Monitoring GLM Degradation CWG

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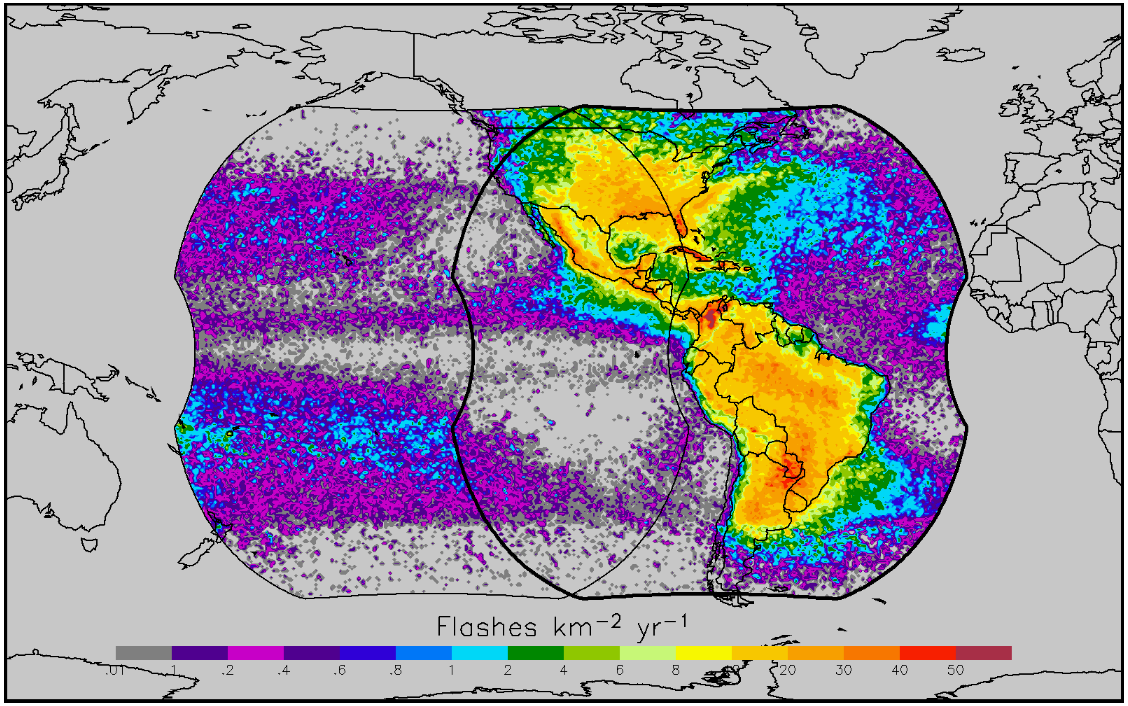
3rd GOES-R GLM Science Meeting

December 1-3, 2010

GOES-R Geostationary Lightning Mapper (GLM)

GLM Characteristics

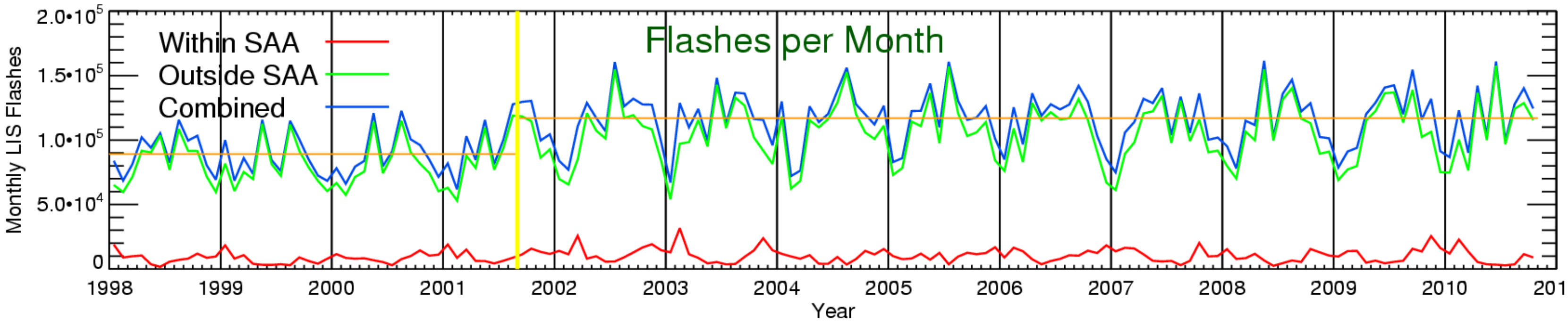
- Staring CCD imager (1372x1300 pixels)
  - Single band 777.4 nm
  - 2 ms frame rate
  - 8 km nadir to 14 km at edge
  - 70-90% flash detection
  - Backgrounds ~2.5 min

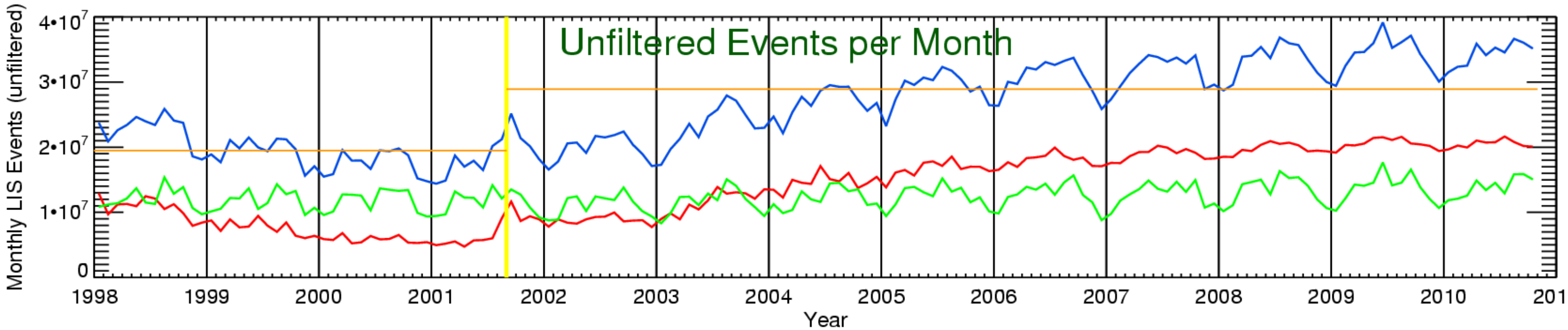


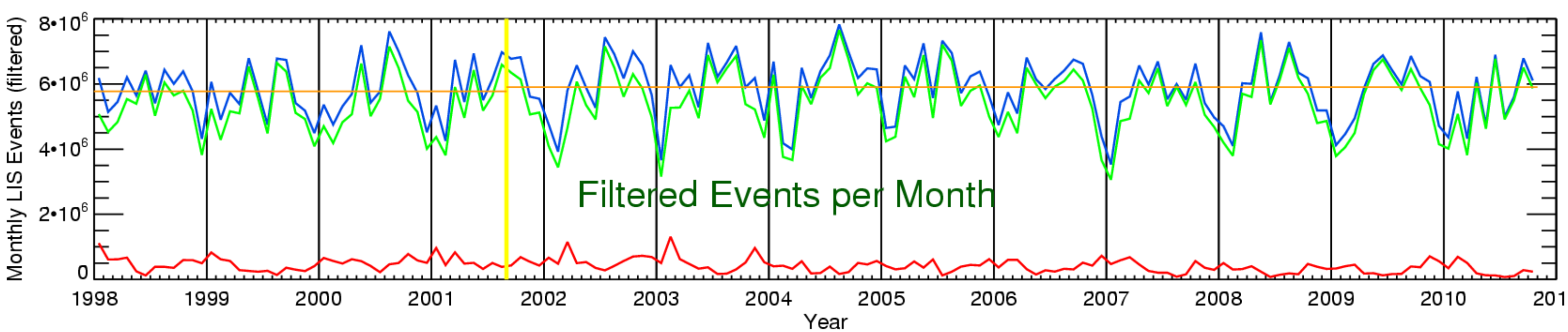
Monitoring GLM Performance

- 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

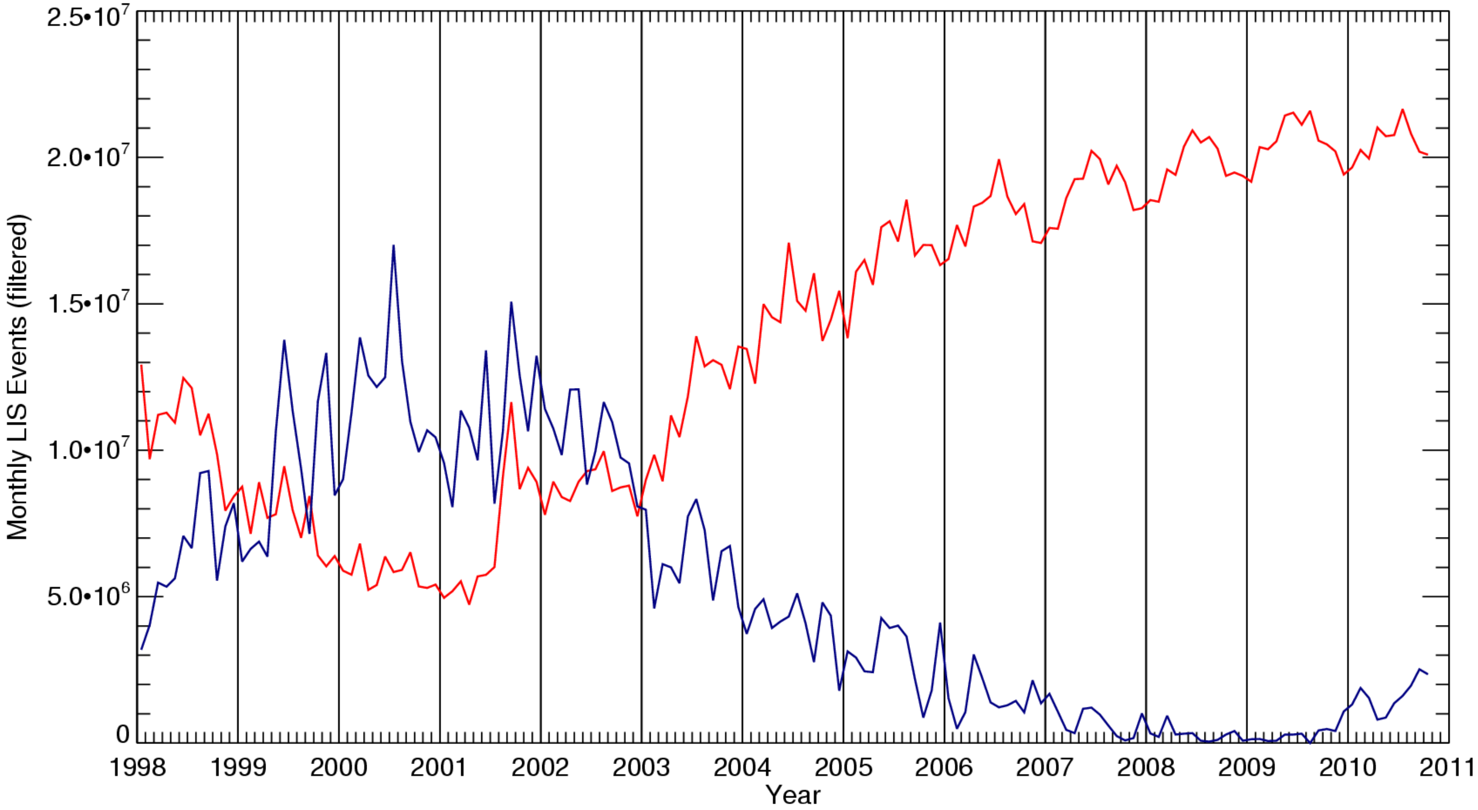
LIS Trend


Flashes per Month
Within SAA
Outside SAA
Combined
Monthly LIS Flashes
2.0•10^5
1.5•10^5
1.0•10^5
5.0•10^4
0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Year


Unfiltered Events per Month
Monthly LIS Events (unfiltered)
4•10^7
3•10^7
2•10^7
1•10^7
0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Year

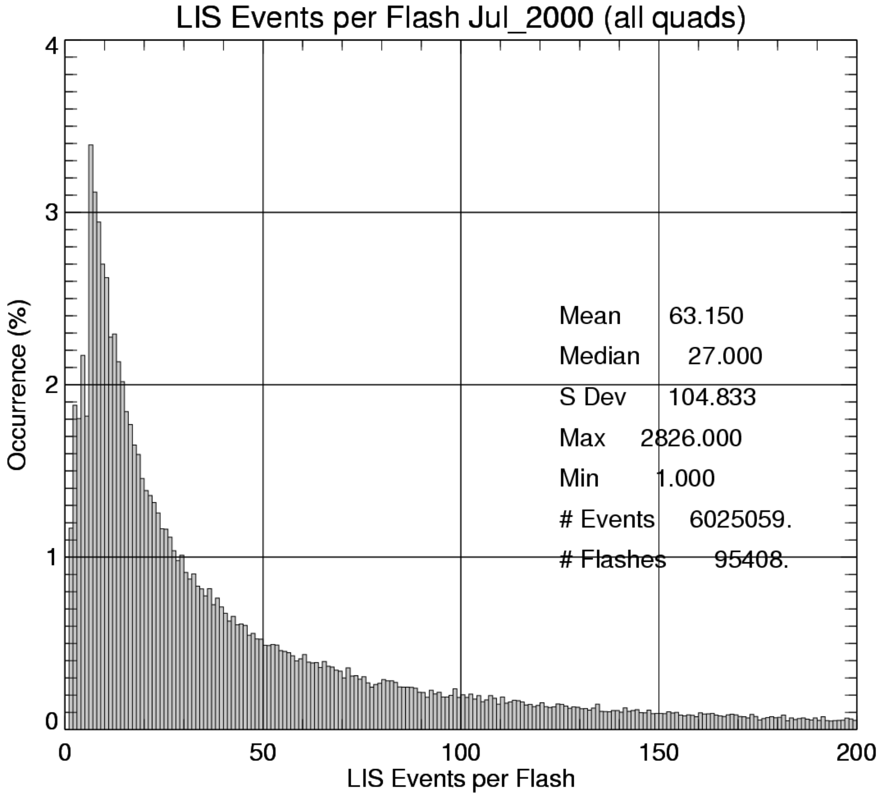

Filtered Events per Month
Monthly LIS Events (filtered)
8•10^6
6•10^6
4•10^6
2•10^6
0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Year

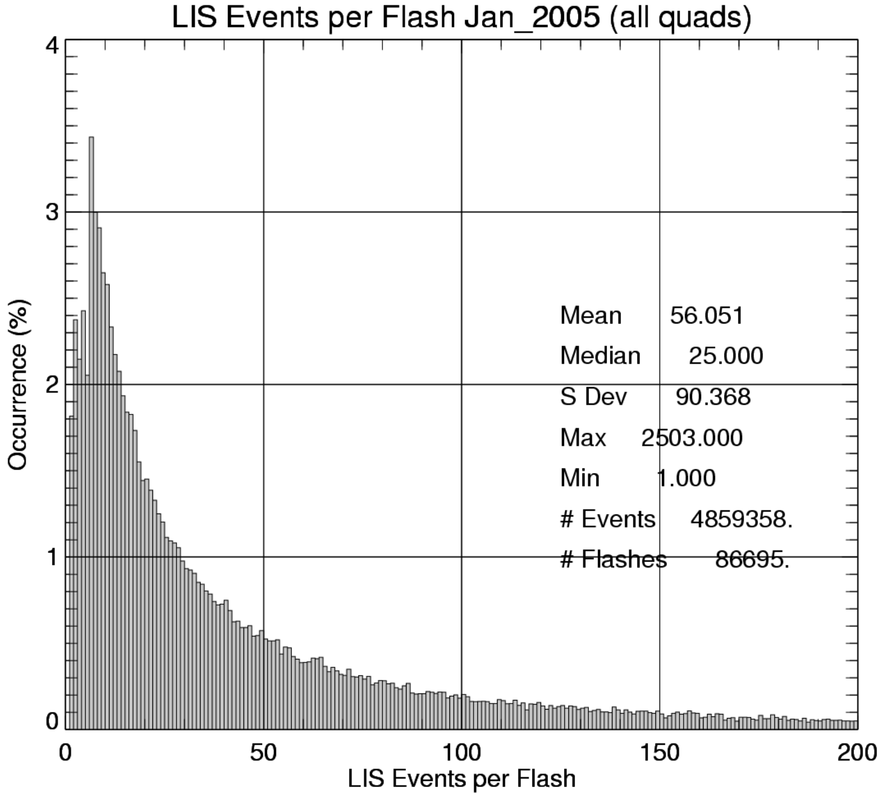
LIS Trend

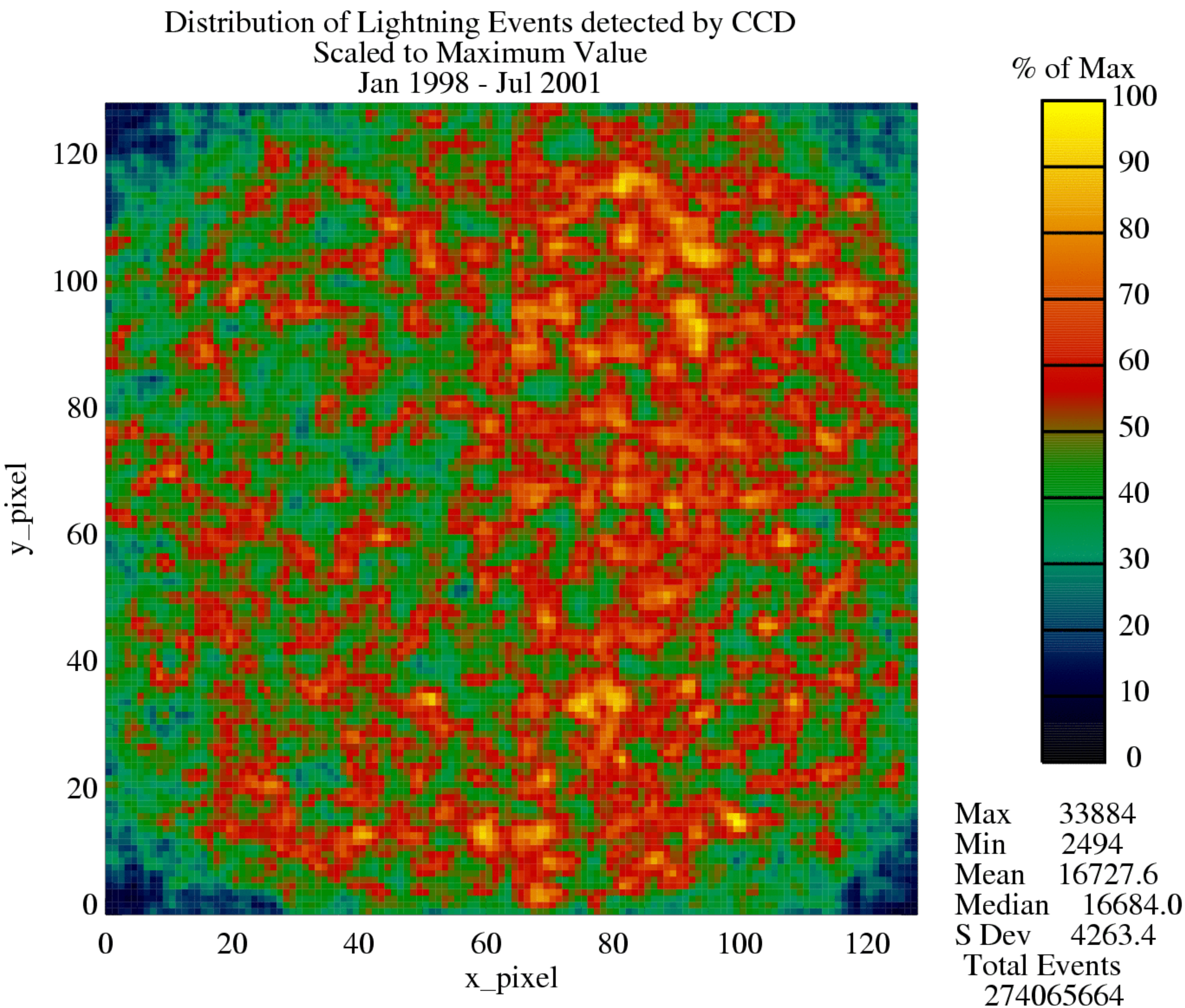


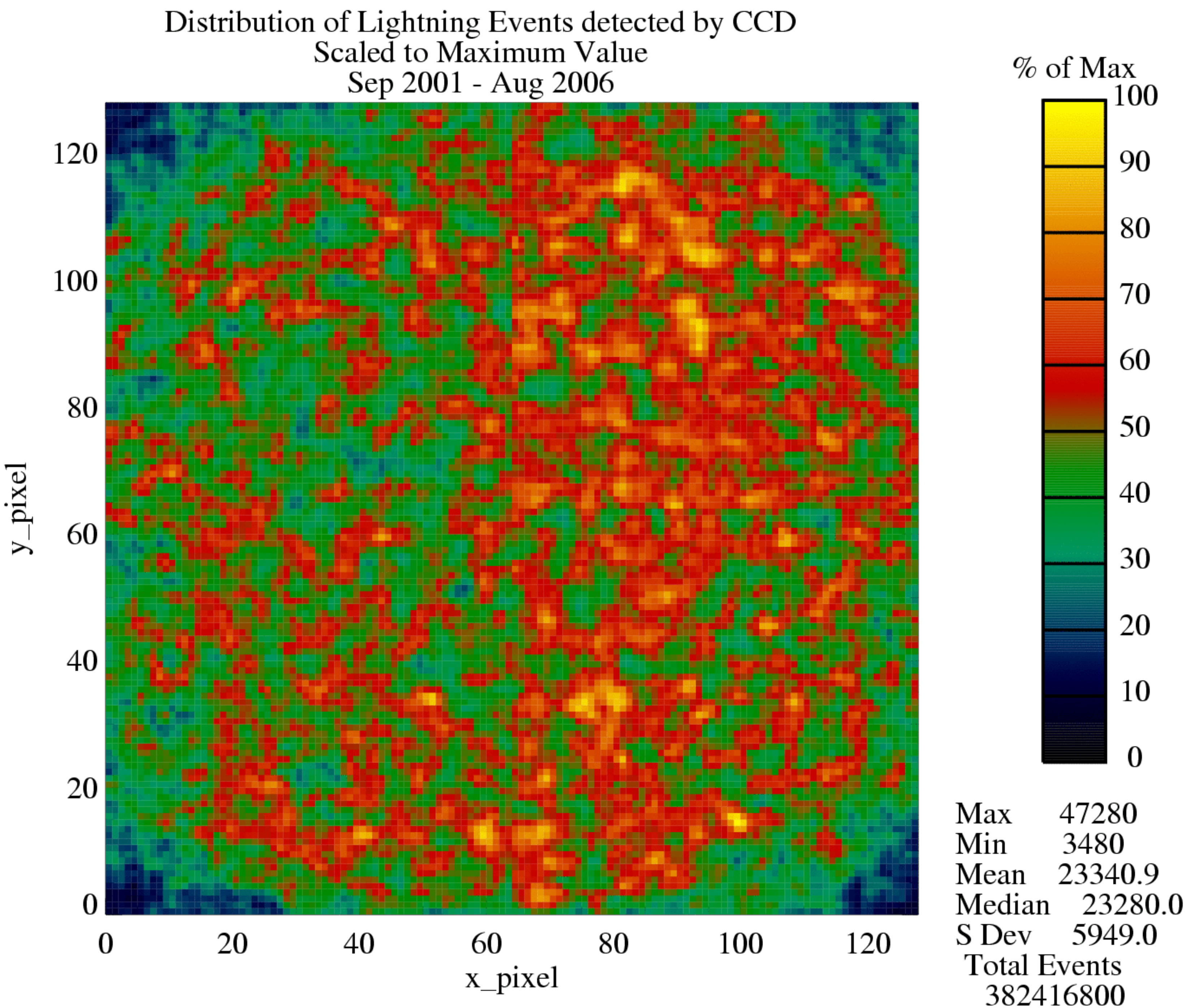
Time series of LIS event rate over the SAA (red) and the monthly sunspot number (blue) (*100000).

LIS Events per Flash






Distribution of Lightning Events detected by CCD
Scaled to Maximum Value
Jan 1998 - Jul 2001
% of Max
100
90
80
70
60
50
40
30
20
10
0
120
100
80
60
40
20
0
y_pixel
0
20
40
60
80
100
120
x_pixel
Max 33884
Min 2494
Mean 16727.6
Median 16684.0
S Dev 4263.4
Total Events
274065664



Distribution of Lightning Events detected by CCD
Scaled to Maximum Value
Sep 2001 - Aug 2006
% of Max
100
90
80
70
60
50
40
30
20
10
0
y_pixel
120
100
80
60
40
20
0
x_pixel
0
20
40
60
80
100
120
Max 47280
Min 3480
Mean 23340.9
Median 23280.0
S Dev 5949.0
Total Events
382416800

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.*

Deep Convective Clouds (DCC)

Deep Convective Clouds provide stable targets:

- DCCs are cold and bright clouds near the tropopause in the tropics (30° S to 30° N)
- DCCs provide stable radiance observations in the solar reflective bands
  - Little scattering or attenuation
  - Nearly constant albedo
- No other information necessary to calibrate with DCCs
  - No atmospheric profile adjustments needed
  - No surface information required
- Use LIS data as proxy for GLM since designs are similar
  - Look at observed LIS radiances from 1998-2010

Lightning Imaging Sensor (LIS) and Visible and Infrared Scanner (VIRS) on TRMM

	LIS Pre-boost	VIRS Pre-boost	LIS Post-boost	VIRS Post-boost
Inclination	35°		35°	
Altitude	350 km		402.5 km	
FOV (across)	583 km	720 km	668 km	833 km
FOV (diagonal)	870 km		1001 km	
Pixel FOV (nadir)	3.7 km	2.2 km	4.3 km	2.4 km
Observation time	83 s		92 s	
Orbital Period	91.3 min		92.4 min	
Scan mode	Staring	Cross-track	Staring	Cross-track
Wavelength	777.4 nm	10.8 μm	777.4 nm	10.8 μm
Diurnal Sample	46 days	47 days	46 days	47 days

TRMM boost completed August 22, 2001

LIS Background saved every ~35 s

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

Methodology (Cont'd)

- Use Coincident VIRS IR Brightness Temperature (Tb) to define Deep Convective Clouds (DCC) between 30°N and 30°S
- Geolocate LIS background (BG) pixels onto VIRS Tb map
- If VIRS Tb < 205K then identify as a cold cloud target

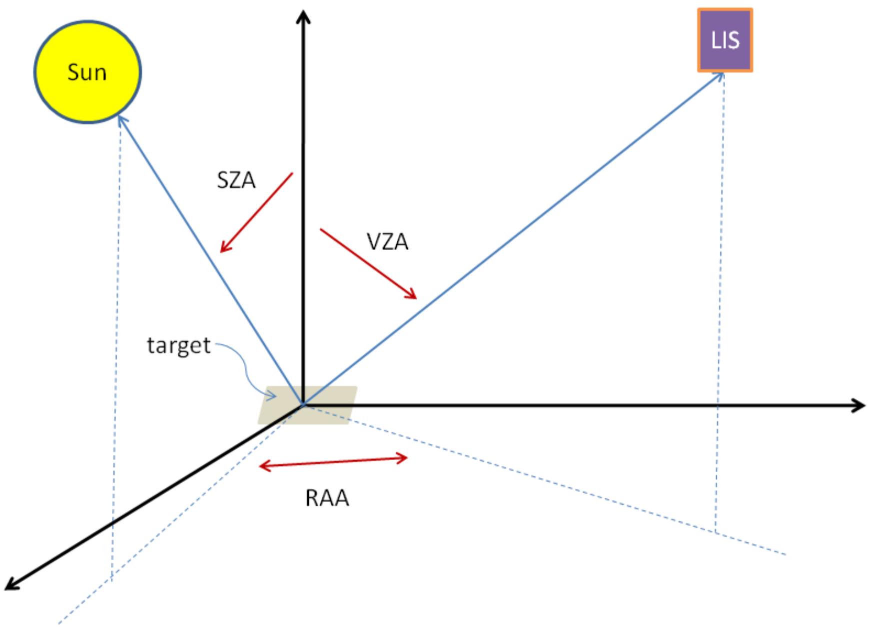
Methodology (Cont'd)

- For each LIS pixel compute:
  - Solar Zenith angle (SZA)
  - Viewing Zenith angle (VZA)
  - Relative Azimuth Angle (RAA)
- Compute σ: The standard deviation of LIS radiance for each pixel and its 8 surrounding pixels

P_1	P_2	P_3
P_4	P_i	P_5
P_6	P_7	P_8

Methodology (Cont'd)

- Use pixels that meet following criteria:
  - Tb < 205K
  - SZA < 40°
  - VZA < 40°
  - 10° < RAA < 170°
  - $\sigma/\rho_i < .02$

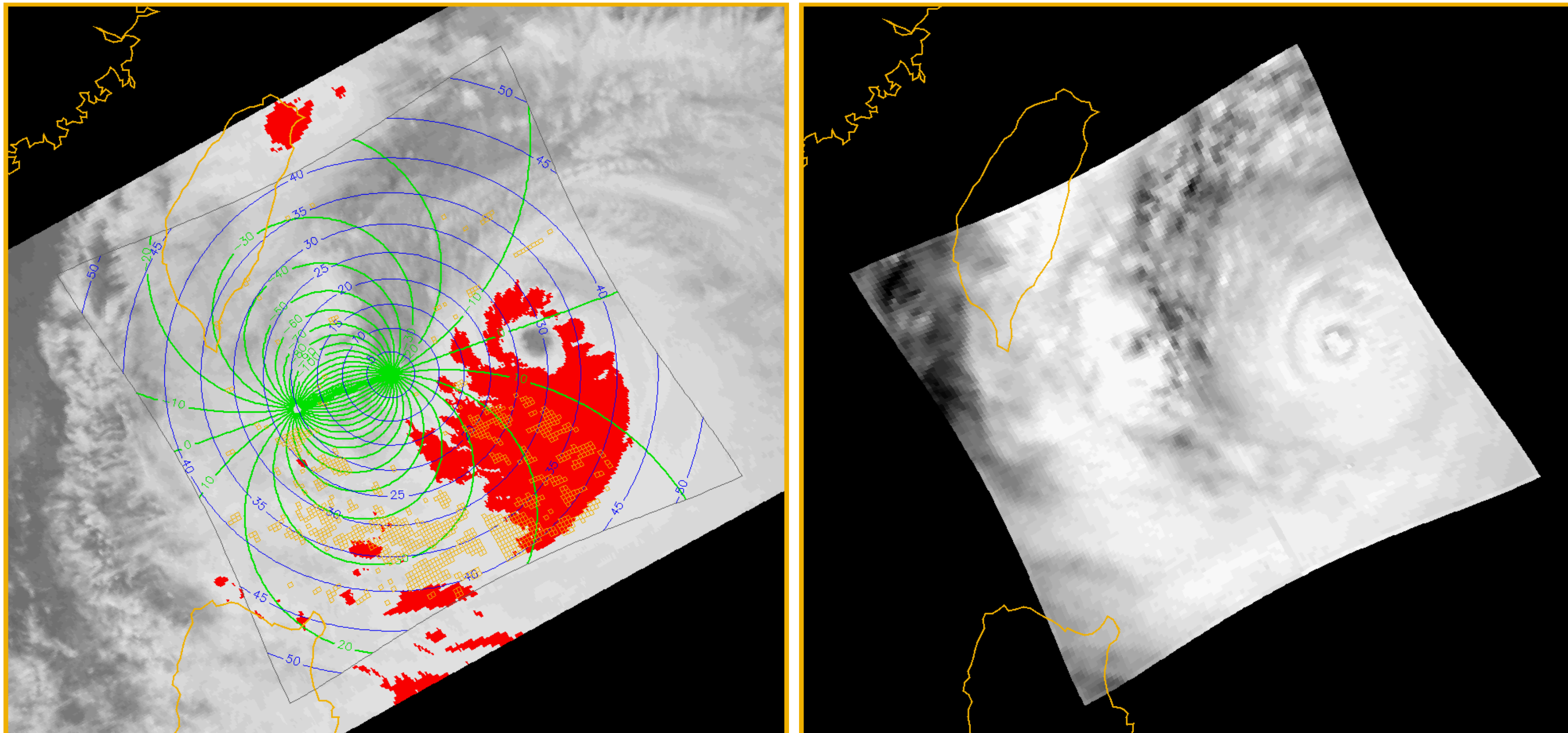


Assume constant solar radiance throughout the period

Assume random distribution of VZA, RAA, and SZA

Methodology (Cont’d)

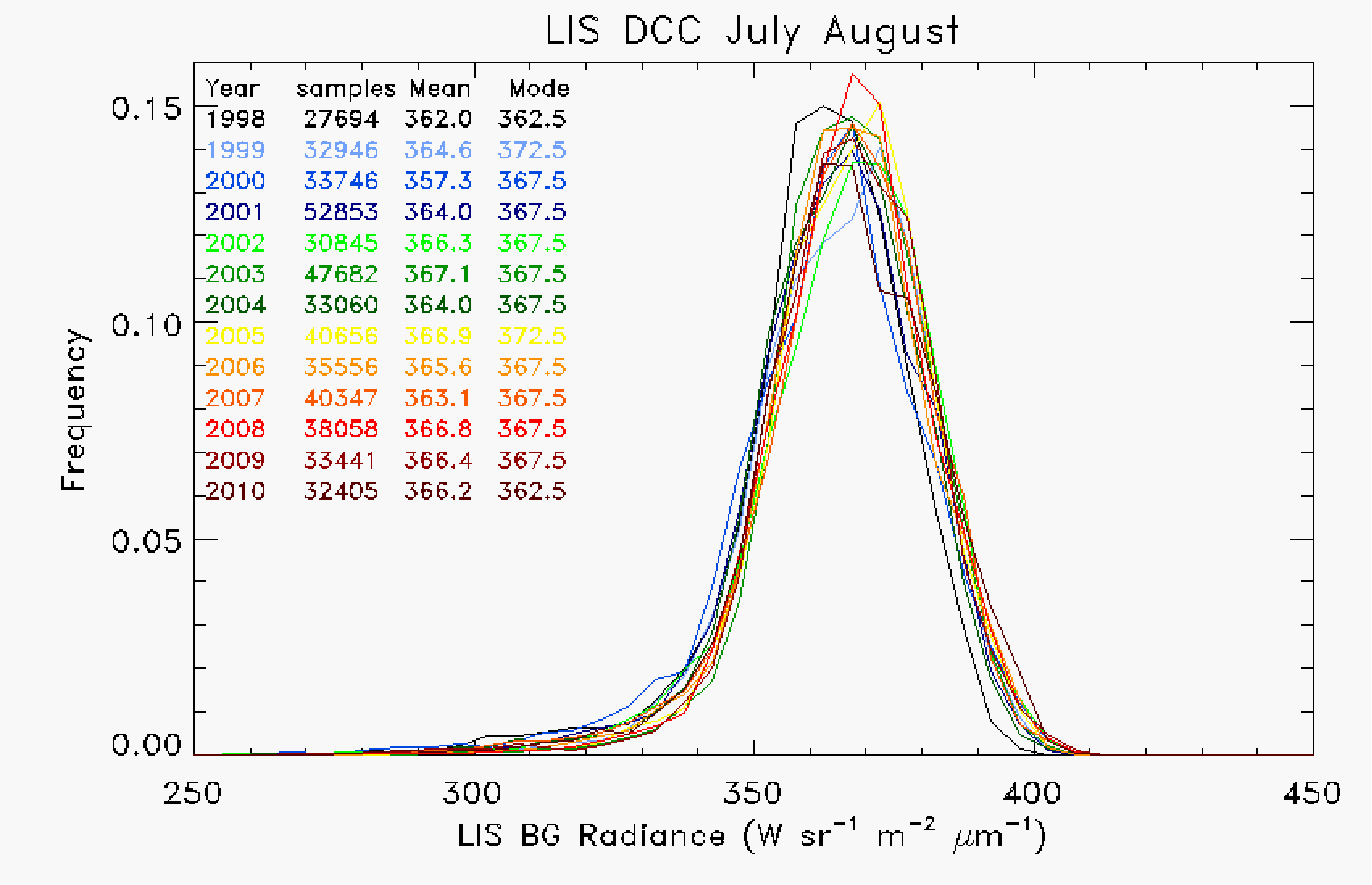
TRMM LIS observations of Deep Convective Clouds



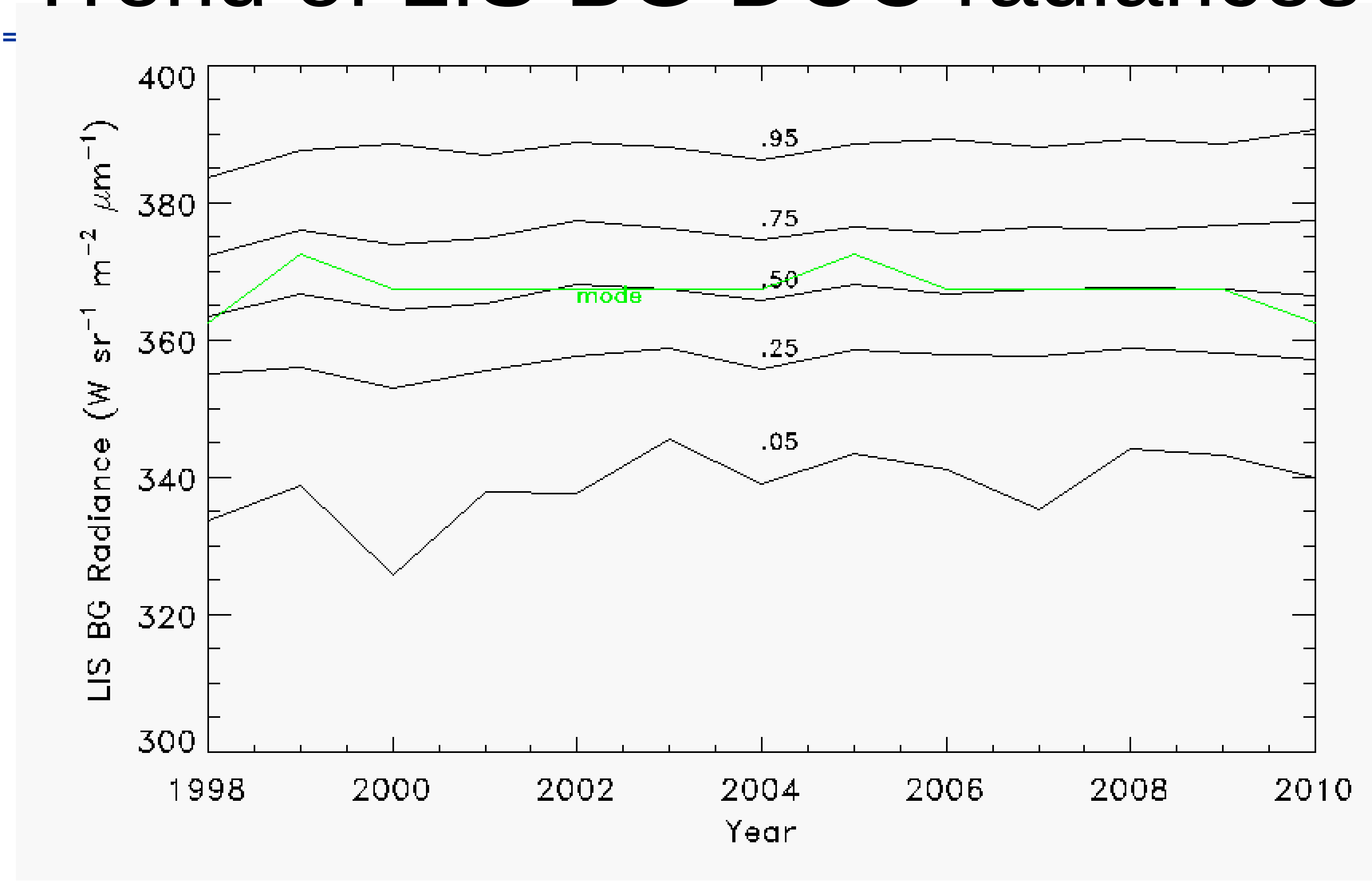
Super Typhoon Haitang

DCCT Results

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

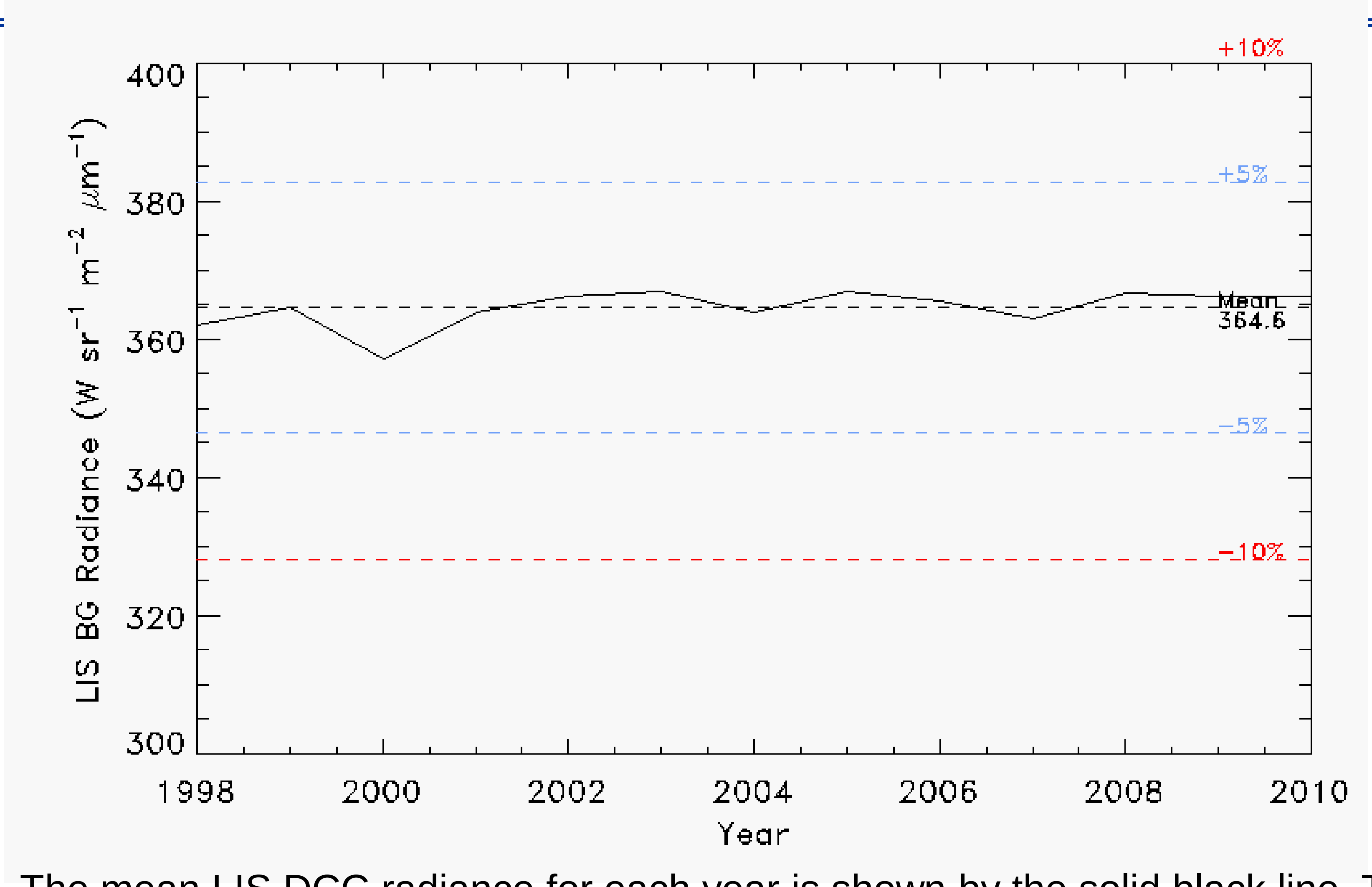


Trend of LIS BG DCC radiances



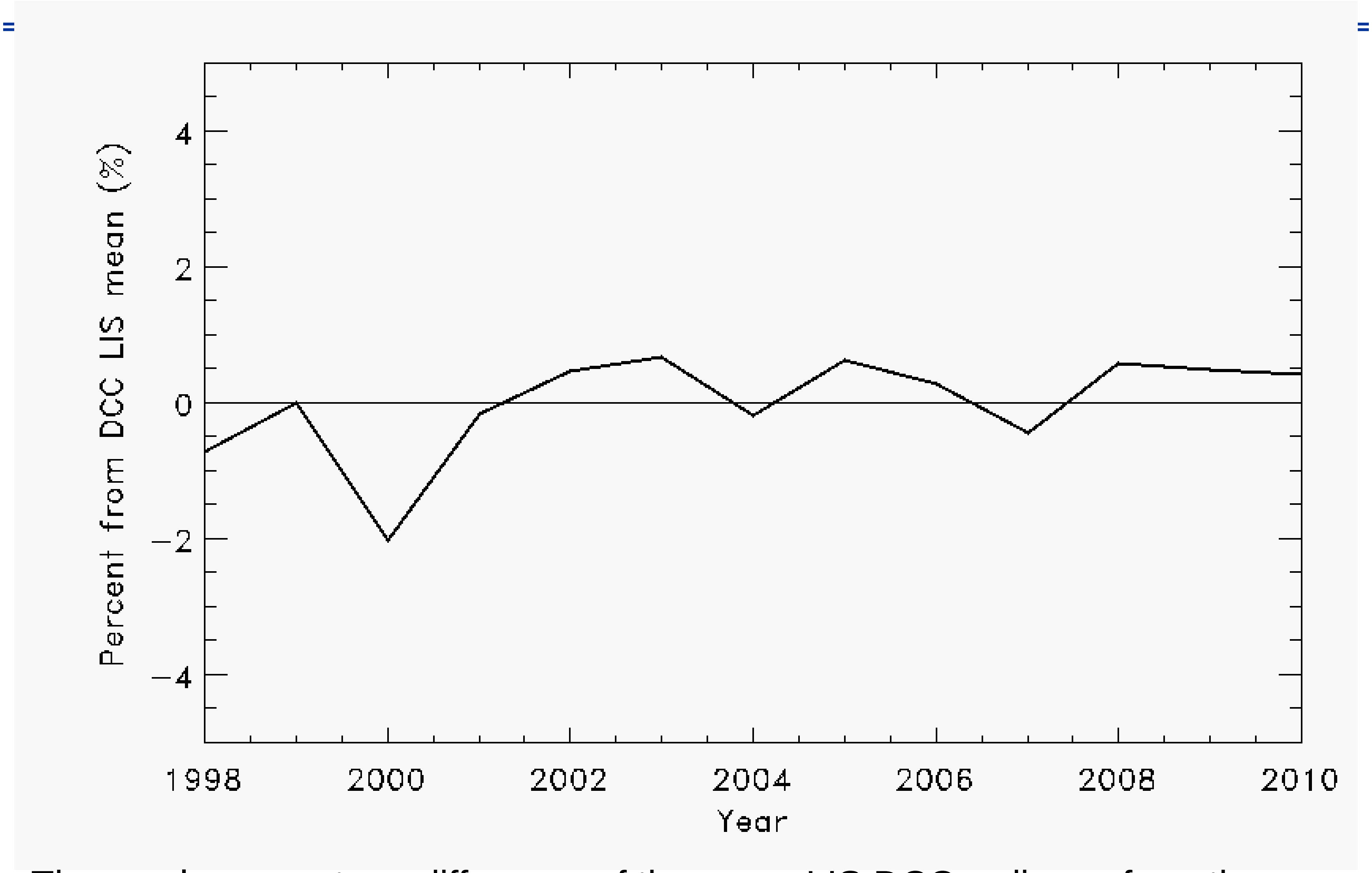
Each solid line indicates trend for percentile indicated. The green line is the mode.

Trend of LIS BG DCC radiances



The mean LIS DCC radiance for each year is shown by the solid black line. The black dashed line is the mean of the yearly means (360.9). The blue and red dashed lines indicate the values for 5% and 10% deviance from the mean.

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.

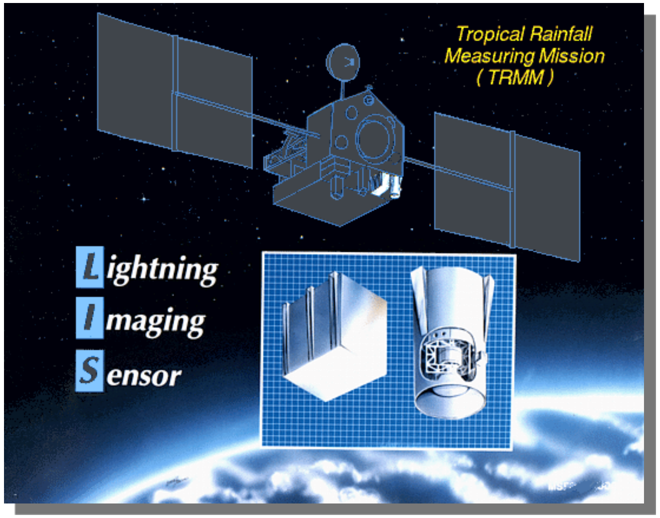
DCCT Conclusions

- 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

Additional

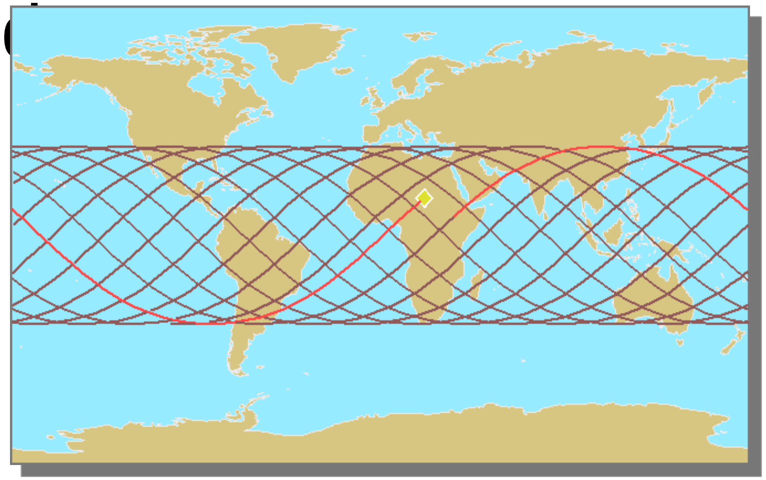
- Examine how event, flash and group statistics change over the LIS lifetime
  - Radiance
  - Size
  - Duration
  - Number of groups
  - Number of events
- Examine changes in pixel array over time
  - See if any individual pixels change in sensitivity

LIS



•Frame-to-frame subtraction isolates lightning transients against bright daytime background

- Dependent on background radiance



DCCT Feasibility Study for Using Background Radiances to Monitor GLM Radiance Stability and Degradation

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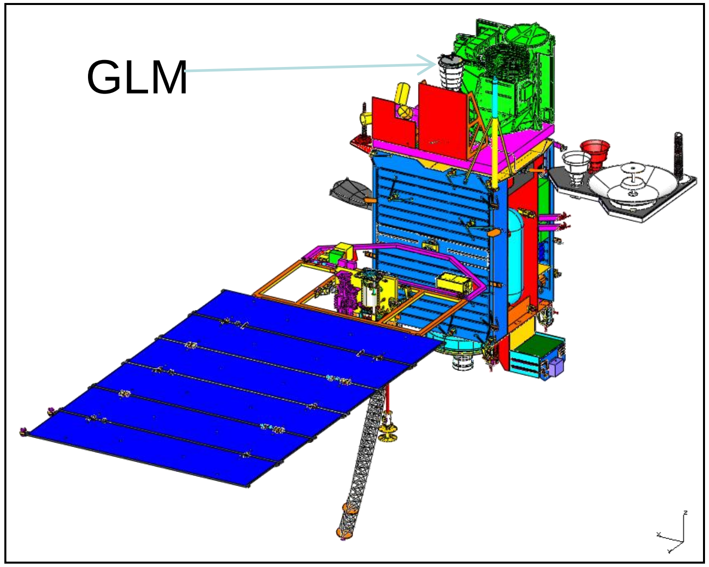

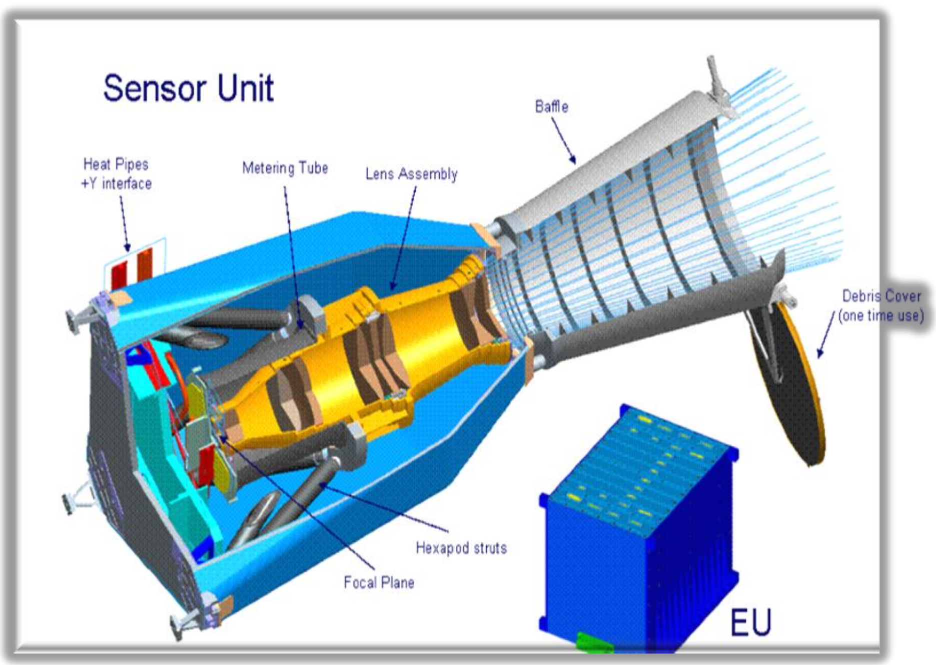

GLM Characteristics

- Staring CCD imager (1372x1300 pixels)
  - Single band 777.4 nm
  - 2 ms frame rate
  - 7.7 Mbps downlink data rate
  - Mass: 114 kg- SU (66 kg), EU (48 kg)
  - Avg. Operational Power: 290 W
  - Volume w/ baffle (cm^3): 81x66x150
- Near uniform spatial resolution/ coverage up to 52 deg lat
  - 8 km nadir to 14 km at edge
  - 70-90% flash detection
- L1 and L2+ products produced at Wallops for GOES-R Re-Broadcast (GRB)
- < 20 sec product total latency

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)