INFLUENCE OF THE SURFACE AIR TEMPERATURE OVER ASIAN-PACIFIC REGION ON THE SUMMERTIME NORTHEASTERN ASIAN BLOCKING HIGH*

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Received December 3, 2003; revised July 10, 2004

ABSTRACT

Synthesis analysis and singular value decomposition (SVD) methods were used to study the impact of surface air temperature (SAT) over Asian-Pacific region on the summertime northeastern Asian blocking high (NABH) with NCEP/NCAR Reanalysis Data. The results showed that 500 hPa geopotential height and SAT fields over Asian-Pacific region shared the similar pattern of East Asian Pacific (EAP) wave train; there was steady remote response relationship between the EAP wave train in summer and the "+−+" pattern of tropical SAT in zonal direction from former winter to summer; there were two relative negative(positive) Walker circulations over the tropical Indian Ocean and Pacific when being more(less) summertime NABH. The influence of sea surface temperature anomaly (SSTA) on the summertime NABH was possibly as follows. The special distribution of SSTA in tropical zonal direction continuously forced the tropical convection and zonal circulation from former winter to summer, and led them to act anomaly. Finally the abnormal conditions were transported to middle-high latitudes through EAP wave train and yielded the advantageous or disadvantageous atmospheric circulation background for the summertime NABH.

Key words: summertime northeastern Asian blocking high (NABH), surface air temperature (SAT), synthesis analysis, SVD analysis, East Asian Pacific wave train

I. INTRODUCTION

Blocking high which is always concerned by meteorological community, because its activity closely connects with the weather and climate, and often leads drought and flood as well as extremely warm and cold over certain areas. Meteorologists in China have paid close attention to the impact of middle-high latitude blocking high on precipitation in China, especially on that over the Yangtze and Huaihe River Basin (Tang 1957; Chen 1957; Tao and Xu 1962). After analyzing the effects of the Eastern Hemispheric blocking highs on the precipitation over the Yangtze and Huaihe River Basin as well as Baiu in Japan, Wang (1992) pointed that NABH had important effects on the Meiyu over the Yangtze and Huaihe River Basin. In recent years, Zhang and Tao (1998) have studied the effects of general atmospheric circulation in middle-high latitudes over Asia on the precipitation over East Asia by analyzing the anomaly distribution of monthly and seasonal average circulations. The result showed that the atmosphere situation over Okhotsk Sea

* This work was supported by the National Natural Science Foundation of China under Grant of No. 40233033 and No. 40475040.

impacted two-wave trains of East Asia in zonal and meridional directions in summer. Then the two-wave trains affected the rainfall abnormity during the Meiyu period in East Asia in summer. After analyzing the circulation characteristics for the serious flood over China in 1998, Lin and Zhang (2000) found that the high onset over Okhotsk Sea was one of the key conditions leading to flood over the Yangtze River Valley. Zhu et al. (2001) studied the impact of 500 hPa planetary scale circulation on the dual Meiyu over the Yangtze River in 1998. The result indicated that the blocking high around Okhotsk Sea enhancing (weakening) and west part of the western Pacific subtropical high weakening(enhancing) led the rainfall around middle and lower reaches of the Yangtze River and the Northeast China to increase(decrease). Chen et al. (2001) investigated the influence of blocking high position in middle-high latitudes of East Asia on the location of torrential rain in China in July of 1998 through analyzing moist potential vorticity and pointed that NABH affected rainfall of China greatly. Lu and Huang (1998) and Mao et al. (2001) indicated that there was affinity between SSTA in western subtropical Pacific and summertime NABH. Based on the former studies, the relation between the summertime NABH and SAT over Asian-Pacific region was further studied.

II. DATA AND METHOD

The data used are monthly NCEP/NCAR reanalysis data (Kalnay et al. 1996), including the Northern Hemispheric 500 hPa geopotential height field in summer from 1980 to 2000, surface air temperature (SAT) from November 1979 to August 2000, outgoing longwave radiation (OLR), 200 hPa velocity potential (VP), sea surface temperature anomaly (SSTA), zonal wind (U), meridional wind (V), vertical velocity. The methods used are synthesis analysis and singular value decomposition (SVD) analysis.

III. RESULT ANALYSIS

There were many definitions for the blocking high. According to the results identified by computer, Mao Hengqing's definition was the best one to describe the summertime northeastern Asia blocking high (NABH). We therefore adopt Mao Hengqing's definition in our research. The definition was that the high center located at 110—150°E, 50—75°N; moving velocity was less than eight degrees in longitude each day; the continuous period was more than five days; and there was a closed high center at the average field. According to this criterion, we can choose 11 years, named 1980, 1982, 1983, 1986, 1990, 1991, 1992, 1995, 1996 and 1998 whose days of NABH were larger than 20 days, as the years being more NABH days, and other 5 years, named 1981,1984,1985,1989 and 1994 whose days of NABH were less than 11 days, as the years being less NABH days in summer. Then the differences between the year being more NABH and the year being less NABH were analysed as follows.

1. *The Differences of* 500 *hPa Geopotential Height and SAT between Being More and Less NABH in Summer*

It was seen from Fig. 1 that the difference distribution of 500 hPa geopotential height field and SAT between more and less NABH in summer almost shared the same pattern.

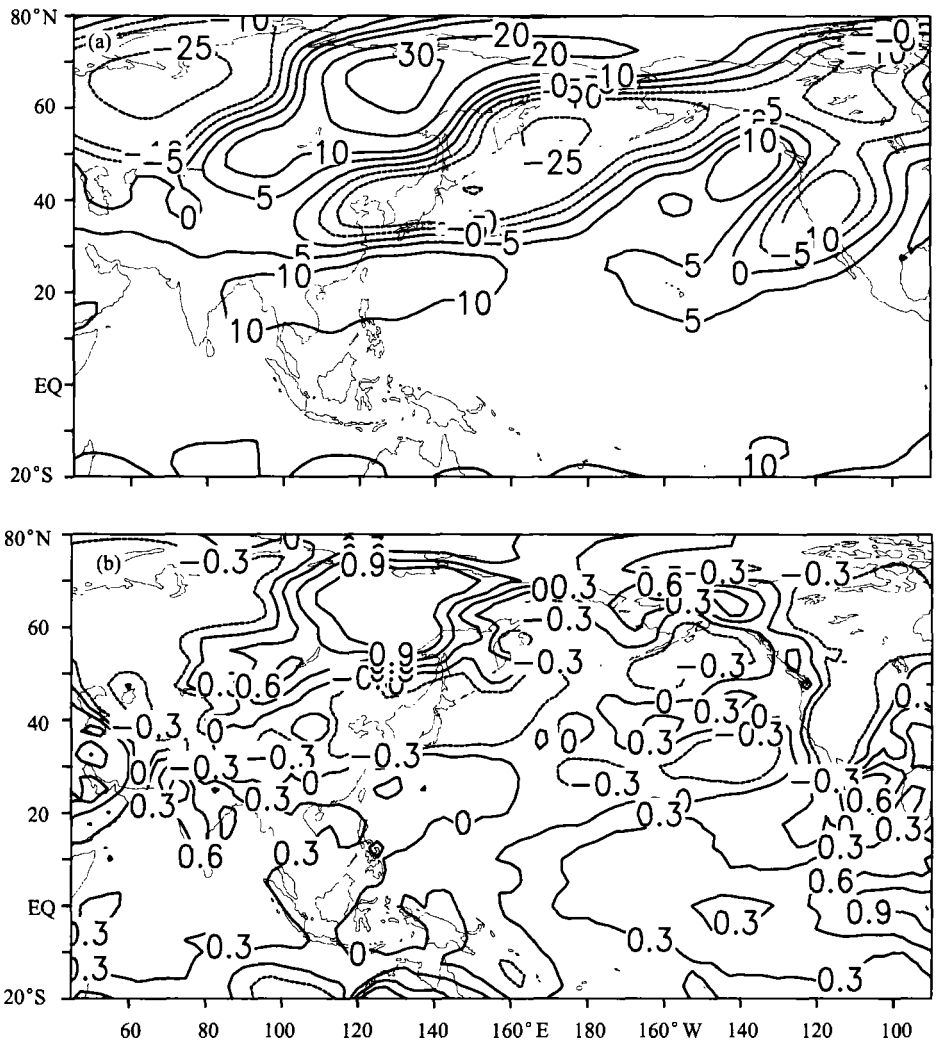


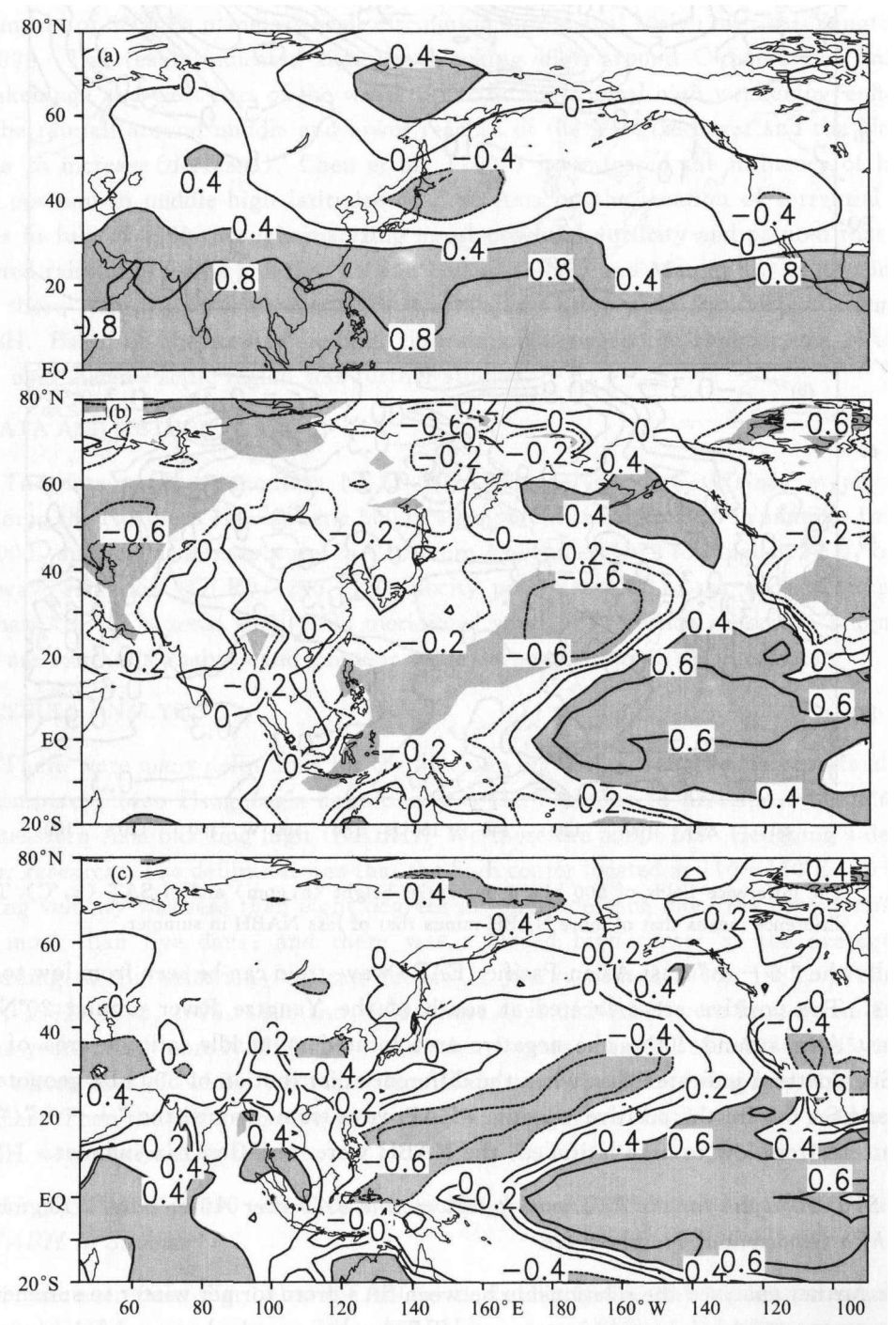
Fig. 1. The difference fields of 500 hPa geopotential height (a, gpm) and of SAT (b, °C). The difference means that of more NABH minus that of less NABH in summer.

Especially the "+−+" East Asian-Pacific (EAP) wave train can be seen from low to high latitudes. The positive areas located at south of the Yangtze River around 20°N and Northeast Asia around 70°N; the negative area located at middle latitude area of East Asia. Such pattern indicated that when the difference distribution of 500 hPa geopotential height and SAT were the positive(negative) EAP wave train, named the "+−+"("−+−") pattern from low to high latitudes, the NABH were more(less) in summer.

2. *The SVD Analysis for the Relationship between the SAT over Asian-Pacific Region and 500 hPa Geopotential Height Field*

For further analysed the relationship between SAT from former winter to summer and 500 hPa geopotential height field in summer, SVD analysis method was used separately to

extract the best coupled mode existing in these two fields. Because the variance contribution of the first singular vector for each season exceeded 99. 9%, and the correlation coefficients for corresponding time series were 0. 70, 0. 76 and 0. 82 all that passed the test at 0. 001 confidence level, the sim-correlation coefficient of the first



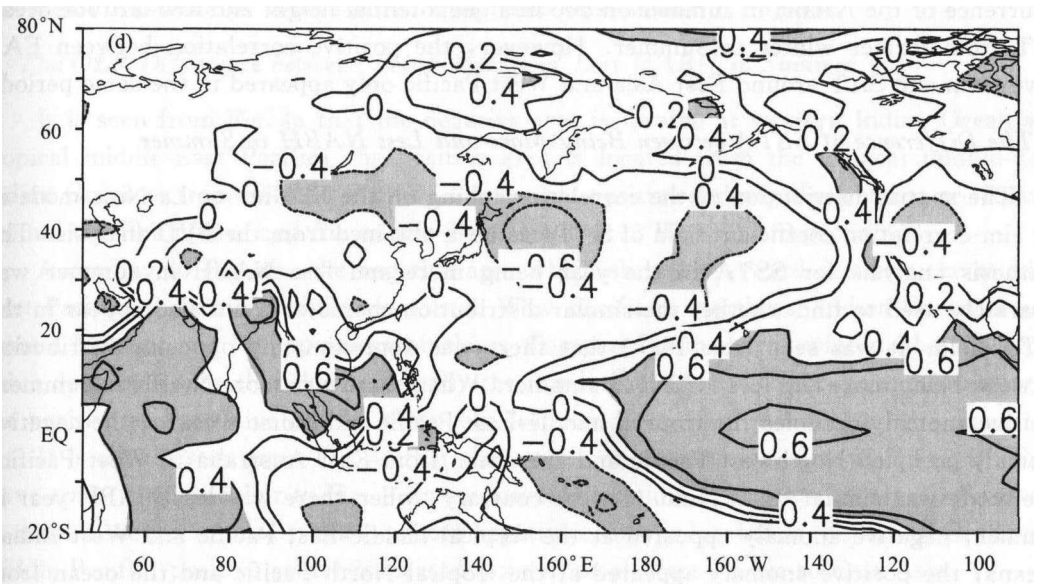


Fig. 2. The first sim-correlation coefficient between the 500 hPa geopotential height (left field) and SAT fields (right field). (a) 500 hPa geopotential height field, (b) former winter SAT, (c) former spring SAT, and (d) summer SAT. The shaded areas are those which have passed 0.05 confidence level examination.

singular vector for each season was analysed. Sim-correlation coefficient that represents the spatial structure of two coupled correlation fields is the correlation coefficient between the left (right) field and the left (right) singular vector. If the correlation coefficient passes a certain significance level, there is teleconnection characteristic for the two variations in corresponding areas.

The pattern shown in Fig. 2a was similar to that shown in Fig. 1a. The EAP wave train which passes 0.05 confidence level examination can be clearly seen. There were positive correlation areas occupying Northeast Asia and low latitude area, and the negative correlation area occupying the area from Japan to West Pacific. It was the significant characteristics shown in Figs. 2b, 2c, and 2d that there was "+−+" or "−+−" pattern in the meridional direction, and the former winter and spring phases were almost opposite to the summer one. During the former period, the "+−+" EAP wave train was not clear; but it was obvious in summer. Such result was almost the same as that of the synthesis analysis. In the tropical zonal direction from West India Ocean to East Pacific, the first sim-correlation coefficient distribution of SAT continuously shows a "+−+" pattern in which the positive correlations appear in low latitudes of middle-East Pacific, India Ocean and South Asia; the negative correlation occupied an area from West Pacific in low latitudes to the middle of North Pacific. Such relationship intensified; but the correlation areas shrink southwards from former winter to summer. So when SAT took on El Nino (La Nina) mode from former winter to summer, the "+−+" ("−+−") EAP wave train appeared in meridional direction on summertime 500 hPa geopotential height. The teleconnection characteristics shown by SVD results indicated that there was stable positive correlation between "+−+" ("−+−") EAP wave train which was advantage to

occurrence of the NABH in summer on 500 hPa geopotential height and low latitude ocean SAT from former winter to summer. However, the positive correlation between EAP wave train and SAT around East Asia and West Pacific only appeared in the same period.

3. *The Difference of SSTA between Being More and Less NABH in Summer*

The spatial distribution of the correlation taking on the El Nino or La Nina mode in the sim-correlation coefficient field of SAT has been obtained from the SVD analysis. The synthesis analysis for SSTA in the year being more and less NABH in summer was separately used to find whether the similar distribution character could also appear in the SSTA field. It was seen from Fig. 3 that there was approximately opposite distribution between being more and less NABH in summer. When there was more NABH in summer, positive anomaly occupied the tropical middle-East Pacific and Indian Oceans; the negative anomaly occupied Northwest Pacific and the ocean from East Australia to West Pacific. The mode was similar to El Nino. On the contrary, when there was less NABH year in summer, negative anomaly appeared at the tropical middle-East Pacific and West Indian Oceans; the positive anomaly appeared at the tropical North Pacific and the ocean from

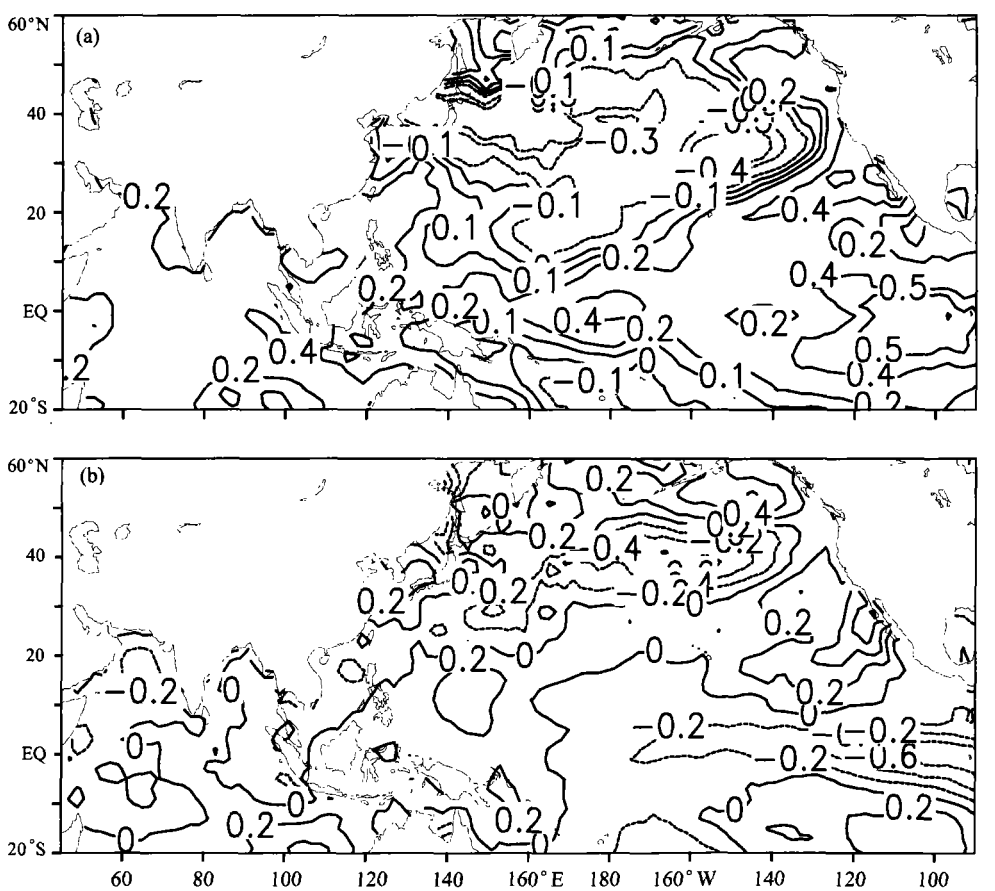


Fig. 3. The distribution of SSTA in the year being more (a) and less (b) NABH in summer.

Northeast Australia to West Pacific. The mode was similar to La Nina.

4. *The OLR Difference between Being More and Less NABH in Summer*

It is seen from Fig. 4a that the negative area is located at western Indian Ocean and tropical middle-East Pacific; the positive area is located from the tropical middle-East Indian Ocean to tropical West Pacific. The largest positive and negative centers are located around the Philippines and the middle-East Pacific(170°W,5°S), respectively.

According to Fig. 4b, the negative area which shrank eastward occupies the middle-East Pacific; the main positive areas from West Pacific to Northeast Indian Ocean occupy around Mariana and Philippines archipelago. Compared with that in winter, the difference value decreases over all fields, especially the low latitude where the scope and intensity of the positive and negative centers obviously decrease.

It is clearly seen from Fig. 4c that there are two wave trains. One is "+ − +" EAP wave train, being similar to Fig. 1, in meridional direction. The other is "+ − +" pattern in zonal direction around tropics, whose negative center is located at the Indian Ocean and middle Pacific; positive center is located from tropical West Pacific to East Asia.

The results have indicated that remarkable difference appears from former winter to summer OLR fields, especially from those of the tropical ocean, between being more and less NABH in summer. It is in favor of occurring NABH in summer that the convection from East Indian Ocean to West Pacific weakens(strengthens), while the convection over the middle-East Pacific Ocean strengthens(weakens).

5. *The Difference of* 200 *hPa Velocity Potential between Being More and Less NABH in Summer*

It is seen from Fig. 5 that there is an obvious "+ −" pattern in the zonal diction both in former and simultaneous periods. From former winter to summer, the largest positive and negative centers stand on the same two-areas. The largest positive center occupied the West Pacific warm pool over east of Philippine; the largest negative center occupied the tropical East Pacific around 100°W. The difference over Indian Ocean transformed from positive center in former periods to negative center in the simultaneous period. Therefore a "− + −" pattern appeared over the tropical area in zonal direction according to Fig. 5. It meant that there are relative convergent area over West Pacific; and relative divergence area over East Pacific on 200 hPa from former periods to simultaneous period. And in the simultaneous period, the relative area also appeared over the Indian Ocean.

6. *The Vertical Circulation Difference between Being More and Less NABH in Summer*

The VP distribution has indicated that the high-layer divergent and convergent centers are steadily located around 10°N. Thus the vertical circulation along 10°N is analyzed. It is seen from Fig. 6 that the vertical circulation is almost opposite in the year being more to the year being less NABH in summer. In the year being more NABH, the relative sinking airflow is located around 140−160°E and the relative ascending airflow in low-layer is located around East Pacific and middle Indian Oceans. On the contrary, in the year being less NABH, the relative ascending airflow is located around 160−180°E and the

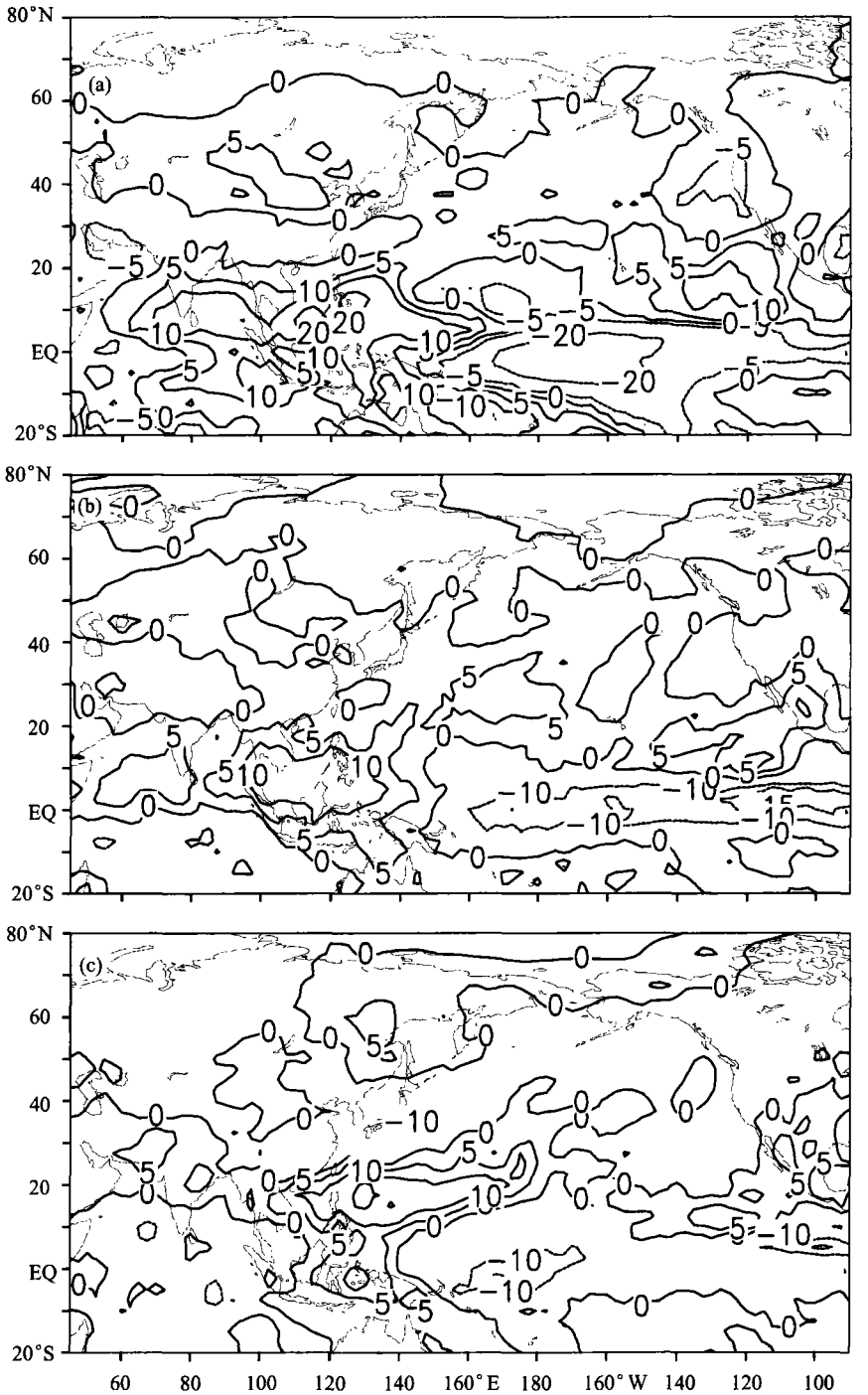


Fig. 4. The OLR difference fields (W/m^2) between being more and less NABH in summer. (a) former winter; (b) former spring; (c) summer.

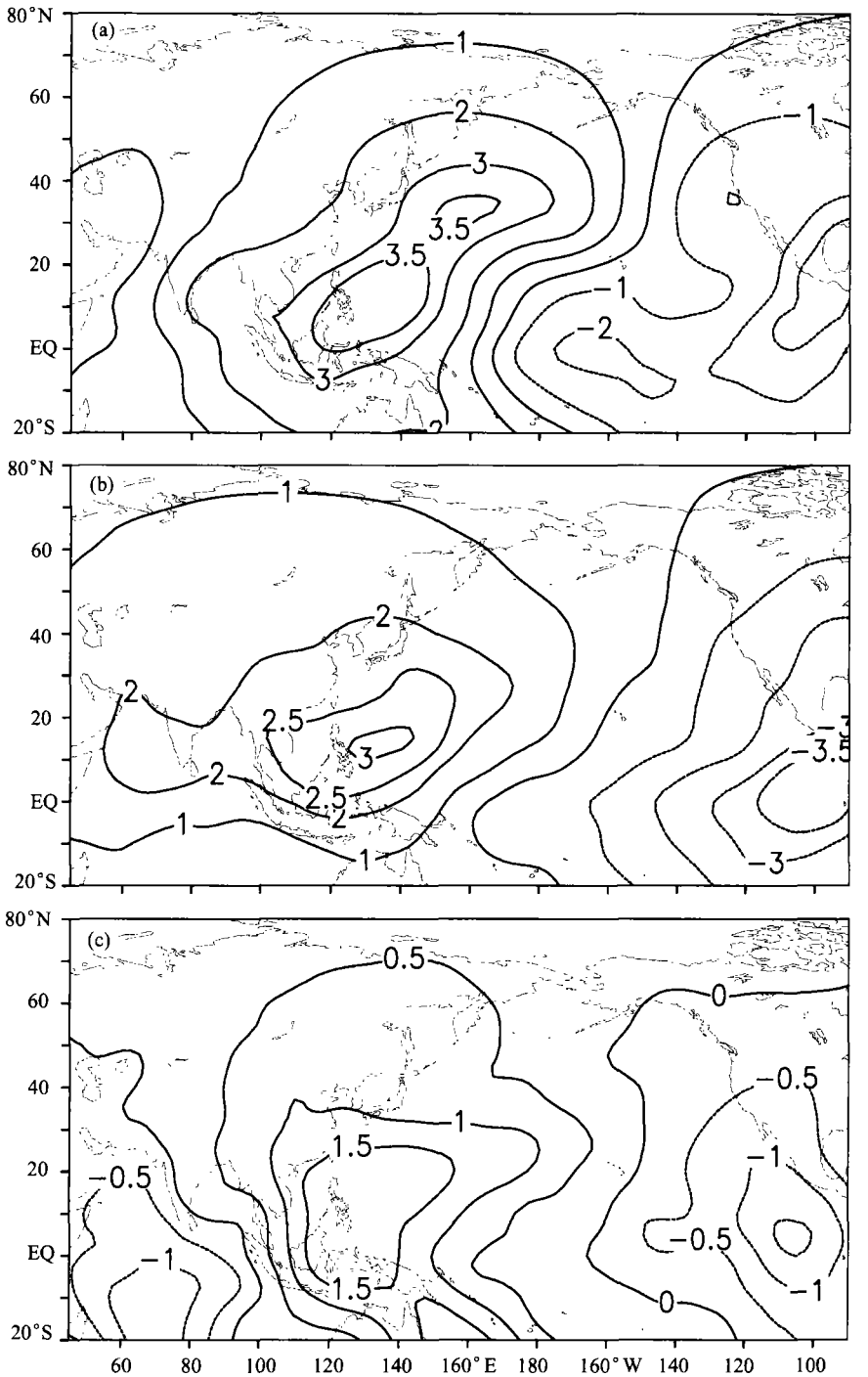


Fig. 5. The difference of 200 hPa VP between being more and less NABH in summer ($\times 10^{-6}$). (a) former winter; (b) former spring; (c) summer.

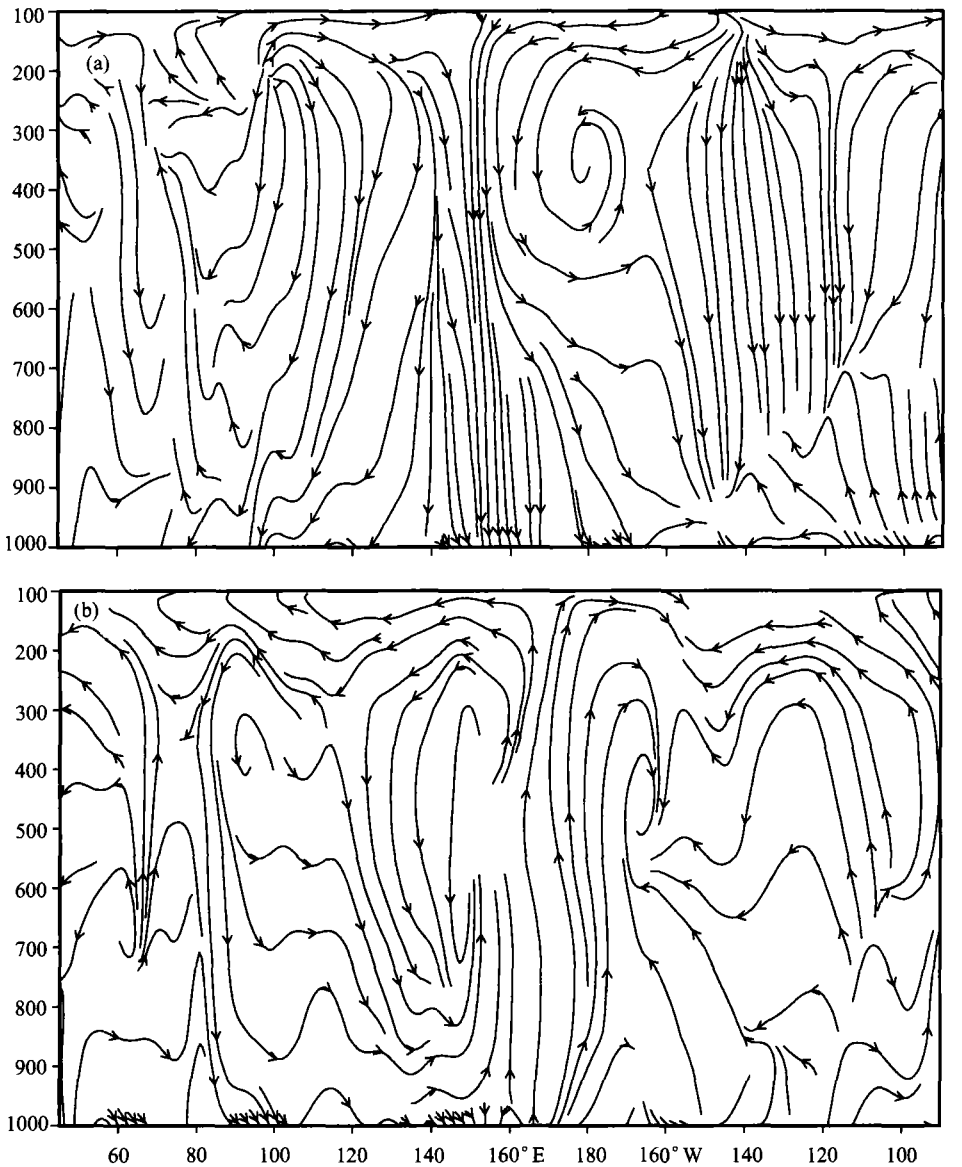


Fig. 6. The height-longitude cross-section diagram of vertical circulation along 10°N for (a) the year being more NABH in summer, and (b) the year being less NABH in summer.

relative sinking airflow in low-layer is located around East Pacific and Indian Oceans.

Compared to the OLR and the VP on 200 hPa, it can be found that the positive (negative) center of OLR is homologous to the positive(negative) VP center on 200 hPa. On the high layer, relative divergence whose difference of VP is negative and relative convergence whose difference of VP is positive are located at the tropical East Pacific and West Indian Oceans as well as West Pacific. In the simultaneous period, the "− + −" pattern existed both in the difference field of 200 hPa VP and OLR from west to east, namely there were two big relative opposite Walker circulations located at tropical Pacific

and Indian Oceans in zonal direction. The relative sinking branch is located at the tropical West Pacific where the difference of OLR is positive. The relative ascending branch is located at the tropical East Pacific and Indian Oceans where the difference of OLR is negative. The similar characteristics also exist in the vertical circulation field. When there is more(less) NABH in summer, the relative sinking(ascending) airflow is located at West Pacific and the relative ascending (sinking airflow) is located at East Pacific and Indian Oceans.

It is obvious that concerning the year being more (less) NABH in summer, the distribution of "+ − +" ("− + −") appears in SSTA field from former to simultaneous period; the opposite tropical convection and opposite vertical circulation led two relative opposite Walker circulations which located at the two Oceans; and positive/negative phase of EAP wave train came forth on the 500 hPa geopotential height field. Therefore, the influence of SSTA on NABH in summer possibly was that there was a certain distribution mode in zonal direction over the tropical Ocean from former winter to summer. Under such persistent powerful thermal forcing, the tropical convection and the zonal circulation acted anomaly. Then the effects were transported to middle-high latitudes through EAP and produced the advantage or disadvantage atmospheric circulation background for the occurrence of summertime NABH.

IV. CONCLUSIONS

Through analyzing the typical differences on 500 hPa geopotential height field, SAT field, tropical convection and vertical circulation field between the year being more and less summertime NABH, the main conclusions could be drawn as follows.

(1) There is a spatial distribution, EAP wave train, on the difference fields of 500 hPa geopotential height and of SAT between the year being more and less summertime NABH. Northeastern Asia area is a positive difference area.

(2) The SVD analysis results have indicated that when the distribution of SAT in low latitudes took on El Nino (La Nina) mode from former to simultaneous period, "+−+" ("−+−") EAP wave train appeared on 500 hPa geopotential height field in summer. The "+ − +" pattern, which is advantageous to occurrence for the NABH on 500 hPa geopotential height, had a positive correlation with the summer SAT over East Asia-Pacific area, while such positive correlation between EAP and SAT over corresponding areas began from former winter, and maintained to summer.

(3) The distribution of "−+−" pattern exists both in the difference field of 200 hPa VP and OLR in zonal direction at low latitudes. It means that there are two big relative opposite Walker circulations located at tropical Pacific and Indian Oceans in zonal direction. The relative sinking branch is located at the tropical West Pacific; the relative ascending one is located at the tropical East Pacific and Indian Oceans. The similar characteristics exhibit on the vertical circulation field, namely the relative sinking (ascending) airflow located at West Pacific and the relative ascending (sinking) airflow located at East Pacific and Indian Oceans when the year being more (less) NABH in summer.

(4) The physically conceptual model describing the influence of SSTA on the

summertime NABH could be that a certain zonal SSTA pattern existing over tropical ocean from former winter to summer leads the tropical convection and zonal circulation to act anomaly. Then these effects are transported to middle-high latitudes through EAP and produce an advantageous (disadvantageous) atmospheric circulation background for the occurrence of summertime NABH.

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