Nowcasting Applications for the GOES-R Geostationary Lightning Mapper (GLM)

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(GOES-R GLM Lightning Detection Science Team)

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http://www.goes-r.gov

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Outline

• GOES-R Mission Overview
• GLM Instrument
• GLM Applications
  – NWS Concept of Operations for Lightning
  – Severe Storms
  – Data Assimilation
  – Precipitation
• Summary

Geostationary Lightning Mapper (GLM)
Mission Overview

The GOES-R Series is the next generation of GOES satellites that will provide a major improvement in quality, quantity, and timeliness of data collected. The GOES-R Series will provide improved detection and observations of meteorological phenomena that directly impact public safety, protection of property, and economic health and development.

- Improve hurricane track & intensity forecasts
- Increase thunderstorm & tornado warning lead time
- Improve aviation flight route planning
- Data for long-term climate variability studies
- Improve solar flare warnings for communications and navigation disruptions
- More accurate monitoring of energetic particles responsible for radiation hazards to humans and spacecraft
- Better monitoring of Coronal Mass Ejections to improve geomagnetic storm forecasting
## GOES-R Series Products

### Baseline Products

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<thead>
<tr>
<th>Advanced Baseline Imager (ABI)</th>
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<tr>
<td>Aerosol Detection (Including Smoke and Dust)</td>
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<td>Aerosol Optical Depth (AOD)</td>
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<td>Legacy Vertical Moisture Profile</td>
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<td>Legacy Vertical Temperature Profile</td>
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<td>Radiances</td>
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<td>Rainfall Rate/QPE</td>
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<td>Reflected Shortwave Radiation: TOA</td>
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<td>Total Precipitable Water</td>
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<td>Volcanic Ash: Detection and Height</td>
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*KPP (Key Performance Paramater)

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<th>Geostationary Lightning Mapper (GLM)</th>
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<td>Lightning Detection: Events, Groups &amp; Flashes</td>
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<th>Space Environment In-Situ Suite (SEISS)</th>
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<td>Magnetospheric Electrons &amp; Protons: Med &amp; High Energy</td>
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<td>Solar and Galactic Protons</td>
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<th>Magnetometer (MAG)</th>
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<td>Geomagnetic Field</td>
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<tr>
<th>Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)</th>
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<td>Solar Flux: EUV</td>
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<td>Solar Flux: X-ray Irradiance</td>
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<tr>
<th>Solar Ultraviolet Imager (SUVI)</th>
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<td>Solar EUV Imagery</td>
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### Future Capabilities

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<th>Advanced Baseline Imager (ABI)</th>
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<td>Absorbed Shortwave Radiation: Surface</td>
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<td>Aerosol Particle Size</td>
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<td>Aircraft Icing Threat</td>
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<td>Cloud Ice Water Path</td>
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<td>Currents: Offshore Downward Longwave Radiation: Surface</td>
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<tr>
<td>Enhanced “V”/Overshooting Top Detection</td>
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<td>Flood/Standing Water</td>
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<td>Ice Cover</td>
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<td>Low Cloud and Fog</td>
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<td>Ozone Total</td>
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<td>Probability of Rainfall</td>
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<td>Rainfall Potential</td>
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<td>Sea and Lake Ice: Age</td>
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<tr>
<td>Sea and Lake Ice: Concentration</td>
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<tr>
<td>Sea and Lake Ice: Motion</td>
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<td>Snow Depth (Over Plains)</td>
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<td>Surface Albedo</td>
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<td>Surface Emissivity</td>
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<td>Tropopause Folding Turbulence Prediction</td>
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<tr>
<td>Upward Longwave Radiation: Surface</td>
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<tr>
<td>Upward Longwave Radiation: TOA</td>
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<tr>
<td>Vegetation Fraction: Green</td>
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<tr>
<td>Vegetation Index</td>
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<td>Visibility</td>
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GLM Observations of Severe Storms

May 3 1999 Oklahoma Tornado Outbreak
1-minute of observations from TRMM/LIS
Total Lightning Dominates During OK Tornado: 3 May 1999

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

In-cloud lightning dominates tornadic supercell ... 95% of the lightning is in-cloud
OK Tornado Outbreak 3 May 1999

Active lightning region in tornadic supercell ... correlates with radar hook echo and velocity couplet
Lightning Detection

Table 3. 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.

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<tr>
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<th>POD</th>
<th>FAR</th>
<th>CSI</th>
<th>HSS</th>
<th>lead time (all)</th>
<th>lead time (tornado)</th>
</tr>
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<tbody>
<tr>
<td>Total lightning</td>
<td>79%</td>
<td>36%</td>
<td>55%</td>
<td>0.71</td>
<td>20.65 mins</td>
<td>21.32 mins</td>
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Schultz et al., 2011

National Average for Tornado warning lead-time is only 14 minutes

Operational national demonstration, Phase I April-September 2012, of the total lightning algorithm via the Hazardous Weather Testbed (at request of NWS)
GLM Applications

- GLM – Lightning mapping, alerts
- GLM + ABI – Severe and high impact weather
- GLM + ABI + GPM - Precipitation
- GLM + NWP – Data Assimilation
- GLM Fused Products for Nowcasting
  – with Radar, Ground-Based Lightning (CG, IC), NWP
NWS Concept of Operations and Operational Requirements for Lightning Data

Source: NWS
Added GLM Value for Severe Storm Operations and Decision Aids

- Small Air Mass Thunderstorm
  - Huntsville “Monrovia” Microburst, 20 July 1986
  - Pulse air mass storm, 65 dBZ max Z
  - Pea size hail, 40 kt outflow
  - 110 total lightning, 6 CG strikes

Cloud top temperatures continue cooling after reaching the mature stage as cirrus anvil fills imager fov

From Wakimoto and Bringi, 1988; Photos, K. Knupp; cloud sequence at right from Ted Fujita.
Lightning Connection to Storm Updraft, Storm Growth and Decay

- Total Lightning — responds to updraft velocity and concentration, phase, type of hydrometeors, integrated flux of particles
- Dual-Pol WX Radar — responds to concentration, size, phase, and type of hydrometeors—integrated over small volumes

Growth, Zdr > 0
Glaciated, Zdr < 0

Adapted from Goodman et al, GRL, 1988; Wakimoto and Bringi, MWR, 1988; Kingsmill and Wakimoto, MWR, 1991; Zeng et al., 2001; Gatlin and Goodman, JTECH, 2010
GLM “Deep Dive” Validation Tool
CHUVA Campaign validated lightning data set over Sao Paulo, Brazil 2011-2012

• Science Goals:
  – Provide total lightning observations in support of the CHUVA field campaign.
  – Provide unique proxy data for the GLM and ABI by making correlated measurements with SEVIRI.
  – Intercompare with other lightning networks-performance assessments for on-orbit val.

• CHUVA- (“Cloud processes of the main precipitation systems in Brazil: A contribution to cloud resolving modeling and to the GPM (GlobAl Precipitation Measurement)”)
Total Lightning Coincidence Studies
18 mos. Coincidence with LIS (2010-2011)

ENTLN (at left):
• Large spatial variability
• Best coverage from west TX to about 200km off East Coast
• Very little coverage in Atlantic or S. America

WWLLN (below):
• Smooth, consistent coverage (but low total lightning detection efficiency)
Satellite Proving Grounds for User Readiness

- Bridges the gap between research and operations
- Utilizing current systems (satellite, terrestrial, or model/synthetic) to emulate future capabilities
- Infusing products and techniques into NWS operations with emphasis on AWIPS and transitioning to AWIPS-II.
- Putting prototype products in hands of forecasters
- Keeping lines of communication open between developers and forecasters
- Allowing end user to have say in final product, how it is displayed and integrated into operations
GOES-R Proving Ground Applications and Product Demonstrations

Baseline Products
- Cloud and Moisture Imagery
- Volcanic Ash: Detection and Height
- Hurricane Intensity
- Lightning Detection: Events, Groups & Flashes
- Rainfall Rate/QPE
- Total Precipitable Water
- Fire/Hot Spot Characterization
- Cloud Top Phase
- Cloud Top Height
- Cloud Top Temperature
- Derived Motion Winds
- Aerosol Detection
- Aerosol Optical Depth

Future Capabilities of High Priority Desired by NWS
- Aircraft Icing Threat
- Convective Initiation
- Enhanced “V”/Overshooting Top Detection
- Low Cloud and Fog
- SO₂ Detection
GOES-R PG Partnership with NOAA’s Hazardous Weather Testbed

works with users to accelerate use of products

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

Demonstrate and evaluate GOES-R products and capabilities within an operational warning environment
GOES-R Proving Ground

• Proving Ground Paper published in July issue of the Bulletin of the American Meteorology Society
• Highlights HWT and NHC demonstrations
• Forecaster Feedback
Total Lightning Demonstrations at the GOES-R Proving Ground

• **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**
  – Implemented in NSSL-WRF, OU/CAPS ensemble, and High Resolution Rapid Refresh (HRRR)
  – Estimates total lightning from vertical ice content and flux within cloud objects (see McCaul et al., 2009)
Total Lightning Data Used Within NWP Models Provides Better Initial Conditions

- GLM Total lightning proxy data from the ENTLN were assimilated into the WRF-ARW model at cloud-resolving scales.

- **Improved Initial Conditions** can provide a better physical background at analysis time towards improving short term high impact weather forecasts (~3h).

- Lightning data also used to limit the presence of spurious convection (and cold pools). Key in radar data sparse areas.

- To alleviate the need to use proxies for lightning in the model (e.g. lightning threats), **full charging/discharge physics** are currently being implemented into WRF-ARW within the NSSL 2-moment microphysics.

*Courtesy of A. Fierro, CIMSS/NOAA*
Proving Ground Forecaster Feedback: 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 …the PGLM (pseudo GLM) data gave me more confidence in my warning.”
- “Total lightning data preceded the CG network (NLDN) 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.”

“We saw several instances where the total lightning was picking up on storms before the AWIPS lightning [NLDN] program picked up on them. One could see the utility of this in the future, bringing with it a potential for lightning statements and potentially lightning based warnings.”

Pat Spoden (SOO, NWSFO Paducah, KY)
NWS Vision to Integrate ABI and GLM Products with Other Data and Models

A Potential Operational Example: Convective Initiation/Severe Wx

How can we integrate the information in future tools?

Why NWS needs this?

- Situational Awareness
- Warning confidence
- Decision Support (venues)

Situational Awareness:
User comment: ‘Cloud Top Cooling product is an excellent source of enhancing the situational awareness for future convective initiation, particularly in rapid scan mode’.

AWC Testbed forecaster
(June 2012)
NWS Vision to Integrate ABI and GLM Products with Other Data and Models

A Potential Data Fusion Example: QPE
Can we do a Blended TPW-like QPE?

Why NWS needs this?
Atmospheric Rivers
Heavy rain/snow
Flood/Blizzard
Drought
Convective Storms
Transportation
Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates

(Robert Adler and Nai-Yu Wang)

Limitations of infrared-based rain estimates:

-- Only “see” the top of precipitating cloud;
   (though cloud growth or structure can be considered)
-- May treat cold cirrus clouds as intense convection;
-- May misrepresent convective rain: location, area
   and rain intensity;
   (especially under relatively uniform cold cloud shields in mature MCSs)
(but geostationary rain estimation still very important because of temporal
resolution and rapid access)

How would lightning information help?
-- Provide information associated with convection location and intensity (~
   rainfall rate)
-- Lightning information will be used to define convective cores “unseen” by
   IR and eliminate IR cloud top minima incorrectly identified as “convective”
Identification of Convective Cores by Adding Lightning

* Estimates of Convective ID evaluated by PR;
* CST and CSTL run in an area (600x600 km²);
* 2000 cases (> 20 lightning flashes) are selected;

Lightning improves convective detection (POD); lowers FAR


Lightning and Precipitation

• The IR-lightning Convective-Stratiform Technique (CSTL) shows significant improvements when compared with the Self-Calibrating Real-Time GOES-R Rainfall Algorithm (SCaMPR).

• The CSTL can catch the convective or heavy precipitation region very nicely and even comparable to passive microwave TMI retrievals.

Instant rainfall estimates of a squall-line system by (a) passive microwave (TMI), (b) precipitation radar (PR), (c) SCaMPR, and (d) CSTL-lightning algorithm (CSTL) on 20-km resolution (courtesy Bob Adler, Nai-Yu Wang).
GPM-era Unified Precipitation Processing (Concept)

- GCOM-W (AMSR-2)
- MEGHA TR. (MADRAS)
- GPM (DPR&GMI)
- NOAA-POES (AMSU&MHS)
- MET-OP (AMSU&MHS)
- NPP/JPSS (ATMS)
- DMSP/DWSS (?) (SSMIS)
- TBD
- GOES-R (ABI, GLM)

NOAA GPM-PPS (Cross calibrated MW Radiances, Precipitation Products & NOAA Unique Products (MIRS)) (OSPO/NESDIS)

PPS Products (L1-C & NUPS)

Multi-sensor Precipitation Algorithms MPE, CMORPH & Q2 (GAUGE+WSR-88D + GOES-R)

GAUGE

WSR-88D

NWS/RFC/WFO
NWS/Centers
FNMOC
NESDIS
JCSDA
CLASS

Legend
Sensor or satellite
Processor
End User
Summary

Pre-launch demonstrations with GLM proxy data benefits users to prepare them to fully exploit all GOES-R instruments and capabilities

- **Exploratory Algorithms and Future Capabilities**
  - New Products and Applications
  - Multisensor-Multiplatform
  - Nowcasing and Data Assimilation

- **GOES-R Product Demonstrations and Training**
  - GOES-R capabilities demonstrated and evaluated by users
  - Forecaster Evaluation and Feedback