The Geostationary Lightning Mapper (GLM) on the GOES-R Series

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Boulder, CO

Natural Hazards and Lightning

- Tornadoes
- Hailstorms
- Wind
- Thunderstorms
- Floods
- Hurricanes
- Volcanoes
- Forest Fires
- Air Quality/NOx

L1 Requirements for Lightning Detection

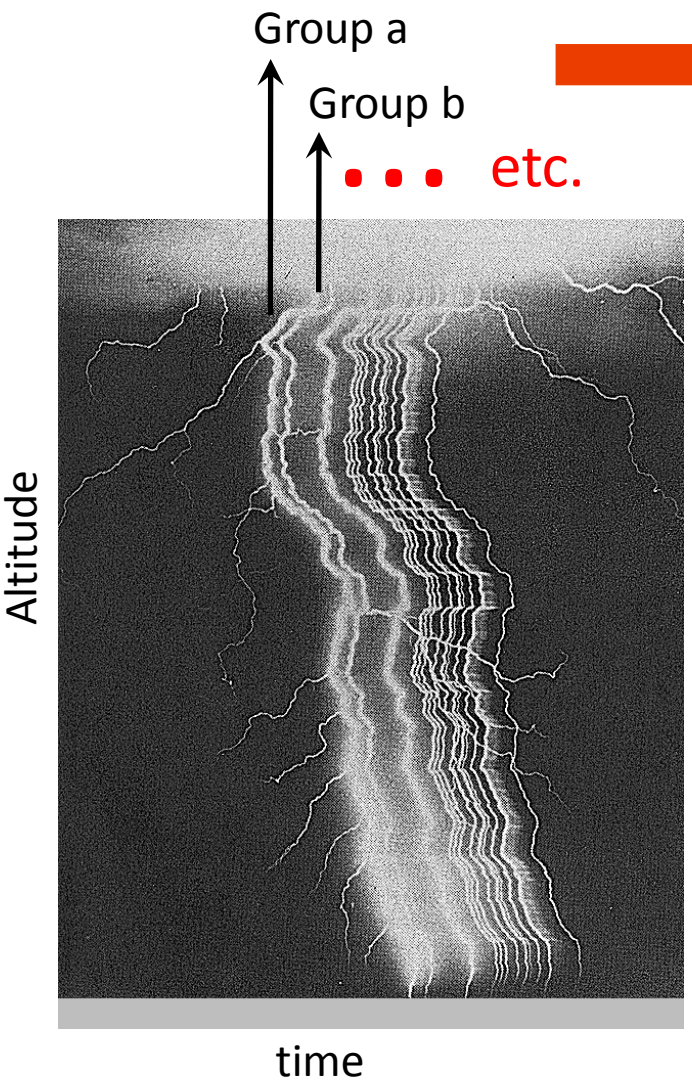
3 component products- L1 events, L2 groups and flashes)

Name	User & Priority	Product Geographic Coverage	Vertical Resolution	Horizontal Resolution	Mapping Accuracy	Measurement Range	Measurement Accuracy	Product Refresh Rate /Coverage Time	VAGL	Measurement Precision	Temporal Coverage Qualifiers	Product Extent Qualifier	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Lightning Detection -Events -Groups -Flashes	GOES -R	Full Disk	Sfc to Cloud Top.	10 km	5 km	Real Time	70% minimum Flash Detection Efficiency (FDE)	Continuous	20 sec	5% (Std. Dev. of FDE)	Day and night	Quantitative out to at least 65 degrees LZA and qualitative beyond	Cloud cover conditions permitting obs. of lightning associated with threshold accuracy	Over lightning cases and mesoscale-sized surrounding regions

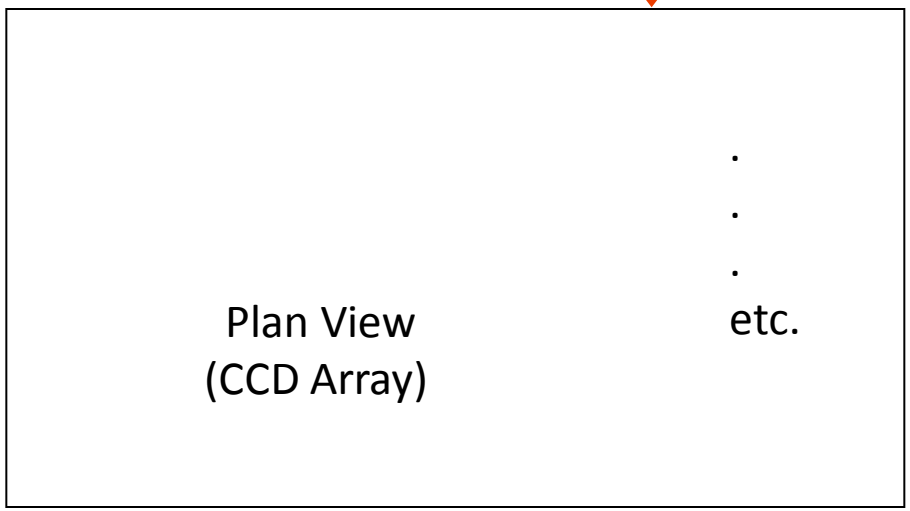
- LIRD Changes Aug 2009- product refinement, reduced latency (from 59 to 20 sec)

A Time-Resolved Ground Flash

(Methodology based on 12 years successful on-orbit experience with TRMM LIS)

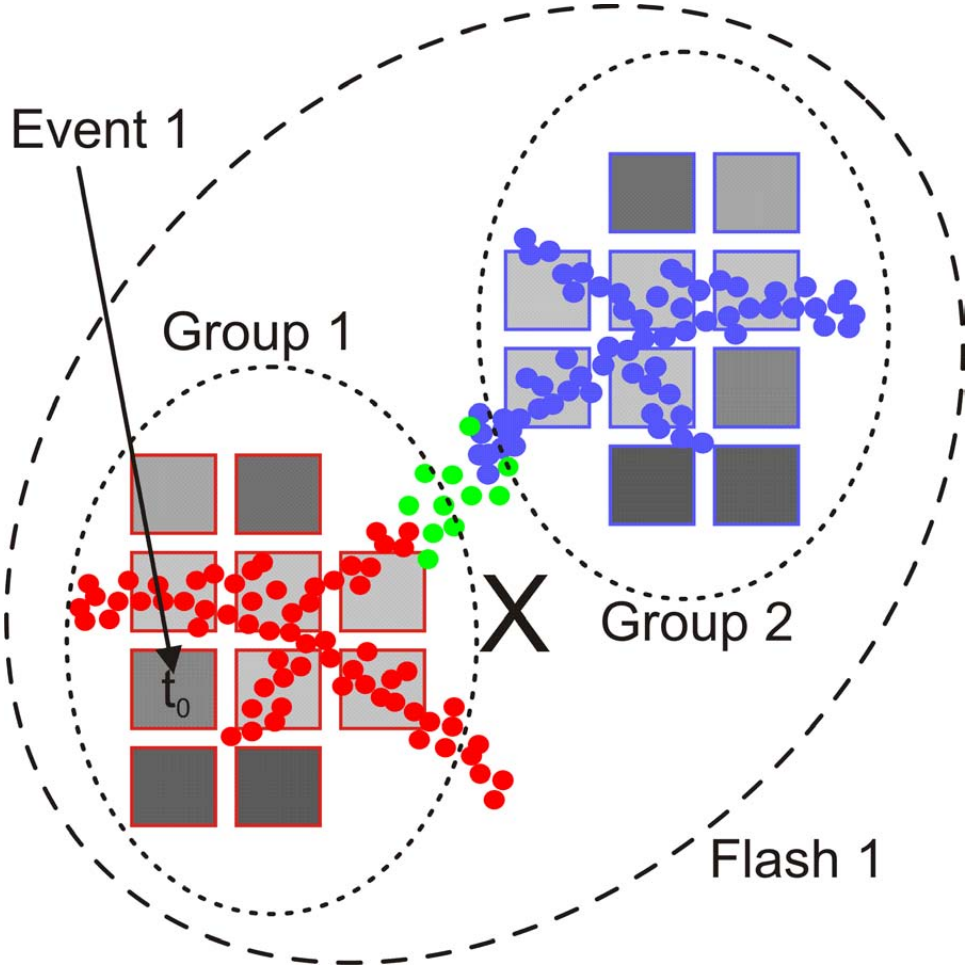


Groups Help Us Track the Strokes and other components of the lightning flash!



Testing and Validation
(data used in generating GLM proxy)

- Dots (red, green, blue) are LMA* data
- Gray squares are (simulated) GLM data
- Time is indicated by color
  - Red first
  - Green next
  - Blue last
- GLM radiance is indicated by greyscale (lighter = greater amplitude)
- Shown is a single flash with 2 groups and 20 events
  - Amplitude weighted centroid is indicated by the large X
  - Time of flash is time of first event
  - The two groups (red & blue) are close enough in time/space to be clustered into a single flash (16.5 km & 330 ms)
  - In this example, the green LMA pulses did not create an optical pulse large enough to be detected by the (simulated) GLM (below threshold)



* LMA: VHF Lightning Mapping Array (GLM Proxy Data source)

Event Processing (L1B)

- An event is anything that exceeds the threshold
  - Noise, Proton hit, or lightning pulse
  - All events are transmitted to the ground along with housekeeping and subsampling of the background levels
  - Ground processing determines which events are lightning pulses by looking for strings of pulses, both spatially and temporally (coherency)
  - End-product is time-tagged, geolocated, measured, lightning (PORD Requirement)

Algorithm Overview (L2+)

- The algorithm takes input Level 1B events (time, location, amplitude) and clusters them with other events that have similar temporal and spatial characteristics

- The GLM produces a series of events (time series) which are clustered by the GLM algorithm into L2 groups and flashes, similar to the basic lightning flash data of the National Lightning Detector Network (NLDN) system (i.e., not an imager)

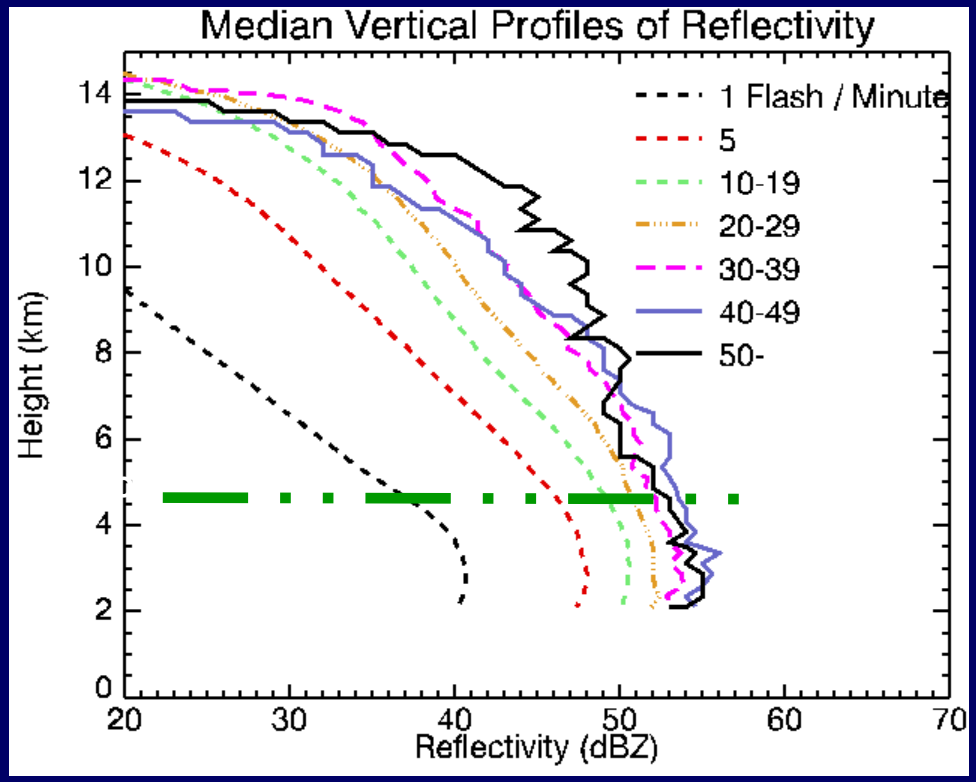
- The data rate from the GLM is highly variable and can range from as little as 0 events per second (when hemispheric lightning rates are very low) to perhaps as many as 40,000 events per second for very, very brief periods during widespread severe storm episodes

- The GLM algorithm must be able to process this wide dynamic range of data rates while producing output groups and flashes in under 4 seconds (verified by speed tests)

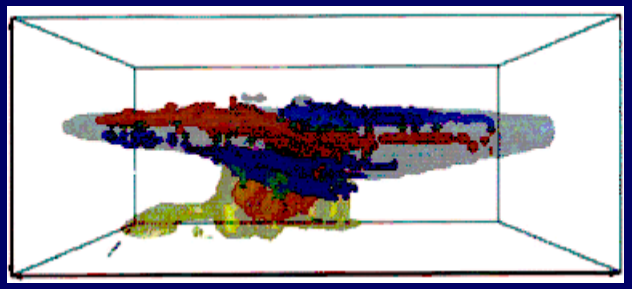
Physical Basis: Flash Rate Coupled to Mass in the Mixed Phase Region

TRMM PR and LIS

(Cecil et al., Mon. Wea. Rev. 2005)



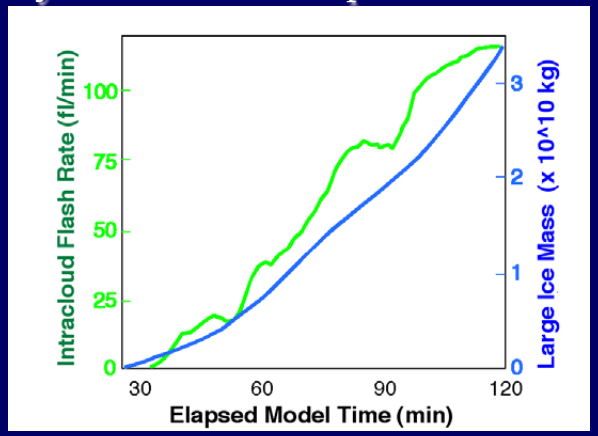
Process physics understood



Storm-scale model with explicit microphysics and electrification (Mansell)

Ice flux drives lightning

Physical basis for improved forecasts



IC flash rate controlled by graupel (ice mass) production (and vertical velocity)

Physical Basis:

Lightning Connection to Thunderstorm Updraft, Storm Growth and Decay

- Total Lightning —responds to updraft velocity and concentration, phase, type of hydrometeors, integrated flux of particles
- WX Radar — responds to concentration, size, phase, and type of hydrometeors- integrated over small volumes
- Microwave Radiometer — responds to concentration, size, phase, and type of hydrometeors — integrated over depth of storm (85 GHz ice scattering)
- VIS / IR — cloud top height/temperature, texture, optical depth

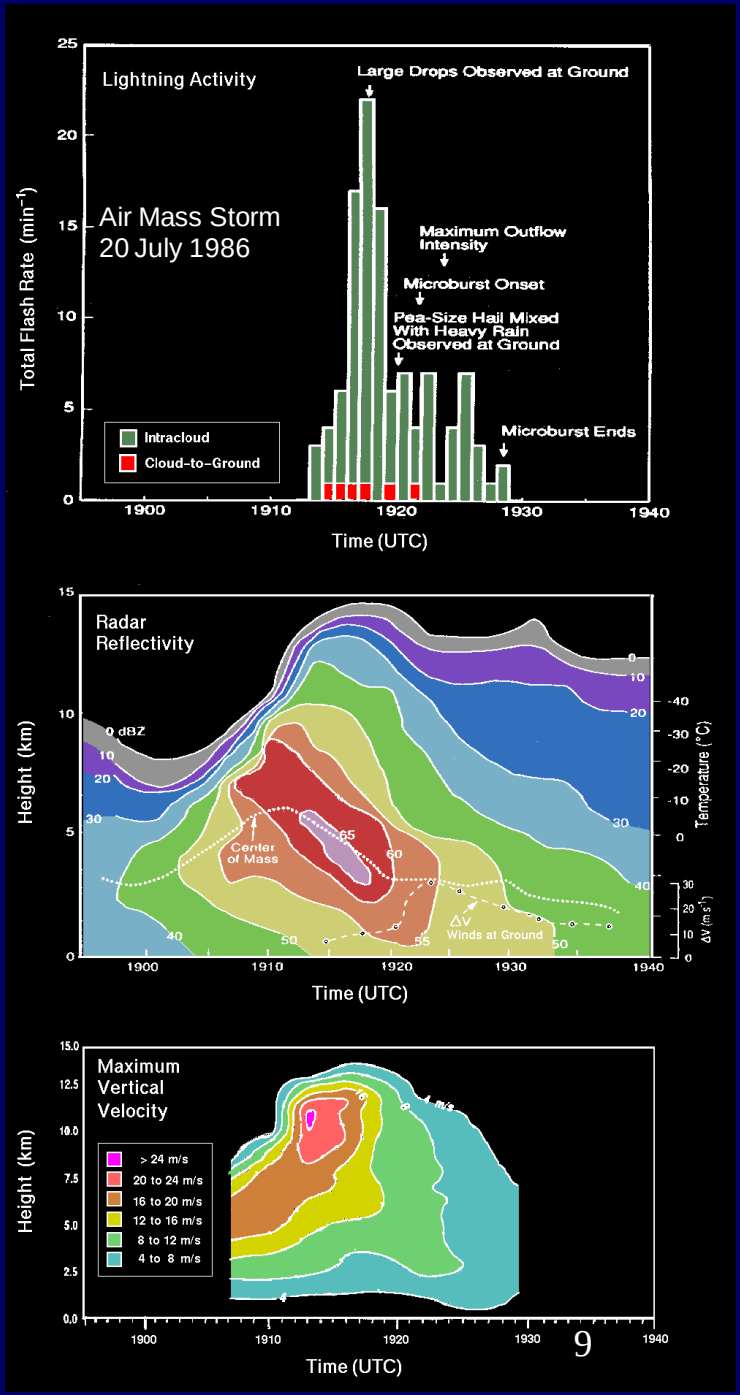
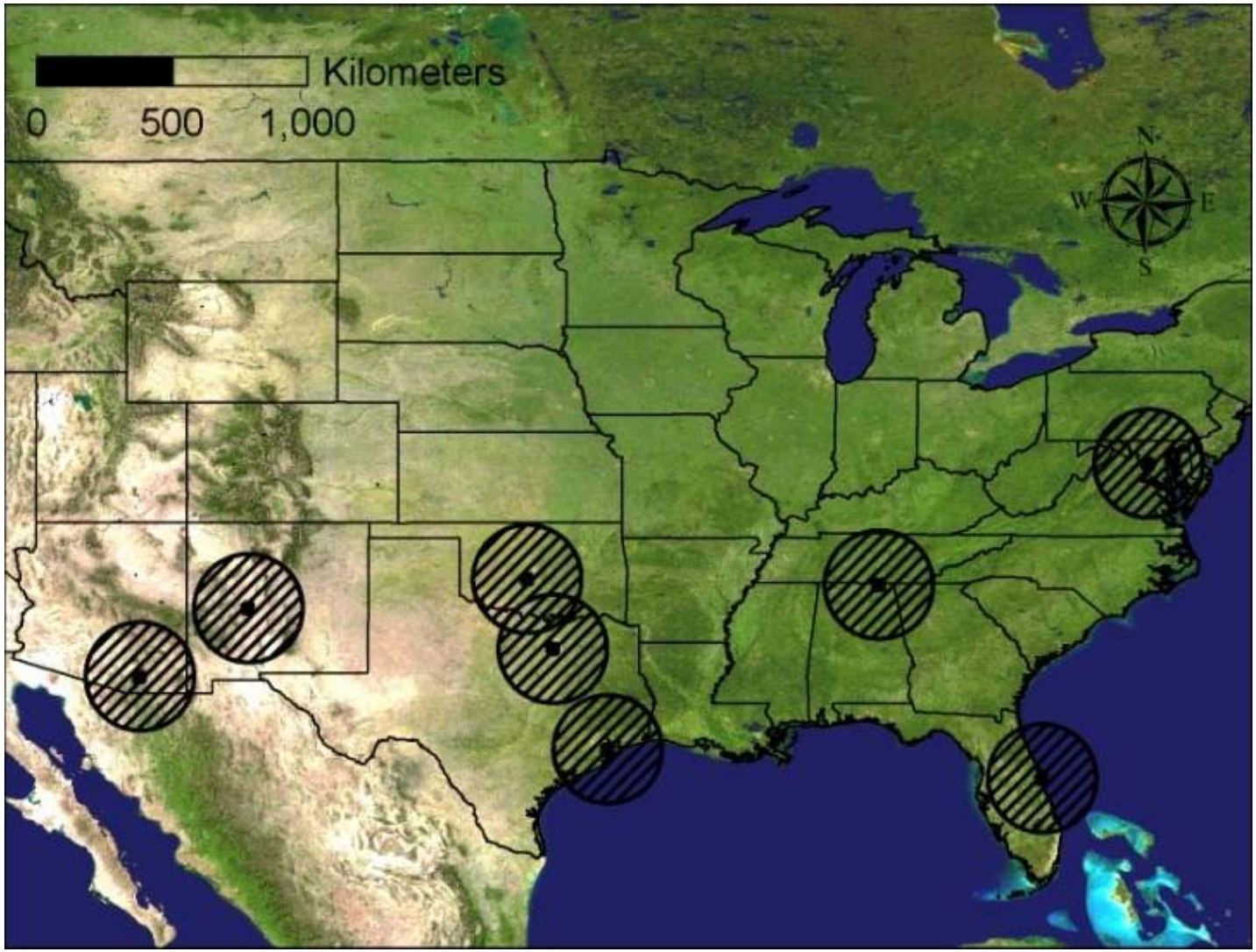


Figure from Gatlin and Goodman, JTECH, Jan. 2010- adapted from Goodman et al, 1988; Kingsmill and Wakimoto, 1991

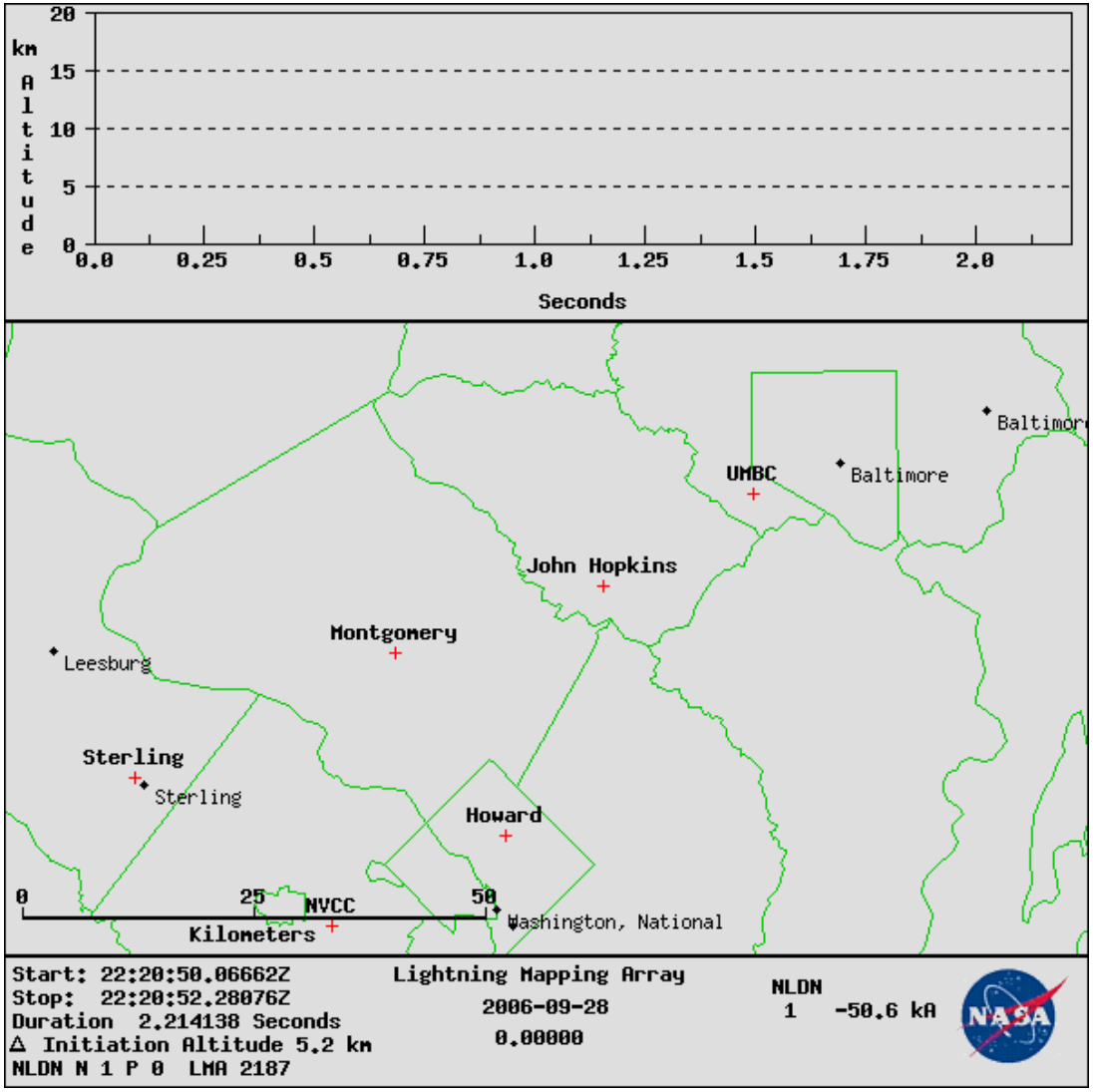
Regional Operational and Research VHF Total Lightning Networks in USA



DCLMA Area Lightning Discharge

- 2.2 sec hybrid flash
- 50 km horiz extent
- Initiation at 5.2 km
- VHF Sources 2187
- CG strike at 2 s

GLM will map initiation and propagation of each flash, detect in-cloud and CG lightning, but unable to distinguish between them based on the optical properties alone



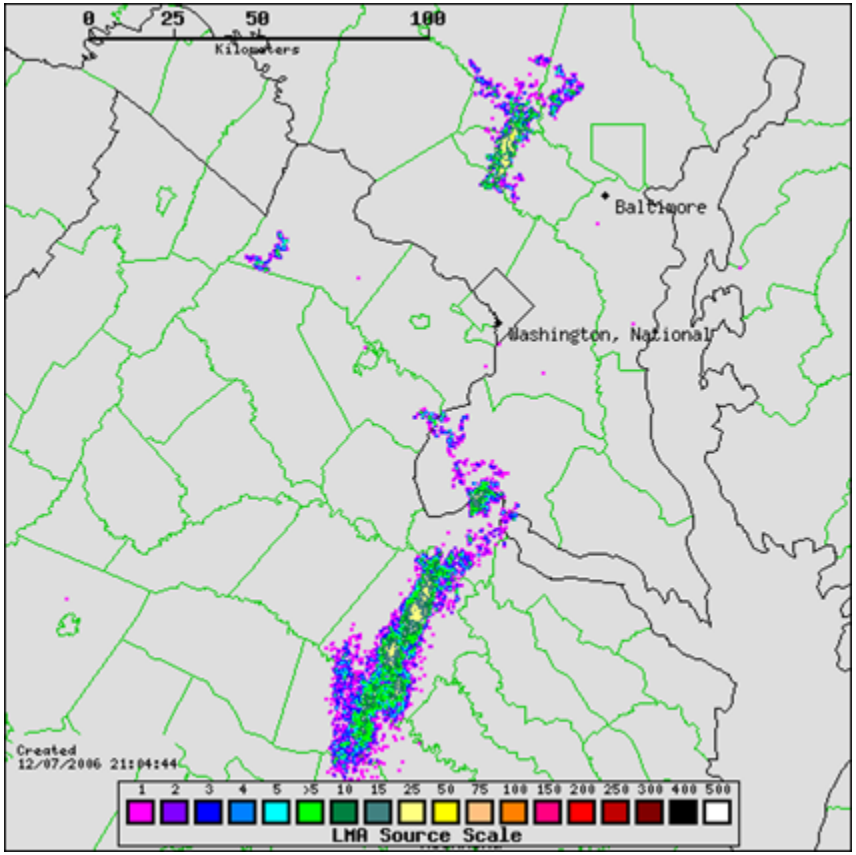
http://branch.nsstc.nasa.gov/PUBLIC/DCLMA

Animated gif

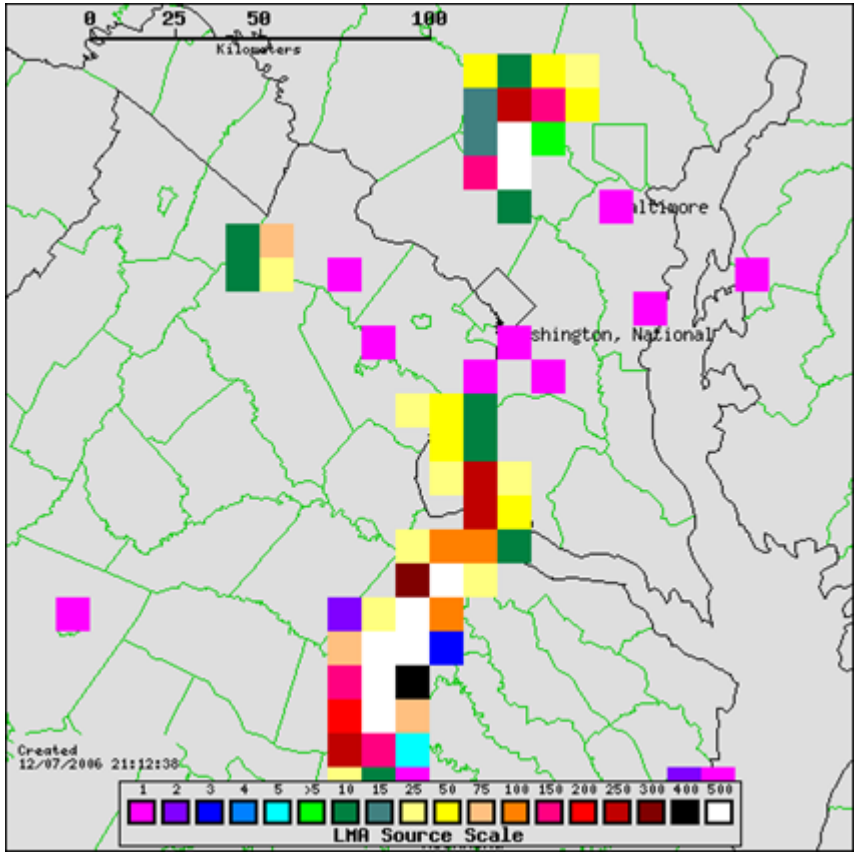
GLM Proxy Data: Sterling WFO

DC Regional Storms November 16, 2006

Resampled 5-min source density at 1 km and 10 km



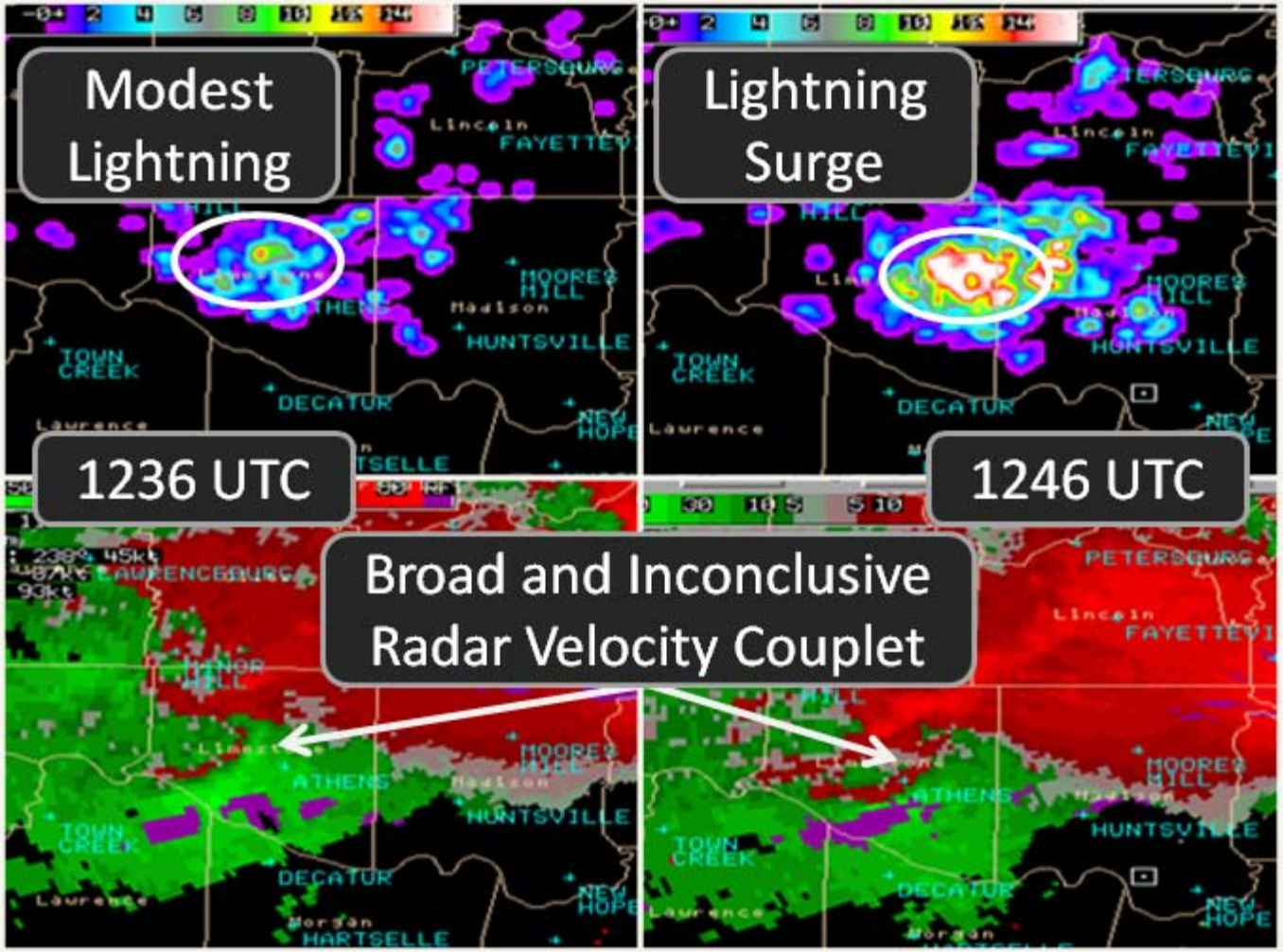
LMA 1 km resolution



LMA @ GLM 10 km resolution

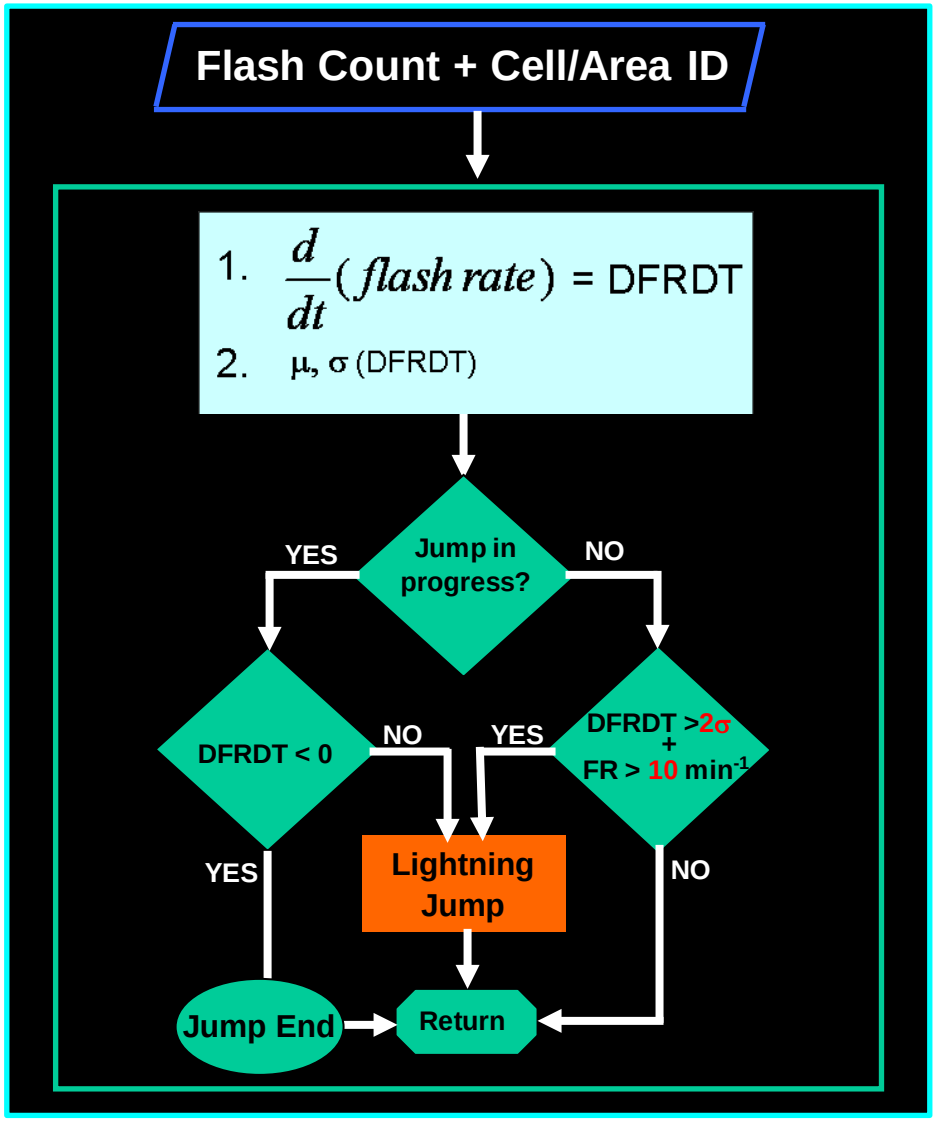
GLM Testbeds at Huntsville, AL; Norman, OK; Sterling, VA; KSC, FL

Lightning Trends Depict Storm Intensification



Total lightning (Upper) from the North Alabama LMA coincident with NEXRAD radar-derived storm relative velocity (Lower) at 1236 (Left) and 1246 (Right) UTC on 6 May 2003. The lightning surge of over 200% occurs 14 minutes prior to a confirmed tornado touchdown. Image courtesy of Geoffrey Stano and SPoRT.

Lightning "Jump" 2σ -Algorithm



85 thunderstorms

69 non-severe

38 severe:

22 – supercells

2 – low topped supercells

1 – LEWP

2 – tropical

2 – MCS

1 – MCV

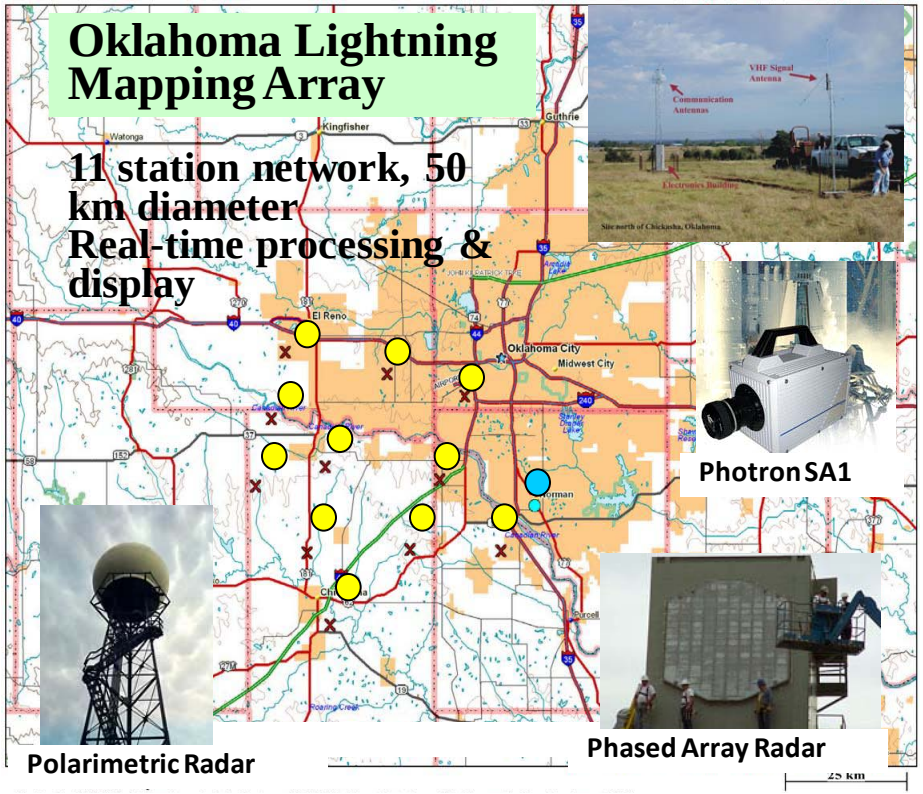
8 – multicellular

2σ	POD	FAR	CSI	HSS
Within 100 km				
Severe only	87%	23%	69%	0.82
Severe and Non-severe	87%	33%	61%	0.76
Within 150 km				
Severe only	87%	26%	67%	0.80
Severe and Non-Severe	87%	33%	61%	0.75

Schultz, Petersen and Carey, Dec. 2009, JAMC (2σ)
Gatlin and Goodman, Jan. 2010, JTECH (1σ)

Ground Truth Validation

Sustained ground validation, airborne campaigns, international collaborations



University of Oklahoma/National Weather Center/NSSL/SPC/HWT

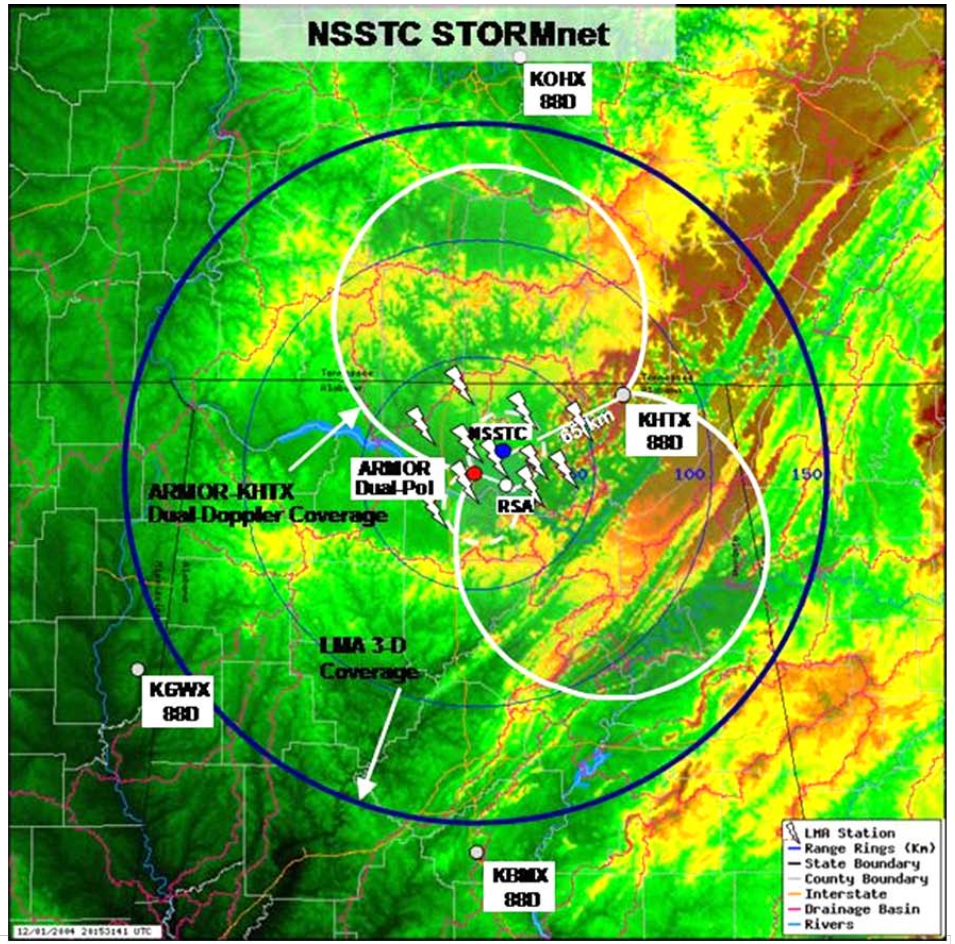
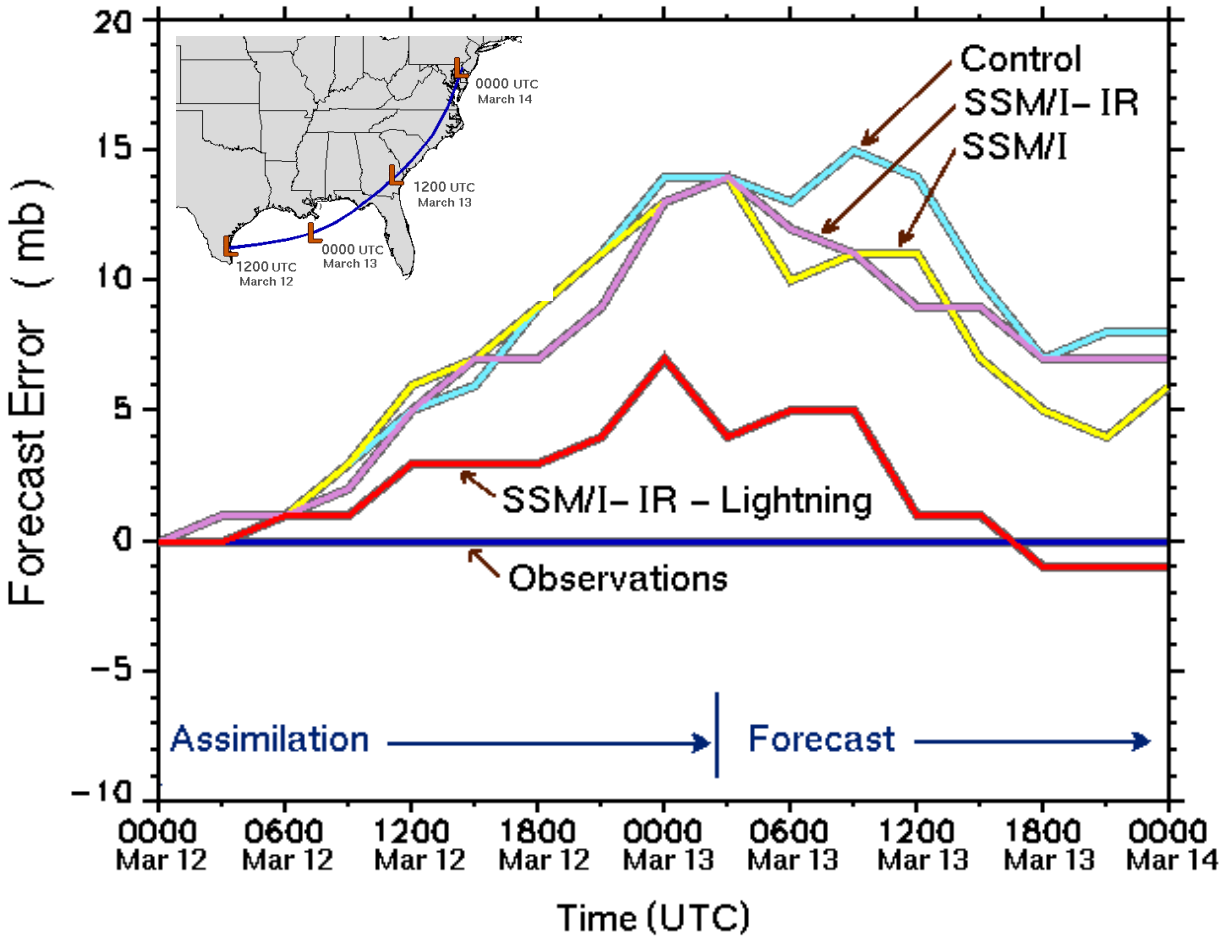


Figure 2. NSSTC STORMnet. KHTX and NSSTC ARMOR dual-Doppler lobes are indicated in white. LMA antenna locations indicated in red. Approximate 2-D coverage area of LMA network indicated by blue 150 km range ring.

Lightning Data Assimilation: Reduces Forecast Error

March 13, 1993 Superstorm (Alexander et al., 1999 MWR)



Lightning assimilated via latent heat transfer functional relationship

WRF Lightning Threat Forecasts
Methodology

1. Use high-resolution 2-km WRF simulations to prognose convection for a diverse series of selected case studies

2. Evaluate graupel fluxes at -15C level; vertically integrated ice (VII=cloud ice+snow+graupel); dBZ also considered, but set aside because of nonlinearities

3. Calibrate WRF LTG proxies using peak total LTG flash rate densities from North Alabama LMA (NALMA) vs. strongest simulated storms; relationships ~linear; regression line passes through origin

4. Truncate low threat values to make threat areal coverage match NALMA flash extent density obs

5. Blend proxies to achieve optimal performance

6. Study CAPS 4-km ensembles to evaluate sensitivities

Background

- High-resolution explicit convection WRF forecasts can capture the character and general timing and placement of convective outbreaks well;

- Traditional parameters used to forecast thunder, such as CAPE fields, often overestimate LTG threat area (see next page); CAPE thus must be considered valid only as an integral of threat over some ill-defined time;

- No forward model for LTG available for DA now; thus search for model proxy fields for LTG is appropriate;

- Research results with global TRMM data agrees with models (e.g., Mansell) that LTG flash rates depend on updraft, precip. ice amounts (see page after next)

WRF Lightning Threat Forecasts

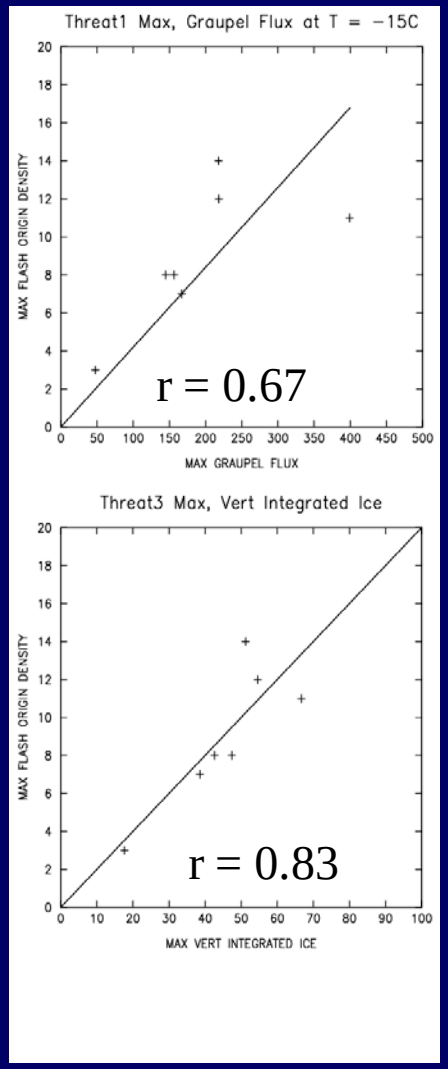
Methodology

1. Regression results for threat 1 "F_1" (based on graupel flux, FLX = $w*q_g$ at T=-15 C):

   $F_1 = 0.042*FLX$ (require $F_1 > 0.01$ fl/km^2/5 min)

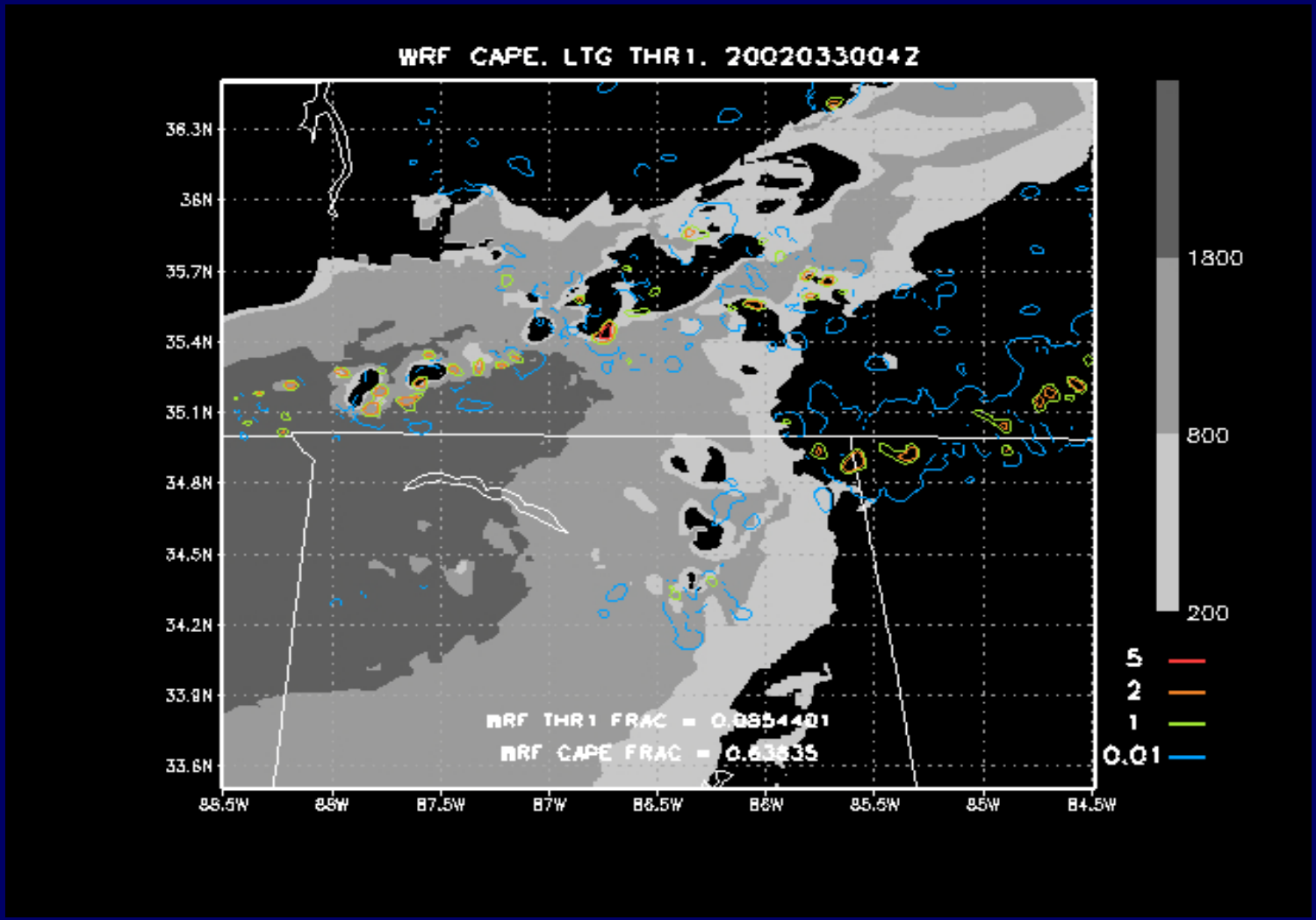
2. Regression results for threat 2 "F_2" (based on Vertically Integrated Ice, VII, cloud ice + snow + graupel from WRF WSM-6):

   $F_2 = 0.2*VII$ (require $F_2 > 0.4$ fl/km2/5 min)

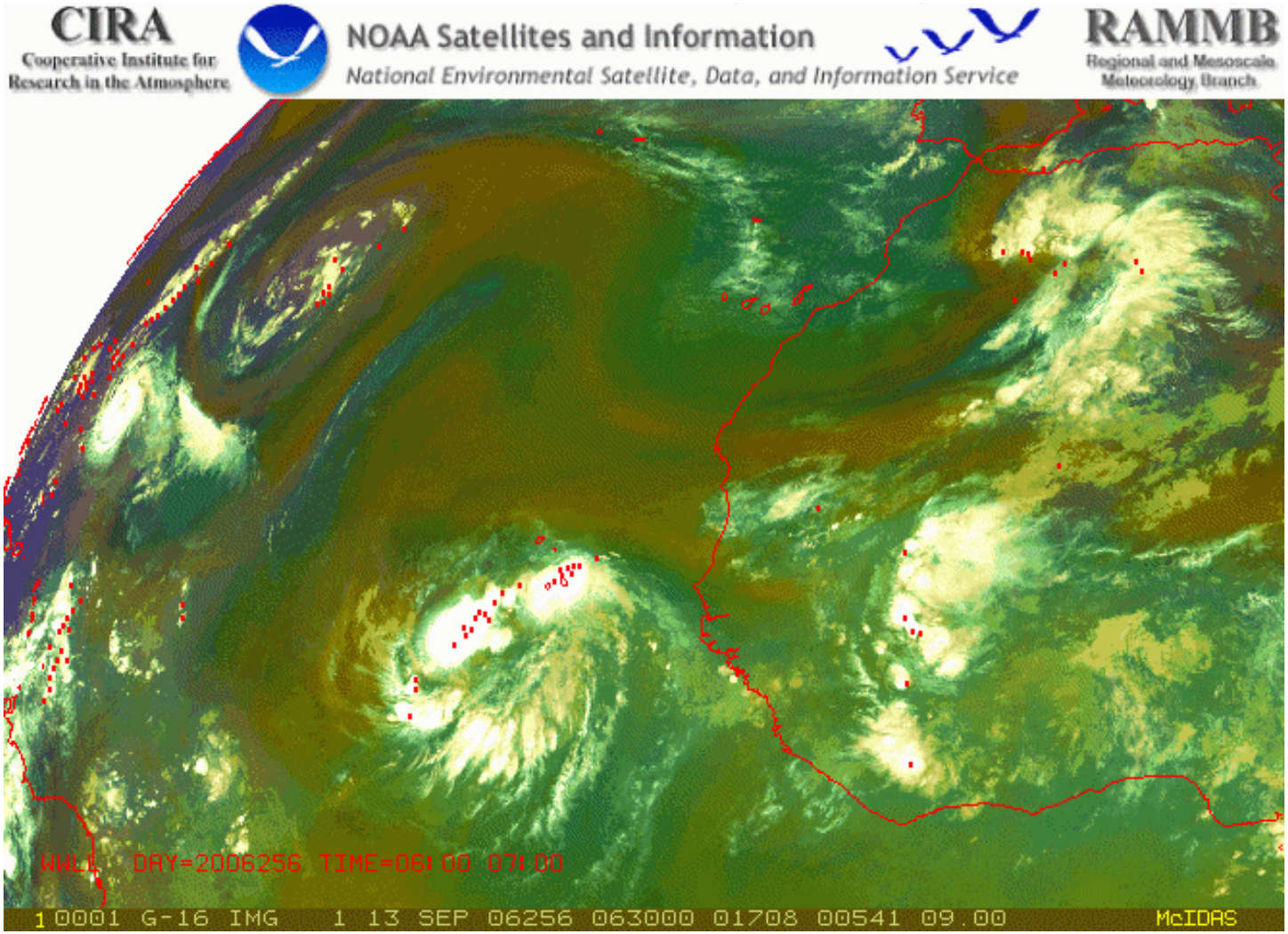


Comparison of Areal Coverage: CAPE vs Threat 1 Graupel Flux

CAPE overpredicts lightning threat area



RGB Air Mass Product with WWLLN Lightning



Evaluations underway-WWLLN (expands to 60 stations Dec 2010); Vaisala GLD360; WxBug WTLN

Summary

- GLM instrument development on schedule
- Ver. 1 of ATBD, Val Plan, Proxy Data, L2 Prototype S/W
  - Product demonstrations at NOAA Testbeds
    - Hazardous Weather Testbed (Spring Program with VORTEX-II IOP, Summer Program)
    - Joint Hurricane Testbed (NASA GRIP, NSF PREDICT)
    - Aviation Weather Testbed (NextGen)
    - Continue Regional WFO demonstrations (Norman, Huntsville, Sterling, Melbourne, …)
- Outreach and Training
  - Develop Lightning Detection Fact Sheet
  - Total Lightning Training Module
- New Risk Reduction/Advanced Product Initiatives
  - Data Assimilation
  - Combined sensors/platforms (e.g., ABI/GLM + GPM QPE)
- Validation and Proxy Data
  - Campaign in Sao Paulo, Brazil in collaboration with InPE/CPTEC and EUMETSAT MTG Lightning Imager Science Team