The ENSO Impacts on Taiwan Climate

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Abstract

ENSO is the most well known climatic phenomenon that influences the climate in many parts of the world on the interannual time scale. A standard analysis procedure for identifying the ENSO impacts on Taiwan climate has been established. It includes correlation coefficient analysis, contingency table analysis, composite analysis, and regression analysis. Statistical significance of the signals is evaluated in each step of the analysis procedure.

The preliminary results of the relationship between Nino3.4 and the precipitation/temperature variations in Taiwan and their applications are presented in the report. The ENSO signals can be classified into two categories. The category of linear signals shows opposite signs of the anomalies in El Niño and La Niña phases, while the category of nonlinear signals does not show the opposite relationship between precipitation/temperature anomalies and different ENSO phases. In the linear category, the most significant signals are found during the months of September-November. Taiwan tends to be drier (wetter) than normal during September-November in the developing years of El Niño (La Niña). The temperature analysis results suggest that Taiwan tends to be colder (warmer) in September-October, but warmer (colder) in November-January during the El Niño (La Niña) developing years. Therefore, the temperature anomaly changes sign in November, while ENSO stays mature in the same phase. The El Niño signals are associated with the biennial mode of ENSO when La Liña is in lead. However, the La Niña signals do not show clear relationship with the biennial mode.

The secondary ENSO signals in the linear category appear in spring (February-March), which is the late mature phase of El Niño or La Liña. Taiwan is wetter (drier) in the El Niño (La Liña) years. However, the spring signal is much weaker than that in autumn and has significant decadal-scale variations.

The nonlinear signals are much stronger in El Niño than in La Niña years. During the El Niño developing years, Taiwan tends to be dryer in March-April and colder in March-September. The currently under-constructed seasonal forecast auxiliary ENSO monitoring system and its applications will be discussed.

Keywords: ENSO, Taiwan climate, seasonal forecast auxiliary tool

1. Introduction

ENSO is one of the best-known air-sea coupled climate systems. Identifying the ENSO signals is naturally a fundamental step in an attempt to make monthly-to-seasonal forecasts. Taiwan climate belongs to the complicated East Asian monsoon system. In late December and January, Taiwan climate variations are mainly affected by extratropical weather systems. From February to May, Taiwan climate variations can be influenced by both extratropical and tropical systems. In the summer months from June to August, the variations are mainly caused by tropical disturbances. And from September to early December, Taiwan climate variations can again be influenced by both extratropical and tropical systems. In addition to the complexity of the weather disturbances from higher and lower latitudes, their influence can further by complicated by the mountainous terrain in Taiwan. Therefore, although the total area of Taiwan island is about 3600 km^2, it can be divided into five climate regions, namely, the north, central, south, east and mountainous areas. In this study, we have investigated the ENSO signals in the whole island and each area.

2. Data and Analysis Procedure

The station data used in this study include the monthly data from 1951 to 2005 at 20 stations maintained by the Central Weather Bureau (Figure 1). No missing data are recorded in these 20 stations. There are 5 stations in the north area, 4 in the central, 3 in the south and 8 stations in the east area. The data of ENSO indices is downloaded from the website of Climate Prediction Center/ NOAA (http:// ttp://www.cpc.noaa.gov). We also use the NCEP/NCAR Reanalysis data set to investigate the large-scale patterns associated with the ENSO signals. The station climate signals that cannot find associated large-scale patterns will not be documented as the useful information for predictions.

The schematic diagram of the construction procedure of using ENSO information to build a seasonal forecast auxiliary tool is illustrated in Figure 2. We will start from identifying Taiwan ENSO signals using correlation analysis and contingency table methods. Then use the composite analysis method to examine the large-scale features associated with Taiwan ENSO signals. Only the signals that have consistent associated large-scale features will be selected and verified by regressing the large-scale parameters on the time series of ENSO indices. The ENSO indices examined in this study include Nino.4 (5°S-5°N, 160°E-150°W), Nion.3.4(5°S-5°N, 120°-170°W), Nino.3(5°S-5°N, 150°-90°W), Nino.1+2(10°S-EQ, 90°-80°W), Nion.West(EQ-15°, 130°-150°E). However, in this presentation we will only introduce the results in reference to Nino3.4.

3. Analysis Method

3.1. Correlation Analysis

The correlation analysis approach is to identify the ENSO climate signals based on the correlation coefficients of station data and Nino indices. The correlation coefficients are computed with the time lags from –13 months (the Nino index leads precipitation/temperatuer data for 13 months) to +13 months (the Nino index lags precipitation/temperature data for 13 months). The station data includes monthly, bimonthly and tri-monthly temperature and precipitation.

In addition to using the Student-t test to check the correlation significance at each station, we also checked the field significance of the correlation at the north, central, south, and east areas by using Monte Carlo resampling method to generate 1000 correlation patterns of precipitation/temperature and Nino indices. The simulated correlations are used to determine the global significance through the procedure described below. We count the histogram of how many stations in which the correlation coefficients of the precipitation/temperature and Nino indices are significant at the 5% significance level. Based on the histogram, we then chose the cut-off number of the upper 5% number of stations as the threshold (S_{95}) of the number of significant stations for determining the climate signal. In other words, if there are *s* stations that the correlation coefficients of the precipitation and Nino indices are significant at the 5% significance level, when $s \geq S_{95}$ we say that the correlation satisfies the climate signal criterion.

In addition to the interannual scale of variations, ENSO has pronounced interdecadal scale of variations. The robustness of the correlation between ENSO and local climate variations on decadal time scale is tested by repeating the correlation analysis at the sliding data windows of 11, 15, and 21 years to identify the periods during which the climate signals are strong.

3.2. Contingency Table Analysis

Following the same procedure as in Lu and May (2004), we identify the ENSO climate signals in Taiwan precipitation/temperature with the time lags from –7 months (the Nino index leads precipitation/temperature data for 7 months) to +7 months (the Nino index lags precipitation/temperature data for 7 months) based on the contingency table analysis. We first classify the precipitation/temperature into tercile classes. The ENSO classification is following the warm and cold phases announced by CPC/NOAA. The contingency tables are constructed accordingly. The significant (at the significance level of 5%) relationship between precipitation/temperature and ENSO is tested at each station and areas. The field significance is tested by first determining the station number threshold (Rs) at each area based on the Monte Carlo resampling method. If in an area there are *r* stations showing significant relationship in their contingency tables, the regional ENSO signal is identified when $r \geq$ Rs.

3.3. The ENSO Monitoring Page

The identified ENSO signals are subsequently verified by examining the exact corresponding relationship between the precipitation/temperature categories and ENSO phases at each station. The evolution of the Nino indices in a time span of three years, centered in the year (Year0) that more than Rs stations have the same features of the signals, is presented in the ENSO monitoring page (http://rdc03.cwb.gov.tw). The real time ENSO indices and large-scale features are monitored according to the statistical and conceptual relationship between ENSO and Taiwan derived from this study.

2. Results

Taiwan ENSO signals in respect to Nino.3.4 are presented in Table 1. The months with significant ENSO signals are listed in the columns of Precipitation and Temperature, the corresponding months in which Nion.3.4 and Taiwan climate are correlated are listed in the columns of Nino.3.4. In the category columns, "H-M" means when ENSO index is high (El Nino) Taiwan is moist, "H-D" means when ENSO index is high Taiwan is dry, "H-W" high and warm, "H-C" high and cold, "L-D" low and dry, "L-M" low and moist, "L-C" low and cold, and "L-W" represents low and warm. The column titles of N; C, S, E represent "North", "Central","South" and "East" areas. Each "*" in the columns of N, C, S, E represent one station. For example, if there are 6 "*" in column E, that means there are 6 stations showing the ENSO signal subscribed to the ENSO phase and climate variable. The numbers in the columns of "Year" are the years in which the ENSO signals appeared.

The detailed results in Table 1 can be summarized as follows. The strongest signals appear in autumn (September-November), which is the near mature phase of El Niño or La Liña. In the relationship with El Niño, we find that the strong signals in Taiwan are associated with the El Niño that follows a La Liña. In other words, Taiwan climate variations appear to be sensitive to the El Niño phase in an ENSO biennial mode when La Liña is in lead. In such years, the September-November in Taiwan tends to be **wetter** (Fig. 3) and **colder** than normal. In the relationship with La Liña, the association with the biennial mode is not clear. Taiwan tends to be **dryer** (Fig. 4) and **warmer** than normal during the developing and near mature phase of La Liña. It is worth noting that Taiwan temperature signals in November-January have different sign with respect to the signals in September-October while the ENSO remains in the same phase.

The secondary ENSO signals in the precipitation appear in spring (February-March), which is the late mature phase of El Niño or La Liña. Taiwan is wetter (drier) in the El Niño (La Liña) years (Figs. 5 and 6). However, the spring signal is much weaker than autumn and has clear decadal-scale variations.

In addition to the linear category signals (the local climate shows the opposite phase of anomaly when the ENSO phases are opposite) described above, there three types of interesting nonlinear type of signals. When the biennial mode of ENSO is dominant, during the spring months of March-April in the El Niño year that after the La Liña, Taiwan tend to be dryer than normal (Fig. 11) and during the February-September Taiwan tend to be colder than normal (Fig. 12). However, when the low-frequency mode of ENSO is dominant, Taiwan tend to be warmer than normal during the summer months of July and August in the La Liña year that follows a preceding La Liña (Fig. 13).

The results in this study is consistent with the previous documents about ENSO and Taiwan climate relationship (Lu 1998) and the biennial oscillations in Taiwan (Lu 2002). Lu (2002) identified the biennial modes in Taiwan's November-December temperature and January-February precipitation. Both modes are associated with ENSO.

3. Applications

A forecast auxiliary tool based on monitoring the real time ENSO evolution is established based on the characteristics of ENSO evolution and Taiwan climate signals. The El Niño has greater potential for the applications because strong Taiwan signals appeared when the biennial mode of ENSO is dominant and the El Niño is preceded by a La Liña. The preliminary results of the auxiliary tool will be introduced at meeting.

References

Lu, M.-M., 1998: Taiwan abnormal climate and ENSO. *Atmospheric Sciences*, 28, 91-114. (In Chinese)

Lu, M.-M., 2002: The biennial oscillations in Taiwan. TAO, 13, 469-498.

Lu, M.-M., and R. J. May, 2004: Using the pre-typhoon season Northwest Pacific typhoon numbers to predict Taiwan summer rainfall. *Atmospheric Sciences*, 32, 407-426. (In Chinese)

Table 1 Summary table of the Taiwan ENSO signals in respect to Nino3.4.

Nino 3.4

Linear

All Island

El Nino

F&M	F&M	H-M	**	****		*	1958 1969 1987 1983 1992 1998	
J&J	J&A	H-M	**	*	*	**		1982
	A&S	H-M		*	*	***		
	O&N	H-M		**		***	1982(站相同)	
	N&D	H-M		**		***		
S&O	M&J	H-D	****	**		****		1965 1972 1982 1997
	J&J	H-D	*****	**	*	******		
	J&A	H-D	*	**	*	*****		
	A&S	H-D		*	**	******		
	S&O	H-D			*	****	1965 1972 1976 1982 1994 1997	
	O&N	H-D			*	****		
	N&D	H-D			*	****		
O&N	M&J	H-D	***	**				1997
	J&J	H-D	****	*				
	J&A	H-D	****	*	*			
	A&S	H-D	***	*	*	*		
	S&O	H-D	**	*	*	*		
	O&N	H-D	***	*	*	*	1957 1963 1972 1976 1997 2002	
	N&D	H-D'	***	*	*	*		
Temperature	Nino3.4	category	N	C	S	E	Year	
M&A	J&F	H-W	*****	**	***	*****	1958 1966 1973 1983 1987 1992 1998 2003	
	F&M	H-W	******	**	***	******		
A&M	J&F	H-W	******	**		*****	1958 1964 1969 1973 1977 1998 2003	
S&O	A&S	H-C	****	*		**		1957 1965 1969 1991 1994
	S&O	H-C	***	*		**		
	O&N	H-C	*****	***		**	1957 1965 1968 1976 1969 1986 1991 1994 1997	
	N&D	H-C	*****	***		**		
	D&J	H-C	*****	***		**		
N&D	J&J	H-W	*****	*	*	****		1957 1965 1982 1987 1997 2002
	J&A	H-W	******	*	*	**		
	A&S	H-W	******	**	*	*		
	S&O	H-W	****	*	*	*		
	O&N	H-W	******	*	*		1951 1957 1963 1965 1968 1982 1987 1994 1997 2002	
	N&D	H-W	******	*	*			
	D&J	H-W	******	*	*			
D&J	J&J	H-W	**		**	****	1957 1965 1987 1997	
	A&S	H-W		*	**	**		

La Nina

F&M	F&M	L-D	**	****		*	1955 1971 1976 1999	
J&J	J&A	L-D		**		****		1954
	A&S	L-D	*	**		****		
	O&N	L-D	*	*		***	1954(站相同)	
	N&D	L-D	*	*		***		
S&O	M&J	L-M	*	*	*	****	1956 1970 1971 1988 1998	1988
	J&J	L-M	***	***	**	******		
	J&A	L-M	**	**	**	******		
	A&S	L-M	**	**	**	******		
	S&O	L-M	*	**		***		
	O&N	L-M	*	**		***		
	N&D	L-M	*	**		***		
O&N	M&J	L-M	***	*	*	******		1950 1964 1973 1975 1988
	J&J	L-M	***	**	**	*****		
	J&A	L-M	****	***	***	*****		
	A&S	L-M	***	**	**	*****		
	S&O	L-M	***	**	**	*****		
	O&N	L-M	****	**	**	*****	1950 1954 1956 1964 1970 1971 1973 1975 1984 1988 1998 1999 2000	
	N&D	L-M	****	**	**	*****		
Temperature	Nino3.4	category	N	C	S	E	Year	
M&A	J&F	L-C	***			**	1974 1976 1996	
	F&M	L-C	***			***		
A&M	J&F	L-C		**	***	**	1950 1951 1971 1989 1996 1999	
S&O	A&S	L-W	****	*	*	***		1950 1964 1970 1973 1975 1988 1995 1998 1999
	S&O	L-W	*****	**	**	****		
	O&N	L-W	******	**	*	*****	1950 1964 1970 1973 1975 1984 1988 1995 1998 1999 2000	
	N&D	L-W	******	**	*	*****		
	D&J	L-W	******	***	**	*****		
N&D	J&J	L-C	*******	***	***	******		1950 1955 1964 1973 1975 1988
	J&A	L-C	*******	***	***	******		
	A&S	L-C	*******	***	***	******	1950 1955 1956 1964 1971 1973 1975 1988 1995	
	S&O	L-C	*******	***	***	******		
	O&N	L-C	*******	***	***	******		
	N&D	L-C	*******	***	**	******		
	D&J	L-C	*****	***	***	*****		
D&J	J&J	L-C	*****	**	***	*****	1950 1954 1955 1964 1970 1973 1975	
	A&S	L-C	**	**	**	*****		

Nonlinear

All Island

El Nino

M&A	J&J	H-D	**	*	**	****		1957 1965 1972 1982 1987 1991 2002
	J&A	H-D	**	*	**	****		
	A&S	H-D	**	***	**	*****		
	S&O	H-D	*	***	**	*****	1957 1963 1965 1972 1976 1982 1986 1987 1991 1994 2002	
	O&N	H-D	*	***	**	*****		
	N&D	H-D	*	***	**	*****		
	D&J	H-D	*	***	**	*****		
A&M	J&J	H-D	*		*	******		1982 1987 1991 1997 2002
	J&A	H-D	*		*	******		
	A&S	H-D	***			******		
	O&N	H-D	*	*		*****	1963 1968 1982 1987 1991 1997 2002	
	N&D	H-D	*	*		*****		
	D&J	H-D	*	*		*****		
A&S	J&J	H-D	*	***		****		
	J&A	H-D	*	**	*	****	1991	
	A&S	H-D		*	*	***		
Temperature	Nino3.4	category	N	C	S	E	Year	
F&M	O&N	H-C	*****				1951 1957 1963 1968 1969 1972 1986 (站相同,年相同)	
	N&D	H-C	*****					
	D&J	H-C	*****					
M&A	O&N	H-C	*		*	***	1968 1972 1976(站相同,年相同)	
	N&D	H-C	*		*	***		
	D&J	H-C	*		*	***		
M&J	O&N	H-C	***	*	*	*	1951 1957 1965 1968(站相同,年相同)	
	N&D	H-C	***	*	*	*		
	D&J	H-C	***	*	*	*		
J&J	J&J	H-C	**		*	**		1965 1972 1982 1997
	J&A	H-C	*******		*	*****		
	A&S	H-C	*******		*	*****		
	S&O	H-C	*******		*	*****		
	O&N	H-C	*******	*	*	******	1951 1957 1963 1965 1968 1969 1972 1976 1982 1987 1997	
	N&D	H-C	*******	*	*	******		
	D&J	H-C	*******	*	*	******		
A&S	A&S	H-C	****	*				1965 1972 1987 1994 1997
	S&O	H-C	****	*				
	O&N	H-C	******	*		*	1957 1965 1968 1972 1976 1987 1994 1997	
	N&D	H-C	******	*		*		
	D&J	H-C	******	*		*		
O&N	A&M	H-W	*****	**	***	****	1982 1983 1987 1997	
	M&J	H-W	**	**	**	**		
	J&J	H-W	***	**	***	**		
	J&A	H-W	**	**	*			

La Nina

D&J	F&M	L-N	****	****	*	****	1950 1955 1971 1974 1989 1999 2000	
	M&A	L-M	****	****	**	****		
	A&M	L-M	****	****	*	***		
	M&J	L-M	***	****		**		
Temperature	Nino3.4	category	N	C	S	E	Year	
J&A	J&F	L-C	****	***	**	***	1950 1955 1974 1985 2000	
	F&M	L-C	****	***	**	**		
	M&A	L-C	****	****	**	**		
	A&M	L-C	****	****	**	*		
	M&J	L-C	****	***	**	**		

Local

El Nino

La Nina

N&D	J&A	L-M	****		1950 1954 1956 1970
	A&S	L-M	***		
	S&O	L-M	***		
	O&N	L-M	****	1950 1954 1956 1964 1970 1971 1975 1984 1998 2000	
	N&D	L-M			
	D&J	L-M	***		
S&O	A&M	L-M	***	1964 1974 1988	
O&N		L-M	****		

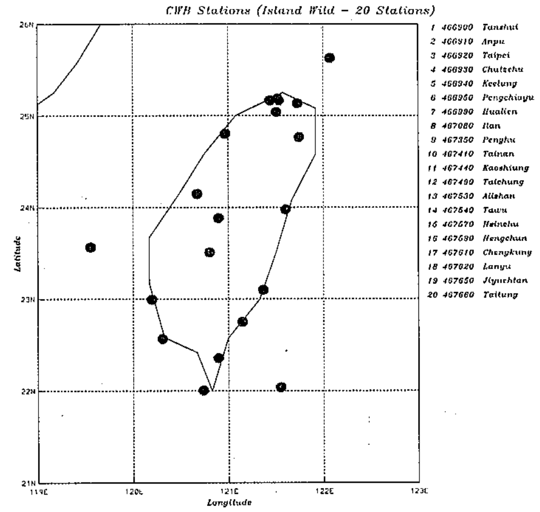

Figure 1. Location map of the station data used in this study for identifying the ENSO signals.

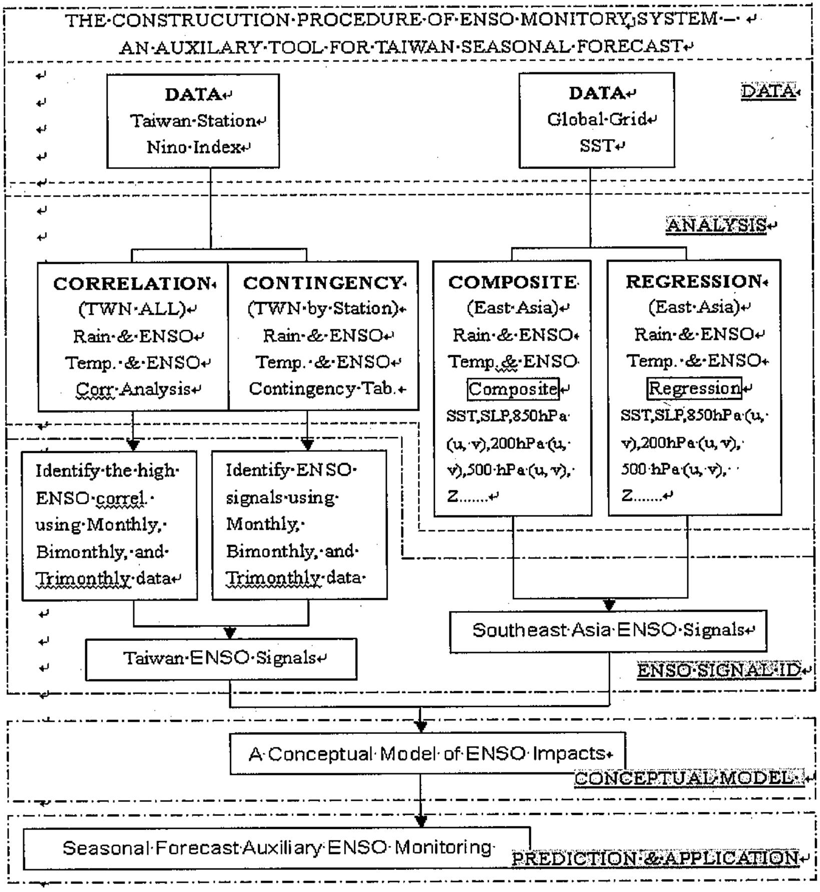

Figure 2. Schematic diagram of the construction procedure of the seasonal forecast auxiliary tool of ENSO monitoring.

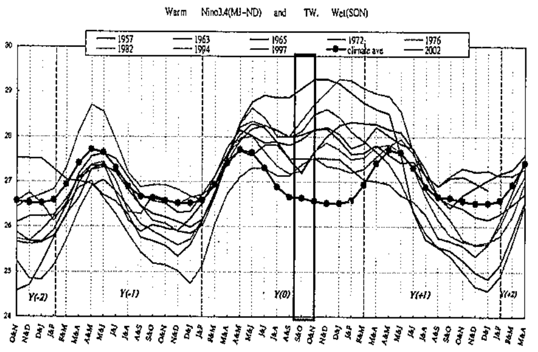

Figure 3. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows wet signals in the months of September-November.

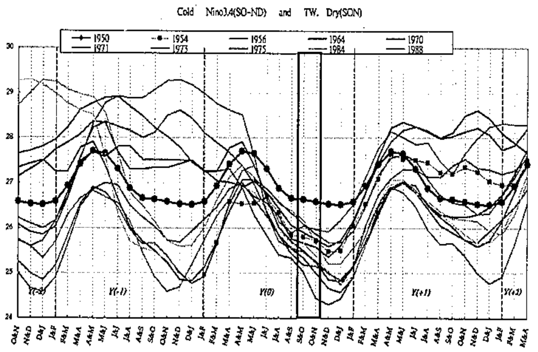

Figure 4. The Nino3.4 evolution before and after the year when ENSO is in cold phase and Taiwan shows dry signals in the months of September-November.

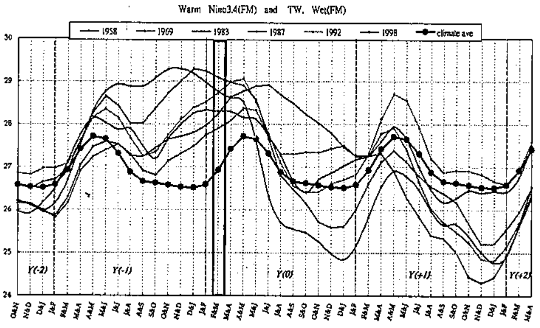

Figure 5. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows wet signals in the months of February and March.

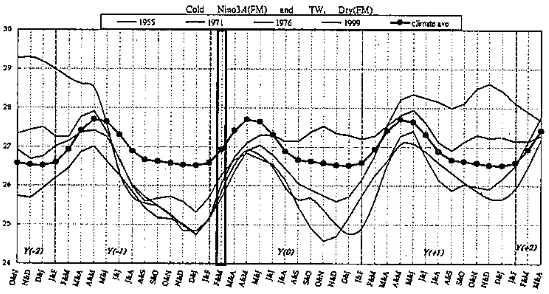

Figure 6. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows dry signals in the months of February and March.

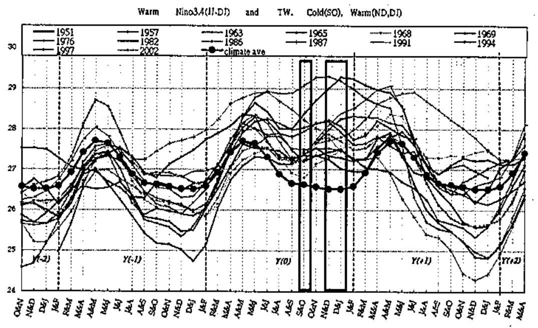

Figure 7. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows cold signals in the months of September and October, and warm signals during November-January.

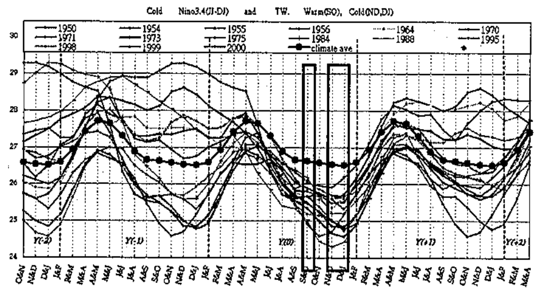

Figure 8. The Nino3.4 evolution before and after the year when ENSO is in cold phase and Taiwan shows warm signals in the months of September and October, and cold signals during November-January.

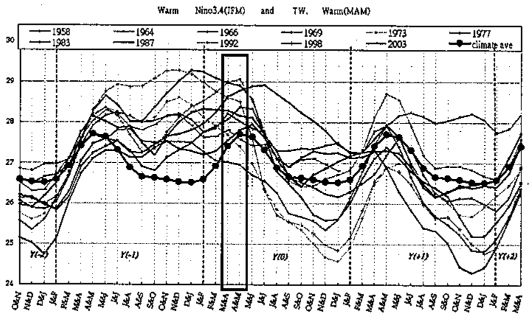

Figure 9. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows warm signals in the months of March-May.

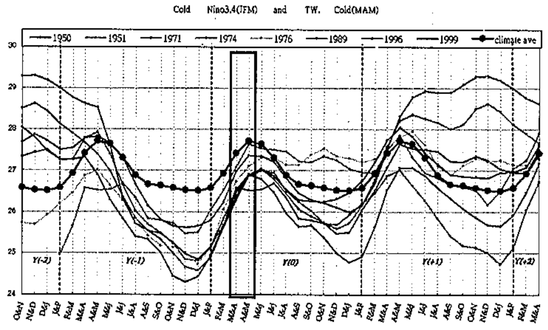

Figure 10. The Nino3.4 evolution before and after the year when ENSO is in cold phase and Taiwan shows cold signals in the months of March-May.

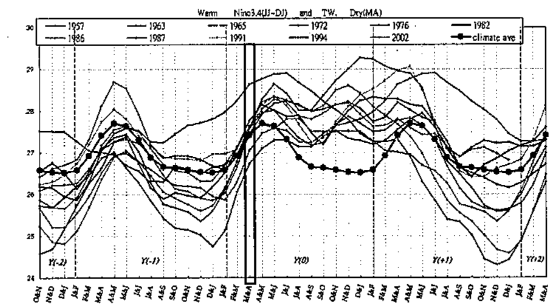

Figure 11. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows dry signals in the months of March-April.

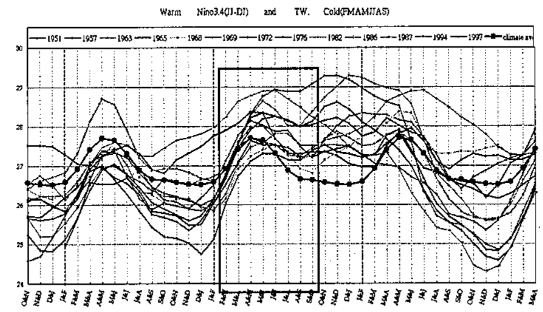

Figure 12. The Nino3.4 evolution before and after the year when ENSO is in warm phase and Taiwan shows cold signals in the months of March-September.

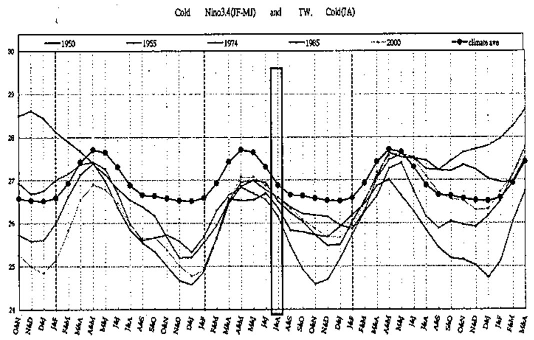

Figure 13. The Nino3.4 evolution before and after the year when ENSO is in cold phase and Taiwan shows cold signals in the months of July and August.