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THE INFLUENCE OF INTERACTION BETWEEN SHIFT OF WARM POOL AND THAT OF THE EQUATORIAL CONVERGENCE ZONE ON ATMOSPHERIC SURFACE WIND FIELDS DURING 1982/83 ENSO

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ABSTRACT

By using a linear and stationary atmospheric model (Luo and Jiang, 1994, Zebiak and Cane, 1987) and the initial data coming from Zebiak and Cane (1987), the influence of interaction between shift of warm pool and that of the equatorial convergence zone (ITCZ and SPCZ) on atmospheric surface stream field and divergence field during 82/83 ENSO is analysed by numerical experiments. The results show that SPCZ is more important than ITCZ in developing phase and mature phase of warm event. The interaction of warm pool and SPCZ is stronger than that of warm pool and ITCZ in the two phases. SPCZ is as important as ITCZ in the initial phase and decline phase of warm event.

Key words: ITCZ and SPCZ, warm pool, ENSO

I. INTRODUCTION

ENSO includes Southern Oscillation (SO) and EI Nino (EN) which are the most important phenomena of annual variation in the tropical atmosphere and ocean. The large scale oscillation called as Southern Oscillation exists in the Pacific and Atlantic. When the pressure of the Pacific increases or decreases, the pressure of Indian ocean from Africa to Australia decreases or increases (Walker, 1923, 1924, 1932). EI Nino is a sudden warming phenomenon of the cold sea water in the coast of southern America from Peru to Ecuador. When SOI is negative, the southern oscillation is related to EI nino. The phenomena are called ENSO event. According to correlation analysis with time lag, the southern oscillation appears before EI nino. The EI nino occuring is a response of ocean to variations of atmospheric surface circulation. The warming SST influences atmospheric variation by feedback mechanism (Chen, 1985, Wyrtki, 1975).

When the warm SST anomaly appears in the tropical Pacific and lasts a long time, we call it as EI nino event (Jiang, 1994). The southern oscillation is related to shift of the equatorial convergence zone (ITCZ and SPCZ). When SOI is negative, the intertropical convergence zone (ITCZ) moves southward. The southern Pacific convergence zone (SPCZ) moves to northeast. Therefore the key variable of interaction between the tropical ocean (thermal factor) and variation of atmospheric surface circulation (dynamic factor) is the shift of warm pool and convergence zone in ENSO cycle. According to the new idea, using an atmospheric model of simple coupled air-sea model (Zebiak and Cane. 1987. Jiang, 1994), we analyse the interaction between warm pool and equatorial convergence zone in different stages. We design a standard experiment and three sensitivity experiments. Difference of the sensitivity experiments and the standard experiment reflects the role of the equatorial convergence zone. The effects of interaction between SPCZ or ITCZ and warm pool on atmospheric surface stream and divergence fields are discussed in the paper.

Ⅱ. ATMOSPHERIC MODEL

According to the linear shallow water equation of general circulation in quasi-steady state, and using dissipation relations of Rayleigh friction and Newtonian cooling, the atmospheric model on an equatorial β plane can be written as:

$$\begin{cases} \varepsilon u_a^n - \beta y v_a^n = -\left(\dfrac{p^n}{\rho_0}\right)_x, \\ \varepsilon v_a^n + \beta y u_a^n = -\left(\dfrac{p^n}{\rho_0}\right)_y, \\ \varepsilon\left(\dfrac{p^n}{\rho_0}\right) + C_a^2\left[(u_a^n)_x + (v_a^n)_y\right] = -Q, \end{cases} \tag{1}$$

where ε, β_0, C_a represent dissipation coeffient, meridional gradient of Coriolis parameter and free atmospheric wave speed respectively. Q is the diabatic heating. u_a^n, v_a^n, p^n are the zonal, meridional wind anomaly and pressure anomaly respectively.

Eliminating u_a^n and v_a^n in equation (1), we obtain an elliptical differential equation.

$$p^n + \frac{C_a^2}{(\varepsilon^2 + \beta_0^2 y^2)}\left[-(p_{xx}^n + p_{yy}^n) + \frac{\beta_0(\varepsilon^2 - \beta_0^2 y^2)}{\varepsilon(\varepsilon^2 + \beta_0^2 y^2)}p_x^n + \frac{2\beta_0^2 y^2}{(\varepsilon^2 + \beta_0^2 y^2)}p_y^n\right] = -\frac{\rho_0}{\varepsilon}\dot{Q}, \tag{2}$$

By using iteration method (iteration coeffient is 1.6), the equation (2) can be solved (Luo et al., 1994).

Ⅲ. DATA AND THE EXPERIMENT DESIGN

1. *Data*

Data come from Zebiak and Cane (1987). There are the monthly mean sea surface temperature anomaly (SSTA), the climatologically monthly mean sea surface temperature (SST) and climatologically monthly mean surface wind stress. The computing domain is over 84×30 grids (2 longitude ×2 latitude).

2. *Experiment Design*

To discuss the importance of interaction between the convergence zone and warm pool in different phases of warm event, we design 4 numerical experiments.

● The standard experiment (EO): the experiment is similar to Zebiak and Cane's work (1987). The atmospheric heating includes the linear heating related to SSTA and the nonlinear heating related to the convergence feedback of water vapor.

$$\dot{Q} = \dot{Q}_s + \dot{Q}_1^{n-1} \tag{3}$$

where Q$_s$ and Q in (3) take the form as following: $Q_s = \alpha T\exp[(\overline{T} - 30°\mathrm{C})/16.7°\mathrm{C}]$, $Q_1^n = \beta[M(\overline{C} + C^n) - M(C)]$, where

$$M(x)=\begin{cases}0 & x\leqslant 0,\\ x & x>0,\end{cases}$$

n denote the nth iteration, C^n is the nth iteration divergence anomaly. $\overline{T}$ the climatic monthly mean sea surface temperature (SST), T the monthly mean SSTA, $\overline{C}$ the climatic monthly mean divergence, α, β the proportion factors, and $\overline{C}=0$.

- Sensitivity experiment 1 (E1) : the climatic monthly mean equatorial convergence zone is involved in E0.
- Sensitivity experiment 2 (EN): we consider the role of ITCZ and neglect the influence of SPCZ.
- Sensitivity experiment 3 (ES): we consider the role of SPCZ and neglect the influence of ITCZ.

The difference between the standard experiment and the sensitivity experiment reflects the role of equatorial convergence zone in ENSO cycle. E0—E1 represents the role of ITCZ and SPCZ. E0—EN is the role of ITCZ. E0—ES reflects the role of SPCZ. ENSO is divided into 4 different phases. They are the initial phase (May, 1982) , the developing phase (September, 1982), the mature phase (December, 1982) and the decline phase (March, 1983).

IV. ANALYSIS OF THE NUMERICAL EXPERIMENT AND INTERACTION BETWEEN EQUATORIAL CONVERGENCE ZONE AND WARM POOL

1. *The variation of climatic monthly mean convergence zones (SPCZ and ITCZ) with time*

Fig. 1 is the climatic monthly mean divergence distribution in March, May, September and December. SPCZ is at 15°S and ITCZ is at 20 °N in May and March (Fig. 1a and Fig. 1d). SPCZ is stronger in March than in May. In September ITCZ moves southward to 5 °N. SPCZ is located in the middle Pacific and its distribution is from northwest to southeast. In December SPCZ moves northeastward. The ranges of ITCZ and SPCZ are enlarged and their intensities are stronger (Fig. 1).

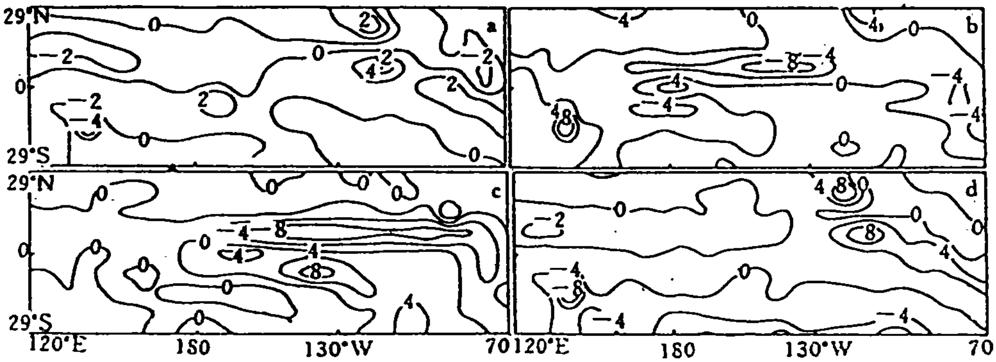

Fig. 1. The distribution of climatic monthly mean divergence ($10^{-6}s^{-1}$).
(a) May (b) September (c) December (d) March

2. *The role of the equatorial convergence zone (ITCZ and SPCZ) in ENSO cycle*

The role of the equatorial convergence zone is divided into two parts. The first part is vorticity anomaly caused by the equatorial convergence zone and reflects the influence of equatorial convergence zone on atmospheric surface stream field. The second part is the divergence anomaly caused by the equatorial convergence zone and reflects its influence on atmospheric surface divergence fields.

1) THE INFLUENCE OF EQUATORIAL CONVERGENCE ZONE ON ATMOSPHERIC SURFACE VORTICITY

From Fig. 2 we can know that the voticity exists in the entire Pacific in the initial phase (Fig. 2a), in the developing phase it is located in the middle and eastern Pacific (Fig. 2b), in the mature phase it exists again in the entire Pacific and its intensity is increased (Fig. 2c), in the decline phase it is located in the northwest and southeast Pacific and its main part in the southeast Pacific (Fig. 2d).

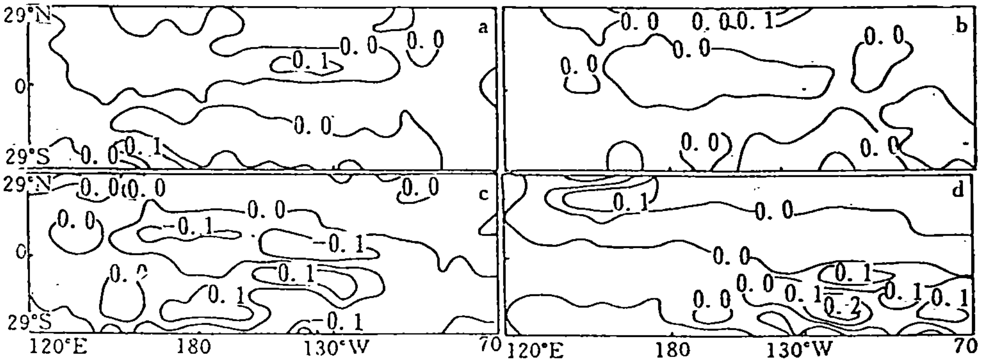

Fig. 2. Anomalies of atmospheric surface vorticity anomaly caused by the equatorial convergence zone($10^{-5}s^{-1}$). a. initial phase; b. developing phase; c. mature phase; d. decline phase.

2) THE DIVERGENCE ANOMALY CAUSED BY THE EQUATORIAL CONVERGENCE ZONE

In the initial phase of warm event the divergence anomaly exists in the entire Pacific and its center is located in the west and middle Pacific (Fig. 3a). In the developing phase it moves to the middle east Pacific and its intensity increases (Fig. 3b). In the mature phase it moves continually to the east and is located near 130°W (Fig. 3c) . In the decline phase it is in the eastern Pacific (Fig. 3d).

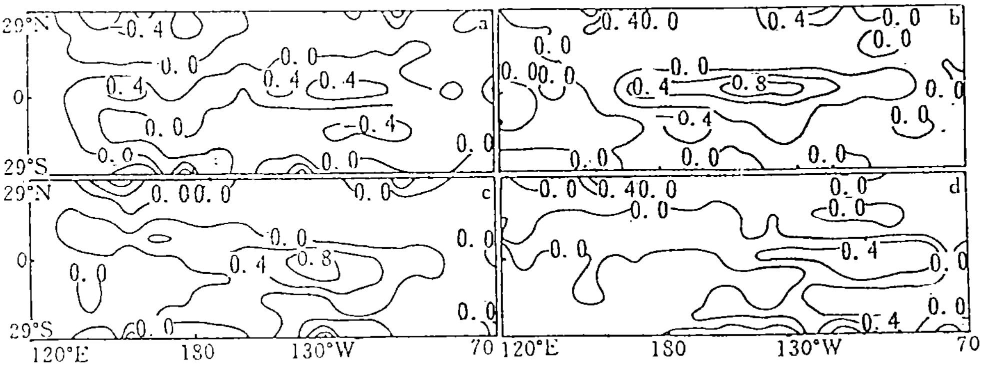

Fig. 3. Anomalies of atmospheric surface divergence caused by the equatorial convergence zone ($10^{-6}s^{-1}$). (a), (b), (c) and (d) are the same as Fig. 2.

Comparing Fig. 2 with Fig. 3, we can see that the influence of the equatorial convergence zone on atmospheric surface stream and divergence fields is very different and the influence range of the equatorial convergence zone on atmospheric surface stream fields is larger than that on atmospheric surface divergence fields in the mature and decline phases.

3. *The role of ITCZ in ENSO cycle*

1) THE VORTICITY ANOMALY CAUSED BY ITCZ

Fig. 4 is the vorticity field in the ITCZ, which influences the entire Pacific vorticity fields in the initial phase of warm event (Fig. 4a). The vorticity anomaly caused by ITCZ is located in the eastern Pacific in the developing phase (Fig. 4b). In the mature phase ITCZ influences northwest Pacific (Fig. 4c). In the decline phase it influences the entire Pacific again. The most sensible regions are the northwest and eastern Pacific.

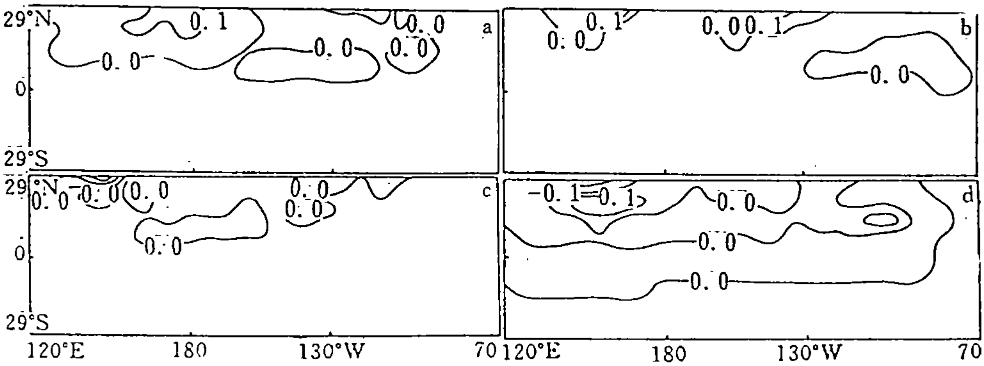

Fig. 4. Atmospheric surface vorticity anomaly caused by ITCZ ($10^{-5}s^{-1}$).
(a), (b), (c) and (d) are the same as Fig. 2.

2) THE DIVERGENCE ANOMALY CAUSED BY ITCZ

The influence of the ITCZ on the vorticity fields is similar to that on divergence fields, but its influence range can reach the southern hemisphere. The most sensible region is also in the northwest Pacific (Figure omitted).

4. *The role of SPCZ in ENSO cycle*

1) THE INFLUENCE OF SPCZ ON ATMOSPHERIC SURFACE VORTICITY

In the initial phase, SPCZ influences the atmospheric surface vorticity of western and eastern Pacific and the strongest influence region is the western Pacific (Fig. 5a). In the developing phase, it influences the voticity of the middle Pacific (Fig. 5b). In the mature phase, the situation is similar to that of the developing phase, but its influence is stronger (Fig. 5c). In the decline phase, its influence regions are in the eastern and southeast Pacific (Fig. 5d).

2) THE INFLUENCE OF SPCZ ON ATMOSPHERIC SURFACE DIVERGENCE

When the warm pool moves from the western Pacific to the eastern Pacific and ENSO changes from the initial phase to the decline phase, the influence range of SPCZ varies from the west to the east. The situation is similar to that of Fig. 5 (Figure omitted).

5. *The relative importance of SPCZ and ITCZ in ENSO cycle*

Comparing Fig. 4 and Fig. 5, we know that the influence extent of ITCZ and SPCZ is similar in the initial and decline phases. Generally SPCZ influences the southern hemi-

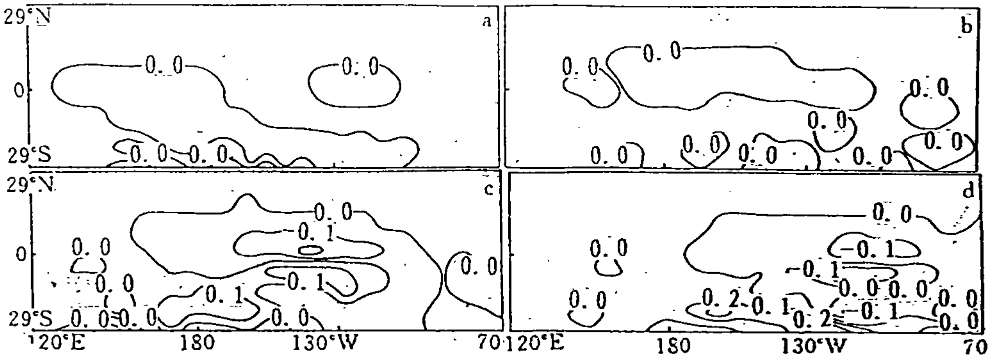

Fig. 5. Atmospheric surface vorticity anomaly by SPCZ ($10^{-5}s^{-1}$).
(a), (b), (c) and (d) are the same as Fig. 2.

sphere and ITCZ influences the northern hemisphere. Their influence on the other hemisphere is very small. In the developing and mature phase SPCZ is more important than ITCZ. Their importance are determined by the location of warm pool and shift of ITCZ and SPCZ. Therefore the allocation of the equatorial convergence zone and warm pool determines their influence ranges.

V. THE ROLE OF ITCZ AND SPCZ IN OCEAN-ATMOSPHERE SYSTEM

From the initial phase to decline phase, the influence of the equatorial convergence zone is mainly in the western Pacific, the middle Pacific, the middle-east Pacific and the eastern Pacific. The evolution and the equatorial convergence zone evolution are evidently different. The evolution of ITCZ and SPCZ can not explain their influence ranges. In 1982/83 ENSO event the warm pool moves from the western Pacific to the eastern Pacific. Its variation is similar to that of the influence ranges.

Therefore, the possible influence mechanism of ITCZ and SPCZ on the atmospheric surface wind fields is: the warm pool heats the low-level atmosphere and causes atmospheric convergence and vertical motion, which produces the convective heating (Webster, 1988) . The heating influences the atmospheric motion. ITCZ and SPCZ are superposed in the convergence effects caused by warm SST and causes a stronger vertical motion and precipitation, which influences the atmospheric surface wind fields.

VI. CONCLUDING REMARKS

We use a simple atmospheric model in a coupled air-sea model system to study the role the equatorial convergence zone in ENSO cycle. We find that ITCZ and SPCZ are important in ENSO cycle. The interaction between the equatorial convergence zone and warm pool causes the variation of atmospheric surface vorticity and divergence, which are intensified from the western Pacific to eastern Pacific. The roles of ITCZ and SPCZ are different in various phases of the warm event. In the developing and mature phases SPCZ is more important than ITCZ. In the initial and decline phases SPCZ is as important as ITCZ. Their influence on the atmospheric surface vorticity and divergence fields is also different in various phases. The cause to bring about the difference will be studied in future.

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