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LOW-FREQUENCY VARIATION OF WESTERLY WIND EVENTS REGULATED BY ENSO SST

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1. INTRODUCTION

Occurrence and characteristics (e.g. frequency, amplitude, duration, zonal fetch) of westerly wind events over the equatorial western Pacific are observed to have year-to-year variations in phase with ENSO (Harrison and Vecchi 1997; Verbickas 1998; Vecchi and Harrison 2000). Strong westerly wind events (named westerly wind bursts (WWB)) are usually frequent, long lasting, and have wide zonal fetch before and during El Niño, but infrequent and short lived during La Niña. It is found that WWB occurred only over SST higher than 29°C, and these winds migrated eastward in tandem with the 29°C isotherm during the 1997/98 El Niño development (McPhaden 1999).

There are indications from recent studies (McPhaden 2004; Lengaigne et al. 2003; Yu et al. 2003; Yu 2004) that WWB are modulated/regulated by ENSO SST. Yu et al. (2003) hypothesized that the warm pool displacement controlled by ENSO imposes a constraint for the generation of WWB. Recent high resolution QuikSCAT wind and TMI SST observations clearly show that high-frequency WWB events have a low-frequency variation associated with the warm pool movement on ENSO timescales (Fig.1), and hence support the regulation effect of the warm pool on WWB.

The study presents the observational analysis of the association of WWB with ENSO SST structure and speculates possible dynamic mechanism governing the scale interactions between WWB generation and ENSO background.

2. OBSERVATIONAL EVIDENCE

Evidence of the modulation of equatorial westerly winds by the warm pool displacement is shown in Fig.1, using QuikSCAT wind and TMI SST observations. Only westerly winds (zonal wind≥0) are plotted and the warm pool location is measured by the 29°C SST isotherm (red). Both the wind and SST are the averages over the equatorial band [5°S, 5°N].

Fig.1 indicates that the frequency, amplitude, zonal fetch, and the easternmost longitude of westerly wind events were closely associated with the warm pool movement on ENSO timescales. Strong westerly wind events were most frequent and had largest zonal fetch during the 2002 El Niño.

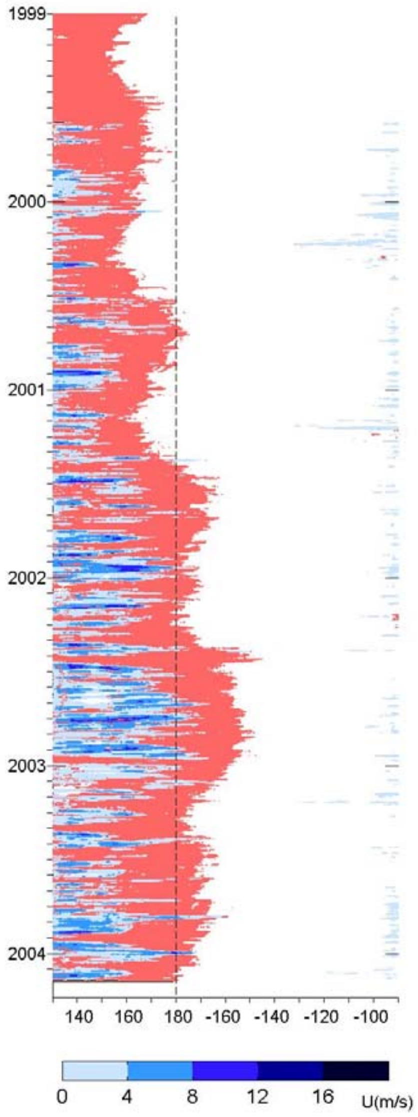

Fig.1 Evidence for the modulation of westerly winds (blue) by the warm pool displacement represented by 29°C SST isotherm (red). The blue color increment is 4 m/s.

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3. CORRELATION WITH ENSO SST

The warm pool displacement had a phase different from the evolution of Niño3 SST index, and the two resonated only during the 2002 El Niño year (Fig.2). Hence, it is not a surprise to see that characteristics of westerly wind events have different correlations with the warm pool displacement and the Niño3 SST index (Figs.3-4). For example, the easternmost longitude of strong westerly winds typical of WWB has a correlation of 0.66 with the easternmost longitude of the 29°C SST isotherm and the correlation of the pair does not change with ENSO phase (Fig.3). On the other hand, the correlation of the easternmost longitude of WWB with Niño3 index shows that the pair has only a weak relationship during El Niño period and no relationship in other years (Fig.4).

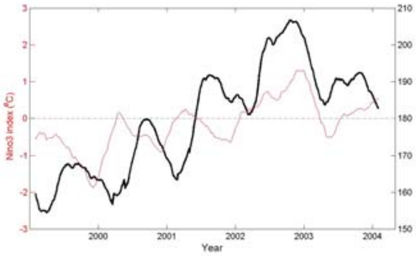

Fig.2 The warm pool displacement (represented by the 29°C SST isotherm) has a phase different from the Niño3 index in non El Niño years.

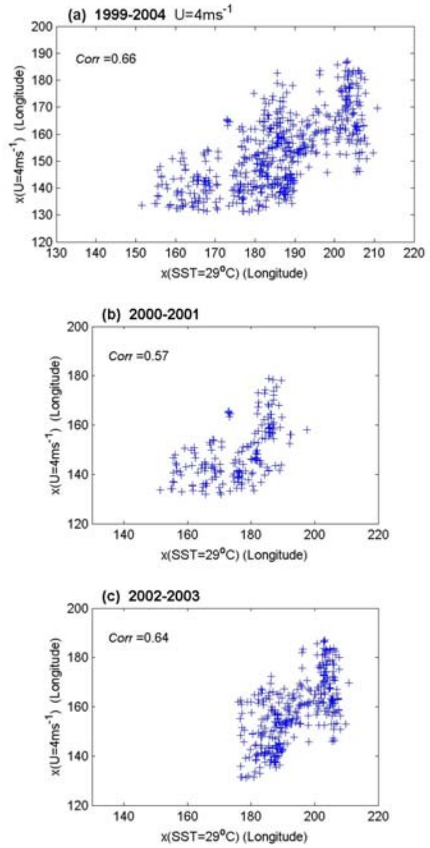

Fig.3 Correlation of the easternmost longitude of WWB with the easternmost longitude of the 29°C SST isotherm.

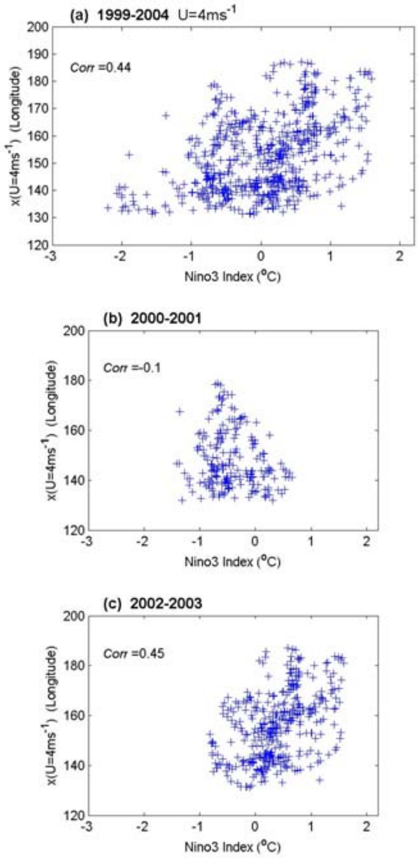

Fig.4 Correlation of the easternmost longitude of WWB with the Niño3 SST index.

4. MECHANISM OF ENSO REGULATION

Strong westerly wind events are generally induced by atmospheric transient forcing such as the convective phase of Madden-Julian Oscillation, intrusion of mid-latitude cold surges, the formation of single or paired tropical cyclones, and/or the combined effects of the three (Yu and Rienecker 1998). However, in some years (mostly during La Niña), very few WWB occur even though all the three atmospheric transient forcing frequent and co-exist over the western equatorial Pacific (WEP).

Yu et al. (2003) analyzed the association of the WWB activity with ENSO background conditions during contrasting ENSO phases, such the onset period of the 1982/83 and 1997/98 El Niños, and the mature phase of La Niña in 1999/2000, and suggested that the *location* of the warm pool plays a role in preconditioning the generation of WWB. The central mechanism is the coupling between high SST and low sea level pressure (SLP) in the WEP, which allows the east-west migration of low SLPs along with the warm pool on ENSO timescales. Positive SLP gradient is established in the WEP when the warm pool/low SLP center are displaced eastward, which then provides a favorable background to enhance the effects of atmospheric transient forcing on the SLP gradient and facilitate the generation of WWB. On the other hand, the SLP gradient in the WEP is near zero or negative when the warm pool/low SLP center are displaced westward, during which WWB can be generated only if the atmospheric transient forcing is large enough to overcome the background condition. The role of warm pool displacement on the generation of WWB under the influence of atmospheric transient forcing is shown in a schematic diagram in Fig.5. As the warm pool moves in phase with the ENSO evolution, the modulation of WWB by the warm pool enables WWB to vary on ENSO timescales (Fig.6).

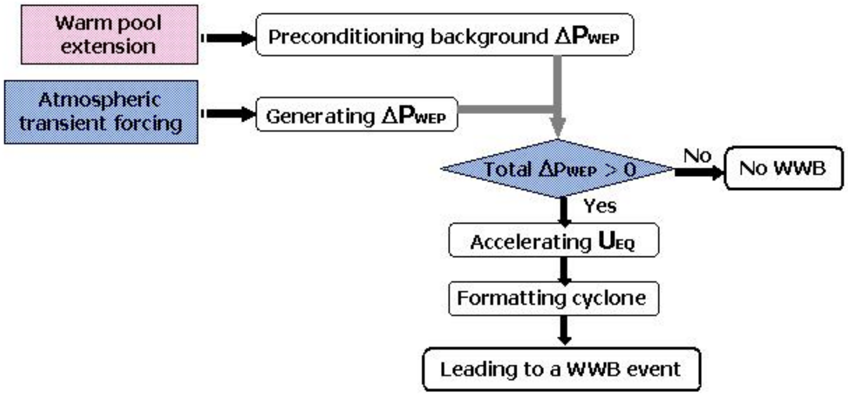

Fig.5 Schematic diagram shows a role of warm pool displacement in modulating the effect of atmospheric transient forcing on the SLP gradient in the WEP, the latter is a key factor in leading to the generation of WWB.

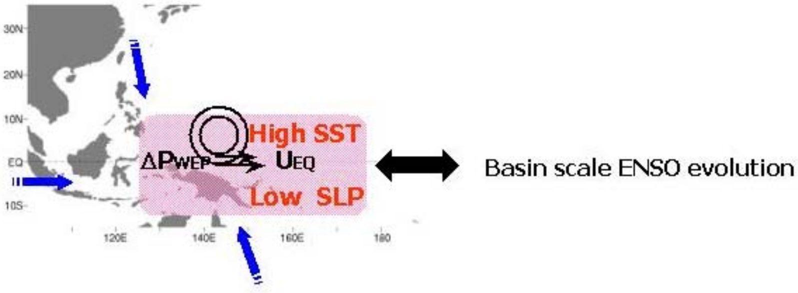

Fig.6 Schematic diagram shows the scale interaction between the generation of WWB and the basin-scale ENSO system. The modulation effect of the warm pool enables WWB to vary on ENSO timescales.

5. SUMMARY

Major features of the study are summarized as follows.

(1) The study presents evidence derived from satellite observations that WWB have a low frequency variation modulated/regulated by the large-scale ENSO SST.

(2) The study suggests that the warm pool location index rather than the Nino3 index can best characterize the ENSO-regulated WWB.

(3) The study describes a possible dynamic role of the warm pool in modulating the effects of atmospheric transient forcing on the SLP gradient in the equatorial western Pacific and on the generation of WWB.

The modulation of WWB by ENSO SST may have the following potential implications.

(1) WWB are important to ENSO dynamics, irregularity, and prediction (Neelin et al. 1998; Philander and Fedorov 2003). That WWB are modulated by ENSO SST rather than an external random forcing suggests that WWB's role in ENSO phase transition is part of the ENSO system itself, not an external agent (Eisenman et al 2004).

(2) WWB can be projected efficiently onto ENSO dynamics and influence ENSO development only if they possess an optimal spatial pattern and/or a low-frequency component (Moore and Kleeman 1999; Roulston and Neelin 2000; Eisenman et al. 2004). That WWB are modulated by ENSO SST suggests that the interaction of WWB with ENSO system is an important element of the coupled ENSO dynamics and should be included in ENSO models.

(3) Characteristics of WWB can be formulated as a function of the state of the warm pool and be parameterized in models.

ACKNOWLEDGMENTS

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