Very active sprite-producing thunderstorms observed over Argentina and Brazil

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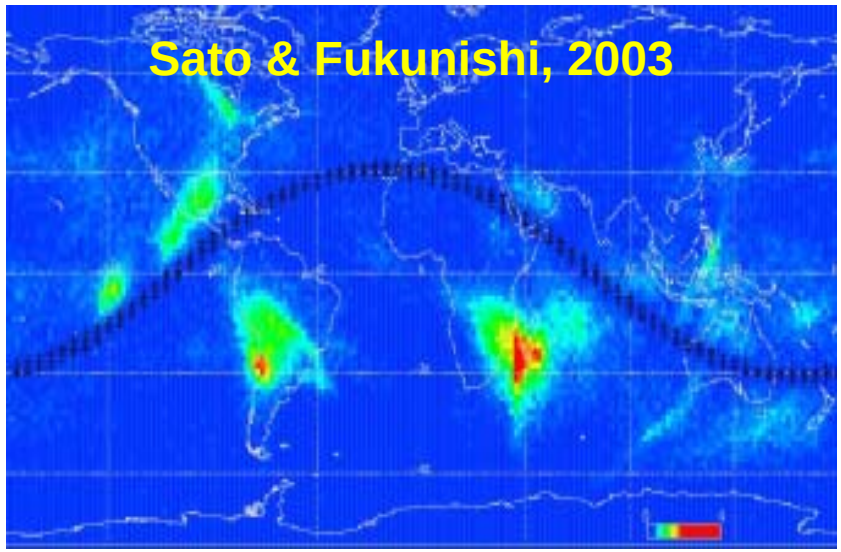
Southern Brazil Sprite Campaign

Feb-Mar., 2006



Recent lightning ULF/ELF studies indicate high TLE occurrence over South America.

Coordinated balloon and ground-based measurements of sprite energetic over South America
(PI: R. Holzworth,
U. of Washington).

Ground Instrumentation

Imaging (USU):

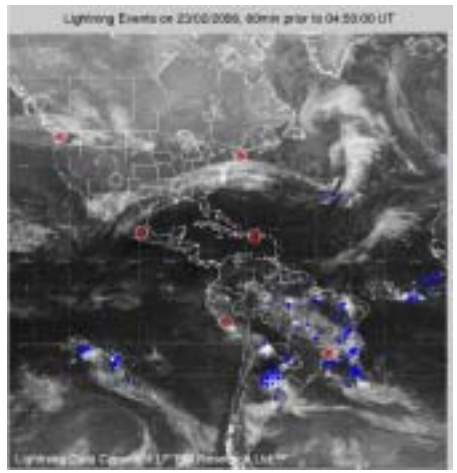
- Two intensified Xybion CCD cameras (unfiltered)
- Field mode: 16.7 ms exposure with
- GPS timing (1ms accuracy)

ELF/VLF Sensor (Duke University):

- 1 Hz to 30 kHz Electric and Magnetic Fields
- Unambiguous polarity and direction finding
- Integrated GPS for ~20μs absolute timing

World Wide Lightning Location Network (WWLLN):

- Global network of VLF sensors (3-30 kHz)
- Detects 15-20% of all CG lightning
- Spatial accuracy of ~10 km
- Timing uncertainty < 30 μs



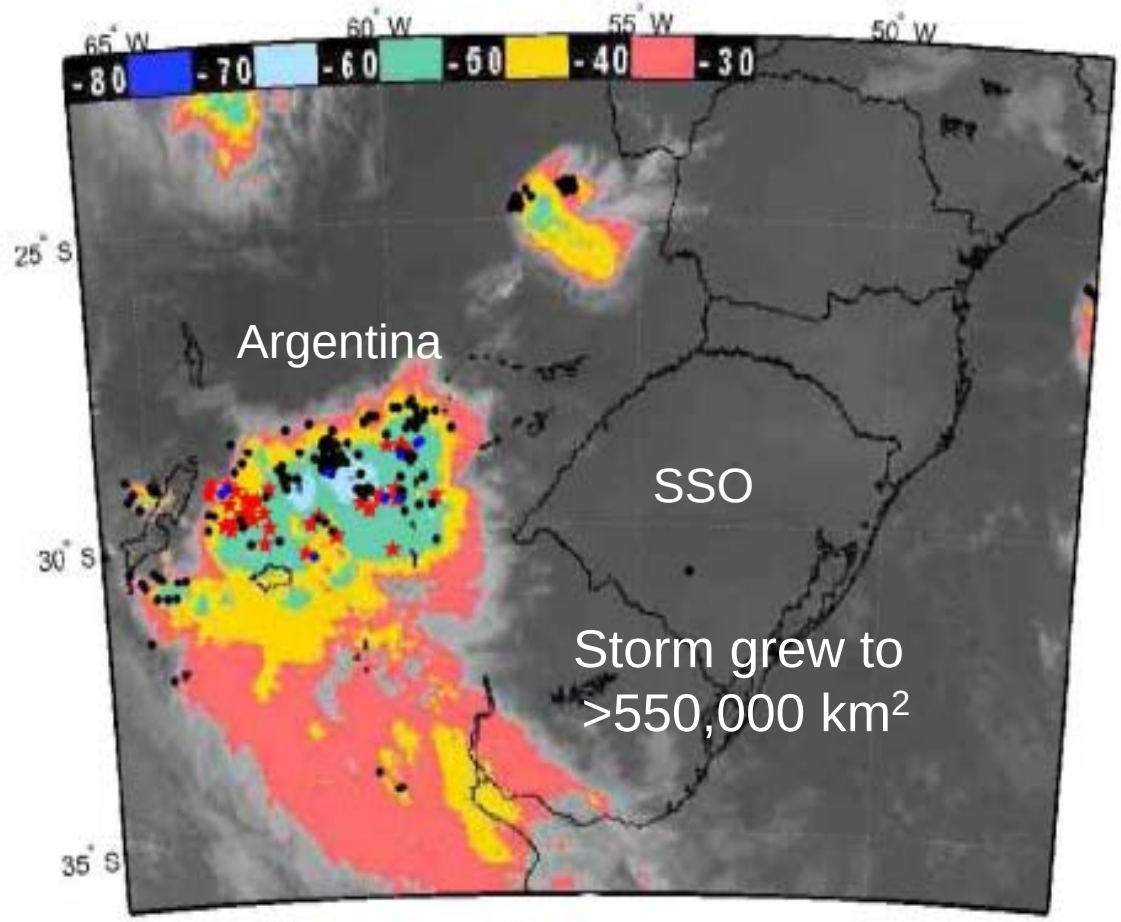
Feb.23, 2006 Mesoscale Thunderstorm

(Thomas et al., EOS Feature, March 3, 2007)

- Thunderstorm system over Argentina at a range of 500-1000 km

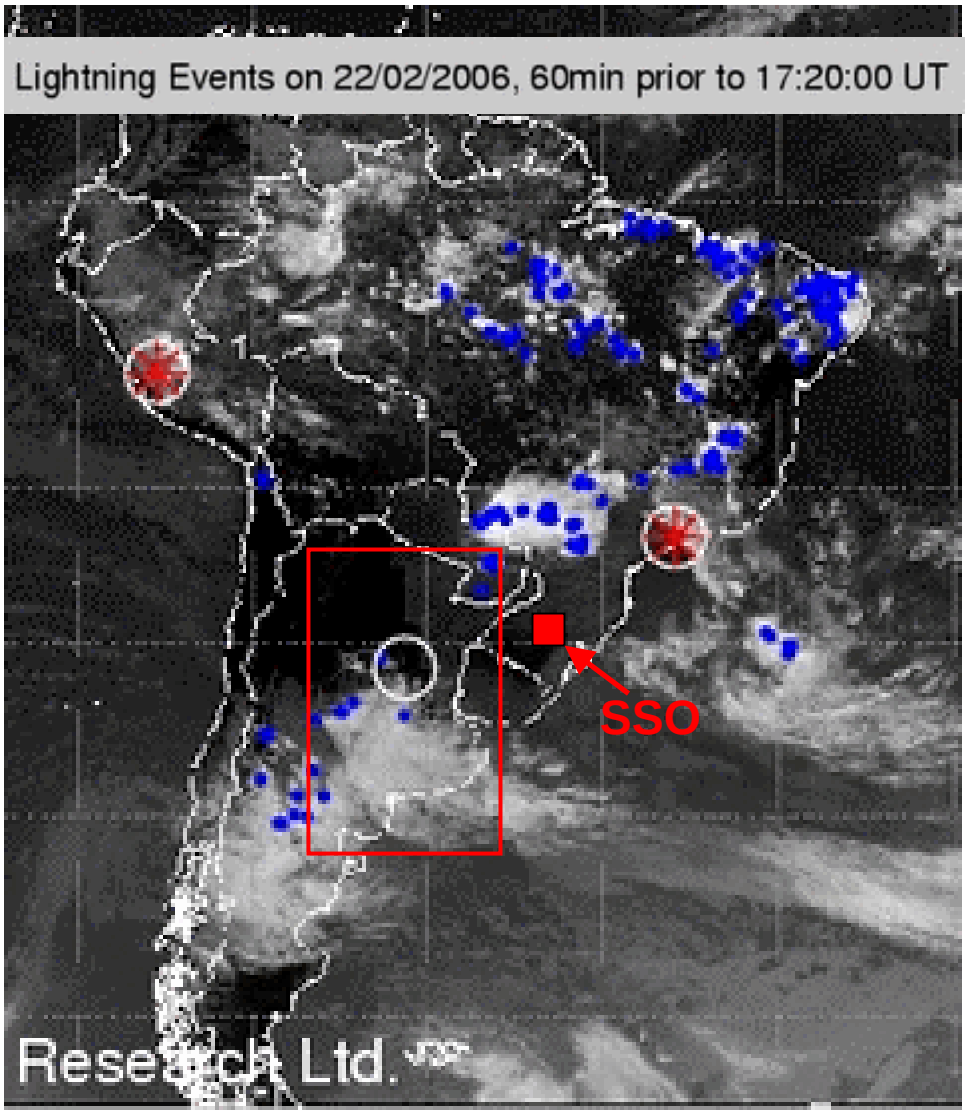
- TLEs were imaged for over 6 hours originating from multiple regions of the storm

- 445 TLEs (sprites, halos and a few elves) recorded (the 3rd largest Spriting storm on record)



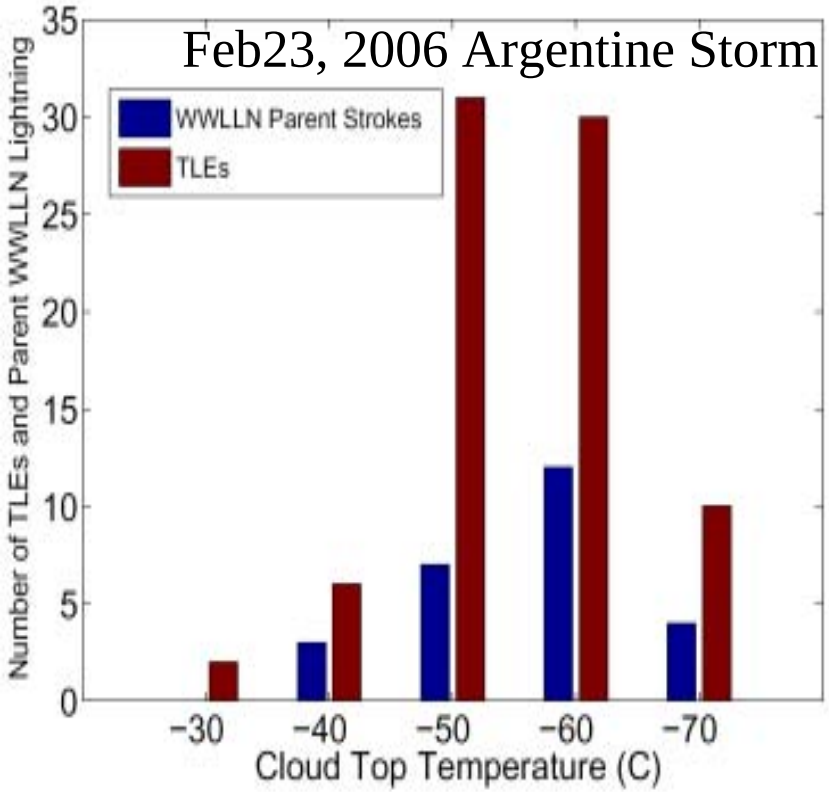
TLEs (stars) and WWLLN (black dots) 06:15 -06:45 UT

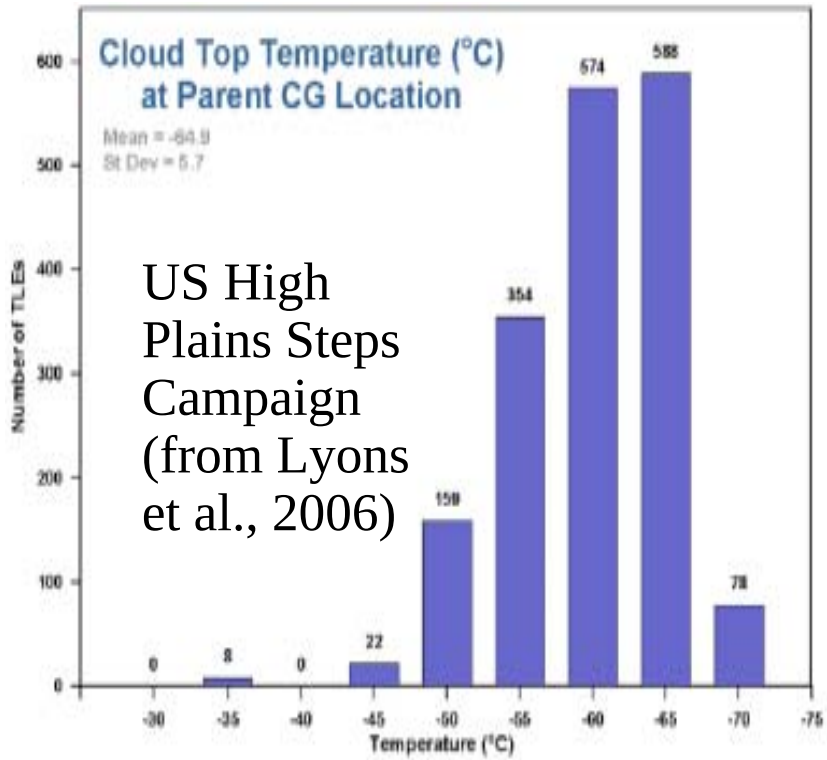
Feb. 22-23, 2006 Mesoscale Thunderstorm



Cloud-top Temps and TLES

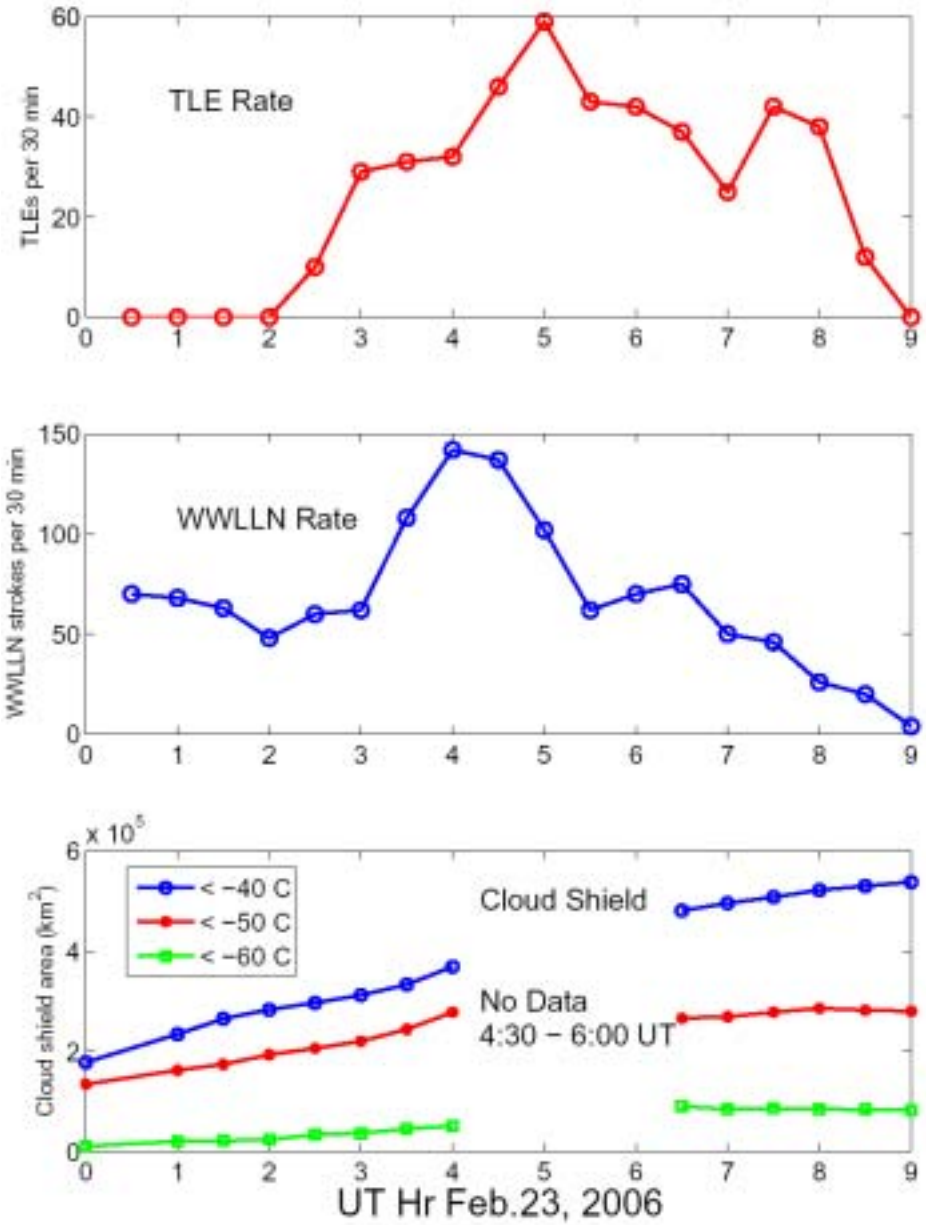
(Solorzano et al., AGU Fall Meeting , 2007 and Sao Sabbas et al. next talk this session)





Argentine and US High Plains storms similar, although higher percentage of Argentine TLEs above clouds warmer than -60 C

TLE / WWLLN Rate and Cloud Top Temps



- Observed TLE rate grows with storm size until data gap in IR images
- WWLLN peaks at ~04 UT and TLEs at ~05 UT

(Solorzano et al., AGU Fall Meeting , 2007 and Sao Sabbas et al. next talk this session)

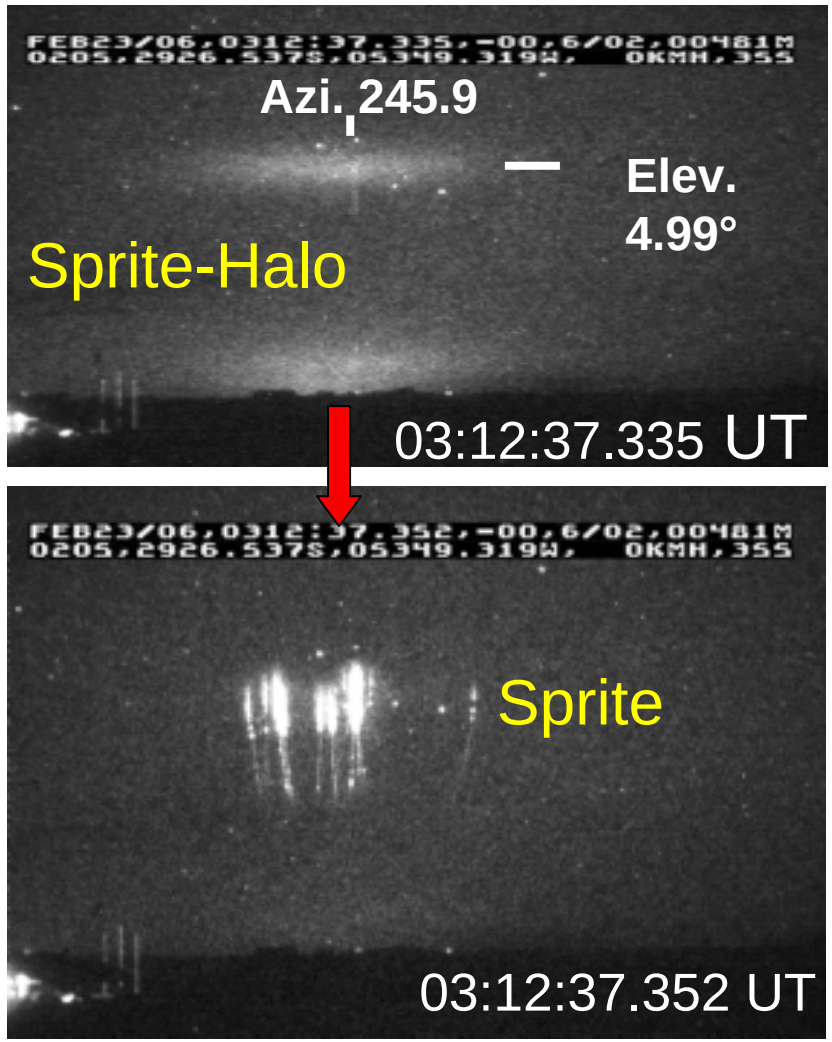
Example Sprite-Halo Data

(Bailey et al., AE23A-0896, this meeting)

- 6 hrs of observations 23 Feb. 2006
- 121 sprite-halo events over Argentina
- A total of 182 halo and sprite-halo were observed (i.e., about 40% of total TLEs).

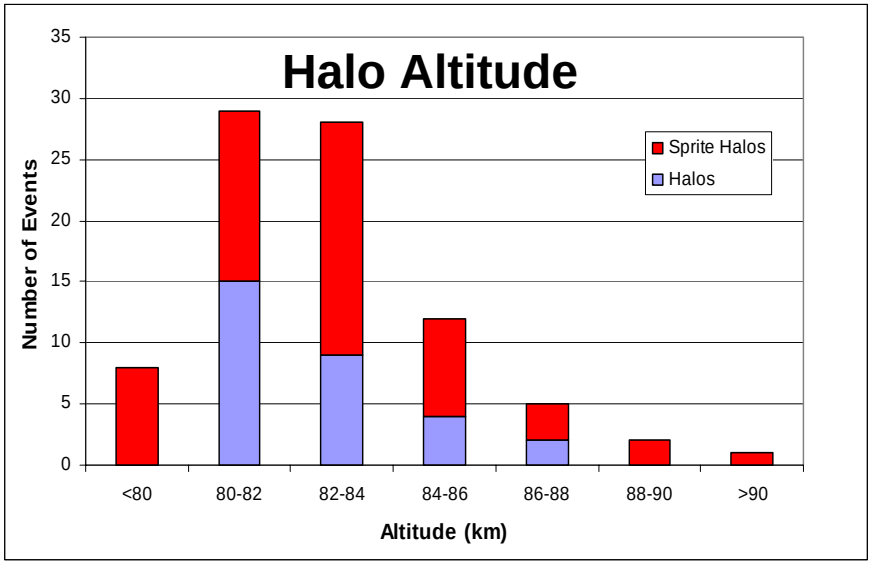
Typical Sprite-Halo

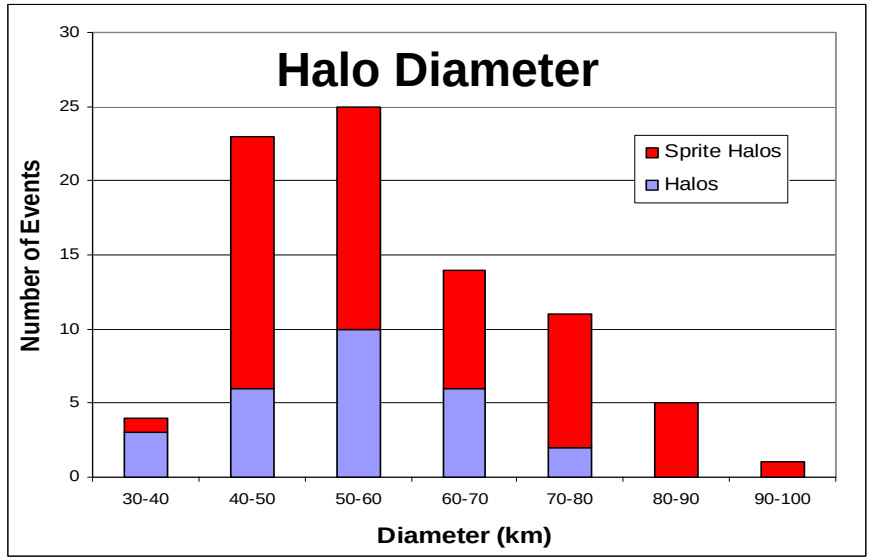
Images 17 ms apart



Halo Results

(Bailey et al., AE23A-0896, this meeting)



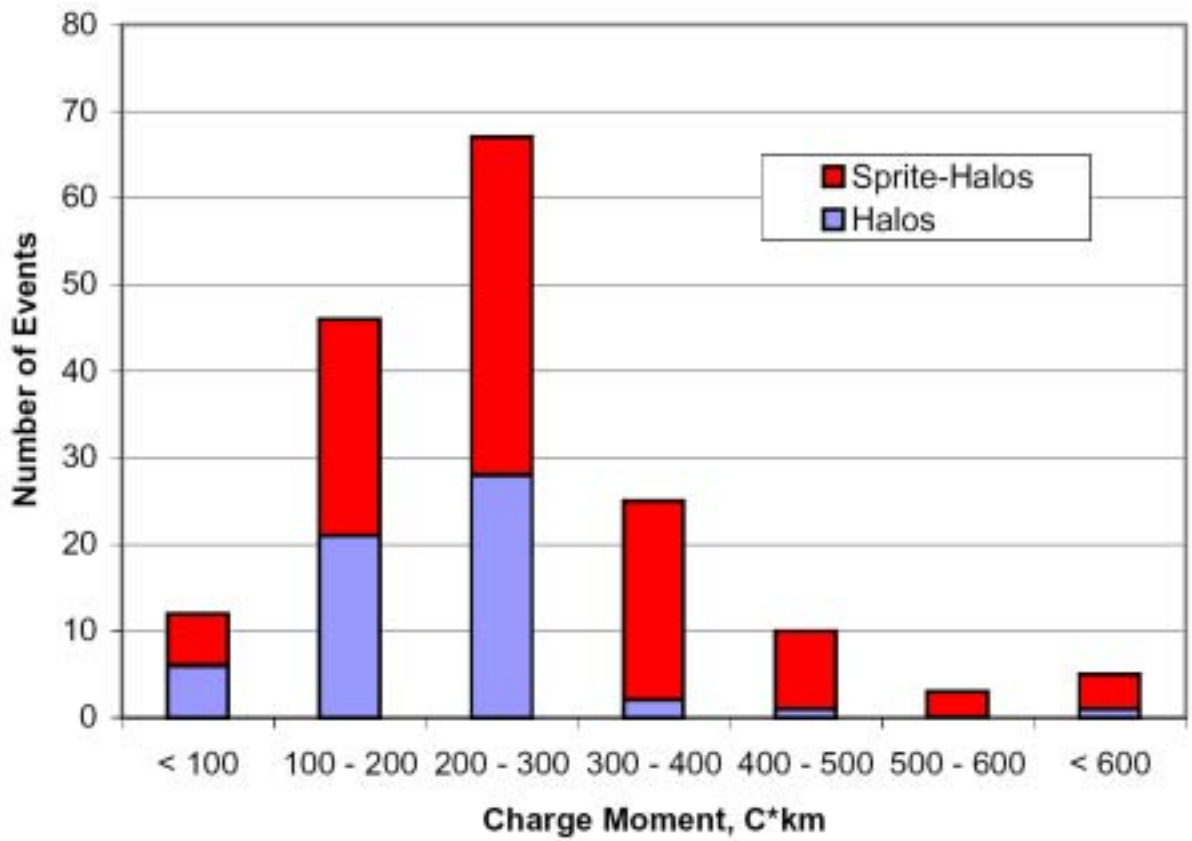


- 84 events correlated with WWLLN located lightning:
  - mean altitude = 82.7 km (range: 78 – 91 km)
  - mean diameter = 58 km (range 31 – 93 km)
- Similar to US High Plains:
  - 4 events: height ~78 km, diameter 66 km, (Wescott et al., 2001)
  - 34 events: height ~80 km, diameter 86 km, (Miyasato et al., 2002)

Sprite-Halo/Halo Impulsive Charge Moment Changes

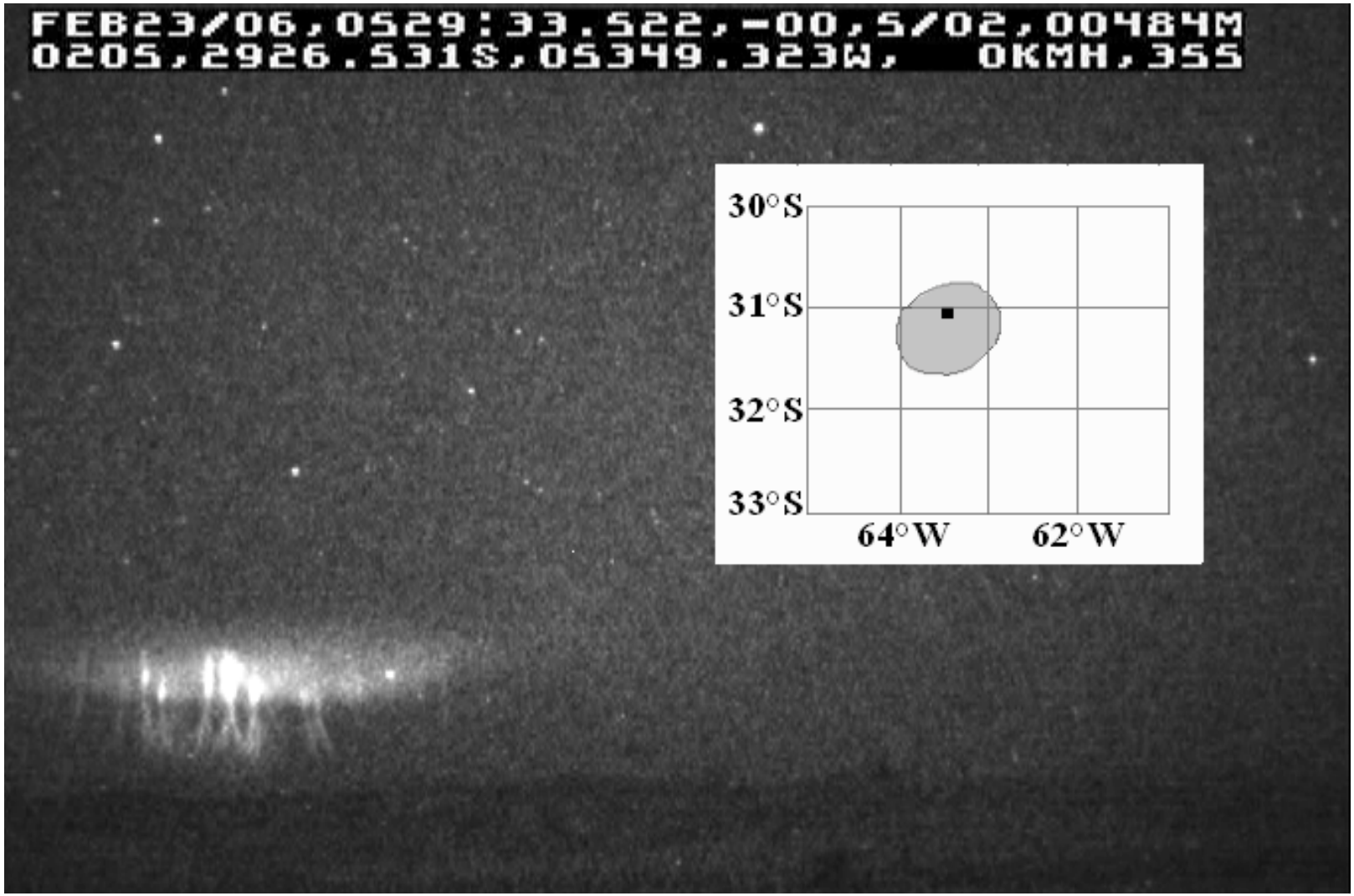
(Bailey et al., AE23A-0896, this meeting)

- Mean impulsive (2 ms) charge moment change ~255 C-km
- Threshold appears lower than US High Plains (Cummer and Lyons, 2005) – more analysis needed



Sprite-Halo Driven by -CG

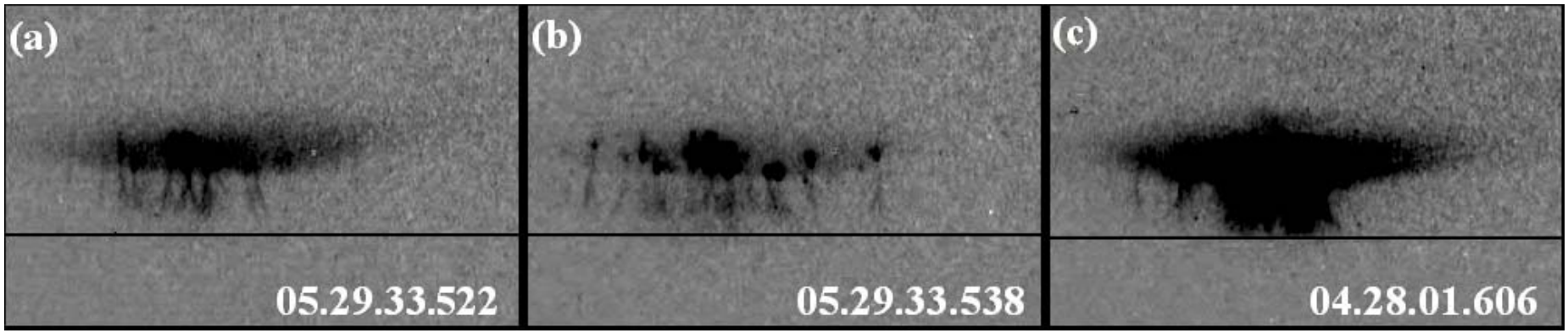
(Bailey et al., AE23A-0896, this meeting)



Comparison of –CG and +CG Sprite-Halos

(Bailey et al., AE23A-0896, this meeting)

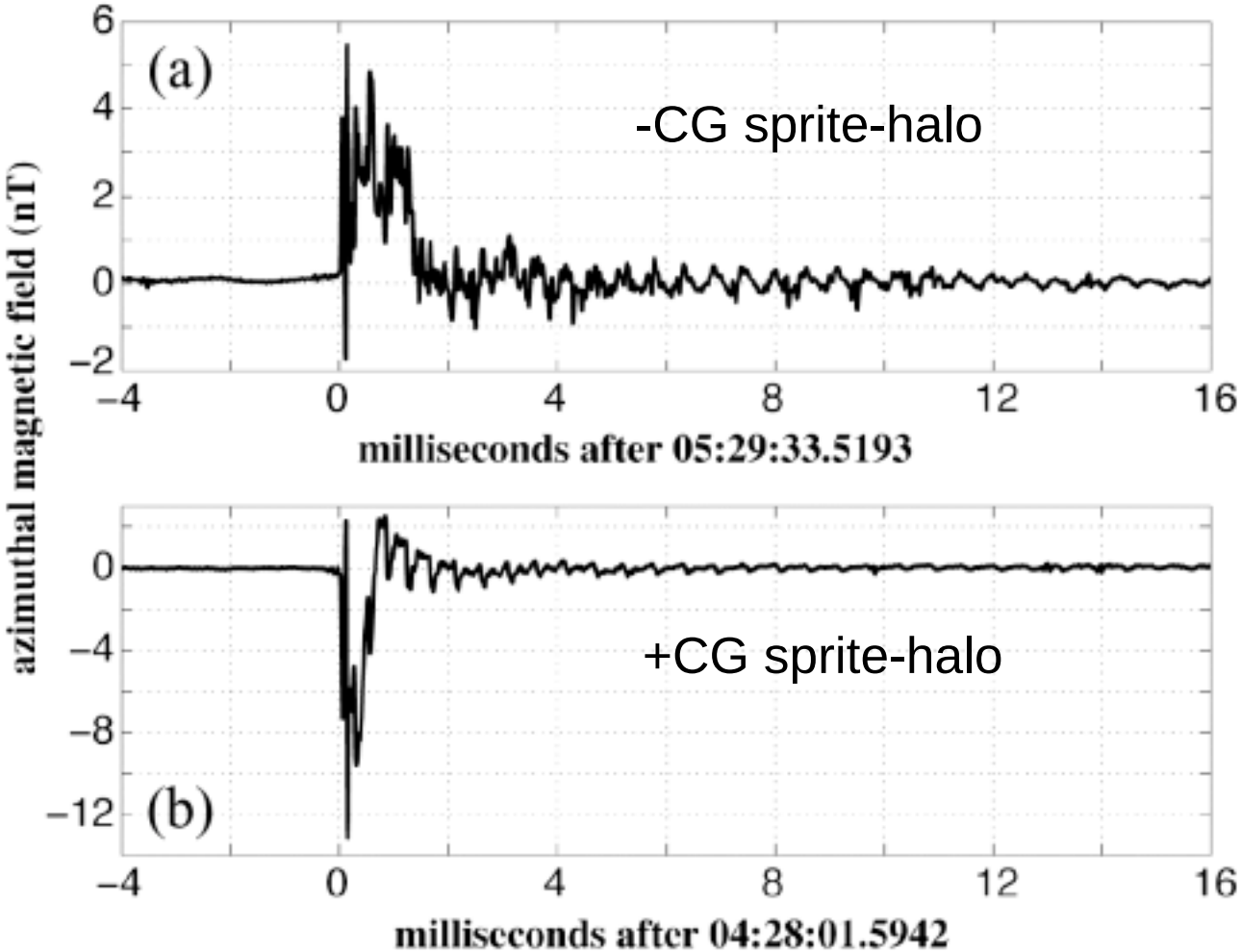
-CG Frame 1 -CG Frame 2 +CG



Black line is horizon at ~60 km altitude

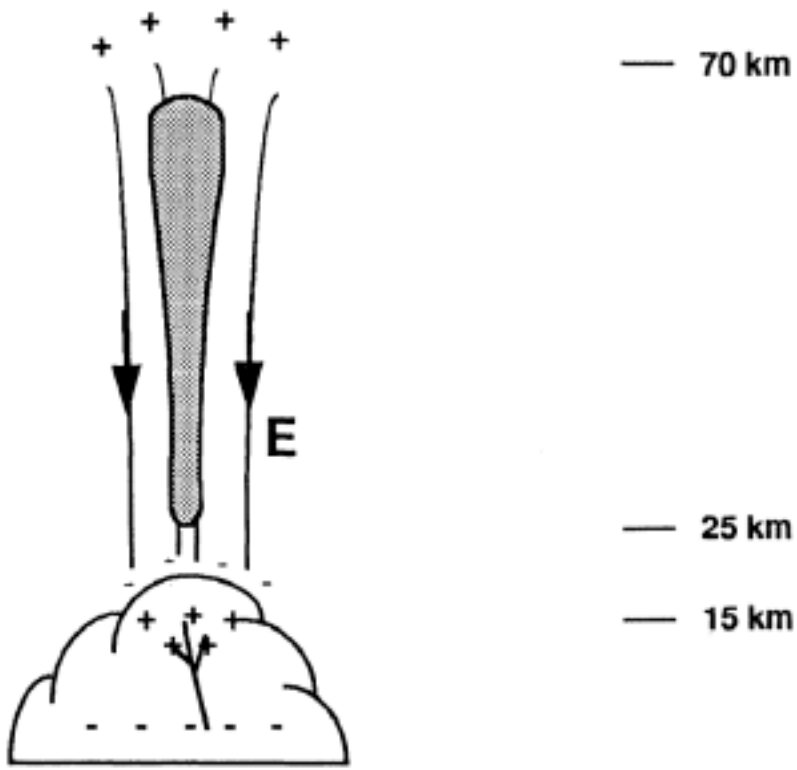
ELF/VLF Waveforms

(Bailey et al., AE23A-0896, this meeting)



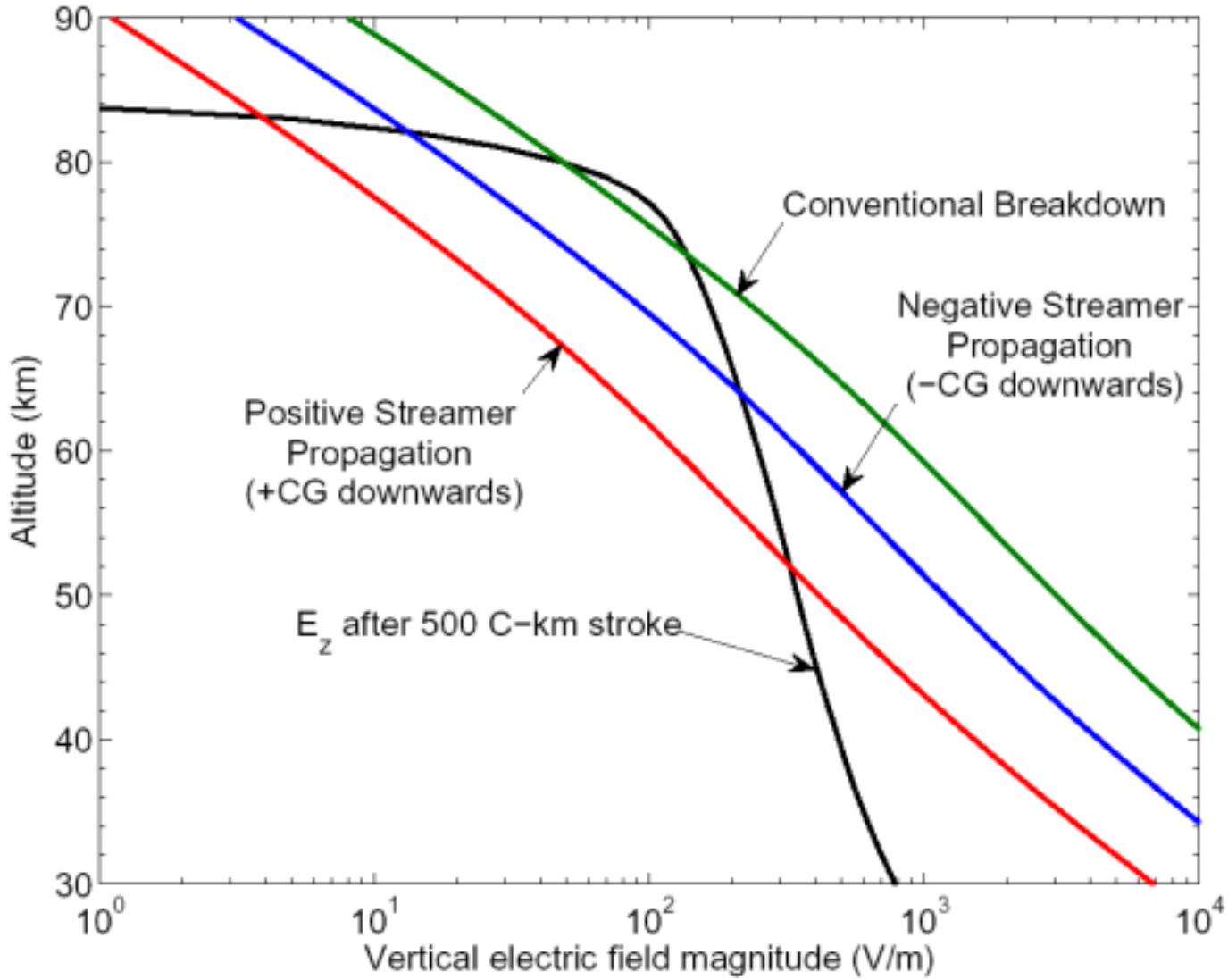
-CG and Sprite Models

- Quasi-Static Electric Field after –CG directed upwards
- Runaway break-down model requires downward Electric Fields

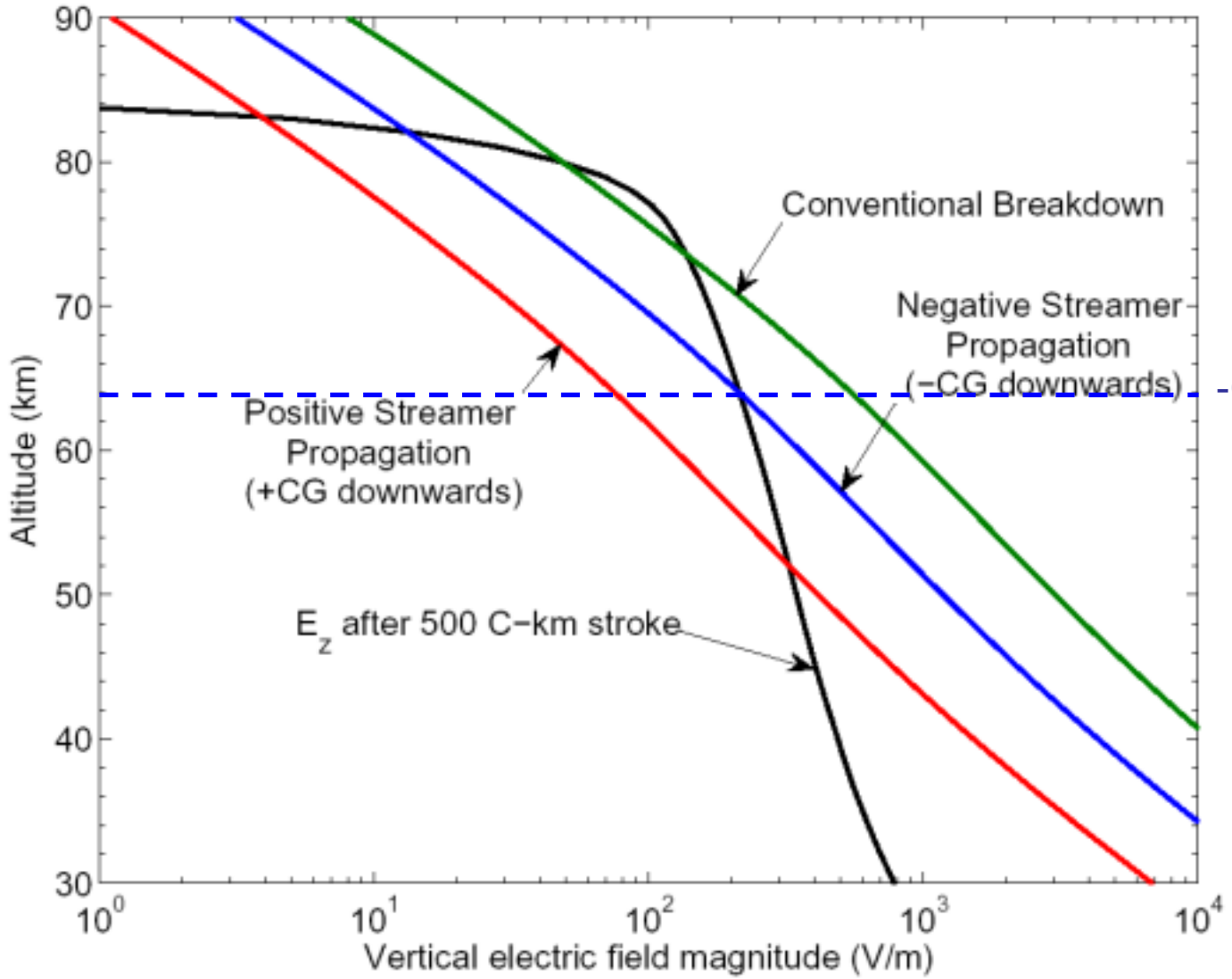


From Fig. 7 Roussel-Dupre and Gurevich, JGR, 1996

-CG and Sprite Models



-CG and Sprite Models



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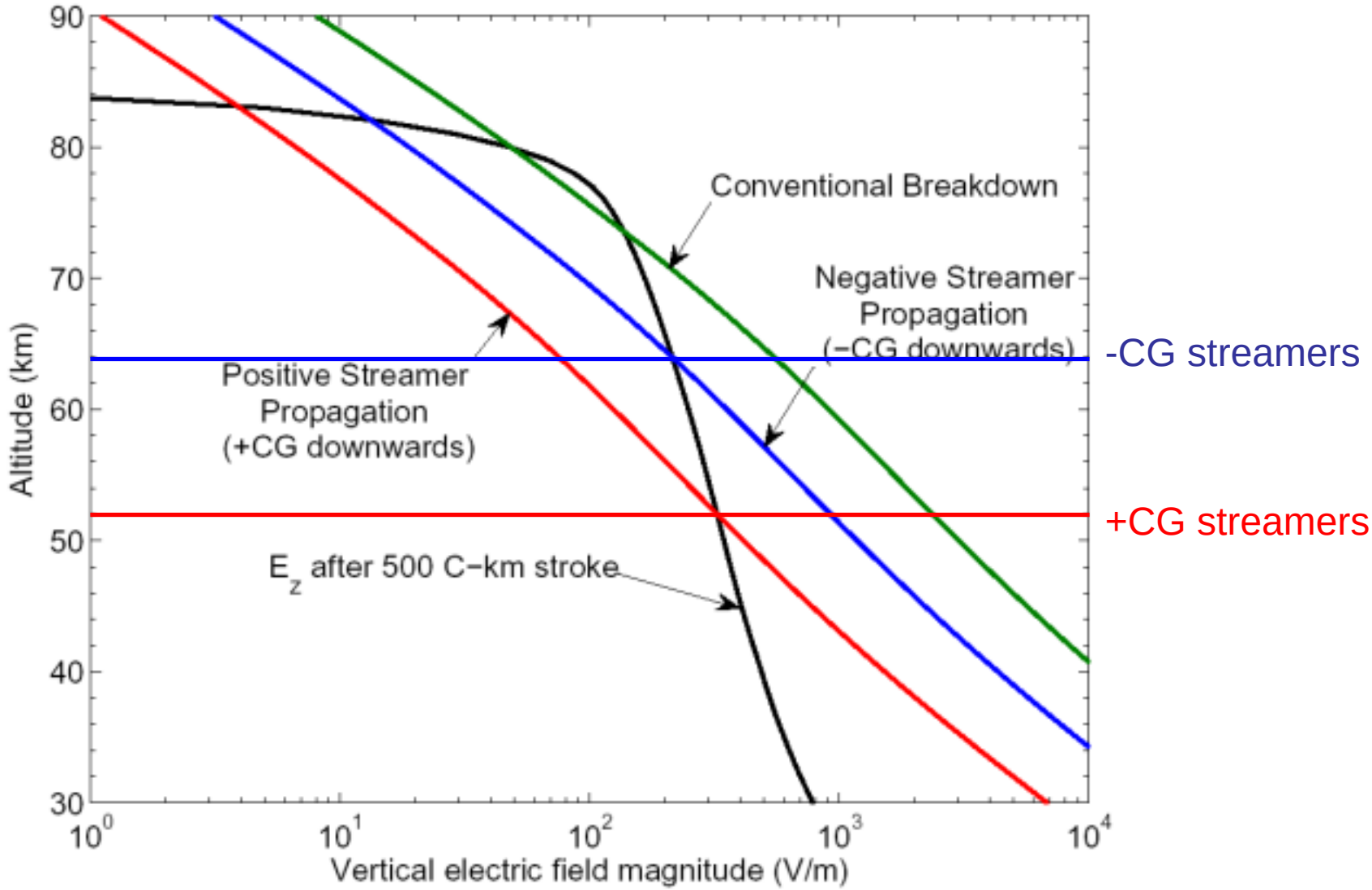
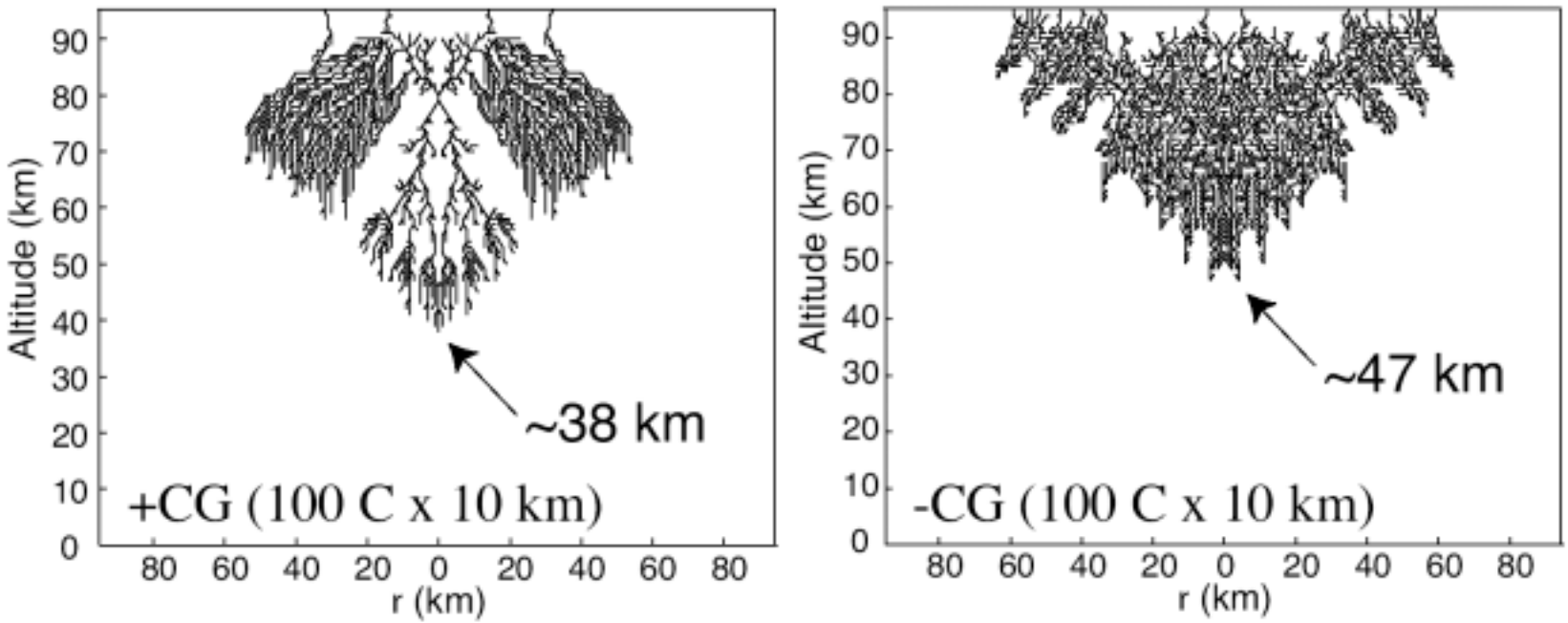


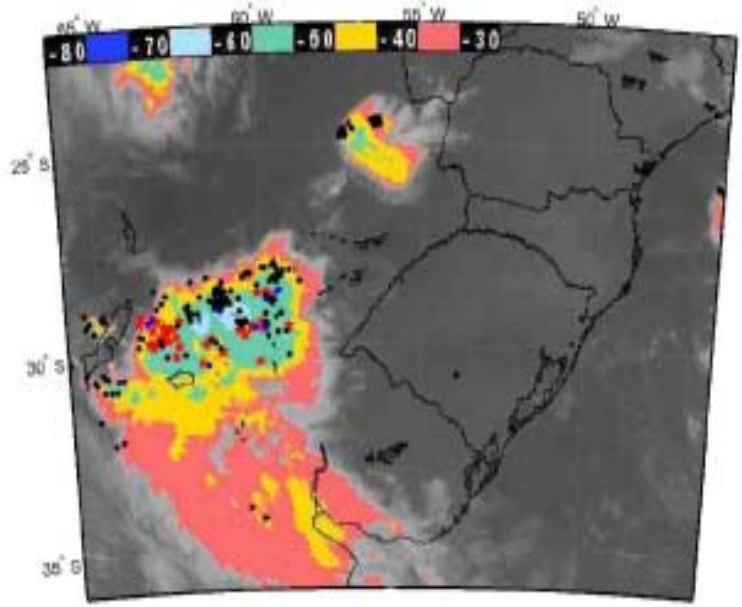
-CG and Sprite Models

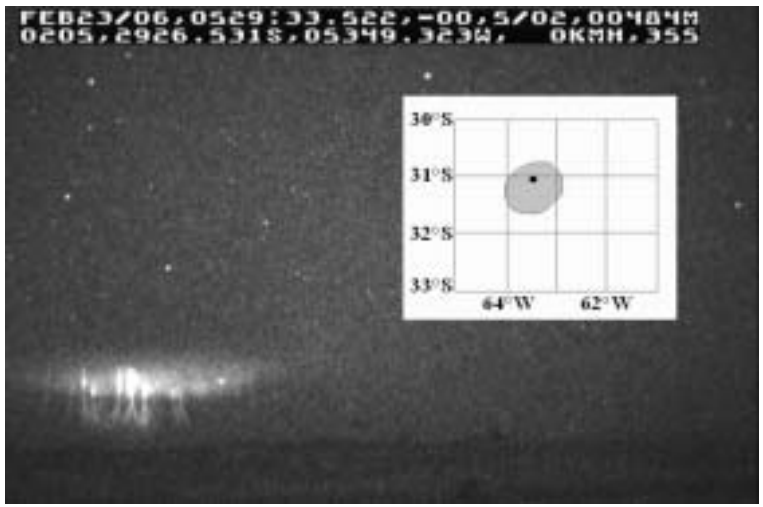


From Pasko et al. GRL, 2000

Conclusions

- 3rd most active sprite storm reported
- Most sprites in stratiform region
- More sprites above cloud regions warmer than -60 C compared with US High Plains
- Halo altitude and diameter similar to US High Plains
- Impulsive charge moment changes appear lower than U.S. High Plains – more analysis needed
- Rare -CG sprite-halo observed, only 3rd confirmed, first time over land-based mesoscale storm

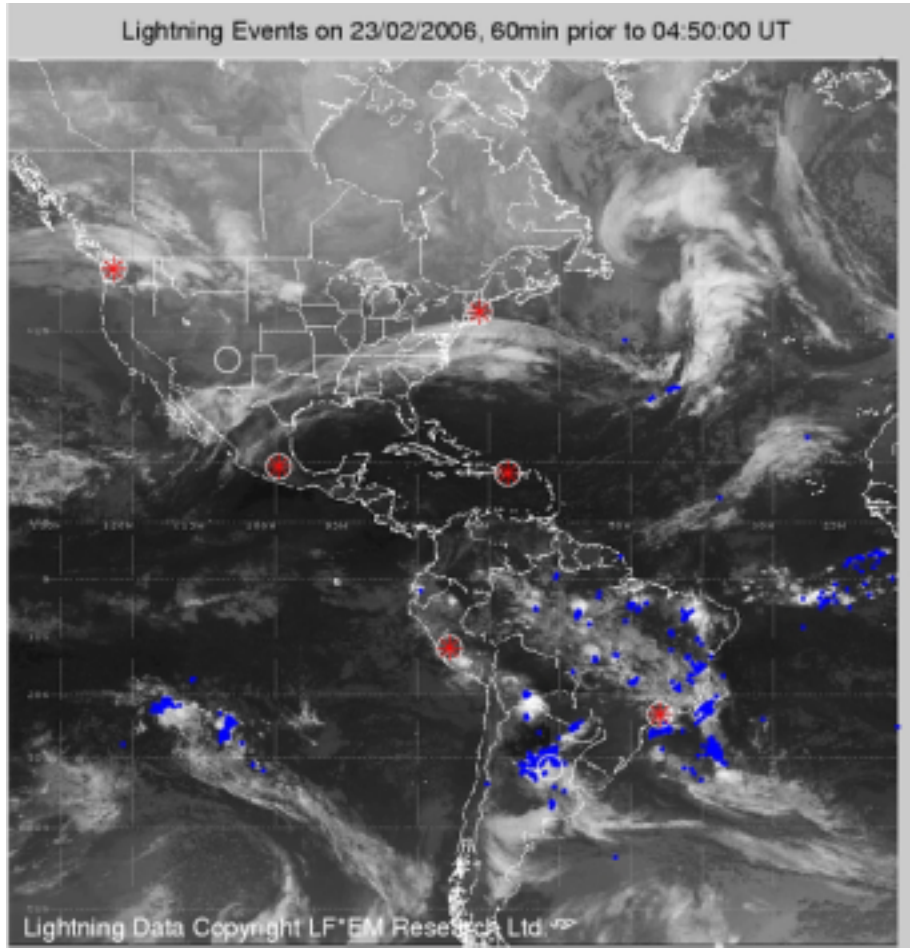




World Wide Lightning Location Network (WWLLN)

WWLLN:

- Global network of VLF sensors (3-30 kHz)
- Detects 15-20% of all cloud to ground lightning
- Spatial accuracy of ~10 km
- Timing uncertainty < 30 μs.
- WWLLN data updated every 10 minutes
- Used during campaign to monitor storm conditions in near real time.

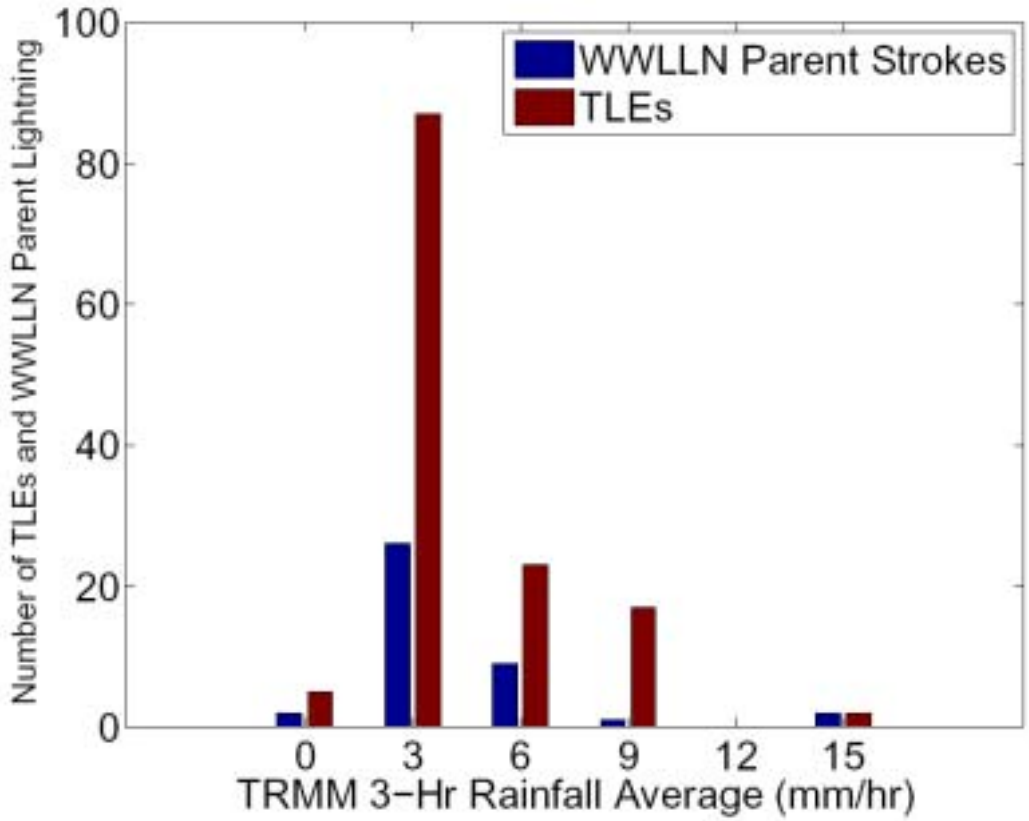


http://webflash.ess.washington.edu/

TLEs / WWLLN and TRMM 3-HR Rainfall

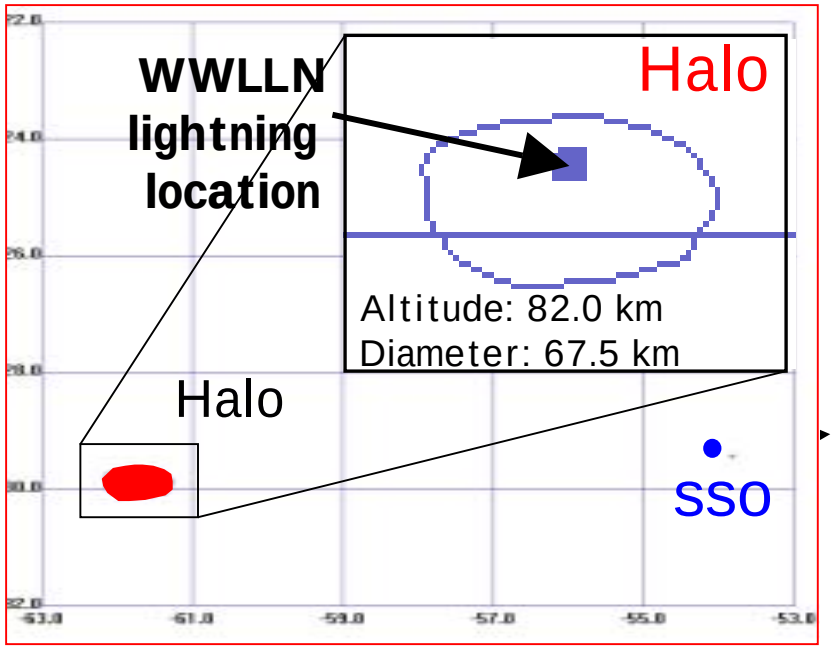
(Solorzano et al., AGU Fall Meeting , 2007)

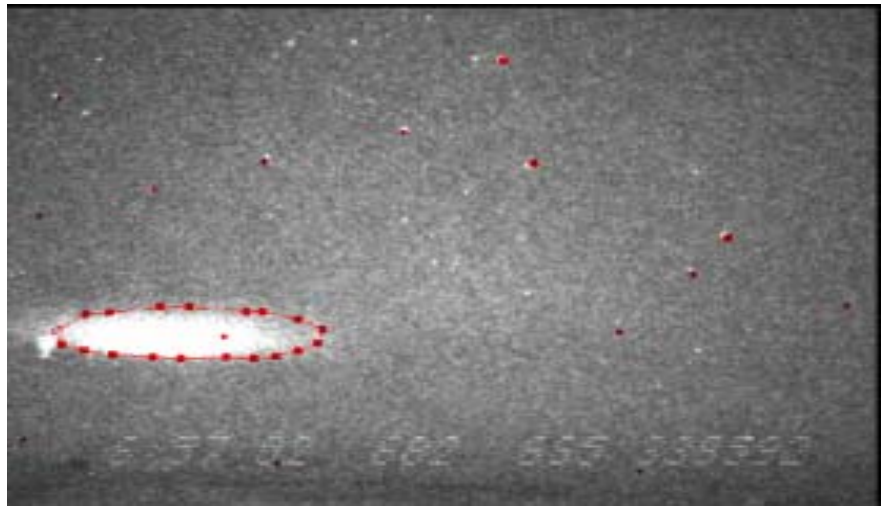
Most TLEs occur in regions with low to moderate rainfall, ie. the stratiform region of the storm



Halo Analysis

(Bailey et al., AE23A-0896, this meeting)



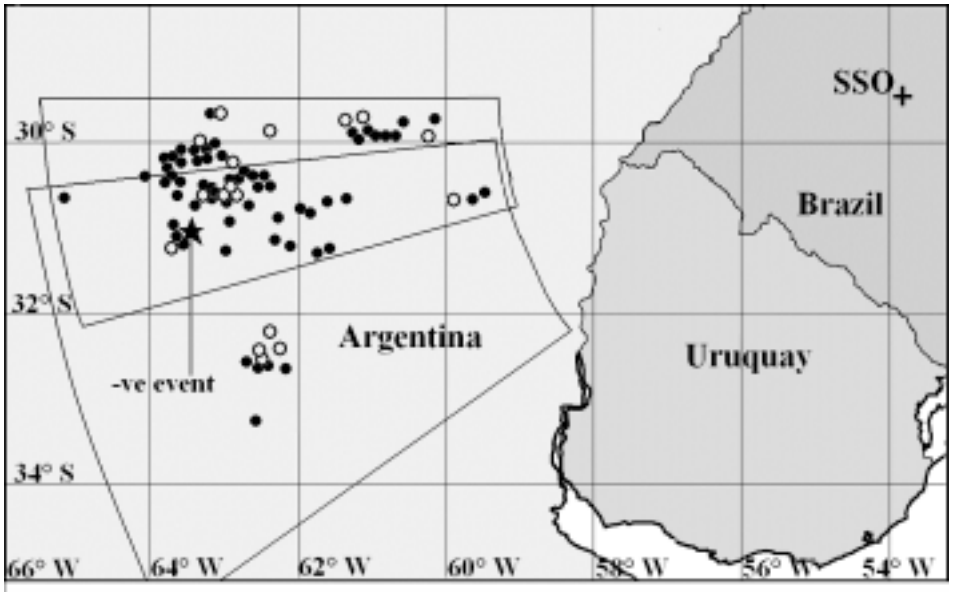


Assumed center of halo is within ~5 km of the parent lightning strike (Wescott, et al., 2001).

- Using star field to calibrate image data and obtain azimuth and elevation of halo event.
- Full account taken of refraction at low elevations.
- Map outline of each halo for various altitudes to determine best coincidence with WWLLN lightning location.
- 84 WWLLN halo events yielding a good estimate of their central altitudes and their diameters.

Events within +/- 30 min. of –CG Sprite-Halo

(Bailey et al., AE23A-0896, this meeting)



Events from 05 – 06 UT
Star: -CG Sprite-Halo
Open circles: TLEs with corresponding WWLLN
Solid circles: TLE without corresponding WWLLN

Time (UT)	TLE Type	Azimuth (°N)	Range (km)	Polarity	Impulse Charge Moment Change
05:21:59.198	Sprite	262.0	899	+ve	32 C. km
05:23:42.963	Sprite *	255.8	963	+ve	95 C. km
05:27:29.459	Sprite	258.7	957	+ve	-
05:28:59.969	Sprite-halo *	262.2	900	+ve	311 C. km
05:29:33.522	Sprite-halo *	257.9	944	-ve	-503 C. km
05:34:08.291	Sprite	262.7	882	+ve	151 C. km
05:34:08.625	Sprite-halo	260.5	862	+ve	383 C. km

March 3-4 Storm