International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

June 2022 | Issue 51 | Volume 14 | Number 2 | Pages 248-253

RELATIONSHIP BETWEEN THE RAINFALL FROM TRMM SATELLITES AND RAINFALL FROM GROUND RAINFALL STATIONS

J. Itsarawisut [1] P. Thammasaeng [1] T. Laosuwan [2]

1. Department of Physics, Faculty of Science, Mahasarakham University, Kantarawichai District, Maha Sarakham, Thailand, jumpol.i@msu.ac.th, pairat.t@msu.ac.th
2. Space Technology and Geo-Informatics Research Unit, Faculty of Science, Mahasarakham University, Kantarawichai District, Maha Sarakham, Thailand, teerawong@msu.ac.th

Abstract- The rainfall measurement with the use of meteorological satellites is another option for determining the amount of rainfall that falls on a region, particularly in locations without ground rainfall stations, such as forest areas and high mountain areas were setting up a ground station would be inconvenient. Therefore, the main objective of this research was to analyze the relationship between the rainfall from Tropical Rainfall Measuring Mission (TRMM) meteorological satellites and the rainfall from ground rainfall stations in Roi Et Province which located in the central part of the Northeastern region of Thailand. The methodology for this study was conducted in 2020 using the monthly rainfall data measured by TRMM meteorological satellites and the ground rainfall data from the Thai Meteorological Department (TMD) from a total of 12 stations in Roi Et Province. The two sets of data were then analyzed for statistical correlation by a simple linear regression method. The results of the linear regression analysis of the two variables (x and y variables) were the rainfall data from measurements from meteorological satellites and the ground rainfall data measured by spatial interpolation using inverse distance weighting (IDW) method obtained the value of R^2 in a good criterion. The month with the highest coefficient of determination (R^2) was September with an R^2 of 0.875. The month with the lowest R^2 was October with an R^2 of 0.534. The results of this study represented that the rainfall data from the TRMM meteorological satellites was effective for estimating rainfall. Additionally, it could be applied for estimating the amount of rainfall in areas with no ground rainfall stations or other areas of interest onwards.

Keywords: Remote Sensing, Digital Image Processing, TRMM Satellites, Linear Regression.

1. INTRODUCTION

Global warming, climate variability and climate change are phenomena that represent changes occurring in the atmosphere and affecting the global system, atmosphere, and living organisms. Global warming has led to various consequences, for example, drought in some areas caused by no seasonal rainfall and unusual weather conditions. In addition, global warming is also a major cause of marine cyclones that are more frequent and intense, whether it is a hurricane, cyclones and typhoons in various regions around the world, as well as heavy rainfall and flooding in many areas [1].

In case of Thailand, although it has not been affected by severe climate changes, it has begun to suffer from various natural disasters more often due to Thailand is located on the Indochina Peninsula and its borders is close to both the Pacific Ocean on the east and the Indian Ocean on the west. Changes from global warming that occurred in the Indian and Pacific Oceans therefore affected the climate of Thailand and were an important variable in the level of severity of climate variability, such as heavy rainfall, flooding and drought, etc. This is a phenomenon that has a high influence and is important to rainfall and drought conditions in Thailand including El Nino and La Nina phenomena [2].

Based on the meteorological and hydrological data, especially "rain", which is an important parameter for water management whether it is water resource planning, watershed management, reservoir management, flood warning, rainfall data, which is close to real time, it is therefore very significant for evaluating floods [3].

According to the study of meteorological and hydrological data in Thailand, in addition to relying on data collected on the ground, it can currently also be studied using data from Remote Sensing Technology [4-6] due to over the past 3 decades, there were the applications of remote sensing technology namely data from earth resource survey satellites, meteorological satellites, radar systems, Global Navigation Satellite System (GNSS) etc., which have been developed rapidly. Also, it can survey data in a large area at a lower cost than ground surveying, so it has led to the applications in various fields such as land use/cover, drought, flood, land surface temperature, carbon dioxide, particulate matter, etc. [7-12].

In addition, the terrestrial precipitation measurements of Thai Meteorological Department (TMD) in Thailand are measured by the height of precipitation falling on an area with a rain gauge, measured in mm or inches. The measured data is the amount of rainfall that falls directly to the ground, but the amount of rainfall is only representative of the data at the measured area that cannot be representative of the area far from the rain gauge station [13, 14].

The rainfall measurement with the use of meteorological satellites is another option that can measure the amount of rainfall that covers a wide area throughout especially areas with no ground rainfall stations, such as forest areas and high mountain areas where are not convenient to set up a ground station [15-17]. From researching related documents, it was found that there was a study that aimed to bring the results of the Tropical Rainfall Measuring Mission (TRMM) to be applied in various areas such as La Plata Basin in South America [18], Xinjiang in Northwest China [19], Kelantan River Basin, Malaysia [20], Tianshan Mountains in Xinjiang, China [21], etc. In Thailand, there were studies about the applications of the rainfall data from meteorological satellites as well, such as Validation of TRMM Rainfall Data Over Basins in Northeast Thailand [22], The relationship between satellite rainfall and the gauge rainfall in Nan River Basin [13], Comparison of rainfall from TRMM with rain gauge station in upper Nam Phong River basin, etc. [23].

From the above-mentioned importance, the main objective of this study was to analyze the relationship between the rainfall from TRMM meteorological satellites and the rainfall from the ground rainfall stations. In this study, the selected study area was in Roi Et Province, located in the central part of the northeastern region of Thailand. This aims to represent that rainfall data from TRMM meteorological satellites can be used for estimating rainfall in different areas of Thailand.

2. MATERIAL AND METHOD

2.1. Study Area

Roi Et Province (Figure 1) is located in the central part of the Northeastern region between 15°24' N to 16°19' N latitude and 103°16' E to 104°21' E longitude with a total area of 8,299.46 km^2. The topography is generally a plateau with meters above mean sea level of 120-160 m approximately. There are mountains in the north which connect from the Phu Phan Mountain Range in the central part of the province with the characteristics of undulating plain.

The lower part is characterized as a plain along the Mun River and its branches, such as the Chi River, the Phlapphla River, and the Tao River.The wide lowland area is known as "Thung Kula Ronghai" with an area of about 128 km^2, with the characteristics of flat basin. The climate is in the tropical rain category with the average rainfall of 1,196.8 mm^3, with heavy rainfall in June-October. It is hot and dry in March-May. The provincial administration is divides into 20 districts, 192 Sub-districts and 2,446 villages.

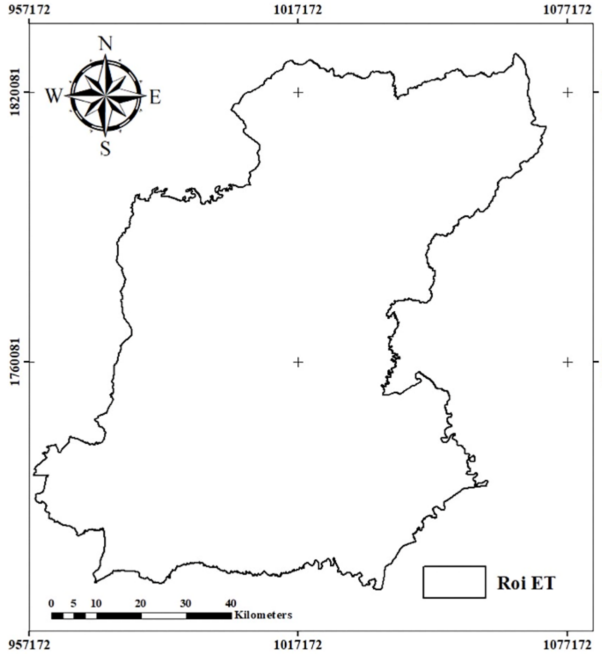

Figure 1. The study area

2.2. Data

2.2.1. The Rainfall Data from TRMM Meteorological Satellites

A meteorological satellite called TRMM is a joint project of the National Aeronautics Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) launched on November 27, 1997 [24]. TRMM meteorological satellites have a non-sun-synchronous orbit at an altitude of 403 km with an inclined orbit at an angle of 35° to the equator. The rainfall data measured from TRMM meteorological satellites had the advantage of having spatial coverage with a pixel resolution of 25×25 km^2 and was able to be measured the distribution of rainfall and the speed of the storm. Therefore, this study aimed to use 2020 monthly rainfall data from the measurement of TRMM (TMPA/3B43) Rainfall Estimate L3 1 month 0.25-degree×0.25-degree V7 (TRMM_3B43).

2.2.2. Rainfall Data from Ground Rainfall Stations

This study collected rainfall from 12 ground rainfall stations in Roi Et Province, divided into 11 ground rainfall stations of TMD, namely Selapoom Station (No. 1), Suvarnabhumi Station (No. 2), Thawat Buri Station (No. 3), Prathumrat Station (No. 4), Nong Phok Station (No. 5), Phon Thong Station (No. 6), Kaset Wisai Station (No. 7), Pho Chai Station (No. 8), Muang Suang Station (No. 9), Thung Khao Luang Station (No. 10), Roi Et Station (No. 11), and Roi Et Agricultural Meteorological Stations (No. 12).

2.3. Methodology

In this study, the researcher has divided the research method into sub-sections and can describe the steps as follows.

2.3.1. Rainfall Data Analysis

The first part was the collection of rainfall data from TRMM meteorological satellites: The researcher downloaded TRMM_ 3B43, the monthly 2020 rainfall data from EARTHDATA (https://earthdata.nasa.gov/ search? q=TRMM+3B43). This data is a file extension NetCDF (Network Common Data Form) that converted rainfall data from NetCDF file extension to TIFF extension with Geographic Information System (GIS). For the collection of rainfall data from ground rainfall stations, the researcher had imported the geographic coordinates of all 12 ground rainfall stations, which obtained the monthly rainfall from January to December of 2020 according to the locations of the ground rainfall stations used in this research. Each rain measurement consists of province names, station names, station codes and geographic coordinates, which are latitudes and longitudes. The data obtained from rainfall stations was formatted by taking latitude and longitude in degrees, minutes, seconds (Degree Minute Second: DMS) to convert to Decimal Degree (DD) format and then import into the program via GIS for further processing.

2.3.2. Spatial interpolation

Since ground rainfall stations did not cover the study area, the interpolation method was used in the purpose of numerical prediction for the area with no data to ensure continuity of data in all areas. Estimating the area data using GIS technique will result in raster format data. This study used inverse Distance Weight (IDW) interpolation, which relies on the principle that nearby positions inevitably have a spatial relationship in calculating values at the desired location. The position of the nearest station will be more significant than far positions. Thus, this is an approximation of the unknown point from the linear sum of the known value. Then, such the position was weighted to be limited by distance. This weighted value will change by the distance from the unknown point to the next known point. The nearest known point is the most important or the most weighted value in the estimation of that unknown point.

2.3.3. The Analysis of Statistical Correlation with Simple Linear Regression

In this study, the statistical correlation was conducted by using a simple linear regression method. At any rate, single variable linear regression is sometimes referred to as simple linear regression, which means a model of the relationship between two variables using a straight line. When the linear relationship between the two variables is significant, linear regression will provide a simple model for predicting the value of the dependent variable by using the value of the independent variable. Therefore, simple linear regression allows us to use one variable to predict about another variable and test the hypothesis of the relationship between two variables. In addition, simple linear regression can represent the linear relationship between the dependent variable and the independent variable.

3. RESULT

For the analysis of the relationship between the rainfall from meteorological satellites and the rainfall from ground rainfall stations, this study had divided the findings into 3 parts as follows: 1) The results of collecting rainfall data from TRMM meteorological satellites and the rainfall data from ground rainfall stations 2) The results of spatial interpolation 3) The results of statistical relationship analysis by simple linear regression method.

3.1. The Result of Collecting the Rainfall Data

In this study, the annual rainfall data from TRMM meteorological satellites can be shown in Figure 2. For the rainfall data from all 12 ground rainfall stations in Roi Et province, including Selaphum Station, Suvarnabhumi Station, Thawat Buri Station, Prathumrat Station, Nong Phok Station, Phon Thong Station, Kaset Wisai Station, Pho Chai Station, Muang Suang Station, Thung Khao Luang Station, Roi Et Station, and Roi Et Station, can be shown in Table 1.

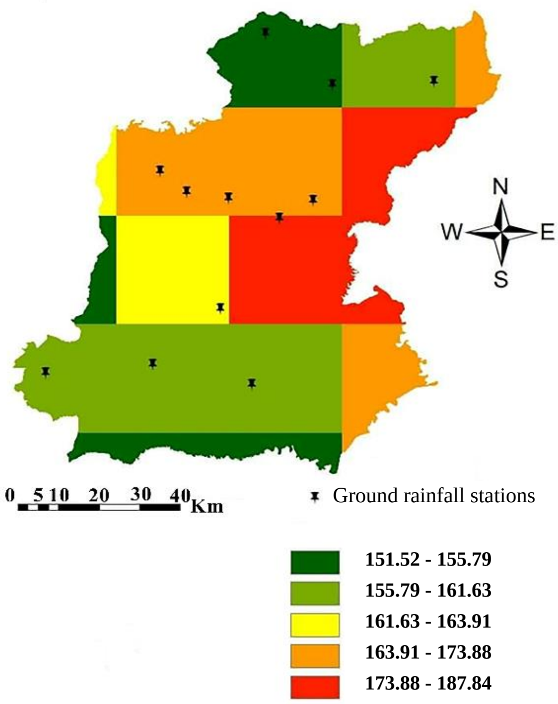

Figure 2. Annual rainfall from TRMM satellites in 2020

From Table 1, the table representing the monthly rainfall data from all 12 stations in Roi Et Province can be described as follows: In January, there was no rainfall or no rain at all 12 stations. In February, there were the highest rainfall of 11.7 mm in Selaphum Station (No. 1) and the lowest rainfall of 3.7 mm in Thung Khao Luang Station (No. 10). In March, there were the highest rainfall of 50 mm in Roi Et Agricultural Meteorological Stations (No. 12) and the lowest rainfall of 4.3 mm in Muang Suang Station (No. 9). In April, there were the highest rainfall of 112.4 mm in Roi Et Station (No. 11) and the lowest rainfall of 14.7 mm in Prathumrat Station (No. 4). In May, there were the highest rainfall of 314 mm in Kaset Wisai Station (No. 7) and the lowest rainfall of 73.4 mm in Phon Thong Station (No. 6).

In June, there were the highest rainfall of 146.3 mm in Nong Phok Station (No. 5) and the lowest rainfall of 15.7 mm in Prathumrat Station (No. 4). In July, there were the highest rainfall of 207.9 mm in Selaphum Station (No. 1) and the lowest rainfall of 64 mm in Suvarnabhumi Station (No. 2). In August, there were the highest rainfall of 789.2 mm in Roi Et Agricultural Meteorological Stations (No. 12) and the lowest rainfall of 314.3 mm in Prathumrat Station (No. 4). In September, there were the highest rainfall of 400.2 mm in Roi Et Station (No. 11) and the lowest rainfall of 122.9 mm in Prathumrat Station (No. 4).

In October, there were the highest rainfall of 90 mm in Nong Phok Station (No. 5) and the lowest rainfall of 0.5 mm in Thung Khao Luang Station (No. 10). In November, there were the highest rainfall of 2.9 mm in Thung Khao Luang Station (No. 10). In December, there was no rainfall or no rain at all 12 stations. The annual rainfall was 1,117.17 mm and the average annual rainfall was 167.09 mm. From the rainfall data from all 12 stations in the areas of Roi Et Province, it shows that there was the highest rainfall in August and the lowest rainfall or no rainfall in January and December.

Table 1. Rainfall data from all 12 rainfall stations (mm)

No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Annual
1	0	11.7	12.8	70.5	236.2	70.4	207.9	714	365.4	16	0	0	1704.9	189.4
2	0	0	0	0	176	44.6	64	493	287	0	0	0	1064.6	212.92
3	0	0	6.5	87.4	148.2	46.2	121.2	478.7	355	0	0	0	1243.2	177.6
4	0	0	0	14.7	84.4	15.7	143.4	314.3	122.9	57.9	0	0	753.3	107.6
5	0	0	0	0	185.7	146.3	122.8	658.3	322.6	90	0	0	1525.7	254.28
6	0	0	0	20	73.4	84.5	110.5	424.3	167.5	40	0	0	920.2	131.46
7	0	0	0	28.9	314	0	0	0	0	0	0	0	342.9	171.45
8	0	0	0	87	161	61	0	0	0	0	0	0	309	103
9	0	0	4.3	100.3	206.1	88.5	103	504	0	0	0	0	1006.2	167.7
10	0	3.7	6.2	111.2	180.5	56.2	155.4	545.8	216.8	0.5	2.9	0	1279.2	127.9
11	0	10.8	26.6	112.4	123.2	30.4	144.9	661.1	400.2	21.1	0	0	1530.7	170
12	0	5.8	50.0	112.3	172.1	25	131.3	789.2	395.9	44.1	0	0	1725.7	191.74
Total													1117.17	167.09

3.2. Results of Spatial Interpolation

The results of spatial distribution analysis of annual rainfall by IDW spatial interpolation method in the study areas in Roi Et Province can be shown in Figure 3.

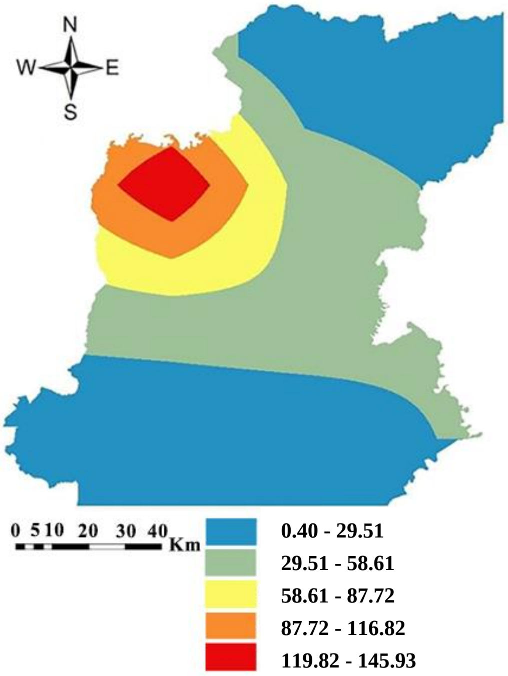

Figure 3. Monthly and annual rainfall by IDW in 2020

Furthermore, the analysis of spatial distribution for rainfall by IDW estimation method of monthly rainfall can be described as follows. In January, there were the highest rainfall distributions of 2.80 mm and the lowest rainfall distributions of 0.28 mm.

In February, there were the highest rainfall distributions of 15.79 mm and the lowest rainfall distributions of 1.79 mm. In March, there were the highest rainfall distributions of 55.67 mm and the lowest rainfall distributions of 14.08 mm. In April, there were the highest rainfall distributions of 94.86 mm and the lowest rainfall distributions of 66.16 mm. In May, there were the highest rainfall distributions of 299.59 mm and the lowest rainfall distributions of 155.32 mm.

In June, there were the highest rainfall distributions of 141.24 mm and the lowest rainfall distributions of 75.58 mm. In July, there were the highest rainfall distributions of 378.52 mm and the lowest rainfall distributions of 227.73 mm. In August, there were the highest rainfall distributions of 703.42 mm and the lowest rainfall distributions of 585.31. In September, there were the highest rainfall distributions of 391.17 mm and the lowest rainfall distributions of 251.87 mm. In October, there were the highest rainfall distributions of 41.18 mm and the lowest rainfall distributions of 25.41 mm. In November, there were the highest rainfall distributions of 59.22 mm and the lowest rainfall distributions of 22.69 mm.

In December, there was no rainfall distribution or no rainfall. From the spatial distribution analysis of annual rainfall by IDW spatial interpolation method can be described as follows: The highest rainfall distribution was 145.93 mm and the lowest rainfall distribution was 0.40 mm. The spatial distribution analysis of rainfall by the IDW estimation method showed that the highest rainfall distributions were in August and there was no rainfall distribution or no rainfall in December.

3.3. Results from Statistical Correlation with Simple Linear Regression

The results of the analysis of the relationship between the rainfall from TRMM meteorological satellites and the rainfall from ground rainfall stations through the IDW spatial interpolation can be explained as follows. In January, the analysis results obtained the Equation $y = 0.4143x + 1.0403$ and the coefficient of determination (R^2) of 0.697. In February, the analysis results obtained the Equation $y = 0.2285x + 7.3822$ and the coefficient of determination (R^2) of 0.640. In March, the analysis results obtained the Equation $y = 0.4231x + 18.712$ and the coefficient of determination (R^2) of 0.703.

In April, the analysis results obtained the Equation $y = 0.1468x + 61.587$ and the coefficient of determination (R^2) of 0.613. In May, the analysis results obtained the Equation $y = 0.6109x + 83.855$ and the coefficient of determination (R^2) of 0.721. In June, the analysis results obtained the Equation $y = 0.3223x + 79.044$ and the coefficient of determination (R^2) of 0.590. In July, the analysis results obtained the Equation $y = 0.1875x + 252.04$ and the coefficient of determination (R^2) of 0.573. In August, the analysis results obtained the Equation $y = 0.5108x + 322.02$ and the coefficient of determination (R^2) of 0.701.

In September, the analysis results obtained the Equation $y = 0.6263x + 121.81$ and the coefficient of determination (R^2) of 0.875. In October, the analysis results obtained the Equation $y = 0.2457x + 27.514$ and the coefficient of determination (R^2) of 0.534. In November, the analysis results obtained the Equation $y = 0.487x + 20.335$ and the coefficient of determination (R^2) of 0.692. In December, the rainfall data were not available from both the rainfall data measured by TRMM satellites and the rainfall data from ground rainfall stations.

According to the analysis results of the coefficient of determination (R^2) in 2020, the month with the highest coefficient of determination (R^2) was September with the coefficient of determination (R^2) of 0.875. In addition, the month with the lowest coefficient of determination (R^2) was October with the coefficient of determination (R^2) of 0.534.

4. CONCLUSIONS

Rain is regarded as the beginning of the hydrological cycle before it circulates into water and flows along the hydrologic cycle. Rain is the key factor considered as priority in the fields of hydrology and rainwater management that results in surface water and groundwater that humans can use for consumption and for other livelihoods, which all human activities depend on water. Rainfall data can be considered crucial and necessary for research or study of physical and environmental characteristics both at the levels of small-sized to large-sized areas. But the rainfall data from rainfall stations are lack of spatial and temporal continuity. Currently, remote sensing technology has been developed to be function of measuring and tracking rainfall. Nonetheless, the data from a TRMM meteorological satellite, one of the satellites that can represent spatial rainfall that is easy and quick to access, which is suitable for studying spatial distribution patterns of rainfall due to it is the information obtained from all actual measurements. The rainfall data from TRMM satellites is therefore an alternative data for studies or research where it is necessary to use spatial rainfall data.

The main objective of this study was to analyze the relationship between the rainfall from TRMM meteorological satellites and the rainfall from ground rainfall stations. The results of the analysis of the linear relationship between the rainfall data measured from TRMM meteorological satellites and the rainfall from ground rainfall stations that passed the process of IDW spatial interpolation of the study areas in Roi Et Province in 2020 obtained a coefficient of determination at a good criterion.

Moreover, the results of this study are consistent with several research studies in Thailand such as the research of Thupkratoke, et al. (2013) [22], which aimed to compare the distribution and to analyze discrepancies and the relationship between the monthly rainfall data from TRMM meteorological satellites and Thailand meteorological stations in the Mekong, Chi and Mun basins, the research of Phonkasi (2016) [13], which studied the relationship between the rainfall from TRMM meteorological satellites and the rainfall from the Meteorological Department's rainfall station in the Nan basin.

For the analysis of the relationship between the rainfall from TRMM meteorological satellites and the rainfall from ground rainfall stations in Roi Et Province in this study, it was shown that rainfall data from TRMM meteorological satellites can be used to estimate rainfall effectively. However, rainfall from the TRMM meteorological satellite is limited in terms of spatial resolution. Since it has a resolution of 0.25 degrees, which is suitable for national or regional studies, this limitation must be accepted. However, considering the accuracy of the data, the TRMM satellite rainfall data is considered to be low inaccuracies and has a good correlation with ground rainfall stations data.

ACKNOWLEDGEMENTS

This Research was financially supported by Mahasarakham University, Kantarawichai District, Maha Sarakham, Thailand.

REFERENCES

[1] T. Rotjanakusol, T. Laosuwan, "Inundation Area Investigation Approach using Remote Sensing Technology on 2017 Flooding in Sakon Nakhon Province Thailand", The Journal of Studia University of Vasile Goldis Arad., Life Sciences Series, Vol. 28, No. 4, pp. 159-166, 2018.

[2] T. Rotjanakusol, T. Laosuwan, "Surface Water Body Extraction Using Landsat 8 Images and Different Forms of Physical Models", The Scientific Journal of Faisal University, Vol. 21, No. 2, pp. 218-223, 2020.

[3] W. Ruairuen, K. Jaroensutasinee, M. Jaroensutanee, "Flash Flooding Area Prediction by GOES-9 Satellite Data", Walailak J. Sci. and Tech., Vol. 2, No. 2, pp. 135-148, 2005.

[4] I. Olthof, N. Svacina, "Testing Urban Flood Mapping Approaches from Satellite and In-Situ Data Collected

during 2017 and 2019 Events in Eastern Canada", Remote Sensing, Vol. 12, No. 19, p. 3141, 2020.
[5] S. Samsonov, A. Baryakh, "Estimation of Deformation Intensity above a Flooded Potash Mine Near Berezniki (Perm Krai, Russia) with SAR Interferometry", Remote Sensing, Vol. 12, No. 19, p. 3215, 2020.
[6] H.J. Ban, Y.J. Kwon, H. Shin, H.S. Ryu, S. Hong, "Flood Monitoring Using Satellite-Based RGB Composite Imagery and Refractive Index Retrieval in Visible and Near-Infrared Bands", Remote Sensing, Vol. 9, No. 4, p. 313, 2017.
[7] J.H. Kim, O.S. Kwon, J.H. Ra, "Urban Type Classification and Characteristic Analysis through Time-Series Environmental Changes for Land Use Management for 31 Satellite Cities around Seoul, South Korea", Land, Vol. 10, No. 8, p. 799, 2021.
[8] Y. Uttaruk, T. Laosuwan, "Drought Analysis Using Satellite-Based Data and Spectral Index in Upper Northeastern Thailand", Polish Journal of Environmental Studies, Vol. 28, No. 6, pp. 4447-4454, 2019.
[9] T. Laosuwan, T. Gomasathit, T. Rotjanakusol, "Application of Remote Sensing for Temperature Monitoring: The Technique for Land Surface Temperature Analysis", Journal of Ecological Engineering, Vol. 18, No. 3, pp. 53-60, 2017.
[10] Y. Uttaruk, T. Laosuwan, "Drought Detection by Application of Remote Sensing Technology and Vegetation Phenology", Journal of Ecological Engineering, Vol. 18, No. 6, pp. 115-121, 2017.
[11] P. Meena, T. Laosuwan, "Spatiotemporal Variation Analysis of Atmospheric Carbon Dioxide Concentration using Remote Sensing Technology", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 48, Vol. 13, No. 3, pp. 7-13, September 2021.
[12] P. Pradabmook, T. Laosuwan, "Estimation of PM_{10} using Spatial Interpolation Techniques", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 49, Vol. 13, No. 4, pp. 33-39, December 2021.
[13] S. Phonkasi, "The Relationship between Satellite Rainfall and the Gauge Rainfall in Nan River Basin", Research Journal Rajamangala University of Technology Thanyaburi, Vol. 15, No. 1, pp. 51-56, June 2016.
[14] Thai Meteorological Department, "Weather Forecast", https://flood.gistda.or.th/, 15 December 2021.
[15] Z. Liu, C.L. Shie, A. Li, D. Meyer, "NASA Global Satellite and Model Data Products and Services for Tropical Meteorology and Climatology", Remote Sensing, Vol. 12, No. 17, p. 2821, 2020.
[16] M.P. Hung, W.T. Chen, C.M. Wu, P.J. Chen, P.N. Feng, "Intraseasonal Vertical Cloud Regimes Based on CloudSat Observations over the Tropics", Remote Sensing, Vol. 12, No. 14, pp. 2273, 2020.
[17] B. Zhang, C. Cao, T.C. Liu, X. Shao, "Spectral Recalibration of NOAA HIRS Longwave CO_2 Channels Toward a 40+ Year Time Series for Climate Studies", Atmosphere, Vol. 12, No. 10, p. 317, 2021.
[18] F. Su, Y. Hong, D. Lettenmaier, "Evaluation of TRMM Multisatellite Precipitation Analysis (TMPA) and Its Utility in Hydrologic Prediction in the La Plata Basin", Journal of Hydrometeorology, Vol. 9, No. 4, pp. 622-640, 2007.
[19] X. Lu, G. Tang, M. Wei, L. Yang, Y. Zhang, "Evaluation of Multi-Satellite precipitation products in Xinjiang, China", International Journal of Remote Sensing, Vol. 39, Vol. 21, pp. 7437-7462, 2018.
[20] M. Tan, K. Tan, V. Chua, N. Chan, "Evaluation of TRMM Product for Monitoring Drought in the Kelantan River Basin, Malaysia", Water, Vol. 9, No. 1, p. 57, 2017.
[21] Y. Zhang, G. Hanati, S. Danierhan, Q. Liu, Z. Xu, "Evaluation and Comparison of Daily GPM/TRMM Precipitation Products over the Tianshan Mountains in China", Water, Vol. 12, No. 11, p. 3088, 2020.
[22] P. Thupkratoke, R. Suwanwerakamtorn, "Validation of TRMM Rainfall Data Over Basins in Northeast Thailand", The 1st Conference on Geoinformatics for Graduate Student and Young Researchers, pp. 220-230, 2013.
[23] M. Suwannasri, H. Prasanchum, S. Phonkasi, "Comparison of Rainfall from TRMM with Rain Gauge Station in Upper Nam Phong River Basin", The 14th National Academic Conference, Kasetsart University Kamphaeng Saen Campus, pp. 198-206, 2017.
[24] Global Precipitation Measurement, "The Tropical Rainfall Measuring Mission", https://gpm.nasa.gov/missions/trmm, 15 October 2021.

BIOGRAPHIES

Jumpol Itsarawisut was born in Khon Kaen, Thailand, on August 26, 1975. He received his Ph.D. in electrical and computer engineering from Mahasarakham University, Maha Sarakham, Thailand in 2018. Since 2018, he has been employed at department of physics, Mahasarakham UniversityHis current research interests include digital image processing, cooperative and distributed control, model predictive control, intelligent control, and robotic motion control, etc.

Pairat Thammasaeng was born in Ban Phai, Khon Kaen, Thailand on November 4, 1962. He received the M.S. degree in Physics from Chulalongkorn University, Thailand in 1990. Currently, he is an Assistant Professor at department of physics, Mahasarakham University, Maha Sarakham, Thailand. His research interests are in the electromagnetic wave, physics education, and physical sciences, etc.

Teerawong Laosuwan was born in Hat Yai, Songkhla, Thailand on October 2, 1971. He received the Ph.D. degree in Electrical and Computer Engineering from Mahasarakham University, Maha Sarakham, Thailand in 2012. Currently, he is an associate professor at department of physics, Mahasarakham University. His research interests are in the remote sensing, geo-informatics, GIS modeling, mobile application development, energy technology and drone surveying and mapping, etc.