High Impact Weather Forecasts and Warnings with the GOES-R Geostationary Lightning Mapper (GLM)

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http://www.goes-r.gov

(with highlights from the GLM Science Team and contributions from our partners)

GOES User's Conference
Birmingham, AL
October 19-21, 2011

Outline

- GOES-R Geostationary Lightning Mapper (GLM)
  - ❑ Instrument Characteristics
  - ❑ Driving Requirements, Mission Objectives, Performance
  - ❑ Physical Basis

- User Readiness Demonstrations
  - ❑ GOES-R Proving Ground
  - ❑ Forecaster Feedback

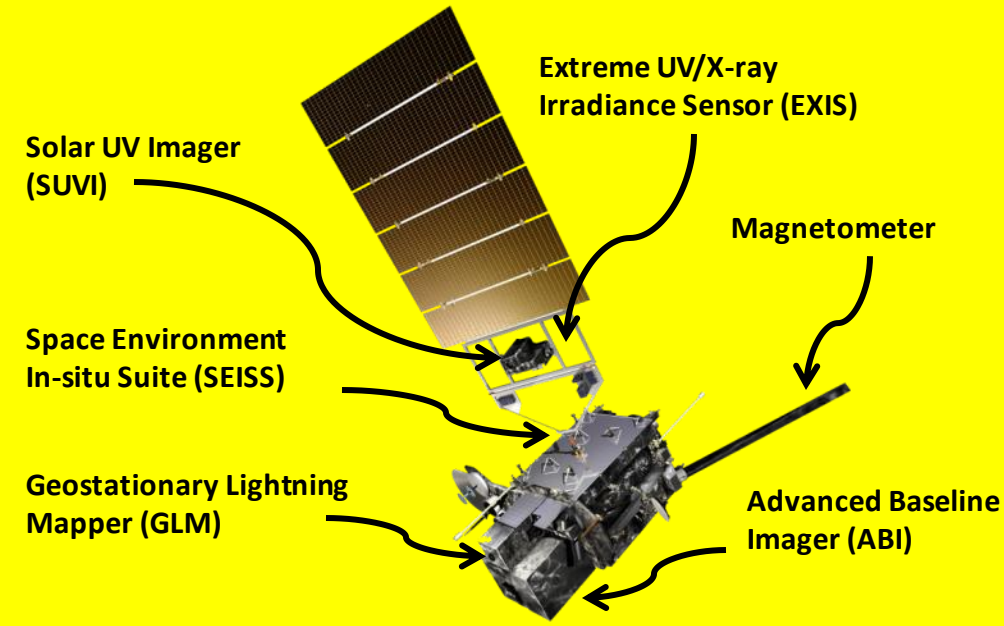
- Cal/Val Field Campaigns
  - ❑ CHUVA Campaign (InPE, NOAA, NASA, EUMETSAT)
  - ❑ Deep Convective Cloud and Chemistry Experiment, DC3
    - (NSF-sponsored, GOES-R Cal WG participation)
    - Lightning Mapping Arrays, Dual-pol radar, etc
    - Front Range of Colorado, Central Oklahoma, Northern Alabama

- Summary

GOES-R Spacecraft

GLM Characteristics

- Staring CCD imager
  - 1372x1300 pixels
- Near uniform spatial resolution of the Western Hemisphere
  - 8 km nadir
  - 14 km edge fov
- 70-90% flash detection
- Single band 777.4 nm
- 2 ms frame rate
- 7.7 Mbps downlink data rate
- < 20 sec product latency

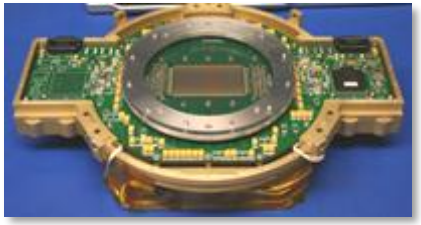


Unique Payload Services:

- High Rate Information Transmission/Emergency Managers Weather Information Network (HRIT/EMWIN)
- Data Collection System (DCS)
- Search and Rescue Satellite-aided Tracking (SARSAT) Repeater
- GOES-R Rebroadcast (GRB)

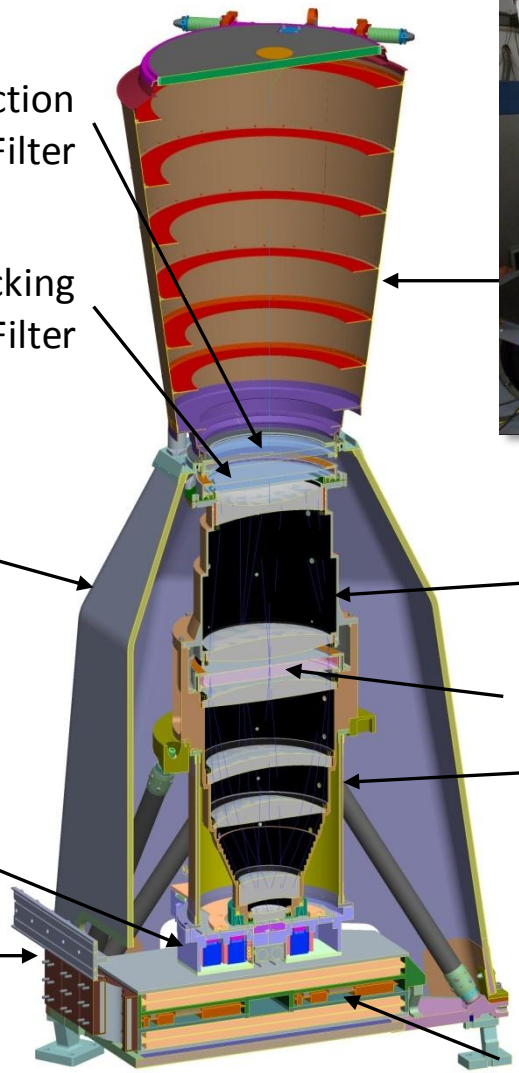
GLM Sensor Unit Overview

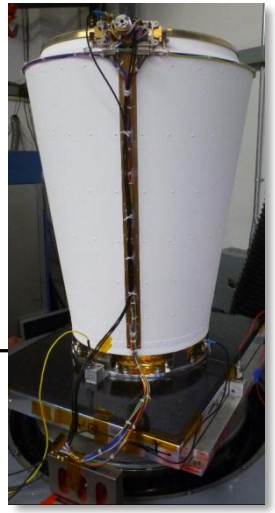
Baffle Support



Focal Plane Array Assembly (FPAA)

Loop Heat Pipes (FPAA) and Thermal Straps (SEB)

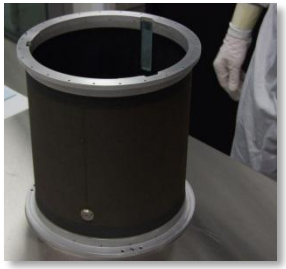




Baffle & Door

Lens Housing & Support Structure

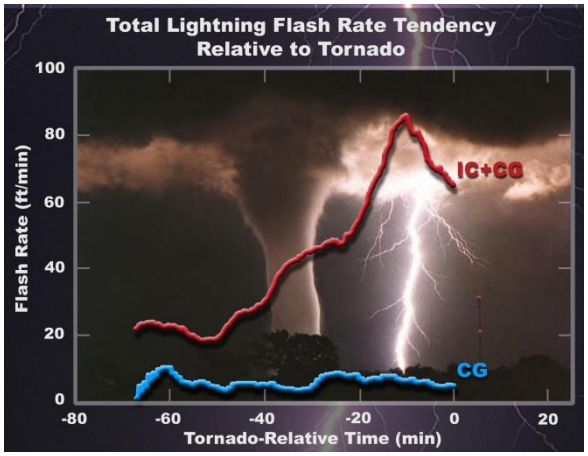
Metering Tube



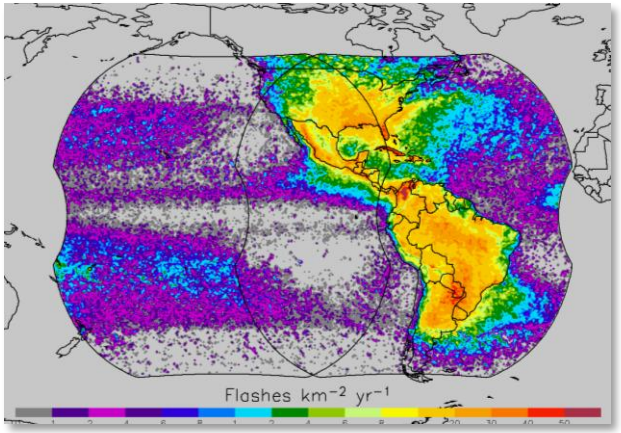
GLM Key Driving Requirements, Mission Objectives, and Performance

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

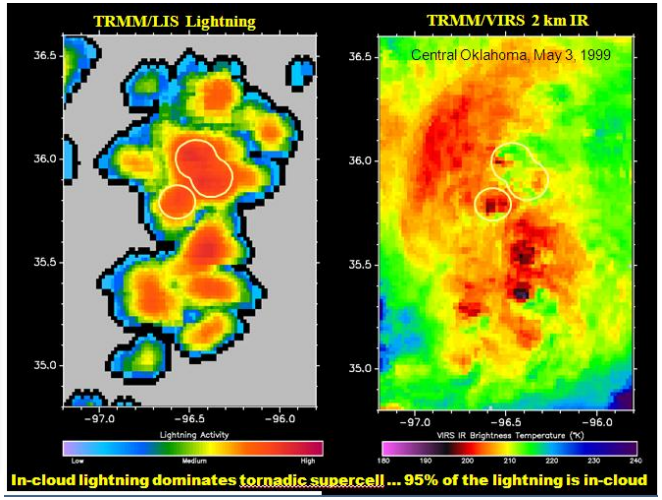
Longer tornado warning time



Decadal lightning data



Storm cell tracking



SATCAST Algorithm: *Lightning Initiation Interest Fields*

These indicators for LI are a subset of those for CI.

They identify the wider updrafts that possess stronger velocities/mass flux (ice mass flux).

In doing so, we may highlight convective cores that loft large amounts of hydrometers across the –10 to –25 ° C level, where the charging process tends to be significant.

Provides up to a 75 lead time on first-time LI.

Courtesy John Mecikalski

Interest Field	MB06 Critical CI Value	Siewert LI Value	15 to 30–min Threshold (This LI Study)	Description
10.7 µm T_B	< 0°C	≤ –13°C	*< 0° C*	Cloud tops cold enough to support supercooled water and ice mass growth; cloud–top glaciation
10.7 µm T_B Time Trends[1]	< –4°C / 15 min (ΔTb / 30 min < ΔTb / 15 min)	≤ –10°C / 15 min	*< –6° C / 15 min*	Cloud growth rate (vertical)
Timing of 10.7 µm T_B drop below 0° C	Within prior 30 min	*Not used*	*Not Used*	Cloud–top glaciation
6.5–10.7 µm T_B difference	Tb Diff: –35°C to –10°C	≥ –17°C	*> –30° C*	Cloud top height relative to mid/upper troposphere
13.3–10.7 µm T_B difference	Tb Diff: –25°C to –5°C	≥ –7°C	*> –13° C*	Cloud top height relative to mid/upper troposphere; better indicator of early cumulus development but sensitive to cirrus
6.5–10.7 µm T_B Time Trend	> 3°C / 15 min	≥ 5°C / 15 min	*> 5° C / 15 min*	Cloud growth rate (vertical) toward dry air aloft
13.3–10.7 µm T_B Time Trend	> 3°C / 15 min	≥ 5°C / 15 min	*> 4° C / 15 min*	Cloud growth rate (vertical) toward dry air aloft
3.9–10.7 µm T_B Difference[3]	*Not used*	*Not used*	*> 17° C*	Cloud–top glaciation
3.9–10.7 µm T_B Time Trend[2]	*Not used*	T–T(t–1) < –5°C and T–T(t+1) < –5°C	*> 1.5° C / 15 min*	Sharp decrease, then increase indicates cloud–top glaciation
3.9 µm Fraction Reflectance[2]	*Not used*	≤ 0.05	*< 0.11*	Cloud top consists of ice (ice is poorer reflector than water at 3.9 µm)
3.9 µm Fraction Reflectance Trend[3]	*Not used*	*Not used*	*< –0.02 / 15 min*	Cloud–top glaciation rate

1 Represents two unique 10.7 µm T_B interest fields in MB06. No 30-min trends were used in Siewert (2008) or in this study.

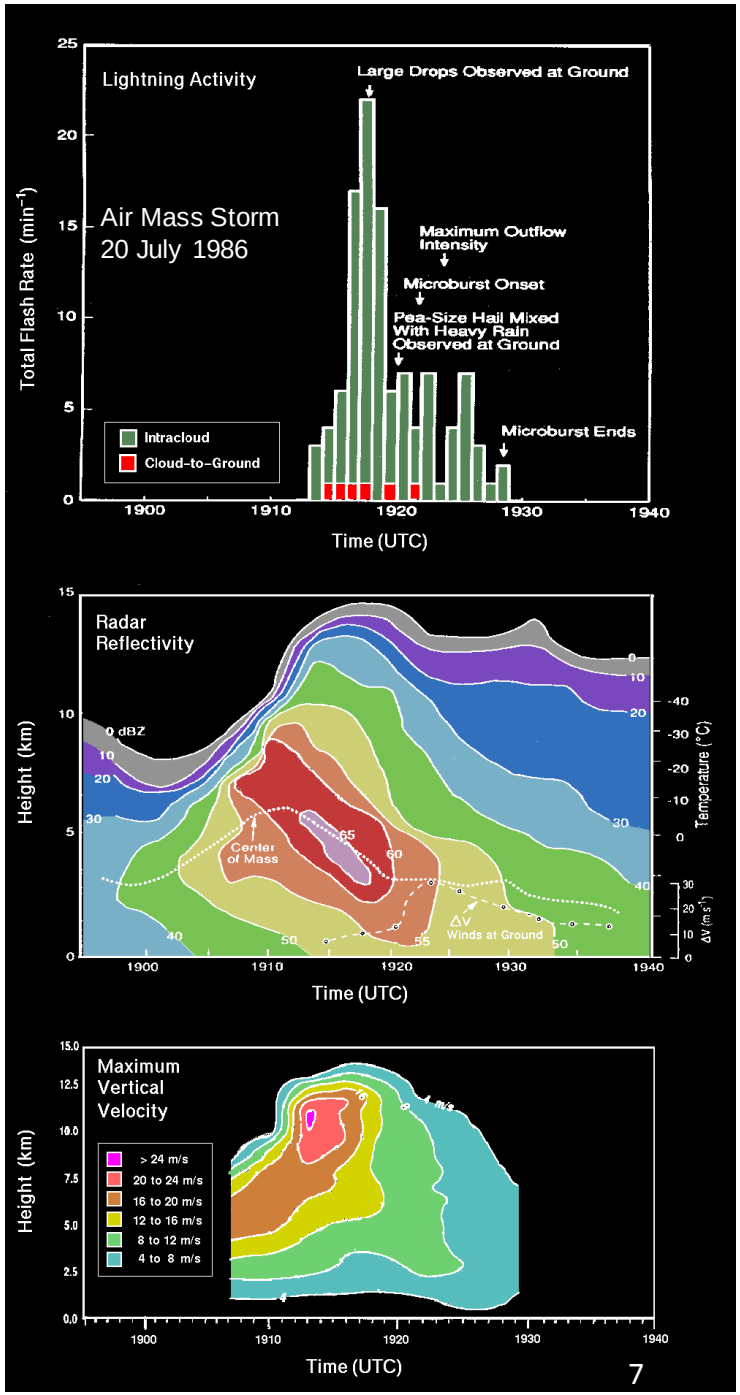
2 Added to MB06 fields by Siewert (2008).

3 Unique to this study.

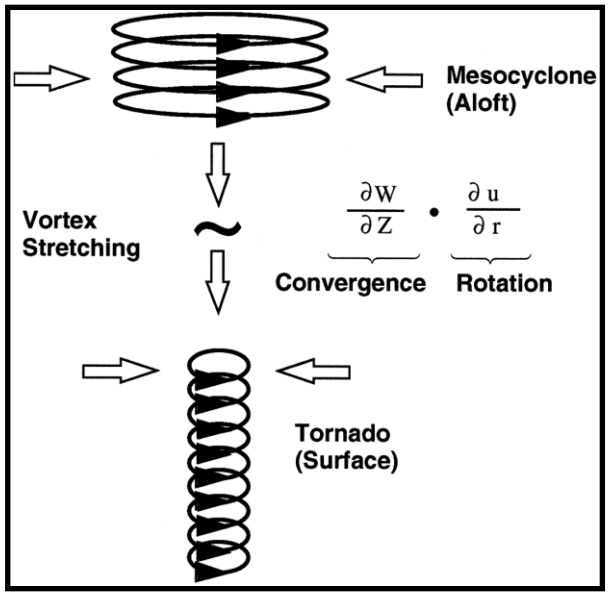
Physical Basis:

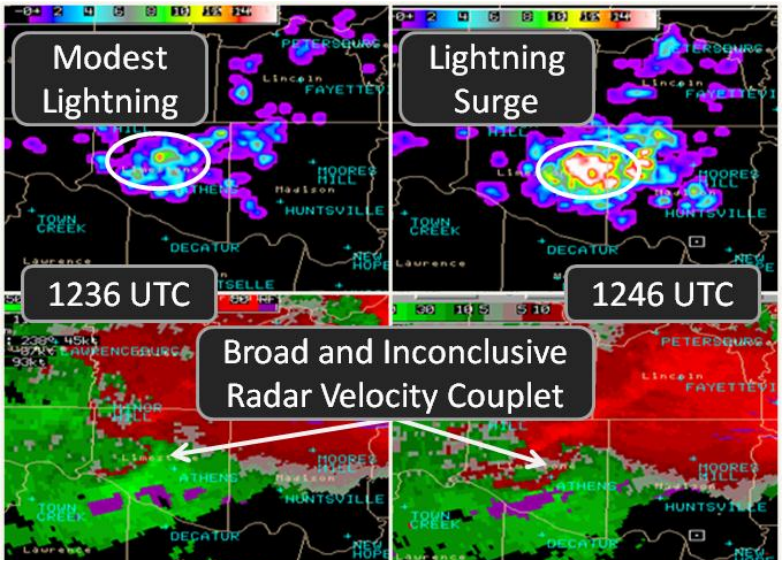
Lightning Connection to Thunderstorm Updraft, Storm Growth and Decay

- 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



GOES R3 Science- Future Capability: GLM Will Improve Severe Weather Warnings





Skill scores and average lead times using the sample set of 711 thunderstorms for both total lightning and CG lightning, correlating trends in lightning to severe weather.

	POD	FAR	CSI	HSS	lead time (all)	lead time (tornado)
Total lightning	79%	36%	55%	0.71	20.65 mins	21.32 mins

National Average for Tornado warning lead-time is only 13 minutes

Courtesy of Chris Schultz – University of Alabama, Huntsville

National Lightning Jump Field Demonstration

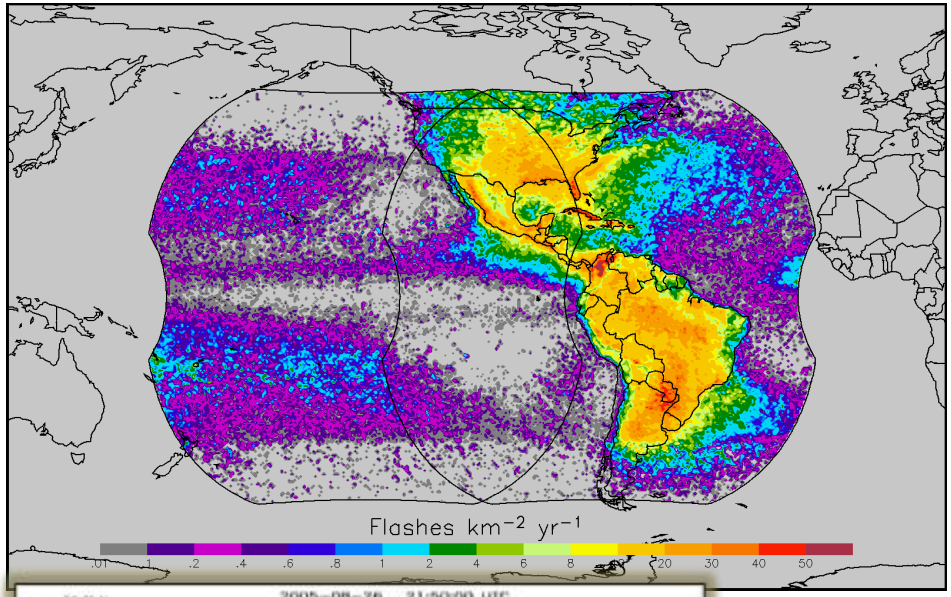
- **GUIDANCE STATEMENT**
  - **"The Lightning Jump Test (LJT) Project shall run an automated algorithm (Schultz et al., 2009) using Total Lightning Data (in particular, LMA data) in order to evaluate its performance and effect on watch/warning operations via severe weather verification, with an eye to the future application of the GLM on GOES-R."**

National Lightning Jump Field Demonstration: Goals

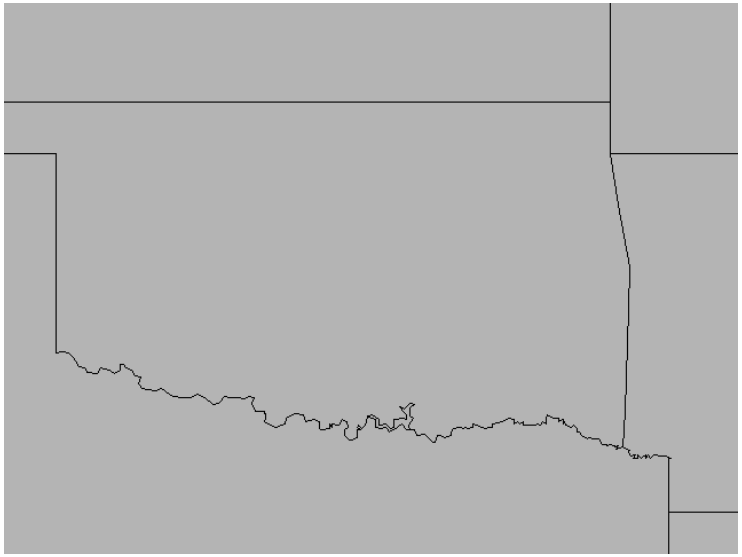
- Establish a fully automated processing method using the "2σ" (2-sigma) algorithm (Schultz et al., 2009).
- This includes automated (but ***not*** real-time) verification in order to calculate and evaluate POD/**FAR**/CSI for severe weather forecasts.
- This is expected to produce a large data set, which can be used for various other post-processing elements, yet to be determined.
- The results of this test are intended to inform the utility of the GLM data from GOES-R.

GOES-R Geostationary Lightning Mapper (GLM)

GLM Combined E-W Coverage

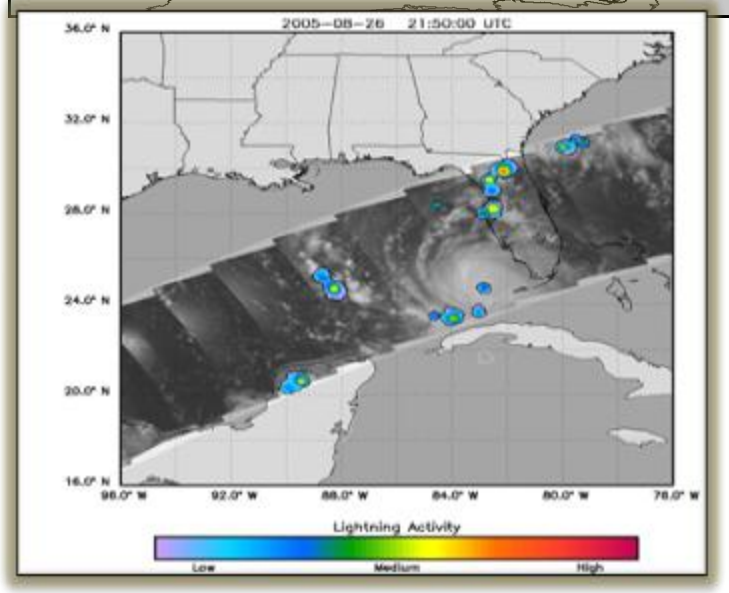


May 3 1999 Oklahoma Tornado Outbreak



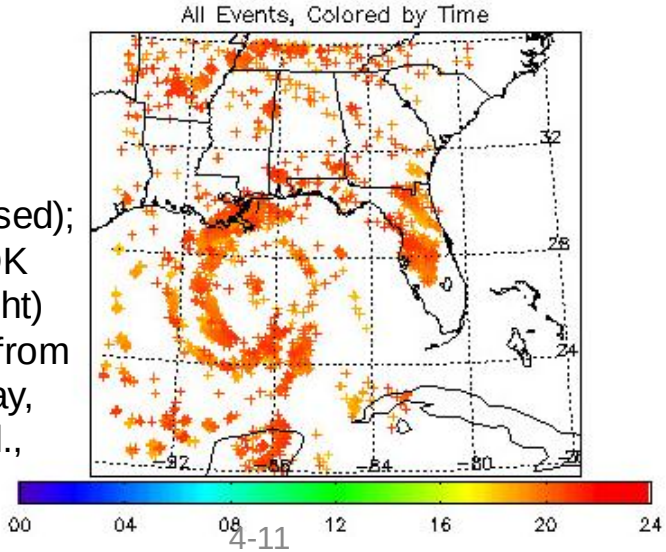
Stroud Animation

1-minute of observations from TRMM/LIS

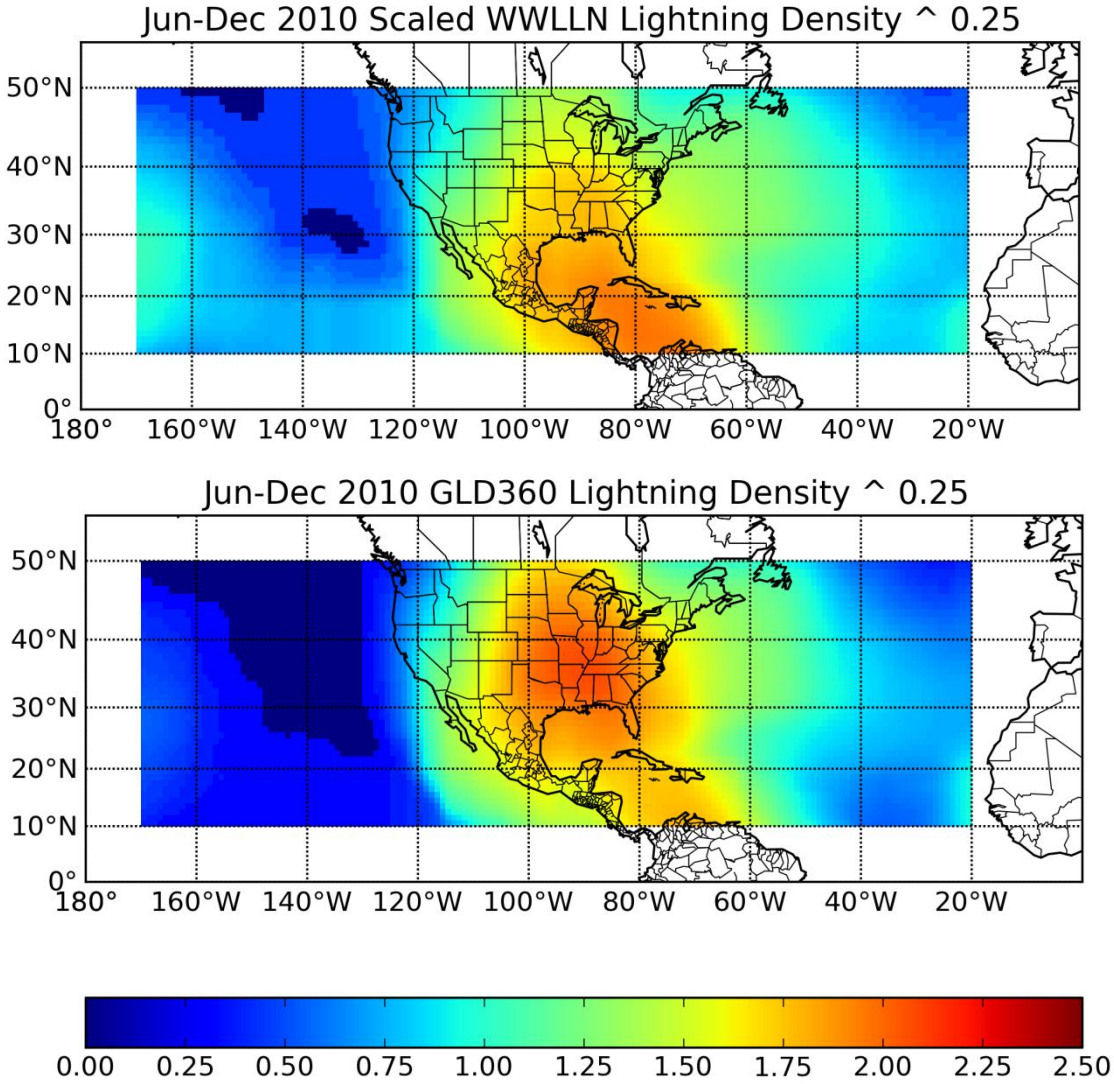


What GLM will see:

(left) LIS background with lightning events superimposed); (upper right) May 3, 1999 OK tornado outbreak, (lower right) Hurricane Katrina lightning from the Los Alamos Sferics Array, August 28, 2005, Shao et al., EOS Trans.,86.

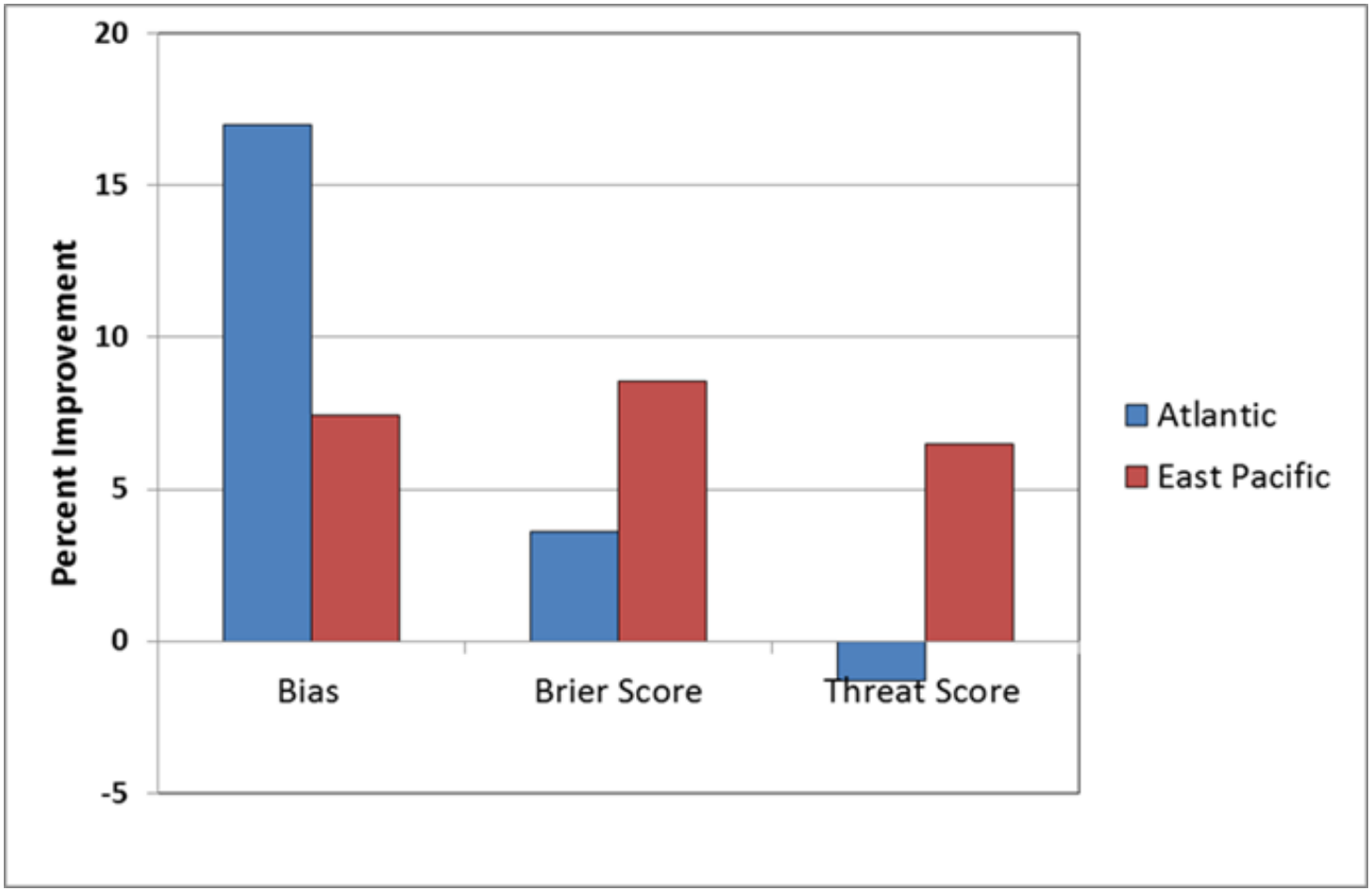


Proxy Data:
WWLLN and GLD360 Jun-Dec 2010



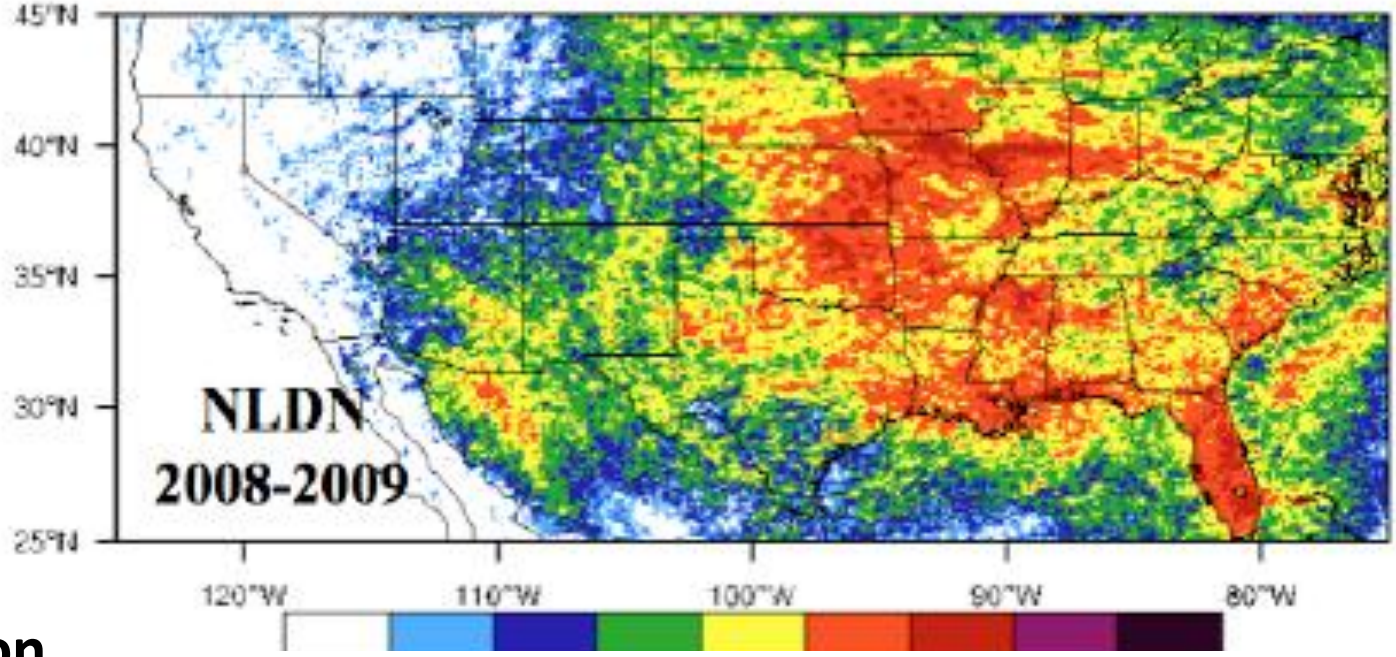
Courtesy Bob Holzworth

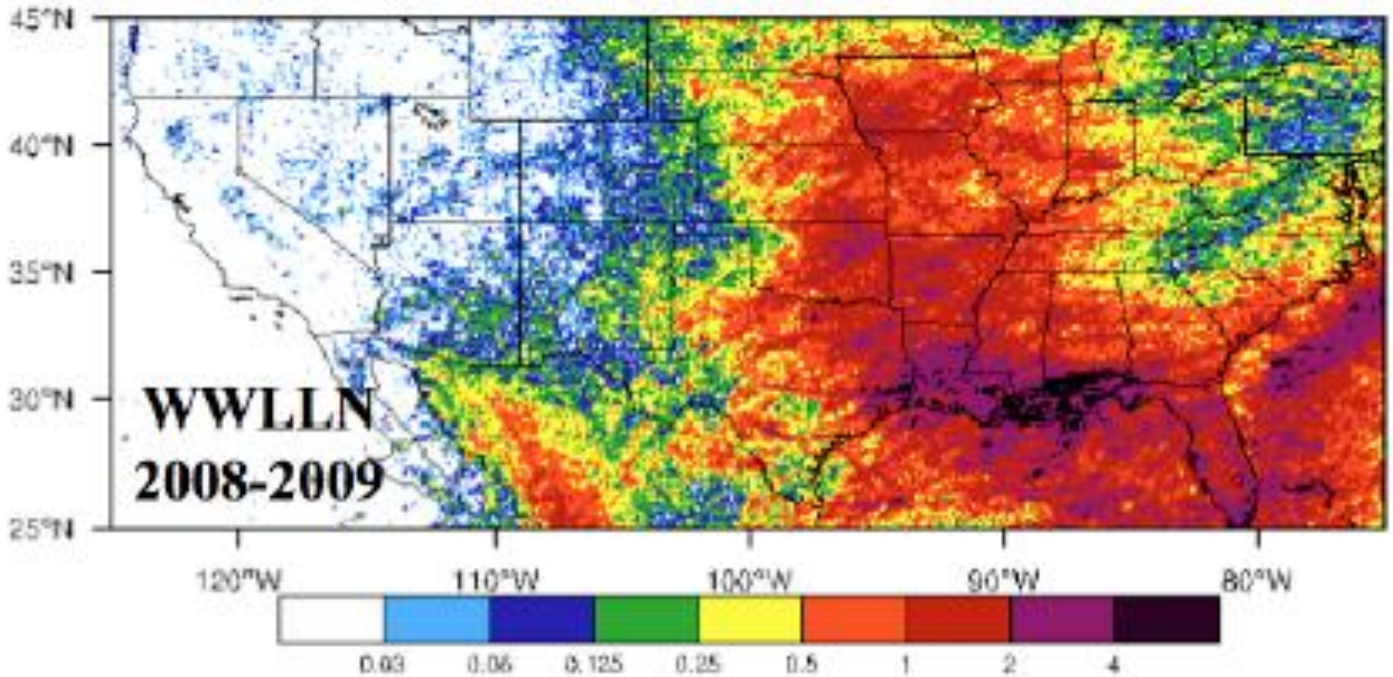
2010 RII Verification Results: Impact of Lightning Input (WWLLN)



Courtesy Mark DeMaria

Data Intercomparison





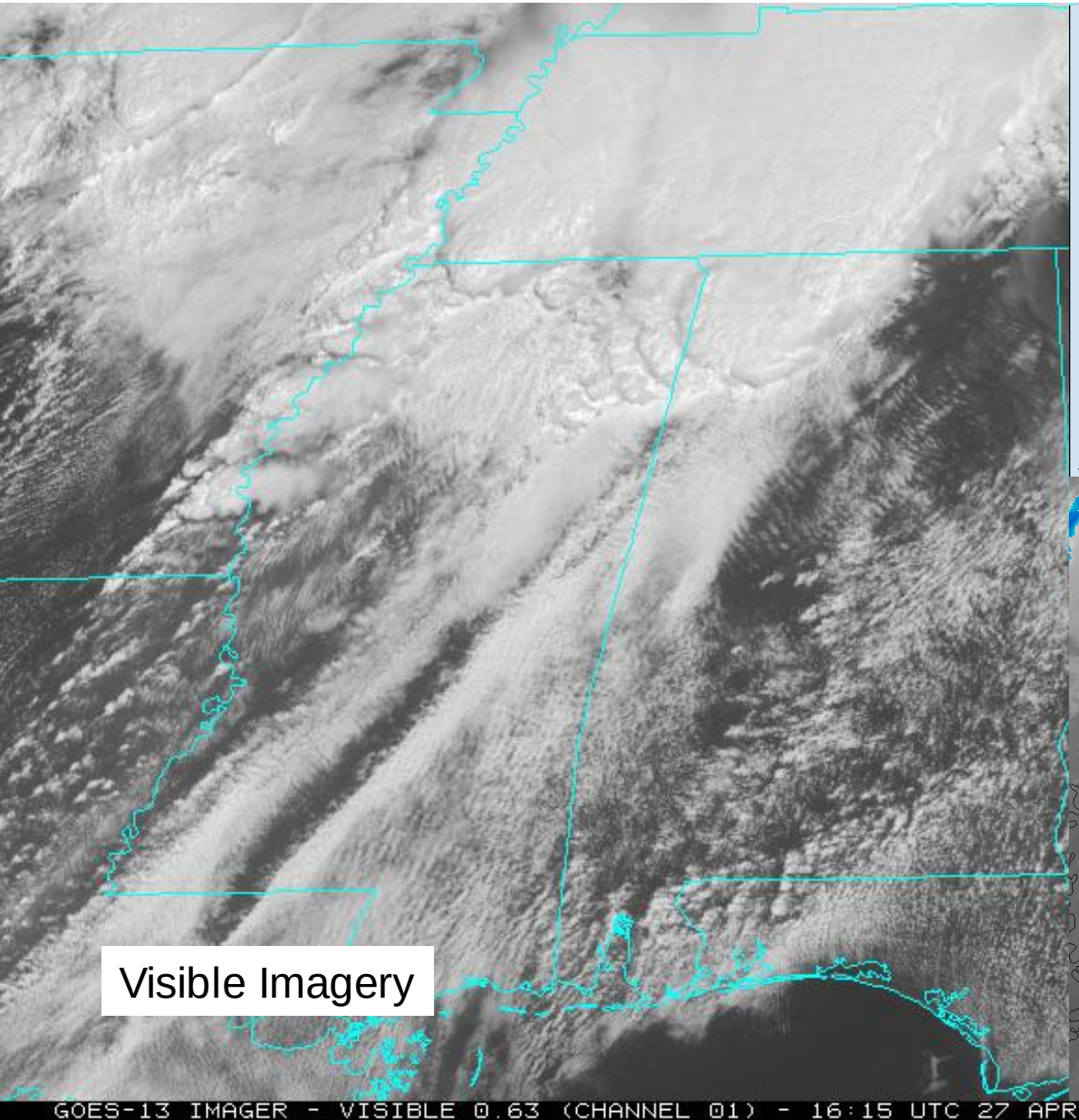
WWLLN Detection Efficiency compared to NLDN

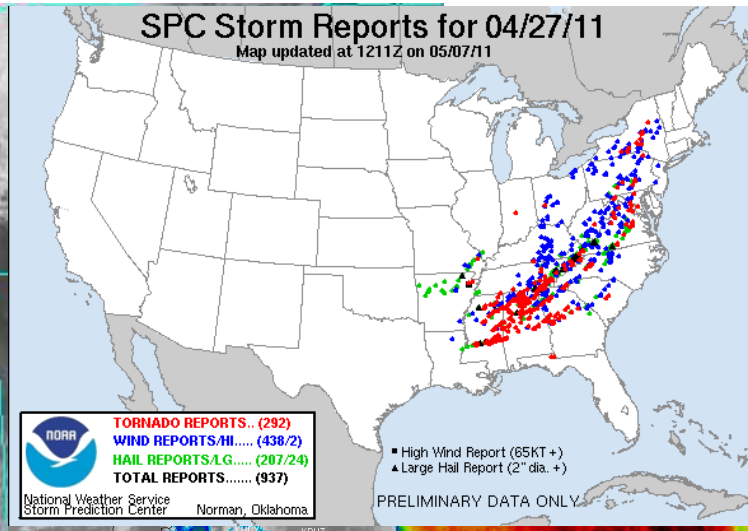
Year	2006-2007	2007-2008	2008-2009
All WWLLN flashes	2,732,366	3,228,444	6,154,394
All (CG) NLDN flashes	29,614,920	27,567,606	24,839,997
Coincidences	1,147,815	1,346,692	2,558,809
CG DE [%]	3.88	4.89	10.30
IC DE [%]	1.78	2.28	4.82
CG + IC DE [%]	2.31	2.93	6.19

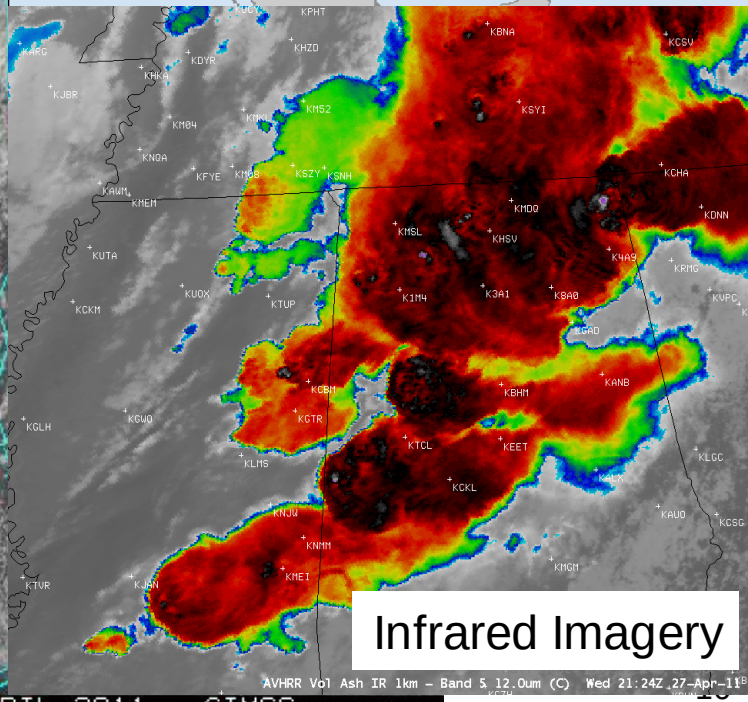
* Study done by independent researcher at UCLA (2010)

Courtesy Bob Holzworth

Tornado Outbreak April 27, 2011





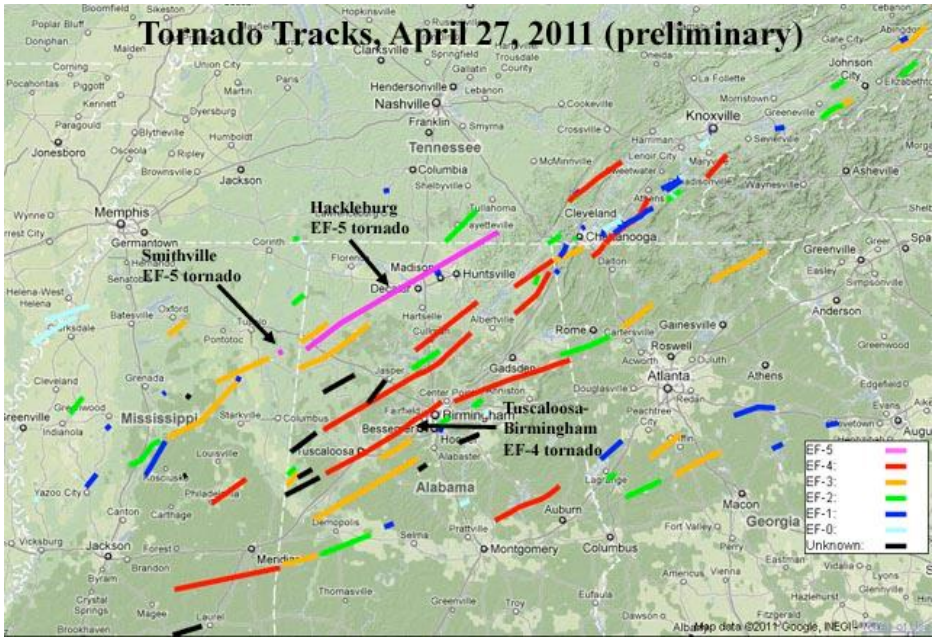


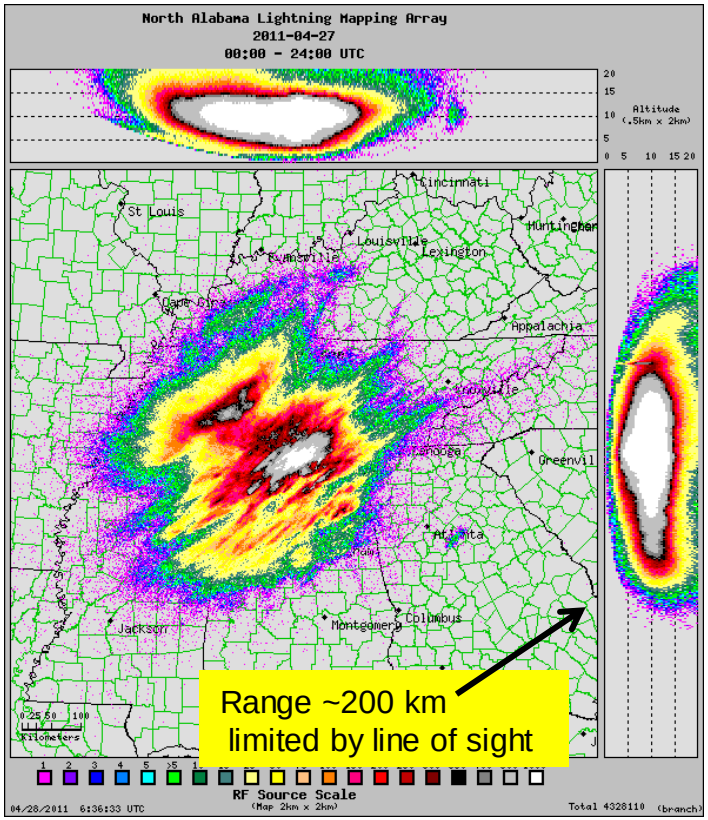
GLM Lightning Testbed 04/27/11

Proxy Data from the North Alabama VHF Lightning Mapping Array (LMA, 13-stations)

- GLM proxy for total lightning, forecaster demonstrations
- Research indicates potential to increase severe storm and tornado warning lead-time up to 20+ min
- NESDIS, OAR, NWS coordinating on a national demo field test to assess "lightning jump" algorithm

- *650,000 in N. Alabama without power for 1 week*
- *TVA replaced 353 transmission structures and lines in 74 days at cost of $25M*
- *Half of the 300+ fatalities in manufactured homes*





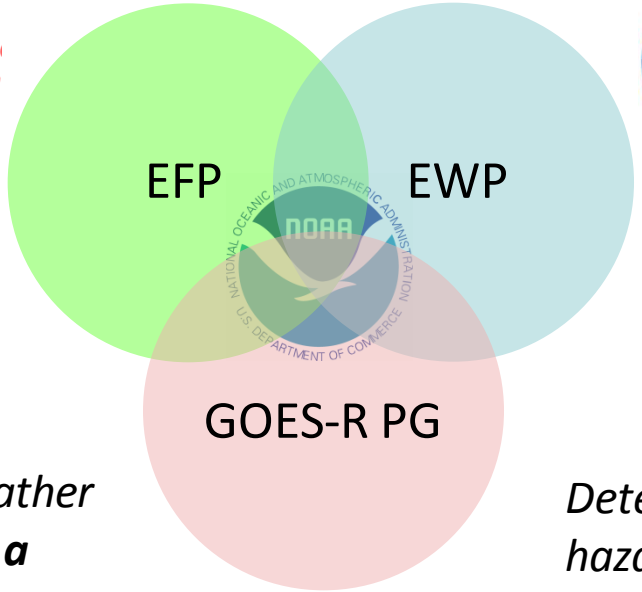
Tuscaloosa, AL Damage

NOAA's Hazardous Weather Testbed

Storm Prediction Center
Norman, Oklahoma

Experimental
Forecast
Program

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



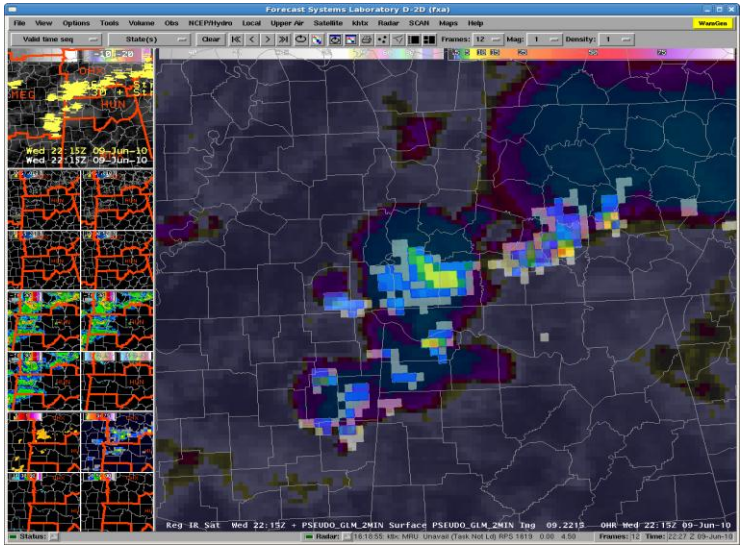
NATIONAL SEVERE STORMS LABORATORY

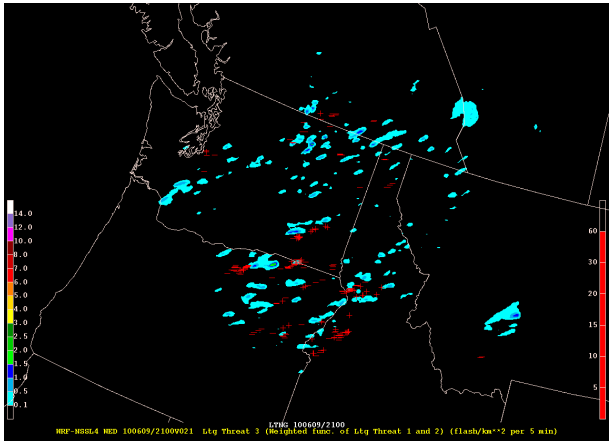
Experimental
Warning
Program

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

Total Lightning Detection

- Pseudo-GLM
  - Data from ground-based total lightning detection networks
    - Huntsville, AL; Washington, DC; Melbourne, FL; and Norman, OK
  - Raw data sorted into flashes and interpolated to an 8km grid
  - Running 2-minute average
- Simulated lightning threat
  - Based on NSSL-WRF 0Z 4km data
  - Estimates total lightning from vertical ice content and flux within cloud objects (see McCaul et al., 2009)





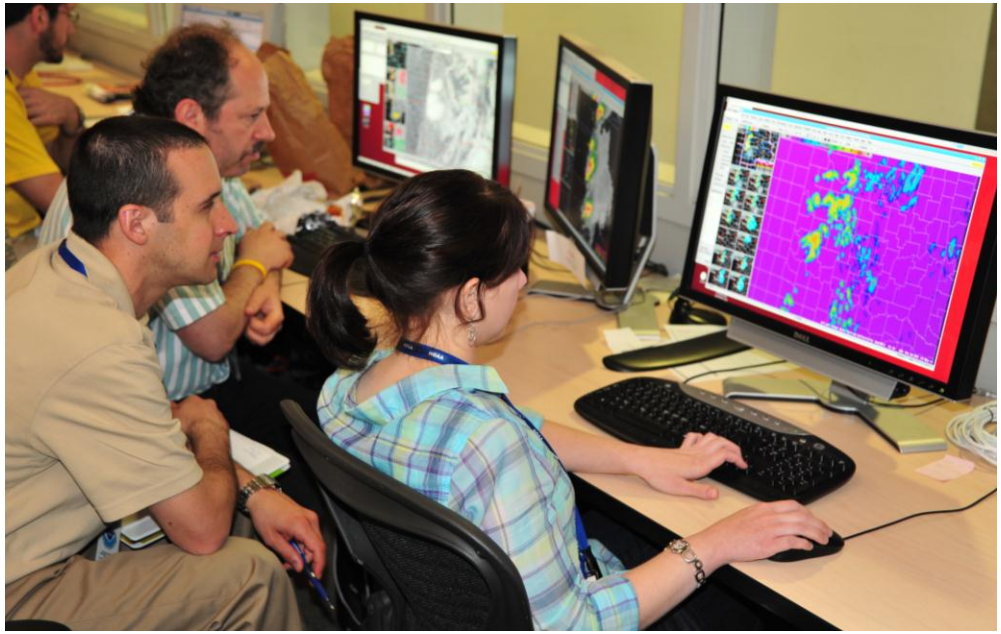
HWT: Forecaster Feedback from 2011 Lightning Detection

- "The total lightning data is an excellent tool for monitoring convection, I see much promise for such data in the future..."

- "I utilized it as a situational awareness product and then kept a watch on my tried and true radar practices to issue the warning. The PGLM data gave me more confidence in my warning…"

Courtesy Chris Siewert and Kristin Kuhlman

HWT: Forecaster Feedback from 2011 Lightning Detection



- "Total lightning data preceded the CG network anywhere from 10-40 minutes. I was able to quickly determine when flash rate was significantly increasing, and then compare with satellite and updraft/downdraft parameters for a nice big picture."

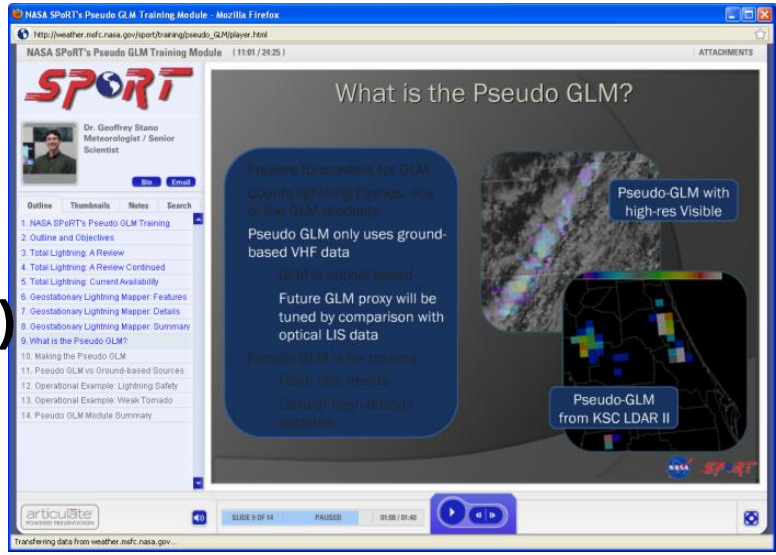
- "Coming into the day, I wasn't quite sure when or where to or why to use the data, but after using it. I really think it has a lot of functionality and is useful in warning operations. I look forward to it as a product from the GOES-R."

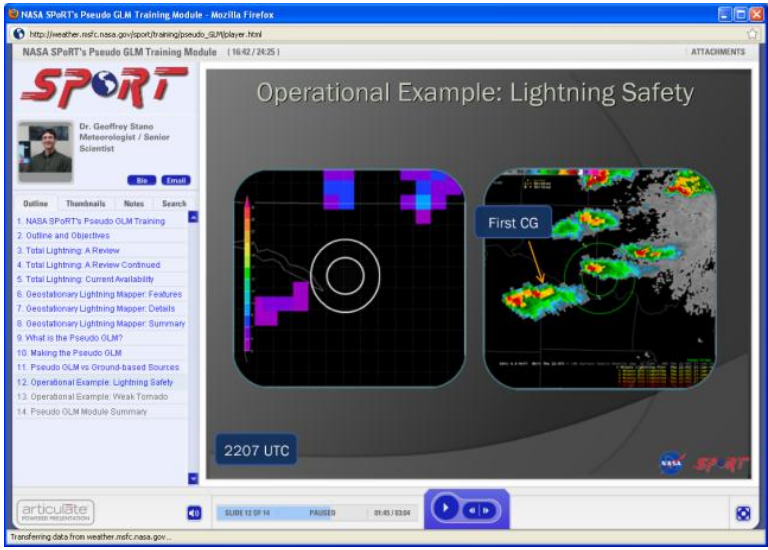
Courtesy Chris Siewert and Kristin Kuhlman

Currently Available Training

- Developed for 2010 & 2011 Spring Program
- Described three features
  - ✓ Total lightning
  - ✓ Geostationary Lightning Mapper (GLM)
  - ✓ Pseudo GLM product
- Included operational examples
- Intended for use before arrival
- Available on Learning Management System
- Available on SPoRT web page

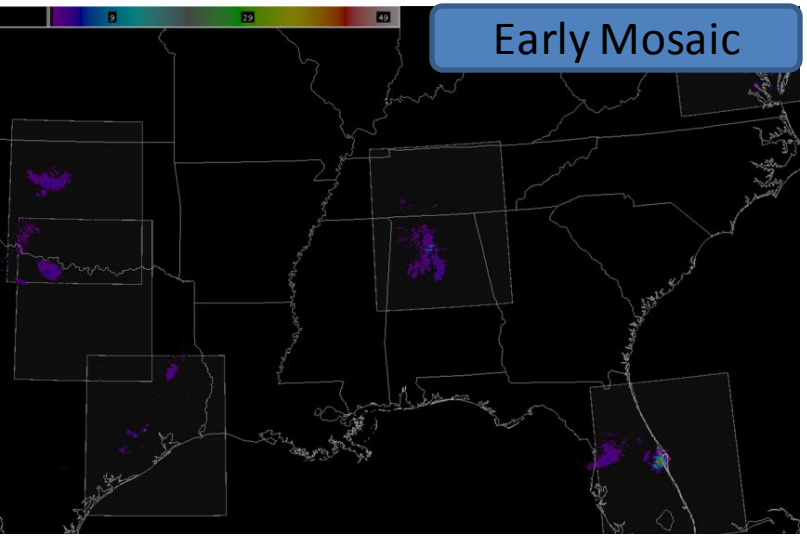
http://weather.msfc.nasa.gov/sport/training/

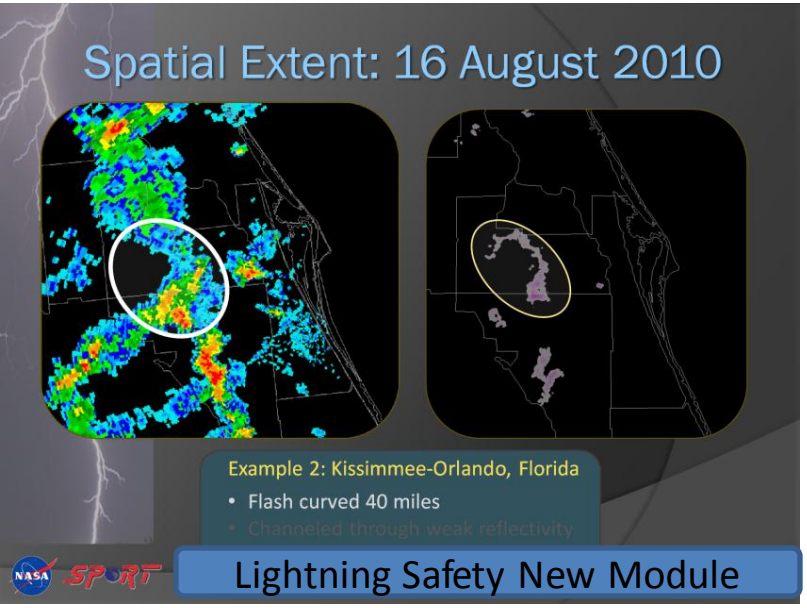




Courtesy Geoffrey Stano

Future Training Activities





New activities

- ➢ Mosaic product (all networks product)
- ➢ New visualizations (maximum density)

New training module

- ❖ Initial use for NWS forecasters
- ❖ Examples to be converted to PGLM

New training has more operational focus

- ✓ Severe weather applications
- ✓ Airport Weather Warnings
- ✓ Lightning safety applications
- ✓ Aim for release before Spring 2012
- ✓ Update current PGLM training

Courtesy Geoffrey Stano

The GLM-CHUVA Campaign

- CHUVA is a Brazilian-led field component of the Global Precipitation Measurement (GPM) mission that will investigate distinct precipitation regimes in Brazil using a series of regional Intensive Observation Period (IOP) field campaigns.
- The name (which means rain in Portuguese) is derived from the experiment title: ***C***loud processes of t***H***e main precipitation systems in Brazil: A contrib***U***tion to cloud resol***V***ing modeling and the the GPM (Glob***A***l Precipitation Measurement).

Participation in CHUVA

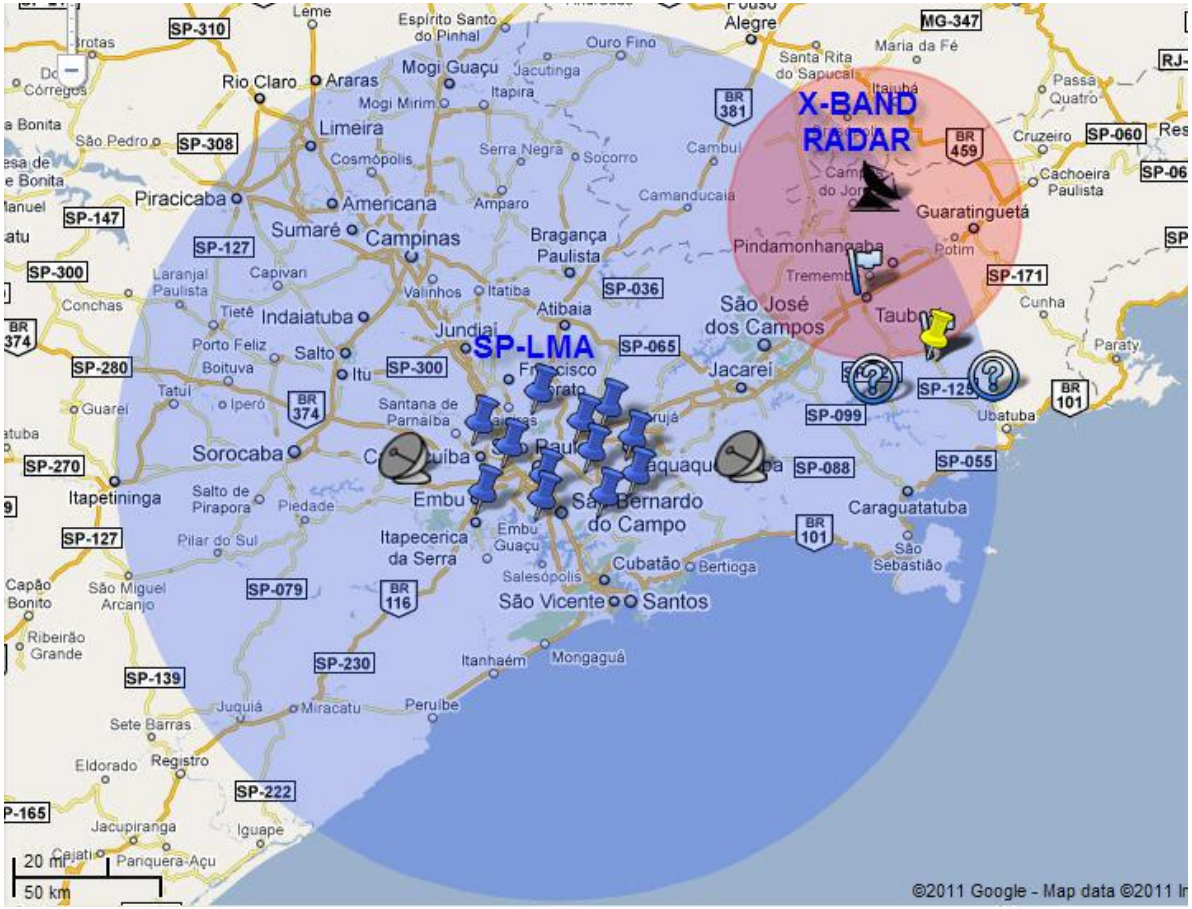
São Luiz do Paraitinga Campaign

Target of Opportunity of Field Campaign

- Leverage observing assets associated with CHUVA with U.S. supplied portable LMA network and European supplied LINET to generate proxy data for GLM and ABI that include total lightning and MSG SEVIRI (Spinning Enhanced Visible and Infrared Imager).
- Allow GLM and Combined AWG/R3 teams to better address and assess several areas of on-going research
  - Develop/Validate algorithms, applications, and proxy data
  - Assess validation systems performance.
- Intercompare and assess data from multiple lightning networks including LMA, LINET, WWLLN, ENTLN, RINDAT, ATDnet, WSI, GLD360, STARNET.
- Provide total lightning observations in support of the CHUVA campaign.
  - Storm electrification/physics
  - Storm – lightning relationships
  - Nowcasting applications

Network Configuration

São Paul Lightning Mapping Array (SPLMA)



- Network provides 3-D mapping out to 150 km and will overlap with CHUVA radar
- 2-D coverage realized out to 250+ km.
- Sites selected and surveyed (Dec 2009, Jul 2010, Jun 2011).
- Equipment shipped Sep 2011
- Deployment scheduled for Sept-Oct 2011.
- CHUVA IOP is 1 Nov to 23 Dec 2011.
- Plans coming together for extended observations in Jan and Feb 2012.

Courtesy Richard Blakeslee

Universidade Presbiteriana Mackenzie

Courtesy Scott Rudlosky, Jeff Bailey

Universidade Presbiteriana Mackenzie

Courtesy Scott Rudlosky, Jeff Bailey, Rachel Albrecht

Courtesy Scott Rudlosky, Jeff Bailey, Rachel Albrecht

Summary

- GLM Instrument Development on Track
- Proving Ground continues to grow and plans are in place for continued demonstrations of new applications/capabilities with forecasters
- Content being developed for forecaster and end user training
- Cal/Val tools in development for monitoring GLM performance