

ANALYSIS OF RAINFALL IN THE EASTERN THAILAND

*Wonlee Nounmusig¹

¹Faculty of International Maritime Studies, Kasetsart University, Thailand

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ABSTRACT: Eastern Thailand needs for water increases daily due to population growth, economic developments, and urbanization. The main source of water in the region is mainly from the rain. Therefore, understanding of rainfall pattern in this region is required to support the planning of water management. In this study, the patterns of rainfall in eastern Thailand are analyzed by using statistical analysis. The data used from 15 rain gauge stations (the period in 1969-2008) of Thai Meteorological Department (TMD). The 40-year average of rainfall is found 1921mm. The region has abundant of rainfall during May to September due to Southwest monsoon, especially in windward location. The highest of rainfall and rain day found in August at Khlong Yai with exceeding 1000mm and exceed 25day, respectively. The results show yearly rainfall has been a tendency to decrease. The significant correlation between monthly rainfall and ENSO indices has the largest number in the transitional period (April, May, and October).

Keywords: Rainfall, Eastern Thailand, Correlation, ENSO

1. INTRODUCTION

Eastern Thailand is a region of Thailand lying between the Sankamphaeng Range to the north and the Gulf of Thailand to the south. The border of the region is Cambodia on the east and central Thailand on the west. Eastern Thailand consists of 7 provinces (Chachoengsao, Chanthaburi, Chonburi, Prachinburi, Rayong, Sa Kaeo and Trat) covering an area of 34,381km² and accounts for 6.7% of the country. In 2010, approximately 62.49% is an agricultural land proposes, 22.92% for forest land, 6.84% for urban and built-up land, 2.46% for a water body and 5.29% for miscellaneous land as shown in Fig. 1[1]. In addition, a major industrial zone (the Eastern Seaboard) which plays a key role in Thailand's economy is also located in the region. Thus, the need for water in the region increases daily due to population growth, economic developments, and urbanization.

The main source of water in the region is mainly from the rain. Too much or too little rain can have disastrous effects on the agricultural, industrial, and others consumption sectors. For example, severe drought of the region in 2005 led to a conflict in water resource allocation caused a fall in crop production and the industrial sector shipping water by truck from nearby regions [2].

In general, the climate in Thailand is dominated by northeast monsoon and southwest monsoon [2-3]. Abundant of Thailand Rainfall is not only caused by the monsoon but also by the Inter Tropical Convergence Zone (ITCZ) and tropical cyclones. Thus, the monsoons are also controlled by the ITCZ. Seasonal movement of the ITCZ near the equator, which play critical roles in

transporting heat, driving ocean circulation and supplying precipitation due to surface convergence, induces large-scale monsoonal wind regimes [4-6].

Many researchers indicated that the El Niño – Southern Oscillation (ENSO) cycles have influenced Thailand monsoon rainfall on interannual scales [5-8],[10-14]. The variations in the position and intensity of the ITCZ are associated with climate phenomena known as the ENSO. Anomalies in the ITCZ and monsoon rainfall are typically in phase with the anomalies in central and eastern Pacific Ocean. Moreover, recent studies have indicated that the factor influences on the Thailand Monsoon rainfall are not only the ENSO [9]. Strong Indian Ocean Dipole (IOD) events are also a significant factor that impacts Thailand Monsoon rainfall. However, the effect of the interaction IOD and ENSO on Thailand Monsoon rainfall remains unclear [8]. Most of the IOD events are not related to ENSO. It is different both in Walker circulation and periodicities of El Niño and IOD events [8], [10].

The study and understanding of relationships between rainfall and ENSO in eastern Thailand are required to support the planning of water management. The main objectives of this study are to report climate patterns and to analyze eastern Thailand rainfall by using statistical analysis. The study includes a limited analysis of rainfall dynamics caused by monsoon activity.

2. DATA AND METHODS

2.1 Data Used

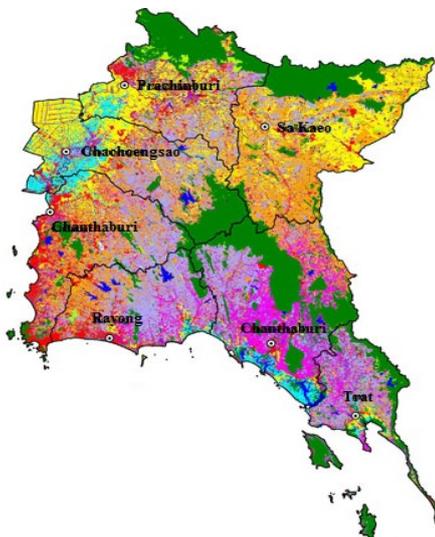
2.1.1 Rainfall data

15 rain gauge stations during 1969 to 2008

from the Thai Meteorological Department (TMD) were used to analyze rainfall distribution pattern. Table 1 shows the description of the 15 rain gauge stations used in this study. The mean annual rainfall and rainy day in eastern Thailand were shown in Table 2. The maximum of rainfall and rain day found at Khlong Yai (Station ID. 501201) with 4713 ± 701 mm. and 192 ± 19 day, respectively.

2.1.2 Climate in Thailand

The climate in Thailand is divided into three seasons as follows: 1) southwest monsoon season (mid-May to mid-October). The southwest monsoon prevails and brings warm and wet air from the Indian Ocean to Thailand.



Land use type	Area	
	km ²	%
Urban and built-up land	2,353.02	6.84
Urban and built-up land	2,353.02	6.84
Agricultural land	21,485.01	62.49
Paddy field	4,876.80	14.18
Field crop	5,560.24	16.17
Perennial	6,385.67	18.57
Orchard	3,197.02	9.30
Horticulture	41.27	0.12
Pasture and farmhouse	154.28	0.45
Aquatic plant	1.08	0.003
Aquaculture land	1,268.47	3.69
Integrated farm/Diversified farm	0.17	0.0005
Forest land	7,879.94	22.92
Dense forest	433.92	1.26
Disturbed forest	7,446.02	21.66
Waterbody	844.49	2.46
Waterbody	844.49	2.46
Miscellaneous land	1,818.04	5.29
Other or miscellaneous land	1,604.50	4.67
Marsh and swamp	213.54	0.62
Total	34,380.50	100.00

Fig. 1 Land use map in eastern Thailand [14].

Table 1 Description of the 15 rain gauge stations

Station ID.	Station Name	Lat. (°N)	Long. (°E)	Elev. (m)
440201	Aranyaprathet	13°42'00"	102°35'00"	47.0
423301	Chacherngsao*	13°33'57"	101°27'30"	69.4
480201	Chanthaburi	12°37'00"	102°06'48"	2.9
459201	Chon Buri	13°22'00"	100°59'00"	0.9
478301	HuaiPong*	12°44'00"	101°08'00"	43.3
430401	Kabin Buri	13°59'00"	101°42'26"	10.2
501201	Khlong Yai	11°46'00"	102°53'00"	2.0
459202	Ko Sichang	13°09'42"	100°48'07"	24.9
459205	Lam Chabang	13°04'37"	100°52'33"	80.7
459203	Phatthaya	12°55'12"	100°52'10"	58.9
480301	Phriu*	12°31'00"	102°10'00"	22.3
430201	Prachin Buri	14°03'00"	101°22'00"	4.1
478201	Rayong	12°38'05"	101°20'45"	2.6
459204	Sattahip	12°41'00"	100°59'00"	16.0
440401	Sa Kaew	13°47'20"	102°02'05"	40.9

Table 2 Mean annual rainfall and rain days with standard deviation

Station ID.	Recording Period	Mean annual			
		Rainfall (mm)	Std.	Rain days(Day)	Std.
440201	1969-2008	1372	175	130	13
423301	1989-2008	1323	200	120	14
480201	1969-2008	2917	484	167	14
459201	1969-2008	1276	216	118	13
478301	1969-2008	1392	277	119	16
430401	1970-2008	1653	238	132	11
501201	1969-2008	4713	701	192	19
459202	1969-2008	1222	320	102	13
459205	1993-2008	1160	200	103	12
459203	1981-2008	1119	234	106	11
480301	1969-2008	3166	636	171	23
430201	1969-2008	1862	286	134	13
478201	1981-2008	1362	288	114	15

Eastern Thailand has also abundant rain occurs in this period. The wettest month in the region is in July to August. 2) Winter or northeast monsoon season (mid-October to mid-February). The northeast monsoon brings cold and dry air from China to upper Thailand. 3) Summer or pre-monsoon season, mid-February to mid-May. This is the transitional period from the northeast to southwest monsoons. The weather becomes warmer, especially in upper Thailand. April is the hottest month for all regions of Thailand.

2.1.3 ENSO indices

Sea surface temperature anomaly (SSTA) data for equatorial regions of the Pacific Ocean which calculated from the HadISST1 [8] were used for this study. The regions included here were Niño3 (the area averaged SST from 90°W–150°W and 5°S–5°N), Niño4 (the area averaged SST from 160°E–150°W and 5°S–5°N), and composite region Niño34 (the area averaged SST from 120°W–170°W and 5°S–5°N).

The Indian Ocean Dipole (IOD) intensity is represented the gradient in the difference between sea surface temperatures of the western equatorial Indian Ocean (50°E-70°E and 10°S-10°N) and the southeastern equatorial Indian Ocean (90°E-110°E and 10°S-0°N). This gradient is named as Dipole Mode Index (DMI). When the DMI is positive then, the phenomenon is referred as the positive IOD and when it is negative, it is referred as negative IOD [8]. The Southern Oscillation Index (SOI) is defined as the normalized pressure difference between Tahiti and Darwin. There are several slight variations in the SOI values calculated at various center. The SOI data used here were calculated using the method given by Ropelewski and Jones [9-10].

2.2 Data Analysis

The Pearson correlation coefficients (r) were used for investigation significant relationships between rainfall data and ENSO indices (SSTAs, SOI, IOD) as shown in Eq. (1).

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (1)$$

where n is the number of data, x_i and y_i are the data set at the time I , and \bar{x} is defined as in Eq. (2),

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (2)$$

The significance test of correlation can be calculated with a t statistic using the Eq. (3).

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad (3)$$

The null hypothesis was rejected at a significant level of α when $|t|$ is more than or

equal to $t_{\frac{\alpha}{2}, n-2}$.

3. RESULTS AND DISCUSSION

3.1 Rainfall

3.1.1 Annual rainfall and rain day

Fig. 2 shows an average annual rainfall in the eastern region of Thailand. The 40-year average of rainfall is 1921mm. The linear trend indicates that the average annual rainfall has been a tendency to decrease. When El Niño (La Niña) phenomenon is identified, the SSTAs in the Niño34 region is above the threshold of +0.5°C (-0.5°C).

Although the correlation between average yearly rainfall and Niño34 is weak ($r=-0.28$), most of the average yearly rainfall is below normal during El Niño year especially in 1987 1992and 1997 (1843 1577 and 1613mm, respectively). Eastern Thailand rainfall variations in La Niña year tend to be opposite those of El Nino. The average yearly rainfall in La Niña year is mostly above the average as in 1974, 1975, 1988, 1999 and 2000 with each year exceeding 2000mm. Moreover, when considering only in the ENSO year (excluding normal year), it is found that the average yearly rainfall has the significant correlation with Niño34 ($r=-0.46$).

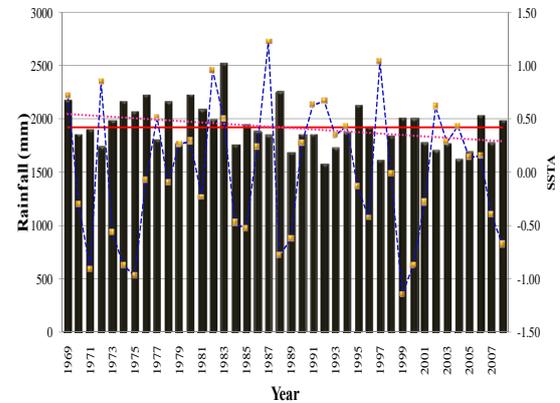


Fig.2 Average yearly rainfall in eastern Thailand (— represent the 40-year average of rainfall, ... represent a linear trend, bar represent the amount of rainfall, and --■-- represent the sea surface temperature anomaly region Niño34).

Table 3 and 4 summarize the significant correlation between ENSO indices and average yearly rainfall and rainy day, respectively at 15 stations. The correlation between average yearly rainfall and all of ENSO indices is mostly weak ($r<=-0.51$). The rainfall has only the significant correlation with Niño and SOI correlation in station ID 440201 and 459202. When considering the correlation between the ENSO indices and rainy day, rainy day in most of the station has the significant correlation with ENSO indices.

Table 3 Correlation between the ENSO indices and average yearly rainfall at 15 stations

Station ID	Niño3	Niño34	Niño4	SOI	DMI
440201	-0.33	-0.45	-0.49	0.52	0.10
423301	-0.16	-0.25	-0.26	0.36	0.21
480201	-0.03	-0.08	-0.01	0.03	0.05
459201	-0.29	-0.33	-0.31	0.32	-0.08
478301	-0.13	-0.20	-0.20	0.24	-0.20
430401	-0.08	-0.18	-0.23	0.21	0.00
501201	-0.02	-0.09	-0.11	0.02	0.24
459202	-0.33	-0.39	-0.37	0.37	-0.26
459205	-0.44	-0.42	-0.30	0.44	-0.51
459203	-0.16	-0.20	-0.14	0.23	-0.26
480301	0.15	0.05	0.05	-0.08	0.22
430201	-0.29	-0.31	-0.31	0.31	-0.06
478201	-0.20	-0.25	-0.21	0.25	-0.23
459204	-0.12	-0.18	-0.24	0.25	0.02
440401	-0.07	-0.29	-0.38	0.48	0.56

Note: Correlations in bold are significant at the $p=0.05$ level

Table 4 Correlation between the ENSO indices and average annual rain day at 15 stations

Station ID	Niño3	Niño34	Niño4	SOI	DMI
440201	-0.26	-0.28	-0.33	0.27	-0.06
423301	-0.55	-0.61	-0.54	0.64	0.10
480201	-0.44	-0.45	-0.39	0.42	0.10
459201	-0.56	-0.60	-0.55	0.61	-0.21
478301	-0.31	-0.33	-0.25	0.36	-0.17
430401	-0.39	-0.46	-0.49	0.49	0.00
501201	-0.36	-0.39	-0.38	0.35	0.25
459202	-0.33	-0.34	-0.32	0.30	-0.09
459205	-0.58	-0.70	-0.68	0.71	-0.50
459203	-0.18	-0.20	-0.17	0.22	-0.15
480301	-0.15	-0.23	-0.22	0.19	-0.07
430201	-0.45	-0.54	-0.60	0.50	-0.13
478201	-0.38	-0.40	-0.32	0.41	-0.27
459204	-0.29	-0.38	-0.41	0.40	0.03
440401	-0.42	-0.65	-0.77	0.82	0.62

Note: Correlations in bold are significant at the $p=0.05$ level

3.1.2 Seasonal variation in rainfall

Fig. 3 and Fig. 4 show mean monthly rainfall and rainy day, respectively at 15 stations in East Thailand. All of the stations have a number of rain days exceed 10 day during May to October due to Southwest monsoon. The highest of monthly rainfall and rain day found in August at Khlong Yai (Station ID. 501201) with exceed 1000 mm and exceed 25 days, respectively. In August, the region received plentiful of rain nearly the whole month affected by the periodically active southwest monsoon prevailing. In addition, the monsoon trough lay across the region throughout the month. The maximum of rainfall and rain day was found at Khlong Yai (Station ID. 501201), Phriu (Station ID. 480301) and Chanthaburi (Station ID. 480201) because of windward location. The location of these stations which are the windward side of the mountain is located nearly the Cardamom mountain range for Khlong Yai station and Chanthaburi mountain range for Chanthaburi and Phriu station. Moist wind on the windward side of the mountain, where it cools and condenses, is forced up the slope, leading to abundant of rainfall. The heavy rainfall over the windward slopes depends not only on the elevation of the station but also on the wind velocity perpendicular to the mountain range and on the moist static stability [16]. Thus, enhanced rainfall will occur when the moist wind is strong and reduced rainfall appeared in the weak wind period, especially in windward side of the mountain.

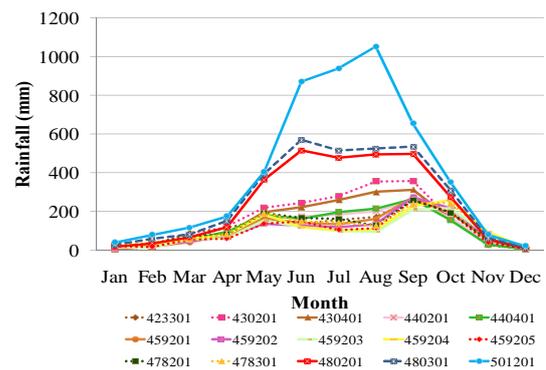


Fig. 3 Mean monthly rainfall in eastern Thailand

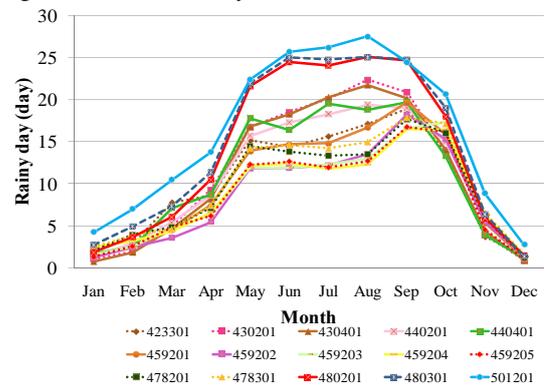


Fig. 4 Mean monthly rainy day in eastern part of Thailand

When considering the correlation between the ENSO indices and monthly rainfall, it is found that correlation between SSTA in the Niño34 region

and Eastern Thailand rainfall at each station is weak. However, the rainfall has the largest number of significant correlation with SSTA in the Niño34 region in the transitional period (April, May, and October) as shown in Fig. 5. The highest number of significant correlations is found at station ID 440401 in April and May with $r=-0.71$ and $r=-0.52$, respectively. For the rainy days, it is also found that the largest number of correlation with ENSO indices is in the transitional period (April, May, and October).

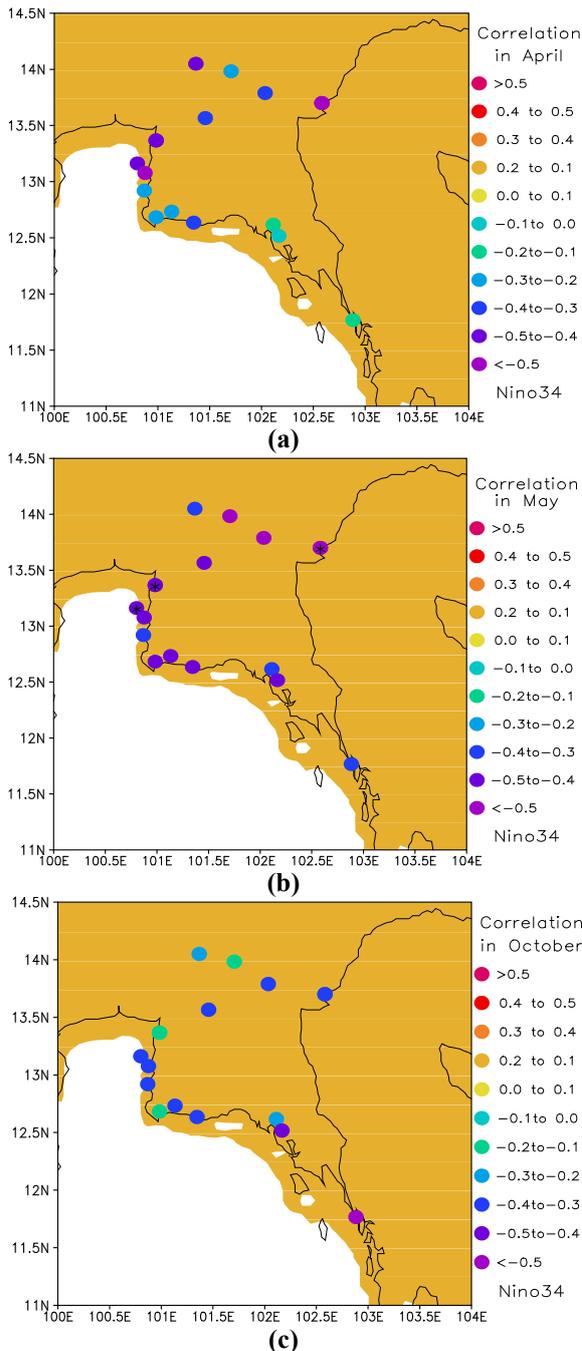


Fig. 5 Correlation map between the Niño34 and average monthly rainfall of 15 stations in (a) April, (b) May and (c) October.

But, the rain days along the nearshore station have no significant correlation with Niño34. The monsoon onset over Thailand is in May [2]. The monsoon onset over the Indochina Peninsula is mostly late during the El Niño event with warm SST anomalies in the central-eastern Pacific, while it is early onset during the La Niña event. Considering wind during monsoon in May, southwest monsoon during La Niña year prevail over the Andaman Sea, Thailand and the Gulf of Thailand is stronger and clearer than neutral year and El Niño year. The strong convective activities appear during the La Niña period over the Indian subcontinent and its surroundings along with Indochina Peninsula which associated with the changes of the Walker circulation and the local Hadley circulation. Opposite to El Niño period, reduced convective activities appear in this period [2],[14-15].

4. CONCLUSION

The 15 rain gauge stations data during 1969 to 2008 from the Thai Meteorological Department (TMD) were used to analyze rainfall distribution pattern. The main source of rainfall in the region comes from southwest monsoon which brings abundant rain during May to October with a number of rain days exceed 10day. The 40-year average of rainfall is 1921mm. Since 1969, the annual rainfall has been a tendency to decrease.

The correlation between yearly rainfall and Niño34 is weak ($r=-0.28$). When considering the correlation between the ENSO indices and monthly rainfall, it is found that the rainfall has the largest number of significant correlation with ENSO indices in the transitional period (April, May, and October). For the rainy days, it is also found that the largest number of correlation with ENSO indices is in the transitional period (April, May, and October). But, the rain days along the nearshore station have no significant correlation with Niño34.

In future work, the atmospheric model will be applied to study the rainfall pattern in Eastern Thailand and mechanism of atmosphere during the transitional period.

5. ACKNOWLEDGEMENTS

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