ความสัมพันธ์ระหว่างปรากฏการณ์เอนโซ่และปริมาณฝนประจำฤดูกาลในพื้นที่ภาคเหนือและภาคกลางของประเทศไทย

Relationship between El Niño-Southern Oscillation and Seasonal Rainfall in Thailand's Northern and Central Regions

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ABSTRACT

This research investigates the existence of a correlation between the El Niño-Southern Oscillation (ENSO), in particular the Southern Oscillation Index (SOI), and the seasonal rainfall amounts along the Greater Chao Phraya River basin in the northern and central regions of Thailand. In the correlation analysis, this research utilized the monthly serial rainfall data of 1952-2014 (63 years) for the North and 1970-2014 (45 years) for the Central Plains and the 3-month running mean (3-mrm) SOI data of 1952-2014. In addition, the correlation analysis was carried out using the 3-mrm Dipole Mode Index (DMI) data of 1952-2014. The correlations between the SOI/DMI and the rainfall amounts were analyzed using the cross-lagged correlation method and verified by the *t*-distribution method. Furthermore, the cluster analysis was applied to the SOI/DMI-seasonal rainfall index distillation datasets to exclude the outliers and the linear regression analysis was subsequently performed to reaffirm the existence of the relationship between the index datasets and the rainfall amounts. In fact, the cross-lagged correlation results revealed that the SOI and the seasonal rainfall index are moderately correlated, with the greatest correlation coefficients of 0.21 and 0.33 for the northern and central regions; and that the correlation between the DMI and the rainfall index is inconclusive. More importantly, the SOI-rainfall correlation results confirm the SOI's predictive ability of the seasonal rainfall and its usefulness in the operation of the country's reservoirs and flood prevention.

Keywords: El Nino-Southern Oscillation (ENSO), El Niño and La Niña, Rainfall, Greater Chao Phraya River basin

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บทคัดย่อ

การวิจัยครั้งนี้ เพื่อศึกษาความสัมพันธ์ระหว่างปรากฏการณ์เอนโซ่และปริมาณน้ำฝนในช่วงฤดูฝน โดยวิเคราะห์ความสัมพันธ์ของดัชนีความผันแปรของระบบอากาศในซีกโลกใต้ และดัชนีปริมาณน้ำฝนในช่วงฤดูฝนเฉลี่ยของพื้นที่ลุ่มน้ำเจ้าพระยาใหญ่ในพื้นที่ภาคเหนือและภาคกลางของประเทศไทยกระบวนการวิจัยดำเนินการการวิเคราะห์ความสัมพันธ์ของข้อมูลปริมาณน้ำฝนรายเดือนในช่วงฤดูฝน (ส.ค.-ต.ค.) ระหว่างปีพ.ศ. 2495-2557 (63 ปี) สำหรับภาคเหนือ พ.ศ. 2513-2557 (45 ปี) สำหรับภาคกลาง และข้อมูลดัชนีความผันแปรของระบบอากาศในซีกโลกใต้ (SOI) ระหว่างปี พ.ศ. 2495-2557 ที่ได้คำนวณเป็นค่าเฉลี่ย 3 เดือนในช่วงเวลาต่างๆ และดำเนินการในวิธีเดียวกันกับข้อมูล Dipole Mode Index (DMI) ระหว่างปี พ.ศ. 2495-2557 ความสัมพันธ์ของ SOI/DMI กับปริมาณน้ำฝน วิเคราะห์ได้จากวิธีการวิเคราะห์สหสัมพันธ์เหลื่อมเวลารายเดือน และตรวจสอบด้วยวิธีการทางสถิติ (*t*-distribution) นอกจากนี้ การวิเคราะห์จัดกลุ่ม ได้นำมาประยุกต์ใช้กับชุดข้อมูลที่คัดและตรวจสอบเพื่อดึงข้อมูลที่มีค่าที่ผิดปกติออกจากกลุ่มข้อมูล และนำไปสู่การสร้างสมการทำนายด้วยระเบียบวิธีการวิเคราะห์การถดถอยเชิงเส้น ซึ่งผลการวิเคราะห์สหสัมพันธ์เหลื่อมเวลาพบว่ามีความสัมพันธ์ระหว่างดัชนีความผันแปรของระบบอากาศในซีกโลกใต้และปริมาณน้ำฝนในช่วงฤดูฝนเฉลี่ยในพื้นที่ลุ่มน้ำเจ้าพระยาพอเพียงสำหรับการยืนยันการมีความสัมพันธ์ โดยมีสัมประสิทธิ์สหสัมพันธ์สูงสุดที่ 0.21 และ 0.33 สำหรับภาคเหนือและภาคกลางตามลำดับ แต่ความสัมพันธ์ระหว่าง Dipole Mode Index และปริมาณน้ำฝนในช่วงฤดูฝนเฉลี่ยนั้นไม่สามารถพิสูจน์ได้อย่างชัดเจน ผลการวิเคราะห์ความสัมพันธ์ชี้ให้เห็นว่าการพยากรณ์ปริมาณน้ำฝนในช่วงฤดูฝนล่วงหน้าจากดัชนีความผันแปรของระบบอากาศในซีกโลกใต้ มีความสามารถใช้ทำนายและเป็นประโยชน์ สามารถนำดัชนีความผันแปรของระบบอากาศในซีกโลกใต้มาใช้พยากรณ์เพื่อบริหารจัดการลดความเสียหายจากอุทกภัย และการปฏิบัติงานอ่างเก็บน้ำ

คำสำคัญ: ปรากฏการณ์เอนโซ่ เอลนีโญ และลานีญา ปริมาณฝน ลุ่มน้ำเจ้าพระยาใหญ่

Introduction

In Thailand, the annual rainfalls are the dominant source of water supply for human consumption and ecosystem maintenance. Following the massive floods in 2011, in which two-thirds of the country including the capital Bangkok were submerged, questions have been raised about the effectiveness and suitability of the conventional practice of rainfall prediction for the reservoir management and flood prevention. Specifically, the 2011 floods resulted in an economic loss of THB1.43 trillion (USD46.5 billion), with the provinces along the Greater Chao Phraya River basin (Figure 1) severely affected. The manufacturing sector bore roughly 70 percent of the total losses because there are six major industrial estates located in the flooded area. According to the World Bank (2011), approximately 90 percent of the damage and losses caused by the 2011 floods were borne by the private sector. Interestingly, it was later concluded that the massive floods were the result of the unprecedented amounts of rainfall in the months of June-October that year.

The El Niño-Southern Oscillation (ENSO) phenomenon refers to an irregularly periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, in which the warming and cooling phases are respectively known as El Niño and La Niña. El Niño is typically accompanied by low rainfall amounts and La Niña by high rainfall amounts in the tropical western Pacific. According to Peskan (2001), the ENSO refers to a phenomenon caused by the simultaneous occurrence of ocean warming and the reversal of surface air pressure at the opposite ends of the tropical Pacific Ocean.

At present, many meteorological institutes rely on the ENSO data for the global rainfall predictions. According to Nicholls and Wong (1990); Dettinger and Diaz (2000), the ENSO phenomenon is the major contributing factor of the year-to-year variability of rainfalls and stream flows around the world. In the Asia-Pacific region, the ENSO concept has been adopted to predict the summer monsoons and the amounts of annual and seasonal rainfalls. For example, Krishna Kumar *et al*. (1999), Krishnamurthy and Goswami (2000) investigated the relationship between the ENSO and the Indian monsoons; Xu and Chan (2001) studied the association between the ENSO and the South China monsoons; and Lau and Wu (2001), Wang *et al*. (2001) documented a correlation between the ENSO and the Northwestern Pacific summer monsoons.

Kripalani and Kulkarni (1997, 1998, 2001) investigated the correlation between the ENSO and the variability of monsoons and rainfalls in Indonesia, Singapore and Thailand. A common view is that a link exists between the rainfall variations and the ENSO. Singhrattna (2003); Singhrattna *et al.* (2005a) reported that the rainfall activity in Thailand is strongly correlated to the post-1980s ENSO phenomenon. Xu *et al*. (2004) reported a strong relationship between the ENSO and rainfall in Thailand's Mae Klong and Ping River basins. Nonetheless, according to Otarig (2000) examined the impact of El Niño on the amount of rainfall at 31 rainfall stations distributed in all region of Thailand, during 1951-2000. The study reveals that El Niño has no statistically significant impact on annual rainfall in Thailand. The different results may be due to the large spatial and temporal variation of monsoon rains.

Singhrattna *et al*. (2005b) documented a strong positive relationship between the post-1980s' Southern Oscillation Index (SOI) and the seasonal rainfall in Thailand as the influence of the El Nino phenomena decreased due to the weakening Walker circulation. Wikarmpapraharn and Kositsakulchai (2010) investigated the relationship between the ENSO and the rainfalls in Thailand's Central Plains and proposed a statistical model that is capable of estimating the standardized precipitation index (SPI) values at least one fortnight in advance at the 10% significance level; and could be applied to the irrigation and water allocation management during the dry period from November to April.

Meanwhile, according to Chansaengkrachang *et al*. (2011), the Indian Ocean Dipole (IOD) exerts influences on the rainfall activity in Thailand and also the rainfall variability in the country is influenced by the ENSO. Moreover, Kusreesakul (2009) documented that the positive IOD is associated with the lower-than-average seasonal rainfall amounts and that the relationship between the negative IOD and the rainfall amounts is inconclusive.

In Thailand, the Meteorological Department is responsible for the long-term precipitation predictions using the Canonical Correlation Analysis (CCA) statistical method and the Extended Reconstructed Sea Surface Temperature (ERSST) dataset, which is the global monthly sea surface temperature analysis derived from the International Comprehensive Ocean-Atmosphere Dataset of the National Oceanic and Atmospheric (NOAA). The prediction results are the above- or below-average 3-mrm precipitations (Smith *et al.*, 2008; Thai Meteorological Department, 2016).

Specifically, this research has statistically investigated the existence of the correlation between the SOI and the seasonal rainfall amounts (i.e. August-October) in Thailand's northern and central regions; as well the correlation between the DMI and the rainfall amounts. Of particular interest is the SOI's predictive power of the rainfall amounts and its usefulness and suitability for the country's reservoir management.

Materials and Methods

Study Data

The records of the past monthly rainfall amounts of the northern and central regions were from the Thai Meteorological Department (TMD) and the Royal Irrigation Department (RID). In the study, the monthly rainfall data were the Thiessen Polygon average rainfall amounts from eight rainfall gauge stations in the North (Mueang Chiang Mai, Phrao Chiang Mai, Mae Taeng Chiang Mai, Ngao Lampang, Mae Tha Lamphun, Mueang Phrae, Mueang Chiang Rai, and Bang Mun Nak Phichit) between 1952 and 2014 (63 years); and six stations in the Central Plains (Sapphaya Chainat, Huai Khot Uthai Tani, Lat Yao Nakhon Sawan, Mae Poen Nakhon Sawan, Khanu Woralakburi Kamphaeng Phet, and Lam Sonthi Lopburi) between 1970 and 2014 (45 years), while the SOI data were between 1952 and 2014.

The 1952-2014 SOI datasets were obtained from the National Oceanic and Atmospheric Administration, Climate Prediction Center (NOAA-CPC). The SOI is an ENSO index that measures the differences in the atmospheric pressure above sea surface between Darwin and Tahiti in the Pacific Ocean. In addition, this research used the 3-month running means (3-mrm) calculated from the 3-month moving average SOI.

Moreover, to investigate the influences of the Indian Ocean Dipole (IOD) phenomenon on the rainfall amounts, this research utilized the 1952-2014 Dipole Mode Index (DMI) data from the INCOIS-GODAS (Indian National Centre for Ocean Information Services-Global Ocean Data Assimilation System). The DMI is a measure of the anomalous zonal sea surface temperature (SST) gradient across the equatorial Indian Ocean, which is defined as the difference between the SST anomaly in a western (60°E-80°E,10°S-10°N) and an eastern (90°E-110°E,10°S-0°S) box.

Study Area

The Greater Chao Phraya River basin is Thailand's largest and most important geographical unit in terms of land and water resources (Thepprasit, 2012), covering the north and central regions of the country with a total area of 15.79 million hectares (ha). The water in the basin is discharged into the Gulf of Thailand, which is part of the South China Sea and the Pacific Ocean.

As illustrated in Figure 1, the headwaters of the Chao Phraya River are in the mountainous terrain of the northern part of the country and consist of four large tributaries: the Ping, Wang, Yom and Nan rivers. The main river system passes through or close to many major population centers of the country including the capital Bangkok, which is situated at the downstream end. The four upstream tributaries flow southward and converge in the province of Nakhon Sawan (C.2) to form the Chao Phraya River. The irrigation projects along the Chao Phraya River basin consist of 26 large, 14 medium and 119 small projects, and the most important irrigation facility is the Chao Phraya Diversion Dam (C.13). The river flows southward through a large alluvial plain, called the Chao Phraya delta area.

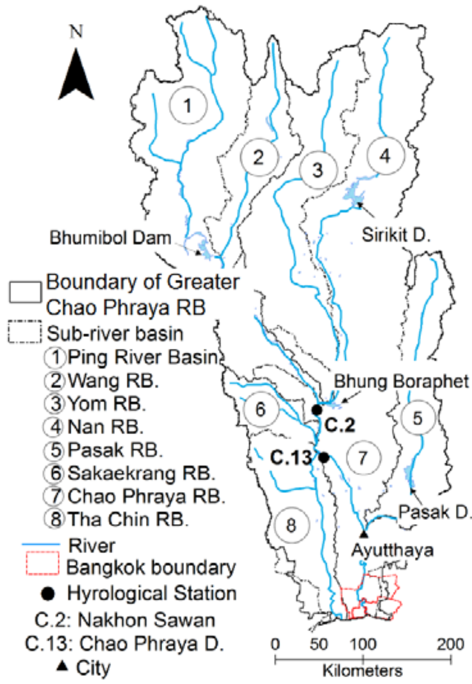

Figure 1 The Greater Chao Phraya River basin

Thailand Climatic Condition

The climate of Thailand is under the influence of monsoon winds of seasonal character, i.e. the southwest and northeast monsoons (Thai Meteorological Department, 2016). The southwest monsoon which starts in May brings a stream of warm moist air from the Indian Ocean toward Thailand, resulting in an abundant rainfall across the country, especially the windward side of the mountains. In addition to the influence of the southwest monsoon, the Inter-Tropical Convergence Zone (ITCZ) and tropical cyclones produce large amounts of rainfall during this period. Specifically, the month of May is the period of the first arrival of the ITCZ to the Southern region before moving northward and lying across southern China around June to early July, which coincides with the dry season over upper Thailand. The ITCZ then moves southerly to the Northern and Northeastern parts of Thailand in August and later over the Central and Southern parts in September and October.

Meanwhile, the northeast monsoon which starts in October brings the cold and dry air from the anticyclone in Mainland China over major parts of Thailand, especially over the high-altitude Northern and Northeastern parts. In short, the southwest monsoon usually starts in mid-May and ends in mid-October, while the northeast monsoon starts in mid-October and ends in mid-February.

Research Methodology

(1) The monthly stational rainfall data from the representative stations were verified for the inter-station correlations by the cross-correlation method and averaged using the Thiessen Polygon method.

(2) The average historical monthly rainfall data of August, September and October of each year for the entire periods of data collection were individually converted into the ratios of monthly rainfall data to the average rainfall data of the corresponding month for the entire period (i.e. 63 and 45 years

respectively for the North and Central Plains). The seasonal rainfall index of each year was then computed by averaging the rainfall ratios of the months of August-October, as expressed in equations 1 and 2.

$$MRFRatio_i = \frac{MRF_i}{\overline{MRF_i}} \quad (1)$$

$$SRFIndex_i = \frac{AugRFRatio_i + SepRFRatio_i + OctRFRatio_i}{3} \quad (2)$$

Where $MRFRatio_i$ is the ratio of monthly rainfall data, MRF_i is the historical monthly rainfall data of any given year, $\overline{MRF}_i$ is the average rainfall data of the corresponding month for the entire period, $SRFIndex_i$ is the seasonal rainfall index of any given year, $AugRFRatio_i$ is the ratio of the August rainfall data, $SepRFRatio_i$ is the ratio of the September rainfall data and $OctRFRatio_i$ is the ratio of October rainfall data.

(3) The 1952-2014 Southern Oscillation Index (SOI) data and the Dipole Mode Index (DMI) data of the same period were converted into the 3-mrm datasets.

(4) The cross-lagged correlation analysis was carried out to examine the pre-clustering relationships between the SOI and the rainfall amounts and between the DMI and the rainfalls for the lag times of 0-8 months (Table 1).

(5) The cross-lagged correlations between the SOI/DMI and the rainfall amounts were verified using the test statistic (*t*-distribution method) (Table 2).

(6) The cluster analysis method was applied to the SOI-rainfall and DMI-rainfall correlations to maximize the homogeneity of the datasets whereby the outliers (extreme datasets) were excluded prior to the linear regression analysis in the absence of the outliers.

(7) The linear regression analysis was performed to reaffirm the relationships between the index data and the rainfall amounts without the outliers; and the corresponding scatter diagrams rendered.

(8) The Markov Chain (MC) method was used to predict the probability of extreme events based on the cluster analysis.

Results and Discussion

The analysis results revealed that the stational rainfall data were generally well correlated, with the correlation coefficients in the ranges of 0.70-0.94 and 0.61-0.79, respectively, for the North and Central Plains, suggesting that the rainfall data were fairly homogeneous.

Table 1 tabulates the cross-lagged correlation coefficients between the SOI and the seasonal rainfall and between the DMI and the rainfall associated with the country's northern and central regions for the lag times of 0-8 months. In the table, the greatest correlation coefficients between the SOI and the seasonal rainfall of the northern and central regions of 0.21 and 0.33 belong to the 0-month lag time (ASO:ASO), with the negative r indicating an inverse correlation between the SOI data and the rainfall. The analysis results revealed that the two variables are moderately correlated. By comparison, the overall lower correlation coefficients of the North (0.11-0.21) in relation to those of the Central Plains (0.15-0.33) could be attributed to the greater distance of the northern region from the Pacific Ocean than the central region from the ocean. In other words, the proximity to the ocean plays a part in the SOI's predictive power of the seasonal rainfall in the country.

Meanwhile, the greatest correlation coefficients between the DMI and the seasonal rainfall of 0.18 and 0.21 of the northern and central regions, respectively, belong to the 0-month (ASO:ASO) and 1-month lag times (JAS:ASO). Interestingly, the correlations between the DMI and the rainfall of the North (i.e. inverse correlation) and the Central Plains (positive correlation) are of opposite directions. The correlational polarity suggests that the association between the DMI and the rainfall amounts is inconclusive. That being the case, the research emphasis is on the correlation between the SOI and the rainfall amounts.

Table 1 The cross-lagged correlation coefficients between the SOI/DMI and the seasonal rainfall index of the country's northern and central regions for lag times of 0-8 months

	Lag Time	SOI and rainfall index Correlation Coefficient		DMI and rainfall index Correlation Coefficient	
	Month	**Northern**	**Central**	**Northern**	**Central**
ASO:(ASO)	0	-0.21	-0.33	-0.18	0.11
JAS:(ASO)	1	-0.17	-0.32	-0.17	0.21
JJA:(ASO)	2	-0.07	-0.32	-0.15	0.20
MJJ:(ASO)	3	0.06	-0.27	-0.18	0.14
AMJ:(ASO)	4	0.14	-0.24	-0.14	0.03
MAM:(ASO)	5	0.14	-0.18	-0.09	0.02
FMA:(ASO)	6	0.14	-0.16	-0.02	0.03
JFM:(ASO)	7	0.12	-0.15	-0.05	0.07
DJF:(ASO)	8	0.11	-0.15	-0.07	0.01

Note: ASO=Aug-Sep-Oct; JAS=Jul-Aug-Sep; JJA=Jun-Jul-Aug; MJJ=May-Jun-Jul; AMJ=Apr-May-Jun; MAM=Mar-Apr-May; FMA=Feb-Mar-Apr; JFM=Jan-Feb-Mar; DJF=Dec-Jan-Feb

To verify the correlations, the test statistic (*t*-distribution method) was applied to the cross-lagged correlation coefficients between the SOI/DMI and the seasonal rainfall index of the country's northern and central regions for lag times of 0-8 months and the results tabulated in Table 2.

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

where the degree of freedom (f) is n – 2.

Theoretically, the null hypothesis (H_0: β1=0) in which the correlation between the SOI/DMI and the rainfall is rejected if the *t-distribution* value in the two-tailed probability (at 95% Confidence Level) is greater than 2.00 and 2.02 (t>2.00 and t>2.02) for the north and central regions. In Table 2, only a handful of the *t*-distribution values associated with the SOI-rainfall correlations are beyond the rejection null hypothesis threshold, suggesting that the SOI's predictive power of the rainfall amounts in the country is restricted to certain months (or periods) of the year.

Table 2 The *t*-distribution of the SOI/DMI and the seasonal rainfall index of the country's northern and central regions for lag times of 0-8 months

Lag Time		SOI and rainfall index *t*-distribution		DMI and rainfall index *t*-distribution	
	Month	**Northern**	**Central**	**Northern**	**Central**
ASO:(ASO)	0	1.66	2.29*	1.41	0.73
JAS:(ASO)	1	1.36	2.23*	1.32	1.38
JJA:(ASO)	2	0.55	2.22*	1.19	1.32
MJJ:(ASO)	3	0.46	1.87	1.39	0.91
AMJ:(ASO)	4	1.12	1.62	1.13	0.18
MAM:(ASO)	5	1.12	1.23	0.68	0.14
FMA:(ASO)	6	1.11	1.05	0.15	0.19
JFM:(ASO)	7	0.93	1.01	0.41	0.46
DJF:(ASO)	8	0.89	0.98	0.57	0.04
t critical (95% confidence level)		2.00	2.02	2.00	2.02

Note: *t-distribution** indicate significance correlation

Moreover, in this research, the cluster analysis was carried out to maximize the homogeneity of the datasets whereby the outliers (extreme datasets) were excluded. The analysis has categorized the datasets into four clusters: Clusters 1, 2, 3 and 4 for low, moderate, high and extreme seasonal rainfalls. In this research, clusters 1-3 are regarded as the normal datasets, while cluster 4 is the outliners which are excluded prior to the linear regression analysis. Interesting, the extreme dataset (Cluster 4) was occurred in the years which tropical cyclones (tropical depression, typhoon). Tropical cyclone affecting Thailand usually moves from the western North Pacific Ocean or the South China Sea.

Figure 2 illustrates, as examples, the clustering results of the periods with the greatest cross-lagged correlation coefficients of the SOI/DMI and the rainfall amounts (i.e. the ASO SOI:ASO rainfall for both the northern (0.21) and central regions (0.33), and the ASO DMI:ASO rainfall (0.18) and JAS DMI:ASO rainfall (0.21), respectively, for the North and the Central Plains).

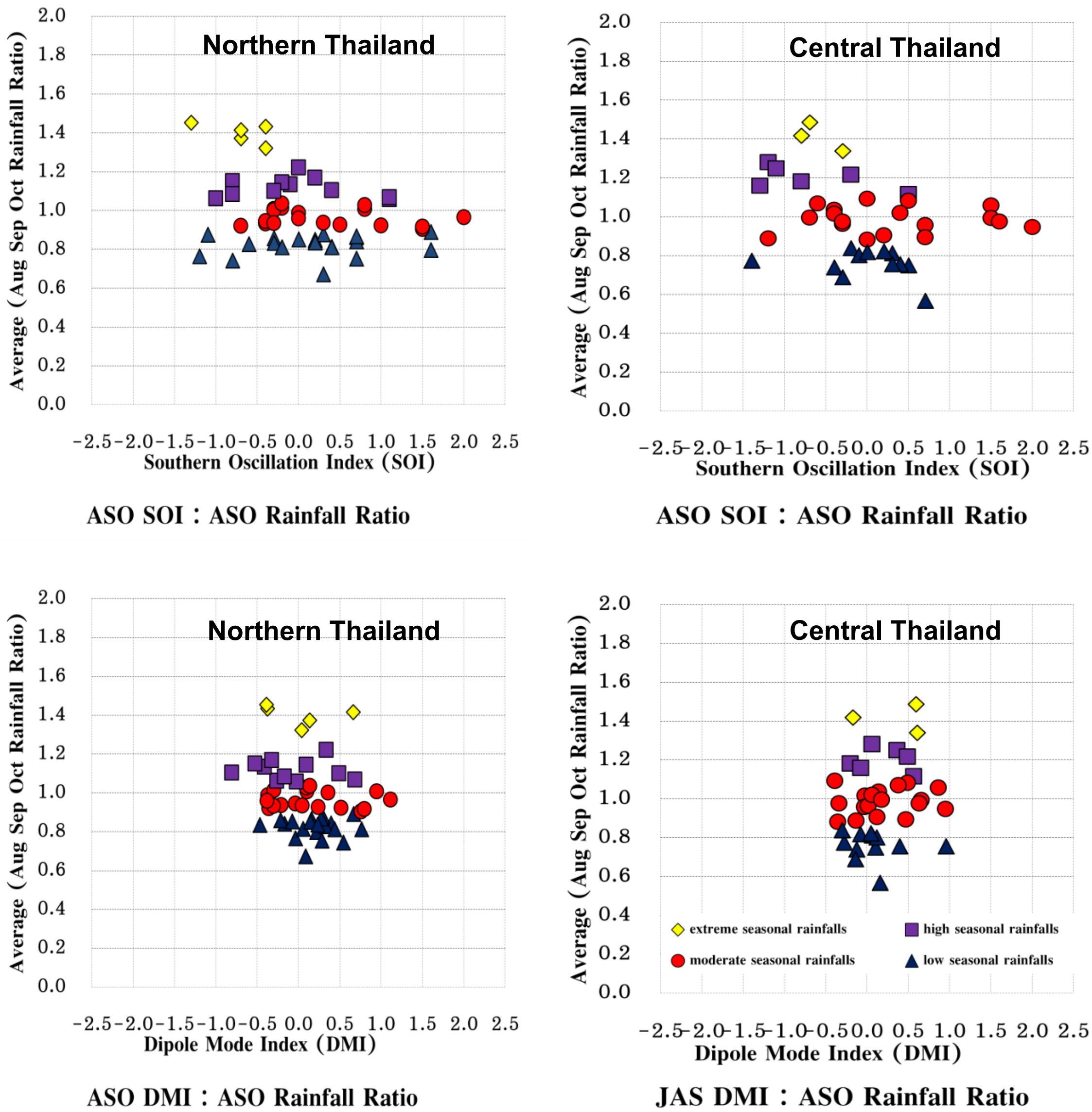

Figure 2 The cluster analysis of the SOI/DMI data and the seasonal rainfall index

The linear regression analysis was carried out on the four aforementioned post-clustering datasets (i.e. without the outliers) and their corresponding prediction equations established (Figure 3). In addition, the scattering plots corresponding to the post-clustering datasets were generated and presented in Figure 3. The prediction equations were showed with upper and lower prediction band by the 70%, 80% and 90% prediction intervals.

As previously mentioned in which the association between the DMI and the rainfall in the country is inconclusive, the analysis focus would thus be on the relationship between the SOI and the rainfall amounts. In Figure 3, despite the greatest SOI-rainfall correlation coefficients, their distributions are relatively dispersed (the two upper images), indicating the moderate SOI's predictive ability of the seasonal rainfall amounts. Interestingly, there were occasions in which the inconsistency between the SOI and the seasonal rainfall activity existed, as evidenced by the diamond-shaped pieces outside the bands.

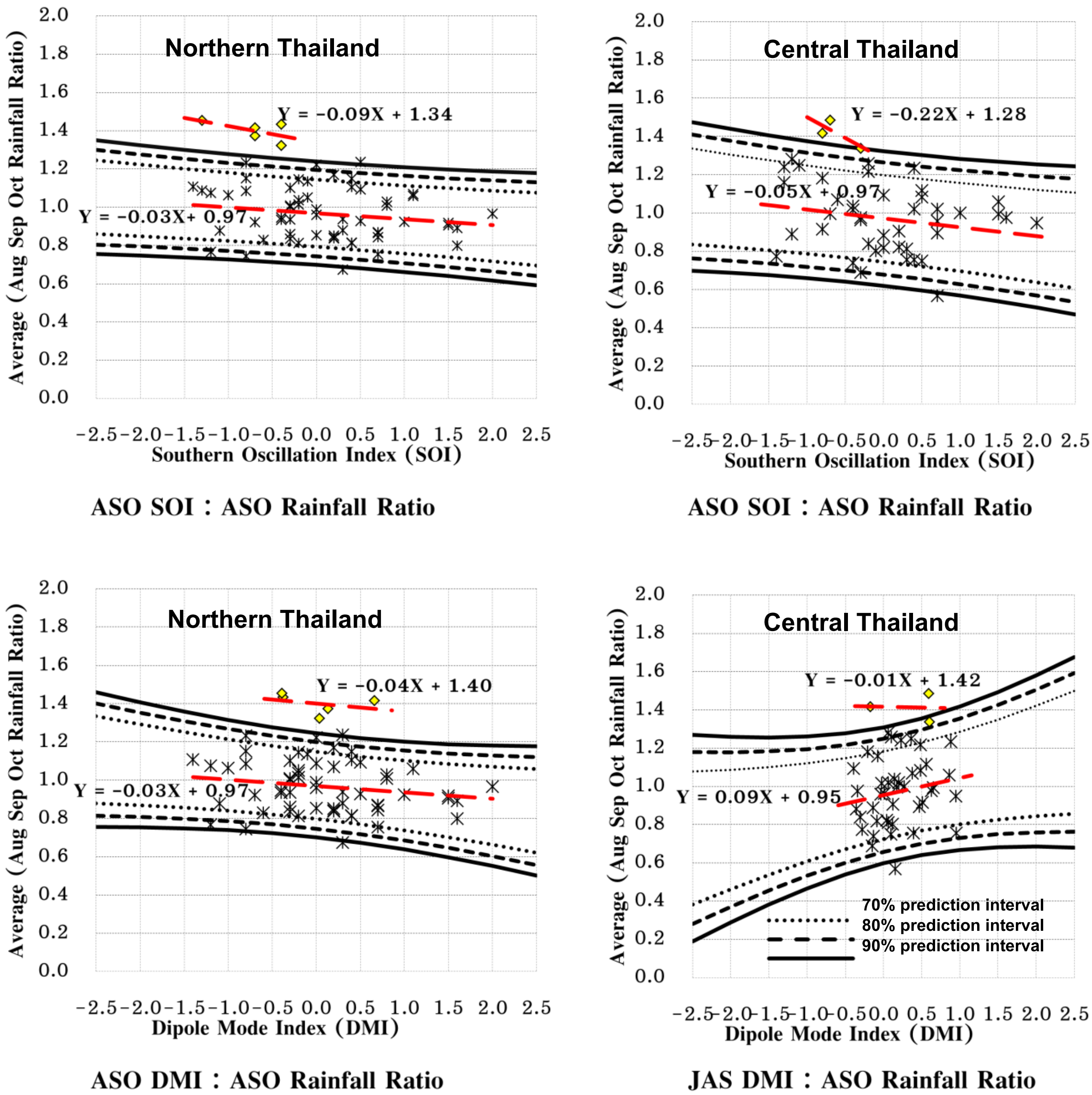

Figure 3 The scattering plots of the periods with the greatest correlation coefficients of the SOI/DMI and the seasonal rainfall

Figure 4 depicts the Markov Chain first order phase transition diagrams of the north and central regions of the country that predict the probability of extreme events (i.e. cluster 4). The simulation results indicated a 22% probability that the northern region would experience extreme weather (rainfall) patterns (i.e. a shift from clusters 3 to 4). Meanwhile, the chance for the central region is 11% probability.

To further verify the SOI's predictive ability of the rainfall amounts, the 2010-2012 seasonal rainfall indices were forecast and the prediction results compared with the observed (actual) data. Table 3 tabulates the forecast (90% prediction interval) and actual seasonal rainfall indices of the North's 0- (ASO:ASO) and 1-month (JAS:ASO) lag times and the Central Plains' 0-, 1- and 2-month (JJA:ASO) lag times. These lag times exhibited the high correlation coefficients between the SOI and the rainfall, while 2011 was the year when Thailand was hit by the massive floods. The findings revealed the insignificant variations between the forecast and actual rainfall indices in the pre- and post-flood years (i.e. 2010 and 2012) but tangible differences in the year when Thailand was severely inundated (2011). It is thus possible to say that, in the absence of extreme weather patterns, the SOI is adequately effective and suitable for the seasonal rainfall prediction in Thailand's northern and central regions.

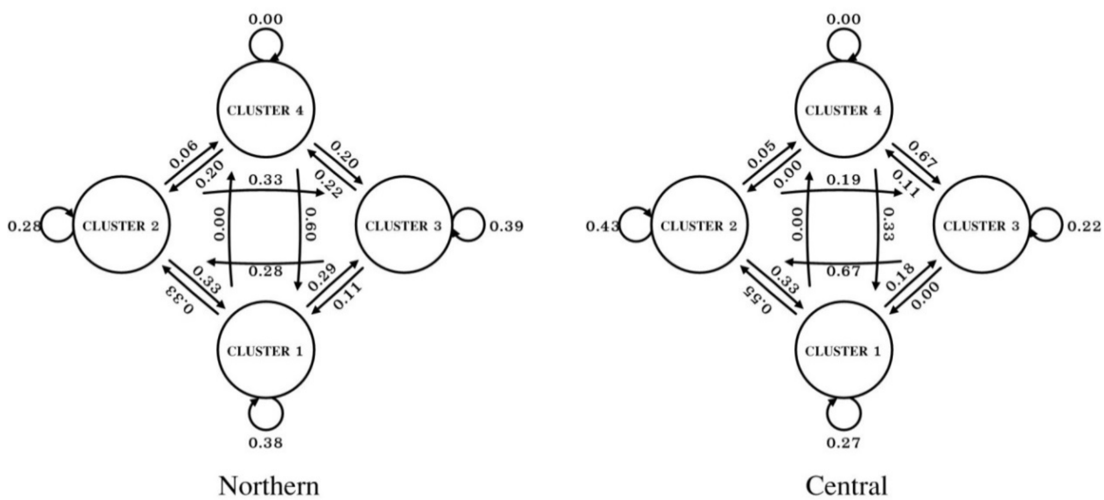

Figure 4 the Markov Chains first order phase transition diagrams of the north and central regions

Table 3 The SOI-driven forecast and actual seasonal rainfall indices of the pre-flood and post-flood years

Region	lag time	SOI:Seasonal rainfall Index	Prediction Equation	2010 prediction (90%)				Extreme SRI Prob.
				SOI	Forecast	Prediction Interval	Observed	
Northern	0	ASO:ASO	Y = -0.09X + 1.34	-1.3	1.012	(0.7794, 1.2447)	1.088	0.00
Northern	1	JAS:ASO	Y = -0.03X + 0.97	-1.1	1.003	(0.7699, 1.2356)	1.088	0.00
Central	0	ASO:ASO	Y = -0.05X + 0.97	-1.3	1.035	(0.7292, 1.3329)	1.241	0.05
Central	1	JAS:ASO	Y = -0.06X + 0.97	-1.1	1.036	(0.7341, 1.3344)	1.241	0.05
Central	2	JJA:ASO	Y = -0.07X + 0.97	-0.8	1.026	(0.7359, 1.3245)	1.241	0.05
Region	**lag time**	**SOI:Seasonal rainfall Index**	**Prediction Equation**	**2011 prediction (90%)**				**Extreme SRI Prob.**
				SOI	**Forecast**	**Prediction Interval**	**Observed**	
Northern	0	ASO:ASO	Y = -0.09X + 1.34	-0.5	0.985	(0.7582, 1.2125)	1.415	0.22
Northern	1	JAS:ASO	Y = -0.03X + 0.97	-0.3	0.978	(0.7499, 1.2051)	1.415	0.22
Central	0	ASO:ASO	Y = -0.05X + 0.97	-0.7	1.004	(0.7079, 1.2992)	1.486	0.11
Central	1	JAS:ASO	Y = -0.06X + 0.97	-0.5	1.000	(0.7061, 1.2933)	1.486	0.11
Central	2	JJA:ASO	Y = -0.07X + 0.97	-0.3	0.993	(0.7029, 1.2821)	1.486	0.11
Region	**lag time**	**SOI:Seasonal rainfall Index**	**Prediction Equation**	**2012 prediction (90%)**				**Extreme SRI Prob.**
				SOI	**Forecast**	**Prediction Interval**	**Observed**	
Northern	0	ASO:ASO	Y = -0.09X + 1.34	0.4	0.955	(0.7291, 1.1816)	0.813	0.00
Northern	1	JAS:ASO	Y = -0.03X + 0.97	0.3	0.959	(0.7313, 1.1858)	0.813	0.00
Central	0	ASO:ASO	Y = -0.05X + 0.97	0.4	0.953	(0.6593, 1.2468)	1.234	0.00
Central	1	JAS:ASO	Y = -0.06X + 0.97	0.3	0.954	(0.6612, 1.2459)	1.234	0.00
Central	2	JJA:ASO	Y = -0.07X + 0.97	0.1	0.962	(0.6734, 1.2513)	1.234	0.00

Extreme SRI Prob. = Extreme seasonal rainfall index by Markov Chain first order phase transition probability

Conclusions

This research has investigated the existence of the correlation between the Southern Oscillation Index (SOI) and the seasonal rainfall amounts along the Greater Chao Phraya River basin in Thailand’s North and Central Plains. In the analysis, this study utilized the monthly serial rainfall data of 1952-2014 (63 years) for the North and 1970-2014 (45 years) for the Central Plains and the 3-month running mean (3-mrm) SOI data of 1952-2014. In addition, the correlation analysis was performed using the 3-mrm Dipole Mode Index (DMI) data of 1952-2014. The correlations between the SOI/DMI and the rainfall amounts were subsequently verified using the *t*-distribution method. Furthermore, the cluster analysis was applied to the SOI/DMI-seasonal rainfall index distillation column to exclude the outliers and the linear regression analysis was undertaken to reaffirm the existence of the relationship between the index datasets and the rainfall amounts. In fact, the cross-lagged correlation results revealed that the SOI and the seasonal rainfall index are moderately correlated; and that the correlation between the DMI and the rainfall index is inconclusive and thus relegated in the subsequent analysis. Moreover, further verification of the SOI's predictive ability of the rainfall amounts was carried out, whereby the 2010-2012 seasonal rainfall indices were forecast and the prediction results compared with the actual indices. The results confirm the moderate predictive power of the SOI to the rainfall amounts in the country's northern and central regions, given the absence of extreme weather patterns and the Markov Chain first order phase was indicated the probabilities of extreme events. More importantly, the SOI-rainfall correlation results validate the SOI's predictive power of the seasonal rainfall and its usefulness in the operation of the country's reservoirs.

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