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by

Ding Yihui

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PROPAGATION OF COLD AIR MASSES IN EAST ASIA AND ITS ASSOCIATED PLANETARY-SCALE FUNCTION

By

Ding Yihui, Academy of Meteorological Science,
State Meteorological Administration

ABSTRACT:

The present paper has delt with the characteristics of propagation of the winter monsoon during cold air outbreaks for 19 cases of 1980—1984 in East Asia as well as the associated planetary-scale effect. It has been revealed that the propagation of cold air mainly shows a mode of 10—20 day period oscillation. Furthermore, the Siberian cold high associated with outbreaks of cold air may lead to the response of a chain of planetary-scale events. This mainly shows up in the fact that the branch of upward motion of the divergent circulation rapidly shifts from the Indonesia-Malaysian region eastward to the eastern Pacific, thus causing the normal-type Walker circulation to reverse its sense. This condition is very similar to the movement of divergent circulation from non-El Nino year to El Nino year. From the dynamic viewpoint, this kind of divergent circulation is favorable to the synoptic development over the eastern Pacific and the western coast of North America.

I. Introduction

In East Asia, a process of cold waves is accompanied with intensive surges of cold air masses. From its origin in Siberia, when cold air masses rapidly move eastward, very strong north winds and northeast winds are generated in the lower atmospheric layer, thus causing the development of winter monsoons. If appropriate circulation exists in South China and the South China

Sea, an apparent cold surge will be generated[1]. This kind of cold surge can rapidly spread southward or propagate to areas near the equator, thus, intensifying convection and phenomena there. Afterwards, latent heat released from precipitation produces an obvious feedback[2] to the large-scale atmospheric circulation in East Asia and the Northern Hemisphere. Therefore a cold wave in East Asia is not only a regional weather process, but it also has an apparent function on a planetary scale.

As pointed out by N. C. Lau and K. M. Lau[3], once a cold wave surges, there are two types of disturbances propagating downstream. One low-frequency disturbance moves toward the subtropical Pacific region. This movement toward the equatorial region is manifested as a new disturbance center, which continuously builds up downstream of the original center. Recently, Pan and Zhou[4] also studied the propagation process of Siberian highs. They pointed out that accompanying the southward motion of the cold high pressure and moving out of the East Asian coastlines, the 200 hPa divergent circulation in the West Pacific Tropical Region intensifies, then rapidly moves eastward. This process actually is a low-frequency weather-scale disturbance slowly moving eastward; the time scale is approximately 10 to 20 days. In the first part of the article, new facts are set forth to prove that this low-frequency propagation is a feature of East Asia cold air mass.

It is generally acknowledged that the planetary-scale function of East Asia cold air masses or the winter monsoon is carried out by Hartley circulation and Walker circulation in local areas. Chang and Lau et al.[2] conducted quite a number of studies on the change in Hartley circulation under cold surge conditions; however, their investigations are limited mainly to the East Asia and West Pacific Regions. In the second part of this article, the planetary-scale function of the winter monsoon is studied in broader scope, thus revealing some remotely related phenomena with the winter monsoon.

II. Data and Computational Methods

The data and examples used in the article are the same as in reference [5]. The data used were the once-a-day data points of the European Intermediate-Range Weather Forecast Center covering five winters (November through February, from 1980 through 1984). The horizontal discrimination rate is 2.5 deg. Long./deg. Lat. These data were initialized. During these five winters, the authors selected a total of 19 processes of strong cold waves. Their cold high pressures generally had similar moving routes, that is, from the Siberian region west of Lake Baikal passes through Mongolia and North China, then moves to East China, and finally goes out to sea. Moreover, when the cold high pressure moves to certain areas, certain intensities are attained. In other words, at the ground center of the Siberian zone of origin atmospheric pressure should be 1055 hPa; upon arriving at the Mongolia and North China Regions, it should be larger than 1040 hPa, and upon arriving at the East Asia Region it should be greater than 1032 hPa. Actually, these 19 examples were processes of large-area cold waves, being the most intensive during these five years.

Based on different locations attained by the cold air pressures, the entire cold wave process is divided into three stages. Stage I: before the onset of a cold surge, the center of the cold high pressure lies in the Siberian origin zone; this is the earliest time-period stage of the cold air process. Stage II: after a surge of a cold wave, the center of the cold high pressure is in the North China Region. Stage III: the center of the cold air pressure moves to East China. Thereafter, a comprehensive average is derived based on these three stages on the global flowfields and divergent wind field (or velocity potential field) of these 19 examples, thus yielding the global-scale flowfield before and after surges of the East Asia cold wave, and images of average in variation of the divergent windfield.

To understand the southward propagation feature of cold air masses in the cold wave, the authors first computed the apparent heat source (Q_1), with the formula

$$Q_1 = c_p\left(\frac{\partial\theta}{\partial t} + \dot{v}\cdot\nabla\theta + \omega\frac{\partial\theta}{\partial p}\right)\left(\frac{p}{p_0}\right)^k$$

In the equation, θ is the potential temperature; ω is the vertical velocity of the p-coordinate. $k = R/c_p$; R and c_p are, respectively, the gas constant and the specific heat at constant pressure. Since a cold air mass (ground high pressure) related to cold wave activity is the principal heat sink (cold source) of the winter atmosphere, analysis of the variation in the Q_1 field of the convection layer can possibly better reveal the features of routing and propagation of a cold air mass than analyzing other meteorological fields. Based on the formula for Q_1, the authors computed the distribution (in the East Asia Region) of Q_1 at 700 and 300 hPa between December 1980 to February 1981; at the same time, the power spectra of various lattice points were also computed. It was discovered that oscillations with a cycle of 10 to 20 days exist in most lattice points; oscillations with a period of 40 to 50 days also exist, but are not as obvious as those with a 10 to 20 day cycle. Later, a wave filtration was carried out on the Q_1 field of the 700 and 300 hPa layer, thus yielding the Q_1 field as a component of the 10 to 20 days.

In the computations of the divergent wind field or the velocity potential field, the authors adopt the double Fourier transform method[5]; these computations are very accurate to the global velocity-potential fields. Refer to reference [6] for the detailed computational method.

III. Propagation Features of Cold Air Masses in a Cold Wave

Fig. 1 is the x-t diagram of Q_1; the figure indicates the time evolution of the heat sink and the heat source along the cold air paths. 700 and 300 hPa can represent, respectively, the situations in the lower and upper convection layers. Because of space limitations, only the situations of one month between

January 16 and February 16, 1981, are reported. This particular month was selected because during this period the cold air masses were the most active in the five winters under study; this includes a very intensive cold wave process (from January 21-30, 1981). Prior to the surge of this cold wave, atmospheric pressure at the ground center of the Siberian cold high pressure was 1085 hPa, which broke the historical record of 1082 hPa set in January 3, 1977. This process of the cold air masses caused intensive drops in temperature over large areas of China, between 10 to 12°C drop in temperature in East and South China. In the coastal regions, there were very strong north winds and northeast winds. From Fig. 1, we can see that in the entire month generally there were three cold wave processes from a Siberian origin propagating southeastward to the South China coast. The most obvious process is the previous stated cold wave between the January 21 and 30. Basically the cold and heat origin propagated along the path of northwest to southeast; there were more apparent for 300 hPa than for 700 hPa. In addition, the 300 hPa propagated about 1 to 3 days ahead of the corresponding 700 hPa. This southeastward propagation of Q_1 possibly reflects the propagation of a weather-scale disturbance with a 10 to 20 day cycle toward the lower latitudes. In other time segments, in the winter of 1980-1981, there were similar phenomena. This indicates that the low-frequency oscillation of 10 to 20 days is an important low-frequency mode of the mid- and high latitudes in winter; this oscillation is closely related to the East Asia cold wave.

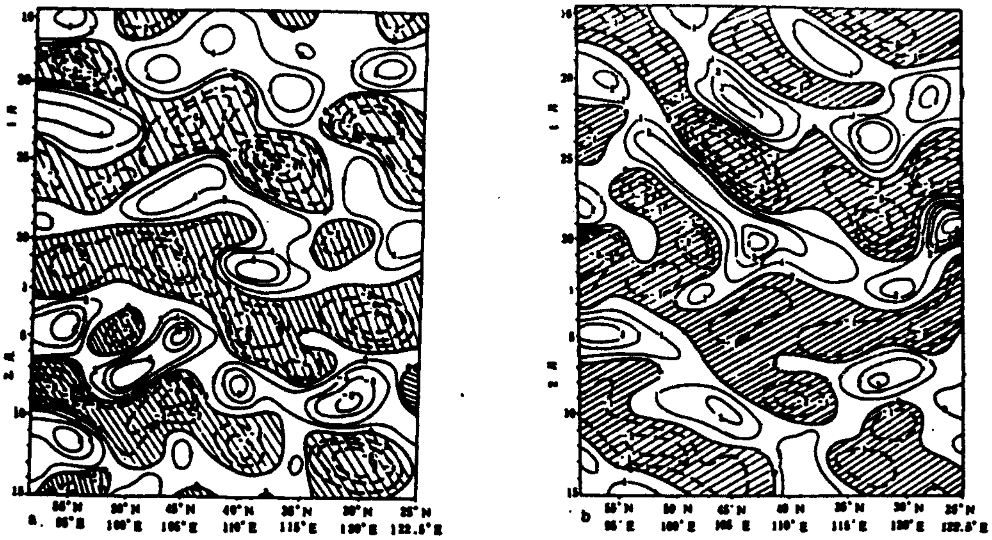

Fig. 1. x-t diagram of apparent heat source Q_1 of low pass wave filtration between January 15 and February 15, 1981: (a) 300 hPa (b) 700 hPa (shaded area represents negative region (heat sink); solid curves represent positive Q_1 (heating) curves; dashed lines represent negative Q_1 (cooling) curves; unit: C/d. The abscissa indicate the average path of the East Asia cold wave.)

IV. Planetary-scale Function of Cold Air Masses in East Asia Cold Waves

As pointed out in the introduction, a surge of East Asia cold air masses (including the establishment, southward penetration, denaturation, and dissipation of the Siberian high) not only is a regional weather process, but also can be explained from the two following aspects: in one aspect, its formation and development are the result of the evolution of large-scale circulation[7-9]; in the other aspect, as a main cold source in the Northern Hemisphere, once the Siberian high surges southward, it will impose significant effects on the planetary-scale circulation. Some previous research pointed out the existence of this remotely related phenomena on a planetary scale to some extent [2,9]. For example, six or seven days before the surge of East Asia cold air masses, in the West Atlantic there is first the formation and buildup of troughs and ridges. Afterwards, when passing the Eurasian continent, formation, development, and breakup of new troughs and ridges in turn occur downstream. This continuous development process downstream steadily continues until eventually it causes the surges of East Asia cold air masses. After the surge of the cold wave, as the process of energy dissipation, cold air activates and propagates downstream. Recently, Ding and Krishnamurti[10] studied this planetary-scale function of the surge of East Asia cold waves. As they pointed out in the cold wave surge process there is the phenomenon of eastward motion of the 200 hPa divergent circulation center of the tropical planetary scale. In the following, the discussion will be continued by relying on more detailed data.

Fig. 2a-c shows the mean flowfield (average of 19 cases of cold waves) of the 200 hPa for the Siberian cold air high at different development stages. It can be seen with the surges of the East Asia cold wave, obvious variation occurs in the large-scale circulation, primarily revealed in three aspects: 1) first, it is the deepening of the East Asia large trough located on the East Asia coastlines in winter; the trough moves eastward for 20 deg. Long. In stage I, the mean position of the large trough is situated at 120 deg. E. In stage III, the large trough moves eastward to the vicinity of 140 deg. E. This apparent deepening and eastward motion will certainly cause a variation and rearrangement of the downstream system. 2) In the upper portion of the convective layer, the Alaska high shows an apparent increase in its amplitude; the corresponding large trough along the East Coast of North America deepens. This variation of downstream circulation is a possible manifestation of energy dissipation of the Rossby wave, and the functioning of the upper stream effect. The amplitude increase of the Alaska high may also be related to the shortening of the wavelength of long-wave troughs on the East Asia coastlines and the East Coast of North America. This process may cause the buildup of the longitudinal direction of the long wave. 3) In the West Pacific tropics and Northern Australia, a pair of anticyclones moves eastward. In particular, the anticyclone circulation at Northwest Australia has its center located in Northwest Australia in its initial period. Afterwards, another new center is formed over the seas northeast of Australia. In a later stage, this center moves further eastward and becomes another center. As mentioned above the eastward motion of the atmospheric pressure couple is related to the formation and eastward motion of an intensive convection and precipitation zone stimulated in an area near the equator after the surge of cold air masses has passed.

In the following, the author and his colleagues discuss the variation in the global-velocity potential field in the surge process of East Asia cold waves. Fig. 3a,b show, respectively, the distribution of the 200 hPa and 700 hPa velocity-potential fields over a time average (average of three stages) of a process of surges of East Asia cold waves. It can be observed that the most intensive center of divergent circulation (ascending branch) (Fig. 3a) is situated in the tropical mid-Pacific (in the vicinity of 150 deg. E.). This position is 30 deg. in Long. more to the east for the winter-average position (in the vicinity of 120 deg. E.) of the 200 hPa divergent center[10]. This shows the response of large-scale circulation to the activity of East Asia cold air masses. If we compare this with the situation of other activity periods of cold surges[2,11], this position is close or slightly to the east to the position of the divergent center as obtained by researchers. The high altitude divergent zone extends eastward from the West Pacific to the East Coast of America; the high altitude convergent zone is situated over the Eurasian continent, Africa, and the Atlantic regions. The distribution of the 700 hPa velocity-potential field is almost the reverse of that of the 200 hPa velocity-potential field, with only some difference in the positions of the divergent and convergent centers. In the lower altitude of the 200 hPa divergent zone, this is the apparent convergent zone (from the West Pacific to the East Coast of America); however, the lower side of the 200 hPa convergent zone is an apparent divergent zone (Eurasian continent, Africa to the Atlantic). So as observed on a global scale, the divergent circulation of the planetary scale is very clear, and it is manifested as the distribution type of waves.

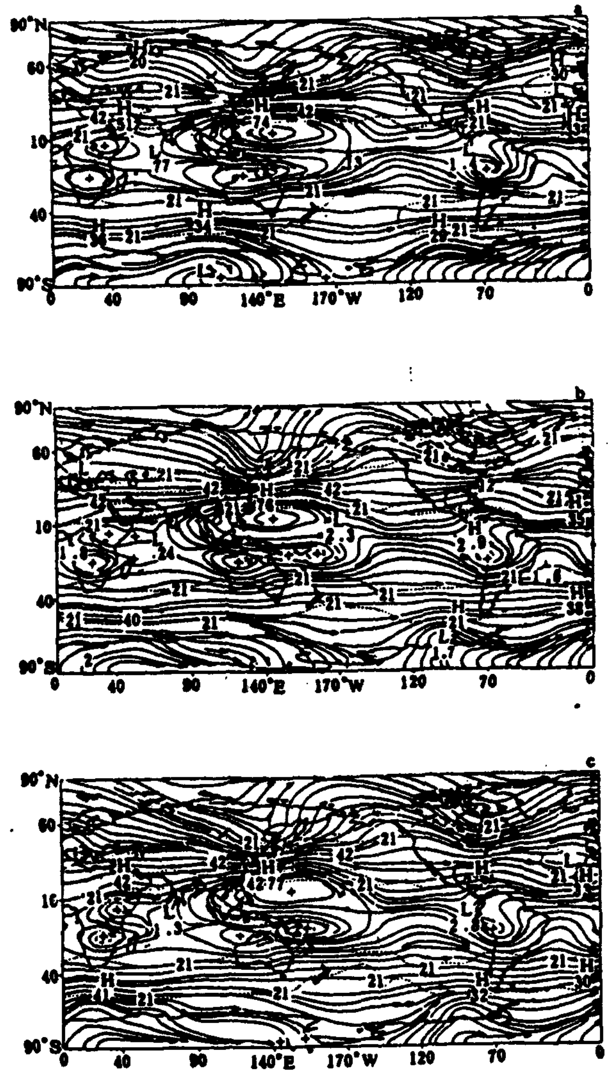

Fig. 2. 200 hPa average flowfields of stage I (a), stage II (b), and stage III (c) of surges of East Asia cold waves (dashed curves are the isopleth of wind speed); unit: m/s

The main effect of the process of surges in East Asia cold waves on the divergent circulation of this planetary scale is manifested in the eastward motion of the position of the circulation center and its development toward downstream. From stage I to stage III, the center of the most intensive 3200 hPa divergent circulation rapidly moves 60 deg. Long. eastward (refer to Fig. 3a). This point can be more clearly observed from

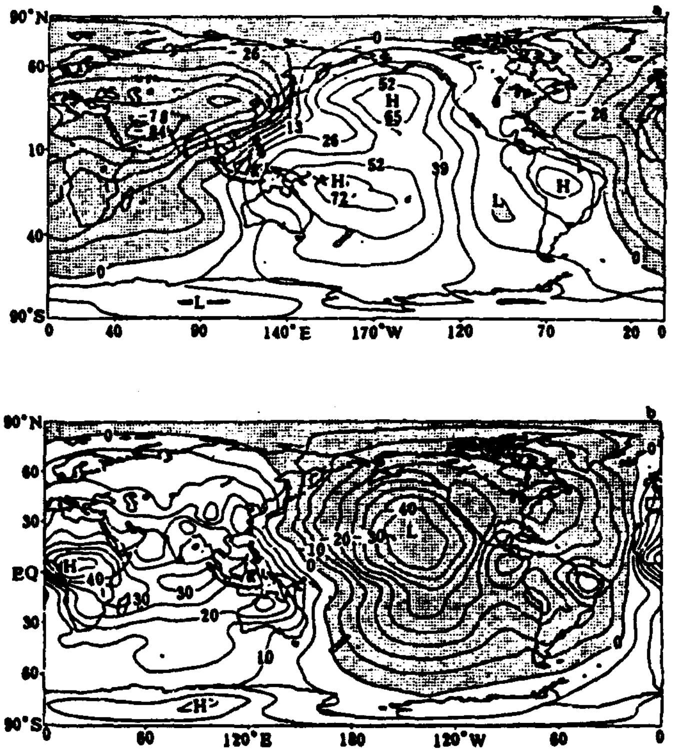

Fig. 3. Velocity-potential fields of time average for the surge process of East Asia cold waves: (a) 200 hPa (b) 700 hPa (shaded area: convergent zone, unit: 10^5 m^2/s) Black dots represent positions of the divergent circulation center in three stages

different stages of a velocity-potential anomalous field (Fig. 4a,b to Fig. 6a,b). (The average velocity-potential field of 19 cases of cold waves at different stages minus the average velocity-potential field in the winters of 1980 through 1984.) These graphs clearly indicate that there is a reverse distribution of convergent circulation before and after surges of cold air. At an early stage, the center of the 200 hPa very powerful divergent circulation is located over the West Pacific Equatorial Region, west of 170 deg. W.; the convergent circulation is situated over the East Pacific Equatorial Region; this indicates the existence of strong Walker circulation as the normal type. However, with the southward motion of the Siberian high and the rapid eastward motion of the divergent circulation anomalous region, the entire East Pacific is controlled by divergent circulation; however, the Mid- and West Pacific, as well as the Eurasian continent, are the divergent circulation zones with distribution basically the reverse in direction as that of stage I. In the later stage, the anomalous divergent circulation over the East Pacific further extends toward the northeast and the southeast, with an influence covering all of North and South America. It should be pointed out that the axial curves of the maximum divergent zone points to the West Coast of North America (including Canada) toward the northeast from the Mid- and East Pacific Equatorial Regions. Later, the axial curves turn southeastward to arrive at the East Coast of the United States. This situation is very similar to that of the PNA type. At that time, the normal Walker circulation has been completely replaced by a reverse-direction east-to-west circulation. In other words, the ascending motion occurs over the East Pacific Equatorial Region and the descending motion occurs over the West Pacific Equatorial Region. Therefore, in the East Pacific equatorial region, there will be intensification of convection and precipitation. However, in the West Pacific

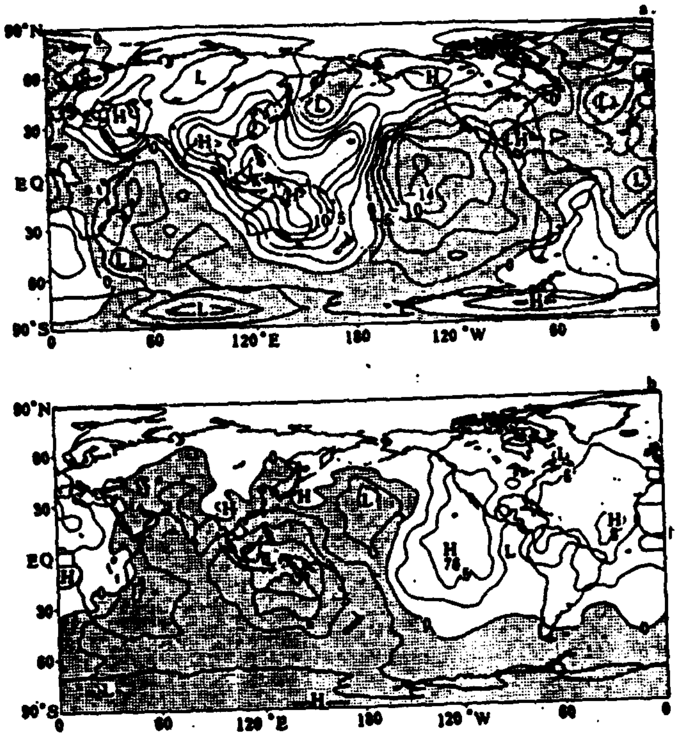

Fig. 4. Velocity-potential anomalous field of time average in the first stage of East Asia cold waves: (a) 200 hPa (b) 700 hPa (shaded area indicates anomaly of the convergent zone, unit: 10^5 m^2/s)

Equatorial Region there will be constraints on convection and precipitation. The evolutionary process of the above-mentioned divergent circulation is very similar to the response process (PNA type) of the atmosphere in the tropics and mid-latitudes to the El Nin^ event. Although the time scales of the two differ, in the former case this is a short-term phenomenon, but in the latter, this is a long-term phenomenon. As revealed by the above-mentioned facts, once the surge of the East Asia cold waves, through the remotely related function of the downstream after an average of five to seven days, the surge may possibly affect weather in the Western United States, and even the Eastern United States.

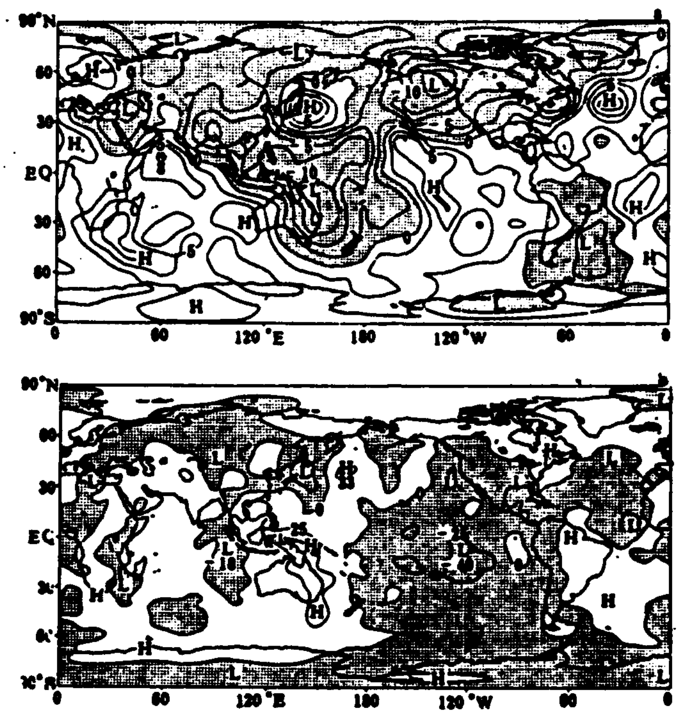

Fig. 5. Velocity-potential anomalous field of time average in the second stage of East Asia cold waves (further explanation is the same as in Fig. 4)

The 700 hPa velocity-potential anomalous field more clearly explains this possibility. Prior to surges of cold air masses, the West Pacific and Indian Ocean Regions represent the convection zone; the most intensive convection zone is situated over Indonesia and New Guinea. The divergent zone is situated over the East Pacific -- North America -- Atlantic Region. This distribution is similar for general climatic situations. After cold wave surges have passed, the distribution of the velocity-potential anomalous field in the lower atmospheric layers is just the reverse as that in the initial stage. Over the East Pacific and Western America, a convergent anomalous region appears. However, over the West Pacific a divergent anomalous field appears. This indicates the apparent weakening or the sign reversal of the original low-level convergent field over the zone. In the latter periods, the center of the most intensive convergence of 700 hPa over the East Pacific rapidly moves eastward; while over the ocean west of the West Coast of North America, there is apparent intensification of the lower altitude convergence, or ascending motion. Refer to Fig. 6a, at that time the situation of the low-altitude convergence and high-altitude divergence occurs. From the viewpoint of dynamics, the coupling of high and low altitudes is very beneficial to the development of weather systems, as the buildup of temperate cyclones in the winter along the West Coast of the United States. Lau et al.[11] also point out that in the latter stage of a cold air surge, there is possibly a strong influence on the weather development along the west coast of the United States by a cold surge over East Asia through intensifying interaction or coupling functions of the mid-latitude and the tropics. This remotely related problem in the downstream merits further research.

V. Conclusions

The paper reports on studies on the planetary-scale function and features of low frequency propagation of 19 surges of East Asia cold waves in the winters of 1980 through 1984. This shows that the southward propagation of cold air mainly is the oscillation of a cycle of 10 to 20 days for a low frequency state. These low-frequency waves move southeastward following the primary paths of cold highs from a Siberian origin to the subtropical and tropical areas. On the other hand, the Siberian high as the main cold source or thermodynamic force of the convection layer in Northern Hemisphere winters will certainly have important effects on large-scale atmospheric circulation. When a Siberian high moves to North China from its origin, and finally moves to East China and South China, a series of responses in the process of a planetary scale process will be induced. In the first several days before surges of cold air masses, the divergent circulation and monsoon activity occur mainly over the South China Sea, Malaysia, and Indonesia. Later, the circulation and the monsoons begin to intensify, and the divergent circulation on a planetary scale rapidly moves eastward. The ascending branch of the divergent circulation rapidly moves eastward from the winter monsoon region (or cold surge region) to the Mid- and East Pacific Equatorial Regions. These activities reverse the direction of normal Walker circulation. This situation is very similar to the movement of divergent-circulation from a non-El Nino year to an El Nino year. When a Siberian high moves from East China to the ocean, and the cold surge is in the latter period of its buildup stage, the intensive ascending branch of the East Pacific divergent circulation obviously extends eastward and intensifies. This will affect the weather development of the East Pacific or the coastline of Southern California. Therefore, the remotely related function of surges of East Asia cold waves at least can have an effect in its downstream, the regions of the American continent.

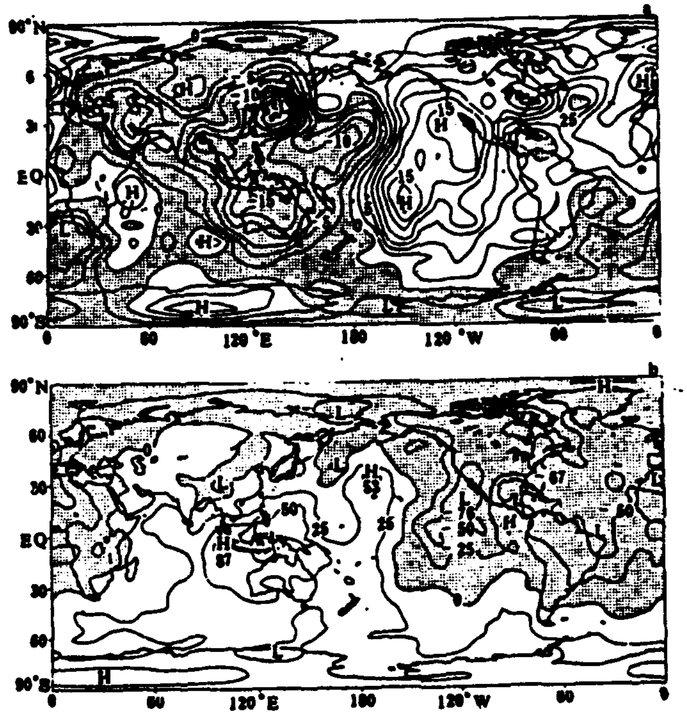

Fig. 6. Velocity-potential anomalous field of time average in the third stage of East Asia cold waves (further explanation is the same as in Fig. 4)

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REFERENCES

[1] Ding Yihui, "Statistical research on East Asia winter monsoons," Redai Qixiang [Tropical Meteorology], 6, 119-128 (1990).

[2] Chang, C. P., and K. M. Lau, Northeasterly cold surges and near-equatorial disturbances over the winter MONEX area during December 1974, Part I, Planetary-scale aspect, *Mon Wea. Rev.*, 108, 298—312, 1980.

[3] Lau, N. C., and K. M. Lau, The structure and energetics of midlatitude disturbances accompanying cold air outbreaks over East Asia, *Mon. Wea. Rev.*, 112, 1309—1327, 1984.

[4] Pan, H.-L., and F. X. Zhou, The 10-20 day tropical-midlatitude interaction during winter monsoons season, *J. Meteor. Soc. Japan*, 63, 829—843. 1985.

[5] Stephens, J. J., and Johnson, K. W., Rotational and divergent wind potentials, *Mon. Wea. Rev.*, 106, 1452—1457, 1978.

[6] Ding Yihui, Tianqi Donglixue Zhongdi Zhenduan Fenxi Fangfa [Diagnostic and Analytic Methods in Weather Dynamics], Science Publishing House, p. 293, 1989.

[7] Tao Shiyan, "Empirical study of cold air activities of winter half-year in East Asia," mimeographed copy of the Central Meteorological Station, 1955.

[8] Chou Yongyan, Zhongqi Tianqi Yubao [Intermediate-Range Weather Forecasting], Science Publishing House, pp. 309-348.

[9] Joung, H. J., and M. H. Hitchman, On the role of successive downstream development in East Asian polar outbreaks, *Mon. Wea. Rev.*, 110, 1224—1237, 1982.

[10] Krishnamurti, T. N., Tropical Meteorology, WMO, No. 364, Switzerland, 1979.

[11] Lau, K. M., and P. H. Chan, Short-term climate variability and atmospheric teleconnections from satellite-observed outgoing longwave radiation, Part I, Simultaneous relationships, *J. Atmos. Sci.*, 40, 2735—2750, 1983.

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