The RELAMPAGO Lightning Mapping Array:

Preliminary scientific results and application to GLM calibration and validation

Timothy J. Lang, Eldo Avila, Rich Blakeslee, Jeffrey Burchfield, Matthew Wingo, Philip Bitzer, Lawrence D. Carey, Wiebke Deierling, Steve Goodman, Bruno Lisboa Medina, Gregory Melo, and Rodolfo Pereyra

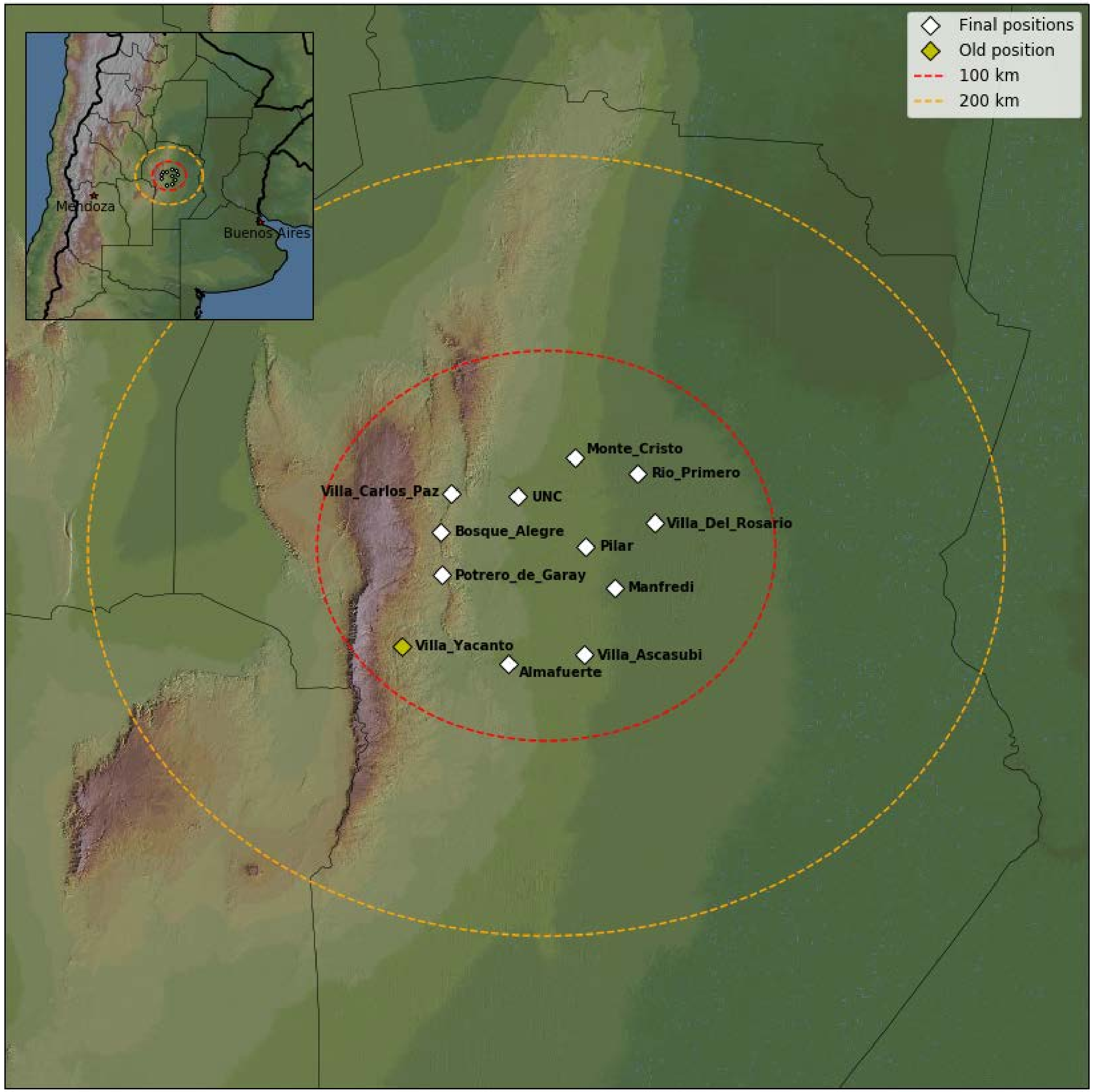
Science Background and Motivation

- 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

GPS antenna

PVC tube containing channel 3 filter

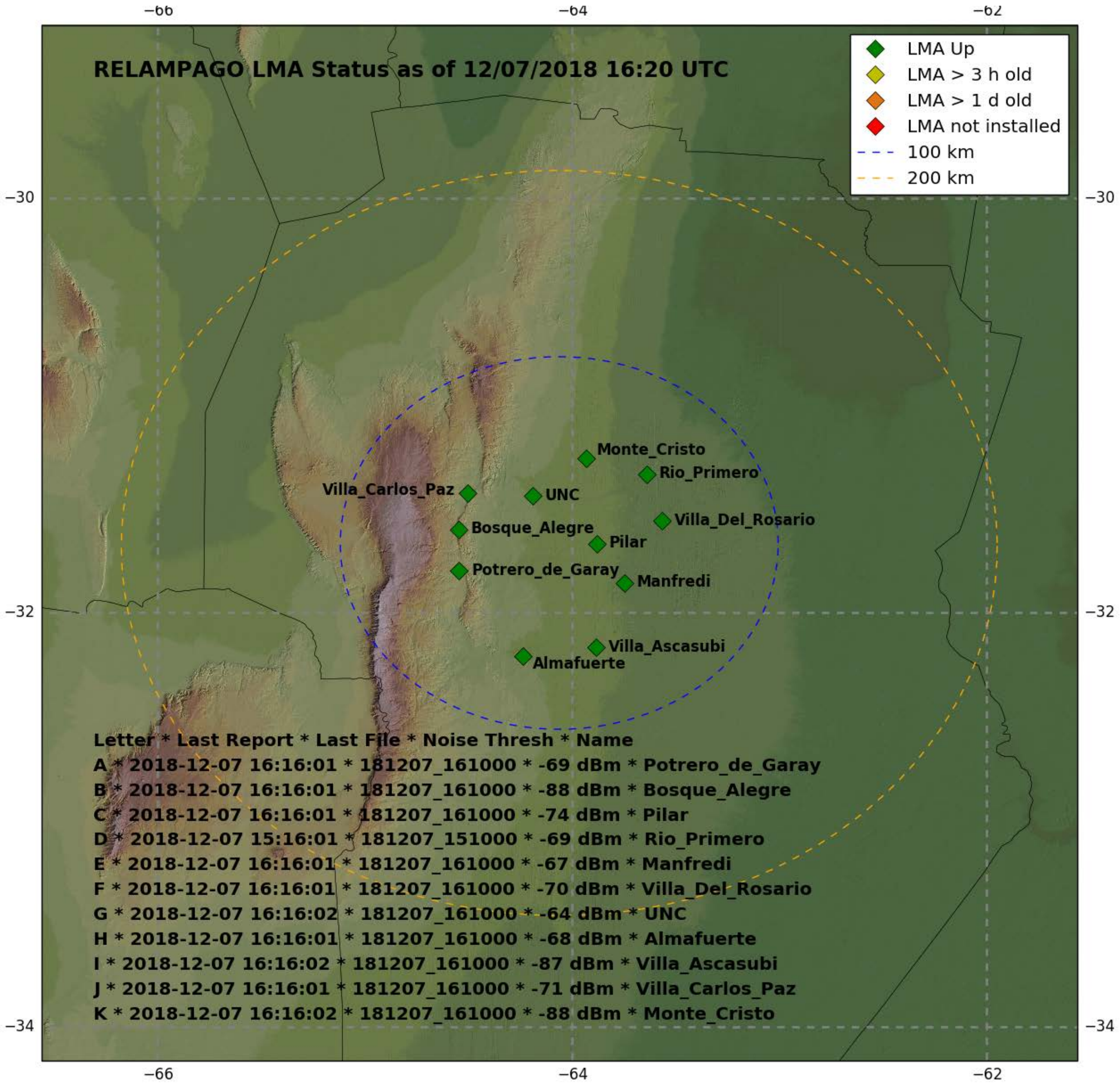
Yagi directional cellular antenna

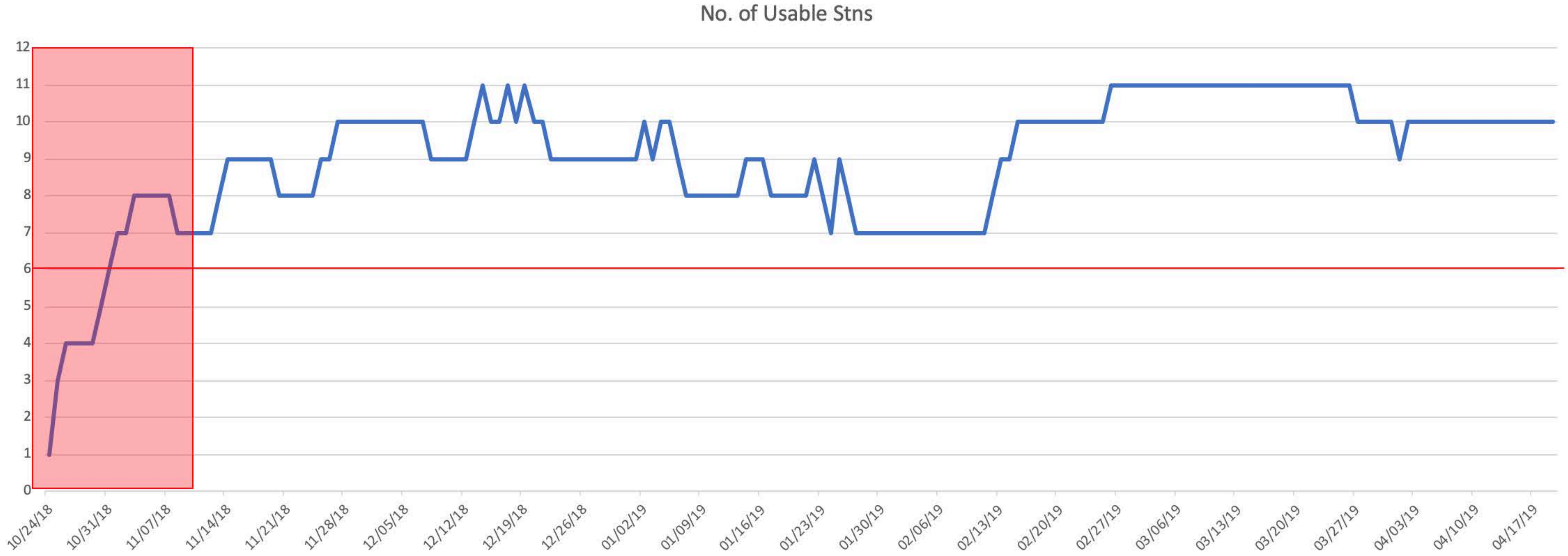
Rubbermaid container with LMA box (Rev. 3), two marine deep cycle batteries, VHF preamplifier, excess cable length

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

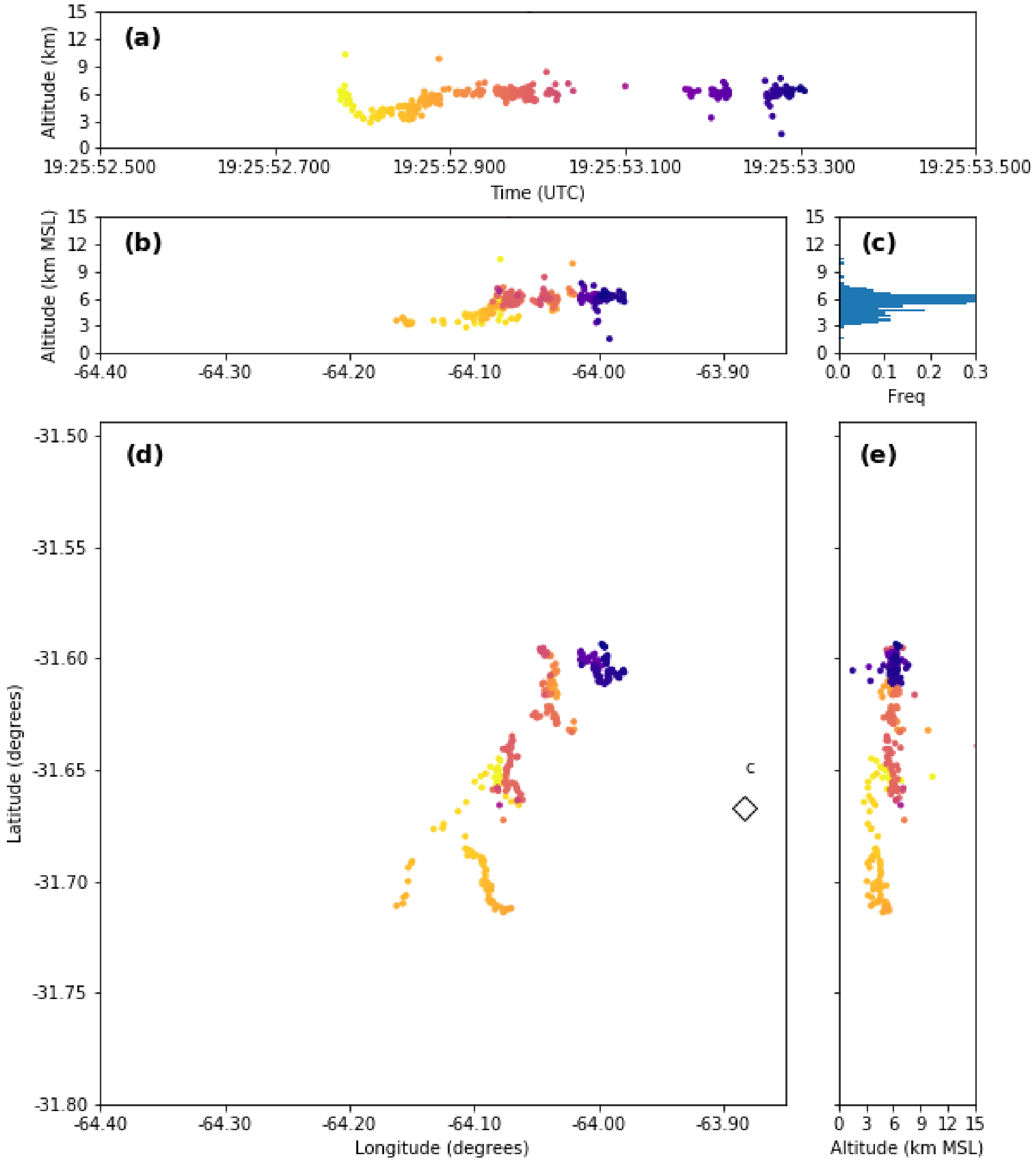




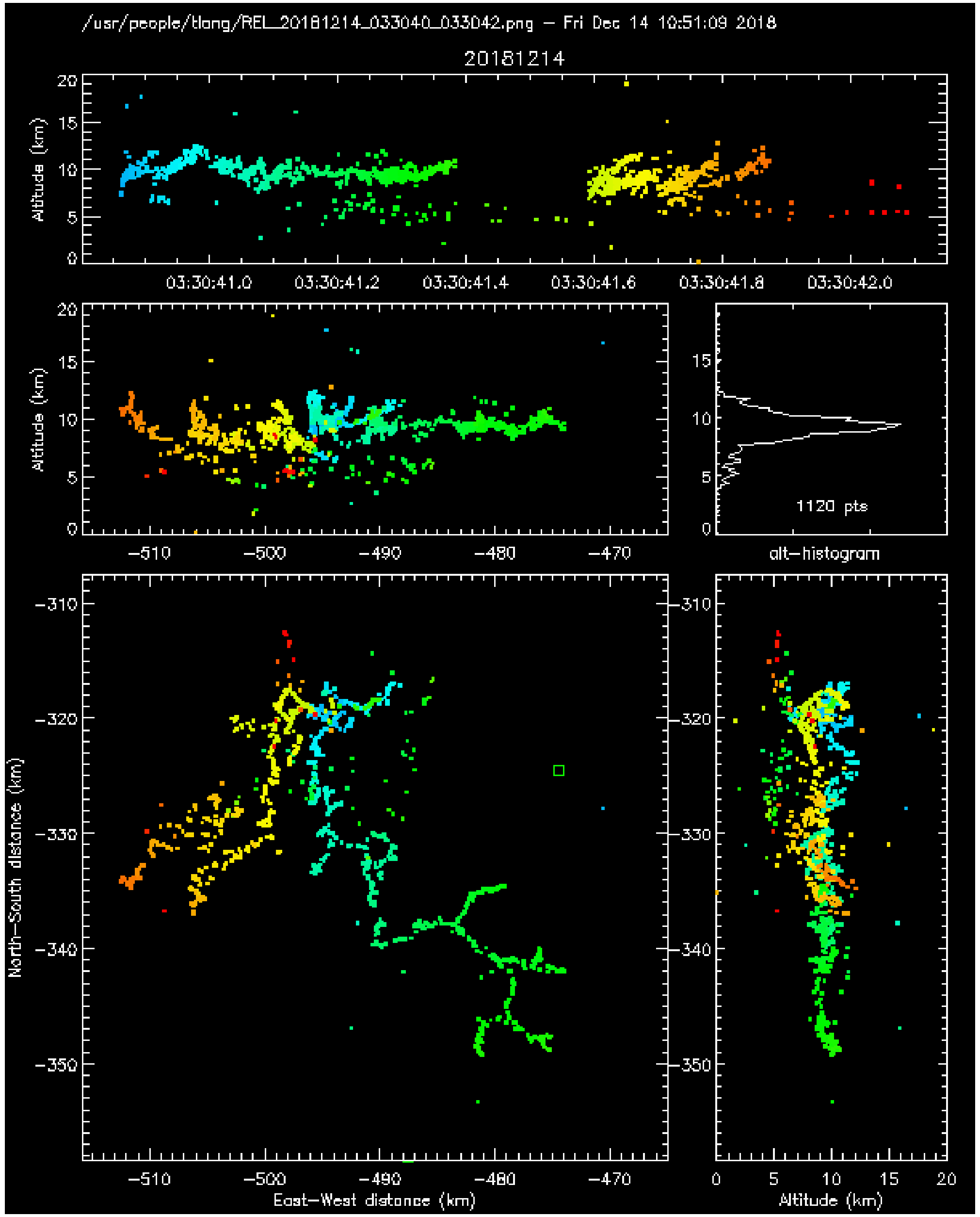
Notable Issues

- 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

Inverted Hybrid Flash (12/5/18)

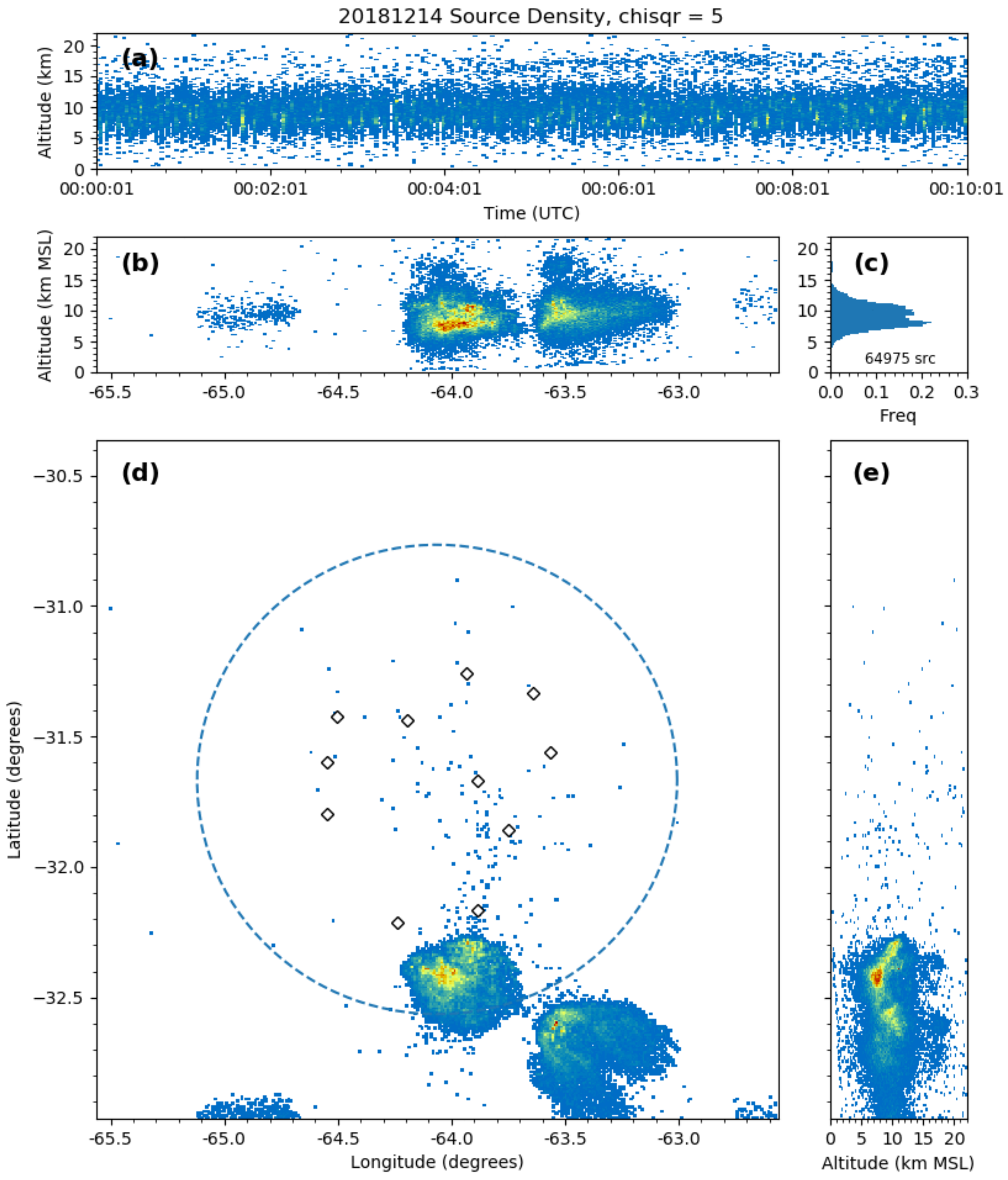


Stratiform Flash (12/14/18)



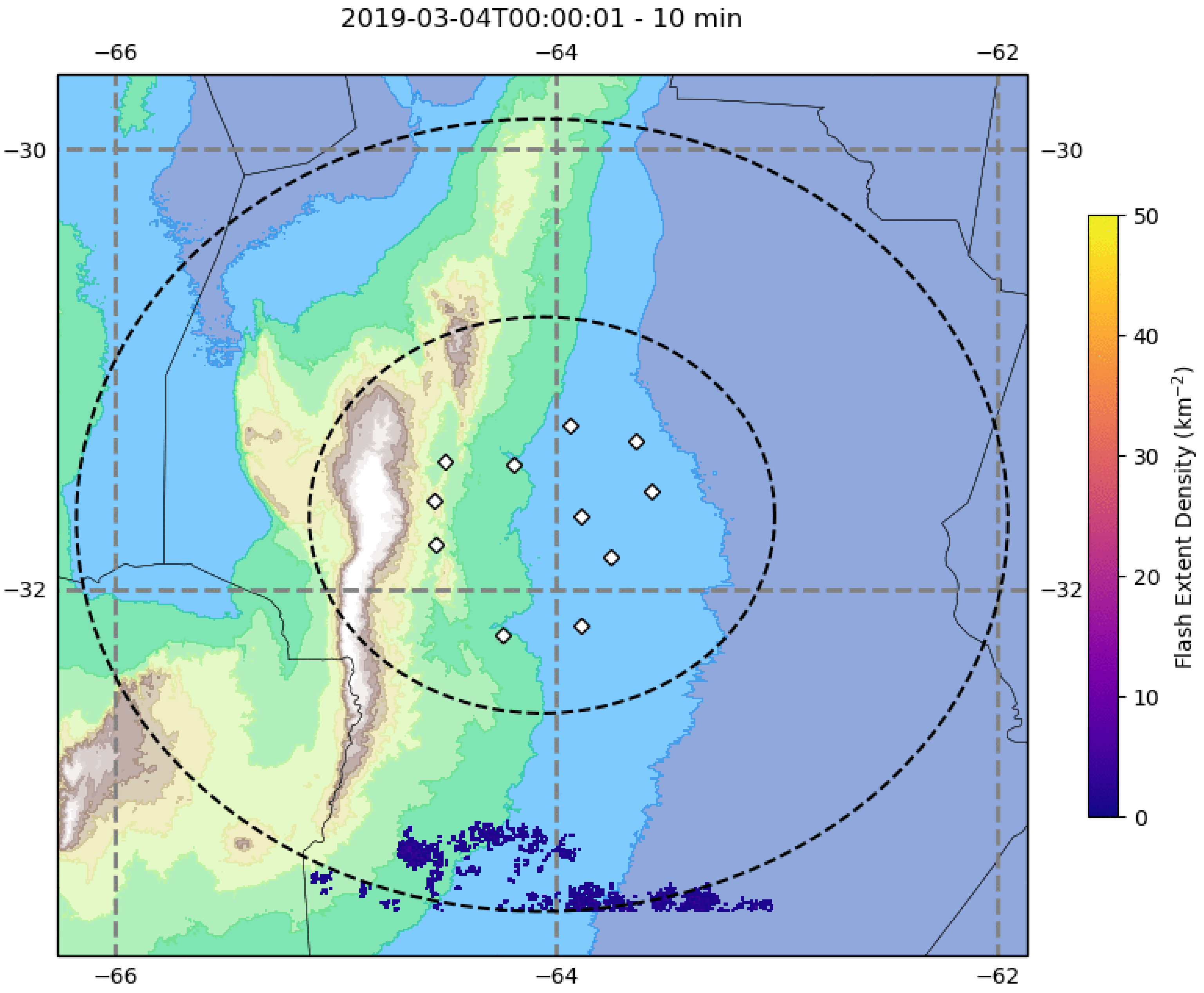
VHF Source Density

12/14/2019 (MCS)

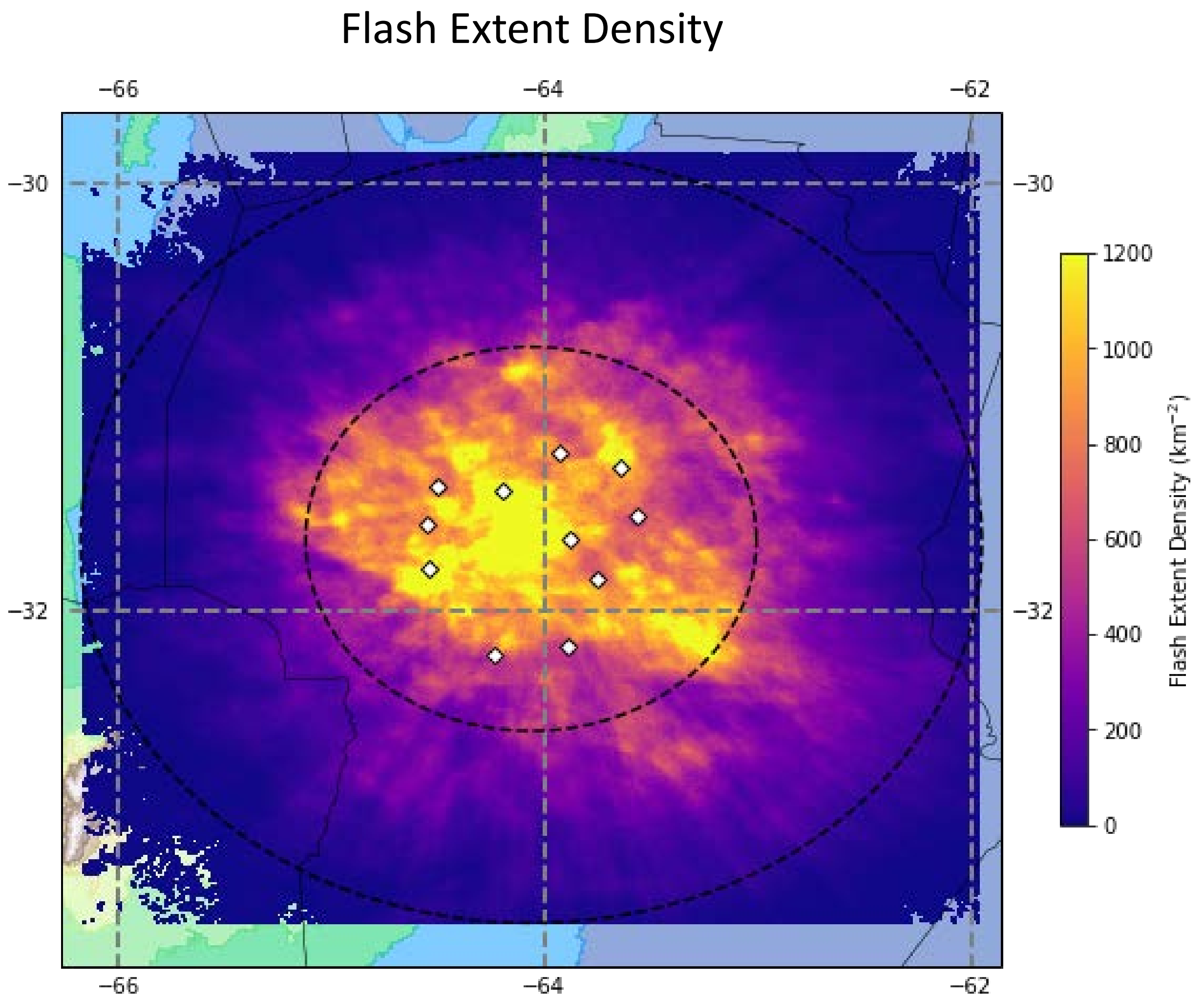


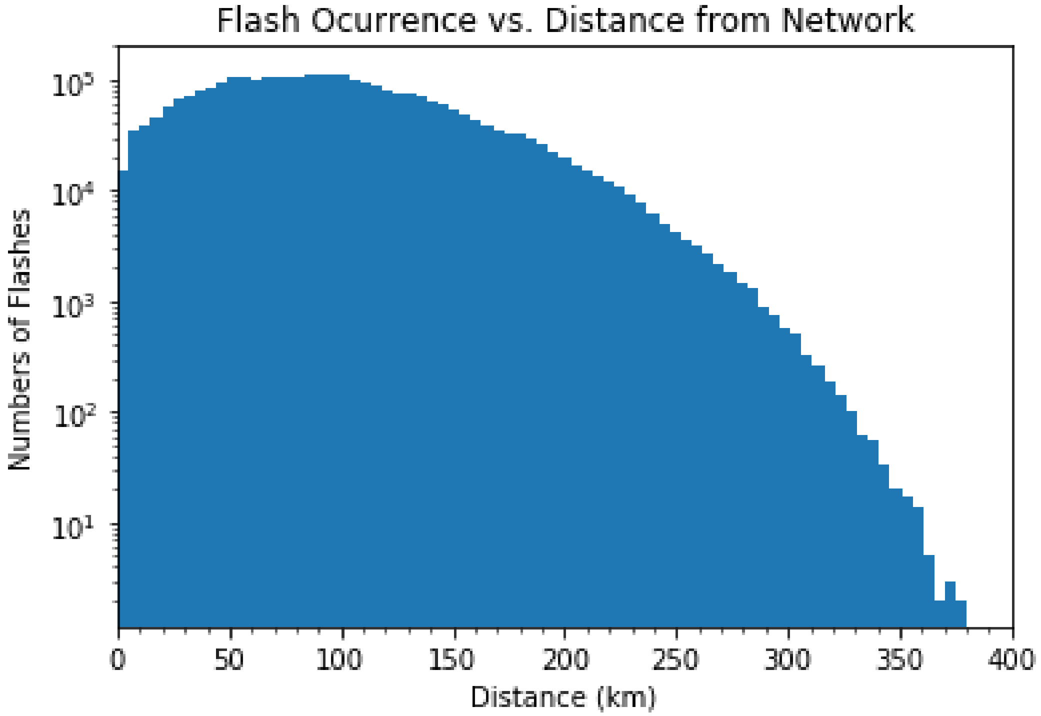
Flash Extent Density (FED)

3/4/2019 (MCS)



Summary Statistics
11/08/2018 – 04/19/2019





1,681,211 flashes within 100 km
Lightning w/in 100 km on 76 of 163 days (46.6%)

1.28M flashes beyond 100 km
Most distant flash = 379 km

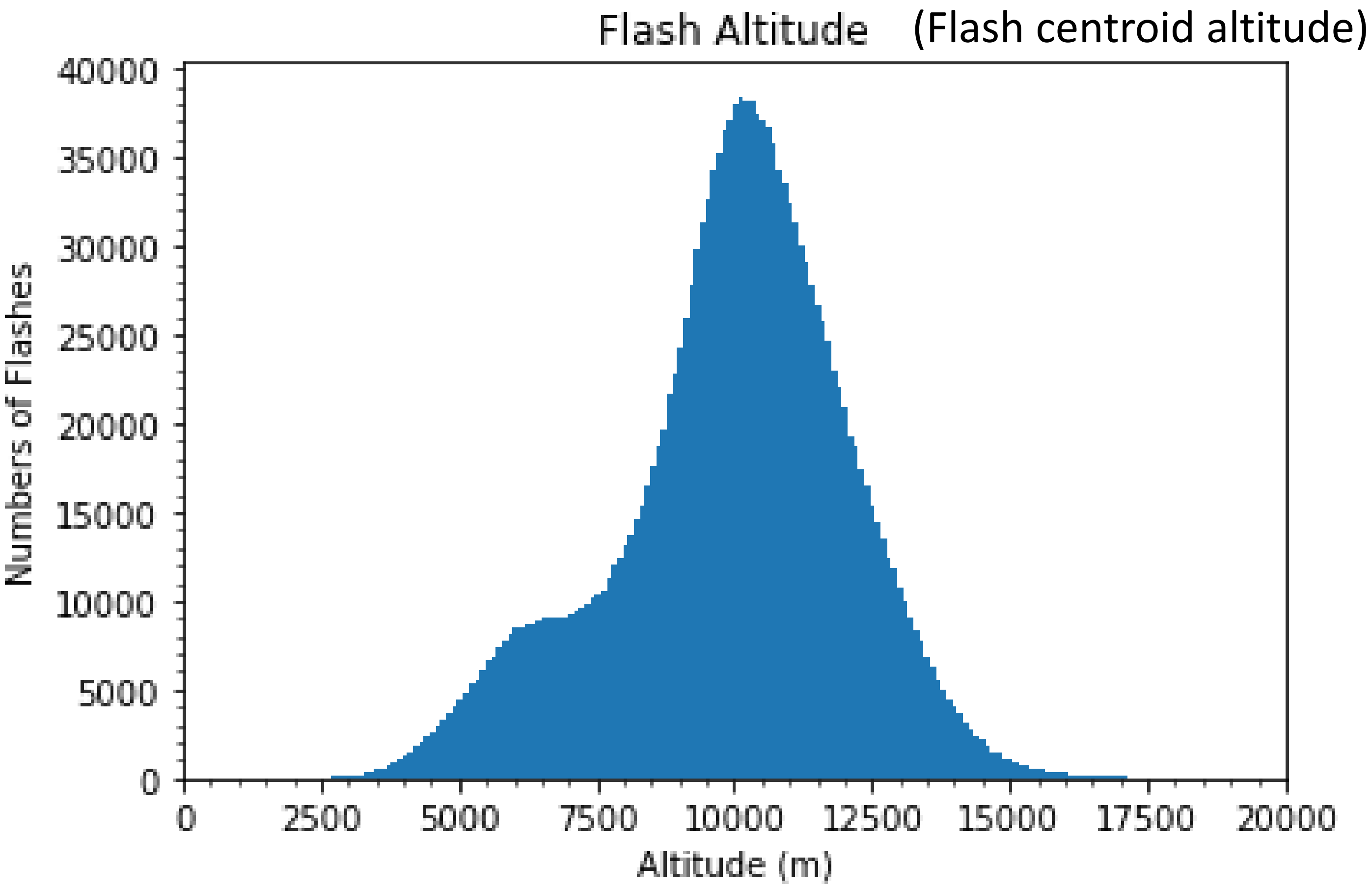
Rank	Date	Total flashes
1	01/25/2019	167174
2	12/14/2018	162276
3	03/04/2019	116888
4	01/02/2019	97863
5	02/24/2019	93115
6	02/22/2019	90617
7	02/10/2019	74360
8	02/11/2019	72495
9	11/11/2018	67177
10	11/12/2018	64517
11	03/08/2019	56528
12	01/09/2019	55938
13	01/23/2019	51256
14	01/26/2019	46306
15	01/29/2019	45207
16	12/27/2018	43310
17	01/06/2019	40193
18	03/31/2019	33707
19	02/08/2019	27157
20	02/09/2019	26478

Top 20 Lightning Days

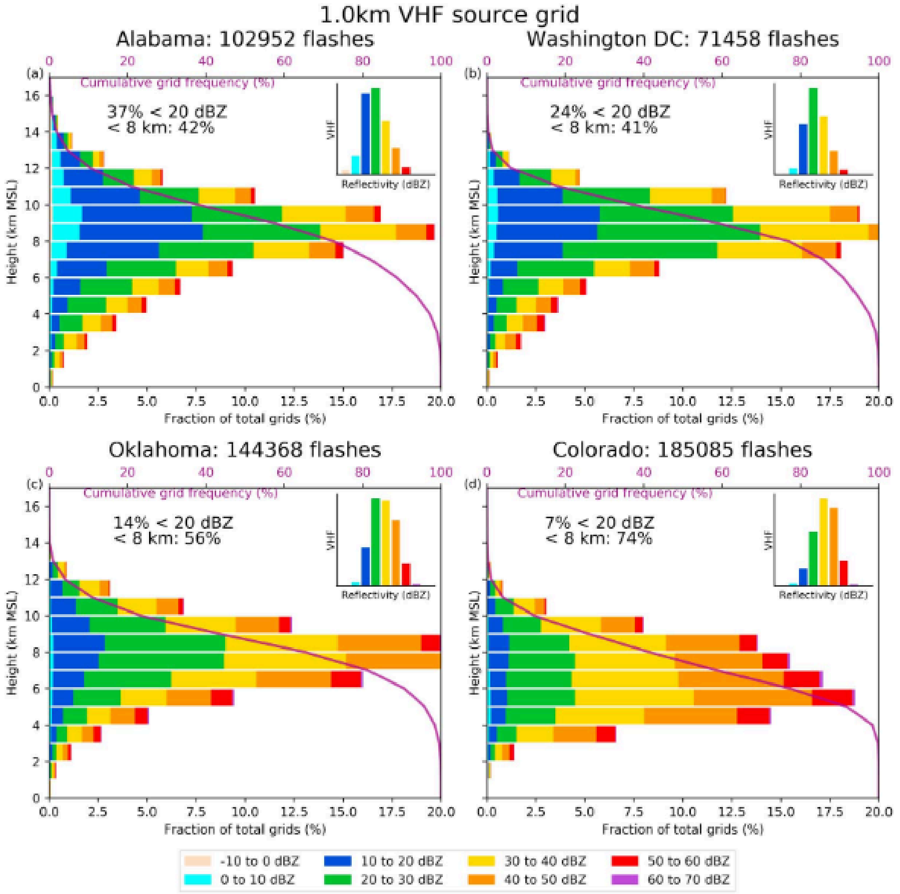
100 km range
Minimum 5 sources

- 3 during main IOP (before Xmas)
- 8 others during CSU radar EOP (before end of Jan)
- 9 during Feb-Mar 2019

Flash Altitudes: Argentina vs. USA



- Argentina altitude ~1 km higher than AL/DC/OK
- High-altitude tail may also be higher (> 15 km)
- Secondary low-altitude peak suggesting anomalous storms & stratiform lightning



Fuchs & Rutledge (2018)

Anomalous days?

1000+ flashes w/in 100 km, > 50% below 7 km altitude

- **11/29-30, 12/1, 12/5** (11/27 – 23%, 12/4 – 24%)
- **12/20-21** (12/19 – 24%)
- **1/10** (1/13 – 23%, 1/15 – 43%)
- **3/15-17** (3/14 – 27%)

Some of these days (e.g., 3/17) appear to include decaying convection/stratiform flashing

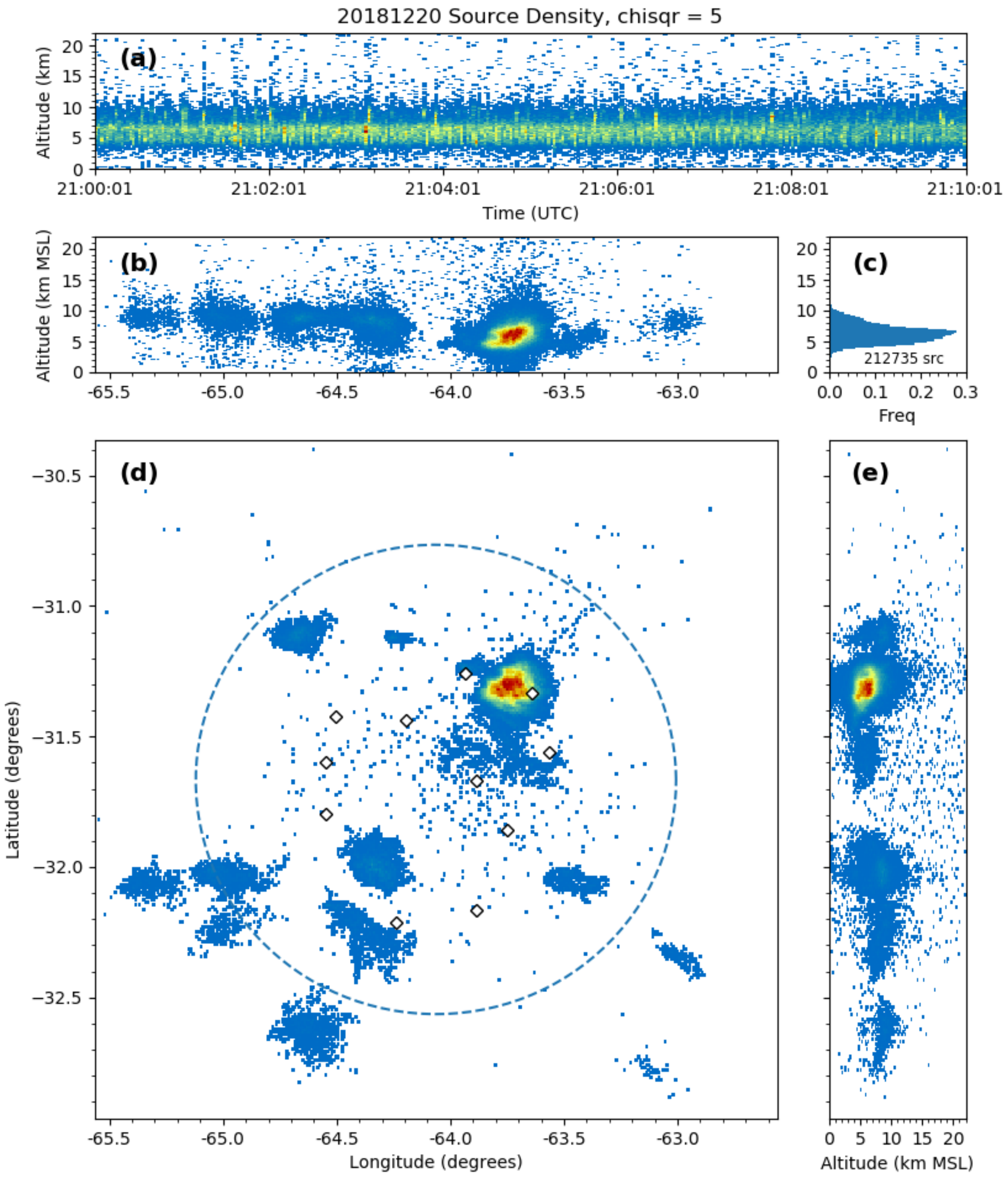
Come in apparent clusters – favorable environments?

Most archetypal high TFR, low-altitude, long-lived case is 12/20

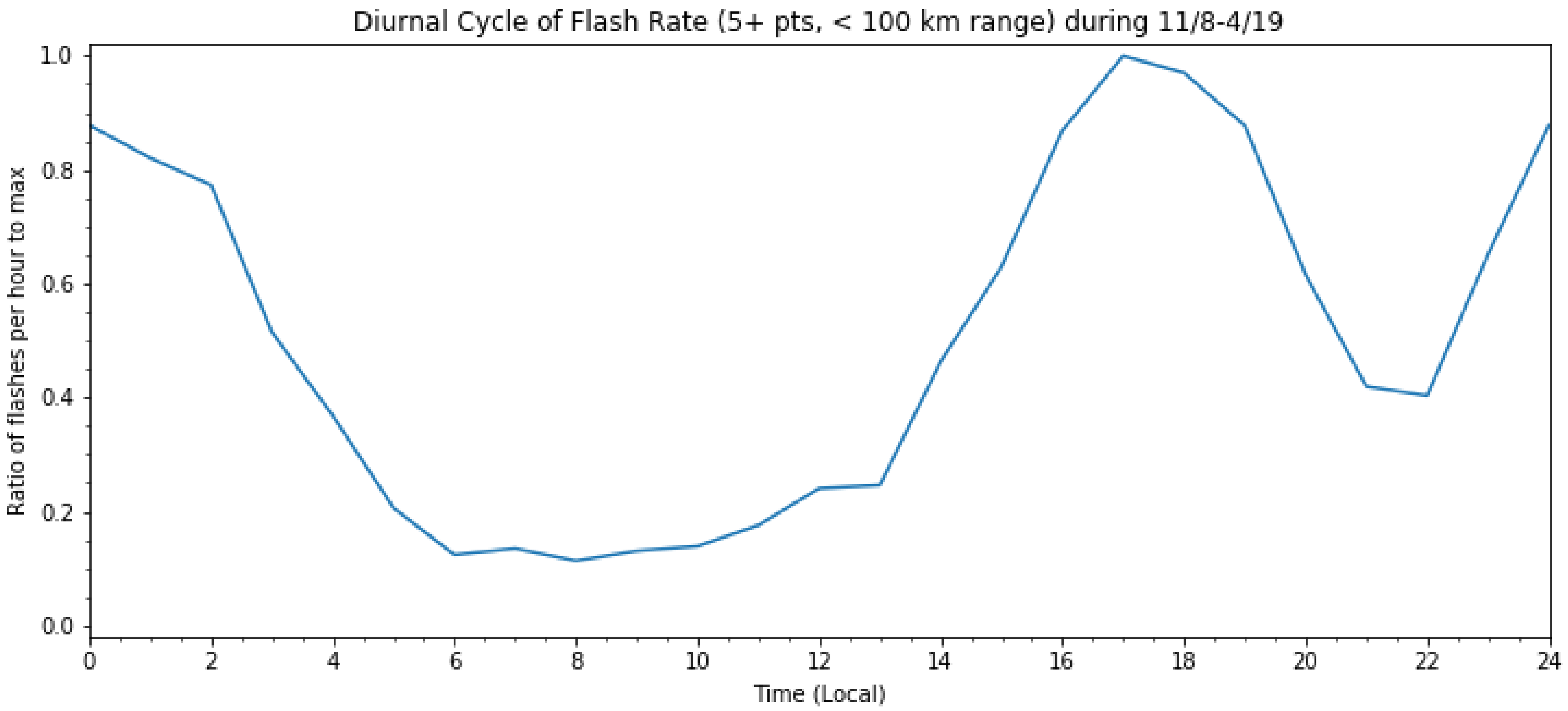
(Of all flashes, 11% have centroids below 7 km)

VHF Source Density

12/20/2019
(Anomalous Storm)



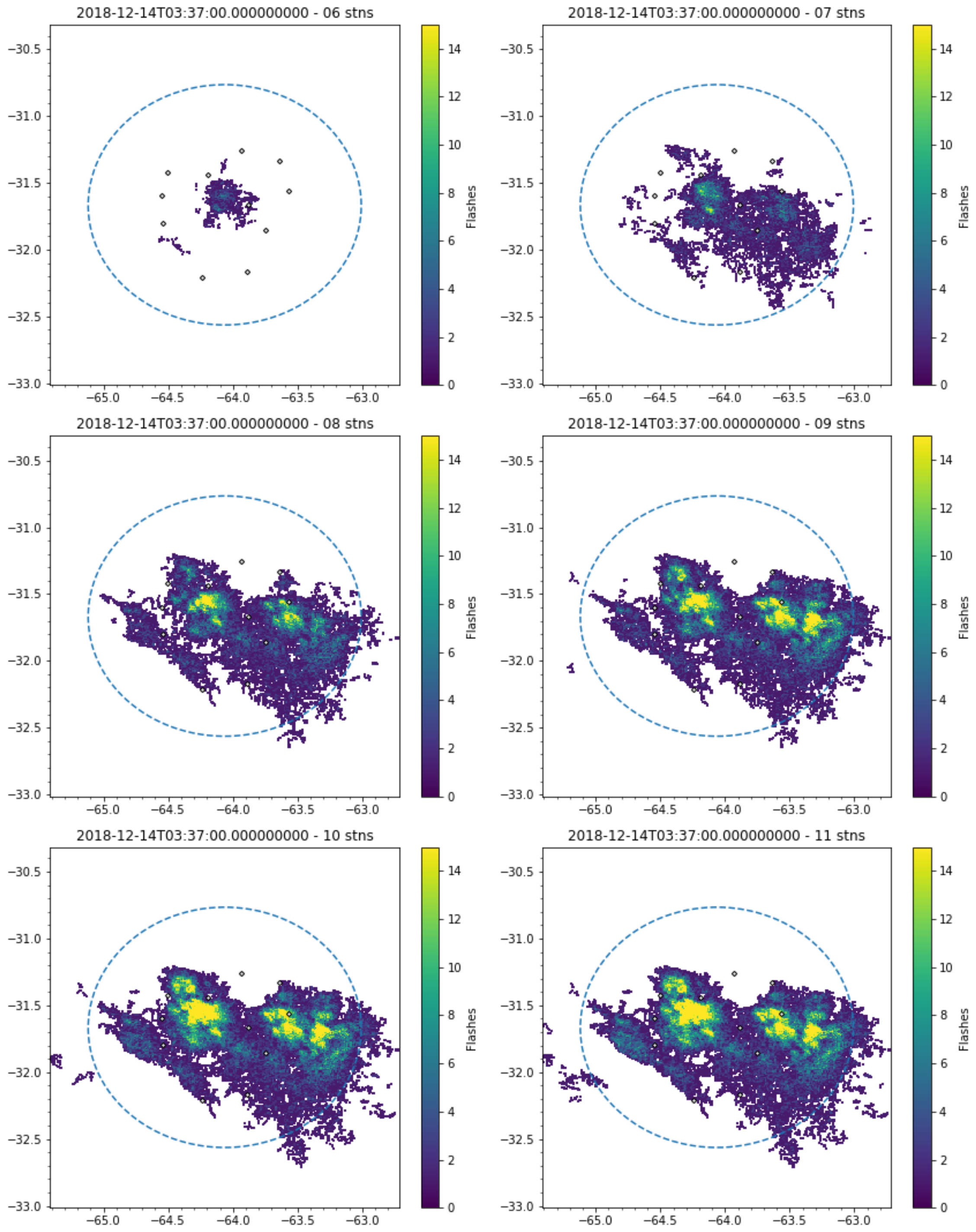
Local time diurnal cycle



- Bimodal diurnal distribution – 5p & 12a peaks, 6-8a minimum
- Storms kick off around 1p each day, initial wave dies at sunset before recovery after 9p

Flash Extent Density

All defaults:
chisqr = 1
npts = 10



Interlude:
Considering the impact of station availability on data

chisqr = 5
npts = 2

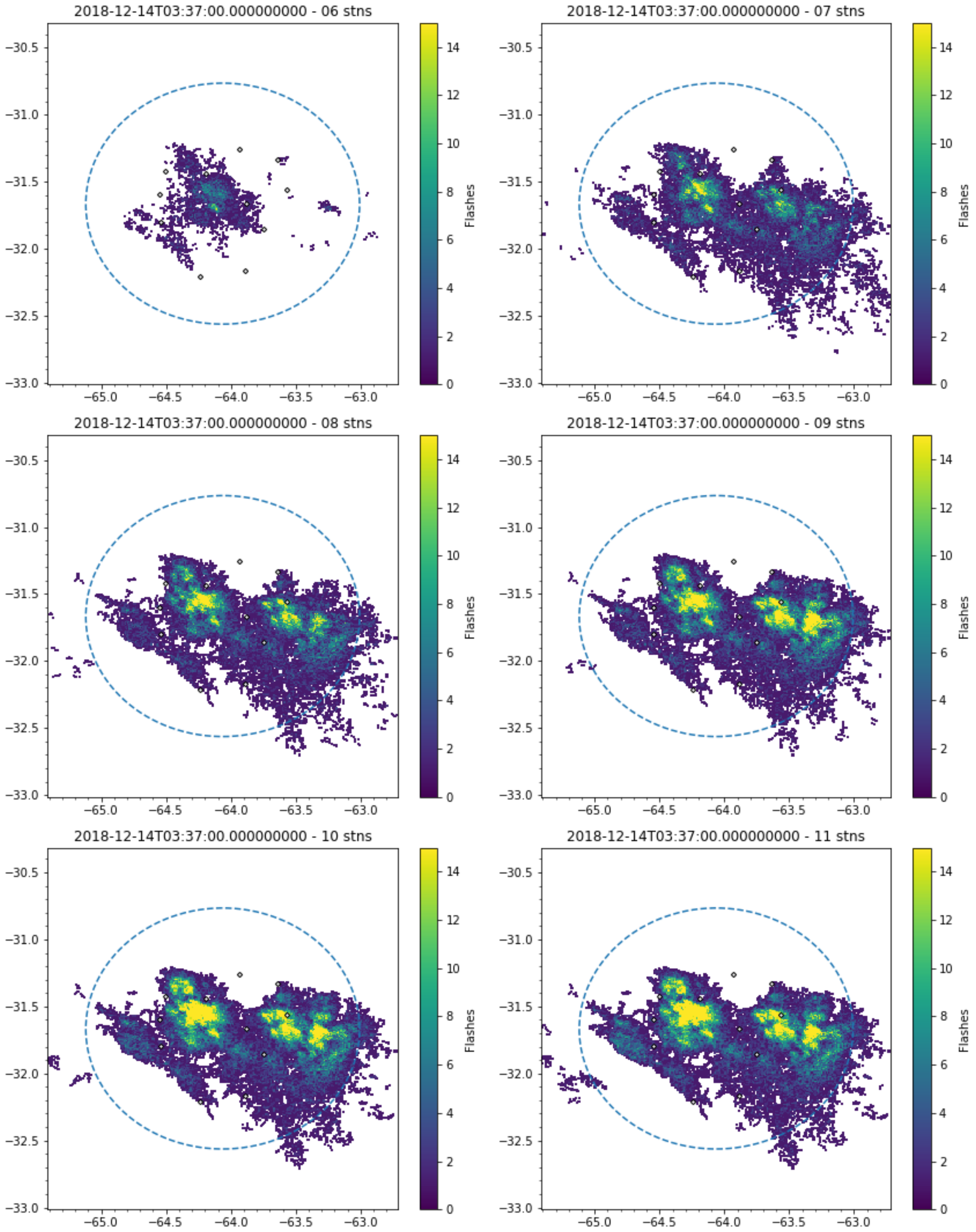
chisqr = 5
npts = 3

chisqr = 1
npts = 5

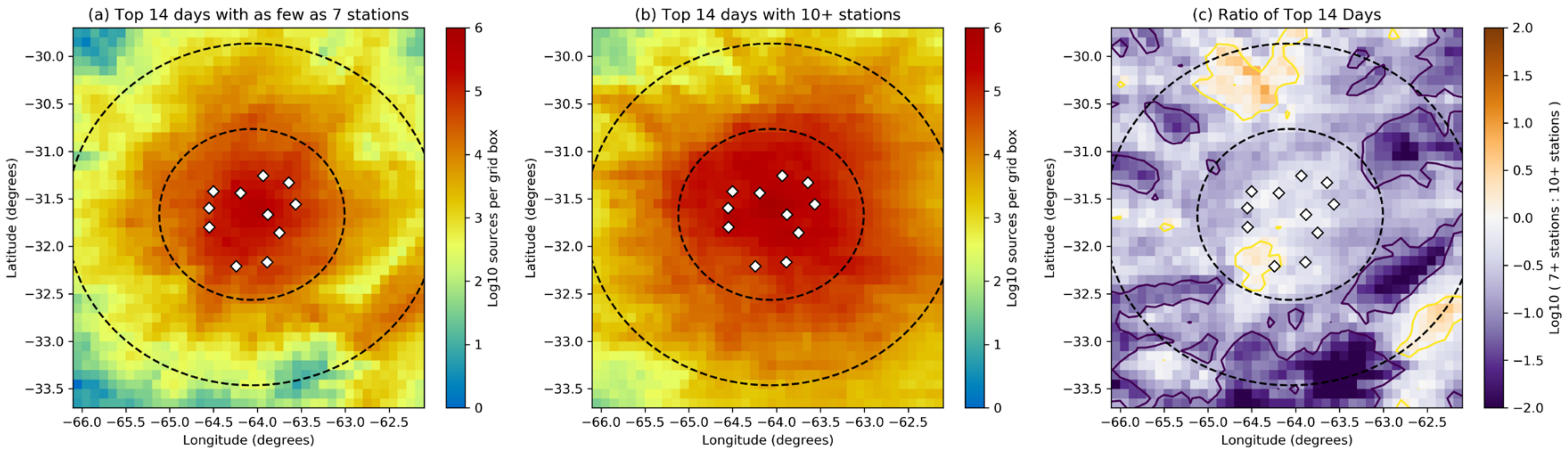
chisqr = 1
npts = 8

chisqr = 1
npts = 10

chisqr = 1
npts = 10

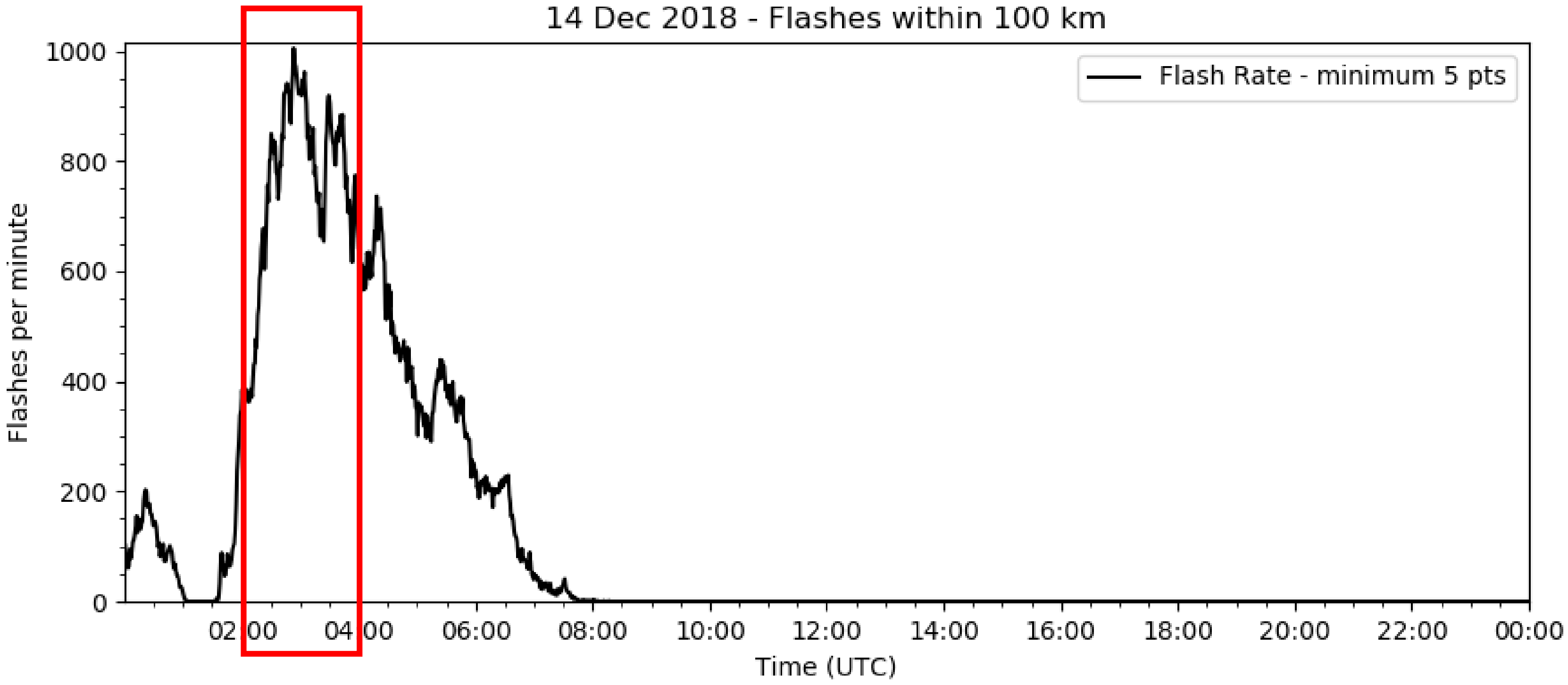


VHF Source Density – Comparing active days with 7-8 stations vs. 10-11

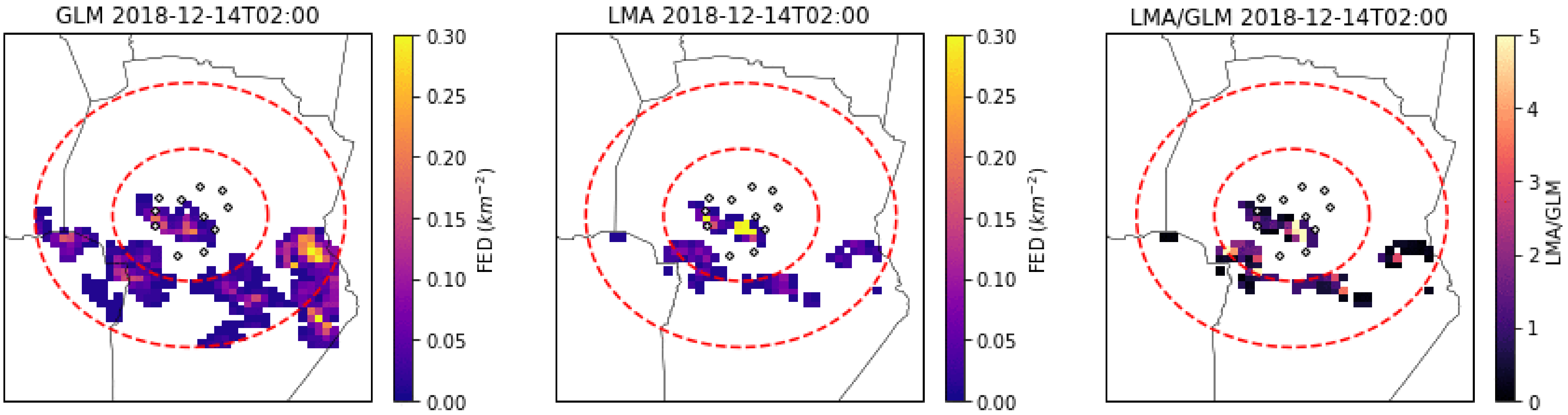


Comparison between GLM and LMA on 12/14

- Using Bruning's lmatools and glmtools to process
- LMA flashes require 10 points
- Interpolate GLM/LMA to common 10-km grid

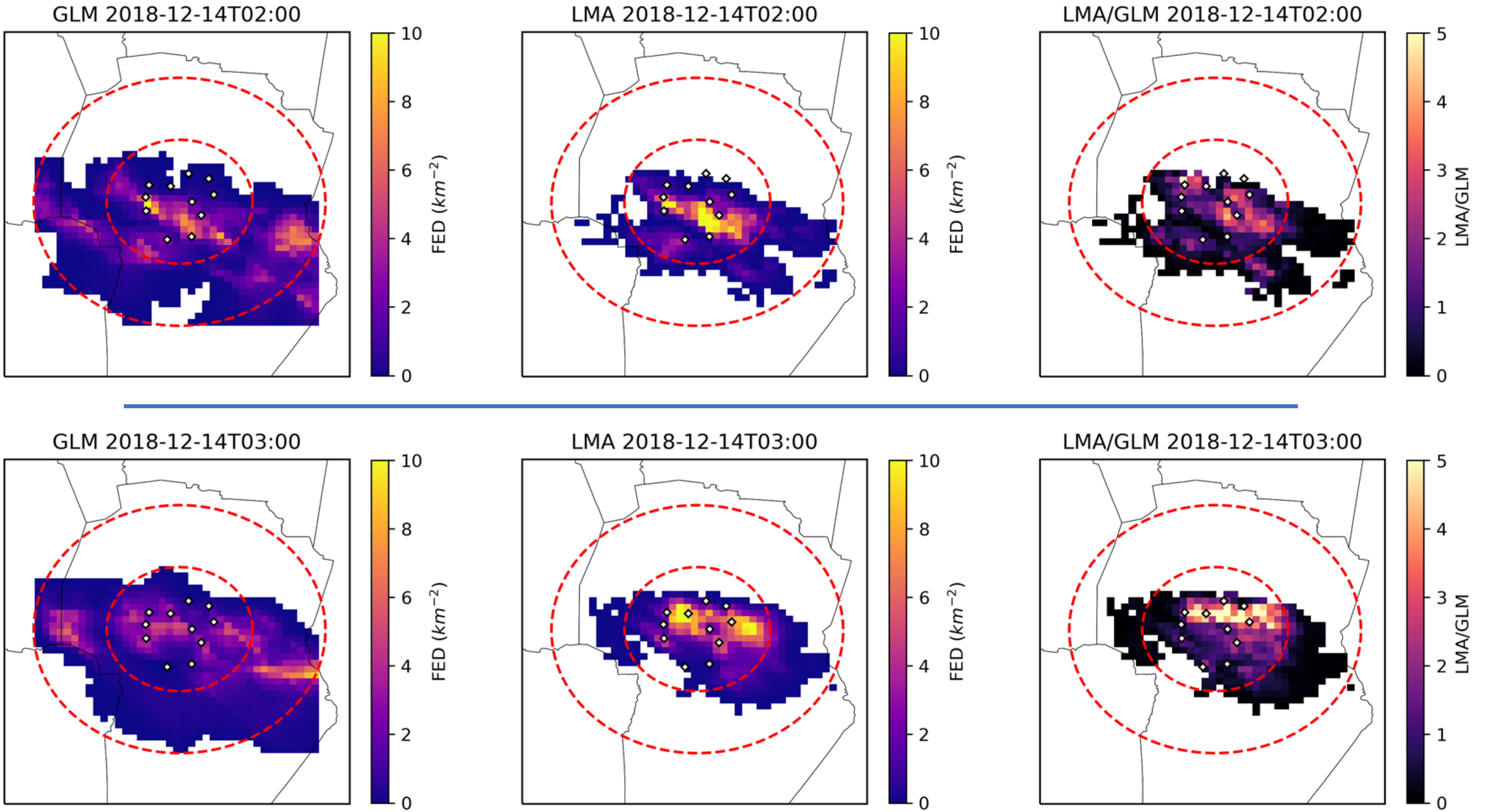


Animation (1-Minute Resolution)



- Within 100 km, GLM cores typically have lower FED, but there are transient periods where values are comparable
- LMA detection efficiency decreases significantly beyond 100 km

1-Hour Summaries



Summary

- RELAMPAGO LMA operations were successful, millions of flashes observed from variety of storm types (incl. anomalous storms)
- Use caution when comparing days with different station availability, but data within 100 km range are good
- GLM comparisons suggest significant underestimate in active cores

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 x 1 x 1 km^3), netCDF4, one file per variable, 10 minutes

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