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Characteristics of change of the SST in the tropical western Pacific and the tropical Indian Ocean and its response to the change of the Antarctic ice area

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Abstract In this paper, by using ocean surface temperature data(COADS), the study is made of the characteristics of the monthly and annual changes of the SST in the tropical western Pacific and Indian Oceans, which have important influences on the climate change of the whole globe and the relation between ENSO(El Niño-Southern Oscillation) and the Antarctic ice area is also discussed. The result indicates that in the tropical western Pacific and the Indian Oceans the change of Sea Surface Temperture (SST) is conspicuous both monthly and annaully, and shows different change tendency between them. This result may be due to different relation in the vibration period of SST between the two Oceans. The better corresponding relationship is obvious in the annual change of SST in the tropical Indian Ocean with the occurrence El Niño and La Niña. The change of the SST in the tropical western Pacific and the tropical Indian Oceans has a close relation to the Antarctic ice area, especially to the ice areas in the eastern-south Pole and Ross Sea, and its notable correlative relationship appears in 16 months when the SST of the tropical western Pacific and the Indian Oceans lag back the Antarctic ice area.

Key words Antarctic ice area. SST. tropical western Pacific Ocean. Indian Ocean. tropical eastern Pacific Ocean.

1 Introduction

Warm Pool is called for the warm water areas in the tropical western Pacific Ocean and the tropical Indian Ocean, which are more stable than those in other areas year by year, and this region plays an important role in global air-ocean interaction. The research shows that anomaly variation of the SST in the tropical western Pacific Ocean and the tropical Indian Ocean is an earlier stage sign in global climate change, it is particularly important that the anomaly variation of circulation in the two regions leads to redistribution of the ocean current of the heat transport poleward and longitudeward in the period of ENSO (Pazan *et al*. 1986), this kind of anomaly change will cause the variation of global climate finally. Owing to the region with its particular property, World Meteorological Organization and International Council of Scientific Union work out Tropical Ocean and Globe Atmosphere Research Programme and carry on TOGA investigation, the aim just is to make an intensive study of the process of the warm pool in the western Pacific.

Many researchers have gone on researches to the ocean surface property of the tropical western Pacific and the Indian Oceans. Because of the different conditions, such as the time series of data and its accuracy, the research results will be a certain influenced. In this paper, we are attempting further to study and analyse the change property of the SST in the tropical western Pacific and the Indian Oceans and its relation to the Antarctic sea ice area by using the data of SST for 1950 – 1992, providing reference for the interaction research of the polar-tropical regions.

2 The change property of the SST in the tropcial western Pacific and Indian Ocean

2.1 The monthly change

In order to reflect the change property of SST in the tropical western Pacific and the Indian Oceans, the annual SST in the tropical western Pacific and Indian Oceans has been given (Bai *et al.* 1993) (figure is omitted), the result shows that the SST of the tropical western Pacific and the Indian Oceans is the highest in the whole sea area, and its mean value reaches above 28℃, this area just is the place where the Walker circulation rises. For convenience of an understanding the change of the SST in the tropical western Pacific (10℃S – 10℃N, 110° – 180℃E) and in the tropical Indian Oceans (10℃S – 10℃N, 42° – 110℃E) in the different seasons, the monthly change curve is given (Fig. 1).

As seen in Fig. 1, the monthly change of the SST in the tropical Indian Ocean is very clear, and monthly mean temperature is 27.5℃, and the highest SST is in April, and the value is 28.6℃. The lowest SST is in August, and the value is 26.5℃, the

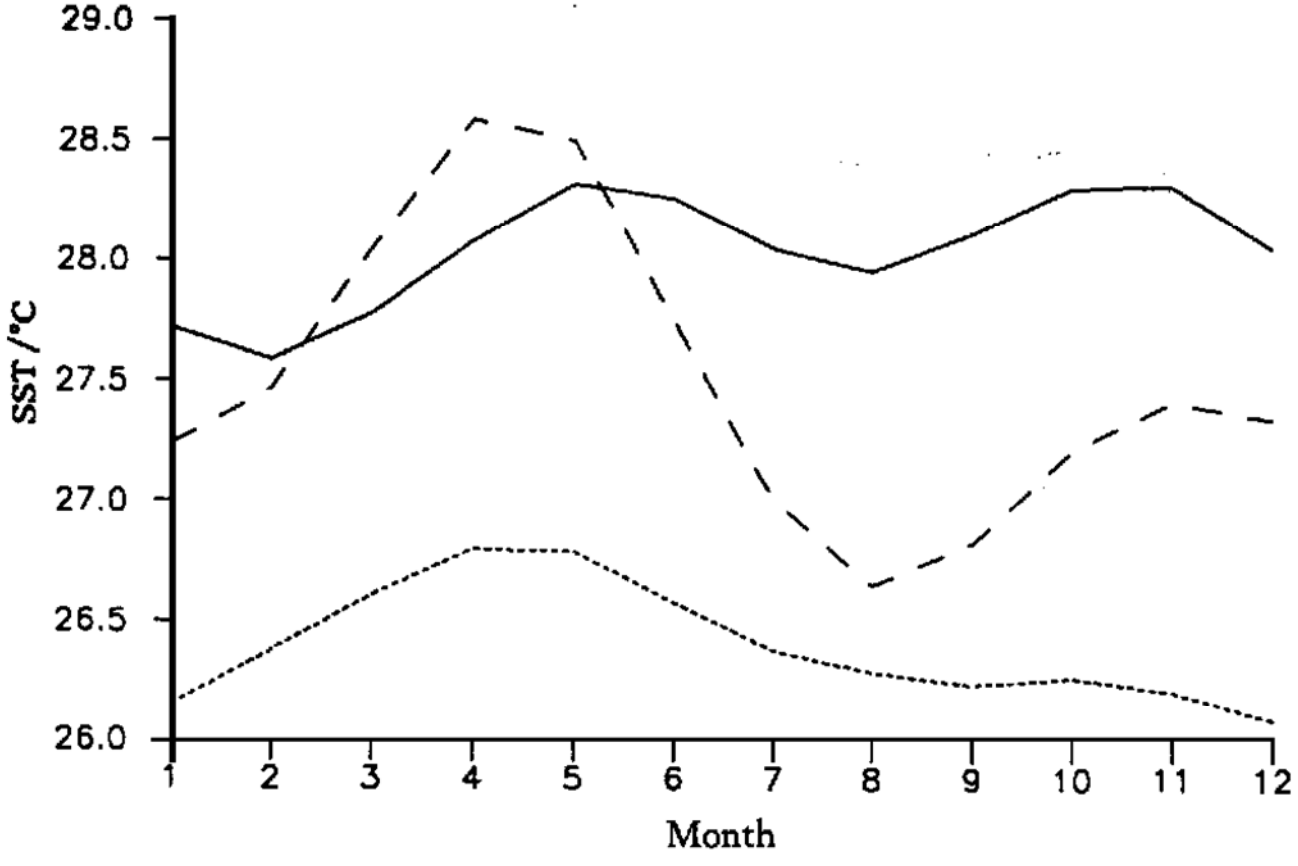

Fig. 1. Monthly change curve of SST in the tropical eastern Pacific(…), western Pacific(——) and Indian Ocean(– –).

annual range is about 2℃. The monthly change of the SST in the tropical western Pacific Ocean is weak relatively, and monthly average temperature is 28.1℃, and the highest value is in May and November (28.3℃), and the lowest value is in February (27.6℃), and the annual range is about 0.7℃. Therefore explanation the monthly change of the SST in the tropical Indian Ocean is clearer than that of the tropical western Pacific Ocean. Another different feature is that monthly average temperature of the tropical Indian Ocean is lower than that of the tropical western Pacific Ocean, and there is an obvious difference in the time when appear the highest temperature and the lowest temperature between the tropical western Pacific Ocean and the tropical Indian Ocean. Thus we can think that although the Indian Ocean is adjacent to the western Pacific Ocean, the difference in the temperature field change property is very obvious between the two Oceans.

2.2 The annual change

The tropical western Pacific and the tropical Indian Oceans are not separate completely, the throughflow between the western Pacific and Indian Oceans can pass seasonally and exchange the water with each other (Inoue and Welsh 1993), this kind of throughflow not only changes monthly but also notably changes annually (Kindle and Hurburlt 1992), the warm water exchange is an important factor so that warm pool is formed and maintained between the tropical western Pacific and the Indian Oceans (Wyrtki 1989).

Furthermore in order to explore the action that the change of SST in the tropical western Pacific and the Indian Oceans plays in the formation of warm pool, we analyze the annual change of the SST in the tropical Indian Ocean and the tropical western Pacific Ocean(Fig. 2). Fig. 2c shows that the annual variation of the SST in the tropical Indian Ocean is obvious and the maximum positive and negative value is in a better corresponding relation with El Niño and La Niña (Fig. 2a). The SST of the tropical western Pacific Ocean also shows a clear vibration, but the relation between them is oposite as compared with the SST in the Indian Ocean, and also there is the oposite corresponding relation with El Niño and La Niña. This result is coincided with the analyses of Huang and Sun (1994).

2.3 The relationship of the SST of the tropical Indian Ocean and the western Pacific Ocean, and that with SST in the tropical eastern Pacific Ocean

In recent ten years, the people pay much attention to the world climate change. Before the 1970′s, the people concentrated attention to the anomaly variation of the SST in the tropical eastern Pacific Ocean and proposed a model of air-sea interaction that influenced on the world climate(Wyrtki 1982), but since the 1980′s, new views have been raised, it has been believed that anomaly change of SST in the tropical Indian Ocean and the western Pacific Ocean caused these areas to become important areas of ENSO. To understand the annual change of the SST in the tropical western Pacific and the tropical eastern Pacific Oceans, the power spectrum of the SST in the tropical Pacific and Indian Oceans has been used(Table 1).

Table 1 shows that period of SST in the tropical Indian Ocean and the tropical west-

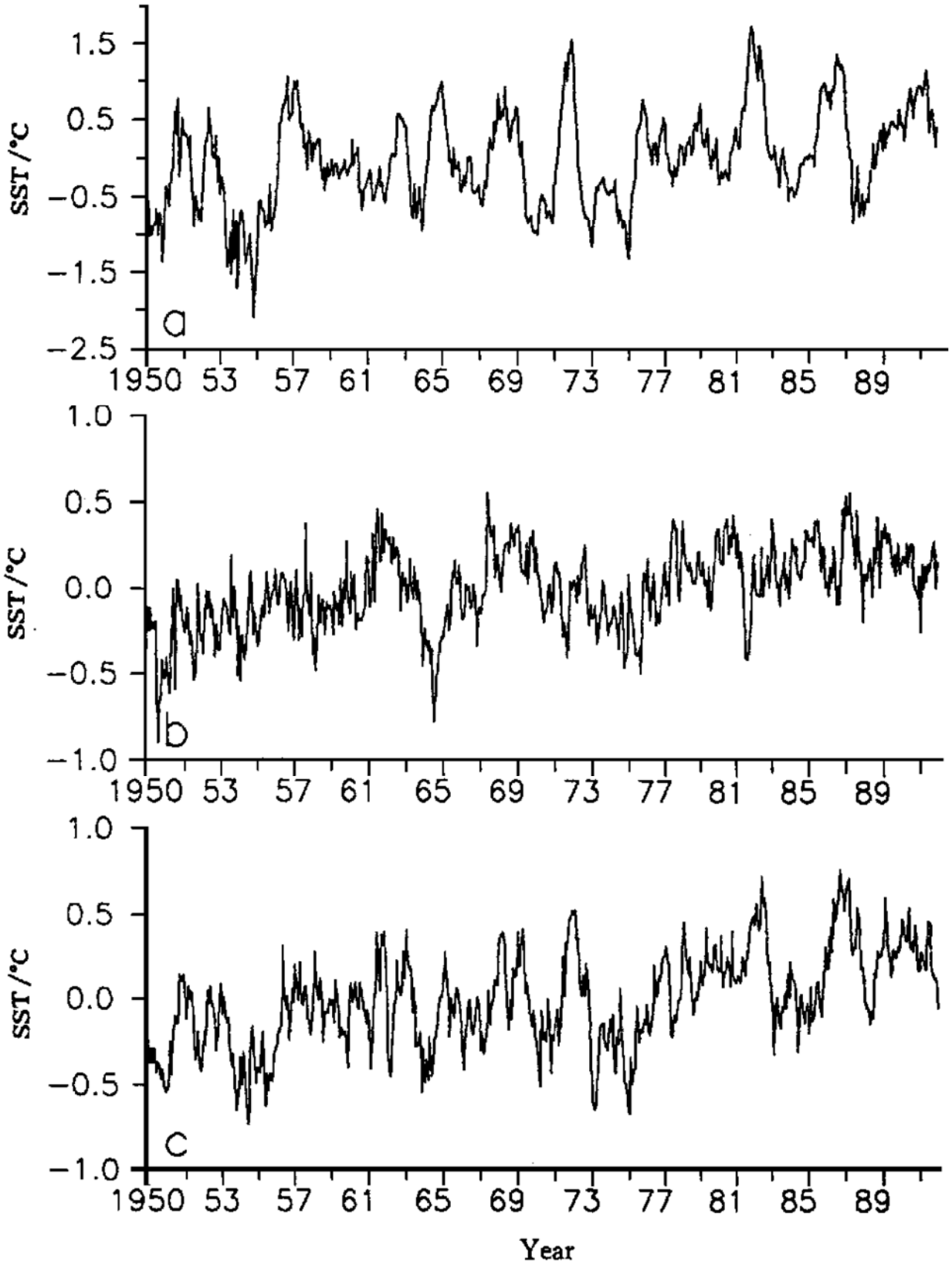

Fig. 2. The annual change of SST in the tropical eastern Pacific (a), the tropical western Pacific (b) and the tropical Indian Oceans (c).

ern Pacific Ocean is greatly different. The main periods of the SST in the tropical Indian Ocean and the equatorial eastern Pacific have 56 months separately, but the main period of the SST in the tropical western Pacific only has 12 months . The first period of the SST in the tropical western Pacific has 112 months, and the first periods of the SST in

the Indian Ocean and the equatorial eastern Pacific have 15.3 and 22.4 months separately. This result shows that the change tendency of the period of the SST in the tropical Indian Ocean is nearly the same as that in the equatorial eastern Pacific, especially the main period, but the period of SST in the tropical western Pacific shows a greater difference from those of the tropical Indian Ocean and the equatorial eastern Pacific. It has been believed that characteristics of SST in the tropical Indian Ocean are different from those in the equatorial western Pacific.

Table 1. The power spectrum(month) of the SST of the tropical western Pacific Ocean, the Indian Ocean and the eastern Pacific Ocean in the equator

	Main period /month	First period /month	Second period /month	Third period /month
Indian Ocean	56	15.3	21	*
western Pacific	11.8	112	42	25.8
eastern Pacific	56	22.4	*	*

* denoting the period not clear.

For convenience of explanation, the following analysis is made of the SST in the tropical Indian Ocean, the equatorial eastern Pacific and in the tropical western Pacific as shown in Fig. 3, its calculation sample is 386 months, significant level $\geqslant 99\%$ when correlative coefficient $r \geqslant 0.17$.

It can be seen in Fig. 3 that the greatest correlation of the SST occurs two times in the tropical Indian Ocean and the western Pacific Ocean, one appears 18 months later when the SST of the tropical Indian Ocean lags that of the tropical western Pacific ($r = 0.35$), and another appears about 6 months later when the SST of tropical Indian Ocean lags that of tropcial western Pacific ($r = 0.44$). The significant corrclative level of 99% appears 20 months later when the SST of the tropical Indian Ocean lags that of the tropical western Pacific or 15 months earlier when the SST of the Indian Ocean surpasses that of the tropical western Pacific. We believe that the change of SST of the tropical Indian Ocean and the western Pacific is an interactive influence, but the tropical Indian Ocean is more active than the western Pacific.

The greatest correlative coefficient of time-lag between the SST in the tropical Indian Ocean and that in the equatorial eastern Pacific is that the latter surpasses the former 3 months earlier($r = 0.70$), and the confidence surpasses 99% far away. The correlative scope achieving 99% of the confidence is from the SST in the equatorial eastern Pacific surpassing that of the Indian Ocean 14 months earlier to that of the former lagging the latter 8 months later, and this notable correlative influence between them lasts for 23 months. Also it can be seen in Fig. 2 that the change tendency between them almost is identical, and only the change of the SST in the eastern Pacific took place 3 months earlier than that in the Indian Ocean.

In the correlation of the SST between the equatorial eastern Pacific and the western Pacific, the correlation of confidence surpasses 99%, which occurs when the former lags the latter $32 \sim 5$ months later or when the former surpasses the latter $8 \sim 20$ months earlier. This result indicates that in the relationship between the SST of the equatorial eastern Pacific and that of the western Pacific, they have interactive influence with each other. The correlative coefficient almost is 0 at the same time, this shows that it is basically in-

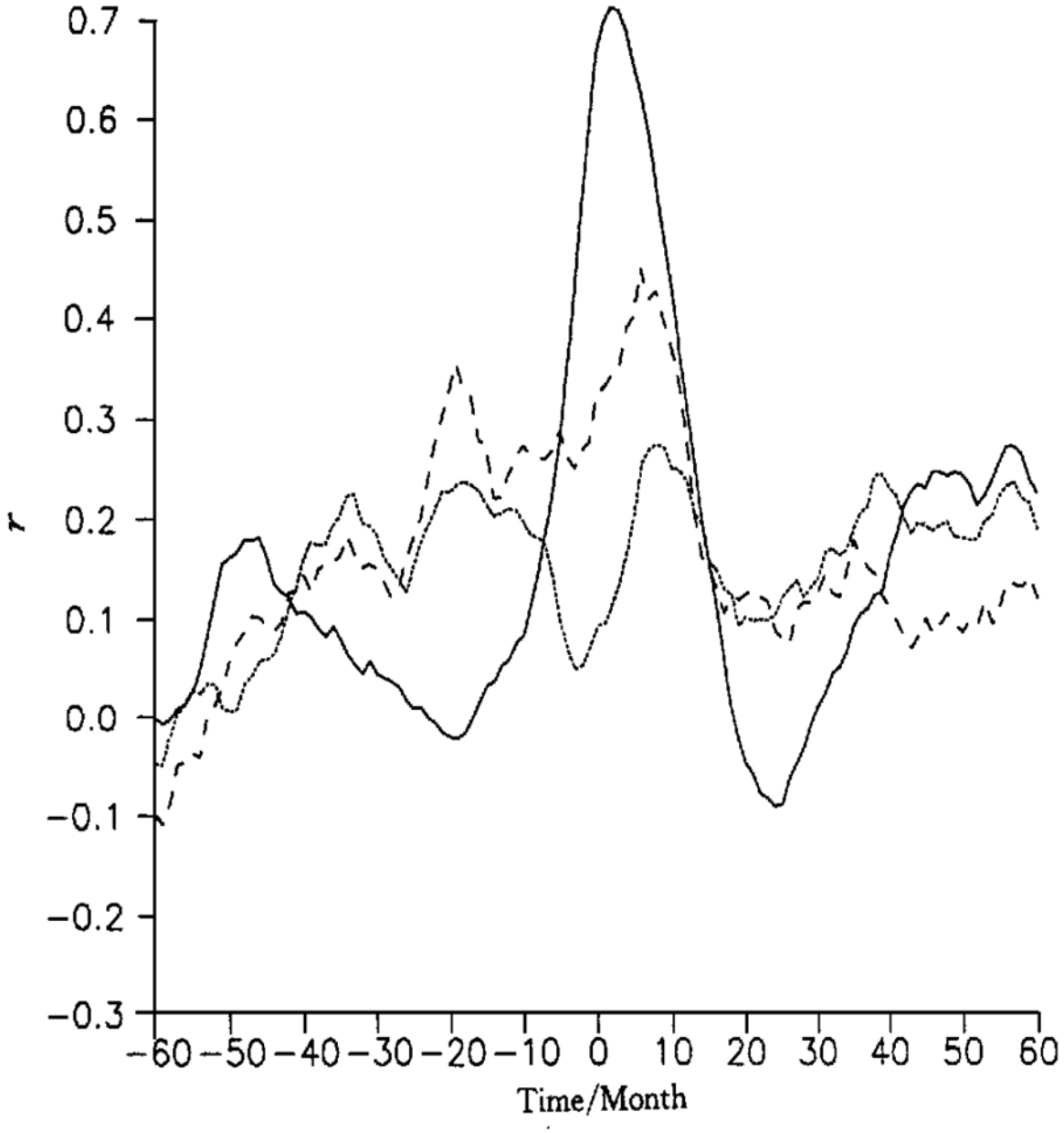

Fig. 3. The time series curves of the running cross correlation coefficients(r) of the SST in oceans. – – : Indian Ocean and western Pacific; ——: Indian Ocean and the equatorial eastern Pacific; ····: western Pacific and the equatorial eastern Pacific.

dependent at the same time and in short-term.

3 The relationship between the change of the Antarctic sea ice area and the SST of the tropical western Pacific as well as the tropical Indian Ocean

The researches indicate that the change of the Antarctic ice area is obvious monthly and annually(Chen *et al*. 1998 ; Xu *et al*. 1992), and certainly it has an influence on the SST in the equatorial Pacific (Peng and Wang 1989; Bian 1988), but the researches on the Indian and the western Pacific Oceans are made very little, so the detailed researches on them seem to be very significant. In order to show the relationship between the Antarctic ice area and the SST in the tropical Indian Ocean and the tropical western Pacific as well as the equatorial eastern Pacific, the ice area on the longitude belts has been analysed (figure is omitted), the result is that correlation between the Antarctic ice

area and SST of the tropical Indian Ocean is exposed in the eastern-south Pole (0° - 120°E) and the Ross Sea (150°E - 110°W). So, analyses have been made of the change of ice area in the above two areas and the SST of the tropical Indian Ocean(Fig. 4).

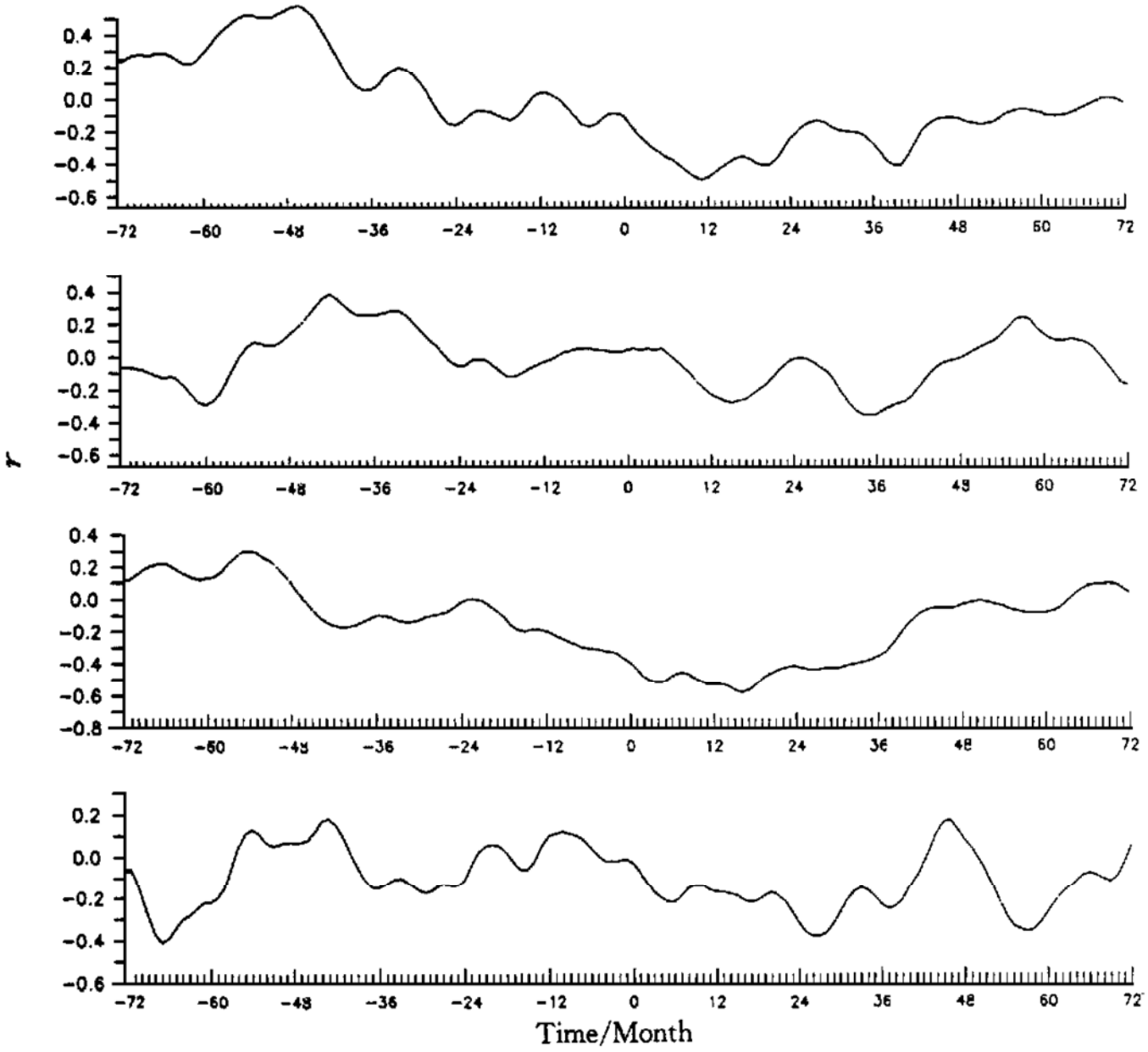

Fig. 4. The time series curves of the running cross correlative coefficients(r) of the different Antarctic ice areas and the SST of the tropical Indian Ocean. Positive denotes sea ice area surpassing the SST. Negative denotes sea ice area stagnating behind the SST. (a) Ice area in 150°E - 110°W and the SST of western Pacific; (b) Ice area in 0° - 120°E and the SST of western Pacific; (c) Ice area in 150°E - 110°W and the SST of Indian Ocean; (d) Ice area in 0° - 120°E and SST of Indian Ocean.

In the running cross correlative course, the sample is kept for 168 months, the confidence reaches 99% or more, when the correlative coefficient is 0.25. As shown in Fig. 4, the relationship between the Antarctic sea ice area and the SST of the tropical Indian Ocean is closer. It is comparatively clear that the ice area of Ross sea area (150°E - 110° W) has an influence on the SST of the tropical Indian Ocean, the coefficient reaches more than 0.25 when the latter surpasses 8 months earlier or when the former surpassed

39 months earlier. This shows that the interactive influence between them exists rearlly, but the greatest negative correlative coefficient appears 16 months later when the SST of the tropical Indian Ocean lags the ice area, and this also indicates that the ice area change in Ross Sea area has an important influence on the SST of the tropical Indian Ocean, and that the ice area of east-south Pole has relatively not strong influence on the SST of the tropical Indian Ocean.

The correlative relationship between the Antarctic ice area and the SST of the tropical western Pacific is less close than that between the Antarctic ice area and the SST of the tropical Indian Ocean. The correlative result indicates that time-lag correlation between the Antarctic ice area and the SST of the equatorial eastern Pacific is identical with that between the Antarctic ice area and the tropical Indian Ocean.

The revealment of this kind of correlation aroused a question that the SST in the equatorial eastern Pacific has an influence on the climate of East Asia or even on the globe which had been confirmed previously, the change of the SST in the equatorial eastern Pacific and the tropical Indian Ocean is almost synchronous, but we do not know how to explain physical mechanism between them, and whether or not it is related to the Walker circulation? This will remain further studying.

4 Discussion and conclusion

The equatorial eastern Pacific and the tropical western Pacific and the tropical Indian Ocean are the critical areas of the interaction between the ocean and atmosphere of the globe, the water temperature variation of this area plays a very important role in Southern Oscillation. From the change of the SST of the tropical Indian Ocean and the tropical western Pacific and the inherent relation between them and their relation with that of the equatorial eastern Pacific, we can obtain the following conclusions.

(1) The vibration period of the SST in the tropical Indian Ocean is different from that of the tropical western Pacific. In the correlation between them the SST of the tropical Indian Ocean plays an important role or, in other words, the change of the SST in the tropical Indian Ocean has an influence on the SST in the tropical western Pacific to a certain extent, and the duration of influence ranges from the same time to 18 months later, and the process of influence will remain further studying.

(2) The vibration period of the SST in the tropical Indian Ocean essentially is identical with that in the equatorial eastern Pacific, and the annual change is very coincided between them, and but their difference is that the change of the former falls behind that of the latter for 3 months. This kind of phenomenon indicates that the change of SST in the tropical Indian Ocean also plays an important role in the global climate, and that the change of the SST in tropical Indian Ocean falls for 3 months behind that of the equatorial eastern Pacific.

(3) In the correlation of the SST in the tropical western Pacific and in the equatorial eastern Pacific, the change of the SST in the equatorial eastern Pacific took place earlier than that in the tropical western Pacific, and it is basically independent at the same time and in short-term.

(4) There is a close relation between the change of the SST in the tropical Indian Ocean and the change of the Antactic ice area. The SST in the tropical Indian Ocean re-

duces when the Antarctic ice area increases or vice versa, the area where the former has an influence on the latter is in 150°E – 110°W, or just in Ross sea area. The greatest correlation conspicuously occurs when the SST in the tropical Indian Ocean surpasses 8 months earlier or when that lags 39 months later.

(5) The change of the SST in the tropical western Pacific also has a certain relation with the change of the Antarctic ice area, but the relationship between them is not so close as that between the Antactic ice area and the SST of the tropical Indian Ocean.

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