CHAPTER 5
POSSIBLE IMPACTS ON PRECIPITATION AND TEMPERATURE

It is widely accepted that the EAWM is an importance climate over the Asian continent during the boreal winter. Its principal characteristic is characterized by two major branches of low-level wind fields. The first branch blows toward the subtropical western Pacific, whereas the second branch turns to South China Sea and penetrates to the tropical region as shown by northeasterly wind (Chen, 2000). The dominant northeasterly wind during winter season over the tropical region has been recognized as the northeast (NE) monsoon (Juneng, 2006). The northeasterly with outbursts of Siberian high is an obvious feature of EAWM that exerts a strong impact on the temperate and tropical planetary-scale circulations and influences the convection over the tropical western Pacific (Ji, 1997).

In addition, Wang (2009) found that the EAWM impacted on precipitation and temperature in the north, northeastern China, Japan and the central North Pacific. Available evidence has indicated that the variability of EAWM exert social-economic impacts on many Asian countries (Ji, 1997; Chen, 2000; Wangwongchai, 2005). Although the NE monsoon over the IDP connected to the EAWM via the path way of low-level wind, the impacts of NE monsoon variability on precipitation and temperature during winter season are largely unknown, compared to the study on summer monsoon in the IDP and its country members (Wang, 2002; Zhang, 2002; Juneng, 2006; Takahashi, 2006; Limsakul, 2010; Takahashi, 2010; Htway, 2011; Yen, 2011).

Most of the studies on EAWM variability aim to obtain an index describing the variation of EAWM, and most of indices were derived by analysis of low-level wind data (Ji, 1997; Chen, 2000; Wu, 2006; Wang, 2010; Liu, 2012). There are simple and complicated methods to determine the indices, which are a method on averaging of meridional wind and the EOF analysis for complex numbers, respectively (Chen, 2000; Wu, 2006, 2008). In practice, the simple concept is more appropriate than the complicate method. The previous section introduced the PC1s as indices derived by the EOF method to reveal NE monsoon variability. However, these indices are somewhat difficult to interpret in practice. It is thus better to construct and use the simple index to reveal the variability of NE monsoon over the IDP.

It is well understood that sea surface temperature variability associated with ENSO events influences interannual rainfall variability in the countries of IDP (Juneng, 2005; Limsakul, 2010; Sen Roy, 2011; Yen, 2011). In terms of air-sea interaction, there is a relationship between ENSO and EAWM resulting in the change of vertical circulation over the Pacific Ocean that presents different circulations occurring in the El Niño and La Niña events (Zeng, 2011). Since there are linkages among them, the first is the linkage between rainfall and ENSO (Juneng, 2005; Limsakul, 2010; Sen Roy, 2011; Yen, 2011), the second is the relationship between ENSO with EAWM (Zeng, 2011), and the last is the linkage between the EAWM and NE monsoon, but it lacks of evidence to show impacts in the IDP region from the NE monsoon, also does the ENSO involve whether or not. To give more understanding on NE monsoon over the IDP, the purposes of this section are as follows: 1) to reveal possible impacts of NE monsoon on precipitation and temperature over the IDP, 2) to propose a simple index representing the NE monsoon variability, and 3) to present coincidence between ENSO and NE monsoon, in terms of weak and strong phases of them.

5.1 Data and Methods

The data used in this study consist of the monthly gridded 850 hPa zonal and meridional wind components of the JRA-25 data set with 1.25°×1.25°horizontal resolution (Onogi, 2007). The wind data were used to construct the leading principal components (PC1s) describing NE monsoon variability over the IDP (5°-30°N, 90°-110°E) during the boreal winter (December-January-February) covering the same period 1979-2010 as the previous section.

5.1.1 Precipitation and Temperature Data

The other data set used for regression analysis is the monthly gridded data of precipitation and temperature from the University of Delaware (UDel) with 0.5°×0.5° horizontal resolution (Matsuura K, 2012a,b). It was obtained from the National Oceanic and Atmospheric Administration/ Office of Oceanic and Atmospheric Research/ Earth System Research Laboratory (NOAA/OAR/ESRL), USA. These data sets is improved, based on the studies of Legates (1990a,b). The data sources of precipitation used to construct the UDel data are as follows (Matsuura K, 2012b):

1. Global Historical Climatology Network version 2,
2. Daily India data of NCAR,

3. African precipitation data of Sharon Nicholson’s archive, and
4. South American precipitation data from Webber and Willmott.

The Global Historical Climatology Network precipitation data contained observation data from 20,600 meteorological stations, approximately. For the NCAR data, there are 4,041 stations spatially covering India. The data in Africa given by 1,338 meteorological stations, and 5,315 stations in South America. The four data sets were merged and blended to create a new of time series data for particular stations. Next, interpolation based on the spherical version of Shepard’s distance-weighting method was employed to construct 0.5°×0.5° gridded data. Finally, station-by-station cross validation was performed to control the quality of the precipitation gridded data set (Matsuura K, 2012b).

For the temperature data set, many sources were compiled for the establishment. They are as follows (Matsuura K, 2012a):

1. Global Historical Climatology Network version 2,
2. The Atmospheric Environment Service, Canada,
3. The State Hydrometeorological Institute, Russia,
4. Greenland Climate Network,
5. The Automatic Weather Station Project,
6. The Global Synoptic Climatology Network, National Climatic Data Center (NCDC), NOAA, and
7. The Global Surface Summary of Day, NCDC, NOAA.

At the same geographical location, all available data were blended together. There are criteria of station data usage such as monthly values were compiled from hourly or daily values when the number of missing data was not greater than five days a month. If there was only the monthly observation data, it was selected. The monthly mean data were interpolated by digital-elevation-model assisted interpolation, spherical version of Shepard’s algorithm with enhanced distance weighting method, and climatologically aided interpolation methods to establish 0.5°×0.5° gridded data. Station-by-station cross validation was employed as quality control (Matsuura K, 2012a).

5.1.2 Analytical Methods

The meridional component was used to construct an index, denoted as the v-index, by simply averaging over the significant area in relation to the PC1s suggested before (5°-15°N, 100°-110°E and 15°-22°N, 106°-116°E), as shown in Figure 5.1, which are related to the PC1s. The possible impacts on temperature and precipitation were then analysed by regression analyses of both anomalies on three indices.

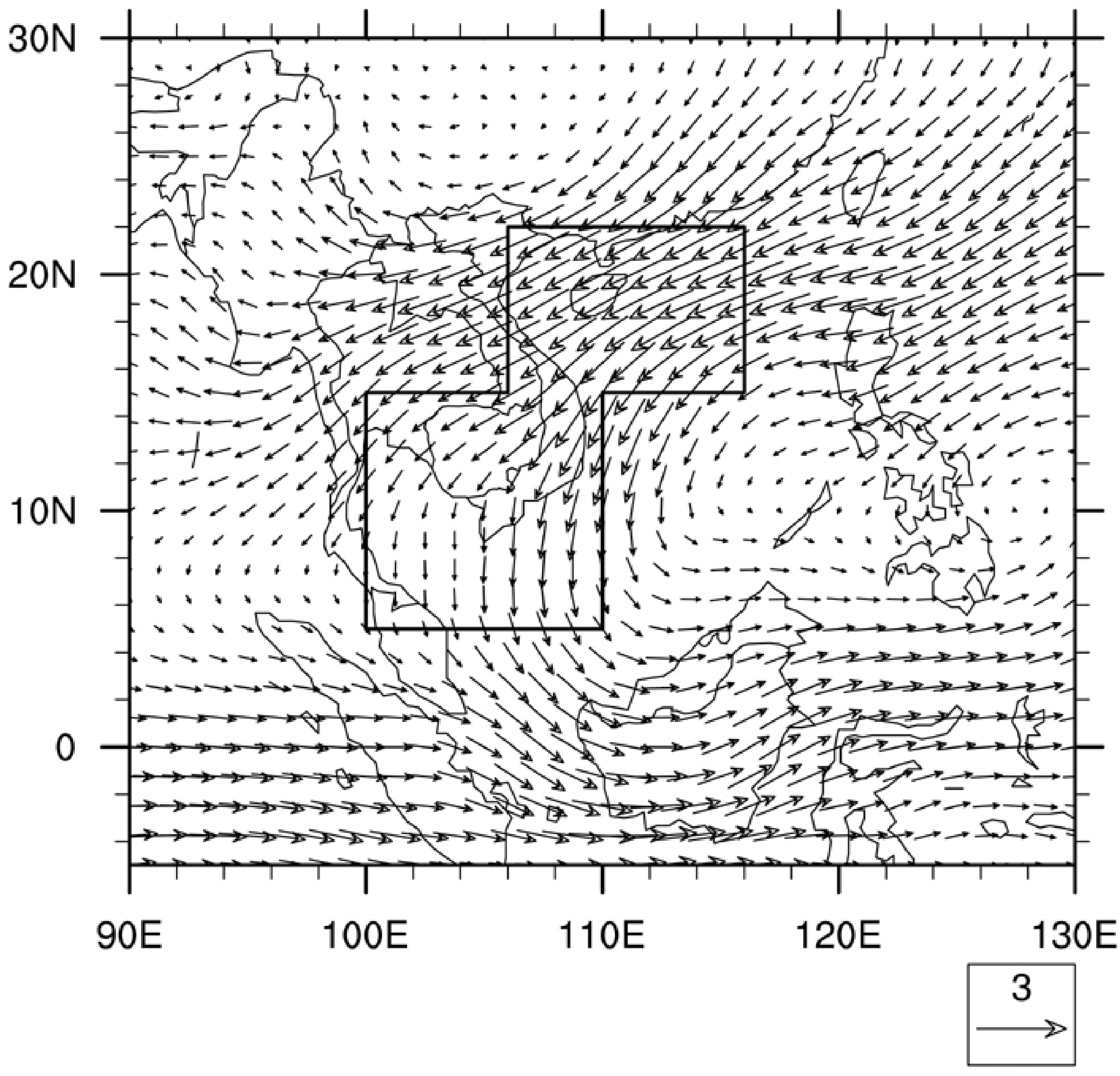

Figure 5.1: The area used for v-index construction (bounding by solid line), and regressed wind anomalies at 850 hPa on the v-index (unit is m/s).

To explore the concurrences between the ENSO events and the strong/weak NE monsoon phases, this study analysed the time series of Niño 3.4 index (Trenberth, 2001), and the time series of NE monsoon indices with occurrences of strong/weak NE monsoon phases using PC1s and v-index. For the Niño 3.4 index, the monthly index version ERSST.V3B (1981-2010 base period) was used for averaging sea surface temperature anomalies over 5°S-5°N, 170°-120°W from the Climate Prediction Center/ National Oceanic and Atmospheric Administration (CPC/NOAA) to classify the appearance of ENSO phenomena. The criterion used to classify the El Niño event was the Niño 3.4 value greater than 0.5°C, whereas a value of less than −0.5°C was used for La Niña event. In addition, a standardized value of the monsoon indices greater than 1SD was classified as the strong phase of NE monsoon, while the value less than −1SD was denoted as the weak phase.

5.2 Possible Impacts of NE Monsoon Variability on Precipitation and Temperature

The variability of the monsoon can be represented by low-level winds (Ji, 1997; Chen, 2000; Wu, 2006, 2008), and derived by a simple method such as averaging the wind components over the representative area (Ji, 1997; Chen, 2000), or a complicated method by analysing the wind components forming in a complex number (Wu, 2006, 2008). The NE monsoon variability over the IDP was revealed by the leading mode of spatio-temporal wintertime wind variability over the IDP, and was identified to be connected with the EAWM. The leading mode given by the EOF analysis for complex numbers consists of the real part (PC1pri) and the imaginary part (PC1sec). The PC1s used to describe the NE monsoon variability over the IDP, and present prevailing 850 hPa northeasterly wind by regression technique. This feature is an important characteristic of NE monsoon (Juneng, 2006).

A plausible connection between EAWM and NE monsoons has been described by circulation characteristic of EAWMthat having a branch of wind blowing along the coast of East Asia (Chen, 2000) linked to the NE monsoon and related to the Borneo vortex causing on precipitation over the Malaysia Maritime (Juneng, 2006). To give basic understanding, climatic spatial distributions of precipitation and temperature are presented firstly.

The spatial distribution of climatic precipitation covering a period 1979-2010 during the boreal winter shows more precipitation on the southern part of IDP, along the coast line area of Viet Nam, and some parts of Guangxi and Guangdong of China than the mainland of IDP including Myanmar, upper part of Thailand, Laos, and Cambodia excepting some parts of Arunachal Pradesh of the Northeast India and northern part of Myanmar (Figure 5.2a).

The possible impact of NE monsoon on precipitation over the IDP is revealed by regression analysis of precipitation on PC1s representing NE monsoon variability. The regressed precipitation patterns on the primary (real) and secondary (imaginary) part of PC1 (Figures 5.2b and 5.2c) show positive over the area from the South Central Coast of Viet Nam to the Mekong Delta, southern part of Cambodia, southern tip of IDP, and central part of Myanmar that indicate the enhancement of NE monsoon strength (increasing of PC1s values), resulting in more precipitation over their areas, and vice versa for the weakening of NE monsoon (decreasing of PC1s values) showing the reducing of precipitation over there in terms of a linear relationship. These results agree with the blowing path way of EAWM connected with NE monsoon that passes the South China Sea penetrating to the IDP (Chen, 2000), which carries moisture from the South China Sea and Gulf of Thailand to eastern coast line and southern areas of the IDP, respectively. On the other hand, the negative presence over areas around Guangxi and Guangdong of China and the northern part of Vietnam, significantly indicates to the strong NE monsoon resulting wind blows more southward with carrying of dry air mass causing of less precipitation over the areas. Nevertheless, precipitation over mainland China and middle part of IDP are not strongly affected by the NE variability.

For the wintertime surface air temperature, the spatial distribution depicts the lower temperature over the Subtropics, whereas the higher values show over the bottom parts of IDP closed to the Tropics area (Figure 5.2d). The possible impact of NE monsoon on temperature was also revealed by regression analysis as shown in Figures 5.2e and 5.2f. The negative area were found most parts of Thailand, Laos, Viet Nam, and Cambodia, particular in the south of northeastern Thailand region, indicating stronger NE monsoon affects more than others. The opposite change in temperature was observed for the positive areas.

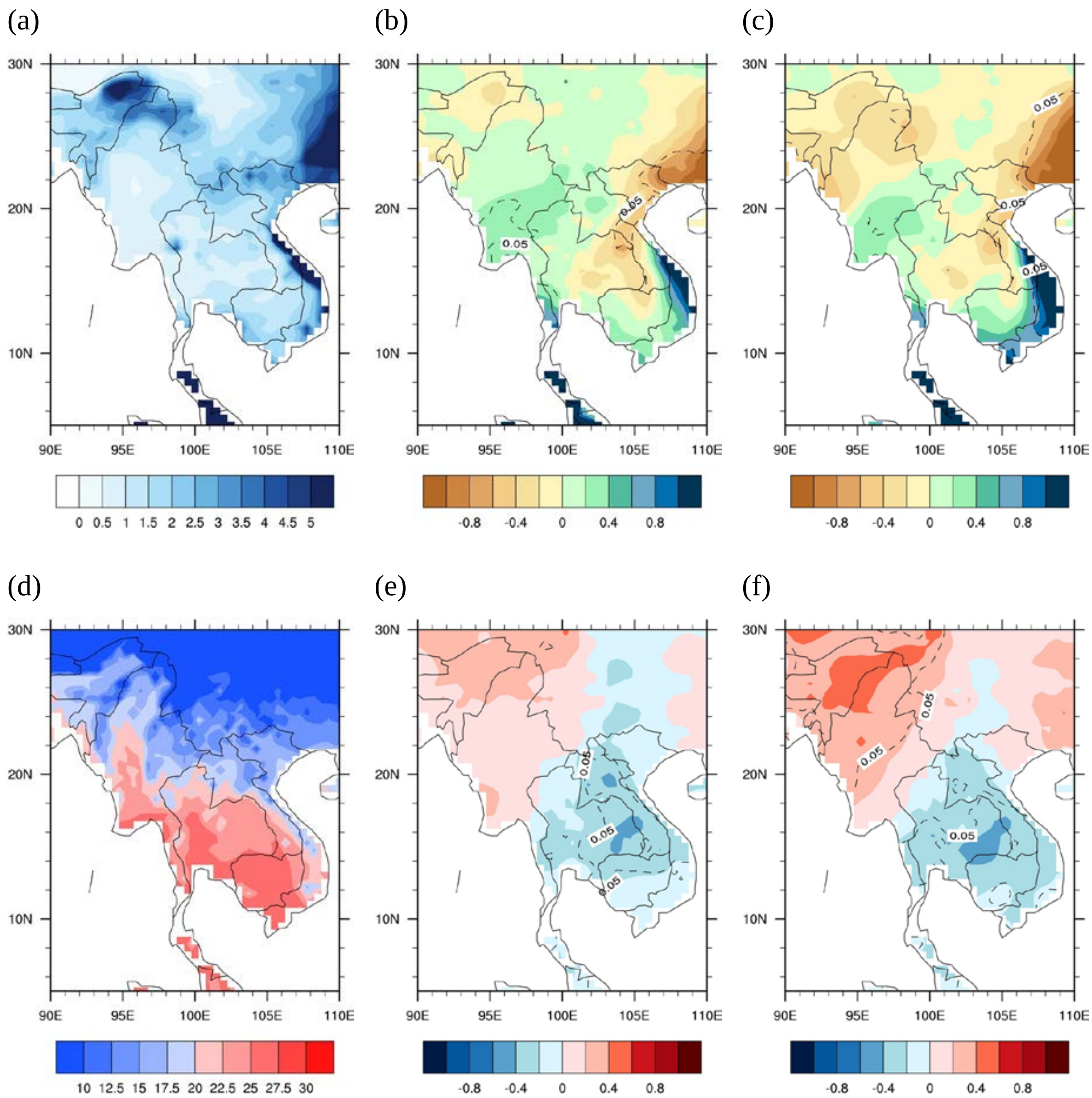

Figure 5.2: Spatial distributions of (a) climatic mean during the boreal winter of monthly total precipitation from 1979-2010, and spatial patterns of regressed precipitation anomaly on (b) PC1pri, and (c) PC1sec. Figures (d)-(f) are similar to (a)-(c) but for the temperature. Shading color shows regression results in unit of cm/month for precipitation and °C for temperature, whereas the dash line represents significant level at 0.05.

The v-index given by averaging of meridional wind was introduced to represent the migration of air from North to South over the significant area related to PC1s (the area bounded by solid line as shown in Figure 5.1). Its spatial pattern of wind presented by regressed anomalies of wind components on the v-index shows principal feature of NE monsoon, which is the strong northeasterly wind over the IDP (Figure 5.1). The correlations between v-index and PC1s are strong (r = −0.76 and −0.96 for PC1pri and PC1sec, respectively) with 0.01 significant level. Their variations agree with each other (Figure 5.3), but it shows in the opposite direction to the PC1s due to the different definitions.

For PC1s, increasing value indicates the strengthening of winds blowing from North to South, whereas increasing v-index value implies to enhancement of wind blowing from South to North due to the sign indicating direction of meridional wind component. Therefore, the decrease (increase) of the v-index value indicates the strengthening (weakening) of NE monsoon over the IDP. To ensure the representativeness of the v-index in terms of its impacts, the possible impacts on precipitation and temperature (Figure 5.4) exhibited by regression of their anomalies on the v-index are compared with the possible impacts given by PC1s.

The results in Figure 5.4 agree with the impacts given by the regression of the precipitation and temperature anomalies on the original PC1s (Figures 5.2b, 5.2c, 5.2e, and 5.2f). This indicates that the simple v-index can be used to describe the variability of NE monsoon, and to present the possible impacts related to its variation instead of the PC1s derived from the complicate method.

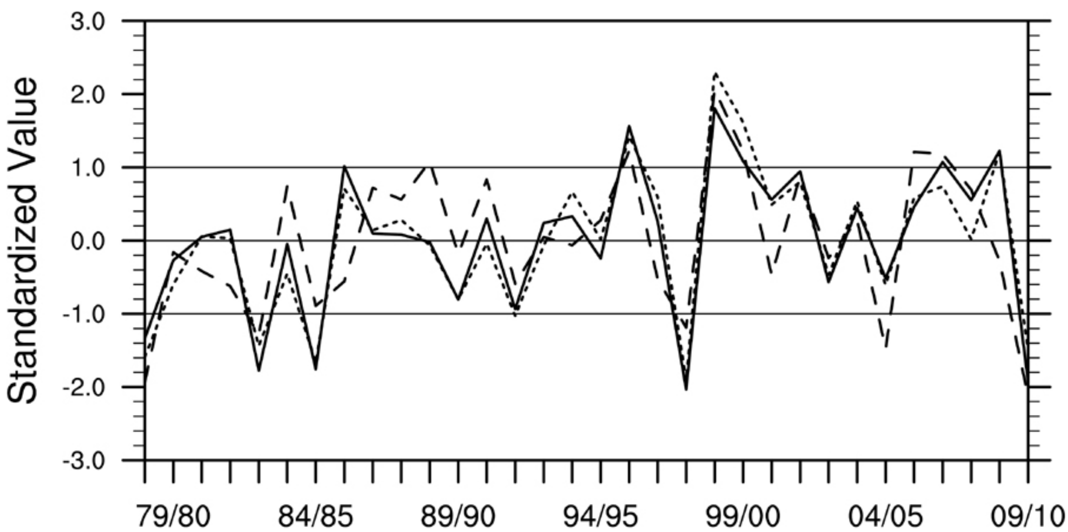

Figure 5.3: Times series of the reverse v-index (solid line), PC1pri (long dash line), and PC1sec (short dash line). Time series of the v-index was shown in opposite sign to keep the same meaning with PC1s that are strengthening NE monsoon related to increasing of PC1s value in positive direction, and vice versa for weakening of NE monsoon.

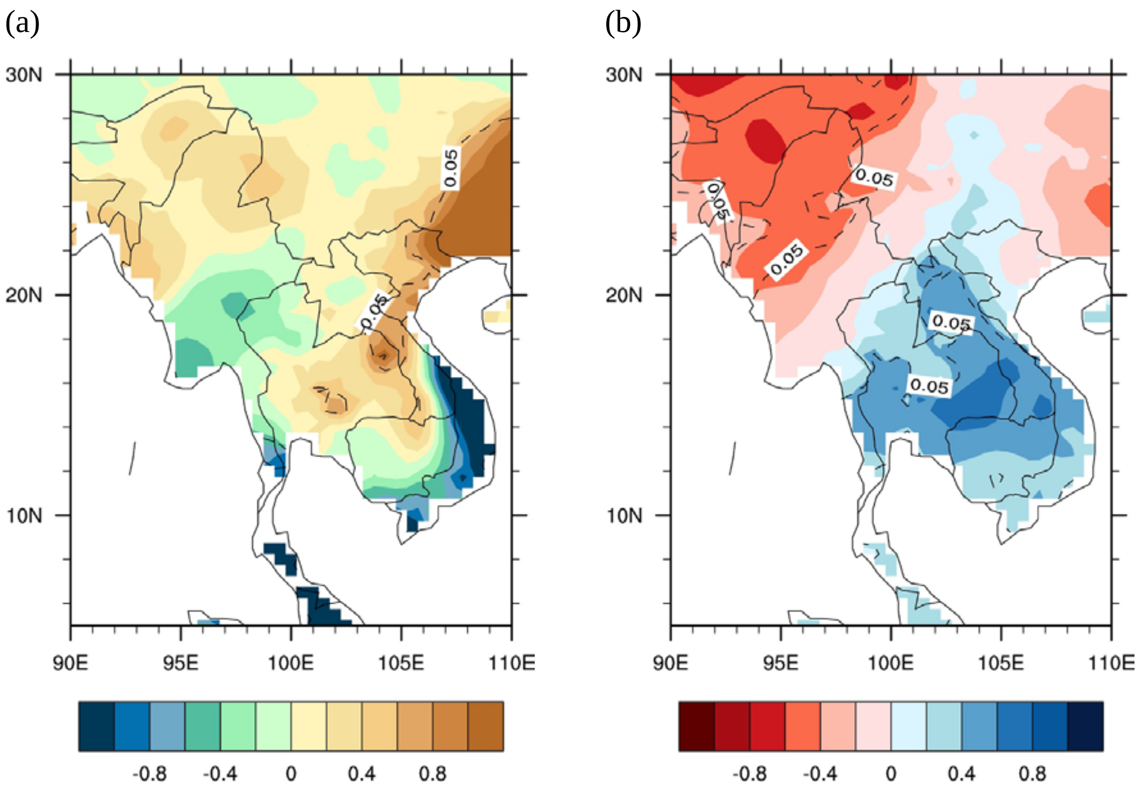

Figure 5.4: Spatial distributions of (a) regressed precipitation anomaly on the reverse v-index, and (b) same as (a) but for the regression of temperature anomaly on the reverse v-index. Shading color shows regression results presented in reverse shading due to the meaning of v-index with units of cm/month for precipitation and °C for temperature, whereas the dash line represents significant level at 0.05.

These results indicate possible impacts of NE monsoon variability on precipitation and temperature that may occur in different phases of the NE monsoon variability. The three indices, PC1pri, PC1sec, and v-index, can be utilized to indicate the NE monsoon strength and its possible impacts over the IDP. Nevertheless, the indices of NE monsoon are not routinely monitored, which differ from the famous climate phenomena, ENSO. Since, there is possible correlation between NE monsoon variability and ENSO. It is worth to point out that there is concurrence between ENSO and NE monsoon events, which leading to make use an ENSO index with the indices representing the NE monsoon variability to speculate the corresponding impacts on precipitation and temperature during winter season.

5.3 Concurrence between ENSO and NE monsoon

It is widely accepted that ENSO influences precipitation variability. Since there is some associations between ENSO and EAWM (Zeng, 2011), and it has possibility to indicate NE monsoon variability by an index monitoring ENSO phenomena. For the NE monsoon, this analysis used the value from 1979/1980 winter (representing the period of December 1979 to February 1980) to 2009/2010 winter (representing the period of December 2009 to February 2010). The first value representing the mean of January and February 1979 was ignored because it was not consistent with the others.

Figure 5.5 shows the results of classification from 1979 to 2010, where as the Niño 3.4 given by the CPC/NOAA was a little extended to cover the study period. It found that strong NE monsoon (denoted as S, whereas 1, 2, and 3 denoted as PC1pri, PC1sec, and v-index, respectively) tends to occur during La Niña events (blue shading as shown in Figure 5.5) that are available in 1985/1986, 1988/1989, 1995/1996, 1998/1999, 1999/2000, 2005/2006, 2008/2009 winters. Weak NE monsoon tends to occur during El Niño events (red shading as shown in Figure 5.5) in 1982/1983 1991/1992, 1997/1998, 2004/2005, 2009/2010 winters. None of strong and weak NE monsoon phases present during neutral phase of ENSO.

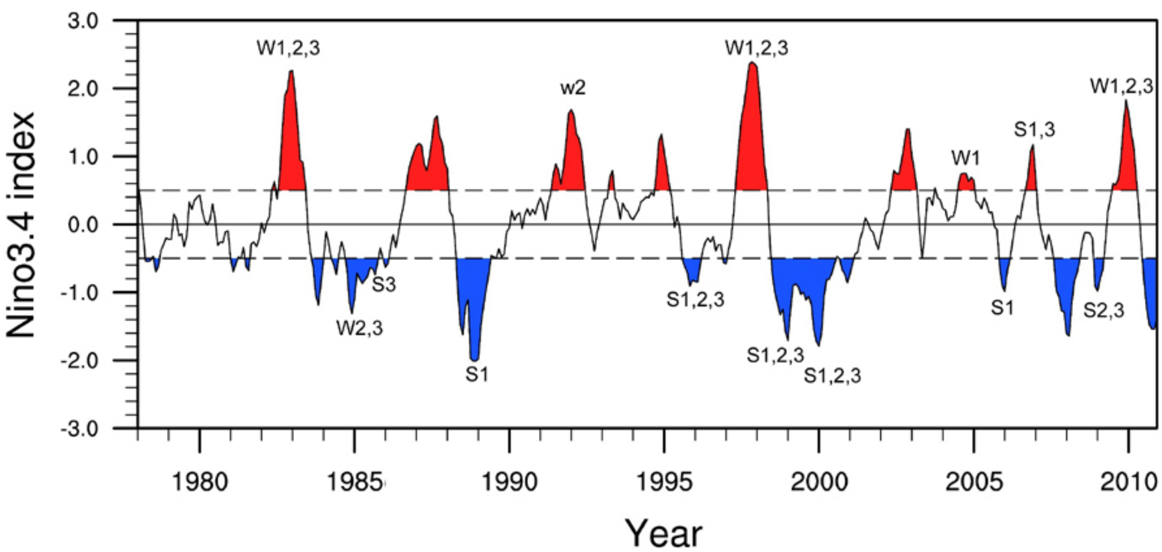

Figure 5.5: Time series of Niño 3.4 indices and occurrences of strong/weak NE monsoon phases. Red color and blue color represents El Niño and La Niña phases, respectively, whereas dash lines show the criteria to classify ENSO event, and S (W) stands for strong (weak) NE monsoon, whereas 1, 2, and 3 denoted as PC1pri, PC1sec, and v-index, respectively.

This result indicates that ENSO may play an important role in the NE monsoon due to atmospheric-oceanic interaction, and has some modulation between ENSO and NE monsoon. This agrees with the correlation between PC1s and Niño 3.4 index as presented in Figure 4.2, and the study of (Zeng, 2011) that proposed the vertical circulation related to EAWM variability. During strong EAWM that exerts strengthened northeasterly wind (Chen, 2000), the zonal Walker circulation and the west Pacific Hadley circulation cells present strengthened low-level easterly and northerly winds, respectively (Zeng, 2011). It results in strengthening the low level northeasterly wind as shown in Figure 3.5.

The numbers of coincident events of El Niño with weak NE monsoon indicated by PC1pri, PC1sec, and v-index are four coincident events for each indices, and the total number of coincident events indicated by all indices is five coincident events. For the coincident events of La Niña with strong NE monsoon, there are five, four, and five coincident events are shown by PC1pri, PC1sec, and v-index, respectively. The total number of coincident events evidenced by all indices is seven of eleven La Niña peaks. These results indicate that weak (strong) NE monsoon tends to present during El Niño (La Niña) event, whereas weak and strong NE monsoon phases do not occur during neutral ENSO phase.

However, there were rarely coincident events of the weak NE monsoon in 1984/1985 La Niña event and the strong NE monsoon in 2006/2007 El Niño event. Since there are other important climate modes (Pavia, 2006; McPhaden, 2008), the two events may be influenced by other factors. For example, the development of the El Niño event in 2006 started late, and decayed rapidly in the winter (Luo, 2008; McPhaden, 2008) that influences large-scale circulation (Krishnan, 2011).

A few special events indicate the importance of other climate forcings that should be considered due to the complicated air-sea interaction, which require further research on two special events to explore and describe the important roles of other climate forcing that affect the NE monsoon variability using modelling for that. So, there are concurrences between La Niña event and Strong NE monsoon, which resulting in more precipitation over the southern tip and coastline of the IDP, whereas there are concurrences between El Niño and weak NE monsoon, which resulting in less precipitation over the southern tip and coastline of the IDP. This result agrees with the study of Zeng (2011) that proposes the mechanism of vertical circulation showing easterly winds in the Pacific Ocean is strengthened during the strong winter monsoon period. This causes more carrying moisture from the Pacific Ocean to the IDP, and vice versa for the weak monsoon. Our results show importance evidence indicating association between NE monsoon and ENSO, and special events of interest. phase.

5.4 Summary

This study revealed the possible impacts of the NE monsoon on precipitation and temperature by the regression of both anomalies on three indices representing the variability of the monsoon. Two indices, PC1pri and PC1sec, were derived by EOF analysis for complex numbers. Since the EOF analysis for complex numbers is the complicated mathematical method, this section newly introduced a simple index (v-index) by averaging meridional wind over the significant area related to PC1s, and found that it has strong correlation with PC1s. This indicates that the v-index can reveal the variability of NE monsoon as well.

The result of the regression analysis showed positive values over the areas from the Central Coast of Viet Nam to the Mekong Delta, southern part of Cambodia, southern tip of IDP, and central part of Myanmar that indicate the NE monsoon strength resulting in more precipitation over these areas. The weakening of NE monsoon represented by decreasing PC1s values showed the reduction of precipitation over there. Whereas more temperature drop in most parts of Thailand, Laos, Viet Nam, and Cambodia when NE monsoon strength becomes stronger than the normal, and vice versa for the weak NE monsoon. Nevertheless, the impacts on precipitation and temperature given by its regression on the simple index (v-index) showed their quite similar spatial patterns to those given by PC1s. Therefore, there is possibility to indicate possible impacts on precipitation and temperature in the IDP by the indices.

On the other hand, this result showed that there is an important role of the ENSO in NE monsoon variation by revealing the coincidence of ENSO with the strong/weak NE monsoon. Three important points can be observed: (1) during neutral ENSO phase, strong and weak NE monsoon do not occur, (2) weak NE monsoon tends to occur during El Niño period, and (3) strong NE monsoon tends to occur during La Niña period. Nevertheless, there are two special coincident events as follows: (1) the weak NE monsoon associated with La Niña event in 1984/1985 and (2) the strong NE monsoon in 2006/2007 during the El Niño event. It requires further research using a modelling system on the two special events to explore the influences of other climate modes affecting NE monsoon variability over the IDP. This finding indicates that the possible impacts on precipitation and temperature over the IDP by the NE monsoon can be indicated by this newly developed index to better understand local impacts of ENSO in the IDP. It is better, if further study using modelling system to understand more on underlying mechanism of winter monsoon based on result of this study.