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PECULIARITIES OF LONG TERM VARIATION OF SEA SURFACE TEMPERATURE IN TROPICAL WESTERN PACIFIC OCEAN

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ABSTRACT: It is necessary to study the tropical western Pacific SST in association with variations of other parts of the globe. Two basic compositions are revealed of long-term variation in SST over three major tropical oceans since the 1950's (linear warming and El Niño-La Niña oscillations) and typical patterns with which they are displayed over the oceans are compared. On the basis of it, difference in long-term variation of SST over western, central and eastern tropical Pacific is analyzed in details. It is pointed out that the El Niño-La Niña oscillations are relatively weak in the long-term variation of SST in the tropical western Pacific and linear warming trend there is replaced by interdecadal oscillations. Further understanding of the peculiarity over the region helps improve short-term climatic predictions in China.

Key words: tropical western Pacific; SST; long-term variation law

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1 INTRODUCTION

Between the SST anomalies in tropical western Pacific and summer monsoon circulation/long-term weather anomalies in East Asia exists a relationship as pointed out by Nitta (1986), Kurihara and Kawahara (1986) and Huang and Li (1988) —positive SST anomalies in tropical western Pacific have strengthened convection around the Philippines and subsequently the subtropical high over Japan and eastern China, leading up to hot and fine weather. It is then obvious that the SST anomaly in tropical western Pacific is directly related with short-term summer climate anomalies and their prediction in East Asia. On the other hand, since the confirmation of El Niño-La Niña oscillations as the strongest signal in the study of SST anomaly in tropical oceans (Fu, 1987) and the earlier findings that negative correlation exists in sea-level pressure between tropical weatern Pacific/Indian Ocean and central and eastern Pacific (Bjerknes, 1969), work on regional peculiarity of long-term variation of SST in tropical western Pacific has been largely neglected.

Previous studies have shown that as compared to tropical eastern and central Pacific, the SST and interannual anomaly of general circulation in the region of tropical western Pacific is only slightly affected by the El Niño-La Niña event. In contrast, air-sea interannual variations and interactions in this region has a more obvious influence on the El Niño-La Niña event (He and Zhang, 1996; Panxing W, Jianxin W and Yan C, 1995). In their study of long-term variation of Pacific SSTA in 1985 ~ 1989, Wang, Dai and Carton et al (1991) discover that Southern Oscillation Index (SOI), defined as differences in normalized monthly mean sea-level pressure between

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Tahiti and Darwin, is composed of local monthly mean pressure that has different frequencies of time and deter that the circulation belongs to two oscillation systems.

On the basis of the study of long-term variation laws of SST over the whole tropical ocean, the peculiarity for the tropical western Pacific is stressed. The "long-term variation" here refers to interannual and interdecadal variations.

2 DATA AND METHODS

2.1 *Data*

A dataset of month-to-month SSTA from NCEP, which is from January 1856 to October 1995 with intervals of 5°×5°, is used in the work.. A total of 550 months (from January 1950 to October 1995) for the tropical region from 32.5°S ~ 32.5°N are covered.

2.2 *Methods*

(1) Regional mean and time running mean

In view of the GrADS (Grid Mesh Data Analysis and Display System) used in the study, the regional mean is denoted as weighted average against area. The value is only a factor away from the regional mean heat-containing sea surface water per unit mass. Its time running mean is defined as

$$\overline{[\mathrm{SSTA}(t)]}_D = \sum_{t=-6}^{6}[\mathrm{SSTA}(t+t)]_D\ /13, t = 7 \sim 544$$

which eliminates most of the intra-annual oscillations.

(2) EOF Analysis

Following Wang (1996), EOF analysis derives 1) eigenvalue ($l_h, h = 1 \sim H$), which is usually converted to variance fitting rate of $r_h, h = 1 \sim H$. r is the parameter of relative measurement of the importance of the h^{th} eigenvector. Focus is placed on the comparison of r_1, which is taken as the parameter of relative measurement of the importance of the first eigenvector. 2) The eigenvector ($X_h, h = 1 \sim H$), which gives the spatial distribution, is not fully studied here. 3) The time coefficient ($T_h, h = 1 \sim H$), which describes the role of X_h in the composition of the time series of SSTA, will be used to discuss the frequency domain of SSTA.

3 PECULIARITY OF REGIONAL MEAN SSTA IN TROPICAL WESTERN PACIFIC

3.1 *Long-term variations of SST over tropical oceans*

In Fig.1, the solid line represents the spatial mean and time running mean curves of month-to-month SSTA for global tropical oceans (spanning from 32.5°S to 32.5°N) in 1950 ~ 1995. It is characteristic of a linear rising trend superimposed with a quasi-periodic oscillation. The trend shows that the SST for the global tropics has risen by about 0.3℃ since the 1950's. According to the definition of El Niño (La Niña) events set by ENSO Monitoring Team (1989), the peaks and valleys are each corresponding to the El Niño (La Niña) events. The amplitude can be 0.3℃ ~

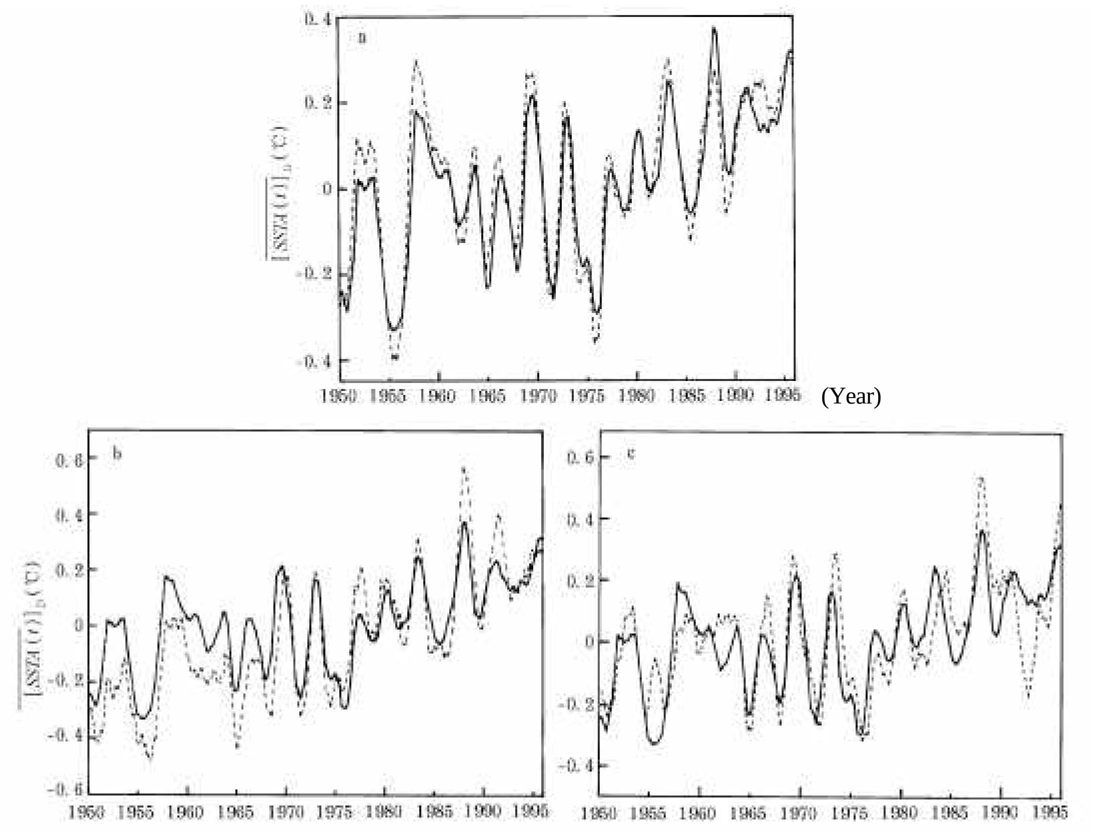

Fig.1 Comparisons of time running mean curves spatially averaged for SSTA
(a) global tropical oceans (solid line) versus tropical Pacific Ocean (dashed line);
(b) global tropical oceans (solid line) versus tropical Indian Ocean (dashed line);
(c) global tropical oceans (solid line) versus tropical Atlantic Ocean (dashed line);

0.5℃ in the disturbance of SST for the whole of the tropical oceans, equivalent to or exceeding the effect acquired by linear growth over the past 50 years or so. These variations should be regarded as the basic long-term variations of SST in the entire tropical ocean across the globe.

3.2 *Long-term variations of SST in the three oceans*

In Fig.1, the dashed line plots the spatial mean and time running mean curves of SSTA in the three main oceans. In comparison with global tropical ocean (solid line), there are still linear warming trends and quasi-periodic oscillations in the curves for each specific ocean. After careful study, the three oceans differ in two basic variations: The linear warming trend is found in all of them, but the one for the Pacific Ocean is the closest to that for the whole tropical ocean due to a vast longitudinal span of 160° in the former ocean in contrast to only 50° for the rest (the Indian and Atlantic Oceans). The result is not surprising. By the degree of warming trends, the Indian Ocean is the strongest while the Atlantic Ocean the weakest. The quasi-periodic oscillation over the Pacific and Indian Oceans show a strong consistence with the whole tropical ocean, though there is a little lagging in the phase of the Indian Ocean. It confirms that the oscillation associated with the El Niño (La Niña) events is obviously reflected in these two oceans. For the Atlantic, it comes and goes, showing high consistence with the whole tropical ocean from mid-1960's to early 1980's with the difference of amplitude just a little lagging behind. It's been much deviated from the whole since the 1980's in terms of consistence with peaks and valleys, except for the 1987-1988 peak, which corresponds to an El Niño event. For instance, the 1982-1983 El Niño peak did not appear until over a year afterwards and a negative anomaly being the strongest for almost 20 years is recorded around 1992. It causes the tropical Atlantic SST to have long-term variations that are less tightly connected with the El Niño (La Niña) events, forming large difference with tropical Pacific and Indian Oceans.

3.3 *Long-term variations of SST in tropical western Pacific*

Fig.2 compares the SSTA for tropical western Pacific (dashed line) and tropical oceans across the globe (solid line). The linear increase is still there but weak. Amplitude is larger in some stages of quasi-oscillatory parts of the curve than others, specifically from the mid-1960's to 1970's and from late 1980's till present. Even for stages of large amplitudes, the oscillatory phases are not determinate in the relation with those for SSTA in the tropical ocean.

Studying Fig.1 and Fig.2 in comparison, obvious differences exist in the oscillatory part of the long-term variation of tropical western Pacific as compared to the global tropical ocean. They are much larger than tropical Pacific and Indian Oceans and even larger than tropical Atlantic. As the oscillatory part of the long-term SST variation for the global tropical ocean is well corresponding with El Niño (La Niña) events, the difference above implies that the El Niño (La Niña) oscillation is relatively weak in the long-term variation of SSTA for tropical western Pacific.

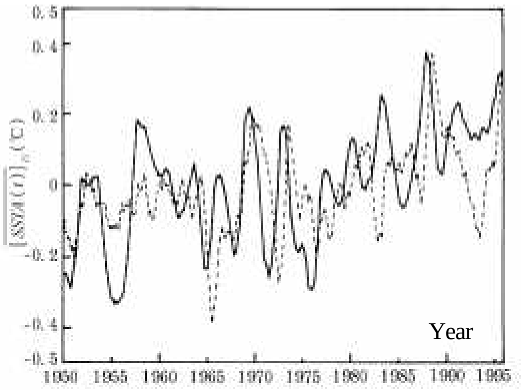

Fig.2 Comparisons between the time running mean curve (dashed line) spatially averaged for SSTA and that for the whole tropical oceans (solid line)

4 EVIDENCES AS PROVIDED BY EOF ANALYSIS

A time serias is taken of the SSTA field from the grid mesh of six regions as listed in Tab.1

Tab.1 Main parameters for the six oceanic regions in the EOF analysis

Name of regions	Code of regions	Longitude of location	Number of grids *n*
Tropical W. Pacific	WP	120°E ~ 170°E	76
Tropical C. Pacific	CP	175°E ~ 135°W	84
Tropical E. Pacific	EP	130°W ~ 80°W	81
Tropical Indian Pacific	I	50°E ~ 100°E	71
Tropical Atlantic	A	50°W ~ 0°	72
Tropical Pacific	P	120°E ~ 80°W	227

(grid intervals to be $\Delta l \times \Delta j = 10^\circ \times 5^\circ$). The latitude spans from 32.5°S ~ 32.5°N and duration covers January 1950 ~ October 1995 for all regions. The length of the serials m=550 and the total number of grids are 84 except for tropical Pacific (238). Tab.1 presents the latitudes across which the regions are located and the number of grids for which there are SSTA data.

For the SSTA (l, j, t) on each grid, normalization is applied on a monthly basis to obtain a series of $\overline{\mathrm{SSTA}}(l, j, t)$ which is free from seasonal variation of variance. The time series of the $\overline{\mathrm{SSTA}}$ field composing the six regions are what analyzed with EOF. As they (except for Region P) come from geographic regions of similar size and degree of freedom (n), results of analysis are comparable. The EOF analysis conducted for the region of tropical Pacific serves as a reference basis.

4.1 *Analysis of variance fitting rate*

Tab.2 gives the distribution of primary variance in the EOF analysis for the six regions. By the EOF principle, r_1 describes the role of the most important normalized mode (i.e. the first eigenvector X_1) in the fitting of the total variance of $\overline{\mathrm{SSTA}}$ time series. It can be interpreted as the intensity of the strongest precursory sign leading to the anomaly of SST. The stronger r_1 , the more obvious the signal will be. The ratio r_1 / r_2 compares two most important normalized modes (X_1, X_2) in the fitting of the total variance of the $\overline{\mathrm{SSTA}}$ time series. The larger the r_1 / r_2, the more predominantly the X_1 is playing the role. In other words, the time series is more simply composed. When r_1 / r_2 approaches unity, the time series is thought to be composed of at least two or more normalized modes, making it a complicated structure.

Tab.2 Covariance fitting rate for the six oceanic regions in EOF analysis

	WP	CP	EP	I	A	P
r_1	0.103	0.208	0.252	0.220	0.165	0.154
r_2	0.079	0.072	0.067	0.066	0.126	0.045
r_3	0.065	0.053	0.061	0.062	0.069	0.040
r_1 / r_2	1.302	2.902	3.781	3.322	1.317	3.404

4.2 *Analysis of time coefficients*

Fig.3 compares the time coefficient of the first eigenvector for the eastern, central and western tropical Pacific and corresponding curve for the whole tropical Pacific in the EOF analysis of the $\overline{\mathrm{SSTA}}$ time series.

In Fig.3a, the oscillation curves for tropical Pacific (solid line) and tropical eastern Pacific (dashed line) are not only consistent in both phase and intensity but corresponding to the timing and intensity of the El Niño and La Niña events (ENSO Monitoring Team, 1989). For instance, four El

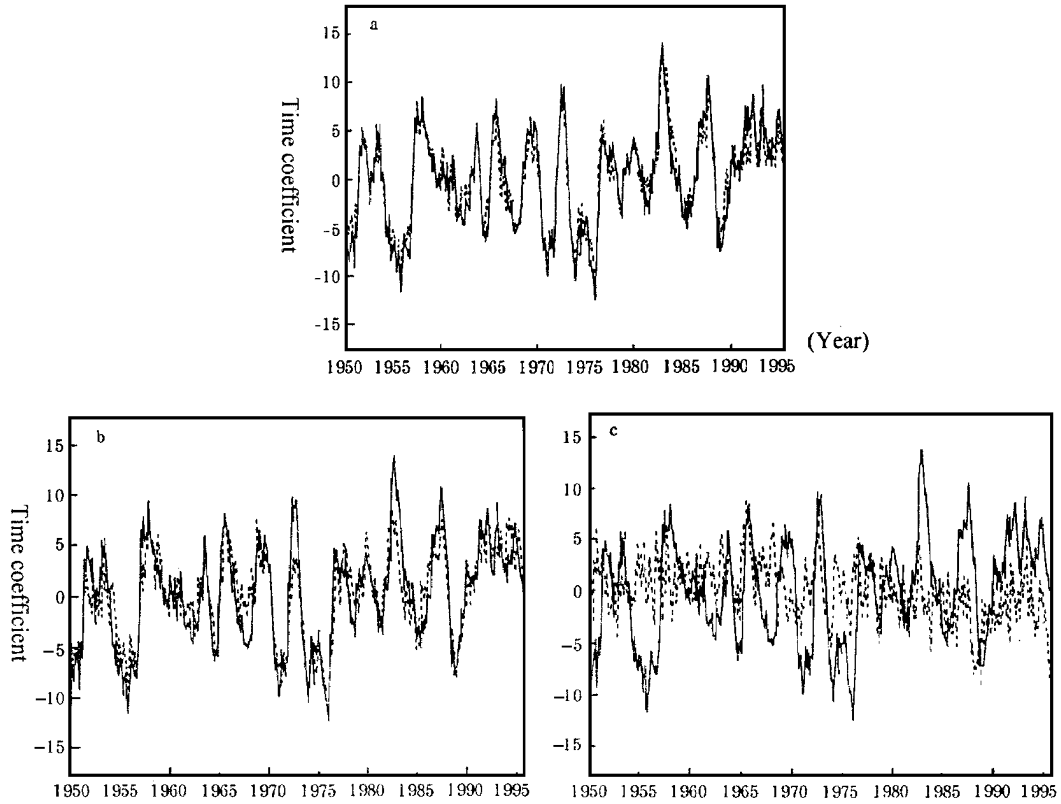

Fig.3 Time coefficient T_1 curves of the first eigenvector of EOF analysis for the time series of SSTA of the eastern (a), central (b) and tropical Pacific oceans; solid line: T_1 curve for tropical Pacific; dashed line: T_1 curve for eastern, central and western tropical Pacific

Niño events, once in the 1950's and early 1970's each and two in the 1980's, are relatively stronger than others. Obvious peaks appear in parts of the curves relevant to the events. It is then clear that the first eigenvector is able to show how important the El Niño and La Niña events are for the long-term variation of SST. In addition, the curves also reflect a trend of linear growth, though with a small variance. They are the two very basic features of variation indicated in the study of regional mean and time running mean curves for SSTA.

The relation of the two curves in Fig.3b is similar to Fig.3a, only being less close to each other. That the early-1970's El Niño event is weakly reflected in the tropical central Pacific is one of such examples. It is then known that the first eigenvector in that region is as indicative as that in the tropical eastern Pacific is.

The two sets of curves in Fig.3c are linked in a way much different from Fig.3a & 3b. The time scale and amplitude are much decreased for the oscillation (the dashed line) in the tropical western Pacific and no obvious association is found between it and the curve (the solid line) for the tropical Pacific as a whole.

Viewing from the EOF analysis results of $\overline{\mathrm{SSTA}}$ time series, we know that the tropical western Pacific is a region in which the most complicated long-term variation of SST are taking place in this part of the Pacific Ocean. Its scale is even less related with the long-term variations of

SST in tropical eastern and central Pacific.

Due to differences of the zonal circulation in the longitudinal circles, parallel illustration of the vertical high latitudes with the weakening of upper-level westerly.

5 CONCLUDING REMARKS

It is summarized that over the past 50 years or so two basic patterns of long-term tropical SST, linear warming and El Niño and La Niña oscillations, are less remarkably shown in the tropical western Pacific as in other parts of the ocean, a fact that has been revealed by the statistic analysis of SSTA in tropical oceans and other regions across the globe. It is therefore concluded that the variation there is of high regional peculiarity. On basis of this analysis, we integrate all research findings mentioned in the Introduction. In view of the large difference of the tropical western Pacific SST from other parts of the tropical oceans in terms of long-term variation, the local atmospheric circulation anomaly that is directly affected by it is expected to differ vastly from other parts of the tropical oceans (He et al., 1996; Panxing Wang et al., 1995; Wang et al., 1991). As the anomaly in the air-sea interactions over the tropical western Pacific directly affects East Asia (Nitta, 1986; Kurihara et al., 1986; Huang et al., 1988), some uncertainty will be with the association of long-term summer weather anomaly in East Asia with the El Niño event. It is therefore necessary to have more study of the regional peculiarity of air-sea anomaly in this region to improve the prediction of short-term summer climate in China.

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