Assessment of Royal Rainmaking Performance with Ground-based Rainfall in Phetchaburi River Basin

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Abstract. *Phetchaburi River Basin is a watershed that connects to the coast. There is a rainy season from May to November. The average rainfall is about 1,000 mm per year, about 200 mm less than the average rainfall in Thailand. Due to the low rain in the area, there is a problem of water shortage for agriculture and consumption. Therefore, the Department of Royal Rainmaking and Agricultural Aviation has carried out Royal Rainmaking operations to increase the amount of rainfall over the basin especially the amount of water flow through the Kaeng Krachan Reservoir. This study assessed the effectiveness of royal rain and terrestrial rain in the Phetchaburi Basin by collecting hourly rainfall data during 09.00-21.00 (12 hrs.) for 14 stations and 4 additional stations studied for installation and radar rain data in the form of a grid obtained from the operation in years 2018-2020. It found that there were 108 days of Royal precipitation during these three years by analyzing the spatial areal using the Invert Distance Weighted technique. The spatial areal rainfall of the two datasets had a correlation coefficient of 0.21, which was a relatively low correlation. Once simulating radar rainfall data, come to the 4 additional stations to find the average daily spatial areal rainfall. The data were then compared with the reference data again. It found that the correlation coefficient increased with correlation coefficient of 0.54. However, it has to wait for the actual measurement results during the Royal Rainmaking Operations Year 2021 from this additional measuring device and use the results obtained to evaluate the achievement of the Royal Rainmaking Operations in the year 2021.*

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Phetchaburi River Basin, Royal rainmaking operation, Radar rain, Spatial areal rainfall, Terrestrial rain

1. Introduction

Natural precipitation is an essential factor in hydrology for planning water management. However, due to the nature of the distribution of the rain that changes both time and place that may result in an insufficient amount of water costs from existing water resources. With the extended visions and the genius image of His Majesty King Bhumibol Adulyadej has been graciously pleased to let's experiment with real rain in the sky for the first time on July 20, 1969. It is still the King's science that helps alleviate the suffering of water shortage for farmers.

Among the changing environmental situation, the Department of Royal Rainmaking and Agricultural Aviation can no longer use traditional methods to solve immediate problems according to the case. Research, development, innovation, and knowledge are needed to modify work processes according to changing conditions, focusing on solving spatial drought problems and integrating with other agencies related such as the Royal Irrigation Department, Department of Water Resources, and the Department of Groundwater Resources to increase efficiency and reduce risks in planning spatial water management through royal rain operations including risk factors and errors that may arise from operations.

Therefore, in this research project, emphasis is placed on evaluating the achievement of the Royal Rainmaking Operations by considering the use of inspections with ground rain data and the study area was selected as the Phetchaburi River Basin. Phetchaburi Province to analyze rainfall conditions, synthesize/interpret the results of the royal rain data, and install additional rain and climate measurement stations to assess the achievement of royal rains and prepare a database of royal rain for further study.

2. Study Area and Data

2.1 Study Area

Phetchaburi River Basin It has a watershed area of approximately 6,254.45 sq.km. Most of the area is in Phetchaburi, Samut Songkhram and Ratchaburi provinces. The basin is rectangular, oriented in the west-east direction, between the latitude of 12° 30' North to the latitude 13° 30' North and Between the longitude 99° 00' East to the longitude 100° 15' East, north adjacent to the Mae Klong Basin. The south is adjacent to the Prachuap Khiri Khan Coastal Basin. West borders adjacent to Myanmar, and East is adjacent to the Gulf of Thailand.

The Phetchaburi River is the main river of the basin. It originated at the Tanaosri Mountains on the west side of the basin. Kaeng Krachan District, a mountain range separating

the border between Thailand and the Union of Myanmar, cannot descend to the east Tha Yang District and has a low mountain range. The cause of the plains between the mountains on the west side of the basin is high mountains, which are the origin of the major tributaries of the Phetchaburi River Basin. Next to the central part of the river basin, the landscape is a river basin. The Phetchaburi River flows through the Kaeng Krachan Reservoir and the Phet Reservoir. The lower area on the east side of the basin is a coastal plain. There is a short stream widely distributed. Most of the rivers flow into the Phetchaburi River and out. The sea around Ban Laem District The river's total length is 227 km, the river capacity is about 250-390 m^3/sec, and the average slope of the river is about 1: 800.

2.2 Information and Scope of the Daily Royal Rain Operation Areas

The data collected consists of data on the Royal Rainmaking Operations of the Hua Hin Royal Rainmaking Center during the year 2018 to 2020, in which the format of the data was obtained and applied Will be data in grids design which shows the area of hope for the achievement of royal rain that will change in every operation, as shown in Fig. 1. The data items received from April 4, 2018, to May 31, 2020, total 148 operations by translating the boundary data of the royal rain making operating area from the received grid data of 148 grid files by using the geographic information process to use as a reference area for estimating the average rainfall from the ground rain measurement station. An example of converting grids data into scope can be shown in Fig. 2.

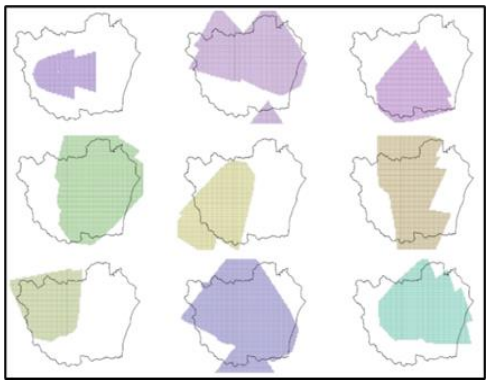

Fig. 1 An example of a data format for the expected area boundary for the achievement of royal rain

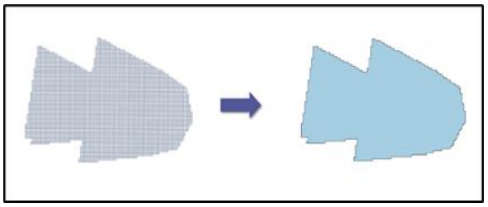

Fig. 2 Determination of grid plot area boundaries

2.3 Hourly Ground Rainfall Data

Collecting hourly rainfall data from 22 ground rain measuring stations, Water Resources Information Institute (Public Organization) The location of the rain measuring station is shown in Fig. 3.

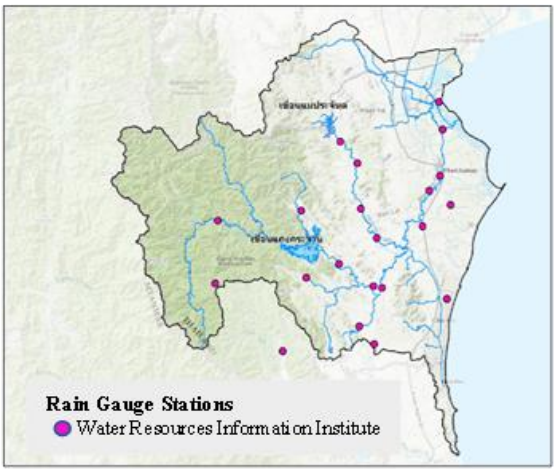

Fig. 3 Location of the rain measuring stations of the Water Resources Information Institute

2.4 Radar Rain Data

From the data of all 148 Royal Rainmaking operations, 108 operations were operating in the Phetchaburi area were selected. The Royal Rainmaking Operations location in Phetchaburi Province, during the year 2018-2020, amounting to 108 operations, are shown in Fig. 4. The results of the Royal Rainmaking Operations in the form of a grid, the interior contains rainfall data which is interpreted from the data of the Royal Sattahip Rain Radar Station. Chonburi has taken to find the mean from every Daily grid with geographic information techniques. An example of calculating the average rainfall is shown in Fig. 5.

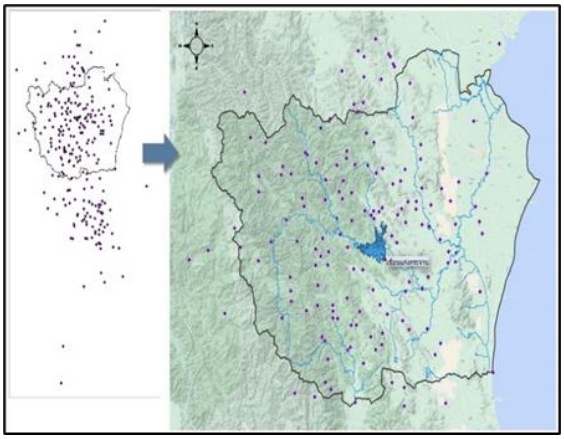

Fig. 4 Map of the location of the Royal Rainmaking operations in the Phetchaburi area during the year 2018 – 2020.

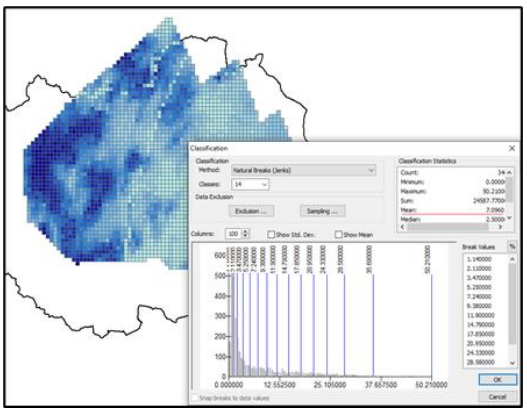

Fig. 5 The average precipitation within the grid

2.5 Installation of Rain Monitoring Stations and Additional Climate Data

The recommendation is to install additional rain and climate data monitoring stations to cover the flight line of the Royal Rainmaking Operations. The research team has superimposed the collected flight line boundaries to provide an overview of the direction and the appropriate flight line for installing additional stations, as shown in Figure 6. From the above flight line map, it can be concluded that the measurement station should be installed. Additional rainwater in the upper watershed area is the target area for making royal rain fill water into the Kaeng Krachan Dam. The researchers determined the location of the rain measurement station and the climate monitoring station to be located in the upper area of the river basin, numbering 4 stations as follows:

1) Ban Krang Camp Station, Huai Mae Phiang Subdistrict, Kaeng Krachan District, Phetchaburi Province

2) Ban Phukhem School Station, Kaeng Krachan Subdistrict, Kaeng Krachan District, Phetchaburi Province

3) Ban Phu Sawan School Station, Phu Sawan Subdistrict, Kaeng Krachan District, Phetchaburi Province

4) Ban Tha Sala School Station, Yang Nam Klat Nuea Subdistrict, Nong Ya Plong District, Phetchaburi Province

3. Methodology

3.1 Determination of Daily Rainfall in Each Station

Ground rainfall from the Water Resources Information Institute (Public Organization) is the hourly data. The cumulative amount of precipitation was taken from 9:00 a.m. to 9:00 p.m. for 12 hours to be the daily rainfall, covering the period of operation until the period of achievement hoping of the royal rain. Summary of daily rainfall data between 2018 and 2020, only 108 days of the Royal Rainmaking Operation in Phetchaburi Province, showing an example of daily rainfall estimates of ground stations. And the daily rainfall data from the analysis results are shown in Table 1.

3.2 Determination of the Spatial Average Rainfall

From the daily rainfall summaries of the ground-based rain-measurement stations, the spatial average was determined using the Inverse Distance Weighted (IDW) method based on the principle that similar locations have spatial correlations in calculating the values at the locations need the location of the nearest station is of greater importance. Thus, the approximation of the unknown point is based on the linear sum of the known values weighted by the distance. This weight changes with the distance from the unknown significance to the next known point relies on the flight line boundary obtained from radar grid data as a reference boundary. The process of estimating spatial averages by the IDW technique from the GIS program is shown in Table 2.

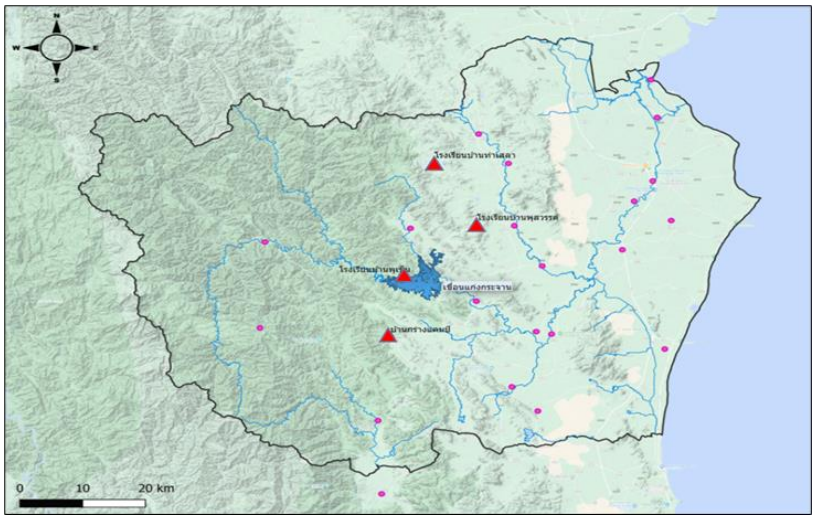

Fig. 6 Map showing the location of the rain monitoring stations and additional climate data

Date-Time	BCAP อบต.หนองญาปล้อง	GALU อบต.กลัดหลวง	GLF003 บางตะบูน	KKCN อบต.สองพี่	KPNT เขาพระเทินทุ	PCH001 เมืองเพชรบุ	PCH002 แก่งกระจาน	PCH003 ท่ายาง	PDAM ทต.ท่ายาง	RCHM อบต.ดอนยาง	RMPT อบต.ไร่ใหม่พั	SWR007 อบต.พุสวรรค์	SWR008 โรงเรียน ตชด.	TATK รพ.สต.ท่าร
13/04/2020 00:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 01:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 02:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 03:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 04:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 06:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 08:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 09:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 10:00	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
13/04/2020 11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13/04/2020 12:00	0	0	0	0		0	0	0	0	0	0	0	0	0
13/04/2020 13:00	0	0	0	0	0	0	0	0	0	0	3.8	0	0	0
13/04/2020 14:00	0.2	0	0	0	0	0	0	0	0	0	4.6	0	0	0
13/04/2020 15:00	3.4	0	0	0	0	0	0	0	0	0	0.2	0	0	0.6
13/04/2020 16:00	2.4	0	0	0	0.2	0	0	0	0	0	0	0	0	0.2
13/04/2020 17:00	4.2	0	0	0	0	0	0	0	0	0	0	6	0	0
13/04/2020 18:00	53.2	6	0.2	17	0	0	0.8	5.6	0	0	0.4	5.8	0	29.8
13/04/2020 19:00	31.6	0.4	1.4	21.6	16.4	1	1.4	0	1	0.6	3.2	9.4	0	55.4
13/04/2020 20:00	1.2	0.2	0.6	10.8	39	2.8	1	0.2	30	2.4	0	19	6.8	7
13/04/2020 21:00	0.4	1.4	1.2	1.4	0.6	1	1.8	2	36.8	4.8	0.2	0.6	31.2	0.4
13/04/2020 22:00	0.8	2.4	0.6	0	0	1.2	1	2.2	0.2	0.4	0.6	0.8	0.8	1
13/04/2020 23:00	0.2	0	0	0	0	0	0.8	0.2	0	0	0	0.2	0	0
14/04/2020 00:00	0	0.2	0	0	0	0	0.4	0	0	0	0	0	0	0
14/04/2020 01:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 Determination of daily cumulative rainfall from hourly data

วันที่	อบต.หนองหญ้าปล้อง	ทต.บ้านลาด	อบต.บางครก	อบต.เขากระปุก	การประปาหน่วยบริการ	อบต.กลัดหลวง	บางตะบูน	อบต.สองพี่น้อง	เขาพระเทินทุง	เมืองเพชรบุรี	แก่งกระจาน	ท่ายาง (บ้านห้วยตะขาบ)	ทต.ท่ายาง	อบต.ดอนยาง	อบต.ไร่ใหม่พัฒนา	หน่วยพิทักษ์ป่า 10	วัดตะเมอกาญจนสถาราม	อบต.พุสวรรค์	รร. ตชด. บเรศวรบ้านห้วยโสก	รพ.สต.ท่าตะคร้อ	อบต.ห้วยลึกใหญ่
4 Apr 18	-		-	-	-	-	-				-	-	-				-	0.6	2.2	-	3.4
11 Apr 18	-		-	0.2	-	-	-				-	-	-	-	-		-	-	-	-	-
15 Apr 18			-	-	-	-	-				-	-	-	-	-		0.8	-	7.0	-	-
16 Apr 18			-	-	-	-	-				-	-	-		-		-	-	-	-	-
17 Apr 18			34.0		53.6	25.4	-				0.2	0.4	35.8		3.2		66.6	36.2	9.6	13.2	6.8
19 Apr 18			-	-	-	1.2	-				-	-			2.2		32.8	13.4	6.0	9.0	11.8
20 Apr 18			-	-	-	-	-				-		-		-		0.6	-	0.2	-	1.2
21 Apr 18			-	-	-	-	-				-	2.0	-				-	-	-	-	-
22 Apr 18			-	-	-	-	-				-	-	-		-		-	-	3.2	-	19.2
24 Apr 18			-	-	-	-	-				-	-	-		-		-	-	-	-	-
25 Apr 18			-	-	-	-	-				-	3.6	-		-		-	-	-	-	-
26 Apr 18			-	-	-	-	-				-	0.4	-	-	-		11.0		4.6	-	2.4
30 Apr 18			-	-	4.4	0.8	-				-	-	23.0		1.0		8.8	0.2	11.2	0.8	24.6
1 May 18			-	-	20.8	3.2	-				-	1.4	7.8		0.2		31.4	1.8	14.2	0.6	29.2
2 May 18			-	-	-	8.0	-				-	-	6.6		-		1.0	3.8	9.4	-	7.6
3 May 18			-		-	2.8	-				-	-	-		-		0.2	1.4	12.4	1.0	11.6
4 May 18			-		-	-	-				-	1.2	-		-		39.2	0.4	0.2	0.2	-
5 May 18			-		-	1.0	-				-	2.0	-		-		51.2	1.4	1.4	-	-
7 May 18			-		-	-	-				-	0.8	-		-		-	0.4	-	-	-
8 May 18			-		-	1.2					-	1.0	-		-		2.8	0.4	0.4	-	-
4 Mar 19	-	-	-	-		-	-		-	-		-	-	-	-		-	0.4	-	-	
15 Mar 19	-	-	-	-	-	-	-		-	-		-	-		-	-	-	-	-	-	
19 Mar 19	-	-	-	-	-	-	-	-	1.0	-		-	-		-	7.2	-	-	1.4	-	
20 Mar 19	-	-	-		-	-	-		6.8	-		-	-		-	0.6	-	-	-	0.2	
21 Mar 19	-	-		-	-	-	-	-	15.6	-		-	-		-	5.4	-	-	-	-	
26 Mar 19	-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-	-	
27 Mar 19			-			-	-		-			0.2			-	0.2	-	-	-	-	
28 Mar 19	0.8	-	-	0.4	0.2	0.2	-	14.6	9.0			-	-	0.2	-	13.0	16.6	2.8	54.8	1.2	
29 Mar 19	-	-	-		-	-	-		0.2	-		-	-	-	-	24.2	-	-	0.6	-	
30 Mar 19	-	-	-	-	-	-	-	0.2	9.8			-	-		-	6.6	-	-	8.0	-	
31 Mar 19	-	-	-	-	-	-	-		-			-	-		-	-	-	-	-	-	
1 Apr 19	25.0	-	-	18.2	-	-	-	52.4	58.0		0.6	-	-	-	-	13.0	0.2	0.4	-	4.6	
2 Apr 19	-	-	-	-	-	1.4	-	2.4	-			8.6	-	-	-	-	-	-	37.2	0.8	
3 Apr 19	-	-	-	0.2	-	5.6	-		0.6			1.4	-		-	2.2	-	-	6.8	-	
5 Apr 19						-	-		16.4							14.6	0.4	0.2	3.8	0.2	
6 Apr 19	-	-	-	-	-	-	-		16.6		-	4.8	-		-	3.0	-	-	0.2	-	
7 Apr 19	4.6	-		3.2	-	2.0	-	36.6	37.6		0.4	1.0	0.4	-	18.6	11.4	2.8	2.2	31.0	8.4	

Table 2 Daily rainfall of the ground rain measuring station

4. Data Analysis Results

4.1 The Results of the Assessment of the Achievement of the Royal Rainmaking Operations

Making the artificial rain helps stimulate the water mass contained in the clouds already floating in the atmosphere. To fall as rainwater following the targeted area that has been defined in each operation. Most of these operations are carried out in the upstream areas to fill the Kaeng Krachan Reservoir. and in the lower areas to help the plantation area from the end of the Phet Dam down to Phetchaburi. It will estimate the amount of rain that falls in the target area, which has been flown only in the Phetchaburi study area between 2018 and 2020, based on the scatter scope information and the expected achievement area imported into the system. Geographic information was already superimposed with the average equivalent spatial rainfall depth for the same period. To study the amount of rainfall that occurs after the Royal Rainmaking operation.

The study results were summarized as follows: From the Royal Rainmaking Operations in Phetchaburi Province during the year 2018 to 2020, It was found that 108 operations were compared with rain data from radar and ground rain data of the Institute of Water Resources Information. (Public Organization) using the IDW technique (Table 2). It was found that the spatial mean correlation coefficient of the two data sets was $r = 0.21$, and the distribution of the data was shown in the Fig. 7.

The correlation values of the two data sets were relatively low. When considering the daily rainfall contour map comparing the radar rainfall data and the average ground rainfall data, it was found that in the upper part of the basin, the targeted area for the Royal Rainmaking to fill the Kaeng Krachan Dam. Several rain stations do not cover flight guidelines. Therefore, the difference in average precipitation is relatively high. Consequently, it is proposed to install additional rain gauge stations in the upper areas of the watershed.

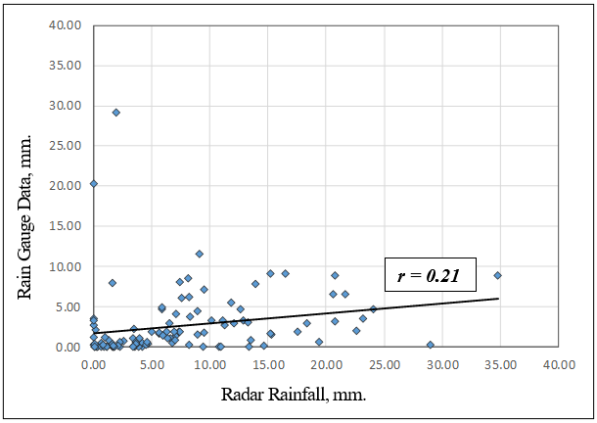

Fig. 7 Relationship between radar rainfall and ground station rainfall

4.2 The Results of the Simulation of Radar Rain Data into the Retrofit Stations

Retrofit stations use climate data monitoring systems installed at various points. The research team has surveyed and checked for suitability for installation. The objective is to establish a measurement system to measure rainfall and climate data in the surrounding areas that occur after the chemical sprinkling of the artificial rain to use such information for research. The data measurement system is designed to use modern technology, such as introducing a high-performance, energy-saving, and versatile microcomputer combined with the Internet of Things (IoT) technology and has chosen to use solar energy as a natural energy source. To focus on this research to be full of quality, standard, modern and environmentally friendly. In the installation of additional stations Completed after the end of the Royal Rainmaking Operations Year 2020 (The Royal Rainmaking Operations Year 2020 started in February end of May 2020) to test the hypothesis that the station installation has enough distribution and number of stations and covers the airways of the Royal Rainmaking. It will help increase the efficiency of ground rain measurement data. The researchers simulated rain data from historical radar data in a grid format to the data of the 4 additional stations, and the average rainfall in the watershed area was calculated from the ground monitoring stations and the 4 new stations using the IDW technique. The data were compared with the radar rain data and ground rainfall data for the year 2018 - 2020 once again. The results of the comparison of the three data sets and concluded that the amount of precipitation received from the 4 new ground rain stations and the amount of rain received from the radar. The correlation coefficient was improved with r = 0.54 and the distribution curve of the relationship, as shown in Fig. 8.

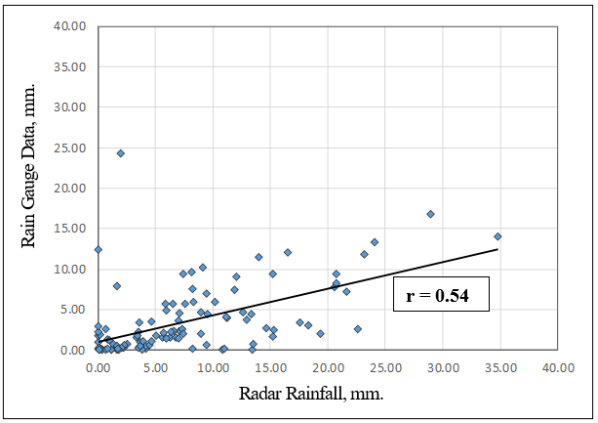

Fig. 8 Relationship between radar rainfall and ground station rainfall (Including the 4 additional stations)

5. Conclusion and Recommendation

This research evaluated the achievement of royal rainmaking by examining the amount of rain measured from the ground rain gauge station of the Water Resources Information Institute. (Public Organization), the hourly rainfall the cumulative daily values were taken using the duration covered for the take-off and the period of precipitation after the operation between 9:00 AM and 9:00 PM. They were then compared with the average daily rainfall obtained from the radar. In the form of a grid, they are distributed according to the area hoping for the achievement of each operation. This research considers that the rain data from the radar is accurate and can be used as reference data in the amount of rainfall to compare the achievements of the Royal Rainmaking.

Based on 148 Royal Rainmaking Operations data obtained from the Department of Royal Rainmaking and Agricultural Aviation. Only the flight lines within the boundary of Phetchaburi province were selected, with 108 data remaining, the number of rainy days 175 days, no rain 3 days. The comparison with the ground data gave a correlation coefficient of r equal to 0.21 due to most flight lines. In the upper area of the basin, adding water to the Kaeng Krachan Dam is important, but the terrestrial rain monitoring station has an inadequate and inadequate distribution in that area. Therefore, the research team conducted a feasibility study of installing additional rain gauge stations and additional climate data in the upper area of 4 stations, namely Ban Krang Camp Station. Huai Mae Phiang Subdistrict Ban Phu Khem School Station, Kaeng Krachan Subdistrict, Ban Phu Sawan School Station, Phu Sawan Subdistrict, Kaeng Krachan District, and Ban Tha Sala School Station Tambon Yang Nam Klat Nuea, Nong Ya Plong District, Phetchaburi Province.

To test the hypothesis of the station installation on the performance of the rain data measurements, the rainfall data from the radar during 2018-2020 was simulated at all 4 stations to find the average daily spatial rainfall. The data were then compared with the reference data again. It appeared that the correlation coefficient increased with the *r*-value being 0.54. Still wait for the actual measurement results during the Royal Rainmaking Operations Year 2021 from this additional measuring device. and use the results obtained to evaluate the achievement of the Royal Rainmaking Operations in the year 2021.

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