Study of radar rainfall estimation using geographic information systems over Chiang Mai province

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Abstract. Weather Radar is an equipment used for detecting the position and direction of atmospheric movement. It was calculated the time travel of electromagnetic wave which sent and received to the objects. The radar reflectance could be estimated amount of water vapor in the cloud, but it was not exact value of surface rain water. Therefore, to examine the relationship and trend between rainfall from weather radar and surface rain gauge station, we use Z-R relationship equation to calculate rainfall from weather radar and compared with rain gauge station. The study area is Chiang Mai province and the chosen period were as March 4th, June 10th and August 10th in year 2013. The data acquisition of rainfall values measured by surface rain gauge station from Northern Meteorological Center and the weather radar map from Lamphun radar station covered 6 upper-north provinces (83 rain gauge stations) which included of the weather radar map from Omkoi radar station covered 63 rain gauge station. The results shown that consistency coefficients of determination (R-Squared) of the rainfall between from rain gauge station and calculated from weather radar map. The interpolation and hot spot analysis were shown the similar relationship and trend of the rainfall from both places in term of spatial analysis.

1. Introduction
Precipitation is a significant role for environment and life such as water source. If we can detect or approximate the amount of precipitation correctly we can manage water system easier. Weather Radio Detection and Ranging (Weather Radar) was used for detecting the position and direction of atmosphere movement. Precipitation scatters these microwaves, sending some energy back to the transmitter, where it is detected by the radar’s receiver. The intensity of this received signal, called the radar echo, indicates the intensity of the precipitation. Measuring the time it takes for the radio wave to leave the radar and return tells us how distant it is and the direction to the target. Doppler radar receiver ‘hears’ waves of a higher frequency if precipitation particles are moving toward the radar, and a lower frequency if particles are moving away. The radar reflectivity can estimate vapor water in the cloud, it is not the value of...
rainfall on the ground. We use Marshall–Palmer Z-R relationship equation to examine the relationship and trend of calculated rainfall from weather radar and compared to a rainfall from rain gauge station.

2. Methodology
The study area covers Chiang Mai province. The area is about 20,107.057 square kilometers, located at latitude 18 degrees north and latitude 98 degrees east, 310 meters high from sea level, width from west to east about 138 kilometers, long from north to south 428 km.

2.1. Data used (Year 2013 data)
- Daily rainfall data of 83 ground stations for each districts of Chiang Mai, Lamphun, Lampang, Mae Hong Son, Chiang Rai, and Tak province.
- Hourly radar data of Omkoi station, Chiang Mai province, covered radius 240 km. At date March 4, June 10 and August 10. Covered 63 ground stations in 5 Northern provinces, including Chiang Mai, Lamphun, Lampang, Mae Hong Son and Tak.
- Hourly radar data of Lamphun station, Lamphun province, covered radius 240 km. At same previous date. Covered 83 ground stations in 6 Northern provinces, including Chiang Mai, Lamphun, Lampang, Mae Hong Son, Chiang Rai and Tak.

2.2. Data Collection
Rain gauge data collected as a table with the station code, station name monthly rainfall and coordinates of each station. The dBZ data collected from radar image at the same position as rain gauge station point and record in table. Then, the dBZ data converted to rain rate R (mm/hr) by the Marshall-Palmer Z-R Relationship: $Z=200R^{1.6}$

Where $Z$ is expressed in linear units (mm^6 m^{-3}) and $R$ is in mm hr^{-1}. The result that can be used to calculate the rain rate in mm/hr from the reflectivity obtained from the radar: $R=0.036^{0.0625} \cdot dBZ$

2.3. Spatial Interpolate by IDW Method
The spatial analyst tool which an interpolated point is estimated based on their distance from known cell values. Points that are closer to known values will be more influenced than points that are farther away. Weights are proportional to the inverse of the distance raised to the power value.

2.4. Hotspot Analysis
The spatial statistics tool group command which calculated by the equation:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} x_j - \bar X \sum_{j=1}^{n} w_{ij}} {\sqrt{n \sum_{j=1}^{n} w_{ij}^2 - \left( \sum_{j=1}^{n} w_{ij} \right)^2} / (n-1)}$$

Where $x_j$ is a value of data point, $w_{ij}$ is a spatial weighted value between data point $i$ to $j$, $n$ is number of all data, $\bar X$ is an average of data and $S$ is a standard deviation of data. The hot spot analysis tool calculates the Getis-Ord $G_i^*$ statistic for each feature in a dataset. For larger the z-score is, the more intense the clustering of high values (hot spot). For smaller the z-score is, the more intense the clustering of low values (cold spot).

2.5. Finding Coefficient of determination ($R^2$)
Used of Microsoft Excel for calculated. R-squared is the proportion of the variance in the dependent variable that is predictable from the independent variable(s). It is a statistical measure of how well the
regression predictions approximate the real data points. An R-squared of 1 indicates that the regression predictions perfectly fit the data.

3. Methodology
Inverse distance weighted (IDW) interpolation and Hotspot analysis were shown in below figures. Amount of rainfall show as: (a) 0 – 39 mm/day, (b) 0 – 4 mm/day, (c) 0 – 21 mm/day and (d). The hotspot cluster trend of rain gauge data and Lamphun radar station data is around top and middle of province. In Omkoi radar station data, the hotspot cluster is around below the province.

![Figure 1](image1.png)

**Figure 1.** Amount rainfall result from IDW interpolation and hotspot analysis result for rain gauge data, Lamphun radar station data and Omkoi radar station data on 4 March 2013.

![Figure 2](image2.png)

**Figure 2.** (a) R-square finding from Lamphun data and (b) R-square finding from Omkoi data on 4 March 2013. R-square is rather low and the R-square from Lamphun radar station data is higher than Omkoi radar station data.

![Figure 3](image3.png)

**Figure 3.** Amount rainfall result from IDW interpolation and Hotspot analysis result for rain gauge data, Lamphun radar station data and Omkoi radar station data on 10 June 2013.

Amount of rainfall show as: (a) 0 – 107 mm/day, (b) 0 – 10 mm/day, (c) 0 – 4.8 mm/day and (d). The hotspot cluster trend of rain gauge data and Omkoi radar station are near bottom of province but. In Lamphun radar station data, the hotspot cluster is around upper-middle of the province.
Figure 4. (a) R-square finding from Lamphun data and (b) R-square finding from Omkoi data on 10 June 2013. From both graph the R-square is rather low. The R-square from Lamphun radar station data is higher than Omkoi.

Figure 5. Amount rainfall result from IDW interpolation and Hotspot analysis result for rain gauge data, Lamphun radar station data and Omkoi radar station data on 10 August 2013.

Amount of rainfall show as: (a) 0 – 107 mm/day, (b) 0 – 10 mm/day, (c) 0 – 4.8 mm/day and (d). The hotspot cluster trend of rain gauge data and Omkoi radar station are near bottom of province but. In Lamphun radar station data, the hotspot cluster is around upper-middle of the province.

Figure 6. (a) R-square finding from Lamphun data and (b) R-square finding from Omkoi data on 10 August 2013. From both graph the R-square is rather low. The R-square from Omkoi radar station data is a bit higher than Lamphun radar station data.

4. Methodology
From the study, we found that spatial interpolate and hotspot pattern from rain gauge has familiar trend along calculated radar image data of Lamphun station more than radar image data of Omkoi station. Because of the data from Lamphun station displayed precipitations in range of could base where most of them fall to the ground. But the data from Omkoi station displayed precipitations in range of middle to top could where not exactly fall direct to the ground. In quantitative of rainfall, the coefficient of determination (R-Square) shown that the relation of each amount rainfall dataset rather low. Due to the
fluctuates from losing data of radar image which is not a continuous storage data same as rain gauge data. Furthermore, misinterpret the reflectivity can cause an error in radar data and discrepant overlapping may cause a spatial error.

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