Annual Variations of the Arctic Oscillation and the Antarctic Oscillation[*]

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The Arctic Oscillation (AO) is a leading mode of climate variability of the extratropical Northern Hemisphere, i.e., a seesaw pattern in which atmosphere pressure at polar and middle latitudes fluctuates between positive and negative phase. The Antarctic Oscillation (AAO) is similar to the Arctic Oscillation, but for the Southern Hemisphere. By use of the NCEP / NCAR January 1958–December 1999 reanalysis data and the AO and AAO indices, some characteristics of the annual variations of the AO and AAO are studied in this paper. The annual and longitudinal variations of correlation coefficients between some meteorological elementary fields and the AO and AAO indices are also investigated.

Key words: Arctic Oscillation, Antarctic Oscillation, annual variation.

1. INTRODUCTION

The Arctic Oscillation (AO) was defined by Thompson and Wallace (1998) as the leading mode of climate variability of the extratropical Northern Hemisphere. They argued that the AO has strongly zonal symmetry and its center lies in the Arctic region. Thompson and Wallace (2000) also pointed out that the well–known tele–connection pattern known as the North Atlantic Oscillation (NAO) is usually regarded as the regional manifestation of the AO

in the Atlantic sector and that the AO and the NAO are largely the same things and the NAO is part of the AO. A growing body of evidence (Thompson and Wallace, 1998; 2000a, b; Wallace, 2000; Clara, 2000) indicates that the AO has wide−ranging effects over the Northern Hemisphere. Thompson and Wallace (1998) argued that the AO rivals the El Niño and the Southern Oscillation (ENSO) in terms of its significance for understanding global climate variability and trends. The Antarctic Oscillation (AAO) is similar with the AO, but for the Southern Hemisphere. Gong and Wang (1999) first researched the AAO and have got some useful findings. Because of the strong similarity between the AO and the AAO (Thompson and Wallace, 1998), we studied the annual variations of the AO and the AAO together in order to further research the rules of their variability and offer some references for the global climate change.

2. DATA

Monthly mean sea level pressure (SLP) field, 500 hPa geopotential height field, 500 hPa zonal wind field and 1000 hPa temperature field on a $(2.5° \times 2.5°)$ mesh are taken from National Center of Environmental Prediction / National Center for Atmospheric Research (NCEP / NCAR) reanalysis data set. The AO and AAO indices here are kindly provided by Dr. David Thompson of University of Washington (Thompson and Wallace, 1998), which are derived from the leading empirical orthogonal function analysis of monthly sea level pressure field poleward of 20° based on the Northern Hemisphere and the Southern Hemisphere, respectively. These data cover the period from January 1958 to December 1999.

3. RESULTS AND DISCUSSION

3.1 *The Annual Variations of the Biggest Negative cross Correlation Coefficients of Zonal−Averaged Values of Monthly SLP in the Respective Hemispheres and Their Corresponding Midlatitudes and High Latitudes*

In this section, we calculate the cross correlation coefficients of zonal mean monthly SLPs covering the period from 1958 to 1999, respectively from January to December, and find out the biggest negative correlation coefficients and their corresponding midlatitudes and high latitudes in the respective hemispheres in order to study the characteristics of their annual variations which can reveal the rule of the annual variations of the intensities of the AO and the AAO and their centers of action.

Figure 1a shows the annual variations of the biggest negative values of cross correlation coefficients of the zonal mean monthly SLPs in the respective hemispheres. In the Northern Hemisphere, the biggest negative correlation coefficient peaks in January and has the smallest one in June. These suggest that the AO exists throughout the year, but the intensity of the AO in summer is much weaker than in winter and the intensity of the AO in spring and autumn lies in between winter and summer. In the Southern Hemisphere, the biggest negative correlation coefficients are smaller in March, April, September and October than those of the other months. It can be seen the intensity of the AAO in winter is as strong as that in summer and there are strongly zonal symmetry in both seasons and the intensity of the AAO are more stable than that of the AO because of the sharply contrasting land−sea distributions.

Figure 1b shows the annual variations of the corresponding two latitudes of the biggest negative cross correlation coefficients of zonal−mean monthly SLP in the Northern Hemisphere. It can be seen from Fig. 1b that the corresponding two latitudes locate southwards during the period from December to next April and the one at high latitudes moves south-

ward 60°N and another one at midlatitude near 30°N, whereas the corresponding two lati-
tudes locate northwards during the period from May to November, especially the one at high
latitude moves to near 90°N during June to October. The above facts suggest that the AO has
bigger meridional scale during the period from December to next April than that of June to
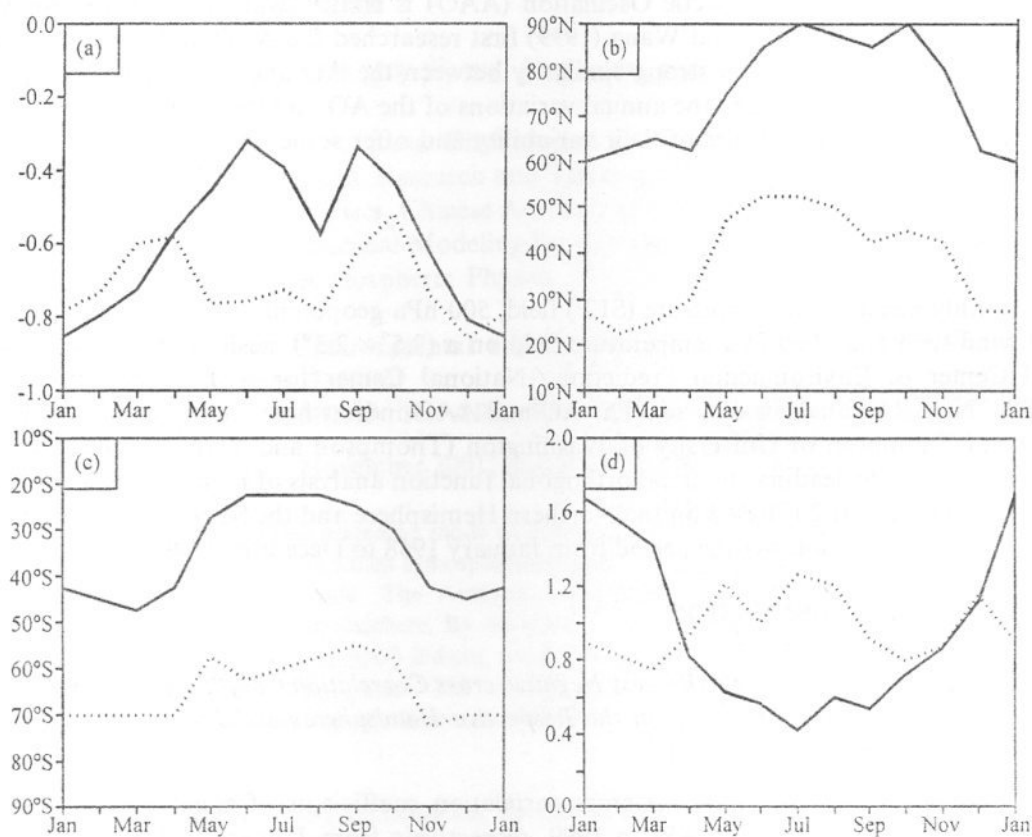October.

Fig. 1. (a) The annual variations of the biggest negative values of cross correlation
coefficients of the zonal mean monthly SLPs in the Northern (solid line) and South-
ern (dashed line) Hemispheres; (b) the annual variations of the corresponding two lat-
itudes (solid line for the one at high latitude and dashed line for another at
midlatitude) of the biggest negative cross correlation coefficients of zonal–mean
monthly SLP in the Northern Hemisphere; (c) same as (b), but for the Southern Hem-
isphere; and (d) the standard deviations of the AO (solid line) and AAO (dashed line)
indices.

For the Southern Hemisphere (see Fig. 1c), both the two latitudes of the biggest negative
cross correlation coefficients of zonal–mean monthly SLP locate more southwards during the
period from November to next April than that of May to October. The one at high latitude
lies at about 70°S and anther at midlatitude near 40°S from November to next April, whereas
the high–latitude one locates near 60°S and the midlatitude one near 30°S from June to Octo-
ber. It can be concluded that the AAO has smaller meridional scales from November to April
than those of May to October.

3.2 *The Annual Variations of the Standard Deviation of the AO Index and the AAO Index*

Figure 1d shows the annual variations of the standard deviations of the AO and AAO

indices. Either the AO index or the AAO index has an annual march with higher values during the cold–season–months of the respective hemisphere and with lower ones during the warm seasons of the respective hemisphere. The standard deviation of the AO index peaks in January and has the lowest value in July, however the standard deviations of the AAO index are varying more stably throughout the year and with lower amplitudes than those of the AO index.

3.3 *The Seasonally and Longitudinally Varying Structures of the Correlation Coefficients between the AO and AAO Indices and Several Zonal–Mean, Meteorological Elementary Anomaly Fields*

3.3.1 Monthly sea level pressure and monthly 500 hPa geopotential height anomaly fields

Figure 2a shows that the annual and longitudinal variations of correlation coefficients between the AO index and zonal mean monthly sea level pressure anomalies based on the data from 1958 to 1999 and area above 95% significance level are shaded. It is evident that there are significant positive and negative correlation zones, respectively locating at the midlatitudes and the high latitudes of the Northern Hemisphere. The covering latitudes of the significant negative correlation area are consistent from January to December covering from 55°N to 90°N and the biggest negative correlation coefficient is above 0.9 and locates near 75°N, whereas the significant positive areas are much bigger in August and in the cold months of the Northern Hemisphere than those of the other months of the year, the former covering the latitudes from 10°N to 50°N and the latter from 30°N to 50°N. It is noted that the area of the significant positive correlation disappear in September, which suggests that the positive relationship between the AO and the sea level pressure field is not significant in September.

For the AAO index (see Fig. 2b), there are also significant positive and negative correlation zones, which are above 95% significance level, respectively locating at the midlatitudes and the high latitudes of the Southern Hemisphere. The areas of negative correlation above 95% significance level are basically consistent from January to December, all of which
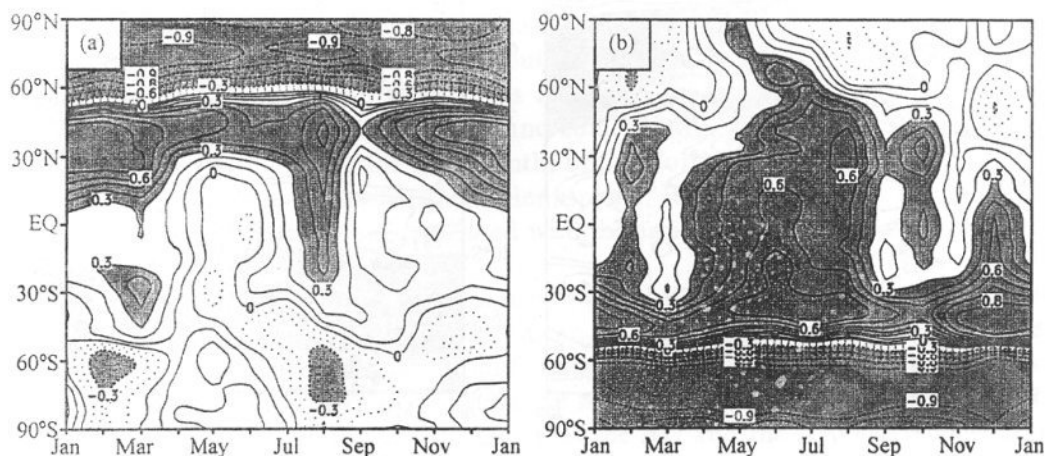

Fig. 2. The seasonal and longitudinal variations of correlation coefficients between the AO indices (a) and the AAO indices (b) and zonal mean monthly sea level pressure anomalies based on the data from 1958 to 1999 and area above 95% significance level are shaded. The positive correlation coefficients are solid lines and the negative are dashed ones.

covering from 60°S to 90°S and the biggest negative correlation coefficient is nearly 1.0 and locates near 70°S. Similar to the AO index, the covering area of the significant positive correlation is bigger in the cold months of the Southern Hemisphere than those in the warm months of the Southern Hemisphere, but in contrast to the AO index, this degree is much higher and correlation areas cover from 50°S to 30°N and even spread northwards near 60°N in winter of the Southern Hemisphere, which suggests that there are also significant positive relationships at the low latitudes and the high latitudes between the AAO index and sea level pressure anomaly field.

The annual and longitudinal variations of correlation coefficients between the AO and AAO indices and zonal mean monthly geopotential height anomalies at 500 hPa based on the data from 1958 to 1999 is similar to those of sea level pressure anomaly field (the figure omitted). For the AO index, both the biggest positive and negative correlation coefficients appear in winter of the Northern Hemisphere, locating near 45°N and 75°N respectively and significant positive and negative correlation zones are basically stable all over the year, whereas, for the AAO indices, the negative and positive correlation zones are similar to those of sea level pressure anomaly field.

3.3.2 Monthly zonal wind field at 500 hPa

Figures 3a and 3b show that the seasonally and longitudinally varying structures of the correlation between the AO and AAO indices and 500 hPa zonal mean zonal wind anomaly field respectively. There are also significant positive and negative correlation zones, which are dominated by meridional dipoles with nodes centered near 45o in the respective hemisphere. In the Northern Hemisphere, the center of the positive correlation zone locates at 55°N and the negative one at 35°N, whereas, in the Southern Hemisphere, the centers of the significant positive and negative correlation zones locate near 40°S and 60°S respectively. The above analysis suggests that the AO and AAO indices can represent the annual variations of the intensity of the westerly wind in the midlatitudes of both hemispheres.
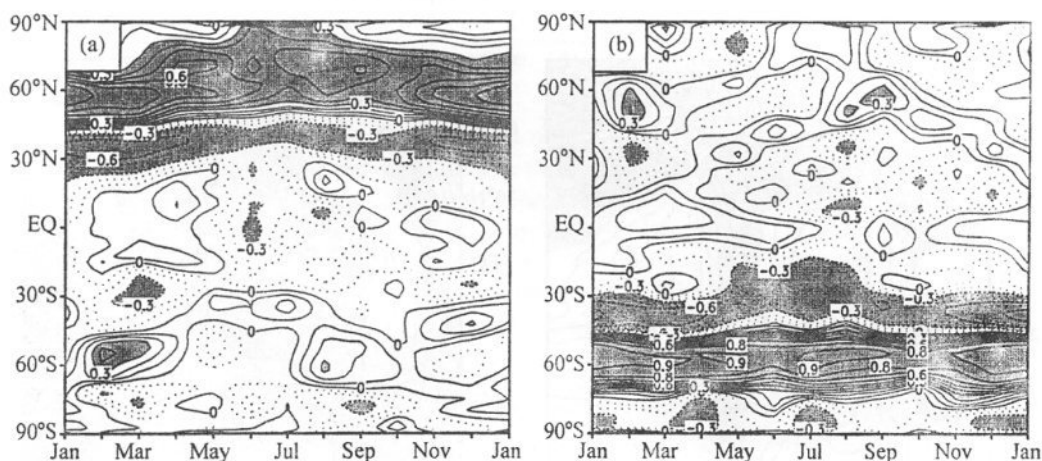

Fig. 3. The same as Fig. 2, but for the zonal mean monthly zonal wind anomaly field.

3.3.3 Monthly temperature field at 1000 hPa

Figures 4a and 4b show that the seasonally and longitudinally varying structures of the correlation between the AO and AAO indices and 1000 hPa zonal mean temperature anomaly field respectively. It is evident that there are also significant positive and negative correlation

zones, however the zonal symmetry is less significant than those of the above three fields. For the AO index, the maximum positive and negative correlation coefficients appear during the cold seasons and centered respectively near 25°N and 45°N and the two correlation zones are largely stably varying throughout the year and the areas of significant negative correlation are much smaller during the warm seasons than those during the cold ones, whereas, for the AAO index, the biggest positive correlation coefficient appears in Autumn of the Southern Hemisphere and locates near 60°S and the biggest negative one in summer of the Southern Hemisphere and near 75°S.
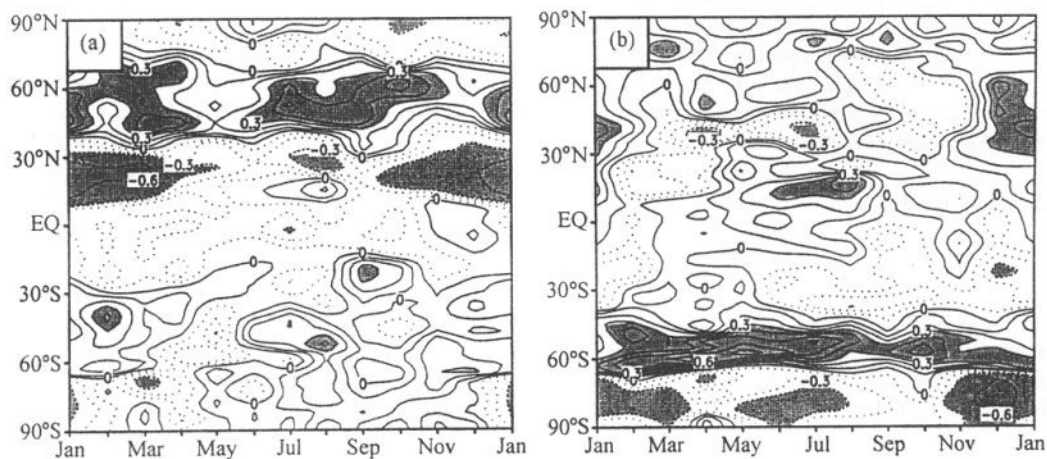

Fig. 4. The same as Fig. 2, but for the zonal mean monthly temperature anomaly field.

4. CONCLUSIONS

The conclusions made in this paper are as follows:

(1) The AO exits throughout the year, but its amplitudes and meridonal scales are somewhat large during the cold months, whereas the AAO has basically similar amplitudes and similar meridional scales during the warm and cold months. The centers of the AO and the AAO locate southwards during the cold months of the Northern Hemisphere and northwards during the warm months of the Northern Hemisphere. It can be said that the annual variations of the AO and the AAO are associated with the annual variations of the distribution of the solar radiation.

(2) Based on studying the relationships between the AO and the AAO and several meteorological elementary fields such as zonal−mean monthly−mean sea level pressure field, 500 hPa geopotential field, 500 hPa zonal wind field and 1000 hPa temperature field, it is evident that there are significantly positive and negative zones in the midlatitudes and high latitudes in the respective hemispheres, which suggest that the AO and the AAO have close relationships with the corresponding meteorological elementary fields in the respective hemispheres.

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