A CASE STUDY ON THE RELATIONSHIP BETWEEN A PRECEDING LA NINA EVENT AND EAST ASIAN SUMMER ATMOSPHERIC CIRCULATION*

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Received April 2, 2004; revised June 24, 2004

ABSTRACT

This study examined the relationship between mature phase of the cold event in 1999 and the East Asian summer atmosphere circulation in 2000. The cold event reaches its mature phase in the autumn and winter of 1999, which is the strongest La Nina episode in recent 11 years. There is a clear anomalous pattern of the atmosphere circulation around East Asia in the summer of 2000, i.e. the negative anomaly centers around the Cherski Mountains and 20°N, 170°E at 500 hPa, the main body of the subtropical high keeps in further northern position than usual and the negative anomaly of precipitation located in southern central China. This pattern is thought as the response to the preceding strong cold event in autumn of 1999. It is also identified that the response of the East Asian atmosphere circulation in summer of 2000 to the strong La Nina event in 1999 belongs to the top rank in recent 43 years. On the other hand, the inactive blocking anticyclone around East Asia in summer of 2000 is associated with the positive SST anomaly and the 850 hPa temperature anomaly around the Bering Sea simultaneously. Nevertheless, although the impact on the summer atmosphere circulation around East Asia from La Nina events could not rank with that from El Nino, the impact could not be neglected especially in a strong La Nina case.

Key words: La Nina episode, East Asian monsoon, atmospheric circulation

I. INTRODUCTION

It is well known that El Nino and La Nina as a pair of apposite phenomena occur alternately. Much more public attention for El Nino episodes is usually paid to since it is frequently reported that El Nino events are associated with many ecological and economic disasters. However, La Nina belonging to the opposite phase of El Nino should also play a relevant role in affecting weather. As pointed out by Philander (1990), El Nino and La Nina deliver the largest signature in and over the tropical Pacific and affect oceanic and

* This study is supported by the program by Minstry of Science and Technology of China (No. 2002DIB20067).

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atmospheric conditions globally.

Wang et al. (2001, hereafter WWO) confirmed that the preceding El Nino events could exert an obvious influence on the East Asian summer atmosphere circulation by 41 years of historical data. Figure 1 shows us that a positive correlation center exceeding 95% confidence level between Z500 (500 hPa geopotential height) in JJA and the SST in Nino-3 area in the preceding autumn (SON) is located around the Cherski Mountains and another large significant positive correlation area almost covers the whole lower latitude with a peak center at 25°N, 180°E. This means that an anomalous blocking anticyclone tends to occur in Northeast Asia during the summer after the El Nino reaches its mature phase, meanwhile the western North Pacific subtropical high extends abnormally southwestward. The related composite figure showed a similar picture as described above. The response of the atmosphere circulation to La Nina event should be opposite to the El Nino according to the correlation map. However, since the response to La Nina is so unclear that WWO could not address it definitely. There is no satisfied certain result provided by not only the composite analysis but also the case study for La Nina. It is still unclear if there is an anomalous pattern over East Asia in summer in response to a preceding strong La Nina event and if it is opposite to that of the preceding El Nino event. If so, since the problems are very important to the seasonal weather prediction over East Asia it is necessary to examine those in detail. The present paper is trying to investigate the atmosphere circulation variation caused by La Nina event from a typical case.

II. DATA

The NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) global atmospheric reanalysis dataset was the primary dataset

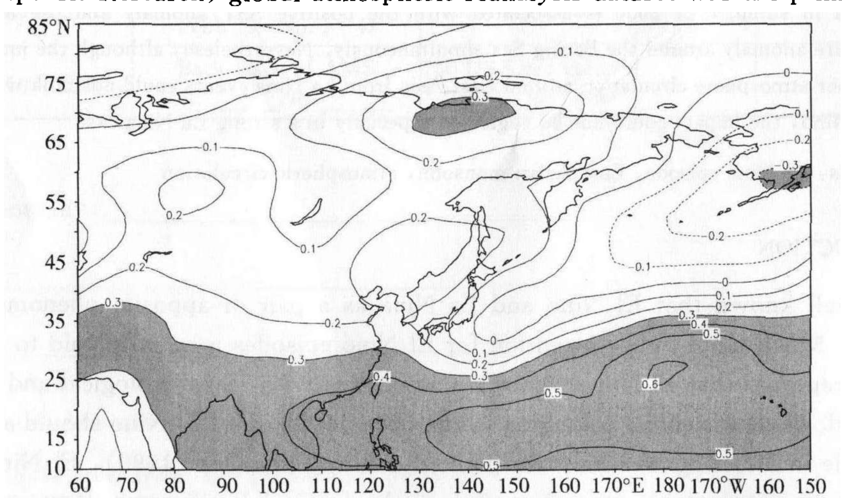


Fig. 1. Seasonal correlation maps between summer (JJA) 500 hPa geopotential height and Nino-3 SST anomaly in the preceding autumn (SON, -1) for the period of 1957—1998. Shaded areas show absolute values over 0.3, exceeding 95% confidence level (after Wang et al. 2001).

used for this study. A detailed description of the data assimilation system that produces this dataset is given by Kalnay and Coauthors (1996). We used monthly mean data on standard pressure surfaces gridded onto a 2.5°×2.5° latitude/longitude grid. In addition, we used monthly SST data from Nino-3 area compiled by Climate Prediction Center/NCEP from 1957 to 2000. The NCEP optimum interpolation (OI) analysis of SST (Reynolds and Smith 1994) gridded onto a 1°×1° latitude/longitude grid from 1999 to 2000 is also used. Monthly rainfall data from 160 Chinese meteorological stations (1958 to 2000) used in this study was obtained from the National Climate Center of China.

III. SEA SURFACE TEMPERATURE ANOMALY

Figure 2 shows the distribution of the seasonal SST anomaly from the autumn (SON) 1999 to the summer (JJA) 2000. The distinct cold water areas cover East Central Pacific and North Pacific, and the warm water area dominates around the so-called warm pool (near the Philippines) from SON 1999 to spring (MAM) 2000. Especially a large negative SST anomaly area (below −1℃) stretches from 170°W to 90°W along the equator in SON 1999, indicating a very strong La Nina. The La Nina reached its prosperity in the winter of 1999. These anomalous phenomena become weak in JJA 2000. Note that the SST anomaly around the North Pacific especially the Bering Sea is just opposite to that around the East Central Pacific in JJA 2000. The positive and negative SST centers in situ are arranged like a wave train (Weng et al. 1999). According to the analysis by WWO, the mature phase of ENSO event in winter, especially in autumn, is well correlated with the atmosphere circulation in the next East Asian summer. We just follow the analysis step of WWO to examine the La Nina case. Figure 3 shows the time series of the SST anomaly in Nino-3 area in SON from 1957 to 2000. The negative SST anomaly value below −1℃ take

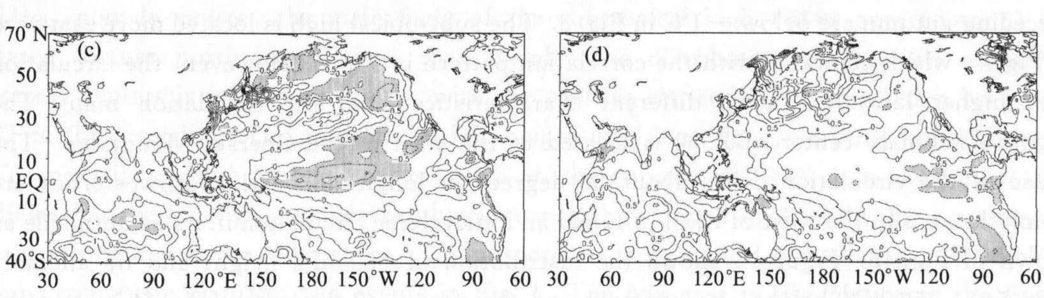


Fig. 2. Distribution of the seasonal SST anomaly for SON 1999 (a), DJF 1999/2000 (b), MAM 2000 (c), and JJA 2000 (d). Shaded areas indicate the values below −0.5℃.

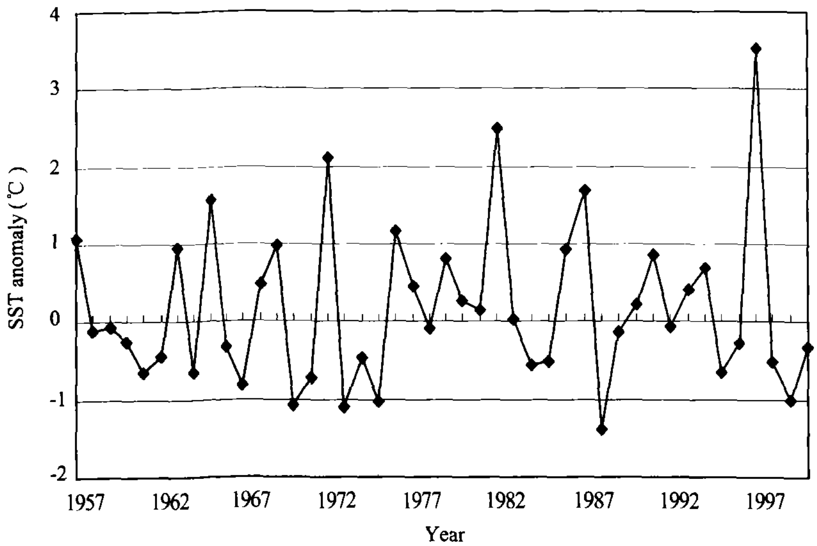


Fig. 3. The time series of the SST anomaly in Nino-3 area in SON from 1957 to 2000.

places only 5 times in history including that in 1999 while the positive SST anomaly value over +1℃ occurs even 9 times. The cold water event in 1999 is very seldom in recent 11 years (since 1988) except for the cold water year of 1988. In addition, this cold event starts from the summer of 1998, lasting for two years. The value of the SST anomaly has ever reached −0.52℃ in the autumn of 1998. The situation is so seldom that we could not find the relative lower value of the SST anomaly lasting for two years more as the cold episode in 1998/1999 rather than trace back to early 1970s.

IV. ATMOSPHERE CIRCULATION PATTERN AROUND EAST ASIA

As mentioned in Section I, WWO indicates that the response of circulation over East Asia to the cold events is not very clear. Here, we reproduce the composites of four cases to show the situation of the response. Figure 4 shows the composite map of 500 hPa height and its anomaly (Fig. 4a), 850 hPa height, its anomaly and the vector of the wind (Fig. 4b) in JJA for the years: 1971, 1974, 1976 and 1989 when the SST anomalies in the preceding autumn are below −1℃ in Fig. 3. The subtropical high is located more eastward in Fig. 4, which coincides with the correlation pattern in Fig. 1. However, the circulation over higher latitudes shows different characteristics from the correlation map. The negative anomaly center of Z500 is located to the west of the Cherski Mountains. The phase of the circulation drifts about 30 degrees in longitude. The southwesterlies are mainly located to the west of the 115°E and an anticyclonic circulation in its eastern side as shown in Fig. 4b. Figure 5 shows the distribution of 500 hPa height and its anomaly (Fig. 5a), 850 hPa height, its anomaly and the vector of the wind (Fig. 5b), and the precipitation in China (Fig. 5c) in JJA of 2000 respectively. A shallow trough extends from the Okhotsk Sea to Korea Peninsula as shown in Fig. 5a. The positive anomaly

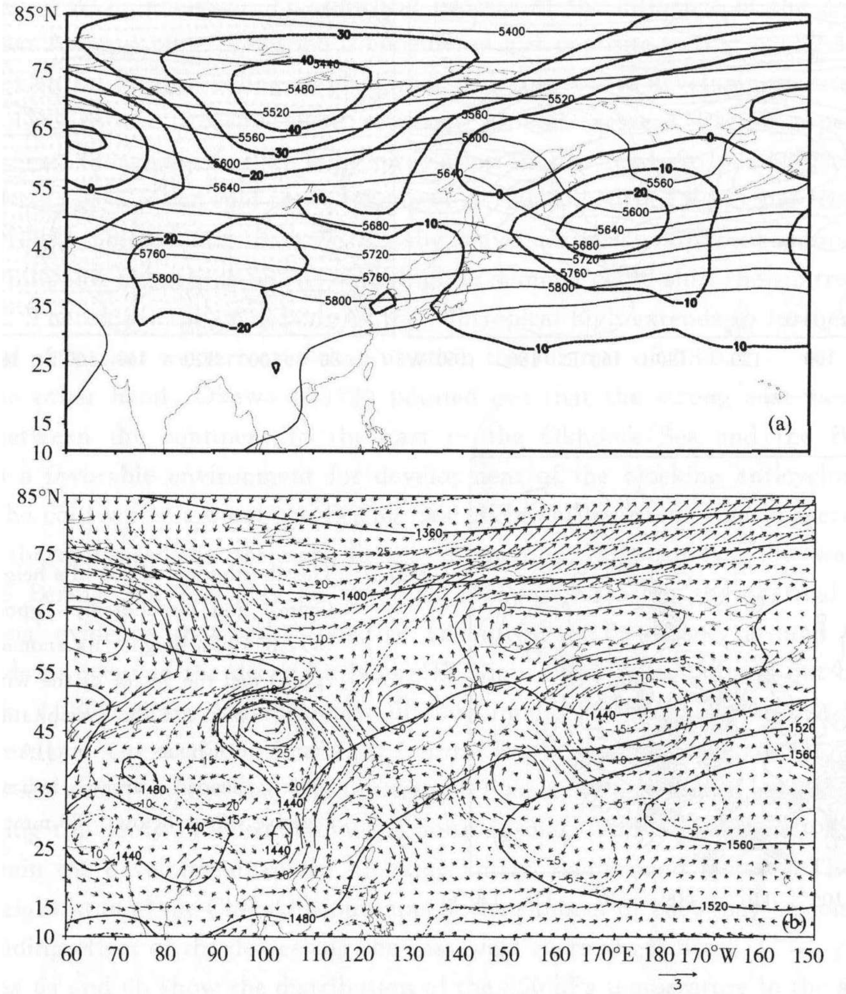
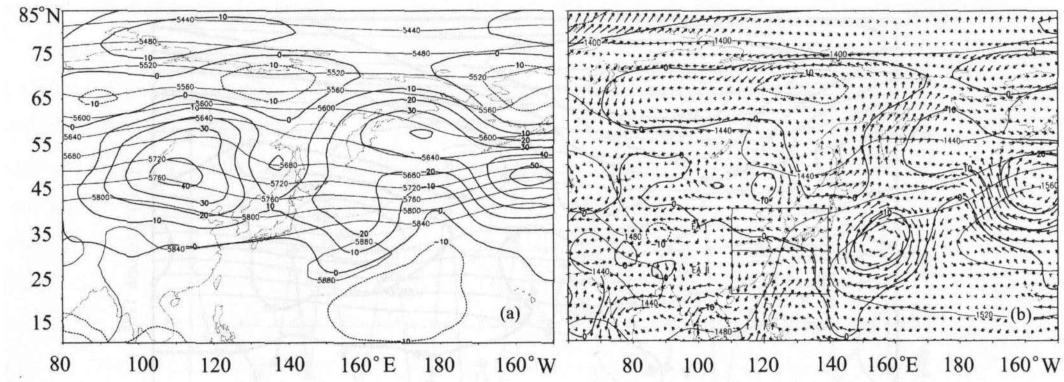


Fig. 4. Composite map of 500 hPa height(gpm) and its anomaly(gpm) (a), 850 hPa height(gpm), its anomaly (gpm) and the vector of the wind (b) for the summer seasons (JJA) in 1971, 1974, 1976 and 1989.

centers are located at 47°N, 110°E and the 57°N, 174°E, and two negative ones are near the Cherski Mountains and Central Pacific respectively. Corresponding to the distribution of the anomaly center, the main body of the subtropical high (5880 gpm contour) is located further northeastern place than usual. The distribution of the two negative anomaly centers is well in agreement with the positive centers of the correlation between SST in the preceding SON and the 500 hPa height in JJA in Fig. 1. In other words, since SST anomaly in Nino-3 area reaches -1°C in the autumn of 1999, it is reasonable to believe that the 500 hPa anomaly height centers in the summer of 2000 display a response to the strong mature La Nina phase. This response is more typical than that in the 500 hPa height composite map for cold events in Fig. 4. The box area in Fig. 5b shows the East Asian key region defined by WWO. Up pane shows EA I area and below pane shows EA II area respectively. We can see that southerly anomaly dominates in the eastern part of the



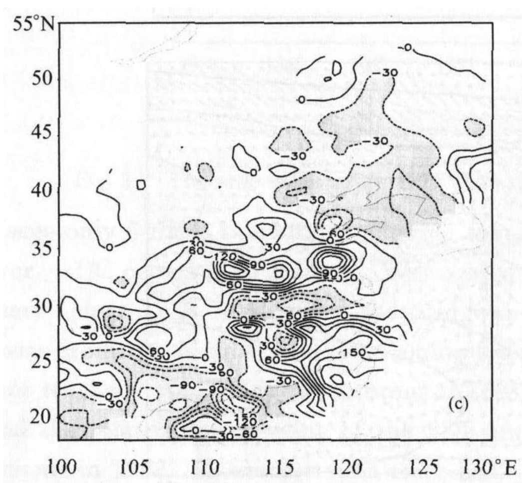


Fig. 5. The distribution of 500 hPa height (gpm) and its anomaly (gpm) (a), 850 hPa height, its anomaly (gpm) and the vector of the wind (m/s) (b), and the precipitation (mm) in China (c) in JJA of 2000. Shaded areas indicate negative values below −30 mm.

EA II area and northeasterly anomaly prevails in the western part of the EA II area. EA I area is covered by the easterly anomaly. The southern central China is to the west of the cyclonic circulation. The main body of the subtropical high (1520 contour) is also located at further northern area than usual, similar to that in Fig. 5a. A long and narrow positive rainfall anomaly area is along 33°N and a negative anomaly is centered to the south of the Yangtze River as shown in Fig. 5c. The negative rainfall anomaly area is apparently associated with the anomalous northeasterly in EA II area as shown in Fig. 5b. Note that the positive anomaly ever covered the area to the south of the Yangtze River in the summer of 1998, the year of El Nino decay which is opposite to that of La Nina decay year in Fig. 5c.

V. DISCUSSIONS

The 500 hPa anomalous circulation pattern in the summer of 2000 is associated with the strong cold event lasting for about two years before as described in Section IV. We consider this as the impact of the preceding La Nina on the East Asian summer circulation according to WWO's analysis. The physical process of the influence of the decay of La Nina on East Asian summer monsoon is considered just opposite to that of the decay of El Nino. The Central Pacific cooling plays an indispensable role in developing western Pacific warming. Due to the Rossby wave response around western Pacific especially the Philippine Sea, the anomalous cyclonic circulation in situ tends to persist from mature phase to decay phase of the cold event (Wang et al. 2000). Nitta (1987) and Kurihara and Tsuyuki (1987) pointed out that the Rossby wave northeastward propagation starting from the Philippine Sea where SST is quite high in summer could shift the subtropical high northward. Therefore, the main body of the subtropical high extends to further northern area instead of further western area than usual in the summer of 2000.

On the other hand, Okawa (1973) pointed out that the strong east-west thermal gradient between the continent to the east of the Okhotsk Sea and the Bering Sea establishes a favorable environment for development of the blocking anticyclone around Siberia. The cold water around the Bering Sea plays an important role in increasing the east-west thermal gradient through air-sea interaction. Oppositely, the warm water around the Bering Sea will play an essential role in decreasing the thermal gradient. Observational evidence shows that positive (negative) SST anomaly around the North Pacific tends to occur in the decay La Nina (El Nino) summer as pointed out by WWO. Weng et al. (1999) show that the phase of the summer SST anomaly around the North Pacific is just opposite to that around East Central Pacific in the first mode (35.1%) of an SVD analysis, which implies that the positive SST anomaly distributed around the North Pacific during the decay La Nina summer is quite normal. This SST anomaly distribution could restrain the development of the blocking anticyclone around Siberia. The negative anomaly height around the Cherski Mountains in the summer of 2000 may be considered as the outstanding effect of the decreasing the east-west thermal gradient.

Figures 6a and 6b show the distribution of the 850 hPa temperature in the summer of 1999 and 2000 respectively. We can see that a cold anomaly area is centered at 65°N, 163°E (extending to the Bering Sea) and a warm one at 45°N, 147°E in the summer of 1999 while two warm areas are centered at 57°N, 173°E and 43°N, 152°E respectively. Note that the air temperature distribution at lower troposphere over the Pacific is well in agreement with SST anomaly distribution in situ, which displays an air-sea interaction. Thus, it is reasonable that the negative (positive) SST anomaly around the Bering Sea plays an important role in increasing (decreasing) the east-west thermal gradient at least in the lower troposphere, which contributes anomalous circulation at 500 hPa. Consequently, the blocking anticyclones frequently occur in the summer of 1999 (figure omitted).

Above results show that the impact of the preceding La Nina on the East Asian summer circulation is not as big as that of the preceding El Nino as pointed by WWO. This may be attributed to the weaker amplitudes of the cold episodes. The negative SST anomaly amplitudes in Nino-3 area are far from the positive ones as shown in Fig. 3. The strongest cold event is found in 1988, whose SST anomaly in Nino-3 area only reached

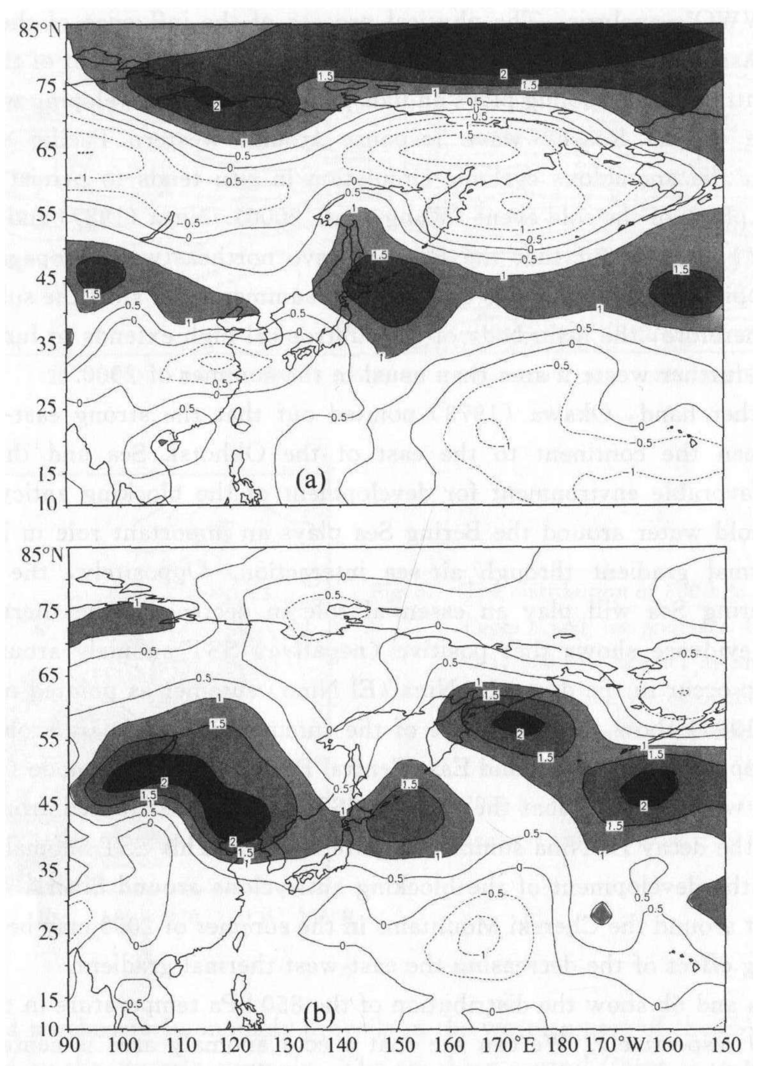


Fig. 6. The distribution of the 850 hPa temperature (°C) in the summer of 1999 (a) and 2000 (b). Heavy (light) shaded areas indicate the values over 1.0°C (below −1.0°C).

−1.38°C. However, the SST anomaly in Nino-3 area could easily exceed +2.0°C in mature phase of El Nino and the strongest one even reached +3.53 °C in 1997, whose absolute value is almost three times of it in 1988. This implies that the negative thermal force from the East Central Pacific on the atmosphere circulation is much smaller in La Nina year compared with that in El Nino year. The La Nina episode also occurred for two years in 1970−1971 as shown in Fig. 3. Quite similar result happened in the summer of 1972. However, the composite ones of the 4 cases do not coincide with the strongest La Nina event as compared with Figs. 4 and 5. It implies that the impact of the long persistent La Nina phenomenon on East Asian summer circulation is measured more obviously. Although the SST anomaly value in Nino-3 area in SON of 1999 is not lowest, the cold episode lasted quite long time i. e. from the summer of 1998 to the spring of 2000.

Therefore, the episode we are studying belongs to the top-rank of the La Nina events.

The EAMI (East Asian monsoon index defined by WWO) is positive (0. 27) in the summer of 2000, which does not coincide with the conclusion for decay La Nina summer pointed out by WWO. But, the result that the negative rainfall anomaly distributed in South Central China is roughly in agreement with WWO's conclusion. If the main body of the subtropical high moves further eastward slightly, the EAMI could become negative value because the 850 hPa anomalous northeasterly may fill with whole EA II area. In other words, the perfect response to the cold event should be the main body of the subtropical high moving northeastward abnormally. However, there are so many factors affecting atmosphere circulation that it is difficult to find a case with pure response to La Nina in real atmosphere observation. Nevertheless, the case we are studying is identified as the best response to the Central Pacific cooling. WWO pointed out that the East Asian monsoon-ENSO interaction becomes more active in recent years, which is also applied to this case.

VI. CONCLUSIONS

We examined the relationship between the strong La Nina event in 1998 to 2000 and the East Asian summer atmosphere circulation in 2000 and obtained the results as follows:

(1) The cold event reaches its mature phase in the autumn and winter of 1999, which is the strongest La Nina episode in recent 11 years. There is a clear anomalous pattern of the atmosphere circulation around East Asia in the summer of 2000, i. e. the negative anomaly centers around the Cherski Mountains and 20°N, 170°E at 500 hPa, the main body of the subtropical high keeps in further northern position than usual and the negative anomaly of precipitation located in southern Central China. This pattern is thought as the response to the preceding strong cold event in the autumn of 1999, which is the top rank of the response to the strong La Nina event in recent 43 years.

(2) The inactive blocking anticyclone around East Asia in the summer of 2000 is associated with the positive SST anomaly and the 850 hPa temperature anomaly around the Bering Sea.

(3) Although the impact on the summer atmosphere circulation around East Asia from La Nina events could not rank with that from El Nino, the impact could not be neglected especially in a strong La Nina case.

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