São Paulo Lightning Mapping Array (SP-LMA): Network Assessment and Analyses for Intercomparison Studies and GOES-R Proxy Activities

Presented by

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Acknowledgments

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- Collaborators and other network participants

Congratulations to SP-LMA team for receiving a NASA Group Achievement Award!

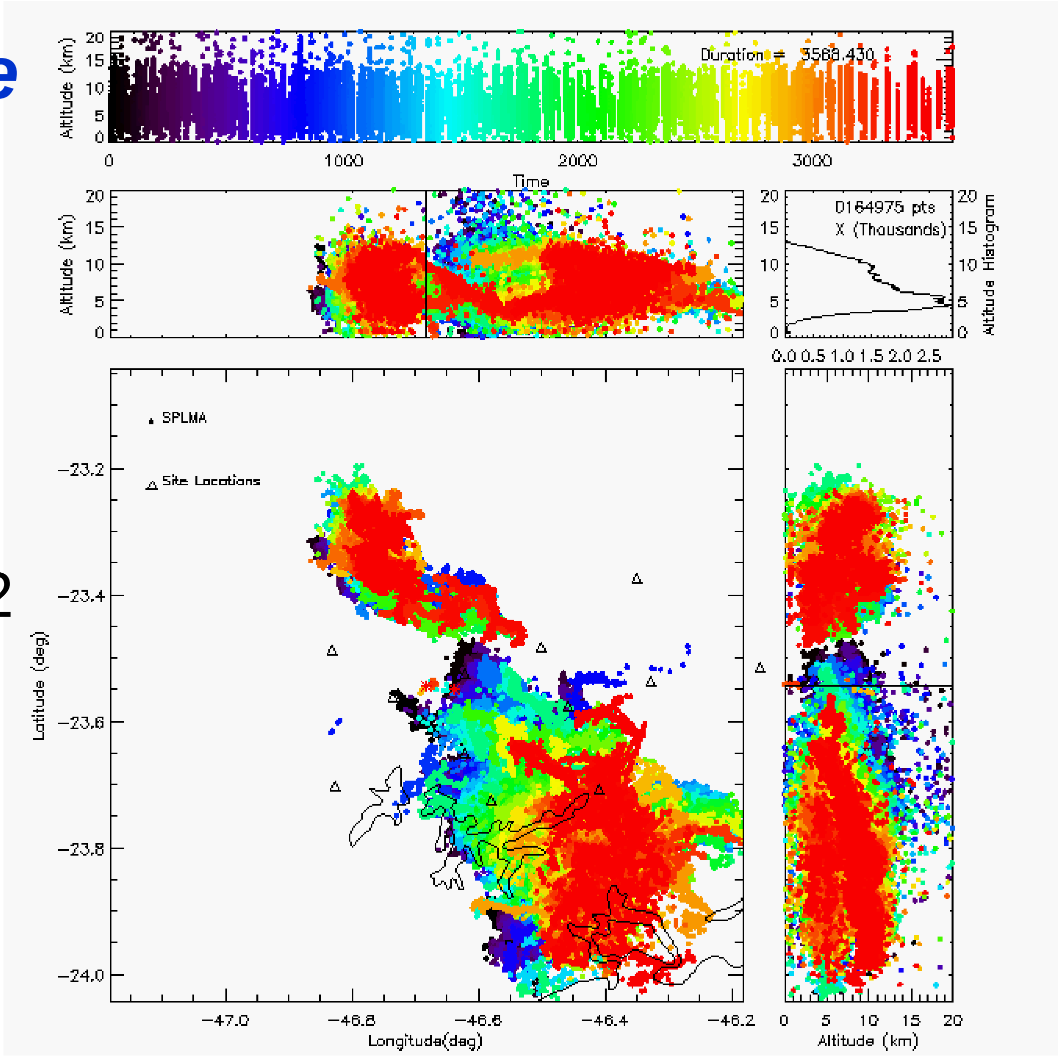
Outline

- Main goal: Make sure users understand the complexity and careful usage of SPLMA data set
- Network geometry and time of arrival technique
- Noise issues
  - Significant TV channel 9 noise source needs to be addressed
- Noise filtering and elimination
- Data analysis and statistics
- Conclusions / Summary

Sample Hour of SP-LMA Lightning
2012-01-19 (2300 UTC)

Excellent Performance

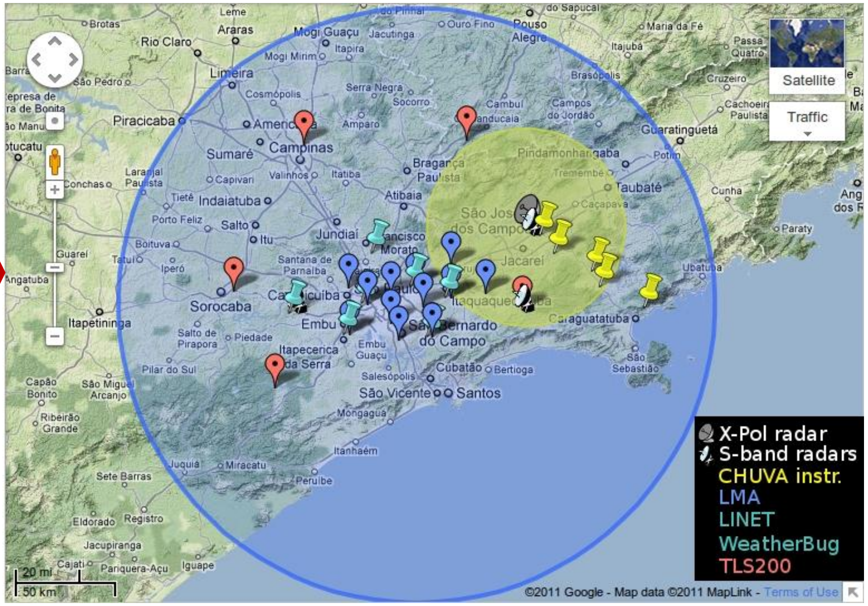
- When carefully analyzed, the SP-LMA provides excellent performance on par with any LMA network
- Figure shows an hour of data from 19 January 2012

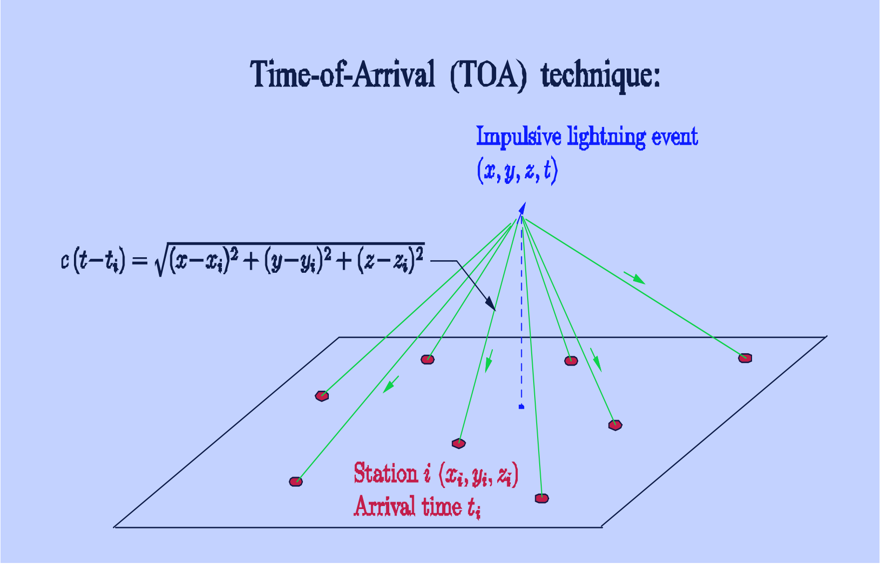


Network Geometry and Time of Arrival

Network Geometry

- Dark blue markers show location of the12 LMA stations (11 TV Channel 8, 1 TV Channel 10)
- Other markers show other systems
- Large blue circle region of 3D LMA
- Yellow circle optimum X-Pol radar coverage

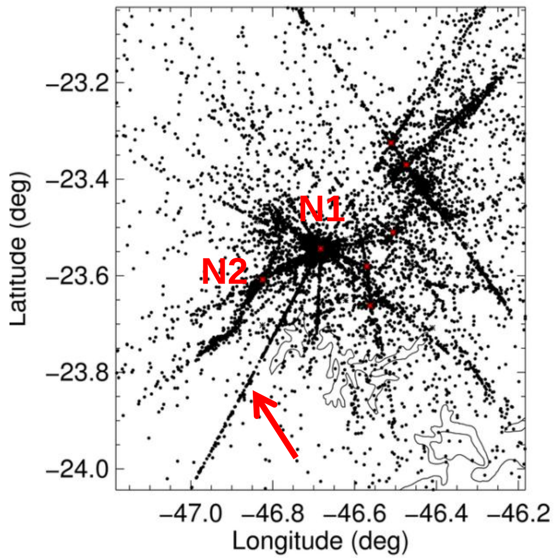




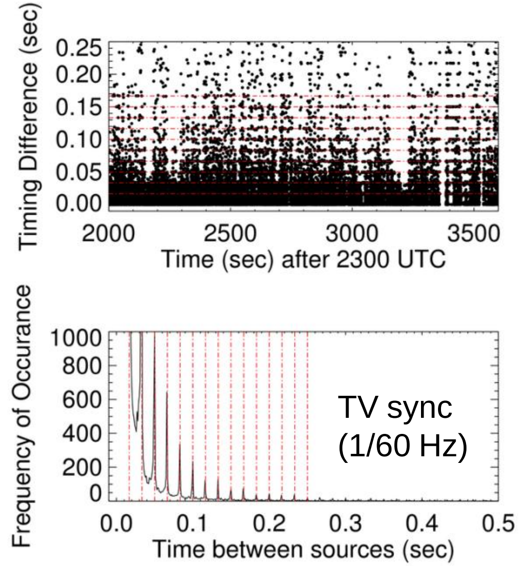
Time of Arrival

- SP-LMA stations detect lightning breakdown processes using unused TV channel (source det. in 80μs window)
- Network maps out the lightning channel in 3D using TOA technique
- N≥6 used to solve for source loc.

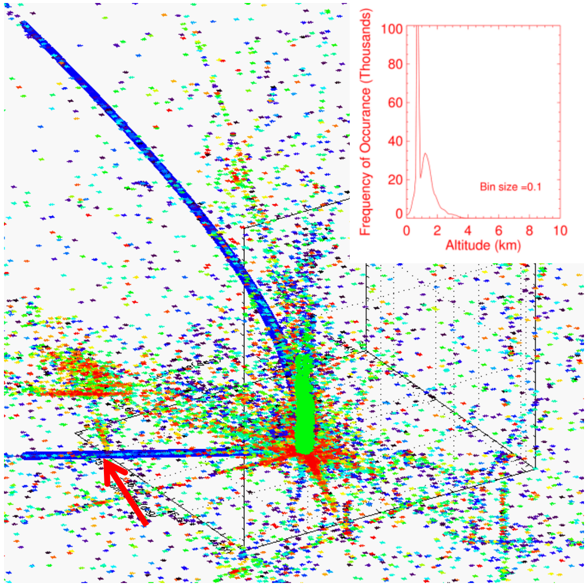
Noise Characterization
2011-12-11 (2300 UTC - all noise hour)



Noise locations



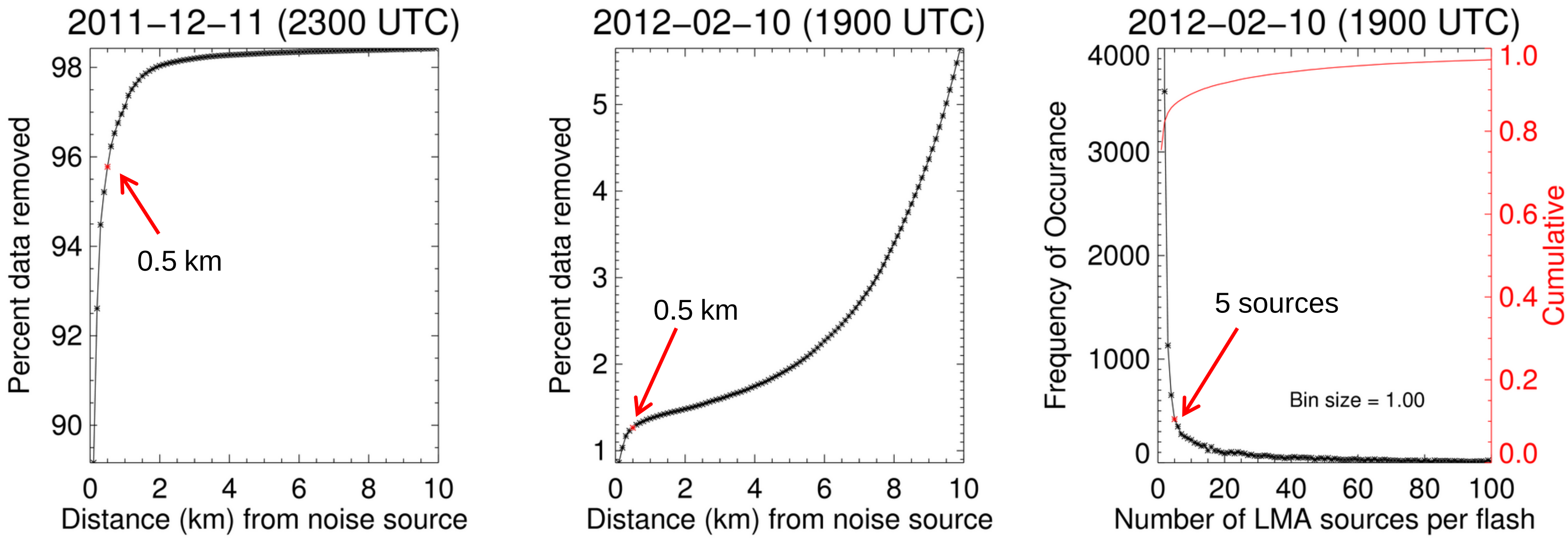
Timing difference between successive sources



Rotated 3D with x-y projection

- Primary noise source is located at a TV (ch 9) tower (N1 - lon: -46.6830, lat: -23.5438)
  - Other noise sources exist but contribute a small fraction compared to the primary (N2 next largest)
  - TV sync pulses create 60 Hz (16.6 msec) multiples in timing difference plots (dashed red lines)
  - Main noise source curves with altitude and is a hyperbola (a=19.50, b=25.69, foci=32.25 km)
  - Not sure why the angle is 237.5 deg (SSW) from X-axis counter-clockwise (red arrows)
- 95.8% of noise is within 0.5 km of N1 and below 4 km (green and histogram inset)
- Hence, a vertically oriented cylinder of varying radius can effectively filter noise
- 'Real' lightning dominates the noise, which tends to be low signal strength

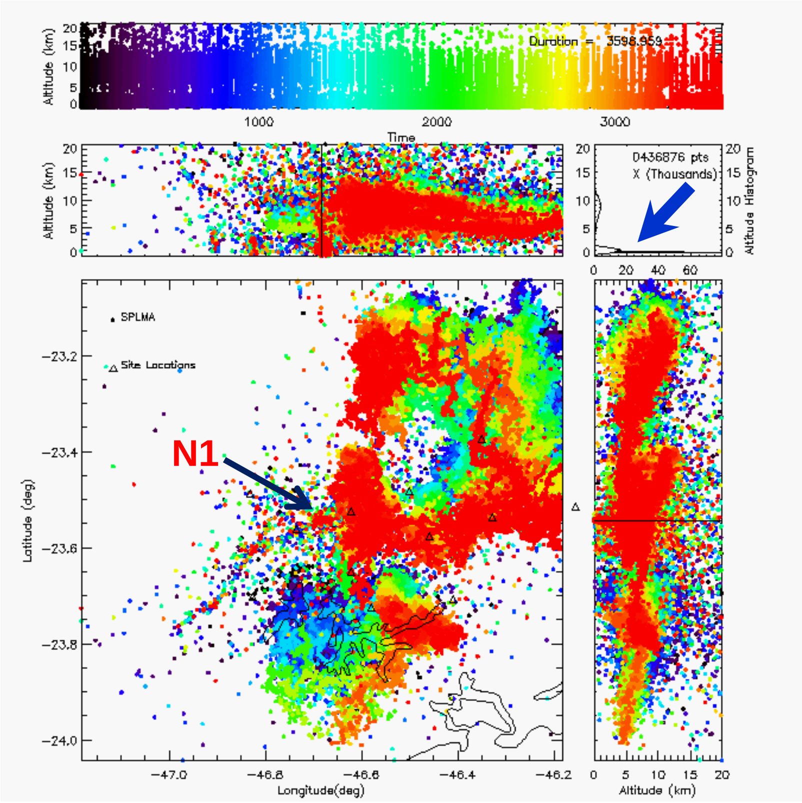
Noise Filtering Criteria and Justification

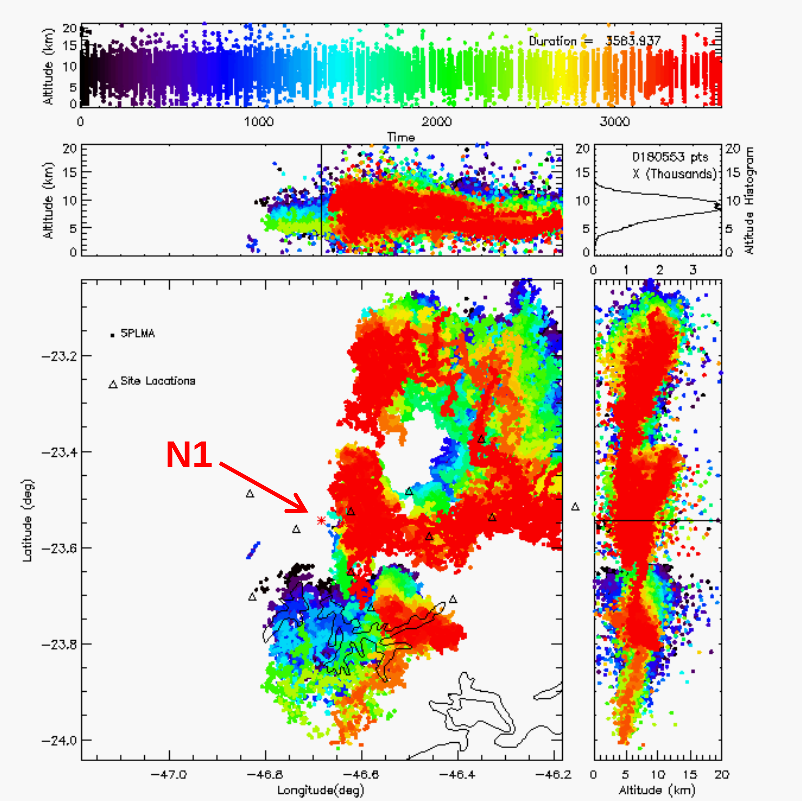


- Good news: Noise filtering versus distance from noise site
  - All noise period (left): 0.5 km cylinder typically eliminates >95% of noise
  - Active lightning period (middle): 0.5 km typically eliminates (mostly noise) < 2.5% of data
  - Some days need larger cylinder radius (0.5 km to ~2.5 km)
- Histogram of number of sources per flash drops off quickly
  - Require >= 5 sources/flash to take out ‘singletons’ (right)
  - ‘Singletons’ will be flagged in the reprocessed data set so they can be easily removed or kept (some may actually be real sources, and desired for other analyses)

Example Noise Rejection - Lightning Period
2012-02-27 (0300 UTC, one hour)

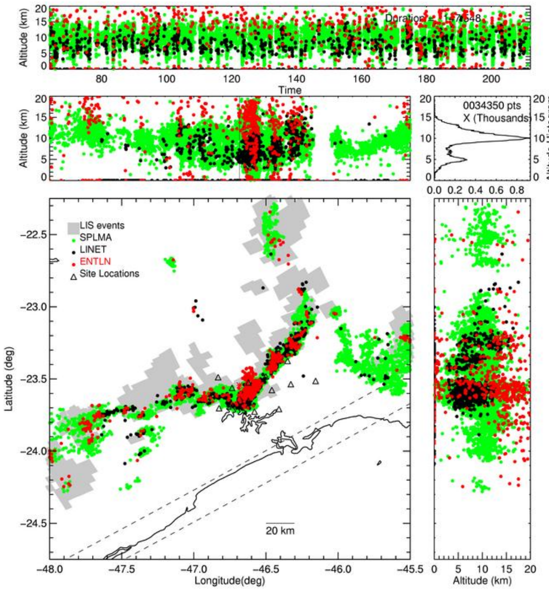
- Prior to filtering, histogram dominated by noise at low altitude (left, blue arrow)
- Eliminate noise **before** grouping into flashes (by applying cylinder filter at N1)
- After noise removal [1 km (52%), singletons (7.7%)], lightning histogram dominates noise
- Filtering effectively eliminated most of noise while retaining most of the lightning, including low altitude sources that likely indicate real CG flashes



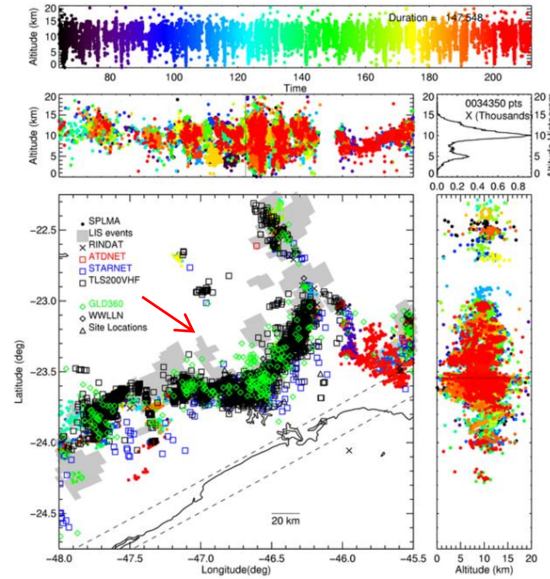


Timing and Spatial Comparison

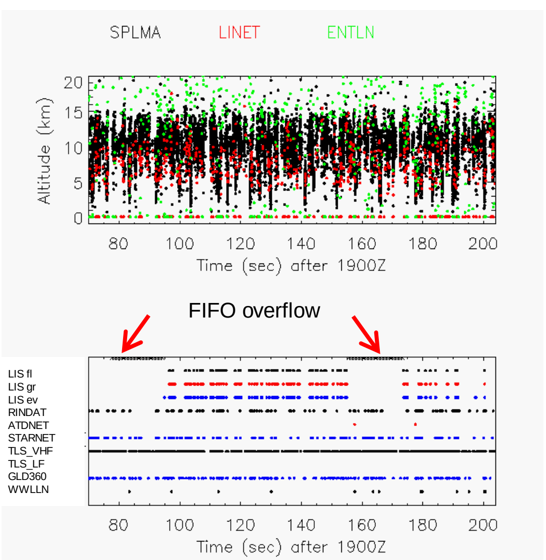
- Good data set for inter-comparisons as all sensor systems have good temporal and spatial correlation
- Some LIS events not detected
  - Could be nearby non-electrified cloud reflection or viewed from edge of cloud
- Majority of flashes detected by most systems (but with different level of detail)
- ENTLN appears to have bias toward higher altitudes (on Stan’s to do list).
- Next slide: animation of upper left panel at a 300 msec rate for each second of time



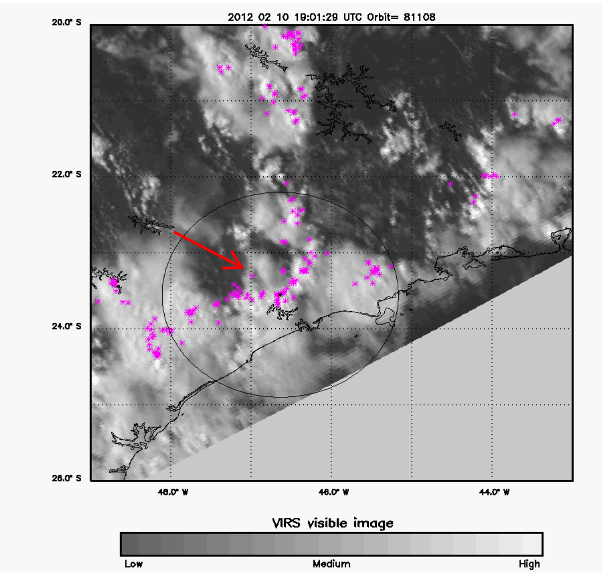
LIS (grey), SPLMA (green) LINET (black), ENTLN (red)



LIS (grey), SPLMA, other 2D sensors



Time Alignment: Top (3D), Bot (2D)

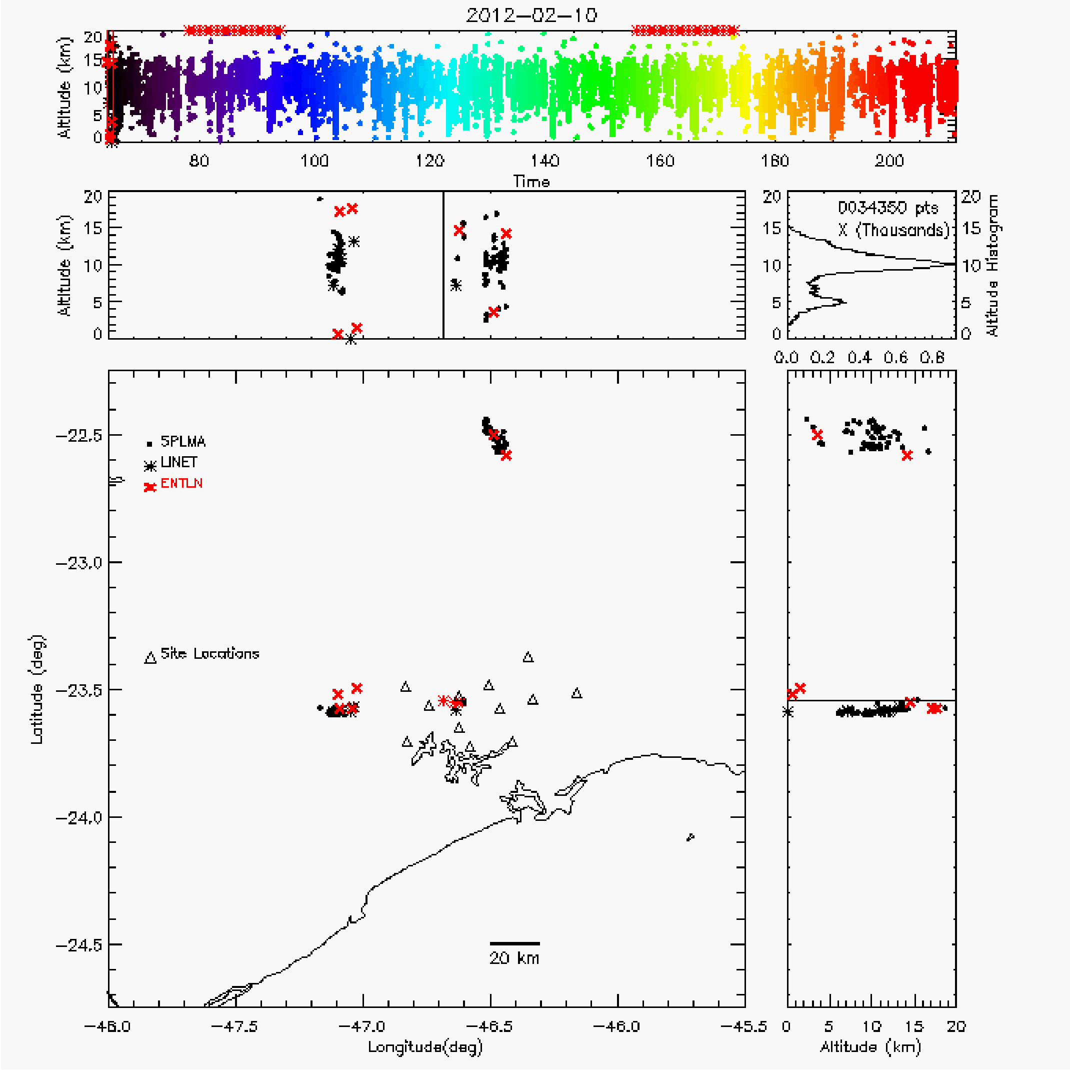


TRMM VIRS visible (LIS flashes overlaid)

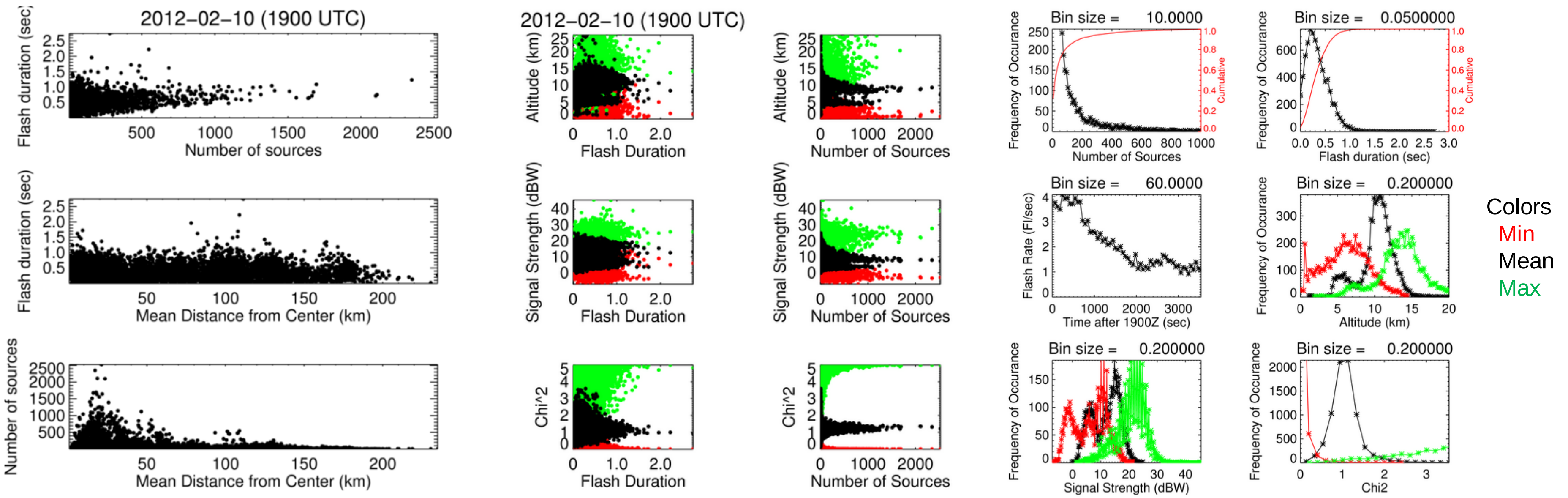
LIS Overpass Animation
2012-02-10 (1900 UTC)

- Red vertical lines (top) are the current data being displayed
- At first no lightning in LIS FOV
- Then LIS has full FIFO (no data)
- LIS lower edge of FOV curves
- Another full FIFO later on (no data)

- Other comments:
  - SPLMA does not detect all LIS events
  - SPLMA and TLS200VHF (not shown) are about tied for detecting LIS events
  - LIS does not detect all flashes
  - Some singletons correlate with LIS events



Statistics for 2012-02-10 (1900 UTC)

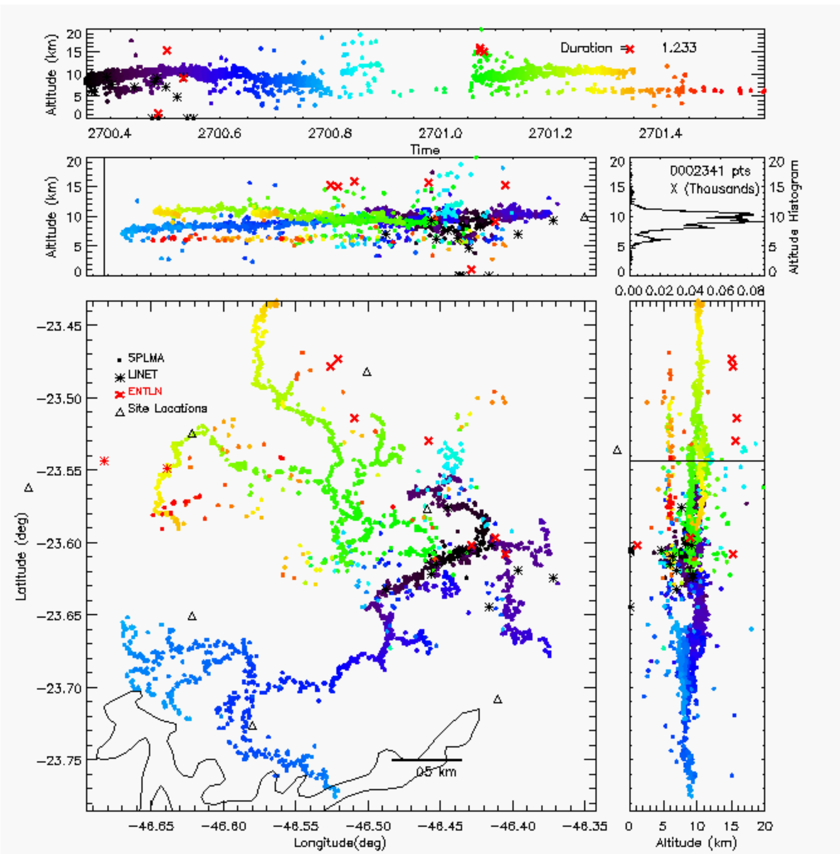


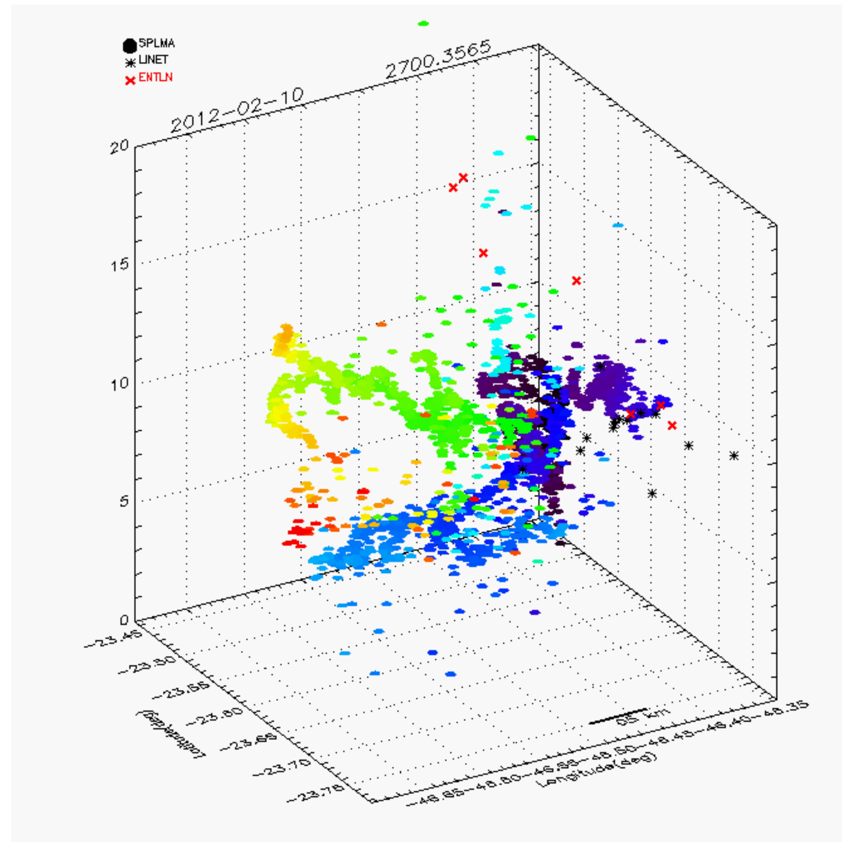
Statistical Analyses

- Bulk statistics provides sanity check of data (otherwise need to check data closely)
- Any residual noise appears to not significantly affect the statistics
- Some key results:
  - Min flash duration is proportional to number of sources per flash but not max flash duration
  - Flash duration is not a function of distance from network center
  - More sources detected at closer distances (expected)
  - Mean charge centers are at 5.5 and 11 km altitude

Data Quality (10 February 2012)
(N sources per flash >= 1000)

- Extensive flash observed on by the SP-LMA with 2341 sources (duration of 1.233 seconds)
- Large extent (~ 35 x 35 km) and excellent detail of charge and channel structure.
- LINET (black star) and ENTLN (red X) detected 10 to 20 sources from this flash

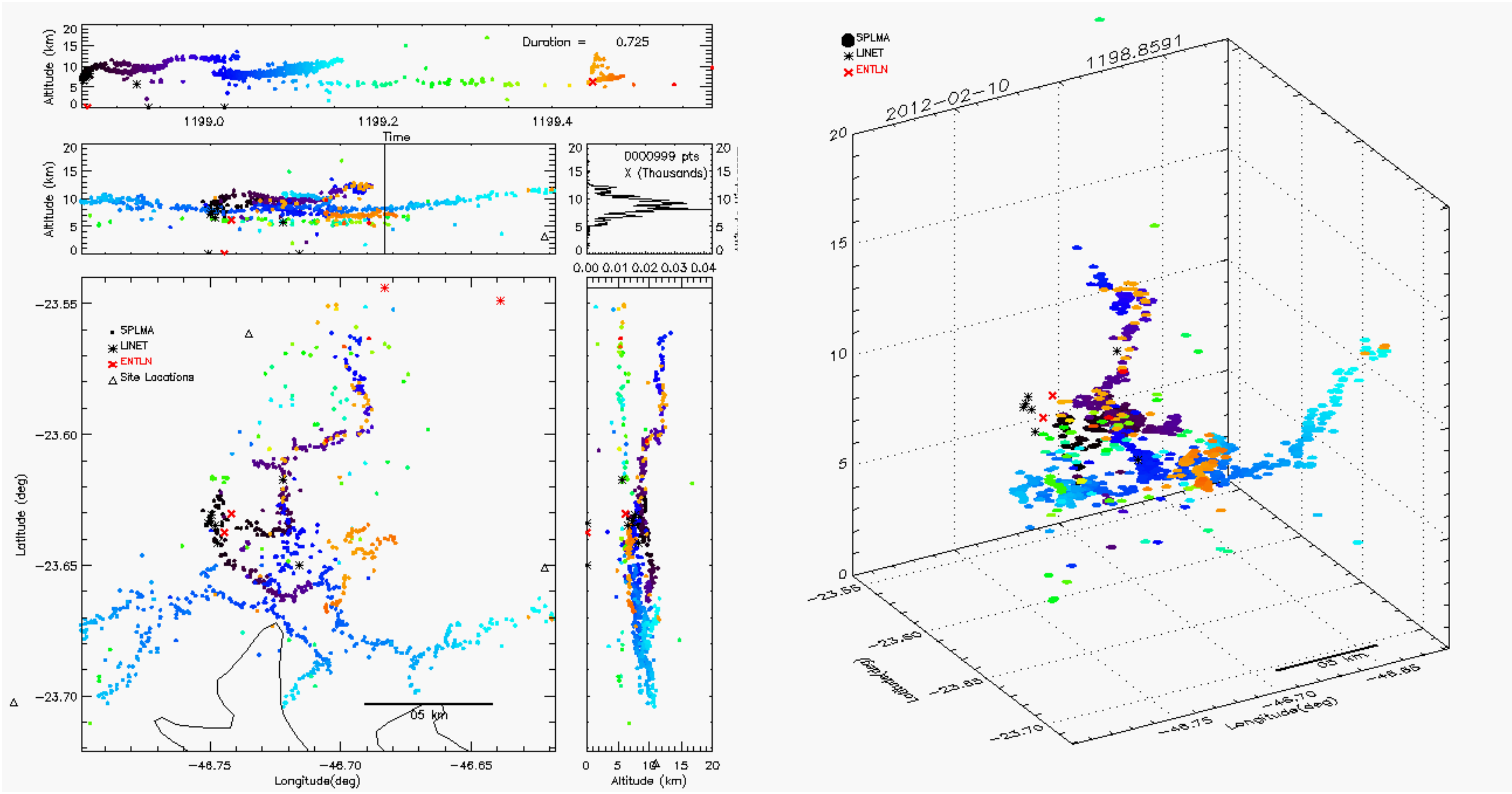




Conclusions / Summary

- SPLMA network collected data from November 2011 to April 2012
- When carefully analyzed, SP-LMA provides excellent performance
- Significant primary noise source but noise easily removed with little adverse affect on lightning data
  - *Lightning data dominates noise, which has low signal strength*
  - *Noise must be removed to generate meaningful monthly climatologies during CHUVA (not shown)*
- Good correlation found between lightning detection systems
  - *Data sets will be valuable for pursuing GOES-R proxy activities*
  - *Care required to inter-compare with LIS (no significant LIS offsets found)*
- Detailed flash analyses, bulk statistics, and climatologies generated
- Revised data set (with primary noise removed) will be submitted to CHUVA archive (~2 months) with tag for singletons

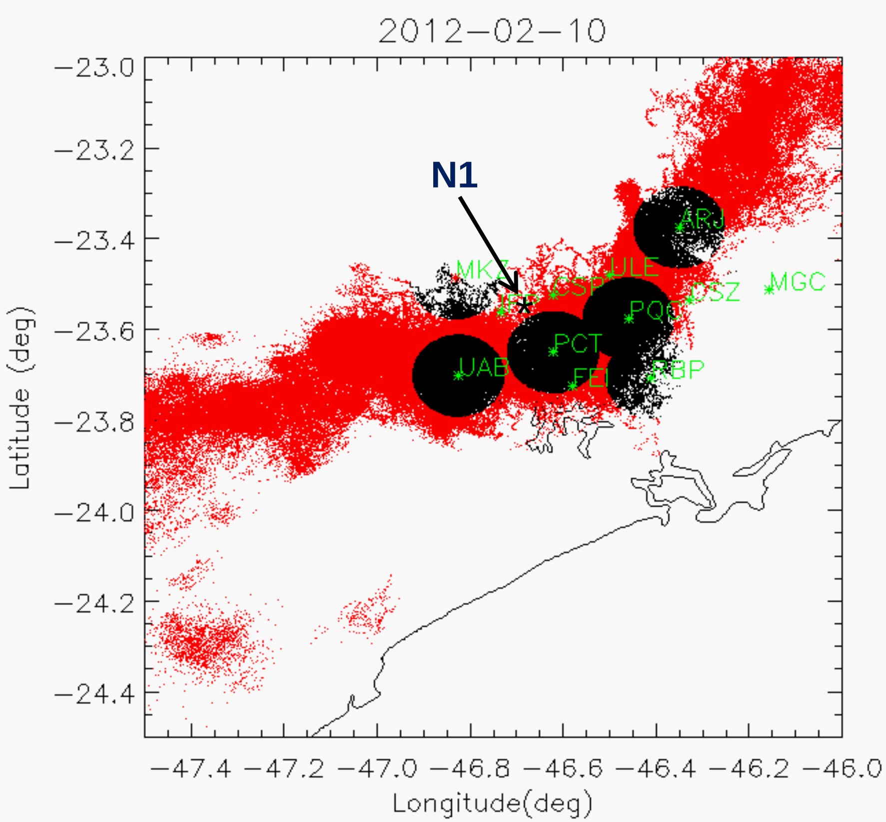
More N sources > 1000 (36 total), Questions?

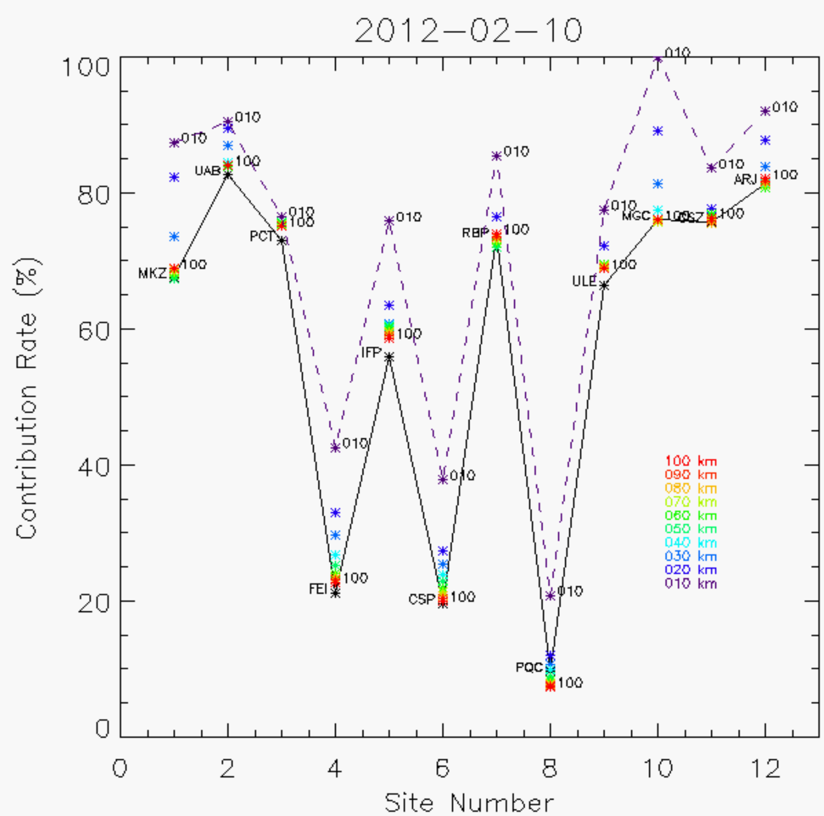


Backup Slides

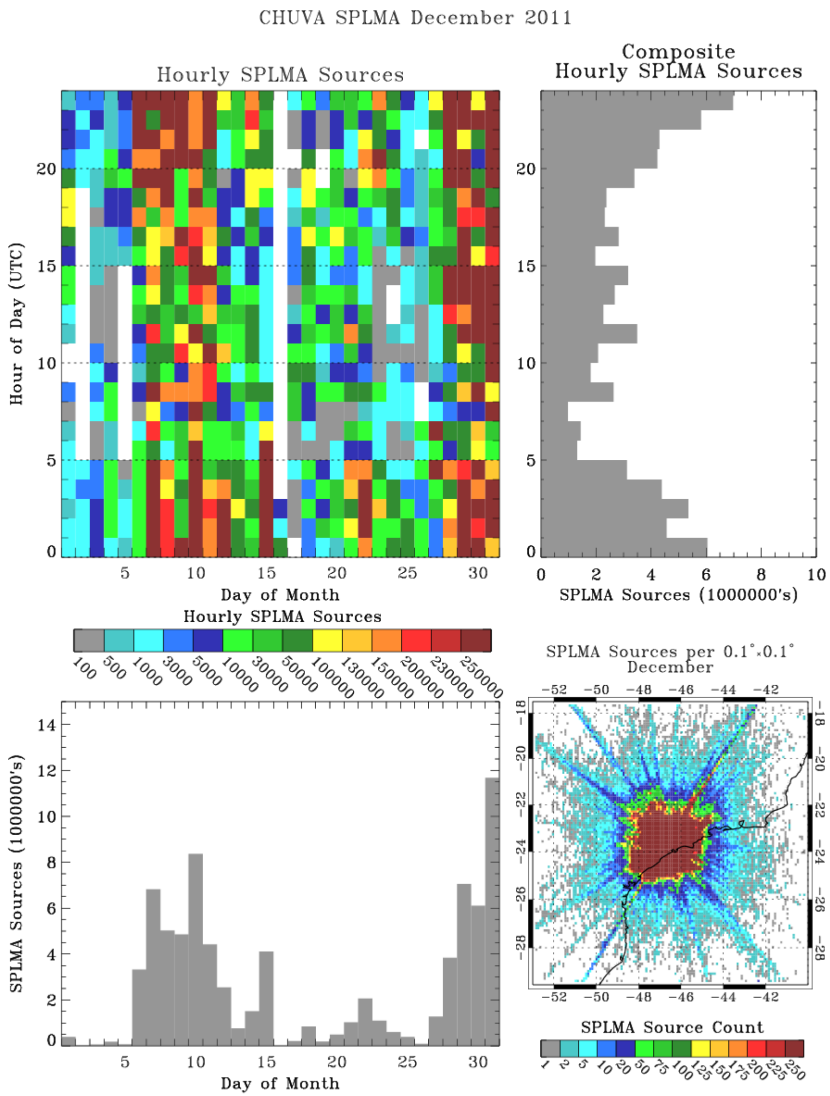
Site Contribution Rate
2012-02-10 (1900 UTC)

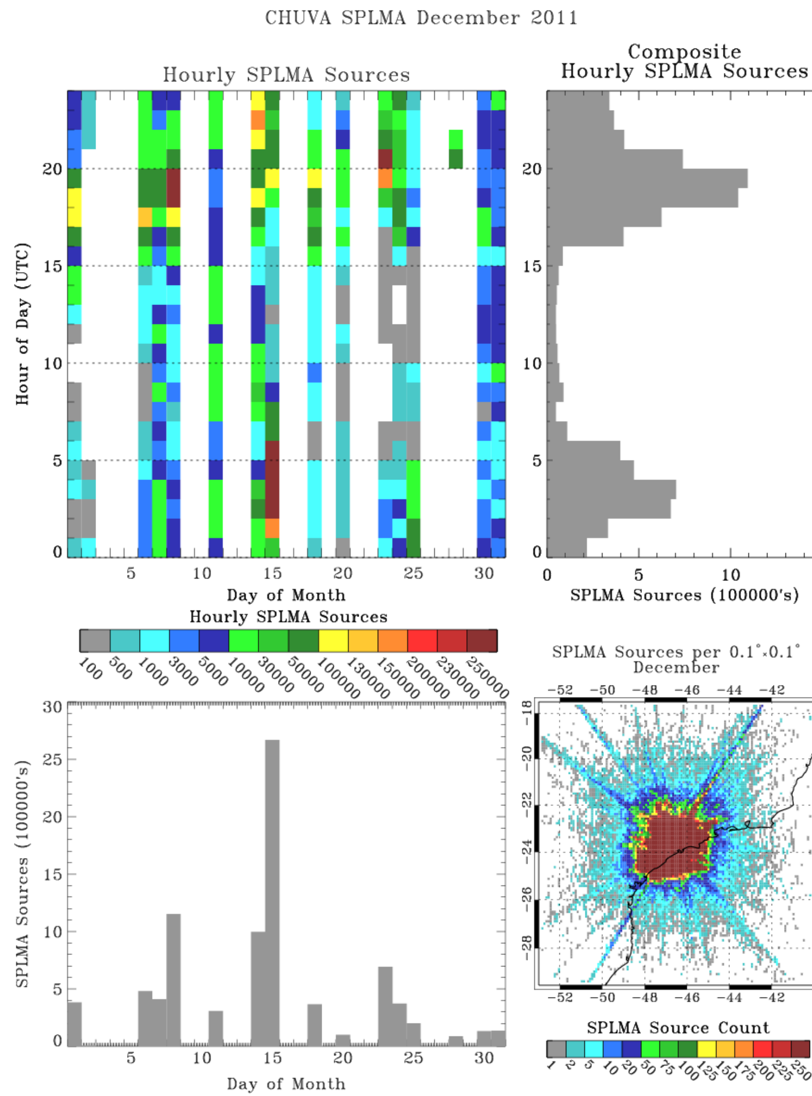
- Contribution rate (proxy for det. eff.) as a function of distance from the site
  - Color codes indicate distances (Solid / Dashed lines are for all / 10 km from site)
  - 10 km range ring for some sites are shown
  - Some data invalid for less than all data due to lack of data near site (MGC, for example)
  - CSP, PQC are noisy sites, FEI is channel 10
  - Contribution rate can increase dramatically but was surprised to see 20 to 10 km jump



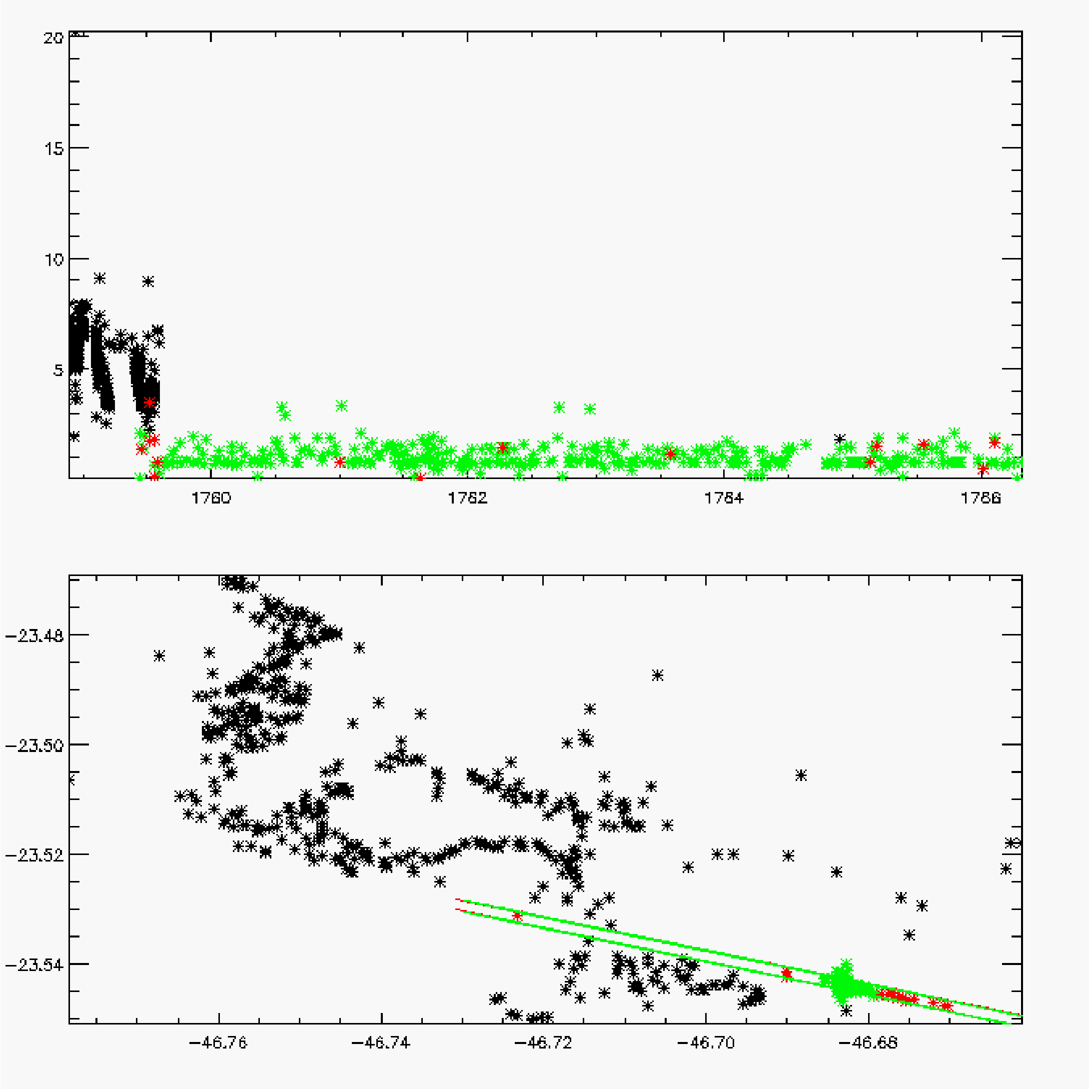


Monthly Activity



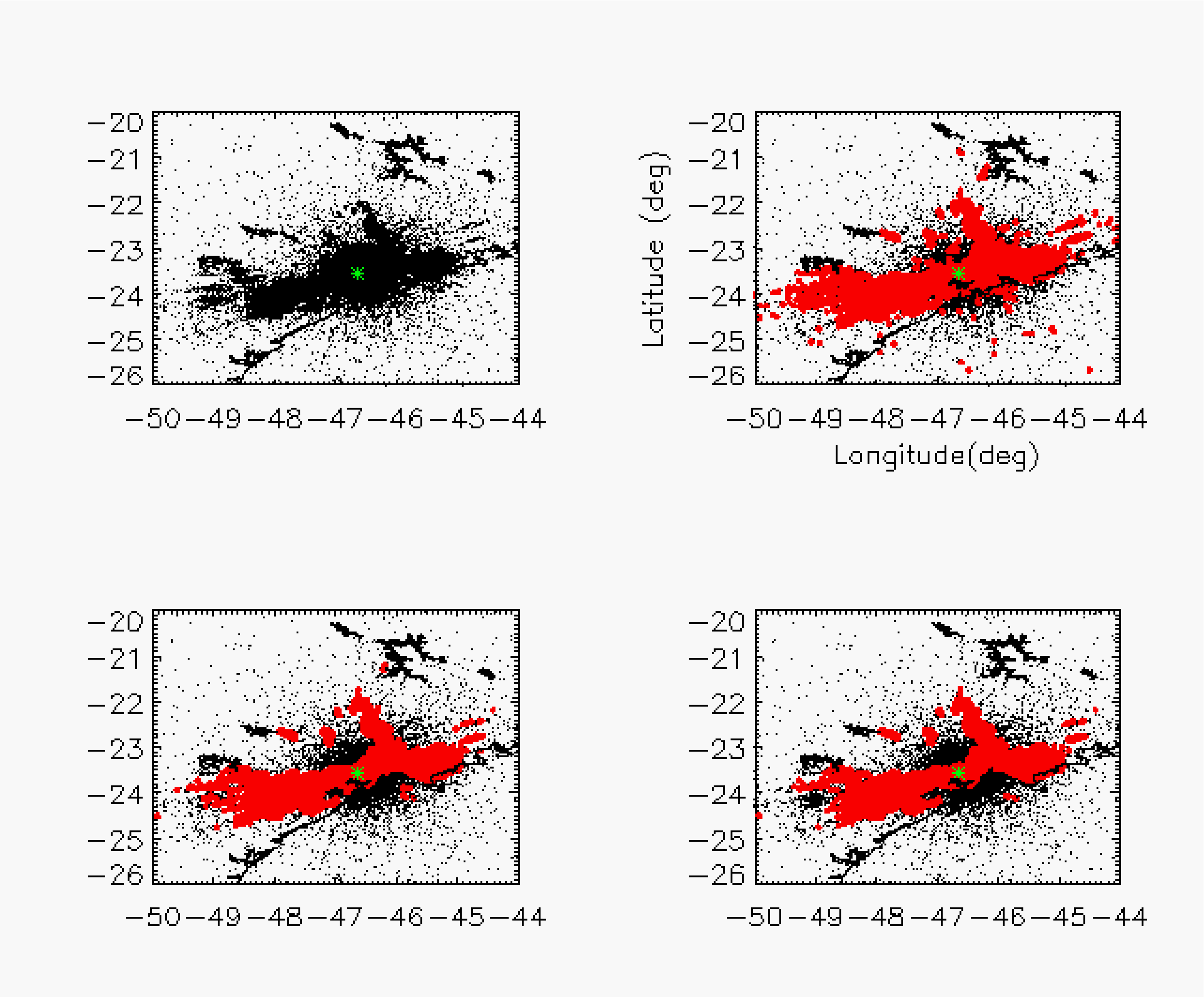


Flash with long noise tail



Singleton (quadrupleton) removal

- Left top: none
- Left right: 3 or more
- Left right: 4 or more
- Left right: 5 or more



McCaul Flash Grouping Algorithm

- Top: Full Range (r^2 dependence)
- Bottom: 0 to 50 km range