台灣四季再定義—以冬季為例

The Redefinition of Taiwan seasons

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ABSTRACT

It is usually thought that a year consists of four seasons: spring, summer, autumn and winter. Taiwan basically follows the rule. Taiwan climate is mainly governed by monsoons. Therefore, the beginning of summer (winter) can be interpreted as the inward movement of summer (winter) monsoons. Considering the important role of mei-yu period, Chen (2000) pointed out that mei-yu should be added as a season between spring and summer.

The overall object of this work is to increase our knowledge of Taiwan seasonal change, especially winter season. Monsoons will be applied to identify the characteristics of winter. International data sets of observations in pentad resolution will be employed. These observed data sets include global and regional data which are NCEP reanalysis, CMAP precipitation, ECMWF reanalysis and CWB data.

Our analyses show that the Taiwan winter monsoons can be divided into two parts. It implies that the first half of winter is dominated by the continental high and the last half of winter is controlled by climate systems over the western North Pacific. Taiwan rainfall associated with the latter time period exhibits positive relationship with the eastern equatorial Pacific sea surface temperature, a feature of El Nino/Southern Oscillation (ENSO).

Keyword: Taiwan winter monsoon, ENSO, climate variability

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1. Introduction

We usually divide a year into four seasons of spring, summer, autumn and winter. Summer is defined as the warmest season and winter the coldest season. As a result, in the Northern Hemisphere, summer is defined as three warmest months of June, July and August. Winter would be the coldest months of December, January, and February. Two seasons of autumn and spring are the transition period between summer and winter. Autumn would be September, October, and November and spring would be March, April and May (Ahrens 2000).

The seasonal change of Taiwan basically follows the above rule; i.e., four seasons in a year. However, it is suggested in Chen (2000) that Taiwan should be composed of five seasons. It means that mei-yu season is added between spring and summer.

Taiwan climate has a distinct feature of monsoons. They are an annual weather phenomenon that the wind blows reversely between winter and summer. Usually in winter the monsoon wind blows from land to sea while in summer the wind blows from sea to land. That the wind direction changes seasonally is developed well in eastern and southern Asia. Summer season of Taiwan can be interpreted as the summer monsoons march in. The summer wind direction is within the range of south, south-east and south-west, mostly south-west. Similarly, winter season of Taiwan can be interpreted as the coming of winter monsoons. The winter wind direction is within the range of north, north-east and north-west, mostly north-east.

Several studies pointed out that the monsoon is a complicated climate system which involves interactions between ocean, atmosphere and land. The magnitude and position of the monsoon is thought to be affected by land processes such as soil moisture, evapotranspiration, surface albedo (Xue and Shukla 1993; Meehl 1994; Lofgren 1995; Yang and Lau 1998) and topography (Murakami 1987; Yanai *et al*. 1992; Yanai and Li 1994).

Wang and LinHo (2002) reported that Asian summer monsoon can be described as three major sub-systems: the Indian summer monsoon, the East Asian summer monsoon and the western North Pacific summer monsoon. They observed that the last two monsoon systems have strong influences on Taiwan rainfall during the rainy season.

Chou *et al*. (2003) investigated the interannual variability of the western North Pacific summer monsoon on the differences between El Nino/Southern Oscillation (hereafter referred to as ENSO) and non-ENSO Years. They found that in the non-ENSO year, anomaly of the western North Pacific summer monsoon is associated with the variation of the meridional temperature gradient in the upper troposphere. However in the ENSO developing and decaying years, anomaly of the western North Pacific summer monsoon is related with ENSO-related SST anomalies.

Since Asian summer monsoon is highly correlated with the rainfall over this region, it received a lot of attention from simulation modelers and data analyzers (e.g., Chang *et al.* 1998; Chen *et al.* 1992; Huang and Sun 1992; Lau 1992; Wang *et al*. 2001; Chou *et al.* 2003; Hu *et al*. 2000).

Compared to those studies, the research on the Asian winter monsoon is relatively limited. Therefore we aim to investigate the phenomenon of Asian winter monsoons, especially on their characteristics, physical mechanism responsible for them, their interannual variability and relationship with the ENSO. We mainly focus on the following aspects.

(1) meridional temperauture gradient, Aleutian and Siberian high

Zhang et al. (1997) demonstrated that the winter monsoon is driven by the available potential energy produced by the thermal contrast between land and sea. The strong rainfall in the equatorial western Pacific enhances the release of latent heat, and then leads to the local Hadley circulation in the north-south direction.

It is found in Jhun and Lee (2004) that the strong winter monsoon may lead to the excess snowfall in October over the Siberian high, northeastern China, and far eastern Russia. From their GCM model experiments, the change of the snow depth in fall season over the Siberian high and northeastern China is highly correlated to the winter monsoon variability. They suggests that stronger winter monsoon is characterized by a stronger Aleutian low and Siberian high.

(2) onset

To define south China Sea (SCS) monsoon onset which has link with the commencement of the East Asian summer monsoon, Wang et al. (2004) suggests that the Uscs, the 850-hPa zonal winds averaged over the central SCS (5° - 15°N and 110° - 120°E). Compared to previous indices such as outgoing longwave radiation, upper-tropospheric water vapor brightness temperature, high cloud amount, low-level or surface winds proposed by previous studies (e.g., Tanaka 1992, Chen et al. 1996, Yan 1997, Lin and Lin 1997, Zhu et al. 2001, Yan 1997, Zhang et al. 2001) , the index of Uscs is quite simple, concise and meaningful. We are motivated to find out an index or indices to properly describe the Asian winter monsoon.

(3) ENSO and Asian monsoon

Hung et al. (2004) displayed that the ENSO phase has a strong connection with the annual cycle of the Asian monsoon. A symmetric behavior exists between Asian and Australian monsoons. However, preceding Australian summer monsoon rainfalls show no relation with succeeding Asian summer monsoon rainfalls.

In the mature phase of El Nino (low southern Oscillation Index), it is shown in Zhang (1996, 1997) that the winter monsoon in East Asia seems to be weaker because the surface Siberian high, 500-hPa trough and 200-hPa jet stream tends to be weaker. It also implies that the cold surge frequency show a positive relationship with the southern Oscillation Index.

Singh (1995) compared data over two distinct winter monsoon years 1987 and 1988 to study the influence of Bay of Bengal on winter monsoon rainfall. Rao (1999) examined the data during the 122-yr period (1872-1993) to study if the fluctuations of the Southern Oscillation (SO) related to summer and winter monsoon rainfall over the India. He found that there is significant relationship between SO and summer as well as winter monsoon rainfall.

(4) Asian summer and winter monsoon

Sun and Sun (1996) presented that there is usually a strong winter monsoon before a dry summer season, and also a weak winter monsoon before a wet summer season

Dhar and Rakhecha (1983) analyzed the data over Tamilnadu (one meteorological subdivision in India) for the100-yr period (1877-1976) and reported that the southwest monsoon rainfall exhibits a negative dependence on the north east monsoon rainfall.

We attempt to investigate if there is any relation between summer and winter monsoon rainfall over regions of East Asia.

2. Methods

Observed data in the pentad resolution will be utilized. These observed data sets include global and regional data which are described as follows.

(1) NCEP reanalysis

The National Centers for Environmental Prediction (NCEP) reanalysis (Kalnay et al. 1996) will be used in this study. The data set has a spatial resolution on 2.5°x 2.5° latitude-longitude grid and two version: with time period spanned from 1950-2002 and the other from 1979-2002, respectively. Each version has seventeen levels in the vertical. The data set of sea surface temperatures with a resolution of 2°x 2° in NCEP is obtained from the empirical orthogonal function (EOF) which is based on the study of Smith et al. (1996).

(2) CMAP precipitation

We will also apply precipitation data from the Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) (Xie and Arkin 1997) to our study. The time period of data set ranges from January 1979 to December 2002 and has a spatial resolution of 2.5°x 2.5°. Pentad and monthly data can be found in this data set.

(3) ECMWF reanalysis

The European Center for Medium–Range Weather Forecasts (ECMWF) reanalysis (ERA) will be used. It has two data sets, ERA-15 (Gibson et al. 1999) and ERA-40 (Simmons and Gibson 2000), respectively. The time period of ERA-15 spanned from January 1979 to December 1993 with seventeen pressure levels. The spatial resolutions are 1.125°x 1.125° and 2.5°x 2.5°, respectively. The time period of EPA-40 ranged from September 1957 to August 2002 with twenty-three levels in the vertical. The spatial resolution is 2.5°x 2.5°.

(4) CWB data

The data collected from twenty-five ground stations of the Central Weather Bureau (CWB) will be utilized. The data set includes variables such as station pressure, temperature, dew-point temperature, wind speed, wind direction and precipitation.

3. Results

Both NCEP reanalysis and CMAP precipitation data from 1979 to 2002 are utilized for preliminary tests. Figures 1 and 2 present the pentad data of streamline field at 850 hPa level from analysis of the NCEP version 2 which ranged from 1979 to 2002. They are for six periods: 1-18 pentad, 19-26 pentad, 27-38 pentad, 39-50 pentad, 51-66 pentad and 67-73 pentad, respectively. The corresponding velocity larger than 4 m/s is light shading and the velocity larger than 10 m/s is dark shading.

Since we are interested in winter monsoons, Figures 1a and 2c are the focus. Figure 2c (December), pentad data for the first half part of winter, demonstrates that clockwise airflows move around the East Asia. It implies that the East Asia at this time is dominated by the high of continental anticyclone. Compared to Figure 2c, Figure 1a reveals a totally different pattern. It is seen in Figure 1a (Jan-Mar), pentad data for the last half part of winter, that the western North Pacific (southeast Asia) is clearly dominated by systems over the Pacific.

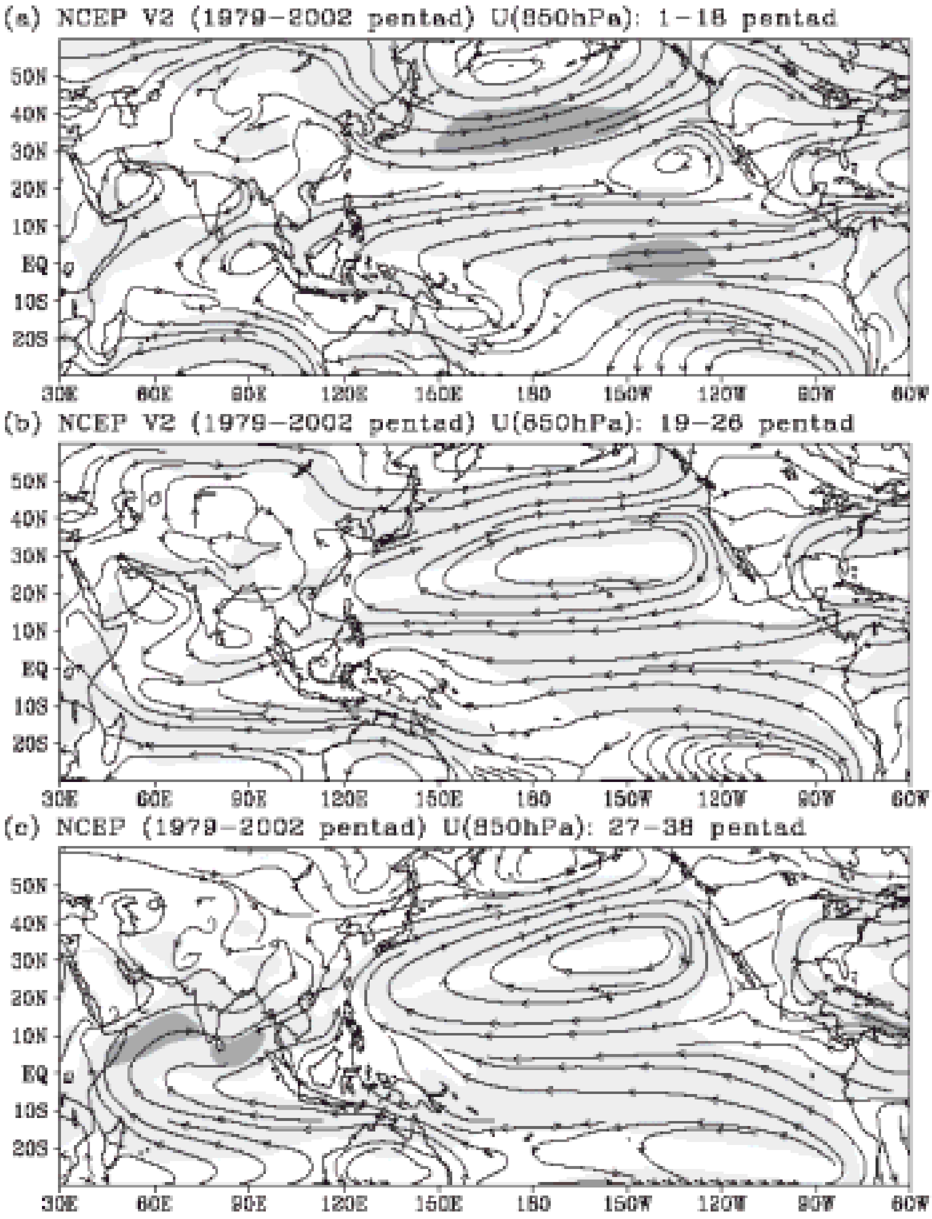

Figure 1. The pentad data of streamline field at 850 hPa level from analyses of the NCEP version 2 which ranged from 1979 to 2002. They are for three periods: 1-18 pentad, 19-26 pentad and 27-38 pentad, respectively.

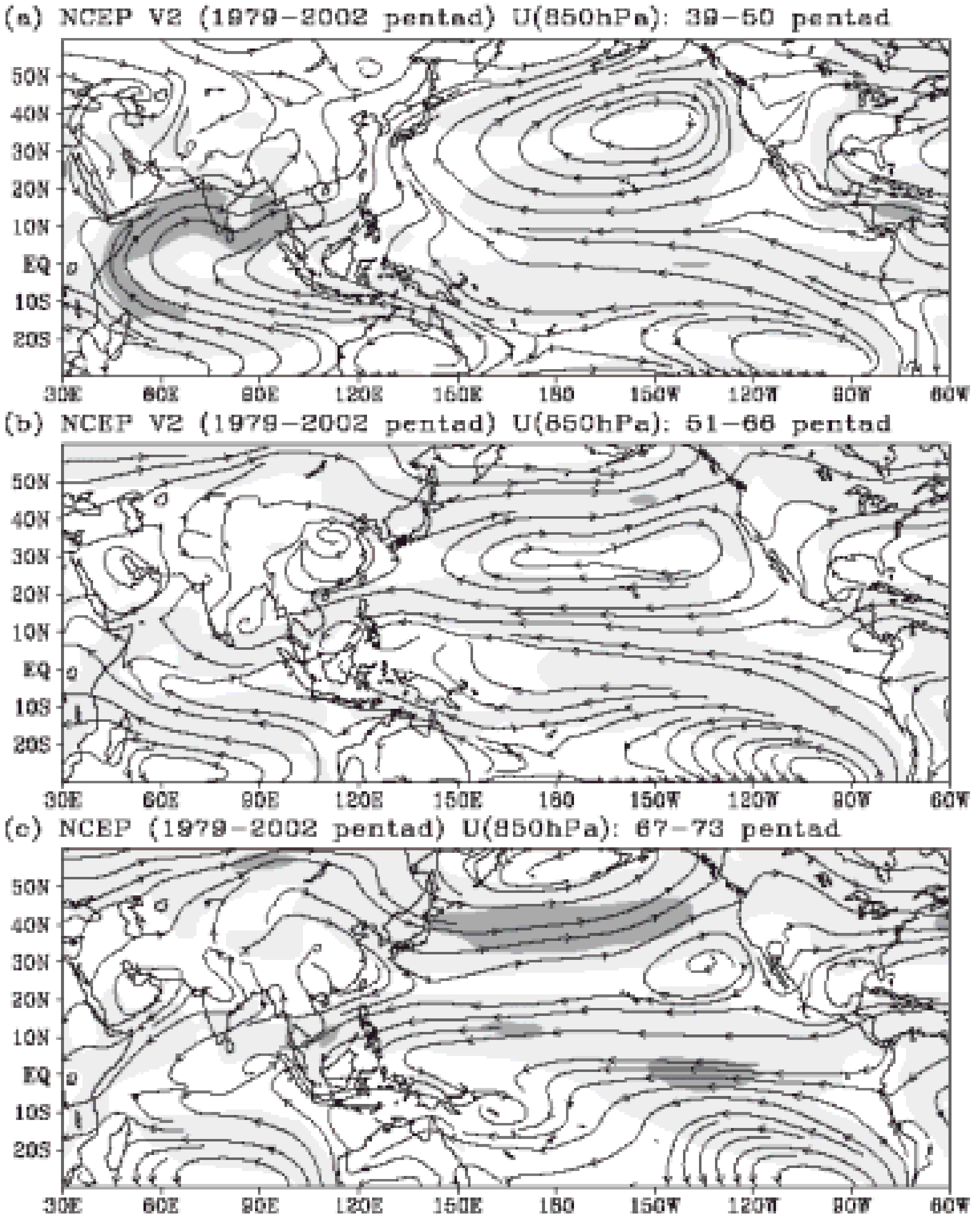

Figure 2. The pentad data of streamline field at 850 hPa level from analyses of the NCEP version 2 which ranged from 1979 to 2002. They are for three periods: 39-50 pentad, 51-66 pentad and 67-73 pentad, respectively

Figures 3a-c are the correlation of Taiwan rainfall to CMAP precipitation for three periods: 51-66 pentad (fall season), 67-73 pentad (December), 1-18 pentad (January-March). It is found that the pattern of December is similar to that of autumn; however, totally different from that of Jan-Mar. Figure 3c indicates that the strength of Taiwan rainfall exhibits a positive relationship with the precipitation over the eastern equatorial Pacific and an inverse relationship with that over western equatorial Pacific.

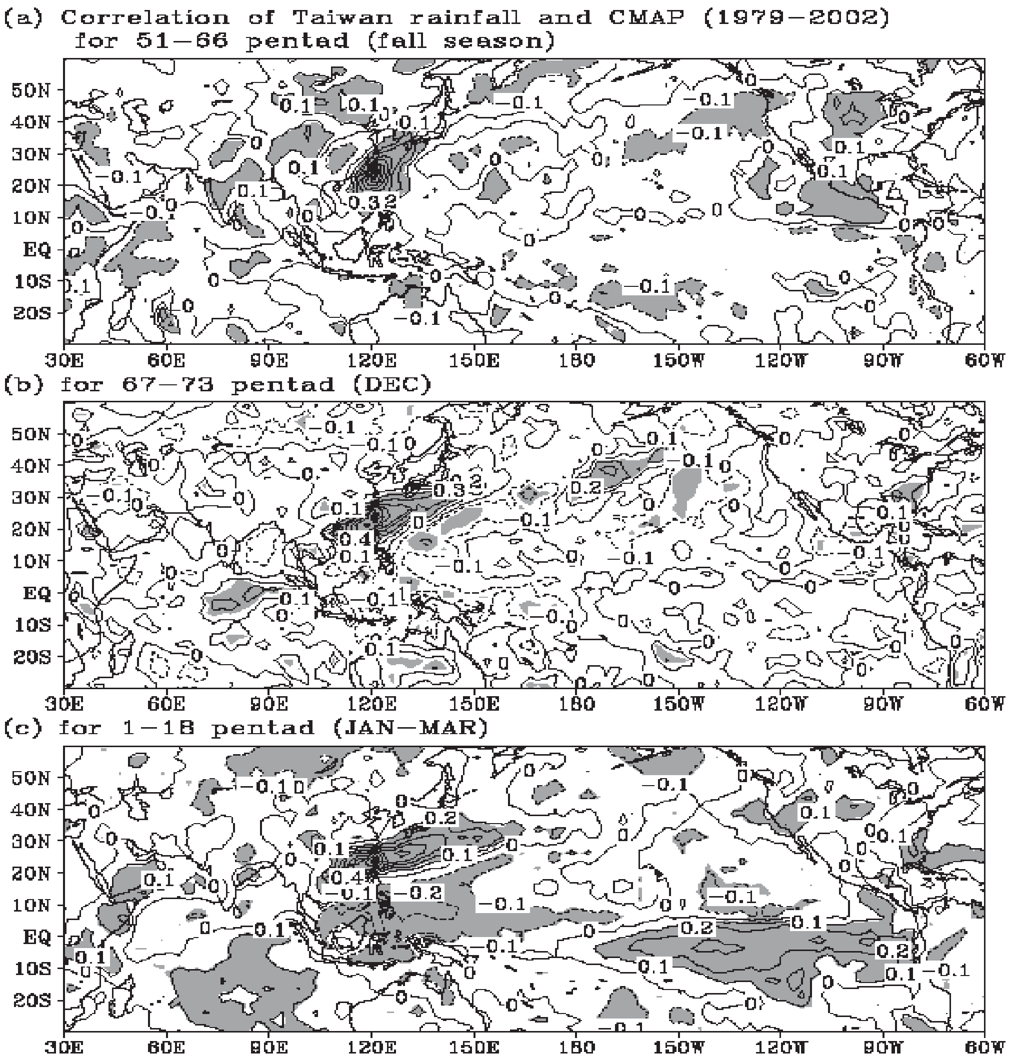

Figure 3 The correlation of Taiwan rainfall to CMAP precipitation for three periods: 51-66 pentad (fall season), 67-73 pentad (December) and 1-18 pentad (January-March).

Figures 4a-c show the correlation of Taiwan rainfall to NCEP Version 2 sea surface temperature (SST) for the same time periods as Figure 3. Figure 5 demonstrates the correlation of Taiwan rainfall to NCEP Version 2 temperature at 1000 hPa for the same time periods as Figure 3. Both SST and temperature at 1000 hPa are considered here because the SST correlation is not reliable in the land area.

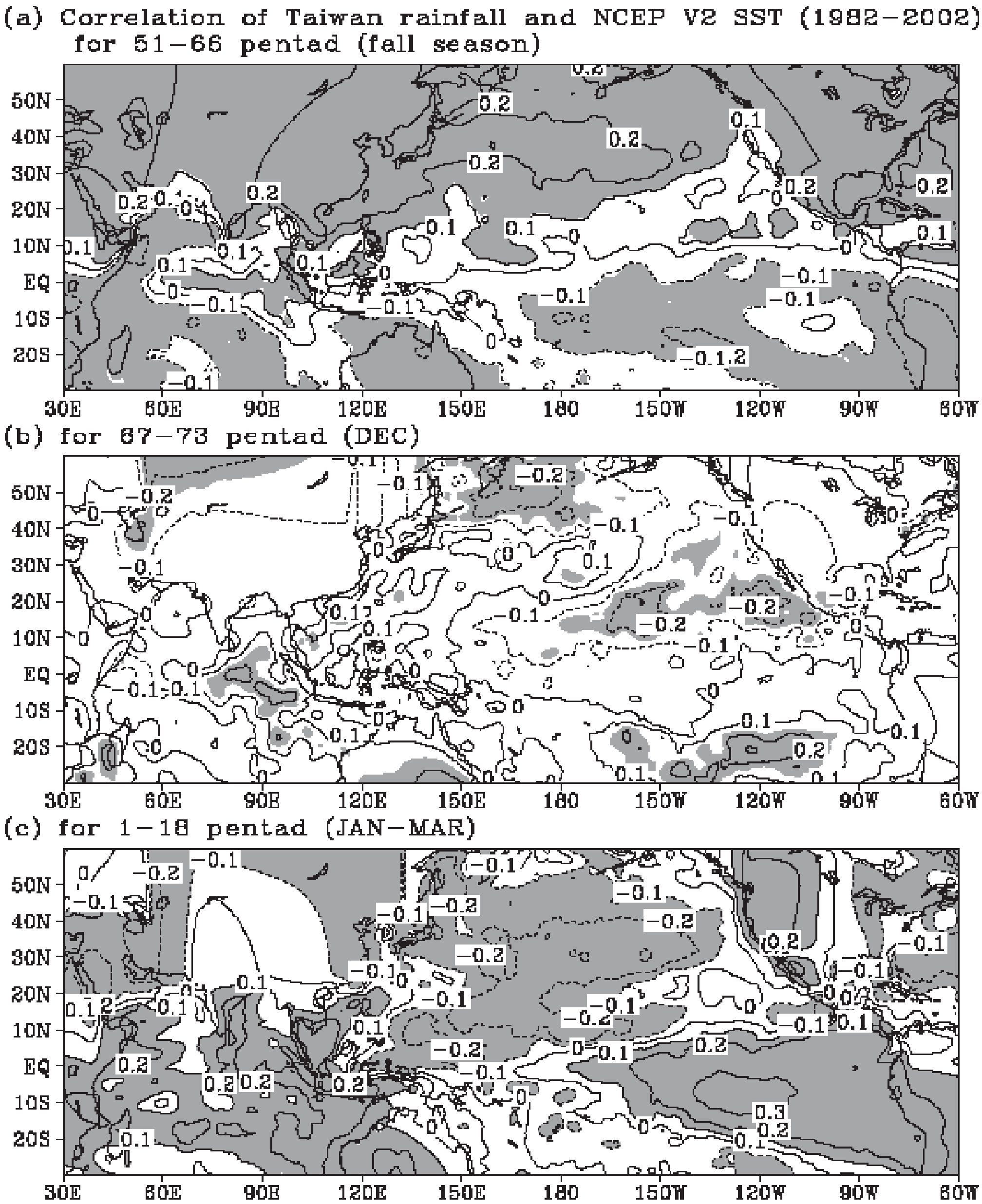

Figure 4 The correlation of Taiwan rainfall to NCEP Version 2 sea surface temperature (SST) for the same time periods as Figure3.

Under this situation, temperature at 1000 hPa will be employed. It is seen that there are two different patterns for the winter season; 67-73 pentads (Dec) for the first period and 1-18 pentads (Jan-Mar) for the second period. Taiwan rainfall appears to be positively correlated with the eastern equatorial Pacific SST (Figure 4c) and precipitation (Figure 3c). It is a phenomenon similar to the ENSO. The positive correlation over the Pacific region can be observed in the higher levels at 850 hPa as well as 200-500 hPa (not shown). It implies that the positive correlation region can propagate upward due to wave dynamics. The above analysis demonstrates that there is some linkage between the pattern of second period of winter and ENSO.

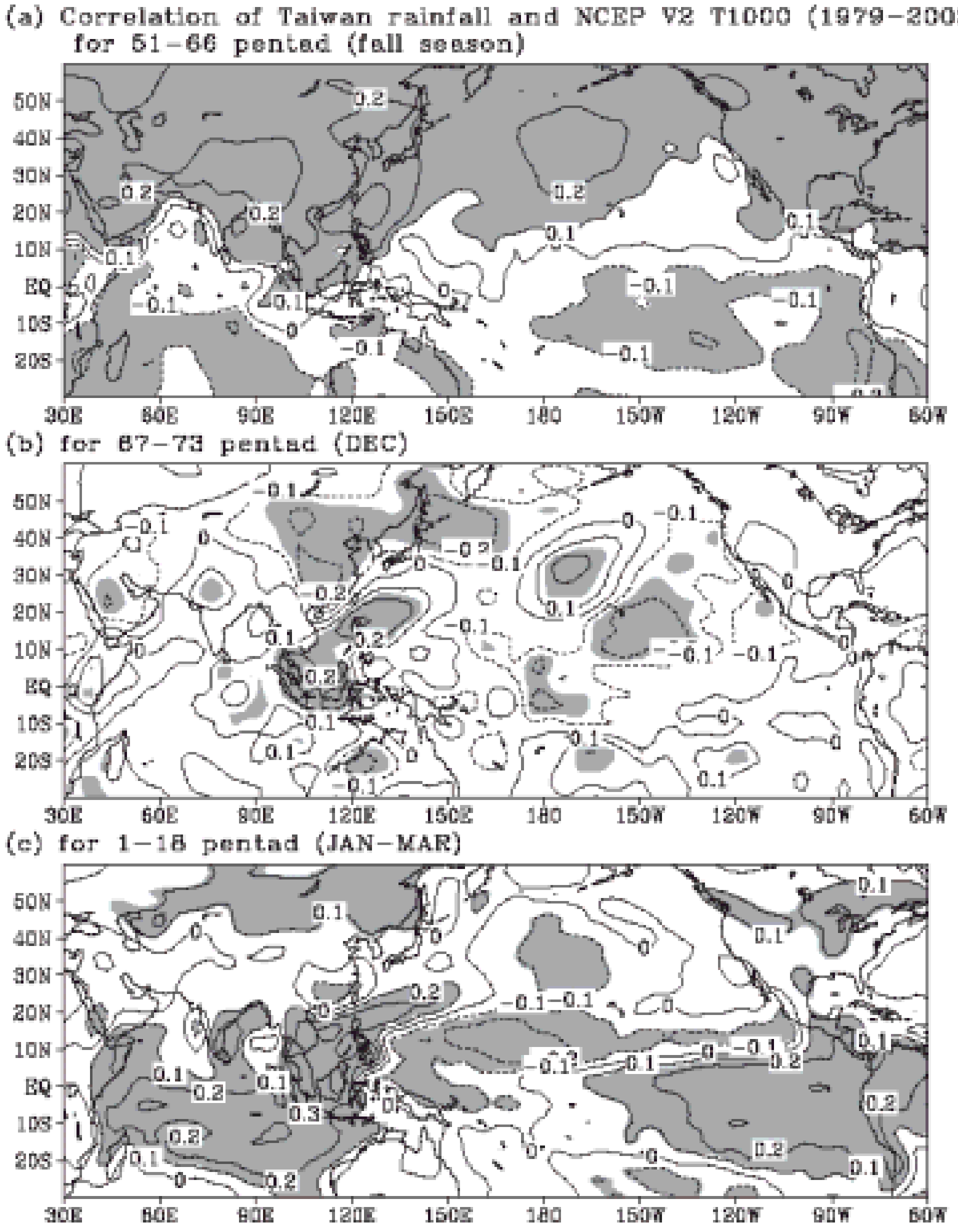

Figure 5 The correlation of Taiwan rainfall to NCEP Version 2 temperature at the level of 1000 hPa for the same time periods as Figure3.

Furthermore, the correlation of Taiwan rainfall and temperature at 1000 hPa in the autumn and December reveals a totally different pattern from Jan-Mar. The Taiwan temperature of autumn and winter is positively correlated to the continental temperature (see Figures 5a-b for the 1000 hPa). The results presented here show that the period of 1-18 pentads is related to the pattern over the Pacific, especially the ENSO system. However, the period of 67-73 pentads is related to the pattern over the Asian continent. And the pattern of 51-66 pentads is similar to that of 67-73 pentads.

4. Discussions and Conclusions

It is seen from our analyses that the Asian winter monsoons can be divided into two parts. It implies that the first half of winter is dominated by the continental high. During this period, Taiwan rainfall and sea surface temperature is highly correlated to the continental patterns. However, the last half of winter is controlled by climate systems over the western North Pacific. Taiwan rainfall around this time exhibits positive relationship with the eastern equatorial Pacific sea surface temperature and precipitation. It suggests that Taiwan climate in the latter part of winter has a similar pattern to El Nino/Southern Oscillation (ENSO).

Several studies have pointed out that the Asia summer monsoons correlate with the ENSO. Our analysis implies the existence of linkage between ENSO and Asian winter monsoons, especially the last half of winter.

One of our analyses (51-66 pentads for fall season and 67-73 pentads for the winter) reveal that the there is not a significant difference between autumn and winter. It means that the onset of Asian winter monsoons needs further investigation.

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