VALIDATION OF Z-R RELATIONSHIPS FOR CENTRAL FLORIDA THUNDERSTORMS

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ABSTRACT

During the summer of 2010, rain gauges were deployed ahead of storms throughout Central Florida. The goal of this project was to be able to gain a better understanding of radar reflectivity (Z) and rainfall rates (R), better known as a Z-R relationship. This is important for hydrological applications such as flash flood forecasting and agriculture. The rainfall rates were noticeably larger than what is expected from the National Weather Service (NWS) Z-R relationship used during the summer. This data was then statistically analyzed using ANOVA to see if weather parameters affected the relationship. These results show that the no single parameter could explain the deviations observed, though the wind speed and the distance from the radar was found to be more significant than humidity or dew point at the surface or aloft.

INTRODUCTION

Meteorologists estimate the amount of rain that has fallen using a technique referred to as the Z-R relationship. This concept relates the reflectivity factor (Z) and the rainfall rate (R), to determine an approximate rainfall total. The relationship used in general practice by the National Weather Service (NWS) to estimate precipitation is the WSR-88D Convective Relationship ($Z=300R^{1.4}$).

Objectives:

- Storm chase and obtain precipitation samples from storms of various varying intensity (as seen in Figure 1)
- Calculate rainfall rates and obtain reflectivity data
- Create a “Z-R plot” with the rainfall rates and reflectivity from our samples
- Compare the Z-R plot to the standard NWS Z-R relationship
- Determine any factors that may cause deviations from the Z-R relationship, such as humidity and dew point

FIGURE 1: Students set up the rain gauges while storm chasing in Osceola County

METHODS

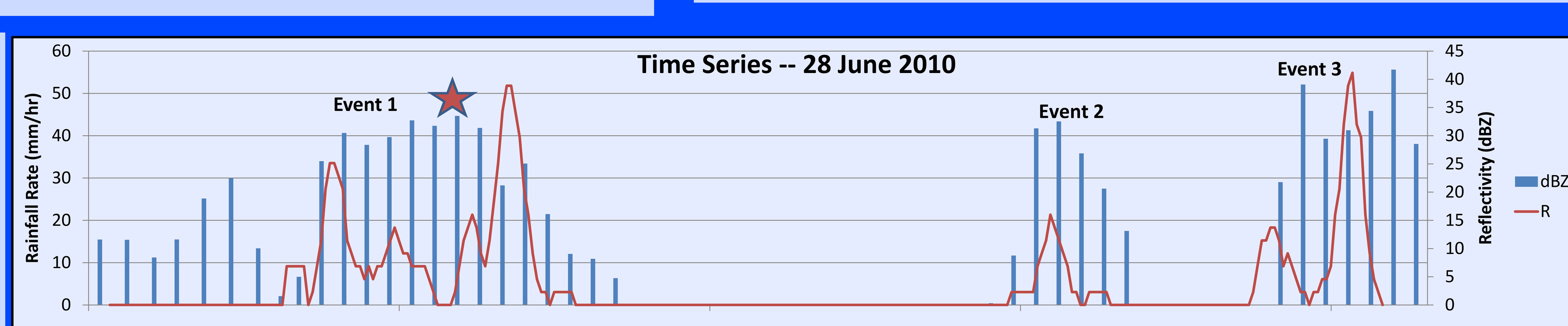
Rain gauges were deployed near storms in order to intercept precipitation. Three devices were utilized: the Davis Weather Station, a standard 8” rain gauge from the National Weather Service, as well as a student-constructed horizontal rain gauge. The Davis Station is a general weather station that logs temperature, humidity, wind speed and direction, precipitation, and other meteorological factors.

Our goal was to deploy the gauges with at least ten minutes before the rain would start. Each gauge had to be leveled and the Davis station wind vane pointed to magnetic north. Weather observations, including the start and end times of the precipitation event were documented throughout the deployment period. After the rain stopped, the amount of rain in each gauge was measured and recorded.

Post-chase, the rainfall rates and reflectivity values were determined in order to assess the Z-R relationship. A weighted five minute average rainfall rate was calculated to provide a clearer spread of data. By entering the start and stop times of the event, and the latitude and longitude of our location, we use a program that outputs the NEXRAD Information Distribution Service (NIDS) reflectivity data for the event. Once all the data was collected in a spreadsheet, the weighted five-minute rain rates are graphed versus the reflectivity this is the Z-R relationship.

Figure 3: The cumulative Z-R relationship for all precipitation events observed throughout the Summer of 2010, along with the standard NWS relationship.

FIGURE 2: Rainfall rate (mm/hr) and reflectivity (dBZ) are graphed with respect to time on 28 June 2010. At the star, you can see where the dBZ peaked before the R.



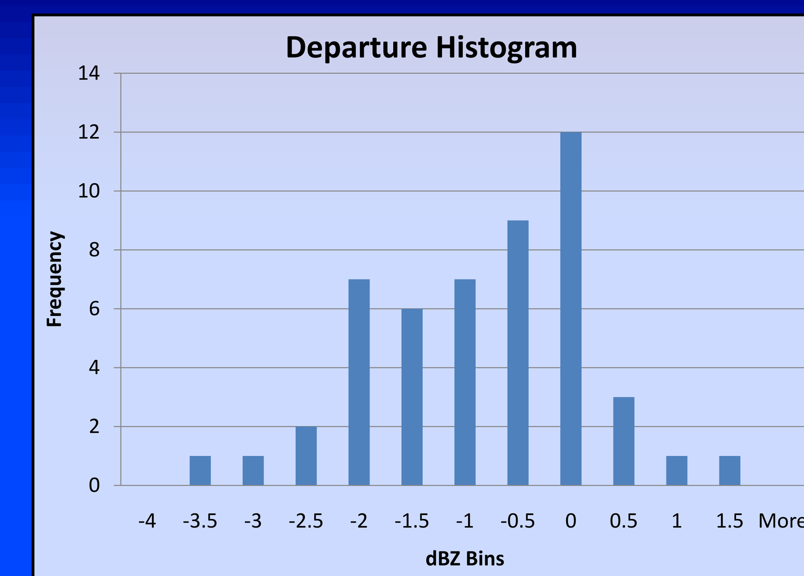


FIGURE 4: The populations of the departures from the standard NWS Z-R relationship

ANOVA ANALYSIS OF DBZ DEPARTURES	Average	Variance	P-Value
Low Winds	-1.34	0.99	
High Winds	-0.88	1.04	0.18
Short Distance	-1.24	0.89	
Long Distance	-0.78	1.19	0.12
Low Dew point (SFC)	-0.77	0.82	
High Dew point (SFC)	-1.22	0.99	0.15
Low Humidity (SFC)	-0.97	1.34	
High Humidity (SFC)	-1.08	0.75	0.71
Low Humidity (Aloft)	-0.88	1.17	
High Humidity (Aloft)	-1.23	0.90	0.23

TABLE 1: The average and variance for each parameter tested statistically, as well as the p-value.

RESULTS

An analysis of three individual events can be seen in Figure 2, which illustrates the reflectivity and rainfall rates across a time series. 28 June 2010 was a prime sampling day, with three events in the course of a few hours. Figure 3 is the Z-R relationship from the collected data. Most rainfall rates we measured throughout the summer were higher than what the NWS Z-R relationship predicted for a given reflectivity value.

The departures between each point and the NWS Z-R relationship were calculated by putting the actual rainfall rate into the relationship ($Z=300R^{1.4}$). The reflectivity value obtained from the NIDS data was then subtracted from the calculated reflectivity value. This value is the departure. The departures were then placed in sample populations and graphed in Figure 4. This shows the frequency that the departure fell into that particular range. You could assume that the reflectivity is low because we are getting higher than expected reflectivity for the rainfall that was observed.

ANOVA tests were run on the reflectivity departures, which were placed into different populations sets based on humidity (aloft and at the surface), dew point (at the surface), wind speed, and the distance from the radar. Since the p-values are not less than 0.05 for any of the relationships, we can assume that none of the parameters are significantly different, though, the distance and wind speed had the lowest p-values and are graphed in Figure 5. Figures 5A and 5C show the Z-R relationship for the precipitation events we observed with respect to the weather parameter that we ran the statistical tests on. Figures 5B and 5D show the reflectivity departure with respect to a particular weather parameter (i.e. low winds versus high winds), as well as the standard deviation. Although the error bars are nearly identical, there is a slight variation in the departures.

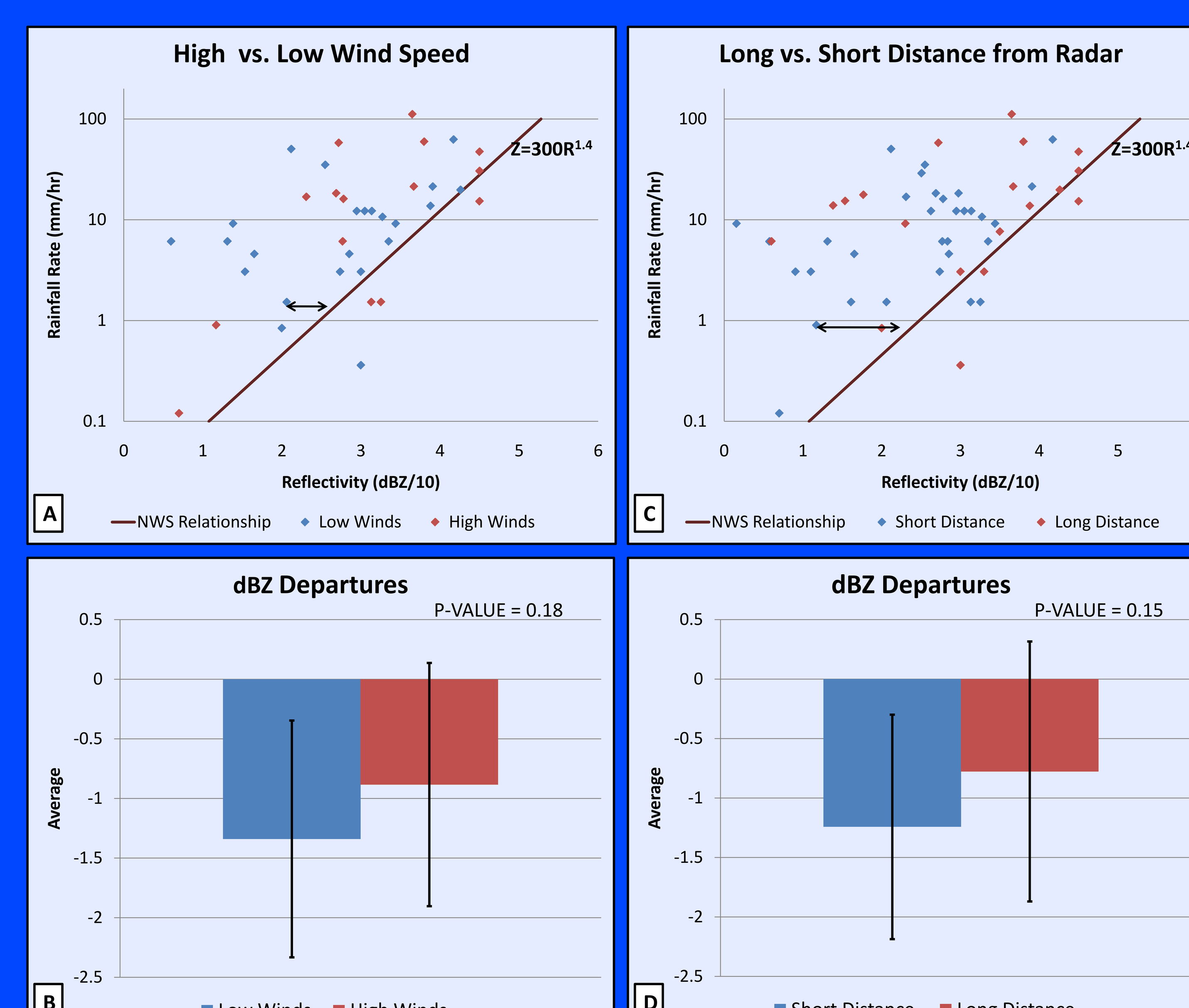


FIGURE 5: Figure 5A shows the Z-R relationship with respect to the wind speed; Figure 5B shows the average departure between the high and low wind speeds and the standard deviations for each. Figure 5C shows the Z-R relationship with respect to the distance from the radar the event occurred; Figure 5D shows the average departure between the long and short distances as well as the standard deviation for each. The arrows in Figures 5A and 5C are representative of the departure from the NWS Z-R relationship.

CONCLUSIONS

In this study we explored the potential affects that meteorological parameters such as humidity, dew point and wind speed have on the Z-R relationship. Through statistical analysis (e.g. Figure 5B and 5D) it was determined that individually, no one factor is clearly the cause for the departures from the NWS Z-R relationship. As can be observed in both Figure 5A and 5C, there is no discernable trend in the data. Meaning that wind speed and the distance from the radar are better discriminators than humidity and dew point. Without further research however, no decisive conclusions can be made. Future work to be done would include the use of a disdrometer, an instrument that determines the drop size distribution, which is more directly related to Z.

FIGURE 6: Professor Splitt checks the radar and compares It to the storms that are visible in order to determine approximately how long we must wait until it begins raining at our deployment location.

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NORTHROP GRUMMAN
Engineering & Science Student Design Showcase
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