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Antarctica Sea-ice Oscillation and Its Possible Impact on Monsoon of South Sea

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Abstract Antarctic sea-ice oscillation index with a seesaw pattern is defined using NCEP/NCAR reanalysis girds data of monthly Antarctica sea-ice concentration from 1979 to 2002. The relationships between the index of winter and the summer precipitations in China as well as the onset date of the summer East Asia monsoon are presented. The study result shows that the grids of correlation coefficients passed 5% confidence level between Antarctic sea-ice oscillation index and Antarctic sea-ice concentration are more than 1/3 of all grids of Antarctica sea-ice, that means the index can represent 1/3 sea-ice area. The winter index has a significant correlation with abnormal summer (June-August) precipitation in China. The area of positive correlation lies in the Yangtze River basin and its south, and that of negative correlation lies mainly in the north of Yangtze River basin. While the winter index is positive (negative), the onset date of South China Sea monsoon is earlier (later), with a probability of 79% (80%). Consequently, a conceptual model is given in term of discussing the possible process between the winter Antarctic sea ice and the monsoon precipitation in China.

Key words Antarctica sea-ice oscillation index, summer precipitation, East Asia monsoon.

1 Introduction

Antarctica is distinguished from the other Earth's climate systems characterized by huge ice sheets, large oceanic areas covered by sea ice, and massive and deep permafrost layers that plays a role as a "cold source". Acting as a cold source of the global atmosphere, it plays an important role in the exchange of heat, momentum and moisture between the southern and northern hemispheres, which have impact on the atmospheric circulations and climate change. The research of the climate changes in the Antarctic and its environmental change has attracted attention of the international scientific community. Changes in the Antarctic sea ice have the potential to influence global climate significantly and is one of the major challenges in modern meteorological research.

In order to get better understanding of the Antarctic sea ice changes there are a variety of measurements and observational plans on Antarctic sea ice in the world.

Research results have revealed the relations and interactions between the Antarctic sea ice and atmospheric circulation[1-3] and in recent years Chinese researchers have worked on the impact of the changes of Antarctic sea ice upon Chinese climate. For example, Li *et al*.[4-5] showed that key-regions of Antarctic sea ice have close correlations to the eastern-China seaside's precipitation in the freshet period of 1973-1986. Bian *et al*.[6] showed the relationships between the temporal and spatial distribution of Antarctic sea ice and the features of western Pacific typhoons and subtropical anticyclone. Xie *et al*.[7] showed influences of the Antarctic sea ice in abnormal years on summer floods in China. In order to make short-range climate prediction in China using southern hemispheric signals, we study the correlations between the impacts changes of Antarctic sea ice in key-regions and precipitation of Yangtze regions in the freshet period and Nanhai monsoon, as well as their interactions using the 1973-2002 NCEP monthly global ice concentrations and 160-station rainfall data of China in the freshet period.

2 Data

Earlier satellite's sea ice observations were compiled as ice charts. In 1991 the US National Climate Center converted 1973～1989 weekly charts from the US Navy/NOAA Joint Ice Center (NIC) into WMO-defined SIGRID digital format. And the US National Snow and Ice Data Center (NSIDC) extended the temporal length of sea ice data by processing microwave radiation data and brightness temperature data of SMMR and SMM/1, but the processing methods of the two data sets were different and therefore created some error. NCEP global sea ice data minimizes such error by re-analyzing and processing the two using a standard scheme. NCEP global sea ice data is 360-month Gaussian continuous unequally spaced gridded dataset from Jan 1973 to Dec 2002. The data is global gridded by 192×94 at 1.875°resolution on longitude with 192 grids and at 1.089°～1.804°resolution on latitude with 94 grids. The NCEP ice concentration which is widely applied is defined as the ice covered proportion in one grid by percentage, if the grid is fully covered with ice and the ice concentration is 100%, if there is no ice in the grid, then the ice concentration is 0. We study the interactions between the changes of sea ice in the Antarctic and Chinese climate in summer by NCEP monthly global ice concentration data from 1973 to 2002.

3 Antarctic sea ice oscillation

Researches about Antarctic sea ice cover and its key regions[8] showed that the seasonal variability of Antarctic sea ice is asymmetric and interannual variability of Antarctic sea ice is obvious, another feature is the seesaw pattern of changes in ice concentrations between the outer region of the Ross Sea and the east Antarctic. Cheng *et al*.'s[9] research revealed that the signal of sea ice over in the outer regions of the Ross Sea and the Antarctic Peninsula is opposite by using the US NSIDC data and Antarctic sea ice concentration data with EOF and SVD methods. It is defined the difference in spatial mean ice concentration between the Ross Sea outer region

(Region A: 61°～63°S, 138°～144°W) and the Bellingshausen Sea (Region B: 61°～63°S, 60°～66°W) as the ASOI (Antarctic Sea-ice Oscillation Index), i. e. ASOI = ICE (A)－ICE (B). After many experiments using NCEP ice data, we find that it is more appropriate to select 23 grids over 62°～66°S, 137°～151°W as Region A and 24 grids over 64°～68°S, 69°～82°W as Region B, and due to the versions and lengths of NCEP ice data, the reselected regions are closer to the South Pole in latitude and more westward in longitude, and the areas are expanded. Fig. 1 presents the simultaneous monthly correlativity between ASOI and ice concentrations from January 1973 to December 2002, indicating that there is a strongly negative zone in Region B centered on 65. 7°S, 85°W with the correlation coefficient of －0. 717, and the ocean around Antarctic continent are positive with two centers: one is in Region A at 63. 8°S, 144. 5°W with the correlation coefficient R＝0. 731 and another is in the western Weddell Sea at 60°S, 7. 5°E with R＝0. 323. In addition, there are two positive correlation centers in the eastern hemisphere located around 63. 8°S, 121. 9°E and 63. 8°S, 178. 1°E with R = 0. 232 and 0. 238 respectively, which are significant at 0. 1% level. We can also know in Fig. 1 that there are 361 grids (is 28. 6% of total) passing significance test at 5% level, suggesting that the ASOI can represents nearly 1/3 Antarctic ice concentration change. As demonstrated in many studies, the interannual and seasonal variations happen mainly in the Ross Sea, Belligshausen Sea and Weddell Sea[8].

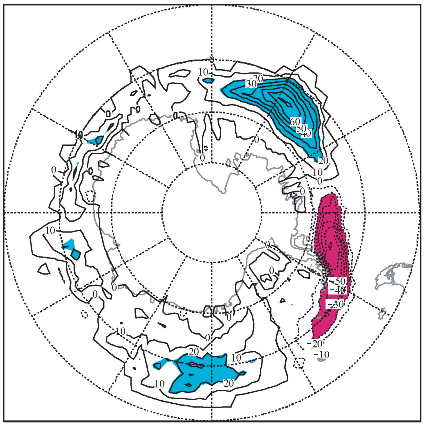

Fig. 1 The correlation between ASOI and Antarctic sea ice concentration of each grid. point for the period of 1973 January～2002 December with red for negative correlation and blue for positive correlation (passed the local 99% significance test is shaded).

ASOI and AAO (Antarctic Oscillation) are different in physical sense. The former is defined to demonstrate that ice concentrations change as a seesaw between the Bellingshausen Sea on the west side of the Antarctic Peninsula and the Ross Sea, which is in correlation to SOI and Nino3 index. The later, on the other hand, is the main pattern of the southern atmospheric circulations in middle and high latitude marked by obvious zonal symmetry representing large－scale exchange between the polar region and midlatitudes, also indicating a seesaw-form variation between the southern circumpolar low belt and subtropical high belt. Hence, the research into anomalous change in ASOI and AAO and its application to climate study serves as a critical approach to the study of climate interactions between Antarctic sea ice and atmosphere.

ASOI power spectral analysis (figure not shown) shows that there are three periods and their significances are at >5% level. The first period is more than 120 months (wave number is 1). Following power spectral analysis, the maximal lag correlation occurs generally at the 1/3 of the series length, i. e. , 120 months in this example (denoted as the period 1) and any longer periods cannot be determined. The 120-month period approximates to the 11-year period of sunspot activity. The second period (called period 2) are 40～60 months, i. e. , 3～5 years (wave numbers are 2～3) which is close to the period of the ocean and atmosphere, for instance, period of El Nino phenomenon as studied by Lin[10]. The third period (period 3) spans 17～30 months (wave numbers are 4～7) for biennial oscillation that is common in the high-level atmosphere, especially in the stratosphere.

The polar regions are the cold sources of the earth's thermal engine. And the changes of oceans and atmosphere in polar regions affect the global atmospheric circulations and weather/climate regimes greatly. The existence of sea ice along with its seasonal and interannual variation is the most prominent feature of polar marine climate. Because of its high reflectance and suppression of the exchange in heat and water vapor between the ocean and air as well as in latent heat, sea ice is bound to influence the air-sea thermal budget at the polar regions. As demonstrated in many studies, there is correlation between the Antarctic sea ice and the global atmospheric action that can influence Chinese weather/climate regimes. Consequently the study of ASOI anomaly is not only favorable to Chinese precipitation forecast in rainy-season based on the teleconnection between Antarctic sea ice and Chinese climate change , but also helpful to estimate the Antarctic sea ice's influence upon global climate change.

4 Relationships between ASOI winter anomaly and Chinese precipitation of the freshet period

The correlations between ASOI of December-February (i. e. austral summer) hereafter as $ASOI_{12\text{-}2}$ and precipitation departures percentage in July-August over China (figure not shown) indicate that positive areas are mainly in the middle and lower Yangtze basin and south of the River with the correlation coefficients significant in excess of 5% level, and negative correlations occur in north of the Yangtze, and most of the correlations fail to pass the significance test at 5% level except a few stations such as that of Beijing and Tianjin.

Fig. 2 presents the interannual curve (solid line) of $ASOI_{12\text{-}2}$ and the interannual rainfall departures percentage averaged over July-August of stations having the positive correlations significant over 5% level including Nanchang, Changsha, Fuzhou, Quxian, Wenzhou, Guangchang, Ji'an, Ganzhou, Hengyang, Chenzhou, Pucheng, Yong'an and Guixi (dashed line). We can see from Fig. 2 that the two lines are similar and from 1977 the $ASOI_{12\text{-}2}$ begins to steadily rise as well as the rainfall in Yangtze basin with the correlation coefficient of 0.36 and statistically significant at 5% level, suggesting that when $ASOI_{12\text{-}2}$ abnormal increases the precipitation is more than mean and when $ASOI_{12\text{-}2}$ abnormal decreases the precipitation is less.

To further study the relation between $ASOI_{12\text{-}2}$ and Chinese summer rainfall, four years of $ASOI_{12\text{-}2}$ which are larger (smaller) than mean square deviation σ are selected as the high (low) $ASOI_{12\text{-}2}$ years, i. e., 1974, 1998, 1999 and 2002 (1975, 1976, 1977 and 1986) for making composite analysis with Chinese precipitation departures percentage (shown in Fig. 3).

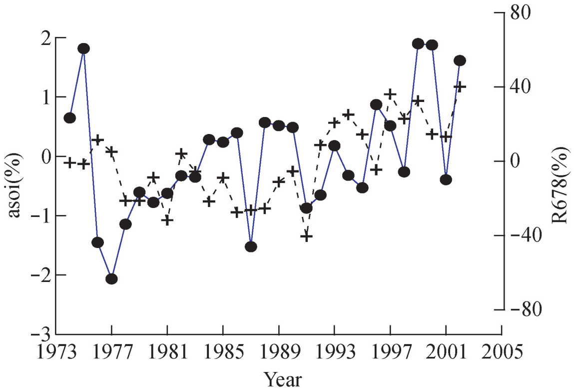

Fig. 2 Time series of winter ASIO12-2 (solid line) and percentages of summer abnormal precipitation over Yangtze River region (dash line).

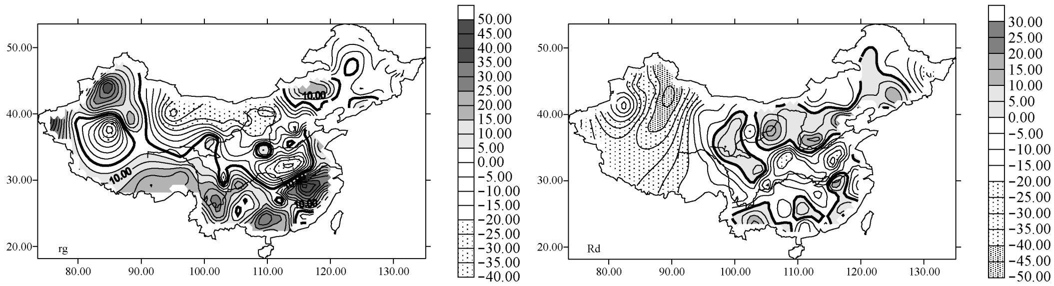

Fig. 3 Composite field of summer abnormal precipitation percentages in China. Separately for the low ASOI (Rg) years and for the high ASOI (Rd) years.

During the low $ASOI_{12\text{-}2}$ years (Fig. 3Rg), precipitation of Yangtze River and Huaihe in the rainy season decreases by >30% compared with normal situation in the middle and lower Yangtze river and Huaihe, while the precipitation increases in the Yellow River and Southern part of Yangtze River. In fact, in 1975 the precipitation of rainy season is less than normal while there is more precipitation in the middle and lower Yangtze river and the northern of China. In 1976 precipitation of rainy season is Pattern I with less rainfall in Yangtze River and Huaihe while more in the north and south of China. The 1977 pattern is similar to the one of 1976. In 1986 the rainy-season rainfall is mostly in the south of the Yangtze River while less precipitation is in the northern of the Yangtze River. Therefore 3 of the 4 low-$ASOI_{12\text{-}2}$ years' precipitations are less than normal in the Yangtze River and Yellow River but more than normal in the north and south of China except 1975.

In the years of high $ASOI_{12\text{-}2}$ (Fig. 3Rd), summer precipitation is more than mean in the Yangtze and the southern of China, especially in the middle and lower of Yangtze and southeast of China where the rainfall is >30%, higher than normal, while precipitation over the zone north of the Yangtze, particularly regions between the Yellow River and Huaihe River and northern of China where precipitation is < 30%, lower than the mean. In fact, in the rainy-season of 1974 national precipitation is categorized as the pattern III, i. e., the rainfall is concentrated in the south of the

Yangtze River while less rainfall is in the north of it (the negative departure zone). The year of 1998 is rich of precipitation over the country and there was a big deluge over the Yangtze which intensity was next to the 1954 equivalent. The precipitation of 1999 is a pattern with flood in the south and drought in the north, leading exceptional rainstorm over the Taihu catchments. The 2002 rainy-season precipitation over China is categorized as pattern III, indicating more precipitation in the south of the Yangtze River and less in the north of it except the bend of the Yellow river. It results that in the 4 years of high $ASOI_{12-2}$ the rain-season rainfall is more in the south of the Yangtze (4/4) and less in the north of it (3/4).

Table 1. Relationship between earlier or latter of summer monsoon on setting in South China Sea and ASOI

Years of earlier	Onset time (month-pentad)	$ASOI_{12-2}$	Years of latter	Onset time (month-pentad)	$ASOI_{12-2}$
1976	5 4	−2.065	1973	6 2	0.646
1977	5 4	−1.144	1974	5 5	1.816
1978	5 4	−0.607	1975	5 6	−1.451
1979	5 3	−0.776	1982	6 1	0.352
1980	5 4	−0.624	1983	5 5	0.282
1981	5 3	−0.327	1984	5 5	0.239
1986	5 3	−1.523	1985	5 6	0.396
1990	5 4	−0.874	1987	6 2	0.570
1992	5 4	0.178	1988	5 5	0.517
1994	5 1	−0.531	1989	6 2	0.488
1995	5 3	0.872	1991	6 2	−0.653
1996	5 2	0.514	1993	6 1	−0.321
1997	5 4	−0.261	1998	5 5	1.897
2000	5 3	−0.394	1999	5 5	1.875
			2001	5 5	1.613
When $ASOI_{12-2}$ are negative, the onset are earlier with the probability of 11/14=79%.			When $ASOI_{12-2}$ are positive, the onset are latter with the probability of 12/15=80%.		

As one of the world-famous summer monsoon regions China rainfall in summer is greatly determined by the intensity of summer monsoon. Study[12] shows that the onset of summer monsoon in South China Sea (SCS) serves as one of the earliest signs for the transition of atmospheric circulations from winter to summer and also is a feature of seasonal transition of the Asian-Australian monsoon region. The SCS monsoon onset is characterized largely by the South-Asian high moving into the northern Indo-China peninsula, the western-Pacific subtropical high keeping on eastward and retreating out of the SCS, northeast (southwest) winds occupying in the high (low) level of SCS, the SCS monsoon trough formatting related to the establishment of ~105~110°E cross-equatorial flow, the development of convective precipitation, abrupt change in temperature and humidity as well as the setting up of the meridional circulation of SCS summer monsoon. The intensity of the monsoon relates to the onset time. Commonly earlier onset associates with stronger monsoon in that year and v. v. The time of summer monsoon onset in SCS is generally based on dynamic and thermodynamic considerations, i. e. , selecting some characteristic parameters which are capable of reflecting the monsoon establishment as indices with certain threshold values. Because of different regions and parameters selected by different researchers[12] the time of summer monsoon onset in SCS are different. Table 1 shows the time of summer monsoon onset in SCS used in our work based on the paper[13]. And the onset before (after) the 4th pentad of May is defined as the early (late) occurrence of the SCS summer monsoon. We can see the relationships between the onset and $ASOI_{12\text{-}2}$ from Table 1 that $ASOI_{12\text{-}2}$ are negative (positive) and the onset are earlier (later) with the probability of $11/14 = 79\%$ ($12/15 = 80\%$). We did composite analysis of early and late onset years in relation to the July-August rainfall. The results show that in the early onset years the rainband is in the north over the Huang River basin and there is less (more) precipitation in the Yangtze valley (South China) while in the years of late onset more rainfall happens in the Yangtze basin and less in the north and south of China. The earliest establishment of SCS summer monsoon is in the first pentad of May and the latest establishment is in the second pentad of June. At most of time, the onsets of SCS summer are in the mid decade of May indicating that $ASOI_{12\text{-}2}$ first affects the establishment of the SCS monsoon and then influences the July-August rainfall in China.

5 Possible process of $ASOI_{12\text{-}2}$ influencine China climate

According to the above analysis, $ASOI_{12\text{-}2}$ probablly affects the time of SCS monsoon onset at first and then the distributions of trainbands over China, and the summer monsoon outbreak occurs mainly in May. Fig. 4 is the correlation field of $ASOI_{12\text{-}2}$ and anomaly of 850 hPa meridional wind (v) in May. We can see that there are negative zones in Australia and nearby oceans, with one each in the east and west that are significant at 5% level. It means that when it is the high $ASOI_{12\text{-}2}$ year, the Australian high is weak in May and v. v. From Fig. 4 we see a negative correlation zone around 110～120°E that is statistically significant at <5% level suggesting that there is obvious negative correlation between $ASOI_{12\text{-}2}$ and the cross-equatorial flows in July～August. Many researches show that there are two cross-equatorial airflows in the Asian monsoon region, one is in the vicinity of 105°E [13] and another is in about 120°E [14]. The two cross-equatorial airflows are opposite in phase and the former is stronger[11]. And from Fig. 4, only the summer cross-equatorial flow in the neighborhood of 110～120°E correlates strongly with $ASOI_{12\text{-}2}$.

In the conceptual model of eastern Asian monsoon proposed by Tao and Chen[15-16] that there is an East-Asian monsoon circulation system relatively independent of the Indian monsoon system in the Asian monsoon system, which consists of systems at mid-low level (Australian cold high, cross-equatorial flow in 105～125°E over eastern Asia, SCS-western Pacific ITCZ, the western Pacific subtropical high, the Meiyu front and westerly trough) and systems at high level (the East Asian portion of the South-Asian high, easterly jet streams in the north and south, and the cross-equatorial currents generated by the easterly jet streams in the south). So we can see high and low $ASOI_{12-2}$ years corresponds to different circulative systems in eastern Asian summer monsoon.

Fig. 5 shows composite field of 850 hPa wind departures in June-August separately for low and high $ASOI_{12-2}$ years. In the low $ASOI_{12-2}$ year there is an anomalous anti-cyclonic

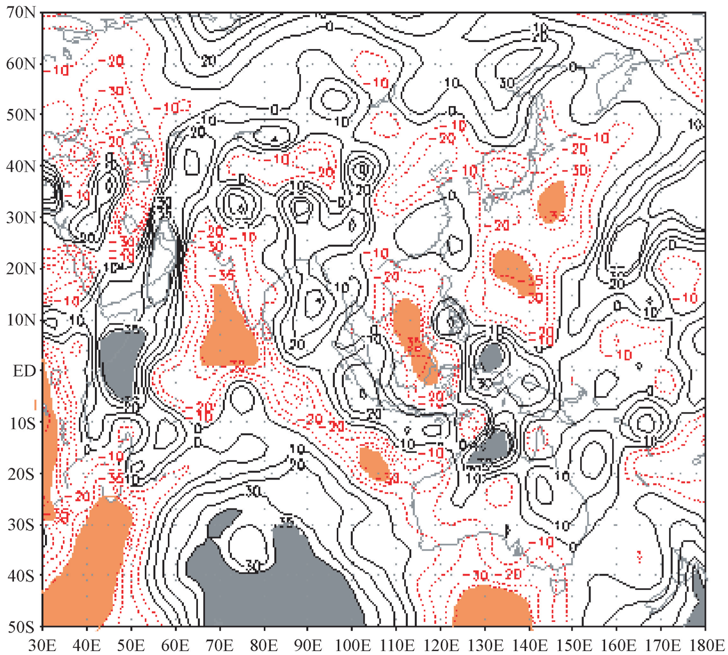

Fig. 4 Correlation field between $ASOI_{12\text{-}2}$ and 850 hPa meridional wind (the isopleths interval is 0.1, positive is solid and negative is dashed. The fractions above 5% are shaded).

circulation in eastern Australia which intensifies the cold high there. There is an anomalous south wind around 105～120°E which makes the low-level cross-equatorial flow stronger. And there is a convergence belt of wind at about 0～10°N in the north (solid line in Fig. 5) suggesting the SCS monsoon trough (ITCZ) is further north. In the low latitude (20～25°E) over the mainland of China there is an anomalous cyclonic circulation centered on the Yun-Gui tableland. And in the high latitude (40～50°E) a vigorously anomalous cyclone is seen centered in the south of Lake Baikal. The Meiyu trough is further north. Between the two low cyclones there is an anomalous anti-cyclone. And the subtropical high extends west. Comparing with Fig. 2Rd we can see that precipitation in July-August over the Yangtze is less and the rain belts are mainly around the Huang River area.

During the high $ASOI_{12\text{-}2}$ year, in contrast, there is an anomalous cyclone in summer (June-August) eastern Australia which makes the cold high weaken there. There is a north wind around 105～125°E in the equator which makes low-level cross-equatorial flow weaker. And there is a distinct convergence band between 0～10°S suggesting the ITCZ is further south. The monsoon trough is formed via the confluence at 20～30°N of warm, moist air brought by SCS southwest wind anomalies and cold air carried by northerly or northwest wind departures, and the trough is positioned further south. In the vicinity of the Yangtze basin, with the subtropical high moving eastward, precipitation is more especially in the south of Yangtze River in sharp contrast to the north.

Table 2 presents the characteristics of summer East Asian monsoon systems for the high and low $ASOI_{12\text{-}2}$ years. And in the years of low $ASOI_{12\text{-}2}$, the Australian high is stronger (the anti-cyclonic circulation departure); low-level cross-equatorial flow is also stronger (anomalies of southerly winds); the ITCZ position is further north (between 0 and 10°N); the subtropical high extends further west; the Meiyu trough is further north (between 30～38°N); and the rain belts are also northward (in the Huang River). In the years of high $ASOI_{12\text{-}2}$, the Australian high is weaker (is the cyclonic circulation departures); the low-level cross-equatorial air is also weaker (northerly wind departures); the ITCZ is further south (between 0～10°S); the subtropical high extends further east; the Meiyu trough is positioned further south (20～30°N); the rain belts are southward (in the Yangtze River).

Table 2. The characteristics of summer East Asia monsoon system for the high and low $ASOI_{12\text{-}2}$ years

East Asian Monsoon system	$ASOI_{12\text{-}2}$ low years	$ASOI_{12\text{-}2}$ high years
Australian high	stronger (anti-cyclonic departure)	Weaker(cyclonic departures)
cross-equatorial flow	stronger(southerly wind departures)	weaker(northerly wind departures)
ITCZ position	further north(between 0～10°N)	further south(between 0～10°S)
subtropical high	further west	further east
Meiyu trough	further north (between 30～38°N)	further south(between 20～30°N)
rain belts	northward(in the Huang River)	southward (in the Yangtze River)

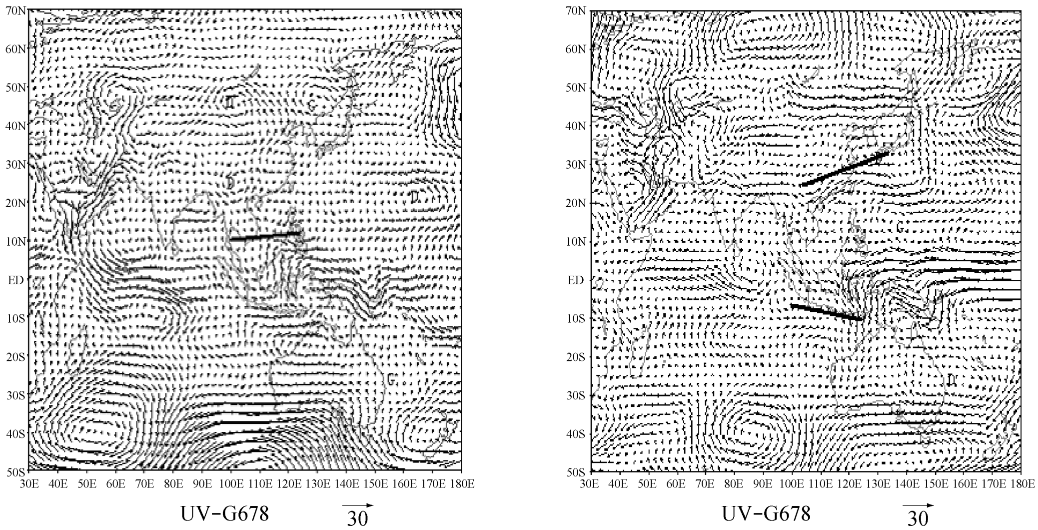

Fig. 5 Composite field of 850hPa wind departures separately for the $ASOI_{12\text{-}2}$ high years (left) and for the $ASOI_{12\text{-}2}$ low year (right), solid line is convergence line.

There is a close association between the southern Australian circulation and East Asian monsoon systems. Chen *et al.*[17] proposed that when ITCZ is strong, Australian high, SCS cross-equatorial flow and southwest monsoon are strong, the subtropical high extending west or north while the Indian monsoon becomes weak and v. v. This conclusion has been confirmed by numerical simulations. He *et al.*[18] imposed on a 1982 July mean field with a low-level anti-cyclonic departure field only limited to the Australian region to represent the cold air onset there, and then integrated for 14 days. And their results showed that with the anti-cyclone imposed the southeast trade wind in the southern hemisphere enhances first and the cross-equatorial flow intensifies after 5 days, then SCS monsoon becomes stronger, and precipitation over the Indo-China Peninsula increase and then spreads into the Yangtze River. The results are similar with characteristics of summer East Asian monsoon systems given by Table 2 for the $ASOI_{12\text{-}2}$ high and low years. According to the above analysis, we summarize the process of $ASOI_{12\text{-}2}$ influencing the summer precipitation over China as follows.

During the low $ASOI_{12\text{-}2}$ years the spring (May) circulations are affected, leading to a strong Australian high, strong eastern-Asian cross-equatorial air and early onset of the SCS summer monsoon (before the 4th pentad of May), and then influence the summer circulations by reinforcing the Australian cold high (anti-cyclonic circulation departures), making the low-level cross-equatorial air stronger (southern wind anomalies), the ITCZ being more northward (0～10°N), extending the subtropical high west, taking the Meiyu trough a more northern location (in 30～38°N) and the summer rain belts of China being northward (over the Huang River area). During the high $ASOI_{12\text{-}2}$ years, on the other hand, the spring (May) circulations are affected in such a way that the Australian high and eastern-Asian cross-equatorial air are weak as well as the SCS summer monsoon breaks out later (after the 4th pentad of May), followed by influencing summer circulations, resulting in the Australian high weaker (cyclonic departures) as well as the low-level cross-equatorial air (northern wind departures), the ITCZ being southward (0～10°S), the subtropical high positioning eastward, the Meiyu trough being southward (20～30°N), and the rainy-season rain belts being southward (over the Yangtze River basin).

6 Conclusion and discussion

The data of 360 monthly NCEP Antarctic sea ice concentrations are used to diagnose the Antarctic sea ice seesaw pattern with defining the difference of concentration between the Ross Sea outer region and the Bellingshausen Sea as the ASOI. Through correlation analysis we study the relationships among the $ASOI_{12\text{-}2}$, Chinese monsoon rainfall and East-Asian summer atmospheric circulations and investigate the possible influencing processes. And the main points as follows.

(1) The synchronous correlation coefficients significant at 5% level between ASOI and Antarctic ice concentration account for roughly 1/3 of the total gridpoints, most of them are in the Ross, Weddell, and Bellingshausen Seas. It suggests that the ASOI is indicative of the interannual variability of ice concentrations in the key regions of Antarctica.

(2) The $ASOI_{12\text{-}2}$ obviously correlates with the July-August rainfall departure over China. When the correlations are positive, the rain belts are mainly in the Yangtze River and its south, with the coefficients significant at 5% lel. The north of Yangtze River is negative correlation zones.

(3) The $ASOI_{12\text{-}2}$ is closely related to the date of SCS monsoon onset. For the negative (positive) $ASOI_{12\text{-}2}$ year, the onset occurs earlier (later) at the probability of 11/14=79% (12/15=80%). The correlativity between $ASOI_{12\text{-}2}$ and departures of 850 hPa meridional winds demonstrates that in the East Asian monsoon region, there are zones of negative correlations (significant at 5% level) in western Australia and the cross-equatorial air region.

(4) Investigation is conducted of possible processes as regards $ASOI_{12\text{-}2}$ influencing summer rainfall over China, together with a conceptual model. It shows that in the low (high) $ASOI_{12\text{-}2}$ year, the circulations are affected in May first leading to a strong (weak) Australian high, intense (feeble) cross-equatorial air, and earlier (later) onset of the SCS monsoon, then further imposed upon summer circulations in such a way that the Australian cold high strengthens (weakens), cross-equatorial flow at low level intensifies (weakens), the ITCZ is located in north (south), the subtropical high extends west (east), the Meiyu trough is in north (south) and rain belts in the July-August are in north (south).

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