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Relationship between the Antarctic oscillation in the western North Pacific typhoon frequency

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Relationship between the Antarctic oscillation (AAO) and the western North Pacific typhoon number (WNPTN) in the interannual variability is examined in this research. The WNPTN is correlated with the AAO in June-July-August-September (JJAS) in 1949—1998 at –0.48 for the detrended time series, statistically significant at 99% level. The tropical atmospheric circulation as well as the sea surface temperature variability over the western Pacific associated with AAO has been analyzed. It follows that a positive phase of JJAS AAO corresponds to the larger magnitude of the vertical zonal wind shear, the anomalous low-lever anti-cyclonic circulation and anomalous high-level cyclonic circulation, and lower sea surface temperature in the major typhoon genesis region in the western North Pacific, thus providing unfavorable environment for the typhoon genesis, and *vice versa*.

western North Pacific typhoon, Antarctic oscillation, atmospheric circulation.

1 Introduction

Typhoon is a very important phenomenon in the atmosphere and has significant impacts on human society in many Asian-Pacific countries around the Pacific Ocean. Chan[1] reviewed the recent studies in the western North Pacific (WNP) tropical cyclone activities. Many studies have considered the impacts of El Niño/Southern Oscillation (ENSO) on WNP tropical storm frequency, intensity, location and the landfalling[2−8]. Some mechanisms have been proposed to explain how ENSO affects tropical storm activities, including the magnitude of vertical zonal wind shear, sea surface temperature, Walker circulation, and western North Pacific monsoon trough[3,9,10] and the relationships between the tropical storm and typhoon activity and the stratospheric quasi-biennial oscillation (QBO) have also been indicated[4].

The ENSO impacts on the typhoon numbers have been discussed in several papers. Saunders et al.[11] showed that ENSO warm episodes are associated with more typhoons over the majority of WNP. However, this finding is different from those of Lander[6]. On the other hand, Wang and Chan[8] indicated the spatial differences in the relationship between tropical storms and ENSO in WNP. In their results, the northwest and southeast regions have the opposite correlation between tropical storm number and ENSO.

Recently, Thompson and Lorenz[12] discussed the signature of the annular modes in the tropical troposphere. They identified that the annular modes in both hemispheres could be connected with the tropical and subtropical atmosphere of the opposing hemisphere. Wang and Fan[13] demonstrated the relationship between the central-north China precipitation and the Antarctic oscillation (AAO).

There are two definitions for the AAO index[14,15]. In this work, the AAO index is defined as the zonal mean normalized sea-level pressure (SLP) difference between

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40°S and 60°S following Wang and Fan[13], based on the analysis of Gong and Wang[14]. In this research, the linear trends for the time series have been removed before any correlation analysis.

2 Data sets

The western North Pacific typhoon record (1945—2004) employed in this research was obtained from the Joint Typhoon Warning Center (JTWC)[16,17]. The monthly sea-level pressure data for 1871—1998, with 5°×5° horizontal resolution, analyzed by the Hadley Center for Climate Prediction and Research, were also applied[18]. The atmospheric monthly reanalyses data (1949—1998) of the National Center for Atmospheric Research (NCAR) and National Center for Environmental Prediction (NCEP) at 17 vertical levels with a horizontal resolution of 2.5°×2.5° were employed as well in this study[19]. We also analyzed the NOAA optimum interpolation (OI) sea surface temperature (SST) monthly data[20].

3 Results

Figure 1 depicts the time series for the June-July- August-September mean (JJAS) AAO, and annual WNP Typhoons number (WNPTN) in 1945—1998. There is significant negative correlation between the two series (correlation coefficient is –0.48 for the detrended series in 1949—1998, significant at 99% level). If the Thompson and Wallace index for AAO is used, the correlation coefficient (CC) between AAO and WNPTN is –0.32, significant at 95% level. The current AAO index is correlated with the Thompson and Wallace index for AAO at 0.80 for JJAS in 1949—1998.

Many studies identified the significant role of the magnitude of vertical zonal wind shear (MWS) in the tropical cyclone activities. Large values of MWS disrupt the incipient tropical cyclone and can prevent genesis, or, if a tropical cyclone has already formed, large MWS can weaken or destroy the tropical cyclone by interfering with the organization of deep convection around the cyclone center[21]. Thus we analyzed the magnitude of vertical zonal wind shear between 150 hPa and 850 hPa, and its correlation to AAO and WNPTN in 1949—1998 is plotted in Figure 2. Figure 2(b) shows that WNPTN is negatively correlated to MWS in the large area of tropical western Pacific round 10°N—15°N east of 145°E (region A) and the South China Sea region (region B) as well, but with positive correlation in regions C and D. Region A is the major area for Typhoon genesis in the WNP, while region B is the area that typhoons frequently pass by. Turning to the AAO-MWS correlation shown in Figure 2(a), the general pattern is reverse to that of the WNPTN-MWS correlation in Figure 2(b), with the positive values in regions A and B, but negative values in regions C and D. Therefore, a positive (negative) phase of AAO is concurrent with the larger (smaller) magnitude of vertical zonal wind shear in region A, providing unfavorable (favorable) conditions to the genesis of typhoon, resulting in less (more) typhoons in this region.

We also analyzed the vorticity field at 925 hPa and depict its correlation coefficients with AAO and WNPTN in Figure 3. It follows that the correlation coef-

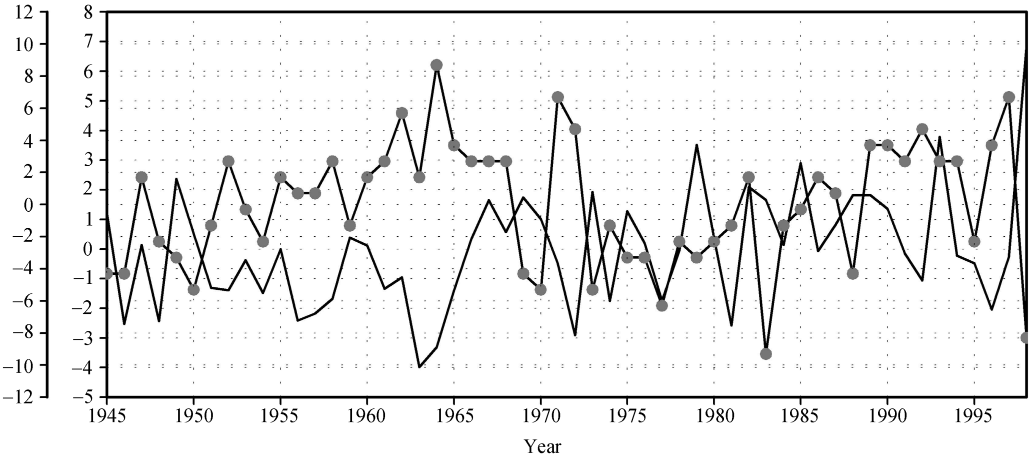

Figure 1 The interannual variation for AAO (solid line) and WNPTN (solid line with dots) in JJAS in 1945—1998. The units for *y*-coordinate are hPa (right) and number (left) respectively for AAO and WNPTN.

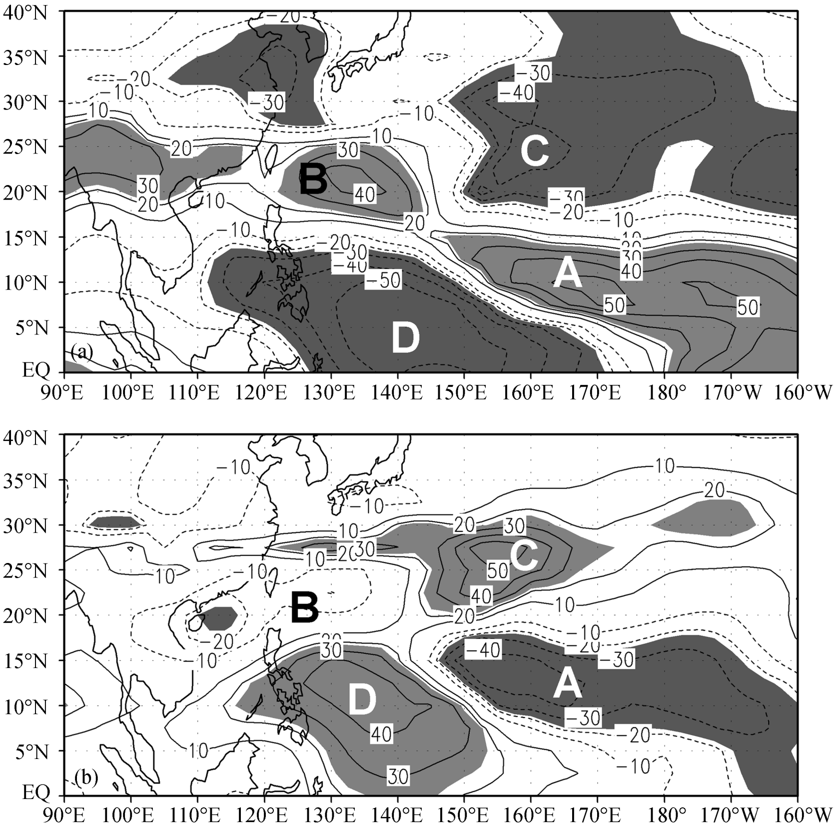

Figure 2 The geographical distribution for the correlation coefficients between the JJAS magnitude of vertical zonal wind shear (between 150 hPa and 850 hPa) and AAO index (a) and WNPTN (b) in 1949—1998. Shaded areas indicate significant correlation at 95% level, estimated by a local student t-test.

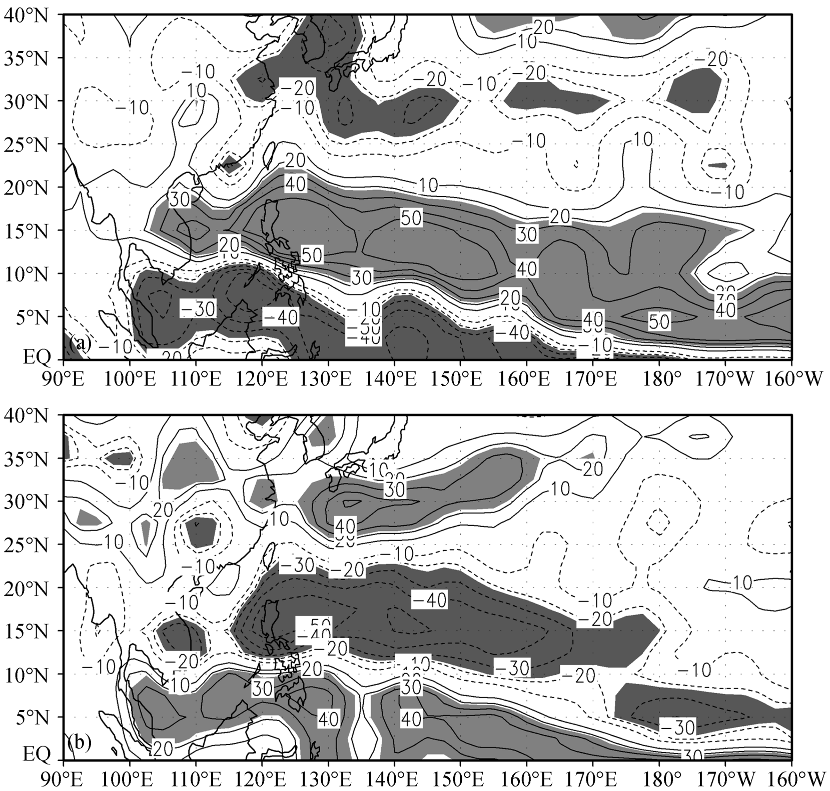

Figure 3 The geographical distribution for the correlation coefficients between the 925 hPa vorticity and the AAO and WNPTN.

ficient of AAO-vorticity is negative north to the equator in the western Pacific sector and positive in the western north Pacific. The above pattern is just similar to the WNPTN-vorticity correlation coefficient pattern, but with reverse signs. Thus the analysis on the vorticity supports the above finding that AAO is negatively correlated with the WNPTN.

Warm ocean water throughout a sufficient depth is a very important pre-condition for the typhoon genesis, fueling the heat engine of the typhoon. Thus, we analyzed the correlation between AAO and WNPTN and the sea surface temperature in JJAS. Figure 4(b) is the WNPTN-SST correlation coefficient diagram, indicating the positive values in tropical western Pacific (region A), a major typhoon genesis region. The AAO-SST correlation map (Figure 4(a)) shows a reversed coefficient in this region. Therefore, positive (negative) AAO anomalies are associated with lower (higher) SSTs in the tropical western Pacific, resulting in unfavorable (favorable) surface thermal condition for the typhoon genesis. Interestingly, the South China Sea region (B) and the region to the east of Australia (C) also have the reverse signs of correlation coefficient between what shown in Figure 4(a) and Figure 4(b), suggesting, again, the negative relationship between AAO and WNPTN.

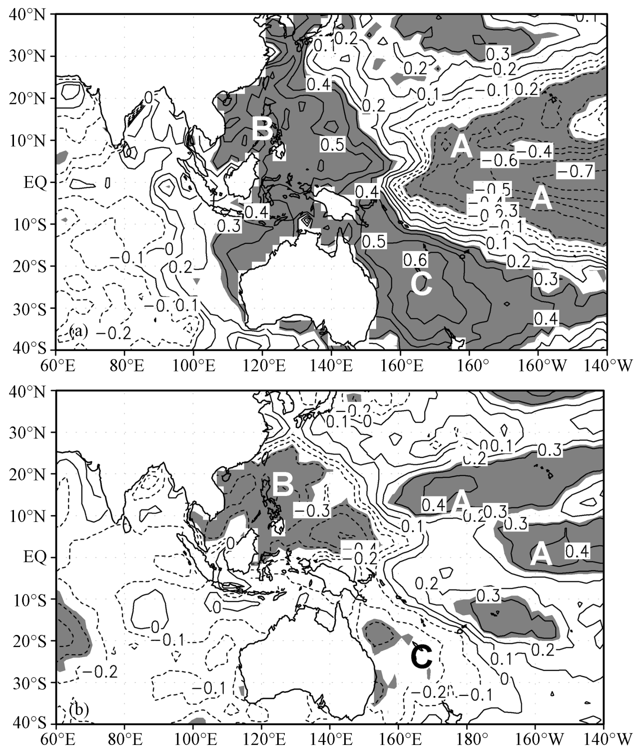

Figure 4 The geographical distribution for the correlation coefficients between JJAS SST and AAO index (a) and WNPTN (b) for JJAS in 1950—1998. Shaded areas indicate significant correlation at 95% level, estimated by a local student t-test.

Now we analyze the velocity variation in the WNP associated with AAO. In Figure 5, we depict the differences of winds at 150 hPa and 850 hPa between positive and negative AAO composites for JJAS in 1949-1998. Positive composite is for the years with normalized AAO larger than 0.5, and negative composite is for the years with normalized AAO less than –0.5. The El Nino years (1951, 1953, 1957, 1963, 1965, 1972, 1982, 1987, 1991, 1997) and La Nina years (1954, 1955, 1956, 1964, 1970, 1971, 1973, 1975, 1988, 1998) are excluded. It follows that anomalous cyclonic circulations dominate in large part of the WNP region at 150 hPa, and anomalous anti-cyclonic circulations are found at 850 hPa, showing a baroclinic structure of the variation in the tropical western Pacific. These changes provide the unfavorable environment for the typhoon genesis and development under positive AAO phase, and *vice versa*.

As noted by previous studies (e.g. Wang and Fan[13], the circulation changes in the tropical western Pacific are associated with AAO via the meridional teleconnection pattern. This teleconnection pattern is located

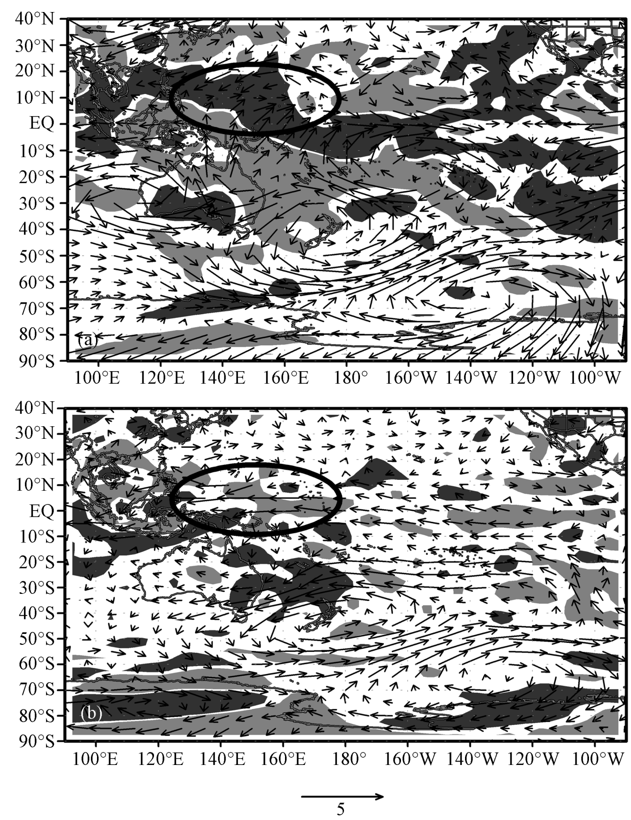

Figure 5 The AAO-based composite differences of JJAS velocity at 150 hPa (a) and 850 hPa (b) during 1949—1998. Positive composite is for the years with normalized AAO larger than 0.5, and negative composite is for the years with normalized AAO less than –0.5. Shaded areas indicate the values larger than $2\times10^{-7}s^{-1}$.

both the high-level and low-level troposphere. As a result, the anomalous low-level convergence and high-level divergence are introduced in the equatorial western Pacific region, causing positive anomalies of the convection in the region. This anomalous convection will in turn affect the convective activities in the western North Pacific via the eastern Asia teleconnection (or the Pacific-Japan) pattern[23], resulting in the anomalies of the typhoon activities.

4 Summary

This research shows a significant negative correlation between the typhoon frequency in the WNP and the Antarctic oscillation in JJAS. The underlying atmospheric circulation and SST variation are investigated. The tropical western Pacific is proved to have the larger (smaller) magnitude of vertical zonal wind shear and cooled (warmed) ocean surface water under the positive (negative) phase of JJAS AAO. It is suggested that the meridional teleconnection in the high troposphere, which exists primarily in the Pacific sector, maybe is responsible for the WNPTN-AAO remote linkage. The long-term simulation results by a coupled climate model support the above finding.

This paper also shows that the teleconnection pattern from the middle and high latitudes of SH to the tropical region of western Pacific may play an important role in the AAO- WNPTN linkage. Through the teleconnection, the convective activities over the equatorial region of the western Pacific are connected to AAO, and, in turn, connected to the convective activities in the western North Pacific, which is associated with the typhoon activities.

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