Sprites and halos produced by positive and negative cloud-to-ground lightning over Argentina and Brazil: Overview of video images, ELF/VLF data and meteorology

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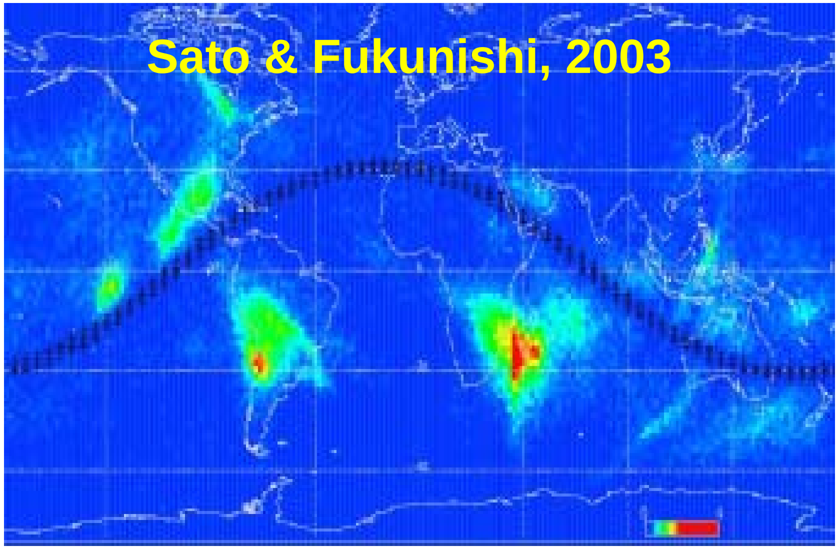
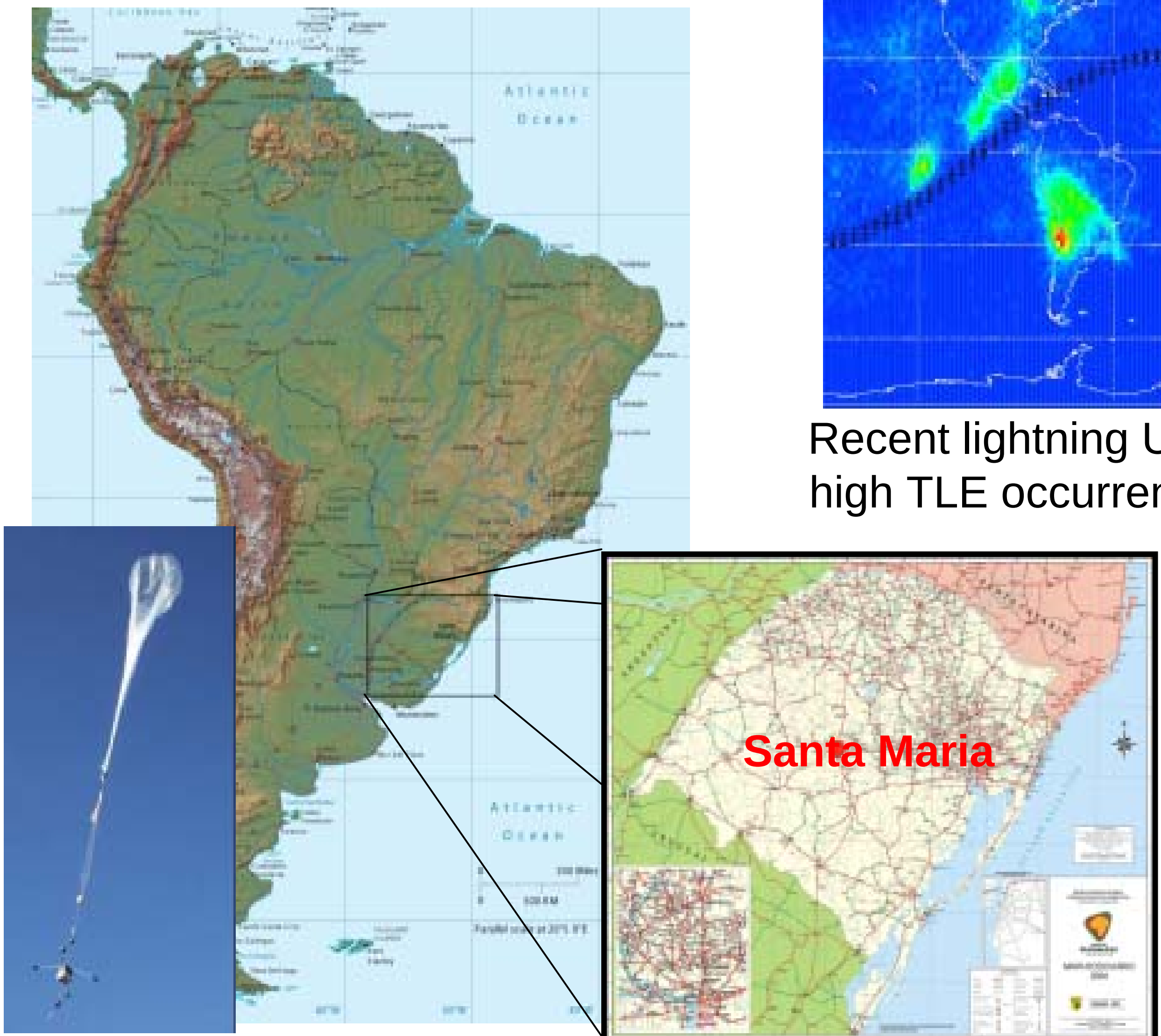
Southern Brazil Sprite Campaign

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):

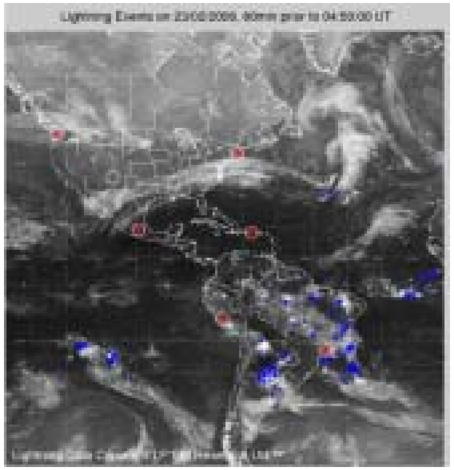
- Two intensified Xybion CCD cameras (unfiltered)
- Field mode: 16.7 ms exposure with
- GPS timing (1ms accuracy)

ELF/VLF Sensor (Duke University):

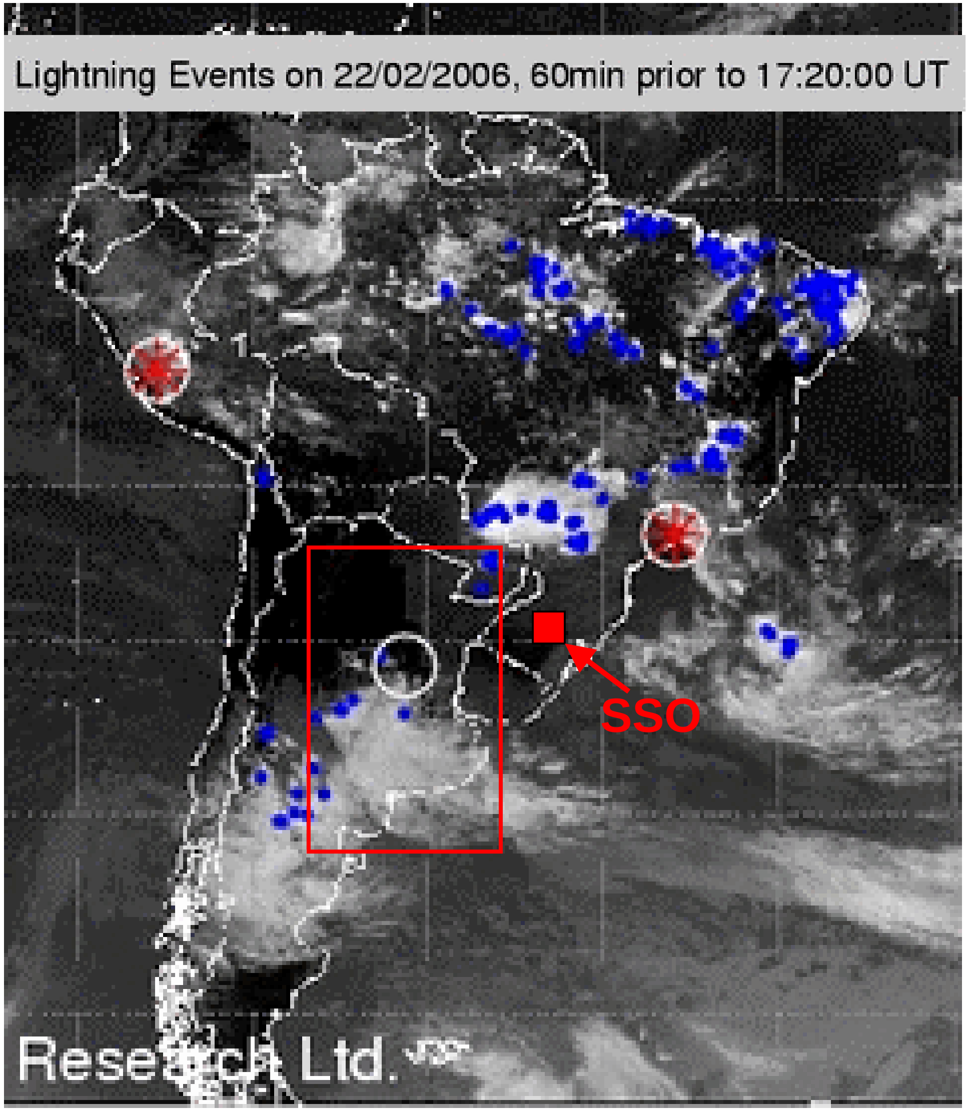
- 1 Hz to 30 kHz Electric and Magnetic Fields
- Unambiguous polarity and direction finding
- Integrated GPS for ~20μs absolute timing

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



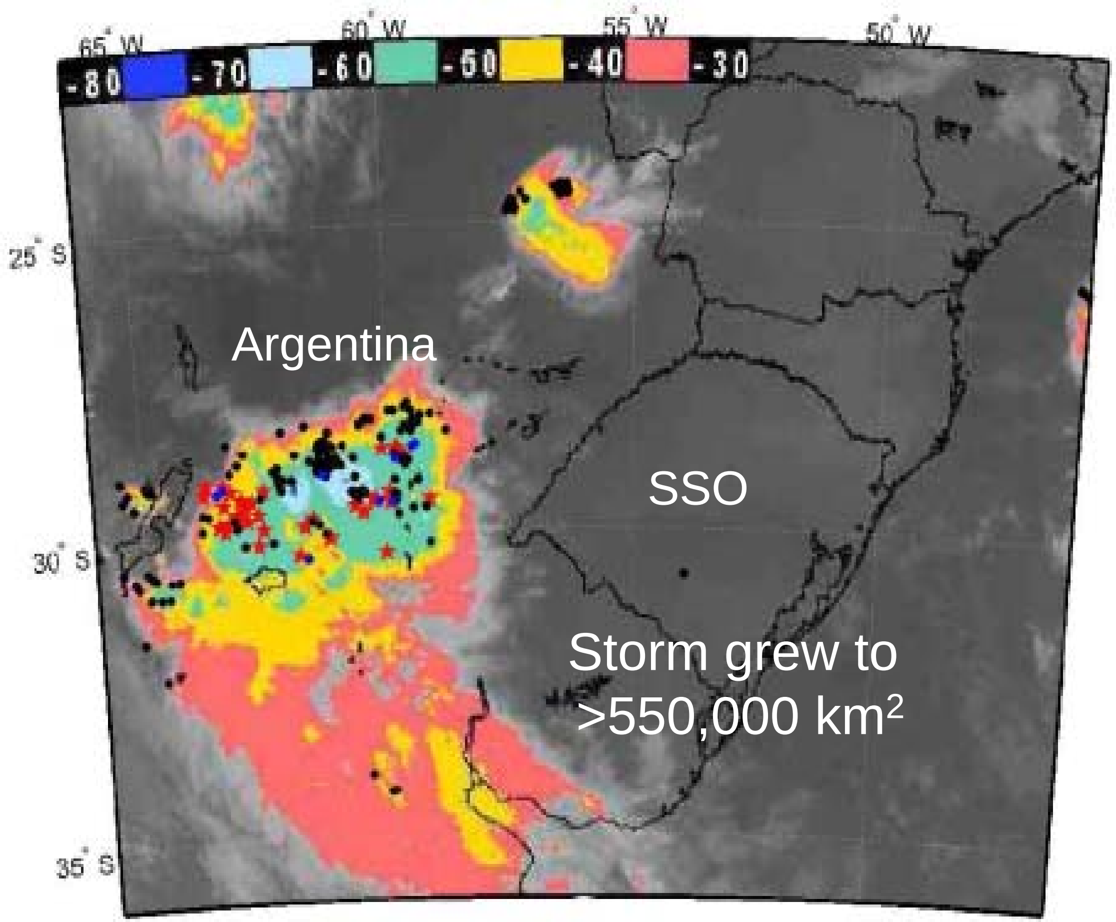
Feb. 22-23, 2006 Mesoscale Thunderstorm



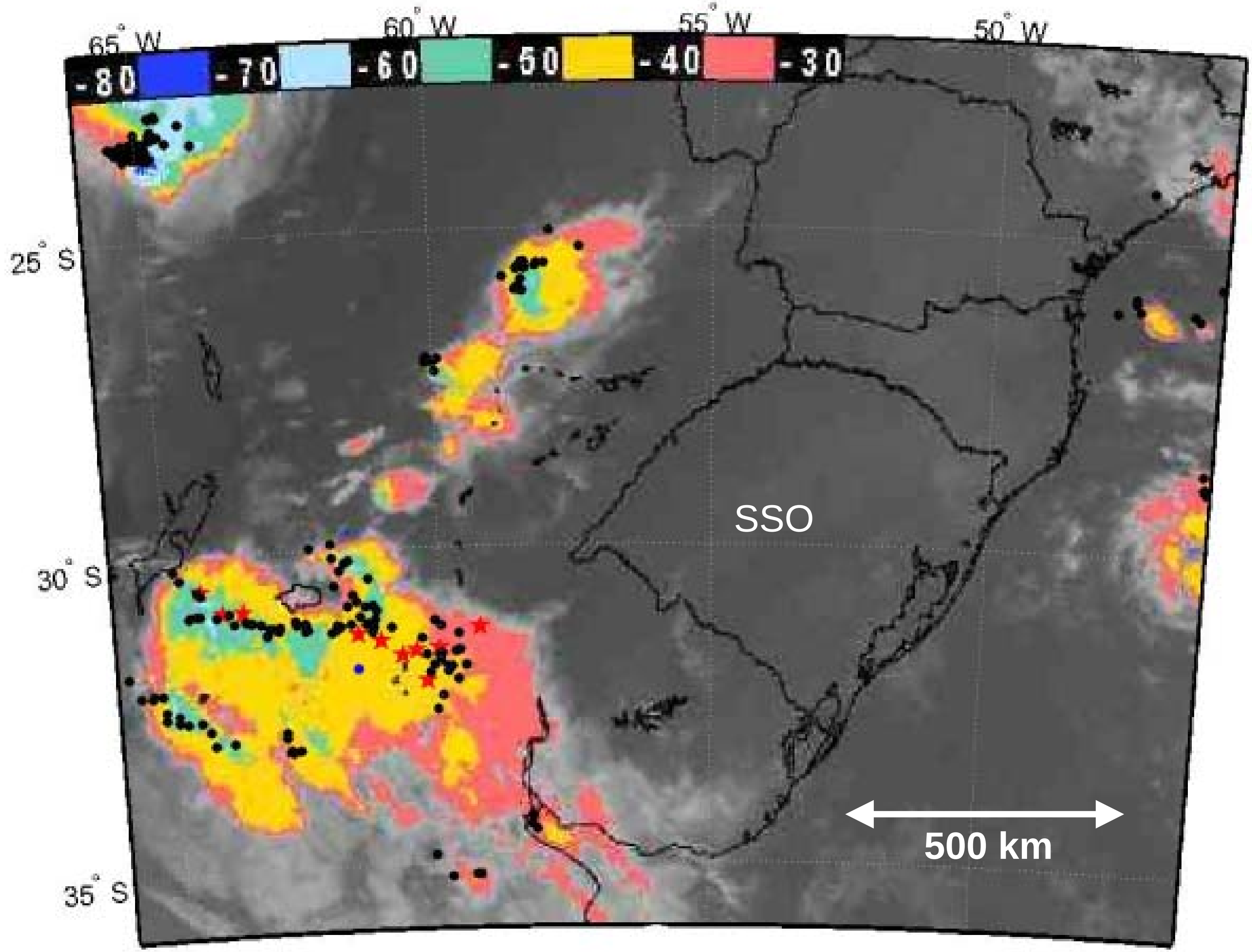
Feb.23, 2006 Mesoscale Thunderstorm

(Thomas et al., EOS Feature, March 6, 2007)

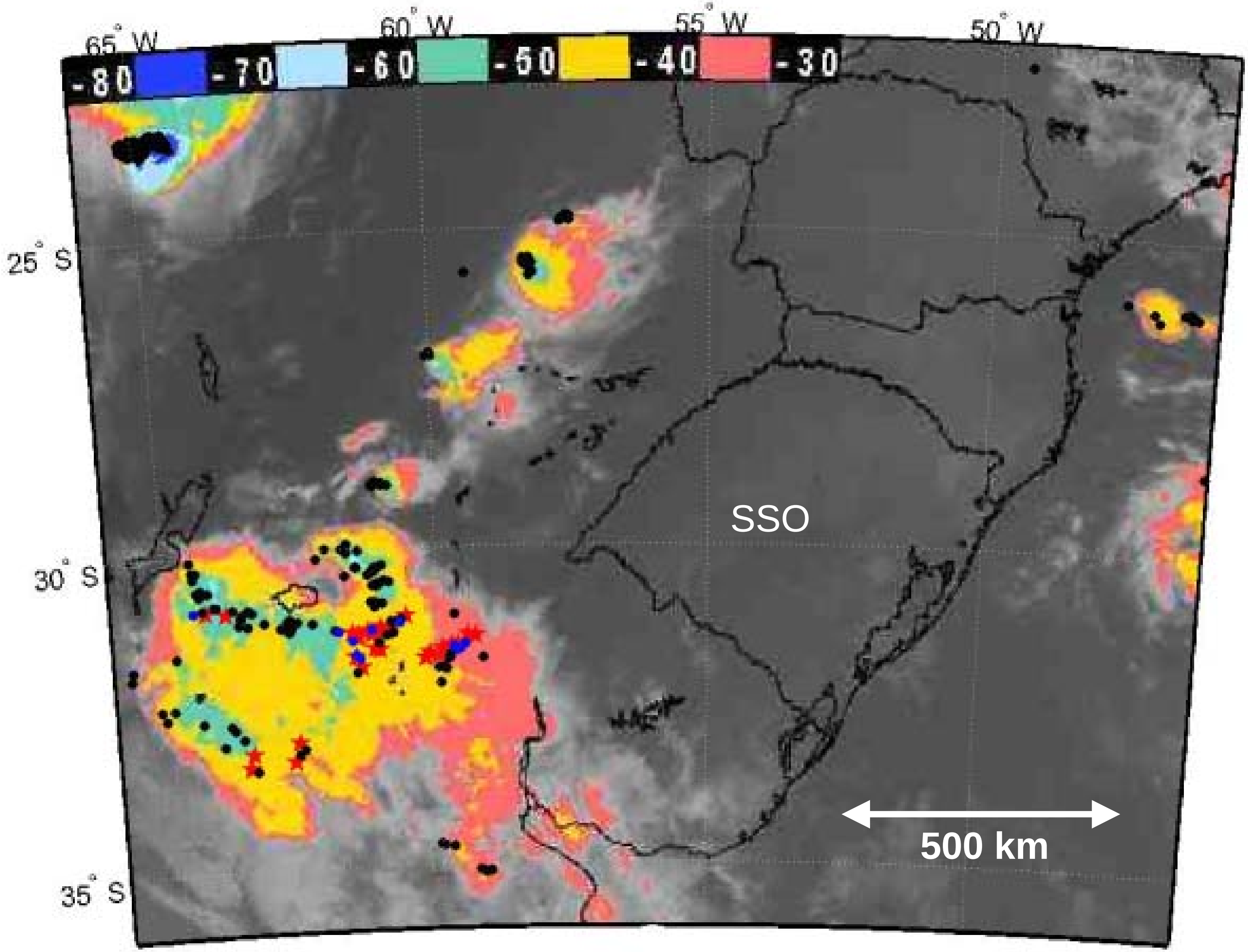
- Thunderstorm system over Argentina at a range of 500-1000 km
- TLEs were imaged for over 6 hours originating from multiple regions of the storm
- 445 TLEs (sprites, halos and a few elves) recorded (the 3rd largest Spriting storm on record)



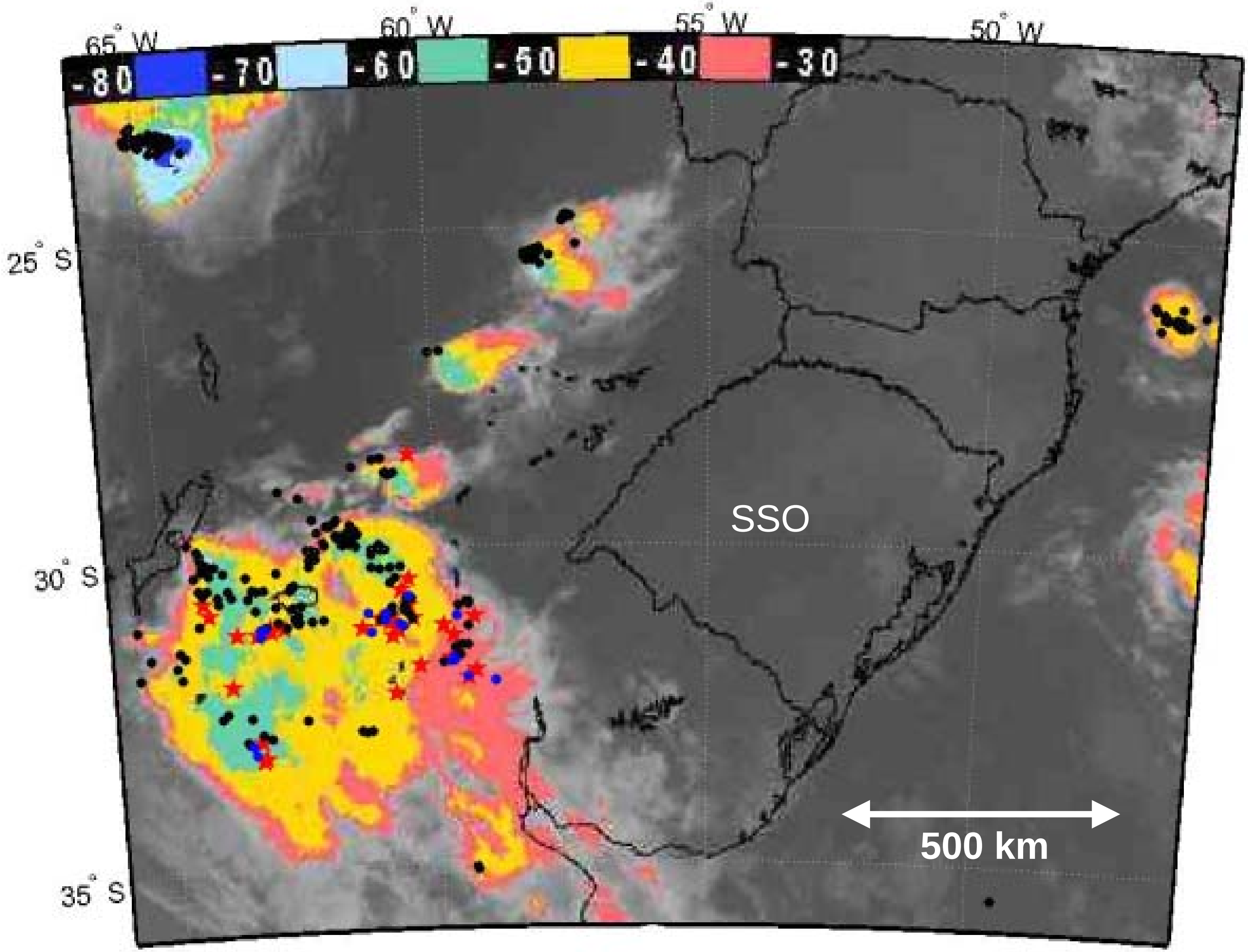
TLEs (stars) and WWLLN (black dots) 06:15 -06:45 UT



Feb. 23 02:30 UT



Feb. 23 03:00 UT



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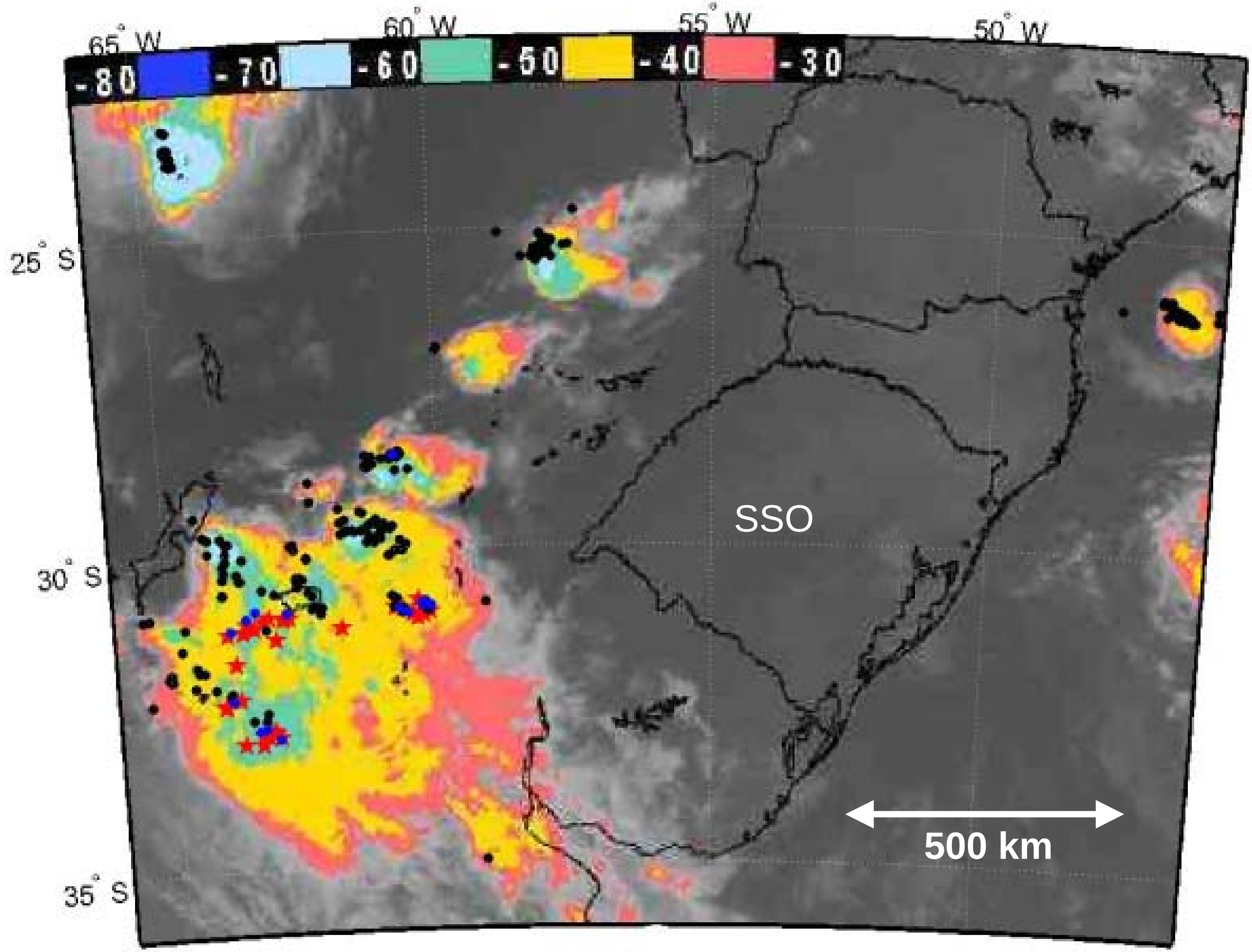

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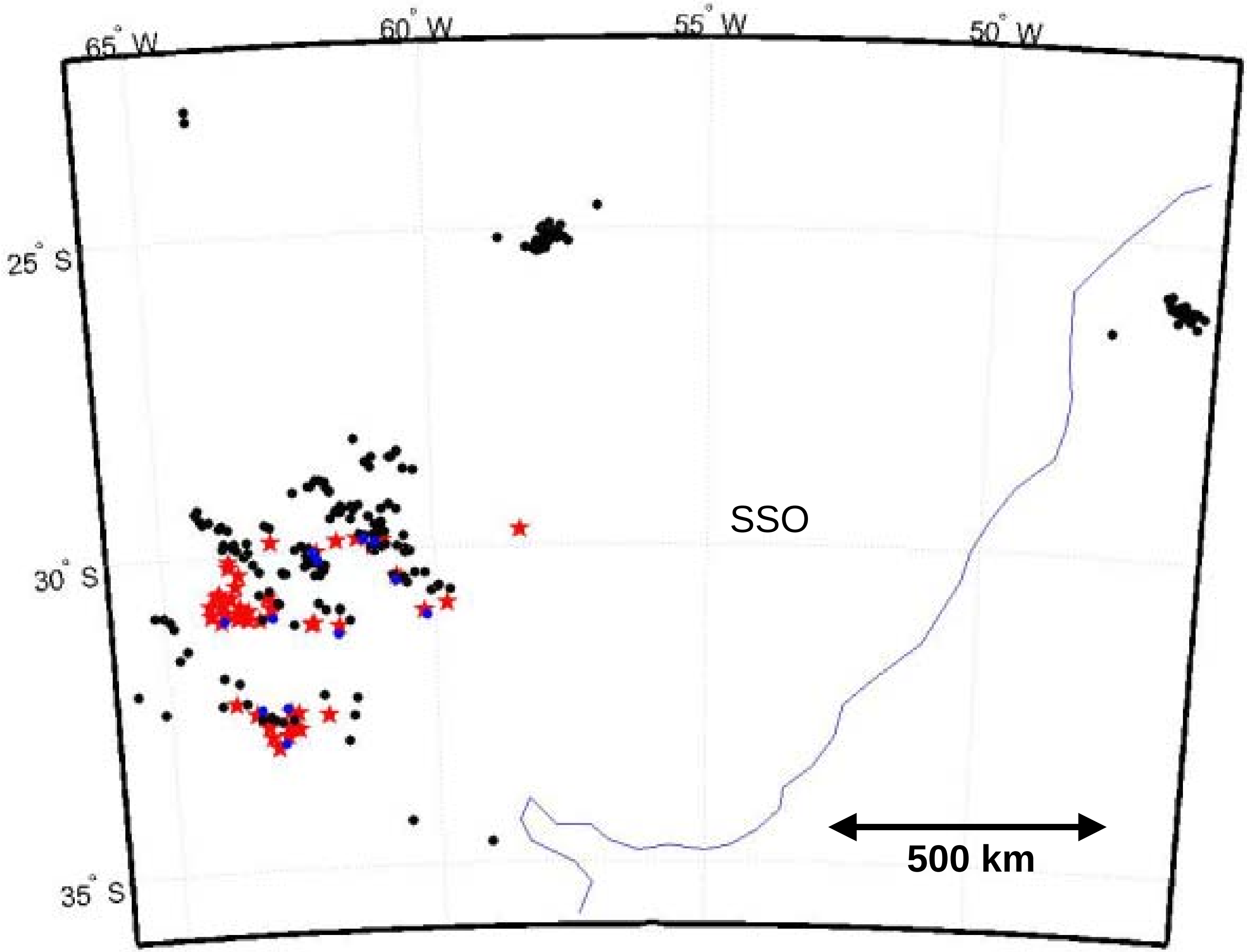

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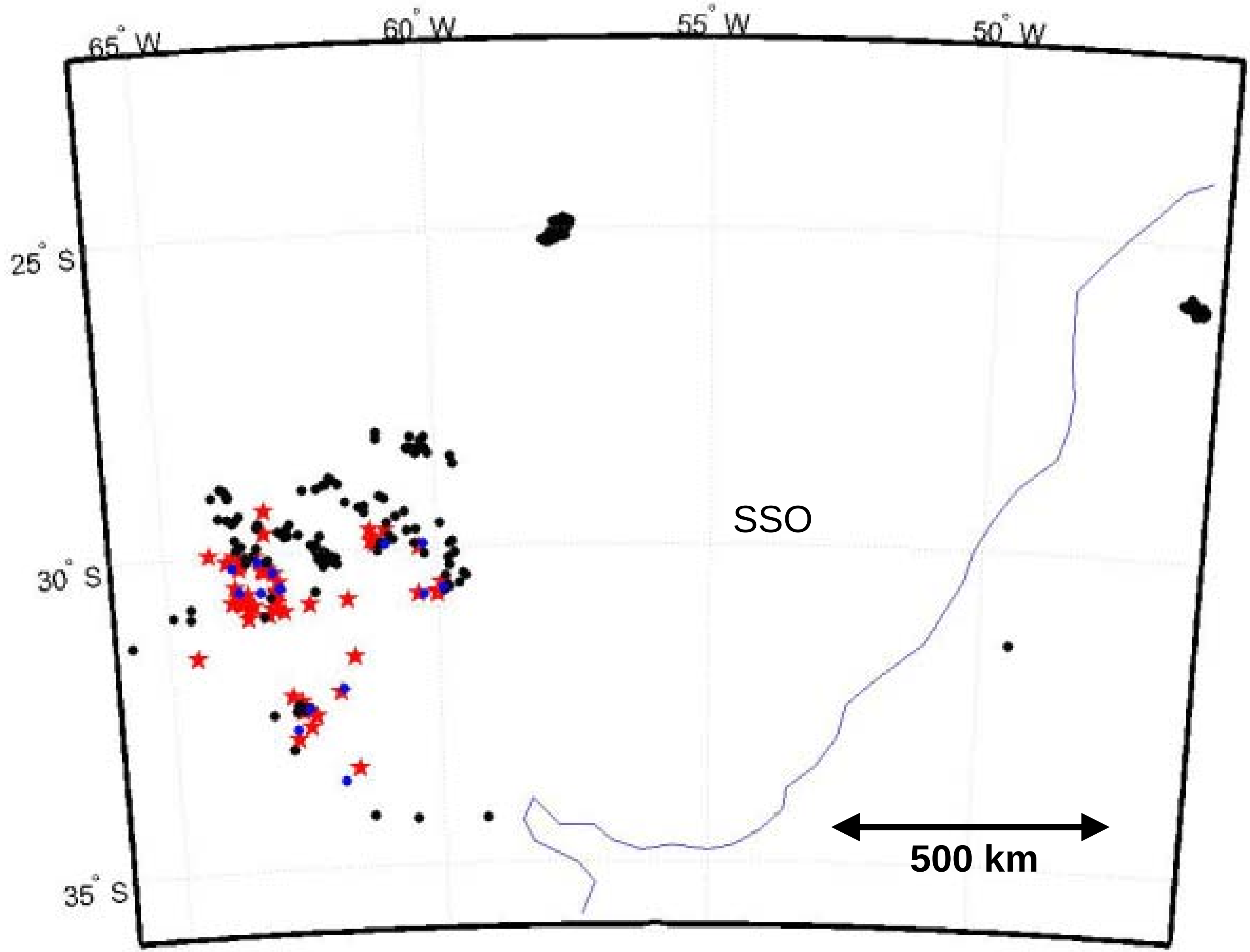

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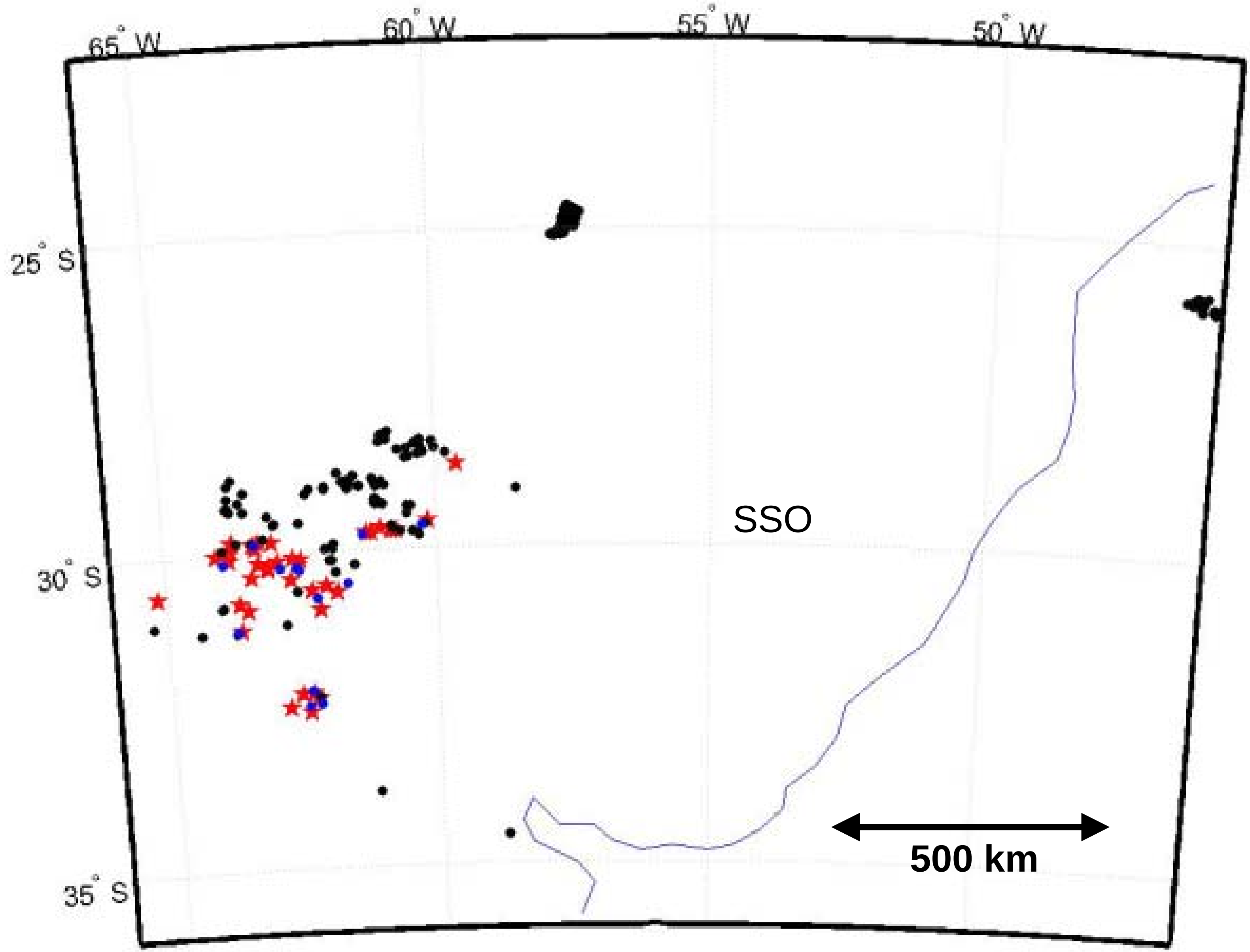

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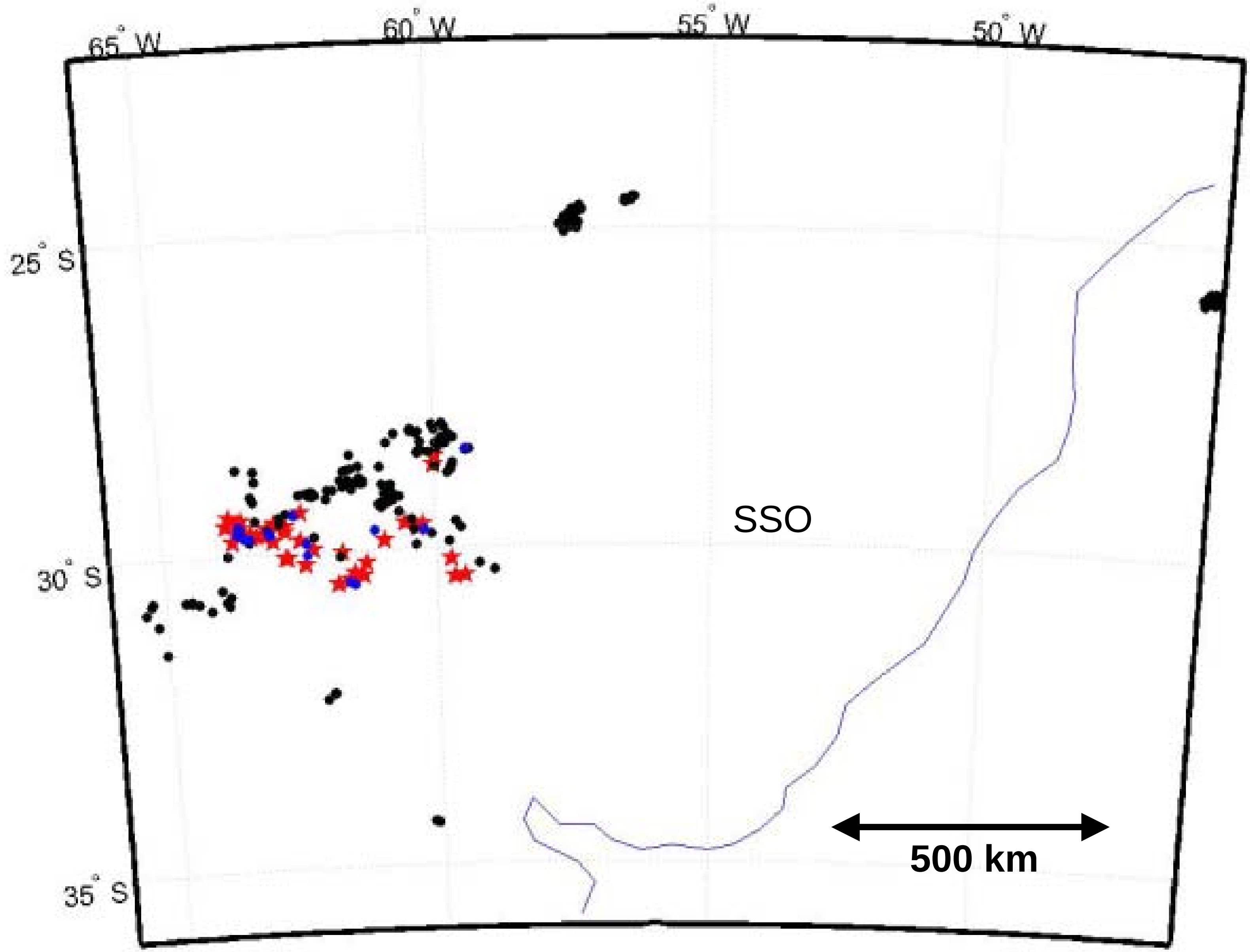

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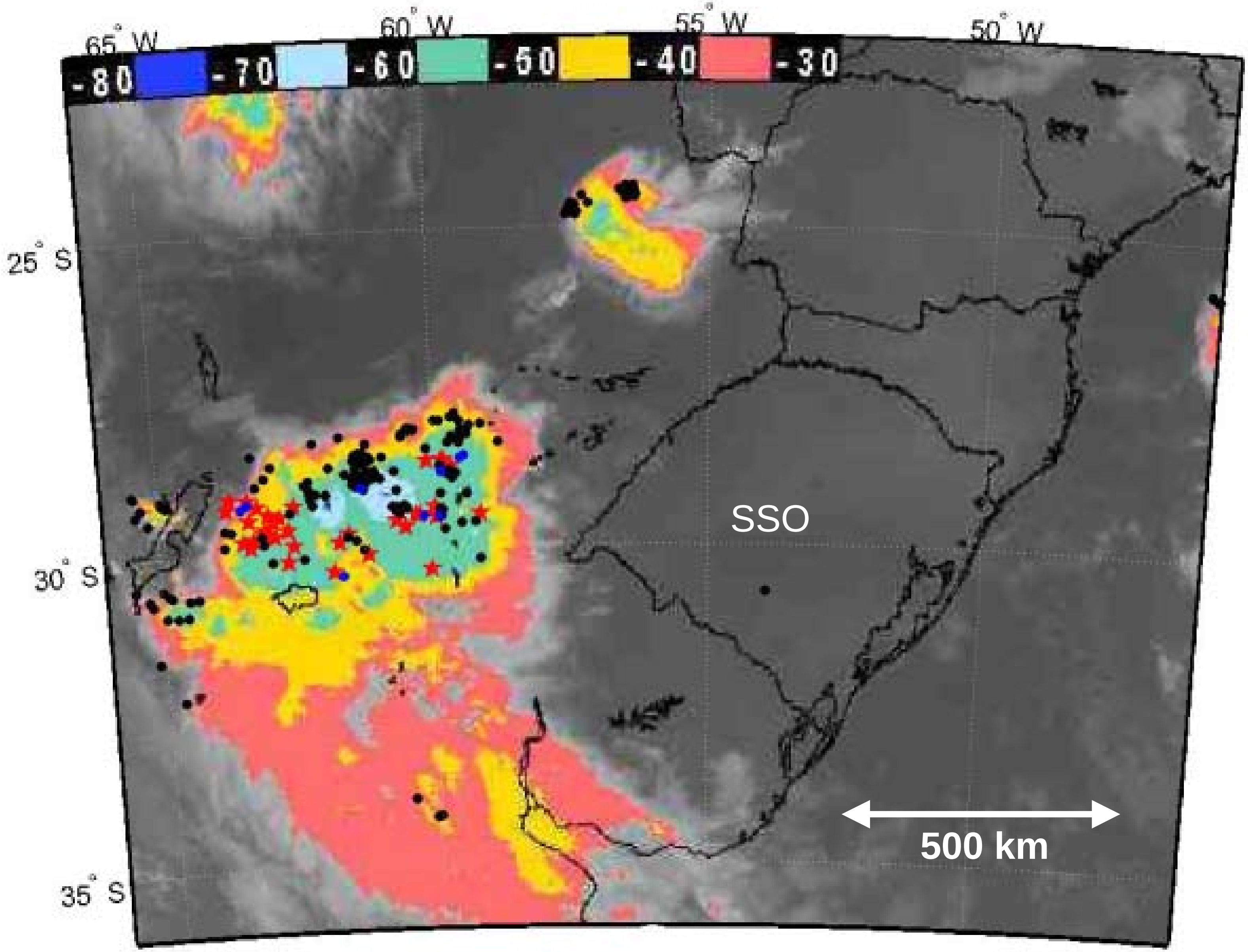

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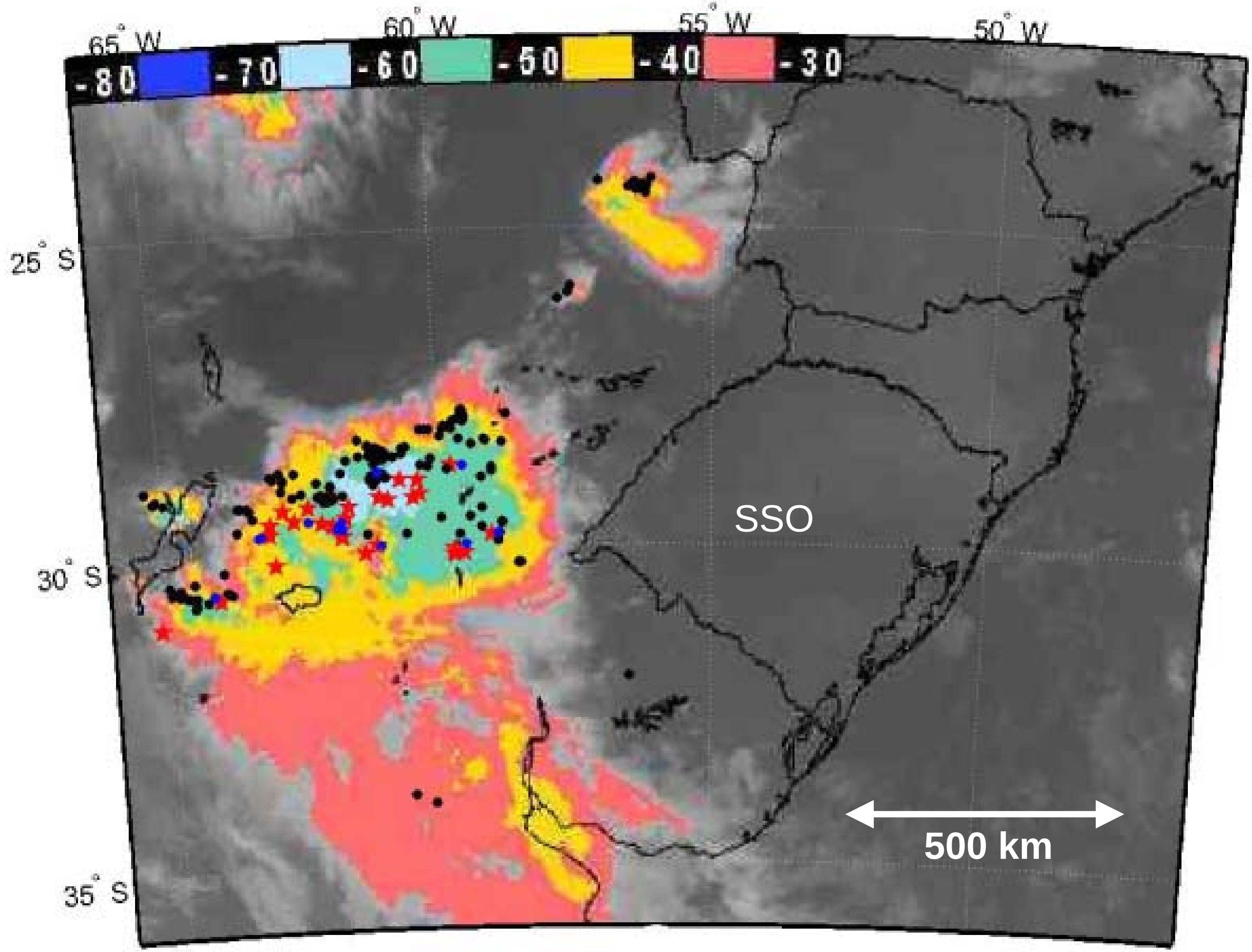
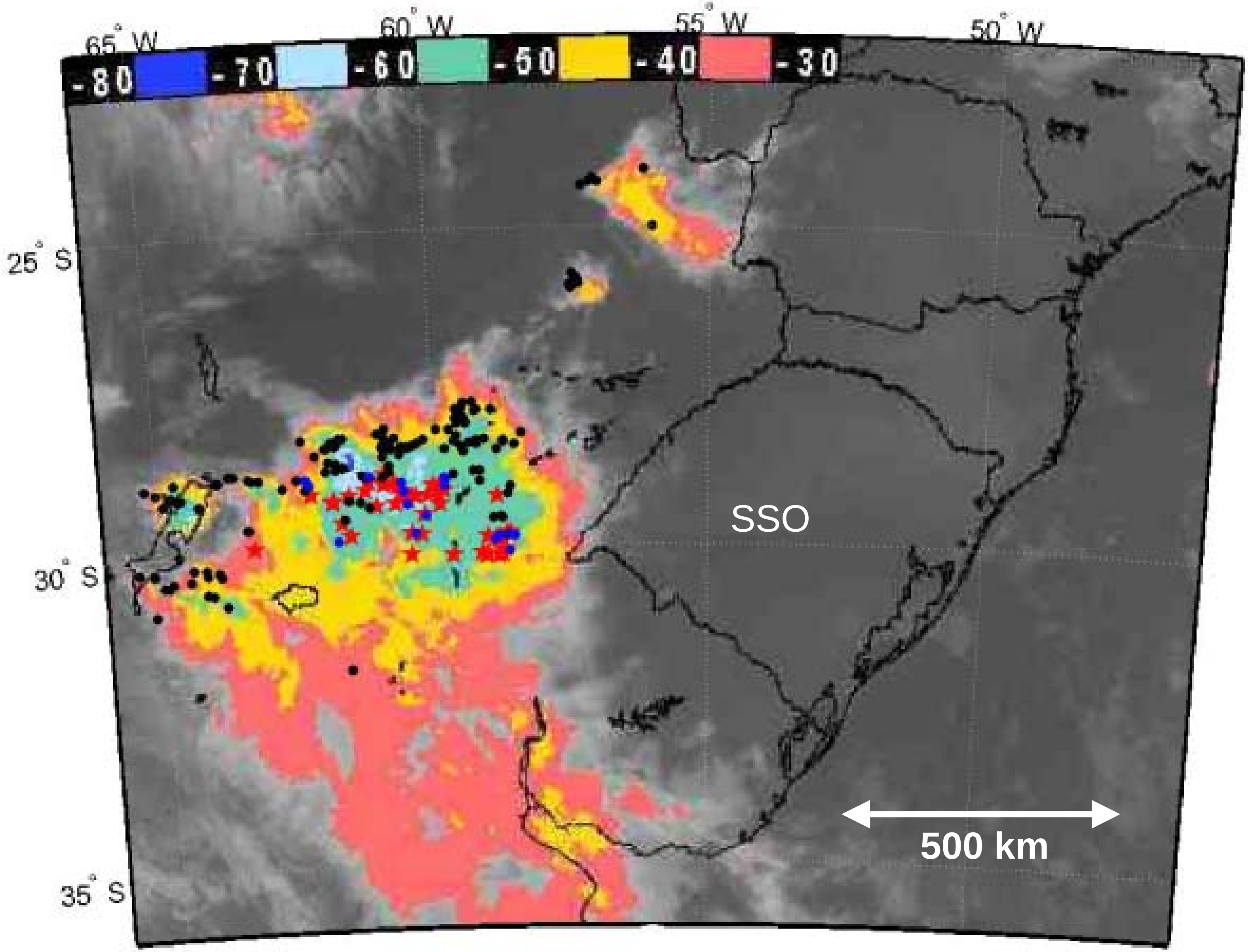


Feb. 23 07:00 UT



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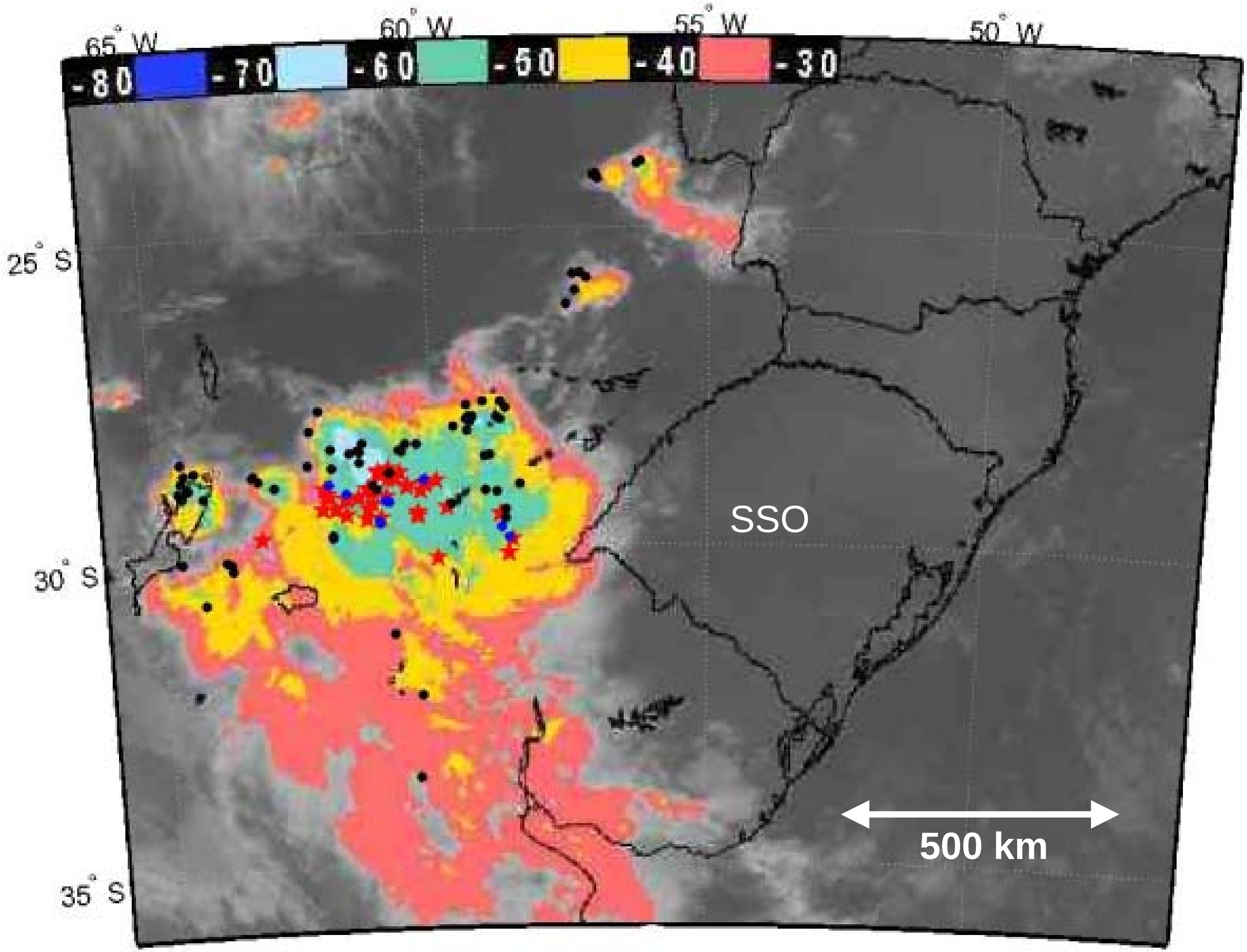
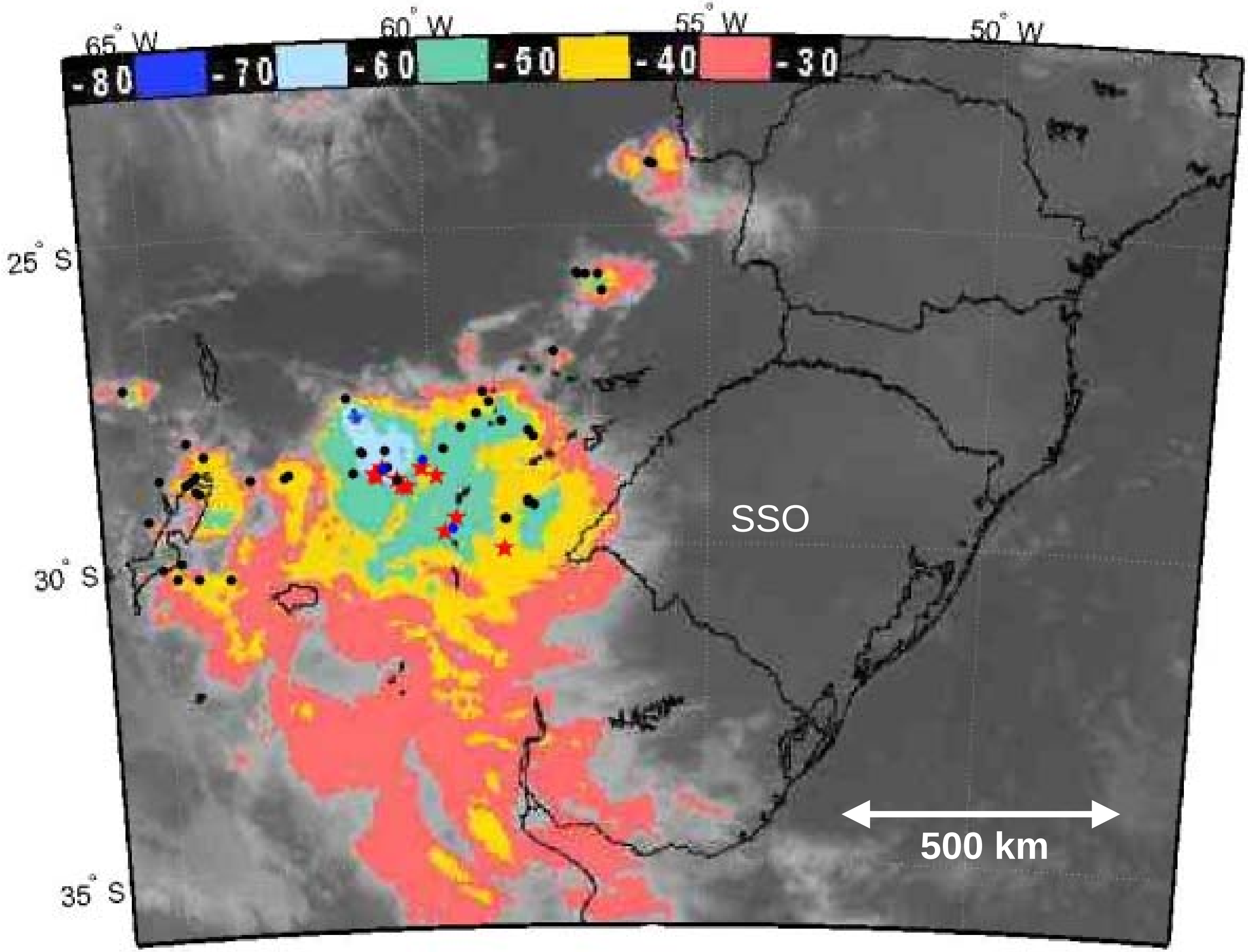


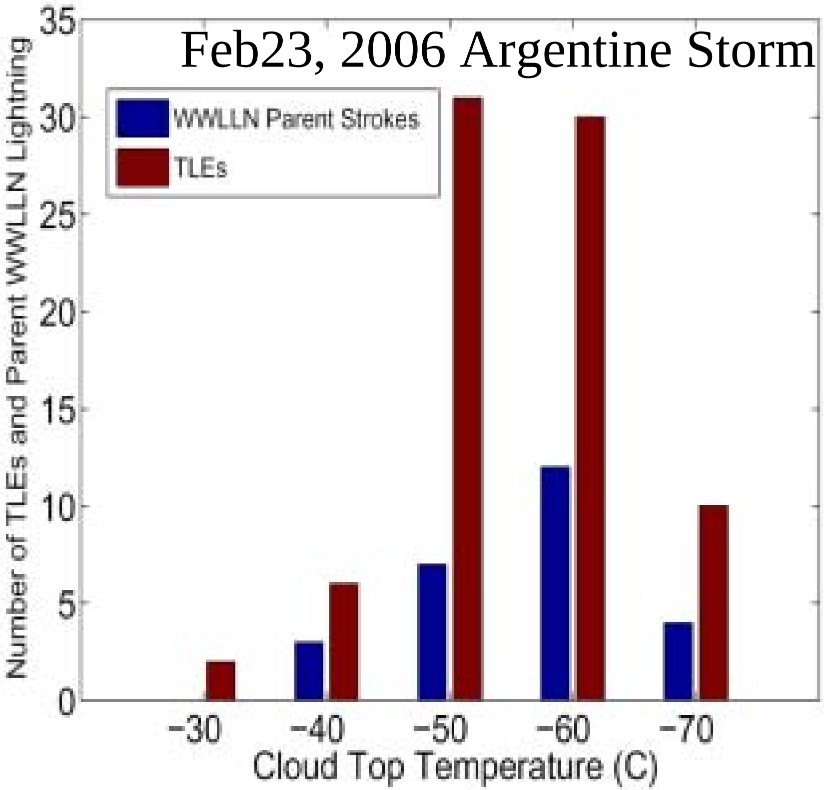
Feb. 23 08:00 UT

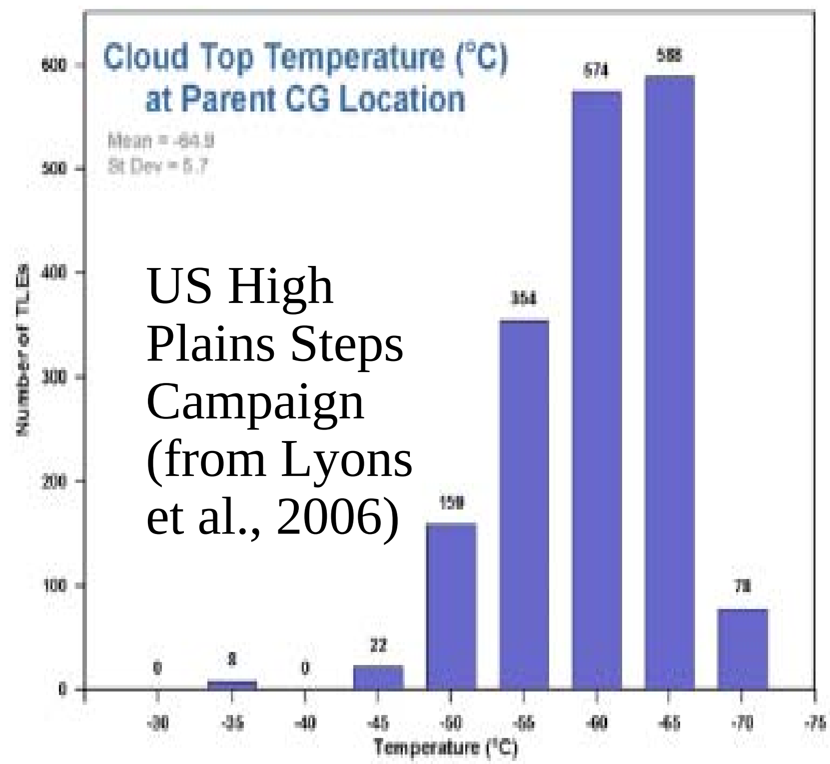


Feb. 23 08:30 UT

Cloud-top Temps and TLES

(Solorzano et al., AGU, 2006 and Sao Sabbas et al. AGU, 2007)



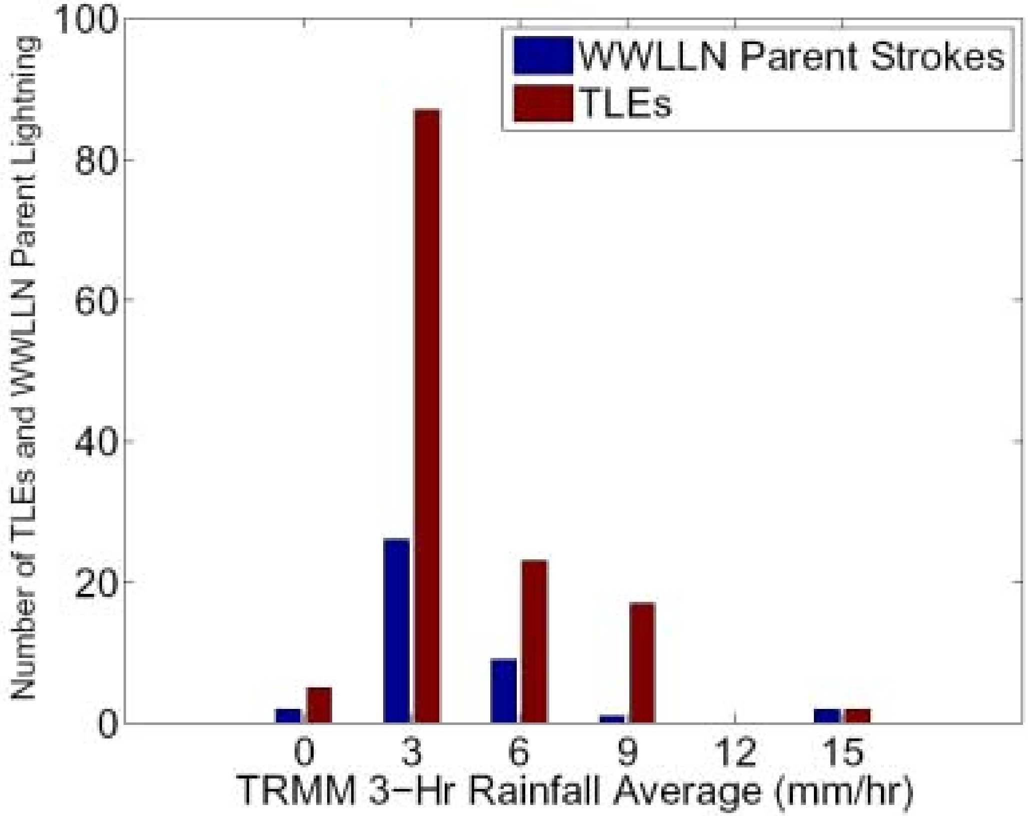


Argentine and US High Plains storms similar, although higher percentage of Argentine TLEs above clouds warmer than -60 C

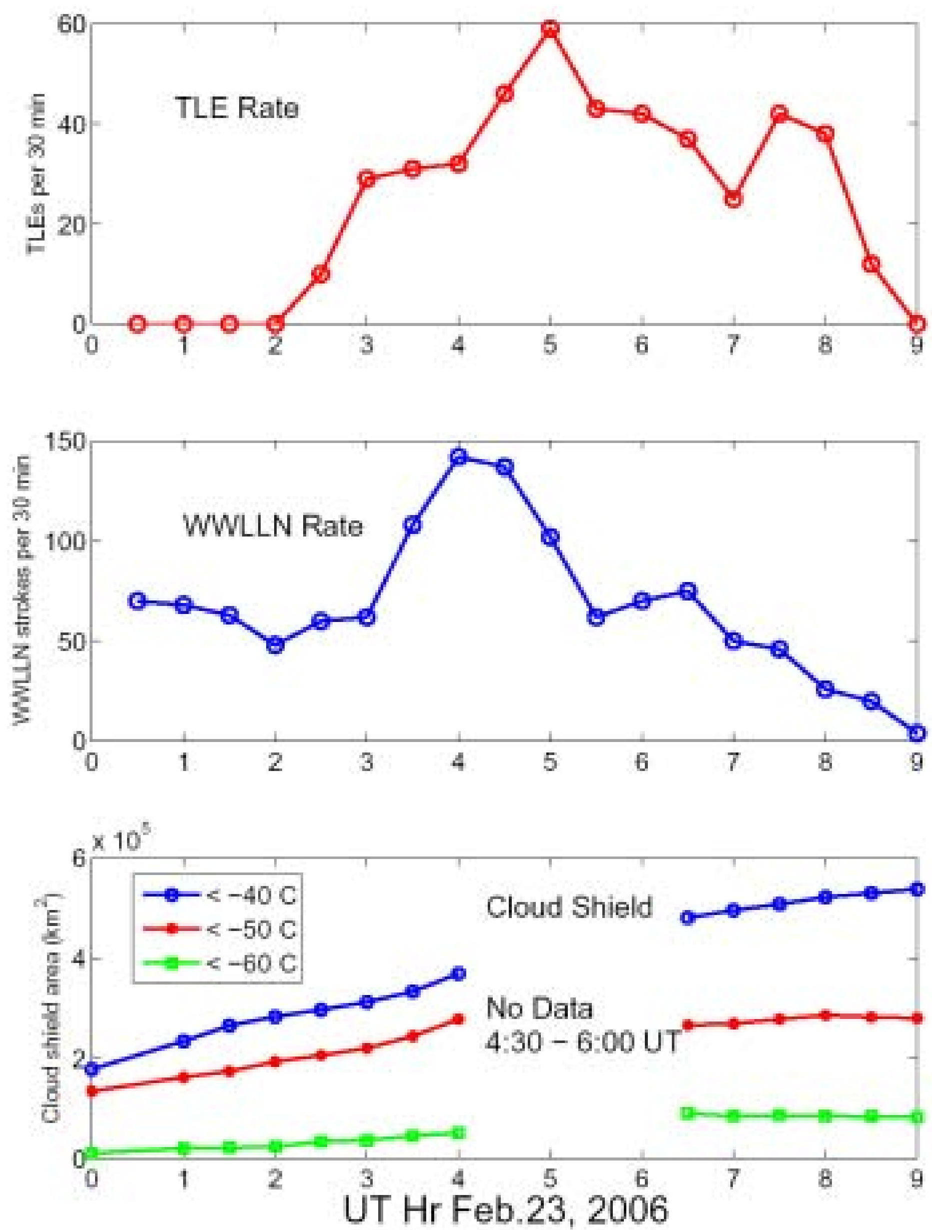
TLEs / WWLLN and TRMM 3-HR Rainfall

(Solorzano et al., AGU Fall Meeting , 2006)

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

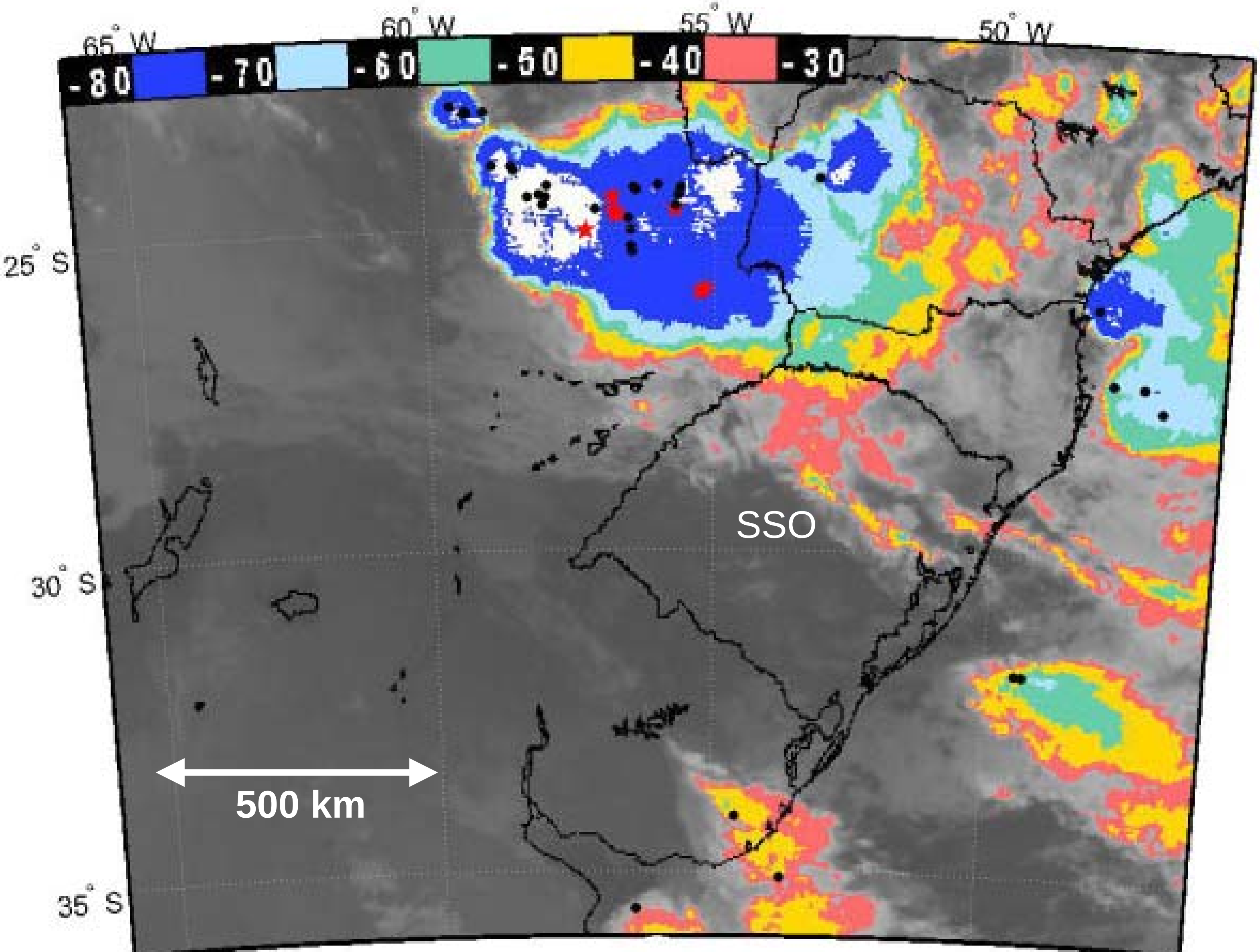


TLE / WWLLN Rate and Cloud Top Temps

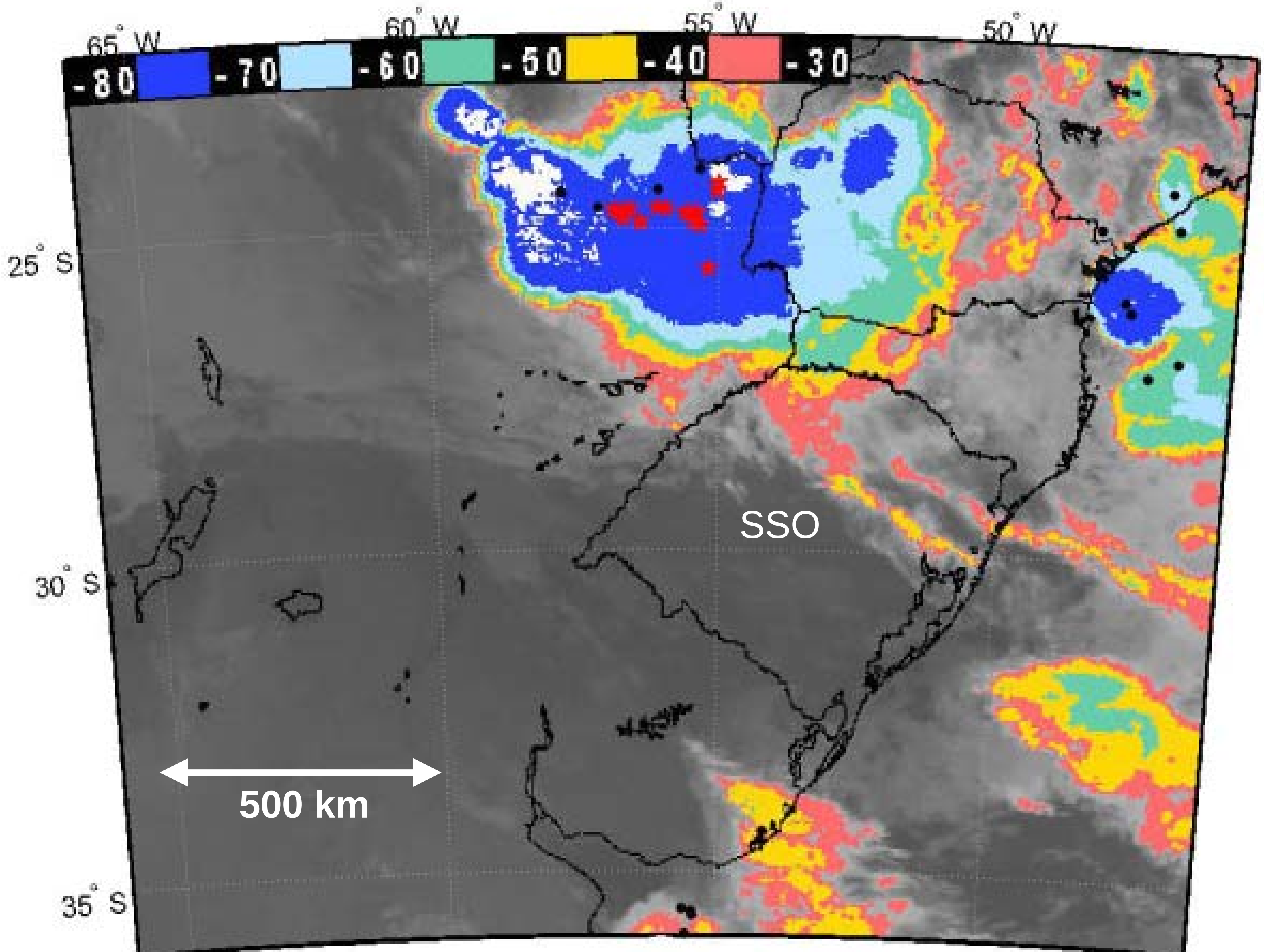


- Observed TLE rate grows with storm size until data gap in IR images
- WWLLN peaks at ~04 UT and TLEs at ~05 UT

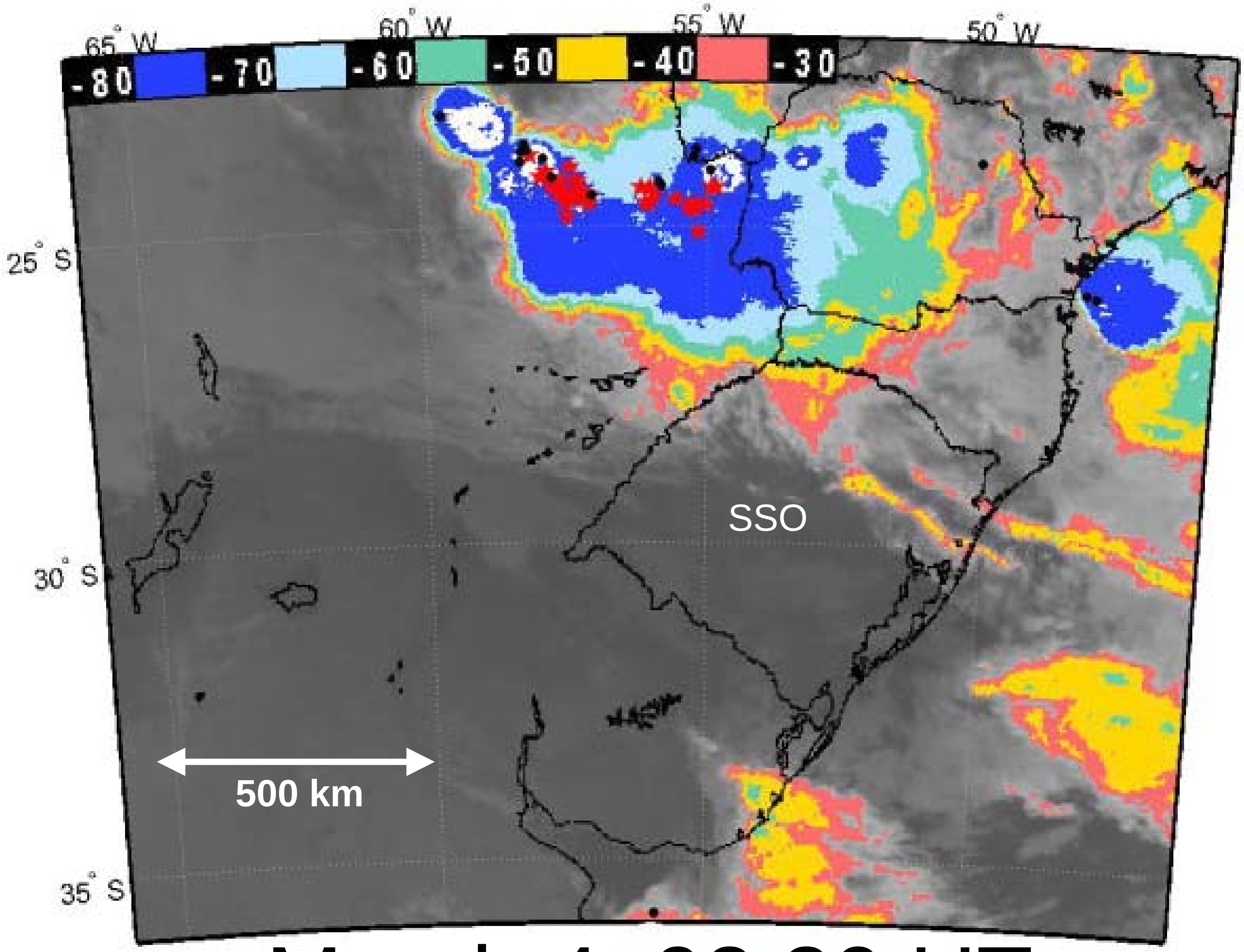
(Solorzano et al., AGU, 2006 and Sao Sabbas et al., AGU, 2007)



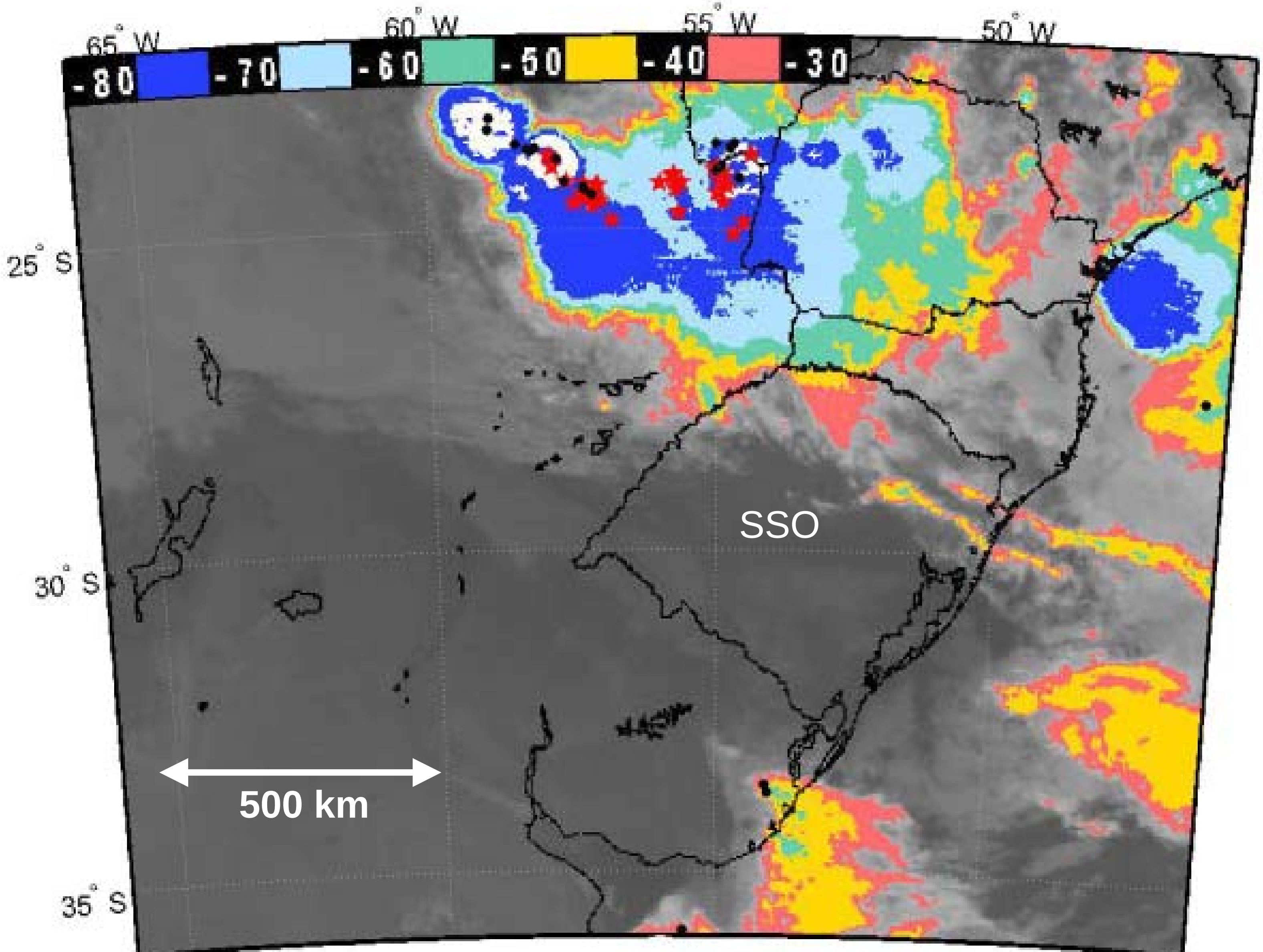
March 4, 01:30 UT



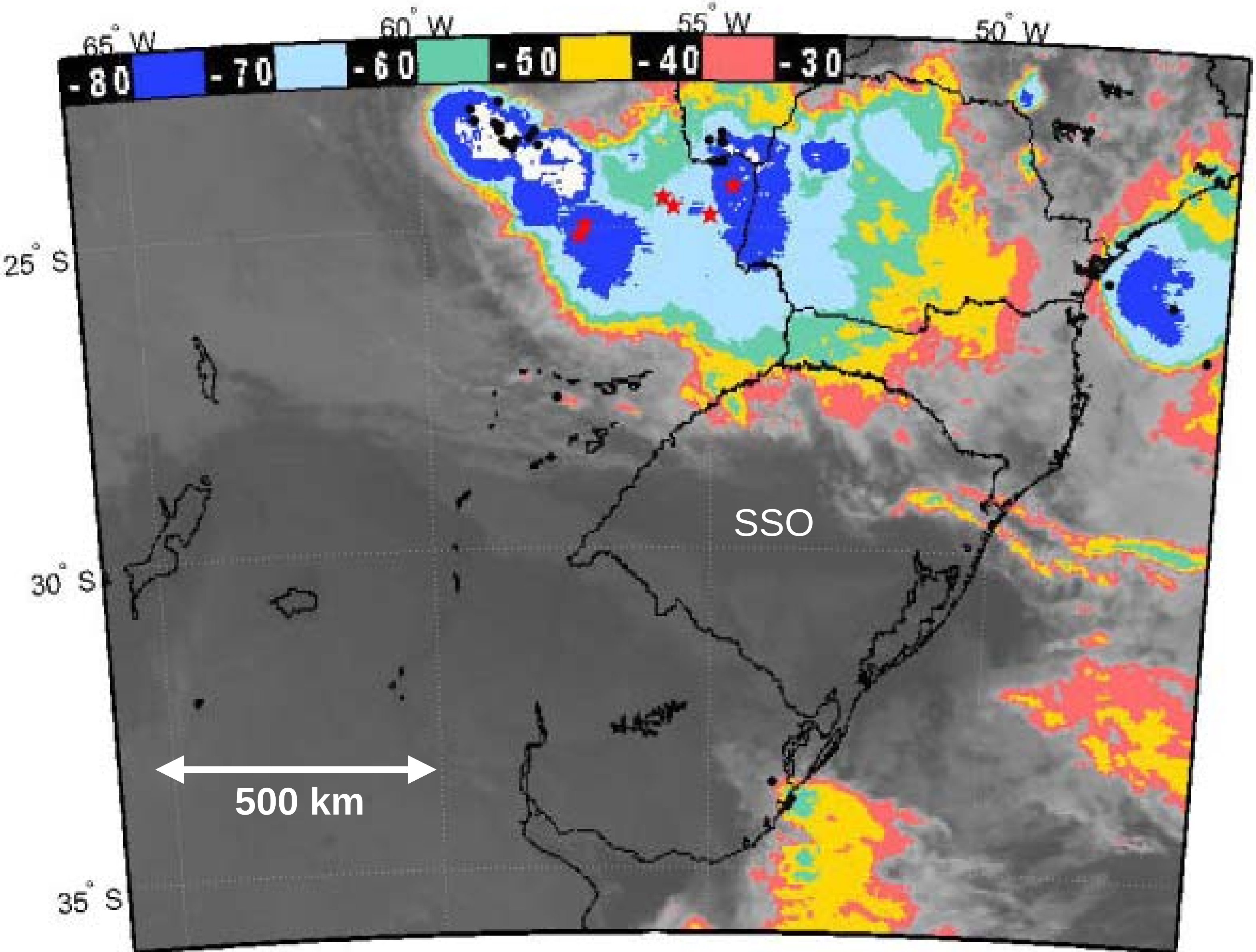
March 4, 02:00 UT



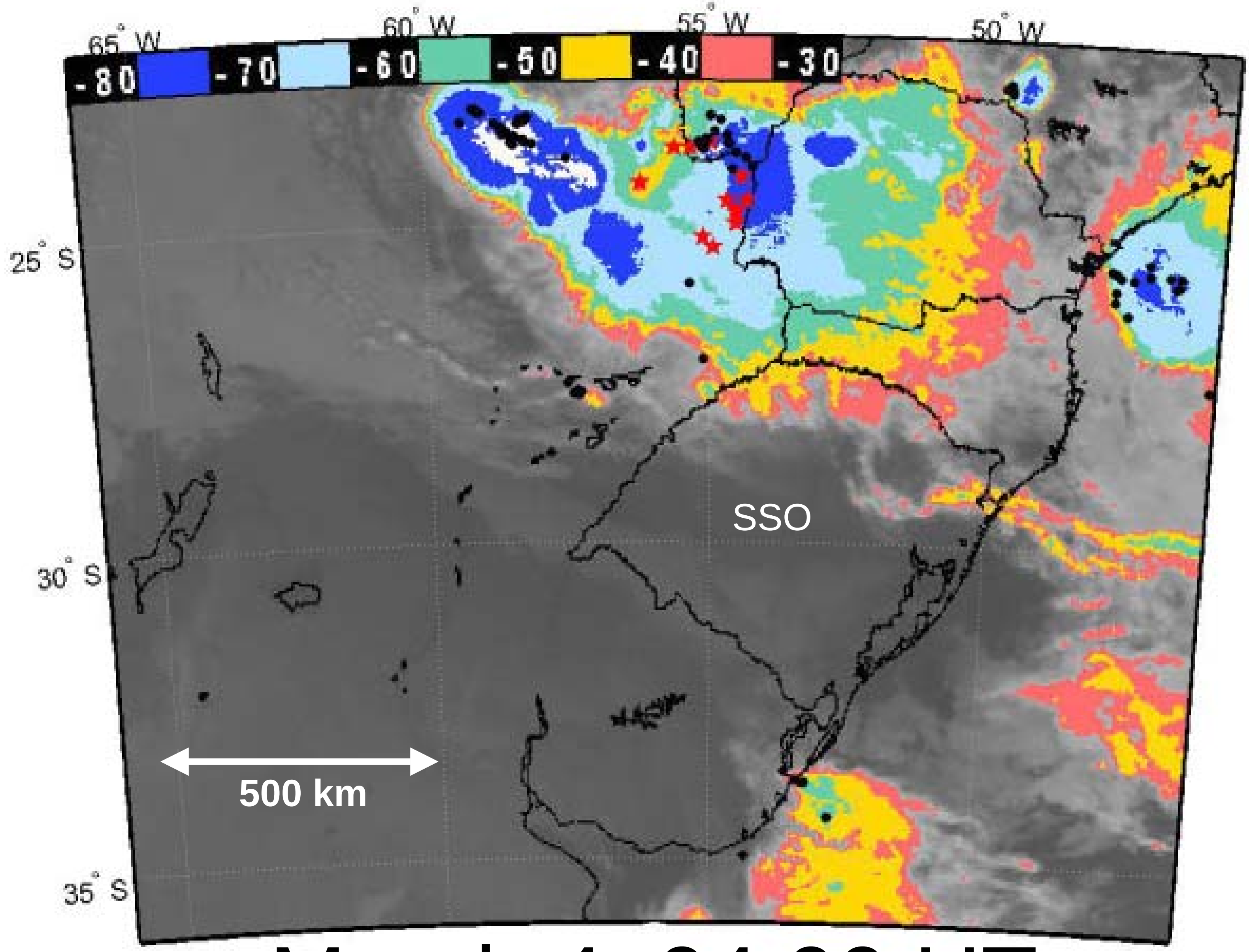
March 4, 02:30 UT



March 4, 03:00 UT



March 4, 03:30 UT



March 4, 04:00 UT

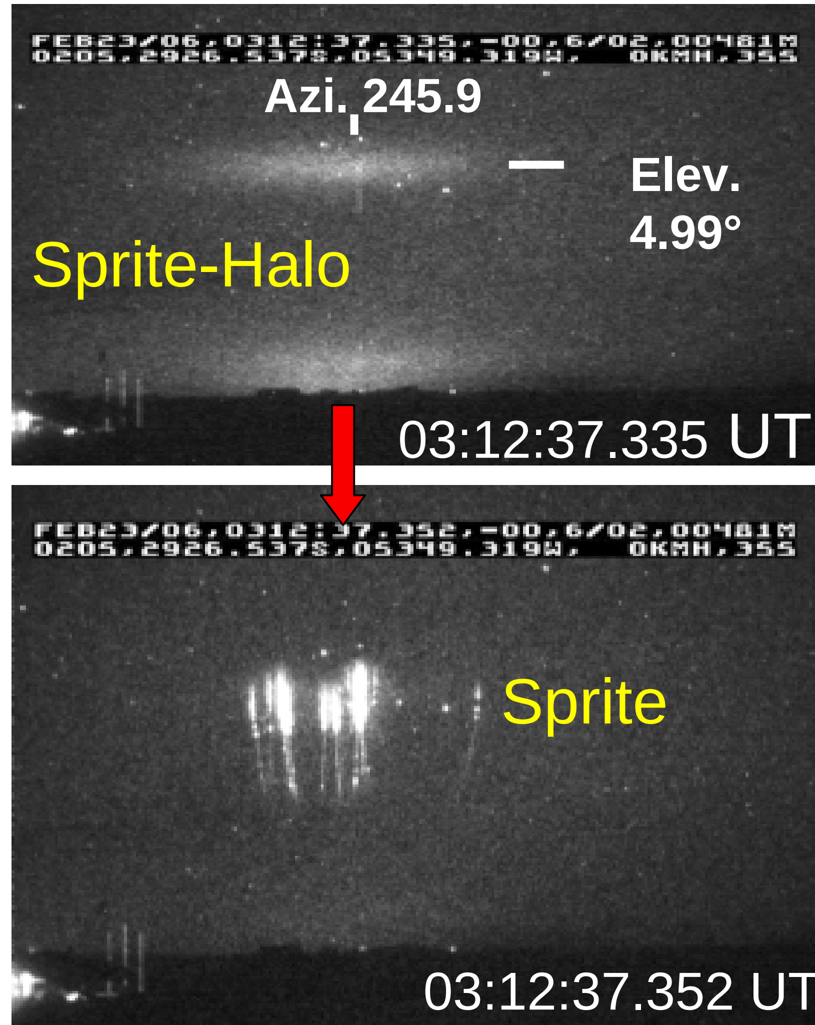
Example Sprite-Halo Data

(Bailey et al., AGU, 2007)

- 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).

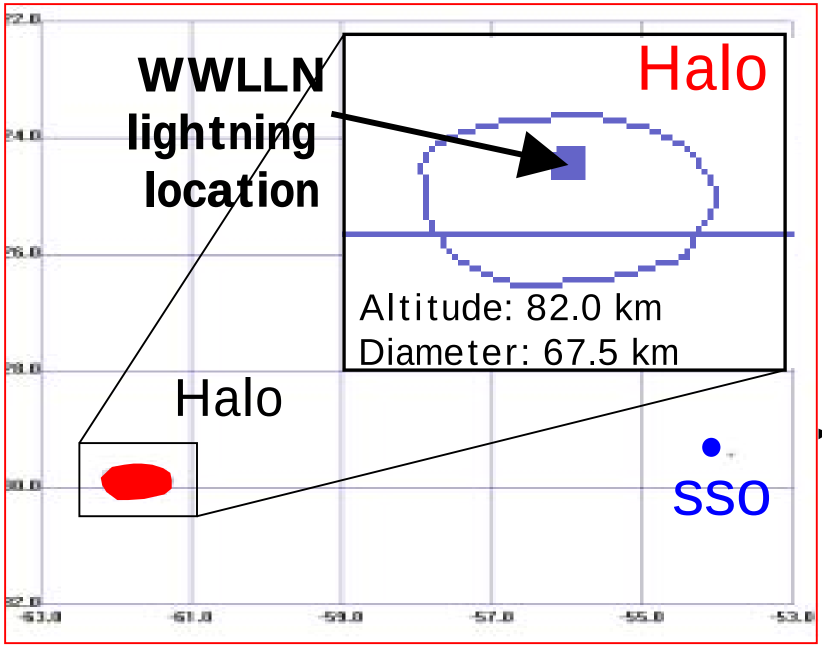
Typical Sprite-Halo

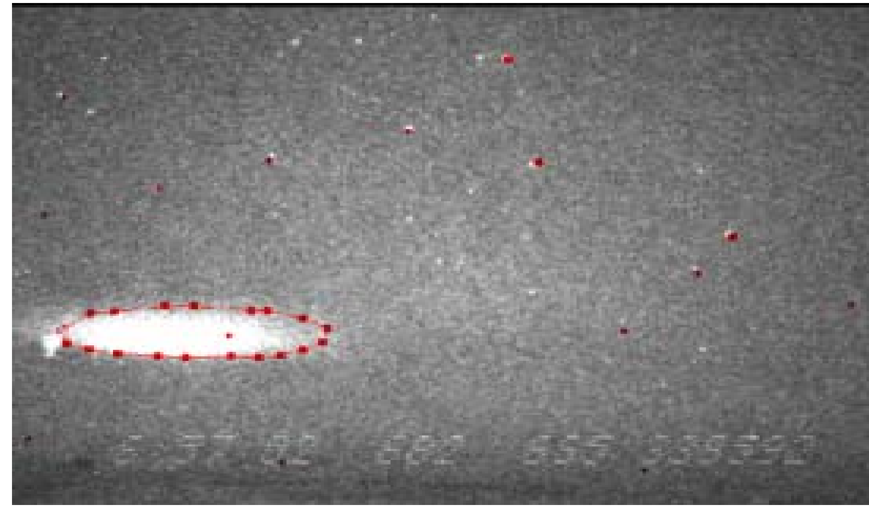
Images 17 ms apart



Halo Analysis

(Bailey et al., AGU, 2007)



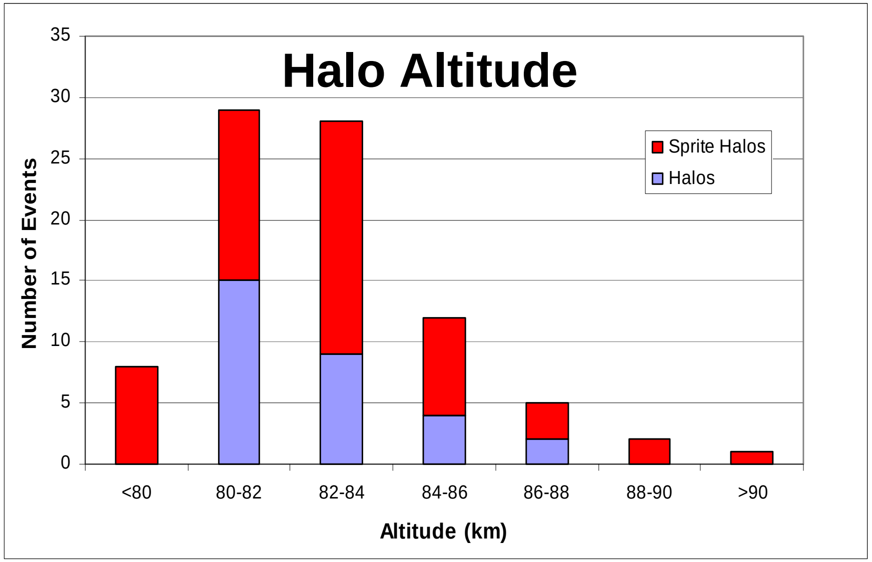


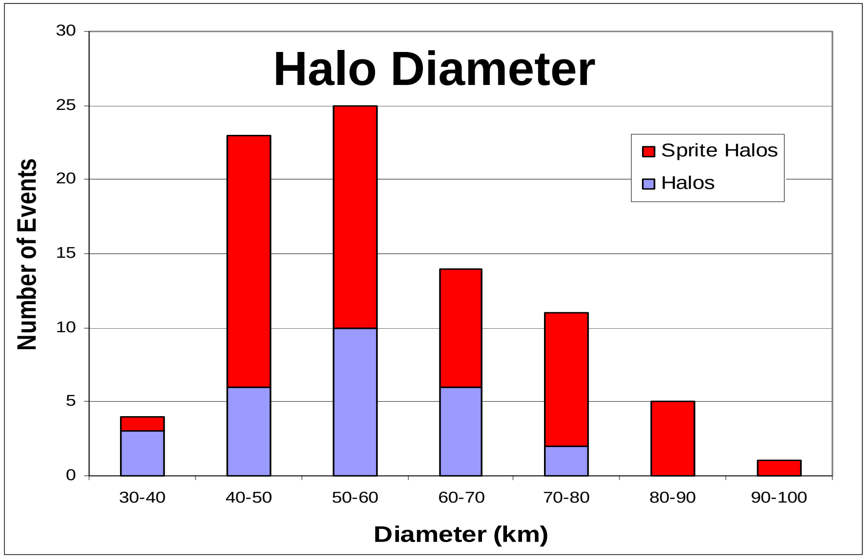
Assumed center of halo is within ~5 km of the parent lightning strike (Wescott, et al., 2001).

- 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.

Halo Results

(Bailey et al., AGU, 2007)



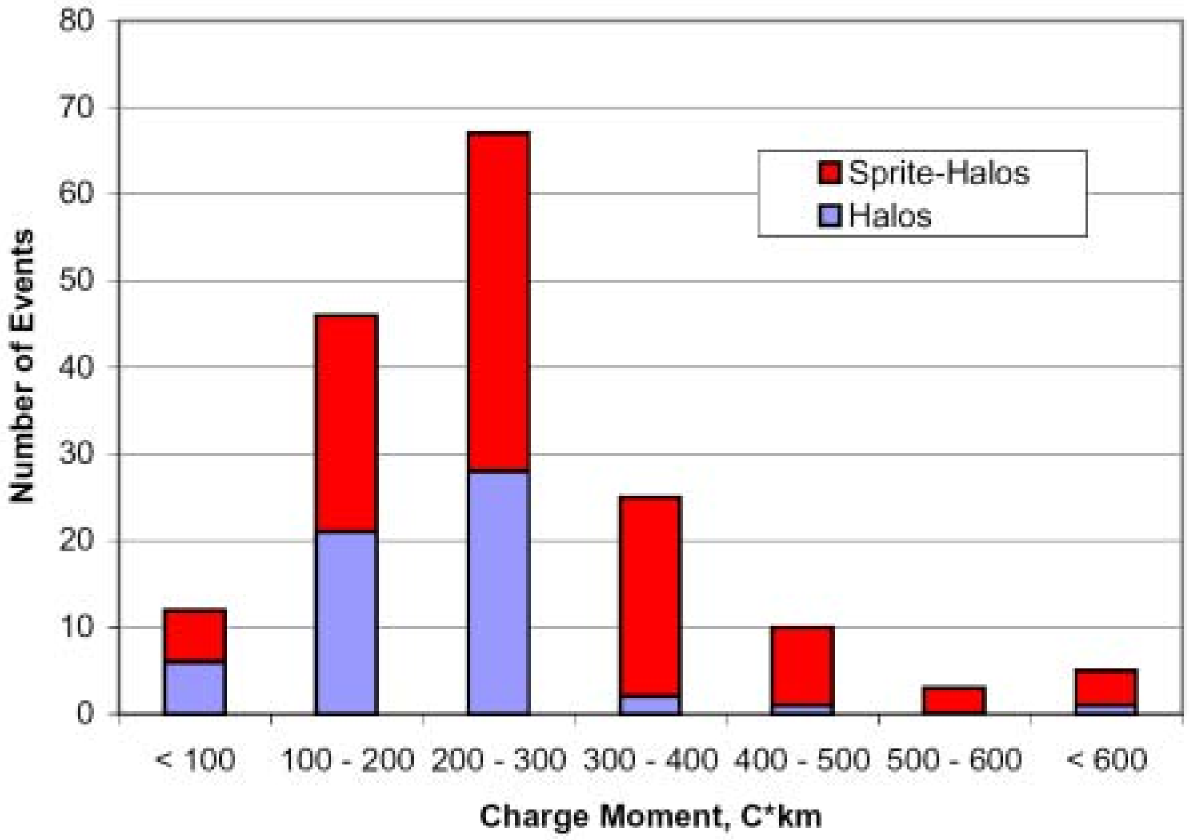


- 84 events correlated with WWLLN located lightning:
  - mean altitude = 82.7 km (range: 78 – 91 km)
  - mean diameter = 58 km (range 31 – 93 km)
- Similar to US High Plains:
  - 4 events: height ~78 km, diameter 66 km, (Wescott et al., 2001)
  - 34 events: height ~80 km, diameter 86 km, (Miyasato et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

Sprite-Halo/Halo Impulsive Charge Moment Changes

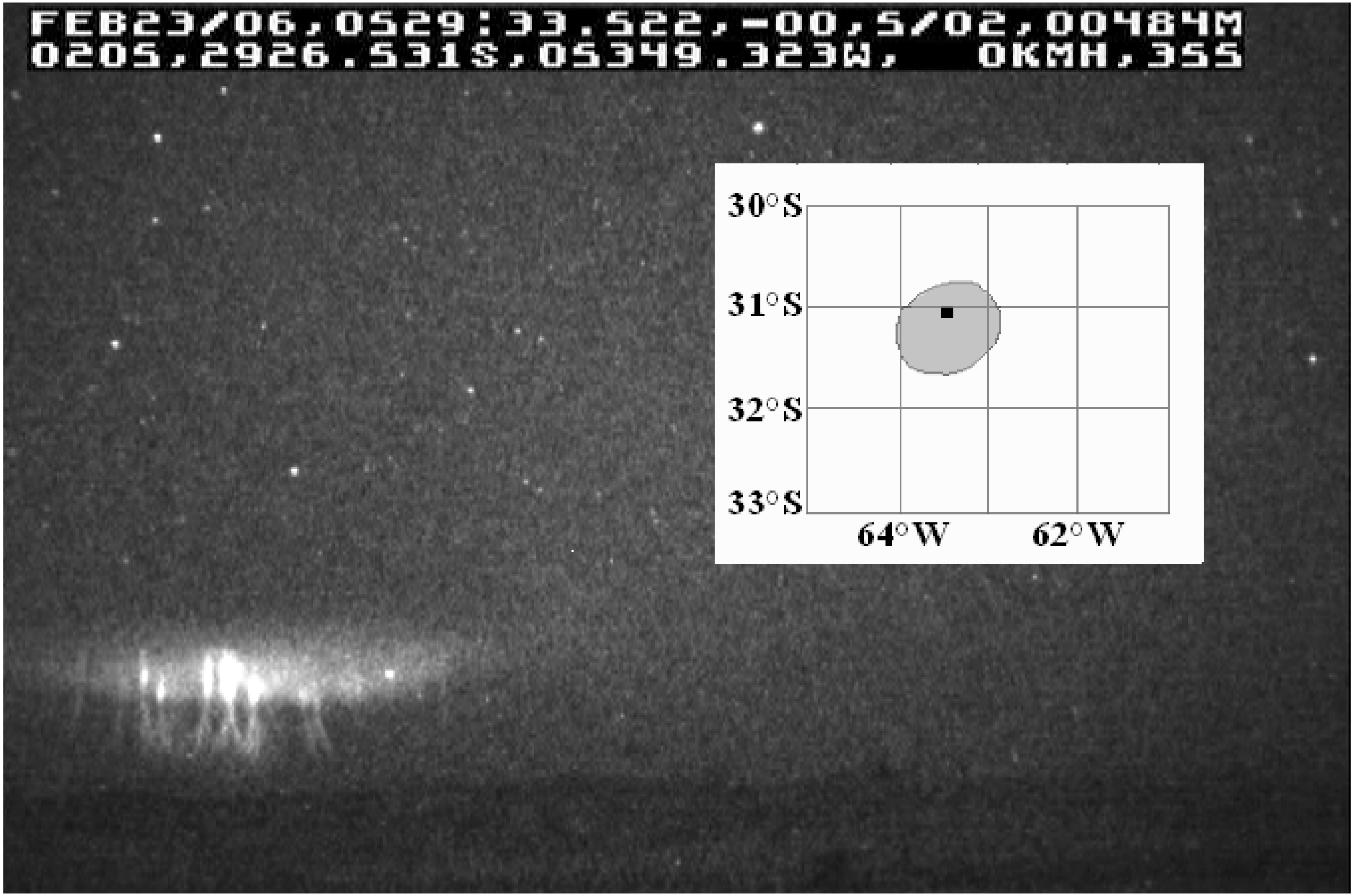
(Bailey et al., AGU, 2007)

- 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

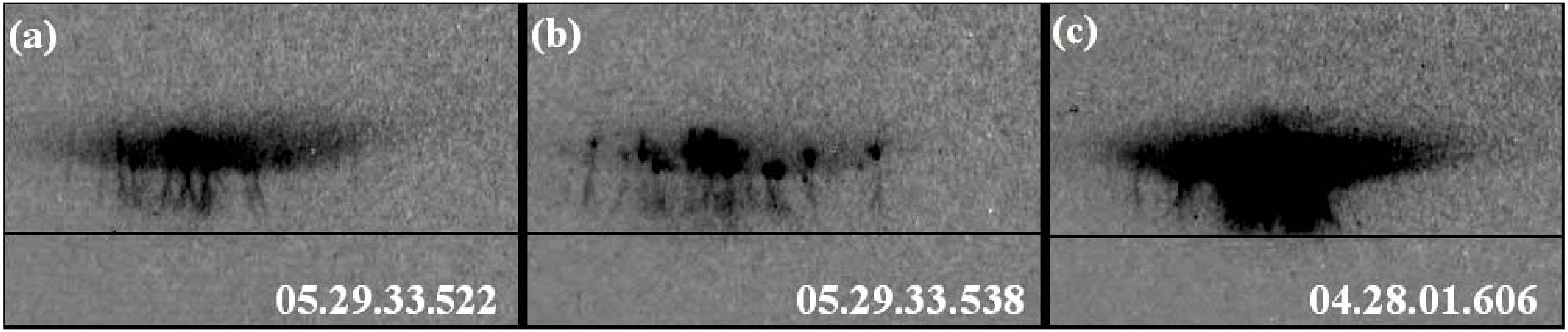
(Bailey et al., AGU, 2007)



Comparison of –CG and +CG Sprite-Halos

(Bailey et al., AGU, 2007)

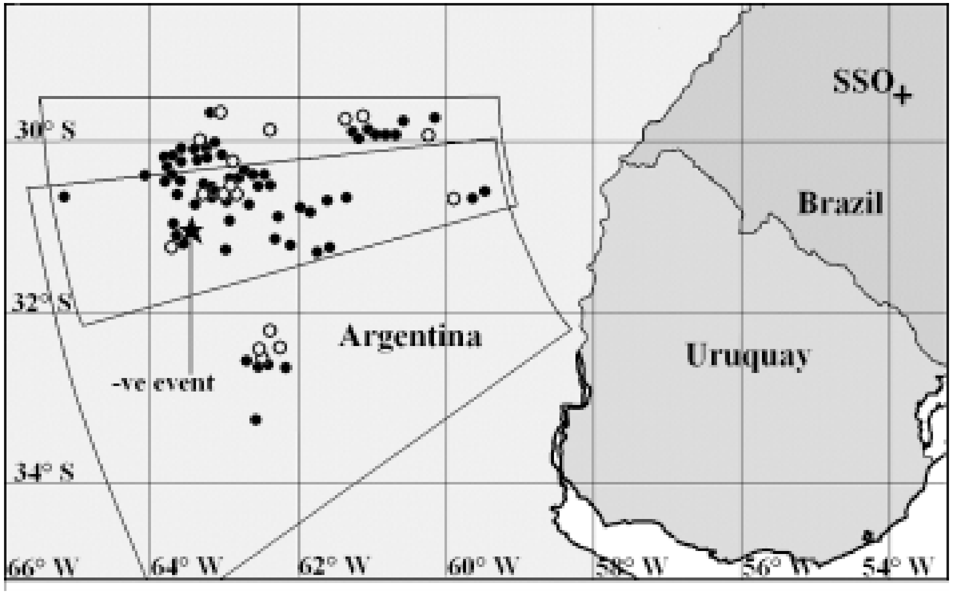
-CG Frame 1 | -CG Frame 2 | +CG



Black line is horizon at ~60 km altitude

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

(Bailey et al., AGU, 2007)

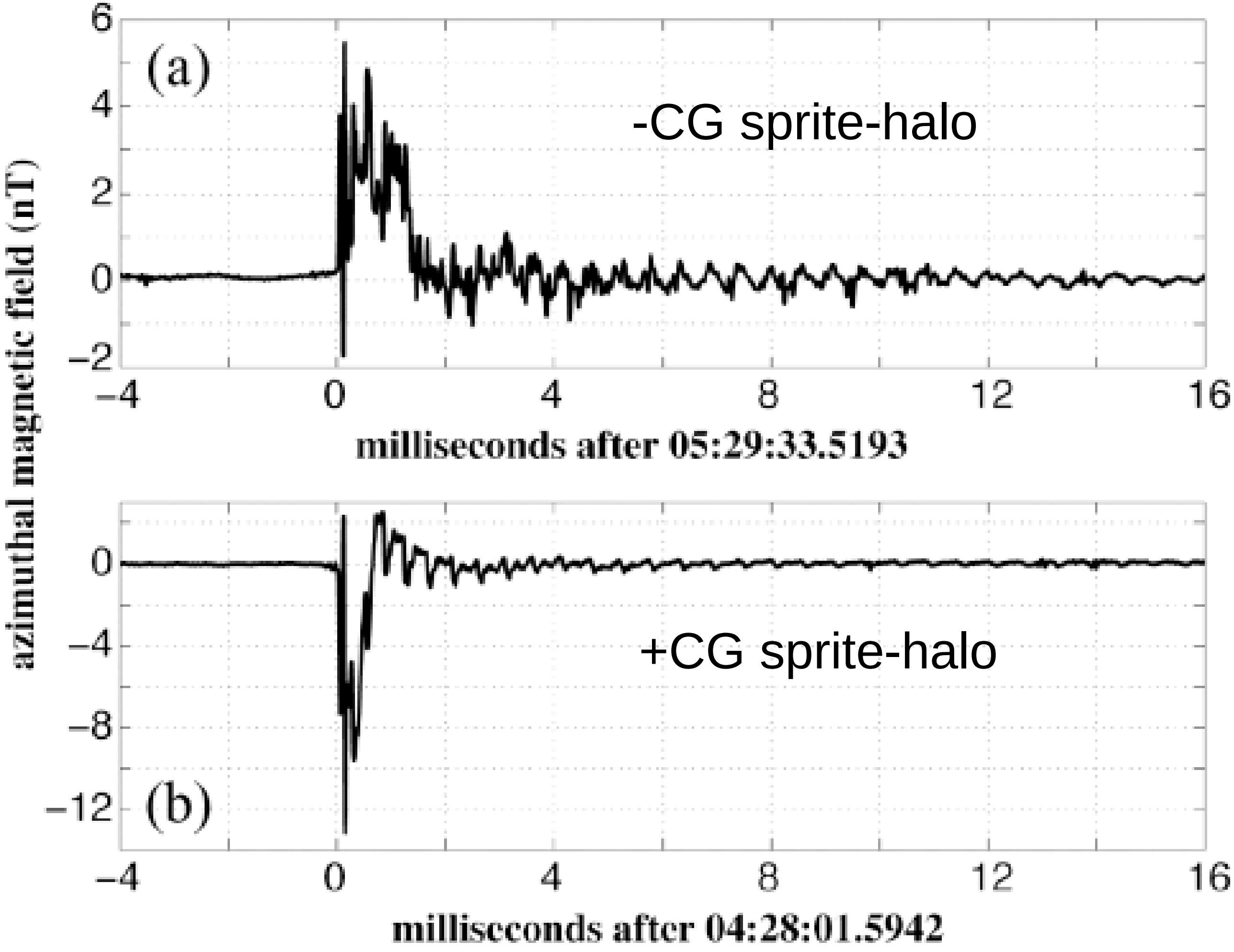


Events from 05 – 06 UT
Star: -CG Sprite-Halo
Open circles: TLEs with corresponding WWLLN
Solid circles: TLE without corresponding WWLLN

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

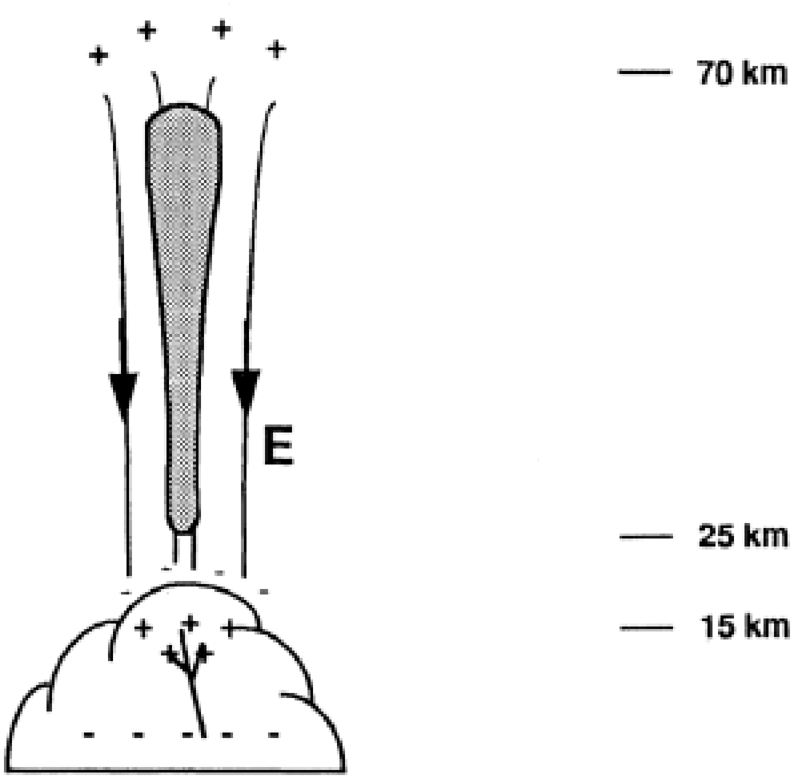
ELF/VLF Waveforms

(Bailey et al., AGU, 2007)



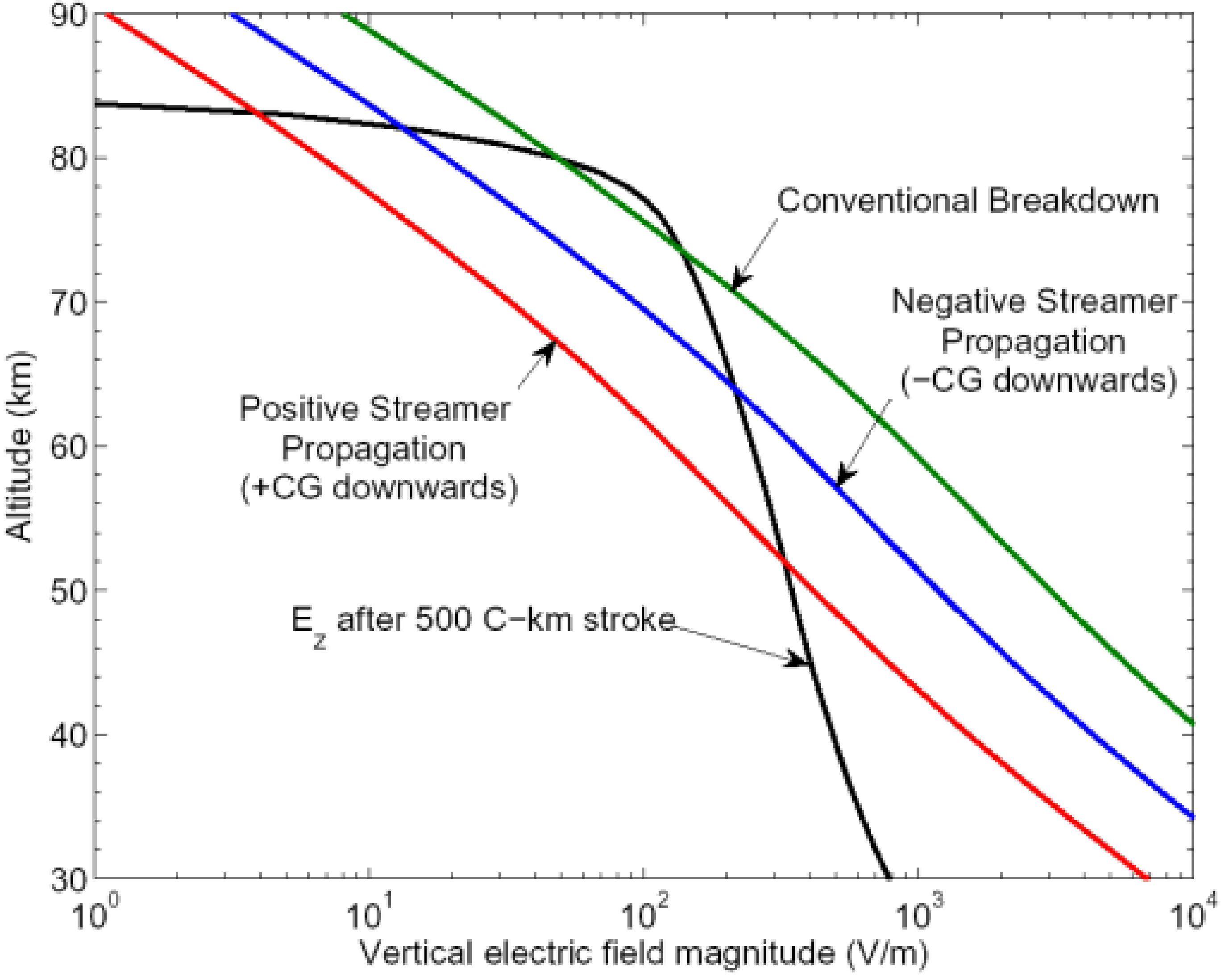
-CG and Sprite Models

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

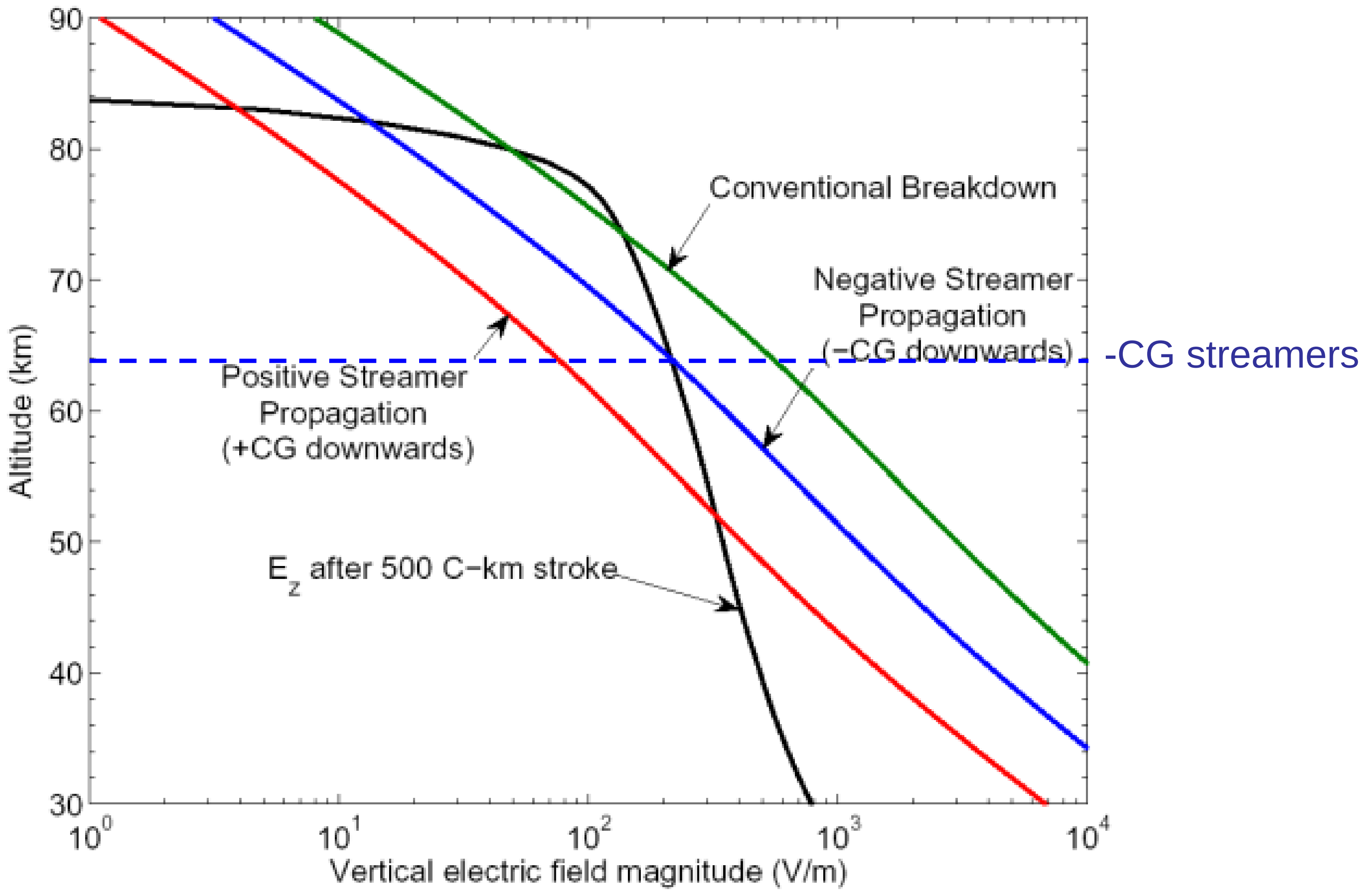


From Fig. 7 Roussel-Dupre and Gurevich, JGR, 1996

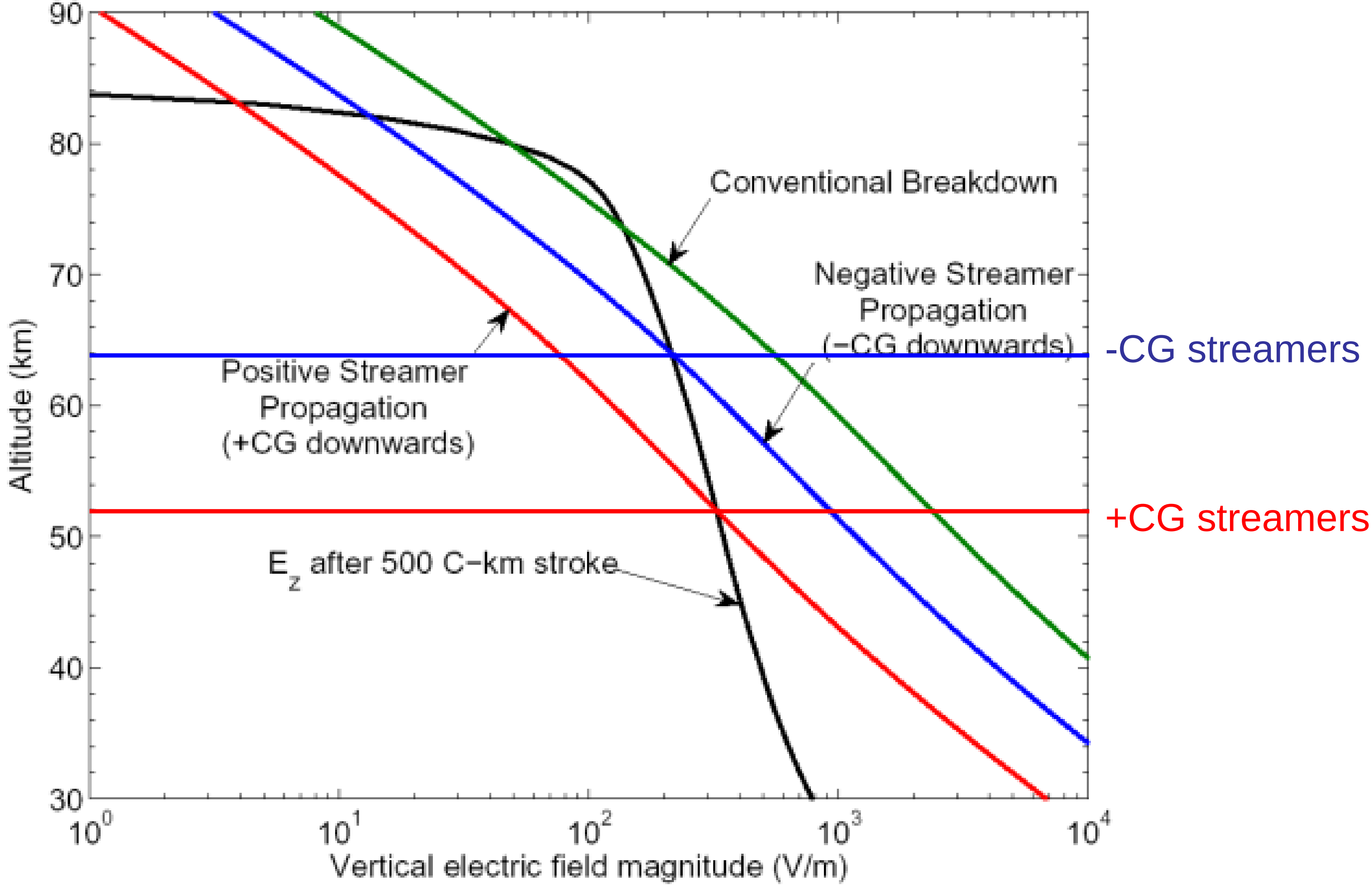
-CG and Sprite Models



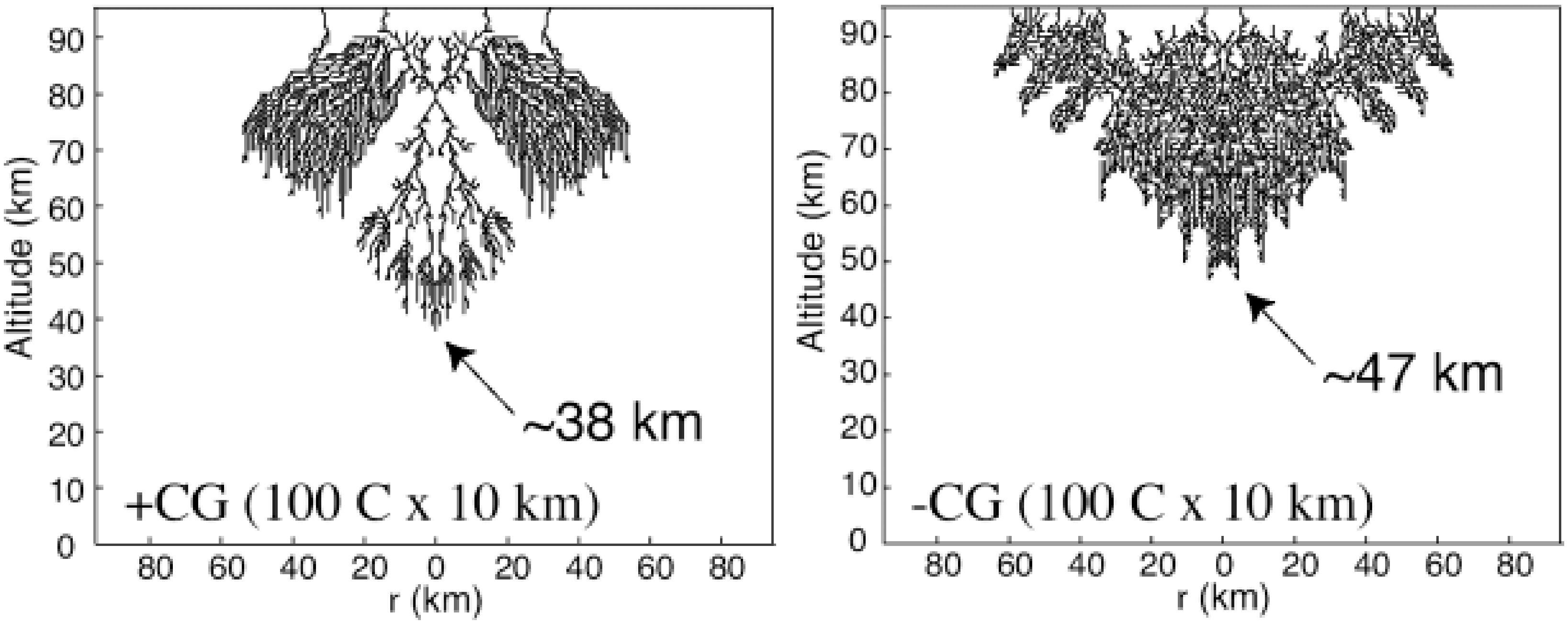
-CG and Sprite Models



-CG and Sprite Models



-CG and Sprite Models



From Pasko et al. GRL, 2000

Conclusions

Feb. 23 MCS Storm:

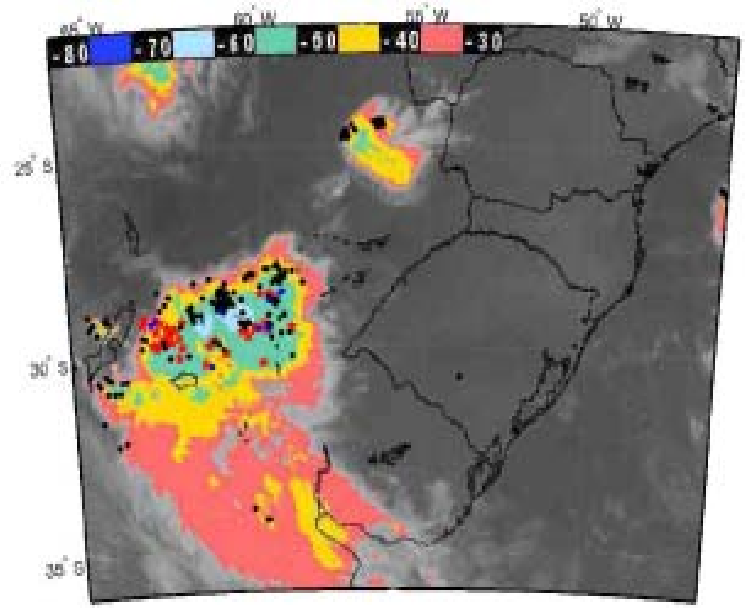
- 3rd most active sprite storm reported
- Most sprites in stratiform region and above clouds warmer than -60 C

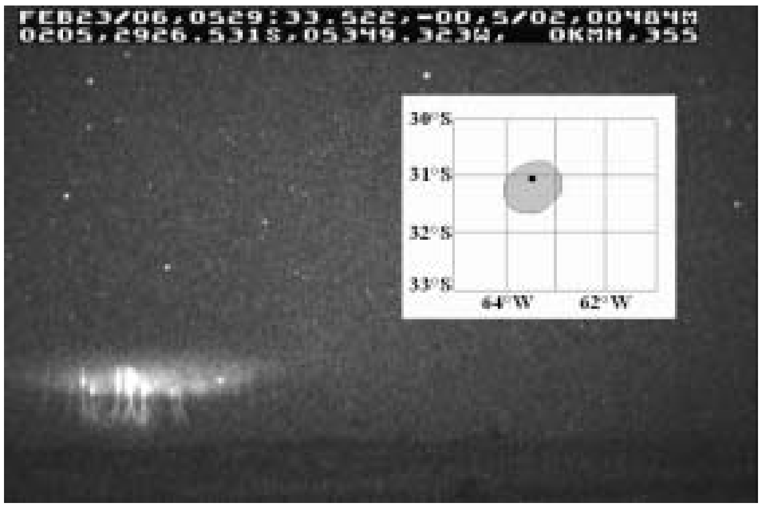
March 4 MCC Storm:

- Most sprites over clouds colder than -70 C

Sprite-Halos and Halos

- 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






7:30:50 293 206 460116