On the General Circulation over Eastern Asia (II)[1]

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Abstract

The principal weather system over Eastern Asia are considered in the different seasons. Section 3a contains a discussion of the winter and the transitional seasons, while sections 3b considers the summer situation. The influence of the Tibetan Plateau on the circulation over the Far East and the weather over China is discussed in the last section.

3. A brief survey of principal weather systems over Eastern Asia

We have seen that the basic currents over Eastern Asia have distinct seasonal differences. So also are the principal weather systems. Therefore in the following we shall discuss the principal weather systems over Asia according to season.

a) Winter and transitional season.

In winter and transitional seasons westerlies prevail over much of the continent. The synoptic systems encountered are mainly disturbances in the westerlies. Among these cold waves and extratropical cyclones are by far the most important. As over other parts of the northern hemisphere cold waves break out during the period of large scale changes of the general circulation in middle latitudes. In winter and transitional seasons there is a major trough off the Asiatic coast. But this quasi-stationary trough is subject to a great variation. This long wave system over the Asiatic coast starts after a period of "anchoring" at its normal position to move eastward with a rapid decrease in intensity. At the same time there is a strong development of an upper trough over the continent. This developed trough moves out of the continent and reforms a new quasi-stationary major trough at the normal position. With this development there will be an outbreak of a cold wave. Figs. 15 a—c illustrate this process.

According to the origin of the cold air and the synoptic development we divide the cold waves into four categories. In the first category the Arctic Sea to west of Nova Zembla is the site for the cold air from which the arctic air through the North Scandinavia, the White Sea and the Barents Sea goes to the north European part of Soviet Union and then from West Siberia and Mongolia invades China. With this cold air is a developing upper short-wave trough which reaches its highest development east of 130° E and then becomes a major trough off the coast. In the second category the site of cold air is the part of the Arctic Sea north of the Asiatic continent. This cold air moves southward to West Siberia. Below 60° N it turns SE-ward and invades Mongolia and China. During its southward

[1] Continued from Vol. 9, No. 4.

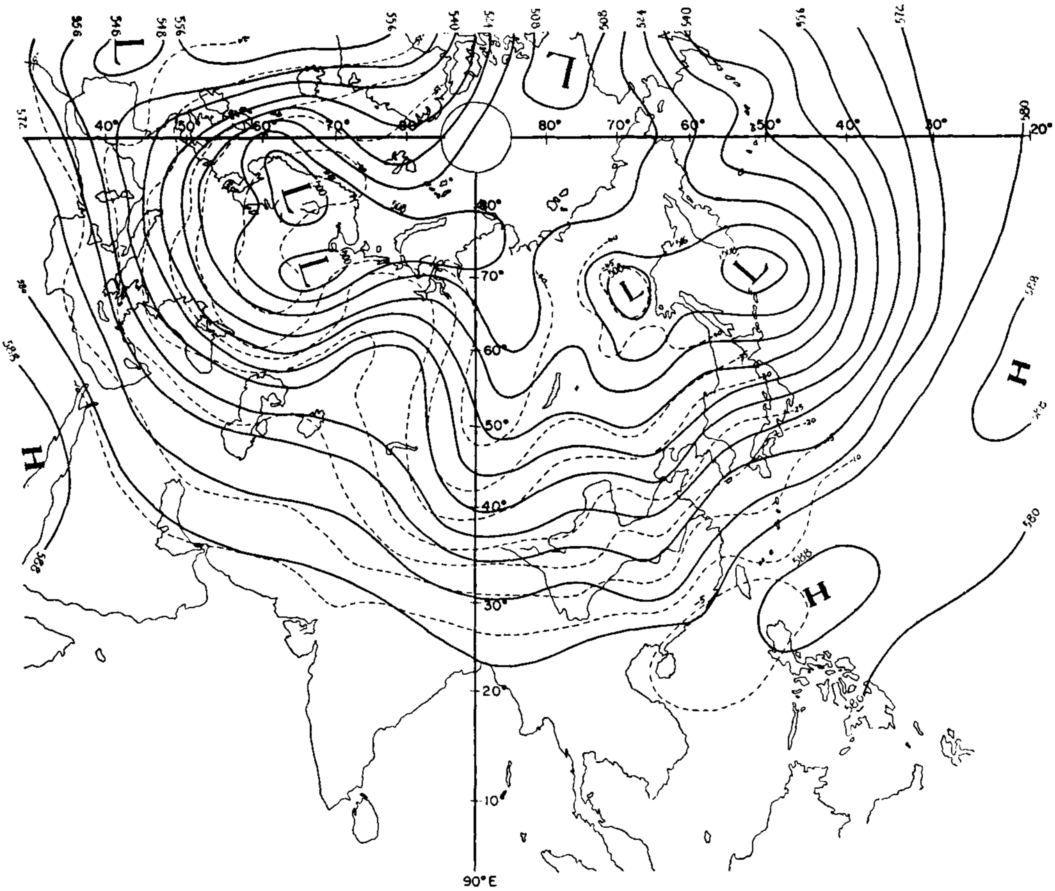

Fig. 15 a. 500-mb chart for February 16, 1955, 1500 Z. The long-wave trough off the Asiatic coast began to move eastward, while a short-wave trough has moved into western Siberia from Europe.

invasion a pressure ridge develops over Urals aloft. At the same time a short wave trough moves southeastward to the east of Urals. As it moves eastward it shows a marked deepening and replaces the original major trough as it crosses the coast. In the third category the source of cold air is originated in West Siberia. During winter a large anticyclone may be stagnant over Western Siberia and Mongolia for many days. The maintenance of this stationary high pressure is related to the blocking over Urals. The air in this high cools through radiation. Gradually it becomes very cold and the surface pressure increases gradually up to a very high value. At last with the collapse of the Ural blocking this intensive cold high breaks out southward and leads to a severe cold weather in China. The fourth category is usually ill-defined. In the beginning there usually appears a wedge of high pressure behind a weak cold front over Ukraine. This wedge moves with the cold front into Asia and gradually develops into an anticyclone. Then the anticyclone turns southeastward across Mongolia and invades China. This type of cold wave generally takes place in connection with strong cyclogenesis over Mongolia.

Extratropical cyclones are also important winter weather systems over Asia. However, because of the confluence of upper currents (see § 1 b), over the continent, except Mongolia and Northeast China, cyclone very seldom develops. We have not seen over this part of the world any developed cyclone which can

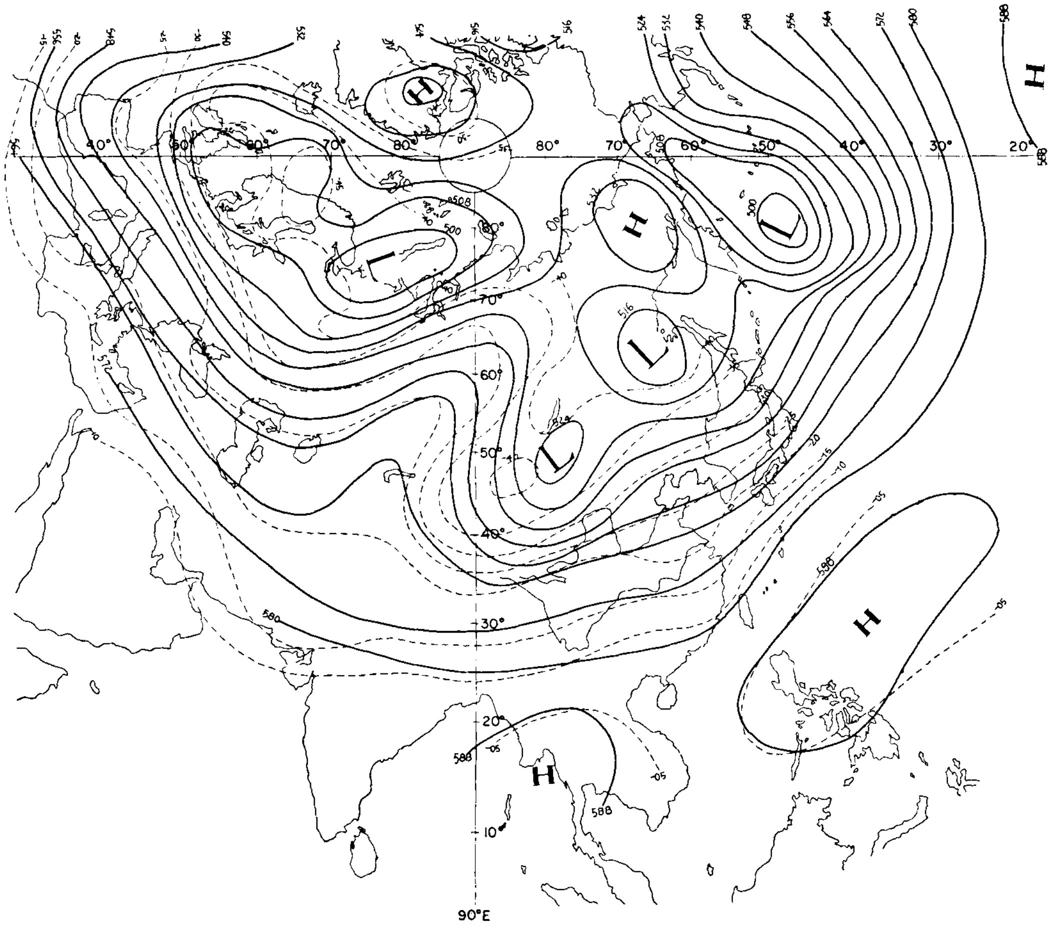

Fig. 15 b. 500-mb chart for February 17, 1955, 1500 Z. On the continent the short-wave trough continued to move eastward and deepened rapidly. The original longwave trough has approached Aleutian Islands.

be compared with those intense cyclones usually observed over North America. The process of cyclone development over the northern part is different from that over the southern part of Eastern Asia. In Mongolia and Northeast China it is a process of development of secondary cyclones. The cyclones over West Siberia from the west are usually old occluded systems and their intensity decreases as moving eastward (fig. 16 a). But when they reach Lake Baikal a secondary cyclone may form near the occlusion point or in retarding part of the cold front. Fig. 16 b will serve as an example of the cyclone development at this stage. This newly formed cyclone usually deepens rapidly as it move eastward. At the same time the mother cyclone to the north very quickly fills. The cyclone reaches its top development when arriving at Northeast China (fig. 16 c). As it moves further eastward it gradually fills and feeds in the Aleutian center of action. The frequency of this type of cyclone is maximum and the intensity also highest in spring. In autumn there is a secondary maximum.

There are two types of cyclogenesis over the Lower Yangtze Valley and the adjacent seas. The first type occurs on cold fronts. When the cold front associated with a cold wave arrives at the Yellow Sea or the East China Sea, it decelerates rapidly. On the decelerated part of the cold front disturbances usually develop. This type of cyclogenesis is similar to the A type of cyclogenesis along the American east

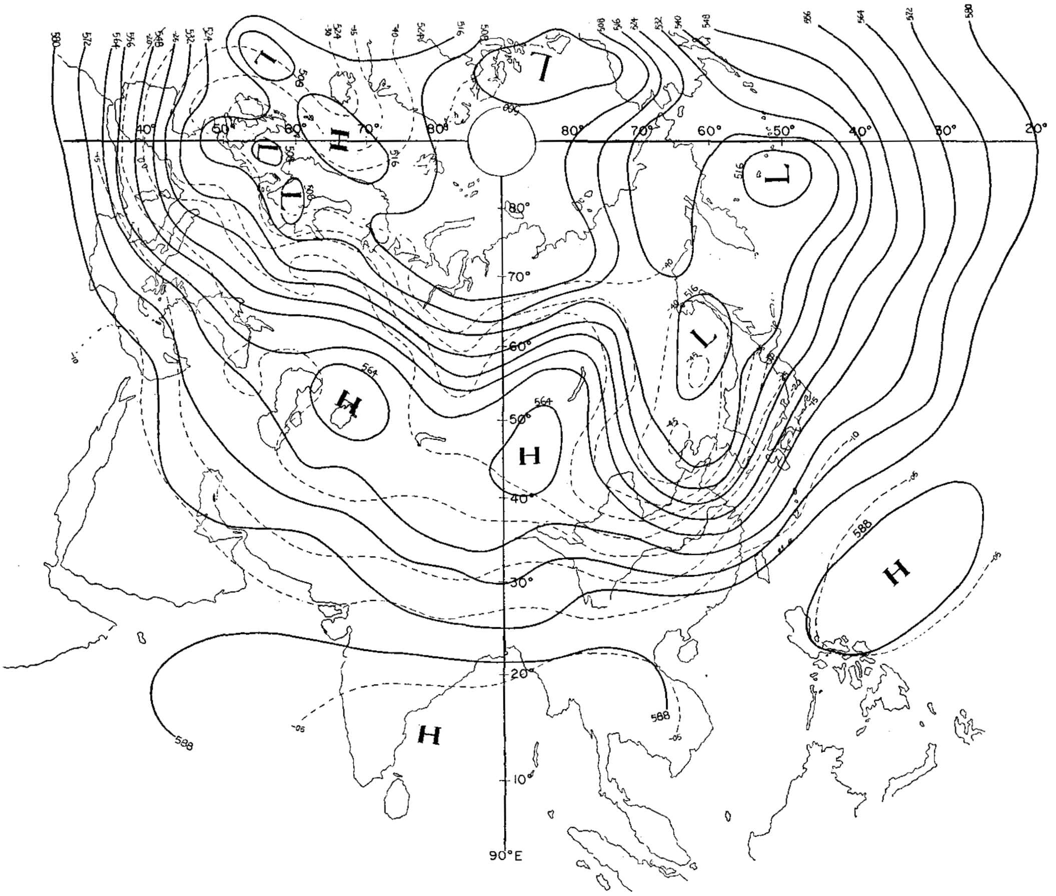

Fig. 15 c. 500-mb chart for February 19, 1955, 1500 Z. The short-wave trough developed to a major trough along the coast, while the original long-wave trough turned into a minor system in the region of Aleutian Islands.

coast described by MILLER (1946). The other type of cyclogenesis is associated with the upper trough coming from the Tibetan Plateau. This upper trough generally fills as it moves eastward. But if there appears strong warm advection in the lower troposphere as the upper trough arrives at the coast, then appears cyclogenesis. On the continent this type of cyclone is in its initial stage, it may only develop over the sea. Figs. 17 a—b illustrate the formation and development of this type of cyclone.

Long wave troughs very seldom come from the west to Eastern Asia. All the major troughs over this continent are developed from minor troughs. There are several kinds of minor troughs moving over East Asia from the west. The first invades East Asia from NW to the rear of the trough where continuous supply of cold air facilitates its development. In winter and the transitional seasons almost all the severe cold air outbreaks and the cyclogenesis over Mongolia are associated with this kind of upper troughs. The second kind of upper minor troughs move to China from the west through the Plateau. The third is the upper disturbance in the jet stream south of the Tibetan Plateau. It may cross Indo-Pakistan to arrive at China. All upper troughs of the second and third types show filling as they move eastward. They are generally very weak when they arrive at China. Thus, they are very indistinct on the surface chart, but they have definite weather with them. Besides, during the period of fairly zonal

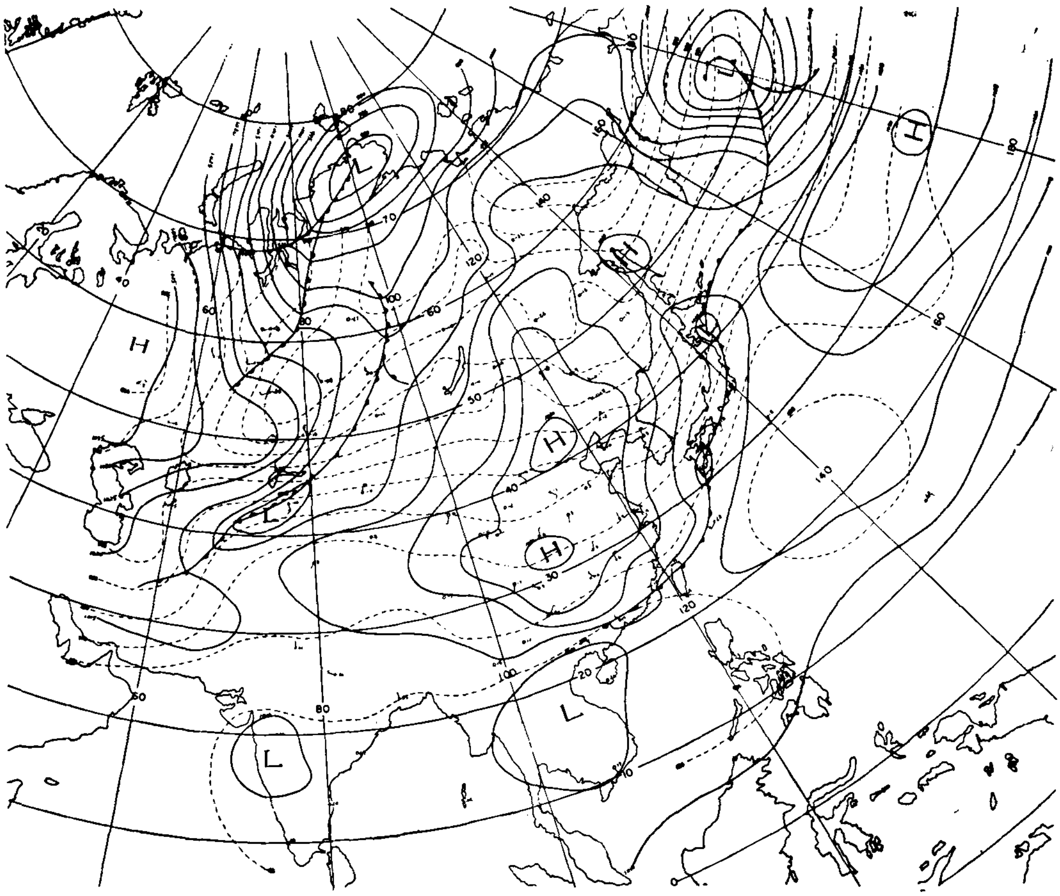

Fig. 16 a. Surface chart for March 18, 1957, 1800 Z, with 500-mb contours (dashed lines) at 1500 Z superimposed. Note that an old occluded front has moved into Western Siberia from Europe.

circulation minor troughs usually form over Sinkiang and move eastward.

Over the SW mountainous region (just to east of the Tibetan Plateau) there usually form small vortices in the lower troposphere (below 700 mb). The vortex in fig. 18 is an example. These small vortices have definite contributions to the bad weather in SW China. Sometimes the bad weather associated with these small vortices may extend to central China. These vortices are different from the cut-off lows in North America. They are much smaller in size.

b) Summer situation

In summer the westerlies retreat to the north of the Yellow River. Over south China the SW monsoon prevails while along the east coast the SE monsoon appears. According to the form and position of the boundary between the westerlies and the SE or SW monsoons, a great variety of flow patterns may appear over this continent. But there are still well-defined and important weather systems, though many are feeble and complicated. The first is the west Pacific subtropical ridge which frequently extends to the continent (fig. 19). Its dominance leads to severe hot and dry weather. The retreat from and advance to the continent of the subtropical ridge is closely related to the middle latitude westerly circulation. During a high circulation index period the west Pacific subtropical ridge is strong and its position does not vary much. In this period the small dis-

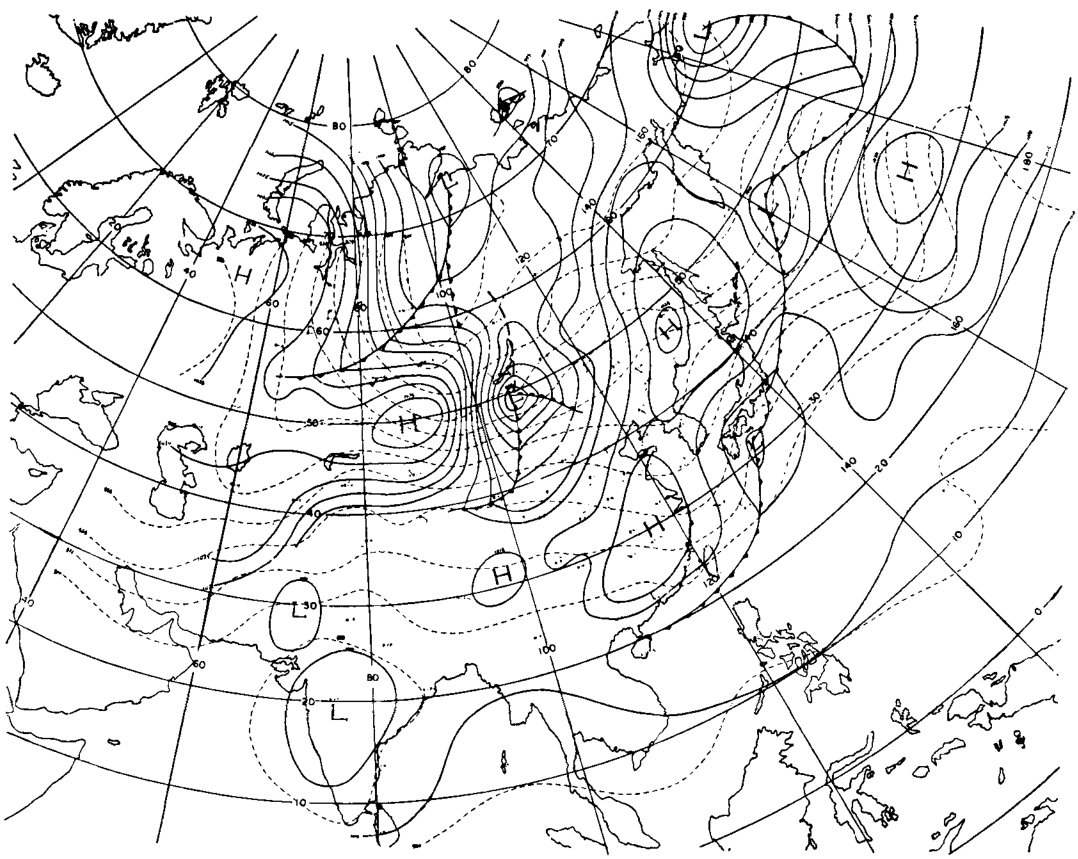

Fig. 16 b. Surface chart for March 20, 1957, 1800 Z, with 500-mb contours (dashed lines) at 1500 Z supermiposed. Note that to the south-east of Lake Baikal a depression has formed, while the old occlusion has filled up rapidly.

turbances in the westerlies move eastward, these small disturbances lead to small oscillations of the position of the subtropical ridge. During a low circulation index period its inland intrusion is the least.

The typhoon is one of the main important weather systems in summer. The number of occurrence and intensity of typhoon has a close connection with the upper subtropical easterlies over the west Pacific and East Asia (see figs. 8a—e). When the easterlies over this part of the world establish earlier and the intensity is stronger than "normal" then typhoons will also occur earlier and the frequency is higher than "normal". The summer of 1953 was an example of early onset of the upper easterlies. In this year the number of typhoons invading the continent was higher than in other years and the first invasion occurred in the beginning of July 1954 was an example of a late onset of the upper easterlies. In this year the first occurrence of a typhoon was about one month later and the number of typhoons invading the continent was less. It may also be mentioned that the frequency of occurrence of strong[1] typhoons shows a more or less periodic variation. Fig. 20 shows the yearly number of typhoons over the NW Pacific in the period 1920—56. From this curve we see a periodic variation with a period of about 5 years. From the curve we

[1] "Strong" is defined by (1) the innermost close isobar is at least 993 mb and (2) the maximum wind is at least stronger than 8 Beaufort.

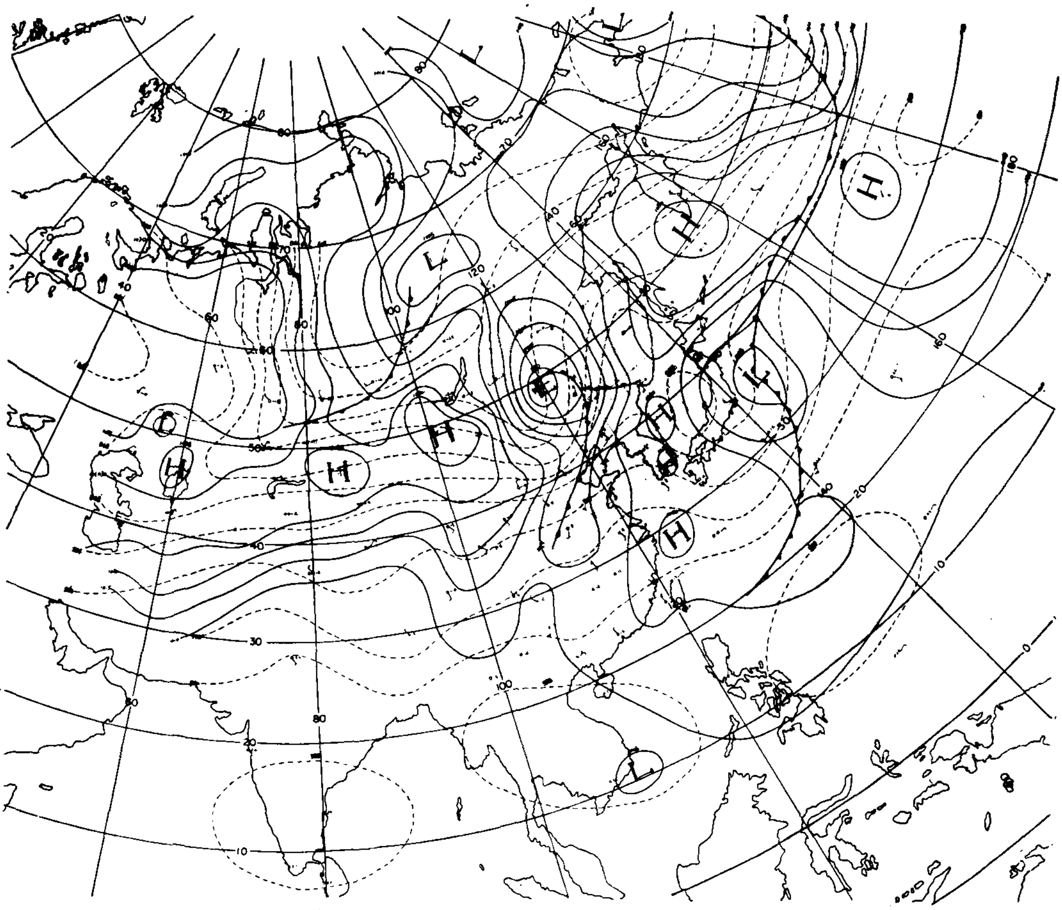

Fig. 16 c. Surface chart for March 21, 1957, 1800 Z, with 500-mb contours (dashed lines) at 1500 Z superimposed. *Note that the depression has moved eastward into North-East China.*

can also see that there is a strong decrease in the total yearly number of strong typhoons. The average yearly number in the period 1920—1956 is about 20. Before 1935 the yearly number was in general higher than 20 and after 1935 in general lower than 20.

Since the typhoon is an important dangerous weather system to China it is subject to wide studies, statistically and synoptically. It is found that the track and recurvature of a typhoon is closely connected to the circulation over a wide area. Unlike the hurricane, the typhoon usually has two recurvatures. In the first recurvature the track changes from SE-NW to N and in the second recurvature it turns to NE. Thus the track is different from an ideal parabola. The first recurvature usually occurs when the trough over Bering Sea deepens. Fig. 21 is an example of this type of track. The movement of typhoons was also studied theoretically by Hsieh and Chen (1956).

The third weather system in summer we shall mention is the cold front which comes from NW. Under favorable conditions it may reach as far as south of Yangtze River and lead to a rather cold weather in summer. In NW China its occurrence is rather frequent. Most of the thunderstorm and hail damage in China is in summer associated with this front.

To conclude this section we may add a few words about the intertropical convergence zone. Over the continent is in summer a huge heat low which occupies almost whole India and China. If, during this period, the west

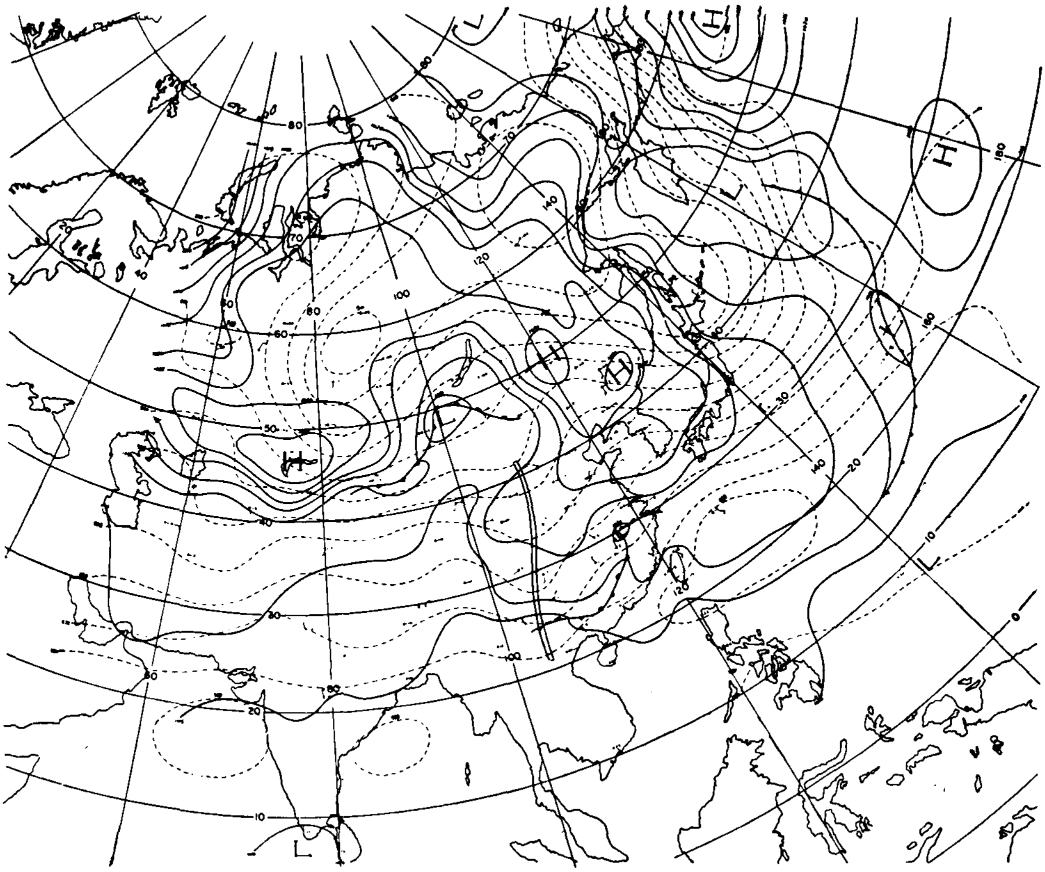

Fig. 17 a. Surface chart for February 1, 1957, 1800 Z, with 500-mb contours (dashed lines) at 1500 Z superimposed. Double heavy lines represent the current trough position on 500-mb level, while double dashed lines trough position 24 hour before. Note that there is cyclogenesis in the Lower Yangtze.

Pacific subtropical anticyclone reaches Japan and the Yellow Sea (35° N), then there will be convergence between the subtropical easterlies and the SW monsoon. Fig. 22 is an example of this convergence line (see also fig. 4). It is warmer north of the convergence zone and cooler to the south of it. Thus the baroclinity is reversed to the normal. The structure of this convergence zone over China is quite similar to that over India (HSIEH, 1951, SAWYER, 1947).

4. *The influence of the Tibetan Plateau on the circulation over the Far East and the Weather over China*

The Tibetan Plateau has roughly the shape of an ellipsoid. Its major axis is over 3,000 km long and its minor axis over 1,400 km. Connected with the adjacent Plateau, the Sinkiang-Mongolian Plateau, their width can be compared with that of the westerlies and their extension can be compared with the wave length of long wave. Its average height is over 4 km, occupying more than $^1/_3$ of the troposphere. Such a huge intrusion in the westerlies will no doubt have a profound dynamic influence on the general circulation. Considering it as a radiating body well high in the atmosphere it will also have a thermal influence on the circulation. In the following are some concrete dynamic influences of the Tibetan Plateau on the circulation over the Far East and the weather over China.

a) The dynamic effect of the Tibetan Plateau

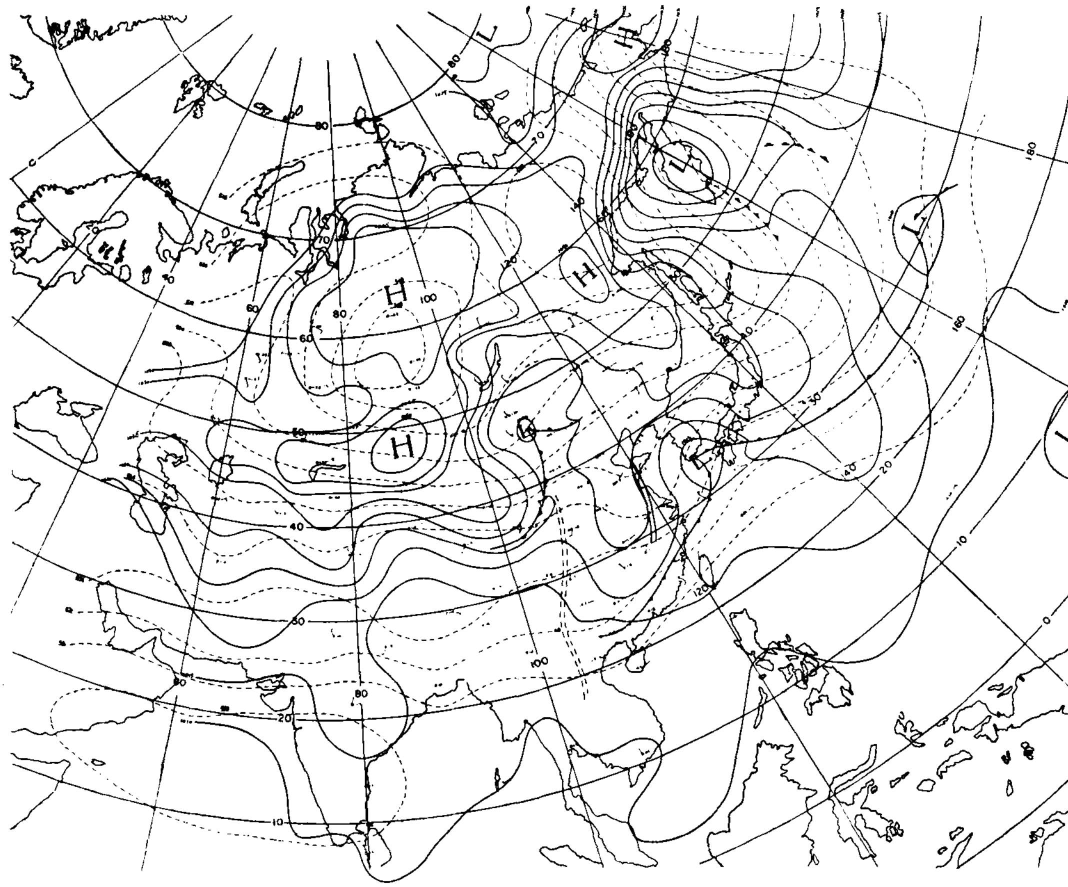

Fig. 17 b. Surface chart for February 2, 1957, 1800 Z, with 500-mb contours (dashed lines) superimposed. The depression formed in the Lower Yangtze has deepened and moved into Yellow Sea.

(i) Splitting and confluencing of the westerlies

The Tibetan Plateau is roughly of ellipsoidal shape with a major axis oriented in W—E direction. This will split the westerlies and force them to flow around it. The splitting of the westerlies is very pronounced on daily 500 mb chart. Due to the fact that in a rotating fluid the motion has a strong tendency to be quasi-two-dimensional (provided that the poleward temperature gradient is not large enough, which is usually the case in the atmosphere) the splitting is also observed well high above the Plateau. Fig. 23 is a typical example of a 500 mb map. On this map there are two branches of the westerlies, one flow to the north and the other to the south of the Plateau. As the two branches encircle around the Plateau a trough is dynamically formed in the southern branch and a ridge dynamically formed in northern branch. Both of them are clearly shown in fig. 23. The warm advection in front of this trough is very important for the weather over the eastern part of the Plateau.

In each branch of the westerlies there is a jet stream as discussed in previous sections.

The southern jet is very steady, not only in its daily position, but also in the average yearly position. The steadiness of this jet has a pronounced influence on the rainfall distribution over China. This is easily explained, since disturbances carrying rain are steered by the upper current.

From the facts that the axis of the southern

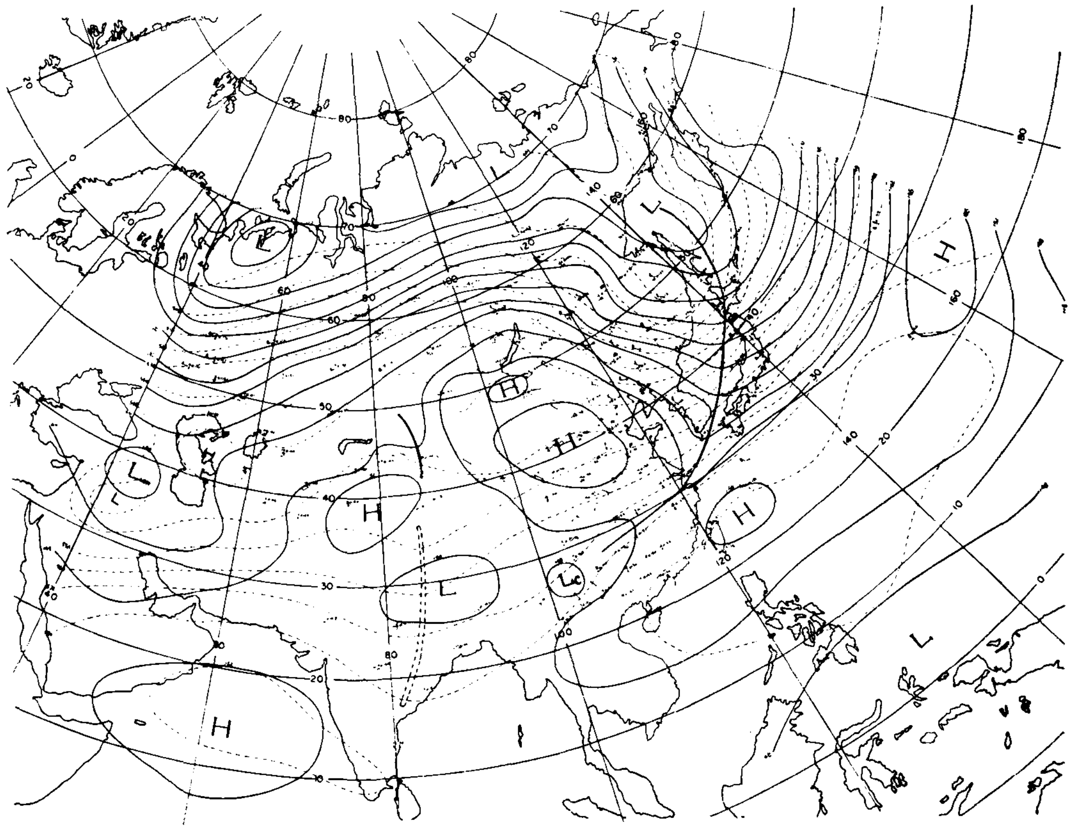

Fig. 18. 850-mb chart for January 11, 1957, 1500 Z, with 500-mb contours (dashed lines) superimposed. Notice that in South-West China there exists a small cyclonic circulation (SW-vortex) marked by Lc.

jet is just along the southern periphery of the Tibetan Plateau and once formed, it is very steady in position, we may conclude that this jet is at least anchored by the Tibetan Plateau. It is also very possible that its very formation is a dynamical result of the Plateau.

In fig. 3 we see a shear line (see I § 1 a). The formation of this line may be attributed to the Tibetan Plateau. On this shear line small vortices are very frequently formed (fig. 18). These vortices are called "SW vortices". They are not immovable. But once they move downstream, they usually dissipate. Only under special circumstances they may develop.

The convergence in the lee of the Plateau has a profound influence on the weather development over China. It hinders the development of cyclones over most part of Eastern China. This explains that once the above mentioned vortices move downstream they dissipate. Only over NE China which is out of the convergence zone cyclones may have pronounced development.

(ii) The damping effect on the large eastward moving troughs

The Tibetan Plateau has the effect to cut the large eastward moving troughs into two sections. The southern part is left to the west of the Plateau. It gradually dissipates there or it may sometimes cross Pamir to reach the Indo-subcontinent and then move downstream in the southern branch of the westerlies. The northern part of the mother trough keeps on shifting eastward but with decreasing intensity. It has a chance to redevelop only after reaching Lake Baikal. To illustrate this process we have prepared figs. 24 a—b. In fig. 24 a we see that a large trough (marked AA) to the east of the

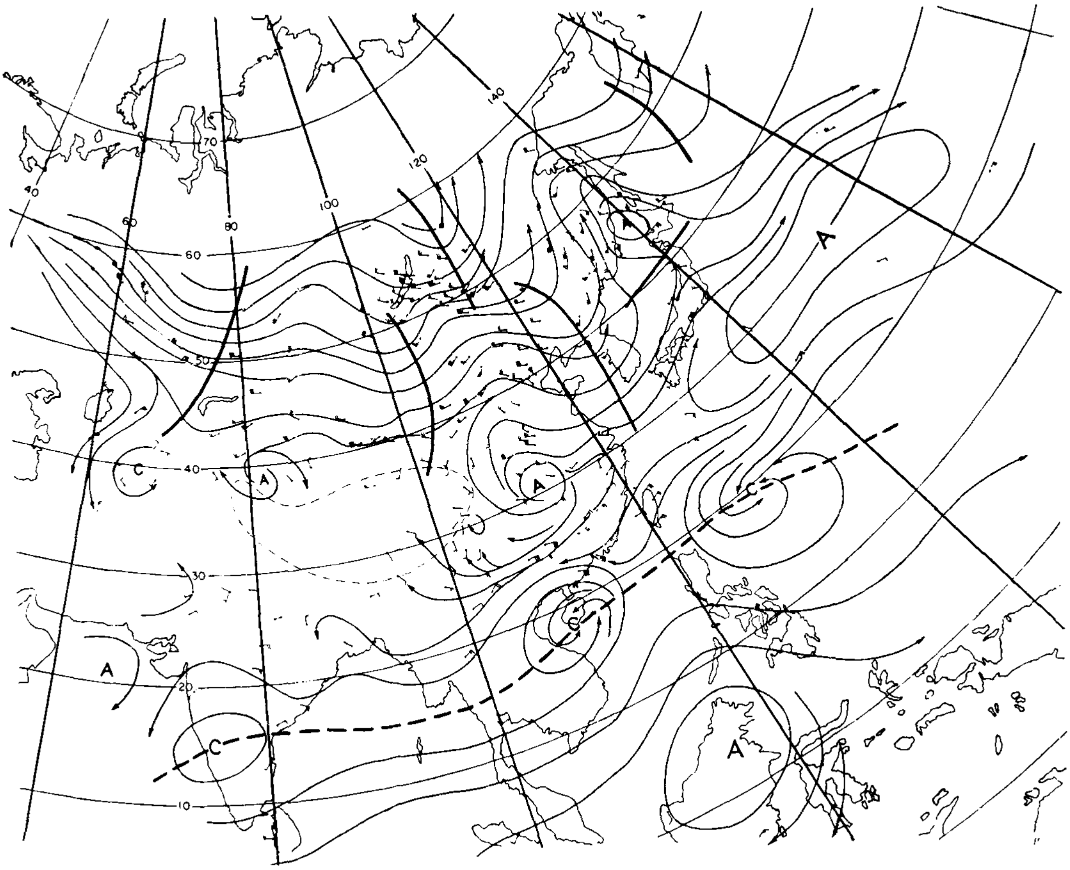

Fig. 19. Streamlines at 3 km for August 31, 1956, 0300 Z, typical flow pattern when subtropical ridge extends to the continent.

Plateau is in the process of breaking. Two days later (fig. 24 b) the northern section moves eastward with decreased intensity while the southern part is left on the original place. It is also frequently observed that as a large trough approaches the Plateau they weaken very rapidly. The southern part of the trough dissipates and only the northern part can be traced eastward.

It must be pointed out, however, that during a period with a zonal current disturbances of small amplitudes may cross over the Plateau.

(iii) The shelter effect

Due to the shelter effect of the Plateau there is a region, the so-called "dead water", in which the wind is weak in the lower layer and major disturbances are almost absent. There are only "SW-vortices" and sometimes minor

Fig. 20. Number of typhoons per year over NW Pacific.

waves. In winter there is very often a thin layer of cold air in this region. This layer of cold air has a definite influence on the weather in SW China. Fig. 25 is an example of a mean sounding for a winter month over Hsinching which illustrates the thermal structure of the atmosphere in the "dead water" region. In this mean sounding an inversion is very pronounced. Its mean intensity reaches 8° C.

To illustrate further the shelter effect we have further computed the distribution of the average west wind speed on the 3 km level in the winter months. Over the region of "dead water" the speed is smallest, even east wind appears. It is interesting to note that there is a symmetrical region of "dead water" to the west of the Plateau.

b) The seasonal variation of the influence on the circulation

All the phenomena discussed above belong to winter situations. In summer the Tibetan Plateau is no longer in the main part of the

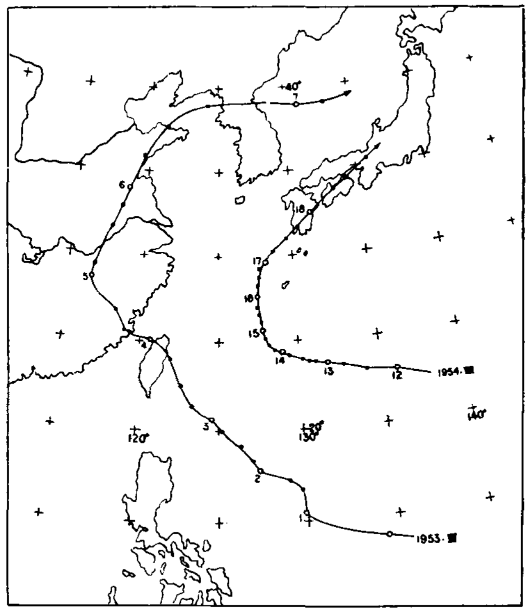

Fig. 21. Examples of the square-headed track of typhoon.

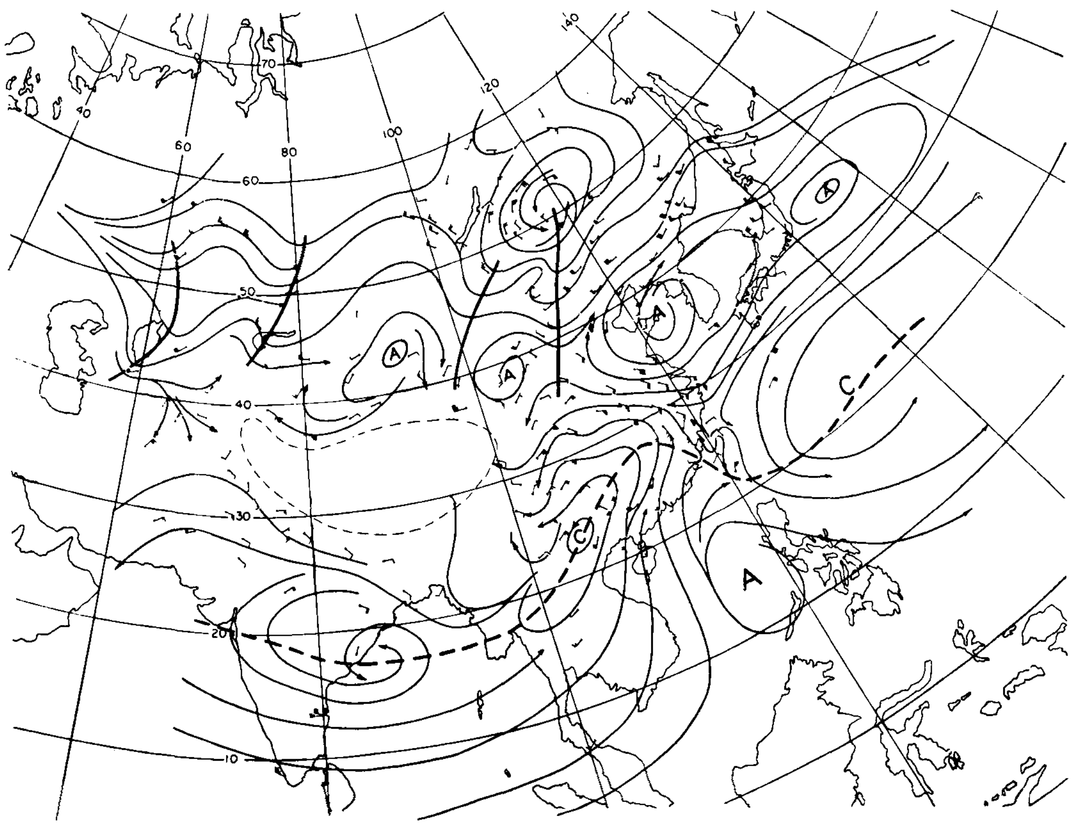

Fig. 22. Streamlines at 3 km for July 29, 1956, 1500 Z, illustrating a monsoon convergence over China.

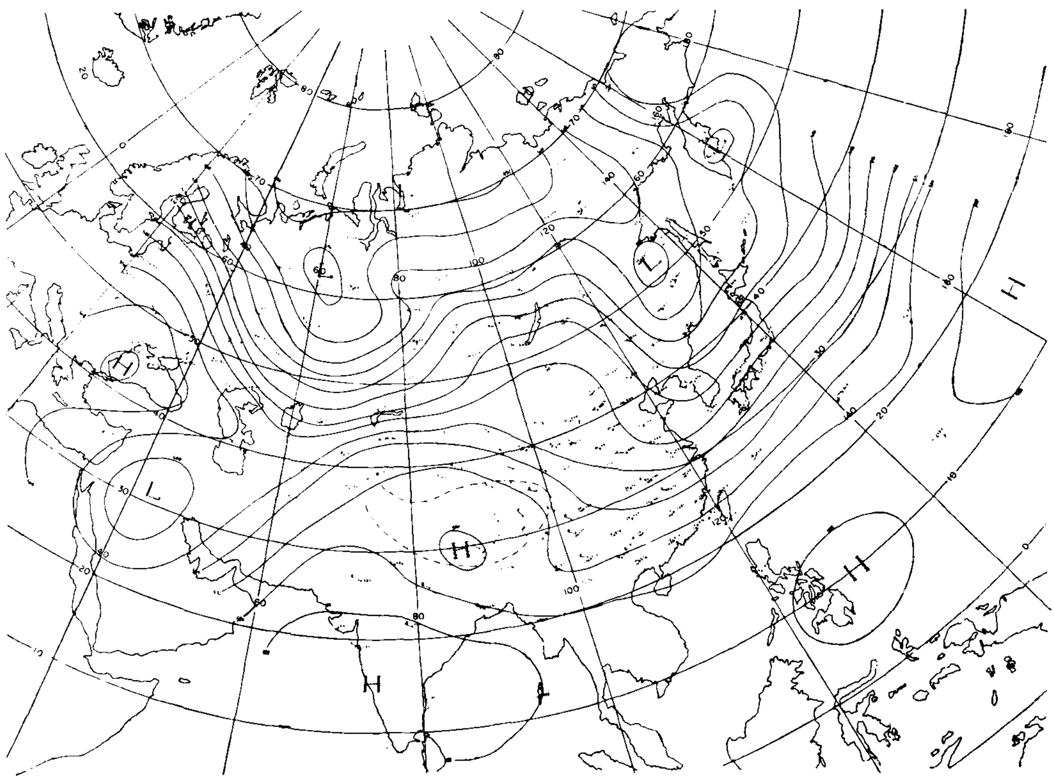

Fig. 23. 500-mb chart for January 22, 1957, 1500 Z. Note that over Tibet the westerlies split into two branches.

westerlies and the situation is entirely different from that of the winter. One striking phenomenon in the summer cases is that in the main (fig. 5) the wind blows cyclonically around the Plateau on the 3 km level, while on 6 km (fig. 2 b), there is a huge anticyclone with its center over the SE corner of the Plateau. On 9 km (figure not reproduced) the center is shifted westward. This indicates that the temperature over the Plateau is higher than the surrounding free air.

From the mean monthly upper air charts one may reach the conclusion that the above anticyclone is nothing but a subtropical high. However, from the distribution of mean vertical motion on 6 km (fig. 2 b) we find that almost over the entire anticyclone there is upward motion with an average speed about 1.00 cm/sec. This upward motion may be estimated to reach as high as 9 km. This is just opposite to the dynamic requirement of a dynamic anticyclone. This indicates that the thermal influence of the Plateau (which will be discussed in a later section) on the formation of this anticyclone is important; at least it helps to form a closed center in the subtropical ridge belt.

In figs. 4—5 we see a low over Indo-Pakistan. This is formed in the following way. As the SW monsoon advances NE-ward, it is forced to turn around by the Arakan Mountain and the Tibetan Plateau resulting an easterly current just south of Himalaya. Thus, the so-called Indian heat low is at least not of purely thermal origin.

From above we may notice that the dynamic influence of the Plateau on the circulation has a very large seasonal variation. This is in contrast to the viewpoint that topographical influence on the circulation does not vary seasonally since topography is a fixed feature in space. The dynamic effect of a mountain

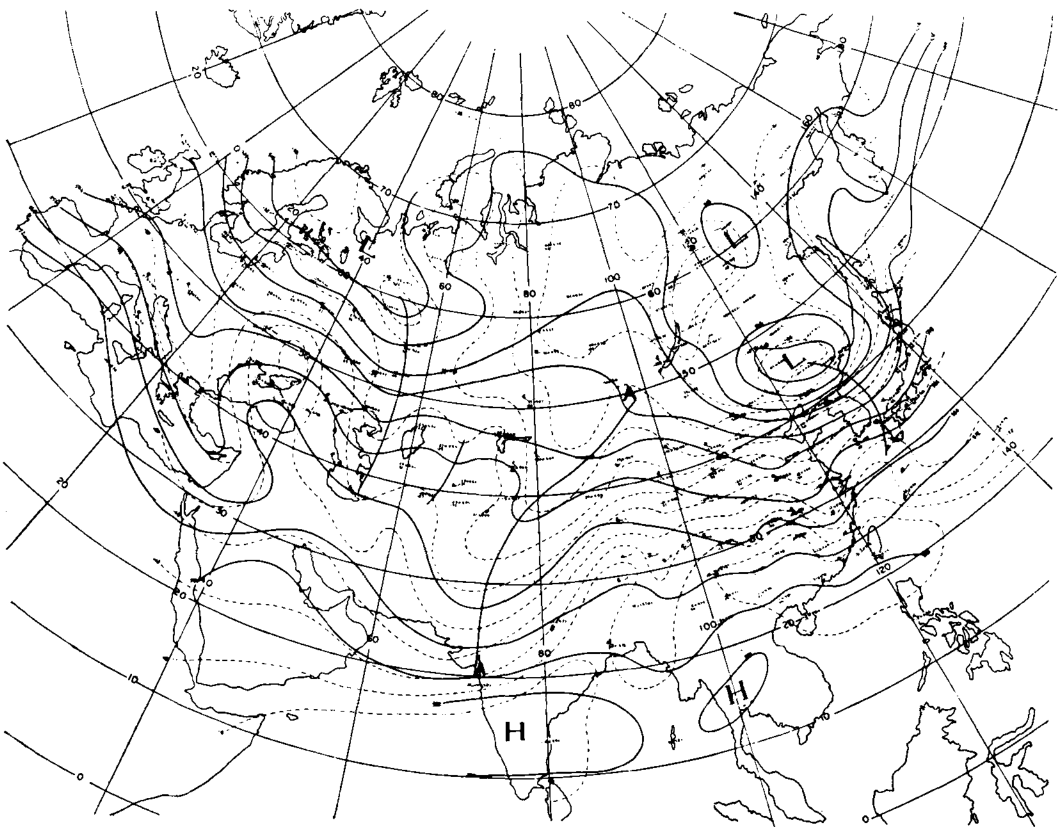

Fig. 24 a. 500-mb chart for February 9, 1957, 1500 Z. Note the long-wave trough AA in the early stage of cut-off.

is closely associated with the current which flows over or around it. Since the current which strikes the Plateau varies seasonally the dynamic effect of the plateau will vary accordingly.

c) The Tibetan Plateau, a warm source or a cold source?

Some meteorologists determine a mountain as a warm or a cold source by comparing the temperature over mountain with the surrounding free air of the same height and latitude. However, temperature is not a proper indicator for this purpose. A region with high (of low) air temperature does not necessarily mean a warm (or a cold) source, because high or low temperature may be produced in several ways, for example by advection, vertical motion, radiation, etc. A warm source must constantly supply heat to the air while a cold source must constantly withdraw heat from the air. In order to keep a quasi-steady state over a warm (or a cold) source the air must be cooled (or warmed) by some other means as by upward (or downward) motion or cold (or warm) advection. Under this definition we have examined whether the Tibetan Plateau is a warm or a cold source.

First we have calculated the short-wave absorption and long-wave cooling between 700 and 500 mb over China. From the calculations over the limited number of upper air stations over the Plateau we may give the following estimate: The average long-wave cooling is about $-1.6°$ C/day in summer as well as in winter. The short-wave absorption is about $0.6°$ C/day in summer and $0.2°$ C/day in winter. Thus, the net radiation cooling is about $-1.4°$ C/day in winter and $-1.0°$ C/day in summer.

Secondly, from the monthly precipitation we have computed the condensation heating. Because the cloud thickness is on the average

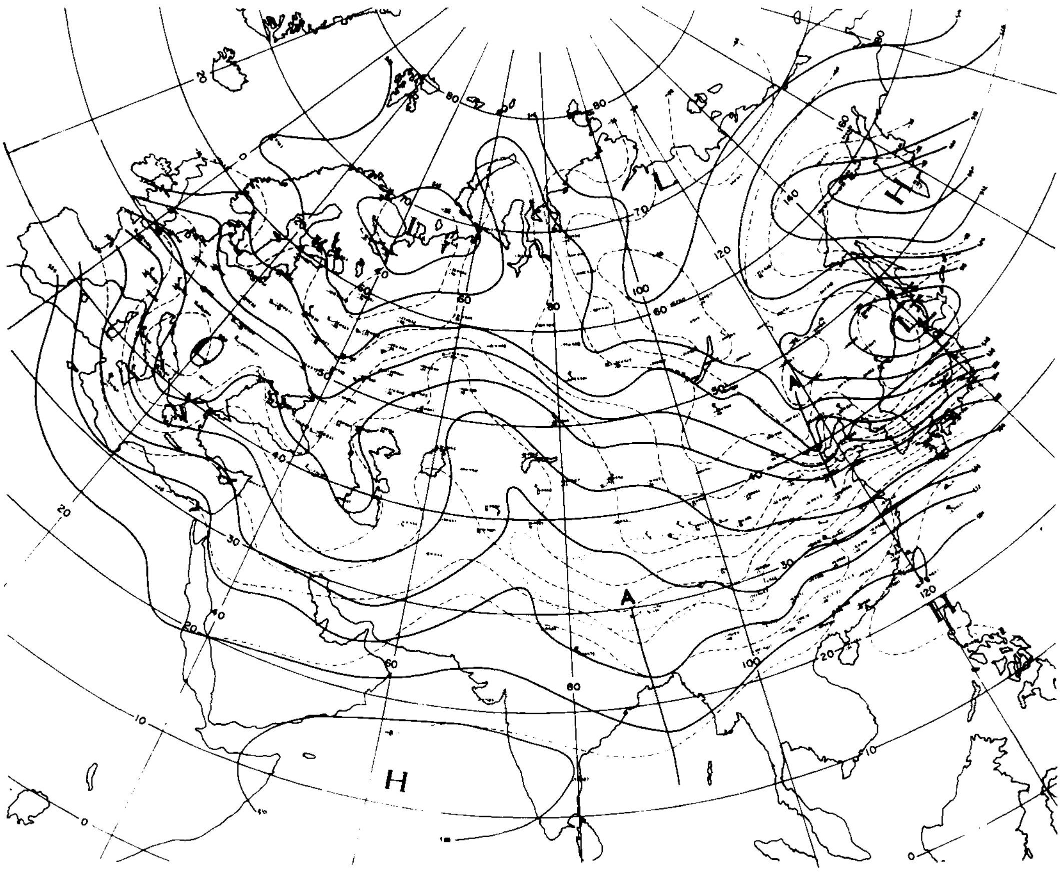

Fig. 24 b. 500-mb chart for February 11, 1957, 1500 Z. The cut-off is complete; the northern part of the trough AA has moved to North China, the southern part has moved eastward along the southern periphery of Tibet.

below 1,500 m and the condensation level is below 1,000 m above the ground over Tibet we may assume that the heat of condensation is totally absorbed by the air with 200 mb thickness above the Plateau. The average monthly precipitation in summer on the Plateau is estimated to be about 60 mm. Thus, the condensation heating is about 2° C/day. In winter the precipitation is very small over the Plateau, the condensation heating may thus be neglected.

From the above the balance between radiational cooling and condensation heating is seen to be + 1.0° C/day in summer and — 1.4° C/day in winter.

We shall first discuss the heat balance over the Plateau in summer. We have seen that over the Plateau the average upward motion is about 1.0 cm/sec, giving an adiabatic cooling about —3.0—3.5° C/day and that the cold advection has been estimated to about—0.2° C/day. The sum of the two terms gives a total cooling about — 3.5° C/day. Together with the above calculated heating the air within the 200 mb thickness over the Plateau suffers a cooling about —2.5° C/day. This cooling must be balanced by some heat supply. From the distribution of the difference between soil and air temperature (chart not shown) it is seen that over the Plateau the soil temperature is on the average more than 5° C higher than that of the air (at 2 meters above ground). This gives a temperature lapse rate of 2.5×10^{-2} °C/cm. Thus, the air may obtain a large amount of heat from the ground through turbulence. Suppose that the heat obtained in this way is entirely absorbed by the air within the investigated 200 mb thickness and just

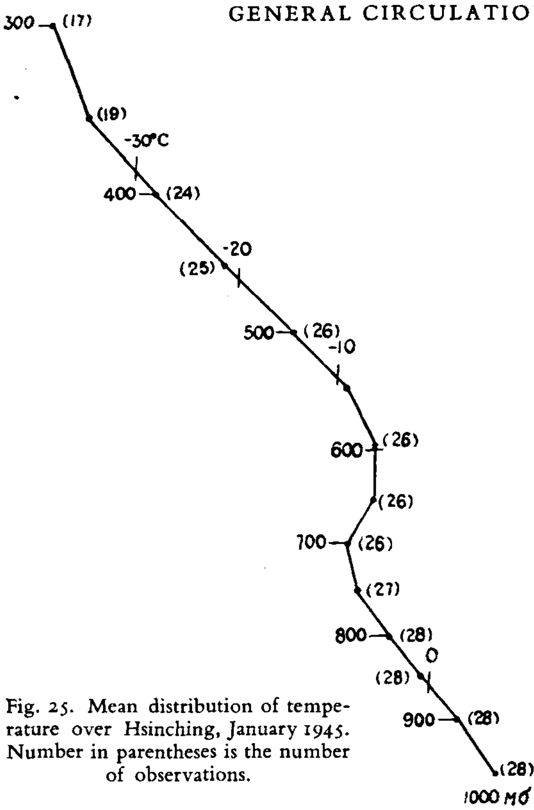

Fig. 25. Mean distribution of temperature over Hsinching, January 1945. Number in parentheses is the number of observations.

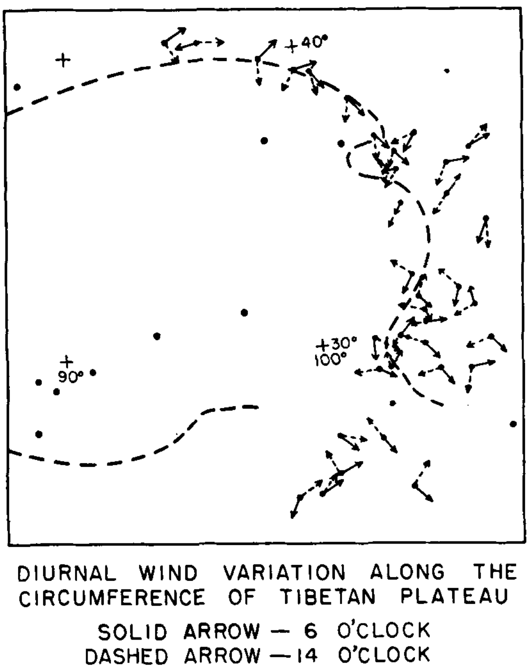

Fig. 26. Mean April diurnal wind variation along the circumference of Tibetan Plateau. Solid arrow: wind at 6 o'clock (L.T.), dashed arrow: wind at 14 o'clock (L.T.).

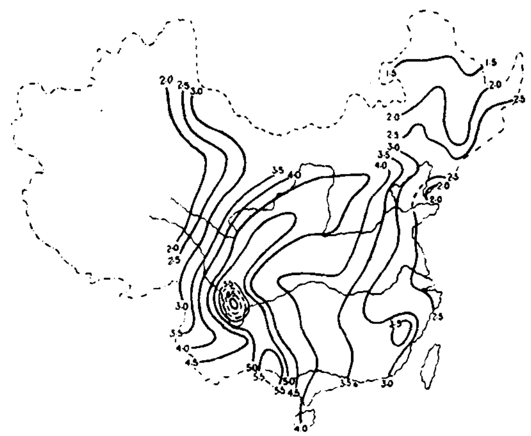

Fig. 27 a. Distribution of the mean amplitude of diurnal variation of pressure over China (April, 1952—53).

balances the cooling, then the average turbulent austausch coefficient near the ground would be about 250 cm^2 sec. This seems a little too small. This is because that in our computation the heat used for evaporation is left out. When this is considered the coefficient would be raised.

The situation for winter is complicated. It is different for different regions. For the SE Plateau, the net radiation is about $-1.4°$ C/day and the warm advection gives a warming about $+1.2°$ C/day. These two terms are about in balance. In this region we have upward motion of about 1.0 cm/sec in winter. This gives a cooling of about $-3.5°$ C/day. The heat of condensation is negligible here in winter. The cooling must be balanced from the heat obtained from the ground through turbulence. This requires that the soil temperature is higher than the air temperature. This is just what the observations show. On an average the soil temperature is about 1—2° C higher than that of the air in this region.

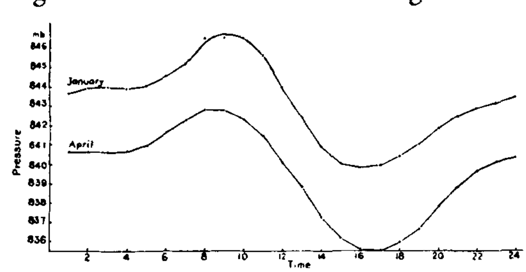

Fig. 27 b. Mean hourly pressure at Si-chang (January and April, 1952—53).

The situation for the rest of the region is difficult to estimate due to the lack of data. However, from the discussions about the vertical motion over the Plateau it seems that there exists a downward motion of about 0.5 cm/sec. Accepting this value, then the adiabatic heating due to this downward motion would over-balance the radiational cooling. Neglecting advection which is not known over this part of the world the Plateau would receive heat from the air, or at least the air would not obtain heat from the Plateau.

From the discussion above it may be concluded that the Plateau is a warm source in summer and its SE part also plays the role of a warm source in winter while the rest is most probably a cold source in winter.

Another thermal influence of the Tibetan Plateau is reflected in the daily wind variation. In the day time the Plateau is heated up much more rapidly than the surrounding free air. At night the Plateau cools much more rapidly than the surrounding free air. In accordance with this thermal variation we may expect that the wind will have a component toward the Plateau in day time and a component out from the Plateau at night. This effect even exists in winter. Fig. 26, the mean for April, is given as an illustration. In this figure the solid arrow is the resultant direction of the surface wind at 6 o'clock in the morning and the dashed arrow is that at 14 o'clock in the afternoon. This figure clearly shows the mentioned effect. A similar situation also exists clearly over Indo-Pakistan. Thus relative to the Plateau there is a convergence of wind in the afternoon and a divergence in the early morning. The order of convergence reaches 10^{-6}/sec which is quite a high value.

It is found that on the east slope of the Plateau the diurnal variation of pressure (fig. 27a) is very great, especially in spring when the diurnal variation of air temperature is largest. For example, the mean diurnal range of pressure variation over Sichang (27.9° N, 102.3° E, fig. 27b) is as large as 7 mb with an average maximum 3-hour tendency of 5 mb at 14^h (120° E.C.T.). This diurnal variation of pressure has only one maximum and one minimum and is just out of phase with the temperature wave. This character suggests a thermal origin of its formation, i.e. this very large diurnal variation of pressure may be related to the diurnal variation of the divergence field mentioned above.

To summarize, we may conclude that the Tibetan Plateau plays a very significant role in the circulation over Asia and the weather development over China. In the past when the influence of the earth's surface on the circulation was mentioned, it usually meant the thermal effect of land-and-sea distribution. This is only one part of the story. From the above discussion we see that the Plateau not only has a mechanical but also a thermal effect on the general circulation.

To be continued in a following issue of this journal.

THIS REPORT IS A SUMMARY OF THE FOLLOWING PAPERS:

CHAO JIH-PING, 1956: A preliminary study of the rhythm of the ultrapolar process over Eastern Asia, *Acta Meteor. Sinica*, **27**, 113—126 (in Chinese).

DAO SHIH-YEN, 1952: An analysis of the weather process during the period of cold air outbreak in China. *Synoptic Monthly*, **2**, 35—51 (in Chinese).

— 1952: An analysis of a major cold wave in November 1951. *Synoptic Monthly*, **2**, 37—46 (in Chinese).

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— 1955: An empirical study of the process of cold air outbreaks in Far East in winter-half year. 66 pp. Mimeograph (in Chinese).

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