The Estimation Rainfall Using Infrared (IR) band of Himawari-8 Satellite over Thailand

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***Abstract* – This paper studied the quantitative precipitation estimation (QPE) rainfall over Thailand by Himawari satellite, data set used in July to September 2015. The technique was computation of the relation equation between rain and temperature of clouds by the exponential equation; $R = 1.183\times10^{11} \exp(-0.036382\times T^{1.2})$. Optimal interpolation based on regression against observed z values of surrounding data points, weighted according to spatial covariance values which used the Kriging method, the matching method and adjust data to observation by G/R. The results showed that the quantitative precipitation estimation (QPE) amount of rainfall with satellite was distribution pattern similar to the results of measurements of meteorological stations which were the related to observations that the statistics regression are the correlation coefficient (CC) value 0.80, the mean absolute error (MAE) value 1.55 and the root mean square error (RMSE) value 2.51. The correction of QPE used the statistics verified; the probability of detection (POD) value is 0.81, the threat score (TS) quiet high value is 0.73, the false alarm ratio (FAR) is 0.06 and probability of false detection (POFD) is the quiet low value 0.08. Therefore, Himawari satellite algorithm is a good performance to estimate rainfall in the area.**

1. Introduction

Currently, scientists have estimated rainfall with the remote by using weather radar and meteorological satellite instead of installed observation stations over forest areas and steep mountains. Scientists trying to estimate the spatial rainfall from meteorological satellites are as follows. Rasamee, Swanwerakamtorn (2000) had studied the qualitative precipitation estimation (QPE) from 42 rain gauges observation by the geographic information system (GIS): Thiessen Polygons, Moving Average, Moving surface, Trend surface and Kriging method. The results showed that the Moving Average with Inverse Distance Weight (IDW) got results of the spatial rainfall in the area better than other methods. Watcharee Veerakachen and Itthi Sa-nguandee (2007) had studied satellite rainfall estimation in Thailand using FY-2C Infrared data which cloud top temperatures (IR-1) are derived directly by processing FY-2C raw data received from DVB-S system. The relationship between IR-1 data and rain rate collected from Thailand Meteorological Department (TMD), in Northern part of the country, has been analyzed. The result shows, for cold cloud ($IR\text{-}1<253K$), polynomial relationship between IR1 and rain rate with acceptable R^2 at 0.79. Kamol P.N Sakolnakhon. and Sarintip, T. (2013) studied the verification statistics used in evaluating of the estimate rainfall from satellite over Thailand during 2000-2010 periods. The satellite data from GSMaP_MVK (TRMM/TMI, Aqua/AMSR-E, ADEOS-II/AMSR, DMSP/SSMI) have resolution grid about 0.1degrees from the Japan Aerospace Exploration Agency (JAXA), rainfall observed from stations of Thailand Meteorological Department (TMD). The assessment of the accuracy GSMaP_MVK has two experiments, the first experiment studied the estimated rainfall over all seasons, the summer (mid-February to mid-May), rainy (mid-May to mid-October) and winter (mid-October to mid-February). The second examined the estimated rainfall from tropical cyclones. Results showed that GSMaP_MVK is under estimated rainfall form observation, perfect in rainy season, and quite weak in summer season. Watcharee Veerakachen, Mongkol Raksapatcharawong and Shinta Seto (2014) had studied the performance evaluation of Global satellite mapping of precipitation (GSMaP) products over the Chao Phraya river basin in Thailand. The experiment using GSMaP data of GSMaP_MVK (moving vector with Kalman Filter) is a non-real time and GSMaP_NRT is a near real time, results of GSMaP_NRT is quite good but not sufficient for real time. Kamol P.N Sakolnakhon and Sarintip, T. (2014) had studied the qualitative precipitation estimation (QPE) cover Thailand with an hour data during May to November 2014 from the geo-satellite of Fy-2E and used technique of the Inverse Distance Weight (IDW) method. Results showed that the temperature of cloud ($IR1<253K$) which R-T relationship in a polynomial of the relation temperature (IR1) and rain rate is acceptable; R^2 is 0.6673, CC is 0.8269, POD is 0.78 and TS is 0.66, are perfect enough accuracy of FY2E algorithm. It indicates a good performance to the estimated rainfall in the area.

2. Study Area and Data Sources

2.1 Study Area

Our study area is Thailand which is situated in Southeast Asia, adjoined to Laos and Burma (Myanmar) to the north, Cambodia and the Gulf of Thailand to the east, Burma and the Andaman Sea to the west, and Malaysia to the south. Its total area is twice Wyoming size, about 514,000 square kilometers (198,455 square miles). The length of its coastline measures 3,219 kilometers (2,000 miles), is located latitude 〖5.62〗^o N to 〖20.45〗^o N and also 〖97.37〗^o E to 〖105.62〗^o E. Its capital city, Bangkok, is the most populated city in Thailand. Located in the central region, Bangkok is the center of Thailand's economic and political activities. Major part is the north, the northeast, the central, the east and the south.

2.2 Satellite Data

In order to Japan Meteorological Agency (JMA) provides the geostationary satellite above surface about 38,600 kilometer which is located Around 140.7 degrees east covering the East Asia and Western Pacific regions, continuous Himawari satellite observation every 10 minutes by cloud service of internet, have 16 bands (IR: 10.5-12.5um, IR1: 10.5-11.5um, IR2: 11.5-12.5um, IR3(WV): 6.5-7.0um, IR4: 3.5-4.0um, Band1: 0.4310-0.4790um, Band2: 0.5025-0.5175um, Band3: 0.6250-0.6600um, Band4: 0.8495-0.8705um, Band5: 1.601-1.619um, Band6: 2.253-2.268um, Band7: 3.740-3.960um, Band8: 6.061-6.425um, Band9: 6.890-7.010um, Band10: 7.258-7.433um, Band11: 8.440-8.760um, Band12: 9.543-9.717um, Band13: 10.25-10.61um, Band14: 11.08-11.32um, Band15: 12.15-12.45um and Band16: 13.21-13.39um) which are different frequency in each band. In the experiment used only the infrared (IR) of band13 which is 10.25-10.61um during July to September 2015, measure every 10 minute but we selected to use only at 00UTC satellite data/hour.

2.3 Ground Data

The rain gauge stations network of Thai Meteorological Department (TMD) compose of the surface stations, Agro-meteorological stations and Hydro-meteorological stations about 122 Stations measuring in every hour.

3. METHODOLOGY

In this study can be divided into the research (figure 1), in following;

3.1 Precipitation Rate Equation

The original equation modified the brightness temperature according to the convective equilibrium level temperature prior to computing rainfall rate. The estimation rainfall from satellite can compute from the relationship between rainfall rate and temperature of cloud in infrared band (IR), follow equation 1 (Vicente et al. 1998).

$$R=1.183\times10^{11}\exp(-0.036382\times T^{1.2}) \quad (1)$$

where R is the rainfall rate in mm/h and T is temperature in Kelvin.

3.2 Interpolate Methodology

In this experiment, the interpolate method was selected to estimate rainfall in each grid point data by Kriging method, optimal interpolation based on regression against observed z values of surrounding data points, weighted according to spatial covariance values, assigns weights according to a (moderately) data-driven weighting function, rather than an arbitrary function. All interpolation algorithms (inverse distance squared, splices, radial basis functions, triangulation, etc.) estimate the value at a given location as a weighted sum of data values at surrounding locations. Almost assign weights according to functions that give a decreasing weight with increasing separation distance.

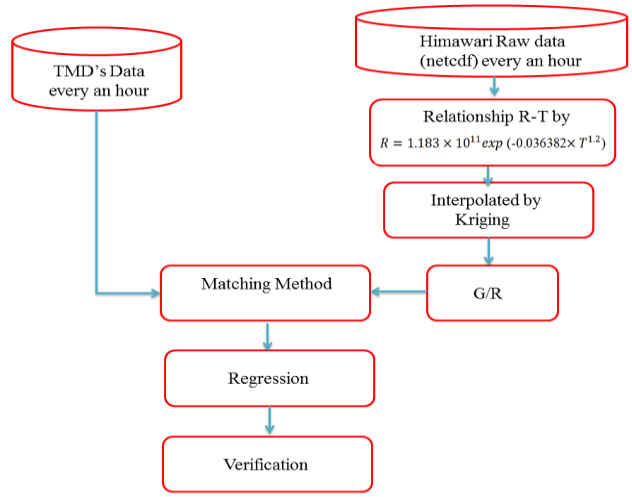

Figure 1 Flow chart of procession.

3.3 The Statistic Regression and Verification

To determine the accuracy of the information about the amount of rain with an inspection of the rain at the station that statistics are often used to monitor include the following.

a) Mean Absolute Error (MAE) measures the average of the absolute deviation between the estimations and observations. Absolute error retains the differences in magnitude that would otherwise be reduced because positive and negative differences would cancel each other to some degree. The range of MAE is 0 to infinity and the perfect score is 0.

b) Root Mean Square Error (RMSE) is similar to MAE measure the mean error magnitude, only it gives greater weight to the larger error because the differences are square before adding. The range of RMSE is 0 to infinity and the perfect score is 0.

c) The correlation coefficient (CC) also called Pearson's product moment correlations. The coefficient correlation is a measure of the strength and direction of the linear relationship between two variables. The correlation coefficient may take any value between -1.0 and +1.0.

d) The probability of detection (POD) or simply the hit rate is the fraction of the observed 'yes' events that were also forecasted 'yes' events. The POD ranges from 0 to 1 and a score of 1 meaning perfect forecast. This score is sensitive to hits, but it ignores the false alarms.

e) The false alarm ratio (FAR) is a touchstone of the fraction of predicted 'yes' events that actually did not happen. This score ranges from 0 to 1 and a score of 0 implies perfect forecast. This score is sensitive to false alarms, but it ignores the missed events.

f) The probability of false detection (POFD) or in simple words the false alarm rate is fraction of the observed 'no' events rainfall, the Special rainfall that were incorrectly forecast as 'yes' events. This score ranges from 0 to 1 and the perfect score is 0. While it is sensitive to false alarms, it ignores the missed events. It includes the correct negatives in place of hits (in FAR).

g) The threat score (TS) or critical success index (CSI) tells us how well did the forecast 'yes' events correspond to the observed 'yes' events. This score ranges from 0 to 1; where 0 indicates no skill and 1 indicates a perfect score. It is the most accurate when correct negatives have been removed from consideration. This score is sensitive to hits while it penalizes both misses and false alarms.

4. RESULTS

Detail of results, the correlations between QPE from satellite to rain gauges observation in each month with consider rainfall distribution from TMD's rainfall scale: light rain 0.1-10mm, moderate rain 10.1-35.0mm, heavy rain is 35.0-90.0mm and very heavy rain is greater than 90.1, are showed in figure 2-4.

Figure 2 shows the distribution of light rain, moderate rain, and heavy rain in Thailand. It is found that a light rain from rain QPE is distributed over a light rain from rain gauge observations, while the group of moderate rain, heavy rain is distributed similarly.

Figure 3 shows the distribution of light rain, moderate rain, and heavy rain in Thailand. It is found that the group of a light rain from rain QPE is distributed is distributed similarly a light rain from rain gauge observations, the group of heavy rain and also very heavy rain are distributed similarly, while the group of moderate rain cover Ranong, Pung Nga provinces is different from observation.

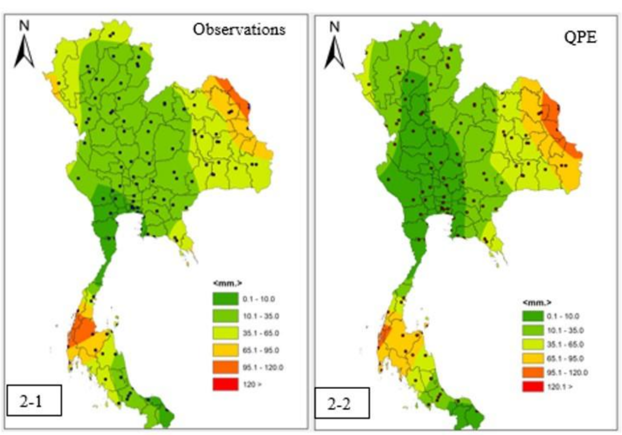

Figure 2 Showing the distribution of rainfall data from rain gauges station in Thailand (2-1), the distribution of QPE from Himawari-8 satellite data (2-2) in July 2015.

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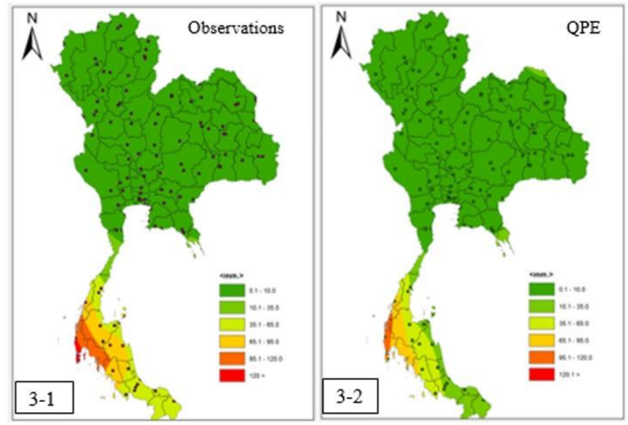

Figure 3 Showing the distribution of rainfall data from rain gauges station in Thailand (3-1), the distribution of QPE from Himawari-8 satellite data (3-2) in August 2015.

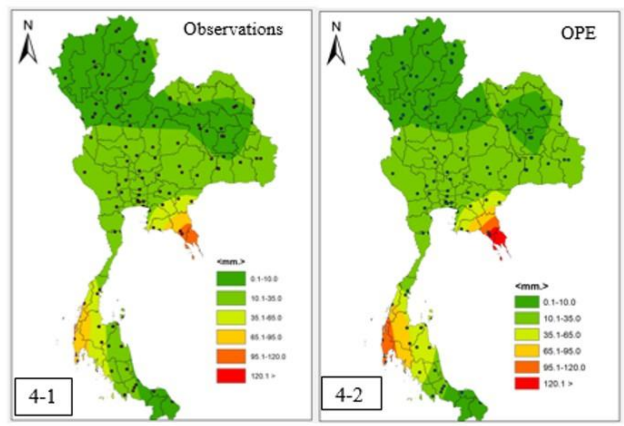

Figure 4 Showing the distribution of rainfall data from rain gauges station in Thailand (4-1), the distribution of QPE from Himawari-8 satellite data (4-2) in September 2015.

The statistics relation showed R2 is higher value 0.76, the correlation coefficient (CC) is 0.87 and the mean absolute error (MAE) is 10.32, the root mean square error (RMSE) is 17.31 in August 2015, and R2 is lower value 0.63, CC is 0.79, MAE is 14.25, RMSE is 17.31 in September 2015, total number observation is 144 are in figure 5-7 and table 1.

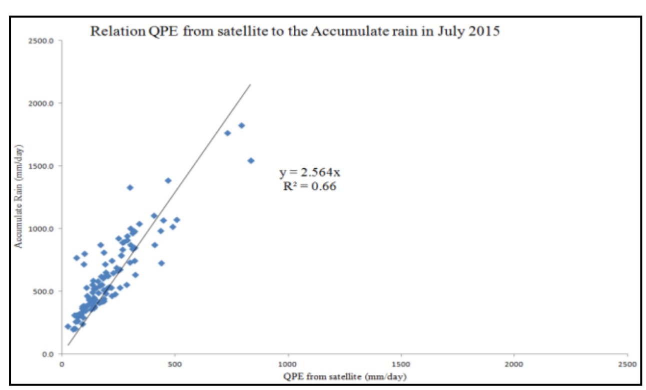

Figure 5 Comparison between the accumulated rain and QPE from satellite in July 2015. Relation the accumulated rain of observations to

QPE from satellite showed in a diagonal line.

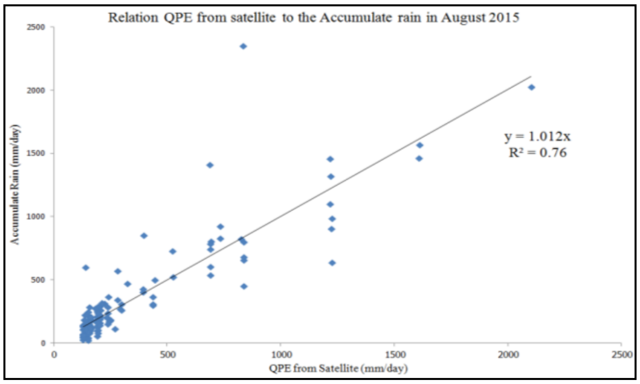

Figure 6 Comparison between the accumulated rain and QPE from satellite in August 2015. Relation the accumulated rain of observations to QPE from satellite showed in a diagonal line.

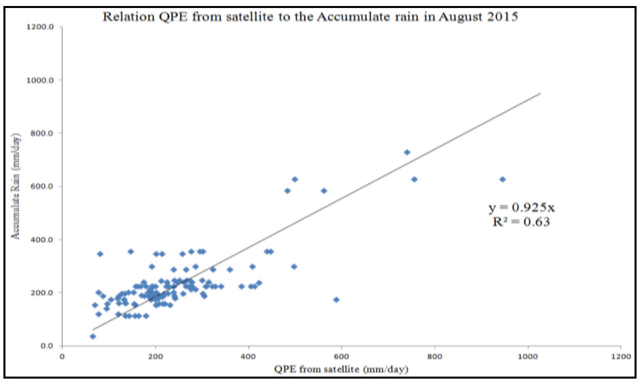

Figure 7 Comparison between the accumulated rain and the qualitative precipitation estimation (QPE) in September 2015. Relation the accumulated rain of observations to QPE from satellite showed in a diagonal line.

Table 2: To determine the accuracy of the information about the amount of rain with an inspection of the rain at the station that statistics are often used to monitor include the following. QPE and observation are hit value about 2610, False alarm is 208, Miss is 509 and Correct rejection 424, which are POD high value is 0.83 and TS is 0.78 are approach to 1, while FAR is 0.07 and POFD is 0.32 are approach to 0 in August 2015. The results indicate that the prediction accuracy is quite good, while POD and TS are quiet low 0.63 and 0.62, FAR, PFD are 0.22 and 0.62 in September 2015.

The study of QPE from the satellite meteorology with the relationship between the temperature of the cloud and rainfall in the area by the geo-satellite in infrared (IR) band of FY-2E (Kamol P.N. Sakolnakhon and Sarintip, T., 2014) and Himawari as same as the equation, QPE results from Himawari satellite showed a similar products from FY-2E.

5. Conclusions

In order to the original equation modify the brightness temperature according to the convective equilibrium level temperature prior to computing rainfall rate, the estimation rainfall from satellite can compute from the relationship between rainfall rate and temperature of cloud in infrared band (IR) in the each grid point, and also was applied Kriging method to interpolate. The results correspond to the common from R-T relationship which can be express as $R=〖1.183\times10〗^{11} \exp(-0.036382\times T^{1.2})$. Comparison between QPE from satellite to observation in each month, it can be seen that QPE is distribution light rain, moderate rain, heavy rain and also very heavy rain similar observations, the regression statistic output of linear and QPE function, it showed that linear function provide high R2 , low MAE and RMSE. The statistic verification POD and TS quit approach to 1.0, and also FAR and POFD quit approach to 0.0 that indicated the algorithm R-T relationship can calculate QPE in the area.

6. References:

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Table 1 The results of model regression of both data.

Month	*a*	R^2	MAE	RSME	CC	No. Obs.
July 2015	2.564	0.66	14.42	22.05	0.81	144
August 2015	1.012	0.76	10.32	17.31	0.87	144
September 2015	0.925	0.63	14.25	25.21	0.79	144

Table 2 The statistics verification QPE from satellite in July 2015.

Month	Hit	False alarm	Miss	Correct rejection	POD	FAR	POFD	TS
July 2015	346	1331	139	1845	0.75	0.12	0.21	0.74
August 2015	2610	208	509	424	0.83	0.07	0.12	0.78
September 2015	1988	40	1131	471	0.63	0.22	0.41	0.62