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GLOBAL STRUCTURE OF THE SOUTHERN OSCILLATION

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1. INTRODUCTION

The Southern Oscillation (SO) is now recognized as one of the dominant climatic fluctuations in the tropics with the time scale of several years or so. In recent years the SO coupled with the anomalous sea surface temperature (SST) over the central through the eastern Pacific has been called the El Nino/Southern Oscillation (ENSO). This ENSO has been revealed to be an importand modulator of the climatic anomalies in the middle and high latitudes of the northern hemisphere through the Rossby-wave propagation mechanism (e.g., Horel and Wallace, 1981 etc.). The circulation anomalies in the higher latitudes of the southern hemisphere associated with the ENSO are also apparent (e.g., Trenberth, 1976 etc.). The SO (or ENSO) may be, therefore, characterized as a part of the global circulation anomalies with the time scale of several years.

The current study attempts to explore the three-dimensional structure of the circulation anomalies over the entire globe associated with the ENSO events in the tropics. Of major interest is to understand the whole scenario of the ENSO as a normal mode of the global climatic system. In this paper, a particular interest will be paid to the zonal structure of the wind field in the tropics and the time evolution of the anomalous circulation at 200 mb through a cycle from the El Nino to the anti-El Nino and to the next El Nino event over the entire globe.

2. DATA AND METHOD OF ANALYSIS

Monthly climatic data for the world (upper air data) of 18 years (1964 to 1981) is the main data source. The NMC tropical operational wind field analysis is additionally utilized. The objectively-analized global data set (5°x5°) of U,V,T,Z were produced by using the least-square method (Pan, 1979) to fit the time-filtered data (of more than 320 stations as well as the NMC grid-point wind field of about 80 points) to truncated spherical harmonics of wavenumber 0 to 5. The Rhomboidal truncation was adopted. The recursive time filter was used to deduce the anomalies of 30 to 60 month period associated with the ENSO events.

In addition to the data set thus produced, the global sea level pressure data set (Krishnamurti et al., 1985) and the global SST data set compiled at NOAA were also analized.

3. ANOMALOUS WIND FIELD IN THE TROPICS

In the tropical troposphere, the ENSO manifests itself as a zonally-oriented direct (heat-induced) circulation cell along the equatorial Pacific i.e. the "Walker circulation" (Bjerknes, 1969). In a mean state, the upward branch is located over the warm, moist Indonesian maritime continent, whereas the downward motion is located over the relatively cool and dry central through eastern Pacific. The circulation cell along the equatorial plane is shifted eastward or is extremely weak at the minimum phase (i.e., El Nino phase) of the ENSO. As this local Walker circulation is characterized as a part of the global east-west circulation (Krishnamurti, 1971; Krishnamurti et al., 1973), the east-west circulation in the tropics should modulate or should be modulated by the ENSO events.

Fig. 1 shows the time-longitude cross sections of the zonal wind at 200mb and 700mb along the equator (10°N-10°S), composited for each phase of the SO cycle by using 4 SO cycles. Category 1 denotes the anti-El Nino phase (the coldest SST anomalies in the eastern Pacific) and category 5 denotes the El Nino phase. A remarkable feature in the two diagrams are eastward propagation of the anomalies particularly from the Indian Ocean toward the eastern Pacific with a phase speed of about 5° longitudes. Here, one category roughly corresponds with 5-7 months. The anomalies over the south America through Africa show, in contrast, a standing type oscillation particularly at 200 mb. The easterly (westerly) anomalies at 200mb well corresond with the westerly (easterly) anomalies at 700mb over the Indian Ocean through

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the Pacific. At category 5 (El Nino phase), the easterly anomaly reaches its maximum at 200 mb while the westerly anomaly at 700mb shows its maximum over the central Pacific region. These features suggests the eastward propagation of the anomalous east-west circulation over the Indian Ocean-Pacific Ocean sector associated with the ENSO events.

4. TIME EVOLUTION OF ANOMALOUS GLOBAL CIRCULATION AT 200 MB

Anomalous streamfunction as well as velocity potential fields were produced from the filtered U, V anomalies. Fig. 2 shows the composite anomalous streamfunction field at 200mb for category 1, 2, 3, 4 and 5 (i.e., the first half of the SO cycle). The definition of each category is the same as Fig. 1. Category 1 (anti-El Nino phase) shows the anomalous westerly over the equatorial central Pacific and the anomalous easterly over the Indian Ocean, which suggests the stronger than normal convection over Indonesian region. A reversed PNA-like pattern is noted over the northern Pacific through north America. The cyclonic circulation anomalies over the equatorial central Pacific is also apparent coupled with the anti-cyclonic circulation anomalies to the south of it. Category 2 shows a very similar pattern as a whole to that at category 1, which may imply a strong persistence of the anomalies at the anti-El Nino phases. Category 3 shows a drastic change of the anomalous circulation over the entire globe. This phase denotes the intermediate stage from the anti-El Nino to the El Nino. One of the remarkable features is a development of the anti-cyclonic circulation over Australia, which may imply the intensification of the subtropical high over there. Another dominant feature is an appearance of the cyclonic circulation anomalies over the northern subtropics, particularly over the southern part of Eurasia through north Africa. Associated with these circulation changes, the zonal wind anomalies in the tropics are reversed to those at anti-El Nino phases (category 1 and 2). Category 4 corresponds with the beginning stage of the El Nino, where the anti-cyclonic circulation over Australia shifts more eastward, and the pattern of Rossby-wave train appears over the norhtern and the southern Pacific region. At category 5 (El Nino phase) the circulation anomalies over the Pacific are further intensified, which suggests the stronger than normal convection over the central through the eastern Pacific. The overall features are nearly opposite to those at category 1.

Thus, the circulation change from the anti-El Nino (El Nino) to the El Nino (anti-El Nino) seems to occur at the relatively short intermediate stage, presumably initiated with the change of the anomalies over Eurasia , Indian Ocean through Australia.

5. CONCLUSIONS

Through the preliminary analysis of the filtered wind and circulation anomalies associated with the SO, significant changes of the circulation field were depicted over the entire globe. The eastward propagation of the east-west circulation in the tropics was confirmed, which has also been discussed in Yasunari (1985). Rossby-wave like patterns are apparent over the northern and southern Pacific region during the El Nino and anti-El Nino phases. Other remarkable features are the appearances of the deep cyclonic (anti-cyclonic) circulation anomalies over the southern part of Eurasia through north Africa and of the deep anti-cyclonic (cyclonic) circulation anomalies over Australia during the intermediate phase from anti-El Nino (El Nino) to El Nino (anti-El Nino). These results suggest the important role of the circulation changes over Eurasia, Indian Ocean through Australia on the evolution of the whole ENSO cycle.

The results of further detailed analysis of the global aspects of the ENSO will soon be issued elsewhere.

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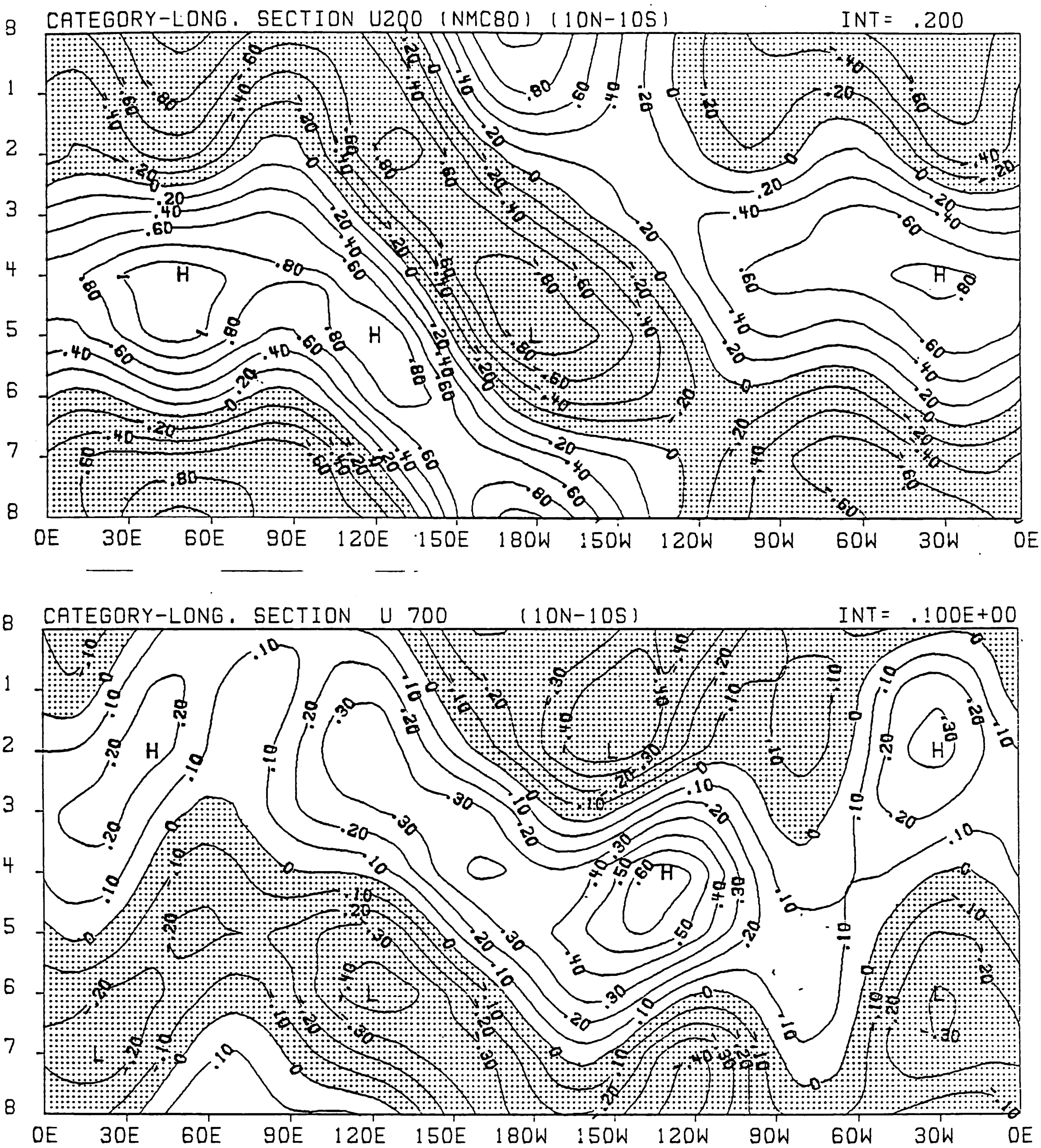
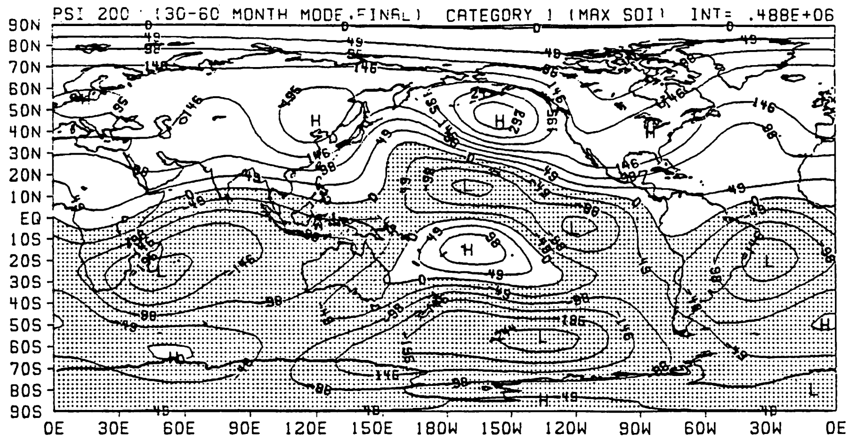
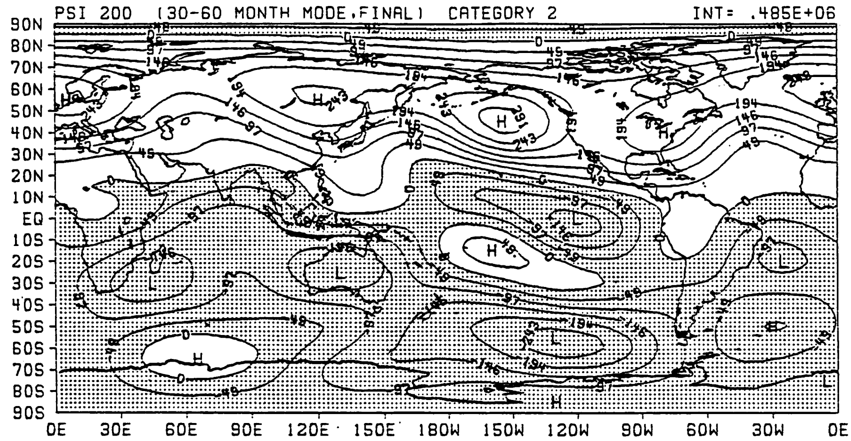


Fig. 1 Category-longitude sections of zonal wind at 200mb (upper) and 700mb (lower) along the equatorial belt (10°N-10°S) composited with 4 SO cycles. 1 SO cycle is devided by 8 categories. Category 1 denotes the anti-El Nino phase, and category 5 denotes the El Nino phase. Each category has a length of 5-7 months. Units are $0.2\ ms^{-1}$ (upper) and $0.1\ ms^{-1}$ (lower), and negative (easterly) anomalies are shaded.



1 (anti-El Nino)



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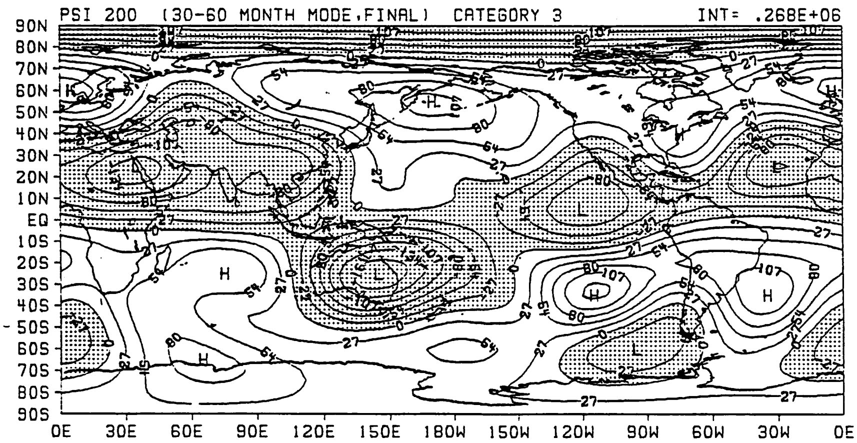

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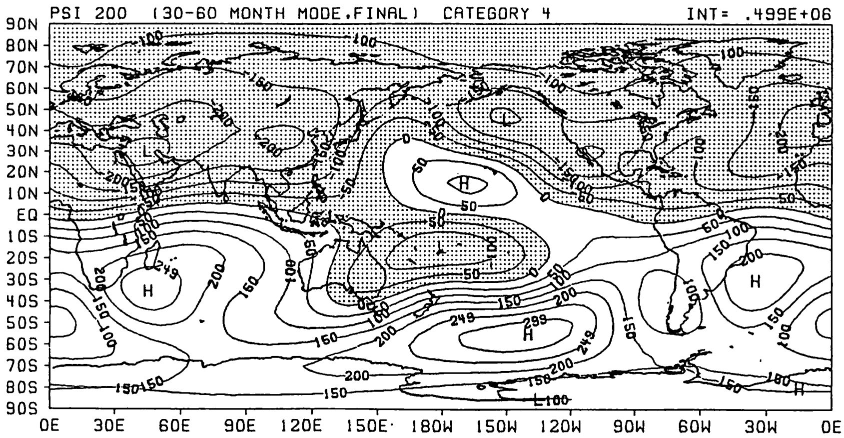

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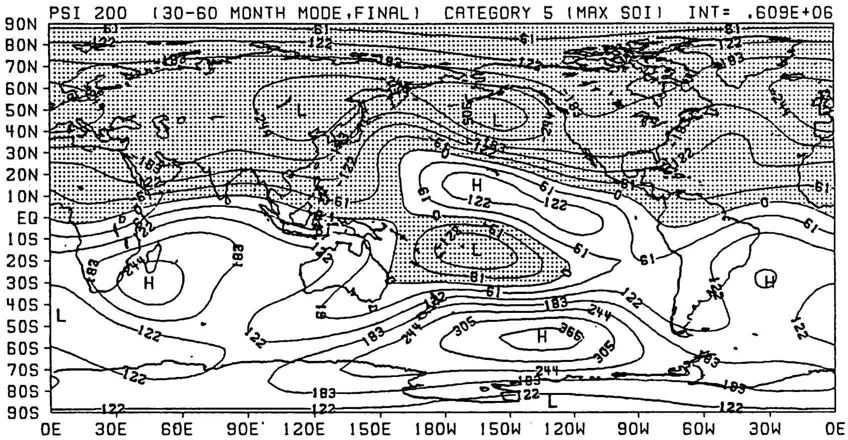

5 (El Nino)

Fig. 2 Global maps of filtered stream function at 200 mb for category 1 through 5 composited with the 4 SO cycles. Contour intervals for each map are shown at the upper-right corner of each map. Units are m^2s^{-1} . Negative values are shaded.