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Fate of ENSO phase on Upper Northern Thailand, a Case Study in Chiang Mai

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Abstract

This paper presents the impact of ENSO phase (El Niño and La Niña) on the variability of temperature and rainfall in Chiang Mai province, Upper Northern Thailand, and to identify the relation between ENSO index and temperature and rainfall. The study used data from four weather stations located at the altitude ranging from 320 to 1400 m a.s.l., covering the period of 1988 to 2011. We used two indexes, NIÑO3 (sea surface temperature based) and SOI (Southern Oscillation Index, atmospheric pressure based) to relate their impacts on temperature and rainfall several months in advance. The relationships of ENSO phases and the weather elements were higher by using SOI than NIÑO3. The corresponding results of correlation between 3-month running mean of SOI and monthly rainfall, T_{max} and T_{min} are found, especially during March to June in strong and medium ENSO years. The anomaly of T_{max} related on SOI was shown higher than T_{min}. Considering monthly rainfall, a significant decrease was found in May and June in only strong and medium ENSO events and the rainfall pattern differed significantly from the normal pattern. The variations of temperature and rainfall could be predicted by the SOI one to several months in advance and can be applied in other provinces in mountainous zone in Upper Northern Thailand.

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Keywords: ENSO, Temperature variability, Rainfall variability, Upper Northern Thailand

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1. Introduction

Recently, climate variability and change is considered to be one of the most serious global and local problems affecting all sectors with adverse impacts on environment, human health, food security, economic activities, natural resources and physical infrastructure (IPCC, 2007; Mary and Majule, 2009). El Niño/Southern Oscillation (ENSO) is known as the major cause of inter-annual (year-to-year) climate variability in the Pacific Northwest and around the world regions. ENSO variations are more commonly known as El Niño phenomenon (the warm-dry phase of ENSO) or La Niña phenomenon (the cold-wet phase of ENSO). The ENSO extreme phases are always linked with the events of droughts and floods in the world, which seem occurred with enhanced frequency and duration in recent years (Diaz et al., 2001; Anderson et al., 2002) and also in future (Paeth et al., 2008). The increased cloudiness and rainfall associated with La Niña periods typically reduces daytime temperatures and keeps nights warmer but during El Niño events, reduced cloudiness means daytime temperatures are typically warmer than normal, exacerbating the effect of lower than normal rainfall by increasing evaporation (Bureau of Meteorology, 2014). Although the ENSO affects the weather in large parts of the world, the effects depend strongly on the location and the season. The strongest effects on precipitation are in South-East Asia and the western Pacific Ocean, especially in the dry season. For temperature, the effects are found throughout most of the tropics (Royal Netherlands Meteorological institute, 2014). Reviewed by Oldenborgh and Burgers (2005) of the skill of seasonal weather forecasts, as the ENSO is well predictable at lead times up to at least half a year, mostly of the ENSO teleconnections compared to the variability of the weather are relatively weak. The most effective method used by the previous studies was the statistical variability in running correlation.

In Thailand, the effects of ENSO on the anomaly of rainfall were revealed (Kripalani and Kulkarni, 1997; Tangtham et al. 1999; Otarig, 2000; Shrestha and Kostaschuk, 2005; Nounmusig et al., 2006). There is a strongly relationship between ENSO events and the southwest monsoon in Thailand since 1980 (Singhrattna et al., 2005). Suwanabatr and Mekhora (2002) indicated that events caused by El Niño-induced weather changes had some impacts on the stabilization of upland agriculture in the vulnerable areas, as in Chiang Mai, Chiang Rai. A recent study by Ueangsawat and Jintrawet (2014) found that only medium and strong phases of ENSO (El Niño and La Nina) are shown significantly effects to rainfall and streamflow in Ping river watershed, due to the high spatial variation of the watershed. The aims of this paper are: to search for the effects of ENSO to the temperature and rainfall in a few stations locating on the altitude difference location and to use ENSO indices as a predictor of temperature and rainfall in the Chiang Mai province areas..

2. Methodology

2.1. Data and study sites

The three study sites located on three differ altitude in Chiang Mai Province, Northern Thailand were used in this study. They were Ang Khang (ANK), Pang Dha (PAD), and Multiple Crop Center (MCC), with an altitude of 1,200; 720 and 320 m a.s.l., located at 504921/2201292, 475293/2084543 and 496136/2077992 Universal Transverse Mercator (UTM) zone 47N, respectively. The daily maximum (T_{max}) and minimum (T_{min}) temperature and rainfall during 1988-2013 were averaged to the monthly data and used to establish relationship with the ENSO indices.

The ENSO indices based on the Sea Surface Temperature (SST), NIÑO3, and the pressure base, SOI (Southern Oscillation Index), during the same period of the weather data were downloaded from the NOAA website. The 3-month running mean (3-mrm) of the indices are calculated and used for analysis correlation with temperature and rainfall.

2.2. Analysis method

The previous study (Ueangsawat and Jintrawet, 2014) revealed that the ENSO indices of SOI, NIÑO3, and NIÑO3.4 showed significant correlation with some months of rainfall in the Ping River Basin. The study found that the identification of annual ENSO phase (El Niño and La Nina) and then classifying the strength of the ENSO phases into weak, medium and strong was necessary before predicting the effects of the ENSO phases on weather conditions. The strengths of El Niño and La Niña are identified by applying the NOAA approach (Ueangsawat and Jintrawet, 2014). Then the monthly temperature (T_{max} and T_{min}) and rainfall data of each year was classified following the ENSO phases classification. The cross correlation between 3-mrm and monthly data of rainfall, Tmax and Tmin were performed for identifying lead relationships. The method was used in the previous studies such as Dettinger et al. (2000), Chiew and McMahon (2002) and Reda et al. (2013). The correlation method using in the study was Pearson's correlation coefficient (r) which was calculated by following equation:

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

Where r was Pearson's correlation coefficient; x_i and y_i were the values of ENSO index and weather parameter (rainfall, T_{max} or T_{min}) respectively at the time i; ($\bar{x}$) and ($\bar{y}$) was the average of the ENSO index and the weather parameter; and n was the total number of year. The t-test was used to test for the statistical significant of the correlation coefficients calculated as the equation:

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

The $t_{(n-1),0.5}$ was considered for determination significant of r values by comparison with the critical value at $t_{(n-1),0.5}$.

3. Results and Discussions

3.1. ENSO phase signal and defining ENSO index

As defining for ENSO phase with the ENSO indices of SOI and NIÑO3, we found that the value of the both indices moving for five consecutive of positive (negative) rising (down) by the rule of ENSO phase classification were mostly found between MJJ (May-June-July) and MAM (March-April-May), as shown in Figure 1. Thus, the signal of the ENSO phases was defined in MJJ to MAM. Comparison the value of cross correlation coefficient between the indices and rainfall, T_{max} and T_{min} of the three sites, the agreement results were found. The higher correlation coefficients were found in SOI than NIÑO3, and the significant correlation coefficients were not found in weak events of the ENSO phases. The results were agreement with the testing in the average data in Ping river basin (Ueangsawat and Jintrawet, 2014). Thus, to considerate the relationship and impact of the ENSO indices to rainfall and temperature in the study sites, only the data in medium and strong year were used to analyze the lead correlation.

3.2. Significant lead correlation

Since the lower relationship of NINO3 with rainfall and temperature than with SOI, only the results of SOI testing were described. The relationship of SOI and rainfall under the ENSO phases must be positive because positive value of SOI related to La Nina phase (high rainfall) and negative value of SOI related to El Niño phase (low rainfall). On the other hand, the relationship of SOI and temperature under the ENSO phases must be negative because in the positive value of SOI (La Nina), temperature will be decreased but the negative value of SOI (El Niño), the temperature will be increased. The positive correlation coefficients between SOI and rainfall were mostly found in March to June.

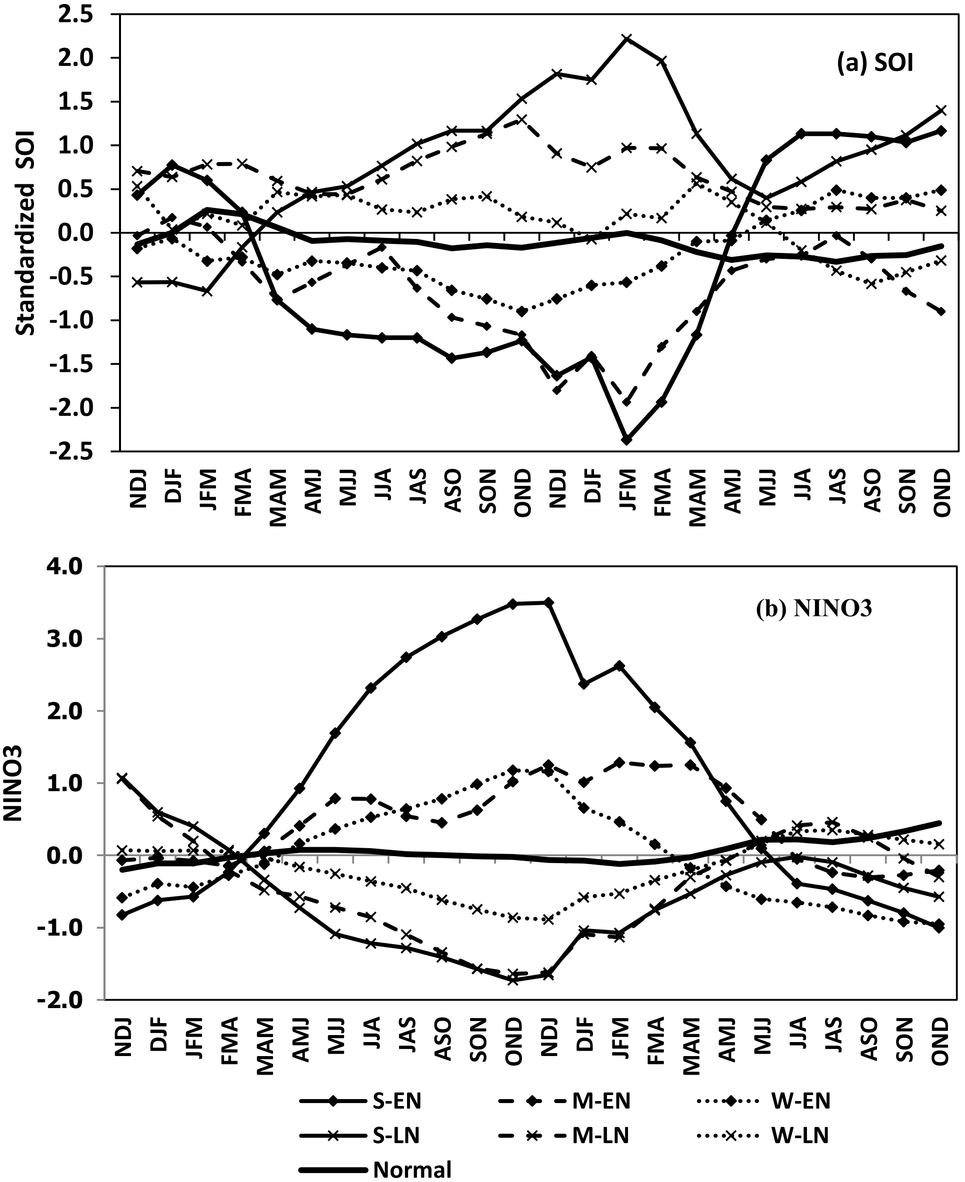

Figure 1. The average values of 3-month running mean SOI (a) and NINO3 (b) in strong (S), medium (M) and weak (W) events of El Nino phase (EN) and La Nina phase (LN), and in normal events.

Notably, the negative correlation coefficients between SOI and T_{max} and T_{min} were also mostly found in the same time, as shown in Table 1, excepted for rainfall in June of ANK station and for T_{min} in March of CMU station. The significant correlation coefficients between SOI and temperature (T_{max} and T_{min}) were found to be a higher value and a longer lead correlation than rainfall. Since the limit of observed period was relative short, the 7 medium and strong events of the ENSO phases (El Niño and La Niña) were found and used to analyze for the correlation coefficients. However, the study expects to approach the forecasting of rainfall and temperature by using ENSO indicator in local scale. The result showed the highest correlation by linear regression between DJF of SOI and June of T_{min} in highland station (ANK) with $r^2 = 99.0\%$ and between OND of SOI and June of T_{max} in lowland station (CMU) with $r^2 = 84.6\%$.

Table 1. The correlation coefficients (r) between 3-monthly running mean of SOI and the month of rainfall, Tmax and Tmin which show some relationship agreement with the ENSO signal during the strong and medium events. The bolded numbers are the significance correlation at 5% level.

	Rainfall									
	JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM
					ANK					
MAR	0.447	0.500	0.448	0.401	0.457	0.441	0.491	0.487		
APR	0.377	0.345	0.291	0.238	0.381	0.330	0.428	0.426	0.422	
MAY	0.462	0.591	0.705	**0.756**	**0.741**	**0.766**	**0.738**	**0.733**	0.707	0.614
JUN	-0.114	-0.093	-0.105	-0.132	-0.130	0.186	0.124	0.075	0.111	0.229
					PAD					
MAR	0.118	0.234	0.330	0.401	0.429	0.203	0.238	0.235		
APR	0.399	0.261	0.267	0.271	0.371	0.200	0.241	0.250	0.293	
MAY	0.237	0.275	0.302	0.335	0.451	0.381	0.400	0.404	0.410	0.389
JUN	0.458	0.507	0.509	0.456	0.442	0.612	0.587	0.519	0.546	0.577
					CMU					
MAR	0.340	0.416	0.495	0.527	0.516	0.584	0.577	0.590		
APR	0.377	0.346	0.379	0.394	0.542	0.339	0.447	0.457	0.500	
MAY	0.499	0.668	0.631	0.613	0.605	0.536	0.502	0.500	0.491	0.577
JUN	0.513	0.556	0.501	0.422	0.357	0.488	0.492	0.480	0.532	0.548

	Tmax									
	JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM
					ANK					
MAR	-0.486	-0.533	-0.644	-0.660	-0.716	-0.728	**-0.797**	**-0.775**		
APR	-0.512	-0.493	-0.493	-0.452	-0.562	-0.485	-0.574	-0.547	-0.535	
MAY	-0.539	-0.531	-0.596	-0.611	-0.733	-0.683	**-0.743**	**-0.745**	-0.709	-0.633
JUN	-0.707	-0.707	-0.724	-0.724	**-0.806**	-0.519	-0.598	-0.621	-0.634	-0.607
					PAD					
MAR	-0.290	-0.414	-0.426	-0.466	-0.531	-0.160	-0.251	-0.303		
APR	-0.499	-0.501	-0.440	-0.442	-0.579	-0.137	-0.242	-0.305	-0.330	
MAY	-0.507	-0.545	-0.566	-0.622	-0.746	-0.305	-0.382	-0.451	-0.450	-0.427
JUN	-0.368	-0.377	-0.374	-0.428	-0.567	-0.066	-0.168	-0.247	-0.259	-0.223
					CMU					
MAR	-0.598	-0.670	**-0.740**	**-0.735**	-0.665	-0.686	-0.691	-0.679		
APR	-0.490	-0.498	-0.452	-0.404	-0.522	-0.400	-0.495	-0.485	-0.531	
MAY	-0.625	-0.596	-0.677	-0.706	**-0.816**	**-0.778**	**-0.824**	**-0.848**	**-0.827**	**-0.755**
JUN	**-0.900**	**-0.842**	**-0.890**	**-0.890**	**-0.920**	**-0.795**	**-0.832**	**-0.867**	**-0.885**	**-0.855**

	Tmin									
	JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM
					ANK					
MAR	-0.516	-0.554	-0.634	-0.657	**-0.756**	**-0.766**	**-0.835**	**-0.818**		
APR	-0.497	-0.516	-0.552	-0.543	-0.646	-0.699	**-0.753**	-0.721	-0.680	
MAY	-0.527	-0.518	-0.604	-0.633	**-0.746**	**-0.807**	**-0.833**	**-0.810**	**-0.761**	-0.675
JUN	**-0.826**	**-0.835**	**-0.900**	**-0.917**	**-0.968**	**-0.976**	**-0.995**	**-0.992**	**-0.986**	**-0.940**
					PAD					
MAR	0.102	0.136	0.061	0.095	0.127	-0.353	-0.338	-0.261		
APR	-0.094	-0.065	-0.104	-0.046	-0.042	-0.540	-0.514	-0.434	-0.425	
MAY	-0.142	-0.026	-0.101	-0.075	-0.119	-0.534	-0.529	-0.472	-0.452	-0.349
JUN	-0.480	-0.462	-0.555	-0.541	-0.510	**-0.856**	**-0.806**	**-0.766**	-0.733	-0.675
					CMU					
MAR	0.170	0.370	0.454	0.537	0.577	0.306	0.339	0.375		
APR	-0.249	-0.324	-0.193	-0.094	0.046	-0.140	-0.054	-0.037	-0.091	
MAY	-0.552	-0.463	-0.505	-0.469	-0.468	**-0.792**	**-0.770**	**-0.757**	**-0.776**	**-0.778**
JUN	-0.592	-0.562	-0.655	-0.654	-0.560	**-0.824**	**-0.752**	**-0.746**	**-0.747**	-0.725

Table 2 The anomaly from normal year of average monthly rainfall, maximum temperature(Tmax) and minimum temperature (Tmin) in the years affected by the strong and medium El Nino at the 3 difference altitude stations, Ang Khang (ANK, 1400 m), Pang Dha (PAD, 720 m) and Chiang Mai University (CMU, 320 m).

	Station	ENSO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rain	ANK	EN	-8.0	20.4	-27.9	-28.8	-154.3	-52.9	69.3	-70.0	-66.8	-109.4	98.3	34.3
		LN	22.7	-18.6	217.3	112.1	43.2	-45.1	-28.8	-29.7	16.2	-38.0	-35.2	-22.9
	PAD	EN	-8.5	4.3	-20.8	-32.1	-89.2	-71.9	6.6	-44.1	107.7	-32.5	-25.3	37.6
		LN	4.9	8.2	5.1	2.6	33.6	41.9	45.6	38.6	50.9	-8.5	-30.3	-1.5
	CMU	EN	-9.4	1.5	-31.0	-32.9	-61.1	-21.2	68.0	-71.6	-66.3	-33.7	-51.8	28.5
		LN	-3.6	-9.2	9.8	14.5	98.1	118.6	-34.5	27.4	-40.3	25.4	-52.1	-21.8
Tmax	ANK	EN	0.5	-0.4	1.8	1.6	2.3	1.3	0.0	0.7	0.2	-1.0	-0.7	-0.3
		LN	-1.6	-1.0	-3.1	-2.8	-1.9	-0.9	-0.3	-0.9	-0.5	-0.8	-0.6	-1.6
	PAD	EN	1.8	1.1	2.8	3.0	3.3	2.9	0.8	1.6	1.1	0.3	0.3	0.9
		LN	0.0	0.0	-3.7	-2.4	-1.4	-0.3	0.9	0.4	0.0	-0.4	-0.1	-1.0
	CMU	EN	-0.3	-0.8	0.8	1.1	2.3	2.1	-0.3	0.7	0.3	-0.7	-0.5	0.4
		LN	-0.6	-0.3	-2.3	-2.0	-1.2	-0.7	0.6	0.0	-0.1	0.2	0.5	1.1
Tmin	ANK	EN	-1.1	-0.8	-0.3	0.4	0.5	0.2	-0.6	-0.5	-0.7	-0.2	-0.4	-0.2
		LN	3.2	0.9	1.5	1.3	0.8	0.7	0.5	0.6	1.8	1.8	-0.4	1.3
	PAD	EN	-0.7	-1.4	-0.1	0.0	0.1	0.5	-0.4	-0.3	-0.5	-0.5	-1.4	-1.1
		LN	-0.5	-1.0	-1.2	-1.9	-0.8	-0.5	-0.1	-0.3	0.1	0.4	-1.0	-0.5
	CMU	EN	-0.8	-1.8	-0.8	-0.1	0.4	0.7	-0.1	0.1	-0.3	-0.5	-1.2	-0.7
		LN	1.3	-0.2	0.6	-0.7	-0.5	-0.1	-0.2	-0.3	-0.3	0.3	-0.8	-0.6

There were showed the T_{min} and T_{max} predicting for 4 and 6 months lead time. The significant correlation in Table 1 showed the possibility to predict 1-9 months in advance by using SOI. For rainfall, a numbers of significant correlation were rarely occurred because of the high inter-annual variation of each month rainfall in the stations. However, in ANK showed a highest coefficient to r = 0.766 of the correlation between NDJ of SOI and May of rainfall.

3.3. Observed rainfall results

The comparison of the anomaly of average rainfall, T_{max} and T_{min} during the strong and medium El Niño and La Niña years among the 3 stations are shown in Table 2. In Section 3.2 the signals of El Niño and La Niña were occurred in middle of the first year (MJJ) to the initial of the next year (MAM), but the signals were effective responded in the next year. The effects obviously found in the three stations by decreasing of rainfall during March to October except July in strong and medium El Niño phase, and in La Niña phase, the similar results in the three stations were found increasing during March to May but the increasing of rain during June to October depend on the stations. The effects of the El Niño phase to increase T_{max} were mostly found during March to September. The highest increasing was found in May. In contrast of the La Niña phase, the decrease of T_{max} can be found during January to December. The highest decreasing of T_{max} was found in March. For T_{min}, in the El Niño phase, the increases were mostly found in May and June with less than 1 degree. in La Nina phase, the decrease of T_{min} was found in PAD and CMU stations in some months, but in highland station (ANK) showed a little bit increase throughout the year which may be from the cloudiness for higher rainfall in the station. A similar result of the effects of El Niño years was reported in a study in Northeast Thailand (Nounmusig et al., 2006) that the decrease of rainfall was found obviously in June (-36.7%) but in this study found in May (34.7-52.6%). For La Niña year, the strong anomalies of rainfall increase were found in early rainy season.

4. Conclusions

The corresponding of linear correlations between ENSO phase (El Niño and La Niña) and rainfall, Tmax and Tmin studied in the three stations differing in altitude of Northern Thailand were found mostly in the months of March to June. There were some significant and high correlation coefficients, especially, for Tmax and Tmin. The results showed the effects of strong and medium ENSO phases on rainfall and air temperature in lowland, upland and highland in Northern Thailand. The correlation revealed a possibility of using SOI to predict rainfall, Tmax and Tmin in the stations in Chiang Mai province, Thailand and may be applied to other province in upper northern Thailand.

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