

FMU Rep. III - 3.9
(SEPTEMBER 1973)



INDIA METEOROLOGICAL DEPARTMENT
FORECASTING MANUAL

PART III

DISCUSSION OF TYPICAL SYNOPTIC WEATHER SITUATIONS

3.9 SOUTHWEST MONSOON – TYPICAL SITUATIONS
OVER INTERIOR PENINSULA AND COASTAL ANDHRA PRADESH

BY

N. M. PHILIP, V. SRINIVASAN AND K. RAMAMURTHY.

ISSUED BY

THE DEPUTY DIRECTOR GENERAL OF OBSERVATORIES
(FORECASTING)
POONA - 5

FORECASTING MANUAL REPORTS

- No.I-1 Monthly Mean Sea Level Isobaric Charts - R. Ananthakrishnan, V. Srinivasan and A.R. Ramakrishnan.
- No.I-2 Climate of India - Y.P. Rao and K.S. Ramamurti.
- No.II-1 Methods of Analysis: 1. Map Projections for Weather Charts - K. Krishna.
- No.II-4 Methods of Analysis: 4. Analysis of Wind Field - R.N.Keshavamurthy.
- No.III-1.1 Discussion of Typical Synoptic Weather Situations: Winter - Western Disturbances and their Associated Features - Y.P. Rao and V. Srinivasan.
- No.III-3.1 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Active and Weak Monsoon conditions over Gujarat State - Y.P. Rao, V. Srinivasan, S. Raman and A.R. Ramakrishnan.
- No.III-3.2 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Active and Weak Monsoon conditions over Orissa - Y.P. Rao, V. Srinivasan, A.R. Ramakrishnan and S. Raman.
- No.III-3.3 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over Northwest India - M.S.V. Rao, V. Srinivasan and S. Raman.
- No.III-3.4 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over Madhya Pradesh and Vidarbha - V. Srinivasan, S. Raman and S. Mukherji.
- No.III-3.5 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over Uttar Pradesh and Bihar - V. Srinivasan, S. Raman and S. Mukherji.
- No.III-3.6 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over West Bengal and Assam and adjacent States - V. Srinivasan, S. Raman and S. Mukherji.
- No.III-3.7 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over Konkan and Coastal Mysore - V. Srinivasan, S. Raman, S. Mukherji and K. Ramamurthy.
- No.III-3.8 Discussion of Typical Synoptic Weather Situations: Southwest Monsoon: Typical Situations over Kerala and Arabian Sea Islands - V. Srinivasan, S. Mukherji and K. Ramamurthy.

(Contd.on back cover page)

FORECASTING MANUAL

Part III - Discussion of Typical Synoptic Situations

3.9 Southwest Monsoon - Typical Situations over
Interior Peninsula and Coastal Andhra Pradesh

by

N.M. Philip, V. Srinivasan and K. Ramamurthy

Contents

1. Introduction
2. Southwest Monsoon over Interior Peninsula and Coastal Andhra Pradesh - General Discussion.
3. Survey of synoptic situations affecting Interior Peninsula and Coastal Andhra Pradesh.
4. Weak Monsoon.
5. Deep depression moving from Northwest Bay of Bengal to south Rajasthan across south Madhya Pradesh - 25 to 30 July 1967.
6. Low pressure area moving from northwest angle of Bay to Rajasthan - 16 to 20 July 1968.
7. Low Pressure area over West Central Bay moving inland in a northwesterly direction - 23 to 27 August, 1971.
8. Axis of Monsoon Trough far south of the mean seasonal position - 18 to 22 July 1967.
9. East-west oriented trough line across the Peninsula - 21 to 26 September, 1967.
10. North-south trough - 15 to 17 July, 1967.
11. Weak Monsoon - Typical situations.

APPENDIX

REFERENCES AND SELECTED BIBLIOGRAPHY

DIAGRAMS

1. Introduction

This report deals with the typical synoptic situations associated with strong and weak monsoon conditions over Interior Maharashtra (excluding Vidarbha) Andhra Pradesh and Interior Mysore during the Southwest Monsoon season. This area comprises of the seven meteorological sub-divisions* - Madhya Maharashtra, Marathwada, North Interior Mysore, South Interior Mysore, Rayalaseema, Telangana and Coastal Andhra Pradesh. After reviewing the general meteorological conditions over these sub-divisions, a survey is made, of the synoptic situations which affect the weather in these areas during the season. A detailed discussion of ~~eight~~^{selected} typical synoptic situations leading to strong and weak monsoon conditions over these sub-divisions has also been included in the latter part of the report.

2. Southwest Monsoon over Interior Peninsula and Coastal Andhra Pradesh

2.1 General features:

The southwest monsoon normally advances into South Interior Mysore by the beginning of June. Advancing gradually northwards, it covers the entire Peninsula during the second week of June. However, large year-to-year variations occur in the dates of onset. An examination of the actual dates of onset of monsoon over Coastal Andhra Pradesh and the various sub-divisions of Interior Peninsula, during the past two decades (1953-1972), brings out the following points:-

- i) On nearly 50% of the occasions, the onset of the monsoon into Interior Mysore was during the first or second week of June, while over the rest of the sub-divisions, it was during the second or third week of June.
- ii) On nearly 80% of the occasions, the onset took place into Interior Mysore and Rayalaseema before the middle of June; on an equal percentage of occasions, the monsoon had advanced into the other sub-divisions further north

* The meteorological sub-divisions of Madhya Maharashtra, Marathwada, North Interior Mysore, South Interior Mysore, Rayalaseema and Telangana, whenever they are referred to as a group, will be called in this report as 'Interior Peninsula' for the sake of brevity of language.

by 18th June.

- iii) The monsoon may set in over these sub-divisions as early as the fourth week of May or as late as the last week of June.
- iv) On nearly 70-80% of the occasions, the monsoon covers the entire Peninsula within 2 to 5 days of its advance into South Interior Mysore. There has been one instance (1971) during the last 20 years when the monsoon advanced into all these sub-divisions on the same day (29 May). A time lag of as much as 15 days has also occurred between the monsoon advancing into South Interior Mysore and Marathwada.

2.1.2 The advance of the southwest monsoon along the west coast of Peninsula is judged mainly on the basis of rainfall and the lower tropospheric flow pattern. However, when we consider the Peninsula to the east of the Ghats, the advance of monsoon may not always be uniquely defined by an increase in rainfall. The northern limit of the monsoon over the Interior Peninsula and Coastal Andhra Pradesh, is usually identified by the northward extent of the strong lower tropospheric westerlies, changes in cloudiness, thunderstorm activity and, to a certain extent, by the fall in day temperatures; the northern limit of the monsoon in Interior Peninsula and Coastal Andhra Pradesh need not always be associated with increased rainfall activity, unlike in the case of west coast or the other parts of the country.

2.1.3 The withdrawal of the monsoon usually takes place from the northern parts of the Peninsula by the first week of October. As mentioned in Para 2.3 of FMU Report No. IV-18.4 on 'Northeast Monsoon', there is at present no well-defined criteria laid down for the withdrawal of the southwest monsoon from south Peninsula. The southern parts of Coastal Andhra Pradesh, South Interior Mysore and Rayalaseema continue to get rainfall during October and November also, and hence a withdrawal of southwest monsoon from these areas is not usually mentioned.

2.2 Rainfall

2.2.1 The mean monthly, seasonal and annual rainfall and the number of rainy days in Madhya Maharashtra, Marathwada, Coastal Andhra Pradesh, Telangana, Rayalaseema, North and South Interior Mysore, are given in Table I. They are also given in Fig. 2.1.

TABLE - I

Mean monthly rainfall (cm) and number of rainy days*

	Jun.	Jul.	Aug.	Sep.	Season's Total**	Annual
1. <u>Madhya Maharashtra</u>						
Rainfall (cm)	15	28	18	16	77 (84%)	92
Rainfall as % of season's Total	19	36	23	22		
No. of rainy days	8	13	10	9	40 (79%)	49
2. <u>Marathwada</u>						
Rainfall (cm)	14	17	14	20	65 (84%)	77
Rainfall as % of season's Total	22	26	22	30		
No. of rainy days	8	11	9	9	37 (81%)	45
3. <u>Coastal Andhra Pradesh</u>						
Rainfall (cm)	10	15	15	17	57 (57%)	101
Rainfall as % of season's Total	18	26	26	30		
No. of rainy days	6	10	9	9	34 (63%)	53
4. <u>Telangana</u>						
Rainfall (cm)	13	24	19	19	75 (81%)	93
Rainfall as % of season's Total	18	32	25	25		
No. of rainy days	8	14	12 11	10	43 (79%)	54
5. <u>Rayalaseema</u>						
Rainfall (cm)	6	8	10	13	37 (54%)	68
Rainfall as % of season's Total	16	22	27	35		
No. of rainy days	4	6	6	7	23 (57%)	41
6. <u>North Interior Mysore</u>						
Rainfall (cm)	9	13	10	13	45 (67%)	67
Rainfall as % of season's Total	20	29	22	29		
No. of rainy days	7	10	8	8	33 (68%)	47
7. <u>South Interior Mysore</u>						
Rainfall (cm)	18	31	21	14	84 (68%)	124
Rainfall as % of season's Total	21	37	25	15 17		
No. of rainy days	9	13	11	9	42 (63%)	67

* From Memoirs of the India Meteorological Department Vol. XXXI Part III.

** Season's Total as percentage of annual rainfall indicated within brackets.

2.2.2 Southwest Monsoon season is the wettest period of the year in Madhya Maharashtra, Marathwada and Telangana and to some extent in Interior Mysore. About 80% of the annual rainfall occurs in this season in the first three sub-divisions, about 65-70% in Interior Mysore and only about 55% in Coastal Andhra Pradesh and Rayalaseema. Among the seven sub-divisions, South Interior Mysore is the rainiest while Rayalaseema is the least rainy during the Southwest Monsoon season. Northeast Monsoon rainfall also contributes nearly 30-35% of the annual total in Coastal Andhra Pradesh and Rayalaseema and about 20% in Interior Mysore, so that in these sub-divisions, the rainfall in both the seasons is significant.

2.2.3 In all the seven sub-divisions, rainfall increases from May to June as the monsoon advances over the Peninsula. The increase is very well-marked in the areas in the north - viz. Madhya Maharashtra, Marathwada and Telangana, while in the divisions further south, it is less pronounced. The rainfall further increases in July, the increase being considerable in the sub-divisions such as Madhya Maharashtra and Telangana. From July to August there is a general decrease in rainfall all over the area except in Rayalaseema and the eastern portions of South Interior Mysore. In September, there is again an increase over most areas. When we examine the rainfall figures of individual stations in north Madhya Maharashtra, Marathwada, Telangana and north Coastal Andhra Pradesh, we notice two maxima in rainfall - one in the earlier half of the monsoon and the other towards the end of the monsoon (or in October in the case of north Coastal Andhra Pradesh). In the case of Rayalaseema and the eastern parts of Interior Mysore, there is only one maximum which is noticed in September. The increase in rainfall in September/October over these sub-divisions i.e. the second maximum is due to depressions/low pressure areas from the Bay moving westwards across north or central Peninsula and the location of the east-west oriented trough associated with the retreating monsoon over these areas.

2.2.4 Over Madhya Maharashtra and Interior Mysore which lie on the lee side of the Western Ghats, rainfall distribution is very much influenced by the Ghats. The isohyets run in a north-south direction over these sub-divisions, nearly parallel to the Ghats. The western districts of these sub-divisions get considerably more rainfall and rainfall falls off rapidly as we go eastwards. The area stretching from southeast Madhya Maharashtra to Rayalaseema and southeast Interior Mysore, is one of the driest areas in the country during the southwest monsoon period (particularly in the first three months June to August). In contrast, north Madhya Maharashtra, Marathwada and Telangana get more rainfall since they are nearer to the depression track, inspite of their being situated to the lee side of the Ghats.

2.2.5 The co-efficient of variation of rainfall for the season as a whole is of the order of 30% to 40% over Interior Peninsula and Coastal Andhra Pradesh. The relatively dry belt extending from southeast Madhya Maharashtra to Rayalaseema and southeast Interior Mysore (referred to in the previous para) has the maximum co-efficient of variation. In individual months, the coefficients are more and in the dry belt they reach 100% in the months of July and August (i.e.) in these areas, a place may go dry even for a whole month.

2.3 Heavy Rainfall

2.3.1 During the height of the monsoon (i.e. in the July and August), the northern divisions of Madhya Maharashtra, Marathwada and Telangana and north Coastal Andhra Pradesh may get heavy to very heavy rain in association with the movement of low pressure areas and depressions when these sub-divisions lie in the southwest sector of the disturbance. However, such occasions may be only few in number particularly in North Madhya Maharashtra and Marathwada. The other synoptic systems listed in para 3.1, though they may produce increased monsoon activity, do not normally cause heavy or very heavy rainfall. The western districts of Madhya Maharashtra and Interior Mysore, adjoining the Ghats also have heavy rains when the monsoon strengthens along the west coast. Other areas of

Interior Peninsula and Coastal Andhra Pradesh do not usually get any heavy falls. However, towards the end of the monsoon season, all the districts of Interior Peninsula and Coastal Andhra Pradesh are liable to heavy rains, in association with the movement of the systems across the north or central Peninsula. Heavy falls may also occur in Interior Peninsula, particularly the south sub-divisions during 'break' monsoon conditions when low pressure systems move across south or central Peninsula, though such falls may only be isolated.

2.3.2 The record rainfall at the various observatory stations, monthwise, are given in the departmental publication 'India Weather Review - October-December, 1963'. The heaviest falls in Interior Peninsula and Coastal Andhra Pradesh, during this season have been of the order of 20 to 30 cms in the northern and eastern parts and 10 to 15 cms in the other parts. The falls are usually heavier in July and September than in the other two months.

2.4 Rainfall over Poona and Hyderabad

2.4.1 An analysis of the daily rainfall at Poona and Hyderabad during the monsoon season (June-September) for the period 1901-70, has been made, in respect of the distribution of daily rainfall as well as the length of the spells of rainfall. The results are given in the following Tables.

8
TABLE II

(a) i) Frequency distribution of daily rainfall amounts (in cm) at Poona during the months June to September (Period 1901-1970)

Month	No. of rainy* days	Rainfall in Cm.				
		0.25-2.49	2.5-4.99	5.0-7.49	7.5-12.49	≥ 12.5
June	487	404 (84)	64 (13)	15 (3)	3	1
July	942	825 (87)	87 (9)	18 (2)	11 (2)	1
August	596	541 (91)	46 (8)	7 (1)	2	0
September	521	420 (81)	72 (14)	21 (4)	6 (1)	2
Season's Total	2546	2190 (86)	269 (10)	61 (3)	22 (1)	4

(Figures within brackets indicate percentages)

* A rainy day is defined as one with a rainfall of 0.25 cm or more.

...

ii) Frequency of length of continuous wet spells* at Poona.
Period of data 1901 - 1970

Month	Length of Wet Spells (days)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
June	148	47	23	13	8	2	3	3	1	1	5	-	1	-
July	138	62	39	31	18	12	16	5	1	5	2	1	-	2
August	181	54	24	16	10	6	2	3	-	1	1	-	-	-
September	144	50	27	21	10	3	2	-	3	-	1	-	-	-

* Days of rainfall of 0.25 cm or more

...Contd.

(b) i) Frequency distribution of daily rainfall amounts (in cm) at Begumpet during the months June to September (Period 1901-1970)

Month	No. of rainy* days	rainfall in cm.				
		0.25-2.49	2.5-4.99	5.0-7.49	7.5-12.49	≥ 12.5
June	481	400 (83)	64 (13)	13 (3)	4 (1)	0
July	777	649 (83)	106 (14)	15 (2)	7 (1)	0
August	666	566 (85)	74 (11)	21 (3)	4 (1)	1
September	678	524 (77)	114 (17)	26 (4)	12 (2)	2
Season's Total	2602	2139 (82)	358 (14)	75 (3)	27 (1)	3

(Figures within brackets indicate percentages)

* A rainy day is defined as one with a rainfall of 0.25 cm or more.

....

ii) Frequency of length of continuous wet spells* at Begumpet (Period 1901 - 70)

Month	Length of wet spells (days)											
	1	2	3	4	5	6	7	8	9	11	12	13
June	199	65	37	6	5	1	-	-	-	-	-	-
July	217	77	40	29	17	7	3	1	1	-	2	-
August	189	81	41	17	14	7	1	-	1	-	-	-
September	176	79	29	26	6	6	2	1	1	-	-	-

* Days of rainfall of 0.25 cm or more

2.4.2 The analysis brings out the following results:-

1. Poona:

- i) The number of rainy days is a maximum in July; this is the month of peak monsoon activity in Poona.
- ii) On 80% to 90% of the occasions, rainfall has been less than 2.5 cms. Heavy rainfall (≥ 7.5 cm) is rare at Poona; it has occurred only on 26 occasions in the past 70 years (i.e. not even one per monsoon season) and they were mainly in July and September.

- iii) Frequency of occurrence of rainfall of 5 cm or more is highest in July and September; then comes June. August has the least number of occasions. August is a month of minimum monsoon activity. The decrease in monsoon activity in August and again its increase in September are well brought out by these tables. One of the reasons for the decrease of rainfall in August is the greater frequency of occasions of 'breaks' in this month, and the subsequent increase in September is due to the trough system shifting south and low pressure areas and depressions moving along more southerly latitudes as will be discussed later in Sec. 3.
- iv) The heaviest amounts in the different months at Poona have been about 13 cms.
- v) Rain spells are slightly longer in July than in the other months. 85% of the spells are of duration 3 days or less in June, August and September, while in July only about 70% of the occasions are of the duration 3 days or less. The longest spell has been 14 days in July. There have been 2 years in June when there was no rainy day (rainfall exceeding 2.5 mm) in Poona.
- vi) It has been found that over 50% of the occasions of rainfall of 2.5 cm or more have been associated with a depression or a low pressure area from the Bay.

2. Hyderabad:

- i) The number of rainy days is a maximum in July.
- ii) On 85% of the occasions, rainfall does not exceed 2.5 cm in June, July and August. In September, falls exceeding 2.5 cm occur on a little more number of occasions; in this month the number of occasions of rainfall less than 2.5 cm is only on 77%. Like Poona, heavy rainfall (≥ 7.5 cm) is rare at Hyderabad also. In all, during the past 70 years, heavy rainfall has occurred only on 30 occasions, of which nearly half the number of occasions has been in September.

- iii) The frequency of higher amounts being slightly more in September is consistent with the changes in the synoptic pattern that occur in September as discussed in subpara (iii) above, under "Poona".
- iv) The heaviest falls have been about 19 cms.
- v) 85% to 95% of the spells do not exceed 3 days. Longer spells (5 days or more) are most frequent in July; next comes August. The longest spell during the 70 years has been 11 days in July 1903 and in July 1967.

2.5 Thunderstorms

2.5.1 The eastern portions of the areas which we are discussing in this report get more thunderstorms than the western portions. Taking the southwest monsoon season (June to September) as a whole, Madhya Maharashtra and Interior Mysore get about 10 to 15 days of thunder, while in Coastal Andhra Pradesh, it is 30 to 40 days. Thunderstorms are common at the time of onset and advance of the monsoon over these areas. But the activity considerably decreases after the monsoon sets in. It is less than 2 days in a month in Madhya Maharashtra and Interior Mysore in July and August. However, the activity increases once again in September (at the time of the withdrawal of the monsoon from the northern parts of the country), when the east-west oriented trough line* runs across the north Peninsula.

2.6 Squalls

2.6.1 Squalls associated with thunderstorms occur over Coastal Andhra Pradesh and Interior Peninsula in June at the time of advance of the monsoon and to a less extent in ~~September~~ September when the east-west oriented trough passes across the Peninsula. During the other months, squalls are mostly of the rainsquall type and they occur when the monsoon current is strong over the Peninsula and the lower tropospheric winds are strong. On such days, the general wind may also be strong and gusty during most of the day. The squalls are generally from some

* See Sec.3.

westerly direction. Some workers have studied the squalls at individual stations; a summary of their results in respect of Poona, Bangalore and Begumpet are given below:

Poona:

In June and September squalls are likely ^{to} be associated with thunderstorms. There are squalls in the height of the monsoon also, particularly in July when the monsoon activity is at its height. In 20 years (1930-1949) there have been 9 occasions of squalls in July. Such monsoon squalls are generally of speed 65-80 kmph, although on rare occasions they have reached about 95 kmph. In these two months (July and August) the direction of the squall is mainly from southwest to west. In addition, when the Arabian Sea branch of the monsoon is strong along Konkan, prolonged spells of strong winds occur in Poona, and winds remain strong for a major part of the day, the gust speed frequently exceeding 50 kmph. In the beginning of the monsoon season, when the monsoon has not completely established over the country, western disturbances may move across north-west India. In association with the western disturbance, the heat low over Rajasthan and Pakistan may intensify and increase the pressure gradient to the south, over north Arabian Sea, south Rajasthan, Gujarat State and the adjoining areas. On some rare occasions, the steep pressure gradient may extend further south as far as north Peninsula, when strong gusty surface winds may prevail over Poona (for a recent example, refer to charts of 15-16 June 1973).

Bangalore:

Although the maximum number of squalls occur in May, they still continue in June, July and August when the average number of days of squall is 2-3 per month. By September, they decrease appreciably. In July and August, these squalls are in the nature of rainsqualls, though during many of them large Cu or Cb have been reported. About 65% of the squalls in June, 90% ^{of} those in July and 55% of those in September are from the direction southwest, west or northwest. They are

generally of speed 30–40 mph, and a maximum speed of about 60 mph had been recorded in June.

Begumpet:

Although May is the month of Maximum number of days with squall, they continue in June and July also; thereafter they progressively decrease in number. In June and July there are about 2–3 days of squalls per month. The squalls during the monsoon period are generally from a direction southwest to northwest and the speeds reach upto 80 kmph. Very rarely they go upto 110–115 kmph.

2.6 Upper winds

2.6.1 The upper winds over Bombay, Goa, Bangalore, Begumpet and Visakhapatnam give a fair representation of the wind field over the whole of the north and central Peninsula.

2.6.2 The main feature of the wind distribution over the Peninsula is the lower tropospheric monsoon westerlies overlain by the upper tropospheric easterlies. Westerlies prevail in the lower and middle troposphere upto about 500 mb. In the mean, the westerlies are about 20–25 kt. strong (in the mid-monsoon months) in the lower troposphere, decreasing in speed with height. With the strengthening of the Arabian Sea monsoon current or in association with the formation of a depression or a low over the Bay of Bengal, and its movement across the country, the westerlies in the lower troposphere become strong reaching 40–50 kts. When the monsoon trough is well-marked, even without a low or a depression, such a strengthening of the winds has been noticed, particularly when the trough is to the south of the normal position. These strong westerlies have a core at a height of 850 mb (1.5 km) with a speed of 40–60 kts. Quite often, this low level jet persists for a few days, with certain amount of north-south movement. The core of the jet is found usually across the central and southern parts of the Peninsula and it rarely shifts to the north Peninsula.

2.6.3 The layer between 500 mb and 300 mb is a zone of transition from westerlies to easterlies and light winds prevail in this layer. At about 400 mb, the easterlies appear and they gradually increase with height and reach a maximum of 60-70 kts (in the mean) at about 150-100 mb over Interior Peninsula and Coastal Andhra Pradesh. The surface of the maximum wind has a slope; it is between 14 and 15 kms over the south Peninsula, and slightly higher (about 16 km) in north Peninsula.

2.6.4 In the mean, the core of the easterly jet stream lies near about the latitude of Trivandrum at a height of about 14.5 to 15.0 km with a core speed of 80-85 kts. However, on daily charts, the upper easterly jet shows periodic strengthening and weakening as well as north-south movement across the Peninsula. The maximum occasionally reaches a strength of 100-120 kts and on very rare occasions, upto 140-150 kts. Sometimes the easterly jet has two maxima, one over the south Peninsula and the other at a slightly higher latitude (near Goa). It has been noticed (vide discussions of typical synoptic situations in Secs. 6,7 and 8) that the easterly maximum shifts to north Peninsula during occasions of strong monsoon over Interior Peninsula and Coastal Andhra Pradesh.

2.6.5 It is noticed that during the height of the monsoon season (July and August) the maximum winds over Interior Peninsula and Coastal Andhra Pradesh are generally in the range of 60-100 kts. Occasions exceeding 100 kts have been very few in number in the north Peninsula (Begumpet and Vishakapatnam); they are relatively more in south Peninsula (Bangalore). These instances are also mostly in July. The highest wind speeds reached are about 130-140 kt in July. An analysis of the maximum wind data of Begumpet, Vishakhapatnam and Bangalore is given in Table III.

TABLE III

Percentage frequency of occasions of maximum upper winds
in different speed ranges

Month	Station	Period of data	30-39 mps	40-49 mps	50-59 mps	60 mps	Highest speed reached (mps)	Total No. of Observations
July	Vishakapatnam	67-71	41	51	6	2	73	195
	Begumpet	67-71	39	50	10	1	69	262
	Bangalore	68-72	21	46	31	2	64	219
August	Vishakhapatnam	67-71	65	34	1	0	55	205
	Begumpet	67-71	56	41	3	0	59	229
	Bangalore	68-72	40	47	13	0	58	213

The table shows that occasions of stronger maximum winds are more in July than in August. In the case of Begumpet and Vishakhapatnam, in particular, this feature is more pronounced.

2.7 Upper air temperatures

2.7.1 The mean tephigrams of Begumpet and Vishakhapatnam for active, normal and weak monsoon days in Telangana and north Coastal Andhra Pradesh respectively are given in Figs. 2.7.1. The main features brought out by the tephigrams are:

- i) There is no significant change in the dry bulb temperatures whatever may be the monsoon activity in the sub-divisions. The lapse rate is slightly more than the moist adiabatic lapse rate over the major portion of the atmosphere. The main difference lies only in the moisture content above 700-800 mb level, a feature which has been pointed out in the case of other sub-divisions in the earlier FMU Reports on Monsoon. (FMU Report Nos. III-3.1, III-3.3, III-3.4, III-3.5, III-3.6, III-3.7 and III-3.8).
- ii) During active monsoon days, the air is fairly moist upto the mid-tropospheric level; (at very high levels (300 mb and above) the number of observations of dew point is rather small to reach a definite conclusion).
- iii) The moisture content also remains very nearly the same upto about

700–800 mb level, irrespective of the monsoon activity and above this level, moisture content becomes less and less as the monsoon activity decreases. In the case of Begumpet, during dry days, the moisture is depleted even in the lower troposphere.

2.7.2 Typical individual day's tephigrams of Begumpet and Vishakhapatnam on days of active and weak monsoon in Telangana and North Coastal Andhra Pradesh respectively are given in Fig. 2.7.2.

2.8 Monsoon activity

2.8.1 Table IV gives the percentage frequency of occurrence of vigorous*, strong, normal and weak monsoon days in the seven sub-divisions of Interior Peninsula and Coastal Andhra Pradesh during the southwest monsoon season.

* For a definition of Vigorous, Strong, Normal and Weak Monsoon refer to Appendix I.

TABLE - IV

Percentage frequency of occurrence of Vigorous*/Strong, Normal, Weak and Dry days
(Based on data June to September 1967-71)

Sub-division	June				July				August				September				June to September								
	V	S	N	D	V	S	N	D	V	S	N	D	V	S	N	D	V	S	N	D					
Madhya Maharashtra	1	5	42	34	18	3	4	39	48	6	1	4	45	46	4	2	8	35	35	20	2	5	40	40	12
Marathwada	0	4	29	15	52	0	8	29	29	34	1	7	35	24	33	1	7	27	15	50	0	7	30	21	42
Coastal Andhra Pradesh	0	3	42	34	21	1	6	39	43	11	1	4	39	46	10	1	7	34	41	17	1	5	38	41	15
Telangana	0	3	44	33	20	3	9	34	43	11	2	5	33	53	7	3	14	28	32	23	2	8	35	40	15
Rayalaseema	0	1	31	22	46	1	1	34	29	35	1	1	30	30	38	1	3	33	21	42	1	2	32	25	40
North Interior Mysore	0	1	50	35	14	0	5	49	43	3	3	4	37	46	10	0	7	39	33	21	1	4	44	39	12
South Interior Mysore	0	2	44	31	23	0	2	50	42	6	1	1	43	36	19	1	6	33	31	29	1	3	42	35	19

* V -- Vigorous; S -- Strong; N -- Normal, W -- Weak monsoon with some rain; D -- Weak monsoon without any rain.

2.8.2 The important features that are brought out by the Table are:-

- i) Weak monsoon condition is the common feature of weather in all these sub-divisions, occurring on 50%-60% of the occasions. In Rayalaseema it is the highest (65%). It is also interesting to note that in Marathwada and Rayalaseema nearly 40% of the days is dry. Taking into account individual months also, dry days are prominent in Marathwada and Rayalaseema compared to other sub-divisions. This feature of more dry weather days over Marathwada than in the contiguous sub-divisions of Madhya Maharashtra or Telangana is an interesting local peculiarity worth noting by the forecasters.
- ii) Next in importance, is the normal monsoon conditions, occurring on 30% to 40% of the occasions.
- iii) Strong to vigorous monsoon conditions occur only on about 5% to 10% of the occasions (i.e.) hardly on 1-2 days in each month; vigorous monsoon is almost rare. In this connection, it is interesting to compare the monsoon activity to the west of the Ghats, in Konkan and Coastal Mysore (vide Table III of FMU Rep. No. III-3.7) where active to vigorous monsoon conditions occur on nearly 20%-25% of the occasions, in the first half of the season.
- iv) Taking the months individually, in the northern four sub-divisions (viz. Madhya Maharashtra, Marathwada, Telangana and Coastal Andhra Pradesh) strong to vigorous monsoon occurs on a little more number of occasions in July and September than in the other two months. It is least in June. In the three southern sub-divisions (Rayalaseema and Interior Mysore), strong to vigorous monsoon is of some significance only towards the end of the season. Taking into account all the sub-divisions, September has the maximum frequency of active monsoon days.

3. Survey of Synoptic Situations affecting Interior Peninsula and Coastal Andhra Pradesh

3.1 The synoptic situations associated with a strengthening of the monsoon over Madhya Maharashtra, Marathwada, Telangana, Rayalaseema, North and South

Interior Mysore and Coastal Andhra Pradesh are as follows:-

- i) Monsoon depressions and low pressure areas from the Bay
- ii) Well-marked seasonal monsoon trough in a southerly position
- iii) A cyclonic circulation/low pressure system (700 mb-500 mb) in the Bay of Bengal and another in the Arabian Sea with a trough connecting them running across the Peninsula.
- iv) Upper air cyclonic circulation over the Peninsula.
- v) North-south oriented trough in the monsoon westerlies.

All these systems do not affect all the seven sub-divisions; and some of them are more common in certain sub-divisions than in the others. A statistics of the frequency of occurrence of strong to vigorous monsoon conditions in the seven sub-divisions, in association with the different synoptic situations is given in Table V.

TABLE - V
Frequency distribution of Active/Vigorous monsoon days associated with various synoptic situations
(Based on data June to September 1967-1971)

	Madhya Maharashtra			Marathwada			Coastal Andhra Pradesh			Telangana											
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug									
1. Depression or low	3	5	6	7	21	7	2	7	6	9	24	2	4	4	7	17	1	10	6	14	31
2. Seasonal Monsoon Trough	1				1		2				2		3			3				5	
3. East-west oriented trough over the Peninsula with low/cyclonic circulation over Bay and Arabian Sea	7	3	6	6	16	4	1	2	3	10	10	2	1	1	5	9	4	1	1	6	12
4. Upper Air cyclonic circulation	1	1			2		1	1		2	2	1	1	1		2		2	2	4	8
5. North-south trough			2	2	2	1	2	1	2	3	3	3	1	1		4		1	2		3
6. Others			1	1	1		2	2		2	2	1	1	1		1			1		1
Total No. of occasions	10	10	8	15	43	6	12	13	12	43	43	4	12	8	12	36	5	19	11	25	60

	Rayalaseema			North Interior Mysore			South Interior Mysore					
	Jun	Jul	Aug	Jun	Jul	Aug	Jun	Jul	Aug			
1. Depression or low	1			1	6	7	4	18	1	1	1	2
2. Seasonal Monsoon Trough					1			1				
3. East-west oriented trough over the Peninsula with low/cyclonic circulation over Bay and Arabian Sea	1						2	2		3		3
4. Upper Air cyclonic circulation	1	1	1	3	1	1	2	6	1	1	1	8
5. North-south trough	1	2	2	5		2	2	4				10
6. Others						1	1	1	2	1	2	5
Total No. of occasions	1	3	3	10	2	8	11	32	3	3	3	11
												20

3.2 Depressions and low pressure areas from the Bay of Bengal

3.2.1 Depressions and low pressure areas that form over the north Bay of Bengal during the southwest monsoon season, usually move across the country in a westnorthwesterly direction. Associated with their passage, there is a general strengthening of the monsoon over the country. North Coastal Andhra Pradesh, Telangana, Marathwada and North Madhya Maharashtra which are near the track of the monsoon depressions and lows get active monsoon conditions, particularly when the disturbances move across Orissa and South Madhya Pradesh to southeast Rajasthan. Since heavy rains extend to about 3° - 4° of latitude to the south of the depression track, the northernmost districts of the four sub-divisions of Coastal Andhra Pradesh, Telangana, Marathwada and Madhya Maharashtra may even experience heavy rains. But when the track is more to the north viz. over north Orissa and north Madhya Pradesh, though there may be an increase of rainfall in the area from north Coastal Andhra Pradesh to north Madhya Maharashtra, the monsoon activity in these sub-divisions may not be more than "normal". This increase of rainfall so far to the south of the depression track is likely only in the earlier half of the southwest monsoon season when the rainfall area associated with depressions and lows is more extensive than in the later half. Depressions and low pressure areas which take a northwesterly or northerly track from the Bay, may not affect these sub-divisions.

3.2.2 Towards the end of the monsoon season (i.e. in September), depressions and low pressure areas form over the Bay of Bengal at more southerly latitudes and travel across the north Peninsula, when the whole of Andhra Pradesh, Interior Maharashtra and Mysore States, sometimes, get extensive rainfall with active to vigorous monsoon conditions.

3.2.3 The rainfall area and the rainfall pattern associated with a monsoon depression/low, is dependent upon the position of the low pressure system and the wind field associated with it. When a depression/low is over north Bay of Bengal, north Coastal Andhra Pradesh and adjoining Telangana may have rainfall. Sometimes,

rainfall may extend further westwards even upto Madhya Maharashtra and Marathwada. In some cases, rainfall may be confined to the area from north Coastal Andhra Pradesh to north Madhya Maharashtra, while in a few cases it may extend southwards to north Interior Mysore also. An examination of the daily synoptic charts shows that such variations in rainfall distribution are associated with the variations in the wind patterns. Some of the typical patterns are described below:-

- i) The depression may be over the north Bay of Bengal or Orissa coast and the zone of convergence between northerlies/northeasterlies and westerlies may extend quite a distance to the west of the depressions centre, even as far as north Madhya Maharashtra. The southward slope of the convergence zone with height is only moderate. In such cases, monsoon activity is confined to the area from North Coastal Andhra Pradesh to north Madhya Maharashtra. In these cases the low pressure system over North Bay or Orissa coast is usually well-marked.
- ii) When the low pressure system over North Bay and Orissa coast is somewhat weak, the convergence zone between northerlies/northeasterlies and westerlies, has a large slope, rapidly shifting southwards with height. In such cases, monsoon activity may extend as far south as Interior Mysore; but the rainfall amounts may not be as high as in case(i) above.
- iii) The depression or low pressure area may be at a more southerly latitude than in case(i) (i.e.) in West Central Bay off Coastal Andhra Pradesh, when the zone of convergence discussed in (i) may lie further to the south and affect Rayalaseema and Interior Mysore also. We come across this type of synoptic situation generally towards the end of the season (i.e. September).
- iv) The convergence zone associated with the depression or low over the head Bay may only extend a short distance westwards, in which case the rainfall may be only of a limited extent. There may even be a north-south oriented ridge over the western Peninsula on the surface chart and in the lower troposphere, when rainfall over the western Peninsula is comparatively light.

v) In a few cases, although the depression/low may weaken off on crossing coast and may not be noticeable in the surface or lower troposphere, the associated cyclonic circulation in the mid-tropospheric levels (700-500 mb) may still persist and may be seen moving westwards across the Peninsula and causing weather (see Sec.7 FMU Rep. No. III-3.7 for a case somewhat similar to this type).

3.2.4 Summing up, it may be stated that the areal extent of the rainfall associated with a monsoon depression/low is mainly dependent on the associated wind field. The southward extent of the slope with height of the convergence zone, generally delineates the southern limit of the rainfall area associated with the low pressure systems from the Bay. In all these cases, rainfall may increase as the depression/low approaches the sub-division and continue over the sub-division, until the depression or low moves away to the west or weakens off. Usually each spell of such rain may last for 2 to 4 days. However, if a fresh low forms over the head Bay and a convergence zone/trough line still remains near the sub-divisions, a second spell of rainfall may start without any perceptible lull in monsoon activity.

3.2.5 It may be seen from Table V that 50% of the occasions of strong to vigorous monsoon in Madhya Maharashtra, Marathwada, Coastal Andhra Pradesh, Telangana and North Interior Mysore are associated with a low pressure system from the Bay of Bengal moving in a westerly direction across the central parts of the country or north Peninsula. While the northern districts of Madhya Maharashtra and North Interior Mysore may have rainfall, being close to the zone of convergence, the districts adjoining the ghats (immediately on the lee side) in south Madhya Maharashtra and North Interior Mysore also usually have rainfall (sometimes even heavy) on such occasions, on account of the strong westerlies striking the Ghats, since the lower tropospheric westerlies generally strengthen in association with depressions/lows over the Bay. Rayalaseema and South Interior Mysore are too far to the south to be affected by such systems.

3.3 Seasonal monsoon trough

3.3.1 The mean position of the seasonal monsoon trough in the mid-monsoon season is over the Gangetic Plains. At 0.9 km, its axis passes through New Delhi, Allahabad and Asansol. However, the trough is in the mean position only on 40% of the occasions in the month of July and August. On 25% of the occasions it is to the south of the normal position (i.e.) over Madhya Pradesh and Vidarbha. Occasionally it shifts even further south to north Coastal Andhra Pradesh and north Telangana, when Coastal Andhra Pradesh, Telangana and to some extent Marathwada and the northern districts of Madhya Maharashtra and North Interior Mysore may get active monsoon conditions. But such instances are few and far between as may be seen from Table V. The trough does not persist at such low latitudes for more than 1 or 2 days. There may or may not be any embedded low in the trough. South Interior Mysore and Rayalaseema being far to the south do not get active monsoon in association with the monsoon trough.

3.4 East-west oriented trough across the Peninsula with a low pressure system over Bay of Bengal and Arabian Sea

3.4.1 Next in importance to depressions and low pressure areas is the east-west oriented trough across the Peninsula with two 'lows', one each in the Bay of Bengal and Arabian Sea. This is essentially an upper air feature and is not seen at 700-500 mb levels. Sometimes a cyclonic circulation may also move along the trough across north Peninsula, causing localized increase in rainfall. This type of synoptic situation is more pronounced at the time of advance of the southwest monsoon (June) and towards the end of the monsoon season (September), when the trough across the Peninsula may extend through a deep layer of the atmosphere (lower as well as mid-troposphere) than in the mid-monsoon season, when it is mainly in the mid-troposphere.

3.4.2 In June, on a few occasions, usually at the time of the advance of the monsoon, a low pressure area or an upper air cyclonic circulation may be present only in the Arabian Sea, with an east-west oriented trough extending from the low

eastwards across the western Peninsula. Sometimes, the system in the Arabian Sea may only be a trough of low pressure and not a closed cyclonic circulation (see Sec.6 of FMU Report No. III-3.1, for a case of this type).

3.5 Upper Air Cyclonic Circulation

3.5.1 Upper air cyclonic circulations moving across Coastal Andhra Pradesh and Interior Peninsula, activate the monsoon there. The circulation is better marked in the layer 700-500 mb and is usually noticed

- i) at the time of advance of the monsoon over the area
- ii) during weak monsoon conditions as well as in 'break' conditions over the country when the westerly field over the Peninsula is weak or disorganised and
- iii) towards the end of the monsoon season.

3.5.2 Sometimes a depression or a low from the Bay may weaken off on entering land, but the associated mid-tropospheric circulation may persist and travel westwards (see Sec.6 for a case of this type). While some of the upper air cyclonic circulations may be well-marked and traceable from day-to-day, moving sequentially from east to west, in some other cases there may not be a regular progression or continuity in the movement of these cyclonic circulations. These circulations affect mostly Telangana, Rayalaseema and Interior Mysore. It has been noticed that, in most cases, such upper air circulations are usually embedded in the north-south or east-west oriented troughs.

3.6 North-south oriented Trough in Monsoon Westerlies

3.6.1 North-south oriented troughs form in the lower tropospheric monsoon westerlies particularly during epochs of weak monsoon conditions over the country. The trough may extend, sometimes, from Uttar Pradesh or Bihar to Rayalaseema and Interior Mysore. There may be cyclonic circulations of small extent embedded in the trough. While in a few cases the trough may have a progressive movement from west to east, often it may be either quasi-stationary or show

irregular movement over the Peninsula. The weather associated with such a trough is usually isolated or scattered thundershowers; very rarely they cause active or vigorous monsoon. Only in Rayalaseema the north-south trough activity appears to be significant. In this connection a reference is also invited to the discussions on north-south troughs over the country in Sec.3.8 of FMU Rep.No.III-3.4 (on Madhya Pradesh and Vidarbha) and Sec.6 of FMU Rep. No.III-3.2 (on Orissa).

3.6.2 Now we will discuss these typical synoptic situations, in relation to the activity of the monsoon caused by them in the different meteorological subdivisions.

3.7 Madhya Maharashtra

3.7.1 Depressions and lows that form in the Bay and move westnorthwestwards across the country and the convergence zone associated with them are the most important synoptic systems that cause active to vigorous monsoon conditions in this sub-division. They account for 50% of the occasions. These systems usually affect north Madhya Maharashtra more than south Madhya Maharashtra, since north Madhya Maharashtra is nearer the track of these low pressure systems. But towards the end of the season when the low pressure systems move along a more southerly latitude, south Madhya Maharashtra may also be affected by them. Heavy to very heavy rains may occur in north Madhya Maharashtra when a depression comes close to the area.

3.7.2 The lower tropospheric westerlies usually strengthen over the Peninsula in association with the formation of low pressure areas and depressions over the Bay and their movement across the country or when the seasonal trough is well-marked. When these strong westerlies strike the western ghats heavy to very heavy rains occur there (ref. para 3.2.5); and on such occasions, the rainfall extends slightly over the lee side also and the places in south Madhya Maharashtra close to the Ghats on the lee side, may also get appreciable rainfall.

3.7.3 Next in importance is the east-west oriented trough across the Peninsula connecting two lows, one in the Arabian Sea and the other in the Bay. During the height of the monsoon, such a system is seen mainly in mid-troposphere and the trough line is also over north Madhya Maharashtra or even slightly further north; its effect is mostly over north Madhya Maharashtra. During 'break' monsoon conditions as well as at the time of advance and withdrawal of monsoon, an east-west oriented trough may run across south Peninsula, connecting two lows - one in the Bay of Bengal and the other in the Arabian Sea. On such occasions the trough may extend downwards to the lower levels also, below 700 mb. Either the whole of or only parts of Madhya Maharashtra may be affected depending upon the position of the trough line on the day's charts. Sometimes the low pressure system may be only in the Arabian Sea, either as a low pressure area or even as a trough of low pressure. As southeast Madhya Maharashtra is relatively unaffected by any of the synoptic systems discussed above, the rainfall in this portion is very much less than in the other portions of Madhya Maharashtra.

3.7.4 The other synoptic systems are hardly significant in so far as Madhya Maharashtra is concerned.

3.8 Marathwada

Marathwada is very similar to Madhya Maharashtra, in that (i) the depressions and lows from the Bay and (ii) east-west oriented trough across the Peninsula are the major synoptic features responsible for active to strong monsoon conditions in this sub-division.

3.9 Coastal Andhra Pradesh

Like Madhya Maharashtra and Marathwada, Coastal Andhra Pradesh also gets rainfall in association with depressions and lows in the Bay and the east-west oriented trough across the north Peninsula. The seasonal monsoon trough (particularly when it ^{is} well to the south of the normal position) may also cause active monsoon conditions on a few occasions. In all these cases, it is more the

northern districts of Coastal Andhra Pradesh that are affected, rather than the southern districts. In addition, the north-south oriented trough during weak monsoon periods causes weather over the sub-division.

3.10 Telangana

Monsoon depressions and lows form the major synoptic system causing active to vigorous monsoon in Telangana; they account for a little over 50% of the occasions. Heavy to very heavy rains may occur in association with these systems (particularly depressions). Next in importance is the ~~upper air cyclonic circulation over the area~~ ^{east-west oriented trough}. Among the seven sub-divisions, which we are considering in this report, Telangana has got the highest number of active monsoon days. The number of occasions of active monsoon is the highest in September; to a certain extent it is so in Madhya Maharashtra and Coastal Andhra Pradesh also.

3.11 Rayalaseema

The number of occasions of active monsoon conditions is very small in Rayalaseema. The synoptic situations causing active monsoon conditions over the area are

- i) upper air cyclonic circulations and
- ii) north-south trough

These synoptic conditions are more likely during a generally weak or 'break' monsoon over the country. In this respect Rayalaseema is very much different from the other sub-divisions discussed above.

3.12 North Interior Mysore

North Interior Mysore gets active monsoon conditions in association with depression and lows. As discussed in para 3.2.3, when the depression or low has a large southward slope with height or when it is at a more southern latitude, North Interior Mysore, particularly the northern districts, experience active monsoon conditions. With strong lower tropospheric westerlies, the districts adjoining the Ghats may also get good rainfall, as discussed in para 3.7.2 under

Madhya Maharashtra. Thus while the northeast and western districts may get good rainfall, the central districts generally go dry. In this connection, the dry belt from southeast Madhya Maharashtra to Rayalaseema referred to in para 2.2.4 may be recalled. Like Rayalaseema, North Interior Mysore also gets rainfall with north-south oriented troughs and upper air cyclonic circulations, which are more characteristic of general weak monsoon conditions over the country as a whole.

3.13 South Interior Mysore

3.13.1 Upper air cyclonic circulations which are characteristic of weak monsoon conditions over the country, cause the largest number of occasions of active monsoon in this sub-division. Similar to North Interior Mysore and South Madhya Maharashtra, the western districts of South Interior Mysore adjoining the Ghats get active monsoon with strong lower tropospheric westerlies.

3.13.2 Agumbe which is in the extreme western part of South Interior Mysore in the Ghats area (at an elevation 659 m asl) is well-known for its heavy rains. Its mean rainfall in July and August is even more than that of Cherrapunji as may be seen from the following Table (Table VI).

TABLE - VI

	Rainfall (in cm)				Season's Total
	June	July	August	September	
Agumbe (based on data from 1952 to 1970)	159	275	206	78	718
Cherrapunji (based on data from 1901 to 1950)	268	242	180	112	802

4. Weak Monsoon

4.1 Weak monsoon conditions occur in Coastal Andhra Pradesh and Interior Peninsula under the following synoptic situations:-

- i) During a 'break' monsoon period or generally weak monsoon over the country, the lower tropospheric westerlies over the Peninsula are usually weak and they are also not deep. Under such conditions, only isolated or scattered thundershowers occur and monsoon is generally weak over Coastal Andhra Pradesh and Interior Peninsula also. However, if there is a well-formed north-south trough over the Peninsula or an upper air cyclonic circulation moves across the Peninsula, even active to vigorous monsoon conditions may occur in the sub-divisions affected by these systems.
- ii) During periods of generally good monsoon activity over the rest of the country, the eastern districts of Interior Mysore, Rayalaseema, south Coastal Andhra Pradesh and adjoining Telangana experience weak monsoon conditions. However, further north over north Coastal Andhra Pradesh and adjoining northern portions ^{of} Telangana, Marathwada and north Madhya Maharashtra, there may be well-distributed rainfall. ~~Monsoon may be well-distributed~~ ~~xxxxxxx~~ Monsoon may be even active in these sub-divisions, if a depression or low from the Bay is moving across south Orissa or south Madhya Pradesh or if the axis of the monsoon trough is well south of the normal position. However, if the depression or low is moving farther north across north Orissa, extreme north Madhya Pradesh and south Uttar Pradesh, the northern parts of Coastal Andhra Pradesh and Interior Peninsula also may experience weak monsoon.
- iii) If the western end of the monsoon trough is towards foot-hills of Himalayas and a pronounced north-south ridge lies over western Peninsula and Rajasthan, monsoon may be weak in Interior Peninsula and Coastal Andhra Pradesh. North Coastal Andhra Pradesh, however, may get rainfall if the eastern end of the seasonal trough is extending into north and adjoining west central Bay.
- In the following sections we will discuss a few typical cases of strong and weak monsoon in Coastal Andhra Pradesh and Interior Peninsula.

5. Deep Depression moving from Northwest Bay of Bengal to South Rajasthan across South Madhya Pradesh - 25 to 30 July, 1967.

5.1 During the second half of July 1967, there was ~~very~~ good monsoon activity in the Peninsula, when the seasonal monsoon trough lay across the central parts of the country and two deep depressions from the Bay of Bengal and an upper air cyclonic circulation moved across Orissa, Madhya Pradesh and Vidarbha. In this section, we will discuss the case of the first of the two deep depressions which moved from northwest Bay of Bengal to south Rajasthan across south Madhya Pradesh between 26th and 30th. This case has already been discussed in detail in Sec. 4.3 of FMU Report No.III-3.4 and hence in the present discussion we shall confine ourselves to the salient points in so far as Coastal Andhra Pradesh and Interior Peninsula are concerned.

5.2 On the morning of 25th July 1967, a well-marked low pressure area lay over north Bay of Bengal (Fig. 5.1). The circulation associated with the low was well-marked and extended upto 400 mb level with a southwestward tilt with height towards the cold air (Fig. 5.2). Another well-marked low pressure area was also present over Kutch, southwest Rajasthan and south Pakistan. In the lower troposphere the convergence zone associated with the low pressure area over north Bay lay over south Orissa and southeast Madhya Pradesh. Further westwards, there was a ridge of high pressure over Telangana, Vidarbha and West Madhya Pradesh. The Arabian Sea branch of the monsoon was strong, and the pressure gradient along the Konkan coast (Vengurla-Veraval) was nearly 7 mb as against the normal of 4-5 mb. The lower tropospheric westerlies over the Peninsula were also generally strong (30-40 kts). On this day (25th), the monsoon was mostly normal over Coastal Andhra Pradesh and Interior Peninsula. Over the Western Ghats, very heavy rains had fallen and in the extreme western districts of Madhya Maharashtra and Interior Mysore adjoining the Ghats, there was appreciable rainfall. The moderate falls over Telangana were apparently due to the presence of an upper air cyclonic circulation over southeast Madhya Pradesh, Vidarbha and north Telangana, during the

preceding 24 hrs; this circulation had weakened by 25th morning.

5.3 The well-marked low pressure area concentrated into a depression on the morning of 26th with its centre near $20.5^{\circ}\text{N } 88.0^{\circ}\text{E}$ (Fig. 5.3); the associated convergence zone (in the lower troposphere) extended from south Orissa-north Coastal Andhra Pradesh to Vidarbha (Fig. 5.4). As a result, there was an increase in rainfall in Coastal Andhra Pradesh and Telangana and the monsoon became strong in Telangana. The monsoon westerlies over the Peninsula were very strong, reaching upto 50 kts, resulting in continued very heavy rains in Western Ghats; some moderate falls were also reported in the interior districts of Maharashtra and Mysore on the lee side of the Ghats.

5.4 The depression deepened during the course of the day (26th), crossed coast during the night and was centred on the morning of 27th near Keonjargarh (Fig. 5.5). The associated cyclonic circulation extended upto 400 mb level, without much of tilt upto 500 mb level (Fig. 5.6) (a feature normally noticed with deep depressions). The areal extent of the circulation increased with height and in the mid-tropospheric levels (500 mb) it covered an area extending north-south about 15° of latitude and east-west about 30° of longitude. The associated convergence zone in the lower troposphere was over southeast Madhya Pradesh, Marathwada, Vidarbha and adjoining southwest Madhya Pradesh. With the movement of the depression inland and extension of the convergence zone westwards, rainfall considerably increased (on 27th) in Madhya Maharashtra and Marathwada where the monsoon became strong to vigorous. In Coastal Andhra Pradesh and Telangana, it was only normal. Very heavy rains upto 30 cm or more were recorded in the Ghats; in the immediate leeward side of the Ghats, over south Madhya Maharashtra and north Interior Mysore also, moderate to heavy rainfall occurred. It may be noted that in North Interior Mysore where monsoon was strong, two stations, Bidar and Belgaum, had moderate to heavy rains - Bidar was close to the convergence zone associated with the depression and Belgaum was just close to the Ghats in the field of strong lower tropospheric westerlies. Over the remain-

ing stations of the sub-division (North Interior Mysore) rainfall was only light to moderate. The 24 hour pressure changes were more on the western side, giving an indication that the depression will continue to move in a westerly direction.

5.5 Moving rapidly westwards across East Madhya Pradesh, the deep depression was centred on 28th morning near Chhindwara (Fig. 5.7). The associated convergence zone extended from Vidarbha and West Madhya Pradesh to south Gujarat State and adjoining north Madhya Maharashtra. The monsoon westerlies continued strong over the Peninsula (Fig. 5.8). The monsoon was strong in Madhya Maharashtra and Marathwada; rainfall was also widespread in Telangana and Coastal Andhra Pradesh. Very heavy rains continued over the Ghats - with some moderate to heavy falls in the adjoining areas on the lee side.

5.6 The deep depression now began to move northwestwards, weakened and lay as a depression on 29th morning to the northeast of Ratlam (Fig. 5.9). There was a steep rise of pressure in the rear. As the depression moved northwest, rainfall considerably decreased in Coastal Andhra Pradesh, Telangana and Marathwada. Monsoon was vigorous only in Madhya Maharashtra. As on the previous day, very heavy rain fell over the Ghats and moderate to rather heavy falls in the lee side immediately to the east of the Ghats.

5.7 During the next 24 hrs, the depression weakened further and moved northwestwards; as a result, rainfall decreased further in Coastal Andhra Pradesh, Telangana, Marathwada and Madhya Maharashtra where monsoon became weak to normal though very heavy rains continued over the Ghats with some moderate falls in the districts immediately on the lee side in south Madhya Maharashtra and north Interior Mysore. The monsoon trough continued well-marked over north Madhya Pradesh; however, there was no significant rain in the interior Peninsula as it was far to the south of the monsoon trough.

5.8 The important points to be noted in the case are:

- i) As the track of the depression was over south Orissa and south Madhya Pradesh, the rainfall belt associated with the depression extended southwards to Coastal Andhra Pradesh, Telangana, Marathwada and Madhya Maharashtra and the extreme northern districts of North Interior Mysore. Moderate to heavy falls occurred over these areas. In Coastal Andhra Pradesh, it was mostly the northern districts that got rainfall.
- ii) Initially, though the system was only a low pressure area/depression over the North Bay, the associated cyclonic circulation was well-marked and extended upto the mid-troposphere. Even at this stage (25 and 26th), rainfall extended upto Telangana, as the lower tropospheric convergence zone associated with the low/depression, extended well towards the west.
- iii) By 27th, rainfall increased in Marathwada and north Madhya Maharashtra as the deep depression moved westwards. It began to decrease considerably by 29th over most of Interior Peninsula, when the depression began to move away in a northwesterly direction.
- iv) The rainfall due to the depression covered the region from north Coastal Andhra Pradesh to north Madhya Maharashtra, including Telangana, Marathwada and the extreme northern districts of North Interior Mysore. Rainfall over these sub-divisions associated with the depression was mostly moderate to heavy. There were also a few heavy falls in Marathwada and North Madhya Maharashtra. Heavy rains associated with a monsoon depression extends about 3 to 4 degrees of latitude to the south of the depression track. In the present case, with the depression moving across southwest Madhya Pradesh, there was heavy rain in Marathwada and north Madhya Maharashtra which were within 4 degrees of latitude to the south of the depression track.
- v) There was also good rainfall in Interior Mysore. It was more in the western parts of the sub-division adjoining the Ghats. During this period, the low level westerlies over the Peninsula were very strong reaching 40-50 kts and the Ghats had very heavy rains. The rainfall also extended a little to the east over the adjoining lee districts. Rayalaseema did not get any significant rainfall during this period.

- vi) The circulation associated with the depression covered an extensive area in the upper air and it was becoming more and more extensive at the upper levels (upto 500-400 mb). The rainfall area associated with the depression was also quite extensive; this is generally so with depressions in the earlier part of the monsoon season.
- vii) The sub-tropical ridge in the upper troposphere lay along latitude 32°N , in more or less the normal position for the month. The upper easterly flow was well-marked over the north India. The depression, therefore, took a westnorthwesterly course. The upper tropospheric easterlies reached 60-90 kts upto Lat. 25°N .
- viii) The satellite pictures gave a good indication of the zone of convergence extending westwards from the depression. ESSA 2 pictures showed the heavy overcast area extending from the Bay of Bengal westwards to Vidarbha and West Madhya Pradesh on 26th (Fig. 5.10). Nimbus II pictures of 28th (Fig. 5.11) also showed the well-defined cumuliform bands to the north of the depression centre and heavy overcast area to the south.

6. Low Pressure Area moving from the Northwest Angle of Bay to Rajasthan - 16 to 20 July, 1968

6.1 Depressions and low pressure areas which move in a westnorthwesterly direction from northwest Bay to Rajasthan activate the monsoon over the country as a whole. However, in the Interior Peninsula, although rainfall may increase, the increase is only marginal and usually it does not exceed normal monsoon activity. But, when the upper air cyclonic circulation associated with such a low pressure system is well-marked and it also shows a large southward tilt with height, the circulation may lie over the Interior Peninsula in the mid-tropospheric levels; and under such conditions, rainfall over the Interior Peninsula may be significant and the monsoon activity may become even strong. The rainfall may extend southwards into northern parts of North Interior Mysore also. We shall discuss in this section a low pressure area which moved from northwest Bay of Bengal to south Rajasthan and caused a spell of rainfall in the Interior Peninsula between

18th and 21st July 1968 with strong monsoon conditions in some sub-divisions on one or two days.

6.2 On 16th July 1968, a low pressure area developed over northwest angle of the Bay and the adjoining Orissa and Gangetic West Bengal. The associated cyclonic circulation extended upto 500 mb level. It persisted over the same area on 17th also (Fig. 6.1) and became well-marked in the upper air (Fig. 6.2). The cyclonic circulation showed a southwestward slope with height towards the cold air and was over southeast Madhya Pradesh and adjoining Coastal Andhra Pradesh at 500 mb level. At this stage, Coastal Andhra Pradesh and Telangana alone were affected and the main rainfall belt was further north over East Madhya Pradesh, Orissa and East Vidarbha.

6.3 By 18th morning, the low moved to northeast Madhya Pradesh and the upper air cyclonic circulation continued well-marked sloping southwestwards with height towards the cold air (Fig. 6.3). At 600-500 mb levels it lay over Telangana and adjoining areas and rainfall extended into Marathwada also (see last chart in Fig. 6.3).

6.4 By 19th morning, the low pressure area moved to northwest Madhya Pradesh and also weakened (Fig. 6.4). The associated upper air cyclonic circulation continued to extend to almost 400 mb level (Fig. 6.5). In the mid-troposphere, the circulation covered the Interior Peninsula upto Rayalaseema in the south. On this day, the rainfall increased considerably over the Interior Peninsula; Telangana had strong monsoon while the other sub-divisions had normal monsoon. Rainfall amounts of the order 3-4 cm were recorded at a number of places.

6.5 By 20th, the low pressure area moved further westnorthwestwards and merged into the seasonal trough. While the cyclonic circulation associated with the low moved northwest in the lower troposphere, the circulation in the mid-troposphere appears to have been cut off from the lower level circulation and continued to move westwards and was over Madhya Maharashtra, Konkan and adjoining

areas (Fig. 6.6). On this day also, rainfall was reported from all the seven sub-divisions of Interior Peninsula and Coastal Andhra Pradesh, with vigorous monsoon in Marathwada and normal monsoon in the other six sub-divisions (see last chart in Fig. 6.6). Amounts upto 8 cm were recorded. Subsequently the mid-tropospheric circulation over Maharashtra State moved away westwards and weakened and rainfall gradually decreased over the Interior Peninsula.

6.6 To sum up,

- i) The synoptic situation discussed in the present section was noteworthy in two respects viz:
 - a) Though it was only a low pressure area on the surface chart, the upper air cyclonic circulation associated with the low was well-marked and extended upto the mid-troposphere. The low caused good monsoon activity over the country.
 - b) The system had a good southerly slope with height and in the mid-troposphere the cyclonic circulation moved across the Interior Peninsula and caused a spell of normal to strong monsoon activity there.
- ii) While the surface low and the lower tropospheric cyclonic circulation moved northwest towards the seasonal low and weakened, the circulation in mid-troposphere got separated from the lower one after sometime and continued in a westerly direction and caused weather over Maharashtra State.
- iii) There was a progressive increase and a subsequent decrease of rainfall over the sub-divisions as the system moved west in the upper air.
- iv) The cyclonic circulation in the mid-troposphere tilted southwards upto Rayalaseema and caused normal monsoon activity in Rayalaseema and Interior Mysore. Such a southward extension of the rainfall with a low pressure area far to the north appears to be mainly due to the large slope of the system and the consequent presence of the circulation at higher levels over the Interior Peninsula.
- v) In a well-marked depression or deep depression where the slope of the cir-

tulation with height is not large, although the rainfall may be heavy to very heavy in the southwest sector of the depression, the general rainfall belt does not extend far to the south. However, in cases where the slope with height is large, (which is usually the case with a low pressure area or a weak depression) rainfall extends far to the south, though the rainfall may not be so heavy as in the case of the more intense systems. Under such synoptic conditions, even North Interior Mysore may get rainfall when the low pressure system is moving across Orissa or north Madhya Pradesh.

vi) During this period, the upper tropospheric easterlies were quite steady and there was good evidence of two easterly maxima - one over the extreme south Peninsula and the other over the north Peninsula in the latitudinal belt of 18-20°N.

7. Low Pressure Area over West Central Bay moving inland in a Northwesterly direction - 23 to 27 August, 1971

7.1 Towards the end of the monsoon season, depressions and low pressure areas form in more southerly latitudes, over the Central Bay and cross Andhra Coast; they generally move in a northwesterly direction towards Vidarbha and later may even recurve. In association with these systems the Interior Peninsula and Coastal Andhra Pradesh get good monsoon activity. Two monsoon depressions which formed in West Central Bay off Andhra Coast have been discussed in Sections 4.4 and 6.2 of FMU Report No. III-3.4 on Madhya Pradesh and Vidarbha - one moving towards Vidarbha and the other taking a more westerly course towards north Konkan. In this Section we will discuss the case of a low pressure area, which formed off Andhra coast and moved northwest.

7.2 On the morning of 22nd August, 1971, the seasonal monsoon trough was extending into west central Bay of Bengal across the north Andhra coast, and by the next morning a well-marked low pressure area formed there (Fig. 7.1). The associated cyclonic circulation was also well-marked, extending into the mid-troposphere with a southward slope with height towards the cold air side (Fig. 7.2). The convergence zone associated with the low, lay over the central

Peninsula between 14°N and 17°N , in the lower troposphere.

7.3 The low moved northwest and was off Coastal Andhra Pradesh on 24th morning (Fig. 7.3). The associated cyclonic circulation continued well-marked upto 400 mb with a southwestward tilt with height (Fig. 7.4). The satellite picture of the disturbance on this day was classified as Stage 'C' (Fig. 7.5). The convergence zone in the lower troposphere, extended from South Coastal Andhra Pradesh to Madhya Maharashtra across Rayalaseema and North Interior Mysore. On this day there was fairly widespread rainfall over Andhra Pradesh, Interior Mysore, Madhya Maharashtra and Marathwada with a few heavy falls. Monsoon was active to vigorous in Coastal Andhra Pradesh and Interior Mysore. The significant amounts in the Peninsula east of the Ghats, were in and near the zone of convergence during the preceding 24 hrs. At many places, rainfall was associated with thunder.

7.4 The low pressure area moved further northwest, crossed coast and lay over southeast Madhya Pradesh, east Vidarbha and the adjoining areas on 25th morning (Fig. 7.6). The associated cyclonic circulation continued to be marked extending upto 500 mb, sloping southwestwards with height (Fig. 7.7). The convergence zone in the lower troposphere was over Marathwada, North Madhya Maharashtra and north Konkan.

7.5 As the low pressure area moved inland northwestwards, rainfall increased in Madhya Maharashtra and Marathwada where monsoon became strong. Monsoon continued vigorous in North Interior Mysore. Rainfall decreased in Coastal Andhra Pradesh. Heavy amounts of 8 to 9 cm were reported in Madhya Maharashtra, Marathwada and adjoining North Interior Mysore. The area of rainfall was to the southwest of the surface position of the low, ^{nearly coinciding with} the area of the associated cyclonic circulation in the mid-troposphere and the lower tropospheric convergence zone.

7.6 On 26th morning, the low persisted over East Vidarbha and neighbourhood and the associated cyclonic circulation became less marked in the mid-troposphere.

~~and~~ (Fig. 7.8). The convergence zone in the lower troposphere was over Marathwada, North Madhya Maharashtra and neighbourhood. Monsoon continued strong to vigorous in Madhya Maharashtra and Marathwada and heavy falls of the order 7-10 cm were recorded. Rainfall decreased in North Interior Mysore (see last chart in Fig. 7.8).

7.7 By 27th the low pressure area weakened into a trough extending from northwest Madhya Pradesh to Orissa (Fig. 7.9). With the northward shift of the system rainfall decreased in all the seven sub-divisions and monsoon became normal over Madhya Maharashtra and Marathwada. Monsoon activity, however, was good further north in Madhya Pradesh and Vidarbha.

7.8 In this sequence of charts we find:

- i) The low pressure area caused well distributed rainfall in Interior Peninsula and Coastal Andhra Pradesh with strong to vigorous monsoon conditions in some of the sub-divisions. We have already discussed in para 2.2.3 about the double maxima in rainfall in the sub-divisions of Madhya Maharashtra, Marathwada, Telangana and north Coastal Andhra Pradesh. Such lows and depressions which travel across the north Peninsula towards the end of the southwest monsoon season partly contribute to the second maximum in rainfall.
- ii) Although it was only a low pressure area, the circulation extended upto the mid-troposphere. The rainfall was also fairly widespread with some rather heavy to heavy falls. At many places in Coastal Andhra Pradesh and Interior Peninsula, rainfall was accompanied by thunder.
- iii) As the low moved further north into Madhya Pradesh and weakened into trough on 27th, rainfall decreased considerably and monsoon became weak in Andhra Pradesh and Interior Mysore. Rainfall was still fairly widespread in North Madhya Maharashtra and Marathwada which were closer to the low pressure system.

- iv) The area of significant rainfall in association with the low was either along and near the zone of convergence in the lower troposphere and/or in the area covered by circulation in the middle troposphere, if the circulation was well-marked extending upto the mid-troposphere. These features give an useful indication regarding the area where most of the weather may be expected.
- v) During the period when the seasonal monsoon trough was well to the south of its mean position, the pressure departures were positive over north India and negative to the south.
- vi) In the upper troposphere, the anticyclone over Tibet, India, Pakistan and Iran was well-marked and there was no major trough in westerlies affecting India. The high pressure cell shifted from Tibet westwards to Afghanistan and Iran during this period (Fig. 7.10 a to d).
- vii) The upper tropospheric easterlies extended northwards upto the latitude of Delhi and the core of strong winds was noticed in the latitudes of 18°N – 23°N from north Thailand to India till the 25th, with the passage of a wind maximum from Thailand across north Peninsula (Fig. 7.11 a and b). There was some evidence (on some days) of two maxima – one over Sri Lanka and the near equatorial area and the other over North Peninsula.
- viii) The low pressure area discussed in this section was embedded in an extended east-west oriented trough (700–500 mb) from off Arabia coast to Andaman Sea and satellite pictures showed heavy overcast clouding to the south of the trough line. It is interesting to note another belt of clouding along and near the Himalayas (see Fig. 7.5) (for another instance of a similar type of cloud distribution see para 8.8).

8. Axis of Monsoon Trough far south of the Mean Seasonal position – 18 to 22 July 1967.

8.1 The eastern end of the axis of the seasonal monsoon trough often shifts southwards into the head Bay and sometimes even extends further south into West Central Bay; in contrast, the western end rarely shifts south to that extent.

The western end shifts ^{as} far to the south as 20 to 22°N, when a low pressure system is over Gujarat or northeast Arabian Sea; but such occasions are rare. Since the eastern end of the axis of the seasonal trough is more often in a southerly position than the western end, Coastal Andhra Pradesh and Telangana are more affected by the oscillations of the trough than the sub-divisions further west viz. Madhya Maharashtra or Marathwada. In this section, we will discuss a case when the axis of the seasonal monsoon trough was far to the south of its mean position, both in the east and the west.

8.2 On the morning of 18th July 1967, the axis of the seasonal trough was (on the surface chart) from Punjab-Haryana to Orissa and thence into West Central Bay (Fig. 8.1). The wind field over north and central India was light to moderate in the lower and mid-troposphere (Fig. 8.2). The heavy rise of pressure in the north with slight falls in the south over the Peninsula, was an indication that the seasonal trough may shift further south. During the next 24 hrs, a rapid southward shift of the western end of the seasonal trough occurred and its position on the morning of 19th was from Gujarat State to West Central Bay across Vidarbha and Coastal Andhra Pradesh (Fig. 8.3). In contrast to the previous day (18th), the trough became well-marked in the upper air also and extended upto 500 mb level, with the usual southward slope with height, particularly above 700 mb (Fig. 8.4). An embedded cyclonic circulation was also noticed over Vidarbha, Telangana and the adjoining areas. There is some evidence to suggest that the cyclonic circulation might have moved inland from West Central Bay off Andhra Coast in the preceding 24 hrs.

8.3 With the shifting of the trough southwards and the westward movement of the cyclonic circulation embedded in it, there was considerable increase in rainfall (on 19th) in Madhya Maharashtra, Telangana, Coastal Andhra Pradesh and North Interior Mysore, where the monsoon became strong to vigorous. Rainfall of 5 to 7 cm was reported from a number of stations in these sub-divisions. Although there was some rainfall in Madhya Pradesh through which the seasonal

trough moved south in the past 24 hrs, there was more rainfall over the north Peninsula.

8.4 On 20th, the axis of the trough persisted in the same position while the embedded cyclonic circulation moved further west into Saurashtra and Kutch and adjoining northeast Arabian Sea where it was noticed from the sea level upwards upto 400 mb (Fig. 8.5). The pressure changes and departures also confirmed such a westward movement of the low. The lower tropospheric westerlies were strong over the Peninsula south of the trough line and the western Ghats had heavy rains. The monsoon was strong in Telangana and Marathwada, while in the other sub-divisions rainfall decreased (see last chart in Fig. 8.5).

8.5 During the next 24 hrs, the trough began to move northwards and on 21st morning it was running from North Rajasthan to Orissa on the surface chart; pressure changes suggested a further shift of the trough towards the foot-hills of the Himalayas (Fig. 8.6). The 'low' over Saurashtra and Kutch also weakened and pressures rose heavily over this area. Although the trough shifted north in the surface and lower troposphere, it remained over north Peninsula from Orissa to south Gujarat in the mid-tropospheric levels (700-500 mb) with an embedded cyclonic circulation over southeast Madhya Pradesh and Telangana (Fig. 8.7). On account of this, rainfall persisted over the Interior Peninsula though its intensity became less except in Telangana where it was vigorous. The vigorous monsoon over Telangana was caused by ~~any~~ ^{the} upper air cyclonic circulation over southeast Madhya Pradesh and Telangana. Similar conditions persisted on 22nd also and Coastal Andhra Pradesh and Telangana had strong to vigorous monsoon (see inset in Fig. 8.6).

8.6 Such occasions of monsoon trough coming far to the south of its mean seasonal position are rare in the height of the monsoon. However, towards the end of the season (in September), we come across such situations more frequently; but in September the seasonal trough becomes indistinct on the surface chart and the trough may be noticed only in the upper air charts (in this connection vide discussion in Sec.3).

8.7 During this period 18-22 July 1967, the upper tropospheric easterlies were spread over a very broad belt covering the entire country. Even Delhi reported easterlies of 70-90 kts (maximum wind) on 18th and 19th. The strongest winds in the easterly belt shifted northwards to near about 18-23°N, well to the north of the mean seasonal position (see time-section along 77°E for 150 mb level - Fig. 8.8).

8.8 The satellite pictures for the period showed a wide area of heavy clouding extending from ^{On an} ~~Orissa~~ to Malaysia across the south Peninsula, corresponding to the monsoon trough with another band extending from Western China southwestwards to Himalayas, with clear or lightly clouded skies in between over northern and central India (Fig. 8.9). This type of cloud distribution is unlike of the monsoon.

9. East-west oriented Trough Line across the Peninsula - 21 to 26 September, 1967

9.1 Towards the end of the monsoon season (i.e. in September) as the monsoon starts withdrawing from northern India, an east-west oriented trough forms over the north Peninsula and extends into Bay and Arabian Sea. In October, this flow pattern shifts further south and gets stabilised. In September, the east-west oriented trough is noticed mainly in the upper air particularly between 850 mb and 500 mb. Upper air cyclonic circulations may move along the trough from east to west. While scattered thundershowers may be associated with the trough, there may be increased rainfall when a low moves along the trough. A few heavy falls may also occur in association with such a moving low. The low and the trough may be seen better in the upper air charts (lower and mid-troposphere) than in the surface isobaric field. Pressure change and departure charts may be, sometimes, useful to trace the low and its movement. Such an east-west oriented upper air trough may be noticed in June also when the monsoon is advancing over the country; in mid-monsoon months, such a trough may be seen during 'break' conditions.

September 1967

9.2 An east-west oriented trough line formed on 21st extending from the east central Bay to the east central Arabian Sea across the Peninsula in the lower and mid-troposphere and it became well-marked by 22nd. It persisted almost upto the end of the month, although it became less-marked towards the end. The hemispherical charts showed that the east-west oriented trough extended over a large longitudinal belt from Arabian Sea to South China Sea (Fig. 9.1).

9.3 Along this trough, a cyclonic circulation moved westwards across the central Peninsula, from the Bay to the Arabian Sea. It travelled from south Coastal Andhra Pradesh on 21st to off Konkan coast by 25th. The cyclonic circulation could be traced back upto 19th when it was over the Andaman Sea. The 0.9 km/1.5 km wind charts for the period clearly show the movement of the low across the central parts of the Peninsula. At higher levels, we notice only the east-west oriented trough, and the circulation embedded in it could not be located, partly due to lack of crucial wind observations at these higher levels. By 26th another low developed over North Bay and while the one off Konkan persisted, with a trough across the north Peninsula connecting the two circulations.

9.4 Under the influence of these systems, monsoon activity was good over the Peninsula for about a week between 22nd and 28th. Strong to vigorous monsoon conditions prevailed on a few days in Coastal Andhra Pradesh and Interior Peninsula. The trough had a slope (with height) towards the south and was noticed upto 500 mb, above which zonal easterlies prevailed. The embedded cyclonic circulation was better seen (in the lower troposphere) in the morning than in the evening charts. The time-section of Hyderabad clearly shows the passage of the cyclonic circulation across the station on 22nd (Fig. 9.2).

9.5 Two typical days charts 22nd and 26th during this period are given in Figs. 9.3 to 9.6 to illustrate the east-west oriented trough and the embedded cyclonic circulations. On 22nd the cyclonic circulation embedded in the east-west trough was over south Coastal Andhra Pradesh and the adjoining Rayalaseema

and Telangana. On 26th there were two 'lows' - one over the north Bay and the other off Konkan coast, with an east-west trough connecting the two (vide para 9.3). There was fairly widespread rainfall over the whole of north Peninsula from Konkan to Coastal Andhra Pradesh and Orissa, on 26th and 27th. For the other days of the period, the 1.5 km upper air and rainfall charts are given to indicate the trough across the Peninsula, the movement of the cyclonic circulation embedded in the trough and the associated rainfall distribution (Fig. 9.7 a to d).

9.6 The rainfall associated with the trough was spread out on either side of the trough and the falls were more concentrated in the area of the low (in this connection, vide para 12.3 of the report on 'Northeast Monsoon', dealing with rainfall associated with east-west trough - FMU Rep. No.IV-18.4).

9.7 The satellite pictures for the period showed the following features:-

- i) Extensive broken to overcast clouding was seen from the Arabian Sea to Vietnam and south China Sea associated with the east-west trough (23rd evening satellite picture is given as ~~an~~ ^{an} example (Fig. 9.8).
- ii) Cloudiness to the south of the trough was far more extensive, reaching as far south as the equator.
- iii) Generally the clouds were of convective type in the form of cloud clusters of varying sizes.
- iv) A heavy overcast blob of clouding corresponding to the moving cyclonic circulation in the trough could also be seen on some days.

10. North-South Trough - 15 to 17 July, 1967

10.1 North-south oriented troughs form in the monsoon westerlies during periods of generally weak monsoon or 'break monsoon' over the country. They usually appear over the Gangetic Plains and the central parts of the country. During weak or 'break' monsoon periods, the pressure pattern and the wind field become weak over the Peninsula and a north-south trough develops there

also, particularly in the eastern half of the Peninsula. The trough in the Peninsula may occasionally get linked up with the north-south trough in the low level monsoon westerlies further north. The weather associated with the north-south trough over the Interior Peninsula is usually scattered light to moderate thundershowers, with weak to normal monsoon activity. However, the trough may cause strong monsoon over Interior Peninsula, when there is also simultaneously another perturbation in the mid- or upper troposphere. In such cases, most of the south and central Peninsula may have good monsoon activity. In this section we will discuss one such case.

10.2 A 'break' in the monsoon set in over the country on 7th July 1967, and came to an end by about the 11th. However, the seasonal monsoon trough did not shift appreciably southwards but continued to remain north of its mean position. The general lower and mid-tropospheric wind field over the country also weakened. In this weak wind field, a north-south trough developed, which lay on the morning of 14th extending from East Uttar Pradesh to Tamil Nadu, in the lower troposphere. A cyclonic circulation of small extent also lay off Andhra coast between 850 mb and 500 mb levels. In the mid-troposphere, another cyclonic circulation was also noticed over the south Peninsula (Figs. 10.1 and 10.2). The pressure gradient over the country was weak and pressure change and departure distributions were characteristic of 'break' conditions. The north-south trough from Uttar Pradesh to Tamil Nadu persisted on 15th and 16th, while the cyclonic circulation moved from off Coastal Andhra Pradesh to Marathwada (Figs. 10.3 and 10.4). The wind field continued weak over most country in the lower and mid-troposphere and was tending to break up into vortices particularly between 2.1 and 3.6 km. The cyclonic circulation over south Peninsula also moved westwards and weakened.

10.3 By 17th, the wind field slightly strengthened and the westerly flow in the lower troposphere was becoming organised; simultaneously the north-south trough weakened and the flow pattern changed considerably subsequently (Figs. 10.5 and 10.6). By 19th the monsoon trough shifted to a relatively low

latitude when its position was from Gujarat State to West Central Bay across Vidarbha and Coastal Andhra Pradesh.

10.4 On account of the presence of the north-south trough over the Peninsula in the lower troposphere and the movement of the cyclonic circulation from off Coastal Andhra Pradesh to Marathwada, there was good rainfall activity in the Peninsula on 15th and 16th, when monsoon became strong to vigorous in Madhya Maharashtra and Andhra Pradesh, and normal in Marathwada and North Interior Mysore (see last chart in Figs. 10.3 and 10.4). Most of the rainfall was associated with thunderstorms and a number of places in these sub-divisions recorded 3 to 5 cm of rainfall. An isolated heavy fall of 10 cm occurred in Telangana. There was an east-west oscillation of the trough line, in addition to the movement of a cyclonic circulation from off Coastal Andhra Pradesh to Marathwada discussed already. Perhaps on account of these factors, the rainfall associated with the trough was not confined to a narrow zone along the trough line but spread out over the entire Interior Peninsula (the heavier falls were in the neighbourhood of the cyclonic circulation). In this connection, it may be relevant to recall the common situation during the pre-monsoon season where a quasi-stationary wind discontinuity or trough line is seen in the lower troposphere over the Peninsula and the weather is mostly confined to the region of the trough line.

10.5 During this period, the strong upper tropospheric easterlies extended northwards upto about 23°N and the strongest winds were displaced northwards to the latitudinal belt 18°N - 20°N .

11. Weak Monsoon

11.1 Typical Synoptic Situations

A few instances of weak monsoon over Coastal Andhra Pradesh and Interior Peninsula are given below. Detailed discussions are not given as these case histories have been discussed in earlier FMU Reports in a different connection, reference to which ^{is} are indicated.

S. No.	Monsoon activity over Coastal Andhra Pradesh and Interior Peninsula	Date	Synoptic Situation	Reference to earlier FMU Report
1.	Normal in Madhya Maharashtra and Interior Mysore and weak in other sub-divisions	28 July 1965	A deep depression was centred near Chakulia and a low pressure area was over West Madhya Pradesh. The depression was too far away to affect Interior Peninsula and Coastal Andhra Pradesh. There was good rainfall in the districts of Madhya Maharashtra and Interior Mysore adjoining the Ghats.	FMU Rep.No. III-3.6 - Sec.4 (Figs.4.3 and 4.7)
2.	Normal in South Interior Mysore and weak in other sub-divisions	3 Aug.1965	Western end of the axis of seasonal trough was towards foot-hills of Himalayas and a ridge was over Western India.	FMU Rep.No. III-3.6 - Sec.7 (Fig.7.5)
3.	Normal in Madhya Maharashtra and weak in other sub-divisions	14 Aug.1965	-do-	FMU Rep.No. III-3.7 - Sec.8 (Fig. 9.1.1)
4.	Weak in all sub-divisions	13 Aug.1967	A Low pressure area was over southwest Uttar Pradesh and the axis of the seasonal trough was over central Uttar Pradesh, Bihar Plains and Sub-Himalayan West Bengal. The trough and the low were well to the north, and did not affect the Interior Peninsula and Coastal Andhra Pradesh. As the lower tropospheric westerlies were also not very strong, there were no significant rain in the districts of Madhya Maharashtra and Interior Mysore adjoining the Ghats.	FMU Rep.No. III-3.6 - Sec.9 (Fig.9.3)
5.	Normal in Rayalaseema and weak in other sub-divisions	7 Aug.1965	'Break monsoon' conditions without any low pressure system moving across the Peninsula.	FMU Rep. No. IV - 18.3 (Figs.1 a, 1 b and 1 c)

APPENDIX

Specifications for the strength of Monsoon over land areas (Taken from DDGF's Forecasting Circular 1 of 1973)

<u>Descriptive term</u>	<u>Specifications</u>
Weak monsoon	Rainfall less than half the normal.
Normal monsoon	Rainfall half to less than $1\frac{1}{2}$ times the normal. (mention of 'normal' monsoon may not be necessary in general)
Active/strong monsoon	i) Rainfall $1\frac{1}{2}$ to 4 times the normal ii) The rainfall in at least two stations should be 5 cm, if that sub-division is along west coast and 3 cm, if it is elsewhere. iii) Rainfall in that sub-division should be fairly widespread of widespread.
Vigorous monsoon	i) Rainfall more than 4 times the normal. ii) The rainfall in at least two stations should be 8 cm if the sub-division is along the west coast and 5 cm if it is elsewhere. iii) Rainfall in that sub-division should be fairly widespread or widespread.

1. While describing the activity of the monsoon,

- i) The normals of stations, wherever available should be used.
- ii) Till normals for all the stations are available the following procedure should be adopted:

Number of stations in a sub-division with normals	a
Normal for these stations	b
Average normal for the sub-division	b/a
Total number of stations reporting rainfall	c
Actual total rainfall reported by these stations	d
Therefore, the average rainfall for the sub-division	d/c

Compare d/c with b/a and describe the activity of the monsoon accordingly, other conditions being fulfilled.

- 2.i) In the sub-divisions, where the percentage of hill stations is high, the hill stations must be also taken into account for describing the activity of the monsoon. In other sub-divisions, the hill stations will be excluded.
- ii) The monsoon activity will be described in all the sub-divisions of north-east India as is done for sub-divisions of other regions.
- iii) The monsoon activity need not be described over the Bay Islands and the Arabian Sea Islands.

REFERENCES AND SELECTED BIBLIOGRAPHY

1. Alvi, S.M.A. and Punjabi, K.G. 1966: Diurnal and seasonal variation of squalls in India. IJMG Vol.17 pp.207-216.
2. Ananthakrishnan, R. and Pathan, J.M. 1970: On some features of the space time variation of rainfall over India and neighbourhood. I.M.D. pre-published Scientific Report No. 118.
3. Bedi, H.S. and Kulandaidasan, S. 1967: An objective method of forecasting pentad rainfall at Bangalore during monsoon season. IJMG Vol.18 pp.536-539.
4. Blandford, H.F. 1886: Rainfall of India. Memoirs of I.Met.D. Vol.III.
5. Das, P.K. 1968: The Monsoons. National Book Trust, New Delhi.
6. Desai, B.N. : Synoptic climatology of the Indian sub-continent. IMD Meteorological and Geophysical Reviews No.2.
7. Doraiswamy Iyer and (Miss) Pradhan, R.N. 1956: Monthly frequencies of rainfall in India. Memoirs of I.M.D. Vol.XXX Part VI.
8. George, C.J. 1962: Rainfall peaks over west coast and east coast of Peninsular India. IJMG Vol.13 pp.1-14.
9. George, P.A. 1949: Low stratus clouds over Bangalore. IMD Sc.Notes Vol.X No.123.
10. India Met. Department. 1963: Extremes of maximum and minimum temperatures ($^{\circ}\text{C}$) and heaviest rainfall (mm) in the 24 hrs period based on data upto 1963. India Weather Review - Oct-Dec. pp.692-713.
11. India Met. Department. 1971: Rainfall Atlas of India.
12. Jagannathan, P. and Khandekar, M.L. 1962: Predisposition of upper air structure in March to May over India to the subsequent monsoon rainfall of the Peninsula. IJMG Vol.13 pp.305-308.
13. Joseph, P.V. and Raman, P.L. 1966: Existence of low level westerly Jet stream over Peninsular India during July. IJMG Vol.17 pp.407-410.
14. Krishnaswamy, K.R. 1951: Some characteristics of rainfall at Poona. IJMG Vol.2 pp.51-56.
15. Krishnaswamy, K.R. 1954: A study of the self-recording rain-gauge charts of Bangalore. IJMG Vol.5, pp.157-163.
16. Koteswaram, P. 1950: Upper level lows in low latitudes in the Indian area during southwest monsoon season and breaks in the monsoon. IJMG Vol.1 pp.162-164.
17. Koteswaram, P. 1958: The Easterly Jet Stream in the Tropics. Tellus Vol.10.1 pp.43-57.
18. Malurkar, S.L. and Desai, B.N. 1943: Notes on forecasting weather in India. IMD Tech. Notes No.1.

19. Malurkar, S.L. 1950: Notes on analysis of Weather of India and neighbourhood. IMD Memoirs Vol.XXVIII Part IV.
20. Mokashi, R.Y. 1971: The axis of the tropical easterly jet stream over India and Ceylon. IMD pre-published Scientific Report No.156.
21. Mukherjee, A.K. and Natarajan, G. 1958: Westward moving sea level low pressure systems in the south Bay of Bengal during southwest monsoon. IJMG Vol.19 p.285.
22. Narasimhan, V.L. and Zafar Md. 1947: An analysis of hourly rainfall records at Poona. IMD Sc. Notes Vol.IX No.110.
23. Parthasarathy, K. 1958: Some aspects of the rainfall in India during southwest monsoon season. Symposium on Monsoons of the World. New Delhi, pp.31-35.
24. Parthasarathy, K. 1958: Maximum point rainfall and frequency of rainfall of ten inches and over in 24 hours over India. Symposium on Meteorological and Hydrological aspects of Floods and Droughts in India, New Delhi, pp.31-36.
25. Pisharoty, P.R. and Asnani, G.C. 1957: Rainfall around monsoon depressions over India. IJMG Vol.8 pp.15-20.
26. Rai, D.B. 1958: Effect of vertical wind shear on rainfall at Poona during southwest monsoon season. IJMG Vol.9 pp.92-94.
27. Rai Sircar, N.C. 1955: Some aspects of monsoon rainfall in India. IJMG Vol.6 pp.217-224.
28. Raghavan, K. 1964: Influence of the western Ghats on the monsoon rainfall at the coastal boundary of the Peninsular India. IJMG Vol.15 pp.617-620.
29. Ramabhadran, V.K. 1954: A statistical study of the persistency of rainy days in the monsoon season at Poona. IJMG Vol.5 pp.48-55.
30. Ramachandran, G. 1967: Rainfall distribution in India in relation to Lat./ Long and Elevation. IJMG Vol.18 pp.227.
31. Ramakrishnan, K.P. 1952: Normal rainfall for each degree square of coordinates for the Indian Peninsula south of Lat. 15°N. IJMG Vol.3, pp. 64-68.
32. Ramakrishnan, K.P. 1953: The stronger squalls of Poona. IJMG Vol.No.4, pp.243-248.
33. Ramakrishnan, K.P. and Narayanan, J. 1956: A study of Fifty years rainfall of Vishakapatnam. IMD Memoirs Vol.XXX Part IV.
34. Ramakrishnan, K.P. and Gopinatha Rao, B. 1958: Some aspects of non-depressional rain in Peninsular India during the southwest monsoon. Symposium on Monsoons of the World. Session V No.4 pp.195.

35. Ramakrishnan, K.P. and Krishnan, A. 1958: Spells of heavy rain and rainless days at selected stations in India. Symposium on Meteorological and Hydrological aspects of Floods and Droughts in India. pp.164-167.
36. Ramamurthy, K. 1962: Squalls at Begumpet. IJMG Vol.13, pp.485-487.
37. Ramamurthy, K. 1969: Some aspects of the 'break' in the Indian Southwest monsoon during July, August. IMD FMU Report No. IV-18.3.
38. Ramamurthy, K.M., Keshavamurthy, R.N. and Jambunathan, R. 1965: Some distinguishing features of strong and weak monsoon regime over India and neighbourhood. Symposium on meteorological results of IIOE Bombay, pp.350-361.
39. Raman, P.K. and Raghavan, K. 1961: Diurnal variation of thunderstorms in India during different seasons. IJMG Vol.12, pp.109.
40. Ramaswamy, C. 1967: The problem of the Indian Southwest monsoon. Prince Mukarram Jah lectures 1967 under the auspices of the Indian Geophysical Union, Hyderabad.
41. Rao, D.V., Vittal Sharma, V. and Lal, S.S. 1950: Studies on forecasting local rainfall in India with the help of precipitation index. IJMG Vol.1, pp.105-111.
42. Rao, K.V. 1955: Objective method of forecasting rain at Poona during southwest monsoon. IJMG Vol.6 No.4, pp.358-361.
43. Rao, K.N. 1958: Heavy rainfall in India. Symposium on Flood and Droughts in India. p.11.
44. Rao, K.N. 1958: Average amount of rainfall on a rainy day in India during the southwest and northeast monsoons. Symposium on Monsoons of the World. Sec.V pp.209-212.
45. Rao, K.N. and Raman, P.K. 1958: Diurnal variation of rainfall in India. Symposium on Floods and Droughts in India. pp.186-191.
46. Rao, K.N. 1959: Rainfall of Hyderabad State (Pre-reorganization). IMD Memoirs Vol.XXXI Part II.
47. Rao, K.N. and Raman, P.K. 1961: Frequency of days of thunder in India. IJMG Vol.12, p.103.
48. Rao, K.N., George, C.J. and Abhyankar, V.P. 1971: Nature of the frequency distribution of Indian rainfall (Monsoon and annual). IMD Pre-published Sc. Report No. 168.
49. Rao, Y.P. and Hariharan, P.S. 1959: Heavy rainfall in Deccan (Desh) on 30, 31 August 1956. IJMG Vol.10 pp.231-234.
50. Rao, Y.P. and Desai, B.N. 1970: Remarks on the nature and origin of the low level Jet off Somalia and over the Indian Peninsula during the southwest monsoon. IJMG Vol.21, pp.651-653.
51. Rao, Y.P. and Ramamurthy, K.S. 1968: Climatology of India and neighbourhood. IMD FMU Rep. I-2.
52. Rao, Y.P., Srinivasan, V., Ramakrishnan, A.R. and Raman, S. 1970: Southwest Monsoon - Active and Weak monsoon conditions over Orissa. IMD FMU Rep. III-3.2.

53. Roy, A.K. 1946: Air masses in India. *IME Tech.Notes No.16.*
54. Roy, A.K. 1958: On the usefulness of pressure departure charts in forecasting monsoon weather. *Symposium on monsoons of the world. Session IV-3, p.173.*
55. Seshachar, C. 1947: A discussion of hourly rainfall and associated wind direction at Bangalore. *IMD Sc. Notes Vol.IX No.102.*
56. Shukla, J., Das, S.K. and Sethumadhavan, A. 1968: Forecasting pentad rainfall anomaly over Coastal Andhra Pradesh in July. *IJMG Vol.19 pp.446-448.*
57. Sinha, K.L. 1952: An analysis of the space distribution of rainfall in India and Pakistan. *IJMG Vol.3 pp.1-16.*
58. Staff of the Institute of Tropical Meteorology, Poona. 1964: Meso-scale study of rainfall over Poona and neighbourhood. *IJMG Vol.15, pp.537-546.*
59. Srinivasan, V. and Ramakrishnan, A.R. 1970: Location of monsoon trough over India in the lower troposphere during July, August. *Symposium on Tropical Meteorology, Hawaii.*
60. Srinivasan, V., Raman, S. and Mukherji, S. 1971: Southwest Monsoon. Typical situations over Madhya Pradesh and Vidarbha. *IMD FMU Rep.No. III-3.4.*
61. Srinivasan, V. and Ramamurthy, K. 1973: Northeast Monsoon. *IMD FMU Rep. No. IV-18.4.*
62. Thiruvengadathan, A. 1972: Poona district rainfall. *IJMG Vol.23, pp.219-221.*
63. Walker, Gilbert, G. 1924: Frequency of heavy rainfall in India: *I.Met.D. Memoirs Vol.XXIII Part VII.*
64. Bhaskara Rao, N.S., Khambete, N.M. and Joshi, K.S. 1973: Satellite Clouding Associated with the Monsoon Trough. *IMD Pre-published Sc.Report No.199.*

DIAGRAMS

FIG. 2-1 MEAN MONTHLY RAINFALL CHARTS FOR INTERIOR PENINSULA

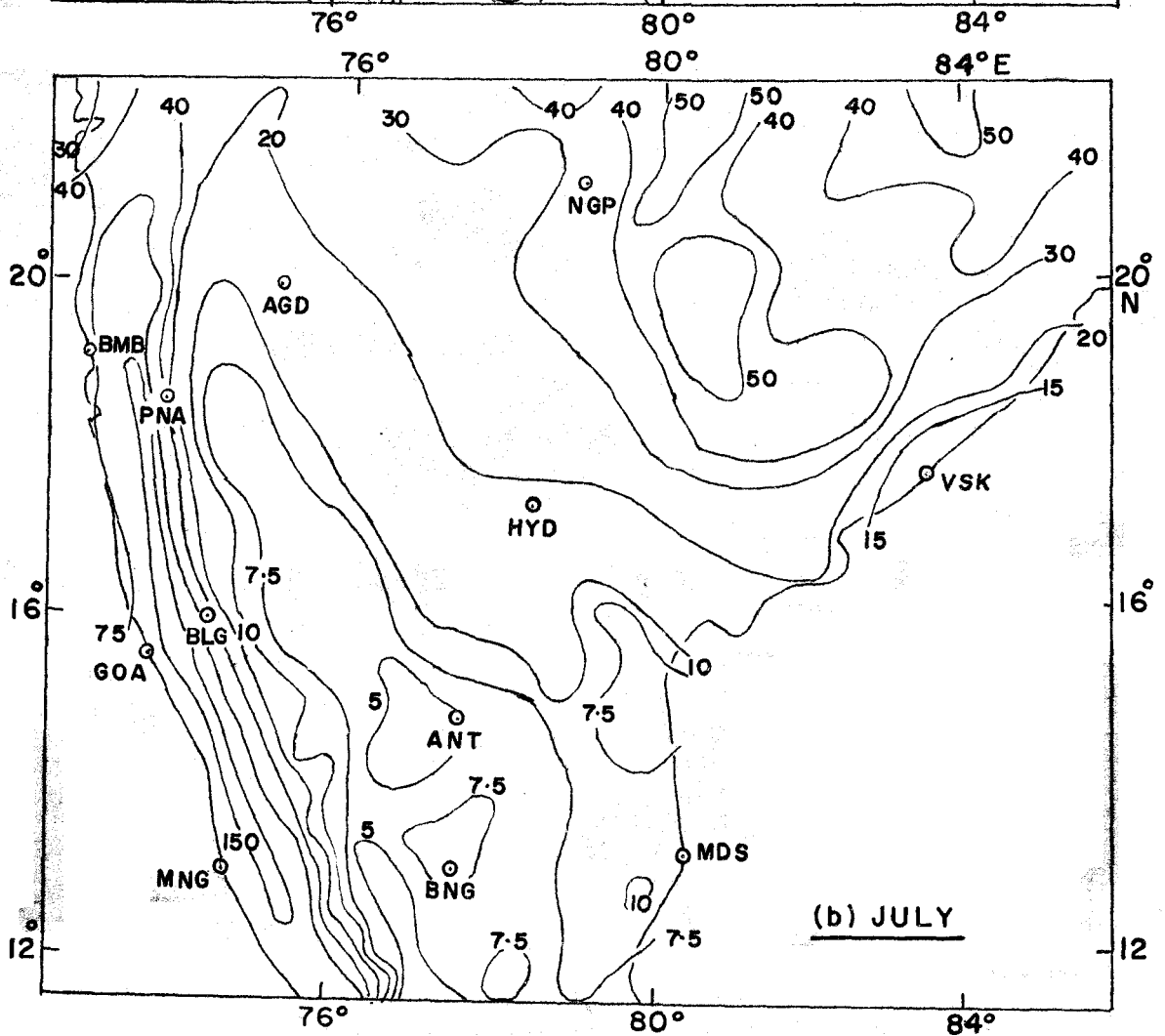
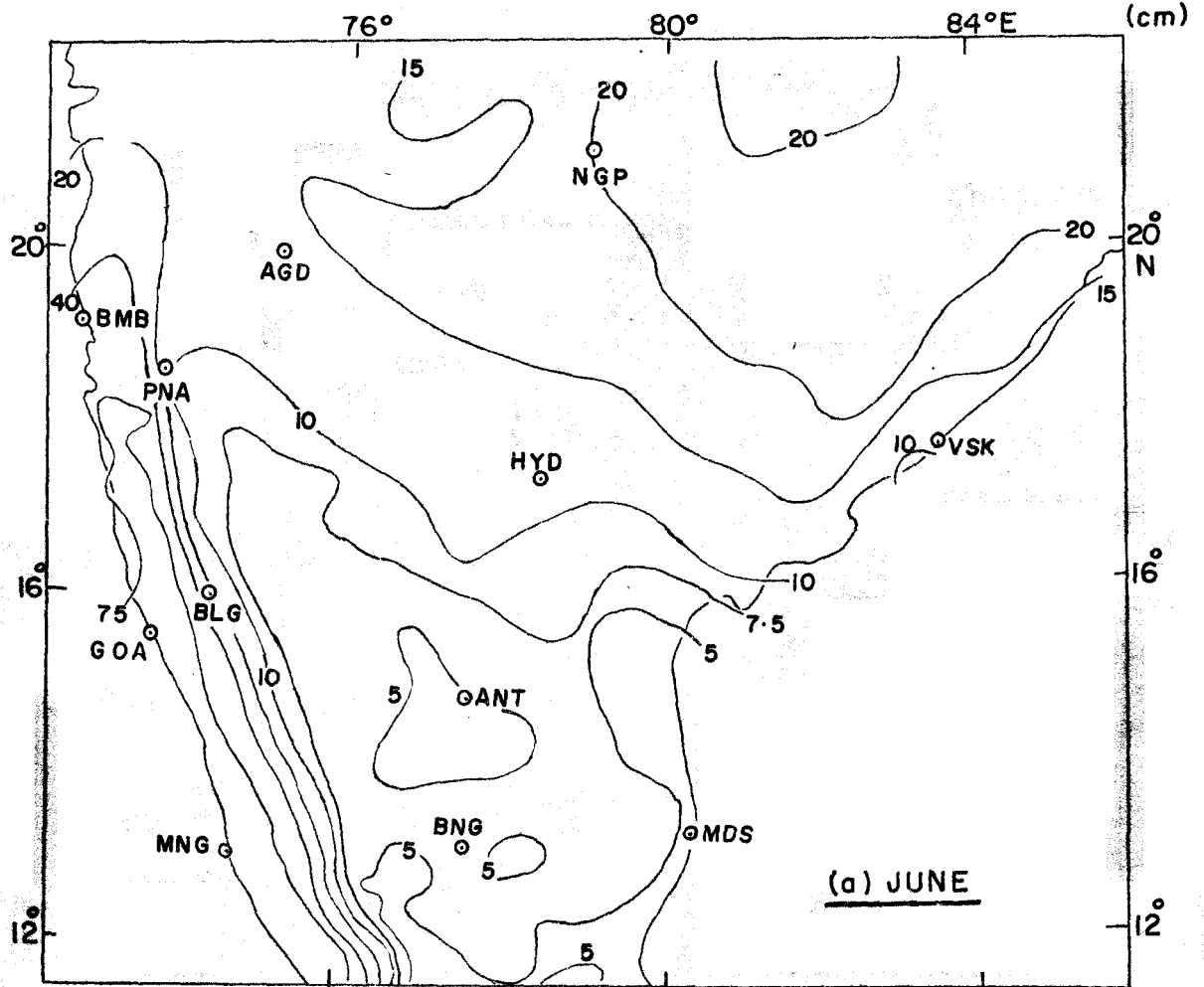
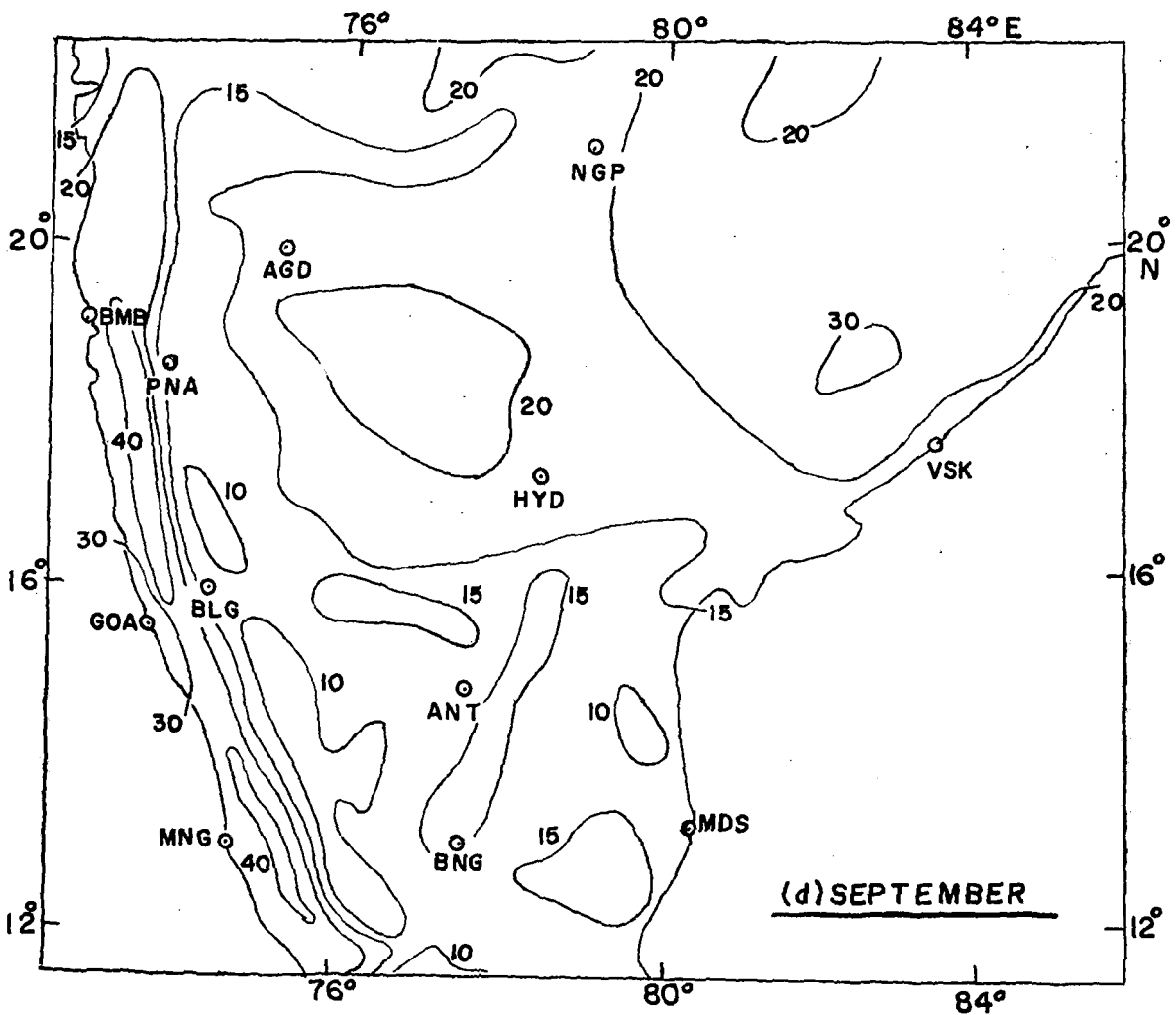
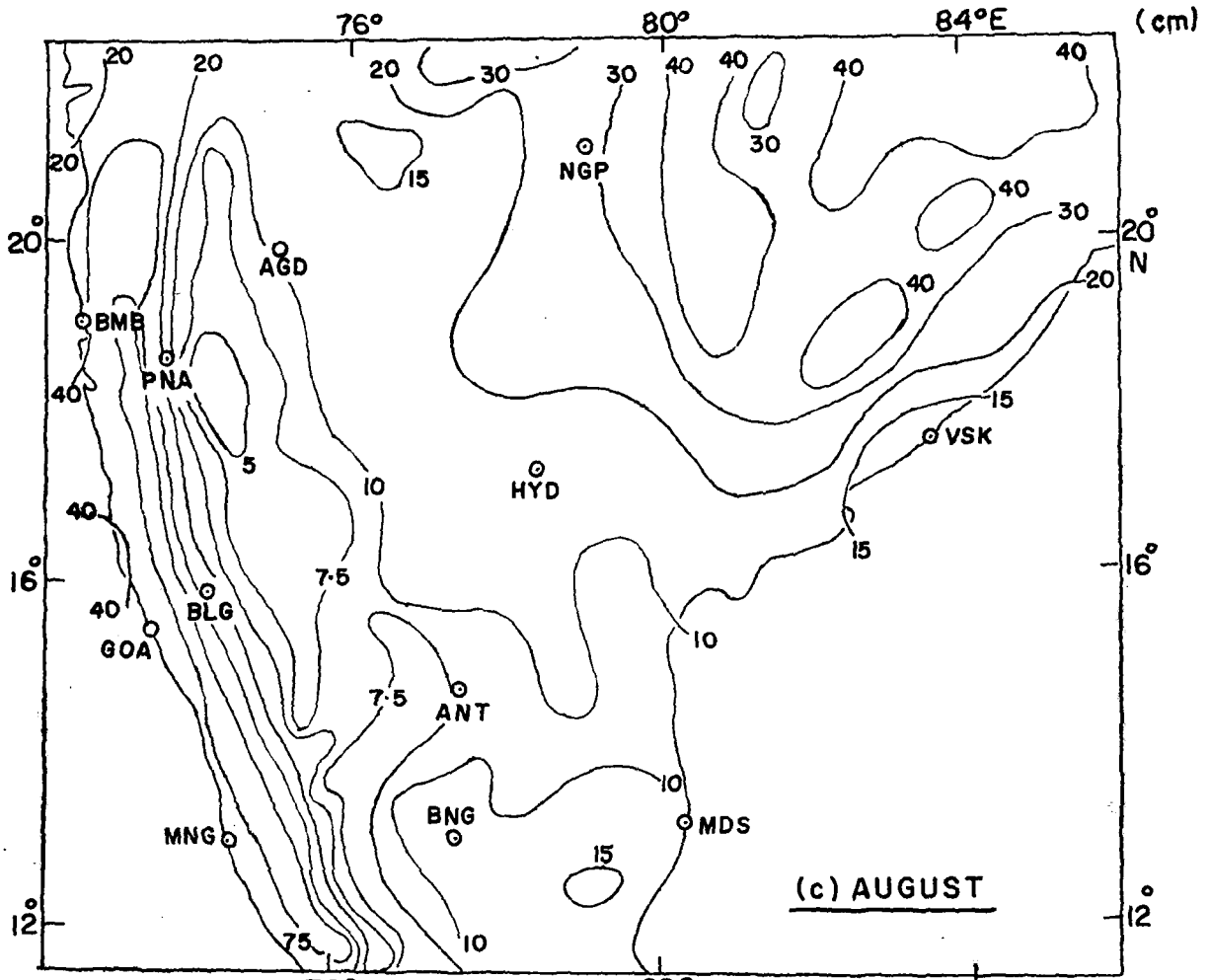


FIG. 2.1 MEAN MONTHLY RAINFALL CHARTS FOR INTERIOR PENINSULA



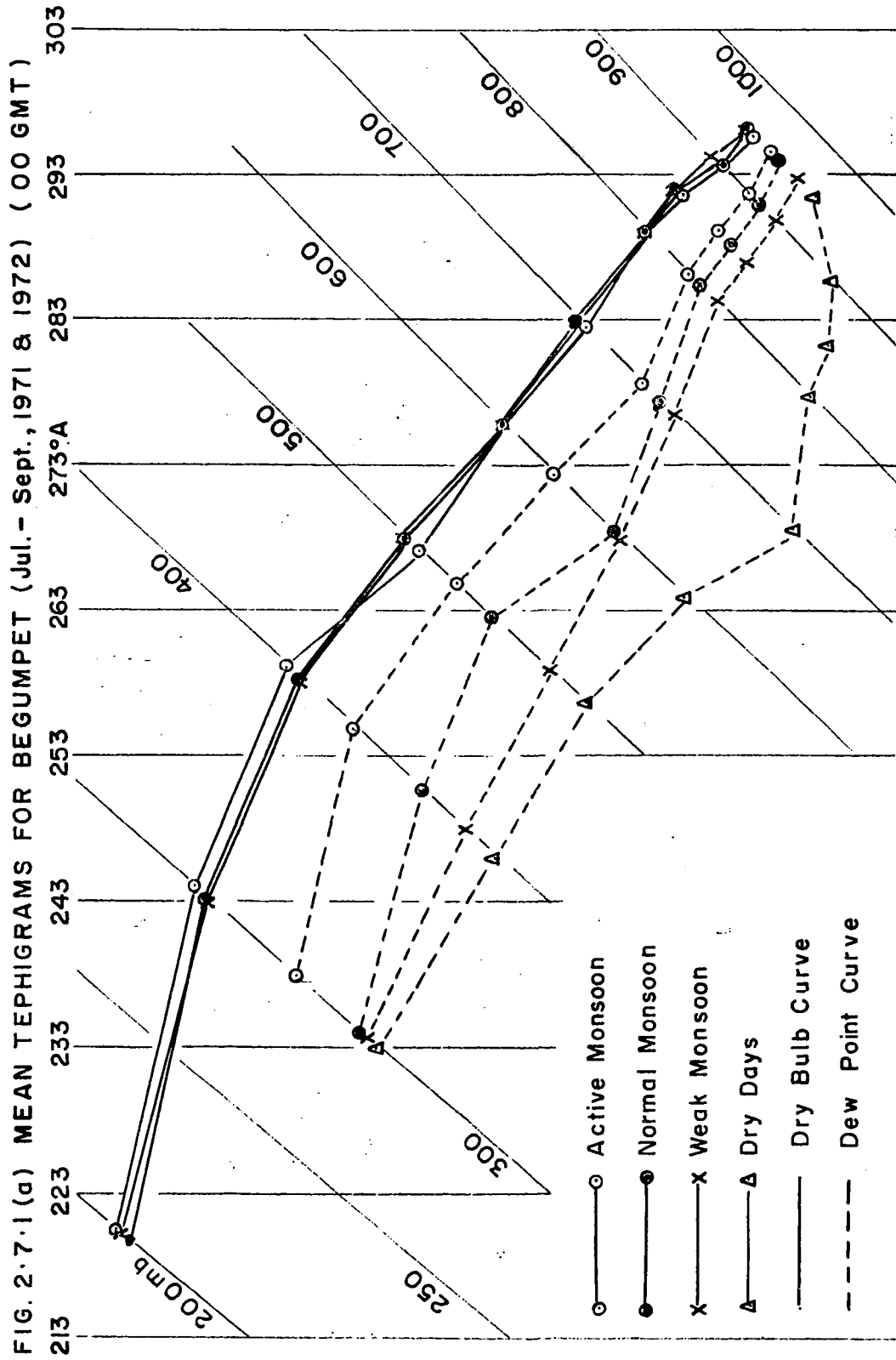


FIG. 2.7.1 (b) MEAN TEPHIGRAMS FOR VISAKHAPATNAM (Jul. - Sept., 1971 & 1972) (00GMT)

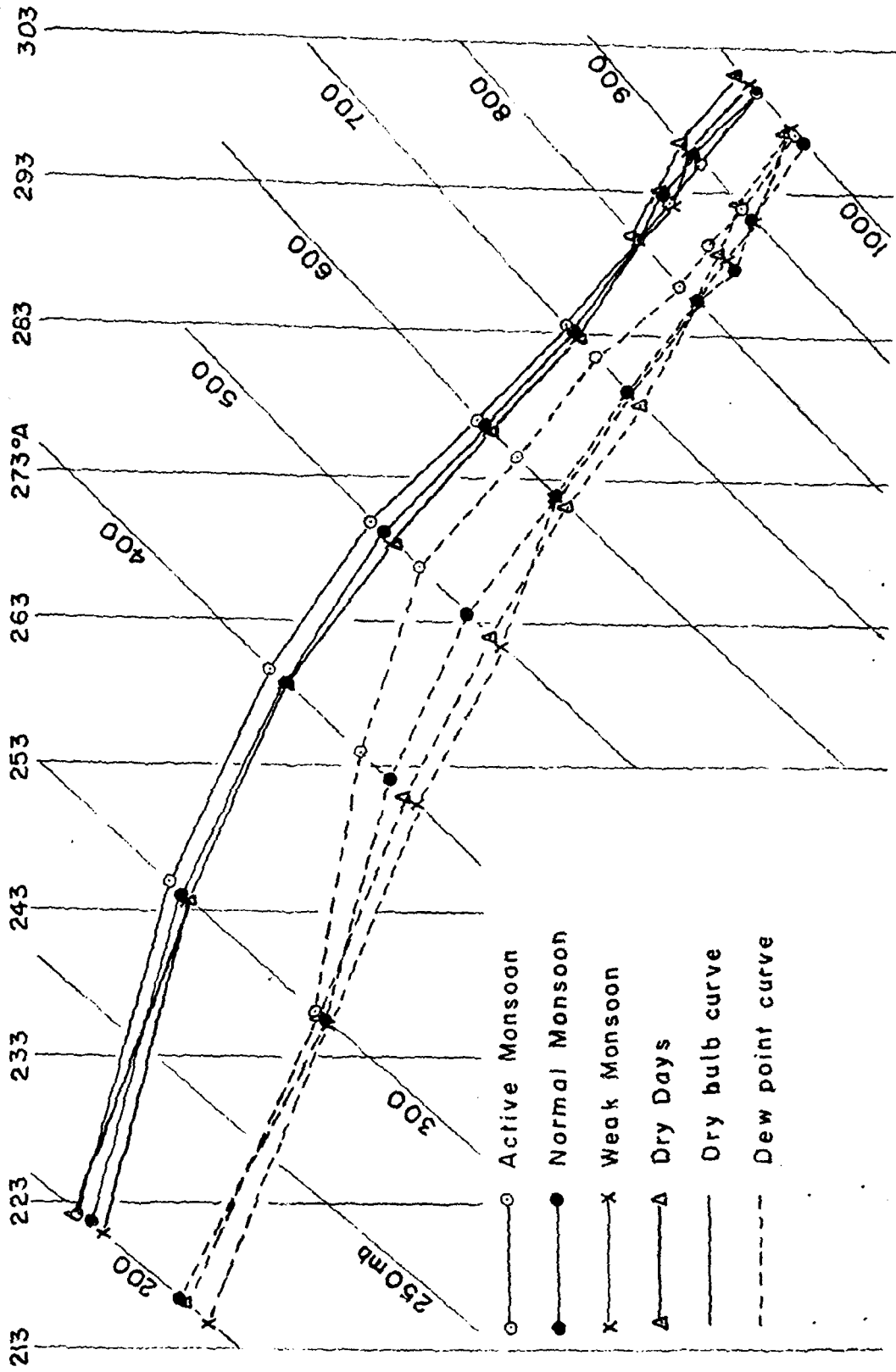


FIG. 2-7-2 (a) TYPICAL TEPHIGRAMS OF BEGUMPET (00 GMT)

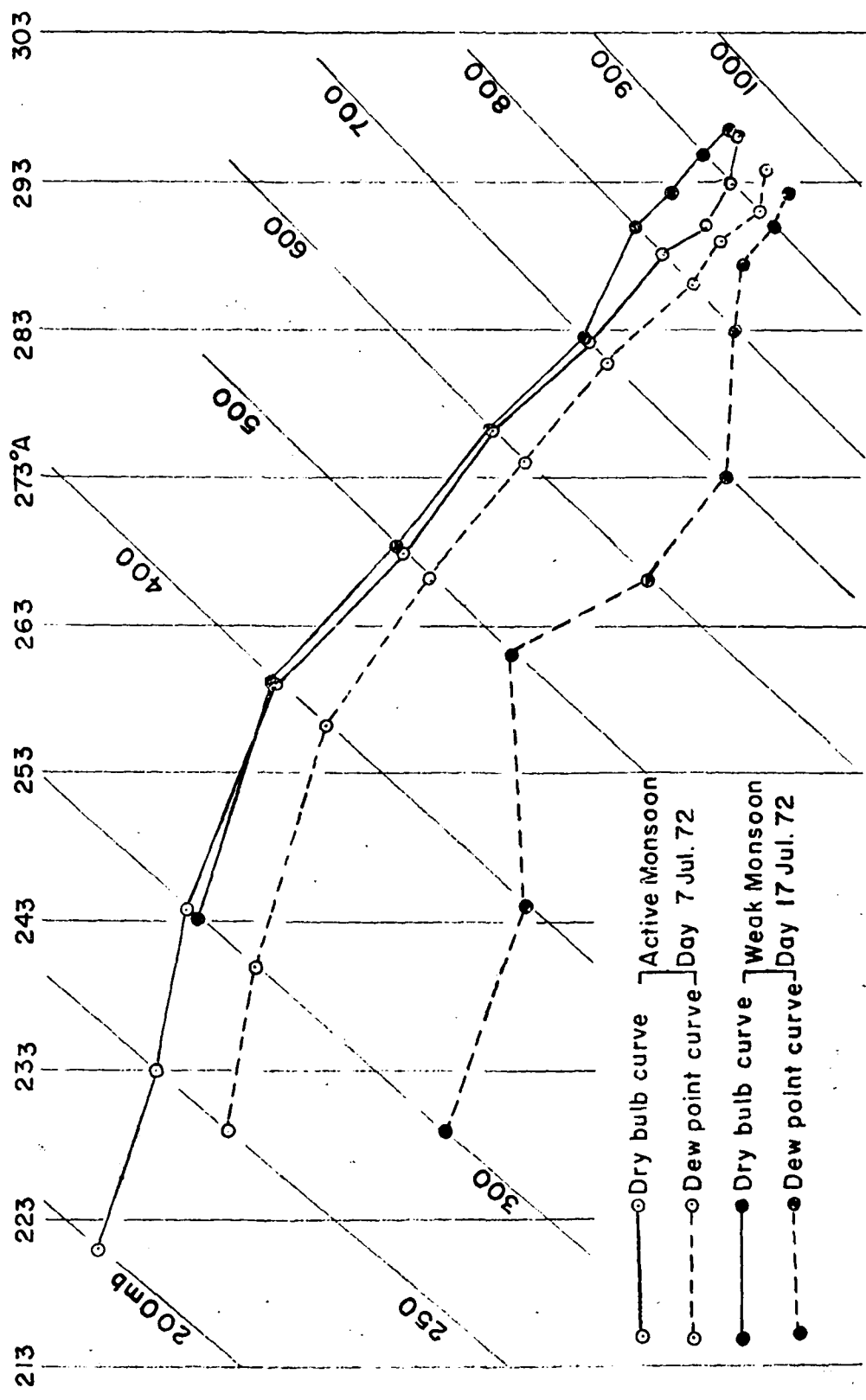


FIG. 2.7.2 (b) TYPICAL TEPHIGRAMS OF VISAKHAPATNAM (00 GMT)

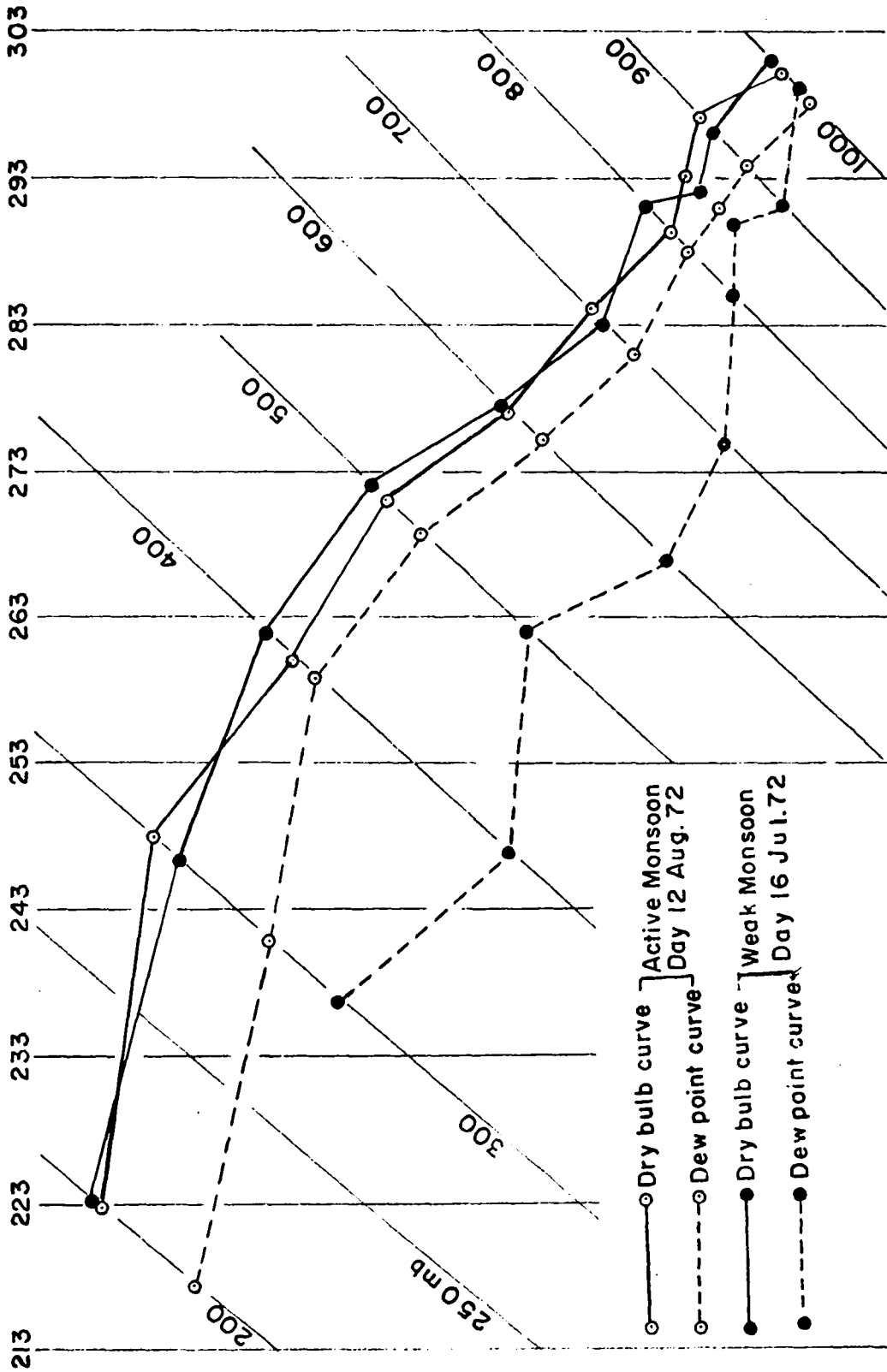


FIG. 5-1 SYNOPTIC CHARTS 0300 GMT 25 JUL. 67

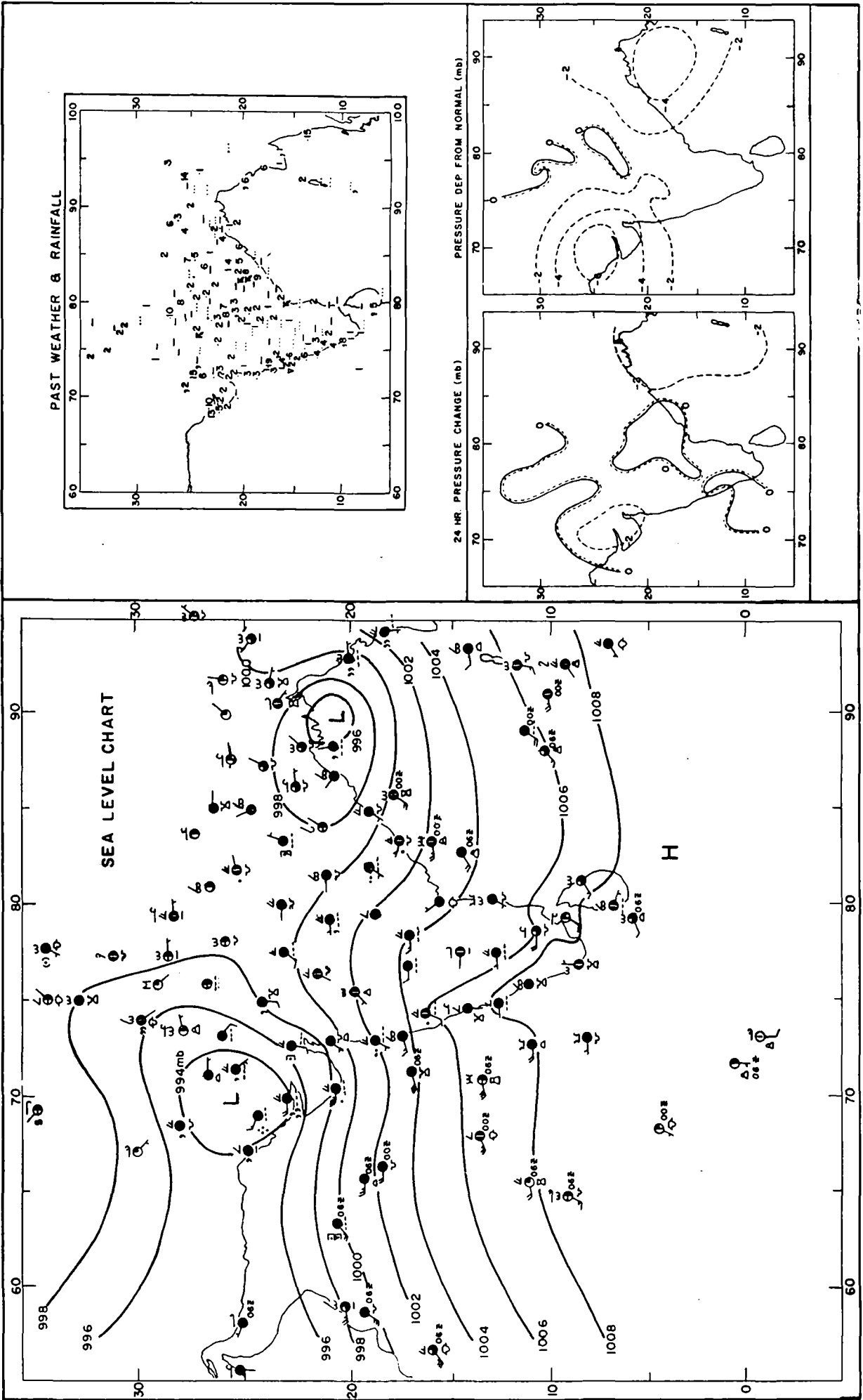
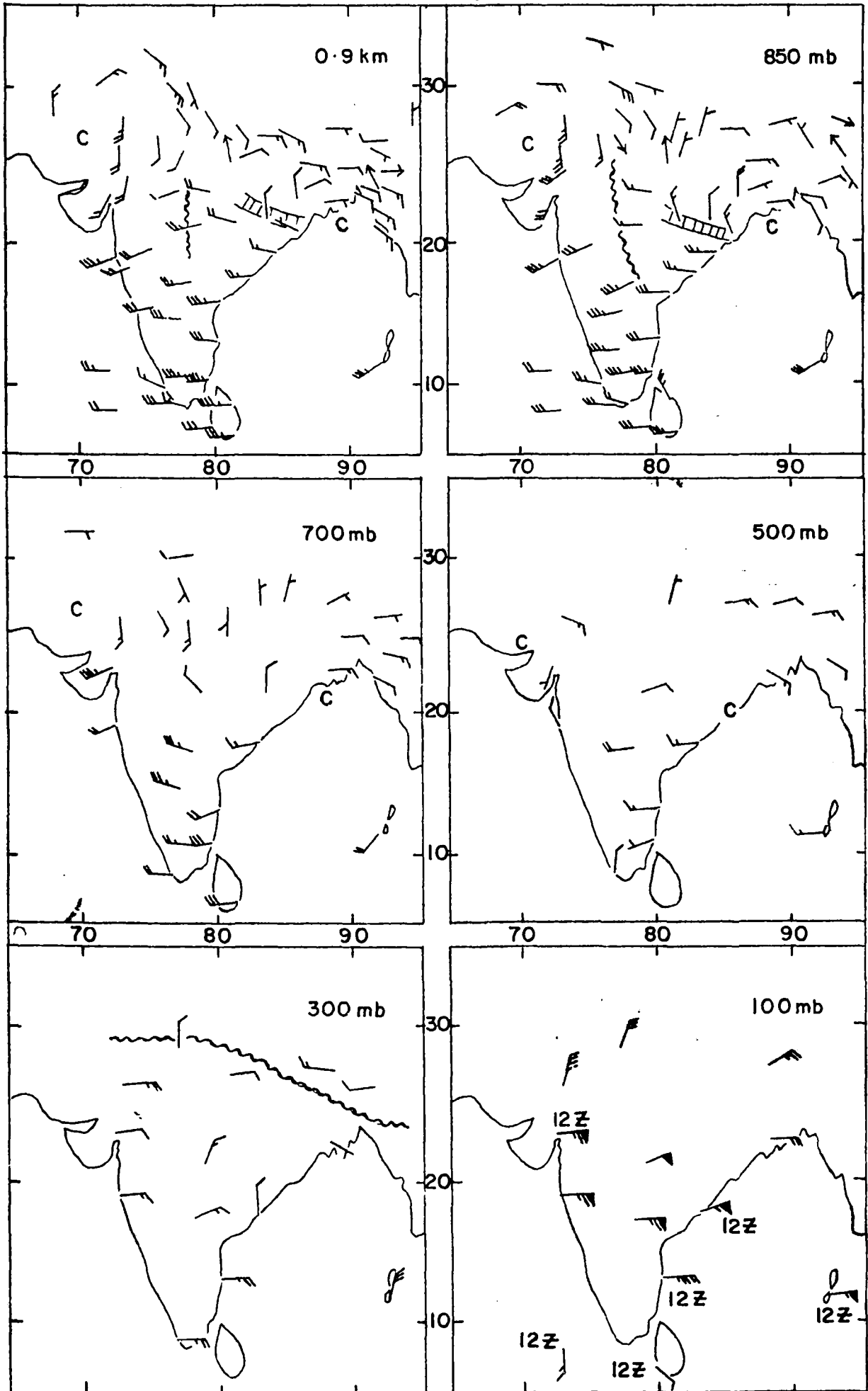
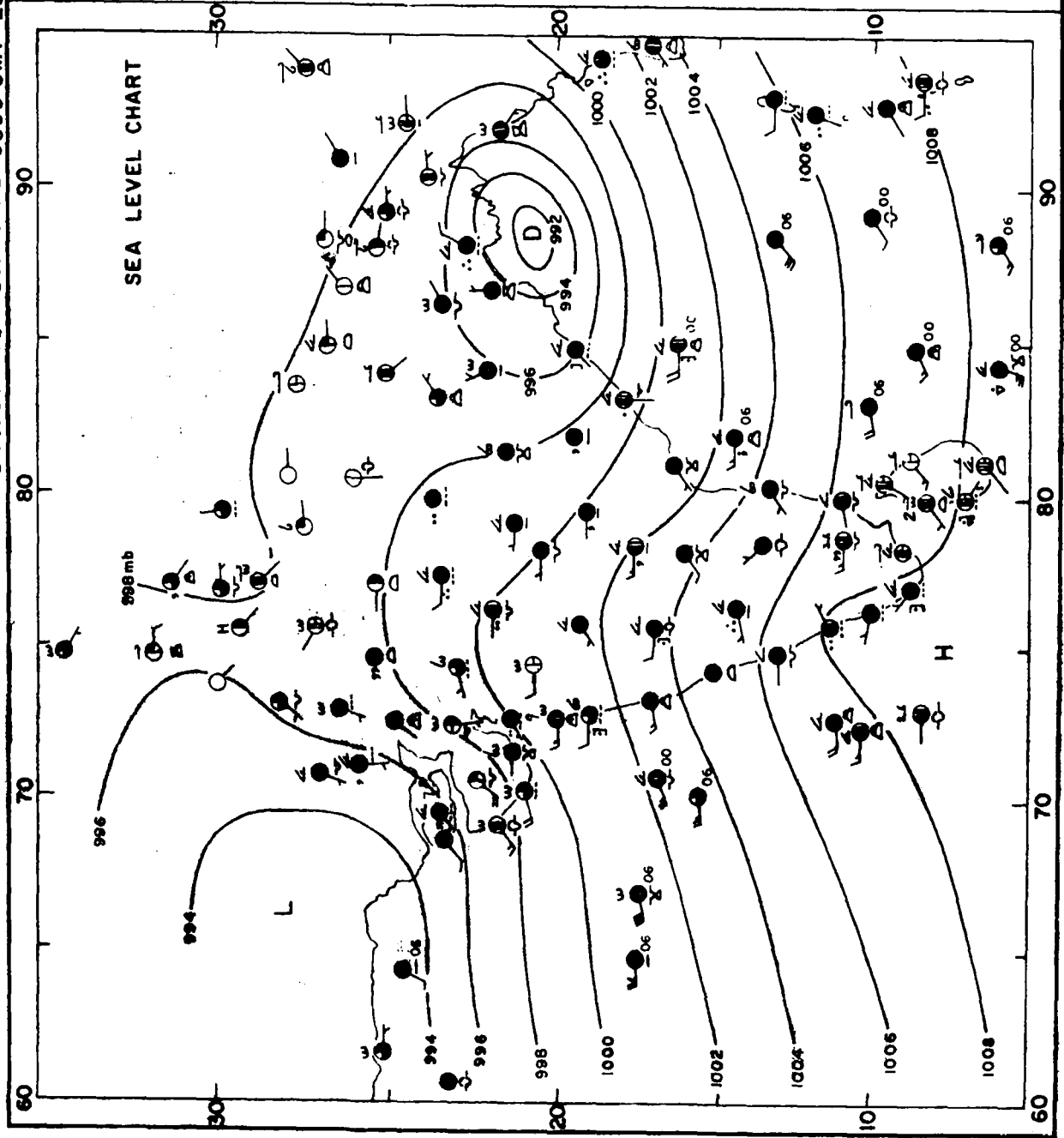


FIG. 5.2 UPPER WINDS 00 GMT 25 JUL. 67

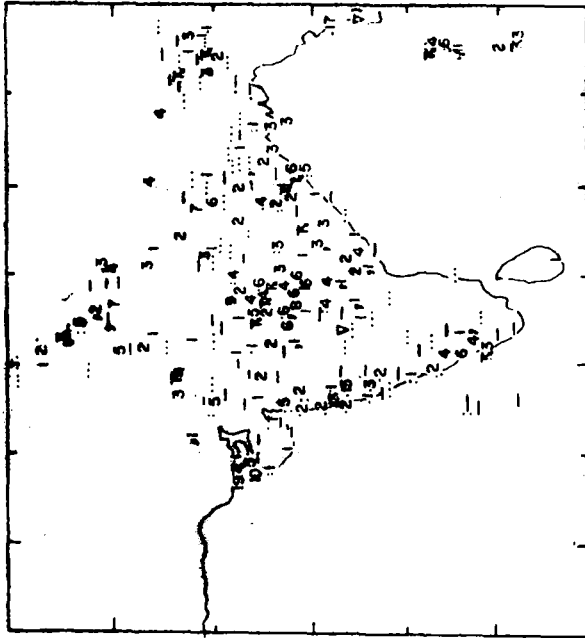


C-Centre of cyclonic circulation Z-Zone of Convergence ~~~~~ Ridge line

FIG. 5-3 SYNOPSIS CHARTS 0300 GMT 26 JUL 67



PAST WEATHER & RAINFALL



24 HR. PRESSURE CHANGE (mb) PRESSURE DEP. FROM NORMAL (mb)

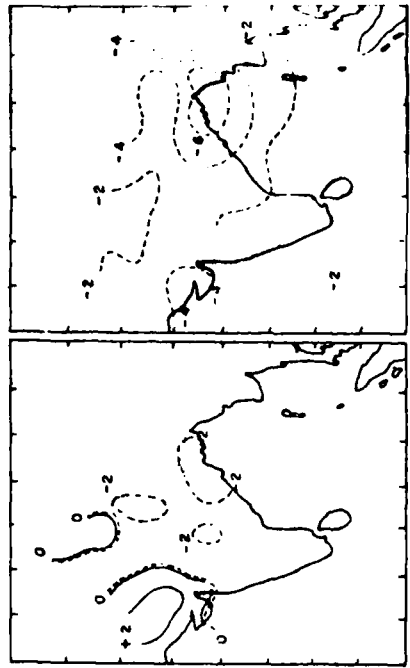
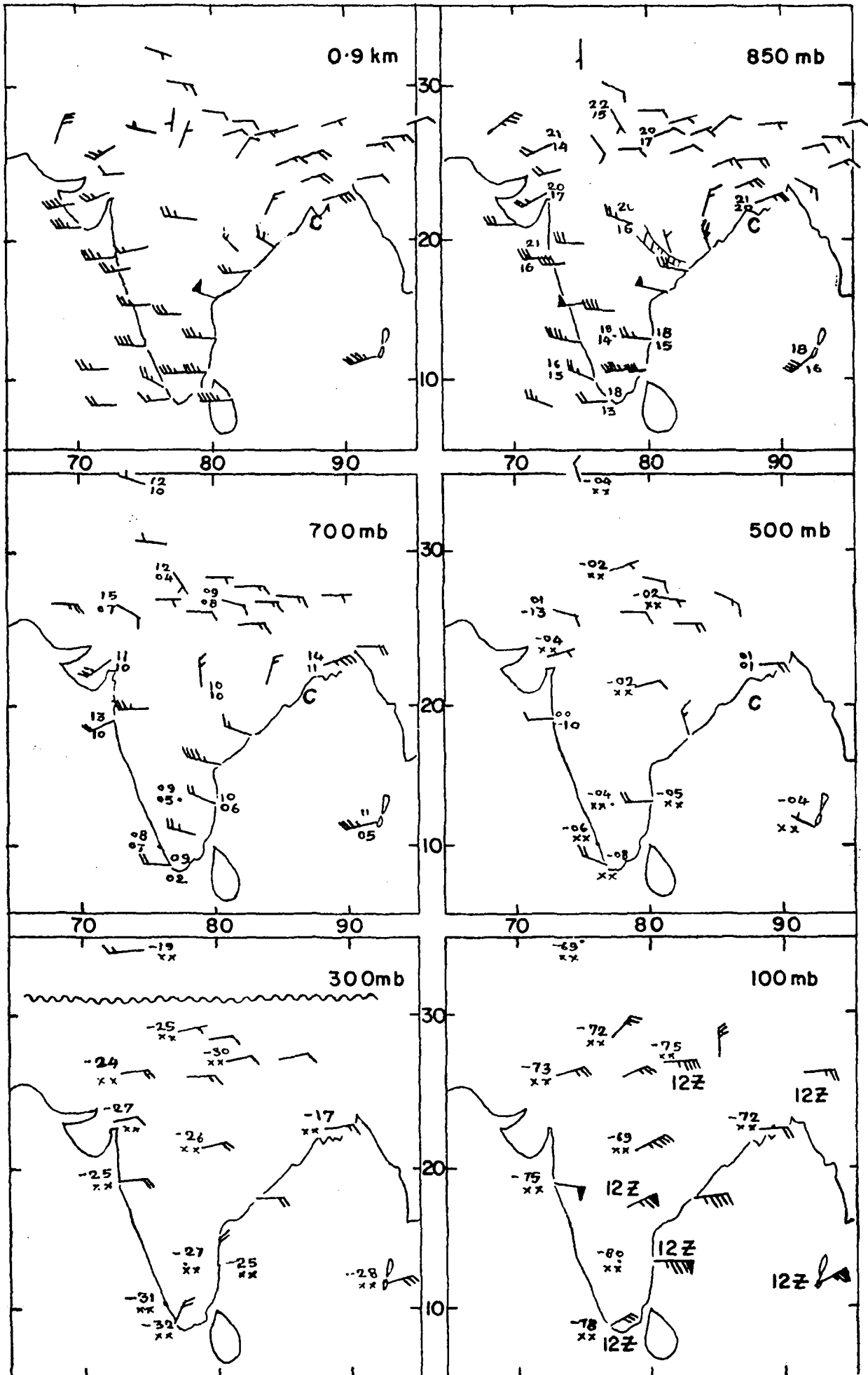


FIG. 5.4 UPPER WINDS OOGMT 26 JUL.67



C-Centre of cyclonic circulation **Z** Zone of Convergence **~** Ridge line
 Plotted figures TT & T_dT_d

FIG. 5.5 SYNOPSIS CHARTS 0300 GMT 27 JUL. 67

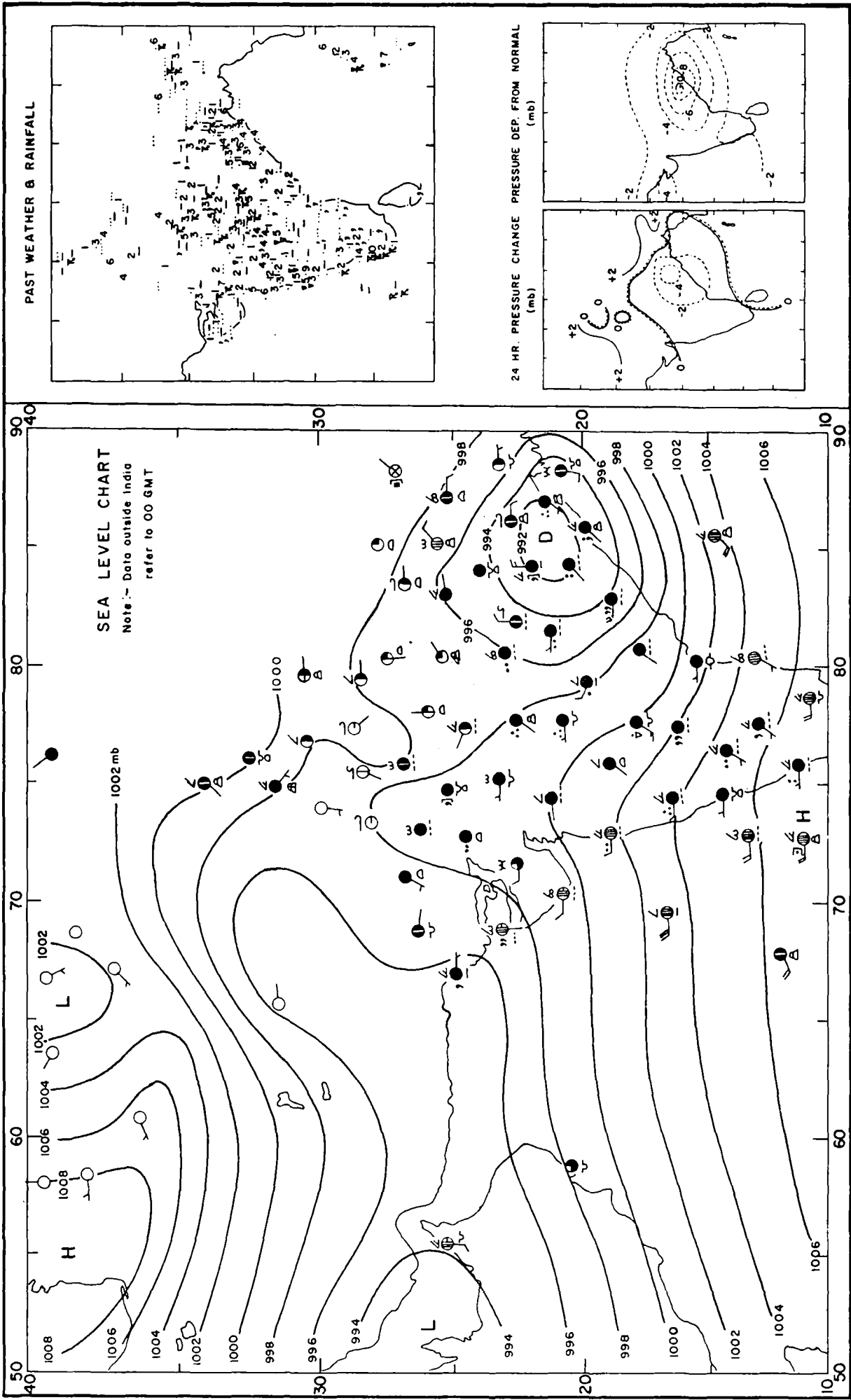
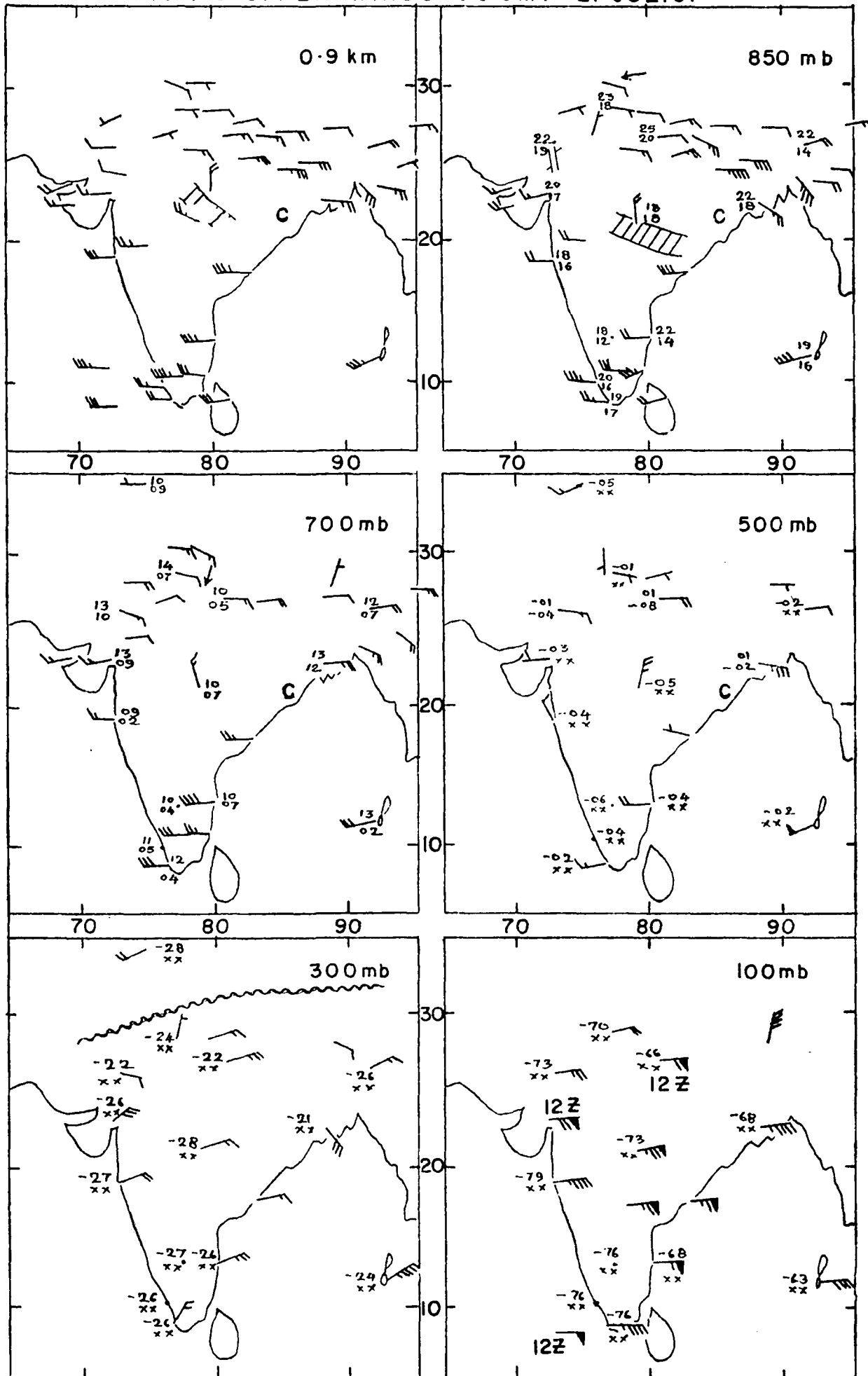


FIG. 5.6 UPPER WINDS 00GMT 27 JUL.67



C - Centre of cyclonic circulation **////** Zone of Convergence **~~~~~** Ridge line
 Plotted figures TT & T_dT_d

FIG. 5.7 SYNOPSIS CHARTS 0300 GMT 28 JUL. 67

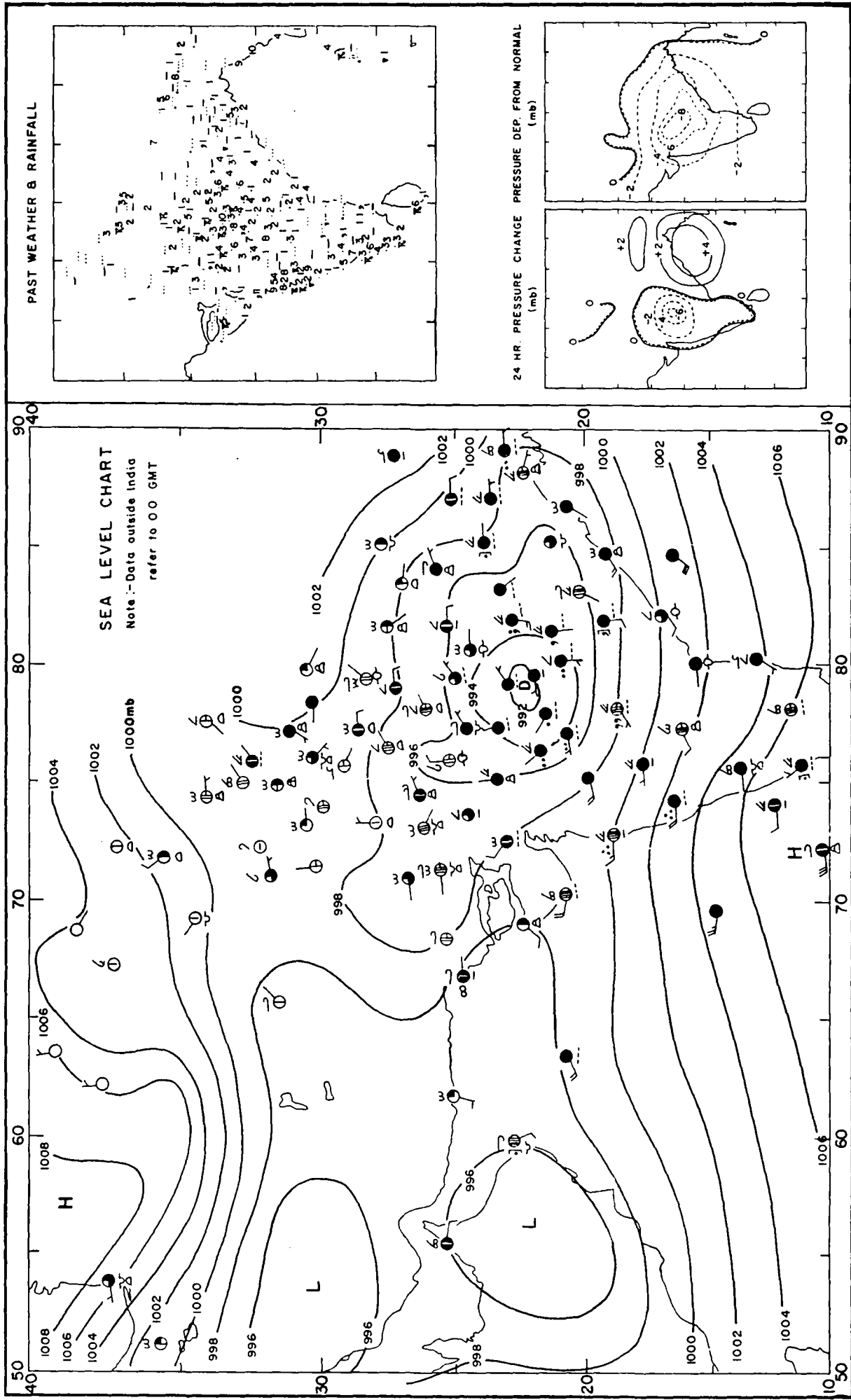
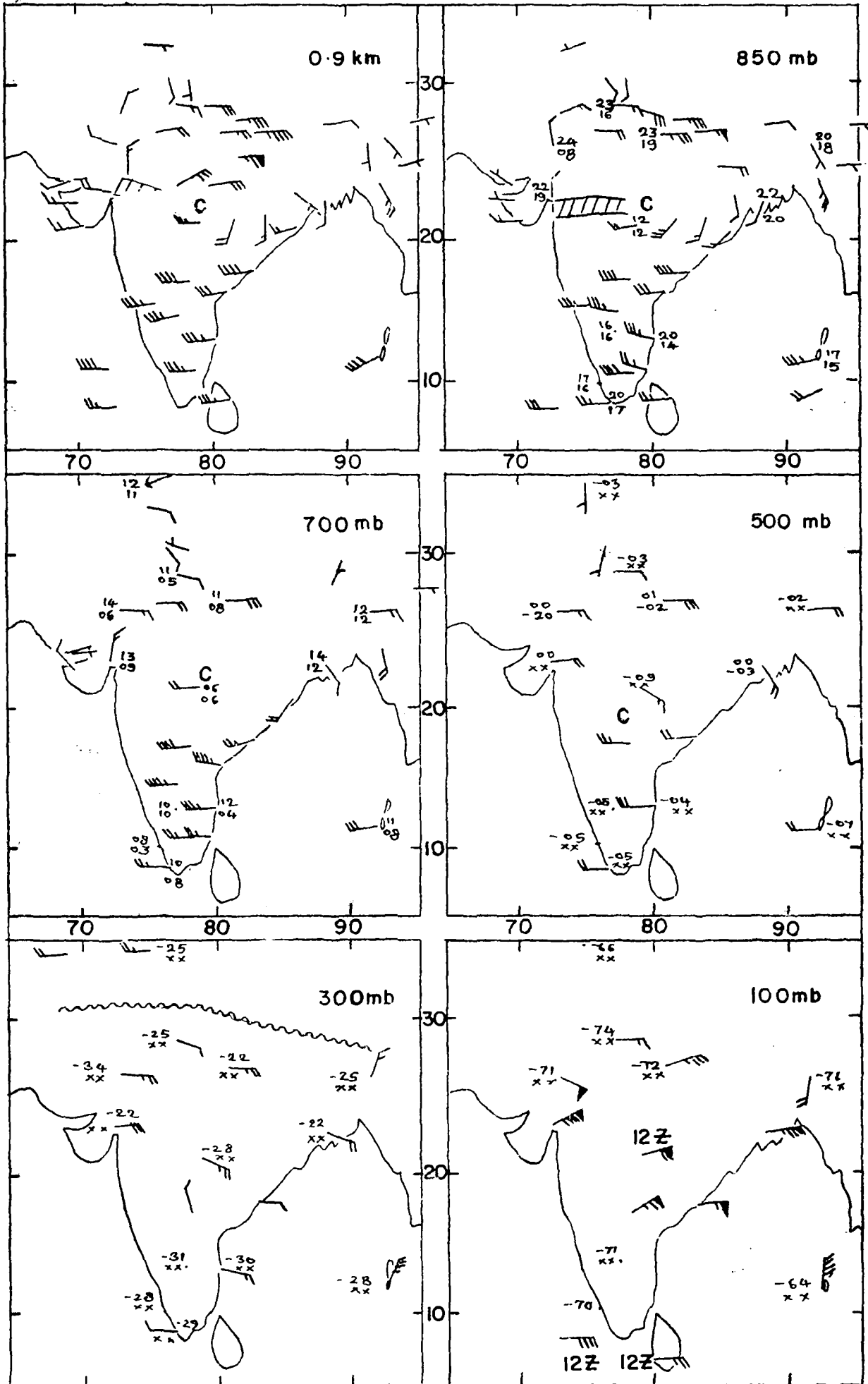


FIG.5.8 UPPER WINDS 00 GMT 28 JUL.67



C-Centre of cyclonic circulation |||| Zone of Convergence ~~~ Ridge line
 Plotted figures TT & T_dT_d

FIG. 5.9 SYNOPTIC CHARTS 0300 GMT 29 JUL.67

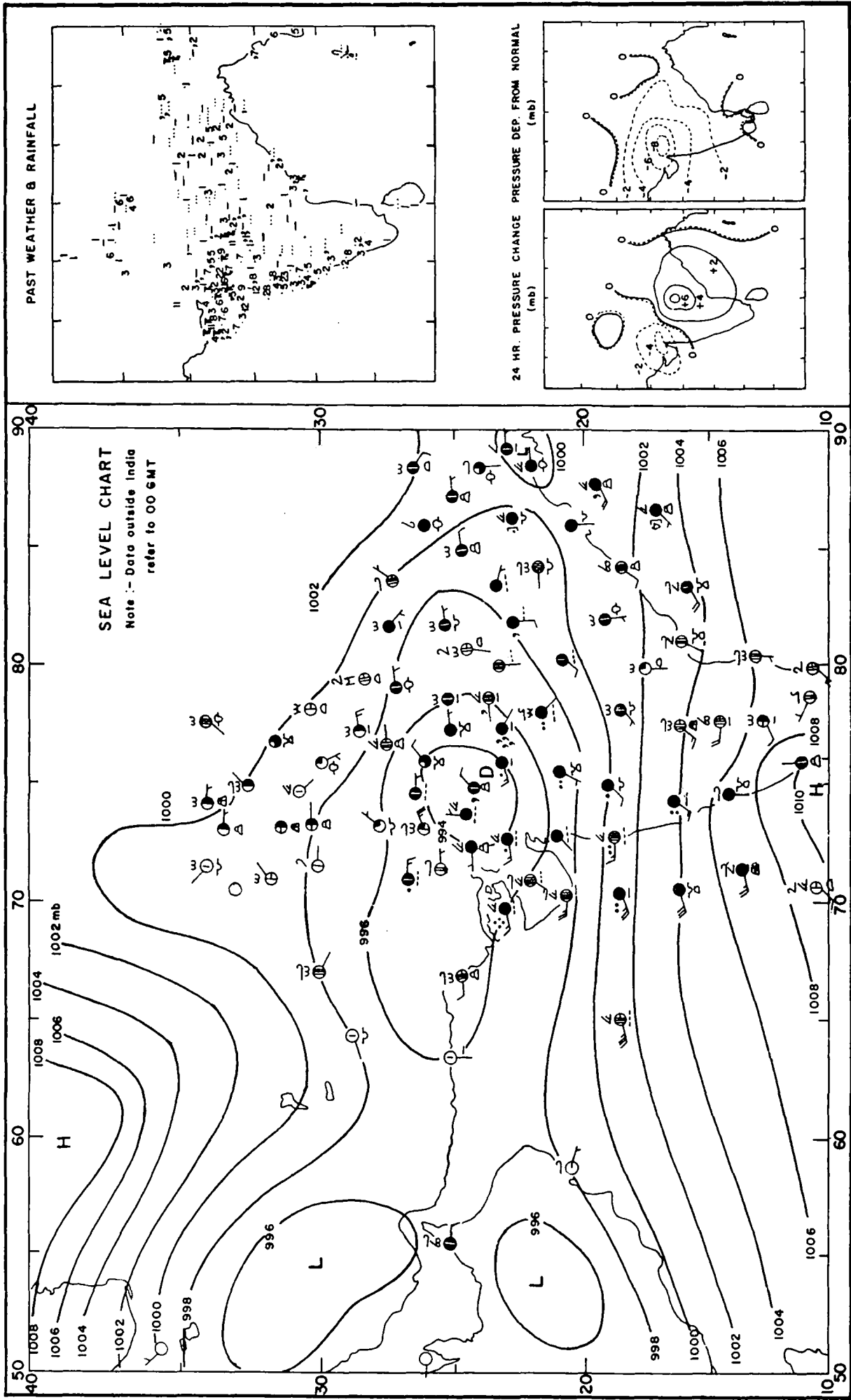


FIG. 5-10

ESSA - 2

26 JULY 67

ORBIT 6501

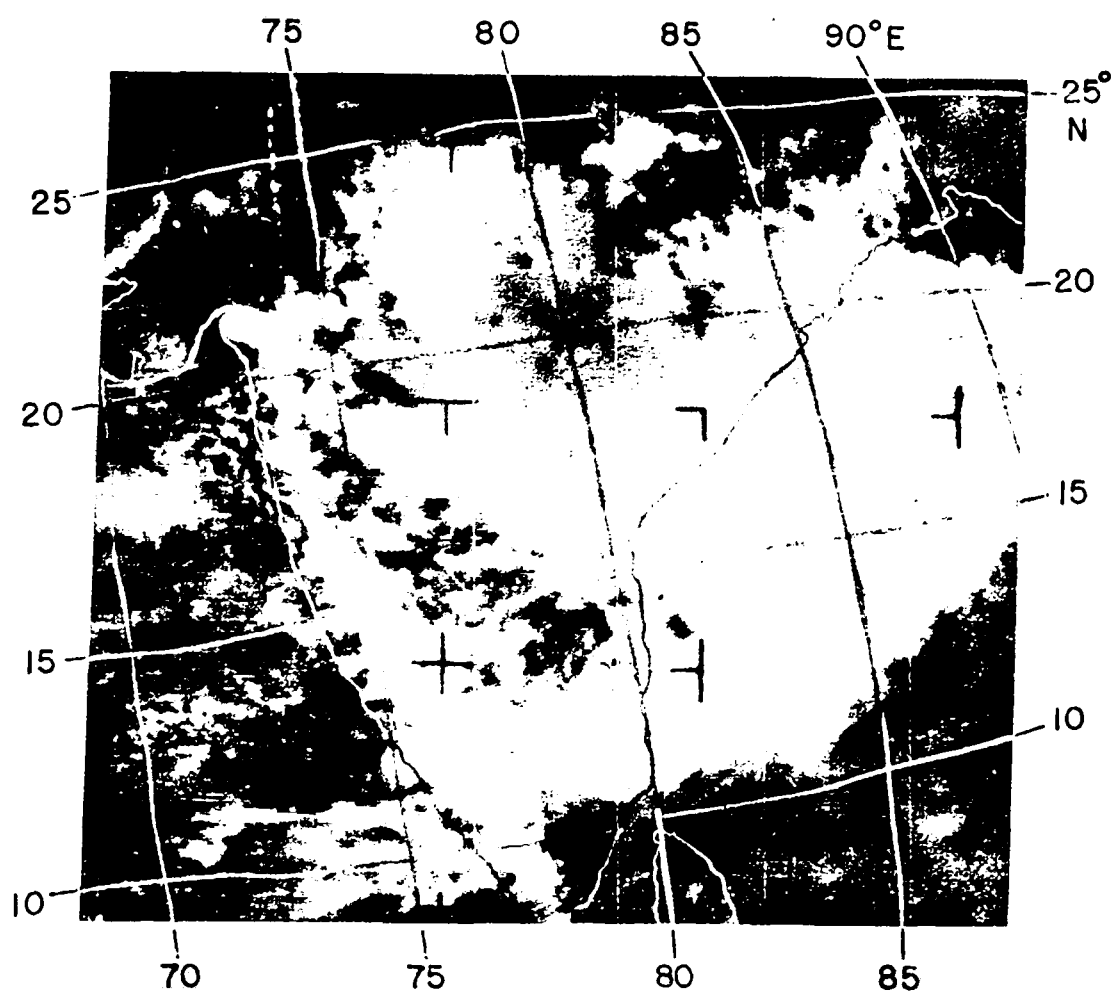


FIG. 5·11
NIMBUS - 2

28 JUL. 67

ORBIT 5844

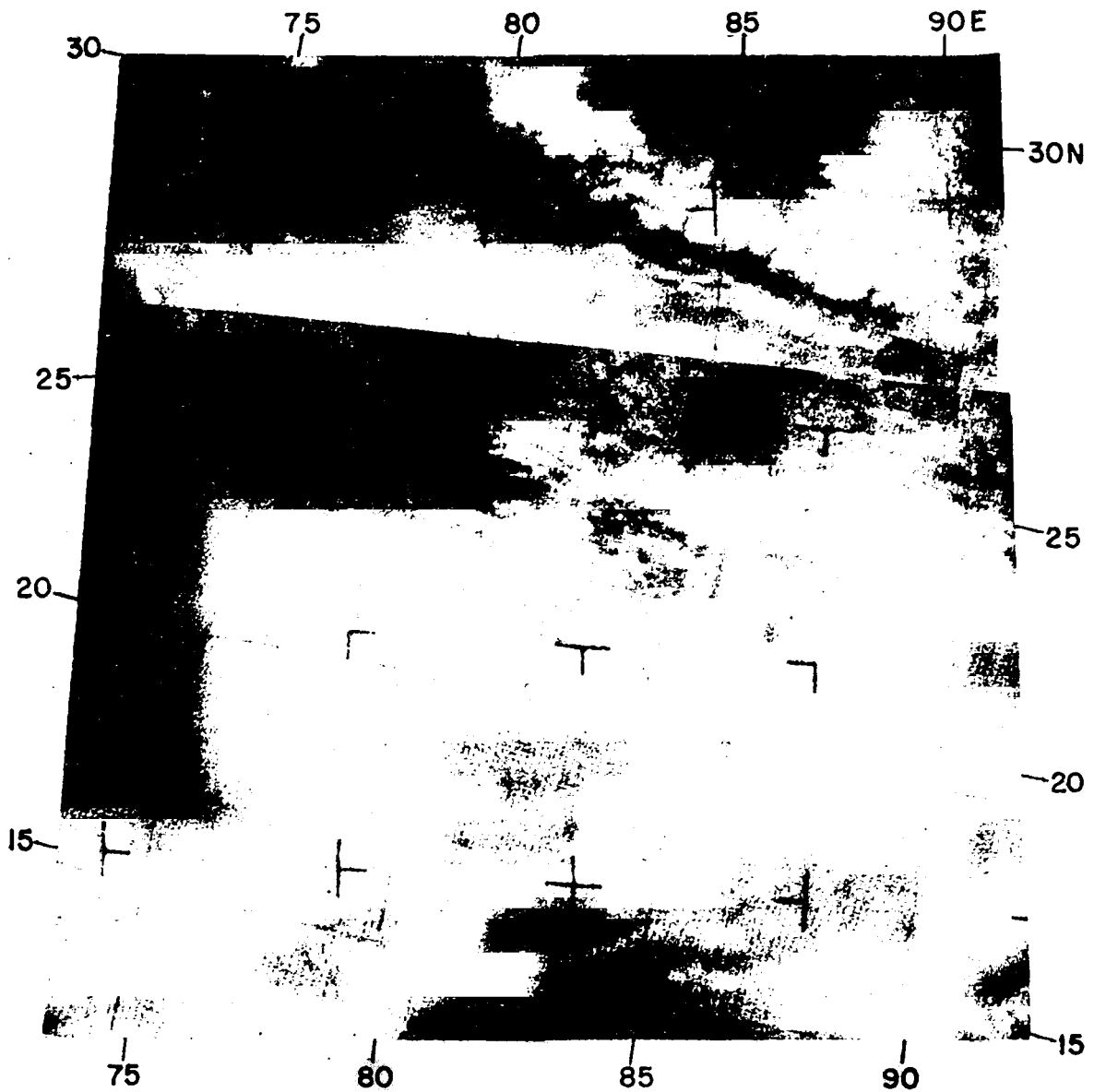
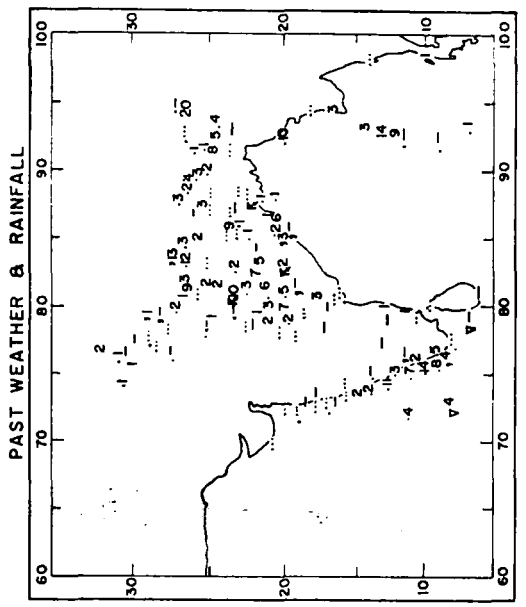
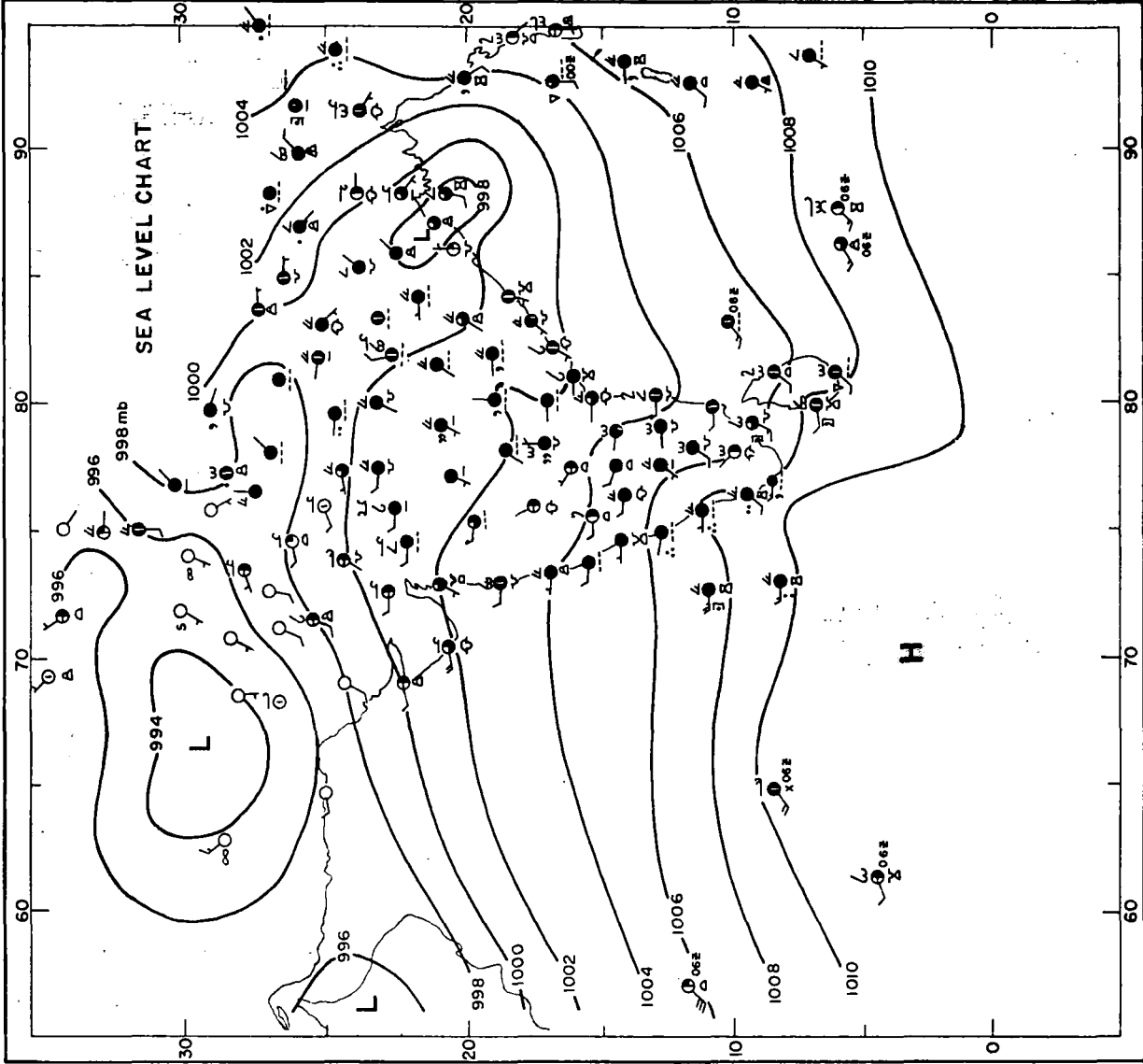
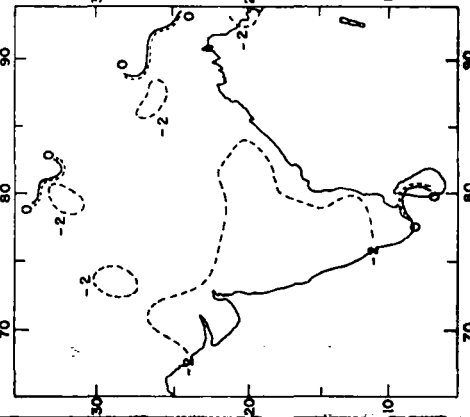


FIG. 6-1 SYNOPTIC CHARTS 0300 GMT 17 JUL. 68



24 HR. PRESSURE CHANGE (mb)



PRESSURE DEP FROM NORMAL (mb)

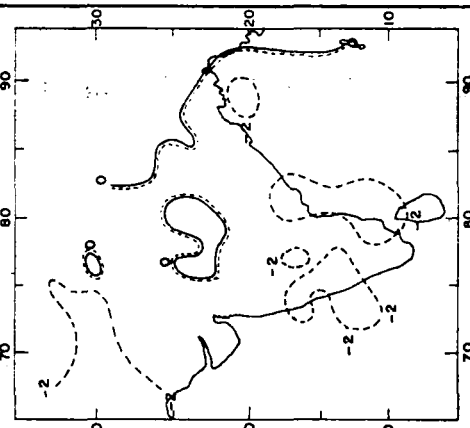
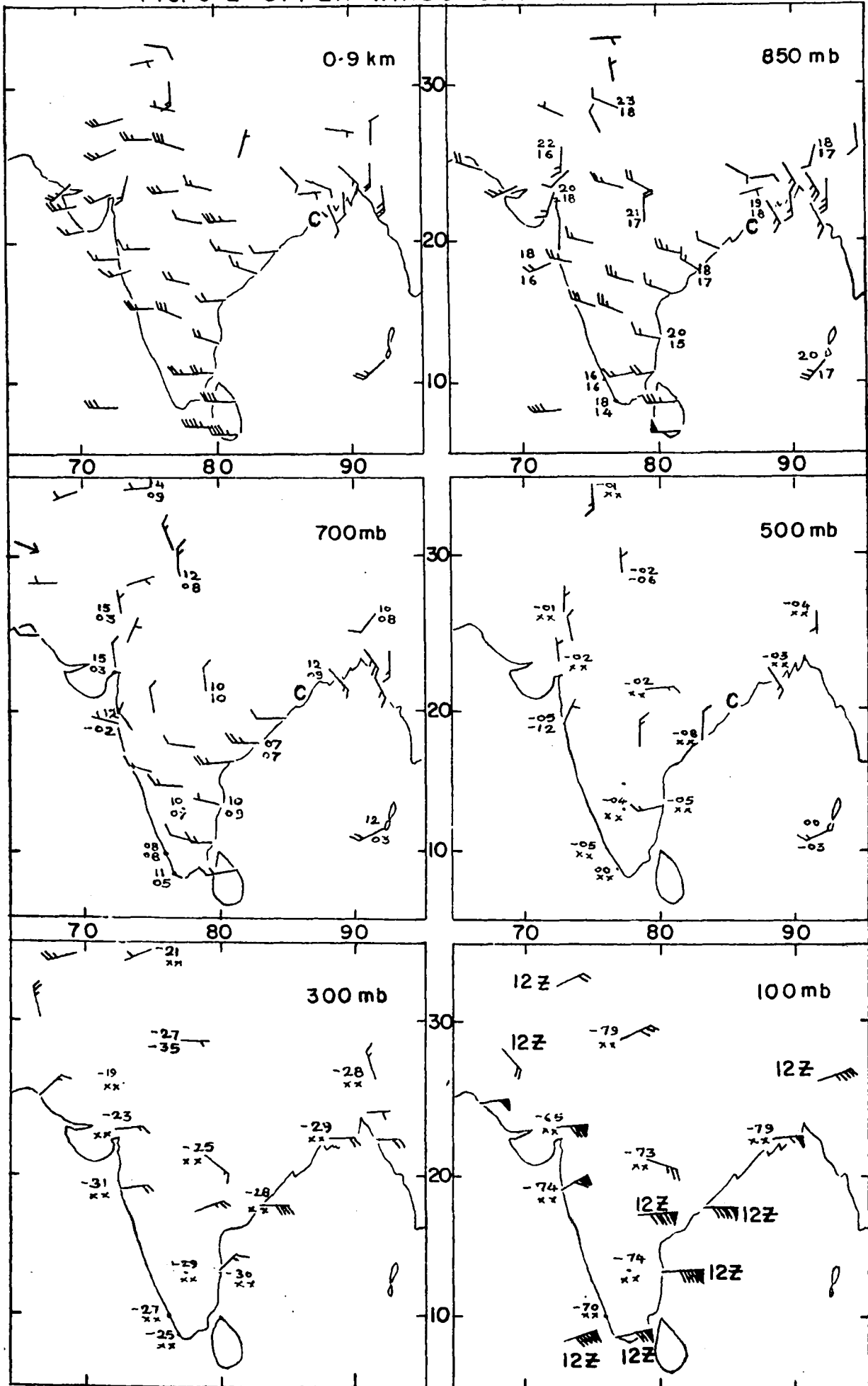


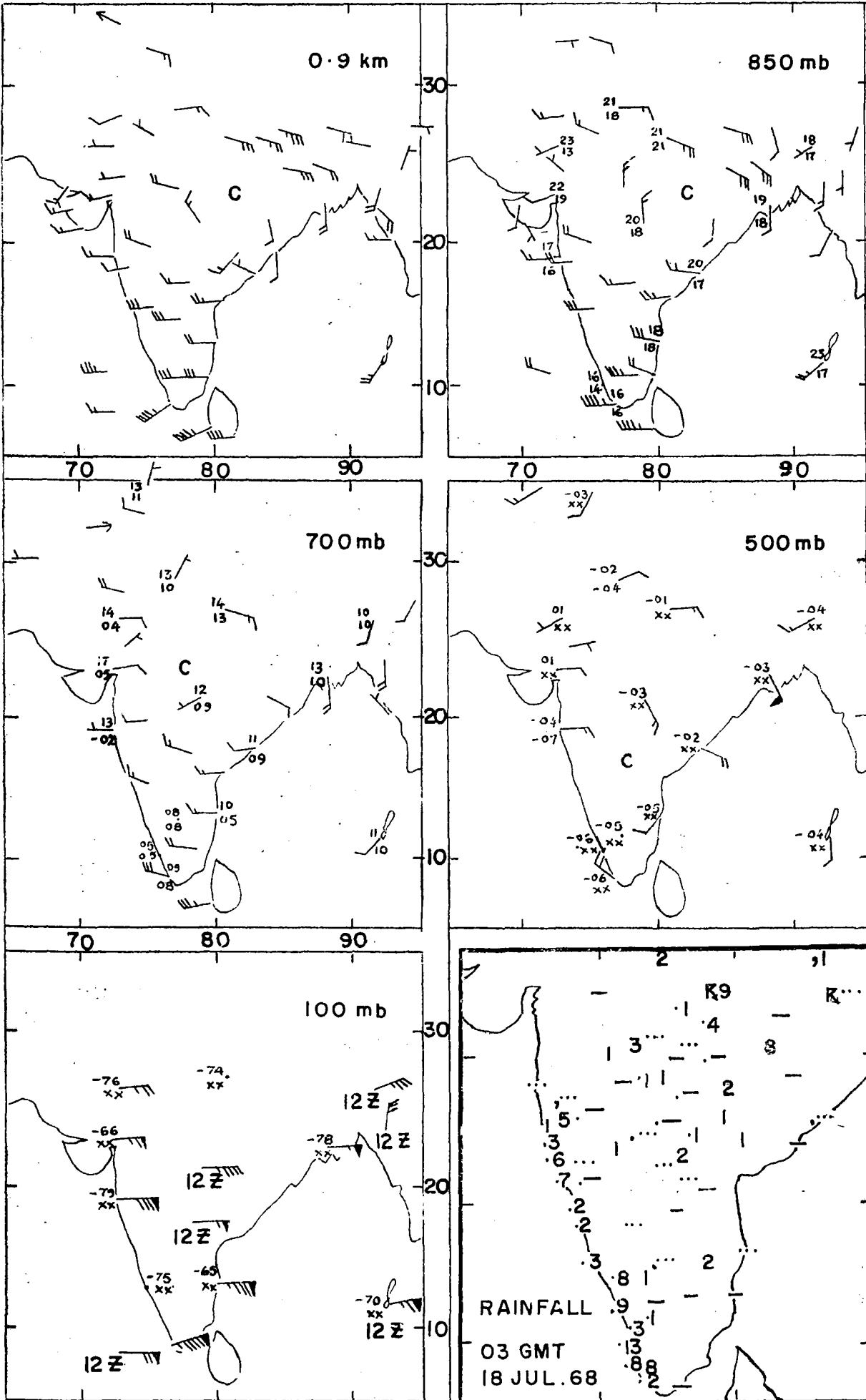
FIG. 6.2 UPPER WINDS OOGMT 17 JUL. 68



C - Centre of cyclonic circulation

Plotted figures TT & T_d

FIG. 6-3 UPPER WINDS 00 GMT 18 JUL. 68



C-Centre of cyclonic circulation

Plotted figures TT & T_dT_d

FIG. 6.4 SYNOPTIC CHARTS 0300 GMT 19 JUL. 68

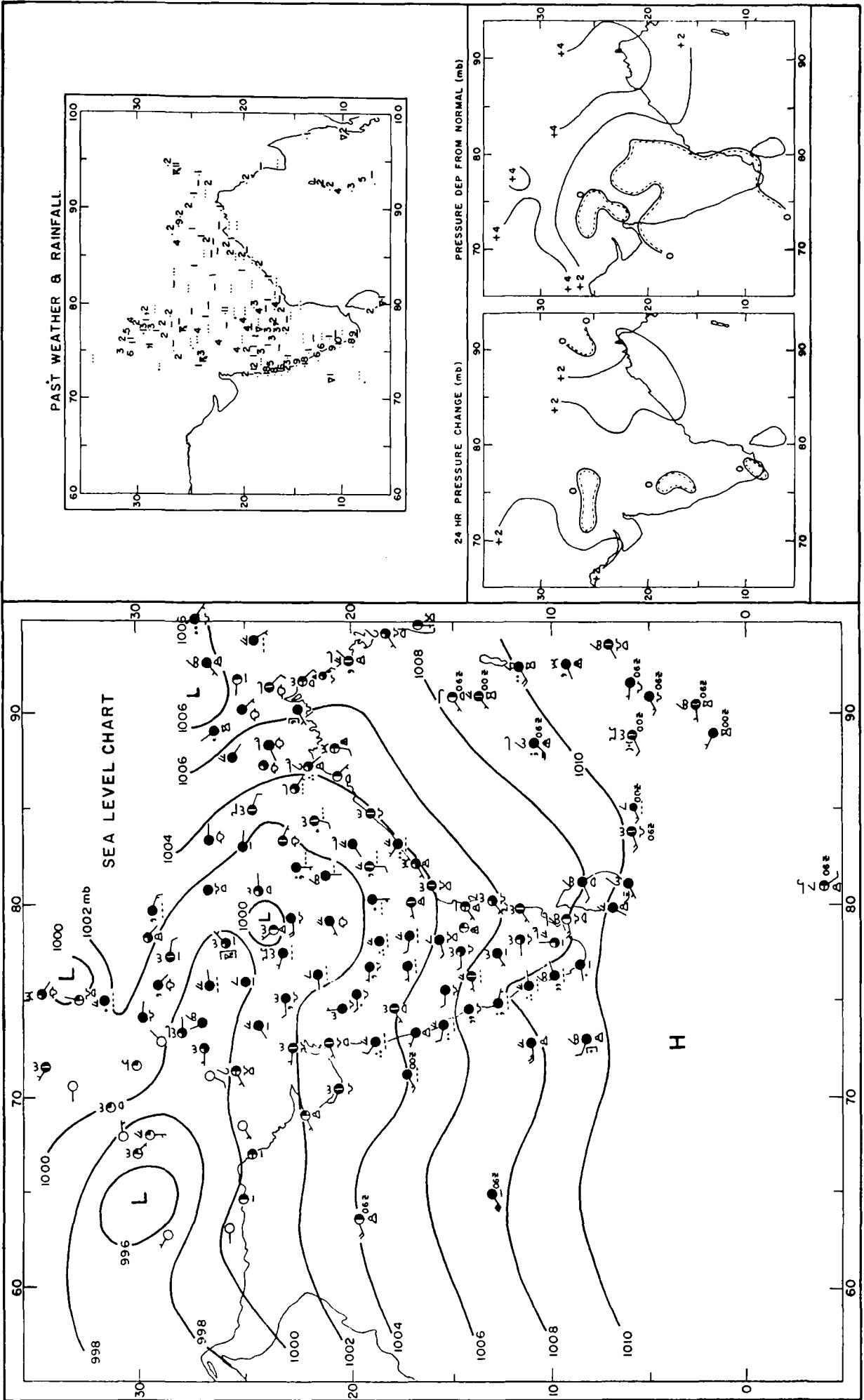
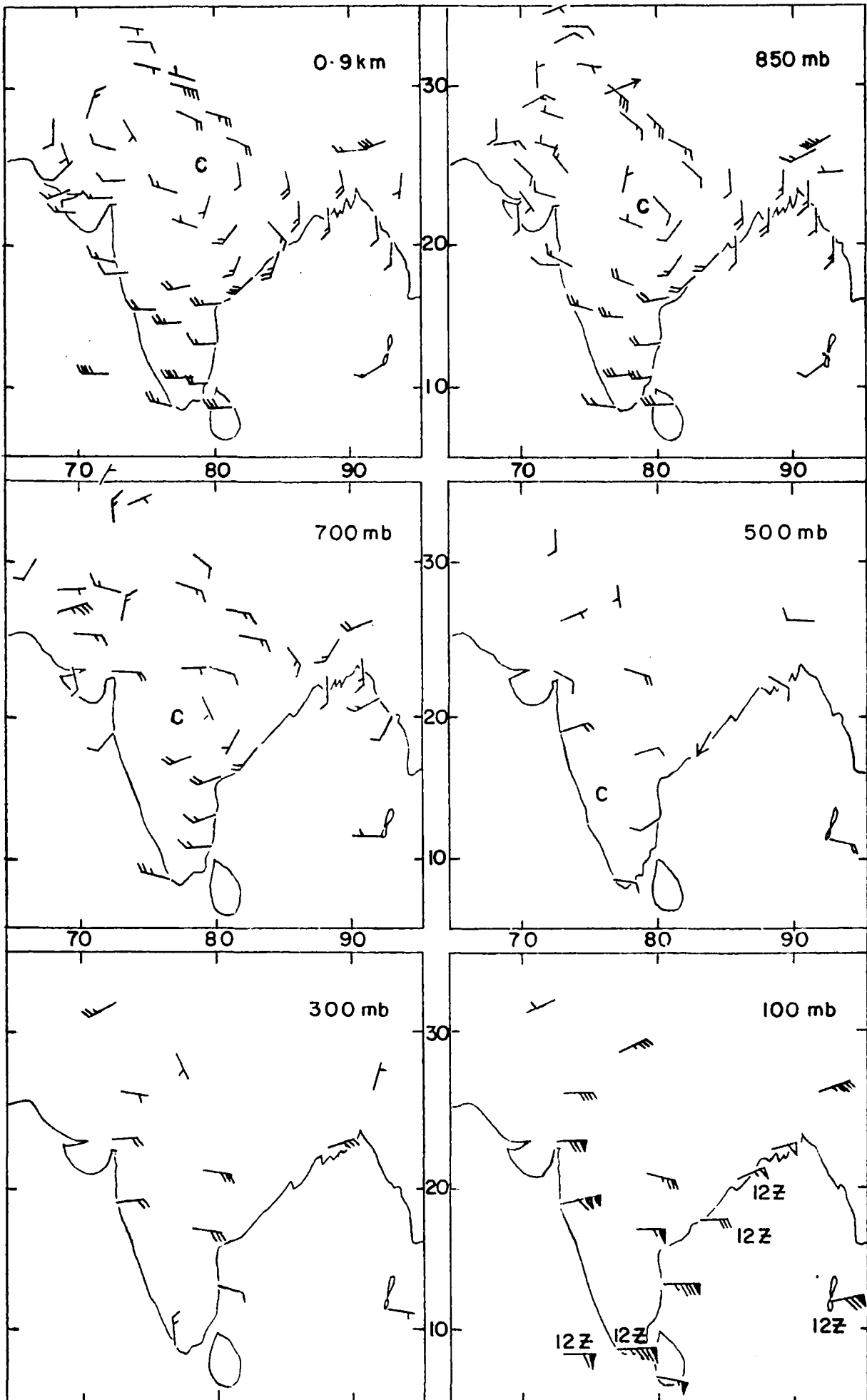
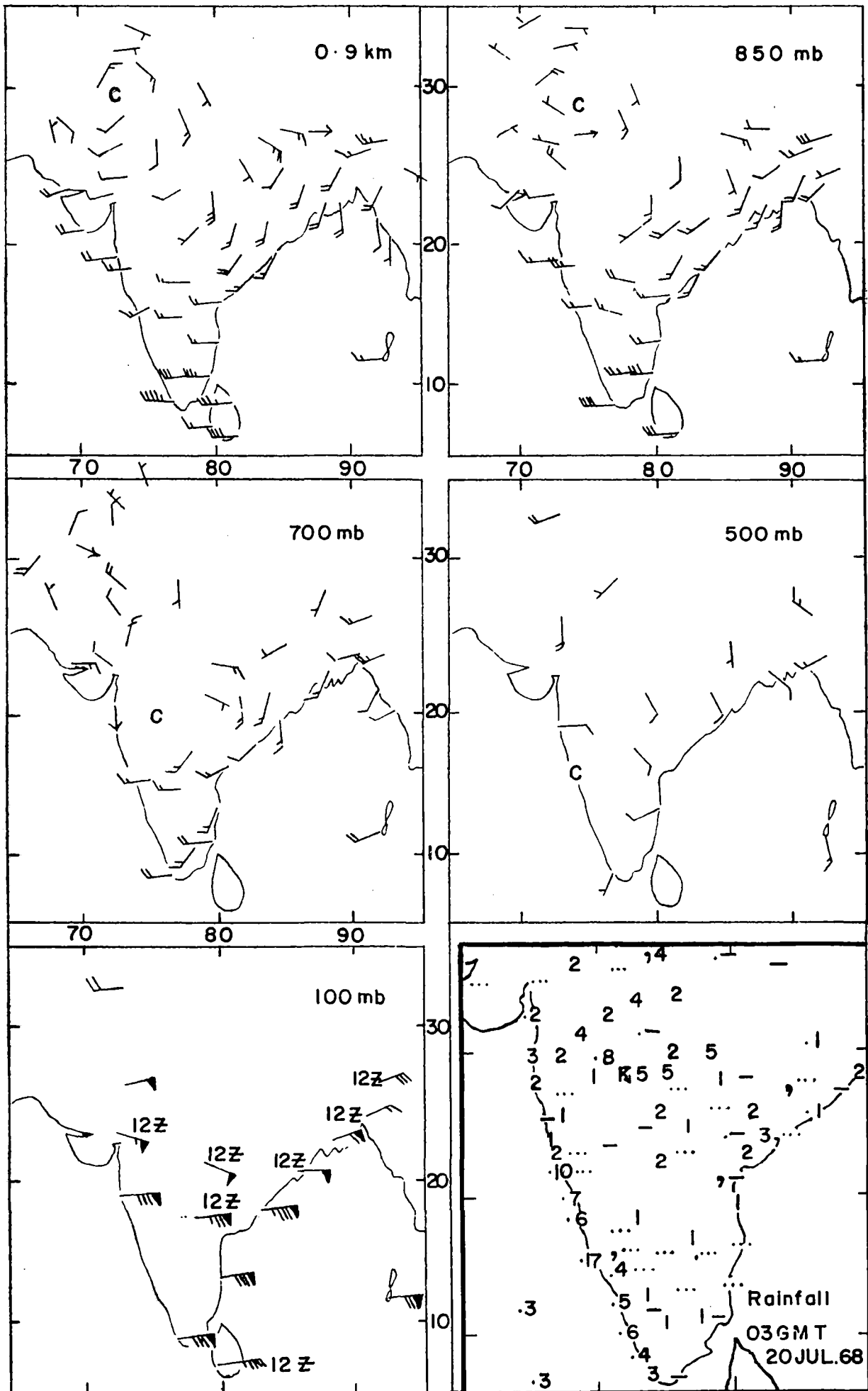


FIG. 6.5 UPPER WINDS OOGMT 19 JUL. 68



C- Centre of cyclonic circulation

FIG. 6.6 UPPER WINDS 00GMT 20 JUL. 68



C-Centre of cyclonic circulation

FIG. 7.1 SYNOPTIC CHARTS 0300 GMT 23 AUG 71

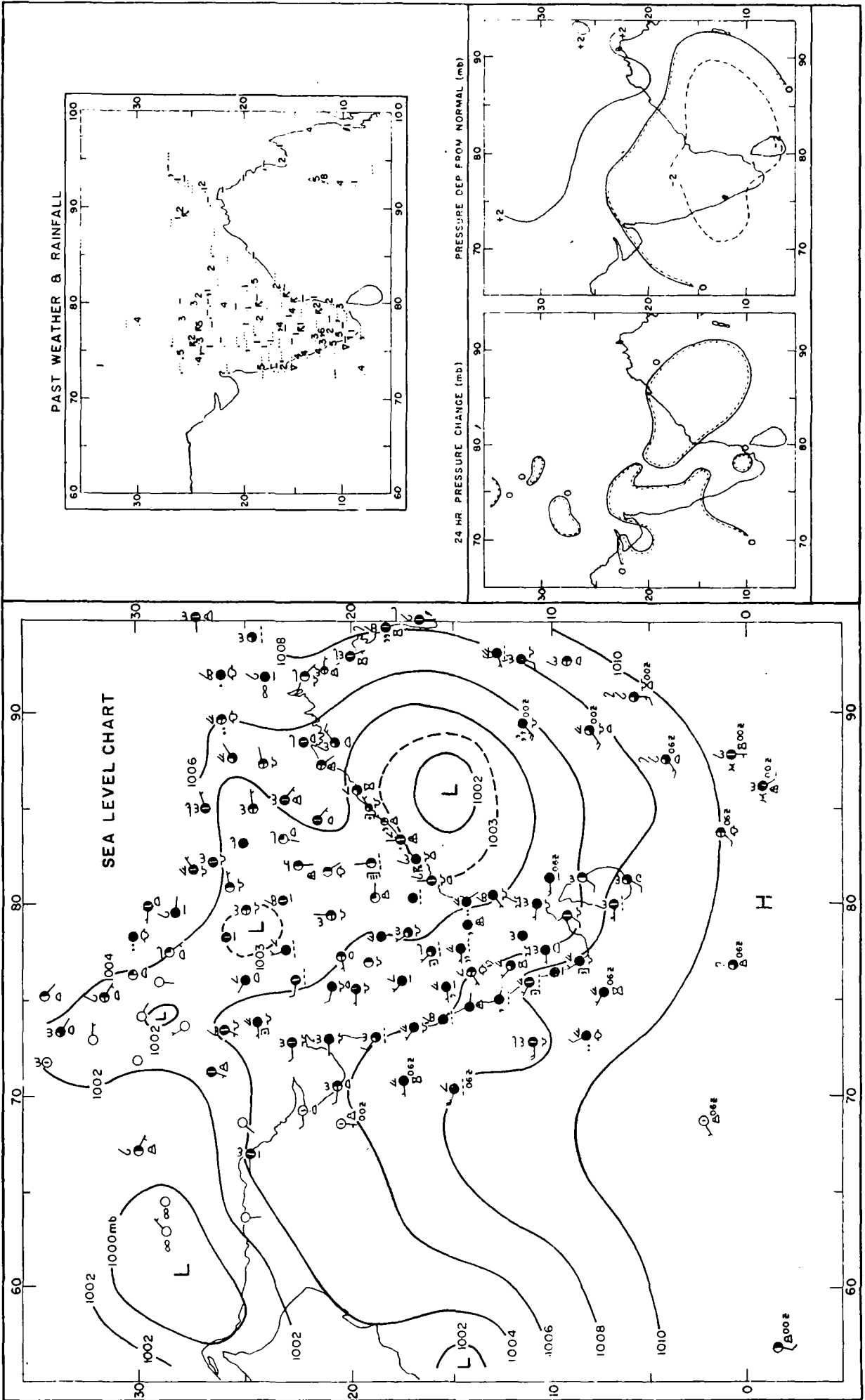
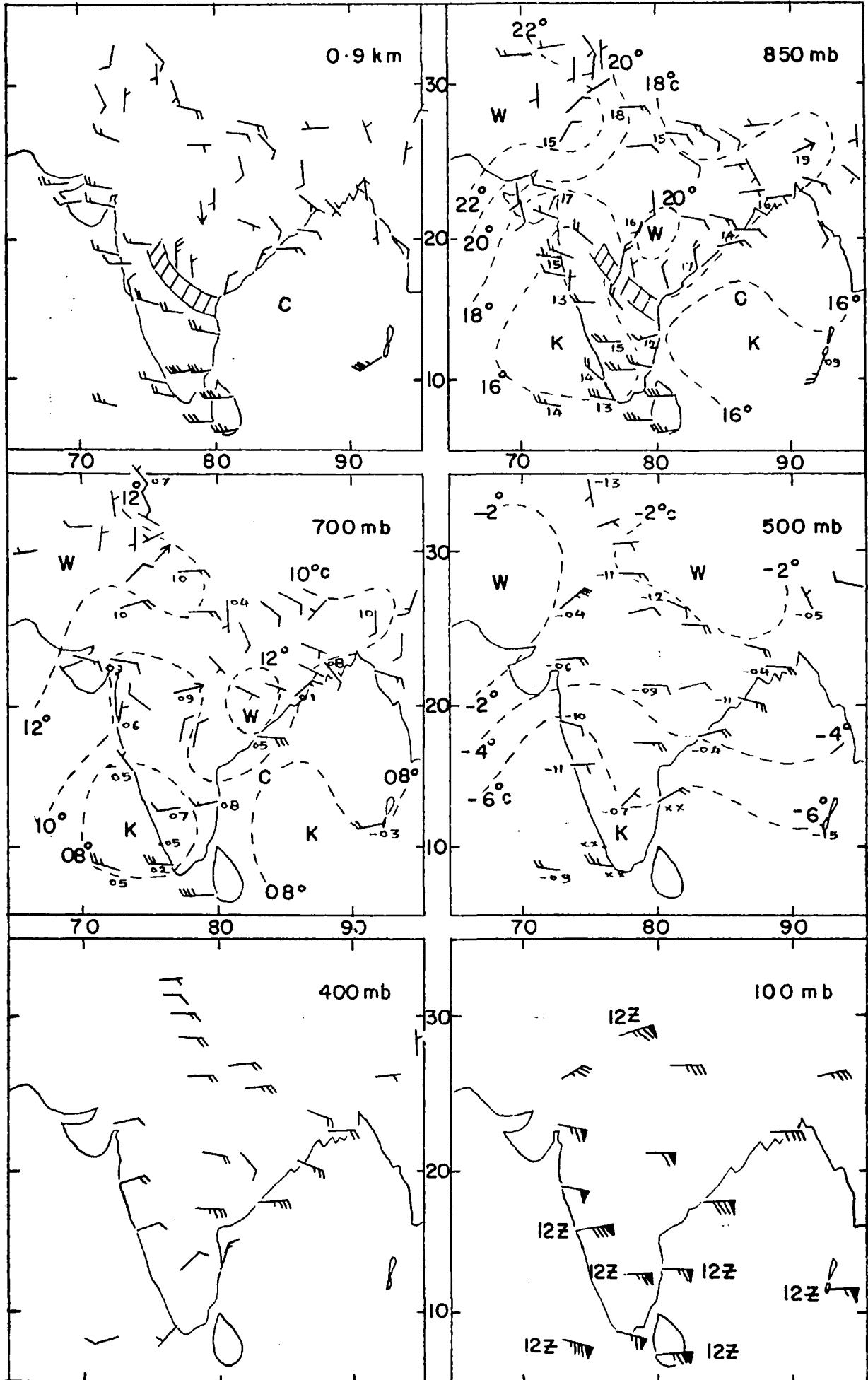


FIG. 7-2 UPPER WINDS 00 GMT 23 AUG. 71



C-Centre of cyclonic circulation ||||| Zone of Convergence W-Warm K-Cold
 ----- Isotherm Plotted figures $T_d T_d$

FIG. 7-3 SYNOPTIC CHARTS 0300 GMT 24 AUG. 71

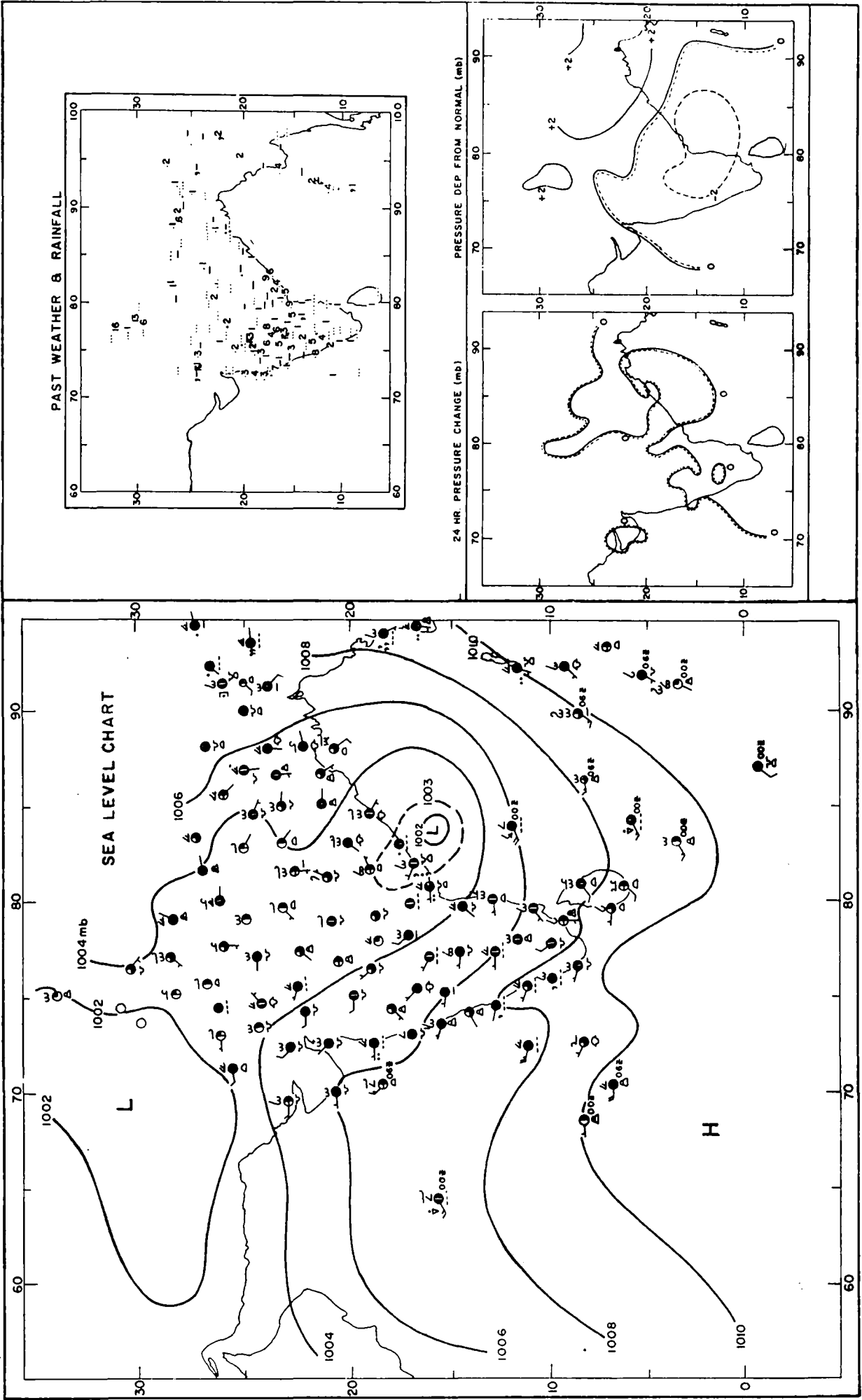
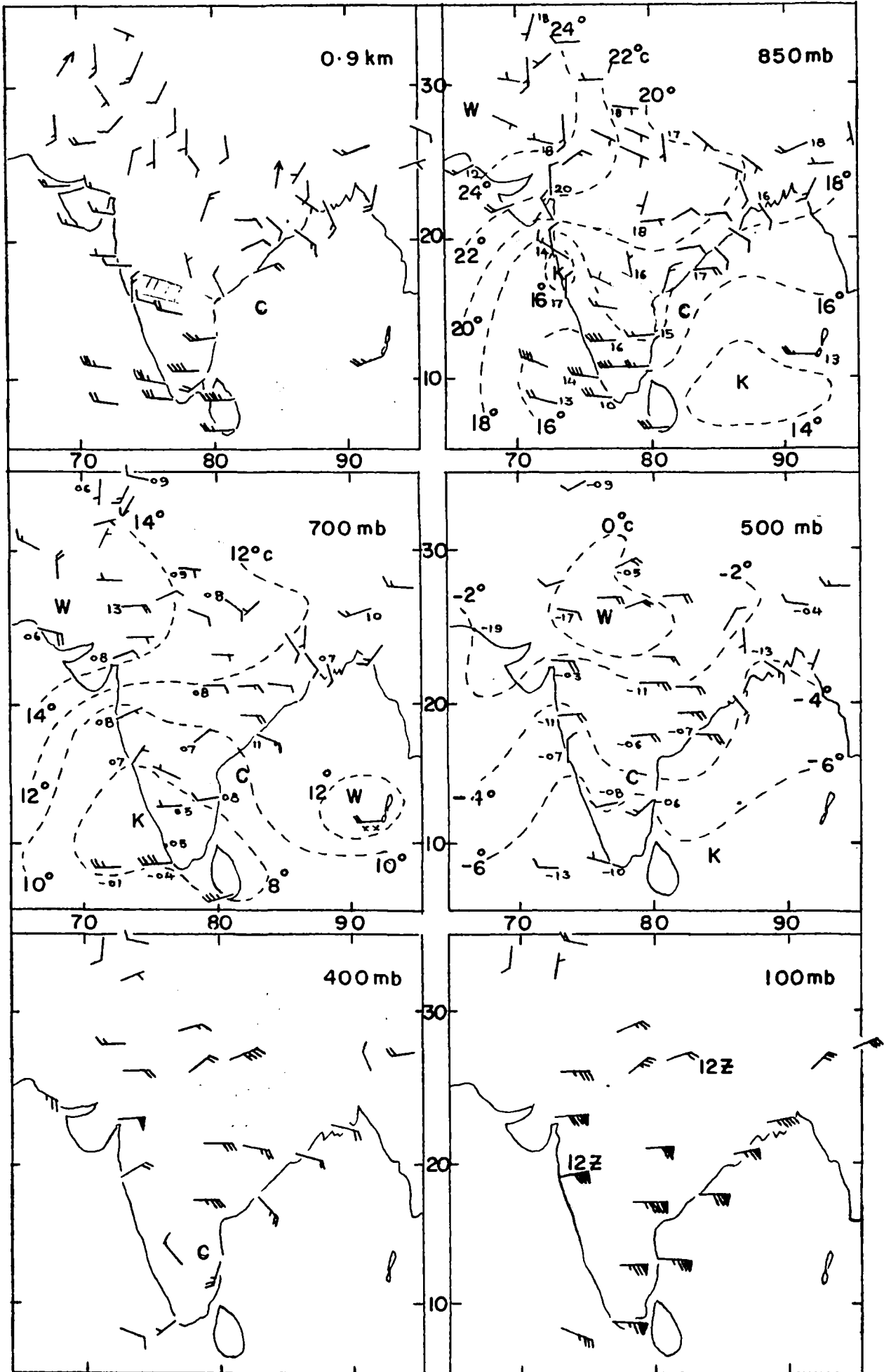


FIG. 7.4 UPPER WINDS OOGMT 24 AUG.71



C-Centre of cyclonic circulation |||| Zone of Convergence W-Warm K-Cold
 ----- Isotherm Plotted figures $T_d T_d$

FIG. 7.5 ESSA-8 DATE 24 AUG. 71



ORBIT : 12322 TIME : 0529 GMT ORBIT : 12321 TIME : 0341 GMT

FIG. 7-6 SYNOPTIC CHARTS 0300 GMT 25 AUG. 71

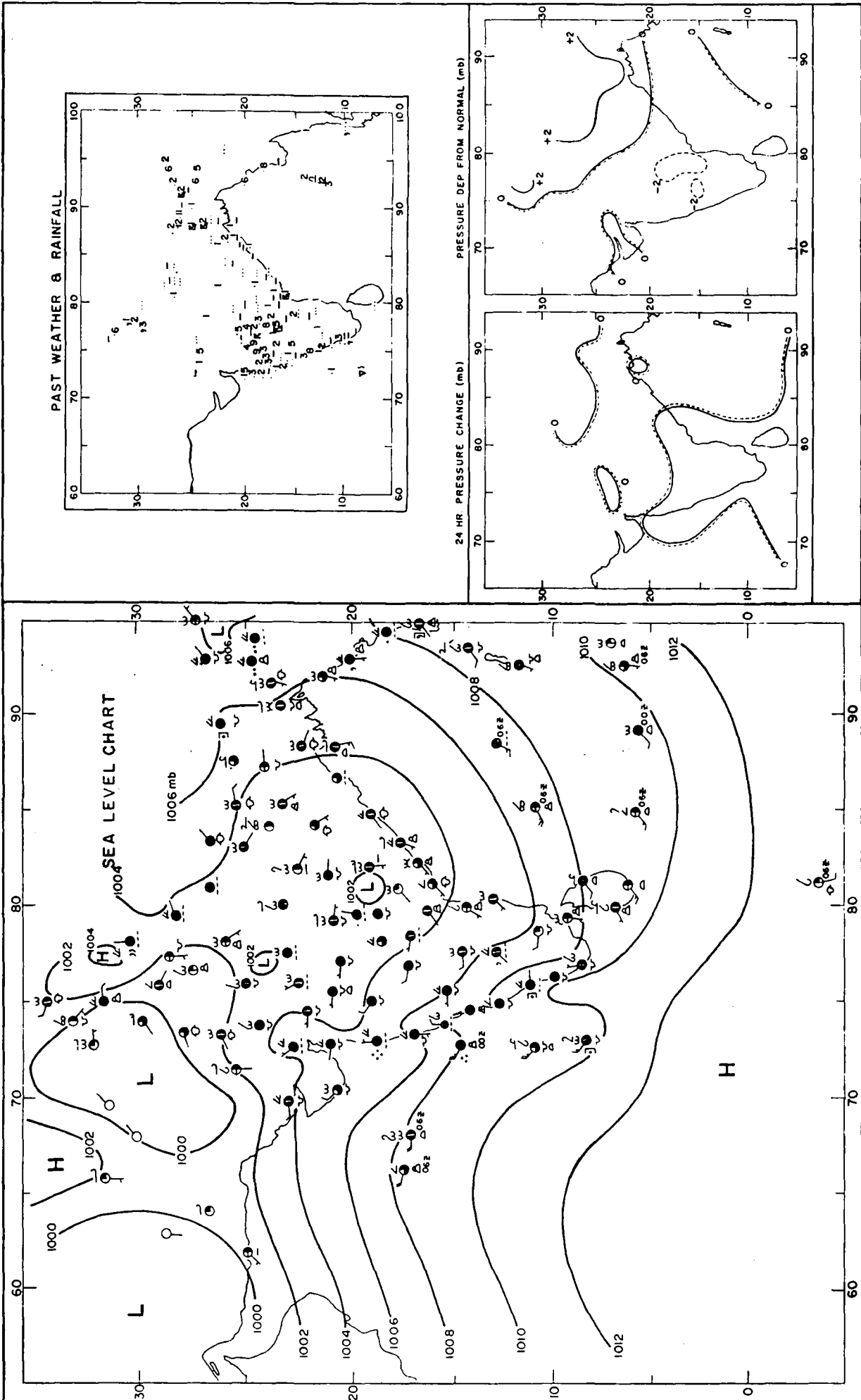
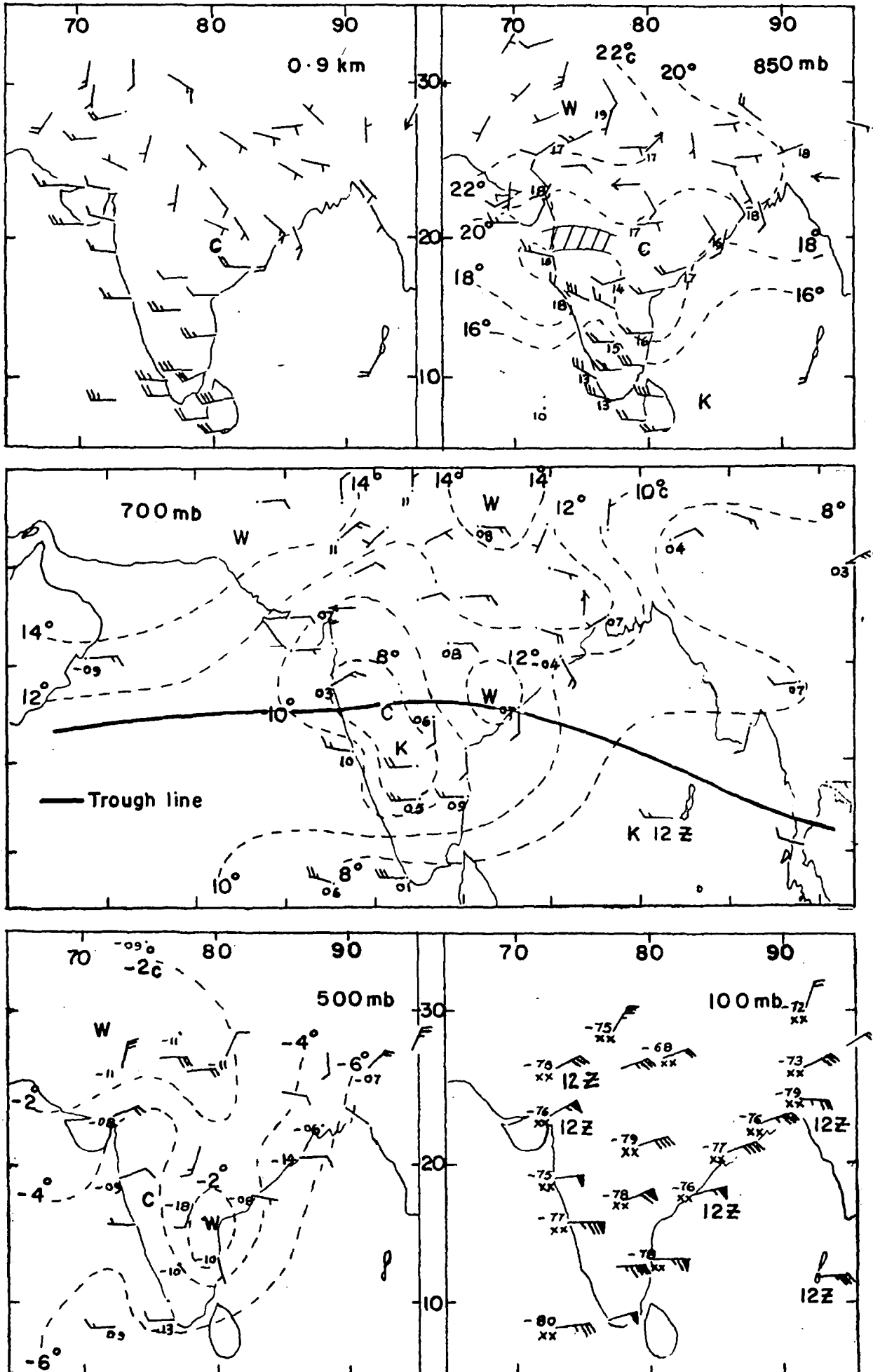
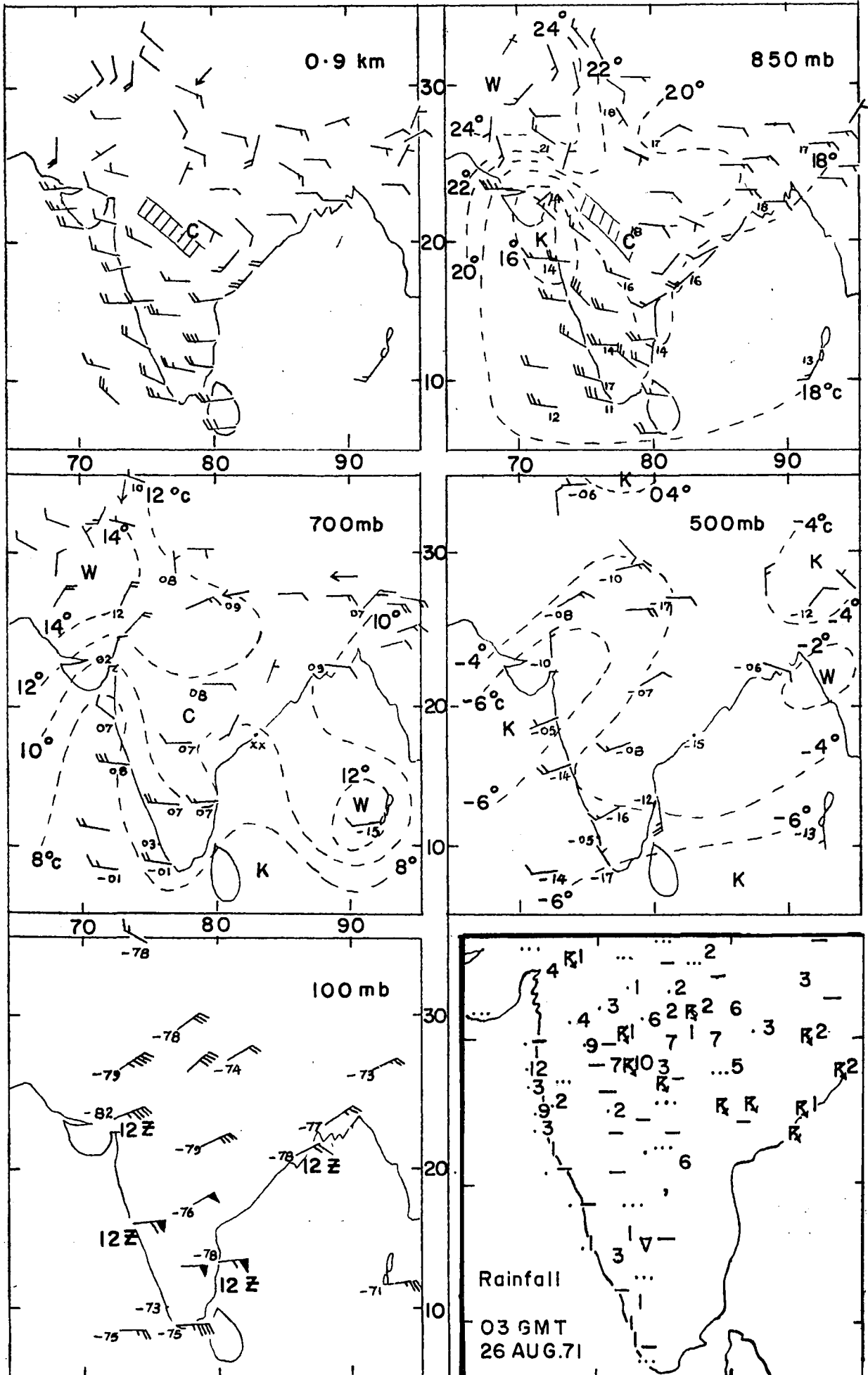


FIG. 7.7 UPPER WINDS 00 GMT 25 AUG. 71



C-Centre of cyclonic circulation **||||** Zone of Convergence W - Warm
 K - Cold ----- Isotherm Plotted figures $T_d T_d$

FIG. 7.8 UPPER WINDS 00 GMT 26 AUG. 71



C-Centre of cyclonic circulation **|||||** Zone of Convergence ----- Isotherm
 K- Cold W-Warm Plotted figures $T_d T_d$

FIG. 7-9 SYNOPTIC CHARTS 0500 GMT 27 AUG. 71

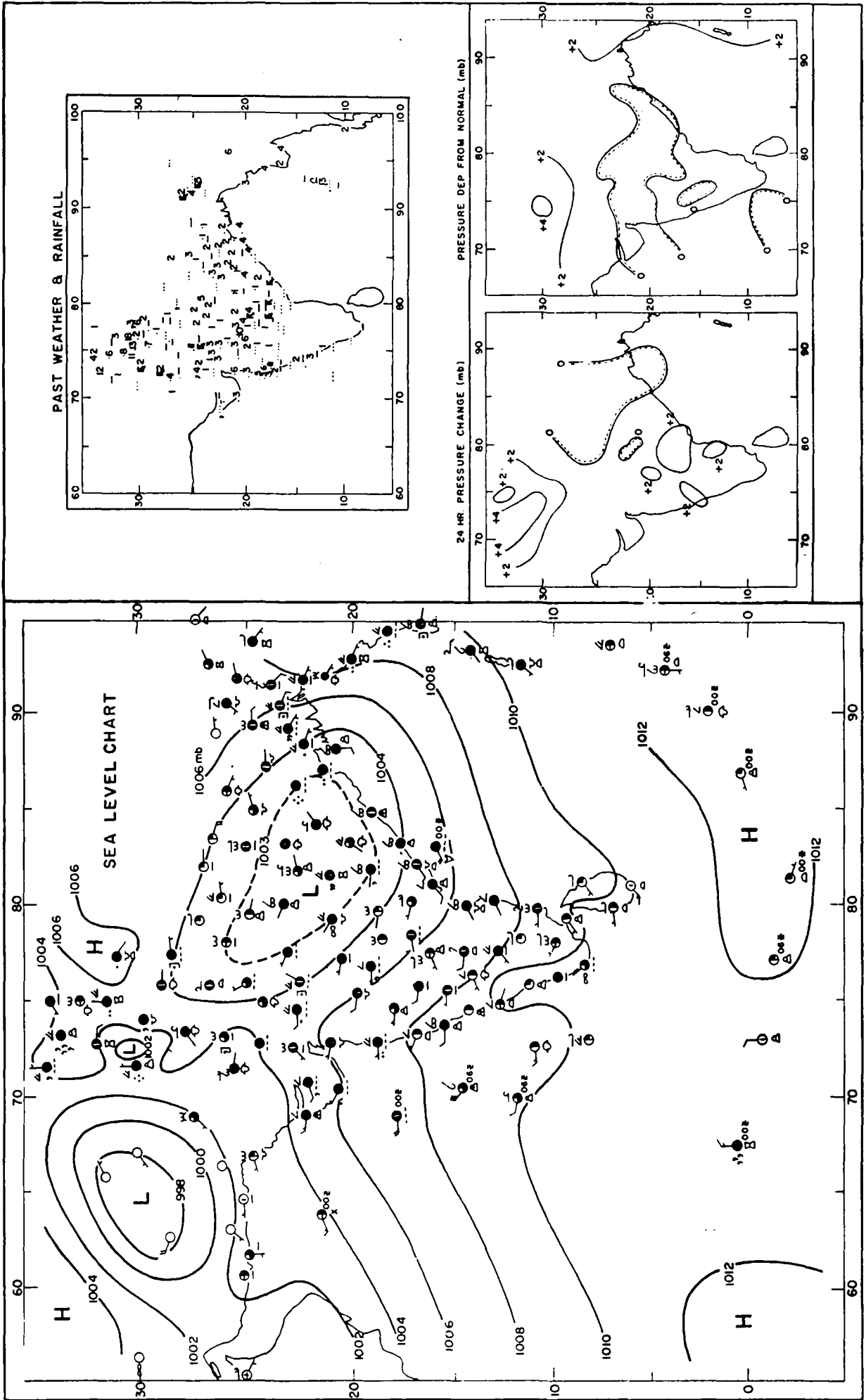


FIG. 7-10

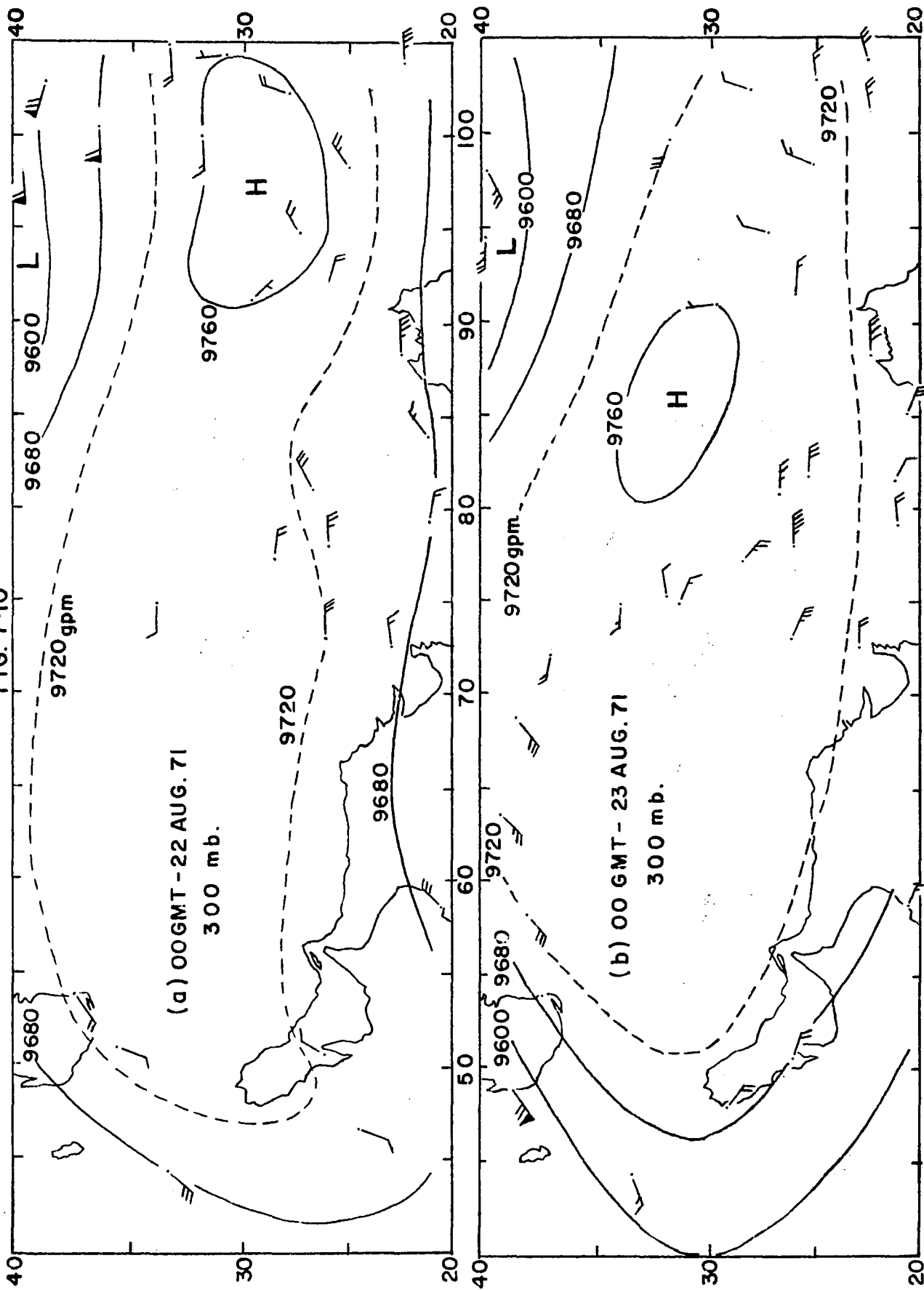


FIG. 7-10

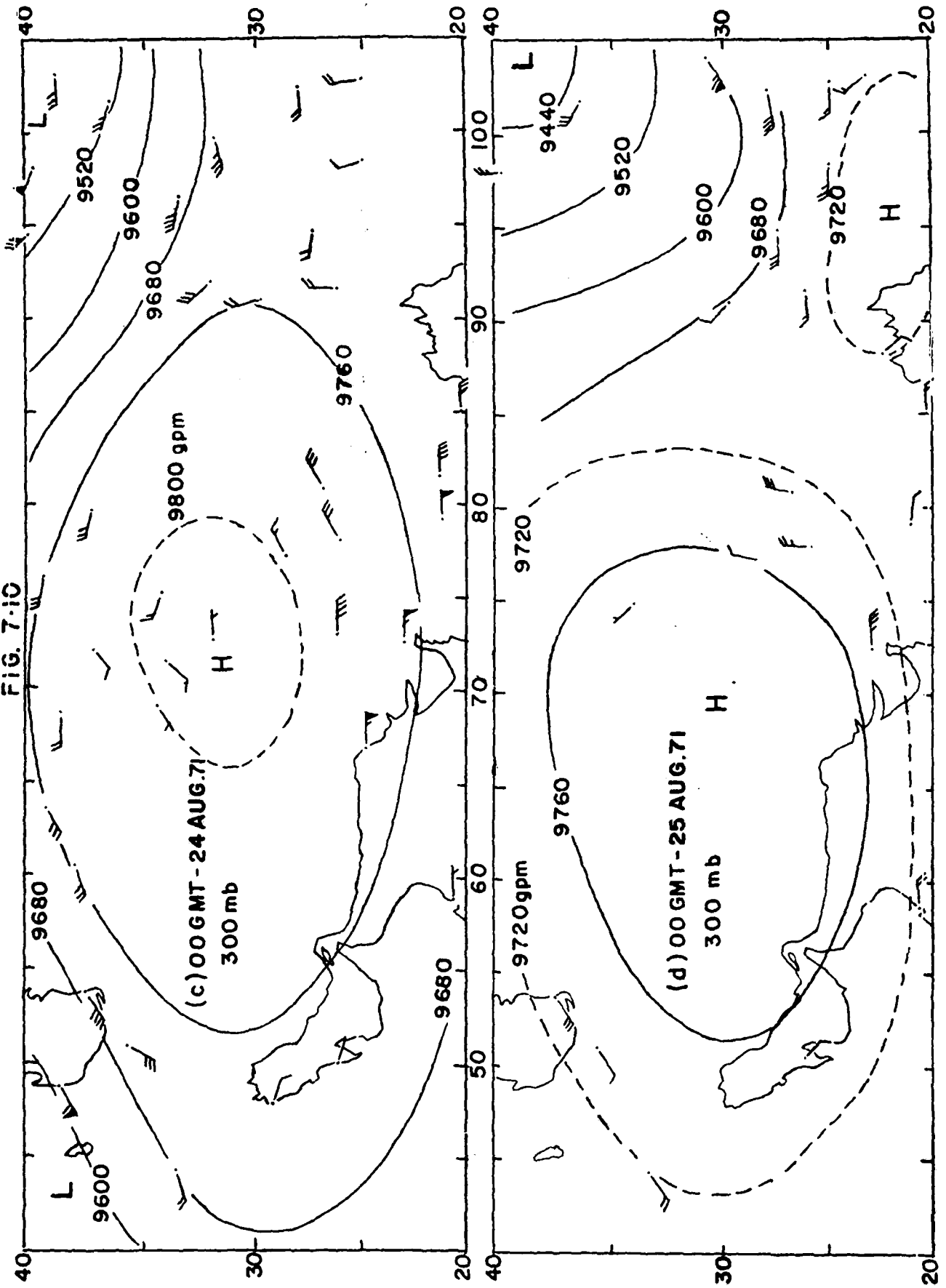


FIG. 7-11

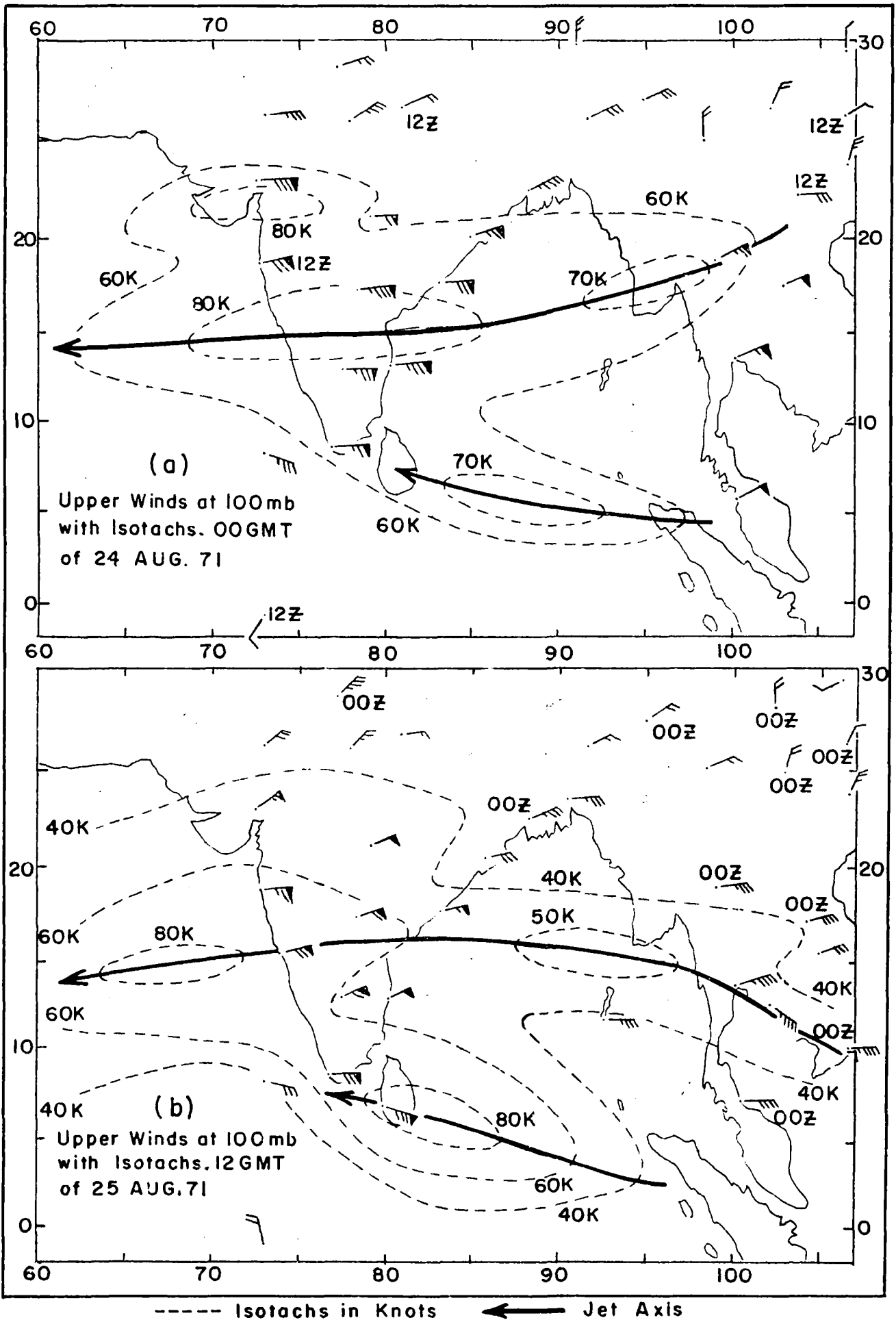


FIG. 8.1 SYNOPTIC CHARTS 0300 GMT 18 JUL. 67

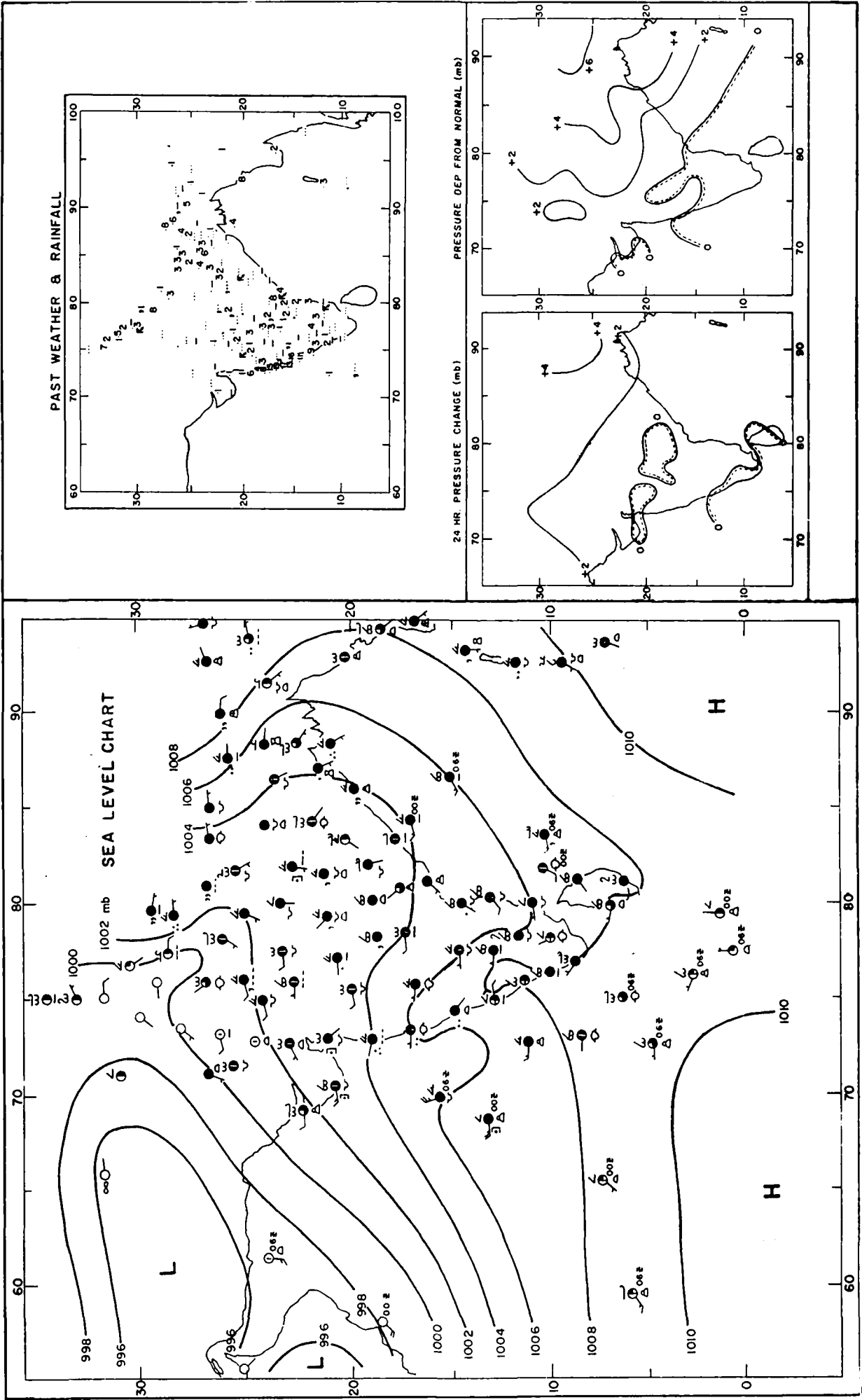


FIG. 8.2 UPPER WINDS 00 GMT 18 JUL. 67

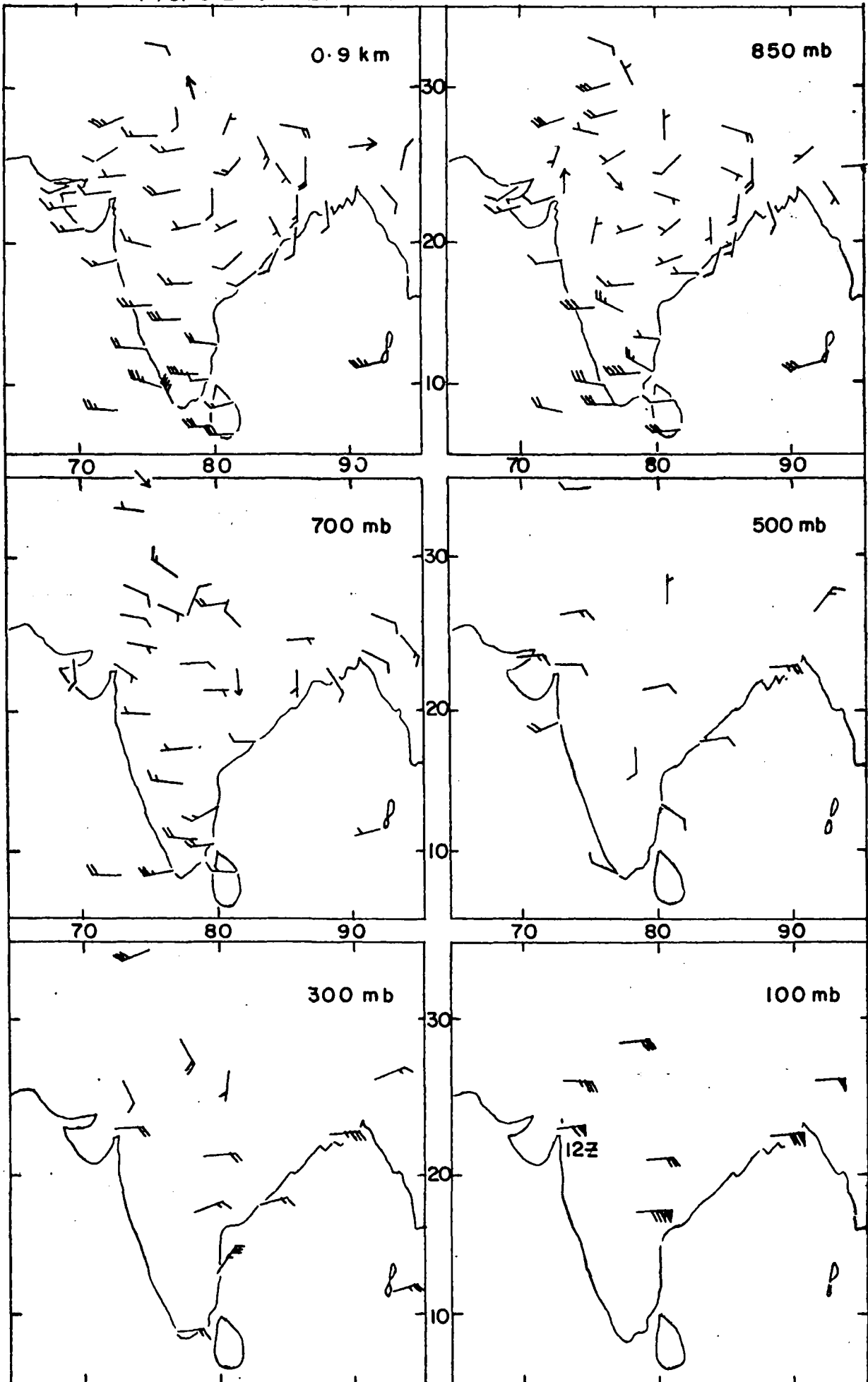


FIG. 8-3 SYNOPTIC CHARTS 0300 GMT 19 JUL. 67

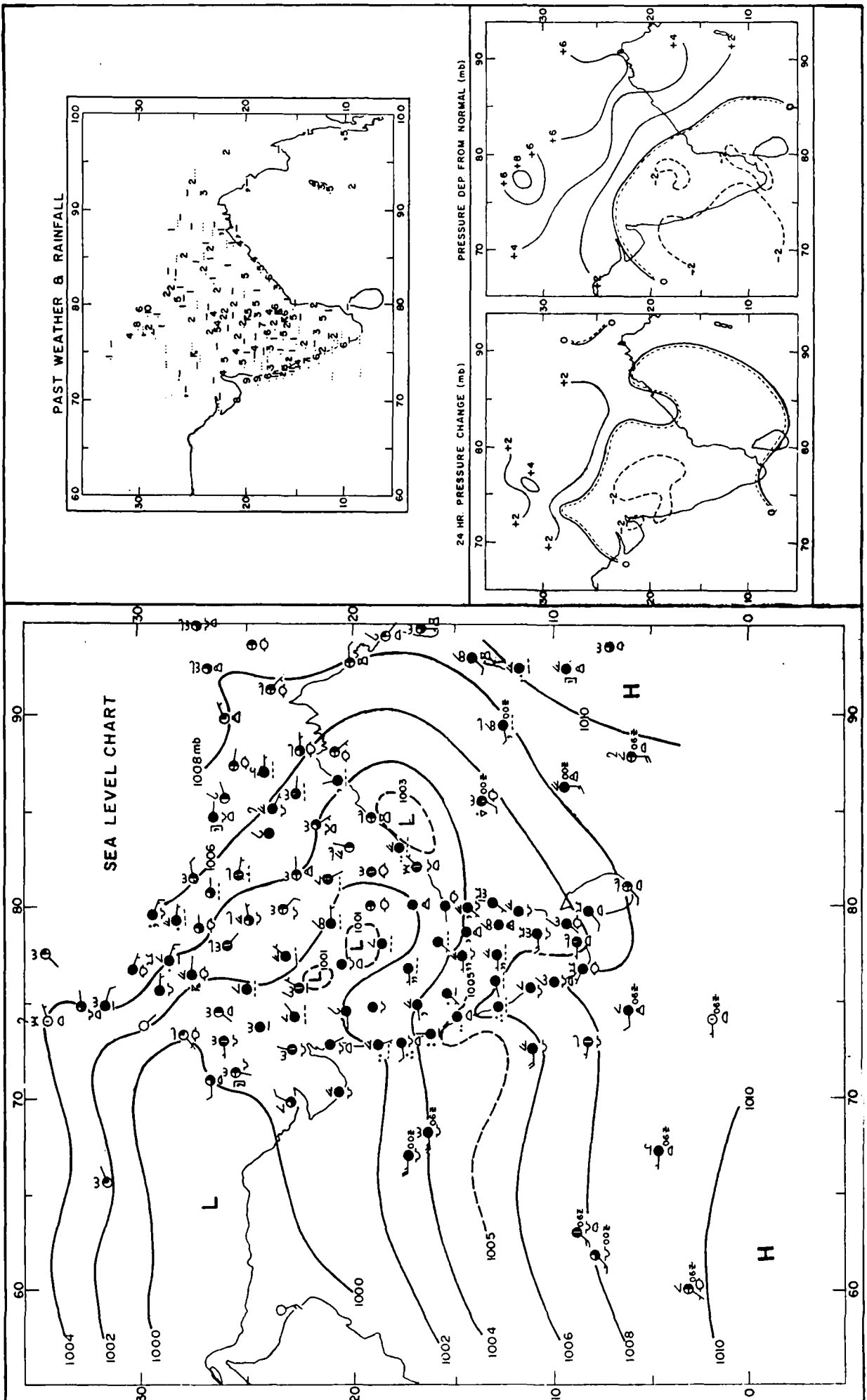
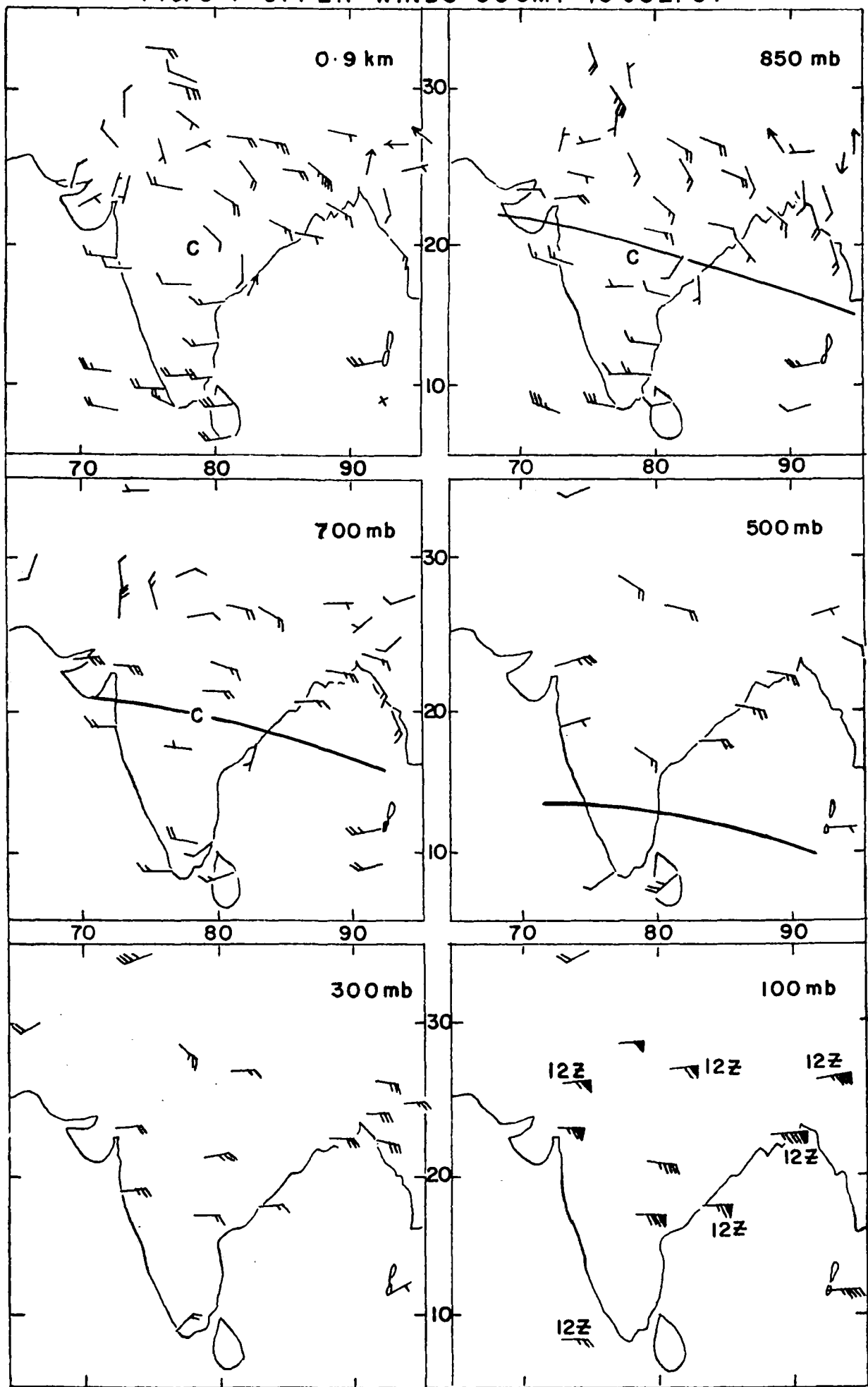
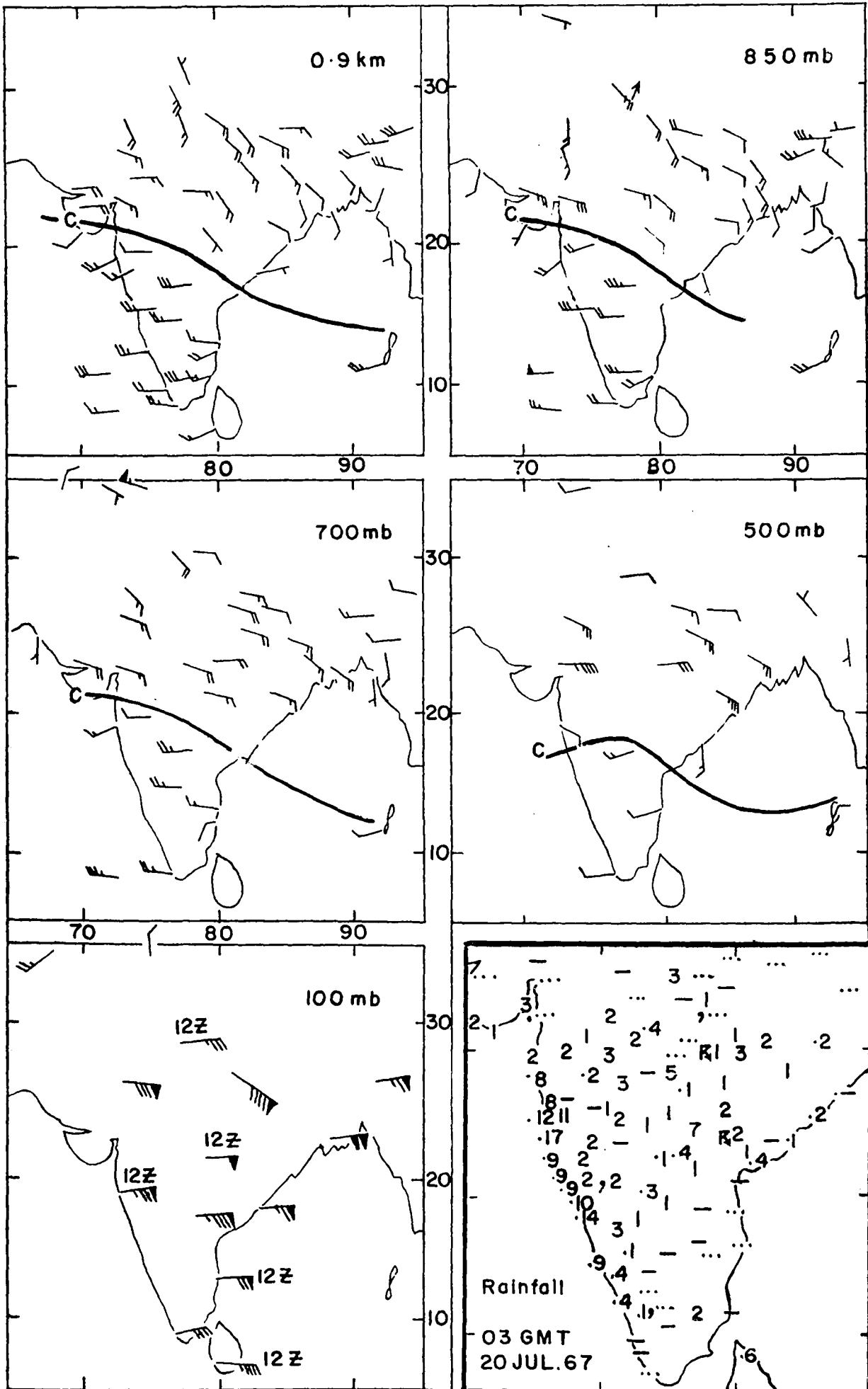


FIG. 8-4 UPPER WINDS OOGMT 19 JUL. 67



C- Centre of cyclonic circulation — Trough line

FIG. 8.5 UPPER WINDS OOGMT 20 JUL.67



C-Centre of cyclonic circulation

— Trough line

FIG. 8-6 SYNOPTIC CHARTS 0300 GMT 21 JUL. 67

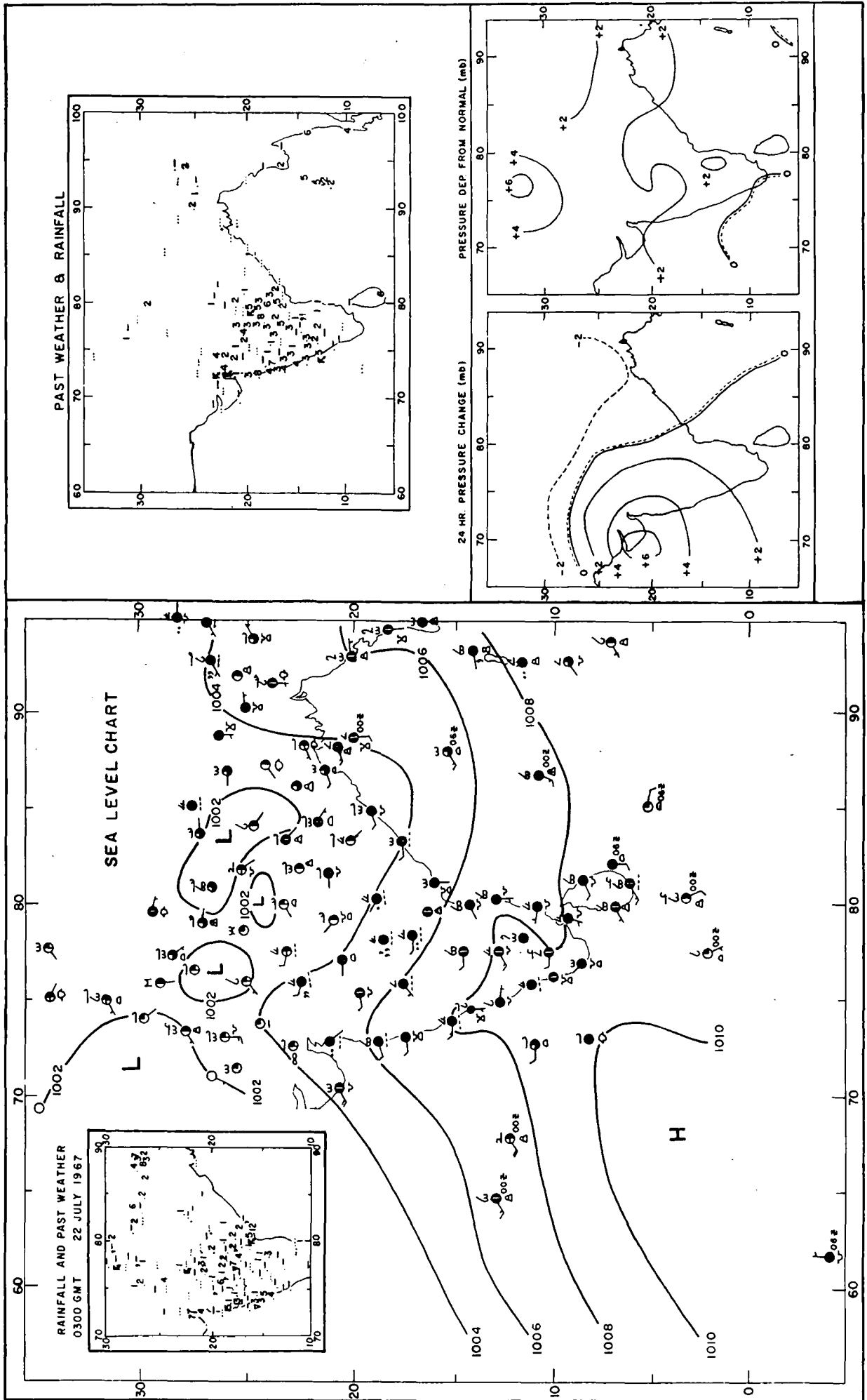
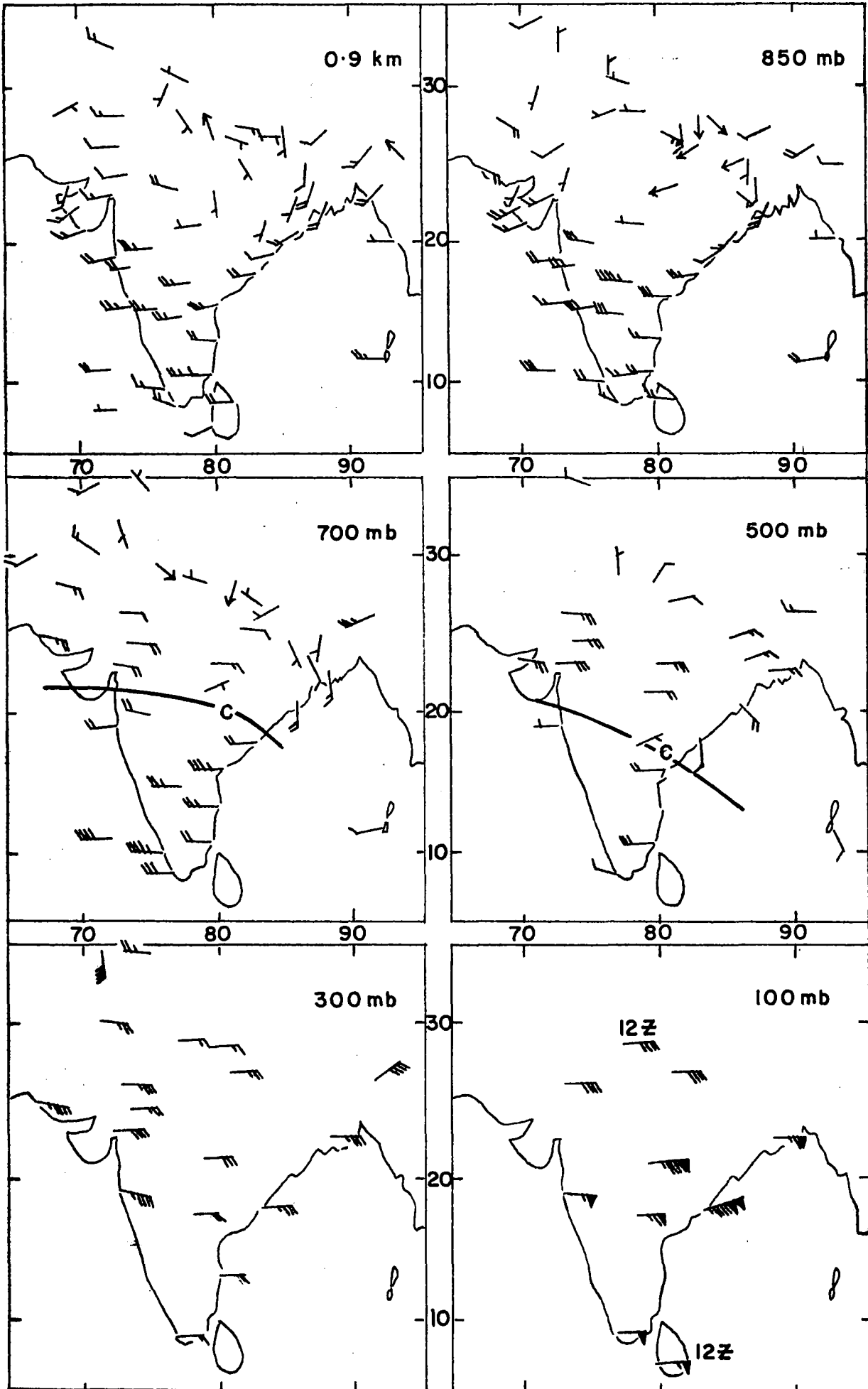
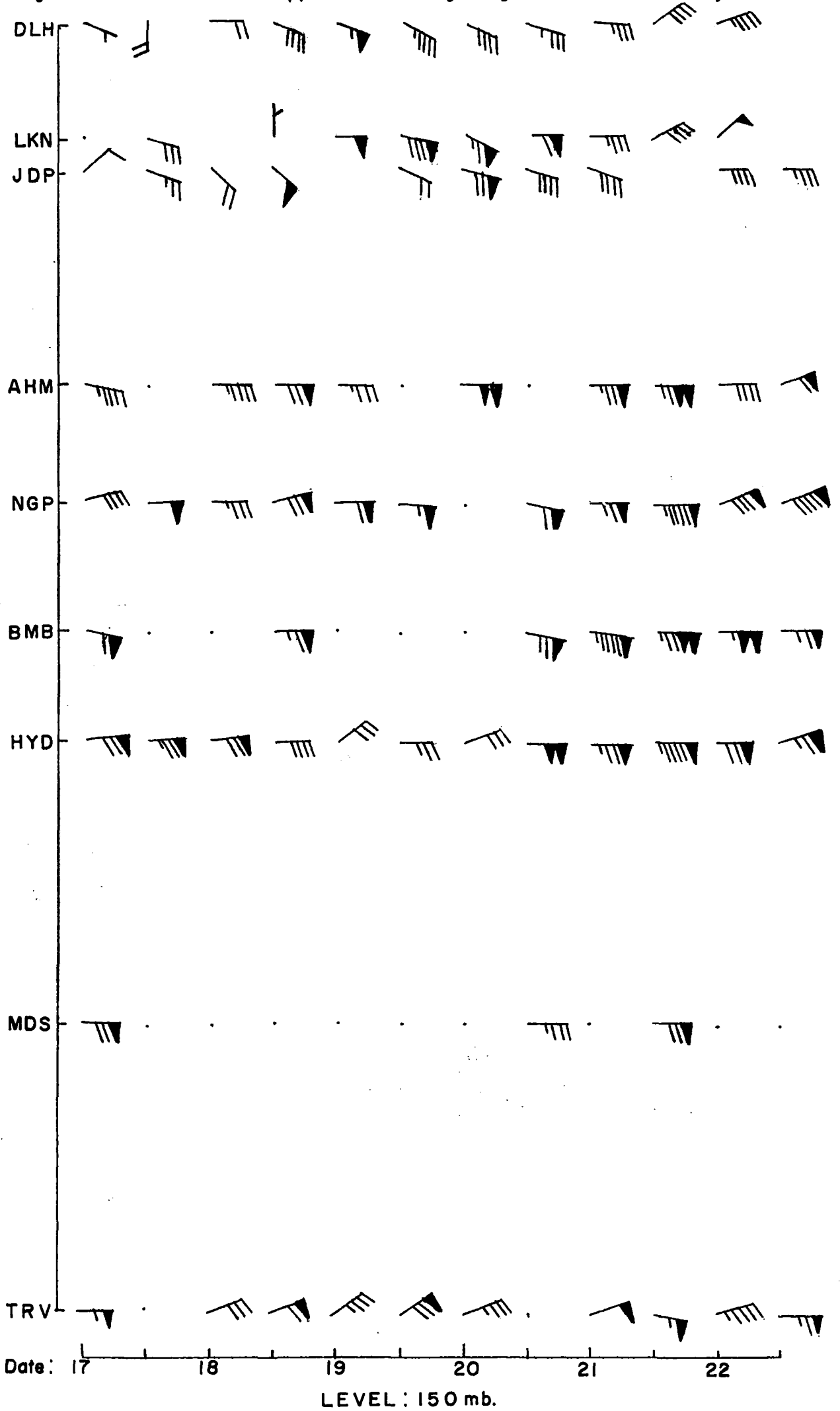


FIG. 8.7 UPPER WINDS OOG GMT 21 JUL. 67



C - Centre of cyclonic circulation — Trough line

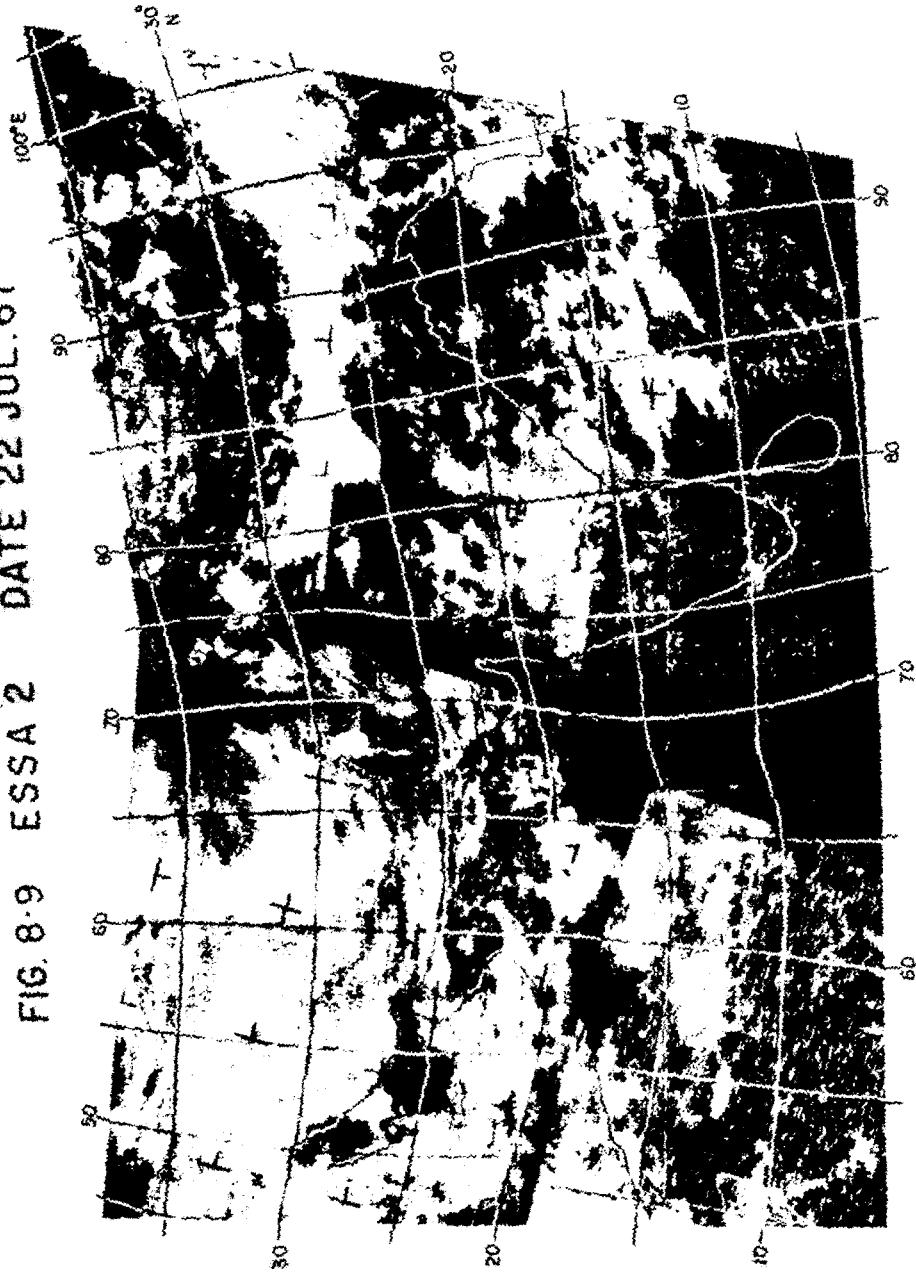
Fig.8-8 Cross Section of Upper Winds along Long.77°E : 17 to 20 July 1967.



Date: 17 18 19 20 21 22

LEVEL : 150 mb.

FIG. 8-9 ESSA 2 DATE 22 JUL. 67



ORBIT : 6451 TIME : 0352 GMT ORBIT : 6450 TIME : 0159 GMT

FIG. 9-1 700 mb UPPER WINDS 00 GMT 26 SEPT. 67

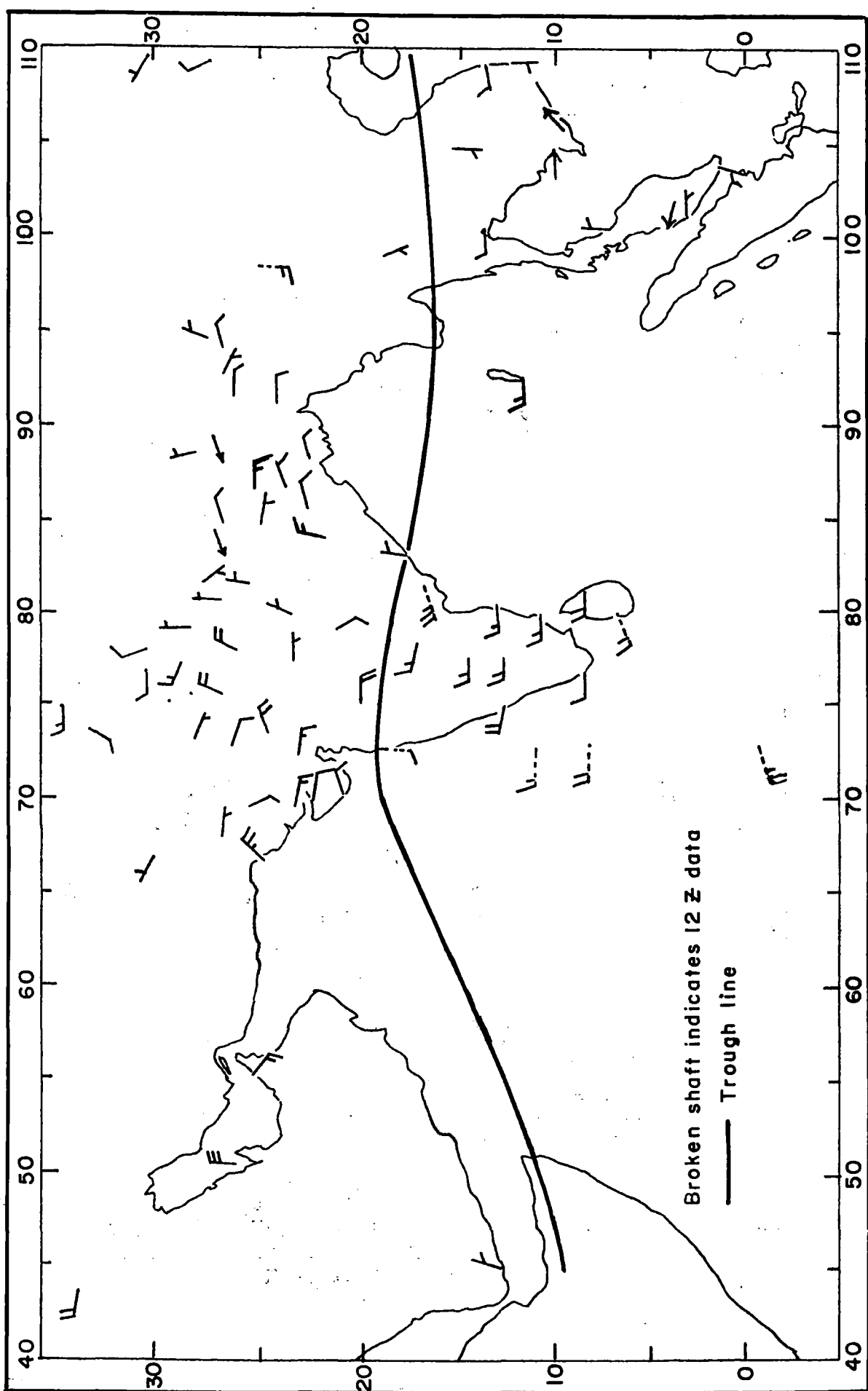


FIG. 9-2 TIME SECTION CHART FOR HYDERABAD (20-26 SEPT. 67)

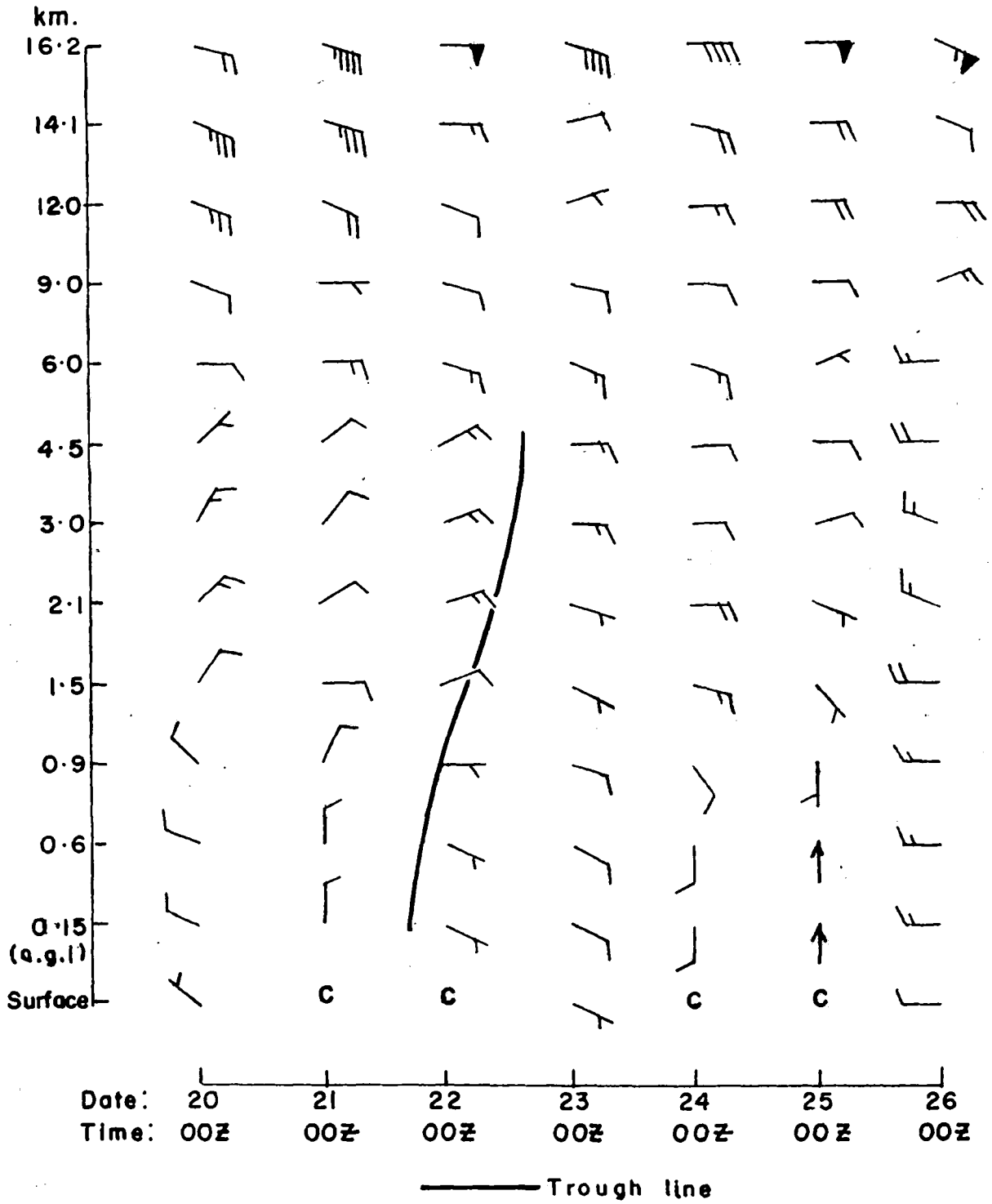


FIG. 9.3 SYNOPTIC CHARTS 0300 GMT 22 SEPT. 67

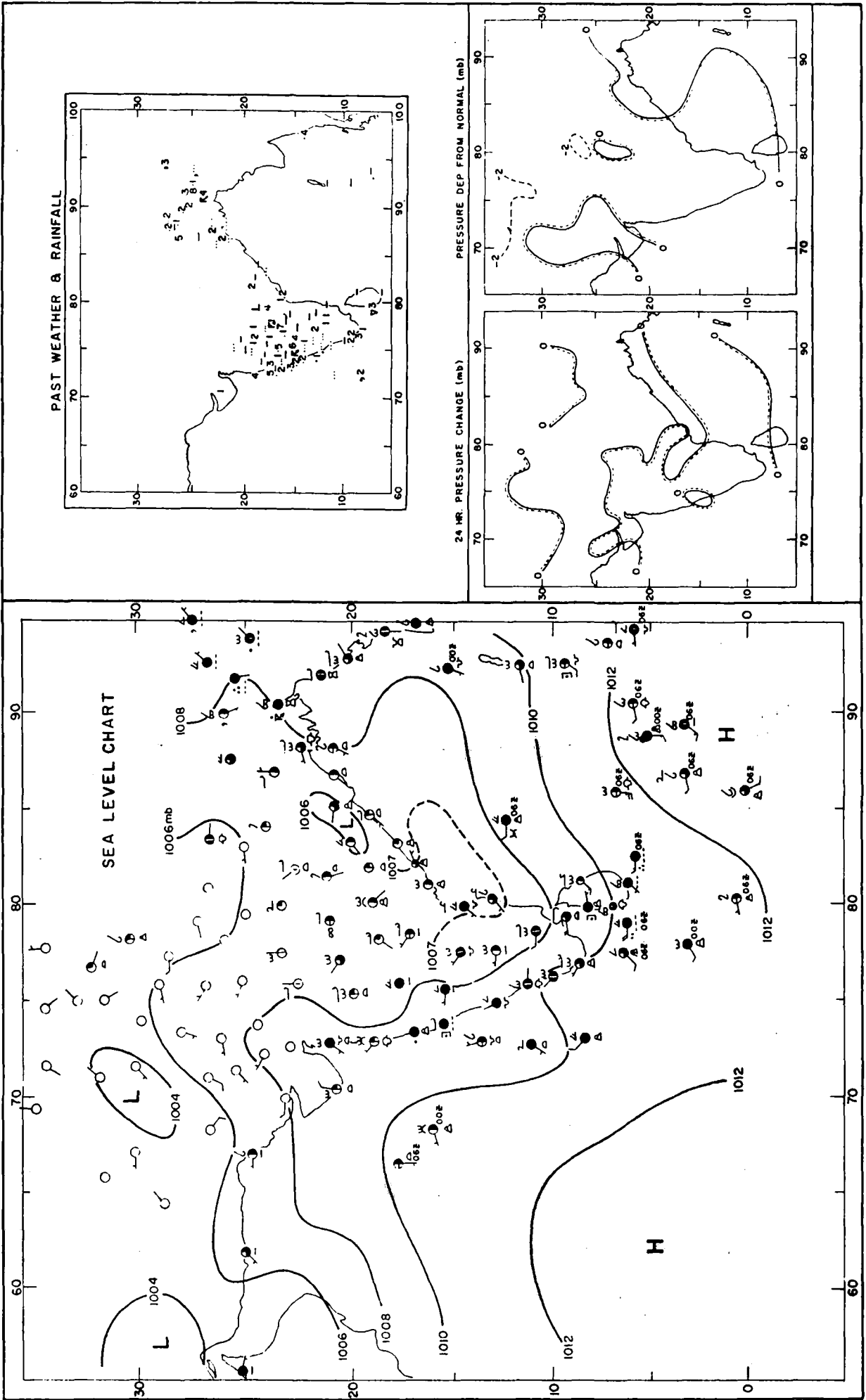
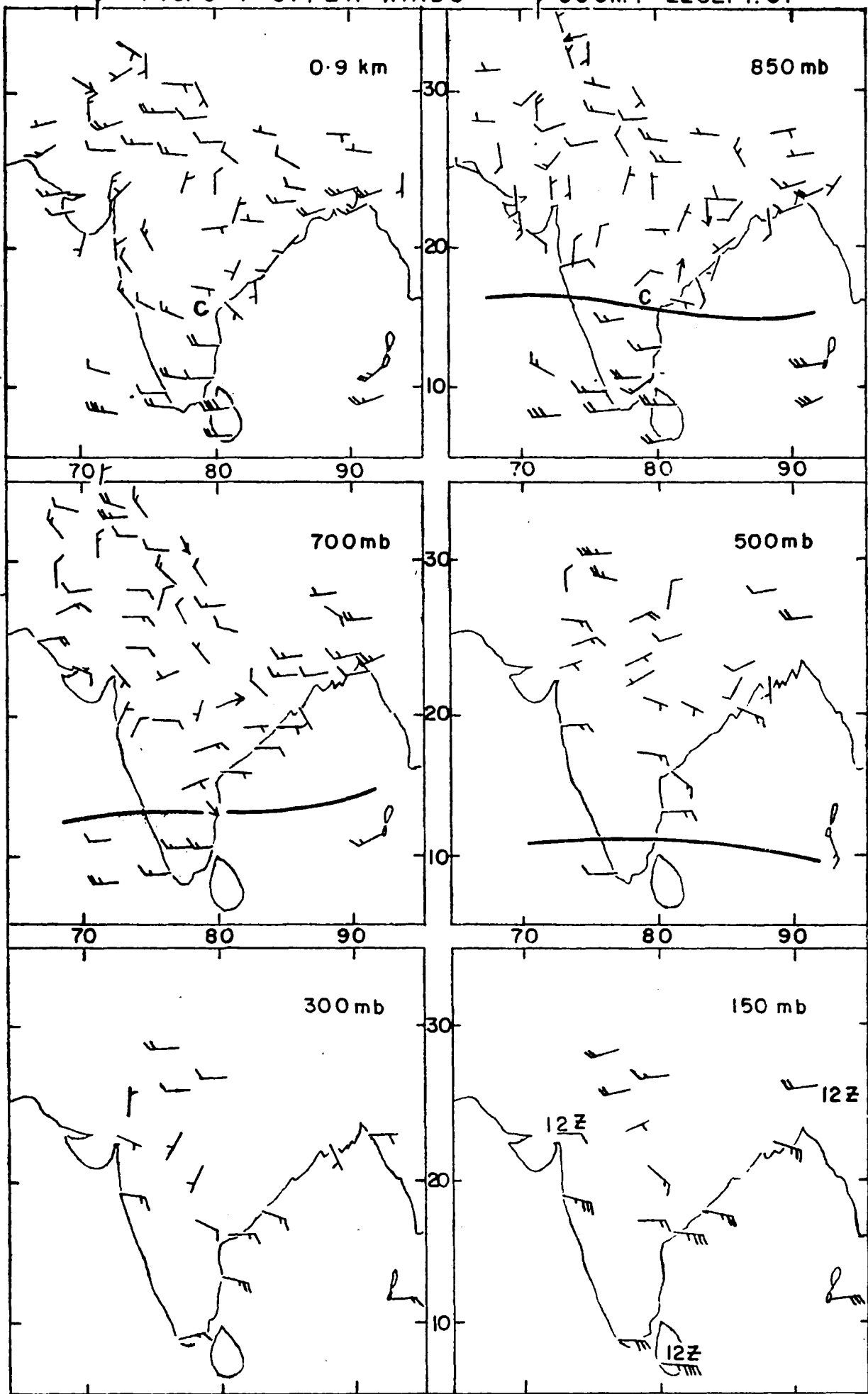


FIG. 9.4 UPPER WINDS

00GMT 22SEPT.67



— Trough line C-Centre of cyclonic circulation

FIG. 9.5 SYNOPTIC CHARTS 0300 GMT 26 SEPT. 67

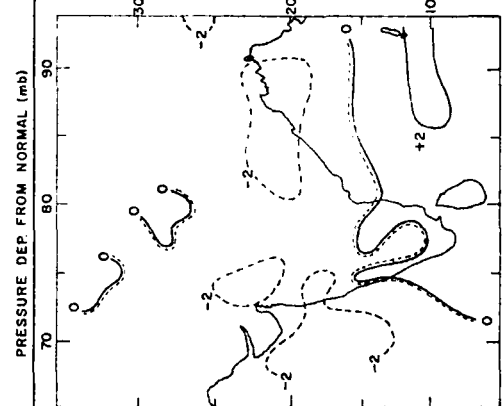
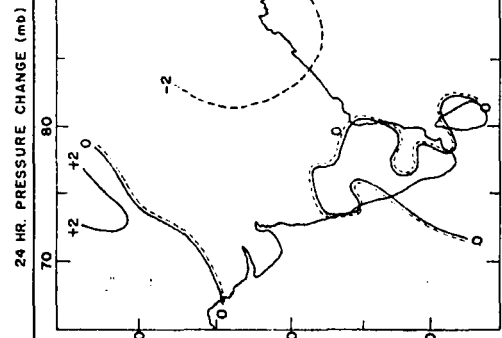
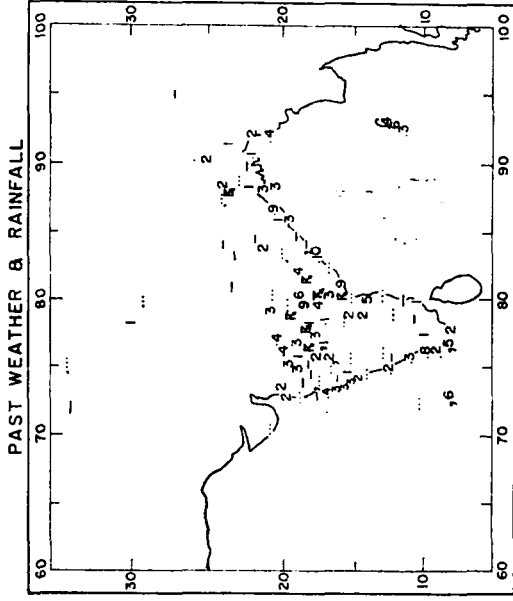
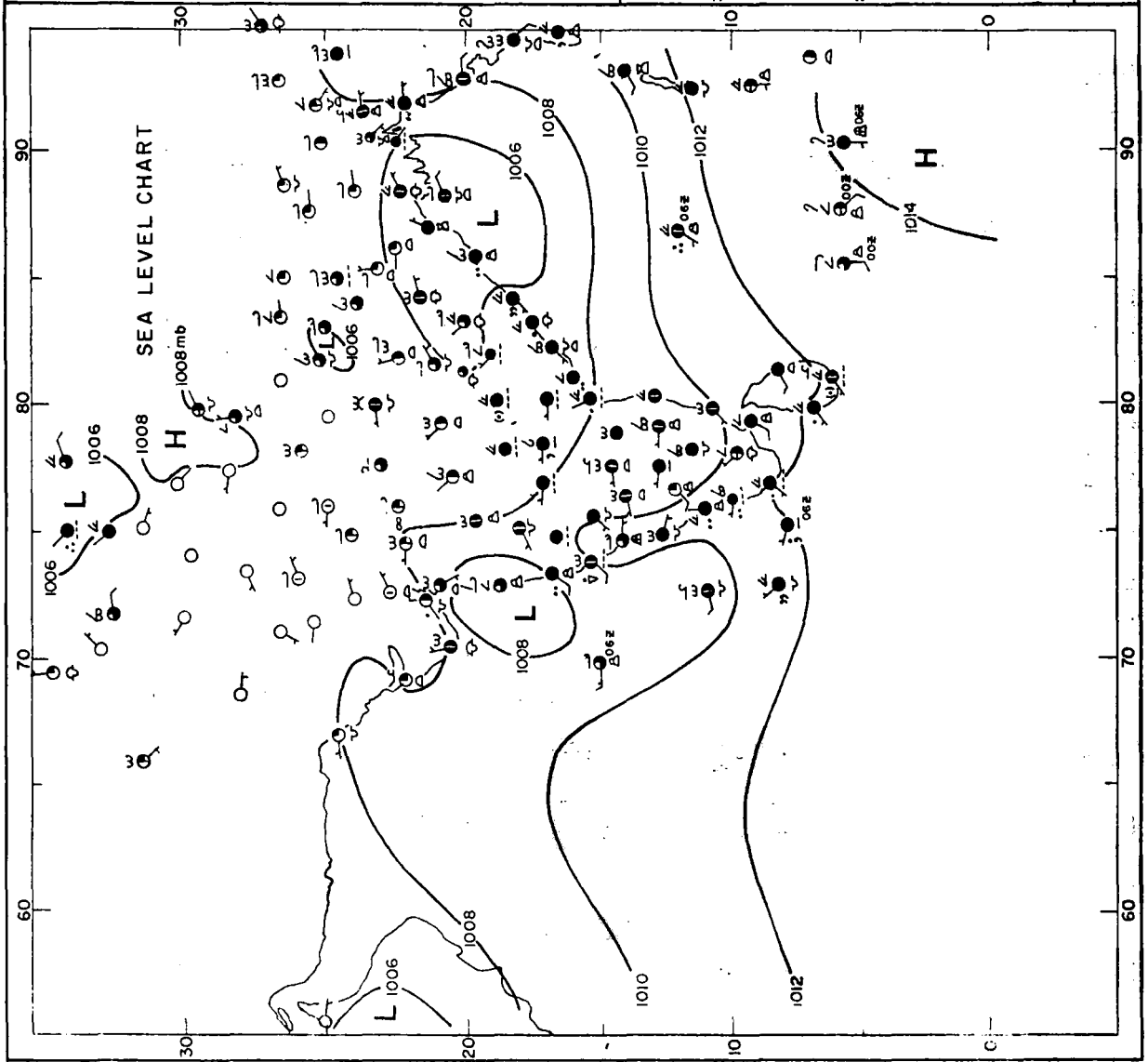
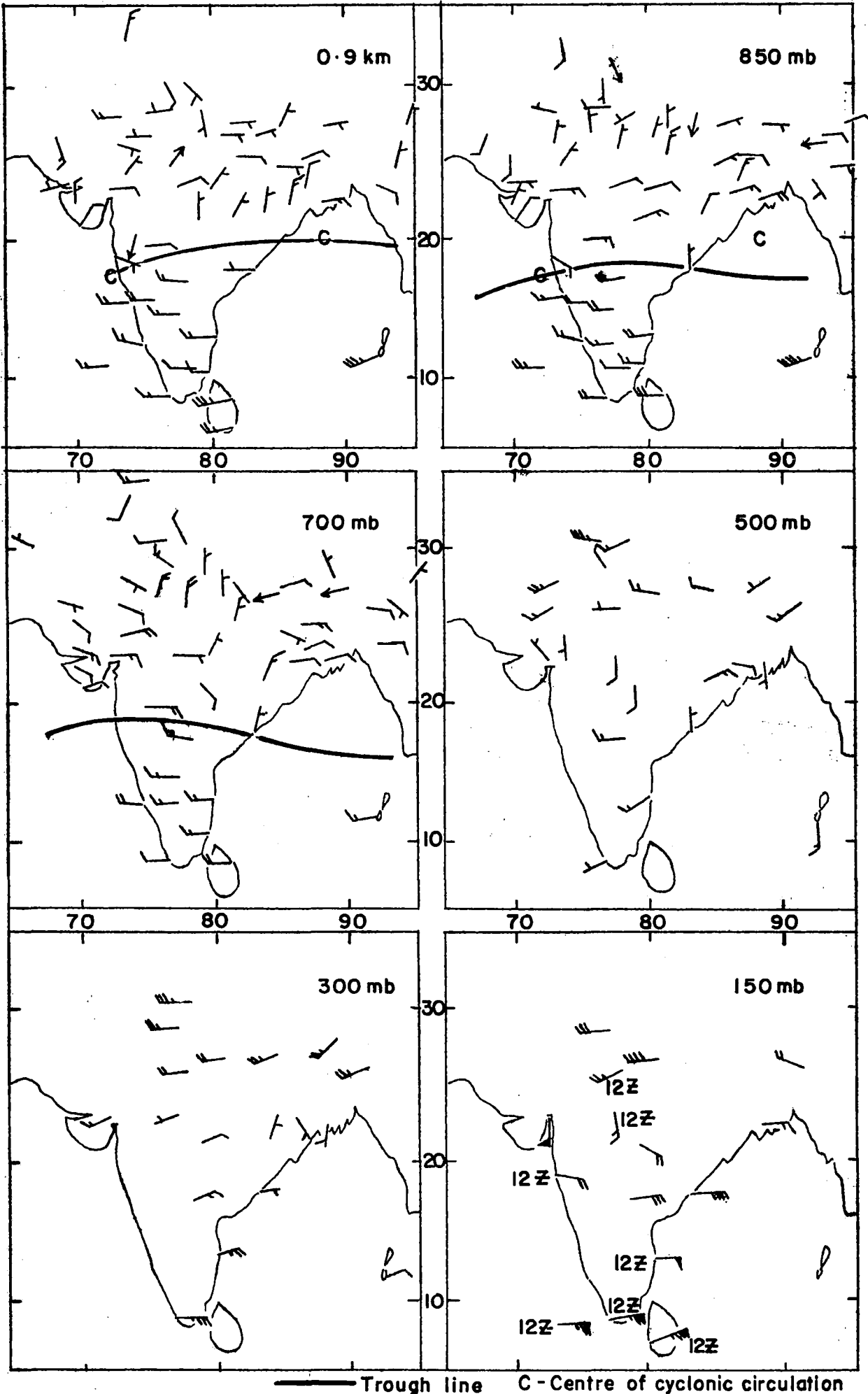


FIG. 9.6 UPPER WINDS 00 GMT 26 SEPT. 67



— Trough line C - Centre of cyclonic circulation

FIG. 9.7(a)

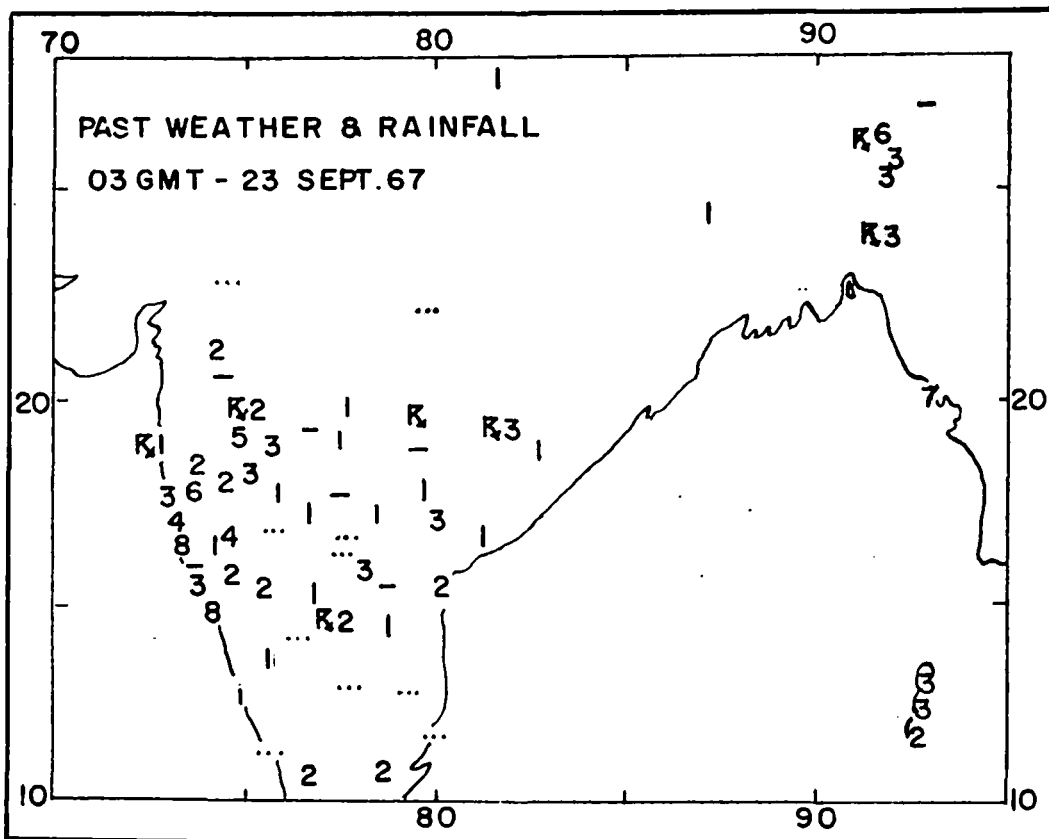
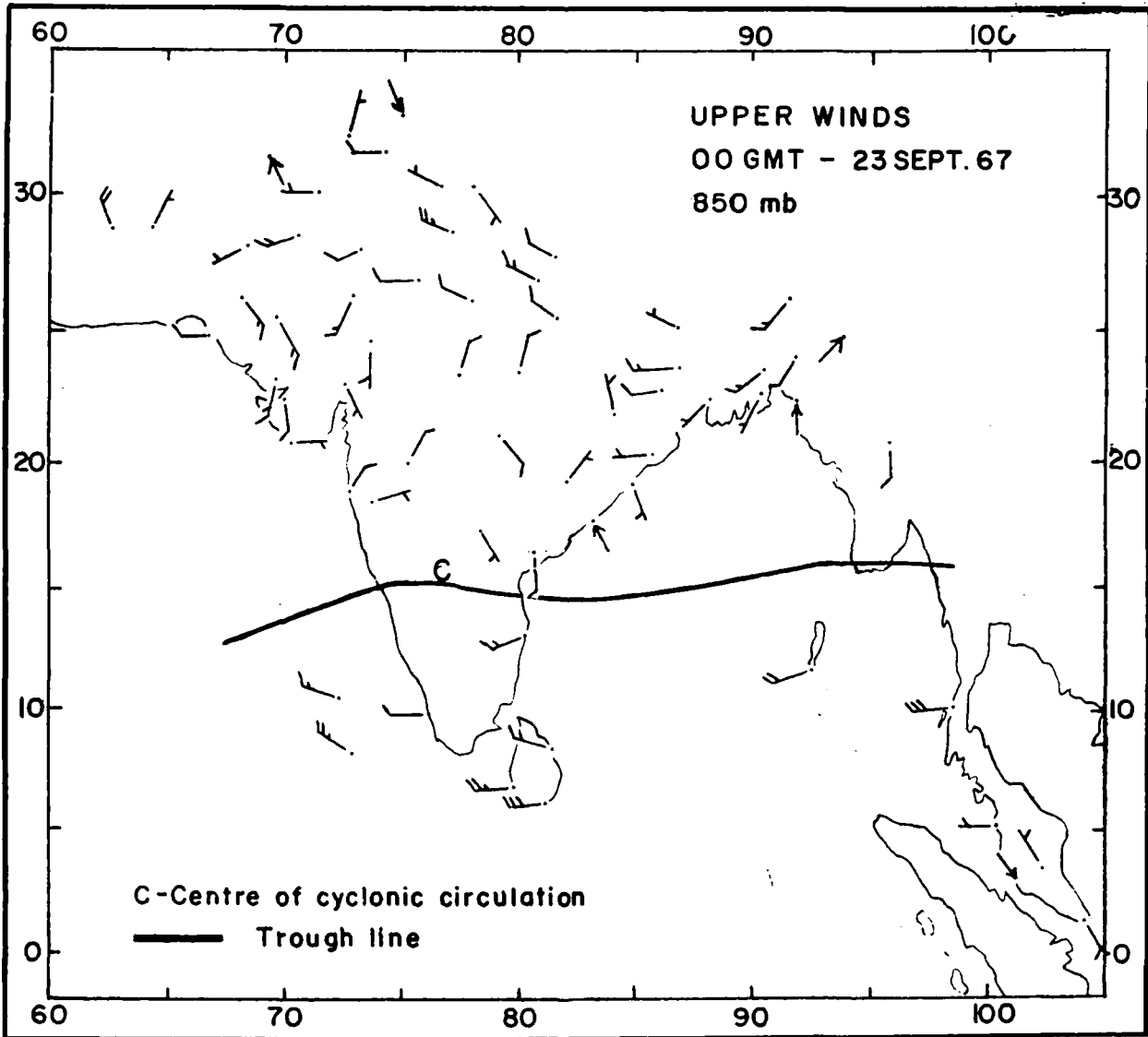


FIG. 9.7(b)

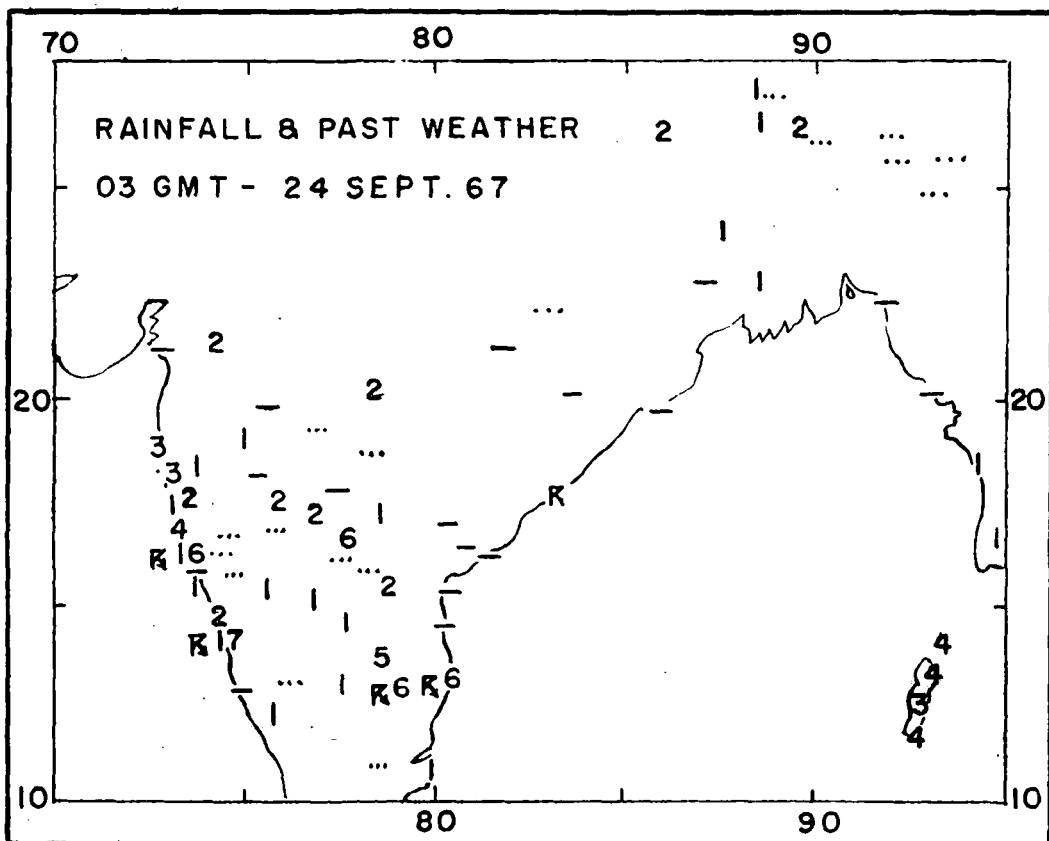
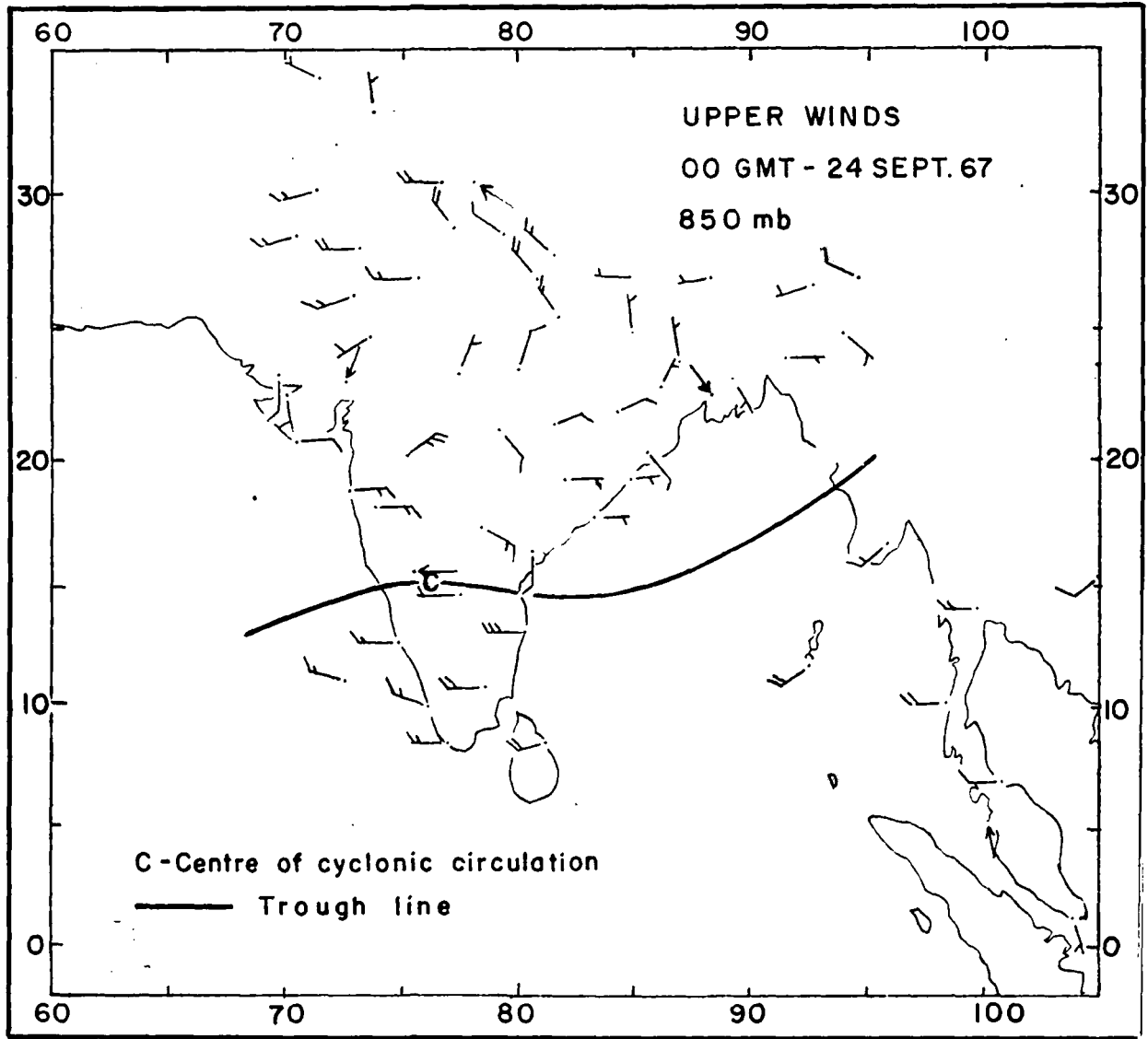


FIG. 9.7 (c)

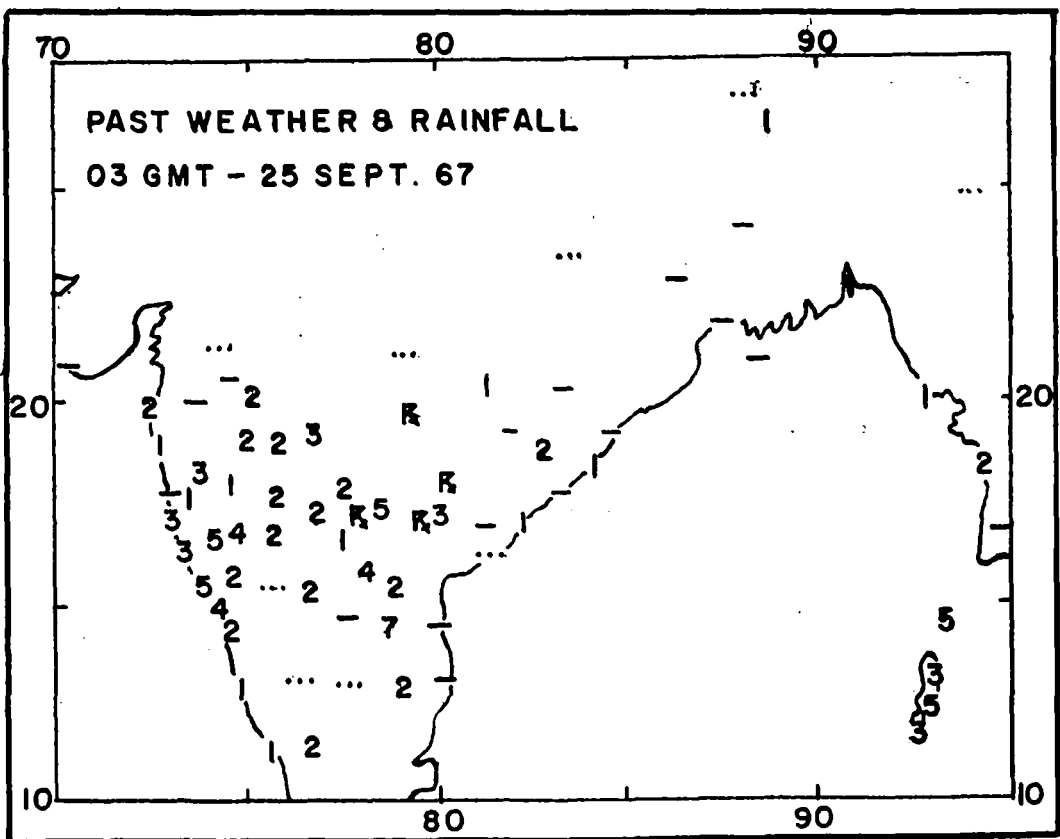
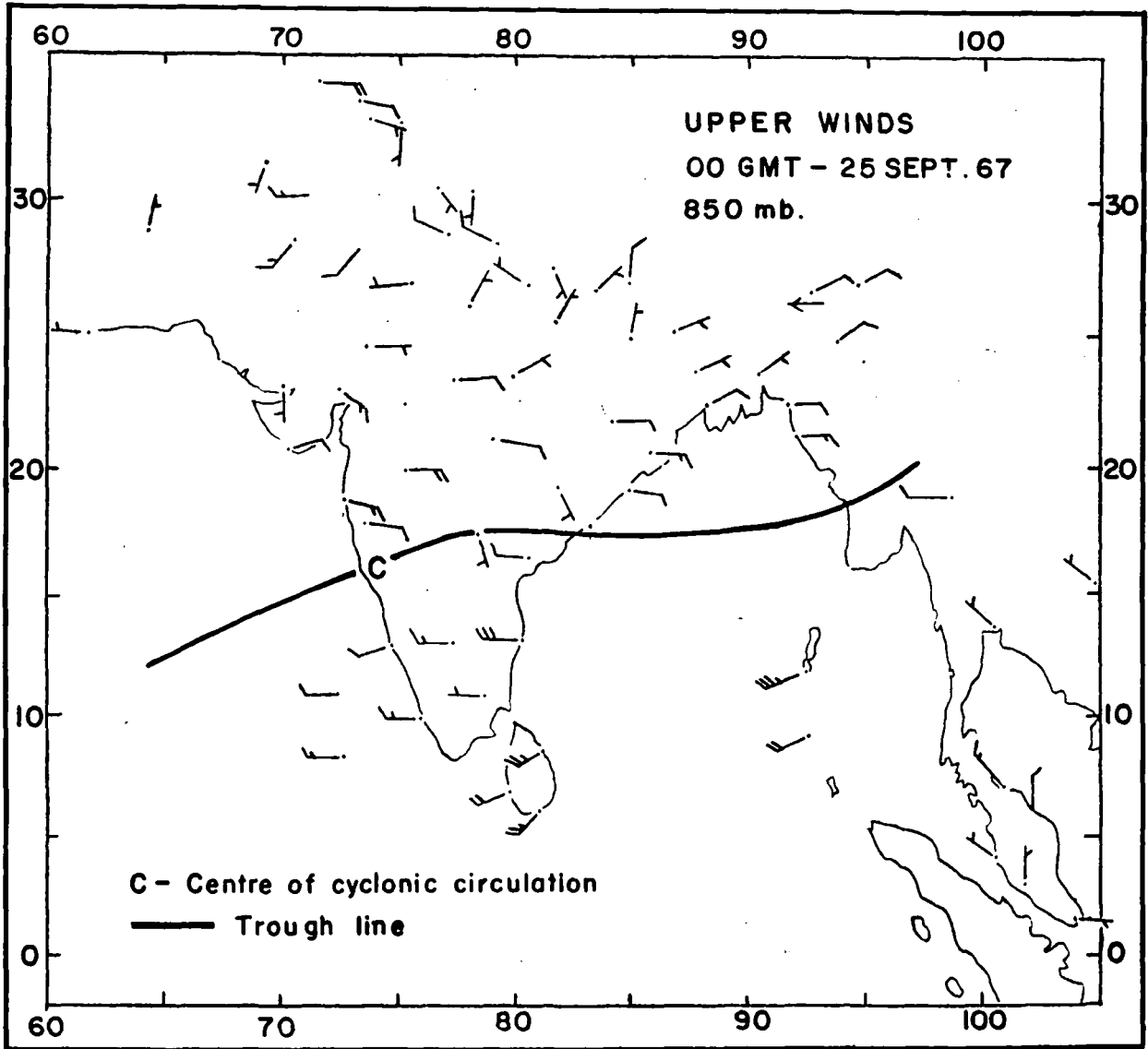


FIG. 9.7 (d)

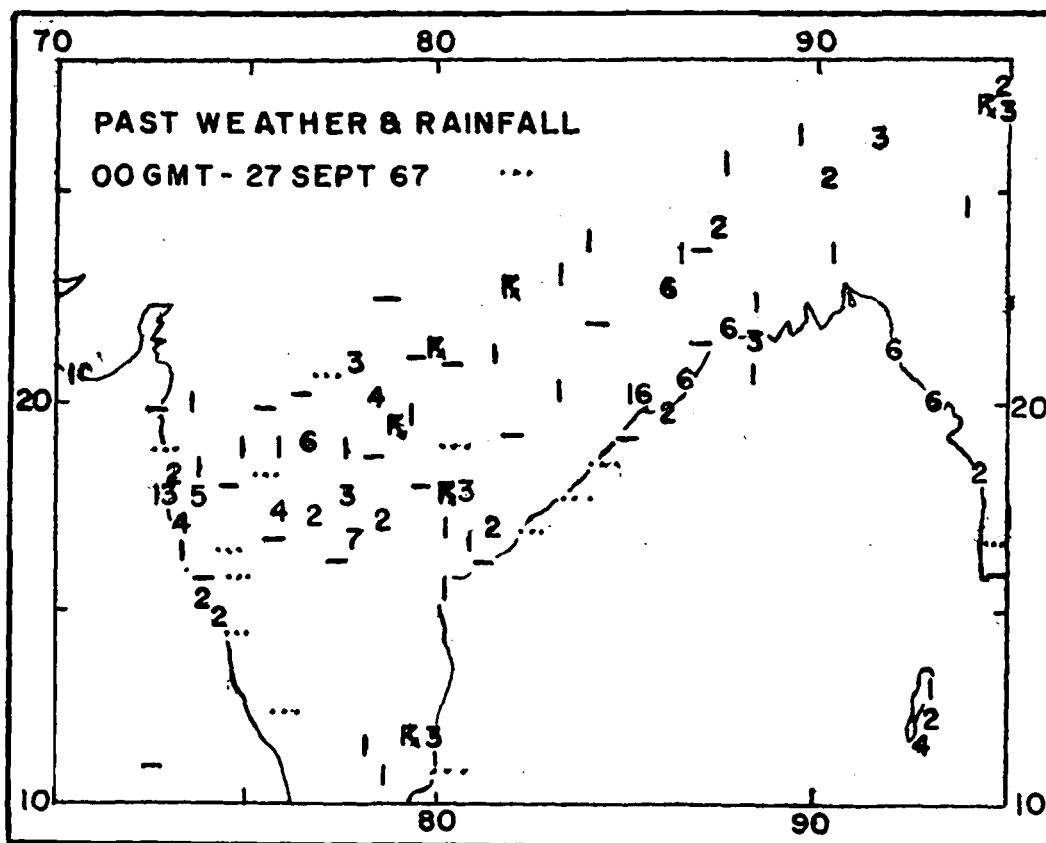
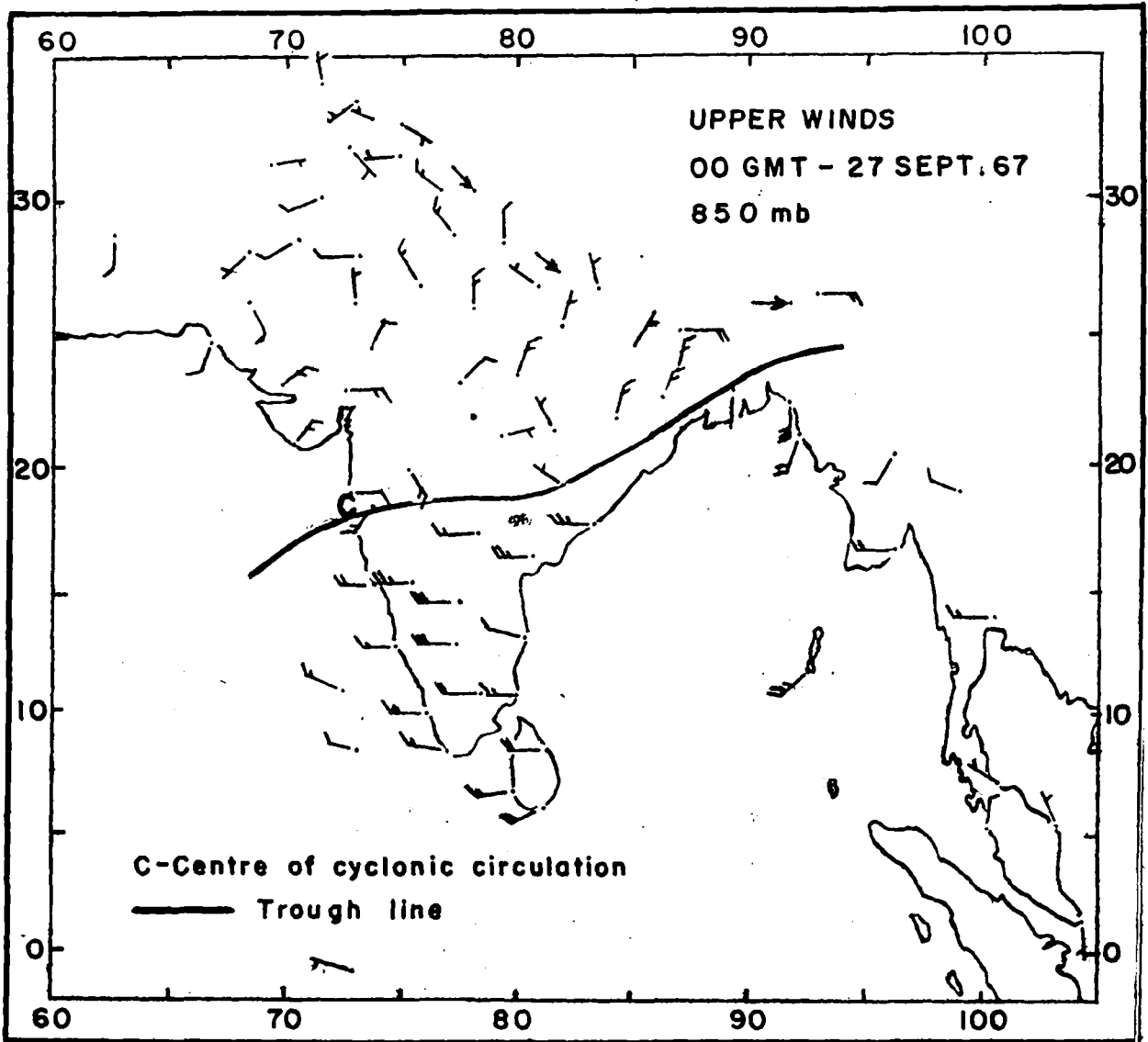
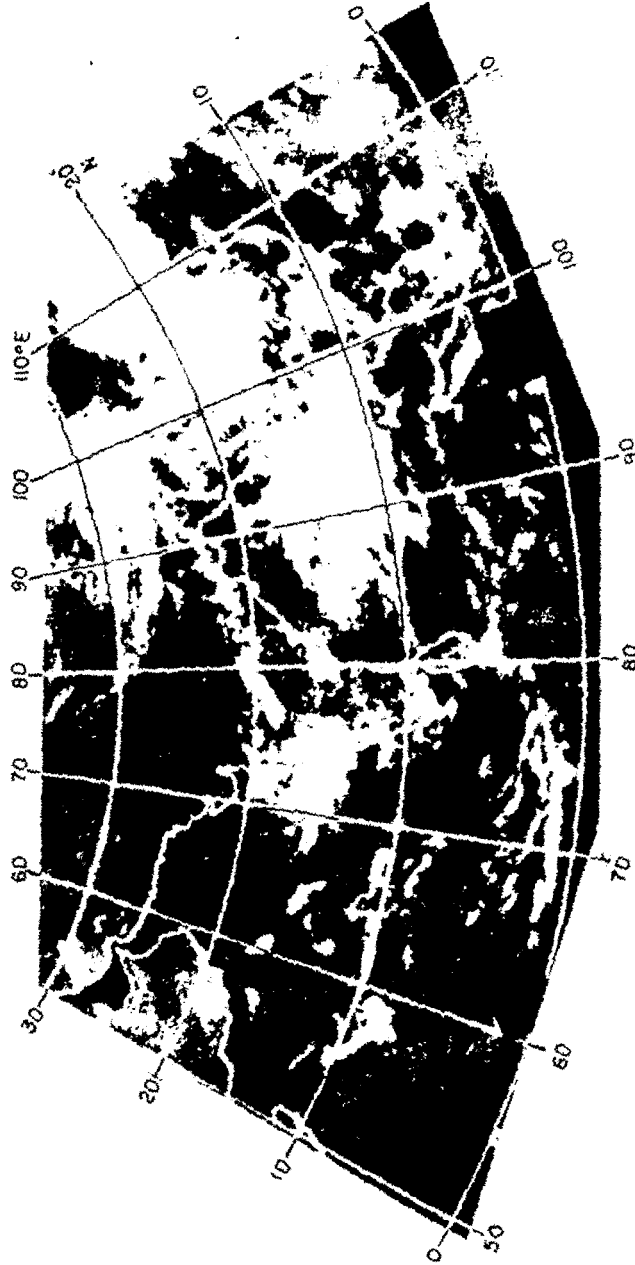


FIG. 9-8 ESSA 3 ORBIT 4468, 4469, 4470 DATE 23 SEPT. 67



Copied from Catalog of Meteorological Satellite Data - ESSA 3 & ESSA 5 Television Cloud Photography
(ESSA Publication : Key to Meteorological Records Documentation No. 5-315)

FIG. 10-1 SYNOPTIC CHARTS 0300 GMT 14 JUL. 67

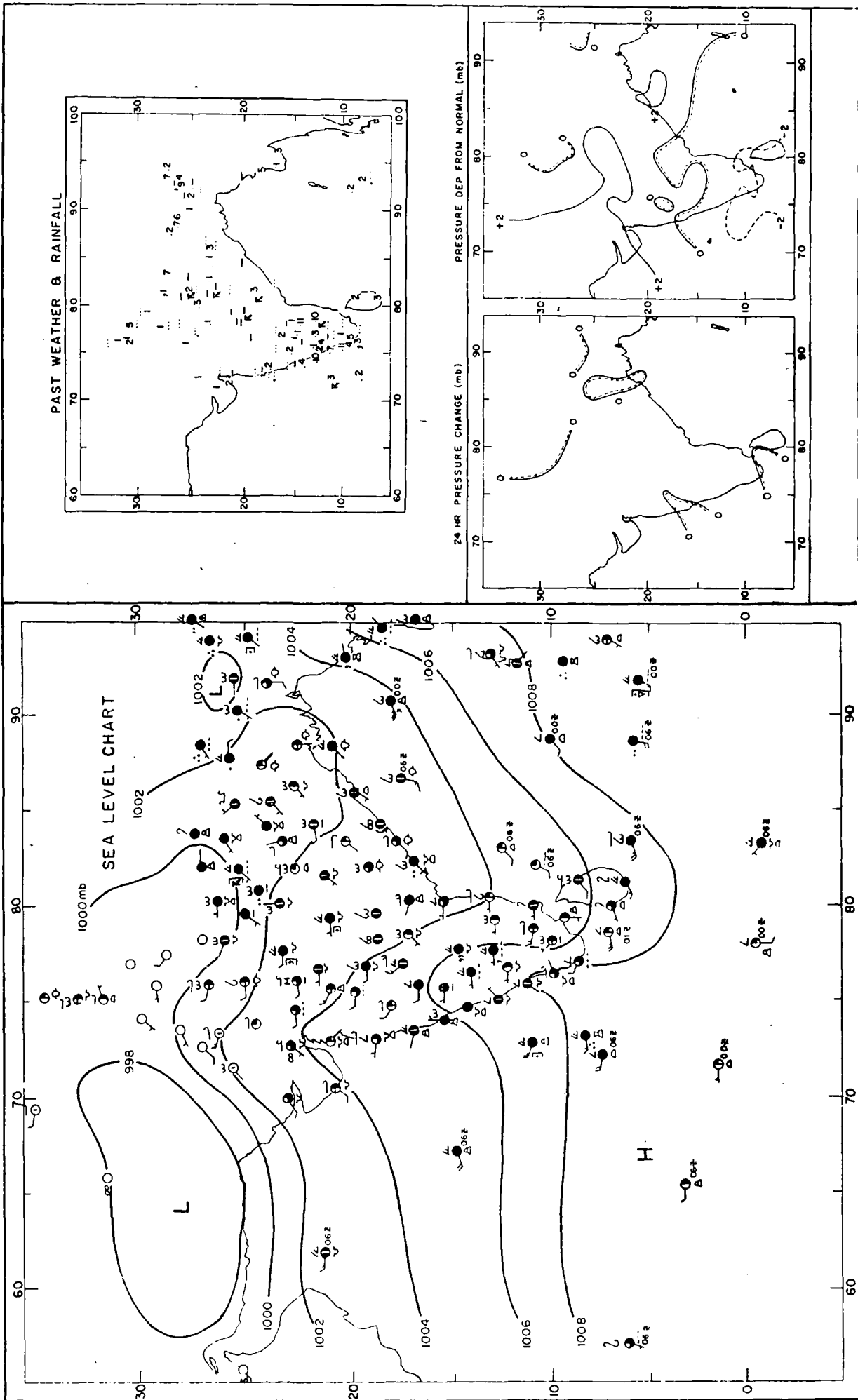
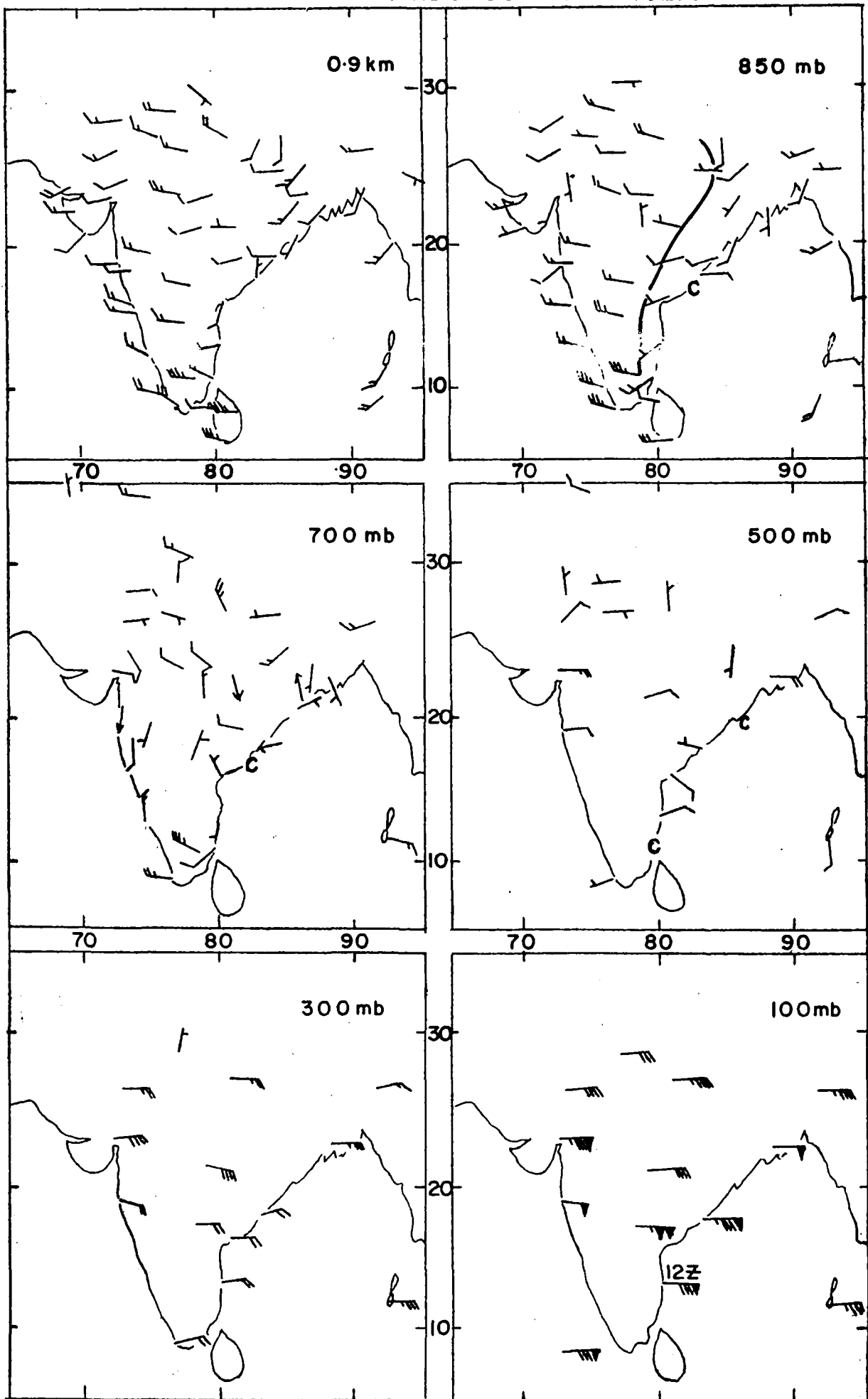
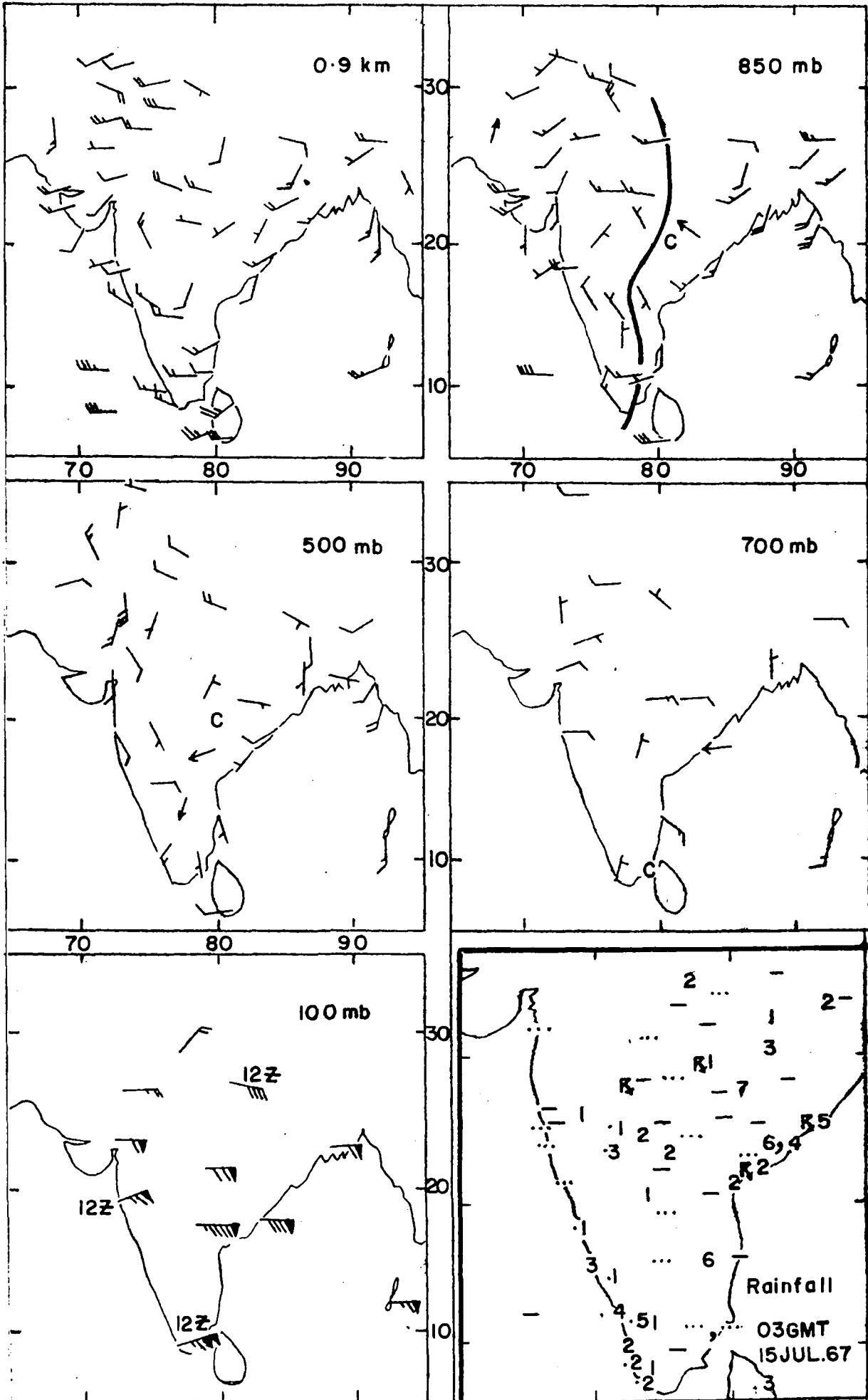


FIG. 10·2 UPPER WINDS OOGMT 14 JUL. 67



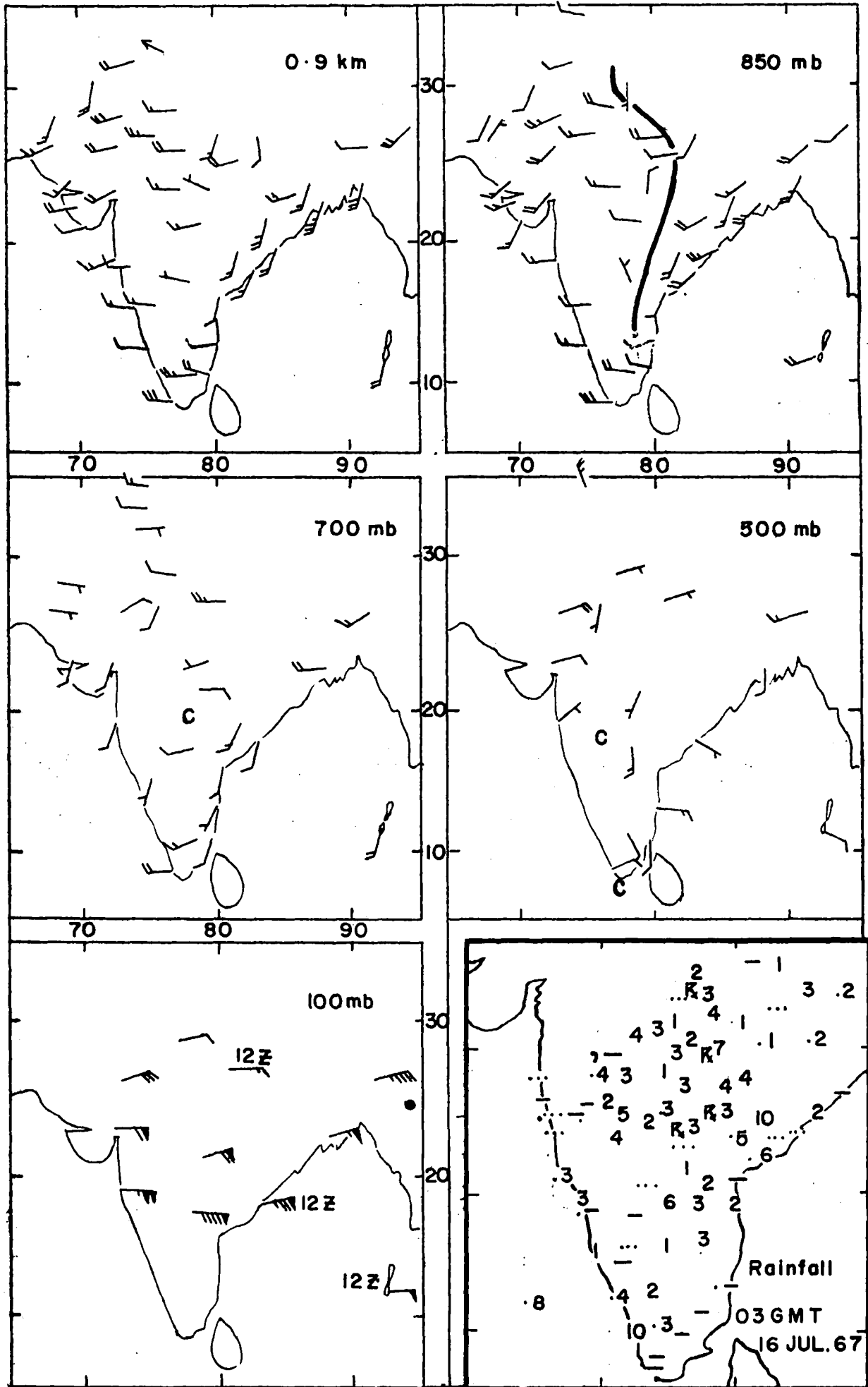
C - Centre of cyclonic circulation ——— Trough line

FIG. 10.3 UPPER WINDS 00 GMT 15 JUL. 67



C-Centre of cyclonic circulation — Trough line

FIG. 10.4 UPPER WINDS 00 GMT 16 JUL. 67



C-Centre of cyclonic circulation — Trough line

FIG. 10-5 SYNOPTIC CHARTS 0300 GMT 17 JUL. 67

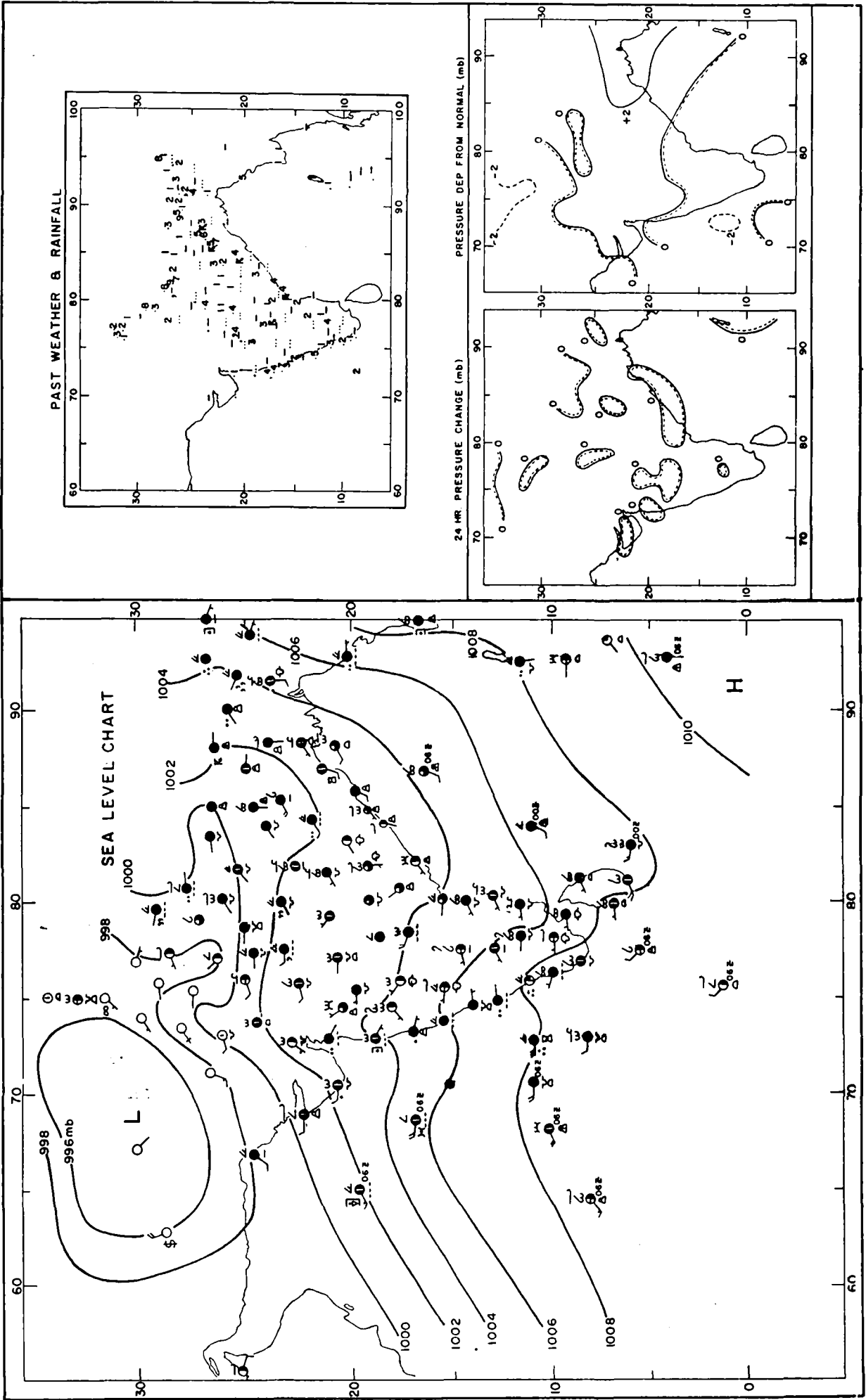
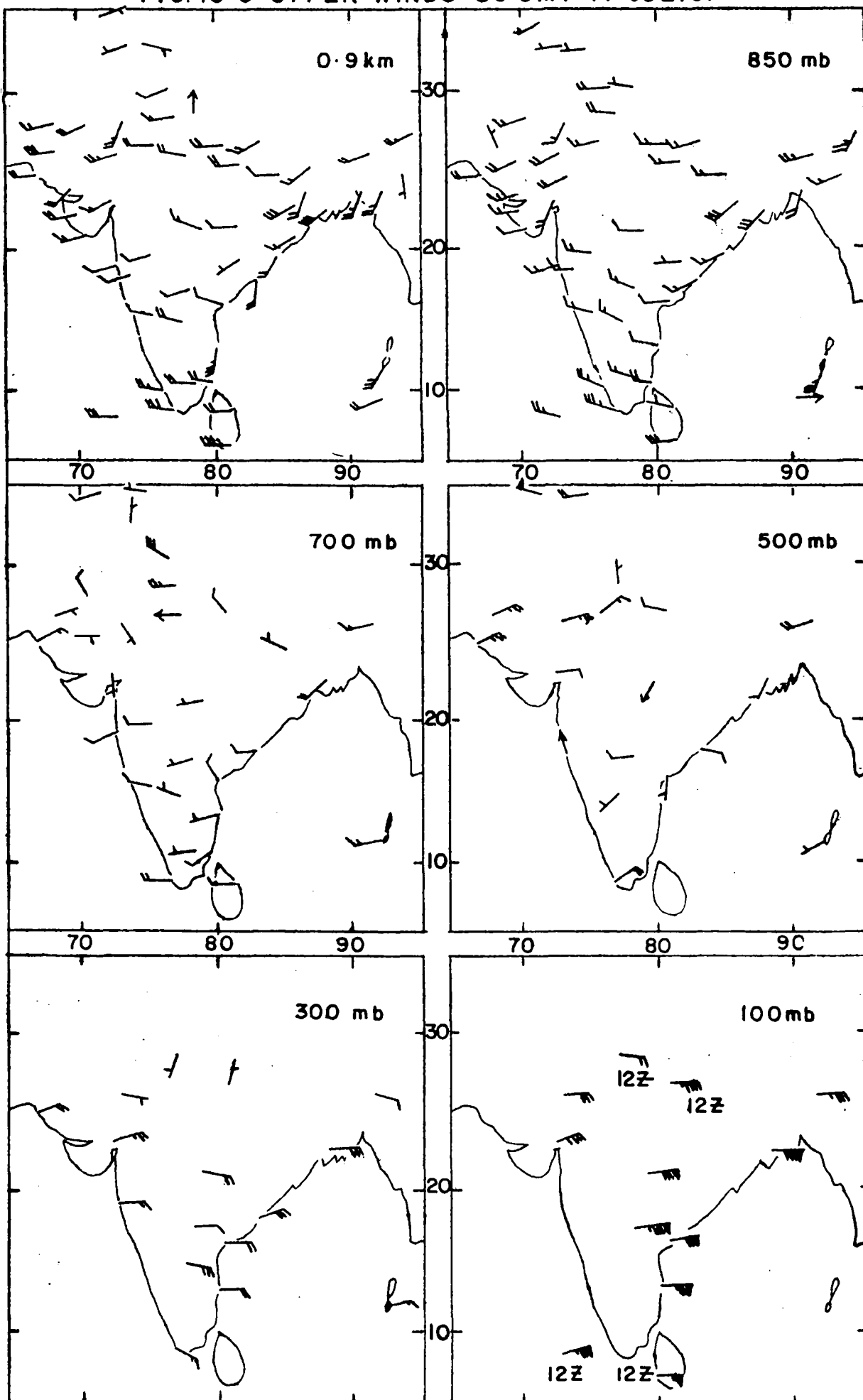


FIG. 10·6 UPPER WINDS 00 GMT 17 JUL. 67



- No. III - 4.1 Discussion of Typical Synoptic Weather Situations :
Weather over the Indian Seas during the Post-Monsoon Season
- V. Srinivasan and K. Ramamurthy.
- No. IV-13 Rainfall of India - P. Jagannathan.
- No. IV-16 Microseisms and Weather - A.N. Tandon and S.N. Bhattacharya.
- No. IV-17 Medium Range Forecasting - K.R. Saha and D.A. Mooley.
- No. IV-18.1 On the Criteria for declaring the onset of the southwest
monsoon over Kerala - R. Ananthakrishnan, U.R. Acharya and
A.R. Ramakrishnan.
- No. IV-18.2 Monsoons of India: Synoptic Features associated with onset
of Southwest Monsoon over Kerala - R. Ananthakrishnan,
V. Srinivasan, A.R. Ramakrishnan and R. Jambunathan.
- No. IV-18.3 Some aspects of the "Break" in the Indian Southwest Monsoon
during July and August - K. Ramamurthy.
- No. IV-18.4 Northeast Monsoon - V. Srinivasan and K. Ramamurthy.
- No. IV-20 Evaporation - N. Ramalingam.
- No. V-I Techniques of High Level Analysis and Prognosis :
1. Organization and Methods of Analysis - P.K. Das,
N.C. Rai Sircar and D.V. Rao.