TOTAL LIGHTNING AND RADAR REFLECTIVITY: A STUDY AND APPLICATION

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ABSTRACT

Studies have shown there is a certain relationship between lightning flash rate and radar reflectivity, but the correlations vary due to the weather pattern changes in different regions and seasons. Many of the past studies were based on cloud-to-ground (CG) lightning data, and some studies were based total lightning data from LDAR covering small areas.

In this study, we will utilize the total lightning data from the Earth Networks Total Lightning Network (ENTLN) and radar data from the National Weather Service (NWS). We attempt to analyze the relationship between the total lightning data and radar reflectivity for the CONUS and other regions that ENTLN has good coverage. One application from this study is to create a current precipitation map solely based on the total lightning data for regions that lack of radar coverage.

1. INTRODUCTION

Recent research (Liu 2011) has indicated a strong correlation between total lightning data from the Earth Networks Total Lightning Network™ and severe storm activity. It has now enabled a practical and cost-effective proxy radar alternative - PulseRad℠ - which can be used to track precipitation in real-time over large areas and to monitor potential flooding and drought conditions. While radar is a proven valuable tool in weather forecasting and alerting, many areas of the world lack the resources to deploy and operate radar systems. PulseRad overcomes these limitations.

2. CORRELATION OF TOTAL LIGHTNING TO SEVERE WEATHER EVENTS

For several decades, numerous studies have focused on lightning flash rates along with storm characteristics such as radar reflectivity, storm cell height, vertically integrated liquid (VIL) and precipitation. In the storm formation stage, severe thunderstorms display some characteristics, such as high in-cloud (IC) flash rates, of lightning flashes. The greater number of strong updrafts during a severe thunderstorm results in more charging overall, leading to greater numbers of ICs and positive CGs (Lang and et al. 2000 and 2002). Past studies have also shown that the CG flash rate has no correlation with tornadogenesis and that using CG lightning flash patterns exclusively to detect tornado formation is not practical (Perez et al. 1997).

3. EARTH NETWORKS TOTAL LIGHTNING NETWORK (ENTLN) AND LIGHTNING CELL TRACKING

The Earth Networks Total Lightning™ (ENTLN) provides detection of both in-cloud (IC) and cloud-to-ground (CG) lightning on a continental scale. Earth Networks utilizes ENTLN data combined with sophisticated algorithms to track lightning cells and create advanced alerts. A lightning cell is a cluster of flashes with a boundary as a polygon determined by the flash density value for a given period. The polygon is calculated every minute. The cell tracks and directions can be determined by correlating the cell polygons over a period of time. By counting the flashes in the cell, it is possible to estimate the lightning flash rate (flashes/min). The cell speed and area are also calculated.

To simplify the calculation, a convex polygon, which is the cell polygon at the time, is generated from each of the closed contours. In most cases, the cell polygon is similar to the previous minute polygon, so the correlation between the two polygons is straightforward. Special care is taken to link the cell polygons and produce a reasonable path of the moving cells. When a storm cell regroups after weakening, based on the trajectory of the cell and the time-distance of two polygons, a continuous cell path may be maintained. With the lightning cells maintained during the life of the storms, the comparison of the lightning flash rate and radar reflectivity for the areas inside the cells can be done.

The high sensor density of the ENTLN and the improvement in the detection efficiency on the server side, especially in IC flash detection, make it practical to track and predict severe weather in real-time. Studies have shown that severe weather often occurs minutes after the total lightning rate reaches its peak, and tracking the rise of total lightning flash rate provides severe weather prediction lead times [Liu et al. 2011]. By using the ENTLN total lightning data, a real-time lightning cell tracking system and subsequent Dangerous Thunderstorm Alert (DTA) system have been developed, enabling advanced warning of severe weather with average lead times of 15 to 30 minutes of impending weather (Figure 1). Investigation of the relationships between the total lightning flash rate and the radar reflectivity inside the lightning cells has unveiled statistical models that can be used to create a proxy radar map from total lightning data for convective storms.

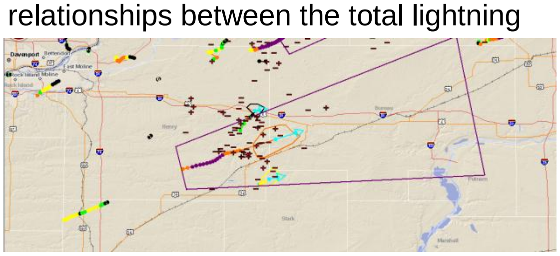

Figure 1: ENTLN total lightning data is used to generate purpose Dangerous Thunderstorm Alert (DTA) polygons and storm cell tracks to monitor severe weather activity

4. LIGHTNING FLASH RATE AND MAXIMUM RADAR REFLECTIVITY

When plotting the lightning flash data on top of the radar reflectivity map, one can see that most of the lightning activity occurs in the areas with high dBZ values (>30dBZ) (Figure 2). The lightning flash rate for a location is calculated by counting the number of flashes in the area within an 8km radius over a period of 6 minutes.

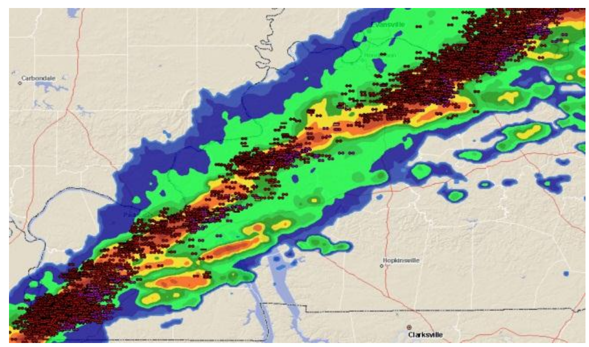

Figure 2: Lightning activities corresponding to high dBZ values

To study the relationship between lightning flash rate and radar reflectivity, the composite radar maps, which have the maximum dBZ reflectivity from any of the reflectivity angles of the NEXRAD (U.S. National Weather Service) weather radar, are used. For each composite radar dBZ reflectivity map with certain scan intervals, a lightning cell map is generated by using the lightning cell tracking system. The median lightning flash rate in each lightning cell (polygon) and the median radar reflectivity value in the corresponding polygon are recorded as a sample (Figure 3). Since all

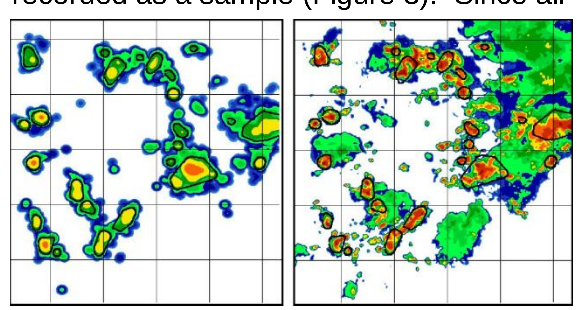

Figure 3: Comparison of lightning rate to radar dBZ values in the flash cells (left); and corresponding radar cells (right)

the samples are collected from the lightning cell polygons, this ensures that only the convective storms were considered in the study. From the samples, the statistic variables such as mean and modal can be calculated. The statistics clearly indicate logarithmic increase in maximum radar reflectivity with increasing total lightning flash rates. The relationships vary in different climate regions and seasons.

5. PROXY RADAR FROM TOTAL LIGHTNING

To quantify the relationships between the lightning flash rates and the dBZ values of the composite radars, three climate regions were chosen in CONUS (Contiguous United States). The three regions include mid-latitude east, subtropical and mid-latitude west. The seasons are divided into the warm season from June to September, and the cold season for the rest of the year. Applying the statistical model to each climate region in the different seasons, the lightning flash rates can be converted to the relative dBZ values, which in turn can be used to create a simulated radar map, known as PulseRad℠. Additional climatic regions and associated correlations can be easily developed for any region of the world.

Early studies have shown that a high lightning rate or a sudden jump in total lightning rate is usually the precursor to severe storms. Likewise, the high dBZ values or sudden increase of dBZ values in the PulseRad system can be used as an indicator for intensifying storms. Like regular Doppler radar maps, the PulseRad map can also be used for precipitation estimation (Figure 4). By combining historical PulseRad data, it is possible to issue drought or flooding warnings in areas during convective storm seasons.

Many geographical regions have similar climates and lightning characteristics, thus the statistical models can be adjusted and applied. As long as ENTLN total lightning data is available, PulseRad can be created for any region with a known climate. A regional or national implementation of an Earth Networks Total Lightning Network facilitates the data necessary to establish PulseRad coverage for a desired area.

6. CONCLUSION

This analysis confirms the correlation between the logarithmic scale of the total lightning rate (dBR) and maximum radar reflectivity (dBZ) in convective storms. By converting the dBR to dBZ, a proxy radar map (PulseRad) can be created utilizing data from the Earth Networks Total Lightning Network. PulseRad is the first practical radar alternative capable of coverage on a national and continental scale required for weather nowcasting in areas that lack radar coverage and for improving the lead time and accuracy of severe weather warnings.

The detection of both IC and CG flashes provide necessary data used to create an affordable radar alternative, storm cell tracking, and advanced severe weather warning products. PulseRad is a lower cost, but reliable and effective, alternative radar. By enabling advanced alerting for dangerous storms, PulseRad can be used for tracking precipitation in real time over large areas, monitoring for potential flooding and detecting possible drought conditions. This enabling technology will provide enhanced weather visualization and forecasting capabilities for many areas of the world.

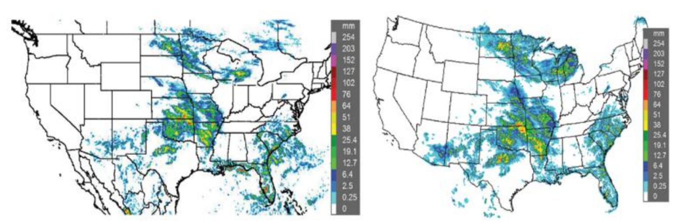

Figure 4: 24-hour precipitation estimate from PulseRad (left) and NWS (right), Courtesy of NWS, http://water.weather.gov/precip/index.php

REFERENCES

Liu C., Heckman S., 2011: Using Total Lightning Data and Cell Tracking in Severe Weather Prediction, 91st AMS meeting.

Lang, T. J., and Rutledge, S. A., 2002: Relationships between convective storm kinematics, precipitation, and lightning. *Mon. Wea. Rev.*, 130: 2492–2506.

Lang, T. J., and Rutledge, S.A., Dye, J. E., Venticinque, M., Laroche, P., and Defer, E., 2000: Anomalously low negative cloud-to-ground lightning flash rates in intense convective storms observed during STERAO-A. *Mon. Wea. Rev.*, 128: 160–173.

Perez, A. H., and Wicker, Louis J., and Orville, Richard E., 1997: Characteristics of Cloud-to-Ground lightning associated with violent tornadoes. *Weather and Forecasting*, 12: 428–437.