P 12.6 A RADAR-BASED CLIMATOLOGY OF THUNDERSTORMS IN THE GREAT PLAINS: APPROACH AND PRELIMENARY RESULTS

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1.) Introduction

A thunderstorm climatology is defined as the complete record of observed thunderstorms for a given time and space, where thunderstorms are defined as deep convection producing lightning. Thunderstorms and their associated hazards are responsible for millions of dollars in damage each year. A climatology is an important tool that can be used to make characterizations about an entire population. A true thunderstorm climatology does not exist.

There have been studies to develop climatologies of thunderstorms. One study uses observed thunder (Changnon 1988). Observed thunder is highly dependent on the atmosphere through which the thunder passes and may not accurately represent individual thunderstorms. Other studies use radar data to determine thunderstorm frequency. (Kuo and Orville 1973, Reap and Foster 1979, Falconer 1984 and Michaels et al, 1987) Some use manually digitized radar (MDR) data. (Reap and Foster 1979, Falconer 1984 and Michaels et al, 1987) MDR data is archived once an hour for a 45 km^2 grid and are therefore coarse spatially and temporally. Another study uses lightning flash density and flash duration to determine the length of a thunderstorm event (Huffines and Orville 1999). This may not accurately portray a thunderstorm event because individual lightning strikes do not equate to individual thunderstorms.

The objective of this research is to create a radar-based climatology of thunderstorms in the Great Plains in order to characterize them. According to the Center for Great Plains Research at the University of Nebraska-Lincoln, the Great Plains is defined the area from the Rocky Mountains to Omaha and North Dakota to the Texas Panhandle. This project will not only identify individual thunderstorms but will also create tracks that contain information on cloud to ground lightning strikes associated with each thunderstorm. Of specific interest is whether or not a radar-based climatology is more robust than lightning strikes in determining thunderstorm frequency. The other focus of this research is to see how cloud to ground lightning multiplicity and peak current change as a function of thunderstorm lifecycle. Other studies have concluded that multiplicity of lightning strikes undergoes a fifteen minute cycle. (Doztek et. al, 2005) The authors contend that that study may not represent all thunderstorms as only one storm was analyzed (Doztek et. Al, 2005).

2.) Data

The radar data used is level II composite reflectivity data from the

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National Climatic and Data Center (NCDC). This data has a temporal resolution of five to twelve minutes depending on the VCP that the radar is operating on. Ideally most of the data will have a temporal resolution of five to six minutes when the radar is not in clear air mode. The spatial resolution is about 1 km^2. Both spatial and temporal resolutions are much smaller than the resolution of the MDR data. The radar data is station by station data and can only be collected for a maximum of 24 hours per order.

Cloud to ground lighting data is from Vaisala and includes strike and flash data. Strike data includes every strike and peak current. The flash data is broken up into multiplicity and the peak current of the first strike. Flash data will be used for this research.

The last data set that is used is the North American Regional Reanalysis (NARR; Mesinger et al. 2006) data. In order to provide a first guess of cell motion the u and v components of storm motion are used.

3.) Methodology

There are two algorithms that are used in this study: 1) An algorithm that parses through all of the lightning data to thin the data and identify events and 2) an algorithm that is used in the identification, tracking and lightning association of thunderstorms. The minimum reflectivity threshold that is used is set at 40 dBZ. This reflectivity value may be lowered to 30 dBz to follow suit with that of Barjenbruch and Houston (2006).

In order to eliminate radar sites that may not have any data an event selection algorithm is used. This algorithm spatially and temporally clusters cloud to ground lightning strikes. Lightning strike data is changed into epoch time starting from 1970 and put into 5 km^2 bins. The algorithm steps forward chronologically, defining the bounds of the event as it proceeds. Since the event inherently moves with time it is important to have the bounds of the event change as well. A dynamic grid allows for the spatial extent of the event to change with time, further reducing the amount of radar sites needed. The algorithm then determines what radar sites would have recorded the event. The radar site information, along with lightning strike data, is stored in files of each event.

The next step is to collect radar data for each event to create a mosaic image. W2 Merge from the WDSS-II program is used to create the mosaics. Once the mosaic is created then the Thunderstorm Observation by Radar (ThOR) algorithm can be used to identify and track thunderstorms.

The first step for ThOR is to identify each individual cell. The algorithm checks every grid box of radar data until the reflectivity reaches a certain threshold. Once the threshold is met ThOR flags the grid box as being a cell. Then the algorithm searches the grid boxes around the flagged box to identify higher values of reflectivity. This process continues until the surrounding reflectivity values decrease below the reflectivity threshold, then the grid with maximum reflectivity value is defined as the center of the cell. This process is repeated until all the data for one time step in analyzed.

The tracking and lightning association element of ThOR follows that of Barjenbruch and Houston (2006). Once all the cells have been identified in the first time step, ThOR uses the u and v components of storm motion to determine where the cell will be at the next time step. This is repeated for all cells. During the next time step ThOR identifies all the cells again and then compares the current cell location with the predicted location. If the cell is located within a 12 km radius of the predicted location then ThOR flags the cell or cells as the same cell in the previous time step. If two or more cells are located within 12 km of the predicted location those cells are also considered the initial cell. Once again the algorithm predicts where the cells will be at the next time step. This results in possible tracks branching out like a tree. As events start to get longer, actual storm cell motion is used to predict where the cell may be, rather than using the u and v component of storm motion. This tracking process is repeated until the cells either move out of the Great Plains or dissipate. This results in numerous tracks for each possible cell. The track associated with the least amount of error is considered to be the cell track. The final step of ThOR is to associate lightning with the track of the cell. If cloud to ground lightning strikes are within a specific distance threshold to the cell track then the cell is considered a thunderstorm. Lightning flash data, such as peak current and multiplicity, are associated to cell tracks.

The last step is to visualize the output data. Thunderstorm tracks and lightning flash density maps will be created. This data will be analyzed using ArcGIS. In ArcGIS, lightning characteristics will be analyzed as a function of thunderstorm lifecycle.

4.) Results and Future Work

The event selection algorithm and ThOR are nearing completion. ThOR is currently in a testing phase and has been tested on a single case. Results so far have been promising. Some corrections are being done to improve the tracking piece of the algorithm. The event selection algorithm is being tested on a small case study. Once the events have been identified, data from the radar sites must be collected from NCDC.

ThOR will be tested using a variety of different convective modes to see how well it does. It is unclear how ThOR will handle quasi linear convective systems. Another one of the concerns is that ThOR will miss thunderstorms where the lightning is in-cloud only.

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