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# Upper Air Circulation associated with a Western Disturbance

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ABSTRACT. Upper tropospheric circulation associated with the development of a western disturbance which was active over India and Pakistan from 28 to 31 December 1960 has been studied with the help of the Asian charts. It was observed that between 26th and 28th a meridional type circulation developed at 300-mb level in the Middle-East and the South-Russian Region. As a result, the upper air trough in the westerlies extended deep into the north Arabian Sea and a strong northwesterly jet developed upstream of this trough by the 28th. It was on this day that a feeble western disturbance aolng Makran coast intensified. On the 29th the meridional circulation at 300-mb level was destroyed. Probable causes of these developments in the upper air as well as at the surface have been discussed.

## 1. Introduction

A western disturbance which was active over the Makran coast on 28 December 1960 was lying as a well-marked sea level low "over Sind and adjoining northwest Rajasthan with associated closed upper air cyclonic circulation extending upto 2 km a.s.l. and trough aloft upto 10 km a.s.l." on 29th (*Indian Daily Weather Report*, 29 December 1960). It moved to Punjab (P) and neighbourhood on the 30th morning and was lying over south Punjab (I) and west Uttar Pradesh on the 31st as a well marked upper air low. It moved away across Punjab-Kumaon hills by 1 January 1961. Under its influence there was widespread weather activity over the northwest parts of Indo-Pakistan.

To study the origin, movement and intensification of this western disturbance, 12 GMT Asian charts were prepared for levels 700, 500, 300, 200 and 100 mb for the period 26 to 31 December 1960 utilising the Moscow broadcast upper air data along with those available for Middle-East and India. For the study of surface characteristics, top charts prepared at M.M.O. Santacruz (Bombay) extending west upto 25°E and north upto 45°N were utilised.

## 2. Origin and movement

Tracing the origin of this western disturbance it was observed that it did not move from west as was normally expected. Instead, a feeble low pressure area which was located on 261800 GMT surface chart close to the southeast of Tehran was found moving southeast and was in the Zahidan-Kerman area by 271200 GMT. Its southeasterly movement continued further and it reached the Makran coastal region of Arabian Sea by 280300 GMT (Pasni showed a pressure-rise at 271200 GMT and a fall of 3·1 mb at 280300 GMT). It was at its southernmost position in the Arabian Sea at 281200 GMT after which it suddenly took a northeasterly course and entered India. Its course (at the ground and at 700-mb level) is shown in Fig. 1.

In Fig. 2 are given the 700-mb constant pressure charts for the period 25 to 31 December 1960. It can be seen that a feeble

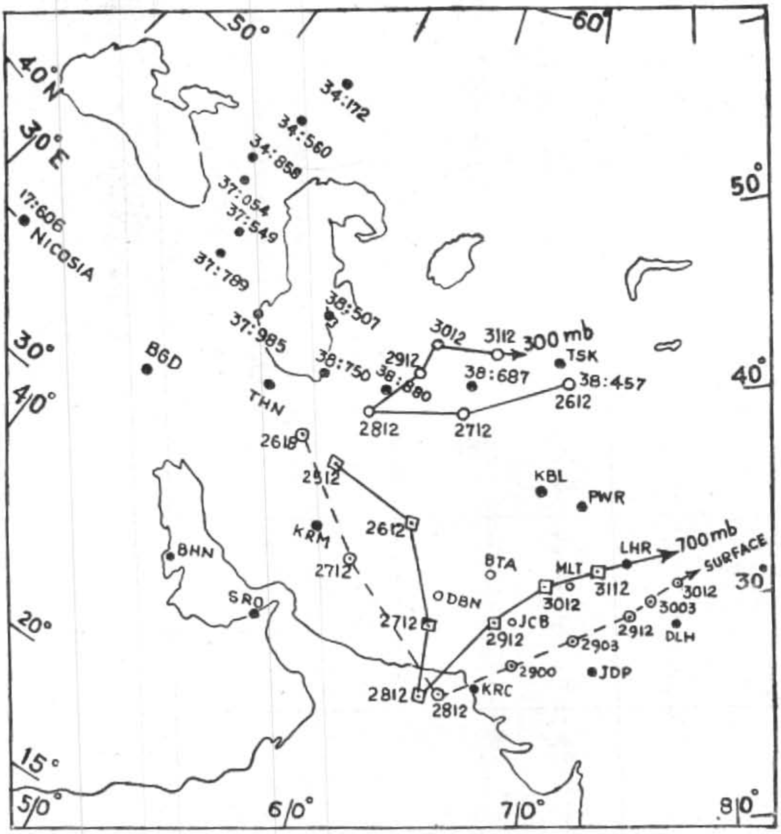



Fig. 1

cyclonic circulation which was centred north of Kerman at 251200 GMT moved to its northeast by 261200 GMT. It reached south-east of Dalbandin by 27th and was still quite feeble. By 281200 GMT it moved to Arabian Sea off Makran coast and intensified. Afterwards it took a northeasterly course as can be seen from the charts of 29th, 30th and 31st.

In Fig. 3 are given the constant pressure charts of 300 mb for the period 26 to 31 December 1960. It can be seen that on 26th and 27th the airflow in the Tehran-Kerman area was northwesterly. At 500-mb level also the flow in this area was northwesterly but was very feeble. It is apparent, therefore, that the surface low was steered southeast

TABLE 1

| Date and time (GMT) of observation | Name of station in or near centre of the low | Fall in pressure (mb) in 24 hrs | Remarks |
|---|---|---|---|
| 280300 | Pasni | 3·1 | Centre of the low to the south of the station |
| 281200 | Pasni | 4·7 | |
| 290300 | Bikaner<br>Phalodi | 9·9<br>9·1 | |
| 291200 | Chru | 7·1 | |
| 291800 | Hissar<br>Delhi | 7·0<br>6·2 | |
| 300300 | Hissar<br>Ambala | 4·4<br>4·4 | |

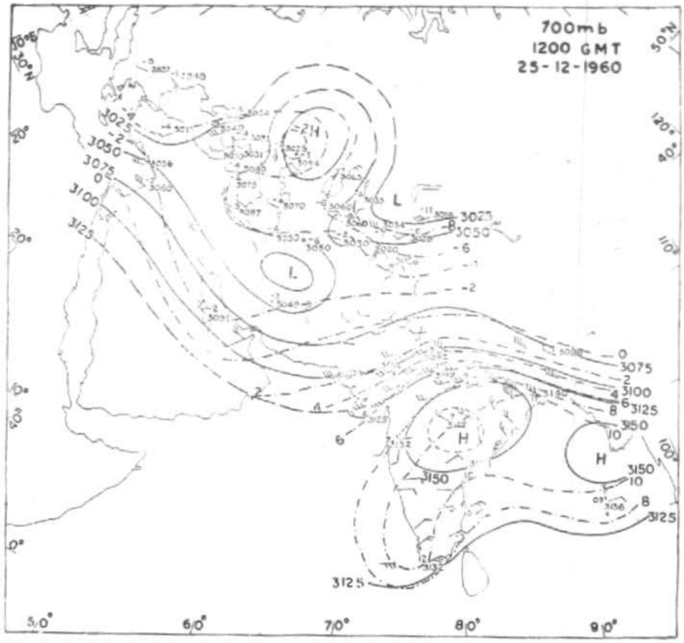



Fig. 2(a)

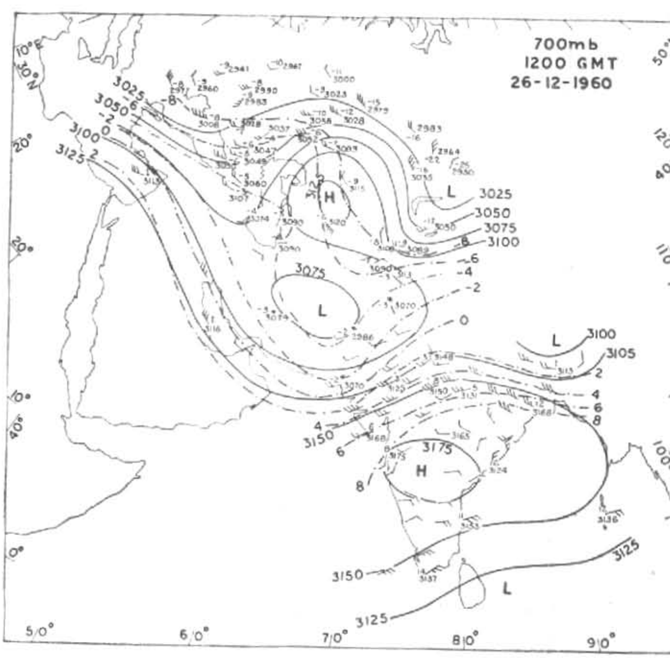



Fig. 2(b)

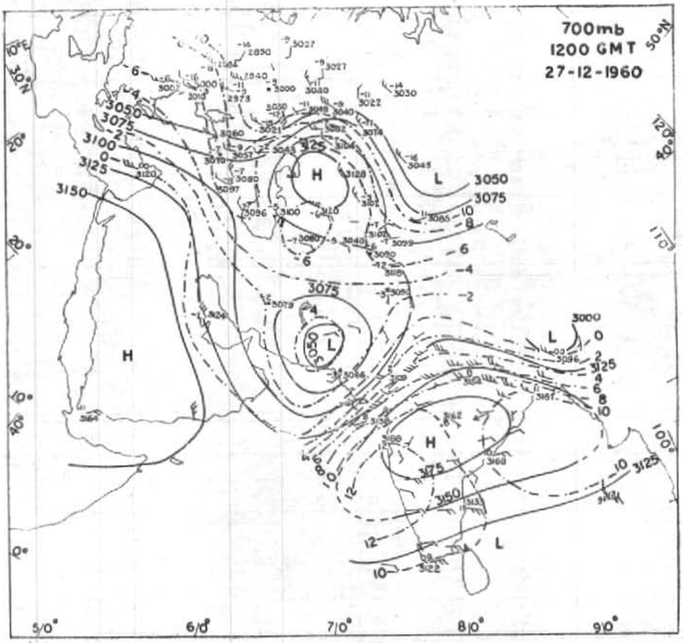



Fig. 2(c)

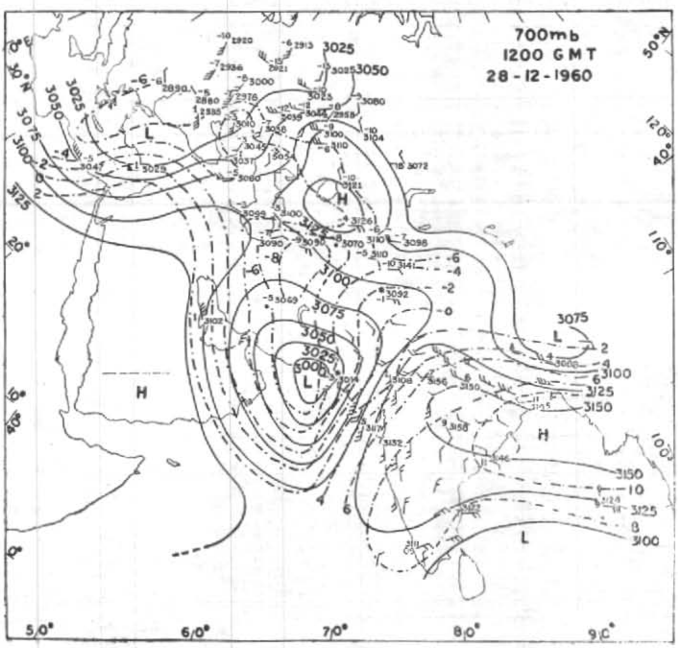
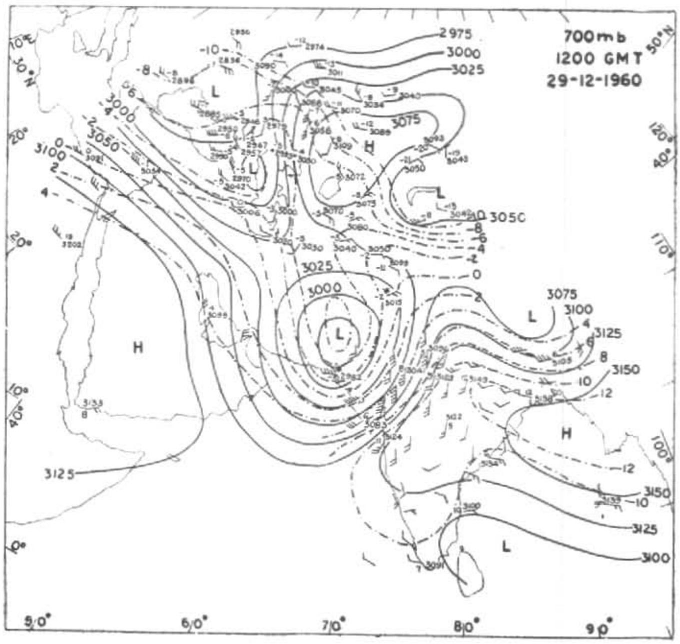



Fig. 2(d)


700 mb
1200 GMT
29-12-1960
2975
3000
3025
3050
3075
3100
3125
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H
L
50°
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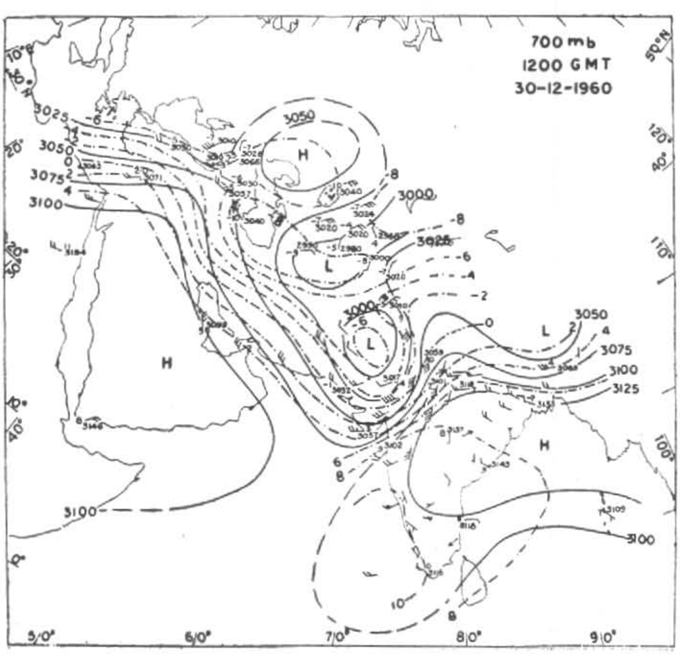
80°
90°

Fig. 2(e)


700 mb
1200 GMT
30-12-1960
3000
3025
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3100
3125
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50°
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Fig. 2(f)

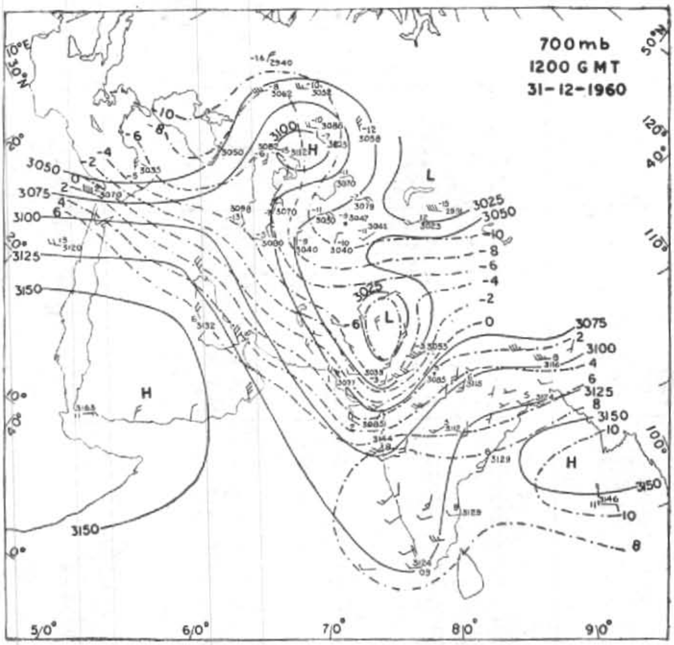


Fig. 2(g)

by the upper tropospheric flow (probably at 300 mb) which also led it from 29th onwards in the northeasterly direction as can be seen from the relevant charts of Fig. 3.

**3. Intensification**

The low which remained inactive upto 27th began to intensify as it approached the coastal region. It deepened considerably on the 28th while over the sea and remained intense even on the 29th when it was over land. It continued to be active on the 30th and 31st also. An idea of its intensification can be made from Table 1 in which the fall of pressure in or near the centre of the low in 24 hours is given.

Though the fall of pressure in the centre of the low on the 28th is not available, it seems reasonable to assume that it must have been considerably higher than 10 mb, a value which was shown on the 29th when the low was over land.

A very significant intensification as it was, it must have got a very favourable upper tropospheric circulation for its development. How this favourable circulation was evolved will be discussed below.

**4. Upper tropospheric flow**

On the 261200 GMT 300-mb constant pressure chart (Fig. 3 a) can be seen a well developed ridge in the westerlies in the Caspian Sea region directed NE—SW. Downstream of this ridge is a low pressure area where cold air incursion is taking place. Embedded in this cold air is a low centered near Lat. 40°N, Long. 70°E. East of this low the pressure gradient is quite high. This low extends upto 200-mb level but is not traceable at 500-mb level or below.

Development in the next twentyfour hours was interesting. On the 271200 GMT 300 mb chart (Fig. 3b) it can be seen that the upper air low moved westsouthwest and was centered near Lat. 38°N, Long. 64°E. Another

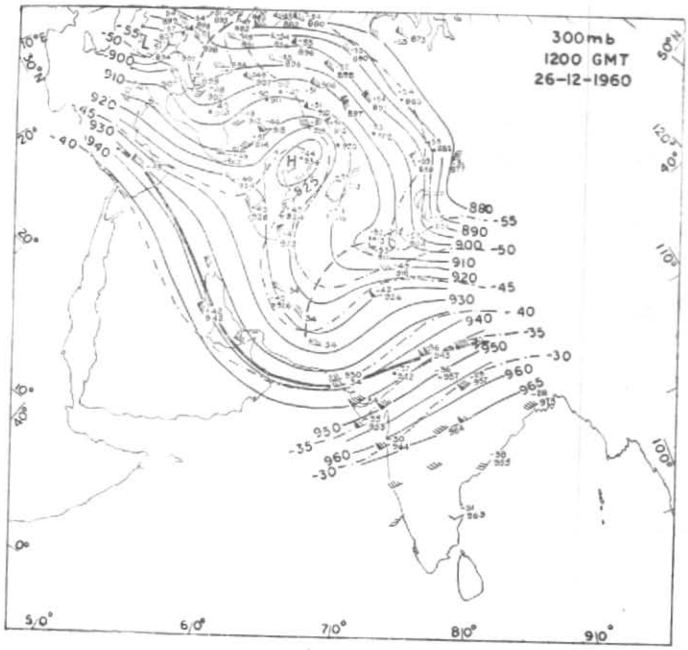


Fig. 3(a)

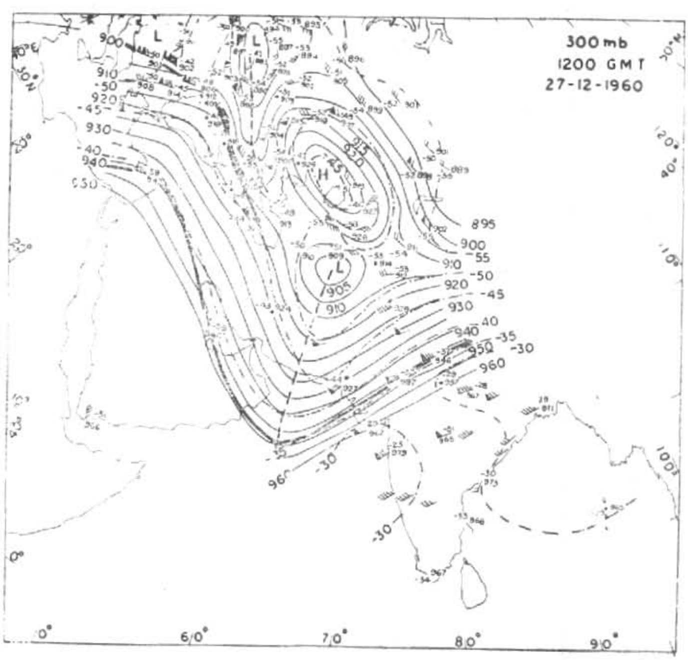


Fig. 3(b)

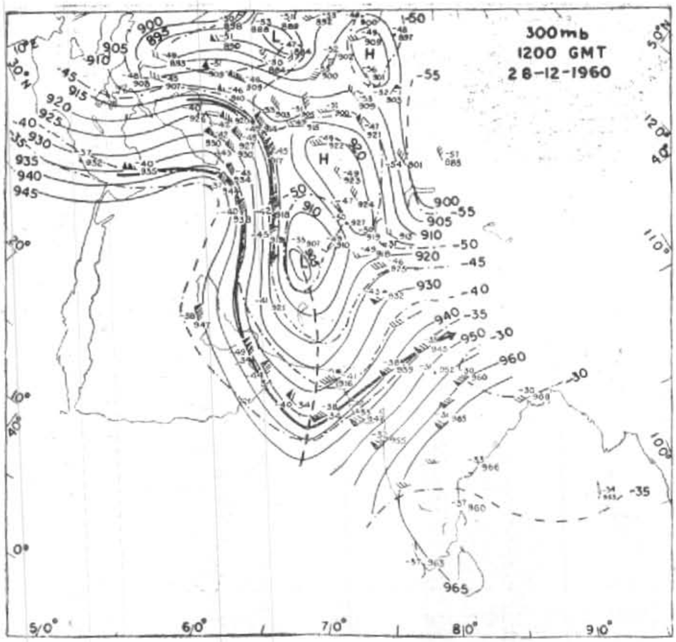


Fig. 3(c)

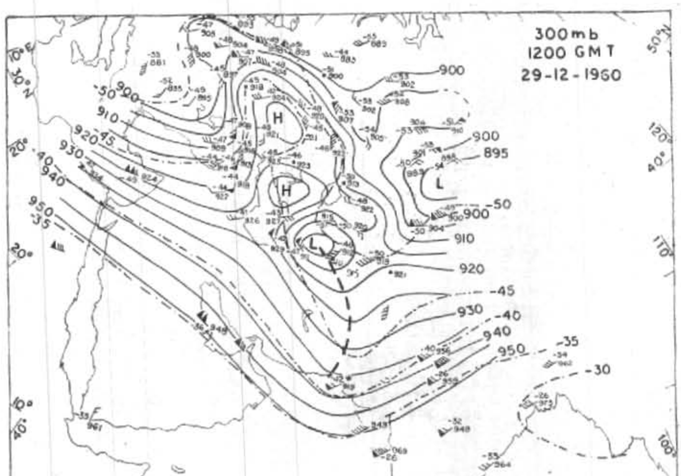


Fig. 3 (d)

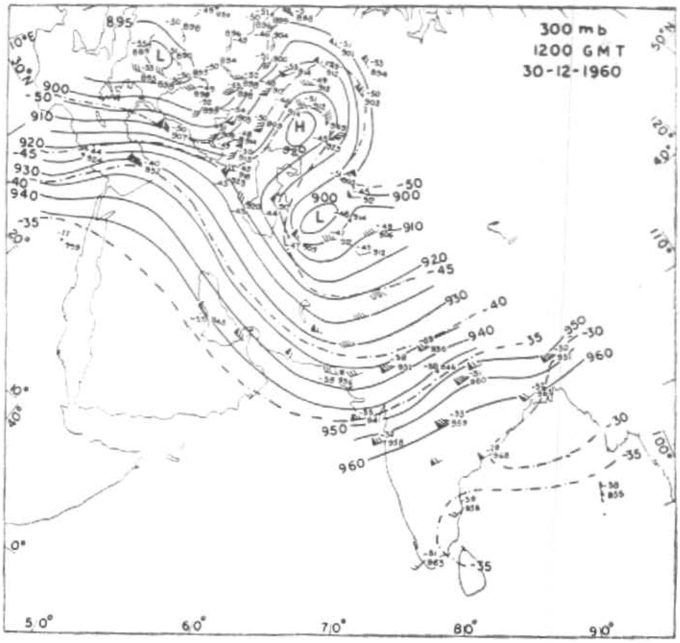


Fig. 3(e)

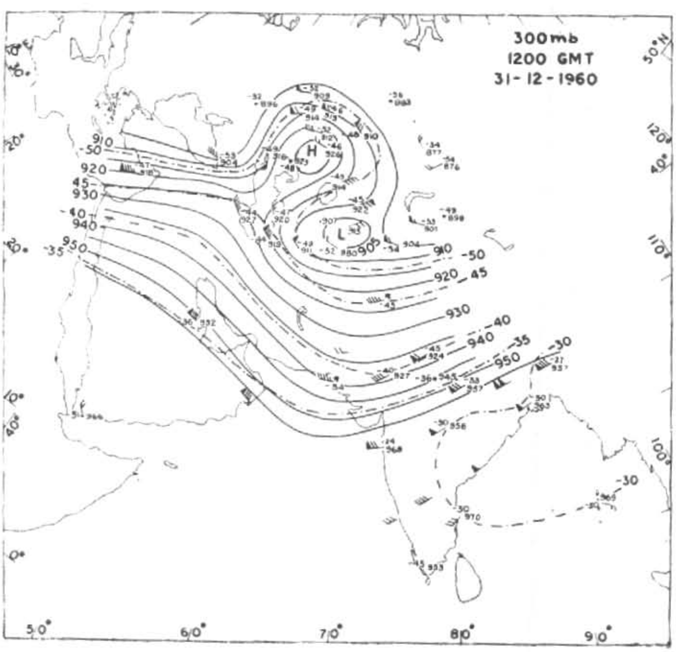


Fig. 3(f)

low situated along 25°E, the previous day, moved east and could be seen extending its trough-line upto Caspian Sea in the southeasterly direction. Under the combined influence of these two lows the ridge over the Caspian Sea region was cut off into an anticyclone which lay over Aral Lake extending NW-SE (Berggren *et al*. 1949). The westsouthwesterly moving low was seen upto 100-mb level on this day but still it was not traceable at 500 mb or below. Circulation at its centre at 300-mb level, however, weakened. The trough in which the low was situated extended to the south in the Arabian Sea upto at least 15°N.

This low continued on its westsouthwesterly path the following day also and on the 281200 GMT chart (Fig. 3c) could be seen centered near Lat. 37°N, Long. 58°E. Circulation at its centre at 300 mb weakened further but it extended its influence below to 500-mb level and was traceable at 100 mb also. The anticyclone to the north remained practically stationary and the low to the northwest of this anticyclone moved away northeastwards.

Another ridge along Long. 42°E covering Black and Caspian Seas developed by 28th and the trough downstream extended further south showing at the same time very little movement to the east (Fig. 3c). It was in this trough that the westerly moving low was situated.

After 28th this low reversed its course and the circulation at its centre at 300-mb level (Fig. 3d) strengthened. It was not traceable, however, at 100-mb level now. And as it moved east the ridge which developed to its west the previous day weakened. In fact, this ridge was not traceable south of Lat. 40°N on the 29th where it was most prominent on the 28th. The trough associated with this low moved east and the anticyclone to the north disappeared. Actually with the change of the course of this low the upper tropospheric circulation which was highly meridional on the 28th became quite zonal on the 29th, especially south of Lat. 40°N.

For the next two days (Figs. 3e and 3f) as this low moved very slowly towards northeast the upper tropospheric flow south of Lat. 40°N remained more or less zonal, though the ridge to the northwest of the low strengthened.

From the above description it is apparent that the changes in the upper tropospheric circulation in the middle latitudes (with which we are concerned) from 26th onwards were mainly controlled by the upper air low which took an unusual course to WSW for two days before turning NE.

## 5. Discussion

Considering the effect of the WSW'ly movement of the upper air low from 26th to 28th on the upper tropospheric circulation of that period it was observed that —

(1) As a result of this movement of the low the trough associated with it showed very little movement to the east; on the other hand it extended southward reaching deep into the north Arabian Sea.

(2) It was a low embedded in the cold polar air as the temperature configuration in Fig. 3(a) indicates. Moving WSW, therefore, it increased the temperature-gradient ahead of it by bringing cold air nearer to warm air in the ridge. As a result, the temperature-gradient to the southeast of Caspian Sea steadily increased from 26th to 28th as Table 2 indicates (see the temperature-gradient increase between stations 37 : 985 and 38 : 880 between 26th and 28th).

(3) By moving west, it also caused the increase in the pressure-gradient to its west. This increase was brought about in two ways. Firstly, by its mere movement the low pressure area associated with it shifted westward. Secondly, due to this WSW'ly movement of the low, the upper tropospheric trough in which it was embedded remained almost stagnant and extended more and more to the south. And as it extended southward, warm air from more and more southerly latitudes moved north to its west

TABLE 2

**Contour height (tens of gpm) and temperature (°C) of 300-mb level at some stations during 26-28 December 1960**

| Date and time (GMT) of obsn. | Bahrein 40 : 427 | | Kerman 40 : 841 | | Lenkoran 37 : 985 | | Ashkhabad 38 : 880 | |
|---|---|---|---|---|---|---|---|---|
| | Ht. | Temp. | Ht. | Temp. | Ht. | Temp. | Ht. | Temp. |
| 261200 | 941 | —42 | 926 | —45 | 926 | —45 | 915* | —50* |
| 271200 | 946 | —39 | 924 | —43 | 920 | —44 | 910 | —50 |
| 281200 | 947 | —38 | 921 | —41 | 938 | —40 | 907 | —53 |

* Estimated values

(Wexler 1951, Namias and Clapp 1951) and built up the upstream ridge extensively (Fig. 3c). These two processes of pressure gradient increase to the west of the low can be inferred from Table 2.

It can be seen (Table 2) that on the one hand the height values of Kerman and Ashkhabad (38 : 880), situated in the trough, steadily decreased because of the approach of the low towards these stations, the contour heights of Bahrein and Lenkoran (37 : 985) showed spectacular increase due to the building up of the preceding ridge. Lenkoran being near the apex of the ridge showed much more increase than Bahrein which lay to its southeast. The rush of the warm air which built up the ridge showed its effect first at Bahrein (on the 27th) and then at Lenkoran (on the 28th) which lies much to the north. At Bahrein both height and temperature increased to a maximum on the 27th whereas over Lenkoran it was on the 28th. Ashkhabad being all the time under the influence of the cold low showed no temperature-rise whereas all other stations showed this rise. The increase in the pressure-gradient between 26th and 28th to the west of the low is apparent if we compare the height values of Lenkoran and Ashkhabad or those of Bahrein and Kerman (Table 2) on these days.

All these effects of the WSW'ly movement of the upper air low could be best seen on the 28th when it was at its westernmost position. It was centred to the SW of Ashkhabad and the associated trough extended even south of Lat. 15°N along Long. 65°E. The preceding ridge was very well developed extending roughly upto 50°N along Long. 42°E. The pressure and temperature gradients downstream of the ridge and west of the low were quite intense. It was a picture of strong meridional circulation in the middle and upper troposphere in this region.

(4) As expected, the concentration of pressure and temperature gradients downstream of the strong ridge resulted in the development of an intense jet with its core near Sharjah by 28th (Table 4). The evolution of the jet-stream between 26th and 28th took place as follows :

On the 26th a jet stream with its core near Nicosia (Fig 3a) was extending from the Mediterranean through Persian Gulf to India more or less on its seasonal course (Heastie and Stephenson 1960). On the 27th (Fig. 3b) it showed a tendency to move north between Nicosia and Bahrein and to extend south between Bahrein and Karachi (wind direction at Bahrein changed from 310° on the 26th to 340° on the 27th). Its core also shifted further east of Nicosia as could be inferred from the weakening of wind at this station and strengthening at Bahrein (Table 3). By 281200 GMT, however, the wind at

**TABLE 3**

**Wind direction (dd—in tens of degrees) and speed (ff—in knots) at 300-mb level**

| Station | Date and time of observation (GMT) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 260000 | | 261200 | | 270000 | | 271200 | | 280000 | | 281200 | | 290000 | |
| | dd | ff | dd | ff | dd | ff | dd | ff | dd | ff | dd | ff | dd | ff |
| Nicosia | — | — | 27 | 86 | — | — | 26 | 77 | 25 | 88 | 22 | 117 | 27 | 78 |
| Bahrein | — | — | 31 | 72 | — | — | 34 | 108 | 33 | 91 | 33 | 85 | 33 | 72 |
| Karachi | 24 | 64 | — | — | 21 | 76 | — | — | 21 | 51 | — | — | 20 | 51 |

Nicosia backed significantly (from 260° on 271200 GMT to 220° on 281200 GMT) and at Bahrein it maintained its NNW'ly direction suggesting that the jet stream shifted northward between Nicosia and Bahrein. Actually the jet stream on the 28th took the route Nicosia, Erivan (37 : 789), Lenkoran and thence on a SE'ly course to east of Sharjah and further to Arabian Sea upto 65°E after which it took a sharp turn to NE (Fig. 3c) exhibiting extreme meandering. The core between Nicosia and Bahrein was situated over Erivan on this day, and another core developed near about Sharjah.

To examine the nature of this jet stream a meridional cross-section for 281200 GMT was prepared along Long. 45° which apparently passed through the core of the jet at the crest of the ridge. Fig. 4 shows this cross-section. It can be seen how steep a temperature gradient existed between stations 37 : 789 and 37 : 549 and also between 34 : 858 and 34 : 560. The tropopause which was the highest at 37 : 789 (151 mb) only lowered a little northward and extended upto 34 : 858. The average tropopause height in this region was 12·5 km (172 mb) and average tropopause temperature 210°A. There was a definite break in this tropopause northward of 34 : 858. Stations 34 : 560 and 34 : 172 showed an average tropopause at a height of 11·1 km (232 mb) but the tropopause temperature remained still low, *i.e.*, 211°A. From these characteristics of the tropopause it appears that the former was of the subtropical impulse type and the latter, of middle latitude type as defined by Defant and Taba (1958).

The core of the jet stream was located over station 37 : 789 (Erivan) at a height of about 12·6 km (slightly above 200 mb) below the apex of the tropopause which, as said earlier, did not show any break. This jet stream was apparently of the subtropical type (Koteswaram 1953). Another jet could also be seen to the north of this jet between stations 34 : 858 and 34 : 560 with its core below 200-mb level. It was actually the jet which was seen across the Black Sea on the previous day. It was also of the subtropical type which lay near the break line between the subtropical impulse tropopause and the middle latitude tropopause.

Table 4 gives the aircraft reports on the 28th and 29th. It can be seen in this table that AII reported NNW wind of strength 146 kt near Sharjah on the 28th at a level of 38,000 ft which reduced fast downstream. It was supported by BOAC also which flew only a few hours later. It reported a NNW'ly wind of 130 kt strength at a height of 34,000 ft. It also indicated a rapid reduction of speed to the SE. It appears, there was a jet core situated near about 38,000 ft just east of Sharjah where temperature was —60°C. These agree well with the height and the temperature of the core at the crest of the

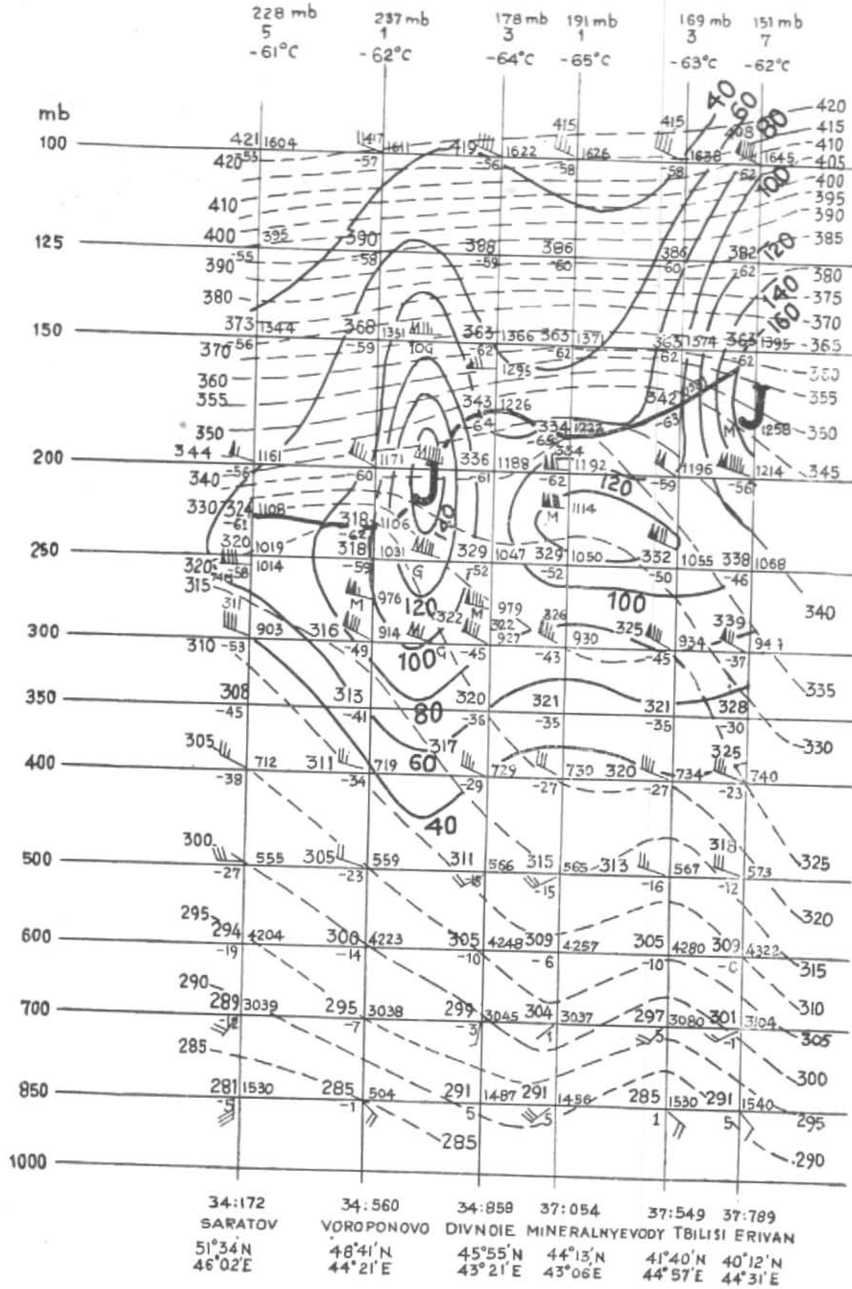


Fig. 4. Height, kind and temperature of tropopause

**TABLE 4**

| AII Boeing 707 flying from Beirut to Bombay at levels 34,000 ft (BRT-50°E) and 38,000 ft (50°E-near BMB) on 28 December 1960 from 0345-0813 GMT | | | BOAC Comet IV flying from Bahrein to Bombay at level 34,000 ft on 28 December 1960 from 0915-1251 GMT | | | AII Boeing 707 flying from Cairo to Bombay at level 38,000 ft on 29 December 1960 from 0025-0500 GMT | | |
|---|---|---|---|---|---|---|---|---|
| Region of flying | Av. Wind | Temp. | Region of flying | Av. Wind | Temp. | Region of flying | Av. Wind | Temp. |
| BRT | | | BAHREIN | | | CAIRO | | |
| | 305°/50k | | | Ascent | | | | |
| 40°E | 310°/78k | | Sharjah | 330°/130k | —49°C | AIK | Ascent | |
| 45°E | 320°/87k | | 58°E | | | 40°E | 270°/30k | —50°C |
| | | | | 305°/125k | —44°C | | | |
| 50°E | | | 60°E | | | BHN | 310°/125k | |
| | 340°/146k | —60°C | | 300°/60k | —42°C | | | |
| 55°E | | | 64°E | | | SHJ | 315°/115k | |
| | 320°/90k | | | 210°/90k | —38°C | | | |
| 60°E | | | 68°E | | | | | |
| | 240°/90k | | | | | | | |
| 68°E | | —45°C | | 185°/120k | —37°C | | | |
| | | | 71°E | | | KRC | 240°/90k | —43°C |
| | 220°/80k | | | | | | | |
| BMB | | | BMB | | | BMB | | |

ridge, *i.e.*, at Erivan. There was another core in the NE wing of the jet near Delhi. This extremely meandering character of the jet was very favourable for intense cyclonic developments at the surface, especially where it took a NE turn (Riehl *et al.* 1952, 1955). It was here that the western disturbance under consideration was situated on the 28th. So its rapid and intense development was quite natural, particularly when it had the added advantage of being over the sea.

It is apparent from the above discussion that the surface low intensified on the 28th along the Mekran coast due to the favourable development of the upper tropospheric trough (300 mb) between 26th and 28th; especially due to the concentration of a jet stream core close to its northwest (Fig. 3c). A comparison of the flow at 300-mb level (Fig. 3) in relation to the movement of the surface low (Fig. 1) will make it also clear that the latter moved with the tropospheric flow (300 mb) throughout the period.

The development of the upper tropospheric circulation between 26th and 28th was apparently connected with the movement of the upper air low to WSW. This low which brought about the condition of blocking (Namias and Clapp 1951) in the upper troposphere (300-mb level) in the region under consideration moved west at the rate of about 6° longitude per day between 26th and 28th. Its WSW'ly movement seems to be connected with the presence of a weak pressure region to its SW on the 26th (Fig. 3a). This weak pressure area was extending on this day from ground upto 300-mb level and was not connected with any significant cyclonic development, at the ground. It appears, therefore, that its development, at least in the middle and upper troposphere (upto 700-mb level there was feeble low—Fig. 2) was a dynamic consequence of the development of a strong warm ridge to its west (Fig. 3a) as discussed by Nyberg (1949).

Table 5 gives the 300-mb contour height and temperature values of stations situated between the ridge and the low on the 26th. It can be seen from the table that the low pressure area east of the ridge grew in intensity between 26th and 27th (see a general

TABLE 5

Contour height (in tens of gpm) and temperature (°C) at 300-mb level

| Station | 26-12-60 1200 GMT | | 27-12-60 1200 GMT | | 28-12-60 1200 GMT | | 29-12-60 1200 GMT | |
|---|---|---|---|---|---|---|---|---|
| | Ht. | Temp. | Ht. | Temp. | Ht. | Temp. | Ht. | Temp. |
| 38 : 687 | 912* | — | 909 | —51 | 910 | —48 | 912 | —46 |
| 38 : 880 | 917* | — | 910 | —50 | 907 | —53 | 911 | —47 |
| 38 : 750 | 922 | —47 | 915 | —48* | 919 | —45 | 929 | —42 |
| 38 : 507 | 924 | —45 | 913 | —48 | 918 | —42 | 927 | —43 |

*Estimated values

fall in height values on 27th) pulling in more and more of cold air (see the general decrease in temperature). As a consequence, the low embedded in the cold air was also pulled westward. And it continued to move west as long as the low pressure area grew in intensity, *i.e.*, upto 28th (see the fall in height and temperature values of station 38:880 between 27th and 28th). It reversed its course as soon as the low pressure area started filling up, *i.e.*, between 28th and 29th.

From the above discussion it is apparent that—

(*i*) The low moved WSW due to the growing low pressure area to its west and consequent drawing in of the cold air in which the low was embedded.

(*ii*) The low pressure area grew in intensity between 26th and 27th unaccompanied by any development at the ground. It appears, therefore, that this growth was connected with the growth of the ridge to its west.

On the 27th the ridge was cut off; so the process of deepening of the low pressure area would have stopped but for the growth of another ridge by 28th. So the very minor growth between 27th and 28th (only height decrease at 38:880) was due to the growth of another ridge by 28th. On the 29th again, because of the presence of this ridge, further deepening in the region of the low was expected. But there was overall rise in the height values on this day (Table 5). The reason for this reversal appears to be the cutting off of the low from the cold-air-supply by the anticyclone to the north on the 28th (Fig. 3c).

From the above discussion it appears that the mechanism of developments in the upper troposphere between 26th and 29th was as follows (Nyberg 1949) :

As is well known the air from low latitudes as it moves north acquires anticyclonic relative vorticity and hence ultimately takes a turn to south forming a ridge at its northernmost position. And as it rushes southeastward from the ridge following approximately a constant absolute vorticity trajectory it creates a pressure fall to its left. In the case under consideration, it seems that the low pressure area appearing southeast of the Caspian Sea in Fig. 3a was being created in the same way. The warm air from the Mediterranean rushing north built up the ridge in the Caspian Sea region and created a pressure fall to its southeast. And because of this pressure-fall the cold air was being drawn in causing the confluence of warm and cold air-masses downstream of the ridge. Thus, in this region was available a thermally direct circulation with rising warm air and sinking cold air resulting in the increase in height values in the region of warm air and decrease in that of cold air at the level of advection (300 mb). As a result both the ridge and the trough grew in intensity as long as the supply of cold and warm air continued and confluence maintained. This thermally direct circulation also released kinetic energy which strengthened the wind downstream. So the consequence of the confluence of warm and cold air masses was to increase the transverse temperature and pressure gradients and to strengthen the air-current downstream. This process operated up to 28th after which the cold air supply was cut off and the confluence destroyed. The result was the filling up of the low pressure area and the destruction of the ridge (Fig. 3d).

The extension of the low upwards as it moved west was due to the sinking of the cold air in which it was embedded (Palmen 1949 and Nyberg 1949). But as it moved east this sinking stopped and the low extended downwards but was not traceable in the upper layers (100 mb).

Let us now consider the intensification of the surface low on the 28th. As said earlier, the low showed quite intense development on this day and admittedly for such a development a very favourable upper tropospheric field of divergence was necessary. This field was provided to the low mainly by the jetstream which was situated with its core near Sharjah on the 28th. As is well known, the left side of the entrance of a jetstream (Riehl *et al.* 1955) is very favourable for the cyclogenesis at the surface. And that was what happend to the low which was situated in the trough southwest of Karachi on the 28th. It was also just ahead of the confluence entrance region of the trough (upto the maxima of the jet) when vorticity advection would be maximum (Petterssen 1956). Besides, it was over the sea facilitating adequate moisture supply. So it was no wonder that the intensification took place on the 28th. Actually the structure of the jetstream on the 28th in relation to the trough was very favourable for its intensification as discussed by Riehl *et al.* (1952).

As for the movement of the surface low, it has been already shown that the low was steered by the upper tropospheric flow at 300 mb. The 500-mb flow was all along too feeble for this purpose. It may be mentioned that in other cases too it has been observed that for steering of western disturbances the lowest level to be considered is 300 mb. Western disturbances move sometimes even faster than the average wind at 500-mb level in that region.

### 6. Conclusions

From the above study the following conclusions can be drawn —

(1) Western disturbances need not necessarily be considered moving from the west, as has been emphasized in the past writings.

(2) The movement and the intensification of western disturbances are controlled by the upper tropospheric circulation (lowest, 300-mb level) in the Middle-East and the Southern Russian regions.

(3) For the prediction of intensification of any western disturbance the position and the configuration of the upper air trough in the westerlies in the Middle-East as well as those of any jetstream embedded in it in relation to the surface low have to be watched.

(4) As for the development of blocking situations in the upper tropospheric westerlies, it appears that the confluence of warm and cold air masses downstream of a growing ridge is an important factor. It is a process by which both the ridge and the trough grow in intensity

and warm and cold air-masses are pulled more and more to the north and south respectively.

(5) This process of blocking stops as soon as any of the warm or cold air supply is cut off resulting in the destruction of the confluence.

## 7. Remarks

It is apparent that a thorough study of the western disturbances can only be made with the help of charts covering Eurasia and North Africa. But the radiosonde/rawin observations in the regions of Middle-East and North Africa, especially in Iraq, Iran and Afghanistan are so few that the satisfactory construction of these charts is a difficult problem. Availability of more and more aircraft observations especially of jet aircraft, therefore, is of immense help in filling up this gap. It is also necessary to obtain Russian upper air observations for both morning and evening instead of evening only as at present.

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