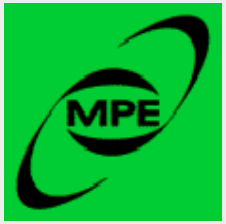
Fermi GBM Observations of TGFs
&
Fermi GBM TGF Catalogs

Michael S. Briggs
on behalf of the Fermi GBM TGF Team

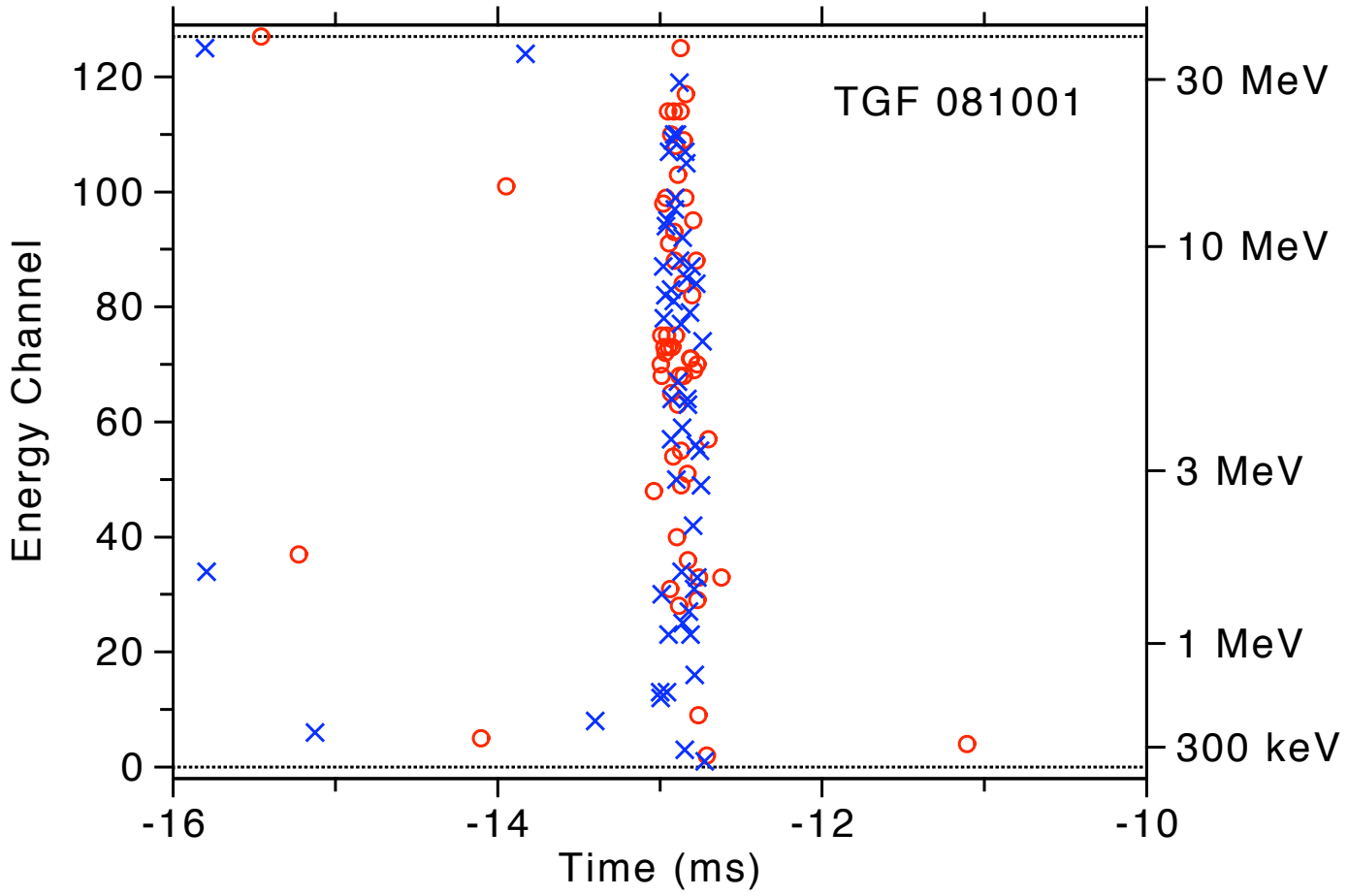


Max-Planck-Institut für extraterrestrische Physik

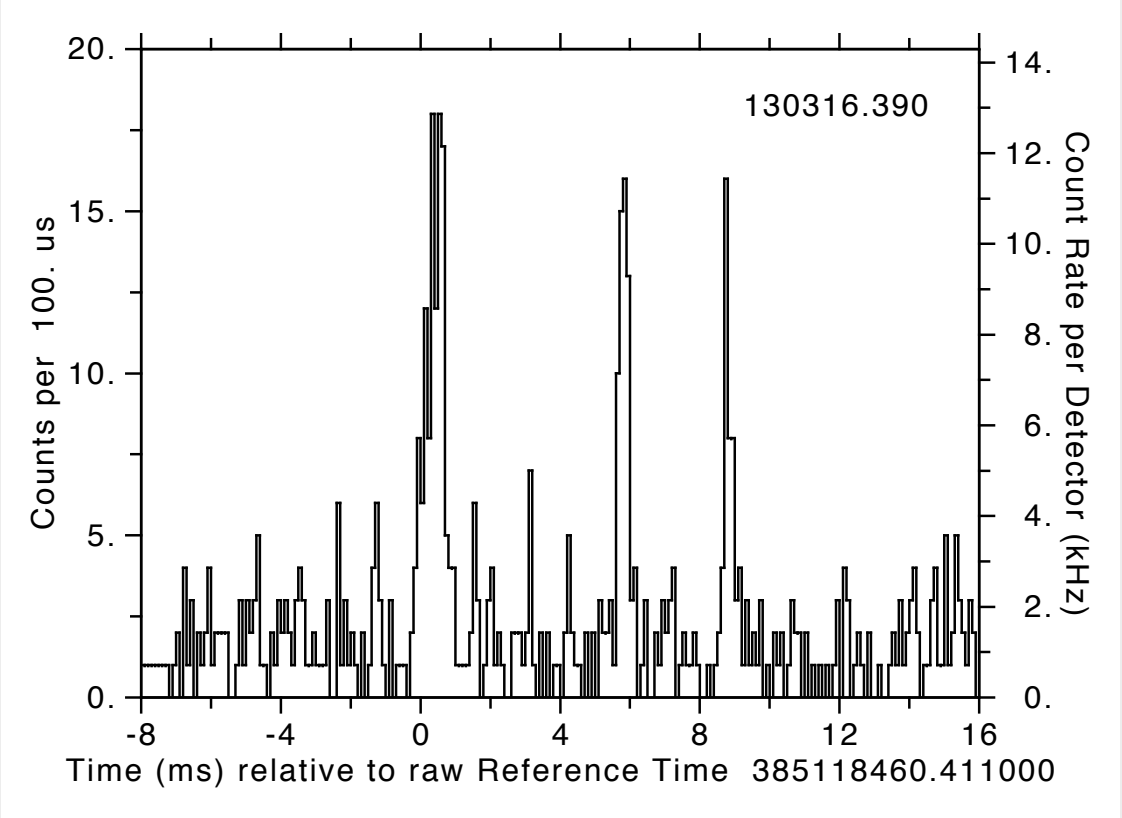
University College Dublin

GBM BGO Detector

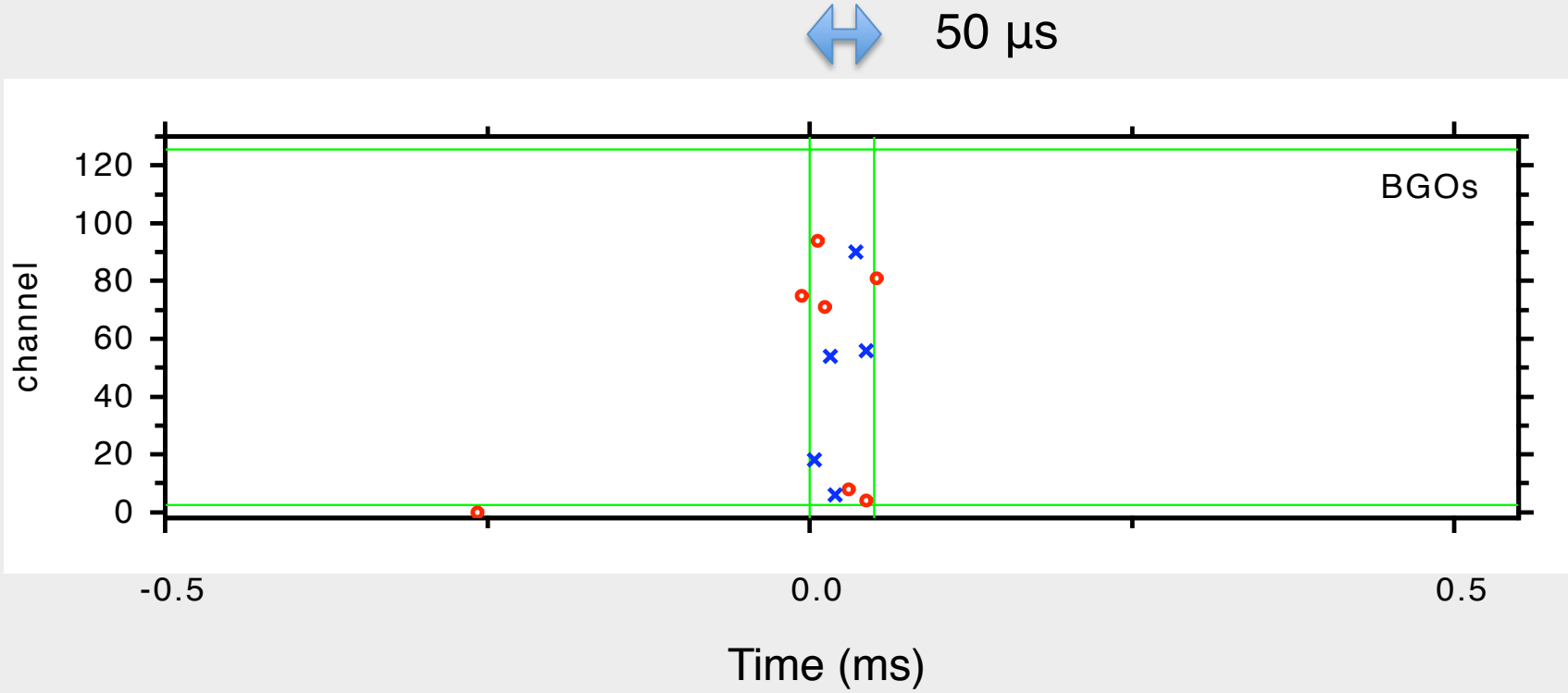
What is a TGF?


TGF 081001
Energy Channel
120
100
80
60
40
20
0
-16
-14
-12
-10
Time (ms)
30 MeV
10 MeV
3 MeV
1 MeV
300 keV

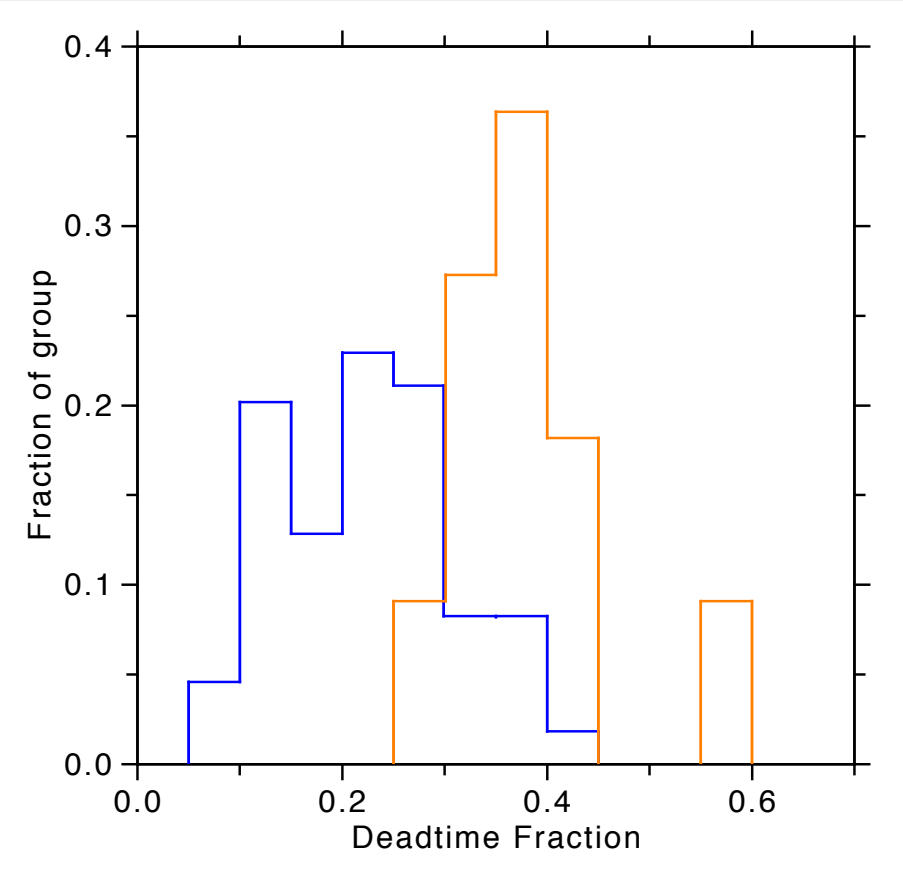
20% of triggered TGFs have multiple, separated pulses. Most are doubles, some triples:



Foley, et al. (2014)

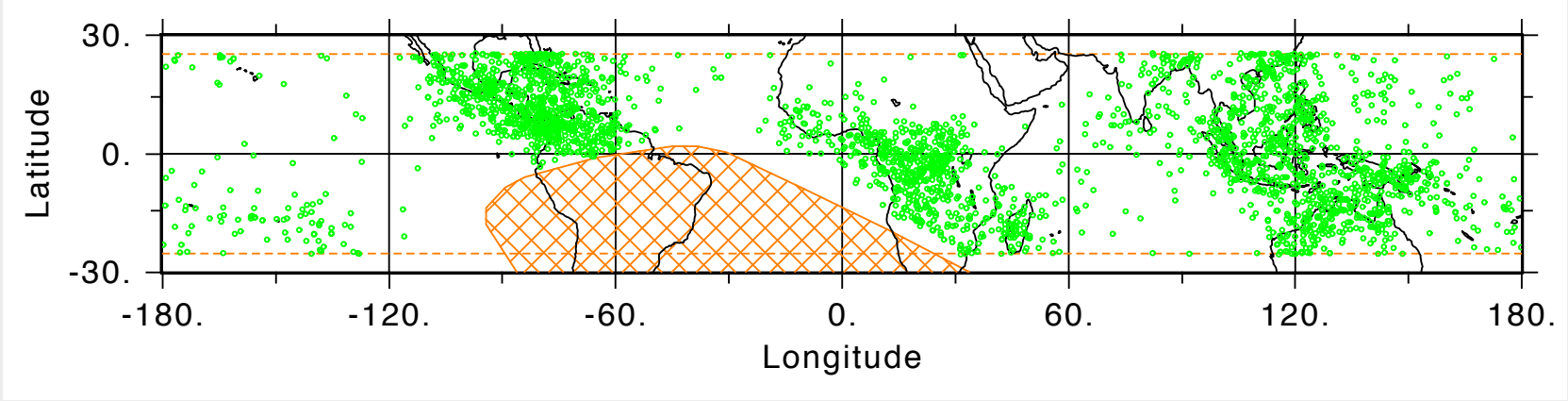


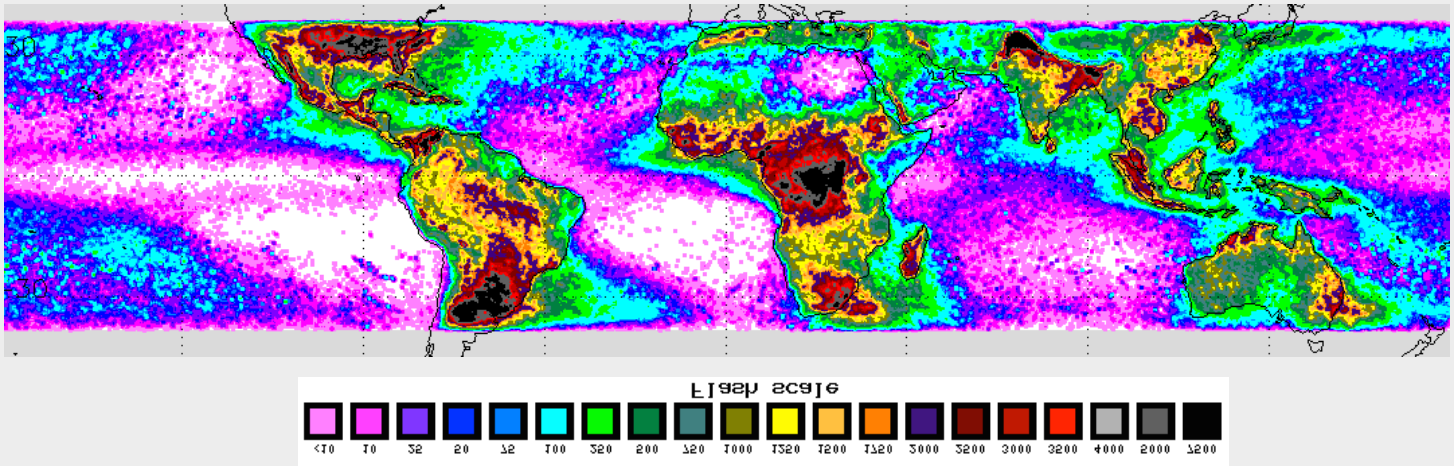
P = 2.3E-14



The shortest TGFs have higher deadtime. There likely remains a bias against detecting very short TGFs.

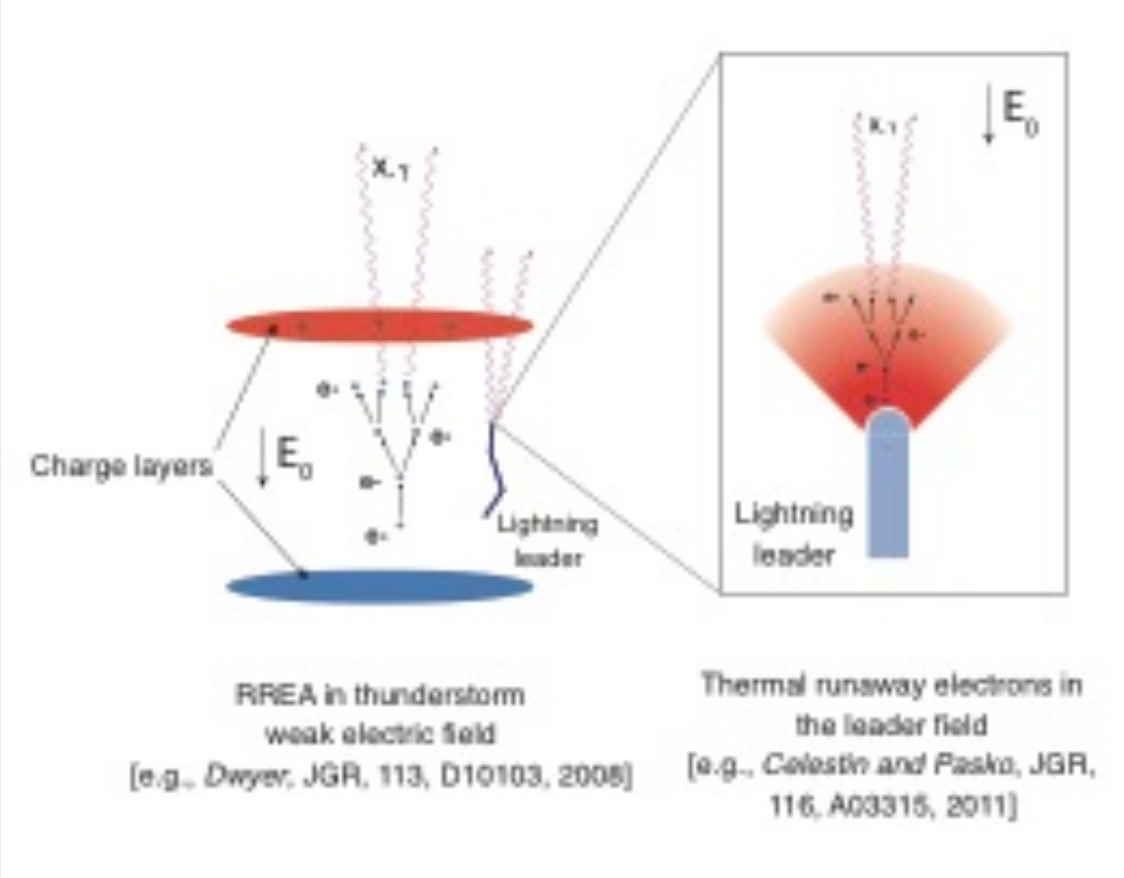
Fermi Locations at the times of 2700 GBM TGFs





Lightning Activity, as observed with the Lightning Imaging Sensor (LIS)

Two theories for electron-acceleration for TGFs. The gamma-rays are from bremsstrahlung.



From Sebastien Celestin

Runaway Electron Avalanches by Relativistic Feedback

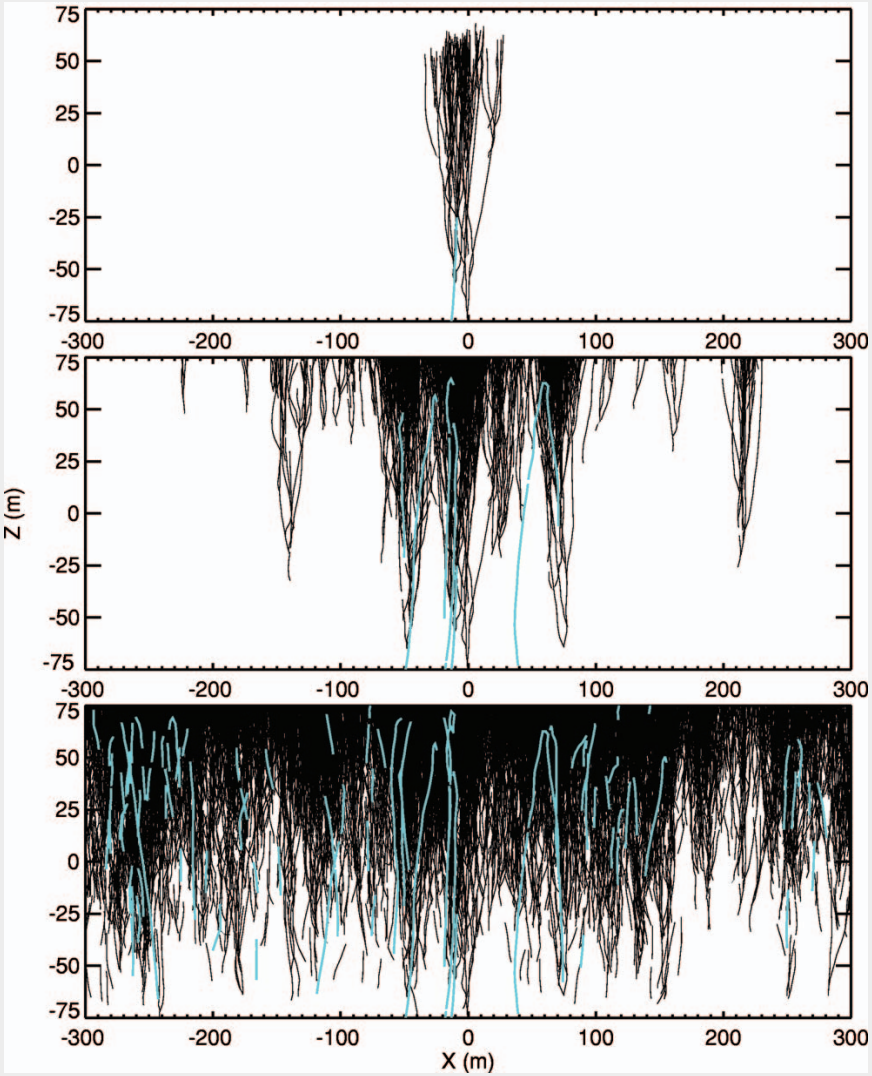
J. Dwyer (2007)

E = 750 kV / m
for 150 m,
➔110 MV potential

Initial avalanche from a single 1 MeV seed electron.

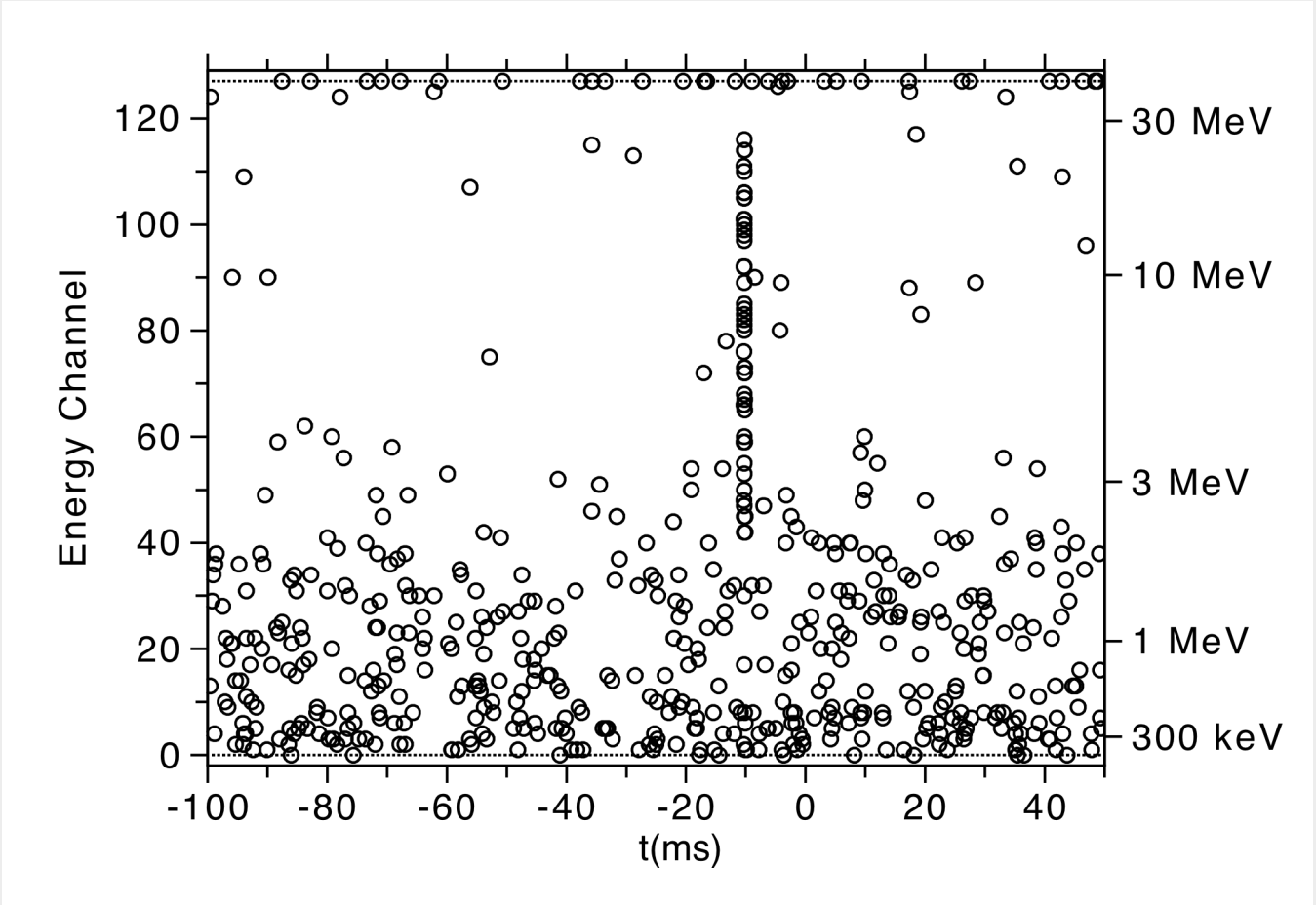
Additional avalanches produced by x-ray and positron feedback.

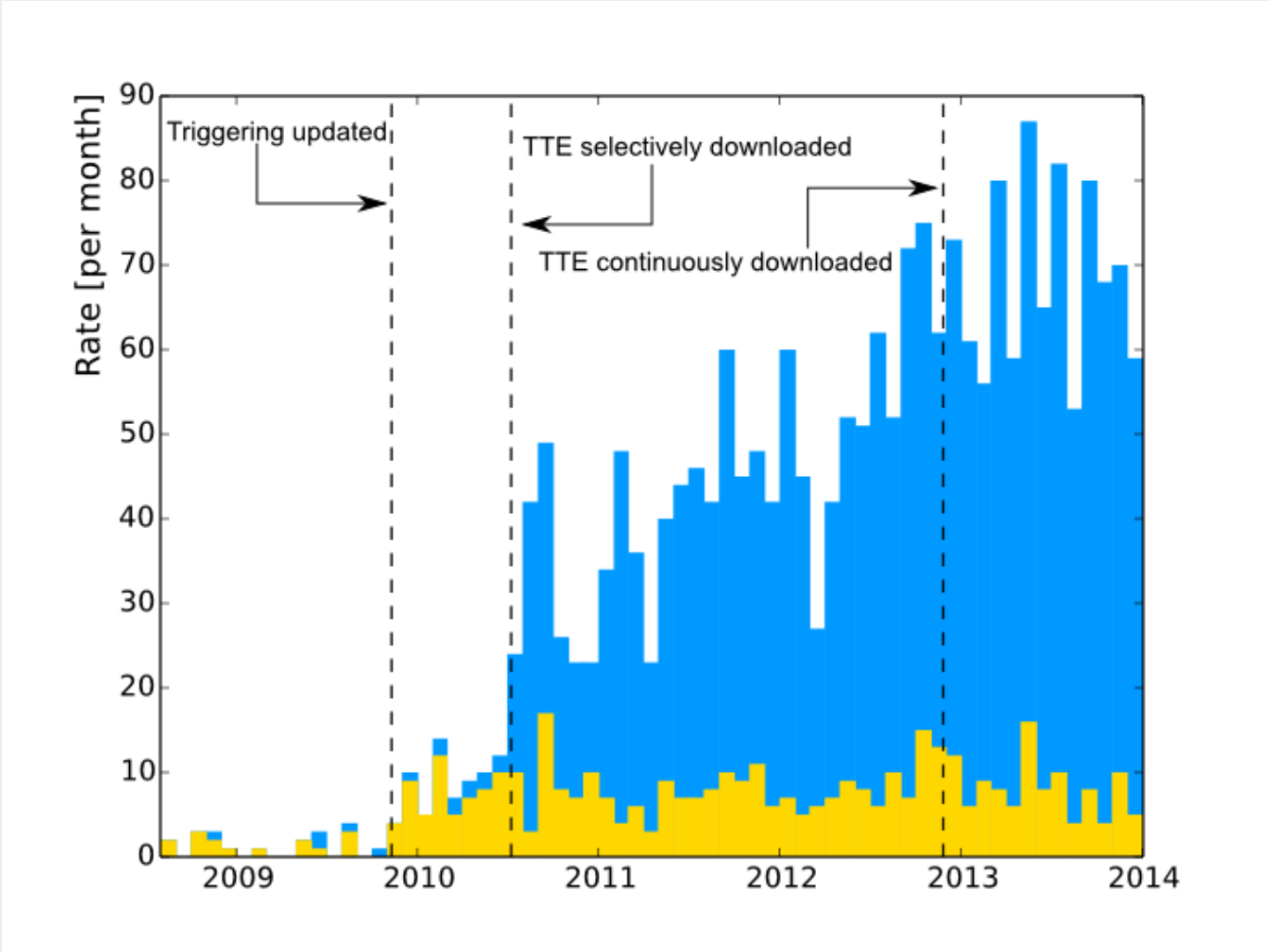
Black = Electron
Blue = Positron



Finding GBM TGFs

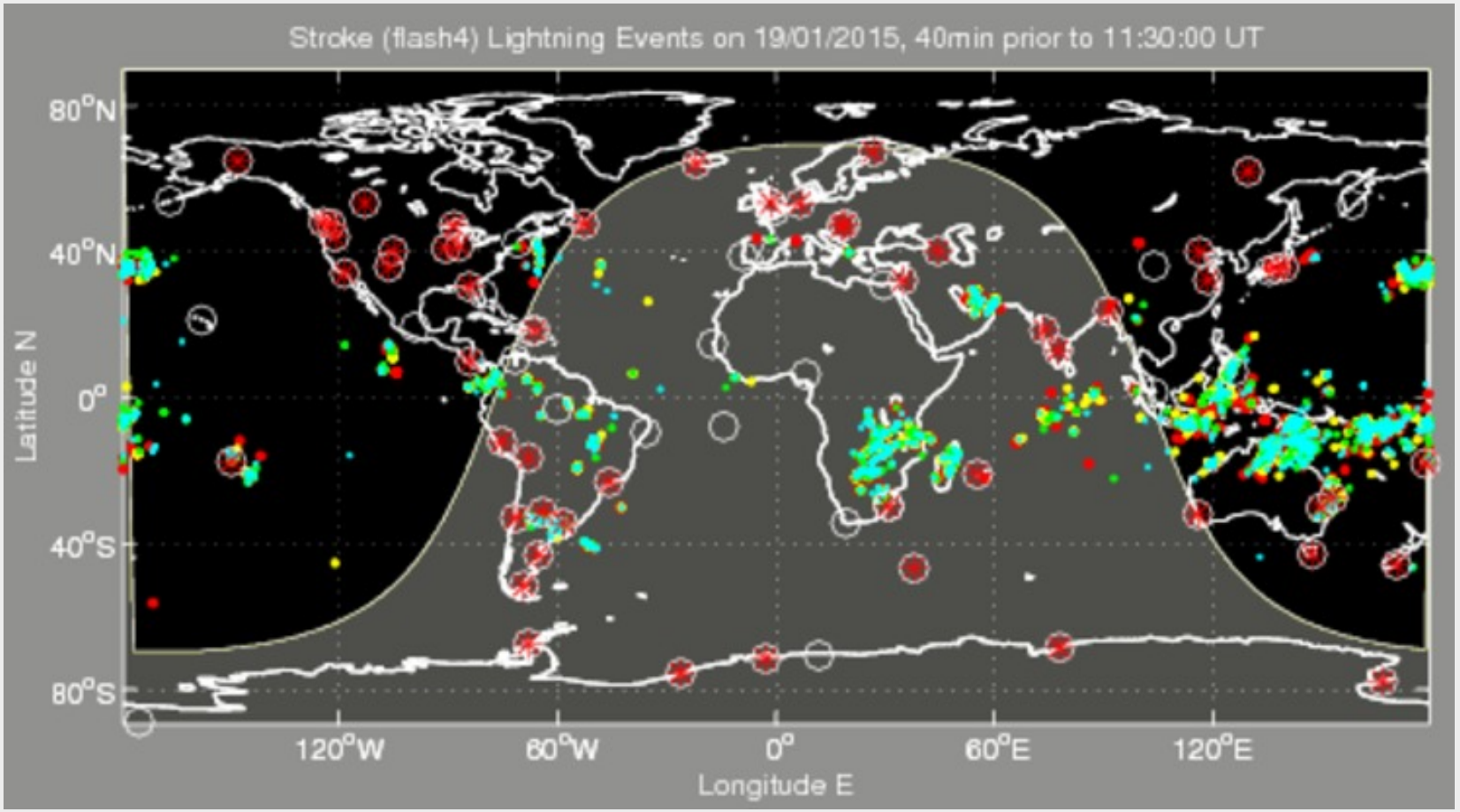
150 ms of BGO data



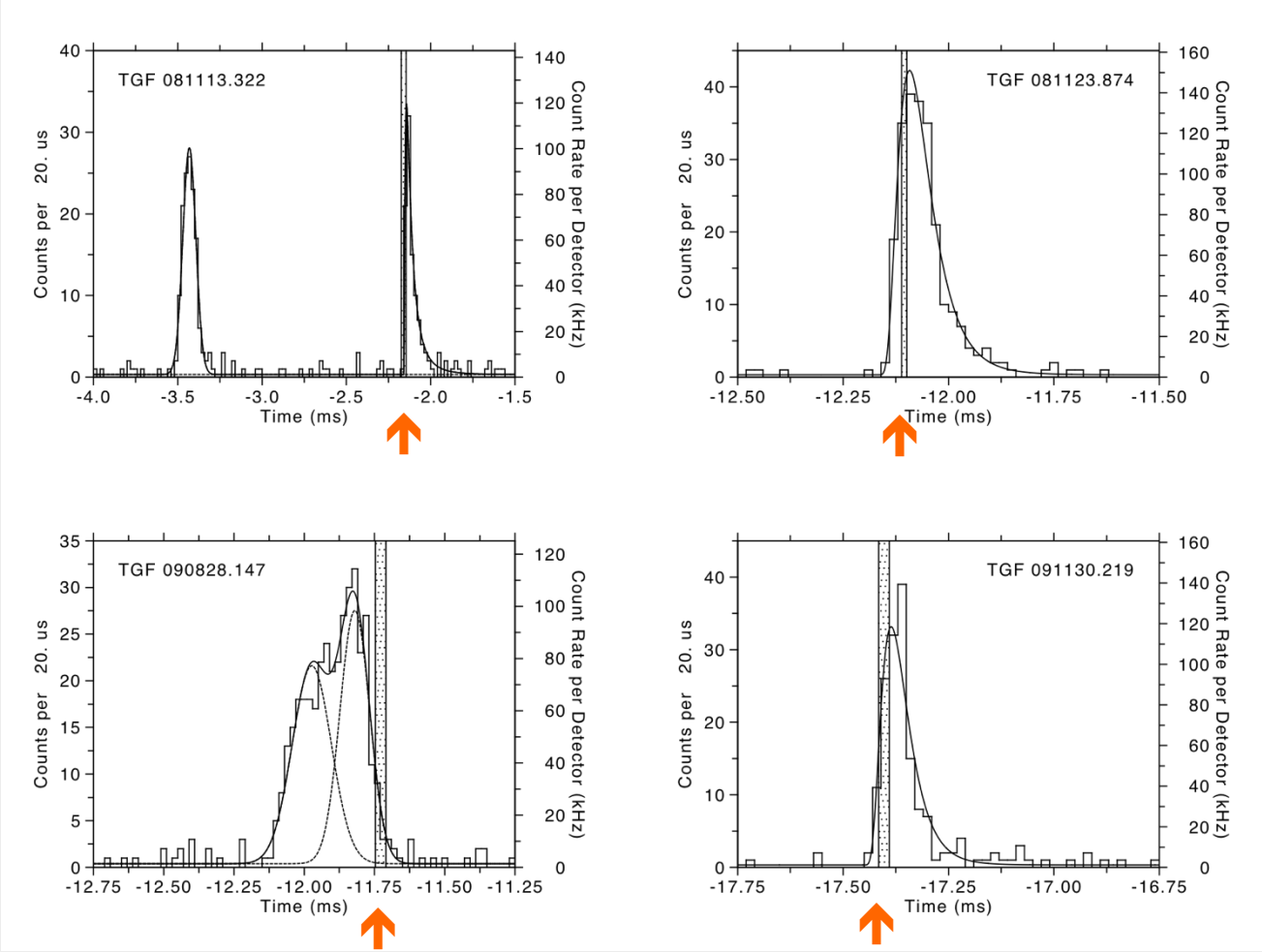

Rate [per month]
90
80
70
60
50
40
30
20
10
0
2009
2010
2011
2012
2013
2014
Triggering updated
TTE selectively downloaded
TTE continuously downloaded

Lightning, Radio and Storms

World-Wide Lightning Location Network (WWLLN)
Very Low Frequency (VLF) Radio

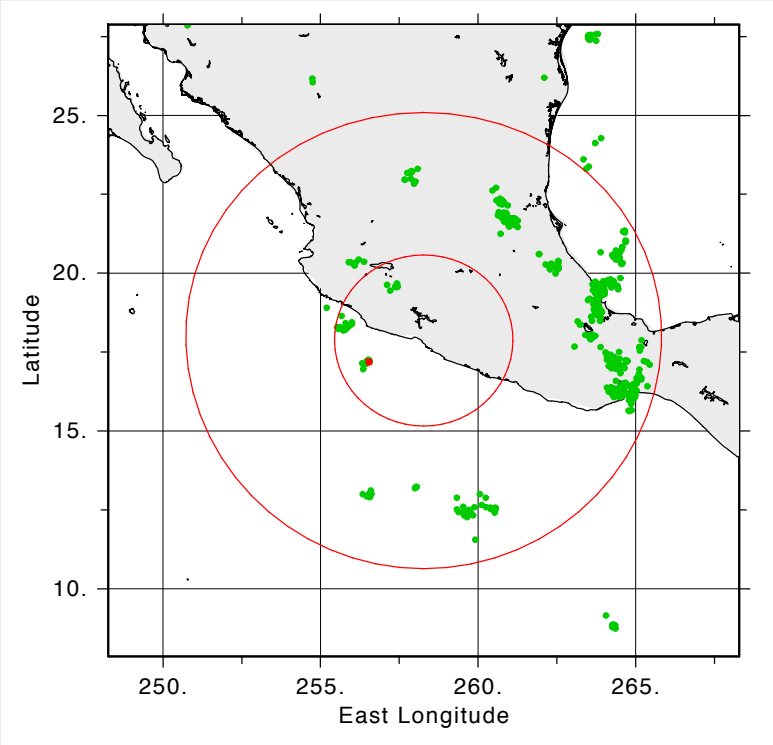


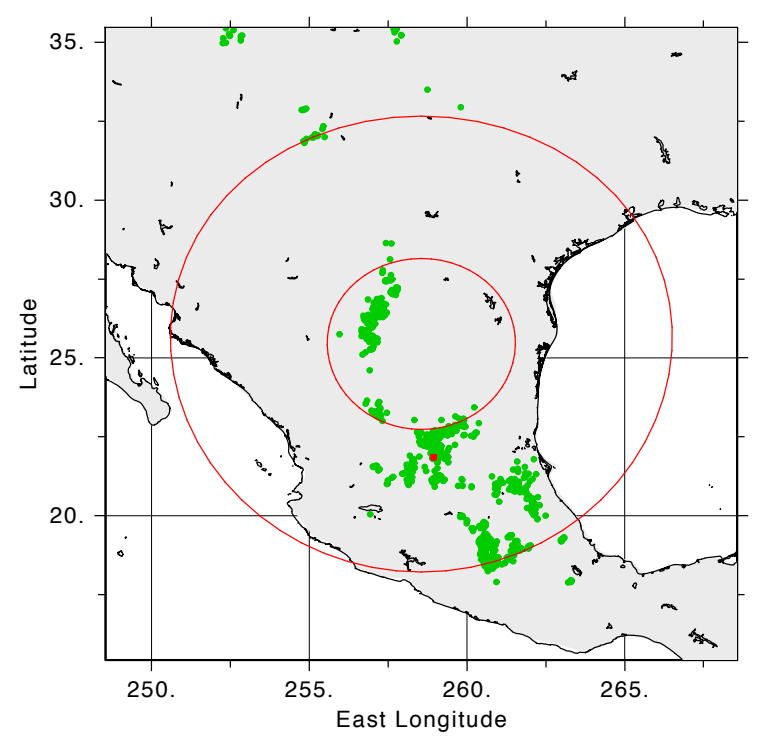
Correlating TGFs in gamma-rays (GBM) with lightning via radio (WWLLN)



Connaughton et al. (2010)

WWLLN Maps for ±10 minutes



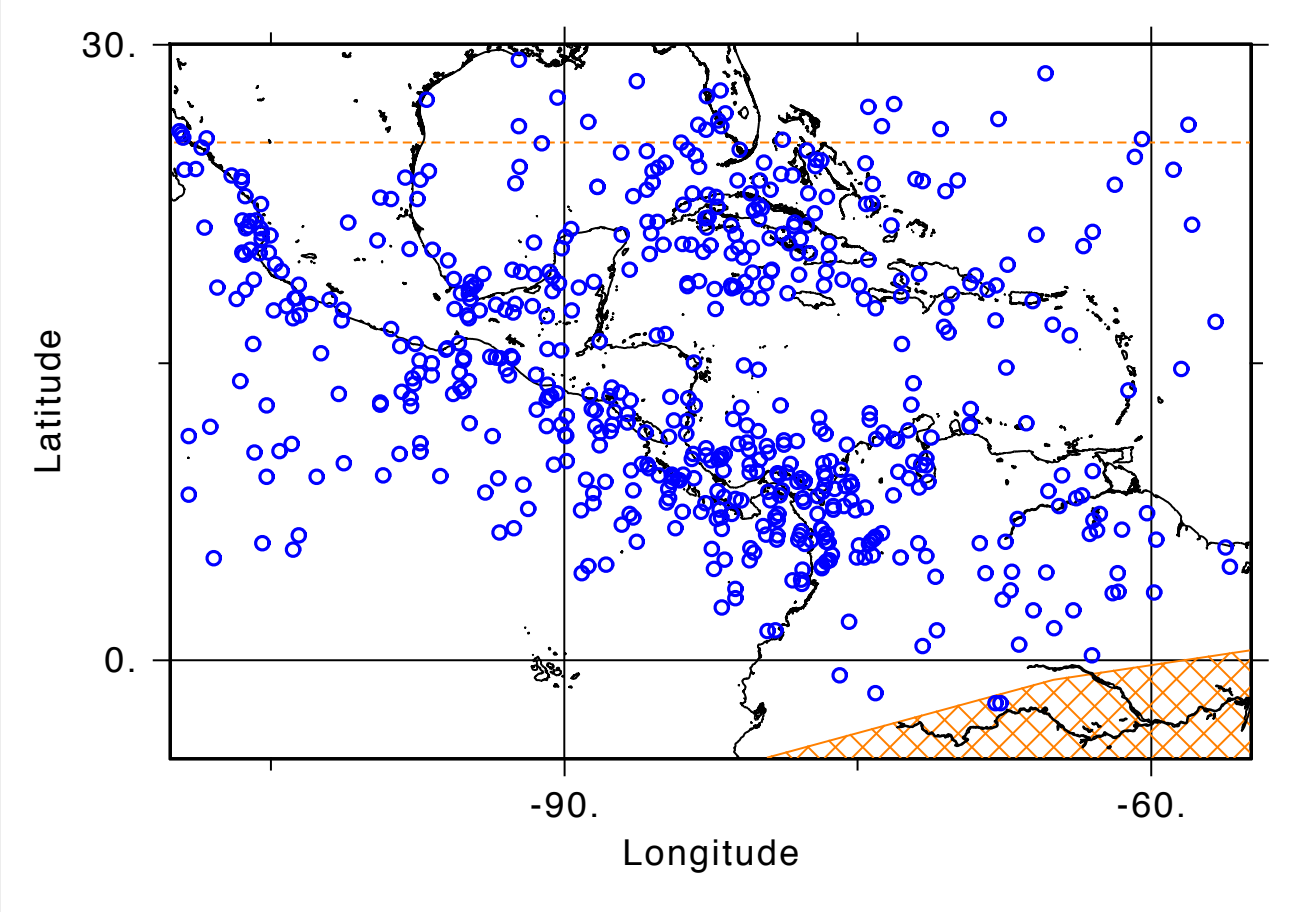


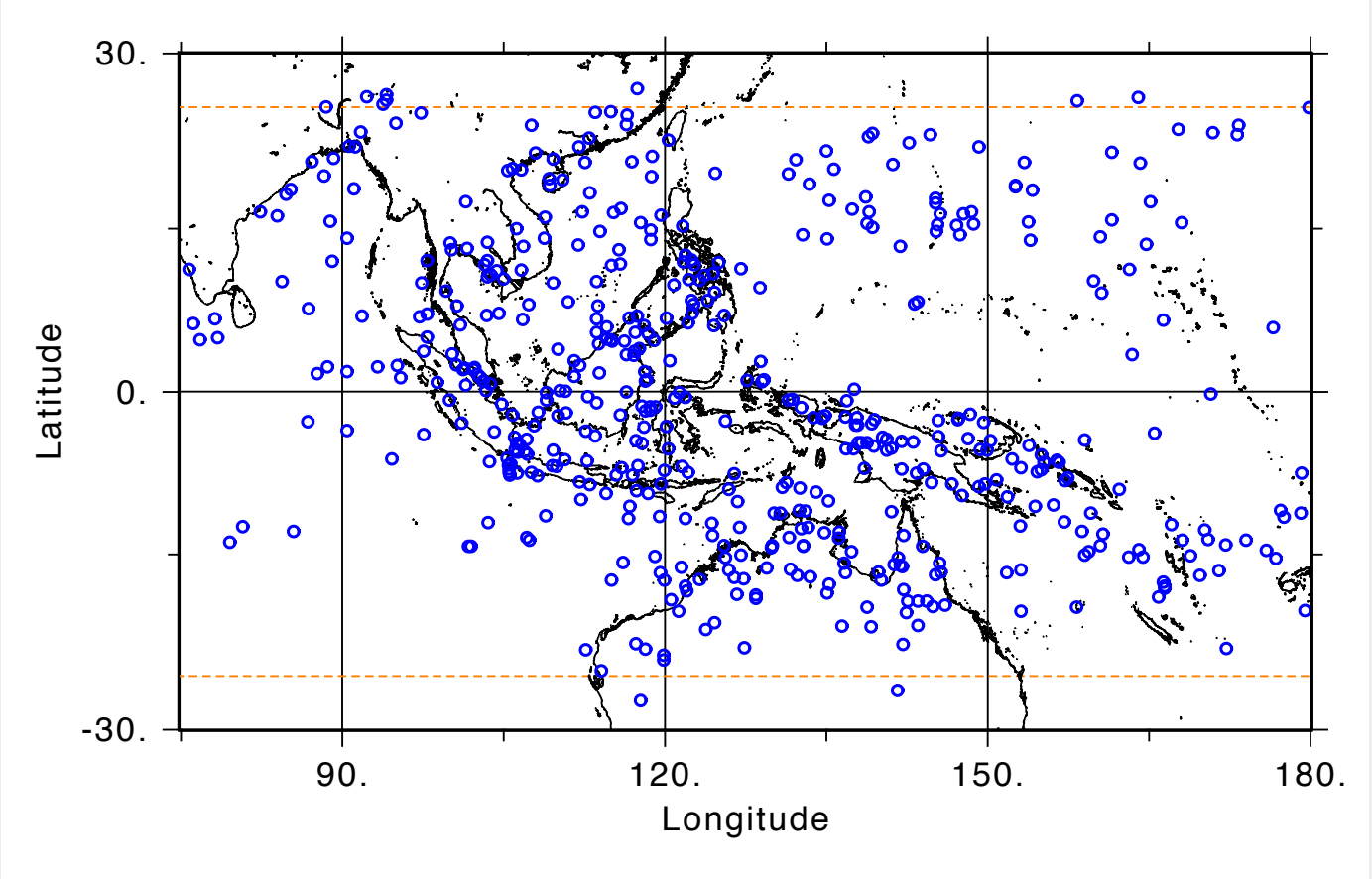
Radio / γ-ray offset: 58 μs
Chance P < 0.4%

Radio / γ-ray offset: 9 μs
Chance P < 0.9%

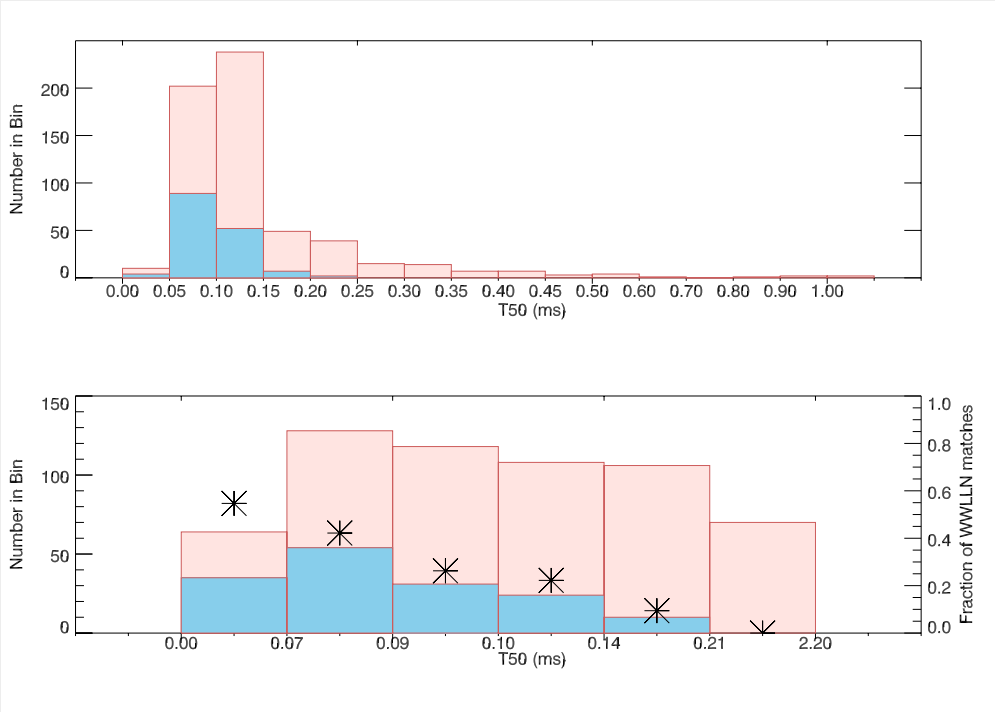
Technique of
Connaughton et al., 2010

VLF localizations, ~10 km uncertainty
Regional maps from sample of 1341.




30.
0.
-30.
Latitude
90.
120.
150.
180.
Longitude

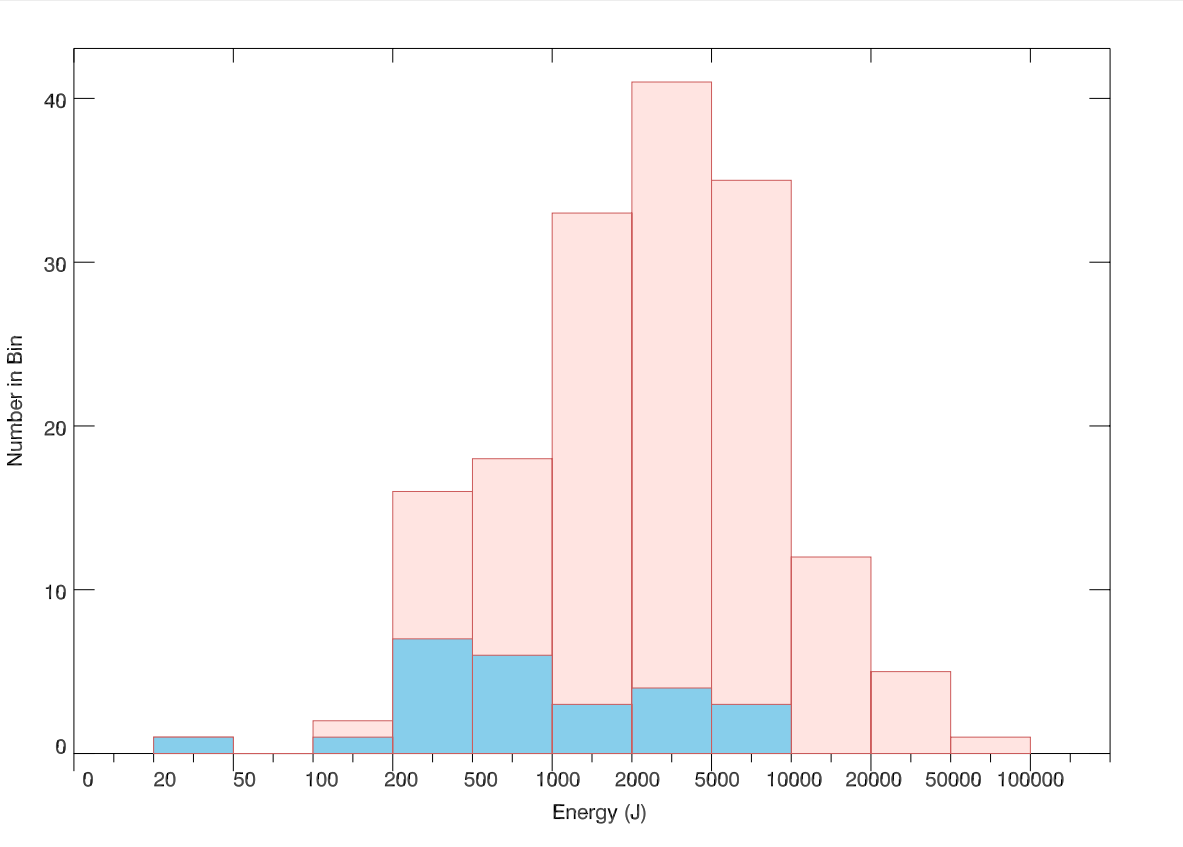
The probability of detecting radio emission from a TGF is anti-correlated with TGF duration ➔ most TGF-associated radio emission is directly from TGFs, rather than associated lightning radiation.



Connaughton et al. (2012)

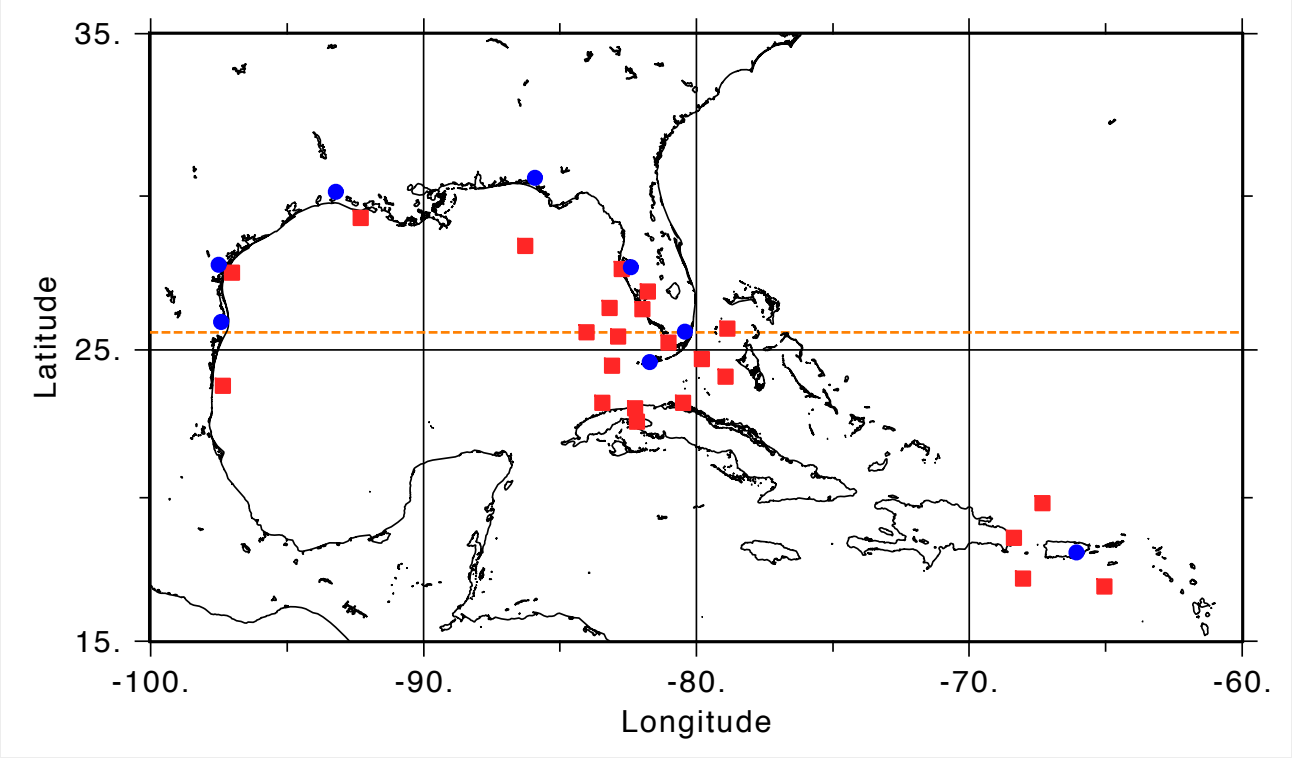
salmon: All 594 TGFs
blue: TGFs with simultaneous WWLLN sferics
asterics: fraction with simultaneous

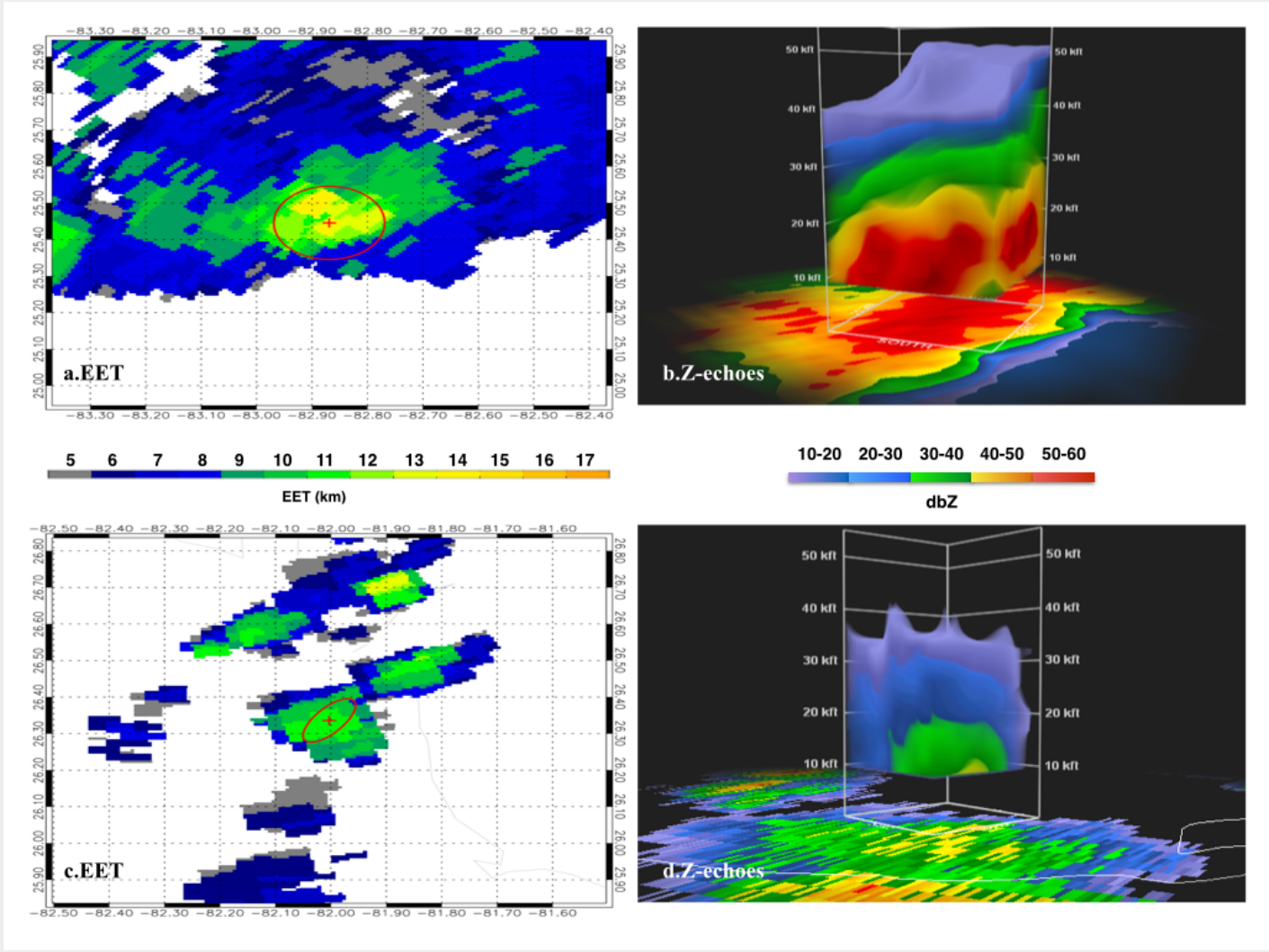
WWLLN-measured radiated energy: simultaneous sferics (pink) and non-simultaneous (teal)



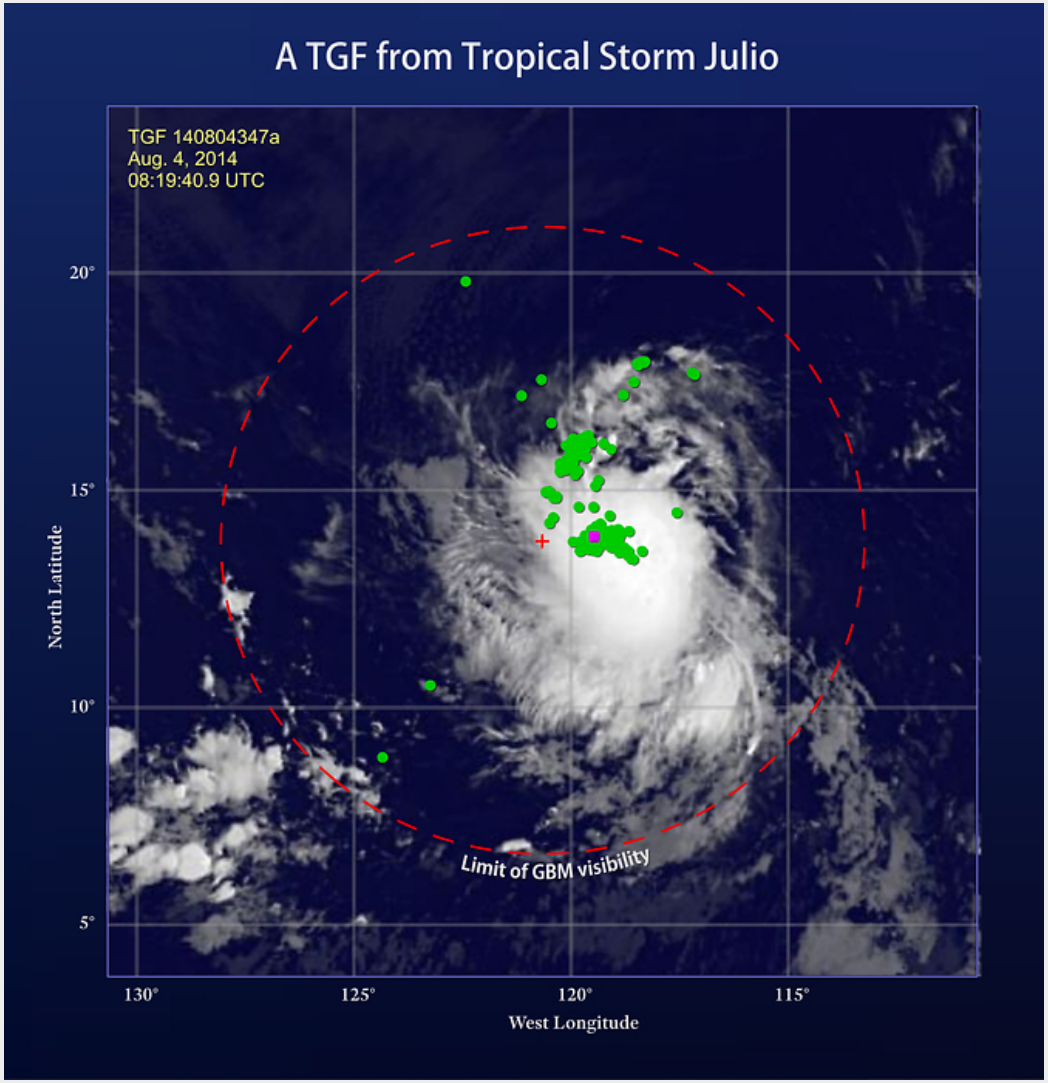
Connaughton et al. (2012)

TGF-producing storms: Observing TGF locations (red) with NEXRAD Doppler Weather radars (blue)

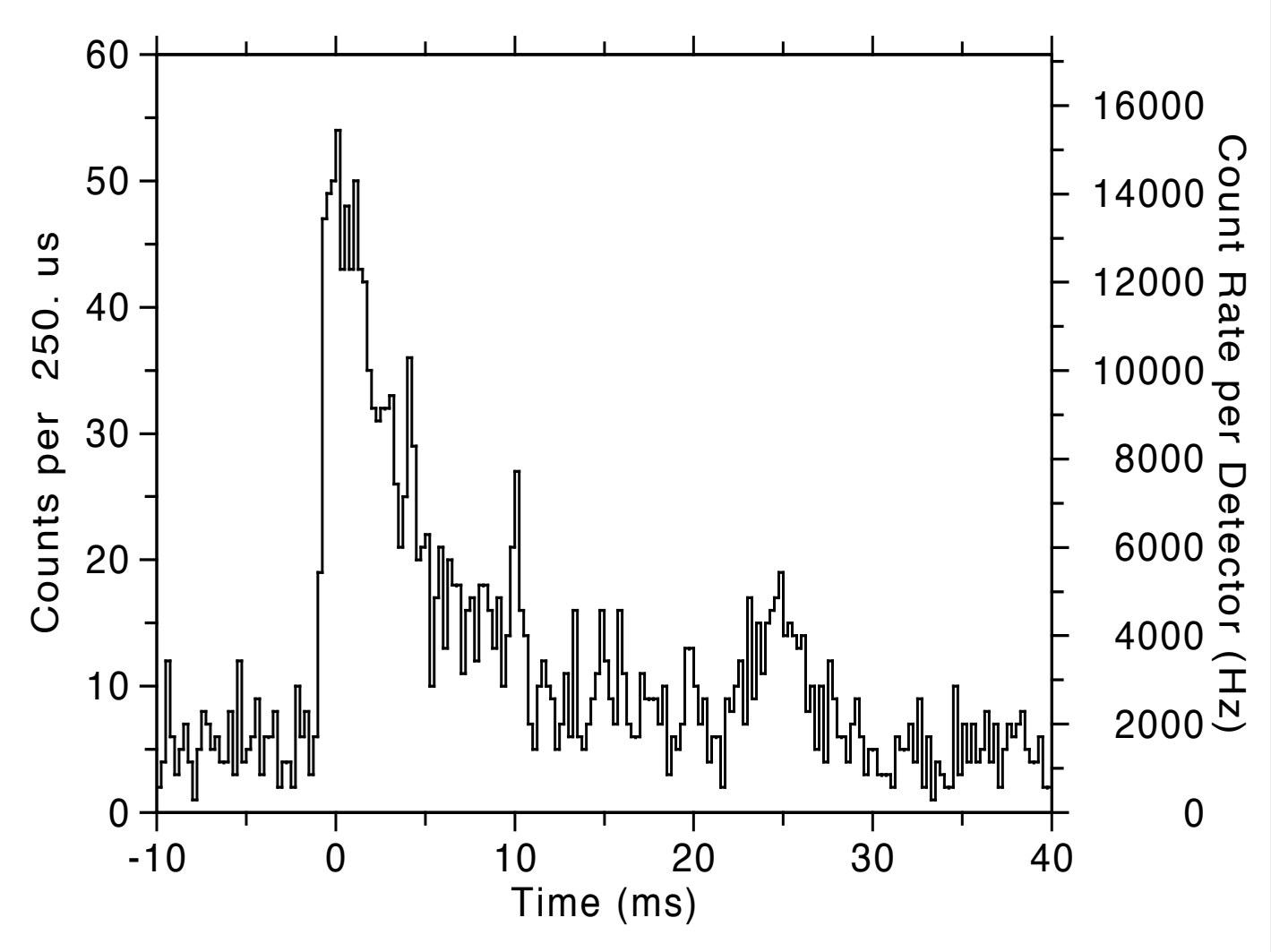


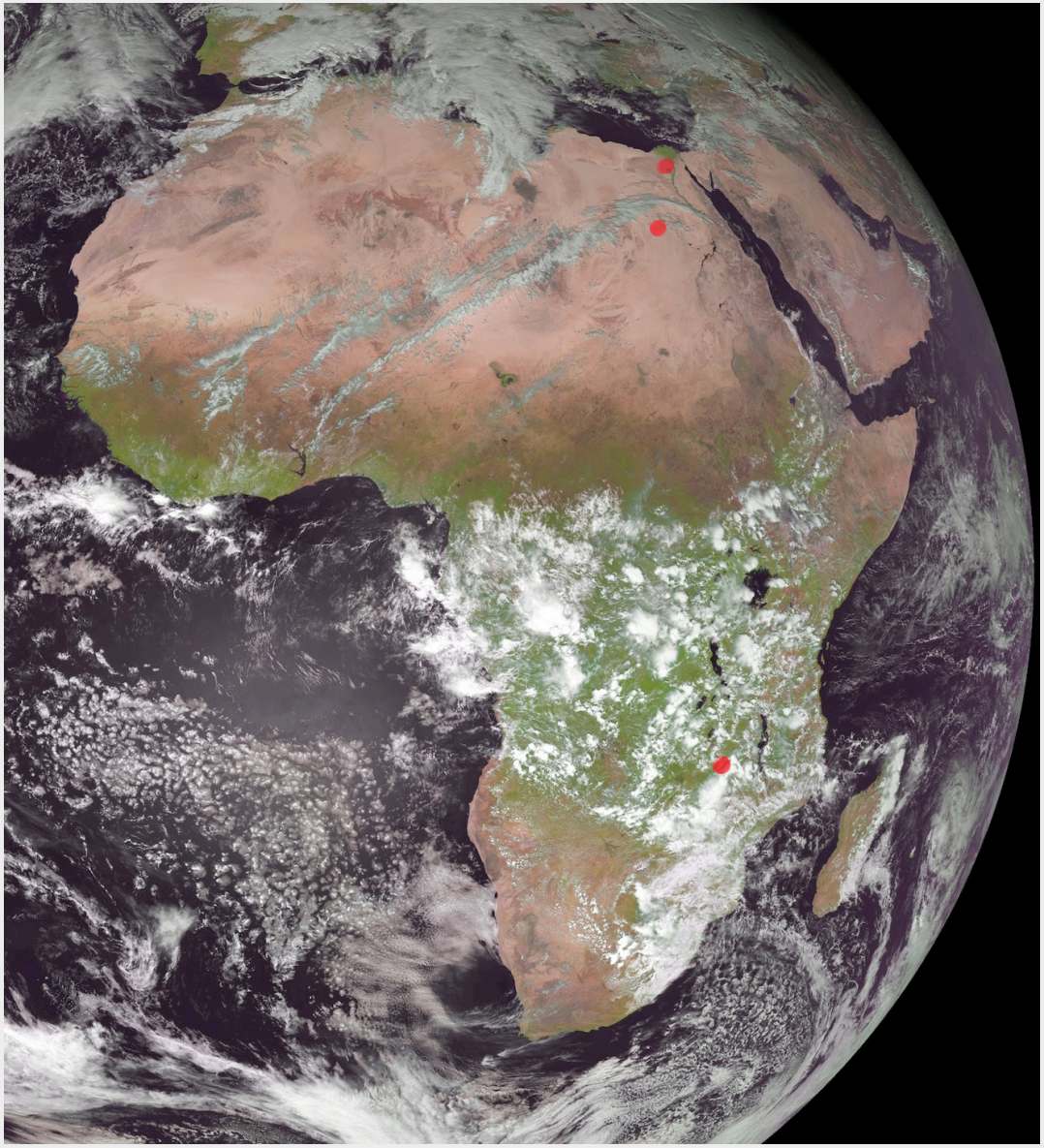


NEXRAD radar: Enhanced Echo Tops (EET) and radar reflectivity (dBZ)

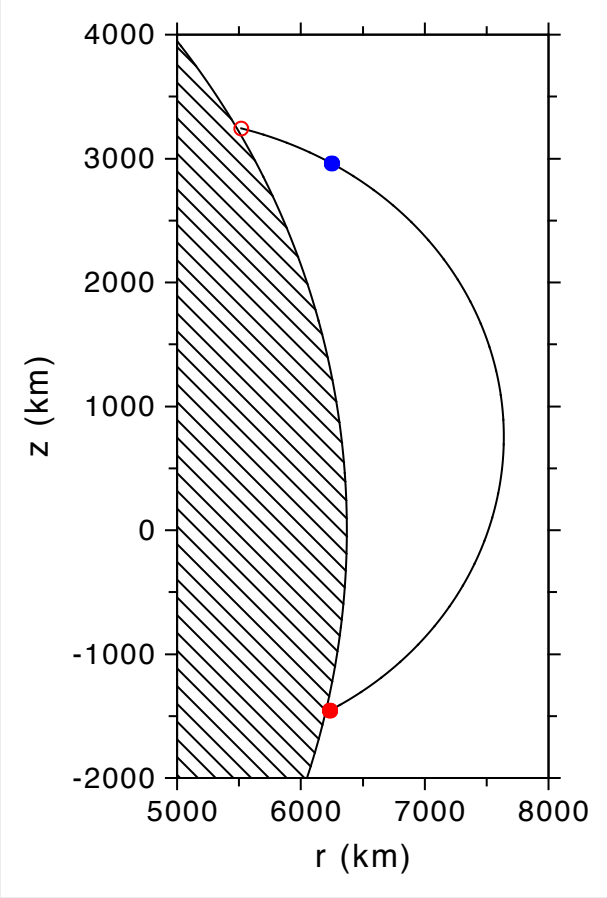

A TGF from Tropical Storm Julio
TGF 140804347a
Aug. 4, 2014
08:19:40.9 UTC
20°
15°
10°
5°
North Latitude
Limit of GBM visibility
130°
125°
120°
115°
West Longitude

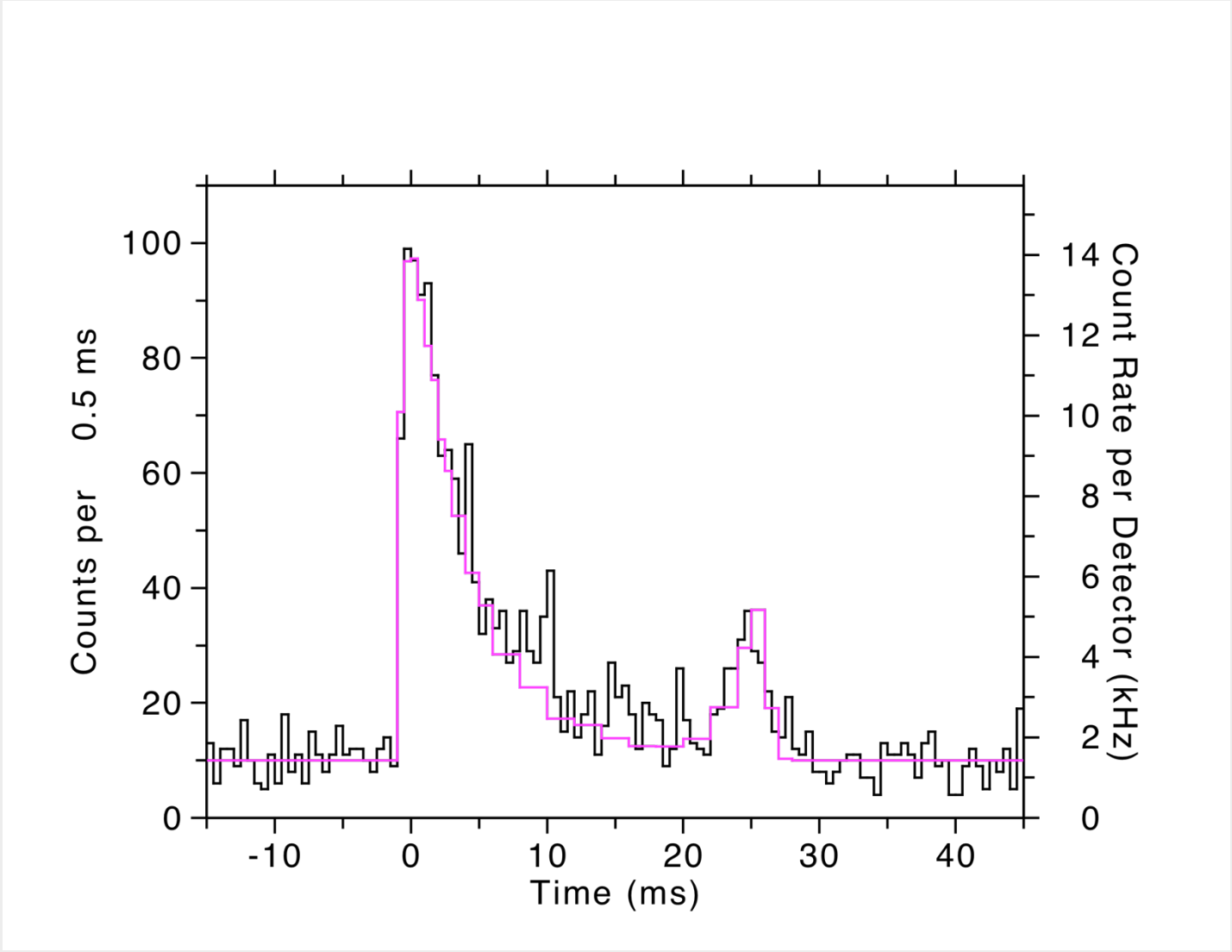
Terrestrial Electron Bursts (TEBs)


Counts per 250. us
Count Rate per Detector (Hz)
Time (ms)
0
10
20
30
40
50
60
0
2000
4000
6000
8000
10000
12000
14000
16000
-10
0
10
20
30
40

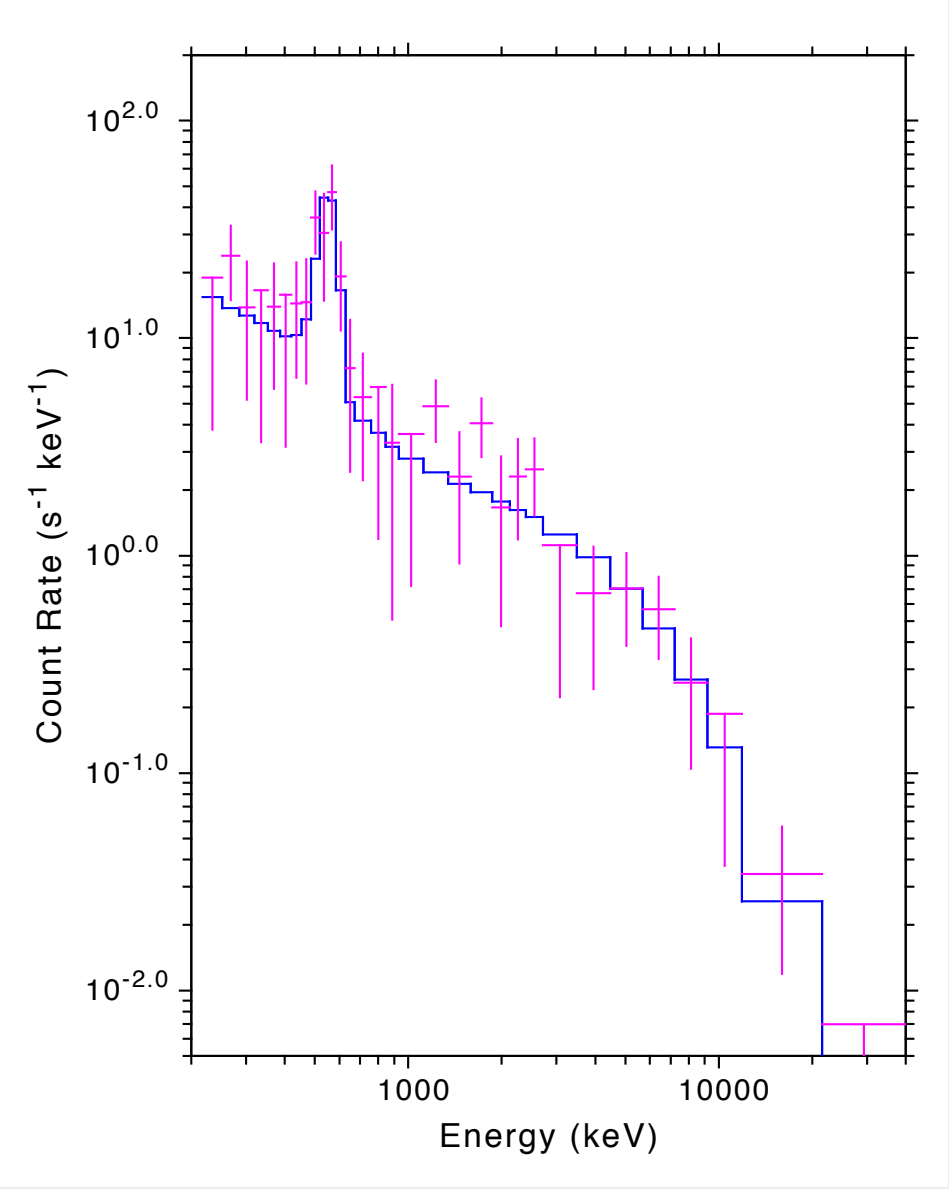


Meteosat 9 image



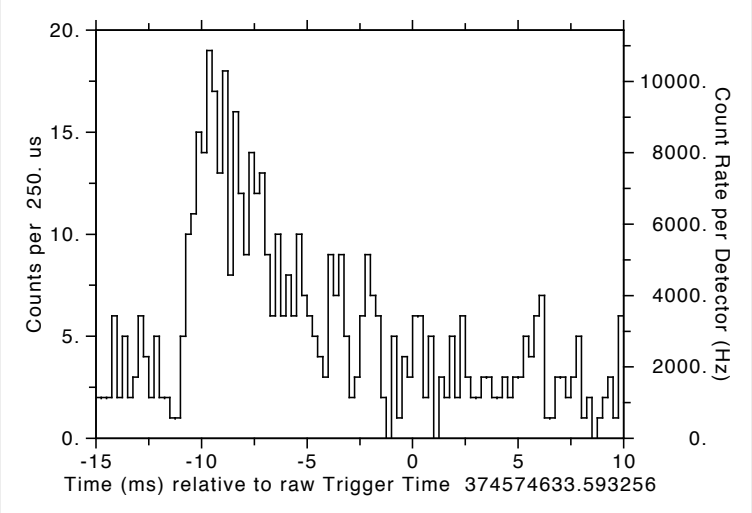


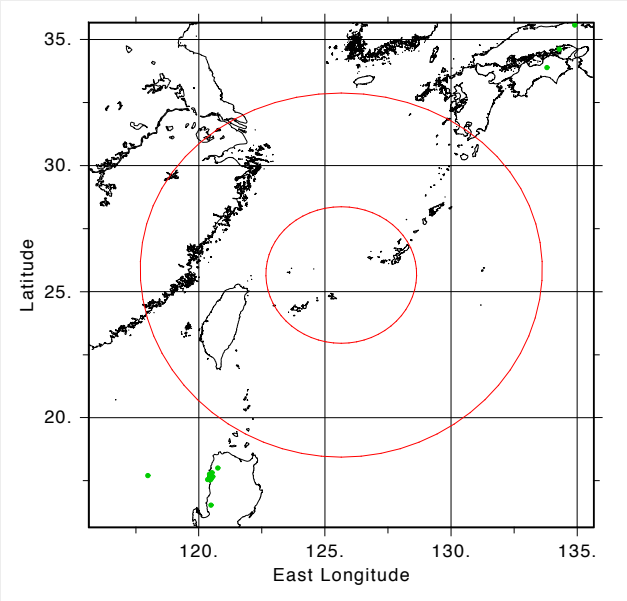
Magenta: simulation by J. Dwyer

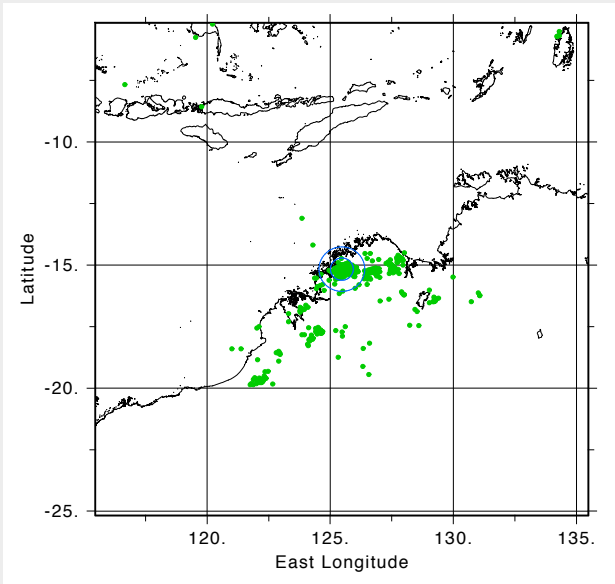


511 keV: Positrons annihilating directly on Fermi

TEB Identification







Multiple criteria:
511 keV line,
Lightning activity at possible source locations,
Mirror pulse,
Time history as predicted for TEB,
Asymmetry of detector signals.

GBM TGF Catalogs

First GBM TGF Catalog

The first GBM TGF catalog was released in January: http://gammaray.nsstc.nasa.gov/gbm/science/description.html

It has data for 2704 TGFs through 2014 July 31, including 476 triggered TGFs. High quality: cosmic rays removed by checking Fermi LAT calorimeter data.

Data included: time, spacecraft location, count intensity, duration, …

Note: all GBM γ-ray data is available from the Fermi Science Support Center (FSSC).

Second GBM TGF Catalog

The second GBM TGF catalog will be released by January. Besides updating the existing tables to ≈3450 TGFs through 2015 June 24, it will add additional data and software:

Terrestrial Electron Burst (TEB) Table (~30),
Table of VLF associations / localizations (≈1300) !
VLF maps of lightning activity,
Software for using GBM Time-Tagged Event (TTE) data.