Evaluating lightning detection signatures at different technologies: A contribution to GOES-R and MTG

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... and many others that participated in CHUVA-GLM Vale do Paraiba field experiment

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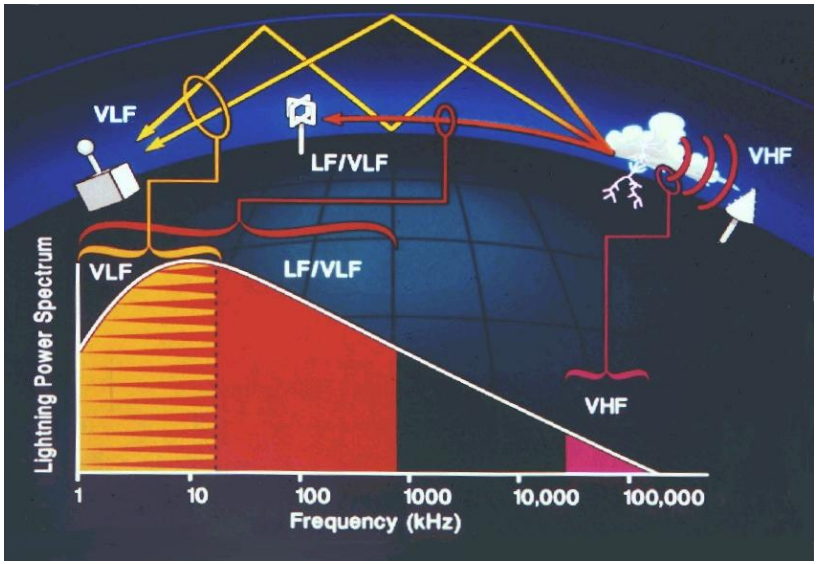
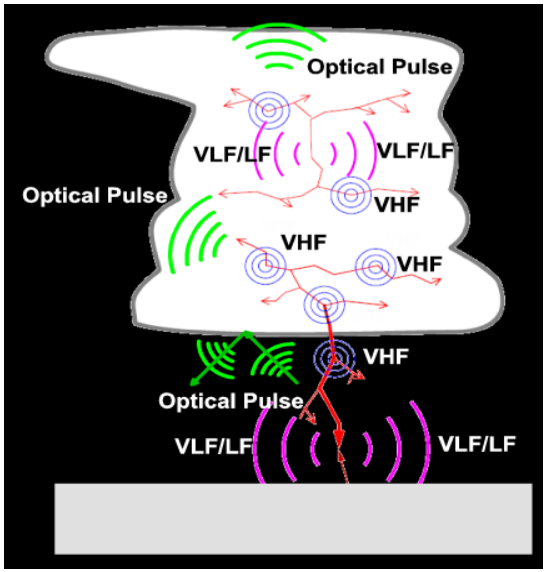
Motivation

- Different technologies are being used to create proxy data for GOES-R GLM and MTG-LI:
  - different frequencies (e.g., ELF-VHF, optical), detection type (sky/ground waves, line of sight, electrical and/or magnetic fields), location methodology (TOA or interferometry)
- Understanding the differences between each lightning detection network is import before assessing their detection efficiency.



(after Cummins et al., 2000, ISMM)



(by Hartmut Höller)

Objective

- Our goal is to describe what each technology measures/detects in respect to LMA sources.

- Assuming that the Lightning Mapping Array (LMA) can capture the majority of lightning discharge processes:
  - correlate LMA sources/flashes in space and time with 9 other Lightning Location Systems (LLS)
  - What are these LLS measuring? (*sferics*, *leaders*, *return strokes*, *cloud pulses* or a *complete lightning channel*)

Data

- Lightning data from CHUVA Project:
  - **CHUVA** = **C**loud processes of t**H**e main precipitation systems in Brazil: A contrib**U**tion to cloud resol**V**ing modeling and to the GPM (Glob**A**l Precipitation Measurement))
  - CHUVA = “rain” in Portuguese

- As part of GOES-R and MTG ground validation activities, CHUVA-GLM Vale do Paraíba field experiment collected lightning data from 10 different LLS in São Paulo, Brazil, from November 2011-December 2012.

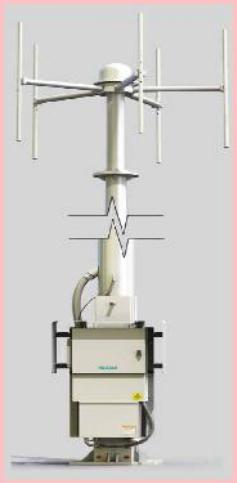
Data

Deployed total lightning networks :

12 LMA sites (VHF)

7 LINET sites (VLF-LF)

5 TLS200 sites (LF-VHF)



7 EN sites (ELF-LF)

Operational networks :

- RINDAT (LF)
- STARNET (VLF)
- WWLLN (VLF)
- GLD360 (VLF)
- ATDnet (VLF)
- BrasilDAT (ELF-LF)

6 High Speed Video Cameras

8 Field-Mills

Satellite Observations :

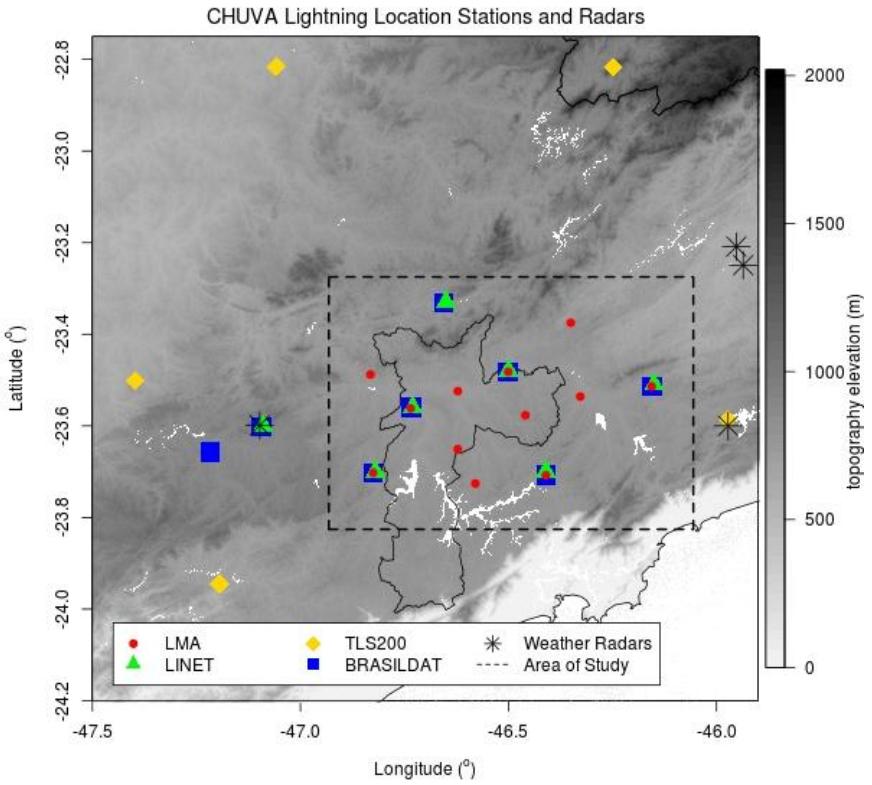
- GOES-12
- MSG

TRMM-LIS

Methodology

- Lightning sources, strokes and optical pulses used in this study are those that occurred during TRMM LIS overpasses.

- Area of study:
  - rectangle around SPLMA with up to 10km of distance from the outer-most sensors
  - LMA, LINET, denser-EN, and Vaisala TLS best detection efficiency and location accuracy (*)



(*) The actual D.E. and L.A. numbers of each network are beyond the scope of this study and will not be addressed.

Methodology

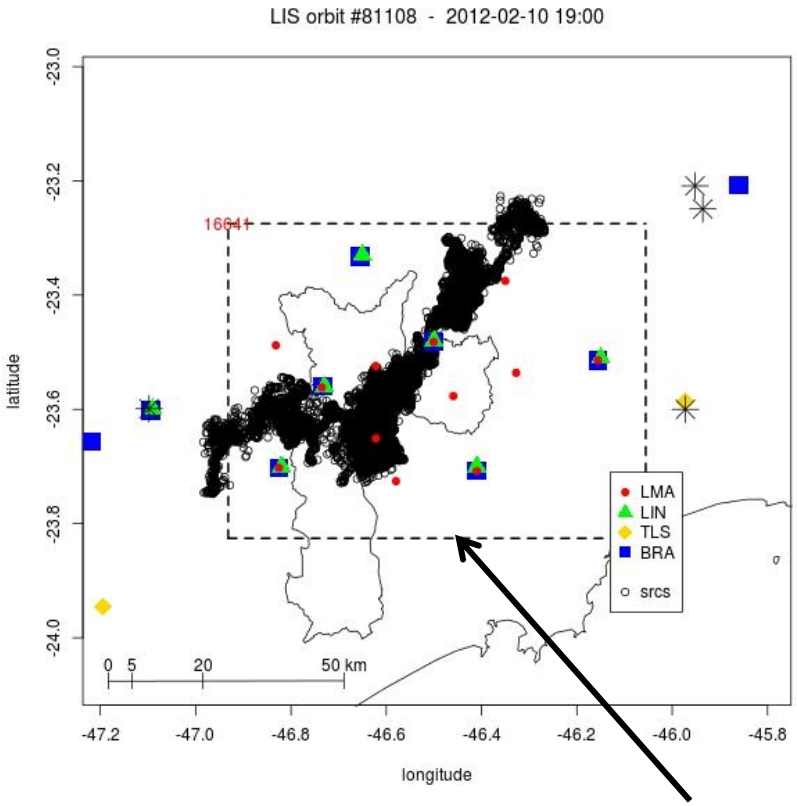
- **LMA data as reference**
  - Grouped LMA into flashes (SPLMA level_2) - Bailey et al. 2014 (ICAE).
  - Selected LMA flashes that occurred within LIS view time and within our area of study, but also allowing sources outside this area to complete LMA flashes.
  - Only orbits with more than 10 LMA flashes (w/ 10+ sources each) are considered.

- **Space and time matching with LMA sources**
  - each stroke/source/pulse was matched to sources of LMA flashes
  - Δt = 330 ms (used by LIS to compose a flash)
  - Δs = 50 km (to account for location accuracy of long range LLS).

- **High Speed Camera**
  - At least one negative CG recorded in video during a LIS overpass.

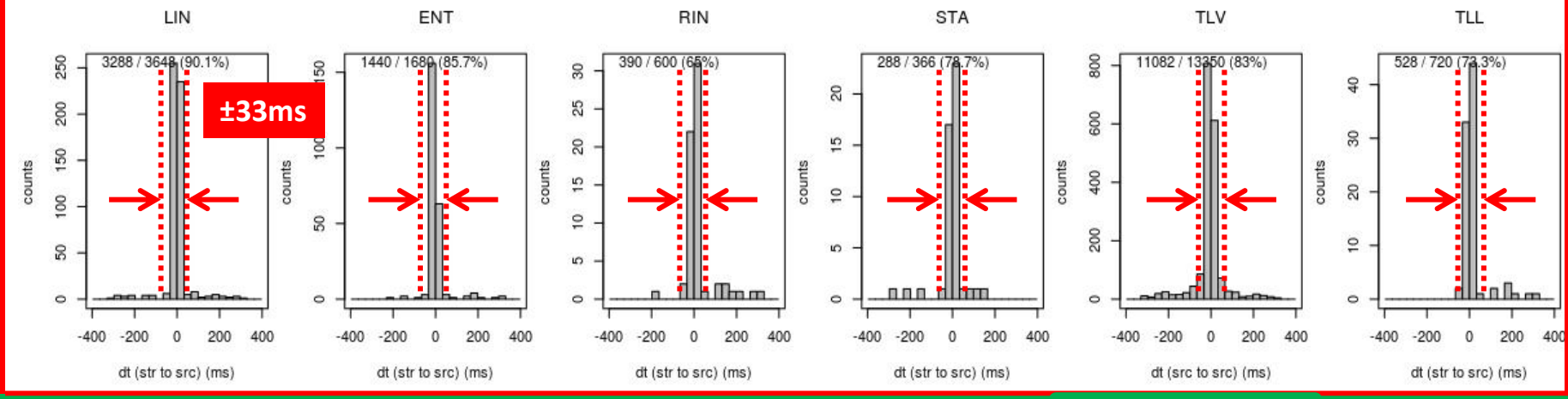
Results (Part I)

- Statistics from a single LIS overpass (Orbit #81108):
  - Time difference (Δt) distributions of:
    - LMA individual source matched to LLS stroke/source/pulse
    - LMA first source of matched flash to LLS stroke/source/pulse
  - Space difference (Δs) distributions of:
    - LMA individual source matched to LLS stroke/source/pulse

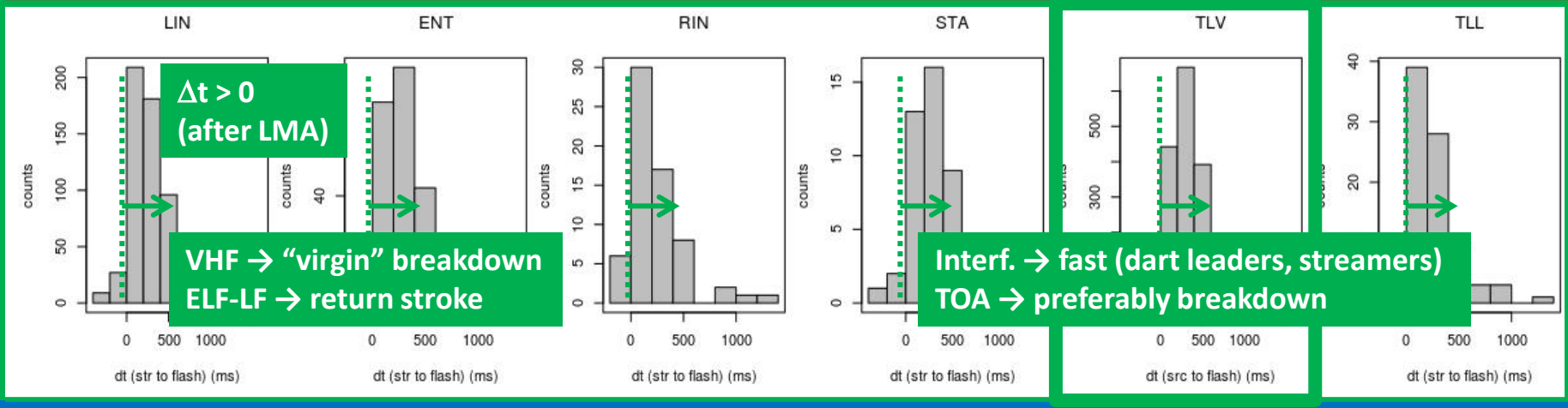


LIS orbit #81108 - 2012-02-10 19:01:34 (90s of viewtime) - 165 LMA flashes

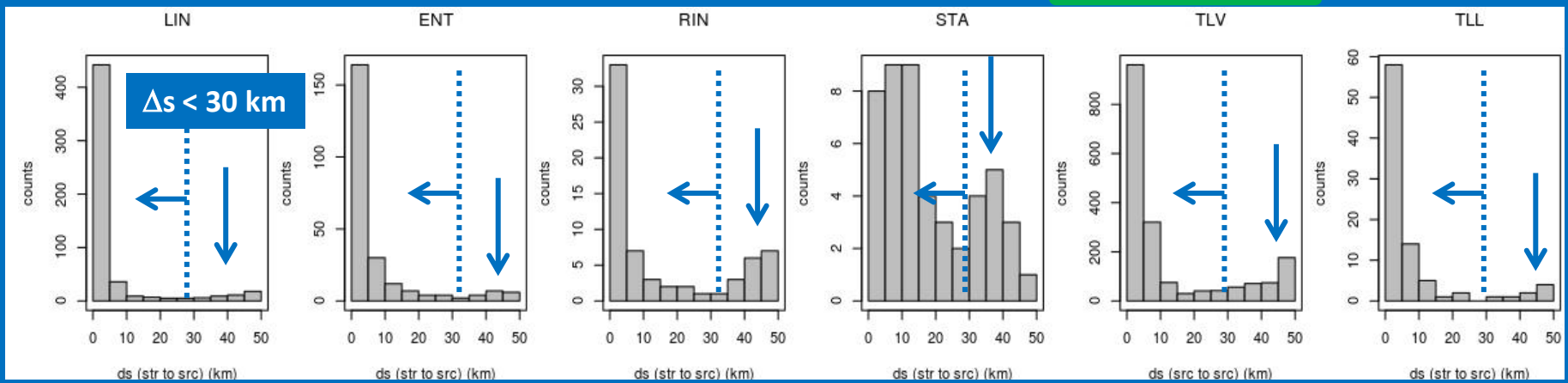
$(t_{LMA\ src} - t_{LLS})$



$(t[_{LMA\ 1^{st}\ src}] - t_{LLS})$



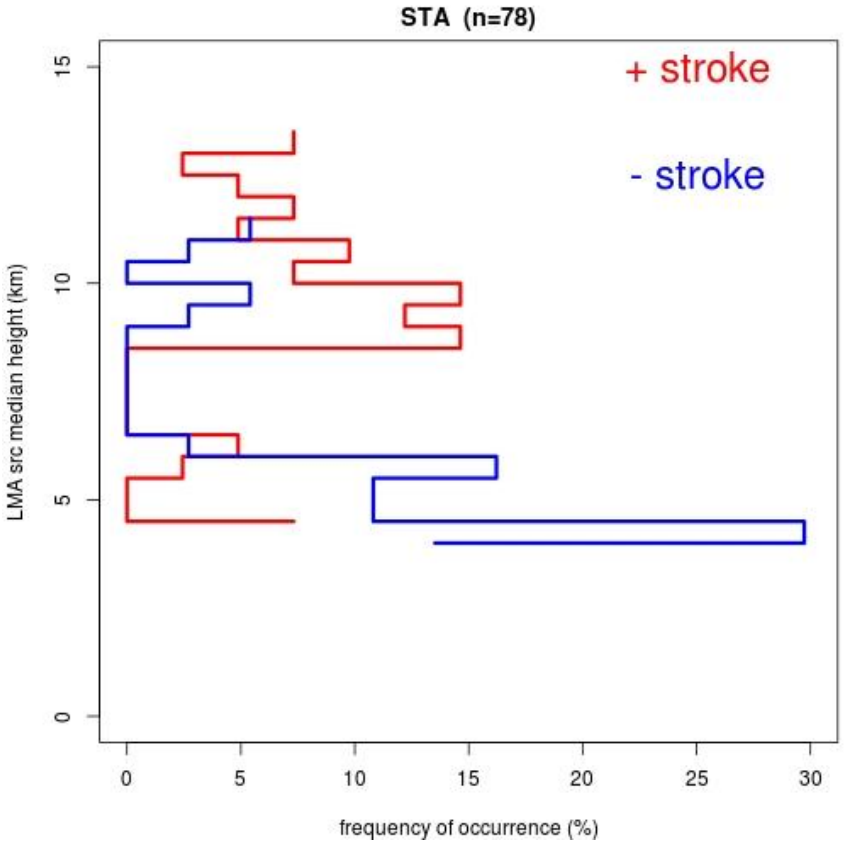
$\Delta s\ [\ LMA_{src}$ to LLS]

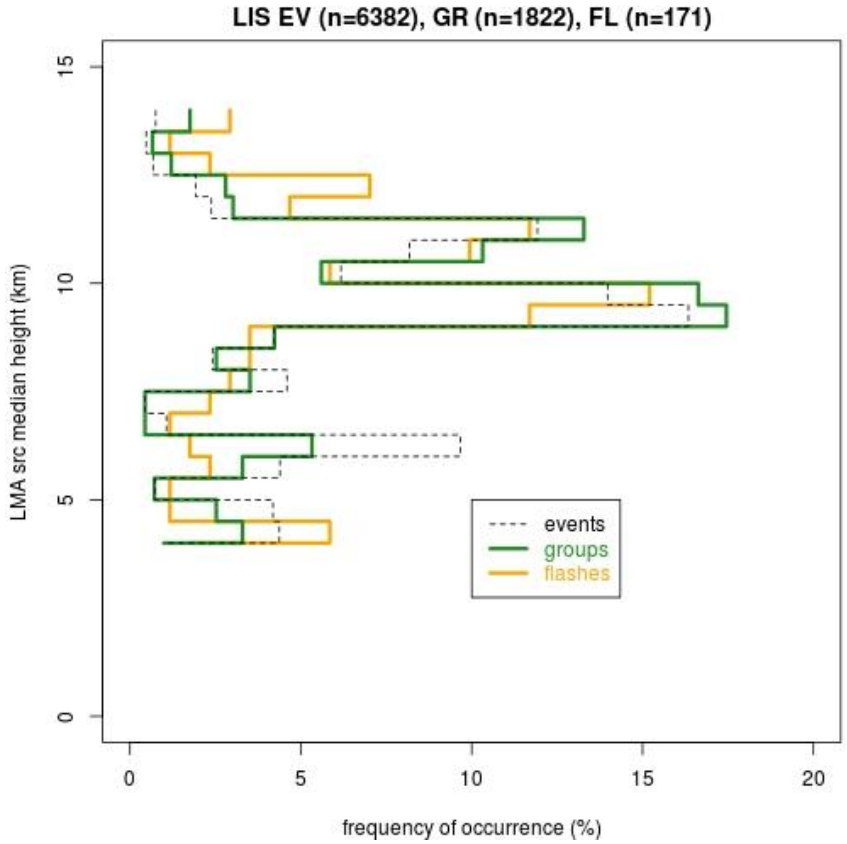


Results

Where are in altitude are most of LMA sources when also detected by other networks?

- Frequency of occurrence of STARNET strokes and LIS pulses as a function of median height of sources from matched LMA flash





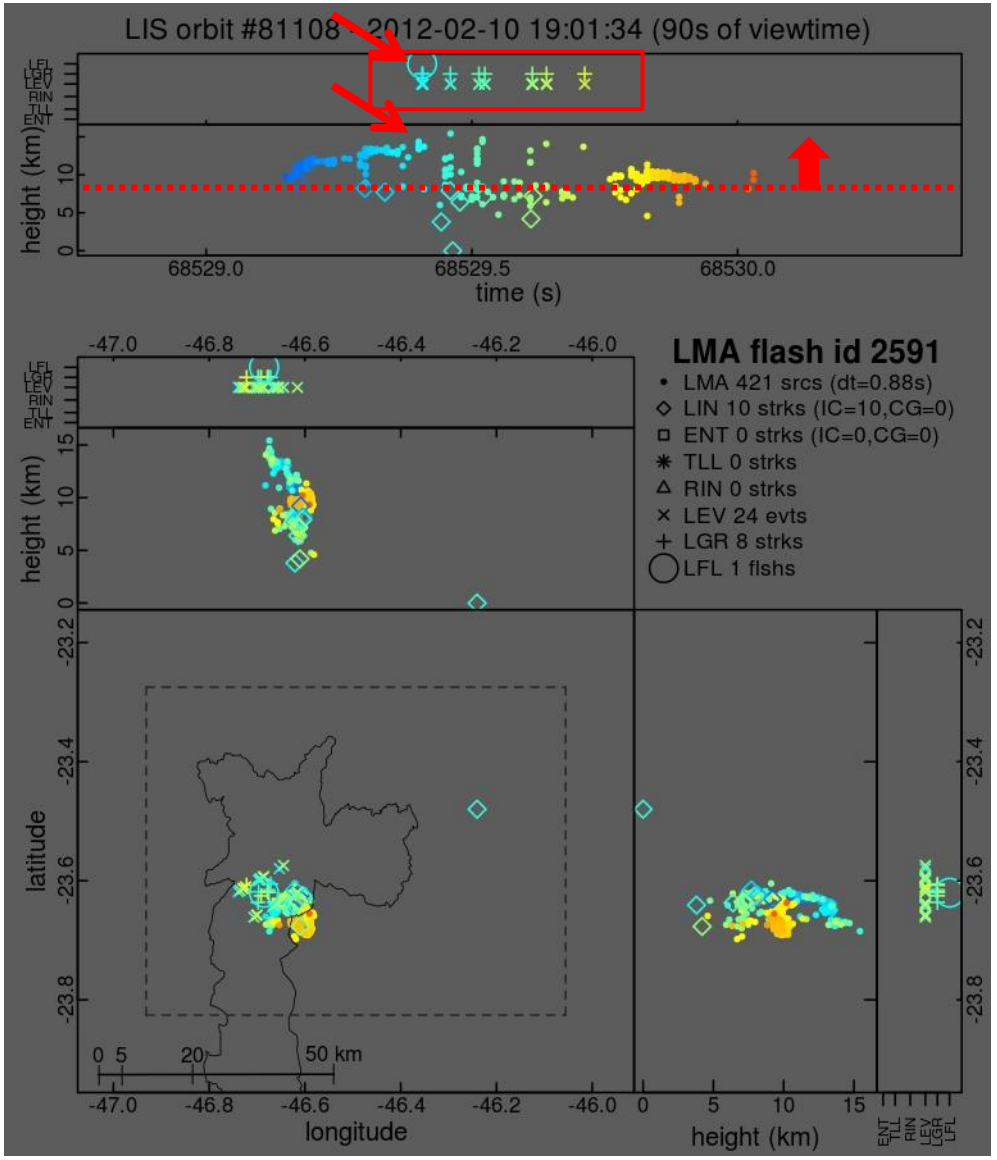
Results

Examples of LMA flashes matching LLS strokes/pulses:

LMA flash (id = 2591):

- IC flash:
  - detected by LMA – VHF
  - detected by LIN – LF
  - detected by LIS - optical

- Breakdown propagating to high levels of the cloud (>9 km):
  - LIS detected flash
  - LIS flash location tends to be positioned at the region with higher altitude sources



Results

High-Speed Video Camera (PRELIMINARY RESULTS):

Negative CG flash:

- One negative CG recorded in video during a LIS overpass:
  - Orbit #81576 2012-03-11, LIS flash starting at 19:01:34 UTC
- The recordings were done by a Phantom v711 high-speed video camera located at a distance of ~15 km from the CG strike.
- The frame rate used was 4,000 images per second. Each image is time stamped with GPS precision.

(Play slow-motion video using Photron)

Results

High-Speed Video Camera:

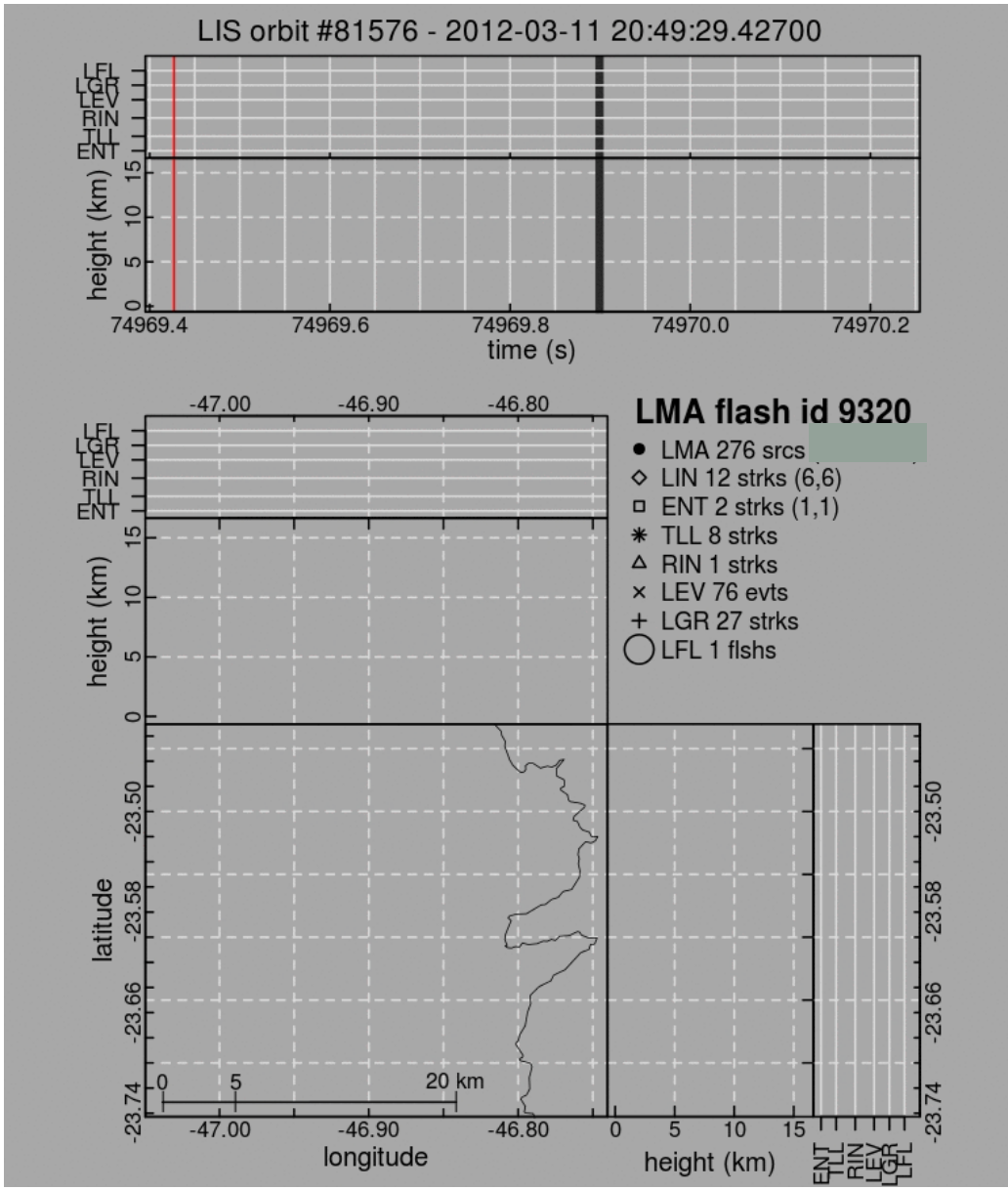
Results

High-Speed Video Camera:

Negative CG flash:

- Video: 6+ strokes
- LIS: 1 fl, 27 gr, 76 ev
- LMA: 276 sources
- LIN: 6 ICs, 6 CGs
- ENT: 1 IC, 1 CG
- TLL: 8 strk
- GLD: 1 CG (=1st LIN strk)
- Not detected by ATD, STA, WWL

- All networks detected negative peak currents (-24.3 kA to -4.3 kA)



Conclusions

- Different LLS measure different parts of the lightning process (thus they are complementary to each other)

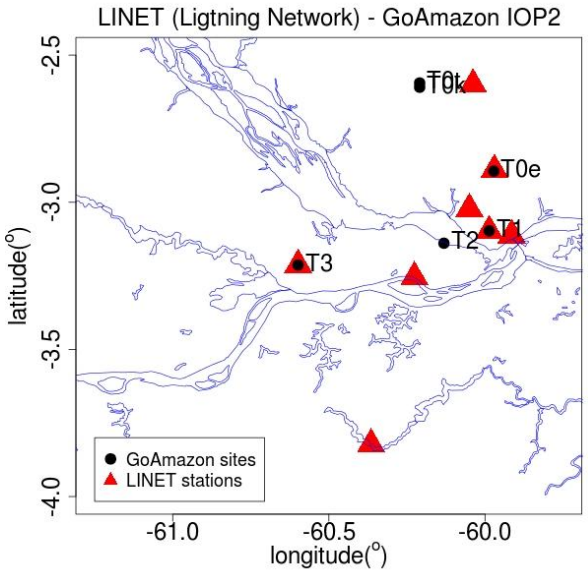
- Most of strokes/pulses/sources occurred after first LMA source:
  - VHF measurements → more "virgin" processes of the breakdown
  - ELF-LF measurements → come from the return strokes

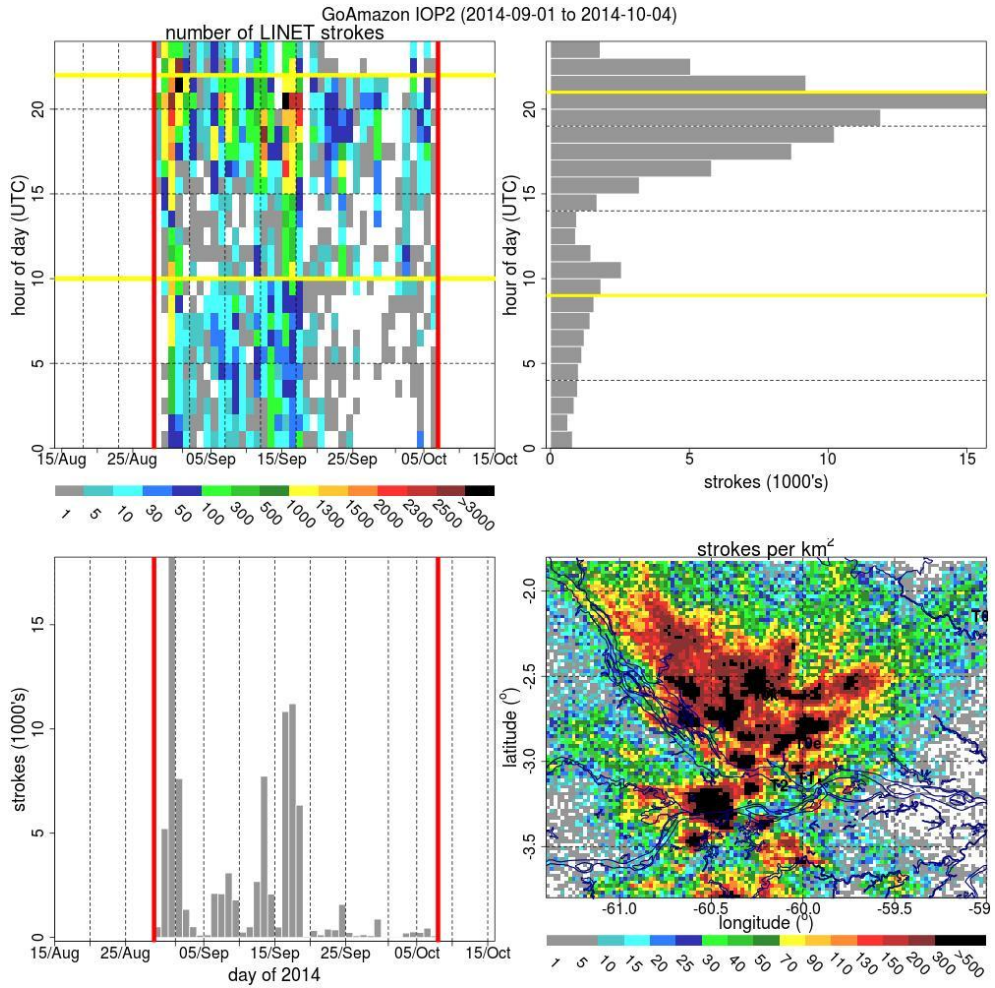
- VHF interferometry, generally, source detection comes after the first LMA source [Mazur et al., 1997; Cummins and Murphy, 2009]:
  - TLV (interferometry) → Fast-propagating (10^6-10^7 ms^{-1}) processes (fairly continuous on VHF emissions for tens of ms – e.g., dart leaders, streamers)
  - LMA (time-of-arrival) → Preferably breakdown processes (10^4-10^5 ms^{-1})

- High-speed video:
  - All LF-networks and LMA detected at least one stroke
  - Only GLD360 (VLF) detected one stroke

Future work that could contribute to GLM/LI Cal/Val activities

- LINET operated in Manaus from 29 Aug 2014 – 07 Oct 2014 (ACRIDICON-CHUVA)
  - Intercomparisons between LINET, STARNET and LIS





- LINET will be operating in Sao Paulo from Sep 2015 – Apr 2016

Thank you for your attention!