APPLICATIONS OF HIGH-RESOLUTION LIGHTNING DATA

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LIGHTNING RESEARCH AT CSU

Recent research at Colorado State University involving the use of lightning mapping array (LMA) data is reviewed. LMAs can be used to infer total lightning flash rates, charge structures, and to map the size and spatial distribution of flashes. Robust relationships between total lightning and environmental parameters have been observed, providing evidence for the control of certain dynamical and microphysical processes on lightning activity. Observed relationships between total lightning and thunderstorm characteristics have been developed into flash rate parameterizations. LMAs may also provide useful ground validation for satellite-based lightning observations.

LMA FLASH COUNTING

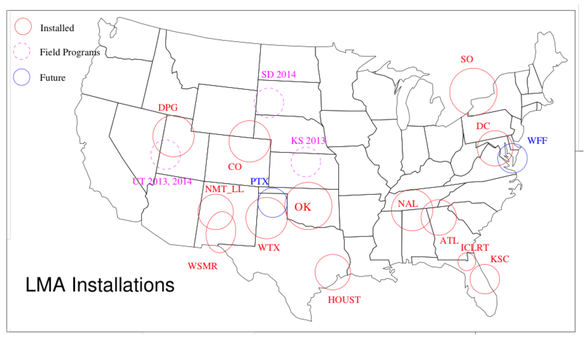

Figure 1: Locations of temporary (purple), permanent (red), and proposed (blue) LMA networks in the United States *(credit: Bill Rison, New Mexico Tech)*

- LMA networks detect most cloud and ground flashes with a high degree of accuracy
- Using flash counting algorithm, can determine flash rates and map location and size of each flash

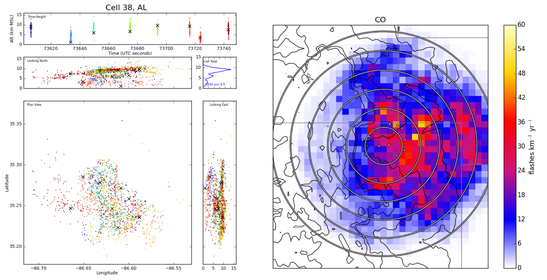

Figure 2: Lightning flashes identified by the flash algorithm (left) and average flash density from the Colorado LMA for 2012 (right).

LMAs could serve as ground validation for satellite-based lightning observations

LIGHTNING AND ENVIRONMENT

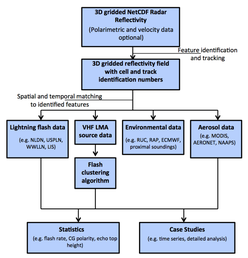

Figure 3: Schematic of the CLEAR cell tracking algorithm

- Lightning dataset analyzed with CLEAR, a modular framework to objectively identify, track convective cells
- Attributes various types of data to tracked cells allowing for statistical analysis of large datasets

- Lightning behavior was examined for thousands of cells in four different regions with LMA networks in the CONUS
- Regional variability in flash rate attributed to thermodynamic and aerosol environment

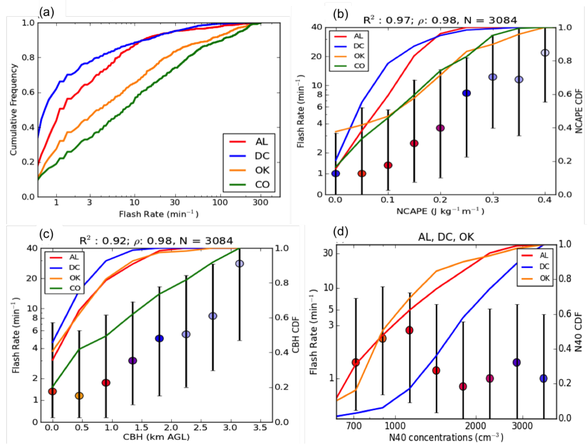

Figure 4: (a) CDF of storm-total flash rate by region, (b) relationship of median flash rate to NCAPE, lines indicate NCAPE CDFs in each region (right axis) (c) as in (b) but for cloud base height and (d) as in (b) but for N40 (Colorado data not included).

- Flash rate in non-severe storms dependent on environment
- Implications for lightning jump algorithms

Region	Alabama	DC	Oklahoma	Colorado
TFR non-severe (min^{-1})	1.4	0.4	3.6	7.5
TFR severe (min^{-1})	80.5	39.8	124.2	105.6
Difference factor	56	98	33	13

Figure 5: Median flash rates in severe vs. non-severe storms and factor difference for four different regions of the CONUS.

CLEAR's modular capabilities could allow for analysis of a large satellite dataset, e.g., GLM

LIGHTNING AND STORM CHARACTERISTICS

1) Flash rate and simple storm parameters well correlated for a sample of Colorado storms during DC3

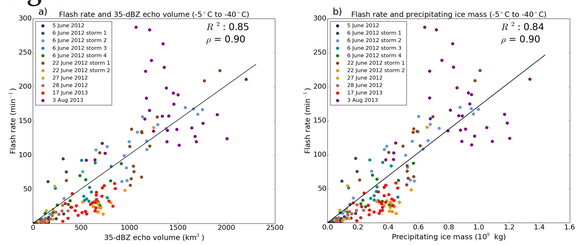

Figure 6: Scatterplots of flash rate (f) versus a) 35-dBZ echo volume ($VOL35$) and b) precipitating ice mass (PIM).

a) $f = (1.01 \times 10^{-1}) \times VOL35$ b) $f = (1.72 \times 10^{-7}) \times PIM$

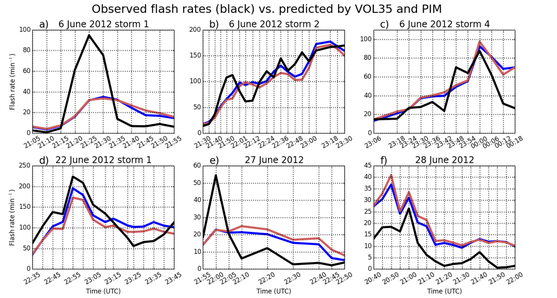

Figure 7: Flash rates predicted by $VOL35$ (blue) and PIM (pink) versus observed flash rate (black) for six Colorado storms.

2) VOL35 scheme tested on a large dataset (4322 thunderstorm cells)

- Average error of 9.1% over all cells; best in low NCAPE environment (majority of cells)

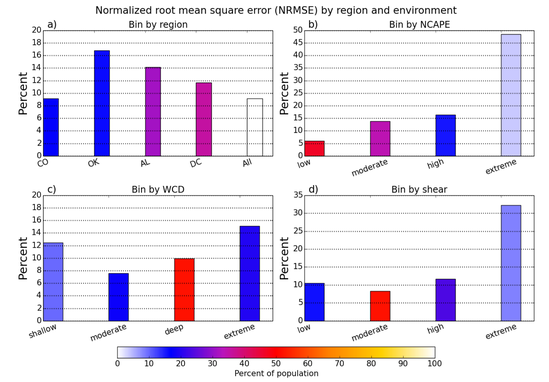

Figure 8: $VOL35$ scheme RMSE as a function of a) region, b) NCAPE, c) warm cloud depth, and d) surface-6km shear.

3) Flash rates related to flash sizes; flash size (extent) may control NO_x production

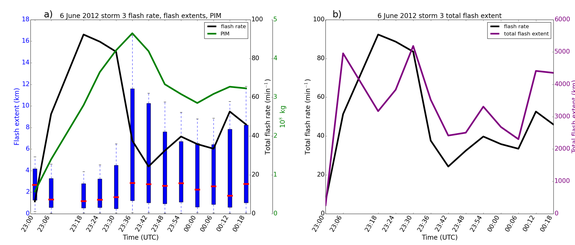

Figure 9: Flash rate (black) versus a) median and range of flash extents and b) total flash extent for a Colorado storm on 6 June 2012.

ONGOING RESEARCH

1) Merging satellite and LMA flash rate data

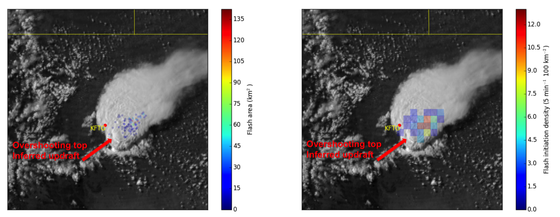

Figure 10: LMA flashes colored by area (left) and LMA flash initiation density (right) superimposed on GOES-14 visible imagery from 20 May 2014 22:46 UTC. *(Satellite data provided by Dan Lindsey, CIRA)*

- Smaller, more frequent flashes adjacent to inferred updrafts: consistent with increased turbulence, small pockets of charge in updraft vicinity

2) Nowcasting of storm anomalous propagation

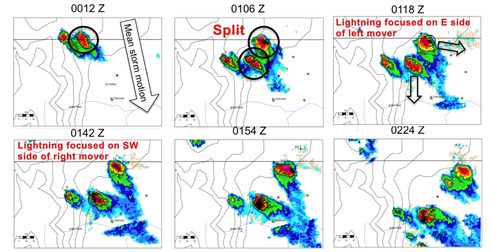

Figure 11: Case study of a splitting supercell in Colorado. LMA source locations generally consistent with motion of left- and right-movers.

- Lightning concentration could be used to infer updraft location and storm movement

Can GLM be used to examine spatial variability of lightning in a storm?