



GOES-R Geostationary Lightning Mapper (GLM): Algorithm and Instrument Report

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with contributions from the GOES-R GLM AWG and Science Team

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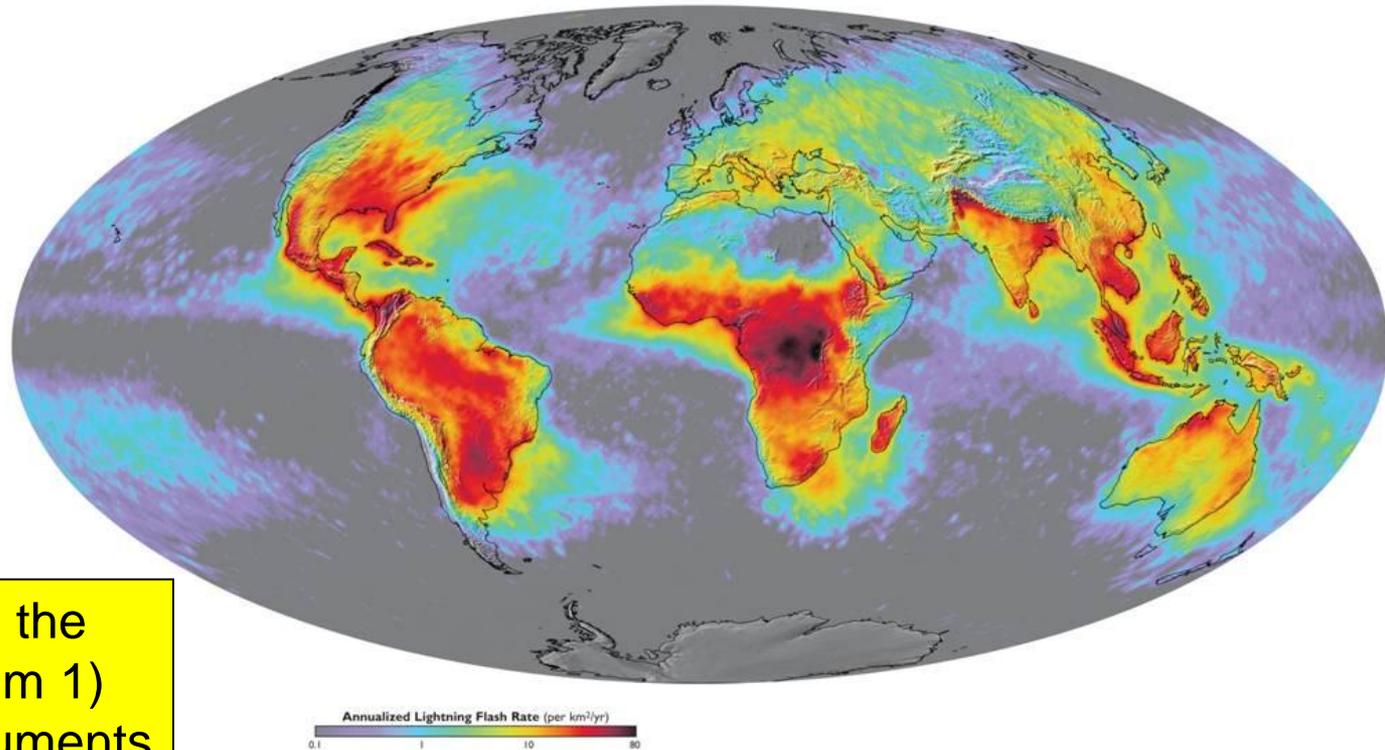
<http://www.goes-r.gov>

AMS 7th Annual Symposium on Future National Operational
Environmental Satellite Systems-JPSS and GOES-R

Seattle, WA
23-25 January, 2011

Outline of Presentation

1. GLM Instrument Update
2. Performance Cal/Val
3. Science and Applications
4. User Readiness Demonstrations
5. Summary

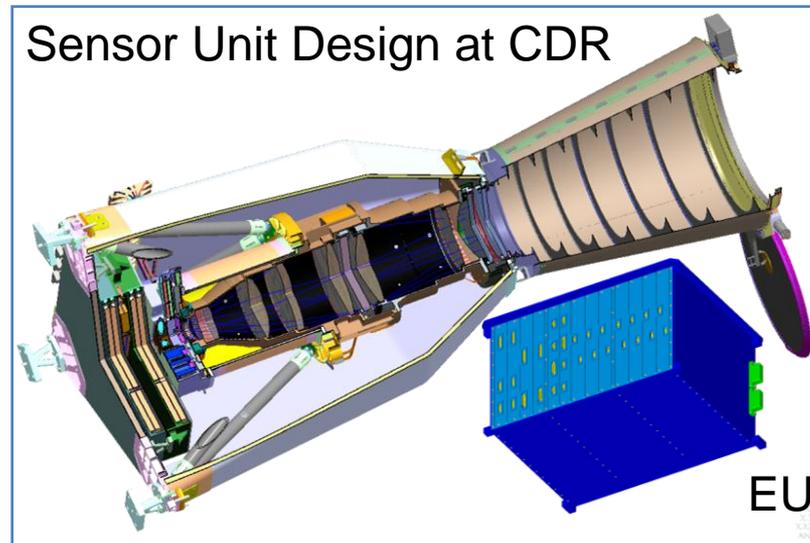
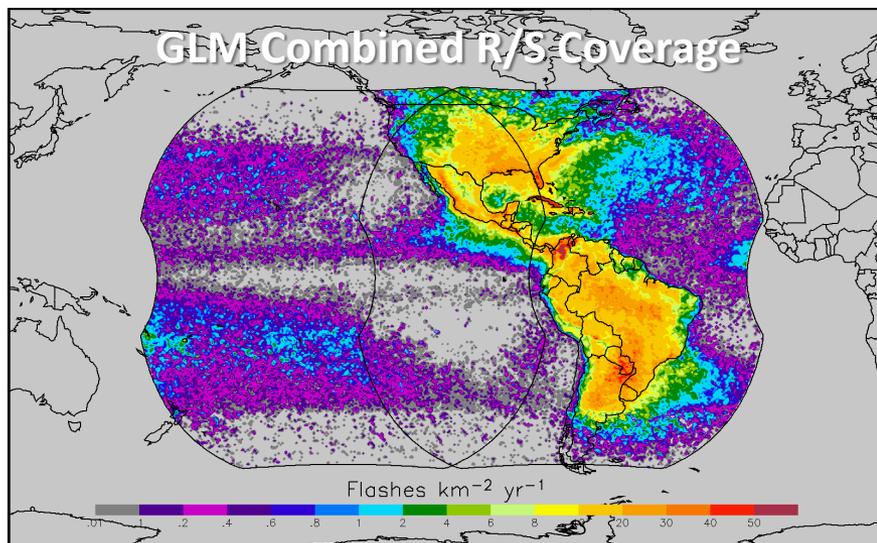
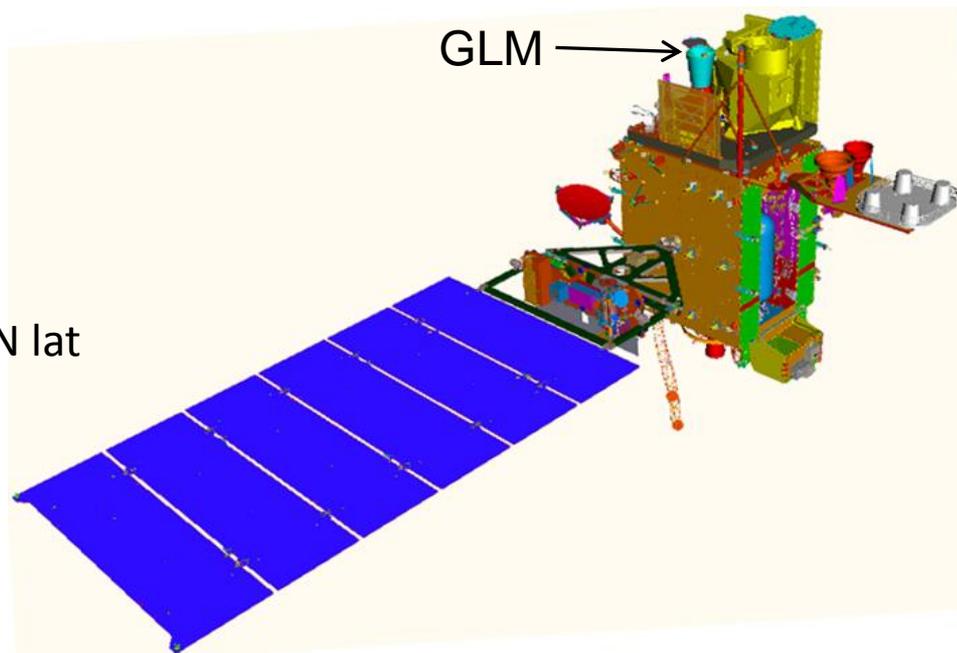


Global lightning from the
NASA OTD (Orbcomm 1)
and TRMM/LIS instruments

GOES-R Geostationary Lightning Mapper (GLM)

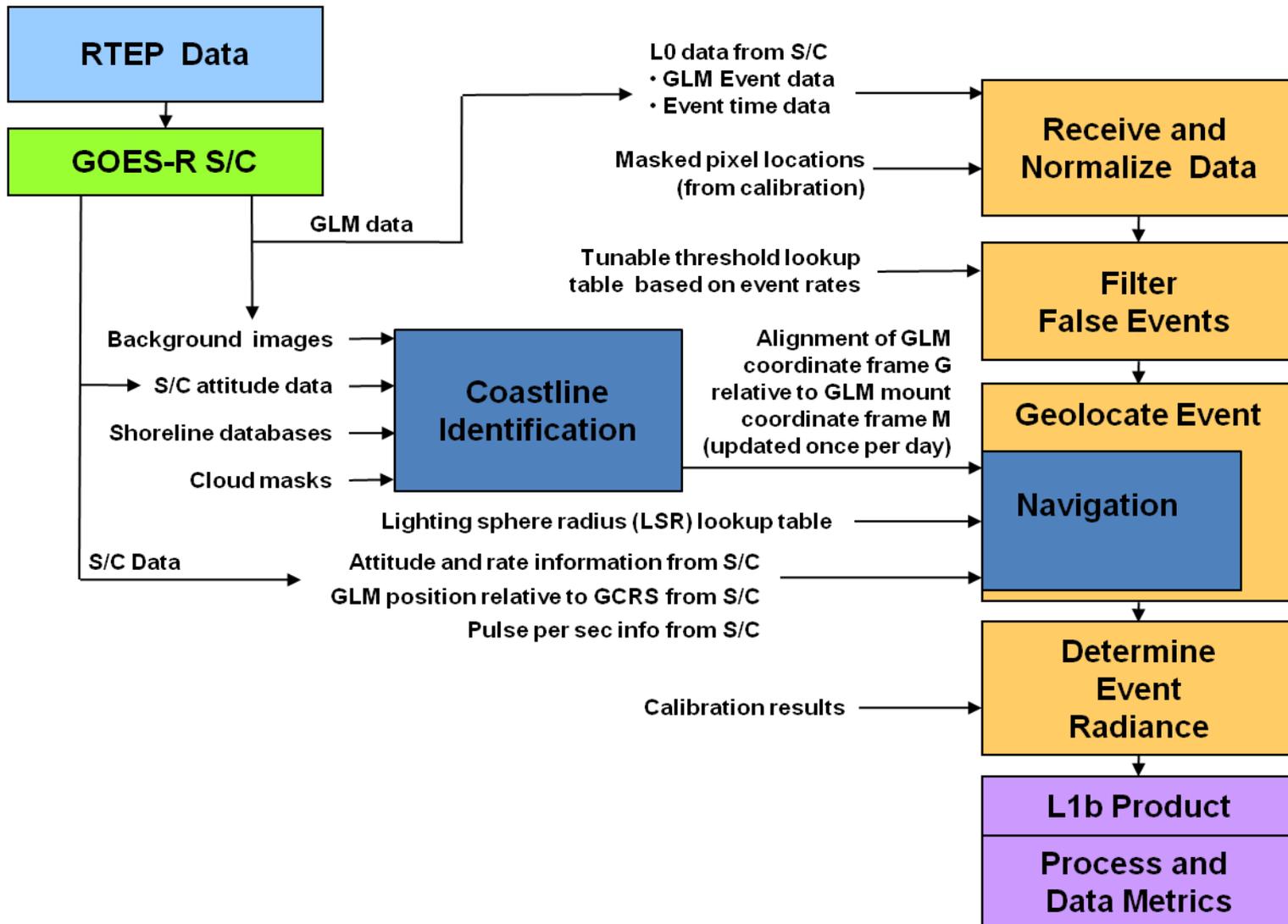
GLM Characteristics

- Staring CCD imager (1372x1300 pixels)
 - Single band 777.4 nm
 - 2 ms frame rate
 - 7.7 Mbps downlink data rate
- Near uniform spatial resolution to 52 deg N lat
 - 8 km nadir to 14 km at edge
 - 70-90% flash detection
- Product Availability (event, group, flash)
 - < 20 sec total latency
 - satellite rebroadcast and internet



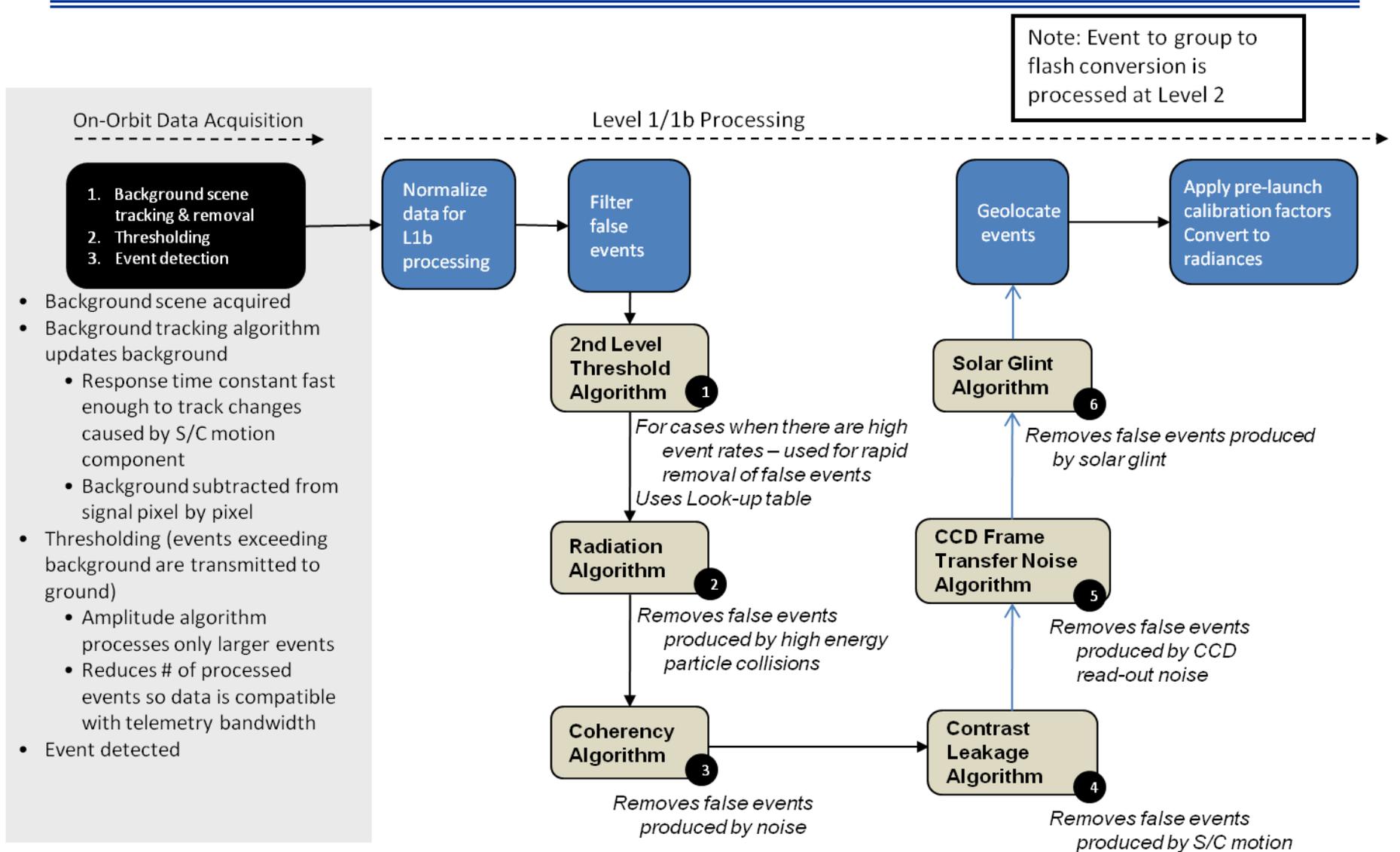


GLM GPA Functions and Interfaces





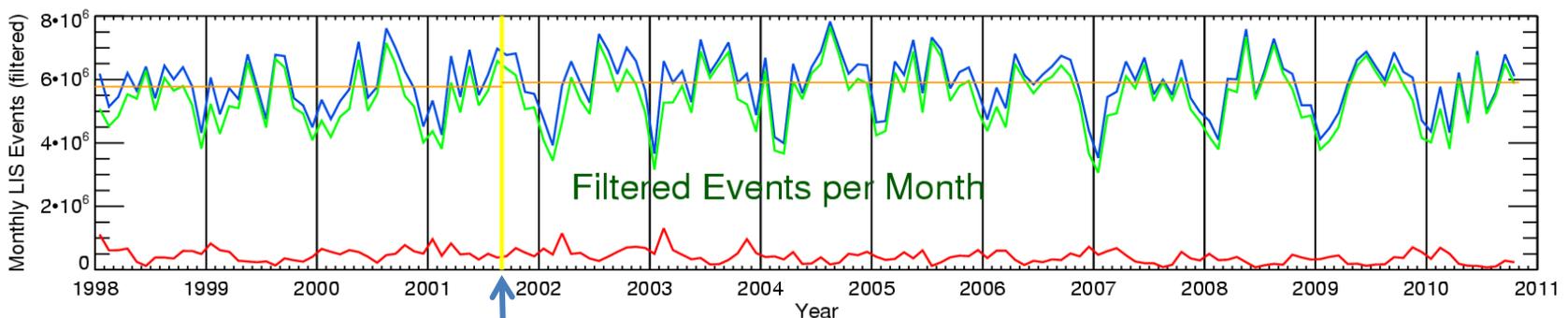
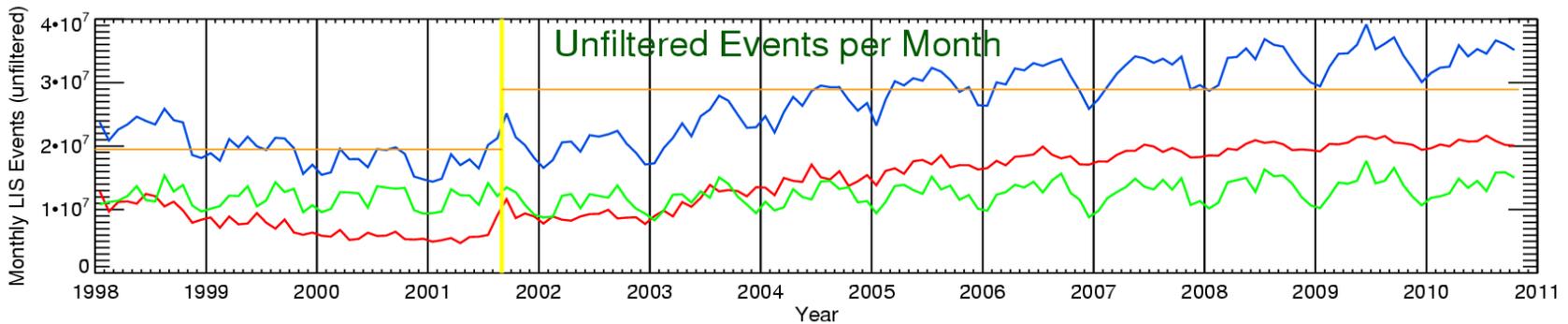
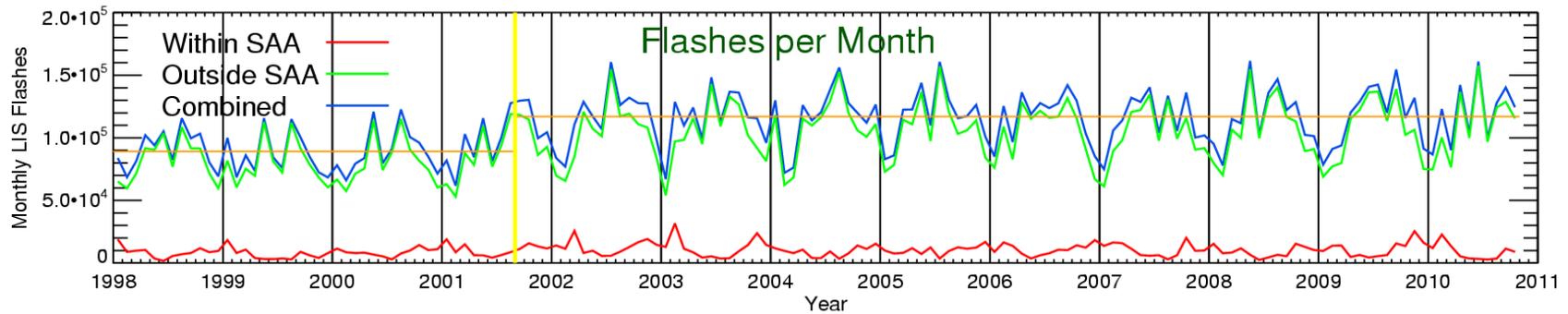
Ground Processing Algorithm Block Diagram



Monitoring GLM Performance

- Use LIS observations as data base
 - Similar design
 - 13 years of data
- Monitor pixel array
 - Monitor individual pixel ability to detect events
- Lightning statistics (regime/location/season)
 - Event, group, flash radiance
 - Group, flash size
 - Events per group
 - Events, Groups per flash
 - Event duration
- Background radiance calibration
 - Monitor background calibration stability

LIS Monthly Trend: 1998-2011



TRMM Boost Aug 2001

Deep Convective Cloud Technique (DCCT)* Applied to LIS Background Radiances

Purpose: Determine if Deep Convective Cloud Technique (DCCT) can be used as a stable target for monitoring stability of GLM to meet Measurement Precision Requirements

*References:

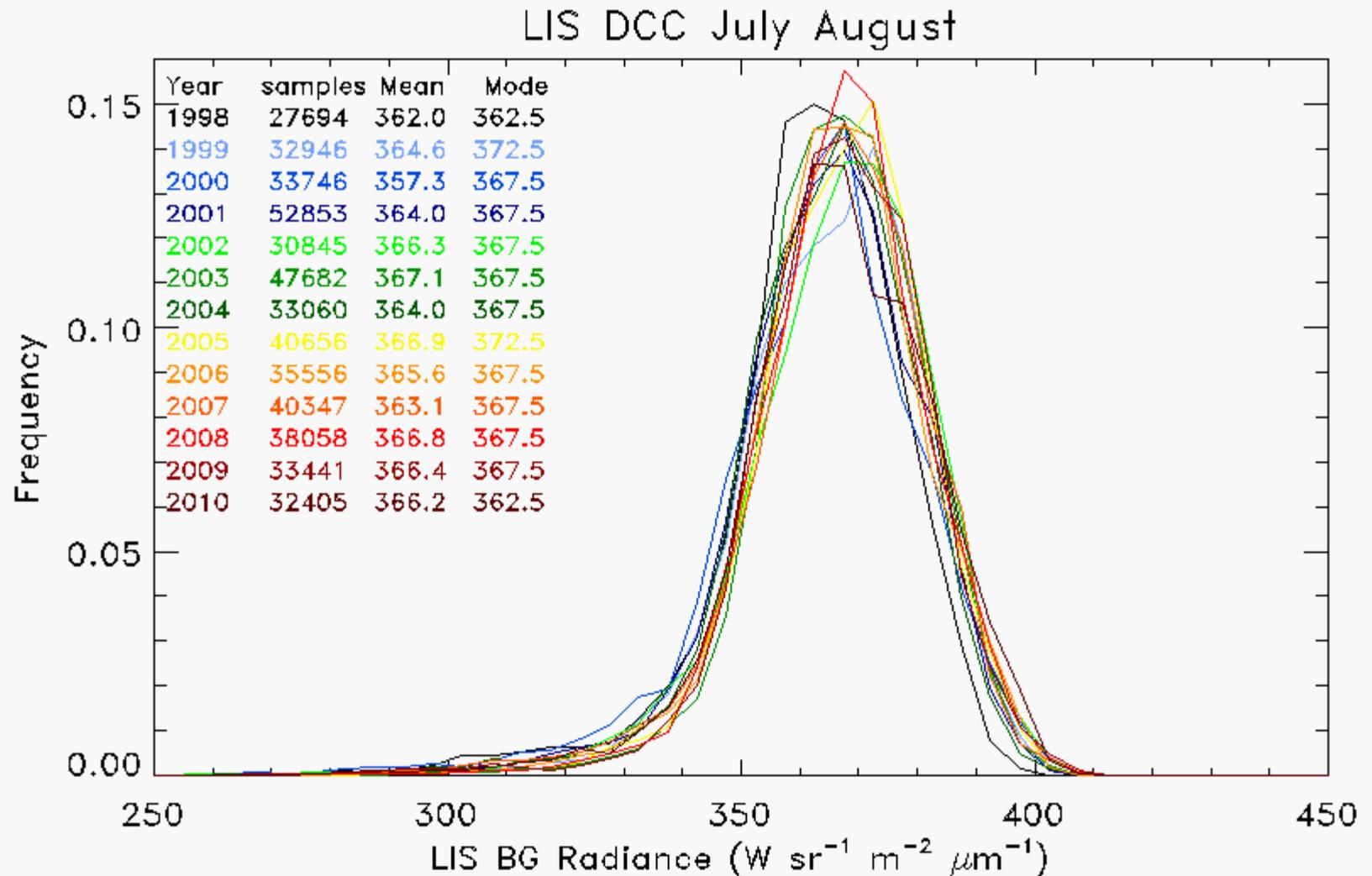
- Doelling, D. R., V. Chakrapani, P. Minnis, L. Nguyen, The calibration of NOAA-AVHRR visible radiances with VIRS. *Proc. AMS 11th Conf. Atmos. Radiation, Madison, WI, Oct 15 –18, 614-617, 2001.*
- Minnis, P., L. Nguyen, D. R. Doelling, D. F. Young, W. F. Miller, Rapid calibration of operational and research meteorological satellite imagers, Part I: Use of the TRMM VIRS or ERS-2 ATSR-2 as a reference. *J. Atmos. Ocean. Technol.* 19, 1233-1249, 2002.

Methodology

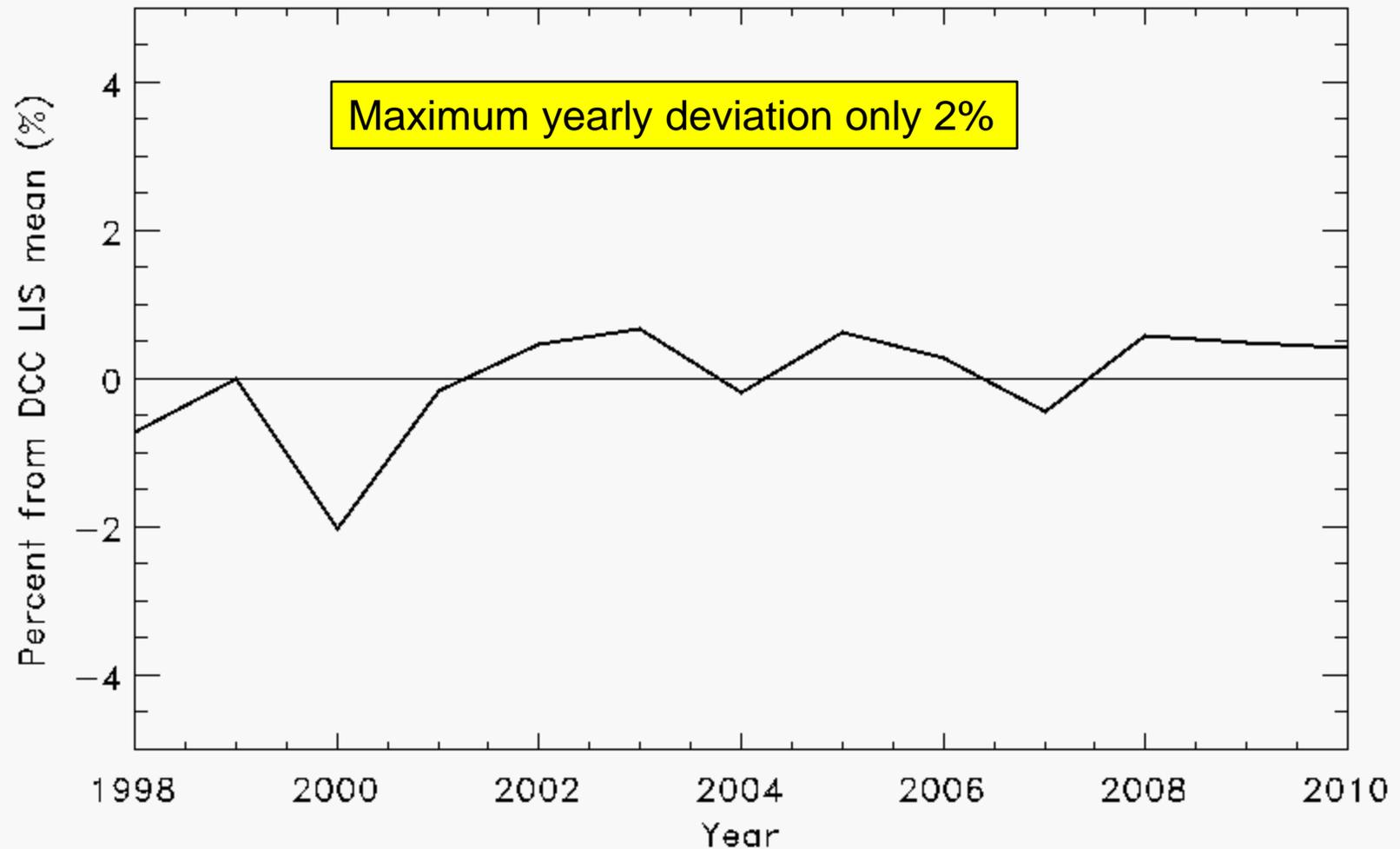
For each July and August from 1998 through 2010:

- Convert LIS observed counts for each background pixel into radiance values
- Get adjusted LIS radiance (ρ)
 - adjust to SZA of 0° (divide by cosine of SZA)
 - assume Lambertian surface
- Determine coincident LIS and VIRS pixels

LIS BG DCC Radiance Distribution for July and August (1998-2010)



Trend of LIS BG DCC radiances



The yearly percentage difference of the mean LIS DCC radiance from the mean year is shown by the solid black line.

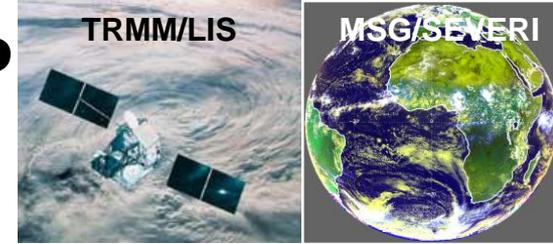
DCCT Conclusions

- The DCCT method to monitor radiance measurement precision is successfully applied to TRMM LIS and VIRS for the period 1998-2010
 - The maximum yearly deviation is 2%
 - The maximum deviation occurs in 2000
 - A slight increase in mean observed LIS BG DCC radiance is observed – however, this trend is not evident if only post-boost pixels are used
 - Instrument appears stable and well within 5% over its lifetime
- The DCCT method appears applicable to monitor GOES-R GLM radiance measurement precision using ABI and GLM (“AWG deep dive tool”).
- The DCCT method may also be applicable to GLM in the GSICS framework for GEO-LEO radiance inter-calibration



CHUVA Ground Validation IOP

Sao Paulo, Brazil 2011-2012



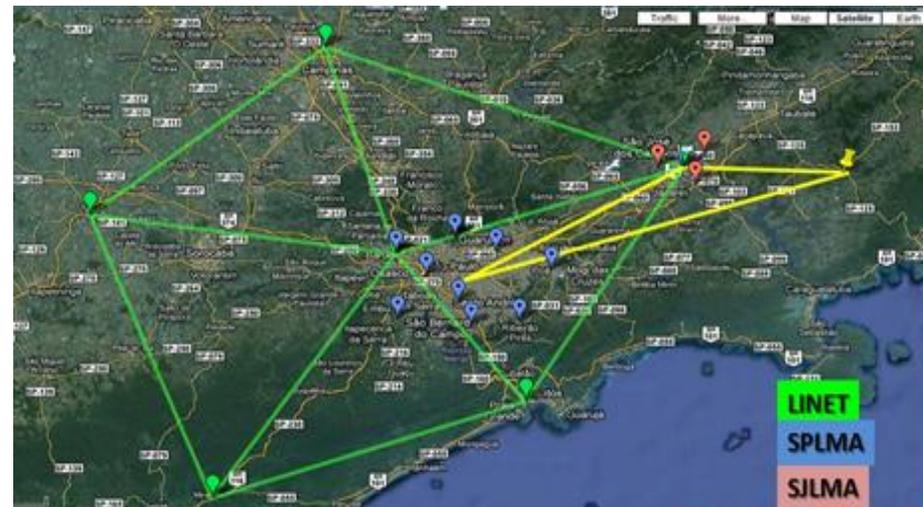
- **Field Campaign**

- Leverage observing assets associated with CHUVA with U.S. supplied portable LMA network (and European supplied LINET) to generate proxy data sets for GLM and ABI that include total lightning (LIS and ground-based) and SEVERI.
- Allow GLM and Combined AWG/Science teams to better address and assess several areas of on-going research

- **Science Objectives:**

- Algorithm and Proxy Data Validation
- Validation Systems Performance Assessment
- Storm Electrification/Physics
- Applications for GLM+ABI+...

- **Key scientific measurements:** VHF 3-D Lightning Mapping Array (LMA), LINET, TRMM/LIS, MSG SEVERI (ABI proxy data), high speed digital video, VLF lightning networks, dual-pol radar, electric field change, airplane in-situ microphysics, and ancillary meteorological data



Partners and Collaborators

GLM Science Team

Richard Blakeslee, NASA (LMA lead)

Larry Carey, [Jeff Bailey](#), UAH (NOAA funded to deploy LMA)

John Hall, UAH (Web support for real time network operations)

Monte Bateman, USRA (proxy data, other analyses)

Many others (and other GOES-R teams) (algorithm and proxy val)

InPE (CPTEC, ELAT) and USP

Luiz Machado, InPE/CPTEC (overall CHUVA lead)

[Rachel Albrecht](#), InPE/CPTEC

[Carlos Morales](#), USP (Electrification processes lead)

[Osmar Pinto Jr.](#), InPE/ELAT Research Group

EUMETSAT MTG Lighting Imager Science Team

Hartmut Hoeller, DLR (LINET lead) (Collaborator)

Commercial Data Providers

Vaisala LS8000, WeatherBug WTLN (Collaborator)

Project Schedule

Calendar Year 2011 (cont.)

February final site selection surveys, LMA in procurement

August Initial checkout and ICAE

- Attend ICAE (August 8-12, Rio de Janeiro, Brazil)
- LMA Deployment follow-up (as necessary) following ICAE

Aug-Dec Network operation (operation will continue ~1 yr)

- CHUVA Intensive Observation Period (1 Nov to 23 Dec 2011)
- Network operations from Aug 2011-June/July 2012

Calendar Year 2012

Jan-June Network operations continue

June/July End operations

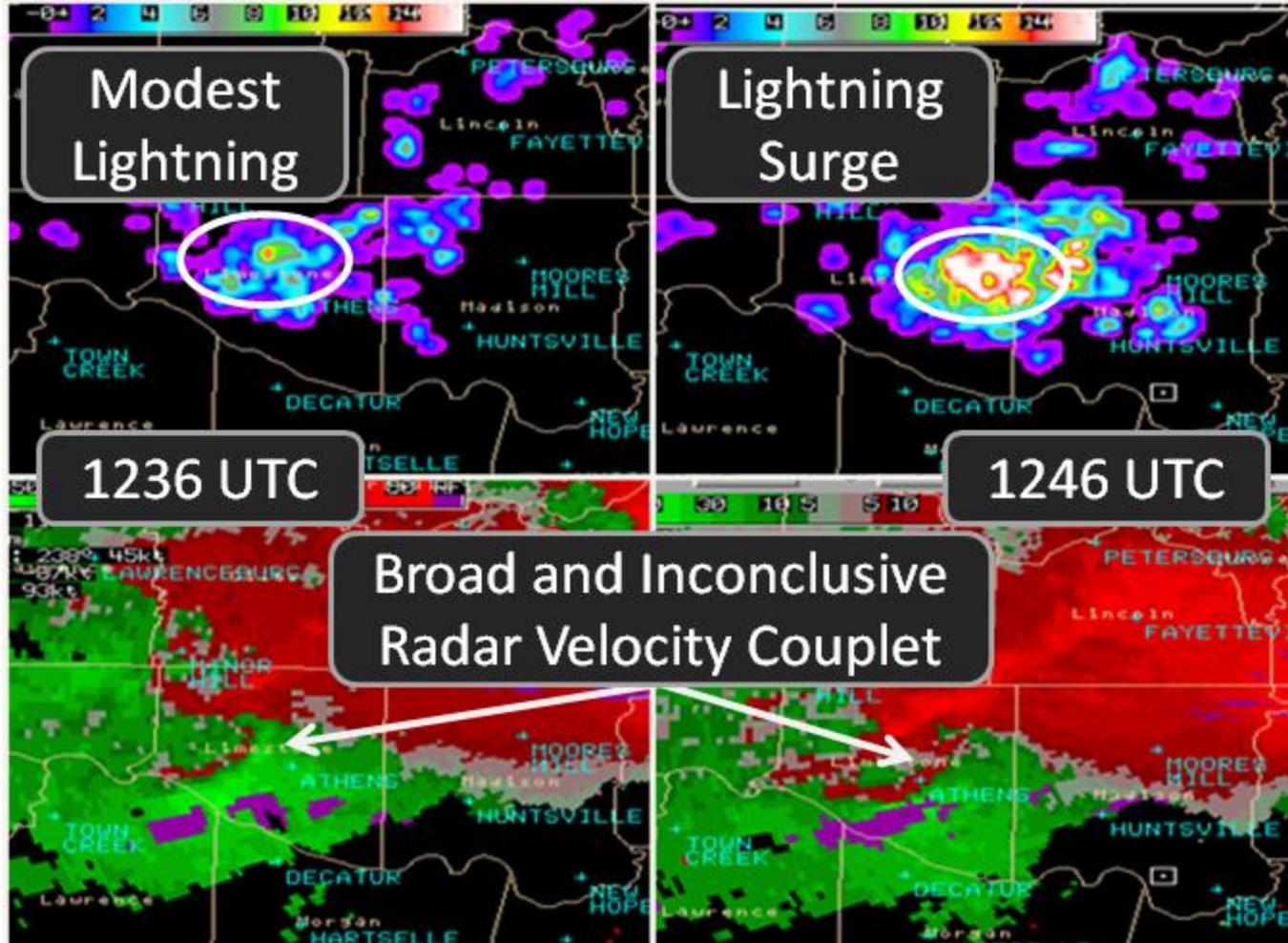
- Exact end date TBD
- De-install and pack-up stations
- Ship LMA back to the United States

Natural Hazards and Lightning

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



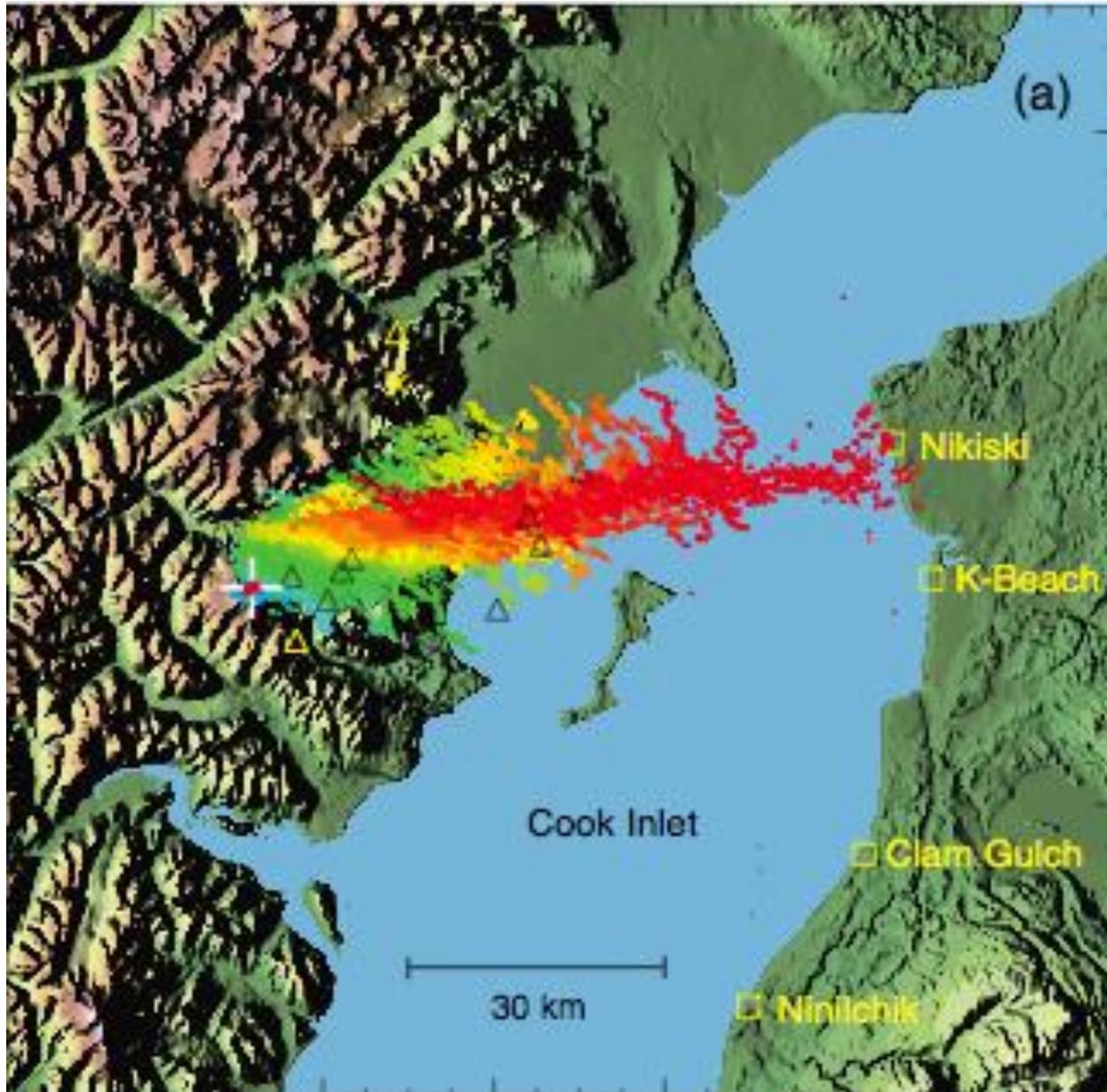
Total Lightning Increases with Storm Growth and Updraft Intensification



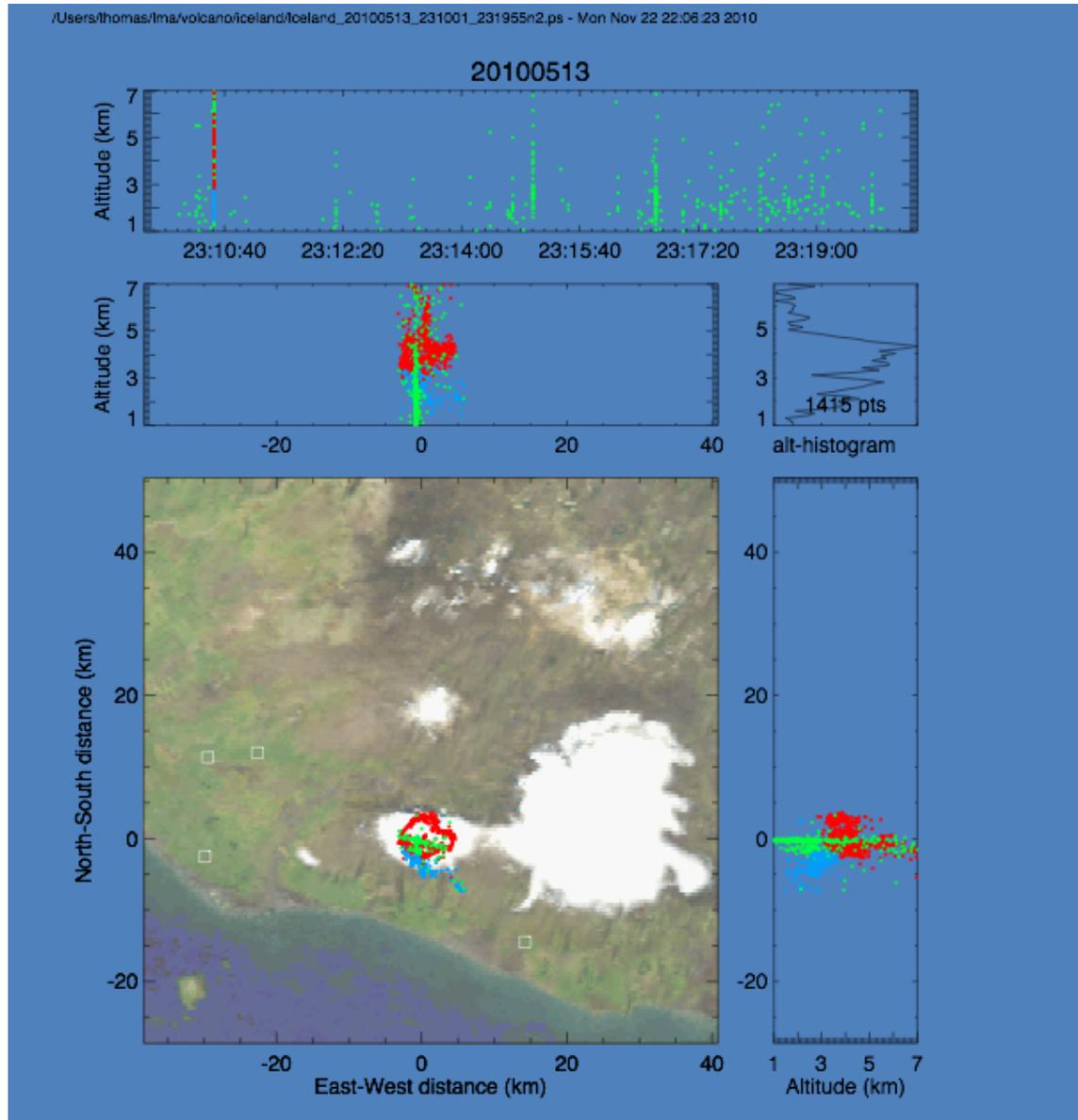
Aviation-Convective Weather Hazards

- Since there are few surface-based radar and/or other meteorological observations covering most of the oceans, convective intensity and associated aviation hazard potential (i.e., turbulence, icing, lightning, volcanic ash) are evaluated using satellites
- Ultimately, the goal is a combined GOES-R GLM/ABI algorithm for the detection of aviation hazards associated with convection. Such an algorithm should improve aviation routing and safety in the vicinity of thunderstorms, thus reducing the number of related incident reports and suspected storm-related accidents

Volcanic Lightning: Eruption of Redoubt Volcano



Volcanic Lightning: Eyjafjallajökull Eruption, Iceland 2010

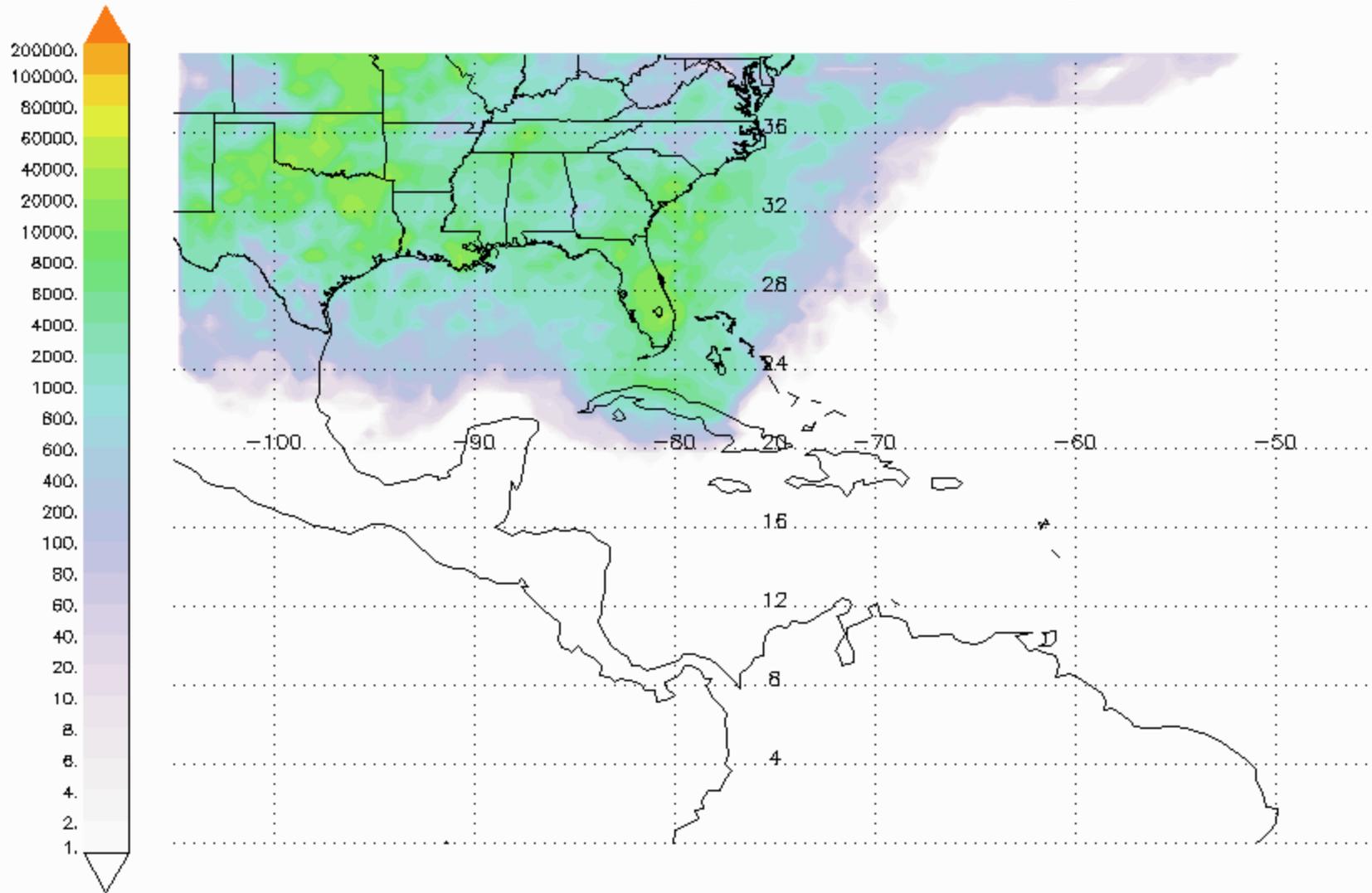


GLD-360 'Validation': GLM Proxy over Remote Regions

- Within the lightning science and applications community, there is a need for lightning data over the oceans and other remote regions (i.e., global).
 - E.g., enroute aviation applications, hurricane studies, GLM proxy
- LIS (OTD) is an ideal proxy for GLM but there is no temporal continuity (snapshots).
- What are the potential options for global (or very large remote region)?
 - World Wide Lightning Location Network (WWLLN)
 - Vaisala Global Lightning Dataset (GLD360)
 - Other ground-based VLF-based long-range networks
- WWLLN is more mature and better characterized
 - 30% cloud-to-ground (CG) flash detection efficiency (DE) for peak current > 30 kA
 - CG Flash Location Accuracy (LA) $\sim 15 - 30$ km

NLDN Lightning: August-September-October 2010

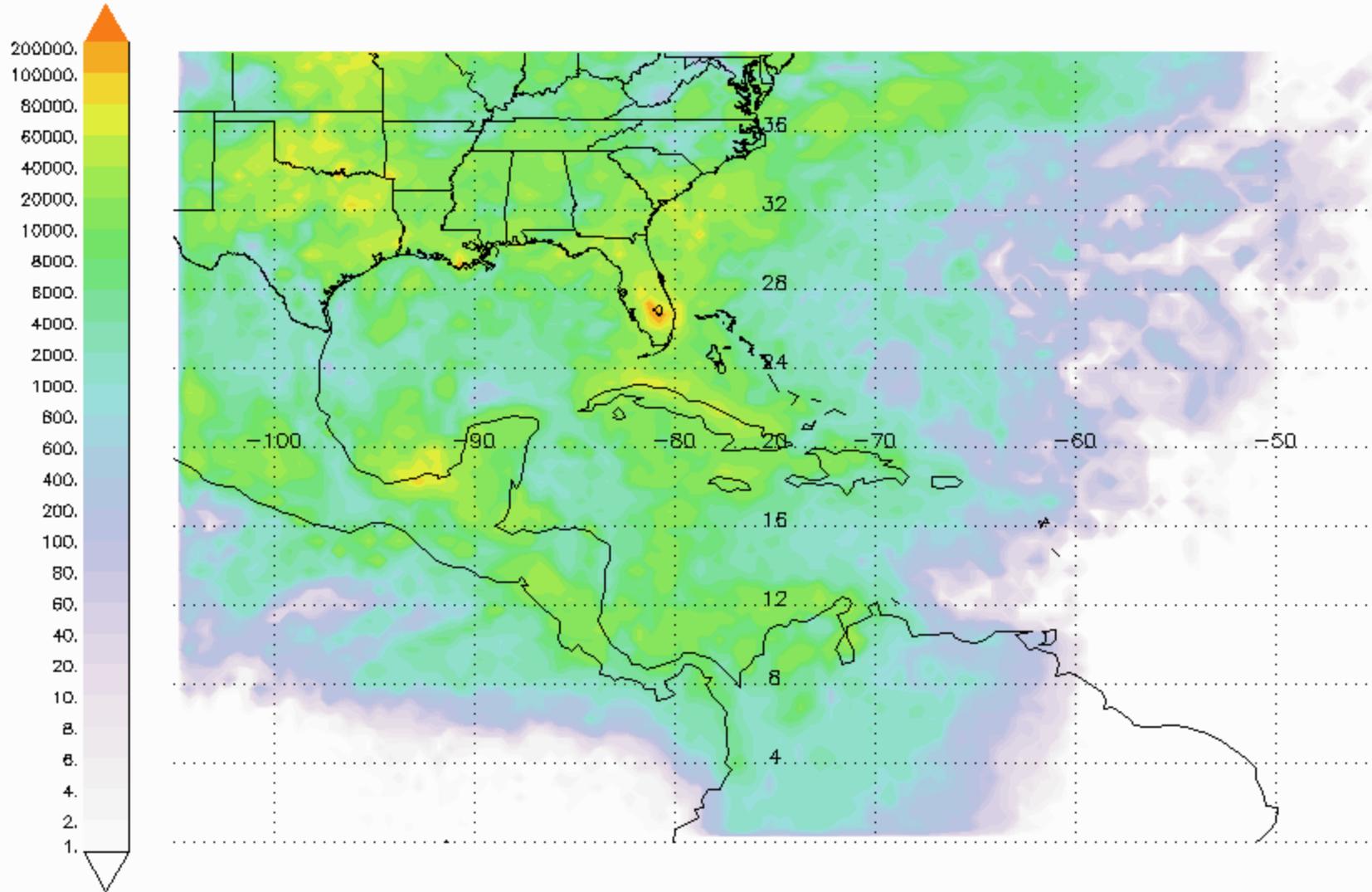
NLDN Stroke Count (0.5 deg): 59 overlap days from Aug–Oct 2010



* Overlap days: 8/17/2010, 8/24/2010 – 9/15/2010, 9/21/2010 – 10/5/2010, 10/12/2010 – 10/31/2010

WTLN Lightning: August-September-October 2010

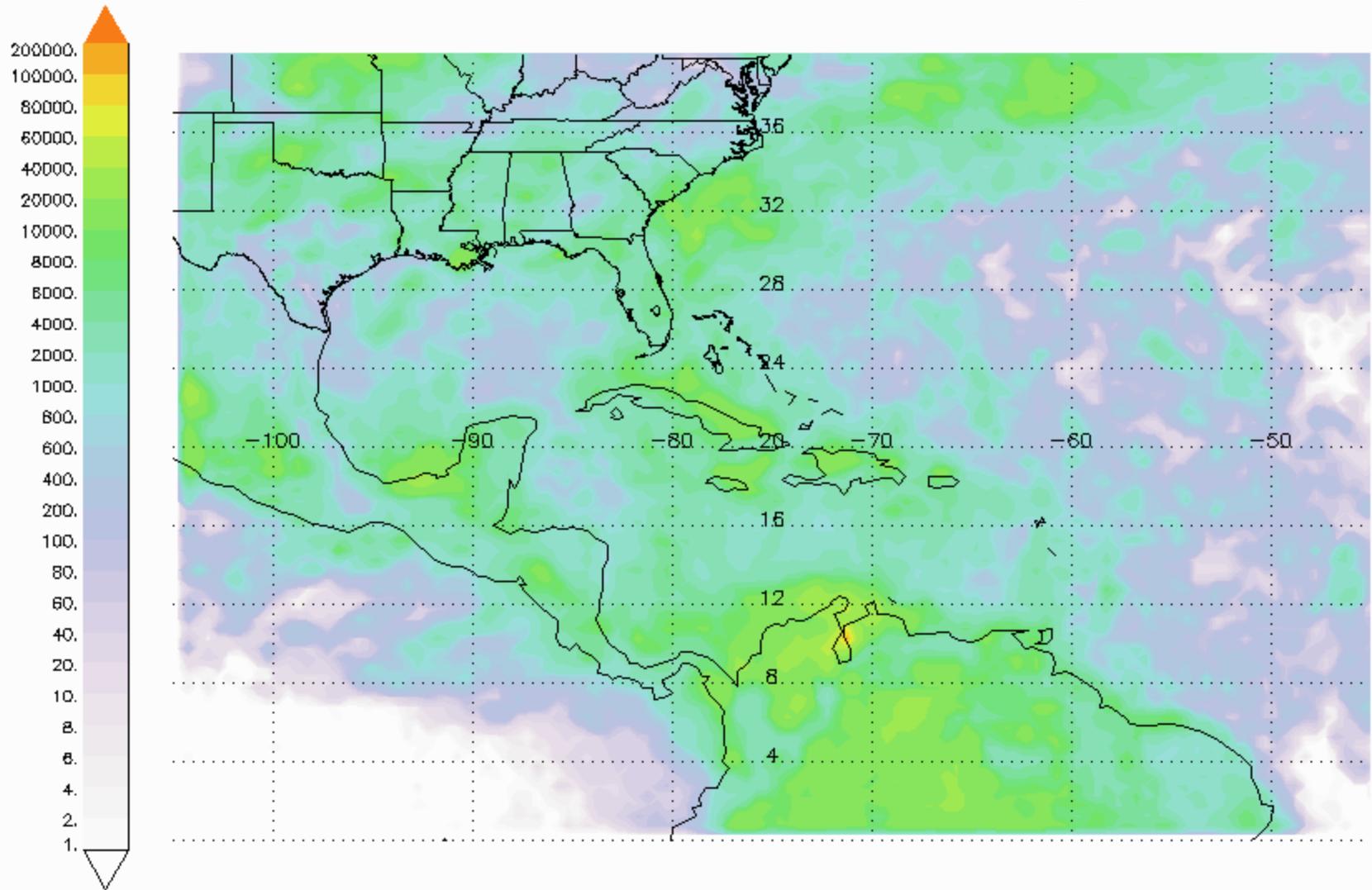
WTLN Stroke Count (0.5 deg): 59 overlap days from Aug–Oct 2010



* Overlap days: 8/17/2010, 8/24/2010 – 9/15/2010, 9/21/2010 – 10/5/2010, 10/12/2010 – 10/31/2010

GLD360 Lightning: August-September-October 2010

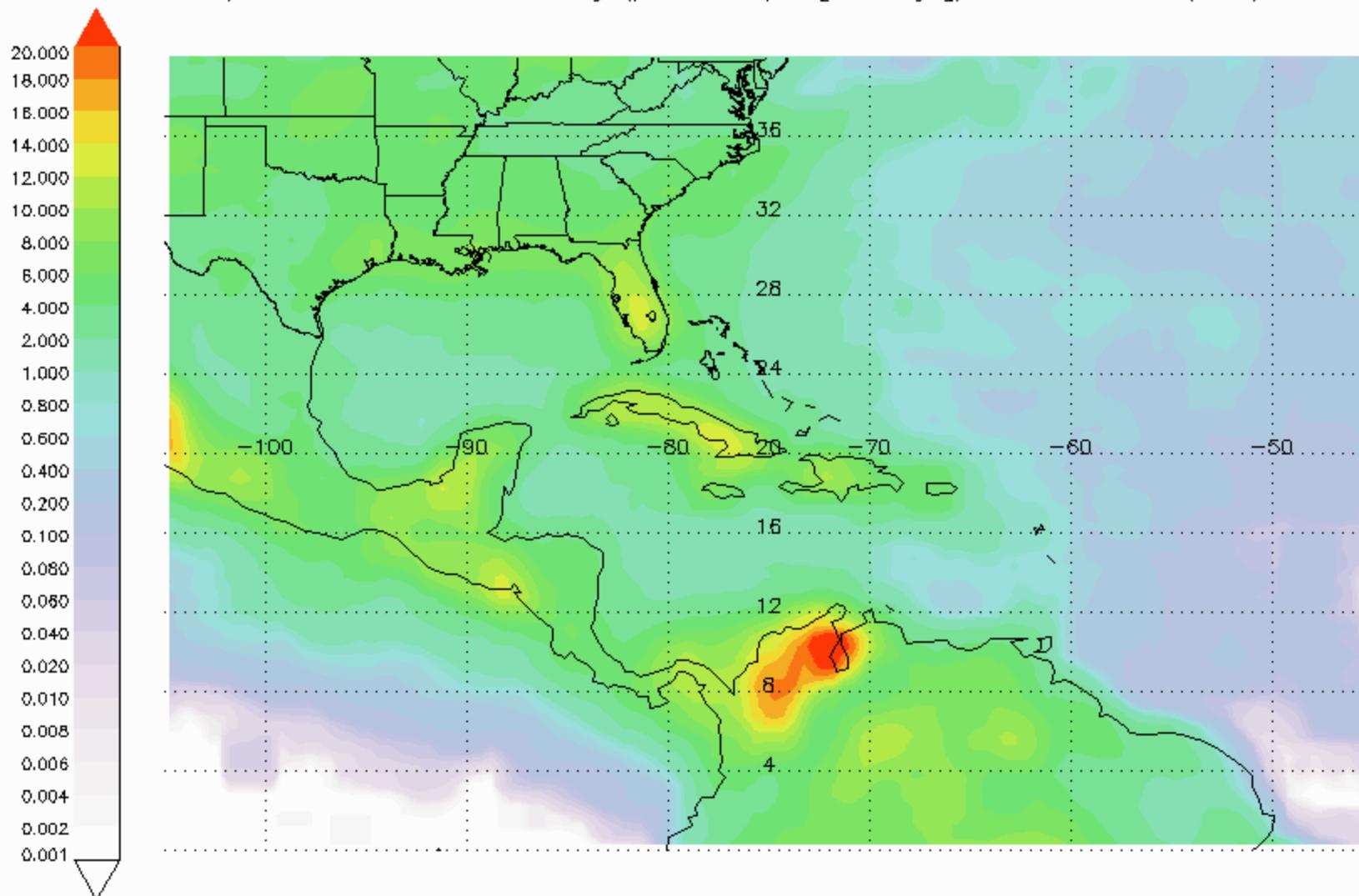
GLD360 Stroke Count (0.5 deg): 59 overlap days from Aug–Oct 2010



* Overlap days: 8/17/2010, 8/24/2010 – 9/15/2010, 9/21/2010 – 10/5/2010, 10/12/2010 – 10/31/2010

LIS/OTD Total Lightning Climatology: August-September-October

LIS/OTD Seasonal Flash Density (per km² per [90-days]) for 1995–2005(V2.2): ASO



Of critical importance- need to understand commercial ground-based lightning detection systems for 1) GLM proxy data set development, and 3) potential use in GLM on-orbit cal/val, and 3) potential applications using integrated observing systems

HWT: Forecaster Feedback from 2010



“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)

* <http://ewp.nssl.noaa.gov/>

* <http://goesrhwt.blogspot.com/>

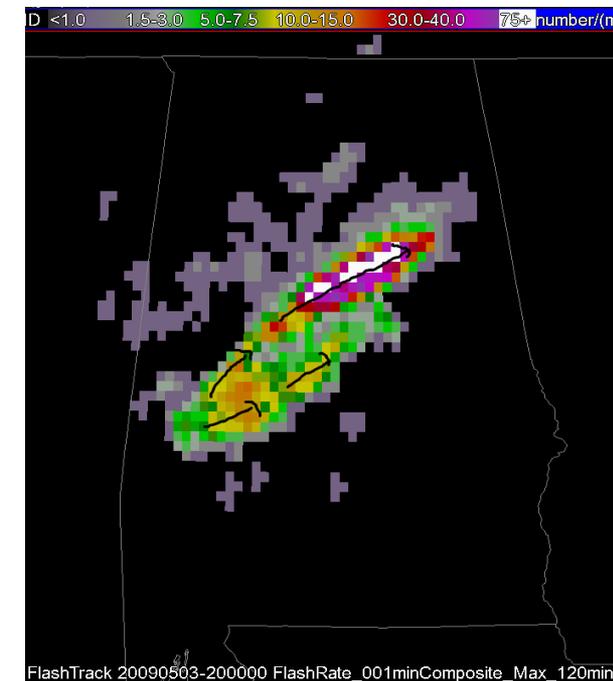
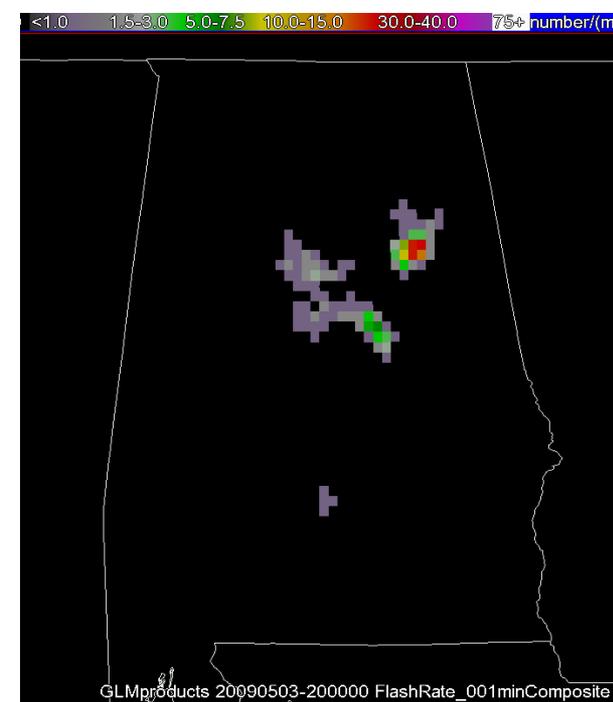
HWT: Forecaster Feedback from 2010

- * “lightning data provide a reassurance that I can see leading me to make a warning decision a little earlier due to having more confidence in imminent severe weather.”
- * “would be of great benefit to aviation forecasting in those situations where there is a developing shower or embedded thunderstorms in stratiform rain.”
- “[GLM] will also prove very beneficial as we get more into decision support services, especially to support the safety of responders to incidents who are exposed to lightning hazards.”
 - Frank Alsheimer (SOO, NWSFO Charleston, SC)



Suggestions for Future Testing:

- **Additional Products:**
 - Rate of change of flash rate (as a gridded product, not a line graph)
- **More Events:**
 - Winter Weather (convective snow bands)
 - Landfalling tropical cyclones
 - Fire & Aviation Applications
- **Increased guidance from research**
 - Flash rates expected with different convective modes and associated severe weather occurrence
 - Relationship of flash density with radar signatures typical of severe weather



Summary

- GLM instrument development on schedule
 - CDR in December 2010
 - FM1 delivery in 2012
- AWG-ATBD, Val Plan, Proxy Data, L2 Prototype S/W delivered
- Product demonstrations at NOAA Testbeds, WFOs, NCEP
- New Risk Reduction/Advanced Product Initiatives
 - Data Assimilation: JCSDA FFO 2010 funding two new GLM investigations
 - High Impact Weather Working Group- GOES-R DA focus on short-range NWP
 - Combined sensors/platform products (e.g., ABI/GLM ; ABI/GLM/GPM)
 - NASA GPM - GLM proxy data 12-mo. campaign in Sao Paulo in partnership with InPE and CHUVA GPM pre-launch ground validation program
 - NSF Deep Convective Cloud and Chemistry (DC3) Experiment 2012