ABE
Agricultural and Biological Engineering
https://ph04.tci-thaijo.org/index.php/abe/index
Published by the Faculty of Engineering, Khon Kaen University, Thailand

Range dependent errors in radar rainfall estimation

Ratchawatch Hanchoowong*

Department of Civil Engineering, School of Engineering and Industrial Technology, Mahanakorn University of Technology, Bangkok, 10530, Thailand

*Corresponding author.
Email address: rhanchoowong@gmail.com

Received 22 March 2024
Accepted 23 April 2024

Abstract

Effect of the Earth's curvature and increasing of radar beam as a function of range from a radar site cause the observation altitude and measurement volume to increase with range from the radar. This leads to error in radar rainfall estimates as a function of range. The objective of this paper was to study error characteristic of initial radar rainfall estimates of the Pimai radar as a function of range by considering the errors in term of differences between logarithmic of rain gauge and the corresponding radar rainfall data which were calculated by using the climatological *Z-R* relationship of the study area ($\log R_G - \log R_R$). Thirty-nine rainfall events recorded from the Pimai radar and 50 automatic rain gauges data during 2003-2004 were used in this study. The results of this study showed that error in initial radar rainfall estimates of the Pimai radar increase as a function of range at the range greater or equal to 70 km from the radar site. This range dependent error can be further used to adjust initial radar rainfall estimates for the Pimai radar to be equivalent to ground rainfall using rain gauge data.

Keywords: Radar rainfall, Range dependent error, Pimai radar, Effective range

1. Introduction

Weather radar can continuously detect and measure precipitation clouds immediately when rain covers a wide area. It provides rainfall data with high spatial resolution up to 1x1 square kilometers and can measure rainfall data every 6 minutes. Due to these special features, weather radar has become a popular tool for measuring rainfall quantities. However, weather radar differs from conventional rain gauges because it does not directly measure precipitation amounts but uses data from measuring the intensity of electromagnetic waves reflected back to the radar receiver. After these waves interact with raindrops, the strength of the electromagnetic waves received by the radar receiver is converted into radar reflectivity (Z). Radar reflectivity depends on the number and distribution of raindrops (Rainfall Drop Size Distribution) within a unit volume of the surveyed atmosphere. When using radar reflectivity data to estimate rainfall amounts, it is converted into rainfall intensity data (R) using a suitable Z-R relationship equation for the studied area [1].

Generally, weather radar measures radar reflectivity values above the ground surface. Therefore, when using radar to measure rainfall quantities at locations far away from the radar station, the influence of the Earth's curvature and the widening of radar waves with distance affects the altitude and volume of the surveyed atmosphere where rainfall is detected. This results in an increase in altitude and volume of the surveyed atmosphere with distance from the radar station, leading to increased discrepancies in rainfall estimates from the radar with distance from the radar station.

The objective of this article is to study the characteristics of discrepancies with distance in rainfall estimates from radar, which are initially calculated using the average Z-R equation of the studied area ($Z=56.5R^{1.5}$) [1].

2. Materials and methods

2.1 Checking the quality of rainfall data from rain gauge stations

In this study, the quality of rainfall data from automatic rain gauge stations during the years 2003-2004 was examined. A total of 50 stations were examined using the Double Mass Curve method and Time Series Plot analysis. Station A01 was excluded from the analysis because it is located within a radar shadow, meaning it is less than 10 km away from the radar station, resulting in no radar data available in that area. Therefore, only 49 rain gauge stations were used for quality assessment. The results showed that all 49 stations, comprising stations A02 to A50. It can be concluded that the rainfall data from all 49 stations examined are reliable and can be used for further study.

2.2 Checking the quality of radar data

The CAPPI radar image data at a height of 2.5 km. Only rainfall events with radar CAPPI image data that passed the quality assessment criteria were selected. This means that there were no deviations due to radar signal interference, abnormal radar wave attenuation, electronic issues, or non-rain signal detection problems. In this study, only rainfall events with complete CAPPI radar image data were considered. Additionally, to avoid issues related to non-rain signals (noise), only radar reflection data with values greater than 15 dBZ were used for analysis. Furthermore, to mitigate the impact of radar signals caused by insects, radar reflection values exceeding 53 dBZ were considered as 53 dBZ [2].

2.3 Checking for outliers in radar rainfall data and rainfall data from corresponding rain gauge stations

Preliminary outlier detection: For each rainfall event, the relationship between the distribution of radar rainfall data, estimated using the equation $Z=56.5R^{1.5}$, and rainfall data from corresponding rain gauge stations was examined.

Upon detecting outliers as described in step 1: Outliers were considered for removal based on standardized residuals, which have values less than -2 or greater than +2 [3], for each data pair. These outliers were removed from the rainfall event data set comprising 39 events, after they were identified from the relationship between radar rainfall estimated using the equation $Z=56.5R^{1.5}$ and rainfall from corresponding rain gauge stations for each rainfall event.

3. Results and Discussion

3.1 Effects of discrepancies with distance occurring in radar rainfall estimation

Case 1) Segment 1 (< 70 km): There is a linear relationship with a zero slope, indicating that the discrepancy in Segment 1 remains constant with distance, with a constant discrepancy of 0.1320. Segment 2 (70 km): There is a linear relationship with a slope of 0.0003, indicating that the discrepancy in Segment 2 changes with distance, as shown in Figure 1.

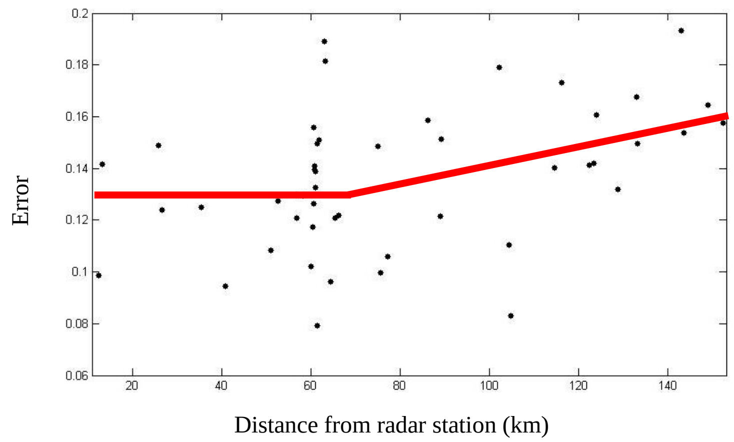

Figure 1 The relationship between the discrepancy in radar rainfall quantity and the distance from the radar station (< 70 km) and (70 km).

Case 2) Segment 1 (< 90 km): There is a linear relationship with a zero slope, indicating that the discrepancy in Segment 1 remains constant with distance, with a constant discrepancy of 0.1299. Segment 2 (90 km): There is a linear relationship with a slope of 0.0005, indicating that the discrepancy in Segment 2 changes with distance, as shown in Figure 2.

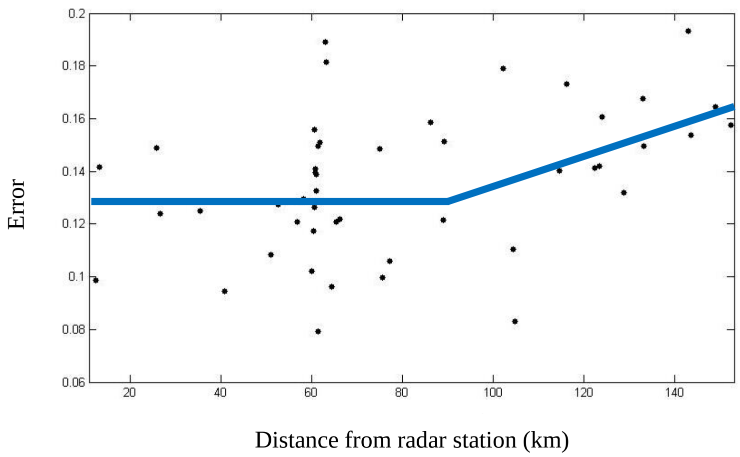

Figure 2 The relationship between the discrepancy in radar rainfall quantity and the distance from the radar station (< 90 km) and (90 km).

Case 3) Segment 1 (< 105 km): There is a linear relationship with a zero slope, indicating that the discrepancy in Segment 1 remains constant with distance, with a constant discrepancy of 0.1327. Segment 2 (105 km): There is a linear relationship with a slope of 0.0006, indicating that the discrepancy in Segment 2 changes with distance, as shown in Figure 3.

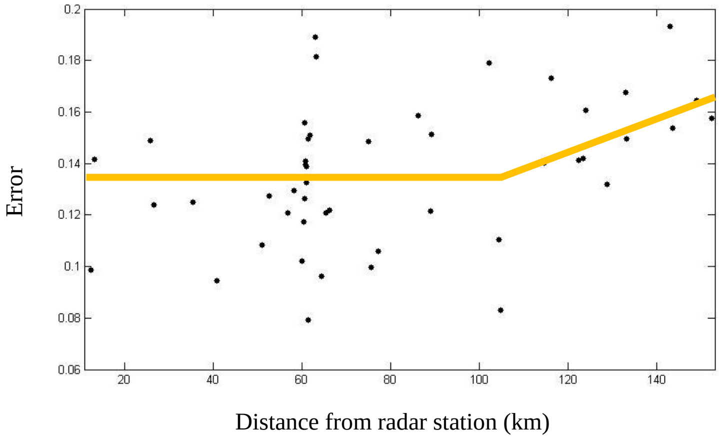

Figure 3 The relationship between the discrepancy in radar rainfall quantity and the distance from the radar station (< 105 km) and (105 km).

3.2 The characteristics of discrepancies with distance in radar rainfall estimation suitable for the area

The analysis of the characteristics of discrepancies with distance in radar rainfall estimation suitable for the area, which arise from the influence of the Earth's curvature and the widening of radar waves, was conducted by considering the coefficient of determination (R^2). This coefficient indicates the relationship between the discrepancy and the distance from the radar station, calculated from the relationship equation in Cases 1, 2, and 3. It reflects how closely related the two variables are; if they have a strong correlation, the value will be close to 1 [4].

The study found that the R^2 values in Cases 1, 2, and 3 were 0.859, 0.770, and 0.657, respectively. Thus, it can be concluded that the relationship between the discrepancy in radar rainfall quantity and distance in Case 1, which exhibits a constant discrepancy with distance from the radar station between 0-70 km and increases with distance from the radar station at distances greater than or equal to 70 km, is the most suitable for the study area. This finding is consistent with the study results of Chumchean et al. [5].

In the study, it was found that the discrepancy in rainfall quantities detected by the Kurnell radar, a C-band radar located in Sydney, Australia, increases with distance beyond 55 km from the radar station. This discrepancy is less than the distance of 70 km obtained from this study, which aligns with the fact that S-band radars, being larger, are more accurate in measuring radar reflectivity values at longer distances compared to C-band radars [6].

4. Conclusions

1. The discrepancy in rainfall estimation from the radar monitored by the Phimai radar station remains constant at distances less than 70 km from the radar station and increases with distance beyond 70 km from the radar station.

2. The results of the study on the discrepancy with distance in rainfall estimation from the radar can be applied to preliminarily adjust radar rainfall at the Phimai radar station for future studies [6]. This will be beneficial in improving the accuracy of radar rainfall estimation.

5. Acknowledgements

This study would like to express gratitude to the officials of the Royal Rainmaking and Agricultural Aviation Center, the Phimai Royal Rainmaking Research Operations Center, and the Hua Hin Royal Rainmaking Research Operations Center for providing data analysis and various conveniences during the study.

6. References

[1] Chumchuen S. Analysis of the performance evaluation of rain enhancement operations: rainfall assessment by radar weather surveillance in the Northeastern Region of Thailand. Final report. Bangkok: Royal Rainmaking and Agricultural Aviation Department. 2009.
[2] Futon RA, Breidenbach JP, Seo DJ, Miller DA, O'Brannon T. The WSD–88D rainfall algorithm. Weather Forecasting. 1998;13: 377-395.
[3] Sirirangsi P. Data Analysis: Application of Statistics in Research. King Mongkut's University of Technology North Bangkok. 2008.
[4] Anagnostou EN, Krajewski WF, Smith JA. Uncertainty quantification of mean-areal radar-rainfall estimates. J Atmos Ocean Tech. 1999;16:206–215.
[5] Chumchean S, Shama A, Seed A.Radar rainfall error variance and its impact on radar rainfall calibration. Physics and Chemistry of the Earth. 2003;28:27–39.
[6] Chumchuen S, Hanchoowong R. Correction of Radar Rainfall Estimation Using Rain Gauge Data. The 15th National Civil Engineering Conference. Ubon Ratchathani University. 2010.