The RELAMPAGO Lightning Mapping Array: Deployment, quality control, and data products

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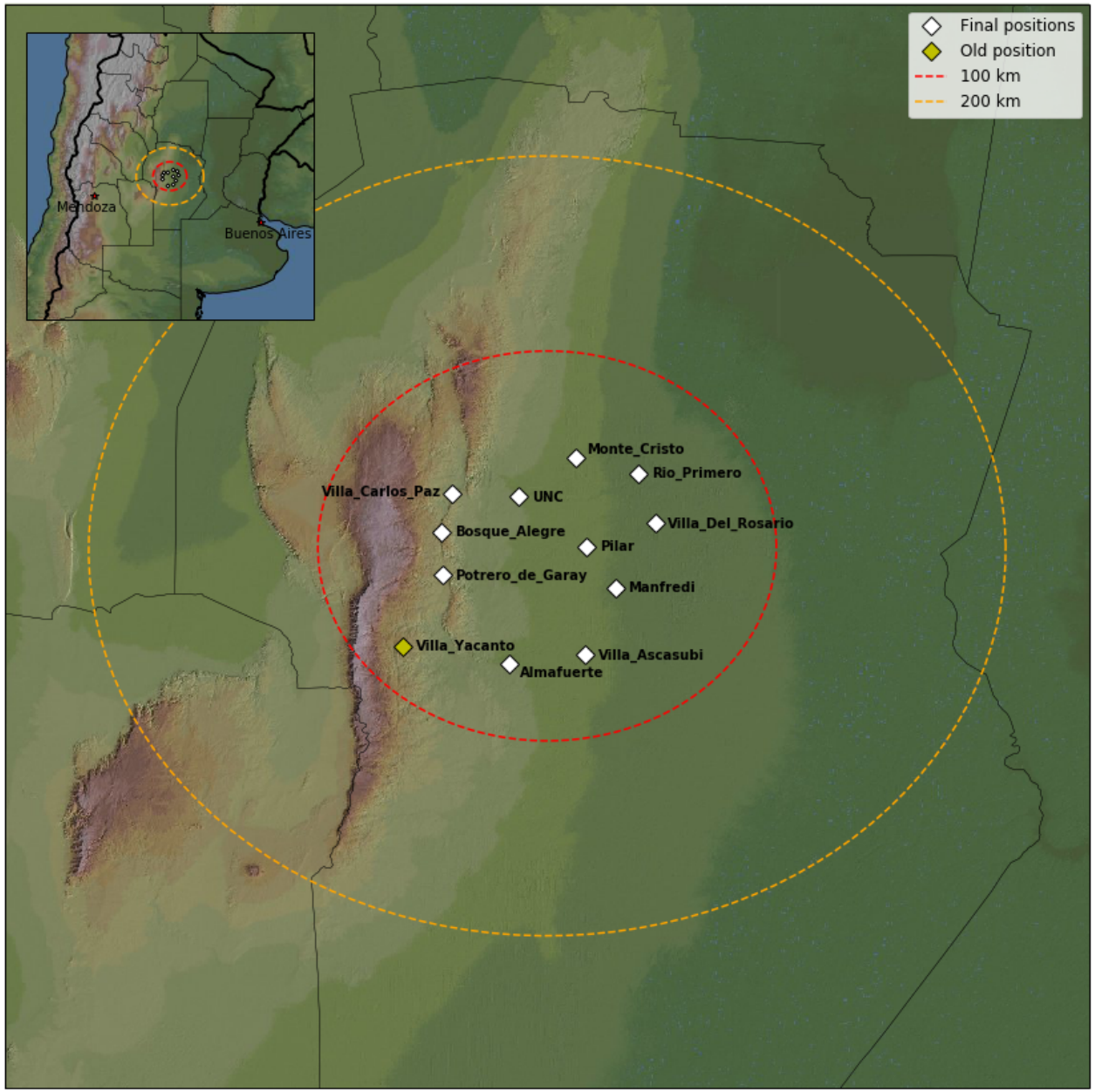
Science Background and Motivation

- RELAMPAGO (*Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations*) was a National Science Foundation (NSF) field campaign to understand intense and severe convection in central Argentina, near the Sierras de Cordoba mountain range.

- In order to address RELAMPAGO science goals, as well as to assist with ground validation of the Geostationary Lightning Mapper (GLM) instrument on the GOES-16/17 satellites, NASA Marshall Space Flight Center (MSFC) installed an 11-station Lightning Mapping Array (LMA) in this region.

Network Map

- 11 stations in center of Cordoba province, Argentina
- Installation began 10/24/18
- Valid ops 11/8/18 thru 4/19/19 (163 days, including RELAMPAGO IOP/EOP)
- Teardown began 4/30/19



RELAMPAGO LMA Station

- PVC construction, joints and connections supported with duct tape, wire, zip ties, and glue

Tetrahedral VHF antenna

PVC tube containing channel 3 filter

GPS antenna

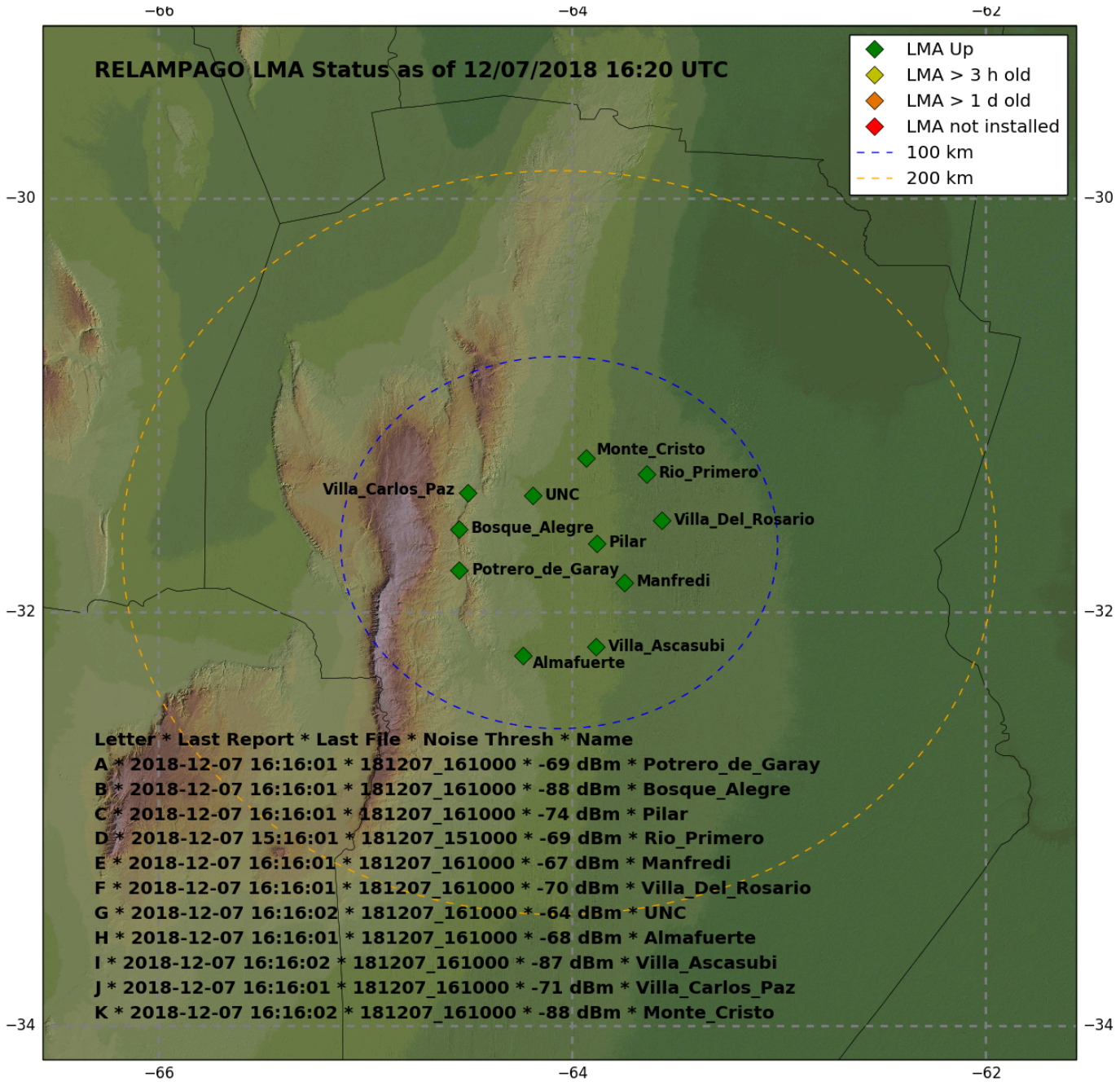
Yagi directional cellular antenna

Rubbermaid container with LMA box (Rev. 3), two marine deep cycle batteries, VHF preamplifier, excess cable length

Solar panel (pointed northward)

Network status map
(updated hourly)

- Networking established via CloudGate modem with 3G speed, 1 GB monthly bandwidth per station
- Reverse SSH tunnel to central NSSTC server enabled remote login and cronjob-driven reporting
- Useful for diagnosing and helping troubleshoot power, connectivity, GPS, and LMA board issues



LMA Time of Arrival Principles

$$t_i = t + \frac{\sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}}{c} \quad (1)$$

Where t is the time the radiation is emitted from source location (x, y, z), (x_i, y_i, z_i) is the location of station i, and c is the speed of light. With the time of arrival of the radiation from a breakdown event measured at six or more stations, the four unknowns x, y, z and t can be found with the least-squares fit to Equation (1).

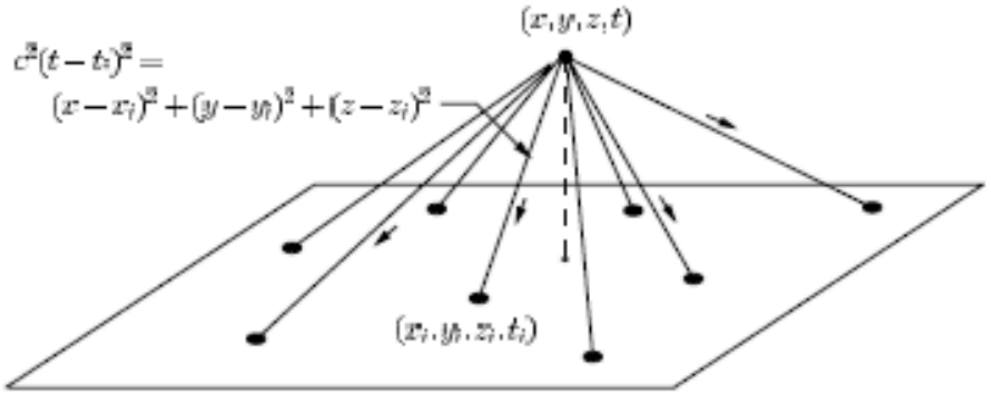
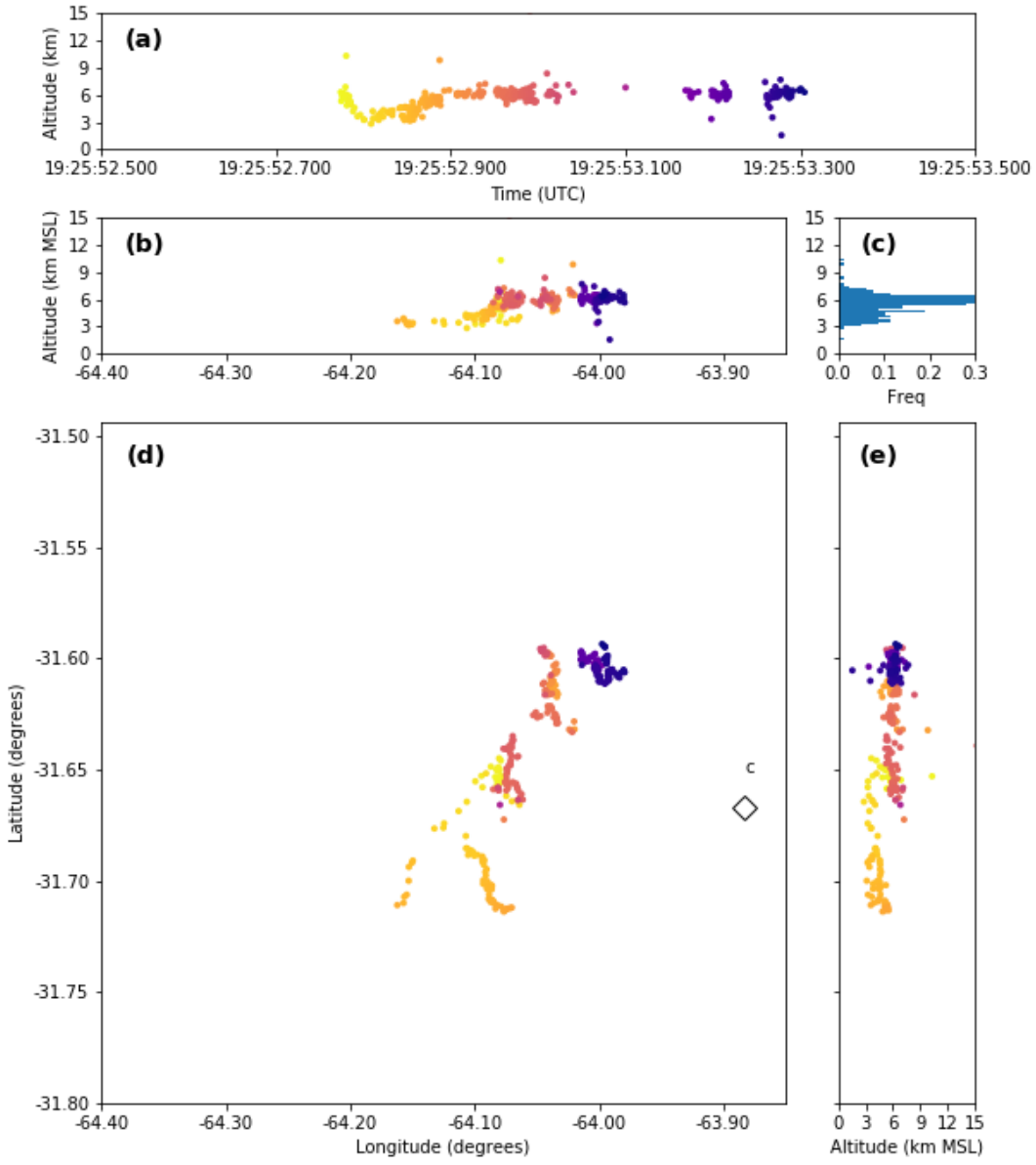


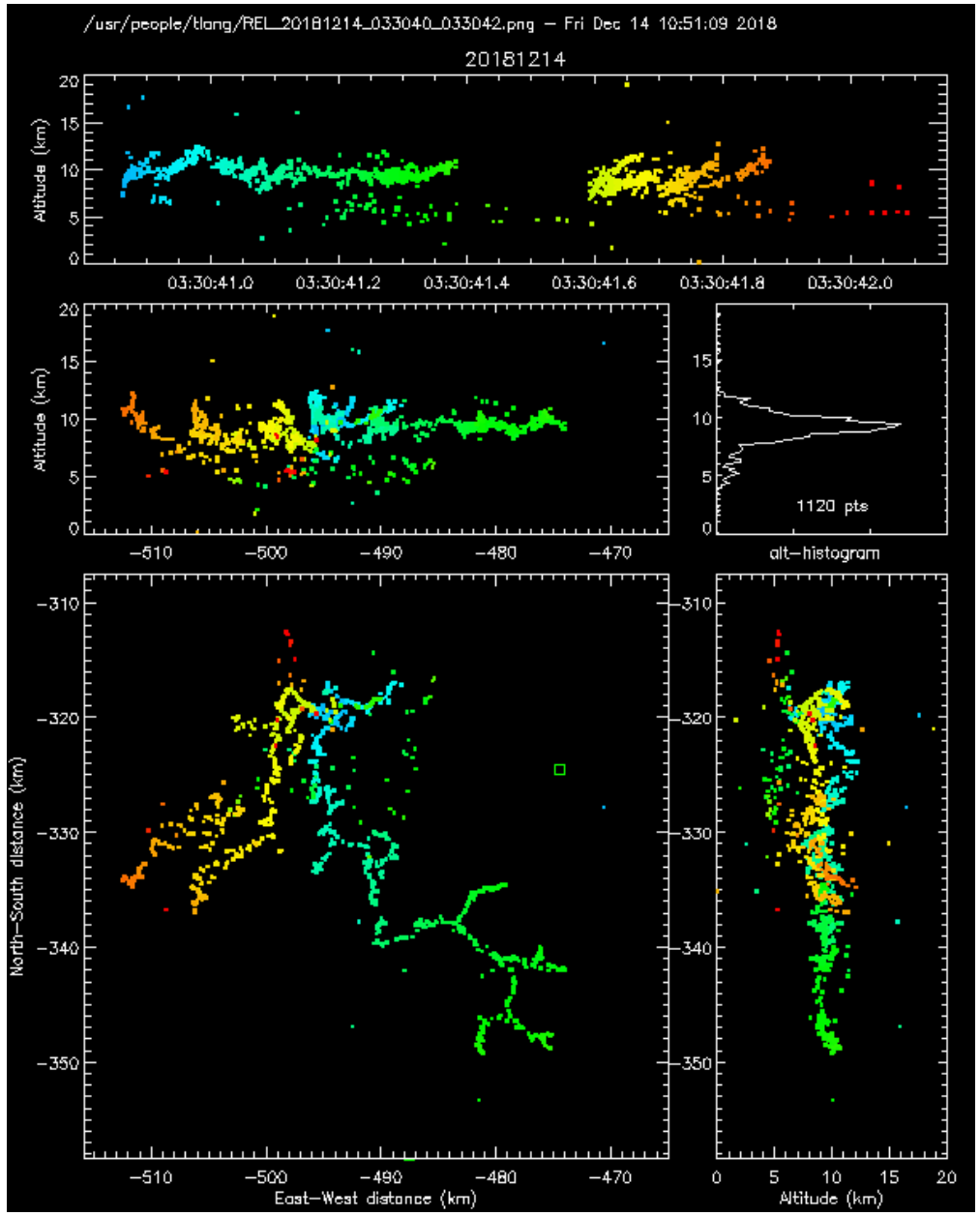
Figure 2: Basic TOA technique. Measurements of the arrival times t_i at N>=4 locations are used to determine the location and time of the source event (x, y, z, t).

NASA GHRC

Inverted Hybrid Flash (12/5/18)

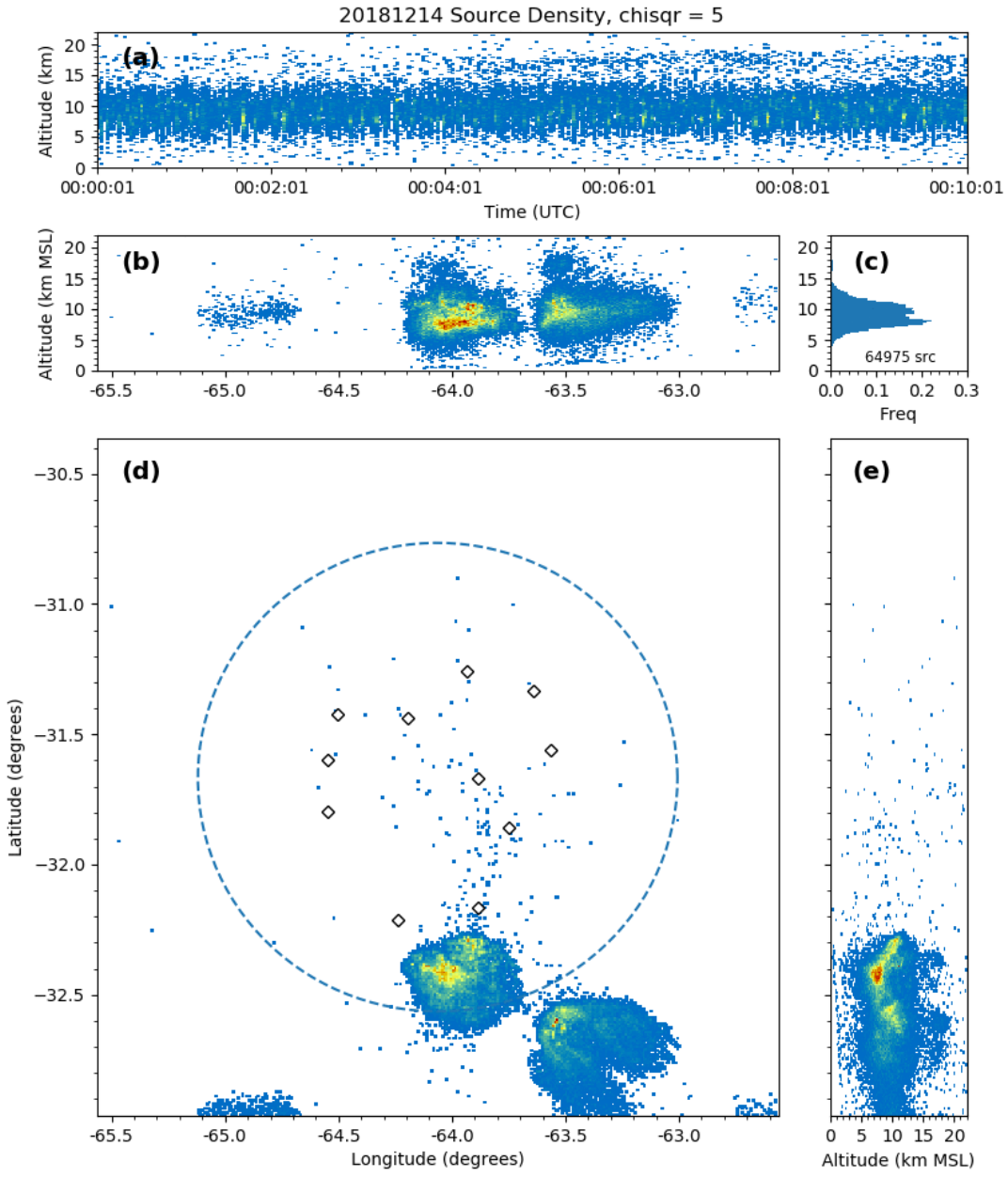


Stratiform Flash (12/14/18)



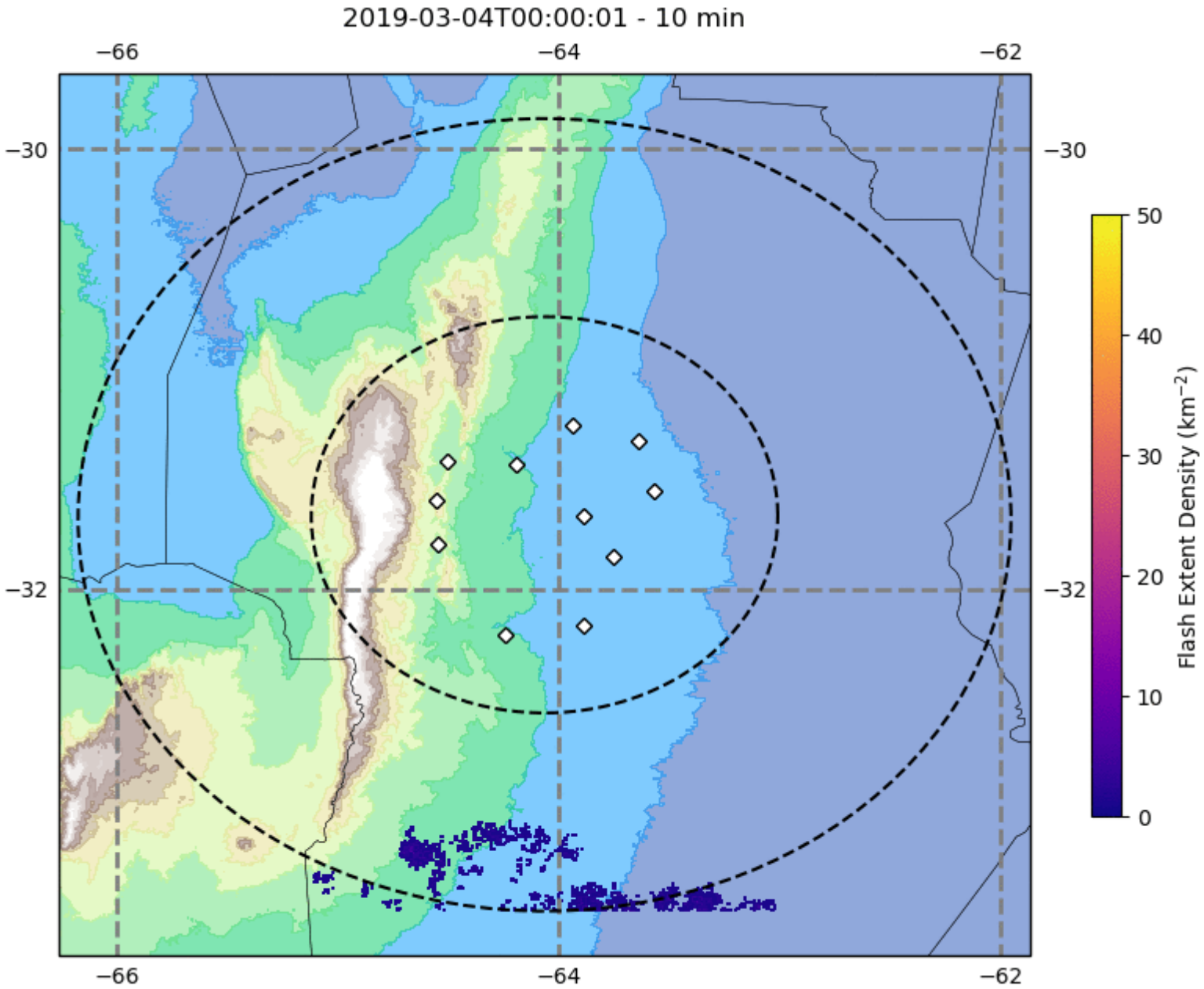
VHF Source Density

12/14/2018 (MCS)



Flash Extent Density (FED)

3/4/2019 (MCS)



Radio frequency interference!

- Hello, Villa Yacanto, we must be going!

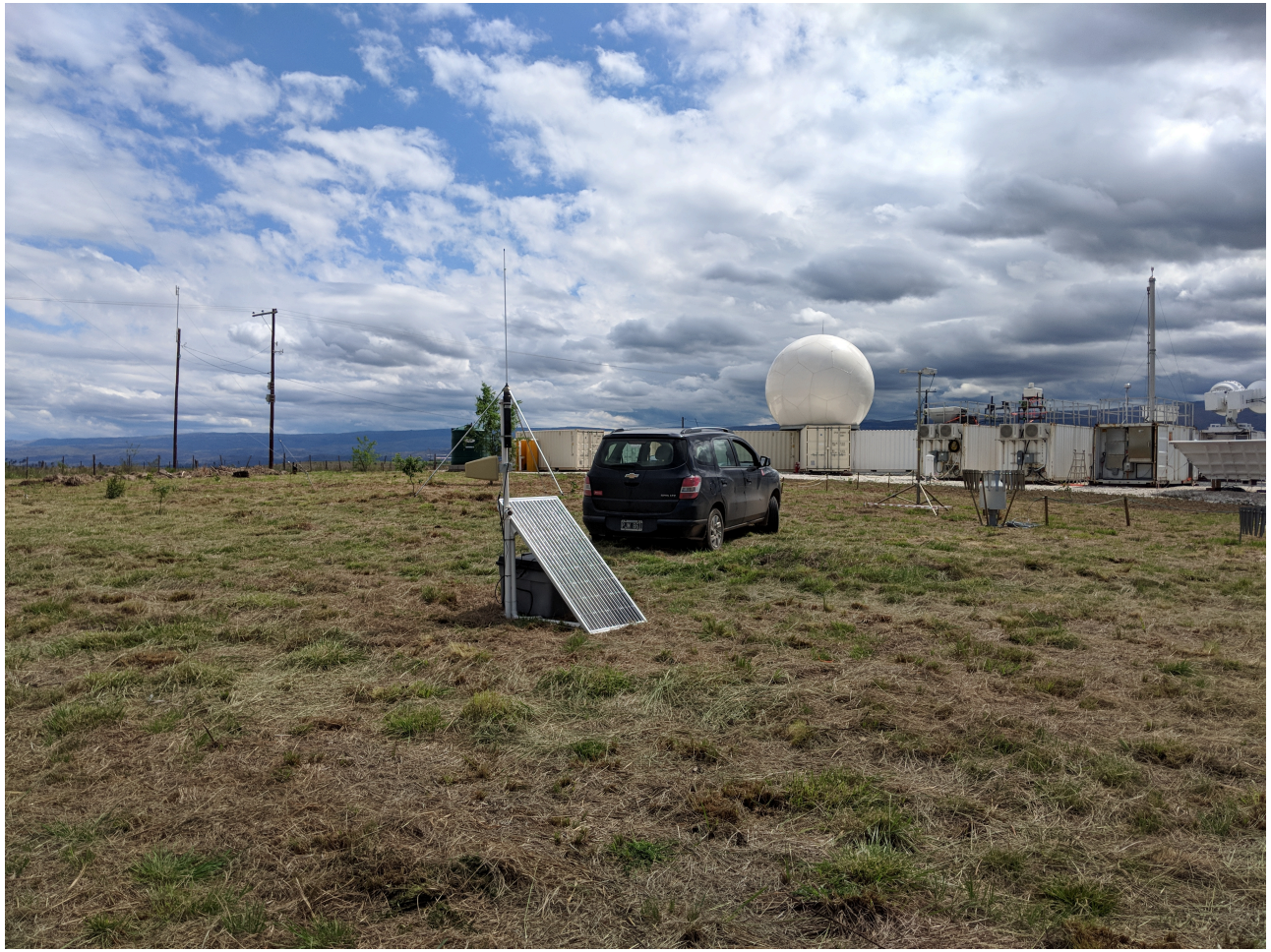


Image from Jeff Burchfield

Temperamental PLCC chips!

- Good GPS data go in, but they don't come out!

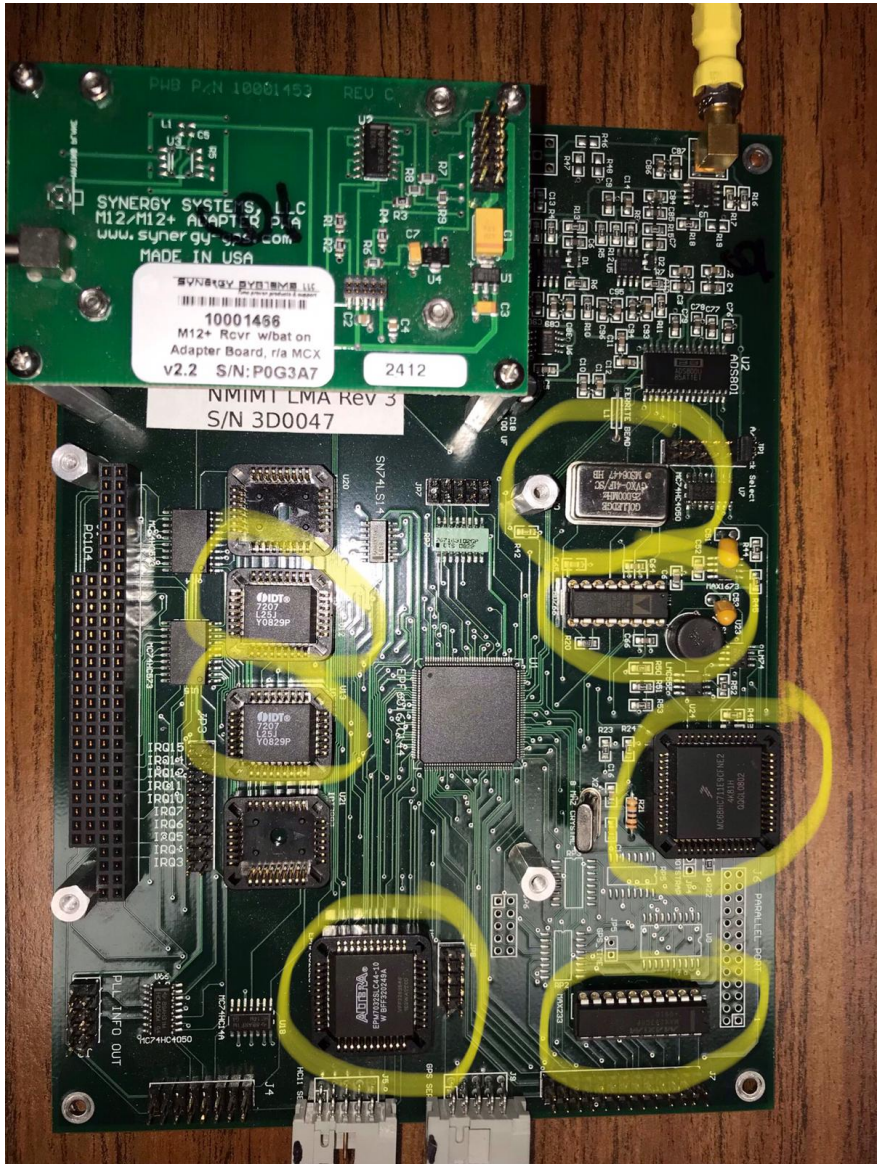


Image from Matt Wingo

Plagues of pests!

- Wasps, ants, and rodents, oh my!

Image from Bruno Lisboa

Tempests!

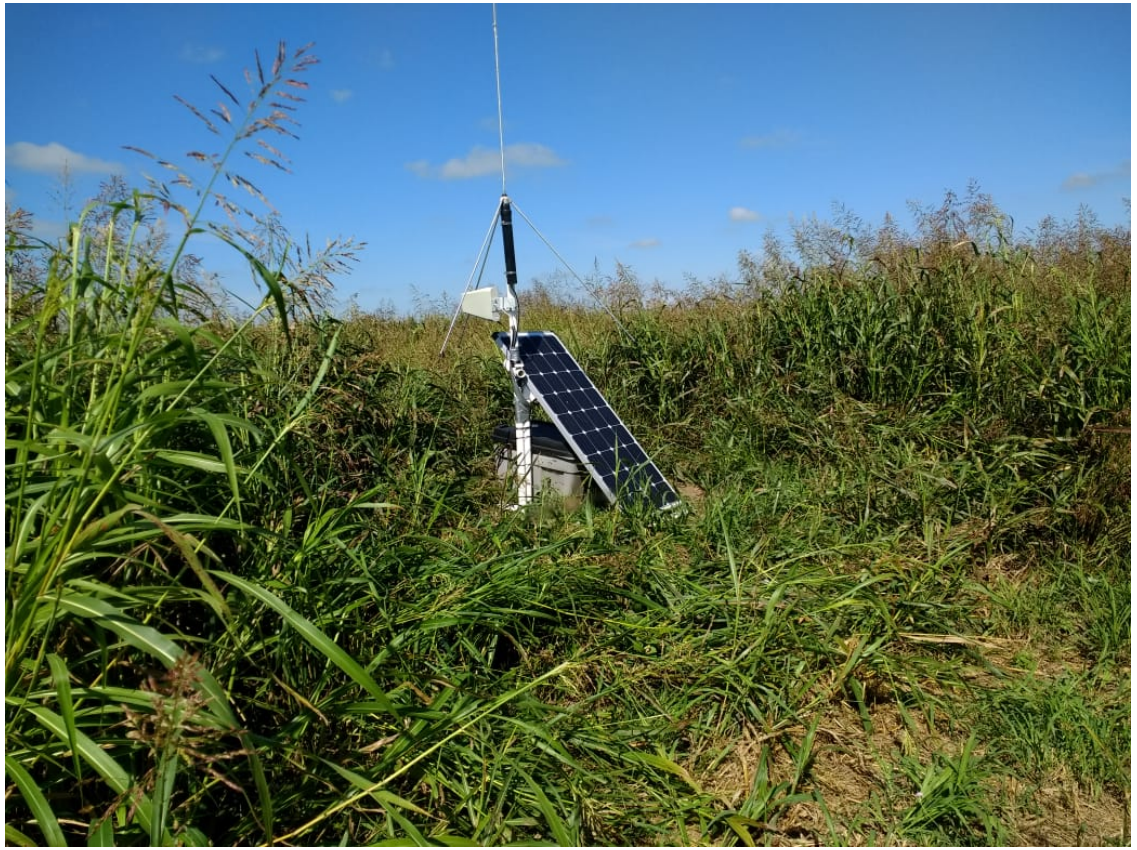
- PVC and duct tape awfully convenient, but storms laugh at them

Image from Eldo Avila

#RELAMPAGO_LMA_Problems

Before

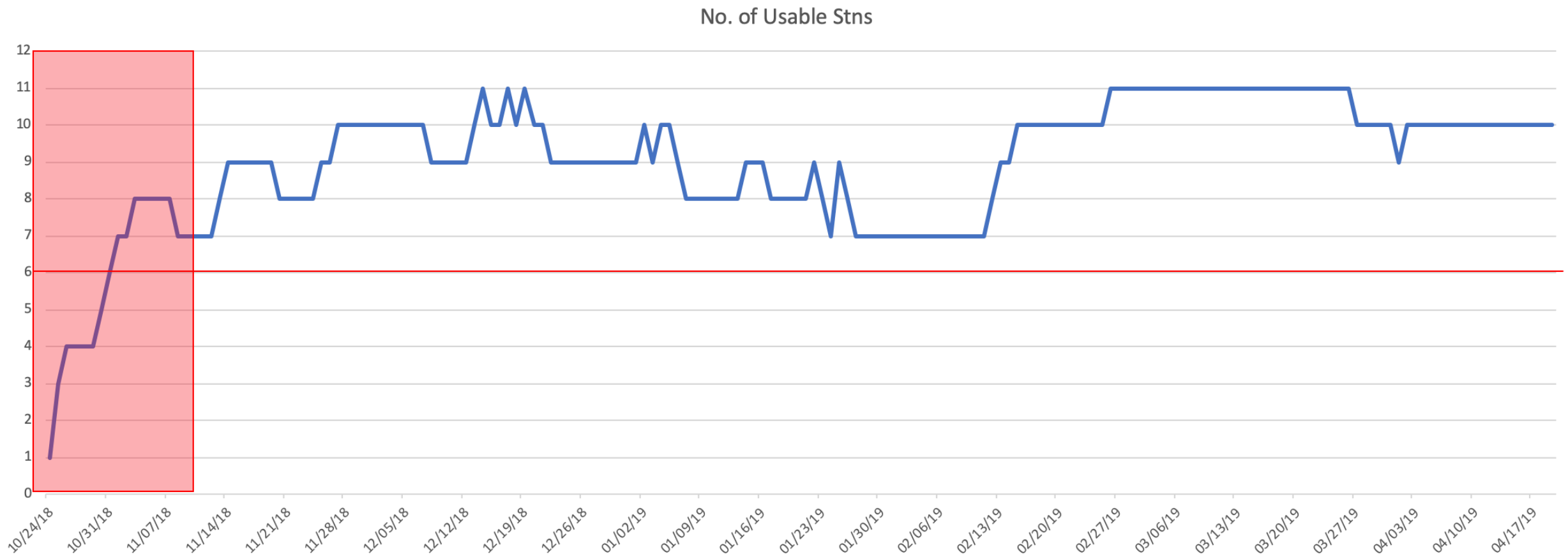
After



Weeds!

- Where’s Monte Cristo?

Images from Eldo Avila

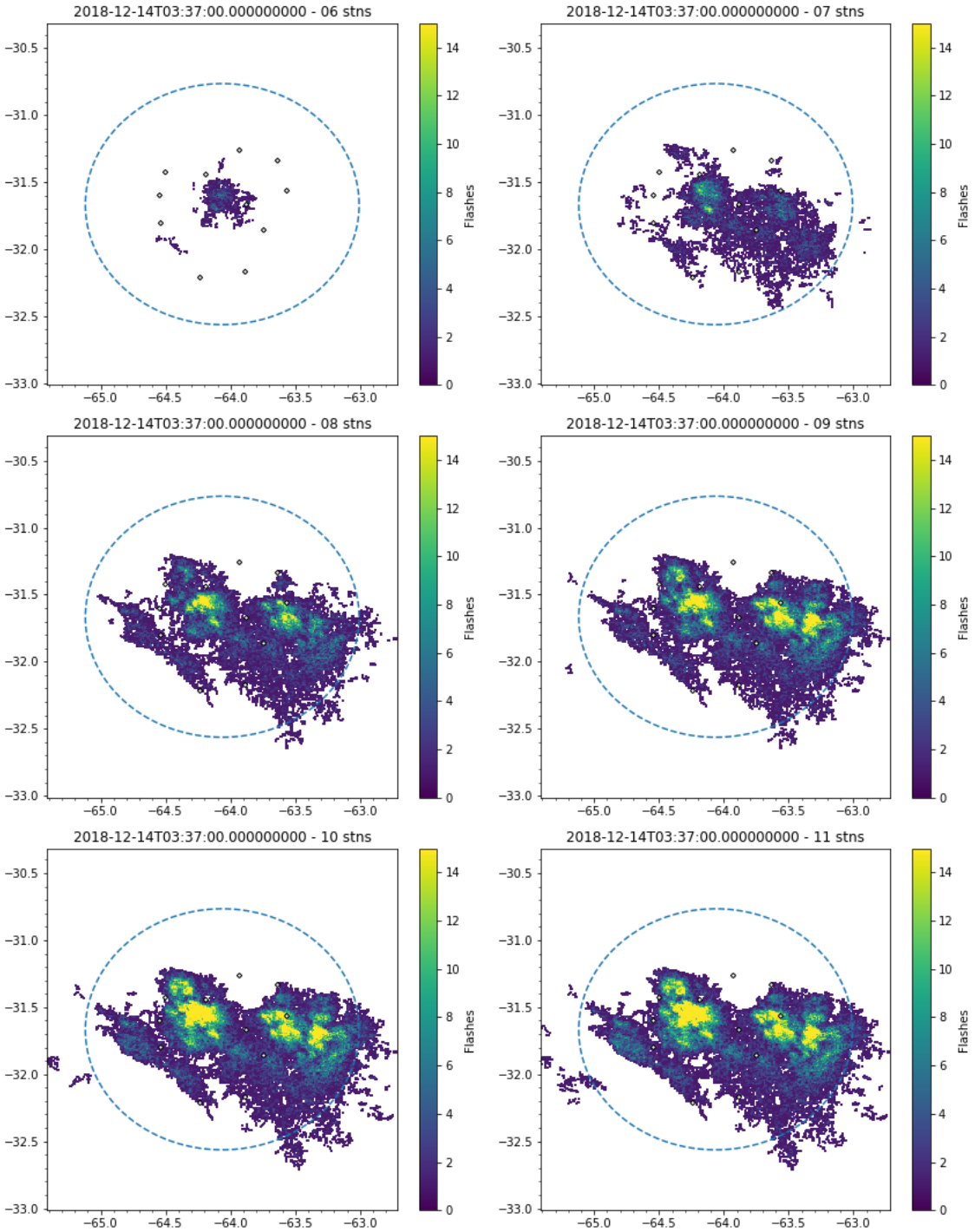


Notable Issues

- LMA board, GPS cable, and hard drive failures
- Maintenance mistakes (e.g., not reconnecting cables)
- Power problems (especially in April)
- Elevated noise (> -70 dBm) at some sites
- Wind damage
- Insect infestations

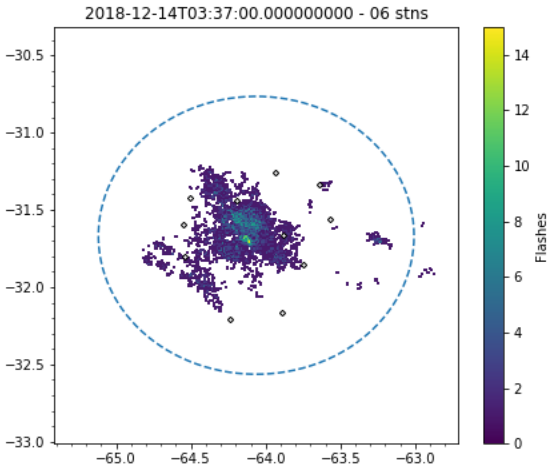
Flash Extent Density

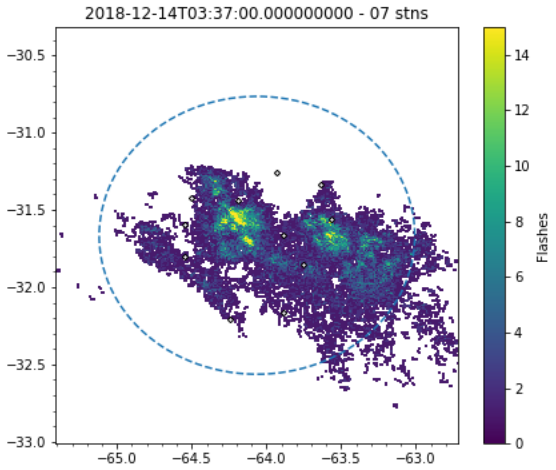
All defaults:
chisqr = 1
npts = 10



Considering the impact of station availability on data

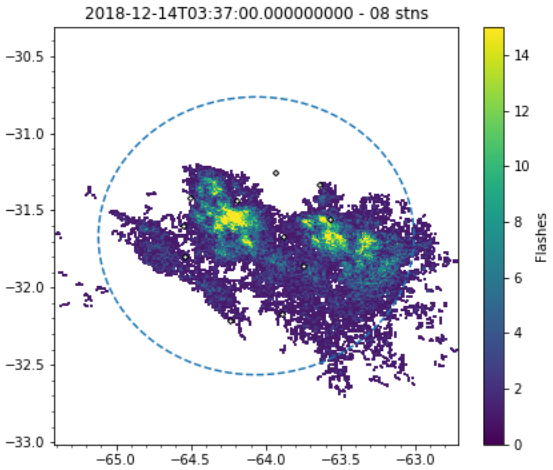
chisqr = 5
npts = 2

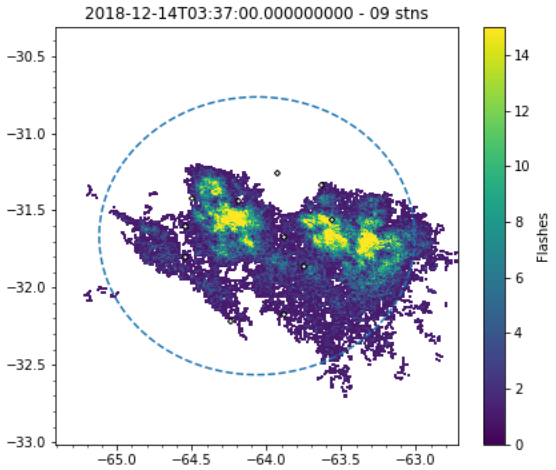




chisqr = 5
npts = 3

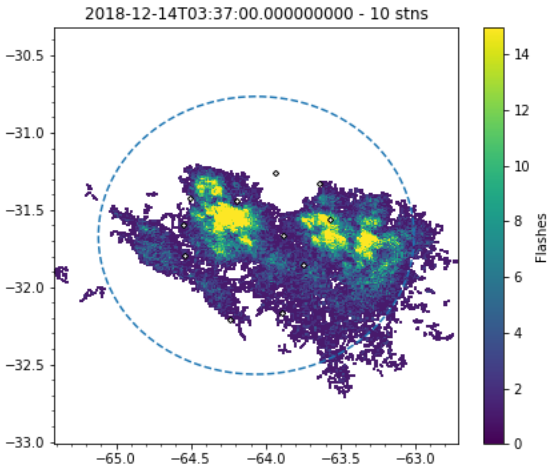
chisqr = 1
npts = 5

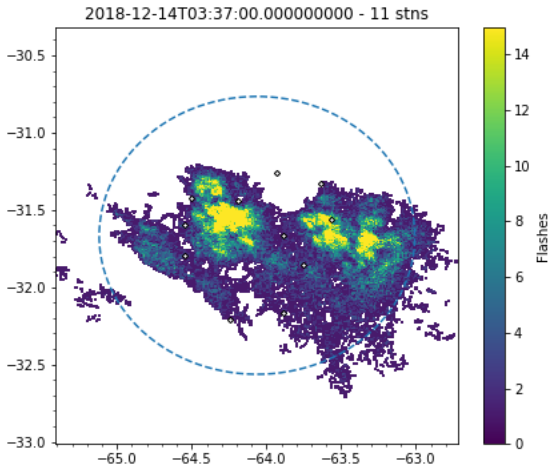




chisqr = 1
npts = 8

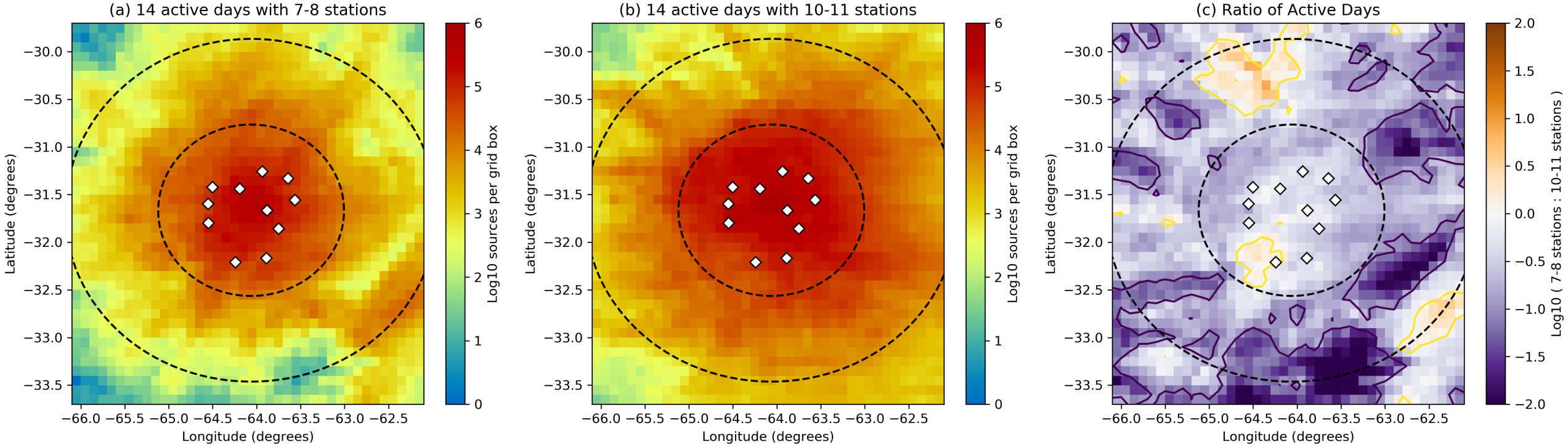
chisqr = 1
npts = 10





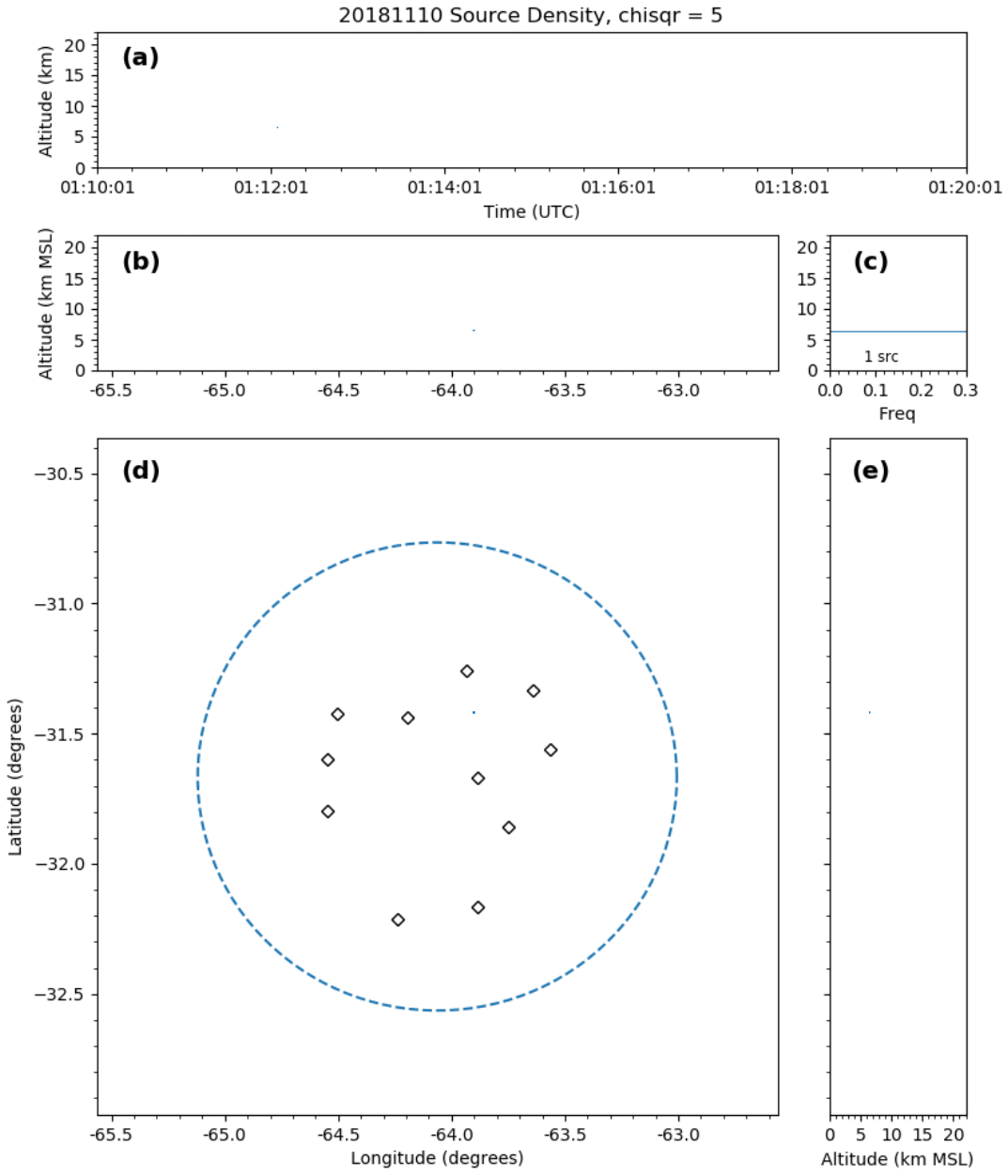
chisqr = 1
npts = 10

VHF Source Density – Comparing active days with 7-8 stations vs. 10-11



VHF Source Density

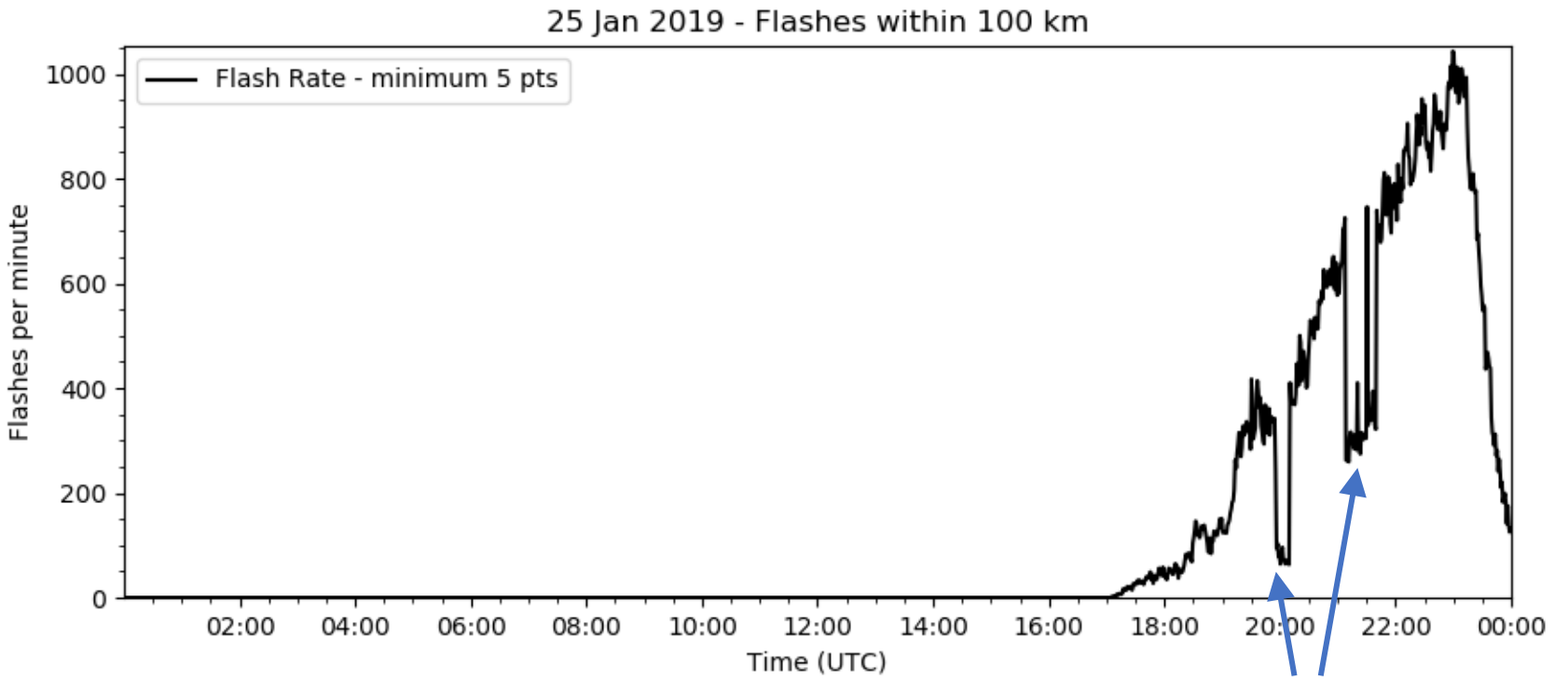
11/10/2018 (Supercell)



(Note fluctuations in density, caused by stations rolling in and out of service)

Total Flash Rate

01/25/2019 (MCS)



Available stations drop to 6

RELAMPAGO LMA Processing and Product Creation

- Individual VHF sources were considered in the analysis if their goodness of fit value $\chi^2 \leq 5$

- Flashes identified following Fuchs et al. (2016) algorithm as implemented in https://github.com/deeplycloudy/lmatools (DBSCAN clustering)

- Flash criteria: No more than 150 ms or 3 km between successive sources, maximum duration 3 seconds, minimum 5 sources in a flash

RELAMPAGO LMA Data Products

- Level 1 – Source locations, standard ASCII LMA format, 10-minute files
- Level 2 – Flashes identified (minimum 5 pts), HDF5, 10 minutes
- Level 3 – Gridded flash products (1 min x 1 x 1 x 1 km^3), netCDF4, one file per variable, 10 minutes

List of Level 3 Products

*_flash_extent.nc & *_flash_extent_3d.nc: Flash extent density (km^{-2} or km^{-3}; i.e., number of flashes that pass through a given pixel/cube in the given time bin)

*_flash_init.nc & *_flash_init_3d.nc: Number of flashes that initiated within the given pixel/cube and time bin

*_footprint.nc & *_footprint_3d.nc: Footprints (mean area/volume in km^2/km^3) of flashes that occurred within pixel/cube and time bin

*_specific_energy.nc & *_specific_energy _3d.nc: Specific energy (mean; J/kg) of flashes that occurred within pixel/cube and time bin

*_total_energy.nc & *_total_energy _3d.nc: Total energy (J) of flashes that occurred within pixel/cube and time bin

*_source.nc & *_source_3d.nc: Number of sources (km^{-2} or km^{-3}) that occurred in grid element

*_flashsize_std.nc & *_flashsize_std_3d.nc: Standard deviation (km^2 or km^3) of flash sizes within grid element

Summary

- RELAMPAGO LMA operations were successful despite many deployment issues – 163 continuous days of ops
- Use caution when comparing days with different station availability, but data within 100 km range are good
- Some days have < 7 stations (e.g., 11/10/18, 01/25/19, 04/01/19) during temporary outages

Data available at:
https://goes-r.nsstc.nasa.gov/home/dataset/relampago-lma

- Password controlled, contact Timothy Lang (timothy.j.lang@nasa.gov) and Geoffrey Stano (gts0007@uah.edu) for access