CHINESE GEOGRAPHICAL SCIENCE
Volume 15, Number 1, pp. 22–28, 2005
Science Press, Beijing, China

# IMPACTS OF ANTARCTIC OSCILLATION ON SUMMER MOISTURE TRANSPORT AND PRECIPITATION IN EASTERN CHINA

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**ABSTRACT**: Using NCEP/NCAR reanalysis data and monthly precipitation over 160 conventional stations in China, analyses of moisture transport characteristics and corresponding precipitation variation in the east part of China in summer are made, and studies are carried out on possible influence on moisture transport and precipitation in summer by the variation of Antarctic Oscillation (AAO). The results show that the abnormal variation of the AAO affected the summer precipitation in China significantly. The variation of AAO can cause the variation of intension and location of Northwestern Pacific High, which in turn cause the variation of summer monsoon rainfall in the eastern China.

**KEY WORDS**: Antarctic Oscillation; moisture transport; summer precipitation anomaly; China

CLC number: P461 Document code: A Article ID: 1002-0063(2005)01-0022-07

## 1 INTRODUCTION

Summer precipitation in China is a phenomenon happening in the south-north oscillation process of the East Asian summer monsoon, and the monsoon is in essence resulted from the joint effects of the planetary scale circulation of thermal convection between Southern Hemisphere and Northern Hemisphere and the thermal contrast of sea-land (ZENG and LI, 2002). Studies show that the changes in the circulation of the Winter Hemisphere play an active role in the interaction between the two hemispheres (ZHAO and WANG, 1979). Therefore, the circulation of Southern Hemisphere affects significantly the East Asian summer monsoon.

GONG and WANG (1999) at the first time studied the Antarctic Oscillation (AAO). The AAO is zonally symmetric, and its active center is located in the Antarctic region. The AAO reflects the variation of the intensity of the mid-latitude westerly in the Southern Hemisphere, and is the basic structure of the Southern Hemisphere atmospheric circulation and the dominant pattern of climatic variability. The study by FAN *et al*. (2003) showed that the AAO is not only close related with the meteorological element fields in the Southern Hemisphere, but also associated with the mid-latitude element fields in the Northern Hemisphere. Especially in the northern summer, the AAO is significantly positively correlated with tropical and northern mid-latitude sea level pressure (SLP) and 500hPa height fields, and the positive correlation area in June–August may reach the vicinity of 60°N. THOMPSON and WALLACE (2000) investigated the structure and seasonal changes of AAO and their influences on mean circulations and trade wind intensity. When the AAO strengthens, the high-latitude westerly and equatorial trade wind also enhance, and the mid-latitude is warmer than average while the polar area is colder. Further more, the spring precipitation over the southeast part of South America is distinctively affected by AAO (SILVESTRI and VERA, 2003). When the AAO in spring is in positive (negative) phase, the anticyclonic (cyclonic) circulation anomaly prevails at the upper level over the southeast part of South America, which weakens (enhances) moisture convergence, thus reducing (increasing) precipitation. The activities of AAO strongly modulate ENSO signals, and further affect precipitation over the southeast part of South America.

It was generally understood that the variation of drought/flood in the eastern part of China in summer was determined by moisture transport that is intimately correlated with monsoon(HUANG *et al*., 1998; SIMMONDS

Received date: 2004-01-25
Foundation item: Under the auspices of the National Natural Science Foundation of China (No. 40233037)
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*et al*., 1999; ZHANG, 2001). The whole-layer integrated moisture transport flux reflected the process of redistribution of the substance and energy in the atmosphere, which is worth of further study. However, questions still remain on how the summer moisture transport and precipitation will vary in the eastern part of China, and how such a variation is connected with the interannual anomaly of the AAO. In this paper, we tried to reveal the possible relationship between moisture transport and interannual precipitation variability in the eastern China and the AAO.

## 2 DATA AND METHODOLOGY

Data used in the article are: the NCEP/NCAR global daily wind and specific humidity fields at 8 levels, i.e. 1000, 925, 850, 700, 600, 500, 400, 300hPa; global daily surface pressure; the monthly mean SLP, the duration of the data is from 1958–1999, with grid scale 2.5°× 2.5°; the monthly precipitation data over 160 synoptic stations in China with the period from 1951 –2000 (provided by National Meteorological Center of China).

The analyses techniques used include composite and correlation analysis and linear regression analysis.

Using the data mentioned above, the whole layer moisture transport flux vector $Q$ and its divergence $D$ can be calculated by

$$Q=\frac{1}{g}\int_{p_s}^{p_t}\vec{V}q\,\mathrm{d}p$$

$$D=\mathrm{div}Q$$

where $\vec{V}$ and $q$ are wind vector and specific humidity at different levels, respectively; $p_s$ and $p_t$ are lower bound (surface pressure) and upper bound (taken as 300hPa) of the air column, respectively; $g$ is the gravitational acceleration. So the daily zonal and meridional moisture transport flux and moisture flux divergence for the whole layer from surface to 300hPa can be obtained. Note that the summer precipitation in the paper means the total amount for the period of June, July and August (JJA) while other elements indicate average values for the same period if there is no particular explanation. Only the anomalous fields of moisture transport flux and summer rainfall in China are used in this article.

Studies (GONG and WANG, 1998; THOMPSON and WALLACE, 2000) showed that the most prominent characteristic in variation of large scale atmospheric circulation in middle to high latitudes in the southern hemisphere was AAO, i.e. a relationship of the "seesaw" style standing wave in sea level pressure (SLP) between a belt around 40°S and the Antarctic continent. In this paper, we also defined the standardized difference of zonal mean SLP anomaly in 40°S and 65°S as AAO index (AAOI, unit: hPa). In the paper the eastern part of China is the eastern area of 110°E in China territory.

## 3 MOISTURE TRANSPORT AND PRECIPITATION ANOMALY IN SUMMER

Fig. 1 is the distribution of correlation coefficients between 850hPa zonal-mean meridional wind ($V$) and the AAOI. There existed significant positive correlation between AAOI and 850hPa $V$ wind in about 45°N during May–June and negative correlation in 30°N during June–September. This means that the $V$ wind in the low level of troposphere will decrease in 30°N during the high index polarity of the AAOI in summer.

Fig. 2 is for distribution of correlation coefficients between summer moisture flux vector modes and the AAOI. It may be seen that there existed quite good statistical correlation between interannual variation of AAO and moisture transport in the eastern China. The variability of AAO was related to the moisture transport in the Southern Hemisphere circumpolar low belt and in the tropical middle and eastern Pacific, but also notably correlated with moisture transport in westerly belts in Eurasia continent around 40° N and the eastern China. When the westerly transport belt in the high latitudes in the Southern Hemisphere was intensified (intensification of the AAO) while the easterly transport in the tropical middle and eastern Pacific was intensified, the moisture transport in the eastern China was correspondingly weakened, and vice versa.

To investigate the impact of interannual anomaly of the AAO, in the time series of the AAOI, over one standard deviation was chosen as a criterion of interannual anomaly of the AAO. Composite analyses were carried out for anomalies of summer moisture flux vector fields and corresponding summer precipitation in China during the years with positive/negative anomalies of the AAOI.

During the high index polarity of the AAO, the Northwestern Pacific Subtropical High (NWPSH) became southward, with existence of a strong cyclonic zone from the eastern China to the western Japan. As a result, a relatively strong water vapor convergence came into existence in the Changjiang valley (Fig. 3a). Correspondingly, precipitation was increased in the Changjiang River valley and the Northeastern China, while decreas-

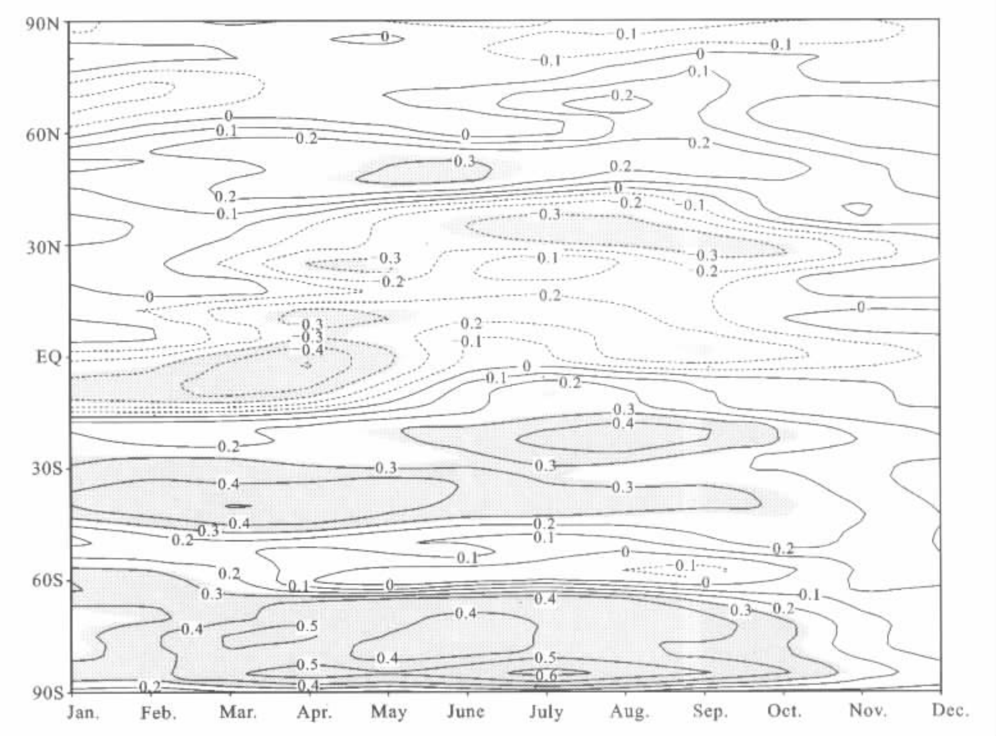


Fig. 1 Correlation coefficients between 850hPa zonal-mean meridional wind ($V$) and the AAOI (1958−1999, areas exceeding the 95% confidence level are shaded)

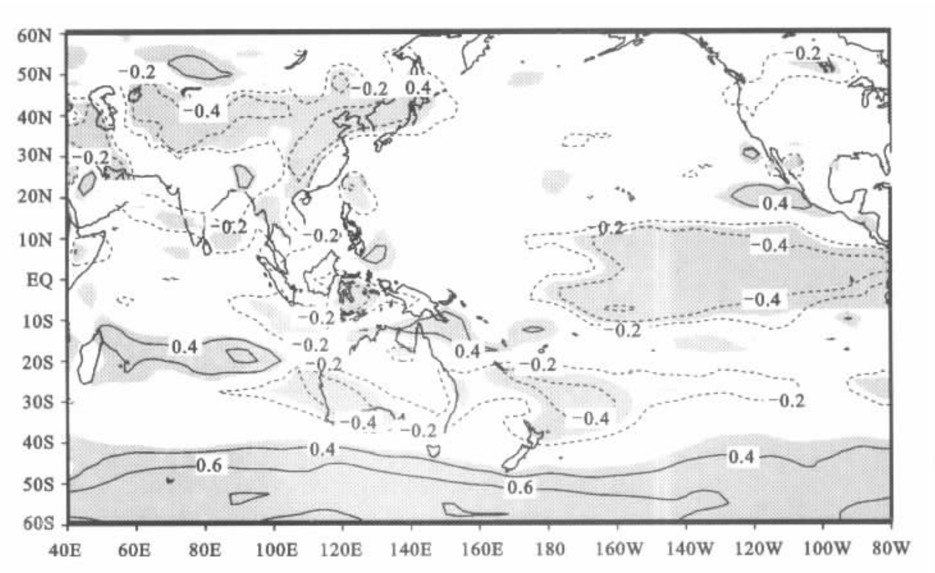


Fig. 2 Correlation coefficients between summer moisture flux vector modes and the AAOI (in JJA 1958−1999, areas exceeding the 95% confidence level are shaded)

ed in South China and North China (Fig. 3b). On the contrary, during the low index polarity of the AAOI, the NWPSH tended to be located more northward, while a strong water vapor flux anomaly zone appears in the eastern Asia (Fig. 4a). Correspondingly, the precipitation appeared in patterns of less than normal in the most parts of the Changjiang River valley, more than normal in North China and South China (Fig. 4b).

Fig. 5 is the correlation coefficients between MeiYu rainfall intensity (ZHAO, 1999) in Changjiang River valley during June−July and AAOI (solid line), and North China rainfall anomalies during July−August and AAOI (dashed line). The variation of AAOI in April and May significantly correlated with MeiYu precipitation anomaly, while the variation of AAOI in July and August significantly correlated with precipitation anomaly in

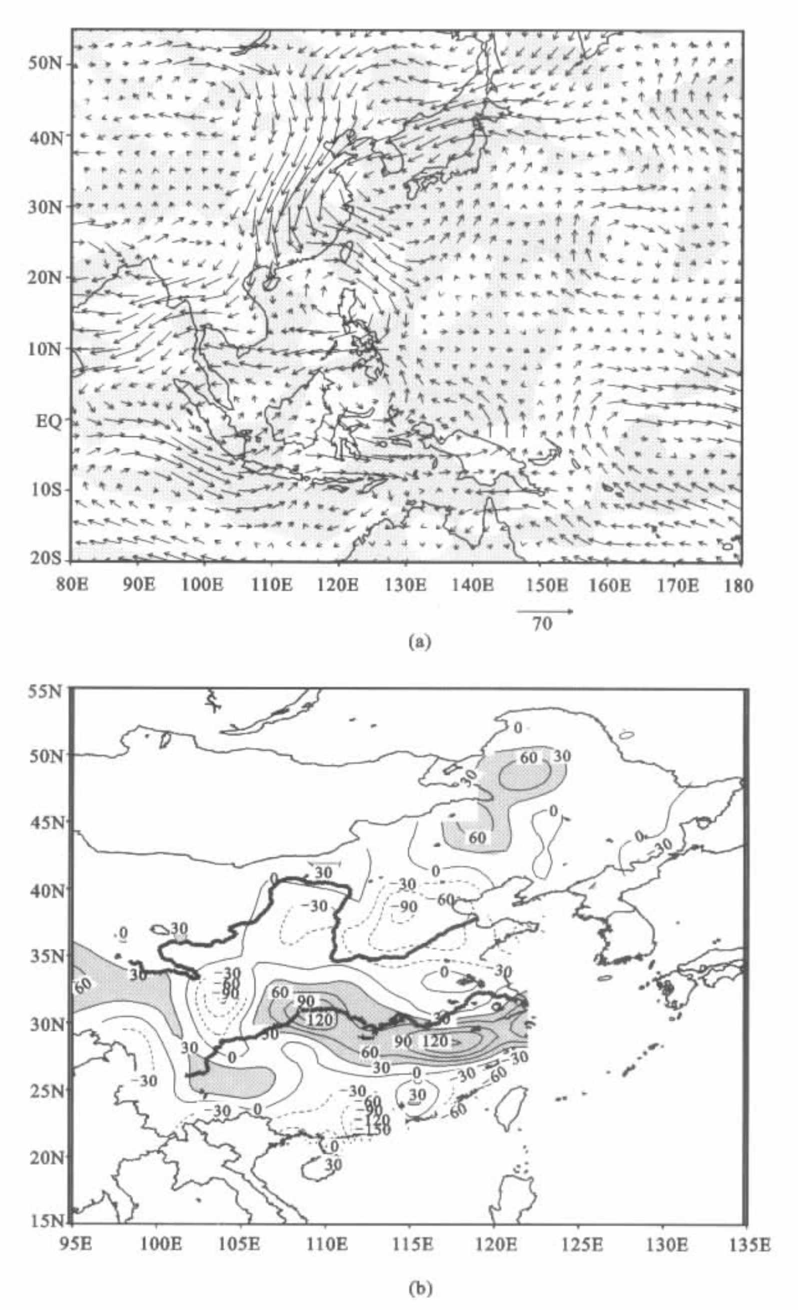


Fig. 3 Composite diagrams for summer moisture flux vector and divergence anomalies during the years with high index polarity of the AAOI (for Fig. 3a, the unit is $10^{-6}$ kg/(s·m$^2$), and shaded areas indicate negative divergence anomaly) and for summer precipitation anomaly in China (for Fig. 3b, the unit is mm, and shaded areas indicate positive anomaly over 30mm, in JJA 1958–1999)

North China rainly season during July–August.

## 4 IMPACT OF AAO ON NORTHWEST PACIFIC SUBTROPICAL HIGH

In the contemporaneous correlation diagram of the Changjiang River valley precipitation in China and 500hPa height field (Fig. 6a), corresponding to more precipitation in the Changjiang River valley, NWPSH intensified and became southward, the Blocking High near Lake Baikal and northeast Asia intensified, while the cyclonic zone over Japan also intensified. This height field pattern is favorable to the confluence of cold and warm air over the Changjiang River valley. The distribution of the correlation coefficient between AAOI averaged in April and May and the mean 500hPa height field of June–August (Fig. 6b) is very similar with that between the Changjiang River valley precipitation and 500hPa

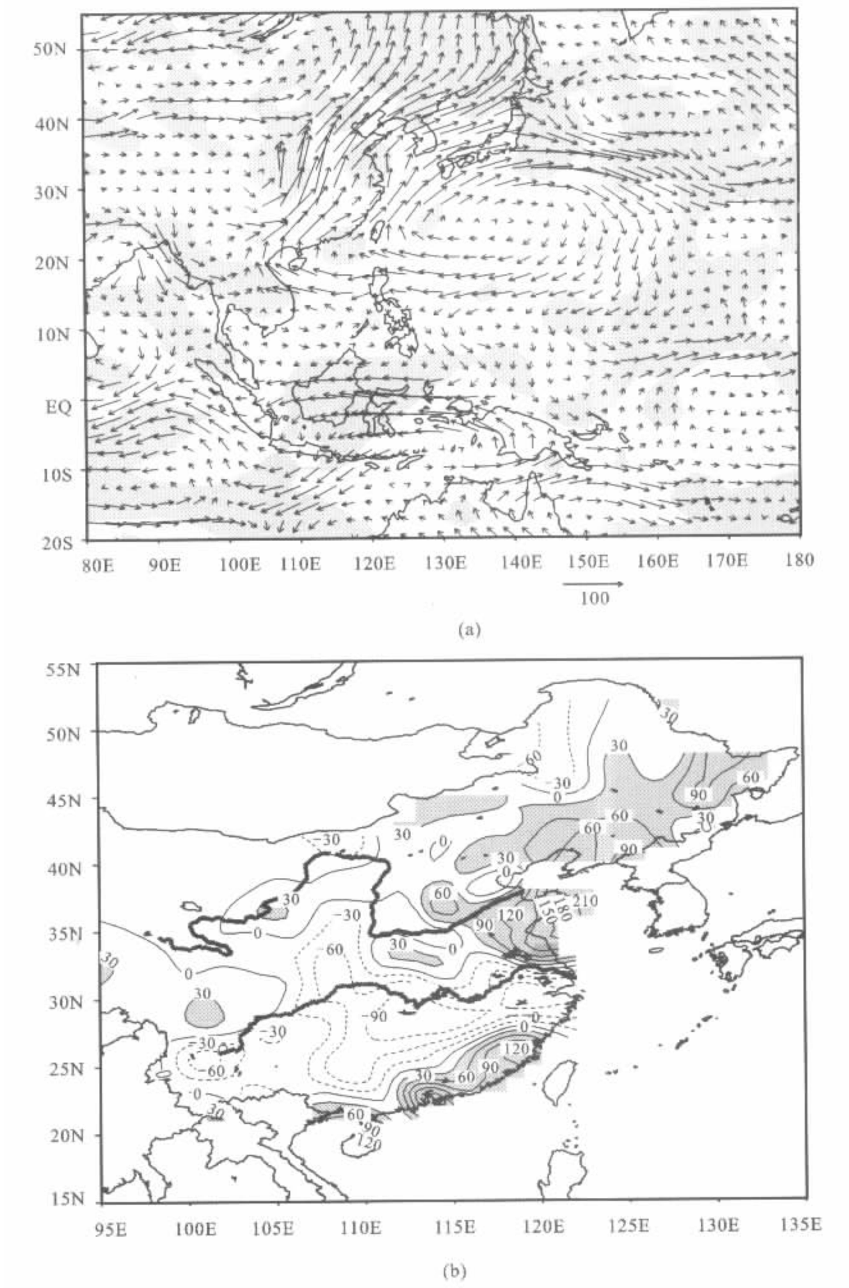


Fig. 4 Same as Fig. 3, but for the low index polarity of the AAOI

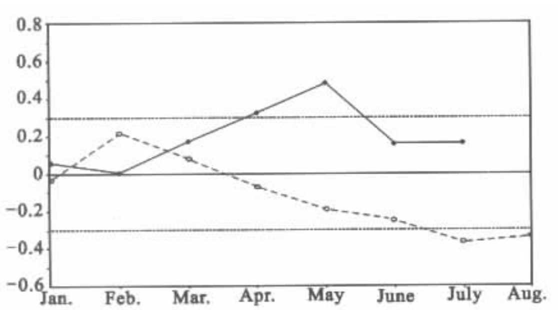


Fig. 5 Correlation coefficients between MeiYu rainfall intensity during June–July and AAOI (solid line), and the North China rainfall anomalies during July–August and AAOI (dashed line) (1958–1998, dotted lines denote the 95% confidence level)

height field. This suggests that the variation of AAO can significantly influence the anomalous changes of summer NWPSH, viz. its changes in position and intensity, thus leading to the significant interannual variations of precipitation over the Changjiang River valley and Northeast China.

## 5 CONCLUSIONS AND DISCUSSION

Based on the analysis on effect of variation of the AAO on the summer moisture transport and rainfall in the eastern part of China, we draw the conclusion as follows:

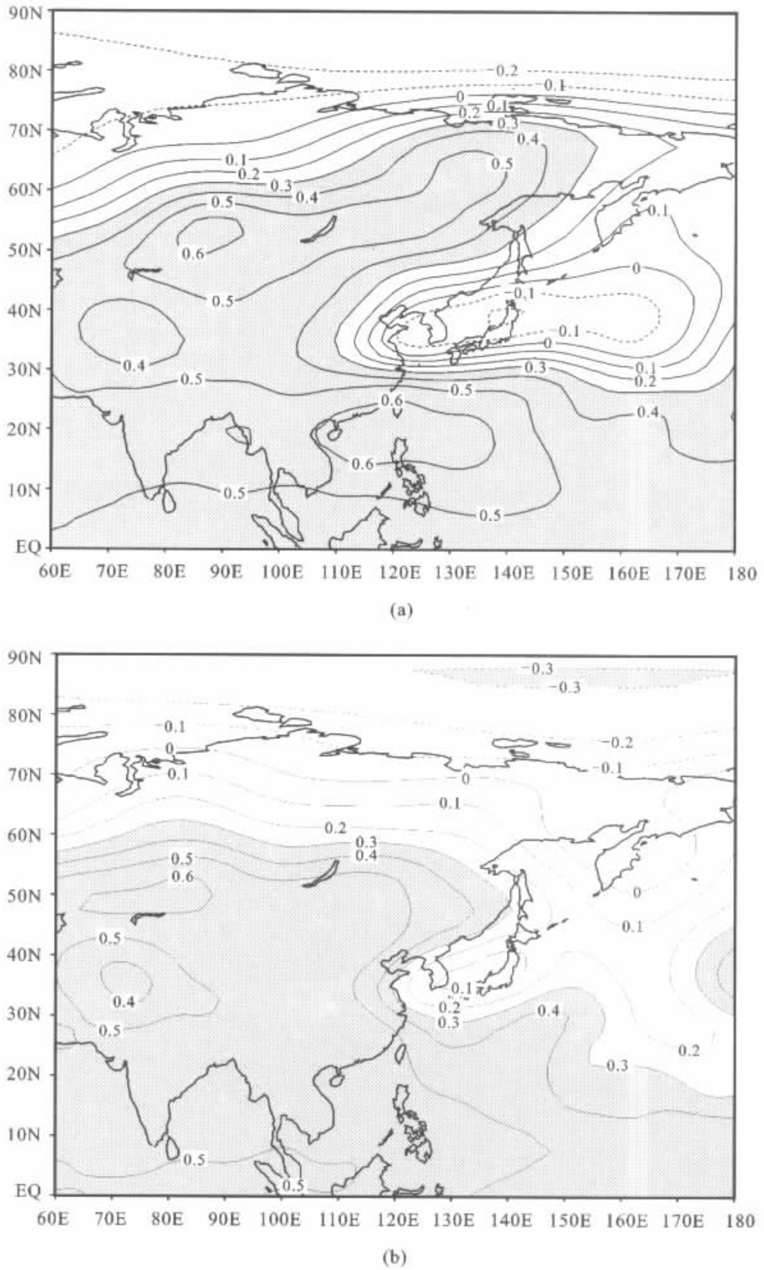


Fig. 6 Distribution of the correlation coefficients of 500hPa height fields with contemporaneous the Changjiang River valley precipitation (a) and AAO index averaged in April and May (b) (in JJA 1958−1999, areas exceeding the 95% confidence level are shaded)

(1) There is significant correlation between 850hPa zonal-mean meridional wind ($V$), the moisture transfer of the summer monsoon and the AAOI over 30°N−50°N in the eastern part of China in summer.

(2) Impacts of prophase Antarctic Oscillation(AAO) on the subsequent summer precipitation in the eastern part of China is analyzed. The correlation coefficient between June−July rainfall in Changjiang River valley and April−May AAO index is 0.3−0.5, and the correlation coefficient between July−August rainfall in North China and July AAO index is 0.36, which exceeds the confidence level of 99.9%.

(3) The interannual anomaly of the AAO matched well with summer precipitation anomaly in China, being major characteristics of alternative rainfall patterns between the Changjiang River valley-Northeast China and North China-South China.

(4) The variation of AAO can significantly influence the anomalous changes in position and intensity of NW-PSH, thus leading to the significant interannual varia-

tions of summer precipitation anomaly in China.

There are many more factors affecting summer precipitation in China, e.g. Arctic sea ice, tropical SST and so on, and interactions might exist among these factors. Therefore, it is not enough to depict them in linear relations only. There is a need to use better techniques for thorough future study.

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