Measuring the Electric Field During Thunderstorms by the Telescope Array detector

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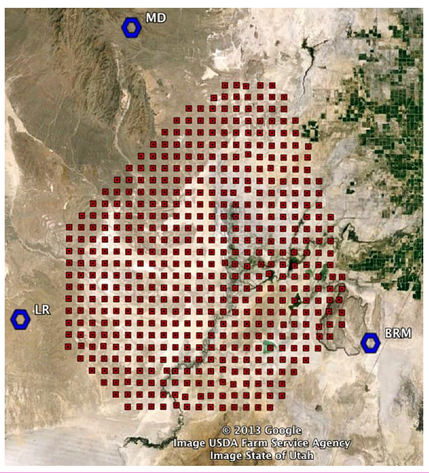
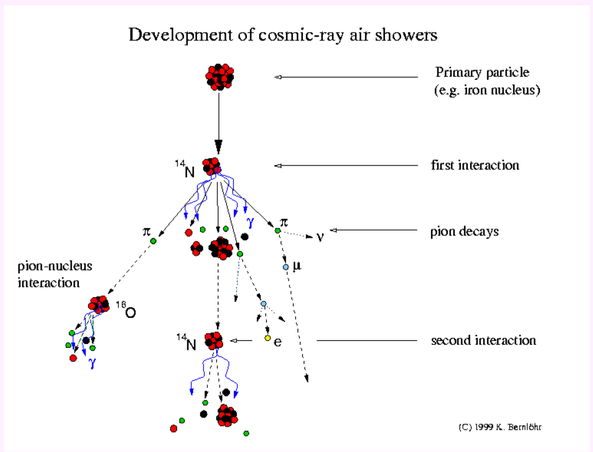
ABSTRACT:

Acquiring knowledge of electric field strength and structure inside a thunderstorm is key to understanding lightning and thunderstorms' impact on the development of cosmic showers. Given data from the Telescope Array Surface Detector (TASD), we observed variations in cosmic ray shower intensity. These variations were found to be on average between 0.5-1% with and up to 2-3%. These observations were detected in both deficit and excess. The rate variations were also correlated with lightning and thunderstorms. In order to more closely study these variations, we ran low- and high-energy simulations of electric fields within thunderstorms using CORSIKA. These simulations yielded a reasonable result of electric field magnitude variations between 0.2-0.4V, which in turn has informed our understanding of the electric field within storms and its effect on cosmic ray showers.



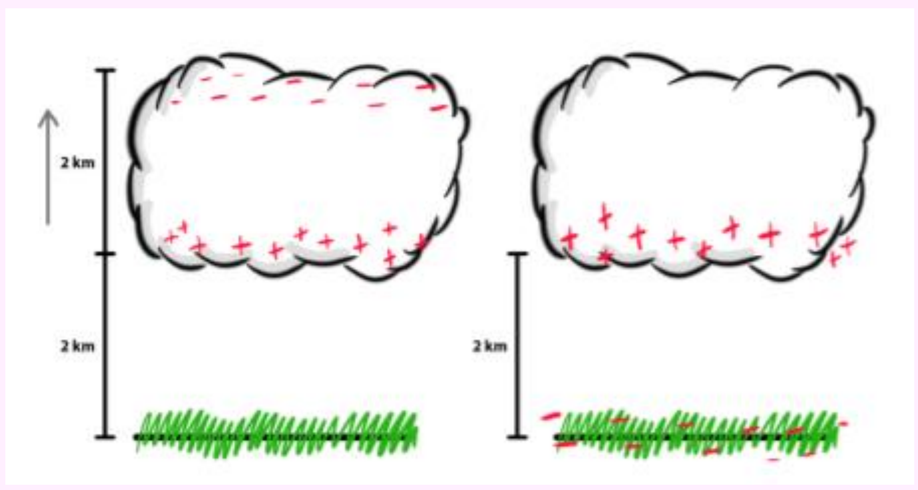
This is the Telescope Array Surface Detector (TASD. Located in Southwestern Utah, the TASD covers a 1.2 km grid. The red filled dots represent the 507 SD scintillators, which are plastic and sensitive to charged particles. The Blue Hexagons indicate the fluorescence detector. The northernmost fluorescence detector is called Middle Drum while the southern fluorescence detectors are referred to as Black Rock Mesa and Long Ridge.

Extensive Air Showers



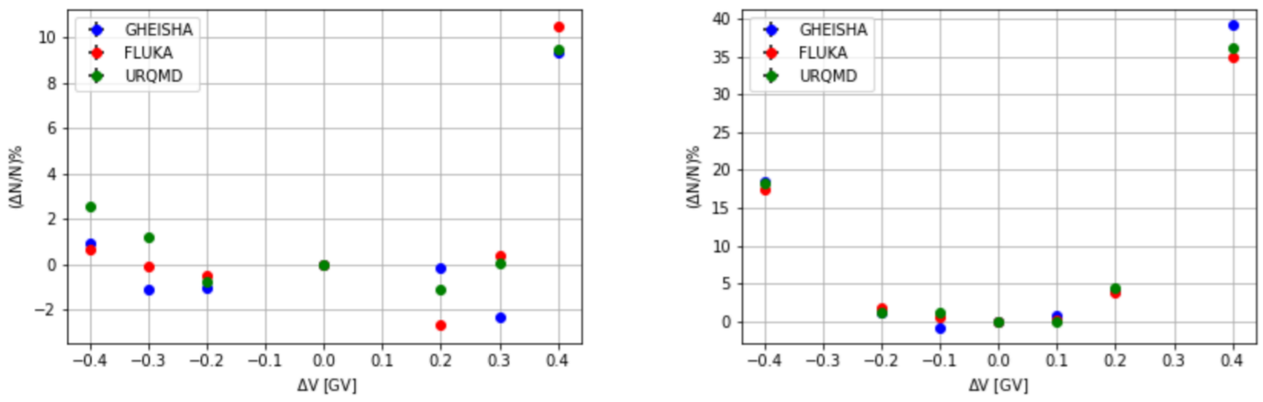
The development of a Cosmic Ray Shower. Scientists are unable to study Cosmic Ray Showers directly, so rather the cascade of particles referred to as the Extensive Air Shower (EAS). Our project studies the variations in the EAS as it porpgates through the electric field of thunderstorms. This method is safer than historical methods of measuring the electric field and relies on ground-level surface detectors.

Monte Carlo CORSIKA Simulations



The simple parallel plate capacitor model for our CORSIKA simulations.This project creates Monte Carlo simulations using the Cosmic Ray Simulations for Kascade (CORSIKA). Electric fields ranged between -2000 to 2000 V/cm, using two different types of models: intracloud and cloud-to-ground. Each model is 2km wide, ranging from 3.4 - 5.4km and 1.4 - 3.4km respectively.

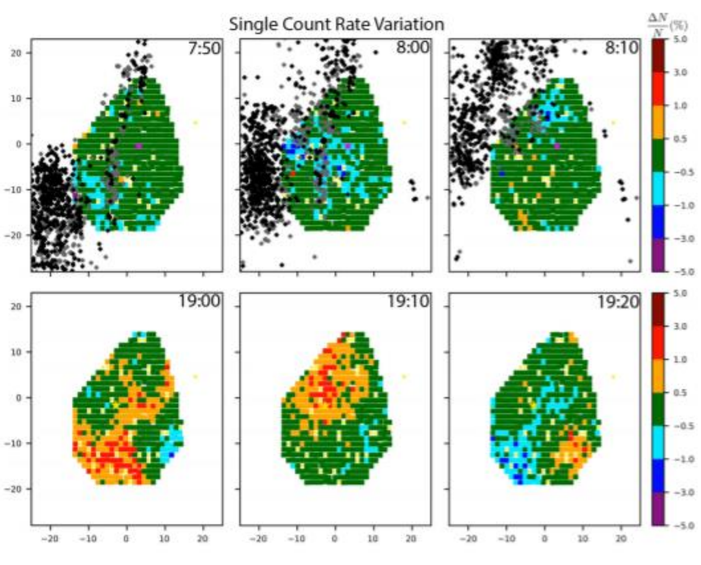
Component Excesses & Deficits:



Above Left: Change in GV potential vs. %-change in particle intensity for the Intracloud model.
Above Right: Change in GV potential vs. %-change in particle intensity for the cloud-to-ground model.

These graphs indicate excesses and deficits in particle distribution and intensity upon reaching the TASD. The change in intensity indicates a deficit in particle intensity until a +/- change in potential, after which point there are observed excesses.

Observations at the TASD



Evolution of Intensity Change over time. These images represent changes in the single count rate change (ΔN/N) in storm data from over the TASD. This storm is from September 27, 2014.

The reds represent increasing excesses, while the blues represent deficits. In addition, these graphs represent the data from the NLDN. The black dots represent the lightning present at the time of the storm.

Future Plans:

We will continue to investigate the past 14 years of observations by the TASD more thoroughly, using the National Lightning Detection Network (NLDN) and the Lightning Mapping Array (LMA) data from the same time period. To interpret the TASD observations more precisely, we need to know the polarity of the thunderstorm. This could in principle be achieved by implementing an array of Electric Field Mills (EFMs) at the Telescope Array site, which will allow us to better understand the polarity of the observed thunderstorms and therefore model them. Currently, an Electric Field Mill remote station has been installed approximately in the middle of the Telescope Array site for testing. Next steps will include processing that data in tandem with the recent data from the TASD.

References:

"Observation of Variations in Cosmic Ray Shower Rates During Thunderstorms and Implications for Large-Scale Electric Field" International Cosmic Ray Conference 2021, Berlin Germany.