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THE RELATIONSHIP BETWEEN ENSO AND EAST ASIAN MONSOON REVEALED BY TAIWAN CLIMATE VARIATIONS

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1. INTRODUCTION

ENSO remains to be the most valuable information for regional climate forecasts. The predictions of ENSO and its associated large-scale atmospheric circulation patterns are potentially useful for weather disaster preventions. However, since ENSO is not the only influential condition to local climate variations and it is never the same in two different events, it becomes of tremendous importance to identify and understand the reliable ENSO-related local climate signals.

The relationship between ENSO and East Asian monsoon have been extensively documented in literatures (e.g. Wang and Li, 2004, and the references therein). East Asian climate is known for its distinct seasonality and complicated geographical variations (Ding, 2004; Chan and Li, 2004; Chang et al. 2004; Wang and LinHo, 2002). Influenced by ENSO and the seasonal cycles of East Asian monsoon, the variations of Taiwan climate reveal interesting responding features to the SST and surface wind anomalies over the eastern marginal seas of the Asian continent, which can be used as verifications for conceptual and numerical studies of ENSO and East Asian monsoon.

In this paper, we will present how ENSO can strongly influence the autumn and winter climate in Taiwan. The primary impact is on Taiwan's temperature variations, which can be understood as a reflection on the relationship between South China Sea and ENSO SSTA (Shen and Lau, 1995; Tomita and Yasunari, 1996, Lu 2002). However, the autumn temperature signal can be weakened by precipitation fluctuations associated with tropical cyclones and subtropical frontal systems. The strong ENSO events that show large-scale anomalous interactions between the Northern and Southern Hemispheres are the ones capable of resulting in systematic precipitation fluctuations in Taiwan.

2. DATA AND ANALYSIS PROCESURE

The station data used in this study include 54 years (1980-2003) of monthly data at 20 stations maintained by the Central Weather Bureau of Taiwan (CWB). No missing data are recorded in these 20 stations during the entire period of analysis. The data of ENSO indices is downloaded from the website of Climate Prediction Center/ NOAA (http:// ttp://www.cpc.noaa.gov). The NCEP/NCAR Reanalysis data set is used to investigate the large-scale patterns that result in the ENSO and Taiwan climate relationship.

The ESNO signals are identified using the correlation analysis and contingency table methods. The large-scale patterns are identified using the composite analysis method. Because the number of stations is geographically limited (a small island with complex terrains), vigorous statistical tests are conducted by repeating the correlation and contingency table analyses for four ENSO indices (Nino.4, Nion.3.4, Nino.3, Nino.1+2) and with the time lags from –13 months (the Nino index leads station data for 13 months) to +13 months (the Nino index lags station data for 13 months) based on the monthly, bimonthly and tri-monthly averaged station precipitation/temperature data. The correlation significance at each station is checked with the Student-t test. The field significance of the correlation is measured using Monte Carlo resampling method to generate 1000 correlation patterns between the station data and Nino indices, whereby S_{95}, the cut-off value for the number of significant stations, is determined by the upper 5% limit based on the histogram of the stations satisfying the significance test of the correlation. In other words, if the real data shows there are *s* stations having the correlation significant at the level of 5%, then the significance requirement can be satisfied when $s \geq S_{95}$.

The correlation analysis can only capture the linear relationship between ENSO and local climate. For the purposes of verifying the linear signals and investigating the non-linear part of the relationship, we performed contingency table analysis, 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). The contingency table analysis is based on the tercile classes of Taiwan precipitation/temperature data and the three phases of ENSO record posted at the website of CPC/NOAA. The significant (at the significance level of 5%) relationship between precipitation/temperature and ENSO is tested at

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each station and also for the entire Taiwan area. The field significance is tested by, first, determining the station number threshold (Rs) based on the Monte Carlo resampling method. If the real data shows there are *r* stations having significant relationship in their contingency tables, then the significance requirement can be satisfied when $r \geq$ Rs.

The reliability of the ENSO-Taiwan climate relationship is investigated using the composite analysis method based on the NCEP/NCAR reanalysis data, which is independent of the data of ENSO indices and Taiwan station data. The years selected for making the composite are the ones when there are at least Rs stations showing the same type of ENSO response.

3. RESULTS

The significant ENSO-Taiwan climate relationship is summarized in Table 1. During the El Niño developing years, five types (E1, E2, E3, E4, E5) of Taiwan climate signal are identified. The five types, respectively, represent: E1 - Taiwan has a clod autumn (Sep-Nov) and warm winter (Nov-Jan), E2 - dry autumn and ward winter, E3 - warm winter (Jan-Mar) and dry spring (Mar-May), E4 - warm early winter (Oct-Dec), and E5 - cold spring and early summer (Mar-Jul). Note particularly that except 1997, the other years of E3 all appeared in the year following the development of a La Niña. The La Niña signal shows different characteristics than its El Niño counterpart. Two types of Taiwan climate variations (L1, L2) have been identified. L1 and L2 represent the sign reversing relationship of E1 and E2, respectively. During the period of 1950-2003, there exists 17 El Niño and 19 La Niña years. The sum of types E1 and E2 occupies 47% of the El Niño years and the sum of L1 and L2 occupies 57% of the La Niña. Hence, about half of the ENSO events are potentially useful for local climate predictions and applications in Taiwan.

Of particular note is that Taiwan temperature anomalies change sign during the same phase of ENSO. Figure 1 shows that the temperature variations in Taiwan reflects the SSTA evolution over the western Pacific, which is associated with East Asian winter monsoon and the Philippine Sea anticyclone documented by Wang et al. (2000) and Wang and Zhang (2002). After separating all influential El Niño years (the sum types E1-5) into type E1 (cold SO in Taiwan) and type E2 (dry SO in Taiwan), we find that the dry condition occurred when SSTA is significant over the Indian Ocean and a pronounced area of converging the North Hemispheric northerly and the South Hemispheric southerly winds appears over the western Pacific (Fig. 2). The upper level winds and La Niña composite diagrams (figures not shown) show consistent pictures for suggesting that the ENSO associated autumn rainfall fluctuations in Taiwan are caused by the shift of tropical deep convection and the associated SSTA and circulation variations over the Indian Ocean, South Asia and northern Australia.

4. FORECAST IMPLICATIONS

ENSO is the only climate phenomenon that can be predicted with skill in one or two seasons ahead. It is highly desirable to extract useful information from ENSO predictions for practical usages. Taking Taiwan as an example, we find that the useful ENSO information is not in the areas where the Nino indices are defined. It is necessary to correctly predict how the SST and surface wind anomalies over the Indian Ocean and the eastern marginal seas of the Asian continent evolve with ENSO.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Chan, J. C. L, and C. Li, 2004: The East Asia winter monsoon. *East Asian Monsoon*, C. P. Chang (Ed.), World Scientific, 54-106.

Ding, Y., 2004: Seasonal march of the East-Asian summer monsoon. *East Asian Monsoon*, C. P. Chang (Ed.), World Scientific, 54-106.

Hung, C.-W., H.-H. Hsu, and M.-M. Lu, 2004: Decadal oscillation of Spring rain in Northern Taiwan. *Geophy. Rev. Lett.* 17, 699-710.

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

Wang, B., R. Wu, and X. Fu, 2000: Pacific-East Asia teleconnection: How does ENSO affect East Asian climate? *J. Climate*, 13, 1517-1536.

Wang, B, and Q. Zhang, 2002: Pacific-East Asian teleconnection, part II: How the Philippine Sea anticyclone established during development of El Niño. *J. Climate*, 15, 3252-3265

Wang, B. and LinHo, 2002: Rainy seasons of the Asian-Pacific monsoon. *J. Climate*, 15, 386-398.

Wang, B., and T. Li, 2004: East Asian monsoon-ENSO interactions. *East Asian Monsoon*, C. P. Chang (Ed.), World Scientific, 177-212.

Shen, S. and K. M. Lau, 1995: Biennial oscillation associated with the east Asian summer monsoon and tropical sea surface temperatures. *J. Meteor. Soc. Japan*, 73, 105-124.

Tomita, T., and T. Yasunari, 1996: Role of the northeast winter monsoon on the biennial oscillation of the ENSO/monsoon system. *J. Meteor. Soc. Japan*, **74**, 399-413.

Table 1 Summary of the ENSO-Taiwan climate relationship

(a) El Niño

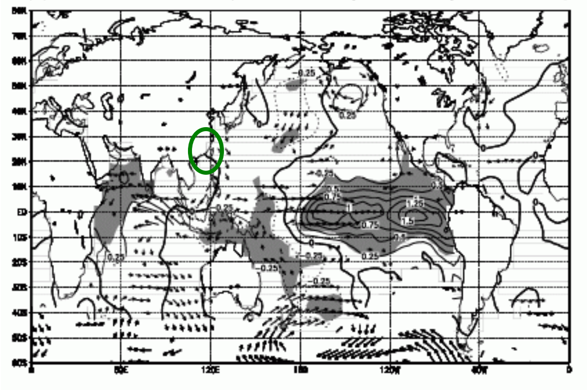
Signal Type	Year
[E1] SON(cold) → NDJ(warm)	1957,1968,1990,1994,1997
[E2] SON(dry) → NDJ(warm)	1957,1972,1982,1997,2002
[E3] JFM(warm) → MAM(dry)	1965,1987,1991,1997,2002
[E4] OND(warm)	1965,1972,1982,1987,1997
[E5] MAMJ(cold)	1951,1957,1965,1968,1997

(b) La Niña

Signal Type	Year
[L1] SON(warm) → NDJ(cold)	1950,1970,1975,1983,1988,1995
[L2] SON(wet) → NDJ(cold)	1950,1954,1956,1967,1970, 1971,1973,1975,1988

FIGURE 1

El Niño-Taiwan Composite: Sep.-Oct., SST&925hPa Wind



El Niño-Taiwan Composite: Dec.-Jan., SST&925hPa Wind

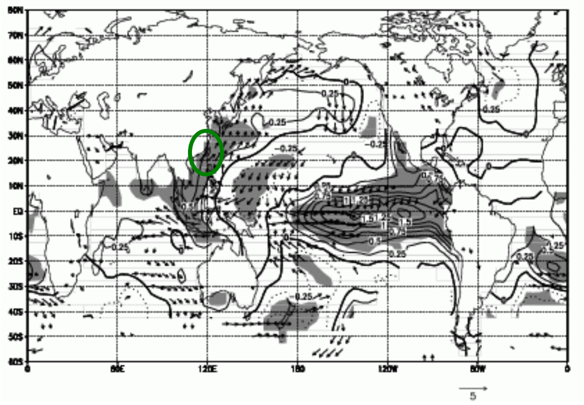
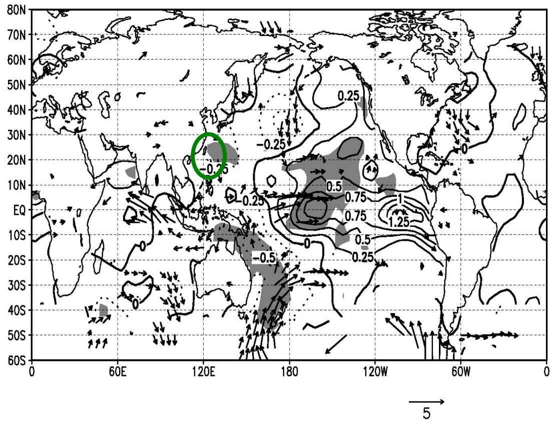


FIGURE 2

El Niño-cold Taiwan SO Composite: SST&925hPa Wind



El Niño-dry Taiwan SO Composite: SST&925hPa Wind

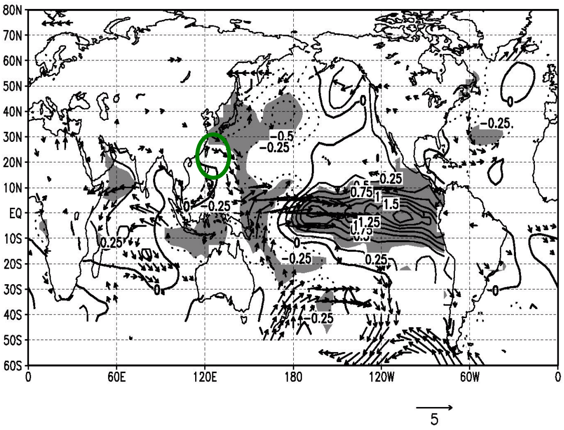


Figure 2. The composite relationship between SSTA and 925-hPa wind anomalies, during the September-October of (upper) type E1: El Niño year and Taiwan is cold, and (lower) type E2: El Niño year and Taiwan is dry. The contour interval for SST is 0.25°C. Shading denotes regions of difference at 95% confidence level. The location of Taiwan is marked in the circle.

Figure 1. The composite relationship between bi-monthly SSTA and 925-hPa wind anomalies, during the months of (upper) September-October and (lower) December-January of the developing and mature phases of the El Niño. The contour interval for SST is 0.25°C. Shading denotes regions of difference at 95% confidence level. The location of Taiwan is marked in the circle.