TOTO-Cheyenne 2019: Ionizing Radiation from Thunderstorms on Cheyenne Mountain

Sandra Miarecki[1], Matthew McHarg[1], Jacob Harley[1], J Eric Grove[2], and Eric Wulf[2]

[1]US Air Force Academy
[2]Naval Research Lab DC

November 22, 2022

Abstract

We present our results on the second year of TOTO-Cheyenne (TGFs On Top Of Cheyenne), a continuing collaboration of the US Air Force Academy and the Naval Research Laboratory. The project's goal is to study the ionizing radiation as lightning strikes near the antenna farm on the top of Cheyenne Mountain, near Colorado Springs CO. Thunderstorms and accompanying lightning produce ionizing radiation on time scales from milliseconds to minutes. This radiation includes terrestrial gamma-ray flashes, hard X-rays from stepped leaders, gamma-ray glows, and thunderstorm ground enhancements. Recent measurements indicate that getting up close and personal with the storms might produce more details about the complex processes inside. The US Rocky Mountains offer the opportunity to do just that by getting closer to the charge layers. This year's experiment (starting in May 2019 and continuing to October 2019) involved the setup of a high speed camera at the Air Force Academy facing south to watch Cheyenne Mountain plus the reinstallation of a small gamma-ray and X-ray detection system (NaI and plastic scintillators) on the mountain. This year has proven to be a very active storm year. As of 20 July, there were already 25 strikes within 2 km of the detector (compared to 1 strike during the summer 2018).

TOTO-Cheyenne: Ionizing Radiation from Thunderstorms on Cheyenne Mountain

Sandy Miarecki, Geoff McHarg, Jake Harley – US Air Force Academy
Eric Grove, Eric Wulf – Naval Research Laboratory

BACKGROUND:

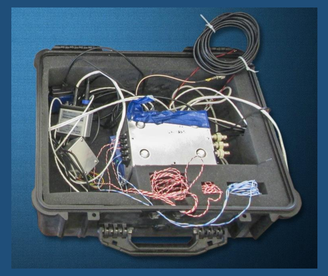
- Year 2 of study of high-energy radiation from thunderstorms in Colorado
- Put detector up close and personal to the charge layers, on top of isolated mountain
- Cheyenne Mountain is 9570 ft (2917 m), southern end of extended mountain range
- Radiation detector at base of radio towers at 9440 ft (2877 m), cinder block building
- High speed camera watching from afar to correlate radiation data with actual strike
- Camera on mountain sees lightning and changes color (pink) with close strike

2019 RECAP

- 23 days of storms during summer 2019 (1 Jun to 1 Oct)
- 158 total NLDN strikes within 5 km, 141 -CG, 17 +CG
- 74 total camera strikes: 20 strikes within 5 km of detector
- 1 positive strike at 0.14 km away on 22 Jul at 22:17:57 Z
  - No excess radiation recorded in detector on mountain
  - Camera already full from local storms that day, no data

DETECTOR:

- Two 3x3” cylindrical NaI (Tl) crystals (with Bridgeport)
- Two 2x2x2” plastic scintillator cubes (with Bridgeport)
- One 1x1x1” plastic cube (readout by a silicon PMT (SiPM) and Bridgeport)
- Beagle Bone Black running Ubuntu Linux 14.04
- Pressure, temperature sensors, Trimble Copernicus II GPS
- Housekeeping data to SQLite database every second
- Effective energy range of 100 keV to 12 MeV
- Pulse-per-second (PPS) from GPS to all modules
- Records internal oscillator time at arrival of PPS
- Beagle Bone to USB hub, readout few per second
- System clock time plus PPS time allows the signals from all 5 detectors to be time-aligned (1 ms accuracy) to look for coincident events



HIGH SPEED CAMERA:

- Phantom V2011 - 1 MP digital camera
  - Widescreen CMOS sensor up to 22 GP/sec at full resolution of 1280 x 800, > 22,000 fps
  - Used 60,000-67,000 fps for field of view
  - Exposure 4 μs every ~15 μs
  - Auto-triggering feature (set and forget)
  - Maximum of 20 events per day (without reset)
- Located on 5th floor of Fairchild Hall, facing south
- Approximately 18.5 miles (30 km) away from detector
- Time synchronized to GPS (accuracy ~ 5 ns)

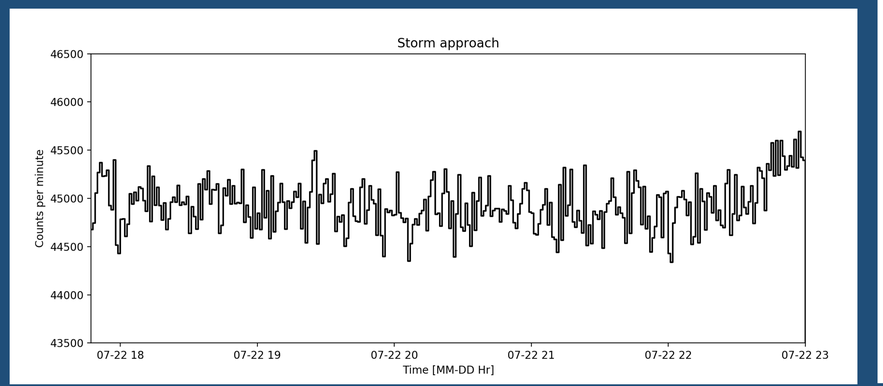


Figure 1: Total background count rate in the five scintillators during the approach of a thunderstorm on 22 July 2019. The time series starts shortly before a strong but distant +CG reported by NLDN at 22:17:57Z (145 kA, 7.4 km away) and ends after a moderate +CG at 22:46:51Z (38 kA, 0.14 km away), when radon washout is visible as an increase in background count rate. No excess counts were detected from the very close +CG. Count rates are dominated by the 3x3” NaI(Tl) detectors.

NLDN positive CG strike list for 22 July 2019

TIME	ms	kA	LAT	LONG	km
22:17:57Z	691	145.2	38.766	-104.944	7.39
22:38:35Z	188	78.6	38.757	-104.921	5.17
22:43:50Z	695	60.6	38.748	-104.909	3.91
22:46:51Z	454	37.9	38.743	-104.866	0.14
22:49:03Z	735	26.7	38.682	-104.950	10.00

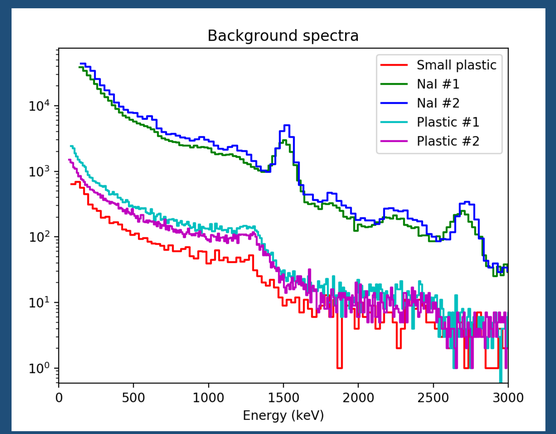


Figure 2: Sample background spectrum in each of the five scintillators. Prominent background lines are visible in the NaI(Tl) detectors at 1460 keV from ^{40}K and 2614 keV from decay of ^{232}Th. Compton back-scatter peaks from the two lines are visible in the plastic scintillators.

Mountain strike (-CG) on 16 July at 21:10:22Z

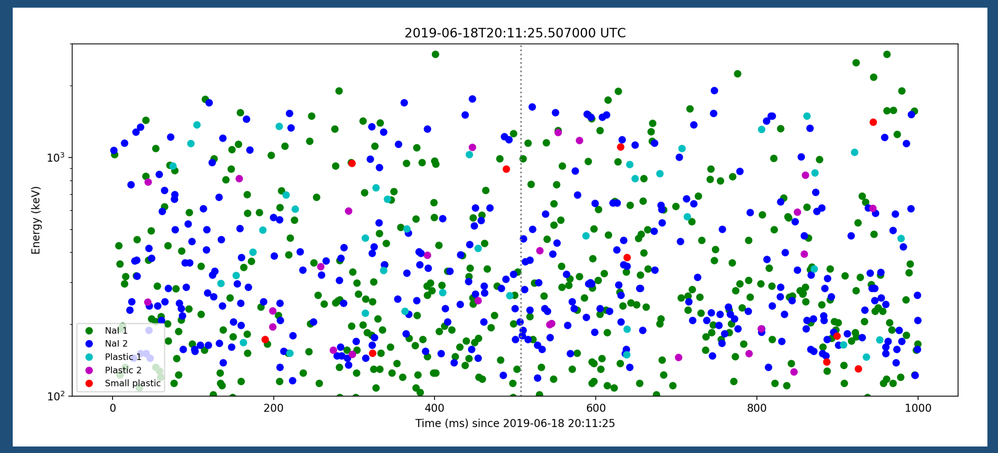


Figure 3: Scatter plot of photon energy as a function of time for events surrounding the 92 kA -CG that struck ~1.8 km away on 18 June 2019 at 20:11:25Z. Events are color-coded by scintillator. No excess events from the approaching stepped leader are visible. Attenuation of hard X-rays is expected in the intervening atmosphere and materials of the building in which the detectors are housed.