13C.3 INTERANNUAL VARIATIONS OF WINTER TO SUMMER TRANSITION OF THE LOW-LEVEL CROSS EQUATORIAL FLOW OVER THE SOUTH CHINA SEA

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1. INTRODUCTION

The low-level cross equatorial flow over the South China Sea can be separated to summer and winter regimes. The transition from winter to summer regime is associated with the withdrawal of the stationary ridge of the Western Pacific Subtropical High from the South China Sea (SCS). Identifying the interannual variations of the seasonal transition and the associated large-scale anomalous patterns is a fundamental aspect of understanding the Southeast Asian monsoon system. For this purpose the present study is conducted.

The outline of this paper is as follows. First, we document the phenomena of the winter to summer low-level flow transition over the SCS. In order to describe the interannual variations of the transition timing, a transition index is needed. Using the index, we find that the winter to summer low-level flow transition can be grouped into four types, namely, early, normal-early, normal-late, and late. Although the transition process is similar between different groups, the associated large-scale anomalous patterns are not. Using composite method we subsequently examine the differences in the large-scale patterns associated with different transition types. The main factors causing interannual variations are also investigated. The results do not show consistent differences in large-scale anomalous patterns between the groups of normal-early and normal-late. However, clear differences are found between the early and normal groups, and between the late and the normal groups as well. Although the anomalous patterns emerge in fall or early winter before the transition, they cannot persist after the transition.

2. DATA

The data used to identify the flow transition are daily averaged data from the NCEP-NCAR reanalysis data set for the period of 1958-2000. The large-scale anomalous patterns are identified using the monthly and pentad data. The precipitation data used is the CMAP data set. Monthly OLR data is used as a proxy for tropical convection. The SST data used is Reynolds reconstructed monthly data set.

3. TRANSITION DEFINITION

The transition index is defined based on the geographical patterns of the first EOF of the 850hPa vorticity. The first EOF corresponds to the seasonal cycle, which clearly shows the out-of-phase structure of the vorticity along the equator and 15°N. A vorticity dipole over the SCS with the negative center over Borneo and the positive center over the Gulf of Tonkin is noticed. Based on this dipole structure, a transition index SCSIDX is defined as follows.

$$SCSIDX = F * VOR_{scsn} * (VOR_{scsn} - VOR_{scss})$$

where F = 0 if $VOR_{scsn} < 0$ or $VOR_{scs} > 0$, otherwise F = 1. VOR_{scsn} is the average vorticity over the area of 110-120°E and 10-20°N and VOR_{scss} is the average vorticity over the area of 105-110°E and 5°S-5°N.

In average, the SCSIDX increases in steps after it changes from zero to positive. The first peak appears on Julian Day 145 (May 25th) and the second mount appears on Day 163 (June 12th). The average maximum magnitude of SCSIDX appears in the Julian Days of 217-235 (August 4-22). Therefore, SCSIDX can reasonably reflect the development of the strength of the summer monsoon trough over the SCS.

For defining the transition date, we set two criteria: (1) the first day of continuous five days of SCSIDX > $0s^{-1}$, among these five days there are at least three days in which SCSIDX > $10^{-4}s^{-1}$, then the first day is chosen as a candidate for the transition day, (2) within the 45 days after the transition candidate, if the number of days which do not satisfy the criterion (1) is less than 30, then the candidate is identified as the transition day.

The histogram of the transition dates of SCSIDX shows a bimodal structure. Two peaks appear at the pentads averaged over the Julian Days of 140-145 and 150-155, respectively. Based on the distribution, we group the years into early,

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normal-early, normal-late and late four classes. The corresponding years and the ranges of the transition date are summarized in the following table.

TRANSITION CLASS	YEAR
Early (before 5/15)	1966, 1986, 1996, 1999, 2000
Normal-early (5/16-30)	1958, 1960, 1961, 1962, 1965, 1967, 1974, 1976, 1978, 1979, 1980, 1988, 1989, 1990, 1997, 1998
Normal-late (5/31-6/19)	1963, 1964, 1969, 1970, 1971, 1972, 1973, 1975, 1981, 1982, 1984, 1985, 1987, 1991, 1994, 1995
Late (after 6/20)	1959, 1968, 1977, 1983, 1992, 1993

4. LARGE-SCALE PATTERNS

The 20 days of transition process represented by the pentad data of 925, 850, 200hPa winds and OLR (if available) composite centering at each year's transition pentad for each group are examined. The results indicate that the transition processes in different groups are rather similar. Before the transition, the low-level westerly wind over the Bay of Bengal intensifies. The associated convection also intensifies. The SCS is occupied by low-level anticyclonic circulation, which is a portion of the ridge of the westward extending Western Pacific Subtropical High. The SCS anticyclone weakens sharply during the onset and convection becomes active. After the onset, the low-level westerly flow at the Bay of Bengal can penetrate the SCS and extend to the western Pacific.

The differences in the associated large-scale anomalous patterns between different transition classes are further examined using composite method. We find that the difference between the normal-early and normal-late types is insignificant. Therefore, the normal-early and normal-late are grouped together to represent the normal condition. After examining the differences between the early / late and normal groups, we find clear differences (significant at the 5% significance level) in both contrast pairs.

In the early transition year, the SST anomalies over the Philippine Sea and the far western Pacific are warmer than normal. The warm anomalies can be traced back to the warm SST over the SCS in the November of the previous year. The warm SST anomalies are associated with abnormally strong southerly surface winds. The fact that flow transition over the SCS is earlier than usual may be resulted from the large-scale condition, which is favorable for strong low-level convergence over the Bay of Bengal, SCS and the surrounding maritime continents.

In the late transition years, the SST anomalies over the far western tropical Pacific are colder than normal. The cold anomalies can be traced back to the cold SST over the marginal seas near Australia and Indonesia in the October of the previous year. The cold SST anomalies are associated with abnormally low SLP over the eastern Pacific first over both Northern and Southern Hemispheres in boreal autumn and then over the Southern Hemisphere only in boreal winter. There are strong low-level equatorial westerly winds in association with the anomalous large-scale SLP patterns. It is suggested that the delayed transition is caused by the condition that a large area from the Arabian Sea to the western Pacific is under the anomalous subsidence side induced by the abnormal upward motion over the South Eastern Pacific.

It should be noted that although in the early and late transition classes the consistent large-scale anomalous patterns between various fields can be identified at least one season before the transition, the anomalous patterns are not maintained after the transition.

There is no clear correlation between the interannual fluctuations of the transition timing of the low-level cross equatorial flow over the SCS and the fluctuations of the ENSO phases. However, one distinct feature worth to mention is that after the cold phase during the boreal winter, the possibility of a delayed transition is small.

5. ON-GOING WORK

The differences in the intraseasonal-scale characteristics of tropical convection and extratropical circulation patterns between different groups are currently under study. These differences and their relationship with the monsoons over the Arabian Sea, Bay of Bengal and Western Pacific are also under study and will be presented at the conference.