INTERRELATION BETWEEN EAST-ASIAN WINTER MONSOON AND INDIAN/PACIFIC SST WITH THE INTERDECADAL VARIATION*

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Received May 22, 1997; revised November 18, 1997

ABSTRACT

Investigated statistically is the interrelation between East Asian winter monsoon (EAWM) and SST over sensitive areas of the Indian and Pacific Oceans, with focus on the relation of EAWM to strong ENSO signal area, i.e., the equatorial eastern Pacific (EEP) SST. Evidence suggests that the EAWM variation is intimately associated not only with the EEP SST but with the equatorial western Pacific "warm pool" and equatorial Indian/northwestern Pacific Kuroshio SST as well: the EAWM and ENSO interact strongly with each other on the interannual time scales, exhibiting pronounced interdecadal variation mainly under the joint effect of the monsoon QBO and the monsoon/SST background field features on an interdecadal basis—when both fields are in the same phase (anti-phase), strong EAWM contributes to EEP SST rise (drop) in the following winter, corresponding to a warm (cold) ENSO cycle; the EAWM QBO causes ENSO cycle to be strong phase-locked with seasonal variation, making the EEP SST rise lasting from April—May to May—June of the next year, which plays an important role in maintaining a warm ENSO phase.

Key words: East-Asian winter monsoon, ENSO cycle, interdecadal variation, QBO (quasi-biennial oscillation), equatorial eastern Pacific (EEP)

I. INTRODUCTION

As important climate systems on a local basis, Asian monsoon and ENSO affect greatly global climate, which is a subject of interest in atmospheric research in the world. Numerous studies show that Asian monsoon bears a close relation to ENSO (Webster and Yang 1992; Yasunari 1990; Huang and Wu 1987; Wu and Lau 1992; Sun et al. 1988; Ni et al. 1995; Qian 1993; Wang and Zhao 1979; Chen et al. 1991). Due to their respective complexity, the following problems remain to be dealt with.

(1) Overdue emphasis on local characteristics. Asian monsoon consists of East Asian and Indian subsystems, relatively independent but interrelated. Foreign colleagues placed

* Supported by the National Natural Science Foundation of China under Grant ATM-49705062.

focus on Indian monsoon associated with ENSO whilst we Chinese meteorologists had focus on the East Asian monsoon-ENSO relation. Thus, some divergence appears in their findings. On the other hand, an ENSO event is not an isolated phenomenon, responsible not only for EEP SST anomaly but for significant SST variation in other areas of the Indian/Pacific. For this reason, focus only on EEP SST anomaly seems insufficient.

(2) Disagreement of criteria of interannual variation in monsoon activity. The difference in using different criteria for monsoon intensity has produced great difficulty in the study of monsoon-ENSO relation on an interannual basis, thus leading to discrepancy between some results.

(3) Interaction between EAWM and ENSO cycle at different scales of time. As the monsoon and SST vary on multi-time scales at different rates, will their relationship change with time? This is a problem that needs further study.

Starting with EAWM interannual variations and disassociation of the interannual from interdecadal scales, we make approach to these problems to investigate the interrelation between EAWM and SST variation of the Indian/Pacific as a whole, whereupon the relation of EAWM to ENSO cycle and interplay between interannual anomaly and interdecadal variation are examined in order to gain even fuller understanding of EAWM-ENSO cycle relation.

II. DATA AND CALCULATION SCHEME

1. *Data*

Data used are all monthly means, consisting of a) 1873—1993 northern sea level pressures, compiled by U. K. Meteorological Office; b) 1854 — 1990 global SST (December—February); c) 1951—1990 cloudiness; and d) 1971—1990 wind stress.

2. *Calculation Scheme*

(1) *EAWM intensity index*

Following Guo (1983) and Shi et al. (1996), monthly and seasonal EAWM vigor index is defined as the sum of 7 normalized zonal sea level pressure (SLP) differences (110 minus 160°E) over 20—50°N at a 5° interval (totaling in 7 latitude circles) and the sum is again normalized, viz.,

$$MI_t = \sum_{i=1}^{7} (SLP^*_{1it} - SLP^*_{2it}),$$

$$MI^*_t = \frac{MI_t - \overline{MI}}{\sigma_{MI}},$$

$$i = 1,2,\cdots,7 \text{ (latitude circle)}; \ t = 1,2,\cdots,121 \text{ (year)}$$

where $\overline{MI}$ and σ_{MI} are the average and mean square deviation, respectively, and SLP^*_{1it} and SLP^*_{2it} represent normalized (denoted by asterisk) SLP in the i-th latitude and t-th year at 110 (160°E). For summer monsoon, pressure is low (high) over the land (sea) so that the greater the index, the weaker the monsoon and vice versa for EAWM.

(2) *Smoothing correlation coefficients*

The coefficient is given as

$$r_{xy}(t_0) = \frac{\sum_{t=t_0-N}^{t_0+N}[x(t) - \bar{x}(t_0)][y(t) - \bar{y}(t_0)]}{\frac{1}{l}\sqrt{\sum_{t=t_0-N}^{t_0+N}[x(t) - \bar{x}(t_0)]^2 \sum_{t=t_0-N}^{t_0+N}[y(t) - \bar{y}(t)]^2}},$$

in which $\bar{x}(t_0) = (1/l)\sum_{t=t_0-N}^{t_0+N} x(t)$ with $l = 2N+1$ stands for smoothing window length.

Calculation of correlatively of EAWM index with Indian/Pacific SST involves the following considerations: a) data usefulness. 1873—1990 data are used for point-to point correlation and 1944—1990 for point-to-surface (consisting of points thereof with data available) and b) multi-scale features of the two interacting system. The time series of filtered 11-point smoothing means is taken as an interdecadal background field ($\tilde{x}$), and that with $\tilde{x}$ removed as an interannual counterpart ($x' = x - \tilde{x}$).

III. SENSITIVE AREAS OF THE INTERACTION BETWEEN EAWM INTERANNUAL ANOMALY AND INDIAN/PACIFIC SST

The synchronous correlation coefficients of intensity indices with SST on an interannual basis in 1944—1990 are given in Fig. 1, where one sees that EAWM is in appreciably negative correlation with the SST of the equatorial Indian, central/eastern Pacific and Kuroshio with the coefficients passing 0.01 significance and even 0.001 in the central/eastern Pacific. In contrast, EAWM correlation is positive with the "warm pool" and area around the Midway Islands, with correlation passing 0.01 significance over the "warm pool".

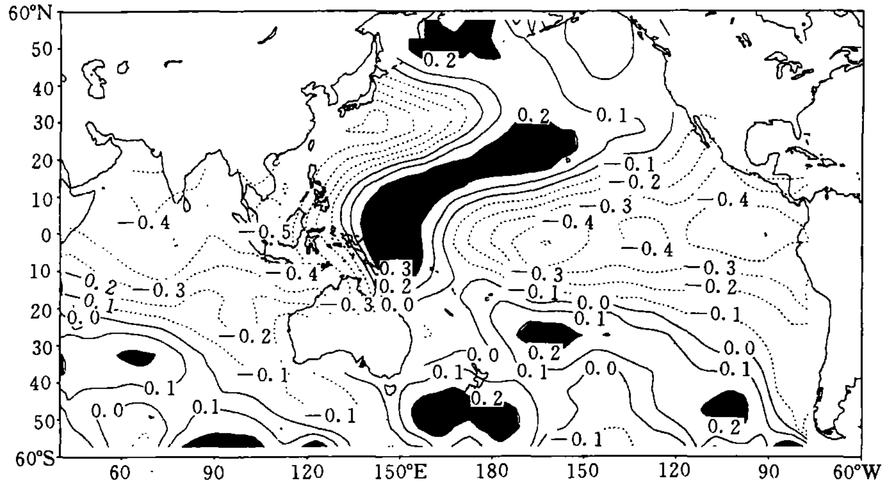

Fig. 1. Plot of coefficients of EAWM intensity indices simultaneously correlated with Indian/Pacific SST.

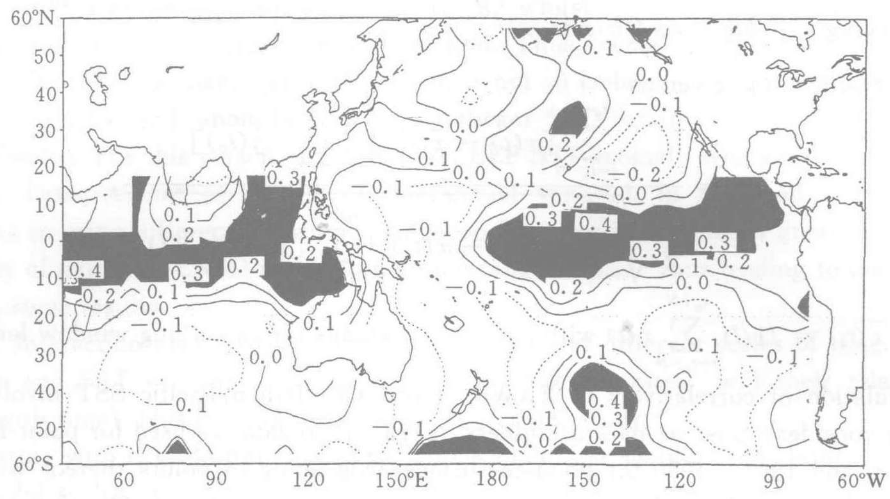

Fig. 2. Lagged correlation of previous EAWM intensity indices with Indian/Pacific SST in the next winter.

Statistically, to find the influence of the vigor variation on SST is to gain the information on EAWM varying before the SST experiences change. For this reason, lagged correlation is performed of previous EAWM and SST in the following winter, as illustrated in Fig. 2. It is seen therefrom that the correlatively changes more greatly with strongly positive correlation of 0. 01 significance in the equatorial central/eastern Pacific and Indian Oceans and weekly negative correlation in the western Pacific.

From the synchronous and lagged correlations we come to the following:

(1) There exist four sensitive areas of importance: the central eastern and western Pacific, and Indian Oceans at equatorial latitudes, and the warm pool of the NW Pacific—all are located at tropics and subtropics.

(2) The equatorial Indian SST variation is in phase with that of the central/eastern Pacific and in anti-phase with the western Pacific counterpart.

(3) EAWM is very closely related in variation to SST in the EEP as a sensitive ENSO signal area. For example, stronger EAWM is associated with a negative anomaly of the EEP SST and a cold ENSO phase in the same winter and with a reversal in the following winter.

(4) From the anti-phase of EEP SSTA related to the same and the following EAWM, it can be inferred that the EAWM QBO probably plays a significant part in the change of ENSO phases.

Evidently, EAWM is intimately related to the phase change, which, however, poses the following questions:

- Is such a relationship really true at all time? If not, what factors are involved?
- Do there actually exist effects of EAWM QBO upon ENSO cycle?They are dealt with in what follows.

IV. INTERDECADAL VARIATION OF RELATION BETWEEN EAWM AND EEP SST

From the foregoing analysis one sees a close relationship of EAWM to EEP SST on an

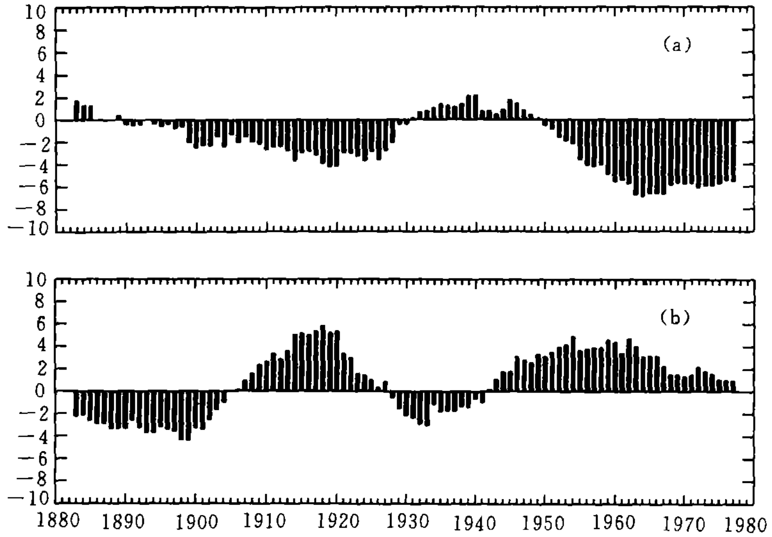

Fig. 3. Smoothing correlation features of EAWM intensity indices related to EEP SST for 1873−1990: (a) Synchronous correlation; (b) Lagged correlation.

annual basis, which is, however, indicative only of general correlatively in 1944−1990. Many studies show that the atmosphere varies thermally much faster as compared to oceans and in view of the different variation features their correlation may experience change as time goes. And how does the change occur? For this, smoothing correlation analysis is conducted with the window length $l = 21$ and $|r_{xy}(t_0)| \geq 0.42$ at significance level $\alpha = 0.05$.

Figure 3 presents the distribution of 21-year smoothing correlation coefficients of 1873 − 1990 EAWM with EEP SST. From Fig. 3a we see that the correlation on an annual basis is marked by salient interdecadal variation, being negative prior to the 1930s, quite small, though more or less positive, for the 1930s to 1940s and, from 1950s to 1990 there exists a negative correlation with maximal correlativity. From Fig. 3b we also see that indicator of the EEP SSTA is characterized by interdecadal variation, that is, the correlatively is negative from the 1870s to the early 20th century, positive thenceward to the late 1920s, negative from the 1930s to the early 1940s, and positive thenceforth to 1990.

Clearly, the simultaneous and 1-year lagged correlativities show pronouncedly interdecadal variation, suggesting the correlations in anti-phase, implying vigorous (feeble) EAWM associated with a cold (warm) ENSO phase in the same year and reversal in next winter for the record length except for the 1890s and 1945−1949. But this does not mean that the correspondence is always true, i.e., frequent and intense EAWM does not always imply a cold ENSO phase in the same winter and a warm one in the next year. For instance, the correspondence exists subsequent to the 1950s but does not in the 1930s. Statistically, therefore, whether previous strong EAWM contributes to El Nino happening depends not merely on the difference in interannual conditions but on interdecadal background in particular.

V. POSSIBLE CAUSES OF INTERDECADAL VARIATION IN RELATIONSHIP BETWEEN EAWM AND EEP SST

11-year smoothing averaging made of time series of EAWM intensity indices and EEP SST for the study period yields variation on a basis longer than 10 years, revealing in fact the characteristics of their interdecadal backgrounds, as shown in Fig. 4.

It is seen therefrom that (1) EAWM is in an inactive period from the beginning of this century to the 1920s, with a lower SST background in the target area, called a cold interval during which the monsoon is in positive correlation with the posterior SST on an interannual basis (see Fig. 3b), suggesting that the previous strong EAWM is associated with the SST rise in the subsequent winter; (2) from the 1920s to 1940s, EAWM is in another inactive span (slightly stronger than the anterior counterpart) in which the SST background is however in a warm period during which time previous intense EAWM corresponds to the SST drop in the following winter; (3) from the 1950s to 1980s EAWM is in an active period and the background EEP SST in another warm interval, meaning that EAWM is positively correlated with the SST rise in the next winter.

Above analysis indicates that as EAWM is interdecadally in the same regime as the background EEP SST, implying inactive (active) EAWM accompanied by lower (higher) SST, previous strong EAWM favors the EEP SST rise in the next winter, and as they are in an opposite regime reversal will happen.

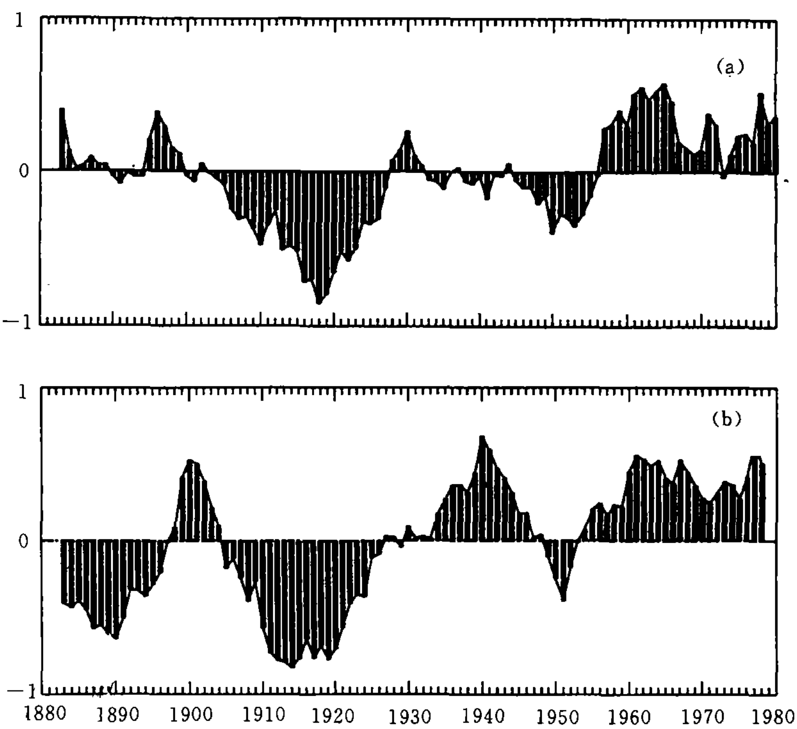

Fig. 4. Temporal variation of 11-year smoothing averaging of EAWM intensity indices (a) and EEP SST (b).

This fully illustrates that the variation in phase of their interdecadal backgrounds acts as a strong controlling means of their relation on an interannual basis. Thus, we are led to believe that one of the important causes of governing the variation in the relation between EAWM and ENSO cycle is none other than the phase matching of their interdecadal background fields.

VI. INFLUENCE OF EAWM QBO UPON ENSO CYCLE

To illustrate the influence the following problems are to be dealt with: (1) Is the EAWM QBO really existent? (2) Is the QBO related to an El Nino event? (3) How are they associated with each other?

The EAWM intensity indices have been treated in terms of singular spectral analysis (Xu and Zhu 1998) and it is found that the QBO component accounts for 10.6% of total variance, indicating its innegligible importance. Additionally, wavelet analysis yields the result that the wavelet coefficient of the indices exhibits quite intense amplitudes at 20—30 month periods (Xu and Zhu 1998), thereby demonstrating that the QBO is actually present.

No doubt the EAWM QBO is remarkable, and what is its relation to ENSO events? To answer the question, two facts are offered.

(1) As given in the foregoing analysis, the distributions of smoothing correlation coefficients of the intensity indices and EEP SST are almost in anti-phase between their synchronous and lagged analyses, which reveals that EAWM is responsible for the anti-phase of the SST variation in two succeeding years, thereby displaying that its QBO possibly plays an important role in the EEP SST rise or drop.

(2) The EAWM intensities associated with El Nino events after the 1950s based on Fig. 5 are listed in Table 1.

Table 1. EAWM Intensities and El Nino Events

Year of EAWM intensity*		Year of El-Nino
1952 s	1953 w	1953
1956 s	1957 w	1957
1962 s	1963 w	1963
1964 s	1965 w	1965
1968 w	1969 e. w. *	1969
1971 w	1972 e. w.	1972
1975 w	1976 s	1976
1981 s	1982 w	1982
1985 s	1986 w	1986
1990 w	1991 e. w.	1991

* s (w) stands for strong (weak), and e. w. stands for even weaker.

It is seen therefrom that, of all the El Nino events, nine occurred when relatively

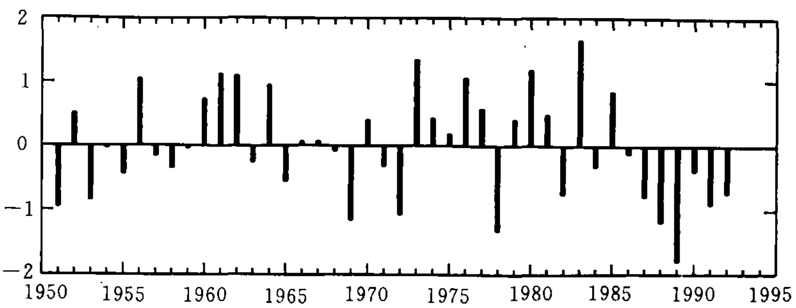

Fig. 5. History of EAWM intensity indices (ordinate) in 1951—1994 (abscissa).

weaker EAWM was preceded by a relatively strong counterpart in the previous winter except the 1976 faint case. This demonstrates that an El Nino event occurs generally in association with the QBO for the change in EAWM vigor and also that the QBO bears a close relation to ENSO events. Admittedly, not all QBO processes give rise to ENSO, which is likely to involve other factors.

The above facts demonstrate that the EAWM QBO has an intimate relation to ENSO cycle. Now a problem arises as to the way they are associated.

To address the problem the EAWM intensity indices were bandpass filtered at first, attaining the QBO component, followed by finding out coefficients of component correlated with a number of air-sea parameters in the months of the same and next year. At first we deal with the correlation with one of such parameters — sea level pressure (SLP).

One can see from Fig. 6 that the simultaneous correlation is positive (negative) between strong EAWM QBO in January and the SLP over the EEP (equatorial western

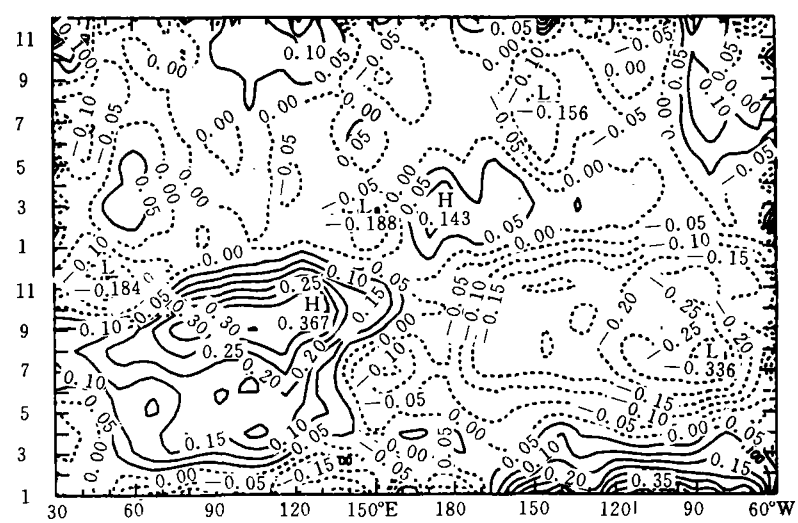

Fig. 6. The QBO component of January EAWM indices correlated to SLP (5°N—5°S, 30°E—60°W) for the months in the same and next year during 1951—1990, with months related to SLP given on the ordinate and longitude on the abscissa.

Pacific/Indian Oceans), meaning SLP rise (drop), well corresponding to a high phase of Southern Oscillation (SO). From correlatively we can infer that as time goes the QBO-related SLP field will experience change. SLP begins to rise in the equatorial Indian/western Pacific during February—March; in the next two months the EEP SLP changes its anomaly sign, indicating the incipience of reduction, corresponding to the start of a low SO phase lasting thenceforth; the equatorial Indian/western Pacific SLP peaks in September with the anomaly sign changed in February—March the next year, leading to the conversion of anticyclonic to cyclonic circulation; the EEP SLP reaches its minimum about December, and begins to rise in the following April—May, corresponding to a high SO phase.

It is evident therefrom that EAWM QBO-related SLP experiences change first in the equatorial western Pacific and then (about two or three months later) in the EEP. At the same time EAWM blows in violence in the spring—summer transition that is maintained till the following spring before changing into a high phase. Obviously, the low SO phase persisting for nearly one year is in association with the duration of an ENSO event.

Figure 7 delineates the 1951—1990 correlation between January EAWM QBO and equatorial Indian/Pacific SST. From the correlatively, we find that the evolution of SST associated with the QBO in a strong EAWM phase is characterized as follows.

(1) The strong QBO phase is accompanied by a positive anomaly in the western Pacific "warm pool" and a negative counterpart in the EEP related to a cold ENSO phase. Subsequently, as the warm water runs eastward from the pool, changing completely into cold water (thus cold anomaly) around May; SST at the EEP eastern boundary begins to rise for February—March and intensifies persistently, travelling westward with the result that the whole EEP is warmed in April—May; the warm anomaly going east out of the pool and that westward from the eastern boundary unite in September around 140°W of the EEP, resulting in an intense SST rise seat for the first time, which then moves eastward and reaches the eastern boundary in December—February, making for maximum rise in the EEP, whose positive anomaly, however, goes out of sight in May, falling again into a cold water period.

(2) The positive EEP SSTA lasts a year or so from March—April (after the QBO in a

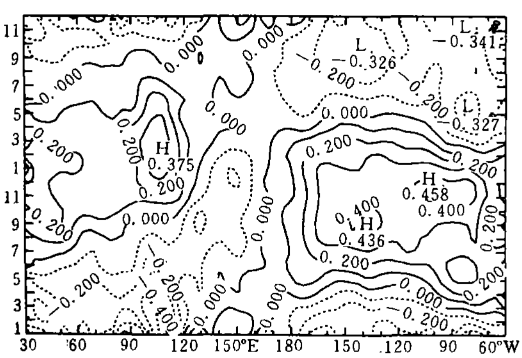

Fig. 7. As in Fig. 6, but for SST.

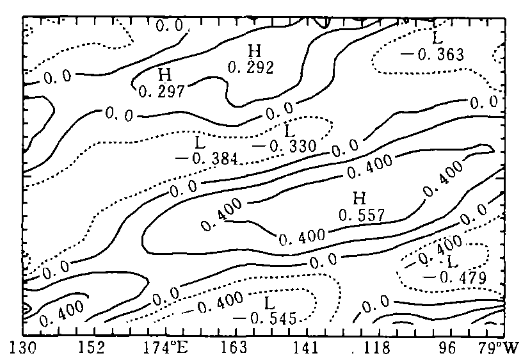

Fig. 8. As in Fig. 6, but for the QBO correlated with the zonal component of wind stress.

strong EAWM phase) to April—May of the subsequent year, a result that agrees roughly with SLP variation, thereby demonstrating the synchronism of the atmospheric system with the sea counterpart.

(3) The EEP SST displays marked standing wave characteristics of quasi-biennial oscillation. Evidently, the component of standing wave accounts for more than that of progressive wave travelling eastward and westward. As a result, the EEP SST rise in relation to EAWM QBO is associated more with weakened upwelling of standing-wave nature on a local basis than warm water E-W travelling, the former perhaps bearing a relation to eastward displacement of Kelvin wave excited by the westerly anomaly of the monsoon over the western Pacific.

(4) With the QBO in a strong EAWM phase, the equatorial Indian Ocean exhibits cold water that moves east, reaching the EEP in about two years to coincide with a cold SSTA phase there. SST rise begins in June at the western boundary of equatorial Indian, peaking in February—March the next year, with the rise roughly two or three months behind that of the EEP.

Figure 8 depicts the pattern of coefficients of January EAWM QBO in correlation to zonal wind stress as an important parameter for atmospheric effect on SST. Over the QBO's strong EAWM phase-associated the wind stress field westerly (easterly) anomaly emerges in the warm pool and the eastern boundary (central/eastern Pacific). As time goes the westerly anomaly in the pool moves east; after May most of the EEP is under the control of westerly anomaly, which continues to travel east and is kept till the around May of the subsequent year. It is about one year that the westerly anomaly takes to cover the journey from the pool to every corner of the EEP.

Figure 9 presents the distribution of coefficients of the EAWM QBO correlated with latent heating as an innegligible parameter for SST effect on the atmosphere. In the QBO' s vigorous EAWM phase-related latent heating field positive anomaly emerges in connection with the pool SST rise, in contrast to negative anomaly in the central eastern Pacific, but positive at the eastern boundary. Subsequently, the positive anomaly of the pool (the EEP eastern boundary) moves east (west), leading to positive latent heating in the main in May over the EEP, a result that is coincident with overall SST rise in the month of the year.

From the four parameters of the air-sea system we arrive at the following facts.

(1) The QBO in a strong EAWM phase corresponds to a cold ENSO phase in the very winter to spring, accompanied by lowered SLP over the pool, westerly anomaly, warm SST anomaly and stronger latent heating as opposed to conditions in much of the equatorial central/eastern Pacific, a phenomenon that is in accord with the hypothesis of Wytrki (1985), stating that the pilling of warm water in the pool is necessary to the initiation of an El Nino event.

(2) While the QBO is in a strong EAWM phase, the pool' s westerly anomaly is characterized by consistent eastward motion, and the related positive SSTA moves east and the counterpart runs west from the EEP easter boundary, and the latter (i. e., the west-travelling positive anomaly) is evidently not under the direct influence of advection caused by the western anomaly but related possibly to the westward displacement due to

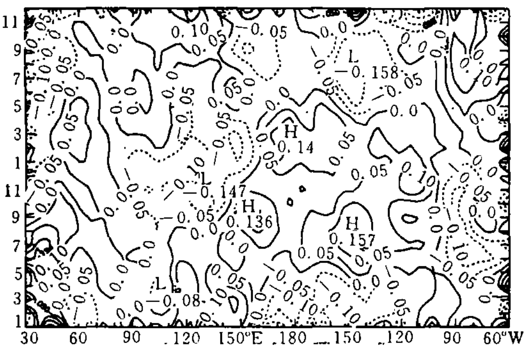

Fig. 9. As in Fig. 6, but for the QBO correlated with latent heating.

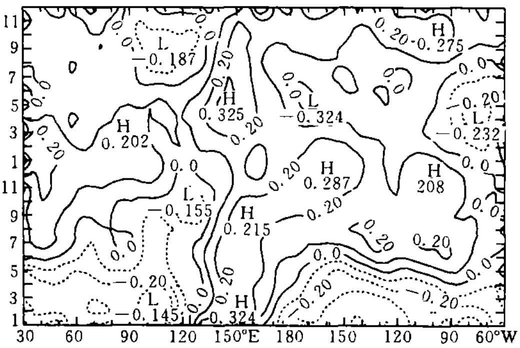

Fig. 10. As in Fig. 6, but for the EAWM index correlated to equatorial SST.

the reflection at the boundary of Kelvin wave excited by the westerly anomaly of the western Pacific origin. In addition, the positive EEP SSTA, once formed, will be persistent, displaying largely features of standing wave, which may be associated with the weaked trade wind. Consequently, the connection of EAWM QBO with EEP SST rise is accomplished via three approaches. 1) The east-travelling westerly anomaly of the pool gives rise to east-advected warm water; 2) The westerly anomaly-excited Kelvin waves that go eastward and are reflected cause the westward thickening of a thermocline responsible for west moving warm water; 3) East-travelling westerly anomaly and cyclonic circulation initiate the weakening of the EEP anticyclonic circulation and thus of the trade wind, thereby hindering the upwelling of oceanic water, leading to SST rise of stronger standing-wave origin.

(3) With the QBO in a strong EAWM phase, each of the air-sea elements exhibits an El Nino precursor first in the pool, spreading eastward and the pool can be assumed to represent a key region connecting EAWM and ENSO variability.

(4) The QBO is closely related to the seasonal ENSO phase-locking. In April—May after strong EAWM, SO begins to fall into a low phase and EEP SST starts to rise, reaching its peak in December—January and ending in May—June in next year, thereby completing an El Nino episode. Evidently, an EAWM QBO cycle corresponds to a warm ENSO phase. Comparison of the evolution of EAWM-associated ENSO cycle to the composite analysis of elements in ENSO events (Rasmusson and Carpenter 1982) shows their closest similarity, leading us to assume that the QBO is likely to play a major role in maintaining a warm ENSO phase and the reasonable phase-locking.

(5) Likewise, the equatorial Indian air-sea system is associated with the EAWM QBO except that its SST rise lags two or three months behind the EEP counterpart and SLP response to the QBO lags behind the SST response to the wind. As a consequence, the EAWM QBO possibly exerts effects upon the equatorial Indian Ocean which, in turn, exercises impact on the atmosphere.

Evidently, EAWM QBO plays a crucial part in maintaining a warm ENSO phase and its seasonal phase-locking there perhaps arise such problems as 1) is the maintenance of ENSO cycle dependent only on the QBO? and 2) are there EAWM impacts on other scales? To address them, a map is presented concerning the January EAWM intensity index (raw data consisting of a full range of scales of its activity) in correlation with equatorial SST for months of the very and subsequent years (see Fig. 10).

It is seen therefrom that the EEP SST associated with total EAWM effects shows no pronounced seasonal phase-locking nor one-year warm phase, thereby indicating that all strong EAWMs are not related to El Nino events, which demonstrates a crucial role of the QBO in sustaining an El Nino episode.

Besides, with the QBO in a strong EAWM phase, the air-sea system anomaly associated with El Nino breeding emerges first in the warm pool with positive SST and cyclonic westerly abnormality moving east, a little later followed by positive EEP SSTA migrating west, both uniting and the travelling east, a process that agrees well with the description of an integrated El Nino event related SST rise in terms of Kelvin wave theory by Harrison and Schopf (1984), who indicated that such a kind of SST rise consists of two phases of anomalous advection: around May the eastern coastal SST rises and spreads slowly westward, followed by stronger SST rise in the central Pacific, spreading fast eastward, in response to summer trade wind disappearing. On the basis of Kelvin wave theory, this phenomenon can be explained in the following way: (1) During a strong EAWM QBO phase, westerly anomaly occurs in the warm pool, which excites Kelvin waves that migrate quickly eastward, reaching the eastern coast in two or three months so that SST rises in March—April along the Peruvian shore and the rise spreads toward the equator because of the Kelvin wave reflection and moves west; (2) The westerly anomaly spreads east, leading to the weakened trade of the wind of the central/eastern Pacific with the result that the warm pool water returns eastward, thus enfeebling, in connection with the weakened trade wind, EEP upwelling responsible for SST rise there. Thus we come to a conclusion that the face-face moving branches of warm water unite into one in August—September, thereby checking the water from westward spreading and, instead, moving east under the action of the westerly anomaly advection.

VII. CONCLUDING REMARKS

From the foregoing analysis we come to the following.

(1) EAWM-Indian/Pacific SST interaction on an interannual basis has such sensitive areas as the EEP (most sensitive of all), equatorial western Pacific, equatorial Indian Ocean and NW Pacific Kuroshio belt.

(2) EAWM-EEP SST relation is marked by salient interdecadal variation and intense EAWM does not always correspond to a warm ENSO phase of the subsequent winter, however, good correspondence has occurred in the past 40 years and the reversal was observed in the 1930s.

(3) EAWM-EEP SST relation is governed by combined phases of EAWM QBO and interdecadal EAWM-SST anomaly. When their interdecadal background fields are in the same phase, vigorous EAWM favors EEP SST rise and relates to a warm ENSO phase in the following winter, and vice versa.

(4) EAWM QBO is closely related to an El Nino event, the connection of their interplay being in the western Pacific warm pool. Under the effect of the QBO, low SLP

of the pool migrates east with anomalous westerly, which is responsible 1) for east-travelling Kelvin wave that causes the thermoline to deepen to the east and SST to rise enough to initiate an El Nino episode, and 2) for east-advecting warm water due to eastward westerly anomaly, reducing the trade wind and thus EEP upwelling, which augments SST rise.

(5) EAWM QBO is responsible for remarkable seasonal ENSO phase-locking, leading to a fact that EEP SST rise persists from April—May to May—June of the next year, a sustainment that plays a crucial part in maintaining a warm ENSO phase.

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