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

A new operational capability to improve storm forecasts and warnings

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AMS 6th Annual Symposium on Future National Symposium on Operational Environmental Satellite Systems-NPOESS and GOES-R

Atlanta, GA

20 January 2010

Natural Hazards and Lightning

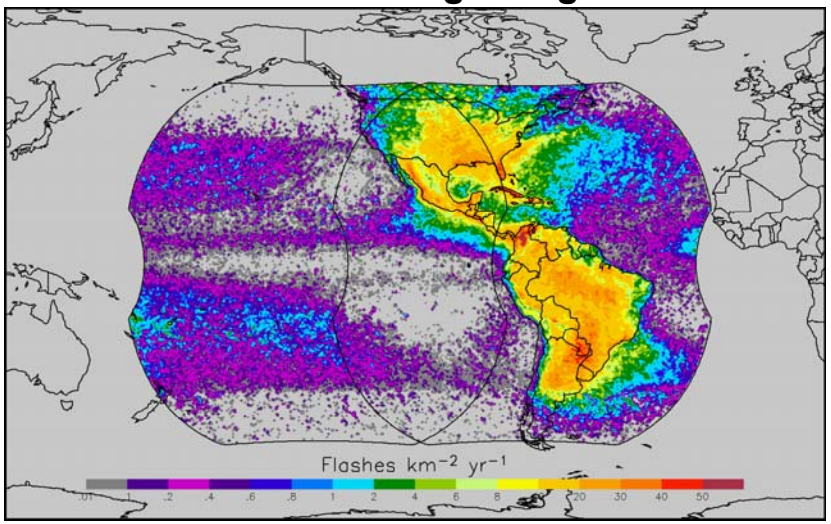
- Tornadoes
- Hailstorms
- Wind
- Thunderstorms
- Floods
- Hurricanes
- Volcanoes
- Forest Fires
- Air Quality/NOx

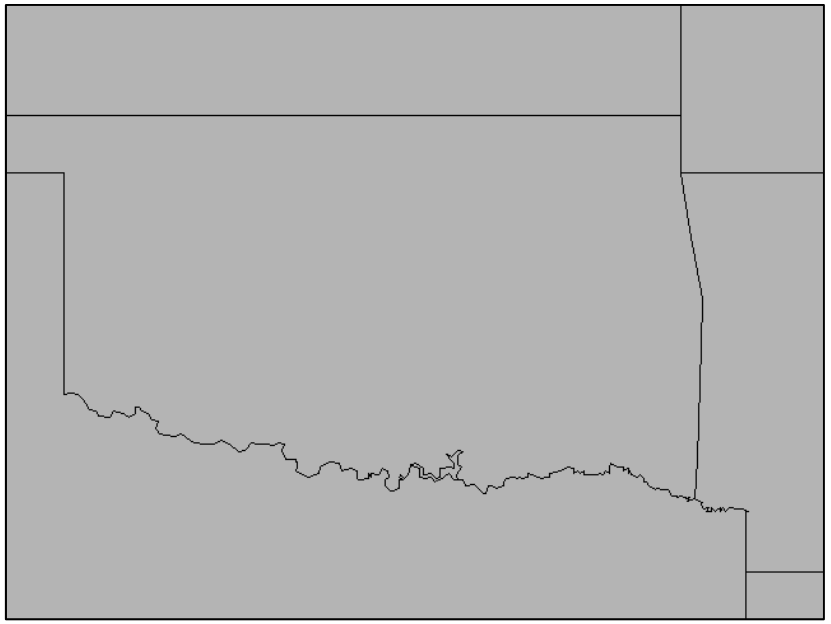
GOES-R GLM Coverage

GLM Characteristics

- Staring CCD imager
  (1372x1300 pixels)
- Near uniform spatial resolution
  8 km nadir, 12 km edge fov
  (OTD spatial resolution from GEO)
- Coverage up to 52 deg lat
- 70-90% flash detection day and night
- Single band 777.4 nm
- 2 ms frame rate
- 7.7 Mbps downlink data rate
  (for comparison- TRMM LIS 8 kbps)
- < 20 sec product latency

LIS/OTD Combined Lightning 1997-2005

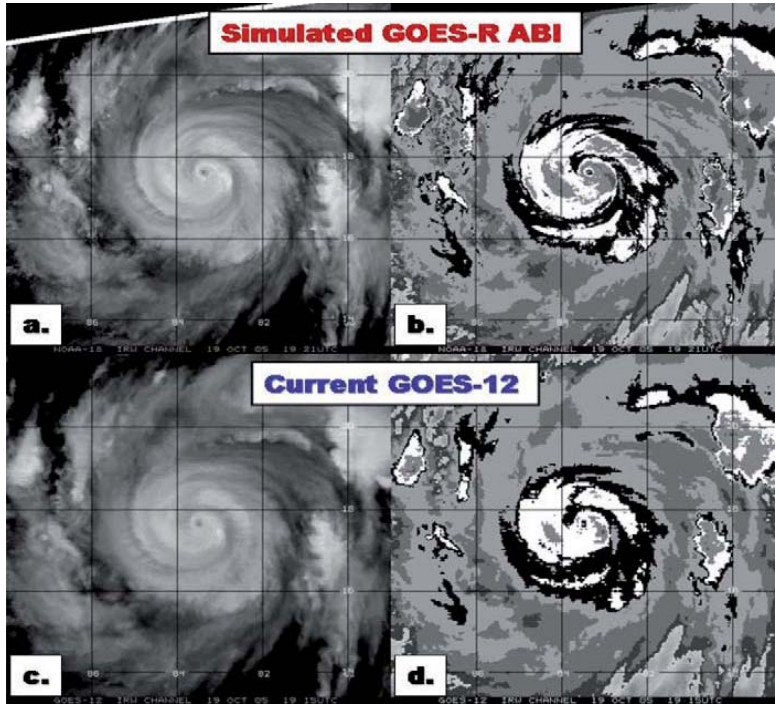




1-minute of observations from TRMM/LIS

GOES-R Hurricane Intensity Estimate

The **Hurricane Intensity Estimate (HIE) product** will produce real-time estimates of hurricane central pressure and maximum sustained winds from the ABI imagery that will be used by NHC forecasters to help assess current intensity trends.



Simulated GOES-R ABI infrared imagery with black/white contrast stretch (a) and "Hurricane" enhancement (b) compared to current GOES-12 imagery (c and d) for Hurricane Wilma on October 19, 2005. The contrast stretch/enhancements show the improved capability to capture small eye features with the ABI.

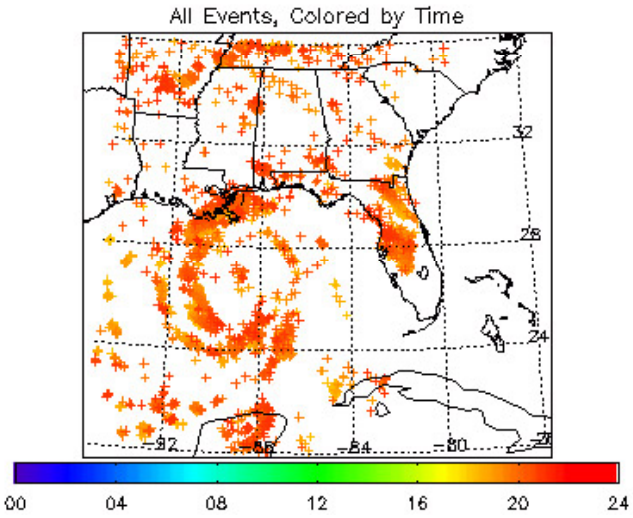
Top, Hurricane Katrina on 28 August, 2005 as it approached New Orleans. Middle and Bottom images are from Hurricane Katrina's damage along the Louisiana and Mississippi coasts.

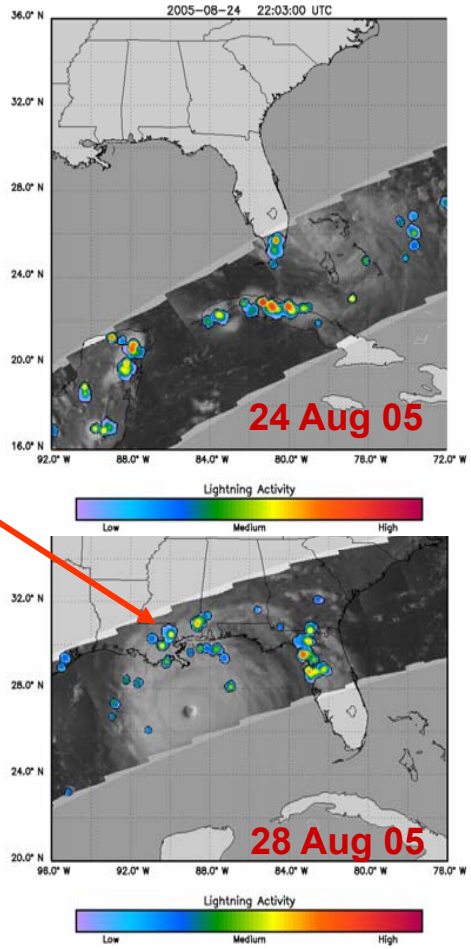
Chris Velden/CIMSS

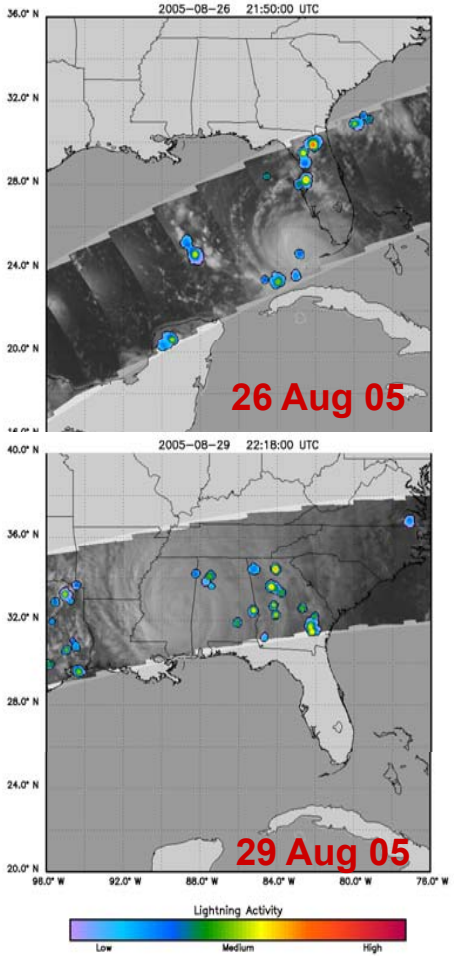
Hurricane Katrina: Lightning Imaging Sensor (LIS)

How does lightning activity vary as TC/Hurricane undergoes intensity change? Is there a useful predictor?

LIS Background Images
read out once per min
4 km ifov @ 777.4 nm
Orbit swath 600 km







Los Alamos Sferics Array, August 28, 2005, Shao et al., EOS Trans., 86

GOES-R Algorithm/Product Readiness

Underpinning Research & Development (new applications & Day 2 Products)	Pre & Post Launch Sensor Calibration and validation	Operational Algorithm Readiness Development and Transition to Operations	Sustained Post Launch Validation and Reactive Science Maintenance	User Readiness
Risk Reduction	Calibration Working Group	Algorithm Working Group	Algorithm Working Group	Proving Ground, Risk Reduction, Training

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)

Algorithm Overview

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

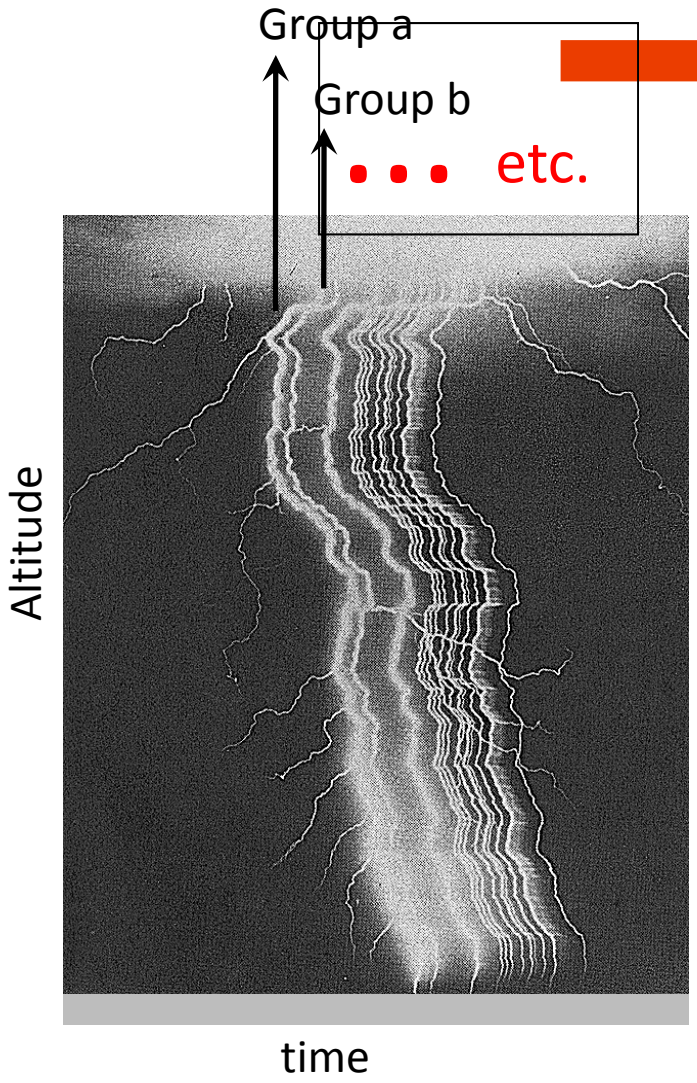
- The GLM produces a series of events (time series) which are clustered by the GLM algorithm into L2 groups and flashes, similar to the basic lightning flash data of the National Lightning Detector Network (NLDN) system (i.e., not an imager)

- 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

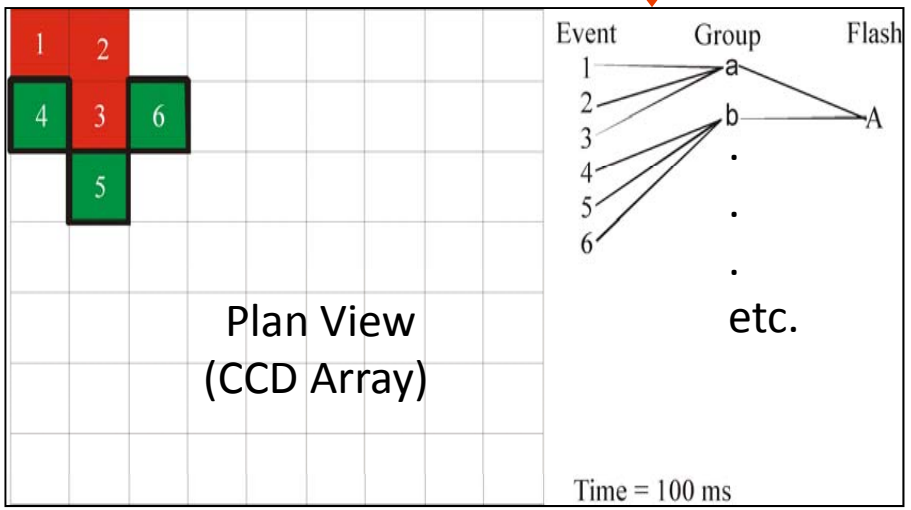
- The GLM algorithm must be able to process this wide dynamic range of data rates while producing output groups and flashes in under 4 seconds (verified by speed tests)

A Time-Resolved Ground Flash

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

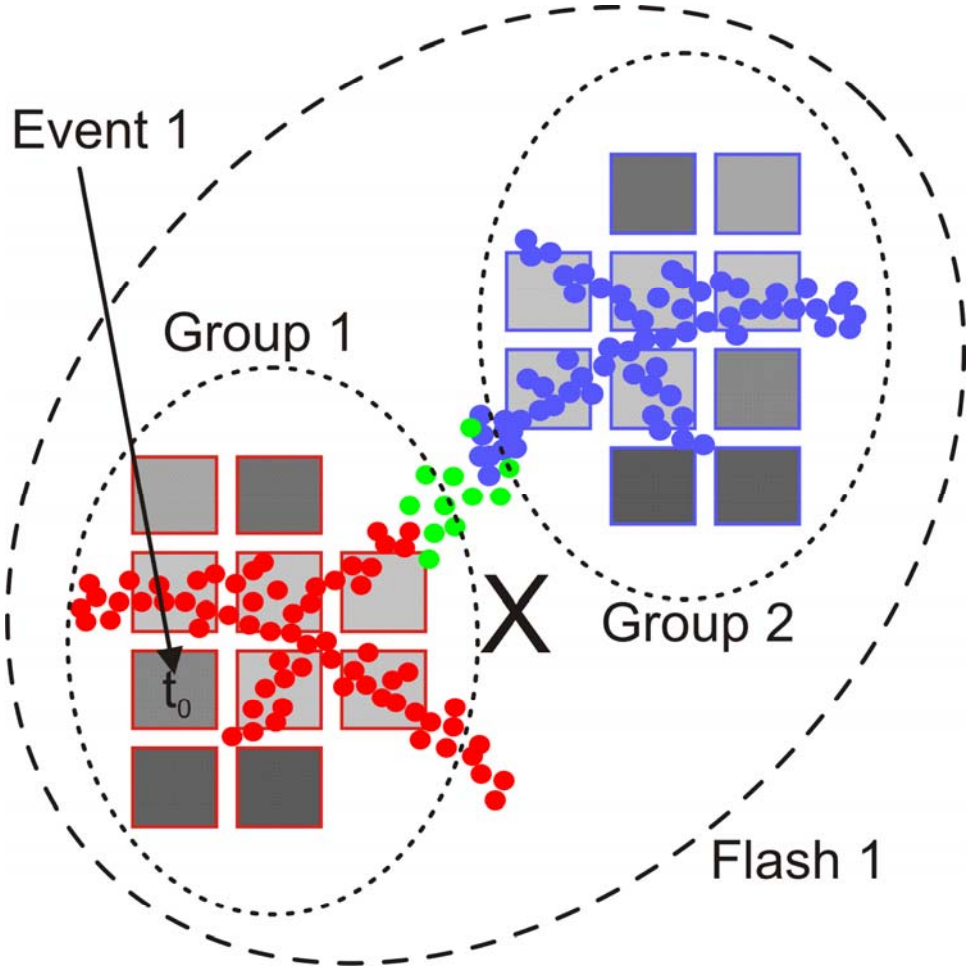


Groups Help Us Track the Strokes and other components of the lightning flash!



Testing and Validation
(data used in generating GLM proxy)

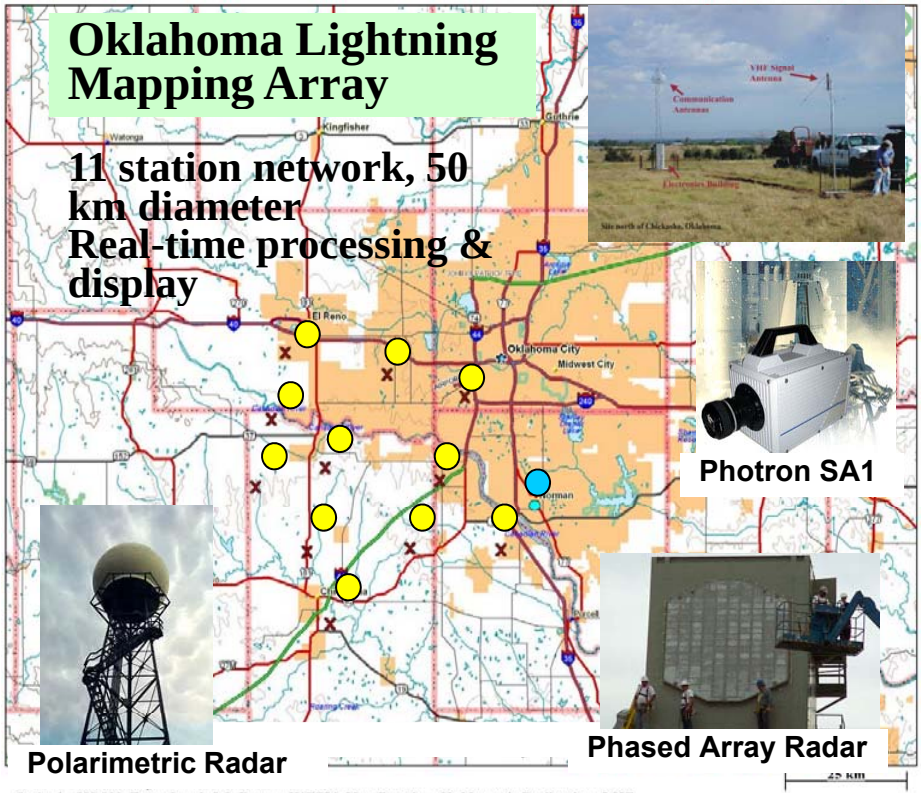
- Dots (red, green, blue) are LMA* data
- Gray squares are (simulated) GLM data
- Time is indicated by color
  - Red first
  - Green next
  - Blue last
- GLM radiance is indicated by greyscale (lighter = greater amplitude)
- Shown is a single flash with 2 groups and 20 events
  - Amplitude weighted centroid 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)

Ground Truth Validation

Sustained ground validation, airborne campaigns, international collaborations



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

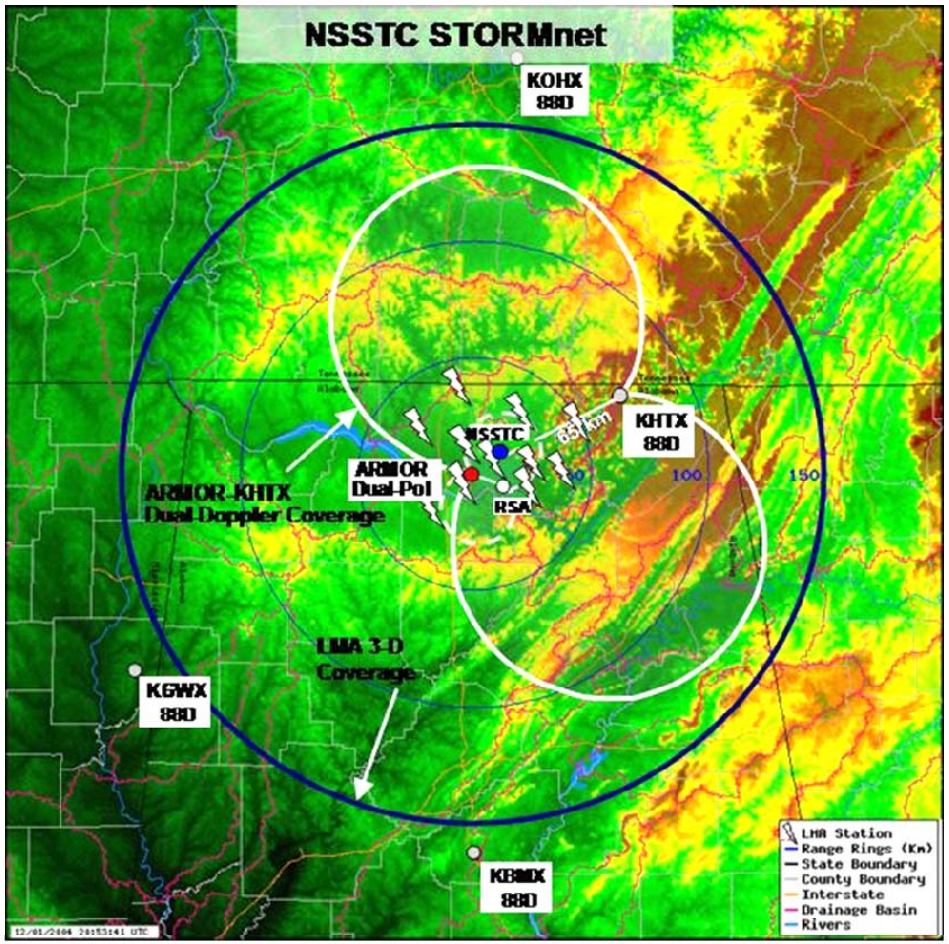


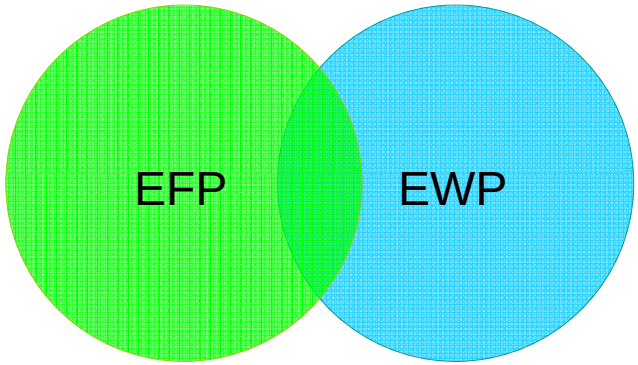
Figure 2. NSSTC STORMnet. KHTX and NSSTC ARMOR dual-Doppler lobes are indicated in white. LMA antenna locations indicated in red. Approximate 2-D coverage area of LMA network indicated by blue 150 km range ring.

GOES-R User Readiness

Proving Ground Examples

NOAA Hazardous Weather Testbed

Experimental
Forecast
Program

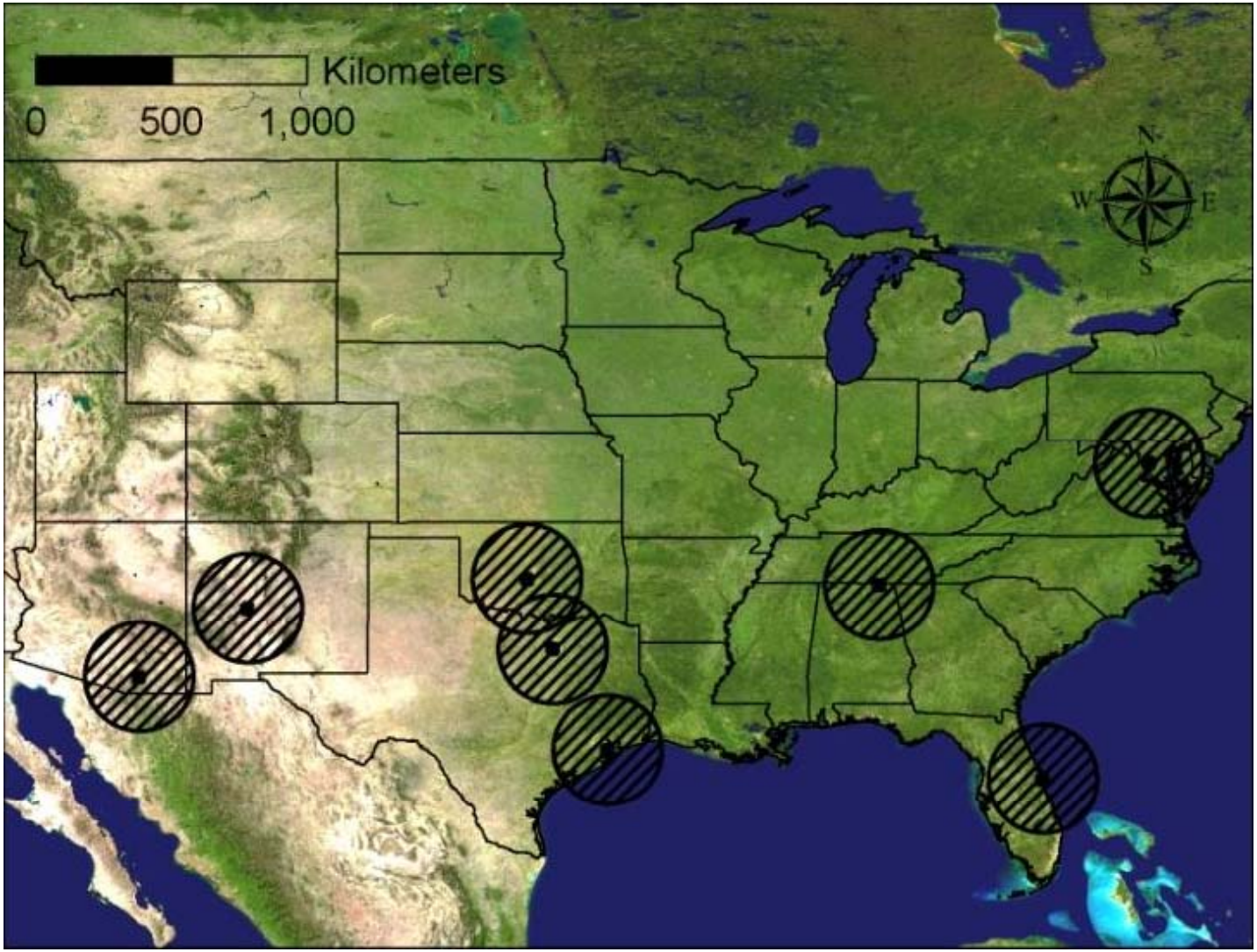


Experimental
Warning
Program

*Prediction of hazardous weather events from **a few hours to a week in advance***

*Detection and prediction of hazardous weather events **up to several hours in advance***

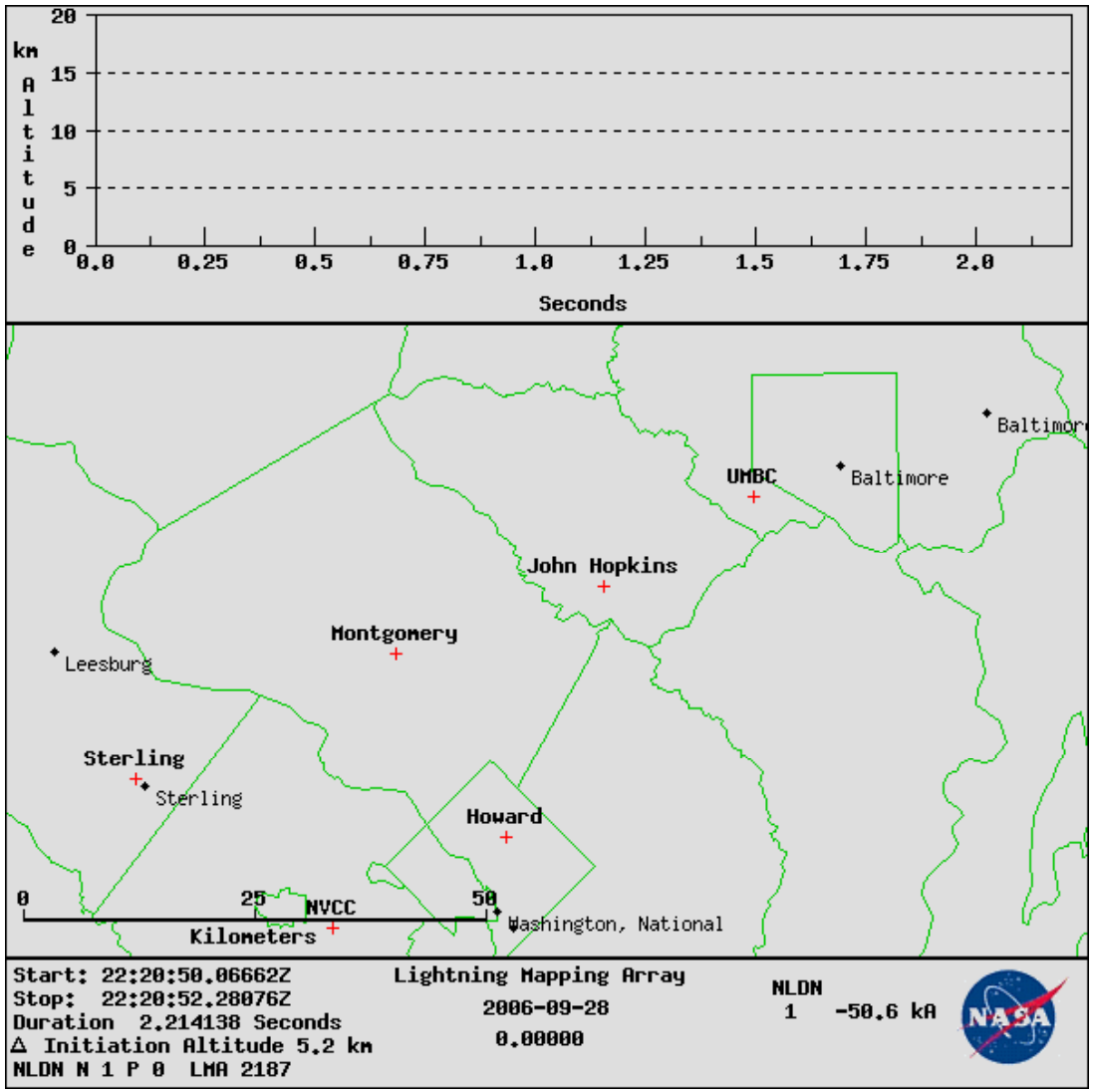
Regional Operational and Research VHF Total Lightning Networks in USA



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

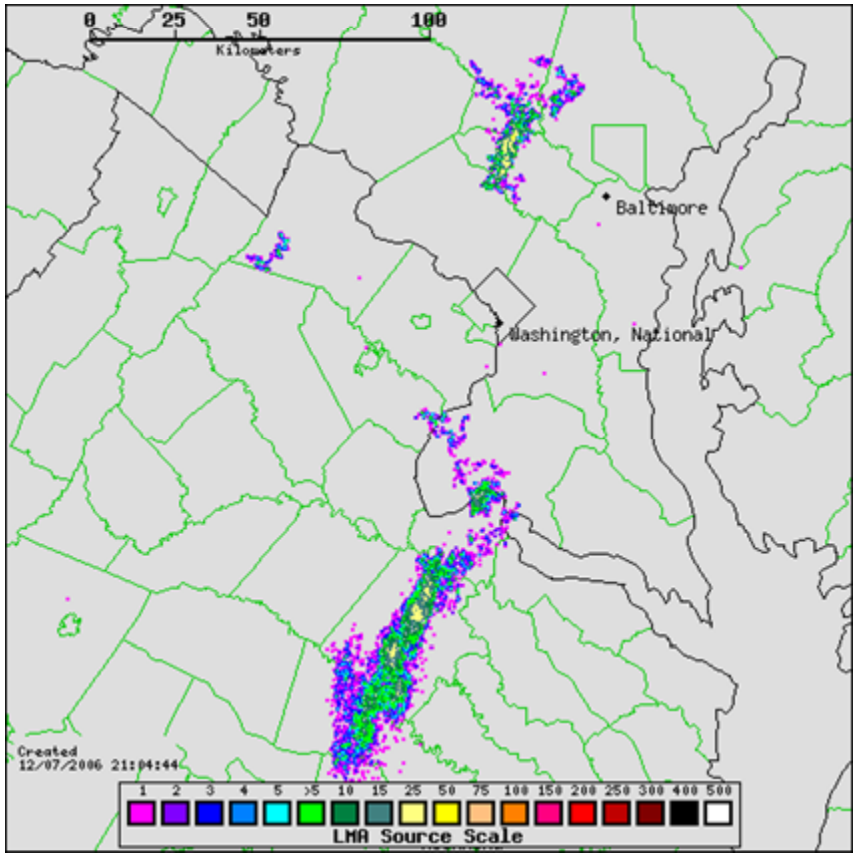


http://branch.nsstc.nasa.gov/PUBLIC/DCLMA

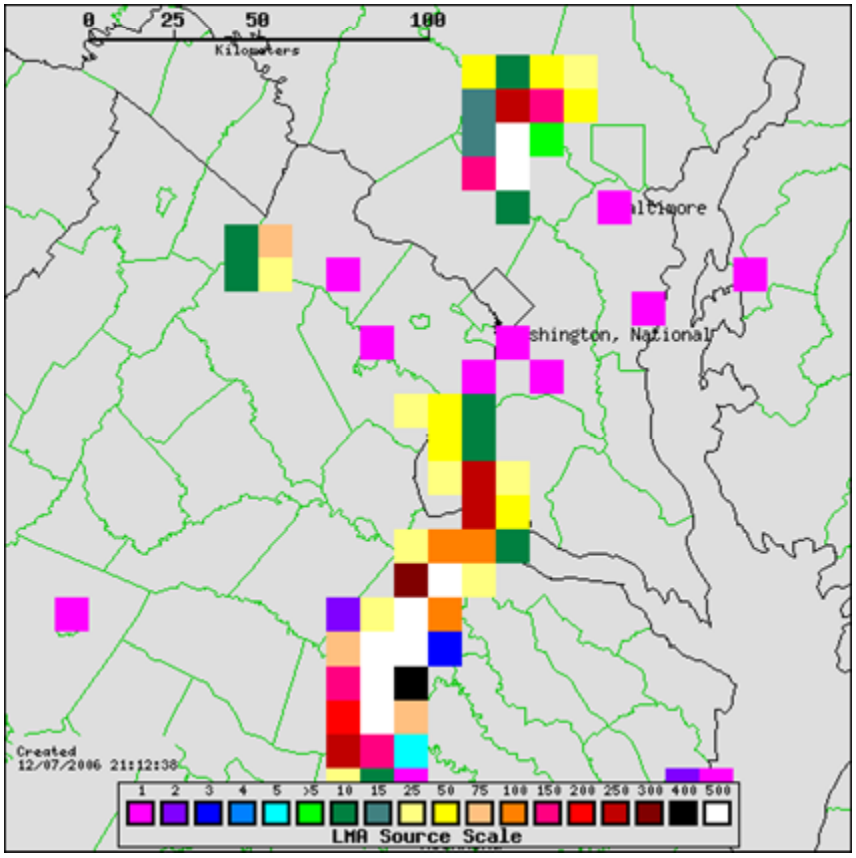
Animated gif

GLM Proxy Data: Sterling WFO

DC Regional Storms November 16, 2006
Resampled 5-min source density at 1 km and 10 km



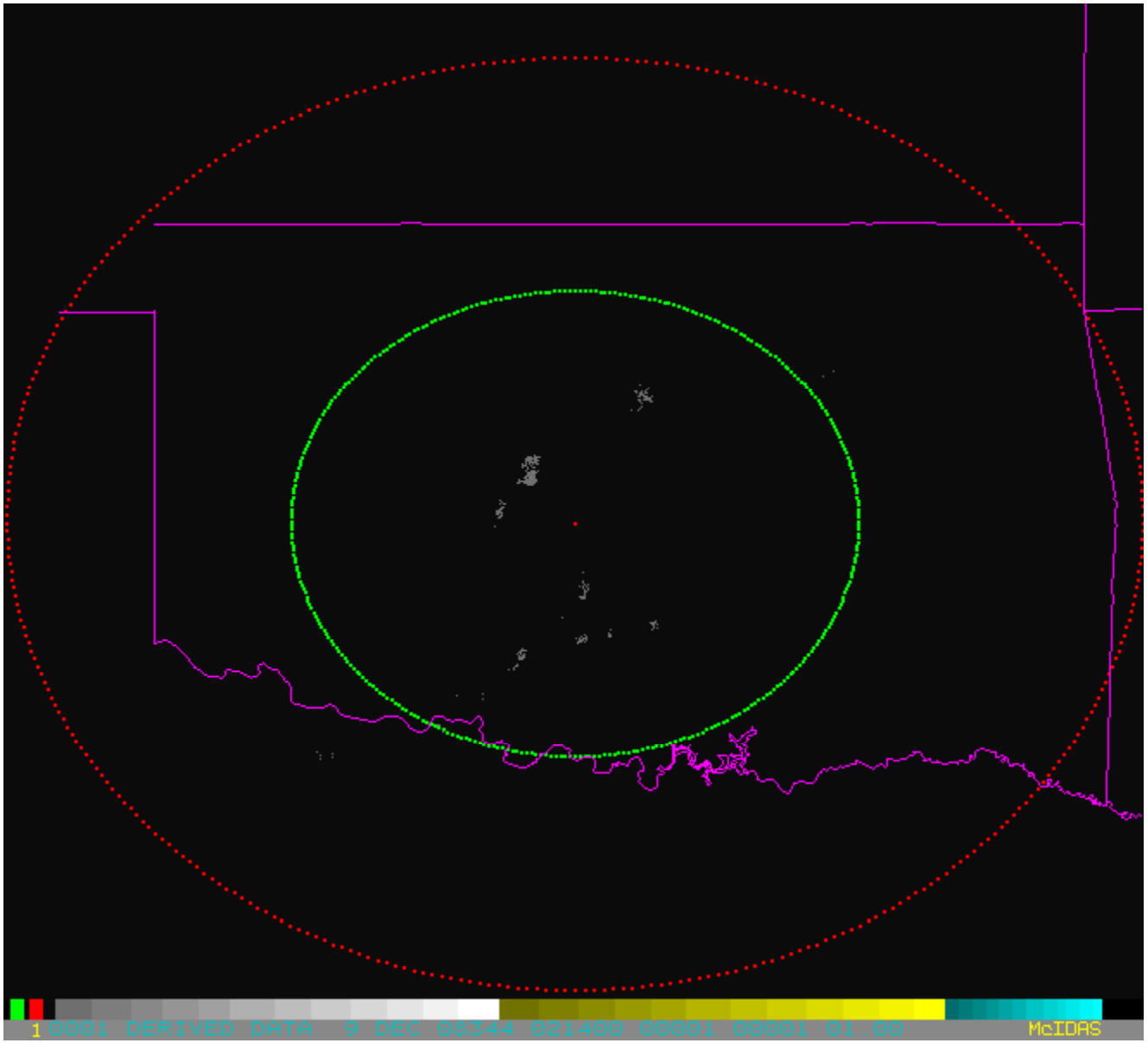
LMA 1 km resolution



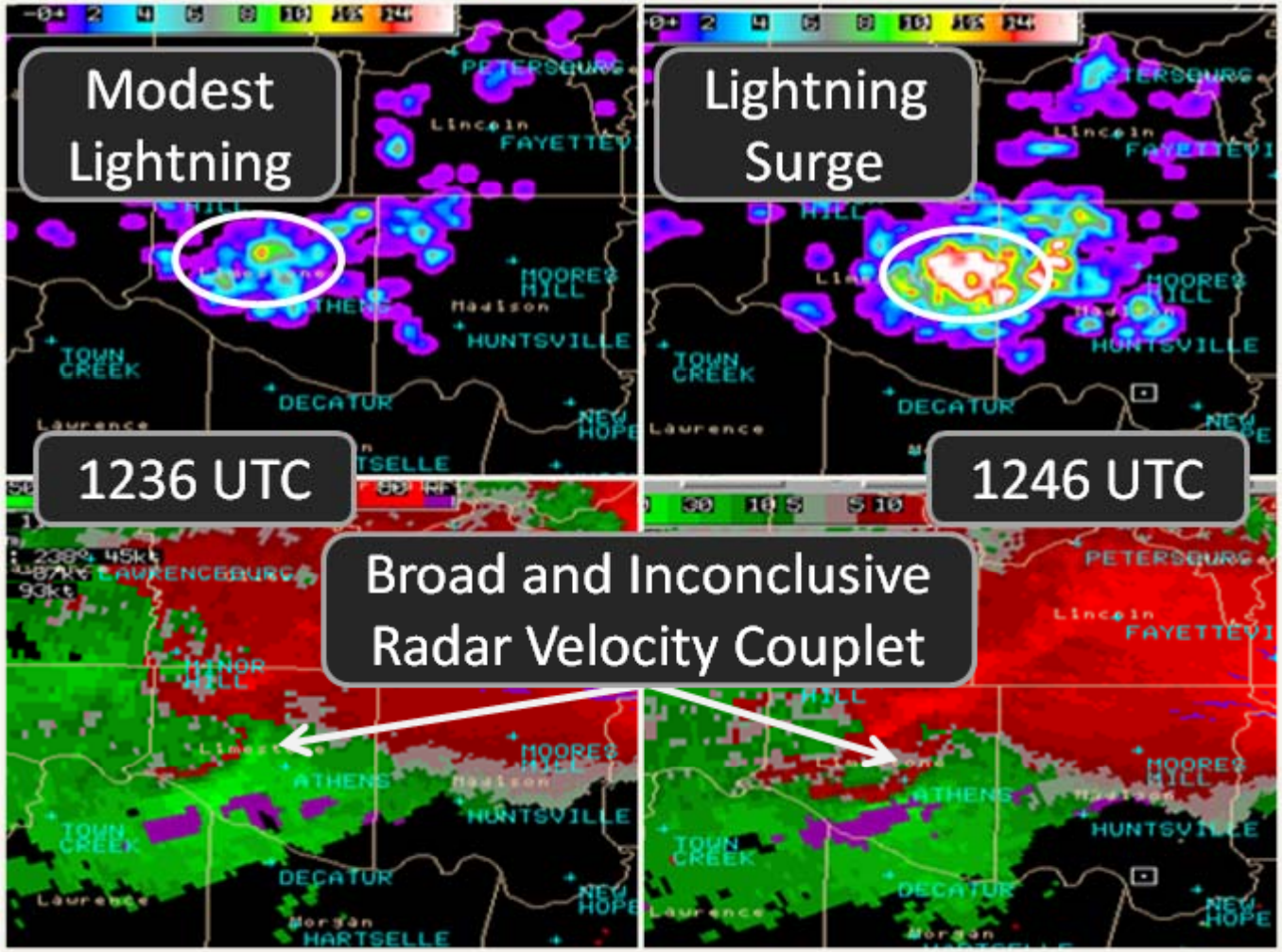
LMA @ GLM 10 km resolution

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

GLM Proxy Data from OKLMA

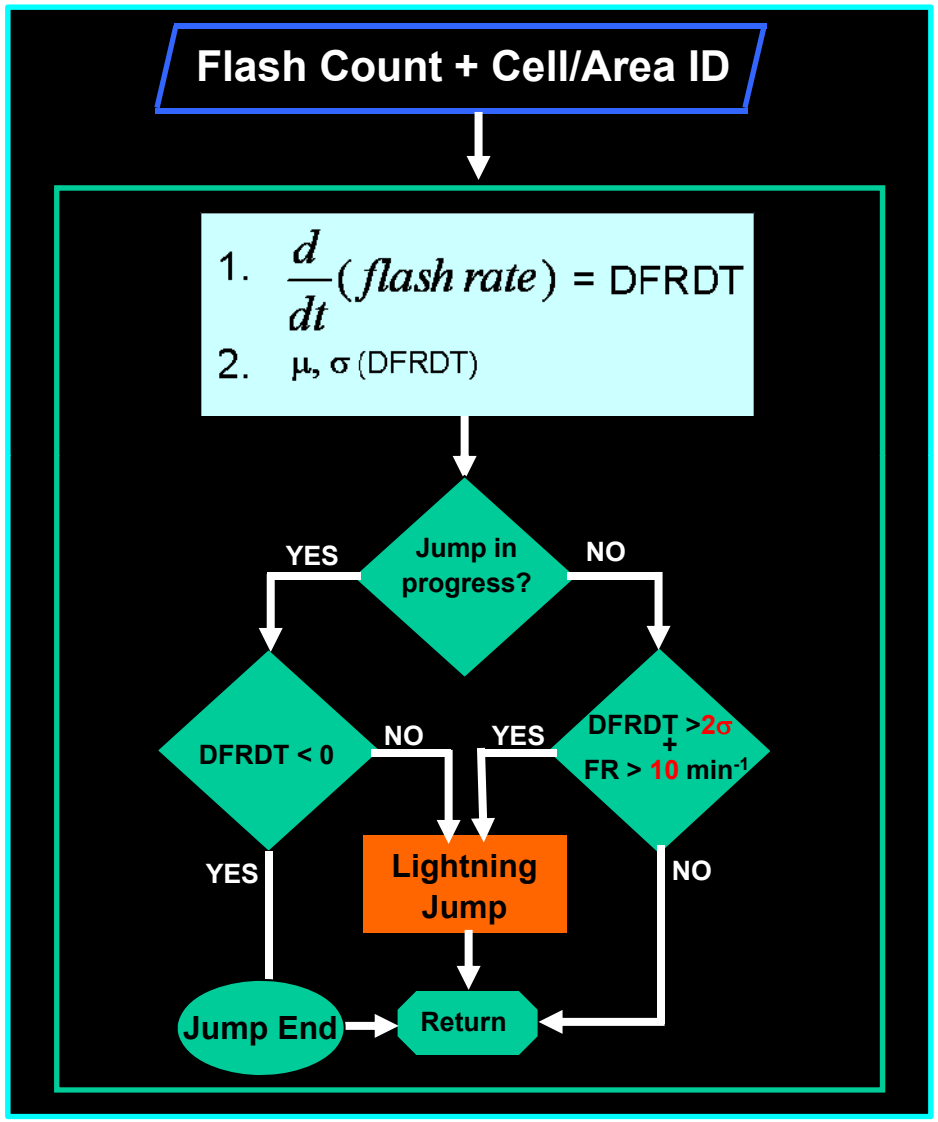


Lightning Trends Depict Storm Intensification



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



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

85 thunderstorms

69 non-severe

38 severe:

22 – supercells

2 – low topped supercells

1 – LEWP

2 – tropical

2 – MCS

1 – MCV

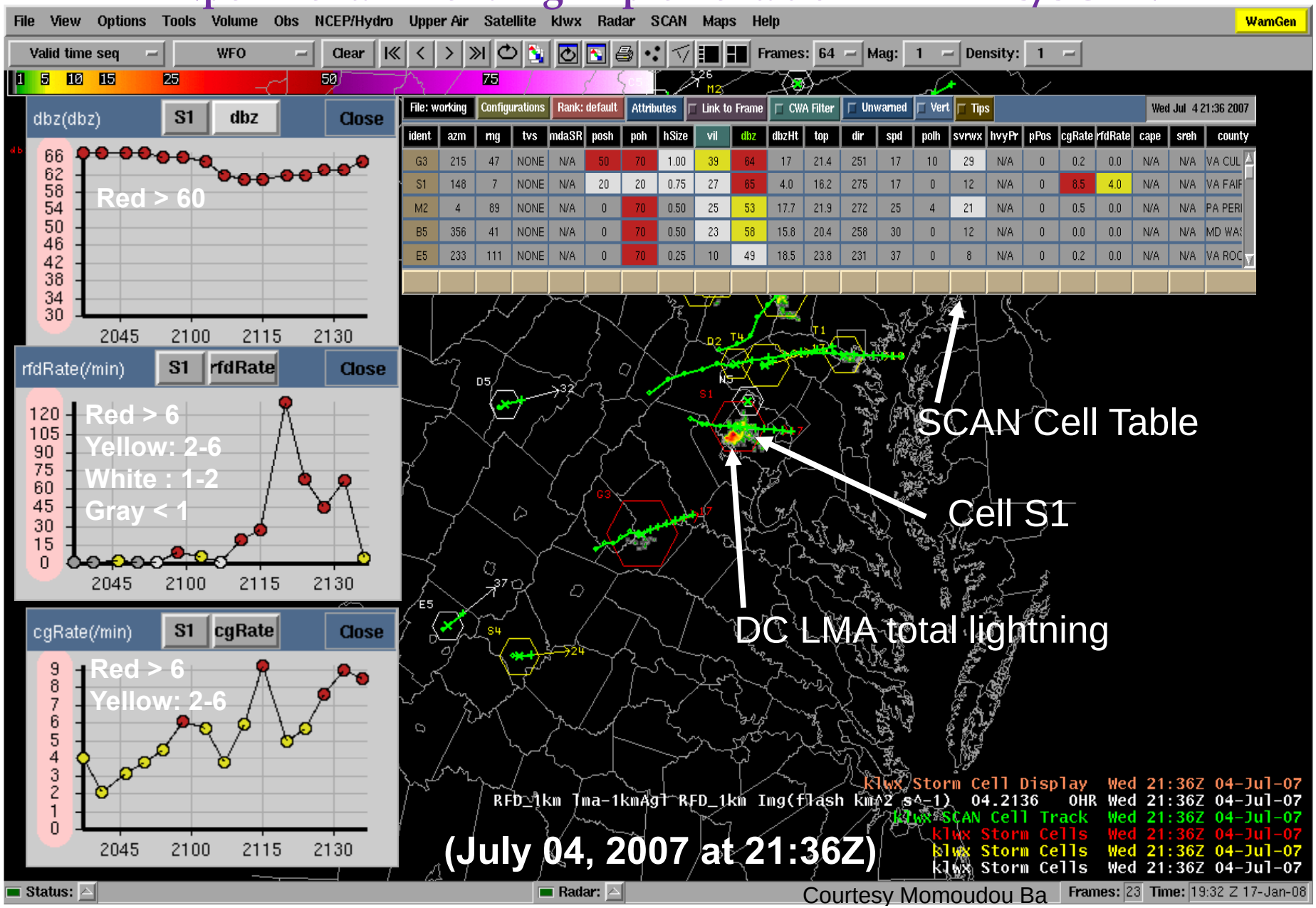
8 – multicellular

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

GLM Lightning Jump Algorithm:

(Gatlin and Goodman, JTECH, 2009; Schultz et al., JAMC, 2009)

Experimental Trending Implementation in AWIPS/SCAN



Courtesy Momoudou Ba

GOES-R User Readiness

Data Assimilation

JCSDA 2010 Data Assimilation Initiative

Funding Opportunity Title: Research in Satellite Data Assimilation for Numerical Weather, Climate and Environmental Forecast Systems

Funding Opportunity: NOAA-NESDIS-NESDISPO-2010-2001902

The JCSDA's goal is to accelerate the abilities of NOAA, DOD, and NASA to ingest and effectively use large volumes of data from current and future satellite-based instruments (over the next 10 years). Maximizing the impact of these observations on numerical weather prediction and data assimilation systems is a high priority of the JCSDA.

New for 2010:

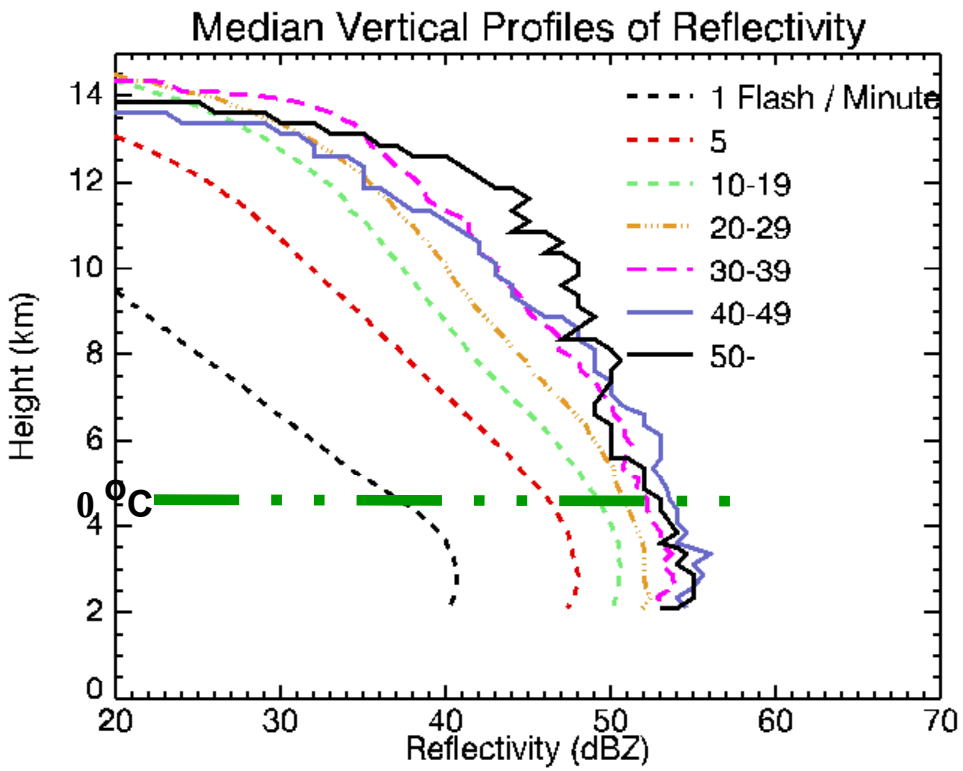
Advanced Instruments (e.g. IASI, ASCAT, SSMIS, Jason-2/3, SMOS, Aquarius, ADM, CrIS, ATMS, **ABI, GLM**, GPM, and other planned research missions) are or will become available over the course of the next decade.

- Impact studies of assimilating future instruments data and products on the forecast of severe weather events (hurricanes, flash flooding, etc) at both global and regional scales.

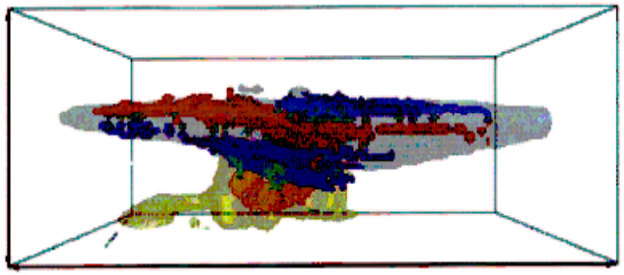
Flash Rate Coupled to Mass in the Mixed Phase Region

TRMM PR and LIS

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



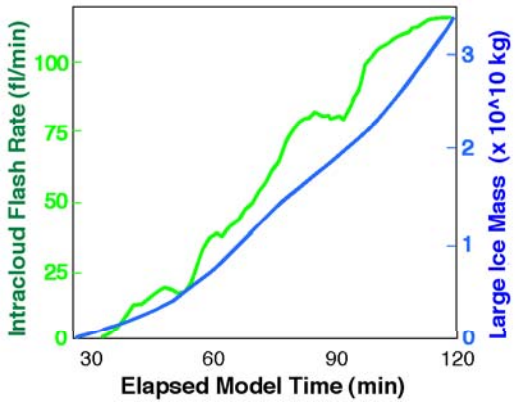
Process physics understood



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

Ice flux drives lightning

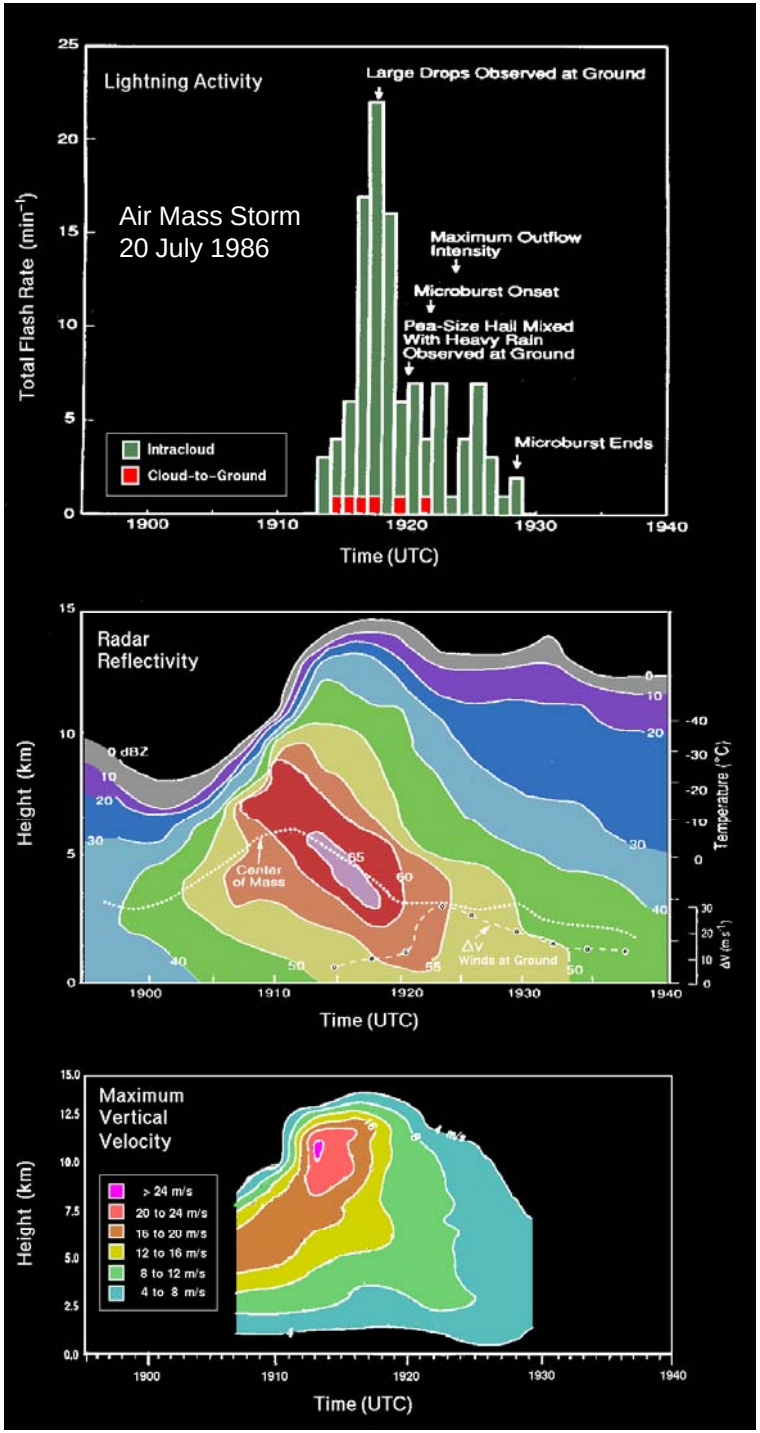
Physical basis for improved forecasts



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

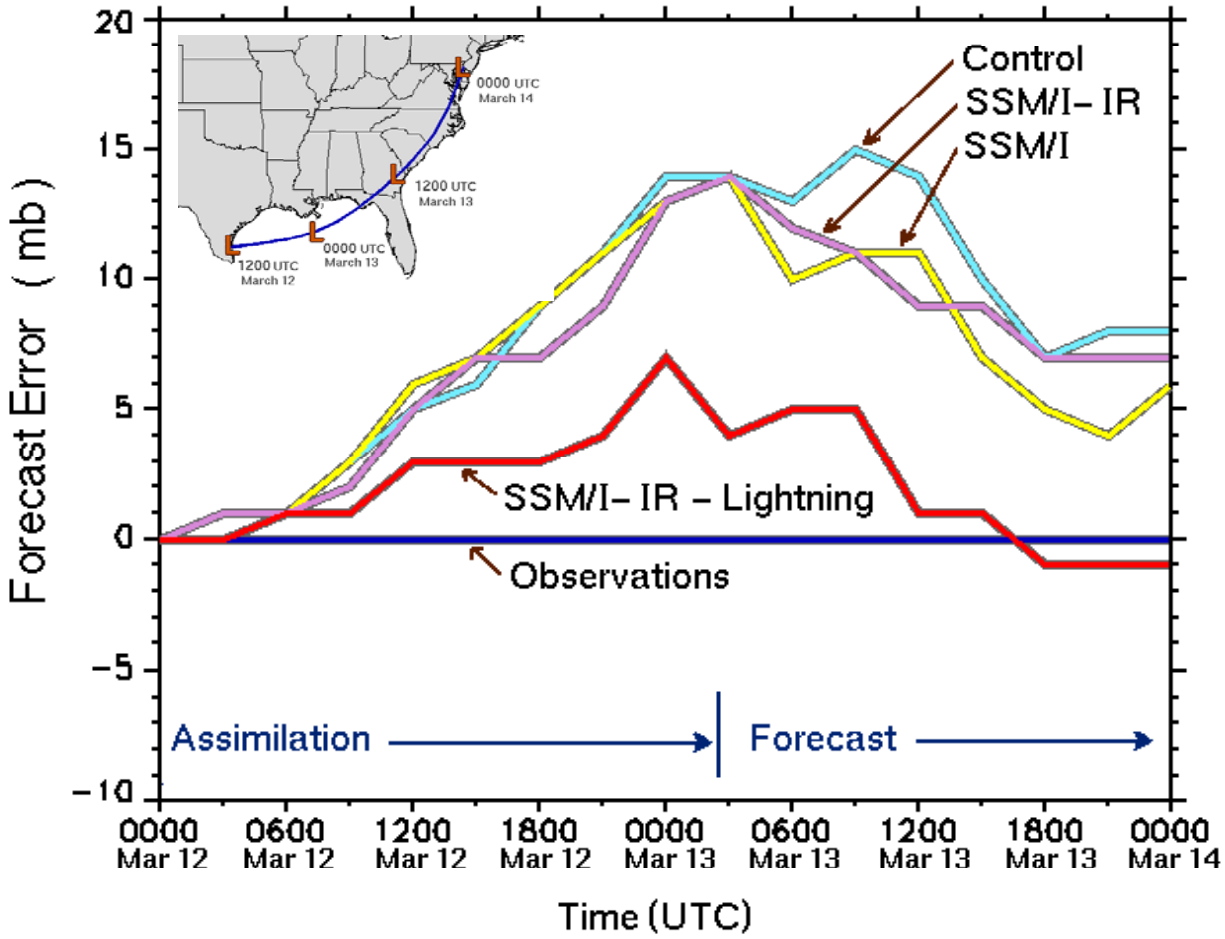
Lightning Connection to Thunderstorm Updraft, Storm Growth and Decay

- 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



Lightning Data Assimilation: Reduces Forecast Error

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



Lightning assimilated via latent heat transfer functional relationship

Summary

- Ver. 1 of ATBD, Val Plan, Proxy Data, L2 Prototype S/W
- Product demonstrations at NOAA Testbeds
    - Hazardous Weather Testbed (VORTEX-II IOP)
    - Joint Hurricane Testbed (NASA GRIP, NSF PREDICT)
    - 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