

Characteristics of Rainfall-Radar Reflectivity Relationship over Lower Northern Thailand

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Abstract

According to the regularly flash flood and landslide occurrences over the lower Northern area in past decade, the appropriate warning system development has been considered more serious in Thailand. Unfortunately, these disaster events mostly occur in the mountainous area, where not only the rain gauges are scarcity and absence, but also the power supply is unavailable. Radar stations had been installed in Thailand for a couple decades, of which the active radius covers the whole area of the country. Therefore, the rainfall detection from radar information becomes one of the interesting approaches to develop effective warning system. Since, the rainfall (R) – radar reflectivity (Z) could be expressed in linear or empirical power function, the investigation of characteristics of Z-R relationship for this risky flash flood area was undertaken under the collaboration between Thai Meteorological Department (TMD) and Naresuan University (NU). Phitsanulok radar station, located in the middle of lower Northern Thailand, was selected to study. The installed radar in this station is DWSR-74C Doppler radar of which active radius is 240 km. The rainfall events during August-September 2007 were analyzed for Z-R relationship. In the study, two techniques of Spatial Probability Technique (SPT) and Buffer Probability Technique (BPT) were proposed. These techniques were developed based on GIS basic function and probability matching method. Using these two techniques, the Z-R pairs can be analyzed for both linear and empirical power relationship. It is found that empirical power function is more appropriate to describe Z-R relationship than linear function for the studied area. However, this research is just the early state of Z-R relationship investigation; the warning system development needs further study on the other parameters that relevant to rainfall and flash flood occurrence.

Key words: Rainfall; Radar Reflectivity; Z-R relationship; Buffer; Spatial; GIS; Thailand

1. INTRODUCTION

As radar station had been installed in Thailand for a couple decades, the active radius of these radar stations cover the whole area of the country. The information from radar has been widely used to develop the accuracy process of rainfall prediction. (Rosenfeld et.al., 1993; Rosenfeld et.al.,1994; Atlas et.al., 1997) Moreover, radar measured rainfall have been applied to several hydrological and environmental modeling,

including real-time hydrological forecast. (Sun et.al, 2000; Vieux, 2003; Trafalis et.al., 2005; Miidla et.al., 2008.) The advantage of using radar information is to obtain the rainfall information for the ungauged area such as mountainous remote area where there are the problems of rain gauges scarcity and unavailability of power supply. Although, there are the radar stations distributed over the country and Thai Meteorological Department provides the radar information of each station via its website as shown in Figure 1, the application of radar information in Thailand is still limited. Thus, this research was set among the collaboration of Thai Meteorological Department (TMD), Royal Irrigation Department (RID) and Naresuan University (NU) to study the characteristics of Rainfall-Radar Reflectivity Relationship over Lower Northern Thailand where the flood warning system is needed. The study is the early stage of radar information investigation for this area which couples GIS technique to Z-R matching process.

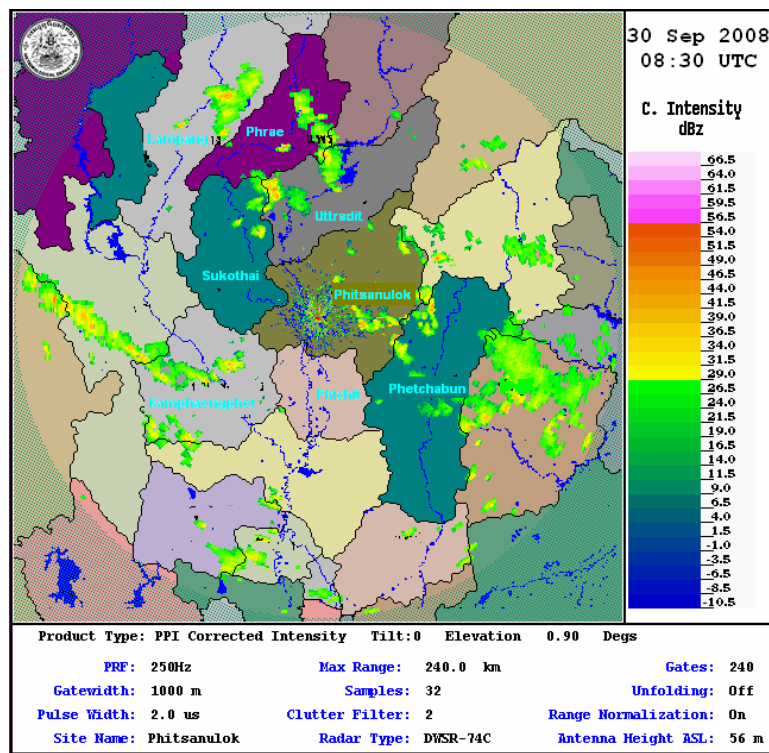


Fig.1 Radar Reflectivity information provided via www.tmd.go.th

Phitsanulok Radar station located in the middle of the area and 27 rain gauge stations distributed over the area were selected to study. The installed radar at this station is C-type Doppler radar of DWSR-74C; of which active radius is 240 km. Fig.2 shows the active measured area with the locations of studied rain gauge stations. As the radar reflectivity, Z (mm^6/mm^3) commonly varies across many orders of magnitude, therefore Z used in this study is the reflectivity expressed in term of dBz as $Z(\text{dBz}) = 10 \times \log_{10} Z(\frac{\text{mm}^6}{\text{mm}^3})$. The radar reflectivity has been measured in hourly basis, whereas the obtained rainfall from automatic gauge stations is in 15-minute basis. Thus,

the normalized process to aggregate 15-minute rainfall into hourly rainfall has been done before analyzing process. The rainfall events occurred during August and September 2007 were analyzed in this study.

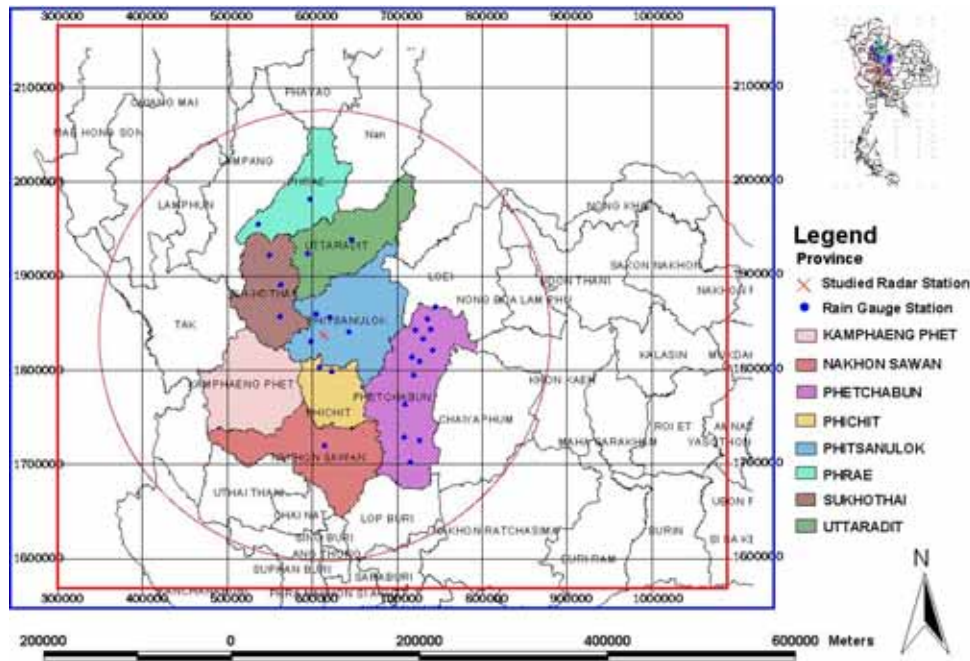


Fig. 2 The active measured area of radar station and the locations of studied rain gauge stations.

2. MATCHING PROCESS

From past researches, several matching process between reflectivity (Z) and rainfall (R) had been proposed such as: Traditional Matching Method (TMM), Probability Matching Method (PMM), Window Probability Matching Method (WPMM) and Window Correlation Matching Method (WCMM). (Calheriros & Zawadzki, 1987; Atlas et.al.,1990; Rosenfeld et.al., 1993; Rosenfeld et.al.,1994; Piman et.al.,2007) In all process except TMM, the matching is done between the Cumulative Distribution Functions (CDFs) of Z and R as described in Equation (1) and Fig.3.

$$\int_{R_i}^{\infty} P(R)dR = \int_{Z_i}^{\infty} P(Z)dZ \quad (1)$$

where $P(R)$ is the probability density function of rainfall from gauge measurement and $P(Z)$ is the probability density function of radar reflectivity. The matching of Z and R is done at the same probability level.

In this study, two techniques of Spatial Probability Technique (SPT) and Buffer Probability Technique had been proposed. SPT is the process using the interpolation basic function of GIS to estimate radar reflectivity over the rain gauge station at the corresponding time of measurement. In this process, it is assumed that raindrops vertically fall downward. As rainfall (R) is the measured rainfall at time t for a rain gauge location, the reflectivity (Z) can be calculated by Kriging interpolation from the

surrounding measured reflectivity data at time t . Then, for any time t , the corresponding data of $Z - R$ can be obtained. The matching is done by probability matching as equation (1) above to avoid the timing error.

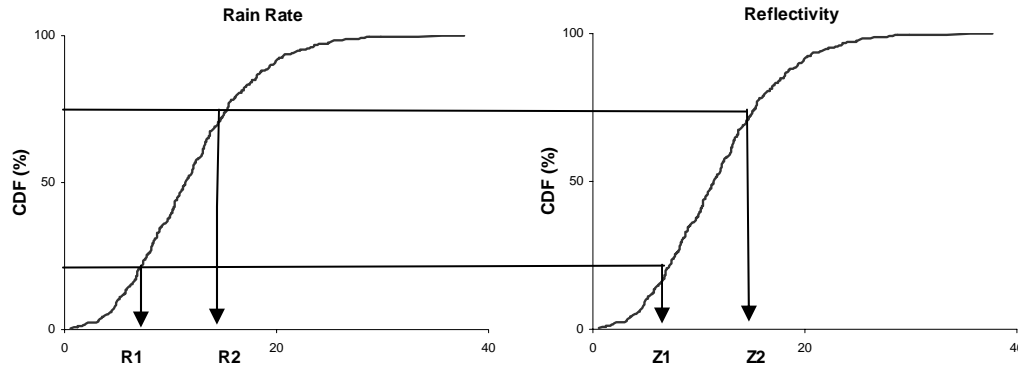


Fig. 3 Probability Matching

BPT is the process that was developed in order to decrease the error from wind effect under the assumption that raindrops may not vertically fall into the rain gauge because of wind effect. BPT uses the buffer basic function of GIS to estimate the radar reflectivity over the rain gauge station at the same time. The Z value which corresponds to R value at time t can be calculated from the arithmetic mean of Z values detected at time t within 1 km buffer area above the rain gauge. Then, the matching is also done by probability matching. Fig. 4 shows SPT and BPT diagram over the rain gauge location.

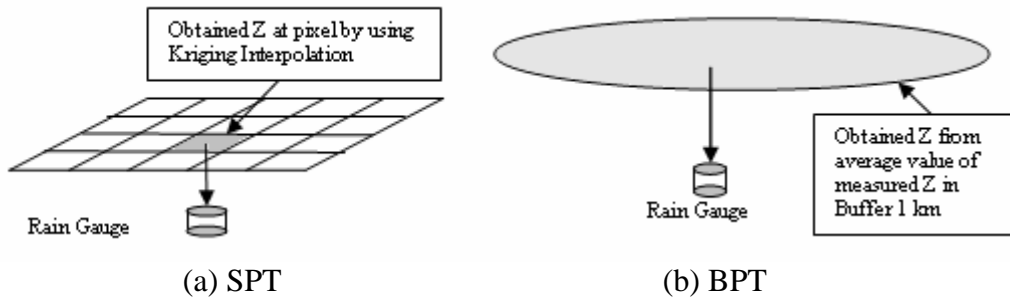


Fig.3 SPT and BPT diagram over the rain gauge location

3. REFLECTIVITY – RAINFALL RELATIONSHIP

In general, Z - R relationship can be described by the empirical power law relationship (Marshall & Palmer, 1948; Battun, 1973) which can be expressed as:

$$Z = aR^b \quad (2)$$

where a and b are coefficients that depend on location and difference in climatology such as season, type of rain. These coefficients are independent on rainfall itself. However, the Z - R relationship can be expressed in linear Z - R relationship for equilibrium rainfall condition as steady tropical rain. (List, 1988)

4. STUDIED PROCESS

The rainfall from automatic rain gauges was measured every 15-min, whereas the reflectivity from radar was measured once an hour. Thus, the normalized process for rainfall should be done prior to SPT and BPT process. The 15-min rainfall was normalized by aggregating into hourly rainfall with the same time interval as radar measurement. The Z-R relationship investigation had been done for both linear and empirical power function which the studied process is shown in Fig. 4.

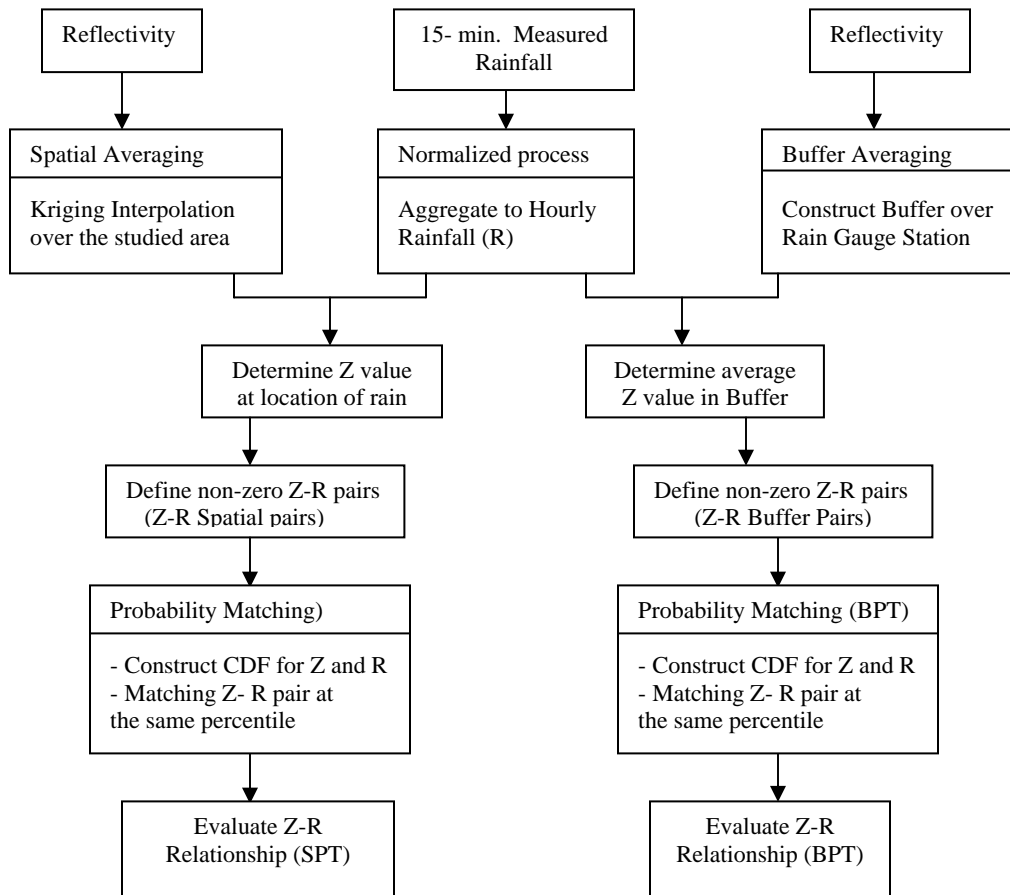


Fig.4 Studied process

4. RESULTS AND CONCLUSIONS

From rainfall events occurred during August-September 2007, there are 664 non-zero Z-R pairs obtained from SPT, whereas, 448 non-zero Z-R pairs are obtained from BPT. These non-zero pairs were then processed by probability matching in order to obtain matching Z-R pairs. With these pairs, the Z-R relationships were then evaluated. Considering these matching pairs with two functions of linear and empirical power, it shows high correlation between Z and R for both SPT and BPT process. Using linear function as shown in Fig.5, the obtained R² are 0.821 and 0.806 for SPT and BPT

process, respectively. Whereas, using empirical power function as shown in Fig.6, the obtained R^2 are higher as 0.9424 and 0.9655 for SPT and BPT process, respectively.

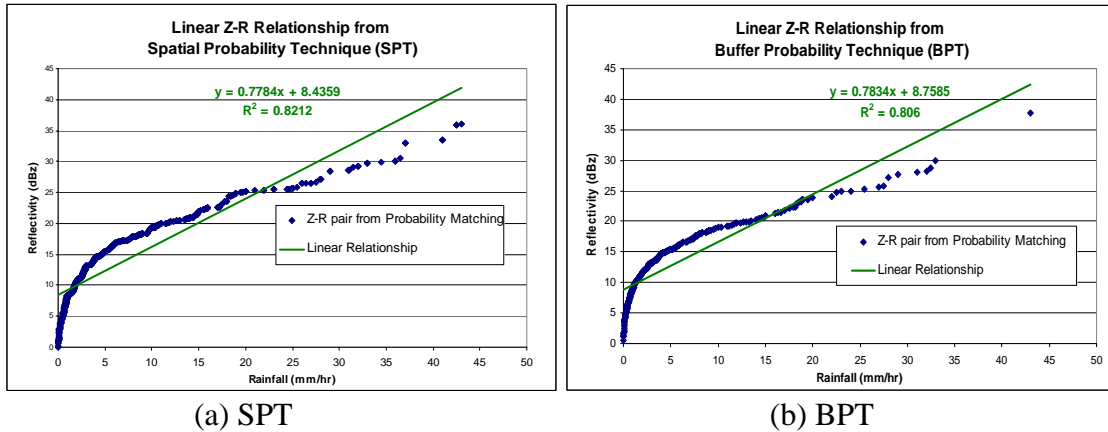


Fig. 5 Linear Z-R Relationship

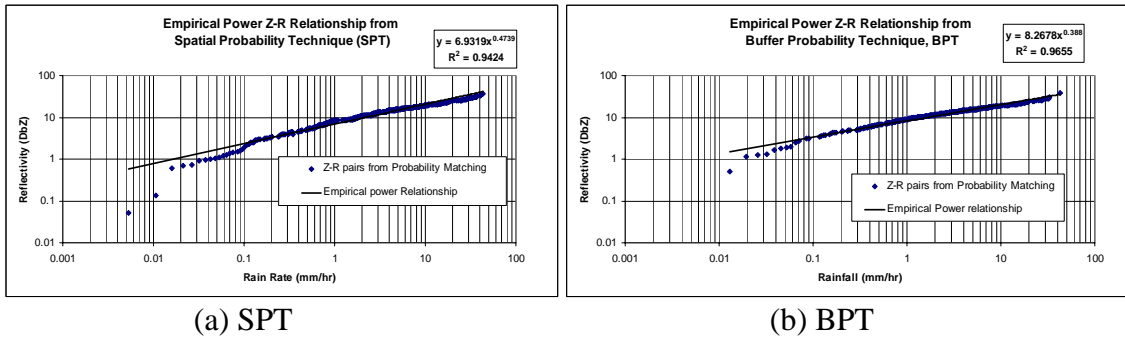


Fig. 6 Power Function Z-R Relationship

In order to determine the residual and standard error of estimation from these functions, the process of regression analysis was applied. Table 1 shows the regression statistics output of linear and empirical power function of both SPT and BPT process. It is shown that linear function provides less R^2 , higher residual sum of squares and higher standard error than empirical power function in both processes. Therefore, it can be concluded that empirical power function is more appropriate to describe Z-R relationship than linear function for the rainfall-radar information over Phitsanulok radar station. The results also correspond to the common form of Z-R relationship which can be expressed as $Z = aR^b$, where a, b function parameters. Comparing between SPT and BPT, it can be seen that BPT provides slightly better results. However, this study emphasized only on Z-R relationship investigation, the further study should be done with the other parameters and applied the obtained Z-R relationship to develop the disaster warning system in the future.

Table 1 Result of Statistical Outputs

Regression Statistic Parameter	Z-R Linear Relationship		Log(Z) – Log (R) Linear Relationship (Z-R empirical power function)	
	SPT	BPT	SPT	BPT
Regression Sum of Squares	22870.266	9260.563	53.658	20.142
Residual Sum of Squares	4977.943	2229.189	3.278	0.719
R Square	0.821	0.806	0.9424	0.965
Standard Error	2.984	2.660	0.0765	0.0478

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