The Geostationary Lightning Mapper (GLM) on the GOES-R Series:
A new operational capability to improve storm forecasts and warnings

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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
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

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<tr>
<td>Risk Reduction</td>
<td>Calibration Working Group</td>
<td>Algorithm Working Group</td>
<td>Algorithm Working Group</td>
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# L1 Requirements for Lightning Detection

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

<table>
<thead>
<tr>
<th>Name</th>
<th>User &amp; Priority</th>
<th>Geographic Coverage</th>
<th>Product Resolution</th>
<th>Vertical Resolution</th>
<th>Horizontal Resolution</th>
<th>Mapping Accuracy</th>
<th>Range</th>
<th>Measurement Accuracy</th>
<th>Temporal Coverage</th>
<th>Temporal Precision</th>
<th>Qualify</th>
<th>Qualify</th>
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<tr>
<td>Lightning Detection - Events - Groups - Flashes</td>
<td>GOES-R</td>
<td>Full Disk</td>
<td>Sfc to Cloud Top.</td>
<td>10 km</td>
<td>5 km</td>
<td>Real Time</td>
<td>70% minimum Flash Detection Efficiency (FDE)</td>
<td>Continuous</td>
<td>20 sec</td>
<td>5% (Std. Dev. of FDE)</td>
<td>Day and night</td>
<td>Quantitative out to at least 65 degreesLZA and qualitative beyond</td>
</tr>
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- 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!

Plan View (CCD Array)
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)
Ground Truth Validation

Sustained ground validation, airborne campaigns, international collaborations

Oklahoma Lightning Mapping Array

11 station network, 50 km diameter
Real-time processing & display

Polarimetric Radar
Phased Array Radar

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**

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

**Experimental Warning Program**

*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
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” $2\sigma$ -Algorithm

Flash Count + Cell/Area ID

1. $\frac{d}{dt}(\text{flash rate}) = \text{DFRDT}$
2. $\mu, \sigma(\text{DFRDT})$

Jump in progress? YES

DFRDT < 0 NO

YES Lightning Jump

NO FR > $10 \text{ min}^{-1}$

YES Jump End

Return

NO

- 85 thunderstorms
- 69 non-severe
- 38 severe:
  - 22 – supercells
  - 2 – low topped supercells
  - 1 – LEWP
  - 2 – tropical
  - 2 – MCS
  - 8 – multicellular

Schultz, Petersen and Carey, Dec. 2009, JAMC (2$\sigma$)
Gatlin and Goodman, Jan. 2010, JTECH (1$\sigma$)
GLM Lightning Jump Algorithm:
(Gatlin and Goodman, JTECH, 2009; Schultz et al., JAMC, 2009)
Experimental Trending Implementation in AWIPS/SCAN

(SCAN Cell Table)

Cell S1

DC LMA total lightning

(July 04, 2007 at 21:36Z)

Courtesy Momoudou Ba
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