P6R.13

RADAR RAINFALL ESTIMATION AND RAIN GAUGE COMPARISON STUDIES AT WALLOPS ISLAND, VIRGINIA

MiKayla M. Taffe* and Paul A. Kucera
Department of Atmospheric Sciences
University of North Dakota
Grand Forks, ND 58202

1. INTRODUCTION

Between June 2004 and April 2005, the NASA S-Band polarimetric Doppler radar (NPOL) observed precipitation events along the Eastern Shore of Virginia. The radar was deployed in Oyster, VA, which is located about 75 km SSW of the NASA/Wallops Flight Facility. In collaboration with NASA, Howard University, and the University of North Dakota, a dense rain gauge network was designed and implemented (15 rain gauges located over a distance of about 8 km) at Wallops Island, VA. The network is being used for detailed comparisons with NPOL radar rainfall estimates.

Observed radar rainfall error consists of inherent radar system error (hardware) and an apparent error due to the natural rainfall variability within a radar sample volume. This method of verification is known as the radar rainfall error separation method (ESM). The main focus of the study will be to analyze the dense rain gauge network and NPOL radar observations for a period of July 2004-April 2005 in an effort to improve our understanding of the NPOL radar rainfall estimation error. An overview of the project, a description of the rain gauge design and observational network, and a discussion of the methodology and results will be presented in the study.

2. DATA AND METHODOLOGY

In this study, we have used three months of rainfall data obtained from the dense rain gauge network deployed at Wallops Island, Virginia to validate the results of the NPOL rain measurements at a distance where ground clutter and brightband contamination are negligible. The three months of observation were taken from June 2004 – August 2004, which include three of the rainiest months observed at Wallops Island. The dense network (Fig.1) provides nearly continuous spatial sampling of rainfall from 0 – 8 km (Fig. 2) to achieve an estimation of the small scale rainfall variability. Data from the Wakefield WSR-88D radar (KAKQ) and the TRMM satellite were also used as other means of validation during the project.

* *Corresponding author address*: Department of Atmospheric Sciences, P.O. Box 9006, University of North Dakota, Grand Forks, ND 58202, USA. e-mail: mikayla.taffe@und.nodak.edu.

Figure 1: GIS image of Wallops Island, VA showing the fifteen Howard University gauge locations and the eight NASA gauge locations.

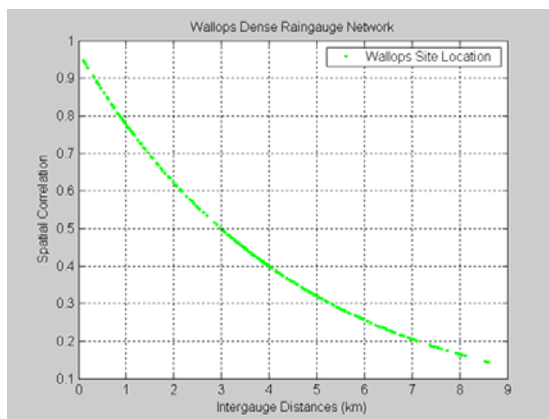

Figure 2: An example spatial correlation plot showing the sampling region from 0-8 km for the Wallops Island dense rain gauge network. The correlation was obtained using the latitude and longitude coordinates of the 15 rain gauges deployed on the island.

Before data analysis was performed, both raw rain gauge and radar data were quality controlled and further processed. A quality control check of the rain records was essential as the tipping bucket rain gauge has a tendency to be unreliable for obtaining high-quality observations if not serviced and checked periodically. Checks were performed after frequency and accumulation plots were made for monthly rainfalls. By doing a gauge-to-gauge comparison, major discrepancies could be discerned and replaced with a bad flag value (-99.0) in the dataset. With a valid dataset of continuous one-minute rainfall rates, datasets of 15 minute and hourly accumulations were then made. The hourly accumulations could be matched and compared with the continuous hourly radar data. Before this could be done, however, the radar data also underwent quality control checks. Using a QC algorithm developed for NPOL at UND, the radar data were processed. Using a series of seven tests, the algorithm examines the radar data for echo reliability and removes backlobes, sidelobes, and other non-meteorological echoes (see the paper by Theisen et al. (2005) for more details).

Using the latitude and longitude coordinates of each of the 15 gauges, a window was then extracted over each gauge from the radar data set. Each window was ±2 km and ±2° from each location. Using this window, the radar data and rain gauge rainfall could be easily compared. To gain a sense of the correlation between each gauge, the 15 minute and hourly rain records were matched with one another and a correlation fit was used to obtain the spatial correlation of each of the gauge pairs. The next step was to convert the NPOL and KAKQ data to rainfall estimates to compare the performance of the conventional NEXRAD *R*(*Z*) relationship as listed in Ryzhkov et al. (2005) to the actual rainfall. The standard NEXRAD *R*(*Z*) relation used was:

$$R(Z) = 1.70 \cdot 10^{-2} Z^{0.714} \qquad (1)$$

or

$$Z = 170 R^{1.4} \qquad (2)$$

where Z is expressed in mm^6 mm^{-3} and R in mm h^{-1}. Ryzhkov et al. (2005) developed a "synthetic" algorithm $R(Z, K_{DP}, Z_{DR})$ that uses different combinations of radar variables depending on the rainfall rate estimate with the conventional *R*(*Z*) relation. This algorithm was implemented into our study to better estimate the rainfall.

3. DISCUSSION AND RESULTS

Through this study we have obtained our best dataset during the month of July. NPOL captured ten days of rainfall events during this time and the dense network of gauges was deployed for the full duration. Examples of the spatial correlation between gauges for 15 minute and hourly rainfall accumulations are shown in Fig. 3 and Fig. 4.

As seen in each of the plots, the correlation, however significant, drops off as a function of distance. However, by comparing the 15 minute and hourly accumulations, the correlation is much stronger for longer time durations. In summary, this analysis shows that longer time scales and shorter inter-gauge distances are better correlated while shorter temporal and longer spatial scales have greater rainfall variability. This pattern also held true for both June and August data.

Taking the rain gauge data obtained in July and estimating rainfall rates from the radar data, a scatter plot (Fig. 5) was constructed to show the radar rainfall estimates versus the rain gauge rainfall. The blue symbols represent the standard *R*(*Z*) relation from Eq. 1. The green symbols represent the polarimetric algorithm developed by Ryzhkov et al. (2005).

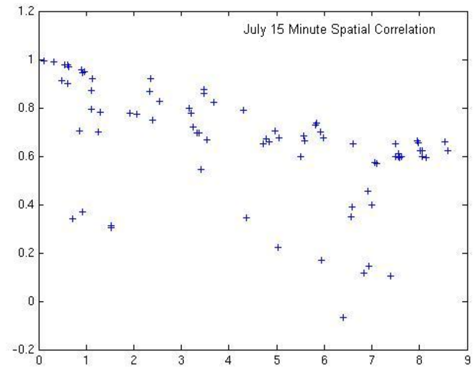

Figure 3: Plot showing the spatial correlation for the July 2005 15-minute rainfall accumulations as a function of distance.

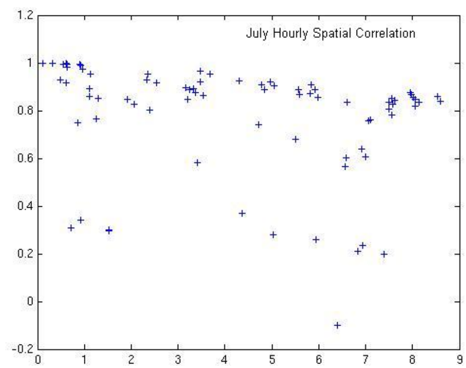

Figure 4: Same as Fig. 3 except for 1-hour rainfall accumulation.

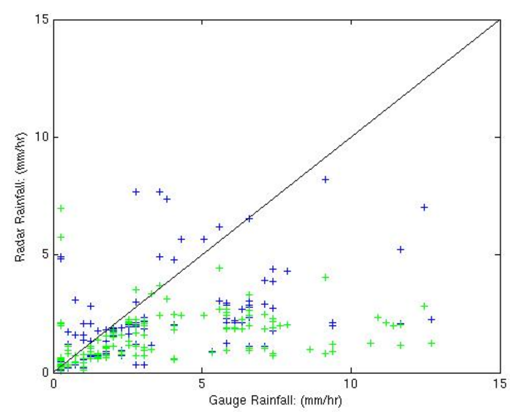

Figure 5: Scatter plot showing radar estimated rainfall vs. gauge rainfall for July 2004. Blue symbols represent the standard *R*(*Z*) relation and green symbols represent the polarimetric algorithm for estimating rainfall.

Figure 5 is clearly showing that using the NPOL radar variables, both the standard *R*(*Z*) relation and the polarimetric algorithm are underestimating the rainfall according to the hourly rainfall total averaged over each gauge. According to the month of July and the ten rain events, the standard *R*(*Z*) algorithm outperforms in term of the bias the polarimetric algorithm. The rain gauge observations had several outliers of extreme high rainfall rates (not shown). These observations are questionable and currently being evaluated. These results are preliminary will it is expected that the comparisons will improve with further investigation of the differences.

4. CONCLUSIONS AND FUTURE WORK

In summary, we have looked at a dataset observed during July 2005 as preliminary analysis of NPOL and the dense rain gauge network. We have also looked at the radar rainfall versus the recorded gauge rainfall and have observed the underestimation of rainfall rates from NPOL using the standard $R(Z)$ relation and the blended polarimetric algorithm. Noting the significant underestimation at higher rain fall rates, we are currently examining the possible reasons for the differences and will quantify the errors in future analysis. Also, KAKQ radar data will be compared to NPOL to help understand the discrepancy between NPOL and the rain gauge observations.

Statistical evaluations are also underway that will examine three accuracy measures which will include the probability of detection (POD), probability of false detection (POFD), and a critical success index (CSI) of the NPOL radar as compared to the ground observations.

5. ACKNOWLEDGMENTS

This research has been funded in collaboration with NASA through a collaboration with Howard University. We are grateful towards Lester Atkinson and the other NASA radar engineers who assisted in radar operations to obtain a high resolution radar dataset and to Dr. Everette Joseph who facility the deployment of the dense rain gauge network.

6. REFERENCES

Ryzhkov A. V., T. J. Shuur, D. W. Burgess, P. L. Heinselman, S. E. Giangrande, and D. S. Zrnic, 2005: The Joint Polarization Experiment. *Bull. Amer. Meteor. Soc.*, **86**, 809-824.

Theisen, C. J., P. J. Frank, and P. A. Kucera, 2005: A quality control algorithm for NPOL during CRYSTAL-FACE. Preprints, *32nd Conference on Radar Meteorology*.