International Journal of GEOMATE, Dec., 2018 Vol.15, Issue 52, pp.206-213
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.52.66452
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

RAINFALL TREND BY LINEAR REGRESSION ANALYSIS OVER INDOCHINA PENINSULA DURING 1981-2017 (37 YEARS)

Usa Humphries[1] Pramet Kaewmesri[1,*] and Pariwate Varnakovida[1]

[1]Department of Mathematics, Faculty of Science, King Mongkut's University of Technology Thonburi (KMUTT), 126 Pracha-Uthit Road, Bang mod, Thung Khru, Bangkok 10140, Thailand

*Corresponding Author, Received: 11 Jul. 2018, Revised: 02 Aug. 2018, Accepted: 20 Oct. 2018

ABSTRACT: The objective of this study used data from the Global Rainfall Climatology Project (GPCP) global gridded data observation to statistical analysis rainfall over the Indochina Peninsula (from 1981 to 2017 (37 years)) with a domain of 2.5° by 2.5° grid spacing. The central tendency (mean, range, etc.) and dispersion (S.D, CV, etc.) were used in the statistical analysis. For identifying the trend in the rainfall data, the statistical analysis of linear regression was used in this study. The results in this study were shown the total amount of rainfall changes over three periods that were period I (1981-1990), period II (1991-2000), period III (2001-2010) and period IV (2011-2017). In the basic statistical was analyzed rainfall annual, rainfall monthly, and regression monthly rainfall analysis over ICP. In basic statistical was shown the highest annual mean rainfall was 2017, which recorded an amount of 162.91 mm. The record indicated the standard deviation correlating the highest annual mean rainfall was 51.99 mm. From the results of the linear regression analysis revealed downward trends in the rainfall for the months of April, July, October, and December and an upward trend for other months. In this study was shown the overall trend of the spatial pattern over ICP.

Keywords: GPCP, Rainfall, linear regression analysis, and ICP

1. INTRODUCTION

The Indochina Peninsula (ICP) is a terrain and unique identity of geographically. The location of ICP situated between the Indian Ocean and the South China Sea. The countries in the ICP include Cambodia, Laos, Myanmar, Vietnam, Thailand and some territories of Malaysia [1], [2], [3]. Hence this area is influence from two kind monsoon wind of seasonal character i.e. southwest monsoon which begins in May brings a stream of warm moist air from the Indian Ocean towards land causing substantial rain over the country in ICP. Other monsoon wind is northeast monsoon that starts in October. This monsoon brings the cold and dry air from the anticyclone in mainland over major parts of ICP, especially which is higher latitude areas. On the other hand over the Malaysia southern and western Thailand, the northeast monsoon causes mild weather and abundant rainfall around this area.

The agriculture is the leading branch of the regional economy over ICP. In general, the climate factor is main of important natural part of agriculture. Another reason, because the background of climate changes are more impact over this area especially important for sustainable development of the economic power engineering, agriculture, runoff water, etc.

However, in recent years, several extreme or heavy rainfall events have been reported over the country in ICP. For example, an extreme rainfall event occurred on March 23-30, 2011 caused severe big flooding over east of southern Thailand. The accumulated rainfall rage from 200 mm to 1,200 mm across the east of southern Thailand with the Malaysia Peninsula. Surat Thani province in the east of southern Thailand was recorded the most rainfall immediately by NASA, as represented in Fig.1. The flooding in this event was affected by 842,324 people, 8 provinces and killing 13 people [4-5]. The rainfall behavior can be change possibly due to climate change. So, the extreme event has increasingly important in analyzing the rainfall.

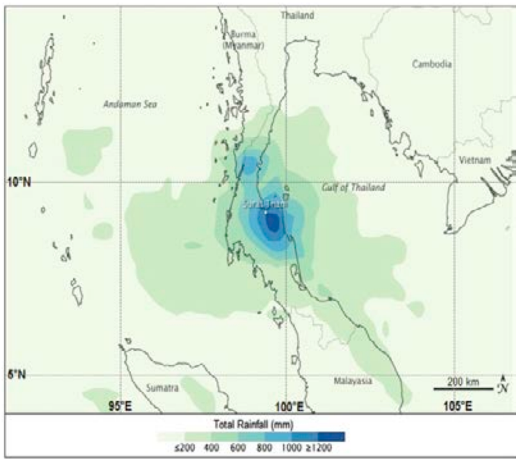

Fig. 1 The accumulate rainfall of March 23-30, 2011, resulting in a heavy flooding event [4-5].

However, the understanding the mechanism of long-term climate over the ICP has been important and interested. In this research, the statistical analysis examined historical long-term climates over the ICP. If understanding mechanism climate over ICP through statistical analysis that can help the risk assessment policies for increasing demands from agricultural, industrial and domestic sectors in the ICP.

2. METHODOLOGY

2.1 Statistical analysis

The data obtained over the period of 1981 to 2017 over ICP. Statistical analyses were performed to assess any significant difference analyses were performed to assess any significant difference among within the months and years under study on the data and graphs were constructed to illustrate the changing trends within the months and the years for the period. The statistical analysis was used to determine the measure in this study that includes meaning, median, S.D., kurtosis, skewness, min, max, range and linear regression. For identifying the trend in the rainfall data, the statistical analysis of linear regression was used.

Linear regression is one of the simplest methods to calculate the trend of data in the time series. The equation of the linear regression line is written by

$$Y = a + bX, \tag{1}$$

while Y is the dependent variable. X is the independent variable. The slope line is b and a is the intercept (value of Y when $X = 0$). The slope line has described the trend of rainfall. If slope line is positive that means rainfall increase trend. But, if the slope line is negative that means rainfall decrease trend. In this study the dependent variable Y is rainfall and the independent variable X is the year. Linear regression requires the assumption of normal distribution. In this study, the null hypothesis is that the slope of the line is zero or there is no trend in the data. The probability (P value) was shown the significance of the slope line. The line and statistical of linear regression analysis were used to calculate in this study. The P value from the analysis is the test for the significant level α =0.05.

The value of c-square (R^2) or the square of the correlation from the regression analysis was used to show how strong the correlation and relationship between the variables X and Y. The value is a fraction between 0.0 and 1.0. An R-square (R^2) value of 1.0 means that the correlation becomes strong and all points lie on a straight line. On the other hand, an R-square (R^2) value of 0.0 means that there is no correlation and no linear relationship between X and Y [6].

2.2 Rainfall observation data

The Global Rainfall Climatology Project (GPCP) monthly product provides a consistent analysis of global rainfall from an integration of various satellite data set over land and ocean and gauge analysis over land. Data from rain gauge station, satellites, and sounding observation have been to estimate monthly rainfall on a 2.5 degree global grid from 1979 to the present. The spatial of GPCP observation cover area is between latitude 180 degree east to 180 degrees west and longitude 50 degrees north to 50 degrees south [7-8]. The careful combination of satellite-based rainfall estimates provides the most complete analysis of rainfall available to date over the global oceans and adds necessary spatial detail to the rainfall analyses over land. In addition to the combination of these data sets, estimates of the uncertainties in the rainfall analysis are provided as a part of the GPCP products.

2.3 Study area

The ICP region is located at a latitude of 5°N to 30°N and a longitude of 90°E to 110°E, and consists of Cambodia, Laos, Myanmar, Vietnam, Thailand and some territories of Malaysia, as shown in Fig 2.

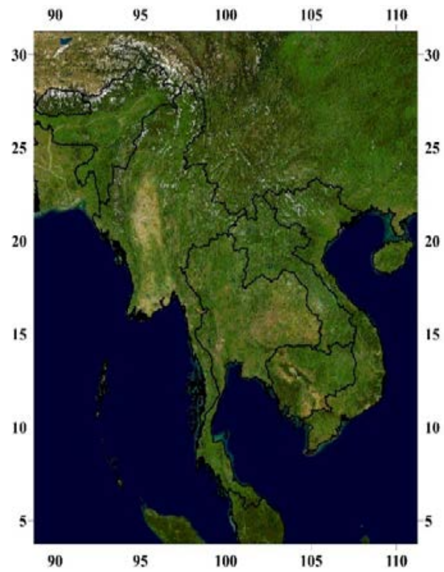

Fig. 2 Domain of study area (Indochina Peninsula (ICP))

The climate of Indochina Peninsula is under the influence of monsoon winds of seasonal character that is pre-monsoon, southwest monsoon, and northeast monsoon. The pre-monsoon starts period from March to April every year. This monsoon is the transitional period from the northeast to the southwest monsoon. This period, the weather has warmer ICP especially Thailand, Laos, Malaysia, Myanmar and etc. The southwest monsoon which starts in May to October that brings a stream of warm moist air from the Indian Ocean towards ICP causing abundant rain over the country, especially the windward side of the mountains.

Over ICP, the rainfall is not only occurred by the southwest monsoon. Furthermore, the Inter-Tropical Convergence Zone (ITCZ) and tropical cyclones produce a large amount of rainfall over ICP. The northeast monsoon starts period from November to February. This period, the wind brings the cold and dry air from anticyclone from the South China Sea (SCS) and China mainland. It causes mild weather and abundant rainfall along with some part of ICP. For example it abundant rainfall along the eastern coast of Thailand and southern Thailand.

The observation data from The Global Rainfall Climatology Project (GPCP), in particular, basic characteristics of rainfall, their monthly, were used for establishment of atmospheric rainfall dynamics in ICP.

Data of observation over atmospheric rainfall obtained from the following gridded point and used for study over ICP during 1981-2017.

3. RESULTS AND DISCUSSION

For determination of rainfall change this study used 1981-2017 observation data, which were separated into 10-years in 1981-1990 periods, 10-years in 1991-2000 periods, 10-years in the 2001-2010 period, and 7-years in 2011-2017.

Consider analysis shows that under the influence of global climate change in ICP, from 1981-2017 (almost 37 year period) total amount of rainfall experiences the following changes: during the period rainfall amount varies from 31.69 mm to 265 mm (Fig. 3).

In the period I (during 1981-1990), the total amount of rainfall changes from 36.29 mm to 265.35 mm. The rainfall changes from 47.80 to 86.54 mm (in pre-monsoon), changes from 177.44 to 157.66 mm (in southwest monsoon), and changes from 115.87 to 36.34 mm (in northeast monsoon).

In period II (during 1991-2000), this period is shown more validate and the highest rainfall (187.61 mm) than another period (period I (157.66 mm), period III (163.35 mm), and period IV (156.51 mm)) in October. The total amount of rainfall change from 47.15 to 94.62 mm (in pre-monsoon), change from 178.48 to 187.61 mm (in southwest monsoon), and changes from 115.89 to 40.43 mm (in northeast monsoon).

In period III (during 2001-2010), the total amount of rainfall change from 60.24 to 89.82 mm (in pre-monsoon), change from 183.16 to 156.51 mm (in southwest monsoon), and changes from 121.54 to 31.69 mm (in northeast monsoon).

In period IV (during 2000-2017), this period is shown more validate and the highest rainfall (248.49 mm) than another period (period I (231.38 mm), period III (223.12 mm), and period IV (224.24 mm)) in September. The total amount of rainfall change from 63.07 to 83.15 mm (in pre-monsoon), change from 183.44 to 156.51 mm (in southwest monsoon), and changes from 125.98 to 41.07 mm (in northeast monsoon).

However, the trend of all periods was shown similarly trend rainfall. The all periods rainfall were shown the minimum trend in the every February, while the maximum is recorded in the every July.

In the mentioned period, according to data on rainfall (1981-2017) during three 10-year periods with 7-year periods is observed the change in rainfall amount according to periods (during the period I to IV period). During the period I and II, the annual of rainfall increased by 72.64 mm, from period II to III period, decreased by 26.53 mm, and from period III to IV period, increased by 22.96 mm. In general, for 37 years, the rainfall is increased by 69.07 mm (Fig. 4).

Materials of observation over the annual rainfall amount in the course of years (1981-2017) are presented in Fig. 5 The maximum rainfall was recorded in 2017 (162.91), and the second maximum was recorded in 1999 (162.58), and the third maximum was recorded in 2000 (158.63), while the minimum rainfall was recorded in 1992 (131.27), the second minimum was recorded in 1989 (136.33), and the third minimum was recorded in 2014 (136.74).

From Table 1, the year with the highest annual mean rainfall was 2017, which recorded an amount of 162.91 mm. The record indicated the standard deviation correlating the highest annual mean rainfall was 51.99 mm. The high standard deviation value can be easily correlated with the high rainfall rage. The rainfall rage signifies the difference between the maximum and minimum annual rainfall.

Skewness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right [6].

Kurtosis is a measure of data peakedness or flatness relative to a normal distribution. That is, data sets

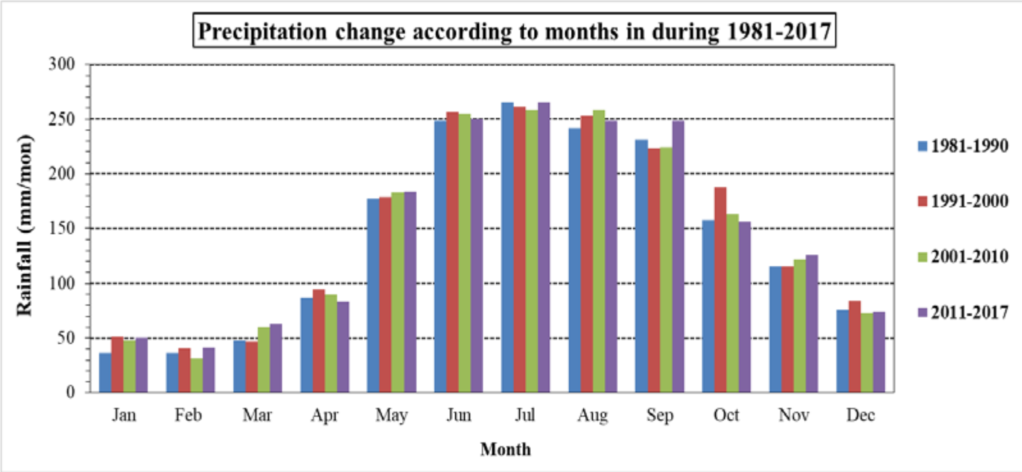

Fig. 3 Rainfall means for each period according to a month in 10 years period from 1981 to 2010 and 7 years period from 2011 to 2017 over ICP.

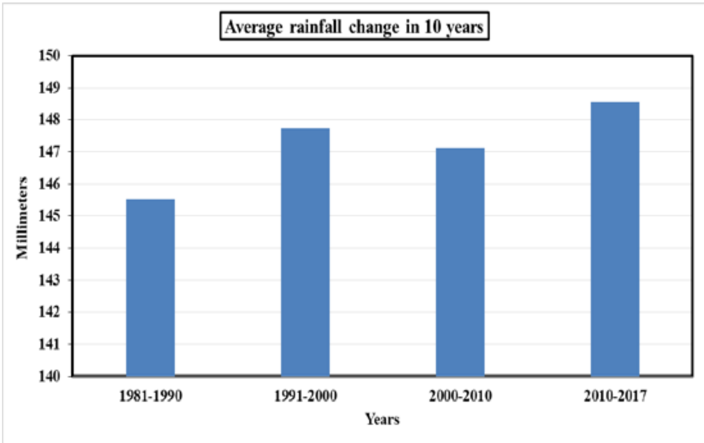

Fig. 4 Rainfall mean in 10 years period from 1981 to 2017 over ICP

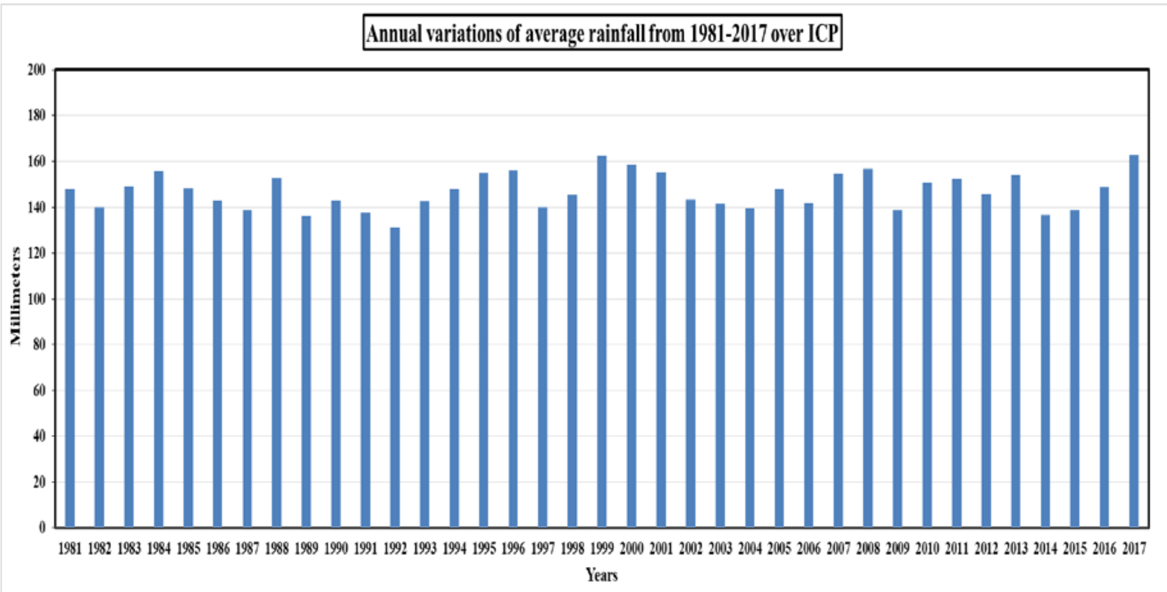

Fig. 5 Annual variation of rainfall means from 1981 to 2017 (37 years) over ICP

with high kurtosis tend to have a district peak near the mean, decline rather rapidly, and have a heavy tail. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution [6].

Table 2 clearly revealed that July had the highest Standard deviation. The highest amount of average monthly rainfall was recorded in July (262.50 mm) and contributed to 14.87% of annual rainfall, followed by June (252.57 mm) and August (250.51 mm) with contributed to 14.30% and 14.19% respectively. The lowest was recorded in February (37.08 mm) and contributed to 2.10% of annual rainfall, followed by January (46.04 mm) and March (53.88 mm) with contributed to 2.61% and 3.05% respectively.

Table. 1 Descriptive basic statistical method of rainfall annual over ICP

Year	Annual	Mean Annual	Median	S.D.	Kurtosis	Skewness	Min	Max	Range
1981	4434.90	147.83	147.85	49.06	-0.24	0.10	37.54	264.14	226.61
1982	4202.10	140.07	136.63	49.02	-0.14	0.25	33.85	271.01	237.16
1983	4478.10	149.27	145.41	49.55	0.47	0.08	26.80	300.87	274.07
1984	4672.50	155.75	154.93	55.67	-0.46	0.11	32.16	287.44	255.29
1985	4447.50	148.25	142.62	48.64	-0.42	0.21	38.15	265.06	226.91
1986	4291.80	143.06	145.57	45.64	-0.30	-0.14	29.48	248.53	219.04
1987	4164.60	138.82	132.47	45.25	0.58	0.59	31.83	271.75	239.92
1988	4581.60	152.72	152.70	55.10	-0.49	0.19	30.92	280.97	250.04
1989	4089.90	136.33	133.60	44.46	0.05	0.41	35.89	261.10	225.21
1990	4295.10	143.17	144.74	45.53	0.22	0.14	32.71	262.20	229.48
1991	4129.20	137.64	131.42	47.25	0.76	0.54	29.31	282.88	253.57
1992	3938.10	131.27	130.50	42.87	-0.36	-0.02	26.01	240.12	214.11
1993	4278.90	142.63	136.96	46.91	0.43	0.59	40.60	282.75	242.15
1994	4440.00	148.00	151.99	51.31	-0.19	-0.06	24.43	283.29	258.86
1995	4649.70	154.99	154.55	51.58	-0.55	-0.02	32.84	273.70	240.86
1996	4688.10	156.27	161.45	51.41	-0.54	-0.16	36.61	274.85	238.24
1997	4202.70	140.09	139.39	46.34	0.02	0.14	30.32	276.20	245.87
1998	4363.20	145.44	144.91	45.79	0.66	0.53	35.22	286.58	251.35
1999	4877.40	162.58	162.10	55.86	0.59	0.39	39.05	359.76	320.72
2000	4758.90	158.63	164.03	53.43	-0.11	0.16	35.16	326.46	291.30
2001	4660.50	155.35	157.47	52.04	-0.19	0.08	38.99	302.83	263.84
2002	4305.00	143.50	139.84	48.30	0.23	0.41	37.05	294.67	257.62
2003	4248.90	141.63	140.46	47.19	-0.48	0.18	38.13	268.13	230.01
2004	4191.00	139.70	132.74	48.57	0.20	0.53	32.55	283.59	251.04
2005	4442.40	148.08	149.78	48.41	-0.84	-0.09	36.06	246.97	210.90
2006	4254.60	141.82	143.20	49.42	-0.22	0.10	27.82	268.32	240.49
2007	4639.80	154.66	158.80	52.16	-0.40	0.06	33.56	302.30	268.74
2008	4706.10	156.87	163.66	48.28	-0.28	-0.06	38.96	276.48	237.51
2009	4164.30	138.81	139.56	47.22	-0.58	0.06	32.18	251.36	219.18
2010	4523.10	150.77	157.56	45.94	-0.59	-0.21	30.92	244.59	213.67
2011	4578.30	152.61	154.42	55.85	-0.86	-0.16	37.76	272.11	234.35
2012	4378.50	145.95	153.67	45.60	-0.45	-0.09	29.74	257.07	227.33
2013	4623.60	154.12	166.26	48.17	-0.68	-0.31	35.13	259.56	224.43
2014	4102.20	136.74	141.69	40.85	-0.47	-0.08	30.92	237.98	207.06
2015	4163.70	138.79	141.58	44.76	0.32	0.10	23.86	292.30	268.44
2016	4463.10	148.77	150.73	45.31	-0.54	-0.13	34.51	244.63	210.11
2017	4887.30	162.91	169.97	51.99	-0.31	-0.11	34.38	286.94	252.56

Table. 2 Descriptive basic statistical method of rainfall monthly over ICP

Month	Annual	Mean Annual	Median	S.D.	Kurtosis	Skewness	Min	Max	Range	C.V.
Jan	1381.20	46.04	21.51	57.66	4.78	2.11	3.74	321.70	226.61	1.25
Feb	1112.40	37.08	24.23	37.49	5.35	2.23	5.68	209.70	237.16	1.01
Mar	1616.40	53.88	44.26	41.09	4.67	2.00	8.56	220.77	274.07	0.76
Apr	2669.10	88.97	80.04	48.29	1.29	1.12	14.02	247.42	255.29	0.54
May	5412.00	180.40	180.91	64.34	-0.28	0.04	28.98	351.47	226.91	0.36
Jun	7577.10	252.57	214.14	115.51	2.05	1.39	64.95	663.97	219.04	0.46
Jul	7875.00	262.50	222.15	116.77	2.12	1.41	100.42	702.33	239.92	0.44
Aug	7515.30	250.51	221.71	104.03	0.87	1.03	92.30	600.41	250.04	0.41
Sep	6913.50	230.45	229.93	86.39	-0.85	0.05	54.53	416.72	225.21	0.37
Oct	5012.40	167.08	170.53	83.45	1.57	0.67	15.18	522.18	229.48	0.50
Nov	3579.60	119.32	74.76	99.80	-0.39	0.77	3.07	426.35	253.57	0.83
Dec	2303.70	76.79	30.82	93.64	0.97	1.41	2.57	370.56	214.11	1.21

The results of the linear regression trend analysis of ICP is presented in Table 3. The trend of rainfall from January to December for 37 years. This calculation has been computed for each month independently.

Table 3 revealed downward trends in the rainfall for the months of April, July, October, and December and an upward trend for other months.

Since the probability value (P value) from the regression analysis for the slopes of the monthly trend lines was greater than the significant level $\alpha = 0.05$, the null hypothesis (H_0: there is no significant difference in the mean annual rainfall among the climate zones in ICP of thirty-seven years), fail to reject. That means there is no statistically significant trend in monthly rainfall data for ICP. Additionally, the R square statistic also indicated a very weak relationship between the variables, rainfall, and year.

Table. 3 Regression monthly rainfall analysis over ICP.

Month	Regression	R square	P value	Significant
Jan	y = 0.3849x + 38.723	0.0744	0.10	No
Feb	y = -0.0235x + 37.529	0.0005	0.90	No
Mar	y = 0.5447x + 43.528	0.0901	0.07	No
Apr	y = -0.1076x + 91.016	0.0031	0.74	No
May	y = 0.1576x + 177.41	0.0046	0.69	No
Jun	y = 0.1608x + 249.51	0.0075	0.61	No
Jul	y = -0.1235x + 264.85	0.0062	0.64	No
Aug	y = 0.3449x + 243.95	0.035	0.27	No
Sep	y = 0.323x + 224.32	0.0349	0.27	No
Oct	y = -0.3099x + 172.96	0.012	0.52	No
Nov	y = 0.302x + 113.58	0.0143	0.48	No
Dec	y = -0.0263x + 77.291	0.0002	0.94	No

Fig. 6 was shown the spatial pattern trend of slope regression over ICP. The brown color was mean downward trends of rainfall over ICP. On the other hand, the light blue color was mean upward trends of rainfall over ICP. For example, the rainfall over northern and northeastern Thailand was shown an increase trend rainfall (blue color). On the other hand, the rainfall over Bangladesh, northern Myanmar, and the Gulf of Thailand were shown decrease trend rainfall (brown color).

4. CONCLUSION

This study was considered analysis shows that under the influence of global climate change in ICP, from 1981-2017 (almost 37 year period). In the period I, the total amount of rainfall changes from 36.29 mm to 265.35 mm. In period II, this period is shown more validate and the highest rainfall than another period. In period III, the total amount of rainfall change from 60.24 to 89.82 mm (in pre-monsoon), change from 183.16 to 156.51 mm (in southwest monsoon), and changes from 121.54 to 31.69 mm (in northeast monsoon). In period IV, this period is shown more validate and the highest rainfall than another period.

In the basic statistical was shown the highest annual mean rainfall was 2017, which recorded an amount of 162.91 mm. The record indicated the standard deviation correlating the highest annual mean rainfall was 51.99 mm.

From the results of the linear regression analysis revealed downward trends in the rainfall for the months of April, July, October, and December and an upward trend for other months. In this study was shown the overall trend of the spatial pattern over ICP in Fig. 6.

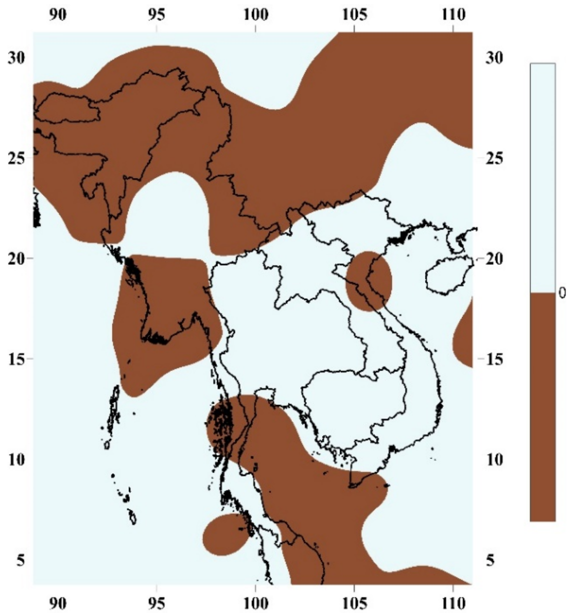

Fig. 6 The spatial pattern of regression trend over ICP.

5. ACKNOWLEDGMENTS

The authors would also like to thank Prof. Dr. Zhu Jiang from the Institute of Atmospheric Physics Chinese Academy of Science for support everything. The authors are also very grateful to the Department of Mathematics, Faculty of Science, King Mongkut's University of Technology Thonburi (KMUTT) and the Computational and Applied Science for Smart Innovation Cluster (CLASSIC), Faculty of Science, King Mongkut's University of Technology Thonburi (KMUTT) for the support. The authors acknowledge the financial support provided by National Research Council Thailand (NRCT). This research was fully supported by the International Research Network (IRN) (IRN5701PDW0002).

6. REFERENCES

[1] Sooktawee S., Humphries U., Limsakul A., and Wongwises P., Low-level wind variability over the Indochina Peninsula during Boreal Winter, Int. J. Environ. Sci. Develop, Vol 3, 2012, pp.129-135.

[2] Sooktawee S., Humphries U., Limsakul A., and Wongwises P., the Spatio-temporal variability of Winter Monsoon over the Indochina Peninsula, Atmos, Vol 5, 2014, pp.101-121.

[3] Humphries U., Kaewmesri P., Wongwises Archevarapuprok B., and Sooktawee S., Simulation of large-scale resolution IAP DCP model for pre-monsoon and southwest monsoon events over Indo China Peninsula, Research Journal of Applied Sciences, Vol 13, Issue 4, 2018, pp. 94-102.

[4] Loo Y Y., Billa L., and Singh A., Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia, Geoscience Frontiers, Vol6, Issue 6, 2015, pp.817-823.

[5] Kaewmesri P., and Humphries P., Simulation of an unseasonal heavy rainfall event over southern Thailand using the Weather Research and Forecasting (WRF) model, SAUSSUREA, Vol 1, 2018a, pp.1-18

[6] Nature M., Gyimah O V., and Ampiaw F., Statistical Analysis of Rainfall Trend for Volta Region in Ghana, International Journal of Atmospheric Sciences, Vol 2014, 2014, pp. 1-12.

[7] Adler R F., Huffman G., Chang A., Ferraro R., Xie P., Janowiak J., Rudolf B., Schneider U., Curtis S., Bolvin D., Gruber A., Susskind J., Arkin P., and Nelkin E., The version 2 Global Rainfall Climatology Project (GPCP) monthly rainfall analysis (1979-present). J. Hydrometeor, Vol 4, Issue 6, 2003, pp.1147-1167.

[8] Adler, R. F., Gu G., and Huffman G., Estimating Climatological Bias Errors for the Global Rainfall Climatology Project (GPCP), Journal of Applied Meteorology and Climatology, Vol 51, 2012, pp. 84-99.

[9] Kaewmesri P., Humphries U., and Sooktawee S., Simulation on High-Resolution WRF Model for an Extreme Rainfall Event over the Southern Part of Thailand. International Journal of Advanced and Applied Sciences, Vol 4, Issue9, pp. 26-34.

[10] Kaewmesri P, Humphries U, Wangwongchai A, Wongwies P, Archevarapuprok B, and A, Wongwies P, Archevarapuprok B, and Sooktawee S., The simulation of heavy rainfall events over Thailand using microphysics schemes in weather research and forecasting (WRF) model. World Applied Sciences Journal, Vol. 35, Issue 2, 2017b, pp. 310-315.

[11]Kaewmesri. P, Humphries. U, Archevarapuprok. B, and Sooktawee. S., The Performance Rainfall during Rainy Seasonal over Thailand by Using Preliminary Regional Coupled Atmospheric and Oceanic model. International Journal of GEOMATE, Vol. 14, Issue 45, 2018b, pp. 109-115.

[12] Lagidze L., Matchavariani L., and Paichadze N., The Influence of Circular Processes on Change in Precipitation in the Scope of Climate Change, International Journal of GEOMATE, Vol.13, Issue 39, 2017, pp.213-219

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.