Rainfall variability over the Indochina peninsula during the Boreal Winter, Part I: Preliminary data analysis

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Abstract

This study analyzed gridded precipitation data of the Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation data set over the Indochina peninsula during the boreal winter (December to February) from 1951 to 2007 to demonstrate its variability. The empirical orthogonal function (EOF) technique was employed. The first mode of EOF analysis accounts for about 42.6% of the total variance. The temporal variation signal of the leading mode representing the variability shows interannual variation, and the corresponding spatial pattern shows large changes in magnitude over the southern part and the eastern coast of the Indochina. The variability was examined to reveal its correlation to the sea surface temperature (SST) that indicates the relationship between rainfall variability and SST in the Pacific Ocean. The results suggest that the El Niño/Southern Oscillation does not high significantly influence the rainfall variability over Indochina during the winter season, in contrast to the effects from the subtropical areas in the North Pacific Ocean. Further studies are needed to provide a better understanding of the mechanisms in relation to the climate variability over the Indochina.

Keywords: Rainfall, Variability, Indochina, EOF, Sea Surface Temperature, Winter

1. Introduction

The Indochina Peninsula comprised of seven nations, which are Burma, Cambodia, Laos, Peninsular Malaysia, Singapore, Thailand, and Vietnam, and is a part of the Southeast Asia. There are studies in various aspects of climatology focusing on the Indochina, the Southeast Asia, and countries locating in these regions. Juneng and Tangang (2005) suggested that the evolution of anomalous rainfall in the Southeast Asia is in-phase with the ENSO evolution, and showing high correlated to each other. As supported by the views of country perspective, the interannual rainfall amounts of Thailand tend to be larger (lower) than the normal condition during the La Niña (El Niño) event (Limsakul et al., 2007) as well as the interannual rainfall variability in the central Vietnam is out-of-phase with the time series of the Nino3.4 index (Yen et al., 2011). There is an important role of ENSO to rainfall over the region.

Although there is the relationship between rainfall variability over the Southeast Asia and ENSO (Juneng and Tangang, 2005), it obviously related to ENSO during summer season (Chen and Yoon, 2000). During winter season, the principal spatial pattern of rainfall over the Southeast Asia shows large variation over the Borneo (Juneng and Tangang, 2005). The pattern does not capture the principal characteristic of rainfall over the Indochina due to the rainfall over the Borneo accounts more variation of rainfall than that in the Indochina during the winter season. Nevertheless, there is the possible relation among the winter monsoon governing the Indochina, rainfall over the region during winter season, and the forcing from
sea surface temperature in the Pacific Ocean such as the ENSO (Sooktawee et al., 2013). The variability of rainfall over the Indochina is interesting to reveal, and that can give more understanding for the climatic variability of the region.

This study aims to present the variability of rainfall over the Indochina, and presents its relation to the SST forcing particularly in the Pacific Ocean. The data analysis was employed for the purposes as the preliminarily for studying further.

2. Data and Methodology

The data used in this study consist of gridded precipitation data, atmospheric parameters, and sea surface temperatures (SST). The gridded precipitation data were extracted from the Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) of the Water Resources products (Yatagai et al., 2012). We use the version V1003R1 for analysis. The horizontal resolution of the data is 0.25°, spanning and covering the study period from 1951 to 2007. The data were extracted for the study domain (4°-25°N, 90°-112°E) defined as the Indochina peninsula as shown in Fig. 1. The Hadley Centre Sea Ice and Sea Surface Temperature data set has 1°×1° horizontal resolution (HadISST), and it starts from 1870 to present (Rayner et al., 2003) were used for an analysis related to the sea surface temperature.

The precipitation data were used to analyze to present the major spatio-temporal mode using the empirical orthogonal function (EOF) method. The EOF method has been used to decompose a space-time field into spatial patterns and associated time series (Hannachi et al., 2007). Firstly, the precipitation anomalies were calculated based on the study period, and then the anomalous data were decomposed into modes of space and corresponding time series. The time series has been used to describe the variation as the variability (Hannachi et al., 2007). The correlation analysis and the composite analysis were employed to investigate the relation of the rainfall variability over the Indochina to SST anomalies, and present the influence of SST forcing.

![Fig. 1. The study domain representing the Indochina, and the shading representing topography provided by the ETOPO5 dataset (unit is meter).](image-url)
3. Rainfall Variability over the Indochina

To understand the normal status of rainfall during the boreal winter in terms of spatial distribution, the distribution of rainfall shows large magnitude of rainfall over the southern part and the eastern part of the Indochina peninsula as shown in Fig. 2a. It agrees with the characteristics of the East Asian monsoon (EAWM) that the winds blow from the temperate region passing the South China Sea penetrating to the tropical region (Chen et al., 2000). It also has possible relation to the El Niño–Southern Oscillation (ENSO), and the strong EAWM would enhance the ascending air over the equatorial area (Zeng et al., 2011). These will affect on precipitation over some areas of the Indochina or related to the rainfall variability over the Indochina whether or not?

The leading mode of rainfall variability over the Indochina exhibited by the EOF analysis and it accounts 42.6% of the total variance. The spatial pattern of the first EOF mode (EOF1) exhibits large variation of rainfall over the southern part of the Indochina and the central part of the Vietnam, which quite similar to the climatic mean pattern of the rainfall (Fig. 2), and that agrees with the large contribution of the first mode to the total variance. The corresponding principal component time series of the leading mode (PC1) shows interannual variation (Fig. 3). Both of spatial EOF1 and corresponding time series PC1 suggest that when the magnitude of PC1 increasing in positive, the rainfall over the positive area identified by EOF1 (the southern part of the Indochina and the central part of the Vietnam) would more increase than that of the rainfall in the main land of the Indochina. On the other hand, the decreasing of PC1 value in negative direction means the rainfall over the southern part of the Indochina and the central part of the Vietnam would more decrease than that of the rainfall in the main land of the Indochina.

![Spatial patterns of (a) the climatic rainfall over the Indochina during boreal winter (DJF) for the period of 1951 to 2007 and (b) the first EOF mode.](image-url)
The spatial pattern of the leading mode is quite similar to the previous study of Sooktawee et al. (2013) that mentioned the northeast monsoon over the Indochina possibly affects rainfall over the southern part and the central part of Vietnam, and it has possible relation to the ENSO. Therefore, this study conducts the correlation analysis to reveal the linear relationship between the rainfall variability and SST anomalies in the Ocean. Correlation coefficients were plotted to reveal the relation covering most of the Pacific Ocean and the Indian Ocean as shown in Fig. 4a. The result shows positive significant correlation over the subtropics area around 15°-30°N, 150°-200°E (hereafter referred to as SA) in the North Pacific Ocean. The positive correlation indicates that the warming (cooling) of SST in the SA of the Pacific Ocean related to increasing (decreasing) of rainfall in the southern part of the Indochina and the central part of the Vietnam, and vice versa for the negative correlation. The negative significant correlations present over the equatorial central Pacific Ocean and some areas in the Indian Ocean. Nevertheless, the negative correlation in the equatorial Pacific Ocean is not fully conformable to the cool phase pattern of the ENSO, and also it does not show the obvious different pattern to the ENSO pattern. The magnitude of the negative correlation in the equatorial Pacific Ocean is smaller than the positive correlation. This will possible to show some evidence such as less correlation to the ENSO index.

The spatial pattern difference between the correlation map and the ENSO pattern suggests that the anomalous SST over the whole area representing the ENSO phenomena does not significantly influence rainfall variability during winter season in terms of linear relationship. To investigate further, we perform composite analysis to reveal the different pattern of anomalous SST between strong and weak phases of rainfall variability over the Indochina. The criteria that the standardize value of PC1 greater than 0.6 was categorized into the strong phase, whereas the value is smaller than −0.6 was classified into the weak phase. The difference pattern (Fig. 4b) suggests that SST in the subtropics area of North Pacific Ocean becomes warmer than the normal during strong phase of the rainfall variability and cooler than the normal over the central-east Pacific Ocean. The cool pool does not extend southward as the cold tongue representing La Niña pattern, not only this, but also the warm SST in the SA in the North Pacific Ocean does not present as a part of the Boomerang shape. Therefore, the SST anomalies in the Pacific Ocean representing the ENSO play fewer roles on
the variability of rainfall over the Indochina in terms of linear relationship than the SST anomalies over the SA in the North Pacific Ocean during wintertime.

In view of the relationship between the variability of rainfall during winter season (DJF) represented by PC1 to SST anomalies in various months, we perform lead-lag correlation analysis to further investigate. The SST anomalies in the SA of the North Pacific Ocean were averaged, and used them to determine the relationships with the variability of rainfall over the Indochina. Whereas, the Nino3.4 area (5°N-5°S, 170°-120°W) representing ENSO phenomenon (Trenberth and Stepaniak, 2001) was used to determine the lead-lag correlations. The Fig. 5a shows the positive relation between the variability of rainfall over the Indochina (PC1) and the SST anomalies over the SA in the Pacific Ocean. The positive correlation means that the increasing (decreasing) of SST anomalies in that area related to rising (reducing) of the rainfall variability magnitude indicating more (less) rainfall over the Indochina. The significant correlations present six months before and after the winter season that implies the warming SST anomalous over the SA of the Pacific Ocean triggers more rainfall over the Indochina and after that the rainfall sends signal back to that area of the Ocean.

For the ENSO, the lead-lag correlation between the rainfall variability and the Nino3.4 shows less significant correlation than that of the SA in the North Pacific Ocean, and the significant correlation coefficients are negative (Fig. 5b). The negative correlation between the PC1 and Nino3.4 indicates the increasing (decreasing) of rainfall over the Indochina
related to cool (warm) phase of ENSO, but it is not strong, comparing to the SA in the North Pacific Ocean, in terms of linear relationship.

Fig. 5. The correlations of PC1 to (a) the SST anomalies over the SA in the Pacific Ocean and (b) the Nino3.4 index. The −1, 0, and 1 are the ND(0)J(1), D(0)JF(1), and JFM(1) averages, respectively.

From these analyses, they show that the forcing of SST anomalous in the Pacific Ocean affects rainfall variability over the Indochina. The ENSO does not play a greater role on rainfall variability comparing to the SA in the North Pacific Ocean. These agree with the relationship between rainfall in the Southeast Asia and ENSO that shows the large variation of rainfall over the Borneo (Juneng and Tangang, 2005). Nevertheless, the influence of ENSO on rainfall variability over the Indochina in this study was shown by the data analysis. Another perspective given by the modeling is important to give more understanding. Moreover, the Pacific Decadal Oscillation would be of interest for study further due to it related to the SST in the North Pacific. There are the plenty of understandings required for more understanding of climate variability over the Indochina such as the mechanism of SST forcing affects the rainfall variability.

4. Conclusions

The rainfall variability during boreal winter (December to February) over the Indochina peninsula was exhibited by the EOF technique. The leading mode of the variability accounts 42.6% of the total variance, and shows the interannual variation. Its spatial distribution presents large rainfall variation over the southern part over the Indochina and the central part of Vietnam, whereas its temporal variation shows the correlation to the SST anomalies, particularly in the Pacific Ocean.
The spatial patterns given by correlation and composite analyses, and the lead-lag correlation analysis suggest that the ENSO does not significantly influence rainfall variability during winter season in terms of linear relationship, comparing to the SA in the North Pacific Ocean. The warming (cooling) of SST in the SA region related to increasing (decreasing) of rainfall in the southern part of the Indochina and the central part of the Vietnam, and vice versa for the negative correlation. The warming SST anomalous over the SA of the Pacific Ocean triggers more rainfall over the Indochina, and after that the rainfall sends signal back to that area of the Ocean. For the ENSO, the lead-lag correlation between the rainfall variability and the Nino3.4 shows less significant negative correlation indicating that the increasing (decreasing) of rainfall over the Indochina related to cool (warm) phase of ENSO. Nevertheless, studies on the climate variability over the Indochina are needed such as the study using modeling to give more understanding on mechanism, and the study related to the PDO.

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References

