Article ID: 1006-8775(2001) 01-0041-12

INTERDECADAL VARIATIONS OF INTERACTION BETWEEN NORTH PACIFIC SSTA AND EAST ASIAN SUMMER MONSOON

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ABSTRACT: Identification of key SST zones is essential in predicting the weather / climate systems in East Asia. With the SST data by the U.K. Meteorological Office and 40-year geopotential height and wind fields by NCAR / NCEP, the relationship between the East Asian summer monsoon and north Pacific SSTA is studied, which reveals their interactions are of interdecadal variation. Before mid-1970's, the north Pacific SSTA acts upon the summer monsoon in East Asia through a great circle wavetrain and results in more rainfall in the summer of the northern part of China. After 1976, the SSTA weakens the wavetrain and no longer influences the precipitation in North China due to loosened links with the East Asian summer monsoon. It can be drawn that the key SST zones having potential effects on the weather / climate systems in East Asia do not stay in one particular area of the ocean but rather shift elsewhere as governed by the interdecadal variations of the air-sea interactions. It is hoped that the study would help shed light on the prediction of drought / flood spans in China.

Key words: northern Pacific SST; East Asian summer monsoon; East Asian summer land-sea temperature difference (LSTD); general circle wavetrain

CLC number: P732.6 **Document code:** A

1 INTRODUCTION

Backing on the Eurasian Continent and facing the capacious Pacific Ocean on the eastern and southern side, the region of East Asia cuts across three zones of tropical, moderate and frigid climate. As a typical monsoon climate, the region is marked by huge thermodynamic difference between land and sea, with dry and cold winter but warm and humid summer, being completely different between the two seasons. For a long time, the particular geographic environment has prompted the Chinese meteorologists to focus on the effects of oceanic anomalies in the adjacent oceans on the weather / climate in China, as they tend to cause disastrous weather and climatic anomalies in some parts of the nation, i.e. the floods of the Changjiang River (the Yangtze) basin and drought over north China. Owing to previous research featured by both extent and depth, some of oceanic waters have been isolated as key SST zones to have potential effects on the East Asian climate. Ge and Yu[1] point out that the ridgeline of the subtropical high would be 1 ~ 2 degrees of latitude southward and it is wetter in the flood season of the basins of the Changjiang / Huaihe Rivers if the SST is persistently higher than normal for more than 2 months in the Kuroshio region of middle latitudes in winter and spring. Xu[2] shows the linkage between the SST in the northwest Pacific and the second northward jump of the ridgeline. Emphasizing the importance of the north Pacific SST, Wu and Chen[3] and Mao and Xu[4] report that the PNA-pattern circulation is more closely related with the north Pacific SST than with the equatorial Pacific SST so that the thermal

Received date: 2000-05-22; **revised date:** 2001-02-23
Foundation item: National Key Program for Developing Basic Sciences (G1998040900(I)); Natural Natural Science Foundation of China (49975025)
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winds caused by the anomalies in the former waters would lead to anomalies in the intensity of the easterly and westerly winds in the west Pacific and in the location of the subtropical high and consequently bring forth anomalies in the summer monsoon in the middle and lower reaches in the Changjiang River basin. In their study of features displaying during seasonal transitions in drought or flood years within the monsoon regions of East Asia, He, Wen and Luo[5] conclude that an anticyclone usually forms, following the principle of thermal winds, over waters south of Japan where the SST is higher in the flood year, which overlaps and intensifies the subtropical high in the west Pacific. The line of ridge maintains around 25°N and brings abundant rainfall to the basins of the Changjiang / Huaihe Rivers. Over past few years, increasing attention has been paid to the study of SST in the equatorial central and eastern Pacific and ENSO and conceptual models have been set up that illustrate the climatological relationship between ENSO and the summer monsoon in East Asia. With an air-sea coupled model, Yang, Xie and Huang[6] associate higher (lower) SST in the equatorial central and eastern Pacific in April ~ June with drier (wetter) spans in the basin of the Changjiang River. Yang, Xie and Huang[7] make headway in understanding how the warming of ENSO is accompanied in the tropics by the weakened Walker cell in the equatorial central and western Pacific, reduced air pressure and intensified converging and ascending motion in the surface layer, and it is displayed in summertime as significant reduction in the circulation of summer monsoon in India and intensification of summer monsoon in East Asia. Zou and Ni[8] conduct a diagnostic study that indicates variations taking place in different members of the Asian summer monsoon during episodes of the El Niño and La Niña phenomena and close relationship between the summer precipitation in east China and the developing phase of ENSO cycle, which is most strongly reflected in the middle and lower reaches of the Changjiang River and the south of China. Recently, Wu and Meng[9] propose a conceptual model in which the gear-like coupling in the air-sea system of Indian Ocean – Pacific area is closely related with the ENSO while Li, Qin and Sun[10] argue that coordination between the tropical Indian and Pacific Oceans is more realistic with the observed fact of the general circulation.

It is drawn from the discussion above that viewpoints can be varied with the data, method and researcher. For the key SST zones so far summed up for the weather / climate in East Asia, there are at least two of them in the Pacific region. But which is the one that is the most important, crucial and significant? Can we solve the problem of forecasting destructive weather in China by studying its anomalies? Why do the effects of key SST zones on East Asia summer monsoon derived with these methods fail to comply with facts observed in some years and what causes it? As we see it, after elaborate study, the previous work were conducted in terms of seasonal or interannual variations while interdecadal variations, which are quite remarkable, are also present in the SST fields and climate systems involved. It is then consequent to expect the generalized computation, which neglects this particular background of climate, to yield results that are accurate for some specific periods but insignificant for others, which are experiencing another state of the climate. As many of the relevant research[11] indicate, a major drastic change was reported in mid-1970's in global climate and SST fields. It is therefore necessary to study the mutual relationship between the SST and East Asian summer monsoon by setting against two of its different backgrounds before and after this point. The aim of this paper is to study how the SST is linked with the East Asian summer monsoon, whether the key SST zones would shift and how, against different background of interdecadal variations. It is hoped that the study provides revelations for the prediction of drought and floods in China.

2 DATA AND METHODS

The 1°×1° SST data by the U.K. Meteorological Office and 2.5°×2.5° geopotential and wind fields by NCAR / NCEP from 1958 to 1997 (a total of 40 years) are used in the work. The precipitation data are 45-year long ones recorded at 160 standard stations nationwide as compiled by the China Meteorological Administration. The methods employed are EOF, single-point correlation and composite analysis etc.

3 SHIFT OF KEY SST ZONES IN MID 1970's

3.1 *A new presentation of East Asian summer monsoon*

A number of approaches have been stemmed out from previous research and two main points of view can be concluded here. One is the monsoon index defined from the angle of circulation. Although it is good at describing the state of monsoon circulation, the method fails to address the state of monsoon precipitation, another important characteristic of the monsoon system. One example is the index used by Webster and Yong[12]. The other index is one that defines the East Asian monsoon intensity by examining the difference of thermodynamics between land and sea. Work in this aspect is typified by Guo[13], who seeks the sum of all values with the monthly mean pressure less than –5 hPa every 10 latitudes (subtracting 110°E from 160°E) over a domain from 10°N to 50°N, and then takes the ratio of the yearly value to the multi-yearly one to be index for summer monsoon intensity. Improved by Shi and Zhu (1996), the index performs better. Encompassing the difference of air pressure systems between land and sea, the index is able to reflect in some degree the land-sea thermodynamic difference in the monsoon of East Asia with improved performance in the reproduction of precipitation.

In this work, a new method by Sun et al[14] is introduced for defining inter-annual anomalies of summer monsoon intensity in East Asia. Representing the monsoon intensity by land-sea thermodynamic contrast, the index is capable of depicting the thermodynamics in both the zonal and meridional circles. The difference between the surface air temperature in the East Asian monsoon region (part of the continent from 27°N to 35°N and east of 105°E) and the SST over the subtropical northwest Pacific (15°N ~ 30°N, 120°E ~ 150°E) is used to express the east-west thermodynamic difference; the difference between the air temperature in the south of China (part of continent south of 27°N and east of 105°E) and the SST in the South China Sea (105°E ~ 120°E, 5°N ~ 18°N) is used to depict the north-south thermodynamic difference. They are then sought for a weighted sum and designated to be the index for land-sea temperature difference (LSTD), which is written as $LSTD=4/5*(T_{EC}-SST_{STNWP})+1/5*(T_{SC}-SST_{SCS})$. It performs well in reflecting the circulation situation of the East Asian summer monsoon and its relationship with the anomalies of monsoon precipitation. For detailed procedures and implications, refer to reference [12].

Fig.1 gives inter-annual variations of LSTD in the summer of East Asia from 1958 to 1993. It shows that both inter-annual and inter-decadal (dashed line) variations are significant with LSTD. Before mid-1970’s, the LSTD shows more and larger positive values, indicating a stronger summer monsoon in East Asia; after it, the LSTD shows more and larger negative values, suggesting a weaker summer monsoon there. Following Sun’s definition, when LSTD $>$ 1.0, the year is assumed to be strong in land-sea temperature contrast and so is the summer monsoon in the region; when LSTD is $<$ –1.0, the otherwise is true. As a result, the year 1959, 1961, 1967, 1971, 1978 and 1990 are high in LSTD, 4 of the 6 years taking place before the mid-term of the 1970’s; the years 1980, 1982, 1983, 1987, 1989, 1992 and 1993 are low in LSTD, all of the 7 years taking

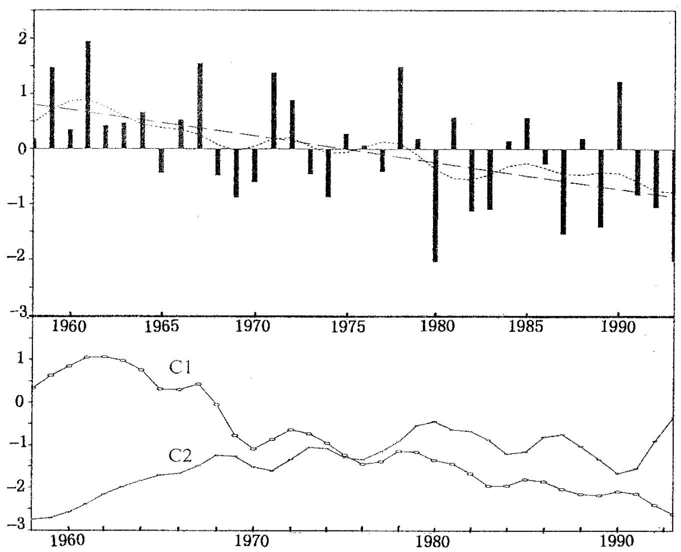

Fig.1 Histogram of inter-annual evolution of land-sea temperature difference (LSTD) index in the summer of East Asia. Dashed line: the trend; dotted & dashed line: 9-point smoothing curve; C1: M–K evaluation; C2: M–K evaluation

place after the mid-point of the decade. Better understanding is reached of the inter-decadal features from a 9-point smoothed curve. As shown in the figure, the curve is all in the positive territory from 1958 to the early 1970's but all in the negative territory from the late 1970's to early 1990's, having the mid-term of the 1970's in the transition. For better determination of the East Asian summer monsoon's climatic turning point around mid-1970's, the M-K method is used to carry out an evaluation for abrupt-change points. The search isolates the turning point between 1975 and 1976 and strong (weak) overhaul performance of the summer monsoon in 1958 ~ 1975 (1976 ~ 1993).

3.2 *Key SST zones in close relationship with East Asian summer monsoon and its inter-Decadal transfer*

First, let's look at Fig.2, which integrates both strong and weak LSTD for the distribution of SSTA in the Pacific Ocean. With a strong LSTD, the SST field displays as a large stretch of positive anomaly with the center at 41°N, 170°E, in the north Pacific, centers around two points in the northwest Pacific but shows as continuous zones of negative anomalies in the tropical central and eastern Pacific. In the weak LSTD years, however, the north Pacific is all of negative SSTA while the equatorial central and eastern Pacific is dominated by strong positive SSTA, with the central value at 1°C and the whole structure of the Pacific SST field is of the El Niño type. It is then seen that the anomaly of the East Asian summer monsoon is indeed corresponding to the SST field accordingly. When the summer monsoon is strong, the SST is anomalously high in the north Pacific region but anomalously low in the equatorial central and eastern Pacific region. The SST field is just the reversed with weak summer monsoon. It is understood that the north Pacific and equatorial central and eastern Pacific are two regions that closely correlate with the East Asian summer monsoon.

Substantial changes did take place in the mid-1970's for the East Asian summer monsoon and Pacific SST. What is the link between them? Tab.1 gives the correlation between the LSTD index and various parts of the Pacific Ocean. It is seen in the table that the summer monsoon (LSTD) in East Asia is well correlated with two oceanic areas in the north Pacific (30°N ~ 50°N, 180° ~ 150°W) and the equatorial central and eastern Pacific (10°S ~ 10°N, 180° ~ 90°W), in 1958 ~

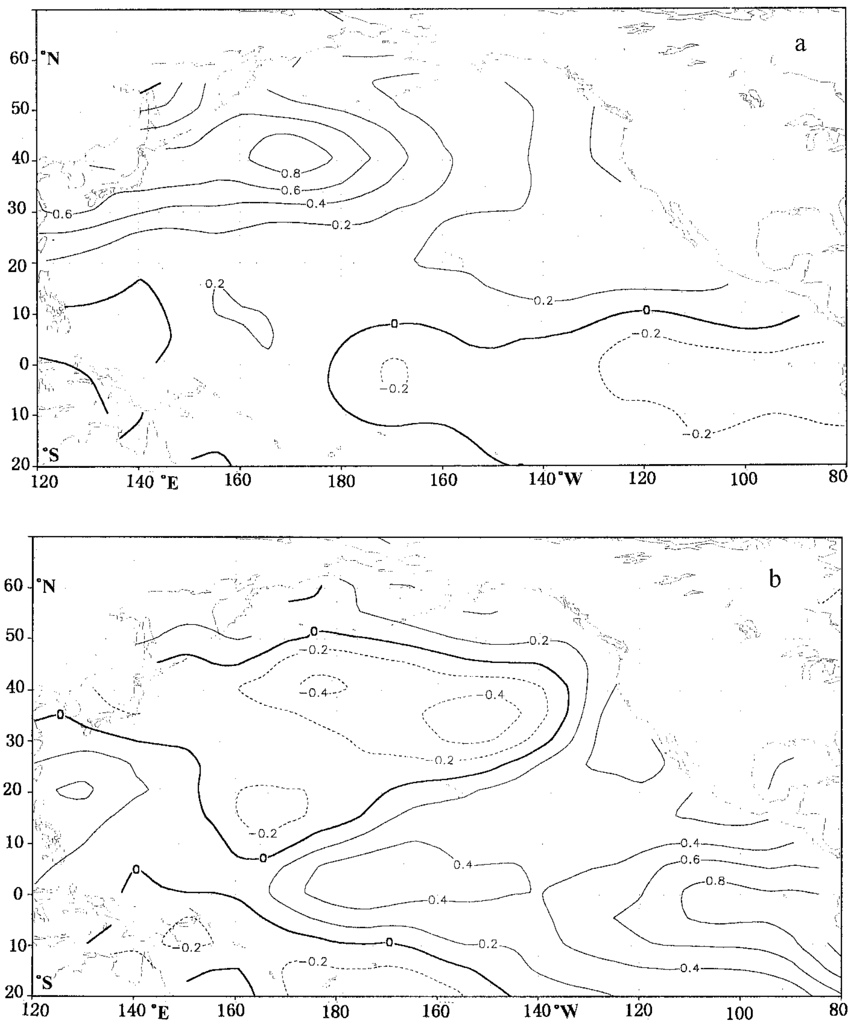

Fig.2 Distribution of SSTA in the summer of high (a) and low (b) LSTD years in the Pacific Ocean

1993. The correlation goes as high as 0.423 and –0.371 and passes the 0.05 level of significance in both areas. The East Asian summer monsoon, as what we have discovered, varies inter-decadally in the correlation with these zones. For the period from 1958 to 1975, the LSTD corresponds well with the north Pacific zone with a coefficient of 0.401 while having little relation (only –0.0514) with the zone in the equatorial central and eastern Pacific. For the period from 1976 to 1993, the former relationship becomes less remarkable while the latter one gets much significant, having 0.01 level of significance. It may be likely that the key SST zones that have close relationship with the East Asian summer monsoon transfer elsewhere around 1976.

Fig.3 gives the correlation between the LSTD in the summer of East Asia and the SSTA in Pacific Ocean. It is shown that from 1958 to 1975 the oceanic zone having the relatively large correlation with SST is in the north Pacific with little correlation between the LSTD and the equatorial

Tab.1 Correlation of East Asian land-sea temperature difference (LSTD) index with SSTA in various zones of the Pacific Ocean

	Land-sea temperature difference in East Asia summer (LSTD)		
	1958～1993	1958～1975	1976～1993
SSTA in north Pacific	0.423	0.401	–0.047
SSTA in the equatorial central & eastern Pacific	–0.371	–0.0514	–0.558
Test of significance level	$\lvert r\rvert_{0.05}=0.3246$	$\lvert r\rvert_{0.02}=0.3810$	$n=36$
	$\lvert r\rvert_{0.05}=0.4438$	$\lvert r\rvert_{0.02}=0.5155$	$n=18$

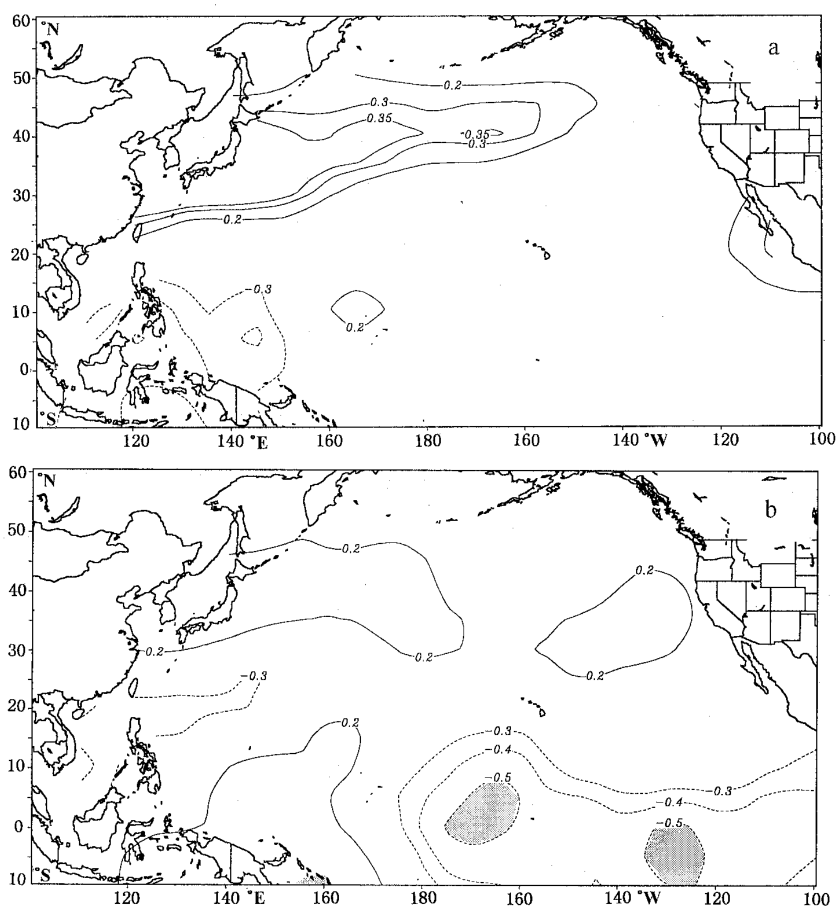

Fig.3 Distribution of simultaneous correlation between the LSTD in the East Asian summer and SSTA in the Pacific Ocean

central and eastern Pacific; the large correlation zone moves to the equatorial central and eastern Pacific while the correlation between LSTD and the north Pacific drops to a insignificant level. It is graphically illustrated that the key SST zones did transfer around 1976.

4 CAUSES FOR INTER-DECADAL TRANSFER OF CORRELATION BETWEEN NORTH PACIFIC ZONES AND EAST ASIAN SUMMER MONSOON

4.1 *Influence of inter-annual and inter-decadal variations of East Asian summer monsoon on the SSTA in the Pacific Ocean*

Following the definition of strong and weak LSTD years presented in previous sections, we find that 4 of the strong LSTD years occurred before 1976 and all 7 weak LSTD years appeared after 1976. It is now obvious that variations on the inter-decadal as well as inter-annual scale can be extracted by studying the intensity of the LSTD years with the air-sea interactions around the year 1976 specifically picked up.

Fig.4 gives the distribution of the differences of flow fields between strong and weak LSTD years. It displays the situation in which the flow field for the strong LSTD year is subtracted from that for the weak LSTD year. On the level of 850 hPa (Fig.4a), the Southwest Monsoon, by route of the Arabian Sea, India Peninsula, Bay of Bengal and Indo-China Peninsula, moves over the East Asian continent and weakens while the zonal westerly intensifies in the middle and high latitudes of the Eurasian Continent; a cyclone of anomalies forms over the north Pacific with the center at 50°N, 175°W when the cold northerly west of the cyclone transforms itself into a westerly in the selected area of the north Pacific and converges with the continental westerly advancing from East Asia. Consequently, the westerly in that locality becomes much more active so as to hasten the latent release of seawater and turn up colder water in deeper depth and reduce the SST constantly in the region of the north Pacific Ocean. In the meantime, the westerly is strengthened and the easterly weakens near the tropical equatorial Pacific, forcing the SST in the equatorial central and eastern Pacific to rise constantly. On the level of 200 hPa (Fig.4b), the center of the anomalous cyclone over the north Pacific is about 10° displaced as compared with lower levels; there is a cyclone over the Korean Peninsula and an anti-cyclone is active over the Okhotsk Sea, southern China and the Indo-China Peninsula. The interactions of these systems result in the convergence in the north Pacific region of a westerly turning away southwest of the cyclone over the Korean Pen. and a cold northerly flow coming from the north, activating the local westerly. For the tropical area, on the other hand, a strong anti-cyclone appears over the equatorial eastern Pacific, anomalously strengthening the along-equator easterly winds south of the anti-cyclone. Examining the anomalies at various levels of flow fields, we observe that the westerly gets strengthened and remains in a stable condition in all levels of the troposphere over the north Pacific, which is favorable for persistent fall of SST there. In contrast, the low-level westerly and high-level easterly are intensified in the equatorial central and eastern Pacific so that the Walker cell is weakened and the SST is increased on a persistent mode.

4.2 *Interactions of north Pacific SST and East Asian summer monsoon on the inter-annual and inter-decadal scales*

In the previous section, we have discussed from the point of flow field the driving effects of the anomalies of the East Asian summer monsoon on the Pacific SST in the increase or decrease of the temperature in different parts of the ocean. Next, we should start from the geopotential field to study the interactions between the monsoon and SST in order to isolate the causes for the geographic transfer of key SST zones in the ocean.

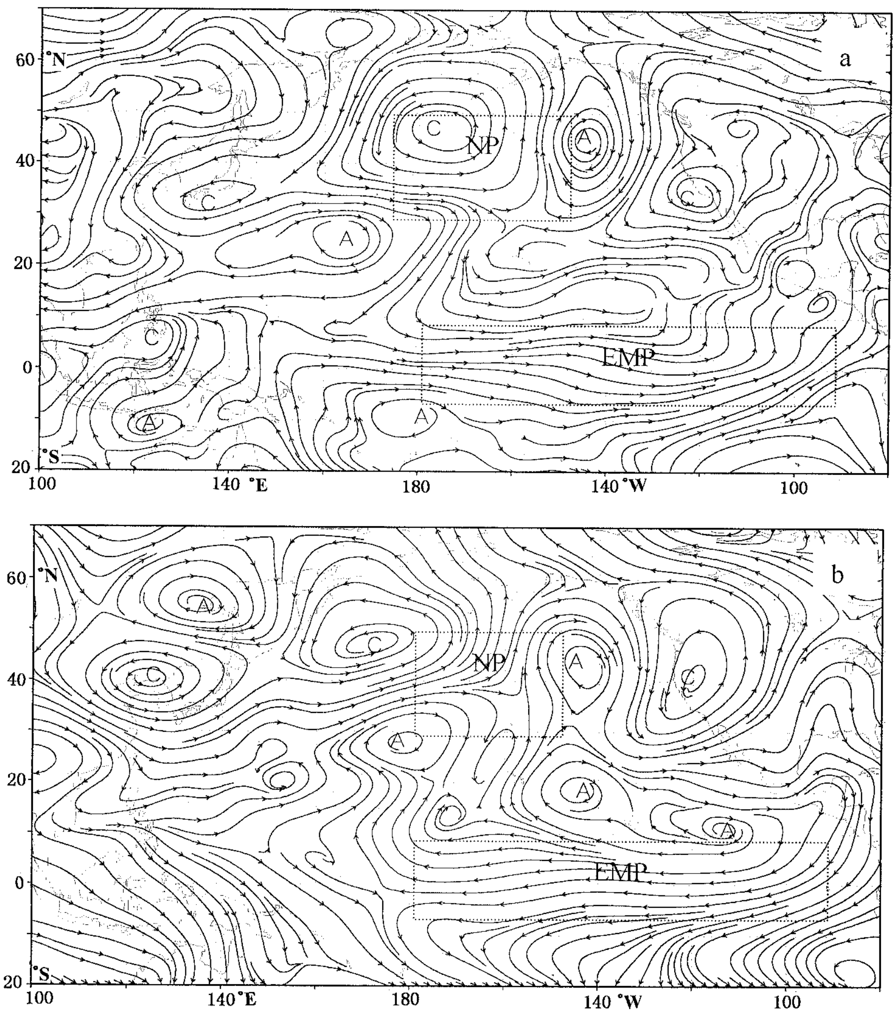

Fig.4 Difference of flow field in the summer of high and low LSTD years between 850 hPa (a) and 200 hPa (b) levels

By the distribution of LSTD intensity, we know that high LSTD years are mostly seen in the period 1958 through 1975 and low LSTD years all in the period 1976 through 1993. The former period corresponds to a strong overhaul performance of the summer monsoon in East Asia and the latter to a weak one. In view of it, climatic backgrounds for different inter-decadal scales can be represented with composite fields of extreme state of high and low LSTD anomalies, highlighting the role of the factor of thermodynamic difference in East Asia. Then, the inter-annual anomalies of the north Pacific SST are studied against such background to determine the interactions between the monsoon in East Asia and the SST in the Pacific Ocean on the inter-annual and inter-decadal scales.

Fig.5 presents the anomalies of the 500-hPa geopotential field in summer of high and low LSTD years. For the high LSTD year, as shown in the figure, a well-defined wavetrain is present along the route from the Philippines, Indo-China Pen., southern China, Changjiang (the Yangtze) – Huaihe River region, Korean Pen., southern Japan, Okhotsk Sea, north Pacific Ocean and all the way till the west coast of North America. Negative anomalies are dominant over the Philippines, Indo-China Pen., southern China and the Okhotsk Sea, producing low geopotential height, while positive anomalies are controlling the Korean Pen. and north Pacific, causing high geopotential height. Furthermore, the northeastern Pacific Ocean is negatively anomalous and the west coast of North America is positively anomalous. Such distribution patterns have given rise to weakened Okhotsk Sea high and meridional circulation in the middle and high latitudes, northward but weakened west Pacific subtropical high and northward advancement of the westerly winds. The summer monsoon is thus made easier to progress to northern latitudes to interact with colder air from the north and to push the Mei-yu (sustained) Rain front to locations more to the north, bringing more precipitation to northern China. In addition, the lowered geopotential field over the Philippines is favorable for the enhancement of convection and rainfall in the northern part of China, but the situation also exposes the basins of the Changjiang-Huaihe Rivers to homogeneous intense flow of the summer monsoon and intrigues drought. For the low LSTD years (Fig.5b), however, the wavetrain is distributed much the same, though with an alternative "+, –, +, –, +, –" distribution of centers from the Philippines, Indo-China Pen. to the west coast of North America. It is indicative that the interactions between the east-west / north-south land-sea thermodynamic differences and the SST anomalies in north Pacific are made possible through this very wavetrain. When the LSTD is large (the summer monsoon is strong in East Asia), a "–, +, –, +, –, +" pattern is formed from the Philippines, Indo-China Pen. and the west coast of North America, which is to be named a positive wavetrain phase. The phase will be negative when the LSTD is small (the summer monsoon is weak in East Asia) and we observe a "+, –, +, –, +, –" pattern through the above regions. The situation is increasing the high in the Okhotsk Sea and the meridional circulation in the middle and high latitudes, pushing the subtropical high and westerly disturbance towards the south. It is easier for the northern colder air to move south to meet the summer monsoon over the Changjiang – Huaihe Rivers' basins and bring more rain there but dry weather in north China. Apart from it, the low geopotential in and around the Philippines is also a favorable factor for the increase of precipitation over the basins. Because of its resemblance, in a large circle route, of what the Chinese meteorologists have named the "EAP" pattern (East Asia-Pacific), the wavetrain is called a "great circle wavetrain".

Now that a wavetrain is present and links the thermodynamic difference in East Asia (summer monsoon) with the region of north Pacific, why was the SST in this region well related with the summer monsoon in East Asia and precipitation in north China before mid-1970's but poorly related afterwards? To solve the problem, we need to study the effects of SST anomalies on the general circulation and the East Asian summer monsoon.

Following the inter-decadal backgrounds we have presented for the intensity of summer monsoon, we now turn to the analysis of the effects of the inter-annual anomalies of north Pacific summer SST on these backgrounds. From the curves of SST evolution averaged over summer in the region of north Pacific (30°N ~ 50°N, 180° ~ 150°W), we subtract the peak year of composite 500-hPa geopotential field from the valley year and make the result a forcing of increased north Pacific SST for the field. Years selected through the procedure pass the *t* test of 0.05. As shown in Fig.6, there are a center of negative anomaly in the Philippines and Indo-China Pen., positive anomalies in eastern China, the Korean Pen. and southern Japan and negative anomalies over the Okhotsk Sea; the north Pacific atmosphere is controlled by a positive anomalous center, with negative values in the northeast Pacific and positive values on the west coast of North America. The anomalous distribution of the geopotential height is quite agreeable with the climatic background

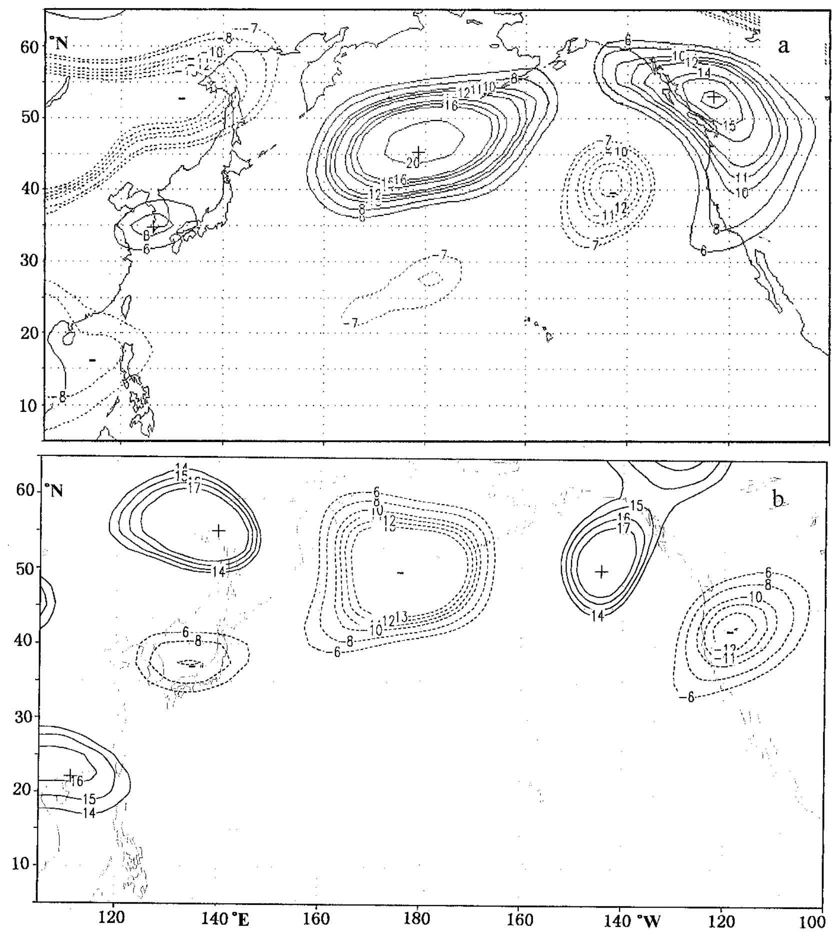

Fig.5 Distribution patterns of anomalies of 500-hPa geopotential field in the summer of Asian-Pacific region in high (a) and low (b) LSTD years in East Asia

for a strong summer monsoon in East Asia (Fig.5a) but just the opposite to the one for weak monsoon (Fig.5b). It suggests that the atmospheric anomalies excited by rising SST in the summer of north Pacific goes in phase with the great circle wavetrain existent with the background of strong summer monsoon in 1958 ~ 1975. It results in the superposition of anomalies and strengthening of the great circle wavetrain and consequently, the linkage between the East Asian summer monsoon and the north Pacific SST. For the period 1976 through 1993, however, the forcing of atmosphere by the north Pacific summer SST goes out of phase with the climatic background for weak summer monsoon, weakening the great circle wavetrain and the linkage between the East Asian summer monsoon and the north Pacific SST, loosening it in effect.

4.3 *Inter-decadal variation of the relationship between oceanic zones in equatorial central and eastern Pacific and East Asian summer monsoon*

For the past few years, the increasing research of the ENSO event at home and abroad has associated the SST anomalies in the equatorial central and eastern Pacific with the climate in East

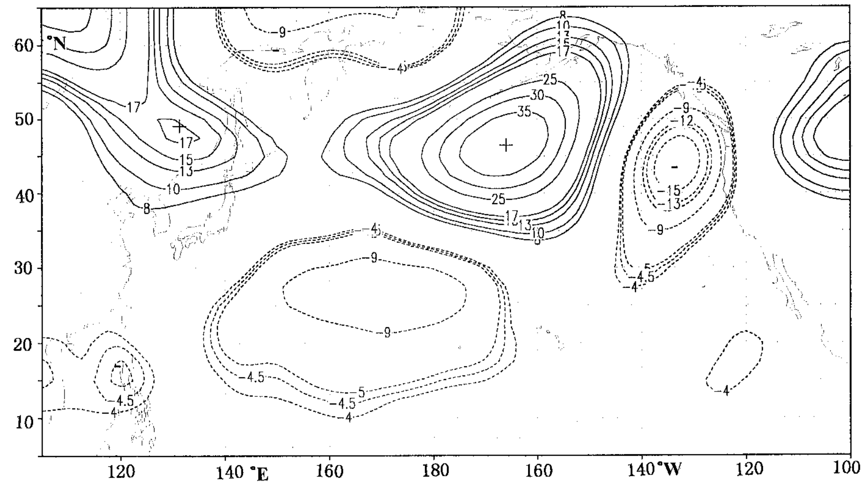

Fig.6 Anomalies of 500-hPa geopotential field as induced by the inter-annual anomalies of SST in the summer of north Pacific Ocean

Asia by means of some links. Some of the works argue that it is necessary to study the anomaly of the Walker cell if one wants to study the relationship between the SST in the equatorial central and eastern Pacific and the East Asian monsoon. Its ascending branch is in the west Pacific and the Philippines and descending branch in the equatorial central and eastern Pacific, linking the anomalies of SST in this part of the ocean with those of the general circulation in East Asia.

As the Walker cell is an enclosed zonal circulation traversing over the tropical Pacific, in which the westerly prevails in the upper levels and the easterly dominates the lower levels, the difference in the zonal winds between the upper and lower levels for a selected domain in 10°S ~ 10°N, 140°E ~ 120°W of this part of the ocean is used to depict the anomalies of the Walker cell. It is called the Walker Cell Index (WCI). Tab.2 gives the correlation between the WCI and the East Asian summer monsoon and SSTA in the equatorial central and eastern Pacific. Being in very close relationship, the anomalies of the Walker cell are shown to be almost out of phase with the SSTA in the equatorial central and eastern Pacific while inter-decadal variations are found with the relationship of the former with the East Asian summer monsoon, which appeared to have little relevance in 1958 ~ 1975 by a correlation coefficient of –0.0184 but changed drastically in 1976 ~ 1993 by a coefficient of 0.4786 and passage of the 0.05 level of significance. It is concluded, therefore, that it may be through the Walker cell that the East Asian summer monsoon over the time after 1976 has become much closely linked with the equatorial central and eastern Pacific.

Tab.2 Correlation between the Walker Cell index and the SSTA in the equatorial central and eastern Pacific and LSTD in the summer of East Asia

	Walker Cell Index (WCI)		
	1958～1993	1958～1975	1976～1993
SSTA in the equatorial central & eastern Pacific	–0.8245	–0.8958	–0.7138
LSTD in the East Asian summer	0.2959	–0.0184	0.4786

5 CONCLUDING REMARKS

a. A new method and index are introduced to describe the intensity of the East Asian summer monsoon well reflecting the inter-annual and inter-decadal anomalies. Due to significant changes taking place with both the monsoon and the Pacific SST around the mid-point of the 1970's, key SST zones having close correlation with the monsoon have transferred elsewhere. Before the mid-1979's, the East Asian summer monsoon was closely linked with the north Pacific; after it, the former turns to have close relationship with the equatorial central and eastern Pacific.

b. The reason why the East Asian summer monsoon has loosen its relationship with the north Pacific is presented below. Before mid-1970's, the great wavetrain, induced by large land-sea thermodynamic difference in East Asia and existent from the Philippines, Indo-China Pen., north Pacific to the west coast of North America, went in phase with the wavetrain induced by the anomaly of SST in the summer of north Pacific. After mid-1970's, the two wavetrains went out of phase, becoming less defined and reducing the links between them.

c. The shift of key SST zones to equatorial central and eastern Pacific after the middle term of the 1970's may be the result of significant changes in the Walker cell, which strengthens the links between the central and eastern Pacific and East Asia. It remains to be further studied.

Acknowledgements: Mr. CAO Chao-xiong has translated our paper into English.

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