Analyzing relationship between the interannual rainfall variability and the ocean indices as related to flooding in Northeast Thailand

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***Abstract*— The objective of this study was to analyze the relationship between annual rainfall and the ocean indices as summer monsoon, the Indian Ocean Dipole (IOD) and the El Niño-Southern Oscillation (ENSO), as corresponding to the flooding in the Northeast by integrating Geo-informatics Technology and statistical. In the whole Northeast, rainfall and flooding are the greatest importance for agriculture, human societies and animals. The result revealed that, the Northeast was a approximate mean annual rainfalls range of 900-3000 mm. Mostly of mean annual rainfall was highest in northeast, while lowest in southwest of the Northeast. The mean annual rainfalls had relationship with the summer monsoon (WNPMI and IMI) and were 0.468 and 0.421, respectively. Moreover, it was found that heavy rain in the Northeast was induced by strong summer monsoon. In addition, the relationship between annual rainfall and IOD (DMI) was 0.109. It was the high DMI value which induced to low rainfall. Furthermore, between the annual rainfall and ENSO (MEI) was 0.689 which also corresponding to DMI. Moreover, a flooded areas was the highest at 10,125.58 km^2 in 2010 and follow by 8,854.86 km^2 as correspond with a second of highest in 2002. However the ocean indices can be explain a variability of rainfall and flooding in the Northeast. The a variability of rainfall and extreme of flooding in the Northeast are dependent on dynamic factors and included climate change. So the people should adapt to the climate variability or climate change for sustainability of natural resource and good wellbeing.**

Keywords: Climate change*, *rainfall*, *flooding*, *Ocean indices

I. Introduction

The Southeast Asia is susceptible to the climate change at both regional and global scale because of its location on the Equator zone. Which faces vulnerability caused by the interaction between the Pacific and Indian oceans. This region is known for three well known phenomenon's caused by the ocean and hence, creating climate change worldwide. Those phenomena are: the Asian monsoon, the Indian Ocean Dipole and the El Niño-Southern Oscillation (Lau and Yang, 1997) [1]. The inconsistency of rainfall affects the lives of countless people in The Northeast of Thailand, especially farmers and agriculture professionals (Mongkolsawat et al., 2010) [2]. Generally, they will need to rely on the rain water drained from public infrastructure; especially in the agricultural sector which is the main occupation for most individuals. The plants must be grown in quantities that fit to the needs for growth and if any plants receive too little or too much rain or experience drought or flood, plants will be damaged. The unpredictability of recent bad weather, floods and severe natural disasters has had an adverse effect creating surmountable damage not to just the property of citizens, but life itself, especially to those in low-lying areas of the river where flooding occurs most frequently. The northeastern region of Thailand faces floods every year. According to Mongkolsawat et al. (2003) [3], each year, the intensity is different and has resulted in damage to agriculture, the economy and social housing.

The Asian monsoon is characterized with a distinct seasonal reversal of wind and clear partition between dry and wet season in the annual cycle, which is related with the seasonal reversal of the large-scale atmospheric heating and steady circulation features (Webster et al., 1998; Ding and Chan, 2005; Trenberth et al., 2006) [4-6]. The Asian summer monsoon, the most energetic components of the earth's climate system, exhibits distinct regional characteristics. Differing from two continental monsoon components, the Indian summer monsoon (ISM) and the western North Pacific summer monsoon (WNPSM) are the oceanic monsoons driven primarily by meridional gradients of sea surface temperature. Tao and Chen (1987) and Murakami and Matsumoto (1994) [7-8] gave a detailed description of this mode and referred to it as the Indian Ocean Dipole (IOD); they also showed that the IOD significantly influences the rainfall in the Indian Ocean rim countries (Saji et al., 1999) [9]. From this literature, it can be understood that until the late 1980s the El Niño influenced the ISMR extensively. Various indices of El Niño, such as the Southern Oscillation index, have been used in the seasonal prediction of the Indian summer monsoon by many researchers as well as the India Meteorological Department (IMD). But, in recent years, ENSO has lost its impact on the Indian summer monsoon (Krishna Kumar et al., 1999; Kripalani and Kulkarni, 1999) [11-12]. Though there were protracted and intense ENSO events in the 1990s, the ISMR was always normal. In a recent study, Ashok et al. (2001) [13] discovered that there are apparent complementary interdecadal changes between the ENSO–ISMR and Indian Ocean Dipole (IOD)–ISMR relationship. They concluded that the frequent occurrence of IOD events was the cause for the weakening of the relationship between the ISMR and ENSO (Saji et al., 1999; Webster et al., 1999) [9-10]. From some atmospheric general circulation model (AGCM) sensitivity experiments, Ashok et al. (2001), in agreement with Behera et al. (1999) [14], infer that the IOD phenomenon modulates the meridional circulation by inducing anomalous convergence (divergence) patterns over the Bay of Bengal during positive (negative) IOD events, leading to excessive (deficit) monsoon rainfall over the monsoon trough region. They further conjecture from observations that during the years, such as 1997, when the ENSO co-occurred with the positive phase of the IOD, the ENSO-induced anomalous subsidence is neutralized/reduced by the anomalous IOD-induced convergence over the Bay of Bengal.

The guidelines and procedures for correct preparation to respond to the prevention and mitigation of disasters caused by climate variability are very important. It is important to build knowledge and understanding and in particular a clear understanding of the mechanisms that link rainfall variability and climate change on both regional and global scale.

II. OBJECTIVES

a. *To study the variability of spatial rainfall in the Northeastern of Thailand.*
b. *To analyze relationship between an annual rainfall and ocean indices as related to flooding.*

III. STUDY AREA

The Northeast is one of the distinct main physiographic features of Thailand and covers about one-third of the total area of the kingdom. It lies between the latitudes of 14° and 19° N and the longitudes of 101°and 106° E (Figure. 1). Land area of the Northeast of Thailand is about 170,000 km^2. Average rainfall varies from 1,000 mm. in the Southwest to 2,000 mm. in the Northeast. The rainfall is unevenly distributed during the rainy season (May to October), with over 80% occurring during August and September. Physiographically, the main area of the Northeast is formed by the so-called Korat plateau and a part of the central highland. The Phu Phan range lies in a Northwest-Southeast direction, dividing the plateau into two basins, the larger Korat basin to the south and the smaller Sakon Nakhorn basin to the North. The two basins are characterized by gently undulating alluvial plains with scattered trees and patches of forest remnants. Flood risk area in the Northeast is a result of large rainfalls, the increased frequency and volume of surface run-off, the rising levels of river beds and human modification of land. The main rivers overflow their banks frequently resulted in devastating floods (Mongkolsawat et al., 2003) [15] (Figure 1).

IV. DATA SOURCE

Daily rainfall was collected from 311 meteorology station as from the Department of meteorology, Ministry of information and communication technology during 1996–2010 (15 years) while Ocean indices such as Indian Monsoon Index (IMI) and Western North Pacific Monsoon Index (WNPMI) of the Summer Monsoon, Multivariate ENSO Index (MEI) of the El Niño-Southern Oscillation or ENSO and Dipole Mode Index (DMI) of the Indian Ocean Dipole or IOD were collected from National Aeronautics and Space Administration (NASA) during 1996-2010. (15 years)

While flooded areas during year 2001-2004 were collected from the Geo-Informatics Centre for Development of Northeast Thailand, Faculty of Science, Khon Kaen University, flooded areas during 2005-2010 were collected from The Geo-Informatics and Space Technology Development Agency (GISTDA), Ministry of Science and Technology.

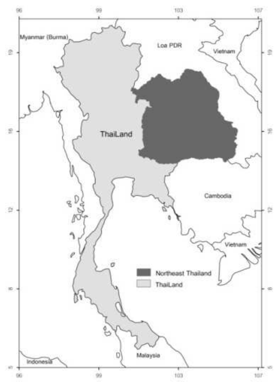

Figure 1. Study area.

V. METHODOLOGY

a. *The construct of spatial annual rainfall*

The ArcGIS 9.3 was used for interpolation of annual rainfall with the Kriging Method (Thavorntam et al., 2007) [16] to cover the studied areas. It presents the distribution of the spatial annual rainfall in the Northeast from 2001-2010.

b. *Relationship between annual rainfall and ocean index analysis*

Linear regression was used to analyze the relationship between the annual rainfall and the ocean index as the IMI and WNPMI of the summer monsoon, DMI of the Indian Ocean Dipole or IOD and MEI of El Niño-Southern Oscillation or ENSO (Krusreesakul, 2009) [17]. It presents the correspond and trend of climate variability or climate change in the Northeast from 1996–2010.

c. *Corresponding of flooding a annual rainfall and ocean indices analysis*

The analysis of flooded areas was correspond as both statistics and distributed of spatial annual rainfall, and the ocean indices as IMI and WNPMI of the summer moonsom, DMI of the Indian Ocean Dipole (IOD) and MEI of El Niño-Southern Oscillation (ENSO). It presents extreme of flooded were affected by climate variability or climate change from 2001–2010 in the Northeast.

VI. Results and Discussion

a. Distribution of Rainfall

Mean annual rainfalls in The Northeast were 1,488.60, 1,620.30, 1,314.50, 1,406.80, 1,402.20, 1,389.00, 1,389.00, 1,671.15, 1,447.30 and 1,434.10 mm. for the years 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 respectiry. Particularly the highest of mean annual rainfall was 1,671.15 mm. in year 2008, while the lowest were_1,389 mm. in both years 2006 and 2007. But the lowest of minimum annual rainfall was 678 mm. and also the highest of maximum annual rainfall was 2,974 mm. in the year 2001. However it show similar sptial pattern of increasing amount from southweast to northeast direction. (Figure 2) The approximate mean annual rainfalls range of 900-3000 mm., mostly of mean annual rainfall was highest in northeast as Nakhon Phanom, Nongkai and Bung Kan provinces, while lowest in southwestern as Nakhon Ratchasima and Chaiyaphum provinces.

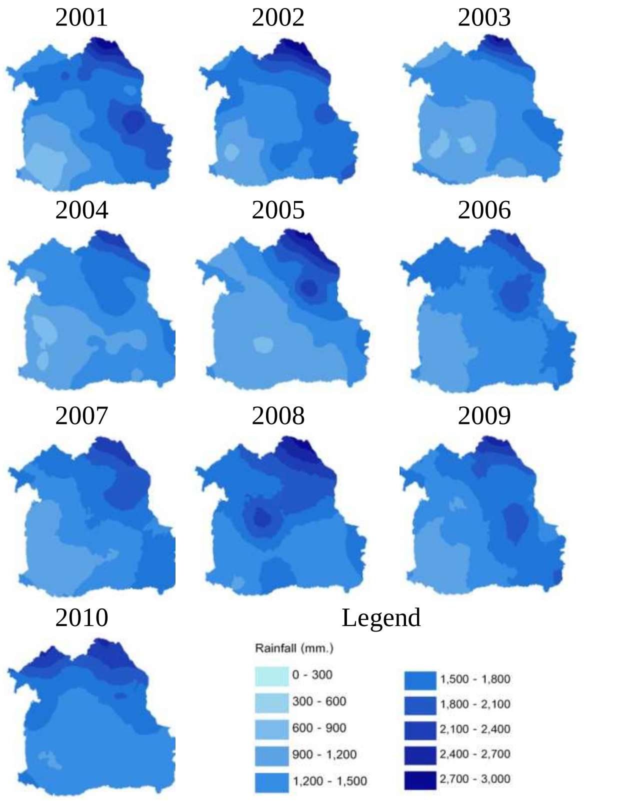

Figure 2. The distribution of spatial annual rainfall in the Northeast of Thailand from 2001–2010.

b. The relationship of an annual rainfall and the ocean indices

1. The annual rainfall and the summer monsoon

The mean annual rainfall had relationship with 2 indices as IMI and WNPMI and it was found that relationships were R = 0.421 and R = 0.468, respectively. It represented that a mean annual rainfall was in relationship with a WNPMI more than a IMI or annual rainfall in the Northeast was effected from the Pacific Ocean more than the Indian Ocean of monsoon. The focus was on prominent months of interactive as June, August and September of WNPMI as the first rainy timeframe was from May to July and second rainy timeframe was August to October in the Northeast rainy season (Mongkolsawat et al., 2010) [18]. It was found that the WNPMI of June and August was the lowest in 1998, (Figure 3a) and lowest WNPMI was -1.717, and also lowest of mean annual rainfall was 1,187 mm. in the year 1998. While the highest of average WNPMI was not corresponded with annual rainfall in 2009, it was because rainfall may depend on other indices or other factors. But mostly, average WNPMI had corresponding with annual rainfall in period studies (Figure 3b). It shows the relationship of rainfall in the Northeast was affected by WNPMI or the Pacific ocean of monsoon.

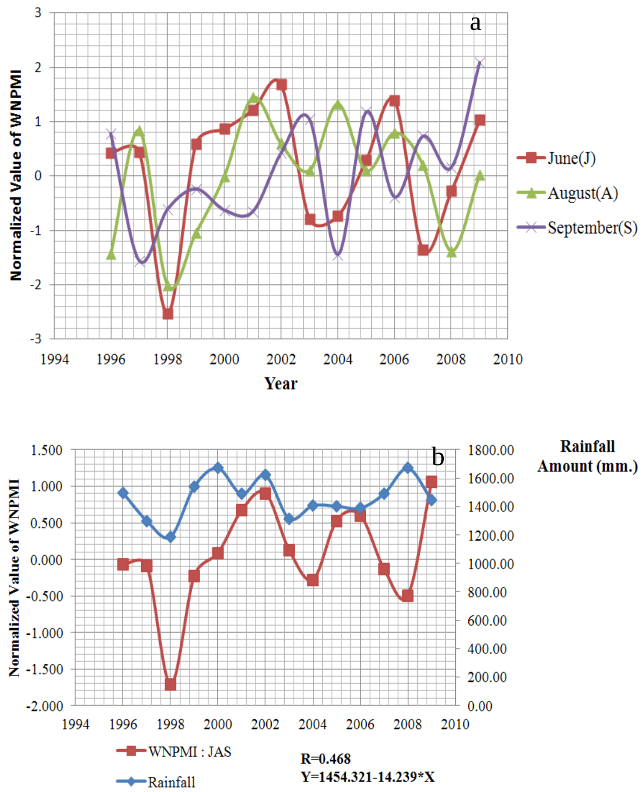

Figure 3. The prominent interactive months of WNPMI[a] and the relationship between annual rainfall and WNPMI in the Northeast [b] from 1996-2009.

2. The annual rainfall and the IOD

The rainfall availability was found associate with the IOD. Saji andYamagata, (2003) [19], Saji et al., (1999) [13] and Webster et al., (1999) [14] suggested that IOD variability may modulate rainfall over Africa and Indonesia in opposite directions-a positive phase of IOD, when sea surface temperate (SST) is anomalously cool in the eastern Indian Ocean and warm in the western Indian Ocean may lead to droughts over in Indonesia or eastern Indian Ocean and heavy rainfall or floods over in equatorial East Africa or western Indian Ocean. The annual rainfall in Northeast of Thailand was in relationship with DMI of IOD (R=0.109). It was found that a average DMI was the highest at 1.441 in 1997, and It induced to lowest mean annual rainfall of 1,187 mm. in year 1998. Moreover, the positive IOD was in 1997, 2003, 2009 and 2010 as induce trend as low annual rainfall in those year while the negative IOD was 1996, 1998, 1999, and 2005 as induce trend as high annual rainfall in those year (Figure 4b). In addition, DMI priority sensitive was in October, November, December and August respectively. (Figure 4a)

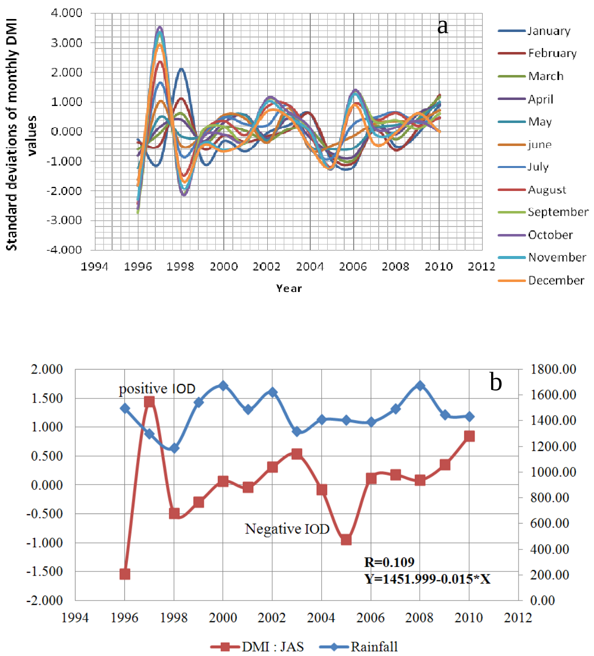

Figure 4. The monthly DMI of IOD (a) and the relationship between annual rainfall and DMI in the Northeast [b] from 1996-2010

3. The annual rainfall and the ENSO

The rainfall availability was found associate with the ENSO (Saji andYamagata, 2003) [19]. The characteristic of bimonthly MEI as from May–December were high in 1997, while January-May were high in 1998. It represented that the El Niño started from May 1997 to May 1998. While the La Niña started from May 1998 to the end of the year 2000, also La Niña in 2008. (Figure 5a) The annual rainfall in the Northeast has relationship with the MEI of ENSO (R=0.689). It was found that the highest MEI of 1.547 was strong El Niño in 1997. But the El Niño started from 1997-1998. So it induced to mean annual rainfall at the lowest of 1,187 mm. in year 1998. While the lowest average MEI of -0.927 was strong La Niña in 1999. But the La Niña started from 1998 - 2000 and also La Niña in 2008. So it induced to high mean annual rainfall of 1,620 mm. and 1,671.15 mm. in years 2000 and 2008 respectively. (Figure 5b).

This relationship was corresponded with IOD. As DMI and MEI were high, but mean annual rainfall was low. While also DMI and MEI were low, annual rainfall was high. The characteristic of precipitation of Thailand in year 1998 was affected from El Niño during 1997-1998. (Climatological Center, 2010) [20] According to Kane (1999) [21], this relationship was represented the anomalies heavy rainfall or flood over in the Northeast affected from La Niña while the anomalies drought over in the Northeast was affected from El Niño.

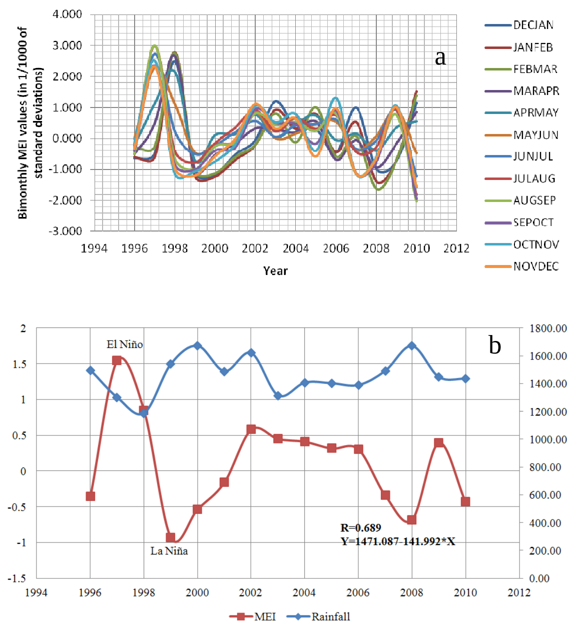

Figure 5. The bimonthly MEI of ENSO (in 1/1000 of standard deviations) (a) and the relationship between annual rainfall and MEI in the Northeast [b] from 1996-2010.

c. The correspond of ocean indices annual rainfall and flooding from 2001-2010

The Northeast was regularly flooded every year since 2001-2010. The highest of flooded area was 10,125.58 km^2 (2010) followed by 8,854.86 km^2 (2002) while the lowest of flooded area was 1,454.68 km^2 (2009) and more detail in Table 1.

The highest of mean annual rainfall of 1,671.15 mm. in year 2008 was corresponded with moderately flooded area of 5,628.72 km^2. While the second of highest flooded area of 8,854.86 km^2 was also corresponded with second of highest mean annual rainfall of 1,620.30 mm. in year 2002. Moreover the highest of flooded area of 10,125.58 km^2. was corresponded with moderately mean annual rainfall of 1,434.10 mm. in year 2010. Which some flooded areas and mean annual rainfalls were discrepant in also year, as the mean annual rainfall were low but the flooded area were high in years 2006 and 2007. Because which locations or basins were difference of rainfall and flood extreme. Such as the highest mean annual rainfall as Nakon Phanom Nongkai and Bung kan province in Songkram subbasin or northeastern of the Northeast. (Figure 2) It induced to regularly floods every year. Particularly, regularly flooded every year on floodplain in Mun and Chi basins and Songkram subbasin of the Northeast. However, mostly of flooded in the Northeast was affected by precipitation of entire Khong, Chi and Mun basins in the Northeast.

Table 1.The mean annual rainfall and flooded areas in the Northeast from 2001-2010

Year	Annual rainfall (mm.)	Flood Area (sq.km.)
2001	1,488.60	4,790.37
2002	1,620.30	8,854.86
2003	1,314.50	3,148.28
2004	1,406.80	4,175.83
2005	1,402.20	3,735.34
2006	1,389.00	6,150.17
2007	1,389.00	4,147.25
2008	1,671.15	5,628.72
2009	1,447.30	1,454.68
2010	1,434.10	10,125.58

Which some the ocean indices were corresponded within mean annual rainfall and flooded area. It was found that a lowest flooded area was corresponded with a lowest of IMI in year 2009, and moreover a high of IMI was corresponded with a high of flooded in year 2006. while a mean annual rainfall was in relationship with a WNPMI more than a IMI. It that represented the IMI was correspond with the flooded area more than mean annual rainfall, but the WNPMI was correspond with mean annual rainfall more than the flooded area, for the other ocean indices were vaguely correspond with the flooded area. (Figure 6)

However, the rainfall and flooding in the Northeast are dependent on several dynamic factors and other factors, particularly of especial characteristics of basins as ecosystem, climate factors, soil permeability, wetland alteration, land use, floodplain management and planning and other (Brody et al., 2012) [22].

VII. Conclusions and Suggestions

a. *Conclusions*

The main point of this study was to understand in climate variability or climate change in the Northeast. It represented the spatial distribution of annual rainfall, the relationship between the annual rainfall and the ocean indices as related to flooding in the Northeast. It was found that a approximate mean annual rainfalls range of 900-3000 mm, mostly of mean annual rainfall was highest in northeast, while lowest in southwestern.

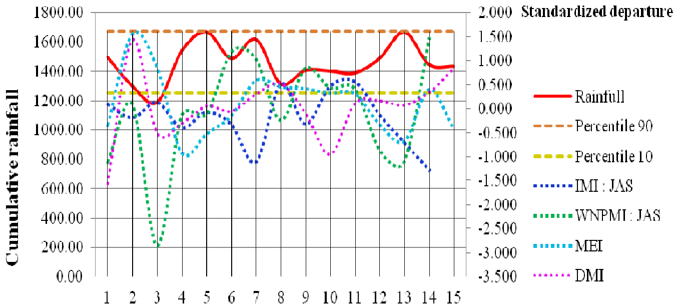

Figure 6. The annual rainfall in the Northeast compared with the ocean indices from 1996-2010.

Mostly, annual rainfall had relationship with the ocean indices as IMI and WNPMI of the summer monsoon, DMI of IOD and MEI of ENSO. It represented to the ocean indices can be explain variability of rainfall and flooding in the Northeast from those relationship and correspond. Moreover, It was found some the ocean indices were corresponded within mean annual rainfall and flooded area, and some the ocean indices were discrepant. However, the a variability of rainfall and extreme of flooding in the Northeast are dependent on several environmental dynamic factors and included climate change. So the people in the Northeast should adapt to the climate variability or climate change for sustainability of natural resource and good wellbeing.

b. *Suggestion*

This study was considered in the relation of rainfall and each ocean phenomenon only. It cannot be explained within interaction of the various of rainfall and flooding in the Northeast of being unclear. The rainfall and flooding were discrepant in some relation of ocean indexs. Further, it should use other climate or flooded data source or alternative approache of analysis such as climtice modeling method, analysis of relationship within climate and disasters various in the Northeast based on long-term data source and remotely data and others.

Acknowledgment

This work was supported by the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission.

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