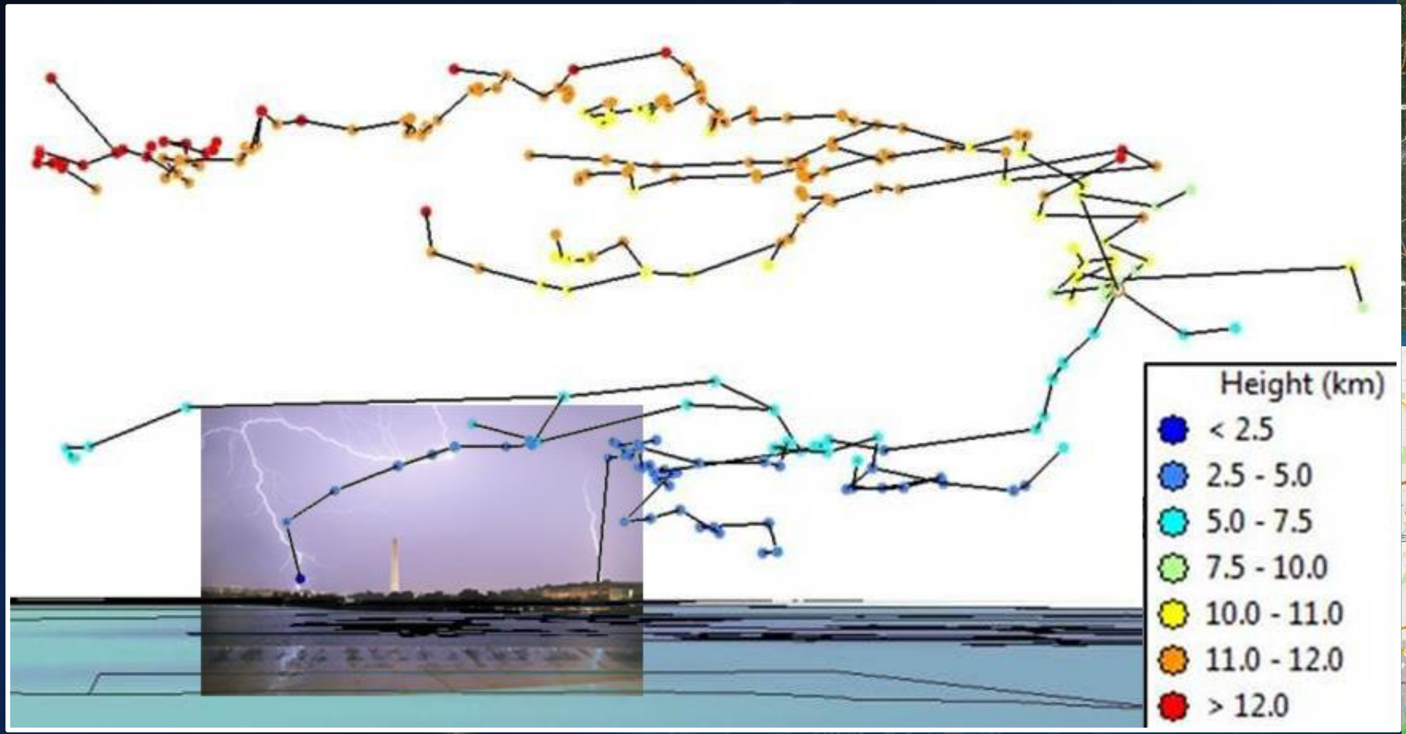
Tim Lang

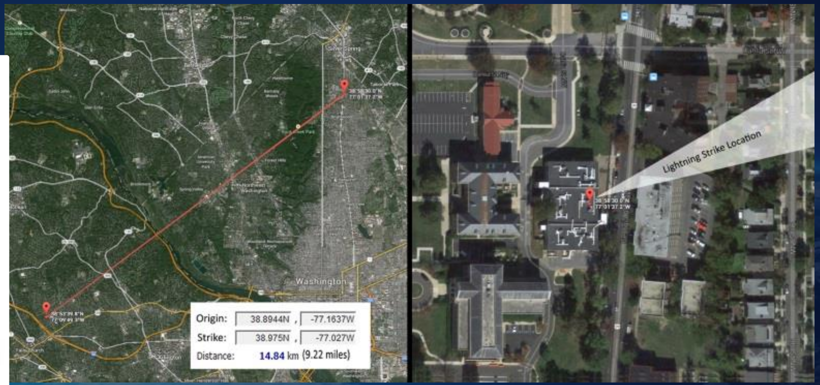
Lightning Flash - 300 km, 5 sec duration

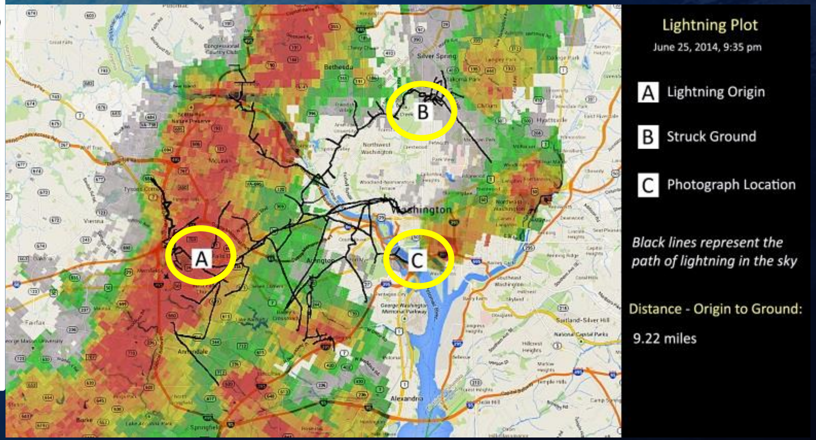


Mapping a “bolt from the blue”

A lightning flash originates near Silver Spring, MD and strikes the ground 9 miles distant in Falls Church, VA



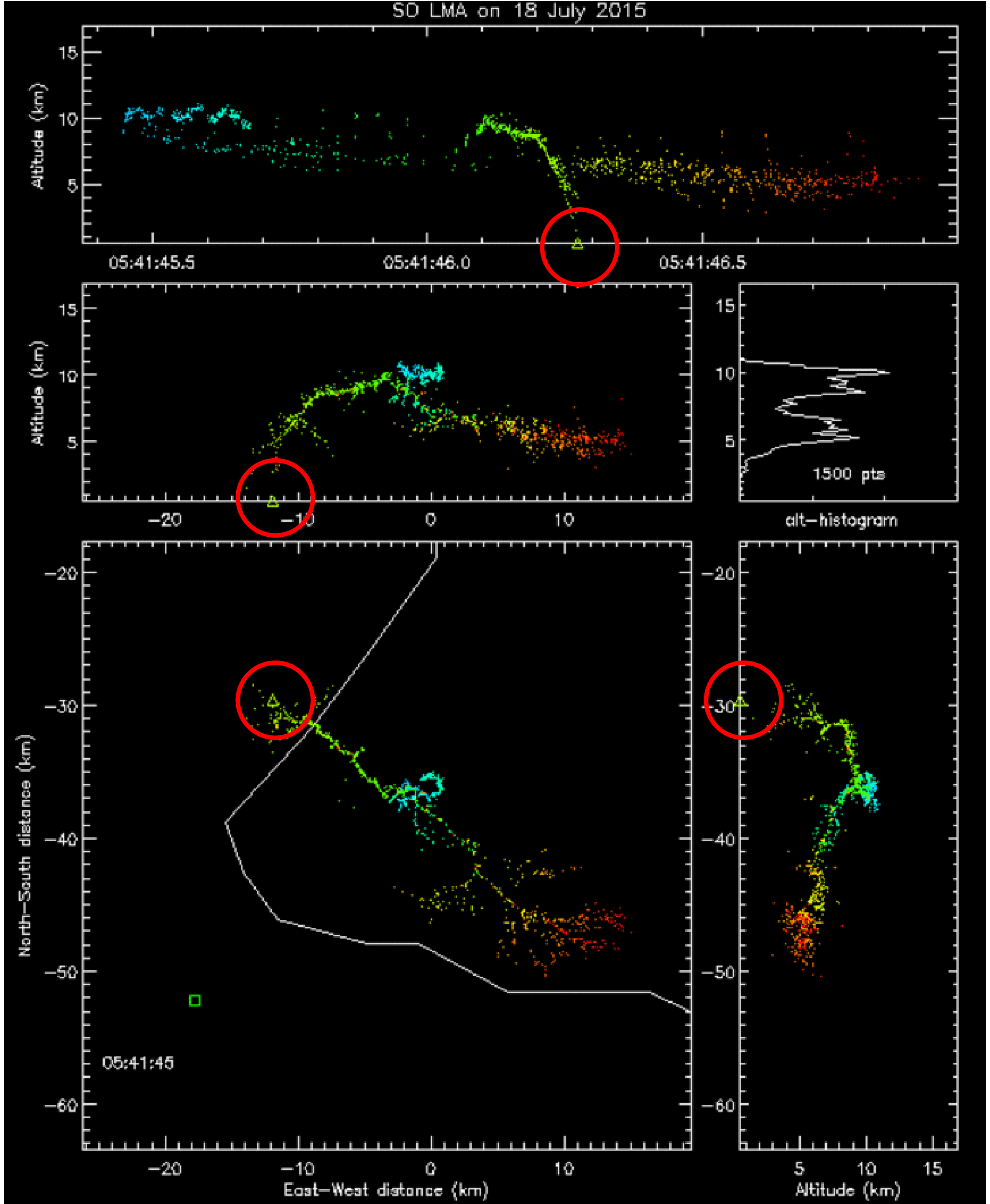




Courtesy Scott Rudlosky, Patrick Myers

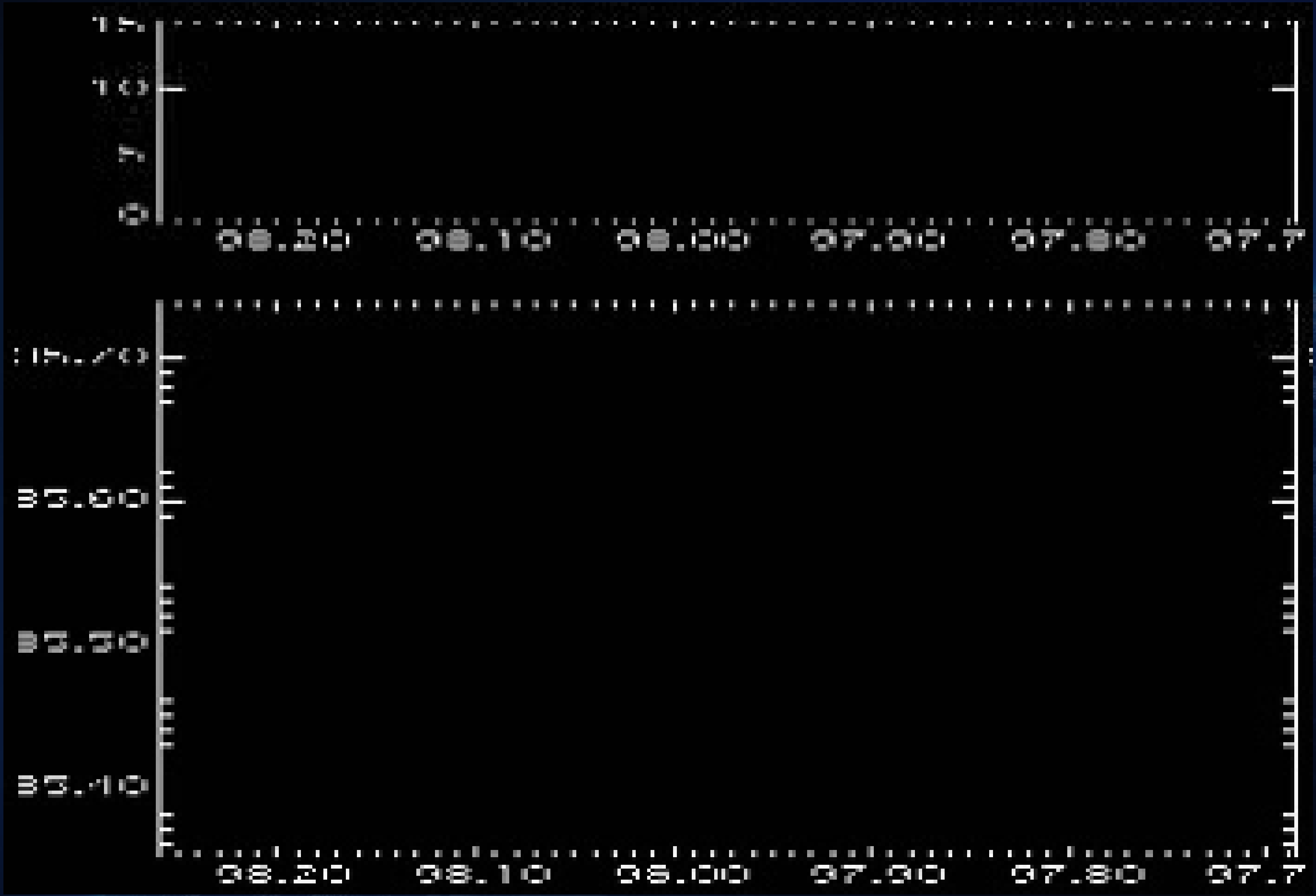
A Bolt from the Blue

Burlington facing Lake Ontario ~0541 UTC
Courtesy David Sills, ECCC with permission



Courtesy David Sills, ECCC

OKLMA-LIS Animation



Refer to Thomas et. al., Geophys. Res. Lett., 2000

GLM Lightning Detection: How it works

Lightning from Space: Lightning appears like a pool of light on the top of the cloud as the discharge lights up the cloud like a light bulb.

Daytime Challenge: During day, sunlight reflected from cloud top totally “swamps out” and masks the lightning signal. Daytime lightning detection drove the design.

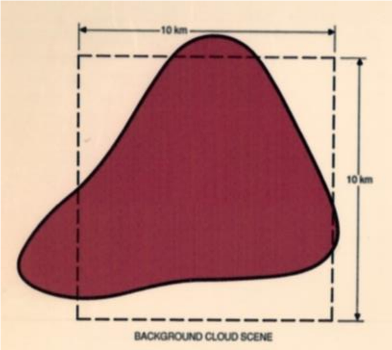
Solution: Special techniques must be applied to extract the weak, transient lightning signal from the bright, background noise.

ISS Image
April 30, 2012

Spatial

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

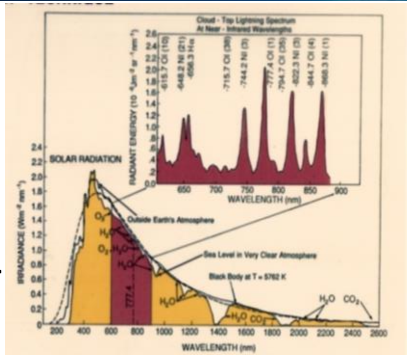
Pixel field-of-view 4-10 km.



Spectral

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

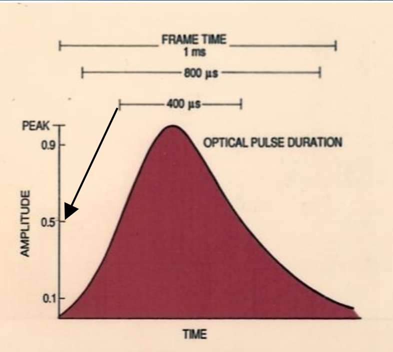
LIS uses 1nm filter at 777.4 nm.



Temporal

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

LIS/GLM use 2 ms frame rate.

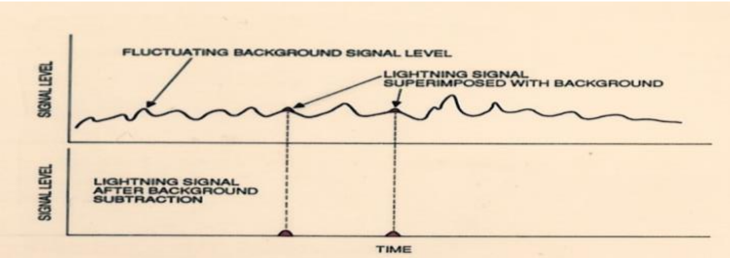


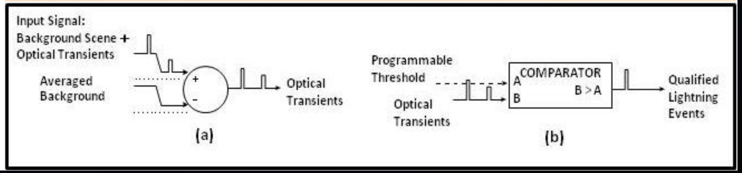
- *Even with spatial, spectral and temporal filters, background can exceed lightning signal by 100 to 1 at the focal plane.*
- *The final step is a frame-by-frame background subtraction to produce a lightning only signal*
- *Filtering results in 10^5 reduction in data rate requirements while maintaining high detection efficiency for lightning .*

Background Subtraction

Optimal subtraction of background signal levels at each pixel.

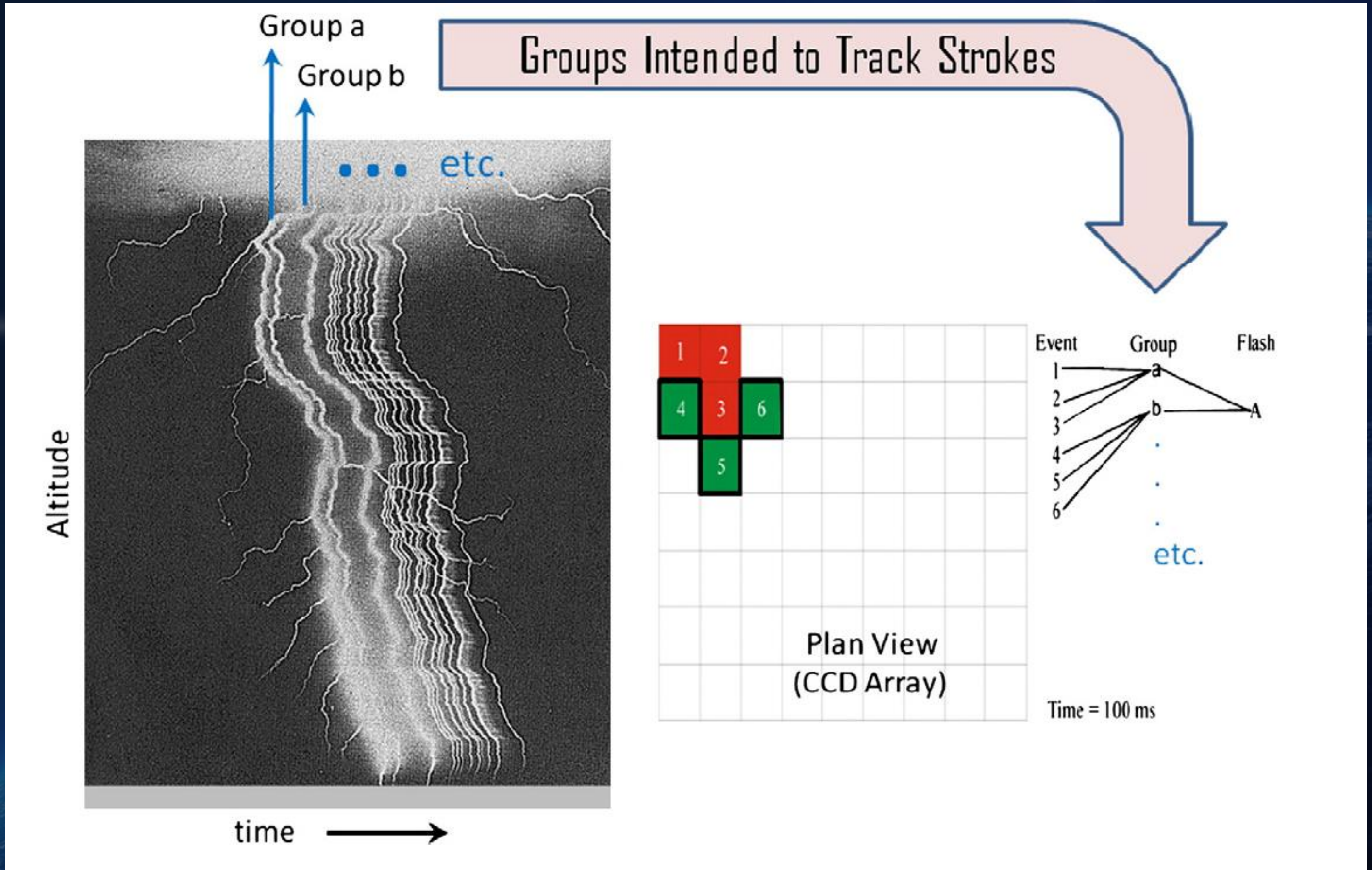
Transient events selected for processing.





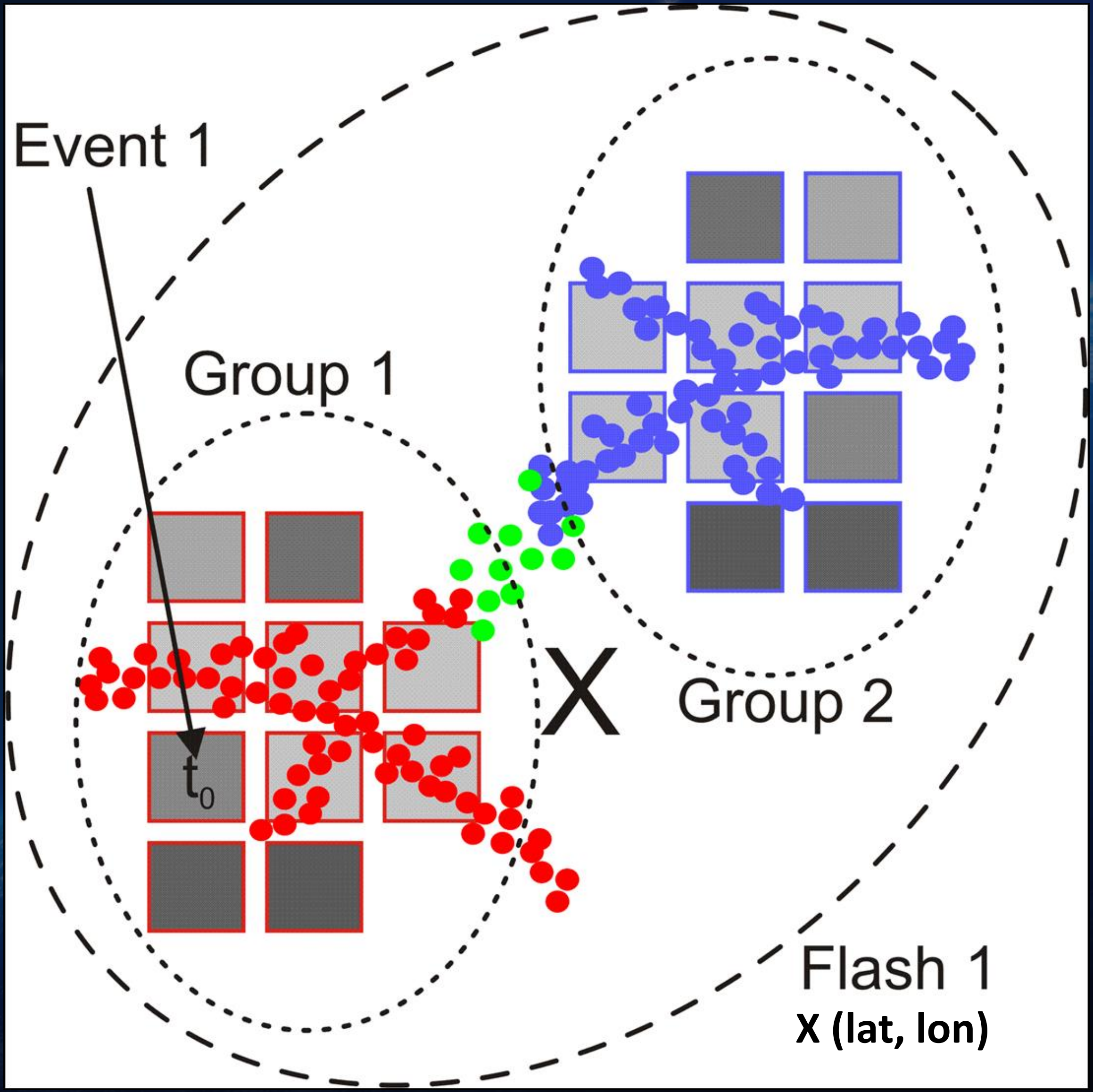
GLM L2 Algorithm

Lightning
Cluster
Filter
Algorithm



Steven J. Goodman, Richard J. Blakeslee, William J. Koshak, Douglas Mach, Jeffrey Bailey, Dennis Buechler, Larry Carey, Chris Schultz, Monte Bateman, Eugene McCaul Jr., Geoffrey Stano, The GOES-R Geostationary Lightning Mapper (GLM), *Atmospheric Research*, Volumes 125–126, May 2013, Pages 34-49, ISSN 0169-8095, http://dx.doi.org/10.1016/j.atmosres.2013.01.006.

How GLM Represents a Lightning Flash



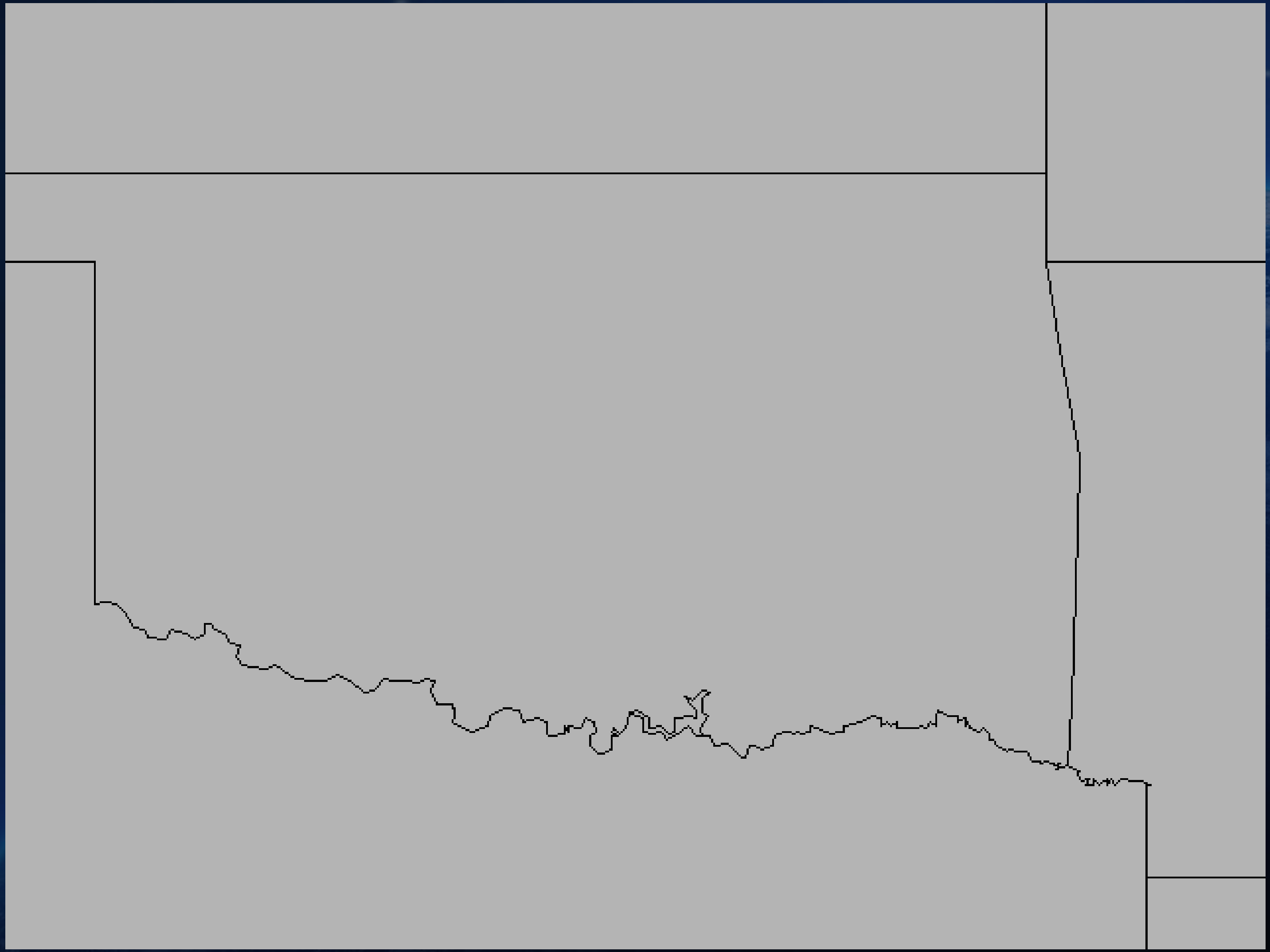
GLM NetCDF File Format

GLMNetCDF_data_structure:

- xtype
- event_id
- event_time_offset
- event_lat
- event_lon
- event_energy
- event_parent_group_id
- group_id
- group_time_offset
- group_lat
- group_lon
- group_area
- group_energy
- group_parent_flash_id
- group_quality_flag
- flash_id
- flash_time_offset_of_first_event
- flash_time_offset_of_last_event
- flash_lat
- flash_lon
- flash_area
- flash_energy
- flash_quality_flag
- product_time
- product_time_bounds
- lightning_wavelength
- lightning_wavelength_bounds
- group_time_threshold
- flash_time_threshold
- lat_field_of_view
- lat_field_of_view_bounds
- goes_lat_lon_projection
- event_count
- group_count
- flash_count
- percent_navigated_L1b_events
- yaw_flip_flag
- nominal_satellite_subpoint_lat
- nominal_satellite_height
- nominal_satellite_subpoint_lon
- lon_field_of_view
- lon_field_of_view_bounds
- percent_uncorrectable_L0_errors
- algorithm_dynamic_input_data_container
- processing_parm_version_container
- algorithm_product_version_container

Total Lightning Detection

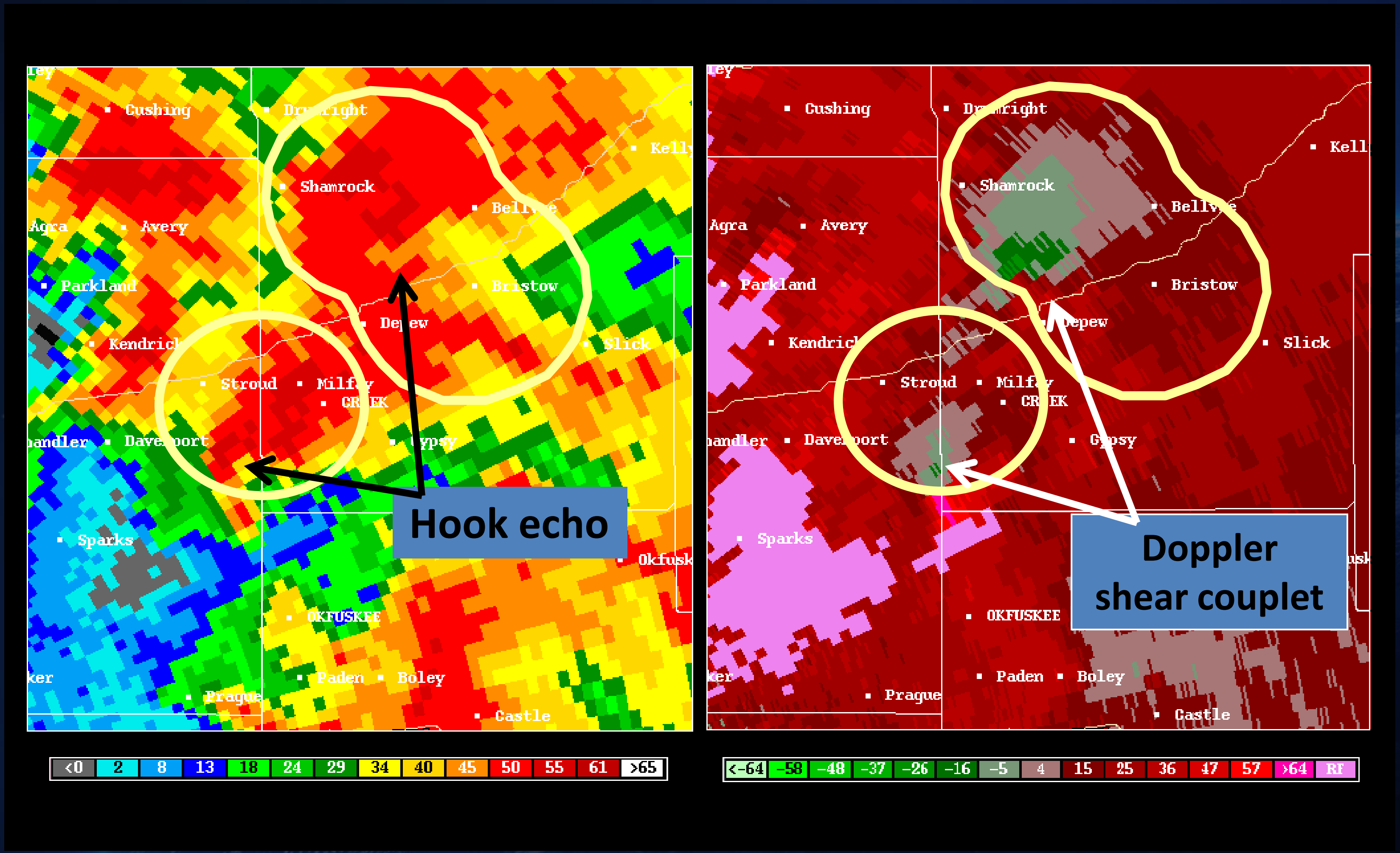
1-min TRMM/LIS overpass, May 3, 1999 tornado outbreak



Stroud, OK EF3 and Tornado Outbreak 3 May 1999

NEXRAD Reflectivity

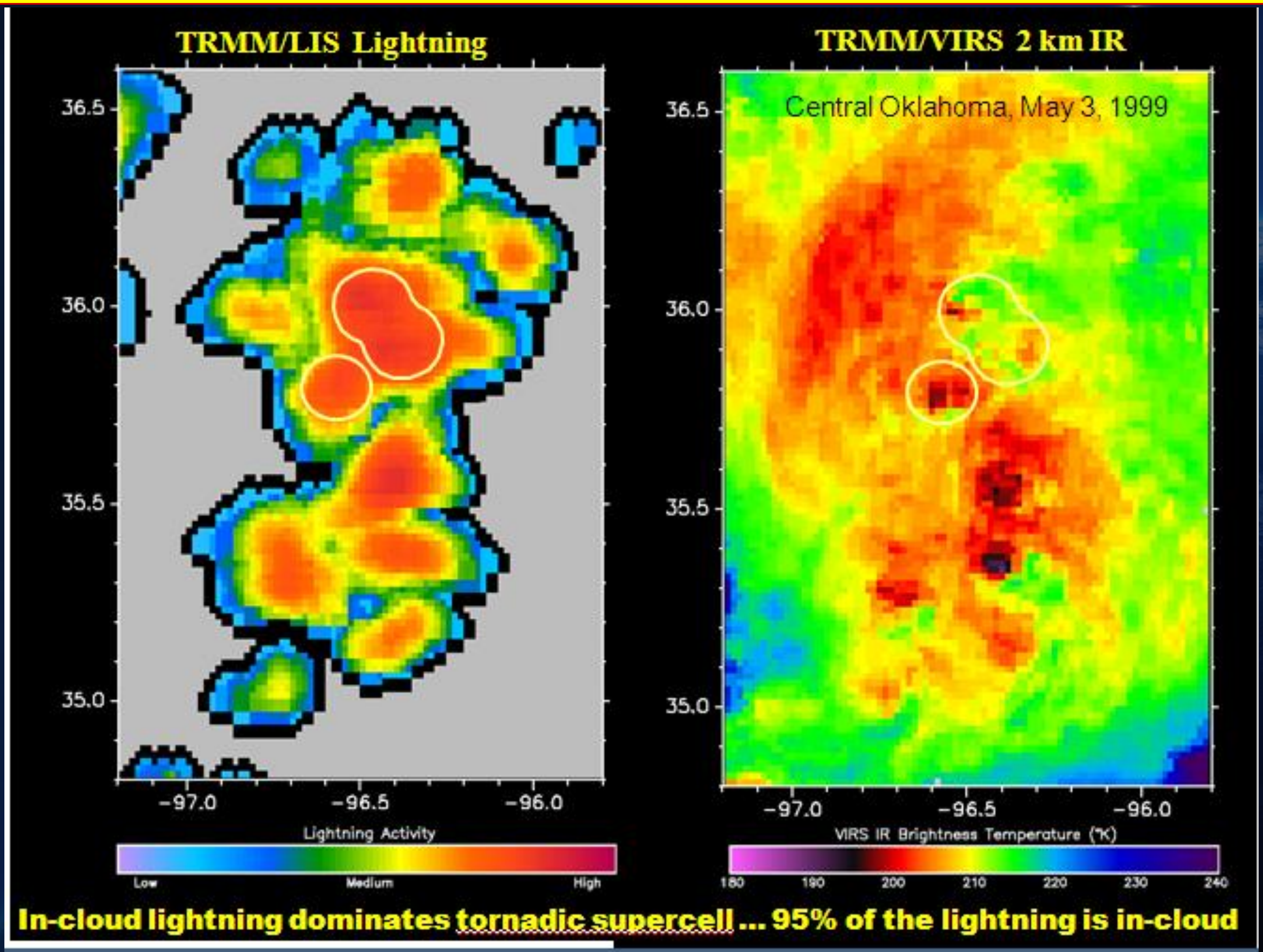
NEXRAD Velocity



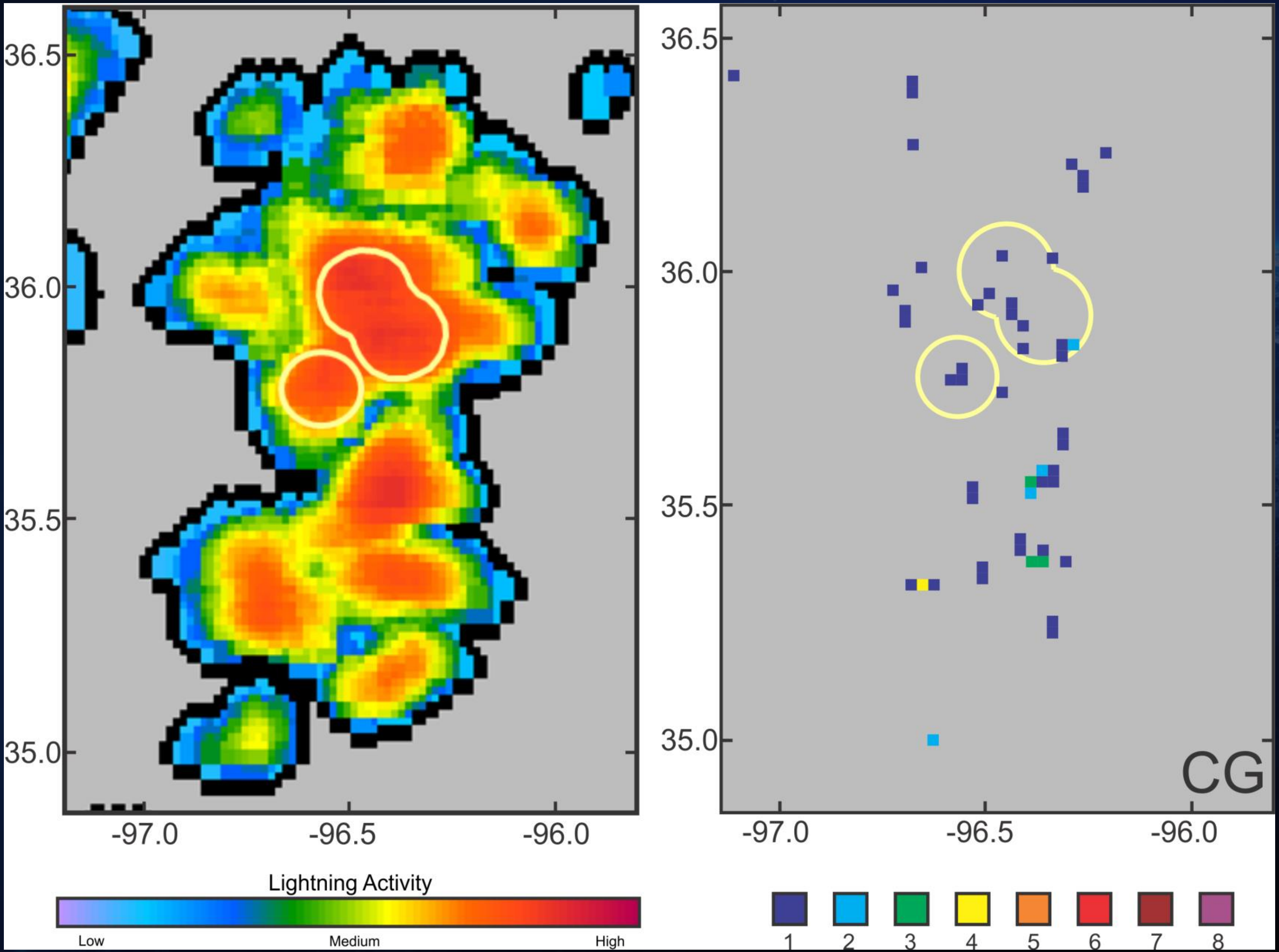
Active lightning region in tornadic supercell … correlates with radar hook echo and velocity couplet

Total Lightning During OK Tornado Outbreak 3 May 1999

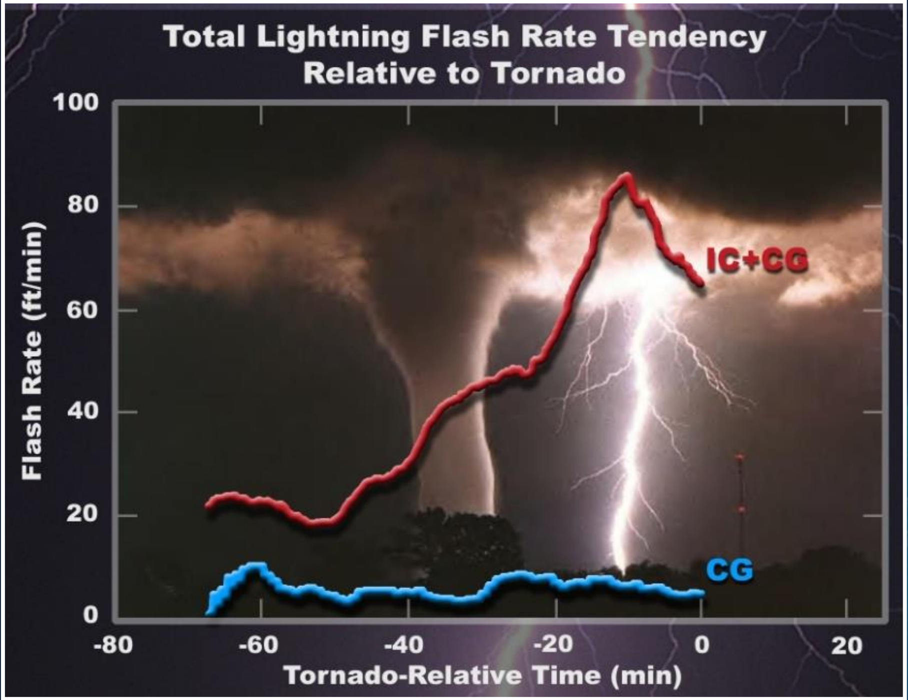
GLM and ABI Combined (with radar) characterizes storm intensification and decay)

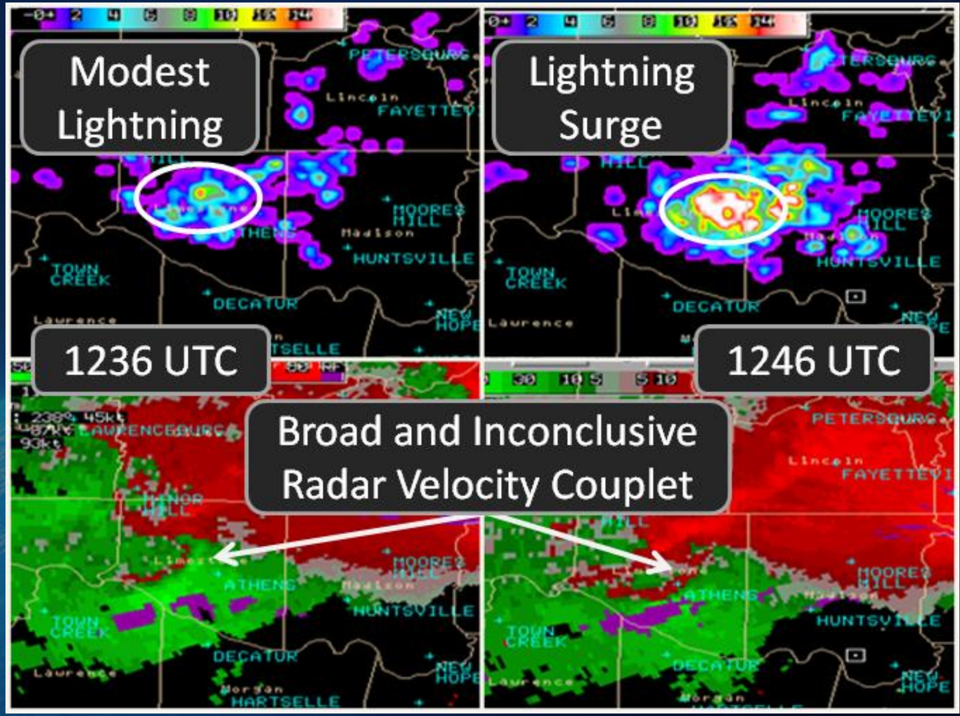


Total Lighting vs CG Only



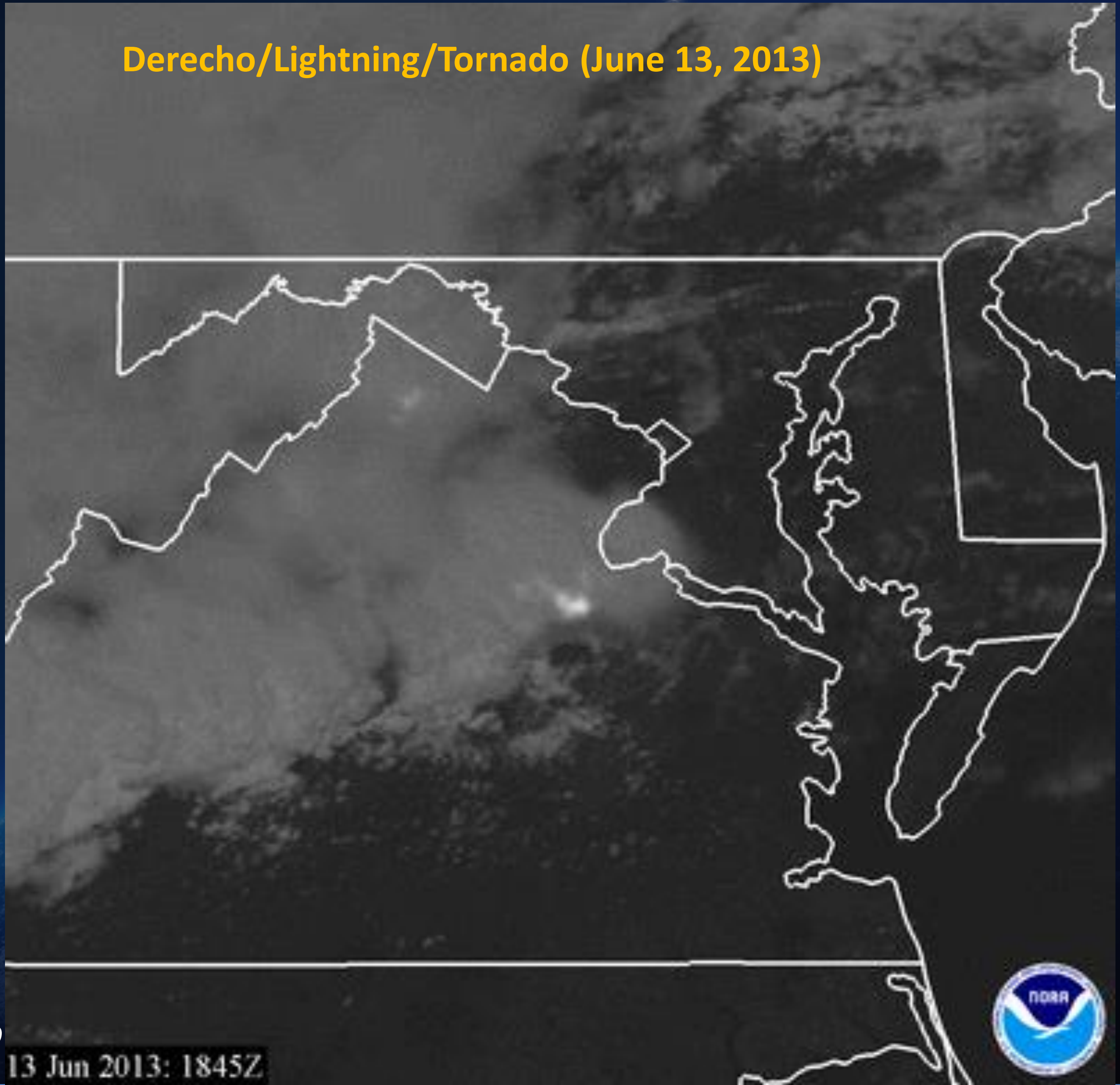
Total Lightning Increases with Storm Growth and Updraft Intensification





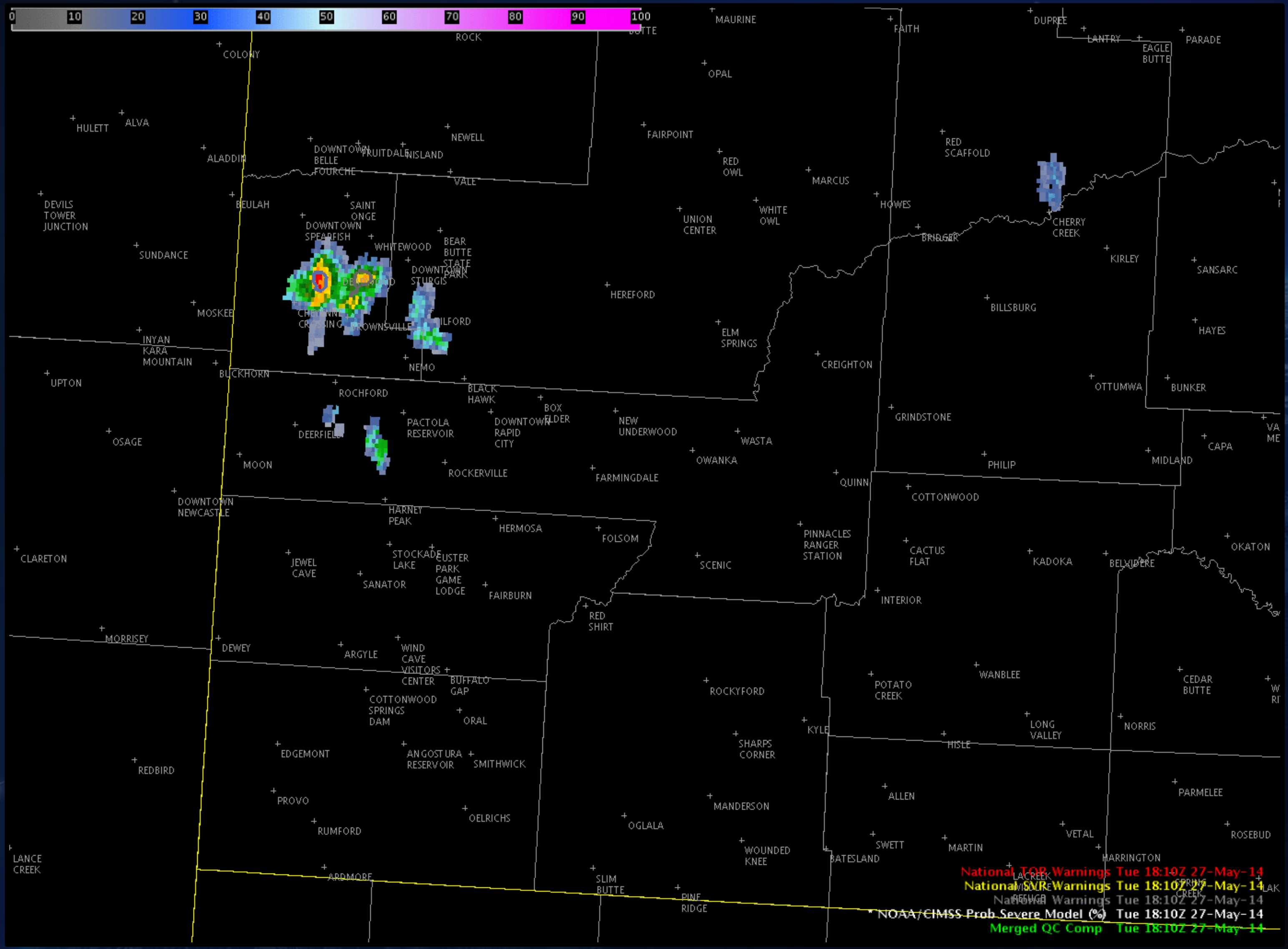
National Average for Tornado warning lead-time is 14 minutes

GOES-R Fusion of 1-min Imagery With Total Lightning



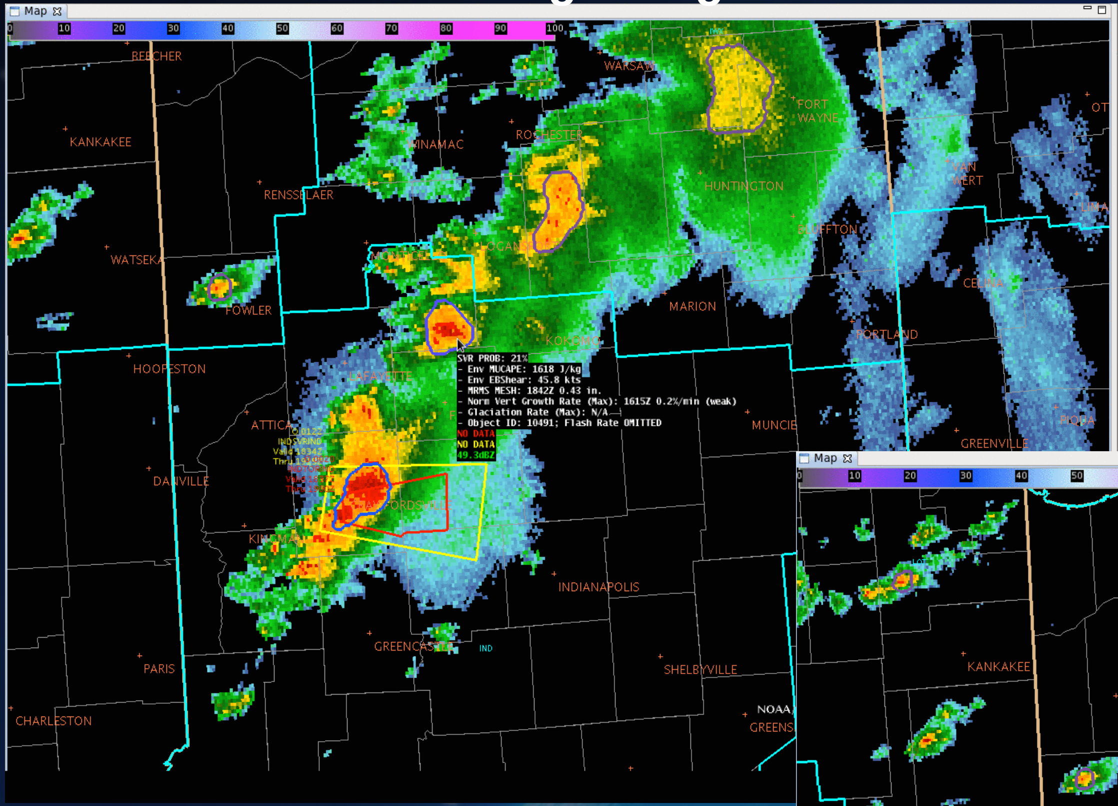
Courtesy of Scott Rudlosky, CICS-MD

Probability of Severe Convection



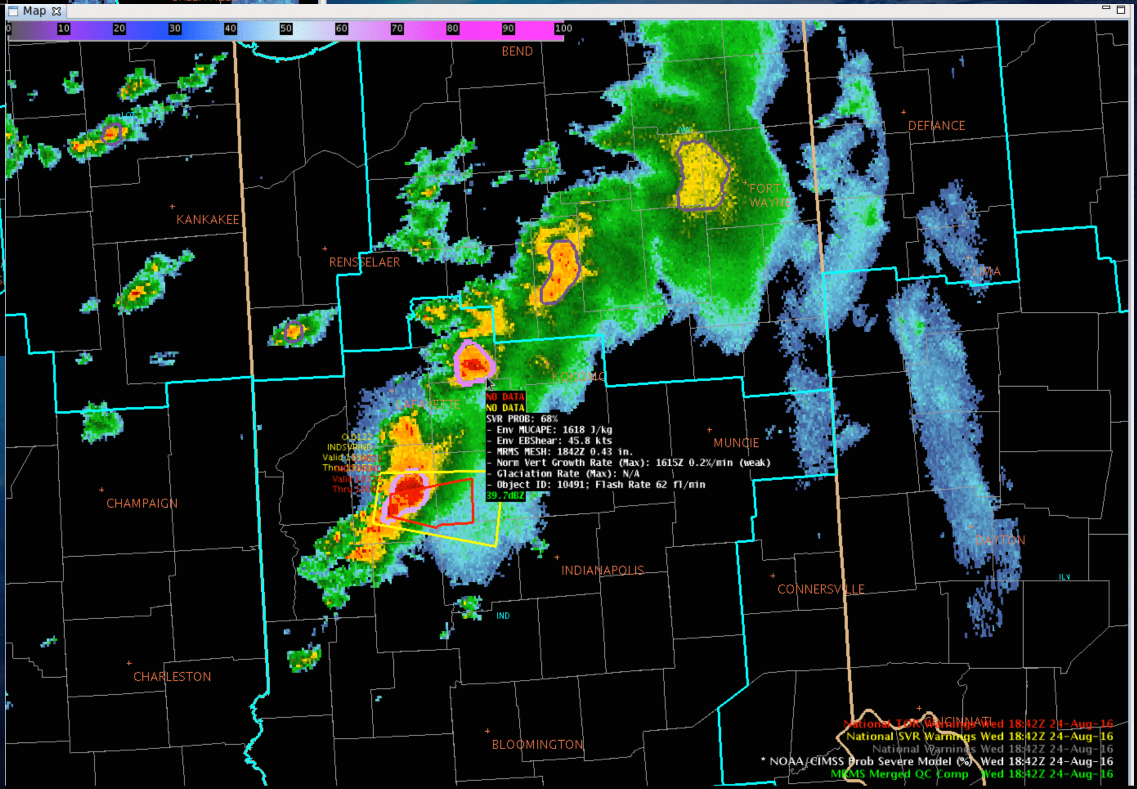
http://goesrhwt.blogspot.com/2016/08/surprise-indiana-tornadoes-and-total.html

Without lightning: 21%



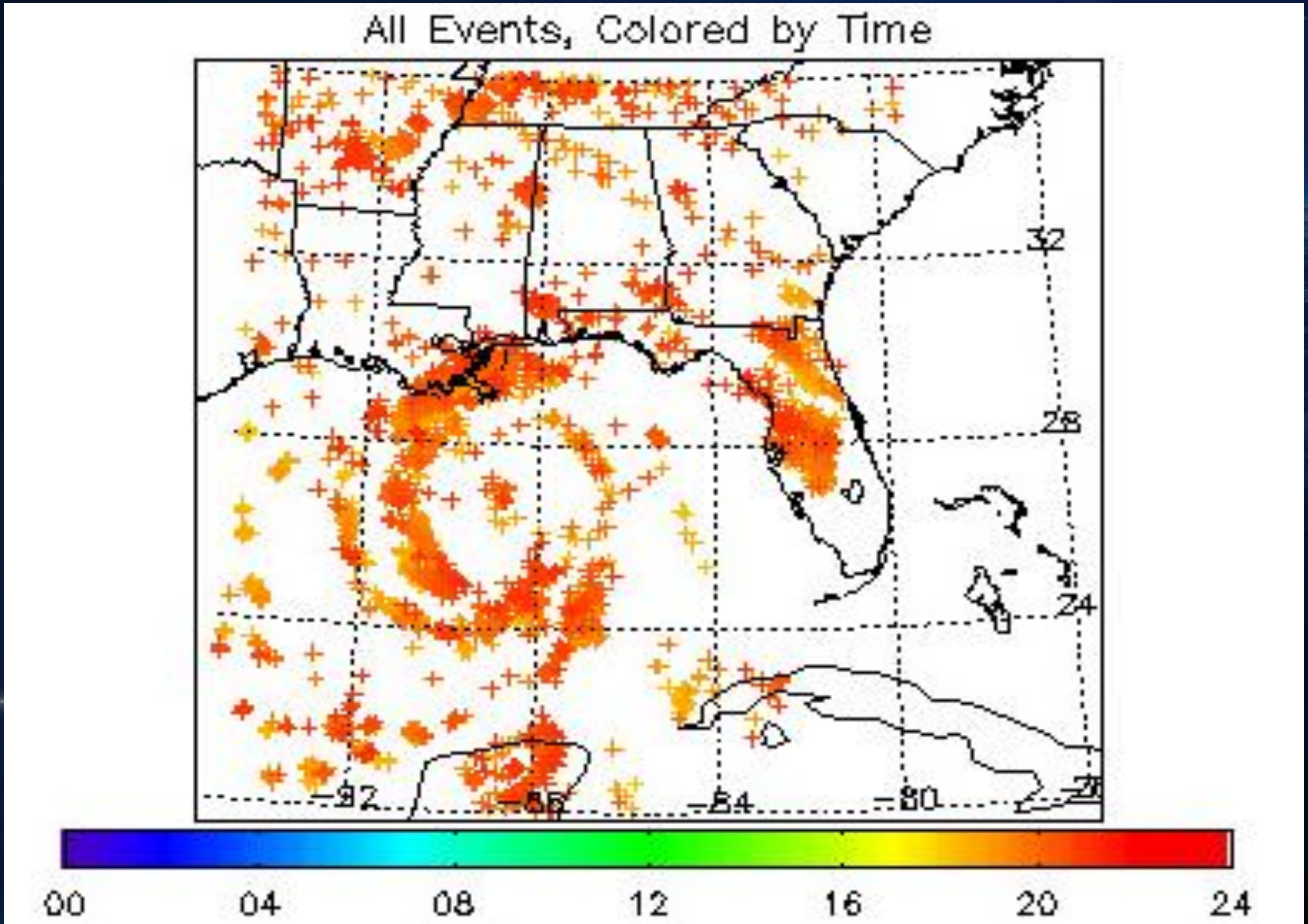
Kokomo, IN storm 8 minutes prior to first warning (8/24/16)

With lightning: 68%



ProbSevere Example

Hurricane Katrina



NHC Tropical Cyclone Cristina Discussion, June 10, 2014

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CZC MIATCDEP3 ALL
TTAA00 KNHC DDHHMM

TROPICAL STORM CRISTINA DISCUSSION NUMBER   6
NWS NATIONAL HURRICANE CENTER MIAMI FL       EP032014
800 PM PDT TUE JUN 10 2014
```

Cristina is intensifying this evening. The compact central dense overcast has become more circular, and hints of an eye have been apparent in geostationary satellite images. The initial intensity is increased to 55 kt, in agreement with unanimous Dvorak classifications of 3.5/55 kt from TAFB, SAB, and UW-CIMSS ADT.

Although the curved bands beyond the inner-core region remain fragmented, a considerable amount of lightning has been occurring in a rain band located about 120 n mi to the south-southwest of the center. Recent research has documented that lightning in the outer bands of the tropical cyclone circulation is often a precursor of significant intensification. The only apparent factor that could limit strengthening during the next couple of days is mid-level dry air, which has been an issue for Cristina during the past day or so. In about 3 days, Cristina is expected to move into an environment of stronger southwesterly shear and over cooler waters, which should end the strengthening trend and cause the cyclone to weaken. The NHC intensity forecast is slightly higher than the previous one, and is pretty close to the intensity model consensus IVCN.

Where are the Most Intense Thunderstorms on Earth?

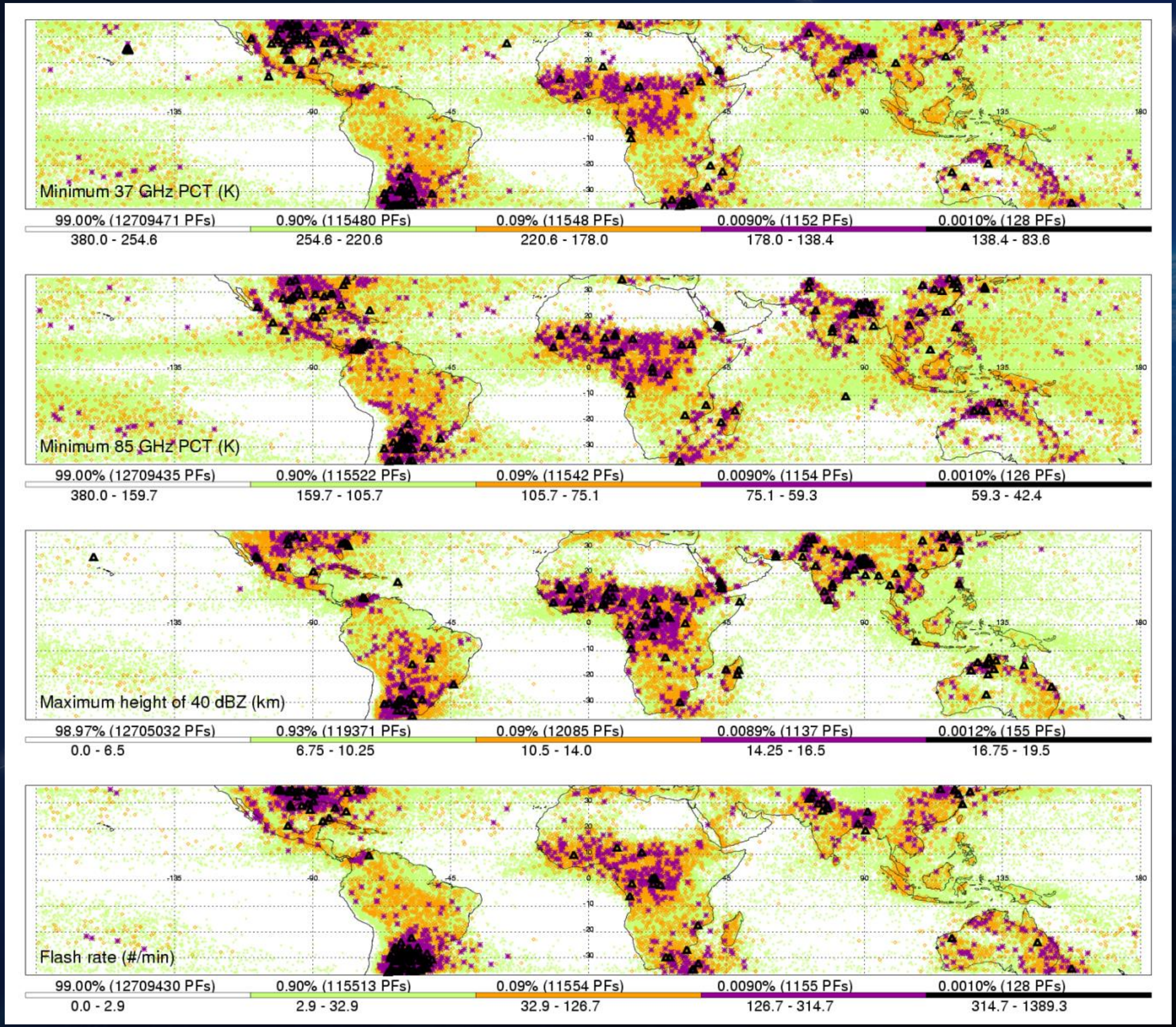
(E. J. Zipser, Daniel J. Cecil, Chuntao Liu, Stephen W. Nesbitt and David P. Yorty)
Bulletin of the American Meteorological Society, August 2006

TMI_{37}

TMI_{85}

PR

LIS



-Most intense convective storms on earth; color code indicating their rarity.

-The deepest and most electrically active storms, indicated by the black triangles, also have large amounts of precipitation-sized ice and hail, as indicated by the very cold microwave brightness temperatures.

-A line of storms in northern Argentina produced more than 1000 discharges per minute, the greatest flash rate observed to date.

-During the eight year period 1998-2005 nearly 13 million storms have been observed by the suite of instruments on the Tropical Rainfall Measuring Mission.

1997-1998 El Nino Lightning

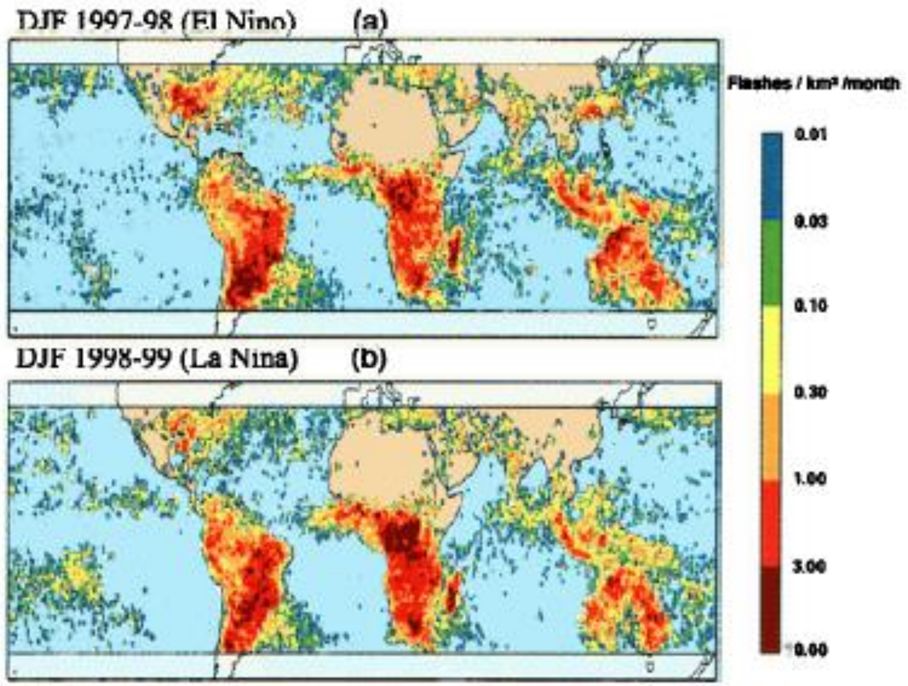


Figure 1. Seasonal distribution of lightning during the 1997-98 ENSO winter period December 1997-February 1998 (top panel) and the 1998-99 LaNina winter period December 1998-February 1999 (bottom panel) derived from observations made by the NASA Lightning Imaging Sensor (LIS).

Goodman et al., GRL, 2000

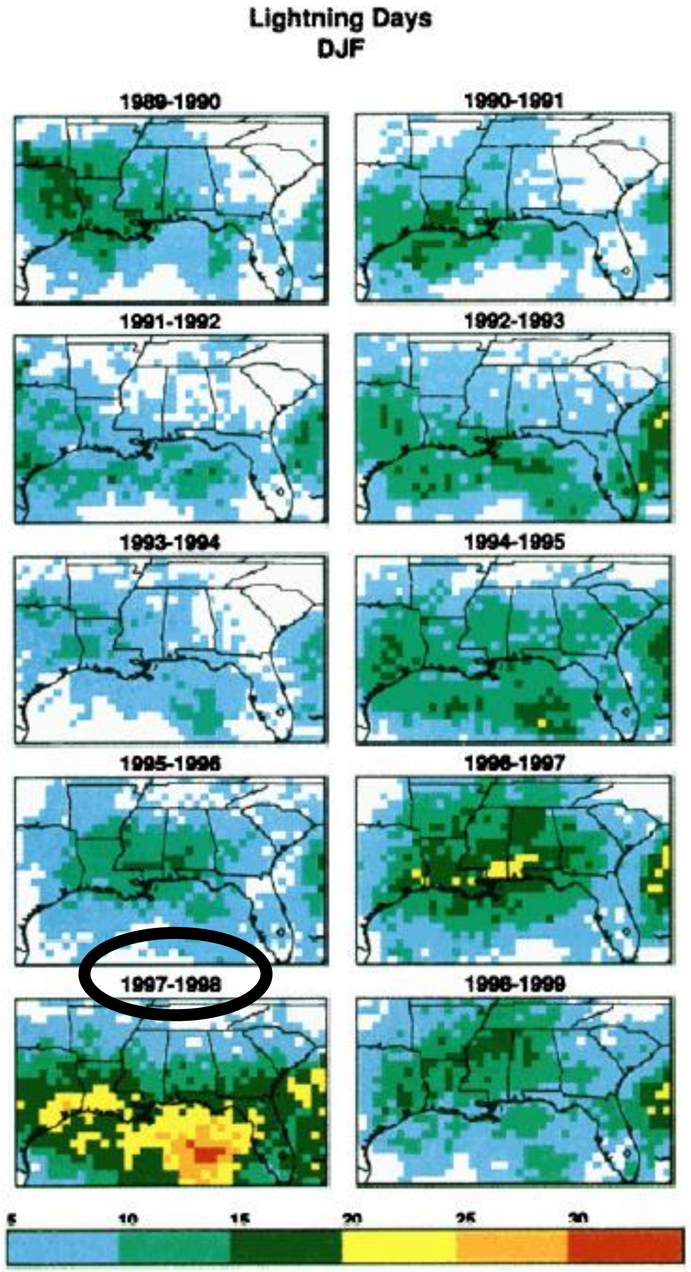
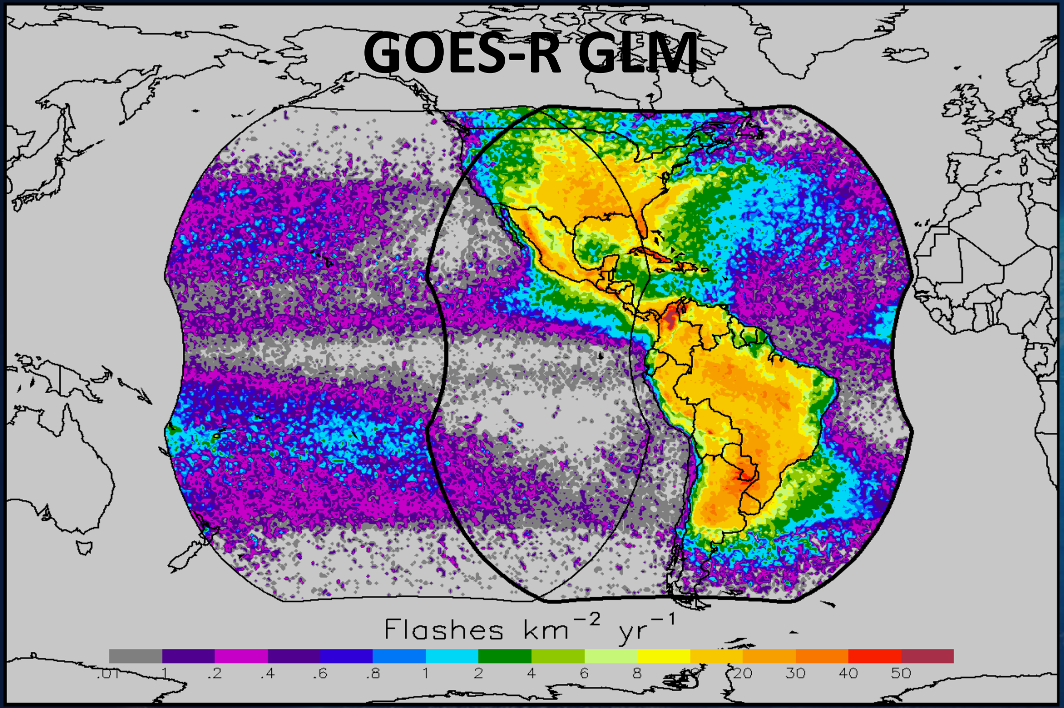
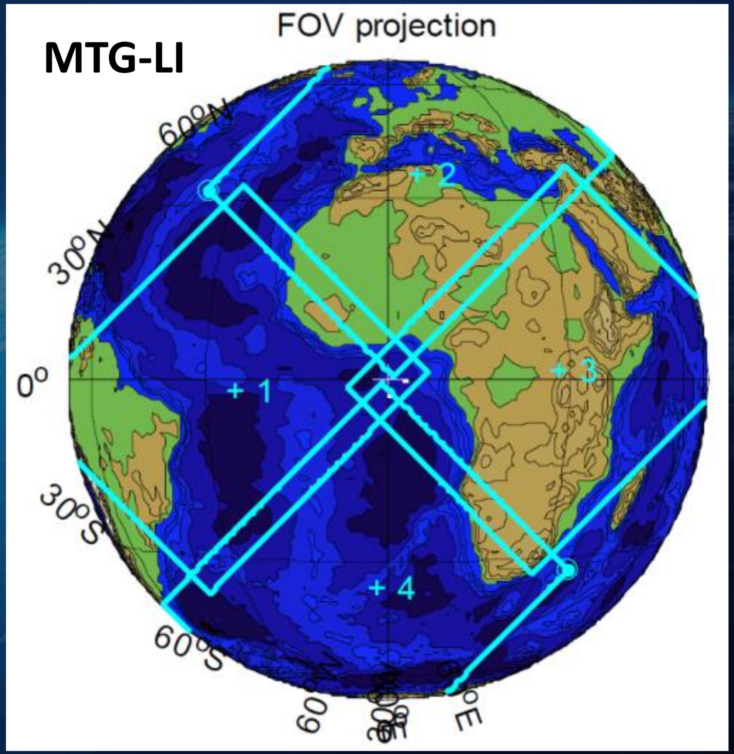


Figure 2. Number of cloud-to-ground lightning days per 0.5° × 0.5° grid box during winter (DJF) 1989-1999.

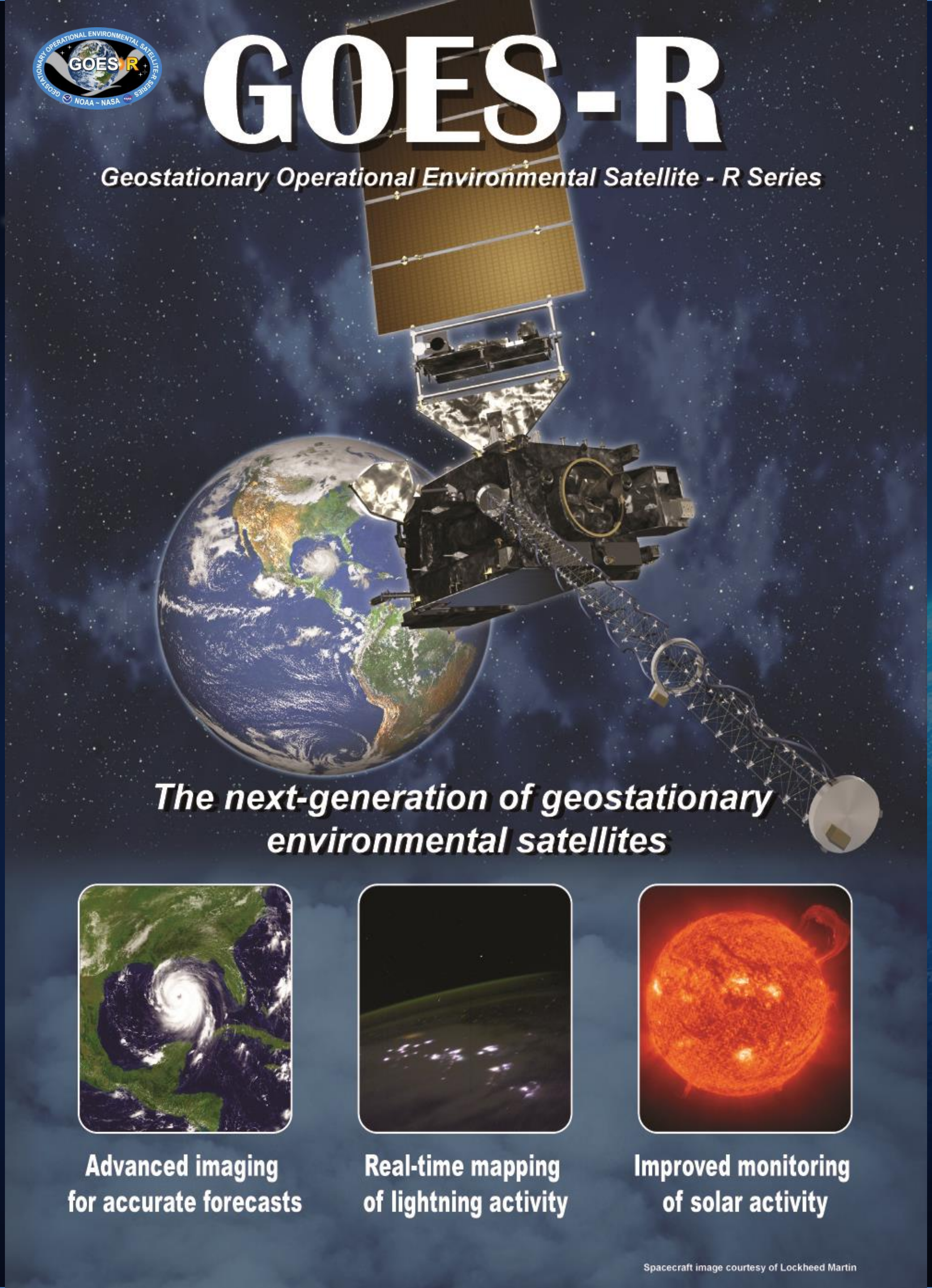
Coverage for the GOES-R GLM and MTG Lightning Imager

Goal: Globally Consistent Lightning Database





MTG-LI courtesy Jochen Grandell, EUMETSAT



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