Global Oceanic Climate Anomalies in 1980's

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ABSTRACT

The climate in the 1980's is characterized by the appearance of two strong ENSO events and by the warmest decade in global mean temperature. Whether there is a linkage between ENSO and global warming ? This paper shows the climate anomaly patterns over the global ocean in the 1980's and their comparison with that of ENSO composite mode and that simulated by $2 \times CO_2$, indicating the role of super ENSO in the establishment of new climate regime in the 1980's.

Key words: Climate anomaly, ENSO, Global warming

I. INTRODUCTION

Although the climate anomalies occur almost every year here and there around the world, it should be pointed out that there are two important aspects in the global climate in the 1980's:

(1) The decade of 1980's is the warmest one since 1900. Four warmest years in the global mean temperature records all appear in this decade which is followed by some warm years in the early 1990's (IPCC, Climate Change 1992, the supplementary report to the IPCC Scientific Assessment).

(2) The 1982–83 ENSO event is the strongest one in this century (Rasmusson and Wallace, 1983), which was followed by another rather strong ENSO event in 1986–87 within the same decade (Fu et al., 1992).

So far we still know very little why the 1982–83 ENSO event was so strong? What are the unique oceanic and atmospheric dynamics to create this event? Why the time interval between two strong events is much shorter than usually (Quinn, 1987)? Are they related in certain extent to the global warming? For instance, does the warm earth provide the background which is favorable for the development of strong ENSO events? On the other hand, we know very little either why the 1980's was extremely warming all over the globe? Do CO_2 and other trace gases in the atmosphere increase abruptly in that decade? The answer is no. Did the so-called super-ENSO event in 1982–83 stimulate the feedback process in the atmosphere warming (Flohn et al., 1992)? For instance, would the enhancement of global evaporation and tropical convection in relating to the development of ENSO event be favorable to the water vapour feedback process in the greenhouse effect?

As a first step towards understanding these questions, this paper will make an analysis on the major features of the climate anomalies over the global ocean in the 1980's, mainly for the Northern winter and their linkages with the global warming and the ENSO phenomenon. Section 2 presents the analysis on the decade mean departure fields of thermal and dynamic variables over the ocean for the 1980's and followed by a further study on the changes within the decade in Section 3. Section 4 presents the abrupt feature of the establishment of new *climate regime in the 1980's. Section 5 is a brief discussion on the possible linkage between* super ENSO and global warming in the 1980's.

II. GLOBAL OCEAN CLIMATE IN THE 1980's

1. *Sea Level Pressure*

Since the most strong signals appear mainly in the Northern winter, the analyses in this *section and later on are focused on the season of December, January and February, except* where mentioned for other seasons especially. It is seen from the sea level pressure departure field that the strong departures are shown in the North Pacific: a deepening Aleutian low with the seasonal mean departure of −6.0 hPa, while the increasing pressure appeared in most part of the tropics and subtropics in all seasons, especially over the Pacific (see Fig. 1), indicating a strong Pacific high in this period. As a result, the meridional pressure gradient in the middle latitudes of the Pacific is strengthened obviously. Over the Atlantic, the sea level pressure pat*terns changed from season to season: a deepening Iceland low in the season of September to* November and a weakening one in the season of March to May (Figures are not shown).

The sea level pressure departure pattern for Dec.−Feb. (DJF) of the 1980's from the mean of 1950−1979 is quite similar to the composite pattern for that of warm episode (van Loon, 1986), especially the deepening Aleutian low and the positive departure over the central and western tropical Pacific, while the negative departure over the eastern equatorial Pacific is not as strong as that for warm episode.

On the other hand, the model simulated DJF mean sea level pressure for $2 \times CO_2$ minus

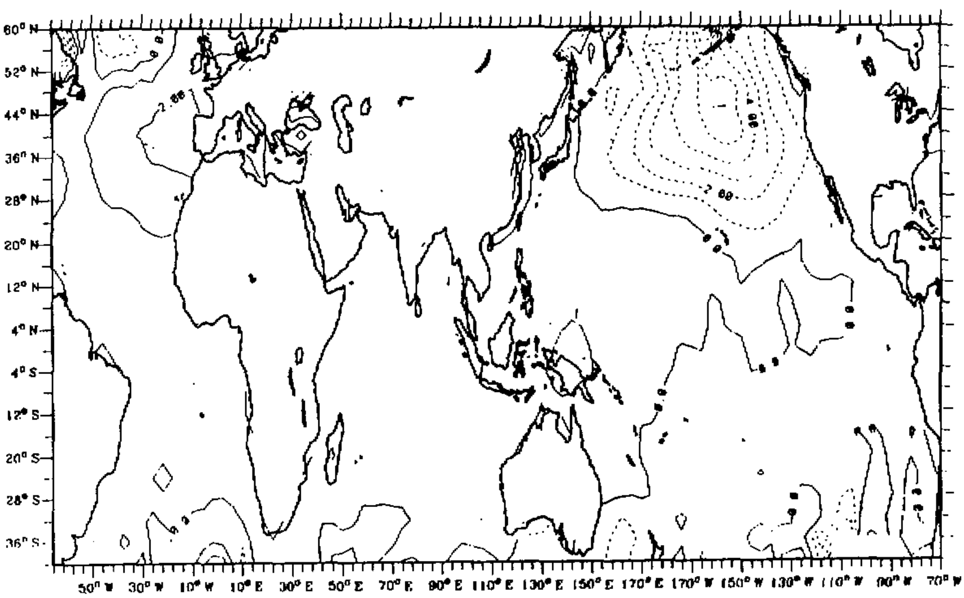

Fig. 1. Seasonal mean (Dec.− Feb.) sea level pressure departure (SLPD) over global ocean for 1980's.

$1 \times CO_2$ shows also a deepening Aleutian low with a center of −6.0 hPa (Boer, 1991). It also shows a positive departure area over the North Atlantic similar to that of the 1980's. It seems hardly to distinguish the contributions of ENSO phenomenon and that of global warming from each other to this observed decade mean sea level pressure pattern.

2. *Surface Wind Field*

In relating to sea level pressure pattern, the surface wind field shows the strong signal also over the Pacific. In the field of zonal component, U (Fig. 2a), there is an enhanced subtropical westerlies along 30°N (+3.0 m / s in departure from 1950−1979) and an enhanced equatorial westerlies over the western and central Pacific (+1.5 m / s) as well. This feature is in an opposite direction with that of $2 \times CO_2$ simulation. Under the $2 \times CO_2$, there would be weaker lower tropospheric westerlies in the northern middle latitudes (Washington and Meehl, 1989). Fig. 2a shows also easterly anomalies over the regions of both northeast and southeast trade wind zones in the Pacific, representing the enhancement of the trade wind systems in both hemispheres. Over the Indian Ocean and Atlantic Ocean, the trade winds were also enhanced.

In the field of meridional component, V (Fig. 2b), the distribution of meridional flows matches with the deepening Aleutian low very well over the North Pacific and with the enhanced North Atlantic high and the Iceland low over the North Atlantic region. Another interesting feature is the enhancement of equatorial convergence resulting from the strong northerly flow to the north of the equator and the strong southerly flow to the south over almost three ocean basins. This is an indicator of enhancement of global mean Hadley Circulation.

In summary, the atmospheric circulation over the global ocean in the 1980's is characterized mainly by the enhancement of the strength of atmospheric basic flows as well as the mean meridional circulation, especially over the Northern Hemisphere. This feature is in the opposite direction with that simulated climate under $2 \times CO_2$ in which the basic zonal flows are weaker due to the reduce of meridional thermal gradient (Manabe, 1991).

3. *Sea Surface Temperature and Specific Humidity*

As seen from Fig. 3a, the strong cooling occurred in the North Pacific where there was a deepening Aleutian low and in the northern Atlantic where there was a deepening Iceland low. Such a cooling is mainly related to the upwelling of cold water below the surface under the strong action of deep pressure system and perhaps the evaporative cooling due to strong surface wind. The rest of ocean, mainly the Southern Ocean were warming, especially in the tropical Pacific and South Atlantic. With such a departure pattern, the global mean north−south thermal gradient was stronger (Figure 4), especially over the Pacific and Atlantic oceans which supports the enhancement of global atmospheric circulation as mentioned above.

The field of specific humidity near surface showed similar pattern as that of sea surface temperature, but with the signal even strong over the tropical Pacific where there were strong horizontal convergence and high sea surface temperature (Fig. 3b). Such a circumstance is also favorable to the development of atmospheric convection in the tropics and therefore the release of latent heat flux over there which provides the energy source for the development of Hadley circulation.

In relating to the energy source, Fig. 5 presents the changes of warming pool in the western Pacific. Its area increased from 110 km^2 in the period of 1950's−mid−1970's to 160 km^2 in

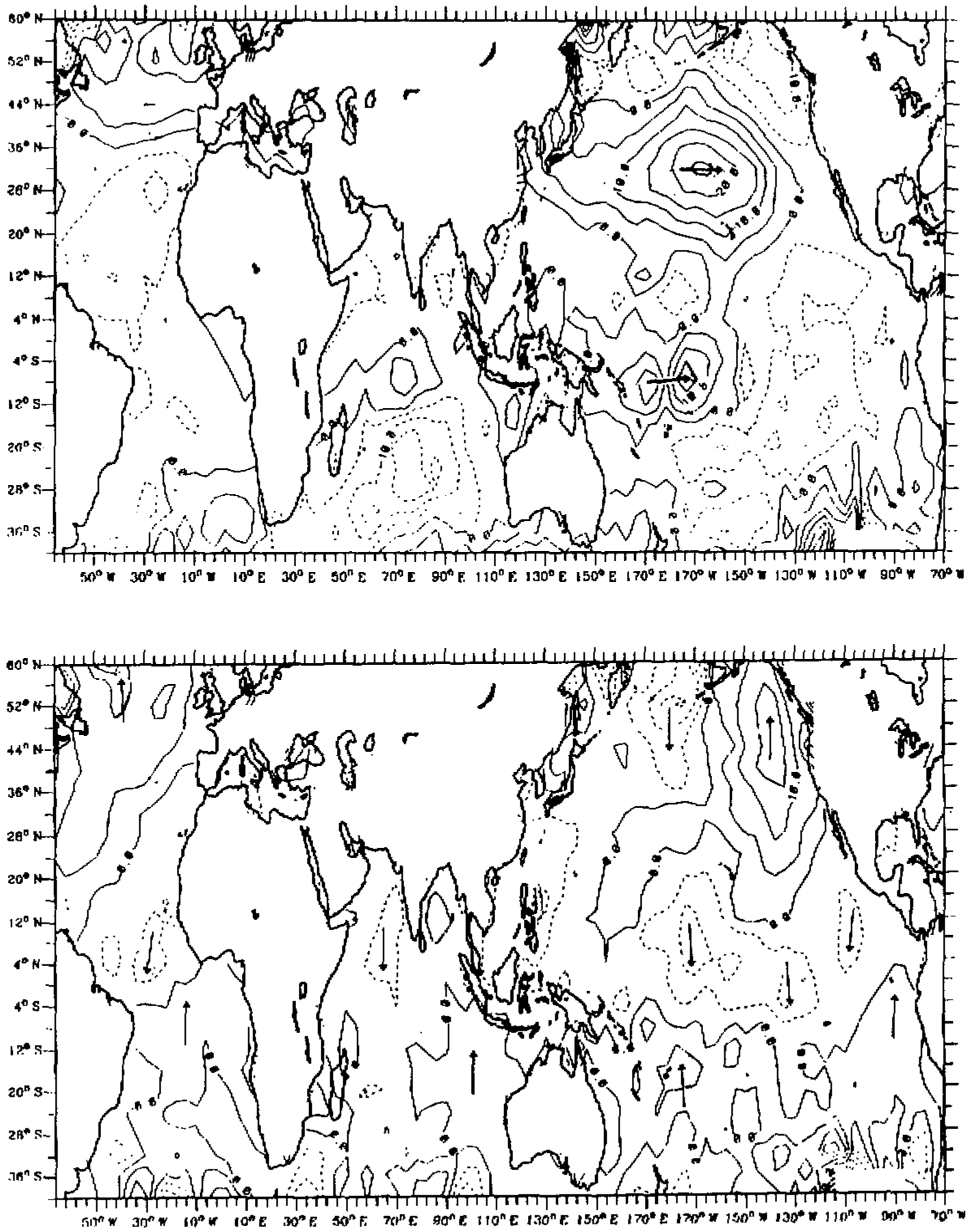

Fig. 2. As in Fig. 1a, but for two components of marine surface wind (a) u–component and (b) v–component.

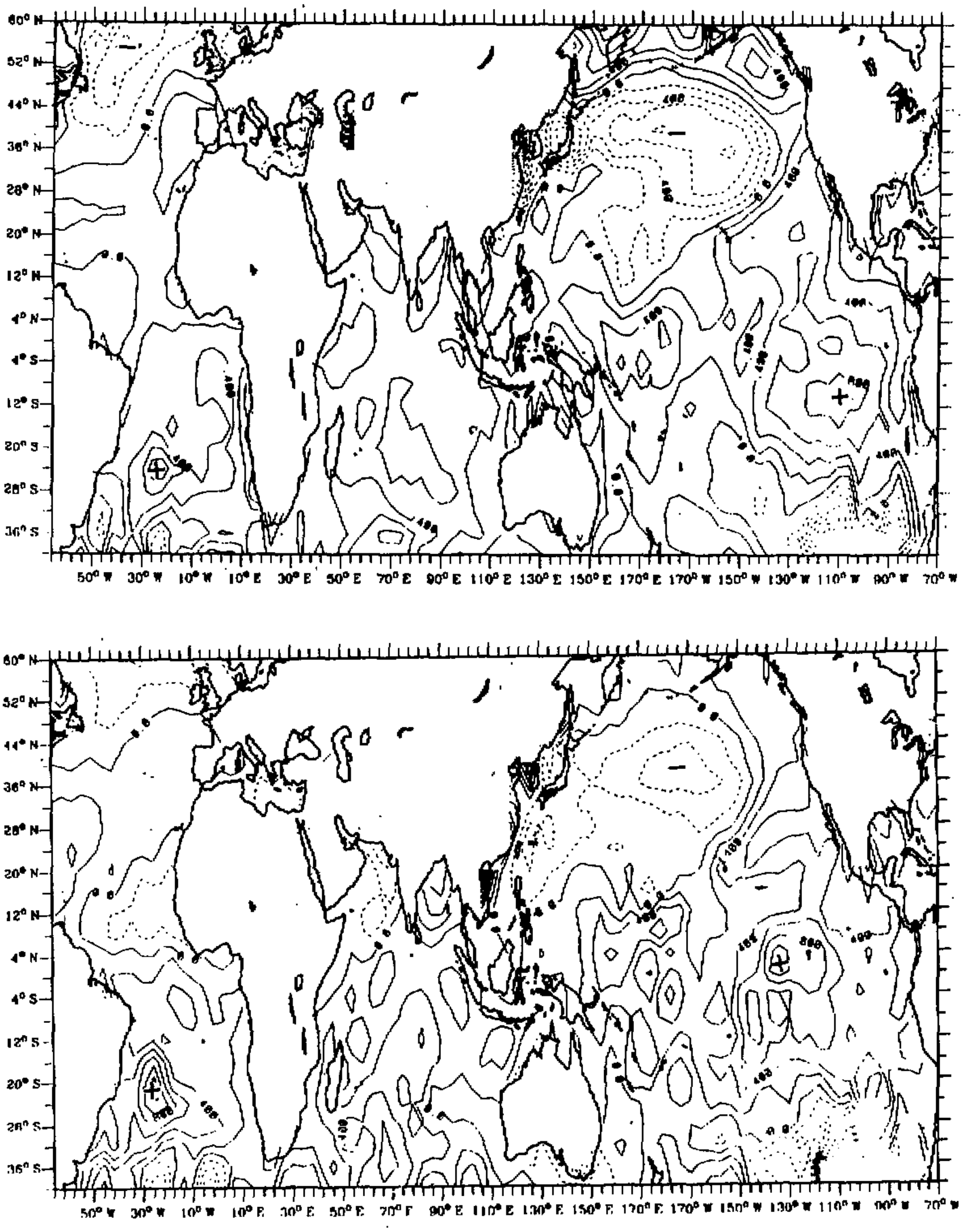

Fig. 3. As in Fig. 1a, but for (a) sea surface temperature and (b) specific humidity.

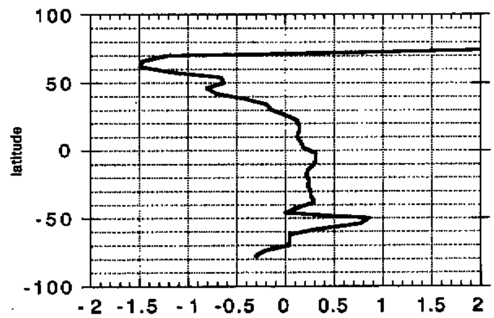

Fig. 4. The meridional profile of zonal mean sea surface temperature over the global ocean in January of 1980's.

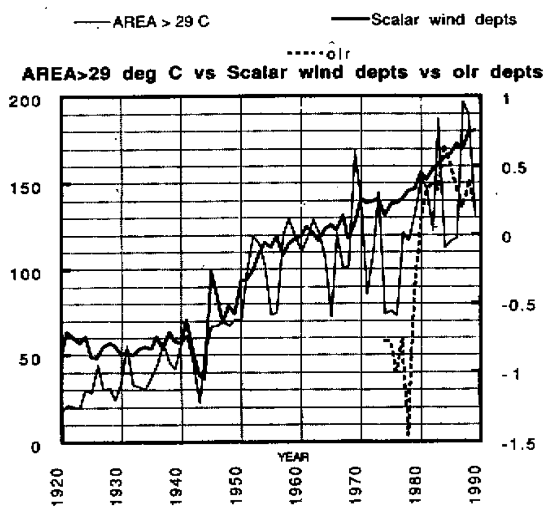

Fig. 5. The variation of the area of warming pool in the western Pacific (> 29°C). (Fletcher,J. Personal communication).

the 1980's (Fletcher, J. personal communication). This expanding warming pool is very likely the energy source to furnish the atmosphere to enhance the circulation.

The internal consistence between the thermal fields and dynamic fields over the global ocean may provide a possible interpretation for the climate anomalies in the 1980's. We shall discuss this aspect later on.

III. CLIMATE VARIATION WITHIN THE DECADE OF 1980's

As mentioned in the last section, the most pronounced feature of climate anomalies during the 1980s is the enhancement of atmospheric circulation. Therefore the time evolution of the representative variables for the strength of mean circulation is going to be analyzed first.

1. *Westerlies and Trade Wind over Northern Ocean*

Fig. 6a presents the variation of u component of surface wind over the latitude of 34°N–54°N of global ocean for the period of 1979–1990 in which both the observed wind and the geostropheric wind are given in order to assure the reliability of data. First of all, the internal consistence between U_o and U_g in this figure in both their year to year variation and the trend indicates that the so–called bias in the surface wind report over the ocean is not significant to mask the natural behavior for the period and region which we have discussed (Fu et al., 1995).

There is a pronounced enhanced trend in the middle latitude westerlies of the Northern Hemisphere for about 3 m / s during this period which is superimposed by a quasi–biennual variation. The t–test values are 5.09 and 4.98 for U_o and U_g respectively and reach at the significant level of $\alpha = 0.005$. The trade wind system over the northern ocean shows also an enhanced trend significantly as presented in Fig. 6b. The t–test values for the trend in U_o and U_g reach the significant level of 0.005 too. Therefore the enhancement of the westerlies and trade wind reflects not only in their departure from the climatological mean, but also in the trend within this period.

2. *Sea Surface Temperature and Humidity*

The global mean sea surface temperature shows clear ENSO signals for the events of 1982–83 and 1986–87 and even in the weak one in 1979, but no warming trend in this period (Fig. 7a). The global mean air–sea humidity difference, Qs–Qa (Fig. 7b) shows also strong ENSO signals in all the three events mentioned above. Especially the Qs–Qa enhanced significantly in the 1982–83 event and then almost remained at the same level in the next event, i.e. 1986–87. Therefore there is a pronounced increasing trend in the humidity field during this period.

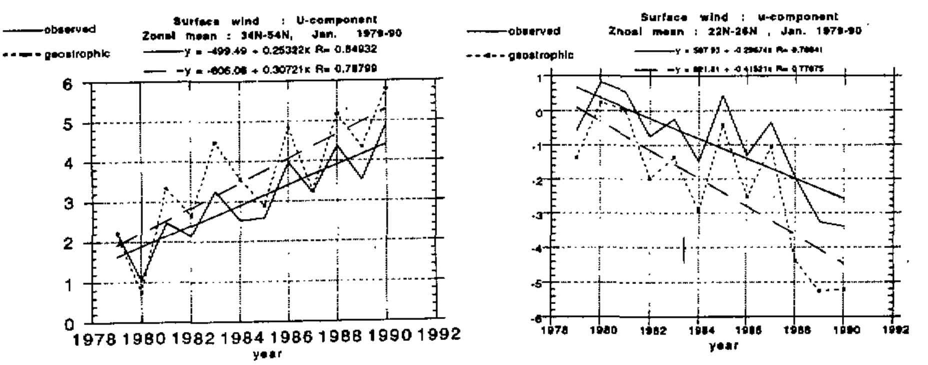

Fig. 6. The variation of u–component of surface wind over the ocean in the 1980s for latitude of (a) 34–54°N and (b) 22°N. U_g and U_o are the geostrophic wind and the observed one respectively. Dashed line is the linear fitting.

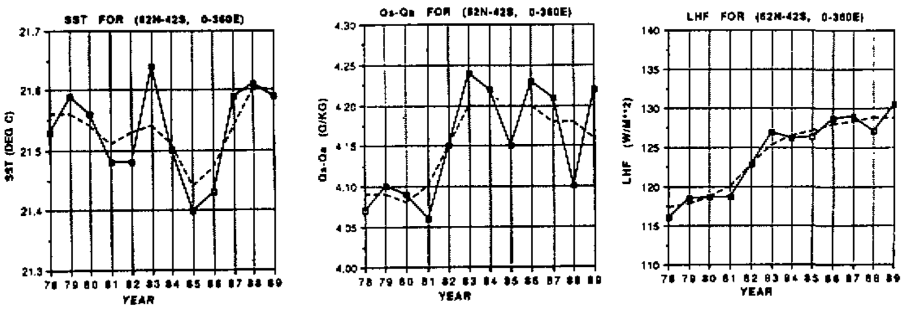

Fig. 7. (a) The variation of global mean sea surface temperature in 1980's; (b) same as Fig. 6a, but for $Qs-Qa$, air–sea humidity difference; (c) same as Fig. 6a, but for air–sea latent heat flux.

3. *Air–Sea Latent Heat Flux*

The global mean air–sea latent heat flux (Fig. 7c) shows the strong enhancement during the warm episodes of two recent ENSO events, but it did not recover from the previous level during the cold episodes and therefore an increasing trend appeared in this period as that in the $Qs-Qa$. The enhancement of latent heat flux during this period is also related to the enhancement of surface wind as shown in Fig. 2.

IV. ABRUPT CHANGES OF OCEANIC CLIMATE IN MIDDLE 1970's

The time evolution of many variables for the period of 1950–1990 shows an abrupt feature in their changes, indicating the establishment of new regime of global climate in the 1980's.

1. *Southern Oscillation Index*

The Southern Oscillation index which describes one of the major characteristics of global atmospheric low frequency motion presented an abrupt decrease around 1976 and since then it has been well below the mean until recently, with only few occasions to be slightly above the mean. That means the negative phase of Southern Oscillation was rather weaker during this period. Such a behavior indicates that the global tropical circulation has now come into a new regime very likely (Fig. 8a, NOAA Environmental Digest, 1990).

2. *Global Tropical Land Air Temperature*

The tropical temperature (Fig. 8b, Diaz, quoted from NOAA Environmental Digest, 1990) increased abruptly around later 1976 too and is remained well above the mean. No negative value is shown until recently. Since the major heat sources in the tropics are located over the land area, the increasing temperature over there indicates the enhancement of tropical heating, which may provide the energy sources for the new climate regime. Since the temperature referred here is that over the land, but not over the ocean and not the sea surface temperature, the warming trend over there cannot be attributed to the appearance of strong ENSO events.

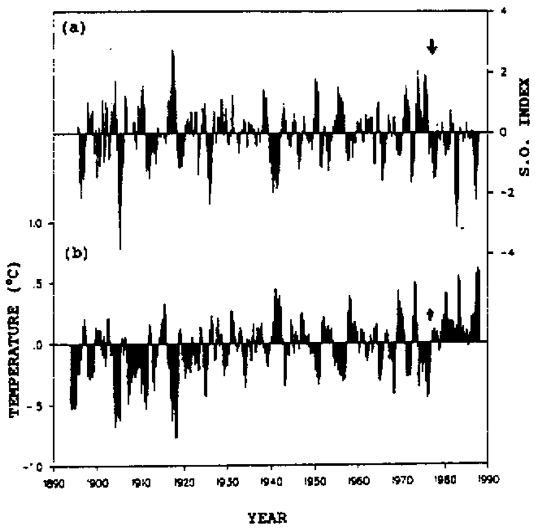

Fig. 8. (a) Time series of Southern Oscillation index since 1895 based on Tahiti–Darwin monthly sea level pressure; (b) average air surface temperature anomalies (with reference to 1950–1979 period) over the tropical land area (After NOAA Environmental Digest, 1990).

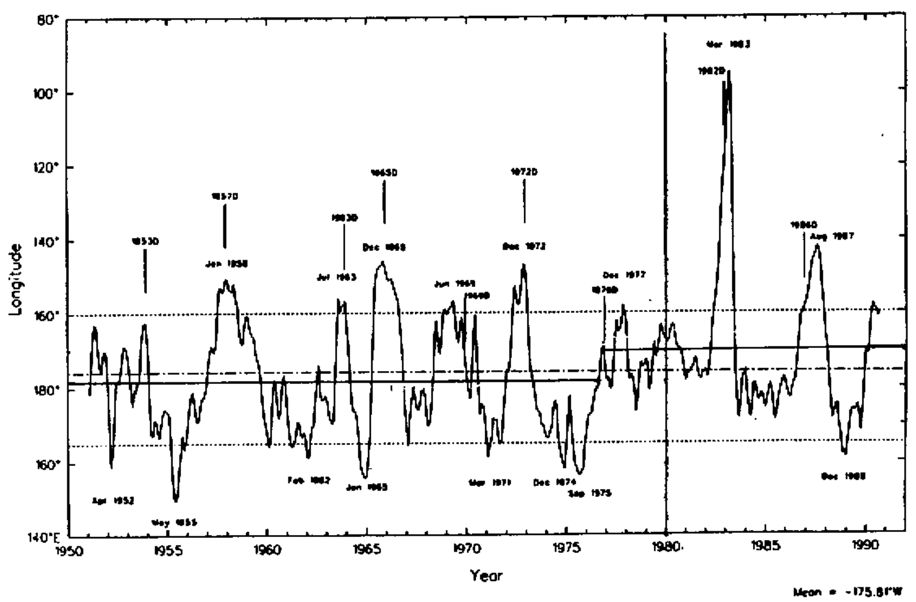

Fig. 9. The variation of the eastern edge of the warming pool (based on 28.5°C thermal line).

3. Equatorial Warming Pool

However, the equatorial warming pool in the western Pacific is another major heat source in the tropics. Both the size of warming pool and the eastward extension of this pool show an abrupt development feature. For instance, The eastern edge of the 28.5°C thermal line has been used to indicate the eastward extension of the pool (Fu, Fletcher and Diaz, 1986). Fig. 9 shows that it shifted from the mean longitude of 178.54°W during the 1951–1976 to 170.54°W afterwards. An about 8 longitude eastward shift of this heat source would no doubt have significant impact on the global climate.

4. North Pacific High

The subtropical high over the North Pacific is one of the atmospheric action centers, which has significant influence on the weather and climate in the eastern Asia. The persistent changes of this system often result in dramatic changes in the regional climate in large domain (see Fig. 10). During recent period, it was enhanced in later 1976 and maintains strongly until recently (Fu et al., 1990). The climate regime over the eastern Asia seems to be closely related to this action center. Superimposed on the curve of subtropical high index, there is a curve of sea surface temperature for the eastern equatorial Pacific which shows a continuous equatorial warming after middle of 1976.

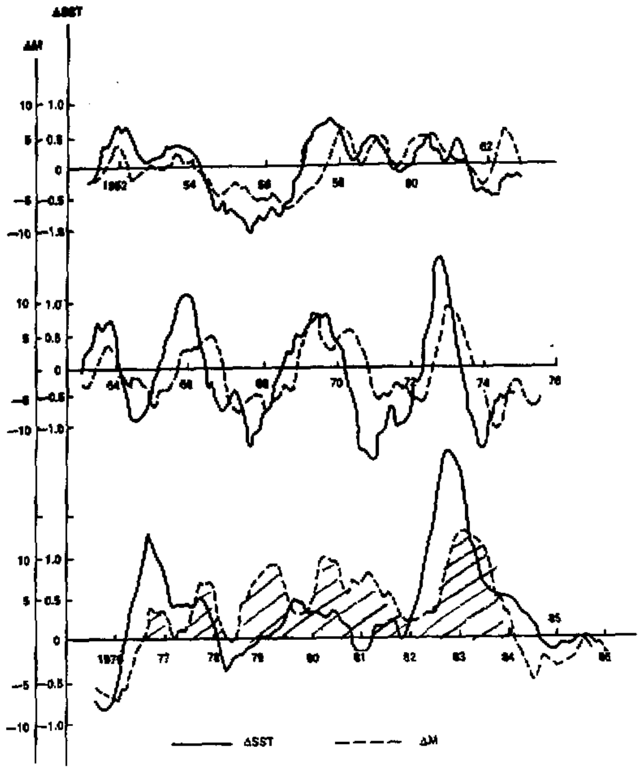

Fig. 10. The variation of Northwest Pacific high index since 1950.

V. DISCUSSION ON THE POSSIBLE LINKAGE BETWEEN ENSO AND GLOBAL WARMING

Based on above analysis, it may be concluded that the climate in the 1980's seems to enter a new regime which is characterized by the enhanced global atmospheric circulation, mainly in the Northern Hemisphere. This is the interdecadal climate variability.

The energy source for the circulation enhancement is mainly due to the increasing south-north thermal gradient, the baroclinic energy. The appearance of two super ENSO events in 1982–1983 and 1986–1987 created much warmer temperature over the global tropical ocean and the more active tropical convections which results in the release of latent heat over there and then warming the upper troposphere too. Both make their contributions to the enhancement of meridional thermal gradient.

On the other hand, the background state of warming earth, such as continuous warming over the tropical land, due to certain reasons which we don't know yet now, may provide the favorable conditions to the development of super ENSO events. In addition, the strong trade wind during this period would also be favorable to the build up of ocean dynamics of ENSO.

As a feedback, the enhancement of global ocean evaporation during the super ENSO may also stimulate the green house effect in the atmosphere resulting in the continuous warming. However this greenhouse effect is mainly due to the H_2O rather than to the CO_2. Since the enhancement of global ocean evaporation and the increasing atmospheric moisture are limited mainly in the tropics, the warming would appear also mainly in the tropics as we observed, which is significantly different from that simulated under $2 \times CO_2$ in which more warming appears in higher latitudes than in low latitudes.

It is our notion that the observed climate anomalies in the 1980's are mainly attributed to the appearance of two super ENSO events rather than to the global warming of CO_2 effect. On the other hand, the interdecadal climate variability due to some known reasons may provide the background conditions, such as the strength of atmospheric flow and global mean temperature, which are favorable to the development of strong ENSO events.

Of course, the linkage between ENSO phenomenon and global warming must be a nonlinear interaction process in the climate system, the simple analysis of this paper is just to provide some observed aspects and to draw much attention to this interesting question.

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