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RAIN FALL FLUCTUATIONS-BREAKS-ASSOCIATED SYNOPTIC SYSTEMS

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ABSTRACT

Two types of Monsoon conditions i.e, Active Monsoon and Break Monsoon over a Tropical Country (India) are studied in detail by using various methods of analysis like cross sections, Time Sections, Coutour Analysis of 700 mb (lower troposphere), 500 mb (middle troposphere) and 200 mb (upper troposphere) and streamline analysis.

Consistent results are arrived at in distinguishing the Break monsoon condition to that of an Active or Normal Monsoon condition.

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INTRODUCTION:

The southwest monsoon, no doubt accounts for 80% of the total annual rainfall over India, but the distribution of rainfall in space and time is highly variable. The establishment of the monsoon over the whole country is called the Active monsoon or normal monsoon. In between the "Burst" and "Retreat" of the monsoon from the country, there is an interesting period of monsoon activity with spells of heavy rains and lulls of no rain or traces of rain. The later is called a "Break" in the monsoon, during such breaks there can be heavy rainfall in a small region. This is a weak monsoon period. These alterations or vagaries in the monsoon, form an interesting study and the problem of forescasting these vagaries is one of the most difficult tasks. Earlier studies on this aspect were scanty and unreliable as sea level data and pilot baloon charts could not provide complete information. In addition to this the data during the rainy season or active monsoon were meagre. This became a handicap in furthering the knowledge in this direction.

With the advent of sophisticated instruments like Radio Sonde and Rawin, accumulation of Aerological Data however has revealed that the space and time variations especially of the wind flow aloft are surprisingly large. Considering the sequence of events over wide areas in the tropics in the lower atmosphere upto about 600 mb. the steadiness of the flow is undeniable. In the lower troposphere, the course of events is very uniform especially the important intake of heat and moisture from the oceans which is dependant partly on the surface wind.But extreme restlessness exists in the upper troposphere.

The author with his synotic experience of the weather systems over India has made an attempt in the present study to understand the "Breaks" in the monsoon rainfall.

The weakening of the monsoon giving rise to partial or total interruption of rains for several days over major part of the country and simultaneous activation over sub-Himalayan region generally attributed to the shift of the monsoon trough to the foot of Himalayas. The monsoon trough is the most well known synoptic system associated with the monsoon after it gets established. This is also known as the equatorial trough (Riehl 1954). The axis of the monsoon trough runs at the 950 mb. level through New Delhi, Aligarh, Banda, Daltonganz, Hazaribag, Naydumka, Bogra, Tura, Gauhati and Tezpur (Ramaswamy 1967). The monsoon trough undergoes variations in its daily position at sea-level and lower troposphere. During well distributed monsoon activity (with no depressions) it occupies a southerly position. During the so called "Breaks" the axis shifts to the north and lies near the foot of Himalyas (Ramaswamy 1965).

Examining the available literature on this subject one finds very limited studies. Koteswaram (1950) related these "Breaks" to the westward movement of low pressure systems in the Equatorial Easterlies in the middle troposphere across south Bay of Bengal. Malurkar (1950) suggested that the northward movement of the seasonal trough is due to accentuation of seasonal low pressure cells in west China presumably due to a more southerly incursion of extra tropical disturbances than is usual for the season. He also postualted that the "July" Breaks are atleast partly caused by the absence of monsoon pulses crossing the equator from South to North over Indian Longitudes. Parthasarathi (1954) stated in connection with floods in the rivers near Eastern Himalayas during Break, that the synoptic situation is the shift of the sea-level monsoon trough towards the foot of Himalayas and the total absence of Easterly winds in Uttar Pradesh, Bihar and Assam. Raman (1955) has attempted to correlate the "Breaks" with the northward movement of "Typhoons" in the southwest Pacific. Koteswaram (1956) has shown that the equatorial Easterlies at 500 mb. spread as far as north of Latitude 18^{O}N. during a Break period. Pisharoty and Desai (1956) observed that the appearance of western disturbances during the middle of the monsoon period is closely associated with "Break". Kulkarni (1956) studied the period of "Breaks" in the southwest monsoon in July and August which ocurred during 1934-40 in relation to eastward moving westerly waves. It is observed that the Break conditions precede by at least two westerly waves in rapid succession and that the maintaiance of such Break condition needs the continuance of such waves. The Break condition ceases and the axis of the monsoon trough shifts southwards to its normal position soon after a low pressure area from the East arrives over Head Bay of Bengal and simultaneously the westerly waves disappear from the Indian area. Apparently this is associated with the re-establishment of an East west ridge of "high" pressure over west China and Tibet. George (1957) while contradicting the Raman's (1955) view -point argued that the effect of the typhoons in the south-west Pacific does not extend to Indian area and he supported the view of Malurkar (1950), Koteswaram (1950, 1956).

The average altitude of Himalayas does not exceed anywhere beyond 5.2 km. so Ramaswamy (1958) has studied the 500 mb. contours with data extended to higher latitudes. These contour maps showed that during the active monsoon over India there is a "high" over Tibet and Eastern Himalayas and a "Low" over central and peninsular Inadia. But during weak monsoon he noticed a trough over the Himalayas while the high over the Tibet and the low over central and Peninsular India were absent.

He further pointed out a high over north caspian sea during active monsoon and this high is found to be absent during weak monsoon and in its place there is a cut off low.

Further, added to the individual day 500 mb. patterns he presented mean 500 mb. patterns during the above two spells which showed a good consistency with the patterns for the individual days taking into consideration high latitude patterns also. He further presented mean zonal wind components over Calcutta and Delhi during the active and weak monsoon spells which clearly indicate the domination of westerlies over north west upto very high levels. He supplemented his studies with time sections over west Pakisthan and north India. The wind speeds of 60 knots at 300 mb. reached 78 knots at 200 mb. level during Break. The horizontal shear on the equatorward side of these winds corresponded to that of a typical Jet Stream.

While appreciating the broad scale patterns and of the 700 mb. (monthly mean) cahrts Ramaswamy discussed the flow patterns and systems therein for the above two selected cases and described the Active monsoon characteristics, differing from that of Break Monsoon.

Pisharoty and Asnani (1960) presented the idealised flow pattern at 500 mb. level during normal monsoon and break monsoon conditions. They found that prolonged Breaks in the Indian Monsoon are accompanied by pronounced changes in the 500 mb. patterns.

A detailed study a single situation of 1957 by Ramaswamy (1962) yied some interesting results in connection with Breaks. He discussed in detail the study of a synoptic situation over India during a period of eight days (3rd Aug. '57 to 10th Aug. '57, 4-9th Aug. '57, being the Break period whereas 3rd Aug. '57 and 10th Aug. '57 are being the days of normal monsoon before and after Break respectively). He has done, for this period of study, different methods of analysis which included surface maps, 500 mb. contour analysis, during, before and after Break, cross-sections of zonal winds and time sections and monthly mean 700 mb. maps. With these analysis he has shown systematic variations in the flow patterns to distinguish Break or weak monsoon from that of active or normal monsoon. He presented 500 mb. pattern during the earlier stages of the Break, peak of Break, and normal conditions after the Break. (Fig. 1a, 1b). The patterns of the 500 mb. level revealed that during the period of study the middle latitude trough in the westerlies approached Tibet from West. The amplitude of this trough increaed and moved into Tibet while the "High" over Tibet began to shift eastwards. The movement of the trough over to Tibet seemed to have resulted in the collapse of "high" over the area. The anticyclonic cell over Iran and Arabia protruded into the central parts of India in the rear of the large amplitude trough during the early stages of the Break, extended over the Peninsular India during Break and has gone back to its normal position after the Break.

The time sections over Calcutta and New Delhi during the period of study show that under break conditions the westerly component in the winds is much stronger in the middle troposphere and the easterly component is weaker in the upper troposphere.

He also presented the cross-sections of zonal winds along 75°E during this period. His results indicate during active monsoon an Easterly Jet core near 15°N with a secondary maximum near Latitude 20°N, and the westerly Jet is near 50°N. During Break the easterly Jet core has shifted slightly southward and the secondary maximum at 20°N above has developed Jet intensity. The latitudinal distance between the easterly Jet and Westerly Jet cores is reduced to 12 degress of latitude form 31 degress under normal conditions. His remarkable observation is that during Breaks in the Indian southwest Monsoon, the westerly Jet intrudes into Indo-Pakisthan, the easterly Jet developing a secondary core to the North of the main Jet core thus resulting in two Jets of entirely different types coming very close to each other.

Koterswaram (1963) while examining the structure of Asian summer monsoon, studied the flow patterns at 700 mb. and 200 mb. levels. The contour and isothermal analysis at these levels at different stages of the monsoon (Burst, active, Break and Retreat) revealed interesting points. The monsoon trough shifted to the extreme north of the country and the Tibetan plateau was surrounded by anticlockwise (Cyclonic) circulation at 700 mb. during Break. The warmest area extended from Iran to Tibet. At "Low" latitudes, a weak low had formed over Bay of Bengal and the westerlies appeared to the South indicating a revival of monsoon there. In the upper troposphere the pattern was typical. An anticyclonic cell was located over Tibet and Easterlies to the South have extended upto Latitude 30°N. The ridgeline has shifted northwards to Tibet. The circumpolar westerlies blew to the North of the ridge line and the westerly Jet Stream shifted to 42°N. He finally concludes that the Break seems to be a stage of the monsoon circulation with its core shifted farthest North over Tibet instead of one of disruption fo the monsoon caused by the incursion of circumpolar westerlies.

It is seen from the studies of Ananthakrishnan and Ramakrishnan (1963) that the area of strongest Easterlies at 14 km. is near Latitude 10^{O}N while the same has shifted to 19^{O}N during Break. They presented the troughlines at different levels between the Easterly and westerly air for an active monsoon and Break monsoon period respectively.

Desai (1966) supported the suggestions of Petterssen(1953) that the low level circulation of the Indian monsoon is a self sustaining system and the westerly Jet is not a part of the monsoon itself, India being to its South, and that the position of partition between middle latitude westerlies and easterlies to the south during July active monsoon and Break remains about the same along latitude 30^{O}N.

Dhar and Changraney (1966) made a study of meteorological situations associated with heavy rainfall in Assam and attributed the same to the "Break" conditions. This is only a descriptive or statistical study.

Desai (1967) commenting on the studies of Ananthakrishanan and Ramakrishnan (1963) agreed with the figures of trough lines at different levels, during active monsoon which show inclination upto 6.0 km. However he found during "Break" an equatorward slope in the trough lines.

Most of the above explanations on "Break" monsoon were based on single case studies. So the author extended the studies for a five year period (1961-65) with a view to get at a consistent picture of break conditions. The study includes the flow patterns in the lower, middle and upper troposphere to distinguish Break conditions from that of active monsoon. A prelminary investigation was conducted by the author first for the earlier years 1958, 1959 and 1960 and the study in detail was extended for the years 1963 to 1967.

PRELIMINARY STUDY :

This study enabled the author to select two types of situations (Fig. 2 and 3).

(1) North Break Monsoon (Rains confined to south with meagre precipitation in the North).

(2) South Break Monsoon (Rain occuring in North India with meagre in South.

The pressure distribution in these two cases differ markedly from the normal.

In the former case the monsoon low has weakened and it occupied either the whole of North India (Fig. 2a) or the monsoon trough is shifted considerably to the south (Fig. 2c, 2d) and extended into the Bay. The monsooon air is discouraged from entering the northern parts. Normally the southward shift of the monsoon may not perfectly block the monsoon air in which case a narrow stream may be entering the Assam region where rain is received. The blocking would be better if the southward shift of trough extends more into the Bay of Bengal. During long periods when this type of pressure distribution exists, weak low pressure pulses would be travelling westward over North India giving rise to considerable precipitation in small areas but without appreciavly changing the monsoon activity over the rest of the country. If the pulse happens to be a strong one the monsoon will be strengthened and is extended into North India, completely modifying the existing conditions.

Heavy rains in North India with meagre rainfall in the south are the features of South Break monsoons. The monsoon trough is pushed towards the Himalayas (Fig. 3). When the pressure gradient is small over south India this disparity in the rainfall distribution is much more (Fig. 3a). When an easterly low pressure wave moves across North India, the rainfall in that regions is further intensified. These two cases emphasize the influence of the location of the monsoon trough on the rainfall distribution over the country.

It is a matter of interest to know, what type of synoptic situations would be favourable for rainfall over the whole country. A few of them are presented in figure 4. In general the monsoon low is intense and the monsoon low is intense and the monsoon trough occupies the normal or slightly southerly position and does not block the monsoon air from entering North India. The activity in the trough is indicated by the presence of low pressure cells. Under these conditions copious rainfall is received throughout the country. A synoptic sequence is presented in Fig. 5 which is in fact the continuation of the situation shown in Fig. 2b.

AEROLOGY

LOWER TROPOSPHERE:

Typical flow patterns at 1.5 km during the north break monsoon and south break monsoon are presented in Figs. 6a, b and c, d respectively. In the former case the belt of the monsoon westerlies has limited width and is confined only to South of 20^{0} latitude, however the strength of the westerlies seem to be more than normal. In the figure 6a a weak easterly stream flows only along the southern boundary of the Himalayas. These easterlies are in fact the downward extension of the upper easterly current. In between these two oppositely directed streams there is a large area with very weak cyclonic circulation. Thus the situation very clearly shows how the westerlies are confined to southern latitudes. In Figure 6b the monsoon westerly belt is not completely blocked from entering the north Indian region. A narrow stream fed by the westerlies enters the Bengal region as a southerly wind, and over rest of the North India variable winds prevail. At higher levels it is found that the trough line, which runs along the northern border of the monsoon westerlies, is situated in a more southerly position than normal.

The usual monsoon trough could not be located in Fig.6c except over a small area at 30^{0} latitude north of Delhi. In both the Figures 6c and 6d the monsoon trough is situated at higher latitudes than normal. Westerlies prevail over the whole country with reduced strength.

DETAILED STUDY -BREAKS:

The results of the preliminary investigation reported earlier and the conflicting views expressed by different workers on the "Break" Monsoon using very limited data, encouraged the author to take up a more detailed study of Break conditions of the monsoon during the years 1963-67. The author used different methods of analysis for the interpretation of the Break Monsoon conditions over the India Sub-continent.

Fortunately the author could secure surface and upper air data of Northern Hemisphere for the period mentioned above. He utilized the same for 700, 500 , and 200 mb. contour analysis, in addition to the cross-section of zonal winds for 1963.

METHODS USED FOR THE STUDY:

Various methods of study have been undertaken to understand the Breaks and the associated synotic patterns. The methods used are:

(1) Cross-Section of zonal (Ramaswamy 1962, Koteswaram 1958, Hess 1948).
(2) Vertical time sections (Ramaswamy 1962).
(3) Contour analysis at 700 mb., 500 mb., 200 mb. levels (Ramaswamy 1962, Koteswaram 1963, Pisharoty and Asnani 1960).

Contour Analysis for 700, 500 and 200 mb. levels are done for the years 1963, 1964, 1965, 1966, and 1967 for the five selected cases. Care is taken in drawing the contours so that consistent features of synoptic situations are manifested.

1 - Cross sections of zonal winds from surface to 21 km. are prepared for five cases in the years 1963, 1964, 1965, 1966 and 1967 along longitude 75^0E for the following dates (Figs. 7, 8, 9, 10 and 11).

YEAR	BEFORE BREAK (NORMAL MONSOON)	BREAK (PEAK OF BREAK)	AFTER BREAK (REVIVAL OF NORMAL MONSOON)
1963	8th July	11th July	18th July
1964	5th July	15th July	23rd July
1965	1st August	12th August	23rd August
1966	21st August	25th August	30th August
1967	2nd July	5th July	13th July

2 - The Time sections are shown for the three years though the same has been done for all the five years in order to avoid repitions (Fig. 12)

Calcutta and New Delhi are chosen for the study so that a comparison can be made with similar studies made by Ramaswamy (1962). The above stations are selected for the monsoon trough passes through these and these stations also lie in the regions where the wind changes from Westerlies to Easterlies.

CROSS-SECTION OF ZONAL WINDS:

NORMAL MONSOON :

Please refer Figs 7, 8, 9, 10 and 11. The following are the important characteristics worth mentioning.

1 - The Easterly Jet is located in the regions 10^{o} - 15^{o}N in all the cases.

2 - The westerly Jet was located at Alam Ata (Lat. 43^{o}N, 76^{o}E in the year 1963. This could not be located for the rest of the years 1964-67 as it is situated beyond the cross-section since the present analysis is limited 34^{o}N.

3 - The distance between the Easterly and westerly Jet cores ranges from 30^{o} to 34^{o}.

4 - The easterlies increased at higher levels from 6.0 km. upwards upto 18.0 km.

5 - There is neither pronounced shear of wind nor the equatorward movement of westerlies.

6 - The intensity of easterly Jet reached 80 to 100 knots.

BREAK MONSOON:

1 - The easterly Jet shows a northward shift Koteswaram (1963) has observed northward shift of the easterly Jet in his studies, whereas earlier Ramaswamy (1962) reported a southward shift which the author could not find in the present study of Koteswaram (1963) and Ananthakrishnan and Ramakrishnan (1965).

2 - The westerly Jet shifts southwards during Break in the year based on one

year data. A similar result has been reported by Ramaswamy 1962.

3 - The latitudenal distance between the two jets is found to be 20-25° as against 30-34° under normal conditions (Ramaswamy 1962), however reported a distance of 12° latitude between the two jet cores based on one year data.

4 - The easterlies increase in strength and persist during Break. This feature is also found in the results of Koteswaram (1963) whereas Ramaswamy (1962) reported a decrease instead of an increase.

5 - There is a pronounced horizontal wind shear between 20° and 35°N above 10 km. This agress with the observation of Ramaswamy (1962).

6 - The strength of easterly Jet decreases during Break.

<u>TIME-SECTIONS</u>: (Please refer Figs. 12a , 12b.).

<u>CALCUTTA</u>:

1 - During normal monsoon conditions the westerlies at lower levels change to easterlies above 4.5 km and these easterlies increase with height upto 10.0 km.

2 - During break conditions the lower westerlies extend upto 7.2 km above which weak easterlies prevail, compare to normal monsoon conditions.

NEW DELHI :

1 - During normal monsoon, the winds are variable at lower levels and change to easterlies at 7.2 km. and these easterlies increase with height to 18.0 km.

2 - During break, the westerlies are dominant upto 12.00 km. above which lie weak easterlies.

On occasions easterlies are observed at lower levels after the Break due to the existence of a depression in the Bay of Bengal. The observations clearly indicate the northward shift of the monsoon trough.

700 MB. CONTOUR ANALYSIS: (Please refer Figs. 13, 14, 15, 16).

1 - The monsoon trough from its original position (active monsoon) shifted north and lay close to the foot of Himalayas during "Break". This observation is in agreement with previous studies (Parthasarathi 1954, Parthasaradhi 1960, Ramaswamy 1962, Koteswaram 1963).

2 - No pronounced ridge over Soviet Russia is found during active Monsoon east of 70^{o}E (1958) in the daily 700 mb. chart. Ramaswamy reported the existance of a pronounced ridge over Soviet Russia from his mean 700 mb. chart and suggested, that similar ridge to exist on daily 700 mb. chart.

3 - A closed "Low" over Eastern India and Assam found during active monsoon

became an extended "low" over the same region during "Break" (except in 1966).

4 - The high located between 60° - 70°N and 60 - 120°E during active monsoon moves westwards during break.

5 - A "High" over Pacific area during active monsoon receded during Break.

6 - A very deep trough extending from 70°N to 45°N is located during Break (Koteswaram 1963).

7 - The Tibetan Plateau is surrounded by cyclonic circulation during break (Koteswaram 1963).

8 - In some of the cases, westerlies to the south of the low in the latitudes indicate the revival of monsoon (Koteswaram 1963).

9 - The concentration of westerlies continued in the rear of the trough even during Break with a slight southward shift. This shift is not so much as reported by Ramaswamy (1962).

<u>500 MB. CONTOUR ANALYSIS:</u> (Please refer Figs. 17, 18, 19, 20).

1 - The middle latitude trough in the westerlies during the active monsoon approached Tibet, moved eastward during Break with increased amplitude. The same is reflected in the observation of Ramaswamy (1962).

2 - The northern and southern ends of the above trough are also displaced to the east during break as found from the studies of Pisharoty and Asanani (1960) whereas the central portion of this trough over Sinkiang had a slight retrograde motion during break pressumably due to accentuation and southward extension of "High" further to the northeast over USSR. This is reported by Pamaswamy also (1962).

3 - The "High" over Soviet Russia extending from 60°N to 70°N and from 65° to 115°E (Ramaswamy located it at 55° - 70°N and between 85° -

- 115^{0}E) caused the Subtropical westerly Jet Stream to split into two branches, and retrogrades during Break. Such observation is made by Ramaswamy (1962).

4 - The "High" over the Tibetan region during active monsoon is displaced to East and the "High" either collapsed or moved Eastward during "Break" Similar observation is noticedin the studies of Ramaswamy (1962).

5 - The ridge from the Pacific High during the active monsoon also recedes during Break and in its place, a well marked trough appeares over China. (Pisharoty and Asnani 1960).

6 - There is a pronounced ridge over the North Caspian Sea and Stalingrad region during active monsoon and is absent during Break. In this region a cut-off low during Break as reported by Ramaswamy (1962) could not be located.

7 - The southern branch of the westerly belt is almost a straight west to east current between 35^{0} and 45^{0}N.

8 - Good concentration of westerlies between 40^{0} and 50^{0}N (in some cases 60^{0}N) reached Jet intensity during Break at this level and aloft.(Ramaswamy 1962).

9 - The anticyclonic circulation over Ceylon and neighbourhood has been displaced towards northeast during Break.(Pisharoty and Asnani 1960).

10 - 500 mb. level is found to be an ideal level for the present study (Roy Berggren 1957, Pisharoty and Asnani 1960).

<u>200 MB. CONTOUR ANALYSIS</u>: (Please refer Figs 21, 22, 23, 24,)

1 - The trough from 70^{0}N - 30^{0}N and from 0^{0} - 20^{0}E moved eastward during "Break".

2 - The trough from 60^{0}N to 30^{0}N and from 80^{0} to 90^{0}E retrograde during "Break".

3 - The trough from 60^{0}N to 40^{0}N and from 100^{0} to 120^{0}E becomes deep, moves

westward during Break.

4 - A well marked low over south Peninsular India as reported by Ramaswamy (1962) during active monsoon is absent at this level.

5 - The ridge line (bet 25°N and 35°N on the average) moves southward during Break, and this ridge shows a cellular structure during Break.

6 - The ridge is found to lay almost over the "High" at 500 mb. level which extended into central India. Ramaswamy (1962) reported the existence of ridge over Tibet, but according to the present studies the anticyclone is over Iran and Indian plains,(Koteswaram 1963).

7 - The upper ridge is lying slightly north of monsoon trough during active monsoon whereas Koteswaram (1963) found the same lying almost over the monsoon trough.

8 - The westerlies blow to the north of the ridge line and the westerly Jet shifted south to 40°N during Break. This result is reflected in the cross-section of zonal winds. The subtropical Jet stream shows more meandering during active monsoon, straightens during "Break".

9 - During active monsoon the strong anticyclone extending from the Caspian Sea to North east Arabian sea is conspicuous. This ridge was found even 500 mb. also. This feature was noticed in the studies at 500 mb level by Pisharoty and Asnani (1960) and Ramaswamy (1962).

10 - Two waves in the upper easterlies and two in the westerlies are found during normal monsoon. Koteswaram (1963) reported only one in the easterlies. The easterlies continue over India in the Upper levels during "Break". The easterly Jet shifts northward indicating an increase in the easterly circulation (Parthasarathy 1960, Koteswaram 1963) and on the contrary Ramaswamy (1962) found a decrease. The present results show an agreement with studies of Koteswaram (1963).

GENERAL SUMMARY

The relatively large amplitude trough extending to south of $40^{o}N$ over Russia, Turkestan move slowly eastwards over Tibetan plateau which exercise a sheltering effect on the westerlies flowing over and near it, resulting in the weakening of westerlies above the plateau compared to those at the same level to the East and west of it. Further these troughs get retarded and at the sametime, the horizontal amplitude increases due to the weakening of Basic current (Berggren, Bolin and Rossby 1949, Rossby 1950, Ramaswamy 1962). It is futher observed that the North and South ends of this trough move faster than the middle portion (Pisharoty and Asnani 1960) and this may be due to the accentuation and southward extension of High further to the northeast of USSR (Ramaswamy 1962).

While the trough invades the Tibetan plateau the high over it gets displaced Eastwards or sometimes destroyed. This effect is most pronounced at 500 mb. levels (Ramaswamy 1958, 1962) during this process there is a complete reversal of flow pattern over north India from easterlies to westerlies at this level.

The middle latitude trough which penetrates into North India is associated with a Jet in the rear of the trough line at 200 mb. level. Associated with this trough, upper level divergence is predominant ahead of the trough (Riehl 1954, Pettersen et al. 1955, and Ramaswamy 1956). The forward region of the troughline lies along the foot of Himalayas and as such the moist southwest monsoon current pervades the regions in the lower troposphere. Hence the upper level divergence and low level convergence contribute to the heavy rainfall along the foot of Himalayas (Ramaswamy 1962, 1967).

Associated with the slow eastward movement and extension of the large amplitude trough into India at 500 mb. level, the High over Arabian Sea and Iran shifts southwards and protrudes into India. This appears to be responsible for prevailing dry conditions over central and penensular India (Ramaswamy 1958, Pisharoty and Asnani 1960, Ramaswamy 1962).

The confluence of the easterlies caused by the southward protrusion of Iranian High and the prevaliling easterlies over peninsular India result in the intensification of the easterlies in the region.

In association with southward shift of Iranian High, it is reasonable to expect the southward shift of westerly Jet. This is clearly evident from the cross-sections (Fig. 7, 8, 9, 10, 11) in which it is observed that the lateral distance between westerly and easterly Jet cores during the Break period decreases considerably from that of a normal monsoon period.

It is observed that the Tibetan High persits at higher levels even in weaker state. Associated with it the easterlies are observed to increase with height along the southerh periphery of the "High" and to concentrate into a Jet stream (80 knots) with its core at 15°N.

The role of the interaction of subtropical westerly Jet stream with the easterly Jet stream during the development of break in south west monsoon is found to be an important factor whereas during the normal monsoon the westerly Jet moves far to the north of Himalayas and the easterlies hold sway over Indias Koteswaram (1958, 1960).

From the above studies it is clear that unless we probe the lower middle and upper troposphere and follow the flow patterns at these levels during various stages of monsoon it may not be possible to assess the factors responsible for the break condition. Hence it is obvious that the studies must always be extended latitudenally and longitudenally so that the extratropical systems and their subsequent movement or changes are clearly minifested in the variations of surface weather (Hutchings 1963).

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Fig. 1a

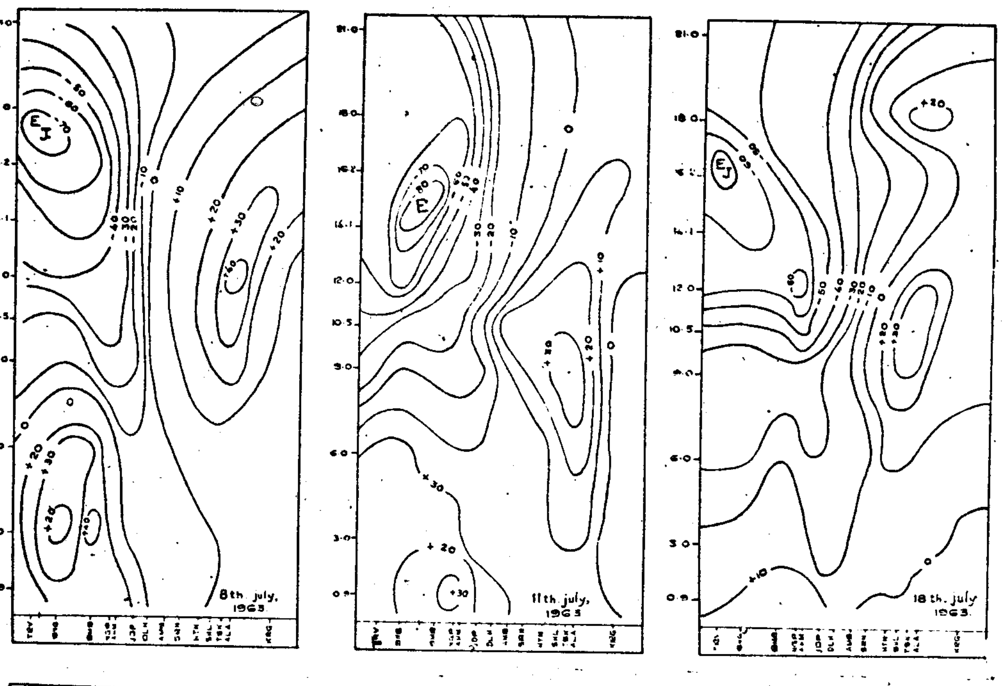
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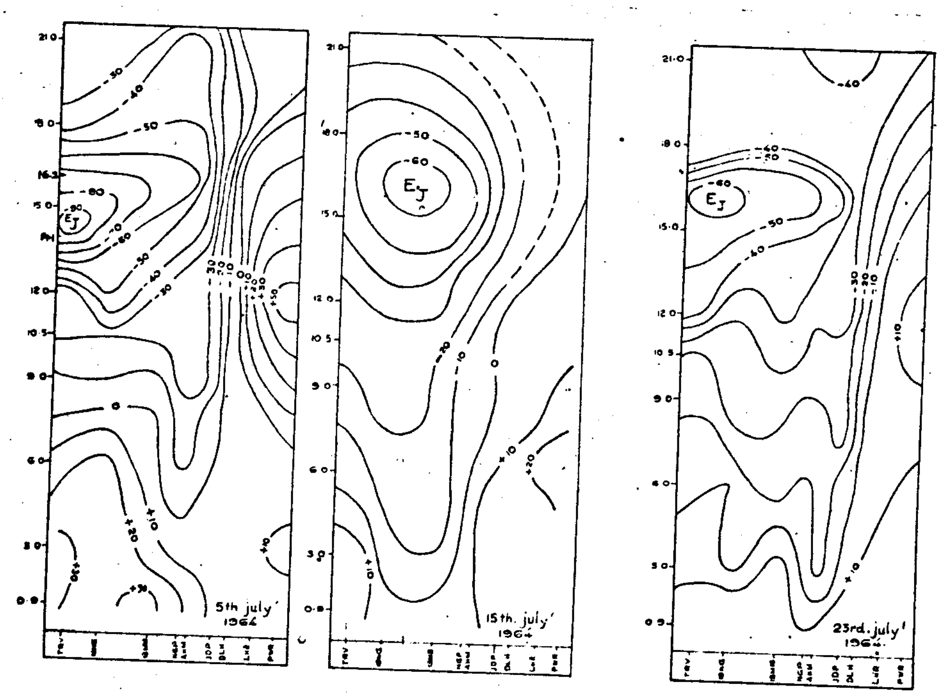
Fig. 1 b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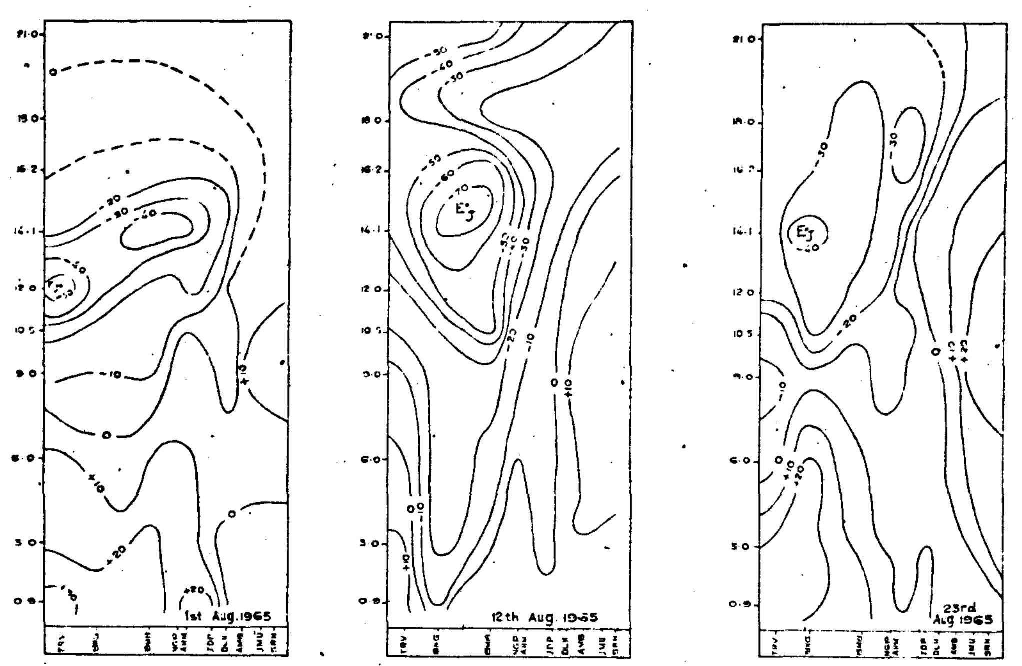

1st Aug.1965
12th Aug.1965
23rd Aug.1965

Fig. 1c.

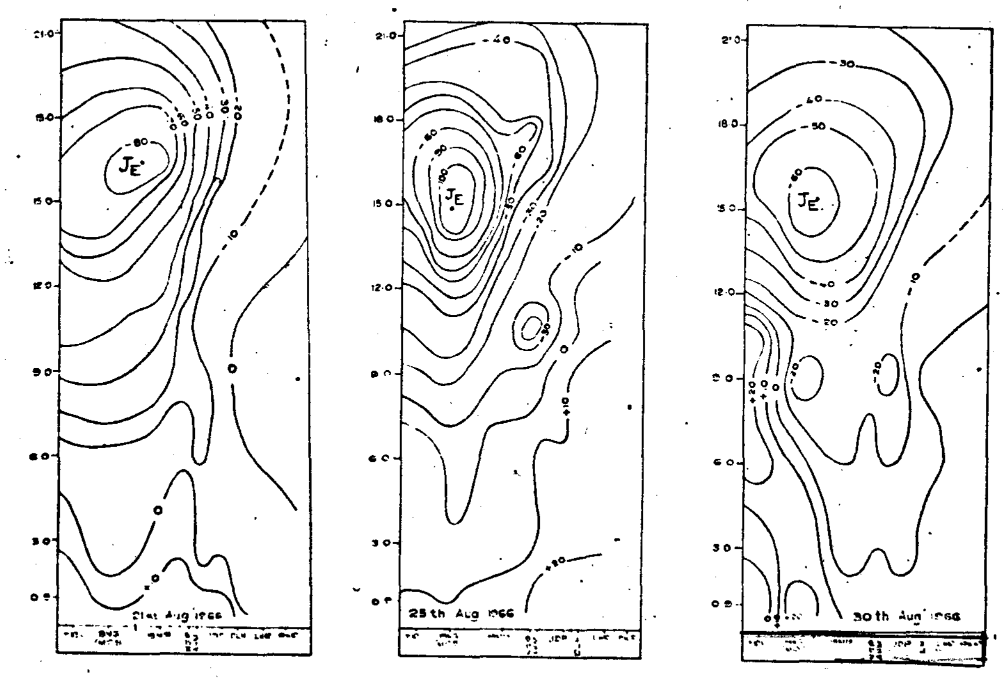

21st Aug.1966
25th Aug 1966
30th Aug 1966

Fig. 1d

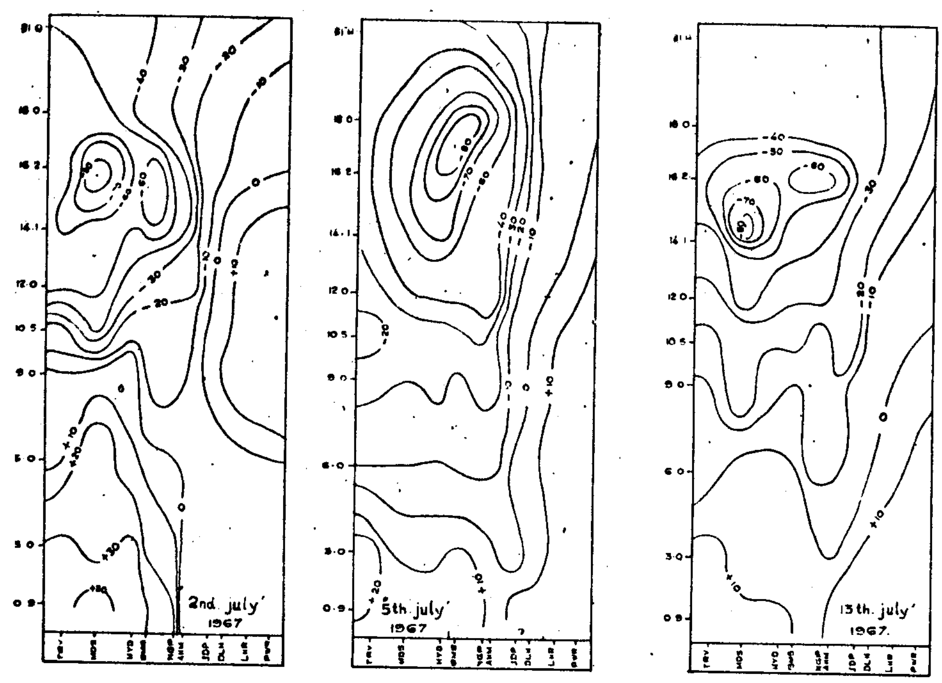
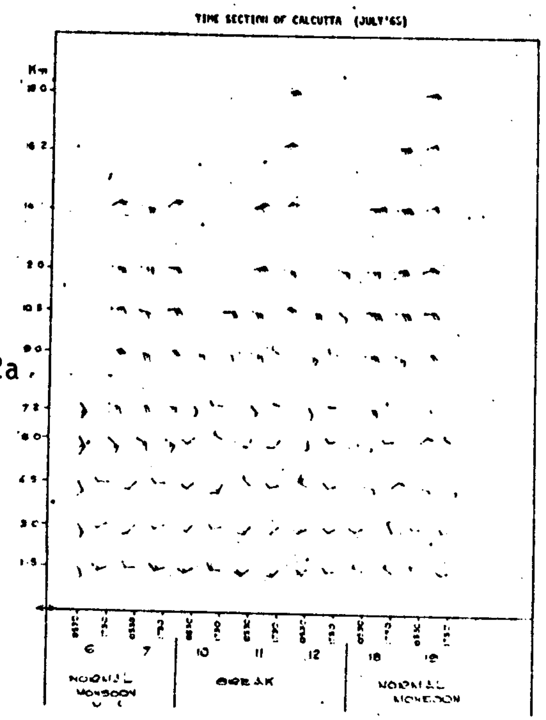


Fig. 1e



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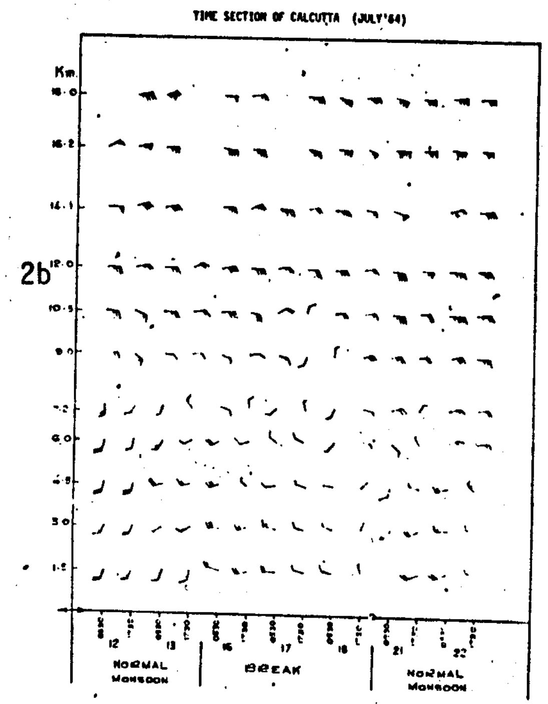

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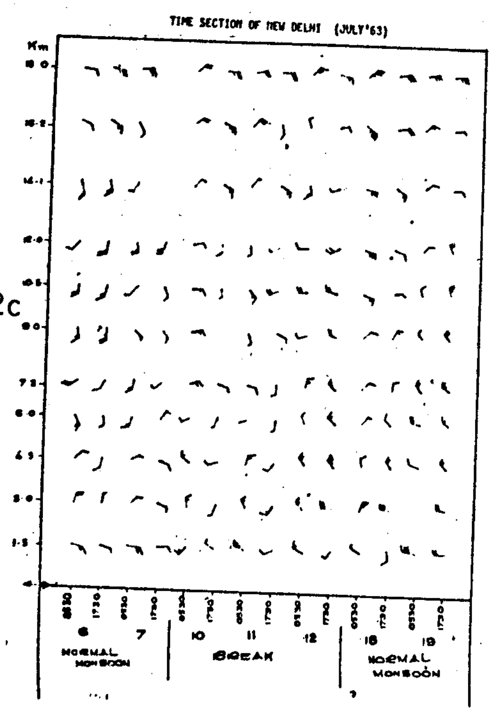

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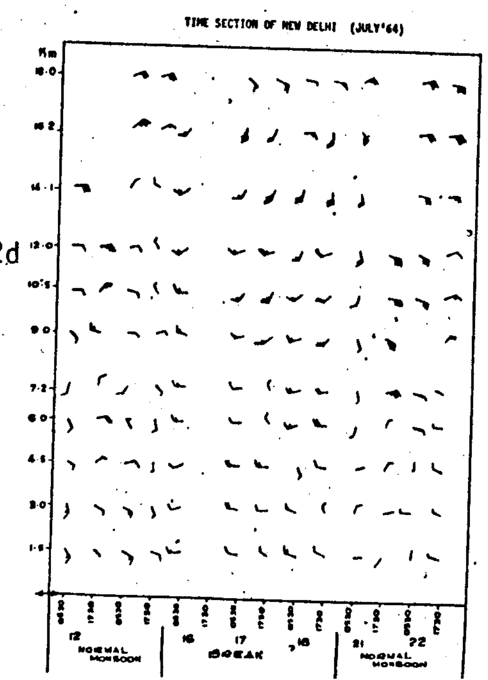

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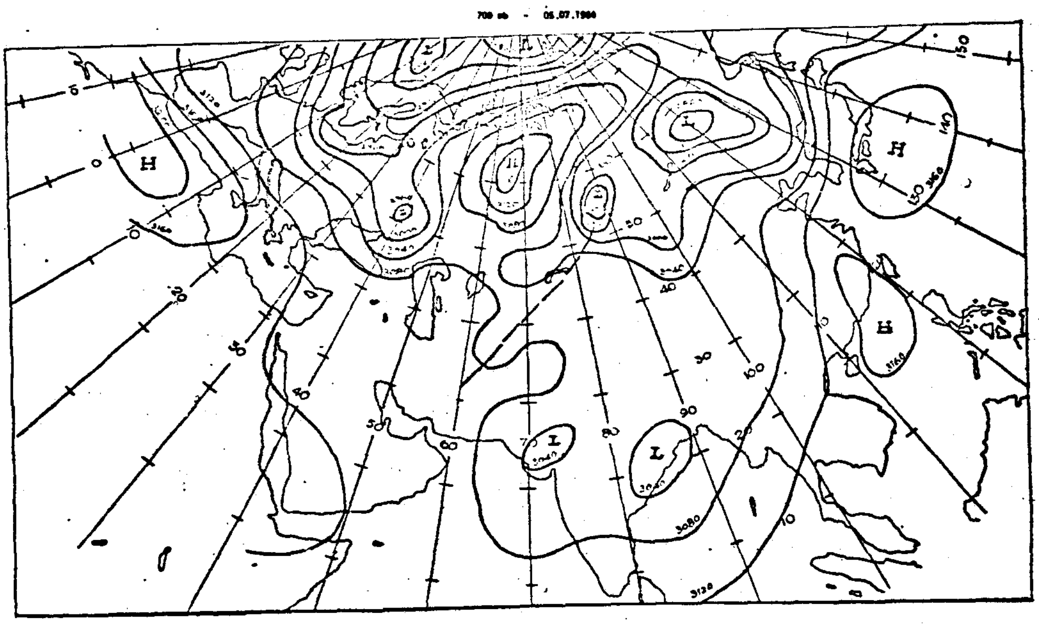
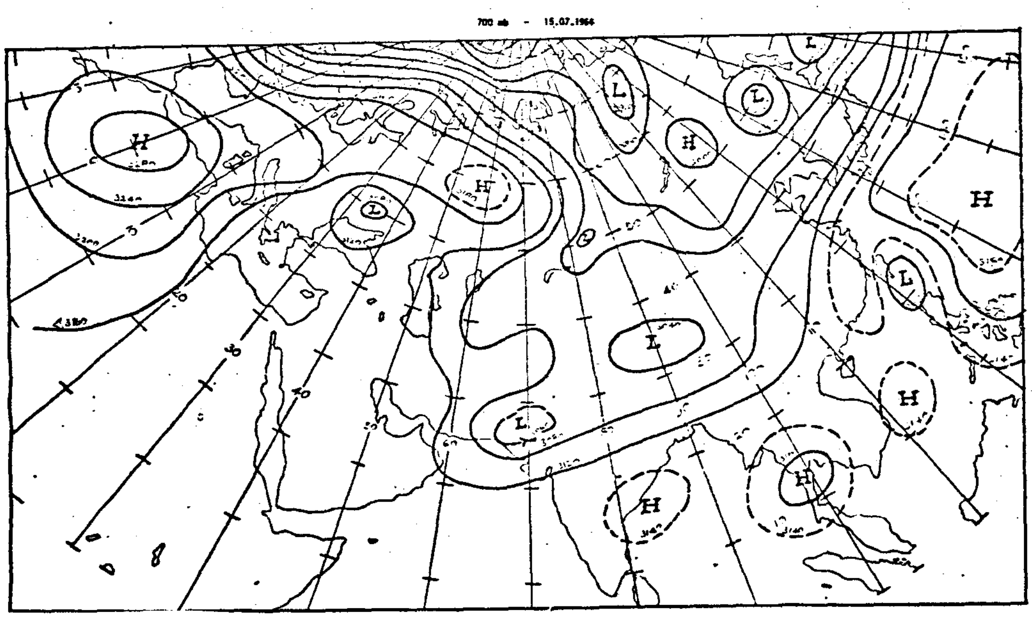


Fig. 3a



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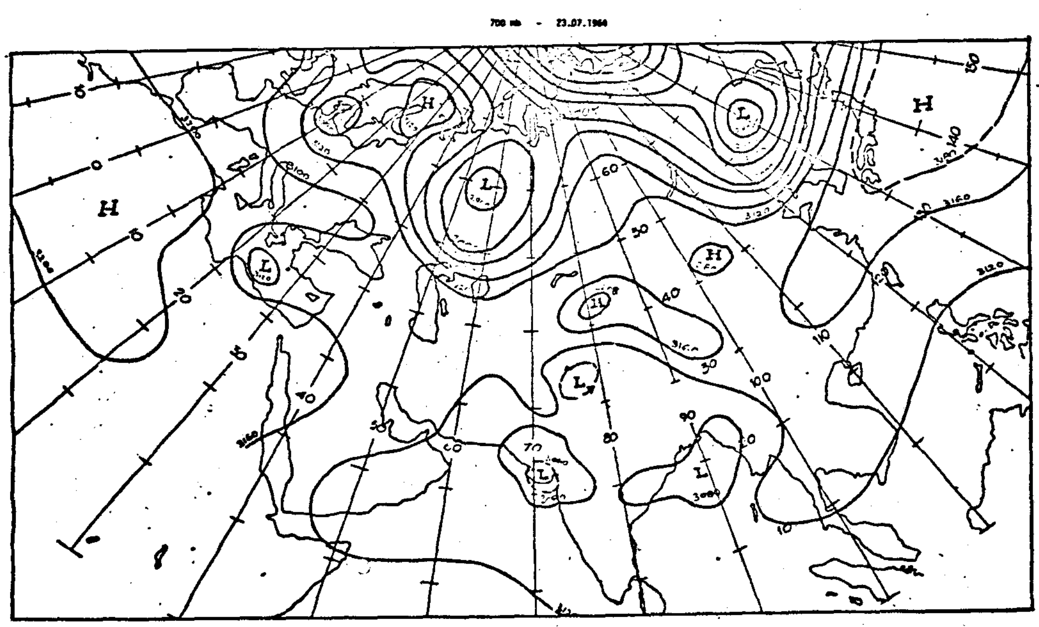
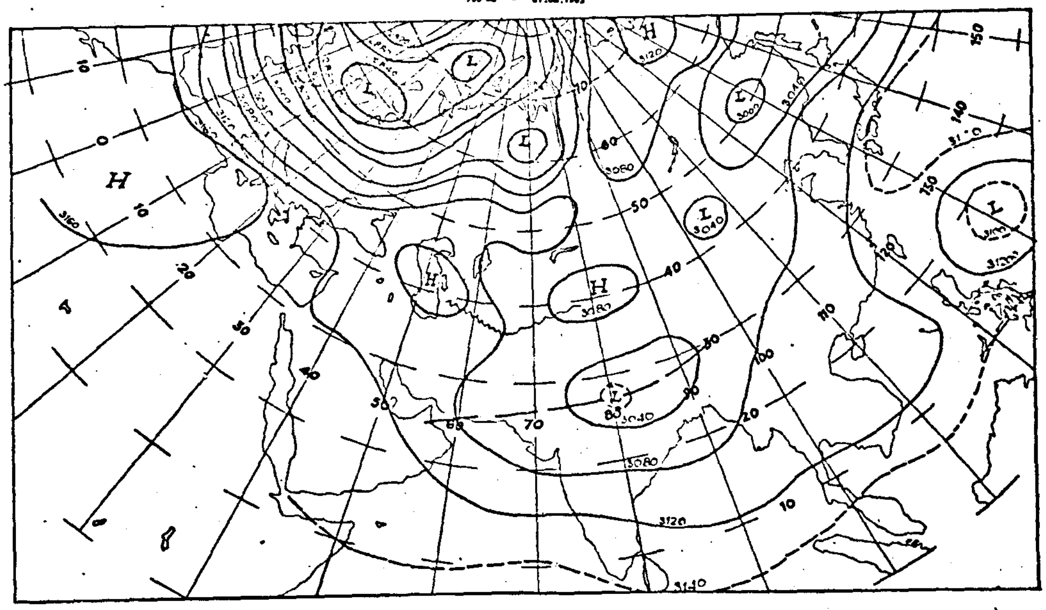


Fig. 3c

700 mb - 01.08.1965



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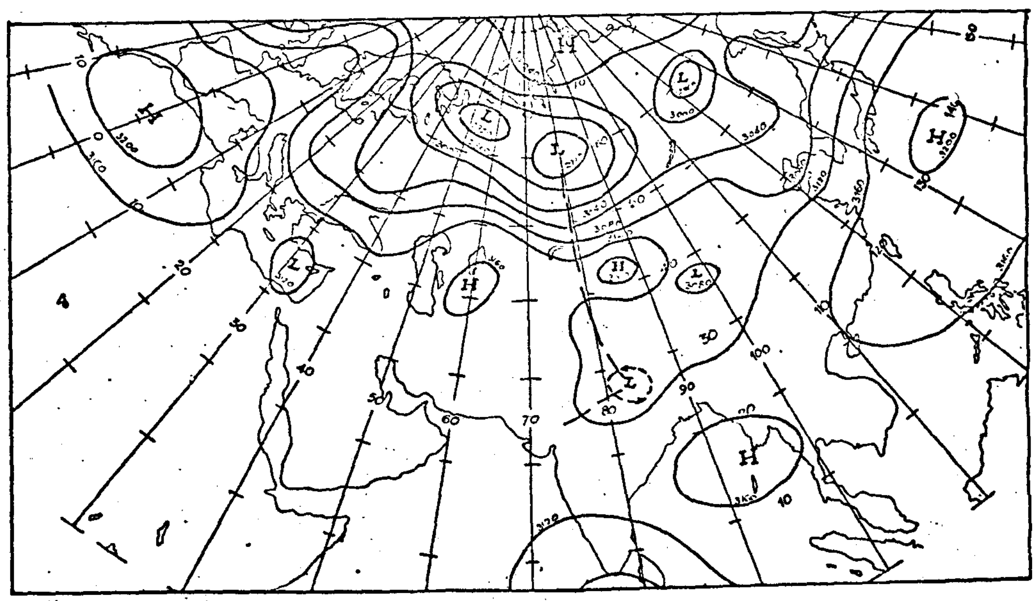


Fig. 3e

700 mb - 23.08.1965

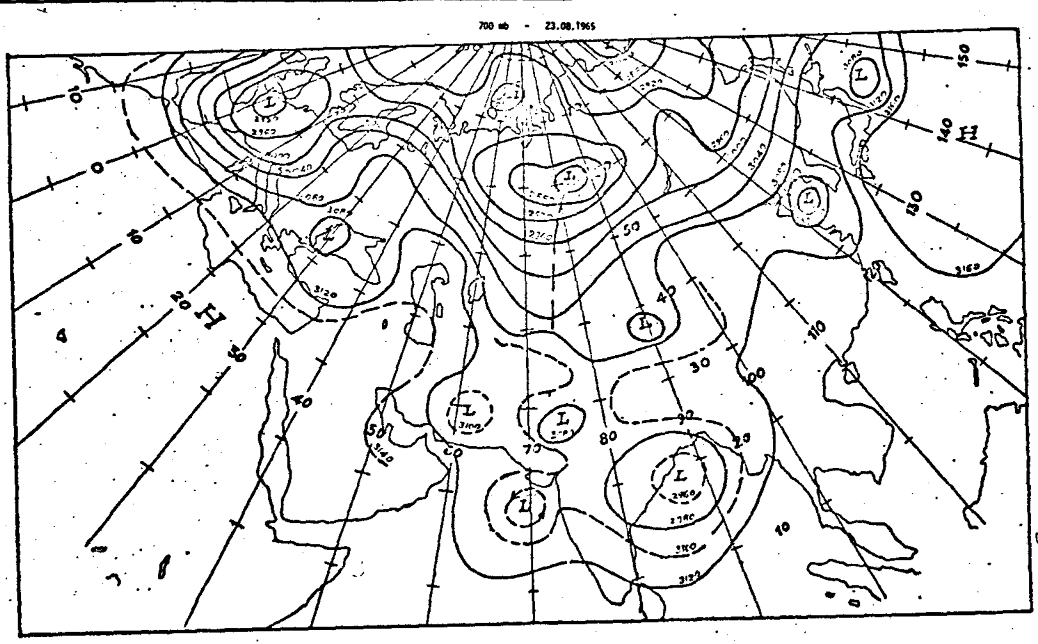


Fig. 3f

700 mb - 21.08.1966

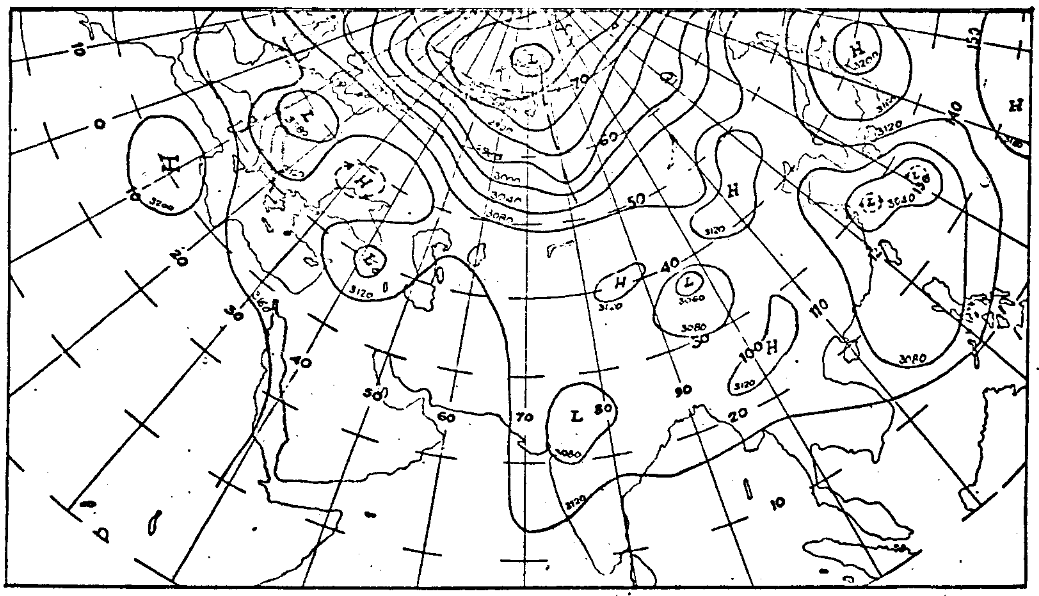


Fig. 3g

700 mb - 25.08.1966

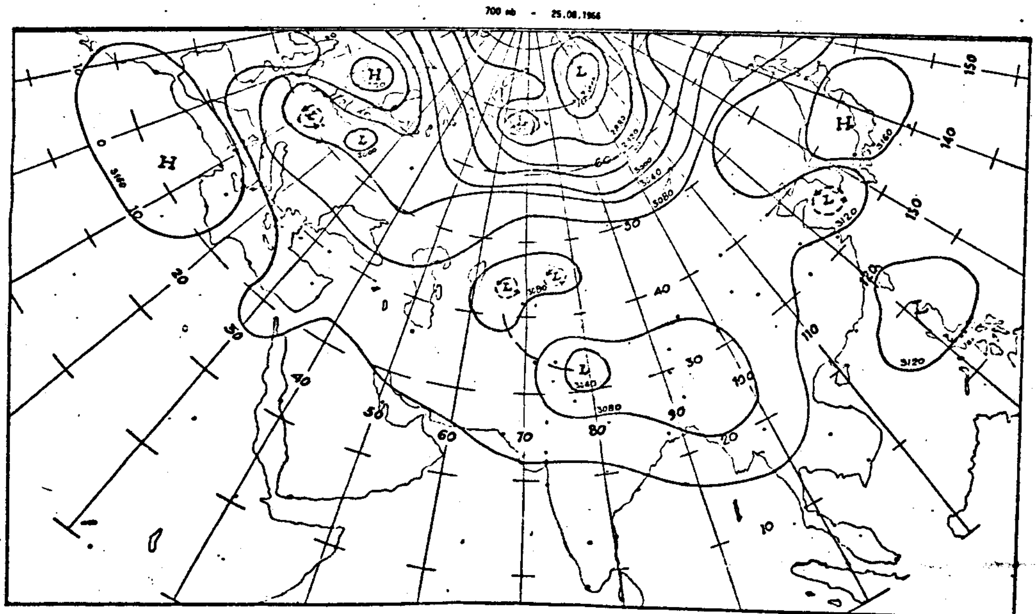


Fig. 3h

700 mb - 30.08.1966

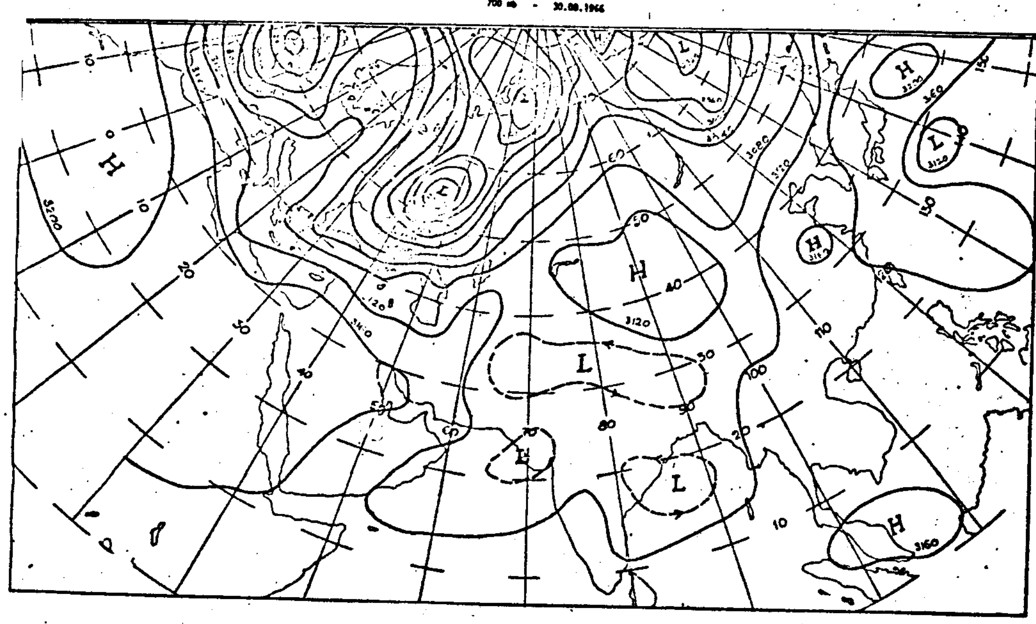
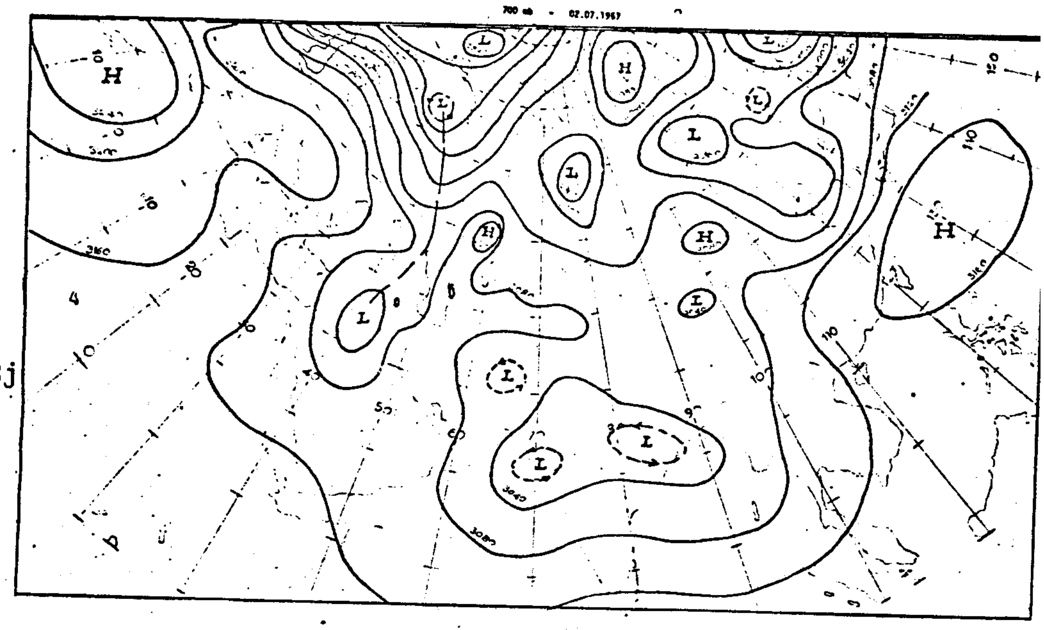


Fig. 3i



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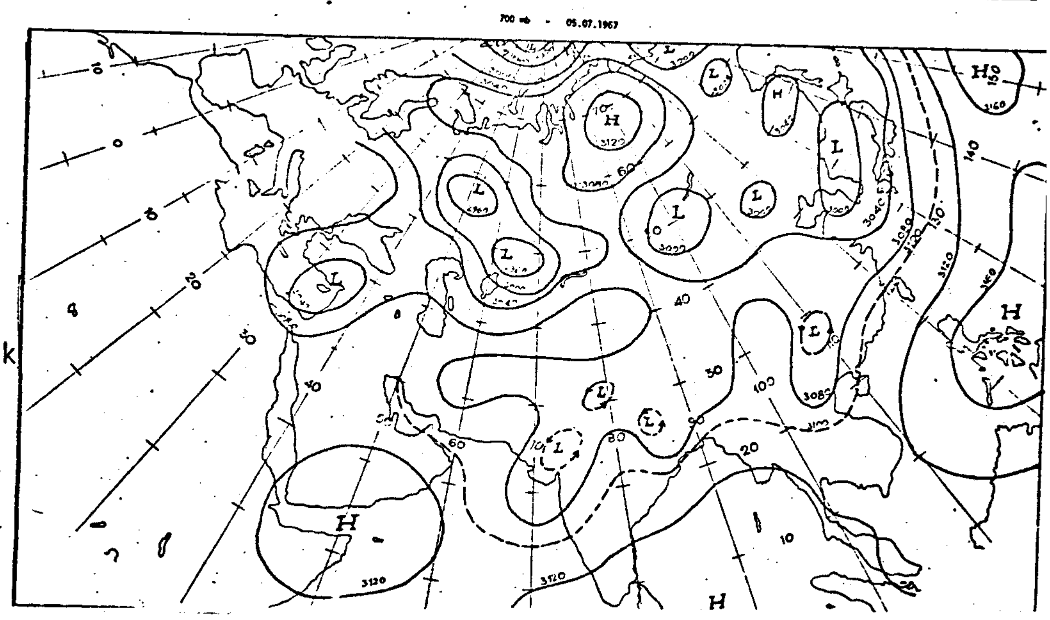

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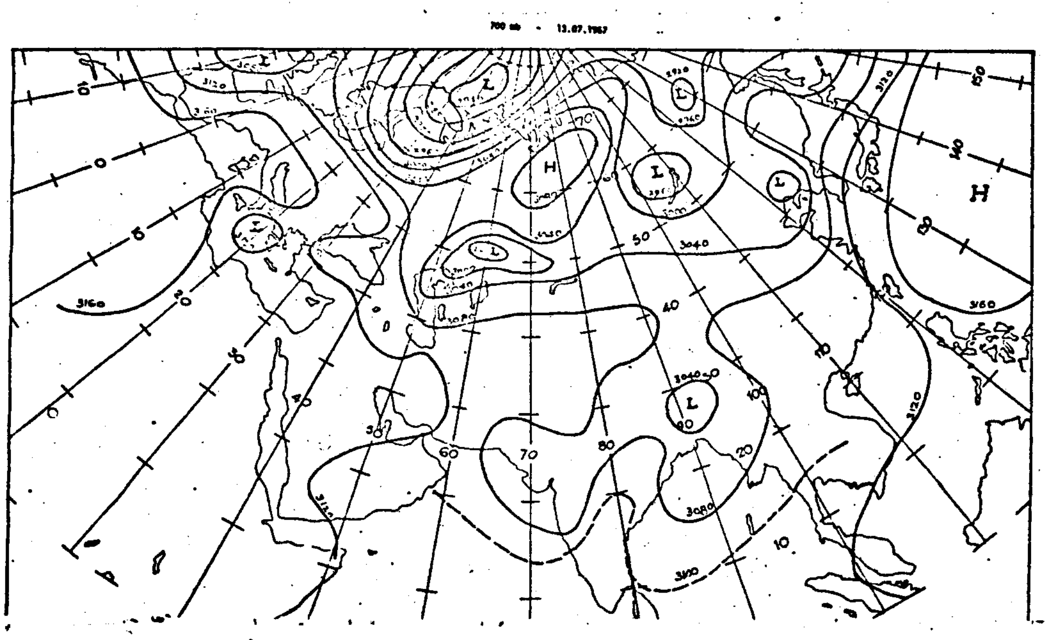
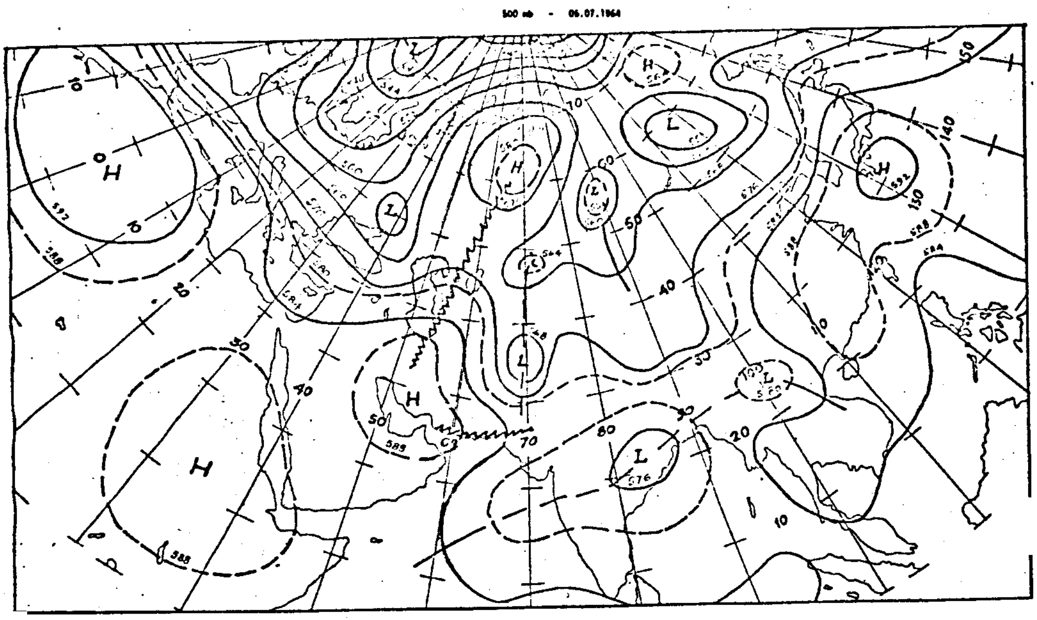


Fig. 3ℓ

Fig. 4a



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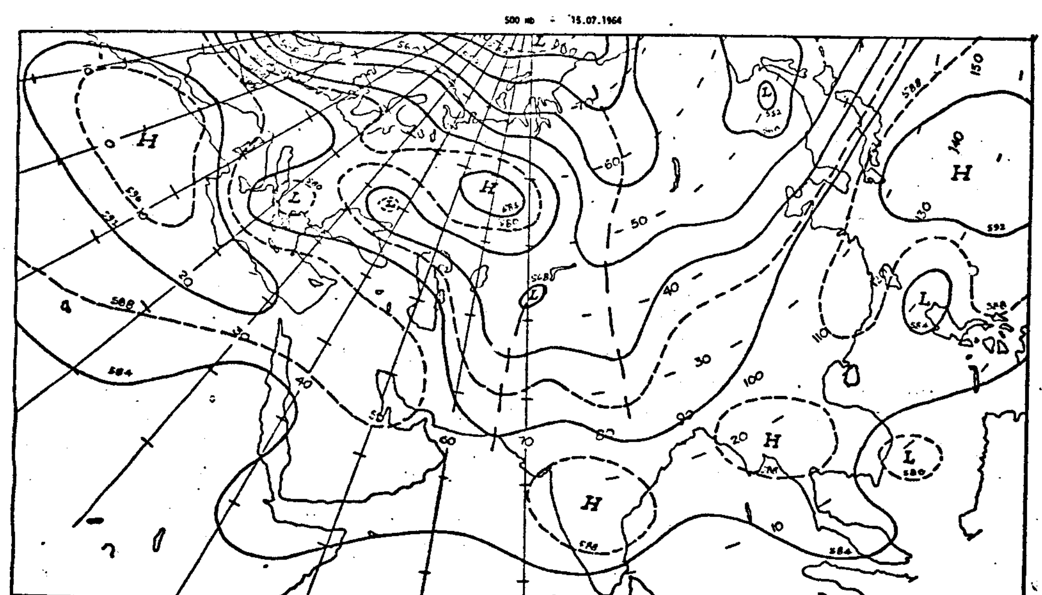

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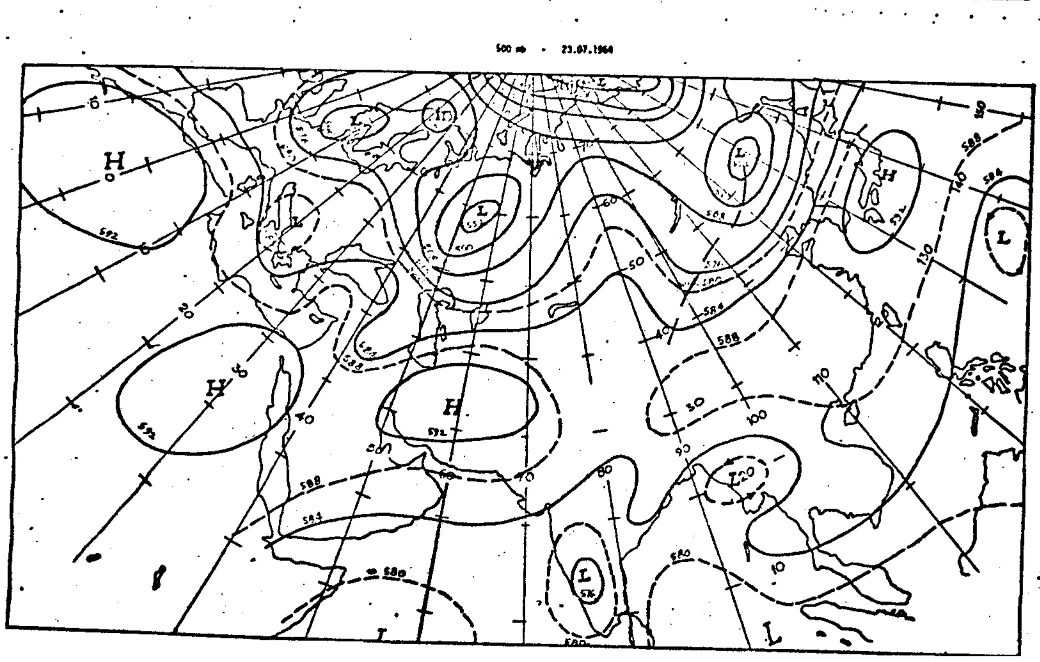

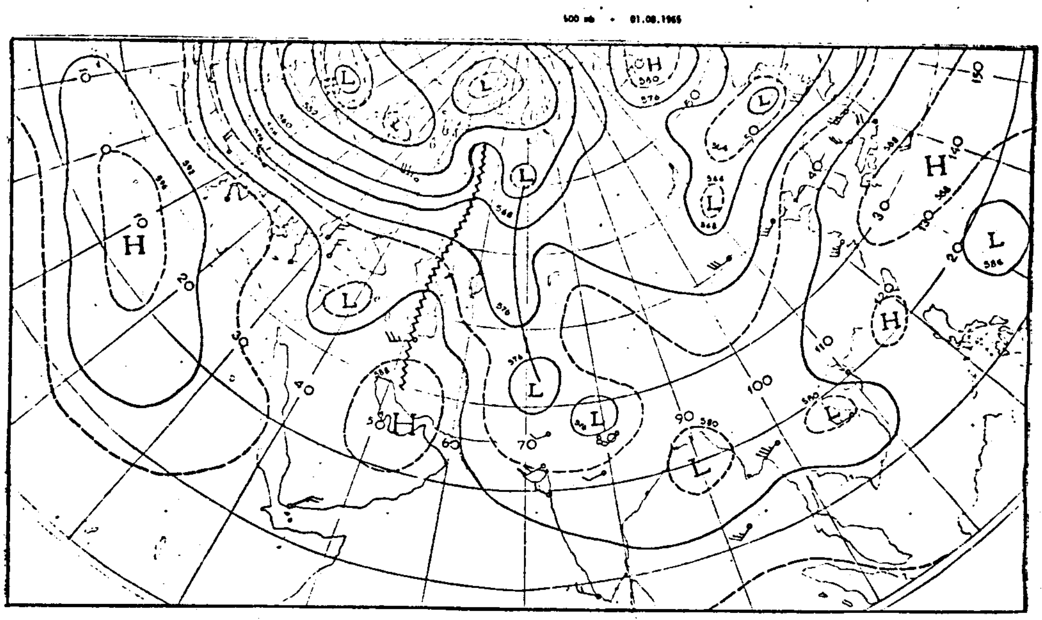

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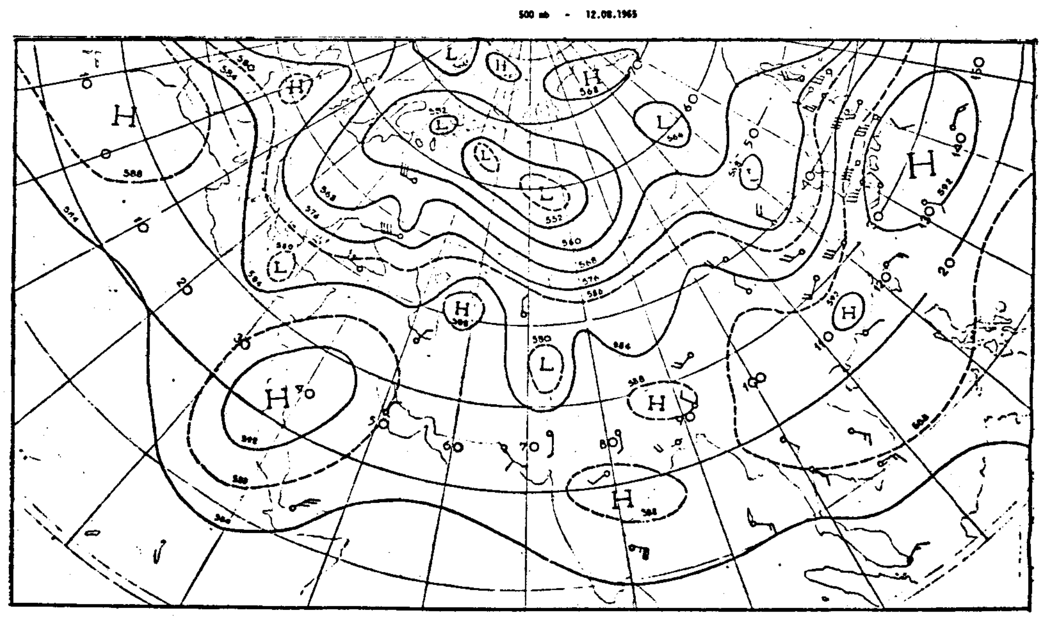

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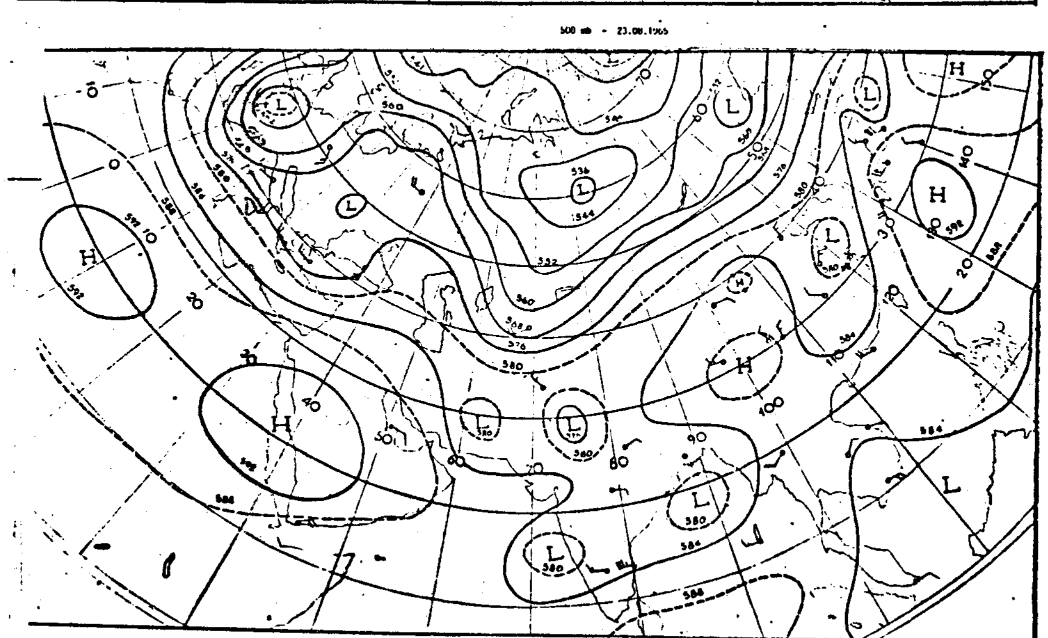

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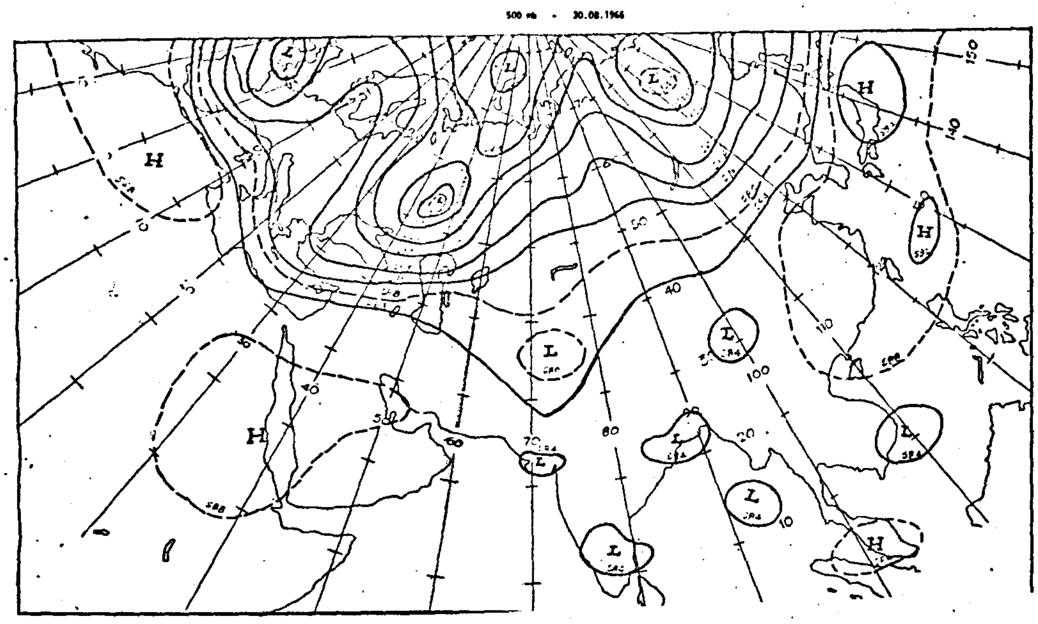

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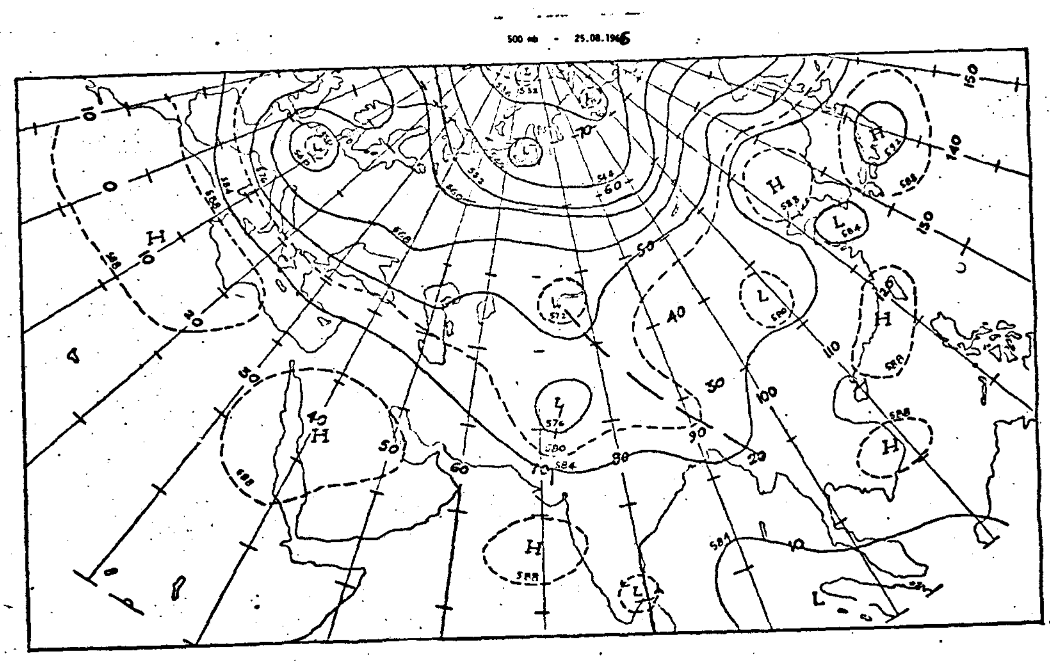

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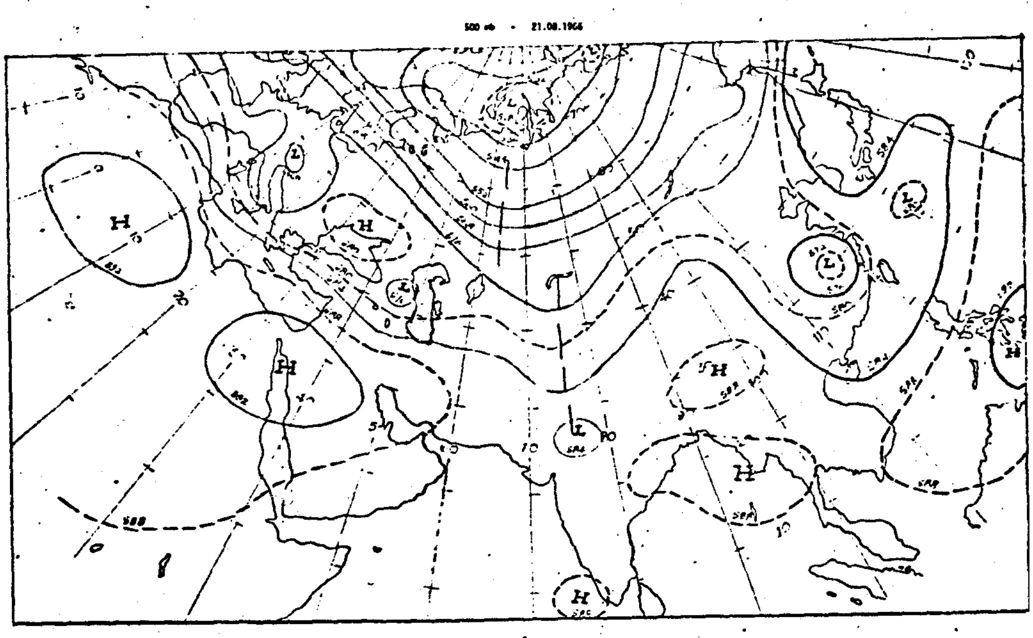
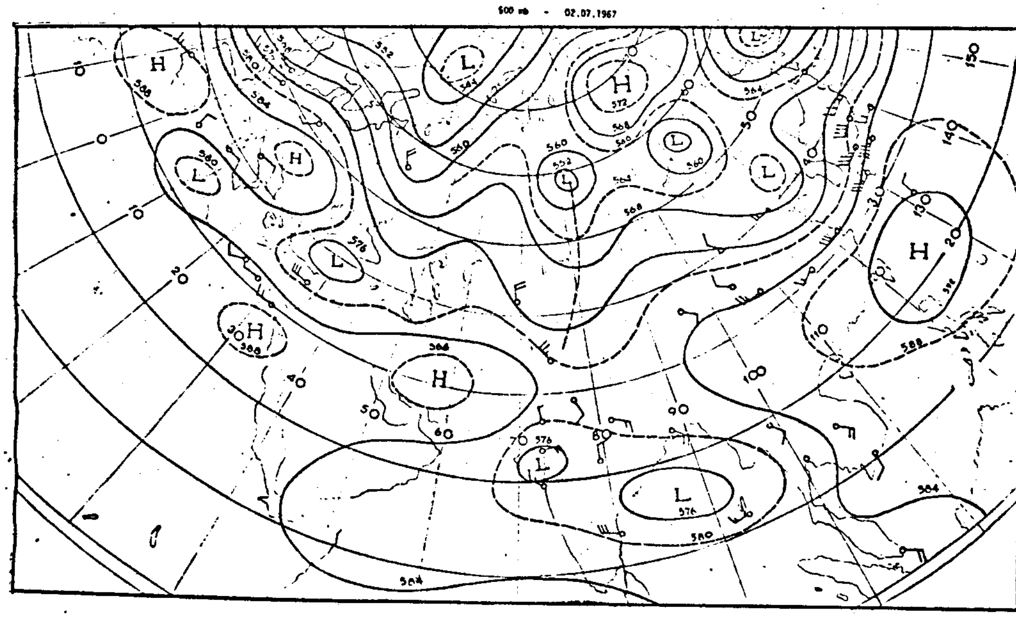


Fig. 4g

500 mb - 02.07.1967



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500 mb - 06.07.1967

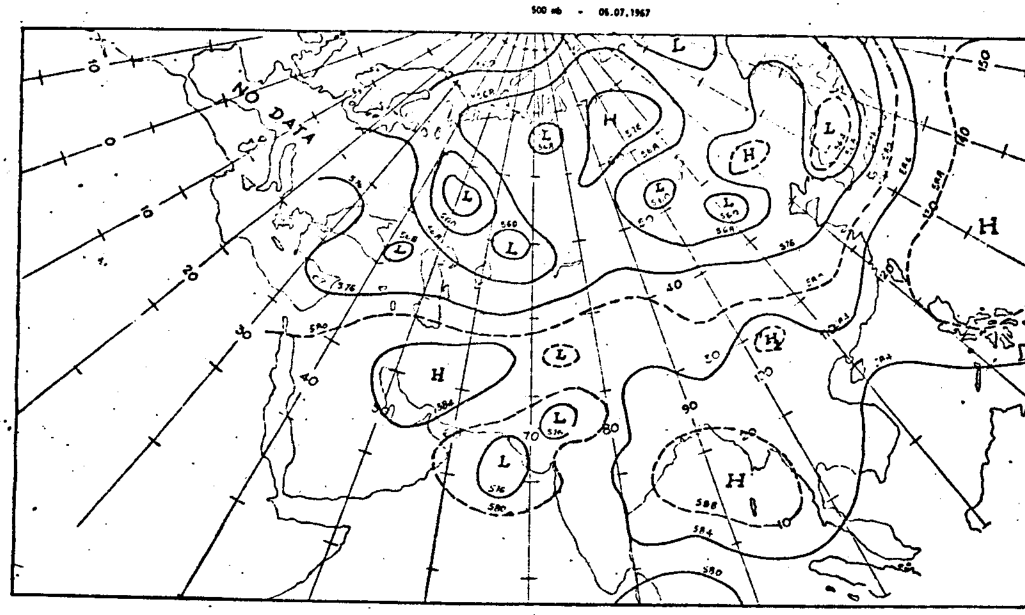
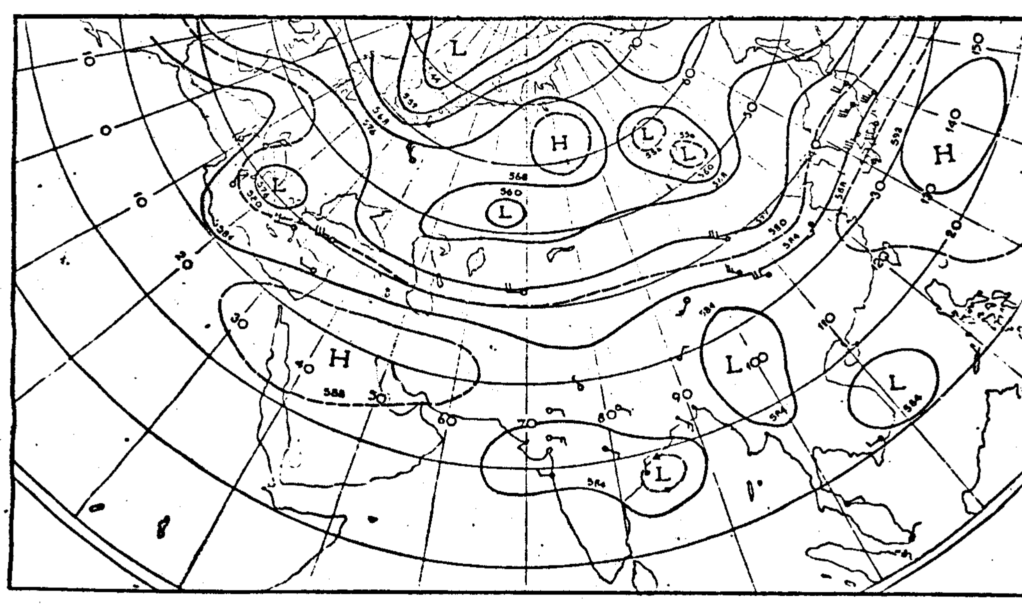


Fig. 4k

500 mb - 13.07.1967



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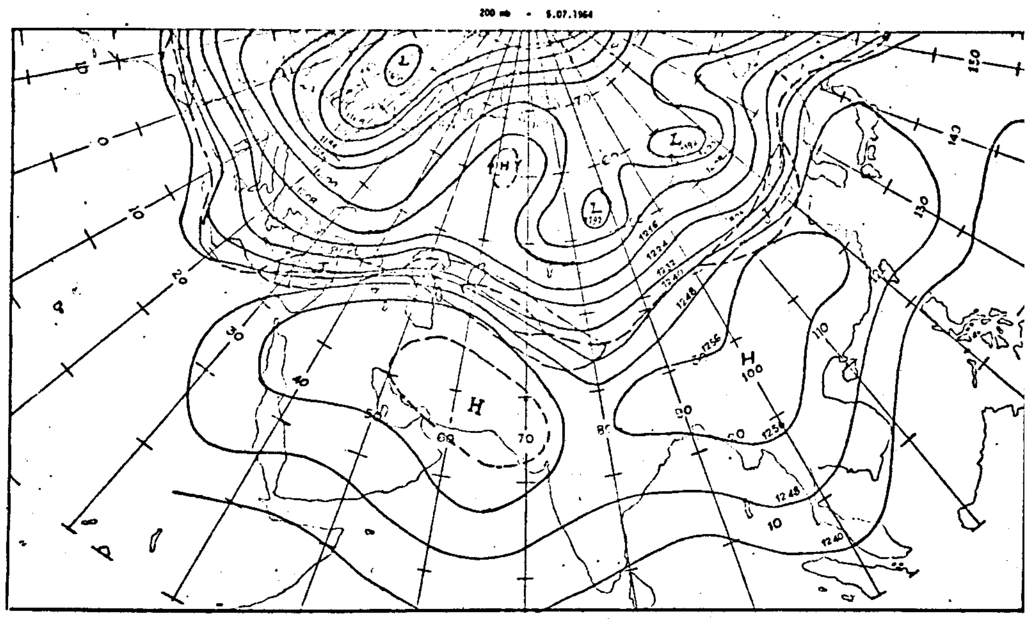
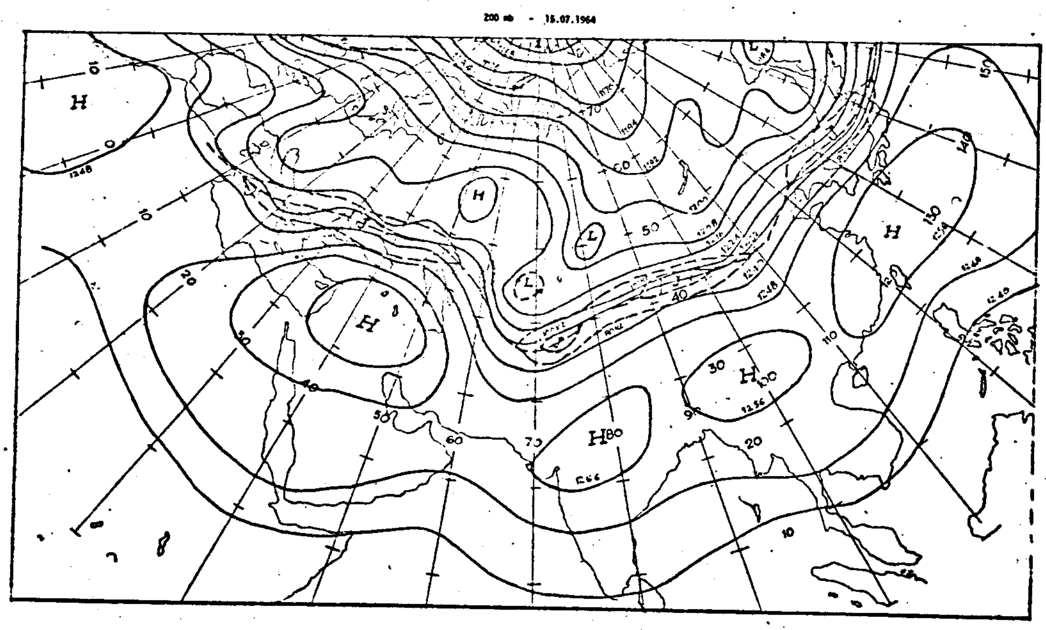


Fig. 5a



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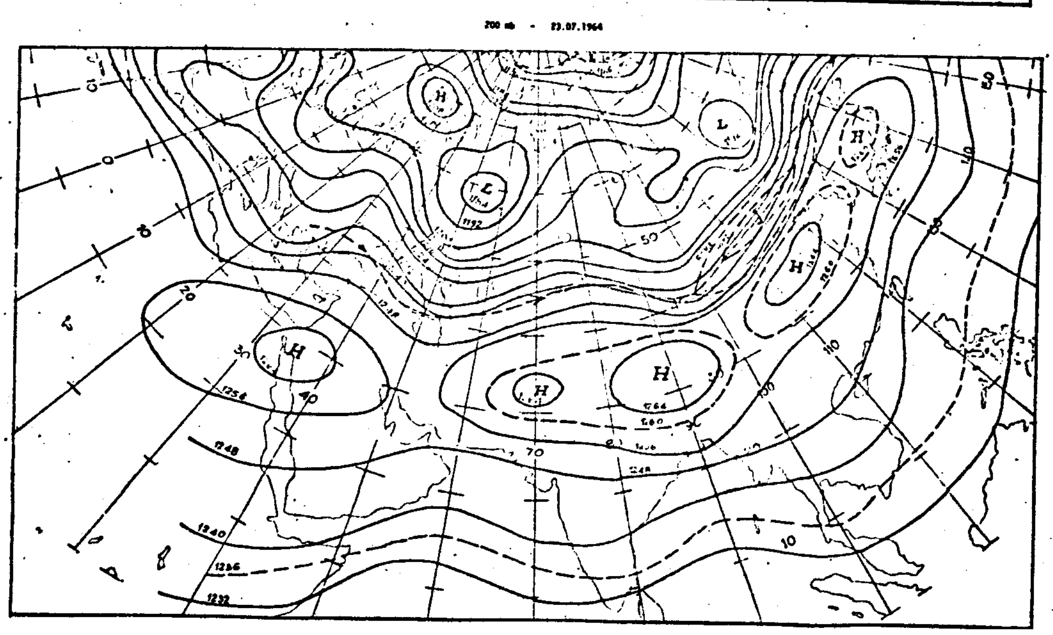


Fig. 5c

200 mb - 01.08.1965

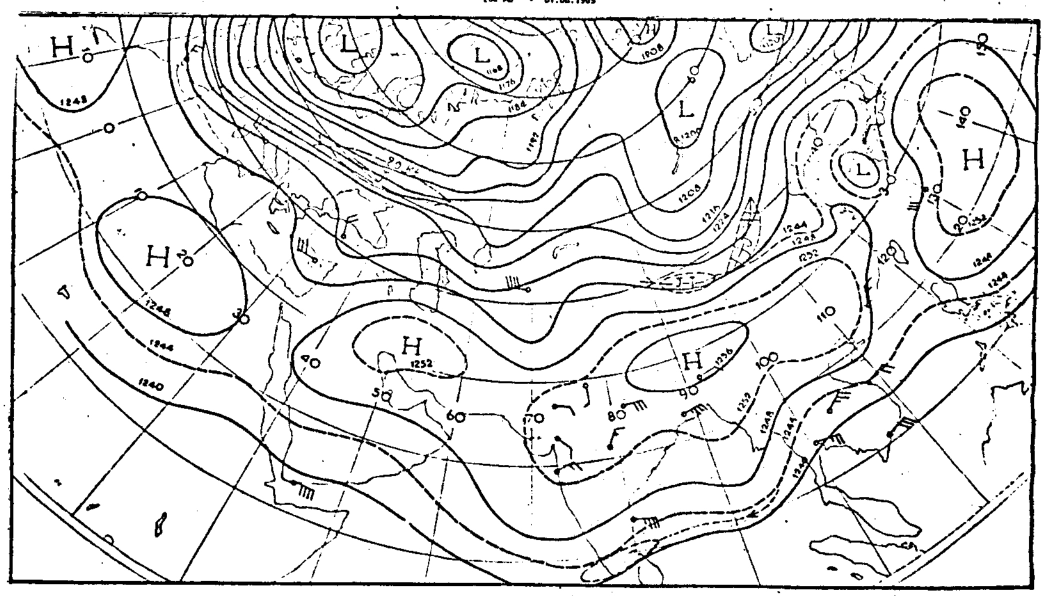


Fig. 5d

200 mb - 12.08.1965

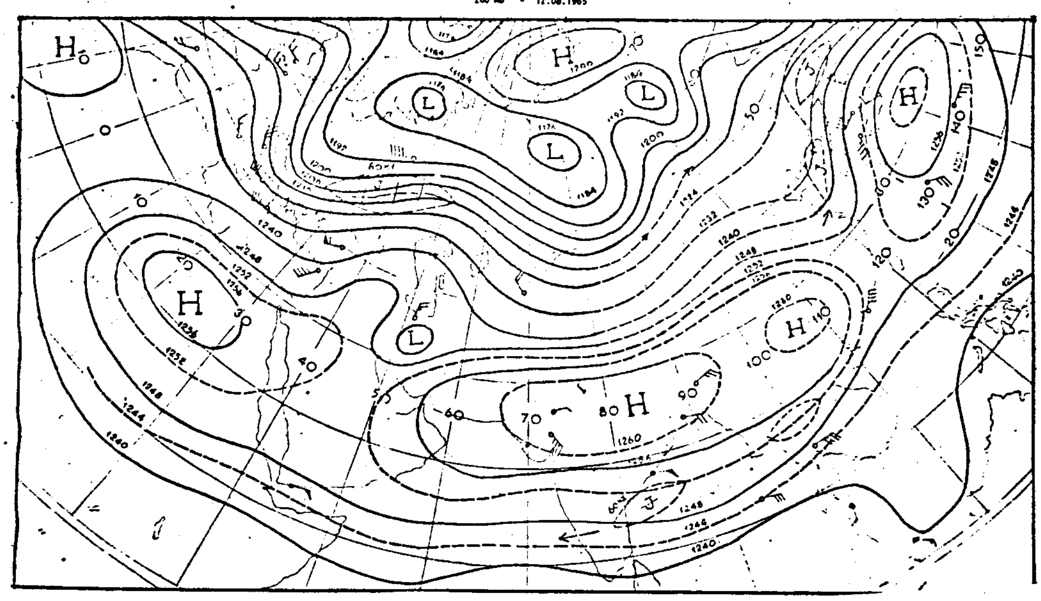


Fig. 5e

200 mb - 23.08.1965

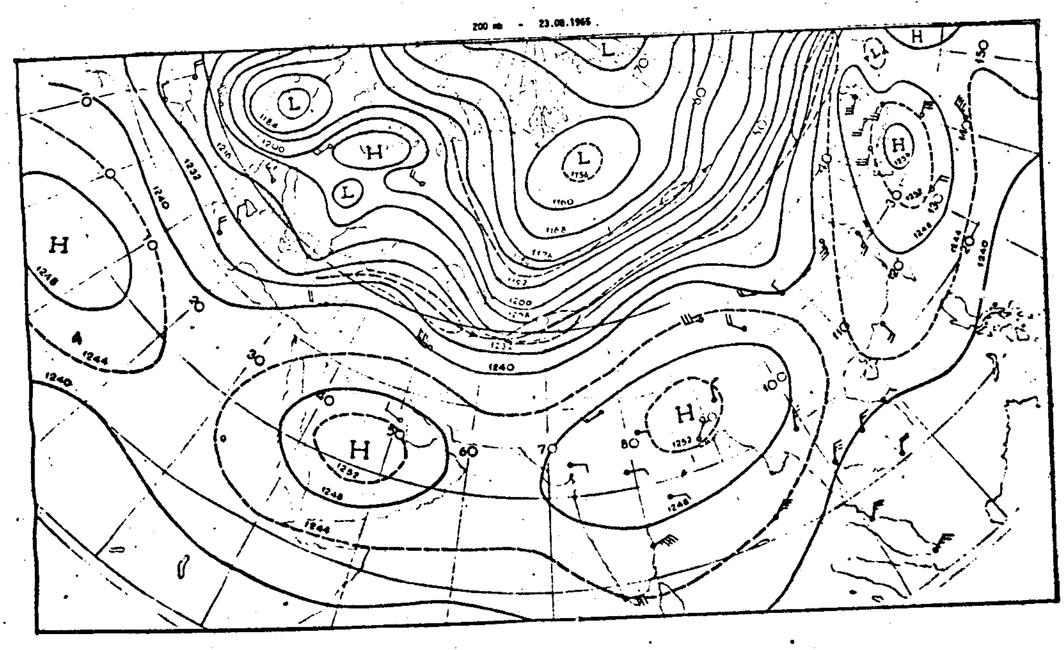


Fig. 5f

200 mb - 21.08.1966

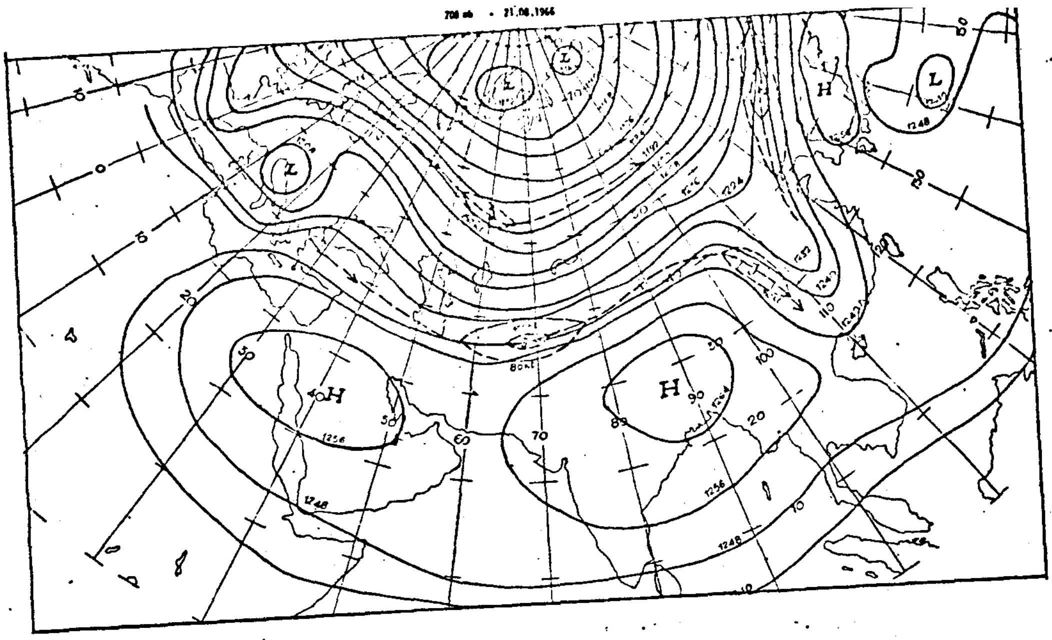


Fig. 5g

200 mb - 25.08.1966

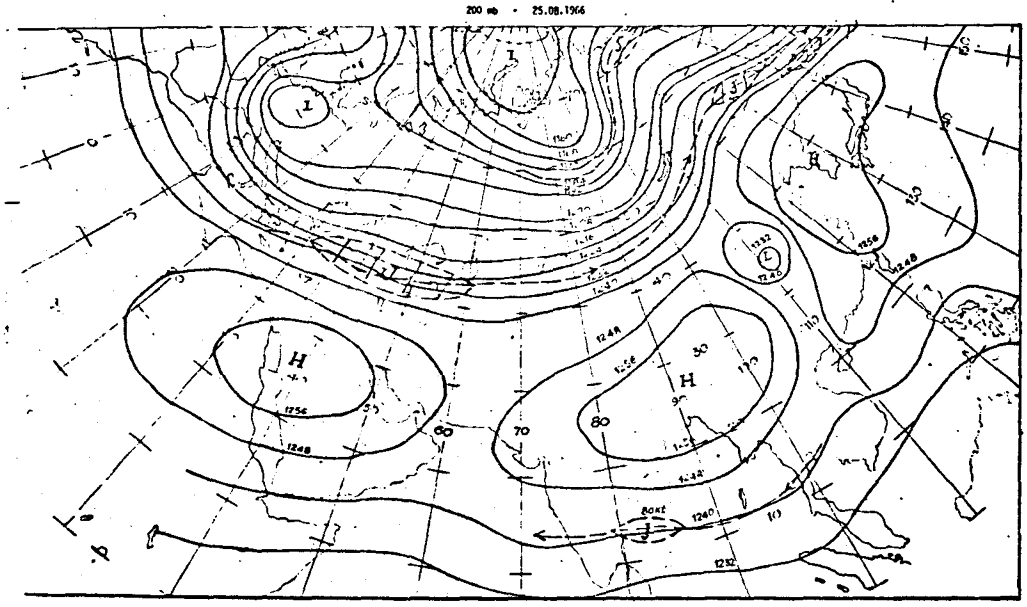
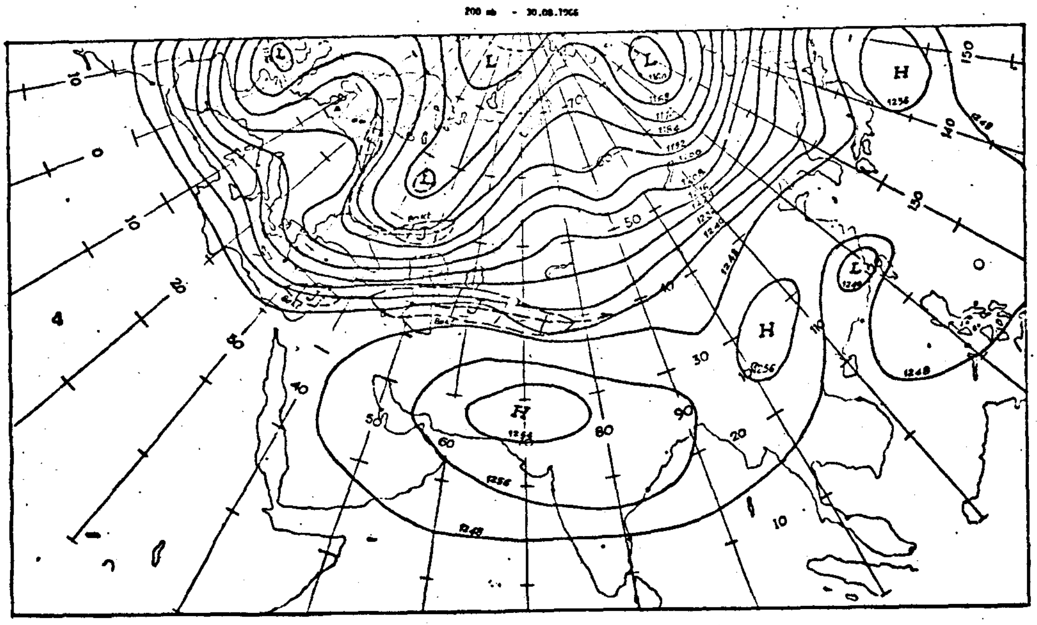


Fig. 5h

200 mb - 30.08.1966



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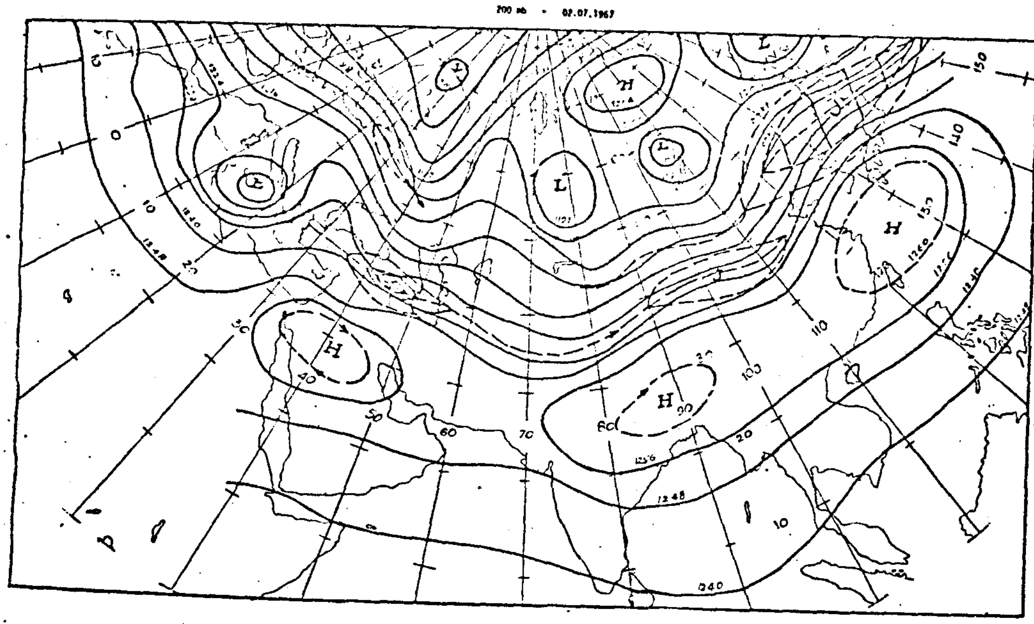

Fig. 5j

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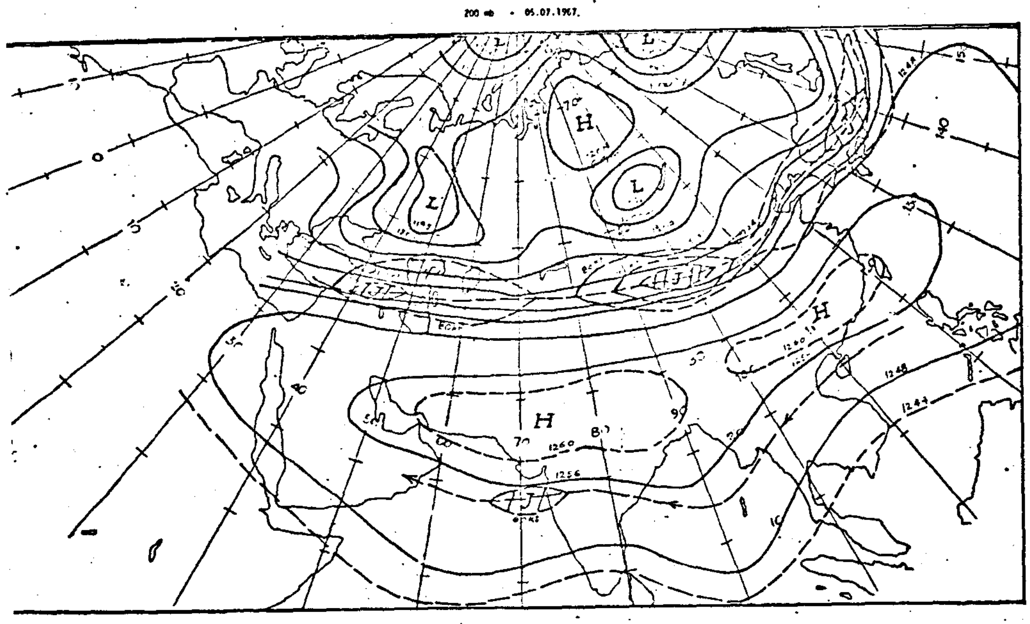

Fig. 5k

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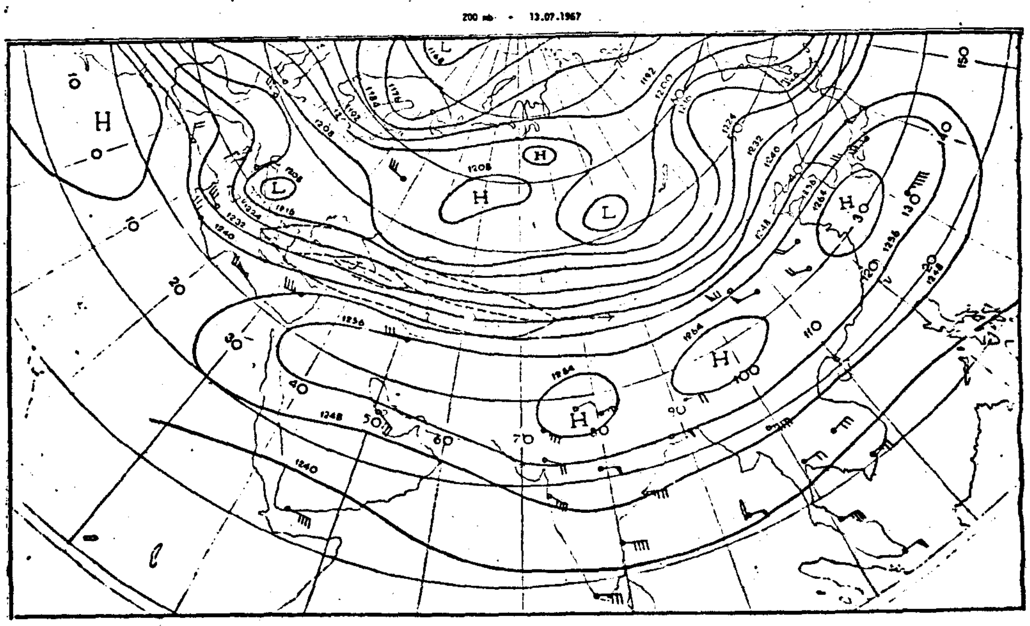

Fig. 5ℓ