P512 Monitoring Atmospheric Electrification for Operations and Collaborative Studies at the U.S. Army West Desert Test Center

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1. Introduction

The West Desert Test Center (WDTC) located at Dugway Proving Ground in western Utah is the primary testing facility for Department of Defense chemical and biological defense. State of the art testing laboratories and extensive field test grids at Dugway Proving Ground are roughly an hour and a half drive from Salt Lake City, in the remote West Desert of Utah. In addition to chemical and biological defense testing, the range hosts a variety of training and live fire exercises throughout the year. In support of the missions at WDTC, the Meteorology Branch of the Data Sciences Division at WDTC maintains a vast array of observation systems, sensors, and capabilities covering the range and the surrounding area. The data generated by these systems are used for test records, local climatology used for test planning, monitoring of conditions during test execution, local forecasting, and the issuance of watches and warnings for hazardous weather conditions impacting life and safety of range activities. During the warm season, thunderstorms present a threat to the safety of range personnel and equipment, particularly during late July and August when the North American Monsoon is active. To mitigate the risks that thunderstorms pose to personnel and equipment, the Meteorology Branch maintains a twelve-station lightning mapping array (LMA) and a network of fifty CS110 electric field mills (EFM).

2. Lightning Mapping Array

WDTC's LMA network locates in three dimensions impulsive sources of radio frequency radiation in an unused portion of the very high frequency (VHF) television band (60-66 MHz) (Rison et al., 1999; Krehbiel et al., 2000). VHF radiation sources are known to be associated with lightning. At least six active LMA stations are required to develop a 3D time series that determines latitude, longitude and altitude of VHF sources emitted by lightning. This remote sensing technology provides more detailed observations and hence warning of in-cloud and cloud-to-ground lightning for high-impact targets across the test range.

Each station consists of a VHF antenna and receiver, a GPS antenna and receiver, LMA motherboard, PC104 computer, pre-amplifier, logarithmic amplifier, a Redline radio and antenna to provide communications (Figure1). Solar panels with batteries provide power to the LMA station and communications relay. WDTC's LMA network consists of 12 LMA stations (Figure 2) strategically located near and across the range, as well as a central processing server that hosts the data ingest, station monitoring, production of real-time density and point source images. The LMA website is also hosted on a central processing server that allows users to access a repository of historic graphical data products and raw data files.

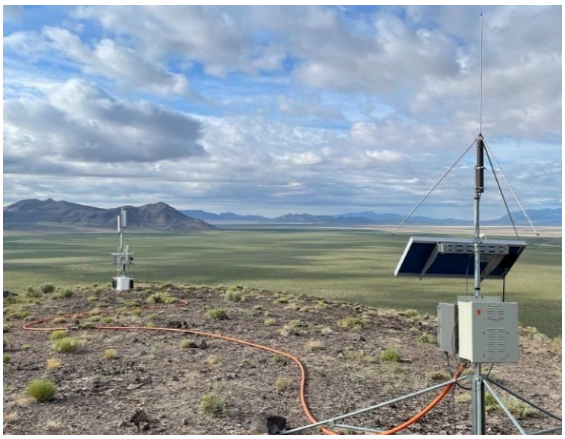


Figure 1 Lightning Mapping Array Receiver and Data Relay Equipment

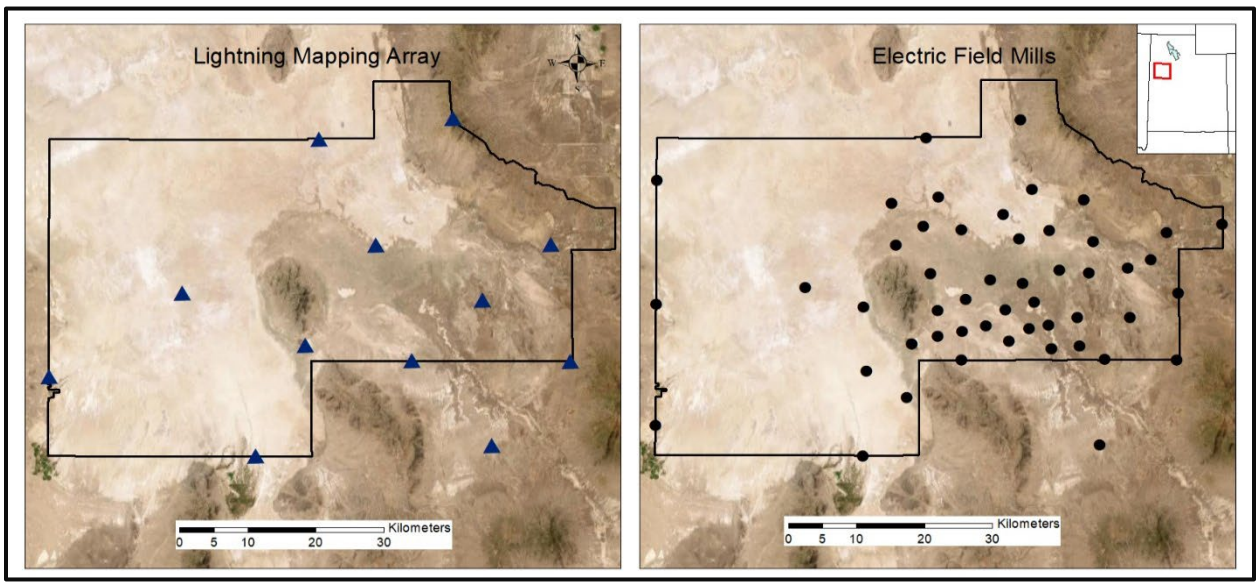


Figure 2 Lightning Mapping Array Receivers (left) and Electric Field Mill locations (right).

3. Electric Field Mills

The Meteorology Branch at the WDTC maintains a network of 50 electric field mills (EFMs) for monitoring ambient atmospheric electric charge. These charge values are primarily utilized operationally to maintain situational awareness and for range safety and help meteorologists in the issuance of lightning warnings and subsequent all-clear notifications for range operations. Campbell Scientific CS110 electric field mills are deployed across the range to provide sufficient coverage over high-activity test grids and critical infrastructure. Kimball & Gallagher 2008 previously documented a 28-station layout across the eastern part of the test range. The network has since been expanded to 50 stations covering the entire installation as shown in Figure 2. Nearly all the stations are on the valley floor at an elevation of 4300-4400ft. Stations 8 and 20 are located in the eastern portion of Dugway at an elevation of approximately 4800 ft on relatively flat terrain, while station 9 sits atop Sapphire Mountain at nearly 4800ft and roughly 500ft above the surrounding valley floor.

Each EFM site (Figure 3) consists of a CS110 mounted downward facing at a height of 2m on a Campbell Scientific CM10 galvanized steel tripod. A small solar panel (50W or greater) is attached to the south facing leg of the tripod, connected to a Morningstar Sunsaver-10 charge controller which is located inside a Campbell Scientific ENC 16/18 fiberglass enclosure.

The charge controller is connected to a 12V 80Ahr deep cycle battery to provide power during overnight hours or periods when cloud obscuration limits the energy produced by the solar panel. A Freewave P-CE spread-spectrum (1350-1370MHz) radio connected to a Astron Wireless Technologies Model 1370-8 Yagi antenna provides two-way communication with the instrument. The site is grounded using a 5ft long copper rod driven into the ground with copper wire connectors to the tripod, fiberglass enclosure, and CS110 mounting hardware.



Figure 3 Electric Field Mill Site.

The CS110 EFMs have a measurement range of 0 to ±22,300 V/m and a lightning strike efficiency of 95% within 5 miles (CS 2023) and are programmed to sample at 1Hz. Limitations in the radio network used to relay the data back for collection reduce the frequency of transmitted observations to once a minute instantaneous measurement. The 1Hz data is retained on the CS110 onboard CR1000 datalogger for roughly three days which allows for manual collection of data for events of interest. Parameters in the logger data table are electric field, instrument status, leakage current, panel temperature, battery voltage, and internal relative humidity.

Inside the Meteorology Branch's operations room, the EFM data are displayed using the Real-Time Monitoring and Control Software that is part of Campbell Scientific's Loggernet software. The display contains a table layout of the most recent data from each station and an aggregate line chart of all the operational stations. The electric field value will be highlighted when greater than or less than 2000 V/m to alert the meteorologist on duty who is responsible for issuing lighting warnings. During quiescent conditions, the line chart provides an easy qualitative method to identify outlier stations that may need maintenance.

4. Electric Field Mill Observations During Blowing Dust

The primary purpose for the EFM network is to inform meteorological operations in decision support for potential lightning hazards over the range. The EFM network operates continuously, year-round and measurements have been made of elevated ambient atmospheric charge not associated with thunderstorms or deep moist convection.

An informal examination of human observer generated METAR reports for Michael Army Airfield (KDPG) revealed that observations of blowing dust on station or at distance were most frequently reported in April and May, but possible in any month with rare instances observed in November, December and January. Two recent cases of blowing dust, resulting in triboelectrification recorded by the WDTC EFM network are highlighted where the measured electric field exceeded the 2000V/m value that is highlighted in the real-time data display.

4a. Observations During 18 April 2023 Dust Storm

On 18 April 2023, a negatively tilted short wave trough moved across the Great Basin region. A cold front associated with the short-wave trough moved south across Utah, crossing the range midday. Post-frontal winds from the NW increased with gusts to 40kts that lofted a large amount of dust. The weather observer at Michael Army Airfield recorded a surface visibility of ¼ of a statute mile (SM) for the 1850UTC METAR. A Vaisala PWD22 at the airfield recorded a 1-minute

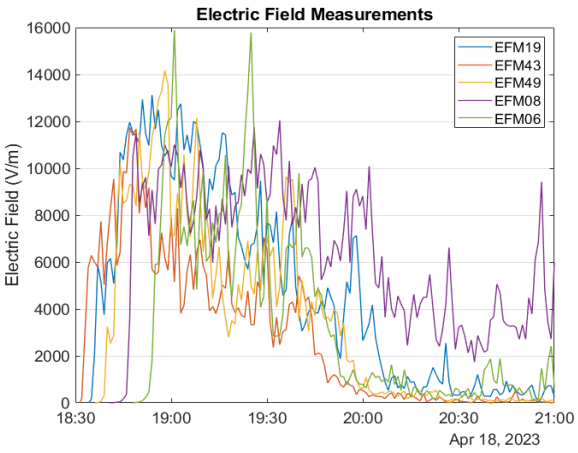


Figure 4 EFM Measurements in during and after the cold front.

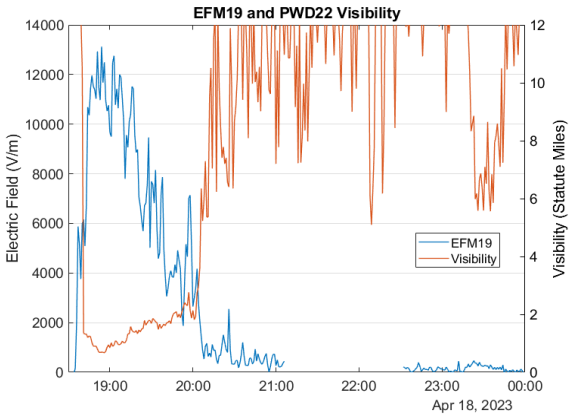


Figure 5 EFM measurements (blue) with visibility measurements (orange).

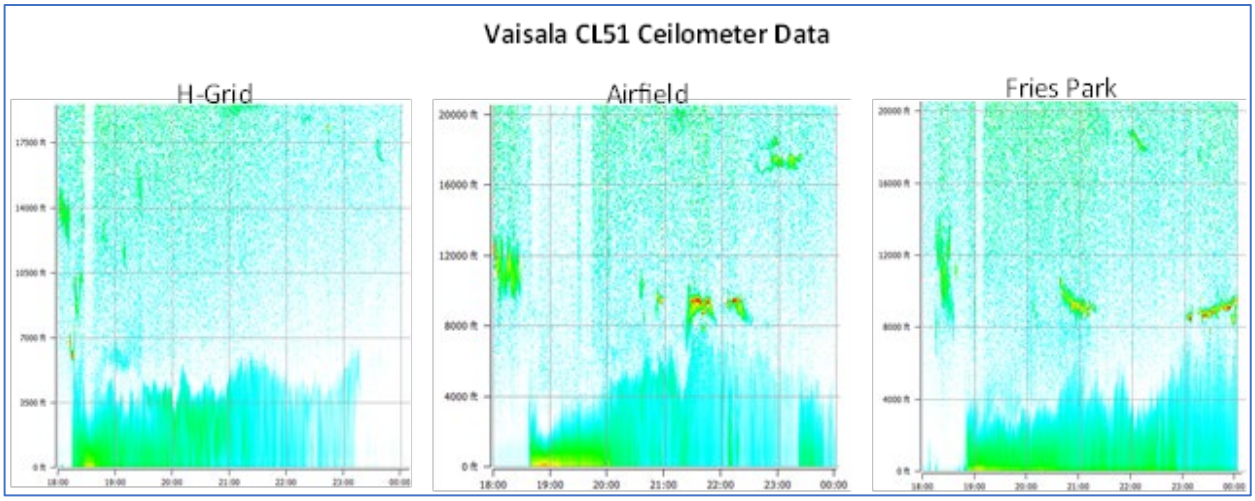


Figure 6 Ceilometer backscatter showing the depth of dust in the post-frontal airmass.

average visibility of 0.7SM at the time of the METAR. EFM19 and other nearby EFM station measurements shown in Figure 4 document magnitude of the triboelectrification measured at the arrival of the dust laden cold front with Figure 5 showing the decrease in visibility at the same time as the electric field measurements increase. Ceilometer data in Figure 6 shows the backscatter from the dust in the boundary layer at three different locations across the range. EFM19 located at the airfield recorded a peak charge of 13000 V/m at 1854UTC at the same as the maximum ceilometer backscatter values are seen near the surface.

4b. Measurements during Blowing Dust on 17 June 2024

On 17 June 2024, a dry cold front crossed the range in the afternoon, reaching the airfield between 2000-2100UTC. The prefrontal winds were out of the NW at 10-15kts gusting to 20kt and post-frontal winds increased to 25-30kts with a peak gust of 44kts from the NW. Surface visibility decreased after 2000UTC from 25SM to 10SM at 2100UTC and the final manual observation of the day at 2300UTC surface visibility at the airfield was 5SM. The PWD22 recorded visibility (Figure 7) aligns with the manually observed report and the decreased visibility coincided with increased electric field measurements. Other EFMs near the airfield showed elevated electric field values though the peak values among the stations vary considerably. In Figure 8 the CL51 backscatter data at the airfield shows the increase in dust with the arrival of the front, and the depth of the frontal layer with enhanced elevated backscatter at the airmass transition. Ultimately, shallow clouds formed at the top of the frontal layer beginning around 2300UTC, at the same time as the maximum low-level backscatter from the dust is recorded corresponding to the maximum electric field measurement in Figure 7.

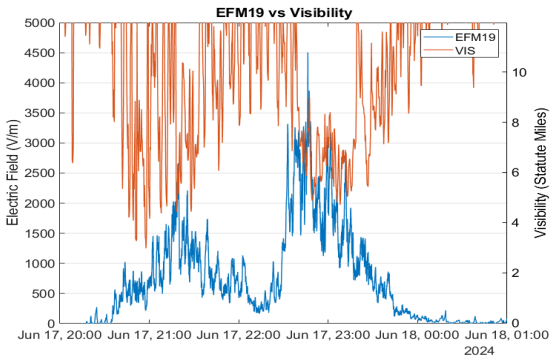


Figure 7 EFM measurements (blue) with visibility measurements (orange).

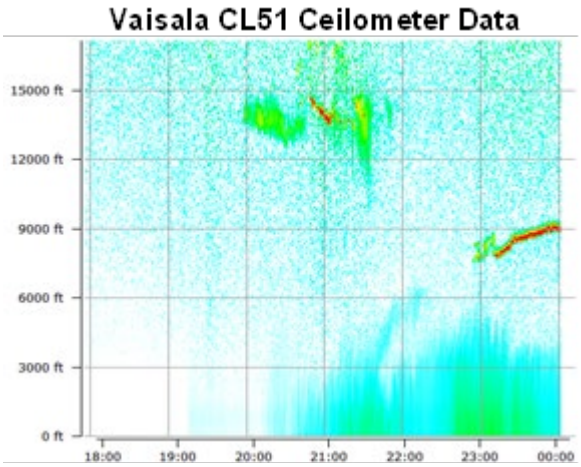


Figure 8 Backscatter data from the airfield ceilometer.

5. Discussion and Future Efforts

The WDTC Meteorology Branch will continue to collect LMA and EFM data for phenomena of interest to range operations and those interests submitted by the meteorology community. The relationships between wind speed, visibility, dust and electric field measurements will be investigated as more cases are collected. The Branch currently does not have a method to quantify the aerosol concentration and size distributions, but we are looking into cost effective outdoor measurement systems for sampling high aerosol concentrations to identify the aerosol properties that result in the triboelectrification measured by our EFM network. The dust cases shown here may be useful to the Lightning Advisory Panel for developing launch commit criteria for blowing dust and dust storm conditions. The University of Utah operates a 15-station LMA centered approximately 60 miles to the south (Belz et al, 2014), and combining data from both arrays may be a future collaboration effort.

6. References

Belz, J., et al. Lightning Detection at the Telescope Array Cosmic Ray Observatory. XV International Conference on Atmospheric Electricity, Norman, OK 2014

Cambell Scientific (2023) CS110 Electric Field Meter. Available online https://s.campbellsci.com/documents/us/manuals/cs110.pdf

Kimball, Margaret B., and F. Gallagher. P2.11 Operational Evaluation of Lightning Precursors from a Network of Field Meters at Dugway Proving Ground. 3rd Conf. on Applications of Lightning Data, New Orleans, LA 2008

Krehbiel, P. R., R. J. Thomas, W. Rison, T. Hamlin, J. Harlin, and M. Davis (2000), Lightning mapping observations in central Oklahoma, Eos Trans. AGU, 81(3), 21–25.

Rison, W., R. J. Thomas, P. R. Krehbiel, T. Hamlin, and J. Harlin (1999), A GPS-based three-dimensional lightning mapping system: Initial observations in central New Mexico, Geophys. Res. Lett., 26, 3573–3576