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INDIA METEOROLOGICAL DEPARTMENT

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PART III

DISCUSSION OF TYPICAL SYNOPTIC WEATHER SITUATIONS

3·2: SOUTHWEST MONSOON – ACTIVE AND WEAK MONSOON OVER ORISSA

BY

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3.2 Southwest Monsoon - Active and Weak Monsoon over Orissa

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1. General

1.1 The monsoon sets in over Orissa during the second week of June. The mean rainfall over the state during the southwest monsoon season (June to September) is 114 cm - which is about 75% of the annual rainfall of 150 cm. The mid-monsoon months of July and August account for nearly two thirds of the season's total rainfall. During these two months, the number of rainy days also increases to 15-16 per month, which is the highest for Orissa in the year. Though the monsoon withdraws from Orissa only by mid-October, there is a decrease in rainfall from 34 cm in August to 24 cm in September. When the distribution of rainfall over the different districts of the state for July and August is examined (Fig. 1.1) it is noticed that mean monthly rainfall increases progressively from the coastal districts north-westwards towards inland. In both the months the districts of Sundargarh and Sambalpur in northwest Orissa, get the highest rainfall while the coastal districts of Puri and Ganjam in southeast Orissa, get the lowest rainfall. This may, in part, be due to the orographic influences in interior Orissa.

1.2 There is no radiosonde station in Orissa; the nearest stations are Calcutta and Vishakhapatnam - 100 to 150 km from Orissa. In view of such close proximity, there may not be any serious discrepancy in taking the ascents at these two stations to be fairly representative of the upper air conditions over Orissa. The mean monthly tephigrams of Calcutta and Vishakhapatnam for July and August (Fig. 1.2) show high humidity in the lower and middle troposphere with lapse rates close to saturated adiabat. Thus, with plentiful moisture and no inhibiting influence of any inversion, conditions over Orissa are favourable, for development of weather even with weak systems. This is reflected, to some extent, in the very small number of completely dry days taking the state as a whole (see Table I).

1.3 The synoptic situations that activate the monsoon over Orissa may be broadly divided into following types:-

i) monsoon trough

ii) low pressure area

iii) monsoon depression and

iv) north-south oriented trough

The degree of rainfall activity caused by these systems is very much dependent on their intensity as well as their location with reference to Orissa. In the absence of any of these systems, the weather over Orissa is mainly dry. The frequency distribution of occurrence of rainfall over Orissa in association with these different systems during July and August 1967 and 1968 is given in Table I. In this table weak monsoon condition has been sub-divided into three categories -- viz. dry weather, weak monsoon with only isolated rainfall and weak monsoon with more than isolated rainfall - to distinguish cases of dry or nearly dry weather from cases of small amounts of rainfall over a number of stations.

TABLE I

No. of occasions of different types of monsoon activity and associated synoptic situations

Synoptic situation of day \ Monsoon activity next day	Vigorous	Active	Normal	Weak		
				With more than isolated rainfall	With isolated rainfall	Dry
Monsoon trough over Orissa and neighbourhood		4(3)	11(9)	5(4)	2(2)	
Low pressure area over Orissa and neighbourhood		9(7)	11(9)	7(6)		
Depression over Orissa and neighbourhood	3(2)	5(4)	8(6)			
North-south trough over Orissa and neighbourhood			9(7)	3(2)		1(1)
No significant feature			2(2)	12(10)	24(20)	8(6)

(Figs. in brackets refer to % frequency)

1.4.1 Monsoon trough: The monsoon trough is a major feature on the synoptic chart during this season. In the mean, the axis of the trough runs to the north of Orissa, across Bihar Plateau and Gangetic West Bengal in the lowest levels of the troposphere. However, on individual days, the location of the monsoon trough is found to vary considerably from its normal position. One of the preferred positions of the eastern end of the monsoon trough is slightly to the south of the normal position - across north Orissa and the adjoining Gangetic West Bengal. This usually happens when the monsoon trough extends into the Bay of Bengal in association with the formation of low pressure systems over the north Bay.

1.4.2 The monsoon trough is sometimes seen only in the very low levels; at other times it extends through a fairly deep layer of the troposphere. The rainfall occurs mainly in the neighbourhood or to the south of the trough line. Thus the rainfall over Orissa is very much dependent on the location of the trough line with reference to the state. The cases of weak monsoon conditions with trough across Orissa and neighbourhood given in Table I relate to occasions when the monsoon trough was located either over extreme south of Orissa or slightly to the north of Orissa.

1.5.1 Low pressure areas and depressions: Low pressure areas and depressions constitute the most effective synoptic situations that cause active to vigorous monsoon conditions over Orissa. On an average about 3 depressions and 3 to 4 low pressure areas form over North Bay of Bengal in July and August and affect Orissa. Prior to the formation of a low or depression, the monsoon trough extends into the North Bay; if the trough is well-defined and runs across Orissa and neighbourhood, even at this stage Orissa may get rainfall. Sometimes the lows and depressions are noticed earlier in the middle and upper troposphere, before they are seen on the surface chart. Some of them can also be traced from the east across Burma.

1.5.2 The monsoon depressions in July and August mostly cross north Orissa coast; those crossing West Bengal coast or south Orissa coast are relatively small in number (Table II).

TABLE II

Depressions crossing Orissa and neighbouring coasts

Period	No. of Depressions crossing							
	South of 18°N (Andhra coast)		18°-20°N (South Orissa coast)		20°-22°N (North Orissa coast)		Beyond 22°N (West Bengal coast)	
	Jul.	Aug.	Jul.	Aug.	Jul.	Aug.	Jul.	Aug.
1891-1895	-	-	-	1	6	2	2	-
1896-1900	-	-	-	2	6	9	1	-
1901-1905	-	-	1	2	4	4	3	-
1906-1910	-	-	-	-	3	7	1	1
1911-1915	-	-	-	3	3	4	2	1
1916-1920	-	-	1	2	4	4	1	3
1921-1925	-	-	-	3	6	7	2	-
1926-1930	-	-	-	4	7	5	5	2
1931-1935	-	-	2	1	6	8	-	1
1936-1940	-	-	2	2	4	7	2	2
1941-1945	-	-	1	-	10	6	2	2
1946-1950	-	-	1	-	7	8	1	1
1951-1955	-	-	2	1	4	9	1	-
1956-1960	-	-	1	3	4	5	1	2
Total	-	-	11	24	74	85	24	15

1.5.3 Vigorous monsoon conditions are invariably associated with depressions. It is well known that the rainfall in association with lows and depressions are mainly to the south of the track, the northern region getting relatively light falls. Particularly with depressions the heaviest rain is in the southwest

quadrant. As the depression or low moves to the west of Orissa, marked improvement in weather takes place over the state.

1.5.4 An examination of the synoptic situations associated with rainfalls of 20 cm and above in a day over the various stations in Orissa during July and August of 1958-1968 showed that on all such occasions, there was a depression over or near Orissa. When rainfalls of 10 cm to 20 cm were considered it was seen that 49% of the occasions were associated with depressions, 37% with low pressure areas and 14% with other systems.

1.6 North-south oriented trough line: When the axis of the seasonal trough shifts northwards to foothills, generally westerly flow prevails over the whole of India in the lower and middle troposphere. At times, some wave-like disturbances travel eastwards in these westerlies - though their movement may not be very regular. These troughs are sometimes noticed only in the lower troposphere to the south of the Himalayas; occasionally they are also seen in the middle troposphere and appear to be connected with middle latitude westerly systems further north. As these systems approach Orissa from west, rainfall occurs over Orissa. Very often only a portion of Orissa may get rainfall with such troughs. It will be seen from Table I that with north-south oriented troughs the monsoon activity over Orissa is either normal or weak. However, isolated heavy falls on such occasions are not ruled out.

1.7 When none of the above systems affects Orissa and its neighbourhood, the monsoon activity over Orissa is weak, being mainly dry on a majority of occasions. Generally, on these days, either the monsoon trough is far to the north of Orissa, or depressions or lows, after crossing Orissa coast have shifted to Madhya Pradesh.

1.8 In the subsequent sections, typical cases of active and weak monsoon conditions over Orissa will be discussed.

2. Monsoon Trough over Orissa (6 to 9 July 1962)

2.1 One of the synoptic features associated with rainfall over Orissa is the monsoon trough lying over the sub-division and extending into the Bay. Such occasions often precede the formation of low pressure areas and depressions over the North Bay of Bengal, when the monsoon may become active over Orissa. A situation of this type is discussed in this section.

2.2 On 3rd July 1962, the eastern portion of the axis of the monsoon trough was running along 24°N across Bihar Plateau, Gangetic West Bengal and East Pakistan on the surface chart (Fig. 2.1). A north-south oriented trough was also noticed from East Uttar Pradesh to Orissa upto 850 mb. Aloft, a cyclonic circulation was present in the Bay off Orissa and Andhra coasts upto about 500 mb (Fig. 2.2). On the 4th, the monsoon trough was more or less in the same position as on 3rd, on the sea level chart. The north-south trough could now be noticed over Orissa and adjoining areas on the surface chart also. Weather was mainly dry over Orissa on this day. By 5th morning, the monsoon trough was rather diffuse and was extending from Haryana to North Bay across Orissa (Fig. 2.3). A feeble low could also be seen over Orissa, embedded in the trough. The pressures over Orissa and neighbourhood were, however, rising by 1-2 mb and the pressure departures were about one mb above normal. In the lower and middle troposphere a trough/cyclonic circulation was noticed over Orissa and adjoining Bay (Fig. 2.4). Over the rest of north India the flow pattern was disorganised. Scattered light to moderate rainfall occurred in Orissa.

2.3 On 6th morning, though the monsoon trough remained in nearly the same position as on 5th, the pressures registered a fall of about 2 mb over Orissa and North and adjoining Central Bay; the departures were about one mb below

normal (Fig. 2.5). In the upper air, easterlies were establishing over the Gangetic plains upto 850 mb level (Fig. 2.6). There was an increase in rainfall activity over Orissa and Gangetic West Bengal with some stations reporting 2 to 5 cm apparently due to the intensification of the low/trough over the area in the surface and lower troposphere during the preceding 24 hrs.

2.4 On the 7th, the axis of the monsoon trough was running from Ganganagar to Paradeep and further southeastwards towards Rangoon and was well-marked (Fig. 2.7). The pressures continued to fall and were 2-3 mb below normal over Orissa and the Bay north of 15°N. The trough was well-marked in the upper air also running across Orissa and the Bay and was noticeable upto 500 mb with a southward slope with height (Fig. 2.8). There had been fairly widespread rain accompanied by thunder over north Orissa. Simultaneously pressures were also falling rapidly over Sind, Saurashtra and Kutch and adjoining northeast Arabian Sea where a low was developing, though such simultaneous developments over the Arabian Sea and North Bay may not always occur. Rather abrupt changes occurred in the monsoon trough between 6th and 8th. Whereas the trough was ill-defined, seen only below 1.0 km and was located in a northerly position in the beginning, it became well-marked, extended upto the middle troposphere and was in a southerly position by 8th.

2.5 During the same period, a low pressure area was also seen travelling westwards from South Vietnam to Central and North Bay across Burma as could be inferred from the isobaric pattern, 24-hr. pressure changes and low level windfield. Apparently due to the arrival of this system from the east, a closed low formed over North Bay and adjoining Orissa in the eastern end of the monsoon trough on 8th morning (Fig. 2.9); it extended upto 400 mb (Fig. 2.10). On this day (8th) the monsoon was active over Orissa, Puri recording 15 cm, Sambalpur 9 cm and Bhubaneshwar 8cm. The heavy falls were in the immediate neighbourhood of the trough line in the lower troposphere.

2.6 On 9th morning, the low pressure area was over Northwest Bay and was well-marked (Fig. 2.11 and 2.12). Monsoon continued to be active over Orissa, Puri reporting 10 cm, Bhubaneshwar 7 cm, Jharsuguda 6 cm and Sambalpur, Koraput and Gopalpur 5 cm each. The region of heavy rain was again in the neighbourhood of the trough line in the lower troposphere during the preceding 24 hrs. It may be noted that whereas the pressure departures over Orissa and the Bay were 2–4 mb below normal, the pressure changes were very small. Subsequently the low developed into a depression.

2.7 Between 2nd and 4th July, the monsoon trough was well to the north of Orissa with the flow patterns over north India akin to break conditions and weather was mostly dry over Orissa. Subsequently with the developments in the Bay and the northeast Arabian Sea, the trough shifted southwards and became well-marked. The presence of the well-marked trough across Orissa activated the monsoon over the sub-division, which had nearly general rain between 6th and 9th with a few heavy to very heavy falls on the last two days.

3. Depressions from Bay of Bengal Moving Across Orissa

3.1 During the southwest monsoon season depressions form over North Bay of Bengal and move inland causing heavy to very heavy rains over Orissa. While many of them cross north Orissa and adjoining Gangetic West Bengal coast, some of them travel further to the south. In this section, cases of two depressions, one crossing south Orissa and the other moving across north Orissa are discussed.

3.2 Depression from Bay moving across south Orissa - 5 to 7 August 1964

3.2.1 Towards the end of July 1964, 'break' monsoon conditions set in over India and continued into August. On 2nd August the westerlies were prevailing upto the foot-hills of the Himalayas in the lower troposphere (Fig. 3.1). In the middle troposphere, an east-west oriented trough line was seen across the Peninsula, from off south Maharashtra—north Mysore coasts to East Central Bay

and Andaman Sea, in marked contrast to typical break situations when usually a ridge lies over these areas. The next day (3rd) there was not much of a pressure gradient over North Bay (Fig. 3.2). Over Central Bay the monsoon strengthened considerably, and ships reported heavy rain, squalls and thunderstorms during the course of the day. There was a general fall of pressure over central and north India and the Bay of Bengal; the pressure departures were about -2 mb over North and Central Bay of Bengal. The middle tropospheric trough over the Bay intensified into a cyclonic circulation over West Central Bay, as could be seen by the changes in winds at Vishakhapatnam, Madras and Port Blair (Fig. 3.3). On a comparison of the westerlies over the south Peninsula and the Bay in the lower and middle troposphere on 2nd and 3rd, it is seen that on 3rd there has been a strengthening of the westerlies, particularly over the latitudinal belt 12°N to 17°N. Whereas on 2nd the strong westerlies were confined to south of 10°N, they extended upto about 17°N on 3rd. The monsoon was generally weak over Orissa on this day (3rd).

3.2.2 On 4th a low pressure area formed over North Bay, where on the previous day the pressure gradient was weak (Fig. 3.4). The eastern end of the axis of the monsoon trough also shifted southwards and was running across north Orissa. The monsoon continued strong/vigorous over the Central Bay. The pressures fell slightly over Orissa and North and Central Bay and the pressure departures over these areas were -2 mb. The pressures rose over the rest of the country. Although a low had formed over the North Bay and was extending from surface to 400 mb, still, westerlies were prevailing from West Uttar Pradesh to North Assam in the lower and middle troposphere (Fig. 3.5). Thus, though the monsoon trough was noticeable on the surface chart from northwest Uttar Pradesh to North Bay, it was not seen in the upper air. It was only on 4th evening that easterlies could be seen over northeast India in the lower troposphere for the first time, as the low over North Bay was intensifying. There was increased rainfall activity over Orissa on 4th.

3.2.3 The system intensified further and concentrated into a depression with centre at 03 GMT of 5th August near Lat. 19.5°N and Long. 88.0°E (Fig. 3.6). The monsoon trough was running from southwest Uttar Pradesh to the centre of the depression across central parts of Orissa. The pressures fell by 2 mb along coastal Orissa and Northwest Bay where the pressure departures were -4 mb. The cyclonic circulation in the upper air was well-marked extending upto about 400 mb over the entire Central and North Bay of Bengal (Fig. 3.7). The zone of convergence between northerlies and westerlies was over southwest Orissa at 0.9 km but aloft it was having a southward tilt. Orissa had fairly widespread light to moderate rain on this day.

3.2.4 The depression deepened during the next 24 hrs and was close to south Orissa coast about 70 km southeast of Puri on 6th morning (Fig. 3.8). The pressure fall during the preceding 24 hrs over Orissa was 4 mb and the departures along south Orissa coast were -8 to -10 mb. Winds in the lower troposphere along Orissa-West Bengal coast increased to about 30 kt and the cyclonic circulation was probably extending upto 400 mb with no appreciable southward tilt with height, in contrast to the marked southward slope in the earlier stages (Fig. 3.9). Rainfall over Orissa was widespread, though mostly moderate. The heavy rains were to the southwest of Orissa, over southeast Madhya Pradesh and adjoining Telangana. As northeasterlies prevailed over most of Orissa and the zone of convergence between the northeasterlies and westerlies was further to the south, Orissa did not get heavy falls in spite of the deep depression being so close to Orissa coast.

3.2.5 The deep depression crossed coast near Puri on the evening of 6th and rapidly weakened. On 7th morning it lay as a trough of low pressure over north Orissa (Fig. 3.10) though the cyclonic circulation was extending upto about 7.0 km in the upper air (Fig. 3.11). The pressure rise over the depression field with falls everywhere else is significant. Nearly general rainfall continued over Orissa on this day also.

3.3 Depression from Bay moving across north Orissa - 8 to 11 August 1964

3.3.1 The system described in above paragraphs moved away westwards but the monsoon trough continued to be across Orissa. On 8th morning its axis was running from Gujarat State to East Central Bay of Bengal across north Madhya Pradesh and Orissa. It was also well-marked on the surface as well as the lower and middle troposphere, with two cyclonic circulations embedded in it, one over Gujarat State and the other over North Bay and Orissa (Fig. 3.12 and 3.13). A third cyclonic circulation associated with a typhoon was also noticed over Vietnam and south China Sea. The monsoon westerlies were strong over the Peninsula in the lower troposphere, with speeds of 40-50 kt. The easterlies which extended from Assam and East Pakistan to northwest India to the north of the trough line were also fairly strong. On this day the pressures were falling over lower Burma suggesting the approach of a low pressure area from the east. The sequence of changes in pressure and the lower tropospheric wind field over Burma, between 8th and 10th, would indicate the movement of a low pressure area from across deltaic Burma to North Bay in a northwesterly direction. During this period heavy rains were also reported from stations in coastal Burma. By the evening of 8th a low formed over the Bay. Next morning (9th), an extended low pressure area was lying in the Central Bay from off Orissa coast to off Arakan coast; the pressures were falling over this area by about 2-3 mb and the departures were -6 to -8 mb (Fig. 3.14). The cyclonic circulation probably extended upto 400 mb (Fig. 3.15) with a southward tilt with height. The rainfall was fairly widespread over Orissa.

3.3.2 By 10th morning, the low rapidly intensified into a deep depression which was centred near 19.5°N and 88.5°E (Fig. 3.16). The pressure gradient over Central Bay was strong, being of the order of 14 mb in 6 degrees of latitude. However, compared to 9th, there was a decrease in rainfall over Orissa while the low was concentrating into a depression The area of significant rainfall on 10th was to the west of Orissa, over the convergence zone

(in the lower troposphere) between northerlies/northeasterlies and westerlies/ northwesterlies during the previous 24 hrs. The cyclonic circulation extended upto 500 mb (Fig. 3.17). The westerlies over the Peninsula continued to be very strong. A well-marked zone of convergence was lying over south Orissa and the adjoining southeast Madhya Pradesh in the lower troposphere on 10th morning. The pressure changes on the morning and evening charts of 10th indicated a westnorthwesterly movement for the depression; the pressure departures in the area of the depression were about -10 to -12 mb.

3.3.3 The deep depression crossed Orissa coast near Chandbali during the night of 10th and lay on the 11th morning with centre just east of Keonjhar (Fig. 3.18). The depression continued to be deep with a pressure departure of -12 mb near the centre. The monsoon became vigorous over Orissa during the preceding 24 hrs and heavy to very heavy rain (upto 17 cm) fell over south Orissa in the southwest quadrant of the depression, corresponding to the zone of convergence in the lower troposphere. Fig. 3.19 shows the upper wind chart. The deep depression continued its westnorthwesterly course and was centred near Jabalpur on 12th morning. With the westward movement of the depression, the rainfall over Orissa decreased considerably and the eastern portions of Orissa were practically dry. By 13th morning, the system moved away northwestwards and weakened. Simultaneously the axis of the seasonal trough also shifted to the north of Orissa. As a result, the monsoon activity over Orissa became weak.

3.3.4 An interesting feature of the upper tropospheric circulation during this period was that the easterlies were strong; over south Bay and south Peninsula the maximum wind speeds were about 100 kt on most of the days during the period. On 10th evening, all the stations to the south of 15°N (Minicoy, Trivandrum, Madras and Port Blair) reported maximum winds of 100-120 kt.

3.3.5 To sum up, prior to the formation of the depression discussed above, the monsoon trough was to the south of its normal position and was lying across

Orissa during 7th to 10th when the monsoon was normal to active over Orissa. As the deep depression moved across Orissa it caused very heavy rains leading to vigorous monsoon conditions on 11th. The heavy rainfall area was to the south of the track of the depression. When the depression moved away westnorthwestwards and the monsoon trough also shifted to the north of Orissa, there was rapid improvement of weather. It is well known that the region of heavy rainfall associated with monsoon depression is in the southwestern quadrant of the depression. To the north, the rainfall is generally light or moderate. The occurrence of heavy rains, therefore, depends upon the track of the depression in relation to the sub-division. Thus Orissa may be expected to have heavy rains in association with depressions crossing north Orissa or West Bengal coast. However, if they cross further south, Orissa may not have heavy rain excepting the extreme southern portion. The two examples discussed, bring out this point clearly.

4. Depression in North Bay of Bengal with Associated Monsoon Trough across Orissa - 31 July to 4 August 1967

4.1 Monsoon depressions mostly form over Northwest Bay of Bengal and they activate the monsoon over Orissa as in the cases discussed in Sec. 3. On a few occasions depressions develop further east in the Bay. Though they may be somewhat away, rainfall increases over Orissa, if the monsoon trough in which the depression or low is embedded, is well-marked and over-lies Orissa. One such situation is discussed in this section.

4.2 On 28th July 1967 the satellite pictures showed extensive cloud belt from northeast Arabian Sea to southwest Pacific (Fig. 4.1). The seasonal monsoon trough was well-marked and was running from northwest Madhya Pradesh to head Bay of Bengal (Fig. 4.2) on the surface chart on 29th July. Pressures were falling over Burma by 1-2 mb and many stations in Burma reported good amounts of rainfall. Orissa had isolated rain. In the upper air a cyclonic

circulation was also noticed over East Pakistan, northeast Bay and adjoining Burma between 850 mb and 500 mb (Fig. 4.3). By the evening of this day, pressure changes over north Burma and adjoining East Pakistan were more marked being -3 to -4 mb and the departures were also of the same order over the area.

4.3 By 30th July, the monsoon trough continued to be well-marked over North Bay where a low had formed. (Fig. 4.4). In the upper air (Fig. 4.5), it was running from south Rajasthan across Orissa to North Bay where a cyclonic circulation was seen from about 900 mb to 400 mb. The area of maximum pressure fall also shifted westwards to North Bay. Associated with these developments there was an increase in rainfall over Orissa compared to the previous day. There were also a few heavy falls over Orissa and Gangetic West Bengal (Sandheads 8 cm and Sambalpur 12 cm to the south of the axis of the seasonal trough), the rainfall having occurred mainly after 1200Z of 29th. Note the formation of a convergence zone in the lower troposphere over Orissa on 30th 0000Z pibal chart.

4.4 By the 30th evening the lower and middle tropospheric trough over North Bay and the adjoining area shifted southwards and continued well-marked. The southward shift of the trough line was well indicated by the progressive changes in the upper winds of stations such as Calcutta and Akyab between 29th morning and 30th evening.

4.5 On the morning of 31st, the low pressure area (in the eastern end of the monsoon trough) concentrated into a depression (probably deep) centred near 19°N and 90°E (Fig. 4.6). The changes in the pressure and the upper winds along Burma coast would suggest the formation of the depression on 31st being preceded by the movement of a low into the Bay across coastal Burma. The monsoon trough was passing through Orissa in the surface and in the lower and middle troposphere where it was well-marked with moderate to strong easterlies to the north (which were extending from Assam to Punjab) and strong westerlies to the south (Fig. 4.7). The pressure falls were larger over Orissa than either to the

north or south, suggesting a movement of the depression towards the Orissa coast. Many stations in Orissa reported rainfall, with half the number of stations recording 3 cm or more during the preceding 24 hrs. The rainfall to the north of the trough line was light, while to the south of it, the amounts were significantly higher and falls upto 5 to 6 cm were reported from some stations. The upper air cyclonic circulation associated with the depression probably extended upto 400 mb.

4.6 During the period 29-31, there were significant changes in the upper tropospheric as well as lower tropospheric flow over Central Bay and Andaman Sea. On 29th evening winds over Port Blair changed to strong northerlies (40-50 kt) between 250 and 150 mb levels and the northerlies were also seen even at 400 mb level on 30th evening (Fig. 4.8). By 31st the winds over the Peninsula (Hyderabad, Nagpur and Madras) showed a pronounced northerly component at some levels in the upper troposphere. Simultaneously the pressure gradients also increased considerably over Central Bay and Andaman Sea. In the lower troposphere, winds reached 50 kt over Port Blair on 31st morning from 20/25 kt on 29th. The rainfall increased considerably on 31st over North Bay ~~of~~ Islands ~~Bengal~~ where amounts of the order 9-14 cm were recorded.

4.7 On the morning of 1st August, the deep depression was centred near Lat. 20°N and Long. 88°E (Fig. 4.9 and 4.10). While the pressure falls over the area were small the pressure departures were more than 8 mb below normal in the central region. In the upper air, cyclonic circulation was seen to extend upto 400 mb (Fig. 4.11) being nearly vertical upto about 600 mb and with a slight tilt with height between 600 mb and 400 mb. Orissa continued to have widespread rainfall, with the greater falls to the south of the trough line, as on the previous day. The deep depression crossed north Orissa coast during the night of 1st and weakened.

4.8 In this example, it was noticed that the monsoon trough which was to the north of Orissa on 29th July, progressively shifted southwards; a low pressure area formed in the eastern end of the trough on 30th July in Northeast Bay; this subsequently developed into a deep depression probably under the influence of a low from the east and moved across Orissa. The monsoon trough was across Orissa and was well-marked in the surface and lower and middle troposphere. Even though the low/depression was somewhat away from Orissa in the initial stages, the sub-division commenced to have heavy rain from 30th itself and active monsoon conditions prevailed during the subsequent three days till the depression moved to East Madhya Pradesh and adjoining north Orissa and weakened. Another point of significance was the general light rainfall to the north of the trough line with relatively heavier falls to the south.

5. Active Monsoon Conditions over Orissa caused by Low Pressure Areas

5.1 In Secs. 3 and 4 we have discussed situations of active monsoon over Orissa in association with depressions from the Bay of Bengal. Some of the low pressure areas that form over North Bay move inland without developing into depressions and cause good monsoon activity. Though the amounts of rainfall may not be as high as those associated with depressions, still, rainfalls of the order of 10 cm to 20 cm have been recorded with low pressure areas affecting Orissa. Low pressure areas may not have a regular movement, very often persisting over an area for a few days. The rainfall over Orissa due to low pressure areas is also dependent upon the relative location of the system with reference to the sub-division. In this section, cases of two low pressure areas which formed over North Bay and caused active monsoon over Orissa will be discussed. In one case, the low moved across northern parts of Orissa and active monsoon conditions prevailed over the whole of Orissa, while in the other, the low moved northwestwards across West Bengal towards Bihar Plains causing heavy rains in northern parts of Orissa.

5.2 Low pressure area from Bay of Bengal moving across northern parts of Orissa (14 to 16 July 1962)

5.2.1 A deep depression which was off Hainan (in south China Sea) on 11th morning moved in a westerly direction and crossing Viet Nam coast, lay as a depression over northern portions of Thailand on 13th (Fig. 5.1). Subsequently it weakened and emerged as a low pressure area into Northeast Bay of Bengal on the 14th morning (Fig. 5.2). The upper winds, pressure changes and departures as well as rainfall distribution over Burma on 13th and 14th clearly indicated the westward movement of this system across the Arakan coast into the Bay (Figs. 5.3 and 5.4). With two other cyclonic circulations, one developing over northeast Arabian Sea and the other weakening over West Madhya Pradesh, easterlies were prevailing over most of north India in the lower troposphere and the monsoon trough was running at 0.9 km a.s.l. on 14th from northeast Arabian Sea to North Bay across south Madhya Pradesh and Orissa (Fig. 5.5). The ~~elevated~~ cyclonic circulation over Bay extended upto 500 mb. The weather was mainly dry in Orissa, with an isolated fall of 1 cm at Sambalpur. There was also very little rain over the rest of northeast India. However, over Burma and along East Pakistan coast, the rainfall was widespread and also heavy to very heavy at places. Although the trough was lying across Orissa, the subdivision did not get any substantial rain since it was to the rear of a well-marked low over West Madhya Pradesh. The pressure changes were slightly negative over North Bay and East Pakistan. Over Burma, Northeast Bay and adjoining East Pakistan the pressure departures were -4 to -5 mb.

5.2.2 On 15th morning the low pressure area persisted over Northeast Bay without appreciable movement (Fig. 5.6). However, the pressure gradient over Central Bay had increased since 14th. The associated upper air cyclonic circulation also extended upto 400 mb and was well organised (Fig. 5.7). There was a general fall of pressure by 1 mb over Orissa, Gangetic West Bengal and Bihar, with a marked rise over East Pakistan and Burma. Compared to the pre-

vious day (14th) there was considerable increase in rainfall over Gangetic West Bengal and along Orissa coast with one or two heavy falls - Sagar Island reported 8 cm and Sandheads and Puri reported 7 cm each. During the course of the day, the low pressure area moved northwestwards across northern parts of Orissa. Many stations in Orissa reported good amounts of rainfall on the evening of 15th with Titilagarh and Gopalpur recording 8 cm and 7 cm respectively.

5.2.3 On 16th morning the low pressure area was located over Bihar Plateau and neighbouring areas on the sea level chart (Fig. 5.8). The associated circulation in the upper air was extending upto 9.0 km and continued to be well-marked (Fig. 5.9). There was widespread rainfall over the whole of northeast India, which is rather difficult to anticipate from the previous day's charts. Monsoon was active over Orissa with five stations reporting 5 cm to 8 cm of rain. Pressures were rising over most of Orissa and were falling by about 2 mb to the north. The negative pressure departures were also greater over areas to the north of Orissa, being -2 mb.

5.2.4 With the shifting of the low pressure area further away from Orissa to extreme north Madhya Pradesh and adjoining south Uttar Pradesh, rainfall activity over Orissa decreased considerably on 17th, with only a few stations in the extreme northern portions of Orissa reporting 1 to 2 cm of rainfall (Fig. 5.10). By 18th the low moved further northwestwards to south west Uttar Pradesh and adjoining East Rajasthan and the eastern end of the axis of the seasonal monsoon trough also shifted well to the north of Orissa. The rainfall over Orissa decreased further and it was generally very light and scattered (Fig. 5.11).

5.3 Low pressure area from Northeast Bay of Bengal moving northwestwards into West Bengal and Bihar and causing heavy rains over north Orissa (2 to 3 August 1965)

5.3.1 On 1st August 1965, the axis of the monsoon trough was well to the north of Orissa, and its eastern end was extending into Northeast Bay of

Bengal (Fig. 5.12). In the upper air a trough/circulation was noticed over this area upto about 600 mb without much slope with height (Fig. 5.13). Pressures were falling over northeast India, East Pakistan and adjoining Burma, where the pressure departures were -3 to -4 mb. Orissa was almost dry on this day. There was heavy rain along the Arakan-Chittagong coast.

5.3.2 By 2nd morning a low pressure area developed over East Pakistan, the Head Bay and Gangetic West Bengal (Fig. 5.14). To the west of 85°E, the monsoon trough was close to foot-hills of Himalayas, akin to the situation during 'breaks'. Except over the central region of the low, where the pressures were probably falling slightly, there was a general rise of pressure in the neighbouring areas; the pressure departures were -2 to -4 mb over the area. However, the associated cyclonic circulation was more marked than on the previous day and was seen in the upper air upto 500 mb (Fig. 5.15).

5.3.3 In association with the low, there was an increase in rainfall in Gangetic West Bengal and adjoining north Orissa where a few stations reported heavy to very heavy rain of 8 cm to 14 cm. This area was to the south of the trough in the lower troposphere during the past 24 hrs.

5.3.4 The low moved northwestwards to central parts of West Bengal and neighbourhood on the morning of 3rd (Fig. 5.16) and was weakening as inferred by the pressure rise all over the area as well as from the weakening of the upper air circulation (Fig. 5.17). The rainfall was mainly over West Bengal and Bihar Plateau and was extending southwards to north Orissa also. Further south, there was a sharp decrease in rainfall. With the shifting of the low away from Orissa, the intensity of rainfall also decreased over north Orissa. During the next 24 hrs, the low further weakened and the axis of the monsoon trough was running on 4th morning from Bihar Plains to lower Assam, well to the north of Orissa leading to weak monsoon conditions over the whole of Orissa.

6. Trough in Westerlies in the Upper Air

6.1 Whenever the monsoon trough is well to the north of Orissa, steady westerlies prevail over Orissa in the lower and middle troposphere, with generally anticyclonic shear. This is associated with dry weather over the state. However, occasionally troughs form in these westerlies and cause substantial rainfall over Orissa; these falls are generally of convective nature. Two such situations are discussed in this section.

6.2 Case 1 : 23 to 25 August 1966

6.2.1 "Break" monsoon conditions were setting in over the country on 22nd August 1966. The monsoon trough was running on the sea level chart from Punjab to north Assam through Uttar Pradesh and Bihar Plains (Fig. 6.1). In the lower troposphere (Fig. 6.2) southwesterlies/westerlies were extending upto the foot-hills of the Himalayas. A feeble trough line was seen over East Madhya Pradesh and Telangana upto about 500 mb. This trough was apparently the remnant of a low pressure area which was earlier persisting over northeast Madhya Pradesh for almost a week. In the middle latitudes the movement of a trough in the westerlies was also seen (Fig. 6.3 a and b). There was significant rainfall over the Gangetic plain to the east of 82°E; Orissa had a few light showers.

6.2.2 The surface and upper air synoptic features on the morning of 23rd may be seen in Figs. 6.4 and 6.5. The axis of the monsoon trough was close to the foot-hills of the Himalayas. The trough in the westerlies over the country had slightly moved eastwards. Though Orissa was dry, there was well distributed rainfall from West Uttar Pradesh and north Madhya Pradesh to Assam and East Pakistan; the southward extension of rainfall over north Madhya Pradesh and Bihar Plateau was apparently due to the presence of the westerly trough, to the west of the area.

5.2.3 On the morning of 24th, the trough in the westerlies in the lower and middle troposphere was over West Bengal (Fig. 6.6). The movement of the trough on 23rd and 24th, could be traced by following the changes in the upper winds over Uttar Pradesh and northeast India from chart to chart. The rainfall belt shifted eastwards on 24th with marked clearance to the west of Long. 83°E; the rainfall also extended to Orissa where some stations reported moderate rainfall. With the moving away of this trough further eastwards subsequently, the main rainfall belt also shifted eastwards and the rainfall over Orissa decreased progressively during the next 2 days.

6.3 Case 2 : 6 to 9 August 1965

6.3.1 During the first fortnight of August, 1965, break monsoon conditions were prevailing over the country. On 6th the axis of the seasonal trough was running close to the foot of the Himalayas (Fig. 6.7). A trough was also seen along the east coast of the Peninsula. Orissa had registered scattered light rain during the preceding 24hrs. Pressure changes were mostly within $\pm$ 1 mb over the country. Pressure departures were characteristic of break monsoon, being above normal over most of the country except along and near the foot-hills of the Himalayas and the extreme south of the Peninsula; it was + 2 mb to + 4 mb over large tracts in the central parts of India. In the lower troposphere westerly winds had extended right upto the foot of the Himalayas (Fig. 6.8). Note the strong westerlies of 25 to 35 kt, north of 25°N with weaker winds to the south.

6.3.2. On 7th morning the surface isobaric pattern was more or less the same as on the previous day. The rainfall pattern, the pressure changes and departures were also similar to those prevailing on the previous day. However, in the lower troposphere a trough was seen extending from Tamil Nadu coast to sub-Himalayan West Bengal (Fig. 6.9). On 8th morning also the rainfall was scattered over Orissa.

6.3.3 The surface synoptic features on 6th and 7th described above continued to be seen on 9th and 10th August, 1965. The lower tropospheric trough shifted westwards and its positions can be seen in Figs. 6.10 and 6.11 which depict the upper winds on 9th and 10th respectively. The trough was either over or to the west of Orissa below 850 mb on these two days. With the westward shift of the trough the rainfall increased in Orissa and there were two reports of 10 cm and 12cm of rain on 10th and one report of 10 cm on 11th. Between 9th and 10th a trough/low also moved westwards across the south Peninsula in middle troposphere. The trough in the westerlies over Orissa and Madhya Pradesh appears to have been coupled with this system in easterlies moving across the south Peninsula.

6.3.4 These two cases of the troughs discussed above occurred during break periods when the monsoon westerlies prevailed over the whole of India. In the first case the trough was seen in lower and middle troposphere and it showed a regular eastward progression, causing rainfall as it approached Orissa. Rainfall decreased over Orissa when the trough moved away eastwards. Hemispherical charts also showed the movement of a trough in westerlies across southern Russia, Tibet and West China at the 500 and 300 mb levels. In the second case, the trough was seen mainly in the lower troposphere and showed a westward movement though the movement was not very regular. Rainfall increased when the trough came over Orissa and slightly to the west of it. In the second case there were one or two heavy falls of the order of 10 cm. In this case, the hemispherical charts for 8, 9 and 10 showed a ridge over Tibet and adjoining areas at 500 mb and 300 mb levels in the rear of a westerly trough (Figs. 6.12 and 6.13).

7. Weak Monsoon over Orissa

7.1 In the earlier sections we have seen that active monsoon over Orissa is usually associated with some disturbance over or near Orissa - such as a depression, a low pressure area or a trough line. Even during the break conditions, Orissa gets rainfall if a trough happens to be in the neighbourhood of Orissa.

In the absence of any such disturbance the monsoon is weak over Orissa. One such occasion of weak monsoon when the monsoon trough was well to the north of Orissa is discussed in this section.

7.2 During the period 31 July, 1967 to 4th August a deep depression from the Bay of Bengal crossed north Orissa coast and moving westnorthwestwards weakened and merged with the seasonal low. In association with this system, Orissa experienced active to vigorous monsoon conditions from 31 July to 2 August 1967. However, as the monsoon trough continued to be over or close to Orissa, the wet spell persisted till 5th. On 4th the monsoon trough started shifting northwards. On 5th the axis of the trough shifted well to the north of Orissa and passed through Ferozpur, Hardoi and Krishnagar on the sea level chart (Fig. 7.1). A low pressure area was also seen over Gangetic West Bengal and neighbourhood on the surface chart and this extended in the upper air upto at least 2 km (Fig.7.2). In association with the low, heavy rains occurred over Gangetic West Bengal and the rainfall area also extended southward to the northeastern parts of Orissa.

7.3 On 6th, the eastern portion of the trough shifted further northwards and its axis was running on the sea level from Faizabad to Sabour and thence eastnortheastwards towards North Assam (Fig. 7.3). The low over Gangetic West Bengal became less marked. In the lower troposphere also the axis of the eastern half of the trough was roughly along 25°N (Fig. 7.4). With the northward shift of the trough and the weakening of the low over Gangetic West Bengal there was a marked decrease in rain over Orissa and Gangetic West Bengal; compared to the previous day, only isolated light to moderate rainfall was recorded on 6th morning in Orissa.

7.4 On 7th, the axis of the monsoon trough on the sea level chart was along Ferozpur, Najibabad, Faizabad and Tura (Fig. 7.5). In the lower troposphere, winds over Orissa and neighbourhood were strong westerlies of the order of 20-30 kt (Fig. 7.6). This westerly flow was extending upto Lat. 25°N i.e. well to

the north of Orissa. The monsoon activity over Orissa remained weak on this day with scattered light falls. The trough continued to be well to the north of Orissa for the subsequent two days also with moderate to strong westerly flow over Orissa resulting in weak monsoon conditions over Orissa. By 10th, the trough shifted southwards and a cyclonic circulation also developed over Gangetic West Bengal, as a result of which the monsoon once again revived over Orissa.

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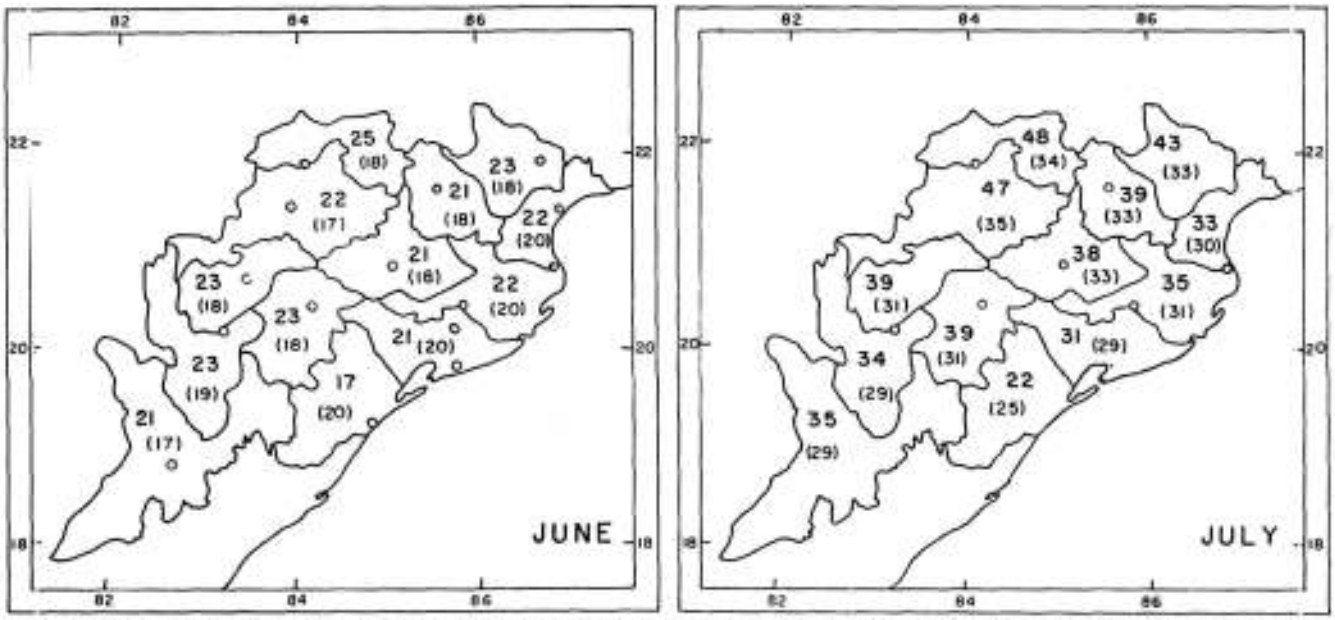
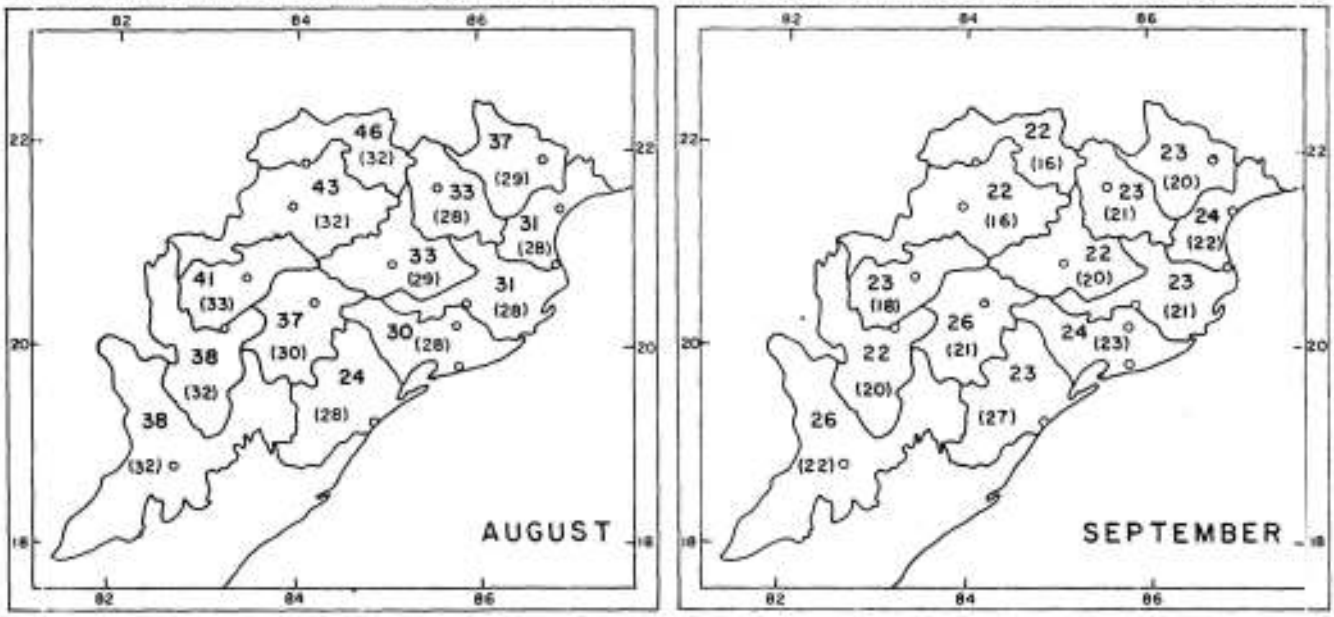
DIAGRAMS

FIG.1·1 MEAN MONTHLY RAINFALL - ORISSA



FIGJRES INDICATE RAINFALL (cm) IN THE DISTRICTS: FIGURES IN BRACKETS GIVE THE PERCENTAGES IN THE SEASON'S TOTAL



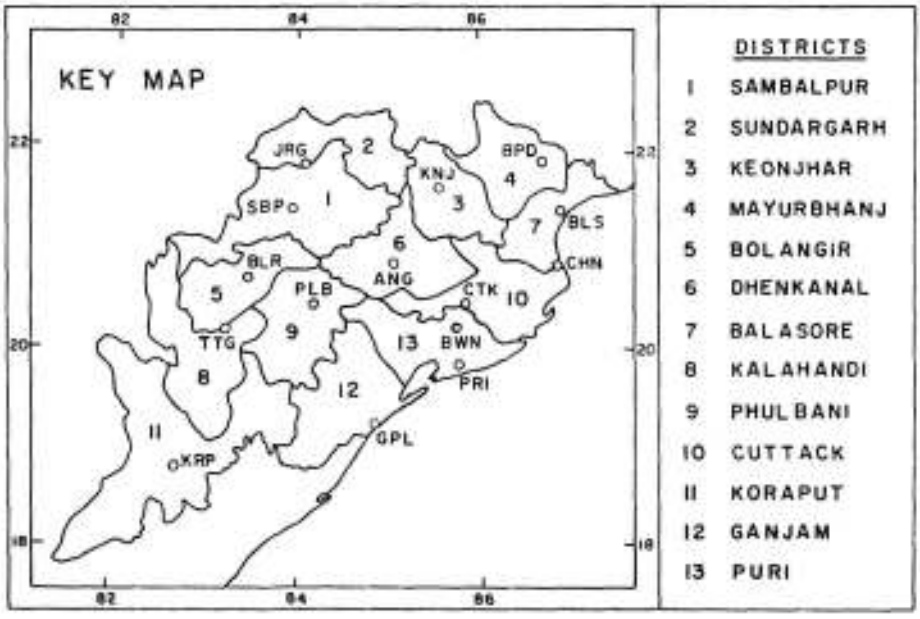
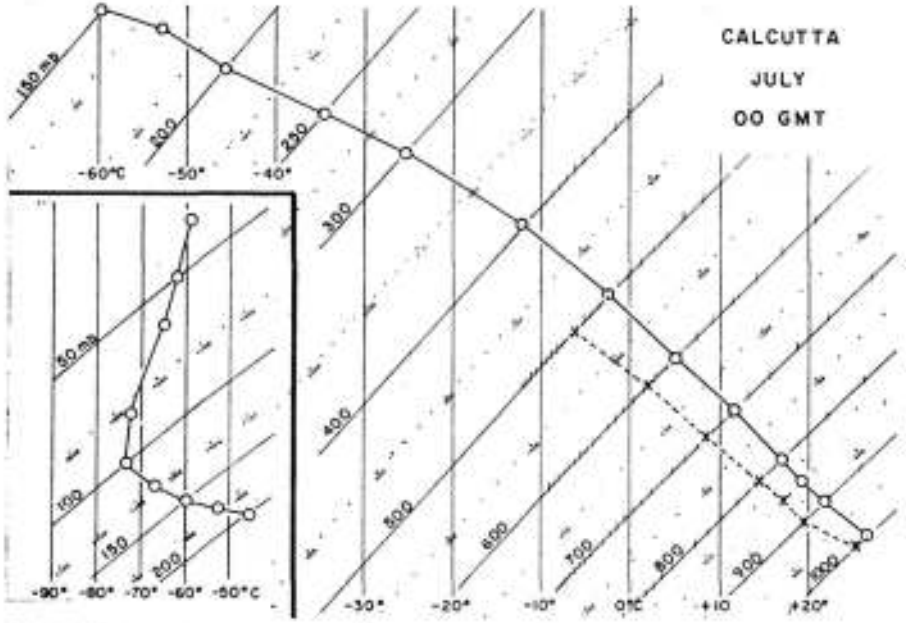
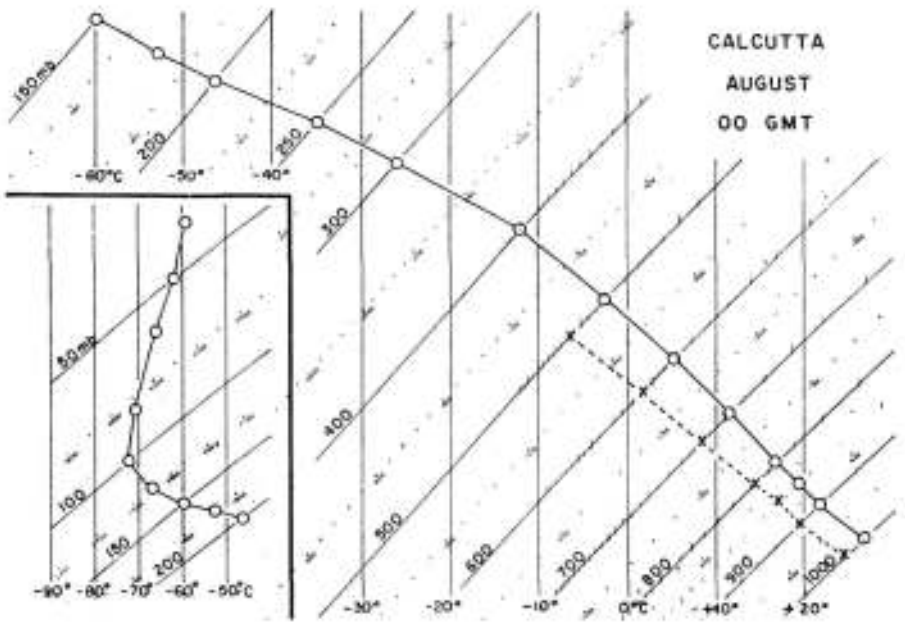
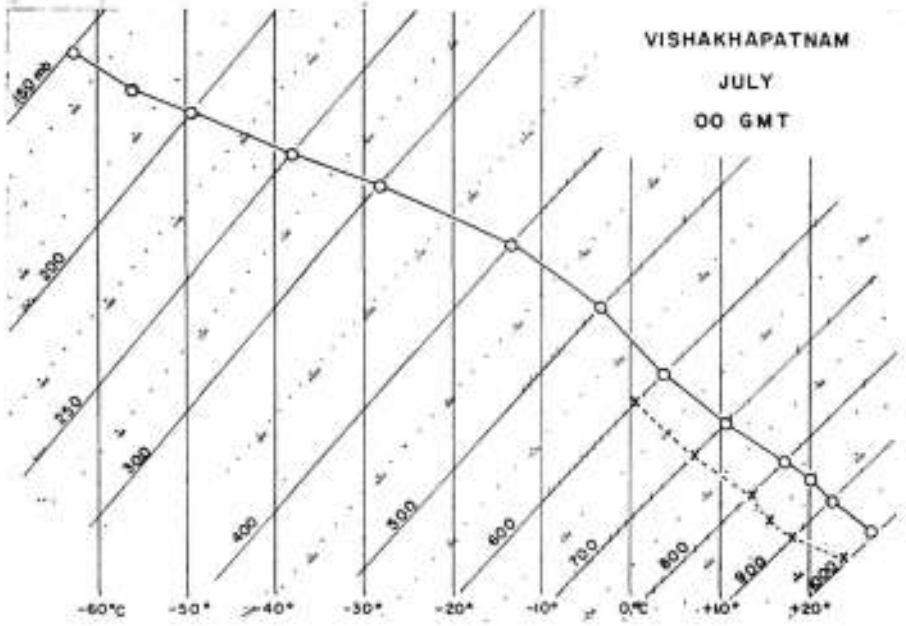


FIG. I·2 MEAN TEPHIGRAMS – CALCUTTA AND VISHAKHAPATNAM







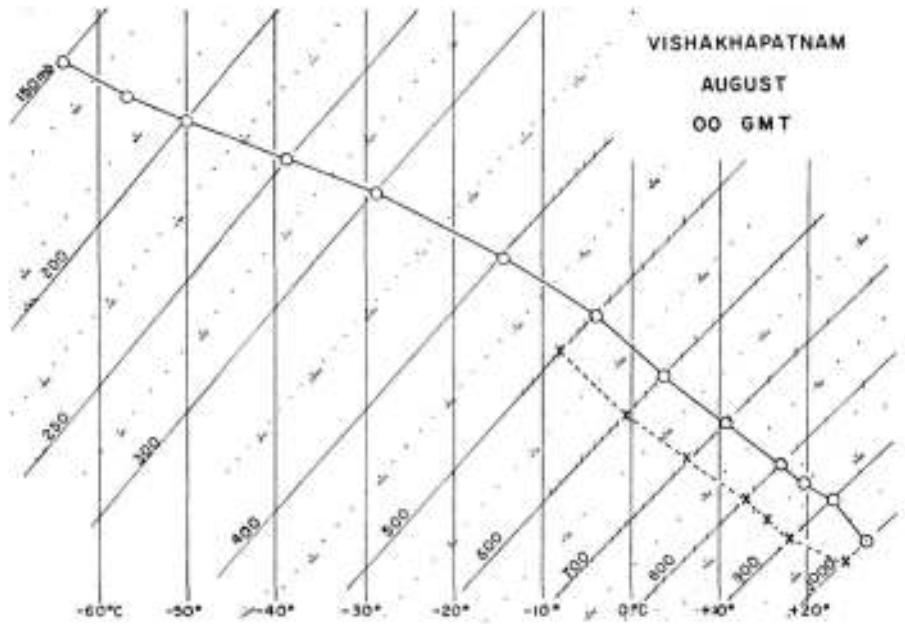
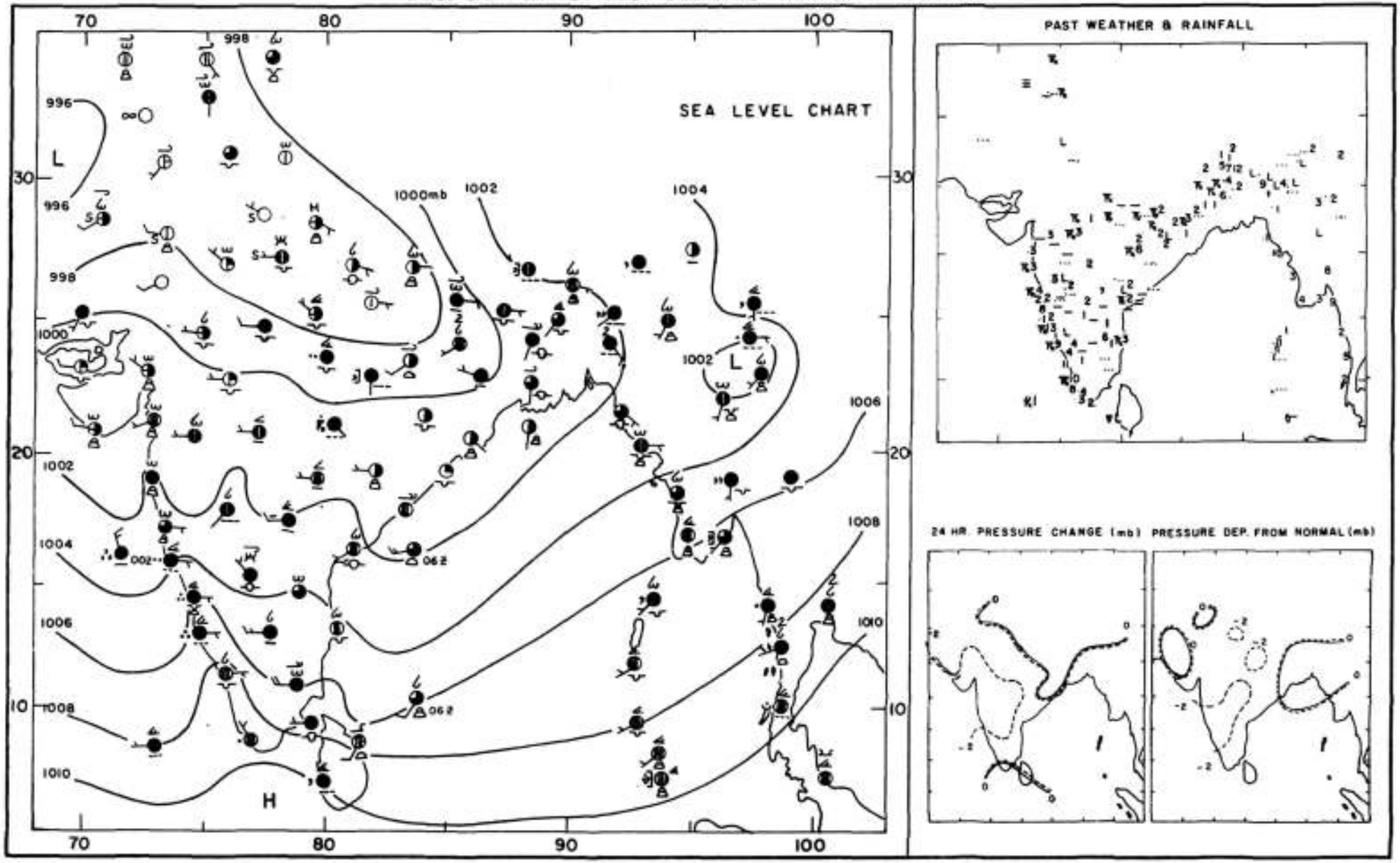
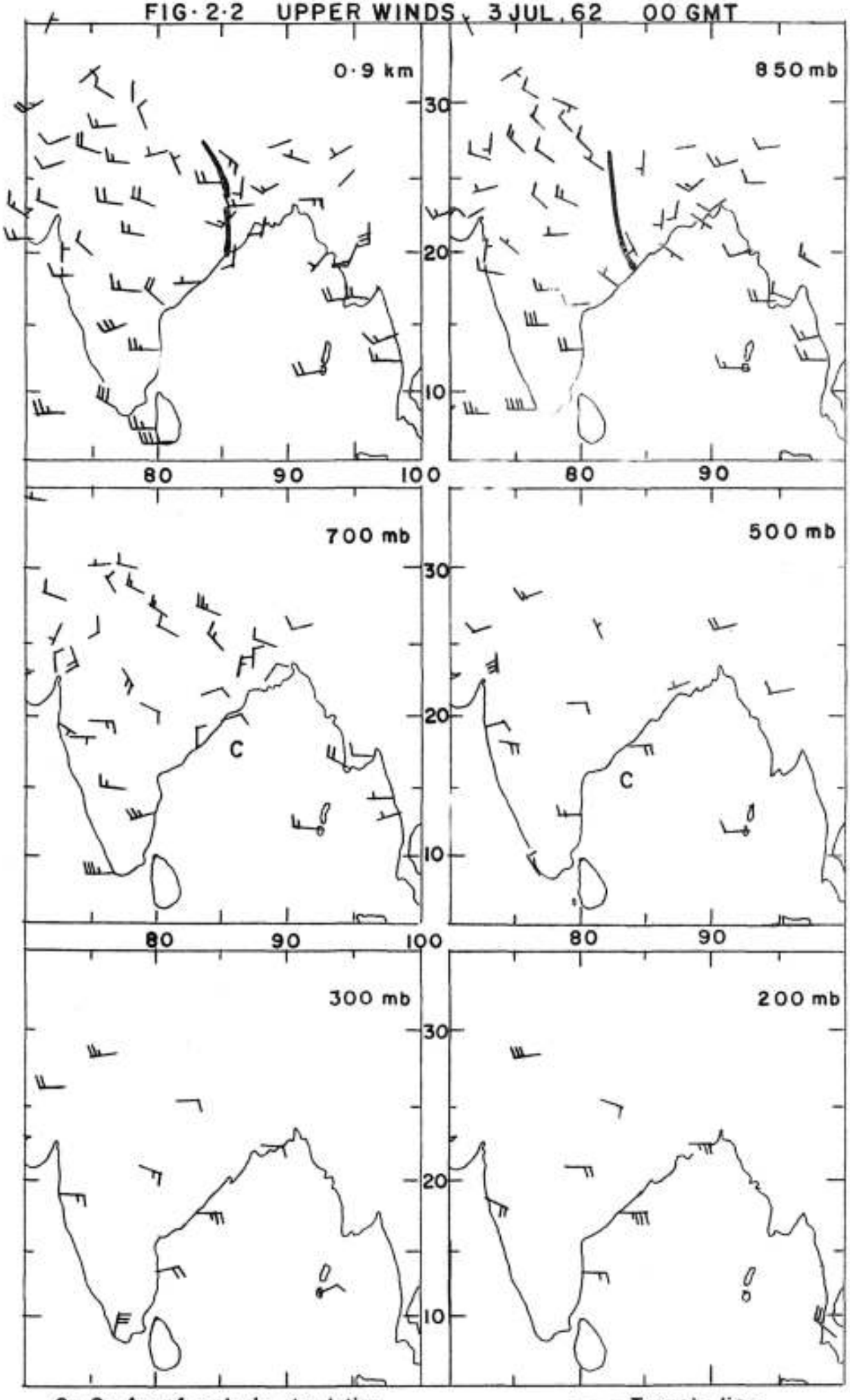


FIG. 2·1 SYNOPTIC CHARTS 0300 GMT 3 JUL.62



FIG·2·2 UPPER WINDS, 3 JUL. 62 00 GMT



C– Centre of cyclonic circulation

—— Trough line

FIG. 2·3 SYNOPTIC CHARTS 0300 GMT 5 JUL. 62

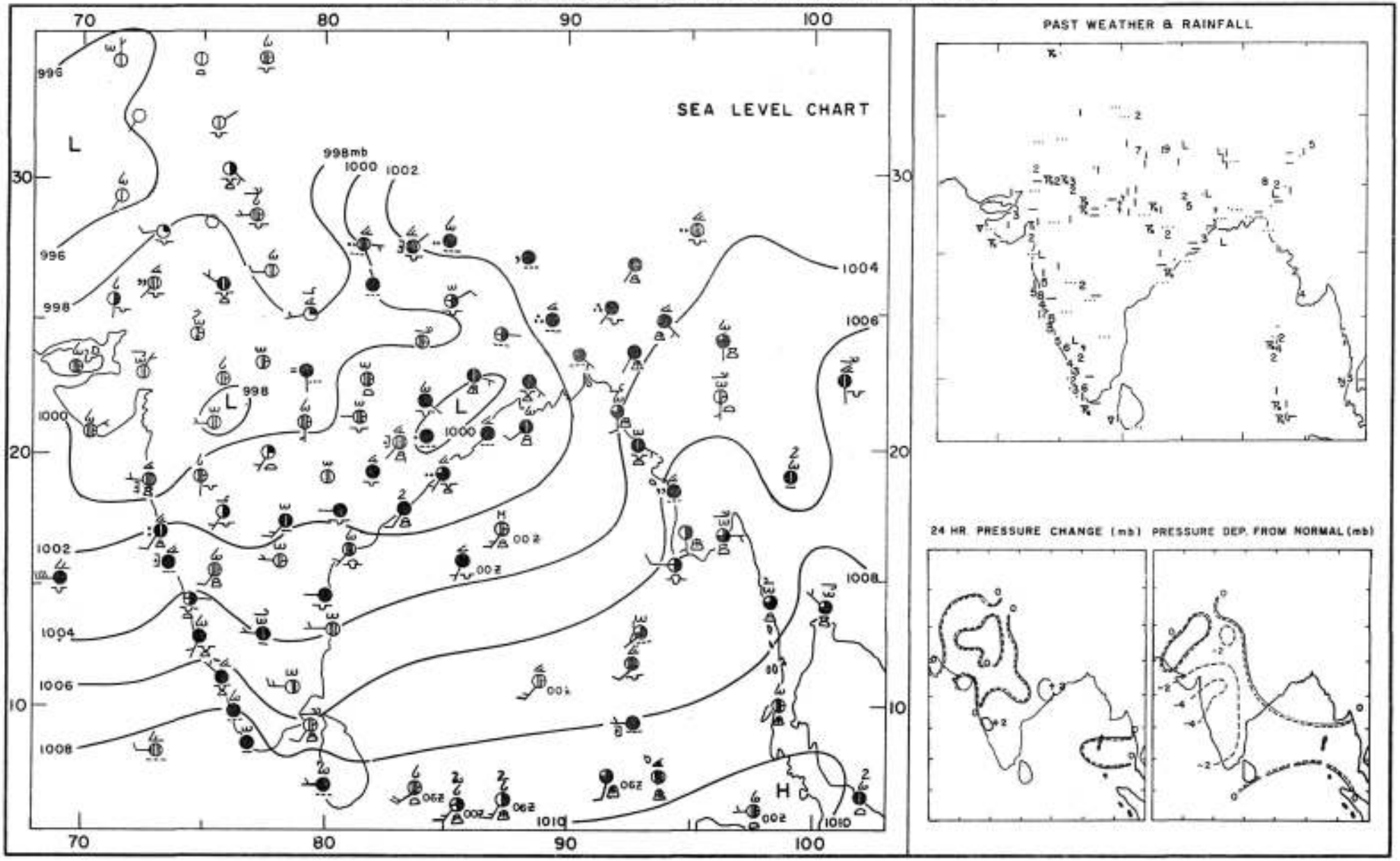
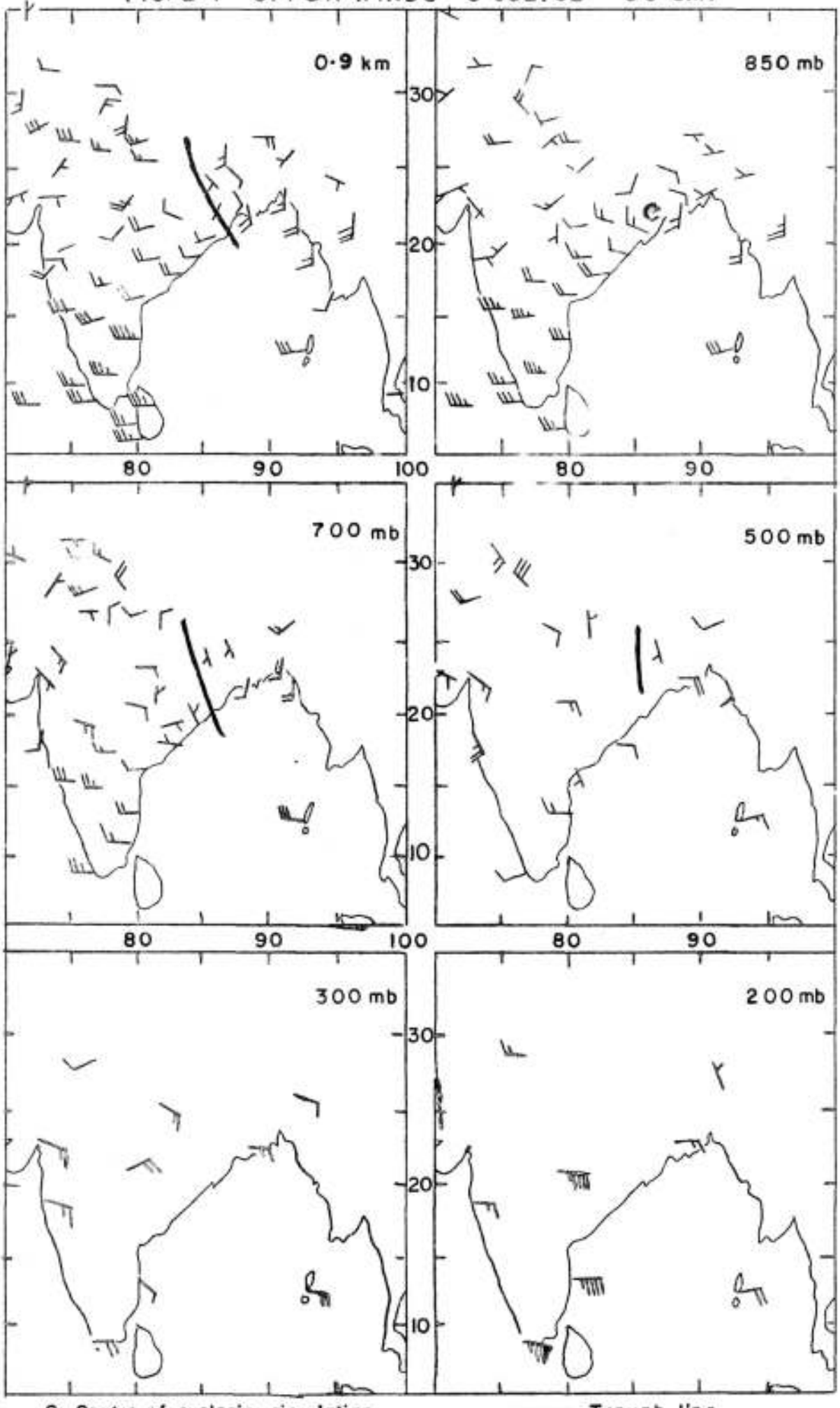


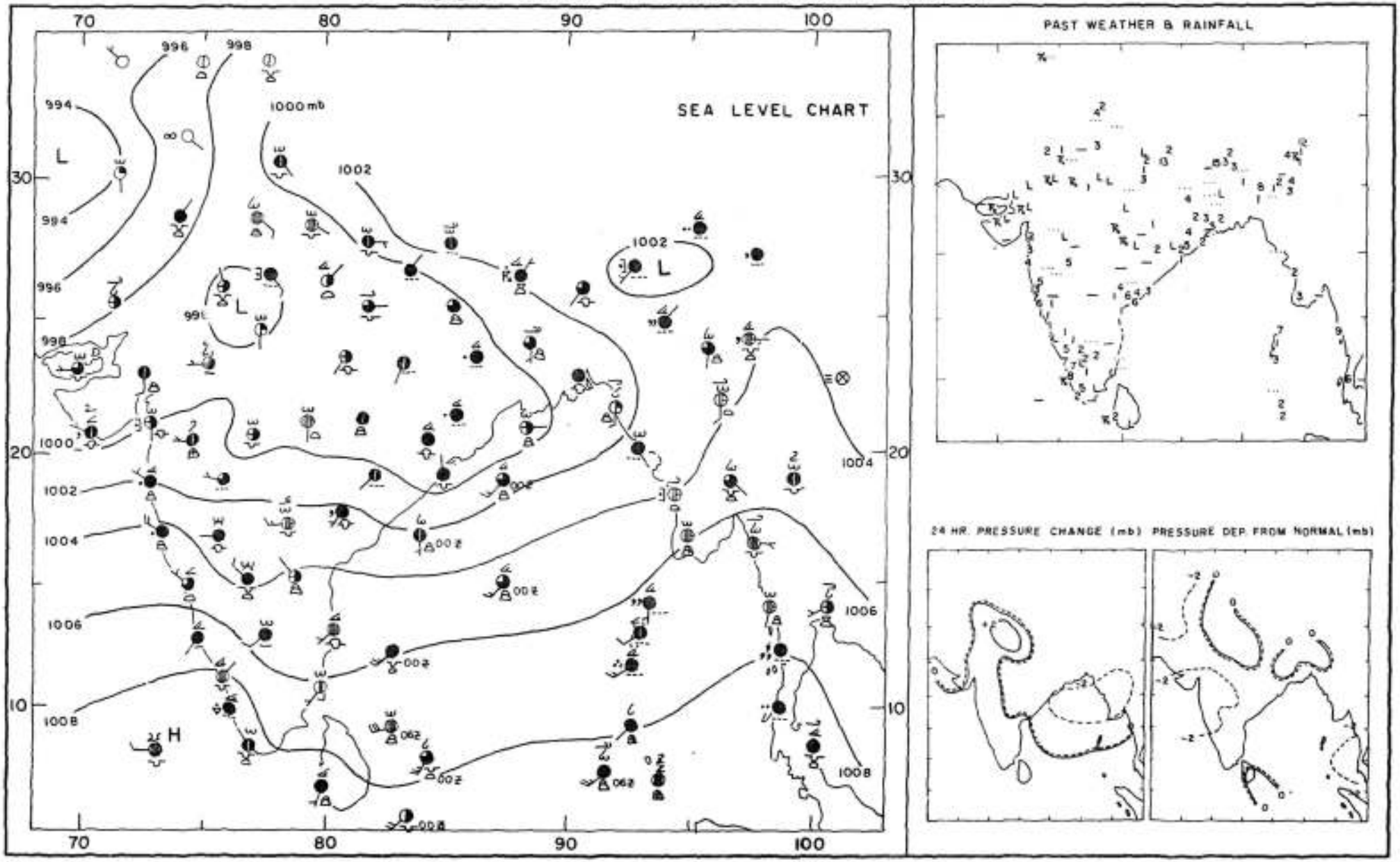
FIG: 2·4 UPPER WINDS 5 JUL. 62 00 GMT



C–Centre of cyclonic circulation

Trough line

FIG. 2·5 SYNOPTIC CHARTS 0300 GMT 6 JUL. 62



FIG·2·6 UPPER WINDS 6 JUL·62 00 GMT

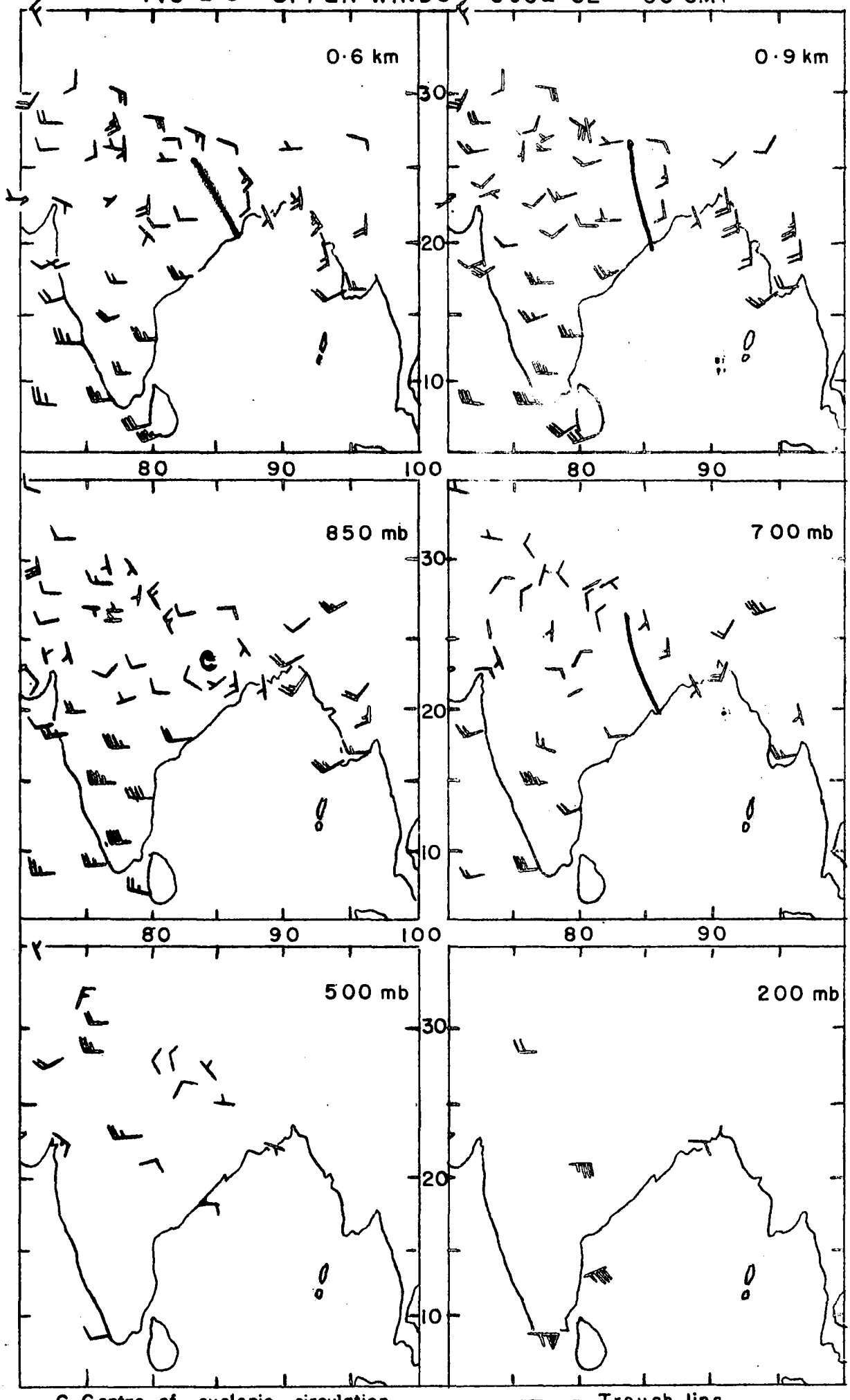


FIG.2-7 SYNOPTIC CHARTS 0300 GMT 7 JUL. 62

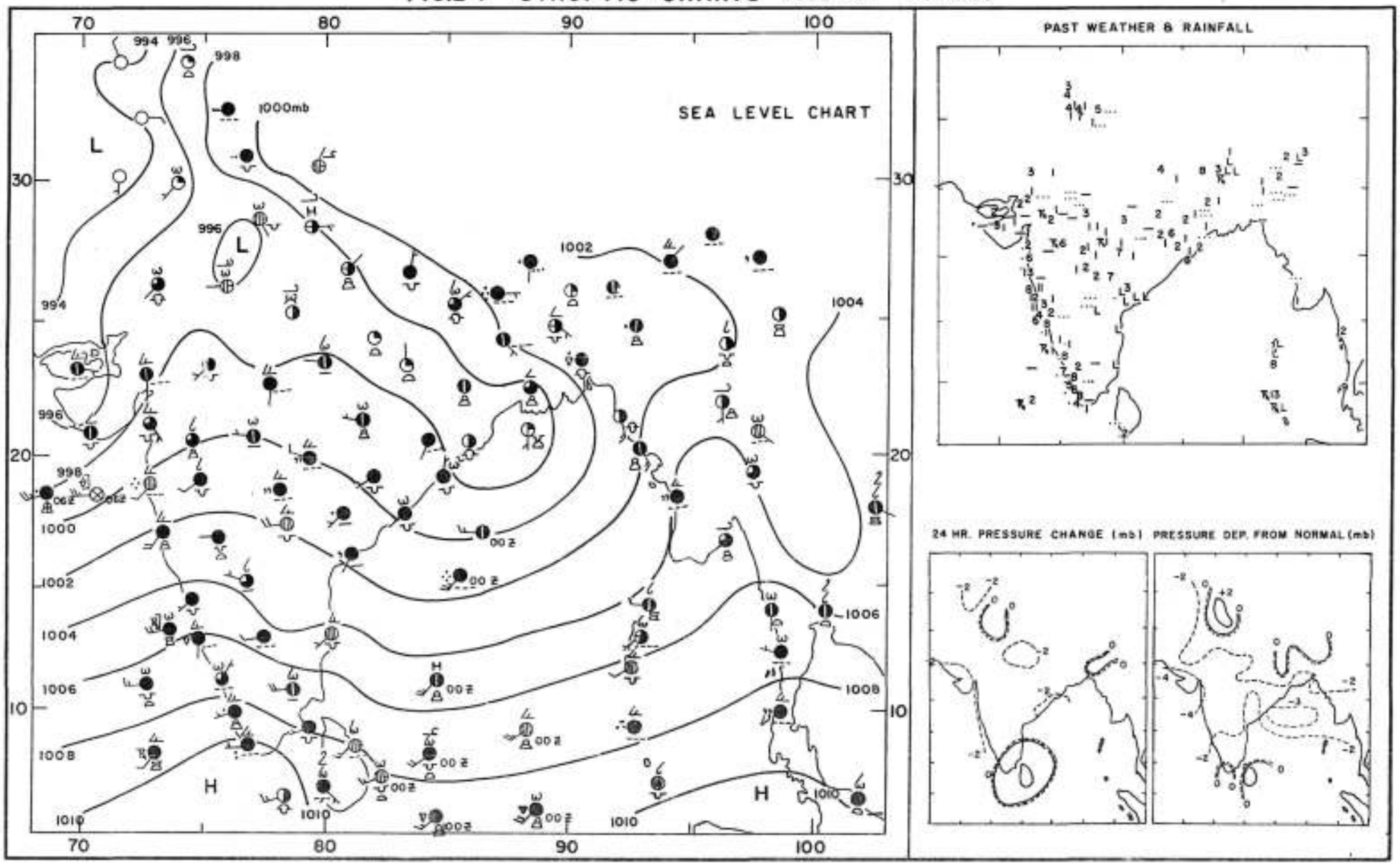


FIG. 2-8 UPPER WINDS 7 JUL. 62 00 GMT

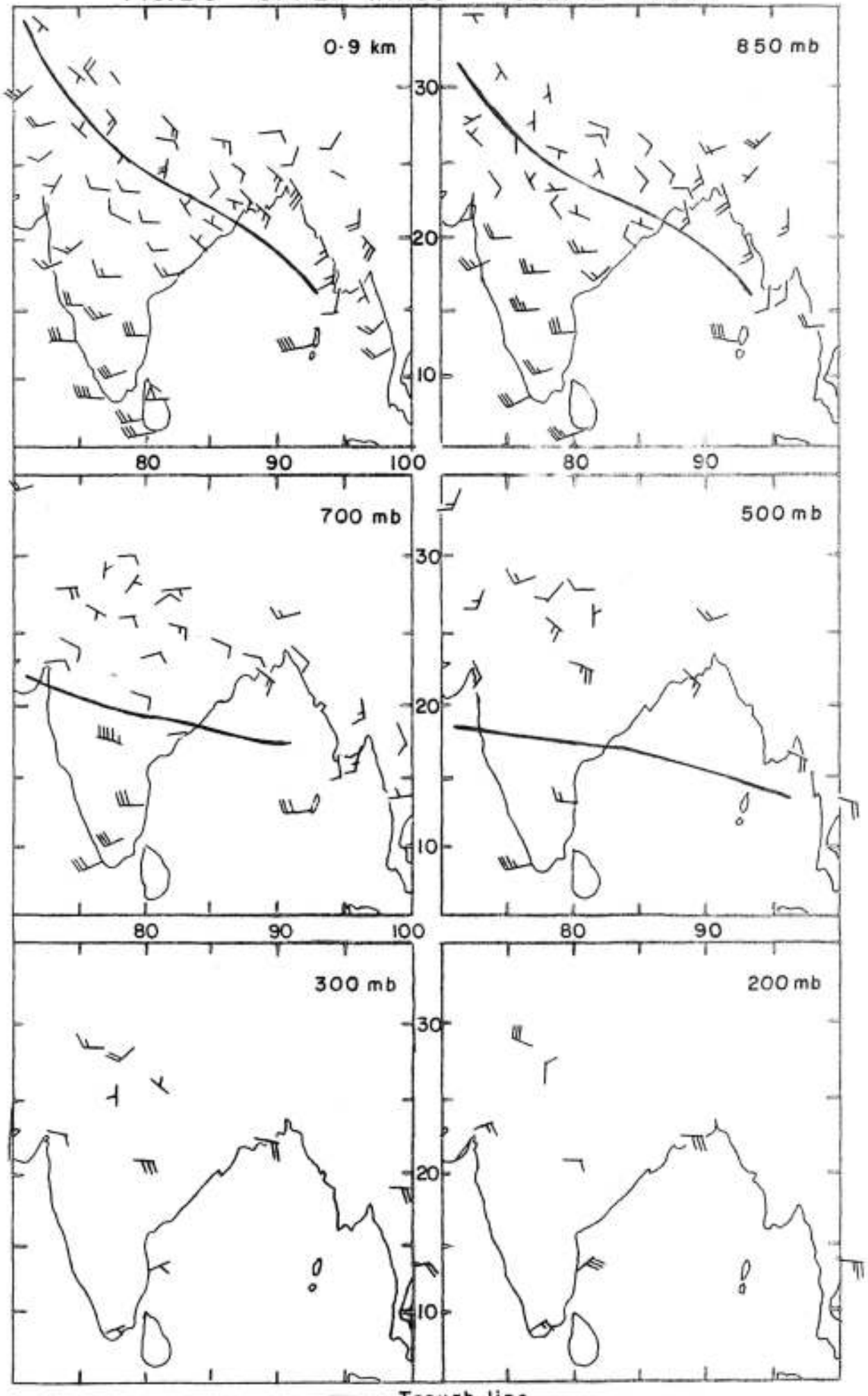
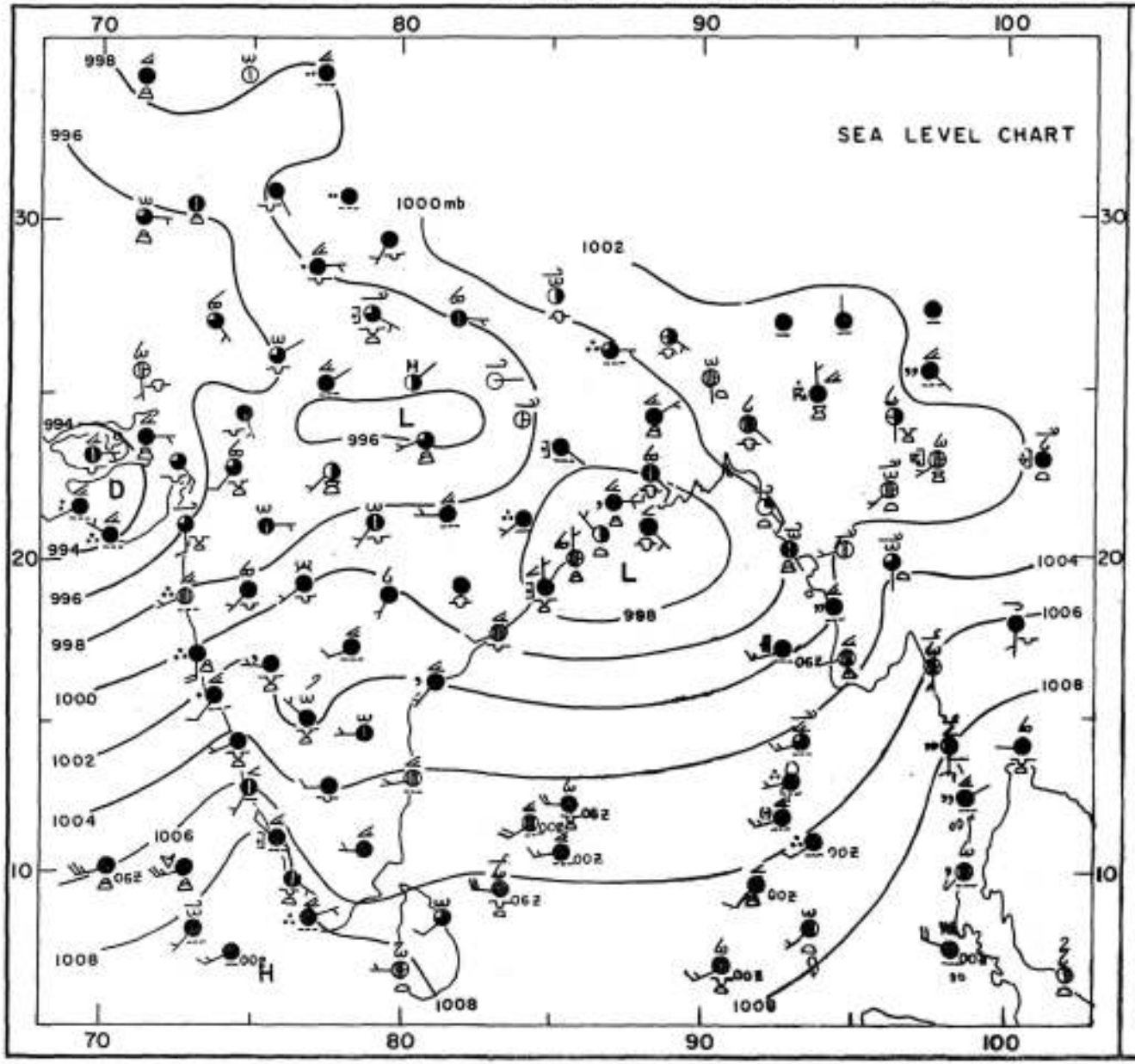
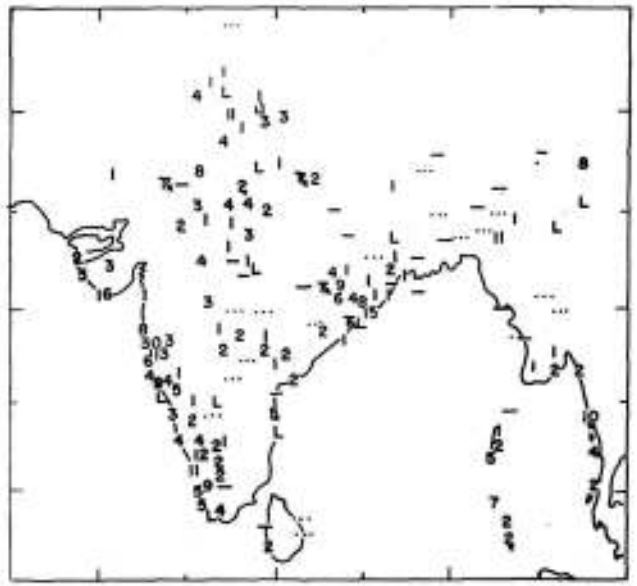


FIG.2·9 SYNOPTIC CHARTS 0300 GMT 8 JUL. 62





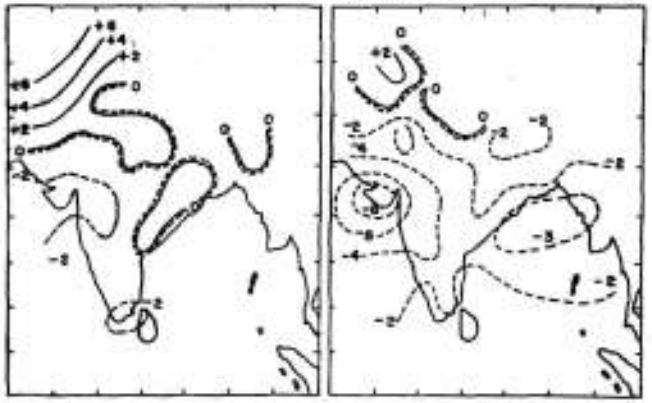
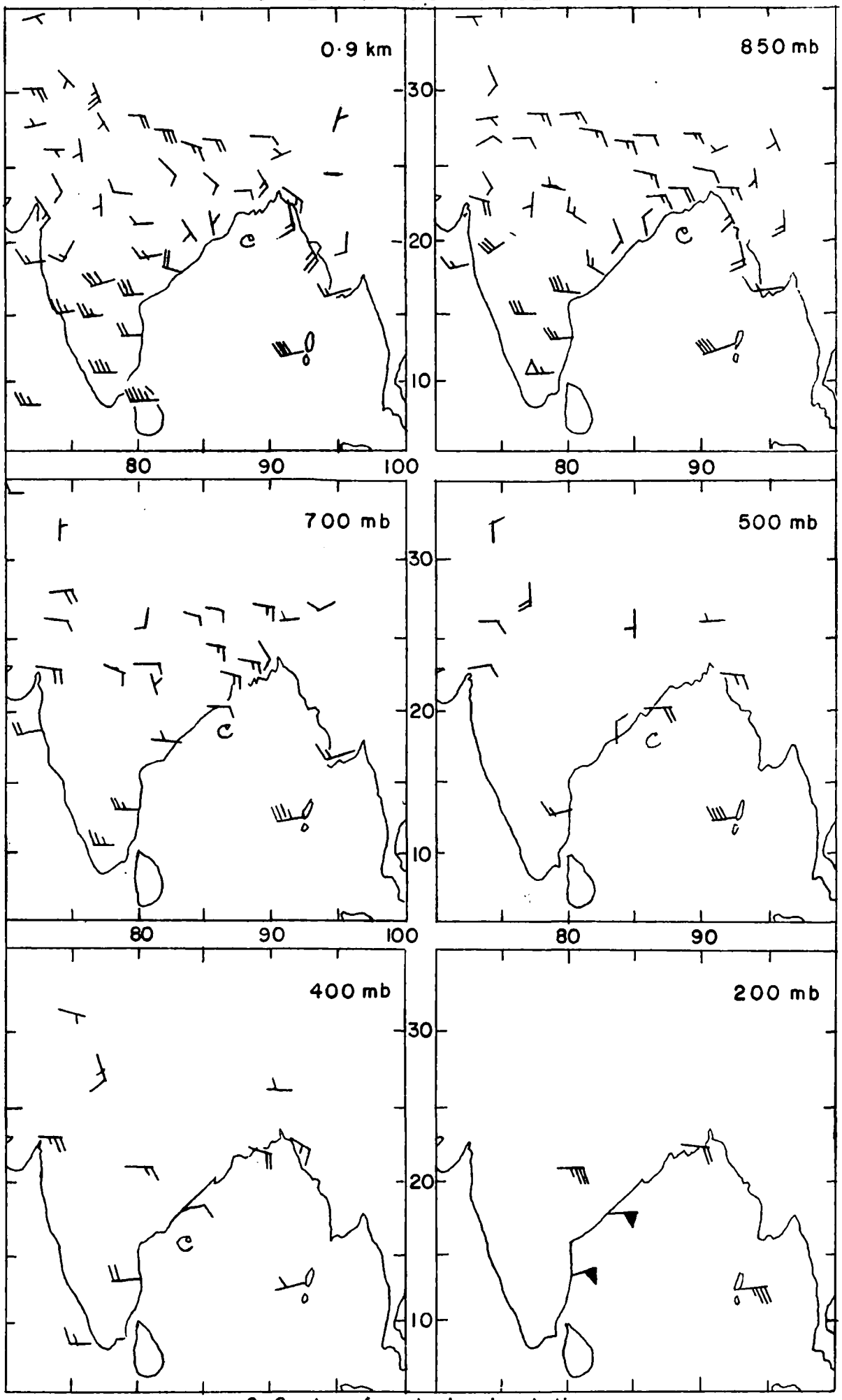


FIG. 2·10 UPPER WINDS 8 JUL. 62 00 GMT



C-Centre of cyclonic circulation

FIG.2·II SYNOPTIC CHARTS 0300 GMT 9 JUL. 62

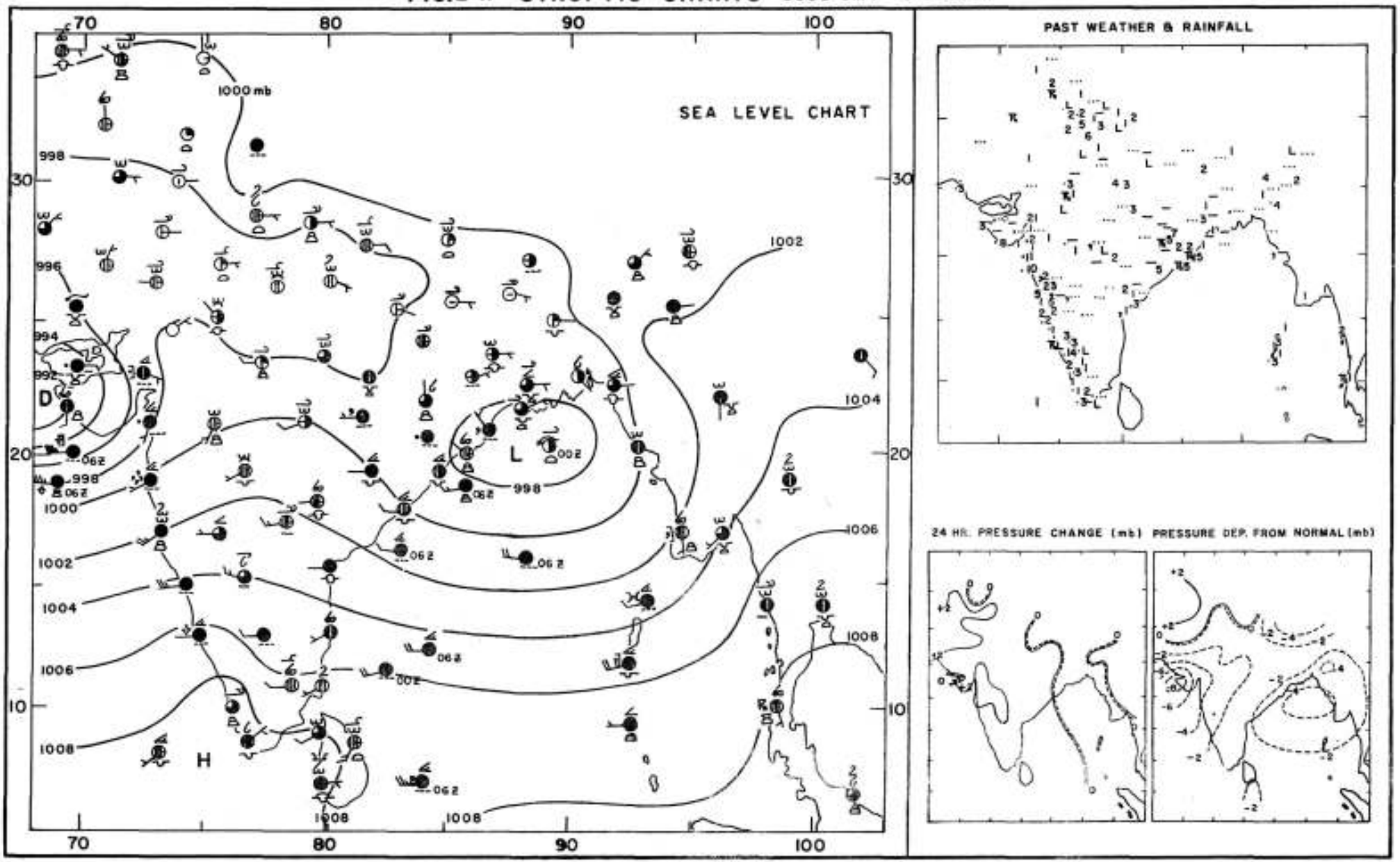
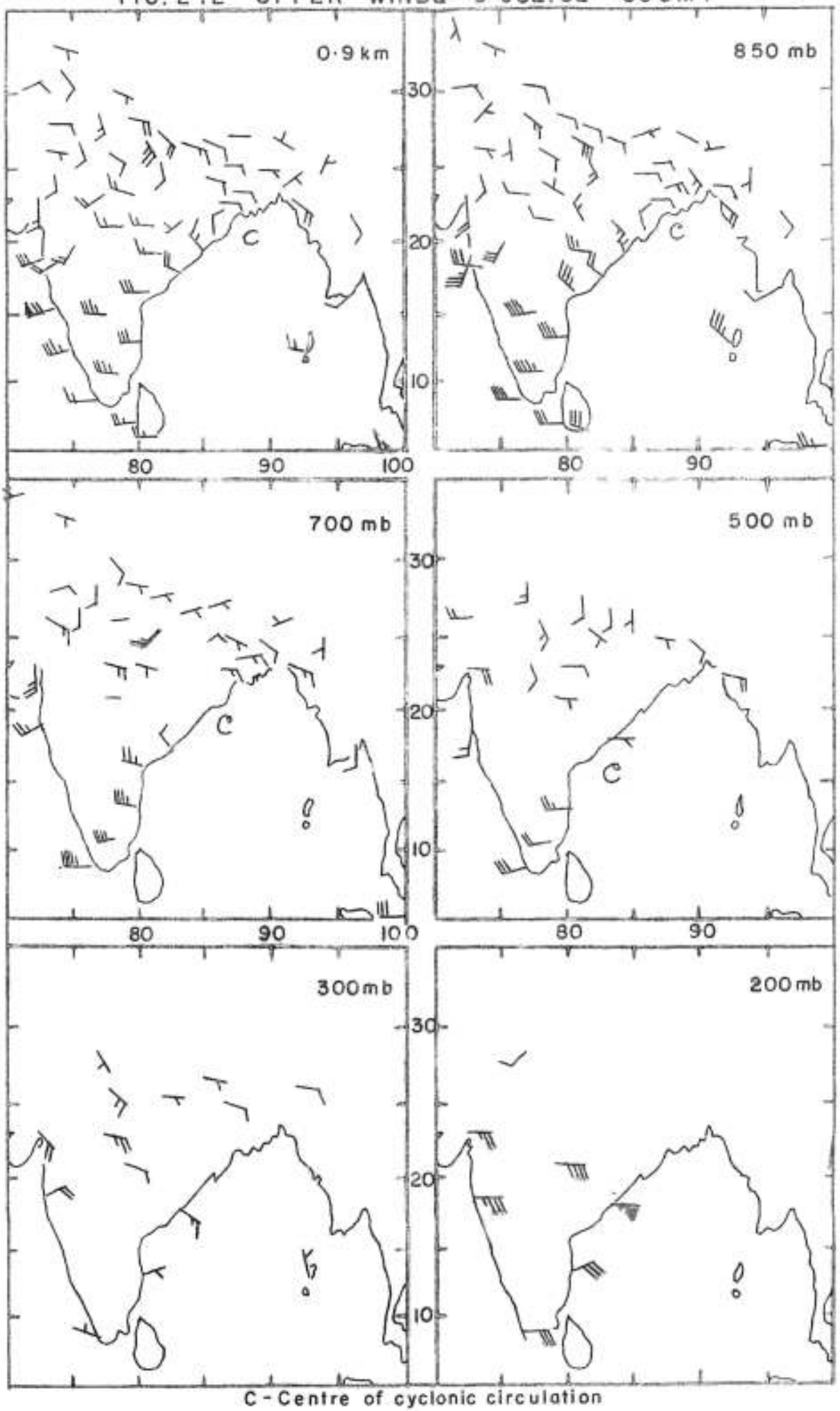


FIG. 2·12 UPPER WINDS 9 JUL. 62 00GMT



C - Centre of cyclonic circulation

FIG. 3·1 UPPER WINDS 2 AUG. 64 00GMT

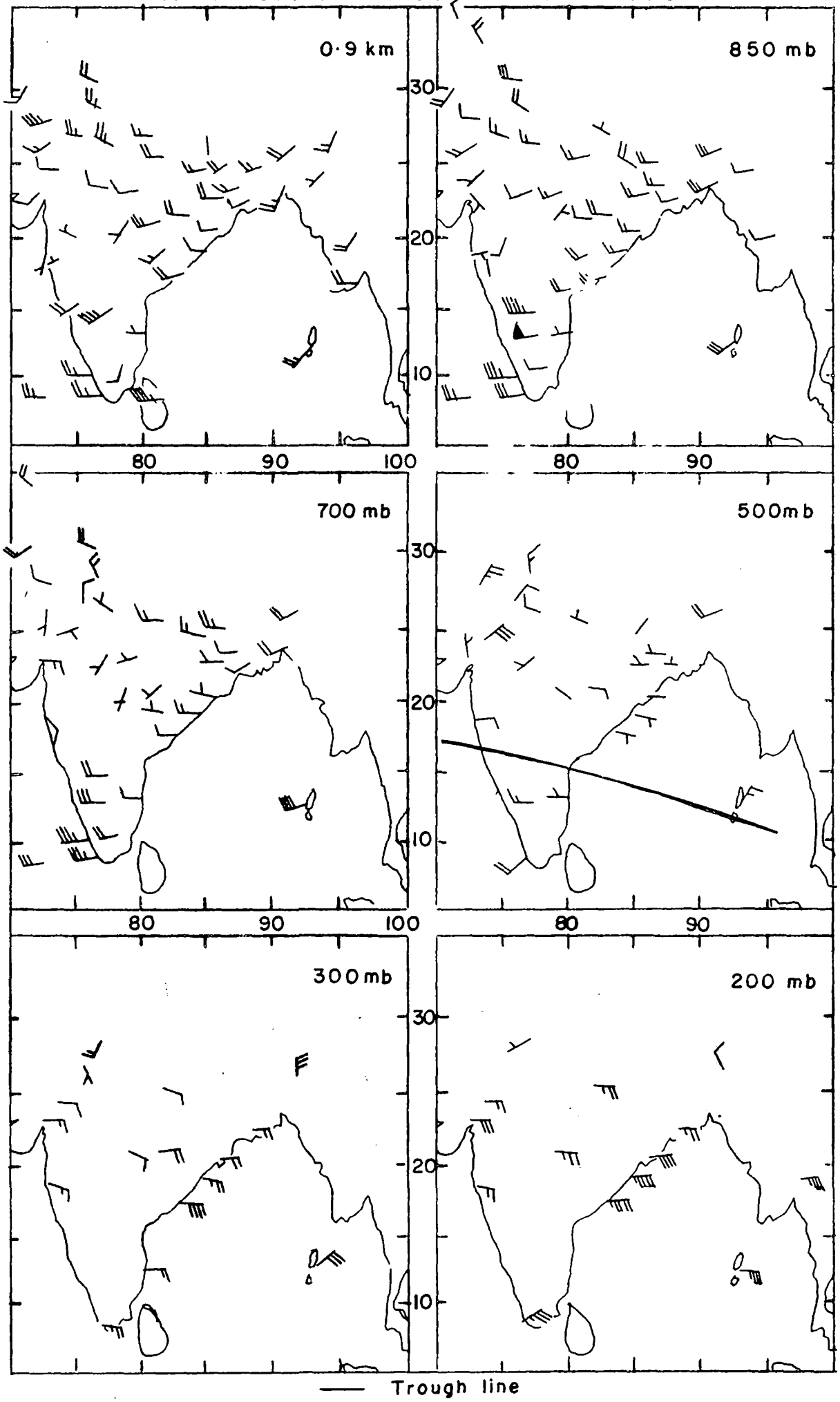


FIG.3·2 SYNOPTIC CHARTS 0300 GMT 3 AUG. 64

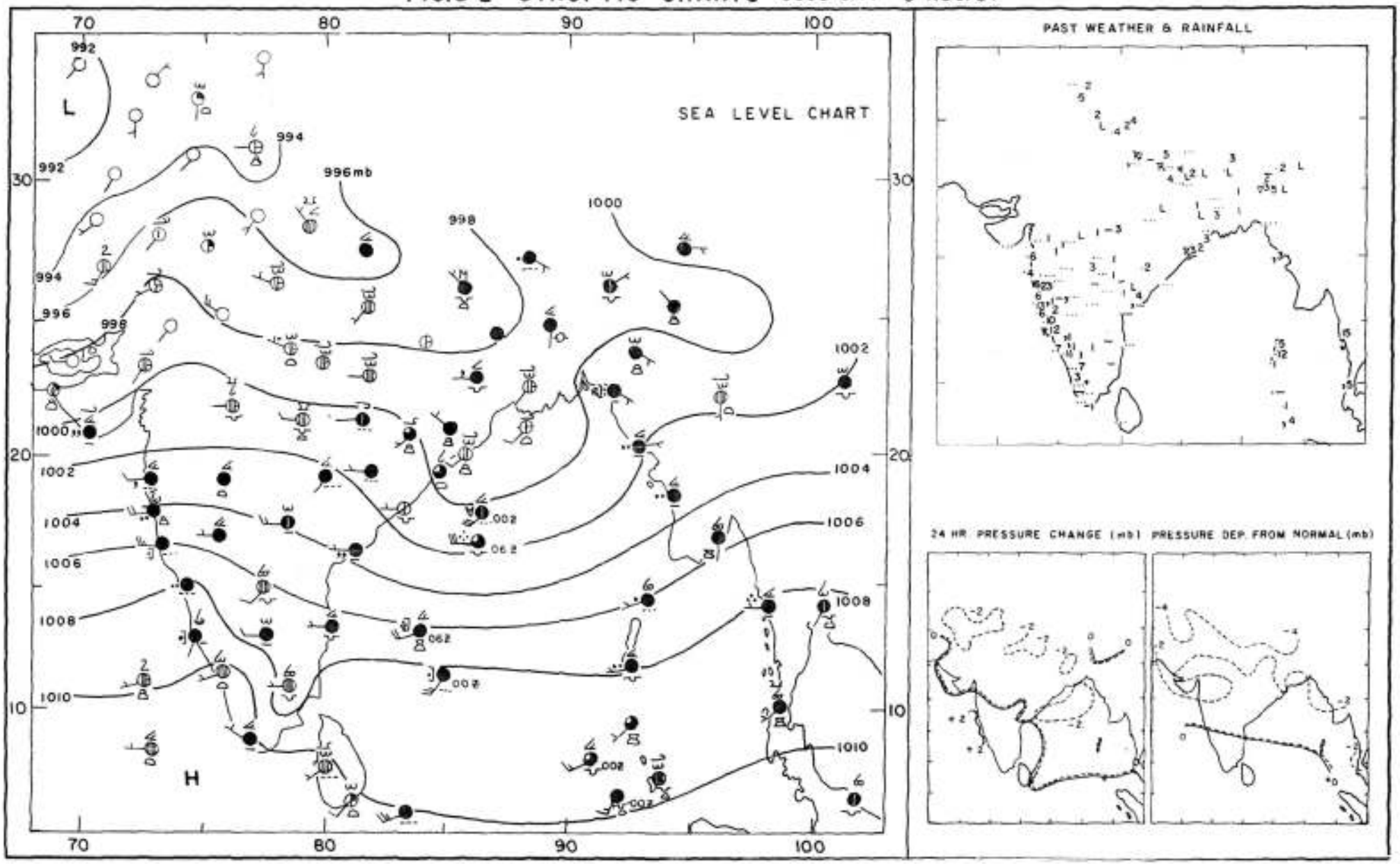
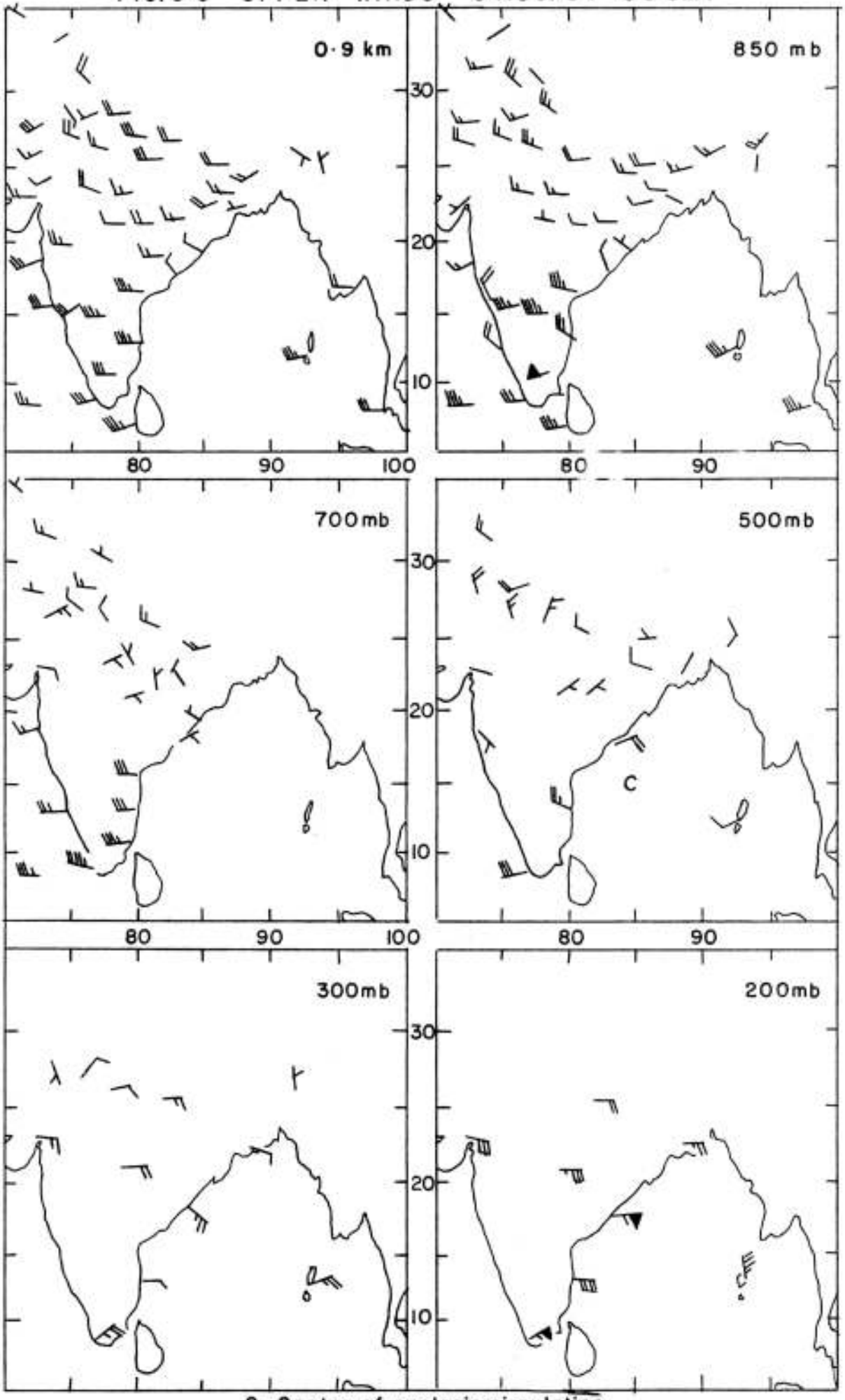


FIG. 3·3 UPPER WINDS 3 AUG. 64 00 GMT



C – Centre of cyclonic circulation

FIG.3-4 SYNOPTIC CHARTS 0300 GMT 4 AUG. 64

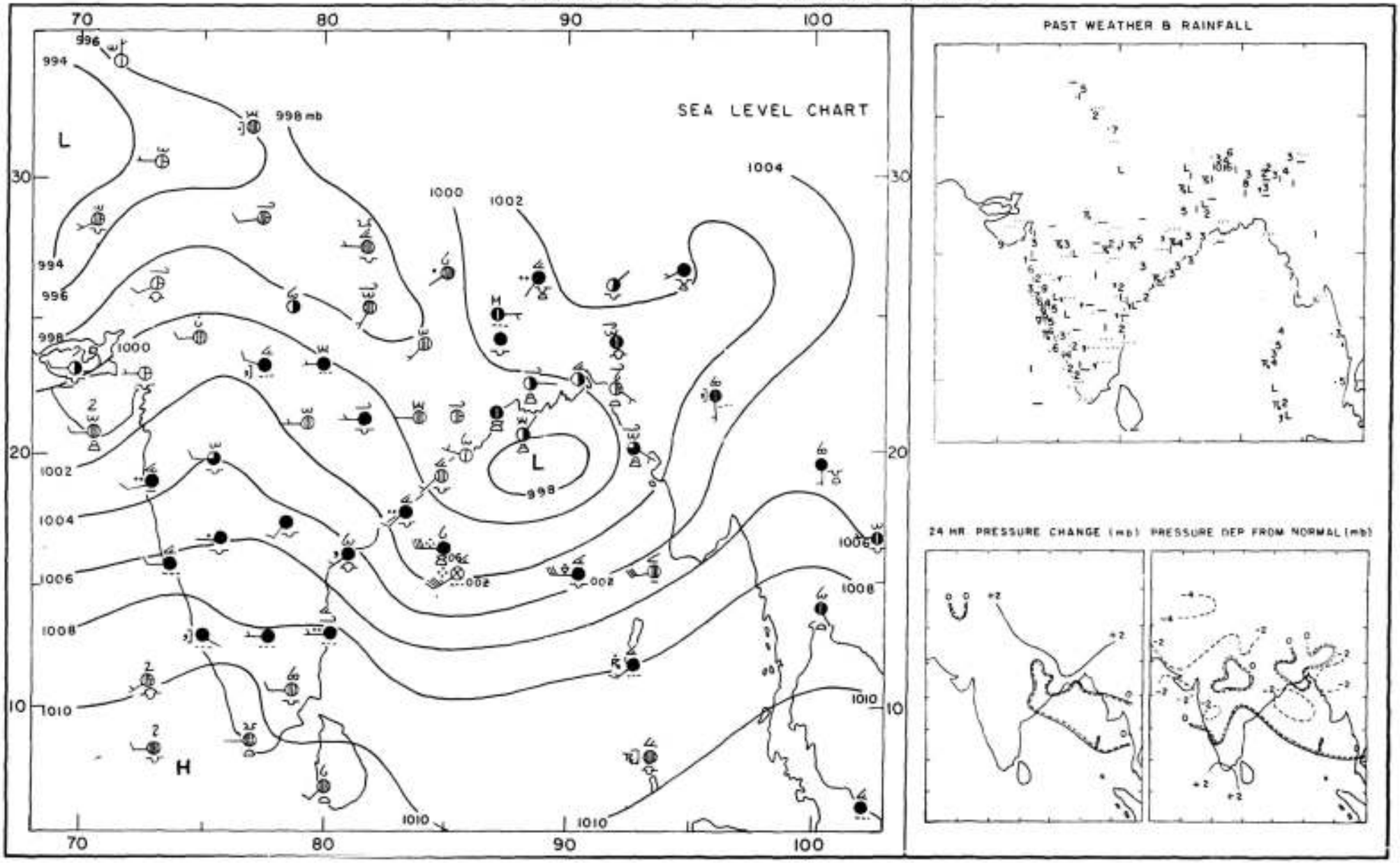
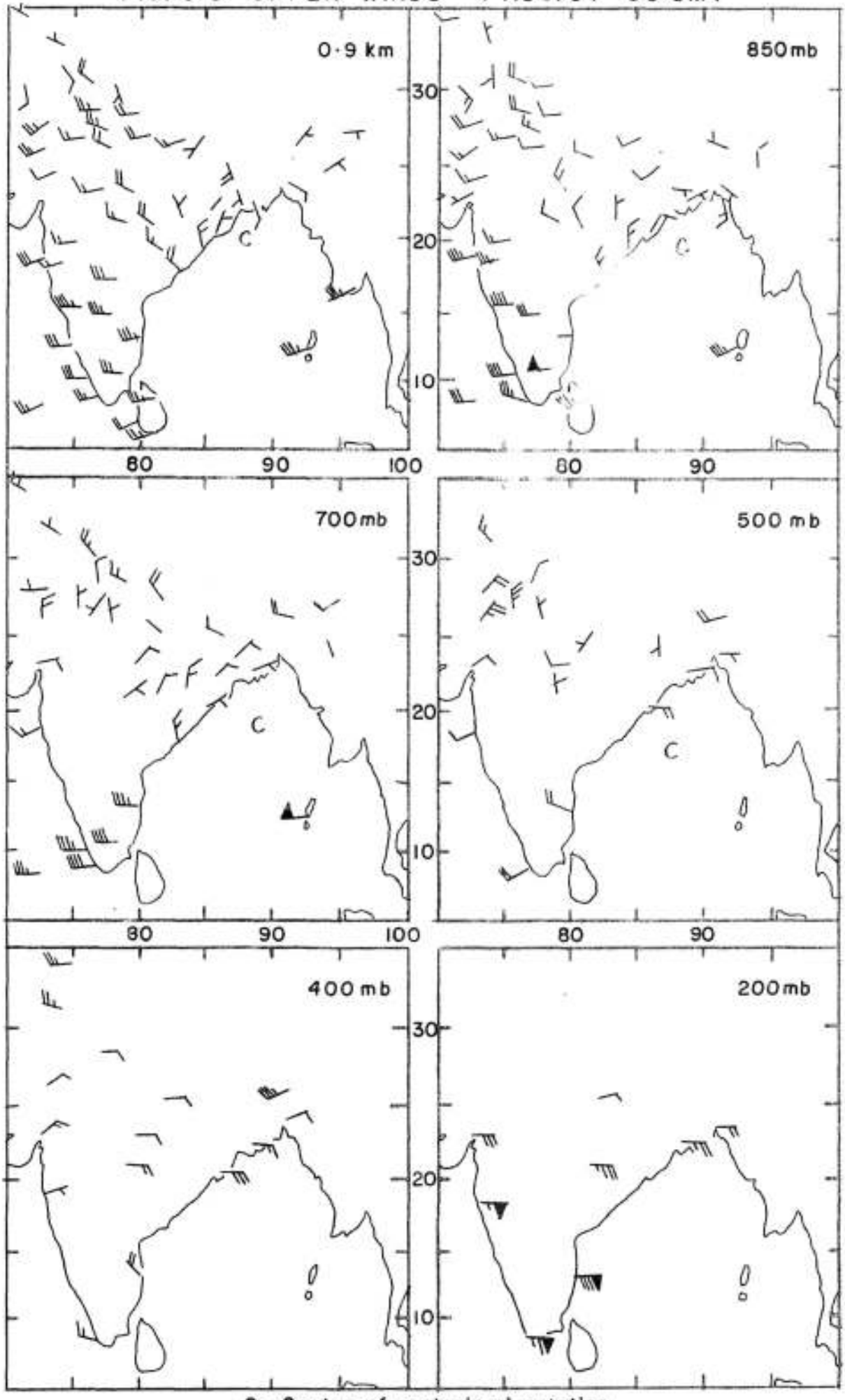


FIG. 3·5 UPPER WINDS 4 AUG. 64 00 GMT



C - Centre of cyclonic circulation

FIG. 3·6 SYNOPTIC CHARTS 0300 GMT 5 AUG. 64

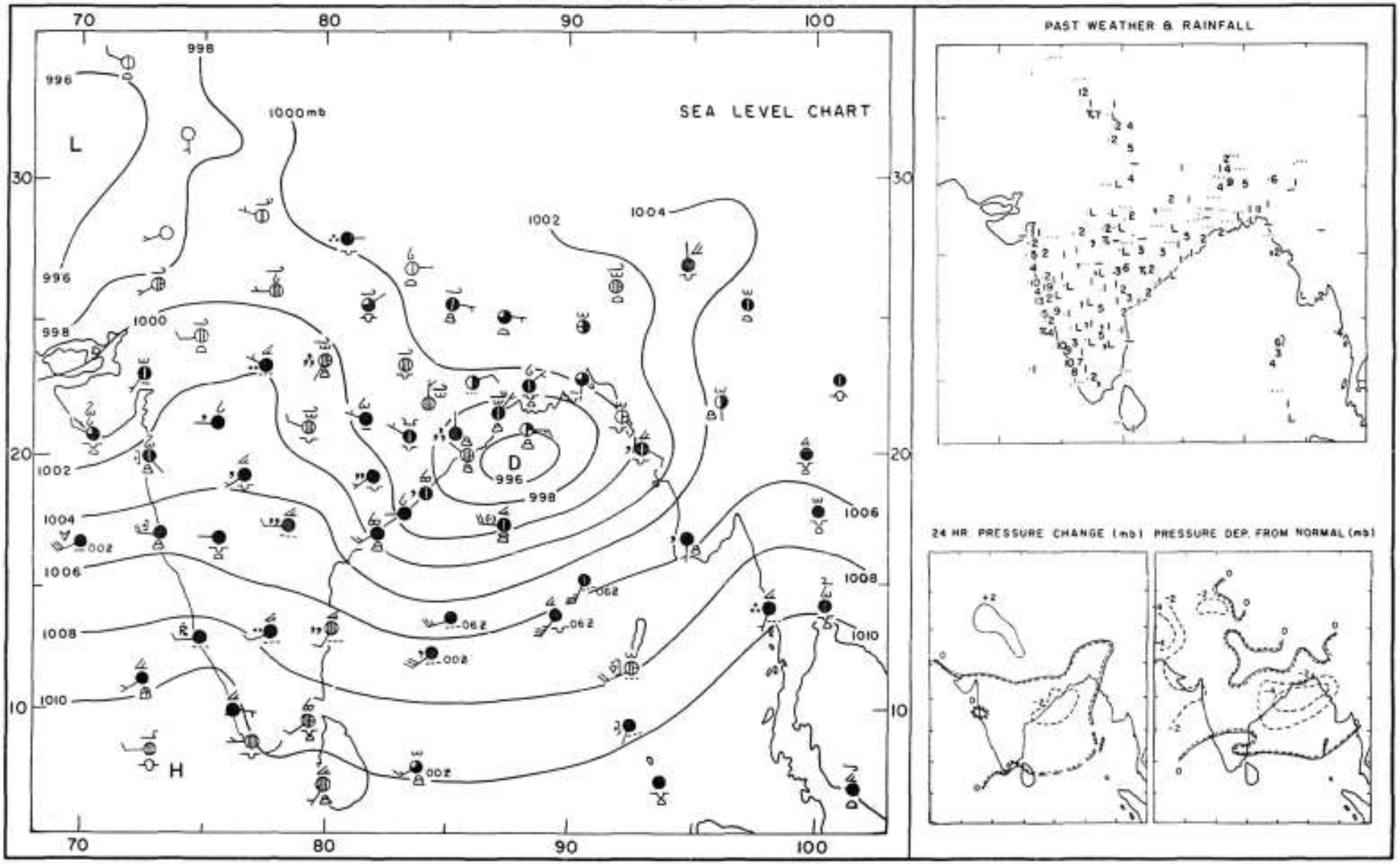
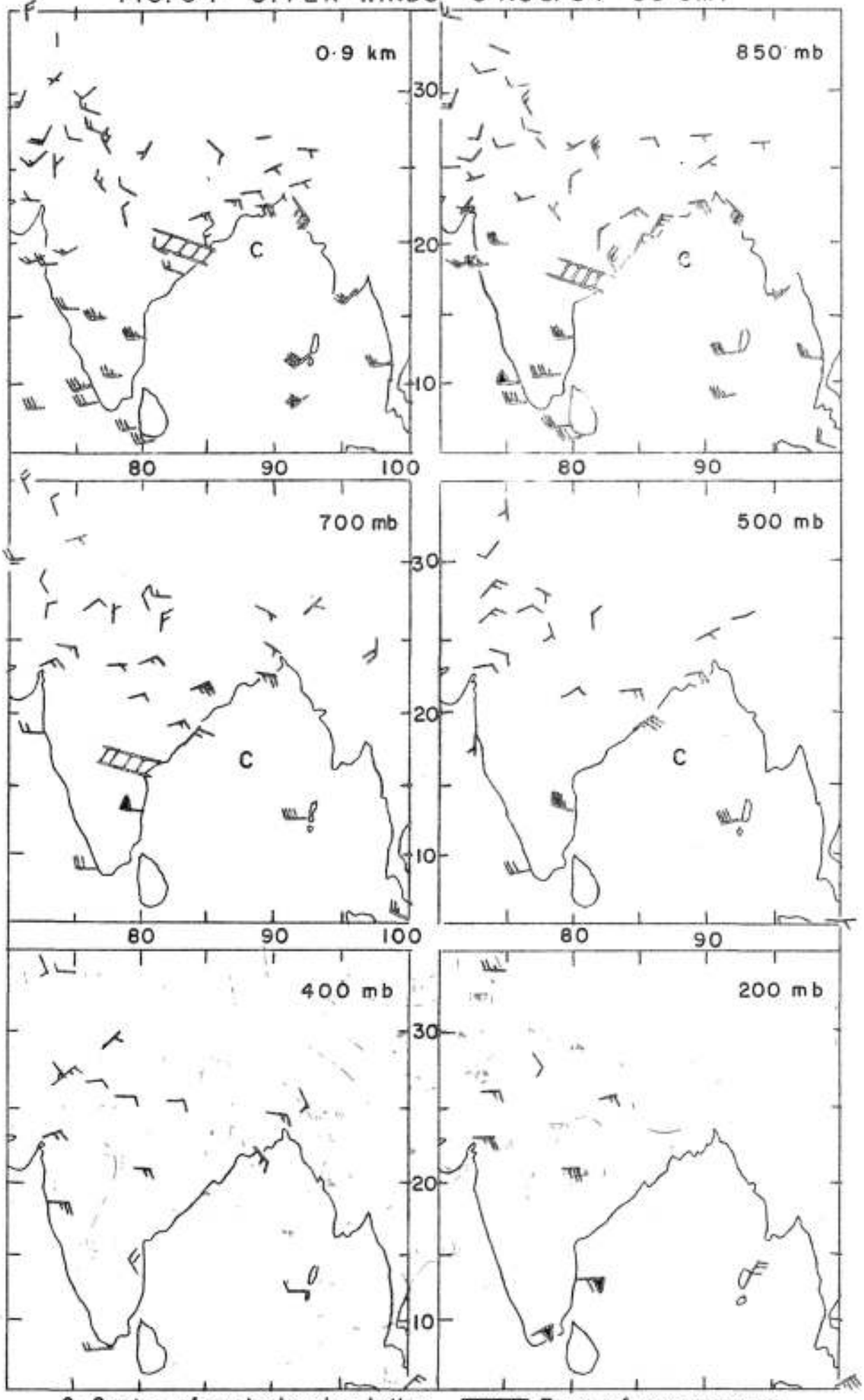


FIG. 3·7 UPPER WINDS 5 AUG. 64 00 GMT



C- Centre of cyclonic circulation ////// Zone of convergence

FIG. 3·8 SYNOPTIC CHARTS 0300 GMT 6 AUG. 64

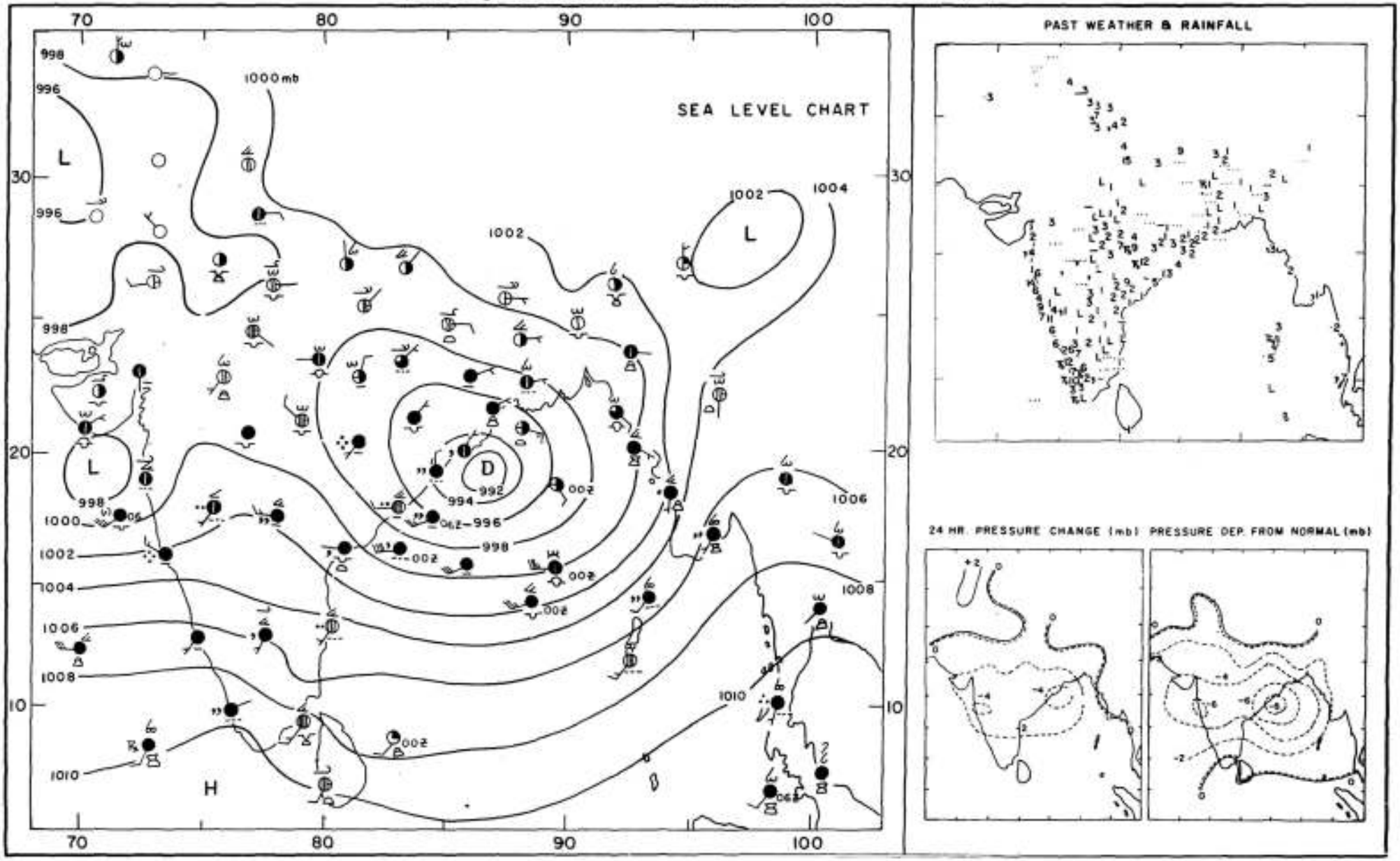
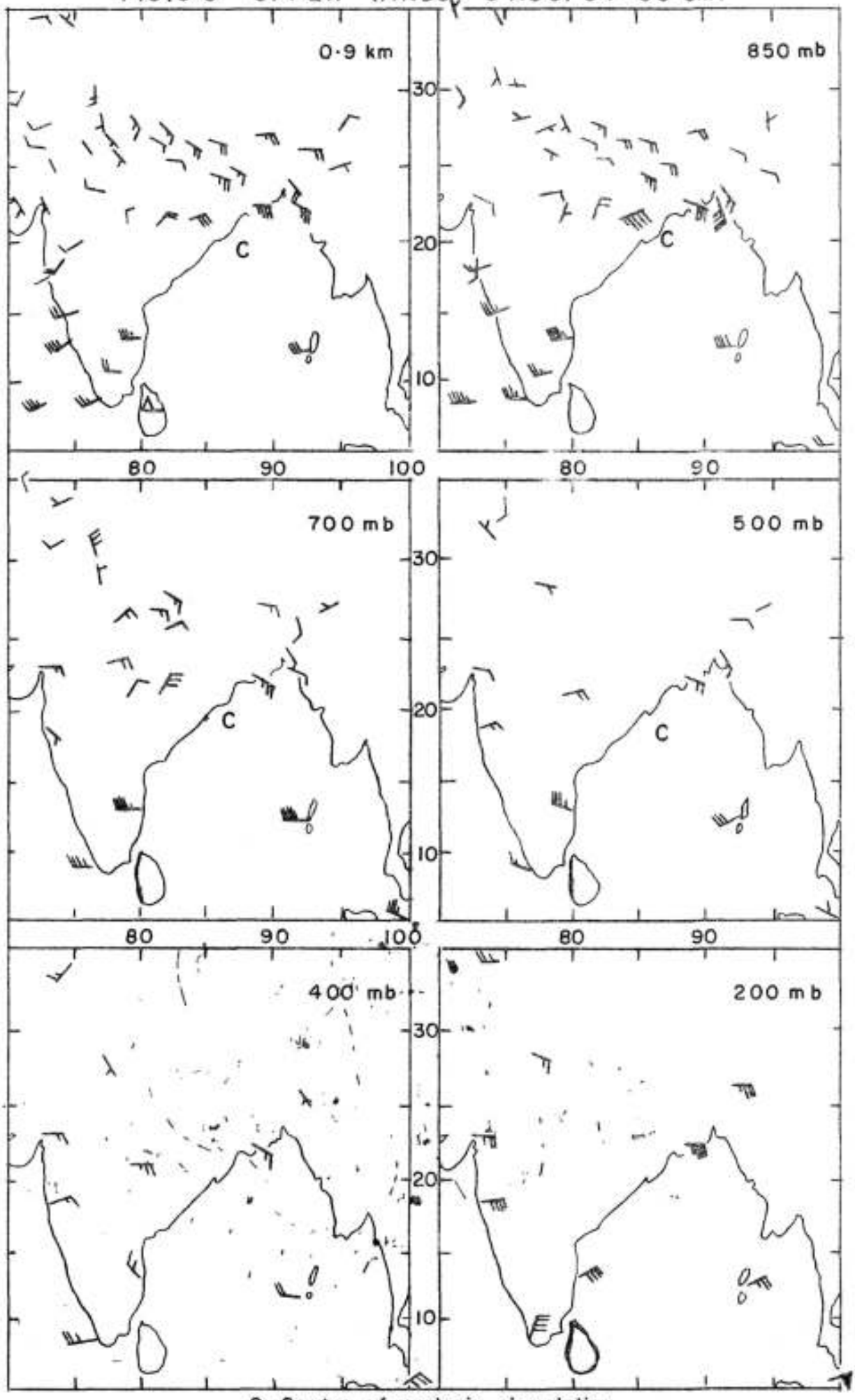


FIG. 3·9 UPPER WINDS 6 AUG. 64 00 GMT



C - Centre of cyclonic circulation

FIG.3·10 SYNOPTIC CHARTS 0300 GMT 7 AUG. 64

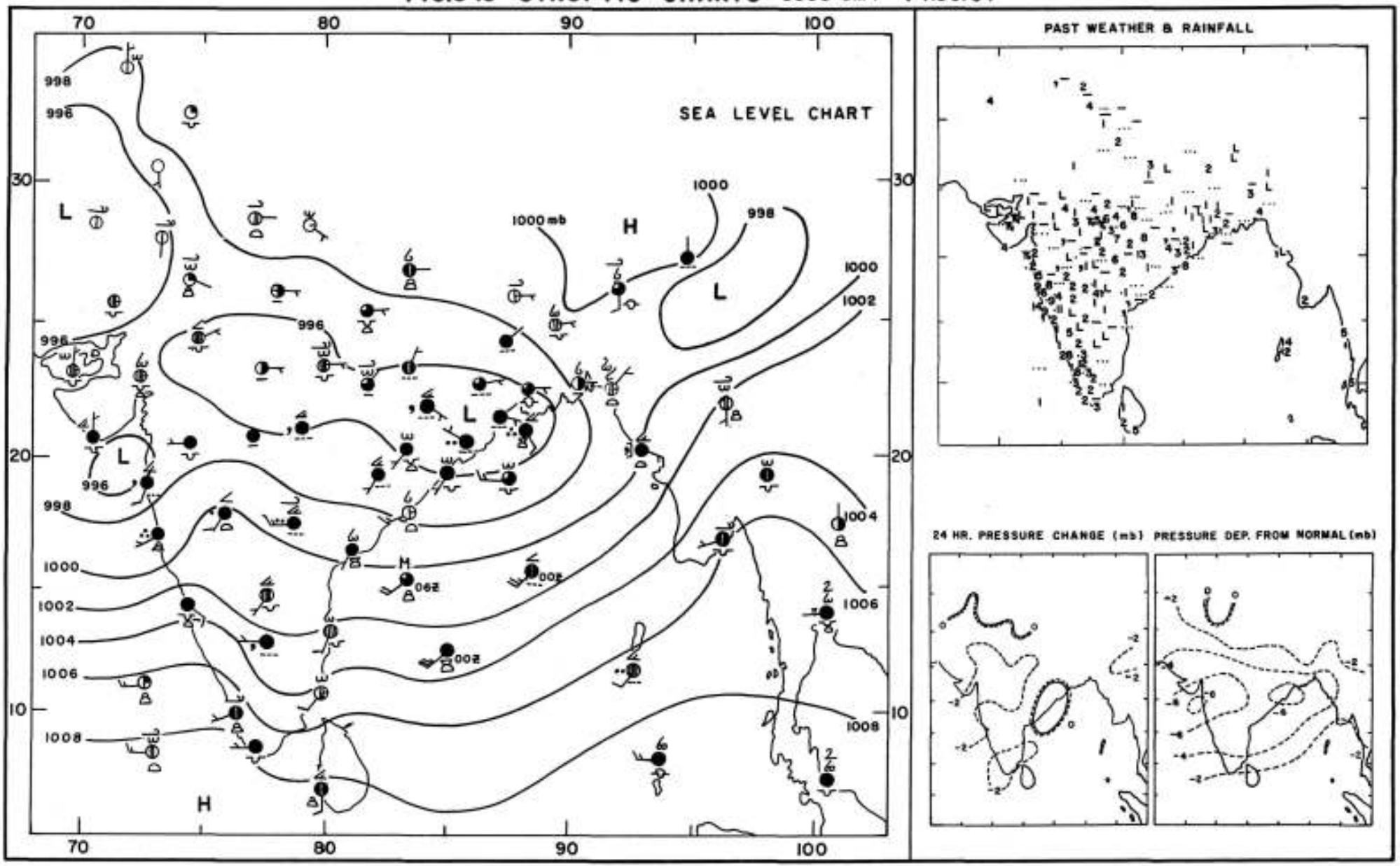
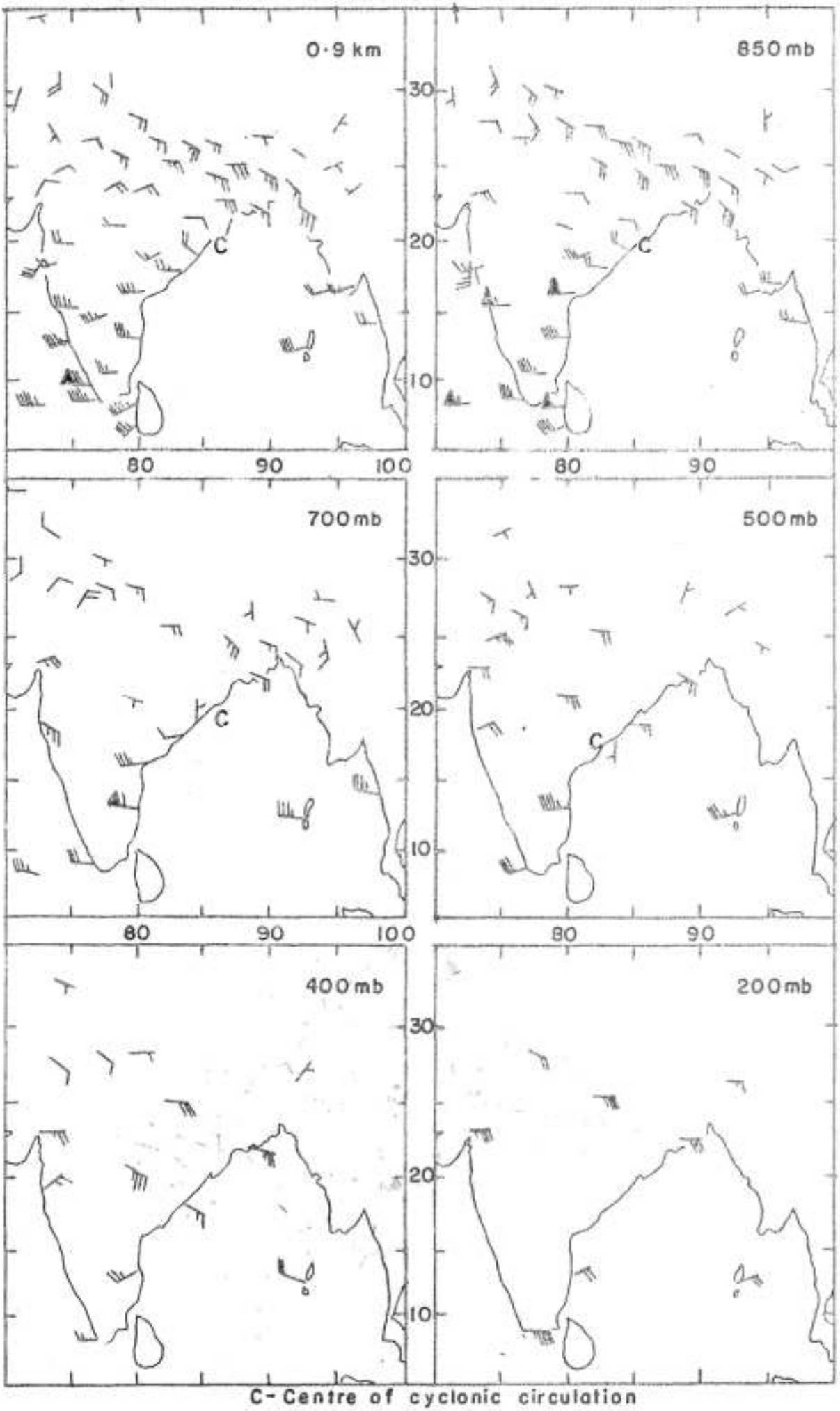
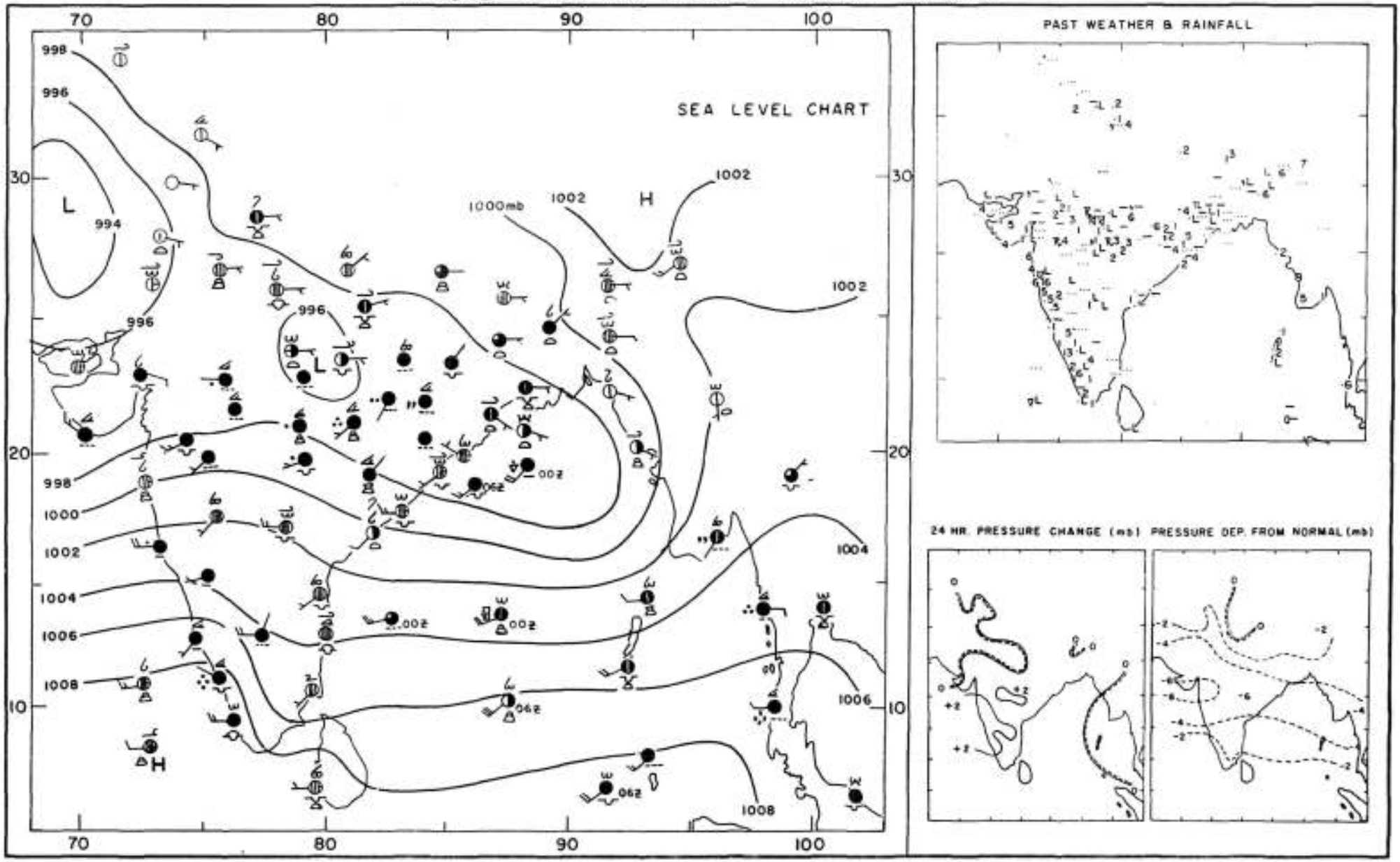


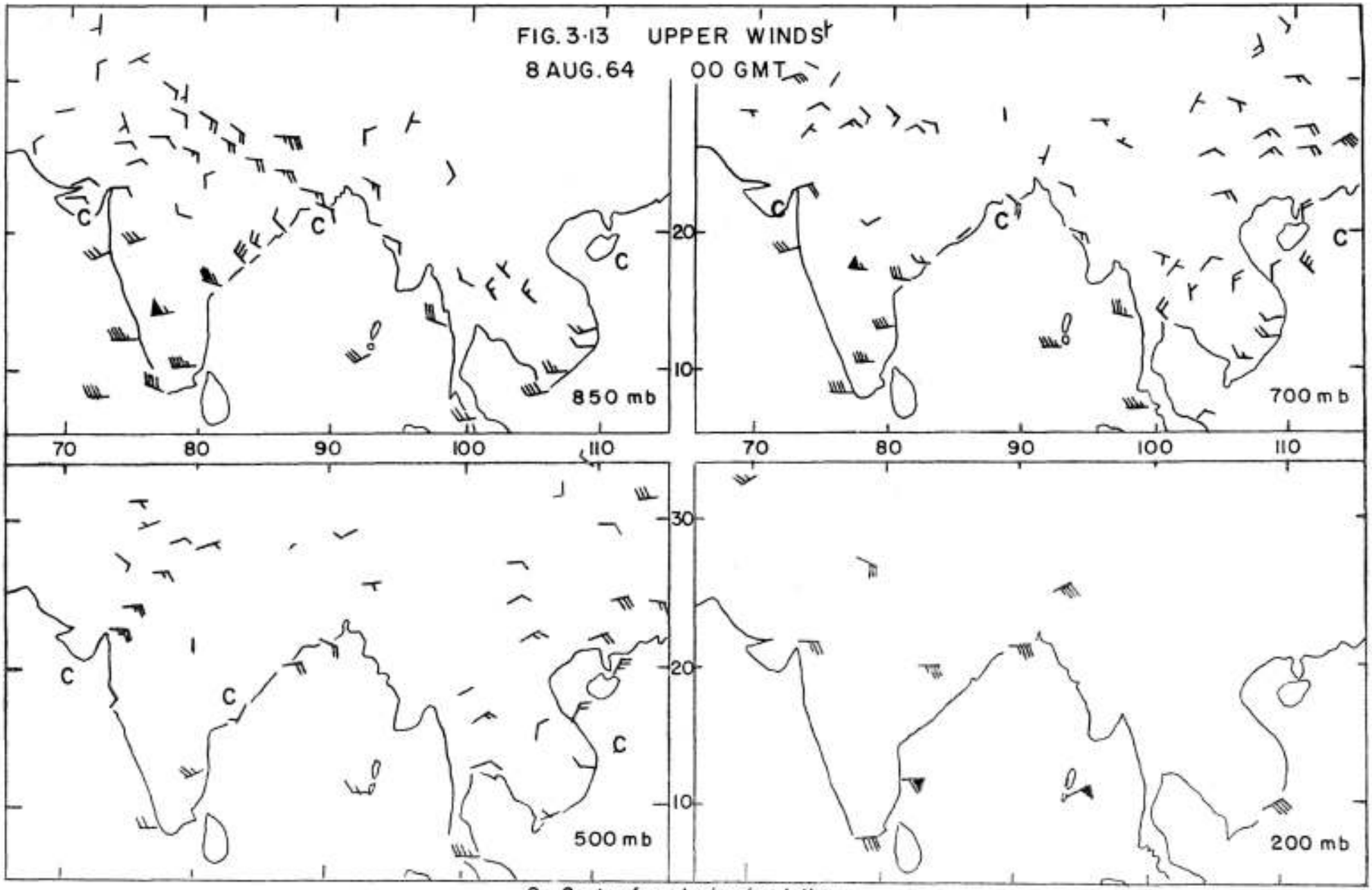
FIG. 3·11 UPPER WINDS 7 AUG. 64 00 GMT



C- Centre of cyclonic circulation

FIG3-12 SYNOPTIC CHARTS 0300 GMT 6 AUG. 64





C – Centre of cyclonic circulation

FIG.3-14 SYNOPTIC CHARTS 0300 GMT 9 AUG. 64

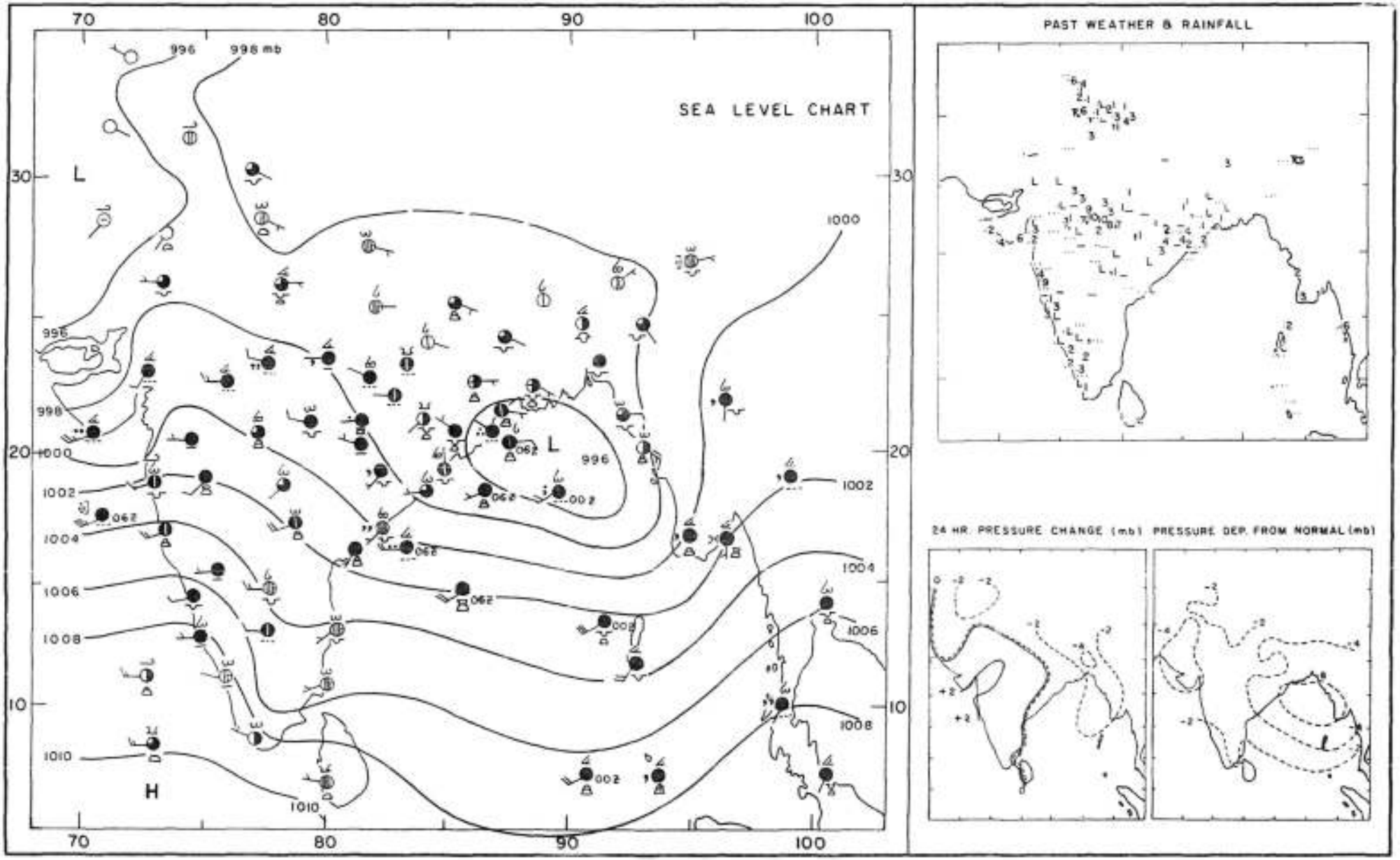
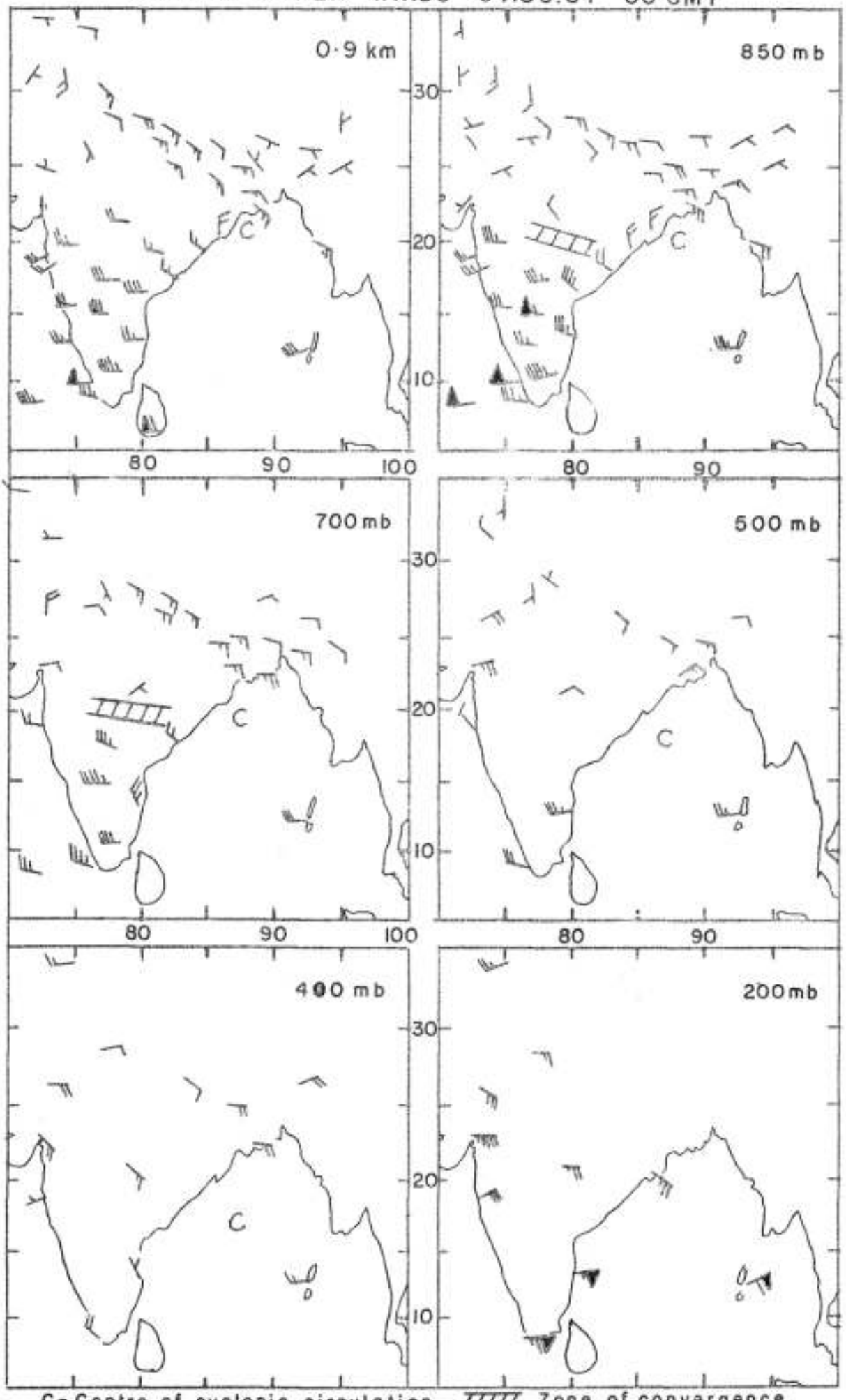


FIG. 3·15 UPPER WINDS 9 AUG. 64 00 GMT



C- Centre of cyclonic circulation Zone of convergence

FIG.3·16 SYNOPTIC CHARTS 0300 GMT 10 AUG. 64

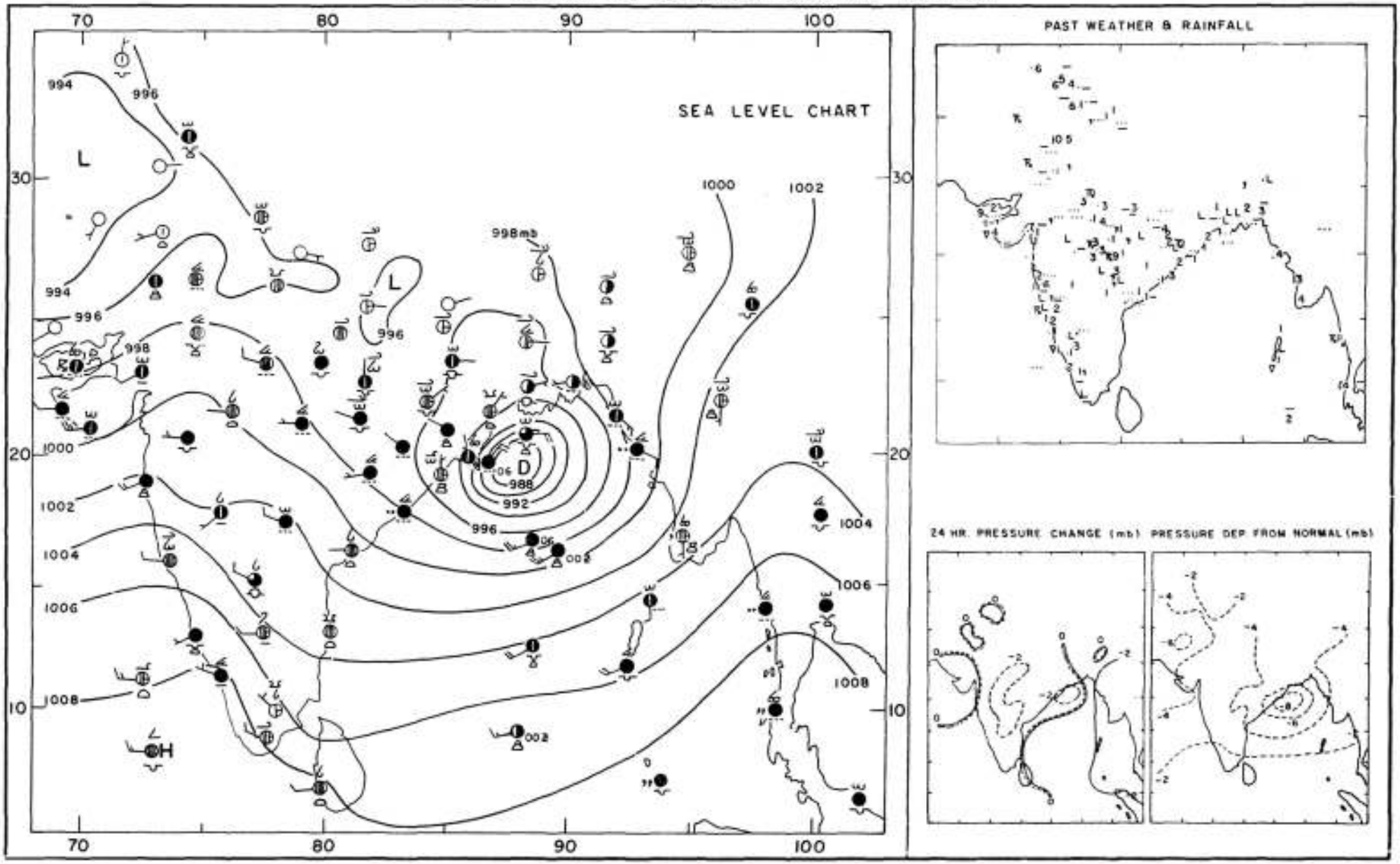


FIG. 3·17 UPPER WINDS 10 AUG. 64 00 GMT

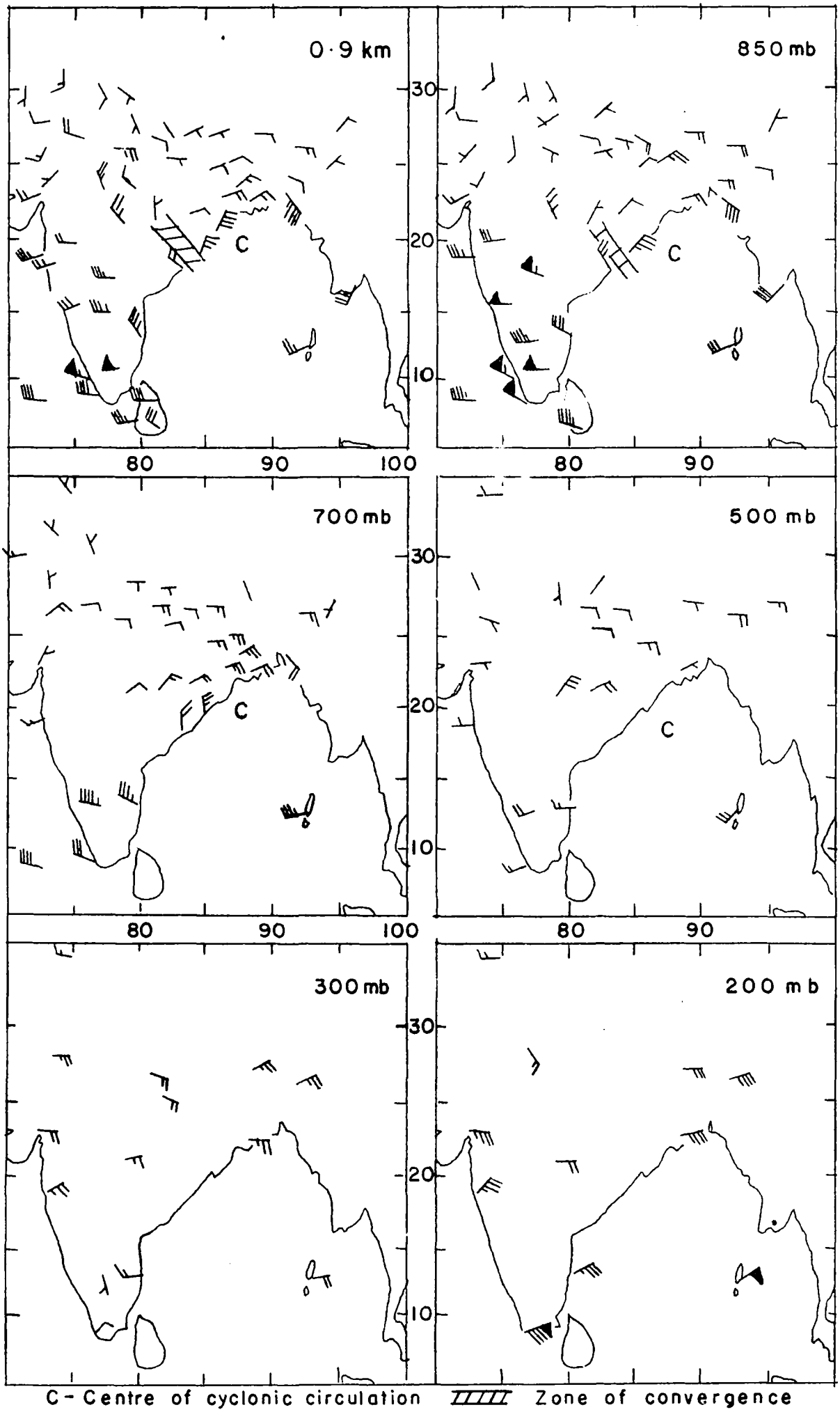


FIG.3-18 SYNOPTIC CHARTS 0300 GMT 11 AUG. 61

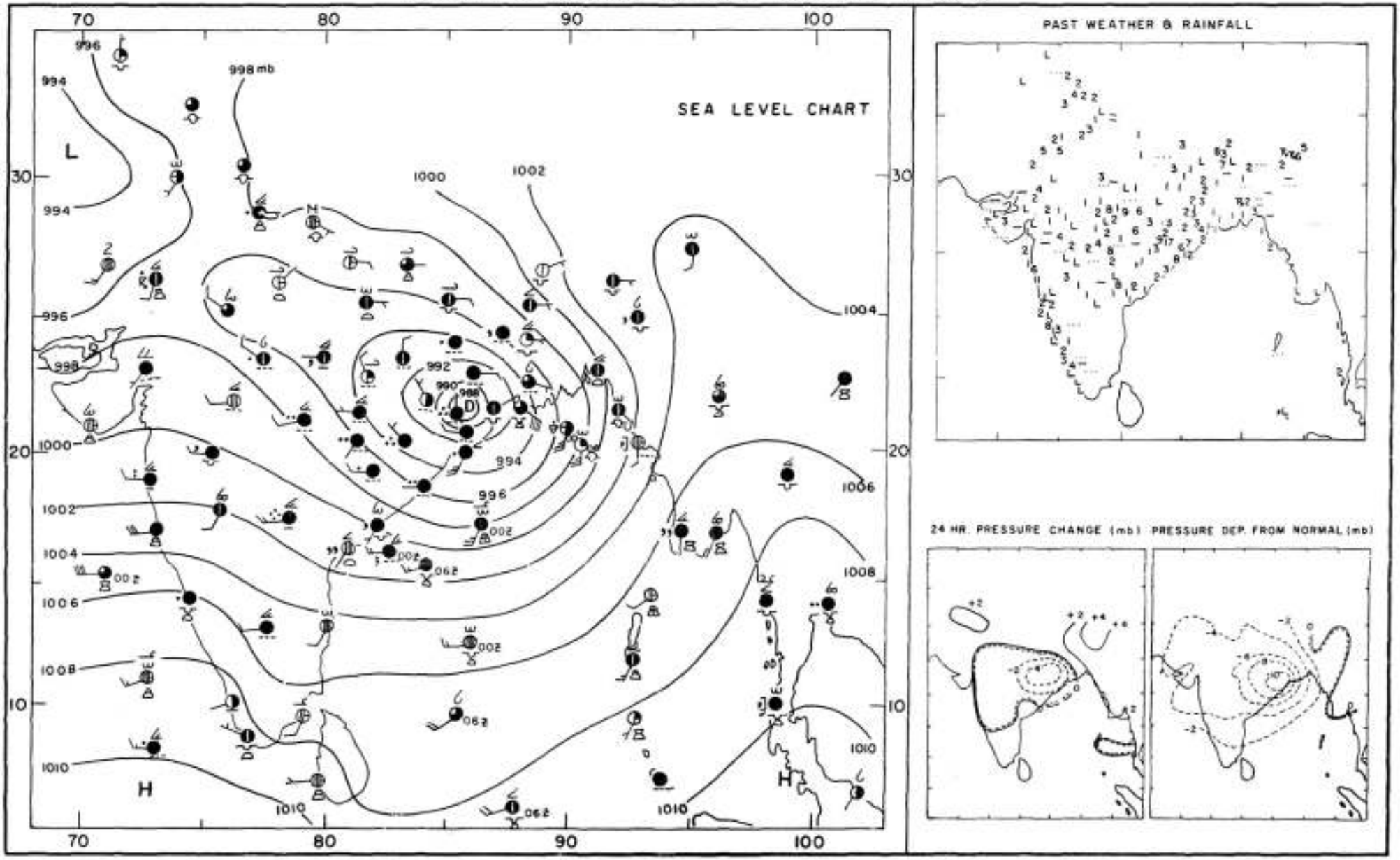
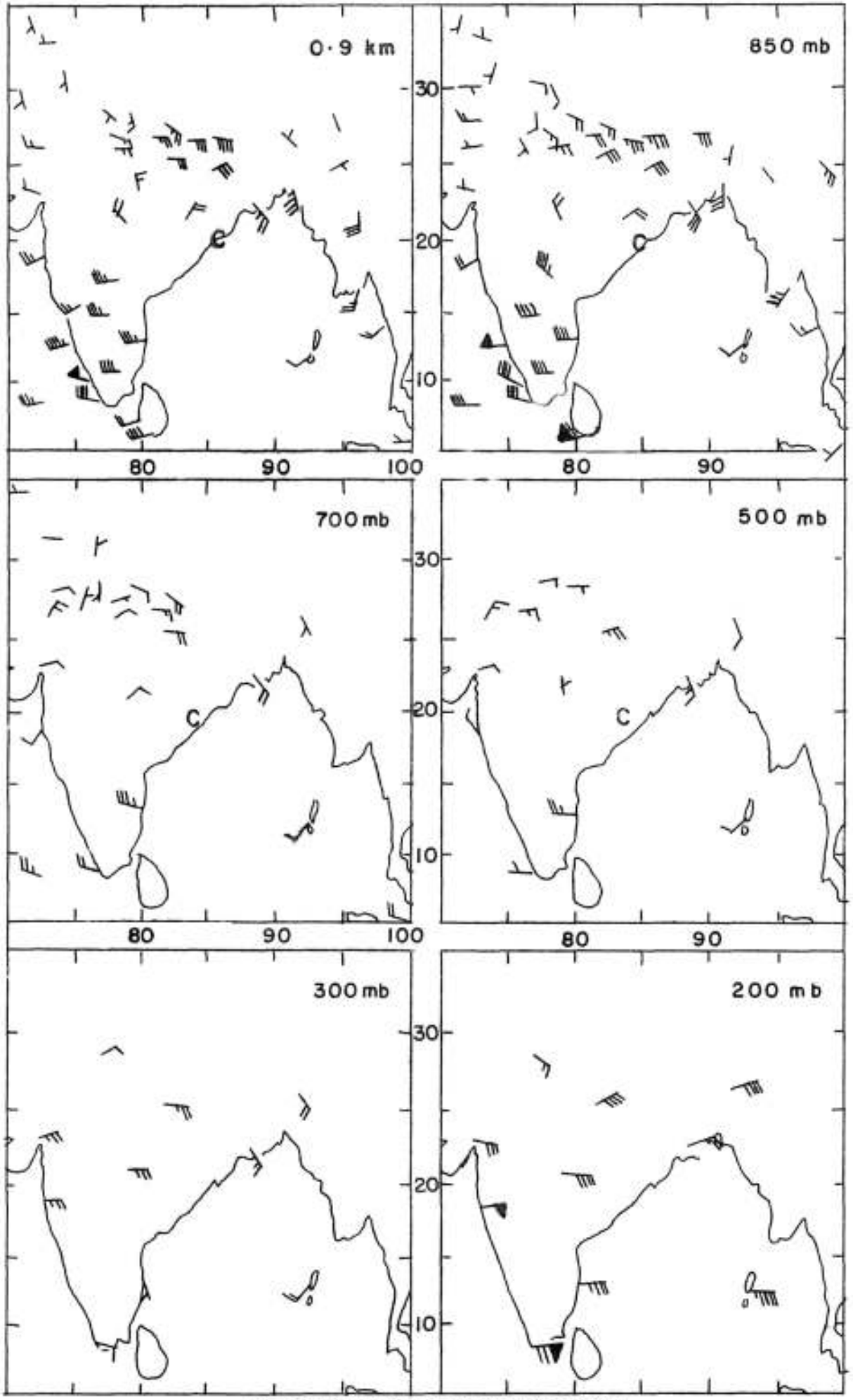
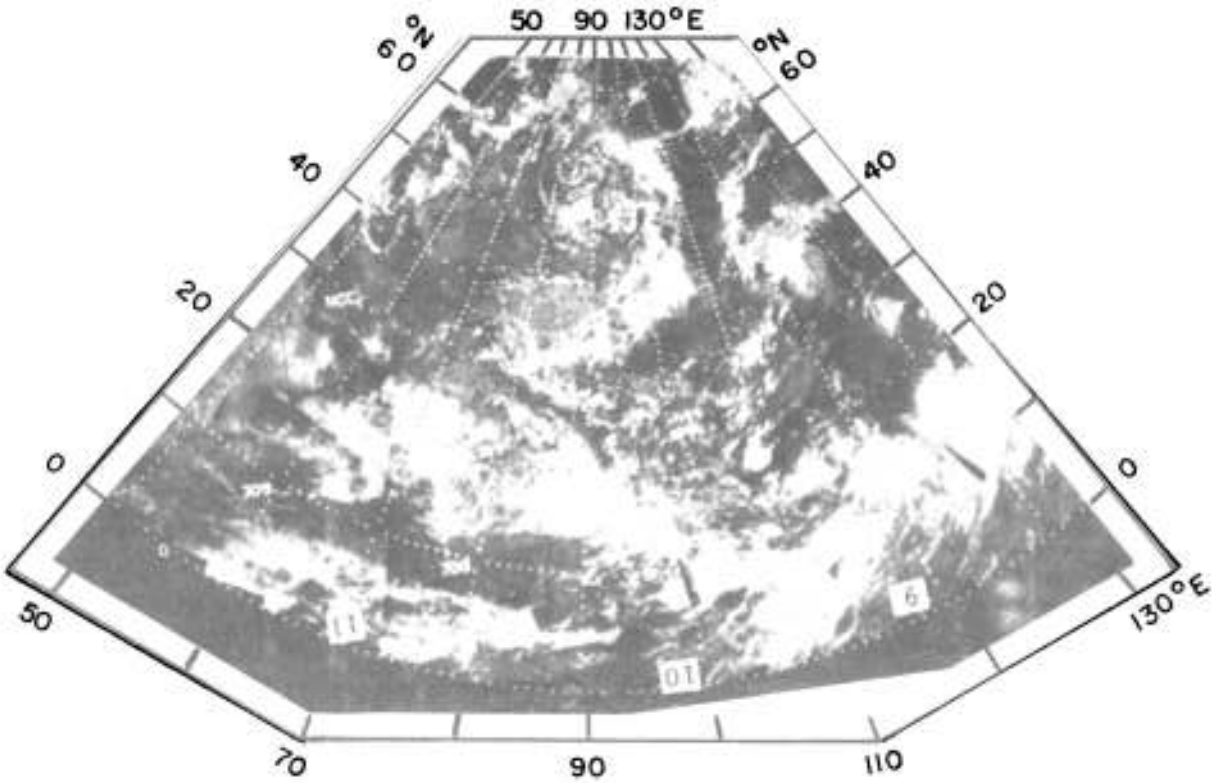


FIG. 3·19 UPPER WINDS 11 AUG. 64 00GMT



C – Centre of cyclonic circulation

FIG. 4-1 ESSA-5 28 JUL 1967



Copied from "Catalogue of Met. Sat. Data ESSA-3 and ESSA-5 Television Cloud Photography" (ESSA Publication KMRD No. 5-315.)

FIG. 4·2 SYNOPTIC CHARTS 0300 GMT 29 JUL. 67

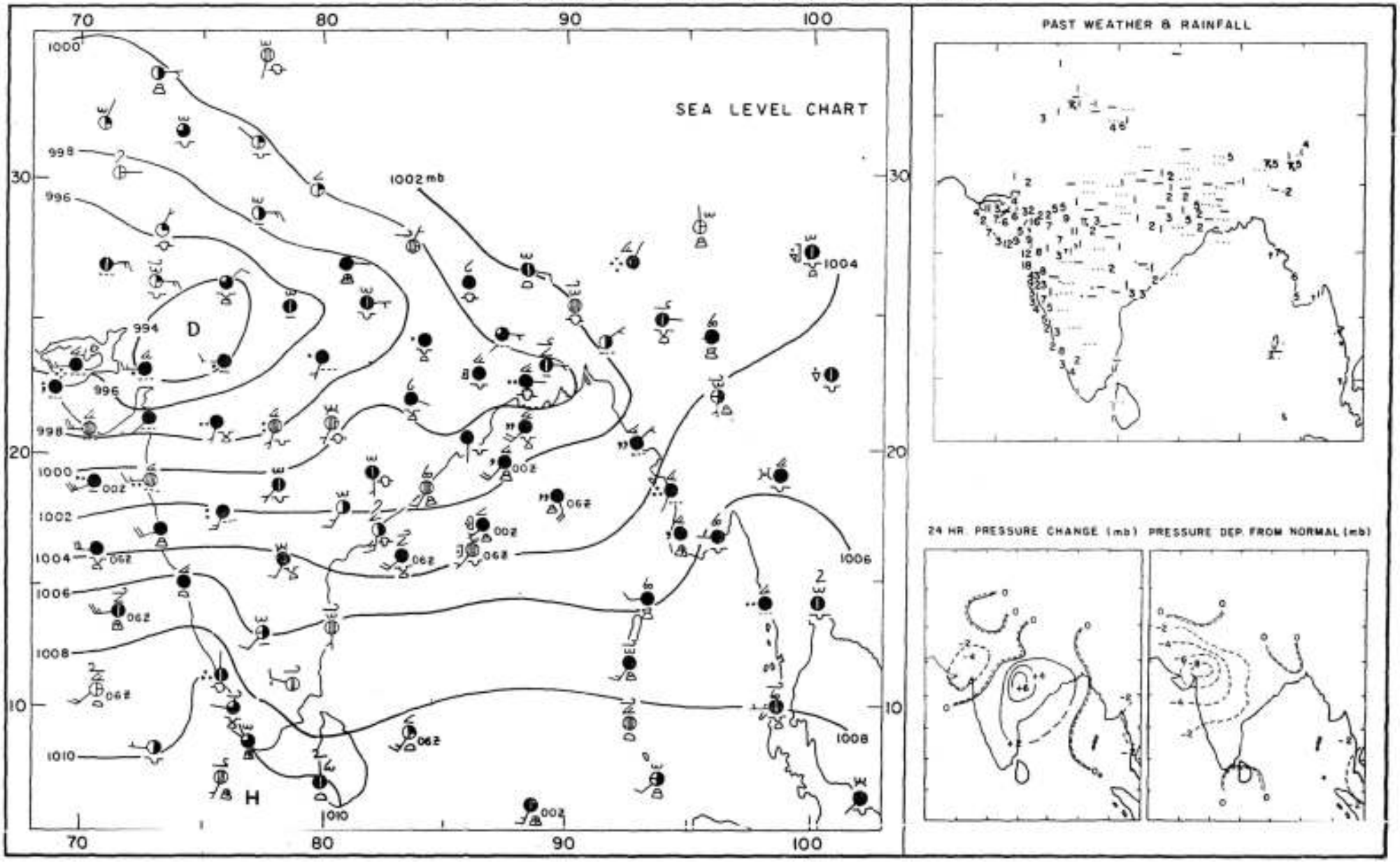
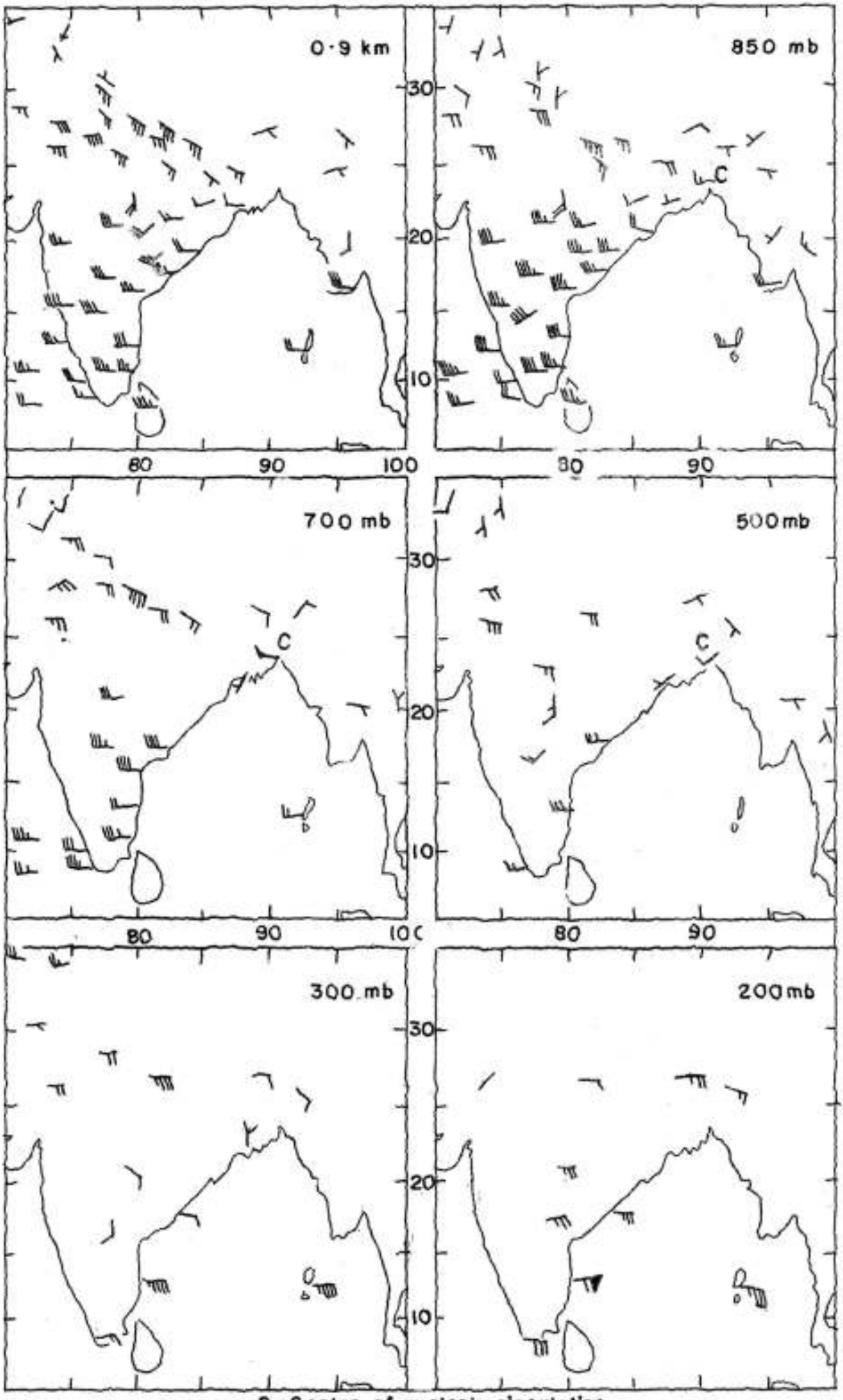


FIG. 4·3 UPPER WINDS 29 JUL. 67 00 GMT



C – Centre of cyclonic circulation

FIG. 4·4 SYNOPTIC CHARTS 0300 GMT 30 JUL. 67

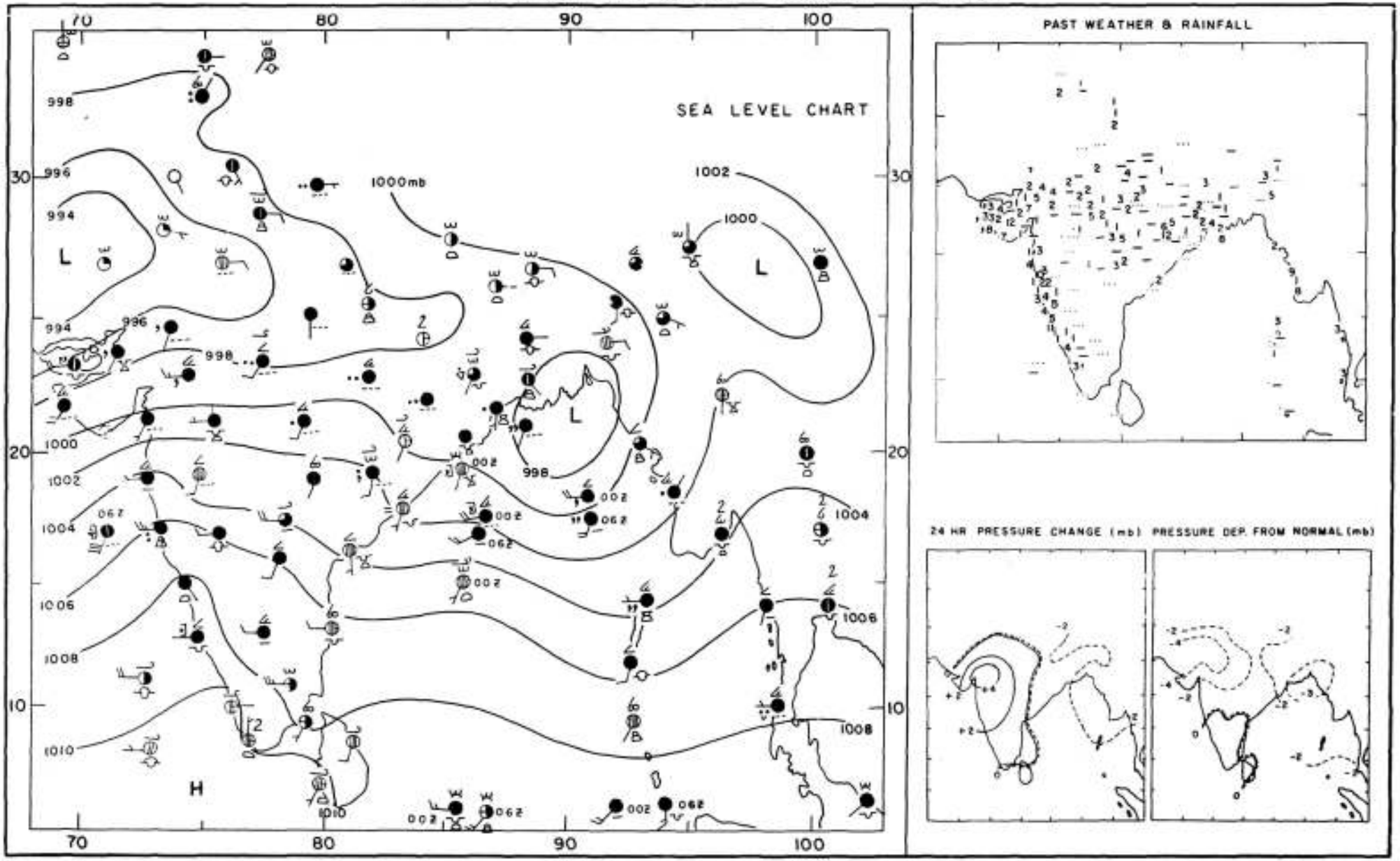
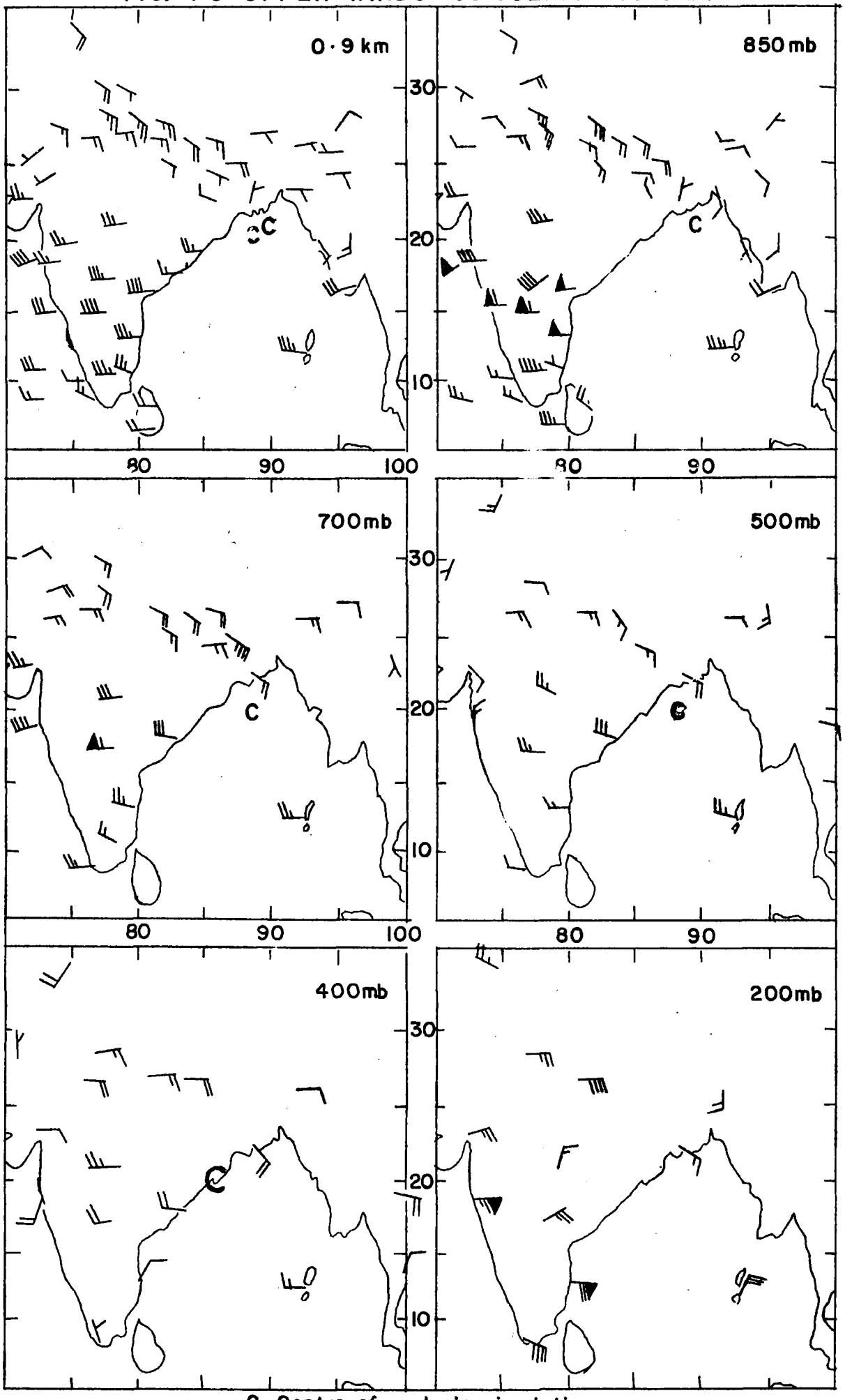


FIG. 4·5 UPPER WINDS 30 JUL. 67 00 GMT



C-Centre of cyclonic circulation

FIG. 4·6 SYNOPTIC CHARTS 0300 GMT 31 JUL. 67

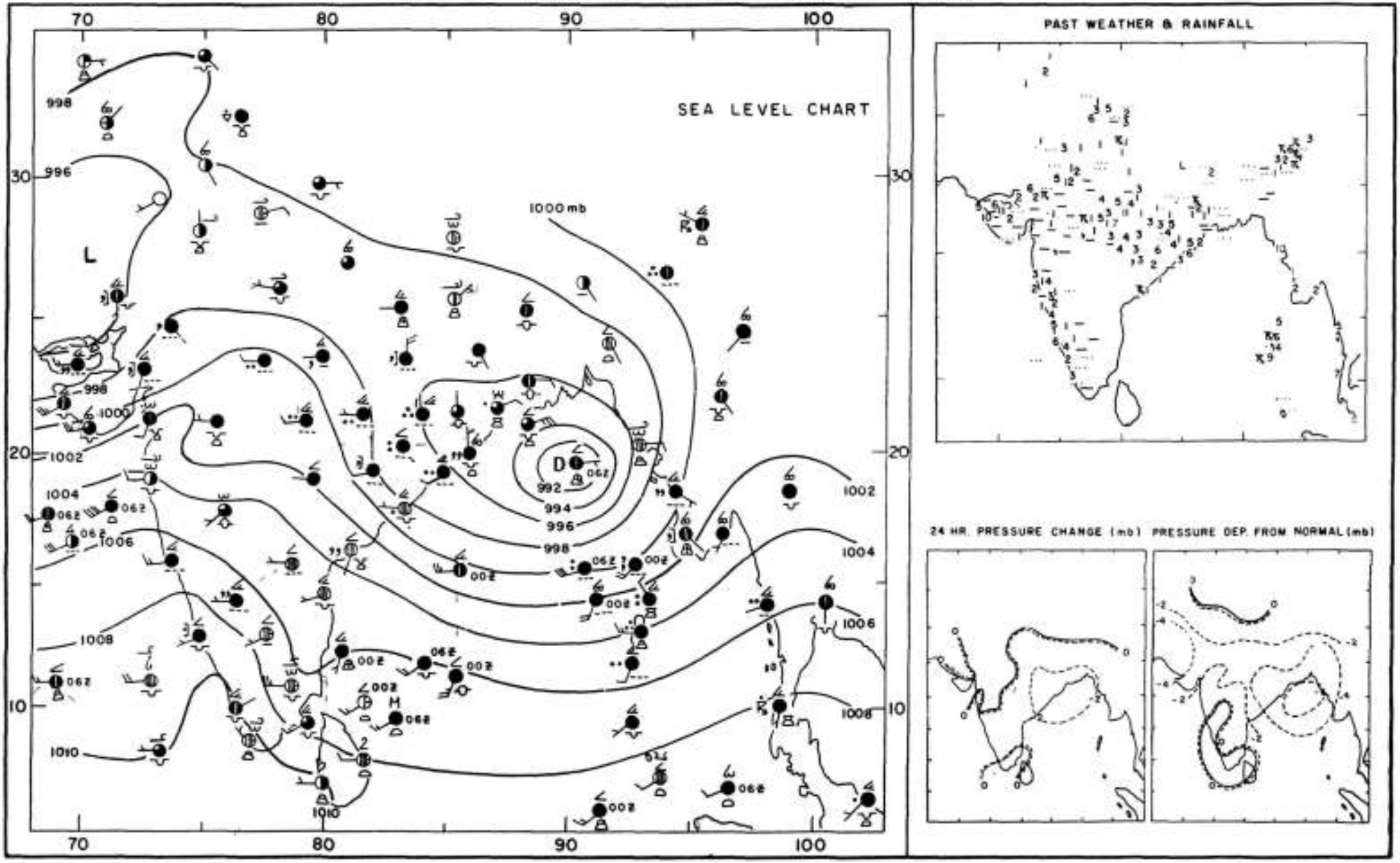


FIG. 4·7 UPPER WINDS 31 JULY 67 00GMT

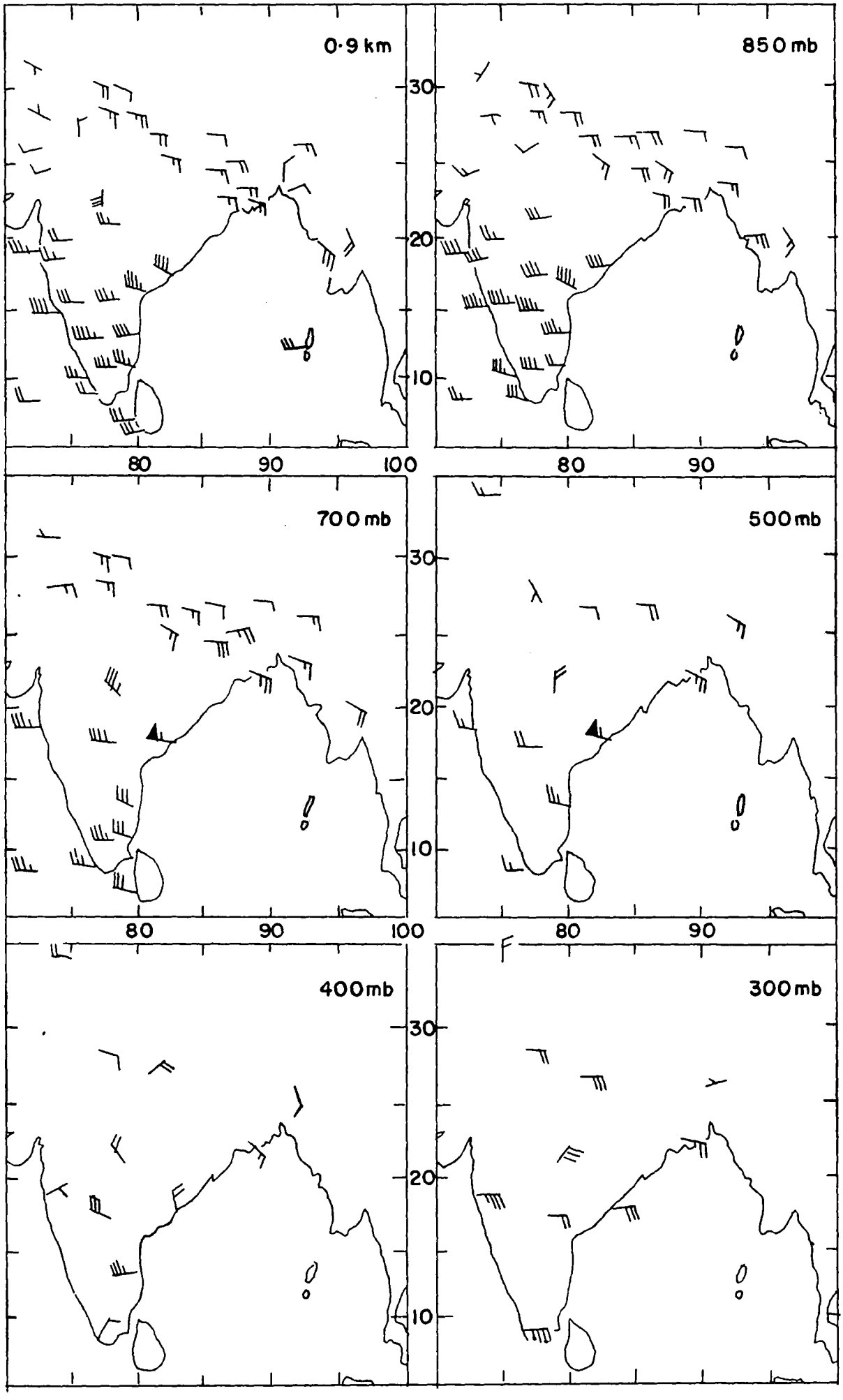


FIG. 4·8 UPPER WINDS

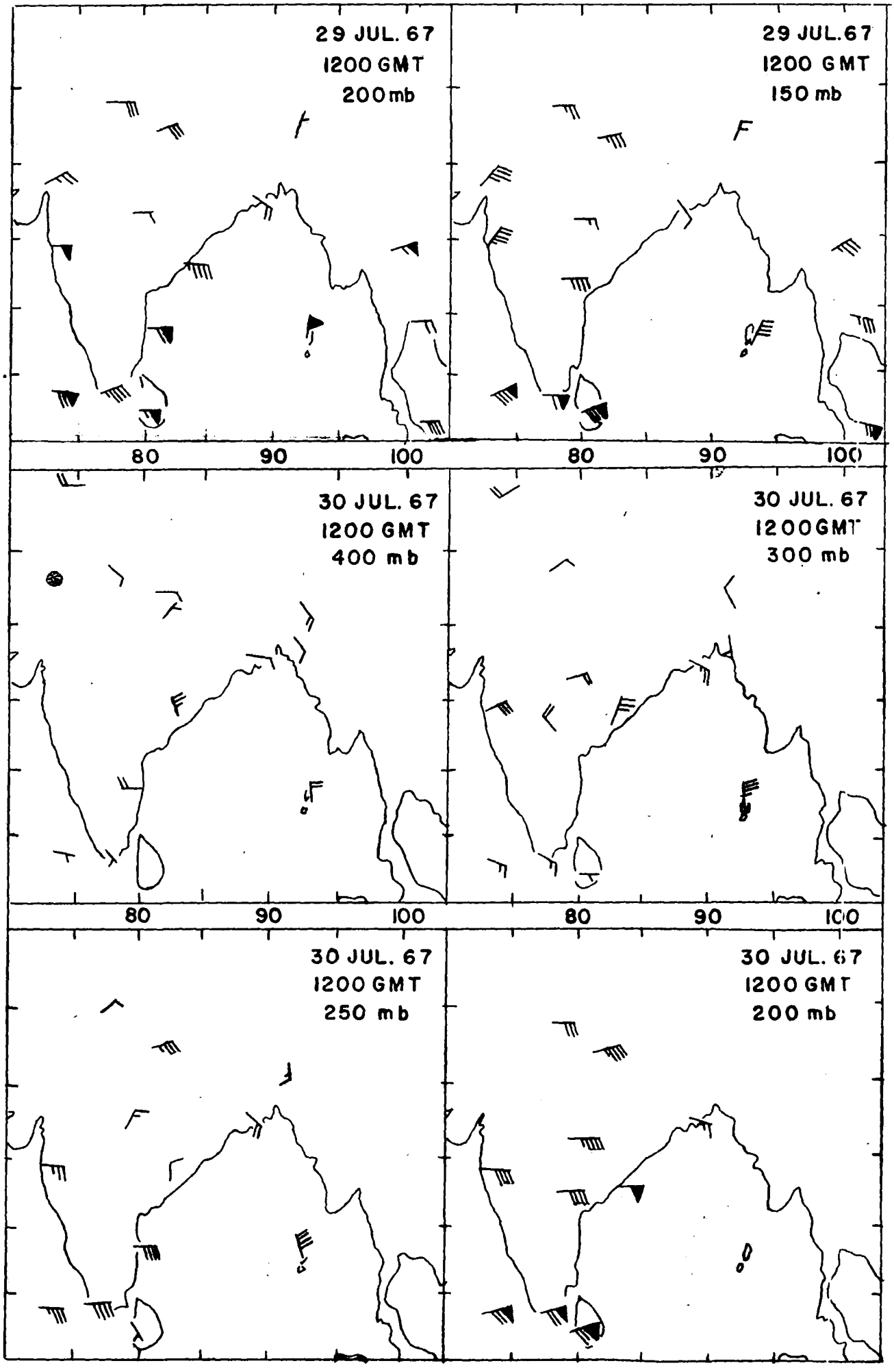
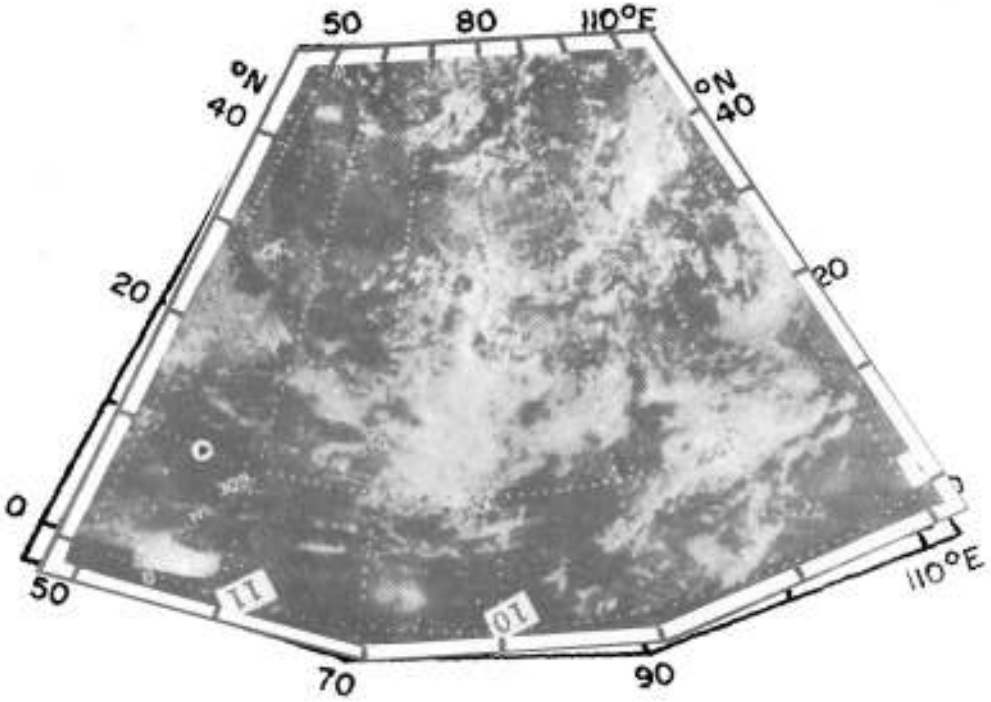


FIG.4-9 ESSA-5 1 AUG 1967



Copied from "Catalogue of Met. Sat. Data ESSA-3 and ESSA-5 Television Cloud Photography" (ESSA Publication KMRD No. 5-315

FIG.4·10 SYNOPTIC CHARTS 0300 GMT 1 AUG. 67

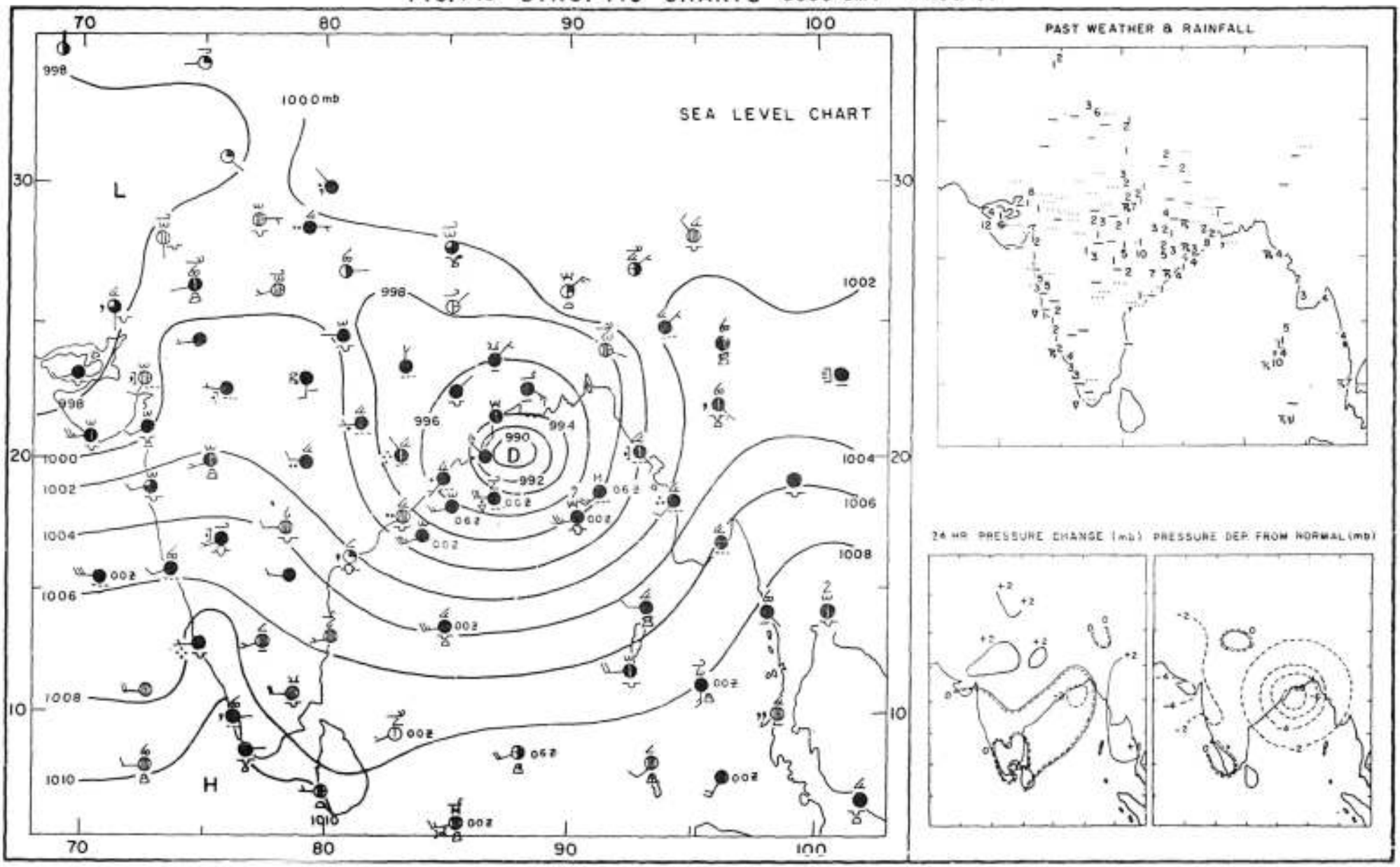
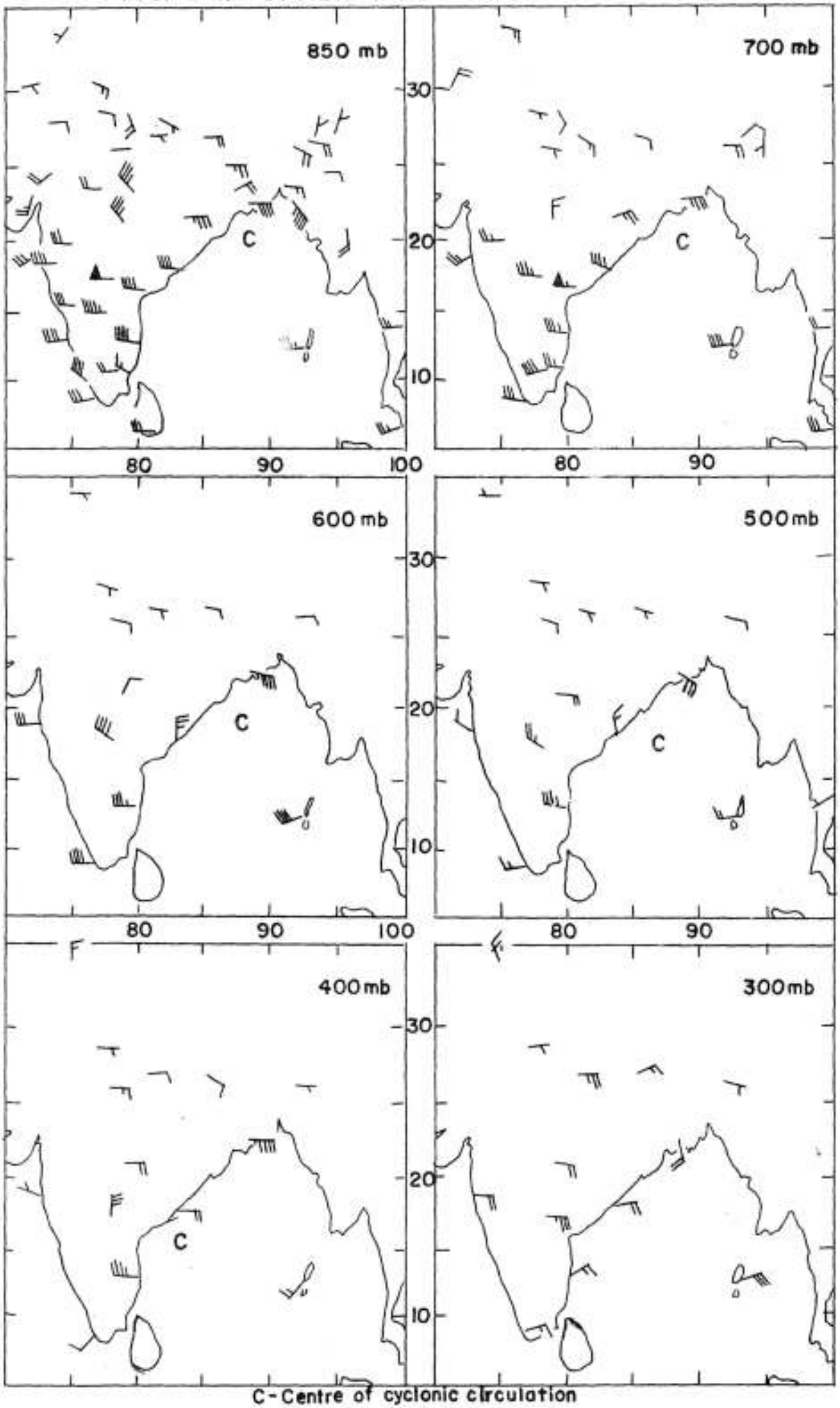


FIG. 4·11 UPPER WINDS 1 AUG. 67 00 GMT



C - Centre of cyclonic circulation

FIG. 5-1 SYNOPTIC CHARTS

13 JUL. 62

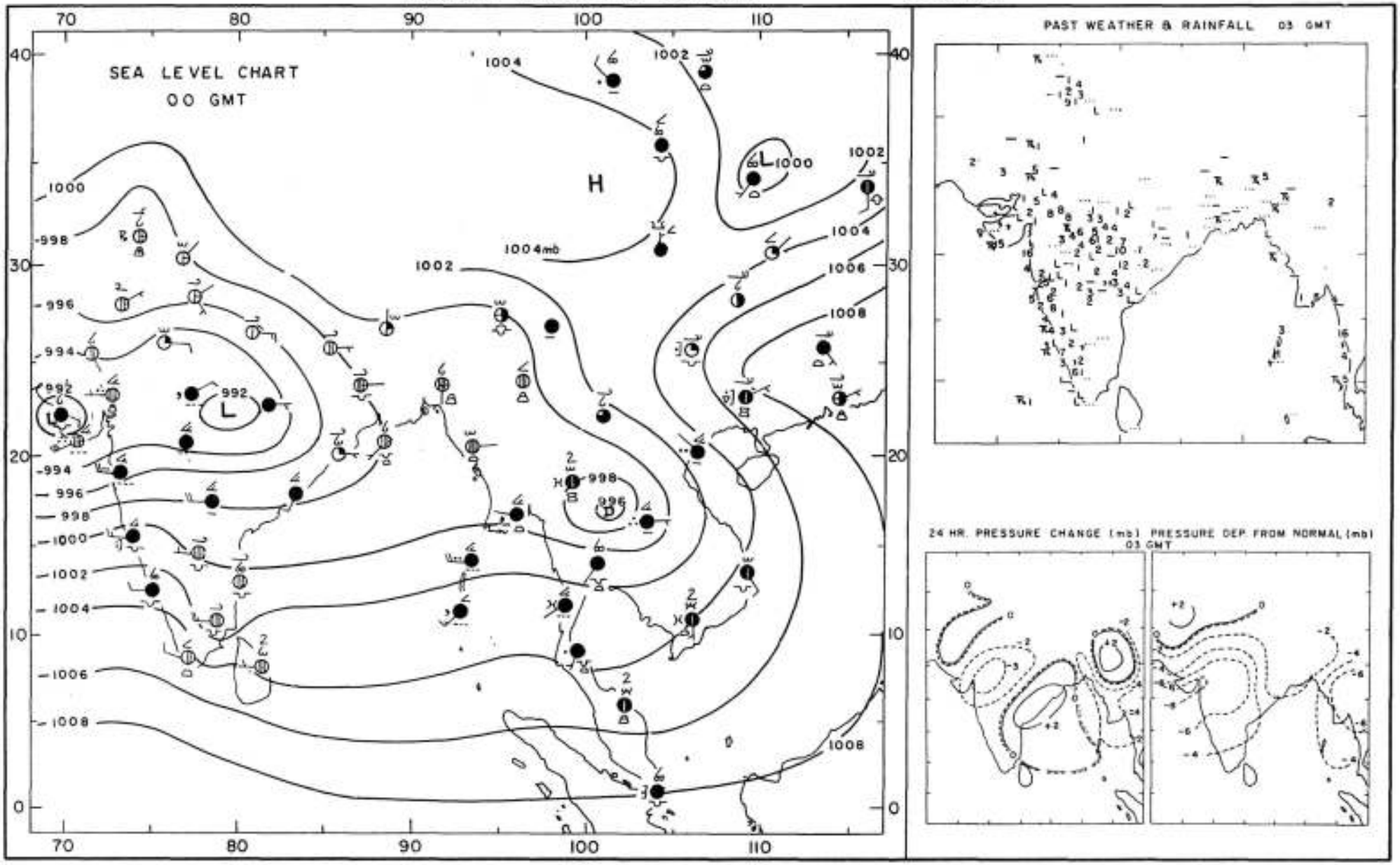


FIG.5·2 SYNOPTIC CHARTS 0300 GMT 14 JUL.62

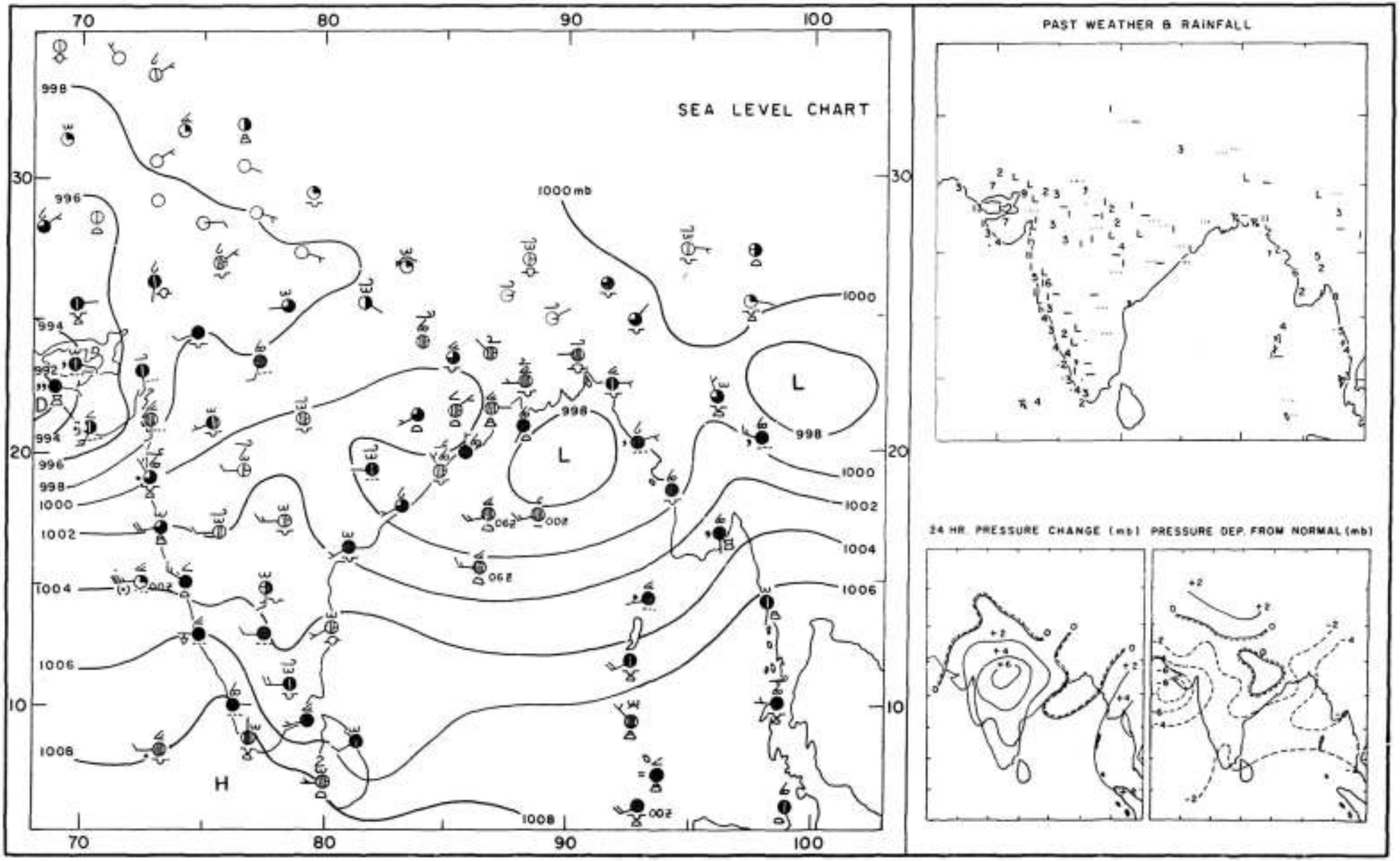
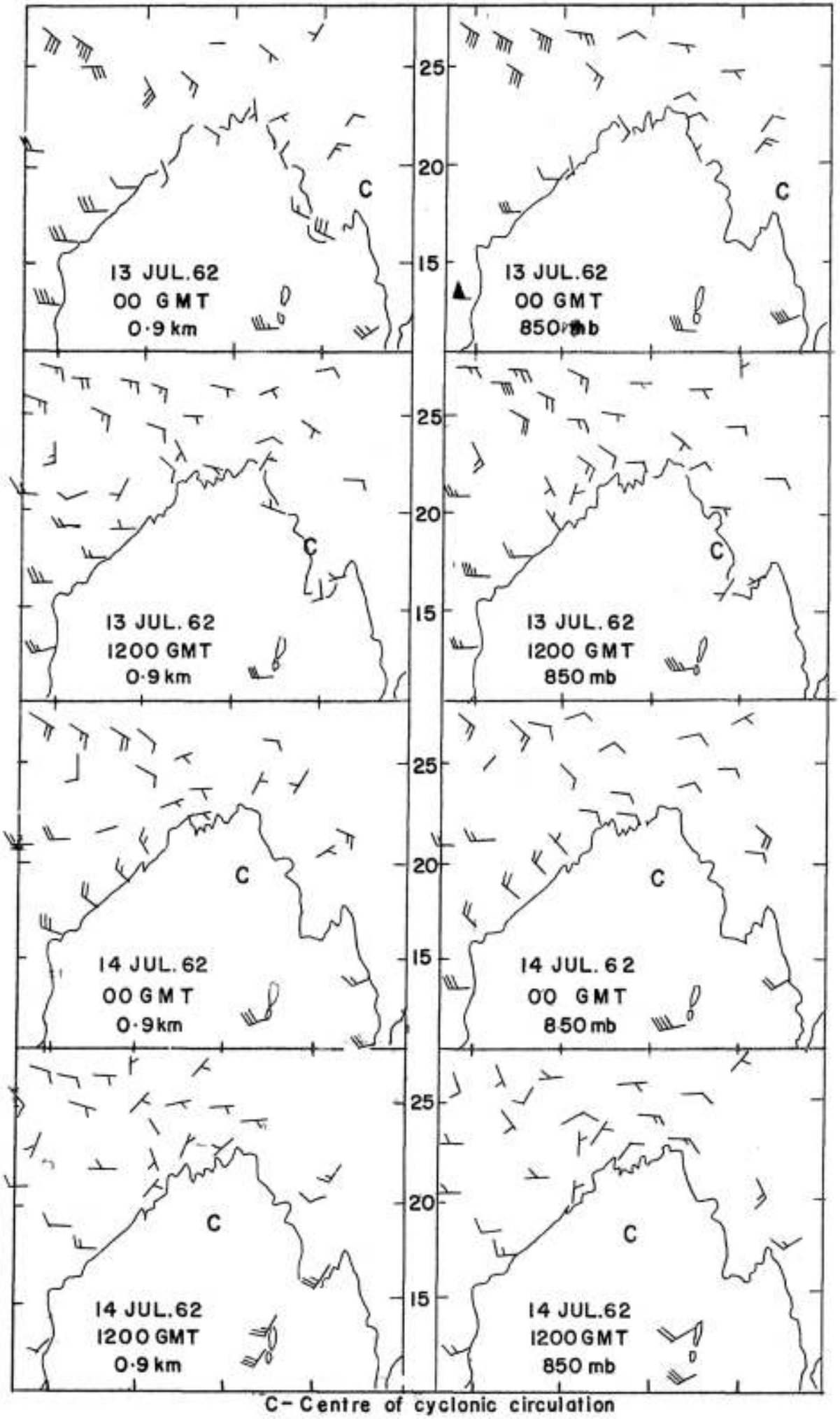
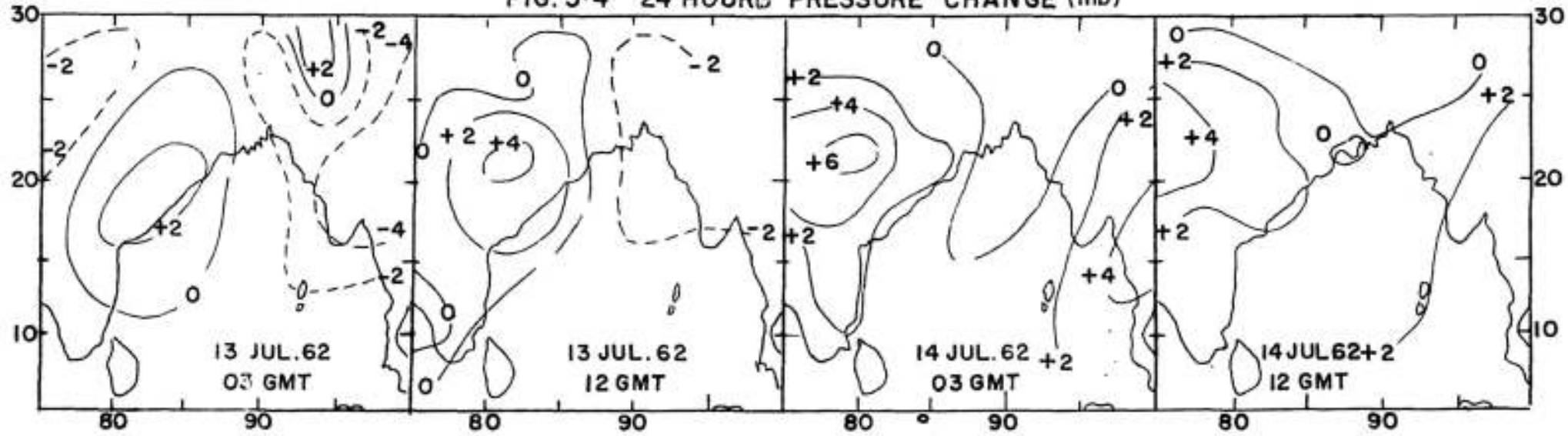


FIG. 5·3 UPPER WINDS



C– Centre of cyclonic circulation

FIG. 5-4 24 HOUR PRESSURE CHANGE (mb)



PRESSURE DEPARTURE (mb)

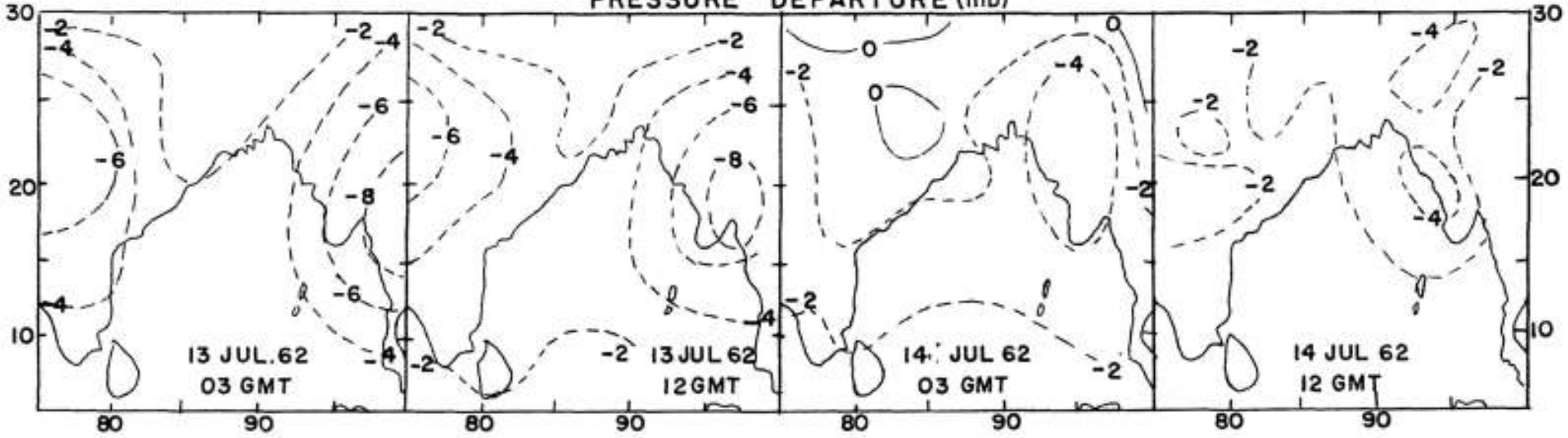
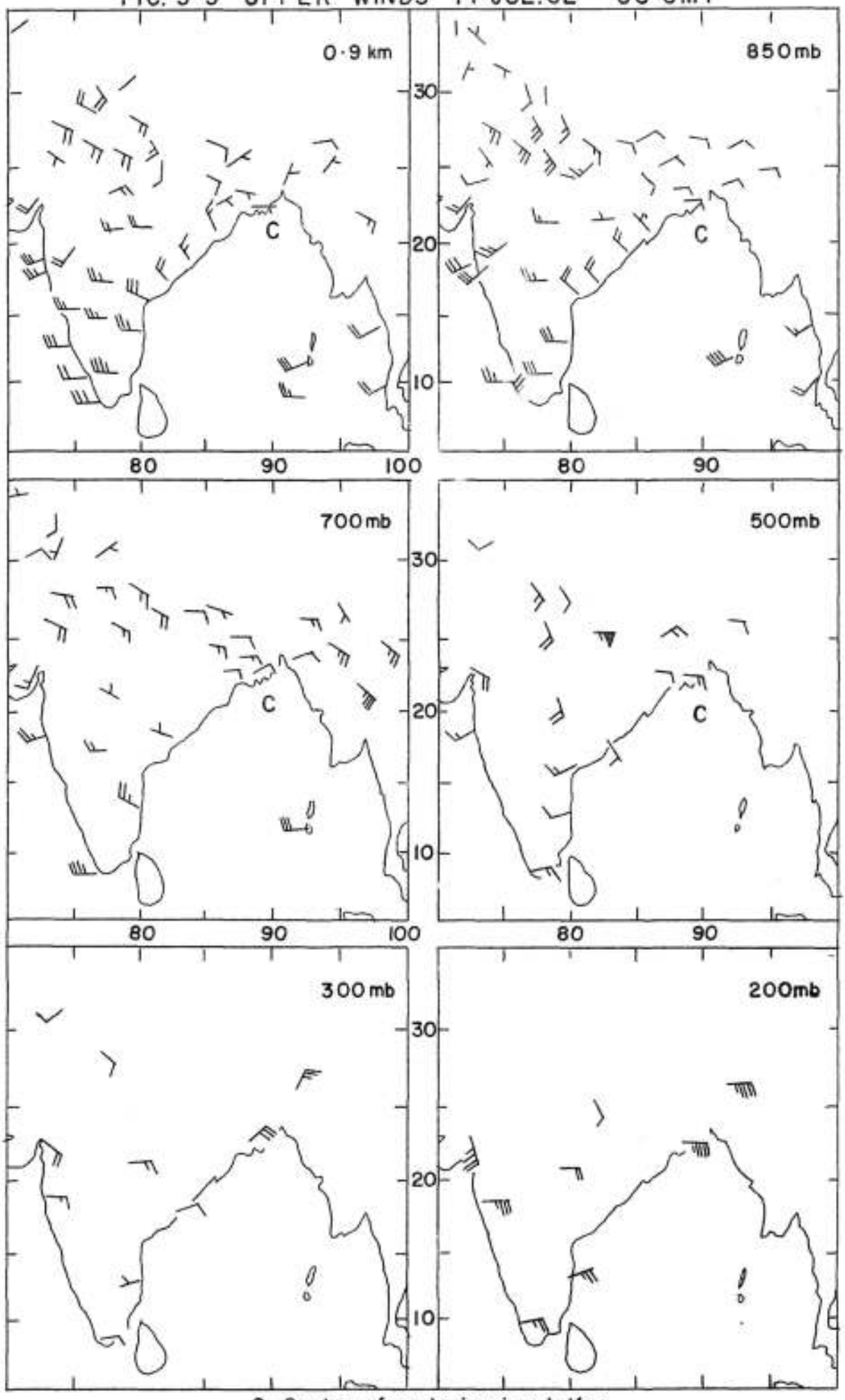


FIG. 5·5 UPPER WINDS 14 JUL.62 00 GMT



C–Centre of cyclonic circulation

FIG. 5·6 SYNOPTIC CHARTS 0300 GMT 15 JUL. 62

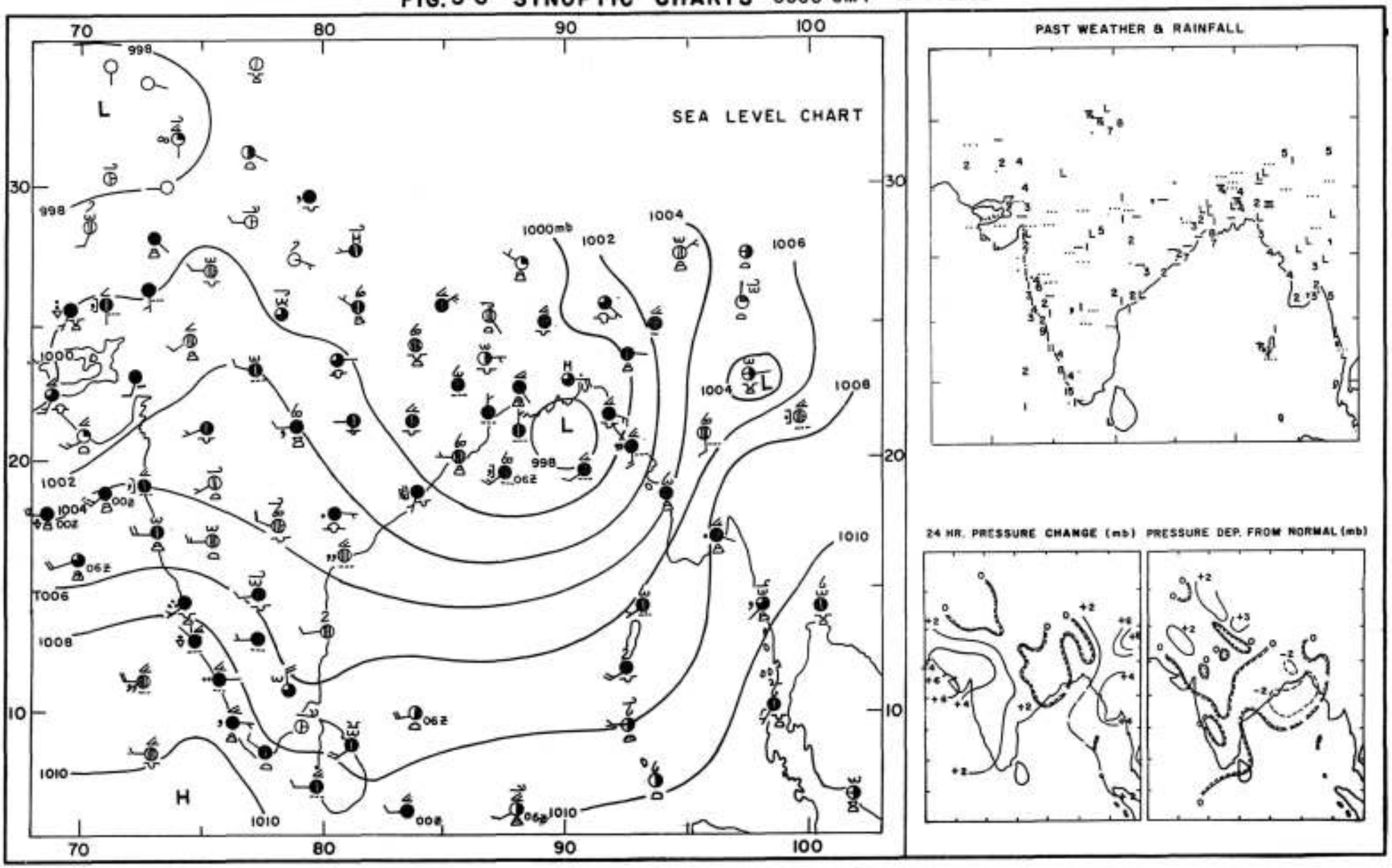
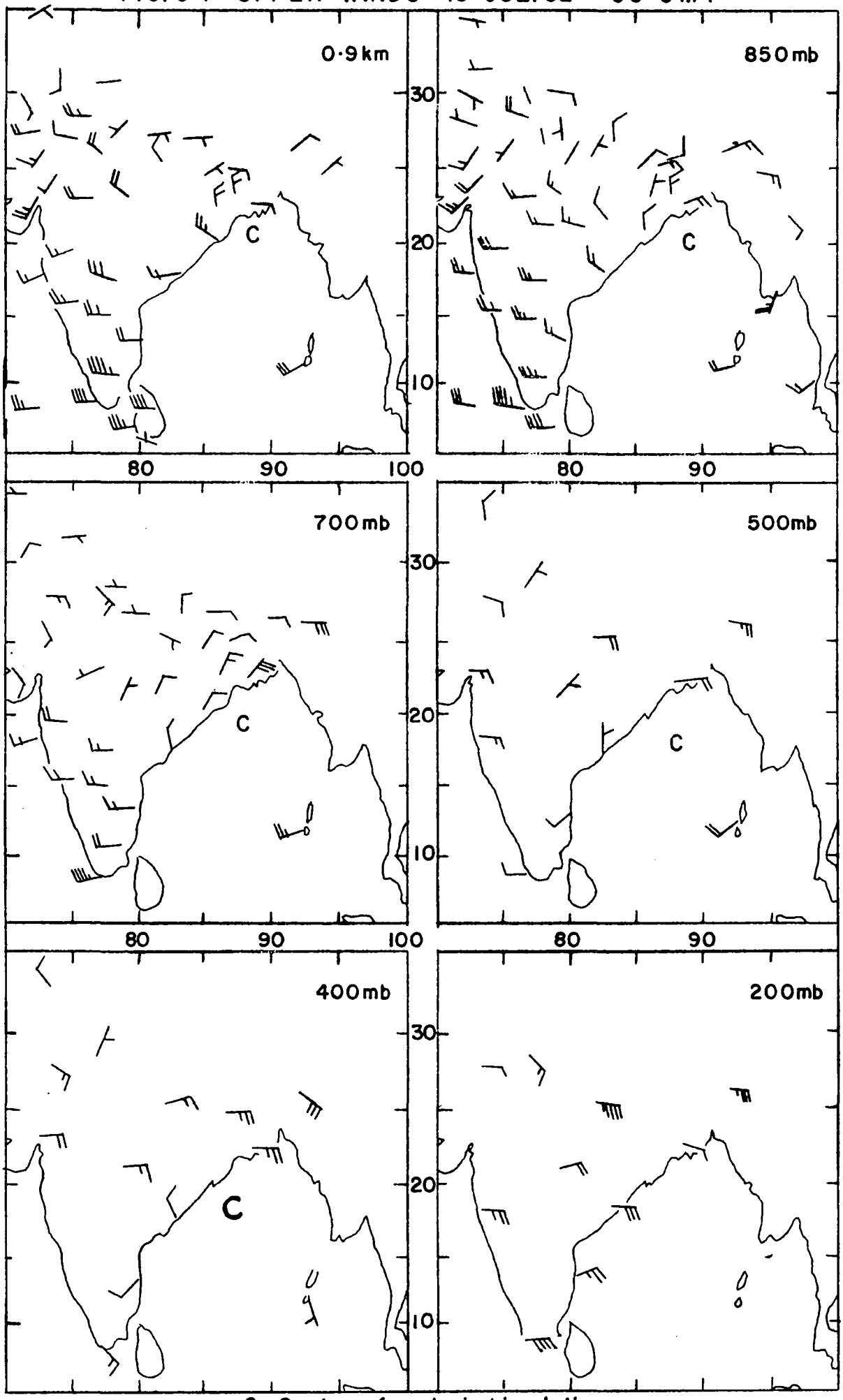


FIG. 5·7 UPPER WINDS 15 JUL. 62 00 GMT



C - Centre of cyclonic circulation

FIG. 5-8 SYNOPTIC CHARTS 0300 GMT 16 JUL. 62

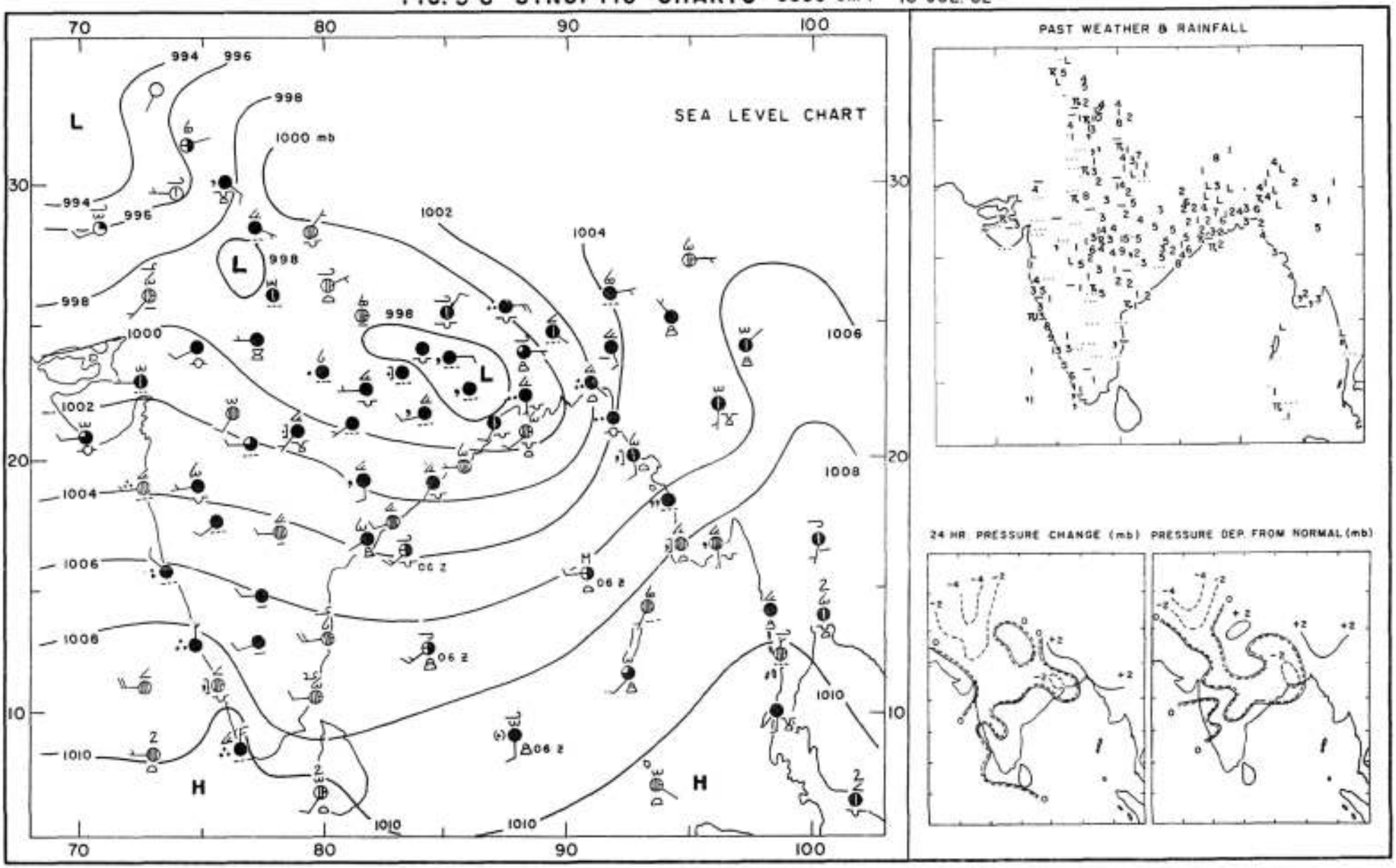
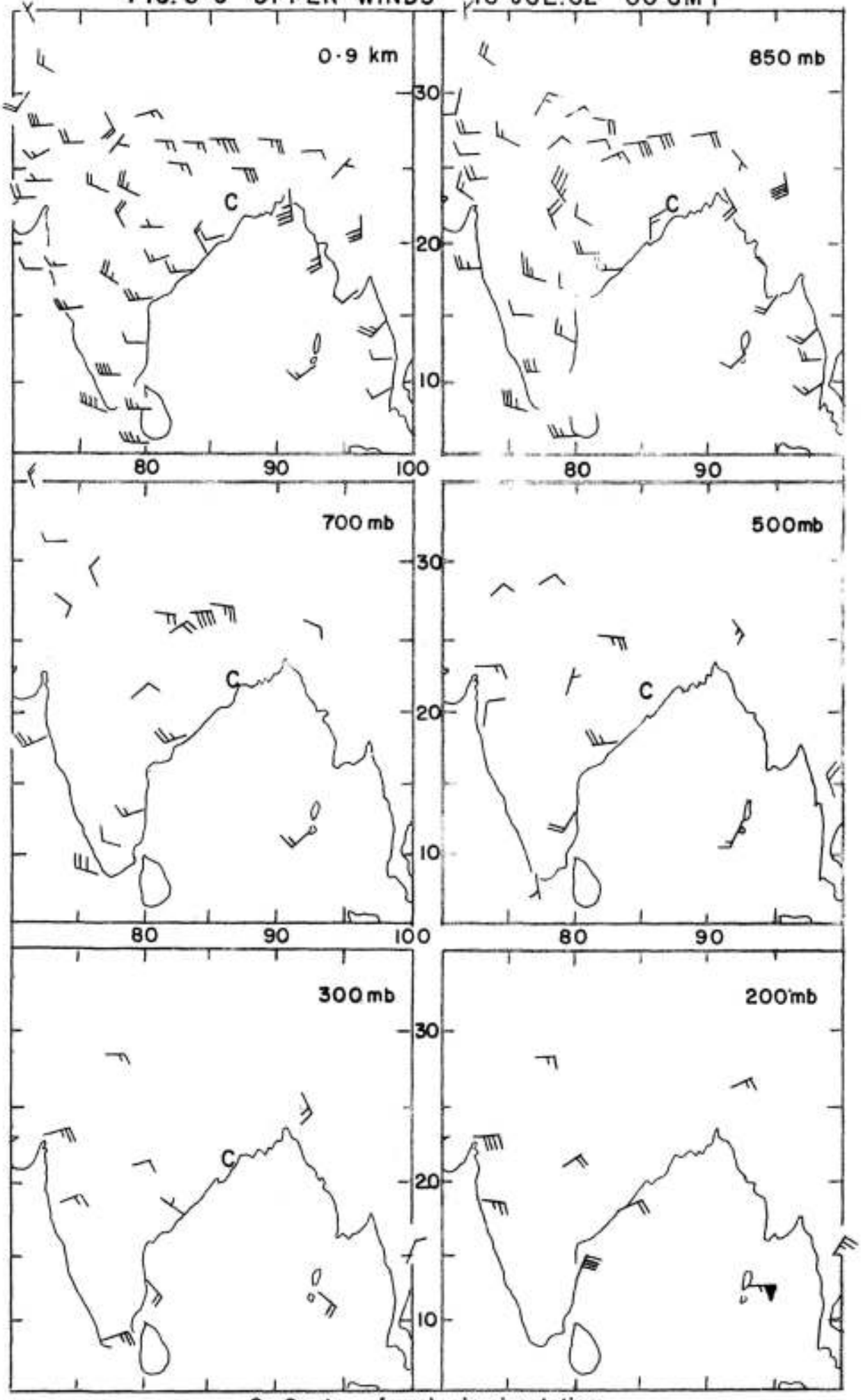


FIG. 5·9 UPPER WINDS 16 JUL. 62 00 GMT



C– Centre of cyclonic circulation

FIG.5-10 SYNOPTIC CHARTS 0300 GMT 17 JUL. 62

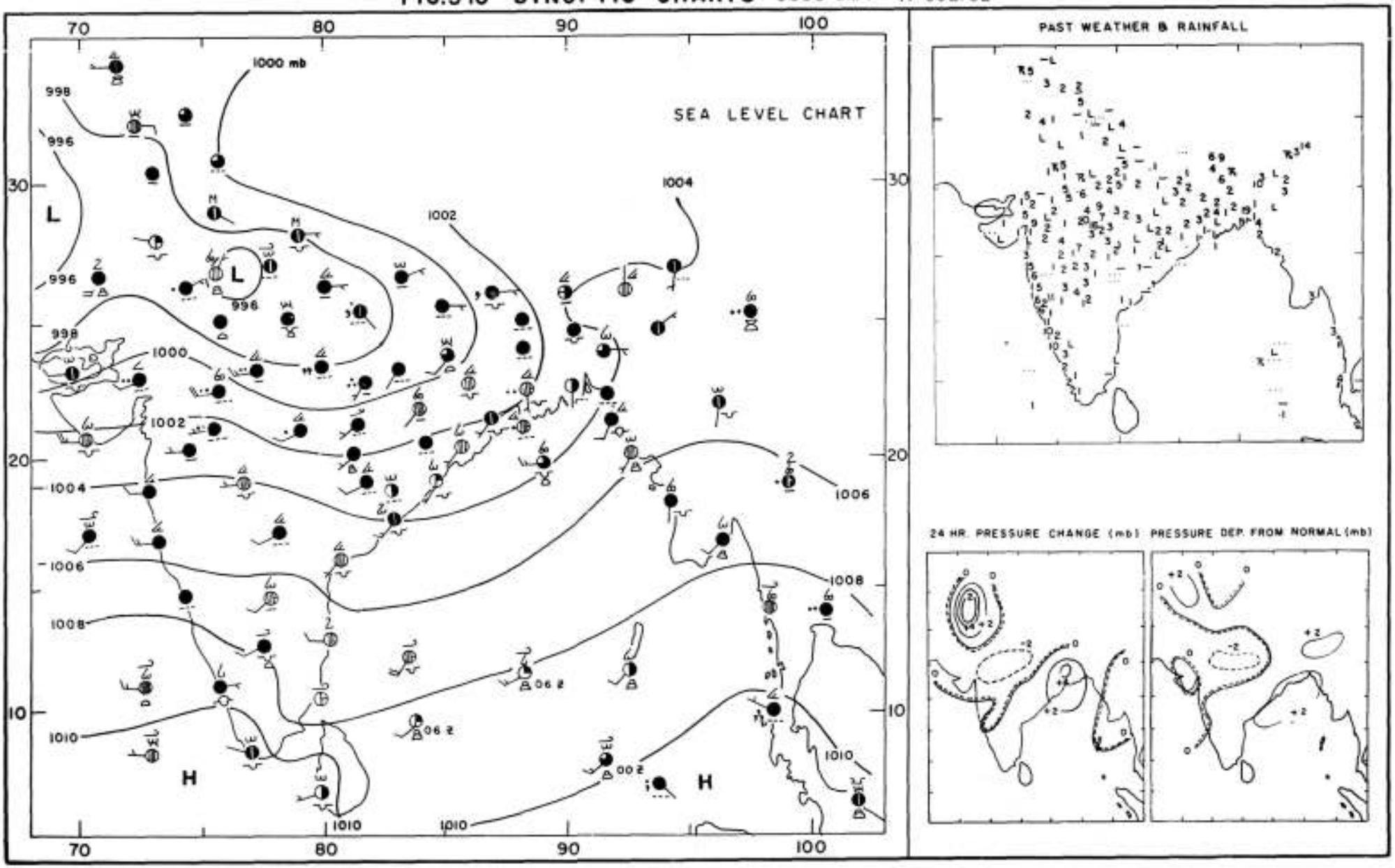


FIG. 5·11 SYNOPTIC CHARTS 0300 GMT 18 JUL. 62

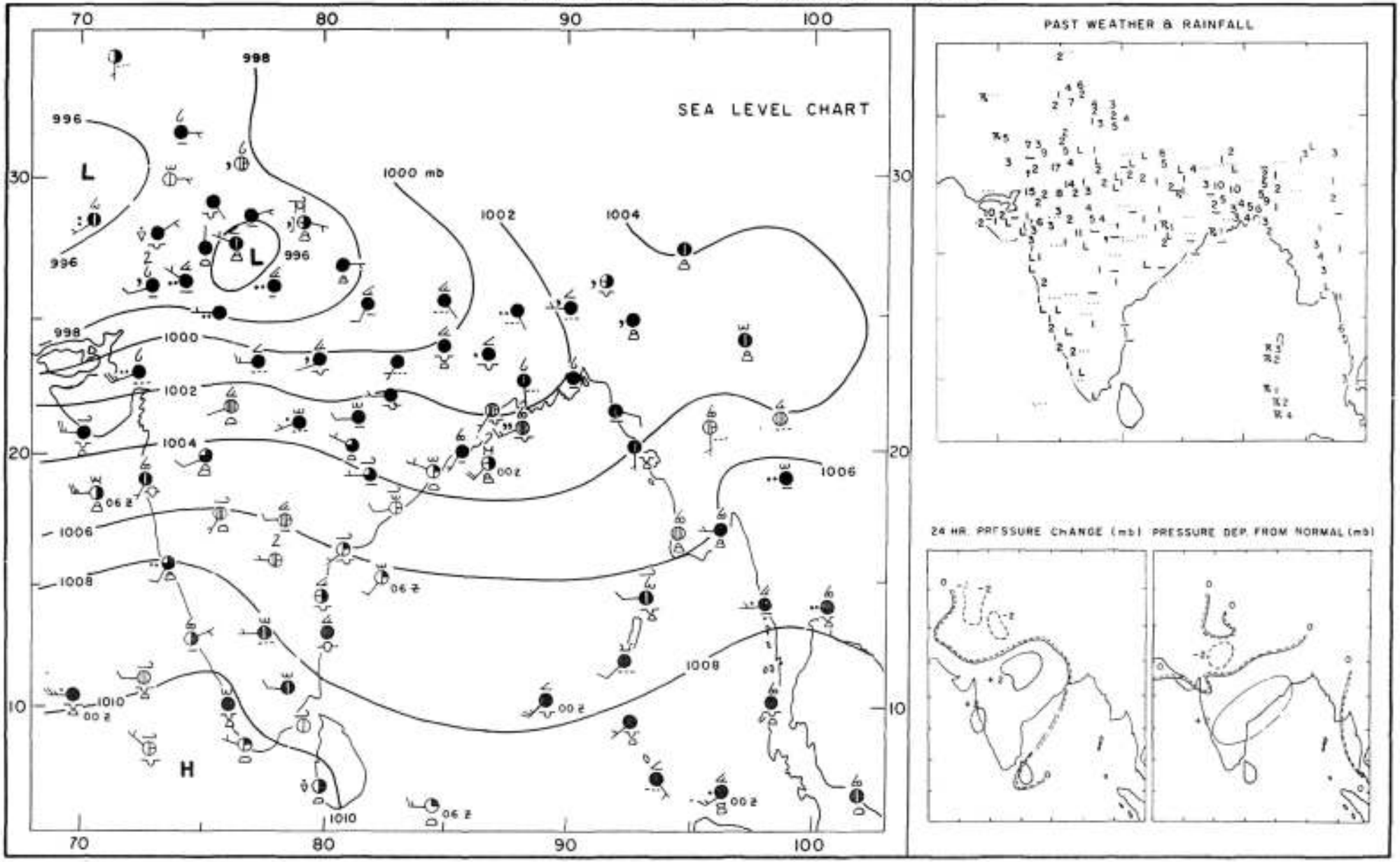


FIG.5·12 SYNOPTIC CHARTS 0300 GMT 1 AUG. 65

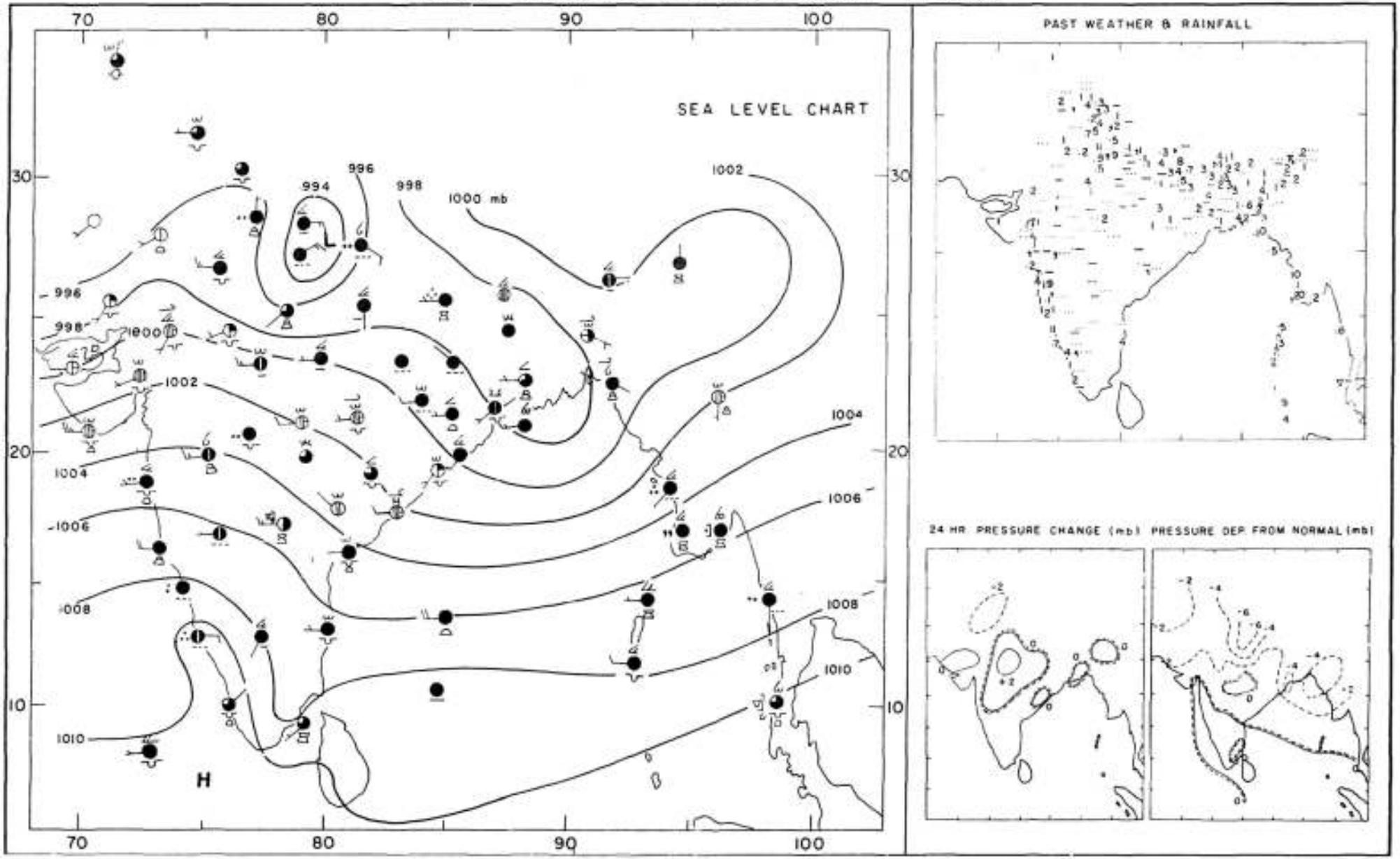
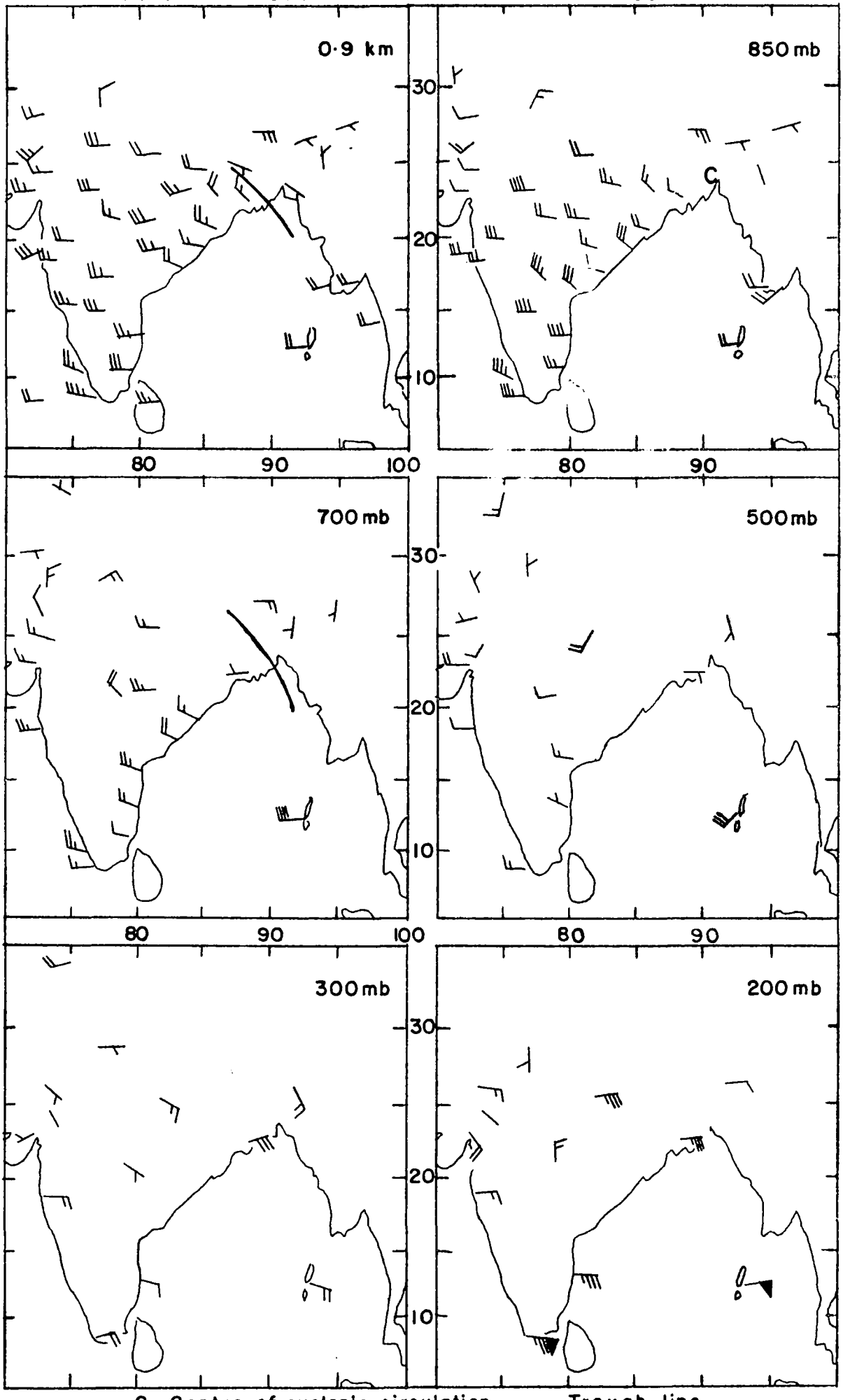


FIG. 5·13 UPPER WINDS 1 AUG 65 00 GMT



C – Centre of cyclonic circulation —— Trough line

FIG.5·14 SYNOPTIC CHARTS 0300 GMT 2 AUG. 65

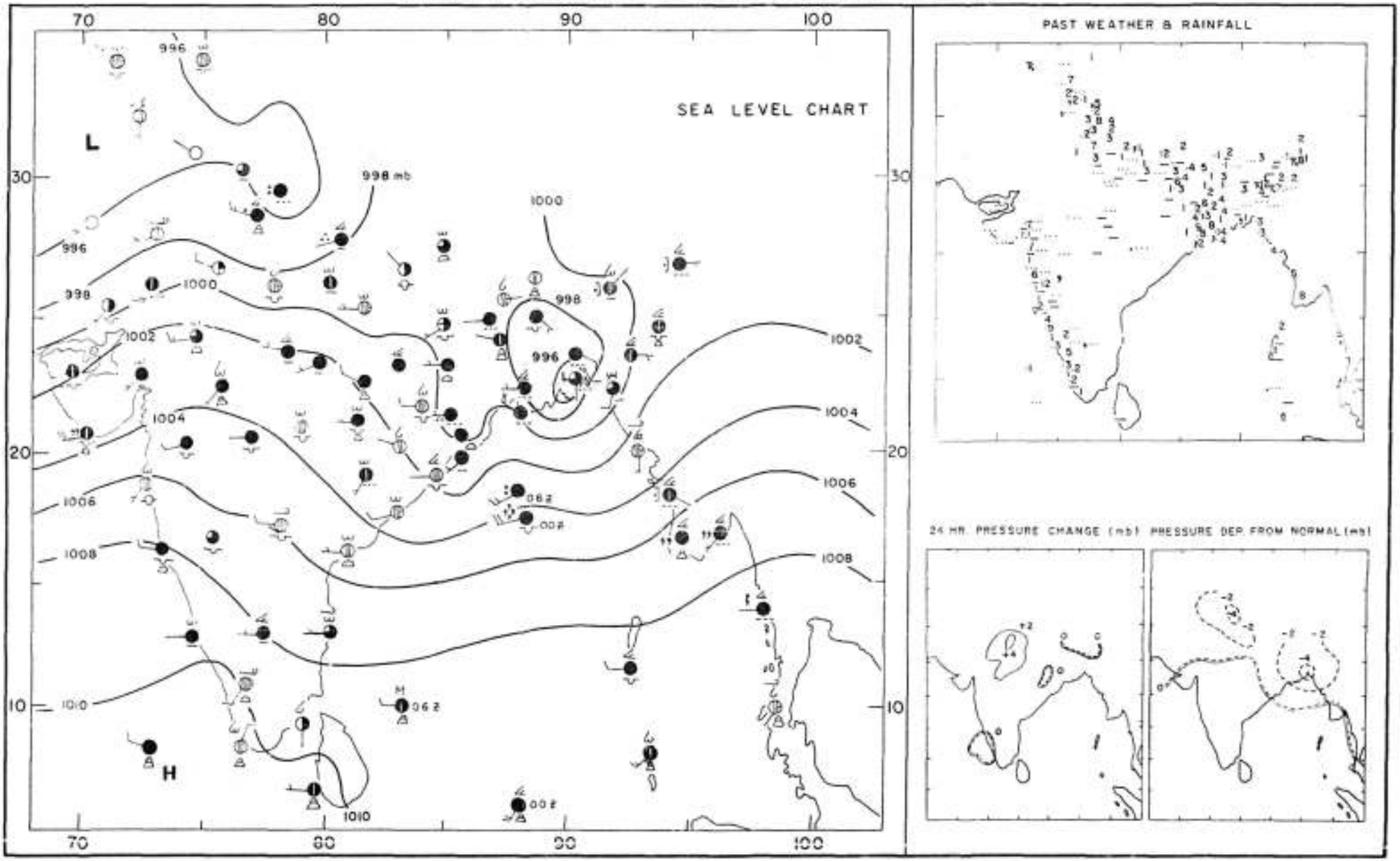
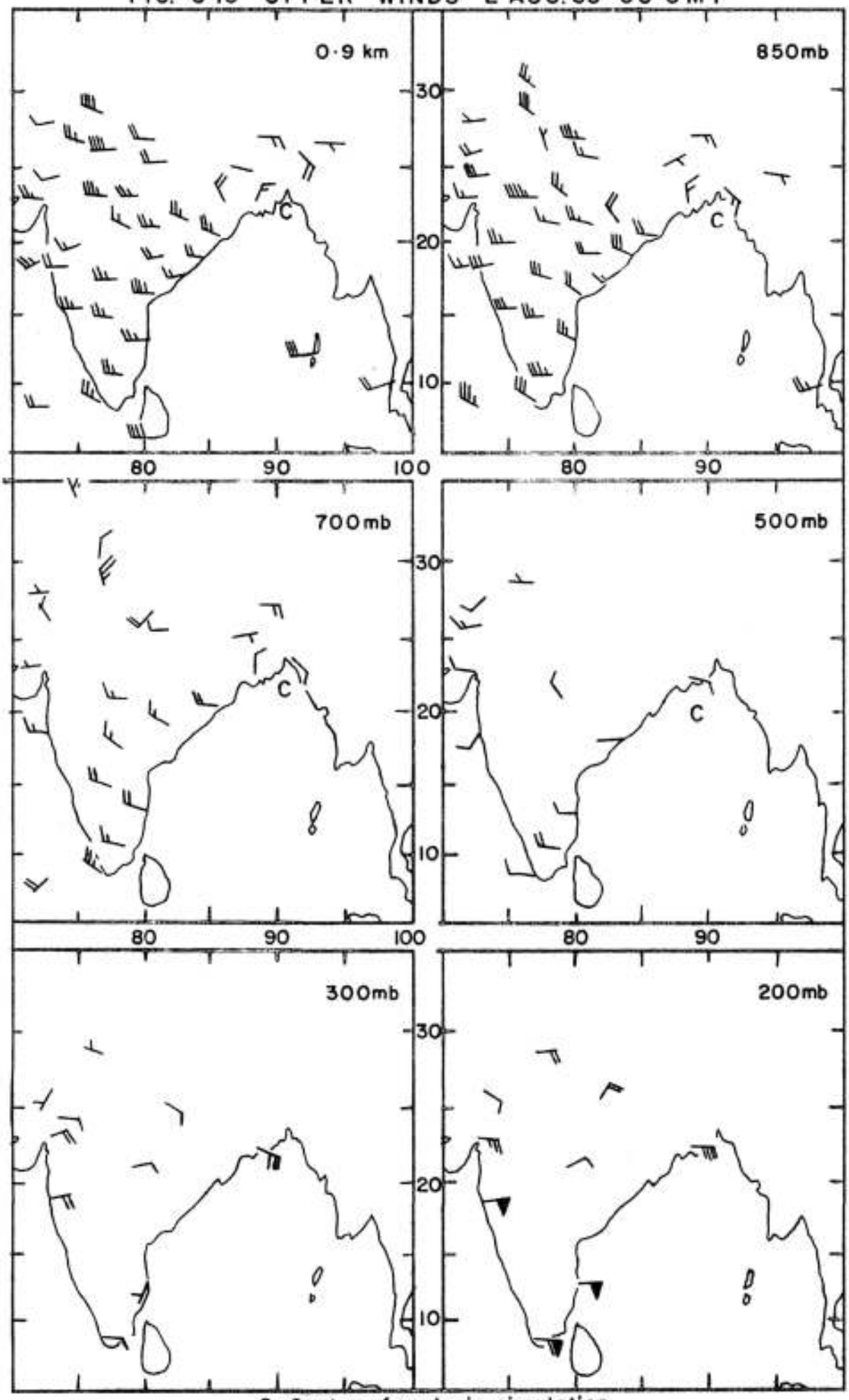


FIG. 5·15 UPPER WINDS 2 AUG. 65 00 GMT



C–Centre of cyclonic circulation

FIG. 5·16 SYNOPTIC CHARTS 0300 GMT 3 AUG. 65

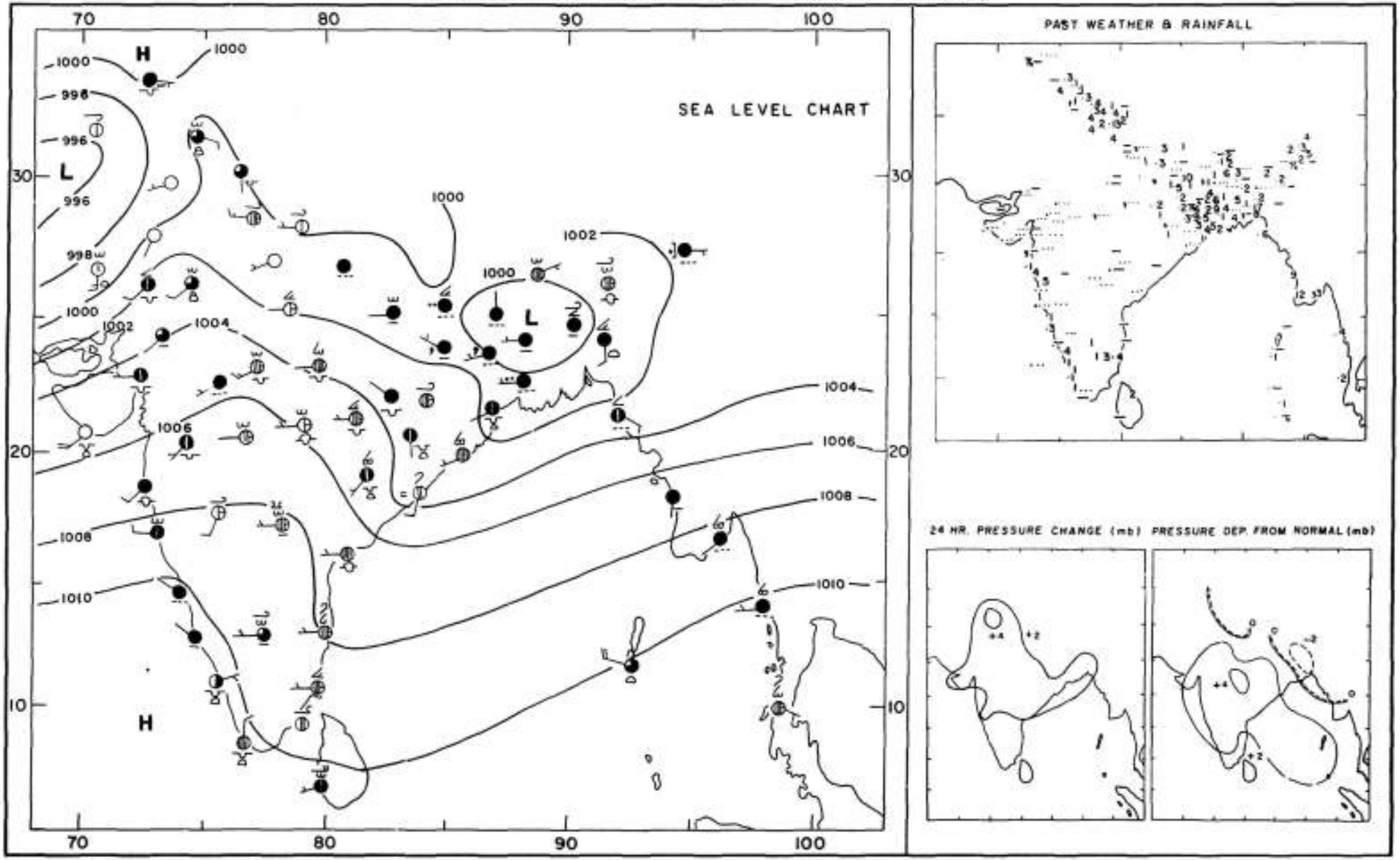


FIG. 5·17 UPPER WINDS 3 AUG. 65 00 GMT

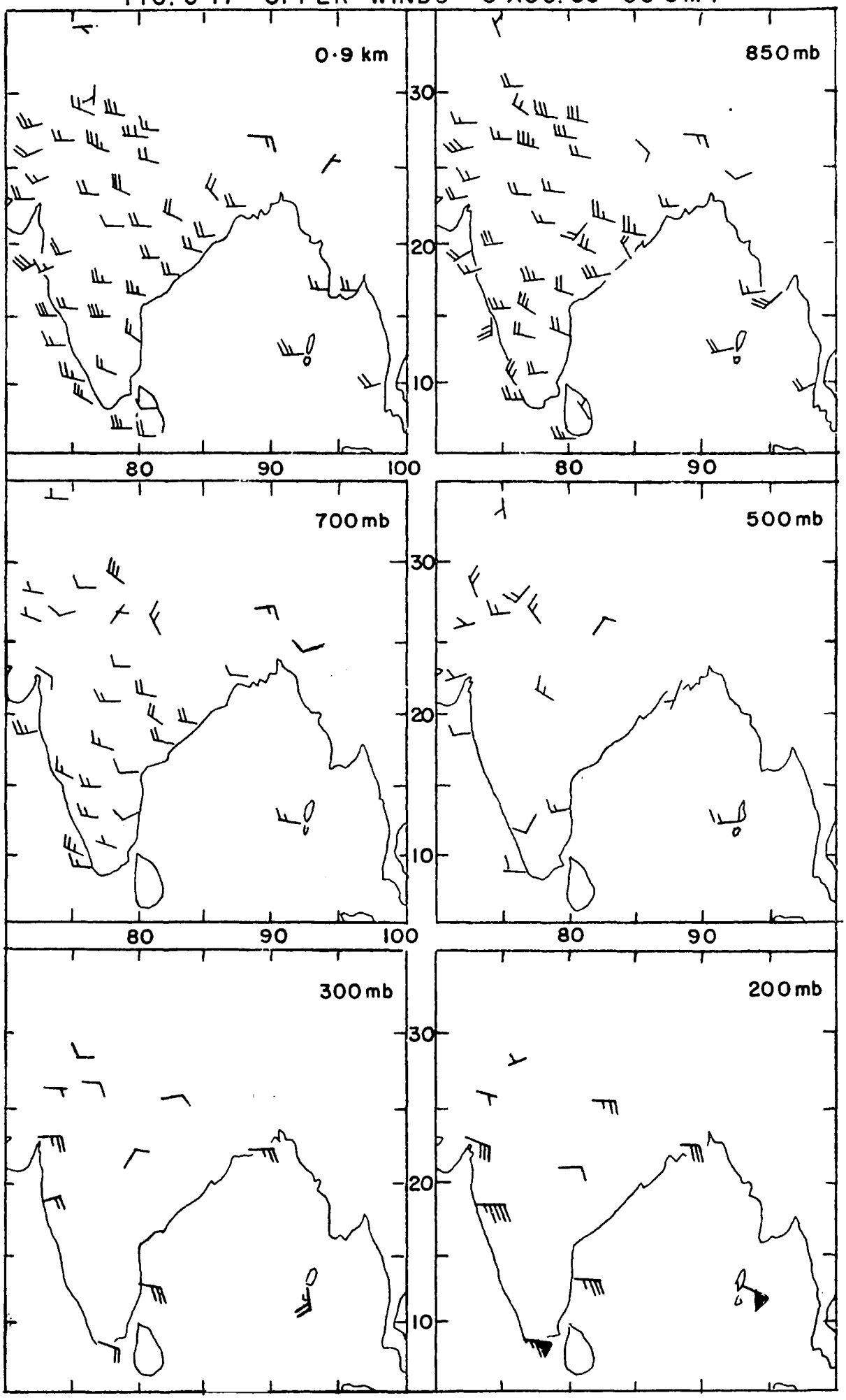


FIG. 6·1 SYNOPTIC CHARTS 0300 GMT 22 AUG. 66

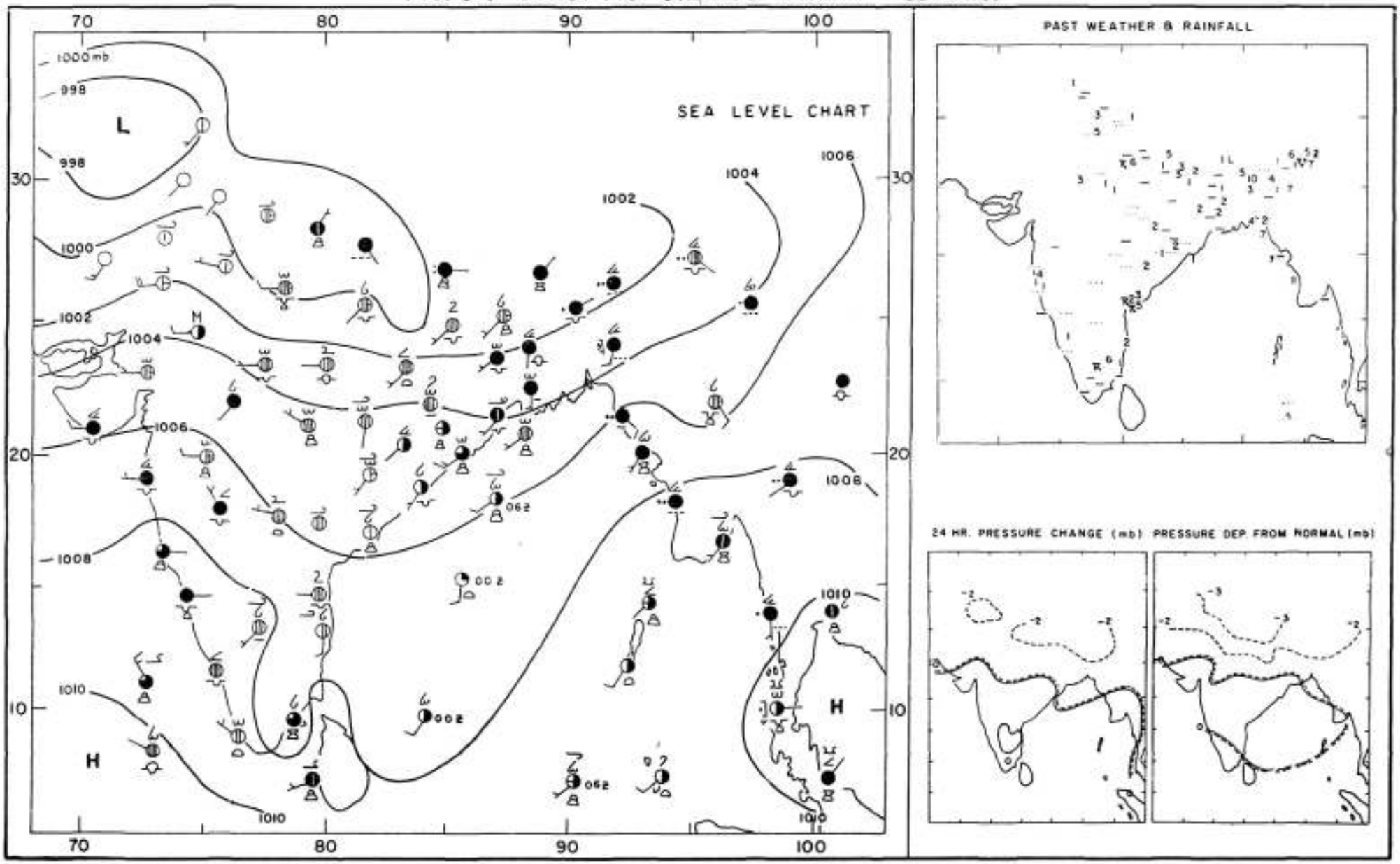


FIG. 6·2 UPPER WINDS 22 AUG. 66 00 GMT

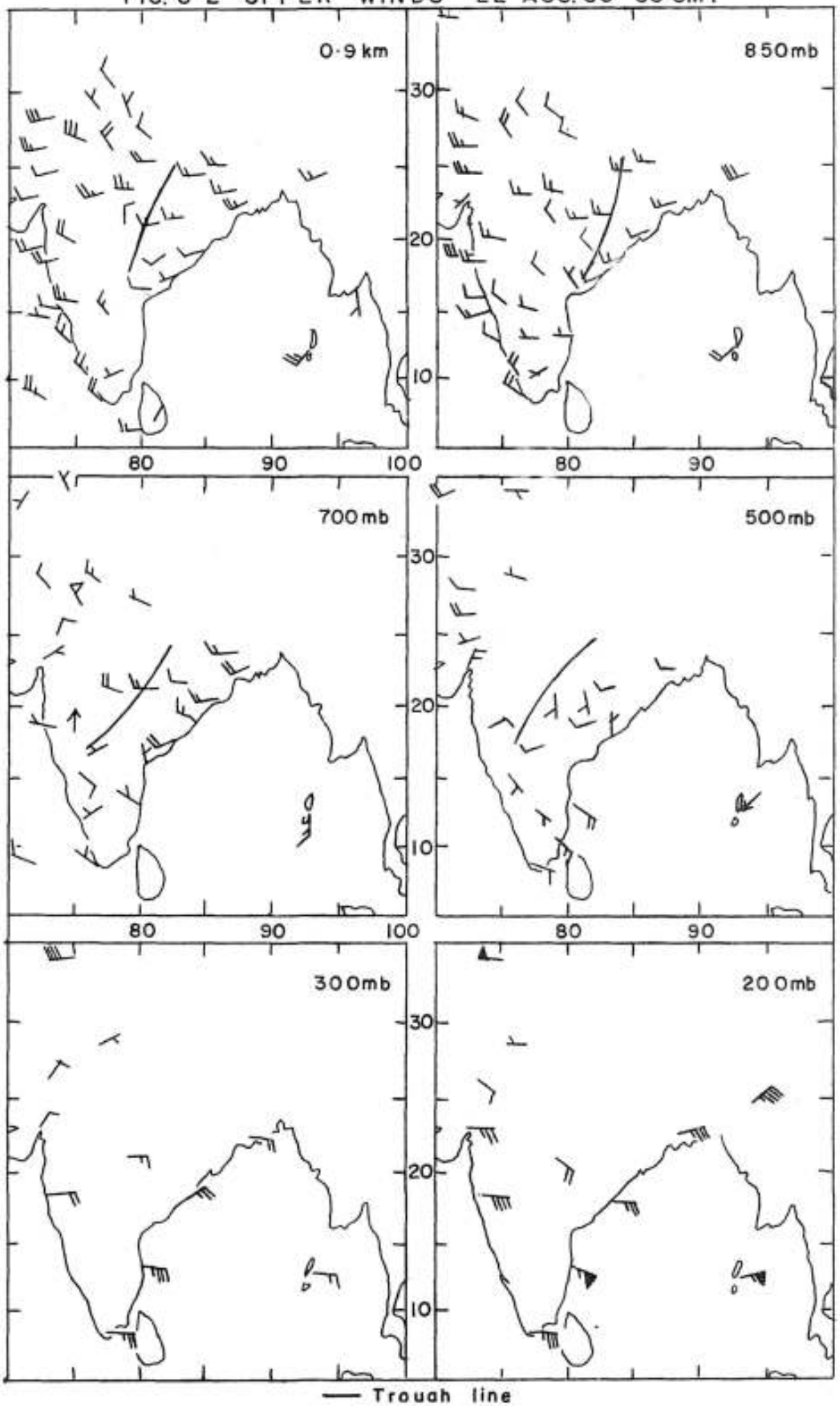


FIG. 6·3 (a) UPPER AIR CHARTS (500 mb)

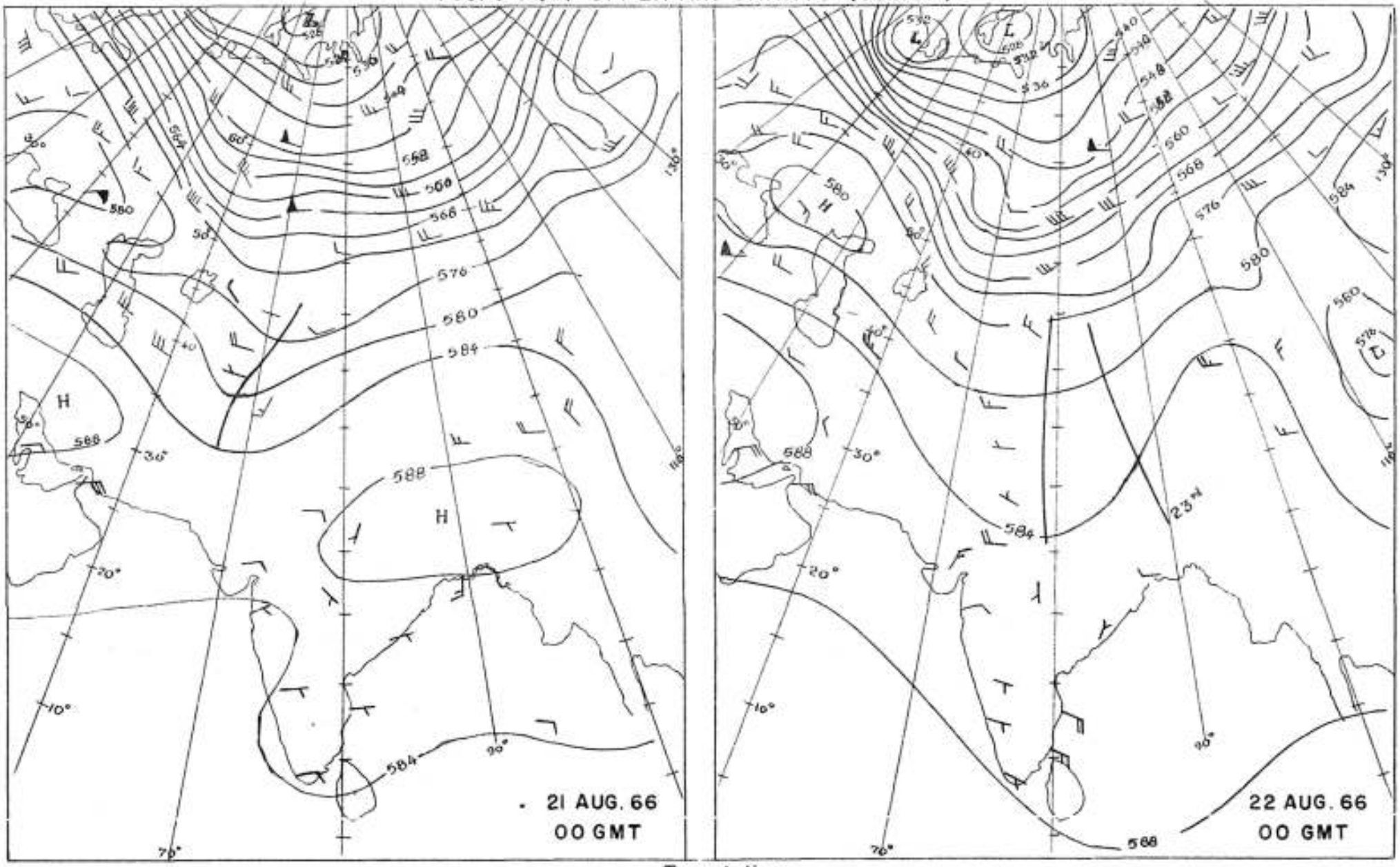


FIG. 6·3 (b) UPPER AIR CHARTS (300mb)

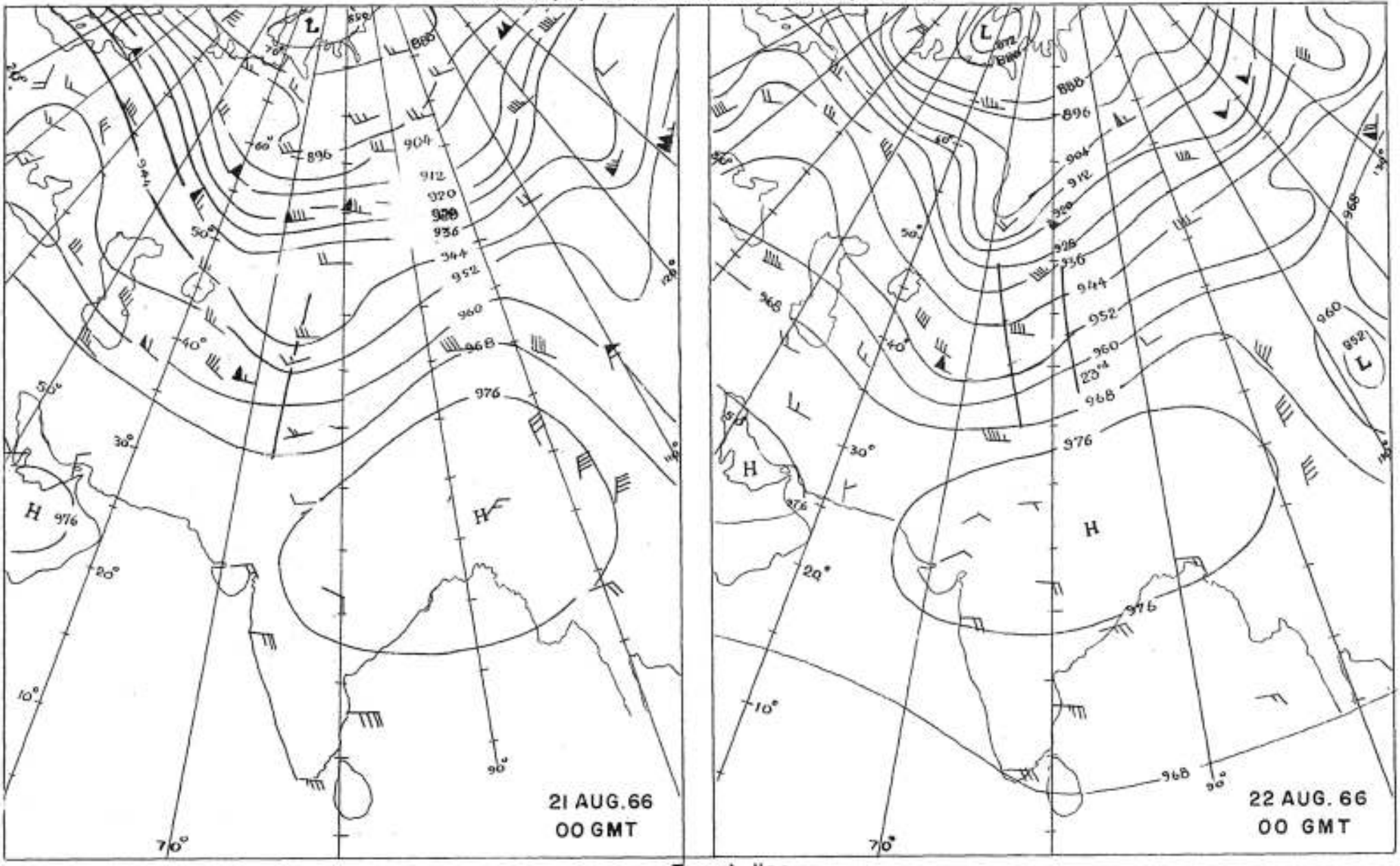


FIG. 6·4 SYNOPTIC CHARTS 0300 GMT 23 AUG. 66

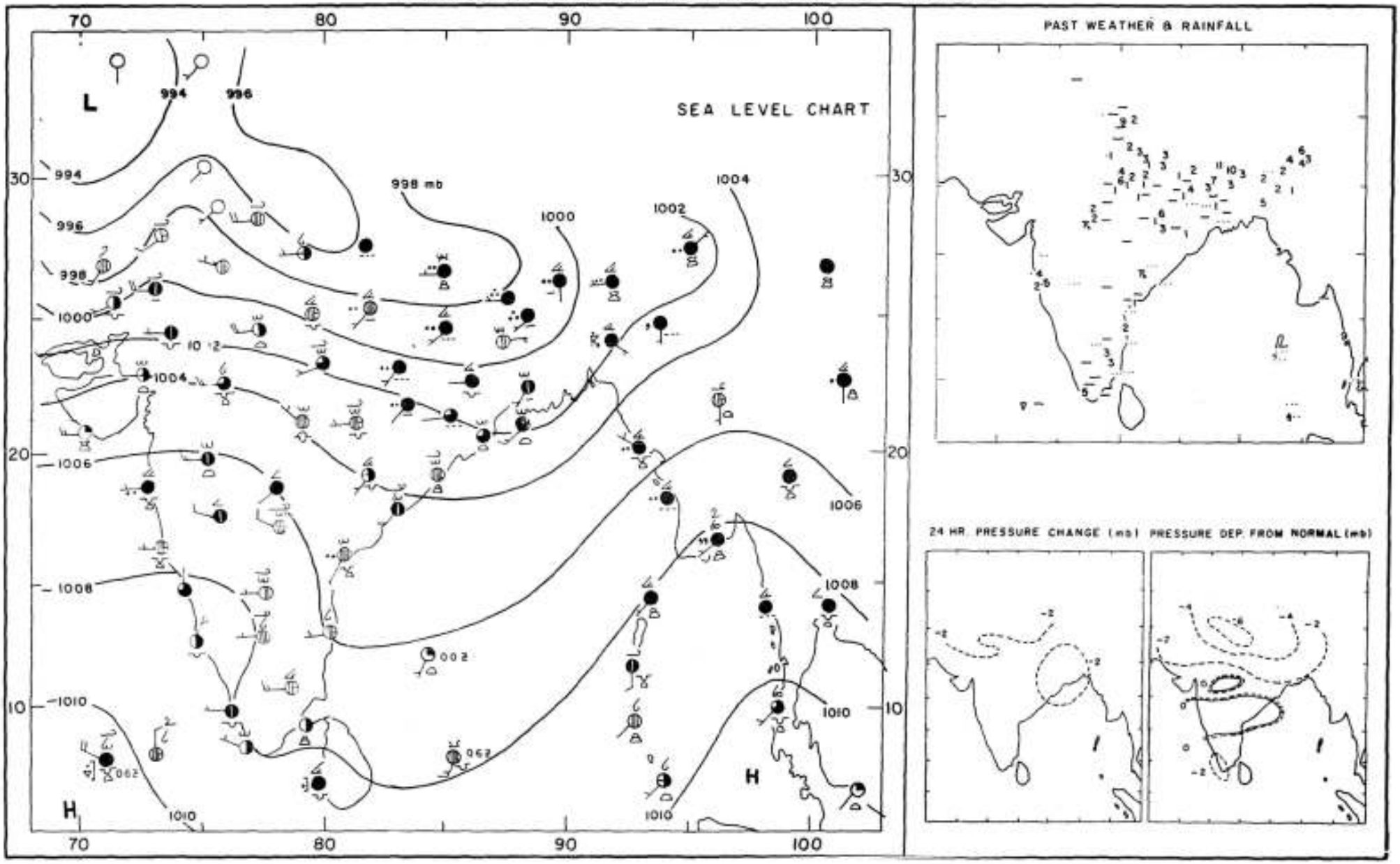


FIG. 6·5 UPPER WINDS 23 AUG. 66 00 GMT

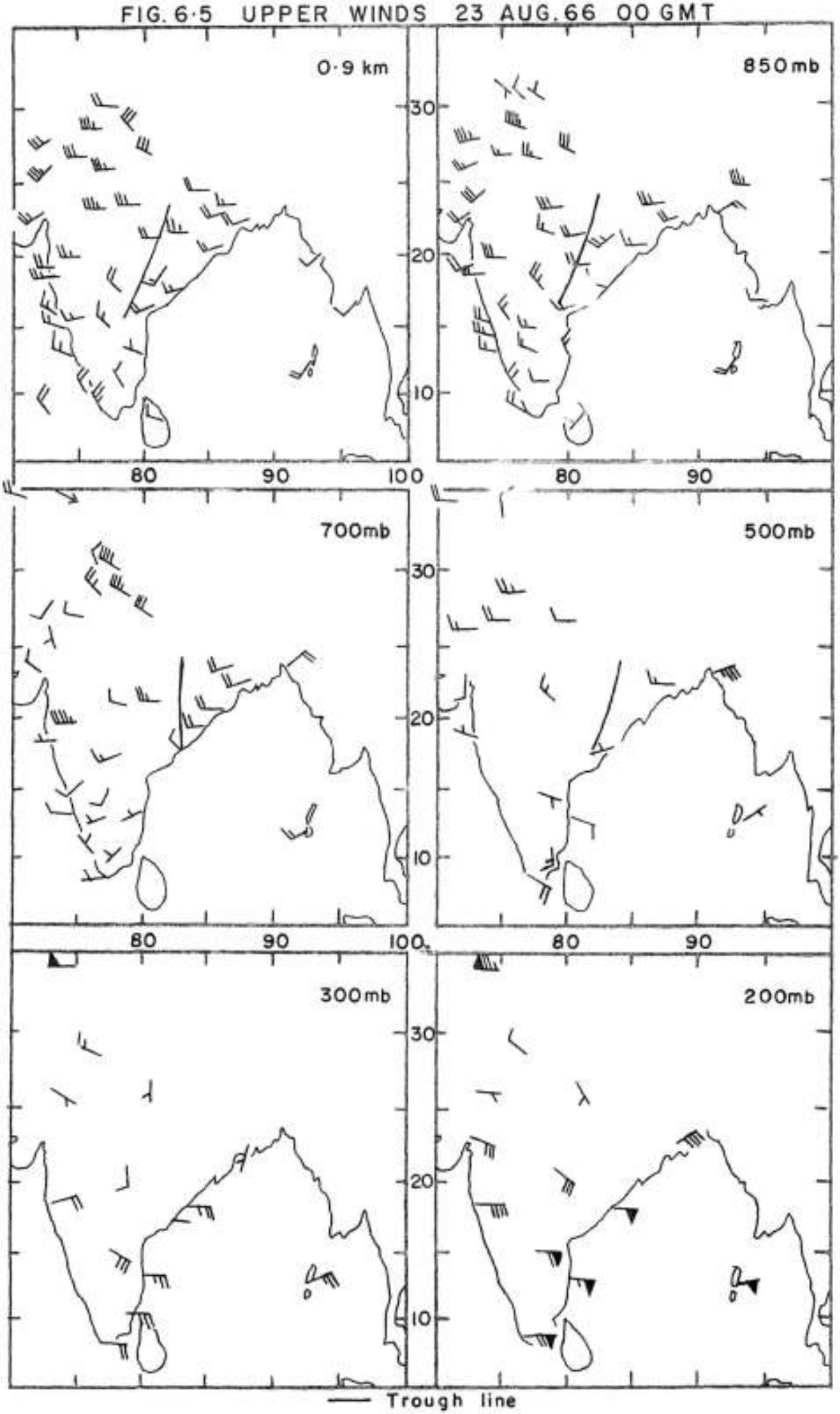


FIG. 6·6 UPPER WINDS 24 AUG. 66 00 GMT

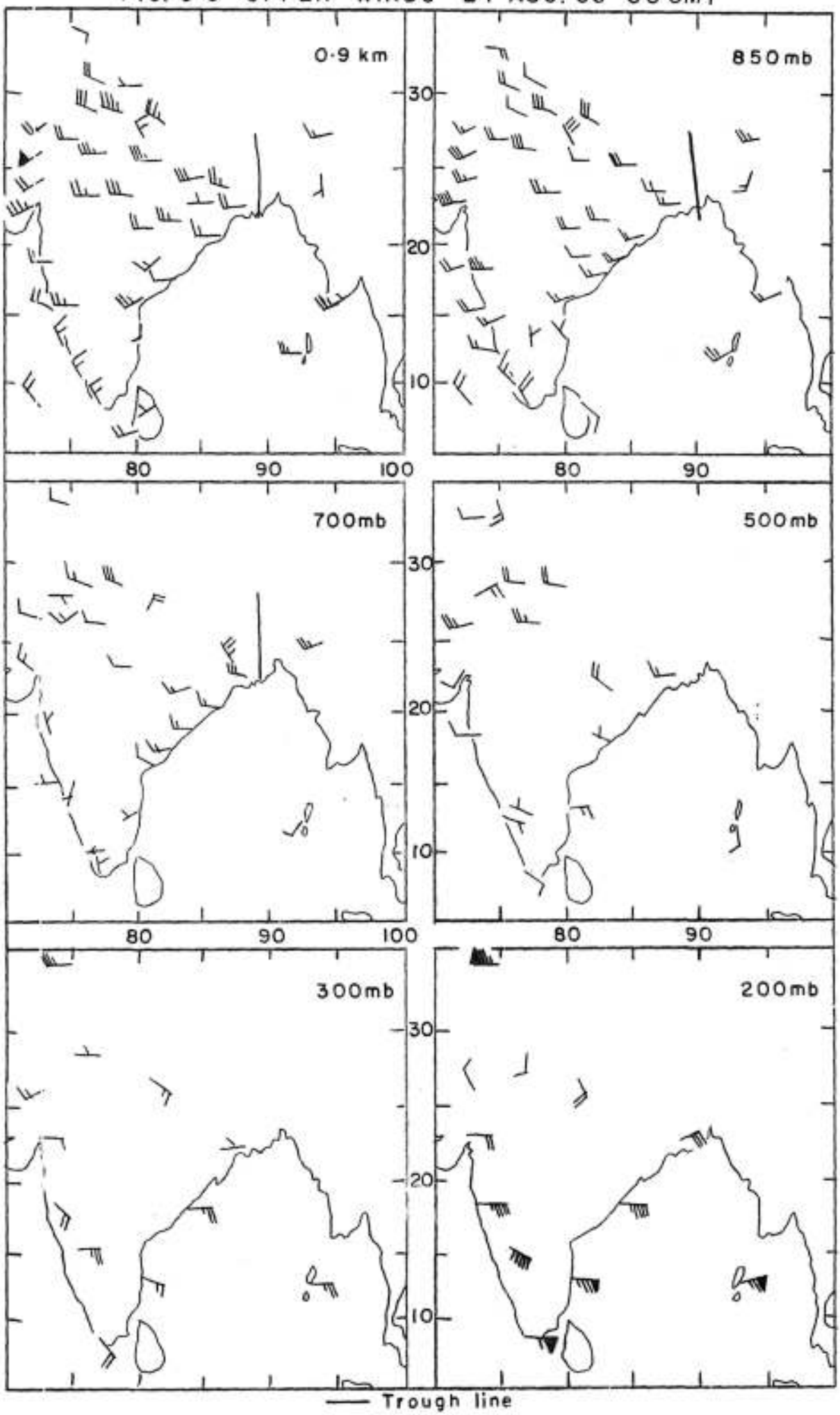


FIG.6·7 SYNOPTIC CHARTS 0300 GMT 6 AUG 65

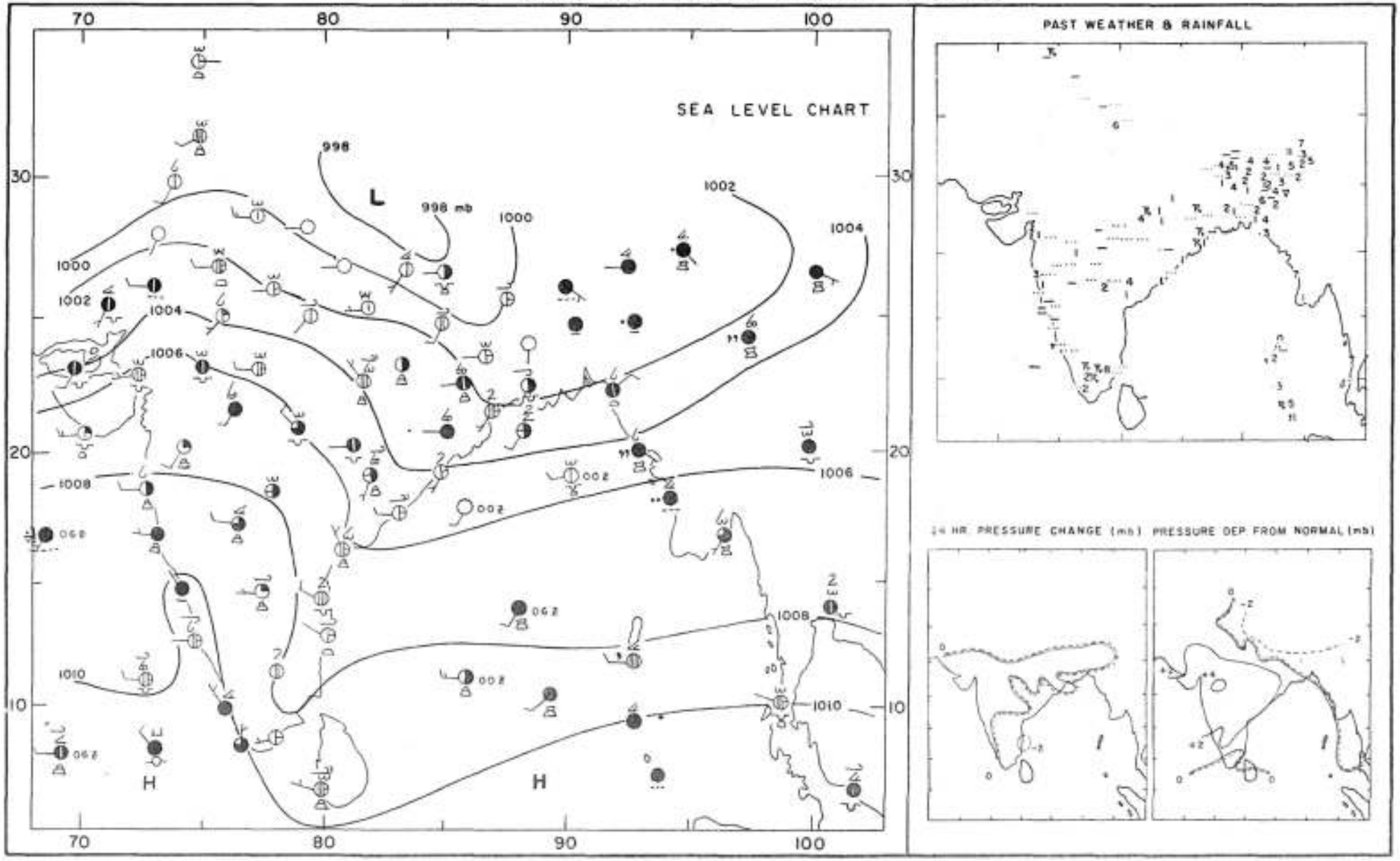


FIG. 6·8 UPPER WINDS 6 AUG. 65 00 GMT

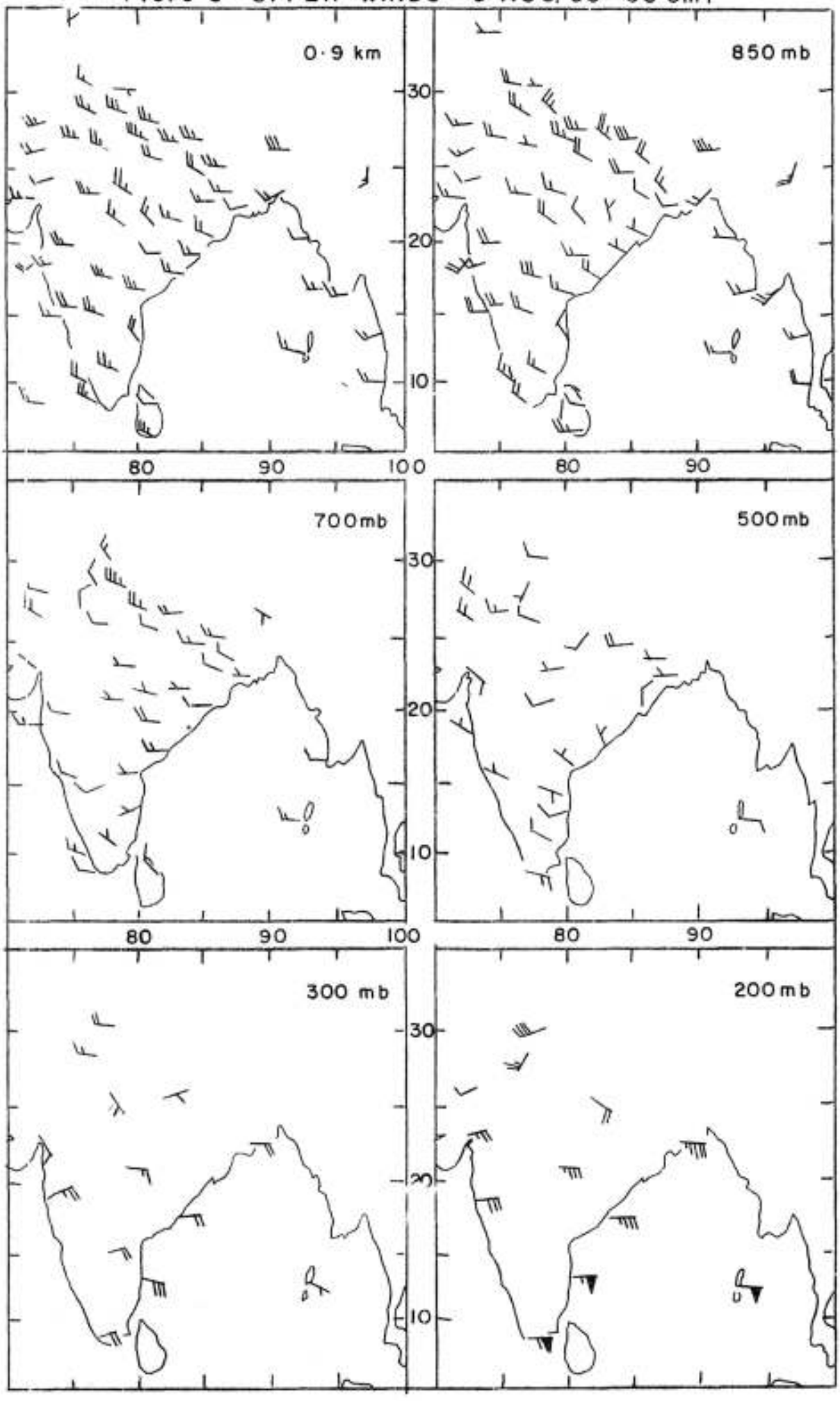


FIG. 6·9

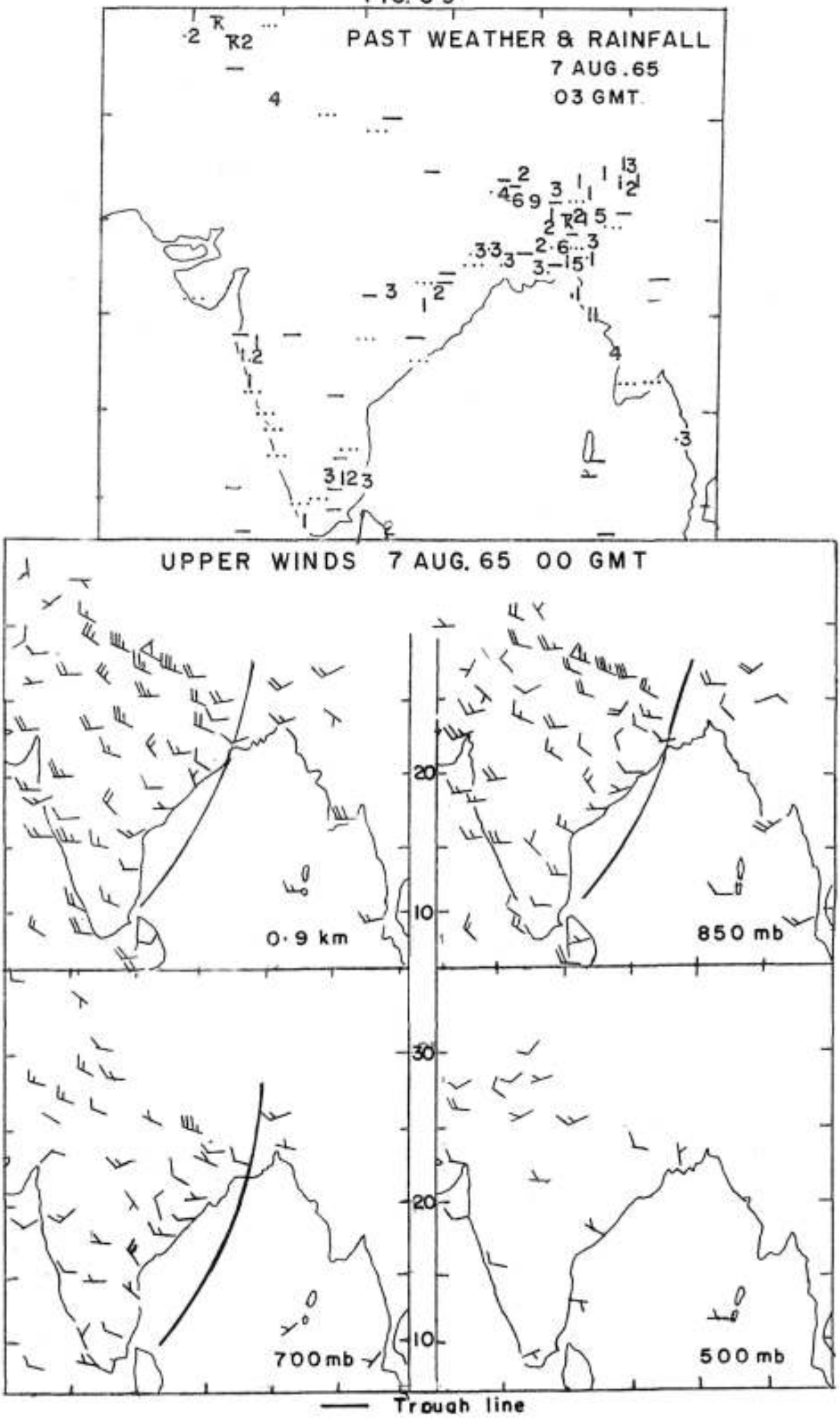

PAST WEATHER & RAINFALL
7 AUG. 65
03 GMT
UPPER WINDS 7 AUG. 65 00 GMT
0·9 km
850 mb
700mb
500 mb
Trough line

FIG. 6·10

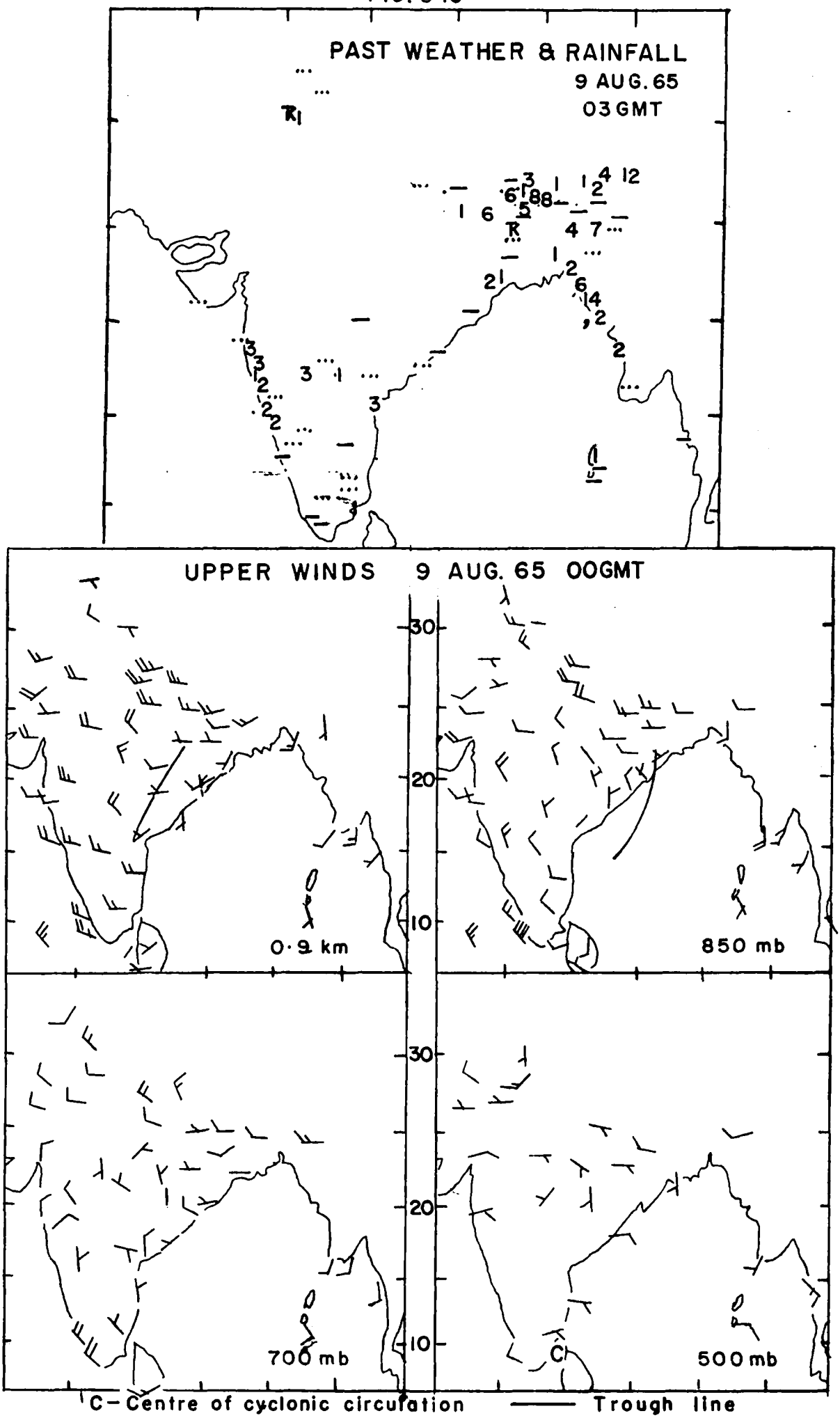

PAST WEATHER & RAINFALL
9 AUG. 65
03 GMT
UPPER WINDS 9 AUG. 65 00GMT
0·9 km
850 mb
700 mb
500 mb
C
30
20
10
C – Centre of cyclonic circulation
Trough line

FIG. 6·11

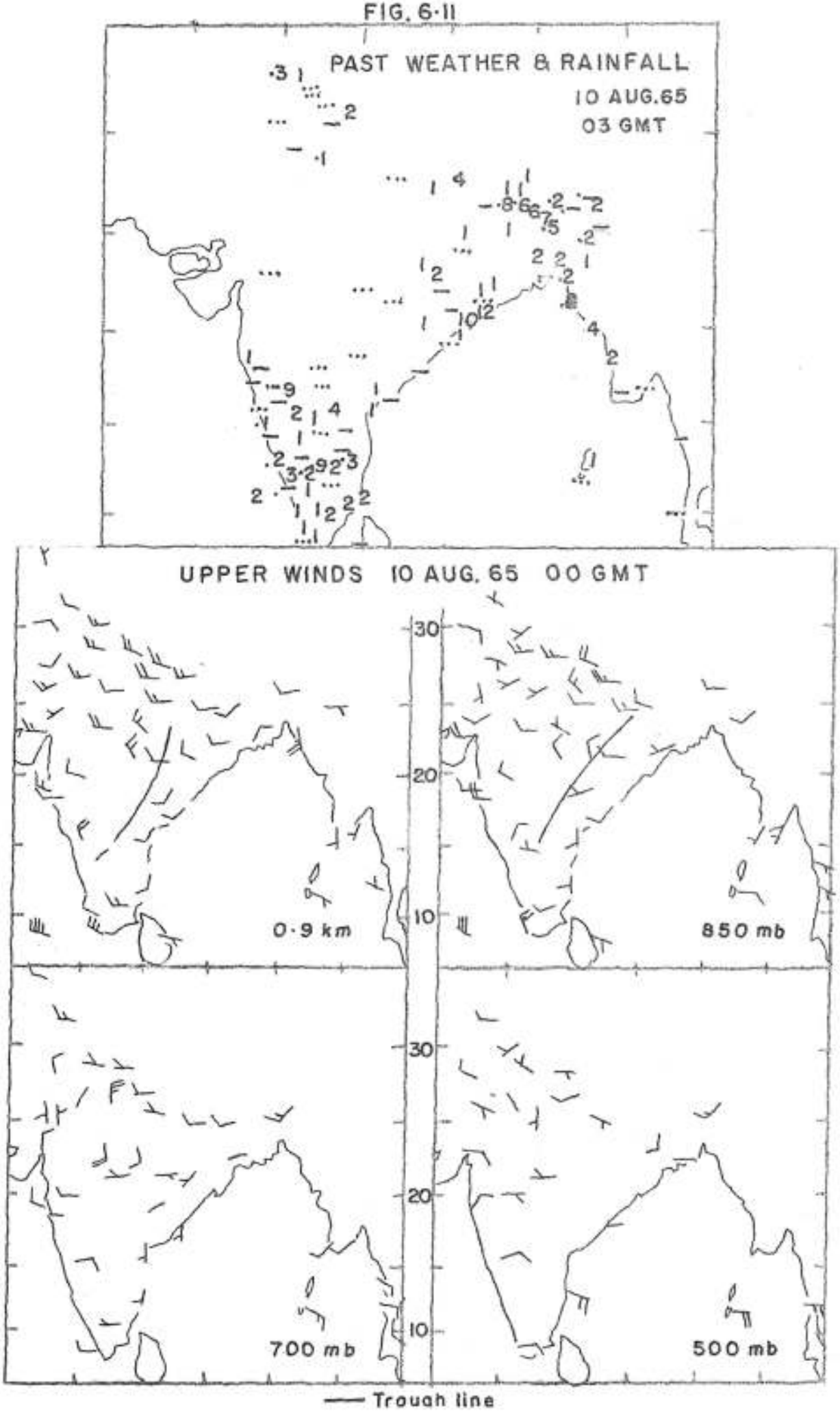

PAST WEATHER & RAINFALL
10 AUG.65
03 GMT
UPPER WINDS 10 AUG. 65 00 GMT
0·9 km
850 mb
700 mb
500 mb
30
20
10
Trough line

FIG. 6-12 UPPER AIR CHARTS 8 AUG. 65

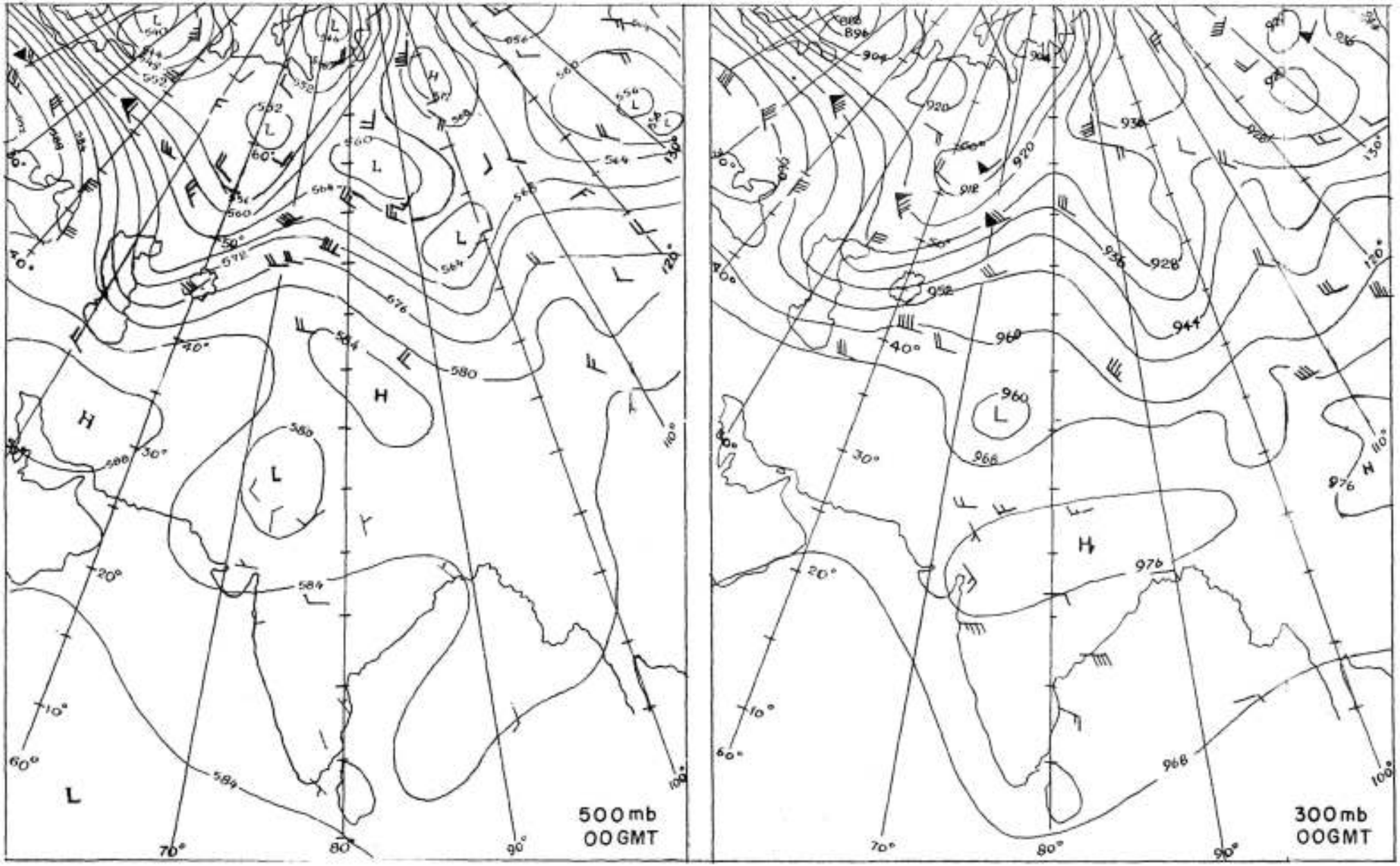


FIG. 6-13 UPPER AIR CHARTS 10 AUG. 65

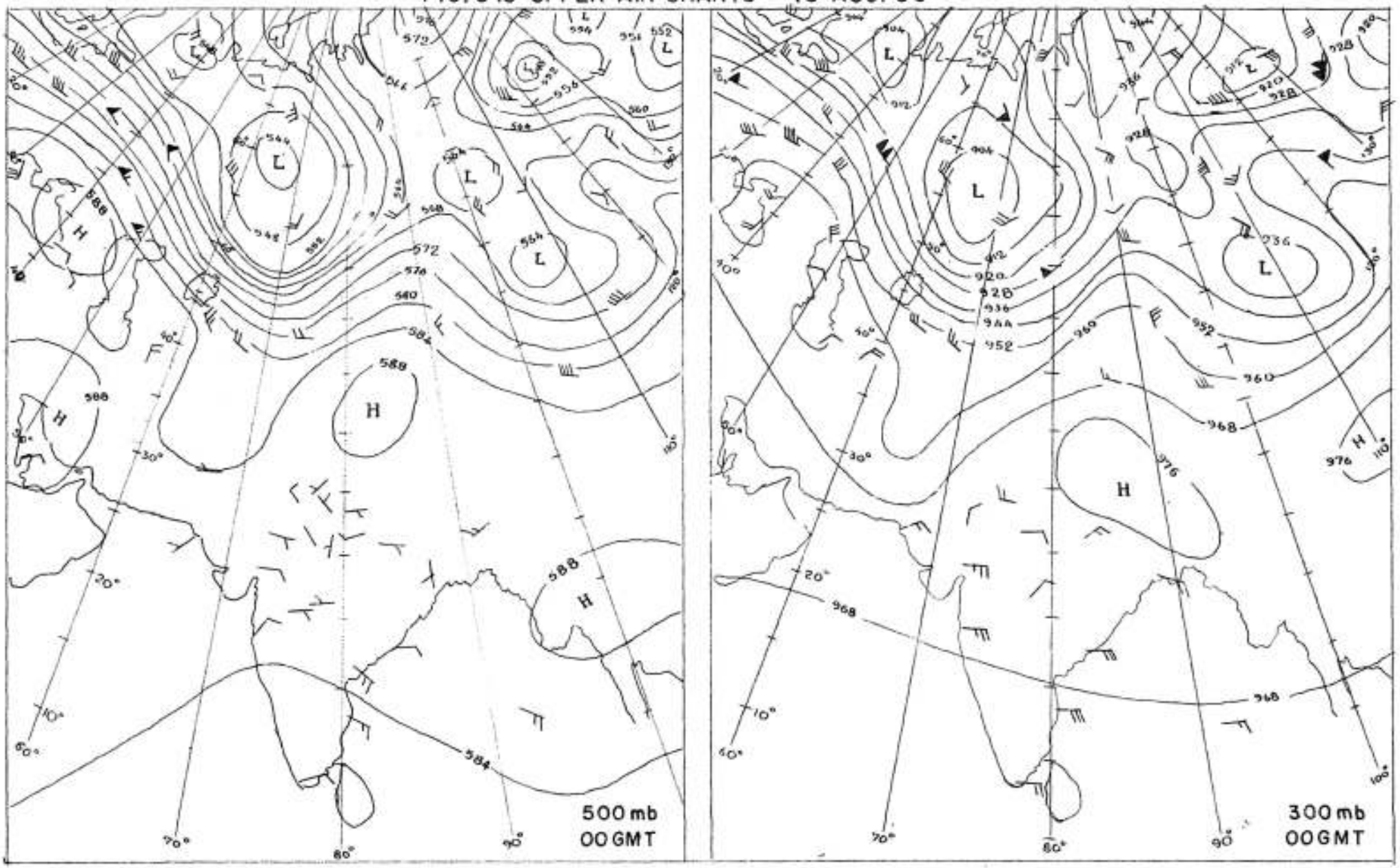
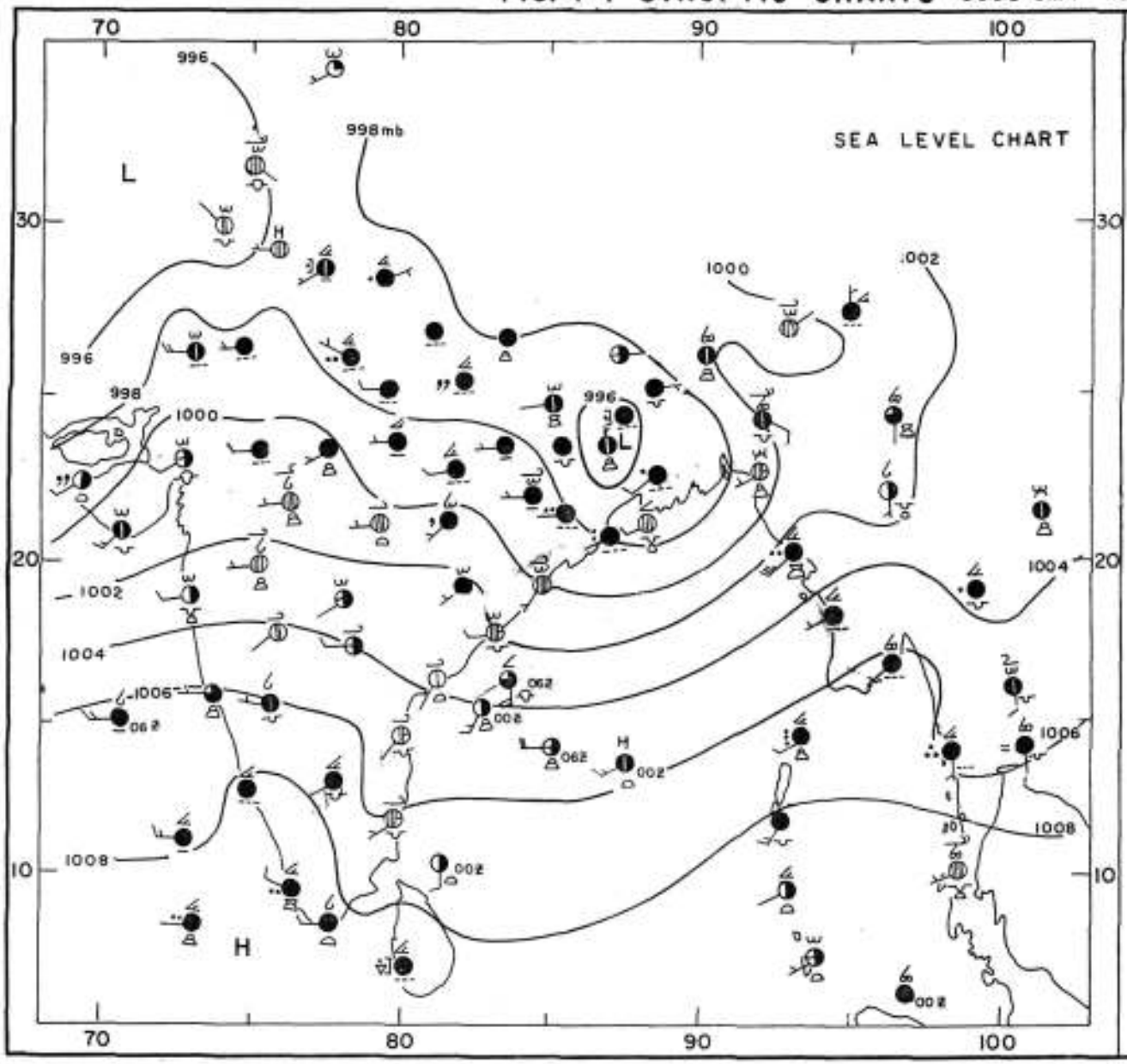


FIG. 7·1 SYNOPTIC CHARTS 0300 GMT 5 AUG. 67



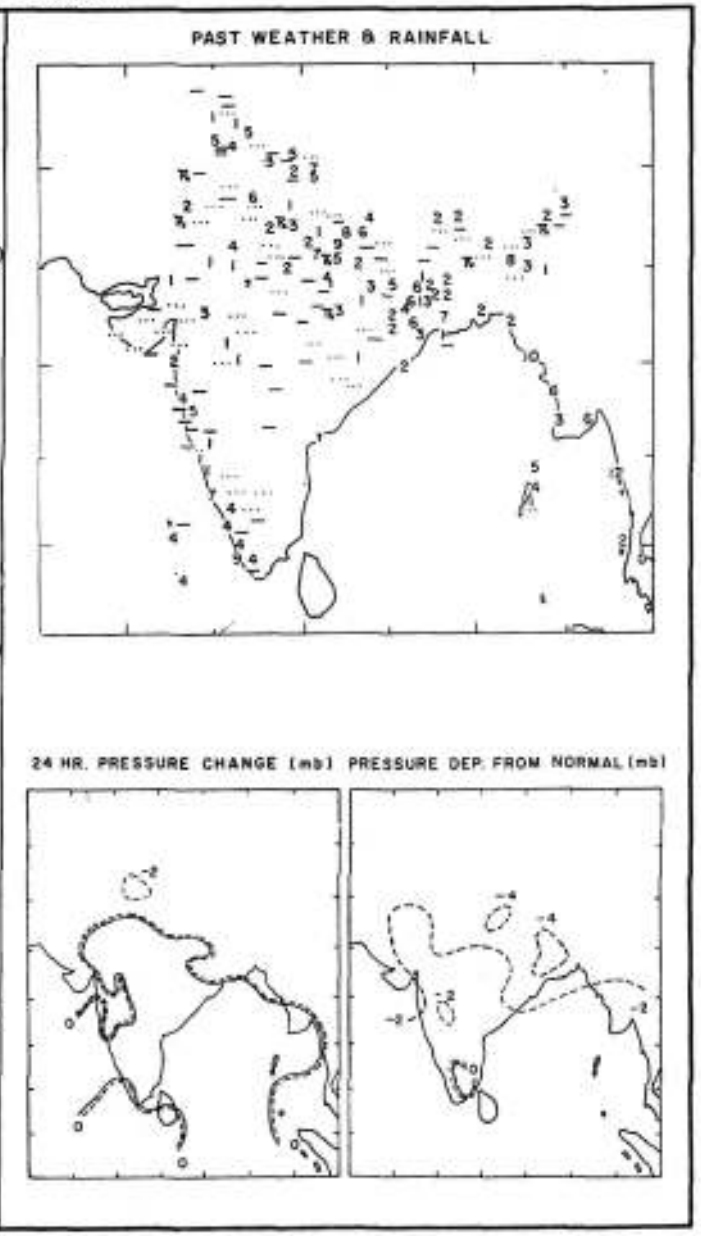
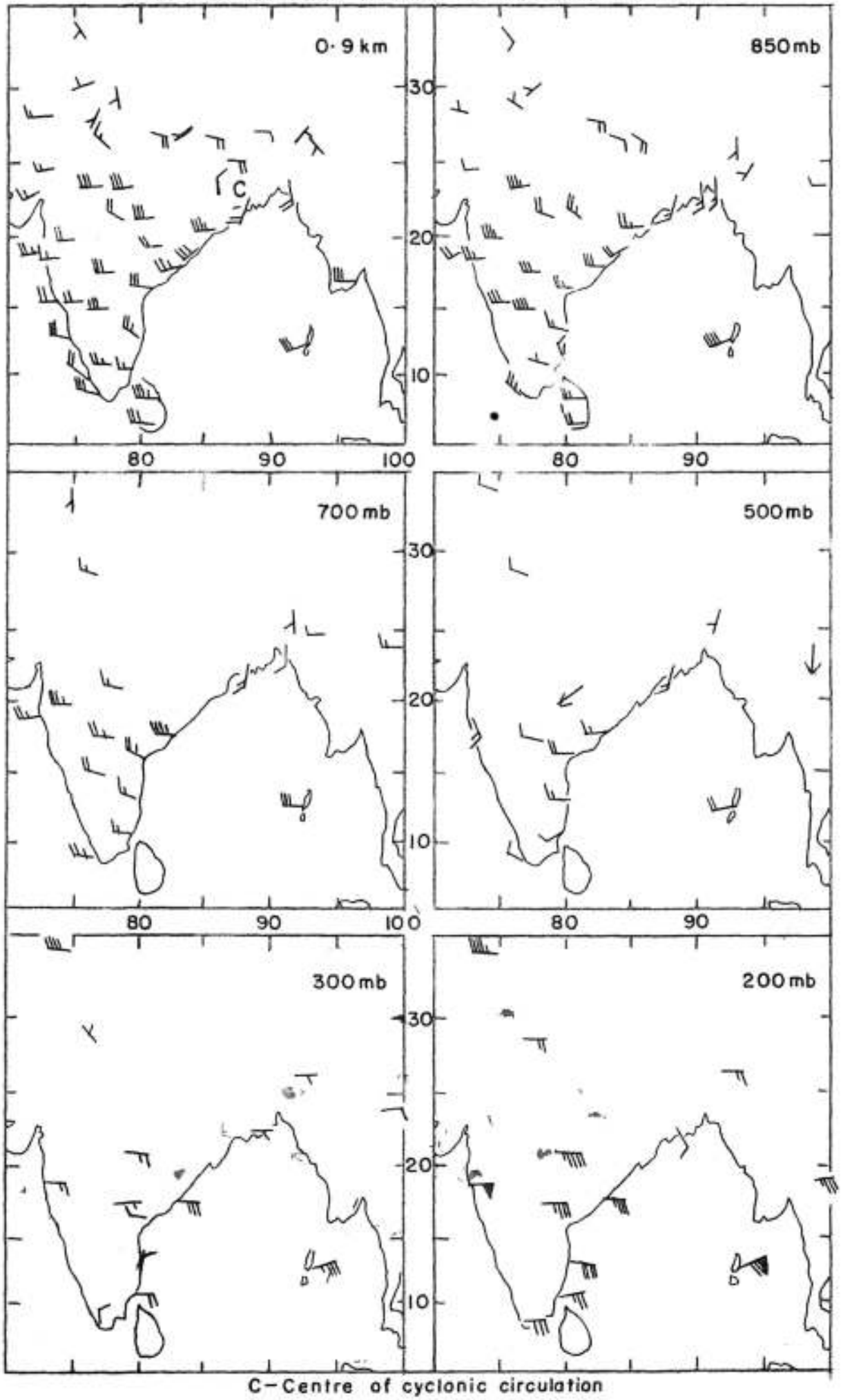


FIG. 7·2 UPPER WINDS 5 AUG. 67 00 GMT



C – Centre of cyclonic circulation

FIG. 7·3 SYNOPTIC CHARTS 0300 GMT 6 AUG 67

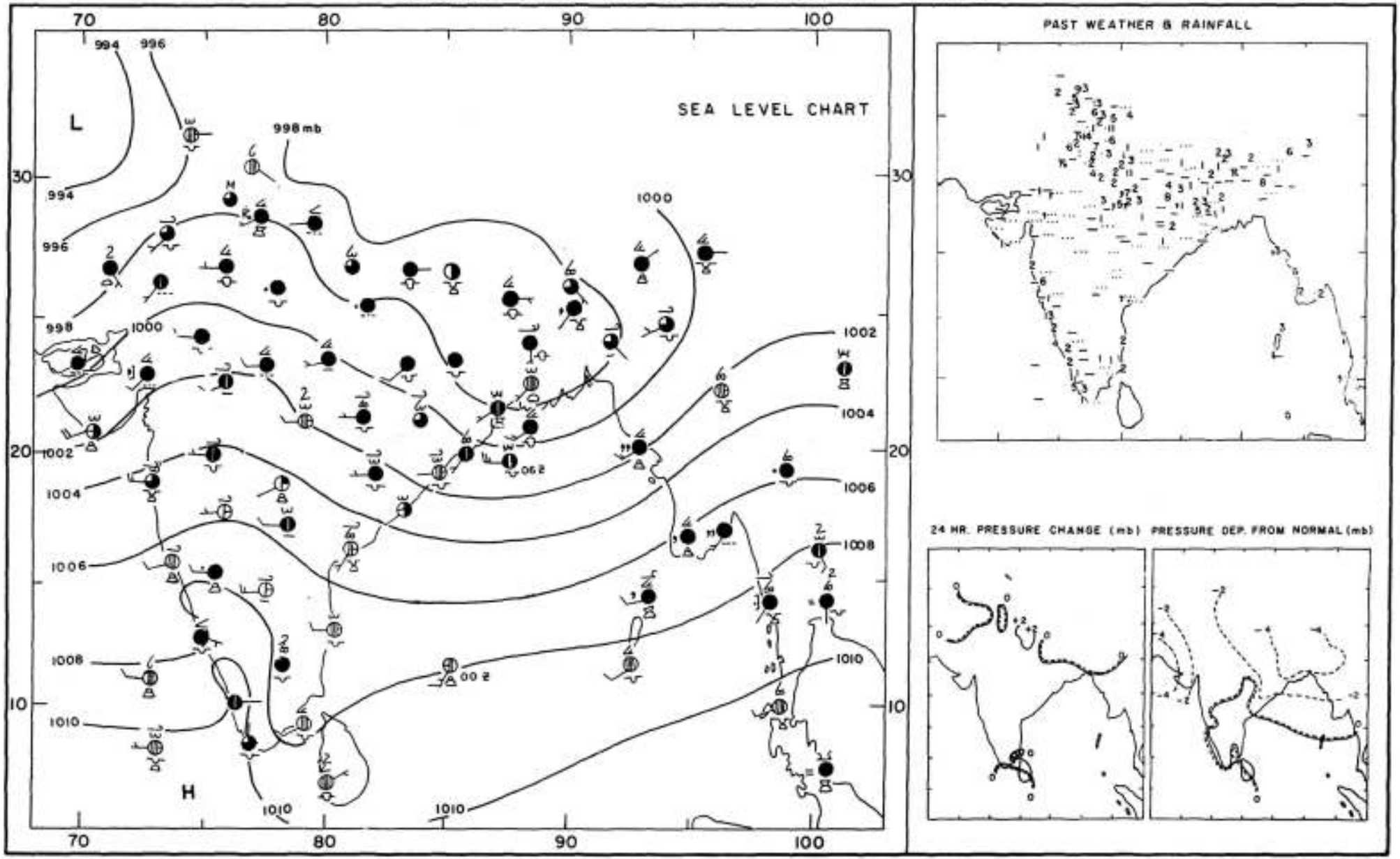


FIG. 7·4 UPPER WINDS 6 AUG. 67 00 GMT

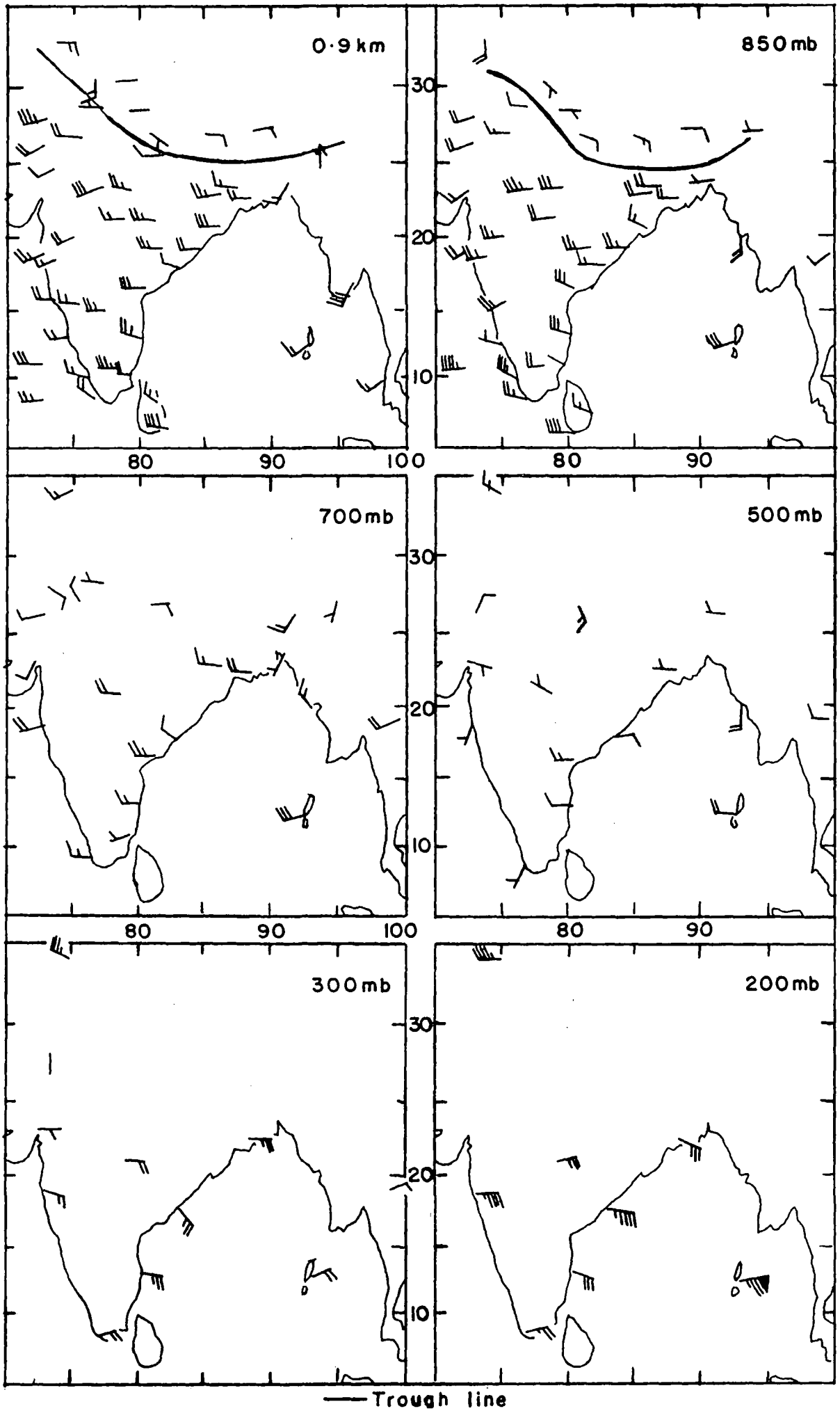


FIG. 7·5 SYNOPTIC CHARTS 0300 GMT 7 AUG. 67

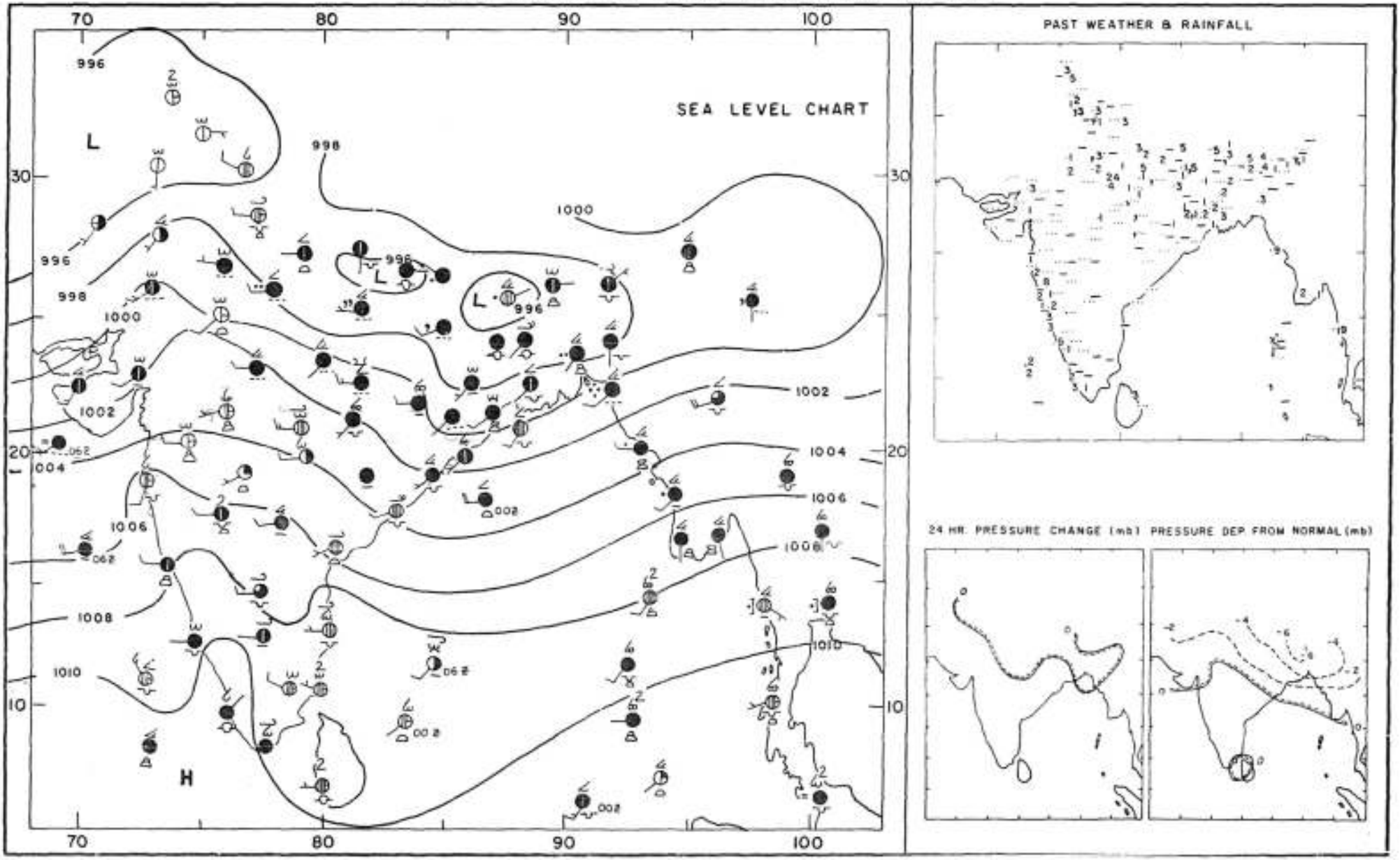


FIG. 7·6 UPPER WINDS 7 AUG. 67 00 GMT