Effects of Sea Surface Temperature Anomalies off the East Coast of Japan on Development of the Okhotsk High*

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ABSTRACT

The study examined effects of sea surface temperature anomalies (SSTAs) off the east coast of Japan on the blocking high over the Okhotsk Sea in June by diagnostic analysis and numerical simulation. Firstly, based on 500-hPa geopotential height fields, the Okhotsk high index (OKHI) for June from 1951 to 2000 is calculated and analyzed. The result indicates that the OKHI has obvious inter-annual and inter-decadal variations, and there are 9 yr of high OKHI and 8 yr of low OKHI in 50 yr. Secondly, by using the OKHI, the relationship between the Okhotsk high and the 500-hPa geopotential height anomaly is investigated. The results indicate that the “+−+” pattern of geopotential height anomaly crossing Eurasia in the mid-high latitudes and the “+-−” pattern of geopotential height anomaly from high to low latitudes over East Asia are in favor of the formation and maintenance of the Okhotsk high. The relationship between the OKHI and the SSTA over the North Pacific is investigated in early summer by using correlation and composite analysis. We found that when the blocking circulation over the Okhotsk Sea occurs, there is an obvious negative SSTA off the east coast of Japan in early summer. We simulated the effects of the negative SSTA of east coast of Japan on the atmospheric circulation anomaly over East Asia through the control and sensitivity experiments using NCAR CAM3 model in order to confirm our analysis results. The simulation shows that the negative SSTA off the east coast of Japan results in the significant positive 40 gpm 500-hPa geopotential height anomaly over the Okhotsk Sea and the negative anomalies off the east coast of Japan which might contribute to the formation and development of the Okhotsk high in June.

Key words: Okhotsk high, sea surface temperature anomaly (SSTA), numerical simulation

1. Introduction

The blocking high, as a large-scale high circulation system formed in the development process of long-wave trough and ridge in the westerlies, usually occurs in mid-high latitudes. It is essentially the variation of atmospheric low frequency anomaly. The large-scale circulation condition caused by blocking high is usually called blocking condition. The blocking high often occurs in some fixed regions. Its long-term maintenance accompanied by special circulation patterns over its upper and lower reaches usually causes large-scale weather/climate anomaly, thus leading to severe weather/climate disasters in neighboring areas.

The maintenance of East Asian blocking high in summer can stabilize the rainbelt of Meiyu over the Yangtze River Valley, thus causing the large-scale flood weather. Wang (1992) made comparatively comprehensive studies on relationship between Eurasia blocking high and Meiyu over the Yangtze River, Huaihe River, and the Sea of Japan. He pointed out that high frequency of Eurasian blocking high in summer appears in the Ural Mountains, the Lake Baikal, and the Okhotsk Sea; the highest frequency of blocking anticyclone in Meiyu season appears near the Okhotsk Sea (50°-70°N, 131°-150°E). In addition, there is a positive correlation between the frequency of Okhotsk high and the duration of Meiyu period and precipitation in Meiyu period over the Yangtze and Huaihe Rivers. Yang (2002) discovered that, the southerly subtropical high forced by East Asian blocking high is the direct reason for the abundant Meiyu and southerly rainbelt in summer over the middle and

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lower reaches of the Yangtze River since the 1980s. Moreover, there is a close relationship between the severe floods in China’s history and long-term maintenance of blocking condition in the Okhotsk Sea. For example, the flood in the Yangtze-Huaihe River Valley in 1954 was due to the constant existence of East Asian blocking high (Chen, 1957); the frequency of blocking high in the summer of 1998 was also one of the major reasons that caused unusual excessive rainfall in the Yangtze River, Songhua River, and Nenjiang River; During 1998, several excessive-rainfall periods were corresponding to the activity of Okhotsk high (Tao et al., 2001). According to other studies (Ren, 1989), the temperature in Northeast China is slightly lower when the Okhotsk high is slightly stronger, whereas the temperature is slightly higher. In conclusion, it is necessary to realize and interpret the formation and maintenance mechanism of Okhotsk high in summer, since the Okhotsk high has great influence on weather/climate in summer in China (Tang, 1957).

Since the 1940s, the formation and development mechanism has been studied successively through inner mechanism and external source forcing. Charney and Devore (1979) considered that multiple equilibria of atmospheric circulation is the theoretical basis for the existence and transition of blocking circulation and zonal circulation in atmospheric movement. Hoskins et al. (1983) suggested that there is a close relationship between energy transportation of synoptic-scale baroclinic waves and maintenance of blocking high. Long (1964) pointed out that blocking high could be regarded as a special solution to nonlinear solitary vortex or solitary wave. Later, Luo and Ji (1989) brought forward envelope Rossby soliton theory and gave a proper interpretation to the formation and maintenance of dipolar blocking. Austin (1980) and Miao (1984) considered that nonlinear interactions among waves are important energy for the formation and maintenance of blocking high. In addition, Zhu (1964) considered that there is a significant relationship between existence of topography and heat source and formation of blocking high, and there are significant effects of abnormal variation of SST on the formation and maintenance of the blocking high.

It is found that the effects of SST on blocking may be divided into two kinds. On the one hand, the SSTA induces remote correlation wave train to form the blocking by influencing mid-high latitude circulation. Huang et al. (1987, 1992a, b) and Wu and Wang (1998) considered that the SSTA in the equatorial Pacific avails to the development of East Asian blocking high. Research results of Lu and Huang (1996, 1998) indicated that there are significant effects of SSTA in western tropical Pacific on blocking highs over Northeast Asia. On the other hand, temperature difference leads to the active blocking high. Okawa (1973) pointed out that the zonal temperature gradients formed by the rapid temperature increase of land surface in early summer in the eastern Siberia and the relative low temperature of sea surface in the Bering Sea promote the formation of blocking highs over East Asia. Zhu and Zhu (1982) also showed that zonal asymmetry heating forcing plays an important role in the process of blocking high formation. Wang (1992) showed that huge sea-land thermal contrast may be the factor to induce the transmission of Rossby wave, which may enlarge the amplitude of blocking high near the Okhotsk Sea. In addition, many numerical research results indicated that there is a close relationship between sea-land thermal contrast and the formation and maintenance of blocking (Kikuchi, 1969, 1971; Kutzbach et al., 1977; Chervin et al., 1980; Shukla and Bangaru, 1979; Ji and Tibaldi, 1983).

However, the effects of SST over other regions in the North Pacific on blocking high over East Asia in summer are less discussed. Wang et al. (2001) brought forward a possible mechanism for the formation and maintenance of blocking high over East Asia in ENSO decaying year: When El Niño occurs strongly in autumn, the SSTA is usually negative in mid-high latitudes in the western North Pacific. The negative SSTA that cools the atmosphere will last until next summer. The land between the Siberia and Okhotsk Sea is quickly heated by the solar radiation in summer, so as to heat up the air above the land surface. Therefore, strong temperature gradients emerge between
the continent and middle and low layers of troposphere over the northwestern Pacific, and the blocking high over East Asia becomes active.

In June 1998, strong blocking high constantly existed in mid-high latitude region over East Asia. Meanwhile, negative SSTA appeared obviously in the sea area off the east coast of Japan. Does the SSTA anomalies significantly influence the Okhotsk blocking? Is the mechanism brought forward by Wang et al. (2001) reasonable? This paper is to study the possibility by diagnostic analysis and numerical simulation.

2. Data and methods

2.1 Data

The following data are used in the study:

(1) NCEP/NCAR 500-hPa daily and monthly mean geopotential height field data during 1951-2000, with a spatial resolution of 2.5° × 2.5°;

(2) NCEP/NCAR monthly mean surface temperature data during 1951-2000, with equally distributed 192 grids latitudinally and 92 Gaussian grids longitudinally;

(3) Hadley Center’s monthly mean SST data namely HadISST1, which is developed from GISST. The data are global monthly mean grid data since 1870, covering an area of 89.5°S-89.5°N, 179.5°W-179.5°E, with a spatial resolution of 1° × 1°. We use 50-yr data in 1951-2000 for composition and analysis.

2.2 Methods

It is generally considered that, since the monthly mean blocking situation reflects constant activities of daily blocking system and represents the low frequency part after filtering the high frequency wave, the blocking situation should be studied by monthly mean height fields (Zhang et al., 1992). Moreover, studying the blocking by monthly mean height field avails to better investigate the process of effects of external condition on the blocking. Many research results also indicated that, in summer the Okhotsk high occurs more frequently in June (Ren, 1989; Tang, 1957). This paper is to study the blocking situation indirectly by investigation of the circulation background in favor of the formation and maintenance of Okhotsk blocking in June.

According to the definition methods of Zhao (1999), we select 50°-60°N, 120°-150°E to represent Okhotsk high area, and calculate standardized values of the height of this area (the sum of height value of all grids in this area) in June of each year as the Okhotsk high index (OKHI) in June of each year by using 500-hPa monthly mean geopotential height data. The size of the index indicates the strength of the circulation anomaly. If OKHI > 1.0, it indicates that the height anomaly is more than one standard deviation, and on the 500-hPa monthly mean geopotential height field, there is an obvious high pressure ridge over the Okhotsk Sea, and the blocking high is active. On the contrary, if OKHI ≤ −1.0, the blocking high is inactive.

2.3 Model instruction

The model adopted is NCAR CAM 3.0 (NCAR Community Atmosphere Model), a latest version of global atmospheric circulation model series developed from CCM0A version in the 1980s by NCAR. As a global spectrum model, it adopts triangle spectrum truncation, and has a horizontal resolution of T42, latitudinally 128 grids equally distributed, and longitudinally 64 Gauss grids. It adopts η-coordinate and 26 layers in vertical. Time integral adopts semi-implicit scheme with a time step of 20 min. The model includes physical processes such as radiation, cloud, convection, land surface, boundary layer, etc. For the details of the model, please refer to the model description document (Collins et al., 2004).

The model provides three operational ways: one drives model atmosphere by taking monthly mean SST as boundary field, called Data Ocean Model (DOM); the second runs in coupling with a simple ocean model including sea ice model part, called Slab Ocean Model (SOM); and the third runs in coupling with ocean, land and sea ice models, called Community Climate System Model (CCSM). All the three operational ways include ocean, land, and air, composing an integrated land-air system model. We adopted DOM in our experiment.

A series of verification studies (Dong et al., 1997; Gao et al., 2004) indicated that NCAR’s atmospheric
circulation model can preferably describe the large-scale climate characteristics in East Asia. The simulated height field, wind field, and temperature field are close to the observed fact, and they have been widely used in climate simulation studies.

3. Variation characteristics of Okhotsk high index

Figure 1 gives the change of OKHI (denoted as $I_{\text{OKH}}$) in June from 1951 to 2000. We can see from Fig.1 that the inter-annual change of OKHI is obvious. Totally 9 yr (1954, 1966, 1975, 1986, 1988, 1989, 1992, 1995, and 1998), in which the index is higher than 1.0, and the blocking high is active, are called year of blocking high; totally 8 yr (1958, 1961, 1962, 1964, 1965, 1969, 1972, and 1978), in which the index is lower than $-1.0$, is called year of non-blocking high. Among the 9 yr of blocking high, 5 yr (i.e., 1975, 1986, 1989, 1992, and 1998) has the index higher than 1.5. Moreover, in 1998 the index reached 1.7, which matched well with the long-term maintenance of Okhotsk high in June. In the 8 yr of non-blocking high, the index in 1961, 1962, 1965, 1969, and 1972 is lower than $-1.5$, and reaches $-2.5$ in 1972. We can see from the curve that the index has a decreasing trend before the 1970s when the frequency of occurrence of Okhotsk high reduced, and it presents a distinct increasing trend after the 1970s when the frequency of occurrence of Okhotsk high enhanced. During 50 yr, the year of blocking high appeared every 5 or 6 yr, once in the 1950s, 1960s, 1970s, and three times in the 1980s and 1990s, respectively; the years of non-blocking high were concentrated prior to the 1970s, mostly in the 1960s.


4. Okhotsk high and 500-hPa geopotential height field

We studied the correlation between OKHI in June and 500-hPa geopotential height, and obtained the distribution of correlation coefficients (Fig.2). From Fig.2 we can see that there is a strong positive correlation to the west of Ural Mountains, where the highest correlation coefficient is higher than 0.4; there is a weak negative correlation to west of the Baikal; and there is a strong positive correlation near the Okhotsk Sea with its center located around (55°N, 135°E) and highest correlation coefficient higher than 0.8, which has exceeded the significance level of 0.001. The distribution shows “+−+” pattern latitudinally over Eurasia. It indicated that the geopotential height anomaly in the Okhotsk Sea was relevant to the remote correlation structure over the westerlies in mid-high latitudes: when the blocking maintains in the Okhotsk Sea, the geopotential height is high there, low in the Baikal, and high in the Ural Mountains; when the blocking maintains in the Baikal, it turns into reverse distribution latitudinally in mid-high latitudes over Eurasia. Meanwhile, corresponding to the strong positive

![Fig.2. Distribution of the correlation coefficients between $I_{\text{OKH}}$ and 500-hPa geopotential heights for June (shaded areas indicate regions where the correlation is significant to the 0.05 confidence level).]
correlation in the Okhotsk Sea, there is a negative correlation in the sea area off the east coast of Japan, where the highest correlation coefficient is lower than $-0.3$, exceeding the significant level of 0.05, while there is again a positive correlation in tropical region.

In addition, by composing the 500-hPa geopotential height and its anomaly in blocking high year (figure omitted), we may find in height fields a “ridge-trough-ridge” pattern from west to east in Eurasia: high pressure region to the west of Ural Mountains, low trough region to the west of the Baikal, and strong high pressure ridge near the Okhotsk Sea. In the anomaly field, it is latitudinally distributed as “+−+” pattern over mid-high latitudes in Eurasia. The strong positive anomalies exist in the Okhotsk Sea with maximum above 50 gpm at the center. With negative anomalies in the sea area off the east coast of Japan, it resembles dipolar pattern in East Asia. When the anomaly wave train exists the westerlies in middle latitudes are divided, the longitudinal circulation develops; frontal area is slightly northward, cold and warm air currents meet over or to south of the Yangtze River, usually causing raining and flood. Almost reverse distribution features are shown in the composition map in the non-blocking high year.

The result of composition analysis is matched with the result of correlation analysis, and is also consistent with the previous studies (Tao et al., 2001; Zhang et al., 1992): the 500-hPa geopotential height anomaly has a positive correlation between Okhotsk Sea and the area near the Ural Mountains, but it becomes negative correlation between the area near the Baikal and sea area off the east coast of Japan. That is, when positive height anomaly exists in the Okhotsk Sea, it is positive height anomaly near the Ural Mountain, but negative height anomaly near the Baikal and in sea areas to east of Japan, and vice versa. The condition of anomaly circulation avails to the formation and maintenance of Okhotsk high.

5. Okhotsk high in June and sea surface temperature in North Pacific

Composition of SSTA in the Pacific was made respectively of blocking high year and of non-blocking high year (Figs.3a, b). It is seen from Fig.3a that, when the Okhotsk high is active, the negative anomalies in the equatorial middle and eastern Pacific are most distinct with central values below $-0.8^\circ$C. There is a large area of negative value to the south of 30°N, in which the most distinct negative anomalies exist in the area (35°-45°N, 140°-170°E) off the east coast of Japan centered around (40°N, 155°E) with a maximum anomaly value below $-0.6^\circ$C. It is positive anomalies to the east of Philippine Archipelago and northern part of the equatorial eastern Pacific. In non-blocking high year (Fig.3b), the distribution of SSTA is almost contrary to that in blocking high year: obvious positive anomalies exist in the sea area off the east coast of Japan. The scope of anomaly area is slightly southward compared with the negative anomaly area in Fig.3a, with an anomaly center located around

![Fig.3. Composites of the SSTA over the North Pacific for June when $I_{OKH}$ is over 1.0 (a, blocking years) and below $-1.0$ (b, non-blocking years) (solid lines: positive anomalies; and dashed lines: negative anomalies; unit: °C).](image-url)
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(35°N, 165°E) and central value above 0.6°C. It is negative anomalies in the area to the east of Philippine Archipelago. There are a large area of distinct negative anomalies between 20° and 30°N, but no corresponding positive anomalies in Fig.3a. It is positive anomalies in the equatorial middle and eastern Pacific, but not as strong as the negative one in Fig.3a, which cannot be regarded as obvious El Niño conditions. Comparing with the two figures, it is most obvious that the SSTA is relatively strong in the sea area off the east coast of Japan, and there is a reverse distribution in blocking and non-blocking high years.

It is seen from the distribution map of correlation coefficient between OKHI and simultaneous SST in the North Pacific (figure omitted) that, the negative correlation is most distinct in the area off the east coast of Japan centered around (35°N, 160°E), with a maximum correlation coefficient below -0.4, exceeding the significance level of 0.01. The area of second lowest negative correlation coefficient is in the equatorial middle and eastern Pacific with central value below -0.3. The distinct positive correlation is located to the east of Philippine Archipelago with a maximum correlation coefficient above 0.4.

It indicates that there is a close relationship between Okhotsk high in June and simultaneous SST in the North Pacific. When there is a blocking high in the Okhotsk Sea, the geopotential height anomaly is very high, and then there is a distinct negative SSTA in the sea area off the east coast of Japan and a positive SSTA in sea area to the east of Philippine Archipelago. When the geopotential height anomaly in the Okhotsk Sea is on the low side, the distribution reverses. Moreover, so far as the distributions of height field and SST field are concerned, when the SSTA is low in the sea area off the east coast of Japan, the geopotential height anomaly is also low over the area. It is probably relevant to the strong air-sea interaction, which will be discussed in Section 8.

6. Analysis of typical case in 1998

In the summer of 1998, the most severe flood occurred in the whole valley of the Yangtze River since 1954. The maximum precipitation anomaly in June is located in the middle and lower reaches of the Yangtze River with anomaly value over 100%. The studies (Tao et al., 2001) indicated that there is a close relationship between the flood and long-term maintenance of blocking in Eurasia.

It is seen from the 500-hPa daily height map (figure omitted), the blocking high appeared unusually frequently in the summer of 1998. There is the blocking maintenance in the Okhotsk Sea in most times of June, and stable long wave ridge except June. It is seen from the map of 500-hPa monthly mean height and its anomaly (Fig.4), the distribution characteristics are similar to composition map with the Okhotsk height field in blocking high year. The height field in Eurasia is in “ridge-trough-ridge” pattern. There is a broad ridge area in the Okhotsk Sea with high pressure ridge between 130° and 150°E and westward leaning ridge line. In the field of geopotential height anomaly, it is “+++” pattern from west to east in Eurasia. There is strong positive geopotential height anomaly in the Okhotsk Sea with central maximum above 80 gpm. The circulation condition became the large-scale circulation background for Okhotsk high maintenance in June 1998.

It is seen from the map of SSTA in June 1998 (Fig.5) that, there are distinct negative anomalies in the sea area off the east coast of Japan (35°-45°N, 155°-180°E) centered around (40°N, 170°E) with a maximum anomaly below -1.5°C, and the central value of negative anomalies is also below -1.5°C in

![Fig.4. 500-hPa geopotential height (thin solid lines) and its anomaly (bold solid lines: positive anomalies; and bold dashed lines: negative anomalies) for June 1998 (unit: dagpm).](image-url)
7. Numerical simulation on effects of sea surface temperature anomalies on Okhotsk blocking in early summer

According to the above analysis, there is a close relationship between negative SSTA in the sea area off the east coast of Japan in June and Okhotsk blocking. In this way, does the SSTA avail to the formation and maintenance of Okhotsk blocking? We studied it by the following numerical experiments.

7.1 Experiment design

(1) Comparison experiment (Exp.C): Taking the model climate SST as boundary condition, the model runs for a 10-yr period, in which the mean of the latter 8 yr is taken as the result of the comparison experiment.

(2) Sea surface temperature anomaly experiment (Exp.A): According to the distribution of SSTA in June 1998 (Fig.5) and the compositive one in blocking high year (Fig.3a), the anomaly area is selected as 35°–45°N, 155°–175°E. In this area, as the downstream boundary of the model, the bogus SSTA data are added to the climate mean SST field in May and June, while other parameters are not changed. Figure 6 gives negative SSTA data added to the anomaly experiment. The anomaly center is located at (40.4°N, 163.1°E) and (40.4°N, 165.9°E), with central maximum of –1.5°C. Started respectively from eight various atmospheric initial conditions (May 1 in the 3rd-10th years in Exp.C), the integration runs for two-month period. Taking the average result of eight integrations as simulation results of sensitivity experiment, we only analyzed the result in June.

7.2 Experiment results

Figure 7 gives the distribution of 500-hPa geopotential height in June and its anomaly (difference between results of Exp.A and C; through t-check, the difference in shadow area exceeds the significance level of 0.05) simulated by Exp.A. It is seen from the map that, in the geopotential height field, the equivalent geopotential height line is relatively flat and gradual, except a weak ridge in northern Okhotsk Sea and a shallow trough in southern Okhotsk Sea. This is similar to the situation that when Okhotsk high exists, the westerlies will be divided into two branches. There is an obvious height anomaly distribution of “+–+” pattern in mid-high latitudes over Eurasia: positive anomaly near the Ural Mountains, negative anomaly near the Baikal, and positive anomaly in the Okhotsk centered around (55°N, 140°E), with central maximum above 40 gpm. With negative anomaly in the sea area off the east coast of Japan, it is dipolar pattern in East Asia. The above distribution is very similar to the compositive 500-hPa geopotential height anomaly in blocking high year.

It indicates that, the distribution of height anomaly caused by negative SSTA in the sea area off the east coast of Japan is roughly similar to the situation in blocking high year (Fig.3a); the large-scale circulation anomaly condition avails to the formation and maintenance of Okhotsk high; there might be significant effect of negative SSTA in the sea area off the east coast of Japan in early summer on Okhotsk blocking.

8. Discussions and conclusions

By using methods of composition analysis and
correlation analysis, through blocking high index, this paper analyzed variation characteristics of month-scale blocking high in the Okhotsk Sea in June and its relationship with SSTA in North Pacific, and studied the effect of negative SSTA in the sea area off the east coast of Japan on Okhotsk blocking by using model simulation. We have drawn the following conclusions:

(1) The inter-annual variation of OKHI in June is distinct. The analysis result of 500-hPa geopotential height and its anomaly in blocking high year and non-blocking high year indicates that, in the year when Okhotsk high is active, the remote correlation wave train is latitudinally of “+-+” pattern over mid-high latitudes in Eurasia, there is a positive geopotential height anomaly near the Okhotsk Sea and the Ural Mountains, and there is a negative height anomaly near the Baikal and sea area off the east coast of Japan. The distribution of height anomaly in non-blocking high years is almost contrary to that in blocking high years. This validates the conclusion drawn by Wang (1992) that the Okhotsk high is linked with the wave train.

(2) There is a close relationship between Okhotsk high in June and simultaneous SST in the North Pacific. In the year when the Okhotsk high is active, the SSTA is negative in the sea area off the east coast of Japan and the equatorial middle and eastern Pacific, and positive to the northeast of Philippines. In non-blocking high years, the distribution of SSTA is reversed in shape. The 500-hPa circulation field in June 1998 is typically Okhotsk high situation, while simultaneously in the SSTA field of North Pacific there is a distinct negative anomaly in the sea area off the east coast of Japan.

(3) The results of numerical simulation experiment indicate that, when in May and June, relative strong negative SSTA is added to the sea area off the east coast of Japan in the model, there is a relatively large positive height anomaly in June near the Okhotsk Sea (above 40 gpm in the center), with verified significance. It is considered that the negative SSTA in summer makes significant contribution to the formation of Okhotsk high.

According to the analysis at 500-hPa geopotential height and its anomaly in years of blocking high and non-blocking high, it indicated that there is a reversed variation trend of geopotential height between areas of Okhotsk and off the east coast of Japan. What is the mechanism for the reversed variation like a seesaw? According to Wang’s study (1992) on the correlation relationship between outgoing longwave radiation (OLR) at a key point (30°N, 150°E) in June and 500-hPa geopotential height field, the connecting line between the positive and negative correlation centers forms a route of wave train along Caspian Sea-Baikal...
Lake-the Okhotsk Sea-off the east coast of Japan. In Fig.2, a route also exists in connecting the positive and negative correlation centers along Caspian Sea-Baikal Lake-the Okhotsk Sea-off the east coast of Japan. The two routes are roughly similar, especially very similar between the Okhotsk Sea and off the east coast of Japan. The reason for existed differences of the western part of the two routes may be that, Wang (1992) studied the correlation between OLR and 500-hPa geopotential height by the use of pentad mean data; this paper studies the correlation between the OKHI and 500-hPa geopotential height by the use of monthly mean data. However, the route is likely the Rossby wave propagation route, finally reaching the sea area off the east coast of Japan, which is different from the remote correlation wave train of East Asia-Pacific pattern caused by sea surface temperature anomaly in tropical western Pacific warm pool brought forward by Huang et al. (1987, 1992a, b). Wang (1992) considered that the propagation of the wave train is likely caused by sea-land thermal contrast.

Analysis results indicate that, when distinct negative SSTA exists in the sea area off the east coast of Japan, there is a negative height anomaly over the area, and simultaneously positive height anomaly in the Okhotsk Sea. It is generally considered that, the atmosphere over the tropical and temperate zones in summer is in equivalent barotropic condition. Due to the air-sea interaction, cold sea surface is all corresponding to low geopotential heights in upper air. On the contrary, warm sea surface is corresponding to high geopotential heights (Wu and Wang, 1998). The relationship between upper atmosphere and sea area off the east coast of Japan is a possible factor to promote the formation and maintenance of the Okhotsk blocking circulation system in the upper air of the Okhotsk Sea which probably enhances the upper-lower layer allocation relationship off the east coast of Japan. The complicated relationship of air-sea interaction might be the reason for the long-term maintenance of Okhotsk high, which needs to be further studied.

The results of numerical experiments indicated that, when there is a negative SSTA in the sea area off the east coast of Japan, the relatively strong positive geopotential height anomaly and high ridge will be over the Okhotsk Sea in June, and simultaneously the negative anomaly will appear in the sea area off the east coast of Japan. The anomaly circulation situation provides an advantaged large-scale circulation background for the formation and maintenance of the Okhotsk blocking. It indicates that, the negative SSTA off the east coast of Japan in early summer may have significant effects on Okhotsk blocking. The effect is likely caused by strong sea-land thermal contrast, between the land near the Okhotsk Sea heated rapidly by strong solar radiation in early summer and the cold sea surface off the east coast of Japan. We could see from composition map (Fig.8) of land surface temperature anomaly in June of blocking high year that, there is a strong positive anomaly in East Siberia with central maximum above 2°C, and a negative anomaly off the east coast of Japan. The distribution in non-blocking high year is reversed (figure omitted). Therefore, comparing with the mechanism brought forward by Wang et al. (2001), it may be explained that, in early summer, if the SSTA off the east coast of Japan is negative, the OLR is low, which has cooling effect on the atmosphere over the area; when the land near the Okhotsk Sea is rapidly heated by
strong solar radiation, the atmosphere over the area is heated accordingly. The strong land-sea thermal contrast formed in this way enlarges the geopotential height anomaly difference between the East Siberia and sea area off the east coast of Japan in middle troposphere, providing advantaged large-scale circulation background for the formation and maintenance of Okhotsk blocking, and the blocking high becomes active.

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