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Formation of upper anticylones and their blocking activity during winter over Asia

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ABSTRACT. The results of the study of 65 cases of the formation of anticyclones in the upper westerlies over Asia and adjoining west Europe, their areas of occurrence and blocking activities, during the winter and transition season of November-April, are presented in this paper. It has also been shown with the help of a detailed case-study of 1-7 April 1969, that the anticyclones which formed over Iran and persisted for more than 5 days behave as blocking systems and dominate the circulation over Asia. These blocks are however weak when compared with Atlantic and Pacific cases but satisfy all the well known characteristics of blocking action.

1. Introduction

1.1. The development of blocking action over the Pacific and Atlantic oceans have been the subject of several investigations. Rex (1950) made a semi-statistical study of 112 cases of blocking action in the upper westerlies over these regions and their effects on the climate over Europe. A detailed study of blocking action in western Atlantic was also made by Miller and Venderman (1951). The effects of large blocking highs in the mid-Pacific and northeastern Atlantic areas on the general circulation in the Northern Hemisphere westerlies, have been studied by Elliot and Smith (1949). A case of the development of a cut-off high which developed into a major circulation system and dominated the conditions over western Europe, was investigated in detail by Berggren, Bolin and Rossby (1949).

1.2. We present the results of the study of 65 cases of the formation of anticyclones in the upper westerlies over Asia, their areas of most frequent occurrence and blocking activities, during the winter period November—April. The study has been made with the help of the hemispherical charts of the Northern Hemisphere Analysis Center (N. H. A. C.), New Delhi, for the period 1963-1969. The detailed study of a blocking high at a rather low latitude and which effected the circulation over India, is also included.

2. Development of anticyclones at 500 mb and their tracks

2.1. The daily weather maps of 500 mb were examined and cases of the development of the anticyclones in the westerlies, were compiled except for those which were formed with their centres north of 60°N and west of 40°E. The anticyclones with life periods less than 48 hours were excluded from the study. The cases with life periods of less than five days were grouped separately with those which persisted for five days and more. While the former generally did not show any blocking action, the latter were found to indicate it, as evidence by the development of persistent high pressure, retrograde movement, development of the train of low pressure systems and their obstructed eastward movement. The average of Atlantic and Pacific blocks was found by Rex (1950) as 14 and 12 days, respectively. The Asiatic blocks being weaker comparatively, the minimum life period of five days was, therefore, chosen for considering the blocking cases over the area.

2.2. It was found that during the six-year period of 1963-1969, there were 67 cases of anticyclone development at 500 mb during the period, November-April. 62 of these formed between 40-75°E and there were only five occasions when the anticyclones developed east of 75°E. Out of these five cases, on two occasions these were formed over Mongolia and on the remaining three occasions the development occurred over Sinkiang. The life periods of these cases were however less than 5 days.

2.3. In Fig. 1·1, we present the number of anticyclones which developed over the various 5 degree longitude belts between 40°E and 80°E and latitude 30°N and 60°N. As it was found that the anticyclones which formed with their centres

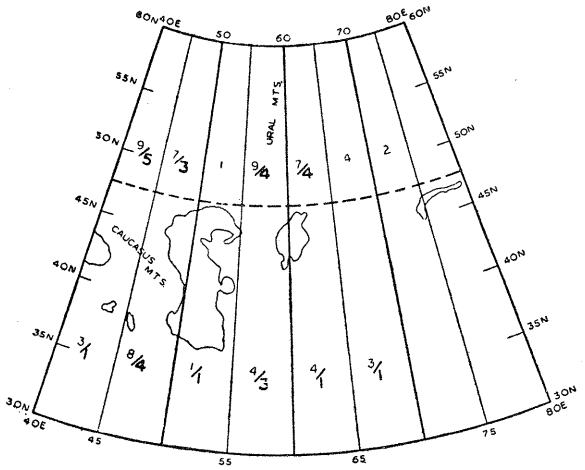

Fig. 1·1

Number of anticyclones developed over 5° longitude belts during Nov-Apr (1963-1969). Bold figures indicate number of anticyclones with life period 5 days and more

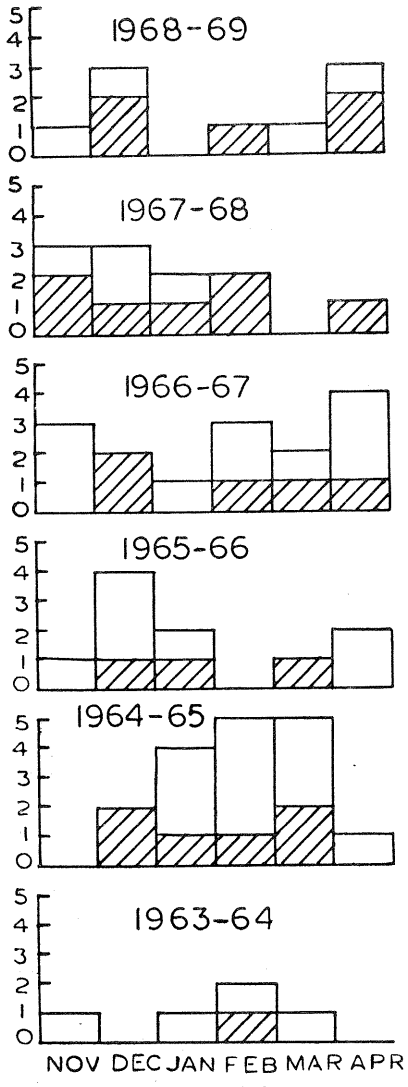

Fig. 1·2

Histograms showing the number of anticyclones formed during Nov-Apr (1963-1969). Hatched portion indicates number of anticyclones with life period 5 days and more

north of latitude 47-48°N, did not generally affect circulation over India, the area in Fig. 1·1 has been divided in two portions by the latitude line of 47·5°N which runs just north of the Caspian Sea. Elliot and Smith (1949) also divided blocking action in low-latitude and high latitude cases. They however, put the division line at 57·5°N and found that the frequency of high latitude class was higher than that of the low latitude class. Similar conclusion can be arrived from the cases studied by us. However, to find the places of maximum recurrence of the anticyclone formation in the area, we divided it further by 5° meridional lines. The total number of the recurrence of the first formation are indicated in small figures and the number of anticyclones which had life periods of 5 days and more are indicated in bold figures. It will be seen that maximum number of recurrence is found in the longitudes near Caucasus and Ural mountains. Between these two maxima, a sharp fall in the formation of anticyclones with their centres between 50-55°E is noticeable. During the cold season, the distinct frequency minima of anticyclogenesis over all major inland water bodies except those which are frozen, have been also pointed out by Petterssen (1956).

2.4. Monthly and yearly variations of the formation of anticyclones are illustrated in Fig. 1·2 by means of histograms showing the number of occasions of the formation of anticyclones in the upper westerlies over Asia (east of 40°E and south of 60°N). The total number of highs formed during winter varied from 5 to 17 and the highs with life periods of more than 5 days varied from 1 to 7. The year 1963-1964 was marked with a minimum anticyclogenesis followed with a maximum in 1964-1965. A second maximum of 15 was observed during 1966-1967. During the remaining three years the total number of occasions of high formation was between 9 and 11. The yearly variations, therefore, appear irregular. Similar results were found by Rex (1950) in the yearly variations of blocking activity in Atlantic and Pacific. We, however, did not find any resemblance in month to month variations also.

2.5. The tracks of the centres of the 26 anticyclones with life period of 5 days and more, are presented in Figures 2·1 and 2·2. Out of the 67 cases of anticyclone formation, which are presented in this study, 33 cases developed during the first three months of the winter and transition season and the remaining 34 cases developed during the latter half of the season. The tracks of 12 anticyclones which persisted for 5 days and more during the first half of the period, *viz.*, November-January are shown in Fig. 2·1

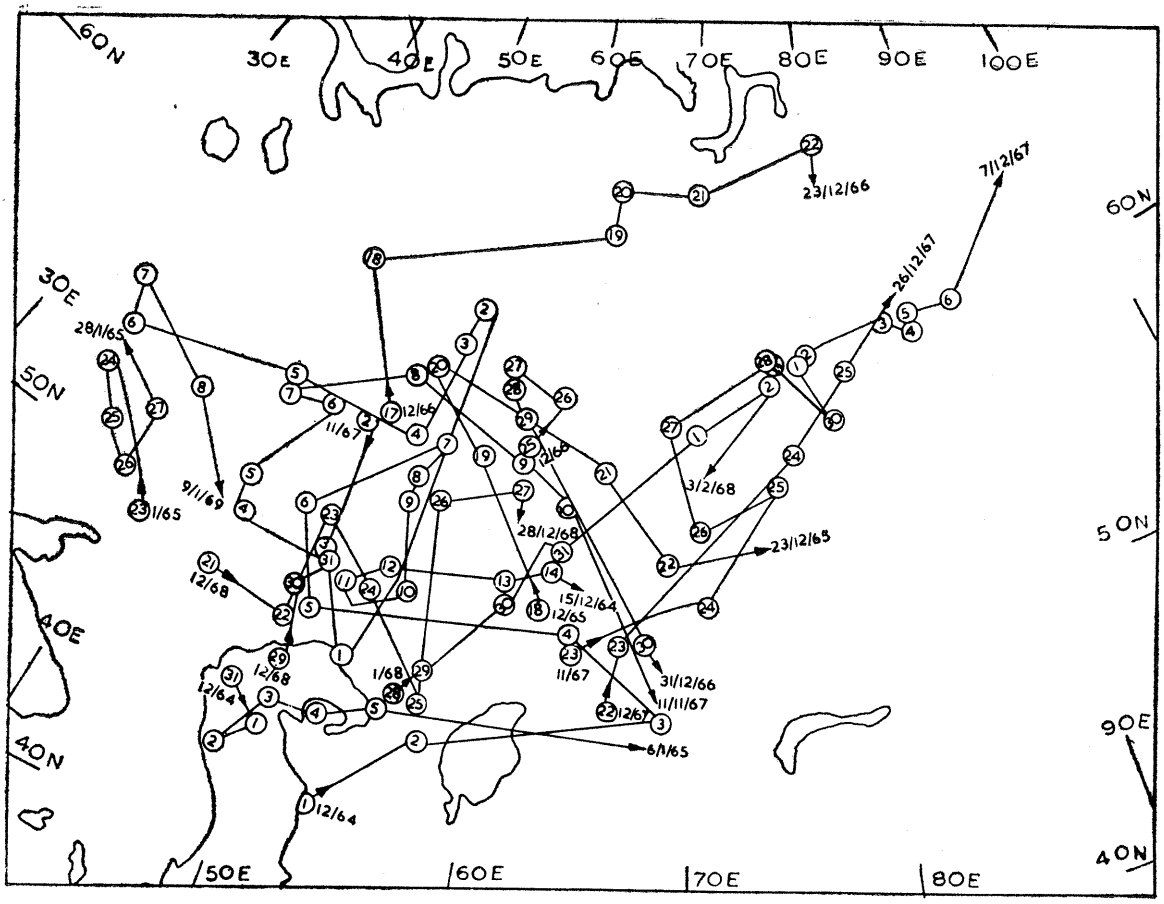

Fig. 2·1. Tracks of centres of anticyclones at 500 mb for the period Nov-Jan (1963-1969)

Similarly, the tracks of the blocking cases of February—April, are shown in Fig. 2·2. It is seen from these tracks that the initial movement of the anticyclone is generally slow and they show a tendency of shifting northward. In some of the cases initial southward shifting can be also noticed. The retrograde motion takes place during the first 3-4 days itself. The final movement is eastwards with average speed of about 7-10 degrees per day. Faster movements of about 12-15 degrees per day are also observed. In some cases, anticyclones were found to intensify even after a few days of their eastward motion. On such occasions the anticyclones became stationary or moved westward, during the intensification period, and later resumed their easterly track. As already stated in para 2·4, the year 1963-1964 was marked with minimum frequency of anticyclogenesis, and there was only one case of blocking high during the month of February 1964. It had the maximum life period of 21 days. On two other occasions, the blocking highs persisted for 2 weeks. In a large number of cases, the life period varied from 8 to 12 days. Another interesting feature which may be observed from Figures 2·1 and 2·2, is that the anticyclogenesis is mainly concentrated between 40-70°E. There is marked decrease as we go east of 70°E. A northward shift in the activity can be also noticed from Figs. 2·1 to 2·2.

3. The case of 2-7 April 1969

3.1. *Synoptic situation*

3.1.1. A recent case of the development of a high in upper westerlies over Iran was chosen for detailed study. It was formed at the southern most position of all the 27 cases which had life-period of five days and more. Its formation, blocking activity and retrograde motion, are illustrated with the help of 500 mb charts in Figs. 3·1 to 3·5.

3.1.2. The upper tropospheric flow pattern in the middle latitudes over Asia, was predominantly zonal during the last week of March 1969. A low

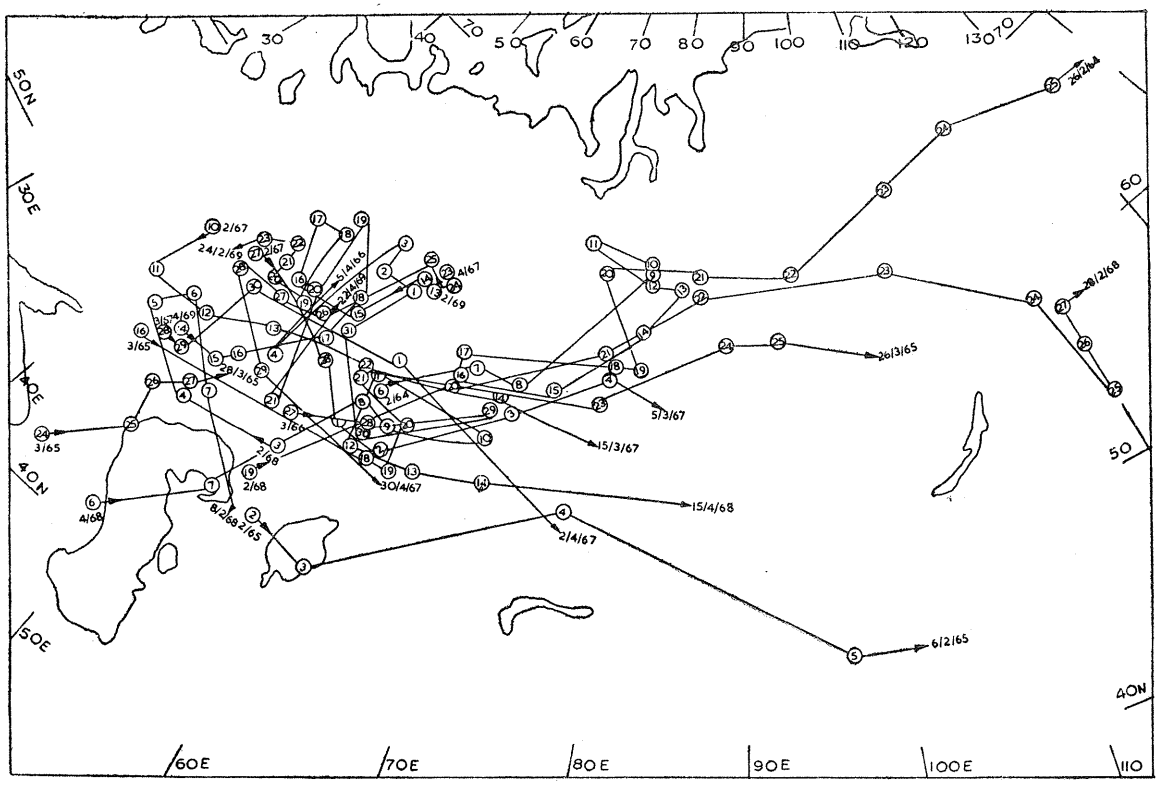

Fig. 2.2. Tracks of centres of anticyclones at 500 mb for the period Feb-Apr (1963-1969)

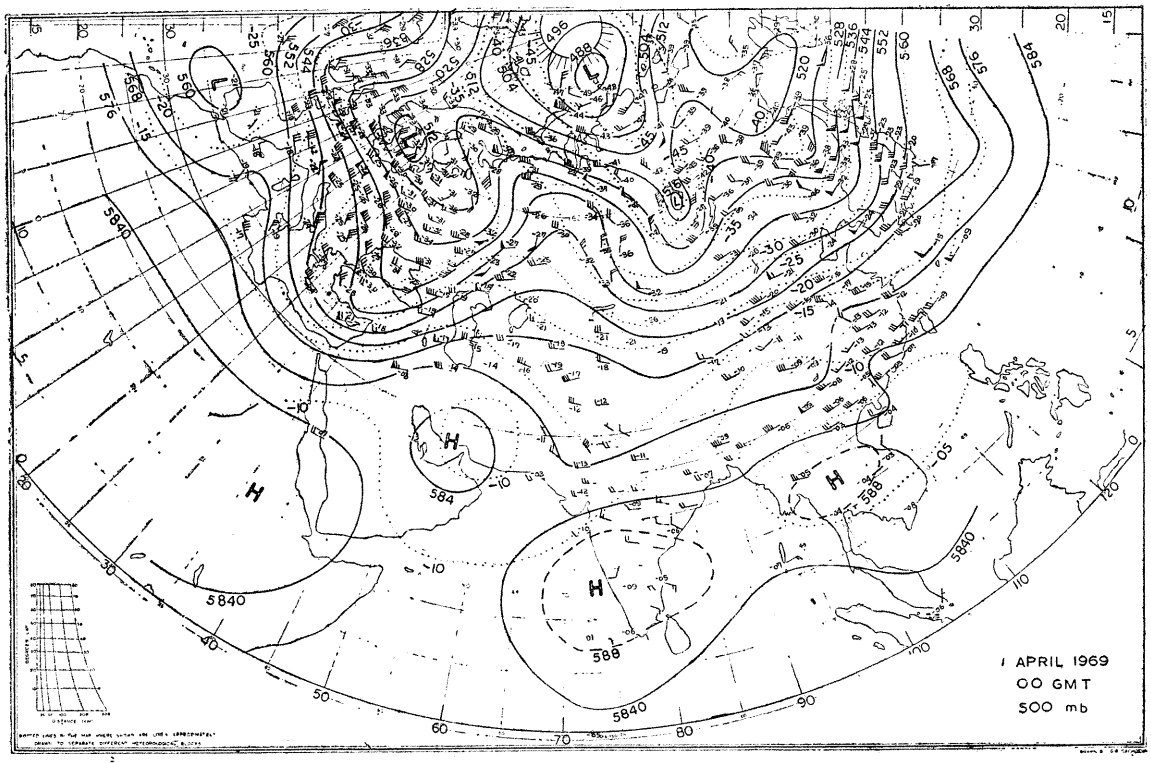

Fig. 3.1

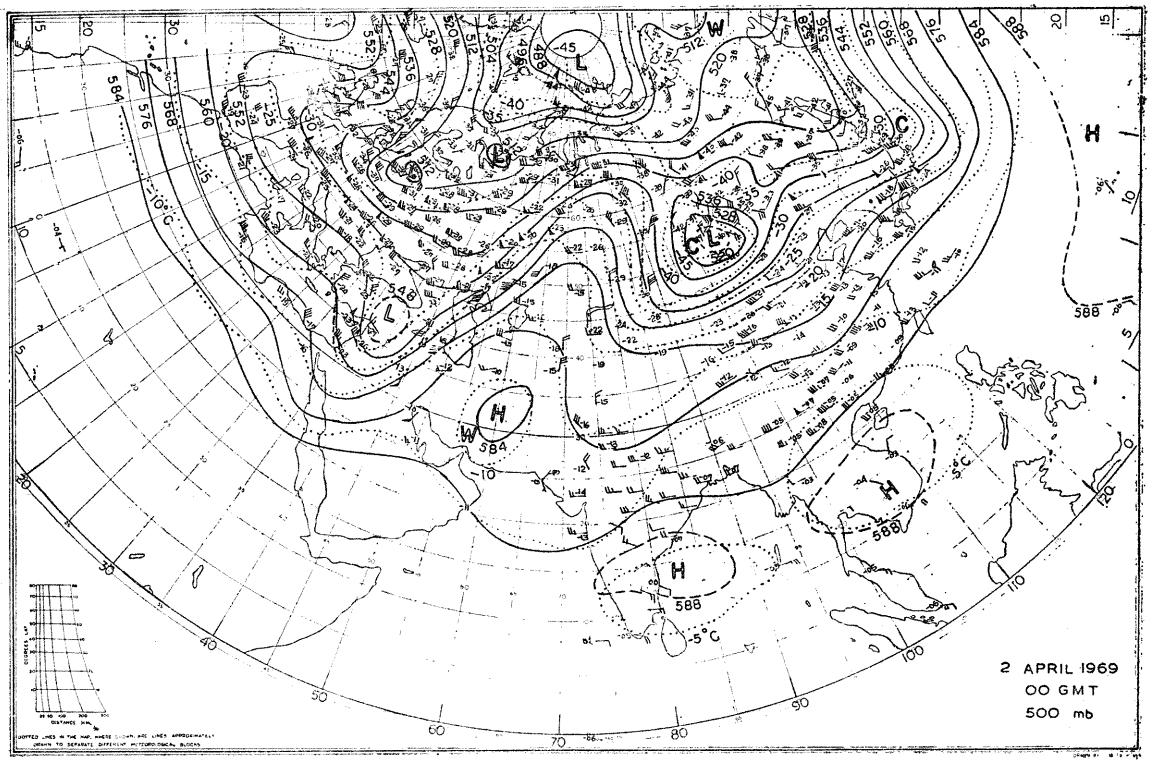

Fig. 3.2

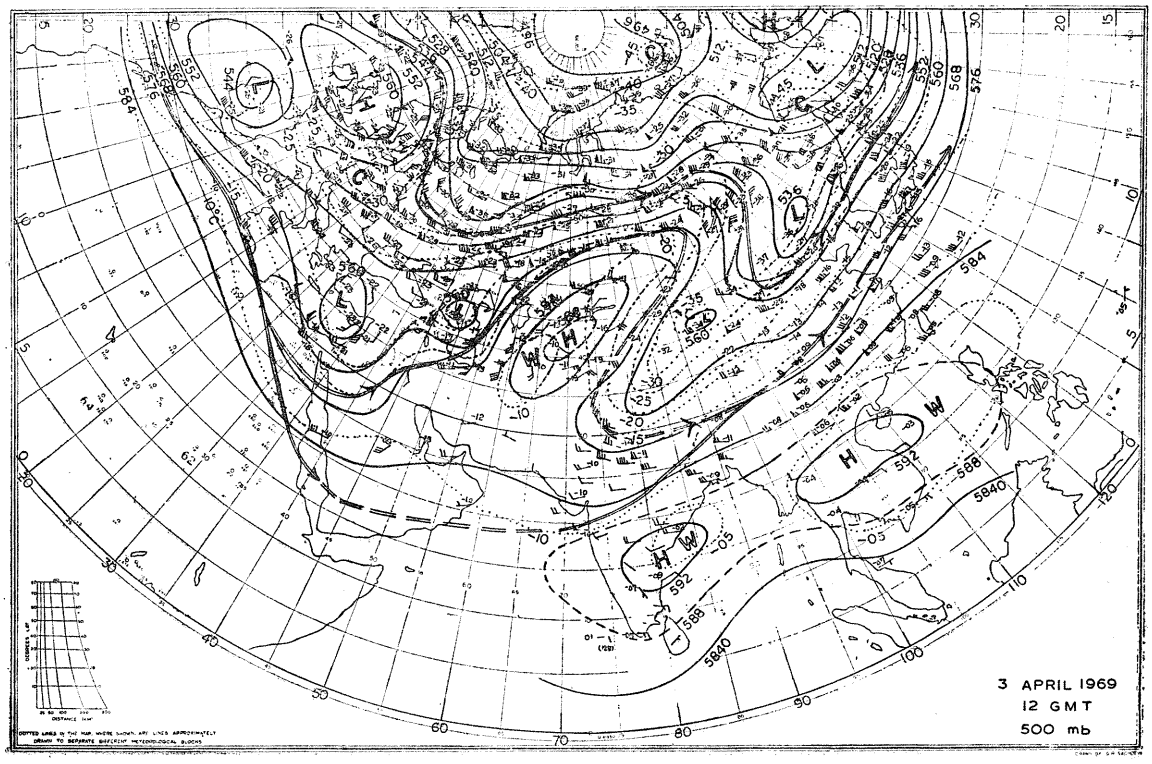

Fig. 3.3

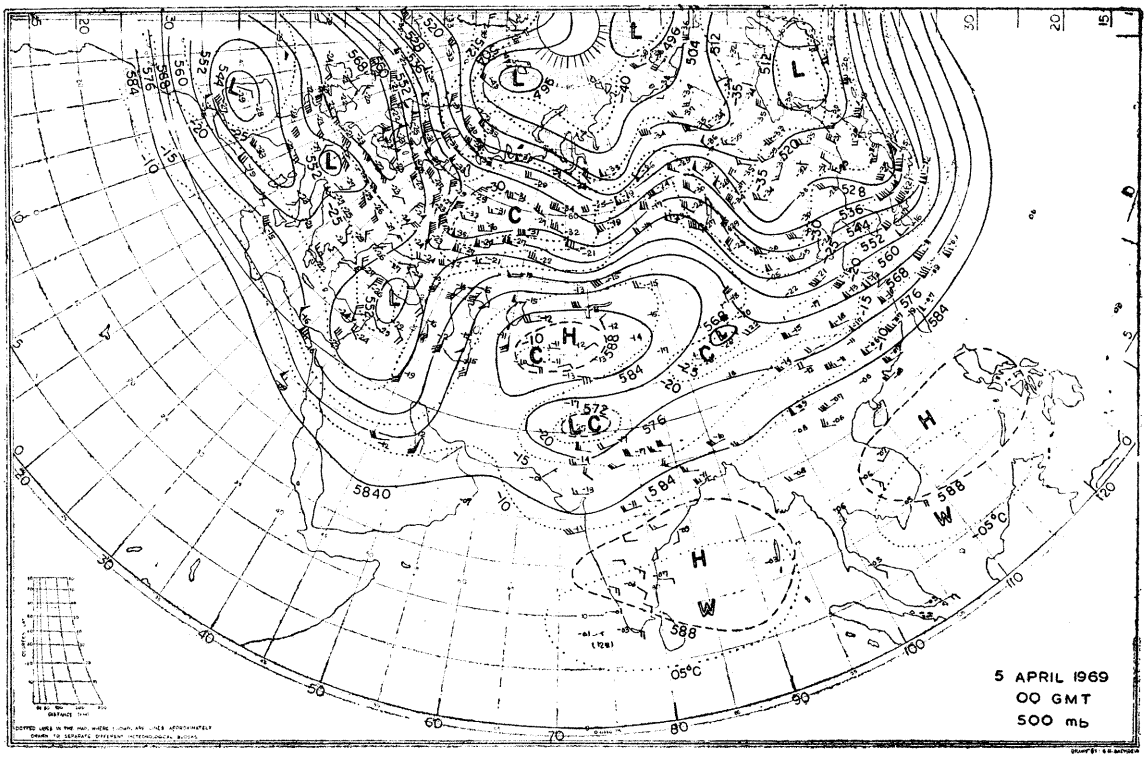

Fig. 3.4

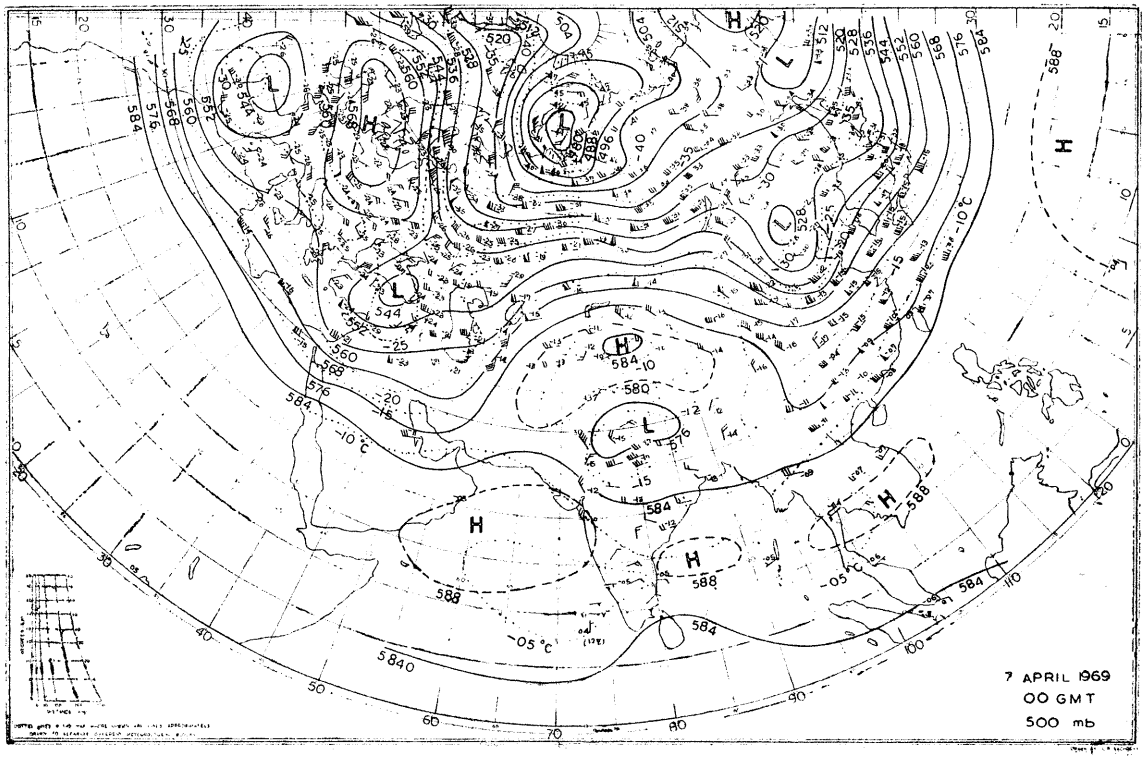

Fig. 3.5

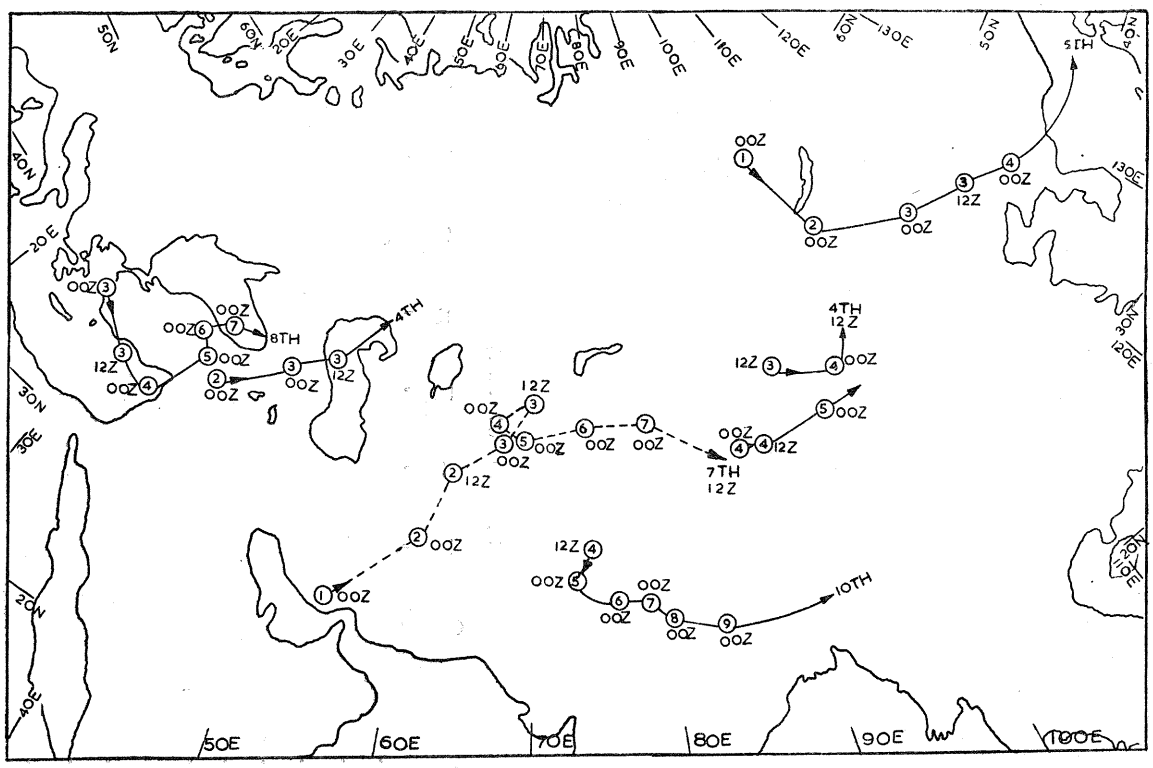

Fig. 3·6. Tracks of Lows and Highs at 500 mb during 1-10 April 1969

pressure area over west Europe moved eastwards and was lying north of the Black Sea on 31 March 1969. The flow pattern in the higher latitudes was however of the cellular type and was marked with migratory lows moving east. The change in the pattern commenced with an outbreak of polar air over Siberia on March, 31. On 1 April 1969, this outbreak of polar air extended southward and a cold low was formed at 500 mb to the northeast of Lake Baykal (Fig. 3·1). The north-south orientation of isotherms was well marked. In the west a well marked trough developed over the Black Sea and the associated isotherm pattern with this trough was also typical. A ridge lay between the two systems and a closed high was formed over Iran with its centre approximately at 28°N, 55°E. On the next day, Fig. 3·2, the low over Siberia shifted south and intensified. The thermal trough extended into north India and West Pakistan. A low developed over Turkey and a warm ridge extended from Arabia to west Siberia. In this, ridge a closed warm pool of—10°C was lying over Iran. The zonal flow over Asia thus completely changed to the meridional type.

3.1.3. The low which was lying south of Lake Baykal on 2 April took an easterly course thereafter. On the evening of 3 April (Fig. 3·3) another low formed further south, over east Sinkiang and adjoining areas and was centered near 42°N, 94°E. The high moved northeast and was centred near 43°N, 71°E. The low over Turkey also moved northeast and was lying over the Caspian Sea. Another low, which developed on the morning of 3 April over the Aegean Sea and adjoining Turkey moved in a south easterly direction and was centred west of Cyprus on the same evening.

3.1.4. The anticyclone was almost stationary between 3rd and 5th morning and its axis became more east-west (Fig. 3·4). East of the anticyclone, cold air continued to extend southwards during this period and another low formed on the morning of 4 April over southern parts of Sinkiang. On the same evening, a low developed further south over Jammu-Kashmir and adjoining West Pakistan. This low got cut-off from the main trough and moved southward during next 24 hours. It later moved eastwards and was lying as a low pressure area over northeast Assam on 10 April 1969. It movement till 7 April was slow and was of the order of 2-3 degrees per day. The life period of the low was 7 days, whereas the two lows of Sinkiang

area were weak comparatively and hardly survived for 24 hours or so. They initially moved in an easterly direction and weakened rapidly. To the west of the anticyclone, the low over the Caspian Sea moved in a northeasterly direction and weakened into a shallow trough on 4 April. The low over the Mediterranean Sea continued its southeasterly movement till 4 April and thereafter took a northerly course. It was lying over the Black Sea on 7 April (Fig. 3.5) and weakened thereafter. The anticyclone moved fast in an easterly direction during 5-7 April and weakened. It was observed as a ridge at 300, 200 and 100 mbs, on the evening of 7 April. The flow pattern in the middle latitudes over Asia, changed thereafter to zonal flow. The tracks of the low pressure systems and the high, described above, are shown in Fig. 3·6.

The splitting of the subtropical jet stream at 200 mb was well marked during the period. A branch of it moved north along the trough on the west of the anticyclone. After circumventing the high, it merged with the main jet near north Assam. As an illustration, the approximate position of jet axes at 200 mb are shown with the thick lines in Fig. 3·3. Another important feature noticed in the initial stages of the development, was the intensification and northward shift of subtropical high cells over peninsular India and SE Asia during 1-3 April at 500 mb. Later, with the formation of a cut-off low over Jammu & Kashmir and adjoining West Pakistan the high over peninsular India weakened and again moved south.

3.2. *Zonal Index*

3.2.1. The zonal index is a convenient factor for measuring large scale changes in the circulation pattern. In Fig. 4·1, the fluctuations of the daily values of the zonal index at 500 mb for 10°W-150°E, between 35-55°N (Curve I), serve as an indication of the low index circulation prevailing over Eurasia during 2-7 April 1969. A fall in hemispherical zonal index (curve II) for these latitudes was also seen between 3-7 April. A detailed picture of latitudinal variations of zonal indices over Eurasia, is given in Fig. 4·2. Values of the geostrophic zonal speed for 10°W-150°E, were computed for successive latitudinal bands, 10 degrees in width and extending from 20°N to 70°N latitude, at each tenth meridian. Isolines of the geostrophic zonal speed have been drawn for each 4 mps. Intermediates are drawn by dashed lines. The westerly flow stronger than 16 mps has been indicated by hatching. The speed maxima line is drawn by double dashes.

On 28 March a strongly peaked maximum of 20 mps was observed at 40°N. During next three days it moved south to 30°N where it persisted till 7 April. The maximum value in the peak was of 18 mps on 2 April and 20 mps on 5-6 April. On the remaining days it was near 17 mps. The second maxima in the northern latitude was found at 60°N on 30 April and later it shifted further

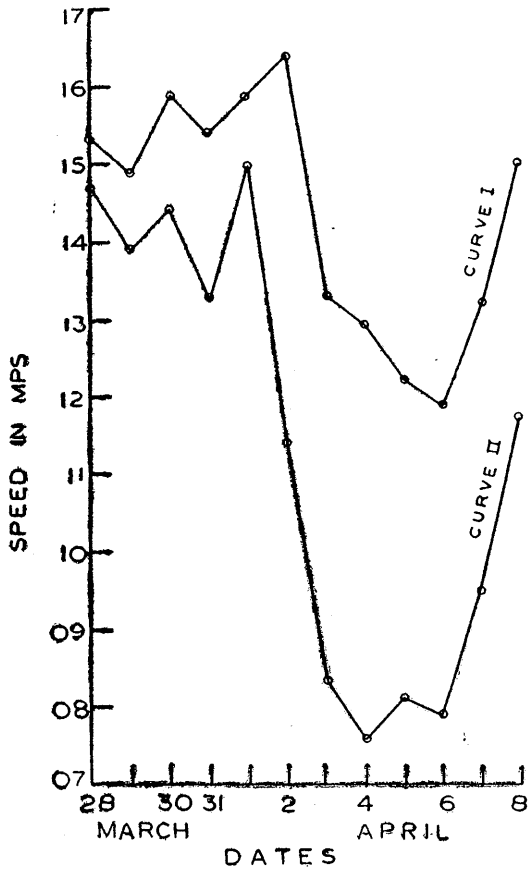

Fig. 4.1. Daily values of 500 mb zonal index between 35°—55° N

Curve I—Values for Northern Hemisphere
Curve II—Values for 10°W to 150°E

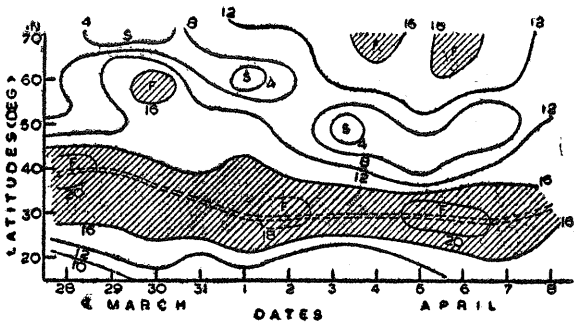

Fig. 4.2. Mean zonal speed in mps at 500 mb (10°W—150°E)

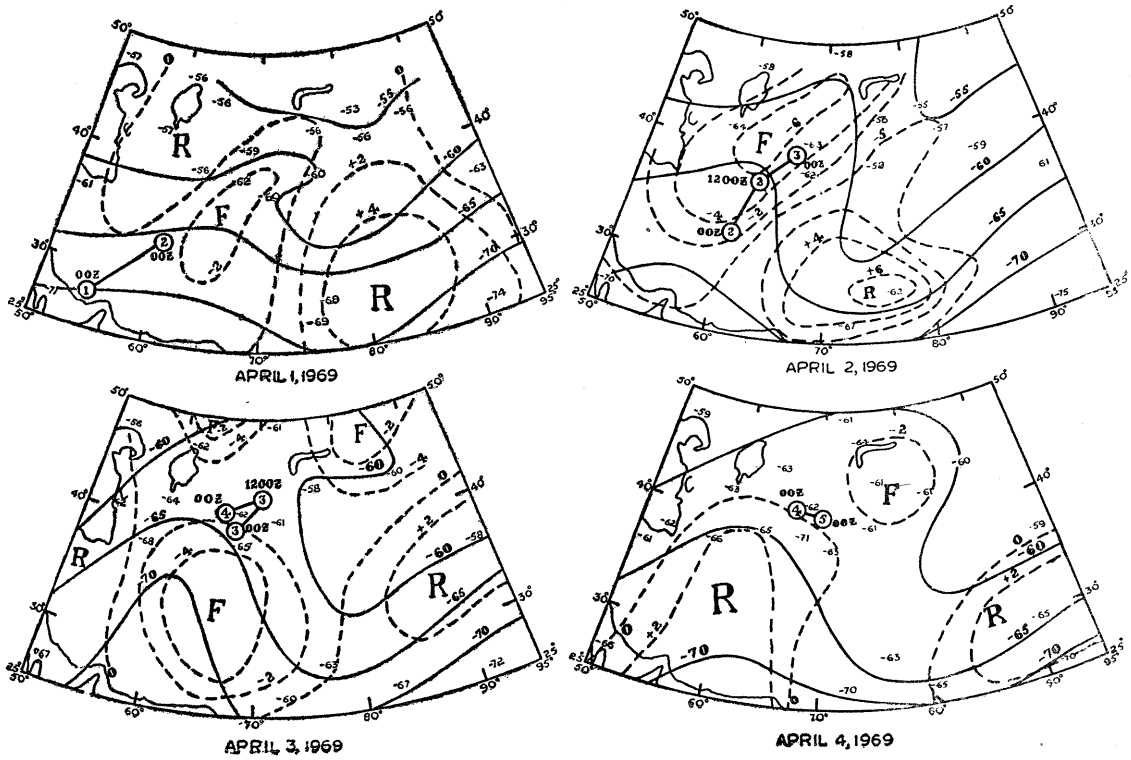

Fig. 5. Temperature field at 100 mb

Continuous lines—Isotherms at 5°C interval, Dashed lines—Isopleths of 24-hr Temperature changes at 100 mb

north and was noticed between 60-70°N during 3-7 April 1969. Reihl *et al.* (1952) have shown that high index is characterized by a single strongly peaked maximum in mid-latitudes. With low index in winter, the profile generally has two maxima, one around 60°N and the other near latitude 25°N. The value of geostrophic zonal speed shown in Fig. 4·2 and zonal indices for 35-55°N in Fig. 4·1, clearly show the low-index circulation prevailing during 2-8 April.

3.3. *Movement of the anticyclone*

3.3.1. Defant and Taba (1959) found that tropical impulses play a dominating role in effecting changes in mid-latitude circulation. From the study of tropopause height and temperature associated with blocking situation over Europe, the pronounced invasion of subtropical air into Europe was observed by them.

3.3.2. Due to non-availability of tropopause data for the Chinese region, east of the anticyclone, the tropopause changes associated with the formation and movement of the anticyclone and outbreak of cold air over northern parts of India, could not be studied. The temperature field at 100 mb over the area was, therefore, examined.

3.3.3. In Fig. 5, the temperature field and the changes in temperature during past 24 hours at 100 mb, have been presented for 1-4 April 1969. The isopleths of 24-hour temperature changes on 1 April when an anticyclone formed over Iran, indicate northward movement of cold stratospheric tropical air over north Afghanistan and adjoining Uzbec area. The temperature further fell over this area on 2 April. Simultaneously a rise in temperature took place over Jammu & Kashmir and adjoining areas on this date. This resulted in well marked trough ridge pattern in the isotherms on April 2. It will be seen from the 24-hour track shown in these charts that the movement of the anticyclone in the next 24 hours was in the direction of the area of temperature fall at 100 mb during past 24 hours. On 3 April we find that the temperature field was weak and temperature changes less marked. The isopleths of — 4° C indicated three areas of temperature fall. During 3-4 April the anticyclone was practically stationary. The change in its orientation from north-south to east-west, however, took place during this period. The temperature field further weakened on 4 April and thereafter. The tropical cold stratospheric air shifted back to south and temperature over the area rose generally. The eastward movement of the anticyclone was slow from 3 to 4 April and it

later moved rapidly eastwards. The low over Jammu & Kashmir was formed on 12 GMT of April 4. The rises in temperature at 100 mb were well marked on 2 April suggesting southward movement of warm stratospheric polar air east of the anticyclone.

4. Discussion

4.1. Rex (1950) found that blocking action is most frequently found in two relatively narrow longitudinal zones in the northern hemisphere, one centred at 10°W longitude (Atlantic) and the other at 150°W longitude (Pacific). In this study we have found a preferential area between 65 and 70°E for the development of anticyclones in the upper westerlies.

4.2. In the case study presented in this paper, a migratory high formed over Iran on 1 April due to advection of warm air from westsouthwest. Temperature at 500 mb over Iran and adjoining areas, rose by 4-6 degrees Centigrade from 00 GMT of March 31 to 00 GMT of 1 April. The warm air was advected from westsouthwest.

4.3. During this period, the out-break of polar air took place over central Asia through Siberia. This blocked the eastward movement of the anticyclone which was formed over Iran on 1 April and a train of lows developed to the east and west of it. The southward flow of cold air at 500 mb extended into northern India crossing Pamir mountains and a low formed over Jammu & Kashmir and adjoining parts of West Pakistan. It will be seen from Fig. 3·6 that in addition to the low over Jammu & Kashmir, three more lows were formed on the eastern side of the anticyclone. Two of these were formed over Sinkiang and did not survive for long. The other two lows had a life period of 6-7 days and moved southward initially before taking an easterly course. In the west, the lows took a northerly course, as they approached the block. The blocking action of the anticyclone is also evidenced by its retrograde motion, splitting of the subtropical jet and the lowering of zonal index for the period. It may be seen that the anticyclone which persisted for five days and more behaved as blocking system and dominated the circulation over Asia. These blocks are, however, weak in comparison to the Atlantic and Pacific blocks. Only 40 per cent of the anticyclone which formed in mid-latitude circulation over Asia and adjoining Europe, develop as blocking system.

4.4. During the winters of 1963–1969, no significant development of anticyclones took place to the east of 80°E in the mid-latitude upper westerlies over Asia. The formation of well developed low pressure systems is also inhibited in this area due to the vast orographic complex of the central Asia, extending from Himalayas to Altay mountains in Mongolia. The two lows which formed over Sinkiang on 3 and 4 April 1969, did not survive long, due to the effect of orography.

4.5. The blocking systems which develop south of 48°N and east of 60°E are found to effect the circulation over the Indian sub-continent, as east of these blocks, cold lows form over north India and neighourhood. Some of the western disturbance over north India might be caused by this mechanism.

4.6. The development of the blocking system at low latitudes, splits the subtropical jet, one branch of it moves northward along the trough on the west of the anticyclone and the main jet shifts south with reduced wind speed in the core. In the east of the anticyclone, the two branches merge again. It can be seen from Fig. 3·3 that the northern branch of the jet coincides with the temperature concentration at 500 mb.

4.7. It has been shown in the case study that the temperature fields at 100 mb, particularly its changes during 24 hours, provide a reliable indication about the movement, intensification and weakening of the upper tropospheric anticyclone.

5. Acknowledgements

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