U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-19-016

One-Year Electric Field Study at the North Slope of Alaska Field Campaign Report

C Liu T Lavigne

June 2019

ARM

DOE/SC-ARM-19-016

One-Year Electric Field Study at the North Slope of Alaska Field Campaign Report

C Liu, Texas A&M University-Corpus Christi
Principal Investigator

T Lavigne, Texas A&M University-Corpus Christi
Co-Investigator

June 2019

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AGU	American Geophysical Union
ARM	Atmospheric Radiation Measurement
DOE	U.S. Department of Energy
GEC	Global Electric Circuit
MPL	micropulse lidar
NSA	North Slope of Alaska
OYESNSA	One-Year Electric Field Study-North Slope of Alaska
UTC	Coordinated Universal Time

Contents

Figures

1.0 Summary

The Global Electric Circuit (GEC) of the atmosphere provides a unique prospective of the changing climate around the Earth. Monitoring this global electrical signature provides details of the global nature of electrified clouds and thunderstorms that are occurring. Using this very inexpensive measurement system, we can provide much-needed information about the vast electrical system that surrounds us, as well as gaining an understanding of how the electrical properties of global precipitation systems are changing over time.

Prior to the OYESNSA field campaign (http://atmos.tamucc.edu/oyesnsa/; https://www.arm.gov/research/campaigns/nsa2017oyesnsa/), much of the electric field data used to compare to the physical properties of electrified clouds were collected in the Antarctica. With the inclusion of this high-quality data set in the Arctic, it allows for the simultaneous observation of the electric field at both poles. Preliminary results from the One-Year Electric Field Study-North Slope of Alaska (OYESNSA) field campaign already show that the GEC appears to be indeed a truly global phenomenon, with very similar fair-weather observations being taken at both poles. This first six months of data has already been uploaded to the ARM Data Center, and preliminary results have been presented at the American Geophysical Union (AGU) 2017 meeting with very positive feedback (http://atmos.tamucc.edu/oyesnsa/AGU_2017_Poster.pdf).

The North Slope of Alaska provides a unique location for collecting these electric field measurements. Besides being at the opposite pole from many previous measurements, this site provides a rare opportunity to use the other instruments at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility's Barrow, Alaska observatory, such as the Ka-band radar, upward-facing lidar, vertical profile of meteorological measures, and other aerosol measurements. This allows for the unique chance to not only provide information about the global signature of the GEC, but also the physical inputs to the local electric field, by analyzing the physical properties of the simultaneous cloud, wind, and aerosol properties occurring with the electric field. Barrow, Alaska is home to some unique cloud formations that undoubtedly influence the electric field. This field campaign allows for the quantification of the influence to the electric field of these cloud types, as well as other unique phenomenon such as blowing snow. Already, the first six months of data have shown correlations of the electric field to radar reflectivity properties, cloud types, and increased wind (blowing snow and aerosol). Providing an understanding of these inputs to the local electric field, will improve modeling techniques of this system both locally and globally.

Although the year of measurements from the OYESNSA field campaign have already provided insight into these important questions and goals, a longer-term, high-quality data set is needed to ultimately provide the critical climatology required to understand this truly global and ever-changing system. That is why we have requested a two-year extension to the OYESNSA field campaign to lengthen this data set. Fortunately, all the equipment has withstood the first 24 months of the field campaign, and no additional instrumentation or support resources are required. This extension would allow not only for the short-term, diurnal, and seasonal variations to be explored, but also the interannual variability of the GEC. This interannual variability is the measure that can truly shine some light on the variability of the climate and electrical properties of storms on a year-to-year basis.

2.0 Results

In June 2017, a team of scientists, including Dr. Chuntao Liu and graduate student Thomas Lavigne, visited the ARM North Slope of Alaska (NSA) observatory at Barrow. With the help of the local ARM support team, two CS110 electric field meters and an anemometer were installed on a 20-foot tower as shown in Figure 1. Since then, the instruments have been successfully collecting observations and transferring them back to Texas A&M at Corpus Christi in real time.

Figure 1. Field campaign setup. Left panel shows the setup of the two CS110 electric field meters, and the RM-Young Alpine anemometer at the ARM Barrow site. Right panel shows internal components of the heated box, including the power, communication, and wiring setup.

In order to establish an “absolute” measure of the vertical electric field at NSA, rigorous calibration was conducted. To remove the influence of the metal mounting pole, as well as other nearby instrumentation, a ground-level, upward-facing measure of the vertical electric field was taken simultaneously to the downward-facing CS110s on the pole. The upward-facing measurement was taken far away from any metal or powerline influences, and provides the “true” undisturbed vertical electric field measure. The two operational CS110 instruments on the pole were then calibrated to match these values (shown below in Figure 2).

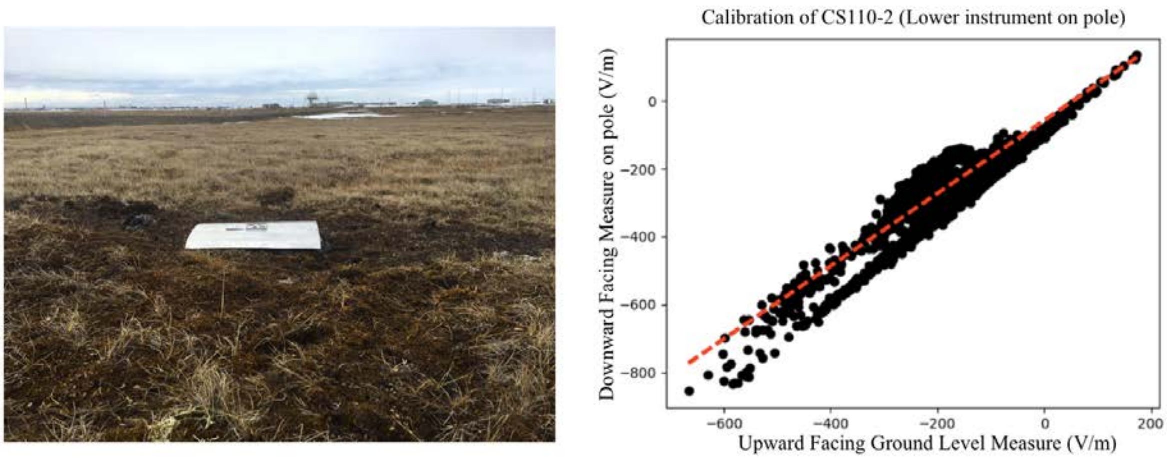

Figure 2. Example of calibration technique. Left panel shows the ground-level upward-facing CS110, which is significantly far away from any metal/electrical influences. Right panel shows the simultaneous upward- and downward-facing electric field measurements. A slope value of 0.823 and y-intercept of 54.97 were determined to be the calibration factors for the lower instrument.

The first validation of the fair-weather measurement is the diurnal variation at UTC time. As shown in Figure 3, the first three months of data show a diurnal variation of the electric field at NSA that is consistent with the famous "Carnegie curve", and more importantly it captures the phase and amplitude of diurnal variation similar to the climatology established at Vostok Station in Antarctica.

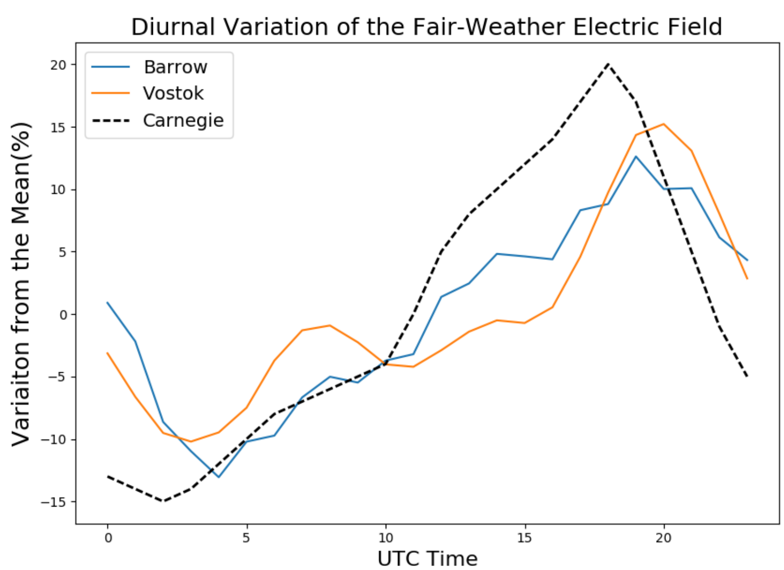

Figure 3. Diurnal variation observed in the fair-weather electric field at the North Slope of Alaska (Blue), Vostok Station Antarctica (Orange), and the yearly Carnegie curve (dotted). Only data from July-October, 2017 were used in the Barrow and Vostok curves.

One big advantage of collecting the electric field at the NSA is the abundant observations at NSA that can provide valuable environment information. For example, electrified cloud due to the charge separation in summertime could lead to a local electric field change. As shown in Figure 4, though very rare at Barrow even in summertime, a strong electrified thunderstorm near Barrow led to a strong variation of local electric field that was captured by CS110.

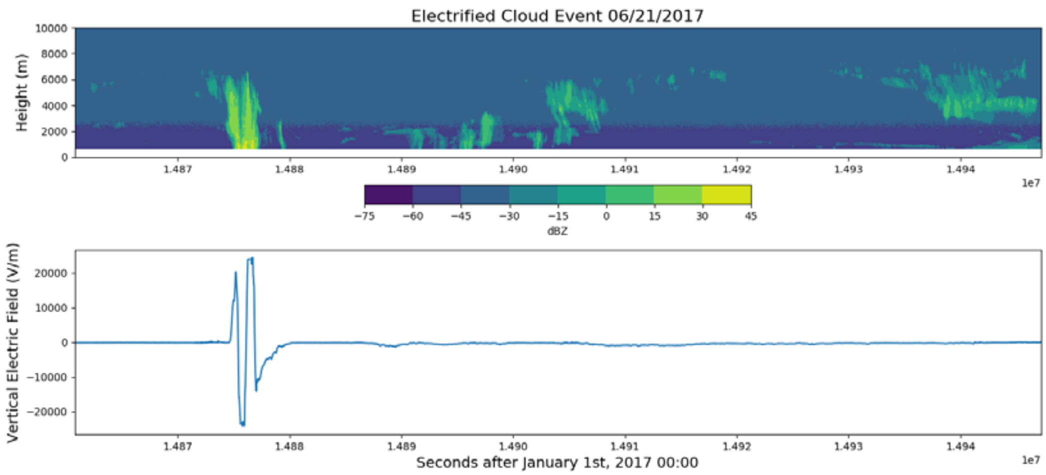

Figure 4. Example of simultaneous comparison of the one-second measured electric, and the co-located upward-facing Ka-band radar reflectivity. Data were collected on June 21, 2017. Analyzing the cloud's influence on the electric field allows statistics to be created for many different cloud types and properties.

The Ka-band radar shows clearly the radar echo reaching above 30 dBZ, indicating significant electrification in the clouds that is also observed in the electric field. Much weaker influences can also be noticed from clouds with lower reflectivity values. By combining both Ka-band radar data and electric field data, we are able to separate non-fair weather observations (Figure 5).

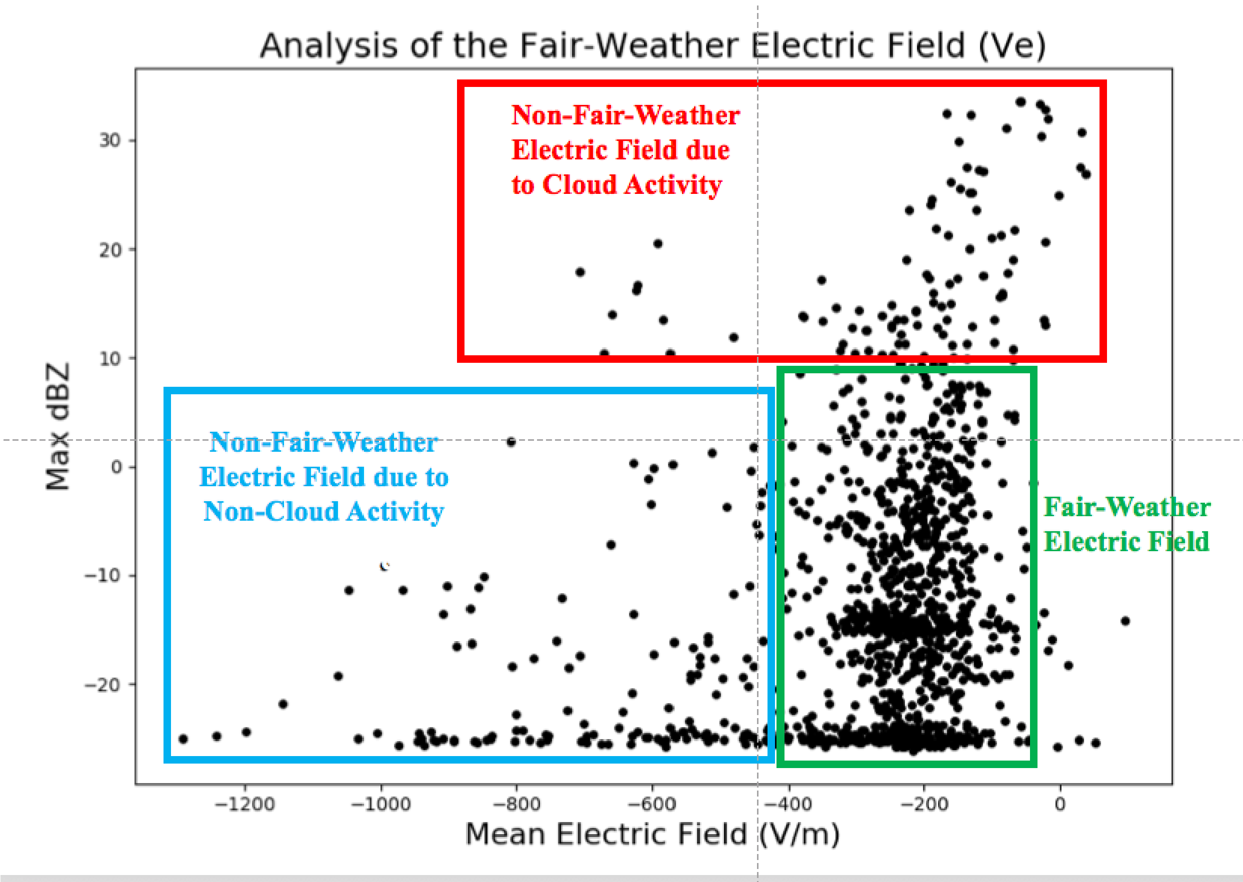

Figure 5. Breakdown of the 10-minute-averaged electric field values versus maximum reflectivity observed during the one-week calibration period. Three distinct regions of the electric field with associated cloud activity were observed.

We also found that local aerosol or blowing snow could influence the local electric field, which can be indicated by lidar and wind observations. Figure 6 shows how this further supplementary data is extremely useful. During this day, virtually no significant cloud activity was present according to the Ka-band radar. However, strong perturbations in the vertical electric field were still present. Using the micropulse lidar (MPL), it is apparent that the strong variability in the electric field occurs during periods of large MPL backscatter (increased aerosol activity).

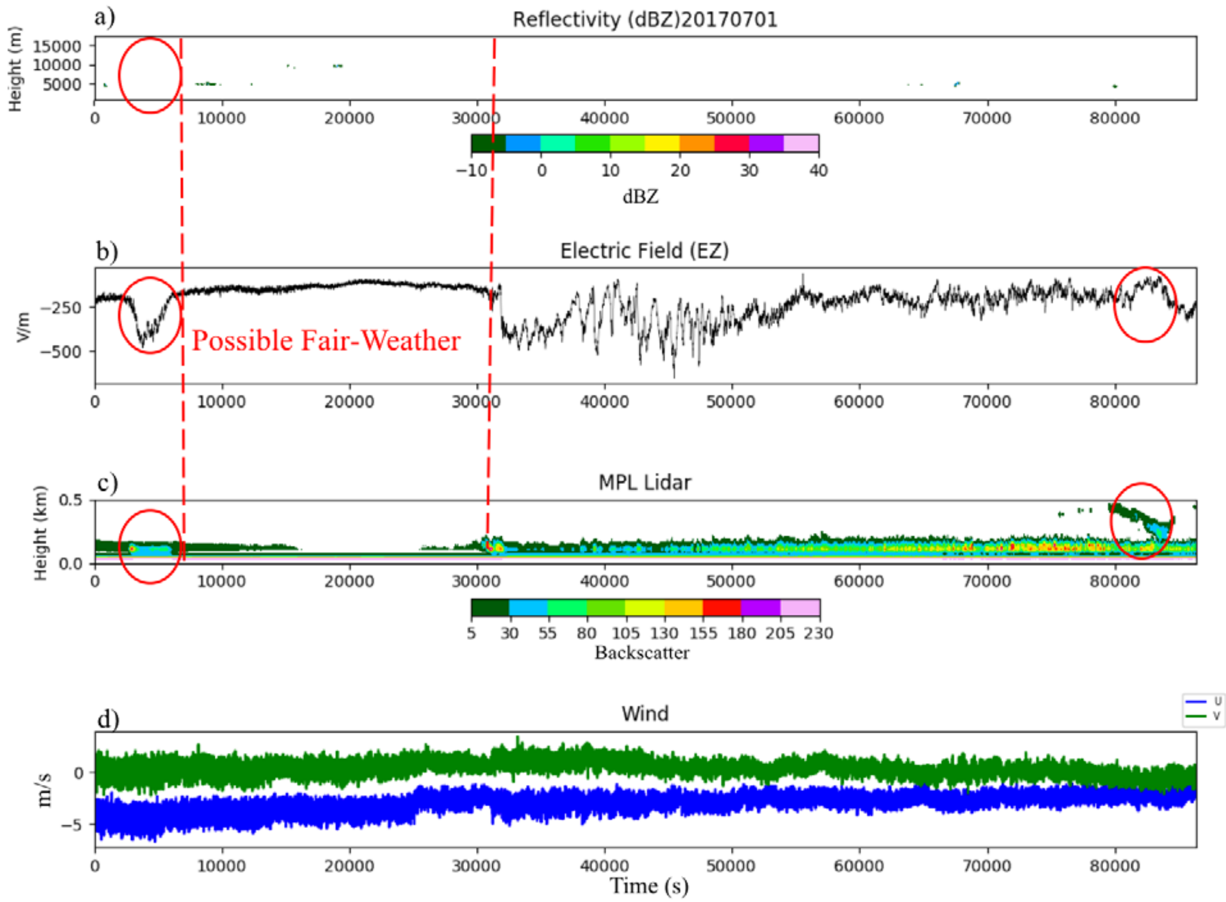

Figure 6. Example of simultaneous comparison of the b) one-second measured electric, and the collocated upward-facing a) Ka-band radar reflectivity, c) vertical micropulse lidar, as well as d) wind vectors. Data were collected on July 1, 2017.

A very stable electric field is observed during periods when there is no significant cloud or aerosol activity. During the first two years of data collection, this has been a consistent signature. This provides encouraging preliminary results that using both the Ka-radar and MPL, it is possible to distinguish between the fair-weather and locally influenced electric field. We are examining these data together and anticipate a new method of categorizing the electric field based on the lidar and radar observations.

Preliminary results show that during periods with no significant cloud activity as well as suppressed aerosols, the electric field is very stable (small standard deviation), as well as with absolute values in the known fair-weather range. Figure 7 shows a scatter of the electric field versus the standard deviation of the electric field on June 6, 2018. Green stars represent 10-minute periods meeting the threshold for no significant clouds as well as low aerosol values. The red stars indicate that significant localized influences are present during a 10-minute average. This method allows for the radar and lidar supplementary data to define a known range of acceptable electric field values with their associated standard deviations. This would allow for more robust and accurate simultaneous comparisons to other fair-weather electric field measurements around the globe, without the need for such extensive supplementary data in the other regions. This is ongoing research.

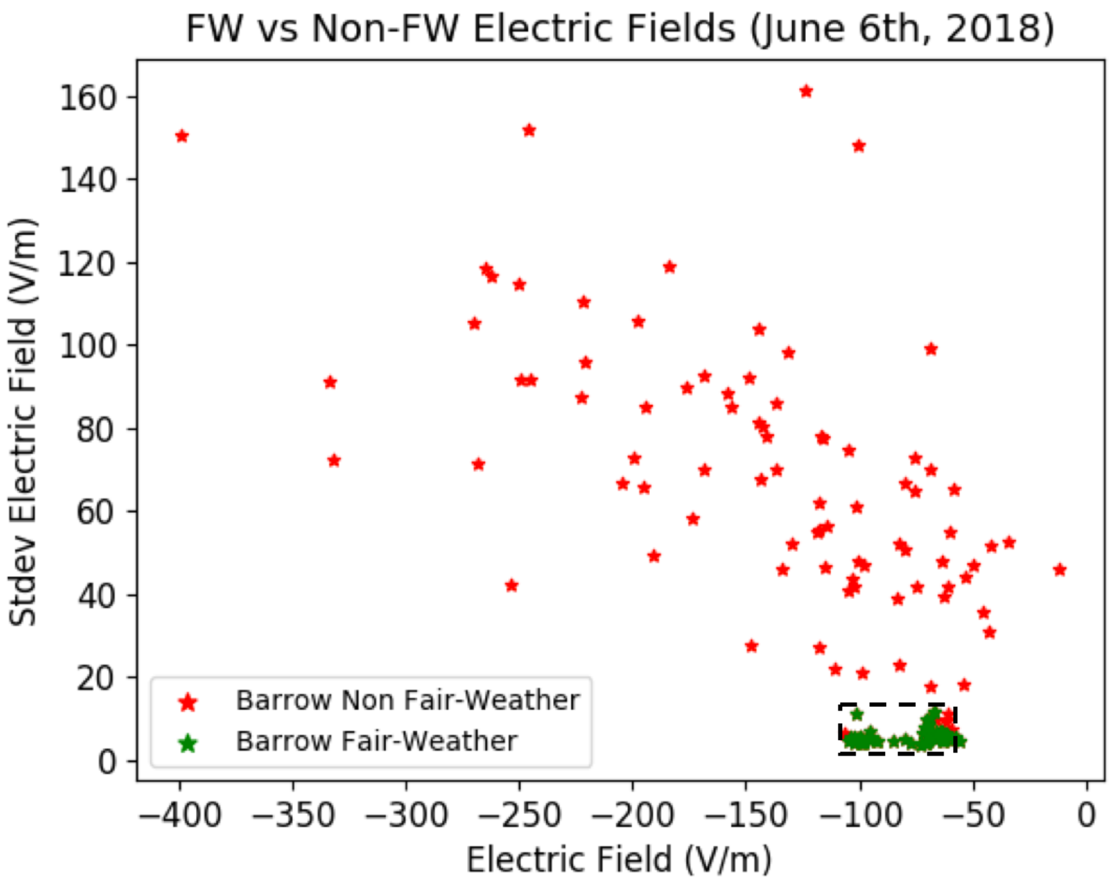

Figure 7. Scatter of the absolute electric field versus the standard deviation of the electric field on June 6, 2018. Each star represents a 10-minute averaged value. Green stars represent fair-weather values determined by the MPL backscatter. Red stars indicate 10-minute periods with enhanced backscattering and are defined as non-fair weather.

Some key results are summarized below:

- OYESNSA field campaign establishes much-needed electric field measurements in the Northern Hemisphere at a latitude of 71°N.
- Preliminary results show remarkable similarities between the diurnal variations of fair-weather electric field at the North and South Poles, indicating a truly global system.
- With the use of the calibration techniques, absolute electric field measurements are available. These absolute measurements can be compared to various other data sets such as cloud radar reflectivity, aerosol, and wind to understand the factors related to the local variation of electric field.

3.0 Publications and References

3.1 Peer-Reviewed Journal Articles

Lavigne, T, C Liu, W Deierling, and D Mach. 2017, "Relationship between the global electric circuit and electrified cloud parameters at diurnal, seasonal and interannual timescales." *Journal of Geophysical Research* 122(16): 8525–8542, doi:10.1002/2016JD026442

Peterson, M, W Deierling, C Liu, D Mach, and C Kalb. 2018. "Retrieving Global Wilson Currents from Electrified Clouds Using Satellite Passive Microwave Observations. "*Journal of Atmospheric and Oceanic Technology* 35(7): 1487–1503, doi:10.1175/JTECH-D-18-0038.1

3.2 Conference Presentations

Lavigne, T, and C Liu. 2017. "Preliminary Findings from the One--Year Electric Field Study in the North Slope of Alaska (OYES-NSA), Atmospheric Radiation Measurement (ARM) Field Campaign." American Geophysical Union fall meeting, San Francisco, California.

4.0 Lessons Learned

- Though two CS110 provided valuable measurements of the electric field, there are complications during the first 24-months of the field campaign. For example, during spring and fall season, freezing rain has caused some problems to the instruments, and some data are not collected or have bad values during these periods. All these events could lead to sensitivity change of the instrument. Therefore, maintenance and calibration of the instruments are required every year or two.
- Compared to the simultaneous electric field measurements at Corpus Christi, Texas, we have found cases showing consistent variations between two stations. This is a very encouraging result that may verify the unity of the GEC, which has been a challenge to prove at instantaneous perspective. Though further analysis is still needed to validate this result, this is already the biggest excitement we have found.
- Because the fair weather electric field is an indicator of the GEC system, it may be used to monitor the global thunder storm activities. To make this a valuable measure, long-term consistent measurement is required. Based on the first 24 months of operation, we believe that it is possible to maintain CS110 at NSA station and collect reliable data continuously for a long term. This could be the first step toward establishing a semi-permanent measurement at NSA.

www.arm.gov

U.S. DEPARTMENT OF
ENERGY

Office of Science