# 11B.1 ESTABLISHMENT OF THE LOW-LEVEL WIND ANOMALIES OVER THE WESTERN NORTH PACIFIC DURING ENSO DEVELOPMENT

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## 1. INTRODUCTION

The low-level wind anomalies over the western North Pacific play an important role in the relationship between the El Niño-Southern Oscillation (ENSO) and the western North Pacific-East Asian climate system (e.g., Chang et al. 2000; Chou et al. 2003; Lau et al. 2001; Lau and Nath 2000; Nitta 1987; Wang et al. 2001). In this study, the focus is on how the anomalous low-level anticyclone is established in the developing phase of El Niño.

## 2. THE MODEL AND EXPERIMENTS DESIGN

To examine mechanisms establishing the anomalous low-level anticyclone over the western North Pacific, an atmospheric model of intermediate complexity (Neelin and Zeng 2000) and a simple land surface model (ZNC) with prescribed SST are used. The atmospheric model constrains the flow by quasi-equilibrium thermodynamic closures and is referred to as QTCM1 (quasi-equilibrium tropical circulation model with a single vertical structure of temperature and moisture for deep convection). To simulate ENSO-related low-level wind anomalies, both El Niño and La Niña SST are used as the forcing. The ENSO experiments are forced by two-year SST from the ENSO developing year (Year 0) to the ENSO decaying year (Year 1). The El Niño SST is obtained from the composite of the six strongest El Niño events (1957-58, 1965-66, 1972-73, 1982-83, 1991-92, 1997-98). Similarly, the La Niña SST is calculated from the composite of the six strongest La Niña events (1970-71, 1973-74, 1975-76, 1988-89, 1998-99, 1999-2000).

## 3. OBSERVATIONS AND EXPERIMENTS

Figure 1 shows the composite differences of SST, 850 hPa winds and precipitation in the winter (from the end of Year 0 to the beginning of Year 1) when El Niño is mature. In the maturing winter, a strong anomalous anticyclone is found over the western North Pacific and the El Niño-associated westerly wind anomalies extend only to 150°E (Fig. 1a). The anomalous low-level anticyclone is believed to be a Rossby-wave response to the suppressed convection that is associated with the low-level divergence anomaly over the western Pacific. Strong negative precipitation anomalies over the western Pacific and the Maritime continent which is associated with the suppressed convection.

Figure 1b shows the model simulations with the prescribed ENSO SST and the anomalous low-level anticyclone over the western North Pacific is well simulated. The negative precipitation anomalies associated with the suppressed convection over the western Pacific are also simulated, but these negative precipitation anomalies do not extend as westward into the eastern part of the Indian Ocean as the observation shown in Fig. 1a. To understand the role of the SST anomalies in the different regions, an experiment forced by the ENSO SST over the eastern Pacific is conducted and the results are shown in Fig. 1c. Without the cold SST anomalies over the western Pacific and the warm SST anomalies over the Indian Ocean, the anomalous low-level anticyclone and the associated negative precipitation anomalies over the western North Pacific (Fig. 2b) are weaker than in Figs. 1a and 1b. Experiments forced by the SST anomalies over the western Pacific and the Indian Ocean show that the cold SST anomalies over the western Pacific alone can also induce an anomalous low-level anticyclone and the corresponding negative precipitation anomalies over the western North Pacific, while the warm SST anomalies over the Indian Ocean induce relatively weaker responses (not shown).

## 4. MECHANISMS FOR ESTABLISHING THE LOW-LEVEL WIND ANOMALIES

The moist static energy budget is examined to understand the mechanisms that induce the suppressed convection. In QTCM1, the ENSO-induced change of the moist static energy budget vertically averaged through the troposphere can be written

$$\frac{p_T}{g}\bar{M}\nabla\cdot\mathbf{v_1}' = -\frac{p_T}{g} < \mathbf{v}\cdot\nabla(q+T) >' + F^{\mathrm{net}'} - \frac{p_T}{g}M'\nabla\cdot\bar{\mathbf{v}}_1, \quad (1)$$

where $(\bar{\ })$ denotes the climatology, $(\ )'$ is the anomalies induced by ENSO, $(\ )_1$ denotes the first baroclinic mode under convective quasi-equilibrium constraints, and $\langle\ \rangle$ denotes vertical average over the troposphere with $p_T$ as the depth of the troposphere. $T$ is atmospheric temperature, $q$ is moisture, $g$ is gravity, and $\mathbf{v}$ is horizontal velocity. The heat capacity at constant pressure, $C_p$, and the latent heat per unit mass, $L$, are absorbed by $T$ and $q$, so $T$ and $q$ are both in energy unit. $M$ is the gross moist stability (Yu et al. 1998) and is defined by

$$M = \langle\Omega(-\partial_p h)\rangle, \quad (2)$$

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where $h$ is moist static energy. $\Omega(p)$ is the vertical structure of vertical velocity from the baroclinic wind

$$\omega(x, y, p, t) = -\Omega(p)\nabla \cdot \mathbf{v_1}(x, y, t), \quad (3)$$

where $\omega$ is pressure velocity. $\nabla \cdot \mathbf{v_1}$ is positive for low-level convergence and upper-level divergence. $\Omega(p)$ is positive, so $M$ is positive too. $F^{\rm net}$ is defined as the net energy input into the atmospheric column:

$$F^{\rm net} = S_t^{\downarrow} - S_t^{\uparrow} - S_s^{\downarrow} + S_s^{\uparrow} - R_t^{\uparrow} - R_s^{\downarrow} + R_s^{\uparrow} + E + H, \quad (4)$$

where subscripts $s$ and $t$ on the solar ($S^{\downarrow}$ and $S^{\uparrow}$) and longwave ($R^{\uparrow}$ and $R^{\downarrow}$) radiative terms denote surface and model top, and $R_t^{\downarrow} \approx 0$ has been used. $H$ is sensible heat flux and $E$ is evaporation.

The term on the left of (1) is an anomalous heating associated with the divergence anomaly, $\nabla \cdot \mathbf{v_1}'$. In the tropics, anomalous heating is associated with ascending motion, i.e. $\nabla \cdot \mathbf{v_1}' > 0$, while anomalous cooling is associated with descending motion, i.e. $\nabla \cdot \mathbf{v_1}' < 0$. The anomalous heating is balanced by vertical average of the horizontal advection of moist static energy, net energy input into the atmospheric column, and an anomalous gross moist stability ($M'$) mechanism. The analysis (Chou 2004) shows that the first term on the right of (1), an anomalous horizontal advection of moist static energy averaged over the troposphere, is the most dominant term of all three. To examine the effect of $-\langle \mathbf{v} \cdot \nabla(T+q)\rangle'$, a climatology of $-\langle \mathbf{v} \cdot \nabla(T+q)\rangle$ obtained from the control run with the SST monthly climatology is used for both El Niño and La Niña experiments, so the effect of $-\langle \mathbf{v} \cdot \nabla(T+q)\rangle'$ is suppressed. Figure 1d shows the results with the SST anomalies only over the eastern Pacific. Comparing to the results of Fig. 1c, the anomalous low-level anticyclone and the negative precipitation anomalies over the western North Pacific have disappeared. This indicates that $-\langle \mathbf{v} \cdot \nabla(T+q)\rangle'$ is a dominant effect on suppressing convection over the western North Pacific in the experiment with the SST anomalies over the eastern Pacific.

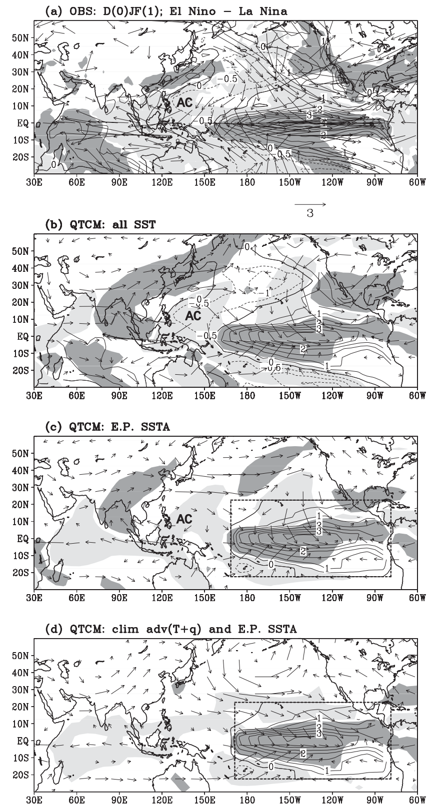


Figure 1. Composite differences of the D(0)JF(1) SST (contour), 850 hPa winds and precipitation (shading) between the El Niño and La Niña for (a) observations and model simulation forced by the ENSO SST over (b) all oceans, (c) the eastern Pacific, and (d) the eastern Pacific with suppressed horizontal advection of moist static energy. Contour interval for SST is 0.5°C. Precipitation anomalies above +0.5 mm day$^{-1}$ are dark shading and below -0.5 mm day$^{-1}$ are light shading. The detail discussion can be seen in Chou (2004).

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