Initial Results from PhOCAL 2012 Field Operations

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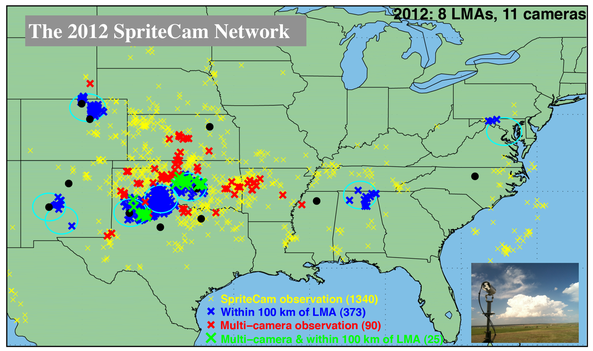
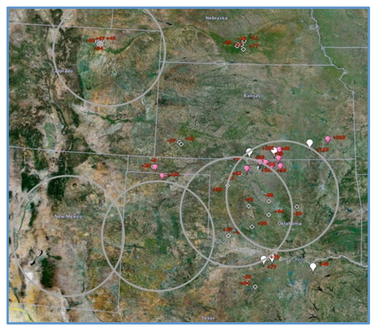
PhOCAL: Physical Origins of Coupling to the upper Atmosphere from Lightning

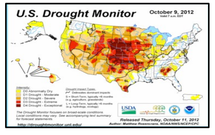
The Goal: Provide quantitative measurements of the rare, energetic lightning producing TLEs so that modelers can reduce their assumptions and validate models with actual observations.

The Task: Obtain *coordinated* High Speed Imager (HSI) records of both the TLE *and* the parent lightning discharge, within a 3-D Lightning Mapping Array (LMA), so that both the source function and the resultant middle atmospheric response can be fully documented. Both fixed-based and mobile systems are employed, monitoring over the U.S. High Plains.

The 2012 SpriteCam Network







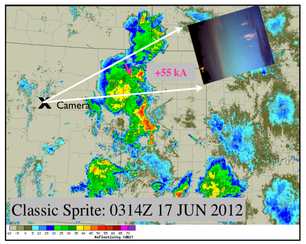
The Great Drought of ~~2011~~ 2012

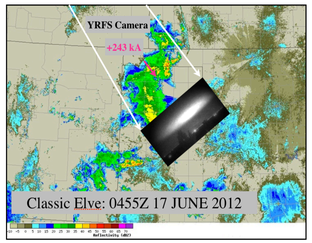
Optical Sprite Observations from YRFS

	JUNE	JULY	AUGUST
Long Term Average 1994-2000	367	499	122
SUMMER 2012	11	2	21

The ongoing drought severely impacted TLE activity. Yet with 11 sprite cameras and a mobile van, over 1300 TLEs were captured, with 373 over LMAs. Mobile Phantom HSI systems captured 18 TLEs, 20 CGs and 4 SP+CGs in an LMA.

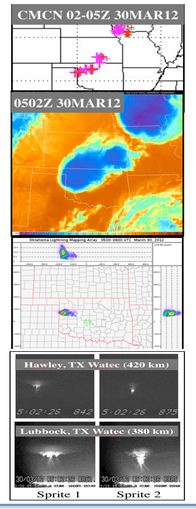
A Gigantic Elve (17 JUN 12) Over North Texas

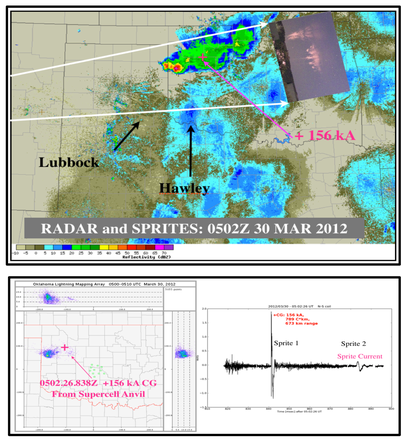




The expansion in the number and types of cameras is allowing us to capture a variety of TLEs, with the space above a given LMA accessible by one of the several cameras surrounding them. A north Texas MCS produced 6 sprites (color DSLR camera) and an exceptional elve lasting for 3.5 ms, produced by a 243 kA +CG (iCMC, + 90 C km). It is not clear if a halo was also involved.

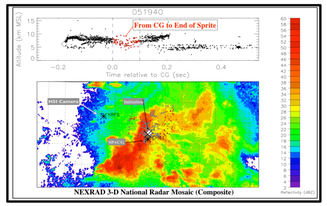
A SP+CG from a Supercell Anvil (30 MAR 12)

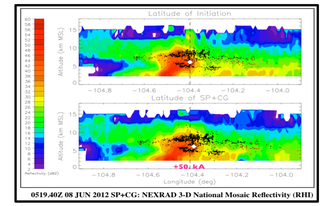


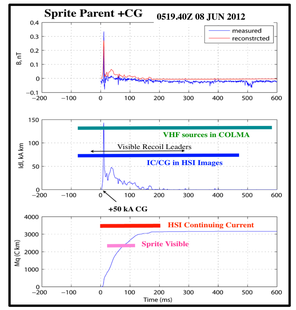


A +156 kA CG in the anvil some ~50 km downwind of a hail-producing supercell core induced two distinctly different sprites, the first with a halo, the second with a clear sprite current.

The First High Speed Images of 4 SP+CGs Inside an LMA (08 JUN 12)





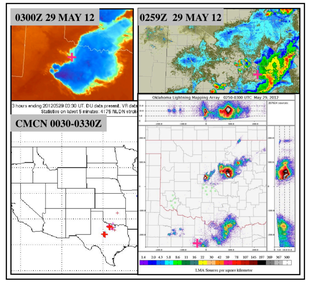


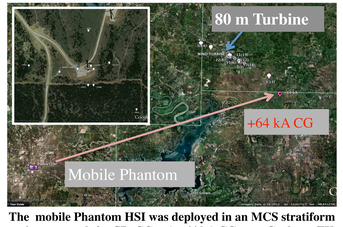
On 08 JUN 12, a disorganized cluster of thunderstorms formed east of the Front Range. One cell, beginning as a splitting supercell in Wyoming moved south into the new Colorado LMA. For two hours, upon evolving into more of an asymmetric MCS with a stratiform region of ~10,000 km^2 with about 50% positive CGs, it produced 20 sprites, as confirmed by two SpriteCam systems in central NM. Four of the SP+CGs where also captured at 3000 ips by the Phantom HSI at Yucca Ridge - believed to be the first ever inside an LMA. This allowed for a detailed analysis of the parent storm charge structure, the relationship of the CG and its continuing current to the ignition of the sprite, and the height, area and volume from which the charge was lowered to ground. The SP+CGs initiated near the convective core, but drew from the surrounding stratiform before coming to ground from around 6 km AGL altitude. The storm exhibited normal polarity. The illustrations display the results from one SP+CG. The table summarizes the averages for all four (occurring with about a 10 minute period).

METRICS FOR 4 SP +CGs IN COLMA

First LMA source leads first high speed imager (HSI) light	2 ms
Recoil leaders visible below cloud base	4/4 events
First LMA source leads SP+CG	221 ms
SP+CG peak current	44 kA
Blooming in HSI after SP+CG (indicates extended RS?)	~5 ms
HSI suggests M-components in continuing current	4/4 events
Minimum average sprite ignition delay time	~16 ms
Maximum sprite visible duration (Watec)	~92 ms
Continuing current duration in HSI	328 ms
Length of LMA sources being detected	643 ms
Length of light visible in HSI images	668 ms
Distance from HSI to SP+CG	45.7 km
Zq average (range 5.4 to 6.8 km AGL)	6.0 km AGL
iCMC average for sprite parent +CGs (SP+CGs)	150 C km
"Impulse" charge lowered	26 C
CMC at sprite ignition	620 C km
Charge lowered at sprite ignition	104 C
Charge lowed by end of sprite	342 C
CMC of total discharge	3638 C km
Total discharge charge lowered	610 C
Area of charge removal (SP+CG until end of sprite)	101 km^2
Area of charge removal (SP+CG until end of discharge)	497 km^2
Volume of charge removal (SP+CG until end of sprite)	125 km^3
Volume of charge removal (SP+CG until end of discharge)	770 km^3
Charge density in sprite removal volume	2.74 C/km^3
Charge density in total discharge removal volume	0.79 C/km^3

19 NLDN Reports from LTUL Event (29 MAY 12)



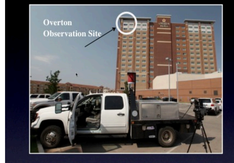


The mobile Phantom HSI was deployed in an MCS stratiform region to search for SP+CGs. A +64 kA CG near Graham, TX initiated 19 NLDN - detected Lightning Triggered Upward Lightning (LTUL) event, all –CGs (-10 kA average). Ten were within ~300 m of an 80 m wind turbine.

Some Findings

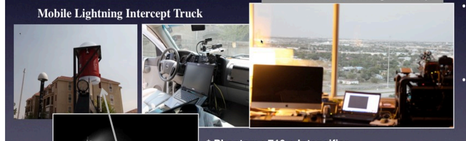
- In the 08JUN12 storm, the mean iCMC value for the 4 SP+CGs was +150 C km, a typical value for sprite parents reported by the CMCN. The charge was lowered from ~6 km AGL.
- The mean total charge lowered was 610 C, with 104 C and 342 C lowered at the ignition and end of the sprite luminosity. CMCs were 3638, 620 and 2052 C km, respectively.
- The volume discharged through the end of the sprite averaged 125 km^3, indicative of the removal of 2.7 C/km^3 from the volume. The positive reservoir was above the melting layer.
- While the 2012 High Plains convective season was marked by drought, the placement of over a dozen fixed and mobile cameras allowed capture of >1300 TLEs, many above LMAs.
- Phantom HSI captures included a variety of sprites and a long-lived elve (+halo?) (~3.5 ms).
- Though uncommon, SP+CGs can originate in the downshear anvil of a supercell, such as the one shown here from 30 MAR 12 in the OKLMA.
- The mobile Phantom HSI van captured a number of +CGs in MCS stratiform regions. One near Graham, TX resulted in a Lightning Triggered Upward Lightning event from an 80 m wind turbine. This LTUL resulted in a record number of NLDN reports (19 -CGs, 10 within ~300 m of the turbine). A gigantic jet was also imaged by a SpriteCam over the OKLMA.
- DSLR cameras with NIR-extended coverage can routinely image sprites as well as convectively generated mesopause gravity waves - also captured by the Suomi NPP satellite.
- An advanced Lightning Intercept Vehicle (LIV) has been readied for deployment during the upcoming 2013 convective season, targeting SP+CGs within LMAs in the central U.S.

2nd Intensive Operations Program (IOP): 24 MAY – 04 JUN 2012 Lubbock, TX



Fixed-base multi-sensor optical array

Mobile Lightning Intercept Truck

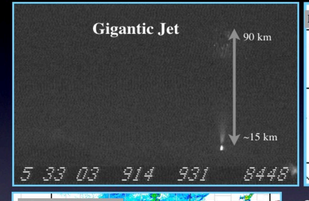


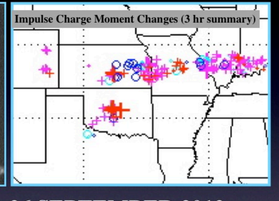
Deployed mobile vehicle with Phantom + Watec cameras into 4 LMAs in 3 states (TX, OK, NM)

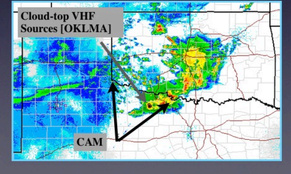
- Overton Hotel was fixed base of operations, command and control, and HSI sprite imager site
- Successful forecasting allowed intercepting MCSs on 8 of 9 nights
- Captured at least 20 high speed sequences of CGs in sprite-capable storms traversing LMAs (came within 30 seconds of "holy grail" shot)
- Drought, severe smoke and dust suppressed storms and hampered operations, but the field experiment design was confirmed

* Phantom v710 + Intensifier
* Watec 902H2 Ultimate (wide angle)
* Watec 902H2 Ultimate (zoom lens)
* Watec 902H2 Ultimate w/ light pollution filter
* HVX-200 HD time lapse
* Canon EOS 600D with extended IR range
* Canon ESO 5D Mark II high ISO

Gigantic Jet Emerges from Top of Isolated Tall Cell at End of Large MCS







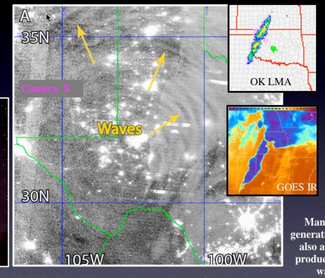
26 SEPTEMBER 2012

* +iCMCs in central OKLMA indicate sprites
* But only some small -iCMCs in north Texas
* At 0533Z, the Hawley, TX camera records a gigantic jet.
* Initial LMA analyses (Mark Stanley) shows VHF returns from top of small but intense cell with possible tropopause penetrating turrets at southern end of convective system (arrow)
* The meteorological scenario conforms with that of most prior GJ observations.
* Within range of expanded OKLMA for more detailed LMA analyses

New Techniques for Monitoring Convectively Generated Mesopause Gravity Waves

New high-ISO, extended IR range DSLRs can monitor both sprites and gravity waves (in color.) Multiple cases were noted during the 2012 campaign.

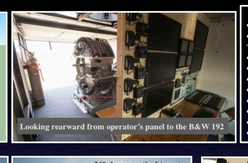
On 15 APR15, the Lamy, NM camera monitored sprites from a TX-OK linear MCS – and a train of outwardly expanding gravity waves, likely at ~85 km altitude. The waves are very clear in animations.



Then…it was discovered the DNB (day/night band) on the newly launched Suomi NPP satellite was able to detect gravity waves in the airglow layer. This image was taken at the same time as the image on the left. The circular gravity wave train is emanating from the deep convection in north TX and western OK.

Many TLE-generating storms also appear to produce gravity waves.

The Lightning Intercept Vehicle [LIV] - Ready to Roll (September, 2012)



INITIAL CONFIGURATION

- (4) 90-degree Watec CG monitors
- Phantom v7.3 (with Intensifier for TLEs); horizontal or fisheye
- All-sky CG camera; HD event camera
- Watec 902U TLE video
- Local E-field ; GPS timing all data
- Cordin 400,000 fps streak camera
- Sirius XM Baron Weather Display
- Enhanced cellular communication
- Beckmann & Whitley 192: million ips
- DVR video data logging

The LIV can target either TLEs or SP+CGs

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