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**LIGHT AND FAST
TERRESTRIAL GAMMA
FLASH RECORDER**

A Terrestrial Gamma-ray Flash (TGF) is a ~millisecond burst of radiation

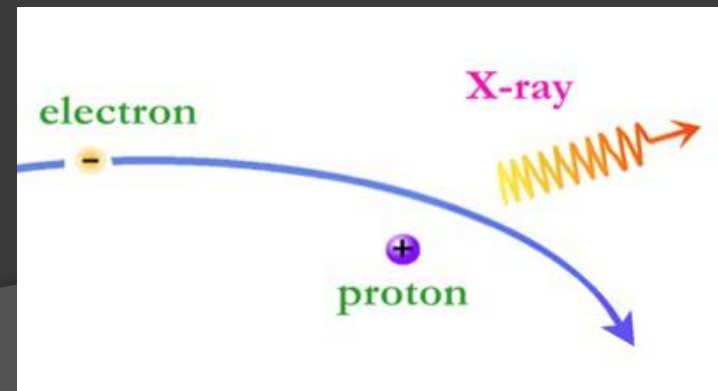
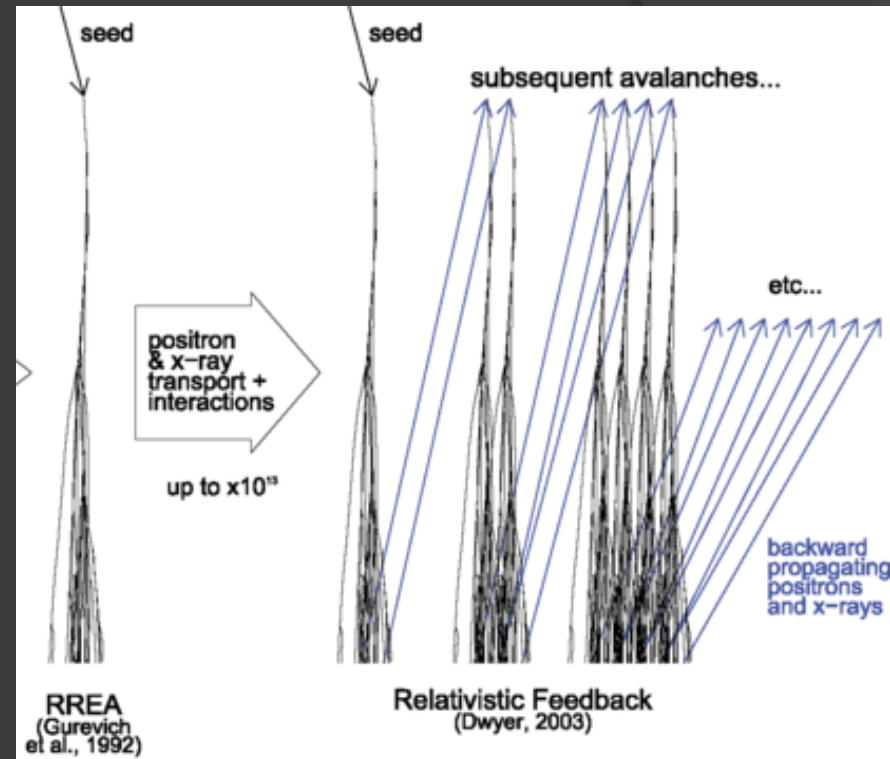
- Produced from lightning strikes
- Beamed from within thunderstorm, 10-15 km up in the atmosphere
- Accelerated electrons with energies up to tens of MeV (this is disputed)
- Short duration on the order of 0.1 to 2 ms
- Extraordinarily bright $\sim 10^{18}$ gamma rays

TGF's can be harmful

- High energy electrons scattered by TGF's can escape the atmosphere and hit orbiting spacecraft (Dwyer et al., 2008; Briggs et al., 2011)
- Radiation is intense enough to create health concern for passengers and crew (Dwyer et al., 2010)

TGF's are created by high energy electrons

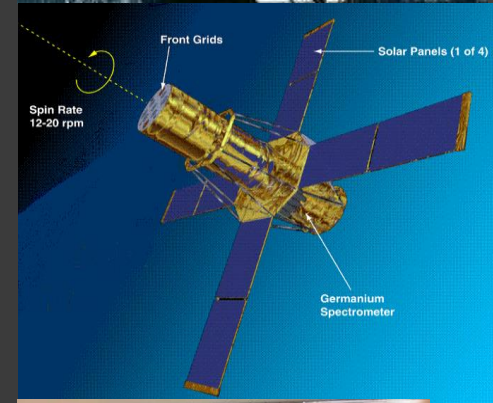
- Electrons are accelerated via strong electric field inside a thundercloud. These high energy electrons collide with the air and emit gamma rays through bremsstrahlung interactions. (Kippen, 2012)
- Still unsure what causes the initial avalanche of electrons



*Bremsstrahlung
interaction*

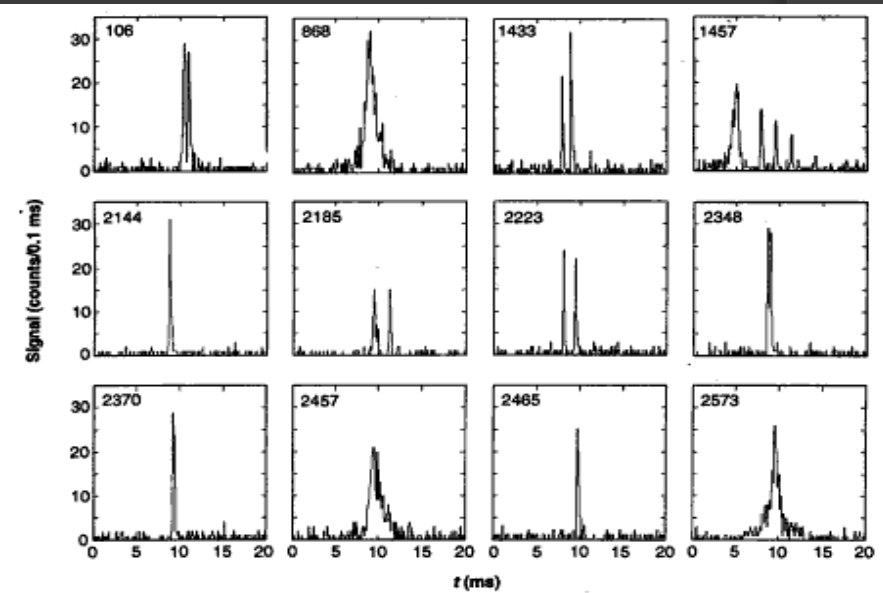
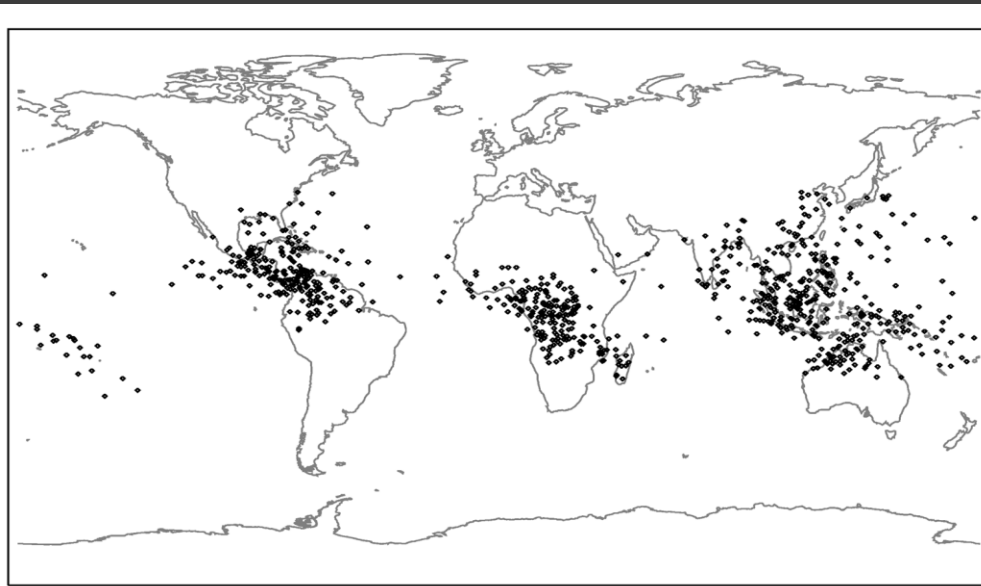
Previous detection of TGF's

- ◎ BATSE 1994
 - First detection
 - Found association with thunderstorms
- ◎ RHESSI 2005
 - Measured many TGF's,
 - Energies greater than 20 MeV
 - Association with Intra Cloud (IC) lightning
- ◎ Adele 2009-present
 - Flown on a plane at ~14 km
 - ADELE passed by 1213 lightning flashes within 10km horizontal distance and saw only one TGF (Smith, 2011)



Light and Fast TGF Recorder (LAFTR) aims to answer questions about TGF's

- What is the low intensity end of the luminosity distribution?
- What production model is favored by the time substructure?

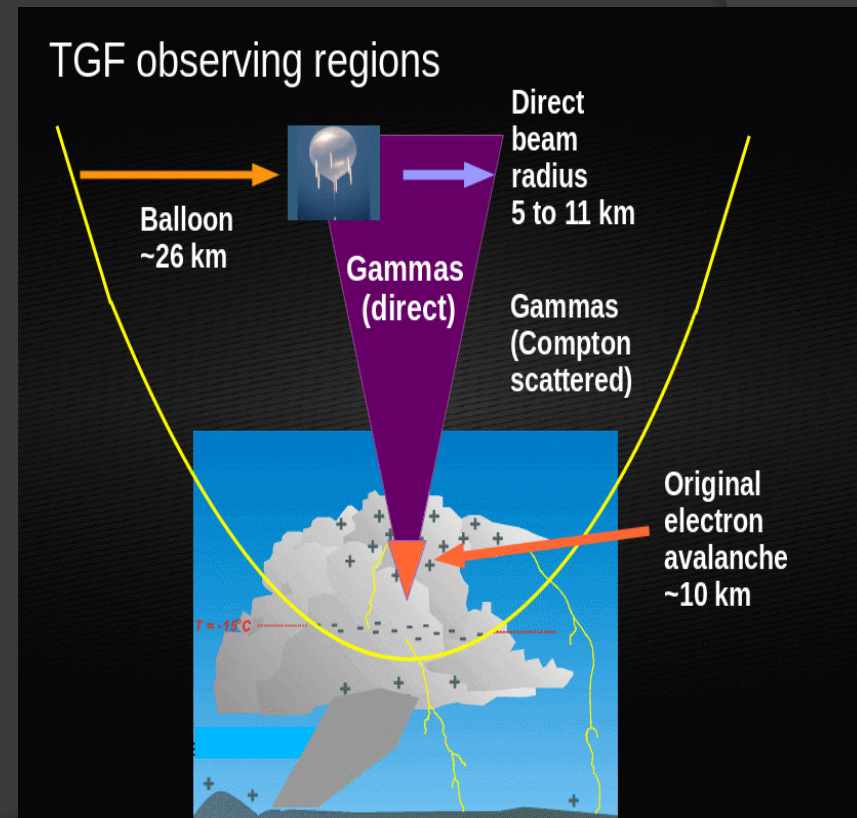


TGF map from RHESSEI satellite data

TGF time profiles from BATSE satellite data (Fishman et al. 1994, *Science*)

LAFTR has advantages over previous detectors

- Get closer to the thunderstorm
 - Gain signal according to $1/r^2$
 - Some atmospheric absorption is eliminated as compared to satellites
- Lightweight, micro payload design allows for wide deployment
- High time resolution

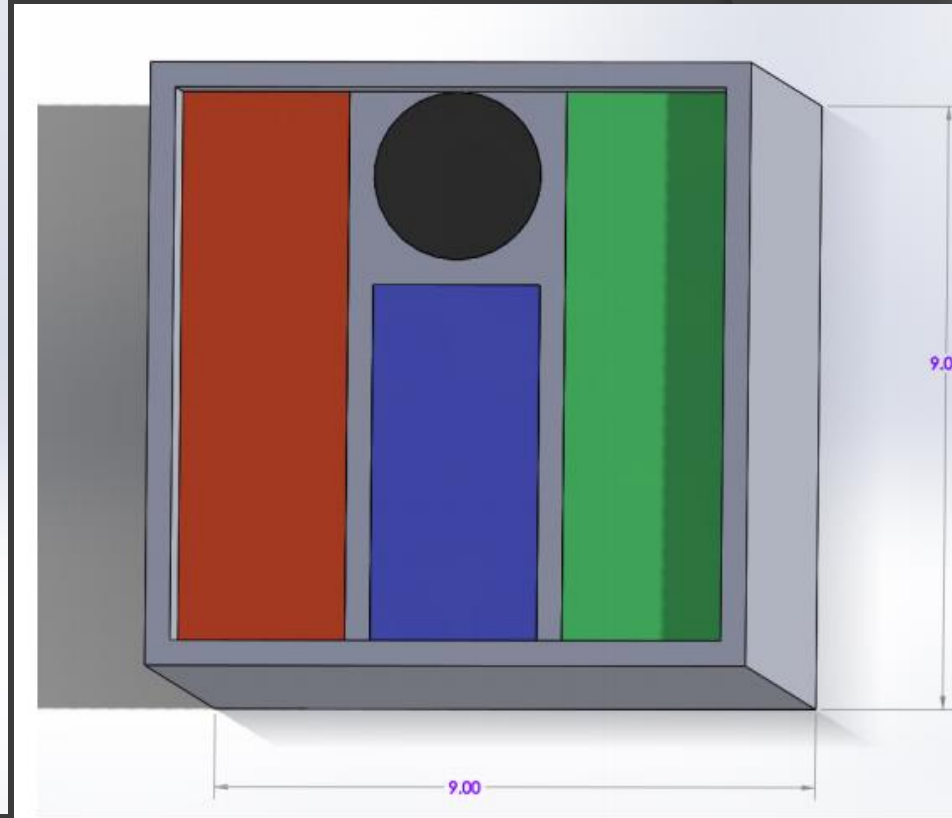
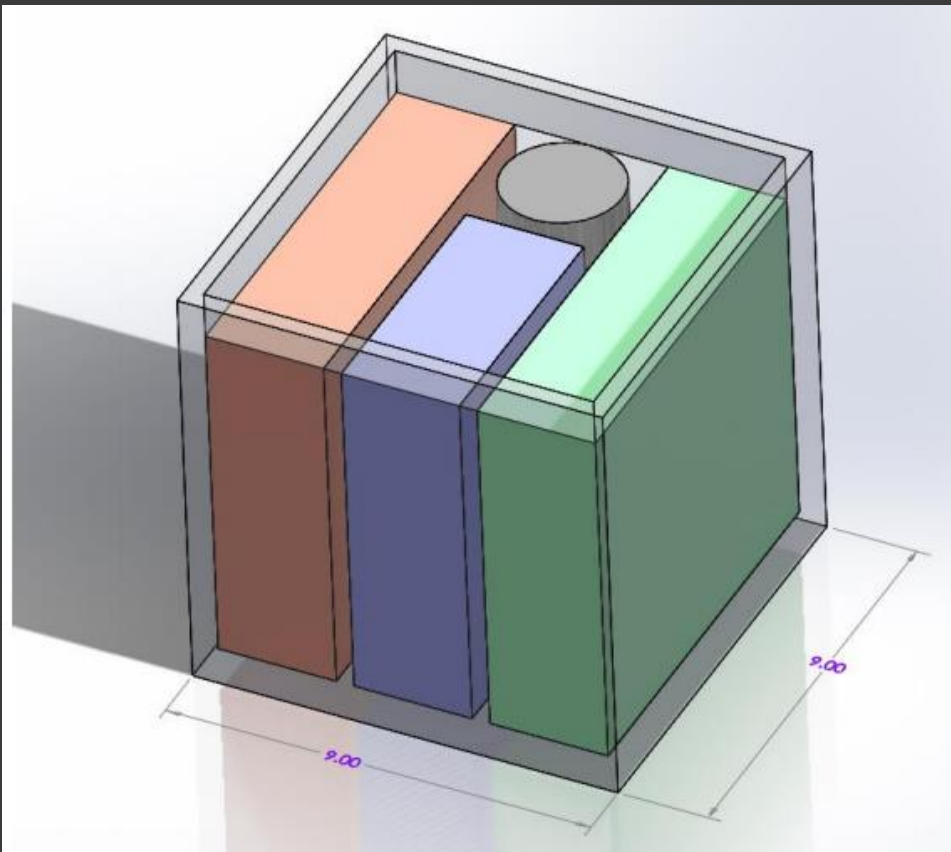


Mechanical design requirements

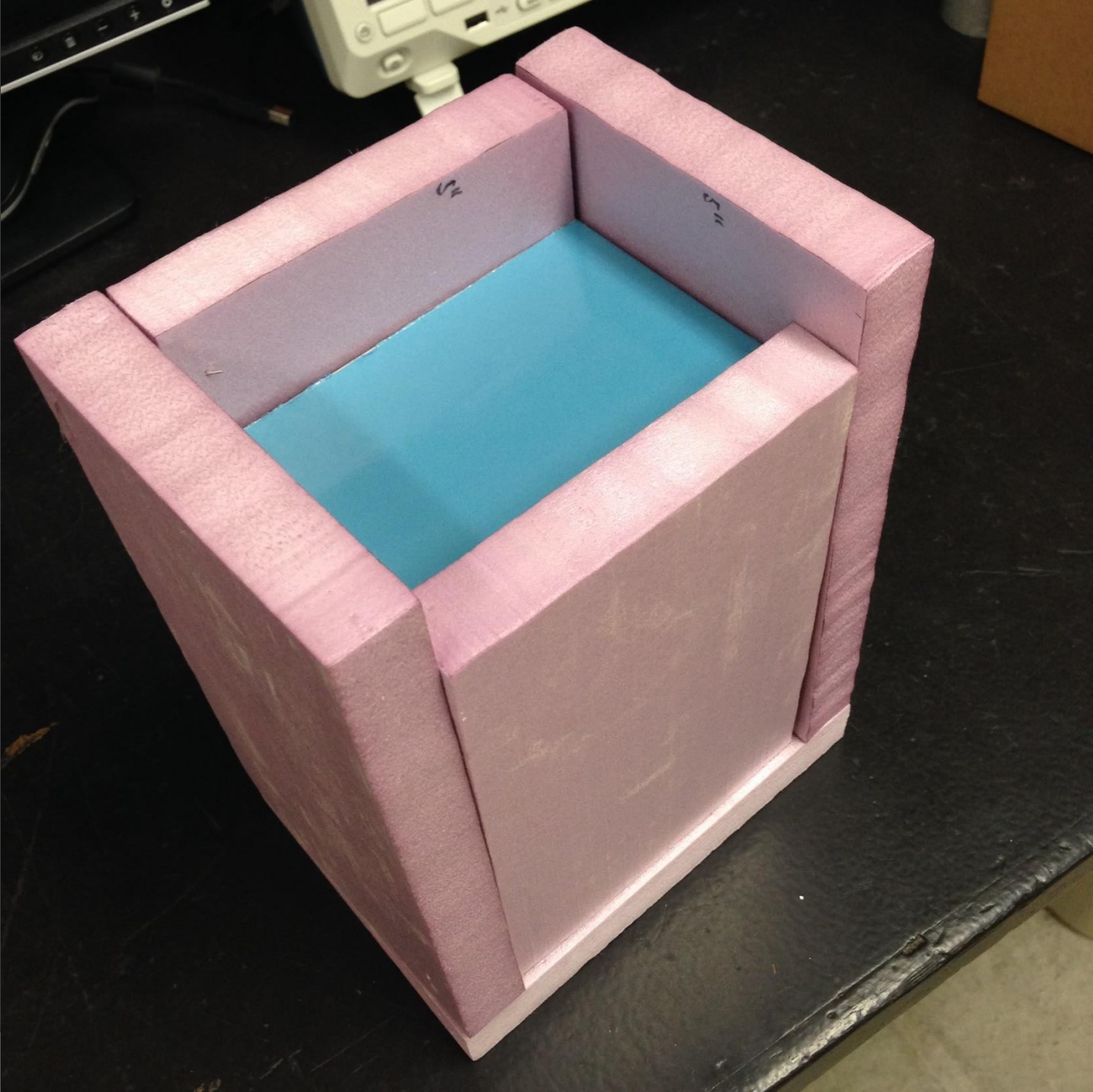
- Withstand forces of up to 2 g's on takeoff and 10 g's on parachute deployment.
- Shield electronic components from noise.
- Total weight less than 6 lb.
- Keep payload thermally stable.

Design

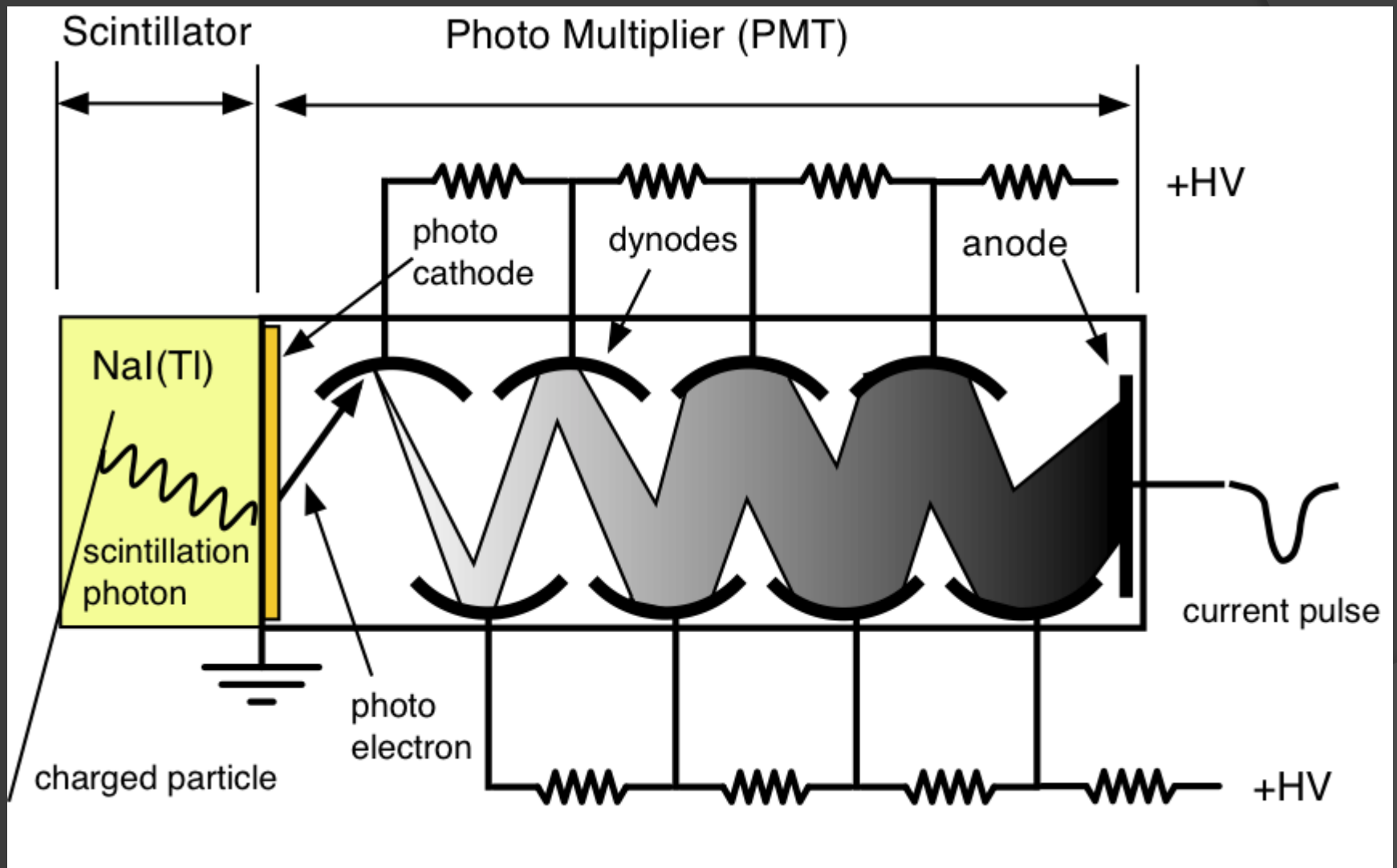
- ① Surround individual components in aluminum enclosures to avoid noise.
- ① Enclosures placed into a custom made expanded polystyrene foam (Styrafoam) box.
- ① Foam box wrapped in aluminum foil to reflect radiation from the sun and provide extra noise protection.



Transparent portion is the foam, blue case represents the power supply, green is the UCSC board, red case is the MSU board, and the black case is the detector (PMT). Units given in inches



PMT's

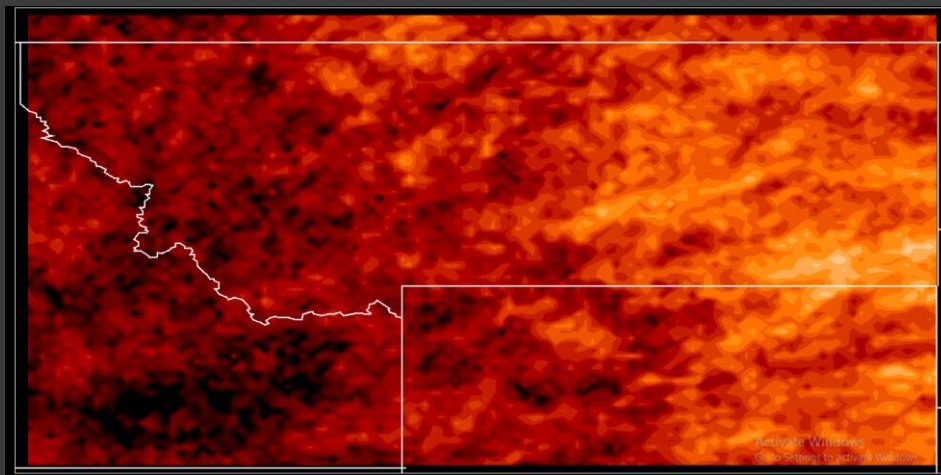


Our PMT

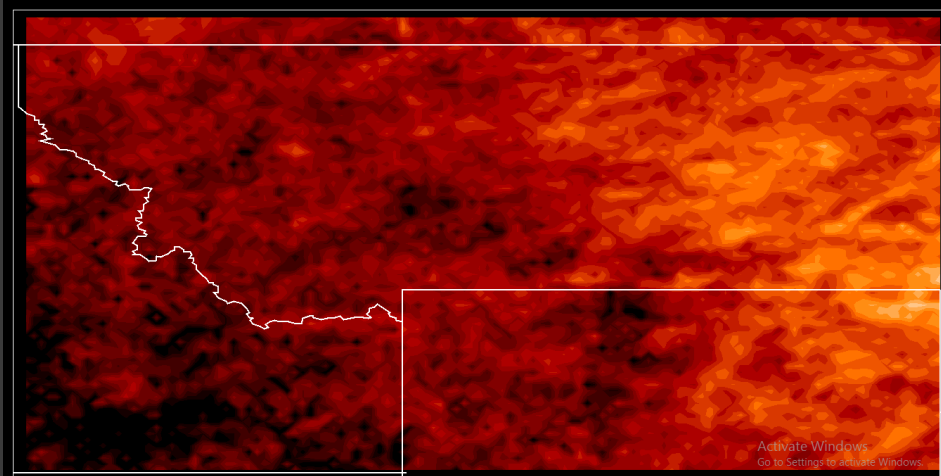


Where/When to Launch

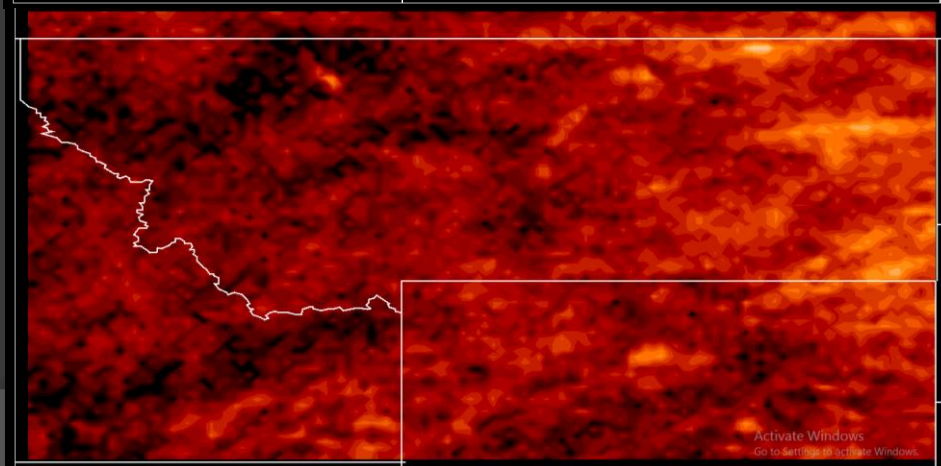
June



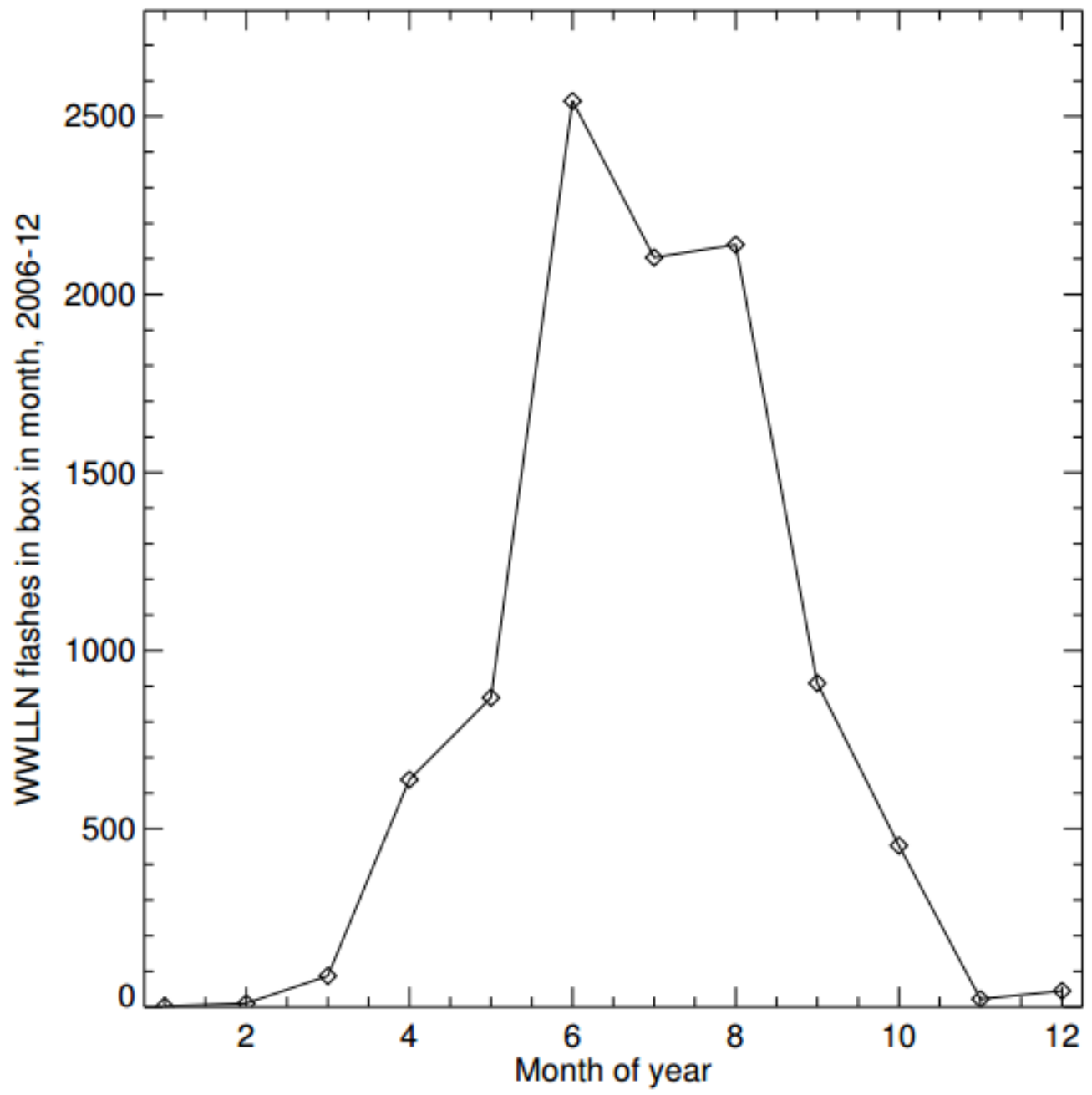
July



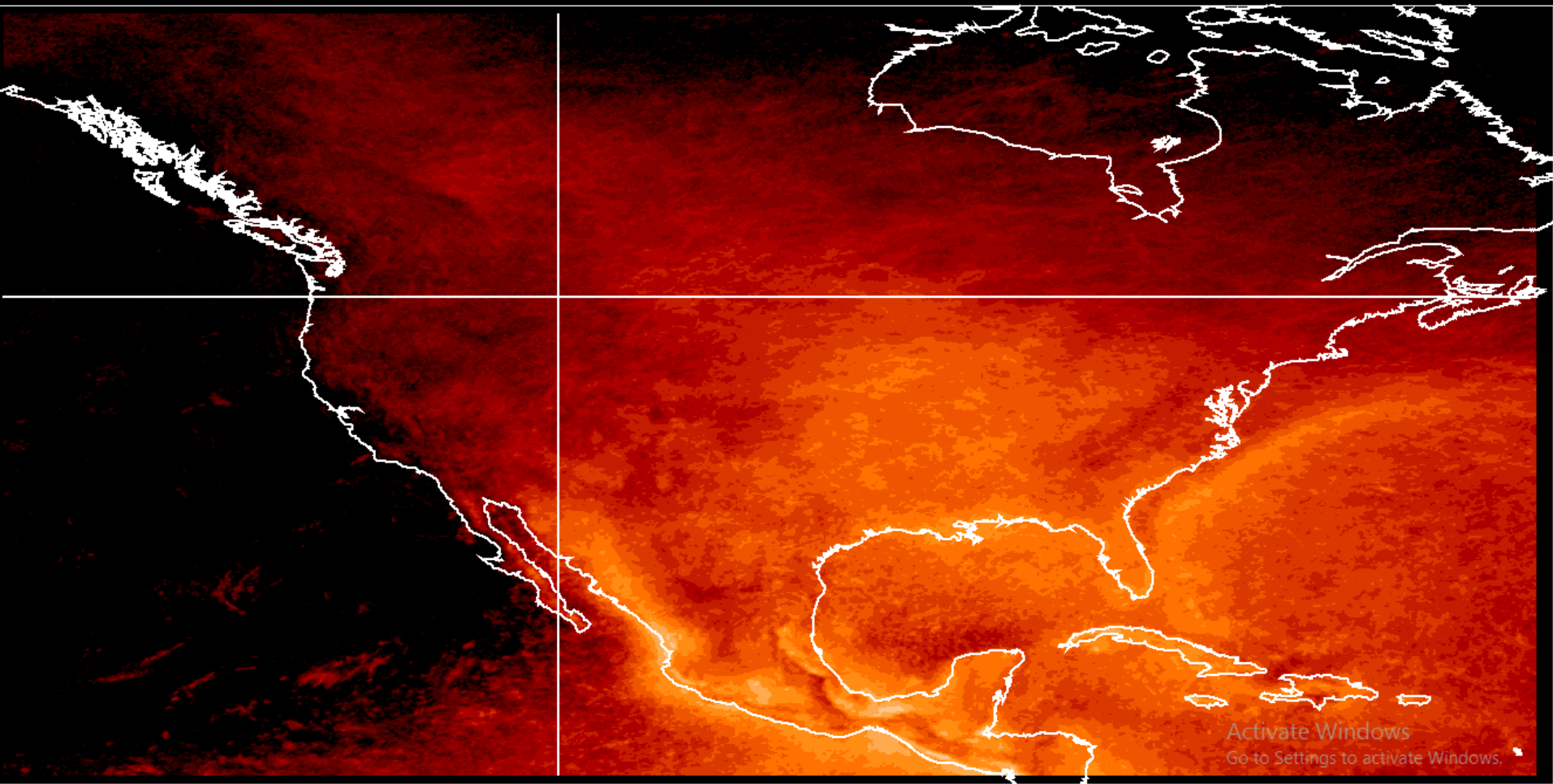
August



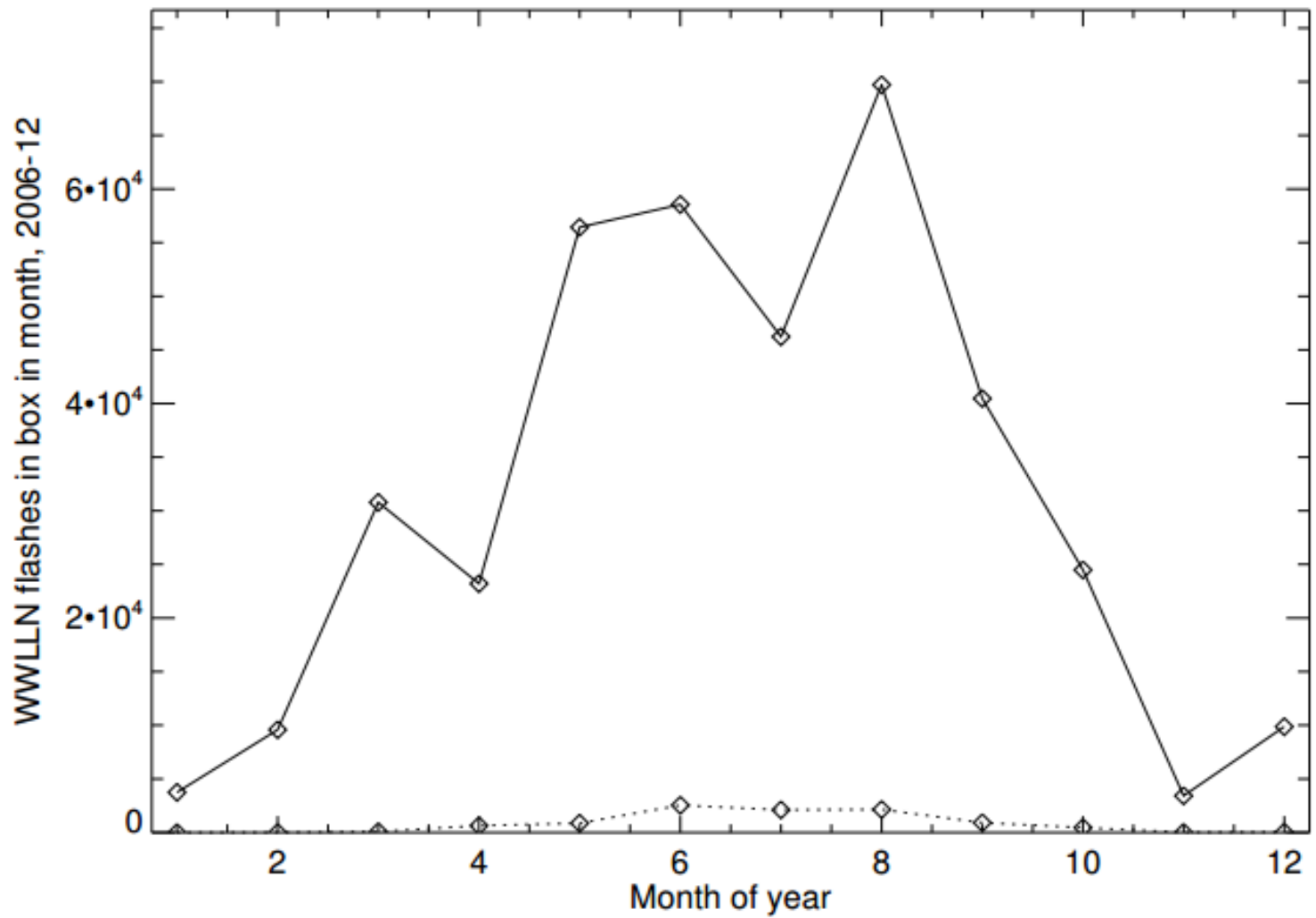
Contour maps of Lightning flashes around Montana over summer months. Brighter spots have a higher concentration of lightning.



Here or There



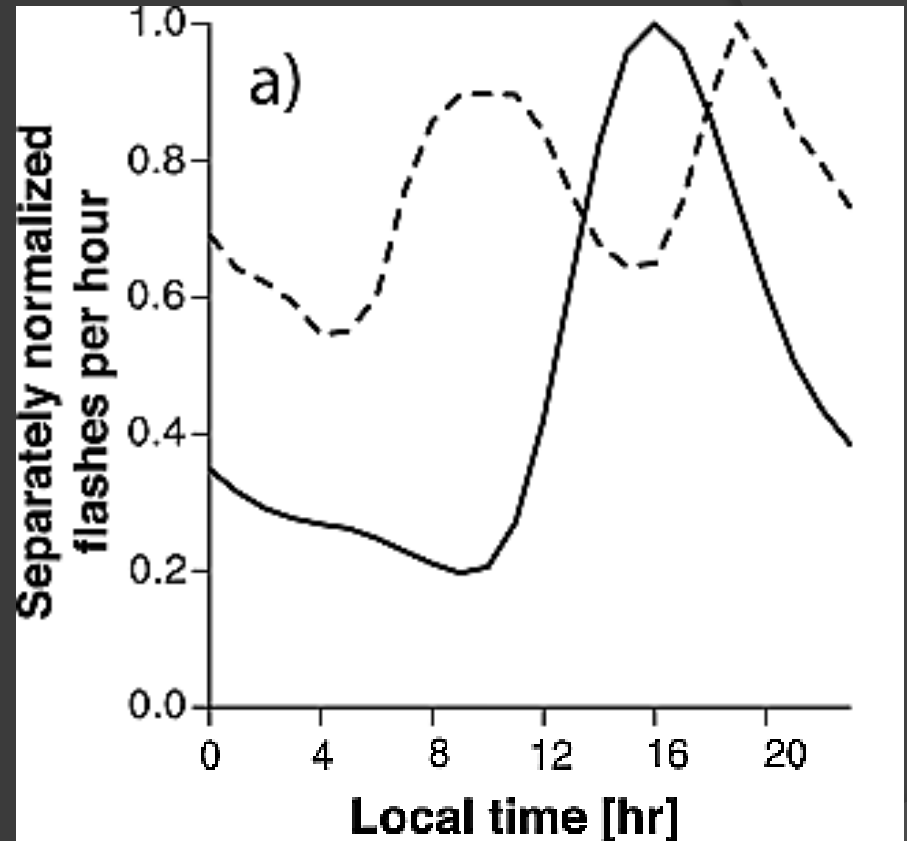
Contour map of lightning flashes in North America over the months of May, June, July, August, September. Data collected from the World Wide Lightning Location Network (WWLLN) 2006-2012



Solid line represents Florida Institute of Technology (~Orlando) and the dotted line represents Montana State University (Bozeman)

Limitations

- ⦿ WWLLN picks up less lightning flashes during nighttime hours
- ⦿ Less effective at picking up Intra-cloud lightning



Flashes per hour as captured by the NLDN (solid lines) and the WWLLN (dashed lines). The domain of the study was (25°N – 45°N and 125°W – 75°W). Bozeman is 45°N and 111°W . (Abarca, 2010)

References

1. D. M. Smith *et al.* , Science **307**, 1085 (2005).
2. D. Smith. (2015). Results and Prospects for Terrestrial Gamma-ray Flashes [PowerPoint slides].
3. M. Kippen. (2012). Terrestrial Gamma-ray Flashes [PowerPoint slides]. Retrieved from <http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-12-26453>
4. D.M. Smith, J.R. Dwyer, B.J. Hazelton, B.W. Grefenstette, G.F.M. Martinez-McKinney, Z.Y. Zhang, A.W. Lowell, N.A. Kelley, M.E. Splitt, S.M. Lazarus, W. Ulrich, M. Schaal, Z.H. Saleh, E. Cramer, H.K. Rassoul, S.A. Cummer, G. Lu, R.J. Blakeslee, Geophys. Res. Lett. **38**(8), L08807 (2011b)
5. Abarca, S. F., K. L. Corbosiero, and T. J. Galarneau Jr. (2010), An evaluation of the Worldwide Lightning Location Network (WWLLN) using the National Lightning Detection Network (NLDN) as ground truth, J. Geophys. Res., 115, D18206, doi:10.1029/2009JD013411.