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Characteristics of change in the Antarctic sea ice area and its relation to SST in the tropical Pacific

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Abstract In this paper, the characteristics of change in the Antarctic sea ice area are analysed by using the observed data from 1973 - 1986. The analysed results show that the monthly and annual change of the Antarctic sea ice area is obvious, the biggest change value is in 160°E - 120°W and 60°W - 100°E, the smallest value is in 110°E - 160°E and 120°W - 60°W. The relation between the Antarctic sea ice area and the Sea Surface Temperature (SST) in tropical Pacific is close, and the relation between the Antarctic sea ice area in each longitude belt and SST in tropical Pacific shows a clear difference. It is obvious that the Antarctic sea ice areas in 0° - 90°E and 100°E - 110°W have a different feedbacking relation with SST in the tropical Pacific. The notable relationship occurs in the 3 - 4 and 41 - 45 months, that quite tallies with the occurrence of El Nino.

Key words Antarctic sea ice area, SST in the tropical Pacific, El Nino.

1 Introduction

Before the 1980′s, Antarctic investigations and their research data were relatively few. Since the 1980′s, along with the development of the science and technology and the application of advanced scientific measurement instrument, the people not only make the researches on the tropical Ocean, but also expand the studies on the Antarctic. The Antarctic is an important studied area listed as one of 3 plans of research in World Ocean Circulation Experiment (WOCE), and that also is the key district in Joint Global Ocean Flux Study (JGOFS), Global Atmosphere Research Plan (GARP), and World Climate Research Programme (WCRP) and International Geosphere-Biosphere Programme (IGBP). However, because of the special condition of the Antarctic, it is difficult to gain data in the ocean, thus, the studies in there are far less made than the researches at the tropical Ocean or, particularly, in content.

The Antarctic, together with Nroth Pole and Qinghai-Tibetan Plateau is the one of three sensitive areas of macroclimates. The area is covered by ice and snow all the year round, and its main feature is that the temperature is very low, and lowers 20℃ as compared with the Nroth Pole. The Antarctic ice sheet adjoins with the Southern Ocean, which is the major thoroughfare linking up three oceans (Pacific, Atlantic Ocean, Indian Ocean). So, the Antarctic sea ice has an important influence over the ice-air on upper atmosphere circulation or over the ice-water on the marine environment (Bian 1988; Lu *et al*. 1996; Peng and Wang *et al*. 1989; Zhao and Ji 1989), and the researches on the variation of Antarctic sea ice are very important for the variation in ocean temperature and for the whole global climate change.

This paper is based on Antarctic sea ice data of 1973 – 1986, the monthly and annual changes have been studied and, particularly, the sea ice area change on each longitude belt is analyzed, and attempt is also made to clarify its change, the property and, Particularly, the relation between Antarctic sea ice and SST of the tropical Pacific. It will provide theory foundation for the influence of Antarctic sea ice on the tropical Pacific ocean and global climate change.

2 The property of Antarctic sea ice

Researches indicated (Chen *et al*. 1989) that in the Antarctic sea ice covers an area about 19×10^6 km^2, and annual change of covering is obvious. The smallest scope only is 1/10—1/20 of the biggest scope, hence the Antarctic sea ice coverage and its physics property will have the important effect to the annual global climate change.

2. 1 Characteristics of the monthly change of the Antarctic sea ice area

From the monthly change of the Antarctic sea ice area, the change value of sea ice area was accumulated month by month, and the monthly change curve is given (Fig. 1) for 50°S southward in 1973 – 1986.

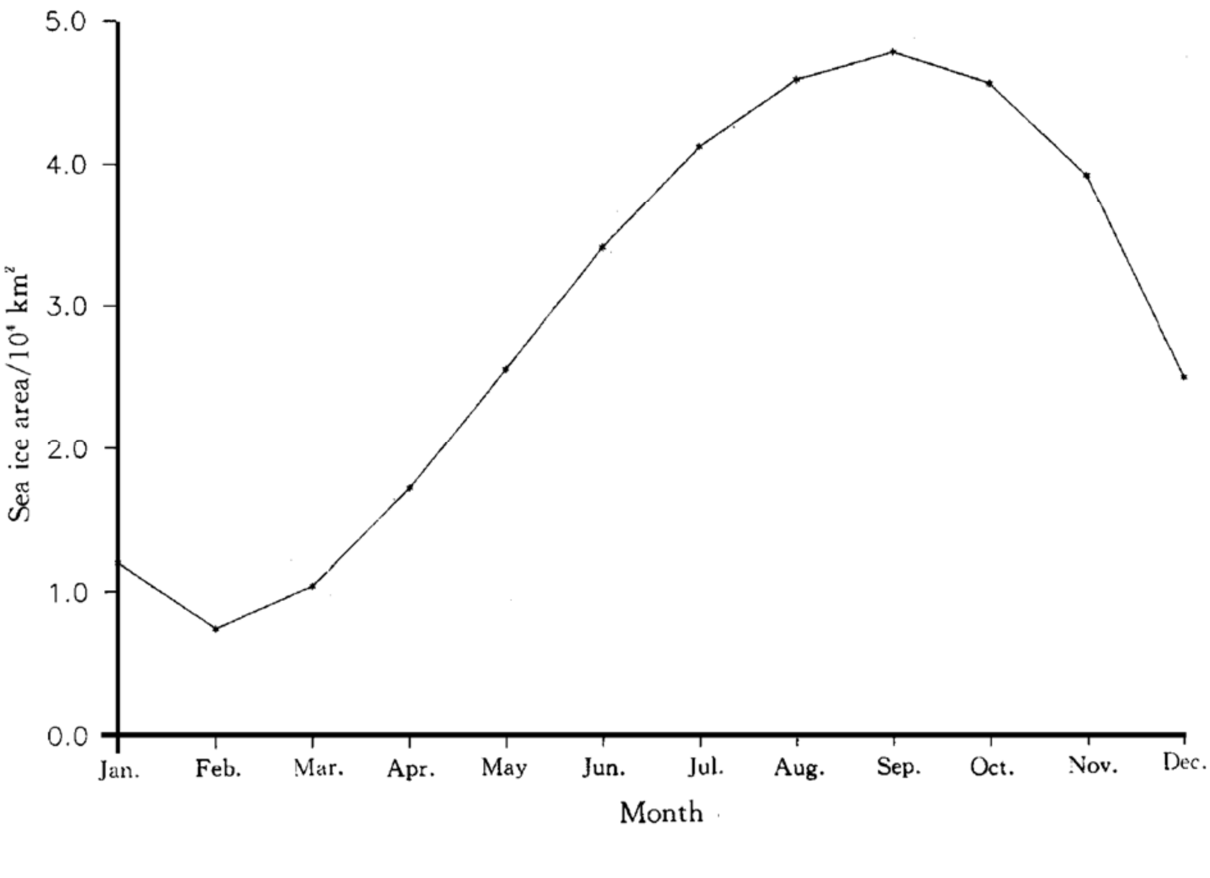

Fig. 1. The monthly change curve in the Antarctic sea ice area.

As seen in Fig. 1, the smallest value of the Antarctic sea ice area is in February, and the biggest value is in September, the biggest value is nearly about 5 times the smallest one. The occurring of this phenomenon is adaptable to the seasonal change of the Southern Hemisphere temperature, and in the summer (February) sea ice area reduces, and in the winter (September) sea ice area increases. The result is identical with the result of Jacka (1983).

In order to show the change property along the longitude of Antarctice sea ice area, we analyze the data of per 10 longitude belts (Fig. 2). It shows that the smallest value basically is in February, the biggest value is in September. But it is worth noticing that in 10 longitude belts the Antarctic sea ice areas change conspicuously. The change anomaly in the whole circumpolar sea ice has two biggest value areas and two smallest value areas, the biggest values are located in 160°E – 120°E and 60°W – 100°W and the smallest values are located in 110°W – 150°E and 120°E – 60°W. The biggest value areas just are in the Ross sea and the Weddle sea area, and this is identical tendency with the sea ice change in the northern border of the Antarctic as indicated by Lu *et al.* (1996). It can be seen from Fig. 2 that the biggest change anomal of the Antarctic sea ice area ranges form -45×10^4 km^2 to 40×10^4 km^2, and differs from the smallest one in more than 80×10^4 km^2.

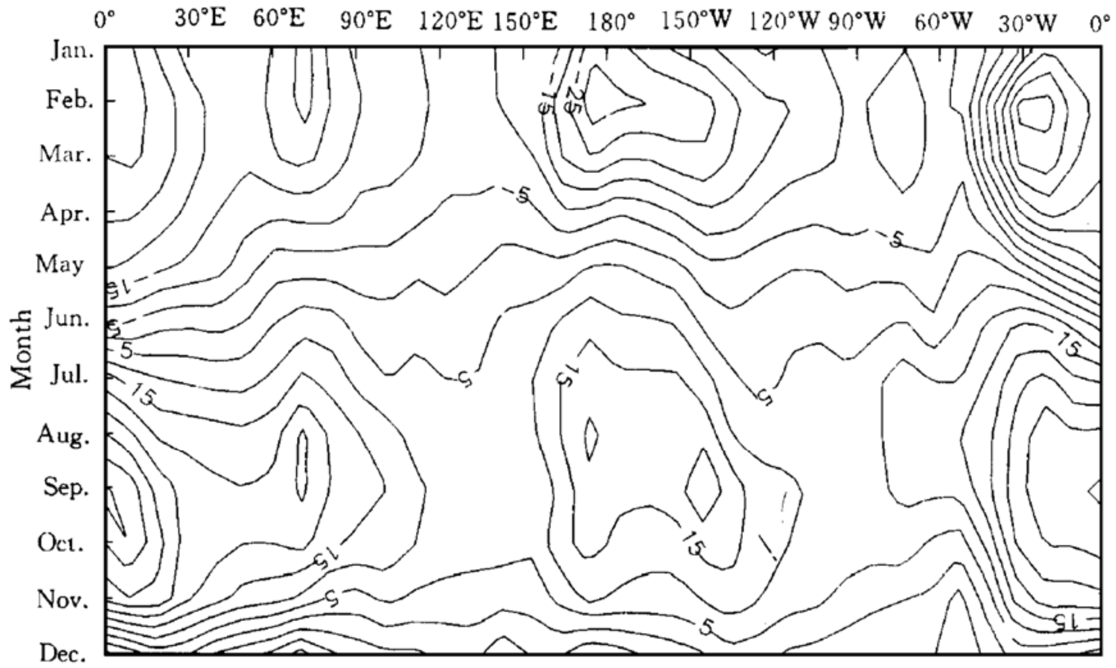

Fig. 2. The time-space distribution curve of the change anomaly of the Antarctic sea ice area.

2.2 Characteristics of annual change of the Antarctic sea ice area

The annual change anomaly of ocean and atmosphere is very important in the sea-air interaction researches. So, the annual change is the important problem when we discuss the change of the Antarctic sea ice area. In order to show the problem, Antarctic sea ice area data in 1973—1986 are dealt with and drawn in Fig. 3.

As seen in Fig. 3, the annual change of Antarctic sea ice is very obvious in 14 a, the biggest value is 20×10^4 km^2, the smallest value is -40×10^4 km^2. In the discussion, we know that the difference in the monthly change of the Antarctic sea ice area is obvious on

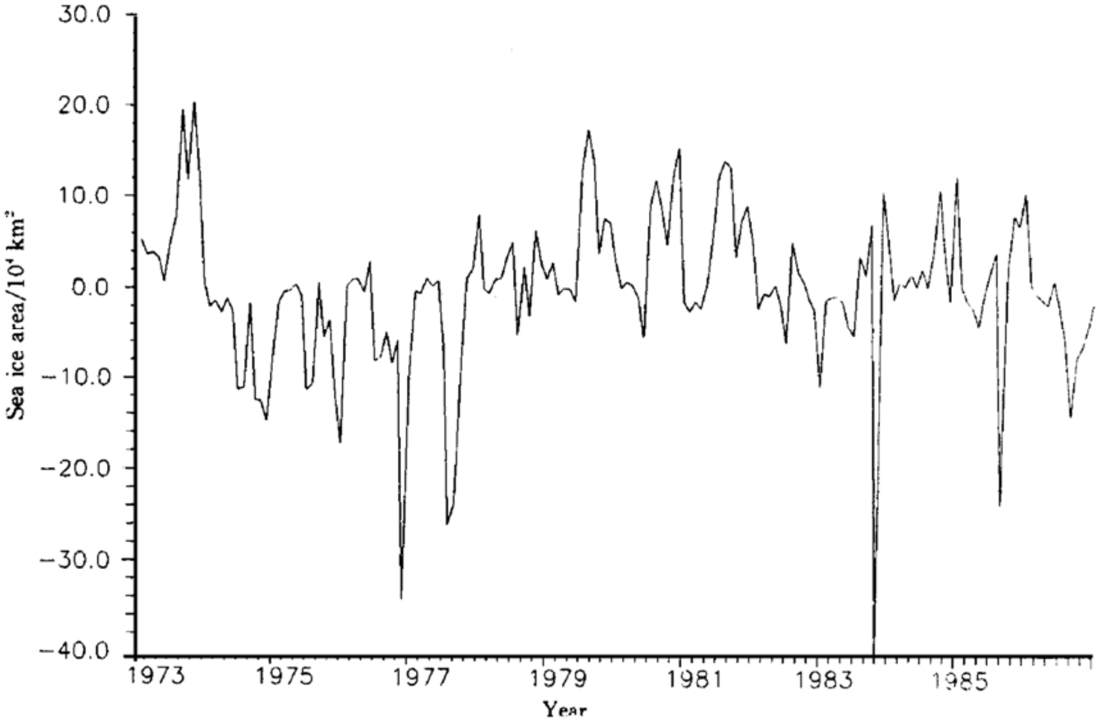

Fig. 3. The time series curve of the change anomaly of the Antarctic sea ice area.

each longitude belt, but the difference in the annual change is also obvious. the annual change of Antarctic sea ice area is also comparatively clear in 60°W – 100°E and 160°E – 120°W.

3 The relation between Antarctic sea ice areas and the SST of the eastern tropical Pacific

The change of the Sea Surface Temperature (SST) of the eastern tropical Pacific plays an important role in the climate change of the eastern Asian area and the world (Xie 1991; NIPR 1989), and is the important signal where the El Nino phenomenen will occur. Therefore, the study of SST of the eastern tropical Pacific is a very important work in research of the occurring of El Nino and the world climate change. Because the increase and decrease of the Antarctic sea ice area can directly influence the Pacific, the Atlantic and the Indian Ocean, which adjoin with the Antarctic, so that the relation between Antarctic sea ice and SST of the tropical Pacific has been analysed.

3.1 The relation between average value of Antarctic sea ice area and the SST of the tropical Pacific

For convenience of discussion, the average value of sea ice area and the average value of SST in 5°N – 5°S, 85°W – 175°W of 1951 – 1986 were analyzed (Fig. 4). In view of the relation between the average value of sea ice area and that of SST of the tropical Pacific in the same time to the time-lag 72 months, it is negative-positive feedbacking relation, but the leading position is clearly occupied by the negative feedbacking.

The scope of negative feedback is SST lagging sea ice for 0 – 3 months, and the related coefficient is −0.58 and significant level ≥0.001. The related coefficient is 0.29

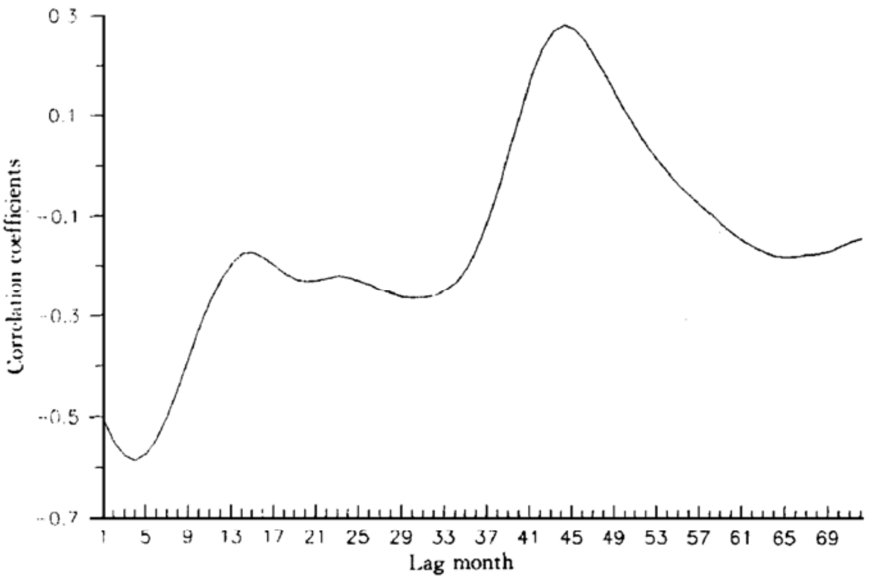

Fig. 4. The time series curve of the time-lag correlation coefficients (r) between the average value of Antarctic sea ice and the SST in the tropical Pacific.

to the positive feedback of SST lagging sea ice for 43 months. This phenomenon can be showed, the Antarctic sea ice is leading effect in the relation between Antarctic sea ice area and SST. There are 40 months from negative feedbacking of SST lagging sea ice 3 months to positive feedbacking of SST lagging sea ice 43 months. It has been verified in the analysis. Difference can also be seen from the influence of the change of the Antarctic sea ice area influences over the SST along each longitude of the equator, and the notable area of its influence is in the eastern Pacific of the equator.

3.2 The relation between the Antarctic sea ice area of each longitude belt and the average value of SST

Owing to the fact that there are great fifferences in the monthly or annual change of sea ice area in each longitude, so we think the correlation between the change of the sea ice area of each longitude belt and SST also shows a great difference. The Fig. 5 shows the correlation between the change of Antarctic sea ice area of different longitudes and SST in the time and space distribution. As shown in Fig. 5, the correlation between the change of the sea ice area in each longitude belt and SST has a clear difference.

The Antarctic sea ice area from 0° – 50°E and 60° – 90°E, is in the negative-positive-negative feedbacking relation with SST in the tropical Pacific, but in that from 100°E – 120°W the negative-negative-positive feedbacking relation with SST in the tropical Pacific. The relative lag-time reduces along with the increasing of longitude belt in 0° – 120°W scope, and the time interval of related coefficient decreases from 43 months to 30 months.

4 Discussion and conclusion

(1) The monthly change of Antarctic sea ice area is obvious and its change has a

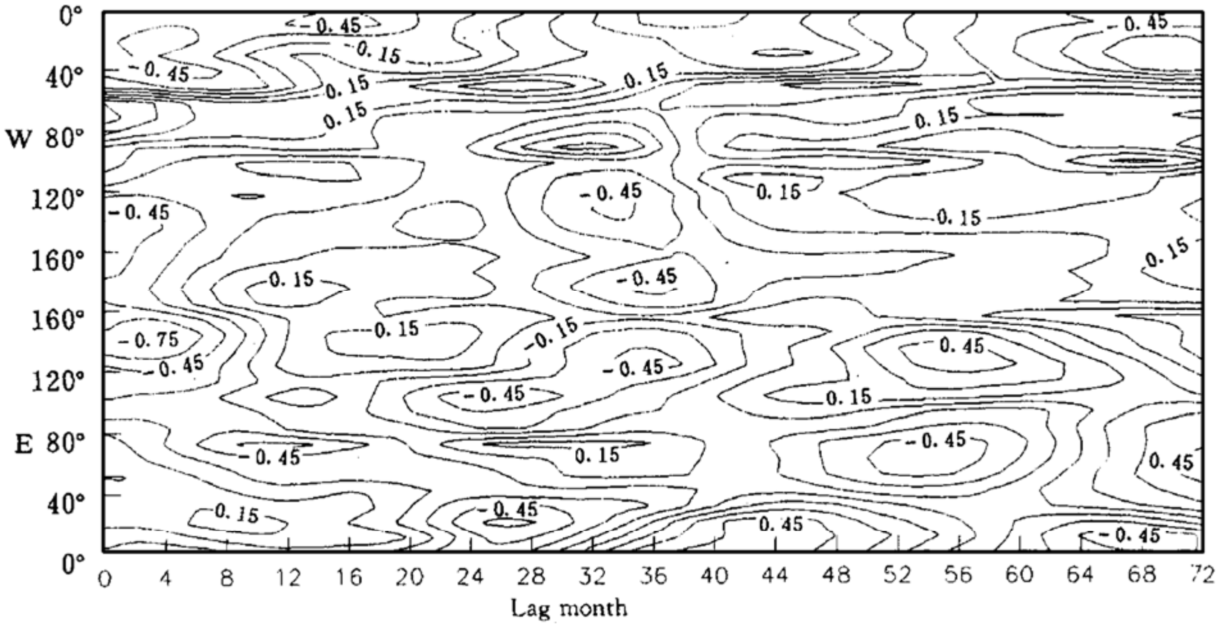

Fig. 5. The time series curve of the time-lag correlation coefficients(r) between the Antarctic sea ice in each longitude belt and the SST in the tropical Pacific.

relation with the movement of the shining angle of the sun. The biggest change anomaly is in September, and the smallest change anomaly is in February. The biggest change scope anomaly is in 60°W – 100°E and 160°E – 120°W, and these areas lie correspondingly in the Ross Sea and the Weddle Sea area. The smallest change scope is in 110°E – 160°E and 120°W – 60°W, and the maximum of change anomaly between them is in -45×10^4 km^2 – $+40\times10^4$ km^2. The annual change of the Antarctic sea ice area is also obvious, the biggest change area is identical with the biggest monthly change area of the Antarctic sea ice area. The change of the Antarctic sea ice area will play an important influence on the long-term change of marine environment and atmosphere circulation around it.

(2) The average change value of the Antarctic sea ice area and the average value of the SST in the tropical Pacific have a closer relation. In the relation between them, the greatest correlation is for 3 months (negative relation) and 43 months (positive relation) in SST in the tropical Pacific lagging the Antarctic sea ice area. This is due to the difference in the self vibration periods in SST of the tropical Pacific with the Antarctic sea ice area. Through the calculation of the power spectrum, we find the main period of the whole South Pole sea ice area change is 168 months, and the first period is 15. 2 months, and the second period is 21. 9 months, and the third period is 12. 3 months. But the main period of the SST in the tropical Pacific is 40 months, and the first period is 24 months, and the second period is 16 months. This result is coincided with the analyses of Xie *et al*. (1994).

(3) The average change value of the South Pole sea ice area differs in each longitude belt, so the difference can also be shown when analyses of SST are made. In the sea ice of the circumpole, from 0° – 120°W, the influence is the clearest to the SST in the tropical Pacific; and also there exists the clear difference in them, the difference is caused by the South Pole sea ice in different change period and in different area (Its main

period is 18.7 months in 0° – 50°E, 84 months in 60° – 170°E and 168 months in 170°W – 120°W). But it is very small influence to the SST in the tropical Pacific. This paper is presented by using the change of Antarctic sea ice of each longitude belt and its influence on the SST in the tropical Pacific, which is more useful than the average value of the whole Antarctic sea ice.

(4) The change of the Antarctic sea ice area exerts influences over the equator SST, mainly in the eastern equator of the Pacific Ocean (85° – 145°W). It is not clear whether it influences over that in the west part. The occurring of this phenomenon possibly has the close relation with ocean circulation, and this still remains to be further researched.

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References

Bian LG (1988): The change of the Antarctic sea ice and the relation of the equator SST. Meteorological science academy institute periodical, 3(2):219 – 222.

Chen SM, Bian LG, Jia PQ *et al*. (1989): A Collection of Antarctic Scientific Explorations, No. 4. Beijing: China Ocean Press, 1 – 164.

Jacka TH (1983): A Computer Data Base for Antarctic Sea Ice Extent. ANARE Research Notes 13, Antarctic Division, Department of Science and Technology, Australia.

Lu LH, Bian LG, Zhang YP (1996): Research development of interaction and the influence between Antarctic and climatic environment in world. Beijing: Science Press, 1 – 12.

National institute of Polar Research(NIPR)(1989): The Antarctic Oceanography. Trans. into Chinese by Xie SM and Fan XL, 1992, Beijing: China Ocean Press, 115 – 116.

Peng GB, Wang BG (1989): The Antarctic sea ice influence to the northwestern the Pacific subtropical high pressure and its ocean atmosphere circulation background. Journal of science, 34(1): 56 – 58.

Xie SM (1991): The Antarctic sea ice. Oceanologica disaster and forecast. Beijing: China Ocean Press, 155 – 186.

Xie SM, Hao CJ, Qian P *et al*. (1994):The variation feature of the Antarctic sea ice (II). Acta Oceanologica Sinica, 13(1):73—84.

Zhao HG, Ji JZ (1989): The time and space change feature of Antarctice sea ice and its influence to atmosphere circulation. Meteorology, 15(2):3 – 8.