by Dr Choglin Liu, Dr Stan Heckman & Dr Elena Novakovskaia

WHEN LIGHTNING SPEAKS

Total lightning detection for proxy radar analysis

Research has confirmed that detection of both in-cloud and cloud-to-ground flashes provides essential data used to create affordable radar, storm cell tracking, and advanced severe weather warning solutions

Recent research 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. Although 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.

Storm characteristics

Lightning flash rates have been the subject of numerous studies of storm characteristics such as radar reflectivity, storm cell height, vertically integrated liquid, and precipitation for several decades. Severe thunderstorms have certain characteristics in lightning flashes, such as high in-cloud (IC) flash rates in the storm formation stage. The greater volume of strong updrafts during a severe thunderstorm results in more charging overall, leading to greater numbers of ICs and positive cloud-to-ground (CG) flash rates. Past studies have also shown that the CG flash rate has no correlation with tornadogenesis (the process by which a tornado forms) and that using CG lightning flash patterns exclusively to detect tornado formation is not practical.

The Earth Networks Total Lightning Network (ENTLN) provides detection of both IC and CG lightning on a continental scale. Earth Networks uses ENTLN data combined with sophisticated algorithms to track lightning cells. 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. But in the case of a sharp rise in the flash rate, or cell split or merger, the correlation of subsequent cells is not obvious. Special care is taken to link the cell polygons and produce a reasonable path of the moving cells. When a

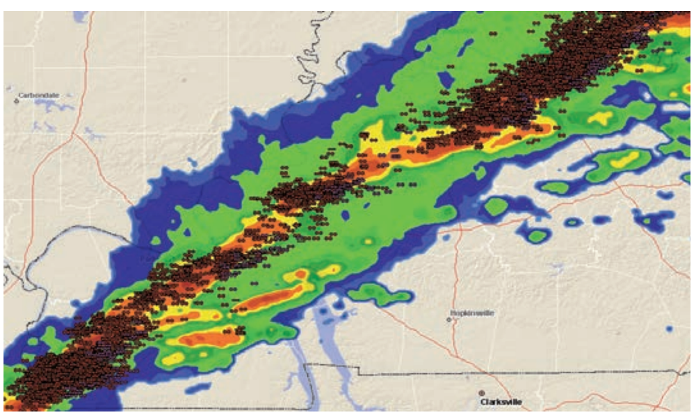

Figure 1: Lightning activities corresponding to high dBZ values

> "By counting the flashes in the cell, it is possible to calculate the lightning flash rate"

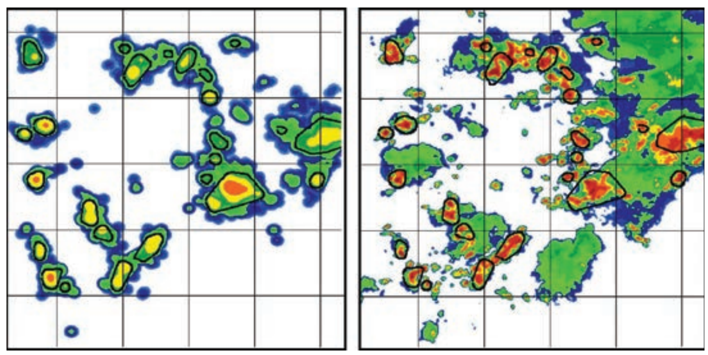

Figure 2: Comparison of lightning rate to radar dBZ values in the lightning flash cells (left) Lightning cells; (right) Corresponding radar cells

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 improved detection efficiency on the server side, especially in IC flash 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 the total lightning flash rate provides severe weather prediction lead times. By using the ENTLN total lightning data, a real-time lightning cell tracking system and subsequent dangerous thunderstorm alert system have been developed. 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.

Flash rate data

When plotting the lightning flash data on top of the radar reflectivity map, one can see that most of the lightning activities happen in the areas with high dBZ values (>30dBZ) (Figure 1). The lightning flash rate for a location is calculated by counting the number of flashes in the area within a five-mile radius over a period of six minutes.

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 (US 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 2). Since all 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.

Proxy radar from total lightning

To quantify the relationships between the lightning flash rates and the dBZ values of the composite radars, three climate

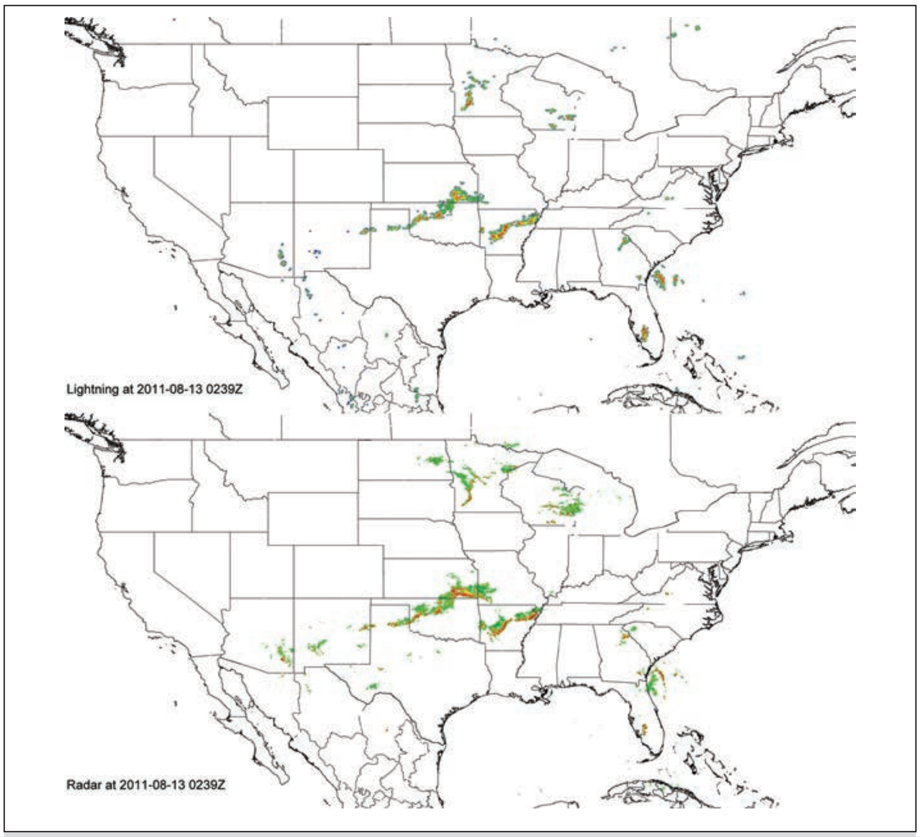

Figure 3: PulseRad (top) and Doppler radar (bottom) comparison

regions were chosen in 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 the simulated radar map, known as PulseRad (Figure 3). 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 ENTLN facilitates the data necessary to establish PulseRad coverage for a desired area.

Accurate and practical alternative

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 using data from the ENTLN.

PulseRad is arguably the first practical radar alternative capable of coverage on a national and continental scale that is useful for weather nowcasting in areas that lack radar coverage, as well as for improving the lead-time and accuracy of severe weather warnings.

The detection of both IC and CG flashes provides the 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, which enables advanced alerting of dangerous storms, and can be used to track precipitation in real time over large areas, as well as to monitor potential flooding and drought conditions. This enabling technology will provide enhanced weather visualization and forecasting capabilities for many areas of the world. ∎

Dr Choglin Liu is chief architect; Dr Stan Heckman is senior lightning scientist and Dr. Elena Novakovskaia is senior research scientist with Earth Networks (www.earthnetworks.com).

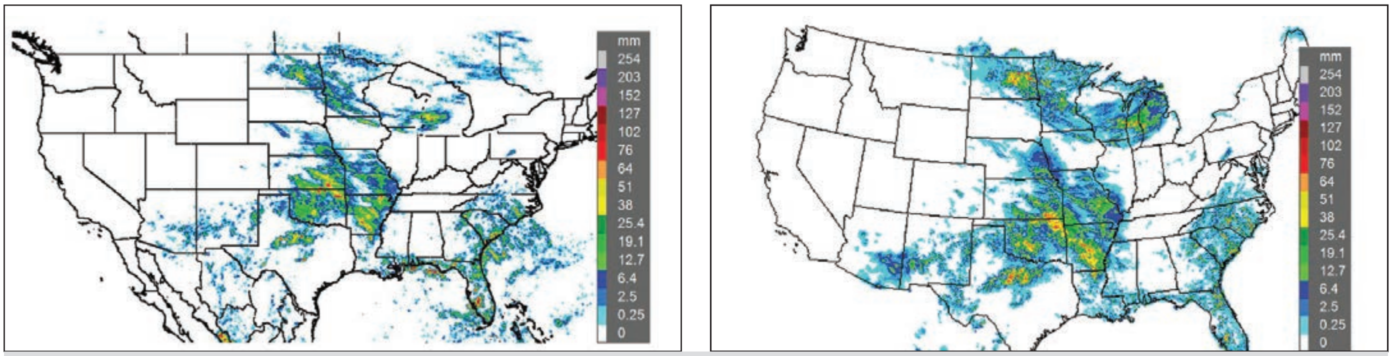

Figure 4: 24-hour precipitation estimate visualizations for 8/13/2011, from PulseRad (left) and NWS (right), courtesy of NWS Advanced Hydrologic Prediction Service, http://water.weather.gov/precip/index.php